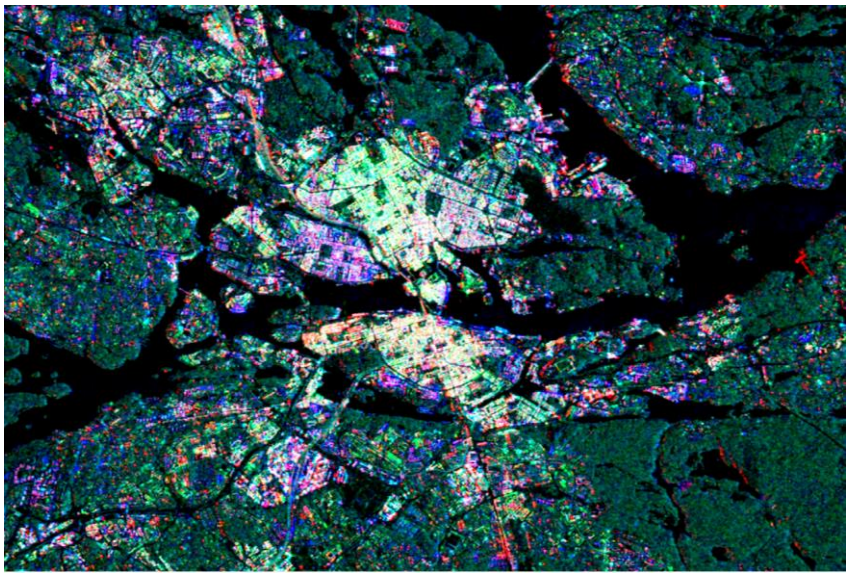
European Association
of Remote Sensing Laboratories
Special Insterest Group 'Temporal Analysis of Satellite Images'

The 2nd International Workshop on Temporal Analysis of Satellite Images

June 17-18, 2015
Stockholm, Sweden



Workshop Programme
&
Abstract Book

Editor
Yifang Ban
KTH Geoinformatics

Remote Sensing for Sustainable Development: Progress, Challenges and Opportunities in Europe and the World

Welcome to the 35th symposium of the European Association of Remote Sensing Laboratories, accompanied by the 2nd International Workshop on Temporal Analysis of Satellite Images and the 7th EARSeL Workshop on Remote Sensing of the Coastal Zone.

The symposium and the workshops will focus on such areas as Remote Sensing for sustainable development since achieving sustainable development is the overriding challenge of the 21st century. The United Nations is in the process of defining a post-2015 development agenda with a set of Sustainable Development Goals, to be finalized in September 2015. To reach these Sustainable Development Goals, timely, accurate and consistent information are needed. Since the launch of Landsat-1 in 1972, many Earth Observation satellites have been launched providing vast amount of such critical data and information to support environmental change monitoring, urban planning, resource management, disaster assessment and mitigation, and climate change modeling, among others.

The Symposium and the workshops will bring together 230 participants from 40 counties including scientists, practitioners and students. In addition to the European participants, around 60 participants are international, from Brazil to China to the US, from Canada to New Zealand to South Africa. This will make the Stockholm symposium and workshops the most international conference in the EARSeL history. The symposium and the workshops have plenary sessions, thematic sessions, and poster sessions where participants will share their latest experience and results on remote sensing research, development and applications in many areas. Snapshots of the progress, challenges and opportunities of Remote Sensing in Europe and the world will be presented.

I cordially welcome you in Stockholm! I wish all of us fruitful discussions and a successful EARSeL2015.

Yifang Ban, Professor
KTH Royal Institute of Technology

On behalf of the Organizing Committee
2015 EARSeL Symnposium and Worshops

Table of Contents

General Information

Introduction

This booklet contains organizational and programme information as well as all abstracts for the 2nd International Workshop on Temporal Analysis of Satellite Images, held at the main campus of KTH Royal Institute of Technology, Stockholm, Sweden during June 17-18, 2015.

Registration

The Registration Desk for the Symposium is located in E-Atrium at Lindstedtsvägen 3 on KTH main campus and will be opened according to the following schedule:

Tuesday, June 16, 2015 8:00 – 18:00
Wednesday, June 17, 2015 8:00 – 18:00
Thursday, June 18, 2015 8:00 – 12:00

WiFi

Free WiFi is available on KTH campus. To log in please use the following information:

WiFi: KTH-Conference
Password: hHgF3bSa

Information for Speakers

Speakers are requested to bring their presentation in PowerPoint or PDF on a USB stick and upload the presentation file at least 15 minutes before the respective session begins, or at an earlier break.

Each session room is equipped with a computer/ projector, a microphone, and a pointing device. If you have a PPT containing a video or animation, please inform the KTH volunteers in the session and ensure that both ppt and video files are in the same folder. Presentations from personal laptops are not permited to minimise the transition time between presentations.

Speakers are also asked to identify themselves to the session co-chairs, who should also be in the room 15 minutes before the respective session. Speakers are asked to stay within the time given to your presentation (either 13 or 18 minutes in total), in order to allow a few questions.

A Speakers Preparation Room (E32) is available for the authors (See map on Page 10).

Hours of operations are as follows:

Wednesday, June 17, 2015 8:00 – 18:00
Thursday, June 18, 2015 8:00 – 12:00

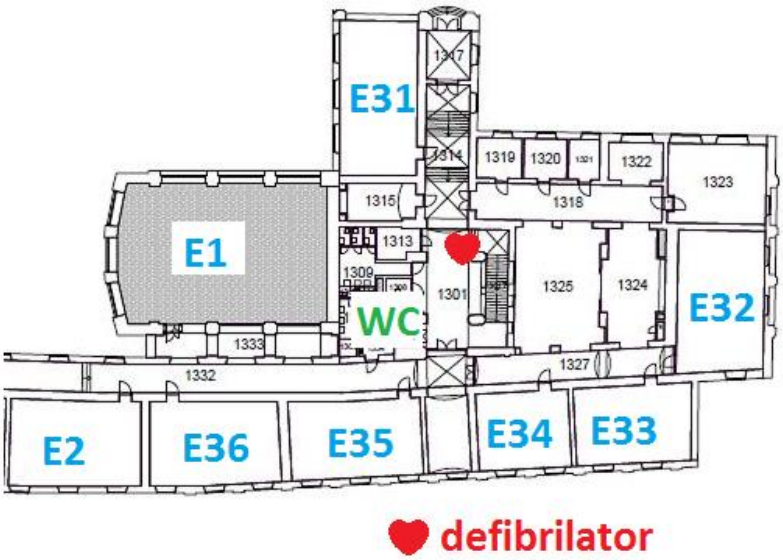
Information for Poster Presentations

Authors are requested to attend their posters during the Poster Session. For each poster, a poster board is reserved with a dimension of 120 cm x 90 cm (H x W). Material necessary for pinning the poster to the board is available on the poster boards or at the registration desk. Authors are requested to mount their posters on the day of their poster session and remove the posters by 18:00 on Wed., June 18.

Direction to Symposium Venue on KTH Campus

Take the subway ‘Red Line’ towards Mörby Centrum, get off at Tekniska Högskolan. Then walk for 3 minutes following the route in the map below.

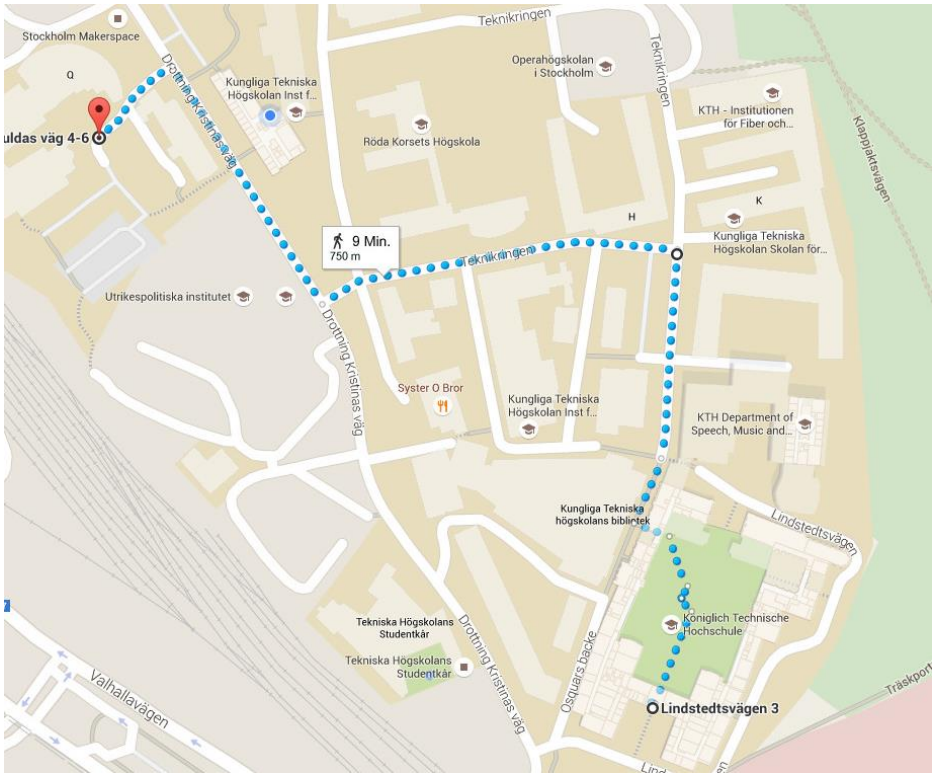
Floor Plan



Social Events

Lunch

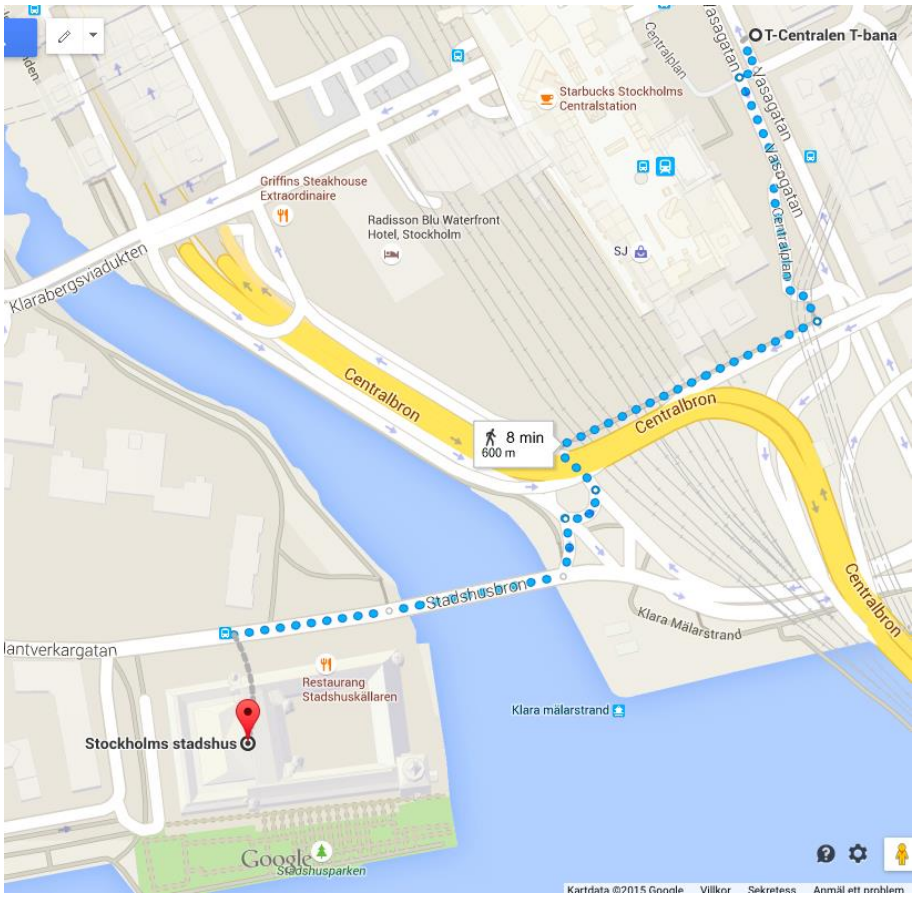
All lunches will be held in Restaurang Q on KTH Main Campus. See map below for direction.



City Hall Reception

All conference and workshop participants are cordially invited by the City of Stockholm for a Buffet Reception at 6-8PM on June 17 at the famous City Hall of Stockholm, where Nobel Banquet is held in December every year.

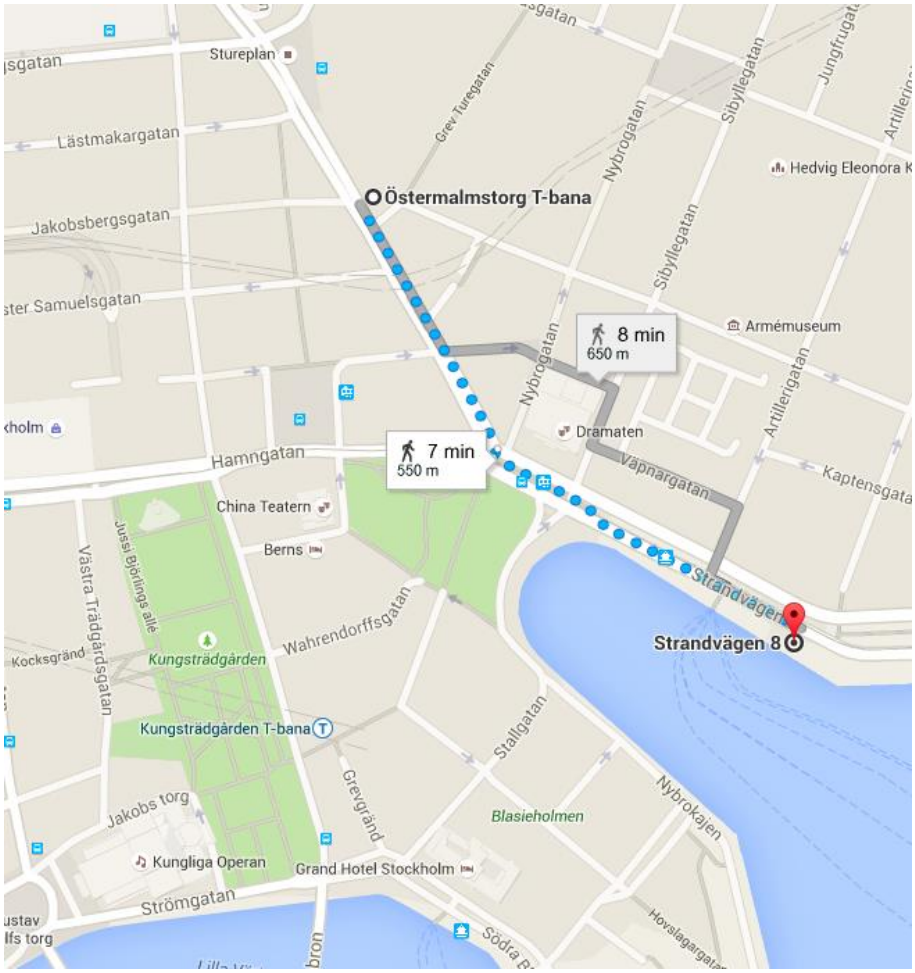
See map below for directions. Take the subway towards “Fruängen” for three stops to T-Centralen and take the exit to Vasagatan. Exit on Vasagatan, cross the street and turn left following Vasagatan to the south towards the waterfront. When arriving at Vattugatn, turn right and cross under the motorway to go towards stadshusbron, then cross over the bridge to the City Hall.



Gala Dinner

The symposium gala dinner will be held on board a steamboat cruising the Stockholm Archipelago at 7-10PM on June 18.

See map below for directions. Take the subway ‘Red Line’ towards “Fruängen” for two stops to Östermalmstorg and take the exit to Birger Jarlsgatan. Take the escalator up, arrive right in front of the restaurant “Fridays”. Turn left turn following Birger Jarlsgatan until arriving at Dramaten, the Royal Theather. Cross the Street towards the waterfront and follow Strandvägen until arriving at Kajplats 16 (Strandvägen 8).



Scientific Committee

Prof. Yifang Ban	KTH Royal Institute of Technology, Sweden
Prof. Lorenzo Bruzzone	University of Trento, Italy
Prof. Peijun Du	Nanjing University, China
Prof. Lars Eklundh	Lund University, Sweden
Prof. Paolo Gamba	University of Pavia, Italy
Prof. Peng Gong	University of California, Berkeley, USA & Tsinghua University, China
Prof. Håkan Olsson	Swedish University of Agricultural Sciences, SLU, Sweden
Dr. Thuy Le Toan	CNRS-CNES- Université Paul Sabatier, France
Prof. Jonathan Li	University of Waterloo, Canada
Prof. Eberhard Parlow	Basel University, Switzerland
Dr. Jiali Shang	Agriculture and Agri-Food Canada, Canada
Prof. Uwe Stilla	Technische Universitaet Muenchen, Germany
Dr. Hannes Taubenböck	German Aerospace Center (DLR), Germany
Prof. Xiaojun Yang	Florida State University, USA

Ognization Committee

Yifang Ban	KTH Royal Institute of Technology, Sweden
Alexander Jacob	KTH Royal Institute of Technology, Sweden
Jan Haas	KTH Royal Institute of Technology, Sweden
Deliang Xiang	KTH Royal Institute of Technology, Sweden
Heide Bierbrauer	EARSeL Secretariat

Sponsors and Exhibition

Symposium and Workshop Session Overview

Monday, June 15, 2015		
8:00am - 9:00am	Registration Location: E-Atrium	
9:00am - 10:30am	PL-1: Symposium Opening and Plenary Session 1 - ESA & GEO Location: E1	
10:30am - 11:00am	Coffee Break 1 Location: E-Atrium	
11:00am - 12:30pm	MON-1: Urban Remote Sensing - 1 Location: E1	MON-2: Cultural Heritage and Education Location: E2
12:30pm - 1:30pm	Lunch Break 1 Location: Restaurang Q	
1:30pm - 2:30pm	PL-2: Plenary Session 2 - BIOMASS & Change Detection Location: E1	
2:30pm - 4:10pm	MON-3: Forestry Remote Sensing - 1 Location: E1	MON-4: 3D Remote Sensing Location: E2
4:10pm - 4:30pm	Coffee Break 2 Location: E-Atrium	
4:30pm - 6:10pm	MON-5: Agriculture Remote Sensing Location: E1	MON-6: Thermal Infrared Remote Sensing - 1 Location: E2
6:15pm - 8:15 pm	Icebreaker Location: Restaurang Syster O Bror	

Tuesday, June 16, 2015		
8:20am - 10:00am	TUE-1: LiDAR & RADAR Data Processing Location: E2	TUE-2: UAVs & Airborne Hyperspectral Remote Sensing Location: E1
10:00am - 10:30am	Coffee Break 3 Location: E-Atrium	
10:30am - 12:30pm	TUE-3: Urban Remote Sensing - 2 Location: E2	TUE-4: Vegetation and Vegetation Dynamics Location: E1
12:30pm - 1:30pm	Lunch Break 2 Location: Restaurang Q	
1:30pm - 2:30pm	PL-3: Plenary Session 3 - Future Earth Location: E1	
2:40pm - 4:00pm	TUE-5: Land Cover and Validation Location: E1	TUE-6: Thermal Infrared Remote Sensing - 2 Location: E2
4:00pm - 4:30pm	Coffee Break 4 Location: E-Atrium	
4:30pm - 6:00pm	TUE-7: Poster Session Location: E-Atrium	TUE-8: EARSeL Council Meeting Location: E31

