→ MAPPING URBAN AREAS FROM SPACE CONFERENCE

ABSTRACT BOOK

4–5 November 2015 | ESA–Esrin | Frascati, Rome (Italy)

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Programme

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11:20	11:40	The Global Human Settlement Layer	Pesaresi, Martino	EC,JRC
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14:20	14:40	A comparative study with the new European Settlement Map	Florczyk, Aneta	JRC
14:40	15:00	Use of satellite imagery for updating the French NSDI	Cantou, Jean-Philippe	IGN
15:00	15:20	Using Pléiades Data for Large Scale Production of VHR Land Cover in Urban Areas of Austria	Stemberger, Wolfgang	GeoVille
15:20	15:40	National Land Cover Data (CadasterENV Sweden) for Urban Mapping and Monitoring	Jönsson, Camilla	Metria AB
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16:30	16:50	VHR Land Cover Map of Rome Obtained Using a Citizen Science Approach	Del Frate, Fabio	Univ. of Rome Tor Vergata
16:50	17:10	DECUMANUS project: semantic platform for Smart Urban Ecosystem applications based on EO data	Pecci, Julia	Indra
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09:00	09:20	Continuous Thermal Monitoring of Cities from Space	Keramitsoglou, Iphigenia	NOA
09:20	09:40	Urban Energy Budget Estimation from Sentinels: The URBANFLUXES Project	Chrysoulakis, Nektarios	FORTH
09:40	10:00	Mapping urban surface characteristics for urban energy flux modelling	Heldens, Wieke	DLR
10:00	10:20	Local Climate Zones as a new standard for mapping urban areas?	Bechtel, Benjamin	Univ. of Hamburg
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1.0 Opening Session

Welcome Talk

Borgeaud, Maurice
ESA-ESRIN, Italy

Welcome Talk

S-1 Products and Mission

Potin, Pierre
ESA-ESRIN, Italy

S-1 Products and Mission

S-2 Products and Mission

Gascon, Ferran
ESA-ESRIN, Italy

S-2 Products and Mission

1.1 Global

Global Urban Footprint – A Key Step in Characterizing the Global Human Settlements Pattern from Space

Esch, Thomas; Heldens, Wieke; Hirner, Andreas; Keil, Manfred; Marconcini, Mattia; Roth, Achim; Zeidler, Julian
German Aerospace Center (DLR), Germany

The ongoing global phenomenon of people migrating to cities is referred to as urbanization and primarily manifests itself in the continuous and often rapid spatial expansion of urban agglomerations. Nevertheless, the dimension and structuring behind this process can be considered as a spatial continuum ranging from rural to urban settlements. Accordingly, gathering a detailed global knowledge about the size, form (e.g., compact or spread) and spatial distribution (e.g., dispersed or nucleated) of different types of settlements represents a major issue to better understand urbanization and develop effective mitigation, adaptation and management strategies. The German TanDEM-X mission has collected two global coverages of very high resolution synthetic aperture radar (SAR) X-band imagery with a spatial resolution of about three meters in the years 2011/2012 and 2012/2013. This radar data set provides Earth observation imagery in an extraordinary spatial detail that outmatches any existing global coverage with optical data. In this paper we present i) the technique implemented to identify and map human settlements in a so far unique spatial detail of ~12m, and ii) demonstrate the potential to characterize human settlements properties and patterns as well as the urban morphology (e.g., in terms of building height) using the worldwide data available from TanDEM-X mission. The basic approach towards the fully-automatic detection and delineation of built-up areas from very high resolution SAR imagery is presented by describing the corresponding operational processing environment – the Urban Footprint Processor (UFP) - and the resulting geo-information product - the Global Urban Footprint (GUF) settlement mask. Along with this, we introduce a procedure that exploits the information provided by the GUF settlement mask to facilitate an effective spatial and structural characterization of human settlement forms and patterns from the local to the continental scale. Moreover, we present an outlook on add-on products describing the built-up density and the average building height within the human settlements delineated in the GUF. These analyses are based on optical imagery (built-up density) and a digital elevation data generated in the context of the TanDEM-X mission. The results of the study indicate the high potential of the developed geo-information products to support the analysis of urbanization patterns, the urban-rural continuum, peri-urbanization, spatiotemporal dynamics of settlement development as well as population estimation, vulnerability assessment and global change modeling.

The Global Human Settlement Layer

Pesaresi, Martino; Ehrlich, D.; Ferri, S.; Florczyk, A.; Freire, S.; Halkia, M.; Julea, A.; Kemper, T.; Soille, P.; Syrris, V.
EC JRC, Italy

The project GLOB-HS “Global Human Settlement Analysis for Disaster Risk Reduction” is supported by the EC JRC in the frame of the institutional research activities for the years 2014-2016. Scope of GLOB-HS is developing, testing and applying the technologies and analysis methods integrated in the JRC Global Human Settlement Analysis Platform (GHSAP) for applications in support to global disaster risk reduction initiatives (DRR). GHSAP uses geo-spatial data, primarily remotely sensed and population. GLOB-HS also cooperates with the Group on Earth Observation on SB-04-Global Urban Observation and Information, Int. partners (WB, RADI, SANSA) and the UN (incl. UNISDR on Global Assessment Reporting on DRR).

The GHS information production system was successfully tested with a globally representative set of satellite data in the metric spatial resolution range (0.5to10m-resolution), and successfully applied for the production of the first continental analysis of European built-up areas using 2.5-m-resolution input image data. During 2014 GLOB-HS

delivered the preliminary results on processing of global multi-temporal satellite data for analysis of human settlement, using decametric spatial resolution imageries collected from the Landsat platform in the past 40 years. A GHS partnership was launched on 22 October 2014 at the end of a two-day workshop hosted by the JRC with the support of the Group of Earth Observation (GEO). To mark the event, a manifesto was signed. It calls for a collaborative and integrated approach to advance knowledge on GHS and an understanding on how they are changing. The increasing capabilities of Earth Observation satellites combined with rapid advances in geospatial sciences, analytical methods and computing power have made possible detailed, measurable and globally consistent descriptions of the human-made habitat. The manifesto promotes full and open access to the data offered through these advances and to the GHS information generated from them. The partnership will support initiatives such as the concurrent post-2015 processes on sustainable development, climate change and disaster risk as well as the UN Third Conference on Housing and Sustainable Urban Development (Habitat III, 2016).

The GHS data update and improvement will be supported by EC using Sentinel1,2 global input data. A pre-operational phase is foreseen in the years 2016-2018. If successful, this phase will bring to the definition of a new Copernicus service in 2018+. Preliminary results of the application of the GHSL automatic information extraction workflow to Sentinel 1,2 data will be presented.

A Continuous Infrastructure Index for Mapping Human Settlements

Small, Christopher (1); Nghiem, Son (2)
1: Lamont Doherty Earth Observatory, Columbia University, Palisades, NY 10964, United States of America; 2: NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 , United States of America

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 will 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 will be 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.

EO4Urban: Multitemporal Sentinel-1A SAR and Sentinel-2A MSI Data for Global Urban Services

Ban, Yifang (1); Gamba, Paolo (2)
1: KTH Royal Institute of Technology, Sweden; 2: University of Pavia, Italy

With more than half of the world population now living in cities, and 2.5 billion more people expected to move into cities by 2050, urban areas pose significant challenges on the environment. Although only a small percentage of global land cover, urban areas significantly alter climate, biogeochemistry, and hydrology at local, regional, and global scales. Thus, accurate and timely information on urban land cover and their changing patterns is of critical importance to support sustainable urban development. At present, the information urban planners and decision makers needed to support planning activities are either non-existent, dated or collected through time-consuming field survey or visual interpretation of images. Through its synoptic view and the repeatability, satellite remote sensing can provide timely and accurate information necessary to map urban land cover and monitor urbanization. With the recent launch of Sentinel-1A and planned launch of Sentinel-2A in 2015, high resolution SAR and optical data with global coverage and operational reliability become routinely available. They provide excellent opportunity to develop novel methods and algorithms for operational urban services and products to support smart and sustainable planning.

The overall objective of this research is to evaluate multitemporal Sentinel-1A SAR and Sentinel-2A MSI data for global urban services using innovative methods and algorithms, namely KTH-SEG, a novel object-based classification method for detailed urban land cover mapping, and KTH-Pavia Urban Extractor, a robust algorithm for urban extent extraction. Ten cities around the world in different geographical and environmental conditions are selected as study areas. Sentinel-1A SAR and Sentinel-2A optical data will be acquired during vegetation season in 2015 and 2016. Historical ENVISAT ASAR and ERS-1/2 SAR data will be selected from the archives for monitoring of urban development. KTH-SEG, an advanced segmentation method will be further developed for multiresolution segmentation of Sentinel-1A SAR and Sentinel-2A MSI data based on edge-aware region growing and merging algorithm using parallel computing. The post-segmentation classification is performed using support vector machines. KTH-Pavia Urban Extractor, the proposed processing chain for urban extent extraction includes urban extraction based on spatial indices and Grey Level Co-occurrence Matrix (GLCM) textures, an existing method and several improvements i.e., parallel computing, SAR and optical data preprocessing, enhancement, fusion and postprocessing. Both KTH-SEG and KTH-Pavia Urban Extractor will be adapted, improved and applied to Sentinel-1A SAR, Sentinel-2A MSI data as well as their fusion.

Two end users have committed to participate in the project, namely the Urban and Regional Development Department at the Stockholm County Administrative Board in Stockholm, Sweden and National Geomatics Center of China at the National Administration of Surveying, Mapping and Geoinformation of China in Beijing, China. This gives us a unique opportunity to develop much needed urban services.

This research and development is expected to produce a pilot global urban services demonstrator using multitemporal Sentinel-1A SAR and Sentinel-2A MSI data. The project will contribute to i). better understanding of the urban products and services that the end users require; ii). development of novel and robust methods and algorithms for improved urban services to planners to support smart and sustainable urban development; ; iii). better understanding of the capacity of Sentinel-1A SAR and Sentinel-2A optical data for detailed urban land cover mapping and urbanization monitoring; iv). the goals and activities of GEO SB-04 Global Urban Observation and Information Task and the UN post-2015 sustainable development goals.

Mapping Infrastructure and Population for Disaster Planning in Urban Areas with Remote Sensing and Census Data

Yetman, Gregory George (1); MacManus, Kytt (2); Doxsey-Whitfield, Erin (3); Chen, Robert S (4)
1: Columbia University, United States of America; 2: Columbia University, United States of America; 3: Columbia University, United States of America; 4: Columbia University, United States of America

Understanding the interactions between environmental and human systems, and in particular supporting the applications of Earth science data and knowledge in place-based decision making, requires systematic assessment of the distribution and dynamics of human population and the built human infrastructure in conjunction with environmental variability and change. The NASA Socioeconomic Data and Applications Center (SEDAC) operated by the Center for International Earth Science Information Network (CIESIN) at Columbia University has had a long track record in developing reference data layers for human population and settlements and is expanding its efforts on topics such as intercity roads, reservoirs and dams, and energy infrastructure. SEDAC has set as a strategic priority the acquisition, development, and dissemination of data resources derived from remote sensing and socioeconomic data on urban land use change, including temporally and spatially disaggregated data on urban change and rates of change, the built infrastructure, and critical facilities.

We report here on a range of past and ongoing activities, including the Global Human Settlements Layer effort led by the European Commission's Joint Research Centre (JRC), the Global Exposure Database for the Global Earthquake Model (GED4GEM) project, the Global Roads Open Access Data Working Group (gROADS) of the Committee on Data for Science and Technology (CODATA), and recent work with ImageCat, Inc. to improve estimates of the exposure and fragility of buildings, road and rail infrastructure, and other facilities with respect to selected natural hazards. New efforts such as the proposed Global Human Settlement indicators initiative of the Group on Earth Observations (GEO) could help fill critical gaps and link potential reference data layers with user needs. We highlight key sectors and themes that require further attention, and the many significant challenges that remain in developing comprehensive, high quality, up-to-date, and well maintained reference data layers on population and built infrastructure. The need for improved indicators of sustainable development in the context of the post-2015 development framework provides an opportunity to link data efforts directly with international development needs and investments.

1.2 European Reginal and National Mapping

Copernicus High Resolution Layer Imperviousness for an operational monitoring of built-up areas throughout Europe

Schleicher, Christian (1); Weichselbaum, Jürgen (1); Gangkofner, Ute (1); Sannier, Christophe (2); Langanke, Tobias (3)
1: GeoVille, Austria; 2: SIRS, France; 3: European Environment Agency, Denmark

The idea of a pan-European High Resolution Layer (HRL) of Imperviousness was born in early GMES research projects, comprising the EC FP6 geoland and the ESA GMES Service Elements SAGE and Land, in order to provide insight into urban development as one of the pressing environmental challenges in Europe and to overcome shortcomings from infrequent or too coarse land monitoring initiatives. This initial service development and demonstrations led to the first-ever operational tender in the frame of GMES Land Monitoring by the European Environment Agency. A first pan-European product was generated utilizing the high-resolution IMAGE2006 satellite database as part of the "GMES Fast Track Service Precursor on land monitoring 2006" by a consortium of European Earth Observation companies. The first product was updated for the reference year 2009 in the frame of the FP7 project geoland2. The latest update was established for the reference year 2012 as part of the GMES Initial Operations. New sensors from the Copernicus satellite missions, especially Sentinel-2, are expected to foster substantial improvements in terms of data quality and consistency.

The objective of the HRL Imperviousness is the consistent monitoring of changes in built-up areas as well as imperviousness levels on a pan-European scale. With its superior resolution (20m intermediate product, 100m validated end-product), it supplements the well-established CORINE Land Cover database with spatially more detailed information on the location, extent and development of impervious surfaces and a more frequent 3-years update cycle (2006-2009-2012). As input for the reference years 2006 and 2009 mostly bi-temporal image data from SPOT and IRS-P6 with 20m resolution were used, whereas for the update of the HRL Imperviousness to 2012 two different coverages made up from IRS-P6, Resourcesat-2 and SPOT4/5 (Coverage 1) and Rapid Eye (Coverage 2) were utilized. Sentinel-2 are expected to be the most relevant input dataset for further updates.

The production methodology is based on the proven relationship between the Normalized Difference Vegetation Index (NDVI) and vegetation presence, or absence, respectively. Main challenges are to mitigate scene-wise deviations in acquisition dates and vegetation phenology, different sensor characteristics, as well as limitations in image quality. Based on a operational calibration and modelling approach, a per-pixel estimate of imperviousness is derived. While the HRL Imperviousness 2006 was established using a visual calibration approach applied individually to each data set, the update and change mapping is now based on an automatic calibration of the recent NDVI to the original imperviousness degrees. This step is followed by a procedure that extracts built-up change candidates with lower and higher probability. Those candidates are visually checked to differentiate true changes from classification errors. Inside built up areas imperviousness changes are calculated based on the differences of imperviousness between the actual and the reference year considering certain spectral and spatial thresholds (Gangkofner et al. 2010).In order to derive a consistent time series of status and changes of built-up area and imperviousness levels, the full spatial resolution intermediate products are integrated to a pan-European consistent dataset and aggregated to 1ha resolution.The HRL Imperviousness supports to analyse pressures to ecosystems or the vulnerability of people and infrastructure to natural hazards. As such, it is a key information source for policy evaluation, for information to the public and enabling policy makers to base their decisions on more evident data sources (cf. EEA, SOER 2015).

References

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Production and validation of the European Urban Atlas for 2006 and 2012

Sannier, Christophe (1); Alexandre, Pennec (1); Fabrice, Dazin (1); Justine, Perrin (1); Hans, Dufourmont (2); Hugo, Poelman (3); Gabriel, Jaffrain (4); Jochen, Dahmer (5); Heinz, Gallaun (6)
1: SIRS, France; 2: EEA, Denmark; 3: EC DG Regio, Belgium; 4: IGN FI, France; 5: GAF AG, Germany; 6: Joanneum Research, Austria

The Urban Atlas provides European, comparable and detailed 20-class land use and land cover map data for the main Functional Urban Areas (FUAs). The 2006 edition covered more or less all EU urban areas with more than 100,000 inhabitants and all EU27 member state capital cities as defined by the Urban Audit, whilst the 2012 update when completed, will be covering in addition to the cities mapped in 2006, all urban areas with a population above 50,000 inhabitants corresponding to a total of 695 FUAs. The 2012 extension and update of the Urban Atlas does not only provide an update of the 2006 exercise but also a spatial extension more than doubling the number of FUAs and area covered and a thematic extension by increasing the number of classes in rural areas from 3 to 10. This raises a number of challenges particularly linked to the complex changes of the 2006 Larger Urban Zones delineation and the extension to a large number of smaller urban areas. The methodology adopted is based on the optimisation of the production process based on a careful blend of automated Object Based Image Analysis (OBIA) techniques and Computer Assisted Photo-Interpretation (CAPI) to ensure the most efficient methodology is applied whilst exceeding the minimum quality requirements. Whenever possible, processing steps were combined to avoid unnecessary duplication of tasks.

To ensure the highest level of homogeneity and compliance with the product specifications, a thorough internal independent validation procedure was developed at FUA level as part of the 2006 exercise and adapted for the 2012 update and extension. A comparison between the internal validation procedure and independent external validation exercises is made for selected representative FUAs. Results show that the internal validation procedure tend to provide lower accuracy than that of the independent validation exercise. Analysis suggests that a potential explanation could be related to the different sampling and response design procedures applied.

Conclusions are drawn by presenting the status of the production to date and future prospects for the development of the product.

A comparative study with the new European Settlement Map

Florczyk, Aneta Jadwiga; Kemper, Thomas; Pesaresi, Martino
Joint Research Centre, European Commission, Italy

The European Settlement Map (ESM) 2014 is a built-up density map produced by applying the general Global Human Settlement Layer (GHSL) methodology to the pan-European GMES/Copernicus imagery collection. This collection consists in SPOT-5/6 pan-sharpened images of 2.5 and 1.5m spatial resolution. In total, more than 3,500 scenes were processed and classified at 2.5m resolution ESM has been produced in support of EU policy making. Currently, ESM is available as a 100m map, while the 10m product will be released in the near future. The high level of semantic abstraction of the built-up class allows straightforward rescaling of the ESM to other spatial resolutions. The ESM can be used in a range of applications (examples) that require high spatial resolution settlement information and may be used to complement or substitute other products, such as the European Imperviousness (SSL), CORINE Land Cover (CLC) or Urban Atlas (UA).

In this study we present a comparison of the ESM with other products, namely SSL, CLC and MODIS urban, by using cartographic data as a reference. The reference set consists in building footprints, which were gathered from available cadastre datasets. Open Street Map data has been considered as well. The final reference set covers the whole Tuscany region, Turin and Pavia cities. The analysis has been done at 10m resolution using 5km2 tiles. The quality of the datasets under test has been compared with the built-up density in the reference set. In general, the results show that all products overestimate the total built-up area with respect to the values calculated from the reference data (at least double as much). Apart from the analysis of commission and omission errors, a detailed analysis of the built-up density of the tiles has been performed. As for the balanced accuracy, ESM has better performance always. According to the informedness, ESM also outperforms the other sources in all the built-up density ranges (greater than 0.2%).

Use of satellite imagery for updating the French NSDI

CANTOU, Jean-Philippe; CHAMPION, Nicolas; LEONARDI, Isabelle; SEMPERE, Jean-Paul
IGN, France

Topic of the paper : point out technical and operational issues linked to the use of Pleiades and SPOT 6/7 imagery on the French territory. IGN took part in the commissioning phase of the French satellite systems Pleiades designed by CNES, and SPOT6/7 designed by Airbus Defence and Space. Willing to promote both systems, IGN experimented the suitability of both data sources for the requirements of the French NSDI and their use in various mapping processes. For the past two years the satellite capacity has been tested and image products assessed as complements or substitute to aerial data : coverage in mono/stereoscopic modes, horizontal precision performance and information content potential for land use and land cover mapping, 3D vector accuracy of captured urban topographic features, DEM quality over bare soils and forest canopy. As far as the French NSDI updating is concerned, Pleiades 20 km swath and 70 cm GSD seems well suited to survey man-made changes (towns, infrastructure,...) with a good performance in XYZ data capture of medium size features (houses, paths,...) and in the generation of DEM over mountainous areas and coasts particularly sensitive to erosion. Meanwhile, SPOT 6/7 with its 60 km swath and its 1,5 m GSD proved able to provide a full coverage of the metropolitan territory every year, opening the way to change detection and land use updating at a higher frequency.

