ADVANCING HORIZONS FOR LAND COVER SERVICES ENTERING THE BIG DATA ERA

Second joint Workshop of the EARSeL Special Interest Group on Land Use & Land Cover and the NASA LCLUC Program

Abstract book

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Editorial

DEAR WORKSHOP PARTICIPANT, DEAR EARSEL MEMBER, DEAR NASA COLLEAGUE,

every two years we convene to discuss our ideas, challenges, dead-ends and solutions, which remote sensing assisted land use and land cover (LULC) science and applications brought to light and experience. This way we synthesize what research teams around Europe, the USA and beyond achieved last years, demonstrate and review upon recent and current activities, and provide an overview of emerging trends to cover for latest developments and societal needs. We are aware that due to the multitude of LULC and land use cover change studies on local, national, continental and global levels performed and initiated from science, industry, and public administration, the Workshop can not cover for all aspects. However, every time we build on previous experience and attract prestigious scientists to a brain storming event focusing on discussion and participants' contributions to the maximum extent (please refer specifically to the unique Workshop structure). Main session titles and topics, keynote speakers and chairs, particularly support the advancement of our knowledge and trigger vivid discussions around most pronounced topics of concern and development nowadays. We therefore thank you for your presence and contribution. Wish to enjoy our talks and socialize among all of us, who pursue and live for and from the Remote Sensing application in Land Use and Land Cover.

With our sincere and humble regards,
Ioannis Manakos & Garik Gutman

ID 3

OBJECT BASED CLASSIFICATION USING SPECTRAL AND INVENTORY DATA IN NATIVE MIXED BEECH, FIR AND SPRUCE FOREST ON IGMAN MOUNTAIN

MERISA OSMANOVIC[1], AHMET LOJO[1], BESIM BALIĆ[1], AZRA ČABARAVDIĆ[1], FILIP HÁJEK[2]

[1]Faculty of Forestry, University of Sarajevo, Bosnia and Herzegovina
[2] Forest Management Institute branch Frýdek-Místek, Czech Republic

Presenting author e-mail address: merisaosmanovic@gmail.com

Abstract

Forest classification in Bosnia and Herzegovina is challenging due to native mixed, multilayer, uneven aged forests. The most important tree species fir, spruce and beech creates complex of tree composition. The main aim of this paper was to find the best segmentation parameters for multi-resolution segmentation in order to perform classification of mixed beech, fir and spruce forests on mountain Igman.

In this research was being carried out multi-resolution segmentation using spectral data. In eCognition software different segmentation parameters were examined for creating optimal image objects (segments) for classification. Scale parameter was examined in order to control / create the best image object size.

Different compactness and shape parameters (homogeneity criteria) for image objects were examined and compared.

Classification was carried out with image object whose segmentation parameters proved to be the best in presenting the complex conditions in the field.

Keywords: forest classification, segmentation parameters, spectral data, native mixed forests, e-Cognition

ID 40

IMPROVING GLOBAL LAND-COVER MAPS WITH SENTINEL: THE S2GLC PROJECT

STANISLAW LEWINSKI[1], EWA BILSKA[1], ARTUR NOWAKOWSKI[1], MICHAŁ KRUPIŃSKI[1], SEBASTIAN ALEKSADROWICZ[1], ELKE KRÄTZSCHMAR[2], CONRAD BIELSKI[3], CHRISTIAN THIEL[4]

[1] Space Research Centre, Polish Academy of Sciences, (CBK PAN), Poland
[2] Industrieanlagen-Betriebsgesellschaft mbH, (IABG mbH), The Geodata Factory, Germany
[3] EOXPLORE UG, Germany
[4] Friedrich-Schiller-Universität, The Department of Earth Observation at the Institute of Geography, Germany

Presenting author e-mail address: stlewinski@cbk.waw.pl

Abstract

The European Space Agency (ESA) through its Scientific Exploitation of Operational Missions (SEOM) element, are funding a project entitled Sentinel-2 Global Land Cover or S2GLC for short. This project will focus on the classification of Sentinel imagery for the purpose of producing a global land cover map. The project began on February 1, 2016 with a total duration of 2 years and is led by Space Research Centre of Polish Academy of Sciences (CBK PAN) with three partner organisations. In order to maximise the output of this study, five test sites were chosen to test and validate the applied classification techniques: Italy, Germany, Namibia, Columbia, and China. Each test site covers an area approximately 200 000 km2 and are found in a variety of bio-geographical locations in order to maximise the types of land-cover to be classified. The choices were a balance between access to good validation data, landscape variability, and the technical realities of testing multiple classification algorithms and methodologies. The first part of this study is an extensive review of the currently available Global Land Cover (GLC) maps and databases. The review study is expected to be ready around the time of the conference and the team believes that it is a perfect venue to present our review to get constructive feedback from the users of GLC databases in attendance. This review, together with feedback from the community, will influence the choices in algorithms and image processing methodologies tested within the scope of this study. The second and third parts of the study are testing of the land-cover classification methodologies and validation of those methods respectively in order to produce not only the highest quality maps, e.g. accuracy >80%, but also harmonised with

current GLC products. In order to achieve this complex goal, many different tests of object-oriented as well as pixel based classification approaches will be made. In parallel, advanced data collection strategies for training and validation will be investigated. While the majority of the applied land-cover classification techniques will be based on optical imagery acquired by Sentinel-2 (S2), the team understands that globally this challenge can be supported by the Sentinel-1 SAR data. The different approaches will be benchmarked in order to understand the influence of a variety of factors on the performance of the proposed methods. Factors will include feature relevancy, the impact of atmospheric correction, the selected minimal mapping unit, seasonal changes, the incompleteness of training data, image mosaicking, and multi-temporal S2 data. The final part of the project will be to make recommendations based on the research for future S2 based GLC products. The poster will present initial stages of the project, working assumptions, directions, and potential problems. The goal of this presentation is to make potential end-users aware of the on-going work and make contact with researchers willing to share their experiences on this topic.

Keywords: Sentinel-2, global land cover, land cover classification

ID 43

CROP AND BIOPHYSICAL PARAMETERS MAPPING BASED ON SENTINEL-2 AND LANDSAT DATA FOR JECAM-UKRAINE TEST SITE

ANDRII SHELESTOV[1,2,3], NATALIIA KUSSUL[1,2], MYKOLA LAVRENIUK[3,1]

[1] Space Research Institute NASU-SSAU, Ukraine
[2] National Technical University of Ukraine "Kyiv Polytechnic Institute", Ukraine
[3] Integration-Plus, Ukraine

Presenting author e-mail address: andrii.shelestov@gmail.com

Abstract

Sentinel-2 and Landsat-8 data availability make it possible crop state monitoring and mapping along the vegetation season with high resolution. As well as Ukraine is one of the biggest agricultural producers in the world, it is important to build accurate crop type maps and monitor the crop state indicators for major crops. Different vegetation indexes, Leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (FAPAR) are important biophysical indicators that enable monitoring and quantitative assessment of vegetation state. During the last years we have collected big datasets of ground measurements for crop type mapping and vegetation state validation at JECAM –Ukraine test site (Kyiv region).

Using ground measurements dataset we have built and investigated crop type and biopar maps based on Sentinel-2 and Landsat-8 time series for Kyiv region. The results show that data fusion from different optical sensors allows to improve the time resolution and accuracy of mapping.

Detailed results based on optical and radar data we will present during the workshop.

Keywords: biophysical parameters, LAI, FAPAR, agriculture, JECAM, product harmonization

ID 45

AUTOMATIC SELECTION OF CLASSIFICATION THRESHOLDS FOR CHANGE DETECTION IN LAND COVER

ARTUR NOWAKOWSKI, STANISLAW LEWINSKI

Space Research Centre, Polish Academy of Sciences, Poland

Presenting author e-mail address: anowakowski@cbk.waw.pl

Abstract

In satellite image analysis, change detection in Earth surface is an important area of research and application work. There is a need of developing tools, which can accurately detect changes in land cover. One of the most popular approach to change detection is based on comparison of two land cover classification results.

The classification results could be obtained using various algorithms, e.g. support vector machine, neural network, boosting, random forest, maximum likelihood etc. The algorithms make a decision about class of actual pixel based on some measure, e.g. number of votes (random forest), weighted sum of responses of weak classifiers (boosting), class distance (minimal distance algorithm), probability (Bayesian classifier), etc. The classification decision is made based on automatic thresholding of used measure taking into account maximization of overall accuracy on training set.

In change detection problem, there are considered two classification results of the same area but based on the imageries acquired at different time stamps. In traditional approach two classification results are obtained using two independent classification processes. In the paper we propose to incorporate into that procedure an additional element - mutual information from two imageries assuming that changed land cover represents relatively small percent of whole area. By analyzing edge locations of areas classified as same-type land cover in two imageries for different values of classification threshold we obtain an experimental relation, which we call as a measure of compatibility of two classifications. In the maximum point of the measure, two classifications are the most compatible in terms of location of borders of same-class areas what implies the minimal number of false positives in change detection, what contributes in increase of change detection accuracy.

Proposed methodology is fully automatic and has been practically verified using Landsat images of Warsaw from year 2002 and 2013.

Keywords: change detection, automatization, Landsat, land cover

ID 56

THE LONG TERM SUSTAINABILITY OF LAND MONITORING THROUGH AN EVOLVING SPACE COMPONENT

GEOFFREY MALCOLM SMITH [1,2]

[1]Specto Natura Ltd., United Kingdom
[2] NextSpace contractor team

Presenting author e-mail address: geoffsmith@specto-natura.co.uk

Abstract

The use of EO data in the land domain is currently undergoing a number of significant changes driven by technology developments, increased observing capacity and the establishment of operational programmes which will have a considerable impact on land monitoring in Europe and beyond. New EO systems, including, but not limited to the Sentinels, are being launched into orbit to give new imaging capabilities and the ability to image the surface more regularly to cope with cloud cover and record phenological changes and dynamic behaviour. This is the beginning of the first era of near real-time delivery of 'stabilised' land products at the field and city block scale. The sustainability of the current EO capabilities and their integration with other satellite assets through "Multi-Source Land Imaging" will therefore be a key driver for our ability to monitor and manage our rapidly changing environment. This level of sustainable monitoring is unique and will allow users to change and expand their information systems in the knowledge that the returns on the investments made can be realised over the next decades at least. To reinforce this commitment to sustainability, but also to broaden the utility of the Sentinel fleet, the European Commission is now taking the first steps in preparation for the next generation of Sentinels which will fly around 2030. This work is gathering user requirements from current and potential new users of EO data to assess how completely the Copernicus space and land service components address their needs. From this analysis it will be possible to propose evolutions of the service comments of Copernicus and provide "high level technical mission requirements" for the space component. A number of routes to engagement are being pursued to capture both general thematic requirements and specific application-oriented needs. On behalf of the European Commission's NextSpace contractor team an invitation is extended to all those attending the Workshop and from across the EARSeL Special Interest Group on Land Use & Land Cover and the NASA LCLUC Programme communities to discuss their thoughts on how the future Sentinels could support land monitoring.

Keywords: Sentinels, land, sustainability, next generation

ID 57

CREATION, PUBLISHING AND MAINTAINING OF SEAMLESS, HIGH PRECISION LAND USE DATABASE FROM VARIETY OF AVAILABLE VECTOR DATA SOURCES ON EXAMPLE OF OPEN LAND USE MAP INITIATIVE

DZMITRY KOZHUKH[1], KAREL CHARVAT[1], TOMÁŠ MILDORF[2]

[1] Help Service - Remote Sensing s.r.o., Czech republic
[2] University of West Bohemia, Czech Republic

Presenting author e-mail address : dmitrii@hsrs.cz

Abstract

Nowadays there are becoming more and more free, open vector data sources in individual European countries from which land use can be derived directly or implicitly. Among such data sources there are sources that are published by state mapping agencies of individual countries such as digital cadastral data, spatial plans, topographic databases, but also crowd sourced databases (for example OpenStreetMap). Those high resolution datasets in contrast to global and pan-European datasets can be used to create very precise land use maps that are invaluable for planning activities of individuals and companies (for example individual who decides where to buy a family house or logistic company who decides where to build new warehouse etc.). In this paper the description of approach how to create harmonized land use dataset with seamless coverage and high spatial resolution from existing open vector data sources, how to publish and maintain such dataset is provided. The approach has been developed within Open Land Use Map pilot of Sdi4Apps project. It has been applied to the three regions so far: Czech Republic, Latvia and Flanders region of Belgium.

Keywords: land use, data harmonization, data integration

ID 62

EARLY EVALUATION OF THREE MSI SURFACE REFLECTANCE PRODUCTS

M. CLAVERIE, E. VERMOTE, J. JU, J.C. ROGER, O. HAGOLLE, P. DEFOURNY, C. JUSTICE, J. MASEK

Abstract

Maintaining consistent datasets of Surface Reflectance (SR) is an important challenge to ensure long-term quality of Climate Data Records. The recently availability of Sentinel-2A MSI data with a high temporal and spatial sampling offers a unique data source to monitor the land surface globally. To go from a top-of-atmosphere reflectance product (level L1C) to a surface reflectance product (level L2A), it is necessary to correct for the atmospheric effects and to mask for clouds. In this study, we evaluate three existing L2A processors developed by three distinct space agencies:

- Sen2Cor processor (Main-Knorn et al. 2015), developed by the DLR and implemented as the official L2A processor by ESA; it relies on the Atcorr model and includes AOT inversion based on dark pixel detection.
- The MACCS (Multisensor Atmospheric Correction and Cloud Screening) processor, developed by CNES (Hagolle et al. 2015); it relies on the SOS method and includes an AOT inversion and cloud detection based on a multi-temporal approach.
- The 6S model-based processor, developed by NASA as an adaptation of the Landsat-8 atmospheric correction algorithm (Vermote et al. 2015); the AOT inversion is based on spatially explicit spectral ratio maps derived from the MODIS and MISR heritage.

Three evaluation approaches are presented in this study. The first approach used the Aerosol Robotic Network (AERONET) data set (Vermote and Kotchenova 2008). For each temporal matching between MSI data and AERONET data, a 10x10km subset of MSI SR (from the three processors) and AERONET-derived SR are compared. Second, we use a methodology to cross-compare MSI data and MODIS data acquired on the same day (Claverie et al. 2015). This method includes: (i) a surface anisotropy adjustment, based on the VJB Bidirectional Reflectance Distribution Function (BRDF) method, to adjust Terra and Aqua MODIS data to MSI sun-view geometry, and (ii) a spectral adjustment, based on an innovative approach, called ASBAF (Adaptative Spectral Band Adjustment Factor), calibrated using 160 globally distributed Hyperion scenes. Finally, we evaluate the three cloud masks based on product inter-comparison and comparison with 2 external datasets: (i) manual cloud mask using a limited number of MSI scenes; (ii) cloud detected by the Cloud-Aerosol

Transport System (CATS) onboard of ISSS, for which we found periodic coincidence acquisitions (10 minutes delay) with MSI in South America (close to the 45° south latitude).
The results from the above study are presented based on first semester of data from MSI on board of Sentinel-2A.