Wednesday, June 17, 2015				
8:20am - 8:50am	PL-4: Plenary Session 4 - Forestry Remote Sensing in Sweden Location: E1			
8:50am - 10:10am	WED-1: Forestry Remote Sensing - 2 Location: E1		WED-2: Image Processing: Optical Data Location: E2	
10:10am - 10:40am	Coffee Break 5 Location: E-Atrium			
10:40am - 12:10pm	WED-3: General Assembly for EARSeL Members Location: E1			
12:10pm - 1:15pm	Lunch Break 3 Location: Restaurang Q			
1:15pm - 1:30pm	WS-PL1: Opening of Workshops Location: E1			
1:30pm - 2:30pm	PL-5: Plenary Session 5 - The Swedish EO Program & Multitemporal Analysis (Symposium & Workshop Joint Session) Location: E1		WS-PL2: Workshop Keynote - The Swedish EO Program (Joint with PL-5) Location: E1	
2:00pm - 2:30pm	WSCZ-1: Workshop on Remote Sensing of the Coastal Zone: Baltic Sea Location: E2			
2:30pm - 3:00pm	Coffee Break 6 Location: E-Atrium			
3:00pm - 5:00pm	WED-4: Oceans, Coastal Zones & Inland Waters Location: E35	WED-5: Multitemporal Analysis and Change Detection (Symposium and Workshop Joint Session) Location: E1	WSCZ-2: Workshop on Remote Sensing of the Coastal Zone: Baltic Sea Location: E2	WSTA-1: Agriculture Location: E31
6:00pm - 8:00pm	City Hall Reception Location: Stockholm City Hall, Hantverkargatan 1			

Thursday, June 18, 2015				
8:20am - 9:40am	THU-1: Hyperspectral Remote Sensing and New Instruments Location: E35	WSCZ-3: Baltic Sea Location: E2	WSTA-2: Glacier, Ice Sheet and Permafrost Location: E1	WSTA-3: Image Processing Location: E31
9:40am - 10:10am	Coffee Break 7 Location: E-Atrium			
10:10am - 11:50am	THU-2: Disaster Management Location: E35	WSCZ-4: Land-Sea Interaction Location: E2	WSTA-4: Urban Location: E31	WSTA-5: Landscape &Vegetation Dynamics Location: E1
12:00pm - 12:30pm	PL-6: Symposium Closing Location: E1			
12:30pm - 1:30pm	Lunch Break 4 Location: Restaurang Q			
1:30pm - 3:10pm	WSCZ-5: New technologies and in situ measurements Location: E2		WSTA-6: Forestry Location: E35	WSTA-7: Temporal Analysis Techniques Location: E1
3:10pm - 3:40pm	Coffee Break 8 Location: E-Atrium			
3:10pm - 4:00pm	WSCZ-6: Poster Session Location: E-Atrium		WSTA-8: Poster Session Location: E-Atrium	
4:00pm - 5:40pm	WSCZ-7: Workshop on Remote Sensing of the Coastal Zone Location: E2		WSTA-9: Landuse and Land Cover Change Location: E1	
5:40pm - 5:50pm	WSTA-PL3: Temporal Analysis Workshop Closing Location: E1			
7:00pm - 10:00pm	Gala Dinner Cruise Location: Archipelago Dinner Cruise, Strandvägen, berth no 16.			

Workshop Programme

Wednesday, June 17, 2015	
1:15pm - 1:30pm E1	**WS-PL1: Opening of Workshops** Session Chair: **Prof. Yifang Ban**, KTH Royal Institute of Technology, Sweden
1:30pm - 2:30pm E1	**WSPL-2: Plenary Session 5 - The Swedish EO Program & Multitemporal Analysis (Symposium & Workshop Joint Session)**
3:00pm - 5:00pm E1	**WED-5: Multitemporal Analysis and Change Detection (Symposium and Temporal Analysis Workshop Joint Session)** Session Chair: **Prof. Yifang Ban**, KTH Royal Institute of Technology, Sweden Session Chair: **Prof. Eberhard Parlow**, University Basel, Switzerland
3:00pm - 5:00pm E31	**WSTA-1: Agriculture** Session Chair: **Prof. Xiangming Xiao**, University of Oklahoma, United States of America

Thursday, June 18, 2015	
8:20am - 9:40am E1	**WSTA-2: Glacier, Ice Sheet and Permafrost** Session Chair: **Prof. Eberhard Parlow**, University Basel, Switzerland Session Chair: **Dr. Ian Anthony Brown**, Stockholm University, Sweden
8:20am - 9:40am E31	**WSTA-3: Image Processing** Session Chair: **Dr. Ruth Sonnenschein**, EURAC, Italy
10:10am - 11:50am E31	**WSTA-4: Urban** Session Chair: **Dr. Xiaojun Yang**, Florida State University, United States of America Session Chair: **Dr. Maik Netzband**, Ruhr-University Bochum, Germany
10:10am - 11:50am E1	**WSTA-5: Landscape and Vegetation Dynamics** Session Chair: **Prof. Margareta Ihse**, Stockholm University, Sweden Session Chair: **Prof. Le Wang**, The State University of New York at Buffalo, United States of America
1:30pm - 3:10pm E35	**WSTA-6: Forestry** Session Chair: **Dr. Achim Röder**, Trier University, Germany Session Chair: **Prof. Rutherford Vance Platt**, Gettysburg College, United States of America
1:30pm – 3:10pm E1	**WSTA-7: Temporal Analysis Techniques** Session Chair: **Prof. Lars Eklundh**, Lund University, Sweden Session Chair: **Prof. zhang lei**, institute of remote sensing and digital earth, China, People's Republic of
3:10pm - 4:00pm	**WSTA-8: Poster Session** Session Chair: **Alexander Jacob**, KTH Royal Institute of Technology, Sweden Session Chair: **Jan Haas**, KTH Royal Institute of Technology, Sweden
4:00pm – 5:40pm E1	**WSTA-9: Landuse and Land Cover Change** Session Chair: **Prof. Nina S.N. Lam**, Louisiana State University, United States of America Session Chair: **Prof. Arnon Karnieli**, Ben Gurion University, Israel

Session WS-PL1: Opening of Workshops

Welcome Address: **Chair, EARSeL SIG Temporal Analysis of Satellite Images**
Eberhard Parlow, University Basel, Switzerland

Welcome Address: **Chair, EARSeL SIG Remote Sensing of the Coastal Zone**
Salvatore Marullo, ENEA, Italy

Welcome Address: **EARSeL President**
Lena Halounova, Czech Technical University in Prague, Czech Republic

Welcome Address: **Coordinator, Nordic Network for Baltic Remote Sensing**
Susanne Kratzer, Stockholm University, Sweden

Welcome Address: **Local Organizer and Co-chair, EARSeL SIG Temporal Analysis of Satellite Images**
Yifang Ban, KTH Royal Institute of Technology, Sweden

Session WS-PL2: - The Swedish EO Program & Multitemporal Analysis (Symposium & Workshop Joint Session)

The Swedish Earth Observation Program

Olle Norberg
Swedish National Space Board, Sweden; Olle.Norberg@snsb.se
Keynote

Multitemporal Analysis of Vegetation Dynamics in Different Climate Regions

Lars Eklundh
Lund University, Sweden; lars.eklundh@nateko.lu.se

Earth orbiting satellites provide information on global vegetation dynamics with a spatial and temporal resolution that no other observation systems can match. The useful data generated by these satellites help us investigate and understand interactions and feedbacks between the climate system and the ecosystems. Based on satellite data we can tackle a number of urgent global issues related to vegetation, e.g. estimation of carbon uptake by vegetation; deforestation and forest degradation; monitoring of disturbances due to drought or insect attacks; changing growing seasons; and vegetation change in sensitive regions, like the world's drylands and the Arctic. The ability to address these and many other pressing issues is improved by continued development of both the global data collection infrastructure and new exciting developments in remote sensing science.

Optimal use of satellite time-series data for dynamic vegetation monitoring requires proper understanding and use of the remotely sensed signals. Global time-series of NDVI data from NOAA and MODIS sensors are of tremendous importance for understanding global change processes. Using these data, both long-term trends and short-term variations have been observed in sensitive geographical areas. However, accurate vegetation modeling also requires data that more directly relate to vegetation biophysical processes, e.g. albedo, fractional absorbed photosynthetically active radiation (fAPAR), and leaf area index (LAI). Though radiative transfer modeling is normally required to derive these, also physically based vegetation indices can be useful. An example is the recently developed plant phenology index (PPI), which is linear with LAI and relates strongly to gross primary productivity (GPP). Use of these data demonstrates interactions between the climate system and the vegetation seasonality.

It is also necessary to continue developing methods for efficient time-series processing. Traditionally, linear regression has dominated for mapping trends in satellite data; however, new and more efficient algorithms have recently been developed. One of these is DBEST, which can be used for estimation of non-linear vegetation variations based on time-series segmentation. It is also important to continue developing efficient and accurate data smoothing algorithms that can handle data with biased noise and long data gaps. This will be particularly important for managing large volumes of time-series data produced by Sentinel-2, Venus, and other new sensor systems. Novel data smoothing methods, e.g. combining the spatial and temporal domains, will offer new and efficient data processing solutions.

Session WED-5: Multitemporal Analysis and Change Detection (Symposium and Temporal Analysis Workshop Joint Session)

Multitemporal Remote Sensing for Monitoring, Reporting and Forecasting Ecological Conditions of the Appalachian Environment

Yeqiao Wang
University of Rhode Island, United States of America; yqwang@uri.edu

The Appalachian Trail traverses along the high elevation ridges of the Appalachian Mountains in the eastern United States, extending about 3,676 kilometers across 14 states, from Springer Mountain in Northern Georgia to Mount Katahdin in central Maine. The north-south alignment and high elevation setting of the Appalachian Trail provide an ideal barometer for early detection of undesirable changes in natural resources, from development encroachment to climate change and the effects on phenology, forest conditions and landscape characteristics. This paper presents a study that is to: 1. develop a comprehensive set of seamless indicator data layers consistent with the Appalachian Trail environmental "Vital Signs"; 2. establish a ground monitoring system to complement remote sensing observations; 3. assess historical and current ecosystem conditions and forecast trends; and 4. develop an Internet-based implementation and dissemination system for data visualization, sharing, and management to facilitate collaboration and promote public understanding of the environment. The study employed multiple remote sensing data products provided by the Terrestrial Observation and Prediction Systems (TOPS) for monitoring of phenology and climate change, forest condition and landscape dynamics of the study area. The data products include MODIS Land Cover Dynamics (MOD12Q2), Land Cover Type (MOD12Q1), Vegetation Indices (MOD13A2), Leaf Area Index FPAR (MOD15A2), NDVI (MOD13Q1); Global Inventory Modeling & Mapping Studies (GIMMS) NDVI; North American Carbon Program (NACP) modeled productivity data (GPP, NPP, NEP); Surface Observation and Gridding System (SOGS) Metrological Data; among others. The study revealed a regional pattern of landscape dynamics and revealed the trends and variations of land surface phenology along the Appalachians in different ecoregion provinces and sections. The metrological data revealed the variation and trend of changing temperatures and precipitations in the past decades. The extracted information and revealed patterns help understand the changing Appalachian environment. By integrating time series seamless remote sensing data and modeling

products that link climate models (e.g., through TOPS) and ecological models (e.g., habitat suitability) with in situ observations (e.g., USFS Forest Inventory and Analysis data), the study creates a coherent framework for data integration, monitoring, reporting and forecasting to improve the understanding of the Appalachian environment for natural resource management and biodiversity conservation.

Using multi-scale change detection analysis to inform conservation practices in Kruger National Park, South Africa

Paul Aplin[1], Hannah O'Regan[1,2], Christopher Marston[1], David Wilkinson[3]

[1]University of Nottingham, United Kingdom; [2]Evolutionary Studies Institute, University of the Witwatersrand, South Africa; [3]Liverpool John Moores University, United Kingdom; paul.aplin@nottingham.ac.uk

Monitoring land cover change over time is invaluable for informing environmental management and conservation practices. In Kruger National Park (KNP), South Africa, changes to vegetation distributions are of particular interest, and these are affected by both natural (e.g. climatic and biotic) and anthropogenic (e.g. artificial water resource) influences. Land cover monitoring is typically conducted using remote sensing, and standard approaches tend to use relatively coarse spatial resolution satellite sensor imagery such as 30m resolution Landsat Operational Land Imager data. This scale of observation can limit the accuracy of output land cover maps, and can also constrain the thematic detail (i.e. number and nature of land cover classes). Also, accurate land cover classification relies on corresponding reference (e.g. field) data, and this is both expensive to obtain and historical data are scarce. Here, we present accurate and detailed information of land cover (especially, vegetation) change in southern KNP from 2002 to 2014, using a combination of medium (Landsat) and fine resolution (e.g. 4m QuickBird) imagery, supplemented by intensive field survey data. Specifically, we compare differences in canopy cover across these different scales of observation. This comparative analysis answers two key questions – what thematic information is lost when using medium resolution imagery, and how has land cover changed over the last decade? The analysis directly addresses prevailing management concerns in KNP such as the hypothesized 'scrubbing up' of the Skukuza thickets in the recent past.

Object-based trend analysis of land use change within a wildlife corridor in India

Rutherford Vance Platt, Monica Vini Ogra
Gettysburg College, United States of America; rplatt@gettysburg.edu

Located in the foothills of the Indian Himalaya, Rajaji National Park was established largely to protect and enhance the habitat of the Asian elephant (elephas maximus) and tiger (Panthera tigris). In 2002 the Van Gujjars, indigenous forest pastoralists, were voluntarily resettled from Chilla Wildlife Sanctuary in Rajaji National Park to Gaindikhata, a nearby area where they were granted land for agriculture. In this study we used a variety of remote sensing approaches to identify changes in land cover associated with the resettlements. The goal of this research is to assess whether the resettlements can be considered a 'win-win' from a land systems science perspective. Our methods were as follows:

1. Use object-based image analysis (OBIA) to develop accurate land cover classifications pre-resettlement based on VHR and Landsat imagery. In OBIA, imagery is first segmented into homogeneous objects (polygons) and then classified based on spectral response, texture, geometry and context. Many studies have found that OBIA yields higher classification accuracy than pixel-based methods for land cover classification and change detection.

2. Based on the OBIA, identify the pre-resettlement land cover classes of 'recovery objects' (objects in Chilla Sanctuary where settlements were removed), 'agricultural use objects' (objects representing agricultural expansion in Gaindikhata), 'non-agricultural use objects' (the area of grazing and biomass collection within 1 km of 'agricultural use objects') and 'reference objects' (the remaining objects in the landscape).

3. Using trend analysis of Landsat imagery, assess the gradual and abrupt changes in vegetation that took place in 'recovery', 'agricultural use', 'non-agricultural use', and 'reference' objects post-resettlement. To conduct the trend analysis we used BFAST (Breaks For Additive Season and Trend), which decomposes a time series (in this case NDVI derived from Landsat 5 and 7, 1998-2014) into trend, seasonal, and remainder components. BFAST also identifies breaks in the seasonal components that can be linked back to disturbances or land cover changes.

We found that the OBIA classification yielded high average class accuracies, and we were able to make class distinctions that would have been difficult to make using a traditional pixel-based approach. Pre-resettlement, the 'recovery areas' were classified as mixed forest and riparian vegetation. In

contrast, the ‘use areas’ were classified primarily as grass dominated, brush dominated, and plantation forest, and were located relatively far away from riparian areas. Following the resettlement, the trend analysis showed a sudden change in the seasonal variation of NDVI in areas converted to agriculture. Areas neighboring the new agricultural land experienced sudden decreases in NDVI (suggestive of discrete disturbances) at a higher rate than the same land cover types elsewhere. At the same time, these neighboring areas experienced a gradual overall increase in NDVI which could be caused by an expansion of leafy invasive shrubs such as Lantana in areas heavily used for biomass collection. The ‘recovery areas’ also experienced a gradual increase in NDVI, but we lacked evidence to connect this to the resettlement. Our findings support the claim that the resettlement has shifted pressure from more ecologically valuable to less ecologically valuable land cover types, and suggest that to some degree forest use pressure has shifted to the Gaindikhata landscape. The study employs a novel synthesis of OBIA and trend analysis that could be applied to land change studies more broadly.

Change Detection and Multi-Temporal Analysis of Gully Erosion in the Tsitsa River Catchment, South Africa, using eCognition Software

Simone Norah Pretorius[1,3], Harold L Weepener[1], Jacobus J Le Roux[2], Paul D Sumner[3]

[1]Agricultural Research Council- Institute for Soil, Climate and Water, Private Bag X79, Pretoria, 0001, South Africa; [2]University of the Free State, Department of Geography, University of the Free State, Bloemfontein, 9300, South Africa; [3]University of Pretoria, Department of Geography, Geoinformatics and Meteorology, University of Pretoria, Pretoria, 0002, South Africa; simone.pretorius7@gmail.com

The Department of Water and Sanitation is planning a water resource development in the Mzimvubu River Catchment, Eastern Cape, South Africa. The Mzimvubu River is on record, the only large river network in South Africa without a dam. The proposed dam site falls within the catchment area of the Tsitsa River, a tributary of the Mzimvubu river. Land use is dominated by rural, subsistence farming including cattle grazing. Previous studies conducted in the catchment highlighted the erosive nature of the soils which have resulted in widespread soil erosion and gully formation. Sediment produced from this erosion will ultimately reduce the capacity and life span of the dam which is a major concern for planners and managers of the Mzimvubu dam project. Thus, it is important to determine the extent of gully erosion in order to mitigate its effects and improve the dam design. Previous studies conducted in 2007 mapped gully erosion across South Africa using manual digitising techniques in a GIS environment. These techniques were time-consuming and contained human error and bias. This study aimed to explore the use of Object based image analysis in particular eCognition Software to classify gully erosion on a large catchment scale. Using SPOT 5 images from 2007 and 2012 in eCognition a time series analysis of gully formation was conducted. The normalised difference vegetation index and the modified normalised difference water index layers were calculated in eCognition. A ruleset was developed using object brightness values from each layer as well as their relationship to neighbouring objects and texture. The gullies classified in eCognition from SPOT 5 2012 images were used to create an updated gully location map of the dam catchment area. The results were compared with the results of the same ruleset conducted on 2007 SPOT 5 images in order to determine changes in gully sizes and highlight new gully development. The use of eCognition removed the human error component and proved to be considerably less laborious. Results of the eCognition analysis were compared with results from the manual digitisation and an accuracy assessment was carried out. eCognition was unable to separate gullies from unpaved roads which are numerous in the dam

catchment area. This was solved using a digitised road network in a GIS. The study could be improved upon by using higher resolution imagery such as aerial photographs, Quickbird, Geo-eye-1 or Ikonos. Future studies could also make use of LiDAR data to extract gullies using depth. The results of this study could assist engineers and managers of the dam project in mitigating and monitoring the effects of gullies on the sediment yield in the catchment.