Public partnerships in France tasked IGN to collect of the institutional demands, translate them into Pleiades and SPOT acquisitions requirements over the national territory and produce and disseminate geocoded image products to French public authorities. This focal point position put IGN in a unique position to master the constraints and trends in the demand for Earth observation revisit at HR and THR resolution levels, in the context of the growing “open data” phenomenon and of non “satellite fluent“ newcomers.

Despite the relatively weak penetration of satellite data in the current institutional mapping processes, the revisit capacity of these systems combined with the ongoing work to finance a perennial collaborative procurement of image coverages should foster their use, namely in the preservation of agricultural and natural land.

Using Pléiades Data for Large Scale Production of VHR Land Cover in Urban Areas of Austria

Stemberger, Wolfgang (1); Banko, Gebhard (2)
1: GeoVille, Austria; 2: Umweltbundesamt, Austria

The Land Information System Austria (LISA) is an initiative for the implementation of a homogeneous land cover and land use solution throughout Austria. Due to the collaborative development efforts, LISA meets the needs of governmental institutions on state, provincial and municipality level. The conceptual basis consists of an object oriented data model that describes classes of land cover and land use together with a number of attributes. The data model implements the EAGLE (EiONET Action Group on Land Monitoring in Europe) data model on national scale and provides all necessary components to be transformed into an INSPIRE compliant dataset.

The land cover part of the data model defines 15 classes (e.g. “Buildings”, “Other constructed areas”, “Bare soil”, “Screes”), which describe the appearance on the earth’s surface. For each of the classes a minimum object size was defined, which starts for many classes at an area of 25 m². Objects below this size are merged with neighbouring objects in order to reduce the number of sliver polygons and to optimise the look-and-feel of the resulting map. Furthermore attributes were defined for all classes which provide additional information for each land cover object (e.g. area, height, biomass index). The LISA data model and the production chain for operationally mapping land cover have been developed in the frame of two projects (2009-2012) as part of the Austrian Space Applications Programme (ASAP) of the Austrian Research Promotion Agency (FFG). These activities were continued within the ESA funded CadasterENV Austria project (2012-2015). While the first projects focused on creating the land cover maps with orthophotos and airborne laserscanning data, it was the aim of CadasterENV Austria to expand the production methodology for the ingestion of Pléiades imagery. While orthophotos are produced operationally each year for a third of Austria (resulting in a three-year-cycle for the entire country), acquisitions of the Pléiades constellation are possible in a more flexible and cost-efficient manner for ad-hoc requests and smaller areas. As a result up-to-date VHR land cover maps may be produced as flexible as Pléiades images can be acquired. It is important to mention that the LISA land cover maps are purely derived of remote sensing data and thus do not depend on additional thematic GIS data.In the CadasterENV Austria project the LISA processing chain was adapted for the use of Pléiades data. More than 5,800 km² of Pléiades data were acquired for the cities of Linz, Salzburg and Vienna and their urban hinterland. For the tasking of these satellite scenes it was crucial to specify an incidence angle near nadir in order to avoid tilting of buildings and trees in case of incidence angles larger than 10 degrees. This Pléiades coverage was complemented with orthophotos as well as WorldView-2 imagery and used for the production of VHR land cover maps for the main urban areas of Austria, totalling in more than 10,000 km², which is about an eight of entire Austria and approximately one third of the permanent habitable area. The products were completed in August of 2015 and can be freely downloaded from the project’s website (www.landinformationsystem.at).

National Land Cover Data (CadasterENV Sweden) for Urban Mapping and Monitoring

Jönsson, Camilla (1); Moström, Jerker (2)
1: Metria AB, Sweden; 2: Statistics Sweden, Sweden

The need of a homogenous and nationwide Land Cover (LC) database is critical in a world of increased human pressure on natural resources. Increased human pressure such as urban structures enhances the demands for monitoring and landscape planning on different scales and for multiple purposes. To ensure long-term usefulness a LC database must be updated on a regular basis in a cost-effective manner. A LC database should also be adapted to a multi-purposed usage and be suitable for further analysis and processing. CadasterENV is an initiative to create a multi-purpose LC mapping system at national scale. Biotope mapping of Stockholm and Statistics in urban areas are two examples where CadasterENV has and will serve as a basis for further processing and analysis.

National Land Cover Data (CadasterENV Sweden) for Urban Mapping and Monitoring

The objective of CadasterENV Sweden is to implement a multi-scale and multi-purpose Land Cover mapping and monitoring system in Sweden, according to national user specifications. CadasterENV is an initiative to create a national consensus for a multi-purpose LC mapping system at national scale. The system will be comprised of two components:

a Land Cover (LC) mapping component based on HR (High Resolution) and VHR (Very High Resolution) satellite data,

a Land Cover Change (LCC) alert component, based on HR satellite data.

The project is carried out in close cooperation with major LC actors in Sweden e.g. Swedish Environmental Protection Agency, Statistics Sweden, Board of Agriculture and is funded by the Data User Element program of the European Space Agency (ESA).

Classification of land cover is based on satellite imagery and LIDAR data. The main data sources have been SPOT-5 (HR) and Pleiades (VHR). The use of HR data has been in preparation for the upcoming Sentinel-2 and time series. LIDAR is also an important data source within the project as a complement to VHR EO-data.

HR is used to meet the requirements of a nationwide and cost effected method. VHR is used over lager cities to meet the higher demands on geographical delineation accuracy for urban planning.

Land cover classification is pre-processed and post-processed with additional geospatial data from Lantmäteriet (Swedish mapping, cadastral and land registration authority), Swedish Transport Administration, Board of Agriculture and Swedish Forest Agency to add information on land use to the initial land cover classification. Geocoded administrative data from the Swedish Tax Agency are used to derive information on land ownership and to classify green space in terms of public access. Calculations of population proximity to urban green areas are based on Statistics Sweden's population register geocoded to location of dwellings by use of authoritative address records from the National Mapping Agency.The users have emphasized a need for a homogenous and nationwide LC database, which can be updated, on a regular basis in a cost-effective manner. The classes and attributes of the LC data model are primarily based on an analysis of user requirements. The aim is that the LC mapping and LCC Alert system will be fully integrated into a national monitoring system to continuously update the LC/LU data in Sweden.The production line for CadasterENV has been adapted t for further processing and analysis such as the following two examples of analysis of urban green structure and biotope mapping

Analysis of urban green structures with an adapted CadasterENV

In growing cities, balancing the need to develop land for housing with preservation of green space is a true challenge. City planners have the seemingly contradictory task of creating dense and green cities. In order to find out how green Swedish cities are, Statistics Sweden has undertaken a study on green structure in the largest urban areas. The statistics are widely used to assess urban planning policies and for monitoring of environmental objectives. Examples of measures that have been produced are; Total green space per capita, Public green space per capita, Number of green areas by size, etc. In the future CadasterENV Land Cover data can form the basis for further processing, to provide a product suitable for these statistical exercises.

Biotope mapping in Stockholm County with an adapted CadasterENV

The Stockholm region is growing dramatically. High-quality comprehensive planning documents are required to meet the demand of new housing constructions and infrastructure. A reliable, up to date biotope map is essential for general and detailed planning in the region, as well as for the municipalities. Stockholm County consists of 26 municipalities. In many applications regarding green infrastructure and green corridors, homogenous seamless datasets are needed in order to be able to run different models and receive reliable results that can be used for regional planning. Biotope mapping usually requires manual interpretation of aerial photos. The main goal of this project was to provide satellite based input to the production of the biotope map as to facilitate its production. By further processing CadasterENV for this particular purpose, semi-automatically derived delineations and attributes were delivered. Some classes in the existing biotope map will likely be obtained via this method, while others will require subsequent manual yet facilitated interpretation of aerial photos.

1.3 Tools and Platforms

TEP Urban - Collaborative Service Platform for Earth Observation-based Exploration and Generation of Thematic Information on the Built Environment

Esch, Thomas (1); Marconcini, Mattia (1); Metz, Annekatrin (1); Hirner, Andreas (1); Asamer, Hubert (1); Böttcher, Martin (2); Storm, Thomas (2); Brito, Fabrice (3); Mathot, Emmanuel (3); Soukup, Tomas (4); Stanek, Filip (5); Vondrak, Vit (5)
1: German Aerospace Center (DLR), Oberpfaffenhofen, Germany; 2: Brockmann Consult, Geesthacht, Germany; 3: Terradue, Frascati, Italy; 4: GISAT, Prague, Czech Republic; 5: IT4Innovations - VSB-Technical University of Ostrava, Ostrava-Poruba, Czech Republic

The upcoming suite of Sentinel satellites in combination with their free and open access data policy will open new perspectives for establishing a spatially and temporally detailed monitoring of the Earth's surface. The Sentinel fleet will provide a so-far unique coverage with Earth observation (EO) data and new possibilities with respect to the implementation of innovative methodologies, techniques and geo-information products and services. However, the capability to effectively and efficiently access, process, analyze and distribute the mass data streams from the Sentinels and high-level information products derived from them poses a key challenge. This is also true with respect to the necessity of flexibly adapting the processing and analysis procedures to new or changing user requirements and technical developments. Hence, the implementation of operational, modular and highly automated processing chains, embedded in powerful hard- and software environments and linked with effective distribution functionalities, is of central importance.

This contribution introduces the TEP Urban project that aims at the utilization of modern information technology functionalities and services to bridge the gap between the technology-driven EO sector and the information needs of environmental science, planning, and policy. Key components of such a system are currently developed in the TEP Urban project. This includes the implementation of an open, web-based platform employing distributed high-level computing infrastructures (Platform as a Service – PaaS) as well as providing key functionalities for i) high-performance access to thematic data (Information as a Service – InaaS), ii) modular and generic state-of-the art pre-processing, analysis, and visualization (Software as a Service – SaaS), iii) customized development and dissemination of algorithms, products and services, and iv) networking and communication. These services and functionalities are supposed to enable any interested user to easily exploit and generate thematic information on the status and development of the environment based on EO data and technologies.The TEP Urban platform is supposed to initiate a step change in the use of EO data by providing an open and participatory platform based on modern ICT technologies and services that enables any interested user to easily exploit and generate thematic information on the status and development of the built environment.

VHR Land Cover Map of Rome Obtained Using a Citizen Science Approach

Del Frate, Fabio (1); Carbone, Francesco (2); Mitraka, Zina (1); Schiavon, Giovanni (1)
1: University of Rome Tor Vergata, Italy; 2: GEO-K SRL

The "Citizen Scientists" (CS) concept is one of the emerging fields recognized as a key element to increase EO capabilities. This technology and culture can be used to enable communities of citizens to provide essential information for deeper analysis of remotely sensed information [1]. However, in such a context, metrics and processes for data quality assessments are issues of crucial importance to document the usefulness of the results that can be produced.

In this work a CS project addressing accurate classification of Very High Resolution (VHR) optical imagery, with less than 50 cm spatial resolution, taken over the Rome urban area, Italy, is presented. Besides the data, the "scientists" (students of the University of Rome "Tor Vergata") have been provided a neural network based toolbox for image processing plus additional scripts to test the accuracy of the obtained results. The area extension includes the main historical city and its surroundings covering more than 70 km2.The considered land cover classes are: buildings, asphalted areas, natural, water, bare soil, vegetation. Each tile, with dimension 2000x1000, has been assigned to the "scientist" who mainly has to perform two tasks: image classification and accuracy evaluation. The automatic image classification is performed using the Neumapper Toolbox which is a free distributed package enabling image classification via neural networks [2]. Neural networks have greatcapabilities as a pattern recognition method for multi-source remotely sensed data because of the parallel nature of the processing. In particular, it has been shown that multilayer perceptrons (MLP) maybe an efficient alternative to conventional statistical approaches for automating image classification [3],[4]. With Neumapper the CS can easily manage the whole processing in a unique user friendly software environment. Moreover, the CS is invited to use a few scripts, developed in python language, implementing the following tasks: generation of a given number of validation points randomly distributed over the image, localization of the generated points in Google Earth, realization of a confusion matrix based on the generated (manually labeled) points and the classified image. An assessment of the global result has been carried out by means of an external validation and it confirmed an overall accuracy around 95%. Even if an on-line assistance service has been also set-up to support the participants in their operations, no particular difficulties have been registered until now. The idea is indeed to extend the project to other urban areas to be mapped so as to yield very precise land cover atlas.

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DECUMANUS project: semantic platform for Smart Urban Ecosystem applications based on EO data

Pecci, Julia; Garzón, Antonio; Palacios, Marino
Indra Sistemas, S.A. Mar Egeo nº 4, 28830 San Fernando de Henares (Madrid)

DECUMANUS project (DEvelopment and Consolidation of geo-spatial sUstainability services for Adaptation of environmental and cliMAte chaNge Urban impactS) is an FP7 project which started in December 2013 and it will end on May 2016. This project has as its main objective the development and consolidation of a set of sustainable services based on EO data. These services should allow city managers to incorporate geo-spatial products and geo-information services in their climate and environmental change strategies to support the sustainable management of the cities of Europe. More information about Decumanus project on: http://www.decumanus-fp7.eu Decumanus has created a set of products called Urban Ecosytem which, considering the city as a particular ecosystem, monitor each of the possible element of such ecosystem and its influence in the population by using 6 categories of EO products: Climate Change (meteo parameters), Land Monitoring, Energy Efficiency, Citizen Health, Water Quality and PopulationImpact assessment. One of themost important innovations of this project, is the deployment of those EO based products in an advanced middleware with semantic capabilities. This semantic middleware is called SOFIA2 (http://sofia2.com) and it has been developed by Indra. SOFIA2 is an Internet of things (IoT) Interoperability Platform with a Big Data approach. The mission of SOFIA 2 within Decumanus consists on reaching the “coexistence”, integration and interactions of Decumanus products/services with the maximum number of all other elements which supply information about the city, including citizens observations and new sensors. This mission includes a set of simple exploitation and analysis tools with future vision of exploitation as Big Data and Analytics implementations. It will also show a dashboard which gives a general “first look” vision of the configurated parameters and an advanced Geoportal (based on the Indra solution called iViewer). The integration of Decumanus products in SOFIA2 implies the creation of a general ontology for Smart Urban environment geo-spatial products. SOFIA2 and IViewer have their own open-source versions, which allow any citizen or manager to develop its own smart application on a “cloud”. Additionally, commercial version, with higher computer requirements and functional capabilities, allows the development of adapted and advanced applications for smart urban applications. SOFIA2, fed with European cities data and even pan-European information (i.e. from Copernicus program), will allow the definition of multiples applications and it constitutes a powerful tool for managers and citizens in smart urban environmental studies. Decumanus will serve for the demonstration of this concept. This article will show the results of the first phase of the implementation of SOFIA 2 and iViewer over Decumanus Basic products and services for Urban Ecosystem.

Big Data Analytics for Detailed Urban Mapping

Espinoza-Molina, Daniela; Alonso, Kevin; Schwarz, Gottfried; Datcu, Mihai
German Aerospace Center (DLR), Germany

When we look at current developments in Earth Observation and satellite images, we are facing both Big Data issues as well as a high interest in detailed urban mapping. As a consequence, new concepts for exploration and information retrieval are urgently needed. To this end, we propose to explore urban and similar image data via an image information mining approach in which the main steps are feature extraction, classification, semantic annotation, and interactive query processing. In addition, we deal with the integration of multiple sources of information such as synthetic aperture radar (SAR) images and their metadata, semantic descriptors of the image content, as well as other publicly available geospatial data sources expressed as linked open data for posing complex queries in order to support geospatial data analytics.

A recently published approach lays the foundations for the development of powerful analysis tools that focus on urban image interpretation using ontologies and linked open data [1, 2]. We introduced a system architecture where a common satellite image product is transformed from its initial format into to actionable intelligence information, which includes image descriptors, metadata, image tiles, and semantic labels resulting in an EO data model. This opens the way toward an automated identification and classification of urban areas, their infrastructure (e.g., airports), geographic objects (e.g., rivers), and industrial installations. Applications that may result from this work can be a semantic catalogue of urban images to be used in crisis situations or after a disaster.

We also created a SAR image ontology based on our EO data model and a three-level taxonomy classification scheme of the image content. Our approach links, for instance, high-resolution TerraSAR-X images with information from CORINE Land Cover (CLC), Urban Atlas (UA), GeoNames, and OpenStreetMap (OSM), which are represented in the standard triple model of the resource description frameworks (RDFs).

In order to allow interactive querying of images, the stRDF model and the stSPARQL query language have been implemented in the Strabon system, which is freely available as open source software. Strabon extends the well-known open source Sesame 2.6.3 RDF store and uses PostGIS as its spatially enabled backend DBMS.

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2.5 Urban Climate

Continuous Thermal Monitoring of Cities from Space

Keramitsoglou, Iphigenia (1); Kiranoudis, Chris (1,2); Sismanidis, Panagiotis (1,2)
1: National Observatory of Athens, Greece; 2: National Technical University of Athens, Greece

In the context of global climate change, most Mediterranean cities have undergone significant warming during last decades which is more pronounced in the summer. Urban Heat Island phenomenon has an additive effect on the regional warming. Meanwhile, the increase in the mean air temperature is accompanied by the increase in the frequency of hot extremes. Therefore, appraisal and quantification of spatially distributed heat wave risk are required to develop innovative tools and services for the subsequent design of targeted measures and strategies. This was the motivation behind the development of a fully automated system for the continuous monitoring of Land Surface and Air Temperatures (LST and AT, respectively) of European cities in real time every 5 minutes at 1km resolution. Realizing the importance of monitoring the thermal urban environment and the existing gap in data and system availability, the Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing of the National Observatory of Athens (IAASARS/NOA) has developed a system for continuous monitoring the urban thermal environment at high spatial and temporal resolution. This work presents a system based on the data acquired by Meteosat Second Generation 2 – Spinning Enhanced Visible and Infrared Imager (MSG2-SEVIRI) Rapid Scanning Service (RSS) downscaled to 1 km. It is using several algorithms developed by our team as well as products and procedures from Eumetsat Satellite Application Facility on support to Nowcasting/ and Very Short-Range Forecasting (SAFNWC version MSG v2013). In the current implementation, Numerical Weather Predictions (NWP) necessary for SAFNWC are retrieved from the Global Forecasting System (GFS of the U.S. National Climatic Data Centre) for the entire Earth with a grid size of 0.25 degrees. The developed system comprises five major modules, namely: i) SEVIRI image acquisition, ii) nowcasting of clouds and other atmospheric parameters, iii) derivation of LST and AT from clear sky thermal infrared radiances; iv) sharpening of LST using Support Vector Regression Machines (SVM) and iterative gradient boosting; and v) resampling of AT to 1km. For the demanding retrieval of AT, a first guess atmospheric profile is utilized from GFS and subsequently the radiances at satellite are simulated by RTTOV radiative transfer model. The solution is iterated until the simulated and measured radiances converge. The system offers four significant advantages: 1) it exploits the high temporal resolution of SEVIRI RSS imagery (5 min), 2) it enhances the spatial resolution of the retrieved temperatures (LST and AT) down to 1 km, 3) it covers a large number of cities around the world, and 4) the derived products are available in real time.

