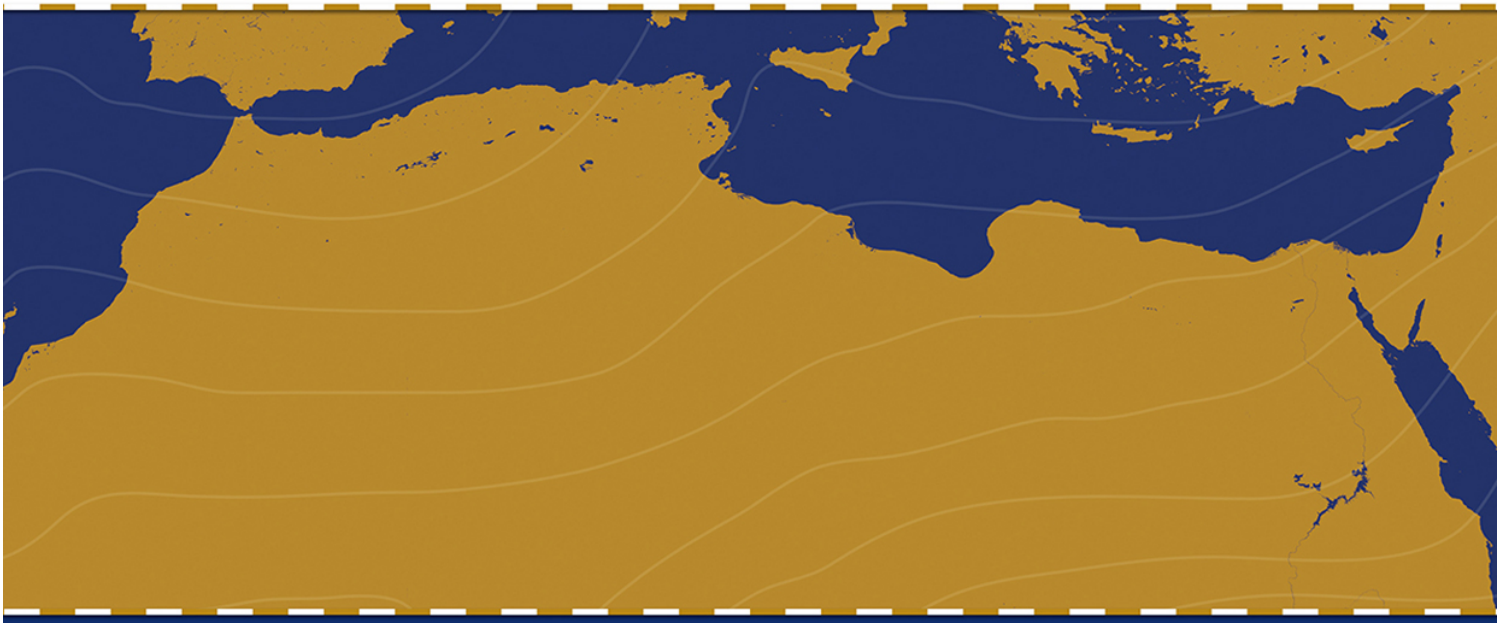
→ MWBS | MAPPING WATER BODIES FROM SPACE 2015 CONFERENCE



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18–19 March 2015 | ESA-ESRIN | Frascati (Rome), Italy

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Opening Session

Welcome talk

Borgeaud, Maurice
ESA-ESRIN, Italy

Sentinel-1 mission overview and status

Potin, Pierre; Rosich, Betlem; Miranda, Nuno
ESA / ESRIN, Italy

As part of the European Copernicus programme (formerly Global Monitoring for Environment and Security - GMES), the Sentinel-1 mission, based on a constellation of two SAR satellites, ensures continuity of C-band SAR observations, building on ESA's and Canada's heritage on satellite SAR systems (ERS, ENVISAT and RADARSAT). Sentinel-1A has been launched from Kourou on a Soyuz rocket on 3rd April 2014. The second satellite Sentinel-1B is planned to be launched early 2016. The Sentinel-1A satellite reached its nominal orbit on 7 August 2014. The In-Orbit Commissioning phase was completed on 23 September 2014, followed by the so-called operational qualification phase started (ramp-up). This ramp-up operations phase, defined for programmatic and technical reasons, is a phase during which the capacity of the overall system, including the ground segment operations, will progressively be increased, together with the gradual release of the operationally qualified products. This ramp-up phase is expected to be completed in May 2015; at this stage the routine operations will start. Full operation capacity of the mission will be reached once the In-Orbit Commissioning phase of Sentinel-1B and the subsequent constellation operational qualification phase will have been completed.

The oral presentation will provide an overview of the Sentinel-1 mission, including the mission characteristics, the SAR modes and products, the approach for the observation scenario, the access to data, etc. The status of the mission at the time of the workshop as well as some early demonstration of applications will also be presented.

S-2 Products and Mission

Hoersch, Bianca
ESA-ESRIN, Italy

The temporal mapping of water bodies from the perspective of climate modelling

Hagemann, Stefan
Max Planck Institute for Meteorology, Germany

Group on Earth Observations (GEO) Water Activities and Strategy

Bérod, Dominique
GEO Secretariat, Switzerland

Many natural disasters cannot be anticipated due to the often poorly understood nature of complex environmental systems. Earth observations can reduce risks through the provision of information required to support preparedness and political decisions. In this context, the intergovernmental Group on Earth Observations (GEO) was established in 2005 to build the Global Earth Observation System of Systems (GEOSS), through the coordination of efforts of its 97 Member States and 87 Participating Organizations (Feb 2015). The full value of GEOSS lies in its ability to integrate information across disciplines, providing easy, open and organized access to in situ and satellite observations that enable an increasingly integrated view of our changing Earth. From nine Societal Benefit Areas, this presentation will focus on Water.

GEO water tasks address diverse areas such as: defining the data and systems needed for improved water-cycle forecasting; interlinking weather forecasting systems with other Earth observation systems, especially for flood and drought; supporting efforts to improve the monitoring of water quality, coordinating observation system of cold regions; and capacity building.

The newly adopted GEOSS Water Strategy provides a framework to maintain and enhance water cycle observations, allowing closure of the water budget at national, regional and global scales, and promoting strategies to facilitate the chain of data acquisition, from measurement to deliverables. The ultimate goal of the GEOSS Water Strategy is to support decision-making systems in domains such as domestic and useable water supplies, adaptation of water resource systems to the impacts of climate change, water-related health and welfare needs, information needs of the water-energy-food security nexus, and access to water for ecosystems and biological systems.

GEO works towards the provision of coordinated, comprehensive and sustained Earth observations for sound decision-making and policy, and contributes to the definition and quantification of indicators for the sustainable development goals in support of the United Nations post-2015 development agenda.

Earth Observation in the Context of the Convention on Wetlands

Perceval, Chris

Secretariat of the Ramsar Convention, Switzerland

Significant progress has already been made within the context of the Ramsar Convention on the use of earth observation to help improve management of wetlands (i.e. which includes all freshwater and coastal areas, brackish and saltwater shallow areas).

Through a partnership with the Japanese Aerospace Exploration Agency it has been possible to develop a more detailed understanding of where mangrove ecosystems exist along coastlines, and changes over time. Through partnership with European Space Agency it has been possible to generate significant datasets for wetlands within regions such as the Mediterranean and Africa. A 'Mediterranean Wetlands Observatory (MWO)', for example, was created under the MedWet initiative of the Ramsar Convention, for supporting wetland conservation decision making. On the basis of these experiences, it is now widely recognised that the availability of time sequenced data can help drive improved management and well-targeted restoration projects within wetlands.

There are certain key factors that will affect the future of Earth Observation's effectiveness in the context of the Ramsar Convention, such as how trends and impacts are analysed, what information is presented to target audiences, and what options are available for how to respond. This presentation will describe some recent work on Earth Observation and wetlands, and some possible options for how to move forwards to enhance implementation of the Convention.

1.2: GLOBAL DATASETS AT MODERATE RESOLUTION

Surface Freshwater Extent and Storage Variability at Basin-to-Global Scale from Multi-Satellite Observations.

Papa, Fabrice ; Prigent, Catherine [2]; Aires, Filipe [3]; Frappart, Frederic [4]

1: Institut de Recherche pour le Developpement IRD, LEGOS, France; 2: LERMA-CNRS, Observatoire de Paris, Paris, France; 3: Estellus, France; 4: OMP-LEGOS-GET, Toulouse, France

Terrestrial waters, despite being less than 1 % of the total amount of water on Earth's ice-free land, are essential for life and human environment, and play a major role in the global water cycle and climate variability. As a consequence, there is a widespread demand for accurate and long-term quantitative observations of their distribution over the whole globe. Here, we present a remote sensing based-approach data set that quantifies the monthly and 10-day distribution and area of land-surface open water at the global scale (~25 km sampling intervals) over 15 years (1993–2007). These estimates are generated from complementary multiple-satellite observations, including passive (Special Sensor Microwave Imager) and active (ERS scatterometer) microwaves along with visible and near-infrared imagery (advanced very high-resolution radiometer; AVHRR).

Results for 1993 to 2007 exhibit a large seasonal and inter-annual variability of the inundation extent, which are in good agreement with the variations of other related hydrological variables such as precipitation and river discharge. In addition, our analysis reveals an overall decline in global average maximum inundated area of 6% during the fifteen-year period, primarily observed in tropical and subtropical South America and South Asia. Moreover, the largest declines of open water are found where large increases in population have occurred over the last two decades, suggesting a global scale effect of human activities on continental surface freshwater.

For large river such as the Amazon basin, we further combined our surface water extent estimates with radar altimeter-derived water level time-series and DEM data (e.g. ASTER-GDEM) to derive the spatio-temporal variability of surface freshwater storage. For the first time, we estimate the mean annual amplitude of surface water storage in the Amazon to be of ~1200 km3, which contributes to about half of GRACE-derived total water storage variations. During the extreme climatic events that recently affected the Amazon basin, such as the exceptional droughts of 1997 (October–November) and 2005 (September–October), these new observations help to map the surface water volume anomaly. We also estimate that during these dry events the water stored in the river and floodplains of the Amazon basin was, respectively, ~230 (~40%) and 210 (~50%) km3 below the 1993–2007 average. In 2005, it represents more than half of the anomaly of minimum terrestrial water stored in the basin as estimated using GRACE observations.

Finally, we will illustrate how these new 15-year data sets of surface water extent and storage represent an unprecedented source of information for continent-to-global hydrological, land surface and climate modeling or for the preparation of future satellite missions. In particular, a spatial downscaling methodology have been tested in combination to auxiliary information (MODIS, SAR or DEM data) to increase the spatial resolution of the inundation extent, from 25 km to 100 m. This new high-resolution dataset is essential in the frame of the future NASA-CNES satellite mission SWOT.

Multi-year Envisat ASAR observations in support of global mapping of inland water bodies

Santoro, Maurizio [1]; Wegmüller, Urs [1]; Lamarche, Celine [2]; Bontemps, Sophie [2]; Defourny, Pierre [2]; Arino, Olivier [3]

1: GAMMA Remote Sensing, Switzerland; 2: Université catholique de Louvain, Earth and Life Institute, Belgium; 3: ESA-ESRIN, Italy

Spaceborne Synthetic Aperture Radar (SAR) images of the backscattered intensity provide synoptic and repeated information on land surface properties thanks to the independence from cloud cover and solar illumination. High resolution modes (1-30 m spatial resolution) allow continuous monitoring at the expenses of large coverage; moderate resolution modes (100 -1,000 m spatial resolution) allow regional to global monitoring with frequent revisit times. During the Envisat mission (2002-2012), the Advanced SAR (ASAR) instrument was operated according to such logic. The high resolution Image Mode and Alternating Polarization Mode (20 m spatial resolution) were used for dedicated studies; the moderate resolution Wide Swath Mode (150 m spatial resolution) was operated to obtain regional coverages; the Global Monitoring Mode (1,000 m spatial resolution) was used in the so-called background mode when the instrument was not being operated according to a request. As a result of 10 years of acquisition, the archive of ASAR images presents consistency of acquisitions in one specific mode for virtually any region of the Earth.

Detailed and accurate information on spatial extent and type of water bodies at the global scale and moderate resolution is a means to assist and/or improve the parameterization of climate models, which currently use approximations or datasets at coarser resolution. The capability of repeated Envisat ASAR observations of the radar backscatter to map and monitor water bodies was demonstrated in (Bartsch et al., 2008; Brisco et al., 2009; Reschke et al., 2012; Kuenzer et al., 2013). Most studies required that the SAR backscatter was low to correctly detect water bodies. While such assumption may be met in regional studies with the availability of a large dataset of SAR observations, it is invalid at global scale because the density of ASAR observations is uneven (low number of observations, observations concentrated during specific seasons etc.). In a pilot study (Santoro et al., 2014), we recently reported on the potential offered by multi-temporal metrics of the ASAR backscatter (temporal variability and minimum backscatter) to map open permanent water bodies with a simple thresholding algorithm. Such metrics are able to withstand seasonal and environmental conditions, assuming a rather uniform distribution of observations in time. Given the availability of repeated backscatter observations in multi-year ASAR datasets, we recently generated a global indicator of open and permanent water bodies in support of the global land cover mapping of the Climate Change Initiative Land Cover (CCI-LC) project (Santoro et al., 2013). For this, the simple thresholding approach has been expanded with regional refinements to reduce the classification error due either to the variable timing and/or amount of ASAR data worldwide. With the present and future Sentinel-1 satellites, there is a concrete possibility to extend the time line of multi-temporal C-band observations in this decade, update water body information from ASAR representing 2010 and increase the spatial resolution from 150 m to 20 m at the global scale.

In this presentation, we review the multi-temporal metrics applied to the global dataset of Envisat ASAR observations, highlighting strengths and weaknesses with respect to obtaining a global product of inland open water bodies. We then discuss the potential of such metrics based on ASAR data with respect to the detection of water body dynamics (inundation, flooding). Finally, we present some first water body detection results over selected areas and compare with existing ASAR-based maps. As a result, some indications will be given on the operations of Sentinel-1 to support an operational water bodies monitoring system.

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PROBA-V 10 day Mean Composite Multispectral Data for Water Surface Detection based on HSV color transformation

Bertels, Luc; Smets, Bruno

VITO, Belgium

The PROBA-V microsatellite was launched in May 2013 as a successor for the SPOT-VEGETATION mission. The instrument is fully operational since December 2013 and delivers daily near-global synthesis with a spatial resolution of 300 m and 1 km. The high revisit time and the four spectral bands (Blue, Red, NIR, SWIR) make this instrument ideal for climate impact assessments, agricultural monitoring, food security estimates and surface water resource management. The objective of this work is to develop a global scale multi-temporal and multi-spectral image analysis method for water surface detection based on an algorithm previously developed for MODIS.

To obtain as much as possible cloud free images, 10 day mean composites (MC10) are calculated from the daily top-of-canopy synthesis products. The SWIR, NIR and RED bands of the MC10 images are subsequently color transformed to the Hue, Saturation, Value (HSV) color system. The water bodies are detected based on a decision tree using threshold values on the Hue and Value bands. The status map obtained during mean compositing filters out contaminated pixel, as is pixels covered by snow or clouds. Such pixels are not considered during water body detection. To minimize commission errors the decision tree uses the normalized difference vegetation index (NDVI) and three additional data layers : i) a water body potential mask, derived from the Global Land Survey Digital Elevation Model (GLSDEM). This mask identifies locations which are topographically suitable to hold water bodies; ii) the most recent permanent glacier data from the National Snow and Ice Data Centre (NSIDC). Locations indicated as permanent glacier cannot hold water bodies; iii) A volcanic soil mask, constructed from the data obtained through the Smithsonian Institution, Global Volcanism Program. Dark volcanic soils are frequently confused with water bodies and are therefore not considered in the water body detection algorithm.

The output product holds beside the identified waterbodies a second layer describing the probability of the detected water bodies which was calculated using temporal-sequential statistics. The algorithm was first developed for an

area over the Ethiopian Rift Valley and subsequently calibrated and validated using Google Earth for ten other areas worldwide.

Mapping lakes, catchments and land use impacts on water quality: the GloboLakes 1000

Simis, Stefan GH [1]; Politi, Eirini [4]; Tyler, Andrew N [2]; Brockmann, Carsten [6]; O'Donnell, Ruth [5]; Miller, Claire [5]; Scott, Marian [5]; Hunter, Peter D [2]; Spyrakos, Evangelis [2]; Cutler, Mark [4]; Maberly, Stephen C [3]; Groom, Steve [1]; Ca

1: Plymouth Marine Laboratory, United Kingdom; 2: University of Stirling, United Kingdom; 3: NERC Centre for Ecology and Hydrology; 4: University of Dundee; 5: University of Glasgow; 6: Brockmann Consult

GloboLakes is a 5-year UK NERC funded research programme investigating the state of lakes and their response to environmental drivers of change. The project will establish a near-real time (NRT) satellite based observatory (Sentinel 3) and undertake processing of archived data (MERIS, SeaWiFS) to produce time series of observed ecological parameters and lake temperature for over 1000 lakes globally. The global lakes observatory built on these data sources will support a wide spectrum of landcover, water quality, and climate change research.