A Novel Approach for Object-based Change Detection Using Multitemporal High Resolution SAR Images

Osama Yousif, Yifang Ban
Royal Institute of Technology KTH, Sweden; osama.yousif@abe.kth.se

Change detection using multitemporal remote sensing imagery plays a central role in many fields of applications. Examples include but are not limited to deforestation, flooding and wetland mapping , urban development, and disaster monitoring and damage assessment. The wide spread of remote sensing change detection technique can be ascribed to images' low cost, large geographic coverage, and availability with a wide range of spatial, spectral, and temporal resolutions. Change detection using moderate resolution SAR images (e.g., ERS-2 and ENVISAT ASAR) is often conducted using the pixel-based logic. Recent technological developments allow for design and launch of several advanced SAR systems (e.g., RADARSAT-2, COSMO-SkyMed, and TerraSAR-X) capable of producing images with very high spatial resolution. For high spatial resolution images pixel-based approaches often lead to the creation of a noisy change map. In this research, change detection is proposed using an object-based paradigm. Segmentation subdivides the image into meaningful homogeneous objects based not only on the spectral property, but possibly on the shape, texture, and size properties. To avoid the creation of sliver polygons, most object-based change detection studies adopt multidate images segmentation strategy. This technique produces image objects that are spectrally and temporally homogeneous. Since the objects geometric extent is fixed temporally, this segmentation strategy also helps simplifying change image generation using objects' mean intensities. Multitemporal images comparison is then carried out using existing mathematical operations (e.g., ratioing and differencing). The strong intensity variations within an object, the consequence of high spatial resolution, combined with SAR speckle effect corrupt the estimation of its mean intensity, and consequently, affect the robustness of the estimated change image. A change quantification approach is proposed to take into account the peculiarities of high spatial resolution SAR images—that is, SAR speckle and the associated strong intensity variation. By descending to the pixel level, a new representation of change information, i.e. the change signal, is provided. With this representation, change quantification boils down to measuring the roughness of the change signal. Two techniques to assess the intensity of change at the object-level, based on Fourier and Wavelet transforms of the change signal, are proposed. Their main advantages lie in their ability to capture the dominant change behavior of the object, while being insusceptible to irrelevant disturbances. The proposed change image generation approach is examined using a multitemporal dataset that consists of a pair TerraSAR-X

images acquired over Shanghai in 2008 and 2011, respectively. Qualitative and quantitative analysis of the results demonstrates the superior discrimination power of the proposed change variables compared with the commonly used methods with conventional mathematical operators.

New Methods for Time Series Processing of Image Data in Timesat

Zhanzhang Cai[1], Lars Eklundh[1], Per Jönsson[2]

[1]Department of Physical Geography and Ecosystem Science, Lund University, Sweden; [2]Group for Materials Science and Applied Mathematics, Malmö University, Sweden; zhanzhang.cai@nateko.lu.se

Time-series of high-spatial resolution remote sensing data from satellites like Landsat and Sentinel-2 demand new and computationally efficient methods for information extraction. An existing software package, TIMESAT, has been extensively used for processing data from AVHRR, MODIS, MERIS, and other high-temporal resolution data. However, TIMESAT has so far not been well adapted to high-spatial resolution data and needs to be updated in several respects. Currently, in order to reduce the influence of noise, TIMESAT fits smooth mathematical functions (least-squares fitted asymmetric Gaussian and double logistic functions, and Savitzky-Golay filtering) to time-series of satellite data. It then extracts phenological metrics (beginning and end of the growing season, length of the season, amplitude, integrated value, asymmetry of the season etc.) for each image pixel and growing season. The program fits functions to the upper envelope of the data in order to handle negatively biased noise. It also weights each observation in accordance with data quality labels, such as the MODIS QA flags. The package has been widely applied for data smoothing and extraction of land surface phenology and vegetation productivity during the last ten years. Current improvements of TIMESAT to enable analysis of high spatial resolution data include handling of data with unequal time steps. Furthermore, since these data contain long missing periods, new gap-filling methods are underway. We also develop new and accurate fitting algorithms, which improve on the current methods, and which integrate the temporal and the spatial domains. To enable processing of large data amounts, all algorithms are implemented for parallel processing. To evaluate the new methods we test the algorithms against calibration data from a network of field measurements.

Session WSTA-1: Agriculture

Exploring the potential of time series analysis to map Zimbabwes Fast Track Land Reform

Konrad Hentze
Remote Sensing Research Group, Germany;
k.hentze@geographie.uni-bonn.de

Land has always been a contentious issue in Zimbabwe and was a core demand from liberation movements and independence fighters who routinely called for an equal distribution of agricultural land. The government of the new democratic Zimbabwe met this demand with a thorough land reform program which was partly perceived as inefficient. In the year 2000, a process called jambanja began. In a more spontaneous than planned fashion, poor rural residents started occupying farms and evicting the white owners with (partly brute) force. These movements formed the beginning of the contested Fast Track Land Reform Programme (FTLRP) of Zimbabwe.

I argue that the heated and controversial debate on the success of the FTLRP has neglected to incorporate objective spatial methods of Geomatics. Up to date, no national dataset of farm evictions and possible resulting land use changes exists. This argument is underpinned with a quantitative literature review which highlights significant shortcomings of publications and studies on land reform.

To overcome the considerable lack of timely and spatially accurate statistical data on Zimbabwe's FTLRP, a remote sensing research based framework for temporal analysis is proposed. Through the combination of a dataset of eviction of white commercial farmers and a remote sensing based time series analysis, I attempt to map the yet largely unknown effects of Zimbabwe's land reform.

The presentation will discuss the results of a TIMESAT based phenological analysis preformed on a MODIS NDVI dataset of 11 years. After the calculation of phenological parameters, different classification methods are assessed to produce yearly maps of total agricultural area. It will be assessed critically whether classification results are able to monitor changes according to the political and social changes of land use and land tenure. Landsat scenes will serve as training and validation datasets to validate the results on changing figures of total agricultural area. Furthermore, information collected on the ground in Zimbabwe will be incorporated in the evaluation of classification results.

Tracking the dynamics of paddy rice planting areas through analysis of time series Landsat images

Xiangming Xiao[1], Jinwei Dong[1], Yuanwei Qin[1], Geli Zhang[1], Cui Jin[1], Jie Wang[1], Yuting Zhou[1], Chandrashehkar Biradar[2]

[1]University of Oklahoma, United States of America; [2]ICARDA, CGIAR, Jordan; xiangming.xiao@ou.edu

Paddy rice agriculture affects food supply, climate, water, biodiversity, and ecosystems. It varies substantially over time and space, for example, continuous expansion in northeastern China and rapid loss in southern China in the past decades. However, no maps at fine spatial resolution (e.g., 30-m) are available to document and illustrate the spatial patterns and temporal dynamics of paddy rice planting areas in China. We recently developed an automated, Landsat-based paddy rice mapping system (RICE-Landsat) that uses time series Landsat images and a pixel- and phenology-based algorithm to identify and map paddy rice planting areas. The algorithm is built upon the unique spectral properties of paddy rice during the flooding, transplanting and early part of vegetation growth phases, during which periods the rice paddy field is essentially a mixed pixel of water and green plants with open canopy. In addition, we also used MODIS land surface temperature data and/or air temperature data to define the thermal growing season, which is then used to select appropriate Landsat images in the data analysis. In this presentation, we will introduce the RICE-Landsat processing system, and showcase its applications in tracking the dynamics of paddy rice planting areas in northeastern China over the period of 1986-2015. Our presentation will cover additional case studies beyond the recent publication (Dong et al., 2015, Remote Sensing of Environment).

Evaluation of Agricultural Expansion and Fallow Regeneration in Southern Angola

Anne Schneibel[1], Marion Stellmes[1], Achim Röder[1], Manfred Finckh[2], Rasmus Revermann[2], Joachim Hill[1]

[1]Trier University, Germany; [2]University of Hamburg, Germany;
schneibel.anne@uni-trier.de

The civil war in Angola, which intermittently lasted from 1975 until 2002 had a high impact on population dynamics and the provision of basic supply especially to people in rural areas. During the 27 years of political turbulence, the displacement of the rural population to the cities led to the break-down of the agricultural sector and after the final ceasefire, to large numbers of war refugees returning back to their former homesteads (Kibble 2006). Nowadays, these areas are affected by growing population numbers, bad medical and educational supply as well as insufficient road and railway infrastructure and the rising demand for food (INE 2014, BTI 2014). With only irregular access to cash and the strong dependency on natural resources, the local population relies on fertile areas for cultivation as well as on intact forests to cover the demand for woody products, like fire or construction wood. Further indirect resources that are constrained to the forest are the production of honey and charcoal or the collection of wild fruits (Domptail et al 2013). Our study area has already been subject to large deforestation actions caused by the traditional slash-and-burn agriculture. The study site is situated in a mainly rural area in central Angola and the landscape is composed of intact forest systems, large floodplains as well as steadily growing cities and recently paved roads that border and cross the natural woodlands.

We assessed the trade-off between the ecosystem services crop growth and tree growth, which is the predominant land use change process in the study area. In this context, remote sensing data offers the possibility to capture actual land cover and transformations during the last decades even for those study areas, where fundamental ground data is missing. We provide essential products to evaluate deforestation, agricultural expansion and forest recovery on fallows. One is the precise delineation of new fields from 1989 until today by using multi-temporal, medium resolution Landsat 5 TM and Landsat 8 OLI data. This was done by performing unsupervised classification in connection to high resolution imagery as well as field data. Secondly, we substantiate this product by using Landsat time series with an adapted version of LandTrendr to precisely analyse the local cropping cycle as well as fallow regeneration. We can prove that the expansion of fields rather affects intact forest systems than following a functional cropping cycle and that the rate of deforestation is constantly increasing since 1989. We can

furthermore show that forest succession after the abandonment of fields does not reach the initial level of biomass that was present before the clearing of the woodlands even after 20 years of fallow. In a last step, these products were used as spatially explicit proxies in combination with field surveys and long-term literature data to give information about the trade-off between woody biomass (t/ha) and crop yield (in this case, maize in t/ha) for the last decades.

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Drought estimation maps using multitemporal Landsat data

Argentina Teodora Nertan[1], Andrei Stancalie[2], Laura Mihai[2], Alexandru Dumitrescu[1]

[1]National Meteorological Administration, Romania; [2]National Institute for Laser, Plasma & Radiation Physics, Romania;
argentina.nertan@meteoromania.ro

Among the problems Europe is facing at the beginning of the third millennium, the reduction of the water resources, their degrading quality and the occurrence of ever more severe and frequent droughts are of critical importance.

Causes the complex, some pertaining to the climate change, especially as regards southern Europe, where the trend has already been noticed for diminished precipitation, which leads to diminished accumulated water resources. Experiments carried-out with climatic models have shown that this situation will worsen in future. In southern and south-eastern Europe the precipitation deficit will keep enhancing, in step with the global warming. For the summer time models predict drought-connected hardships in Central Europe and ever more intense and more frequent droughts as the global warming process continues. The use of remote sensing data has several advantages to analyze the effects of drought on vegetation. The information obtained from satellite data cover the repetition of images provides multitemporal measurements and vegetation indices derived from satellite data allow to identify areas affected by drought depending on environmental conditions.

In this context, the present paper tries to prove the usefulness of traditional vegetation indices (Normalized Difference Vegetation Index - NDVI and Normalized Difference Water Index - NDWI), along with a relatively new index, Normalized Difference Drought Index (NDDI) using merged data for multiple dates, in order to obtain more drought information for decision makers. For this study were used Landsat 7 ETM+ data, for the agricultural season (March-September) (2005-2014). The study area was agricultural regions from the Southern part of Romania. All these three indices were calculated from the new bands obtained from merged satellite data. MS bands were merged with the panchromatic band, getting new bands with a resolution of 15 m, using Dual Tree Complex Wavelet transform. To calculate the vegetation indices, Digital Numbers (DNs) representing each pixel of Landsat image were converted into physical units (reflectance). Landsat data were validated using in-situ sepctroradiometer measurements.

NDDI combines information from the NDVI and NDWI data and it is well

known that NDDI has a stronger response to summer drought conditions than a simple difference between NDVI and NDWI. NDDI was compared with Standardized Precipitation Index (SPI) in order to generate the drought maps. NDDI was found to be an optimal complement to in-situ based indicators or for other indicators based on remote sensing data, clearly highlighting the dry periods and areas/ crop types affected by drought.

The present study was achieved under the project Changes in climate extremes and associated impact in hydrological events in Romania (CLIMHYDEX), supported by the Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFSCDI)

Evaluating the response of the Vegetation Condition Index (VCI) to meteorological drought in an agricultural region of China North Plane

Yuanyuan Wang
National Satellite Meteorological Center, China, People's Republic of;
wangyuany@cma.gov.cn

Agriculture management needs efficient drought information. Although meteorological drought indices (such as Standard Precipitation Index, SPI) are useful in drought measurement, they often have limited spatial resolution since they rely on in situ data. Satellites based drought indices (such as Vegetation Condition Index, VCI) can provide drought information over large areas at a higher spatial resolution, but in a way that is quite different from station-based meteorological drought indices (Quiring & Ganesh, 2009). It has been recognized that the existing satellite-based drought indices are more associated with agricultural drought (e.g., vegetation health or crop yield), and the response of vegetation to meteorological drought (precipitation deficits) varies depending on the seasonal timing, land cover type, climate, soil properties, irrigation, etc (Gitelson et al. 1998; Ji & Peters 2003; Bhuiyan et al. 2006; Vicente-Serrano, 2007).

Previous researches often focus on a large area that spanned a range of climatic and ecological zones. In this paper, the response of the VCI to meteorological drought indices was studied over a small agricultural region (with an area of about 47,000 km2) in China North Plane where meteorological drought occurs frequently and irrigation farming is prevalent. We want to understand how VCI responses to SPI temporally and spatially when the climatic and environmental features are relatively uniform, and what factors could account for the variability of the relationship between VCI and SPI in this local region.

The data processing includes two steps. First, different time scales of SPI were calculated on a weekly time-step using 21 meteorological stations in the study region from 1965-2011. Second, VCI was calculated based on MODIS NDVI product (MOD13) from 2000-2001. Prior to VCI calculation, a weighted least squares regression technique (Swets et al. 1999) was applied to the NDVI time series to minimize noise and other artifacts.

The data analysis and results are as follows.
(1) Correlation coefficients between spatially averaged VCI and SPI from different periods were calculated to analyze seasonal variation. It was found that no strong correlations exist before April or after November, which agrees well with previous researches (Vicente-Serrano, 2007). Within the growing season, response of VCI to SPI changes significantly. VCI responds

to short term precipitation deficits (4-, 8-, 12-week SPI) before early June (DOY 113-153), whereas VCI responds to medium or long term precipitation deficits (24-, 48-, 52-week SPI) between June and August (DOY 161-265). The seasonal variation in the VCI response to SPI can be partially attributed to double cropping in the study region. After winter wheat is harvested in June, corn is the main crop. Corn is more drought-tolerant, so the lag between precipitation occurrence and vegetation response changes. Precipitation regime could be another reason. Most precipitation occurs in June and July, and therefore significantly influences SPI on longer time scales.

(2) The correlation coefficients between VCI and SPI during 12 growing season (DOY 113-265, 2000-2011) for each of the 21 meteorological stations were calculated. It was found that VCI of 9 stations show very weak correlations with SPI; r2 is less than 0.1 irrespective of times scales. For the other 12 stations, VCI is correlated with long term precipitation deficits with r2 varying between 0.1 and 0.4. The spatial variability in the strength of the relationship between SPI and VCI is hard to explain using either climatic or environmental factors because they are quite uniform for our study region. We calculated the accumulated NDVI of growing season (NDVI minus background value at the start of growing season) for each station, and found that the accumulated NDVI play a role in controlling the strength of the relationship between SPI and VCI. The larger the accumulated NDVI, the stronger the correlation is between VCI and SPI. It means for regions with more seasonal variation in NDVI, vegetation responds to precipitation deficits more obviously. This phenomenon could be partly attributed to the calculation of VCI which is based on the historical extreme minimum and maximum NDVI values. Regions with a small NDVI range could easily result in dramatic VCI values, although the absolute difference might be small. Perhaps the strength of the relationship between VCI and SPI is weakened due to the inability of describing vegetation condition accurately using VCI in those regions.

For the 12 stations showing a relatively strong correlation between VCI and SPI, we extracted the scales at which the strongest correlation occurred, and found that this scale is affected clearly by the percentage of groundwater irrigation (extracted from the Global Map of Irrigation Areas, version 5). More specifically, VCI responds to 24-, 32-week SPI (52-week SPI) if the stations a have a high (low) percentage of groundwater irrigation. Percentage of groundwater irrigation is negatively correlated with climate aridity index, and positively correlated with soil Available Water Content with moderate magnitude in our study region. Therefore, it is reasonable that vegetation is more sensitive to short-term precipitation deficits in drier location suggested by the higher percentage of groundwater irrigation.

Session WSTA-2: Glacier, Ice Sheet and Permafrost

Glacier dynamics in NW-Spitsbergen using Landsat time series data (1976 – 2014)

Eberhard Parlow, Florian Denzinger
University Basel, Switzerland; eberhard.parlow@unibas.ch

With multi-spectral satellite data from the Landsat series between 1976 – 2014 the dynamic of Monacobreen in NW-Svalbard was analysed by mapping changes in the front position. Monacobreen is a glacier in NW-Svalbard at 79° 24' N and 12° 34' E. The glacier is a famous surging glacier with short-lived events at which it can move much faster than normally with substantial advances. Monacobreen is calving into the Liefdefjord. The area covered by the glacier is approximately 400 km2 with a length of 40 km and a mean ice thickness of 225 m. As a surge glacier Monacobreen shows a temporal and spatial dynamic that is not necessarily triggered by climate change and global warming rather than instabilities of the glacier itself.

Due to a maximum side overlap of adjacent Landsat-orbits (> 80%) the coverage of the area by satellite data is extremely good and compensates for the high cloud coverage of that latitude. The maximum front position was reached around 1998 in the western and central part of the calving front when Monacobreen was combined with the neighbouring Seligerbreen. In the eastern part the advance of Monacobreen continued and the maximum position was reached some years later. Since then there is a continuous retreat of more than 2.5 km of the glacier to a minimum which has never been documented before. In 2013 Monacobreen and Seligerbreen were separated forming two different calving fronts.

Using Landsat satellite data the changes of the position of the glacier front as well as the size of the glacier could be quantified. The analysis shows how surge glaciers could vary in time and space over a very short time.

Analysis of temporal signatures on glaciers using optical satellite data

Solveig Havstad Winsvold, Andreas Kääb
University of Oslo, Norway; s.h.winsvold@geo.uio.no

Remote sensing techniques are ideal for measuring glaciers on a large scale, as they cover remote glacierized areas with relatively little effort. The archive of Landsat satellite scenes is important for the mapping of glaciers, and represents the longest running record available for multispectral Earth observations that have ever been recorded. Sentinel-2, launching in spring 2015, has similar settings to the Landsat TM/ETM+/OLI satellites. These satellites will together promote multi-temporal and multi-sensor based analysis, not least in high-latitude areas.

Optical satellite scenes are often used for glacier mapping purposes like glacier outlines and surface types mapping. The time period between optimal satellite scenes with good mapping conditions, often amount to several years especially in maritime glacier regions with adverse cloud conditions. Rapid glacier changes have already been documented in many glacierized areas in the world. The glacier changes are expected to continue in the future due to climate change, and thus repeated mapping of glaciers is needed, preferably at higher frequencies as today.

Throughout the season, glaciers display a unique sequence of optical properties. The seasonal evolution of a glacier can be tracked through time as the seasonal snow melts away, and the glacier appears. Satellite image time-series of higher temporal resolution can increase the range of information available for glacier surfaces. Each pixel on a glacier has a specific temporal signature that is in most cases different from the temporal signatures of off-glacier terrain, and can thus be used for classification purposes and glacier outline detection. The use of multi-temporal imagery in this way has not yet been fully exploited.