Higher-level products are also produced at the same resolution: Heat Wave Hazard, Cooling Degrees and Discomfort indices. The system as well as the products obtained for 15 cities during summer 2015 will be presented. An initial assessment will also be presented. The system is developed as part of TREASURE project (Thermal Risk rEduction Actions and tools for SecURE cities) funded by the General Directorate for Humanitarian Aid and Civil Protection (ECHO/SUB/2014/695561). TREASURE web site: http://treasure.eu-project-sites.com/ Twitter: @TREASURE_Proj

Urban Energy Budget Estimation from Sentinels: The URBANFLUXES Project

Chrysoulakis, Nektarios (1); Heldens, Wieke (2); Gastellu-Etchegorry, Jean-Philippe (3); Grimmond, Sue (4); Feigenwinter, Christian (5); Lindberg, Fredrik (6); Del Frate, Fabio (7); Klostermann, Judith (8); Mitraka, Zina (1); Esch, Thomas (2); Al Bitar, A
1: Foundation for Research and Technology Hellas (FORTH), Greece; 2: German Aerospace Center (DLR), Germany; 3: Centre d'Etude Spatiale de la Biosphère (CESBIO), France; 4: University of Reading, United Kingdom; 5: University of Basel, Switzerland; 6: Uni

The recently launched H2020-Space project URBANFLUXES (URBan ANthrpogenic heat FLUX from Earth observation Satellites) investigates the potential of Copernicus Sentinels to retrieve anthropogenic heat flux, as a key component of the Urban Energy Budget (UEB). Temperatures in cities are predicted to rise even more in the future, resulting in increased energy demand for cooling systems in low and mid-latitude cities, modifying UEB. A positive feedback cycle occurs in many urban areas, where higher temperatures result in more energy being used for cooling, which in turn adds to heat emissions and increases temperatures further during periods with increased heat wave risk. It is expected that without mitigation measures, energy demand will continue to increase during the warmest months. URBANFLUXES advances the current knowledge of the impacts of UEB fluxes on urban heat island and consequently on energy consumption in cities. This will lead to the development of tools and strategies to mitigate these effects, improving thermal comfort and energy efficiency. In URBANFLUXES, the anthropogenic heat flux is estimated as a residual of UEB. Therefore, the rest UEB components, namely, the net all-wave radiation, the net change in heat storage and the turbulent sensible and latent heat fluxes are independently estimated from Earth Observation (EO), whereas the advection term is included in the error of the anthropogenic heat flux estimation from the UEB closure. A dense network of conventional meteorological stations is used in each case study city: London, Basel and Heraklion. EO data is initially analysed to map urban surface morphology and cover, whilst a new approach has been developed to define Local Climate Zones (LCZ). Using the LCZ as a framework, advanced EO-based methods are used to estimate UEB fluxes: a sophisticated radiative transfer model (Discrete Anisotropic Radiative Transfer) is employed to simulate the net all-wave radiation; the computation of the storage term is based on the Element Surface Temperature Method, supported by the auxiliary datasets; and the estimation of the turbulent heat fluxes is based on the Aerodynamic Resistance Method, supported by standard meteorological measurements. In-situ flux measurements (Eddy Covariance, scintilometry) and bottom-up approaches (inventories, building energy models) are used to evaluate URBANFLUXES outcomes, whereas uncertainties are specified and analysed. The project exploits Sentinels observations, which provide improved data quality, coverage and revisit times and increase the value of EO data for scientific work and future emerging applications. These observations can reveal novel scientific insights for the detection and monitoring of the spatial distribution of the urban energy budget fluxes in cities, thereby generating new EO opportunities. URBANFLUXES thus exploits the European capacity for space-borne observations to enable the development of operational services in the field of urban environmental monitoring and energy efficiency in cities. It is therefore expected to prepare the ground for further innovative exploitation of European space data in scientific activities (climate variability studies at local and regional scales) and future and emerging applications (sustainable urban planning, mitigation technologies) to benefit climate change mitigation/adaptation and civil protection.

Mapping urban surface characteristics for urban energy flux modelling

Heldens, Wieke (1); del Frate, Fabio (2); Lindberg, Fredrik (3); Mitraka, Zina (4); Latini, Daniele (2); Chrysoulakis, Nektarios (4); Esch, Thomas (1)
1: DLR, Germany; 2: GEO-K, Italy; 3: University of Gothenburg, Sweden; 4: FORTH, Greece

Climate surface parameters in urban areas and the urban energy budget are influenced by the urban spatial characteristics. Thus, to model the urban energy budget, a characterization of the urban surface is required. Within the H2020 Project URBANFLUXES it is aimed model the urban energy budget and especially the anthropogenic heat flux using earth observation (EO) data. EO data is especially valuable for the mapping of the urban surface characteristics. The main advantage to do so is the transferability to any city, because objective input data can be generated. The EO methods for URBANFLUXES are developed and applied to three cities: Basel, London and Heraklion.A requirements catalogue has been defined to ensure the EO products are adapted to the needs of the subsequent energy budget models. The required products are divided in morphological parameters and surface parameters. The morphological parameters describe the vertical structure of the urban area and require a detailed digital surface model. For URBANFLUXES, in addition to the surface and elevation models also the building height, sky view factor, building fraction (plan area index) and frontal area index are derived. The surface parameters describe characteristics such as land cover fractions, phenology (NDVI, LAI), albedo and surface temperature. The parameters that are related to vegetation have a higher variability through the year than the built up area. Therefore these parameters are derived multiple times per year, but also at a lower spatial resolution. All products are transferred to the same spatial grid. Various sources of EO data at different spatial and temporal resolution are used, depending on the requirements.As basis for the morphological parameters a lidar DSM and derived DEM is available for the city of Basel and London. For Heraklion a DSM and DEM derived from stereo imagery is available. From the DEM and DSM, the sky view factor, plan area index and frontal area index are calculated according to Lindberg and Grimmond (2010) and Grimmond and Oke (1999). The results are aggregated to a 100 m grid. For the calculation of the surface parameters of Basel it is made use of data of Landsat 8 and Spot 5. The land cover fractions are calculated using a neural network approach (Del Frate et al. 2007)To describe the phenology time series of NDVI are calculated on the Landsat data. Also the albedo is calculated on the Landsat 8. Surface temperature is derived in local scale from the synergistic use of Landsat and MODIS acquisitions (Mitraka et al., 2015). All methodologies are implemented in a way that enables switching to the Sentinel 2/3 data as soon as the data becomes available.The resulting EO products are the input for urban climate models to enable the estimation of anthropogenic heat flux. But they are also used as input for the classification of Local Climate Zones (LCZ). Stewart and Oke (2012) formally defined LCZ as regions of uniform surface cover, structure, material, and human activity that span hundreds of meters to several kilometers in horizontal scale. After successful classification and combination with the modelling results of the URBANFLUXES project, the LCZ could be used as an indicator for regions with certain anthropogenic heat flux characteristics.

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Local Climate Zones as a new standard for mapping urban areas?

Bechtel, Benjamin (1); Mills, Gerald (2); See, Linda (3); Ching, Jason (4); Stewart, Iain (5); Alexander, Paul (6); Feddema, Johannes (7); Foley, Micheal (2); Keramitsoglou, Iphigenia (8)
1: University of Hamburg, Germany; 2: University College Dublin, Ireland; 3: IIASA, Austria; 4: University of North Carolina, USA; 5: University of Toronto, Canada; 6: National University of Ireland Maynooth, Ireland; 7: University of Victoria; 8: Nationa

Detailed information about the layout internal structure of urban areas is needed urgently for a number of applications including planning, energy consumption, and climate impact assessment. While there have been large improvements in the global derivation of urban built-up areas from space, --the internal differentiation of cities according to their morphology or form remains a challenging task. The complexity of urban structures, the heterogeneity of materials, and the multiplicity of spectral properties pose problems in finding a consistent method for the derivation of urban structural types (UST). Accordingly, various typologies – each specific to the characteristics of a particular area of interest – have been used in the past, which severely limits the comparability of such studies among different locations. Hence a common and generic description of urban structures would be an essential first step towards a universal mapping scheme that characterizes the internal configuration of urban areas. In urban climatology the Local Climate Zone (LCZ) scheme has recently been introduced to facilitate communication of urban surface characteristics for heat island studies. The scheme provides a good framework for the discretization of urban areas on a kilometric scale, is largely free of cultural or climatic bias and additionally delivers a large number of quantitative properties for each of its constituent classes. Furthermore, it has been demonstrated that LCZs can be classified in a satisfactory manner using freely available satellite space borne data from both multispectral or SAR sensors such as Landsat 8 and Sentinel 1 & 2, provided sufficient training data for a specific city are available. In this presentation the LCZ scheme is highlighted and its advantages as a standard for UST classification in urban remote sensing are stressed and discussed. The World Urban Database and Access Portal Tools (WUDAPT) initiative is introduced, which aims to collect information about the form and function of urban areas on a global scale using remote sensing and crowdsourcing. Finally, initial results from various cities are presented.

Earth Observation for Urban Climate: Mapping the Local Climate Zones

Mitraka, Zina (1); Chrysoulakis, Nektarios (1); Heldens, Wieke (2); Feigenwinter, Christian (3); Lindberg, Fredrik (4); Grimmond, Sue (5); Del Frate, Fabio (6); Gastellu-Etchegorry, Jean Philippe (7)
1: Foundation for Research and Technology Hellas, Greece; 2: German Aerospace Center, Germany; 3: University of Basel, Switzerland; 4: University of Goeteborgs, Sweden; 5: University of Reading, United Kingdom; 6: Geo-K s.r.l., Italy; 7: Centre d'Etude Sp

Data collected by Earth Observation (EO) satellites provide a valuable source of information for understanding, monitoring, modelling and thus protecting the urban environment. The increasing availability of EO systems and the advances in remote sensing techniques increase the opportunities for monitoring the urban environment and its thermal behaviour. Several parameters related to the urban climate can be derived from EO data, providing valuable support for advanced urban studies and climate modelling. Recently, attention has been drawn to the quantitative description of the urban thermal patterns and their correlations to fundamental surface descriptors. A detailed classification scheme of Local Climate Zones (LCZ) was introduced (Steward and Oke, 2012), based on various former typologies, which explicitly defines urban landscapes according to their thermal properties. The individual classes aim to have relatively homogenous air temperature within the canopy layer and they are defined by fact sheets with both qualitative and quantitative properties.

In this study, EO data are used to derive quantitative information for discriminating between the LCZ and a methodology to combine the different scales and delineate the zones is developed. A set of parameters is estimated from EO data and the methodology is applied to three case studies of the URBANFLUXES project, i.e. Heraklion, Greece, Basel, Switzerland and London, UK. Parameters like the impervious and the pervious surface fraction and the surface albedo were quantified using satellite data. Combining ancillary information for the morphology of the city, parameters like the buildings density and the mean building height and the canyon aspect ratio are also quantified for the study sites. A methodology to handle the different scales of the EO products was established and a Graphical User Interface (GUI) was built to outline the possible LCZ.

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2.6 Sentinel 1methods

Sentinel-1A SAR Data for Global Urban Mapping: Preliminary Results

Jacob, Alexander; Ban, Yifang
KTH Royal Institute of Technology, Sweden

Urban extent and land cover have been mapped using a range of datasets and algorithms. With the recent launch of Sentinel-1A, SAR data with global coverage, operational reliability and quick data delivery became freely available, thus provide excellent opportunity for developing SAR-based methods for global urban mapping. The objective of this research is to evaluate Sentinel-1 SAR data for quick and reliable urban extent extractions in selected cities around the world using the KTH-Pavia Urban Extractor, developed in collaboration between KTH and University of Pavia. This study is part of the EO4Urban project funded by the ESA DUE INNOVATOR III program.Multitemporal Sentinel-1A SAR data over Bejing, China, Milan, Italy, Stockholm, Sweden and Lagos, Nigeria were acquired for this research. The methodology is based on the original approach developed by Gamba et al. (2011) using both spatial indices and texture measures. The overview of the methodology in this research is illustrated in Figure 1 with the improvements highlighted in light and dark green. The improvements mainly involve preprocessing, contrast enhancement, post-processing as well as decision level fusion using multitemporal and multipolarization data. The original method shown in blue is based on "Local Indicators of Spatial Association" (L.I.S.A.), including the Moran index, the Geary index and the Getis-Ord index and GLCM variance and correlation textures. The detailed methodology can be found in Ban et al. (2015) and Gamba et al. (2011). The preliminary urban extraction results showed that urban areas and small towns could be well extracted using a single-date Sentinel-1A SAR data with the KTH-Pavia urban extractor. The urban extraction results are further improved using multitemporal dual orbit Sentinel-1A SAR data. Rigorous accuracy assessments are being performed and will be reported at the workshop.

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Mapping Past and Current Urbanization by Means of ESA Radar Data - the SAR4Urban Project

Marconcini, Mattia; Metz, Annekatrin; Zeidler, Julian; Esch, Thomas
German Aerospace Center, Germany

Starting from the beginning of the years 2000, more than half of the global human population is living in urban environments and the dynamic trend of urbanization is growing at an unprecedented speed. Rapid urban growth brings several challenges, including meeting accelerated demand for basic services, infrastructure, and affordable housing (particularly for the nearly 1 billion people living in informal settlements). Moreover, as cities develop, their exposure to climate and disaster risk increases (e.g., almost half a billion urban residents live in coastal areas, thus increasing their vulnerability to storm surges and sea level rise). In this framework, an effective monitoring of urban sprawl represents a key issue to analyze and understand the complexity of urban environments and ensure a

sustainable development of urban and peri-urban areas.To this purpose, the ESA DUE Innovator III SAR4Urban project aims at implementing - in support of its users the World Bank and GEO Global Urban Observation and Information Task for Societal Benefits (GEO SB-04) - a novel service that allows to automatically and reliably derive maps of past and current extent of urban areas by means of archived ERS/ASAR and novel Sentinel-1 data, respectively.The basic assumption of the intended approach is that given a series of multi-temporal images for a given study area, the temporal dynamics of urban settlements are sensibly different than those of all other non-urban classes. As an example, the backscattering temporal mean of urban areas (due to double bounce reflection) is higher than that of forest areas (which might result in high backscattering in one/few acquisitions due to specific conditions, but in general exhibit lower values).After applying orbit correction, calibration, and terrain correction to the multi-temporal images available over a region of interest in the selected time interval, for each pixel we extract key temporal statistics (i.e., backscattering temporal mean, standard deviation, minimum, maximum, etc.). It is worth noting that for different pixels in the study area, different number of scenes might be available. However - in the hypothesis of a sufficient minimum number of acquisitions for computing consistent statistics - this does not represent an issue. Indeed, we always expect a more stable behavior of the urban class compared to the others (for which the temporal variability is higher). Heterogeneity features are also extracted to ease the detection of lower-density settlements and, finally, specific unsupervised classification schemes are applied to ERS/ASAR and Sentinel-1 data, respectively.

Output of SAR4Urban will include the 2002-2003 urban extent map of entire Africa derived from ASAR WSM data, as well as the urban extent maps of Athens, Beijing, Los Angeles, Mexico City, Atlanta and the Pearl River Delta derived from ERS-1/2 PRI and ASAR IMP scenes. Moreover, the current built-up extent of both these and several African cities will be delineated by means of Sentinel-1A imagery. Preliminary results are extremely promising and confirm the great potential of ESA SAR data for mapping urbanization over time.

Automated updating of urban land cover maps using multitemporal Sentinel-1 data

Riedel, Tanja; Schmullius, Christiane
Friedrich-Schiller-University, Germany

Human activities on the Earth's surface are rapidly altering our environment. Ongoing urbanization is a global phenomenon and one of our world's most pressing challenges. For the monitoring of human-induced changes and to better understand global environmental changes, consistent and reliable global urban area maps are urgently needed. This study was conducted in the framework of the Land Cover CCI project as part of the ESA Climate Change Initiative (CCI) and focuses on the development of an automated processing chain for the updating / improving of the urban class of the CCI-LC global land cover product (resolution ~ 300m) using multitemporal Sentinel-1 SAR data with 20m spatial resolution. The test sites are located in semiarid and arid regions in the Mediterranean and Northern Africa, namely Portugal, Turkey, Israel, Egypt and Tunisia. As demonstrated by several studies SAR data reveals a high potential for urban area mapping. Due to numerous occurrences of double bounce effects, urban areas are characterized by high radar backscatter values in radar images. Multitemporal backscatter statistics and texture measures are particularly valuable tools for the detection of built-up areas and will be used in this study. The proposed methodology takes the UADP (urban area detection parameter) texture measure and the Sentinel-1 multitemporal mean values at VV- and VH polarization as input. The UADP measure calculates the mean radar backscattering difference for each pixel and its surrounding pixels under a neighborhood constraint. The proposed update algorithm consists of two main processing steps: first, an initial urban area mask is produced applying an unsupervised ISODATA classifier. Based on this initial map the update process is performed in the second processing step, considering further parameters such as object size, neighbourhood functions etc. The algorithm was developed for the Tunisia data set. To demonstrate the transferability of the proposed methodology the processing chain was applied to the other four semiarid / arid test sites mentioned above without any adaptions. In the end, the produced map updates of the urban class of the CCI-LC land cover product will be validated. This validation process includes (a) a qualitative validation based on visual comparison with high

resolution imagery, (b), a statistical product validation using reference hexagons and (c) a product intercomparison with other existing land cover products.

Towards a Global Built-up Area Map using Multitemporal Sentinel 1A Data

Salentinig, Andreas; Lisini, Gianni; Gamba, Paolo
University of Pavia, Italy

Urbanization and its impact on the environment is without doubt one of the major global challenges. Satellite-based Earth Observation is the only reasonable approach in order to detect and delineate urban area extents on the global scale. Due to their independence to daylight and weather conditions, SAR data have become not only a complementary source of information, but also has proved their usability as a stand alone source for accurate built-up area extractions. Since its launch in April 2014, the Sentinel 1A SAR sensor acquired thousands of images in different modes. Due to the intended global coverage at high spatial resolution Sentinel 1A data hold a tremendous potential for accurate urban area detection and characterization at the planetary scale. This work deals with the adaption and optimization of an already existing and intensively validated urban area extraction algorithm (Urban EXTractor) for the application on Sentinel 1A data. The UEXT algorithm has been originally developed for ENVISAT ASAR Wide Swath Mode data at a spatial resolution of 75 meters in the framework of the ESA Climate Change Initiative – Land Cover (CCI-LC). The main idea of the UEXT method is based on the assumption that urban areas do not significantly change within short time frames and therefore they can be easily be recognized in multi-temporal images stacks due to the fact that – in contrast to built-up areas - the surrounding areas usually change their appearance throughout annual phenological cycles. The same multi-temporal filtering, averaging and equalization procedure has been applied on Sentinel 1A data at a spatial posting of approximately 20 meters. Starting from the multi-temporal image stack, the algorithm searches for very bright pixels which, in SAR imagery, usually correspond to artificial structures and are consecutively used as starting points for a region growing procedure which is iterated until a specific threshold is reached. Due to the increased spatial resolution of the Sentinel 1A data the parameters of the UEXT algorithm had to be adapted and additional object-based post-processing steps have been applied in order to refine and improve the results. The optimized UEXT 2.0 method has been so far tested on multiple test sites in arid and semi-arid region, because these were the areas where the previous version of the approach, based on ASAR WSM data, provided the poorest results. Advantages and drawbacks of UEXT 2.0 are presented in detail in this work. Furthermore, the potential of cross-polarized VH backscatter is evaluated in the context of global human settlement characterization. To this aim, in all test areas (located in Portugal, Tunisia, Turkey and Israel) an objective reference data set was generated through random selection and consecutive manual labeling of discrete global grid hexagons. The quality of the urban extent extractions have been assessed visually and quantitatively. Results show that the UEXT method can be successfully applied on Sentinel 1A data and that this new generation SAR sensor bears a huge potential for urban area extractions at the local, continental and global scale.

Automatic Generation of Updated Land Cover Maps at Decametric Spatial Resolution for the whole Italian Territory Using Satellite Data

Boutsia, Konstantina (1); Carbone, Francesco (2); Del Frate, Fabio (1); Mitraka, Zina (1); Schiavon, Giovanni (1)
1: University of Rome Tor Vergata, Italy; 2: GEO-K SRL

Although the use of satellite data for land cover/land use monitoring is one of the most addressed topics in scientific remote sensing literature, the implementation of processing chains for the production of regularly updated land cover maps at decametric spatial resolution and at national scale is still a rare case. In fact, on one side, the cost and the not always systematic availability of the data may represent a limiting factor, on the other side, the algorithms developed by the scientific community may not have the necessary robustness for being applied nationwide, which involves a lot of manual corrections and, in turn, unbearable costs. In this context, the launch of the Sentinel 1 and 2, coupled with the free distribution of the data, can yield significant improvements. In particular, the SAR images provided by Sentinel 1 guarantee data availability with a high revisit time even in case of cloudy sky, which can be very important especially in northern regions. In this paper we present the preliminary results obtained by the implementation of a processing scheme using satellite images to provide, and regularly update every six months, land cover maps for the whole Italian territory. Indeed although in Italy some regional institutions have developed local GIS including land cover maps, a consistent nationwide product , at least to our knowledge, is still not existent, especially if an update every six months is considered. Aiming at keeping high both the level of automation and the final accuracy the scheme consists of four steps. In the first step the whole Italian territory is divided in a certain number of tiles. In the second step for each tile a pixel based classification is performed using a multi-layer perceptron neural network (MLP-NN) algorithm [1]. By mosaicing all the classified tiles we obtain what we call the "Master" land cover map. In the third step the update of each classified tile is addressed using new satellite data. To this purpose a change detection algorithm based on Pulse Coupled NN (PCNN) is considered [2]. PCNN is a relatively new technique based on the implementation of the mechanisms underlying the visual cortex of small mammals [3]. Only the changed pixels detected by the PCNN are reclassified with the MLP-NN and the whole updated land cover map is obtained. In the fourth step an accuracy evaluation of the final product is carried out. In our study the "Master" land cover map has been produced using Landsat acquisitions while for the updated versions of the map either Landsat or Sentinel 1 images have been considered. To assure enough robustness and accuracy a restricted number of land cover classes has been considered so far: forest, built areas, water, other natural surfaces. The final results are encouraging: first of all a consistent land cover map of the whole Italian territory with a spatial resolution of 30 m has been produced with an overall accuracy of about 92%. Moreover the PCNN procedure allows us to update the maps using a very high level of automation and keeping the same final accuracy.

