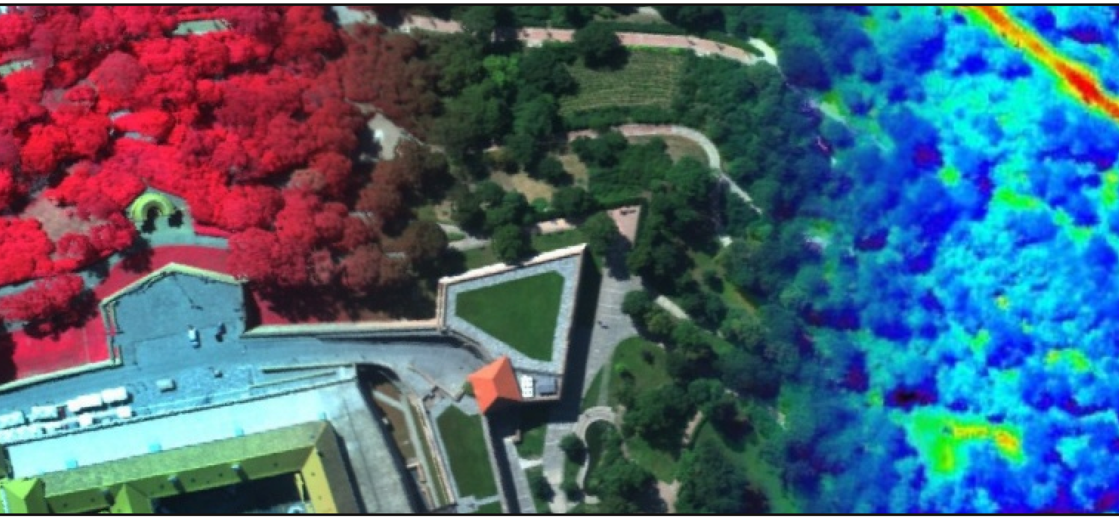
Programme Book

11TH EARSeL SIG IMAGING SPECTROSCOPY WORKSHOP

6–8 February 2019, Brno, Czech Republic



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Overview

Ice Breaker
Workshop Dinner
Tutorials
Workshop venue
City Centre
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Main bus station (Zvonařka)
Train station (Dolní nádraží)
Stránice
Pisárky
Veveří
Zábrdovice
Brno
Staré Brno
Štýřice

Welcome to EARSeL Imaging Spectroscopy Workshop, Brno 2019

CzechGlobe and the Workshop organizing committee warmly welcome you to 11th EARSeL SIG Imaging Spectroscopy Workshop in Brno. The Workshop of the EARSeL Special Interest Group on Imaging Spectroscopy aims to continue the long-term international discussion among researchers and specialists working with innovative imaging spectroscopy Earth Observation technologies. As imaging spectroscopy increasingly expands from traditional airborne platforms towards new ground-based, unmanned airborne and satellite systems, it is finding its way to interdisciplinary research addressing today's key environmental and societal challenges. At the same time, novel prospective spectral signals, as for instance chlorophyll fluorescence or thermal emissions, are being intensively explored.

The 11th EARSeL SIG Imaging Spectroscopy Workshop in Brno brings together students and professionals from universities, research organizations and private companies to present, exchange and discuss their basic and applied research achievements, as well as newly developing concepts related to all aspects of imaging spectroscopy.

We hope that you will enjoy scientific presentations, posters, exhibition booths, complementary excursions and tutorials, followed by attractive social programme including tasting of good Czech beer.

We thank to the Workshop sponsors, members of the scientific and organizing committees, colleagues from the remote sensing team of CzechGlobe and student volunteers for all their efforts to make this Workshop a successful event.

Lucie Homolová and the local organizing team

Scientific Committee

Eyal Ben-Dor (Tel Aviv University, Israel)
Jocelyn Chanussot (Grenoble INP, France)
Jean-Baptiste Feret (Irstea, France)
Claudia Giardino (IREA CNR, Italy)
Luis Guanter (GFZ Potsdam, Germany)
Robert O. Green (NASA JPL, USA)
Lammert Kooistra (Wageningen University, The Netherlands)
Sebastian van der Linden (Humboldt University, Germany)
Zbyněk Malenovský (University of Tasmania, Australia)
Jóse Moreno (University of Valencia, Spain)
Michael Rast (ESA ESRIN, Italy)
Miina Rautiainen (Aalto University, Finland)
Michael E. Schaepman (University of Zürich, Switzerland)
Martin Schlerf (LIST, Luxembourgh)
Christiaan van der Tol (University of Twente – ITC, The Netherlands)
Jochem Verrelst (University of Valencia, Spain)

Organizing Committee

Lucie Homolová (CzechGlobe, Czech Republic)
Jan Hanuš (CzechGlobe, Czech Republic)
Olga Brovkina (CzechGlobe, Czech Republic)
Petr Lukeš (CzechGlobe, Czech Republic)
František Zemek (CzechGlobe, Czech Republic)
Růžena Janoutová (CzechGlobe, Czech Republic)
Heide Bierbrauer (EARSeL Secretariat, Germany)
Lena Halounová (EARSeL Vice-Chair, Czech Technical University in Prague, Czech Republic)
Mathias Kneubühler (SIG IS Chairman, University of Zürich, Switzerland)
Andreas Müller (SIG IS Chairman, German Aerospace Centre DLR, Germany)

Workshop Venue

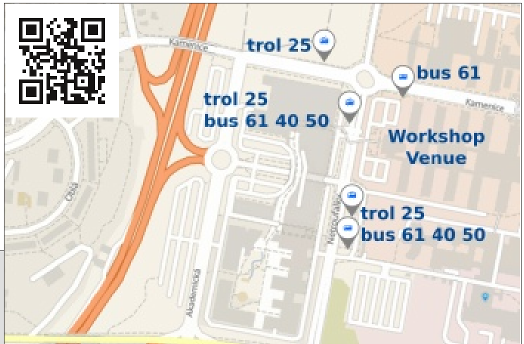
The Workshop is organized at the Masaryk University Campus, Kamenice 5, Brno.

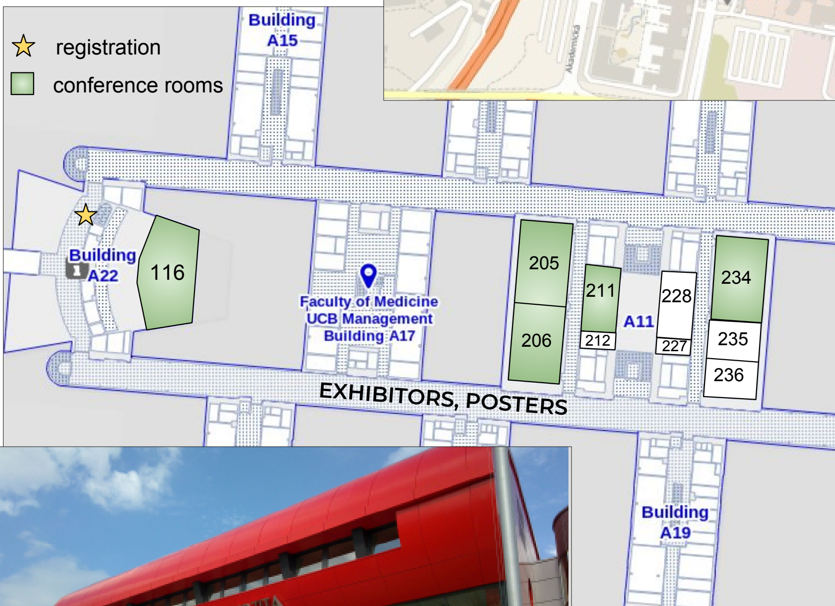
Plenary sessions take place in the aula (A116).

Parallel sessions take place in the lecture rooms 205, 206 and 234.

The small lecture room 211 is available at your disposal to host **small meetings**, **discussions** during the Workshop and **data practical session**.

The corridor is reserved for **posters, exhibitors** and **catering**.





Practical Information

Posters

Please put up your posters on Wednesday morning on a panel with your poster ID (for poster IDs see pages 13 and 14). Posters will remain on the panels for the entire Workshop. We have two dedicated poster sessions:

- Poster session 1 – Wednesday 6 February 2019, 16.20 – 17.20, **see page 13**
- Poster session 2 – Thursday 7 February 2019, 12.40 – 13.40, **see page 14**

Oral Presentations

Oral presentations will be maximum 20 minutes long, including 3–4 minutes for discussion and changeover to the next speaker (your presentation should not be longer than 17 minutes). Keynote presentations will be maximum 35 minutes long, including 5 minutes for discussion.

Please upload your presentation to the computer in the respective lecture room before the start of your session. Personal laptops cannot be used.

Internet Access

Free WiFi access is available using login details given to each Workshop participant at the registration. Besides, eduroam is also available on the university campus.

Best contribution awards

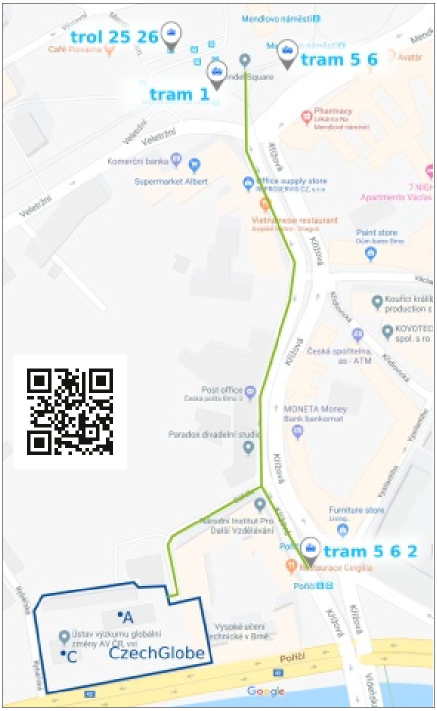
EARSeL will award three best student presentations and posters at the end of the Workshop.

The Workshop scientific committee and the audience will vote and select the most outstanding research contributions that will be awarded with 33% discount on article processing charges in the special issue in Remote Sensing.

Scan to vote

Audience can vote here

Tutorials and Excursions



The pre-workshop tutorials and excursions are organized on 5 February 2019 at CzechGlobe premises (Bělidla 986/4a, Brno).

One excursion to Flying Laboratory of Imaging System is also offered after the Workshop ends on 8 February 2019 at 15.00 (meeting point at the reception desk, Masaryk University Campus).

Building A

Tutorials and registration (room A120, ground floor)

Building C

Spectro lab (basement) and the meeting point for excursions (foyer)

5 Feb 2019
9.00–12.30

- **Tutorial on ARTMO – a toolbox for optimizing and automating mapping of vegetation properties**
  CzechGlobe – Lecture room A120
- **Tutorial on laboratory spectroscopic measurements of leaf and soil optical properties**
  CzechGlobe – Spectro lab

5 Feb 2019
13.30–17.00

- **Tutorial on machine learning based unmixing using the EnMAP-Box**
  CzechGlobe – Lecture room A120
- **Excursion to Flying Laboratory of Imaging Systems at CzechGlobe**
  Meeting point at CzechGlobe, building C foyer
- **Excursion to Plant phenotyping facility at PSI**
  Meeting point at CzechGlobe, building C foyer

8 Feb 2019
15.00–17.30

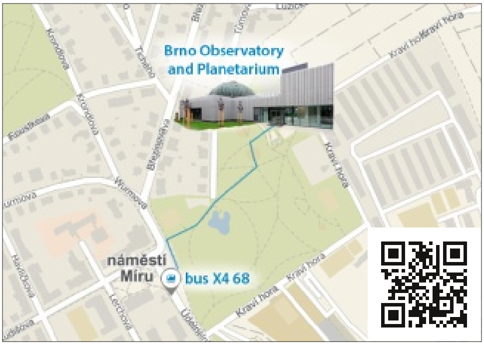
- **Excursion to Flying Laboratory of Imaging Systems at CzechGlobe**
  Meeting point at the reception desk, Masaryk University Campus

Ice Breaker

Ice Breaker will take place at **Brno Observatory and Planetarium** (Kraví hora 522/2, Brno).

Wednesday, 6 February 2019, 18.30 – 21.00

Bus transportation from the Workshop venue will be **arranged**, departure at 17.30.



If you wish to arrive at the Observatory and Planetarium individually, please, note that there is a traffic diversion, therefore you shall take bus X4 either at bus/tram stop Komenského náměstí (opposite the "red church") or tram/trolley stop Údolní/Úvoz (trolley 25, 26). **No transportation** will be provided on the way **back**, you can take bus X4 from "Náměstí míru" stop back to the city centre.

Hvězdárna a planetárium Brno, CC-BY-SA-3.0

Workshop Dinner

The Workshop Dinner will take place at **Starobrno Brewery** (Mendlovo náměstí 158/20, Brno).

Thursday, 7 February 2019, 19.00 – 23.30

Please, **arrive** to the restaurant at the Mendel square **individually**. Mendel square is one of the main public transport hubs, well connected by trolleys 25 and 26, trams 1, 5 and 6.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Programme – Wednesday 6 February 2019

8.30–8.45 Workshop Registration & Office
Location: WS. Registration & Office – A22 Foyer

8.45–9.20 Opening session
Location: A22 – Aula 116
Chair: Lucie Homolová
Dr. Klaus Ulrich Komp (EARSeL Chair), Dr. Mathias Kneubühler (SIG Imaging Spectroscopy Chair), Prof. Michal V. Marek (CzechGlobe), Prof. Michael Rast (ESA)

9.20–10.30 KN-1: Keynote 1
Location: A22 – Aula 116
Chair: Zbyněk Malenovský

Update on Recent Developments in Imaging Spectroscopy from Space by LUIS GUANTER

Low-altitude UAV Remote Sensing Approaches for Vegetation Monitoring by HELGE AASEN

10.30–11.00 Coffee Break
Location: Corridor

11.00–12.45 SPACE-1: Spaceborne Imaging Spectroscopy
Location: A11 – Lecture room 205
Chair: Uta Heiden, Luis Guanter

Commissioning Phase of the Satellite Mission DESIS by Rupert Mueller, Kevin Alonso, MARTIN BACHMANN, Emiliano Carmona, Daniele Cerra, Daniele Dietrich, Birgit Gerasch, Uta Heiden, Harald Krawczyk, Raquel de los Reyes, Valentin Ziel, Ilse Sebastian, Burghardt Günther, Ingo Walter, Thomas Säuberlich

EMIT: A New Space Imaging Spectrometer Mission to Advance Modeling of the Earth System by ROBERT O. GREEN

The Photosynthetic fAPARchl Canopy Fraction Among Six Sites Derived with EO-1 Hyperion Time-Serie by ELIZABETH M. MIDDLETON, Qingyuan Zhang, Petya K. Campbell, David R. Landis, Karl F. Huemmrich

2017 Decadal Survey: Surface Biology and Geology Science and Application with Global Imaging Spectroscopy Observables by ROBERT O. GREEN, David S. Schimel

EnMAP Ground Segment: Design and Status of the Integration and Technical Verification and Validation Phase by MARTIN HABERMEYER, Emiliano Carmona, Sabine Engelbrecht, Uta Heiden, Klaus-Dieter Missling, Helmut Mühle, Andreas Ohndorf, Gintautas Palubinskas, Tobias Storch, Steffen Zimmermann

UAS-1: Imaging spectroscopy from UAS
Location: A11 – Lecture room 206
Chair: Helge Aasen, Juliane Viktoria Bendig

Best Spatial Scale For Crop Classification Using Uncalibrated UAV Data by JONAS E. BÖHLER, Michael E. Schaepman, Mathias Kneubühler

Low-Altitude Multispectral Remote Sensing Disease Recognition in Maize by QUIRINA NOËMI MERZ, Ulrich Buchmann, Katrin Rehak, Simon Strahm, Jürg Hiltbrunner, Frank Liebisch, Achim Walter, Helge Aasen

Using High Spatial Resolution Hyperspectral Imagery to Investigate Grassland Optical Diversity by HAFIZ ALI IMRAN, Loris Vescovo, Damiano Gianelle, Duccio Rocchini

Modelling The Seasonal Traits Of Production Grasslands From UAV-Based Imaging Spectroscopy by LAMMERT KOOISTRA, Lotte ten Harmsen van der Beek, Marston Franceschini, Harm Bartholomeus, Gustavo Togeiro De Alckmin, Clara Berendonk

Predicting Canopy Traits In Tree Diversity Experiments Using Drone-Based Hyperspectral Imagery by KYLE RYAN KOVACH, Charles Andrew Nock

EUFAR: Special session on EUFAR
Location: A11 – Lecture room 234
Chair: Jan Hanuš, Stefanie Holzwarth

10 Years of Airborne Imaging Spectroscopy within EUFAR, the European Facility for Airborne Research by STEFANIE HOLZWARTH, Jan Hanus, Ils Reusen, Elisabeth Gerard, Phil Brown

Airborne Remote Sensing For Monitoring Essential Biodiversity Variables In Forest Ecosystems (RS4forestEBV): A EUFAR Summer School by ROSHANAK DARVISHZADEH, Andrew Skidmore, Stefanie Holzwarth, Marco Heurich, Ils Reusen

Use of Bi-Temporal Hyperspectral Imagery to Determine the Influence of Soil Degradation on Rainfed Crop Yield by ROBERT MILEWSKI, Sabine Chabrillat, Thomas Schmid, Paula Escribano, Monica Garcia, Eyal Ben Dor, Stéphane Guillaso, Marta Pelayo, Marcos Jiménez Michavila

HYLIGHT Activity and Biomass Mapper Tool by JAN HANUŠ, Jan Novotný

12.45–13.30 Lunch break (extended by instrument demo session)
Location: Corridor

13.30–14.15 DEMO-1: Instrument demonstration
UAV demo flight (HySpex)

14.15–16.00

SPACE-2: Spaceborne Imaging Spectroscopy
Location: A11 – Lecture room 205
Chair: Uta Heiden, Sebastian van der Linden

Radiometric Characterization, Calibration, and Correction for the Imaging Spectroscopy Mission EnMAP by TOBIAS STORCH, Hans-Peter Honold, Harald Krawczyk, Kevin Alonso Gonzales, Miguel Pato, Martin Bachmann, Richard Wachter, Martin Muecke, Sebastian Fischer

Urban Gradients – Surface material composition from 30 m hyperspectral remote sensing data by Marianne Jilge, HANNES FEILHAUER, Carsten Neumann, Ji Chaonan, Uta Heiden

Monitoring Of Crop Nitrogen Status Using A Hybrid Inversion Scheme In The Context Of The Future Hyperspectral EnMAP Mission by KATJA BERGER, Martin Danner, Matthias Wocher, Zhihui Wang, Wolfram Mauser, Tobias Hank

Quantitative Vegetation Mapping of California Ecosystems Using Simulated EnMAP Data by SAM COOPER, Akpona Okujeni, Clemens Jänicke, Sebastian van der Linden, Patrick Hostert

The Hyperspectral Sensors DESIS and EnMAP for Aquatic Ecosystems Monitoring – a Sensitivity Study by NICOLE PINNEL, Peter Gege, Anna Göritz

UAS-2: Imaging spectroscopy from UAS
Location: A11 – Lecture room 206
Chair: Helge Aasen, Eija Honkavaara

Drone-based Forest Inventory In Different Seasons Using High Resolution RGB Cameras And Hyperspectral Imaging by OLLI NEVALAINEN, Eija Honkavaara, Niko Viljanen, Raquel Alves de Oliveira, Roope Näsi, Teemu Hakala

Multi Modal Sensing Fosters Drone Application In Breeding: An Example On Sugar Beet Tolerance to Beet Cyst Nematode by FRANK LIEBISCH, Samuel Joalland, Claudio Screpanti, Achim Walter

Introduction Of Variable Relations For Improved Retrieval Of LAI Through the Soil-Leaf-Canopy Model Inversion by ASMAA MAHMOUD ABDELBAKI, Martin Schlerf, Thomas Udelhoven

Assessment Of Downey Mildew Infection on Grapevine Using Hyperspectral In Situ and UAV Data by MIRIAM MACHWITZ, Krittiya Pimkotr, Rebecca Retzlaff, Daniel Molitor, Gilles Rock, Mareike Schultz, Franz Ronellenfitsch, Christian Bossung, Marco Beyer, William Metz, Martin Schlerf

Hyperspectral Ortho-Mosaic From UAV-Borne Hyperspectral Imagery For Discriminating Different Grassland Management Regimes by JAYAN WIJESINGHA, Thomas Moeckel, Frank Hensgen, Michael Wachendorf

VEG-1: Spectroscopy of vegetation
Location: A11 – Lecture room 234
Chair: Petr Lukeš, Miina Rautiainen

A Novel Dataset For Testing Physical Reflectance Models Of Trees by AARNE HOVI, Petri Forsström, Giulia Ghielmetti, Daniel Kükenbrink, Felix Morsdorf, Michael Schaepman, Miina Rautiainen

Vegetation Functional Photoprotection Dynamics Seen From Leaf Absorbance Features by SHARI VAN WITTENBERGHE, Luis Alonso, Zbynek Malenovsky, Jose Moreno

After this Talk You will always map Leaf Pigment Content and not Concentration by TEJA KATTENBORN, Felix Schiefer, Pablo Zarco-Tejada, Sebastian Schmidtlein

Seasonal Course of Leaf Optical Properties and Traits – Linking Structure with Leaf Dorsiventral Reflectance by PETR LUKEŠ, Eva Neuwirthová, Růžena Janoutová, Zuzana Lhotáková, Jana Albrechtová

Understanding Dynamics of Leaf Spectral Properties Under Bark Beetle (Ips typographus, L.) Infestation by HAIDI JAMAL ABDULLAH, Andrew K Skidmore, Roshanak Darvishzadeh, Marco Heurich

16.00–16.20 **Coffee Break**
Location: Corridor

16.20–17.20 **POSTER-1: Poster session 1**
Location: Corridor
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18.30–21.00 **Ice Breaker**
Location: Planetarium
Brno Observatory and Planetarium – Transportation from the Workshop venue will be arranged.
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Programme – Thursday 7 February 2019

8.15 – 8.45 **Workshop Registration & Office**
Location: WS. Registration & Office – A22 Foyer

8.45 – 10.00 **KN-2: Keynote 2**
Location: A22 – Aula 116
Chair: Lucie Homolová

The FLEX Satellite Mission – Update on the Mission Status and our Understanding of solar-induced Fluorescence measured on different Scales by UWE RASCHER

Modelling And Scaling Imaging Spectroscopy Signatures Of Terrestrial Photosynthesis by ZBYNĚK MALENOVSKÝ, Jean-Philippe Gastellu-Etchegorry, Tiangang Yin, Nuria Duran, Nicolas Lauret, Eric Chavanon, Jordan Guilleux, Jianbo Qi, Douglas Morton, Bruce Cook

10.00 – 10.30 **Coffee Break**
Location: Corridor

10.30 – 12.10 **FLUO-1: Terrestrial Chlorophyll Fluorescence**
Location: A11 – Lecture room 205
Chair: Uwe Rascher, Zbyněk Malenovský

Systematic Assessment Of Airborne Sun-Induced-Fluorescence Maps By The Application Of Quality Criteria by VERA KRIEGER, Maria Matveeva, Patrick Rademske, Sergio Cogliati, Alexander Damm, Uwe Rascher

FLUOSPECCHIO: A Spectral Data Base System in Support of a Validation Network for the Upcoming Fluorescence Explorer (FLEX) Mission by ALEXANDER DAMM, Andreas Burkart, Marco Celesti, Sergio Cogliati, Andreas Hueni, Tommaso Julitta, Franco Miglietta, Dirk Schuettemeyer, Simon Trim, Roberto Colombo

Measuring Temporal Patterns of Crop Sun-induced Chlorophyll Fluorescence at Canopy and Plot Scale by NA WANG, Harm Bartholomeus, Lammert Kooistra, Juha Suomalainen, Benjamin Brede, Marcello Novani, Dainius Masiliunas, Jan Clevers

Combining Vegetation Traits with Multi/hyperspectral, Thermal and Fluorescence Measurements across different Scales and Plattforms – First Results from 2018 ESA FLEXSense Campaign by BASTIAN SIEGMANN, Maria Matveeva, Patrick Rademske, Onno Muller, Dzhaner Emin, Norman Wilke, Sascha Heinemann, Lars Grünhagen, Ines Munoz-Fernandez, Christoph Jedmowski, Paul Näthe, Juliane Bendig, Zbyněk Malenovský, Mareike Burba, Andreas Burkart, Tommaso Julitta, Kai Wittneben, Franco Miglietta, Roberto Colombo, Alexander Damm, Mirco Migliavacca, Ilja Reiter, Jan Hanuš, John Gamon, Dirk Schüttemeyer, Matthias Drusch, Uwe Rascher

Investigating Impacts of Avocado Canopy Structures on Simultaneous Solar and Actively Induced Chlorophyll Fluorescence Measurements by Rhys Wyber, JULIANE BENDIG, Deepak Gautam, Arko Lucieer, Zbyněk Malenovský, Barry Osmond, Sharon Robinson

TOOL-1: Data analyzing software, toolboxes
Location: A11 – Lecture room 206
Chair: Jochem Verrelst, Akpona Okujeni

EnMAP-Box 3 Free And Open-Source Imaging Spectroscopy Data Processing in QGIS by ANDREAS RABE, Benjamin Jakimow, Akpona Okujeni, Sam Cooper, Fabian Thiel, Patrick Hostert, Sebastian van der Linden

A Flexible Imaging Spectroscopy Processing Software Suite for Vegetation Studies by PHILIP TOWNSEND, Adam Chlus, Zhiwei Ye, John Chapman, Ting Zheng, Aditya Singh, Fabian Schneider, Natalie Queally, David Thompson, Ryan Pavlick, David Schimel

TOC2TOA: An ARTMO Toolbox to Simulate Top-Of-Atmosphere Radiance Data for Imaging Spectroscopy Applications by JOCHEM VERRELST, Juan Pablo Rivera-Caicedo, Jorge Vicent, Pablo Morcillo, Jose Moreno

FRANCA – A Fully Automated Hyperspectral Processing Chain For FRActioNal Cover Analysis by Valentin Ziel, MARTIN BACHMANN, Stefanie Holzwarth, Uta Heiden

"Get a Look at Image Processing for Students" (GLIMPS) – an Educational Imaging Spectroscopy Tool by DANIEL SCHLÄPFER

12.10 – 12.40 **Lunch break (extended by Poster session 2)**
Location: Corridor

12.40 – 13.40 **POSTER-2: Poster session 2**
Location: Corridor
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13.40 – 15.20

VEG-2: Spectroscopy of vegetation
Location: A11 – Lecture room 205
Chair: Alexander Damm, Philip Townsend

LAI And Cab Retrieval From The Synergetic Use Of OLCI And FLORIS Reflectances by CHARLOTTE DE GRAVE, Jochem Verrelst, Pablo Morcillo Pallarés, Juan Pablo Rivera-Caicedo, Jóse Moreno

Intra-Annual Multi-Temporal Hyperspectral Data for Tree Species Classification of an Extensive Forest Area by ANETA MODZELEWSKA, Krzysztof Stereńczak, Fabian Fassnacht, Rafał Sadkowski

Spectral Invariants in Remote Sensing of Vegetation by MATTI MÕTTUS

LiDAR Data Improves Predictions Of Canopy N And P Concentrations From Imaging Spectroscopy by Michael Ewald, Raf Arts, Jonathan Lenoir, FABIAN EWALD FASSNACHT, Manuel Nicolas, Sandra Skowronek, Jérôme Piat, Olivier Honnay, Carol Ximena Garzón-López, Hannes Feilhauer, Ruben Van De Kerchove, Ben Somers, Tarek Hattab, Duccio Rocchini, Sebastian Schmidtlein

NEON Imaging Spectroscopy: Characterizing Fine-Scale Vegetation Function at the Continental Scale by PHILIP TOWNSEND, Zhihui Wang, Eric Kruger

SOIL-1: Spectroscopy of soils and geology applicaitons
Location: A11 – Lecture room 206
Chair: Veronique Carrere, Veronika Kopackova

Cloud Computing of Remote Sensing Products for Soil Properties Mapping by JOSÉ LUCAS SAFANELLI, José Alexandre Melo Demattê, Sabine Chabrillat, Eyal Ben-Dor, André Carnieletto Dotto, Wanderson de Souza Mendes, Nelida Quiñonez, Benito Roberto Bonfatti, Raul Poppiel, Rodnei Rizzo, Arnaldo Souza Barros, Caio Troula Fongaro

Using Complex And Multi-mineral Natural Systems As Analogues For Modelling Diverse Geochemical Processes On Mars by VERONIKA KOPACKOVA, Lucie Koucká, Jan Jelenek

Impact Of The Spatial Resolution For Mineralogical Mapping From Hyperspectral Sensors HySpex, HYPXIM And EnMAP: Application To The Almeria Sedimentary Basin, Spain by KARINE ADELINE, Véronique Miegebielle, Marine Larrey

Using Imaging Spectroscopy For Detecting And Mapping Of Land-Use Effects On Soil Quality In Dryland by NATHAN LEVI, Arnon Karnieli, Tarin Paz-Kagan

UAV Hyperspectral-3D Fusion for Peatland Biogeochemistry by MARGARET KALACSKA, Juan Pablo Arroyo-Mora, Deep Inamdar, Oliver Lucanus

DEMO-2: Demonstration of data processing
Location: A11 – Lecture room 211
Chair: Jan Hanuš

13.40 – 14.20
Data Processing Chain Of Hyperspectral Imaging From UAV Platform by TROND LØKE

14.20 – 14.50
Integration of LiDAR for Use with Headwall Photonics Hyperspectral Imaging UAVs by FRANCESCO BECCARI

14.50 – 15.20
Online Classification of Spectral Data Using EZ-ID Software by EDWARD SAENZ, Hans-Joerg Fischer

15.20 – 15.40

Coffee Break
Location: Corridor

15.40 – 17.00

VEG-3: Spectroscopy of vegetation
Location: A11 – Lecture room 205
Chair: Jan Clevers, Roshanak Darvishzadeh

The Optical Profile Of Herbaceous Plant Functional Types by ELISA VAN CLEEMPUT, Kenny Helsen, Hannes Feilhauer, Olivier Honnay, Ben Somers

Correction of Spatial Autocorrelation for Comparison of Regional Statistics: a Case Study on Alluvial Vegetation by GILLIAN MILANI, Michael Schaepman, Mathias Kneubühler

Comparison Of Object-based And Pixel-based Random Forest Algorithm For Tree Species Classification Using Airborne APEX Hyperspectral Imagery by ZAHRA DABIRI, Stefan Lang

Integrated Hyperspectral and Multispectral Approach for Mapping Invasive Plant Species Based on Phenological Characteristics by TARIN PAZ-KAGAN, Natalya Panov, Micha Silver, Arnon Karnieli

SOIL-2: Spectroscopy of soils and geology applicaitons
Location: A11 – Lecture room 206
Chair: Eyal Ben Dor, Frantisek Zemek

A Novel Approach for Detecting Petroleum Hydrocarbons Contamination in a Real Manmade Disaster Zone Using Airborne Imaging Spectroscopy by RAN PELTA, Eyal Ben-Dor

Evaluating The Capability Of The Sentinel 2 Data For Soil Organic Carbon Prediction In Croplands by FABIO CASTALDI, Andreas Hueni, Chabrillat Sabine, Ward Kathrin, Buttafuoco Gabriele, Bomans Bart, Vreys Kristin, Brell Maximilian, Van Wesemael Bas

Quantitative Mapping of Ultramafic Rocks in Presence of Abundant Lichens Using Airborne Imaging Spectroscopy and Spaceborne Sentinel-2 And Landsat-8 OLI Data in The Arctic by SARA SALEHI, Christian Mielke

PARACUDA-II Engine as Compared to other Data-Mining Algorithms for the Prediction of Soil Carbon Using Diffuse Reflectance Spectra by ASA GHOLIZADEH, Mohammadmehdi Saberioon, Nimrod Carmon, Lubos Boruvka, Eyal Ben-Dor

SENS-1: New airborne and UAV systems, spectroradiometers
Location: A11 – Lecture room 234
Chair: Robert O. Green, Lammert Kooistra

WaterSat Imaging Spectrometer Experiment (WISE) for Canadian Microsatellite Missions by STEPHEN ACHAL, Shen-En Qian, Martin Bergeron

Simulation and Improvements of the Hyperspectral Images of the SIELETERS Airborne System by OLIVIER GAZZANO, Yann Ferrec, Alain Kattnig, Christophe Coudrain, Laurent Rousset-Rouviere

Analysis Of High Frequency Hyperspectral Remote Sensing Reflectances From Autonomous In Situ Sensors Deployed In Lakes by MARIANO BRESCIANI, Claudia Giardino, Annelies Hommersom, Dario Manca, Tommaso Julitta, Cesana Ilaria, Valentina Della Bella, Rosalba Padula

Implementation Of A UAV – Hyperspectral Line Imager For Ecological Applications by JUAN PABLO ARROYO-MORA, Margaret Kalacska, Deep Inamdar, Raymond Soffer, Oliver Lucanus, Janine Goldman, Tomas Naprstek, Gabriela Ifimov, Erica Skye Schaaf, Kathryn Elmer

19.00 – 23.59

Workshop Dinner
Location: Starobrno Brewery

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Programme – Friday 8 February 2019

8.30–8.45 Workshop Registration & Office
Location: WS. Registration & Office – A22 Foyer

8.45–10.00 KN-3: Keynote 3
Location: A22 – Aula 116
Chair: Petr Lukeš

Promises and Pitfalls in Geometric and Atmospheric Preprocessing of Imaging Spectroscopy Data by DANIEL SCHLÄPFER

The Advantages of Using Hyperspectral Technology in the Middle and Longwave Infrared Region for Tereestial Remote Sensing by EYAL BEN DOR

10.00–10.30 Coffee Break
Location: Corridor

10.30–12.10 VEG-4: Spectroscopy of vegetation
Location: A11 – Lecture room 205
Chair: Olga Brovkina, Zbyněk Malenovský

Analysis of Airborne Optical and Thermal Imagery for Detection of Water Stress Symptoms by MAX GERHARDS, Martin Schlerf, Uwe Rascher, Thomas Udelhoven, Radoslaw Juszczak, Giorgio Alberti, Franco Miglietta, Yoshio Inoue

UAV-Based High-Resolution Image Spectroscopy Towards The Assessment Of Grape Vine Health by OLAF NIEMANN, Roger Stephen, Fabio Visiintini, Robert Skelly, Patricia Bowen, Jose Urbez-Torres, Carl Bogdanoff

Improving Nitrogen Status Estimation in Malting Barley Based on Hyperspectral Reflectance and Artificial Neural Networks by KAREL KLEM

Video Spectroscopy For Tilling Dust Sensing and Visualisation In Agriculture by ANDRÁS JUNG, Michael Vohland, Marianna Magyar, László Kovács, Tímea Jung, Nóra Péterfalvi, Boglárka Keller, Fanni Sillinger, Renáta Rák, Kornél Szalay

Fusion Of Hyperspectral Imagery With Point Cloud Information To Predict Biomass Of Agricultural Crops by THOMAS MÖCKEL, Supriya Dayananda, Jayan Wijesingha, Michael Wachendorf

10.30–12.10 CORR-1: Imaging spectroscopy data corrections, calibrations, processing
Location: A11 – Lecture room 206
Chair: David Ray Thompson, Daniel Schläpfer

Optimal Estimation for Combined Retrievals of Surface and Atmosphere: Algorithms, Results, and Open Source Software by DAVID RAY THOMPSON, Michael Eastwood, Bo-Cai Gao, Robert O. Green, Mark Helmlinger, Vijay Natraj, Winston Olson-Duvall

NASA/JPL Airborne Imaging Spectrometer Campaigns in Support of ESA Satellite CAL/VAL and Simulation by IAN BRUCE MCCUBBIN, Andreas Hueni, Michael Schaepman, Dirk Schuettemeyer, Michael Rast, Hank Margolis, David Thompson, Robert Green, Simon Hook

In-Situ Field Spectroscopy Best Practice Guidelines for the Calibration and Validation of Airborne Hyperspectral Imagery by GABRIELA IFIMOV, Raymond Soffer, Juan Pablo Arroyo-Mora

Mitigating Sensor-Generated Spatial Correlations in Airborne Spectrographic Imaging Data. by DEEP INAMDAR, Margaret Kalacska, George Leblanc, Raymond Soffer, J. Pablo Arroyo-Mora

Towards a Standard for Characterization Hyperspectral Imaging Devices by SIRI JODHA SINGH KHALSA, Chris Durell, David Allen, John Gilchrist, Alex Fong, Kwok Wong

12.10–13.10 Lunch Break
Location: Corridor

13.10–14.30 VEG-5: Spectroscopy of vegetation
Location: A11 – Lecture room 205
Chair: Martin Schlerf, Rahul Raj

On The Estimation Of The Directional Area Scattering Factor From Red-Edge Bi-Directional Reflectance Spectra by RICHARD FERNANDES

When The Water Is Gone – Drought Response Of Leaf Mass Per Area Of Wetland Vegetation Analyzed With Imaging Spectroscopy by HANNES FEILHAUER, Thomas Schmid, Ulrike Faude, Salvador Sánchez-Carrillo, Santos Cirujano

Thermal Hyperspectral Remote Sensing – Ground-based and Airborne Examples from Vegetation Studies by MARTIN SCHLERF, Max Gerhards, Gilles Rock, Kaniska Mallick, Franz Ronellenfitsch, Thomas Udelhoven

Autonomous Spectral Acquisitions for Vegetation Monitoring by PETYA CAMPBELL, Elizabeth Middleton, K. Fred Huemmrich, Dan Mandl, James MacKinnon, Phill Towsend, Craig Daughtry

13.10–14.30 URB-1: Spectroscopy for urban applications and societal challenges
Location: A11 – Lecture room 206
Chair: Mathias Kneubühler, Frantisek Zemek

Response of Leaf Chlorophyll Fluorescence to Traffic Related Air Pollution in Cities by JOLIEN VERHELST, Dimitri Dauwe, Luis Alonso, Jochem Verrelst, Shari Van Wittenberghe, José Moreno, Roland Valcke, Roeland Samson

Real time Airborne Gas quantification using Thermal Hyperspectral Imaging : Application to methane by PIERRE-YVES FOUCHER, Jean-Philippe Gagnon, Xavier Watremez, Stéphanie Doz, Stéphane Boubanga, Martin Larivière, Martin Chamberland

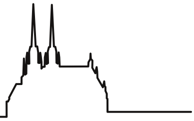
Thermal Infrared Hyperspectral Imaging for Visualization and flow rates Quantification of Methane releases by STEPHANE ALBON BOUBANGA TOMBET, Alexandrine Huot, Frédérick Marcotte, Pierre-Yves Foucher, Eric Guyot, Philippe Lagueux, Martin Chamberland

Exploration of Iron- and Steelworks Dump Sites – Using spectral data from the Visible Light, Near- and Shortwave Infrared (350-2500 nm) to the Mid- and Longwave Infrared (2500-15000 nm) by MICHAEL DENK, Cornelia Gläßer

14.30–15.00 CS: Closing session
Location: A22 – Aula 116
Chair: Lucie Homolová

15.00–17.30 EXC-3: Excursion 3: Flying Laboratory of Imaging Systems at CzechGlobe
Location: Airport
Chair: Jan Hanuš

Poster session 1



Date: Wednesday, 6 Feb 2019, 16.20 – 17.20
Location: Corridor

1 **Photosynthetic Pigments Changes Related To Screening Of Photosynthesis Dynamic Of European Beech And Norway Spruce Trees Using PRI** by DANIEL KOVAC

2 **Seasonal Dynamics Of Lingonberry And Blueberry Spectra** by PETRI FORSSTRÖM, Jouni Peltoniemi, Miina Rautiainen

3 **Seasonal Modelling Of Leaf Optical Properties And Retrieval Of Leaf Chlorophyll Content Across The Canopy Using PROSPECT** by Tawanda Gara, ROSHANAK DARVISHZADEH, Andrew Skidmore, Tiejun Wang

4 **Seasonal Chlorophyll Fluorescence Changes in Citrus aurantium Exposed to Low and High Traffic Pollution.** by DIMITRI DAUWE, Jolien Verhelst, Jochem Verrelst, Luis Alonso, José Moreno, Roeland Samson, Roland Valcke

5 **Estimation Of Crop Biophysical And Productivity Properties Using Radiative Transfer And Spectral Information Analysis** by JAN MIŠUREC, Jiří Tomíček, Petr Lukeš, Karel Klem

6 **Original Method for High Spatial Resolution Classification of Tree Species Using Multi-Temporal Many and Hyperspectral Satellite Data** by OLGA BROVKINA, Olga Grigorieva, Alisher Saidov

7 **Probability Map of Invasive Tree Species Using Hyperspectral and LiDAR Dataset** by ZOLTÁN KOVÁCS, Péter Burai, László Bekő, Gergely Hunyadi, Orsolya Varga

8 **Exploring the Potential of Light Use Efficiency Derived from Eddy Covariance and Reflectance Measurements for Spatial Simulations of Gross Primary Production** by RAHUL RAJ, Lucie Homolová, Petr Lukeš, Daniel Kováč

9 **Is Retrieval of Forest Biochemical Traits Stable over Variety of Environmental Conditions?** by MARIAN ŠVIK, Lucie Homolová, Růžena Janoutová, Barbora Navrátilová, Zuzana Lhotáková, Tomáš Fabiánek

10 **Hyperspectral Analyses of Heavy Metal Contents in Floodplain Vegetation and Soils** by Frank Riedel, MICHAEL DENK, Cornelia Gläßer

11 **High Resolution UAV-based Hyperspectral Imagery For LAI And Chlorophyll Estimations For Wheat Plants With Different Nitrogen Fertilization For Grain Yield Prediction** by MARTIN KANNING, Thomas Jarmer, Insa Kühling, Dieter Trautz

12 **Determination Of Species-Related Forest Stand Characteristics With The Use Of Hyperspectral Data** by MARTYNA WIETECHA, Łukasz Jełowicki, Krzysztof Mitelsztedt, Krzysztof Stereńczak, Stanisław Miścicki

13 **Mapping of Tundra Vegetation Using Satellite Hyperspectral and Multispectral Imagery** by VIKTOR MOCHALOV, Olga Grigoreva

14 **Comparison And Validation Of In-situ Field Spectroscopy And Advanced High Pressure Liquid Chromatography To Assess Pigment Composition In Deciduous Leaves** by FANNY PETIBON, Guido L.B. Wiesenberg, Giulia Ghielmetti, Michael W.I. Schmidt, Michael E. Schaepman, Mathias Kneubühler

15 **Effect of Leaf Epidermal Structure of Arabidopsis Thaliana Mutants to Leaf Specular Reflection** by EVA NEUWIRTHOVÁ, Zuzana Lhotáková, Petr Lukeš, Jana Albrechtová

16 **Chlorophyll Content Estimations Based on CCM-300, Laboratory Measurements and Field Spectroscopy for Tundra Grass Species in The Krkonoše Mountains** by LUCIE ČERVENÁ, Lucie Kupková, Markéta Potůčková, Jakub Lysák, Eva Neuwirthová, Zuzana Lhotáková, Jana Albrechtová

17 **In-Field, UAV-Borne VIS-NIR And Thermal Spectroscopy As Tools For Distinguishing Water Stress Reaction In Common Bean.** by ZUZANA LHOTÁKOVÁ, Milan Urban, Milton Valencia, Alejandro Vergara, Jaumer Ricaurte, Jana Albrechtová, Michael Selvaraj

18 **Method For Acquiring and Comparing Spatially Explicit Measurements of Sun Induced Fluorescence on the Ground** by DZHANER SAMI EMIN, Maria Matveeva, Kelvin Acebron, Benedict Vierneisel, Patrick Rademske, Andreas Burkart, Tommaso Julitta, Uwe Rascher

19 **Prediction of Leaf Area Index using Integration of the Thermal Infrared and Optical Data over the Mixed Temperate Forest** by ELNAZ NEINAVAZ, Andrew. K Skidmore, Roshanak Darvishzadeh

20 **Predictive Performance Of PROSAIL Inversion And PLS Regression For Nitrogen Uptake Estimation Using Sentinel-2 And UAV Images** by CHRISTIAN BOSSUNG, Miriam Machwitz, Adrien Petitjean, Martin Schlerf

21 **Impact Of Environmental And Tree Structural Parameters On The Estimation Of Biochemical Properties For A Sparse Mediterranean Forest With AVIRIS Imagery** by KARINE ADELINE, Thomas Miraglio, Jean-Victor Schmitt, Xavier Briottet, Jean-Philippe Gastellu-Etchegorry, Susan Ustin, Margarita Huesca, Keely Roth, Dennis Baldocchi

22 **Variable Rate Nitrogen Application in Winter Wheat Supported by Low-Altitude Spectral Remote Sensing** by FRANCESCO ARGENTO, Frank Liebisch, Helge Aasen, Achim Walter, Thomas Anken, Nadja El-Benni

23 **Quantifying the robustness of vegetation indices through ARTMO's Global Sensitivity Analysis (GSA) toolbox** by PABLO MORCILLO PALLARÉS, Juan Pablo Rivera-Caicedo, Santiago Belda, Charlotte De Grave, Helena Burriel, Jose Moreno, Jochem Verrelst

24 **A Comparison of Tree Species Classification Acuracy Using UAV Images Acquired with a Snapshot Hyperspectral and a Multispectral Sensor** by ELIAS FERNANDO BERRA, Melina Zempila, Paul Brown, Lee Butler, Michelle L. Hamilton, Rachel Gaulton

25 **HyPlant Derived Sun-Induced Fluorescence – a Way to Understand the Complex Vegetation Signals from Heterogeneous Ecosystems** by Subhajit Bandopadhyay, ANSHU RASTOGI, Uwe Rascher, Patrick Rademske, Anke Schickling

26 **Does Simple Vegetation Indices Can Predict Sun Induced Fluorescence? A Fuzzy Simulations on Airborne Imaging Spectroscopic Data** by Subhajit Bandopadhyay, ANSHU RASTOGI, Sergio Cogliatti, Uwe Rasher, Maciej Gabka, Radoslaw Juszczak

Poster IDs are written in red colour.