ID 4

CROSS-SENSOR MOSAICKING - A NEW APPROACH TO FULFILL FUTURE USER DEMANDS

PETER FISCHER, TOBIAS STORCH, PABLO D'ANGELO, SEBASTIAN FAST

German Aerospace Center, Germany

Presenting author e-mail address: Peter.Fischer@dlr.de

Abstract

The launch of Sentinel-2A on 23rd June 2015 and the following launch of Sentinel-2B in mid-2016 marks a new era in ESA's Earth Observation Program. With a repetition competitive mission design (e.g., sensor specification, observation repetition rate) and a data policy following the rule „free, full and open“, the mission will stimulate a fast amount of existing and new applications.

During the last decades most Land Use / Land Cover applications were enabled and driven by data provided through NASA's Landsat program. ESA's Sentinel-2 program and its related data can act not just as substitute, but also as complementary data source. Sharing to some degree spectral and spatial characteristics, by harmonizing corresponding data sets from both sources the number of use cases can be extended.

Merging data sets from both missions acquired within a short time slot (e.g. date of interest +/- 3 to 5 days) leads towards completely new product families. Besides of the well-known scene-based data processing levels characterized by different quantization and units following naming conventions from level zero to three, we can think now about a new data level four. The envisaged level four dataset will be generated on-the-fly triggered and strictly following the users demand. The user specifies a time-span and an area of interest, the product will be generated and made available according to the given specifications.

In our paper we present an experimental approach to generate such a product. Data from Sentinel-2A and Landsat-8 are combined over a large spatial extent within a given acquisition time slot. The different data sets will be mosaicked, the final product will be one high resolution image.

To adapt the spatial resolution of Landsat-8 scenes to Sentinel-2A, a two-step methodology is applied. In the first step pan-sharpening techniques (e.g. General Fusion Framework, Ehlers fusion, HIS) are applied to resample the imagery from 30 m to 15 m spatial resolution. This step is followed by an interpolation step to equalize the spatial resolution of the Landsat-8 scenes to Sentinel-2A’s resolution of 10 m.

Radiometric adaption of the imagery will be evaluated as a possible strategy to enhance the visual quality of the final product. As not all scenes will overlap with each other, different techniques are possible. In general the scene having the median acquisition date

should be considered as master and the radiometry of the other scenes should be adapted to this scene. In our experiment we will evaluate how such an approach can be extended to non-overlapping regions.

The mosaicking algorithm resolves for each pixel its uniqueness, no mixed pixels are generated. Further processing like classification and change detection which relies on the pixel-based measured spectral characteristics is still possible, as for each pixel the acquisition conditions and the recording sensor is available.

Keywords: mosaicking, image composite, sensor fusion

ID 5

GEOMULTISENS – A COMMON AUTOMATIC PROCESSING AND ANALYSIS SYSTEM FOR MULTI-SENSOR SATELLITE DATA

DANIEL SCHEFFLER[1], MIKE SIPS[2], ROBERT BEHLING[1], DORIS DRANSCH[2], DANIEL EGGERT[2], JAN FAJERSKI[3], JOHANN-CHRISTOPH FREYTAG[4], PATRICK GRIFFITHS[5], ANDRÉ HOLLSTEIN[1], PATRICK HOSTERT[5,6], PATRICK KÖTHUR[2], MATHIAS PETERS[4], DIRK PFLUGMACHER[5], ANDREAS RABE[5], ALEXANDER REINEFELD[3], FLORIAN SCHINTKE[3], KARL SEGL[1]

[1] Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Section Remote Sensing, Telegrafenberg, Potsdam, 14473, Germany
[2] Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Section Geoinformatics, Telegrafenberg, Potsdam, 14473, Germany
[3] Zuse Institute Berlin, Distributed Algorithms and Supercomputing, Takustraße 7, Berlin, 14195, Germany
[4] Humboldt University Berlin, Databases and Information Systems, Rudower Chaussee 25, Berlin, 12489, Germany
[5] Humboldt University Berlin, Geography Department, Unter den Linden 6, Berlin, 10099, Germany
[6] Humboldt University Berlin, Integrated Research Institute on Transformations of Human-Environment Systems (IRI THESys), Unter den Linden 6, Berlin, 10099, Germany

Presenting author e-mail address: daniel.scheffler@gfz-potsdam.de

Abstract

For more than 40 years Earth observation satellites supply continuous record of the Earth's changing surface and landscape. Consequently, remotely sensed data include valuable information for monitoring spatio-temporal changes on global and regional scales. Large fractions of measurements have been continuously archived and are partly available to the public, e.g. in connection with the European Copernicus programme. In the last years the data volume increased steadily by the availability of more Earth observation satellites and improved sensor technology offering wider swaths, as well as higher geometrical, spectral and temporal resolutions.

In order use Earth Observation data to address global challenges such as climate change, population growth, water scarcity or loss of biodiversity, innovative Big-Data technologies are needed that help to manage and analyse the huge amount of available data. Besides computational challenges, new algorithms are needed that combine data from different

sensors in a way that make them directly comparable and therefore foster extended multi-temporal analysis.

The presented GeoMultiSens project addresses these demands by developing a scalable multi-sensor Big-Data system that can process and analyse heterogeneous remote sensing data in the petabyte range. It operates as a partnership between Helmholtz Centre Potsdam German Research Centre for Geosciences (GFZ), Humboldt University Berlin (HUB) and Konrad Zuse Institute Berlin (ZIB).

GeoMultiSens involves the construction of a data infrastructure that is able to process data highly parallel and is able to efficiently store petabytes of data, all with high hardware failure tolerances (ZIB). Novel remote sensing algorithms as well as state of the art techniques for data acquisition, pre-processing and homogenization are developed and implemented into one common processing environment by GFZ. Image classification and time series analysis tools are made available by geoscientists of HUB. All algorithms are adapted to a map-reduce processing scheme together with HUB computer scientists in order to allow high performance parallel processing and very fast information retrieval. A web interface including product visualization and interactive tools for exploration and evaluation of spatio-temporal changes is developed by GFZ computer scientists.

The GeoMultiSens processing system is currently designed to store and automatically process remotely sensed data from space-borne multispectral sensors of high and medium spatial resolution such as Sentinel-2, Landsat 5/7/8, Spot 1-6, ASTER, ALOS AVNIR-2 and RapidEye as an open source software. We present the overall scientific concept of the Big Data system “GeoMultiSens” and we particularly focus on our processing chain used for data fusion and homogenization. We discuss scientific challenges of the GeoMultiSens system and present our ideas to address them.

Keywords: big data, image processing and data fusion, multi-disciplinary applications, long time data series, apache flink

ID 8

SPATIAL STRUCTURE AND SCALING OF AGRICULTURAL NETWORKS

DANIEL SOUSA, CHRISTOPHER SMALL

Lamont-Doherty Earth Observatory, Columbia University, United States of America

Presenting author e-mail address: d.sousa@columbia.edu

Abstract

Considering agricultural landscapes as networks can capture patterns of spatial connectivity relevant for a wide range of applications including pollination, pest management, and ecology. Global agricultural networks have been shown to be well-described with power law rank-size distributions. However, most analyses are regional and therefore include only a subset of the total global network. In this analysis, we test whether the globally observed scale-free property of agricultural networks holds in smaller spatial domains. We ask whether similar properties can be observed on kilometer to meter scales. Examining 9 intensively cultivated Landsat scenes on 5 continents with a wide range of vegetation distributions, we find that networks of vegetation fraction within the domain of each of these Landsat scenes exhibit substantial variability – but still possess similar scaling properties to the global distribution of agriculture. We also find similar results with a 39 km2 IKONOS image. To illustrate an application of spatial network analysis, we show an example of network disruption. We compare two networks with similar rank-size distributions that change in different ways when nodes are progressively removed. These results suggest that treating agricultural land cover as a spatial network can provide a straightforward way of characterizing the connectivity of complex distributions of agriculture across a wide range of landscapes and at spatial scales relevant for practical applications.

Keywords: scaling, rank-size, agriculture, power law, network

ID 12

AUTOMATIC MONITORING OF THE TRANSIENT SNOWLINE ON MOUNTAIN GLACIERS

BAS ALTENA, PAUL LECLERCQ, ANDREAS KÄÄB

Department of Geosciences, University of Oslo, Norway

Presenting author e-mail address: bas.altena@geo.uio.no

Abstract

The extent of a glacier is related to its local climate. Therefore understanding its evolution over time can give an insight into past and present climate. Grasping the dynamics of a glacier is possible through glacier models that combine glacier mass balance with ice dynamics. However, some parameters are not known in advance, therefore model calibration is needed. Several key-variables for such models can be extracted from geospatial data-sets. One of these variables is the snow cover evolution which is directly related to the glacier surface mass balance, and therefore can be valuable in the calibration procedure. In addition, snow cover is detectable by remote sensing, and thus has the potential to be implemented on any glacier. Hence, it is feasible to support modelling of glaciers in a region or world-wide. This study therefore focuses on the automatic detection of the snowline for glacier modeling.

For high mountain glaciers elevation models are often too coarse or outdated, therefore our approach disregards topographic information. Thus the signal is affected by illumination differences that cannot be easily corrected. Nonetheless, our classification is able to distinguish between snow and ice. However, challenges occur at locations which are in cast shadow. This problem is bypassed through an additional shadow detection procedure and the resulting outcome has three classes: "snow", "ice" and "unsure". Pixels within the shade and pixels covered by clouds are assigned to this "unsure"-class. Including this new class diverges from traditional snow mapping. However optical systems have sparse sampling in space and time, therefore its derived products are inherently sparse too.

For the calibration of our approach time-lapse imagery from 2010-2011 over Findelen-glacier, Swiss Alps, are used. The validation of our approach was assessed through time-lapse imagery from 2004-2009 over the neighboring Gorner-glacier. The proposed methodology is calibrated and tested on Landsat imagery. However, the methodology is cross-platform and thus snowlines can be extracted from the Landsat legacy as well as Sentinel-2, resulting in a snow line evolution from present day back to more than 30 years, and with a potential present temporal resolution of a few days.

Keywords: glacier-zones multi-temporal multi-sensor classification automation

ID 16

LAND COVER MAPPING PRIORITIES BASED ON A COMPREHENSIVE DATASETS QUALITY REVIEW IN SUPPORT TO GLOBAL HIGH RESOLUTION LAND COVER MAPPING

MARIAN VITTEK, FRANÇOIS WALDNER, SOPHIE BONTEMPS, PIERRE DEFOURNY

Université catholique de Louvain, Belgium

Presenting author e-mail address: marian.vittek@uclouvain.be

Abstract

An increasing number of land cover datasets from national to global scales were provided in recent years with improved data accuracy for diverse applications. Although efforts were made to integrate these existing maps, several areas in world received little attention and therefore might be source of inaccurate information and upmost source of inconsistencies in resulting studies. The recent availability of high resolution time series challenges the present land cover mapping practices in terms of data volume, level of details and coverage. Furthermore the forthcoming global land cover maps will have to be compatible with corresponding land cover maps obtained for the previous decades either from high or from medium spatial resolution imagery. The overall objective of this study is to present the current availability of land cover datasets at global scale and to identify priority regions in the world for improved land cover mapping. Initially, all available land cover maps from national to global scale were identified and collected. This very comprehensive inventory was followed by suitability analysis considering multiple relevant criteria. Specific properties were considered since it is known that available datasets are characterized by conflicting purposes and target different user groups. In addition to spatial scale suitability, thematic information content relevant to particular land cover classes is evaluated. Further criteria represents timeliness and confidence level with respect to validation datasets. The second part of the study focuses specifically on evaluating the thematic compatibility of datasets in terms of multi-scale legend typology and data aggregation potentials. Five selected datasets were compared based of their ability and mapping potentials to capture spatial patterns and features in landscape and provide information about land cover types regardless of scale. As a result, this study identifies on one hand areas with mapping priorities and on the other hand it highlights relevant limitations of current land cover typology and suggest improvements in perspective of future scale-independent land cover mapping.

Keywords: global land cover, multi-criteria analysis, mapping priorities, multi-scale typology

ID 18

SPATIAL SCALING OF LAND COVER NETWORKS

CHRISTOPHER SMALL, DANIEL SOUSA

Columbia University, United States of America

Presenting author e-mail address: csmall@columbia.edu

Abstract

Spatial networks of land cover are well-described by power law rank-size distributions. Continuous field proxies for human settlements, agriculture and forest cover have similar spatial scaling properties spanning 4 to 5 orders of magnitude. Progressive segmentation of these continuous fields yields spatial networks with rank-size distributions having slopes near -1 for a wide range of thresholds. Multi-decadal observations of spatial land cover networks also show that unity slope rank-size distributions persist as networks grow. We propose a general explanation for this scaling that does not require different process-specific mechanisms for each type of land cover. The same conditions that give rise to scale-free networks in general can produce power law distributions of component sizes for bounded spatial networks confined to a plane or surface. Progressive segmentation of a continuous field naturally results in growth of the network while the increasing perimeters of the growing components result in preferential attachment to the larger components with the longer perimeters. The generality of this process is demonstrated using random fields. Progressive segmentation of two types of random continuous field results in progressions of growing spatial networks with components that achieve unity power law rank-size distributions immediately before explosive percolation occurs. This suggests that the scaling properties and uniform area distribution implied by a unity power law rank-size distribution may be a general characteristic of bounded spatial networks produced by segmenting some continuous fields. The implication is that different process-specific mechanisms may not be required to explain the rank-size distributions observed for the diversity of land cover products described here.

Keywords: spatial, network, urban, agriculture, forest

ID 19

A CONTINUOUS INFRASTRUCTURE INDEX FOR MAPPING HUMAN SETTLEMENTS

CHRISTOPHER SMALL[1], SON NGHIEM[2]

[1] Columbia University, United States of America
[2] NASA Jet Propulsion Laboratory, United States of America

Presenting author e-mail address: csmall@columbia.edu

Abstract

The Landsat program provides more than three decades of decameter resolution multispectral observations of the growth and evolution of human settlements and development worldwide. These changes are often easy to observe visually but accurate repeatable quantification at Landsat's resolution has proven elusive. In part, this is a consequence of the multi-scale heterogeneity and diversity of settlements worldwide. Mapping settlement extent is also confounded by the lack of a single, physically-based, definition of what constitutes urban, peri-urban and other types of settlement. We attempt to resolve both of these challenges by characterizing built environments in terms of their distinctive physical properties. This can be accomplished by combining multi-temporal optical reflectance with synthetic aperture radar backscatter measurements to identify combinations of physical properties that distinguish built environments from other types of land cover. Three well-known examples include an abundance of impervious surface, persistent deep shadow between buildings and high density of corner reflectors at meter to decameter scales. At optical wavelengths, spectral properties of land cover can be represented using standardized spectral endmember fractions to represent combinations of the most spectrally and functionally distinct components of land cover; soil and impervious substrates, vegetation, water and shadow. The spectral similarity of soils and impervious substrates that makes thematic classifications error prone can be resolved by using multi-season composites of spectral endmembers to distinguish spectrally stable impervious substrates from temporally variable soil reflectance resulting from seasonal changes in moisture content (thus albedo) and fractional vegetation cover. By representing the diversity of anthropogenic land use as a continuous mosaic of land cover it is possible to quantify the wide variety of human settlements in a way that is physically consistent, repeatable and scalable. Our strategy is to develop and test algorithms to combine multi-season Landsat and Sentinel-2 optical multispectral imagery with SRTM and Sentinel-1 C-band radar backscatter imagery to produce a Continuous Infrastructure Index (CII) to identify and map changes in the extent of anthropogenic built environments (e.g. urban, suburban, exurban,

peri-urban) worldwide between 2000 and 2015. Rather than attempting to map specific features associated with built environments (e.g. impervious surfaces, buildings, roads), we characterize the combined optical and microwave response of a wide range of built environments to identify the physical properties associated with these features (e.g. spectral stability, persistent shadow, anisotropic backscatter intensity). We then use the most persistent of these properties to derive an optimized index incorporating multiple characteristics measured by both optical and microwave sensors. Variations in relative density of stable substrate (impervious surface), building shadow and corner reflectors are used to define a continuous space of built environment characteristics for different types of human settlement worldwide. Changes in CII between 2000 and 2015 will quantify both vertical and horizontal growth as well as temporal evolution of settlement networks worldwide.