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2.7 Emerging Methods

Characterizing Urbanization Processes in West Africa using Multi-temporal Earth Observation Data

van der Linden, Sebastian (1,2); Schug, Franz (1); Okujeni, Akpona (1); Hostert, Patrick (1,2); Hauer, Janine (3); Nielsen, Jonas Ø. (1,2)
1: Humboldt-Universität zu Berlin, Geography Department, Germany; 2: Humboldt-Universität zu Berlin, IRI THESys, Germany; 3: Humboldt-Universität zu Berlin, Institute for European Ethnology, Germany

Some of the world's fastest growing cities are located in the semi-arid West Africa. Driven by rural-to-urban migration, natural growth rates and by restructuring of land zones from rural to urban, urbanization follows irregular patterns including formal and informal processes often causing urban sprawl with associated infrastructural problems. Earth observation (EO) offers the means to retrospectively monitor patterns of urban expansion and has frequently been applied to map urban extent particularly in the Global South. However, for a better understanding of social, demographic and policy drivers of urban growth, maps are needed that go beyond bio-physical properties directly extracted from EO data. Using Landsat TM/ETM+/OLI data we have monitored the urbanization of Burkina Faso's capital Ouagadougou between 1985 and 2014. In a two-step process we first mapped land cover fractions for six points in time. Subsequently, the temporal pattern of fractions was interpreted together with information from a socio-demographic survey in order to create maps showing different stages of urbanization. The land cover fractions for each time step were derived from multi-seasonal image stacks. Here the often strong differences between dry and wet season often preventing sound analysis were actually utilized to differentiate between, e.g., permanent soil and soil on rain-fed agricultural areas or areas with natural seasonal vegetation. This way, early stages of informal settlement, characterized by often roof-less mud buildings could be identified. Based on multi-temporal information on land cover fractions, the transition of soil to human made materials such as burned bricks could be observed, which typically comes along formalized land rights. We present maps on the spatial-temporal distribution of informal and formal urban areas and show temporal profiles of cover fractions for selected neighborhoods. The applied methodology shows the high potential of high spatial resolution multi-spectral data with high frequent coverage such as Landsat-8 or Sentinel-2. The better 20 m spatial resolution of Sentinel-2 data will allow more reliable mapping of cover fractions. Therefore, an even increased reliability and accuracy of maps on urban coverage can be expected from 2015 onwards.

Earth Observation in support of the City Biodiversity Index

Kleeschulte, Stefan (1); Gregor, Mirko (1); Jaeger, Jochen A.G. (2); Nazarnia, Naghmeh (2); Paganini, Marc (3)
1: space4environment, Luxembourg; 2: Concordia University Montreal, Canada; 3: ESA ESRIN, Italy

The City Biodiversity Index (CBI), also known as the Singapore Index on Cities' Biodiversity, has been specifically developed for monitoring and evaluating biodiversity in cities. In times of an ever increasing population in urban areas - today more than half of the world's population live in cities - this trend poses a range of challenges for cities and their surroundings, not only in terms of resource availability and the quality of urban environments, but also in terms of impacts on biodiversity in cities. Since the 2010 target to halt biodiversity loss has been collectively missed, the new Aichi biodiversity targets aim to improve the status of biodiversity and to reduce the pressures on biodiversity by 2020. Capturing the status and trends of biodiversity, ecosystems and their services has therefore become a central aspect at local, regional and global scales. The CBI has been adopted during COP-10 of the CBD in 2008 and is conceived as a self-assessment tool to evaluate the state of biodiversity in cities and to provide insights for improving conservation efforts. This includes an initial baseline measurement, the identification of policy priorities based on their measurements and then a monitoring at periodic intervals.

The CBI includes 23 indicators from three different categories: Native biodiversity in the city Ecosystem services provided by biodiversity Governance and management of biodiversity During the early implementation of the CBI, it turned out that many cities miss relevant data, personnel and (GIS) skills to assess some of the 23 indicators. The current project addresses this gap and will develop an approach to provide the required information for four indicators which are often difficult for cities to implement:

Indicator 1: Proportion of natural areas in the city

Indicator 2: Connectivity measures or ecological networks to counter fragmentation

Indicator 11: Regulation of quantity of water

Indicator 12: Climate regulation: carbon storage and cooling effect of water

The project partners will use satellite-based data and combine them with appropriate in-situ and ancillary data to produce those indicators. They will be designed in a way to be directly usable by cities to assess their performance regarding the biodiversity targets. During the demonstration phase the indicator will be developed for the cities of Barcelona, Edmonton and Tallinn. In phase 2, the approach will be rolled out to additional non-European cities, such as Addis Ababa and Durban.

On the use of extended vegetation-impervious-soil maps from simulated EnMAP data for characterizing urban functional areas

Okujeni, Akpona; van der Linden, Sebastian; Hostert, Patrick
Humboldt-Universität zu Berlin, Germany

Rapid urban growth is one of the major challenges of the 21st century. Earth is increasingly urbanized, imposing steady pressure upon human-natural urban systems. The forthcoming hyperspectral satellite mission Environment Mapping and Analysis Program (EnMAP) will frequently and globally sample high quality imaging spectrometer data. Novel opportunities for deriving improved descriptions of urban environments will be created. These are relevant for disciplines involved in urban environmental research or urban planning, and include details on the amount and spatial distribution of different impervious, pervious, and vegetation types but also information on the functional land use characteristics. This study demonstrates the potential of the EnMAP mission for providing profound information on urban land use from detailed urban land cover fraction maps. Different hierarchical levels of urban functional areas as depicted by the European Urban Atlas (UA) were used as baseline. This Atlas is part of the local component of the GMES/Copernicus land monitoring services and intends to fill the gap in the knowledge about land use in European cities. In the first step, a simulated EnMAP scene and the combination of support vector regression with synthetically mixed training data were used for quantifying land cover along Berlin's urban-rural gradient. Results demonstrate the value of EnMAP data for accurately mapping vegetation, impervious and soil surface types (MAE < 12%, $R^2 > 0.8$) according to the well-recognized VIS framework. Moreover, EnMAP data allows for extending VIS by the more detailed sub-components roof, pavement, low vegetation and tree (MAE between 7.3% and 21.0%; R^2 between 0.52 and 0.84). In the second step, urban functional areas were characterized using statistical metrics derived from VIS and extended VIS fraction maps at the urban block scale. Results from a random forest classification clearly reveal the possibility for mapping three different levels of urban functional areas with overall accuracies of 96% (3 UA classes), 79% (5 UA classes) and 60% (9 UA classes). Observed relationships between land cover maps and urban land uses demonstrate the value of EnMAP-based mapping for describing functional characteristics of urban areas. Thus, a significant contribution to the automated derivation of reliable and regularly updated urban surface inventories such as the UA can be made.

Mapping Density with Intensity: Spatial Disaggregation of Gridded Population Density using Stable Night Light Brightness

Small, Christopher (1); Elvidge, Christopher (2); Yetman, Gregory (3); Baugh, Kimberly (2); MacManus, Kytt (3)
1: Lamont Doherty Earth Observatory, Columbia University, United States of America; 2: Earth Observation Group, National Geophysical Data Center, United States of America; 3: CIESIN, Columbia University, United States of America

Stable night lights provide globally consistent proxies for lighted development associated with a variety of human settlement types. Gridded census enumerations provide geospatial depictions of human population density associated with residential population distributions. Early work, most notably by Sutton, Elvidge and colleagues, has showed broad spatial correspondence of population density with night light intensity over a wide range of each. However, the large range of sizes of administrative units used in these early studies leads to widely varying spatial resolution of census enumerations, generally resulting in considerable spatial uncertainty of population and large disparities between night light intensity and interpolated population density. Recent improvements in both night light imaging and census data resolution have largely resolved this issue and now allow us to compare stable night light and residential population density with much greater spatial correspondence than previously possible. Quantitative comparison of population density and night light brightness provides a basis for estimation of density/intensity transfer functions in a diverse set of countries with spatially detailed census enumerations. We use night light brightness from the Visible/Infrared Imaging Radiometer Suite (VIIRS) on the NASA/NOAA Suomi

satellite and population density grids from the NASA SEDAC Gridded Population of the World v.4 (GPWv4) product to derive density/intensity transfer functions for a wide range of urban/rural gradients in the USA, Brazil, Sri Lanka, Malawi, South Africa and Portugal. We find multiple forms of bivariate distribution and transfer functions with broad consistency both within and across countries over a range of intensities of development. Comparison with Landsat imagery suggests general consistency with land use inferred from land cover. These results suggest that VIIRS night lights may be used with GPWv4 population density grids in countries with detailed census enumerations to derive more general transfer functions that can be used to produce simple, transparent ambient population products with spatial uncertainty estimates. Such products could be used for testing a wide range of environmental and socioeconomic scenarios in which a transparent depiction of ambient population density is required.

Closing Sessions

1.4 Poster Session

Hierarchical Hybrid Decision Tree Multiscale Fusion for Urban Area Mapping

Iannelli, Gianni Cristian; Gamba, Paolo
Università degli studi di Pavia, Italy

Multi-scale classification is an important tool for urban area mapping, because the objects in an urban scene may have very different spatial scales. In technical literature, this idea is usually performed by means of the same classifier (or ensemble of classifiers) at multiple resolutions, working on sets of features at multiple scales. Although this may be very efficient approach for peculiar situations, it is not generally applicable, as it does not adapt to (very) different scenes. Furthermore, different classification methodologies lead to different results and, consequently, the accuracies may vary for different applications. Accordingly, it can be useful to design a procedure based on the possibility to assemble specialized multi-scale classification chains automatically, according to the classes to be recognized and their peculiar scales or features. In this paper, we present a methodology that combines different processing chains (made by a feature selection and a classification step) and automatically adapts to the spatial (and spectral) properties of the classes available in a urban scene. To this aim, a hierarchical hybrid decision tree architecture is exploited. Typically, in homogeneous decision trees, at each node the same algorithm is used for separation between groups of classes. In our case, the most useful processing chain, composed by the most suitable feature set and the most efficient classifier, is selected per each node. This selection is performed by computing an intermediate accuracy assessment for each processing chain. Only the feature set and classifier pair that produces the best result is selected and assigned to the node. The procedure is then repeated removing the already identified class/classes until all the nodes are identified. In the end, the final classification map is obtained applying the designed framework to the whole dataset. The first prototype of this framework exploits four different sets of features and four different classifiers. The proposed method has been validated on two multi-spectral datasets covering the city of Pavia (Italy) and Xuzhou (China), and having different spatial resolutions. The results have been analyzed using statistical hypothesis tests (i.e. matched-pairs t-tests), showing the usefulness of the proposed method when compared to single processing chains.

Integration of historical maps and multi-temporal optical remote sensing data into a GIS system for studying of the largeRoman urban system expansion since the early twentieth century.

Martino, Luca (1); Loret, Emanuele (2); Sarti, Francesco (3); Fea, Maurizio (4)
1: Serco Spa / European Space Agency (ESA) - European Space Research Institute (ESRIN), Frascati, Italy; 2: University of Rome Tor Vergata, Rome, Italy; 3: European Space Agency (ESA) - European Space Research Institute (ESRIN), Frascati, Italy; 4: Italia

Rome is at the same time a historical and modern city. On one hand its monuments and artistic heritage testify its strong identity. On the other hand, the "eternal city" is open as well to the future and to innovations. Historical identity and modernization are moving forward hand in hand, and this ambivalence is now the true key to urban development. The urban agglomeration of Rome is therefore one of the fastest-growing regions in the world, and this growth has unprecedented effects on sprawl and population dynamics. Our research was conducted to examine past and current effects of the urbanization process, occurred over the large Roman urban system, based on old maps and multi-source and multi-temporal optical remote sensing (RS) data, collected between 1900 and 2014. These changes were then validated via Geographic Information System (GIS) techniques, in a particular procedure applied to urban land/agricultural transformations. The overlay of modern RS data over historic maps within GIS, allowed the understanding of the spatial relationships of past phenomena. The proposed approach, based on geo-statistical methods, was used to calculate the index of innovative space (AP Index), useful for the

monitoring of the urban sprawl phenomenon. Strong evidence of urban expansion over the north-eastern quarter of the city, accompanied by environmental degradation and loss of biodiversity, is provided. Urban infill developments are expected to emerge in the south-eastern areas too, and these might increase urban pressure as well. In conclusion, RS and GIS technologies together with ancillary data can be used to assist decision makers in preparing future plans to find out appropriate solutions to urbanization encroachment.

Remote Sensing Analysis In the area around Tanoor and Rasoon Spring

Bany Mustafa, Batool Mohammad
Ministry of Water and Irrigaton, Jordan, Hashemite Kingdom of

The major task of this remote sensing study is to produce a land-use map for the catchment area of Tanoor and Rasoon spring and thereby assist in the delineation of groundwater protection zones taking into consideration that Tanoor and Rasoon springs are of the main water resources in the area. Knowing the exact land-use and urban area density helps locating potential contamination sources that may pollute the spring system and in identifying areas which are vulnerable to groundwater contamination and therefore in planning for future human activities in the area and to formulate suitable restrictions on land-use. In that way a better protection of drinking water resources from contamination can be achieved. High resolution satellite imagery was used due to the karstic nature of the working area and its sensitivity to pollution. Furthermore, the wide range of topographic and land-use changes required this step where 0.5 meter and 2 meters resolution Pleiades images were purchased.

The geometric correction of the data was performed through the collecting GCPs. At eight geographic locations coordinates were taken by using a differential GPS. After post processing by an external consultant an accuracy of 0.02 to 0.03 m was obtained. The shift between images coordinates and field coordinates ranged from 8 to 11 meter. Therefore, a geometric correction was performed using Pci-geomatica ortho engine.A land-use map has been produced through supervised classification after that an accuracy assessment report was done based on the ground truthing points, 20 points were taken and checked in the field (by a handheld GPS with an accuracy of up to 3 meters). And another 118 points where taking using Google earth as a high resolution data source, however the report resulted in an overall accuracy of 89.13%. Supervised classification was used to extract buildings as potential contamination sources. A NDVI map was produced using ERDAS 2014 to determine the nature and density of vegetation in the area. The analysis of the data was carried out by using the remote sensing software ERDAS2014 and Pci-geomatica2012. The results were exported as shapefiles. The commercial Geographic Information System (GIS) ArcGIS was used to perform post processing and produce final maps.

Building's subsidence observed in Mexico City by remote sensing data.

Poreh, Dave; Riccio, Daniele
Uni Napoli, Italy

Mexico City is well known for its subsidence as a result of excess water withdrawal for many years. Soil deformations in the city areas are classified into two categories: sudden and slow subsidence. Sudden collapse rarely make geo hazard problems, however, slow subsidence usually make huge economic and human related disasters. Cities that were built on unconsolidated clays, silts, peats, or sands are in the danger of sudden and/or slow subsidence. Extreme ground water extractions, flooding, tsunami, earthquakes , etc are exposing the buildings in the danger of subsidence and/or related hazards. Most often the buildings and streets add weights to the region and intensify the soil's stress even more. Meanwhile, monitoring of the buildings extensions and their relationship with ongoing subsidence is crucial.The existing subsidence in Mexico City's metropolitan area because of the over-pumping has been studied in this paper. Maximum of nine meters of subsidence in an area as big as has been

observed in the Mexico City's metropolitan area. The main subsidence is happening because of the water extraction, and consequently compaction of the alluvial sediments. In the subside area, inter granular pressure of aquifers, decreases, and depletion of water at depth is the cause of the observed subsidence.

We studied this subsidence by means of Interferometric Synthetic Aperture Radar (InSAR), Continuous Global Positioning Systems (CGPS), and optical remote sensing data. Fifty two ENVISAT-ASAR, nine GPS stations, and one Landsat ETM+ image from Mexico City area have been analyzed to get better understand of the subsidence rates and its effects on Mexico City's commune. InSAR methods like differential interferometry and Persistent Scatter Interferometry (PSI) carried out, to monitor the existing subsidence. Our InSAR data covers temporal baseline between 2002 until June 2010, and our GPS data cover temporal baseline from 1998 until 2012.

Radar permanent scatterers were extracted with use of three well known methodologies of solving the integer ambiguities of phases in the radar images: bootstrapping, ambiguity function, and integer least square. It worth noting that the newly operated satellites like Sentinel-1 and Radarsat-2 are showing similar patterns of subsidence, stressing the fact that the rate/pattern of progressive subsidence in the study area, is unchanged. For risk assessment, support vector machine (SVM) methodology based on Landsat ETM+ image is carried out to classify Mexico City's populated density area, which further helped us to compare the subsidence rates (from PSI) with populated buildings. Maximum of 378.2 mm annually (from bootstrapping approach) change in Line Of Sight (LOS) direction in radar data, is in good agreement with the previous and newly measured studies. Considering this rate of subsidence, in ten years, it would reach in total of 3.8 meters of displacement, which mainly in the rainy sessions, floods would make real problems. This study shows that, the fastest subsidence in the over mentioned temporal baseline, occurs in the highly populated area, and ongoing subsidence are not slowing down.

Keywords: Mexico City, subsidence, Synthetic Aperture Radar (SAR), GPS, interferometry, Persistent Scatterer Interferometry (PSI).

Mapping the Land Surface Temperature over Urban Areas from Space: a Downscaling Approach

Bonafoni, Stefania (1); Anniballe, Roberta (2); Pierdicca, Nazzareno (2)
1: University of Perugia, Italy; 2: Sapienza University of Rome, Italy

Since decades, the land surface temperature (LST) is a parameter widely considered in the urban area mapping from space. LST has been often retrieved and mapped to evaluate the surface urban heat island (SUHI) using different spaceborne platforms, such as AATSR, ASTER, MODIS and Landsat. Several factors need to be assessed in the LST retrieval from satellite thermal infrared data: sensor radiometric calibration, atmospheric correction, surface emissivity estimation. Particularly, in urban area mapping issue, the satellite sensor spatial resolution may be a limiting factor in detailing the fine scale spatial variability, especially in the presence of impervious surfaces and sharp transitions (e.g., buildings, roads, parking lots, riverside, restricted vegetated zones), such as in a urban texture. The growing demand of remote sensing maps with finer and finer spatial resolution to successfully monitor the SUHI effects at district level and to avoid temperature underestimation stimulates the development of downscaling techniques when the actual sensor measurements do not meet the spatial detail requirements. In this work we perform the downscaling of coarse resolution LST maps from MODIS and Landsat to finer resolutions with the aim to increase the information content of the original maps, using summer satellite images over Milan, Rome and Florence. The downscaling is the enhancement of the spatial resolution of the original pixel data using ancillary information at higher spatial resolution. Different physical and statistical downscaling approaches have been proposed in literature: in this work, a statistical LST downscaling approach regression-based using different spectral indices over heterogeneous urban landscape is proposed, and the reliability assessed. This analysis allows to select the spectral indices and their combinations providing the best results in the LST image sharpening. First, the downscaling was performed using the Landsat TM data over Milan and Rome, assuming the 120 m spatial resolution image as reference. Then, the same downscaling regressive schemes were applied on the contemporary

coarse resolution LST MODIS image and verified with the reference LST Landsat map. A further downscaling assessment at finer resolution was carried out using the LST retrieved from Landsat TM over the city of Florence: in this case the sharpened image was compared with a high-resolution thermal image provided by an airborne survey carried out on July 18, 2010. Two Landsat scenes were processed before and after the flight, with the aim to evaluate the impact of the Landsat TM thermal channel resolution (120 m) on the LST estimation over a heterogeneous urban texture. Again, thermal data were downscaled at 30 m with a statistical algorithm using a regression on different spectral indices. The proposed approaches and comparisons allows us to assess potentials and limits of the LST downscaling performed over an heterogeneous urban area.