Poster session 2

Date: Thursday, 7 Feb 2019, 12.40 – 13.40
Location: Corridor

27 **Evaluation Of A pushframe hyperspectral Camera System** by STEFAN LIVENS, Klaas Pauly, Pieter-Jan Baeck, Joris Blommaert, Bavo Delauré, Dirk Nuyts, Gert Strackx

28 **Assessment of the Estimates of Sun-induced Fluorescence in large masses of Vegetation** by Fernando Rodriguez-Moreno, ZEMEK FRANTIŠEK, Miroslav Pikl

29 **Improvements in the Processing Chain of Thermal Hyperspectral Data from TASI-600** by TOMAS PURKET, Jan Hanus, Lukas Fajmon, Tomas Fabianek

30 **Radiometric Calibration Of Multispectral Cameras On Board Drones Using Field Spectro-radiometers And Handcrafted Low-cost Calibration Panels** by M. PILAR MARTÍN, José Ramón Melendo-Vega, Javier Becerra, Javier Pacheco-Labrador, María José Checa, Adrián Navarro

31 **The EnMAP User Interface - An Overview** by NICOLE PINNEL, Heiden Uta, Asamer Hubert, Dietrich Daniele, Mühle Helmut, Habermeyer Martin, Storch Tobias

32 **Operational DataQC Within The Hyperspectral DESIS And EnMAP Missions - Results Of The DESIS Commissioning Phase** by MARTIN BACHMANN, Kevin Alonso, Emiliano Carmona, Daniele Cerra, Raquel de Los Reyes, Birgit Gerasch, Martin Habermeyer, Harald Krawczyk, Maximilian Langheinrich, Rupert Mueller, Gintautas Palubinskas, Miguel Pato, Mathias Schneider, Peter Schwind, Tobias Storch, Valentin Ziel

33 **Current Status of the FLIS Infrastructure and Pre-processing chain** by JAN HANUŠ, Tomáš Fabiánek, Lukáš Fajmon, Tomáš Purket

34 **Pixelwise Classification Of Hyperspectral Images Based On Deep Convolutional Neural Networks** by LUCAS WITTSTRUCK, Thomas Jarmer, Martin Kanning

35 **Radiative Transfer Simulations of Spruce Forest Canopies Rreconstructed from Terrestrial Laser Scans** by RŮŽENA JANOUTOVÁ, Lucie Homolová, Zbyněk Malenovský, Jean-Philippe Gastellu-Etchegorry, Nicolas Lauret, Jan Hanuš

36 **In-flight Estimation and Correction of Non-Gaussian Spectral Response** by DAVID RAY THOMPSON, Joseph W. Boardman, Robert O. Green, Justin M. Haag, Pantazis Mouroulis, Byron E. Van Gorp

37 **Hyperspectral Lithium-Pegmatite Detection – A Case Study for Hoydalen, Norway** by FRIEDERIKE KLOS, Christian Mielke, Christian Rogass, Nicole Köllner, Friederike Körting, Agnieszka Kuras, Maria Bade

38 **Amospheric Correction Comparison of Alsat Spectral Imagery based on model FLAASH and model 6S** by MOHAMMED AMINE BOUHLALA, Farah Benharrats, Habib Mahi, Madina Asmaa Missoumi

39 **Soil Sampling Strategy Based On Multispectral Sentinel 2 And Hyperspectral EnMAP Satellite Data** by FABIO CASTALDI, Sabine Chabrillat, Bas van Wesemael

40 **Real time Airborne gas detection using Thermal Hyperspectral Imaging.** by STEPHANE ALBON BOUBANGA TOMBET, Alexandrine Huot, Frédérick Marcotte, Pierre-Yves Foucher, Eric Guyot, Philippe Lagueux, Martin Chamberland

41 **Fast And Easy Mineral Classification Using CASI/SASI/TASI Data** by LUCIE KOUCKÁ, Veronika Kopačková, Jan Jelének, Jan Hanuš

42 **Feasibility Study for an Aquatic Ecosystem Earth Observing System** by Arnold Dekker, Nicole Pinnel, CLAUDIA GIARDINO

43 **Mineral Identification And Characterization: An Integrated Approach To Recover Mineralogical Information From Hyperspectral Images** by RONAN RIALLAND, Rodolphe Marion, Véronique Carrère, Charles Soussen

44 **Spectral characteristics of surface soils between Irbid and Al Mafraq (Jordan)** by WAHIB SAHWAN, Bernhard Lucke, Rupert Bäumler

45 **Airborne Multisensors Information for a Zonal Crop Management** by FRANTIŠEK ZEMEK, Miroslav Pikl, Vojtěch Lukas, Michal Kraus, Petr Sirůček, Fernando Rodriguez-Moreno

46 **Narrow-band Soil Spectral Indices for SOC, Clay and Calcium Carbonate Prediction: Literature Review and Performance Evaluation based on the LUCAS Soil Database** by SASKIA FOERSTER, Kathrin Ward, Sabine Chabrillat

47 **Sensor Calibration Facility for Spectral and Thermal Remote Sensing** by JULIANE VIKTORIA BENDIG, Arko Lucieer, Zbyněk Malenovský, Vanessa Lucieer, Luis Gonzalez, Jonathan Roberts, Christoph Rüdiger, Sharon Robinson, Stuart Phinn, Andrew McGrath

48 **Hyperspectral Photoluminescence Imaging as a Tool to Study Degradation of the Outdoor Silicon Solar Panels** by MARIJA VUKOVIC, Vetle Odin Jonassen, Espen Olsen, Sigurd Grøver, Torbjørn Mehl, Ingunn Burud

49 **Hyperspectral Imaging analysis of Scots Pine Wood Wffected by Decay Fungi** by ARNOUD JOCHEMSEN, Gry Alfredsen, Sigrun Kolstad, Boyan Yuan, Nabil Belbachir, Ingunn Burud

50 **Proximal Hyperspectral Outcrop Scanning – A Geological Use Case Study** by FRIEDERIKE MAGDALENA KOERTING, Christian Mielke, Christian Rogass, Nicole Koellner, Friederike Klos, Uwe Alteneberger, Agnieszka Kuras

51 **Retrieving Macrophyte Pigments From Spectral Reflectance** by Paolo Villa, Monica Pinardi, Viktor Toth, Diana Vaiciute, Martynas Bucas, MARIANO BRESCIANI

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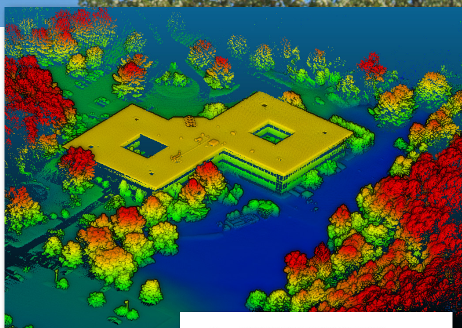

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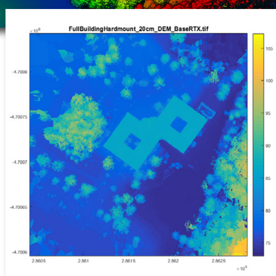

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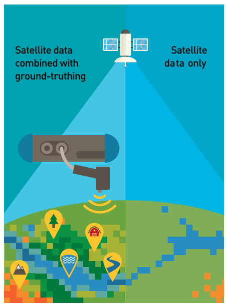

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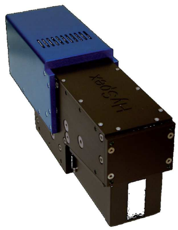

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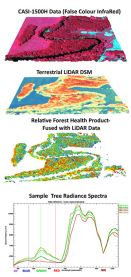

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Imaging Spectroscopy Avancements in Understanding Earth Systems (scientific contributions from 11th EARSeL Imaging Spectroscopy Workshop)

Guest Editors:

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Deadline for manuscript submissions:
31 October 2019

Message from the Guest Editors

Dear Colleagues,

Imaging spectroscopy is a progressive optical remote sensing domain that is increasingly contributing to interdisciplinary research addressing today's key environmental and societal challenges. The imaging spectroscopy knowledge, traditionally based on airborne and limited space-borne sensors, is expanding towards new spatial and spectral perspectives with new ground-based, unmanned airborne and satellite systems. Several up-coming spaceborne imaging spectroscopy missions will in a near future open up new opportunities for hyperspectral mapping and quantitative estimations of land and water surfaces.

This Special Issue will feature the state-of-the-art imaging spectroscopy research presented and discussed in February 2019 in Brno (Czech Republic) at the **11th Workshop of Special Interest Group on Imaging Spectroscopy of the European Association of Remote Sensing Laboratories (EARSeL)**.
Dr. Zbyněk Malenovský
Prof. Eyal Ben-Dor
Dr. Claudia Giardino
Dr. Lucie Homolová
Guest Editors

Keynote talks

Wednesday 6 February 2019

Update on Recent Developments in Imaging Spectroscopy from Space

LUIS GUANTER

Remote Sensing German Research Centre for Geosciences (GFZ), Germany

Despite the rapid development of spectrometer technology and information retrieval methods in the last decade, there is still a gap in the availability of imaging spectroscopy data from space. Pioneering technology demonstration missions such as Hyperion and HICO are no longer operating, whereas the launch of scientific missions such as EnMAP and PRISMA has been substantially delayed in the last years. However, there is an exciting horizon for spaceborne imaging spectroscopy missions. The 2018–2021 time frame should comprise the launch of PRISMA (Italy) and EnMAP (Germany) as free-flying missions as well as the operation of the DESIS (Germany-USA), HISUI (Japan) and EMIT (NASA JPL) spectrometers on board the International Space Station. The 10-m resolution SHALOM (Israel-Italy) commercial mission concept might also join those missions in the coming years. This will be complemented in the second half of the 2020s by the NASA's Surface Biology and Geology (SBG) mission and (upon approval by end of 2019) ESA's CHIME mission, which will produce high-quality data with global coverage and improved temporal sampling.

This contribution will review the current international scenario in spaceborne imaging spectroscopy and will show first results from already operating missions (potentially DESIS and PRISMA) if available.

Low-altitude UAV Remote Sensing Approaches for Vegetation Monitoring

HELGE AASEN

ETH Zürich, Switzerland

In the last 10 years, development in robotics, computer vision, and sensor technology has provided new low-altitude remote sensing tools to capture unprecedented ultra-high spatial and high spectral resolution with unmanned aerial vehicles (UAVs). This development has led to a revolution in geospatial data collection in which not only few specialist data providers collect and deliver remotely sensed data, but also a whole diverse community is potentially able to gather geospatial data that fit their needs. During the last years, both the technology and the procedures have matured. Now, low-altitude remote sensing approaches can deliver spectral VNIR, SWIR, thermal and 3D data that can be used in segmentation, complementation and combination approaches to understand our environment. This talk will reflect on the state-of-the-art in low-altitude remote sensing with UAVs, highlight the importance to understand the full pipeline from data capture to data analysis and show examples of where the technology enables novel approaches – since in the end research and applications matter, not just the platform.

Thursday 7 February 2019

The FLEX Satellite Mission – Update on the Mission Status and our Understanding of solar-induced Fluorescence measured on different Scales

UWE RASCHER

Forschungszentrum Jülich, Germany

In November 2015 the FLEX (FLuoresence EXplorer) satellite mission concept was selected as the 8th Earth Explorer mission of the European Space Agency (ESA). The mission will provide global measurements at an unprecedented spectral and spatial resolution enabling the retrieval and interpretation of the full fluorescence spectrum emitted by the terrestrial vegetation layer. FLEX will have a spatial resolution of 300 meters and will provide a global map every month. This will allow for the first time to study the spatio-temporal dynamics of vegetation fluorescence on this large scale in the course of the seasons.

With this presentation we will give an overview on the mission concept and the current status of the implementation of the satellite. Additionally, the current knowledge how sun-induced fluorescence can serve as an indicator for specific plant stresses and actual photosynthesis will be reviewed. The results are based on various modelling activities and field campaigns that exploit the high resolution signal of the airborne sensor *HyPlant*. *HyPlant* allows airborne mapping of sun-induced fluorescence emission over the whole spectral window of fluorescence emission in physical units. During campaign activities, airborne data acquisition is complemented by a network of ground based instruments, which help to scale the fluorescence signal from its origin in single photosystems to the top-of-canopy.

Maps of sun-induced fluorescence show a large spatial variability between different vegetation types, which complement classical remote sensing approaches. Different crop types largely differ in emitting fluorescence that additionally changes within the seasonal cycle and are related to the seasonal activation and deactivation of the photosynthetic machinery. Additionally, examples how fluorescence can track acute environmental stresses will be presented.

Modelling And Scaling Imaging Spectroscopy Signatures Of Terrestrial Photosynthesis

ZBYNĚK MALENOVSKÝ[1], Jean-Philippe Gastellu-Etchegorry[2], Tiangang Yin[3,4], Nuria Duran, Nicolas Lauret[2], Eric Chavanon[2], Jordan Guilleux[2], Jianbo Qi[2], Douglas Morton[4], Bruce Cook[4]

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A fraction of photosynthetically active radiation (PAR) absorbed by chlorophyll pigments of green plants is re-emitted as fluorescence. The solar-induced chlorophyll fluorescence (SIF) of photosynthetically active vegetation can be retrieved from telluric (oxygen bands) and Fraunhofer solar lines captured in passive spectral observations. It can serve as an indicator of plant primary production impacted by the actual environmental stress. Although the measurement methods and understanding of chlorophyll fluorescence at cellular and single leaf scales are well established, SIF retrieval approaches and interpretation at higher spatial scales, such as plant individuals, multi-species canopies and heterogeneous landscapes, are still subjects of intensive investigations. Number of ground-field, tower-based and also airborne experiments conducted during the past decade revealed physiological and optical complexity of understanding the SIF signal at coarser spatial resolutions. Subsequently, computer models offering physical scaling and understanding of the terrestrial SIF signal in the context of large canopies and landscapes through simulations of fluorescence interactions with Earth objects, have been developed.

In 2016, a three-dimensional (3D) radiative transfer (RT) model DART (Gastellu-Etchegorry et al., 2017) was enabled to simulate and scale the chlorophyll fluorescence emissions from leaves up to complex plant canopies. DART is modelling radiative budget and air-/space-borne images of various Earth surface elements from visible to thermal infrared wavelengths at various spatial and spectral resolutions. It uses detailed 3D representations of plants, where leaves, branches and trunks are created with spatially explicit facets (triangles). Plants of different structural and optical traits are distributed within a 3D scene to mimic natural variability of plant canopies, which ensures realistic simulations of light interactions. SIF emissions in DART are induced by a leaf-level RT model FLUSPECT (Vilfan et al., 2016), which simulates reflectance and transmittance of individual leaves as well as forward and backward leaf chlorophyll fluorescence fluxes of both photosystems (PSI and PSII). The FLUSPECT-DART combination allowed to investigate the influence of plant structural traits (e.g., leaf angle distribution, foliage density and clumping, etc.) on the top-of-the-canopy SIF of a spatially heterogeneous vegetation canopies, as observed by remote sensing optical sensors. Apart from the leaf-to-canopy upscaling, it also allowed for developing and testing a method scaling the canopy SIF measured from tower and airborne sensors down to leaf photosystems (Liu et al. 2018). The ongoing development of SIF functionalities in DART will provide users with new simulated products that cannot be obtained through field and remote sensing measurements, as for instance the canopy SIF escape factor for any modelled landscape.

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Friday 8 February 2019

Promises and Pitfalls in Geometric and Atmospheric Preprocessing of Imaging Spectroscopy Data

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Airborne imaging spectroscopy data has become available in large volumes from a broad variety of imaging sensors. The level of processing of the data is often unclear to an end user and may lead to misinterpretations and confusion for the data end user. In principle, one would expect geometric accurately aligned bottom of atmosphere reflectance values for a consistent data analysis.

Some data providers deliver decent geometric correction, georectification, or even orthorectification solutions, but residual offsets are usually observed if comparing the imagery to reference maps. Boresight calibration is the analytical approach to increase the accuracy of the geometry, but also image warping routines are often chosen to align the data to a map. Three methods of boresight calibration are compared in this contribution: the GCP-based manual method, an orthoimage-based matching method and a self-contained cross-reference matching method. Problems and results are outlined for a sample cases.

New geometric problems occur if dealing with hyperspectral scanner data taken from low altitude drones at spatial resolutions in the cm-range. Problems, which have been unknown from aircraft-based remote sensing. The lack of appropriate terrain representation but also the accuracy limitations of low-cost GPS/IMU systems ask for new solutions in such cases. A sample data acquisition is analyzed which has been taken from 30m above ground, with the goal of single leaf vegetation analysis. The encountered problems show the current limitations of geometric processing of high resolution scanner imagery in terrain.

On the radiometric side, methods for reflectance retrieval have advanced significantly in the last years mostly due to increased calibration accuracy of instruments but also due to better computing power and better scientific knowledge. This processing not only includes the atmospheric correction for transmittance and path scattering effects but also the consideration of three dimensional topographic effects and BRDF effects. As in geometric processing, the high spatial resolution of modern systems in combination with UAV based data acquisition leads to new radiometric challenges to be solved. Some improvements for the correction of topographic effects and incidence BRDF could be made, but high resolution artifacts such as self-shading and cross-illumination of 3D structured objects such as trees shows clear limitations of currently available approaches.

One of the most crucial and still unsolved issue is the treatment of shaded and partially shaded areas. Information in shades is at first strongly influenced by adjacency effects which relate to aerosol scattering in the atmosphere. In order to retrieve the reflectance for such areas, a better knowledge of the aerosol distribution is required and models have to be developed for 3D-modeling of the scattering process. With this respect, some improvements can be shown. Even more challenging is the processing in partially clouded areas where radiometric models approach their limits. For such situations, combinations of empirical correction and atmospheric modeling is the most promising approach in order to allow the use of imaging spectroscopy data with less dependency on clear sky situations. Test results for such processing of low altitude drone data are presented.

The Advantages of Using Hyperspectral Technology in the Middle and Longwave Infrared Region for Tereestial Remote Sensing

EYAL BEN DOR

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Remote sensing in the thermal region using multi- and hyperspectral technology has become attractive to many scientists, space agencies and end users over the last few years. The explicit capability of this technology to extract both temperature and emissivity in the spectral domain provides a new dimension in the remote-sensing field. This capability adds more information to that obtained by traditional optical sensors and hence is a force multiplier for the remote-sensing arena. Multi-, super- and hyperspectral capabilities in the thermal infrared (TIR) region (3–14 mm), that divided into the Mid

Wave Infra Red (MWIR, 3–5 mm) and to the Long Wave Infra Red (LWIR, 8–12 mm), is the driving force for new initiatives by several space agencies. At NASA, part of the HyspIRI hyperspectral mission is to put in orbit a multispectral sensor in the TIR region (8 channels). This activity was followed by an airborne hyperspectral demonstration (HyTES and PHyTIR) that proved the qualitative and quantitative importance of the TIR region. Accordingly, NASA has just recently mounted a super spectral TIR sensor on the international space station (ISS) with six channels in the LWIR region (ECOSTRESS). The current MODIS, ASTER and LANDSAT 8 thermal channels demonstrate the need of thermal information in many applications. Accordingly, new orbital missions with multi and super spectral resolution are planned by many space agencies. Presently, high TIR spectral resolution technology is only available from the airborne domain and its capability is available mainly just to the hyperspectral community. Nonetheless, as the attractiveness of the TIR region grows and the number of airborne TIR–HSR sensors in Europe is growing, several leading institutes now use such sensing devices in the TIR region. As the TIR–HSR technology provides new quantitative and qualitative frontiers that the optical domain cannot, it is attracting more and more attention, with recent studies demonstrating progress for many applications such as mineral and soil mapping, urban island effect, plant physiology, atmosphere gases, non visible clouds detection, water contamination and more. In this lecture, we will review the history of this TIR multi/hyperspectral technology along with the current list of available and operational sensors with their performances for terrestrial remote sensing applications. The advantages and limitation in achieving and processing the data will be highlighted as well. A special emphasis will be given to the added value of the TIR region over the optical spectral domain and to the potential of this technology. We will call upon in this important event to potential users to join the *special interest group* in the TIR hyperspectral domain, which has been established during the preparation of the EUFAR-3 proposal to the EC and within other initiative such as TMAX and TIREX to ESA.

SPACE-1: Spaceborne Imaging Spectroscopy

Wednesday 6 February 2019
Session Chair: Uta Heiden, Luis Guanter

Commissioning Phase of the Satellite Mission DESIS

Rupert Mueller, Kevin Alonso, MARTIN BACHMANN, Emiliano Carmona, Daniele Cerra, Daniele Dietrich, Birgit Gerasch, Uta Heiden, Harald Krawczyk, Raquel de los Reyes, Valentin Ziel, Ilse Sebastian, Burghardt Günther, Ingo Walter, Thomas Säuberlich

DLR, Germanyn

The German Aerospace Center (DLR) and the US company Teledyne Brown Engineering (TBE) have developed the hyperspectral instrument DLR Earth Sensing Imaging Spectrometer (DESIS), which is integrated into the Multi-User System for Earth Sensing (MUSES) installed on the International Space Station ISS. The instrument was launched on June 29 from Cape Canaveral with a SpaceX rocket. The instrument has been integrated into MUSES end of August 2018, which also defines the start of the commissioning phase. After the commissioning phase with functional tests, parameter tuning and performance analysis, the mission enters the operational phase, which is expected at the end of 2018. From this point on, hyperspectral data will be available to the scientific and commercial user community.

In this talk the results of the commissioning phase will be presented including aspects of data quality, operational performance and first data evaluation results.

EMIT: A New Space Imaging Spectrometer Mission to Advance Modeling of the Earth System

ROBERT O. GREEN

JPL Caltech, United States of America

The Earth Surface Mineral Dust Source Investigation (EMIT) has been selected by NASA to measure the Earth's mineral dust source regions from the International Space Station (ISS). EMIT will use state-of-the-art imaging spectroscopy across the visible to short wavelength infrared (VSWIR) spectral region to comprehensively measure the arid land dust source regions of the Earth. The resulting spectroscopically derived mineral composition will be used to improve the dust source region initialization of modern Earth System Models.

Mineral dust emitted into the atmosphere plays an important role in the Earth system impacting direct and indirect radiative forcing, atmospheric chemistry, cryosphere melt, surface hydrology, and the biogeochemistry of ocean and terrestrial ecosystems, as well as being a hazard to human populations. The Earth's dust cycle consists of source, transport, and deposition phases. Source knowledge is required for Earth System Models to simulate the dust cycle and understand current and future impacts of the dust cycle on the Earth system. Currently, detailed composition of the Earth's mineral dust source regions is uncertain.

As part of EMIT, these models will be used to investigate the impact of direct radiative forcing in the Earth system that depends strongly on the composition of the mineral aerosols. These new measurements and derived products will be used to achieve the EMIT science objectives and made fully available to the broad science community for additional investigations. The EMIT project, objectives, planned analyses, and expected data products are presented.

The Photosynthetic fAPARchl Canopy Fraction Among Six Sites Derived with EO-1 Hyperion Time-Serie

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A time series of EO-1 Hyperion satellite images for six study sites representing different vegetation types was compiled and analyzed to estimate canopy parameters related to the absorbed photosynthetically active radiation (APAR), the driver of photosynthesis, using 10 nmwavebands from the full spectrum visible through short-wave infrared (VSWIR) spectra. The sites were a deciduous forest (Park Falls, WI, USA); a coniferous forest (Howland, ME, USA); two tallgrass prairie sites (Konza Prairie, Kansas, USA); a savannah grassland (Skukuza, So. Africa); a cornfield (Mead, NE, USA); and tundra (Barrow, AK, USA), which were located at eddy covariance flux towers. A region covering the footprints of the towers was defined for spectral averaging of the atmospherically corrected 30 m resolution Hyperion reflectance data. Three physically based vegetation parameters were obtained using reflectance from seven VSWIR bands (blue, green, red, far-red, infrared, 2 SWIR) with an advanced radiative transfer model. These important vegetation APAR parameters: the chlorophyll-containing canopy fraction ($fAPAR_{chl}$); the non-chlorophyll canopy fraction ($fAPAR_{non-chl}$); and the fAPAR of the entire canopy ($fAPAR_{canopy}$). A Hyperion-derived chlorophyll index was derived based on a standard chlorophyll (Chl) index based on reflectance centered at 701 and 793 nm, which were compared with the fAPAR parameters and with widely used reflectance indices for canopy greenness. The study revealed that different ratios of the green and non-green canopy components occurred among the sites. The fAPAR parameters were also compared with APAR estimated with the MODIS-APAR equation based on the adjusted Normalized Difference Vegetation Index (NDVI). The $fAPAR_{canopy}$ parameter resembled the NDVI-based fAPAR response vs. Chl across all sites, but demonstrated that the NDVI variable routinely overestimated the actual photosynthetic green component of canopies by 20–40%. Where contemporaneous flux tower data were available, the spectral variables were compared with the reported midday fluxes. The $fAPAR_{chl}$ parameter was successful in estimating Gross Primary Production (GPP) across all sites ($r^2 = 0.83$). This study highlights the importance of full-spectrum spectroscopy for deriving critical vegetation canopy properties from orbital remote sensing.

2017 Decadal Survey: Surface Biology and Geology Science and Application with Global Imaging Spectroscopy Observables

ROBERT O. GREEN, David S. Schimel

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The 2017 Decadal Survey, "Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space" was publically released on the 5th of January 2018 with guidance for new observations of the Earth from space for the next decade. One of the recommended new global observations that supports a diverse set of novel and important science and applications objectives is identified as the designated observable: Surface Biology and Geology (SBG). The SBG designated observable with global coverage supports a broad set of science and applications targets spanning: surface geology and biology processes, active geologic processes, ground and water temperature, gross primary production, snow spectral albedo, functional traits of terrestrial vegetation and inland and near coastal aquatic ecosystems. Furthermore, the SBG observable was assessed to support one or more of the most important or very important science objectives from the Decadal Survey panels and to contribute key elements to the integrating themes of: water and energy cycle, carbon cycle, and extreme events. The candidate measurement approach for SBG is described as, "Hyperspectral imagery in the visible and shortwave infrared, multi- or hyperspectral imagery in the thermal IR." An expanded overview of the new science and applications enabled by the global SBG observable is presented along with the current study activities being initiated to support the guidance of the Decadal Survey.

EnMAP Ground Segment: Design and Status of the Integration and Technical Verification and Validation Phase

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EnMAP (Environmental Mapping and Analysis Program) is a German hyperspectral satellite mission, where the ground segment is operated by the Earth Observation Center (EOC), and the German Space Operation Center (GSOC) of the German Aerospace Center (DLR). The ground segment comprises all the facilities and systems required on Earth to control and operate the mission. It specifically facilitates access for the user segment to the space segment, including the commanding of the satellite, ordering and receiving data, and finally the processing, archiving and distribution of data.

The Ground Segment consists of three sub-segments (the Mission Operations Segment, the Payload Ground Segment and the Processor and CalVal Segment), further decomposed into fifteen subsystems. By the time of the presentation it has just finished its Production Phase, where the subsystems were procured, clearly stating their readiness for integration into the Ground Segment by their Technical Verification and Validation.

These subsystems are now integrated and their common functioning verified.

Two main topics are identified as follows: on the one hand the status of the Ground Segment's subsystems is presented. On the other hand the focus of the presentation lies in the design of the ITVV Phase. During this phase the ground segment and its subsystems have to prove their capability for ordering, commanding, receiving, processing, archiving and distributing the mission's data according to the requirements imposed on it. This is performed in different stages.

The presentation starts with an overview of the development model of the ground segment. This comprises its contributing fifteen subsystems and their interfaces as well as use cases accounting for the dynamic nature of the ground segment. Further the organisation of the requirements is shown, which are validated during the ITVV phase.

Based on that knowledge the different stages of the ITVV Phase are presented, starting out with the subsystem verification on different levels. This is followed by the sketch of the verification of the interfaces and the ground segment's verification based on scenarios.

SPACE-2: Spaceborne Imaging Spectroscopy

Wednesday 6 February 2019
Session Chair: Uta Heiden, Sebastian van der Linden

Radiometric Characterization, Calibration, and Correction for the Imaging Spectroscopy Mission EnMAP

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The high-resolution imaging spectroscopy remote sensing satellite mission EnMAP (Environmental Mapping and Analysis Program, enmap.org) will cover the spectral range from 420 nm to 2450 nm with a spectral sampling distance varying between 4.8 nm and 12.0 nm comprising 262 spectral bands. The expected signal-to-noise ratio at reference radiance level is 500:1 at 495 nm and 150:1 at 2200 nm. The radiometric resolution is 14bits and an absolute radiometric accuracy of better than 5% is achieved. Each of the two 2-dimensional detector arrays of the prism-based pushbroom dual-spectrometer works in a dual-gain configuration to cover the complete dynamic range. EnMAP will acquire 30 km in the across-track direction with a ground sampling distance of 30 m and the across-track tilt capability of 30° will enable a target revisit time of less than 4 days. The launch is scheduled for 2020.

In-flight radiometric characterization and calibration are based on Sun calibration measurements with a full-aperture diffusor for absolute calibration. In addition, a weekly relative calibration monitors the instrument during the complete mission lifetime based on an integrated sphere (on the satellite) coated with Spectralon and illuminated with a Tungsten halogen lamp and a white LED (light emitting diode). These calibration measurements also allow for the regular update of the dead pixel mask containing e.g. hot, cold, and flickering pixels. The frequency of the absolute calibration is scheduled based on a model using previous calibration measurements to minimize the aging of the diffusor. The calibration is complemented with closed shutter measurements before and after each observation for dark signal subtraction and additional deep space measurements every four months for shutter thermal emission monitoring. Due to air-vacuum transition and gravity release, most significant effects are expected during and shortly after launch and therefore, a high frequency of calibration measurements is planned during the commissioning phase. Aging effects within the operational phase can be studied with longer calibration intervals.

Pre-flight radiometric characterization and calibration also consider effects which are not measureable during operations, e.g. spectral and spatial straylight, and verify temperature and radiometric stability assumptions. Furthermore, this provides the first reference and characterization measurements of the calibration equipment on the satellite.

Based on the pre- and in-flight calibration activities, the on-ground fully-automatic processing chain generates standardized Earth observation products with TOA (top-of-atmosphere) radiances and annotates spectral and geometric characterization as well as pixel classification and information for later processing, e.g. geometric and atmospheric corrections. For radiometric correction the following steps are performed: non-linearity correction; dark signal correction; gain matching; straylight correction; and the radiometric calibration as well as data quality control routines including defective pixel flagging, where dead and abnormal pixels are considered, generation of raw and calibrated detector maps, and analysis for striping, banding and other artefacts. The online data quality control and monitoring routines for all acquisitions are complemented by offline data quality activities for selected acquisitions.

The high-quality products will be freely available to international scientific users for measuring and analyzing diagnostic parameters which describe vital processes on the Earth's surface.

Urban Gradients – Surface material composition from 30 m hyperspectral remote sensing data

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Future spaceborne imaging spectrometers such as EnMAP allow for the monitoring the Earth's surface and overcome the time- and cost critical limits of airborne based hyperspectral sensor systems. However, the spatial resolution of EnMAP is 30 m, which is in many cases not sufficient to provide essential information on urban areas and hampers methods that require pure pixel information. Despite the spectral and spatial complexity of urban settlements, characteristic materials can be found in the composition of similar urban structures such as industrial areas, residential areas and open spaces. This study presents a new concept for th analysis of spaceborne imaging spectroscopy data. The presented strategy presumes that the composition of material mixtures changes gradually across urban spaces and thus, gradient analyses applied to urban areas could be a suitable methodology to derive surface material compositions. This information is important for urban climate modeling and specifies the requirements to better describe urban canopy models.

This study focuses on 1) the adaptation of gradient analysis from vegetation ecology to analyze gradual material transitions in the composition of urban surface materials, 2) the mapping of these material gradients in simulated EnMAP data of Munich, Germany, to identify characteristic material compositions and 3) an initial test to transfer the gained results to areas without knowledge about material compositions. Results of the core test area demonstrate the co-occurrences of urban materials along two urban gradients, a rural-to-urban transition and a structural gradient. However, the same models are applied to an area that was not used to develop the regression models. That allows a first conclusion about the robustness and transferability of the gradients. The results demonstrate that even in spaceborne hyperspectral remote sensing data detailed structural information is retained, which for the first time enables the identification of characteristic material compositions in very complex spectral mixtures.

Monitoring Of Crop Nitrogen Status Using A Hybrid Inversion Scheme In The Context Of The Future Hyperspectral EnMAP Mission

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Nitrogen (N) is one of the most important key plant nutrients for agricultural production. To obtain highest yields possible, N-fertilization is often applied in higher amounts than required. This leads to excess levels of nitrate leaching into the ground water or dissolving into the atmosphere and thus posing a threat to environment and human health. Besides, within-field spatial variability of soil characteristics, typically occurring at sandy soils in rain-fed environments, can reinforce these negative effects. Thus, to increase N use efficiency and to reduce environmental impacts, a reliable spatial indicator of crop N status is needed to enable site-specific N applications.

As several satellite hyperspectral Earth observation (EO) missions are due to launch, biochemical and biophysical vegetation properties will soon be monitored over large regions with potentially higher accuracies than it is possible with today's multi-spectral systems. The future German "Environmental Mapping and Analysis Program" (EnMAP) will enable frequent (~4 days) access to high-quality spaceborne hyperspectral data from 2020 onwards. The sensor will provide VNIR to SWIR contiguous spectra assembled by approx. 240 narrow bands at 30 m spatial resolution. Accurate, robust and fast variable retrieval schemes are urgently needed to exploit this high spectral dimensionality. In the past, mainly empirical methods have been applied to estimate crop N content from hyperspectral data via proxies. The applied methods include parametric regressions, such as ratio vegetation indices, or linear non-parametric methods. Some recent studies successfully retrieved N by applying non-linear non-parametric methods, also referred to as machine learning regression algorithms (MLRA), such as random forest (RF) or artificial neural network (ANN) approaches. However, physically based retrieval of N content so far has rarely been carried out for agricultural crops. Therefore, in the actual study we present a hybrid retrieval scheme, combining a well-known radiative transfer model (PROSPECT-D + 4SAIL = PROSAIL) with a flexible and computational efficient MLRA. At first, a simulated training data set stored in a look-up table (LUT) was generated using a re-calibrated PROSPECT-D model for the purpose to estimate leaf protein, which can be directly converted to area-based leaf nitrogen content (N_{area}). A Gaussian processes regression (GPR) model was then trained by the LUT selecting beforehand the most informative EnMAP wavebands for crop N determination through principal component analysis (PCA). The accuracy of direct retrievals of crop N content of wheat and maize from a hyperspectral field experiment are assessed. Additionally, uncertainty intervals of the retrievals – required to assess the impact of errors of the products – are provided. By doing so, the study demonstrates and discusses a possible variable-specific retrieval scheme that can be implemented into the Agricultural Application Module of the EnMAP-Box software. Accuracy and transferability in space and time are a main focus of the EnMAP mission preparation and further research will be dedicated to this issue.

Quantitative Vegetation Mapping of California Ecosystems Using Simulated EnMAP Data

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With the forthcoming launches of the next generation of spaceborne imaging spectrometers, vegetation analyses of large geographic areas utilizing hyperspectral time series will be possible across diverse biomes and ecological gradients. To better understand how to utilize this unprecedented flow of high quality hyperspectral data, the HyspIRI Preparatory Science Campaign has been conducting AVIRIS airborne hyperspectral missions across much of southern California since 2013. Given appropriate pre-processing and end-to-end simulation, these data may be used in pre-flight analyses for several upcoming missions. This study investigates the application of machine learning methods for mapping vegetation fractions in the San Francisco Bay Area using seasonal 2013 AVIRIS imagery which has been simulated for EnMAP characteristics.

Initial atmospheric correction and orthorectification was conducted by NASA JPL, and EnMAP images were simulated from spring, summer, and fall surface reflectance images. Geometric accuracy was further refined through automated co-registration to contemporaneous Landsat imagery. A class-wise empirical brightness correction method was applied to account for varying BRDF effects exhibited by different land cover types and acquisition times. A spectral library of pure image endmembers was synthetically mixed and used to train Gaussian Process Regression (GPR) models. Sub-pixel vegetation class fractions were mapped for different hierarchical levels starting with vegetation vs non-vegetation and progressively distinguishing between woody and non-woody vegetation, trees and shrubs, and finally conifer and broadleaf trees.

GPRs were demonstrated to be an effective method for quantitative vegetation mapping in a heterogeneous landscape, and the additional geometric and brightness corrections were found to be important factors in generating accurate land cover maps. Mapping vegetation fractions was accomplished with low errors (RMSE = 9.22 %), and each increasing step of vegetation complexity was accompanied by an increase in error, with lowest accuracies observed when distinguishing broadleaf trees (RMSE = 27.4 %). For each hierarchical level, much of this error was observed to result from overestimations of near-zero fractions and underestimations of near-full fractions, a limitation not observed when applying a classifier. Visual assessment of the multi-season derived predictions showed much greater interpretability when compared to single date models, though only modest improvements in map accuracy were observed. This work highlights the utility of GPRs with synthetically mixed training libraries for mapping vegetation cover fractions at different hierarchical levels, as well as the need for consistent and high quality data if multi-temporal data is to be used for quantitative land cover mapping.

The Hyperspectral Sensors DESIS and EnMAP for Aquatic Ecosystems Monitoring – a Sensitivity Study

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The aquatic ecosystems of coastal and inland waters are more variable than the open ocean as water constituents and bottom substrates differ considerably in type, concentration and optical properties. Sensors with high spatial, spectral and radiometric resolution are therefore required to provide enough detail for mapping these highly complex environments. Two new hyperspectral Earth observation instruments, designed for monitoring spectrally complex areas, are the DLR Earth Sensing Imaging Spectrometer (DESIS) and the Environmental Mapping and Analysis Program (EnMAP). These hyperspectral sensors both cover a spectral range from 420 nm to 1000 nm in VNIR (and 900 nm -2450 nm in SWIR for EnMAP) and have a spatial resolution of 30 meters. DESIS was already launched to the ISS in summer 2018, EnMAP's launch date will be in 2020. The goal of the present study is to specifically evaluate the performance of DESIS and EnMAP over aquatic ecosystems based on their sensor specifications. For this purpose, a sensitivity study was conducted in order to explore the spectral and radiometric properties of DESIS and EnMAP in the context of optically deep and shallow water mapping. The optical water properties and benthic cover types were chosen to represent typical inland and coastal waters. Forward simulations of hyperspectral measurements were made using the Water Color Simulator software WASI to study the expected DESIS and EnMAP radiances and their signal-to-noise ratios (SNR) for different atmospheric conditions. The impact of sensor noise on the retrieval of water constituents, benthos types and water depth was analyzed by applying inverse modelling to these reflectance spectra. The study assesses the mapping potential and limitations of a DESIS and EnMAP type sensor for these complex environments, which are usually much darker than land surfaces.