Time-series of water quality parameters from the Full Resolution MERIS archive are being generated using the CaLimnos processing chain, a continuation of development of the ESA Diversity-II processor. Examples from Lake Balaton illustrate how lake basin-scale dynamics are captured in the project.

A high degree of automation is sought in all data processing elements. Progress thus far has resulted in the generation of 868 catchments from the 90-m resolution SRTM (56°S - 60°N) and 132 catchments (>60°N) using the 30-m ASTER Digital Elevation Model. This requires repeated and computationally expensive subsetting of high-resolution data sources and generates a substantial volume of rasterized catchment information. Due to the global scope of the project and to support future use of the processing framework beyond 1000 lakes, it is important to incorporate any recent developments and up-to-date repositories holding environmental and geophysical information on inland water bodies. Recent initiatives such as the ESA CCI land/water mask at 300-m resolution and Glowabo from high-resolution satellite imagery are currently under consideration for implementation.

Biodiversity Indication for 300 Lakes Worldwide Using ENVISAT

Odermatt, Daniel [1,2]; Brockmann, Carsten [2]; Philipson, Petra [3]; Paganini, Marc [4]

1: Odermatt & Brockmann GmbH, Switzerland; 2: Brockmann Consult Gmbh, Germany; 3: Brockmann Geomatics, Sweden; 4: ESA/ESRIN, Italy

ESA's ENVISAT satellite acquired an unparalleled archive of optical, thermal and altimeter observations of lakes between 2002-2012. In the scope of the ESA DUE Diversity II project, a comprehensive database is created from these observations, consisting of water quality and quantity parameters for more than 300 inland waters. The database is made publicly available at www.diversity2.info, together with corresponding documentation, several case studies and a collection of Python functions for display tasks and spatio-temporal analyses. The Diversity II inland water database is designed to meet the specific requirements of aquatic biodiversity surveys, but represents beyond this purpose the first globally consistent and reproducible knowledge basis of its kind.

The database consists of water composition, level and temperature variations. Water composition parameters are retrieved from MERIS full resolution imagery and compiled as level 3 GeoTIFF products of monthly, yearly and 9-year aggregation, using a dedicated processing chain for valid pixel identification, atmospheric correction, water type classification and constituent retrieval. The parameters included in each product are chlorophyll-a, suspended matter and CDOM concentration, turbidity, cyanobacteria and floating matter probability. Water level time series are adapted as individual observations from the Hydroweb database (Cretaux et al., 2011), and available as tables and time series figures for about one third of all lakes selected in Diversity II. Monthly lake surface water temperature is taken from the ARCLake database (MacCallum & Merchant, 2011) and merged with the water composition products.

The potential of the Diversity II inland water database is demonstrated in the context of several case studies, wherein local experts assess the information content against the background of recent events and known environmental trends in individual lakes, including Lakes Biwa, Geneva, Nicaragua, Turkana, Vanern, Victoria and Winnebago. Evidence is presented for eutrophication and hypoxia events, floating vegetation proliferation and the occurrence of cyanobacteria blooms, and reference data from various sources is provided for verification and interpretation of these phenomena. The database is accompanied by a collection of Python functions for generic display tasks and analyses. The functions allow for plotting individual maps for each parameter included in the level 3 products, they perform the extraction of statistical quantities for user-defined regions of interest and display the extracted quantities as time series.

1.3: GLOBAL DATASETS AT HIGH RESOLUTION

30 Years' Global Scale Mappingof surface Water Dynamics at 30 m resolution

Pekel, Jean-Francois [1]; Cottam, Andrew [1]; Gorelick, Noel [2]; Belward, Alan [1]

1: European Commission - Joint Research Centre, Italy; 2: Google

The area of our planet's surface covered by liquid water is a surprisingly unknown quantity; some geographic-spaces may be covered by water every day of the year, others may be routinely inundated for period(s) of time in a given year, other appearances may be highly episodic, and even 'permanent' water-features may not be as permanent as expected – river courses shift, new lakes form (especially when artificial dams are constructed) others can disappear. Our knowledge concerning these dynamics at global scale is inadequate and the information gap is significant.

Imagery from polar orbiting satellites have been used to create global maps of the land surface that include water, but these maps are generally characterized by coarse spatial resolution and are static in time, which fails to capture the intrinsic dynamic nature of water surfaces. To address these shortcomings we adapted a water detection methodology initially developed for MODIS for use with Landsat. By exploiting the processing power of the Google Earth Engine platform (20,000 CPU's were used) we were able to process the entire Landsat 5, 7 and 8 archives spanning the last three decades at 30 m spatial resolution. The methodology uses the HSV color space transformation combined with a sequence of dynamic masks (including cloud, cloud shadows, terrain shadows and lava outcrops). A global validation exercise confirmed an overall accuracy for our map of surface water dynamics at > 90%.

Our Earth water watch dataset consistently resolves the global land/water boundary at unprecedented levels of spatial detail, and this will be continuously updated. We document the world's riverine and lacustrine ecotones, and show how they can change within and across years. We map the establishment and disappearance of lakes; we provide a unique coastline erosion/sedimentation record.

The dataset provides a new basis for water resource managers; it serves the biodiversity assessment communities, helps assure food security as well as human (and animal) health through improved assessment of waterborne diseases, water based disease vectors, and even flooding; it will help improve meteorological and climate models through more precise characterization of spatio-temporal variation in surface water forcings, and has implications for urbanization and industrial development.

Landsat's Long-term Acquisition Plan, developed in the late 1990s, has led to continually improving spatiotemporal consistency of coverage. Nonetheless, the earlier archive is less consistent than the latter. Whilst contemporary data acquisitions meet the full 8 or 16 day cycle (Landsat 8 alone or Landsats 7 and 8 together) this is still quite coarse for capturing surface water dynamics. Our method is sensor neutral and we will apply it to other optical sensors, including the Sentinel 2 mission. Reducing overpass intervals to the order of 3 – 4 days should help not only with building better cloud-free dataset, but should also help with early warning and flood monitoring applications.

Assessment of Surface Water Bodies derived from Landsat

Jones, John

U.S. Geological Surey, United States of America

To meet broad scientific and resource management needs the US Geological Survey (USGS) is developing a Landsat-based product named Dynamic Surface Water Extent (DSWE). DSWE can be used to document changes in the number and size of surface water bodies present during the time period of the Landsat Archive. A strategy that combines qualitative, quantitative and applied evaluation of the DSWE has been devised to refine prototype products from the DSWE and document product characteristics for potential users. Sixty eight Landsat path/row locations across the lower 48 states, Alaska, Hawaii and Puerto Rico are used for qualitative assessment of the DSWE through comparison with existing geospatial databases such as the US Fish and Wildlife Service's National Wetland Inventory and the USGS National Hydrography Database. Rigorous assessment of DSWE uncertainty is achieved through various statistical comparisons of surface water bodies measured over subareas of Landsat scenes with surface water bodies derived for the same areas in a systematic fashion from coincident, higher resolution airborne and satellite remote sensing systems. On-going research is aimed at developing most cost-efficient means of generating those evaluation data from remote sensed data as well as in-situ sensors and citizen science. At the same time the utility of prototype water body data for various science and resource applications is being examined by targeted users in USGS as well as other government agencies and Universities.

A consistent Global Water Body Mask based on WorldDEM^{TM}

Tinz, Marek; Riegler, Gertrud; Fahrland, Ernest; Muehlbauer, Stefan

Airbus Defence & Space, Germany

Airbus Defence and Space's WorldDEM™ provides a global Digital Elevation Model of unprecedented quality, accuracy, and coverage.

The product will feature a vertical accuracy of 2m (relative) and better than 10m (absolute) in a 12m x 12m raster. The accuracy will surpass that of any global satellite-based elevation model available. WorldDEM is a game-changing disruptive technology and will define a new standard in global elevation models.

The German radar satellites TerraSAR-X and TanDEM-X form a high-precision radar interferometer in space and have acquired the data basis for the WorldDEM. This mission is performed jointly with the German Aerospace Center (DLR). Airbus DS holds the exclusive commercial marketing rights for the data and is responsible for the adaptation of the elevation model to the needs of commercial users. The worldwide homogeneous acquisition guarantees a DEM with no break lines at regional or national borders and no heterogeneities caused by differing measurement procedures or data collection campaigns staggered in time.

The radar data base acquired in the course of the TanDEM-X mission between the years 2011 and 2014 is a unique data source which can be exploited beyond the global elevation information as such. A global water body indication mask is generated automatically as a "side product" of the DEM generation. This mask will be truly global and consistent covering the whole global land mass. An even more precise and refined water body mask is a side product of the subsequent editing process resulting in the end-user DEM: the WorldDEMTM. This mask provides a classification of the water body extent into ocean, lake/reservoir and river features. The capture criteria for lake/reservoir features is set to 7000 sq.m., which is aligned to a map scale of 1:25,000/1:50,000.

Another information layer derived will be a Global Ocean Shoreline (GOS) layer. This new worldwide GOS vector dataset represents the water-land-mark (mean high water) at the time of data collection.

This paper will give an overview of the TanDEM-X Mission, and the WorldDEM product portfolio. The current status of product development activities regarding Global Water Body Mask and Global Ocean Shoreline layer will be presented including first samples.

A global and long-term inondation extent dataset from multiple-satellite observations, towards the high spatial resolution

Aires, Filipe (1,2,3); Prigent, Catherine (2,1,3); Papa, Fabrice [4]; Fluet Chouinard, Etienne [5]; Lehner, Bernhard [6]

1: Estellus, France; 2: LERMA, Observatoire de Paris, France; 3: Water Center, Columbia University, USA; 4: IRD and IFCWS, Bangalore, India; 5: University of Wisconsin, USA; 6: McGill University, Canada

The Global Inundation Extent from Multi-Satellite (GIEMS) provides multi-year monthly variations of the global surface water extent at about 25kmx25km resolution, from 1993 to 2007. It is derived from multiple satellite observations. Its spatial resolution is usually compatible with climate model outputs and with global land surface model grids but is clearly not adequate for local applications that require the characterization of small individual water bodies. There is today a strong demand for high-resolution inundation extent datasets, for a large variety of applications such as water management, regional hydrological modeling, or for the analysis of mosquitos-related diseases. This paper presents three approaches to downscale GIEMS. The first one is based on an image-processing technique using neighborhood constraints. It requires high spatial resolutions images, for at least a few inundation stages. It has been tested using SAR data. The second approach uses a PCA-representation to perform an algebraic inversion. The PCA-representation is also very convenient to perform temporal and spatial interpolation of complex inundation fields. It necessitates high spatial resolution information for a significant amount of temporal steps. MODIS images have been used in this framework, in environments where the vegetation density is rather low. The third downscaling method uses topography information from Hydroshed Digital Elevation Model (DEM). Information such as the elevation, the distance to river and flow accumulation is used to define a “floodability index” that is used by the downscaling. Three basins will be considered for illustrative purposes: Amazon, Niger and Mekong.

A new dataset named GIEMS-D15 will be presented, it provides the minimum and maximum extent with a resolution of 90 m at the global scale. Furthermore, the extension of the full GIEMS times series from 1993 to present, using SAR data and Hydroshed information, will be discussed.

Using Global Lake Abundance Data to Map Lake Volume and Carbon Content from Space

Kutser, Tiit [1,2]; Verpoorter, Charles (3,2); Rohtla, Liisa [1]; Seekell, David [4]; Sobek, Sebastian [2]; Bastviken, David [5]; Casal Pascual, Gema (6,1); Tranvik, Lars [2]

1: Estonian Marine Institute, University of Tartu, Estonia; 2: Department of Ecology and Genetics/Limnology, University of Uppsala, Sweden; 3: Laboratoire d’Oceanologiee et des Geosciences, University du Littoral Cote d’Opale, France; 4: Department of Env

We have recently mapped all inland waterbodies from space that are larger than 0.002 km2 using Landsat GeoCover data with 14.25 m spatial resolution. This database allows us to make next steps in inland water research. For example, we are currently estimating the total volume of lakes on Earth using the lake database and two different methods – using DEM (slopes of landscapes) and a statistical relationship between the lake size and it’s volume. Most of the carbon in lakes is in the form of dissolved organic carbon (DOC). On the other hand there is often good correlation between the DOC and it’s coloured part CDOM, which can be mapped from satellites.

Satellites with sufficient spatial resolution and sensitivity needed for aquatic applications (Landsat 8 and forthcoming Sentinel-2) do not provide cloud free coverage of the whole Earth yet. Therefore, we are in the process of creating the first global lake CDOM/DOC estimate combining our lake database and CDOM/DOC estimates for lakes on more than 100 Landsat 8 images from all continents. Current estimates on the fluxes of CO2 and CH4 from lakes to atmosphere are based on the previous statistical estimate on the number and size of lakes on Earth (309 million). We have shown that the number of lakes on Earth is 117 million and the size distribution of lakes is slightly different than previously thought. This has implications on the estimate of CO2 and CH4 fluxes from lakes. We are currently in the process of making these new estimates.

1.4: NORTHERN LATITUDES WATER BODIES

Monitoring the dynamics of shallow Arctic water bodies from space

Duguay, Claude

H2O Geomatics Inc. and University of Waterloo, Canada

Shallow water bodies (i.e. lakes and ponds ca. less than 4 m deep) are a ubiquitous feature of Arctic landscapes. There has been growing interest from the scientific community regarding the status of these shallow water bodies, as their growth or disappearance may be an indication of the effects of climate change. Climate warming has accelerated permafrost thaw in many regions of the circumpolar Arctic, leading to a drying of upland areas and an impounding of drainage in subsiding areas. Surface water in the landscape presents a positive feedback that enhances permafrost degradation in wet areas, which may either increase the availability of water to lakes and ponds or increase hydrologic connections between lakes and their surroundings, causing them to drain.

A few studies have used remote sensing to document trends and variability in lake surface areas over the past 50 years. However, there is an overall paucity of observations on the fate of the many shallow water bodies across the Arctic, and variability across regions is poorly known. Research is needed to determine whether expansion or drainage of these water bodies will dominate various types of permafrost landscapes over the coming decades, and which regions of the Arctic will be affected by these changes. In addition, there is a need to monitor changes not only in surface area/extent of water bodies but also that of other parameters indicative of their dynamics (e.g., fraction of bedfast ice, ice freeze-up/break-up dates and duration, surface water temperature, water turbidity, and water level). Long-term monitoring at multiple locations across the circumpolar Arctic is urgently needed to assess the trajectory and magnitude of changes in these parameters.

This paper will provide an overview of recent studies using remote sensing to investigate the dynamics of shallow water bodies in various regions of the Arctic. It will also offer an initial roadmap for a monitoring strategy in light of the recent and upcoming satellite missions. In particular, Sentinel-1/2/3 missions will provide an unprecedented opportunity for furthering our understanding of the response of shallow Arctic water bodies to climate change.

Mapping thermokarst lake changes across arctic permafrost landscapes with dense Landsat time-series

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

1: Helmholtz Centre - Alfred-Wegener-Institute for Polar and Marine Research, Germany; 2: University of Potsdam, Germany

The predicted significant increase in air temperatures in high latitudes over the coming century puts high pressure on vulnerable permafrost landscapes that dominate large parts of the Arctic. Small changes in the climatic pattern may result in a potentially large scale permafrost thaw and consequently the mobilization of previously frozen soil organic matter. The release of this carbon as methane and carbon dioxide, both active greenhouse gases, would result in a positive feedback loop with climate warming (“permafrost carbon feedback”). Arctic Permafrost landscapes, characterized by an abundance of thermokarst lakes, are subject to rapid changes, such as surface subsidence in conjunction with changes in surface wetness, thaw lake formation and expansion, as well as lake drainage. In addition to their role for biogeochemical cycling, Arctic thermokarst lakes provide important habitats and fresh water resources for Arctic settlements and industry. Understanding and quantifying changes in Arctic lake

cover is thus of major interest to various stakeholders from research, land management, subsistence communities, and industry.

Within the framework of the ERC funded PETA-CARB project (Rapid Permafrost Thaw in a Warming Arctic and Impacts on the Soil Organic Carbon Pool) the thermokarst lakes and landscape dynamics of several different study areas in Northern Siberia and Alaska are analyzed with super-temporal remote sensing techniques. Dense time-series image stacks of multispectral Landsat-5 TM, Landsat-7 ETM+, and Landsat-8 OLI data from 1999 until 2014 are utilized for the super-temporal monitoring of thermokarst related land surface processes at 30m spatial resolution. Owing to their high-latitude location Arctic regions are predestined for a high-frequency monitoring due to multiple overlapping image paths. For one of our current focus areas, the Siberian Lena River Delta at the size of Belgium, we processed and analyzed more than 200 Landsat scenes over about 25,000 km2 area for the years 1999-2014. Despite the short snow-free seasons and frequent cloud-cover in such regions most pixels have been cloud-free more than 25 times over the 15-year period allowing for a thorough temporal analysis. Robust trends of different key surface descriptors, such as Tasseled Cap (Brightness, Greeness, Wetness) or NDVI were calculated to map changes of the landscape, in particular the expansion, drainage, and drying of thermokarst lakes. The trajectories of such indicators can be associated with the type, magnitude and timing of specific landscape change processes in Landsat-like spatial resolution of 30 m.