Copernicus Sentinels for Urban Planning in Russia: The SEN4RUS Project

Chrysoulakis, Nektarios (1); Marconcini, Mattia (2); Sazonova, Anna (3); Tal, Abraham (4); Dusgun, Sebnem (5); Parlow, Eberhard (6); Charalampopoulou, Vassiliki (7); Mitraka, Zina (1); Esch, Thomas (2); Cavur, Mahmut (5); Feigenwinter, Christian (6)
1: Foundation for Research and Technology Hellas (FORTH), Greece; 2: German Aerospace Center (DLR), Germany; 3: GRAD—Inform Ltd., Russia; 4: GARD Ltd., Israel; 5: Kuzgun Bilisim Ltd., Turkey; 6: University of Basel, Switzerland; 7: GEOSYSTEMS HELLAS S.A,

After the launch of the Copernicus Sentinels 1, 2 and 3 by the European Space Agency, the availability of free and open Earth Observation (EO) data streams provides totally new opportunities for innovative scientific and commercial geo-information services. With the given spatial resolution and revisiting times, the potential of Sentinels missions to support a wide range of environmental, regional and urban planning and monitoring applications is high. Recently, the ERA.Net-RUS project GEOURBAN developed a set of EO-based environmental indicators for urban planning and a software tool for their on-line evaluation. GEOURBAN mainly focused on the local city level; however, planning in peri-urban and rural areas is particularly important for Russia, given its huge territory and its high number of large cities and scattered settlements. Standard EO-based spatial datasets, such as the European Urban Atlas have proven to be quite valuable for various urban and spatial planning applications. However, this data just exists for the large and medium European cities, but not for the Russian ones. To this end, the main objective of the SEN4RUS (exploiting Sentinels for supporting urban planning applications at city and regional levels in Russia) project, that was recently funded by ERA.Net-RUS Plus, is to take into account the specific requirements of spatial and urban planning in Russia to develop indicators that effectively and efficiently exploit the information content provided by Sentinels mass data streams in support of city and regional planning. SEN4RUS is based on GEOURBAN outcomes, therefore using the expertise and basic techniques developed in the context of GEOURBAN, SEN4RUS will design and implement EO-based services for planners and decision makers that are specifically tailored to the Russian requirements. A key instrument in this context is the further development of a Web-based Information System (WIS) capable of evaluating the EO-derived indicators and provide them in a form that allows easy access and direct implementation into planning procedures. Three Russian cities with different typologies and planning perspectives have been included as case studies: St. Petersburg, Omsk and Vladivostok. To engage the users in the project, a Community of Practice approach will be employed. The innovation of SEN4RUS lies in the development of robust techniques for information extraction and derivation of geo-information products from Sentinel satellite imagery in combination with an improved WIS that is adapted to and optimized for the Russian urban and regional planning system and can be easily understood and controlled by non-experts. Adaptation of the SEN4RUS WIS to forthcoming missions have also been planned, therefore a fully operational tool is expected in the future.

A Comparison of Edge Detection Algorithms Used to Map Land Infrastructure Using QGIS Desktop

Hristova, Valentina Ivanova
Todor Kableshkov University of Transport, Bulgaria

The compared edge detection algorithms are Canny edge detector and SUSAN edge detector. The results are visualized and analyzed in order to extract significant information about edge detection algorithms efficiency when these methods are applied to map the land infrastructure. Positive and negative aspects of the methods are examined in terms to assess their results as advantages and disadvantages. The used image in the paper is over Venice, Italy. The algorithms are implemented by QGIS Desktop 2.4.0.

A Comparison of Segmentation and Classification Algorithms Used to Map Land Infrastructure Using QGIS Desktop

Hristova, Valentina Ivanova
Todor Kableshkov University of Transport, Bulgaria

The compared segmentation algorithms are best merge segmentation by Beaulieu and Goldberg, best merge segmentation by Tilton, normalized cut segmentation by Shi and Malik, tree merge segmentation by Felzenswalb and Huttenlocher. The tree merge segmentation by Felzenswalb and Huttenlocher is chosen based on its optimized features when the method is used to map land infrastructure. The result image from the tree merge segmentation by Felzenswalb and Huttenlocher is classified by Mahalanobis classification and Bhattacharyya classification. Experimental results are shown to illustrate the advantages and disadvantages of the methods. Future plans are created. The used image in the paper is over Venice, Italy. The algorithms are implemented by QGIS Desktop 2.4.0.

Global Estimates of Urban Surface Albedo Time Series with the Use of Cloud Computing

Benas, Nikolaos (1); Mitraka, Zina (1); Chrysoulakis, Nektarios (1); Marconcini, Mattia (2); Esch, Thomas (2); Lantzanakis, Giannis (1)
1: Foundation for Research and Technology - Hellas, Greece; 2: German Aerospace Center (DLR), Germany

The Land Surface Albedo (LSA) is a critical physical variable which influences the Earth's climate by affecting the energy transfer and distribution in the Earth-atmosphere system. Its role is highly significant in both global and local scales, since LSA measurements provide a quantitative means for better constraining global and regional scale climate modelling efforts. Similarly, in urban environments LSA is crucial for the estimation of the local scale radiation and energy budget. In the present study, the LSA was estimated in large urban areas globally, at 0.5 km × 0.5 km spatial resolution and on an 8–day basis, for the period 2001–2014. Products from the Moderate Resolution Imaging Spectroradiometer (MODIS), on board NASA's Terra and Aqua satellites were used, including the directional-hemispherical surface reflectance (black-sky albedo) and the bi-hemispherical surface reflectance (white-sky albedo), both available at 0.5 km × 0.5 km, and the MODIS-derived Aerosol Optical Thickness (AOT), at 1° × 1° spatial resolution. Since LSA also depends on Solar Zenith Angle (SZA), 8-day mean LSA values were computed as averages of corresponding LSA values for representative SZAs. The estimated LSA was analyzed in terms of both spatial and seasonal characteristics, while LSA changes during the period examined were assessed based on a linear regression approach. The effects of the Normalized Difference Vegetation Index (NDVI) and rainfall trends on LSA changes were also assessed. Urban areas were masked using the Global Urban Footprint (GUF) layer, i.e. the DLR global map of built-up areas derived by means of TerraSAR-X and TanDEM-X data acquired between 2011 and 2013. All computations were performed using the Google Earth Engine platform and the data available in its catalog, which include all the above mentioned satellite data. The Google Earth Engine is a cloud

system designed to enable petabyte-scale scientific analysis and visualization of geospatial datasets. Google Earth Engine's consolidated environment, including the abovementioned data, co-located with thousands of computers for analysis, made possible the global-scale urban LSA estimation for the 14-year period and the corresponding statistical analysis. The results revealed substantial spatiotemporal variability of LSA, highlighting the great potential of Earth Observation data in combination with the power of cloud computing in supporting relevant studies.

Urban Aerosol Concentrations from MERIS/AATSR Synergy: A Preparatory Study for Sentinel 3

Beloconi, Anton (1,2); Kamarianakis, Yiannis (3); Chrysoulakis, Nektarios (1)
1: Foundation for Research and Technology - Hellas (FORTH), Greece; 2: Swiss Tropical and Public Health Institute (Swiss TPH), Switzerland; 3: School of Mathematical & Statistical Sciences, Arizona State University, USA

Particulate Matter (PM) concentration is used as an air quality indicator in urban areas; it is highly important for urban planning and epidemiological studies. Numerous research works, analyzing the impacts of PM on human health, have found associations with increased morbidity and mortality. Monitoring of PM concentrations is primarily based on ground measurements. Despite the fact that dense station networks exist, in large cities like London, in situ measurements do not provide detailed information on the spatial distribution of PM at local scale. This reason has prompted an ongoing effort for PM estimation using satellite observations. The present study evaluates alternative spatio-temporal approaches for quantitative estimation of daily mean PM concentrations. Both fine (PM2.5) and coarse (PM10) concentrations were estimated over the area of London (UK) for the 2002-2012 time period, using Aerosol Optical Thickness (AOT) derived from MERIS (Medium Resolution Imaging Spectrometer) / AATSR (Advanced Along-Track Scanning Radiometer) synergistic analysis at 1 km x 1 km resolution. High-resolution (100 m) local urban surface cover and morphology datasets were incorporated in the analysis in order to capture the effects of local scale emissions and sequestration. Spatial (2D) and spatio-temporal (3D) kriging were applied to in situ urban PM measurements to investigate their association with satellite-derived AOT while accounting for differences in spatial support. Linear mixed-effects models with day-specific and site-specific random intercepts and slopes were estimated to associate satellite derived products with kriged PM concentration and their predictive performance was evaluated. The developed method will be adapted to Sentinel 3 series, the first of which (Sentinel 3A) is expected to be launched in late 2015: the synergistic use of the Sea and Land Surface Temperature Radiometer (SLSTR) and the Ocean and Land Color Instrument (OLCI), on board Sentinel-3, is expected to provide improved AOT and thereby to increase its potential to support local scale studies related to urban planning and public health. The statistical models produced in the present study will contribute to the development of an operational tool capable of producing high-resolution PM concentration maps using Sentinel-3 observations. Since all covariates used in the predictive models are satellite-derived products, the methodology can be transferred to other urban areas, to estimate both PM10 and PM2.5, depending on the availability of in situ measurements to calibrate satellite observations. While the MERIS and AATSR 11-year data set is suitable for investigating past PM changes and trends in urban areas, the forthcoming SLSTR and OLCI sensors offer the possibility of downscaling, if combined with the high spatial resolution MSI (Multispectral Instrument) onboard Sentinel-2 series. The common spectral channels of MSI, OLCI and SLSTR provide unique capabilities for synergistic use of observations from these sensors. Such synergistic use is expected to lead to daily PM concentration maps of high spatial resolution, which are necessary in urban air quality studies.

Fusion of Sentinel-1A and Sentinel-2A data for land use monitoring over Veneto region (NE Italy)

Delgado, J. Manuel (1,4); Cian, Fabio (2); Rivolta, Giancarlo (1); Giupponi, Carlo (2); Ruiz-Armenteros, Antonio M. (3,4)
1: Progressive Systems Srl, Parco Scientifico di Tor Vergata, 00133 Roma, Italy; 2: Department of Economics, Ca' Foscari University of Venice, Venice, Italy; 3: Departamento de Ingeniería Cartográfica, Geodésica y Fotogrametría, Centro de Estudios Avanzad

This paper explores the possibilities of synergy of data from Copernicus Program satellites on orbit, e.g. Sentinel-1A and Sentinel-2A, for land cover monitoring purposes.After the launch of Sentinel-1A on 3rd April 2014 and the recent launch of Sentinel-2A on past 23th June 2015, we are able to start combining both data for land cover monitoring.We had used the ascending track 117 of Sentinel-1A products acquired in interferometric wide mode in Single Look Complex format to exploit the interferometric capabilities of this sensor, together with the available Sentinel-2A products, available on Sentinels Scientific Data Hub, over the Veneto region (NE Italy). It has been selected this area since Veneto region is sensitive to flooding and hence, most accurate land cover maps are needed for a better management and control of areas with flood risk and the potential damage that new floods could cause.We have produced several land cover maps and we have compared the different possibilities of creation of these products, derived from SAR, Multi-spectral and the fusion of both data types.These are the first land cover maps with the highest resolution ever generated over Veneto using only free data from European Satellites, such are Sentinel-1A and Sentinel-2A, which will benefit a better economical estimation for being used in risk management and planning.

Mapping Urban Areas in Multitemporal SAR RGB Composites Using SOM and Object-Based Processing

Amitrano, Donato (1); Cecinati, Francesca (2); Di Martino, Gerardo (1); Iodice, Antonio (1); Mathieu, Pierre-Philippe (2); Riccio, Daniele (1); Ruello, Giuseppe (1)
1: University of Napoli Federico II, Italy; 2: ESA ESRIN

According to the United Nations Development Programme, the 21th century is the first “urban century” [1]. In 2014, 3.9 billion people, corresponding to the 54% of the global population, lived in cities [2], and, in 2050, this percentage will grow to 75% [3]. Furthermore, most of this growth concerns developing countries, which have limited capacities to deal with this rapid change.

The growth, often chaotic, of urban agglomerates has a not negligible impact on the environment. In fact, cities are the main responsible for some of the many global problems such as waste production and air and water pollution. Thus, the need for technologies that allow for monitoring and planning this expansion, for predicting and mitigating its effect on natural resources, as well as the exposure of populations to man-induced and natural risks, is growing rapidly.

Satellite imagery constitute a powerful tool for planning the most correct expansion of cities giving a synoptic view at regional scale. The recent launch of Sentinel-1 and Sentinel-2 satellites, under the aegis of the ESA Copernicus programme, represent an unprecedented occasion for the remote sensing community, which finally has the possibility to access data at free of charge both at multispectral and microwave frequencies.

In this paper, we present an innovative method for mapping urban areas from RGB multitemporal SAR derived composites [4], [5]. However, treating this topic, a question arise: how to define an urban area [6] ?Today, no generally accepted definition of “urban land” exists. In fact, urban areas could be defined by their administrative borders, but they often do not reflect the development of a town. Sometimes the boundaries lie beyond the cities built-up area, including rural countryside. Sometimes they lie within the built-up area. Other approaches limit the urban area to the “built-up” area or define it in terms of the areas for which services and facilities are provided. In

any case, the definition of urban area involves some arbitrary decisions in finding boundaries [7]. In fact, towns tend to merge physically and functionally with neighbouring towns and their hinterlands. Therefore there is no hard border for urban areas and in any definition an urban area embraces land cover types not typically urban, such as forest, parks or agricultural land [7].

From the standpoint of remote sensing, the only feature that can be associated certainly to an urban area is the "built environment" which, at the boundary of a city, constitutes a continuum with the rural area. In order to extract a border between the urban environment and the rural one, a dichotomy between these two features has to be created, modeling appropriately the existing urban-rural gradient [6].

We propose to solve this problem by exploiting an object-based processing performed on classified products obtained by SOM clustering of the input RGB SAR composites [5]. The obtained results, either on stripmap resolution COSMO-SkyMed derived products or on scansar resolution Sentinel-1 derived products, testified the reliability of our approach.

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Large scale semi-automated features extraction from very high resolution imagery to assist development and humanitarian efforts

Tigny, Vincent (1); xx, TBC (2); xx, TBC (3); xx, TBC (4)
1: GIM, Belgium; 2: Bill and Melinda Gates Foundation; 3: eHealth Africa; 4: The World Bank

Assistance provided by international organisations to developping countries is often hindered by lack of accurate and up-to-date geoinformation. GIM recently got the opportunity to address this issue by applying its in-depth expertise in object-based image analysis (OBIA) to the development of advanced semi-automated workflows extracting relevant features from a massive amount of very high resolution EO data. Two success stories demonstrating the contribution of space data to a sustainable, resilient and inclusive development will be presented. First case will show how GIM unlocked value from imagery to help stopping polio in Nigeria. In 2014, in the context of the Global Polio Eradication Initiative, GIM supported a large scale immunization effort by processing 100.000 km² of 50 cm resolution Pléiades imagery to map all kinds of human settlements (i.e. from single huts to large cities) with an unprecedented level of detail and detection rate hence allowing for locating and reaching every last child and ending polio. 12 TB of data were processed in 5 months time to extract half a million of buildings or small building groups, 20.000 villages and 1.500 cities that were then visited by the vaccination teams. Thanks to this unique urban mapping effort, the efficiency of the immunization campaigns could be greatly increased to the extent that no new polio case has been reported in this region since more than one year.

The second case story will illustrate how GIM, thanks to the support of ESA and the World Bank, could address the issue of lack of insights on urban sprawl and densification patterns and on urban poverty and its vulnerability to natural disasters in one of the fastest-growing agglomerations in Asia. Historical and current space data was first used to analyse the evolution of the urban extent and density in Metro Manila. The main achievement of this project was however to leverage the availability of very high resolution satellite imagery to map with an unprecedented level of detail all the informal settlements over entire Metro Manila area and parts of surrounding province (circa 750 km²). Moreover no minimum mapping unit was applied what allowed for retaining even the smallest slums. Often overlooked in the development of urban planning policies the latter represent however a very significant proportion of detected informal settlements. Finally, thanks to the power of OBIA methodology, GIM could reach the level of individual housing structures delineation within informal settlements. This in turn allowed for deriving a large set of relevant physical attributes such as average size of buildings, proportions of different building categories, density of buildings, presence of vegetation, etc. These attributes were then used in a model providing an objective classification of the slums into different types.Thanks to these products derived from space data, it is now possible to understand better the development of the city over the last 25 years and to identify the key processes driving current expansion of the city. The delivered products provided a comprehensive and consistent overview on how the land has been consumed and allocated while highlighting specific hotspots and patterns thereby providing leads for further analysis in conjunction with information on e.g. prevailing urban planning policies. Moreover, the informal settlements mapping layer and its attributes provide a reliable input to finally answer the question of the magnitude of the urban poverty issue (e.g. how many slums there are, how are they distributed, are they preferentially linked to specific LULC classes, etc). Likewise the informal settlement typology provided a unique insight and reveals the magnitude of particular aspects of urban poverty such as the example of the so-called "pocket slums". These layers also open up many perspectives in terms of informing decisions regarding the implementation of specific measures and the assessment of their social impact. They can for example support the identification and prioritization of specific and spatially targeted actions such as protection against flood, areas for resettlement or informal settlements upgrading for example in the context of the implementation of the new Flood Management Plan.

Urban Geometry Effects on Effective Emissivity and Surface Temperature Retrieval, Using the UEM-SVF and TUF-3D Models

Yang, Jinxin (1); Wong, Man Sing (1); Menenti, Massimo (2); Voogt, James (3); Krayenhoff, Scott (4); Dou, Youjun (5); Nichol, Janet (1); Chan, P.W. (6)

1: Department of Land Surveying and Geo-Informatics, The Hong Kong Polytechnic University, Kowloon, Hong Kong S.A.R. (China); 2: Faculty of Civil Engineering and Earth Sciences, Delft University of Technology, P. O. Box 5048, 2600 GA Delft, Netherlands; 3

The effect of the built geometry on surface temperature and effective emissivity in urban areas was studied. An effective emissivity was first modelled as a function of the geometry of the built-up space only. This is our urban emissivity model based on the sky view factor, indicated hereafter as UEM-SVF. Second, the effective emissivity was calculated using a micro-climate radiative model, i.e. the Temperatures of Urban Facets in 3-D model (Krayenhoff and Voogt, 2007), indicated hereafter as TUF-3D model. The two effective emissivity data sets were compared and evaluated, and the induced errors in surface temperature retrieval were also evaluated. Firstly, the effective emissivity derived from UEM-SVF was compared with the effective emissivity estimated from TUF-3D model. The effective emissivity from TUF-3D was calculated from the total upwelling longwave flux at the top of the urban canopy determined by the Stefan-Boltzmann flux at the complete surface temperature. Results showed that the effective emissivity derived from UEM-SVF was similar to that estimated using TUF-3D, under the assumption that all elements within a scene have uniform surface temperature and emissivity. The correlation coefficient (r2) was 0.99 and the root-mean-square errors (RMSEs) are 0.002, 0.004, 0.005, 0.004 respectively when the uniform material emissivity is assumed, ε = 0.8, 0.85, 0.90, 0.95 respectively. However, when the surface is heterogeneous, e.g. different materials and/or surface temperatures in a scene, the difference in two sets of effective emissivity was much larger. The degree of discrepancy is highly dependent on the degree of heterogeneity. When the surface temperature of all elements in a scene is assumed to be the same but the surface emissivity is different, e.g. the broad-band material emissivity of rooftops, roads and walls was different, e.g. 0.95 for roof, 0.90 for road and 0.85 for wall, respectively, the RMSEs between the two effective emissivities was larger than 0.01. On the other hand, when the material emissivity of rooftops, walls and roads was taken equal to the spectral emissivity of these materials in the Landsat-8 thermal bands, which are rather similar, thus high correlations and small RMSEs were observed between the effective emissivity values obtained with the UEM-SVF and the TUF-3D model. The r2 in both band 10 and band 11 was 0.99, and the RMSEs were 0.004 and 0.003 respectively. This result is mainly due to the material emissivity of rooftops, roads and walls being similar to each other, e.g. 0.95, 0.949 and 0.95 in band 10; 0.957, 0.958 and 0.957 in band 11.