UAS-1: Imaging spectroscopy from UAS

Wednesday 6 February 2019
Session Chair: Helge Aasen, Juliane Viktoria Bendig

Best Spatial Scale For Crop Classification Using Uncalibrated UAV Data

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Land cover maps of agricultural areas are of importance for monitoring and decision-making. Usually, crop cover is only reported after harvesting, which is a problem for accurate and timely planning, e.g. of water demands in different areas. Therefore, up-to-date information is essential.

To analyse the cultivated area covered by five different crop classes (cereal, grass, maize, rapeseed, sugar beet) in the small-scaled arable landscape in the Swiss Plateau, respective data sets were recorded with two uncalibrated consumer grade cameras on an unmanned aerial vehicle (UAV) with a spatial resolution of 0.05m. These datasets were composed into a single dataset with NIR-red-green-blue bands and resampled to a range of spatial and spectral resolutions at different acquisition dates. With these datasets we analysed the best spatial scale for different spectral subsets and amount of acquisition dates.

In order to compensate for the low spectral resolution of the UAV data, we added textural and morphological features, calculated based on varying structuring element sizes. The final classification process was based on a random forest (RF) classifier. In addition, we tested the improvement of the classification given the availability of parcel borders. The resulting classification maps were evaluated using overall accuracy, kappa coefficient, average accuracy and average reliability metrics.

Low-Altitude Multispectral Remote Sensing Disease Recognition in Maize

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Northern corn leaf blight (NCLB) caused by exserohilum turcicum is a plant disease that causes leaf spots on maize. This impairs photosynthesis and can lead to significant yield losses if infection takes place early (e.g. before flowering). Although fungicides have been developed, a more environmentally sound approach is to plant resistant maize genotypes. In order to recommend the best varieties, it is important to detect and quantify the outbreak of the disease on new hybrids. For the latter, the susceptibility of different maize genotypes to NCLB is rated several times during the vegetation period by a professional (Hooda et al., 2017). These ratings are very time-consuming and not fully objective and sometimes complicated by senescence or environmental stress.

In this contribution, we introduce first results of tracing spatio-temporal dynamics of maize-pathogen interaction with a multispectral camera on a UAV platform. In order to establish a UAV-based rating system of NCLB outbreaks in maize, multispectral data and high-resolution RGB data were compared with on-ground ratings of diseased maize plants. The data was collected on a maize variety trial at Agroscope at the Reckenholz site, Switzerland. 82 different maize varieties with each 3 replicates were planted in the trial. Each plot consisted of one row (4.5m x 0.75m). Infected plant material was dried, milled and distributed in the plots at approximately the 8-leaf stage of the maize plants. After the emergence of the first symptoms of NCLB on the maize plants, all the plots were rated twice a week on the ground by a professional.

For the image data, several flights with a fixed-wing UAV (WingtraOne) were performed. The UAV was equipped with a high-resolution RGB camera (Sony RX1RII, 42 megapixels) and a multispectral camera (Mica Sense Red-Edge M) with 5 bands 475nm (20 nm FWHM), 560nm (20 nm FWHM), 668nm (20 nm FWHM), 717 (10 nm FWHM), and 840 nm (40 nm FWHM). The flight height was 100 m (multispectral) and 50m (RGB) above ground, resulting in a spatial resolution of 6 cm, respectively 0.7 cm.

The data was radiometrically corrected using radiometric reference panels as well as a down-welling light sensor placed on top of the UAV. The scene was generated with Agisoft photoscan and georeferenced with 13 georeferenced (RTK) ground control points placed around the field. The resulting multilayer orthomosaics and digital surface models were further processed to retrieve the spectral signature and plant height of each plot. This data was combined in a segmentation approach to retrieve the spectral information of each row and the spectral information was compared to the visual rating (Aasen and Bareth, accepted).

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Using High Spatial Resolution Hyperspectral Imagery to Investigate Grassland Optical Diversity

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High spatial resolution imaging sensors have been recently used for the characterization of ecosystem structure, diversity, and to detect plant biodiversity based on the varying optical properties of different species or functional groups. The Specim IQ is a novel imaging sensor for in-situ observations which can collect very high resolution images (up to 1-mm^2 pixel size at 1.5 m height; wavelength range 400–1000 nm) and can be used to retrieve the optical-diversity at the ecosystem level. In this study, measurements were performed using the SPECIM IQ camera over different grassland canopies at the Viote del Monte Bondone grassland site (Italy; 46°00'N 11°02'E; 1480–1550 m a.s.l). The grasslands show a very wide range of LAI (varying from 0.4 to 7 m^2/m^2), productivity (31 – 735 g/m^2 green dry biomass), and an extreme range in species composition.

The focus of our study was to investigate the links between "optical diversity" and biodiversity-related plant traits within different grassland canopies. During the summer of 2018, we collected canopy-level hyperspectral images in various 25×25 cm^2 plots characterized by a different number of species. The species richness in the plots accessed by visual estimation by botanical expert and above ground phytomass was clipped which separated between green and non-green material and the green material further separated between legumes and non-leguminous plants. The biomass of oven-dried (at 65 °C for 72 h) samples were measured along with other leaf traits (SLA: Specific Leaf Area, leaf pigment).

We report here some preliminary results on the ability of high spatial and spectral resolution data collected in-situ to explore the links between optical and plant biodiversity in grasslands characterized by an extreme range of species richness (from a few species to more than 20 species per 25×25cm^2 plot). Results on Biodiversity-Productivity Relationships (BPRs) obtained by both in-situ and spectral observations are also described.

Modelling The Seasonal Traits Of Production Grasslands From UAV-Based Imaging Spectroscopy

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Sustainable use of grasslands in intensive farming systems aims to optimize fertilizer inputs to increase grass yields and decrease harmful losses to the environment at the same time. Previous studies have shown that imaging spectroscopy-based techniques are capable of quantifying both structural and chemical grassland traits which can be adopted to support grassland management. However, during the growing season, grassland growth and associated traits vary due to difference in phenological stages under influence of weather conditions (e.g., moisture) and agricultural practices (e.g. fertilization, grazing and irrigation). As a result, one prediction model for the whole growing season might not provide the best accuracy.

In this paper we have investigated to what extent the effects of site-specific fertilizer application on the structural and biochemical traits of grassland vegetation can be predicted by using UAV-acquired hyperspectral images for different observations during the growing season. Imaging spectroscopy data for 120 plots with a range of fertilizer application scenarios were collected from an experimental field at the farm Haus Riswick, near Kleve in Germany, for three different flight campaigns in May, August and October 2017 to cover the whole growing season (i.e. spring, summer and fall). Spectroscopy data were acquired with the Hyperspectral Mapping System (HYMSY) under an Octocopter UAV platform. Directly after the flights, for every plot field measurements of grass height (cm) and fresh and dry biomass (t/ha) were collected. While also samples were chemically analysed for nitrogen (N in kg/ha and %), crude protein, crude fibre and crude ash (all %). For the development of the prediction model, both narrow band vegetation indices and partial least squares (PLS) regression were evaluated by calculating the coefficient of determination (r^2) and the Root Mean Square Error (RMSE). The relationship between the grassland traits for the different time series and the individual narrowband VIs have been analyzed by linear regression The results show there is a division in the performance of biochemical traits and the performance of structural traits which have in general a higher r^2 value. Of the biochemical traits, N (kg/ha) has, in general, the highest r^2 value. N in kg/ha is a yield-based trait, in contrast with the other biochemical traits which are %-based indicating that yield based traits are more feasible to predict than %-based traits. The grass cut of October has the highest r^2 values, followed by May, then August and lastly the integrated dataset. Structural traits can easily be predicted using linear as compared to PLS regression models. However, the biochemical traits N and to a lesser degree N% can be relatively well predicted by PLSR methods. The prediction inaccuracy of August is probably also related to weather influences, since the period before August is characterized as hot and dry. As next step, additional analysis is required how the identified modelling approaches and additionally machine learning based approaches can be transformed to operational UAV services and how these can be scaled to relevant satellite sensors such as Sentinel-2.

Predicting Canopy Traits In Tree Diversity Experiments Using Drone-Based Hyperspectral Imagery

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Drone-based hyperspectral remote sensing presents a new opportunity for quantifying plant growth and canopy structure. However, most studies have focused on crop systems and few studies have tested the potential for drone-based hyperspectral remote sensing in forests, where variation in canopy structure with tree species and/or functional diversity is expected to be related to differences in aboveground productivity. At the the Kreintiz tree diversity experiment in Germany, we collected ground-based data on leaf nitrogen, chlorophyll, specific leaf area, leaf area index, tree height, and diameter, as well as drone-based hyperspectral imagery to explore relationships between leaf traits and spectral reflectance. Approximately 1500 individual leaf spectra across 14 plots (diversity ranging from 1–3 species) were measured using a FieldSpec 4 portable field spectrometer. Leaf area index was estimated using several common field methods at both the plot level and from litter traps at the species level. Leaf nitrogen of several individuals per species per plot was assessed in the lab. Drone hyperspectral imagery was collected using a Cubert S185 VNIR snapshot hyperspectral imager mounted on a UAV flown at 35m to achieve a ground resolution of ~12cm/pix. Ground data was utilized to create predictive models for nitrogen and leaf area index (LAI) at the canopy level using partial least squares regression (PLSR) as recent literature suggests that these two traits contribute primarily to assessing productivity. The traits predicted by spectroscopy were also assessed across the diversity gradient. Results from this study show the effectiveness of using spectra modeled with PLSR to quantify leaf percent nitrogen, chlorophyll, and LAI remotely, with correlation between individual ground sampled leaf spectra and drone-based canopy spectra, with promise for scaling up productivity estimation using remote sensing tools.

Wednesday 6 February 2019
Session Chair: Helge Aasen, Eija Honkavaara

Drone-based Forest Inventory In Different Seasons Using High Resolution RGB Cameras And Hyperspectral Imaging

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Drone-based remote sensing has proven to be efficient tool for various forestry applications, such forest inventory, forest health evaluation and monitoring forest growth. Drones are able to produce data with very high spatial resolution but the covered areas with single flight are limited to areas approximately below one km^2. In operational forest management the forest are often geographically scattered or larger than one km^2 requiring possibly multiple drone systems for operational usage with automate data analysis. Thus, cost-efficient drone systems, measurement planning, data processing and data analysis methods are needed.

At drone system level the cost-efficiency can be improved mostly by using low-cost sensor setups. Whereas in measurement planning and data processing, the cost-efficiency can be improved by collecting the minimum amount of data with as little time spent in post-processing as possible but still enabling the accuracy requirements for the data analysis and the final forest inventory end-products. The cost-efficiency of the data analysis can be improved by utilizing as much information that is available from the sensors and data collected, automation of data analysis and by computational efficiency.

This study presents results from drone-based forest inventory in boreal forest with automated data analysis procedure. Accuracies achieved using different sensor combinations and data analysis approaches will be compared. The multitemporal dataset for this study was collected in Hyytiälä, Finland, in 2017, with six flights between early March and late October. All the datasets were collected with a drone including one or two RGB cameras and a hyperspectral camera. The data is processed to point clouds and RGB and hyperspectral image mosaics.

The data analysis includes individual tree detection and species classification. The tree detection is performed using canopy height model derived from point cloud and the classification using feature-based machine learning with features including spectral features from hyperspectral data, 3D point cloud features from point clouds and RGB textural features from RGB imagery. Data analysis procedures and results using only RGB data will be compared with combination of RGB and hyperspectral data. In addition, the temporal aspects of data collection and analysis will be studied utilizing the multi-temporal dataset. Benefits of crown segmentation to simpler local maxima based method in individual tree detection and feature extraction will be evaluated by comparing computation efficiencies and gained accuracies.

Multi Modal Sensing Fosters Drone Application In Breeding: An Example On Sugar Beet Tolerance to Beet Cyst Nematode

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The rapid development of image-based phenotyping methods based on unmanned aerial vehicles (UAV) has increased our ability to evaluate traits of interest for crop breeding in the field. A field site infested with beet cyst nematode (BCN) and planted with four nematode susceptible cultivars and five tolerant cultivars was investigated at different times during the growing season. We compared the ability of spectral, hyperspectral, canopy height- and temperature information derived from handheld and UAV-borne sensors to discriminate susceptible and tolerant cultivars and to predict the final sugar beet yield. Spectral indices (SIs) related to chlorophyll, nitrogen or water allowed differentiating nematode susceptible and tolerant cultivars (cultivar type) from the same genetic background (breeder). Discrimination between the cultivar types was easier at advanced stages when the nematode pressure was stronger and the plants and canopies further developed. The canopy height (CH) allowed differentiating cultivar type as well but was much more efficient from the UAV compared to manual field assessment. Canopy temperatures also allowed ranking cultivars according to their nematode tolerance level. Combinations of SIs in multivariate analysis and decision trees improved differentiation of cultivar type and classification of genetic background. Thereby, SIs and canopy temperature proved to be suitable proxies

for sugar yield prediction. The spectral information derived the UAV-borne sensor allowed for discrimination between susceptible and tolerant cultivars. This was possible due to successful detection of traits related to BCN tolerance like chlorophyll, nitrogen and water content, which were reduced in cultivars with a low tolerance to BCN. The study shows the high potential of multi-sensor and parameter combinations for plant phenotyping purposes, in particular for data from UAV-borne sensors that allow for standardized and automated high-throughput data extraction procedures.

Introduction Of Variable Relations For Improved Retrieval Of LAI Through the Soil-Leaf-Canopy Model Inversion

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Accurate retrieval of vegetation attributes from remotely sensed data with deterministic physical models remains challenging. One major obstacle of using physical approach via radiative transfer models is the ill-posed inverse problem. To overcome this problem, regularization schemes have been developed for increasing the accuracy of vegetation attribute retrieval. The aim of this study was to evaluate the effect of introducing a variable relation on retrieved leaf area index. The Soil-Leaf-Canopy (SLC) model was used for Look up Table (LUT) generation. We compared two types of LUT, a standard LUT and the regularized LUT. For the regularized LUT, avariable relation between LAI and fCover was introduced from ground measurements collected over 27 plots of potato crop using the cholesky algorithm. Given a covariance between variables, the algorithm enables us to convert uncorrelated random variables to correlated variables through building LUT. The concept of cholesky decomposition is that the correlation matrix via its cholseky factor is decomposed into the product of a lower triangular matrix. Thus, the transpose matrix of lower triangular can be multiplied by random number of input parameters. As additional regularization means, multiple solutions and Gaussian noises were evaluated for standard and regularized LUT to achieve further improvement of estimations.

Results (using first 100 LAI solutions) revealed that the regularised LUT provided significantly better accuracies of retrieved LAI with a lower error (R^2= 0.77, NRMSE= 24.90% of mean) than the standard LUT (R^2= 0.69, NRMSE= 26.58% of mean). Even by adding 1% of Gaussian noise to the regularised LUT, the accuracy increased slightly over the standard LUT (from R^2= 0.72, NRMSE= 25.31 to R^2= 0.77, NRMSE= 24.64%). In conclusion, the novel algorithm proved to be a promising perspective to enhance the retrieval of biophysical parameters, which was inverted from aphysical radiative transfer model.

Assessment Of Downey Mildew Infection on Grapevine Using Hyperspectral In Situ and UAV Data

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Downey mildew is a widespread disease in viticulture with high economic impact, which is caused by Plasmopara viticola (Berk & Curtis). Especially in humid temperate areas, the disease may occur with very high intensity and the European cultivars are particularly susceptible.

Remote sensing based detection of downey mildew may support variable rate applications of fungicides. Furthermore, remote sensing techniques can help analysing the success of different treatments or resistant cultivars on experimental sites. However, very high spatial resolution is necessary for these applications. Nadir UAV (Unmanned Aerial Vehicles) images have shown to provide less information than side-looking imagery because of the row structures in vineyards (Retzlaff et al. 2016). Thus, side looking UAV images seem a promising option for a deep insight into the vine canopy very high spatial resolution. The suitability of hyperspectral data to detect downey mildew infections was shown already in a greenhouse experiment on leaf level by Oerke et al. (2016). In the presented study, the detection of different disease levels was tested at leaf and canopy levels, using hyperspectral in situ and UAV data.

In an experimental vineyard, plants of the cultivar Pinot Gris were infected with downey mildew by artificial inoculation. Six different treatments plus two control plots were tested with four repetitions. Every two weeks the spread of the infection was analysed. Single leaves were categorized and for each plot an infection severity was calculated based on the rating of 2 times 50 leaves. Seven infection ranges were defined according to the interest to wingegrowers (0, 1–5, 6–10, 11–25, 26–50, 51–75, 76–100), for whom the low infection leves are of high importance. In parallel, three leaves (abaxial and adaxial leaf side) per plot of all infection classes were measured with ASD leaf clip. Hyperspectral UAV data were acquired with the sensor GAMAYA OXI VNIR-40 in nadir and off-nadir direction. The leaf clip measurements were analysed by multivariate methods (PLSR and RandomForest) and several indices from literature have been tested. Additionally two band indices were analysed, based on the highest correlation between a normalized difference and infection level. The UAV data were radiometrically corrected using an empirical line correction.

The spectra of infected leaves showed clear differences to healthy leaves even when the disease level was low (<11%). Infection classes could clearly be separated with the different indices at the in situ level. At both levels, leaf and canopy, the correlation based index (825 and 634 nm) and the photochemical reflectance index (PRI) showed the highest correlation (0.67 & 0.64 (correlation based), R2=0.70 & 0.52 (PRI), respectively). At the canopy level, the infection severity could predicted with an RMSE of 8.96% disease level. High infection severity showed higher correlation with the correlation based index (R2=0.5) then low infection severity (R2=0.2).

Downey mildew infection is detectable with hyperspectral data. At in situ level even low disease levels could be detected. However, at canopy level the structural influences limit the detection of lower infection rates and only more severe disease levels can be identified reliably.

Hyperspectral Ortho-Mosaic From UAV-Borne Hyperspectral Imagery For Discriminating Different Grassland Management Regimes

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Grassland ecosystems are valuable providers of ecosystem services such as food provision and carbon sequestration. However, grassland plant communities differ and so does their contribution to ecosystem services. While some grassland types are for example rich in biodiversity, others such as intensively used sown grasslands are poor in biodiversity. Therefore, the identification of the different grassland plant communities is important for evaluating grassland ecosystem services. Hyperspectral (HS) remote sensing plays a significant role in discriminating grassland types. In this study, we used HS snapshot camera image cubes from an unmanned aerial vehicle (UAV) i) to create single HS ortho-mosaic, ii) to develop a model for differentiating grassland types using HS data. UAV-borne HS image cubes were collected from Cubert UHD-185 snapshot camera over four different grasslands in Witzenhausen, Germany just before their first cut. The images were processed to generate single HS ortho-mosaic. To evaluate the effect of the ortho-mosaicking process, the reflectance values of a white calibration plate were used. Reflectance value for twenty sub-sample plots from each grassland were extracted from HS ortho-mosaic for discriminant analysis. Original spectral reflectance and normalised continuum removal reflectance values from four grasslands were utilised to calibrate partial least square (PLS) machine learning algorithm-based discriminant model with repeated cross-validation. Results showed that original reflectance values were changed only slightly (±5%) during the ortho-mosaicking process. Discriminant analyses resulted 0.97 overall classification accuracy (kappa = 0.96) for original reflectance data while 0.90 (kappa = 0.87) for continuum removed reflectance for validation data set. This study demonstrated data from HS snapshot camera images can effectively discriminate between different grassland management regimes. Further, UAV-borne HS data have shown an advantage over field spectroscopy for grassland monitoring in large areas.

EUFAR: Special session on EUFAR

Wednesday 6 February 2019
Session Chair: Jan Hanuš, Stefanie Holzwarth

10 Years of Airborne Imaging Spectroscopy within EUFAR, the European Facility for Airborne Research

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Since its creation in 2000, the European Facility for Airborne Research, EUFAR, evolved into the central network for the airborne research community in Europe. From the beginning until 2018, EUFAR has received funding within the different Framework Programmes of the European Commission. In January 2018, EUFAR became an AISBL (international non-profit association under Belgian law) establishing EUFAR as an independent legal structure and ensuring EUFAR's future.

In 2008, the prominence of hyperspectral remote sensing increased due to joining of the former HYRESSA (HYperspectral REmote Sensing in Europe specific Support Actions) consortium. Via EUFAR Transnational Access, different hyperspectral cameras have been made available to European researchers who do not have access to a suitable research infrastructure in their home country. In order that researchers should continue in future to have access to the most appropriate research aircraft and instrumentation to meet their science objectives independently of EC funding, EUFAR is now working to develop principles of Open Access (OA).

EUFAR also offers the platform to exchange knowledge and promote best practice in airborne research through Expert Working Groups, of which several relate to issues of hyperspectral remote sensing (e.g. hyperspectral data processing, hyperspectral applications for soil, calibration and validation). Several training courses organized for the next-generation researchers have covered different scientific topics dealing with hyperspectral remote sensing.

This presentation will give an overview of EUFAR and its achievements for the hyperspectral research community within the last 10 years.

Airborne Remote Sensing For Monitoring Essential Biodiversity Variables In Forest Ecosystems (RS4forestEBV): A EUFAR Summer School

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Forest management requires the use of comprehensive remote sensing data which enable monitoring of biodiversity changes. Biophysical and biochemical vegetation parameters can characterize changes in biodiversity through changes in ecosystem structure and function. To address this need the University of Twente, Faculty ITC (the Netherlands) in collaboration with the Bavarian Forest National Park and the German Aerospace Center, (DLR) in Oberpfaffenhofen coordinated a summer school in July 2017. The two weeks of summer school was funded by EUFAR and was hosted by the Bavarian Forest National Park and DLR. The 19 participants of the summer school were PhD students and post-docs from 10 EU member states. The summer school offered the field expertise as well as the technical skills to understand and measure a number of essential biodiversity variables (EBVs) in forest ecosystems. Further, the students learned how to process the hyperspectral, thermal, and LiDAR data for the estimation of EBVs. The course contained two days of fieldwork in the Bavarian Forest National Park, and the participants of different themes (Hyperspectral, Thermal, LiDAR) were trained how to perform field measurements of various EBVs in a forest ecosystem. Further, the course participants were taught how to conduct field spectroscopy, thermal spectrometry, and terrestrial LiDAR measurements. Concurrent to the time of field measurements an airborne campaign with the NERC Airborne Research Facility (NERC-ARF) was organized that simultaneously acquired hyperspectral as well as thermal-infrared imaging data using the Specim AISA Fenix and Owl systems, respectively. The second half of the summer school was parallel with the ICARE 2017 conference, and the course participants visited the aircraft exhibition and were welcomed by the airborne research and operator community.

Use of Bi-Temporal Hyperspectral Imagery to Determine the Influence of Soil Degradation on Rainfed Crop Yield

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Bi-temporal hyperspectral data acquired at different seasons over agricultural areas provide the means to derive relevant plant biophysical properties during the growing season, as well as determine soil properties, when the soils are exposed, e.g. during fallow or after harvesting. This combined information can give a detailed insight to interrelated processes of the bio- and pedosphere. For example, to map crop stress caused by soil degradation as shown in this study. In the Mediterranean region cultivation and land use practices have a long history exploiting soils as a natural resource. The soils are an essential factor contributing to agricultural production of rainfed crops such as cereals, olive groves and vineyards. Inadequate land management is endangering soil quality and productivity, and in turn crop quality and productivity are affected. Therefore, the main objective of this work is to map soil and crop variability related to crop stress and land management practices within a Mediterranean environment based on hyperspectral data within the visible, near-infrared, short-wave infrared as well as thermal infrared (0.4–12 µm) and test the transferability of the methods used to future hyperspectral space-borne sensors such as EnMAP, PRISMA, SHALOM, HISUI, SBG. In this study, CASI and AHS hyperspectral imagery was used that was obtained through a Transnational Access grant from the European Facility for Airborne Research (EUFAR) for the project Mapping SOil variability within rainfed MEDiterranean agroecosystems using hyperspectral data – MASOMED. The data was acquired in 2017 during the growing season within the Camarena agricultural area in central Spain. The area is characterized by a Mediterranean climate, a gently undulating relief, evolved soils and traditional rainfed agriculture. Tillage erosion as a result of plowing practices, as well as occasional events of water erosion determine the presence of different soil horizons appearing at the surface, with contrasting soil properties that have previously been characterized using hyperspectral VNIR-SWIR AisaEAGLE and AisaHAWK imagery of the same field in a fallow state in 2011. Simultaneous to the airborne acquisitions, intensive field campaigns took place for the characterization of soil and crop variability. This included field spectroradiometry measurements of the different surface covers and during the 2017 campaign, additional vegetation parameters were determined such as Leaf Area Index (LAI), fractional Photosynthetically Active Radiation (fPAR), leaf chlorophyll content and plant biomass. These vegetation parameters are related to soil degradation stages of selected test sites. First results indicate a strong link between soil parameters, erosion stage and plant vitality. In particular, low crop yields are associated with 1) highly eroded areas, where exposure of the calcite rich bedrock can cause deficiency in nutrient uptake and 2) very sandy accumulation areas that are depleted in nutrients and have low potential for water retention. Whereas highest crop yields are associated with clay and iron rich, moderately eroded soils. This study integrates soil and vegetation analysis of the optical VNIR-SWIR-TIR spectral domain and present preliminary results that show, for this Mediterranean agroecosystem affected by soil degradation, the strong influence of soil quality on crop variability and production.

HYLIGHT Activity and Biomass Mapper Tool

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The joint research activity (JRA) HYLIGHT was part of the EUFAR2 project (2014–2018). The objective of the JRA HYLIGHT was to find synergies between hyperspectral imaging (HSI) and airborne laser scanning (ALS) to improve the processing and analysis of both data types. Within the HYLIGHT, where nine institutions from nine countries were involved, were developed three tools for combined analysis of HSI and ALS data, two tools for improved processing of ALS data using HSI data and eight tools for improving HSI data processing by means of using ALS data.

As an example of the HYLIGHT tools the Biomass Mapper tool developed by CzechGlobe will be presented in this contribution. The Biomass Mapper was designed to estimate individual tree biomass based on concurrent airborne HSI and ALS data. The HSI and ALS data are used to detect individual trees and retrieve their tree height and biomass estimation is based on species-specific, pre-defined allometric equations. Although the species-specific allometric equations are predefined a user can define and use own equations. The main outputs of the software include position of single trees, estimated above ground biomass for a single tree, as well as for a selected area of interest.

This contribution presents an overview of HYLIGHT results with special focus on the Biomass Mapper tool.

VEG-1: Spectroscopy of vegetation

Wednesday 6 February 2019
Session Chair: Petr Lukeš, Miina Rautiainen

A Novel Dataset For Testing Physical Reflectance Models Of Trees

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An understanding of multiangular spectral properties of trees is needed for physical interpretation of remote sensing data. Data from airborne spectroscopy contains effects of background (forest floor) and the atmosphere. Laboratory experiments, although limited in maximum tree size, are suitable for examining tree spectra that are almost free from these confounding effects. We present a dataset comprising multiangular spectra of small trees of different species measured with the FIGOS/LAGOS goniometer in the Remote Sensing Laboratories at University of Zürich, Switzerland during 2018. To support interpretation of the multiangular spectra we measured leaf optical properties and structural properties of trees. Bark spectral properties were also measured for selected trees. The dataset can be used for testing models which characterize directional and hemispherical reflectance of trees. In this conference presentation we will present the dataset, describe details of its acquisition, and show initial results related to modeling of tree spectra.

Vegetation Functional Photoprotection Dynamics Seen From Leaf Absorbance Features

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With ESA's upcoming Fluorescence Explorer (FLEX), not only the retrieval of solar-induced fluorescence (F) becomes a new opportunity for understanding plant functional behaviour, also the photoprotection dynamics can potentially be further understood. The Fluorescence Imaging Spectrometer (FLORIS) on board of FLEX will cover the 500–780 nm range with a bandwidth between 0.1 nm and 2 nm, with a 1 nm spectral resolution in the region of photoprotection dynamics (500–600 nm). Photoprotection dynamics are commonly measured with the Photochemical Reflectance Index (PRI), but this index is prone to several dynamics in the short diurnal term, which could be separated in light avoidance strategies and light photoprotection strategies taking place during light adaptation. To understand these plant dynamical light strategies, hyperspectral vegetation monitoring provides new opportunities, as single dynamical absorbance features might be decoupled when accurately isolated at the functional leaf level.

When exposed to excessive light, several controlled photoprotection mechanisms can be activated in the pigment bed. We studied spectrally contiguous (hyperspectral) transient reflectance and transmittance dynamics of intact leaves by two spectroradiometers (ASD FieldSpec, Handheld) after sudden strong natural illumination exposure under natural-like illumination conditions. During this sudden light adaptation period several dynamic absorbance events related to controlled photoprotection mechanisms occurred. Besides the common absorbance feature related to the chemical xanthophyll conversion, responsible for a linear PRI decrease, several additional overlapping absorbance features were present. Strong conformational pigment bed changes appear to be responsible for a significant reflectance change under stress. The characterization of such fine spectral absorbance features is a further step in the understanding of dynamic plant photoprotection. High spectral resolution in the visible wavelengths of the imaging spectrometers are hence crucial to monitor the functional state of vegetation, and can, in further combination with fluorescence, reveal more on the dynamics of Earth's vegetation functioning.

After this Talk You will always map Leaf Pigment Content and not Concentration

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Plants on the earth surface are indispensable for the production of oxygen and organic matter through photosynthesis. Photosynthetic activity is determined by pigments which absorb solar radiation in the visible wavelengths. Accordingly,

optical remote sensing evolved as an important technology to map variation of pigments such as chlorophyll, carotenoids or anthocyanins. Pigments are usually quantified using either pigment content (i.e. pigment mass per leaf area [µg/cm²]) or pigment concentration (i.e. pigment mass per leaf mass [g/g]). It appears inconclusive which metric to choose, since both metrics are frequently used in the remote sensing community. Moreover, corresponding studies commonly do not justify why either of the metrics was applied. We argue that quantifying pigment concentrations is unsubstantial as 1) pigment concentration predominantly reflects variation in leaf mass per area (LMA) and not pigments per se, 2) in comparison to pigment content the retrieval of pigment concentration is less accurate and 3) pigment concentration cannot be easily scaled to the canopy scale. We thus conclude that remote sensing of pigment content is more appropriate due to its direct relevance for radiative transfer, enhanced scalability and as being a more explicit expression of plant stress and functioning.

Seasonal Course of Leaf Optical Properties and Traits – Linking Structure with Leaf Dorsiventral Reflectance

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Forest top-of-canopy reflectance (TOC) observed by remote sensing instruments is driven by wide range of parameters, including optical properties of leaves, understory and bark together with the structural properties of the forest – spatial distribution of leaves and branches in the canopy. In addition, the instantaneous observation geometry (e.g. the sun and sensor zenith and azimuth angles) largely influences the observed TOC due to the changes in shadow fraction in the canopies. As a result, forest TOC is highly dynamic, following the seasonal patterns of optical and structural properties.

From the abovementioned, the leaf optical properties are the most important. They hold an information on leaf biochemical (chlorophyll and carotenoid content, water content) and structural (leaf thickness, distribution of pigments within a leaf) properties on leaf level. Whereas biochemical effects on leaf reflectance is well understood, the role of leaf internal structure on dorsiventral (two-sided) leaf optical properties asymmetry has been neglected, assuming equal optical properties on both leaf sides. Moreover, leaf optical properties are rarely measured in time, typically focusing on peak vegetation growing season.

In this study, we follow the seasonal trends in leaf-level optical, biochemical and structural properties of five common broadleaved tree species of Central Europe (Populus tremula, Salix caprea, Betula pendula, Alnus glutinosa and Alnus incana). We link their optical properties (e.g. reflectance difference of adaxial and abaxial leaf side, reflectance to transmittance ratio, fraction of specular to total leaf reflectance) with the laboratory analyses of inner leaf structures for contrasting phenological stages from spring to fall. This allowed us to quantify both species and seasonal differences of leaf dorsiventral optical properties and the role of inner leaf structure. Next, we up-scale measured leaf-level dorsiventral optical properties to canopy level using Discrete Anisotropic Radiative Transfer model (DART) for three contrasting vegetation stages – early spring (DOY 115), summer (DOY 212) and fall (DOY 285) to quantify the impact of leaf optical properties parametrization (i.e. assuming equal optical properties on both sides, or dorsiventral leaf optical properties asymmetry) for forest of different species composition, vegetation stage and observation geometries. Finally, we discuss the influence of dorsiventral leaf optical properties parametrization on forest reflectance simulations on forest quantitative product retrievals.

Understanding Dynamics of Leaf Spectral Properties Under Bark Beetle (Ips typographus, L.) Infestation

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Understanding the temporal responses of leaf biochemical and spectral properties under bark beetle infestation provides critical information to identify the infested trees, and could have positive implications for the forest management practice. Nevertheless, the impact of bark beetle infestation on foliar properties across the green to red attack stage is poorly

understood. Here, we explored the temporal response of Norway spruce needles to bark beetle infestation from green to red attack stage in the Bavarian Forest National Park in Germany. An extensive field survey was conducted in the national park in the early summer of 2015 to collect leaf samples from 120 healthy and infested trees. The spectral reflectance of the leaf samples were measured using an ASD FieldSpec3 equipped with an integrating sphere, and foliar biochemical properties (nitrogen, chlorophyll and water content) were studied at three sequential measurements, from mid-May to mid-July. Our results demonstrated that all measured leaf traits had significantly higher values ($p < 0.05$) in the healthy samples compared with the infested ones, and the existing difference between healthy and infested samples increased by the infestation progress. The most pronounced differences ($p < 0.05$) between the mean reflectance spectra of healthy and infested needle samples were found in the NIR and SWIR regions (between 730 and 1370 nm). This observation demonstrated that spectral bands from red-edge and SWIR regions can be used more-targeted to detect bark beetle infestation in the early phase. Our findings have important implications for bark beetle studies that aimed to detect and monitor early stages of bark beetle infestation using remotely sensed data.

VEG-2: Spectroscopy of vegetation

Thursday 7 February 2019
Session Chair: Alexander Damm, Philip Townsend

LAI And Cab Retrieval From The Synergetic Use Of OLCI And FLORIS Reflectances

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Photosynthesis is one of the major processes controlling land-atmosphere CO_2 exchange. The photosynthetic capacity of plant ecosystems is largely a function of available leaf area (LAI) and chlorophyll content (Cab). These biophysical parameters can be accurately inferred by hybrid retrieval schemes combining non-parametric Machine Learning Regression Algorithms (MLRAs) and vegetation Radiative Transfer Models (RTMs). This study is conducted in the framework of the forthcoming ESA's FLEX-Sentinel-3 (S3) tandem mission and is therefore based on simulated spectral data from following sensors: (1) the hyperspectral imager (FLORIS), which will be mounted on the FLEX satellite and will measure the vegetation spectral response in the range between 500 nm and 780 nm, at a high spatial resolution (1nm) and (2) the imaging spectrometer (OLCI) which is already installed on the S3 satellite and has a spectral definition (21 bands between 400 and 1020 nm) that was specifically designed to characterize the atmosphere (aerosol composition, water vapour and illumination conditions) and to retrieve biophysical parameters like LAI and Cab. OLCI and FLORIS Top-Of-Canopy (TOC) reflectances are simulated with a RTM and subsequently contaminated with a specific amount of Gaussian noise. The resulting database of vegetation properties and corresponding TOC reflectances, covering a wide range of canopy realisations, is then used to train the MLRA and generate the retrieval models. These models are based on either OLCI reflectances alone, on FLORIS reflectances alone, or on the combined reflectances of both instruments. The trained models are then validated on reference images which are simulated with an Automated Scene Generator Module (A-SGM). For Cab, the OLCI spectral data alone give reasonable model performances despite the limited number of bands involved (R^2: 0.89; relative RMSE: 17.5%). The use of FLORIS data alone, however, improves greatly the results (R^2: 0.97; relative RMSE: 8.9%). Further, adding together the OLCI and the FLORIS spectra does not significantly improve the results (R^2: 0.96; relative RMSE: 8.3%). Regarding LAI, the improvement of the model performances by using only FLORIS spectra (R^2: 0.82; relative RMSE: 30.7%) rather than only OLCI spectra (R^2: 0.77; relative RMSE: 35.1%) is less obvious but the synergy of both datasets is more advantageous (R^2: 0.86; relative RMSE: 27.8%). Our simulation results show that the synergetic use of both sensors can lead to more robust models for the retrieval of primary biophysical variables.

Intra-Annual Multi-Temporal Hyperspectral Data for Tree Species Classification of an Extensive Forest Area

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Novel remote sensing techniques enable obtaining information about tree species composition, which is one of the most frequently required forest inventory parameter. Applying hyperspectral images has been found as an effective technique to reach that target. While former studies tend to be method-oriented and focus on local scales, tree species composition has been hardly retrieved for wide and diverse areas. Moreover, the use of multi-temporal hyperspectral dataset, which might boost the performance of the classification has still been rarely examined.

Here, we examined a complex and extensive forest area, covering 62 000 ha, namely the Polish part of the Białowieża Forest. The forest is a UNESCO World Heritage Site. It is the most diverse forest in Poland with a mosaic of different site conditions, stocked with varying dominant species, stands with a different number of forest layers and diverse tree age classes. Remote sensing analyses of such a heterogeneous area are highly challenging.

To capture phenological differences among temperate species we used 3 sets of HySpex (VNIR-1800 & SWIR-384) images acquired in different stages (July, August and October) of phenological development. Each of the datasets consists of 40 stripes. The classification was executed using the SVM algorithm. We considered 7 dominant species: Pine, Spruce, Oak, Hornbeam, Birch, Alder, Lime and a summarizing class of other-broadleaved trees. We classified each set of images separately. Accuracies of the classifications were assessed using 100 iterations (split into 70% – training data, 30% – testing).

To produce a final map of dominant species, we developed apixel-voting approach to combine the results of the 3 periods. Merging the results of 3 classifications into one thematic species map effected in the higher correctness of species recognition. We conclude that applying the multi-temporal dataset that captures phenological changes in vegetation is justified as it improves classification results.

Spectral Invariants in Remote Sensing of Vegetation

MATTI MÕTTUS

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The theory of spectral invariants is based on the simple notion that the reflectance of a vegetation canopy between 710 and 790 nm, quantified using its Bidirection Reflectance Function (BRF), follows a simple relationship: $BRF/\omega = pBRF + \rho$, where where p and ρ are two spectrally invariant parameters, and ω is the leaf albedo. The two parameters can be obtained by fitting a straight line through BRF/ω plotted against BRF. If no prior knowledge of leaf albedo is available, "reference leaf albedo" derivable from the standard PROPSECT leaf reflectance model can be used.

The spectal invariants are fully compatible with the more traditional equation of radiative transfer and provide a new way to look at radiative transfer in vegetation. In an early form, spectral invariants are used for producing the popular MODIS Leaf Area Index product; recently, they were used in products derived from NASA's DSCOVR EPIC data.

The interpretations of two parameters of the spectral invariants' equation are related to the radiative transfer theory and the photon recollision probability. However, they can also be used to efficiently decompose the measured spectral reflectance signal into first-order and higher-order components. The weights of the components depend on the light (incident irradiance) conditions on average leaf: the contributions of direct and diffuse illumination. First-order scattering, provided by the direct beam scattered towards the sensor, also explicitly depends on observation geometry, and can have a strong specular component caused by the wax layer on leaf surfaces. The key variable quantifying (the average) light conditions in a spectral image of vegetation is the sunlit fraction α_S, or the fraction of visible foliage which is sunlit inside the instantaneous field of view of the sensor. The sunlit fraction α_S can be calculated from the fitted parameter ρ as: $\alpha_S = \rho\cos\theta_S$, where θ_S is the solar zenith angle. Further, the quantity pBRF is the diffuse irradiace on the average leaf surface.

The decomposition of of reflected radiance and incident irradiation can be applied to scaling from canopy to leaf spectrum. We demonstrate this using the photochemical reflectance index (PRI) which is known to be heavily affected by canopy structure and observation geometry. Extraction of first-order scattering from the remotely sensed signal allows to correct PRI time series for variations in solar angle, and detect PRI variations caused by the scattering anisotropy of pine needles.

The theory of spectral invariants is a promising approach for computer-efficient physically-based analysis of vegetation reflectance spectra. By allowing to extract the first-order scattering component caused by the direct beam, it allows to infer the optical properties of leaves from those of a canopy. Further research is needed on the limits of the applicability of the theory (in terms of spectral regions and canopy types) and the influence of leaf scattering anisotropy on the scaling results.

LiDAR Data Improves Predictions Of Canopy N And P Concentrations From Imaging Spectroscopy

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Imaging spectroscopy has been applied to map chemical leaf traits at the canopy level. However, varying structural canopy properties negatively affect the ability to predict leaf biochemical traits in complex canopies, e.g., in forests. Here, we mapped canopy level leaf nitrogen (N_{mass}) and phosphorus concentrations (P_{mass}) of a temperate mixed forest applying imaging spectroscopy data. We tested whether structural variables derived from airborne laser scanning (LiDAR), can improve predictions of N_{mass} and P_{mass} by delivering information on canopy structure. We trained partial least squares regression (PLSR) models to relate community weighted means of P_{mass} and N_{mass} with 245 hyperspectral bands (426–2425 nm) and 38 LiDAR-derived variables. The model results showed that LiDAR-derived variables improved predictions for both, N_{mass} (R2 cv 0.31 vs. 0.41, % RSMEcv 3.3 vs. 3.0) and Pmass (R2 cv 0.45 vs. 0.63, % RSMEcv 15.3 vs. 12.5). We found a negative relation between the performance of N_{mass} models trained with hyperspectral bands only and increasing structural heterogeneity included in the calibration dataset. The important contribution of canopy structure was further stressed by the PLSR models trained with only LiDAR data. These reached $R2_{cv}$ values of 0.26 for N_{mass} and 0.54 for P_{mass} indicating considerable covariation between biochemical traits and forest structural properties. Having a closer look at the specific canopy variables, we found P_{mass} was negatively related to stand height and to the total cover of tree canopies, whereas N_{mass} was negatively related to the spatial heterogeneity of canopy density. The high importance of structural variables in our study may partly be explained by the presence of two tree species featuring structural and biochemical properties different from co-occurring species. Still, it is likely that functional linkages between structure and biochemistry at the leaf and canopy level are a general phenomenon which enables the application of canopy structure as an important variable to support the mapping of leaf biochemistry over broad spatial extents.