Keywords: urban, settlement, Landsat, SRTM, Sentinel

ID 32

HYPERSPECTRAL IMAGING IN THE VISIBLE TO SHORT WAVE INFRARED SPECTRAL RANGE FOR LAND COVER MAPPING

DAINIS JAKOVELS, JEVGENIJS FILIPOVS, AGRIS BRAUNS, JURIS TASKOVS, GATIS ERINS

Institute for Environmental Solutions, „Lidlauks", Priekuli Parish, Priekuli County, Latvia

Presenting author e-mail address: dainis.jakovels@videsinstituts.lv

Abstract

Spectral imaging data is commonly used for mapping of land cover. Visible and near infrared spectral range is the most studied and used due to relatively cheap Si detectors. Short wave infrared can provide additional information to separate different materials and vegetation types, but requires more expensive optics and detectors. Thermal spectral imaging has become available in recent decades and could complement to land cover classification with information on the thermal emission of materials, but is rarely used due to availability of suitable data. Cross-sensor data fusion allows to combine the advantages of different spectral ranges, thereby striving for improved land cover mapping result.

In this study, three hyperspectral airborne sensor data covering spectral range 400-5000 nm was simultaneously acquired and tested for automatic land cover classification of seven general classes (urban/artificial, bare, forest, shrubland, agricultural/grassland, wetlands, water) and sub-classes specific for Latvia. Data acquisition was performed by Airborne Surveillance and Environmental Monitoring System (ARSENAL) in summer 2015 over three pilot territories (Cesis, Sigulda and Burtnieki) in Latvia to cover the most common classes. Hyperspectral data sets consist of 122 spectral bands in visible to near infrared spectral range (356-950 nm), 100 bands in short wave infrared (950-2500 nm). Classification of land cover was tested separately for each sensor data and fusing cross-sensor data. Simulation of Sentinel-2 data was performed to test performance of future satellite data.

Keywords: Hyperspectral imaging, Sentinel-2 data simulation, land cover, airborne remote sensing

ID 34

EAGLE LAND MONITORING MODEL – FROM CONCEPT TOWARDS PRACTICAL IMPLEMENTATION

BARBARA KOSZTRA[1], STEPHAN ARNOLD[2], NURIA VALCARCEL SANZ[3]

[1] Institute of Geodesy, Cartography and Remote Sensing (FÖMI), Hungary
[2] Statistisches Bundesamt (Destatis), Germany
[3] Instituto Geográfico Nacional (IGN), Spain

Presenting author e-mail address: kosztra.barbara@fomi.hu

Abstract

The EAGLE concept contains an object-oriented data model for land monitoring (LM), that allows the integration of data from "bottom-up" (national to European) information flow with European "top-down" land monitoring activities such as the Copernicus program. The proposed modeling approach can be helpful tool to enable national and European initiatives to fulfill current and future national and European user needs. In doing so, it can be adapted for countries proceeding in different ways and varying pace dependent on the availability and structure of national data.

The EAGLE data model and matrix allow semantic translation between classification systems by decomposing class definitions into Land Cover Components, Land Use Attributes and other Characteristics (e.g. cultivation measures, spatial patterns, status). The data model is flexible enough for integration of LC/LU information extracted from various different information sources, be it remote sensing or in-situ data (new in orbit Sentinel-1 and Sentinel-2, recently opened Landsat archive, Copernicus products, LUCAS point sample ground data, existing national land surveying datasets).

The basics of the concept were developed from 2010 on by the independent expert group EAGLE (European Action Group on Land Monitoring in Europe), resulting in a data model and a conceptual vision of application – presented also in the 2014 EARSeL LCLU WS. Supported by EEA, the group has since then elaborated a number of tangible documents and tools that facilitate the practical implementation of the EAGLE concept for users. These include full documentation of data model content, template database, online EAGLE model population and comparison tool for semantic decomposition, generalization and aggregation rule set. A series of semantic and geometric tests to prove the applicability of the concept have also been carried out.

The poster introduces the results of the latest developments and tests. Further it presents a few use cases of the EAGLE concept from the field of habitat mapping and monitoring (activities from public authorities as well as involvement of citizen science).

Keywords: EAGLE, land monitoring, object orientation, data model, LC/LU

ID 39

IMPLEMENTING THE CHANGE VECTOR ANALYSIS TECHNIQUE FOR ASSESSING SPATIO-TEMPORAL DYNAMICS OF LAND-USE AND LAND-COVER IN THE MU US SANDY LAND, CHINA

ARNON KARNIELI

Ben Gurion University, Israel

Presenting author e-mail address: karnieli@bgu.ac.il

Abstract

Sandification refers to land degradation in sandy areas. Considerable attention has been given to sandification processes in China since vast areas of sandy deserts are located in the north of the country within arid and semi-arid climatic zones. The current paper is aimed at assessing the land-use/land-cover spatial and temporal dynamics over the Mu Us Sandy Land, China, via change detection methodology based on spaceborne images. 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). CVA created four categories of land-cover change – vegetation, exposed sands, water bodies, and wetlands. The CVA's direction and magnitude result in pixel-based maps of the change rather than broad qualitative classes, such as slight-, moderate-, or severe land degradation that previously presented for this region. 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). Careful 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.

Keywords: Landsat, MODIS, NOAA-AVHRR, sandification, change vector analysis, China

ID 44

LARGE SCALE LAND COVER MAPPING USING DATA FUSION AND DEEP LEARNING APPROACH IN UKRAINE

NATALIIA KUSSUL[1,2], MYKOLA LAVRENIUK[3,1], *ANDRII SHELESTOV*[2,3,1], SERGII SKAKUN[4], OLGA KUSSUL[3], SERHII YANCHEVSKYI[1], IHOR BUTKO[1]

[1] Space Research Institute NASU-SSAU, Ukraine
[2] National Technical University of Ukraine "Kyiv Polytechnic Institute", Ukraine
[3] Integration-Plus, Ukraine
[4] University of Maryland, College Park, MD, USA

Presenting author e-mail address: andrii.shelestov@gmail.com

Abstract

A big amount and heterogeneity of free satellite data (SAR and optical) opens room for large scale land cover and land use mapping with high resolution. Large-scale mapping of land cover and land use can be considered as a problem of automated processing of big amount of geospatial data, which may contain various uncertainties (for example, clouded areas). To solve the problem, we propose deep learning method, based on neural network approach and geospatial analysis. It includes three paradigms of computer sciences, namely, the decomposition technique ("divide and conquer") from the theory of algorithms, the method of active learning from intelligent computing, and the method of satellite image reconstruction from image recognition. Such an approach allows us to minimize the participation of experts in solving the problem. Within solving the problem of land cover classification we also investigated three different approaches of data fusion. The most efficient data fusion method is one that could be reduced to the problem of classification on the base of time-series images. Developed automated methodology is based on Landsat and Sentinel-1 and -2 data time series and is applied to land cover mapping and classification for the whole territory of Ukraine.

Keywords: land cover, big data, deep learning, neural network, data fusion

ID 50

TOPOGRAPHIC NORMALIZATION OF MEDIUM RESOLUTION OPTICAL SATELLITE DATA WITH A FINE-SCALE DEM

HEATHER REESE, HÅKAN OLSSON

Swedish University of Agricultural Sciences, Sweden

Presenting author e-mail address: Heather.Reese@slu.se

Abstract

Sweden's national airborne laser scanning has resulted in a nationwide digital elevation model (DEM) with a 2 m grid cell size, which can be used for topographic normalization of optical satellite data. In an alpine vegetation area in northern Sweden, SPOT-5 data were normalized using Teillet et al.'s C-correction and variations on the DEM resolution, namely 1) DEM generalization to 10 m pixel, 2) DEM generalization to 20 m pixel, and 3) direct use of the 2 m DEM for sub-pixel normalization. The best sub-pixel normalization approach used a surface-area based weighting of the elevation derivatives within the 10 m x 10 m SPOT-5 pixel.

The results showed that the first approach produced anomalies in the resulting image; the second approach produced the best reduction in topography-induced spectral differences; and, while the third approach did not provide the best normalization, it did provide valuable insights into the influence of topography at the sub-pixel level. It could be seen that scale of observation was important when applying C-correction, that short and abrupt changes in topography affect correction differently (non-linear effects) depending on the scale of observation, and that the effect of shadow due to short, steep topographic changes could be seen to affect the correction of infrared wavelength bands more than in the visible wavelength bands.

These results will be relevant to our newly funded alpine land cover mapping project using Sentinel-2 data (Swedish Space Agency), as well as other studies which apply topographic normalization to medium resolution data using fine resolution DEMs.

Keywords: topographic normalization, ALS, SPOT, alpine, Sentinel-2

ID 61

TIME SERIES CONSOLIDATION AND DENSIFICATION USING DYNAMIC TIME WARPING TECHNICS

SEBASTIEN SAUNIER[1], BEATRICE BERTHELOT[2]

[1] Telespazio / Vega UK, United Kingdom
[2] Magellium, France

Presenting author e-mail address: sebastien.saunier@telespazio.com

Abstract

The Dynamic Time Warping (DTW) similarities distance is now mainly used in the context of land cover classification. The scope of this work is the use of the DTW technics in the context of multi sensor data fusion. A new method for the production of dense Landsat 8 /Sentinel 2 time series is proposed.

This high level objective is achieved by following two fundamental stages, the consolidation of the sentinel 2 data and the densification of Sentinel 2 data by using Landsat 8 data. The aim of consolidation is to optimize the quantity of available data, in particular to recover value of masked pixel because of cloud or shadow. The densification is a subsequent process dedicated to integrate heterogeneous data into a mono sensor time series, it implies band pass adjustment, geometric re-gridding.

This article describes the overall concept and also the technics that have been used for time series consolidation. The DTW has been successfully apply for consolidation and the accuracy of the estimate is dramatically better compared with the most commonly used method. Also, this article presents the validation methodology and the results of the validation including sensitivity of the methods to different parameters. Furthermore, the first results on Sentinel 2 and Landsat 8 time series data fusion are given. Beside the algorithm performance and benefic improvements are drawn up.

The proposed concept is dedicated to the provision of multi sensor dense time series. The delivered time series is fit for the purposes of different application including LU LC classification.

Keywords: DTW, classification, pixel based, time series

ID 6

A WORKFLOW FOR AUTOMATED SATELLITE IMAGE PROCESSING: FROM RAW DATA TO OBJECT-BASED SPECTRAL INFORMATION

DIMITRIS STRATOULIAS[1], ROLF A. DE BY[1], VALENTYN TOLPEKIN[1], RAUL ZURITA-MILLA[1], WIETSKE BIJKER[1], MOHAMMAD A. HASAN[2], ERIC VERMOTE[3]

[1] ITC Faculty of Geo-Information and Earth Observation, University of Twente, The Netherlands
[2] University of Rhode Island, Kingston, RI, USA
[3] NASA Goddard Space Flight Center, Terrestrial Information Systems Laboratory, Greenbelt, MD, USA

Presenting author e-mail address: dimitris.stratoulias@gmail.com

Abstract

Earth observation has become a progressively important source of information for land use and land cover services over the past decades. At the same time, an increasing number of reconnaissance satellites have been set in orbit with ever increasing spatial, spectral and radiometric resolutions. The available bulk of data, reinforced by the open access policy adopted by several agencies, have reformed remote sensing processing from a use-driven image analysis to a challenge of big data handling of imagery and the associated metadata. This sets a new landscape in remote sensing, not only in the sense of archiving and processing large volumes of information source, but also accommodating the need to provide information in near-real time from the image acquisition which is becoming necessary for rapid emergency responses and decision making.

This study presents a fully automated satellite image workflow developed to process a large data volume accumulated in the Spurring a Transformation for Agriculture through Remote Sensing (STARS) project. STARS aims to address the potential of Very High Spatial Resolution (VHSR) imagery in assisting smallholder farmers in sub-Saharan Africa and South East Asia. One of the main objectives is to analyze the spectral information of this multi-temporal and multi-sensor dataset and establish implementation flows to support stakeholders, decision makers and economic development. Practically, this is a development of a processing flow from raw satellite image to crop-related information assigned per individual smallholder farm plot and the associated products that can be extracted. The proposed workflow extracts meaningful information from a data vault of very high spatial resolution satellite imagery and provides crop reflectance of a time series of multi-sensor

imagery. This development has been the outcome of the realization of the need to develop automated processes from the early stages of the project; moreover, the specifications of the project's tasks have established dependencies on the final product that are specific to both the data source and the objectives addressed. For instance, the size of the smallholder agricultural farms is typically that of a few hectares at most, which translates to only a few pixels in a VHRS satellite image. This means that monitoring such farm plots needs highly accurate georegistered images. Moreover, crop monitoring over the growing season requires accurate surface reflectance products from several different satellite platforms and products.

The developed workflow is based on sequential processing steps for Orthoready and basic satellite image products as typically delivered by image providers. The workflow is fully based on free and open software packages and runs on a Linux machine. Most of the processing is done with R, however Python, FORTRAN, and the Orfeo Toolbox are used as well. This workflow has been tested and applied on a multi-sensor image archive of over 270 VHSR deliveries of WorldView-2, WorldView-3, QuickBird, GeoEye, Ikonos and RapidEye data in five different test areas in South-East Asia and sub-Saharan Africa.

Keywords: Automated processing, workflows, very high spatial resolution, surface reflectance, satellite image

ID 7

EXPLORING LAND USE CHANGE IN SINGAPORE USING GOOGLE EARTH ENGINE

NANKI SIDHU[1], EDZER PEBESMA[1], GILBERTO CÂMARA[1,2]

[1] Institute for Geoinformatics, Muenster, Germany
[2] National Institute for Space Research, Brazil

Presenting author e-mail address: n_sidh01@uni-muenster.de

Abstract

Landscapes of cities and towns undergo continuous change. It becomes paramount to track and forecast these changes for proper resource and urban planning. Many different user groups, both scientific and non-scientific, utilize remote sensing data for their own work and research. Currently available remote sensing datasets are derived using various methods and sensors, and follow different classification systems. The widespread utility of these products therefore demands a thorough exploration of the differences in their qualities and statistical accuracy. Moreover, it must be made possible to handle large volumes of data in an efficient manner, particularly for global scale analysis.