When component temperatures within the observed target are very different, the discrepancy in effective emissivity increases dramatically. From the high resolution airborne thermal image obtained in Hong Kong on August 6th, 2013, the mean temperature of the rooftop is about 328.56 K, the mean temperature of road is 316.64 K, and the mean temperature of the wall is 304.94 K in a built-up area. If the effective emissivity is estimated using the total upwelling radiance at the top of the urban canopy calculated by TUF-3D model and the Stephan-Boltzmann emittance at the complete surface temperature, values larger than 1 were obtained in some cases. This occurs when the range of ratio of building height to street width was from 1 to 4. In these cases, the r2 between the effective emissivity from TUF-3D and UEM-SVF was 0.98, but the RMSE was 0.064 and 0.065 in the Landsat bands 10 and 11. In winter, the difference of component temperataure is smaller than summer (from satellite thermal image, the rooftop temperature is about 297.31 k, and the road temperature is 294.77 k, the wall temperature was assumed as 292.5 K). The RMSE between the effective emissivity from TUF-3D and UEM-SVF was only 0.009 and 0.01 respectively. Results showed that the RMSE is highly related to the different component temperatures in a scene when the material emissivities are same or similar.When the effective emissivity based on the TUF-3D model is calculated by the area weighted exitance of all surfaces and the Stephan-Boltzmann emittance at the complete surface temperature, it does not exceed 1. When using the UEM-SVF model, the effective emissivity will never be larger than 1 since it does not consider multiple scattering and reflection in heterogeneous mixed pixels with different component temperatures. The TUF-3D model revealed that the exitance of the canopy can be higher than the area weighted total emittance, because of the heterogeneity of component temperatures, material emissivities and geometry characteristics in the scene. This is because the surface with

lower temperature can reflect and absorb the higher radiance from other surfaces with higher temperature. The radiance measured by a space-borne radiometer over an urban canopy increases with specific surface area at constant horizontal footprint because of multiple reflection and scattering and this may cause the measured radiance over urban canopy at constant horizontal footprint to be higher than the total area-weighted emittance.

Considering that image pixels in urban areas are heterogeneous and non-isothermal, the effective emissivity calculated using TUF-3D model and UEM-SVF model was evaluated. Errors induced on the urban surface temperature retrieval were also analyzed. A case study on urban areas in Kowloon Peninsula was carried out, and errors induced by effective emissivities and surface temperature retrieval caused by heterogeneous pixels was investigated.

An urban expansion model for African cities using combined multi temporal SAR and optical data

Lopez Herreros, Juan Fran (1); Shimoni, Michal (1); Forget, Yann (2); Grippa, Taïs (3); Wolff, Eléonore (3); Linard, Catherine (2); Gilbert, Marius (2)
1: Signal and Image Centre, Dept. of Electrical Engineering (SIC-RMA), Brussels, Belgium; 2: Biological Control and Spatial Ecology (LUBIES), ULB, Brussels, Belgium; 3: Analyse Géospatiale (ANAGEO), ULB, Brussels, Belgium;

The population of Africa is predicted to double over the next 40 years, driving exceptionally high urban expansion rates. Urbanization has profound social, environmental and epidemiological implications and makes spatial and quantitative estimations of urban change, population density and socio-economic characteristics valuable information for epidemiology and vulnerability assessment. Satellite remote sensing offers an effective solution for mapping settlements and monitoring urbanization at a range of spatial and temporal scales. However, their products are largely dependent on the quality and type of data available and on the detected landscape.

African cites unlike occidental urban planning present a high heterogeneity where the urban areas are not well defined and extensive growth is usual characterised by slums. Factors as heterogeneous building structures, strong cycle of vegetation density and man-made constructions from natural raw local materials are some of the difficulties that urban mapping using remote sensing techniques are challenged with.

Synthetic aperture radar (SAR) technology, being indifferent to weather and illumination conditions, ensures continuous urban monitoring and demonstrates its suitability for operational urban mapping using texture information extracted from SAR data. However, the relationship between the radar signal and the built environment is complex, varying with the configuration of the sensor, the nature of the target, the environmental conditions and the employed data processing techniques. Optical remote sensing on the other hand is dependent on the illumination and frequently limited because the cloud cover conditions however its strength lies in the better resolution and higher temporal availability. One way to overcome these shortcomings is by fusing optical and SAR data.This research is part of a large project, MAUPP, which addresses the Modelling and forecasting of African Urban Population Patterns for vulnerability and health assessments. One of the objectives of the study is to produce an urban expansion model for African cities in three steps:

i) The development of automatic and effective method for the delineation of urban extent using optical and SAR data;

ii) The creation of temporal data base of urban extent and land cover for about 50 African cities in sub-Saharan areas;

iii) The generation of urban expansion models based on Boosted Regression Trees (BRT) method and using remote sensing, statistical and contextual data.

In this work we present the processing method for the delineation of the multi-temporal urban extent of African cities. As a case test, the capital of Burkina Faso Ouagadougou, is selected. This large city of 1.7 million habitants covers an area of 370 km square and contains heterogeneous built up areas and land-covers.Temporal optical data (SPOT, Landsat-TM, Pleiades) and SAR data (ERS-1/2, ENVISAT, SENTINEL-1) will be collected for the period 1994-2015. To ensure consistence in the SAR data observation conditions over time, signal polarization (VV), trajectory (descending orbit) and similar incident observation angle are required. Pre-processing procedures of SAR data include speckle reduction, co-registration and histogram adaptation. Optical data requires mainly georeferencing.The image processing and fusion include the following procedures; Using the grey level co-occurrence matrix (GLCM) we obtain eight different texture images averaged over four directions. Additionally an adapted intersection histogram distance index (HDI) using two selected textures image was found to be a good representation of urban density. To assess the built-up density of an urban area, the probabilities functions related with the non, low-medium and high density built-up area are presented. Such probabilities functions are obtained using a multi-lineal logistic regression from the 8 GLCM textures and three VHR optical training datasets. As for SAR, the GLCM is applied to extract textural features using the optical data. For land cover features several indices are applied including indices for extracting built-up area.The urban area extracted from the SAR and optical products are combined using Support Vector Machine (SVM). This method has the generalization ability and excellent learning performance to solve limited sample learning, nonlinear and high dimension problems.After integrating the entire dataset and processing we mapped and classified the different urban areas according to their built-up density with a 90% confidence. The proposed processing scheme produces new valuable input that will allow the improving of available urban growth models for Africa.

Earth Observation for Urban Sustainable Management – the DECUMANUS project

Metz, Annekatrin; Marconcini, Mattia; Zeidler, Julian; Esch, Thomas
German Aerospace Center, Germany

Climate change poses serious challenges to urban areas and their growing population by increasing occurrence of heat waves, drought, heavy precipitation, cyclones and extreme high sea level events. These changes affect physical infrastructure, water supply, energy provision, transport and industrial production, hence resulting in a variety of ripple effects across different sectors of the city life. In this context, Earth observation (EO) has proven to be an effective tool for supporting decision makers in facing climate change; nevertheless, gaps still exist between the current state-of-the-art and the users' requirements. The FP7 DECUMANUS (DEvelopment and Consolidation of geo-spatial sUstainability services for adaptation and environmental and cliMAte chaNge Urban impactS) project aims at bridging this gap. In particular, DECUMANUS has a principal objective to develop and consolidate a set of sustainable services that allows city managers to incorporate EO-based geo-spatial products and geo-information services in their climate and environmental change strategies to support the sustainable management of the cities in Europe. Furthermore, the project is user defined and driven; indeed, it has full engagement with the partner cities of Antwerp, Helsinki, London, Milan, and Madrid, which are fully integrated in the project workplan by defining requirements, testing products and services, validating results and acting as ambassadors of these technologies for other cities.

The four categories of DECUMANUS service products consist of: i) an urban climate atlas using proven GMES products, ii) land monitoring services providing land consumption information and urban ecosystems assessment tools, iii) city energy efficiency to assess energy consumption and improve energy efficiency in cities, and iv) citizen health tools to alert the population to health risks arising from poor air quality and excessive temperatures in the urban area. For each category, two different types of services have been implemented, namely basic and premium. Basic services include products derived from freely-available EO data (suitable for district-level analyses at larger scale and lower spatial resolution), whereas premium services include products, indicators and models developed and specified on the basis of an active engagement with the planning communities and/or the use of in situ information (suitable for local-level analyses at fine scale and very high spatial resolution).

In the context of DECUMANUS, the German Aerospace Center (DLR) is responsible of the development of the basic and premium land-monitoring services identified by the project user community as most relevant and useful for supporting their climate-change adaptation and mitigation plans. On the one hand, implemented basic services include: i) unsupervised spatiotemporal urbanization mapping by means of ERS-1/2 SAR PRI and ASAR IMP imagery; ii) automatic imperviousness estimation by means of multitemporal Landsat data, and iii)settlement patterns analysis by means of spatial networks. On the other hand, the portfolio of premium services comprises: i) mapping of current and potential green roofs (which are becoming more and more important due to their capability of absorbing rainwater, providing thermal insulation and reducing air pollution); ii) automatic tree detection (i.e., a task which currently is generally carried out by photointerpretation or in situ surveys and requires plenty of time); and iii) automatic bare-soil/sand versus asphalt/concrete discrimination (whose categorization is of great importance since it would allow to identify between areas that generally appear similar in optical imagery but are actually associated with different water permeability). All premium-service products are derived by using VHR satellite/airbone VIS+IR optical imagery together with LIDAR/DSM height information.Ongoing validation activities in cooperation with the project partner cities assess the accuracy of the corresponding EO-based products and confirm their great potential for supporting climate change mitigation strategies both at district and local level.

Validation of Imperviousness High Resolution Layer 2006 and 2009 in Slovakia

Lajčáková, Andrea (1); Rosina, Konštantín (1); Hurbánek, Pavol (2)
1: Slovak Academy of Sciences, Institute of Geography, Bratislava, Slovakia; 2: Catholic University in Ruzomberok, Department of Geography, Ruzomberok, Slovakia

Imperviousness High Resolution Layer (IHRL) 2006 and 2009, i.e. a 100 m resolution raster with 0–100 % pixel values representing share of artificial impervious (built-up) surfaces, was produced using an automatic algorithm based on calibrated NDVI for the area of most of Europe within the frame of GMES precursor activities (for 2006 ±1 year) and Geoland2 (for 2009 ±1 year) and it is distributed by EEA in the framework of the Copernicus land monitoring service.

Some previous studies (e.g. Hurbanek et al. 2010) of small model areas have shown that the IHRL overestimates the share of impervious surfaces in areas with relatively compact (urban) settlement pattern and underestimates it in areas with relatively dispersed (rural) settlement pattern. Countrywide (Ibid.) or European (Maucha et. al 2010) studies of this phenomenon are rather rare. While they usually conclude with a relatively reliable estimate of commission error (using a stratified random sample), they fall short of a reliable estimate of omission error. Estimating omission error with acceptable confidence for a small class requires large sample (Maucha 2011).

The objective of this contribution is to assess the thematic accuracy of IHRL in Slovakia in both 2006 and 2009 using a large random sample of 20 000 pixels. A reference value for each IHRL pixel in the sample is derived by counting the artificial impervious points from a set of total 100 points regularly spread in a 10 × 10 m square lattice overlaid on top of aerial orthophoto. Using the IHRL and reference values in the sample, estimate of commission and omission errors with a relatively acceptable confidence is produced for each of the three different successively produced versions of IHRL 2006, for IHRL 2009, and also for the change layer IHRL 2006–2009.

Acknowledgement

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An open-source, object-based, unsupervised change detection tool for urban expansion monitoring.

De Vecchi, Daniele (1); Harb, Mostapha (2); Dell'Acqua, Fabio (1)
1: Università di Pavia, Italy; 2: EUCENTRE, Italy

Satellite Earth Observation systems grant acquisition repeatability, a feature which can be very important in the context of a typical application, i.e. tracking the evolution of urban areas. With this goal in mind, a new, open-source technique has been developed in a framework of vulnerability estimation, monitoring and forecasting. The technique, developed in the context of some EU FP7 projects [1-3], relies on object-based change detection and post-adjustment of results based on common-sense rules.The developed technique does indeed take advantage of the wide time span typically considered when urban monitoring is performed using Earth Observation data, especially when prediction of future expansion is the intended use of the extracted maps. Long timespans are also involved when dealing with "Big Heritage Data" [4] to reconstruct historical development in the addressed area.

Urban area extraction is carried out relying on a previously developed technique [5] based on moderate-resolution, multi-spectral data. The series of extractions are then provided as input to a second processing stage [6] where continuity in time and reasonable assumptions are used to fix the possible extraction errors from the first phase. Three different filters are included, intended to correct apparently wrong extractions, following common assumptions to favour, and some time enforce, a "regular" behaviour over time.

This paper will illustrate the technique and some test results that have been carried out in specific areas to tune the subsequent development work.

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Identifying Seasonal Urban Thermal Environment in Urban Settings of Abha-Khamish Mushyet Twin Cities (Saudi Arabia) Using Remotely Sensed Data

Al Wadei, Hussein; Mallick, Javed
Faculty of Engineering, King Khalid University, Saudi Arabia

Abha and Khamis-Mushyet, the twin cities of Aseer province, Saudi Arabia is a rapidly urbanizing agglomeration. The cities thus experience various environmental challenges that are true for all the global urban centers. Urban thermal environment is one such issue that the both cities is facing. Being a semi-arid mountainous city, Abha and Khamis-Mushyet's urban thermal environment behaves differentially in comparison to topical as well as temperate climate cold country cities. This study analyzes the seasonal variation in spatial patterns of urban thermal environment and also the effects of terrain on the surface temperature. Temporal variation in distribution and magnitude of urban surface temperature was also studied and analyzed with respect to land use land cover practices using Landsat 8 data of all the four seasons (winter, spring, summer, autumn) for year 2014–15. An anomaly based approach was attempted to quantify seasonal and annual urban thermal environment intensities. The results reveal that the seasonal spatial distribution of surface temperature was affected by land use/land cover (LULC) and topography. Maximum and minimum seasonal urban thermal intensities were observed in summer and winter. Average annual land surface temperature anomaly map aided in identifying urban thermal intensities vulnerable locations in the both cities. The high dense built-up and major commercial/industrial areas display higher surface temperature in comparison with surrounding lands and were found to be the most vulnerable locations. There is gradual decrease of land use/land cover (LULC) classes' surface temperature with the increase in altitude. Therefore, the seasonal spatial variation in surface temperature also reflected the effects of topography on LULC classes. These findings can help urban planners to understand the urban thermal environment and design the green cool parks to counteract thermal intensity effects.

FLIRE: an EO-based DSS for combined flood and fire risk assessment in peri-urban areas

Poursanidis, Dimitris (1); Kochilakis, Giorgos (1); Chrysoulakis, Nektarios (1); Varella, Vassiliki (2); Kotroni, Vassiliki (3); Lagouvardos, Kostas (3); Eftychidis, Giorgos (2); Papathanasiou, Chrysoula (4); Makropoulos, Christos (4); Mimikou, Maria (4)
1: Foundation for Research and Technology, Hellas, Institute of Applied and Computational Mathematics, Nikolaou Plastira 100, Vassilika Vouton, P.O. Box 1385, GR71110, Heraklion, Crete, Greece; 2: Algosystems S.A; 3: Institute for Environmental Research a

Fires and floods are among the natural hazards with the higher social impacts in the 21st century, with economic cost of the order of billions of euros. When these occur in urban and periurban areas, the loss of human lives, the destruction of private and public properties, the degradation of health and quality of life, as well as the disruption of economic activities are among the impacts that cause. Floods that occur after the manifestation of fires, are extremely catastrophic, especially in peri-urban areas. The study of both hazards is based on the same background data and Earth Observation (EO) is a crucial information source, as from the same satellite imagery up-to-date fuel

map can be derived in case of fire modeling in urban and peri-urban areas, while the parameterization of flood modeling in different scales (hydrological modeling in catchment basin level and hydraulic model in the urban area) need dedicated land cover/use information, updatable when needed and suitable for the specifications of the models. The investigation of both fire and flood hazards traditionally has been conducted separately even if the same data are needed. This approach overlook the "collect once – use for many purposes" model which when is adopted, result in the increase of the accuracy and economies, as these phenomena are tightly interrelated; fires exacerbate the flood risk and the preceding flood dramatically reduce the fire risk. In the framework of the LIFE+ project FLIRE an integrated Decision Support System (DSS) was developed for both floods and fires risk assessment and management by adopting the model of "once collect – use for many", by using existence infrastructure and by incorporating extensively EO sources in different phases of the project. The FLIRE DSS is consists of three modules and seven applications unified under the FLIRE Server. The modules for fire management, flood management and weather forecasting have been implemented as web-services. The system has been designed as web-based solution which integrates the abovementioned tools. FLIRE adopt the distributed architecture of the components of the system while the DSS is accessible from the web (www.flire-dss.eu). The FLIRE server uses FTP and HTTP communication protocols and web service technologies. Visual basic, JavaScript, Google Maps API and Ajax have been used for the design and implementation of the FLIRE DSS. The user's interface has been designed and developed based on the user's requirements, goals and needs. ESA's Sentinels missions (1 & 2) is expected to have a crucial role for these steps due to the high temporal and spatial resolution, the high data quality, as well as the free data access policy.

Detecting and analysing informal settlement structures in China by combining high resolution optical and SAR imagery

Wei, Chunzhu (1); Blaschke, Thomas (1); Taubenböck, Hannes (2)
1: University of Salzburg, Austria; 2: German Aerospace Center (DLR),

'Urban villages' is the Chinese version of informal settlement. It is a unique phenomenon that comprises mainly low-rise and congested, often illegal buildings surrounded by new constructions and high-rise buildings. Due to a lack of an unambiguous definition allowing for a spatial delineation of such areas this article investigates a joint use of high-resolution optical and SAR satellite data through building extraction and 3D reconstruction of urban villages in Shenzhen, China. First, potential urban village footprints are extracted through a combined image fusion analysis of multispectral GaoFen-1 (GF-1) and high resolution TerraSAR-X radar (SAR) imagery. Then, building height estimation is performed on the basis of interferometry principles using interferometric X-band SAR (InSAR) from the Tandem-X mission. We generated Digital Surface Models (DSMs) from InSAR processing of two co-registered TanDEM-X image pairs for Shenzhen. While earlier attempts focused on data fusion techniques without the use of a DSM and yielded mediocre results, the integration of height information clearly improves the detection and mapping of urban villages. It can be demonstrated that urban villages and surrounding urban areas are clearly distinguishable through particular combinations of optical data, SAR data and height information. In particular, a rigid analysis identified three types of information as most suitable: 1) Normalized Difference Vegetation Index (NDVI), 2) contextual parameters such as edge and line density from GF-1 multi-spectral imagery, and 3) textural parameters such as Grey-Level Co-occurrence Matrix (GLCM) variables from TerraSAR-X imagery. The additional height information from InSAR clearly improves the detecting of taller buildings surrounding the urban villages. Likewise, the InSAR height information improves the delineating the low-rise and congested urban villages. In conclusion, the fusion of SAR and optical imagery can effectively reveal the footprint characteristics of urban villages. It is an effective means to reduce the effects of layover, shadow and dominant scattering at building location. The 3D building reconstruction model based on urban village footprint maps can reduce the continuous alteration of layover and shadow areas from high-rise buildings in the dense urban area. The proposed methodology based on the optimization of criteria referring to GF-1, TerraSAR-X and TanDEM-X characteristic efficiently integrates urban village footprint extraction and height calculations. Ultimately, the transferability and repeatability of this workflow is analyzed with the aim to establish a standardized monitoring process for urban villages.

An object oriented approach to detect earthquake damage in urban area from VHR optical imagery.

Anniballe, Roberta (1); Noto, Fabrizio (1); Chini, Marco (2); Bignami, Christian (3); Stramondo, Salvatore (3); Scalia, Tanya (1); Martinelli, Antonio (4); Mannella, Antonio (4); Pierdicca, Nazzareno (1)
1: Department of Information Engineering, Electronics and Telecommunications (DIET), Sapienza University of Rome, Rome, Italy; 2: Luxembourg Institute of Science and Technology (LIST), Environmental Research and Innovation Department (ERIN), Belvaux, Lux

When an earthquake occurs a rapid and accurate damage assessment of the hit urban area is essential. In this contest, valuable information can be obtained from Earth Observation (EO) data at Very High Resolution (VHR) which provide detailed information on single structures present in the scene, allowing to produce damage maps at single building level.In this work we propose an object-oriented image analysis approach to detect damaged buildings from a pair of VHR optical images acquired before and after a seism.