Our regional observations provide a basis for an automated pan-arctic monitoring that may allow improved quantification of permafrost thaw and lake change processes aided by our highly automated workflow in conjunction with constantly increasing computation power. The upcoming start of ESA's Sentinel-2 satellite system will provide an additional valuable resource for automated mapping of lake dynamics and the development of satellite-based products for Arctic lake monitoring. We expect that the integration of the soon-to-be-launched Sentinel-2 will provide significant synergies for the repeated monitoring of thaw processes in Arctic landscapes with an unprecedented accuracy and temporal resolution.

Evidence of Recent Changes in the Ice Regime of High Arctic Lakes from Spaceborne Satellite Observations

Surdu, Cristina M. [1]; Duguay, Claude R. [1]; Fernández Prieto, Diego [2]

1: University of Waterloo, Ontario, Canada; 2: European Space Agency, Rome (Frascati), Italy

Arctic lakes, through their ice cover phenology, are a key indicator of climatic changes that the high-latitude environment is experiencing. In the case of lakes in the Canadian Arctic Archipelago, many of which are ice covered more than ten months per year, warmer temperatures could result in fewer lakes that develop perennial ice cover, earlier break-up dates, and thus shorter ice seasons.

A 15-year time series (1997-2011) of RADARSAT-1/2 ScanSAR Wide Swath, ENVISAT ASAR Wide Swath and Landsat acquisitions were analyzed to document the response of ice cover on lakes in the Canadian High Arctic to climate conditions during recent years. Results indicate that some lakes may be transitioning from a perennial to a seasonal ice regime. Earlier melt onset was observed for all lakes, with the smaller lakes situated in polar oases environments experiencing the greatest deficit in ice duration, a function of earlier melt onset (by 14-39 days vs. 2.7-22.5 days for polar desert lakes) and advanced ice-off dates (by 9-23.6 days vs. 1.6-20 days for polar desert lakes). The greatest change in timing of melt onset (39 days early, $\alpha = 0.05$) and summer ice minimum (30 days early, $\alpha = 0.10$) was observed for lake L6 on Devon Island while ice-off for Buchanan Lake occurred earlier by a total of 23.6 days ($\alpha = 0.01$). The only lake that gained ice days as a result of later break-up was Lower Murray Lake (12.5 days later, $\alpha = 0.10$). The residual summer ice generally disappeared earlier on all lakes, by 9-30 days in polar oasis environments and by 1.5-18.8 days in polar desert environments.

Ice cover changes of lakes in the Canadian High Arctic display high correlation with changes in air temperatures at these latitudes, extreme ice events occurring during years with high positive/negative air temperature anomalies.

Refining the Mapping of Lakes in the Arctic: A Landsat Based Approach

Paltan Lopez, Homero Alejandro [1,2]; Dash, Jadu [2]; Edwards, Mary [2]

1: University of Oxford, School of Geography and the Environment, United Kingdom; 2: University of Southampton, Geography and Environment, United Kingdom

Mapping water bodies at regional scales represent a challenge for continuous monitoring of hydrological, climatic and landscape processes. Lakes in the Arctic play an important role in the terrestrial ecosystem for maintaining ecological processes, and are major contributors to biogeochemical cycles. Understanding these processes is vitally important, because climate change is known to alter the biology, hydrology and geographical distribution of lakes. Nonetheless, the occurrence of such processes may not be spatially and temporaly uniform across the Arctic. In a region as sensitive as the Arctic, inadequate representation of lake cover has led to underestimates of their role in the biochemical cycle and as constituents of the landscape.

The need to count on broad multi-temporal lake cover data then leads to the necessity of testing techniques for mapping water bodies from continuous satellite missions which count on rich historical datasets such as Landsat imagery. In this study we have tested a density slicing detection technique for to 617 cloud-free Landsat images for the summer months between 2003 and 2012. Water pixels were then extracted from the shortwave infrared band (Band 5: 1.55-1.75 µm). Following the classification, water detected areas were vectorised, Next, elongated water bodies such as rivers were masked out by applying a compactness function, which differentiated rounded features from elongated ones. Water bodies identified as lakes were integrated into a comprehensive GIS database of Arctic Lakes. An accuracy assessment was done by validating our dataset against high-resolution imagery distributed across different vegetation cover types of the region. This database coupled with supplementary data helped us to understand current distribution of Arctic lakes.

In this way, with an overall accuracy of 80%, we mapped about 3,500,000 Arctic lakes - with a minimum mapping area of 0.0036 km2; these lakes cover nearly 6% of the regional land surface (about 400,000 km2 of lake water). We found that lakes in this region are typically small (< 0.1 km2). Additional lake density and lake fraction mapping and analyses show that lakes are more common in lowland permafrost areas with tundra vegetation. The prevalence of small lakes likely reflects the peculiarities of permafrost hydrology. It is evident from this analysis that the pattern and size of Arctic lakes varies geographically and their distribution clearly demonstrates the heterogeneity of Arctic lake cover both across the Arctic and with a region.

The accuracy of this study leads us to believe that applying a similar methodology on Landsat products, (1980s, 1990s or even current 2010s) would produce similar strong multi-decadal and regional datasets of lakes out of satellite imagery. This approach will enhance the understanding of the way by which lakes represent significant witnesses of climate change in Arctic landscape processes. Therefore, this work provides an opportunity to start exploiting the temporal characteristics and ongoing availability of Landsat mission products to develop multi-temporal lake classification systems at a regional scale.

Mapping water bodies with SAR in high latitudes

Bartsch, Annett (1,2,5); Widhalm, Barbara [1,2]; Högström, Elin [2]; Trofaier, Anna Maria [3]; Leibman, Marina [4]

1: Central Institute for Meteorology and Geodynamics (ZAMG), Austria; 2: Vienna University of Technology, Austria; 3: ESA Climate Office, UK; 4: Earth Cryosphere Institute, Russian Academy of Science, Tyumen; 5: University of Salzburg, Austria

Tundra lowlands are characterized by an abundance of lakes. Many are related to the occurrence of permafrost. Specifically thaw lakes are frequently analysed with satellite data as an indicator for permafrost change and climate change respectively in the Arctic. The majority of these lakes have a diameter smaller than 200m but water fraction is high. Their presence is thus problematic for global remotely sensed products which are based on data of coarser spatial resolution.

Such lakes vary not only over longer time scales but also seasonally as they are often connected to floodplains. A high temporal resolution as well as spatial resolution is required in order to separate between these different types of fluctuations. Suitable records could be provided by Synthetic Aperture Radar data. Past initiatives such as the ESA DUE Permafrost and STSE ALANIS Methane projects focused on open water detection with the aim to provide consistent time series based on Synthetic Aperture Radar data. A number of challenges have been exemplified including varying data availability in space and time, spatial resolution and frequency limitations. The latter includes especially the impact of weather on wave action and subsequent constraints for regular monitoring with C-band sensors. The influence of such dynamics on scatterometer derived soil moisture has been investigated in this context within the framework of the FP7 project PAGE21 (www.page21.eu; GA282700). Limitations by frequency have been further investigated within the joint Austrian-Russian project COLD (FWF I 1401-N29; RFBR 13-05-91001-AH).

This presentation summarizes lessons learned and remaining challenges.

2.1: WATER BODIES IN TEMPERATE AND TROPICAL REGIONS

Mapping Water for Europe: Operational Mapping and Data Products in the context of Copernicus: EU Hydro and High Resolution Layer on Water Bodies. Status, Outline, Developments, Lessons learned

Langanke, Tobias [1]; Vaitkus, Gedas [2]; Schuren, Eugenija [1]; Dufourmont, Hans [1]

1: European Environment Agency, Denmark; 2: Geomatrix UAB, Lithuania

In the context of Copernicus (the programme for the establishment of a European capacity for earth observation - previously GMES), the European Environment Agency (EEA) is currently implementing the pan-European and local components of the GMES/Copernicus Initial Operations land (GIO land) that include the mapping of 5 High Resolution Layers (HRL) on land cover characteristics. One of these HRLs is mapping permanent water bodies (PWB), for 39 countries (almost 6 Million km2) in Europe, for the 2012 reference year. PWB is being produced at 20m x 20m spatial resolution, and distributed as validated 100m x 100m products. This (binary) dataset is mapping all permanent water bodies with a MMU of 1 (20m) pixel. The problem of seasonal fluctuations in water-bodies is addressed by using a seasonal time series of high resolution imagery (3-8 images with 4-6 weeks' time interval), and the European image mosaic IMAGE 2006/2009/2012. From the input data, a water presence index (WPI) is calculated, to identify areas with constant presence of water (with regards to 2006/2009/2012). The HRLs will complement and provide additional information to the existing water related European datasets.

The second water related data product, produced in the frame of Copernicus at EEA is the upgraded EU-Hydro dataset. The pan-European hydrographic dataset EU-Hydro and digital elevation dataset EU-DEM were created in the frame of GMES, for the upgrade work as part of the Preparatory action for Reference Data Access (RDA) in 2009-2012. EU-Hydro is a dataset for all EEA39 countries, providing a photo-interpreted river network, consistent of surface interpretation of water bodies (lakes and wide rivers), and a drainage model derived from EU-DEM with catchments and drainage lines. The dataset is available in first instance for all Copernicus services, in second instance for the assessment of water resources at the European level. A beta version of the dataset is available at EEA. One of the features to be integrated into the upgraded version is the specification of each water body with its codes matching the respective national information systems. This information will be used for facilitating the allocation of other national information reported under European, international or EEA data reporting flows.

Despite the fact that both EU-Hydro and PWB HRL are produced from the same satellite imagery, EU-Hydro is focusing on accurate cartographic representation of surface water features and their attributes, as well as delineation of topologically consistent drainage networks – thus forming also a reference framework for various WFD models and assessments. On the contrary, PWB HRL products are a land characteristics layer derived by statistical analysis of a large multi-seasonal time series of satellite imagery – thus laying the foundation for a long-term monitoring of the de facto status and distribution of the surface water resources across Europe.

We outline the context and status of both the PWB HRL, and EU-Hydro, as being part of the European Copernicus land services, but also in a broader sense as being part of a trend towards higher spatial and temporal resolution LU/LC products.

Water quality of lakes over Europe using Sentinel-2; Atmospheric Correction and Validation

Mangin, Antoine [1,2]; Serra, Romain [1]; Hembise Fanton d'Andon, Odile [2]

1: ACRI-HE, France; 2: ACRI-ST, France

There is a general consensus in the scientific community that recent research results permit to believe that the Sentinel-2 data will provide a very valuable start for a regular monitoring of inland water ecological quality. The main motivation is that Sentinel-2 offers a spatial resolution that allows the observation of most of the continental water lakes and reservoirs and that the spectral definition is sufficient to catch the main components of interest for ecological description of the area (ie the chlorophyll content and the turbidity/transparency). In parallel to that, we assist to an emerging very demanding environmental monitoring through European regulations (typically the Water Framework Directive). We present here the results of research activities that has led to the automatic processing of Sentinel-2 like data (e.g. Landsat 8) over more than 600 lakes in Europe (see eyeonwater.eu). The EO data is automatically extracted on areas of interest, then an atmospheric correction is applied before the water quality (Chlorophyll and turbidity) is estimated. The quality of this retrieval is depending on two important steps : the atmospheric correction and the availability of reliable in situ truth for the fine tuning of Chlrophyll-a retrieval algorithms. We present here a clear and comprehensive assessment of the atmospheric correction, thanks to availability of Take-5 datasets. In situ truth dataset are discussed as well as the capability to expand it for a really statistically sound assessment of retrieval algorithm. All results are becoming available through the platform 'eyeonwater.eu' which is becoming an easy and efficient platform for validation of water quality estimates from (upcoming) Sentinel-2.

Automated Mapping of Surface Water Bodies for Operational Applications in South Africa using Landsat 8 Satellite Imagery.

Mhangara, Paidamwoyo; Mapurisa, Willard; Malahlela, Oupa

SANSA, South Africa

Inland water bodies are a key source of fresh water globally. Earth observation satellites have been proven to a play significant role in monitoring water resources worldwide. In recent years, the mapping of terrestrial water bodies using satellite imagery has been subject of research in remote sensing given the significance of surface water bodies in hydrology, agriculture, human sustenance and economic development. In Africa, the operational use of satellite imagery in monitoring small and large water bodies, water quality monitoring, land cover mapping and hydrological monitoring is increasingly becoming feasible through the availability of free and open source satellite datasets such as Landsat 8 and open source image processing software. In this study we customized and exploited the algorithms and workflows available in the Water Observation and Information System (WOIS) open source software developed through the TIGER-Net Programme to map small and large water bodies in South Africa at a national scale using Landsat 8 data. The aim of the exercise was to develop an automated operational water mapping tool that could be utilized by water authorities in South Africa to regularly inventory and monitor the location and extent of water bodies in the country for registration, validation and licensing purposes. WOIS is a multipurpose system designed as a plugin in QGIS software that is characterized by customized processing workflows for satellite data and integrative tools and models for hydrological modelling and GIS analysis. The methodology applied in this study employed spectral thresholding on Normalized Difference Water Indices (NDWI), Normalized Difference Soil Indices and Normalized Difference Vegetation Indices (NDVI) computed from a radiometrically and geometrically rectified Landsat 8 data before applying a spatial edge detection filter to map surface water bodies. The results were validated using manually extracted water bodies derived from SPOT 6 and yielded an overall thematic accuracy of 92%. The methodology did not perform well in dams characterized by

high euthrophication since the dams were erroneous eliminated as vegetated surfaces during the NDVI thresholding. Misclassifications of shadows as water were also common in rugged and mountainous terrains. Despite the misclassification errors noted above, the automated extraction of surface water bodies at national scale was considered highly feasible thanks to the open source algorithms and workflows available in WOIS. Future work will focus on improving the classification accuracies through the of use hill shades derived from Digital Elevation Model (DEM) analysis to eliminate the notorious shadow effects. The application of robust atmospheric correction techniques such as the Fast Line-of-sight Atmospheric Analysis of Hypercubes will also be explored and implemented as a means of improving classification accuracies in algae infested water bodies.

Monitoring Sahelian Ponds Water Quantity and Quality by Remote Sensing

Grippa, Manuela; Gal, Laetitia; Robert, Elodie; Kergoat, Laurent; Hiernaux, Pierre; Mougin, Eric; Martinez, Jean-Michel

Geosciences Environnement Toulouse (GET), France

The Sahelian region has experienced a dramatic rainfall deficit over the second half of the last century with severe droughts in the early seventies and eighties. In parallel and paradoxically an increase in surface runoff has been observed over the same period of time in different areas of the Sahel. In particular, ponds in pastoral areas of central and northern Sahel have shown a dramatically increase in their surfaces. The hydrological processes responsible for this paradoxical situation, less rain but more surface water, still need to be fully understood. This is fundamental to predict the future evolution of these ponds which provide water for cattle and people living in the area. At the same time it is important to monitor the water quality of these ponds in relation to health issues, particularly regarding diarrheic diseases that are still a major cause of mortality in these areas.

This work aims at better monitor both water quantity and quality of Sahelian ponds using remote sensing data. A case study is presented for the Agoufou pond for which in-situ water height and water turbidity measurements are available within the AMMA-CATCH observatory.

Pond's surfaces derived by classification of optical remote sensing images from high resolution satellite (SPOT, FORMOSAT, LANDSAT) were combined to in-situ water level measurements to estimates pond's volume. Changes in water volume during the dry season were then compared to estimates of open water evaporation to derive water infiltration under the pond. Finally, the total amount of water supplying the pond was calculated by applying a pond water balance equation which takes into account volume changes, evaporation, rainfall and infiltration. This methodology has then been applied to archive data by different remote sensing satellites (SPOT, LANDSAT, CORONA) and aerial photographs to quantify the dramatic changes in the water amount supplying the pond over the last 60 years. This provides a basis to evaluate hydrological model approaches.

Concerning water quality, water turbidity can be used as a proxy for fecal bacteria. In an area where environment survey is minimal or inexistent, water turbidity monitoring may prove very important. However, estimating turbidity by remote sensing in this region is quite challenging given the high aerosols content which complicate atmospheric corrections and the pond's high turbidity values, that are outside the range of most studies. In-situ turbidity and suspended particulate matter measurements in the Agoufou pond were used to evaluate different indexes to derive water turbidity from the reflectance in the red and infrared bands of moderate or high resolution optical sensors (MODIS, SPOT, LANDSAT). This allows monitoring the temporal evolution of pond's turbidity at the seasonal, interannual and decadal scale and linking it to other hydrological parameters, such as ponds' water volume and rainfall that can be helpful to predict its future evolution.

The methodology developed here for the Agoufou pond could be applied to SWOT and Sentinel-2 future data which will provide at the same time water levels, pond's surface and turbidity and can therefore be used to derive large scale estimates of water amount and quality of ungauged Sahelian ponds.

Monitoring the Water Balance of Small Reservoirs in Semi-arid Regions from Space

Annor, Frank Ohene [1,2]; Abbasi, Ali [1]; van de Giesen, Nick [1]

1: Faculty of Civil Engineering and Geosciences, Water Resources Section, Delft University of Technology, Netherlands; 2: Civil Engineering Department, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Multipurpose small reservoirs(surface from 1 to 100 ha) have crucial roles for many livelihoods in rural areas of semi-arid regions like Northern Ghana, Southern Burkina Faso and Zambia. The correct representation of the hydrological functions of the small reservoirs is important for regional (hydro-) climate models and scaling out the intervention. The application of remote sensing techniques to provide meteorological and physical parameters (surface area and volume) over the water surface, where field-based information is rarely available due to logistical and technical constraints, will greatly improve the understanding of the water balance and hydrology of small reservoirs. Open water evaporation as an important component of small water bodies hydrology, remains a difficult and complex process to measure or estimate mainly due to the fact that the required meteorological parameters are rarely measured over these small water surfaces.