NEON Imaging Spectroscopy: Characterizing Fine-Scale Vegetation Function at the Continental Scale

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The National Ecological Observatory Network (NEON) is a nationwide set of field sites intended to be representative of the ecosystems the United States. Over 30 years, each of 70 sites within the 20 eco-climatic domains will be measured to fully characterize changing ecological processes within those domains. A key feature of the NEON experiment is the Airborne Observation Platform (AOP), which will fly over most sites annually, collecting waveform lidar and 400–2500 nm imaging spectroscopy data with an AVIRIS-NG type instrument. Imaging spectroscopy data provide an unprecedented opportunity to assess within- and across-biome variation in functional diversity. Using >1000 field plots across three years (2016–2018) covering most biomes of the US, we map a set of 20 foliar traits related to chemistry, physiology and defense from the imaging spectroscopy data with less than 15% validation uncertainty, including chlorophyll and carotenoids, leaf mass per area, a range of phenolics, leaf structural compounds, nitrogen and several macro- and micronutrients. Analyses across all NEON domains indicate a broad range of trait variability, with the imaging spectroscopy data able to accurately represent the envelope of trait variation represented in the field data. Multivariate trait-variation is broad across all biomes, but our results also indicate that some biomes exhibit within-domain functional trait variability that approaches the variability apparent across all domains. From an imaging spectroscopy perspective, principal components analyses show that image-derived traits capture a high level of dimensionality in comparison to raw spectral data, indicating that algorithms for trait mapping utilize minor features in the spectral data that coarse analyses of hyperspectral data likely ignore. From an ecological perspective, the results show that imaging spectroscopy offers an effective approach to map functional variation where collection of comprehensive field data is impractical.

VEG-3: Spectroscopy of vegetation

Thursday 7 February 2019
Session Chair: Jan Clevers, Roshanak Darvishzadeh

The Optical Profile Of Herbaceous Plant Functional Types

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Our ability to measure plant functioning is essential for better understanding and monitoring ecosystems experiencing environmental and biodiversity changes. To do so, the vegetation status is often described in terms of plant functional types, i.e. collections of species with similar functioning. Although this is typically done by adopting a priori classification schemes (e.g. growth forms and strategy types according to Grime's CSR), these do not necessarily relate best to ecosystem functioning. Instead, post hoc grouping of species, based on their traits relevant for community assembly or ecosystems properties and processes, might provide more insights in the ecosystem's responses and effects. Because these traits also determine the optical properties of plants, it has been suggested that functional types can be distinguished from spectral observations (e.g. optical types (Ustin & Gamon, 2010) and spectranomics (Asner & Martin, 2009)). Today, both functional and optical approaches have mainly been applied to understand global-scale patterns and trade-offs between species, but there is some uncertainty whether the same mechanisms play at local scales. Moreover, in this domain there is a lack of profound comparisons of functional and optical outputs, aiming at a true evaluation of remote sensing data and techniques. In this study we explored the potential of hyperspectral data to assess ecological relationships between 37 herbaceous species dominantly occurring in 11 abandoned and protected communities across Belgium. We measured their hyperspectral signatures, and a range of functional traits describing fundamental plant form and function, resulting in a total of 71 paired observations. Functional traits were selected according to the leaf-height-seed (LHS) plant ecology strategy scheme of Westoby (1998) and the Leaf Economic Spectrum (LES; Wright et al. 2004). Optical traits (i.e. functional traits which can be readily estimated from spectral data), were estimated by calculating a set of vegetation indices (VI) and using a hybrid approach combining PROSAIL and random forest regression (Feilhauer et al. 2016). Emergent functional groups were delineated based on agglomerative hierarchical clustering (Euclidean distance and minimum variance clustering (Ward, 1963)) of the observations in the LHS and LES trait space. Similarly, optical groups were defined by clustering the observations in both the VI and PROSAIL optical trait space. Principal component analysis revealed that the main variability between the observations could be attributed to traits from LES (e.g. SLA, leaf nitrogen content) (PC1 38.5% explained variance), followed by traits describing competitive ability and capacity for sexual regeneration (e.g. plant height, seed weight) (PC2 26.4 % explained variance). In this spectrum of ecological trade-offs, ten functional clusters were identified, separating amongst others grasses, competitive forbs, climbing herbs, and invasive alien forbs. Although this clustering did not correspond directly to its optical equivalent (cophenetic correlation = 0.32, Adjusted Rand Index = 0.18, Fowlkes-Mallows Index = 0.27), each functional group had a unique optical profile. This suggests that hyperspectral data is indeed capable of distinguishing the different plant functional types. Yet, to fully understand the underlying mechanisms and exploit the potential of hyperspectral data further exploration is ongoing.

Correction of Spatial Autocorrelation for Comparison of Regional Statistics: a Case Study on Alluvial Vegetation

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Spatial autocorrelation, inherent to any geographical data, hinders the use of conventional statistical tools based on the assumption of independence. To address this issue, the statistical community has produced an extensive literature on modelling of spatial autocorrelation. While it is common for geographers and ecologists to acknowledge the presence of autocorrelation in data and to quantify it, spatial autocorrelation is rarely considered in remotely sensed images. Moreover, a large gap is still present between the mathematical tools available to model data dependency and their actual use on real geographical datasets.

In our study, we used Student's tests to compare plant traits distribution over multiple river systems. The tests were carried out on maps of eleven plant traits retrieved by imaging spectroscopy. The plant traits were predicted over patches of willow communities along three river systems, forming dense homogeneous areas ideal for a remotely sensed analysis.

The prediction of plant traits was modelled by a PLSR based on 100 ground samples for each trait. We calculated an effective sample size (ESS) to correct the tests for the redundant information present in the datasets. The main consequence of this correction is a reduction of type I error by a decrease of the degree of freedom. An approach using a semi-variogram was used to model spatial autocorrelation based on Griffith [1]. Since the calculation of the ESS based on this approach is computationally expensive, we incrementally increased the number of points considered for the calculation. The increase of ESS with respect to the number of considered points showed a linear relationship. We therefore fitted a linear regression on these two quantities to calculate the ESS for the whole dataset.

The results of the correction showed a drop from the raw sample size to the effective sample size of a factor of 12 to 60. The null hypothesis states here that the average of a plant trait is similar among the rivers. Without the correction, 4 statistical tests out of 66 lead to the rejection of the null hypothesis. With the correction, an additional 11 Student's tests, for a total of 15 out of 66, lead to rejection of the null hypothesis. The correction of the Student's test had a substantial impact on the result of the study. Without the correction, two of the river systems would have been described as different from an ecological point of view, while they are not using the correction.

In brief, our case study shows that the acknowledgment and the quantification of autocorrelation in geographical data is not sufficient to extract evidences from the data without properly including the data dependency in the statistical model. Nevertheless, the tools offered today by statisticians are becoming widely available to the community and should be applied on a regular basis.

[1] D. A. Griffith, Effective geographic sample size in the presence of spatial autocorrelation, Annals of the Association of American Geographers 95 (4) (2005) 740–760

Comparison Of Object-based And Pixel-based Random Forest Algorithm For Tree Species Classification Using Airborne APEX Hyperspectral Imagery

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Tree species composition is an important key element for biodiversity and hyperspectral data provide detailed spectral information, which can be used for tree species classification. There are two main challenges for using hyperspectral imagery: a) Hughes phenomena, meaning by increasing the number of bands, the number of required classification samples would increase exponentially, and b) in a more complex environment, focusing on spectral variability per pixel may not be adequate for definability of tree species. The focus of this study is to compare object-based image analysis and pixel-based classification to assess the definability of uniform-tree stands using airborne hyperspectral imagery. A study area is a riparian mixed forest located along the Salzach floodplain, at the North-West of the city Salzburg. The forested area is a mixture of dominant and plantation trees, water bodies and wetlands, agricultures, buildings and industrial areas. Six tree species including Picea abies, Populus (canadensis and balsamifera), Fraxinus excelsior, Alnus incana, and Salix alba were selected. An airborne prism experiment (APEX) hyperspectral imagery with 288 bands, covering a range of 413 to 2451 nm, and spatial resolution of 2.5 meter was used. The image was calibrated, and Geometrically and atmospherically corrected. A remaining pre-processing was as follow: 1) removing noisy bands, according to statistical measurement (mean >0.8 and standard deviation <0.2), and visual inspection; 2) selection of non-forested areas to reduce the effect of non-vegetation reflectance on MNF transformation; 3) to apply MNF and to select components of which Eigenvalues was more than one and tree stands were visible. 9 MNF components were selected and used for classification. The classification was done on two levels: pixel-level and object-level. To create candidate objects, a multiresolution segmentation algorithm was applied. According to a minimum allowed internal variance, pixels were merged. A machine learning algorithm random forest was then used to train and apply a prediction model for classification. According to a confusion matrix, the object-level classification achieved the overall accuracy of 85 %, and kappa coefficient of 0.805, whereas for a pixel-based classification achieved an overall accuracy of 63% and Kappa coefficient of 0.559. The performance of classes according to producer's accuracy for object-based classification varied between 80% for Fraxinus excelsior, Alnus incana, and Populus canadensis to 91% for Salix alba. As for pixel-based classification, Producer's accuracy varied between 48 % for Populus balsamifera to 56% for Fraxinus Excelsior. The measure of User's accuracy for object-based classification varied between 77% for Alnus Incana, to 93% for Salix alba, as for pixel-based classification User's accuracy varied between 55% for Alnus incana to 78% for Picea abies. To compare the results of two classification approaches McNemar's test was applied. The results showed that airborne APEX hyperspectral imagery has high potential for tree stands discrimination in a complex Environment, such as riparian forest. A comparison of the two classification approaches showed a better performance for object-based image classification compare to pixel-based classification. However, creation of candidate-objects is a key element for OBIA classification, and shall be further investigated.

Integrated Hyperspectral and Multispectral Approach for Mapping Invasive Plant Species Based on Phenological Characteristics

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The spread of invasive plant species (IPS) has been recognized as the second most important threat to biodiversity after habitat destruction. Since the spatial extent of IPS is essential for managing invasive species, the current study aims to identify and map the aggressive invasion plant species of Acacia salicina and Acacia saligna in the coastal plain of Israel. This goal was achieved by integrating airborne imaging spectroscopy with spaceborne multispectral remote sensing data. We developed an integrated approach for mappingthe IPS based on the phenological flowering stage, using hyperspectral and multispectral images. The hyperspectral images at higher spatial and spectral resolutions were used to train the multispectral images at the species level. We incorporated a series of statistical models to classify the IPS location and to recognize their distribution and density. A Support Vector Machine (SVM) classification algorithm was applied twice: first for species classification with the hyperspectral data, then with multispectral data, taking advantage of the flowering phenology, using the trained output data from the first step. The classification yielded an overall kappa coefficient accuracy of 0.89 in the multispectral image. Additionally, we studied the influence of various environmental and human factors on the IPS's spreading by using a random forest (RF) model to understand the mechanisms underlying successful invasions and to assess where IPS have a greater likelihood of occurring. This algorithm revealed that high density of Acacia is positively correlated to elevation; temperature pattern; and distances from rivers, settlements, and roads. Our results demonstrate how integration of remote sensing data in different spectral resolutions assists in determining IPS proliferation, and provides detailed geographic information for conservation and management efforts to prevent their future spread.

VEG-4: Spectroscopy of vegetation

Friday 8 February 2019
Session Chair: Olga Brovkina, Zbyněk Malenovský

Analysis of Airborne Optical and Thermal Imagery for Detection of Water Stress Symptoms

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High-resolution airborne thermal infrared (TIR) together with sun-induced fluorescence (SIF) and hyperspectral optical images (visible, near- and shortwave infrared; VNIR/SWIR) were jointly acquired over an experimental site. The objective of this study was to evaluate the potential of these state-of-the-art remote sensing techniques for detecting symptoms similar to those occurring during water stress (hereinafter referred to as 'water stress symptoms') at airborne level. Flights with two camera systems (Telops Hyper-Cam LW, Specim HyPlant) took place during 11th and 12th June 2014 in Latisana, Italy over a commercial grass (Festuca arundinacea and Poa pratense) farm with plots that were treated with an anti-transpirant agent (Vapor Gard®; VG) and a highly reflective powder (kaolin; KA). Both agents affect energy balance of the vegetation by reducing transpiration and thus reducing latent heat dissipation (VG) and by increasing albedo, i.e., decreasing energy absorption (KA). Concurrent in situ meteorological data from an on-site weather station, surface temperature and chamber flux measurements were obtained. Image data were processed to orthorectified maps of TIR indices (surface temperature (T_s), Crop Water Stress Index (CWSI)), SIF indices (F_{687}, F_{780}) and VNIR/SWIR indices (photochemical reflectance index (PRI), normalised difference vegetation index (NDVI), moisture stress index (MSI), etc.). A linear mixed effects model that respects the nested structure of the experimental setup was employed to analyse treatment effects on the remote sensing parameters. Airborne T_s were in good agreement ($\Delta T < 0.35$ K) compared to in situ T_s measurements. Maps and boxplots of TIR-based indices show diurnal changes: T_s was lowest in the early morning, increased by 6 K up to late morning as a consequence of increasing net radiation and air temperature (T_{air}) and remained stable towards noon due to the compensatory cooling effect of increased plant transpiration; this was also confirmed by the chamber measurements. In the early morning, VG treated plots revealed significantly higher T_s compared to control (CR) plots ($p = 0.01$), while SIF indices showed no significant difference ($p = 1.00$) at any of the overpasses. A comparative assessment of the spectral domains regarding their capabilities for water stress detection was limited due to: (i) synchronously overpasses of the two airborne sensors were not feasible, and (ii) instead of a real water stress occurrence only water stress symptoms were simulated by the chemical agents. Nevertheless, the results of the study show that the polymer di-1-p-menthene had an anti-transpiring effect on the plant while photosynthetic efficiency of light reactions remained unaffected. VNIR/SWIR indices as well as SIF indices were highly sensitive to KA, because of an overall increase in spectral reflectance and thus a reduced absorbed energy. On the contrary, the TIR domain was highly sensitive to subtle changes in the temperature regime as induced by VG and KA, whereas VNIR/SWIR and SIF domain were less affected by VG treatment. The benefit of a multi-sensor approach is not only to provide useful information about actual plant status but also on the causes of biophysical, physiological and photochemical changes.

UAV-Based High-Resolution Image Spectroscopy Towards The Assessment Of Grape Vine Health

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Our project is based in the southern Okanagan Valley, British Columbia, Canada, and is focused on addressing the health/senescence status of grape vines. Earlier work by our group on vineyards with airborne imaging spectroscopy (IS) has demonstrated the need to work with high resolution, non-mixed spectra. To facilitate this need we assembled a UAV-based multisensor payload consisting of a V-NIR imaging spectrometer (Headwall Nano Hyperspec), LiDAR (Velodyne VLP 16), and RGB camera (DJI X5) tied to an Applanix APX 15 INS and RTK GPS. The package was flown on a DJI Matrice 600 hexacopter. Data were acquired in mid-October 2017, at the beginning of the harvest over three different varietals –

Chardonnay, Cabernet Franc, and Syrah. Each varietal was flown at 10 m. a.g.l., with a forward velocity of 3 m/s. This yielded a hyperspectral GSD of 1 cm at the top of the vine and 1.5 cm at ground level. The spectra were collected at full resolution (~1nm and 640 crosstrack elements) of the camera. LiDAR point density was ~7000 points/m². The IS data were atmosperically calibrated using an Emperical Line Calibration approach using light (80%) and dark (20%) targets situated throughout the ROI's. The IS data were orthorectified to the LiDAR DSM. The Chardonnay fruit had been harvested several days prior to our imaging, while the Cabernet Franc and Syrah were still on the plants. This is significant as the plants initiate the senescence process immediately after fruit harvest. The effects of virus infection are varied for the different varietals of grape. The white (Chardonnay) yields no visible discolouration to the leaf (due to leaf roll) prior to senescence. The virus-infected red varietals, however, become increasingly chlorotic as the season progresses. This is the case with both the leaf roll and the red blotch viruses.

While our initial surveys were intended more to demonstrate the capabilities of the system, we did acquire high quality (geometric and radiometric) data over all three varietals. The result was that we acquired spectra that were at the sub-leaf level providing us with unmixed, pure leaf data. As we did not have specifics as to the level of virus infection at the time of the flights, we assumed that progressive senescence represented a change in the leaf biochemistry that might represent conditions analogous to the progressive effects of the virus, so we focused on senescence for this analysis. Increasingly senescent Chardonnay leaves were compared to the pre-senescent red varietals, which had yet to be harvested. Sampled spectra were subjected to continuum removal (550 to 720 nm), and a number of narrow band indices (PRI, NDVI, ARI, REP). The results indicate a clear progression, in spectral response, from fully functioning leaves through senescent (yellow).

A continuation and expansion of the project is occurring in 2018, where field spectra are being collected together with gas exchange (photosynthesis), pigment levels (anthocyanin, chlorophyll, carotenoids), and Nitrogen for known virus infected and healthy plants over a number of dates throughout the growing season, including coincidentally with the flights.

Improving Nitrogen Status Estimation in Malting Barley Based on Hyperspectral Reflectance and Artificial Neural Networks

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Malting barley ranks among crops with narrow optima for nitrogen status and high sensitivity either to insufficient or excessive nitrogen nutrition resulting in low yield or poor malting quality respectively. Very sensitive methods for nitrogen status estimation during vegetation period are thus required to fine-tune nitrogen nutrition within this tight range. Although hyperspectral reflectance represents currently the most efficient method for fast and spatial evaluation of nitrogen status in vegetation, the results vary particularly in response to weather conditions of given year, canopy structure, and genotype. Multifactorial field experiments studying interactive effects of nitrogen nutrition, sowing density, and malting barley genotype on relationships between hyperspectral data and nitrogen status were conducted in three consecutive years. The main approaches taken to improve estimation of nitrogen status utilized the nitrogen nutrition index (NNI) or total nitrogen uptake by aboveground biomass per ground area unit (N uptake), which corrects for the effect of biomass and eliminates the confounding effect of nitrogen dilution during plant development. Furthermore, we employed an artificial neural network to integrate data from multiple reflectance wavelengths and thereby eliminate the impacts of such interfering factors as genotype, sowing density, and year. The results indicate that using NNI and N uptake can significantly reduce the inter-annual variation in relationships to vegetation indices documented for nitrogen content in above-ground biomass. We also documented improved estimation of all nitrogen status indicators, including of nitrogen content, data were used to train an artificial neural network. NNI and N uptake were best predicted by simple ratio pigment index (SRPI) and normalized red-edge – red index (NRERI). Although the key reflectance wavelength, on which the winning neural networks were based, varied depending on estimated nitrogen status parameters and the growth stage, of particular importance for their reliability, were the bands 400–490, 530–570 and 710–720nm. It can be summarized that using the parameters of nitrogen status NNI and N uptake the low prediction accuracy for nitrogen content in above-ground biomass (less than 60%) can be improved to up 85% and by using the neural network to up 94%. In addition, the neural network can serve as a reliable estimator of nitrogen content in above-ground biomass, which is not possible with simple reflectance indices, particularly due to variation, given by the year, genotype and canopy structure.

Video Spectroscopy For Tilling Dust Sensing and Visualisation In Agriculture

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Snapshot hyperspectral imaging provides many benefits for field spectroscopy. Traditionally, point spectrometers were the first choice in field spectroscopy, occasionally complemented by hyperspectral field scanners and recently by snapshot imaging spectrometers. Scanners show some limitations when moving targets or rapidly changing processes have to be captured. The snapshot advantage reveals these limitations and opens novel application fields.

A native snapshot imaging spectrometer captures all spectra and the entire image at the same time without any time delay. It enables this imaging system to capture motion pictures and producing hyperspectral videos. This technique and core technology has been developed, inter alia, by the Cubert GmbH, Ulm, Germany.

In our experiment we used an UHD 185 snapshot video spectrometer (400–1000 nm, 100< bands) to visualize 'floating dust' known as particulate matter (PM). The EU introduced limits for particulate matter (PM10) in 2010. PM10 is particulate matter with 10 micrometers or less in diameter, inhalable into the lungs and thus relevant as risk for human health. Agricultural tilling operations are important PM10 sources affecting air quality and soil fertility (loss of bound organic material and nutrients); additionally, soil particles suspended in the air have marked effects as crystallisation nuclei being relevant for the formation of precipitation.

We measured three different agriculture activities using a standard micrometeorological dust measuring station. Results have been compared to real-time spectral videos to describe rapid dust concentration changes in space and time behind the tractor. Using a hyperspectral video spectrometer tilling dust could better be visualized and classified compared to non-imaging methods, which seems to be a promising tool for aerosol mapping and field documentations. In this research we report about our results, challenges and experiences made with video spectroscopy.

Fusion Of Hyperspectral Imagery With Point Cloud Information To Predict Biomass Of Agricultural Crops

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Above-ground biomass (AGB) is one of the most important crop parameters, crucial for accurately monitoring vegetable crop growth. The ability to non-destructively collect information about AGB makes remote sensing a less time consuming and less labour-intensive tool in agricultural science than traditional methods of crop growth monitoring. Recent results show a clear usage of point clouds retrieved form RGB imagery to estimate AGB of vegetable crops. However, at late successional stages the prediction errors indicating that RGB derive point clouds might not be reliable predictors of AGB of vegetable crops for the whole crop growth period. Using hyperspectral information for AGB estimations is a frequently tested approach, but it has also shown that the spectral signal can be disturbed by conditions in the field, such as dead plant material. Compared with using only optical remote-sensing information, several fruitful results have been obtained in previous studies using multi-source remote sensing data.

In this study, terrestrial hyperspectral measurements for three vegetable crops (tomato, eggplant, cabbage) were collected using the full-frame hyperspectral camera UHD-185 in an agricultural experiment in Bengaluru, India. The spectra covered the visible and near-infrared spectra from 450–950nm with 125 channels (SI). The spectra were collected at five sampling dates throughout the whole growing season. At each sampling date, each sampling plot was measured using a RGB camera mounted on a UAV (DJI 3 Professional). From the resulting images 14 height parameters were extracted (HI) using a structure-from-motion approach. At each sampling date the biomass of five individual plants were completely harvested and weight to receive the total AGB in tons per hectare. Using five machine learning methods (Partial least square regression (PLS), Support Vector Regression (SVR), Random Forest Regression (RFR), Gradient Boosting Regression (GBR), and Linear Gaussian Processes Regression (LGR)) prediction models for AGB using the data from each sensor (i.e. SI and HI) solely and the combined data sets were calibrated. The model accuracies for all three crops were very good with a prediction error of 6.1%, 6.7%, and 9.2% and R^2 values of 0.98, 0.97, and 0.93 for tomato, eggplant, cabbage, respectively.

RFR clearly outperformed the other methods. While for tomato the best performing model was based on HI only, for eggplant the model based on sensor fusion showed the best results. For cabbage the SI data was best.

The results of this study clearly show the advantages of sensor fusion but also revealed that single sensor approaches may outperform the fusion approach. Overall, it could be shown that AGB of vegetable crops can be successfully predicted along the complete growing season. In the future, the stability of the found relationships must be tested on a complete airborne based data collection.

Friday 8 February 2019
Session Chair: Martin Schlerf, Rahul Raj

On The Estimation Of The Directional Area Scattering Factor From Red-Edge Bi-Directional Reflectance Spectra

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It has long been assumed that it is not, in-general, possible to quantify canopy structure from bi-directional reflectance spectra (R) without prior knowledge of foliage optical properties. Knyazhikin et al. (2014) hypothesized that it is possible to measure the directional area scattering factor (D), defined as the reflectance of a similar canopy with foliage single scattering albedo (w) of one, using R between 710nm and 790nm, assuming only contributions from soil collided fluxes and foliage surface scattering are negligible. Their estimate of D (Dhat) corresponds to the ratio of the intercept to (1-slope) of the ordinary linear regression of R/w versus R. In principle Dhat could serve as a new canopy structure parameter derived from both multi-spectral and hyperspectral measurements of R within the red-edge. The goal of this study is to quantify the accuracy and precision of Dhat and, if possible, to suggest improved estimates.

Accuracy and precision of Dhat are quantified assuming sparse (Sentinel 2 MSI), moderate (CHRIS/PROBA) and fine (1nm) spectral sampling. The accuracy of Dhat is quantified using homogenous (DISORD) and heterogenous (FLIGHT) radiative transfer models as well as estimates from measurements where w is measured and soil reflectance contribution is constrained. The precision of Dhat is quantified using established results for the probability density function of the ratio of normal variates together with the confidence intervals of the slope and intercept estimates.

Comparisons suggest that Dhat is a biased estimator of D even under black background conditions. This bias increases with D and changes with the ratio of foliage reflectance to transmittance. The precision of Dhat is a non-trivial function of the confidence intervals of the slope and intercept terms and improves with increasing D.

A new estimator of D, relying on a quadratic functional relationship between R/w and w, is proposed based on the linear relationship between the effective canopy recollision probability and R and accounting for some background effects. The new estimator is shown to have increased accuracy in comparison to Dhat for both black and lambertian backgrounds; although the precision decreases due to the larger confidence intervals of corresponding quadratic versus linear regression model coefficients. While this new estimator is recommended for quantifying D we hypothesize that further aspects of canopy structure can be inferred by exploiting all three coefficients of the quadratic model.

When The Water Is Gone – Drought Response Of Leaf Mass Per Area Of Wetland Vegetation Analyzed With Imaging Spectroscopy

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Plant and community traits of wetland vegetation show a high intra-specific plasticity, originating from the high variability of environmental conditions. Spectroscopy approaches enable the retrieval some of these traits from the spectral reflectance signal of the canopy. This offers the opportunity to analyze spatio-temporal patterns of traits and their plasticity in a changing environment. In the present study, we evaluate an imaging spectroscopy based approach for the analysis of spatial patterns of leaf mass per area (LMA), a key trait for ecosystem functioning and good negative correlate of potential growth rate. The test was conducted in Las Tablas de Daimiel, a National Park in Central Spain. This wetland was affected by a long-term drought, which introduced a pronounced trait plasticity as part of the adaptation mechanisms of the vegetation to reduced water availability as well as a decrease in photosynthetic activity. Airborne HyMap data of the wetland were acquired in 2009 at peak drought intensity. At the same time, a field campaign was conducted and spectral measurements were taken on the ground using an ASD fieldspec 3 spectroradiometer. We applied an inversion of the combined leaf and canopy PROSPECT 5B + SAIL optical properties model on the HyMap data to map the LMA distribution across the wetland. The inversion enabled the pixel-wise retrieval of LMA information from the spectral signal.

To assess trends in plant stress and changing species composition across the wetland due to the long-term drought, we analyzed time series of the normalized difference vegetation index (NDVI) as determined from various multispectral sensors. The mapped LMA values were analyzed within and between stands of different species and communities along a gradient of NDVI change rates.

LMA values retrieved for stands of species with high photosynthetic activity at peak drought intensity closely correspond to the values reported for these species in trait data bases. In line with ecological theory, the observed intra-specific LMA variability is in line with the expected plasticity of this trait along a moisture gradient that is reflected in a change in photosynthetic activity and species composition. We thus conclude that imaging spectroscopy data provide sufficient detail to trace the LMA-response of wetland vegetation to long-term drought stress.

Thermal Hyperspectral Remote Sensing – Ground-based and Airborne Examples from Vegetation Studies

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Over the last three decades airborne hyperspectral imaging became a major tool in environmental remote sensing for studying the Earth's surface mostly operating in the visible to short-wave infrared region (VSWIR). Thermal infrared (TIR) signal provides complementary information on spectral emissivity and temperature of environmental targets, such as rocks and soil forming minerals, specific gaseous components, and vegetation. On vegetation studies, to date only a limited number of scientific studies using hyperspectral TIR image data have been published.

A hyperspectral TIR imaging facility has been operated for 5 years at the LIST with Trier University. The system consists of a Hyper-Cam-LW (Telops, Quebec) and a platform for airborne acquisitions. It can measure the temperature and the spectral emissivity of typical earth surface samples in the 8 to 12 µm range. Here, we show the following examples: 1) Spectral emissivity properties, 2) Detection of water deficit stress, 3) Mapping of canopy temperatures and evapotranspiration.

1) Spectral emissivity properties of plant species: Hyper-Cam images were taken at the ground over 8 species. The images were calibrated and subjected to temperature and emissivity separation using a spectral smoothness approach. For each species, the retrieved emissivity spectrum showed characteristic spectral features presumably caused by biochemical (cellulose, lignin) and structural (hairs, waxy layer) properties of the surface tissues. Spectra were subjected to species discrimination using a random forest classifier which resulted in an overall accuracy of 92% while VSWIR spectra taken over identical leaf samples achieved an OAA of 80%.

2) Detection of water stress using temperature and emissivity based indices: Over a period of 9 days Hyper-Cam images (in conjunction with VSWIR spectra) were taken daily at the ground over 60 potato plants with one half watered and the other half water-stressed. Emissivity spectra and temperature were retrieved from the images and image-based indices (Crop water stress index CWSI, Photochemical Reflectance Index PRI, Moisture Stress Index MSI) were calculated. Water stress as measured through stomatal conductance started on day 2 after watering was stopped. The fastest reacting, i.e., starting on day 7, indices were CWSI, spectral emissivity and MSI, while PRI and NDVI showed no response.

3) Mapping of canopy temperatures and evapotranspiration: Multiple airborne images of surface temperature were acquired over 22 forest plots during a summer day, converted to evapotranspiration (ET) using a surface energy balance model together with meteorological data and compared with in situ measurements of transpiration (sap velocity). Maximum sap velocity and ET was found around 14.00, but declined at different times in the afternoon. Results showed that ET at 9 hrs were same for all three geology types in the study area, but at ET 14–19 hrs were larger over sandstones as compared to schist, suggesting an (at least partial) geologic influence on eco-hydrological processes in the area.

These studies demonstrate that ground and airborne surface temperature and spectral emissivity measurements can well complement VSWIR hyperspectral analysis of vegetation properties and condition, especially for the detection of plant responses to water stress and the quantification of plant transpiration.

Autonomous Spectral Acquisitions for Vegetation Monitoring

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Field, airborne and satellite spectroscopy show great potential for measuring vegetation bio-physical and functional characteristics. Canopy spectra captures the biophysical characteristics associated with vegetation function, which vary diurnally and/or seasonally.

New Generation (NG) authomated spectral systems are needed to reliably capture the diurnal and seasonal dynamics in vegetation function, under varying solar illumination conditions. Consistent and calibrated spectroscopy observations are required at all temporal and spatial scales, to bridge the gap between in-situ leaf, air- and space-borne observations.

This investigation contributes for bridging the gap in Earth observation between field and airborne measurements by implemening autonomous methods for obtaining well-characterized spectral measurements from a field tower and an Unmanned Aerial Systems (UAS) at various illumination conditions. An advancement in the Intelligent Payload Module (IPM) facilitated the implementation of an optimization workflow to collect spectral data for characterizing vegetation reflectance and solar induced fluorescence (SIF).

Our aporach facilitates data comparisons through space and time, and the integration with other spectral satellite and airborne data. The results from the summer of 2018 field and UAS acquisitions demonstrating the technology readiness level will be presented, and the lessons learned and future directions will be discussed.

FLUO-1: Terrestrial Chlorophyll Fluorescence

Thursday 7 February 2019
Session Chair: Uwe Rascher, Zbyněk Malenovský

Systematic Assessment Of Airborne Sun-Induced-Fluorescence Maps By The Application Of Quality Criteria

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When plants absorb light, not all energy is converted by photosynthesis, but excess energy is released as heat or emitted as sun-induced chlorophyll fluorescence (F). This signal, related to the photosynthetic efficiency of plants, has been intensively studied and measured from ground, airborne and satellite. However, retrieving sun-induced fluorescence (F) from remote sensing data is challenging because accurate modeling of atmospheric influences is required.. The advent of the airborne imaging spectrometer HyPlant made possible to produce F maps in high-spatial resolution (1–3 meters), which is a valuable tool to better understand F at relevant ecosystem scale. Currently, two different algorithms are used routinely to retrieve red and far-red F from HyPlant. Both methods are based on the O_2 absorption bands, but while iFLD method employs a semi-empirical atmospheric correction (i.e., bare-soils), the SFM makes use of a physically-based atmospheric modeling (MODTRAN5 code). A common method of testing the reliability of a remotely sensed F product (in this study airborne F maps) is the comparison with "ground truth" data where the atmosphere can be neglected. In this work we tested another possibility of assessing the quality of the airborne F maps, which does not require ground reference measurements. For this purpose we have developed so-called 'quality criteria', which should help to find errors and artefacts that have arisen during F retrieval. This method was used to test the quality of the airborne F maps of 2016 campaign.

By applying the quality criteria, clear differences in the performance of two retrievals were found. Although it was shown that both retrievals performed well in F760 retrieval, even at places with changes from vegetated to non-vegetated sites on pixel scale, iFLD was more robust for retrieving correct absolute values for F760 and F687, while SFM performed less accurate in this term, over- and underestimating F values. Furthermore, previously reported problems with image pre-processing (deconvolution for correcting PSF) of SFM became clear here. This was causing strong artefacts in F687 retrievals from SFM. However, SFM proved to be the more suitable method for identifying small differences on pixel scale. Moreover, this algorithm did not show systematic variations over entire flight lines as observed by the use of iFLD. The physically-based approach of atmospheric correction used with SFM thus provided more interference-free F maps than the semi-empirical correction using non-fluorescent surfaces as in iFLD retrieval. Testing F retrievals on vegetation under different illumination conditions showed the necessity to calculate Fyield for quantification of photosynthesis rates.

The application of the proposed quality features proved to be a valuable tool for assessing the performance of F retrieval on airborne maps. Therefore we propose to use the quality criteria even when sufficient ground references are available, because even if the quality criteria do not replace ground-truth data, they provide important additional information about the quality of the F product of the respective retrieval method.

FLUOSPECCHIO: A Spectral Data Base System in Support of a Validation Network for the Upcoming Fluorescence Explorer (FLEX) Mission

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The satellite mission Fluorescence Explorer (FLEX) is currently under development by the European Space Agency. FLEX will provide global information of fluorescence and photosynthetic activity after its launch in 2022. Coherence of fluorescence observations from in-situ, airborne, and satellite platforms across ecosystems is key to support the development of robust retrieval schemes for plant physiological information from this new data source. The information content of observed fluorescence signals, however, depends on the underlying observational scale. This challenges the comparability and interpretation of fluorescence cross scales. In situ measurements, for example, are representative for small surface areas and are collected in close distance to the surface with high temporal resolution (minute based). Satellite observations are able to collect fluorescence emissions of large areas but lack temporal resolution (monthly based).

In this contribution, we present the design of the FLUOSPECCHIO data base system. The development of this data base system was triggered by the need for coherent cross scale fluorescence measurements (both temporally and spatially) stemming from a growing number of in-situ measurements, airborne and satellite campaigns. The database facilitates the analysis of non-imaging observations, as provided by e.g. the Fluorescence Box (FLOX), manufactured by JB-Hyperspectral Devices and currently establishing as standard for a fast growing in situ measurement network, and imaging data by e.g. the HyPlant airborne fluorescence spectrometer and the Sentinel-3 or -5p satellites. FLUOSPECCHIO also supports storage and analysis of meta data along with auxiliary information stemming from ground based sun photometers and atmospheric Lidar instruments to describe the atmospheric state (e.g. aerosol load, water vapour, etc.). We demonstrate the functioning of the data base system and outline its capability to autonomously read and process various data streams and to facilitate a frequently required inter-calibration of contributing FLOX instruments. Further, we exemplify how the system contributes developing novel processing routines to advance the robustness of fluorescence derived metrics (e.g. accounting for atmospheric disturbances). We discuss the potential to analyze the impact of surface heterogeneity on the comparability of cross scale measurements and to identify optimal locations for a growing in situ measurement network.

Measuring Temporal Patterns of Crop Sun-induced Chlorophyll Fluorescence at Canopy and Plot Scale

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The actual photosynthesis is important for studying crop dynamics. Remote sensing of vegetation has the potential to greatly improve our understanding in this respect. Recently, sun-induced chlorophyll fluorescence (SIF) was proven to be an indicator for the functional status of instantaneous plant photosynthesis. However, the relationships between SIF and photosynthesis, at scales such as canopy and field, in diurnal and seasonal cycles are still not fully understood.

In this explorative study, SIF values were derived from ground and airborne observations with a sub-nanometre spectrometer over two crops: potato and sugar beets. For these crops, diurnal and seasonal SIF measurements were made to: 1) explore how SIF of a certain crop changes in diurnal and seasonal courses at canopy level; and 2) test whether the SIF signal can be measured at field level based on a Unmanned Aerial Vehicle (UAV) platform and study its patterns at diurnal and seasonal time scales. At canopy scale, SIF was monitored using Fluorspec, configured with two channels to measure the downwelling irradiance and the upwelling radiance at point scale in the wavelength range 350–1100 nm, with a spectral resolution (FWHM) of 0.14 nm and a spectral sampling interval of 0.15 nm, at a fixed position over the studied crops during several days from June to August in 2018. In addition, four UAV flights were performed over the study areas during the 2018 growing season. Field measurements consisting of photosynthetically active radiation (PAR), leaf quantum yield (Qy), canopy chlorophyll content (Cab) and leaf area index (LAI) were obtained simultaneously. Results showed that there existed a clear diurnal pattern of SIF for the two crops, both at the canopy and field level, which had a positive correlation with PAR and was negatively related to leaf Qy. The SIF derived from the measurements at three consecutive days performed slightly different because of different weather conditions. At seasonal time scales, SIF of the two crops both showed a similarly declining trend from the end of June to the beginning of August. For potato SIF peaks usually happened earlier over the course of one day as compared with sugar beets. We also found good linear relationships between SIF and LAI as well as between SIF and Cab. Interesting is that the correlation could be improved when the product of LAI and Cab was related to SIF, especially when LAI and Cab or both have a poor relationship with SIF.

Our results outline the potential of SIF as a good proxy of actual crop photosynthesis. It is also indicated that the diurnal and seasonal changes of crop photosynthesis at large scales can be traceable by measuring SIF. The SIF signal can be very helpful in understanding the photosynthetic process of different crops and identifying them. As the results of this explorative study already are very promising, studying SIF using our Fluorspec system, both at the ground and from a UAV platform, will be continued over the next years.

Combining Vegetation Traits with Multi/hyperspectral, Thermal and Fluorescence Measurements across different Scales and Plattforms – First Results from 2018 ESA FLEXSense Campaign

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The ability to investigate the Earth's environment will be greatly improved by hyperspectral satellite data. The FLuorescence EXplorer (FLEX) will be the first hyperspectral mission designed to monitor the photosynthetic activity of the terrestrial vegetation layer by using a completely novel technique measuring the sun-induced chlorophyll fluorescence (SIF) signal that originates from the core of the photosynthetic machinery. In preparation of the upcoming FLEX satellite mission that will be launched in 2022 a large field campaign, namely FLEXSense, was conducted in summer 2018 including representative study sites at several locations in middle and south Europe as well as North America.

During the different field activities airborne data was acquired with the hyperspectral airborne imager HyPlant that consists of two sensor heads. The DUAL module is a line-imaging push-broom sensor, which provides contiguous spectral information from 370 to 2500 nm. The vegetation fluorescence signal is measured with a separate push-broom sensor, the FLUO module, which produces data at high spectral resolution (0.25 nm) in the spectral region of the two oxygen absorption bands covering a range from 670 to 780 nm. The airborne data acquisition was accompanied by several unmanned aerial vehicle (UAV) and ground activities.

As an example of a successful campaign we present first results of a field survey which took place at Campus Klein-Altendorf in Germany on 29.06.2018. Campus Klein-Altendorf is an agricultural research campus near Bonn that is used by various groups from Bonn University and Forschungszentrum Jülich (FZJ) and was selected as one of the core sites of the FLEXSense campaign 2018.

On that day SIF and hyperspectral reflectance data were acquired by HyPlant with 1 and 0.5 m ground sampling distance (GSD). In parallel a fixed-wing glider was used to collect multispectral and thermal image data of the campus with a much higher GSD (0.1 m). In addition rotary-winged UAVs were used to acquire hyperspectral data of one experimental field using a Headwall MicroHyperspec camera as well as the novel AirSIF systems of the University of Tasmania that allows UAV-based point measurements of SIF from different flight altitudes. The entire acquisition of airborne data was supported by the characterization of structural (e.g. LAI, biomass) and functional (e.g. leaf chlorophyll and leaf carotenoid content) plant parameters of different crops on the ground as well as the collection of ground-based SIF measurements using mobile D-FLOX devices.

The availability of such a unique dataset makes it possible for the first time to combine fluorescence measurements, spectrally resolved reflectance, and surface temperature to investigate the actual status of plants. Furthermore, the acquisition of SIF at ground, UAV and airborne level will be used for upscaling analyses to finally link plot and field measurements. The results of this experiment can be very helpful to better understand scale effects on SIF and will broaden our knowledge in this field of research, which can be very valuable for the upcoming FLEX mission.