We present the potential and advantages using temporal signatures for mapping glaciers, and concepts of how to exploit the higher temporal resolution of satellite images in the future. This will be illustrated by several application scenarios using medium resolution satellite images. For example; automatic satellite scene selection for mapping purposes, deriving glacier outlines and surface types, and glacier change detection methods.

Analysis of the surface albedo of West-Greenland using the MODIS MCD43A3 16-day albedo product

Eberhard Parlow, Maurus Suppiger
University Basel, Switzerland, Meteorology, Climatology and Remote Sensing Lab; eberhard.parlow@unibas.ch

Climate change is a highly regarded topic in science and public. The total global average surface temperature increases from 1850 to 2005 amounts 0.76°C and the linear warming trend shows a temperature increase of 0.13°C per decade. In the arctic region the temperature increased for almost twice the global average rate. These changes in Earth climate affect the cryosphere, which includes the ice-sheets of Greenland and Antarctica, continental glaciers, snow, sea ice river and lake ice, permafrost and seasonally frozen ground, in different kinds. Ice sheets are melting, permafrost changes occur and the overall surface albedo decreases.

Greenland is the location of the second largest ice cap on Earth and contains about 2.5 million cubic kilometres (km3) or 10% of the total global ice-mass. If the total ice mass would melt, the sea level would rise up to 7m. Therefore Greenland is highly discussed and an often used location for research.

The major factor which influences the melting process is the temperature-increase. But the temperature-increase in Greenland is not uniformly distributed. The warming in the last 10 to 20 years was much greater on the western side than on the east. Seasonal differences in the warming have been found. In winter the greatest temperature changes occurred. The differences of the mean surface air temperature between trend analyses from 1881 to 1910, varies locally from 7.8°C to 4.4°C. In summer the difference is smaller and varies between 1.1°C and 2.7°C.

Besides the temperature, the surface albedo is important. The albedo is the ratio of total reflected to total incoming solar radiation. The albedo of snow (~0.9) and ice (~0.5) is relatively high compared to other surface-coverage like forests (0.1-0.2), grasslands (0.1-0.2) or the sea surface (0.3-0.6). A surface with a high albedo has a high reflectivity and a low absorption rate. Looking at the Greenland ice cap, the surface air temperature has increased. This affects the surface ice as it strengthens the melting. Melting ice and snow lead to a decrease of the albedo what causes further melting due to a smaller albedo and therefore a higher absorption-rate. Additionally more and more studies are available that describe the negative effect of impurities as soot, ash or black carbon to the ice surface albedo.

Formerly, studies about albedo-changes have to be made with long term in

situ ground measurements. To set up a station is extensive and expensive; to set up a network of stations, to gain an area-wide overview, even more. Since 1972 the first Landsat Multispectral Scanner System (MSS) has been launched, the world scientific community is steadily delivered with high resolution earth images. Nowadays, 40 years later, a huge amount of any kind of datasets from different sensors and in different spectral resolution are available.

The aim of this study is to analyse the albedo of a designated part of the Greenland ice sheet using the MODIS albedo product from NASA (MODIS MCD43A3) and to answer the following questions:
- How did the shortwave and visible albedo change since 2000?
- Did the albedo change occur all over the ice cap?
- Are the albedo changes seasonally different?
- When and where did the major abnormalities occur?

Supertemporal trend analysis of Arctic landscape disturbances based on Landsat time-series

Ingmar Nitze[1,2], **Guido Grosse**[1]

[1]Helmholtz Centre - Alfred-Wegener-Institute for Polar and Marine Research, Germany; [2]University of Potsdam, Germany;
ingmar.nitze@awi.de

Observed and projected climate change in the Arctic increases the vulnerability of terrestrial ecosystems to disturbances. For example, significant increases in air temperatures especially in high latitudes will impact the stability of permafrost landscapes that cover 24% of the northern hemisphere and dominate large parts of the Arctic. Resulting potentially large-scale permafrost thaw and subsequent changes in geomorphology, hydrology, and vegetation as well as mobilization of previously frozen soil organic matter will provide regional to global scale feedbacks that require better quantification. The release of this carbon as methane and carbon dioxide, both active greenhouse gases, would result in a positive feedback loop with climate warming ("permafrost carbon feedback"). The observation of landscape dynamics across spatially extensive permafrost regions, using the remote sensing record for the last decades, is therefore crucial for understanding recent developments in these regions and the prediction of such feedbacks in the 21st century.

Within the framework of the ERC funded PETA-CARB project (Rapid Permafrost Thaw in a Warming Arctic and Impacts on the Soil Organic Carbon Pool) different study areas in Northern Siberia and Alaska are analyzed with remote sensing techniques towards their landscape dynamics. Dense time-series image stacks of Landsat data from 1999 to 2014 for the Lena Delta and from 1985 to 2014 for the Alaska North Slope are utilized for the super-temporal monitoring of thermokarst related land surface disturbances. Owing to their high-latitude location, Arctic regions are predestined for a high-frequency monitoring due to multiple overlapping image paths. Despite their short snow-free seasons and frequent cloud-cover most pixels have multiple acquisitions per year with a range of 50 to 120 and 15 to 60 usable observations over the entire monitoring period in Alaska and the Lena Delta, respectively. The high number of observations allows for the calculation of robust trends of different well established key surface descriptors, such as Tasseled Cap (Brightness, Greeness, Wetness), NDVI or other multi-spectral indices to detect and map disturbances of the landscape on multiple temporal scales. The trajectories of these indicators can be associated with the type, magnitude and timing of specific landscape change processes in Landsat-scale spatial resolution of 30 m. Typical thermokarst related processes include rapid changes such as partial or complete drainage

of thaw lakes as well as gradual processes like thaw lake expansion or surface wetting due to ground subsidence. Multiple other processes can be detected and quantified including Arctic coastal erosion, vegetation greening, and fluvial dynamics.

In addition to the extraction of linear trends, the temporal density of observations provides a great database for the detection of breakpoints or event timing. Furthermore, gradual changes related to a specific change event, e.g. emerging and maturing vegetation after lake drainage, may indicate the timing of the triggering process, even outside the observation period.

Our regional observations provide a basis for an automated pan-arctic monitoring for an improved quantification of thaw processes aided by the highly automated workflow in conjunction with constantly increasing computation power. With the integration of the soon-to-be-launched Sentinel-2, synergies arise to establish the opportunity for the continuous high-frequency monitoring of thaw processes in Arctic landscapes with an unprecedented accuracy and temporal resolution.

Session WSTA-3: Image Processing

The choice of topographic correction on regional land cover mapping in alpine areas using multi-temporal RapidEye images

Ruth Sonnenschein[1], Ruben Remelgado[1], Ion Sola[2]
[1]EURAC, Italy; [2]University of Navarre, Spain;
ruth.sonnenschein@eurac.edu

Operational and effective regional land cover mapping has become possible with the increased availability of high-resolution satellite data and machine learning classifiers. Yet, land cover mapping on a regional scale is demanding in terms of preprocessing as spectral values have to be comparable across and between satellite scenes. This is especially challenging in mountain environments where illumination differences vary strongly between sun-facing and shaded slopes throughout the year. Although a large number of topographic correction methods has been develop to minimize these effects, there is no clear agreement which method to use. Moreover, despite the increase in satellite data, only a few studies have compared topographic correction methods on multi-temporal satellite data. Yet, the importance of topographic correction for multi-temporal classifications is not known.

Here, we performed a comparative study on the effect of topographic correction on a regional multi-temporal classification. We acquired a set of 15 RapidEye images to cover the province of South Tyrol (Italy) with three high-resolution satellite data mosaics for the year 2012. We applied the cosine, gamma, statistical-empirical, C, Minnaert and SCS+c correction and mosaicked topographically corrected images. Muli-temporal layerstacks were then used to derive land cover maps using Random Forest. We evaluated the choice of topographic correction method based on spectral characteristic of single imagery, among imagery and classification accuracies.

All topographic correction methods substantially reduced visual illumination effects in imagery as well as correlations between illumination conditions and spectral bands. Classification accuracies were similar for all topographic corrections and varied between 82 and 86%. However, spatial pattern of land cover classes differed markedly among the topographic corrections, which was most obvious for alpine vegetation classes, e.g. grassland and dwarf shrubs.

Exploring the effects of radiometric normalization of dense Landsat time series for forest monitoring

Frank Thonfeld[1,2], Michael Schmidt[3], Olena Dubovyk[2], Gunter Menz[1,2]
[1]Remote Sensing Research Group, University of Bonn, Germany; [2]Center for Remote Sensing of Land Surfaces (ZFL), University of Bonn, Germany; [3]Department of Science, Information Technology, Innovation and the Arts, Brisbane, Queensland, Australia; frank.thonfeld@uni-bonn.de

The "common radiometric scale" (Song et al. 2001) is a prerequisite of change detection and time series analyses of remote sensing data. It can be achieved by either absolute or relative atmospheric correction methods or a combination of both.

Before the opening of the Landsat archive it was common to normalize images of a time series to one master image. The availability of systematically processed, atmospherically corrected Landsat data, however, changed the preprocessing that can be found in recent studies. Instead of relative normalization many studies are built upon surface reflectance products without further radiometric correction. To date no research has been published taking in account the effects of relative radiometric normalization of Landsat time series that comprise images from all seasons. In this study we explore the effects of radiometric normalization on a dense 29-year Landsat time series over south-western Canada/north-western USA to address the question which radiometric processing is required for time series analysis.

The study site is hilly with elevation ranging from sea level to 3285 m above sea level. The area has a strong climatic gradient, pronounced topography, and complex ecosystem dynamics. Most of the area is composed of forested land. We used all available Landsat images taken between 1984 and end of 2012 available from the USGS Earth Explorer (http://earthexplorer.usgs.gov/) including cloudy images as well as Landsat ETM+ SLC-off data. Radiometric processing included atmospheric correction of all images using the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) atmospheric correction tool. Subsequently to absolute atmospheric correction we applied the Iteratively Re-weighted Multivariate Alteration Detection (IR-MAD) on all images.

For the assessment of the impacts of radiometric normalization on time series two datasets were generated. One included the images after applying LEDAPS (dataset A), the other included the images after the additional IR-MAD processing step (dataset B). The Normalized Difference Vegetation

Index (NDVI) and the Normalized Difference Moisture Index (NDMI) were calculated for each image of those datasets. Profiles of the two indices of each dataset were computed for selected locations. The differences between the different preprocessing strategies – absolute atmospheric correction alone (A) vs. absolute atmospheric correction followed by relative radiometric normalization (B) – were analyzed and interpreted.

Generally, dataset B has higher values than A as long as no clear-cut event occurs, in particular at dates that are distant from the reference image date (i.e., September 2000). That means that subtle long term changes are leveled by the relative normalization procedure. Seasonality is leveled to a large extend by the relative radiometric normalization, too. The difference between dataset B and A is least in images that were acquired close to the day of the year of the reference image. This is caused by phenology and poor illumination conditions in off-seasonal images.

It can be concluded that for mosaicing and compositing techniques data from about the same date/day of year should be considered. Relative radiometric normalization may remove minor differences and noise. If seasonal phenomena such as phenology are to be studied, radiometric normalization should not be applied. Relative radiometric normalization blurs seasonal patterns when applied to atmospherically corrected images. Long-term changes are leveled by the radiometric normalization as well (e.g., forest maturation). From the results we conclude that radiometric normalization of dense Landsat time series including data from all seasons is not useful if long-term and seasonal dynamics are explored.

BRDF correction for Landsat TM/ETM+ data over Amazonian forests

Jasper Van doninck, Hanna Tuomisto
University of Turku, Finland; jasper.vandoninck@utu.fi

Although surface reflectance as measured by spaceborne sensors is mainly determined by surface and atmospheric properties, it is also affected by the angular configuration of the sun, sensor and land surface. This relationship, known as the bidirectional reflectance distribution function (BRDF), has been studied intensively for sensors with coarse spatial resolution and wide swath. BRDF-corrected products are routinely generated for these sensors, because surface reflectance at the edge of a swath (corresponding to a scan zenith angle of 60° in MODIS) can differ strongly from the reflectance at nadir, even when the surface is actually similar. For narrow swath sensors (such as Landsat, with maximum view angles of 7.5°), the influence of the BRDF is much less pronounced, and a Lambertian surface behaviour is usually assumed in routinely generated surface products.

The assumption of Lambertian behaviour in image preprocessing may be adequate when the surface features of interest are spectrally well separable. However, problems arise if the spectral differences among the surface features of interest are subtle. This is the case when the aim is to discriminate among floristically different but structurally similar primary rainforest types in the Amazon basin. Then any radiometric distortion can introduce errors in image interpretation or classification. This study aims at producing BRDF-corrected Landsat surface reflectance images over Amazonian forests.

We take advantage of the opened Landsat archive and the routine production of atmospherically corrected surface reflectance products. This study is based on total of 1608 Landsat TM and ETM+ images from selected scenes that cover undisturbed rainforests between the Atlantic Ocean and the Andes, acquired between the 1980's and 2014. We investigate four methods for BRDF correction, which can be divided into two groups. Methods of the first group empirically estimate the magnitude of the BRDF-induced reflectance gradient for an individual Landsat scene assuming a linear relationship between sensor zenith angle and surface reflectance. This relationship is then used to normalize each Landsat scene separately, or to established a relationship between the empirical per-scene reflectance gradient and the solar zenith and relative azimuth angles using all available images. This relationship is in turn used for normalization to zenith viewing geometry.

The first group of methods can only correct for view angle effects and does

not normalize to a standard solar geometry. The second group of methods achieves full normalization of sun-sensor geometry using the BRDF parameters derived for MODIS. As suggested in previous studies, we use MODIS BRDF parameters to normalize Landsat images either pixel by pixel (using the BRDF parameters of the MODIS pixel corresponding to each Landsat pixel) or using a scene-averaged set of BRDF parameters. Over tropical rainforests, persistent cloud cover makes using the MODIS BRDF parameters difficult, because only a fraction of all 16-day compositing periods throughout the year contain enough cloud free observations to invert the BRDF parameters. To circumvent this problem, we performed a time series analysis on the BRDF parameters for each MODIS pixel that included the detection and filtering of outliers.

The different normalization approaches are evaluated relative to the null-scenario, in which no BRDF correction is applied, using the overlap area between adjacent flight paths.

Spatiotemporal Analysis of the Sand Spits Forming the Coastal Lagoons of Namibia

Robert Behling, Sabine Chabrillat, Robert Milewski
Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences, Germany; behling@gfz-potsdam.de

Coastal lagoons are bodies of water partially or completely separated from the open ocean. At Namibia's west coast, the lagoons are separated from the Atlantic Ocean by sand spits formed along the shore. These lagoons are important habitats for large bird, fish and mammal populations and the sand spits of the lagoons also serve as a natural barrier protecting the shipping at the coastline. In Namibia, Sandwich Harbour and Walvis Bay are two prominent examples of those lagoons. Both are known to be highly dynamic and to have altered their shape several times. Such changes occur due to sediment transport forced by Aeolian processes or either by Longshore or Cross-shore drifts. Since these changes are likely to endanger the habitats, the shipping and the port at Walvis Bay itself, a profound knowledge about the spatiotemporal variations of the sand spits is of high relevance. So far, studies have analyzed historical maps or selected aerial photographs to derive long-term changes between several decades, which serve as input for modelling the relationship between forcing processes and actual sediment transports. However, the high dynamic of the lagoons, require a more detailed analysis of the spatiotemporal sand spit variations, in order to get a profound understanding of such relationships. Against this background, multi-temporal remote sensing opens up new opportunities for the quantification of the spatiotemporal changes and the differentiation of long-term and short-term variations.

At both lagoons, Landsat archive imagery is available since 1984, enabling the analysis of spatiotemporal changes in a time period over 30 years. After the pre-processing –geometric co-registration, conversion to TOA-reflectance, and masking of clouds – approximately 150 data sets are available for each lagoon. Based on the Normalized Difference Water Index (NDWI) the sand spit is separated from the open water in each image of the Landsat time series. This way, the changes of the shape of the sand spit are identified over time. The results have revealed the presence of long-term (several years) and short-term (several weeks) changes as well as the presence of stable parts in the sand spits. In general, both lagoons are characterized by a continuously northwards expansion of the sand spit, which amounts for the northern tip of the sand spit to approx. 500 m for Walvis Bay and almost 1000 m for Sandwich Harbour. The direction of this expansion corresponds to the Longshore drift of the main ocean current (i.e. Benguela current) and the main offshore wind direction at the coastline of

Namibia. The temporal dynamic of the expansion rate and the coupling of the short-term changes to temporal patterns of forcing processes such as wind, tidal and ocean current data, are subject of ongoing investigations.

Session WSTA-4: Urban

Multitemporal Sentinel-1A SAR Data for Global Urbanization Monitoring: Preliminary Results

Yifang Ban, Alexander Jacob
KTH Royal Institute of Technology, Sweden; yifang@kth.se

Since 2008, more than half of the world population has been living in cities. It is estimated that the world is expected to add an additional 1.4 billion urban dwellers by 2030. Although only a small percentage of global land cover, urban areas significantly alter climate, biogeochemistry, and hydrology at local, regional, and global scales. Cities are hot spots of production, consumption, and waste generation. According to the United Nations, cities are responsible for 75% of global energy consumption and 80% of greenhouse gas emissions. Therefore, reliable and timely information on the spatial distribution and the temporal changes of urban areas is therefore critical to a wide array of research questions related to the effect of humans on the local, regional and global environment as well as to support sustainable urban development. With the recent launch of Sentinel-1A, SAR data with global coverage, operational reliability and quick data delivery became freely available, thus provide excellent opportunity for developing SAR-based methods for global urban mapping. The objective of this research is to evaluate Sentinel-1 SAR data for quick and reliable urban extent extractions and urbanization monitoring in selected cities around the world using the KTH-Pavia Urban Extractor.

The methodology is based on the original approach developed by Gamba et al. using both spatial indices such as the Moran index, the Geary index, the Getis-Ord index and texture measures, i.e., GLCM variance and correlation textures. The KTH improvements mainly involve preprocessing, contrast enhancement, post-processing as well as decision level fusion using multitemporal and multipolarization data. Single-date Sentinel-1 SAR data over Milan, Italy, Nanchang, China, Jakarta, Indonesia and Mexico City, Mexico were acquired for the research. Multitemporal SAR data over these cities and other cities will be processed when more Sentinel-1 SAR data become available.

The preliminary urban extraction results showed that urban areas and small towns could be well extracted using a single-date Sentinel-1 SAR data with the KTH-Pavia urban extractor. It is expected that the results will be further improved using multitemporal Sentinel-1A SAR data. Together with historical multi temporal spaceborne SAR data such as ERS-1/2 SAR and ENVISAT ASAR data, Sentinel-1A SAR is a promising and economical data source for global urbanisation monitoring.