In this study, the trends in water surface fluctuations, and thereby water storage in small reservoirs in the Upper East Region (UER) of Ghana were examined. This was done using Radarsat-2 and Landsat-8 datasets from November 2012 till April 2014. Assuming minimal seepage condition during the observation period (when these reservoirs were not used), the water balance of small reservoirs was parameterized to estimate evaporation losses and compared with evaporation estimates from numerical methods based on ground-based (land-based) measurements. The measurements from the field using an Eddy Covariance (EC) System over the water surface correlates very well with the satellite measurements using time series of satellite observations and the numerical (evaporation aerodynamic and energy balance) methods. The results show a great potential for using a combination of Sentinel-1 and Sentinel-2 data sets for operational management of small reservoirs to enhance food production with enhanced irrigation scheduling.

2.2: WETLANDS

Assessment of Wetlands Extend and Sensitivity of the Land Surface Simulations to the Extent of the Water Bodies

Georgievski, Goran [1]; Hagemann, Stefan [1]; Stacke, Tobias [1]

Max Planck Institute for Meteorology, Germany

The sensitivity of the land surface simulations to the treatment of water bodies is investigated. Simulations are conducted with the land surface component (JSBACH) of the Max Planck Institute for Meteorology Earth System Model (MPI-ESM) where a dynamical wetland extend (WEED) scheme has recently been implemented. For that purpose an assessment of the European Space Agency Climate Change Initiative (ESA-CCI) water body (WB) dataset which is a part of the ESA-CCI land cover product, is performed. The assessment of ESA-CCI-WB is threefold. The first two applications are a comparison of ESA-CCI-WB with other available observations and the evaluation of simulated surface water bodies generated by the JSBACH-WEED and the MPI hydrological model (MPI-HM). The third assessment is based on the comparison of JSBACH simulations using prescribed ESA-CCI-WB boundary conditions at the land surface and with the dynamical WEED scheme. JSBACH and MPI-HM simulations are driven by WATCH forcing data based on ERA-Interim (WFDEI) at T63 resolution and 0.5 degrees, respectively.

The following observational data sets are compared to ESA-CCI-WB as well as JSBACH WEED and MPI-HM: (i) Global lake and wetland database (GLWD), (ii) Land surface parameter 2 (LSP2), (iii) Wetland ecosystem map (MATT), (iv) Satellite derived inundation (SIND). All of them differ in their definitions of water bodies, resolutions and observational methods. Therefore they show reasonable disagreement among each other. However, some agreement in global pattern of WB distribution is present. For example, the spatial correlation between ESA-CCI-WB and other datasets shows high values over some major river basins of the world, especially for the LSP2 and GLWD dataset. Zonal distribution of wetlands is also in the best agreement for these two dataset with ESA-CCI-WB, especially in southern tropical latitudes. In the northern hemisphere GLWD data shows underestimation in tropics and overestimate extend of wetlands in extra-tropical latitude. The main characteristic of the model simulations is high overestimation of wetland extend in the tropical latitudes. Furthermore, JSBACH-WEED underestimates wetlands extend in the northern hemisphere, while MPI-HM shows better agreement with observations.

In addition to the assessment of the wetlands extend, the sensitivity of the climate parameters representing hydrologic (evapotranspiration and runoff) energy (temperature and albedo) and carbon (gross primary production) cycle will be presented.

Identification and mapping of Colombia wetlands: An Ecosystem Approach

Flórez Ayala, Carlos Alberto [1]; Estupiñan, Lina [1]; Quiñones, Marcela [2]

1: Alexander von Humboldt Institute, Colombia; 2: Sarvision, Netherlands

We will present a methodology to identify and delineate wetland ecosystems, based on the integration of radar data from Alos Palsar (flooded frequency) with other bio-geophysical layers such as landforms, hydromorfic soils, wet vegetation, and drainage web. A validation approach is used to evaluate accuracy of products.

Among the most important results of the project, wetlands occupy 25% of the continental territory, made up of swaps, peats, flooded forests, mountain lagoons, flooded savannas, mangroves and coastal lagoons.

The advantages of radar information on the identification of water bodies under forest canopy, and the analysis of spatio-temporal dynamics of wetlands are highlighted.

These products become an essential input for the country, allowing to increase knowledge about these ecosystems and design of policies consistent with the reality of the country, to promote conservation and sustainable use of these ecosystems.

Seasonal Flood Dynamics in a Tropical Wetland from Multi-temporal ENVISAT ASAR Data using Harmonic Analysis

Schlaffer, Stefan; Wagner, Wolfgang

Vienna University of Technology, Austria

While floods are usually perceived as devastating natural disasters, seasonal inundations often play an essential role in natural ecosystems and facilitate agriculture in otherwise water-scarce regions. Synthetic aperture radar (SAR) is a common tool for mapping floods and open water bodies due to its strong resilience to cloud cover and its relatively high spatial resolution. SAR backscatter σ^0 is very sensitive to the occurrence of open water due to its properties as a specular reflector. Using multi-temporal time series of SAR acquisitions it is possible to build flood records and to monitor extreme flood events as well as seasonal inundation patterns along rivers and in wetland areas.

The Kafue Flats in Zambia are a large wetland listed under the Ramsar Convention. The runoff regime of the Kafue River, which is the main source of inflow to the wetland, has been highly altered by human activity since the construction of the Itezhi-Tezhi Dam in 1977. Annual precipitation is ca. 2000 mm with a single wet season lasting from November to April. In this study, a multi-temporal dataset consisting of ca. 250 scenes is used to characterise seasonal inundation dynamics. The data were acquired in Wide Swath mode with a resolution of 150 m during the years 2005-2010 by the Advanced SAR (ASAR) on-board ENVISAT. The seasonality in the ASAR backscatter time series was derived by applying a harmonic model on a per-pixel basis. We chose to use three harmonics as these are still sufficient to model variations taking place on a 4-monthly scale.

Results show that σ^0 closely follows rainfall seasonality suggesting that sensitivity of σ^0 to variations in soil moisture in this area is high. The harmonic model succeeds in reproducing the seasonal dynamics. Owing to the fact that the approach is pixel-based it is possible to distinguish different units inside the wetland according to their moisture and flooding regime from the fitted harmonic model coefficients. Permanent water bodies can be classified according to their low backscatter persisting throughout the year. Areas which are only flooded during the annual wet season, on the other hand, are characterised by a high amplitude of the σ^0 time series. Additionally, it is possible to classify flood events taking place out-of-season from the residuals of the applied harmonic model. We

will further assess the possibility to delineate flooding underneath vegetation leading to the so-called double-bounce scattering mechanism. For this purpose, time series of Normalised Difference Vegetation Index (NDVI) can be used as a proxy for vegetation density.

GlobWetland II, a regional pilot project of the Ramsar Convention on Wetlands on the Mediterranean Basi

Weise, Kathrin [1]; Fitoka, Eleni [2]; van Valkengoet, Eric [3]; Guelmami, Anis [4]; Beltrame, Coralie [4]; Paganini, Marc [5]

1: Jena-Optronik GmbH, Germany; 2: Ekby, Greece; 3: TerraSphere, Netherlands; 4: Tour du Valat, France; 5: ESA, Italy

The overall objective of the Ramsar Convention is the conservation and wise use of wetlands by national actions and international cooperation as means to achieving sustainable development. This complex and challenging task requires national, local and international bodies involved in the implementation of the convention to rely on suitable geo-information to better understand wetland areas, complete national inventories, perform monitoring activities, carry out assessments and put in practice suitable management plans based on up to date and reliable information.

The GlobWetland II project (2009-2013) aimed to demonstrate the operational capacity of Earth Observation and geo-information technologies to provide wetland practitioners with effect decision support tools for wetland management and conservation activities. The overarching objective was to contribute to the establishment of a Global Wetlands Observing System (GWOS) in accordance with the Ramsar Strategic Plan and represented a pilot effort by the Ramsar Convention to put in place a regional observation system over the Mediterranean Basin in partnership with the MedWet initiative, the Mediterranean Wetlands Observatory (MWO) and 10 countries from the Southern Mediterranean Basin (from Morocco to Jordan).

The majority of wetlands analysed by the project were coastal and distributed equally along the southern Mediterranean coast. Time-series of Landsat MSS, TM and ETM+ data were used to produce the base geospatial products for three points in time (1975, 1990 and 2005), and then to derive wetland indicators. The project also developed a GlobWetland II toolbox for end-to-end processing of satellite images, and installed the software toolbox at the premises of all partner organisations, with adequate training and capacity building. The project produces 1,800 thematic maps on land use and land cover (including wetland typologies), change detection (for long term trend analysis) and water cycle regimes (including the estimation of annual variations in water tables) for a total of 200 wetlands equally distributed along the 10 countries.

The GlobWetland II toolbox was then used by MWO to produce additional wetland maps and indicators over the remaining 17 Mediterranean countries of the MedWet initiative. Thanks to this extensive mapping effort, MWO was able to determine the changes in Mediterranean coastal wetlands from 1975 to 2005. From the 350 wetlands jointly mapped by GlobWetland II and MWO, 214 wetlands have been selected in 22 Mediterranean countries. These maps were then used by MWO to calculate indicators on the changing areas of the various habitats these wetlands contain. The analysis found that the areas of natural wetland habitats decreased by 10% from 1975 to 2005 (a total loss of 1,248 km2 for the 214 sites). There was a steady loss throughout the period studied. Losses were due primarily to agricultural conversion, but the ultimate responsible factor is urbanization that consumes agricultural areas. Marshes and wet meadows appear to be the most significantly affected habitats (a loss of 10% and 43% respectively). The large water bodies were not always affected by severe losses but the Egyptian lagoons in the Nile delta, so important for biodiversity, lost a dramatic 398 km2. At the same time, the area of artificial

wetland habitats increased by 54% (661 km2 for the 214 sites). This occurred especially from 1975 to 1990, with the rapid development of artificial water reservoirs (+700%).

This analysis has been the subject of a MWO thematic report on the spatial dynamics in Mediterranean coastal wetlands from 1975 to 2005.

Mapping water bodies exploited multi-sensors and multi resolution optical and SAR data: gained experience from plain flood monitoring in Western Europe and Asia

Yesou, Herve [1]; Huber, Claire [1]; Giraud, Henri [1]; Studer, Mathias [1]; Haouet, Sadri [1]; De Fraipont, Paul [1]; Virelli, Maria [2]; Desons, Yves-Louis [3]

1: sertit, France; 2: Italian Space Agency; 3: Science, Applications and Future Technologies Department ESRIN

Since more than 25 years EO data are exploited in the water domain to recover at least two major two aspects, the water resource monitoring and the devastating floods extents and impacts retrieval. The topic of this paper is focused on water resource. Water resources access and management is become a more and more critical issue all around the world, the future will be darker in the context of global chance and would involve tension in numerous regions. Erath observation would play in important role to assess and monitor this resource.

Water bodies monitoring over flood plain is realized over two very different entities both in term of size, and environment, in the Alsatian Flood Plain and on the Yangtze intermediate basin, but very complementary in term of gained experience.

Water bodies, ie lakes and associated wetlands within the middle and lower reaches of the Yangtze, representing 25% of East Asia water resources, wetlands provide service to 330 million of inhabitants such as regulating services such as flood storage; provisioning services such as fishing, and being biodiversity holders. These water bodies are fluctuating influenced by the river runoff, controlled as well as the East Asian monsoon climate and anthropogenic activities. Within this context Poyang Lake is particularly interesting as greatly reacting to seasonal climatic variations, involving water height variations of 8 to 10 meters, and surfaces variations from 700 to 3500 km2. During the last decade, this area suffered of successive moderate to severe droughts with an apparent increase of frequency in regards to the previous decade. This is particularly well documented thanks to the long term monitoring of water surfaces realized within a high revisiting time (12 days) over a period from the end of the 1990 up to now within the framework of the DRAGON ESA MOST projects (2014-2016). This monitoring was initiated based on Low resolution (Vegetation), then Middle resolution (ASAR ENVISAT, MERIS, MODIS) EO time series. The recent years more and more high resolution data, both optical (Deimos, Beijing1, HJ1, SPOT4) and SAR (CSK, TerraSAR) were exploited. In addition a multi sensors and multi_resolution approach is follow in order to validate the extracted water masks. This can for example involve MERIS/ASAR or Landsat/Beijing1 imagery, but also since two years more resolute images such as Pleiades HR, and the different modes of TerraSAR from the ScanSAR at 30m, to the Starring Spot light of half meter of resolution, and this on a basis of monthly acquisition scheme for the 2014-2015 dry season.

Up to now the data acquisition scheme was an opportunistically ones, having as major goal to insure the high temporal revisit initiated during Envisat life period. After a first Sentinel 1acquisition, on the 12 May 2014, at a moment when the satellite was not yet at his nominal orbit, since fall 2014 there are a major chance of paradigm with the arrival of the Sentinel1 data through the ESA Hub. This insures the access of a large data flow, with 5 image by months, ie 16 images from end of September to end of December, covering the entire Poyang Lake. In addition of “classical water masks” extraction, comparison were done with former Envisat data, more precisely with

the large swath WSM mode, and more in relation in term of spatial resolution with ASAR APP data. These analysis enhance the great jump in term of data quality, image contrasts, that have been done with this new generation of sensors. Finally, sinceend of September 2014, the Sentinel 1 data are integrated within the monitoring scheme in synergy with CSK and TerraSAR data. Derived Sentinel products will be presented, such as time of submersion, change rates, and more classical water masks.

Over the Alsatian Plain flood, since 15 ears, few experiences of water bodies monitoring have been realized, mostly based on successive mono sensors approach, SPOT4 Take Five, Pleiades HR, CSK, TerraSAR multimodes. The results highlight the importance of accessing to high revisiting data, as surface variations with are sensitive to river discharge and water table fluctuations, varies positively or negatively , with a within a few days (5 to 10) but also as water bodies are relative small (few ha to few km square) to high resolute imagery. The full development of the Sentinel constellation will procure the requested tools allowing the monitoring of these small water bodies that have been excluded up to now of most of the systematic monitoring.

These works, carried over different landscapes at different temporal and spatial scales, both highlight the coming synergy between the two Sentinels constellation, presenting the advantages and complementarities of the Sentinel “dual” optical sar systems.

[PS1]

2.3: METHODS AND TOOLS

Technological Developments for Automated Production of High Resolution Water Layers

Vaitkus, Gediminas

GEOMATRIX UAB, Lithuania

The report presents a unique experience of large-scale automated geo-computing for the production of HR Water layers during the recent GMES projects – GRDA (EU-Hydro products) and GIO-Land (HRL Water). The current developments related to the production of VHR Water layer (GIO-Local project) are briefly presented as well.

Evolution of the automated HR Water layers production work-flow has been designed for the highest production speed and flexibility in the statistical analysis in order to accumulate the full range of surface water coverages from large time-series of satellite imagery and retrieve “permanent” and “temporary” water areas by introducing a simple Water Presence Index variable and setting it's threshold values.

The production of EU-Hydro reference layer was carried out on the basis of pan-European IMAGE2006 mosaic produced by JRC. The main objective of this project was delineation and classification of water bodies, including natural lakes and rivers, as well as man-made reservoirs and canals. Often the water objects produced by automated classification of satellite imagery were manually edited to achieve topographic consistency. Another important product of the EU-Hydro was HR coastline layer derived from the satellite imagery.

O the contrary, HRL Water was produced as a statistical product reflecting distribution of “permanent” water objects retrieved from a large time-series of satellite imagery collected over the period from 2005 till 2013 (IMAGE2006/2009/2012). Automated production of HRL Water resulted in a large archive of water masks produced from separate IRS6 images all over Europe, which may be useful in long-term monitoring of the climate change, etc.

Both in EU-Hydro and HRL Water production it was critically important to design an efficient data clean-up and filtering work-flow in order to eliminate various classification errors (shadows, radiometry, buildings, etc.) or statistical discrepancies as much as possible before manual revision and QC. Fro this purpose we have developed an automated work-flow, based on multiple layers of ancillary data and step-wise data filtering procedures.

Current development of automated land cover production methods focuses on higher resolution satellite imagery (Spot5/6 – 2.5 m, RapidEye – 5 m, Sentinel2 – 10 m), which means a transition from pixel-based to object-based image classification methods. We are currently working on the development of the “next generation” automated parallel processing work-flows for object-based classification of VHR satellite imagery, production of biophysical parameters, complex statistical analysis of ancillary datasets and filtering of information on the object-based framework. This new technology is dedicated to the production of all the major land cover classes and will be adapted to operation in the distributed environment, including cloud-based satellite data repositories and remote parallel processing centers.