This paper investigates the web based remote sensing platform, Google Earth Engine, and evaluates the utility of this platform for performing raster, vector and array manipulations on Landsat, MODIS and GlobCover (2009) imagery. We assess its capacity to conduct space-time analysis over two sub-regions of Singapore, namely Tuas and the central catchment reserve, for urban and wetlands land use classes. In its current state, this platform has proven to be a powerful tool by providing access to a wide variety of imagery in one consolidated system. Furthermore, it possesses the ability to perform spatial aggregations over global-scale data at a high computational speed. By testing the limits of such a platform, we also examine the challenges that Google Earth Engine faces, which are common to most parallel processing, big-data architectures. Supporting both spatial and temporal analysis is not an obvious task. The ongoing refinement of this system makes it a valuable and promising tool for big data analysts from diverse user groups.

As a use case for exploring Google Earth Engine, we are also able to analyze Singapore's land use and land cover. We highlight the change in Singapore's land mass due to the widespread practice of land reclamation, mainly through dredging. Also, within the region of the central catchment reserve, which is a large protected area, we find that the forest cover is not affected by anthropogenic factors, but instead is driven by the monsoon cycles that affect South-east Asia.

Keywords: Land use change, urban planning, Google Earth Engine, big data architecture, data exploitation

ID11

POTENTIAL OF FUTURE GLACIER MAPPING USING DENSE TIME-SERIES OF OPTICAL SATELLITE IMAGERY

SOLVEIG HAVSTAD WINSVOLD, ANDREAS KÄÄB, CHRISTOPHER NUTH

University of Oslo, Norway

Presenting author e-mail address: s.h.winsvold@geo.uio.no

Abstract

Glaciers are found in mountain or marine regions that are often affected by cloud cover. Currently, snow and ice are typically classified from optical satellite images using multi-spectral band ratios. The recently launched Sentinel-2A satellite and its twin Sentinel-2B (launching in end 2016), has similar characteristics as the Landsat TM/ETM+/OLI satellites. Together, these satellites will produce a tremendous quantity of medium-to-high resolution optical images worldwide suitable for glacier mapping, with increasing temporal resolution and coverage towards the more glacierized higher latitudes due to convergence of the near-polar orbits. Therefore it will be an increasingly challenging task to manually select the best annual or multiannual satellite image with preferable mapping conditions, as is the practice within the current method. Instead, the large amount of information in the dense time-series of the multiple optical sensors calls for new ways of mapping glaciers.

Our example data is based on the above-mentioned robust image ratio-method and show a seasonal variation on glaciers throughout a year, presumably because of the metamorphosis of snow. The dense time-series presented in four application scenarios, was interpreted in two ways: 1) stack statistics for each pixel, and 2) chronological interpretation of the data. First, we synthesize an optimal band-ratio image from a stack of images within one season to compensate for regional differences occurring within a single satellite scene. The second application scenario introduces robust methods to improve automatic glacier mapping by exploiting the above seasonal variation in spectral properties of snow. Typical Sentinel-2 MSI/Landsat 8 OLI high temporal resolution data was simulated using a combination of Landsat TM 5 and ETM+ 7 over a period of 4 years. Third, we explore the spatio-temporal variation of glacier surface types. Finally, we show how the synthesized band ratio images from the first application scenario can be used for automatic glacier change detection. In summary, we have explored automatic algorithms for glacier mapping applications that exploit the temporal signatures in the satellite data time-series.

Keywords: Glacier mapping, Time-series, temporal signatures, optical satellite imagery

ID 17

CAPTURING THE DYNAMICS IN THE FRAGMENTS OF VIRGIN FOREST OF CARPATHIAN REGION USING DENSE SATELLITE IMAGE TIME SERIES

IVÁN BARTON, GÉZA KIRÁLY

University of West Hungary, Faculty of Forestry, Hungary

Presenting author e-mail address: ivan.barton@student.nyme.hu

Abstract

Land cover change dynamic was quite strong in the Carpathian region in the past few centuries. The most affected type was the forest cover. Hopefully some fragments of virgin forests remained for the future and they are providing a great opportunity to study the natural forest structure changes trough the time. These fragments are situated in the following countries: Czech Republic, Hungary, Poland, Romania, Slovakia, and Ukraine. In the dynamics of virgin forest we would like to see if the different uneven aged parts could be separated by the different magnitude of change in trends of growing. Assuming that these old-growth forest fragments didn't have any artificial disturbance at least in the last century we couldn't expect any big disturbance event over the study area. Thus we have to use a dense time series of data to study the trends of the structural changes. Earth observation satellites are providing this data with high resolution for the last 32 years in form of spectral information. Also the availability of the images has become much easier since some image database become freely available for research purposes. Both Landsat and SPOT are providing great archives and the new Sentinel satellites are producing promising imagery for this kind of purposes. A dense time series of images could be assembled from 1984 until 2016. Working on forests with remote sensing is always challenging. The spectral reflection of the vegetation is highly dependent on topographic position and the local weather conditions. Sparse time series analyze period could be misleading by these effects easily with one image per. The small disturbances could stay unrecognized even on high resolution satellite imagery. In a long term observation with dense time series these small events could be seen. The data availability for some period in the past is still problematic thus we have to use multi sensors. During the cross comparison of the different sensors difficulties could arise. However the dense time series of the study area consist of hundreds of images the studied forests are covering only 78 700 ha. To make analysis more effective we have to store the information of images in different way as it used to. Creating a unified GIS based database with a well designed structure of spatial indexes makes the process faster. Some

automated approach had been developed for this kind of trend analyze on satellite imagery. By creating a new automated method which can handle the mentioned difficulties we could carry out the expected trends and derive the region maps of virgin forests fragments in the Carpathian region. After a while with recently launched sensors the system will provide more frequent and more detailed information about the interested regions in the future. We could make rough estimations from the trends for the changes which will complete the field observations of researchers in other fields.

Keywords: forest dynamics, time series, Landsat, Sentinel-2, SPOT

ID 23

MULTI-TEMPORAL LANDSAT IMAGERIES FOR URBAN BUILT-UP AREA EXTENSION ANALYSIS

AKJOL DJENALIEV[1,2], MARTIN KADA[1], OLAF HELLWICH[1], AKYLBEK CHYMYROV[2]

[1] Technische Universität Berlin, Berlin, Germany
[2] Kyrgyz State University of Construction, Transport and Architecture, Bishkek, Kyrgyzstan

Presenting author e-mail address: djakjol@mailbox.tu-berlin.de

Abstract

Historically, the multi-temporal analysis of remote sensing imagery has been an important source for the extraction of land use and urban area information in order to monitor natural resources and urban environments. However, the acquisition of aerial photographs and very high spatial resolution data is very expensive for large geographic areas. It is therefore one of the most challenging tasks to get up-to-date spatial information in developing countries. An alternative to acquire the much needed urban information for large areas is Landsat satellite imagery, which has been available since 1972.

The mapping and analysis of urban territories by using satellite imagery have been playing a significant role in the last decades. Kyrgyzstan is a post-soviet country in Central Asia with the lowest economy in the region. The illegal and uncontrolled extension of built-up areas is affecting the urban economy and vulnerability of citizens to natural hazards like earthquakes. The lack of funding for aerial photography and very high resolution satellite imagery causes intensive use of Landsat products for multi-temporal spatial analysis.

In this study, imagery from Landsat-2 MSS, Landsat-5 TM and Landsat-8 ETM+ for the years 1977, 1991, and 2015 are used for urban built-up area extension analysis. The sub-scenes covering Karakol city in Kyrgyzstan were extracted from three multi-temporal Landsat images. Then, an object-based image analysis has been performed using eCognition Developer software by the company Trimble. An eCognition project with 18 image bands was created, where each satellite image has been analyzed independently. The whole image analysis process is stored in a rule-sets based as an automated workflow system. These include image band rationing, tasseled cap transformations, NDVI and other object characteristics based on shape, texture and class-related features information. It starts with creating individual maps for each satellite image followed by a multi-resolution segmentation. This algorithm can be explained as a bottom-up region-merge technique which starts with single pixel objects and considers homogeneity of neighboring pixels with

regard to colour and shape. Using membership functions of fuzzy logic that is based on characteristics of image objects and a nearest neighbour classifier, land use and land cover classes have been generated for each time period. The change statistics of land use classes including the information of existence, number and area of sub-object classes are tabulated.

The classified urban areas of land use are then re-segmented by a top-down approach and re-classified into built-up and non built-up area classes. The other land use classes are re-classified as non-built-up areas. Afterwards, the topographic maps with 1:50,000 scales from the years 1975 and 1994 in addition to GPS field survey data are used for the classification accuracy assessment. Finally, the common approach of the change detection analysis is generated to map the spatial distribution of built-up area extension.

Keywords: Landsat imagery, object-based image analysis, multi-resolution segmentation, eCognition Developer

ID 25

IMAGEQUERYING – AUTOMATIC REAL-TIME INFORMATION EXTRACTION AND CONTENT-BASED IMAGE RETRIEVAL IN BIG EO IMAGE DATABASES

DIRK TIEDE[1], ANDREA BARALDI[1,2], MARTIN SUDMANNS[1], MARIANA BELGIU[1], STEFAN LANG[1]

[1] Department of Geoinformatics - Z GIS, University of Salzburg, Austria
[2] Department of Agricultural and Food Sciences, University of Naples Federico II, Portici (NA), Italy

Presenting author e-mail address: dirk.tiede@sbg.ac.at

Abstract

ImageQuerying (IQ) is an incremental system for automatic near real-time image information extraction and content-based image retrieval (CBIR), suitable for big Earth observation (EO) data analytics. IQ is built upon a hybrid (combined deductive and inductive) inference engine for low- and high-level EO image understanding, independent of the multi-spectral (MS) imaging sensor. Each MS image or image time-series stored in the EO database is automatically provided by IQ with at least one (or more) thematic map(s), consisting of semantic image-objects in compliance with the increasingly popular object-based image analysis (OBIA) paradigm. Through the IQ graphic user interface, a user can: (1) perform semantic CBIR, where the comprehensive archive of EO image-derived thematic layers is queried, (2) Develop original decision rules, where spatial and temporal operators are input with available image-derived qualitative (categorical) or quantitative (numeric) information layers. For example, semantic trajectories (change/no-change) can be tracked through time by the IQ inference engine, resembling symbolic human reasoning based on a convergence-of-evidence approach. New thematic maps generated by user-defined decision rules steadily expand the knowledge base of the incremental IQ system.

To fill the information gap from sub-symbolic pixels to symbolic image-objects, the IQ's hybrid inference engine comprises several low-level vision modules. The most important one is an expert system (prior knowledge-based decision tree) capable of partitioning radiometrically calibrated MS data (e.g. Sentinel-2A, Landsat-5 to Landsat-8, MeteoSat, RapidEye, WorldView, etc.) into a pre-defined dictionary of color names. Called Satellite Image Automatic Mapper (SIAM), it transforms radiometrically calibrated MS images into preliminary classification maps. Based on these primitive information processing blocks, both quantitative and categorical (nominal) variables like geometry information of the pre-

classification or spectral indexes are automatically extracted from every MS image stored in the EO database. Through the IQ's GUI, image-derived information layers are made available to a user for CBIR or geospatial data analysis applications.

To accomplish efficient geospatial data analysis through time within a user-defined AOI and target time interval, the current IQ implementation adopts an array database system (specifically, RasDaMan) within a client-server solution together with a web-based query interface. The IQ's GUI comprises a graphical query mode. It supports: (i) the selection of existing geospatial semantic queries and (ii) the graphic generation of new geospatial semantic queries. The application domain of geospatial semantic queries is twofold. (1) CBIR. For example, retrieve EO images that are cloud-free across the AOI, or those where a specific vegetation type is found in the AOI, etc. (2) Generation of new information layers. For example, detect flooded areas as a post-classification combination through time of available single-date thematic maps; detect-through-time evergreen vegetation; detect clear cuts as a vegetation cover change in time, etc. For complex semantic image queries, where the user expertise is required to bridge the semantic gap from low- to high-level image information, a knowledge transfer paradigm, from humans to the incremental IQ, is supported by the IQ's graphic query generator.

The test implementation of the IQ system was awarded with the Copernicus Masters 2015 - T-Systems Big Data Challenge.

Keywords: image big data, semantic querying, real-time LULCC analysis, content-based image retrieval

ID 35

MAPPING CROPLANDS USING LANDSAT DATA WITH GENERALIZED CLASSIFIER OVER LARGE AREAS

MUTLU OZDOGAN, APARNA PHALKE

University of Wisconsin Madison, United States of America

Presenting author e-mail address: ozdogan@wisc.edu

Abstract

Accurate and up-to-date maps of agriculture play an important role in the study of food security. However, mapping croplands over large areas with remote sensing using traditional image classification tools involving one time, one place approach requires significant computing and labor resources. Moreover, large area cropland mapping holds extra challenges because of the seasonal changes, variation in crop type and crop intensities. Here we report on a generalized image classifier based on Linear Discriminant Analysis (LDA) and the idea of signature extension applied to temporal statistics of vegetation indices derived from Landsat satellite data combined with climatic and topographic variables. We selected 17 Landsat footprints spread over various climatic zones in Europe, Middle-East and North Africa covering the 2009-2012 period. We further applied the generalized classifier at three different levels: own level where training and testing data are extracted from the same footprint; zone level where training data are extracted from all footprints in a zone; and the global level where all 17 footprints form the source of training data. The results show that the generalized classifier is successful in identifying and mapping croplands with comparable success across all three levels, which shows the efficiency of the algorithm. Further, when the generalization/signature extension approach is applied to randomly selected footprints that were not involved in the original training process outside of the 17 core locations, results are encouraging. The work has important implications for large area cropland mapping using the generalization/signature extension framework that requires very little user input and has the potential to map crop types across regional to global scales with 30m spatial resolution.

Keywords: Landsat, croplands, classification, data mining, generalization

ID 46

CROP CLASSIFICATION AND LAND USE CHANGE MAPS BASED ON TIME SERIES OF LANDSAT AND SENTINAL-2 OPTICAL DATA

MYKOLA LAVRENIUK[1,3], ANDRII SHELESTOV[1,2,3], NATALIIA KUSSUL[1,2]

[1] Space Research Institute NASU-SSAU, Ukraine
[2] National Technical University of Ukraine "Kyiv Polytechnic Institute", Ukraine
[3] Integration-Plus Ltd., Ukraine

Presenting author e-mail address: nick_93@ukr.net

Abstract

The increasing amount of remote sensing data, particularly optical Landsat and Sentinel-2 images causes the "Big Data" problem. To solve this problem and discriminate different crops and grassland during crop type classification, we have developed hierarchical deep learning method that consists of four stages: missing (clouded) data restoration, crop classification based on time-series using ensemble of neural networks, maps filtration and geospatial analysis. To deal with such amount of data we need powerful instruments like Google Earth Engine (GEE). The proposed approach is applied to develop high resolution maps of land cover for Ukraine (1990, 2000, 2010 and 2015) based on Landsat and Sentinel (2015) data and obtained land use changes maps for the last three decades. We have discovered, that area of arable lands is significantly decreased in Western and Northern parts of Ukraine and in the Eastern administrative regions. Long term time series of imagery allowed us to build productivity maps of arable lands for 2000-2005, 2005-2010 and 2010-2015 years in Ukraine and validated at JECAM – Ukraine test site (Kyiv region). Nowadays we can add Sentinel-2 data to improve classification results and to provide more accurate land use changes and productivity maps.