Investigating Impacts of Avocado Canopy Structures on Simultaneous Solar and Actively Induced Chlorophyll Fluorescence Measurements

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Better accessibility to light-weight spectroradiometers suitable for solar induced fluorescence (SIF) measurements from remotely piloted aircraft systems (RPAS) triggers a need to understand effects of canopy structures on integration of RPAS-sensed SIF signals. To our knowledge there is only a limited number of studies examining the relationship between SIF and photosynthetic yields derived from actively induced fluorescence measurements. To address this knowledge gap and provide canopy-level measurements suitable to validate canopy SIF emissions simulated by radiative transfer models, we performed a series of simultaneous nadir canopy measurements of SIF and photosynthetic yields above crowns of avocado trees. We used two identical SIF-measuring spectroradiometers with different field of views and a light induced fluorescence transient instrument called LIFT, designed to collect canopy measurements of photosynthetic yields. One of the spectrometers was coupled with LIFT through a single optical path. By changing the distance between the top of tree canopies and the instruments, we were able to collect measurements integrating varying extents of canopies. These measurements allowed for systematic examination of canopy structural heterogeneity impacts on relationships between SIF and photosynthetic yields. First, we investigated if already published correlations between avocado SIF and photosynthetic yields measured at the leaf-level hold at canopy scales. Before testing if SIF measurements combined with environmental measurements could estimate canopy photosynthetic yields, we used generalized additive models (GAM) to examine the effects of instrument measurement footprint size, photosynthetically active radiation (PAR), actual air temperature, time of day and photosynthetic yields on SIF measurements. It was found that nadir canopy measurements showed the same positive relationships between PAR, electron transport rates and SIF retrievals as those found previously at the leaf-level. Examination of the variables affecting SIF measurements identified PAR and canopy greenness indicators as the most important predictors of SIF. Although overall variability explained varied from 53.6% for electron transport rate (ETR) to 33.8% for photosystem II (PSII) photosynthetic yields, the attempts to estimate photosynthetic measurements based on SIF and environmental variables confirmed PAR intensity as the most important predictor. In general, the obtained results corroborate previous findings for avocado leaves and extend them to canopy scales. Overall, the data and results provide a unique dataset for modelling and scaling SIF emissions towards larger spatial scales with heterogeneous canopy structures.

TOOL-1: Data analyzing software, toolboxes

Thursday 7 February 2019
Session Chair: Jochem Verrelst, Akpona Okujeni

EnMAP-Box 3 Free And Open-Source Imaging Spectroscopy Data Processing in QGIS

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The EnMAP-Box 3 is a toolbox for visualising and processing imaging spectroscopy data and spectral libraries, and is particularly developed to handle data from the upcoming EnMAP (Environmental Mapping and Analysis Program) mission. The integration as a python-based plug-in into [SvdL1] the free and open source geographic information system QGIS 3 makes the EnMAP-Box an ideal platform for sharing and distributing algorithms and methods among scientists and potential end-users. The two main goals are to provide (i) state-of-the-art applications for the processing of high dimensional spectral and temporal remote sensing data and (ii) a graphical user interface (GUI) that enhances the GIS oriented visualization capabilities in QGIS by applications for visualization and exploration of multi-band remote sensing data.

The EnMAP-Box GUI provides a multi-frame viewer for the simultaneous exploration of spectral images and vector data, spectral libraries or models created with the EnMAP-Box API. The GUI is highly interoperable with that of QGIS and optimized to interact between both.

For image processing the EnMAP-Box offers a rich set of processing functionality for (i) machine learning classification, regression, clustering and transformation tasks, (ii) accuracy assessment, (iii) convolution and morphological filtering, (iv) data sampling and random subsampling, as well as (iv) interactive tools for data exploration and preparation (e.g. image band statistics, histograms, scatterplots, raster image mosaicking/ stacking). Several advanced tools use the strength of integrated python packages for an effective processing and visualisation of spectral data: a raster image calculator offers the user the full flexibility of NumPy operations while minimizing efforts for data IO; a time series viewer is optimized for simultaneous visualisation of data from different sensors, acquisition dates, resolutions etc; the spectral library tool allows for processing and labelling of spectral databases to be used in subsequent image processing.

As a joint initiative of the EnMAP Core Science Team a set of applications for domain specific data analysis is currently under development. This includes an interactive radiative transfer models for forward/backward simulation of leaf and vegetation canopy reflectance for agricultural and forest applications (LMU Munich and Univ. Trier), the EnSoMAP application for mapping soil properties and EnGeoMAP for mineral mapping (both GFZ), mapping of coastal and inland water (AWI/HZG) or regression based spectral unmixing (HU Berlin). All interactive tools and applications are integrated into the EnMAP-Box via a standardized and well documented extension point that is also available for external developers. In our presentation we illustrate the novelty of the EnMAP-Box 3 for QGIS and demonstrate advantages and strengths of linking user friendly graphical interfaces with functionality of python and related packages.

[SvdL1]Integration …into ODER development as… for…

A Flexible Imaging Spectroscopy Processing Software Suite for Vegetation Studies

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Mapping of vegetation functional traits is a key application of imaging spectroscopy data, and has increased in recent years with the expansion of airborne imaging spectroscopy data available from NASA, NEON and other sources, as well as the prospect of future global imaging spectroscopy missions. One of the key barriers to the consistent use of imaging spectroscopy data for studies of vegetation function is the necessity for consistent processing of diverse imaging spectroscopy data to enable integration of measurements from multiple time frames and sources, and comparison of results across studies. The development of automated processing workflows are necessary to transit foliar functional trait mapping from research-oriented, site-specific applications to flexible algorithms suitable to be applied to extensive data sets. Here, we present an open-source workflow – called HyTools (https://github.com/EnSpec/HyTools-sandbox) --

programmed in Python to process atmospherically corrected (Level 2) imagery to a range of output products (Level 3 retrievals such as foliar traits which could feed into producing Level 4 derivatives such as functional diversity), including a number of intermediate steps to address scene-dependent variations especially related to illumination variation. HyTools can be adapted to utilize multiple statistical modeling frameworks, including the widely used partial least squares regression (PLSR) approach, and outputs pixel-wise uncertainties, a necessity for most applications. Our current implementation is designed to work with L2 reflectance data from the Jet Propulsion Laboratory science data system (AVIRIS-Classic and AVIRIS-Next Generation), NEON Airborne Observation Platform (AOP), and ATCOR-processed HySpex imagery. The workflow is such that it can be versioned as models are refined and improved. Here we present the implementation of the workflow on AVIRIS-Classic imagery collected by NASA between 2013–2017 over California to support development of methods needed for future spaceborne missions. This workflow provides the foundation to map target observables identified for future missions such as "Surface Biology and Geology" listed in the 2017 Decadal Survey.

TOC2TOA: An ARTMO Toolbox to Simulate Top-Of-Atmosphere Radiance Data for Imaging Spectroscopy Applications

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Deriving spatially-explicit vegetation biophysical variables is one of the main goals of imaging spectroscopy. The land surface reflectance for retrieval of biophysical variables is estimated from these satellite observations through atmospheric corrections. To avoid the limitations of retrieving biophysical variables from surface reflectance data, some studies have demonstrated the possibility to determine biophysical variables directly from at-sensor top-of-atmosphere (TOA) radiance data, without the necessity to go through the atmospheric correction process. At-sensor spectral TOA radiance is the integrated sum of surface reflectance, atmospheric effects and target surroundings convolved with the sensor spectral and spatial response functions. Consequently, the identification of the key input variables that drive TOA radiance is a first mandatory step to retrieve biophysical variables directly from at-sensor TOA radiance data. Once having the drivers along the spectral range identified, it opens the door to develop dedicated TOA radiance retrieval algorithms taking into account the wavelength-dependent role of the atmospheric factors. These drivers can be theoretically identified by means of coupled surface-atmosphere radiative transfer models (RTMs). To exploit at-sensor TOA radiance from RTMs, we need to consider three scales: (1) leaf, (2) canopy and (2) atmosphere; which are associated to two groups of RTMs: vegetation and atmospheric RTMs.

The coupling of leaf and canopy models has been earlier streamlined within the Automated Radiative Transfer Models Operator (ARTMO) scientific software package. We have recently introduced the so-called Atmospheric LUT Generator (ALG) toolbox that permits generating datasets of atmospheric transfer functions from the execution of atmospheric RTMs (e.g., MODTRAN, 6SV) and the OPAC aerosol database. As such, ARTMO provides tools and toolboxes for running a suite of leaf, canopy and atmosphere RTMs and for post-processing applications. In this work we present a new GUI toolbox, named TOC2TOA, that enables coupling surface reflectance simulations with atmospheric simulations, i.e. to reach TOA radiance data. TOC2TOA couples atmospheric transfer functions of atmospheric RTMs with canopy simulations to generate TOA radiance simulations, thereby ensuring that consistent geometry at canopy and atmosphere is preserved. In this first version (1.0), a Lambertian surface is assumed.

Once having TOA radiance data generated, all kinds of applications become possible, such as identifying the driving surface-atmosphere variables and retrieval strategies. This can be seamlessly achieved within the ARTMO toolboxes. Similar as for top-of-canopy reflectance simulations, the TOA data can be further processed by the ARTMO toolboxes. This includes: (1) emulation of coupled leaf-canopy-atmosphere models, (2) global sensitivity analysis (GSA) of these type of coupled models, and (3) retrieval of biophysical variables through the retrieval toolboxes, but then directly based on TOA radiance data, thereby avoiding the atmospheric correction step. In this contribution we will present the TOC2TOA toolbox, as well imaging spectroscopy applications in the fields of emulation, GSA and machine learning retrieval. The GUI toolbox will become freely available to the scientific community.

FRANCA – A Fully Automated Hyperspectral Processing Chain For FRActioNal Cover Analysis

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Hyperspectral data will increasingly be available in the next years due to several Earth-Observation (EO) missions like DESIS, PRISMA or EnMAP, and the increasing number of airborne hyperspectral sensors. This will lead to a huge amount of data, which needs to be automatically processed and can hardly be analysed interactively.

Next, initiatives and projects like NextGEOSS aim at improving the access to EO data and derived products. The NextGEOSS pilot "BIODIVERSITY" aims at demonstrating the use of high resolution Essential Biodiversity Variables (EBVs) derived by EO for habitat monitoring.

An important contribution to the EBVs "ecosystem structure" and "ecosystem function" is the quantification of fractional cover (FCOVER) for the thematic classes vital photosynthetically active vegetation (PV), dry or dead non-photosynthetically active vegetation (NPV) and bare soil (BS).

In order to operationally generate such products based on the upcoming missions, FRANCA was developed, which is a fully automated, hyperspectral processing chain for FRActioNal Cover Analysis. The FRANCA chain consists of several different modular parts: pre-processing, endmember extraction (using spatial-spectral endmember extraction (SSEE)), endmember classification (using a random forest approach), spectral unmixing (using the μMESMA approach for multiple endmember spectral mixture analysis), and post-processing steps (including a per pixel confidence score). The generated output products are the quantitative estimates of PV, NPV and BS for every pixel.

The chain uses a pre-defined configuration file (JSON), which contains all necessary empirically or pre-calculated input parameters. Several new software-related approaches are used: first, the software is encapsulated in Docker images. This has several advantages: an easy scientific exchange with other groups or partners, static versioning and easier re-processing in case of improved input files or parameter sets. The whole chain is build with the Luigi workflow engine, which helps building a complex pipeline of batch jobs. It covers failure and common event handling, task tracking and is also able to parametrize and re-run task on a given schedule. For big data handling it comes with built in Hadoop support. FRANCA is written in Python3, an interpreted high-level programming language, which is open-source, comes with a large and comprehensive standard library and supports automatic memory management.

Within this presentation, selected aspects of the FRANCA approach are given, including the results of airborne and simulated EnMAP data.

"Get a Look at Image Processing for Students" (GLIMPS) – an Educational Imaging Spectroscopy Tool

DANIEL SCHLÄPFER

ReSe Applications LLC, Switzerland

The availability of imaging spectroscopy data and multispectral satellite imagery has been vastly improved in the last decade as platforms and sensors have become substantially cheaper and data acquisition is feasible without much effort. On the other hand, the proper handling and processing of the data is still a difficult step which requires expertise as well as dedicated software tools.

For students and beginners in imaging spectroscopy, the learning curve is steep and professional image processing packages are highly priced. Therefore, a tool was created to 'Get a Look at IMage Processing for Students' (GLIMPS). GLIMPS is an easy-to-use and freely available image processing software tool for educational purposes but also for simple data processing steps. Nevertheless, it covers key functionality to display and analyze hyperspectral and multispectral imagery. This includes: flexible display options for ENVI formatted files and spectral libraries, quantitative image scaling options, empirical reflectance retrieval, spectral index calculations, spectral angle mapping and spectral fitting, change detection, and some image handling and I/O functions.

This paper describes the main functions implemented in the GLIMPS software and the typical workflows for data analysis. A special focus is put on the empirical radiometric processing options. This includes the use of field reference panels of known reflectance to perform an empirical line correction, statistical analysis for dark object subtraction, as well as a combination of both approaches. Rules for optimal use of such reference data for optimal reflectance retrieval are derived based on a use cases with UAV based data acquisitions with the Hyperspec Nano system. A standard use case is described where such preprocessed imaging spectroscopy data is used for vegetation analysis based on vegetation indices on the one hand and using spectral mapping on the other hand. In a second application, the Micasense RedEdge-M sensor is used for change detection for Micasense based data acquisitions is shown. For this case, the radiometric processing is joined with a geometric rectification to achieve best results.

The results of this contribution is not a new advanced image processing technique but rather a guideline for simple but still scientifically sound data processing workflow, e.g. for UAV based airborne imagery. GLIMPS being a tool to allow for such processing shall help to teach remote sensing data processing in a more efficient way and to allow for quick but not too dirty data analyses.

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SOIL-1: Spectroscopy of soils and geology applicaitons

Thursday 7 February 2019
Session Chair: Veronique Carrere, Veronika Kopackova

Cloud Computing of Remote Sensing Products for Soil Properties Mapping

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Processing remotely sensed information with high spatial resolution (e.g. 30m) is a challenge for mapping soil properties in large extent areas, i.e. million km^2 extent. The use of cloud computing might make easy the handle of big data catalogs of Earth-Observation sensors. The aim of the work was to build algorithms within Google Earth Engine (GEE) for processing multitemporal images and digital elevation models, as well as to evaluate the performance of these spatial information for soil properties mapping. The Landsat archive composed of Landsat 4, 5, 7 and 8 were processed by GEOS3 (Demattê et al., 2018) to produce an almost spatially continuous representation of the soil surface in the visible, near infrared and shortwave infrared spectral region in Brazil. Once the satellite images contain small proportions of the soil surface along the year, GEOS3 ensembles the multitemporal occurrences of bare soil into a single product called Synthetic Soil Image (SYSI), which becomes useful for spectroscopy studies. Additionally, terrain analysis was also developed using the digital elevation model of Shuttle Radar Topography Mission (1 arc-second or ~30m) to represent flux and form features of the landscape. For this, Taylor polynomials fitted onto a spheroidal equal angular grid of the elevation by a 3×3 window were used to derive the first and second partial derivatives of terrain. Local morphometric variables (LMV) were calculated from the derivatives: slope, Northernness, Easternness, vertical curvature, horizontal curvature, and mean curvature. The algorithms of GEOS3 and terrain analysis were applied over an agricultural region of one million km^2 in Brazil. The remotely sensed information derived from GEE, i.e. SYSI and LMV, were used to calibrate Random Forest models of topsoil (0–20 cm) clay and sand contents. The use of cloud computing allowed a fast and multi-resolution analysis of the Landsat historical database, and terrain attributes algorithms. A generic benchmark for running GEOS3 comparing R software and GEE showed a reduction of processing time from weeks to minutes. The final spatial resolution (30 m) was defined when exporting the processing results, which were used as predictors for soil properties mapping. Using only the terrain attributes (LMV), the error of prediction (Root Mean Square Error) of clay and sand content was 112 and 164 g kg^{-1}, respectively. Using only the SYSI, the error of prediction was in average 35% lower than using terrain attributes (72 and 116 g kg^{-1} for clay and sand, respectively). The best models were obtained when combining all the information, reaching 69 and 112 g kg^{-1} for clay and sand, respectively. The spatial trends of the Synthetic Soil Image were more evidenced in the final maps of clay and sand contents than the local variations of terrain attributes. The results suggest that spectral information of SYSI are important indicators of the spatial variability of soil attributes within agricultural lands.

Using Complex And Multi-mineral Natural Systems As Analogues For Modelling Diverse Geochemical Processes On Mars

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Martian surface compositional mapping has been greatly built on Earth-based complementary approaches including field work, geochemical experiments, and laboratory measurements of analogue sites and minerals. Up-to-day, there are still many topics needed to be studied in deeper detail such as Mars' subsurface and surface hydrological systems and the geochemical states. For Mars or other planets, the number of in-situ data and ground-truth is very limited, therefore terrestrial minerals are used as analogues and their laboratory reflectance and emissivity spectra are used for mineral composition mapping using the imaging data acquired by the above mentioned orbital spectrometers. In most cases spectral libraries of pure minerals and synthetic mixtures have been employed together with such mapping techniques as Gaussian fitting, simple band ratios, linear unmixing to derive the mineral maps.

In this paper we will demonstrate first results – new spectroscopy data (reflectance and emissivity) acquired under simulated conditions of Martian surface for samples, which represent natural mixtures of different minerals/different mineral combinations:

- collected in open-pit mines, these represent mainly sulfates and other ferric minerals mixed together with different types of phyllosilicates and silicates. Such samples can be used as analogue minerals-indicators for i) hydrothermal alteration processes, ii) pH conditions of the environment where the minerals coexist.
- soil profile samples collected from different soil horizons (A, B, C), these represent different weathering stages developed on various lithologies.

For these samples (total number 50) which represent both, simple mixtures as well as more complex and multi-mineral systems, new spectroscopy data (reflectance over 0.4–16 µm and emissivity from 0.4 to 150 µm) was acquired while simulating conditions of Martian surface at the Planetary Spectroscopy Laboratory (PSL) in DLR, Berlin. Such new data has a high potential to help to find new insights on such key issues as: paleoclimate and climate evolution (e.g., water availability), geochemical states and geological processes over various epochs.

Acknowledgement: This project was supported by EUROPLANET 2020 Transnational Access program.Europlanet 2020 RI has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654208.

Impact Of The Spatial Resolution For Mineralogical Mapping From Hyperspectral Sensors HySpex, HYPXIM And EnMAP: Application To The Almeria Sedimentary Basin, Spain

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NAOMI (New Advanced Observation Methods Integration) research project* provides innovative remote sensing technologies to lead onshore and offshore petroleum exploration. In onshore investigation, surface geological mapping plays an essential role to understand and integrate field analogues within reservoir modeling. The use of airborne hyperspectral remote sensing at very high spatial resolution has already proved to be a valuable asset to produce precise mineralogical maps thanks to expert automated systems. Nevertheless this technique has never been applied to fluids characterization in order to distinguish zones of preferred fluid paths within sedimentary basins.

The main objective is to evaluate the influence of the spatial resolution on the detection and characterization of mineralogical anomalies in the framework of the future hyperspectral spatial missions. To achieve this objective, the area of study focuses on the southeast region of Spain (Province of Almeria) due to very good outcropping conditions. Field campaigns were carried out in May and June 2017 in Tabernas basin (Almeria region) with spectroscopic measurements over diverse rock types and sample collections. Airborne images were acquired at the same period with HySpex hyperspectral sensor (0.4–2.5 µm) at a spatial resolution of 1m. Then, images are spatially resampled to the sensor specifications of the future hyperspectral missions: HYPXIM (8m; CNES) and EnMAP (30m; DLR). Mineralogical maps are built from the tool EnGeoMaP 2.0 with the help of reference and user-defined libraries. This tool is based on a fully automated process to analyze spectral absorption features using the geometric hull feature extraction and on the calculation of spatio-spectral gradients.

Finally, the mineralogical maps are validated with field ground control points (1), sample laboratory DRX analysis (2), geological maps from photo-interpretation of WorldView-2 (50 cm) (3), and regional geological maps (4). Results demonstrate the capabilities of hyperspectral sensors to detect mineralogy and the possible lacks of information at different spatial scales to answer geological challenges.

* TOTAL-ONERA collaborationship

Using Imaging Spectroscopy For Detecting And Mapping Of Land-Use Effects On Soil Quality In Dryland

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Global population growth in the past few decades increase the need in providing food, shelter, and other services, and has resulted in transformation of many natural ecosystems into human-dominated ones. Land-use (LU) dynamics usually accompanied by large increases in exploiting of resources, along with considerable loss of biodiversity, affect ecosystems structure, and function and may cause deterioration of environmental conditions, which is reflected in soil quality (SQ). SQ differences among LU can be observed with airborne hyperspectral imaging spectroscopy (IS). Our aim is to measure SQ performances, based solely on spectral differences, and mapping of soil properties among three LU practices (agro-ecosystems, agro-pastoral grazing, and natural reserves) in an arid dryland environment of the Central Negev Desert, Israel. To achieve this goal we developed and implemented a spectral soil quality index (SSQI) using IS method, which is generated from both laboratory and field spectrometry, for upscaling from point scale to airborne IS at a local scale. To characterize and quantify SQ, an integrative approach of 14 physical, biological, and chemical soil properties were examined and transformed into additive scoreless soil quality indices (SQI), which were compared among LU and geographical units (north, center, and south flight line). Significant differences in SQI values were found in part of all LU and geographical areas. Statistical and mathematical methods for evaluation of soil properties significance and spectral differences were used, including partial least squares – regression (PLS-R) and partial least squares – discriminate analysis (PLS-DA). The PLS-DA classification accuracy results of the laboratory spectral data resulted with an overall kappa coefficient accuracy of 0.95. IS application can be used for SQI assessment, address soil alteration and degradation in areas of land-use changes.

UAV Hyperspectral-3D Fusion for Peatland Biogeochemistry

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Peatlands play a fundamental role in the global carbon cycle. Northern peatlands store one third of the terrestrial carbon derived from atmospheric CO_2. In Canada, they cover nearly one million square kilometres (12% of the landmass). A thorough understanding of this ecosystem's role in climate change mediation and provision of ecosystem services is needed. Peatlands could undergo significant changes to their carbon cycling due to climate change and other drivers such as nitrogen deposition. A main challenge in understanding peatlands is that their structure and function are heterogeneous over both space and time. Due to their large extent and fragile surface structure, large scale studies require remote sensing to better understand these ecosystems at various temporal and spatial scales. While models derived from satellite and airborne imagery have shown promise in estimating key biogeochemical and structural characteristics, they are too coarse to delineate small (< 1 m) but fundamental microtopographic components such as hummocks and hollows. Technological advances in the development of unmanned aerial vehicle (UAV) based hyperspectral imagers and precise 3D terrain reconstructions from Structure from Motion (SfM) have the protentional to revolutionize the biogeochemical geography of peatlands. While SfM has become popular recently in many fields from geology to forestry, most products have been restricted to a point cloud with red-green-blue colour space information. Here, we show novel results from data fusion between ultra-high resolution SfM derived point clouds and 288 band Vis-NIR UAV based hyperspectral imagery. The result is a full hyperspectral point cloud from which the peatland structure and composition at ultra-fine spatial scales (1–3 cm) can be analyzed.

SOIL-2: Spectroscopy of soils and geology applications

Thursday 7 February 2019
Session Chair: Eyal Ben Dor, Frantisek Zemek

A Novel Approach for Detecting Petroleum Hydrocarbons Contamination in a Real Manmade Disaster Zone Using Airborne Imaging Spectroscopy

RAN PELTA, Eyal Ben-Dor

Tel Aviv University, Israel

Crude oil spill disasters caused by men is a global problem as it is widespread and has negative effects on humans and ecosystems. Imaging Spectroscopy (IS) technology has a great potential of detecting and monitoring crude oil contamination, from the air in cases such as oil spills and pipeline leakages. Most studies used airborne IS focused on maritime and coastal areas, while much less focus is given to terrestrial areas, especially to the direct detection of crude oil contamination in areas with bare soil (non-vegetated areas). Studies conducted to map, detect and monitor crude oil contamination from the air, in such places, were under optimal conditions e.g., controlled field condition with artificial "fresh" samples and they based their analysis on a clear spectral features of crude oil petroleum hydrocarbon at 1700 and 2300 nm. This study used airborne IS to detect and map crude oil contamination in far from optimal conditions with a real disaster zone as a study area where the oil contamination was exposed to weather conditions, floods, microbiological processes and rehabilitation efforts for more than three years. In addition, non-optimal illumination conditions at the time of the flight, lack of pure pixels and the absence of a clear spectral feature of petroleum hydrocarbon made the challenge even greater. Nevertheless, by using normalization techniques, vicarious bands selection and supervised machine learning, this study was able to classify contaminated pixels from non-contaminated pixels. The K-fold cross-calibration classification accuracy was as high as 96% and the validation accuracy was 90%. The developed spectral approach in this study shows that IS can be used as an operational and complementary tool for environmental monitoring from the air. The importance of our findings is to show that the IS technology can spot shade on a long term processes of oil contamination over terrestrial areas.

Evaluating The Capability Of The Sentinel 2 Data For Soil Organic Carbon Prediction In Croplands

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The short revisit time of the Sentinel-2 (S2) constellation entails a large availability of remote sensing data, but S2 data have never been used to predict soil organic carbon (SOC) content. Thus, this study aims at comparing the capability of multispectral S2 and airborne hyperspectral remote sensing data for SOC prediction, and at the same time, we investigated the importance of spectral and spatial resolution through the signal-to-noise ratio (SNR), the variable importance in the prediction (VIP) models and the spatial variability of the SOC maps at field and regional scales. We tested the capability of the S2 data to predict SOC in croplands with quite different soil types and parent materials in Germany, Luxembourg and Belgium, using multivariate statistics and local ground calibration with soil samples. We split the calibration dataset into sub-regions according to soil maps and built a multivariate regression model within each sub-region. The prediction accuracy obtained by S2 data is generally slightly lower than that retrieved by airborne hyperspectral data. The ratio of performance to deviation (RPD) is higher than 2 in Luxembourg (2.6) and German (2.2) site, while is 1.1 in the Belgian area. After the spectral resampling of the airborne data according to S2 band, the prediction accuracy did not change for four out of five of the sub-regions. The variable importance values obtained by S2 data showed the same trend as the airborne VIP values, while the importance of SWIR bands decreased using airborne data resampled according the S2 bands. These differences of VIP values can be explained by the loss of spectral resolution as compared to APEX data and the strong difference in terms of SNR between the SWIR region and other spectral regions. The investigation on the spatial variability of the SOC maps derived by S2 data has shown that the spatial resolution of S2 is adequate to describe SOC variability both within field and at regional scale.

Quantitative Mapping of Ultramafic Rocks in Presence of Abundant Lichens Using Airborne Imaging Spectroscopy and Spaceborne Sentinel-2 And Landsat-8 OLI Data in The Arctic

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Regional geologic mapping in northern regions is time consuming and costly, primarily owing to poor accessibility and a short field season caused by snow cover. Space- and airborne remote sensing can facilitate detailed continuous regional mapping in the arctic and subarctic owing to low vegetative cover, although issues such as low illumination and pervasive rock encrusting lichens remain a challenge. In this study, we investigate the use of airborne hyperspectral (HyMap) data and spaceborne multispectral (e.g. Sentinel-2 and Landsat-8 OLI) data for detailed lithological mapping in central West Greenland, where ultramafic (e.g. pyroxenite and peridotite) rock units are exposed with the presence of lichen coatings. The performance of two different approaches namely EnMAP Geological Mapper (EnGeoMAP) and Iterative Spectral Mixture Analysis (ISMA) are tested. The output classification results are quantitatively compared to the geological map available from the study area using the Structural Similarity Index Measure (SSIM). The Iron Feature Depth (IFD) index was derived from Sentinel-2 and Landsat-8 OLI data to map the 900-nm absorption feature as a potential proxy for mapping the spatial extent of mafic-ultramafic bodies. The HyMAP data was convolved to the spectral response functions of Sentinel-2 and Landsat-8 OLI and was used as a reference to compare the different IFD capabilities of the spaceborne sensors directly to the HyMAP using SSIM. Results demonstrate the capability of both airborne and spaceborne data to provide large-scale reconnaissance mapping of geologic materials over vast arctic regions where field access is limited and costs are prohibitive. These results suggest that EnGeoMAP method has a better performance (89% propagation accuracy) than ISMA method (81% propagation accuracy).

PARACUDA-II Engine as Compared to other Data-Mining Algorithms for the Prediction of Soil Carbon Using Diffuse Reflectance Spectra

Asa Gholizadeh[1], Mohammadmehdi Saberioon[2], Nimrod Carmon[3], Lubos Boruvka[1], Eyal Ben-Dor[3]

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Successful estimation of soil carbon in soil with Visible and Near-Infrared (VIS-NIR, 400–1200 nm) and Short-Wave-Infrared (SWIR, 1200–2500 nm) spectroscopy depends mostly on the selection of an appropriate data-mining algorithm. The aim of the current study was to examine the performance of different data-mining algorithms namely Partial Least Squares Regression (PLSR), Random Forests (RF), Boosted Regression Trees (BRT), Support Vector Machine Regression (SVMR) and Memory Based Learning (MBL) with a special focus on the potential of the new data-mining engine PARACUDA-II®, recently developed at Tel-Aviv University (TAU), in predicting soil Oxidizable Carbon (Cox). The study explored whether these techniques show differences regarding their ability to modelCoxfrom VIS-NIR-SWIR dataand to evaluate the interpretability of the results. The dataset consisted of 103 soil samples from a large brown coal mining dumpsite in the Czech Republic. Spectral readings were taken in the laboratory with an ASD FieldSpec III ProFR spectroradiometer under a strict protocol. Spectra preprocessing for conventional data-mining techniques was conducted using Savitzky-Golay smoothing and the first derivative method. PARACUDA-II®, on the other hand, operates based on the All Possibilities Approach (APA) concept, a conditional Latin Hypercube sampling (cLHs) algorithm and parallel programming, to evaluate all of the potential combinations of eight different spectral preprocessing techniques against the original reflectance and chemical data prior to the model development. Comparisons of the results were made in terms of the coefficient of determination (R^2) and the Root Mean Square Error of Prediction ($RMSE_p$). The statistical accuracy obtained using PLSR, RF and BRT indicated that for theCox content, the methods of prediction could give a reasonable indicator based on spectra from soilsamples. While predictions by them were close, BRT outperformed RF, followed by PLSR, whichperformed the least well. While SVMR and MBL yielded almost similar results, they were morehighly predictive than the PLSR, RF and BRT approaches. However, according to the criteria of maximal R^2 and minimal $RMSE_p$, PARACUDA-II®with R^2= 0.80 and $RMSE_p$= 0.12, was considered to be the best technique among the others. This is essentially because of its potential to assess all the available options and extract the hidden models to rise up and yield the best available model. It also surpasses other methods in the automatic procedure it offers, which permits searching for the best available model. It can be concluded that the PARACUDA-II®data-mining approach is a powerful tool for obtaining more significant outputs that cannot be achieved using other techniques. A systematic comparison like the one presented here is important as the nature of the target function has a strong influence on the performance of the different algorithms.

SENS-1: New airborne and UAV systems, spectroradiometers

Thursday 7 February 2019
Session Chair: Robert O. Green, Lammert Kooistra

WaterSat Imaging Spectrometer Experiment (WISE) for Canadian Microsatellite Missions

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The Canadian Space Agency (CSA) undertook a pre-Phase A concept study for WaterSat (a near-UV-visible-near-IR hyperspectral microsatellite mission) for monitoring coastal oceans, estuaries and inland water bodies. To help advance the WaterSat mission study and elevate its technology readiness level, CSA awarded a contract to ITRES to design and build an airborne WaterSat Imaging Spectrometer Experiment (WISE).

The WISE instrument consists of three key subsystems: 1. fore-optics; 2. imaging spectrometer; 3. CCD with its readout, control electronics and software. WISE's fore-optics is a novel wide-angle, compact unobstructed diffraction-limited two-mirror telecentric system. WISE's imaging spectrometer is an innovative compact modified-Dyson design based on ITRES' patent. WISE also incorporates a custom-designed (specifically for near-UV to near-IR imaging spectrometers), large-pixel, high-speed, low-noise CCD with superb dynamic range.

This combination yields a high-performance hyperspectral imaging system with exceptional near-UV/blue sensitivity. Both spatial (keystone) and spectral (smile) distortion are less than 0.1 pixel. The WISE instrument acquires 1500 spatial pixels spanning a 39.46 degree-FOV, up to 288 spectral bands covering a spectral range of 358nm to 992nm with a 2.20nm/pixel average dispersion. It occupies a volume of less than $0.06m^3$, weighs less than 10kg and consumes less than 70W.

WISE instrument, after an 18-month development, was commissioned in early-2018. A series of lab and airborne tests validated the WISE's instrument design, robustness and suitability for high-SNR science applications in costal oceans, estuaries and inland water bodies.

In addition to supporting CSA's WaterSat mission study, WISE's technological innovations and developments will also support CSA's Coastal Ocean Color Imager (COCI) joint feasibility study with NASA and NRL.

Simulation and Improvements of the Hyperspectral Images of the SIELETERS Airborne System

OLIVIER GAZZANO, Yann Ferrec, Alain Kattnig, Christophe Coudrain, Laurent Rousset-Rouviere

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SIELETERS is a dual-band airborne hyperspectral imaging system that covers the mid- and long-wavelength infrared bands (MWIR and LWIR). It is part of the SYSIPHE system that covers bands from 0.4 µm to 11.5 µm [2]. The ground sampling distance of the SIELETETERS instruments is 0.5 m with an 11 cm^{-1} and 5 cm^{-1} spectral resolution, respectively in the MWIR and LWIR bands [1].

During this talk we will present the recent progress we have made to improve the quality of the hyperspectral images acquired by the SIELETERS system. SIELETERS instrument is composed of two Fourier transform spectrometers that acquires hundreds of images while the aircraft is moving to measure many optical path differences for all the targeted area. It is then necessary to perform data registrations to overlap the images and to obtain spectral information. This registration is now performed by a two-step method: we first pre-register the images by using the line of sight recorded during the flight and the digital elevation model, and then we perform images correlations on the pre-registered images. We show the method improves the geometrical quality of the spectral images and the quality of the spectrum on buildings edges.

To further understand the insights of the SIELETERS system and further improve the images, we also developed a calculation program that simulates images taken by the SIELETERS instrument. In particular, the calculations account for the system optical transfer function and for the pixel spectral and spatial responses. The simulation program is now used to improve and to validate the data processing programs of the SIELETERS instruments in several cases that we will describe.

[1] C. Coudrain et al., Opt. Express 23, 16164-16176 (2015)

[2] L. Rousset-Rouviere, et al., 10th EARSEL SIG Imaging Spectroscopy (2017)

Analysis Of High Frequency Hyperspectral Remote Sensing Reflectances From Autonomous In Situ Sensors Deployed In Lakes

MARIANO BRESCIANI[1], Claudia Giardino[1], Annelies Hommersom[2], Dario Manca[3], Tommaso Julitta[4], Cesana Ilaria[1], Valentina Della Bella[5], Rosalba Padula[5]

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The complex aquatic ecosystems, such as lakes, are characterized by a high level of hourly and daily dynamic due to the rapid growth / decrease of phytoplankton, and to the variation of the suspended solids due, for examples, to the wind-induced re-suspension of the bottom sediments. This variability is then changing depending on locations, so that variation in spatial patterns is also a typical feature of these systems. Satellite images have been used widely since many decades to observe and to understand spatial and temporal variability, while the exploration of hourly temporal variability is still limited to geostationary sensors, whose spectral and spatial resolutions are anyway limited for the optically complexity of lake waters. To fill this gap, we are exploring the optical properties of water by acquiring Remote Sensing Reflectance (Rrs) measurements obtained from hyperspectral spectroradiometers mounted on fixed platforms and / or on floating buoys. These sensors allow to gather continuous measurements during the day and for several consecutive days. In particular, Rrs measures were taken by a WispStation in Lake Trasimeno (April-September 2018) and by a ROX sensor floating buoy in Lake Maggiore in July 2018. The WispStation (manufactured by Water Insight) is a fixed position spectrometer system for Rrs and hence also water quality parameters by Rrs inversion. The system measures, every 10 minutes, the radiance and irradiance in the spectral range of 350-900 nm with a spectral resolution of 3 nm. The set-up is based that the instrument will see the water surface at optimal azimuth angles for most of the day. The system on the buoy was instead based on a Rox (manufactured by JB Hyperspectral), a system assembling Ocean Optics spectroradiometers operating in the range 400–950 nm, with a spectral resolution of 1.5 nm. Rrs data collected by both systems were corrected to remove glint. The noise-free data were then analyzed to investigate the chlorophyll-a (chl-a), both in terms of absorption of phytoplankton pigments and as sun-induced fluorescence peak in the read-near-infrared (RED-NIR) wavelengths. This analysis was completed through bio-optical modeling parameterized with the specific inherent optical properties of the two different lakes and the forwarded simulations of the radiative transfer code Hydrolight, where the impact of suspended sediments and colored dissolved organic matter has been included. The Rrs data from WispStation showed that since July 18 there was the peak of chl-a in the RED-NIR and how chl-a concentrations showed variations higher of 100% during the day. The data acquired in Lake Maggiore allowed to evaluate the presence of a small peak due to the fluorescence signal in late afternoon data. The analysis of in situ data presented in this study, will be then exploited in the calibration/validation activities of latest e future satellite sensors such as Sentinel-3 OLCI, FLEX and PRISMA.

Implementation Of A UAV – Hyperspectral Line Imager For Ecological Applications

JUAN PABLO ARROYO-MORA[1], Margaret Kalacska[2], Deep Inamdar[2], Raymond Soffer[1], Oliver Lucanus[1], Janine Goldman[1], Tomas Naprstek[1], Gabriela Ifimov[1], Erica Skye Schaaf[2], Kathryn Elmer[2]

[1]*NRC, Canada;* [2]*ARSL-McGill University*

Hyperspectral line imaging spectrometers (HLIS), also known as pushbroom imaging spectrometers, have been commonly used for airborne data acquisition in a wide variety of applications (e.g. forestry, agriculture, geology). HLIS provide a significant amount of spectral information (i.e. hundreds of contiguous spectral bands) which allows for the characterization of different materials based on absorption features controlled by the chemical composition and structure of the materials. With the recent availability and development of fairly inexpensive, lightweight unmanned aerial vehicles

(UAVs), small form factor HLIS are beginning to be integrated onto UAV platforms (e.g. multirotor helicopters). While there are some examples of "commercial off the shelf – UAV ready" HLIS, their implementation is still a complex process that requires careful configuration as seemingly minor aspects such as instrument misalignments with balancing, produce significant errors in the processed images (e.g. no data pixels, geocorrection errors). In addition, the ultra-high spatial resolution (e.g. 1 cm) at which it is now possible to acquire images with UAV-HLIS, it is also challenging under fairly normal environmental conditions (e.g. wind and sun angle induced shadows). Here we present what we consider to be key aspects on the integration of a UAV-HLIS system for ecological applications. These aspects are related to the UAV-HLIS mechanical integration (e.g. gimbal, GPS/IMU), UAV operations (e.g. mission planning), radiometric calibration and, geometric and atmospheric corrections. More specifically, we describe the implementation of the uCASI (ITRES Ltd.) on the Matrice 600 Pro (DJI) for data collection in three Canadian ecosystems: peatland, mixed forest and an herbaceous ecosystem. Our preliminary results implementing the uCASI (2.9 kg) resulted in integration challenges that required additional engineering before deploying the system. After several attempts to determine the best configuration possible (e.g. weight and balance) and data acquisition parameters (e.g. altitude, speed), the system provided optimal imagery from the aforementioned ecosystems. We found that speeds of 2.7 m/s were ideal for the UAV-uCASI system. In addition, preliminary results indicate a very low proportion of rejected pixels (~1%) after geocorrection, as well as low geo-positional errors in the x and y directions (< 10 cm). Radiometric assessment of the imagery indicate good correspondence between calibrated targets measured on the ground and the HLIS images. Our study highlights the potential of HLIS-UAV platforms for increasing the sampling area in ecosystems, where for instance, a larger number of spectral field plots (e.g. field spectroscopy measurements) can be beneficial for inferring ecological variables.

CORR-1: Imaging spectroscopy data corrections, calibrations, processing

Friday 8 February 2019
Session Chair: David Ray Thompson, Daniel Schläpfer

Optimal Estimation for Combined Retrievals of Surface and Atmosphere: Algorithms, Results, and Open Source Software

DAVID RAY THOMPSON[1], Michael Eastwood[1], Bo-Cai Gao[2], Robert O. Green[1], Mark Helmlinger[1], Vijay Natraj[1], Winston Olson-Duvall[1]

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We describe novel imaging spectrometer atmospheric corrections that fit comprehensive models of the instrument, atmosphere and surface reflectance to the entire Visible / Shortwave Infrared interval from 380–2500 nm. A probabilistic formulation from Optimal Estimation inversion theory accounts for unknown model parameters and measurement noise, permitting rigorous uncertainty propagation. It can estimate spectrally-broad atmospheric perturbations such as aerosol effects that are difficult to retrieve with narrow spectral windows. We describe field experiments in terrestrial and aquatic science investigations where the new methodology improves retrieval accuracy vis a vis conventional atmospheric correction methods. Finally, we describe the open-source ISOFIT codebase (https://github.com/isofit/isofit), an optimal estimation software suite for imaging spectrometer data. ISOFIT can use varied model components including alternative radiative transfer models (RTMs) and statistical descriptions of surface, instrument, and atmosphere. It can run on individual spectra or full data cubes. Applications include in-flight instrument calibration, vicarious calibration and validation, and Earth science investigations.

NASA/JPL Airborne Imaging Spectrometer Campaigns in Support of ESA Satellite CAL/VAL and Simulation

IAN BRUCE MCCUBBIN[1], Andreas Hueni[2], Michael Schaepman[2], Dirk Schuettemeyer[3], Michael Rast[3], Hank Margolis[4], David Thompson[1], Robert Green[1], Simon Hook[1]

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NASA/JPL and the University of Zurich have entered a multi-year cooperation to fly NASA airborne imaging spectrometers in Europe. A first campaign was completed in Summer 2018 comprising research flights on behalf of the European Space Agency (ESA). The scientific goals of the ESA mission were: (a) preparatory activities for the future FLuorescence Explorer (FLEX) and Copernicus Hyperspectral Imaging Mission (CHIME) satellites to support geophysical algorithm development and mission simulation, (b) CAL/VAL for the in-orbit calibration phase of Sentinel3B.

In 2018 two sensor systems were deployed in parallel: (a) AVIRIS-NG owned by NASA and operated by JPL (Thompson et al. 2018), and (b) APEX (Airborne Prism Experiment) owned by ESA and operated by UZH and VITO (Schaepman et al. 2015). The 2019 plan is for flights with AVIRIS-NG and the JPL Hyperspectral Thermal Emissions Spectrometer (HyTES) (Hook et al. 2013) both sensors will be installed on European Aircraft for flights in June 2019.

The acquired data furthermore serve the purpose of comparison of at-sensor radiance and bottom of atmosphere levels to complement the uncertainty budgets that have been established for both AVIRIS-NG and APEX.