We have tested our procedure using images taken by the QuickBird satellite before and after the earthquake that hit L'Aquila city (Italy) on April 6, 2009. Two layers of polygons reporting the damage ground survey of the whole urban area of L'Aquila, coming from two different sources, are used for validation purposes. The first one is related to the survey performed by the National Institute of Geophysics and Volcanology (INGV) Macroiseismic team, while the second one refers to ground survey carried out by the Italian Civil Protection Department (DPC). The geolocated version of the data set has been provided by the Construction Technologies Institute of the Italian National Research Council (ITC-CNR).

As usual in any object oriented image analysis approach, the proposed methodology comprises two steps: the image segmentation, for obtaining a buildings map, and the object classification, for detecting damaged buildings.

In this work the segmentation of the pre-event optical image in objects corresponding to the buildings in the scene is performed using a pre-existing building map provided as GIS layer, but it can also be obtained by means of suitable segmentation/classification algorithms applied to a pre-event VHR optical image.

Once the objects are identified, a feature extraction step is carried out in order to build the classifier input space. Several features can be computed within the objects in order to identify those changed due to the earthquake. Here we consider: a) change metrics derived from the Information theory, such as Kullback-Leibler divergence and the Mutual Information; b) changes in the textural parameters derived from the grey level co-occurrence matrix; c) changes in the colour space, i.e. differences in the Hue, Saturation and Intensity parameters. Instead of using a moving window with fix size, all the aforementioned change features are evaluated at object level, by considering only the pixels within the building footprints.

The discrimination between collapsed or heavy damaged buildings and less damaged or undamaged buildings is performed in the Bayesian framework. A non parametric approach is used as the statistics of the features cannot be easily predicted and a leave-one-out validation approach has been carried out to test the classification accuracy against ground truth. Although the classification performances using EO data are not excellent, similar uncertainties were observed between the ground datasets. Compared to the highly costly and time consuming ground surveys, the EO still appear a valid tool for a rapid response after an earthquake.

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Mapping Urban Dumps from Space

Bilotta, Giuliana
IUAV University of Venice - Comune di Melito P.S., Italy

The Illegal dumps have a heavy impact on the landscape and the urban environment and are a source of danger for the health and safety of the inhabitants. Land monitoring and control bring to the recognition of abuses: the use of satellite remotely sensed data helps to improve the environmental management system. The availability of object-oriented techniques to process satellite imagery allows to detect such situations of illegality.

The traditional image processing and image interpretation methods are usually based only on the information extracted from features intrinsic of single pixel: the object's physical properties, which are determined by the real world and the imaging situation-basically sensor and illumination. A limitation of this method is that it allows evaluating only a part of the information content of the images, without exploring the appearance as important as geometric-textural information. The application of Object Based Image Analysis on very high resolution data allows, with an automatic or semi-automatic process – with a minimal manual participation-a good classification also in presence of high and very high resolution data, where higher is the chance of error. The final classification, through a suitable hierarchy of classes that takes into account the relationships between the produced segmentation levels, may be highly accurate. Thus we introduce other rules for the location of the context, and the relation between the objects increases meaningfully the chance of automatic recognition of objects on the land surface. Object-based techniques allow an elaboration of satellite data to detect an uncontrolled storage of waste. By including a shapefile containing some detected test areas in the segmentation process, we proceed to the recognition of the landfill areas. In this work are also used some cadastral data for the multiresolution segmentation and the object-based classification. This research is still in progress in order to refine the techniques used but already an application of the same methods in other contexts is possible.

Mapping of N'Djamena City for Water Supply and Sanitation Modeling

Bila, Mohammed Danasabe (1); Kötz, Benjamin (2); Tøttrup, Christian (3); Walli, Andreas (4)
1: Lake Chad Basin Commission, Chad; 2: European Space Agency; 3: DHI Graz; 4: GeoVille

Water is essential to human life and all activities of man depend on a constant supply. In African countries human health is impacted daily by lack of access to water. During 2013, 43.6% of cases of worldwide cholera outbreaks were reported from Africa countries with no proper access to adequate water and sanitation resources. Similarly, the WHO estimates that 88% of waterborne diarrheal disease burden is attributable to unsafe water supply, sanitation and hygiene. N'Djamena City, the capital of Republic of Chad has a well laid out city but experiences regular outbreaks of cholera and various forms of waterborne diarrheal disease. Providing water and sanitation to N'Djamena and similar ever expanding urban and semi urban settlements has traditionally being a challenge as the planning process for water supply and sanitation is faced with the absence of updated, reliable maps. The application of new tools and data that can simplify and support water supply and sanitation planning is an important requirement.

The Water Observation Information System (WOIS) Urban Sanitation Planning and Support planning tool developed under ESA Tiger Net project has a model and a mapping component. The tool was used in mapping, estimating, current and future water demands and for the planning for the development of the water supply and distribution system in N'Djamena as a demonstration case. The mapping component is an urban land cover map derived from very high resolution satellite imagery, and the model includes a spatial link table so that urban land cover classes can be attributed with the water demand values available through the model. The model is populated with numbers based upon a combination of population and housing census data, city administration reports, literature and assumptions. The model include settings for analyzing quantitative changes in future urban water demand e.g. in response to population growth and technology scenarios i.e. household improvements and upward movement in sanitation ladder.

The role of multi-temporal satellite imagery for the urban climate study of Bucharest, Romania

Aldea, Mihaela (1); Petrescu, Florian (1); Parlow, Eberhard (2); Gaman, Florian (1); Luca, Oana (1); Iacoboaea, Cristina (1); Sercaianu, Mihai (1)
1: Technical University of Civil Engineering of Bucharest, Romania; 2: University of Basel, Switzerland

One of the main reasons because urban climate became an important issue consists in the rapid growth of the urban population worldwide. Thus, the urban population of the planet has grown from 746 million in 1950 to 3.9 billion in 2014. Based on the United Nations report "World Urbanization Prospects, the 2014 revision" (http://esa.un.org/unpd/wup/), 54 per cent of the world's population lives in urban settlements, while by 2050, this is expected to increase to 66 per cent. Based on both the current trends of the urbanization process and the overall growth of the world's population, by 2050 the urban population of the world will increase with another 2.5 billion people.

Urban climate studies use several types of modern technologies and methodologies. One of the most important approaches is based on the processing of satellite remotely sensed data. There are mainly three types of applications, which are using remote sensing for urban climate studies purposes: urban growth, land use / land cover, and surface urban heat island. All three of them are used within the "Urban Climate Study of Bucharest, Romania" project (http://urbanclimate.utcb.ro). This project is jointly developed by the Institute of Meteorology, Climatology and Remote Sensing from the University of Basel, Switzerland and the Urban Engineering and Regional Development Department from the Technical University of Civil Engineering Bucharest, Romania. Since land-climate relations are crucial to evaluate the state of the urban climate, whether it is urban growth, land use / land cover, or the surface urban heat island, at the basis of all these three types of applications is the land use/land cover classification and further interpretation of the remotely sensed images. Urban growth can be determined and characterised based upon the changes in the land use/land cover classes produced in a city over the time and the urban heat island can be estimated based upon the correlations between satellite derived surface temperature values and the incidence of the land-use types, or the remotely sensed derived indices of differentiation.

The paper presents the use of remote sensing technology applied to multi-temporal satellite imagery for studying urban growth, land use/land cover, and surface heat island in Bucharest, within the "Urban Climate Study of Bucharest, Romania" project.

Remote Sensing and Spatial Indicators for Detecting Urban Trajectories

Netzband, Maik
Ruhr-Univesrsity Bochum, Germany

Satellite data and further geo-information data are used for landscape ecological evaluations, e.g. to predict structural diversity in landscape, to derive quantitative data on open space fragmentation and on interlink of biotope structures. Satellite images are just as much used to identify compensational areas for planning of building land in conurbations or to quantify landscape metrics by means of derived medium and high resolution satellite parameters in order to calculate neighbourhood relations of objects. Within the last two decades landscape structure indices or metrics have been implemented on remote sensing image data for different mapping scales.

Nature, in particular in the suburban cultural landscape is described regarding indicators such as structure (line or planar expansion, cutting, island areas, etc.), dynamics (entry of the modification processes) and texture (neighbourhood relations to other land use forms). This is based on the identification and computation of static and dynamic indicators that help providing a synthetic assessment of suburban landscapes. The indicators will also allow the comparison of the environment's condition in different conurbations. A methodological approach is presented applied to different parts of Europe in growing as well as shrinking urban regions, after which monitoring and evaluation of a landscape diversity in suburban landscapes are feasible on the basis of medium and high resolution satellite data.

Approaching Land cover/Land use Changes using Remote Sensing and Statistical data validation for Urban Policies Improvement

Vlad Sandru, Maria Ioana
Romanian Space Agency, Romania

The present research focus on one specific dimension of environmental quality: land use and land cover, which experience changes over time within urban areas. Land change refers to adaptation in land cover or land use and is measured by comparing these two mentioned ones at two or more points in time.

Obviously, the term land change could refer to developments or several driving forces, which can cause change. One of these is the population dimension, such as the age, structure, mortality, morbidity and migration, which also affect consumption of vegetation and construction of buildings and infrastructure. Population events that increase consumption of vegetation and construction of buildings will change land use, a specific example being the fertility and birth rate. Along the well-known demographic events, a high impact on land cover changes has the human activities, which have modified land in various ways and intensities. Towns may suffer urbanization, suburbanization, residential areas can be converted into commercial areas, the neighborhoods in the city centers can go into slums, and all this driving to land degradation as a result of an extreme form of land-cover change based on involuntary development of Earth resources.

The objective of this research stands for linking and validating existing changes in land cover/land use extracted from Earth Observation satellite data with statistical socio-demographic data, using Pearson correlation coefficient. Acquired results and statements could aid to the development of a regional urban policy, as a key step for maintaining urban space and territoriality updated with a valuable significance in providing the needed direction and course of action to support sustainable urban development.

Sentinel-1A SAR Data for Urban Land Cover Mapping with KTH-SEG: Preliminary Results

Mc Cutchan, Marvin; Jacob, Alexander; Ban, Yifang
KTH Royal Institute of Technology, Sweden

In the light of the constant change that urban areas undergo, it is of vital importance to be able to map the current state of the urban land cover in timely and accurate manner to support sustainable urban development. The objective of this research is to evaluate multi-temporal Sentinel-1A SAR data for urban land cover mapping. This study is part of the EO4Urban project funded by the ESA DUE INNOVATOR III program.

In the previous research of KTH Geoinformatics, we have examined various SAR data for urban land cover mapping including ENVISAT ASAR, RADARSAT SAR and TerraSAR-X data. Multitemporal Sentinel-1A data in both ascending and descending orbits acquired over Beijing and Stockholm during the 2015 vegetation season are selected for this mapping task. These two cities are significantly different in their structure and urbanization rate as well as the surrounding environments, thus provide excellent test scenarios with plenty of reference data. The major classes are covering high-density built-up areas, low-density built-up areasroads, airport, urban green space, roads, airport, agricultural fields, bare soil, forest and water.

The methodology includes image preprocessing, segmentation, classification and accuracy assessment. The core of the analysis is performed with our in-house developed software KTH-SEG, an object-based image analysis tool based on an edge-aware region growing and merging segmentator as well as a support vector machine for post-segmentation classification. In this research, multi-resolution segmentation are being performed with different object scales as some classes might be better assessed with a smaller scale while others require a larger scale in order to be properly mapped.

Preliminary results show that multitemporal Sentinel-1A data have the potential to produce detailed urban land cover maps, The classification accuracy will be assessed both in terms of classic measures such as the kappa value and overall accuracies and more recent methods like the location agreement and quantity agreement. The accuracy may vary depending on the quantity and variability in the Sentinel-1A images used for the classification.

Searching asbestos roofs using satellite imagery

Bilotta, Giuliana
IUAV University of Venice - Comune di Melito P.S., Italy

A long exposure to asbestos is connected to the emergence of harmful diseases that affect the respiratory system. In particular, the friable asbestos is the most dangerous element, because its fibres easily disperse and have a particular aptitude to penetrate into the respiratory system. Despite the risks mentioned above, the number of roofs of buildings containing asbestos is still high in many countries. In Italy there are still many buildings characterized by roofs of a mixture of cement and asbestos, once common for the features of the material, as characteristics of mechanical resistance and its low cost.

An environmental monitoring for detecting the presence of this material in urban areas is generally made by means of expensive dedicated air travels, since typically the airborne payload is a hyperspectral sensor. Unlike the air missions, satellites continuously orbit around the Earth. In particular, some commercial optical satellites in sun-synchronous orbit that monitor at very high geometric resolution are particularly suitable for this type of search.

This paper proposes the use of optical satellite data that, through the analysis object-based, have proved to be effective for detecting asbestos roofs. Legislation requires intervention for the replacement of these roofs, and among the possible replacements is the smart substitution of asbestos roofs with PV roofs for producing energy.

What is proposed could so become a common and much less expensive practice than the current, which involves the use of airborne sensors. The object based techniques for classifying satellite data allow to identifying buildings with roofs made by materials containing asbestos. In particular, in this paper from the start satellite imagery is integrated with cadastral data in vector format (shapefile) to maintain through the various procedures of segmentation and classification, the cadastral information relating to property. The object-based method consists in a Nearest Neighbor classification tool following a multi-resolution segmentation of the whole scene.

The use of neural networks for non-linear spectral unmixing over urban areas

Mitraka, Zina; Del Frate, Fabio
Tor Vergata University Rome, Italy

The high spatial and spectral diversity of man-made structures makes the mapping of urban surfaces with the use of Earth Observation data one the most challenging tasks of remote sensing field. Spectral unmixing techniques, although designed for and mainly used with hyperspectral data, can be proven useful for use with spectral data as well, to assess sub-pixel information. For urban areas, the large spectral variability of urban structures imposes the use of multiple endmember spectral mixture analysis techniques, which are very demanding in terms of computation time and impossible to implement in local computers.

In this study, an artificial neural network is used to inverse the pixel spectral mixture in medium resolution imagery (30 m). A series of Landsat images over Rome, Italy, were used to map the urban surface in a sub-pixel level. A spectral library was built, consisting of endmember spectra, collected from the images, and mixed synthetic spectra. Linear as well as non-linear mixture was assumed. The spectral library was then used to train a neural network and the resulting surface cover maps were compared against similar maps produced from higher resolution land cover information. The estimated versus the reference surface cover abundance images proved a good agreement.

Among the advantages of using a neural network is its ability to capture non-linearities in the spectral mixture and its low computational demand. Such techniques, affordable to implement, can be useful and support various application for urban studies and monitoring. The use of spectral unmixing techniques based on neural networks using medium resolution multispectral imagery, can be proven extremely useful for support of operational applications of the Copernicus Sentinels, because of their quick and accurate performance. With the recent launch of Sentinel-2, the method outlined in this study will be adjusted for and applied to Sentinel-2 imagery after the commissioning phase.

Urban Mapping using Satellite Time Series

Vaduva, Corina (1); Radoi, Anamaria (1); Grivei, Alexandru (1); Schwarz, Gottfried (2); Datcu, Mihai (2)
1: UPB, CEOSpaceTech, Romania; 2: German Aerospace Center (DLR), Germany

As described by [1], a "Satellite Image Time Series (SITS) is a set of satellite images taken from the same scene at different times. A SITS makes use of different satellite sources to obtain a larger data series with short time interval between two images… Sensors with high spatial and temporal resolutions make the observation of precise spatio-temporal structures in dynamic scenes more accessible. Temporal components integrated with spectral and spatial dimensions allow the identification of complex patterns concerning applications connected with environmental monitoring and analysis of land-cover dynamics." When we analyse the development of urban areas, it becomes clear that satellite image time series are highly valuable data sources that can be exploited to describe besides vegetation cycles and land use changes - the dynamics of urban settlements and their infrastructure. Typical examples are given in [2] and [3].

For instance, one can focus on the extraction and analysis of long-term satellite image time series, and on applications in urban development monitoring [2]. Here, a Satellite Image Time Series comprised of more than 100 data sets, covering a time span of over 25 years is extracted from the Landsat data archives, in order to extract the annual built-up surface. The evolution of the built-up areas is then compared against population dynamics for the studied area. Our presentation will focus on the currently attainable results from satellite image time series when being applied to urban scenes: Modern high resolution optical and SAR sensors with good signal-to-noise characteristics open new perspectives for local image classification and quantitative change analysis, while low resolution sensor data are often available over many years and provide more insight into long-term processes. Advanced analysis algorithms allow the identification of typical pixel changes and their confidence levels. Finally, data fusion represents a new perspective for urban mapping.

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Automated Urban Mapping in a Satellite Ground Segment

Datcu, Mihai (1); Espinoza-Molina, Daniela (1); Dumitru, Octavian (1); Schwarz, Gottfried (1); Reck, Christoph (2); Manilici, Vlad (2)
1: DLR IMF, Germany; 2: DLR DFD, Germany

Conventional satellite ground segments collect, process, store, administer, and distribute satellite data without caring for the semantic content of the datasets. In the era of Big Data this concept precludes the efficient exploitation of satellite data as large numbers of irrelevant datasets have to be transferred from their archives to locally separate data analysis sites. On the other hand, if a satellite ground segment would already provide semantically annotated datasets, the number of dataset transfers could be limited to the actually relevant data products and users could concentrate on their proper applications. In order to remedy this situation, the ESA-funded Earth Observation image Librarian (EOLib) project serves to setup the next-generation of Image Information Mining (IIM) systems, implementing novel techniques for image content exploration. Image Information Mining is a new field of study and methodology for automating the mining (extraction) of information from EO archives that can lead to content discovery and the creation of actionable intelligence (exploitation). IIM is more than just an extension of data mining principles and computer vision to satellite images. IIM for EO data also includes the joint mining of accompanying data describing the images, such as headers, metadata, etc. Therefore, IIM is an interdisciplinary approach to automating remote sensing analysis that draws on signal/image analysis, pattern recognition, artificial intelligence, machine learning, information theory, databases, semantics, ontologies, and knowledge management. EOLib will exploit information about Earth Observation (EO) product contents which is usually hidden in raster data, image time series and metadata, thus enabling content-based search in very large archives of high resolution EO data. EOLib will be interfaced to and operated in the DLR Multi-Mission Payload Ground Segment (PGS) of the DLR Remote Sensing Data Center, representing at the same time a general new concept for the operations of Ground Segment infrastructures.

This system is particularly suitable for (semi-)automated urban mapping as the EO product information content represents actionable information for local information mining, including the semantic annotation of image patches. The product information content is a result of feature extraction and auto-annotation and is archived together with an EO product as a distinct product component. Annotations are part of a controlled vocabulary and can be structured in a thesaurus or a graph of semantic concepts. The product annotation is uploaded into a semantic catalogue that can be queried by the users. The catalogue service allows query by annotation and query by example, giving a typical positive or negative representation of the expected or unexpected result. The product information is also used for the local product content inspection.

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Development of Copernicus and EO Based Products as Input to Urban Regeneration Policies in Europe

Serpico, Sebastiano (1); Sannier, Christophe (2); Soukup, Tomas (3); de Martino, Michaela (1); Desclée, Baudouin (2); Jupova, Katerina (3); Krylov, Vladimir (1); Moser, Gabriele (1)

1: University of Genoa, Italy; 2: Systèmes d'Information à Référence Spatiale (SIRS), France; 3: GISAT, Czech Republic

Urban sprawl is a Europe-wide serious problem, not only due to total area taken, but also due to its spatial distribution patterns (leading often to landscape fragmentation) and the composition of land taken (mostly agriculture and natural areas are converted to artificial areas). Finally, also the utilization of urbanized area (no. of inhabitants, no. of jobs) has to be taken into account to assess sustainability of urban development. Land is a finite resource and therefore urban planners need to select land to be used for further development more wisely applying the concept of land recycling. There is a need for a user-oriented service facilitating the identification of suitable sites for redevelopment based on objective criteria and providing flexible insight into these trade-offs on a strategic level for specific areas, still keeping in mind the general policy context. To achieve this goal, the European Urban Atlas alongside the High Resolution Layer on Imperviousness degree together with other related global data sets such as the Global Human Settlement layer and the Global Urban Footprint, represent unique data sets as a basis for developing EO based information services for providing detailed information to policy makers and practitioners on potential land to be (re)developed within existing urban areas thus contributing to reducing urban sprawl.