Detailed results based on Landsat and Sentinel-2 optical data will be presented at the workshop.

Keywords: Big Data, deep learning, GEE, land cover changes, JECAM

ID 48

LAND COVER CLASSIFICATION BASED ON MULTI-TEMPORAL SAR DATA

EDYTA WOŹNIAK[1], WLODEK KOFMAN[1,2], STANISŁAW LEWIŃSKI[1], PAWEŁ WAJER[1], MARCIN RYBICKI[1], SEBASTIAN ALEKSANDROWICZ[1]

[1] Space Research Centre of Polish Academy of Sciences, Poland
[2] Institut de Planetologie et d'Astrophysique de Grenoble, CNRS, France

Presenting author e-mail address: ewozniak@cbk.waw.pl

Abstract

The objective of the work was to elaborate land cover classification using time series of Sentinel-1 SAR data. To fulfill the objective we used the Sentinel-1 ESA Toolbox for dual polarization image classification of A/alpha plane employing unsupervised Whishart classifier and we developed dedicated software (MT_SAR) for multi-temporal, dual-polarization SAR image pre-processing, which is not included in the Sentinel-1 ESA Toolbox. We implemented in the MT_SAR software procedures for calculation of: multi-temporal coherency matrices for single polarization (VV, VH, HH) and dual polarization (VV/VH, HH/HV, HH/VV) normalized multi-temporal coherency matrices H/A/alpha decomposition of multi-temporal coherence matrices.

The pre-processed data were classified in various configurations of inputs. The object oriented approach was used. We tested the influence of the dimension of the segments on the classification results. Several classifiers were applied: Support Vector Machines (SVM), Decision Trees (DT), K-Nearest Neighbors (KNN).

The study was carried out for the area of Warsaw and surroundings. 13 Sentinel-1 satellite images acquired from April to October in 2015 were used in the classification. The basic land cover classes were mapped. We present the classification results and their changes in a function of input used data, segments dimensions and applied classifier.

Keywords: Land cover classification, Sentinel-1 time series, multi-temporal coherence and H/A/alpha decomposition

ID 52

ON THE APPLICATION OF HMMS ON SATELLITE TIME-SERIES FOR HISTORIC AND NEAR-REAL TIME LAND COVER MAPPING: THE LANDSAT CASE STUDY OVER THE SAO PAULO STATE (BRAZIL)

LORENZO IANNINI, RAMSES MOLIJN, RAMON HANSSEN

Delft University of Technology, Netherlands

Presenting author e-mail address: l.iannini@tudelft.nl

Abstract

A big amount of remote sensing data have already been collected on broad scale for several years and even larger volumes are expected in the following years. One of the main scientific challenges awaiting the earth observation community is hence to provide effective assimilation models for the multifaceted spaceborne data series. In this context, the present work intends to promote a vision of land cover (LC) map products leaning towards an the efficient use of multi-temporal data to achieve 'offline' (historic analysis) as well as near-real time (NRT) LC classification and change detection functionalities. The theoretical foundation of the proposed approach is based on the Hidden Markov models and in its practical implementation has logically designed around the Landsat (5 and 8) time series. It should be however remarked that the statistical framework has been designed to easily accommodate other data sources, such as Sentinel-1 and Sentinel-2. The discrete-time state chain model employs short steps of 16 days, that conveniently fits the Landsat revisit time while providing a continuous and temporally dense representation of the land cover dynamics. Two temporal pattern typologies were identified and modeled within the proposed Markov chain architecture: a seasonal and synchrounous behavior which can be associated to the observables of LC classes such as forest and grasses, and a highly asynchronous behaviour, which characterizes the crop observables. The first typology is addressed by introducing time-dependency in state output probabilities, whereas the latter is rendered through a sequence of (sub-class) states interlinked by means of a 'left-right' based model. Such model inherently incorporates crop growth tracking functionalities as an added value. The system has been validated over a case study site within the state of Sao Paulo, Brazil. The area includes the following land use classes: forest/shrubland, water, urban areas, pasture and both permanent and annual crops. Among the crops, sugarcane has been separately trained and classified, as it represents the dominant crop in terms of area and expansion dynamics. The Landsat 5 and 8 imagery from 2003 to the present day (with a time gap between 2011

and 2013) were used to test the technique. Upon proper class training from a combined use of ground surveying information, Google Earth VHR imagery and Landsat time-series, the technique returns very promising results. Class accuracies (producer and user) above 90% are registered for all classes except for pasture and annual crop which record values ranging between 80% and 90%, showing some mutual confusion. In conclusion, both theoretical and practical aspects will be unveiled. Among these, a sensitive outline on the incorporation of the aforementioned supplementary data sources (Sentinel-1 and Sentinel-2) into the algorithm will be drawn.

Keywords: time-series processing, land cover classification, Hidden Markov models, crop monitoring

ID 54

MAPPING TEMPERATE MOUNTAIN FOREST REGROWTH AND DISTURBANCE DYNAMICS USING LANDSAT TIME SERIES

KATARZYNA OSTAPOWICZ

Jagiellonia University Institute of Geography and Spatial Management, Poland

Presenting author e-mail address: katarzyna.ostapowicz@uj.edu.pl

Abstract

Monitoring and assessing changes in forest cover is crucial to address many environmental and resources related questions. In recent years, much progress has been made in landscape-level analysis of forest disturbances and regrown and their spatial and temporal pattern assessment using remote sensing. However, in particular in mountain areas problems with e.g. optical satellite data availability due high cloudiness or concerns due to frequency of data acquisition e.g. Landsat data outside the United States case (e.g. studies which focus on past and going back to 70's and 80's) are faced. This study explores the utility of two-annual pixel-based Landsat composites time series for monitoring and assessing forest regrown and disturbances base on example from the Polish part of the Carpathian Mountains over last thirty years (from 1985 to 2015). In particular, we focus here on detection of secondary succession on abandoned agriculture lands and disturbances (both abrupt and gradual) in private and state forests. We used temporal segmentation of two-annual Landsat composites time series to mapped regrown and disturbance trajectories. Our results show that this approach can provide accurate spatial and temporal characteristics a 30-years history of forest but also agriculture changes in the study region with highly complex land cover/land use spatial pattern and legacies. In general, our results suggest parallel processes, a slight net increase in forest cover but still also a net decrease in forest cover. Forest cover has likely increased due to agriculture lands abandonment intensification (both arable lands and grasslands) and secondary succession but as well afforestation policy in the study region. While disturbances rates relate mostly to long-term degradation cause by simultaneously occurred biotic and abiotic drivers (i.e. species composition – spruce monoculture, atmospheric deposition of sulphur and nitrogen). In general, our results confirm that broad range of change events types and conditions like abandoned agriculture lands, secondary succession and different types of forest disturbances can be mapped at landscape-level with two-annual Landsat time series (multi-years composites) which could be also applied in other land cover change studies not only in temperate zone and mountain areas.

Keywords: change detection, temporal analysis, image compositing, Landsat (TM, ETM+, OLI)

ID 59

NOVEL METHODOLOGICAL APPROACH TO ANALYSIS OF SPATIO-TEMPORAL CHANGE TRAJECTORIES OF WOOD-PASTURES ON AN EXAMPLE OF A CASE STUDY IN THE CZECH REPUBLIC

ANNA PEREPONOVA, MICHAL FOREJT

Czech University of Life Sciences, Prague, Czech Republic

Presenting author e-mail address: pereponova@fzp.czu.cz

Abstract

The research addresses the issue of a methodological approach towards analysis of historic changes in wood-pastures, represented by landscape segments of trees scattered through a mainly grasslands open area, as the oldest land-use type in Europe. Despite their high ecological, cultural, and agricultural importance, these landscapes have recently experienced rapid decline all over Europe due to intensive tree cutting, changes in land use, and lack of regeneration. Although wood-pastures in their originally conceptualized form are currently very sparse in the Czech Republic, some traces of the old areas and occasional new parcels can still be found. Despite the recent increase in the number of related studies, information on historic change patterns of these areas remains incomplete. Data sources are limited and differ in scale and details they provide depending on the period. Therefore, a thorough methodology is needed to study spatial and temporal changes of such landscapes. The main goal of this project is to develop and test an effective approach to assess change patterns of wood-pastures in the Czech Republic at the landscape level. The part of project presented here shows a case study for the sites located in Czech lowlands, selected to reflect different cadasrat areas (thus, different policies) and climate/ geomorphology landscape types. A more convenient and accurate method was developed, which allows to combine the available data sources (archival and modern graphics, such as old maps, aerial photographs, etc., and text documents) from three temporal horizons (the first half of the 19th century, 1950s and the present) and to still be able to get reliable results, regardless of any definition and data representation differences. A new categorization system for grasslands was created for the purpose. Analysis was performed using Microsoft Excel (Microsoft) and ArcGIS 10.2 software (ESRI); namely, manual vectorisation of the segments, and further application of Intersect tool to create a single feature class from the three of each temporal horizons and Field Calculator to organize the codes from the three fields together into a single one in the attribute table and Feature to

Raster tool to sum all features of each trajectory into one group. Consequently, elements of wood pastures were categorised into continuous, extinct and recent. The advantages and limitations of the methodology are further analysed in greater detail and a possible explanation with regard to different types of drivers is suggested.

Keywords: GIS, landscape change, spatio-temporal, trajectories, woody grasslands

ID 63

SHOULD WE DISCUSS LAND COVER ANALYSES IN THE CURRENT PLANETARY DATA RESEARCH? COMPARATIVE PLANETOLOGY AND CLC DISCUSSION

KRZYSZTOF SKOCKI, NATALIA ZALEWSKA

Institute of Aviation, Center of Space Technologies, Remote Sensing Laboratory, Warsaw, Poland

Presenting author e-mail address: krzysztof.skocki@ilot.edu.pl

Abstract

Remote sensing is not only Earth-related activity. Starting from mid 60's, number of spacecrafts travel through Solar System to collect imagery of planets and small bodies, like comets or asteroids. Any of these probes carry cameras and spectrometers to collect planet surface imagery – our base for knowledge of state and processes forming planetary surface. The Mars Global Surveyour mission, first of the long series of advanced orbiters, started to change our understanding of the planet activity and geological history. Now, Mars Express, 2001 Mars Odyssey and Mars Reconnaissance Orbiter missions, as well as two surface mobile robots, MER Opportunity and MSL Curiosity, acquire the data from the surface in various spatial and spectral resolution. Data fusion of is an issue, when both very high-resolution panchromatic data (HiRiSE, better than 1 meter ground resolution), mid-resolution, hyperspectral data (CRISM, 544 channels, 18 meters per pixel), and nearly 2 km resolution for Planetary Fourier Spectrometer on Mars Express mission the data are available. In between, THEMIS data (5 channels, 18 meters per pixel) cover relatively large areas of the Martian surface, and MOLA satellite laser altimetry gives the best DEM available for all Solar System planets.

Standard techniques well known from terrestrial remote sensing, like pan-sharpening or channel indices can be used to detect and map surface features, related to geology, geomorphology or sedimentology. In terms of modified land cover mapping, data, especially from imaging spectrometers, can be used for analysis focused on bare surface classes, like genetic types of sediments, morphological forms and geological layers observed. Interpretation of two of presented cameras give a good similarity to standard Landsat-based sensing and surface interpretation methods.

From other point of view, experience in planetology, related to observation of bare soil, ice, sediments, rock outcrops and morphological features on the planets can be

discussed in terms of terrestrial research, especially for desert areas (both hot and cold). Practical needs related to unified description of planetary surfaces can be discussed on the base of interpretation of CLC class 3.3 – extended and enhanced to level 4 or level 5 will make a base for possible similar planetology-related scheme. Thus, such extended scheme can be discussed to be used for terrestrial applications in the future, with profits for later comparative studies of Earth and planets – it can enable easy seeking procedure to find applicable analog terrains on the surface of Earth.

Keywords: high-resolution panchromatic, hyperspectral, planetology, CLC, data fusion

ID 10

NEAR REAL TIME MAPS OF RICE EXTENT AND CONDITION USING MULTI-SOURCE REMOTE SENSING

NATHAN TORBICK, WILLIAM SALAS

Applied Geosolutions, United States of America

Presenting author e-mail address: ntorbick@appliedgeosolutions.com

Abstract

Rice decision support tools (DST) are limited by scalability, spatial and temporal resolution, and data availability. Remote sensing has played a key role is supporting rice DSTs and we have made significant progress; however, timely information on extent and operational indices that are tied to phenological calendar (e.g., Start Of Season, growth stage, management, and risk) at moderate resolution lack in current tools. We begun implementing operational mapping of rice that fusesALOS-2 PALSAR-2, Sentinel-1, and Landsat 8 at sites in Myanmar, Vietnam, and USA. The approach uses multitemporal imagery that keys off rice phenological charateristics to generate accurate maps of extent shortly into a crop season. By comparing aginst histroical archives or across space a more through characterization of condition, inundation, and growth stage is feasible. We are now testing against new field measurements to understand uncertianty and refine algorithms. A large effort is place on using open source tools, data sharing, and supporitng MRV end users in a transparent and robust fashion.

Keywords: rice, Sentinel-1, PALSAR-2, inundation, emissions

ID 13

AUTOMATED WORKFLOWS, NEW SENSORS AND HIGH DATA INTEROPERABILITY - REMOTE SENSING BASED LAND COVER MAPPING FOR NATURE CONSERVANCY IN RHINELAND-PALATINATE, GERMANY

GREGOR TINTRUP-SUNTRUP[1], SIMON NIELAND[2], TANJA JALKE[1], LUCAS STREIB[1], NIKLAS MORAN[2], NIKLAS KECK[1], BIRGIT KLEINSCHMIT[2], MATTHIAS TRAPP[1]

[1] RLP AgroScience - Intitute for Agroecology, Dept. Environmental Systems, Germany
[2] Technical University of Berlin, Geoinformation in Environmental Planning Lab, Germany

Presenting author e-mail address: gregor.tintrup@agroscience.rlp.de

Abstract

The provision of comprehensive geo-data on ecologically valuable areas and their status is a major precondition for an efficient management and conservation of ecosystems. These data serve as basis for decision making from EU to local level, e.g. EU reporting obligations (NATURA 2000, CAP-Cross Compliance), biotope management and landscape planning of regional and municipal administrations.