The strategy of the ongoing technical developments related to automated processing of large time-series of satellite imagery and operational production of various land cover information layers is aimed at consolidation of the work-flow components into the industrial geo-computing solutions working on parallel processing systems, powered by the open source software. We are focusing on 5-10 m resolution imagery as primary source of information to be used for pan-Eurpean land monitoring projects. The target production capacity for such dynamic elements as water should be at least 1 full-scale coverage every month, under the condition that continuous Sentinel2 coverage provides a cloud-free image of Europe at a monthly basis.

Water Observation and Information System for Integrated Water Resource Management

Schleicher, Christian [1]; Walli, Andreas [1]; Koetz, Benjamin [2]; Bila, Mohammed [3]; Tumbulto, Jacob W. [4]; Chibuye, Hastings [5]; Meyer, Bruno [6]

1: GeoVille; Innsbruck, Austria; 2: European Space Agency (ESA); ESRIN, Italy; 3: Lake Chad Basin Comission (LCBC); N'Djamena, Chad; 4: Volta Basin Authority (VBA), Ougadagou, Burkina Faso; 5: Department of Water Affairs Zambia (DWA); Lusaka, Zambia; 6: S

The Water Observation and Information System (WOIS) [1] was developed within the European Spacxe Agency (ESA) TIGER-NET project to respond to the information needs for Integrated Water Resource Management (IWRM) by African water authorities. The WOIS is a plugin based on and usable in the free and open source GIS software QGIS. It provides comprehensive data processing and analysis capacities for the assessment and monitoring of water resources from watershed to cross-border basin level. It consists of workflows for the derivation of over 28 dedicated water information solutions for IWRM encompassing the entire water cycle. Tools within the system enable for processing of multi-source satellite Earth Observation (EO) data from optical as well as SAR sensors, including integration of hydro-metrological observations for continental Africa. Particular emphasis was put on the processing capacity of free data sources, such as from the Landsat and new Sentinel 1 & 2 satellite missions for various types of water body mapping and monitoring.

The WOIS consists of a plugin for workflow development that works seamlessly with dedicated algorithms for water monitoring and other plugin providers. Each algorithm, including those specified for water body mapping (ie. Small Water Bodies, Lake Shoreline, Wetlands, Flood Mapping), consists of a step-by-step customizable workflow with interactive guidance dialogs which may be run automatically. This enables also less experienced GIS uses to generate relevant products for water resource management. The WOIS, its information and reporting solutions as well as the workflows were developed in close cooperation with the involved African water authorities and agencies as the Nile Basin initiative (NBI), Lake Chad Basin Commission (LCBC), Volta Basin Authority (VBA), Department of Water and Sanitation (DWS) South Africa, Department of Water Affairs (DWA) Namibia, Department of Water Affairs (DWA) of Zambia, the Zambezi Basin Commission (ZAMCOM) and the South African Space Agency (SANSA).

The featured WOIS small water body mapping capacities were requested and implemented for LCBC at Lake Chad, VBA for the northern part of the Volta Basin, DWA Zambia for the Lusemfwa catchment and SANSA for nationwide water body mapping. For those basin commissions and agencies the small water body mapping was performed with the aim of the dedicated WOIS workflows to support and supplement the inventories of water bodies for their development and management. It was demonstrated that this is specifically effective for large scale identification of water bodies including parameters as their location, extent, possibility to access and dry and wet seasonal variations. Main applications for the basin commissions are the support of livestock farming, small dam construction, infrastructure planning and logistic. Hence, the WOIS and corresponding EO data serves as an integrative geo-information based decision support tool, fulfilling direct monitoring and reporting obligations.

For the exploitation capacity of current and next generation satellites, especially the application of Sentinel-1 data for small water body mapping, 18 dedicated trainings were held in Africa and Europe. Beside the system setup and generation of the water information products, the water authorities were trained in the validation, improvement, application and operationalization for further roll-out.

The WOIS and associated training packages can be downloaded for free via www.tiger-net.org. To date the system was downloaded by 130 water management related users in 46 countries. Future support will include refined processing capacities for Sentinel-2 and operational Sentinel based pre-processing services.

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WaMaPro – a User Friendly Tool for Water Surface Derivation from SAR Data

Huth, Juliane [1]; Gessner, Ursula [1]; Klein, Igor [1]; Ahrens, Malte [1]; Hoffmann, Jörn [2]; Kuenzer, Claudia [1]

1: Earth Observation Center (EOC), German Aerospace Center (DLR), Germany; 2: Space Agency, German Aerospace Center (DLR), Germany

The mapping and monitoring of water surfaces such as permanent water bodies, partially inundated regions, and flooded areas is of utmost importance for environmental monitoring and resource management tasks. However, information on water resources and their dynamics is often lacking or insufficient.

SAR data has been already extensively used for water body detection as the preferred data choice, because active sensor systems are independent of solar illumination and weather conditions such as cloud coverage, and therefore most suited for water surface detection and extraction. So far SAR data processing mainly is the domain of remote sensing image analyses experts. Therefore, we'd like to introduce the WaterMaskProcessor, WaMaPro, a tool that has been designed for the usage by scientists, students, and stakeholders and aims to support even non-experts and remote sensing beginners to swiftly derive water surfaces from SAR data. It is capable to handle data of different SAR sensors, such as e.g. Sentinel-1A, ENVISAT ASAR, and TerraSAR-X. The algorithm behind WaMaPro is a knowledge-driven threshold-based approach combined with morphological operations that separates surfaces with very low backscatter, i.e. water surfaces from those with high backscatter, i.e. land surfaces. The output, a product we call water masks, is a binary file containing values for water [1] – lakes, river, flooded areas, inundation etc. – and no-water (0). The tool has been technically implemented as a user friendly plugin for the open source GIS software Quantum GIS. This ensures that WaMaPro is accessible by a large community without inflicting any license fees and costs and can be shared with interested potential users. The plugin can be installed on a powerful server for mass data processing, or on a desktop computer for the processing of individual scenes. Both versions offer multi-dataset capabilities for processing large amounts of data at a time. WaMaPro has been tested for different regions in the world. Several results for test sites in Southeast Asia, China, West Africa, and Europe will be presented in this study. In general, the processing resulted in over 95% accuracy for mainly smooth water surfaces and flat to slightly rolling terrain.

A Probabilistic Framework to characterize Uncertainties in SAR-based Flood Mapping

Giustarini, Laura; Hostache, Renaud; Chini, Marco; Matgen, Patrick

LIST (Luxembourg Institute of Science and Technology, Luxembourg

In this paper we introduce a new probabilistic flood mapping procedure that can be used to estimate for each pixel observed by a SAR sensor, its probability to be flooded or not.

Generally, flood mapping from SAR provides flood extent maps in the form of binary numbers where each pixel can only have integer values, i.e. 1 for flooded, 0 for non-flooded. On the other hand, a flood probability map provides for each pixel its likelihood of being classified as flooded, i.e. 1 for pixels that are certainly flooded, 0 for pixels that are certainly non-flooded, and all intermediate values representing the “uncertain” pixels. This type of flood probabilistic map should reflect the total uncertainty, which is a combination of uncertainties caused by the SAR observation and the applied flood mapping algorithm.

The statistical framework consists of two processing steps. First, we estimate the backscatter distribution representing open water bodies in the so-called flood image. Second, we derive for each pixel its probability of being flooded based on its backscatter value. We therefore use a Bayesian approach that uses as inputs the image histogram and the estimated distribution of open water. The evaluation of uncertain predictions with respect to observed flood extent data is carried out through the generation of reliability diagrams, also commonly referred to as quantile-quantile plots. This technique has previously been used for evaluation purposes in the framework of hydraulic or hydrologic modelling.

Four SAR images have been selected to test and evaluate the approach. They have been selected based on the availability of reliable validation data. The AOIs include the frequently flooded plains of the River Severn (United Kingdom) and the Red River (United States). These two areas correspond to markedly different latitudes, climate conditions and river characteristics, thereby allowing for a comprehensive evaluation of the validity of the procedure.

In all four test cases, the reliability diagrams show a good agreement between the SAR-derived flood probability and validation map.

Applications of these types of flood probabilistic maps are foreseen for data assimilation studies. The direct integration/assimilation into models of flood extents with pixel uncertainty would be extremely beneficial, as they circumvent the intermediate step of water level extraction.

The method to delineate flood probabilistic maps was inspired by the code developed for binary mapping, currently hosted on the Grid Processing on Demand (G-POD) environment of the European Space Agency. Future work will also include the implementation of this additional method on G-POD, to provide both binary and probabilistic maps.

SAR Images derived Water Masks for Altimetry and Hydrology

Fabry, Pierre; Bercher, Nicolas

ALONG-TRACK, France

This work deals with the quasi-automated delineation of water bodies from SAR images (Sentinel-1). It is jointly run with the development of a new generation of water masks aided retrackers in altimetry for hydrology. This work not only highlights the great synergy potential of the Sentinel-1 and 3 missions, but also opens the door to the joint reprocessing (above Level-1) of imagery and altimetry missions that coexisted in the 20 last years. The stakes are high since it may strongly improve the existing times series in alti-hydrology, which are impacted by the lack of a-priori information on the highly variable and complex scenes integrated over large footprints. Moreover the ability to continuously update water masks is of great interest as it will serve many purposes :

- improve the understanding of the waveforms and the continuity of the waterbody signatures within the radar chronograms in traditional (LRM) altimetry thanks to the a-priori knowledge of multiple water bodies within the altimeter footprint (new generation of LRM retrackers),

- assist some advanced empirical SARM retrackers in making an appropriate masking of the multi-look stacks to improve the output 20Hz waveforms,

- detect and flag obvious cases when the water bodies are off-nadir and provide information on slant-range distance correction (the water height measurement being related to a slant-range distance)

- make possible to derive Height-Surface curves in hydrology

- make it possible to combine altimetry and SAR water masks to derive lake bathymetry and later on Height-Surface-Volume curves.

The SAR Level-1 data go through a fast and automated segmentation that is dedicated to images with speckle noise. The segmentation technique that we implemented provides high resolution polygons delimiting the regions from the statistical homogeneity of their pixels' Normalized Radar Cross Section. This region-based segmentation technique is much more robust than a pixel-based clusterization techniques.

During the learning stage of our classifier, an operator selects few pixels in the water areas and the statistical properties of these water bodies are derived from all of the pixels pertaining to the regions. After this learning stage of the classifier, the water classes properties are stored and indexed with the sensor, the acquisition mode, the polarization, the mean incidence angle. We are currently testing the performances in autonomous run after the learning stage.

Our results are very encouraging and we also consider that in the future, it will also be possible to help the water body classification (over segmented SAR images) from the waveforms and multi-look stacks properties (peakiness, advanced statistical criteria) in new retrackers like SAMOSA . A fully automated spaceborn altimetry processing would therefore rely on multiple passes between the processinf of radar images and the waveforms intepretation at an advanced retracker. These are directions for future activities.

1.5: POSTER SESSION

Shoreline Change assessment of Kalpitiya Area using Geographical Information System and Remote Sensing

Mathara Arachchige, Darshani Samanmali; Piyadasa, Ranjana U. K.; Wickramasinghe, Deepthi

University of Colombo, Sri Lanka

Sri Lanka is an island with a coastline of 1585 km. Generally, shorelines are subjected to change and there is a critical need to assess the status of coastal areas since this zone is highly populated and under severe developmental pressure. Moreover, island nations are especially vulnerable to the impacts of climate change including sea level rise and coastal inundation which affect the shoreline.

The objective of this study was to investigate the changes of the shoreline in Kalpitiya, a Kandakuliya area in Puttalam district in Sri Lanka, Using Geographical Information System (GIS) and Remote Sensing (RS) techniques. The 2.5 Km coastal line was selected for this study and most of the fisheries population were living in this area. Field investigations were carried out using tracking locations with Global Positioning System (GPS) and converting data using GPS mapping software such as OziExplorer 3.95.5t version. The shoreline change rate was assessed based on statistical computation of Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM) and End Point Rate (EPR) using Digital Shoreline Analysis System Tool (DSAS) in the ArcGIS 10.1 version. The shorelines were assessed since 1988 year. It was categorized mainly four periods such as a: 1988-2004, b: 2005-2010, c: 2011-2013 and d: 2014 the latest. Both visual interpretation and Remote Sensing techniques were used for the assessment of shoreline changes in Kandakuliya, Kalpitiya area. It was observed that the shoreline has been dynamic and changed positively with accumulation of sand and negatively due to erosion. The maximum sand accumulation rates (m/y) for each study period were as follows: a -12.16, b - 41.06, c - 85.16 and d - 15.4. Interestingly, there was a negative change (loss of beach) in the year 2014, with an average sand loosing rate of 6.9 m/y. The result of this study indicates that efficient and essential to gather more data and information as well as mitigate the risk of coastal zone and erosion within this area. This also raises concerns over the mitigation of possible climate change impacts.

Key words: Shore line change, Kalpitiya, GIS & RS, DASA

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The Extraction of the Spatio-temporal Lake Water Surface Dataset in the Tibetan Plateau over the Past 10 Years

Lu, Shanlong [1]; Xiao, Gaohuai [1,2]; Jia, Li [1]; Luo, Haijng [1,3]

1: State Key Laboratory of Remote Sensing Science, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing 100101, China; 2: State Key Laboratory of Remote Sensing Science, Institute of Remote Sensing and Digital Earth, Chinese

TheTibetan Plateau has the largest number and size of inland lakes with the highest elevation on the planet. The contraction or expansion of these lakes is recognized as sensitive indicators of global climate change. However, till today there is no understanding of spatial and temporal change processes of the lakes and the main factors that control them, due to no long-term time series data of lake water surface area. In this study, on account of the problems of the lacking spatio-temporal process series lake water surface area dataset in the plateau, the inconsistency of the temporal and spatial resolution of the multi-source satellite remote sensing images, which are used for lake water surface mapping, and the unsuitability of the existing water information extraction method that has been used for a wide range of application, an automatic lake water surface extraction method is developed, which combined with lake water surface boundary buffer analyzing and lake by lake segmentation threshold determining, by taking the MOD09Q1 images as the data source, which is the MODIS Surface Reflectance product that provides an estimate of surface spectral reflectance as it is measured at ground level in the absence of atmospheric scattering or absorption. The method is successfully used to extract the 8-day lake water surface dataset of the Tibetan Plateau at 250 m resolution, during the period of 2000~2012. The accuracy analysis results indicated that, compared with water surface data of the 36 sample lakes extracted from the 30m Landsat TM/ETM+ images, the average precision of the proposed method is 95.23%; the extracted daily, monthly, and annual lake water surface area of the Nam Co Lake, the Qinghai Lake, and the Siling Co Lake are consistent with the remote sensing monitoring results generated by other researchers; and the differences of the lake quantities and acreage statistical results of the lakes with area larger than 1 km2, between the second national lake survey and this study, is only 8 and 4.74%, respectively. This study provides a reference method for large scale and long time series single objects (such as water, vegetation, and urban) distribution area extraction. It also provides reliable dataset for the lake change research of the Tibetan Plateau in recent 10 years.

Retrieval of Chlorophyll-a Values in Trichonida Lake (Greece), from Landsat 8 Imagery

Markogianni, Vassiliki; Dimitriou, Elias

HCMR, Greece

The concept of mapping surface chlorophyll-a concentrations in a water body from reflectance or radiance measurements is well established. In the particular scientific effort chlorophyll-a samples, have been collected at 22 different stations, in Lake Trichonida on late October of 2013 and measured in HCMR laboratory. Subsequently, a satellite image of Landsat 8 of the same date with the field campaign was used in order to statistically correlate the in-situ measurements with various combinations of Landsat bands in order to quantify algorithms that best describe this relationship and calculate accurately the concentration of chlorophyll-a. The algorithms derived by regression analysis between the radiation value and the chlorophyll-a concentration in each station or pixel of each transformed image, were applied to other satellite images of different dates but with available in-situ Chl-a data, in order to validate the results. Satellite derived chlorophyll-a values were compared to in-situ chlorophyll-a values originated from other past scientific studies. The initial results confirmed the suitability of the method for assessing the concentration of chlorophyll-a inLakeTrichonidawith relative accuracy when no field data are available.

Mapping Water Bodies with Envisat and Sentinel 1 in Mozambique for Malaria Risk Assessment

José, Santos

Bio-WebServices, Portugal

The World Health Organization report that between 300 and 500 million people around the world suffer from the effects of Malaria many of them children and many of them died every year. In Mozambique, where this specie is endemic, is the major cause of mortality among children affecting around 45% of them every year. One of the main reasons for this mortality are the water bodies since they are one of the main causes that favour the malaria vector propagation and transmissions by representing areas that have a major impact in malaria transmission due to their suitable climate conditions and breeding habitat for mosquitoes. Water bodies are propitious for the development of mosquitoes specially the specie Anopheles the main malaria vector. The objective of this paper is to measure water bodies and potential flooded areas, in Mozambique, using SAR images obtained with Envisat and Sentinel 1. With this data will be possible to measure the dimension of these water bodies and surrounding areas that could be flooded due to extreme climate events. The relation between floods and malaria is due to the fact they assume an important risk factor when they occur since it represents pools of stagnant water and ideal breeding grounds for the Anopheles mosquito. It is also important to measure the proximity from these water bodies to human habitats in order to quantify their impact in the propagation of malaria and risk assessment.