This abstract focuses on the recent results obtained from the exploitation of these data sets, and especially from EO image analysis, within the "URBan land recycling Information services for Sustainable cities" (URBIS) project funded by the European Union within the 2007-2013 Competitiveness and Innovation Framework Program. Within URBIS, a methodology for exploiting the aforementioned data sets to create and temporally update an inventory of potential development areas (PDAs) on the European territory is defined and experimentally validated with three pilot sites (Amiens, France; Osnabrueck, Germany; and Ostrava, Czech Republic).

As a major step in this methodology, pattern recognition, image analysis, and data fusion methods are being applied to SPOT-5 HRG imagery, which is included in the Urban Atlas, to characterize land cover at high spatial resolution (2.5 to 5 m), and are being integrated with the mapping results provided by the Urban Atlas at a coarser spatial scale. Methodological approaches include state-of-the-art texture and spatial feature extraction (e.g., histograms of oriented gradients, semivariogram), pixelwise (support vector machine, random forest), Markovian, and region-based classification, multitemporal statistical modeling, and domain adaptation techniques. Thematic products of interest to the mapping of vegetated and non-vegetated gaps in urban areas and of imperviousness at 5-m resolution are also derived.

Preliminary experimental results with data from the three aforementioned pilot sites were characterized by quite high accuracy in the discrimination of buildings, roads, vegetated areas, bare ground, and water bodies, regardless of the small number of spectral channels of SPOT-5 HRG. The impact of acquisition time and seasonality on the accuracy was also investigated and found relevant especially with regard to the discrimination of vegetated covers.

The experimental results also confirmed the potential of the integration of advanced remote sensing image analysis techniques and of openly available thematic layers for the purpose of characterizing imperviousness, and more generally, thematic information of interest to urban monitoring and planning, at high spatial resolution. The potential of Sentinel-2 data will also be discussed in the framework of the considered application to urban areas and taking into account the open data availability foreseen for the Sentinel missions.

Remote Sensing and Object Classification for assessing the Urban Fabric Vulnerability to Heat Waves and UHI

Borfecchia, Flavio (1); Caiaffa, Emanuela (1); Rosato, Vittorio (1); Pollino, Maurizio (1); De Cecco, Luigi (1); Martini, Sandro (1); La Porta, Luigi (1); Ombuen, Simone (2); Filpa, Andrea (2)
1: ENEA, Italy; 2: Rome 3 University - Architecture Department

Today more than 50% of the world population lives in urban settlements that are continuously growing their infrastructures and build-up areas, often without appropriate planning, with significant changes in land cover/use and consequent changes in biophysical parameters related to their radiation budget, hydrological cycle and to microclimate. Densely urbanized areas, with a low percentage of green vegetation, are highly exposed to the rise in temperature extremal occurrences phenomena like Heat Waves (HW) which are increasing in terms of frequency and intensity, also in temperate regions, due to ongoing Climate Change (CC). Their negative effects may combine with those of the UHI (Urban Heat Island), a local phenomenon where air temperatures in the compact built up cores of towns increase more than those in the surrounding rural areas, with significant impact on the quality of urban environment, on citizens health and energy consumption, as it has occurred in the summer of 2003 on France and Italian central-northern areas. In this context this work aims at designing and developing a methodology based on aero-spatial remote sensing (EO) at medium-high resolution and on most recent GIS techniques, for the extensive characterization of the urban fabric response to these climatic aspects related to the temperature (within the general framework of supporting local and national strategies and policies of mitigation and adaptation to CC). Due to its extension and variety of built-up typologies, the municipality of Rome was selected as test area for the methodology development and validation. First of all, we started by operating through photointerpretation of cartography at detailed scale (CTR 1: 5000) on a reference area consisting of a transect of about 5x20 km, extending from the downtown to the suburbs (including all the built-up classes of interest). The reference built-up vulnerability classes found inside the transect were exploited as training areas to classify the entire Rome territory. To this end, the satellite EO multispectral data, provided by the new sensor Landsat 8 OLI (with perspective to be duly integrated with those acquired by the ESA Sentinel 2 system), were used within a "supervised" classification automatic procedure, based on data mining and “object-classification” techniques. The classification results were then exploited for developing a calibration method, based on a typical UHI temperature distribution derived from MODIS satellite sensor data (summer 2003), to obtain an analytical expression of the vulnerability model, firstly introduced on a semi-empirical basis.

The European Settlement Map (ESM), Urban open space and urban green

Ferri, Stefano; Halkia, Matina
JRC Joint Research Centre, Italy

The first European map of settlements (ESM), representing area covered by built-up structures at 100m of resolution (one pixel representing 1 hectare) was published recently produced and published using the Global Human Settlement Layer (GHSL) methodology developed by the Joint Research Centre of the European Commission.Thanks to the high detail of ESM, architects and urban planners can compare and study the construction of any city across Europe. ESM has been used by policy makers to design and evaluate best practices on territorial cohesion.

While the strength of ESM lies on the geographic extent, resolution and quantitative information ESM reports on the manmade environment, hidden between the buildings there is another component: data about the un-built environment. Some of the data implicitly present in ESM like information about the presence or absence of green has heterogeneous influences and impacts on our cities, and is therefore important to the characterization of the built environment. This data has influence on recreation, ecology, public health, property values, or other socio-economic factors affecting human settlements. This data is important to people and their quality of life, to the environment and its sustainability, to the economy, and its growth potential. Hidden in the built-up, between the buildings there is open/un-built space, from a planning point of view also known as public space. Although ESM does not distinguish between private and public open space, (understood as organized recreation and green areas), when auxiliary data is introduced, un-built space quantified by ESM may reveal opportunities for the valorization and consideration of open space for the general public even when this is private. In the case of open green space, a type of urban open space, for certain environmental considerations (like the heat island effect in cities, or the human footprint) it is not relevant if the open green space is privately or publicly owned. The presence or absence of green urban space is important for certain analyses. Currently, apart from the European Urban Atlas, which maps recreation areas and public gardens as open green space, there is scarcity of data for the mapping of urban green across Europe by comprehensive and objective data. This poster shows how ESM detects open space and how urban green is classified in an urban context.

Tools and Resources boosting Urban Monitoring from Space

Sabatino, Giovanni (1,2); Cuccu, Roberto (1,2); Delgado Blasco, José Manuel (1,2); Rivolta, Giancarlo (1,2)
1: Progressive Systems S.r.l, Italy; 2: ESA Research and Service Support, Italy

The ESA Research and Service Support (RSS) service provides resources to support Earth Observation (EO) data exploitation. The purpose of the service is twofold: on one hand, to ease EO data processing by bringing user's algorithms to data, and on the other hand, to foster the development of new applications and services aimed to deliver value-added products. RSS users are Principal Investigators (PI), scientists, and service providers. In this paper we introduce the RSS service model and present the resources made available to enable and support urban monitoring from space. The environments made available by RSS can be divided in two main service classes: (i) Cloud Toolbox service and (ii) Grid Processing on Demand (G-POD) service. The Cloud Toolbox service provides users with customized virtual machines with pre-installed software plus additional software/packages on request, and with flexible hardware resources (CPU, RAM, Hard Disk) responding to the actual user needs. The Cloud Toolbox is mainly intended for application development, software testing, post-processing, and for those activities requiring for a limited period of time processing resources which are not available on a common PC. The G-POD service provides users with a high performance computing distributed system with (virtually) unlimited capacity. The environment uses the Grid computing paradigm to allow for automatic splitting and parallelisation of the processing jobs. The Grid Processing on Demand service is mainly intended for bulk processing, full mission reprocessing campaigns and all those activities taking full advantage from computing parallelisation. Three

examples of RSS support to urban monitoring from space research activities are presented in this paper: (i) pre-processing campaign of ASAR data for a DLR project focused on urban mapping on a global scale; (ii) provisioning of EO data and Cloud Toolboxes to support The Bartlett School of Architecture (UCL) in urban design projects; (iii) support to Delft University of Technology for a study on Cairo urban area expansion. Moreover RSS makes available SAR interferometric algorithms (SBAS, DORIS/StaMPS) to support studies of subsidence in urban areas.RSS delivers significant value to EO researchers in terms of time and resource savings, thus enabling enhanced scientific productivity.

Urban Growth Mapping of South-East Asia cities for World Bank

Kolomaznik, Jan; Bartalos, Tomas
GISAT s.r.o., Czech Republic

In the recent years a couple of operational urban mapping activities for international financial institutions have been implemented by Gisat in South-East Asia and Pacific region. Mapping services have been delivered in frame of EOWORLD2 and its precursor EOWORLD, both joint initiatives of ESA and World Bank, and PUMA project, follow-up initiative of World Bank. Service cases have aimed to contribute to understanding the extensive urban growth in various metropolitan areas including e.g. Karachi, Mumbai, Dhaka, Colombo or Surabaya by assessment of urban land use development. The service is based on two pillars. First, Earth observation data and techniques are utilized for extraction of both retrospective and up-to-date information on urban land use and subsequently, assessment and comparison of extracted information and their links to the standard statistical information are provided for users within dedicated web-based platform. Land use status and changes are extracted by analysis of optical satellite imagery. Based on previous experience and throughout the course of the projects object-based image analysis techniques of detecting complex land use classes were developed and tuned up at multi-resolution data. Semi-automated workflows preceding manual enhancements support consistent operational implementation of the service for large urban areas. Depending on recency of requested retrospective land use high or very high resolution data are used as baseline for information extraction. The platform for Urban Management and Analysis (PUMA) is web based geospatial software for exploring and analysing integrated spatial data. PUMA adapts open-source software and allows users with no prior GIS experience to access, explore, visualize, analyse and share local, regional and global urban spatial data from a variety of sources in an interactive and customizable way. It supports the objectives of Global Urban Growth Data initiative: it helps the World Bank and its clients to develop a shared understanding of the long-term spatial, economic and environmental implications of land use by assessment of harmonized, comparable urban reference datasets. Services have been defined in a way to be operationally extendable in short or long term update time frame in order to serve as a base for further future monitoring. The service components have also been proven in frame of urban risk domain in Copernicus Emergency Management Service or ESA's initiative EO for a Transforming Asia Pacific.

Contribution of fused Sentinel-1A SAR and Sentinel-2A MSI data to the city Bioversity Index (CBI)

Haas, Jan
KTH, Royal Institute of Technology, Sweden

Continuous urbanization changes the face of our globe raising questions of sustainability, ecological functionality and living quality in peri-urban and urban regions. Remote sensing enables us to obtain timely and reliable information on the state of urban areas and their changing patterns. The overall objective of this study is to evaluate the contribution of fused ESA Sentinal-1A SAR and Sentinel-2A MSI data to the City Biodiversity Index (CBI), the only biodiversity index designed specifically for monitoring and evaluating biodiversity in cities thus enabling inter-urban comparisons. In this study, five of the 23 index components of the CBI are derived with the proposed method, namely proportion of natural areas in the city, connectivity measures, regulation of quantity of water, climate regulation in terms of carbon storage and cooling effect of vegetation and recreation and education (area of parks with natural areas) for the megacity of Beijing, P.R. China. For the connectivity measure index, landscape metrics are used based on the classification result. The combined use of Sentinel-1A SAR and Sentinel-2A MSI data is advantageous over single sensor classification approaches due to the complementary information each sensor provides. In this research, multitemporal Sentinel-1A SAR data over the vegetation season are selected. Sentinel-2A data will be selected when available. The SAR data is processed using the Range-Doppler Terrain correction to remove relief displacements and filtered to remove speckle by a Lee speckle filter. Thereupon, the filtered Sentinel-1A SAR and Sentinel-2 MSI images are co-registered. The image stack is then segmented and classified by an object-based SVM classifier in the KTH-SEG software package. The classification results are then analysed using landscape metrics to determine the degree of landscape connectivity. Consecutively, the five indices are given scores between 0 and 4 according to the CBI framework. The use of fused Sentinel-1A/2A data is expected to produce better urban land cover classification than SAR or optical data alone. The fusion of Sentinel SAR and MSI data has the potential to contribute to urban ecosystem studies in general and urban biodiversity research in particular through their availability and improved spatial and temporal resolutions.

Keywords: Sentinel-1A/2A, Urban land cover, KTH-SEG, City Biodiversity Index (CBI), Landscape Metrics

Highlights: New application domain and methodology for fused Sentinel-1A and Sentinel-2A data Demonstration of the contribution of Sentinel-1/2 data for the City Biodiversity Index Evaluation of Beijing's Biodiversity with five components of the CBI

Space Applications in Support of Future urban development in Armenia

Alhaddad, Bahaaeddin
Starlab Ltd., United Kingdom

Today, nearly half of the world's population lives in cities. In developing countries, people are deserting rural areas while population is rising rapidly. In less than 20 years from now, these two factors will combine to drive over two billion people into urban areas, which in some cases are already overcrowded.

This fast growing of some cities and relocations of commercial and residential areas have produced important changes in the industrial and urban sectors not always following sustainability criteria. As results most urban growth falls outside formal planning controls and many cities suffer poor urban services management, traffic, and congestion, loss of green areas, poor air quality, and noise.

The main advantages of satellite-based EO applications are to bring parties together, to spread and improve idea, to support the decision-making process, and the development and operation of smart services. This way, satellite-based EO products can be used (both quantitatively and qualitatively) to help Armenian local authorities in development assessing the growth of urban areas in order to manage their geoinformation needs.

Sentinel-1 and Sentinel-2 for semiautomatic urban mapping

De Pasquale, Vito (1); Manunta, Paolo (1); Lasillo, Daniela (1); Pennino, I. (2)
1: Planetek Italia srl; 2: CNR-ISSIA (Italian National Research Council- Institute of Intelligent Systems for Automation)

The monitoring of the urban areas and their evolution in time is one of key application of Earth Observation. The aim of this paper is to present an overview of a methodology developed with the main goal to take advantages from the great quantity of data that are coming with free and open access. In particular, in order to derive a status map for urban areas, a combination of SAR and optical data is used, primarily using Sentinel-1 and Sentinel-2 data, but the methodology has been tested also using Landsat-8, RapidEye, SPOT and other data. Chosen a reference period in which it is possible to consider the urban areas substantially unmodified, all SAR and optical data available in that period in the area of interest are used. All the interferometric acquisitions of Sentinel-1 are combined one to each other in order to produce several coherence maps. To reduce the noise, naturally present in SAR data, all the coherence maps are averaged producing only one coherence map of the area in the reference period. The optical data are pre-processed calculating the Top of Atmosphere reflectances. Each Sentinel-2 acquisition is partitioned in three datasets according to the spatial resolution of its bands (three images). All data used, both SAR and optical, are then automatically coregistered. The following step is to individually classify these datasets by means of an object based supervised classification using the European Environmental Agency Imperviousness layer 2012 to train the machine learning algorithms. Finally, the resulting maps are then merged, pixel based, using bayesian rules in order to derive the final map.

The processing workflow described, is implemented in a web based and cloud based system, called DFC (Data Fusion Center), starting from the data search and ends up with final map through a step-by-step process, managed by an open and interoperable system. In fact, it has the capability to interact automatically with the Sentinel-1 and Sentinel-2 catalogs (and other open access catalogs) selecting the appropriate images for the area of interest. Most of the processing steps described above are automatic, but, at this moment, some human supervised steps are present in the production workflow. Both are managed by DFC running the appropriate component or alerting the operator which has in charge the particular processing step which has to be performed. The input files, all the intermediate files and the final maps are also managed automatically by the system in a secure way. Moreover, automatic reporting capabilities and easy visualization of input, intermediate and final data through a web-based interface, complete the characteristics of the system.

EO-Based Derivation of Surface Models to Support Urban Development Activities

Häusler, Thomas; Uttenthaler, Andreas; Carl, Sebastian
GAF AG, Germany

Urban areas, especially in developing countries are the planning hot spots of the future and therefore standardized, accurate and up-to-date geospatial data are needed. Space-based satellite systems can provide very useful information for public authorities and private industry to accurately monitor urban development, to analyze different urban structures and features and to efficiently plan urban infrastructure projects. GAF AG developed and generates, in close co-operation with the Remote Sensing Technology Institute (IMF) of the German Aerospace Center (DLR) and the data providers Airbus DS and DigitalGlobe, some standard products that can be used for different urban applications. The Tri-Stereo Digital Surface Model (DSM) as the high-end standard product within GAF's suite of elevation models is generated from very high resolution (VHR) satellite images with triple stereo coverage (sensor independent). The 0.5 m resolution DSM is produced highly standardized and fully quality controlled and can be generated worldwide. The DSM can be used e.g. for propagation analysis, viewshed calculations and 3D flights to get realistic impressions of the urban structure. The near-nadir ortho image, which is also part of the product, can be used e.g. for building footprint digitalization. As the generation of 3D building models is certainly possible with this stereo data, but as it is also very time-consuming and expensive, urban block models may be the preferred solution. These models structure built-up areas in cities according to different criteria like building density, -type and –function. Furthermore, height values coming from DSM and DTM files are also derived and are part of the product. Most of these processing steps are carried out highly automated. These urban block models are either generated based on the Tri-Stereo product or by using Euro-Maps 3D elevation models. Euro-Maps 3D is a 5m resolution digital surface model generated from IRS-P5 Cartosat-1 2.5 m in- flight stereo satellite data. This DSM is mainly used for regional and trans-national issues, but as buildings and building blocks are very sharply visible, it can be also used for urban applications. This product has also been developed in close co-operation with the Remote Sensing Technology Institute (IMF) of the German Aerospace Center (DLR).

Automatic railway instability detection using satellite SAR interferometry

Hanssen, Ramon; Chang, Ling; Dollevoet, Rolf P.B.J.
TU Delft, Netherlands, The

Irregular settlement of railways, either due to the loading of the trains or local ground deformation, impacts its structural stability and the safety of passengers on board. Conventional methods for structural monitoring of railway use in-situ measurements, from GPS, leveling or special survey trains. These methods are expensive and can only be applied on a limited scale, either in space or time. Moreover, they are usually only used at locations where structural deformation is suspected, requiring a-priori knowledge which may not be available everywhere. Using satellite InSAR, we are able to complement these conventional methods and monitor the kinematic behavior (deformation) of railways with millimetric precision, to detect irregular settlement. Here we use a probabilistic method for InSAR time series post-processing for the automatic detection of anomalies (e.g. railway irregular settlements). It is based on statistical hypothesis testing and the B-method of testing. In this method, we first (1) build a library of canonical kinematic functions, based on physically realistic behavior, such as linear, seasonal, temperature-related, step-wise discontinuities and exponential behavior. Then, (2) we find the best model per InSAR measurement point using multiple hypotheses testing. Particularly to detect irregular settlement of railways, the localized differential deformation between two nearby points (i.e., over 'short arcs') is more important for railway stability than the large deformation of certain point with respect to a far-away reference point. Therefore, we apply the testing methodology on short arcs. Finally, (3) we evaluate the quality of the estimated parameters, and classify the InSAR measurement points along the railway in terms of their temporal behavior. We conclude that irregular settlement of railways can be recognized. Since there are more than 100,000 InSAR measurement points for testing, we use the B-method of testing to increase the computational efficiency and define the optimal testing settings such as the level of significance and the power of the test. Our method is applied to all railways in the Netherlands. The kinematic time series of InSAR measurement points are derived from 73 Radarsat-2 acquisitions between June 2010 and August 2015.

Early warnings for imminent sinkhole collapse risks in urban areas

Hanssen, Ramon; Chang, Ling; van Leijen, Freek J
TU Delft, Netherlands, The

Many areas in the world are susceptible to sinkholes and the associated risk of a sudden collapse of the surface. About 13% of the world's land surface is covered by carbonate rocks which are sensitive to erosion by running water, leading to cavities and potentially sinkholes. In urban areas, sinkhole risks are a direct threat to human lives. Detecting sinkholes is notoriously difficult, as techniques such as ground-penetrating radar (GPR), electrical resistivity tomography (ERT), seismic methods, and microgravity, usually have a very localized range, and are difficult to deploy between buildings. Yet, recently it has been demonstrated that the detection of small depressions using radar interferometry can be indicative for imminent sinkhole collapse site identification. In an earlier study, we have demonstrated that a sinkhole occurring in the south of the Netherlands appeared to be observable as gradual deformation years before the actual collapse. Building on this experience, we designed a warning system to detect locations where the spatio-temporal behavior of the surface, or objects on the surface, has the characteristic fingerprint of a subsurface cavity, or an imminent sinkhole. We apply a robust method of hypothesis testing based on time series of TerraSAR-X and Radarsat-2 SAR data. We report on the characteristics of the method, the ways to deal with false alarms, and the potential for operational deployment.