Remote sensing offers new opportunities for the efficient production of geo-referenced information relevant for the assessment of the ecological state and quality of the environment at a broader range. With the project NATFLO (Remote Sensing Based Objects for Nature Conservancy) the state ministry of environment of Rhineland-Palatinate (RLP) in Germany intends to integrate EO-based approaches into existing administrative processes. It is envisaged to provide the user community with a framework of geo-information meeting the requirements of the different tasks in nature conservancy, e.g. biotope monitoring, landscape planning.

Within this project methods are being developed to produce state-wide vector based high resolution land cover data for RLP (19000 km²) in an automated workflow, identifying land cover (Eionet Action Group on Land Cover Monitoring in Europe (EAGLE)) and habitat information (EUNIS).

An automated workflow (GEOBIA) has delivered state-wide, high resolution land cover objects based on standard aerial imagery and normalised digital surface models. Each individual object has been enriched with a broad range of spatial statistics on site-specific, contextual, textural and spectral parameters in an automated geo-processing workflow on the basis of aerial images, optical satellite data, DEM based information and further geo-data.

A module is being developed for the automated object based calculation of spatio-temporal metrics to make use of satellite time series. Tests have proven the tool being able to tackle large amounts of vector data in an acceptable period of time. The primary field of application is the use of Sentinel 1 and 2 data for the extension of the data base for data mining processes. Further applications are possible, e.g. flagging vector objects with significant changes in cadastral data in order to guide administrative action.

In order to contribute to the efforts of international institutions and frameworks (EEA, INSPIRE, EAGLE) to achieve broader data interoperability, target indicators were chosen in compliance with accepted trans-national vocabularies (EAGLE, EUNIS) and stored in a standardised semantic system (XML/OWL2). These indicators could then be used to formalise the target classes (here: EUNIS habitats) in OWL2. The classification of EUNIS habitats is being realised in a two-step classification approach by using different machine learning (Extra Tree classifier (ET), Classification and Decision Tree (CART)) and feature reduction algorithms (Principle Component Analysis (PCA), ET) to derive the indicators and finally identify EUNIS habitat classes based on its formalisation. The classification and consistency checks regarding the formalisation are realised by ontology-based reasoning.

Main objectives of the project are a) maximum exploitation of existing “standard” data provided by state authorities, b) combination of these data with satellite imagery (Copernicus), c) create land cover objects and achieve data interoperability and d) implement algorithms and methods suitable for automated processing on large scales.

Keywords: land cover, biotope mapping, ontology, interoperability, Sentinel

ID 14

EVALUATION OF FOREST LOSS IN BALIKPAPAN BAY IN THE END OF 2015 BASED ON SENTINEL-1A POLARIMETRIC ANALYSIS

MILAN LAZECKY[1], LHOTA STANISLAV[2], WENGLARZYOVA PETRA[3]

[1] VSB-TU Ostrava, Czech Republic
[2] CZU Prague, Czech Republic
[3] Koalice proti palmovemu oleji, Prague, Czech Republic

Presenting author e-mail address: milan.lazecky@vsb.cz

Abstract

While Landsat and Sentinel-2 data are very valuable for evaluation of forest and land use parameters, these cannot be universally recommended for monitoring forest changes worldwide. Tropical and subtropical areas are usually covered by dense clouds that disallow application of passive observation instruments that sense radiation absorbed by atmospheric bodies. This problem is tackled by Sentinel-1A instrument using radar that penetrates through cloud cover. ESA has prepared Sentinel-1A observation scenarios for these areas in the view of forestry application.

For Balikpapan Bay (Borneo, Indonesia), Sentinel-1A acquires images every 24 days in two polarizations - VV and VH. Using such data, it is possible to distinguish between different basic types of land use. By time series of polarimetrically processed data, we deliver information about changes in native forest - either deforestation or transformation of forest into oil palm plantation can be detected.

We demonstrate practical usability of Sentinel-1A polarimetric analysis in Balikpapan Bay. We deliver frequent information about progress of building debated highway through native forest. We detect and measure extents of illegal deforestation over areas protected also by local municipalities. We detect and delineate areas burnt or damaged by catastrophic fires in Indonesia in autumn 2015.

Keywords: Sentinel-1A, Balikpapan Bay, deforestation, forest loss, SAR Polarimetry

ID 20

THE CLASSIFICATION OF VEGETATION ABOVE THE TREE LINE IN KRKONOŠE MTS. NATIONAL PARK USING REMOTE SENSING HYPERSPECTRAL DATA

RENÁTA SUCHÁ[1], *LUCIE KUPKOVÁ[1]*, LUCIE ČERVENÁ[1], LUCIE JAKEŠOVÁ[1], STANISLAV BŘEZINA[2], JANA ALBRECHTOVÁ[3], BOGDAN ZAGAJEWSKI[4]

[1] Charles University, Faculty of Science, Department of Applied Geoinformatics and Cartography, Prague, Czech Republic

[2] The Krkonoše Mountains National Park, Vrchlabí, Czech Republic

[3] Charles University, Faculty of Science, Department of Experimental Plant Biology, Prague, Czech Republic

[4] University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics and Remote Sensing, Warszawa, Poland

Presenting author e-mail address: lucie.kupkova@gmail.com

Abstract

The paper is focused on the classification of vegetation above the tree-line in the Krkonoše Mts. National Park (KRNAP) using hyperspectral data (APEX, AISA DUAL). The vegetation above the tree-line (altitude above 1,350 m) is the unique ecosystem which is characterized by mosaic of subalpine meadows with *Nardus stricta* and *Pinus mugo* growths, subalpine peat-bog, rocks and of the lichen tundra in the highest parts in the Krkonoše Mts. A legend with eleven classes was created for the classification purposes. Hyperspectral data AISA DUAL with very high spatial (1 m) and spectral (498 spectral bands) resolution has been examined using object based classification and per–pixel classification. Per-pixel classification has been applied also to the APEX data (spatial resolution 3 m, 288 spectral bands). For the per-pixel classification two algorithms were compared: Support Vector Machine (SVM) and Neural net (NN). The object based classification utilized the example-based approach and SVM algorithm. For data reduction Principal Component Analysis transformation was used. In case of pixel-based classification the Support vector machine algorithm shows the best results for both data types. The APEX per-pixel classification brought slightly more accurate results than AISA DUAL per-pixel classification. In summary the best results were obtained by object based classification of AISA DUAL data.

Based on the comparison of the classification assessments of hyperspectral data and multispectral data we can confirm that hyperspectral data gave more accurate results but

just about 10%. It can be caused by the time of data acquisition and it also seems for tundra vegetation that spatial resolution plays a more important role than spectral resolution.
The outputs will be used for detailed mapping, management and monitoring of tundra vegetation. Tundra belongs among the most valuable and also the most vulnerable ecosystem worldwide. Hence, sustainable management and preservation of tundra is important.

Acknowledgement: This research was made possible by the Charles University in Prague project GAUK No. 938214.

Keywords: Vegetation above the tree line, Krkonoše Mountains, Object based classification, Per-pixel classification, Hyperspectral data

ID 21

SUPPLEMENTING AND VALIDATING THE DIGITALGLOBE DERIVED ARCTIC DEM FOR IMPROVED TOPOGRAPHIC MAPS OF GREENLAND

KIRSTY LANGLEY, EVA MÄTZLER, ANDERS WENGEL-HANSEN

Asiaq, Greenland Survey, Greenland

Presenting author e-mail address: kal@asiaq.gl

Abstract

Accurate height information is critical to all aspects of society and development. Topographic maps provide the base maps upon which all other environmental parameters are mapped, allowing change to be monitored and thereby feeding knowledge based responsible decision making.

In Greenland the populated areas have highly accurate technical maps derived from aerial photography and updated with regular ground and airborne surveying. These detailed maps border onto lower resolution base maps constructed in the 1980s with a scale of 1:100 000 for some regions and even older maps with a scale of 1:250 000 for other regions of Greenland. The reduced accuracy and lack of harmonization when crossing this resolution border can have large implications for natural resources and infrastructure as well as for mapping and monitoring ecosystems and environmental change. Drinking water is one example; open surface waters are often the source of drinking water and accurate topographic information is essential to accurately delineate and protect the watersheds.

For a land the size of Greenland, a satellite based solution is the only feasible way to obtain the spatial coverage at an acceptable resolution. Here we present an example of how high resolution satellite data in combination with UAV data and local knowledge can be used to update/improve topographic maps for remote regions.

The area chosen was a 200 km stretch in West Greenland stretching from Sisimiut on the coast, eastwards to Kangerlussuaq. The area has high interest for Greenland due to the town infrastructures, the high rate of tourism and candidacy for UNESCO World Heritage Site status. It is also an important region for US scientists with many research projects being based in the region.

The Arctic DEM compiled from DigitalGlobe imagery provides almost 100% coverage of the region with a 2m posting and 4m accuracy using no ground control. Asiaq surveys, technical base maps and UAV data has been used both to fill in missing data and to validate the DEM. The experience gained in this test region will provide essential understanding on

how to apply the data allowing similar products for other areas in Greenland and around the Arctic.

Acknowledgements: This work would not have been possible without the cooperation of the US National Science Foundation funded Polar Geospatial Center, University of Minnesota.

Keywords: Greenland, high resolution Arctic DEM, multiple data sources

ID 22

APPLICATION OF FIELD HYPERSPECTRAL REMOTE SENSING IN A HEALTH FOREST MONITORING OF THE UNESCO M&B KARKONOSZE RESERVE, SOUTH POLAND

BOGDAN ZAGAJEWSKI[1], ZBIGNIEW BOCHENEK[2], JARLE W. BJERKE[3], ANDRZEJ KŁOS[4], HANS TØMMERVIK[3], ADRIAN OCHTYRA[1], ANNA JAROCIŃSKA[1], MACIEJ BARTOLD[2], EDWIN RACZKO[1], KAROLINA ORŁOWSKA[1], DARIUSZ ZIÓŁKOWSKI[2], JAKUB CZOS[1]

[1] University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Sensing, Warsaw, Poland
[2] Institute of Geodesy and Cartography, Warsaw, Poland
[3] Norwegian Institute for Nature Research - NINA, FRAM - High North Research Centre for Climate and the Environment, Tromsø, Norway
[4] Chair of Biotechnology and Molecular Biology, Opole University, Poland

Presenting author e-mail address: bogdan@uw.edu.pl

Abstract

Forest health is of global concern, and methods for efficient monitoring is continuously improving. The objective of this study was to assess the applicability of hyperspectral remote sensing techniques for forest health monitoring. We conducted the study along the Polish part of Karkonosze National Park, mountain range in southern Poland, which is the M&BTransboundary Biosphere Reserve. It is characterized by beech-fir (Fagus sylvatica – Abies alba)forest intermixed with Norway spruce (Picea abies). Field campaigns were undertaken in May, June and September 2014 and 2015 at 12 sites along an environmental gradient dominated by spruce (Picea abies) and beech (Fagus sylvatica). The following data were acquired from these two species:
hyperspectral leaf characteristics (using ASD FieldSpec 3 hyperspectral spectrometer with a direct contact ASD PlantProbe + ASD LeafClip),
bioradiometric data: surface and air temperatures (IRtec MiniRay pyrometer); content of chlorophyll, protective pigments (anthocyanins), flavonoids and nitrogencontent (Dualex Scientific+™) and chlorophyll fluorescence values (OS1p OptiSciences).

Spectral characteristics were used to analyze spectral response curves and to calculate selected vegetation indices (mNDVI705, VOG1, SIPI, NDLI, ARI1, NDWI, NDII). Bioradiometric data were used as a reference. ANOVA and Kruskal-Wallis statistical tests were applied to verify whether changes occurred in data between measurement campaigns.

Spectral and bioradiometric data were correlated using Pearson or Spearman correlation. The results were validated by RIR Tukey post-hoc test. In case of both species significant differences were observed in spectral characteristics of the near-infrared spectral region and in the short-wave infrared region, which is due to differences in coniferous and deciduous cell structures and water content. Overall, the measurements clearly suggest that both species were in a good condition at all sites, and there were no indications of water stress. Beech contained higher amounts of chlorophyll than spruce. Condition was higher in September. Beech showed more prominent seasonal variation in activity than spruce. The applied hyperspectral remote sensing tools and methods proved to be appropriate for analysis of forest tree conditions at a detailed level; the acquired data precisely depicted vegetation phenology.

Acknowledgements

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Keywords: Imaging Spectroscopy, forest, health condition, remote sensing indices, Giant Mountains

ID 24

COMPARISON OF SUPPORT VECTOR MACHINE, RANDOM FOREST AND NEURAL NETWORK CLASSIFIERS FOR TREE SPECIES CLASSIFICATION ON AIRBORNE HYPERSPECTRAL APEX IMAGES

EDWIN RACZKO[1], BOGDAN ZAGAJEWSKI[1], KOEN MEULEMAN[2]

[1] University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Sensing, Warsaw, Poland
[2] VITO, Mol, Belgium

Presenting author e-mail address: edwin.raczko@student.uw.edu.pl

Abstract

Knowledge of tree species composition in forest is important topic in forest management. Accurate tree species maps allow for much more detailed and in depth analysis of forest biophysical variables. Tree species maps are often required for proper forest cultivation and protection. The research area is located in a north-western part of the Karkonoski National Park, Poland, south of Szklarska Poręba town. The Karkonoski National Park is part of the UNESCO Man and Biosphere (M&B) international reserve network and Natura 2000 biological network.

With help of APEX hyperspectral data we want to produce best possible maps for Karkonoski National Park workforce to work with. APEX processing and correcting of data consisted of geometric, radiometric and atmospheric correction of raw image using DSM of KPN and MODTRAN 4 radiative transfer model. APEX images were corrected by VITO.

Here we present comparison of three classification algorithms: Support Vector Machines (SVM), Random Forest (RF) and Artificial Neural Networks (ANN) for tree species classification. Classified tree species were beech (Fagus sylvatica L.), birch (Betula pendula Roth), alder (Alnus Mill.), larch (Larix decidua Mill) and spruce (Picea alba L. Karst). APEX dataset was atmospherically corrected prior to band selection procedure. To help reduce processing times, band selection procedure was done with help of Principal Components Analysis (PCA). Instead of using PCA transformed bands we decided to follow methodology proposed by Thenkabail et al. (2012) which let us select 40 spectral bands with highest information contribution to first three PCA bands. To compare three selected classification algorithms and to furthermore remove bias introduced by humans into classification results we decided to follow procedure involving random selection of training and testing datasets from prepared dataset. Based on (Ghosh et al., 2014, Braga–Neto and Dougherty, 2004) we

decided to use. 632 bootstrap approach for generation of test and training dataset. Whole procedure is divided into number of separate iterations. Each iteration involves randomly splitting all samples into test and training dataset so that 63.2% of all samples are assigned to training dataset and remaining serve as test dataset that is excluded from classifier training proces.