With the information about water bodies, namely the area and the shape will be possible to produce a risk assessment map that will support the health authorities to adopt policies and measures to prevent the spread of malaria near these areas. Using data presences, climate models and water bodies areas will be possible to produce a susceptibility map where the water bodies will assume the major risk assessment for malaria dissemination in Mozambique. The results confirmed that areas in the proximity of water bodies constitute a major risk factor and so they should be consistently monitored, using radar data due to their accuracy, to prevent a growing situation of mosquitoes, future increase and epidemic situations due to floods.

Wetland Monitoring Using Dual-Polarized X-Band and C-Band Data of Lac Bam, West-Africa

Moser, Linda; Schmitt, Andreas; Wendleder, Anna; Roth, Achim

German Aerospace Center (DLR), Germany

Monitoring of wetlands is a very important task for water management as well as for wetland ecology. Water bodies and wetlands in semi-arid African areas show strong seasonal dynamics throughout the year that require time series imagery with narrow temporal intervals for satellite-based monitoring. The study site for this work is Lac Bam, which is the largest natural lake in Burkina Faso, and as such of high importance for the local inhabitants for irrigated farming, animal watering, and extraction of water for drinking and sanitation. Semi-arid African wetlands often contain areas of floating vegetation or flooded vegetation, which causes difficulties for water body detection and monitoring over time when using synthetic aperture radar (SAR) intensity data or medium to high resolution optical data. The water of Lac Bam is very turbid and sediment-rich, particularly during the rainy season when also strong cloud-cover is a limiting factor for the use of optical data. SAR intensity data has been frequently used to detect open water surfaces. Multi-polarized SAR data, in addition, have proven to be able to detect flooded vegetation, thanks to their ability to distinguish between different scattering mechanisms in different polarizations.

Two different repeat-pass time series have been acquired in X-band and C-band dual-polarimetric mode: TerraSAR-X StripMap data with HH (transmitted and received horizontally)–VV (transmitted and received

vertically) polarization with an interval of 11 days have been acquired from August 2013 until present (January 2015). Radarsat-2 fine beam data with HH (transmitted and received horizontally)–HV (transmitted horizontally, received vertically) polarization with an interval of 22 days have been acquired since October 2014 until present. The Kennaugh decomposition produces four normalized Kennaugh elements from the complex HH and VV, or HH and HV input channels, respectively. A novel image enhancement algorithm called Multi-scale Multi-looking stabilizes the radiometric measurements without loss of geometric resolution. Results demonstrate that open water could be well detected in the Kennaugh element representing the total intensity from both co-polarized HH-VV (X-band) as well as cross-polarized HH-HV (C-band) data. The three remaining polarimetric Kennaugh elements deduced from X-band clearly enable the detection of vegetation in or on water, and can discriminate it from vegetation on land. Applied onto the full time series surface water fluctuations and changes in flooded vegetation can be monitored throughout the year. Seasonal curves extracted from time series of the Kennaugh elements allow concluding to different types of flooded vegetation and the duration of flooding. Results of the analysis are validated based on optical very high resolution data from WorldView-2 with a resolution of 0.5 m, and RapidEye with a resolution of about 6 m for selected dates throughout the time series. Moreover, the performance of TerraSAR-X and Radarsat-2 is compared using data acquired on the same date in October 2014.

Despite the great importance of water management and ecology in African wetlands, regular monitoring is often not carried out and applications of polarimetric SAR imagery in Africa are very scarce. This study contributes to understanding of the dynamics of surface water including flooded vegetation in or floating vegetation on water. It demonstrates the capability of dual-polarimetric SAR imagery for wetland delineation, and concludes to the applicability of Sentinel-1 dual-polarimetric data for almost continuous wetland monitoring.

Algorithms for Remote Sensing Estimation of Chlorophyll-a in Coastal and Inland Turbid Productive Waters using Red and Near Infrared Bands

Gitelson, Anatoly

Israel Institute of Technology, Israel

Advances in the development of the atmospheric correction models have made the retrieval of surface reflectance spectra of coastal waters from the top of atmosphere signals more accurate and inspired the development of advanced retrieval algorithms for estimating chlorophyll-a (Chl-a) concentration in coastal and inland waters. This includes algorithms that employ the red and NIR spectral bands, which are less sensitive than the traditionally used blue-green ratio algorithms to the absorption by colored dissolved organic matter (CDOM) and scattering by mineral particles. We tested such algorithms using comprehensive synthetic datasets of reflectance spectra and inherent optical properties (IOP) related to various water parameters and compared the results with those obtained from field measurements, MERIS and MODIS satellite imagery.

Over 2000 reflectance spectra were simulated using the radiative transfer program HYDROLIGHT, with 1 nm resolution for conditions that are typical for inland and coastal waters. Simulations were based on the findings of many authors for IOP characteristics, and were similar to the assumptions used in the construction of the IOCCG datasets. Field measurements were collected from several coastal and inland water bodies in the USA (lakes in Nebraska, the Chesapeake Bay, the Long Island Sound, lakes in the vicinity of the New York City, and the Hudson/Raritan Estuary), Sea of Galilee (Israel), and Azov Sea (Russia). Field spectrometers were used to collect at-surface reflectance spectra. Water samples were taken and analyzed in the laboratory to retrieve the concentrations of Chl-a and mineral particles through analytical procedures and the IOPs of water (absorption and attenuation) through spectrophotometric procedures.

The MERIS-based two-band NIR-red model R708/R665 was found to be very robust in estimating Chl-a concentrations for a wide range of water conditions, with a minimal sensitivity to CDOM concentration and

fluorescence quantum yield. Algorithms that include NIR bands near 750 nm were less accurate. Algorithms established using proximally sensed data were applied to aircraft and satellite data. The algorithms yielded high accuracies in estimating Chl-a concentrations in diverse water bodies and did not require regional re-parameterization. The results illustrate the tremendous potential of the NIR-Red models based on the spectral channels of MERIS to estimate Chl-a concentration in turbid productive waters, and provide an indication of the excellent results expected from the future OLCI sensor, which contains all the spectral channels of MERIS.

Inventory, Assessment & Monitoring of Glacial Lakes in Uttarakhand State using High Resolution Data

Thapliyal, Asha [1]; Kimothi, Sanjeev [2]

1: Uttarakhand Space Application Centre, India; 2: Swami Rama Himalayan University, (SRHU) Dehradun, India

The Himalaya, is one of the youngest mountain ranges on earth is characterized by a high energy environment due to high relief, steep slopes, complex geological structures with active tectonic process and continued seismic activities. Furthermore, the region has a climatic system with great seasonality in rainfall. In combination, they make natural hazards, especially the water induced disasters a common phenomenon in the region.

The Himalayas are considered to be highly sensitive to Climate Change. The warming rate in the region has been relatively high. The warming in past decades has been found to be progressively higher in the higher elevations (Shrestha et al., 1999, Liu and Chen 2001). The high warming in the region is having profound impacts on the glaciers of the Himalayas. The glaciers of the Himalayas are shrinking at a rapid rate, causing multitude of problems. One of the most visible and tangible impact is the formation, rapid growth and ultimately outburst of glacial lakes (Yamada et al., 1998, Mool et al. 2001).

The glaciers in the Himalayan region are retreating rapidly due to Climate Changes causing the net shrinkage and retreat of glaciers and the increase in size and number of glacial lakes, especially in the high mountains. It contains numerous glaciers and glacier lakes and makes it a storehouse of freshwater. These lakes retained by loose moraine dam are susceptible to outbursts.

There are many glacial lakes along the Himalaya. In Uttarakhand many glacial lakes has developed and may be potentially dangerous. All these lakes have the potential to outbursts and cause flash floods in Rivers flowing in India and possibly beyond. In Uttarakhand the Himalaya shares border with the Nepal, China and other which also abounds in many glaciers and glacial lakes. Many rivers of Uttarakhand originate from the glaciers and glacial lakes located in Uttarakhand Himalaya.

These water bodies are highly dynamic and sensitive to changes in weather and climate. Glacial Lake Outburst Flood (GLOF) is a common geomorphic hazards associated with flood water accompanied with a huge amount of sediments from moraines. A GLOF event can cause morphological changes along a river channel as it flows with the derbies and can also results in the loss of lives and properties along its downstream path. This impact can occur at great distances from the outburst source depending on the magnitude of the outburst.

Height Estimation and Error Assessment of Inland Water Level Time Series calculated by a Kalman Filter Approach using Multi-Mission Satellite Altimetry

Schwatke, Christian; Dettmering, Denise; Boergens, Eva

Deutsches Geodätisches Forschungsinstitut der Technischen Universität München (DGFI-TUM)

Originally designed for open ocean applications, satellite radar altimetry can also contribute promising results over inland waters. Its measurements help to understand the water cycle of the system earth and makes altimetry to a very useful instrument for hydrology.

In this paper, we present our methodology for estimating water level time series over lakes, rivers, reservoirs, and wetlands. Furthermore, the error estimation of the resulting water level time series is demonstrated.

For computing the water level time series multi-mission satellite altimetry data is used. The estimation is based on altimeter data from Topex, Jason-1, Jason-2, Geosat, IceSAT, GFO, ERS-2, Envisat, Cryosat, HY-2A, and Saral/Altika – depending on the location of the water body. According to the extent of the investigated water body 1Hz, high-frequent or retracked altimeter measurements can be used. Classification methods such as Support Vector Machine (SVM) and Support Vector Regression (SVR) are applied for the classification of altimeter waveforms and for rejecting outliers. For estimating the water levels we use a Kalman filter approach applied to the grid nodes of a hexagonal grid covering the water body of interest. After applying an error limit on the resulting water level heights of each grid node, a weighted average water level per point of time is derived referring to one reference location.

For the estimation of water level height accuracies, at first, the formal errors are computed applying a full error propagation within Kalman filtering. Hereby, the precision of the input measurements are introduced by using the standard deviation of the water level height along the altimeter track. In addition to the resulting formal errors of water level heights, uncertainties of the applied geophysical correction (e.g. wet troposphere, ionosphere, etc.) and systematic error effects are taken into account to achieve more realistic error estimates.

For validation of the time series, we compare our results with gauges and external inland altimeter databases (e.g. Hydroweb). We yield very high correlations between absolute water level height time series from altimetry and gauges. Moreover, the comparisons of water level heights are also used for the validation of the error assessment.

More than 200 water level time series were already computed and made public available via the "Database for Hydrological Time Series of Inland Waters" (DAHITI) which is available via http://dahiti.dgfi.tum.de.

Multiscale mapping of Lake Champlain water quality to support public health

Torbick, Nathan [1]; Corbiere, Megan [1]; Stommel, Elijah [3]; Moore, Tim [2]

1: AGS, United States of America; 2: University of New Hampshire; 3: Dartmouth Hitchcock Medical Center

Lake Champlain is a large freshwater lake in the northeast USA that supplies drinking water to hundreds of thousands and supports a diverse socioecological system. Recent research has shown clusters of people diagnosed with Amyotrophic lateral sclerosis (ALS) in the region including adjacent to Bays that undergo chronic cyanobacterial Harmful Algal Blooms (cyanoHABs). ALS is a progressive, fatal disease with an average life expectancy of two to five years from the time of diagnosis. Approximately 90% of cases have no know genetic cause and we hypothesis that a combination of genetic susceptibility and environmental exposure to the cyanotoxin BMAA influence health outcomes. To support our public health investigation we are mapping lake water quality conditions using a multiscale approach. We compiled histroical in situ and concordant Landsat 5 TM and 7 ETM+ and MERIS FR archives to operatiinally map the spatiotemporal dynamics of key lake metrics including chl-a, TP, TN, and PFT. Methods applied an initial data mining routine using exhaustive forward and backward stepwise linear regression using ordinary least squares using an efficient branch-and-bound approach. A correlation matrix was applied to identify potentially correlated or redundant dependent and independent variables. Once these initial data exploration stages were complete, more strategic spatially aware spatiotemporal models were developed. Independent variables (i.e., bands, ratios) were examined for performance and using residuals (i.e., F-stat, adjusted R2, significance values, RMSE, Q-Q plots, Cook's Distance). Akaike information criterion (AIC) was then applied to a subset of strategic models to further help compare models. Using the multicriteria approach the optimal models selected underwent an n-folds cross validation to provide out of sample evaluation statistics (i.e., goodness of fit, RMSE) for lake attribute predictions. A combination of band ratio and shapefilers were found to have moderate success in mapping lake water quality over time to assess trends and risk hot spots. Simultaneously, during a HAB event in St Labans Bay within Lake CHamplain this past summer, we tasked and analyzed Proba CHRIS, E0-1, Rapid Eye, and Landsat 8 OLI to map the distribution and intensity of characteristics. In situ sampling was conducted to collect and measure metrics and toxin levels in St Albans and Mallets Bays. This includes measurements for microcystin, plankton, anatoxin, among other metrics. We present results from our multiscale assessment and promote remote sensing tools to gain a better understanding of aquatic ecosystem services and smart decision making.

Mapping spatiotemporal lake skin temperature trends in the northeast USA

Torbick, Nathan; Corbiere, Megan

AGS, United States of America

Water temperatures are important holistic metrics of climate change and ecosystem functioning that represent an aggregate of air temperature, solar radiation, wind, and limnological forcings. Recent researchn using nighttime AATSR, AVHRR, and MODIS satellite observations found a warming of ~1.0°C / decade from 1985 to 2009 on selected large lakes dispaserded around the Earth. It has also been suggested that increased temperatures are likely to increase the frequency and intensity of Hamrful Algal Bloom events. We sought to answer the question if lake temperature trend in the northeast USA have change din the past three decades using Landsat 5 TM and 7 ETM+ thermal observations. We complied an archive of summer time (July, August, September) Landsat for more than 4,000 small to moderate sized inland lakes in northern New England. We pre-processed imagery using an operational approach based on MODTRAN and OPeNDAP NASA MERRA vertical profiles across 60 pressure layers. We assumed a fixed emissivity of 0.95, a nominal value for water, and calculated temperature using atmospherically corrected radiance in the inverse Planck function to convert from in-band radiance to Celsius degrees. NOAA buoy grount truth shows moderate to strong agreement between the measured and sensed conditions. Spatiotemporal bayesian hierarchical modeling was applied to investgate trends across the region. A diverse set of drivers were tested incluing temperature, solar radition, distance from ocean, and lake size to assess

influence of spatiotemporal trends. The regional products will be introduced and shared openly to the science community.

Why mapping groundwater matters? Groundwater caves from Space in the Circle of Cenotes in Yucatan, Mexico

Lopez-Maldonado, Yolanda

Ludwig Maximilian University of Munich, Germany

Due to the karstic and highly permeable soil of Yucatan, in Mexico, is easy to find groundwater caves plenty of fresh water. Groundwater storage and flow occur in a regional karst aquifer with major cave systems, where groundwater flow is dominated by turbulent conduit flow. In the area there are thousands of these caves, called cenotes, from the Maya word ts'onot that means sinkhole, in which societies extract water for several uses. More than 2000 groundwater caves have been estimated along the region. In this place, where groundwater is the only source of freshwater, the inhabitants have to deal with water problems such as resource scarcity, groundwater pollution, climate change, biodiversity loss, and resource degradation. Furthermore, all data on cenotes remains limited. Some efforts began in 1996 to establish a standardized cenote data collection methodology bridging biological, archeological, and land use aspects for use by local persons, explorers, and visiting interested persons. However, data from past and current satellites is needed and knowledge about those water bodies, is consequently crucial to understand groundwater-human interactions. From the space those cenotes are visible, interspersed with other wáter bodies like poljes and aguadas. This project aims to establish a georeferenced surface karst inventory of groundwater bodies situated principally in the area called Circle of Cenotes, located in the state of Yucatan, Mexico. As a unique hydrologic region in the world, formed due to the impact of a large meteor Circle Cenotes, this region was considered the ideal location to develop the project. Mapping groundwater bodies, or cenotes, will not only expedite direct exploration of the subterrranean rivers but may also provide the basis for a quantified data of groundwater extraction. Mapping will also contribute to water and waste management by generating data for several purposes at local and regional scale in a very sensitive resource based dependent society.

Mapping Water Bodies with SWOT : Classification and Fusion of Simulated Data

Laurent, Guillaume

C-S, France

French American joint mission SWOT, whose launch is planned by 2020, aims at providing accurate and reliable data in order to study and monitor ocean and inland water surfaces. For this purpose, a satellite will be sent into orbit embedding the instrument KaRIN, a radar interferometer allowing scanning large areas on the ground and providing a map of water heights.

One of the steps needed to achieve this goal is to generate a mask of water areas from SAR data. These data are composed of the amplitude image, the interferometry image computed with the phase, and the phase coherence image. Water areas are identifiable on the various data available, however the inherent radar imaging noise, so called speckle degrades the quality of the detection. It is therefore necessary to set up a processing chain to improve the classification performance. Different types of preprocessing are evaluated: adaptive filtering, segmentation algorithm and Markov Random Field regularization. Then these results are used in several data fusion methods: fuzzy fusion, support vector machine, principal component analysis and classifier fusion. Exogenous data from external databases also enhance detection by providing a priori.

All these results are finally compared with the mission requirements, and presented to CNES, which is in charge of the mission jointly with NASA (JPL). The outcomes of the study will provide CNES with new elements in order to focus future studies on the detection process.