Spatiotemporal urbanization analysis in Kuala Lumpur, Manila and Singapore cities

Maik Netzband
Ruhr-University Bochum, Germany; maik.netzband@rub.de

This research work intends to explore the spatial analytical methods to identify both general trends and more subtle patterns of urban growth. In Kuala Lumpur, Manila and Singapore, where the urban areas have experienced an unprecedented rate of growth over the last 30 years. In this uncontrolled situation, city planners lack tools to measure, monitor and understand urban sprawl processes. Multi-temporal remote sensing has become an important data-gathering tool for analyzing these changes. The objective of this study is to explore an approach for combining remote sensing and spatial metrics to monitor urbanization and investigate the relationship between urbanization and urban land use plans. The study areas, consisting of the cities of Kuala Lumpur, Manila and Singapore, were examined using Landsat data from 1989 to 2014. In this study an spatial metric was undertaken to produce urban growth maps and evaluation the characteristics of urban composition. Land cover change analyses at the metropolitan city levels reveal that over the past three decades the significant increase of built-up land in the study area was mainly at the expense of non-forest vegetation cover. The spatial and temporal heterogeneity of the land cover changes allowed the identification of fast and slow sprawling areas. The results of the analysis suggest that at the metropolitan level both the areas of non-forest vegetation and the forest land became more fragmented due to development. Several factors contribute to on-going challenges of spatial planning and urban policy in these megacities, including rapid population shifts, less organized urban areas and a lack of data with which to monitor urban growth and land use changes.

Characterizing Urban Spatial Growth with Satellite Imagery, Neural Networks, and Landscape Metrics

Xiaojun Yang[1], Libin Zhou[2]
[1]Florida State University, USA; [2]Thomson Reuters Lanworth, USA;
xyang@fsu.edu

Over the past several decades, rapid urban growth has been a world-wide phenomenon that can be observed in both developed and developing countries alike. Characterizing spatial patterns of urban growth can help understand urban morphology and the underlying socio-economic processes. In this paper, we present a method to analyze urban growth patterns based on the combined use of satellite images, artificial neural networks, and landscape metrics. The case study site covers a fast-growing Asian metropolis. Our method comprises two major components. Firstly, we obtained two dates of satellite images acquired by Landsat Enhanced Thematic Mapper Plus (ETM+) and Thematic Mapper (TM) respectively. We produced a land cover map for each of the two dates from the remote sensor data through a supervised classification protocol supported with artificial neural networks. We further analyzed landscape structural patterns with a selected set of landscape metrics through a moving window approach. Our results have revealed various stages of urban land transformation within the urban core and the surrounding suburbs. This study has demonstrated the utilities of integrating satellite remote sensing, artificial neutral networks, and landscape metrics that can provide a useful insight into the spatial consequence of urban growth with varying forms of land transformation.

Driving Force Analysis of Land Use and Land Cover Change in Beijing-tianjin Economic Circle of China

Wen bo Xu[1], Jinlong Fan[2]

[1]University of Electronic Science and Technology of China, China, People's Republic of; [2]National Satellite Meteorological Center, Beijing, China;
xuwenbo@uestc.edu.cn

Research on Land Use and Land Cover(LULC) should date back to five decades ago in the field of geoscience, and combining geoscience information system and remote sensing technology has become a mainstream in land use and dynamic monitor of land cover. In this paper, the research area is Beijing-tianjin economic circle. Based on the basic geography data and classification data in the same area obtained in 2010, we use Object-oriented classification method with TM images from 1990 to 2000, and then amend the classification result using backtracking algorithm. At last, we analysis the driving force of land use and cover change through statistic data, and analysis the relationship among land use, land cover dynamic change, economy, population and politics. The result reveals that the synthesized land use and land cover dynamic degree is 3.56% and 4.23% in 1990-2000 and 2000-2010, respectively. Besides, woodland and grassland have a diminishing tendency from 1990 to 2010. Unused land reduces more, wetland has a gradually increased tendency. There is also a significant reduction in arable land each year but an increase of artificial surface.

Session WSTA-5: Landscape and Vegetation Dynamics

Combining niche models and remote sensing to explore short-term habitat suitability temporal dynamics and improving biodiversity monitoring

João Francisco Gonçalves[1,2], Paulo Alves[1], Isabel Pôças[3], Bruno Marcos[1,2], Rita Sousa-Silva[4], Ângela Lomba[1,2], Emilio Civantos[1], António Monteiro[1], João Honrado[1,2]

[1]Research Center in Biodiversity and Genetic Resources (CIBIO) - Research Network in Biodiversity and Evolutionary Biology Associate Laboratory (InBIO); [2]Faculty of Sciences of the University of Porto, Portugal; [3]Biosystems Engineering (CEER), Institute of Agronomy, Technical University of Lisbon, Portugal; [4]Division Forest Nature and Landscape, Department of Earth and Environmental Sciences, Katholieke Universiteit Leuven, Leuven, Belgium; jfgoncalves@fc.up.pt

The on-going declines in biodiversity caused by global and local environmental changes call for improved monitoring and conservation schemes. Remote-sensing (RS) of earth surface stands at the forefront to tackle this challenge, providing a wide range of satellite measurements of environmental variables at different spatial and temporal resolutions. Spatiotemporal dynamics of ecosystem functioning (depicting several facets of matter and energy fluxes in ecosystems) can affect habitat suitability and therefore the persistence of species. In this study we analysed inter-annual habitat suitability dynamics by combining Species Distribution Models (SDM) with multi-temporal RS variables of primary productivity, seasonality, phenology and actual evapotranspiration obtained from MODIS sensor.

Predictors related to landscape composition and structure, and also wildfires were combined with RS variables in a Multi-model Inference (MMI) framework to investigate their relative ability to explain diversity patterns of plants and passerine birds. In order to assess recent habitat suitability dynamics, a multi-temporal mean prediction was obtained by hindcasting and averaging predictions across the entire studied period thus generating a habitat suitability time-series.

MMI results highlighted the strong predictive ability of RS variables related to ecosystem functioning for explaining distribution and diversity patterns by capturing the effects of short-term changes and variability in environmental conditions mainly related to land cover changes, wildfires and intra-annual

weather conditions.

We argue that coupling SDMs with RS functional indicators can provide early-warnings of changes in ecosystem processes affecting habitat suitability well before assessments based on structural indicators, such as those derived from land use/cover maps. Applications of the described methodology range from the improvement of biodiversity monitoring to the design of more effective conservation strategies that consider the spatiotemporal dynamics of habitat suitability for vulnerable species.

Comparison of modelled and satellite-observed start of the vegetation active season in Finland

Kristin Böttcher[1], Tiina Markkanen[2], Tea Thum[2], Mika Aurela[2], Tuula Aalto[2], Ali Nadir Arslan[2]

[1]Finnish Enviroment Institute, Finland; [2]Finnish Meteorological Institute, Finland; kristin.bottcher@ymparisto.fi

We evaluated modelled start of season (SOS) dates in evergreen coniferous and deciduous broadleaved forests in Finland for 2003 - 2010 against satellite-derived SOSs. The detection of SOS from Moderate Resolution Imaging Spectrometer (MODIS) time series was based on: (i) Fractional Snow Cover (FSC) for evergreen coniferous forest (Böttcher et al. 2014) and (ii) the Normalized Difference Water Index (NDWI) for deciduous broadleaved forest (Delbart et al. 2005). Modelled phenological indicators were determined from simulations by the JSBACH (Jena Scheme for Biosphere-Atmosphere) land surface model, driven with bias-corrected regional climate model (REMO) data. We investigated spatial and temporal correspondence of satellite- and model-derived SOSs for the whole Finland and its three boreal sub-regions separately. The mean national SOS dates for the whole time period were highly correlated from the two sources, for both evergreen (R2=0.9) and deciduous (R2=0.88) forests. An early bias of three days for coniferous and a late bias of five days for deciduous forest was observed. Typically interannual variations agreed well between modelled- and satellite-derived SOSs. There occurred some clumping in the modelled SOSs for coniferous forest that was likely connected to the sensitivity of photosynthesis to temperatures above 0 °C, whereas the modelled SOSs for deciduous forests were based on leaf development that is a more gradual process. The spatial correspondence between model- and satellite-derived SOSs varied in boreal sub-regions and was lowest in the northernmost zone. Deviations in sub-region results are likely related to differences in the acclimation of forests to different temperature regimes in the wide latitudinal gradient of Finland. Such acclimation processes are at the moment missing in the JSBACH model.

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Mapping invasive saltcedar distribution with spectral and phenological information from multi-temporal Landsat TM imagery

Le Wang
The State University of New York at Buffalo, United States of America;
lewang@buffalo.edu

Invasive species threaten the functioning of natural ecosystems and cause substantial economic losses at the global scale. Among a number of invasive species, saltcedar is particularly problematic in the southwestern United States though altering riparian zones and native biotic communities. Repeated monitoring of saltcedar distribution over large geographic areas is essential for conservation agencies to locate highly susceptible areas and develop corresponding control strategies. Current studies have mostly concentrated on the mapping of saltcedar distribution with a single remote sensing image acquired during its leaf senescence. Given the spectral variability within saltcedar and the potential spectral confusion between species, our ability to detect saltcedar with the single-scene spectral analysis is still limited. The objective of this study is to develop a new method to detect and map the spatial distribution of saltcedar through integration of spectral and temporal information. The developed method extracts the temporal phenological information from a time series of Landsat imagery for capturing the phenological change of species throughout the growing season, and explores the roles of phenological and spectral features in modeling the occurrence of saltcedar at the Landsat scale. Results indicate that the phenological patterns exhibited by saltcedar and native species are different at the 30m scale. The incorporation of key phenological features and distinctive spectral features can enhance our ability to remotely detect saltcedar. Time series of Landsat imagery are promising in facilitating the mapping of saltcedar distribution over extended areas.

Multitemporal RapidEye-data analyses of semi arid natural vegetation in the Negev, Israel along an climate gradient

Cornelia Gläßer, Stefanie Elste, Christian Götze
Martin Luther University Halle, Germany; cornelia.glaesser@geo.uni-halle.de

Natural vegetation in semi-arid environment is very sensitive in relation to meteorological variability of precipitation and long term changes. Phenological shifts are connected with climate changes and have many applicative, economic, and environmental impacts. Monitoring and assessment of this vegetation type is very important as an indicator for land use changes. The availability satellite data, like Rapid Eye with high repetition time capability and high spatial resolution as well as the red edge band offers new possibilities of change detection of these land cover types, characterized by highly heterogenous distribution and typical life time cycle.

The test site is located in Shaked Park and is part of the Negev Long Term Ecological Research (LTER) site, Israel. It is a slightly hilly area and consist loessial soils. The long term annual average of precipitation of 200mm and occurs only in the winter season. The area is characterized by scattered perennial shrubs, and patches of annual plants. The soil surface is covered by biological soil crusts, lichens, and mosses, which are extremely sensitive to climate changes. The climatic changes are influencing heavily these ecosystems. Based on ground spectral measurements we could use a data set of RapidEye data for three different phenological seasons (2010/11, 2012/2013, 2013/2014) with clear differences in annual amount and distribution of the rainfull. We selected there different vegetation indices, which are best fitted to the characteristic vegetation types (crusts, annual and perennial vegetation). For each vegetation type we analysed the time series of Rapid Eye data (11- 14 scenes per season). For each index we selected the scene with highest index which is compared with the maximum of the photosynthetic activity for this vegetation type. The results were discussed in relation to the meteorological differences (temperature, precipitation, and haze). Only with the time series of the RapidEye data we could integrate the phenological aspects and define the best time windows in the different years to detect the typical life cycle of the vegetation. The mapping of the distribution of the different vegetation types needs three different index maps of different time windows. Finally we produced a colour composition from the results of this three different best fitted index/time window. So we could produce first time for this area a distribution map of the vegetation. Finally we can separate between “seasonal variability” and “changes”. The results were integrated in a climatic gradient within the country and are the database for the assessment

and monitoring of the land use changes of natural vegetation. The developed algorithm can be transformed to long term satellite data sets from the past and continued in the future and will transformed to different scales.

Military Training and Fire Regime Impacts on Tallgrass Prairie Vegetation Degradation

Anne Jacquin[1], Michel Goulard[2], Shawn Hutchinson[3], Stacy Hutchinson[4]

[1]UMR1201 INRA EI Purpan, France; [2]UMR1201 INRA, France; [3]Department of Geography, Kansas State University; [4]Department of Biological and Agricultural Engineering, Kansas State University; anne.jacquin@purpan.fr

Effective monitoring methods for evaluating military land condition using remotely-sensed imagery must be able to distinguish between changes caused by military activities versus those that are natural or a function of weather and climate. This study explores the relationship between fire and long-term trends in tallgrass prairie vegetation at military and non-military sites in the Flint Hills ecoregion of Kansas (USA). The response variable of interest was overall linear trend of surface greenness as measured by the MODIS MOD13Q1 16 day NDVI composite product between 2001 and 2010. The long-term linear trend for both Fort Riley (FRK), a U.S. Army military installation, and Konza Prairie Biological Station (KPBS), a long-term ecological research site operated by Kansas State University, was previously estimated using BFAST time series trend analysis. To explain trends (i.e., positive or no change and negative change), fire regime information (frequency and seasonality) was derived or collected for the study area. Each study site was also divided into spatial strata (103 for FRK and 48 for KPBS) using existing boundaries representing administrative or management units.

A classical spatial statistical procedure is used with the first step being the computation of several non-spatial generalized linear models (GLM) to explain BFAST-derived trends by fire regime and/or stratification. The second step involved constructing spatialized versions of the same GLMs to account for unexplained spatial components not already integrated into each model. The spatial model was constructed with using a four pixel neighborhood.

For the non-spatial models and FRK data, results showed that fire regime explained little (4%) of the observed surface greenness trend compared to strata alone (7-26%). Including both fire regime and strata in non-spatial GLM models yielded little improvement. Model spatialization resulted in approximately a 5% improvement in explanatory power compared to their non-spatial equivalents, but the level of correlation was low indicating the presence of weak spatial structure in the residuals. Both non-spatial and spatial models for KPBS performed better for each explanatory variable and

combination tested. Fire regime alone explained 14% of surface greenness trends versus 39% considering only management unit strata. As with FRK, improvements in model performance when accounting for both fire and strata were minimal. Comparison of the non-spatial and spatial models suggested that spatialization was not necessary as the existing stratification contained a large part of the spatial structure in model residuals. However, with simplified stratification, the spatial component becomes more important.

These data indicate that fire has only a marginal effect on long-term surface greenness trends at FRK despite widespread use of burning as a grassland management tool to improve vegetation health. Interestingly, fire explains much more of the estimated trends at KPBS. Model results including strata improved explanatory power, especially at KPBS. Analysis of predictors based on a spatial model with existing stratification alone is suggesting alternative ways to stratify the sites that yield fewer strata yet achieve similar performance (from 103 to 5 units for FRK and from 48 to 5 units for KPBS) and may provide further insight into additional explanatory variables omitted from this analysis.

Session WSTA-6: Forestry

Multi-temporal forest monitoring in the Sentinel-1 era: first results from Vietnam

Alexandre Bouvet, Stéphane Mermoz, Thuy Le Toan
CESBIO, France; alexandre.bouvet@gmail.com

Since its launch by ESA in April 2014, Sentinel-1 has started to provide multi-temporal time-series of SAR imagery at an outstanding time interval of 12 days. Although the radar frequency (5.3 GHz, C-band) of Sentinel-1 is less adapted to forest monitoring than lower frequencies such as L-band (e.g. ALOS 2) and P-band (e.g. Biomass), the dense time series of Sentinel-1 offer a unique opportunity for monitoring of dynamic changes in forest status and conditions. The short time interval of the Sentinel-1 time series is indeed a big asset to detect changes in the forest cover in near real time. The Sentinel-1 observation strategy defines the Interferometric Wideswath (IW) mode as the pre-defined mode over land. This mode provides dual-polarisation (VV and VH) imagery, at a resolution of 10 meters, with a swath of 250km. All the Sentinel-1 imagery is made available for free by ESA.

To assess the effective potential of Sentinel-1 time-series for forest monitoring in a tropical environment, a preliminary study has been carried out in the region of Tay Ninh, Vietnam, where active rubber plantation is taking place. So far, a time-series of 10 images collected between 18 August 2014 and 11 March 2015 has been used to analyse the evolution of the backscatter of rubber plots, but more images are constantly acquired. The evolution of the backscatter can be related to seasonal changes (from wet to dry conditions) and to logging/regrowth within the rubber plots. The plots were analysed as a function of their age class (from recently cut to mature plots, with 3 intermediary stages), which was determined by a visual interpretation of a high resolution optical image acquired on 15 October 2014, available in Google Earth.

Our analysis shows that the backscatter value of mature rubber plantations is around -14dB at VH, independently of the moisture condition. Logging events are characterized by a sudden drop in the backscatter, from -14dB to around -21dB/-22dB, immediately followed by a slight (but most likely steady) increase with the regrowth of forest or the growth of new plantations. The contrast between mature and logged plots, and therefore the probability to detect a logging event, therefore decreases with time after the logging. Seasonal variations also have a drastic impact on the backscatter. In recently

logged plots, the backscatter was found to decrease steadily from August (-17dB) to February, when it starts to stabilize around -20dB. This corresponds to the transition between wet season (waterlogged soil) and dry season (dry ground). In slightly older plots, the range of VH backscatter between wet and dry season is -14.5dB to -18dB. Mature and young plantations can therefore be confused during the wet season.

The overall lesson that can be learnt from these preliminary results is that the near-real time detection of deforestation events (in this case, logging in a rubber plantation) is possible with Sentinel-1, provided images are effectively available with a short time interval all year-long. If only a few images are used each year, regrowth and seasonal effects can be important sources of missed detection and/or false detection.

Near Real-Time Monitoring of Insect Disturbances in Forest with MODIS Data

Per Ola Olsson[1], Johan Lindström[2], Lars Eklundh[1]
[1]Department of Physical Geography and Ecosystem Science, Lund University, Lund, Sweden.; [2]Centre for Mathematical Sciences, Lund University, Sweden; per-ola.olsson@nateko.lu.se

The northern forests act as carbon sinks and it is estimated that global warming and elevated CO2 concentrations will enhance these forest capabilities to store carbon. However, a changing climate might also increases the frequency and severity of forest disturbance events resulting in reduced capacity of the forests to take up carbon; if disturbances increase more than forest growth there is a risk that forests will turn into sources rather than sinks. Hence, it is important to develop efficient methods that enable early detection as well as monitoring of forest damage, and to estimate the extent of these forest disturbances and the impact they have on the carbon cycle.

One cause of forest disturbance is insects. Insects' response to a changing climate is an area of research with insufficient knowledge. This lacking knowledge makes future prediction of insect attacks uncertain and the importance of efficient monitoring systems crucial. Several studies have concluded that satellite based remote sensing can be used to detect insect damage in forests with high accuracy and various change detection techniques have been tested. Some of these studies are based on time-series analyses.

In this study a general remote sensing method for near real-time monitoring of insect disturbances in forests was developed. The method was developed and tested in the mountain birch forests around Abisko in northern Sweden. The method utilizes MODIS data with 250 m spatial and 8-days temporal resolution. A seasonal trajectory of NDVI for birch forest with no disturbances is identified. This healthy seasonal trajectory is common for all MODIS pixels with birch forest in the area and computed as an average over a large number of MODIS pixels. The method is then applied per-pixel and disturbances are identified as deviations from the healthy seasonal trajectory: when a new observation is available from MODIS, a Kalman filter is applied to handle missing data and data with low quality according to MODIS quality assurance (QA) flags. The deviation of the Kalman filtered NDVI from the healthy seasonal trajectory is computed and the cumulative sum (CUSUM) of deviations is computed. A pixel is identified as damaged when the cumulative sum exceeds a certain threshold. The threshold can be adjusted depending on the purpose of a study. With thresholds set to favor

damage detection in the training data, 86% of the damaged MODIS pixels were detected with 44% of the healthy pixels classified as damaged. The same threshold applied to the evaluation data resulted in 69% detected damage with 52% misclassification of healthy pixels. The main cause of the lower accuracy of the evaluation data was healthy pixels near a river; for these pixels MODIS QA-flags data indicate highest quality but the actual reflectance in the red and near infra-red indicates that atmospheric disturbances influence these pixels.