Keywords: APEX, hyperspectral images, forest species, mapping, SVM, Random Forest

ID 26

A METHODOLOGICAL FRAMEWORK FOR IMPACT ASSESSMENT OF EARTH OBSERVATION FOR ENVIRONMENTAL APPLICATIONS

PREMYSL STYCH[1], LUCIE KUPKOVA[1], MARK NOORT[2], GREGORY GIULIANI[3,4], NICOLAS RAY[3,4]

[1] Charles University in Prague, Faculty of Science, Czech Republic
[2] HCP international
[3] University of Geneva, Institute for Environmental Sciences, EnviroSPACE Lab., Switzerland
[4] Global Resource Information Database (GRID), Switzerland

Presenting author e-mail address: stych@natur.cuni.cz

Abstract

Earth observation (EO) helps to save lives, save money and to save the environment. Still, the usefulness of EO applications is not perceived as self-evident, and marketing is therefore needed. Studies show that in countries that make public sector information available at marginal or no cost, the benefits vastly outweigh the costs and new market opportunities are created for the private sector. Marketing of EO for environmental applications can benefit considerably by using new integrated models as framework for calculation of cost-benefit.

The first part of this paper will consist in presenting a methodological framework for impact assessment of EO for environmental applications. This framework was a cornerstone development of the EU/FP7 project EOPOWER ("Earth Observation for economic emPOWERment", www.eopower.eu), and it consists in a multi-faceted approach that makes use of success stories, marketing toolkits, pilot projects, relentless promotion outside the EO community and capacity building. More specifically, this framework looks at a step-by-step analysis of where the EO application fits (or does not fit) in an conventional economic model, it applies a number of indicators to the application or activity (fit-for-purpose, comparative advantage, complexity to user / ease- of-use, elegance, cost-benefit, sustainability, resilience, reproduction capacity / flexibility, acceptance, level of knowledge transfer required, and ethics, transparency, public accountability, objectivity and impartiality), and looks at the general business environment. The final methodological framework is then a complete impact assessment package that provides a good indication and description of (potential) impact of EO applications and dissemination, networking and promotion activities

and a good insight in the critical missing elements or shortcomings that merit particular attention to improve performance.

This methodological framework has been applied in various regions of the world, notably Europe, northern and southern Africa, and Mexico. We will discuss the broad results of this exercise that show that the success of EO applications is mainly based on:

Provision of support specifically targeted at the end-user, such as processing of images and flexible capacity building adapted to end-user needs;

Specific efforts to remove bottlenecks in developing countries, notably Africa, in the areas of web infrastructure and access to, and availability of, data;

Success stories, where the link with decision-making has been made explicit, with special emphasis on the following: operational and fit-for-purpose aspects, reduction of the complexity of use (by simplifying user operations and/or technology transfer), increase of resilience (by always having a plan B available) and demonstrating reproduction capacity (scalability) of applications.

The second part of the paper will illustrate an application of the methodological framework on the use of EO technologies in the environmental protection sector of the Czech Republic. A close cooperation with national parks on environmental management was carried out and several collected success stories presented the examples of successful EO applications and methods for environmental protection and monitoring.

Keywords: EOPOWER, Earth observation, Impact Assessment, Environmental Applications, EO Marketing

ID 28

SUBALPINE AND ALPINE VEGETATION CLASSIFICATION BASED ON ENMAP HYPERSPECTRAL DATA

ADRIANA MARCINKOWSKA-OCHTYRA[1], BOGDAN ZAGAJEWSKI[1], ADRIAN OCHTYRA[1,2], CHRISTIAN ROGASS[3], CHRISTIAN MIELKE[3], NINA KRISTINE BOESCHE[3], BRONISŁAW WOJTUŃ[4]

[1] University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatic, Cartography and Remote Sensing, Poland

[2] University of Warsaw, College of Inter-Faculty Individual Studies in Mathematics and Natural Sciences

[3] Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Germany

[4] Wrocław University, Faculty of Biological Sciences, Department of Ecology, Biogeochemistry & Environmental Protection, Poland

Presenting author e-mail address: adriana.marcinkowska@uw.edu.pl

Abstract

Monitoring of vegetation is a very important issue in changeable environment, especially in sensitive mountain areas, as alpine regions often respond to small short-term variations of abiotic and biotic components as well as long-term global changes. Spatial techniques, like imaging spectroscopy, allow for detailed classification of different syntaxonomic categories of vegetation and their status.

Based on simulated Environmental Mapping and Analysis Program (EnMAP) data, this study focused on subalpine and alpine vegetation mapping in the eastern part of the Polish Karkonosze National Park. Based on previous studies of this area APEX very high spectral and spatial resolution allowed for identification of vegetation communities (22 classes). It was generalized into 9 vegetation types for EnMAP classification.

The goals of the study was to check possibility of detailed classification of vegetation types offered by 30-meters spatial resolution EnMAP data and to asses the usefulness of this data to classify the subalpine and alpine mountain vegetation types in Karkonosze Mts. For reference patterns of vegetation types was used the vector map of its distribution including following types: grasslands, bog-springs, fens and bogs, ruderal vegetation, rock and scree vegetation, subalpine tall-forbs, deciduous shrubs vegetation, subalpine dwarf pine scrubs, heathlands and forests. The validation was performed based on previous APEX vegetation communities classification and field walks with a Trimble GeoXT GPS receiver. It allowed to

create test and validation dominant polygons of all of classes of vegetation types to be selected, which were used in the Support Vector Machine (SVM) classification method.

The overall accuracy of classification reached 86.2%. Most of classes were identified with good results (6 classes of producer and 5 classes of user accuracy reached more than 80%). The worst results was obtained for heathlands (33% of producer and 74.8% of user accuracy). It shows the potential use of EnMAP imagery in mapping subalpine and alpine vegetation on a vegetation type scale, within a diverse ecosystem such as the Karkonosze National Park.

Keywords: classification, EnMAP, Karkonosze National Park, Support Vector Machine, vegetation types

ID 29

MULTITEMPORAL ANALYSIS OF CHANGES IN RANGE AND CONDITION OF THE MOUNTAIN FOREST STANDS – CASE STUDY TATRAS, POLAND

ADRIAN OCHTYRA[1,2], BOGDAN ZAGAJEWSKI[1], ADRIANA MARCINKOWSKA-OCHTYRA[1]

[1] University of Warsaw, Faculty of Geography and Regional Studies, Department of Geoinformatics, Cartography and Remote Sensing, Poland
[2] University of Warsaw, College of Inter-Faculty Individual Studies in Mathematics and Natural Sciences, Poland

Presenting author e-mail address: adrian.ochtyra@uw.edu.pl

Abstract

Long period of the data acquisition by the satellites of the Landsat mission makes an opportunity to retrospective analysis changes in the environment. Such retrospective research can be useful for the prediction and forecasting future changes. One of the sensitive component of the environment is vegetation which can be used as index of changes in local and even global scale. Because of the specific climate conditions mountain vegetation is especially sensitive. Warming and cooling, strong winds, frosts, insects outbreaks impacts on the condition of vegetation which gives respond in its range. Warming and cooling, strong winds, frosts, insects outbreaks have impact on the condition of vegetation which reflects in its range. Tatra mountains were selected for this study as a research area due to its unique natural value and dynamic changes in vegetation state caused by different factors also natural as anthropogenic.

In this study were used Landsat data acquired since 1987 up to 2011. One of the restriction in the selection process was day of the year to have images from similar phenological period. Selected images were taken between 15th of June to 15th of September. For each image geometric correction was checked and atmospheric correction was performed. Atmospheric correction was done in ATCOR 2/3 software. Next, the method of Maximum Likelihood supervised classification and corrected images with Normalized Difference Infrared Index as an input were used to classify a dominant land cover types. Purpose of this step was to select forested areas and mask other. Normalized Difference Vegetation Index and Moisture Stress Index were calculated for all masked images and used in Decision Tree (DT) classification method. Using DT 4 classes of the forest stands condition were distinguished (poor, medium, good and very good) and each class was differentiated onto subclasses based on the canopy moisture. Finally 9 classes of the condition were

classified. The result are maps and tables presenting state of the forest stands in Tatras in selected dates. Based on conducted analysis an improvement in overall condition is observed but for the most actual data big parts of dead forest were noticed. Reason of this are bark beetle outbreaks. The worst overall condition was observed for the 1987 (133.55 km2 was covered by forest stands where about 21% of it were in the worst condition and 87% were in medium condition), and the best one for the 2005 (152.35 km2 was covered by forest stands where about 75.51% of it were in good condition and 11% were in the best condition). Differences between forest stands area are result among others occurrence of clouds in 1987.

Keywords: Landsat, forest stands, condition, Decision Tree

ID 31

MULTITEMPORAL AERIAL IMAGE ANALYSIS FOR MONITORING OF THE PROCESSES IN THE DEEP COAL MINING LANDSCAPE

RENATA POPELKOVÁ, MONIKA MULKOVÁ, PETR POPELKA

University of Ostrava, Czech Republic

Presenting author e-mail address: renata.popelkova@osu.cz

Abstract

Aerial images represent the important source of information about land cover in a detailed scale in the last seventy years. The paper deals with the possibilities of using of aerial photographs in the study of landscape development influenced by deep coal mining. The authors show the possibilities of multitemporal land cover analysis in the Ostrava-Karvina mining district on the example of analysis of a series of aerial photographs from the second half of 20th century to the beginning of 21st century. The paper highlights not only the specifics of deep coal mining expressions on aerial images, but points to the possibility of understanding of the fundamental processes that are related to land cover changes. On the base of the multitemporal analysis the authors defined seven basic processes that show the trends of landscape development in the area of interest.

Keywords: land cover, aerial photographs, multitemporal analysis, processes, Ostrava-Karvina mining district

ID 33

MAPPING THE DIURNAL THERMAL RESPONSE OF THE URBAN HEAT ISLAND WITH LANDSAT TIRS

CHRISTOPHER SMALL, CHRISTOPHER ZAPPA

Columbia University, United States of America

Presenting author e-mail address: csmall@columbia.edu

Abstract

Since its launch in February 2013, the Thermal Infrared Sensor (TIRS) on Landsat 8 has provided two channel thermal imagery of urban environments worldwide. The 100 m resolution of TIRS combined with the 30 m resolution of the Operational Land Imager (OLI) makes it possible to distinguish spatial variations in aggregate brightness temperature together with subpixel land cover fractions estimated using linear spectral mixture models. Since mission onset in 2013, Landsat 8 has also collected nocturnal thermal imagery of a number of volcanoes and surrounding areas. In the summer of 2015, the collection of nocturnal thermal imagery was extended to include 150 cities worldwide. In this study we use day-night acquisitions of TIRS thermal imagery in conjunction with subpixel land cover fractions to investigate the relationship between land cover, surface temperature and diurnal thermal inertia in a variety of human-modified landscapes. Using two sets of diurnal thermal acquisitions and coincident land cover fraction maps in six diverse environments and climatic zones, we quantify the relationships between diurnal thermal response and land cover in different seasons for different urban typologies along a variety of urban-rural gradients. Representing land cover as subpixel fractions of soil and impervious Substrate, Vegetation and Dark (SVD) surfaces distinguishes the most functionally and physically distinct components of the land cover mosaic and provides a physical basis for quantifying the effects of vegetation, water, shadow and impervious surface on aggregate brightness temperature and diurnal thermal response. Using multi-season composites of SVD fractions provides additional constraints in the form of spectral stability (Small et al. 2014, Small and Milesi, 2015) to better distinguish seasonal changes in Dark fraction related to shadowing and soil moisture. We compare apparent thermal inertia (ATI) with land cover fractions to characterize the thermal response of different land cover types under different illumination conditions to constrain the role of subpixel shadow and skyview on the diurnal thermal response. To investigate the influence of land cover and its diurnal thermal response on the urban heat island we compare spatially aggregated brightness temperatures and ATI with

day and night air temperatures in a variety of settings. In all six environments, daytime and nighttime brightness temperatures show varying degrees of correlation, depending on season and land cover diversity. Although nighttime brightness temperature distributions span smaller ranges than corresponding daytime temperature distributions, nighttime temperature maps show much greater diversity and stronger correlations to land cover than daytime temperature maps. On the basis of these preliminary observations, we expect that ongoing collection of nocturnal thermal imagery by Landsat 8 could contribute significantly to our understanding of the thermal environment of urban areas worldwide.

Keywords: urban heat island nocturnal thermal

ID 42

ASSESSMENT OF LANDSCAPE CHANGE'S IMPACT ON ALPINE SPECIES DISTRIBUTION USING A MULTI-SCALE APPROACH

MICHELE ZURLO[1], CRISTIANA CERRATO[1], MARCO CACCIANIGA[2], RAMONA VITERBI[1], BRUNO BASSANO[1]

[1] Gran Paradiso National Park, Torino, Italy
[2] Department of Biosciences, Università degli studi di Milano, Milano, Italy

Presenting author e-mail address: michele.zurlo@unimi.it

Abstract

There is a strong relation between biodiversity and traditional land use in Mediterrean areas. In these highly human dominated regions traditional acitvities profoundly shape the landscape with strong consequences on biodiversity pattern.

However, in the last few decades the rapid socio-economic change lead to the abandonment of "marginal" land modifying the landscape structures.

Available remote sensing data can provide information about environmental changes, but the occurrence of temporal and spatial gaps (e.g., the limited temporal archive of historical aerial images and the coarser spatial resolution of satellite data) can reduce the applicability of gained information.

Considering the importance of the scale-dependency of ecological processes, we propose a multi-temporal and scale approach, combining remote sensed and field data, to monitor changes in vegetation and landscape structures and to evaluate their role in shaping Alpine species distribution.

The study area is the Gran Paradiso National Park (NW Italian Alps) and we focused both on 5 altitudinal transects, representative of three altitudinal belts, and on landscape level.

At first, from the interpretation of historical aerial photos in sampled areas, we reconstructed the land cover changes occurred during the last decades and we extended this information to the entire Park landscape, through a supervised classification of satellite data. Further, we developed a low-cost procedure of UAV (Unmanned Aerial Vehicle) survey adapted to Alpine environment, integrated with botanical sampling, in order to obtain high-resolution land cover maps in test areas to replace the use of aerial photos in supervised classification of satellite data.

This multi-scale analysis of landscape change allows us to detail how the environmental patterns affect the Alpine animal species distribution ranging from discrete areas to entire Park area.