This contribution gives an overview of acquired target areas, scientific support for the ESA satellite mission, and first results of the sensor comparisons. The datasets are expected to stimulate airborne imaging spectrometer science collaboration between institutions in the United States and Europe.

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Thompson, D. R., Boardman, J. W., Eastwood, M. L., Green, R. O., Haag, J. M., Mouroulis, P. and Van Gorp, B. (2018). "Imaging spectrometer stray spectral response: In-flight characterization, correction, and validation." Remote Sensing of Environment 204: 850-860.

Hook S.J., Johnson W.R., Abrams M.J. (2013) NASA's Hyperspectral Thermal Emission Spectrometer (HyTES). In: Kuenzer C., Dech S. (eds) Thermal Infrared Remote Sensing. Remote Sensing and Digital Image Processing, vol 17. Springer, Dordrecht

In-Situ Field Spectroscopy Best Practice Guidelines for the Calibration and Validation of Airborne Hyperspectral Imagery

GABRIELA IFIMOV, Raymond Soffer, Juan Pablo Arroyo-Mora

Flight Research Laboratory, Aerospace, National Research Council Canada

Field spectroscopy has become an integral part in the validation and, when deemed necessary, scene-based calibration (SBC) (often referred to as vicarious calibration) processing of airborne hyperspectral imagery. The acquisition of high quality ground validation data, along with well documented associated metadata, is paramount for the on-going development and quality assessment of processing methodologies and increased quality of the airborne hyperspectral data.

Although the premise behind the acquisition and processing of spectral field data acquired in near-proximity of either reference or target surfaces is relatively straightforward, in practice the process is challenging, prone to numerous errors in both the data acquisition and processing protocols, and not easily comparable to hyperspectral data derived from remote sensor systems. Therefore, the validation of airborne hyperspectral imagery using field spectroscopy data requires an in-depth understanding of the measurement process which includes (but is not limited to), knowledge of the reference panel characteristics, influence of various scattering mechanisms, upscaling effects, and of the data processing routines. Independent of the ground target's characteristics, there has been a growing demand for common standards and protocols as well as for well-characterised ground targets used in SBC techniques.

In this presentation we cover the procedures developed for the collection of in-situ field measurements in support of SBC of airborne hyperspectral imagery at the Flight Research Laboratory, National Research Council Canada (FRL-NRC). The main objectives of this study were: (1) to collect spectral reflectance of homogenous targets for the calibration and validation of airborne hyperspectral imagery; and (2) to investigate geospatial and spectral variability observed in the field-spectroscopy measurements over multiple field campaigns. The cal/val site is located in close proximity to FRL-NRC, located at the Ottawa International Airport, Ottawa, Ontario and consists of four calibration targets: two permanent areas (asphalt and concrete), and two large deployable calibration targets (grey and black). Preliminary results show 0.70 to 2.66 m differences in recorded GPS measurements and 5 to 10 % spectral variability between trials for the targets. Moreover, the findings of this study indicate that the data quality improves when efforts are taken to minimize contamination of the downwelling irradiance of the field spectroscopy reference and target measurements caused by objects, such as nearby obstructions protruding above the horizon and when sufficient distance from the instrument operator is taken. Other considerations consist of tracking and accommodating panel degradation, improved knowledge of the reference panel characteristics, and ensuring nadir viewing fore-optics. Implementation of a carefully developed best practice guidelines has been shown to improve the quality and accuracy of the resulting airborne hyperspectral imagery.

Mitigating Sensor-Generated Spatial Correlations in Airborne Spectrographic Imaging Data

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[1]McGill University, Canada; [2]Flight Research Laboratory, National Research Council of Canada, Canda

In spectrographic imaging, most applications rely on the assumption that the spatial contribution to the spectrum from each pixel is uniform across its boundaries. This is, unfortunately, not correct. Due to limitations in the optics, detectors, and electronics of spectrographic imagers, the spatial contribution to each pixel is non-uniform and often extends past the pixel boundaries. Consequently, the spectrum from each pixel has contributions originating from within the boundaries of its neighbors, leading to sensor-generated spatial correlations that mask the natural dynamics of the imaged scene. The spatial contribution to each pixel can be characterized by the point spread function(PSF), which is the impulse response function of the sensor. Despite the profound implications, PSFs are ignored in most analyses, especially at the airborne level.

The submission presents a novel algorithm that mitigates sensor-generated spatial correlations in spectrographic imaging data. The algorithm functions by unmixing the spectrum from each pixel based on the theoretical contribution of all neighboring pixels -as calculated from the PSF. To test the performance of the algorithm, the study analyzed two artificially generated hyperspectral images that were simulated from a single high-spatial-resolution image for which 100% of the information content was known. The two images were only distinguished by the simulated PSF. The first image represented an ideal scenario where the PSF was perfectly uniform across the spatial boundaries of each pixel. The PSF of the second image was modeled after the spatial response of the CASI-1500(Compact Airborne Spectrographic Imager). The PSF was gaussian in nature, extending approximately 2 pixels in the across-track and 1 pixel in the along-track. The algorithm was applied to the non-ideal image and assessed based its ability to recover the structure of the spatial correlations observed in the ideal image. The structure of spatial correlations was established using the correlation coefficient. Specifically, the correlation coefficient was calculated between the spectra of adjacent pixels in both the across-track and along-track. This process was repeated for distant neighbors separated by 2 to 15 pixels. The calculated correlation coefficients were grouped by pixel displacement separately in the across-track and along-track. The mean and standard deviation of each group was calculated to quantify the strength and variance of the spatial correlations within each image as a function of pixel displacement.

In the results, the non-ideal image was characterized by stronger spatial correlations than its ideal counterpart. The variance in the spatial correlations was smaller in the non-ideal image. The spatial correlations in the non-ideal image were larger between pixels in the across-track than the along-track. All three trends were amplified when pixels were separated by small distances(<2 pixels). After applying the algorithm to the non-ideal image, the asymmetry between the along-track and across-track correlations was minimized. Moreover, the algorithm was able to recover the natural variance in the spatial correlations that was observed in ideal image. These findings suggest that the algorithm is capable of mitigating sensor-generated spatial correlations. Overall, the developed algorithm has the potential to be a standard pre-processing methodology for spectrographic imaging data.

Towards a Standard for Characterization Hyperspectral Imaging Devices

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Hyperspectral imaging holds great diagnostic, scientific and categorization power. The flurry of industry activity around this technology is a testament to its potential to deliver a wide range of commercial and scientific benefits. However, fundamental aspects of instrument performance are not well characterized or well represented, which hampers application endeavors and commercial market expectations. Establishing a common language, technical specification, testing criteria, task-specific recommendations and common data formats are essential to allowing this technology to achieve its full scientific and economic market potential.

The IEEE Geoscience and Remote Sensing Society has sponsored an IEEE Standards Association Working Group, P4001, to develop a standard for characterization and calibration of hyperspectral imaging devices. The working groups has over 50 members from across the spectrum of industry, academia, standards development organizations and national metrology institutes. Three subgroups have been formed to pursue difference aspects of standardization for ultraviolet through shortwave infrared (250 nm to 2500 nm) hyperspectral imagers:

T1 TERMINOLOGY MISSION STATEMENT:

A fundamental underpinning of establishing methods and means for testing, and for accurately and unambigously conveying product specifications, is having written definitions and well-defined equations (where possible) that objectively and unambiguously define terms germane to Hyperspectral Technology. The focus of this working group is collect, organize and define terms as related to the testing and characterization of Hyperspectral instruments.

C1 CHARACTERIZATION MISSION STATEMENT:

Manufacturers should state clearly the basis tests and quantitative values for their instruments, explained well enough so that anyone in industry can replicate these tests with common optical test equipment and reasonable effort. While testing facilites such as SIRCUS and others provide space-level and NMI testing quality, the focus of this group is to spell out practical means and methods that that do not require such expensive facilities, while still producing characterization values and, if possible, traceable uncertainties on these values.

D1 DATA STRUCTURES MISSION STATEMENT:

The data products coming from Hyperspectral Imaging instruments are what ultimately everyone wishes to use. There is currently no consensus on how standards for these products should be created, structured or coordinated. While it is unreasonable to expect that one standard will suit all applications or instruments, it is the task of this group to lay out means and methods to provide basic, generic structures for header files, data files, encoding and inter-format transfers. These standards can then be used to underlay instrument information, data collection, storage and interpretation that ensures at least a common starting point for data organization.

Each of the above subgroups seeks contributions and recommendations from the community of manufacturers and users of hyperspectral instrumentation. This presentation will provide an update on progress made to date by each of these subgroups.

URB-1: Spectroscopy for urban applications and societal challenges

Friday 8 February 2019
Session Chair: Mathias Kneubühler, Frantisek Zemek

Response of Leaf Chlorophyll Fluorescence to Traffic Related Air Pollution in Cities

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Environmental stress can harm and damage plants, especially in urban environments. Trees growing in cities often suffer from lack of root space, shortage of water and nutrient availability, reduction of sunshine and exposure to air pollution. This air pollution also poses serious health risks for humans. Therefore it is important to get a detailed insight in the spatial and temporal distribution of air pollution in cities. Biomonitoring using urban trees and remote sensing techniques can be a possibility for street-scale and time integrated monitoring of urban air pollution. Trees are resilient and their leaves can adapt their physiology and even morphology to environmental stress in aim to pursue optimal performance. These stress induced leaf changes can be detected using remote sensing techniques, more specifically by measuring leaf chlorophyll fluorescence. Techniques for retrieving the weak fluorescence signal have been refined, making it applicable to monitor stress in plants.

In this HYPERCITY project (https://www.uantwerpen.be/en/projects/hypercity) the potential of leaf chlorophyll fluorescence as indicator for urban air pollution is explored. Furthermore the dorsiventral leaf asymmetry is taken into account as a promising indicator for pollution. We hypothesize that exposure to air pollution alters the physiology and the anatomy of leaves in a way that also alters the leaf dorsiventral asymmetry and chlorophyll fluorescence. Secondly we hypothesize that spectral indices can distinguish between plants growing in areas with contrasting air pollution levels.

In total 56 plane trees (Platanus x. acerifolia) were selected in Antwerp (Belgium) and in Valencia (Spain), spatially distributed over different pollution classes: at busy traffic roads, in residential areas and in urban parks. Bidirectional (upward and downward) chlorophyll fluorescence was measured using the FluoWat leaf clip coupled to an ASD spectroradiometer. To develop dorsiventral asymmetry indices, the spectra were measured twice per leaf: (1) with the adaxial leaf side facing the light and (2) with the abaxial leaf side illuminated. Saturation Isothermal Remanent Magnetization (SIRM), a magnetic leaf biomonitoring approach, was used to map the background pollution at each tree location. In order to interpret the obtained spectral results in terms of air quality, data were correlated with the air quality indicators obtained from SIRM, existing air quality models and leaf characteristics.

The first results show that the downward leaf chlorophyll fluorescence signal is more sensitive to variations in air quality then upward leaf chlorophyll fluorescence. The dorsiventral leaf asymmetry is a promising factor that should not be ignored. When each tree becomes a monitoring station, air quality can be mapped in detail with high spatial resolution.

Real time Airborne Gas quantification using Thermal Hyperspectral Imaging : Application to methane

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Currently large uncertainties exist associated with the quantification of fugitive methane emissions and recent crisis show a lack of real time retrievals allowing operators to coordinate multiple measurements of the most active areas. In this purpose, several gas test campaigns have been conducted by TOTAL and ONERA - The French Aerospace Lab – since 2015, to validate our ability to visualize and quantify in real time plumes of methane in a very large range of flow rate (from 0.5 g/s up to more than 100g/s) from hyperspectral thermal infrared cameras using Telops technology. In this paper, we present in particular recent results from real time airborne methane quantification during the last campaign in 2018. Airborne measurements present particular advantages over ground based-techniques since large areas can be covered efficiently from a safe distance and is not limited by ground topography. The developed quantification algorithm coupled with airborne Telops HyperCam acquisition system provide, for methane in particular, real-time quantitative map (ppm.m) at high spatial resolution, estimation of local concentration (ppm) near the source and leakage flow rate with associated uncertainties. The presented system is a powerful tool dedicated to source attribution and associated flow rate estimation in complex environments.

Thermal Infrared Hyperspectral Imaging for Visualization and flow rates Quantification of Methane releases

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Gas leaks present obvious health, safety and environmental risks. In oil and gas companies for instance, constant monitoring is crucial to preserve on-site personnel security and to prevent damage to the installations. The need for a reliable and cost-efficient gas detection system is of prime importance especially when security threatening situations like gas leaks and emissions occur. Precise localization of the leaks, identification of the chemical nature of the gases involved and quantification of the gas flux emanating from the

leaks may help the incident response team to take actions based on relevant information. In this regard, infrared remote sensing technology offers many benefits over traditional gas detection systems as it allows monitoring and imaging of the incident scene from a safe location. The sensor can be located at distances ranging from tens of meters to several kilometers from the scene, avoiding the need to access restricted and potentially dangerous zones in the installations. The passive infrared hyperspectral imaging technologies are therefore among the solutions that could possibly be used to efficiently and safely address the gas leaks. Telops have developed hyperspectral imaging solutions for gas detection and identification along with some tools for the quantification of gas flow rates emanating for leak source. These solutions were recently used during a methane-controlled release test campaign carried out at National Physical Laboratory in UK. The results presented in this communication show the potential of Telops gas detection and quantification solutions for real time visualization of methane and its dynamic dispersion within production plants.

Exploration of Iron- and Steelworks Dump Sites – Using spectral data from the Visible Light, Near- and Shortwave Infrared (350–2500 nm) to the Mid- and Longwave Infrared (2500–15000 nm)

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The exploration of secondary deposits, including iron- and steelworks dumps, is of increasing relevance in times of limited resource availabilities and increasing raw materials demands. Especially sites with long history may comprise materials, which are valuable under today's world market situation. However, the exploration of historic industrial dumps is challenging due to the anthropogenic material deposition and their heterogeneous composition. Consequently, the exploration of these deposits typically requires time consuming sampling campaigns and subsequent cost-intensive laboratory analyses for material characterisation. Thus, new approaches are required to aid the exploration of iron- and steelworks dumps, to assist material typification and the quantitative assessment of relevant properties within urban mining applications.

As most slags and other by-products show a differing mineralogy and chemistry compared to natural rocks, existing information on spectra of natural formations cannot be directly transferred to such "industrial rocks". However, profound knowledge about the spectral properties of potential target materials is the prerequisite for their successful spectral detection and analyses in remote sensing applications. Thus, this study aimed to: a) extend the knowledge of reflectance properties of a variety of historic and recent iron- and steelworks by-products and b) analyse the potential for spectrally estimating the quantities of relevant chemical constituents.

This study was based on 102 samples, comprising slags, dusts and sludges, of which the majority was collected at the dump site of an electric steelwork, located in Thuringia, Germany, with a long history of iron and steel production by an integrated metallurgical plant since the 1870s. The samples were analysed for their chemical composition via ICP-OES.

Mineral phases were determined by X-ray diffraction. Reflectance measurements covered the visible light, near and shortwave infrared (VNIR/SWIR, 350-2500 nm, ASD FieldSpec Pro) as well as the mid- and longwave infrared (MWIR/LWIR, 2500–15000 nm, Agilent Handheld FTIR 4300). The spectral separability of the different material types was analysed using principal component analyses and hierarchical clustering. Partial least square regression was applied for predicting relevant chemical constituents of iron- and steelworks by-products.

The results showed that VNIR/SWIR as well as MWIR/LWIR spectroscopy is a capable tool to spectrally differentiate a variety of recent and historic iron- and steelworks by-products. Spectral properties and specific features of various slags and other material types were compiled in a spectral-library-like manner for the VNIR/SWIR as well as for the MWIR/LWIR. Based on PLSR modelling, robust predictions ($R^2_{val} > 0.8$) were achieved for CaO, Fetotal, Fe_2O_3, TIC and SiO_2 with moderate prediction errors ($RMSE_{val}$ 2–4 m%). Solid predictions for CaO, Fe_2O_3 and Fe_{total} were obtained using the VNIR/SWIR range, while the robust prediction of SiO_2 and TIC required MWIR/LWIR data due to specific spectral properties of these constituents not found in the VNIR/SWIR. The combination of both spectral ranges improved the predictive performance of the PLSR models but was in some cases achieved at the cost of higher model complexity. In summary, VNIR/SWIR and MWIR/LWIR reflectance spectroscopy was found suitable tools for discriminating and qualitatively as well as quantitatively characterising iron- and steelworks by-products.

Wednesday 6 February 2019

Photosynthetic Pigments Changes Related To Screening Of Photosynthesis Dynamic Of European Beech And Norway Spruce Trees Using PRI

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Irradiance and temperature affect photosynthesis of plants, pigments shifts and reflectance signature. Understanding coupling between photosynthetic activity and shifts in photosynthetic pigments should improve understanding the basis of remote estimation of photosynthesis as the balance between photosynthetic uptake (by chlorophylls) and enhancing protective functions (by carotenoids) during stress episodes is determining for photosynthesis dynamic in varying environments. This work was conducted to contribute to debates on topic of influence of changing pigments and mainly chlorophylls to carotenoids ratio on sensitivity of photochemical reflectance index (PRI) towards photosynthesis dynamic. Data summarizes knowledge acquired during two years of measurements of optical properties and tree physiology measures in controlled environment of phytochambers.

Measurement confirmed affinity of PRI to photochemical and non-photochemical quantum yields and also to photosynthetic light use efficiency (LUE). However, ΔPRI estimated LUE with improved accuracy regardless of changing chlorophylls to carotenoids stoichiometry in leaves. The connection between ΔPRI and LUE did not hold up for measurements taken directly at highest irradiance period, however improved assessment of LUE over the long-term. Measurements revealed that light conditions play significant role in forming daily magnitude of foliar PRI and ΔPRI response. Analysis furthermore showed, that leaf carotenoids and xanthophyll cycle pigments contents per chlorophylls unit also play significant role in developing PRI and also basis for the ΔPRI estimation, the initial PRI_0 of each day. Accurate estimation of PRI_0 changing dynamic with predawn de-epoxidation of xanthophyll cycle pigments is suggested as factor largely improving sensitivity of ΔPRI towards LUE. In consequence of precise estimation of canopy PRI at multiple irradiance conditions and temperature stress levels with excluding changes in illumination angles, ΔPRI shows improved ability to track LUE in trees with diverse responsiveness of photosynthesis to imposed irradiance and temperature changes and changing water availability.

Seasonal Dynamics Of Lingonberry And Blueberry Spectra

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Reliable interpretation of spectra from boreal forests acquired by sensors on air- or spaceborne platforms relies on having access to temporally matching reference data for identifying plant species. The seasonal dynamics of the spectral data originate from the periodical changes in plant physiology within all vertical layers of the forests, from overstory (tree canopy) to understory vegetation. We conducted a research effort over the growing season of 2017 for obtaining multitemporal ground reference data of understory vegetation for spectral characterization of the two most economically important dwarf shrub species in Finland: lingonberry (Vaccinium vitis-idaea) and blueberry (Vaccinium myrtillus). We present the first empirical evidence of the seasonal dynamics of spectra of these species in visible and near infrared to short-wave infrared spectral regions. The spectral shrub data were obtained as multiangular spectral bidirectional reflectance factors (BRFs) using Finnish Geospatial Research Institute's FIGIFIGO instrument. All measurements were made in radiometrically stable and controlled laboratory conditions in order to relate the changes in the spectra to shrub structure and to the optical properties of leaves, flowers and berries. In this poster presentation, we (1) communicate the differences of the seasonal dynamics of lingonberry and blueberry shrub spectra, (2) provide spectra of leaves, flowers, and berries, (3) evaluate the potential of detecting the presence of berries from overall shrub spectra, and (4) report the multiangular BRFs of both study species.

Seasonal Modelling Of Leaf Optical Properties And Retrieval Of Leaf Chlorophyll Content Across The Canopy Using PROSPECT

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Seasonal changes in leaf chlorophyll across the canopy vertical profile provide information on ecosystem structure and functioning. However, studies on the retrieval of leaf chlorophyll content (C_{ab}) using radiative transfer models such as PROSPECT across the canopy vertical profile throughout the growing season are lacking. In this regard, we sought to evaluate the performance of the PROSPECT in modeling leaf optical properties and retrieving C_{ab} across the canopy position throughout the growing season. We collected 588 leaf samples from the upper and lower canopies of deciduous stands over three seasons in Bavaria Forest National Park, Germany. PROSPECT input parameters were measured for all the samples, and their respective reflectance spectra were obtained using an ASD FieldSpec-3 Pro FR spectroradiometer coupled with an Integrating Sphere. To retrieve C_{ab}, we inverted the PROSPECT using a look-up-table (LUT) approach. Our results consistently revealed a strong agreement between the measured and PROSPECT simulated reflectance spectra for the lower canopy compared to the upper canopy, especially in the NIR. This observation concurred with the pattern of C_{ab} retrieval accuracies across the canopy i.e. the C_{ab} retrieval accuracy for the lower canopy was consistently higher (NRMSE = 0.1-0.2) when compared to the upper canopy (NRMSE = 0.122 - 0.269) across all seasons. Results of this study demonstrate that although the PROSPECT model provides acceptable inversion of C_{ab}, subtle seasonal variations in leaf biochemistry and morphology across the canopy potentially affect the performance of the model.

Seasonal Chlorophyll Fluorescence Changes in Citrus aurantium Exposed to Low and High Traffic Pollution

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Orange trees, Citrus aurantium, are deciduous evergreen species and typical urban trees for the city of Valencia in the Mediterranean climate. These ornamental urban trees grow new leaves each spring, summer and autumn, which we call leaf age cohorts. As the leaves stay on the trees for 1.5 years, it provides an opportunity to investigate the effect of leaf age cohort and the seasonal conditions on the photosynthetic efficiency. We hypothesize a changing physiological performance throughout the year depending on the leaf age cohort.

Besides the variations corresponding to altering seasonal conditions and leaf senescence, also the impact of a stressful environment is incorporated in the HyperCity-project. More specifically, stress induced by the traffic exhausts contaminating the air in the city of Valencia is studied. Four orange trees – respectively growing in an area with high and low traffic density – are analysed. This research aims to establish correlations between pollution variables (heavy metals, NO_2 and traffic density), structural characteristics (specific leaf area, leaf water content, chlorophyll content, thickness of palisade- and spongy parenchyma, nitrogen content) and physiological parameters measured with the fluorimeters "Plant Efficiency Analyzer" (Hansatech) and "Pulse-Amplitude-Modulation" (Walz).

Leaves capture and convert light into sugar through a process we know as photosynthesis. However, not all light gets absorbed by the chlorophyll pigments in leaves and is partially transmitted or reflected back into the atmosphere. Our eyes capture a typical leaf reflectance spectrum as green, but actually contains a lot more information that can be investigated with spectroradiometers. Not all light absorbed by the leaves gets photosynthesized. Leaves are only able to convert a certain amount of light, excessive light induces formation of reactive oxygen species that can cause damage. Plants have therefore evolved defence strategies against reactive oxygen species being able to dissipate the excess of light through heat (non-regulated), chlorophyll fluorescence (non-regulated) and non-photochemical quenching (regulated by xanthophyll cycle).

Chlorophyll fluorescence is basically light re-emitted back into the atmosphere and consists a tiny part of the reflectance signal. The more stress, the more chlorophyll fluorescence. This principle means that chlorophyll fluorescence is a sensitive method for early stress detection in vegetation. Applying the PEA and PAM fluorimeters, this research studies the physiological balance between the photosynthetic yield and the non-photochemical quenching depending on the aforementioned conditions. Thirty leaves are sampled in each orange tree (ten per leaf age cohort).

Preliminary data processing revealed an altering physiological performance by the different leaf age cohorts. The seasonal conditions appear to have an impact on the photosynthetic efficiency as well. Also, a significant correlation is established between degree of traffic exposure and the vegetation health status. Further analysis focuses on the influence of exposure time to air contamination. The knowledge acquired during the project should contribute to the development of modelling toolboxes, which generally lack the implementation of stress factors and aid the interpretation of spectra gathered from remote sensing platforms.

Estimation Of Crop Biophysical And Productivity Properties Using Radiative Transfer And Spectral Information Analysis

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Current capabilities of high resolution Earth observation systems provide data giving spatial information on agricultural crops. Therefore, there is a great interest in linking qualitative data (e.g. crop maps) with quantitative indicators of the main biophysical parameters of vegetation which can be further used for analysing current status of crop canopies. Such information has many potential uses in agricultural management from fertilization planning to harvest optimization. PROSAIL radiative transfer model was used for simulating spectral signatures of the six selected crops (winter wheat – triticum aestivum, spring barley – hordeum vulgare, winter rapeseed – brassica napus, alfalfa – medicago sativa, sugar beetroot – beta vulgaris, maize – zea mays) which were further used for estimation of three main biophysical parameters: leaf chlorophyll (Chl) and water content (Cw) together with leaf area index (LAI). Crop optimized parameterization of the PROSAIL model was based on the results of intensive field works focusing on collection of the reference in-situ data on crop biophysics. In-situ data collection was conducted repeatedly during vegetation season to cover different growing stages of the crops. Simulations of the spectral signatures generated by PROSAIL were validated against TOC reflectance data acquired during the field campaigns by ASD Fieldspec-4 spectroradiometer. These data were further used also for validation TOC reflectance signatures extracted for atmospherically corrected Sentinel-2 data. The simulated spectra obtained by crop-specific parameterization of PROSAIL were finally used together with soil moisture layers and qualitative crop map for estimation of the three parameters of interest using Sentinel-2 data.

In addition to quantitative estimation of crop biophysics, temporal dynamics of spectral properties was assessed in order to estimate crop productivity parameters. Experimental growths of winter wheat and winter rapeseed were cultivated in specific conditions with different levels of nutrition. In-situ acquisitions of TOC reflectance accompanied with chlorophyll content, LAI and nitrogen uptake measurements were performed several times during vegetation season. These time series of the data were further used for establishing relationships between spectral information and productivity parameters such as N uptake and yield. The developed methodology was performed on the level of field spectra, but its transformation to the level of airborne hyperspectral data and Sentinel-2 satellite data is foreseen in the nearest future.

Original Method for High Spatial Resolution Classification of Tree Species Using Multi-Temporal Many and Hyperspectral Satellite Data

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Among tasks related to forest monitoring, the classification of forest by species composition is most complex. Spectral properties of different forest formations can vary significantly depending on the vegetation period, growth conditions, crown closeness and other factors. This determines the relatively low efficiency (from one to few forest types and/or average classification accuracy) of the traditionally used methods of image classification applied to forest species identification. The effectiveness of tree species classification can be increased by the processing of satellite multispectral (MS) or hyperspectral (HS) data acquired in different phenological periods. The main objective of the study is to propose a method for tree species classification from satellite MS and HS time-series data using the system of features based on phenological periods.

The first study area is located in the northeastern part of the Gulf of Finland in the Leningrad region of Russia (Berezovye Islands archipelago). The forest stands are composed of pine, spruce, birch and alder. The second study area is located in the eastern Moravian-Silesian region of the Czech Republic (Těšínské Beskydy Mts.). The forest stands are composed of spruce, beech and a scattered admixture of pine, fir and larch.

Multispectral satellite Landsat 8 OLI data (16 scenes) and hyperspectral satellite Resurs-P data (2 scenes) are used in the study. A geobotanical map and a forest inventory map are utilized for training samples and the verification of classification results.

The method for tree species classification based on multi-temporal data consists of two main stages. At the first stage, the image fragments not related to the forest are excluded from the further processing based on the analysis of seasonal changes in the vegetation index NDVI. At the second stage, the changes in the spectral signatures of forest classes are analyzed and new spectral-temporal features are formed for the classification. Euclidian distance, Mahalanobis and Terebizh metrics are applied for the classification depend on the type of feature.

The method involves the specialized database of tree species spectral reflectance with regional peculiarities of the beginning and the end of eight vegetation phenophases (phen). The differences between spectral reflectance of tree species are shown statistically significant in the sub-season of spring vegetation (phen3), the first half of summer (phen4) and main autumn (phen7) in both study areas. Most of the errors are related to the classification of deciduous species (Berezovye Islands) and the identification of pine as birch (Berezovye Islands) or pine as beech (Těšínské Beskydy). The classification using multi-temporal MS data has 1.7 times higher kappa coefficient than the classification using single HS image. Potentially, classification accuracy can be improved, when the method applies with multitemporal satellite HS data, as a new near future HS satellite products of EnMap and/or HyspIRI.

Probability Map of Invasive Tree Species Using Hyperspectral and LiDAR Dataset

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Invasive species are a form of biological pollution, and a serious component of the anthropogenic global changing. Detection of species over a broad region have a high priority in the prevention of natural habitats. This study is focused on Ailanthus altissima whichis the one of the most expensive invasive tree species in Europe. The aim of this study was to test the applicability of different image classification methods using both of airborne hyperspectral and laser scanning data. For the classification, we established 15 classes based on the dominant species, canopy height, and social position. Digital images were acquired from an AISA Kessler hyperspectral sensor of 178 contiguous bands (400–1000 nm), a ground pixel size of 1 m. Airborne laser scanning data (8point/m^2) was recorded by Leica ALS70 sensor. Image classification was applied to the original and MNF (minimum noise fraction) transformed dataset. We found that SVM and MLC (OA: 82.24 %, kappa = 0.79) produced the best accuracy with first 13 MNF transformed bands.

The probability layers of the Maximum likelihood classification were applied in various ways. (I) An Ailanthus sp. prediction map was prepared using the combination of (1) custom threshold values of Ailanthus sp. probability and (2) the rank of the Ailanthus sp. probability among all the classes. (II) A tree species distribution map was created by using the class ratios inside the segmented tree canopies. The most frequent class was assigned to the segment, but the pixels of Ailanthus sp. was weighted in the calculations.

Exploring the Potential of Light Use Efficiency Derived from Eddy Covariance and Reflectance Measurements for Spatial Simulations of Gross Primary Production

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Light use efficiency (LUE) model based on remote sensing provide a promising tool for monitoring spatial and temporal variations of CO_2 uptake (gross primary production; GPP) by terrestrial vegetation. GPP is simulated by the LUE model as a product of light use efficiency term and absorbed photosynthetically active radiation (PAR). Absorbed PAR is calculated as a product of incident PAR and the fraction of incident PAR absorbed by the vegetation (f_{APAR}). The accuracy of GPP simulation by the LUE model, however, depends upon how well the LUE term is quantified. Most of the current studies rely on the constant value of the LUE term for a particular land cover type. However, the spatial heterogeneity in the LUE term within a land cover type due to the different species compositions was well recognized. Temporal change in the LUE term is also apparent due to change in the environmental factors such as air temperature, soil moisture, and vapor pressure deficit. In this study, we considered both the spatial and temporal distributions of the LUE term.

At the spruce dominated forest site Bílý Kříž, Czech Republic, continuous half-hourly measurements of net ecosystem exchange (NEE) are being made at the flux tower using eddy covariance technique. In addition, a spectrometer is also installed at the top of the tower to collect time series of spectral reflectance of a small canopy sector at a 5-minute interval. Moreover, several airborne hyperspectral datasets are available for the area of flux tower footprint. These datasets provide an excellent opportunity to study the temporal and spatial variations in the LUE term. This study has three objectives: (1)

to explore seasonal variations of LUE; (2) to link LUE with the time series of spectral reflectance measurements from tower spectrometer; and (3) to obtain spatial estimates of LUE in order to simulate spatial distributions of GPP. To achieve objective 1, we separated GPP from the NEE measurements at the flux tower using flux partitioning model. We estimated f_{APAR} using the Normalized Difference Vegetation Index (NDVI) from the hyperspectral reflectance measurements from tower spectrometer. Measurements of incident PAR were directly obtained from the flux tower. These time series of GPP, PAR, and f_{APAR} were used in the LUE model to obtain time series of the LUE term. To achieve objective 2, we calculated a number of vegetation indices (VIs) from the time series of spectral reflectance measurements. These VIs include REP (Red edge position), PRI (Photochemical reflectance index), and CI (Chlorophyll index), which are directly related to the leaf biochemical characteristics and LUE. We developed empirical models that linked VIs and the LUE estimated from separated GPP. To achieve objective 3, these empirical models were extrapolated to the region imagined by airborne hyperspectral reflectance. This resulted in the spatial estimates of LUE, and finally the spatially simulated GPP. The methodology adopted in this study provides a direct comparison between GPP and the spectral reflectance at temporal and spatial scales that are relevant in the carbon cycle studies based on GPP.

Is Retrieval of Forest Biochemical Traits Stable over Variety of Environmental Conditions?

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A network of 15 small forested catchments established in the Czech Republic (the GEOMON network) has been used since 1994 for a long-term monitoring of the input-output element budgets and to study the ecosystem response to anthropogenic pressures (e.g., air pollution and soil acidification). The small catchments (22 – 260 ha) are predominantly covered by Norway spruce (Picea abies) forests, they were exposed to different levels of air pollution in the past and represent variety of environmental conditions (e.g., altitude, bedrock, soil types, forest age). During summer 2017 we collected airborne hyperspectral images with the CASI and SASI spectroradiometers (400 – 2400 nm, 162 bands with band width varying between 10 and 15 nm, pixel size of 1 m) and complementary field data on leaf chlorophyll, carotenoid, and water contents and leaf mass per area for 10 out of 15 watersheds (in total 120 trees were sampled at 40 subplots). Taking the advantage of such a rich dataset, the main objective was to optimize the retrieval of biochemical traits for varying conditions in coniferous stands and to test the retrieval stability in respect of varying environmental, forest and data acquisition conditions.

Retrievals were optimized for coniferous stands by employing 3D radiative transfer model DART that allowed simulation of look-up tables for variety of forest and environmental conditions (variable biochemical traits, tree height, tree density, leaf area index, topography, and forest floor), as well as for different image acquisition conditions (i.e., illumination geometry). The look-up tables were used to train a machine learning algorithm, support vector regression (SVR) in combination with feature extraction to retrieve biochemical parameters from the airborne hyperspectral images. The field data on leaf biochemical traits indicated that there were no statistically significant differences between the catchments, nonetheless the variation between the subplots is large and it varies from 35 to 60 ug cm-2 for leaf chlorophyll content, from 4.6 to 7.6 ug cm-2 for leaf carotenoid content, from 0.018 to 0.026 g cm-2 for leaf water content, and from 0.014 to 0.024 g cm-2 for leaf mass per area. The preliminary results of retrieved traits from airborne hyperspectral images show systematic overestimation of leaf chlorophyll content and the most stable estimates across the catchments were obtained for leaf water content. The most influential feature of the retrievals was the terrain topography.

Hyperspectral Analyses of Heavy Metal Contents in Floodplain Vegetation and Soils

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Flood events are of major environmental concern and affect manifold environmental compartments, of which floodplains are among the most affected ecosystems. Floodplains show a large species and habitat diversity, they are essential for flood protection, water retention and the reduction of soil erosion. On the other hand, floodplain ecosystems are heavily exposed to flood events and subsequently to polluted sediment loads and the accumulation of dissolved heavy metals in soils, which gradually enrich in the floodplain vegetation that is often used for fodder production. Especially flood waters passing abandoned open pit mines, industrial areas, intensively used agricultural sites and urban structures are highly enriched with contaminants. Thus, it is necessary to monitor these contaminations. In this study, the potential of VNIR/SWIR (350 - 2500 nm) non-imaging and imaging spectroscopy for the assessment of metal contents in floodplains of the Elbe, which was one of the most polluted rivers in Germany at the end of the 1980s, rivers tested.

A total of 84 soil and 182 plant samples were collected between 2015 and 2016 on two floodplain sites near the Middle Elbe River in Saxony-Anhalt, considering different morphological units (sinks, terraces, and plateaus) and sampling dates. Chemical analyses provided information regarding various element concentrations (e.g. As, Cd, Cr, Cu, Fe, Hg, K, Ni, Pb, and Zn) of soils and vegetation. Spectral information was collected with an ASD FieldSpec Pro FR in the laboratory (soils) as well as in situ (vegetation). Simultaneously to the field measurements, airborne based HySpex-images were recorded. For the estimation of metal contents, different pre-processed soil spectra were used as input for Partial Least Square Regression (PLSR) models and parameters based on spectral plant properties (e.g. ratios, indices) were implemented in Multiple Linear Regression (MLR) and Support Vector Machine (SVM) models.

In general, sinks were characterized by higher soil metal contents and reliable PLSR-model outcomes were obtained for the majority of the analysed elements, with the best prediction results for Pb ($R^2 = 0.89$) and Cd ($R^2 = 0.86$). Interactions between plant parameters and metal concentrations were weaker, whereas missing stress features and comparatively low metal contents in the plants hampered the quality of the model approaches. Promising results were generated for Cd (MLR, $R^2 = 0.75$), As (SVM, $R^2 = 0.61$) and Pb (SVM, $R^2 = 0.56$). Based on interpolations between the sampling points of the soil contents and the adaption of the plant models to the HySpex-images, contamination maps were derived and the spatial distribution of heavy metals could be mapped.

The results of this study demonstrate that hyperspectral remote sensing has the potential to provide reliable information about selected heavy metal contents in floodplain soils and plants. Consequently, hyperspectral data allows the identification of pollutant hot spots and may be included in future monitoring programs of floodplain ecosystems. Here, large potential is seen in data from the upcoming EnMAP (Environmental Mapping and Analysis Program) hyperspectral satellite mission. Results achieved using simulated EnMap data indicated the transferability of the developed models.

High Resolution UAV-based Hyperspectral Imagery For LAI And Chlorophyll Estimations For Wheat Plants With Different Nitrogen Fertilization For Grain Yield Prediction

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The efficient use of nitrogen fertilizer is a crucial problem in modern agriculture. Fertilization has to be minimized to reduce environmental impacts but optimally without negatively affecting yield. In June, 2017 a controlled experiment with eight different nitrogen treatments were applied to winter wheat plants and was investigated with the UAV-based hyperspectral pushbroom camera Resonon Pika-L (400-1000 nm) mounted on a DJI M600 with a flight height of 110 m, resulting in a GSD of 0.1 m. The system, in combination with an accurate IMU and precise gimbal is very stable and capable to acquire hyperspectral imagery of high spectral and spatial quality. Additionally, 48 LAI, chlorophyll and field spectra measurements were taken in the field which were equally distributed across the occurring nitrogen treatments.

Since grain yield itself has no direct effects on the spectral reflection of plants, we present an indirect approach based on LAI and chlorophyll estimations with partial least squares regression (PLSR) from the acquired hyperspectral image data. The resulting models showed a reliable predictability for these parameters with $R^2 >= 0.75$. The LAI and chlorophyll predictions were used afterwards to calibrate a multiple linear regression model (MLR) to estimate grain yield ($R^2 >= 0.80$). With this model, a prediction for each pixel in the hyperspectral image was performed. These yield estimates were opposed to the different nitrogen treatments, which showed that after a certain amount of applied nitrogen, more fertilization does not necessarily lead to larger yield.

Determination Of Species-Related Forest Stand Characteristics With The Use Of Hyperspectral Data

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The constant improvement and development of new methods for the low-cost, efficient and objective description of forested areas is necessary. Currently, the use of remote sensing techniques responds to this demand. Hyperspectral imagery generally exhibits the strongest capacity to classify tree species. Although several studies have involved the creation of tree species maps, few have involved more complex analyses of forest stand characteristics based on principles of forest inventories.

The main purpose of this study was i) to explore the possibility to practically use hyperspectral data on forest inventory, ii) to investigate the accuracy of main tree species, species cover proportion and mixture patterns estimations based on hyperspectral data classifications, and iii) to develop a workflow for the RS-based determination of species-related forest stand characteristics.

Sixteen airborne hyperspectral images were acquired with HySpex VNIR-1800 and SWIR-384 sensors on 19 August 2015 during the second part of growing season in Poland. The study area was the Milicz Forest District of southwestern Poland. Four deciduous tree species (black alder, pedunculate oak, silver birch, and European beech) and coniferous species (mostly Scots pine) were classified using a Support Vector Machine (SVM) classifier (reaching overall accuracy of 91% and kappa value of 0.66).

The main tree species in the sample plots were correctly assessed based on the cover area of 92% of the sampled plots. Species cover proportions were estimated correctly for 75-94% of the sampled plots with a tolerance threshold of ≤10 percentage points depending on the species considered. Morisita's index was used to find similarities in species structures within the sampled plots between the classification map and reference field data. Experimental resuls showed the value 0.92 of the index. Spatial mixture pattern detection was performed for 316 forest stands. The results of the developed method were found to adhere to field data with 69% accuracy. The study shows that hyperspectral data are reliable source for the precise description of forest characteristics such as main tree species, tree species cover proportions and mixture patterns.

Mapping of Tundra Vegetation Using Satellite Hyperspectral and Multispectral Imagery

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The vegetation of tundra is diverse and very susceptible to changing growing conditions. Under climate changes mosses and lichens are replaced by sedge and deciduous plants. Increased human pressure and intensive reindeer herding is accompanied by the degradation of vegetation cover. The process of tundra vegetation restoration is several times slower than in the middle zone of the European continent. It is important to monitor the tundra vegetation for analyzing the dynamic of its changes. The study objectives were to map changes of tundra vegetation cover in the last 10 years and indicate the level of vegetation degradation on the study site.

Time-series satellite hyperspectral Hyperion and Resurs-P data and multispectral Sentinel-2 images were used in the study to map 4 vegetation types – mosses, lichens, sedge and other deciduous plants – and their degradation. Ground truth summer and semi-season data, a geobotanical map and processed remote sensing data were used to distinguish spectral characteristics of vegetation types and vegetation conditions – healthy, weakly disturbed and depressed. The informative spectral bands and minimum sample size were determined for classification of satellite images. Machine-learning algorithms (RF and k-NN), the resampling Cubic deconvolution method, atmospheric correction methods (ATCOR and MODTRAN) and GIS analysis were applied to achieve the study objective.

Map of tundra vegetation contains the types and conditions of vegetation and shows the dynamic of changes in the vegetation boundaries within the study period of 10 years.

Comparison And Validation Of In-situ Field Spectroscopy And Advanced High Pressure Liquid Chromatography To Assess Pigment Composition In Deciduous Leaves

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Functional traits retrieved from remotely sensed data allow monitoring diversity at a variety of spatial and temporal scales. Most common retrievals in remote sensing are based on indices, which depend on specific absorption of leaf optical properties mainly driven by pigment composition across the solar reflective spectrum. Accurate assessment of pigment composition and content is thus of utmost importance to provide reliable indices based retrievals, their validation and ultimately limit uncertainties associated with measurements and validation.