Analysis of natural background and dredging-induced changes in TSM concentration from MERIS images near commercial harbours in the Estonian coastal sea

Siitam, Laura; Sipelgas, Liis; Uiboupin, Rivo

Tallinn University of Technology, Estonia

We studied the changes of total suspended matter (TSM) distribution in Estonian coastal sea with special focus on Paldiski harbor at the Pakri Bay. Pakri Bay is environmentally sensitive area: most of the bay is covered by Natura 2000 Special Protection Area. The purpose of current study was to examine the suitability of remote sensing data to detect the turbidity differences caused by dredged sediments and to evaluate the impact of monthly mean dredging amount to the surface TSM concentration retrieved from satellite images.

The MERIS (Medium Resolution Imaging Spectrometer) Full Swath Geo-located (FSG) products with 300m resolution from years 2006-2010 were used. Images were processed using Case II Regional (C2R) and Free University of Berlin (FUB) processors available in BEAM software. Validation with in situ measurements showed that both processors represent the changes in TSM concentration adequately. C2R processors showed better statistics (R2= 0.61, root mean square error = 0.82 mg l–1, SD = 0.77 mg l–1, mean bias = –0.28 mg l–1) compared to the FUB processor.

For analysis of environmental impact we calculated the differences between monthly mean maps from dredging period (2008) versus non dredging period (monthly mean 2006-2010). A threshold TSM concentration value of >2.26 mg l–1 difference from background TSM was defined as a criterion for dredging impact detection for Pakri Bay. The area of dredging-induced turbidity was between 0.56 and 1.25 km2 and did not reach the environmentally sensitive NATURA 2000 region adjoining Paldiski South Harbour.

Automatic generation of water masks from RapidEye images

Tetteh, Gideon Okpoti

BlackBridge AG, Germany

BlackBridge AG over the years has extended its product portfolios to include large area mosaics. One of the routine and laborious activities carried out during the mosaic generation process is the manual digitization of water masks as part of the colour balancing of the mosaics. The exclusion of objects such as water bodies from images helps to greatly improve the colour balancing process. The Applications Research (AR) department of BlackBridge undertook a development project to identify various ways of improving the overall outlook of RapidEye mosaics. One of the objectives of this project was the automatic creation of water masks from the RapidEye images. A Python-based algorithm was developed to automatically generate water masks from RapidEye images.

The main pre-processing step is to convert the Digital Numbers (DNs) of each image to Top-Of-Atmosphere (TOA) reflectances using the needed values as extracted from metadata file of each image.

An initial water mask is created using the low reflectance of water in the NIR band by applying a simple threshold on the NIR band. The threshold value is extracted automatically from the NIR histogram.

Four additional water masks are created making use of two Simple Ratios (SRs), Normalized Green Index (NGI) and Normalized Difference Water Index (NDWI). The two SRs are calculated between the NIR and Green band, and between the NIR and Red band. The NGI is simply calculated by ratioing the Green band to the sum of all bands in each image. The NDWI is calculated by differencing the Green to the NIR and dividing by the sum of the Green and NIR bands. The four water masks are then created by thresholding the two SRs and indices respectively based on fixed empirical values as extracted by careful examination of the SR, NGI and NDWI values of a number of images.

The next step is to do a logical and (spatial intersection) of all the five water masks to create a single intermediate water mask. This particular step helps to remove objects such as shadows and black surfaces with low reflectance values in the NIR band just like water. Finally, in order to remove very small water bodies and any remaining holes, a morphological operation (opening and closing) is performed to generate the final water mask.

This proposed algorithm was used to extract water masks from six RapidEye Level 3A images. It yielded an Overall Accuracy of 94.6 % and a mean Kappa Statistic of 0.77 using the confusion matrix approach.

Earth observation HIGH resolution techniques for MONITORING and MAPPING the POSIDONIA OCEANICA MEADOWS IN THE TYRRHENIAN Shallow waters (Northern LAZIO, ITALY)

Borfecchia, Flavio [1]; Micheli, Carla [1]; Belmonte, Alessandro [1]; De Cecco, Luigi [1]; Martini, Sandro [1]; Cognetti, Selvaggia [2]; Gnisci, Valentina [2]; Piermattei, Viviana [2]; Marcelli, Marco [2]

1: ENEA, Italian National Agency for New technologies, Energies and Sustainable Economic Development; 2: University of La Tuscia, Laboratory of Experimental Oceanology and Marine Ecology. Porto di Civitavecchia, I-01100 Viterbo, Italy

Despite its key importance in managing and monitoring of the coastal shallow water, until now, due to strong requirements needed in term of spatial and radiometry resolution and acquisition bands only the high-resolution (HR) commercial satellite (i.e. Quick-Bird, World-View 2,..) and airborne broad-band sensors were enough suitable to be exploited for assessing the spatial distribution of benthic cover and seagrass in coastal water. On the other

hand these remote sensing techniques may provide information over limited areas but are unsuitable for extensive characterization of larger coastal regions, which usually could involve prohibitive costs and resources using the most traditional techniques for marine surveys. Although the ground resolution and spatial coverage (about 180 x 180 km.) of older Landsat-like satellite sensors are appropriate, in general their poor radiometry didn't allow their exploitation in this specific sector since the launch on the summer 2013 of the newer Landsat 8 with its OLI sensor and improved radiometry which might be more useful for shallow water monitoring. In this perspective, the next ESA Sentinel 2 satellite dual system will be able to ensure these capabilities with a larger spatial (~ 300X300 km.) and temporal cover improving (two operating satellite platforms) at same time the above cited spectral and radiometric features. In Italy, these segrass and Posidonia oceanica (PO) meadows and habitats are poorly mapped, often the existing maps have poor spatial resolution and the information is dated. Thus this work focused on the implementation of a remote sensing based methodology for mapping the PO meadows along the Latium coast (central Tyrrhenian sea) where shallow waters are often subjected to both increasing anthropogenic impacts and hydrodynamic effects. The Quick-Bird four broad-band multispectral HR data were exploited to obtain a PO distribution in the coast area (about 10 km) of S. Marinella site while a 12-bands Daedalus ATM 1268E strip was processed by means of an original approach for mapping the more threatened PO meadow in the coast near Civitavecchia town. The calibration/validation of the obtained maps was accomplished by means of on purpose acquired sea truth data. In this context a frame (acquired on the last August) of the recently available Landsat 8 OLI data including both the interested areas was preprocessed (Figure 2) in order to test its mapping capabilities with previously developed methods.

Reconstruction of shoreline changes at a natural ground-water lake in northeastern Germany using GIS and RapidEye archive data

Heine, Iris [1]; Oeser, Julian [1]; Kleinschmit, Birgit [2]; Itzerott, Sibylle [1]

1: GFZ German Research Centre For Geosciences, Germany; 2: Geoinformation in Environmental Planning Lab, Technische Universität Berlin, Germany

The Mecklenburg Lake District in northeastern Germany is the largest lakeland area in Central Europe. The lakes are essential for the region with their ecological services and as tourist attraction for the local economy. However, the natural ground-water lakes are characterized by significant fluctuations in their lake levels. Lake Fürstenseer See, near Neustrelitz, Germany is one of the lakes with a massive level increase in the last 5 years. In this study we use a GIS analysis and satellite archive data for the reconstruction and investigation of shoreline changes at lake Fürstenseer See between 2009 and 2014.

In a first step, we modelled former lake areas using a high-resolution over- and underwater digital elevation model (DEM) and in situ level measurements. The modelled shorelines were compared to shorelines automatically extracted from 37 multi-spectral RapidEye archive images recorded between 2009 and 2014. We evaluated two approaches for the automatic extraction of shorelines using Otsu's thresholding on the NIR bands as well as on the normalized difference water index (NDWI). The extracted shorelines were validated with DGPS measurements in 2014 and by visual inspection of the satellite images.

The increase of the water level results in flooding of the shallow parts of the lake with massive influence on the lake's ecology. In the southeastern part of the lake the shoreline has been shifted up to 30 m since 2011. Differences between the reconstructed and the modeled shorelines point out the inaccuracies of both methods. The GIS analysis depends on the DEM and mirrors those inaccuracies, whereas in the analysis of the RapidEye archive data, the automatic classification of the shorelines was challenging. In areas with dense vegetation, the use of satellite images for the reconstruction of water-land-borders fails as the water surface is covered and not visible via satellite.

Exploiting Satellite Image Pairs for Mapping Currents, Bathymetry, Debris, Marine Mammals, and Ocean Bottom

Abileah, Ron

jOmegak, United States of America

Presentation: Oral or poster (if accepted for oral I would like to include a companion poster for post presentation discussion, the poster title and abstract is the same)

The diverse topics addressed in this paper are linked by a common approach, which is to use a pair of satellite images, I1 and I2, of ocean surface to model and subtract the surface wave glint. The two images should be separated by a time interval between 0.2 s and 20 s. The smaller time differences can be delays between pairs of spectral bands in multispectral imaging systems; the larger time differences are possible with a sequence two or more images taken in the persistent-surveillance-mode.

The waves evolve and propagate in the time interval according to a known gravity wave motion model. It is possible to account for wave motion with a convolution kernel, K, which is a function of the time delay, surface current, and depth. The convolution on the first image, K*I1, brings the waves into alignment with I2. When K is adjusted to the exact current and depth the difference I2 – K*I1 is minimized.

An algorithm has been developed to determine the optimum K pixel-by-pixel. This wave motion is thus inverted into current vectors and depth. The short (<10 m wavelength) wind waves are best to map the surface current vectors. The long (50-200 m) waves provide bathymetry (up to 30 m depth). In deeper water the long waves may also provide the vertical velocity profile. Previous papers on this method include the author's work with WorldView2 images [Abileah 2013, Abileah 2014, and Mancini et al. 2012]; [de Michele et al., 2012] with a SPOT-5 image; [Danilo and Binet 2013] using simulations of this technique for the Pleiades constellation.

The waves in ocean images are essential for currents and bathymetry but are at the same time clutter for visibility of anything that is not waves. That would include surface debris, marine mammals on and near the surface, and features on the ocean bottom. Fortunately the subtraction that determine depth and current also deglints, making surface and subsurface features more visible.

The paper will present new results including coral reefs in Antigua and Puerto Rico and the shallow bottom off Cape Cod, Massachusetts. In addition the paper will discuss the possibility for 3D stereoscopic reconstruction of the bottom topography after images are deglinted.

This is not the only method for deglinting and improving visibility. The better known and more widely implemented deglinting simply subtracts a scaled infra-red image from blue-green images. The idea is that IR senses only the surface waves, the blue-green has the same waves and visibility below surface. The IR and blue-green images are presumed to be simultaneous.

A time misalignment is important to consider for two reasons. First, none of the current multispectral imagers have truly simultaneous imaging in multiple bands. There is always a small and not inconsequential time delay between bands due physical constraints in the design of the sensor. Second, a goal of deglinting images using only panchromatic images. Panchromatic images have 4X the resolution of multi-spectral and there is no matching IR at that resolution.

A major focus in this presentation will be on the potential and benefits of exploiting European high resolution satellites: SPOT (SPOT-5 and later are most suitable), the Pleiades constellation, and possible future systems.

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Capabilities and Limitations of Current and Upcoming Satellite Systems for Comprehensive Regional Lake Water Quality Measurements

Olmanson, Leif G.; Brezonik, Patrick L.; Finlay, Jacques C.; Bauer, Marvin E.

University of Minnesota, United States of America

This presentation will review advances over the past decade that have enabled use of satellite imagery for regional scale-measurement of lake characteristics, such as water clarity, chlorophyll, total suspended solids (TSS), and colored dissolved organic matter (CDOM). For example, in the Midwest, USA, historic and recent Landsat water clarity assessments have been conducted on > 25,000 lakes to investigate spatial and temporal patterns and explore factors that affect water quality. Previous Landsat-based assessments of lakes (> 4 ha) have been restricted largely to water clarity because of limited spectral resolution, which does not allow for chlorophyll to be distinguished from non-algal turbidity in optically complex waters. European Space Agency (ESA) MERIS imagery with spectral bands that were selected for water has been used to measure chlorophyll. Results, however, were limited to ~900 (~8.5% of lakes) of Minnesota’s larger lakes (> 150 ha) due to its 300 m spatial resolution. Improvements of the recently launched Landsat-8 and upcoming ESA Sentinel-2 and 3 satellites could greatly expand the capability to assess a broader suite of optically-related water quality characteristics, including chlorophyll, CDOM, and mineral suspended solids (MSS). To explore the potentials and limitations of these systems a field campaign to measure optical water quality characteristics (e.g., chlorophyll, TSS, turbidity, dissolved organic carbon (DOC) and CDOM and in situ reflectance spectra nearly contemporaneously with imagery from Hyperspectral Imager for the Coastal Ocean (HICO) and Landsat 8 was conducted in the summers of 2013 and 2014. Sites in Minnesota and Wisconsin, USA were selected to obtain wide ranges of concentrations of CDOM, chlorophyll, Fe, and MSS, the primary factors that affect reflectance. The HICO imagery was used to simulate Sentinel data, and the water quality data were analyzed to develop retrieval equations for various water quality parameters. This presentation will discuss the improved spectral, radiometric, spatial and temporal characteristics of Sentinel-2, Sentinel-3 and Landsat 8 sensors and evaluate potential improvements in sensing such important variables as chlorophyll, turbidity, MSS, DOC and CDOM in optically complex waters for comprehensive regional assessments of lake water quality. Specific examples to be presented will include (i) HICO-simulated Sentinel-2 data being able to accurately measure chlorophyll in MSS dominated waters, and (ii) Landsat 8 being able to measure higher levels of CDOM than Landsat 7 due to improved radiometric characteristics.

Hybrid Radar-Optical Mapping and Monitoring of Lake Koroneia, N. Greece, using long time series of Earth Observation data and GIS

Mouratidis, Antonios; Doani, Sofia; Karadimou, Georgia; Albanakis, Konstantinos

Department of Physical and Environmental Geography, Aristotle University of Thessaloniki, Greece

Among a plethora of geoscience applications, the combination of Earth Observation data and related image processing techniques, along with Geographical Information Systems (GIS), is a powerful tool for inland water body mapping and monitoring. The most relevant types of satellite imaging being exploited for water surface delineation are (i) SAR (Synthetic Aperture Radar) imagery, using microwaves and (ii) multispectral images, operating in the visible (VIS) - infrared (IR) part of the electromagnetic spectrum. The nature of the surface phenomena involved in radar imaging is inherently different from that of VIS/IR images. Consequently, radar and VIS/IR data are complementary, as they provide different information about the target area.

In this context, the purpose of this study is to implement a hybrid, radar-optical mapping and long-term monitoring approach of inland water bodies, to the largest scale (detail) possible. The study area will be in N. Greece, in particular the lakes Koroneia (primary objective) and Volvi (for validation/comparison).

The existence of these two lakes in the same area consists of a particularly suitable case study, due to fact that the former has undergone dramatic changes throughout the past 40 years, while the latter has remained rather stable. Additionally, hundreds of satellite image, both radar and optical, exist in the archives, as the location is very close to the city of Thessaloniki. These conditions offer an exhaustive research opportunity, where both satellite data and processing techniques can be evaluated, while delivering a product of major importance for water management at regional/local scale. This also addresses the following recommendations for Essential Climate Variables (ECVs) (GTOS, 2009):

1. To develop a method of assessing volume changes using satellite images for estimation of lake or reservoir surface area for a particular date

2. The necessity to continue comparative analysis of the results of in situ and satellite observations for various lakes and reservoirs in order to assess the effect of various factors on the accuracy of satellite water level measurements

Using partially different processing and classification approaches, water bodies will be delineated from the two types of data, in order to reconstruct the historical evolution of the lakes with as much detail as possible. In particular, to the end of detecting water surfaces, the multi-sensor data will:

(i) be used as a complementary source of information in time, with the purpose of observations densification and increasing of temporal resolution,

(ii) resolve ambiguities (e.g. clouds in VIS/IR images, wind in SAR data, presence of vegetation etc.)

(iii) serve for cross-validation and result verification sources of information

Incorporating existing topographic and bathymetric data will enable the conversion of surface area to water volume information and thus the production of a thorough perimeter/area/volume database with respective graphs over a period of about 40 years (since the ‘70s) of satellite Earth Observation data.

Satellite data to be used include the historical archives of Landsat, SPOT, ERS-1/-2, Envisat/ASAR, as well as more recent acquisitions, such as those from TerraSAR-X, Ikonos, Kompsat and the Sentinels (S-1, S-2).

Field work including the extensive use of Global Navigation Satellite Systems (GNSS) (simultaneous to the acquisitions of Sentinel-1 and Sentinel-2) will complement the research for validation purposes.

Continuous Water Bodies Mapping with Sentinel-1 Data

Ostir, Kristof [1]; Kokalj, Ziga [1]; Cotar, Klemen [2]; Ivacic, Matjaz [3]; Beden, Andrej [3]

1: Research Centre of the Slovenian Academy of Sciences and Arts, Slovenia; 2: Space-SI; 3: GeoCodis Ltd.

Land surface water is an important part of the water cycle. Real-time access to the spatial distribution and time-varying information on lakes, reservoirs, rivers, wetlands and floods has a great significance for understanding the interaction mechanism of regional hydrology and climate change, and management of surface water resources. With global climate change and the growing influence of human activities, spatial and temporal distribution changes in surface water resources are increasingly important.