The results show that the method can be applied to detect damage in near real-time, but the present version is sensitive to the reliability of MODIS QA-flags.

Development of a Remote Sensing Based Fast Response System to Support the Management of Storm Calamities in Forests

Oliver Bauer[1], Rudolf Seitz[1], Kathrin Einzmann[2], Markus Immitzer[2], Clement Atzberger[2], Andreas Schmitt[3], Andreas Hirner[3], Andreas Müller[3], Matthias Frost[4], Monika Kanzian[5]

[1]Bavarian State Institute of Forestry (LWF), Freising, Germany; [2]Institute of surveying, remote sensing and land information (IVFL), University of natural resources and life sciences (BOKU), Vienna, Austria; [3]German Aerospace Center (DLR), Oberpfaffenhofen, Germany; [4]Bavarian State Forest Enterprise (BaySF), München, Germany; [5]Austrian Federal Forest Enterprise (ÖBf) , Purckersdorf, Austria; oliver.bauer@lwf.bayern.de

Beside economic losses storm calamities in forests are challenging in ways of crisis management. Fast decisions are required concerning the refurbishment of windthrow areas. Forest owners must consider the location and size of windthrow areas, the amount and removal of affected timber, a reasonable use of resources, financial support options and the situation of the timber market. Therefore, a fast detection of windthrow areas in forests is of highest interest for forest owners. Satellite based remote sensing in combination with geographic information systems (GIS) analysis techniques leading to a more efficient and cost reducing crisis management.

The project ‚Fast Response', funded by the Federal Ministry of Economics and Energy (BMWi), aims to allocate a concept supporting the crisis management of windthrow areas in Bavarian and Austrian forests with remotely sensed methods. The concept is based on three consecutive process steps: (I) an early storm detection, (II) a change detection analysis and (III) a GIS-based analysis.

Based on long term weather forecast models (e.g. the 'Global Forecast System'), we aim to identify and track upcoming storm events that would affect the observation area. This will be also the background for the acquisition of satellite data. The objectives of the change detection are at first a fast estimation of the extent of windthrow areas on a large scale within a few days. Two weeks after the storm a second change detection with different remote sensing data should provide more detailed information due to size and location. A mandatory step to reach the temporal goals is to automatize data processing techniques and change detection analysis implemented on remote sensing data. Since we want to develop a realistic concept for every-day-use, we will only apply existing algorithms for the change detection analysis. The subsequent GIS-analysis combines the detected windthrow areas with previously generated forest maps (e.g. tree

species, timber volume) and geodata (e.g. digital terrain models, administrative borders, etc.). This will lead to additional information of the affected areas (e.g. expected timber losses and logistic aspects).

A first test of the change detection was conducted in summer 2014 on a test site of the Austrian federal forest enterprise (ÖBf) in Austria. We monitored a clear-cut with TerraSAR-X (fast estimation) and WorldView-2 (detailed estimation) data. The results are reasonable and showed the applicability of both SAR and optical data for the purposes of the project.

The final concept will be supplemented by the creation of forest maps as well as the instructions for the forest owners for different storm scenarios. This information will be the basis for a central forestal crisis intervention system, to optimize the cooperation between authorities and forest owners after heavy storms.

Using decadal pixel-based Landsat composites to analyze post-war forest cover dynamics in Angola

Achim Röder[1], David Frantz[1], Stellmes Marion[1], Schneibel Anne[1], Finckh Manfred[2], Chissingu Valter[3], Hill Joachim[1]

[1]University of Trier, Dept. of Environmental Remote Sensing and Geoinformatics, Trier, Germany; [2]University of Hamburg, Biodiversity, Evolution and Ecology of Plants Biodiversität, Hamburg, Germany; [3]University of Lubango, Centre for Biodiversity Studies and Environmental Education, ISCED, Angola; roeder@uni-trier.de

After more than two decades of civil war, Angola is presently experiencing dramatic socio-economic changes. The richness in natural capital (e.g. oil, uranium, diamonds) has promoted one of fastest-growing economies in Southern Africa, with growth rates of 8% in 2014. As part of the efforts to recuperate from the war, massive investments into infrastructure and building are being made, resulting in the establishment or upgrade of transportation networks, urban building schemes and plans to establish dams for electricity production along the streams. While urbanization is one major process reflecting this, the return of people to their former settlement areas has promoted increasing conversion rates of Miombo woodlands to cropland and the extraction of trees for charcoal production. In addition to this, Angola is expected to become a major producer of food for national and international markets, and large irrigation schemes are beginning to appear along major streams.

The Planalto of Angola shows elevations of ~1300 m asl, where an average of 1200 mm to 1800 mm of rainfall per year is received, supporting a network of streams and tributaries that eventually form the Okavango River and feed the iconic Okavango Delta. Vegetation in the upper catchment area is characterized by a transition from dense Miombo forests through woodlands to the more arid units further south, while in valleys different types of grasslands and reeds are found.

Many of the present socio-economic processes pose a risk to the local environment, with Miombo forests being listed as biodiversity tipping point region of global importance, and Angola ranking 5th in Africa's carbon storage pools. At the same time, negative effects are expected to accumulate along the watercourses and eventually threaten the unique ecosystems along the river and in the Delta.

To date, a consistent, exhaustive assessment of deforestation dynamics, in particular after the end of the civil war, is still missing, and only isolated case studies exist. To achieve a synoptic view across the Miombo-Savanna

transition zone, we employed the full Landsat archive available for Angola. Rigorous radiometric pre-processing has been applied, including automated cloud detection and masking, as well as spatially explicit modeling of the radiative transfer based on date-specific estimations of optical thickness and water vapor concentrations. To account for topography-induced illumination variations, a C-correction was employed. Multi-seasonal, pixel-based composites were generated based on time-related seasonal breakpoints to derive large-area image datasets covering coincident phenological states of vegetation. Based on these composites, we mapped forest cover distribution and its temporal dynamics using support vector machine classification. Results of this were related to information on population density, hierarchical road network layers and the distribution of land mines, clearly illustrating spatial gradients of these drivers. These results are essential to understand how post-war demographic developments continue to affect the distribution and spatial configuration of forests, and subsequently support land management schemes facilitating the protection of Miombo forests and woodlands as major hubs of biodiversity as well as important sinks of carbon in southwestern Africa.

Remote sensing indicators of changes in ecosystem functioning related to wildfire disturbances

Bruno Marcos[1,2], João Gonçalves[1,2], António Monteiro[1], Domingo Alcaraz-Segura[3], Mário Cunha[2,4], João Pradinho Honrado[1,2]

[1]Research Centre in Biodiversity and Genetic Resources (CIBIO) - Research Network in Biodiversity and Evolutionary Biology Associate Laboratory (InBIO); [2]Faculty of Sciences of the University of Porto (FCUP); [3]University of Granada, Department of Botany; [4]Geo-Space Sciences Research Centre (CICGE); bruno.marcos@cibio.up.pt

Wildfire disturbances cause modifications in the matter and energy budgets of ecosystems. There is thus a need for methods to assess the consequences of those disturbances in ecosystems. In this regard, evaluation and monitoring based on ecosystem functioning (i.e. different aspects of matter and energy fluxes in ecosystems) have advantages over the traditional use of structural features (e.g. species composition or land-cover), since functional attributes have shorter time responses to disturbances, and are more directly connected to ecosystem services. Remote sensing has particular utility for measuring, monitoring, and developing indicators for fire-related effects on ecosystems. Thus, the ability to quantify ecosystem vulnerability to disturbance, and the spatially and temporally heterogeneous effects of wildfire, with remotely sensed data is critical to characterizing the effects of wildfire disturbances on ecosystems.

In this work, we propose a framework to evaluate and monitor changes related to wildfire disturbances (e.g. occurrence, severity, post-fire recovery and resilience), using remotely sensed proxy indicators of important attributes of the amount, variability and timing of ecosystem functioning (e.g. primary production, seasonality, phenology, surface temperatures, water content), extracted from time-series of satellite observations (e.g. MODIS).

Session WSTA-7: Temporal Analysis Techniques

An adaptive scheme for temporal compositing of the MODIS NDVI product

Jie ZHOU[1,2,4], Li JIA[1,3], Massimo Menenti[2], Ben Gorte[2]

[1]State Key Laboratory of Remote Sensing Science, Jointly sponsored by Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences and Beijing Normal University; [2]Technology University of Delft, The Netherlands; [3]Alterra, Wageningen University and Research Centre, Wageningen, The Netherlands; [4]University of Chinese Academy of Sciences, Beijing, China; j.zhou-1@tudelft.nl

The Maximum Value Composition (MVC) (Holben, 1986) method has been widely used to generate land surface products like vegetation index (VI), Land surface Temperature (LST) and Leaf Area Index (LAI). Optical observations of the Earth surface are heavily affected by clouds and atmospheric conditions to the point that radiometric data collected by satellite cannot be used to retrieve at-surface variables. In most cases the temporal compositing is performed over a constant period of time. For example, the MODIS VI products are composited over a period of 16 and 30 days or one month, while the VI SPOT products are composited over a 10 days period. Long periods have two main impacts on data quality: a) different image pixels may be observed on different dates and b) fast phonological changes cannot be captured (Narasimhan & Stow, 2010). A shorter compositing period, however, will be less effective to remove cloud contamination. Taking into account that cloud cover and type is not equally likely over time due to synoptic climate seasonality, a variable compositing period may be advantageous, We have developed and evaluated a compositing scheme based on an adaptive, time and place dependent compositing scheme. Under this scheme, the compositing period varies for each pixel with the vegetation growth season.

The MODIS daily 500m land surface reflectance product (MOD09GA, from 2001 to 2014) was used to illustrate the scheme. Three examples are presented: two pixels in China and one in the USA (Fig.1). As shown in Fig.1a, the 14 yearly cloud flag time series for each pixel are stacked, and then the probability of cloud – free observations for each day of the year was plotted in Fig.1b. The two troughs in this plot correspond to two periods when observations are frequently contaminated by cloud. The reciprocal of the probability of clear observations (Fig.1c) is an estimate of how many days it takes on average to get at least one cloud free observation. This

estimate is applied as an adaptive compositing period for the pixel.. Compared with the 16 days compositing period, the new scheme captures better fast phonological changes, although in some cases is too sort to remove cloud contamination.

On-going work is focusing on analyzing larger data sets to evaluate better the newly developed adaptive compositing scheme.

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Extending the global NDVI time series of SPOT-VGT with PROBA-V: quality assessment

Carolien Toté, Else Swinnen, Wouter Dierckx, Pieter Kempeneers, Bruno Smets

VITO, Remote Sensing Unit, Belgium; carolien.tote@vito.be

After a successful operation time of 16 years, the SPOT-VEGETATION (SPOT-VGT) sensor ended its operation in May/2014. The successor mission of the PROBA-V sensor provides continuity of the SPOT-VGT time series, with near-daily global coverage at 1km and 300m resolution in the same spectral bands (Blue, Red, NIR, SWIR). Although the PROBA-V sensor was spectrally defined as similar as possible to SPOT-VEGETATION, there are nevertheless differences to cope with, related to differences in the camera system and geometry, but also associated with spectral characteristics. The objective of the Copernicus Global Land Service (CGLS) is to operate a multi-purpose service component that provides bio-geophysical products at global scale, by ensuring timely Near Real Time delivery and consistent time-series of these products.

This study focuses on the extension of the NDVI time series of SPOT-VGT with the PROBA-V sensor. In order to ensure the continuity of the CGLS service at 1km, the methodologies and the processing lines were adapted to the data of the PROBA-V sensor. Quality assessment was performed with the purpose of guaranteeing the compliance of generated products with user requirements, thereby focusing on the similarity of the NDVI derived from VGT and from PROBA-V over the overlapping time period.

The analysis is based on a relative comparison between the NDVI products from VGT and PROBA-V, and on extensive comparison with external datasets, such as from METOP-AVHRR and MODIS. The evaluation is performed on a spatially subsampled global dataset and over BELMANIP and DIRECT sites. The following aspects were investigated: (1) product completeness: quantification of missing or flagged pixels over land; (2) spatial consistency analysis: spatial distribution of (dis)similarities and analysis of residuals per biome type; (3) global statistical analysis; and (4) temporal consistency analysis: variation, realism and smoothness.

For the overlapping period, a very good agreement between VGT and PROBA-V NDVI is found. The spatial consistency analysis indicates that the systematic bias between these products is very small and that more than 70% of the pixels show a bias within the optimal range (±0.05). Taking into consideration that the NDVI is still affected by anisotropy effects, this is a good result. Also over different biomes, the correspondence is very good,

especially for the lower range of NDVI Values. For high NDVI values, there is a slight overestimation for PROBA-V compared to VGT. Temporal evolution of the entire mean global SPOT-VGT archive was evaluated against MODIS NDVI (2001 – May/2014). In addition to the clear difference between the NDVI from VGT1 and VGT2, we observe from 2009 onwards an increasing trend in the global mean NDVI of VGT2, which is most pronounced in the northern hemispherical summer. As an important consequence, the VGT data from overlapping period between VGT and PROBA-V is not representative for the entire VGT data set. The full origin of this trend is at present not entirely clear and further investigation is required.

Time-series analysis of SAR images for detection of ground subsidence in the Scheldt estuary

Jan Walstra, Pierre-Yves Declercq
Geological Survey of Belgium, Royal Belgian Institute of Natural Sciences;
jan.walstra@naturalsciences.be

Within the framework of the GEPATAR (GEotechnical and Patrimonial Archives Toolbox for ARchitectural conservation in Belgium) project, time series of Synthetic Aperture Radar (SAR) images are used for the systematic assessment of ground movement risk across the whole country. Here, we present some preliminary results from an area around Antwerp.

Recent advances in the analysis of time series of SAR images reduce the inherent error sources and allow detection of very small Earth surface displacements. In this study we use the StaMPS/MTI software package, which combines two complimentary algorithms for the detection of spatially correlated deformation: Persistent Scatterer Interferometry (PSI) and the Small Baseline (SBAS) approach.

The processed datasets include 67 ERS1/2 images (period 1992-2001) and 74 ENVISAT images (period 2003-2010). The results indicate a clear contrast in ground stability between the Scheldt estuary (subsiding at rates up to 7.4 mm/year) and the adjacent higher grounds (relatively stable). The most significant subsidence appears in the reclaimed lands (polders) of the present-day port area of Antwerp. Based on geological and geotechnical evidence, we can attribute the observed subsidence pattern to compaction of soft alluvial sediments (clay and peat layers) and overlying land fill material.

Further research will focus on the possible impacts of observed ground movements on exposed built heritage and infrastructure.

Analyses of Recent Surface Dynamic of South African Kalahari Salt Pans Based on Multitemporal Landsat and MODIS Data

Robert Milewski, Sabine Chabrillat, Robert Behling
Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum GFZ, Germany; milewski@gfz-potsdam.de

The consequences of climate change represent a major threat to sustainable development and growth in Southern Africa. Understanding the impact on the biosphere is therefore of great importance in this particular region. In this context the Kalahari salt pans (also known as playas or sabkhas) and their peripheral saline and alkaline habitats are an ecosystem of major interest. Their high level of environmental sensitivity makes them an important environment in which to examine mineralogical, hydrological and ecological responses to climatic variations.

Alkaline soils and sediments are a potentially significant storage of global carbon. Geochemical studies showed that total carbon stock of salt pans is approximately an order of magnitude greater compared to the neighbouring Kalahari Sands. Although their organic carbonate content is negligible salt pan sediments typically contain high concentrations of inorganic carbon in the form of calcium and magnesium carbonate and bicarbonate. These minerals can directly originate from parent material (lithogenic), or from dissolution and in-situ precipitation carbonates (pedogenic). Thus far the surface distribution of these minerals have been only assessed mono-temporally and on a coarse regional scale, but the dynamic of the salt pans, especially the formation of evaporites, is still uncertain and poorly understood. Also local moisture conditions attributed to differences in groundwater flow as well as seasonal flooding have to be considered as they determine intra pan distribution of evaporites. Multitemporal remote sensing techniques allow us to derive this recent dynamic of these salt pans and improve the understanding of major physical processes in these dryland environments.

In this study change detection analysis is applied on Kalahari salt pans using iterative-reweighted Multivariate Alteration Detection (iMAD) developed by A.A. Nielsen (2007) to identify and investigate surface changes. The analyses is based on the available Landsat archive imagery, which covers the last ~30 years. For the complete Landsat time series, a total of 130 bi-temporal change maps have been derived and classified into major change types after their characteristic spectral change pattern. Whereas the Landsat archive provides a good database for the study of long-term changes, it generally lacks temporal density and regularity in image acquisitions to

observe inner annual variation. To fill this gap this study also relies on MODIS data to derive a temporally dense information about the surface status. By fusing the information from Landsat and MODIS sources, accurate spatiotemporal patterns on surface processes can be resolved. As a parameter of major interest the moisture regime of the pan is investigated using a wetness index (NDWI). The wetness information is related to precipitation variability derived from daily rainfall estimations provided by operational meteorological satellite programs like the Tropical Rainfall Measuring Mission (TRMM). By merging this information the actual susceptibility of the salt pans on rain events and groundwater flow can be identified. Furthermore valuable insights about the buildup or loss potential of evaporites can be gained.

Land use mapping in the Brazilian Amazon with remote sensing time series

Victor Maus[1,2], Gilberto Câmara[1,2], Fernando M. Ramos[2]
[1]Institute for Geoinformatics, University of Münster, Germany; [2]Center for Earth System Science, National Institute for Space Research (INPE), Brazil;
mausv@uni-muenster.de

Land cover/use data are important in many socio-ecological applications, for example in developing scenarios for land use and as an input for climate change models. However, for some regions with highly recognized ecological importance, like the Brazilian Amazon, the available land cover/use products either have coarse spatial resolution or they are sparsely mapped over time.

Here we propose a time-weighted Dynamic Time Warping (DTW) for spatiotemporal land cover/use mapping using satellite image time series. This algorithm compares two time series and finds their optimal alignment, providing a robust dissimilarity measure as a result. It also allows similar patterns to match even if they are out of phase in the time axis or if they have irregular sampling frequency.

We ran a case study in Porto dos Gaúchos municipality, Mato Grosso, Brazil. This area has approximately 7,000 km² inside of the Amazon Biome and showed a strong deforestation and cropland expansion in the last decade. We used time series of Enhanced Vegetation Index (EVI) from 2000 to 2014 based on Moderate Resolution Imaging Spectroradiometer (MODIS) product MOD13-Q1 16 day 250 m. Our patterns training sample for classification come from field observations of forest, pasture, single cropping and double cropping. We validated the time-weighted DTW classification by comparing with 325 samples identified by visual classification of Landsat images that are independent of the training samples. The global accuracy of the method was 86.38%, with sensitivity of 91.49% for forest, 88.89% for single cropping, 88.61% for double cropping and 81.25% for pasture. The cropland area estimated with time-weighted DTW was in line with the Brazilian national cropland surveys.