Current calibration approaches linking leaf optical properties measurements and pigment concentrations in the laboratory are generally based on the absorbance of pigments dissolved in a given solution obtained by single-step extraction. Using this approach, the diversity in molecules and variability in distribution within pigment groups cannot be assessed, due to overlapping absorptions of individual pigments. Recent advances in chromatographic analyses enable more advanced discrimination. We have developed a method to determine and quantify pigment composition using advanced High Pressure Liquid Chromatography (HPLC). We apply this method to evaluate the influence of pigment composition on spectral data, and validate vegetation indices.

Beech (Fagus sylvatica) and maple (Acer pseudoplatanus) trees located in the vicinity of the University of Zurich (Switzerland) were selected for this study. Sun exposed and shaded leaves were sampled on a weekly basis at different tree heights between May and September 2018. Investigation of the pigment composition was carried out at leaf level. On the one hand, published and calibrated indices for chlorophyll and carotenoids retrieval were applied to leaf spectral data measured in natura using a contact probe and spectroradiometer as well as simultaneous SPAD measurements. On the other hand, multi-step extraction and quantification of pigment content with HPLC was performed using the same leaves after destructively harvesting them. Statistical approaches have been developed to compare both data sets and accuracy measures.

Preliminary results show that both approaches are sensitive to variations in pigment composition of individual trees when sun exposure, tree height, and maturity stage are taken into account over the growing season. In addition, the developed method allows us to identify, for instance in beech trees (Fagus sylvatica), a dozen of coloured compounds derived either from chlorophylls or carotenoids. Thus, we hypothesize that a more exhaustive description of leaf pigment composition and its evolution over the growing season can help to better calibrate spectral indices obtained from in-situ field measurements or imaging devices.

Effect of Leaf Epidermal Structure of Arabidopsis Thaliana Mutants to Leaf Specular Reflection

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Leaf optical properties (reflectance, absorptance, and transmittance) are defined as the ratio of the incoming light on a leaf, which is reflected, absorbed or transmitted. Leaf reflectance is a combination of 1) diffuse radiation reflected from the leaf surface and from the internal leaf structures and 2) specular reflection exclusively from the leaf surface structures. The study focuses on the relation of leaf reflectance in NIR and SWIR and different leaf epidermal structure of selectedmutants of Arabidopsis thaliana.

We studied anatomical and optical properties of model plant Arabidopsis thaliana in wild-type plants (Columbia) and five mutants (glabra, arpc5, exo70h4-1, tbr, cer) with the comparable internal structure and various modifications in epidermal structure: trichome absence, defects in trichome and pavement cells morphology, trichome cell wall thickness, different shape of wax crystals respectively and other structurally related components which all may affect specular reflection. Optical properties were measured by spectroradiometer (ASD FieldSpec) with Integrating sphere (ASD 190 RTS – 3ZC) which is well adjusted to specular reflection measurements. Anatomical study of leaf epidermal surface structure (will comprise trichome type, density, shape and size) was visualised by ESEM (Environmental scanning electron microscope). We will test the hypothesis that leaves with a smooth surface (without trichomes) have a higher ratio of specular reflection on overall leaf reflectance than leaves with trichomes. Further, we focus on how the trichome morphology influences the total and specular reflectance. Determination of leaf optical properties properly by integrating sphere in Arabidopsis thaliana mutants could help distinguishing genotypes in this model organism and serve for verification phenotyping methods in plant studies. Acknowledgements: The study was supported by the NPUI LO1417 project of the Ministry of Education, Youth and Sports of Czechia and by Charles University Grant Agency (GAUK), 1752218.

Chlorophyll Content Estimations Based on CCM-300, Laboratory Measurements and Field Spectroscopy for Tundra Grass Species in The Krkonoše Mountains

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The relict arctic-alpine tundra located in the Krkonoše Mountains National Park is a unique ecosystem combining arctic, alpine and middle European flora and fauna. Along with the species composition, the chlorophyll content is an important indicator of the ecosystem functioning. Different optical meters are widely used to estimate leaf chlorophyll concentration; however, they are species-dependent. Thus, our goal was to compare the chlorophyll measurements using non-destructive and fast optical chlorophyll content meter CCM-300 (Opti-Sciences, USA) with the laboratory measurements. We focused on three homogenous tundra grasses - original Nardus stricta and expansive Calamagrostis villosa and Molinia caeruela. Twelve plots were selected. Two small randomly selected subplots at each plot were analyzed. The chlorophyll measurements were repeated on the same plots during the 2018 season in June, July and August. Due to the variability of the chlorophyll content in the leaf, the CCM-300 values were measured at two parts of the leaves – at the apex (top) and in the middle of the leaves. The laboratory analyses contained both parts of the leaves. The best agreement between the two methods of chlorophyll content measurement was proved for Calamagrostis villosa for averaged CCM-300 values per leaf (R^2=0.84). On the other hand, the correlation results were poor for Nardus stricta in all the cases (top, middle and averaged CCM-300 values). This may be caused by the narrow leaves which are not covering the whole measurement area, although according to the manufacturer this is not necessary. Also, the LAI, vegetation height, biomass and a ratio of phytomass and necromass (by sorting the biomass at the laboratory and by the RGB image analyses) were measured for all the subplots. The chlorophyll contents will be scaled to the canopy level and the relationships with the field spectral measurements (ASD FieldSpec WideRes 4) will be established. The results of all mentioned in situ measurements and UAV based hyperspectral image data will be used to monitor changes in grass species chlorophyll content distribution during the season and among the years.

In-Field, UAV-Borne VIS-NIR And Thermal Spectroscopy As Tools For Distinguishing Water Stress Reaction In Common Bean.

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Common bean (Phaseolus vulgaris L) is a very important crop, particularly in Central and South America and Africa. With currently changing climate, including shifted precipitation distribution during the growing season, water scarcity can significantly reduce bean yields. The present study aims to contribute to selection and breeding process targeting on lineages adapted to different environments regarding water stress.Our goal is to estimate the potential of UAV-borne VIS-NIR and thermal spectroscopy for detecting water stress and selection of tolerant bean lineages. We focused on 1) the comparison and relationship between in-field leaf contact hyperspectral reflectance with UAV acquired canopy multispectral reflectance; 2) testing how the leaf inclination angle and ratio of adaxial and abaxial reflectance affect the relationships between leaf and canopy reflectance; 3) how the selected spectroscopy approaches are effective in detecting water stress in common bean.

In common bean, paraheliotropic leaf movements – orienting the leaf parallel to incoming solar radiation – protects the plant against photoinhibition and water loss. If we aim to use remote sensing as a phenotyping tool for selection of water stress tolerant lineages, it is important to know how the leaf movements and water stress affect the canopy reflectance.

In August 2018, a field campaign at CIAT (Colombia) experimental fields was conducted; in total 42 of 100 Core collection of Andean and Mesoamerican bean parent lineages differing in drought tolerance were included in the study. Leaf reflectance from adaxial and abaxial side was measured by ASD HandHeld-2 spectroradiometer connected to a contact probe with a leaf clip. A canopy overflight was acomplished with UAV (S1000 DJI) bearing an RGB (Sony alpha 5000),

multispectral (Micasense red-edge) and thermal (FLIR vue pro R) cameras. Leaf physiological traits related to photosynthetic phenotype and chlorophyll fluorescence (and many other) in real field conditions and ambient environmental parameters were collected by MultispeQ (PhotosynQ LLC, USA) handheld device.

Firstly, the ratio of adaxial and abaxial leaf surface exposed to UAV-borne sensor for each genotype will be evaluated from RGB photos for two timing points per day: morning (no water stress, horizontal leaf position) and afternoon (high-light, water stress, vertical leaf position). Then, the relations between leaf level and canopy reflectance will be tested – including only adaxial leaf reflectance and weighed ratio of adaxial and abaxial reflectance. Finally the reflectance and thermal spectral properties of leaves and canopy will be correlated to leaf physiological parameters and potential of stress detection by spectroscopy will be evaluated.

Funding: LO1417

Method For Acquiring and Comparing Spatially Explicit Measurements of Sun Induced Fluorescence on the Ground

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Sun induced fluorescence (SIF) from plants is viewed among the broader scientific community as a valuable new source of information about plant functional status. As a result of the increasing interest, new devices and research lead to rapid improvements of SIF retrieval across spatiotemporal scales with SIF products derive from UAV, airborne, and space borne sensors becoming increasingly available. Validation of such remotely sensed SIF maps requires spatially distributed ground measurements of SIF taken at the exact time of sensor overpass. However, because collecting spatially distributed SIF in larger areas is time consuming the majority of observations will be away from the exact time of overpass.

In this paper we outline an empirical approach to correct for the diurnal cycle and recalculate SIF of for any given moment in time. The approach requires on a single observation of SIF for the location of interest at any time, a diurnal SIF curve for the crop type (modelled or measured), and an estimate of amount of biomass at location of interest and the location of diurnal SIF measurement. To prove the feasibility of the method, we conducted a spatially distributed measurement of SIF in two crops modifying an existing hyperspectral point spectrometer (D-FLOX). Alongside the mobile SIF sampling effort, an identical and intercalibrated device was installed on a permanent position to record the diurnal SIF cycle. Leaf area index (LAI), leaf chlorophyll content, plant height and other relevant biophysical parameters were also recorded at each location.

Spatially distributed SIF from 46 locations (15 in sugar beet and 31 in winter wheat) collected in three separate dates between the hours of 10:00 and 14:00 were recalculated to solar noon using the proposed correction scheme and both raw and corrected SIF values were compared to LAI. We observed a better correlation and linear model performance against LAI for diurnal cycle corrected SIF. The locations in sugar beet were measured at the time of a low altitude overpass of the airborne high resolution hyperspectral sensor designed for SIF retrieval (HyPlant). Therefore, in a second step, SIF estimates in sugar beet were recalculated to the exact time of overpass and diurnal cycle corrected ground SIF values were compared to the HyPlant derived SIF maps.

Establishment of a spatially explicit SIF sampling measurement protocol needs to take into account the compounding effects of plant structure (e.g. LAI) and diurnal cycle of SIF. In this paper we proposed a simple empirical approach to correct for those effects and recalculate SIF for a specific time. Such approach can be used to study the spatial heterogeneity of SIF in small areas, to measure large number of plots in field phenotyping set-ups, or for recalculation of SIF in physical units for any given time of the day, e.g. for validation of airborne data.

Prediction of Leaf Area Index using Integration of the Thermal Infrared and Optical Data over the Mixed Temperate Forest

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Although the retrieval of leaf area index (LAI) as one of the essential biodiversity variable from remote sensing data has shown to be successful over visible/near-infrared (VNIR, 0.3-1.0 µm), shortwave infrared (SWIR, 1.0-2.5 µm), and TIR (8-

14 µm) domains, integration of VNIR/SWIR with the TIR data for LAI estimation has not been addressed yet. Despite the importance, maturity, and availability of the remotely sensed data over VNIR and SWIR regions, TIR remote sensing data (i.e., emissivity spectra) has a number of advantages for LAI estimation. As such, it is known that the emissivity spectra over the TIR domain do not saturate even at relatively high values of LAI. In this respect, the utility of Landsat-8 TIR data together with its optical spectral data was examined to quantify LAI over Bavarian Forest National Park (Mixed temperate forest) in Germany. A field campaign was conducted in August 2015 in the National Park concurrent with the time of the Landsat-8 overpass. LAI was measured in the field for 37 plots. In this study, a number of vegetation indices, which have been widely applied in the literature were used to estimate LAI using VNIR/SWIR data. Furthermore, land surface emissivity (i.e., LSE) was derived from the band 10 of TIRS sensor using the normalized difference vegetation index threshold method. LSE was integrated with the reflectance data as the input layers to examine the LAI retrieval accuracy using the artificial neural network as a machine learning approach. The levenberg-marquardt algorithm was used for network training. LAI was predicted with modest accuracy using vegetation indices (R^2_{CV}=0.63, $RMSE_{CV}$=1.56 m^2m^{-2}, and R^2_{CV}=0.65, $RMSE_{CV}$=1.56 m^2m^{-2} for NDI, and SR respectively). However, when the VNIR/SWIR bands and TIR data (LSE) were integrated, the prediction accuracy of LAI increased significantly (R^2_{CV}=0.79, $RMSE_{CV}$=0.75, m^2m^{-2}). Our results demonstrate that the combination of LSE and VNIR/SWIR satellite data can lead to higher retrieval accuracy for LAI. This finding has implication for retrieval of other vegetation parameters through the integration of TIR and optical satellite remote sensing data as well as regional mapping of LAI when coupled with a canopy radiative transfer model.

Predictive Performance Of PROSAIL Inversion And PLS Regression For Nitrogen Uptake Estimation Using Sentinel-2 And UAV Images

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Nitrogen fertilization according to the actual plant needs is an important issue for farmers, as an over-fertilization can cause negative impacts to ecosystems (e.g. eutrophication of water bodies due to leaching of nitrogen) and increase the cost for farmers. On the other hand an under-fertilization may lead to reduced yield and may affect the profit for the farmer. High resolution spatial information of the actual nitrogen status of plants at the critical development stages can support variable rate application of nitrogen fertilizers according to the plant needs. In this study, the predictive performance of PROSAIL inversion and PLS regression were compared for estimating current plant nitrogen content (also called N-Uptake [kg/ha]) on winter wheat fields. The transferability between different years of both approaches was verified on several fields 2018. Additionally UAV image data was acquired to test the inversion approach in 2018.

Fieldwork was conducted in France and Belgium between April and June 2017 every two weeks (4-times) on 32 plots in France and 18 in Belgium, which resulted in 128 samples in France and 72 samples in Belgium. In the laboratory dry matter content and nitrogen content were measured. These measurements together with field measurements of LAI and biomass were converted into N-Uptake. Altogether 181 wheat samples could be used to calibrate empirical models between LAI (field measurements), biomass and N-Uptake. Sentinel-2 image data were acquired close to the field sampling dates. A PROSAIL look-up table (LUT) was generated representing the variability of plant biophysical parameters of wheat (e.g. average leaf angle) observed on the fields 2017. The LUT was resampled to the spectral resolution of Sentinel-2 and the UAV data. The inversion scheme selects the 100 LUT members with smallest RMSE between simulated and observed spectra and calculates an average of the corresponding LAI and Cab input values, respectively. The PLSR was calibrated using the Sentinel-2 spectra of the pixel closest to the sampling coordinate and the corresponding field/laboratory measurement of 2017. In 2018 a field campaign was conducted to gather independent validation samples (n=18) for testing both model approaches calibrated one year before. Close to the sampling dates on selected fields UAV image data (Parrot Sequoia, 4 bands: G-R-RedEdge-NIR) were acquired (n=13).

The PLSR model leads to a RMSE of 26 kg/ha N-Uptake and the PROSAIL inversion approach obtains a RMSE of 36 kg/ha in 2017. The model application to the 2018 image data lead to an accuracy decrease for the PLSR model with a RMSE of 44 kg/ha while the PROSAIL inversion obtains similar results as in 2017 for Sentinel-2 and UAV image data.

The physical based method shows in this study a higher stability than the statistically based PLSR approach. Our results indicate that the PROSAIL based approach which include information from the RedEdge domain can support variable rate nitrogen applications.

Impact Of Environmental And Tree Structural Parameters On The Estimation Of Biochemical Properties For A Sparse Mediterranean Forest With AVIRIS Imagery

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The monitoring of vegetation biochemical properties is of primary interest to understanding plant functioning and productivity, and other ecosystem functions. Biochemical properties are key indicators for accessing EBV (Essential Biodiversity Variables) by observing variations in biodiversity in terms of species traits. From remote sensing data, the most studied biochemical properties are the leaf pigments (chlorophyll and carotenoids), water and dry matter content, which require high spectral richness in the 0.4-2.5um optical domain - hyperspectral data - and a spatial resolution adapted to the study scale (ecosystem, population or individual). Sparse forest ecosystems are characterized by low tree LAI and low canopy cover values. Therefore, at the individual scale (tree) and for spatial resolutions less than 10m, the estimation of biochemical properties is mainly sensitive to the tree structural characteristics such as Leaf Area Index, woody elements and crown shape. While at the population scale (group of trees) and for coarser spatial resolutions, it is necessary to take into account additional general characteristics of the ecosystem - defining the environment - such as canopy cover, soil type and species distribution. The objective of this study is to assess the impact of both environmental and tree structural parameters on the estimation of biochemical properties for a sparse Mediterranean forest. The study site is an oak woodland savanna ecosystem located in Sierra Nevada, California. Due to the specificities of the study site, the methodology to estimate these properties is a LUT-based radiative transfer model inversion with DART (Discrete Anisotropic Radiative Transfer). The simulation dataset contains simulated top of canopy reflectance that are generated from variation in the parameters of interest (that are to be estimated) and information about the study site derived from the literature and several field measurement campaigns. The 3D scene modelling follows the assumptions of the "simple forest representation" commonly used in the literature (4 ellipsoidal trees on a flat ground). The measured dataset relies on the main parametrization of the simulation dataset except the variation in structural parameters at the tree level (Leaf Area Index, crown geometrical shape and height, trunk and branches, clumping, leaf angle distribution) and environment level (canopy cover, soil type, tree distribution). Then, comparison between the two datasets inside the inversion process requires choosing a spectral selection strategy, a cost function to minimize, and a number of best solutions to average in order to derive the biochemical property estimates. The conclusions of this study will give insights into (i) the best parameterization of the inversion process, (ii) the rank of the most influent structural parameters for each biochemical property, (iii) the orders of magnitude in the precision in biochemical property estimates, and (iv) the performance achieved when applied to AVIRIS imagery at 18m spatial resolution and validated with field measurements.

Variable Rate Nitrogen Application in Winter Wheat Supported by Low-Altitude Spectral Remote Sensing

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Site-specific nitrogen (N) management in precision agriculture is used to improve nitrogen use efficiency (NUE) at field scale. This practice has the benefit to reduce potential emissions of nitrate and nitrous oxide to the environment and provide economic benefits to the farmers. In this project, we aim to combine the information from aerial image data, acquired with unmanned aerial vehicles (UAVs) and satellites, with agro-environmental data to better target the application of N fertilizer via variable rate application (VRA) for relatively small fields, as typical in Swiss agriculture. The work presented (in this poster) is the outcome of a first experiment performed to test the functionality of our sensor system and the problematics involved into monitoring crop growth and development.

The methods consist of a combination of multi-spectral imagery to observe plants in-field variability and measures of the soil nitrate content at reference locations. The data were collected in a field experiment with winter wheat, carried out at the Agroscope research station in Tänikon, Switzerland. The experimental design included three treatments comparing variable rate application (VR) with a standard uniform application (ST) and unfertilized plots (NF). The field

used was characterised by a high spatial heterogeneity including zones with higher organic matter content. The digital information collected from the agroecosystem was used to adjust the second and third split applications in the VR treatments.

The spectral information was acquired with a UAV platform composed of a commercial quadcopter and a four-band multispectral camera including green, red, red edge and infrared channels. The images were stitched together to create reflectance maps after radiometric correction and georeferencing with ground control points (GCP). Index maps of different indices as for example NDVI and NDRE were then produced. The values per pixel were then extracted in GIS to get a mean per plot and used as a qualitative indication of growth and N status to reduce to 50% or increase up to 15% of the fertilizer rate compared to ST.

Overall, the preliminary analysis confirms the possibility to monitor wheat development along the season with aerial images and to get useful information for the crop management. The final yield of VR treatments resulted in the same range as the ST treatments but showed an average fertilizer reduction of 11 kgN/ha.

Quantifying the robustness of vegetation indices through ARTMO's Global Sensitivity Analysis (GSA) toolbox

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Vegetation indices (VIs) are widely used to identify biophysical variables of a vegetated surface using spectral reflectance data. VIs are defined to enhance spectral features sensitive to a vegetation property while reducing disturbance by combining some spectral bands into a VI. There are multiple ways to combine bands to get the desired information, leading to plethora of possible indices. However, it is not always clear if these indices are equally sensitive to the variable of interest, thereby taking confounding factors into account. After all, the reflectance of a pixel is never driven by only one vegetation property. Hence, the question arises how robust indices behave given heterogeneous conditions. Accordingly, to be able quantifying the robustness of VIs, it demands for a systematic approach, thereby introducing a variety of heterogeneity. Such kinds of exercises are typically done within a radiative transfer model (RTM) environment, whereby multiple input variables can introduce a diversity of vegetation scenarios.

With the ambition of evaluating multiple VIs in an efficient way, this led us to the development of a dedicated sensitivity analysis (SA) toolbox whereby rapidly multiple scenarios can be analyzed. SA methods can be either local or global. The main difference between them is that global sensitive analysis (GSA) explores the full input variable space, i.e all input variables are changed together. This method is therefore preferred when analyzing VIs in a systematic way. In view of applying GSA to RTMs, the output can be reflectance, but can also be a calculated VI.

In this work we expanded ARTMO's GSA toolbox with the capability to evaluate VIs. We make use of the Saltelli's method which has been demonstrated to be effective in identifying both the main sensitivity effects and total sensitivity effects of input variables. A newly developed interface allows the user to define one or multiple VI by configuring the index equation and selecting the spectral bands of interest. These bands can be reflectance data, but according to the selected RTM can also be fluorescence or radiance outputs. This configuration can be repeated as many times wanted, i.e. allowing to evaluate multiple indices at the same time.

As a proof of concept, we have identified the most sensitive indices for leaf area index (LAI) and leaf chlorophyll content detection for multiple hyperspectral sensors including HyMap and FLORIS (FLEX) given a wide variety of canopy scenarios. Initial results confirm that greenness narrowband indices such as NDWI, WBI, MCARI, ND750/710 are largely sensitive to LAI and chlorophyll. However, we can also observe a slight influence of confounding variables, such as dry matter content or leaf angle distribution.

Altogether, this toolbox can help identifying the predominant variables for each analyzed VI. As such, it enables to identify the potential application of a VI and to verify its robustness for a specific use. Moreover, as will be shown, given the toolbox' capability of introducing any index formulation, the opportunity is provided to evaluate the sensitivity of new indices, e.g. with multiple spectral bands.

A Comparison of Tree Species Classification Accuracy Using UAV Images Acquired with a Snapshot Hyperspectral and a Multispectral Sensor

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Understanding tree species distribution and health of woodlands is fundamental to disease and pest control and woodland management. Recent disease outbreaks, such as the Chalara dieback of Ash in the UK in 2012, highlight the need for improved tree species distribution maps. A detailed, cost-effective mapping of tree species can be achieved at local scales by using Unmanned Aerial Vehicle (UAV) remote sensing data. In this study, we evaluate the performance of tree species classification using a UAV-mounted snapshot hyperspectral (16 bands in 470-630 nm and 25 bands in the 600-975 nm range) and a multispectral (green, red, red-edge and near-infrared bands) camera. By comparing the two UAV camera systems, we investigate whether more and narrower bands improves classification accuracy in our study area, therefore justifying the use of the more complex hyperspectral system.

UAV multi- and hyperspectral imagery were acquired on 31st October 2018 over mixed deciduous and conifer woodland at Big Wood, Suffolk, UK (Lat/Long: 52.298°; 1.566°). Concomitantly, measurements of relative reflectance were made in the field in order to validate the UAV-derived reflectance estimates. The tree species ground truth was collected in a separate field campaign on 30th October 2018.

Geometric and radiometric calibration of the UAV imagery is being applied in order to harmonize measurements from the different camera systems. While obtaining reflectance from the multispectral camera is relatively straightforward, with calibration parameters supplied by the manufacturer, an in-house workflow had to be devised to derive quantitative information from the hyperspectral raw images, which includes dark and vignetting correction, spectral response characterization, digital number to reflectance conversion and hyperspectral data cube reconstruction. The corrected images (multi- and hyperspectral) are mosaicked using Structure-from-Motion (SfM) approaches, a processing step in which ground control points are used to generate georeferenced orthomosaics with a ground sample distance of ~12 and ~20 cm for the multi- and hyperspectral data respectively.

Following validation of the UAV orthomosaics reflectance (against the ground measured spectra), a machine-learning classification is applied to the multi- and hyperspectral UAV data. The overall workflow consists of spectral feature extraction, spectral feature selection, random forest classifier training and evaluation against the ground survey of trees, and selection of best performing classifier for each of the multispectral and hyperspectral data. This will indicate whether the UAV hyperspectral data produces a significant increase in the overall accuracy of tree species mapping, when compared to UAV multispectral data.

Future work will extend the tree species mapping to larger areas by using satellite imagery. We are currently investigating the use of sub-pixel classification methods that allow UAV imagery (either multi- or hyperspectral, following outcomes from this study) to be used to train (via machine learning algorithms) the imagery from the Sentinel 2 satellites. If such methods are found to be successful, they would allow UAV imagery flown over selected woodlands to be used to help identify the distribution of common trees species in satellite imagery. Ultimately, the aim is to produce tree species and health maps at local to national scales.

HyPlant Derived Sun-Induced Fluorescence - a Way to Understand the Complex Vegetation Signals from Heterogeneous Ecosystems

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Remote sensing of Sun-induced fluorescence (SIF) signal emitted from the core of photosynthetic machinery is a direct opportunity to track and diagnose the actual functional status of vegetation. In fact, SIF is also considered as an indicator of plant photosynthetic activity and its physiological status. This makes SIF a highly relevant and purely attractive research interest for scientific communities. The global space agencies like ESA and NASA have considered plant fluorescence observation missions (i.e. FLEX mission by ESA, OCO-2 mission by NASA) as one of their key project to understand terrestrial ecosystems and vegetation closely. Peatlands are one of the vital ecosystems of the earth which is due to its carbon storage, biodiversity, and distinctive vegetation species. But due to huge heterogeneity, internal diversity, steep environmental gradients, high spatial and spectral variability, it is always a challenge to understand peatland vegetation functionality through remotely sensed vegetation indices (VIs) and SIF signals. Previous studies of SIF were mostly restricting their observation on homogenous ecosystems like croplands, grasslands, and forest areas. Hence, considering this knowledge gap this study is the first to demonstrate the degree of relationship from heterogeneous peatland vegetation together with the SIF and VIs using novel airborne HyPlant data collected during the SWAMP campaign in Poland. Imaging spectrometer 'HyPlant' (the airborne demonstrator for the ESA FLEX mission) was flown for the first time over extremely heterogeneous peatland and surrounding ecosystems during the SWAMP campaign. The campaign was funded by COST Action OPTIMISE, EUFAR, and ESA under the FLEX-EU mission framework at Rzecin peatland in Poland and was held on 11th July 2015. The entire Rzecin peatland and its surroundings are enriched with diverse vegetation groups of vascular and non-vascular plant communities. The target of this study is to explore a comparative analysis of SIF signals and VIs and their relationships obtained from different vegetation groups at ecosystem level (forest, grassland, peatland) and from diverse peatland plants at plant communities level. The VIs and Spectral Fitting Method (SFM) retrieved SIF maps (O_2A and O_2B) were validated (VIs: $R^2 = 0.79$-0.91; SIF: $R^2 = 0.87$-0.92) in support of measured ground spectra before any analysis. A clear positive trend with a good agreement ($R^2 = 0.55$-0.91) and statistically significant ($p<0.01$) relation have been observed between SIF bands (O_2A and O_2B) and greenness indices (SR, NDVI) whereas, a negative trend with a good agreement ($R^2 = 0.40$-0.71) and statistically significant ($p<0.01$) relation have been found between PRI and SIF at large scale vegetation group. Due to huge diversity and low SNR (Signal to Noise Ratio), no such agreements were established between SIF bands and VIs at small scale peatland plant communities, except for some isolated homogenous patches of meadows. Filling the knowledge gap, this work provides a new proof that the degree of relationship between SIF bands and several VIs are highly dynamic and complex with hierarchical scales (large scale vegetation groups to small-scale plant communities) for heterogeneous ecosystems.

Does Simple Vegetation Indices Can Predict Sun Induced Fluorescence? A Fuzzy Simulations on Airborne Imaging Spectroscopic Data

Subhajit Bandopadhyay[1], ANSHU RASTOGI[1], Sergio Cogliatti[2], Uwe Rasher[3], Maciej Gabka[4], Radoslaw Juszczak[1]

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Sun-induced fluorescence (SIF) is explored as a novel remote sensing signal that marked for its potential to be considered as a direct indicator of plant functional activity and health condition. The present state of the art of SIF is extremely relevant and highly attractive field of research for scientific communities and space agencies such as ESA and NASA, due to its ability to quantify plant photosynthetic process. Peatlands are one of the most significant terrestrial ecosystems in the earth that play a vital role in the global carbon cycle. Due to huge heterogeneity, internal diversity, steep environmental gradients, high spatial and spectral variability, it is always a challenge to predict and simulate the SIF signals through commonly used reflectance based vegetation indices (VIs) for heterogeneous ecosystems such as peatland. This research will show for the first time, how narrow-band hyperspectral imaging technology derived VIs and simple fuzzy approach can strongly predict the red (O_2B) and far-red (O_2A) SIF signals from heterogeneous ecosystems of peatland, grasslands and forests. Raster-based fuzzy model attributed with fuzzy membership functions have been considered to simulate the SIF from diverse vegetation groups and further was validated by the measured SIF signals. The study was conducted in and around Rzecin (POLWET) peatland located in the central-western Poland. The study incorporated airborne imaging spectroscopic data of 'HyPlant' acquired during the SWAMP campaign held on 11th July 2015 over the Rzecin peatland. A combination of peatland vegetation groups, natural and managed ecosystems such as mowed meadows, deforested land, grassland, post-agricultural land, riparian forest, rush vegetation, secondary pine forest community, semi-natural pine forest, transition mires, and young deciduous forest have been examined for this study. All the patches were considered from authenticated and detailed botanical survey data from 2015. 'HyPlant' DUAL module derived Simple Ratio (SR), Normalized Difference Vegetation Index (NDVI), Red-edge Normalized Difference Vegetation Index (NDVIre), Enhanced Vegetation Index (EVI), and Photochemical Reflectance Index (PRI) have been used as model parameters and processed through justified fuzzy membership functions. Based on literature supported justifications to SR, NDVI, NDVIre, EVI and PRI indices, which are highly sensitive to SIF, we received high memberships. Furthermore, fuzzy overlay operation has been employed to simulate the SIF signals. Finally, the simulated SIF values of different vegetation groups had been validated through Spectral Fitting Method (SFM) retrieved SIF signals. The result shows statistically significant ($p<0.001$) and good agreement between fuzzy simulated SIF values with established O_2A and O_2B SIF signals with the $R^2 = 0.81$, and $R^2 = 0.90$ respectively. Outcomes of our analyses confirm the model strength for SIF prediction, supported by statistically significant and strong correlation between simulated data and established SIF signals. The high confidence of prediction through fuzzy model employing simple reflectance based VIs is proved to be advantageous in data constraint situations and can also act as a strong proxy for SIF. It can further assume that the model can work as a potential indicator for plant photosynthetic efficiency and health conditions and fill the limitations of SIF data.

he corresponding LAI and Cab input values, respectively. The PLSR was calibrated using the Sentinel-2 spectra of the pixel closest to the sampling coordinate and the corresponding field/laboratory measurement of 2017. In 2018 a field campaign was conducted to gather independent validation samples (n=18) for testing both model approaches calibrated one year before. Close to the sampling dates on selected fields UAV image data (Parrot Sequoia, 4 bands: G-R-RedEdge-NIR) were acquired (n=13).

The PLSR model leads to a RMSE of 26 kg/ha N-Uptake and the PROSAIL inversion approach obtains a RMSE of 36 kg/ha in 2017. The model application to the 2018 image data lead to an accuracy decrease for the PLSR model with a RMSE of 44 kg/ha while the PROSAIL inversion obtains similar results as in 2017 for Sentinel-2 and UAV image data.

The physical based method shows in this study a higher stability than the statistically based PLSR approach. Our results indicate that the PROSAIL based approach which include information from the RedEdge domain can support variable rate nitrogen applications.

Impact Of Environmental And Tree Structural Parameters On The Estimation Of Biochemical Properties For A Sparse Mediterranean Forest With AVIRIS Imagery

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[1]*The French Aerospace Lab - ONERA, Toulouse, France;* [2]*Center for the Study of the Biosphere from Space - CESBIO, Toulouse, France;* [3]*Center of Spatial Technologies And Remote Sensing - CSTARS, University of California, Davis, CA, USA;* [4]*The Climate Corporation, San Francisco, CA, USA;* [5]*Biometeorology Lab, University of California, Berkeley, CA, USA*

The monitoring of vegetation biochemical properties is of primary interest to understanding plant functioning and productivity, and other ecosystem functions. Biochemical properties are key indicators for accessing EBV (Essential Biodiversity Variables) by observing variations in biodiversity in terms of species traits. From remote sensing data, the most studied biochemical properties are the leaf pigments (chlorophyll and carotenoids), water and dry matter content, which require high spectral richness in the 0.4-2.5um optical domain - hyperspectral data - and a spatial resolution adapted to the study scale (ecosystem, population or individual). Sparse forest ecosystems are characterized by low tree LAI and low canopy cover values. Therefore, at the individual scale (tree) and for spatial resolutions less than 10m, the estimation of biochemical properties is mainly sensitive to the tree structural characteristics such as Leaf Area Index, woody elements and crown shape. While at the population scale (group of trees) and for coarser spatial resolutions, it is necessary to take into account additional general characteristics of the ecosystem - defining the environment - such as canopy cover, soil type and species distribution. The objective of this study is to assess the impact of both environmental and tree structural parameters on the estimation of biochemical properties for a sparse Mediterranean forest. The study site is an oak woodland savanna ecosystem located in Sierra Nevada, California. Due to the specificities of the study site, the methodology to estimate these properties is a LUT-based radiative transfer model inversion with DART (Discrete Anisotropic Radiative Transfer). The simulation dataset contains simulated top of canopy reflectance that are generated from variation in the parameters of interest (that are to be estimated) and information about the study site derived from the literature and several field measurement campaigns. The 3D scene modelling follows the assumptions of the "simple forest representation" commonly used in the literature (4 ellipsoidal trees on a flat ground). The measured dataset relies on the main parametrization of the simulation dataset except the variation in structural parameters at the tree level (Leaf Area Index, crown geometrical shape and height, trunk and branches, clumping, leaf angle distribution) and environment level (canopy cover, soil type, tree distribution). Then, comparison between the two datasets inside the inversion process requires choosing a spectral selection strategy, a cost function to minimize, and a number of best solutions to average in order to derive the biochemical property estimates. The conclusions of this study will give insights into (i) the best parameterization of the inversion process, (ii) the rank of the most influent structural parameters for each biochemical property, (iii) the orders of magnitude in the precision in biochemical property estimates, and (iv) the performance achieved when applied to AVIRIS imagery at 18m spatial resolution and validated with field measurements.

Variable Rate Nitrogen Application in Winter Wheat Supported by Low-Altitude Spectral Remote Sensing

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Site-specific nitrogen (N) management in precision agriculture is used to improve nitrogen use efficiency (NUE) at field scale. This practice has the benefit to reduce potential emissions of nitrate and nitrous oxide to the environment and provide economic benefits to the farmers. In this project, we aim to combine the information from aerial image data, acquired with unmanned aerial vehicles (UAVs) and satellites, with agro-environmental data to better target the application of N fertilizer via variable rate application (VRA) for relatively small fields, as typical in Swiss agriculture. The work presented (in this poster) is the outcome of a first experiment performed to test the functionality of our sensor system and the problematics involved into monitoring crop growth and development.

The methods consist of a combination of multi-spectral imagery to observe plants in-field variability and measures of the soil nitrate content at reference locations. The data were collected in a field experiment with winter wheat, carried out at the Agroscope research station in Tänikon, Switzerland. The experimental design included three treatments comparing variable rate application (VR) with a standard uniform application (ST) and unfertilized plots (NF). The field used was characterised by a high spatial heterogeneity including zones with higher organic matter content. The digital information collected from the agroecosystem was used to adjust the second and third split applications in the VR treatments.

The spectral information was acquired with a UAV platform composed of a commercial quadcopter and a four-band multispectral camera including green, red, red edge and infrared channels. The images were stitched together to create reflectance maps after radiometric correction and georeferencing with ground control points (GCP). Index maps of different indices as for example NDVI and NDRE were then produced. The values per pixel were then extracted in GIS to get a mean per plot and used as a qualitative indication of growth and N status to reduce to 50% or increase up to 15% of the fertilizer rate compared to ST.

Overall, the preliminary analysis confirms the possibility to monitor wheat development along the season with aerial images and to get useful information for the crop management. The final yield of VR treatments resulted in the same range as the ST treatments but showed an average fertilizer reduction of 11 kgN/ha.

Quantifying the robustness of vegetation indices through ARTMO's Global Sensitivity Analysis (GSA) toolbox

PABLO MORCILLO PALLARÉS[1], Juan Pablo Rivera-Caicedo[2], Santiago Belda[1], Charlotte De Grave[1], Helena Burriel[1], Jose Moreno[1], Jochem Verrelst[1]

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Sun-induced fluorescence (SIF) is explored as a novel remote sensing signal that marked for its potential to be considered as a direct indicator of plant functional activity and health condition. The present state of the art of SIF is extremely relevant and highly attractive field of research for scientific communities and space agencies such as ESA and NASA, due to its ability to quantify plant photosynthetic process. Peatlands are one of the most significant terrestrial ecosystems in the earth that play a vital role in the global carbon cycle. Due to huge heterogeneity, internal diversity, steep environmental gradients, high spatial and spectral variability, it is always a challenge to predict and simulate the SIF signals through commonly used reflectance based vegetation indices (VIs) for heterogeneous ecosystems such as peatland. This research will show for the first time, how narrow-band hyperspectral imaging technology derived VIs and simple fuzzy approach can strongly predict the red (O_2B) and far-red (O_2A) SIF signals from heterogeneous ecosystems of peatland, grasslands and forests. Raster-based fuzzy model attributed with fuzzy membership functions have been considered to simulate the SIF from diverse vegetation groups and further was validated by the measured SIF signals. The study was conducted in and around Rzecin (POLWET) peatland located in the central-western Poland. The study incorporated airborne imaging spectroscopic data of 'HyPlant' acquired during the SWAMP campaign held on 11th July 2015 over the Rzecin peatland. A combination of peatland vegetation groups, natural and managed ecosystems such as mowed meadows, deforested land, grassland, post-agricultural land, riparian forest, rush vegetation, secondary pine forest community, semi-natural pine forest, transition mires, and young deciduous forest have been examined for this study. All the patches were considered from authenticated and detailed botanical survey data from 2015. 'HyPlant' DUAL module derived Simple Ratio (SR), Normalized Difference Vegetation Index (NDVI), Red-edge Normalized Difference Vegetation Index (NDVIre), Enhanced Vegetation Index (EVI), and Photochemical Reflectance Index (PRI) have been used as model parameters and processed through justified fuzzy membership functions. Based on literature supported justifications to SR, NDVI, NDVIre, EVI and PRI indices, which are highly sensitive to SIF, we received high memberships. Furthermore, fuzzy overlay operation has been employed to simulate the SIF signals. Finally, the simulated SIF values of different vegetation groups had been validated through Spectral Fitting Method (SFM) retrieved SIF signals. The result shows statistically significant ($p<0.001$) and good agreement between fuzzy simulated SIF values with established O_2A and O_2B SIF signals with the $R^2 = 0.81$, and $R^2 = 0.90$ respectively. Outcomes of our analyses confirm the model strength for SIF prediction, supported by statistically significant and strong correlation between simulated data and established SIF signals. The high confidence of prediction through fuzzy model employing simple reflectance based VIs is proved to be advantageous in data constraint situations and can also act as a strong proxy for SIF. It can further assume that the model can work as a potential indicator for plant photosynthetic efficiency and health conditions and fill the limitations of SIF data.

Thursday 7 February 2019

Evaluation Of A pushframe hyperspectral Camera System

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Local monitoring, e.g. for precision agriculture applications has been enabled by the availability of Small Remotely piloted aircraft systems (RPAS). Since RGB cameras have limited capabilities, e.g. for precise detection of stress and diseases in plants, there is a strong demand to employ spectrally more capable imagers, in particular hyperspectral imagers on RPAS systems. Technological advances nowadays allow to make such miniature hyperspectral imagers.

Some are derived from earlier pushbroom designs, but other more radically innovative instruments make use of narrow-band thin film interference filters. A technology developed by imec, a Belgian R&D center in nano-electronics, allows such filters to be deposited directly on image sensors. By using such filters, hyperspectral imagers can be made as small as regular cameras. The most straightforward hyperspectral cameras use filters arranged in a mosaic pattern, which leads to reduced spatial and spectral resolutions.

To avoid this, we developed an alternative hyperspectral camera concept in which a large number of narrow-band filters are arranged in a linewise fashion on the sensor. The camera then captures images in rapid succession while scanning over an area, similar to a pushbroom camera. The images however each give a 2D view of the area, allowing photogrammetric processing. Based on this concept we developed a commercial camera, in collaboration with German camera manufacturer Cubert Gmbh. The S 199 ButterflEYE LS captures 2.1 Mpx frame images with narrowband spectral information.

To complement this, we developed a dedicated image processing chain which runs the frame images through bundle adjustment, camera calibration, orthorectification and reflectance calibration, generating a digital surface model (DSM) and a reflectance hypercube with 5nm spectral bands in the 475 nm to 925 nm range and 5 cm GSD from 47 m above ground level.

The ButterflEYE LS camera was used to conduct RPAS flights in different conditions over a test field with artificial reference targets,. The resulting data products were evaluated in terms of data size, processing steps and times, and spatial and spectral quality with handheld spectrometer measurements as reference. Next, we discuss the outlook of the technology and our processing software for multiple purposes to support agricultural, forestry and environmental monitoring at various scales. Different scenarios with varying platform speeds, flight heights, frame rates, spatial and spectral resolutions are presented.