Keywords: land cover changes, species distribution, landscape ecology, mountain ecosystems, remote sensing

ID 47

MONITORING OF SNOW AND DEBRIS COVERED AREAS FROM LANDSAT DATA; CASE STUDY FROM THE CORDILLERA BLANCA, PERU

MARKETA POTUCKOVA, ZSOLT PARAJ, VIT VILIMEK

Charles University in Prague, Faculty of Science, Czech Republic

Presenting author e-mail address: mpot@natur.cuni.cz

Abstract

The presented study focused on glacier change monitoring in the Cordillera Blanca in the period from 1987 to 2014. The main goal was to create a semi-automatic classification algorithm to discriminate snow, debris-covered snow, vegetation and water in the selected area of interest in the northern part of the mountains. The input data consisted of 29 Landsat scenes (Landsat 4,5,7 and 8) and the ASTER global digital elevation model version 2. Before the classification process, Landsat and ASTER GDEM pre-processing was conducted. Because of the lack of meteorological data and a detailed elevation model, only the Landsat scenes coregistration was performed. Atmospheric corrections provided by the USGS were sufficient for completing our task. The lack of topographic correction was fixed by a separate classifying snow in illuminated and in shadowed areas. Although spectral properties of the selected land cover types were similar, they could be separated by the semi-automatic classification algorithm after setting up the threshold values, using the combination of NDVI, NDWI and NDSI indexes and band 1 of the Landsat images. The classification algorithm was based on masking techniques and further connection of the masks. For the debris-covered snow classification, Paul's criteria (2004) were used. This method was not used in this region before. The proposed algorithm caused some misclassification of the snow and water areas. Elevation criteria helped to minimize this problem. Cloud cover in the study area was one of the main error sources. It was almost impossible to find Landsat scenes with no cloud cover at the end of the dry season. Because of the spectral similarity, cloud cover was usually classified as snow or water area. The results of the classification were compared with the GLIMS Glacier Database and some field measurements. The accuracy assessment was rather difficult due to the general lack of field data in the Cordillera Blanca and the time period selected for glacier monitoring and also due to the specific classification methodology applied. The observation of the snow and debris-covered area change showed that the results were not as consistent, as it was presumed. Based on the classification result, the mean snowline altitude change, which was roughly equal to the equilibrium line altitude

change, was computed. The results showed that the change was not linear, but it had a positive trend for the most of the selected glaciers. No unambiguous rule of the mean snowline altitude change depending on glacier location was discovered. Finally, the effect of slope and aspect on glacier change in the Cordillera Blanca was computed. Generally, areas with a higher slope had higher tendency to change in the monitored period. The reason for this could be that the areas with a higher slope had thinner snow cover, thus these areas changed to rock or debris-covered area more easily than the areas with thicker snow cover.

Keywords: Landsat, classification, ice and snow detection, ELA, Cordillera Blanca

ID 49

LULC CHANGES MONITORING OF WIELKIE BLOTO IN NIEPOLOMICE FOREST BASED ON THE GEOINFORMATION TECHNOLOGIES

KAROLINA ZIĘBA, PIOTR WĘŻYK, MARTA SZOSTAK, PAWEŁ HAWRYŁO

University of Agriculture in Krakow, Poland

Presenting author e-mail address: karolina.anna.zieba@gmail.com

Abstract

To monitoring Wielkie Błoto (Niepolomice Forest, Natura 2000 site at Małopolska Region, South of Poland) following data sources were used: archival topographical maps (1789-1978), digital aerial orthophotomaps (1949-2010), airborne laser scanning data (ALS, 2011) and aerial RGB images (2012, 2015). Manual (on-screen) vectorization was done in ArcGIS Esri (georeference for all materials: coordinate system PL-1992). Wielkie Błoto area was increased from 358.40 ha in 1910 to 408.84 ha in 1949 but later it started shrinking to reach presently 346.51 ha (border length of 8082 m). During last 60 years according to aerial ortophotomaps analysis area decreased by 16.29% (67.41 ha) and border length by 24.91% (2681 m).

Photointerpretation of aerial ortophotomaps allowed to mark following areas on analysed region: low-density housing, open-pit mining, arable land, meadows, pastures, forests and bushes. In the period 1949-2010 area was dominated by meadows and pastures. Because of exploitation of analysed terrain area of arable land has increased from 4.4 ha in 1949 to 9.29 ha in 2010. Dynamics of secondary forest succession on pastures underwent changes during this period. Class “Forests and bushes undergoing changes” in 1949 spread on only 26.25 ha, which was 6.34% of whole area of Wielkie Błoto. In 2010 it grew to 141.7 ha (40.9%). Dynamics of transformation of meadows and pastures to high-growing vegetation is extremely fast. In 1949 pastures and meadows composed 88.07% of analysed area (365.55 ha). In 2010 their combined area shrink to 189,24 ha (54,62%). Sudden changes of landscape are noticeable in ALS point cloud metrics. According to ALS 95th percentile of vegetation height is 1.29 m. Other parameters analyzed of the normalized point cloud ALS (more than 23 million points) which characterized area: 99th percentile = 5.78 m, maximum height (31.26 m), standard deviation (1.47 m), the first echo from laser scanning more than 96% of all 4 analyzed echoes laser.

Keywords: archive topographic maps, aerial orthophotomaps, airborne laser scanning, spatial GIS analyses

ID 55

LOSSES OF AGRICULTURAL LAND IN PRAGUE SUBURBAN AREA 1990 – 2012: DATA SOURCES, EVALUATION, CONSEQUENCES

LUCIE KUPKOVA, PREMYSL STYCH, IVAN BICIK, ONDREJ MICEK

Charles University in Prague, Czech Republic

Presenting author e-mail address: lucie.kupkova@gmail.com

Abstract

Prague hinterland has undergone a strong suburbanization during more than 20 years long period after the collapse of Communism in Czechia in 1989. For reason to document and evaluate the process of suburbanization three data sources were used. Aerial images and QuickBird satellite images were used for a scale detailed and accurate analysis (time series 1997-2000-2007). Urban Atlas data were used as the second data source (Urban Atlas project pursued under the Global Monitoring for Environment and Security/Copernicus Land (GIO land) Programme auspiced by the European Commission). Cadastral records - updated each year in Czechia - were incorporated as the third data source.

The first goal of the study was to compare the used data sources. While Urban Atlas enables evaluation on the scale of blocks of buildings, we supposed that aerial images and QuickBird data allows us to record new buildings of commercial and residential suburbanization and its changes. Therefore it is also useful source to assess topicality of cadastral records that may be not accurate because many owners do not record changes in use of their land.

The second goal was to document the intensity and types of suburbanization processes, especially irretrievable changes of agricultural land like soil sealing. There is a low protection of agricultural land in Czechia regulating a new built-up on the agricultural land with the highest fertility (so called Ist degree of agricultural land preservation).

Based on the analysis of about 10 municipalities in Prague suburban area we can conclude that strong commercial and residential suburbanization was documented. In most cases the arable land (not grasslands) was occupied by new built-up in the suburban zones. Moreover arable land of high quality was used especially for commercial suburbanization.

Concerning data sources, Urban Atlas proved a high level of accuracy and reliability (geographical accuracy and also accuracy as for land use classes identification). VHR aerial and satellite data (QuickBird) enabled to distinguish the built-up in more detailed scale to discriminate individual buildings and to detect each new building in the observed area.

Discussable is the reliability of the cadastral records, this kind of data were not able to detect dynamic changes in the suburban areas.

Keywords: Land Use/Land Cover Changes, Czechia, Urban Atlas, Suburbanization, Agricultural land

ID 60

MULTI-MODAL KNOWLEDGE BASE GENERATION FROM REMOTE SENSING VERY HIGH RESOLUTION IMAGERY FOR HABITAT MAPPING

IOANNIS MANAKOS[1], ELEANNA TECHNITOU[2], ZISIS PETROU[1,3], VALERIA TOMASELLI[4], GIUSEPPE VERONICO[4], CHRISTOS KARYDAS[5]

[1] Centre for Research and Technology Hellas, Greece
[2] Mediterranean Agronomic Institute of Chania, Greece
[3] City College of New York, City University of New York, USA
[4] National Research Council (CNR) - Institute of Biosciences and Bioresources, Italy
[5] Senior Researcher/ Consultant in Geomatics, Greece

Presenting author e-mail address: imanakos@iti.gr

Abstract

Monitoring of ecosystems entails the evaluation of contributing factors by the expert ecologist, which is usually subjective. This is valid for the habitat area assignment in the field; even according to well-defined taxonomies, such as the European Nature Information System (EUNIS), the Annex I of the European Habitat Directive or the recently introduced General Habitat Categories. The aim of this study is to examine to what extent the quantitative variables calculated by the spectral and textural information of the space-borne imagery, may reproduce existing and verified habitat maps. The assessment concerns both the thematic class of each habitat and their extent and boundaries. A large set of attributes is extracted from the imagery, including a number of spectral and texture features, and evaluated. Preliminary experiments in NATURA2000 sites in South-East Italy reached an overall accuracy of 65%, with fluctuating producer's and user's accuracies of up to 100% for specific classes. Concerning the large number of different habitats (>20) and the lack of ancillary information, such as land cover and canopy height, and the use of no a priori expert knowledge, the results suggest the discriminatory power of the extracted attributes. Potential and limitations are discussed in view of supporting the ecologist in an at most objective and reproducible manner. The work is carried our as a preparatory research activity using authors' existing data and information in order to support objectives of the ECOPOTENTIAL H2020 project (grant agreement No 641762).

Keywords: habitat mapping, very high resolution, space-borne imagery, feature extraction, EUNIS

ID 64

CROP DETECTION USING MULTI-TEMPORAL SENTINEL-1 DATA, FEASIBILITY STUDY

STANISŁAW LEWIŃSKI[1], EDYTA WOŹNIAK[1], WLODEK KOFMAN[1], SEBASTIAN ALEKSANDROWICZ[1], MARCIN RYBICKI[1], PAWEŁ WAJER[1], ARTUR ŁĄCZYŃSKI[2], TOMASZ MILEWSKI[2], STANISŁAW NISZCZOTA[2], PRZEMYSŁAW SLESIŃSKI[2]

[1] Space Research Centre, Polish Academy of Sciences, Poland
[2] Central Statistical Office of Poland, Poland

Presenting author e-mail address: stlewinski@cbk.waw.pl

Abstract

Department of Agriculture of Central Statistical Office of Poland (GUS) carried out feasibility study of crop detection base on SAR data.

Warmian-Masurian Voivodeship (province) in northeastern Poland has been selected as a study area. The voivodeship has an area of over 24 000 km2 and landscape is lowland. Beside agricultural fields there are forests stands and numerous lakes.

The classification analysis was performed using Sentinel-1 data. During the vegetation period from April to September in year 2015 all Sentinel-1 data covering area of the voivodeship were downloaded and then multi-temporal set of data containing 13 time points was chosen for further analysis.

Parallel to collecting satellite data intensive field works were carried out. A team of GUS team interviewers visited field points to collect information about 30 cultivated crops. Points were statistically spread across the whole study area.

Sentinel-1 data were pre-processed using S-2 ToolBox and also by Mt_SAR software developed by CBK PAN dedicated to processing multi-temporal, dual-polarization SAR data. Multi-temporal data were classified using different classification approaches. The best way of proceedings (data collecting and processing) was determined after the final validation which was performed based on results aggregated to county level.

ID 65

THE FOURTH LEVEL OF THE LULC CLASSIFICATION IN THE INTEGRATED ENVIRONMENTAL MONITORING IN POLAND

JOANNA GUDOWICZ, ZBIGNIEW ZWOLIŃSKI

Institute of Geoecology and Geoinformation, Adam Mickiewicz University in Poznan, Poland

Abstract

One of the research programs under the Integrated Environmental Monitoring (IEM) in Poland is the monitoring of land cover and land use. The purpose of this monitoring is retrodiction, current inventory and anticipating environmental changes within the selected geoecosystems in terms of local and regional spatial scale and short-, medium- and long-term time scale. Classification of land cover and land use in this program are based on the nomenclature used in the database CORINE Land Cover (CLC, EEA). This database provides a pan-European inventory of geo-bio-physical types of land cover in the number of 44 classes, which are grouped in the 3-level hierarchy and shall be inviolable at all levels. However, monitoring within catchments of the IEM requires another fourth level, which details the classification in order to indicate the more accurately type and direction of changes in land cover and land use. The result of the undertaken analytical work is detailed classification of land cover and land use covering 122 different issues. Developed expanded classification would take into account local environmental conditions of representative catchments of the IEM. Expansion of the classification system on the fourth level of detail based on the following assumptions:

- new issues of the fourth level must be assigned to only one class of the third level,
- division of issues of the higher level must be adequate, it means that the members of that distribution must create a total range equal to the range of the higher level,
- division of issues of the third level should be carried out according to homogeneous criteria, and the members that distribution split mutually exclusive,
- a new issues of the fourth level and their graphical representation must be compatible with the scale of the map, the size of the smallest area on the map, and with basic source information, i.e. satellite images and air-phots, topographic maps, statistics, etc.

As a result of the classification process the number of distinguished issues increase in the class of artificial surfaces from 11 on the third level to 36 on the fourth level, in the class of agricultural areas from 11 to 29, in the class of forests and semi-natural areas from 12 to 34, in the class of wetlands from 5 to 10, and in the class of water bodies from 5 to 13.

Uniform colour legend is designed for developed classification. The legend corresponds to the pallet used in CLC database with slight modifications of some colours as well as assigning hatches to individual issues on the fourth level. The pallet was developed in the form of thematic layer with symbolization of objects stored in the format *.lyr for the fourth level.

ID 1325

EARTH OBSERVATION APPLICATIONS FOR FOREST DISTURBANCE EVALUATION: SUMAVA AND NIZKE TATRY CASE STUDIES

PREMYSL STYCH[1], JIRI SANDERA[1], JOSEF LASTOVICKA[1], JAN KRIZ[1], LUKAS HOLMAN[1], MARTIN RIEDL[2], RADOVAN HLADKY[1,2], BARBORA SMAUSOVA[1], VERONIKA FIKAROVA[1]

[1] Charles University in Prague, Faculty of Science, Czech Republic
[2] Nizke Tatry National Park (NAPANT), Slovakia

Presenting author e-mail address: stych@natur.cuni.cz

Abstract

The environment of the Czech and Slovak Republics has been severely damaged during the period of extensive industrialisation before 1990 and during the following decades as well. To this day, institutions for the protection of the environment attempt to remove the negative impacts of air and water pollution, intensive and largescale resource exploitation, acid rains and insensitive forestry activity that led to an imbalanced composition of forests.

Environmental institutions however deal not only with problems inherited from the past, but also with current issues, such as large scale forest damage caused by storms or bark beetle calamities.

Therefore the goal of this study is to implement Earth Observation (EO) data and methods for monitoring and evaluation of the forest disturbances in Czech and Slovak national parks: Sumava and Nizke Tatry. For this purpose, several EO data sources and methods are used. The forest changes in both national parks are evaluated based on the combination of multispectral, lidar data and insitu data as well. For this purpose SPOT, World View and Landsat data are processed. Objectbased classification (OBIA) and artificial neural networks are the main used method for the classification of forest. For longtime evaluation of forest disturbance and forest health are used the timeseries methods based on the calculation of selected vegetation indices.

Outputs confirm that a complex research using EO data and methods is very useful for evaluation of forest vegetation. A combination of EO and insitu data provides very important information for the managements of national parks. However, the research activities are only one side of the EO benefits for ecosystem services. Capacity building activities and intensive cooperation of the scientists with the members of national parks are

the second part of this process. Joint activities and results carried out in the Sumava and Nizke Tatry National Parks are presented in the second part of this study.

Keywords: Sumava, Nizke Tatry, Forest disturbance, Earth Observation, EO benefits

e-mail: premysl.stych@natur.cuni.cz

eva.stefanova@natur.cuni.cz

miroslav.cabelka@natur.cuni.cz