The results of the time-weighted DTW are spatially distributed, and can contribute to improve Brazil's agricultural statistics. This approach is flexible to account for multiyear crops, double and triple cropping, as well as forest and pasture. The method works with a small amount of patterns training samples and is suitable for generating land cover and land use maps at continental scale using global data sets such as the EVI time series from the MODIS sensor.

Session WSTA-8: Poster Session

New Methods for Time Series Processing of Image Data in Timesat

Zhanzhang Cai[1], Lars Eklundh[1], Per Jönsson[2]
[1]Department of Physical Geography and Ecosystem Science, Lund University, Sweden; [2]Group for Materials Science and Applied Mathematics, Malmö University, Sweden; zhanzhang.cai@nateko.lu.se

Time-series of high-spatial resolution remote sensing data from satellites like Landsat and Sentinel-2 demand new and computationally efficient methods for information extraction. An existing software package, TIMESAT, has been extensively used for processing data from AVHRR, MODIS, MERIS, and other high-temporal resolution data. However, TIMESAT has so far not been well adapted to high-spatial resolution data and needs to be updated in several respects. Currently, in order to reduce the influence of noise, TIMESAT fits smooth mathematical functions (least-squares fitted asymmetric Gaussian and double logistic functions, and Savitzky-Golay filtering) to time-series of satellite data. It then extracts phenological metrics (beginning and end of the growing season, length of the season, amplitude, integrated value, asymmetry of the season etc.) for each image pixel and growing season. The program fits functions to the upper envelope of the data in order to handle negatively biased noise. It also weights each observation in accordance with data quality labels, such as the MODIS QA flags. The package has been widely applied for data smoothing and extraction of land surface phenology and vegetation productivity during the last ten years. Current improvements of TIMESAT to enable analysis of high spatial resolution data include handling of data with unequal time steps. Furthermore, since these data contain long missing periods, new gap-filling methods are underway. We also develop new and accurate fitting algorithms, which improve on the current methods, and which integrate the temporal and the spatial domains. To enable processing of large data amounts, all algorithms are implemented for parallel processing. To evaluate the new methods we test the algorithms against calibration data from a network of field measurements.

Multi-Temporal Pixel Trajectories of SAR Backscatter and Coherence in Tropical Forests

Elsa Carla De Grandi[1], Edward Mitchard[1], Dirk Hoekman[2], Astrid Verhegghen[3], Francesco Holecz[4], Paula Nieto Quintano[1]

[1]University of Edinburgh, United Kingdom; [2]Wageningen University; [3]Joint Research Center; [4]Sarmap; E.De-Grandi@sms.ed.ac.uk

Forest cover dynamics and disturbance can be tracked using a pixel based time-series analysis of multi-temporal Interferometric Synthetic Aperture Radar (InSAR) backscatter and coherence data. In particular, derived features from pixel trajectories in time can be a powerful tool to map changes in tropical forest, where deforestation and forest degradation occur driven by a series of processes such as fire, selective logging, subsistence agriculture and complete clearance of forest due to large scale deforestation. The research presents results from tropical forest environments: Deng Deng National Park (Cameroon), the Ngombe Logging Concession (Republic of Congo) and Sungai Wain Protection Forest (South Kalimantan). Several SAR data with different frequency and resolution were tested including ENVISAT ASAR (C-band), ALOS PALSAR (L-band) and TanDEM-X (X-band). Furthermore, the analysis was undertaken on both TanDEM-X backscatter and coherence at HH polarization. Multi-temporal coherence was employed due to its sensitivity to the upper canopy volume, which causes decorrelation as a function of the amount of vegetation (e.g. disturbance event).

A pixel trajectory is defined as a set of values of all resolution elements (backscatter or coherence) at the same row and column position in the stack of images. The stack is generated by multi-resolution analysis (MRA) at a number of spatial resolutions, enabling analysis in the combined time and space domains. Analysis of the trajectories over an area by means of a set of parameters (features) that characterize its time evolution can give insight on the nature and changes of landcover. The following set of trajectory features was computed: running ratios with respect to a baseline year, linear fitting (trend), coefficient of determination (goodness of fit), dispersion around trend, maximum change relative to mean (swing), statistics of first derivative (variance, kurtosis).

These features are designed to detect in each pixel trajectory the presence of a linear trend, the stationary of the distribution around the linear regression, the occurrence of intermittent events, and the dynamic range of the changes.

Several tests were undertaken. Visual interpretation shows that the running ratio highlights areas of forest disturbance. Moreover, the visibility of

logging roads is enhanced compared to backscatter only imagery. Therefore, the possibility for feature extraction and segmentation is envisaged.

Trajectory features detect and characterize areas of change at a given spatial resolution. The reasons for the changes are due to a variety of causes such as the change in landcover due to natural or anthropogenic disturbance and environmental conditions. In terms of class discrimination, the areas of bare soil and sparse vegetation such as forest savannah are more clearly delineated compared to backscatter imagery. The thread between the observed features and their underlying drivers must be per force established by calling into play inference guided by ancillary knowledge about the ecosystem dynamics and the possible factors of disturbance. Results will be reported showing how multi-temporal features from SAR backscatter and coherence observations enable, in different thematic contexts, the detection of landcover changes and the determination of the landscape evolution in time.

Investigating the effect of fire dynamics on aboveground carbon storage in the Bateke landscape, Congo

Paula Nieto Quintano[1], Edward Mitchard[1], Casey Ryan[1], Tim Rayden[2]
[1]University of Edinburgh, United Kingdom; [2]Wildlife Conservation Society Congo; paulaadriana@hotmail.com

Around 70% of Africa's surface area burns every year, being most fires in Africa's savannahs anthropogenic, provoked for reasons such as to clear vegetation around villages, to clear areas for agriculture, or for hunting and grazing. It is crucial to understand the role of fires for the promotion of sustainable forest and biodiversity management, and for the reduction of emissions from deforestation and degradation (REDD). It has been suggested that managing fire regimes could lead to an increase in tree cover and have a positive biodiversity impact. Additionally this would sequester carbon from the atmosphere.

The Bateke Plateau is a landscape composed of grassland savannah surrounded by tropical forest, situated in the centre of the Republic of Congo, home of elephants and great apes. This area is burned frequently, with most areas burning annually. A preliminary analysis found that most savannah areas have been detected as burning by satellites at least once every 4 years, with more frequent around roads and settlements. Previous research has shown that fire intensity, in addition to fire frequency, has a big effect on tree survival rates. In particular early season fires, or fires started earlier in the day when temperatures are lower, have lower intensities and thus kill fewer trees. This has led to a suggestion that a potential mechanism for carbon sequestration and biodiversity conservation in the region could be a management regime that encourages early season, early morning burning.

The aim of this study is to set up field experiments, use historical satellite analyses, and potentially modelling approaches to quantify the relationships between fire intensity/frequency, woody cover and aboveground biomass in the Bateke landscape. The results will be immediately used to promote better management of this area to enhance biodiversity and carbon storage, as well as driving forward basic scientific research in this understudied ecosystem.

Field experiments are set up, by protecting some areas from burning, and controlling the burning regime in other areas, including annual early and late season burns. The survival and growth rates of trees and seedlings is assessed. Satellite data analyses will be carried out using the 14 year archive of MODIS data (2000-2014) to test for relationships between fire return time and tree cover. Additionally, the large spatial extent of the resulting layers of woody cover and past fire frequency/intensity will provide key inputs into

the model DALEK3 (developed at the University of Edinburgh), a simple pool-based carbon model which enables estimation of how these carbon pools change under different fire return times and provides predictions of carbon sequestration rates and total carbon stocks that could result from different fire regimes.

Determination of optimal acquisition dates for satellite data for field crop classification

Henning Gerstmann, Markus Möller, Cornelia Gläßer
University of Halle, Germany; henning.gerstmann@geo.uni-halle.de

Classification of agricultural land cover classes is limited due to high spectral similarity of crops of close cousinship. However, spectral similarity differs as consequence of different developmental stages of the target crops. These developmental stages are referred as phenological phases. The selection of satellite data sets according to phenological parameters has the potential to increase classification accuracies and to limit the data amount that is required to perform accurate multi-temporal land cover classification. We present an approach to model the current phenological stage of the target classes statistically and link them to phase-specific reflectance properties to pass the optimal data sets to a classification process.

A phenological model was developed that uses a digital elevation model, phenological and temperature observations for the Germany-wide prediction of the target crop's phenological stage as function of accumulated temperatures. The model consists of three steps. First, the daily mean temperatures are interpolated using universal Kriging with elevation as explanatory variable. Second, the growing degree days that have been accumulated to the target phase are calculated. Finally, the critical temperature sum is spatially interpolated to retrieve a Germany-wide data set that represent the modeled day of entry of a phenological phase.

A time series of vegetation indices is calculated from a multi-temporal RapidEye. Spectral vegetation indices that are optimized for the target crops are compared to standard indices (e.g. NDVI, SAVI). The most sensitive band combination for an optimal vegetation index for the separation of the target crops is determined statistically. The crop-specific mean values of the indices are calculated for each data set. In doing so, two index profiles are determined that can be differenced to retrieve the spectral similarity of the crops.

Finally, the acquisition date of the RapidEye data set that provided the highest spectral similarity is coupled to the phenological phase that was modeled for the day of acquisition and can be understood as indicator time frame for the selection of satellite images.

We present an exemplarily application of the workflow on the classification of two winter cereal species (rye and barley) in a study site in central Germany using a time series of RapidEye imagery. The two vegetation index

profiles show a maximal difference in early June, which corresponds to the phenological phases “Flowering” for winter rye and “Heading” for winter barley.

The presented results show the potential of the approach for the detection of indicator phases for optimal image selection when a multi-temporal classification of crops is performed.

Further tests applied on other years will prove if the detected optimal phases can be understood as indicator phases for maximal class separability.

Sentinel-2 is expected to fill the lack of temporal resolution that leads to uncertainties in the index profile calculation. The accuracy of classifications using index images calculated from images acquired on the detected indicator phases is expected to be higher than those of multi-temporal classifications using the spectral information of all selectable acquisition dates. However, this hypothesis is still to validate.

Getting on to the track of potential food baskets: A multitemporal satellite data analysis of East African wetlands

Esther Eva Amler
University of Bonn, Remote Sensing Research Group, Germany;
e.amler@geographie.uni-bonn.de

The 'Millennium Ecosystem Assessment Report on Wetlands and Water' highlights the multi-dimensional importance of wetlands. Especially inland wetlands are vital for food supplied by agricultural production and fisheries. This is of particular importance in the East African region, which has long been a hotspot of food security crises. The year-round water availability and associated fertile soil properties of wetlands provide an excellent resource for local farmers. But wetlands are endangered, e.g. by land conversion, water withdrawals, and overuse. It is estimated that more than 50% of wetlands have been lost globally in the course of the twentieth century.

To balance human claims to wetlands and their protection, spatially explicit information is vital. On a global scale, wetland extent is likely to be strongly underestimated: Land use/ land cover classification systems do not depict wetlands very well and global wetland inventories are not sufficiently precise. While African wetland inventories are either outdated or only usable as coarse estimation basis for wetland extent, an East African regional inventory does not exist. National inventories of Kenya, Uganda, Rwanda and Tanzania (KURT) differ strongly in quality, methodology and availability.

Hence, the motivation of the study is to provide a regionally harmonized wetland inventory for the KURT region using remote sensing data analysis. Basic requirements for a regional wetland map are (a) cross-boundary harmonization to avoid discontinuities, (b) completeness, including a (c) well-documented methodology and (d) validation. These aims shall be acquired by the usage of time series of vegetation indices (VIs). The rationale behind this idea is that wetlands are expected to have a different vegetation signal over time compared to the surrounding uplands. The usage of time series has another important advantage: By the application of maximum value composites of VIs and a decent filtering of extremely low values, a well utilisable VI time series for the complete study area can be used for a phenological analysis. Instead of focusing on a very high spatial resolution, the advantages and abilities of the long, regular and gapless time series of the medium resolution MODIS sensors are used in order to get on to the track of wetlands. In an explorative study, the ability of a time series analysis to map wetlands is tested on four sites. The sites are located in

KURT and represent different typical wetland types of the region, grading from sub-humid to semi-arid climatic zones. Recently, researchers from different disciplines collected extensive ground truth data of these sites. This will support the analysis and is expected to improve the final product's quality significantly.

At the 'EARSeL Workshop on Temporal Analysis of Satellite Images', I would like to present results of this explorative study. Benefits of the usage of the open access MODIS archive for mapping important wetland ecosystems will be demonstrated as well as methodological problems.

Project Background: The 'GlobE Wetlands' project is a transnational research cooperation between East African and German partners (www.wetlands-africa.de) where twenty cooperating institutions from KURT and Germany work in an interdisciplinary partnership. The team aims to reconcile future food production with environmental protection by learning more about and promoting the wise use of wetlands among decision makers and stakeholders in the East African region.

The dynamics of a city. Over 40 years of change in Bucharest and its detection in multitemporal satellite imagery.

Mihaela Aldea[1], Florian Petrescu[1], Eberhard Parlow[2], Cristina Iacoboaea[1]

[1]Technical University of Civil Engineering, Romania; [2]University Basel, Switzerland; mihaela.n.aldea@gmail.com

Bucharest is the Romanian capital city, a city with a special dynamics over time, peculiar in many ways. It went through some important periods of changes, starting with the 40's, extending over two quite significant economical periods that influenced its urban growth. The years when the decision that large masses of people, over 11 million, to be moved into high density, newly built-up urban spaces, came into effect, coincided with the years of the first recorded Landsat images that are available today. Taking this opportunity, we studied the correlation between the dynamics of the Bucharest city and the land use/land change patterns identified from satellite imagery during various stages: the mentioned years of dramatic change; the following period of transition and the opening to the rest of the world economic order; the years following the entrance in the European Union, a period of investments and growth (economic and in construction) and the ultimately downturns at the end of the last decade. Our study will contribute actively, with the case of our capital city, in assessing the degree of reliability of the information obtained from analysing the patterns of land use/land cover from remotely sensed imagery as it addresses the variability of interpretation based on chronological documentation.

Verification and quality assessment of land surface water dataset in North China.

Chuang Liu[1], Ruixiang Shi[2], Zhengxing Wang[3]

[1]Institute of Geographical Sciences and Natural Resourses Research, CAS, China; [2]Institute of Geographical Sciences and Natural Resourses Research, CAS, China; [3]Institute of Geographical Sciences and Natural Resourses Research, CAS, China; shirx@igsnrr.ac.cn

The Global Land Surface Water Dataset in 30m Resolution in 2010 (GlobeLand30 - WTR2010 for short) was developed by National Geomatics Center of China. The dataset have been self - examined by the project team on the original Landsat remote sensing images, including data accuracy and quality assessment. In this study, two steps were taken to validate the data quality in three typical areas, including arid, semi-arid, and wet region. The first step used 10km grid, and the second 1km grid. First, the Google Earth data and MODIS images were used to check the GlobeLand30 - WTR2010 in these three areas in northern China. The sample areas were established by 10 km grid. Based on the sample areas, the missed water were flagged based on the Google Earth data, the grids with more flagged error were selected to conduct second step validation. Second, the choosen grid were estimated based on 1km grid with Google Earth and time serials MODIS imagery, the main task is to differentiate real water change and seasonal variation. Finally, the evaluation method for GlobeLand30-WTR2010 was improved and some suggestions were put forward to improve data accuracy and data quality.

Assessment of Bucharest urban green land-cover changes through time-series satellite data

Maria Zoran[1], Roxana Savastru[1], Dan Savastru[1], Marina Tautan[1], Laurentiu Baschir[1], Adrian Dida[2]

[1]National Institute of R&D for Optoelectronics, Romania; [2]Transilvania University of Brasov, Faculty of Silviculture and Forest Engineering, Brasov, Romania; maria@dnt.ro

Through their environmental, aesthetic, social and economic contributions to residents' health and wellbeing, urban vegetation spaces play a major role in urban ecosystems. From an environmental standpoint, green spaces have an important role to carbon sequestration, mitigation of the effects of storm-runoff and air pollution, production of oxygen, microclimate regulation and conservation of urban biodiversity and soil–water protection. Urban vegetation change is a direct measure of quantitative increase or decrease in sources of urban pollution and the dimension of extreme climate events and changes that determine environment quality. The shape and form of urban vegetation reflectance spectra depends on many factors such as vegetation structure, leaf biochemical composition, soil background, and the view and illumination geometry. In this paper, we describe recent results using time-series satellite remote sensing data from NASA's MODIS Terra/Aqua and NOAA/AVHRR satellite to study urban/periurban vegetation changes in Bucharest metropolitan area in Romania. In order to provide vegetation change detection information have been investigated Normalized Difference Vegetation Index (NDVI) and Leaf Area Index (LAI) biophysical variables. NDVI and LAI are key parameters involved in a variety of ecosystem processes, such as light and rain interception, transpiration, photosynthesis, plant respiration and soil respiration. For instance, LAI has a large impact on reflectance spectra especially in the near-infrared, the visible part of the spectrum is strongly affected by leaf chlorophyll, and leaf water is the prevalent factor influencing the reflectance in the mid-infrared wavelengths. Their precise temporal and spatial assessment is crucial for the understanding of vegetation processes and for the parameterization of ecosystem models that quantify carbon, water, and energy fluxes. Training and validation are based on a reference dataset collected from IKONOS high resolution data. The mean detection accuracy for period 2000 - 2014 was assessed to be of 88%, with a reasonable balance between change commission errors (21.9%), change omission errors (28.6%), and Kappa coefficient of 0.71. Annual change detection rates across the urban/periurban areas over the study period were estimated at 0.79% per annum in the range of 0.45% (2000) to 0.76% (2014).Vegetation dynamics in urban areas at seasonal and longer timescales reflect large-scale interactions between the terrestrial biosphere and the climate system.

Development of an innovative land surface temperature retrieval method in areas of highly dynamic emissivity using thermal-infrared satellite data

Sascha Heinemann
Remote Sensing Research Group (RSRG), Germany; sascha1@uni-bonn.de

How to derive the land surface temperature (LST) particularly in areas of highly dynamic emissivity? For this challenge, I will use thermal-infrared (TIR) satellite data, especially Spinning Enhanced Visible and InfraRed Imager (SEVIRI) data, and compare several different methods to each other (inter-comparison). Based on the results obtained from the inter-comparison, I will determine the best performing methods.

The main task is to develop an innovative method to derive LST-retrievals in areas of highly dynamic emissivity, such as grassland, mixed forests and agricultural regions with large diurnal temperature variations. To develop appropriate correction terms, I will compare these LST data with in-situ data to optimize the methods.

At least two current methods, to be implemented in a programming code (IDL), will be utilized to derive LST-retrievals from SEVIRI data: Method 1: To derive LST-retrievals from SEVIRI by using a generalized split-window (GSW) method (BECKER and LI 1990, WAN and DOZIER 1996). Method 2 (with a similar formulation as method 1): Using the generated LST data of the Land Surface Analysis Satellite Applications Facility (LSA-SAF), based on the GSW method. The brightness temperature will be simulated in this case by using the products of MODTRAN 4.0 to get the appropriate coefficients.