Assessment of the Estimates of Sun-induced Fluorescence in large masses of Vegetation

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The remote estimation of the sun-induced fluorescence in the vegetation has been exposed in fields in which, in addition to the proximal measurements for the verification, there is also a detailed characterization of the atmosphere, besides being an optimal environment, flat surface without interferences. The objective is to evaluate the effectiveness of this methodology in large areas, which implies greater uncertainty in the inputs, the generalization of the calibration of the flight, and the need to assess by confronting all the outputs generated. The data set used in this study is a flight-line over a wooded area located south of Bonn (Germany), covering an area of 1.5km^2. It was acquired simultaneously by the Aisa-Ibis and Aisa-Fenix airborne sensors, while taking the auxiliary measurements necessary for its processing (Spectroradiometer and sun-photometer). The processing chain carried out the radiometric and geometric correction in Caligeo(Specim), the atmospheric correction is supported by Modo-Atcor(Rese), and the calculation of the vegetation indexes and fluorescence estimations were calculated in Matlab-IDL. The information used in the assessment are 2 estimates of the top-of atmosphere radiance, 4 vegetation indices and 4 fluorescence estimates. The study of the radiances allows to verify the correspondence between the sensors, the rightness of the radiometric correction and the anomalous data introduced in the processing chain. The vegetation indices describe different aspects of the vegetation, Normalized-

Difference-Vegetation-Index provides an idea of the general status, Red-Edge-Position-Index allows to detect more subtle changes, Photochemical-Reflectance-Index quantifies the efficiency in the use of light and Water-Band-Index characterizes the water content. These inclinations are general lines, but they are also sensitive to other changes and that is the reason for the selection, this set is the least correlated with each other and with better correlation with the rest of vegetation indices calculated with Aisa-Fenix. The fluorescence estimates differ in the technique for decoupling fluorescence from reflectance. The first is based on the comparison between values recorded inside and outside the absorption band, the second uses a singular value decomposition, the third a simulation of an oxygen-free atmosphere and the fourth performs a least-squares adjustment of the fluorescence and reflectance spectra. There is no relationship between fluorescence and vegetation indexes, but there are factors to which both respond, so the vegetation indexes allow to define transects according to the multifactorial homogeneity, which will also have an effect on the fluorescence. Additionally, the comparison of the fluorescence estimates allows to identify similarities and the effects of changes in radiance. The comparison proves the outstanding correspondence between the sensors, although it seems to be affected by the order of magnitude. The atmospheric correction of Fenix fails to correct the effects caused by changes in radiance, but outside of transitions, monitoring by vegetation indices corroborates the expected variability in a large mass of vegetation. The differences between the 4 methods to estimate fluorescence resides fundamentally in the magnitude, since the patterns coincide, which implies a shared sensitivity to changes in radiance and in a small response to the changes detected by the vegetation indexes.

Improvements in the Processing Chain of Thermal Hyperspectral Data from TASI-600

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The TASI-600 thermal hyperspectral instrument (manufactured by Itres, Ltd.) is a pushbroom, airborne system with the field of view of 40° across-track over 600 spatial pixels that covers the long-wave infrared (LWIR) region between 8.0 and 11.5 µm with 32 spectral bands at 0.11 µm interval. The TASI is equipped by a mercury cadmium telluride detector, which has inherent variation in the signal response for random pixels. The wrong response typically lasts for a few seconds and these pixels (also called as "blinking" pixels) manifest as randomly occurring stripes in the raw data. It is possible to detect the striping artefacts on non-georeferenced raw DN image data with a high-pass filter. In the pre-processing chain of TASI data we implemented a detection of lines affected by the blinking pixels and subsequently applied a spatial averaging of neighbourhood pixels to remove the wrong columns. The application of the high-pass filter is not absolutely successful in removing the artefacts of the blinking pixels, yet it significantly improved the quality of the TASI image data. Another feature of the TASI design is that the across-track resolution of 600 pixels is actually achieved by composing the signal from two adjacent optical paths recorded by a single detector. Small inaccuracies in radiometric calibration might thus cause a difference in brightness between the right and the left side of a TASI image. This artefact can be compensated by using an overlap of about 5% between the sides and computing a ratio between the signal recorded at the right and the left side of an image. Both image sides are then compensated using the average value of the ratio. This contribution summarizes improvements of the TASI pre-processing chain developed by Global Change Research Institute (CzechGlobe) and focuses mainly on the detection of blinking pixels and compensation of radiometric miss calibration between the right and the left image side.

Radiometric Calibration Of Multispectral Cameras On Board Drones Using Field Spectro-radiometers And Handcrafted Low-cost Calibration Panels

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Recent technological advances associated with the use of spectral sensors onboard drones has enlarged the range of potential applications of low-altitude / high-resolution remote sensing for vegetation monitoring both for natural and agricultural ecosystems. The majority of these applications are based on the use of multispectral cameras that allow obtaining spectral indices such the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Red Edge (NDRE) which facilitate the analysis of several vegetation parameters directly related to their spectral response at certain wavelengths. However, the use of these sensors beyond purely qualitative applications requires addressing proper radiometric calibration. The Empirical Line (EL) approach uses natural or artificial targets to linearly correlate image data with field spectra measured simultaneously to image acquisition. In the EL method special care must be taken in selecting the calibration targets. Usually more than two targets are needed, preferably spectrally featureless and homogeneous adequately covering the full spectral range of all sensor bands.

The objective of this work is to analyze the radiometric performance of multispectral cameras installed on board drones in order to assess their potential application to the retrieval of vegetation biophysical parameters. Two field campaigns were performed in July 2018 in central Spain. In both campaigns 5 calibration panels 1.5x1.5 m size were simultaneously measured with the and ASD FieldSpec® 3 espectroradiometer (Analytical Spectral Devices Inc., USA) and a drone-mounted Sequoia multispectral camera (Parrot Drones SAS, France). Images were acquired at different heights (30 to 100 m) to explore the influence of the spatial resolution and atmospheric effects in the calibration. Targets were self-designed using PVC panels covered by ultra-mate finish water-based paint with average VIS-NIR reflectance factors from 0.09 (black) to 0.93 (white). Several rounds of ground-ASD measurements were performed while the drone was flying over the panels. Ten spectra were acquired on each panel at an approximate height of 1.20 meters. Down-welling radiance was used to optimize instrument parameters and measured at the beginning and the end of each panel on a calibrated 99% reflective Spectralon® panel (Labsphere Inc., USA). Original spectra was resampled to camera bands using spectral response functions provided by the camera´s manufacturer.

Comparison between ASD and Sequoia image digital numbers revealed strong (R^2 >0.99) and consistent linear relationships for all bands. However a clear saturation effect was observed in the Sequoia images, especially for the visible bands, that saturate at reflectance values > 0.4. Results reveal a good behavior of the handcrafted low-cost panels which showed stable and consistent reflectance factors in the VIS-NIR region with relative differences < 5% between spectra measured in different rounds after more than 5 hours of panel exposure to environmental conditions (dust, insects and temperatures > 30°C). However, further investigation is needed to produce a range of panels with average albedo below 0.4 so they can be used to properly calibrate sensors with low spectral ranges adapted to specific applications.

The EnMAP User Interface – An Overview

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EnMAP (Environmental Mapping and Analysis Program) is a future German hyperspectral satellite mission providing high quality hyperspectral image data on a timely and frequent basis. Main objective is to investigate a wide range of ecosystem parameters encompassing agriculture, forestry, soil and geological environments, coastal zones and inland waters. The EnMAP Ground Segment will be realized and operated by the German Aerospace Center (DLR) covering all aspects relevant to assure successful mission operations. This comprises controlling and commanding the satellite using multi-mission infrastructures as well as data reception, hyperspectral data processing including calibration, data archiving, data dissemination, and providing web-interfaces to the international user community. From the users' point of view there are two major scenarios of particular interest. On the one hand the handling of image acquisitions based on user requests and on the other hand the order of previously acquired and archived data. This paper provides details on the concepts, design and functionalities of the EnMAP user interface, which consists of two online portals interfaced with several subsystems of the EnMAP Ground Segment:

First the EnMAP Portal (www.enmap.org) provides general EnMAP mission information. It is the central entry point for all users interested to learn about the EnMAP mission, its objectives, status, and results. Second the EnMAP Data Access Portal links to a set of functions for registered users that will support the international EnMAP user community. This portal includes amongst others a proposal portal allowing submission of proposal for all users responding to a Data Announcement of Opportunity (AO). The proposals and the associated research outcome will be presented by an interactive map supporting the establishment of a worldwide user network and guarantee the highest transparency of the proposal-based scientific research projects and their results. Observation requests are issued to order EnMAP data takes and provide all information required for scheduling data takes such as location and extension of the observation area, acquisition time frame, sensor look angle and required data products. Additionally, the platform informs about the conditions and requirements for the EnMAP data access and the ongoing scientific programs and activities. The catalogue browse and order service (EOWEB® GeoPortal) allows browsing and ordering of EnMAP data products that have previously been acquired, processed, and archived in the product library. The operational services offered through the EnMAP (Data Access) Portal will be complemented by a service team, EnMAP Application Support, offering expert advice on the exploitation of EnMAP data.

Operational DataQC Within The Hyperspectral DESIS And EnMAP Missions - Results Of The DESIS Commissioning Phase

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This contribution presents the procedures for ensuring the data quality within the ground segments of the hyperspectral DESIS and EnMAP missions.

In addition to on-board calibration and instrument monitoring, the operational data quality control (DataQC) is embedded directly within the L0, L1B, L1C and L2A processors. Also vicarious CalVal approaches using pseudo-invariant calibration sites (PICS), permanently equipped RadCalNet sites and dedicated airborne and in-situ CalVal campaigns are foreseen to verify the radiometric and spectral data properties.

As the hyperspectral sensor DESIS on board the ISS is currently (as of September 2018) in commissioning phase, this talk will focus on the radiometric and spectral data quality of the DESIS sensor. Examples of this first mission phase will be given, including the in-orbit characterization of spectral (e.g., center wavelengths and spectral smile) and radiometric properties based on vicarious approaches. Also a first summary of the operational DataQC processors will be presented.

To conclude, this contribution will demonstrate the benefits of the DataQC within the processing chain and present the results of the vicarious CalVal activities for DESIS.

Current Status of the FLIS Infrastructure and Pre-processing chain

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Flying laboratory of Imaging Systems (FLIS) is being operated by CzechGlobe for five years now. The core instrument of FLIS is a hyperspectral imaging system provided by Itres Ltd. The hyperspectral system consists of three imaging spectroradiometers (CASI 1500, SASI 600 and TASI 600) that cover the reflective spectral range from 380 to 2450 nm, as well as the thermal range from 8 to 11 um. During its operation the hyperspectral sensors have been upgraded. TASI-600 was equipped by a dual black body calibration and an on-board spectral calibration lamp was added to the CASI 1500 spectroradiometer. The biggest extension of FLIS happened in 2017, when a full-waveform laser scanner Riegl-Q780 was added on board and can be operated synchronously with the hyperspectral system.

The main effort has been put to concurrent upgrade of the pre-processing chain for hyperspectral data. Quality measures that covers analysis of a flight trajectory, data radiometric and atmospheric corrections are under development. During the last year, the most progress has been made in processing of the thermal hyperspectral data.

In this presentation will provide an overview of the current status and of recent upgrades in the FLIS instrumentation and data pre-processing chain. give description of development and current status of the FLIS instrumentation and pre-processing chain.

Pixelwise Classification Of Hyperspectral Images Based On Deep Convolutional Neural Networks

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Abstract—The classification of agricultural crops is of significant interest within the Common Agricultural Policy (CAP) of

the EU. In this respect, hyperspectral remote sensing data is widely used as it provides accurate information of characteristic spectral behaviours of agricultural crops. Due to the similar spectral responses of numerous plants, the correct classification of arable fields is challenging. Convolutional Neural Networks (CNN) are particularly suitable for this purpose due to their applicability allowing good results for complex nonlinear problems. In this work, a pixelwise classification of agricultural crops on AISA-Dual airborne hyperspectral data is performed near the city of Köthen, in the northeast of Germany. For this purpose, a CNN is used to extract deep spectral features of the agricultural crops, which are useful for image classification. The validation of the classification results is based on available data from the Integrated Administration and Control System (IACS). The CNN architecture as well as the depth of CNNs is crucial for the classification accuracy,especially in this case, since only a monotemporal image of the study area is present. The results reveal that the applied method produces comparable results to current studies. As a consequence, it appears that the application of CNNs is suitable for the monitoring of agricultural fields in respect to EU agricultural subsidy controls.

Radiative Transfer Simulations of Spruce Forest Canopies Rreconstructed from Terrestrial Laser Scans

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Advances in high-performance computation resources and exploitation of high-density terrestrial laser scanning (TLS) data allow nowadays modelling of realistic three-dimensional (3D) forest scenes in canopy radiative transfer models. Therefore, we developed an algorithm for reconstruction of 3D Norway spruce (Picea abies Karst. L.) trees having a realistic distribution of woody and foliage elements derived from TLS data. The Discrete Anisotropic Radiative Transfer (DART) model was used to assess an effect of canopy structural details on reflectance simulations of a coniferous forest stand.

The process to build a 3D tree representation from TLS data that were separated to wood and foliage point clouds consisted of three major steps. First, the geometrical construct of a tree wooden skeleton was reconstructed using an algorithm specifically designed for spruces. Second, we developed and applied an algorithm for distribution of shoots within a tree crown. Third, we applied an algorithm for separation of the shoots in two groups by their age (current and older needle shoots). The last two steps were based on voxelization of the foliage TLS point cloud.

In order to evaluate an effect of canopy structure on forest reflectance simulations, we prepared and executed four scenarios, which were based on DART capabilities to parametrize a forest canopy scene. From the geometrically simplest to the most detailed they represented: A) pre-defined tree crown shapes filled with turbid medium with a simple trunk and branches, B) 3D representation of trees reconstructed from TLS with detailed needle shoot transformed to turbid medium, C) 3D representation of trees reconstructed from TLS with simplified shoots retained as facets, and D) 3D representation of trees reconstructed from TLS with detailed needle shoot retained as facets. Bidirectional reflectance factors of all simulated scenarios were compared with actual airborne hyperspectral (CASI and SASI) and Sentinel-2 MSI reflectance data.

The results revealed that reflectance of the structurally simplest scenario (A) showed the largest difference from the measured CASI/SASI and Sentinel-2 reflectance data, especially in the NIR spectral region. A better agreement between the DART simulated and remote sensing reflectance data was achieved when using more complex 3D tree representations, i.e., scenarios (B-C-D). Largest differences between these scenarios were observed in directional reflectance, especially near the hot-spot and high zenith viewing angles. However, the scenarios (B-C-D) did not differ from each other significantly and all produced very similar radiative transfer outputs. As the most efficient solution was identify the scenario (B), because the transformation of shoots in turbid medium reduced significantly the computation time.

In-flight Estimation and Correction of Non-Gaussian Spectral Response

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We present a new method for more accurate in-flight calibration and correction of imaging spectrometer spectral response functions. Non-Gaussian tails of spectral response functions can be difficult to characterize in the laboratory, and calibration can shift during deployment. Consequently, in-flight techniques are useful for vali- dating and updating laboratory measurements. Our approach exploits predictable changes in the shape of the oxygen A band across varying surface elevation, with diverse scene content providing numerical leverage to characterize spectral response tails 3–4 orders of magnitude below the peak. We present a correction to recover the nominal response function, and show case studies based on NASA's Next Generation Airborne Visible Infrared Imaging Spectrometer (AVIRIS-NG). Corrected radiances are better conditioned for downstream ana- lysis by sensitive atmospheric codes. We evaluate accuracy using multiple independent standards: simulation studies; consistency with laboratory measurements; elimination of a surface pressure retrieval bias; better alignment of retrieved reflectance with ground reference data; and statistics of over 250 flightlines from a campaign across the Indian Subcontinent showing consistent improvements in atmospheric correction.

Hyperspectral Lithium-Pegmatite Detection – A Case Study for Hoydalen, Norway

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The hyperspectral detection of Li-bearing minerals in Hoydalen, Norway is a first step to provide a technical solution for a spatially extensive and rapid Lithium prospection. The primary focus of the LIGHTS project (Lightweight Integrated Ground and Airborne Hyperspectral Topological Solution) lies on a variety of mica group minerals with a differing Li-content. To distinguish and map the minerals, SWIR wavelength region data acquired in the field and in the laboratory will be applied. These data will be complemented by the VNIR portion of light region data to obtain a complete understanding on the spectral properties of the Li-bearing minerals. Another key aspect is the focus on minerals that can act as indicators of Li. This is crucial as not all the Li-bearing minerals can be detected using the VNIR-SWIR wavelength region. Field and laboratory measurement and simultaneous acquisition of supplementary geochemical information are the basis for a fully automated, state-of-the-art software and hardware solution for mapping lithium in real time by airborne measurement. This will be achieved by studying the spectral features of Li-bearing minerals from pegmatitic deposits, such as Hoydalen in relation to their Li content, and by characterizing their spectral variation with respect to similar barren other minerals.

Amospheric Correction Comparison of Alsat Spectral Imagery based on model FLAASH and model 6S

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Before electromagnetic radiation used for remote sensing reaches the Earth's surface it has to travel through some distance of the Earth's atmosphere. Constituent particles of the atmosphere can affect the incoming radiation. These effects are caused by absorption and emission phenomena. This leads to distortion of the ground radiometric properties reflectance recorded by the onboard sensor. Atmospheric correction is one of the most important steps in satellite remote sensing image processing, it allows to retrieve the surface reflectance (that characterizes the surface properties) by removing this atmospheric effects. There are various methods and models for atmospheric correction. In this study, FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes) and 6S (Second Simulation of the Satellite signal in the Solar Spectrum) correction models are used to correct Alsat-2B (launched on 26th September 2016) data, by minimize atmospheric effects, especially the scattering and absorption caused by aerosols. The effect of this atmospheric correction was analysed and evaluated against the Alsat-2A (launched on 12th July 2010). Alsat-2A & Alsat-2B form a mini-constellation; therefore, these two satellites must provide the same spectral quality in order to combine their data. This has been done in this present work, where the reflection values of the two satellite sensors, corrected using FLAASH and 6S, have been compared with the same geographical point to minimise the effect of variability of the climatic conditions between two scenes. Finally, the Normalised Difference Vegetation Index (NDVI) before and after atmospheric correction were compared for the two models.

The results show that both models can both basically eliminate the atmospheric effects and can restore the typical characteristics of various surface features spectral better, and corrected reflectance values of Alsat-2B are close to those of Alsat-2A.

Spectral responses of Top Of Atmosphere (TOA) Reflectance are higher than those of surface reflectance corrected by FLAASH and 6S model in blue, green and red bands, but it's opposite in the near-infrared band. Indeed, atmospheric correction reduces the "increase" effect of atmospheric scattering in the visible bands and increases the "reduction" effect of water vapour absorption in the near-infrared bands.

Comparing the two models FLAASH and 6S; FLAASH is fast and easier to use, it offers a simple and easy graphical interface, it has atmospheric models and aerosol already pre-configured. Unlike the 6S model, which gives the user the possibility of configured itself an atmospheric model by introducing important parameters, such as: pressure, water vapour, ozone concentration etc. This makes 6S more difficult to handle but which gives more refined and better results than those obtained with FLAASH. Indeed, after atmospheric correction, the NDVI (Normalized Difference Vegetation Index) increases significantly for the two models, but the contrast of red band and near-infrared band is more increased for 6S model, so 6S can better reflect vegetation biomass and thus highlight the vegetation information.

Soil Sampling Strategy Based On Multispectral Sentinel 2 And Hyperspectral EnMAP Satellite Data

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The sampling strategy for mapping soil properties entails making decisions about sampling design, sample size and sampling location. The availability of a consistent number of ancillary data strongly related to the target variable allows applying sampling strategies according the feature space. In this context, remote sensing spectra acquired at each band can be exploited first to set the sampling strategy and then, after sampling and laboratory measurements, as independent variables for the prediction models of the target variables. We tested different sampling strategies based on the feature spaces, where the ancillary data are the spectral bands of the Sentinel 2 and simulated EnMap data acquired in north-west Germany. Thus, this study aims to evaluate the capability of multispectral (Sentinel 2) and hyperspectral (EnMAP) satellite data to select the sampling locations in order to collect a calibration dataset that covers the SOC variability of the area. Some selection algorithms require to set the number of sampling units in advance (random, Kennard-Stones and conditioned Latin Hypercube algorithm) and others automatically provide the ideal number of sampling units (Puchwein, SELECT and Puchwein+SELECT algorithm). The SOC content and the spectra extracted at the sampling locations were used to build random forest (RF) models. The accuracy of the RF estimation models was evaluated on an independent dataset. Generally, Sentinel 2 provided a more accurate estimation than EnMAP. The highest Sentinel 2 ratio of performance to deviation (RPDv) for the validation set was obtained using Puchwein (RPDv: 2.3), Puchwein+SELECT (RPDv: 2.1) and Kennard-Stones (RPDv: 2.1) algorithm. A strong positive correlation was detected between the standard deviation of the calibration dataset and the validation accuracy, especially where a consistent SOC variability exists. The efficiency of the sampling strategies, as ratio between accuracy and number of samples per hectare, is highest using Puchwein and Puchwein+SELECT algorithm. The achieved results demonstrated that Sentinel 2 data can be exploited to build a reliable calibration dataset for SOC mapping; moreover the efficiency of the sampling strategy selection can be improved using algorithms that provide the number of sampling units. On the other hand, the calibration datasets provided by EnMAP data provided lower SOC variability and lower prediction accuracy. The poorer results obtained by EnMAP as compared to Sentinel 2 were probably due to its coarse spatial resolution (30 m).

Real time Airborne gas detection using Thermal Hyperspectral Imaging.

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Gas leaks and air pollution sources present unquestionable health, safety and environmental risks. A history of crisis management in the Upstream has shown the value of efficient and accurate tools for detecting gas leakages and/or for the characterization of air pollution agents. Knowing about the existence of a leak or the existence of an environmental threat is not always enough to launch a corrective action. Additional critical inputs such as the leak source, the chemical nature of the gas cloud, its direction and speed and as well as the gas concentration must most of the time be gathered in a short amount of time to help secure the hazardous areas. Most of the time gas identification for gas leaks surveys or environmental monitoring involves explosives and/or toxic chemicals. In such situations, airborne measurements offer substantial advantages over ground based-techniques since large areas can be covered efficiently and from a safe distance. In this work, we present our recent results on real-time airborne gas detection up to 4 600 feet above the ground using thermal hyperspectral imaging technology. The Fourier-transform technology used in the longwave (8-12 µm) hyperspectral imaging system fixed on an airborne platform allows the acquisition of airborne hyperspectral data using mapping and targeting modes. These two acquisition modes were used for imaging a ground-based ethylene, methanol and acetone gas-release experiment. Real-time quantitative airborne chemical images of the three gas clouds were obtained, paving the path towards a viable solution for gas leak surveys and environmental monitoring.

Fast And Easy Mineral Classification Using CASI/SASI/TASI Data

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Independent spectral analysis is usually employed to analyse hyperspectral optical (visible: VIS, near infrared: NIR, shortwave infrared: SWIR) and thermal (longwave infrared: LWIR) data. The integration of the spectral information provided by different wavelength ranges and the subsequent complex classification still remains challenging. In this paper we demonstrate the benefits of mineral classification employed to optical and thermal hyperspectral data (CASI and SASI: 0.4-2.5 µm; TASI: 8.6-11.5 µm) when using new tools (QUANTools) developed at the Czech Geological Survey (CGS). The concept is based on the automatic detection of multiple absorption features; moreover it allows quick data processing and classification without requiring endmember definition prior to spectral mapping. As a result 12 mineral classes were identified integrating together the spectral information from CASI, SASI and TASI imaging data. A representative sample for each mapped class was collected and, consequently, semi-quantitative XRD diffraction analysis was conducted to resolve the mineralogy in further detail. We can conclude that the new concept allows for quick integration and classification of the VIS/NIR, SWIR and LWIR hyperspectral data. The approach can increase time/cost efficiency as the validation samples can be collected after image classification targeting specifically the identified surface variability (e.g., mapped classes).

Feasibility Study for an Aquatic Ecosystem Earth Observing System

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This study presents the work developed as a CEOS action for which CSIRO and DLR taken the lead on a feasibility assessment to determine the benefits and technological difficulties of designing an Earth observing satellite mission focused on the aquatic (non-oceanic) ecosystems. In fact, many Earth observing sensors have been designed, built and launched with primary objectives of either terrestrial or ocean remote sensing applications. Often the data from these sensors are also used for biogeochemistry in inland, estuarine, deltaic and near coastal waters as well as for mapping macrophytes, macro-algae, sea grasses and coral reefs. However, such land and ocean specific sensors are not designed for these complex aquatic environments and consequently are not likely to perform as well as a dedicated sensor would.

The results indicate that a dedicated sensor of aquatic ecosystems could be a multispectral sensor with about 26 bands in the 380-780 nm wavelength range for their ability to estimate: algal pigment concentrations of chlorophyll-a, accessory pigments, cyanobacteria pigments (cyanophycoerythrin and cyanophycocyanin especially) as well as other wavelengths relevant for phytoplankton functional types research; sun-induced algal fluorescence; suspended matter, possibly split up into organic and mineral matter; colored dissolved organic matter (CDOM) and discriminate terrestrial from marine sources; spectral light absorption and backscattering of the optically active components; transparency of water such as Secchi disk transparency, turbidity and spectral vertical attenuation of light. Then for optically shallow waters also the ability to measure and map: the water column depth with substratum type and cover; plants floating at or just above the water surface. Extending the range to shortwave helps the retrieval of suspend matter in very turbid waters and support research activities in mapping functional traits in floating/emerging vegetation. By including a specific band at 810 nm allows to explore lakes with high CDOM, since in these lakes the signal detectable by remote sensing sensors occurs as two peaks near 710 nm and 810 nm. Moreover, about 15 bands between 360-380 nm and 780-1400 nm are needed for removing atmospheric and air-water interface effects.

These requirements are very close to defining an imaging spectrometer with spectral bands between 360 and 1000 nm (suitable for Si based detectors), possibly augmented by a SWIR imaging spectrometer. In that case the spectral bands would ideally have 5 nm spacing, although it may be necessary to go to 8 nm wide spectral bands to obtain enough signal to noise. The spatial resolution of such a global mapping mission would be between 17 and 33 m enabling imaging of the vast majority of water bodies (lakes, reservoirs, estuaries etc.) larger than 0.2 ha and 25% of river reaches globally (at 17 m resolution) whilst maintaining sufficient radiometric resolution. As spectral and spatial resolution are the core sensor priorities, the temporal resolution needs to be as high as is technologically and financially possible. In fact, although high revisit frequency is probably not critical for applications focused on benthic mapping and inventory, it is critical for tracking processes such as algal blooming.

Mineral Identification And Characterization: An Integrated Approach To Recover Mineralogical Information From Hyperspectral Images

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Mineral mapping and soil analysis, from airborne or satellite sensors, are two growing topics for the study of environmental issues and the evaluation of the geological interest of large areas. As exemple, such information can be used to monitor industrial plants or to mitigate anthropogenic hazards. The development of new and more performing imaging spectrometers such as AVIRIS-NG or EnMAP makes possible the acquisition of hyperspectral images in the Visible Near-InfraRed and Short-Wave InfraRed spectral domains with high enough spectral resolution and signal-to-noise ratios to allow for analysis of reflectance spectra of soils and rocks in terms of mineral composition (chemistry) as well as physical properties (e.g. grain size, humidity).

The purpose of this poster is to present an integrated approach giving the possibility to a non expert to automatically study the mineralogy of an area from a hyperspectral image. It is based on an impoved version of the AGM (Automatized Gaussian Model) procedure [1]. This spectral deconvolution approach uses the EGO (Exponential Gaussian Optimization) model which accounts for absorption bands affected by saturation and asymmetry. Each modeled Gaussian function is defined by five parameters (wavelength position, amplitude, width, asymmetry and saturation). Using this model inversion, several physical and chemical parameters of minerals can be directly estimated.

The new AGM procedure is divided in four main parts. A first step, based on the estimation of the signal dependent and independent noises in the imaging spectrometer data, gives information about the measurement uncertainties. Then, the parameters of the EGO model are estimated. A nonlinear least-square solver, such as Levenberg-Marquardt or Optimal Estimation, is considered depending on the a priori knowledge (geology of the area, measurement uncertainties, etc.). A third step, using a fuzzy logic system developed at CEA [2], allows, from the estimated model parameters and considering a set of expert rules, to identify the diagnostic absorption features of the reflectance spectrum and so the mineral or the mixture of minerals associated to it. Thus, the database consists in absorption features rather than full reflectance spectra. Finally, several physical and chemical parameters of the minerals can be mapped (e.g., composition, grain size) from the mineral identification and some of the model parameters.

This new approach, automatic and adapted to non-experts operational needs, is validated on AVIRIS and AVIRIS-NG data for areas of geological interest. It allows to identify mixtures of minerals and gives access to several of their physical and chemical characteristics. Future work will include the development of new optimization methods and the creation of new expert rules as well as the use of the various derived parameters to extract quantitative information such as soil moisture content or mineral concentrations.

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Spectral characteristics of surface soils between Irbid and Al Mafraq (Jordan)

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The study of soils in term so-called spectral libraries is far developed. It is can support the digital classification of remote sensing data and re-evaluate previous soil studies.

In Jordan, the last study regarding soil mapping was finished in 1993, and the nation soil maps conducted using the conventional methods. Consequently, the challenges of soil studies are very high and there are increasing needs to use spectroscopy to support them and to improve the environmental monitoring.

The present study aims to describe the spectral characteristics of representative soil types in northern Jordan with consideration of soil properties. 160 soil samples were systematically collected from 35 sites. According to Analytical Spectral Devices (ASD) laboratory measurements, mean soil reflectance spectra (MSRS) were calculated and described with consideration of chemical analysis.

The results showed that spectral behavior depended on iron oxide types and contents. They are the key to describe the alteration of soil colors in the study area.

Airborne Multisensors Information for a Zonal Crop Management

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Recently, agriculture management on arable land is driven mostly by two factor: 1/economic efficiency and 2/ its impact on environment. As a result, more management practices are converging to what is called „precision farming". New approaches require a continuous field information on soil properties, crop development during the vegetation season, and finally crop yield as an input. The objective of the study is to identify and map spatial heterogeneity of soil features in field blocks based on data and information obtained from airborne imaging spectroscopy of soils and vegetation, supported with field and laboratory spectroscopy of samples, and crop yield monitoring. We used three types of airborne data acquired in different (non)vegetation periods in two years: 1) reflectance imaging spectroscopy data in the VNIR and the SWIR regions (CASI and SASI sensors, 5 m, 380-2450 nm); 2) hyperspectral thermal infrared data (TASI, 8-11.5 µm); 3) LiDAR data (Riegl - Q780) with point density of a 5p/m^2. Moreover, yield distribution from the yield monitoring system data acquired during the harvest was used as the "answer" of vegetation on soil properties and orographic conditions. The contents of soil organic carbon (SOC) and clay minerals in soils of each field was estimated from the regression model built on the hyperspectral reflectance data of the bare soil and ground spectral measurements, and physical-chemical properties of sampled soil. In each field, we calculated vegetation indices (REP, NDVI) and the HotSpot analyses to characterize relative homogeneity of green wheat biomass. The results show 1/statistically significant ($p<0.05$) impact of slope on crop yield; 2/stat. significant ($p<0.01$) agreement in spatial pattern of: a) the SOC and green biomass (VIs); b) green biomass and a crop yield. Bare soil emissivity calculated from the airborne TIR data did not display any significant relationship to the soil SOC and a week to the clay contents. A three-level zone management were suggested from the multilayer analysis and it will be operationally tested in the area of a 320 ha next year.

Narrow-band Soil Spectral Indices for SOC, Clay and Calcium Carbonate Prediction: Literature Review and Performance Evaluation based on the LUCAS Soil Database

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Upcoming imaging spectroscopy missions give prospect to large-scale soil mapping, but also call for robust models valid across large regions and for different sensors. Today, soil mapping from hyperspectral imagery is mostly based on multivariate statistical techniques often using local training datasets. As an alternative to these empirical models adapted to local conditions and specific sensors, a range of narrow-band soil indices for soil property prediction has been proposed in the literature in the past few decades. The soil spectral indices are solely based on known characteristic spectral features (such as spectral slopes and absorption depths) and thus believed to be more universally applicable, however, at the expense of a reduced prediction accuracy as compared to empirical locally adapted models. While there are extensive literature reviews about the prediction of soil properties using multivariate statistical techniques, there is so far no comprehensive review study about proposed soil spectral indices nor have their performances been evaluated in a systematic way for a large range of soil environments.

The pan-European Land Use/Land Cover Area Frame Survey (LUCAS) soil database provides an ideal dataset to test spectral indices as it contains a large number of samples taken systematically on a wide range of soils. The LUCAS 2009 survey data used in this study include about 20,000 topsoil samples collected in 25 EU member states on different land use types. Soil samples were analysed for a range of key soil properties comprising texture, organic carbon and mineralogy using consistent standardizes procedures. Furthermore, the LUCAS topsoil database contains spectral measurement data taken in the VNIR-SWIR range under standardized laboratory conditions.

The goal of this study is to review soil spectral indices proposed in the literature focussing on SOC, CaCO3 and clay, and to evaluate the soil property prediction performance of a range of indices based on the LUCAS soil database. In this study we focus on samples taken on agricultural lands and analyse the prediction performance for the entire agricultural subset as well as subsets thereof, e.g. different soil types and soil value ranges. The results will provide general guidance in the choice of suitable soil indices for soil property mapping and, more specifically, they will support the extension the EnSoMAP suite within the EnMAP Box software developed as part of the scientific preparation programme of the EnMAP imaging spectroscopy mission.

Sensor Calibration Facility for Spectral and Thermal Remote Sensing

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Unmanned aircraft systems (UAS) have become a popular remote sensing tool for researchers in many disciplines. UAS sensors for spectroscopy and thermal sensing were miniaturised through technological evolution of semi-conductors and battery technology. However, the data quality obtained with these optical sensors is often limited as a rigorous sensor calibration is missing. The absolute accuracy and consistent performance of these sensors needs to be characterised to make quantitative remote sensing estimates usable operationally. Especially for applications that require high measurement accuracy like sensing of chlorophyll fluorescence, rigorous sensor characterisation is essential. Since there has been no facility that delivers spectral and radiometric calibrations for UAS sensors in Australia, a group of researchers initiated the establishment of such a facility within an Australian Research Council (ARC) Linkage Infrastructure, Equipment and Facilities (LIEF) project. The sensor calibration facility is located in Hobart at the University of Tasmania. It comprises a temperature and light controlled laboratory with solid granite optical benches and opto-mechanic sensor mounting accessories. A uniform light source with spectralon coated, 12" inch integrating sphere enables radiometric calibration (USLR-D12L-NDNN HELIOS, Labsphere Inc., New Hampshire, US). Spectral calibration is facilitated through a spectrally tuneable 0.05 nm spectral resolution monochromator (TLS257-250Q, Newport Corporation, California, US) and pencil style spectral calibration lamps. A blackbody emission source will enable radiometric calibration of thermal sensors. Since UAS missions may involve extreme temperatures, specific calibrations are required to account for changes in sensor behaviour. A foreseen temperature and humidity-controlled chamber might enable calibrating sensors in temperatures of at least 10-40 °C. The project aims to develop standard procedures for quantifying sensor spectral and radiometric characteristics (e.g. dark current noise levels, instrument spectral response functions and non-linearity) as well as protocols for radiometric and spectral calibration (e.g. lens vignetting correction, digital number to radiance conversion, spectral wavelength calibration and sensor noise elimination). The facility will offer these services to the broader remote sensing community from 2019 onwards.

Hyperspectral Photoluminescence Imaging as a Tool to Study Degradation of the Outdoor Silicon Solar Panels

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The studies on degradation and failures in solar panels using contactless measurement methods have so far predominantly focused on thermographic and electroluminescence imaging. These methods enable detection of various types of failures such as hotspots, shunts, material defects and cracks. Another contactless method, which has proven to be promising to detect crystal imperfections, is hyperspectral photoluminescence imaging in the SWIR wavelength region (1000 nm - 2500 nm). This approach makes it possible to map mechanisms for recombination of photogenerated charge carriers in semiconductors, which lead to decreased performance in solar cells. So far, the hyperspectral imaging technique has been used to record radiative photoluminescence from the silicon material in research laboratories after the electrons from the valence band have been excited to the conduction band with a line laser. The goal is, however, to be able to use hyperspectral photoluminescence imaging to inspect degradation of the outdoor solar panels with the end goal of performing effective surveillance and monitoring. In order to do that, the hyperspectral camera needs to detect radiative photoluminescence from the solar panels while electrons are excited with electromagnetic radiation from the sun, as opposed to monochromatic laser light. This approach poses many challenges. The poster aims to present the experiences gathered so far with respect to methodology and preliminary signal recordings conducted with hyperspectral camera of solar cells illuminated with sun. Preliminary results using illumination from a solar simulator in laboratory environments will be presented, as well as analysis of airborne hyperspectral SWIR images of buildings with solar panel installations.

Hyperspectral Imaging analysis of Scots Pine Wood Wffected by Decay Fungi

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Wooden Utility Poles (WUP) have the function to carry power and telephone lines. There are several million wooden utility poles in Norway and many more around the world. These WUP are made of preservative impregnated timbers. The service life of a WUP is dependent on many factors. The most important factor is the reduction in fiber strength caused by wood decaying fungi. Therefore, to estimate the remaining lifetime of the WUP, it is essential to quantify the presence of rot. Currently, the inspection of WUP is usually performed visually and by use of mechanical tools like a drill, hammer or a spade.

In 2018, a project led by NORCE and funded by the Norwegian Research Council and Nettpartner Holding AS was started to investigate the capabilities of using remote sensing for the inspection of WUP. One of the remote sensing modalities in this research is hyperspectral imaging.

In order to understand the effects of basidiomycete decay fungi and wood decomposition in hyperspectral imagery, a lab experiment has been set up in collaboration with the Norwegian Institute of Bioeconomy Research. In the lab experiment, Petri-dishes with Scots pine sapwood (Pinus sylvestris L.) samples on a malt agar medium are infected with two types of decay fungi, a brown rot (Rhodonia placenta Fr.) and a white rot (Trametes versicolor L.). The wood samples are scanned with a HySpex SWIR-384 hyperspectral camera at different stages of rot progression to create a time series of hyperspectral measurement of the effect of the wood-decay for a period of up to sixteen weeks. The primary variables to be monitored in this experiment are wood weight and spectra before and after fungal decay. Two wood moisture levels will be included: dry and conditioned at 20°C/65% relative humidity. After decay spectra of conditioned samples will be measured with and without surface mycelia.

The poster presents the setup and the preliminary results of the time series experiment. Preliminary hyperspectral image analyses results are shown for wood affected by various gradations of basidiomycete rot decay, and a comparison of the spectra from preservative impregnated wood of WUP with and without rot.

Proximal Hyperspectral Outcrop Scanning - A Geological Use Case Study

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Hyperspectral, proximal outcrop scanning provides state-of-the-art, spatial mineral and element analysis in a growing field of geological applications. It enables us to visualize the mineral and element composition of outcrops and mine faces and thus learn about the development of the rock building and weathering processes that were taking place. The hyperspectral imaging sensor system "HySpex" from Norsk Elektro Optikk (NEO) has been used to investigate the influence of rotational measurements and single- vs. multi-station measurements on the data and give an idea about the difference of the presence of field of view extenders for the data acquisition. The sensor system combines a VNIR (400-1000nm) and a SWIR (1000-2500nm) detector which in combination enables the classification of the mineral- and element content of the surface. Based on multi-temporal and multi-station line-scan measurements for a REE-outcrop in Ulefoss, Southern Norway, we are able to provide a guideline for high-quality, time-effective rotational measurements and give insight into the recommended procedures for hyperspectral outcrop measurements.

In comparison to the REE-outcrop you will get to know a few application examples from copper mines in Cyprus, dimension stone quarries in Southern Norway and an inoperative Silver quarry in Central Norway.

Retrieving Macrophyte Pigments From Spectral Reflectance

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Plant traits play a key role in the delineation and quantitative description of vegetation functional features within and across ecosystems. Under a data-driven approach, biological and ecological models rely more and more on the availability, completeness and quality of plant traits used as their input.

During the last decade, hyperspectral imaging sensors have demonstrated their potential for quantifying plant traits in terrestrial ecosystems, especially forests and grasslands. Despite their crucial biogeochemical interactions within aquatic ecosystems, and the important contribution to diversity and function of such environments, only few works have worked on using remote sensing for assessing quantitative traits for aquatic plants, or macrophytes.

Leaf pigments are among the most studied traits using remote and proximal sensing-based spectroscopy, with a specific attention on chlorophylls (a and b), as their content can be linked to nitrogen (N) content and photosynthetic performance.

The main aim of this work is to test and calibrate spectral reflectance-based models for estimating pigments content for floating and emergent macrophyte species common in temperate and continental regions, focusing on chlorophyll a (Ca) and b (Cb), their ratio (Ca/Cb), as well as total carotenoids (Cxc).

The spectroscopy-based pigments models were implemented using high-resolution reflectance (at leaf and canopy scales) data and plant pigment content collected in situ. Best performing macrophyte pigments models were applied to hyperspectral imaging datasets acquired with the APEX sensor for mapping macrophyte pigments. APEX data were collected during airborne campaigns sponsored by EUFAR through Transnational Access action in connection with EU FP7 INFORM project, covering three shallow European water bodies in 2014 and 2016: Lake Hídvégi (Hungary), Mantua lakes system (Italy), and Nemunas Delta (Lithuania).

Leaf Cxc concentration scores measured in our dataset were highly correlated with Ca concentration ($R^2 > 0.8$), thus not permitting an independent estimation of the two parameters. Ca and Cb content were instead retrieved with good reliability ($R^2 > 0.6$) using two-band and three-band spectral indices (SIs). The optimal spectral ranges were different for models at leaf and canopy scale. At leaf scale, best performing models were based on SIs including spectral reflectance around 495-508 nm and 690 nm for Ca, and around 485-489 nm and 661 nm for Cb. At canopy scale, best performing models included SIs exploiting spectral reflectance around 730 nm and 810 nm for Ca, and around 517-525 nm and 600 nm for Cb. The ratio of two chlorophylls (Ca/Cb) was retrieved with lower but still acceptable accuracy ($R^2 > 0.5$), combining spectral reflectance in the ranges around 687-695 nm and 605 nm or 650 nm for leaf and canopy scale, respectively.

Maps of macrophyte Ca content, Cb content and their ratio were derived from APEX data for the three study sites, at canopy scale (3-5 m pixel size). These maps were used for assessing the variability of macrophyte pigments content at species and ecosystem levels, taking into account both within-site and across-site variability factors, thus providing a first high-resolution spatialized insight into aquatic vegetation functional traits assessment.

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