Next, I will deduce an innovative algorithm by integrating results of in-situ data and developed correction terms as well as by comparing further methods to determine the land surface emissivity (LSE):

*The (day/night) temperature-independent spectral indices (TISI)-based method (BECKER and LI 1990, LI and BECKER 1993 and LI et AL. 2000) and the RossThick-LiSparse-R model (LUCHT & ROUJEAN 2000)
*Classification-based emissivity method (PERES and DACAMARA 2005, SNYDER et AL. 1998, SUN and PINKER 2003)
*Normalized difference vegetation index (NDVI)-based emissivity method (SOBRINO and RAISSOUNI 2000, VALOR and CASELLES 1996, VAN DE GRIEND and OWE 1993)
*Temperature emissivity separation (TES) method (GILLESPIE et AL.1996, 1998)

Mapping mosquito habitat in the Caribbean using high and medium resolution imagery

Eva Maria De Clercq
CIRAD, France; eva.de_clercq@cirad.fr

Since the beginning of the use of earth observation for environmental monitoring, epidemiology and disease ecology have greatly benefited from the potential of remotely sensed data. Risk mapping linked to vector-borne diseases – diseases transmitted by an arthropod vector such as ticks or mosquitoes – is inherently dependent on data on the environment, both timely available and detailed in space. This paper zooms in on the tropical island of Guadeloupe and the mapping of the presence and abundance of Aedes mosquitoes, responsible for the region-wide outbreak of Chikungunya over the last year. Aedes mosquitoes also transmit dengue fever, causing high fever, headache, muscle and joint pains. Literature indicates that Aedes mosquitoes are mainly found in urban or highly human-modified environments. High mosquito diversity is equally found in mangroves and forested swamps. On the other hand, seasonality in mosquito density is related to seasonality in temperature and precipitation. In this paper, we evaluate different remote sensing datasets for their use in predicting mosquito presence and abundance in the highly mixed LULC environment of Guadeloupe.

The Caribbean region is particularly vulnerable for emerging diseases, because of the highly varying environments between different islands, a high heterogeneity in climate and vegetation, but also a varying degree of human development index, with poor and underdeveloped islands neighboring highly developed zones. Also, the small scale of the various islands represents an additional challenge for mapping the environment. In order to map Aedes mosquito presence in this heterogeneous environment, we combine land cover data at different scales. Medium and high resolutions are mixed. Tree and building density is extracted from high resolution imagery. For different building densities, meteorological data is confronted with a one-year dataset of daily images of NDVI/EVI, originating from the MODIS 13Q1 dataset (at a spatial resolution of ca. 250 m). These results are compared with the trend extracted from PROBA-V images (NDVI at a spatial resolution of ca. 300 m).

Thermal inertia and its association with UHI during winter and summer over megacity Delhi

Shivesh Berwal
Jawaharlal Nehru University, New Delhi, India; shiveshberwal@gmail.com

Urban centers have grown and expanded exponentially worldwide. Large heat-retaining structures dominates the urban centers which results into dry and warmer urban regions. The altered landscape due to urbanization becomes warmer forming an "island" of higher temperatures. Elevated temperatures because of urban heat islands affect community's environment and quality of life. Geospatial technique has been used to look and model not only at the factors that contribute to the formation of urban UHI but it have been compared with rural regions also. Apart from temperature, the amount of dust in the atmosphere is also a significant contributor in modifying the UHI formation. It is also an attempt to establish the role of land use and land cover patterns and respective thermal inertia affecting this phenomenon. This paper mainly focuses on the analysis of urban heat Island over megacity Delhi during winter by thermal inertia being one of the typical subsurface thermal characteristics. In urban areas context, it measures the sub-surface's ability to store heat during the day and reradiate it during the night. After getting the surface albedo and the land surface temperatures at day and night respectively from MODIS, the apparent thermal inertia was calculated using GIS model platform. The result shows that the urban area has higher apparent thermal inertia than that of the rural area. Which makes the materials in urban area have a rapidly increase in surface temperature than those in the rural area in winter night which caused the formation of the urban heat island.

Multitemporal Remote Sensing for Urbanization Monitoring and Environmental Impact Assessment in China

Jan Haas, Yifang Ban
KTH, Royal Institute of Technology, Sweden; jhaas@kth.se

This study investigates land cover changes, magnitude and speed of urbanization and evaluates possible impacts on the environment by the concepts of landscape metrics and ecosystem services in China's three largest and most important urban agglomerations: Jing-Jin-Ji, the Yangtze River Delta and the Pearl River Delta. Based on the classifications of the Landsat TM and HJ-1A/B image mosaics from 1990 and 2010 with a superior random forest decision tree ensemble classifier, a total increase in urban land of about 28,000 sq. km could be detected alongside a simultaneous decrease in natural land cover classes and cropland. Two urbanization indices describing both speed and magnitude of urbanization were derived and ecosystem services were calculated with a valuation scheme adapted to the Chinese market based on the classification results from 1990 and 2010 for the predominant land cover classes affected by urbanization: forest, cropland, wetlands, water and aquaculture. The speed and relative urban growth in Jing-Jin-Ji was highest, followed by the Yangtze River Delta and Pearl River Delta, resulting in a continuously fragmented landscape and substantial decreases in ecosystem service values of approximately 18.5 billion CNY with coastal wetlands and agriculture being the largest contributors. The results indicate both similarities and differences in urban–regional development trends implicating adverse effects on the natural and rural landscape, not only in the rural–urban fringe, but also in the cities' important hinterlands as a result of rapid urbanization in China.

Multitemporal Sentinel-1A Data for Object-based Urban Land Cover Mapping: Preliminary Results

Alexander Jacob, Yifang Ban
KTH - Royal Institute of Techn, Sweden; aljacob@kth.se

In the light of the constant change that urban areas undergo it is of vital importance to be able to map urban areas accurately in order to monitor these changes and derive possible environmental and other impact factors to support sustainable development.

In the previous research of KTH Geoinformatics, we have examined various SAR data for urban land cover mapping including ENVISAT ASAR, RADARSAT SAR and TerraSAR-X data. The objective of this research is to evaluate multitemporal Sentinel-1A images for urban land cover mapping. Sentinel 1A SAR, similar to ENVISAT ASAR and ERS-1/2 SAR, operates in C-band. Multitemporal Sentinel-1A data acquired over Beijing and Stockholm are selected for this mapping task. These two cities are significantly different in their structure and urbanization rate as well as the surrounding environments, thus provide excellent test scenarios with plenty of reference data. Since there are no images available from the peak vegetated season of those areas yet, we will have to work with the currently available data, which start in October 2014 for this preliminary study.

The analysis is performed with our in-house developed software KTH-SEG, a tool for object based image analysis based on an edge aware region growing and merging segmentator as well as a support vector machine for images classification. In this research, multi-resolution segmentation will be performed with different object scales. Some classes might be better assessed with a smaller scale while other require a larger scale in order to be properly mapped. Especially with medium resolution, it is sometime difficult to accurately map individual buildings, yielding a better analysis based on building blocks. Other features such as roads typically need a smaller scale in order to be detected correctly since their width often corresponds to roughly the width of a single pixel (20-30m).

It is anticipated that multitemporal Sentinel-1A data could produce urban land cover maps in ten classes, covering high density built-up areas, low density built-up areas, managed forest, water, roads, airport runways, water, agricultural fields, bare soil and urban green spaces. The classification accuracy will be assessed both in terms of classic measures like the kappa value and overall accuracies as well as more recent methods like the location agreement and quantity agreement. The accuracy may vary depending on the quantity and variability in the Sentinel-1A images used for the classification.

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Monitoring human-induced land use and land cover changes in the Campos Amazônicos National Park (Brazil) and adjacent areas using NDVI trajectories

Daniel Borini Alves[1,2,3], Fernando Pérez-Cabello[1,2], Marcos Rodrigues Mimbrero[1,2]

[1]University of Zaragoza (UNIZAR), Department of Geography and Spatial Management, Spain; [2]Aragon University Research Institute in Environmental Science (IUCA), Spain; [3]CAPES Foundation, Brazil; dborini@unizar.es

This study aims to analyze the dynamics of land-use and land-cover (LULC) in the Campos Amazônicos National Park (Brazil), monitoring and distinguishing trajectories in NDVI (Normalized Difference Vegetation Index) variations, for the last three decades. The study area, with a total of 26604 km², including the National Park area and a buffer zone of 10km, has been subject to significant LULC dynamics associated with deforestation progress and use of fire. Considering available Landsat (5, 7) time series, it was created a mosaic per year from 1984 to 2013 (paths/rows - 231/66; 231/65; 230/65; 230/66), at a particular period of year, atmospherically corrected using LEDAPS tools. NDVIs values were generated for each mosaic image. Furthermore, the mosaics of 1984 and 2013 still underwent a supervised classification of LULC using the operator maximum likelihood to differentiate five categories: water, forest, secondary/degraded forest, savannah/pasture and crop/bare soil. The trajectories in NDVI variation values were analyzed by R statistical software, in a sample of random points covering 3% of the area, considering intersections of classified categories of LULC. The pixels identified as forests on the images of 1984 and 2013 displayed stable trajectories of NDVI values, with average value 0.824 and coefficient of variation 4%. While the pixels of savannah/pasture, which was periodically affected by fire, had a cyclical variation trajectory, with average NDVI value 0.585 and coefficient of variation 15%. The main regressive trajectory was the transition “forest-crop/bare soil", identifying 2003 as the year of the greatest drop in NDVI values associated with a growing of the deforested areas. Splitting the years into two periods 1984-2002 and 2003-2013, the average of "forest-crop/bare soil" NDVI values changed respectively from 0.818 to 0.574. Therefore, the results show distinct trajectories associated with NDVIs and LULC changes that assist in better understanding the dynamics of ecological processes and the human impacts operating in the area.

A Characterization of the Status and Dynamics of Land Cover in the Active Okavango Catchment Based on Various MODIS Products and Climate Data

Marion Stellmes, Achim Röder, David Frantz, Thomas Udelhoven, Joachim Hill

Environmental Remote Sensing and Geoinformatics, Trier University, Germany; stellmes@uni-trier.de

The Okavango River is one of the large lifelines of Southern Africa. It has its source in the rainy highlands of Angola, forms part of the north-eastern border of Namibia and terminates in the Okavango Delta, the world's largest inland delta and the largest freshwater swamp south of the equator. Accelerating climate change, population growth, and anthropogenic over-utilization of natural resources turn the Okavango Basin with its variety of savannah woodlands and wetland ecosystems into a global hotspot of biodiversity loss and potential land use conflicts.

It is of major importance to support the development of trans-national sustainable land use management strategies. One essential element for optimizing land use management is the assessment of ecosystem performance and resources including their spatial distribution, variability and long-term behavior. To contribute to this objective a multi-component earth observation product was established at a regional scale employing moderate resolution MODIS products covering the time period from 2000 to 2012.

An analysis of a complex system like the Okavango Catchment is in need of several descriptors that allow for a holistic evaluation of the system. We accounted for this complexity by first deriving various information describing the status and dynamics of the Okavango Catchment and secondly evaluate the single components in a combined analysis.

One elementary component is the derivation of major land use systems and functional vegetation types along with their changes over time. For this purpose phenology indicators were derived from the MODIS Enhanced Vegetation Index (EVI) product employing a polynomial spline model approach. Based on this information major land use systems were delineated and, by linear regression analysis, land use/cover conversions and modifications were identified. Another constituent is the climatically unbiased assessment of ecosystem productivity and the dependency of EVI on rainfall variability. This was followed by assessing climatically de-trended rain use efficiency by linking MODIS EVI, serving as a proxy of net primary productivity, and gridded rainfall data. The response of EVI anomalies to rainfall variability was estimated by using distributed lag

models.

One further significant factor is the fire regime, its spatial pattern and frequency, which can be evaluated based on the MODIS fire products. Furthermore, the highly variable water availability affects the extent and duration of inundation and is especially crucial for ecosystem performance in the Delta region. For this purpose, MODIS EVI and reflectance data were utilized to derive a temporally explicit product indicating inundated areas.

Based on the remote sensing products derived, the ecosystems of the Okavango Catchment could be described regarding land cover and its dynamics as well as the fire and inundation regime. The integration of all these products contributes to a comprehensive picture of the status of the Okavango Catchment and Delta and supports the understanding of the ecological dynamics in the entire Okavango system.

Analysis of Land Use and Land Cover Changes in Mississippi Delta Using a Coupled Natural-Human System Framework

Nina S.N. Lam, Yi Qiang, Kam-biu Liu
Louisiana State University, United States of America; nlam@lsu.edu

As one of the most vulnerable coasts in the world, the Mississippi Delta has endured numerous hazards over the past decades. The sustainability of this region has drawn great attention from the international, national, and local communities, wanting to understand how the region as a system develops under intense interplay between the natural and human factors. Land use land cover (LULC) change, as manifested by snapshots of remote sensing images, is considered a key indicator of the processes on the earth surface. Modeling the land use land cover change in this region will help us understand how human interacts with the natural environment, and the resultant models can be used to produce scenarios to examine the potential impacts of stresses and pulses, such as climate change effects, on the sustainability of the Delta.

This paper presents an analytical framework and a modeling approach that can be used to address the challenges in coastal sustainability research. A major problem in the Mississippi deltaic region is significant land loss over the years due to a combination of natural and human factors. The main scientific and management questions in this study are: what factors contribute to the land use land cover changes (LULC) changes in this region, can we model the changes, and how will the LULC look in the future given the current factors? The framework includes six components that are common to most deltaic systems around the world, and they are linked by a central component, which is the land use land cover change. The six components are: (1) a historical evaluation of sedimentation rates and its relation with human activities; (2) linkages between river hydrology and sediment delivery; (3) linkages between sediment and vegetation changes; (4) linkages between land loss and population change; (5) linkages between land loss and critical energy infrastructure sustainability; and (6) adaptive governance in response to land loss and other threats.

To demonstrate the modeling of land use land cover change in a coupled natural-human system modeling context, a study that analyzed the LULC changes of the region was conducted. The study used LULC data between 1996-2006 and applied an artificial neural network (ANN) to derive the LULC change rules from 15 human and natural variables. The rules were then used to simulate future scenarios in a cellular automation model. A stochastic element was added in the model to represent factors that were not

included in the current model. The analysis was conducted for two sub-regions in the study area for comparison. The results showed that the derived ANN models could simulate the LULC changes with a high degree of accuracy (above 92% on average). A total loss of 263 square kilometers in wetlands from 2006 to 2016 was projected, whereas the trend of forest loss will cease. These scenarios provide useful information to decision makers for better planning and management of the region. The methods and findings also provide valuable insights to the management of other hurricane-prone regions.

Human activity impacts on the development of Yangtze estuarine wetland

Zhang Lei
institute of remote sensing and digital earth, China, People's Republic of;
zhanglei@radi.ac.cn

The wetland in the Yangtze Delta plays an important role in coastal protection against erosion, water purification, and habitat maintenance of migratory birds. The Yangtze Delta is one of the largest economic zones (e.g., Shanghai) in China. Human activities severely affect wetland evolution. Wetland mapping was performed from multi-temporal remote sensing data of Landsat during the period of 2000–2010 at intervals of about 5 years, and spatio-temporal changes in wetland characteristics as well as driving forces for such changes were analyzed. Results indicated the Yangtze River estuarine wetland area experienced a net increase of 63% during the period of 2000–2010; from 2005 onwards, however, the rate of increase has decreased. Human activities, including upstream dam construction, estuarine engineering, land reclamation, and ecological engineering, played an important role in wetland evolution during this short period. Reduction of riverine sediment loads led to decreases in the increase rate of estuary wetland; 95% of the estuarine shoreline is embanked by seawalls, which exerts negative effects because closure promotes substantial degradation of wetland areas. Urbanization and expansion of Shanghai facilitated regular land reclamation of wetland and led to 35% wetland loss. Intentional artificial planting of aquatic plants and groyne construction accelerated sediment deposition and wetland formation to compensate for coastal wetland loss

Multi-annual Analysis of the Spatial Distribution of Biocrusts in the Northwestern Negev Sandfield, Israel

Arnon Karnieli
Ben Gurion University, Israel; karnieli@bgu.ac.il

The brightness contrast across the Israeli-Egyptian political borderline is a typical example of a desertification phenomenon triggered by human impacts on a fragile ecosystem. The sand dunes of the Negev (Israel) are almost completely covered by biocrusts undisturbed by anthropogenic activity. These biocrusts consist of microorganisms called cyanobacteria along with fine soil particles. On the other side of the border, in the sand dunes of Sinai (Egypt), such crusts are absent from the topsoil due to intensive trampling by humans and animals. Consequently, the Israeli Negev dunes are stable with more vegetation, while the Sinai dunes are bare and mobile. The two sides of the political borderline, although similar from geological, geomorphological, pedological, and climatic points of view, demonstrate opposing processes of desertification in Egypt and rehabilitation in Israel.

The current project summarizes long-term land cover and land use change studies acquired by different spaceborne systems since 1960s until now. Two desertification indicators are involved. The first is dune stability that was investigated by deriving brightness and albedo values from Landsat, CORONA, and NOAA-AVHRR images. Brightness index is affected by the spatial distribution of cyanobacteria-dominated biocrusts vs. bare sands. The second indicator is vascular plant cover that was calculated from aerial photographs. Results of these independent remote sensing systems similarly and consistently demonstrate the changes in the brightness contrast across the Israeli-Egyptian political borderline with respect to historical events. The contrast decreased when the border was open for human activity and increased when the border was closed.

Spatio-Temporal Dynamics of Land-Use and Land-Cover in the Mu Us Sandy Land, China, Using the Change Vector Analysis Technique

Arnon Karnieli[1], Zhihao Qin[2], Bo Wu[3], Natalya Panov[1], Feng Yan[3]
[1]Ben Gurion University, Israel; [2]Institute of Agro-Resources and Regional Planning, Chinese Academy of Agricultural Sciences, China; [3]Institute of Desertification Studies, Chinese Academy of Forestry, China;
karnieli@bgu.ac.il

The spatial extent of desertified vs. rehabilitated areas in the Mu Us Sandy Land, China, was explored. The area is characterized by complex landscape changes that were caused by different drivers, either natural or anthropogenic, interacting with each other, and resulting in multiple consequences. Two biophysical variables, NDVI, positively correlated with vegetation cover, and albedo, positively correlated with cover of exposed sands, were computed from a time series of merged NOAA-AVHRR and MODIS images (1981 to 2010). Generally, throughout the study period, NDVI increased and albedo decreased. Improved understanding of spatial and temporal dynamics of these environmental processes was achieved by using the Change Vector Analysis (CVA) technique applied to NDVI and albedo data extracted from four sets of consecutive Landsat images, several years apart. Changes were detected for each time step, as well as over the entire period (1978 to 2007). Four categories of land cover were created—vegetation, exposed sands, water bodies and wetlands. The CVA's direction and magnitude enable detecting and quantifying finer changes compared to separate NDVI or albedo difference/ratio images and result in pixel-based maps of the change. Each of the four categories has a biophysical meaning that was validated in selected hot-spots, employing very high spatial resolution images (e.g., Ikonos). Selection of images, taking into account inter and intra annual variability of rainfall, enables differentiating between short-term conservancies (e.g., drought) and long-term alterations. NDVI and albedo, although comparable to tasseled cap's brightness and greenness indices, have the advantage of being computed using reflectance values extracted from various Landsat platforms since the early 1970s. It is shown that, over the entire study period, the majority of the Mu Us Sandy Land area remained unchanged. Part of the area (6%), mainly in the east, was under human-induced rehabilitation processes, in terms of increasing vegetation cover. In other areas (5.1%), bare sands were found to expand to the central-north and the southwest of the area.