Remote sensing, especially radar remote sensing, can provide up-to-date information capable of monitoring surface water bodies and its changes. High temporal resolution of radar data provided by the Sentinel-1 satellite(s) enables almost continuous monitoring, allowing near-real-time mapping of the extent of permanent and temporal waters.

We are currently developing a system for water body detection from Sentinel-1A data. The system is triggered as soon as new data becomes available on the Sentinel Hub, automatically detects water bodies and prepares the results for distribution. It performs the following processing steps:

- geometric pre-processing, including terrain correction, speckle filtering and spatial subseting,
- water detection and filtering,
- modelling and time series production,
- water bodies map dissemination.

Geometric pre-processing is performed with the Sentinel-1 Toolbox. The resulting layover shadow mask and topographically corrected image are cropped to the area covering Slovenia and its surroundings. A map of permanent lakes and rivers is used to automatically determine the lower threshold value for water bodies. The lower water threshold value is set to the 80th percentile of the cumulative histogram of pixel values corresponding to permanent water bodies. Detected water regions are then filtered based on the surface area, overlap with SAR shadow mask and an average surface slope to remove the most obvious misclassifications. The remaining water bodies are used as seeds in the region-growing algorithm. The best available elevation model for the region is used in the last stage of filtering where neighbourhood operations and temporal filtering are applied to determine the presence or absence of water at each pixel.

The presentation will focus on current state of the system development. The first steps are implemented and are now being fully tested. The quality control and web dissemination platform are still being developed. At the moment we are processing the images for Slovenia and its surroundings, using data from October 2014 when Sentinel-1A became available.

Inundation mapping using C- and X-band SAR data: From algorithms to fully-automated flood services

Twele, André; Sandro, Martinis; Wenxi, Cao; Simon, Plank

German Aerospace Center (DLR), Germany

Since the establishment of the ZKI (Center for Satellite-Based Crisis Information) at the German Aerospace Center (DLR), the development of EO-based methodologies for the rapid mapping of flood situations has been of major concern. This can be especially contributed to the fact that inundations constitute the majority of all ZKI-activations as well as activations of the International Charter 'Space and Major Disasters'.

These requirements have led to the development of dedicated SAR-based flood mapping tools which have been utilized during numerous rapid mapping activities of flood situations. The core of these tools is an automatic tile-based thresholding approach (Martinis et al. 2009, 2011, Martinis and Twele 2010) which allows separating inundated regions from land-areas without any user interaction.

Recently, the SAR-based flood detection algorithm has been substantially extended and refined in robustness and transferability to guarantee high classification accuracy under different environmental conditions and sensor configurations with the ultimate goal to allow its implementation in an automatic processing chain (Martinis et al. 2014). The processing chain including SAR data pre-processing, computation and adaption of global auxiliary data, unsupervised initialization of the classification as well as post-classification refinement by using a fuzzy logic-based approach is automatically triggered after new SAR data is available on a delivery server. The dissemination of flood maps resulting from the service is performed through a dedicated web client. With respect to accuracy and computational effort, experiments performed on a data set of >200 different TerraSAR-X scenes acquired during flooding all over the world with different sensor configurations confirmed the robustness and effectiveness of the flood mapping service.

The processing chain has recently been adapted to the new European Space Agency's C-band SAR mission Sentinel-1. The thematic processor has further been enhanced through the integration of the "Height above nearest drainage index" (Rennó et al. 2008) which helps to reduce water look-alikes depending on the hydrologic-topographic setting. In contrast to the current TerraSAR-X based thematic service, Sentinel-1 enables a systematic disaster monitoring with high spatial and temporal resolutions. This is a major advantage since the time-consuming step of tasking new satellite data can be omitted. By minimizing the time delay between data delivery and product dissemination it is expected that the proposed service enhances the value of remote sensing during flood management activities and supports applications in hydrology, where information about the flood extent is systematically assimilated into hydrologic and hydraulic models.

The presentation will introduce to the technical concept of the SAR-based fully-automated processing chains, with a focus on the current status of the Sentinel-1 flood service.

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Remote Sensing for Everybody, Easy to use Data Access in combination with Easy To Use eCognition Essentials Solution

Krebs, Waldemar

Trimble, Germany

The huge amount of available free and commercial satellite data contain an enormous amount of very valuable information. In theory most of this data is available to everyone but in fact to find and get satellite data is still a challenge and requires experts and is very often complicated and intricate. With the Trimble InSphere Data Marketplace plug-in for eCognition Essentials and other eCognition products, users can easily access remote sensing imagery and begin generating results immediately. The platform will be continually expanded, with the following sets currently available:

- The Landsat 8 library features about 5,000 clear sky images of the United States, automatically added to the libraries for eCognition and available free of charge.
- Precision Digital Globe Aerial data from the U.S. and Western Europe is also now available.
- Future data like ESA Sentinel data can easy be linked to the archive and can be easy available in future too.

The easy to use eCognition Essentials solution itself offers experts and non-experts an intuitive user friendly graphical user interface. With immediate access to automated segmentation and classification tasks, the software puts a sample-based image classification workflow right in the hands of a production-oriented user.

The combination enables to cover the entire workflow from image acquisition to GIS ready solution – intuitive and user friendly.

Upwelling-related sea surface temperature variability studied from remote sensing imagery in the Gulf of Finland

Uiboupin, Rivo; Laanemets, Jaan

Tallinn University of Technology, Estonia

The current paper proposes a method for using operational ship of opportunity temperature data at a fixed depth for bias correction of satellite sea surface temperature (SST) images. The bias-corrected SST imagery from MODerate Resolution Imaging Spectroradiometer (MODIS) and Advanced Along-Track Scanning Radiometer (AATSR) sensors were used to calculate mean upwelling characteristics in the Gulf of Finland (Baltic Sea). Firstly, we determined that the operational flow through temperature data at a 4-m depth can be used for validation and bias correction of satellite SST images in cases of wind speed over 5 m s–1. The composite sea temperature maps were calculated from bias-corrected images collected during upwelling events in the Gulf of Finland in 2000–2009. Mean upwelling characteristics were estimated from composite maps for both the northern and southern coasts of the gulf.

- [1] Uiboupin, Rivo; Laanemets, Jaan (2015). Upwelling Parameters From Bias-Corrected Composite Satellite SST Maps in the Gulf of Finland (Baltic Sea) . IEEE Geoscience and Remote Sensing Letters, 12[3], 592 - 596.

Joint Use of SAR Intensity and Coherence Data for Flood Mapping

Pulvirenti, Luca [1]; Chini, Marco [2]; Pierdicca, Nazzareno [3]; Boni, Giorgio [1,4]

1: CIMA Research Foundation, Italy; 2: Luxembourg Institute of Science and Technology; 3: Sapienza University of Rome, Italy; 4: University of Genoa, Italy

The use of SAR data is presently well-established in operational services for flood management. Nevertheless, detecting inundated vegetation and urban areas still represents a critical issue, because the radar signatures of these targets are often ambiguous. Many literature flood mapping algorithm search for regions of low backscatter (that appear dark in SAR images), assuming that the water surface is smooth and acts as a specular reflector of the radar energy. However, inundated vegetation may appear bright in SAR images because of the enhancement of the double bounce effect involving the floodwater and stems or trunks that act as dihedral reflectors. The situation can be even more complicated in flooded urban areas, where both specular and corner reflections of the radar energy may occur.

A valuable tool for tackling the problem of the possible ambiguity of the radar signature of floodwater can be represented by SAR interferometry and, in particular, by the use of the interferometric coherence. It is expected that flooded areas exhibit low coherence that help distinguishing them from non-flooded regions, especially over targets, such as urban areas, where coherence is generally high. Areas characterized by high backscatter combined with high temporal stability present high coherence so that, considering an interferometric pair consisting of one pre-flood image and one image of the flood, low values of this parameter may indicate a change in the scenario caused by the flood, even when no sensible changes of radar intensity is detected. Coherence can be also useful in agricultural areas to distinguish bare terrains (likely coherent, unless agricultural practice as ploughing is carried out in the interval between the two SAR acquisitions) from vegetated ones (generally exhibiting low coherence). This discrimination can be important for flood mapping, as for bare soil an increase of the backscatter may be due to an increase of soil moisture, while for vegetation the increase of the backscatter can be caused by the enhancement of the double bounce effect.

This study analyzes the role of the interferometric coherence in complementing intensity SAR data for mapping floods in agricultural and urban environments. The SAR data used for the analysis consist of the COSMO-SkyMed

(CSK) images of the flood that hit the Emilia region (Northern Italy), due to the overflow of the Secchia River occurred on January 19-20, 2014.

Investigating the hydrological signature of seasonal lagoons in La Mancha Húmeda Biosphere Reserve, Spain with remote sensing technologies

Doña, Carolina [1]; Chang, Ni-Bin [2]; Caselles, Vicente [1]; Sánchez, Juan M. [3]; Camacho, Antonio [4]

1: Department of Earth Physics and Thermodynamics, Faculty of Physics, University of Valencia, Burjassot, Valencia, Spain; 2: Department of Civil, Environmental, and Construction Engineering, University of Central Florida, Orlando, Florida, USA; 3: Depar

La Mancha Húmeda has been designated as a Biosphere reserve since 1980. It is a wetland-rich area located in central Spain that includes several dozens of temporal lagoons, whose water level fluctuates over seasons. Water inflows into these lagoons come from both precipitation/runoff of very small catchment and, in some cases, from groundwater, although some of them also receive wastewater from nearby towns. Most of them lack surface outlets and they behave as endorheic systems, with the main water withdrawal due to evaporation causing salt accumulation in the lake beds, such that most of these lagoons are saline. In order to accomplish the goals enforced by the European Water Framework Directive and the Habitats Directive, which establish that all EU countries have to achieve a good ecological status and a favorable conservation status of these sites, and especially for their water bodies, where several protective law enforcements, in addition to that Biosphere Reserve, including Ramsar and Natura 2000 sites, have been applied. With this requirement, management plans were being developed. A core task to carry out the management plans is the understanding of the hydrological trend of these lagoons with a sound monitoring scheme. To do so, an estimation of the temporal evolution of the flooded area for each lagoon, and its relationship with hydrological patterns and seasonality effect can be achieved by using remote sensing technologies. This study aims to develop a remote sensing methodology to estimate the changing water coverage areas in each lagoon with satellite images with the aid of the ground truth data sets. Landsat-5, 7 and 8 images were used to fulfill this goal. These images are useful to monitor small-to-medium size water bodies due to its 30-m spatial resolution. In this analysis several methods were applied to discern wet and dry pixels, such as water and vegetation indexes, single bands, supervised classification methods and genetic programming. Results were compared with ground-truth data and the classification errors were evaluated by means of the kappa coefficient. Findings indicate that the maximum likelihood (supervised classification) and genetic programming models were both with the best kappa values. While the former has a kappa value of 0.8 and an overall accuracy of 90%, the latter shows kappa coefficients of 0.9 and an overall accuracy of 95%. Our approach offers a useful tool to monitor the hydrological signature of these lagoons which allows for the study of the hydrological trends of these seasonal water bodies. The hydrological closure was summarized by linking precipitation, runoff, and ET with the water area variations over the temporal domain.

Stream Processing for Multi-source Data Fusion applied to Water Bodies monitoring from the Sentinel system

Grizonnet, Manuel [1]; Houpert, Laurence [1]; Giros, Alain [1]; Yesou, Hervé [2]

1: CNES, France; 2: SERTIT Service Régional de Traitement d'Image et de Télédétection, France New challenges are arising from the rapid and systematic dissemination of images provided by the Sentinel system. For instance: would it be feasible to extract useful information from this images stream, as optimally as possible, at the images stream rate? What would be the requirements related to? On one hand, lots of image processing algorithms have been developed to extract many remote sensing image information of various kinds. On the other hand, concepts used by these methods are often difficult to handle. Going from the research algorithms to the real application can lead to issues. The data size, for instance, makes more complex the implementation of algorithms, not to mention their integration in an operational system.

In many ways, the arrival of the Sentinels is a breaking through in Earth observation images processing (massive data, high revisit rate). Therefore, it requires to prepare and to check how the existing algorithms can be adapted to compute Sentinel images flows. In this purpose, CNES has recently initiated a study whose objective is the definition and the development of an "ad hoc" and "on the flow" processing chain, applied to the study case of water bodies dynamic mapping from satellite images. This application will be based on numerous, carefully chosen image processing algorithms.

The development of this demonstrator includes:

- A clear definition of the water bodies we want to extract;
- The identification and assessment of adapted feature extraction algorithms that could be useful in the frame of water monitoring from Optical(Sentinel-2/Sentinel-3) and SAR (Sentinel-1) imagery;
- Identification of exogenous data that could be integrated in the chain
- Hybridization of various methodologies in a dynamic context (multi-temporal and multi-source processing);
- Integration and implementation of the processing chain in a scalable environment to allow to handle large volumes of data.

CNES has already implemented and evaluated lots of information extraction algorithms that could be used in the processing chain for water bodies dynamic mapping including:

- Automatic or supervised classification;
- Image segmentation;
- Feature extraction;
- Object-Based Image Analysis (OBIA);
- Data mining and fusion including exogenous data;
- Multi-temporal image analysis.

The main challenges are now to identify which of those modules can be combined in an operational chain, to evaluate performances that could be achieved and to implement these components in an integrated and scalable system able to handle large volume of data. The presentation will give an overview of state of the art of existing algorithms as well as an overview of the activities planned for the development of the chain. The algorithmic approach will be illustrated with results of comparison of pixel and object-based classification approaches for water bodies detection on Spot4-Take5 multi-temporal image series.

Time series of SAR flood maps to calibrate a LISFLOOD-FP hydraulic mode

Wood, Melissa [1,2]; Hostache, Renaud [2]; Neal, Jeff [1]; Corato, Giovanni [2]; Chini, Marco [2]; Giustarini, Laura [2]; Matgen, Patrick [2]; Wagener, Thorsten [3]; Bates, Paul [1]

1: School of Geographical Sciences, University of Bristol, University Road, Bristol, BS8 1SS, UK; 2: Luxembourg Institute of Science and Technology (LIST), Environmental Research and Innovation Department (ERIN), 41 rue du Brill, L-4422 Belvaux, Luxembour

Synthetic Aperture Radar (SAR) satellites are capable of all-weather day and night observations that can discriminate between land and smooth open water surfaces over large scales. Because of this there has been much interest in the use of SAR satellite data to improve our understanding of water processes, in particular for fluvial flood inundation mechanisms.

In past studies it has been proven that integrating SAR derived data with hydraulic models can improve simulations of flooding. The objective of this work is to see how we can improve LISFLOOD-FP Sub-Grid 2D hydraulic model simulations by only using SAR-derived maps of flood extent. We consider the effectiveness of using real SAR data from the European Space Agency's archive of ENVISAT[1] images to calibrate hydraulic model parameters.

As a test case we applied the method to the River Severn between Worcester and Tewkesbury. We firstly applied the automatic flood mapping algorithm of Giustarini[2] et al. (2013) to ENVISAT ASAR (wide swath mode) flood images to generate a series of SAR-derived flood extent maps. We then created an ensemble of parallel flood extent maps with the hydraulic model (each model representing a unique parameter set). Where there is a favourable comparison between the modelled flood map and the SAR-derived flood extent map we may find the version of the hydraulic model that optimally reproduces the extent of flood water detected on the ground. The model parameters are effectively calibrated using SAR-derived data.

Applying the method to a sequence of SAR acquisitions may provide insight into the advantages, disadvantages and limitations of using a time series of acquired satellite observations.

To complement the investigation we also explore parameter 'identifiabilty' within our sequence of available SAR-derived flood extent maps by adopting the DYNIA method proposed by Wagener[3] et al. (2003). We show when in a sequence of images we might most easily detect the looked-for model parameters from the SAR acquisition sequence.

[1] https://gpod.eo.esa.int/services/

[2] Giustarini. 2013. 'A Change Detection Approach to Flood Mapping in Urban Areas Using TerraSAR-X'. IEEE Transactions on Geoscience and Remote Sensing, vol. 51, no. 4.

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GPOD ESA Platform for Flood Delineation and Flood Hazard Mapping Based on SAR Data

Chini, Marco [1]; Hostache, Renaud [1]; Giustarini, Laura [1]; Matgen, Patrick [1]; Bally, Philippe [2]

1: Luxembourg Institute of Science and Technology (LIST); 2: European Space Agency (ESA-ESRIN)

A SAR-based flood delineation and flood hazard application hosted on the Grid Processing on Demand (G-POD) environment of the European Space Agency is presented. The main objective of the online flood mapping application is to deliver flooded areas using both recent and historical acquisitions of Synthetic Aperture Radar (SAR) data in an operational framework.

The flood mapping application consists of two main blocks:

1) A set of query tools for selecting the “crisis image” and the optimal corresponding pre-flood “reference image” from the G-POD archive.

2) An algorithm for extracting flooded areas using the previously selected “crisis image” and “reference image”.

The algorithms are computationally efficient and operate with minimum data requirements, considering as input data a flood image and a reference image. Stakeholders in flood management and service providers are able to log onto the flood mapping application to get support for the retrieval, from the rolling archive, of the most appropriate pre-flood reference image. Potential users are also able to apply the implemented flood delineation algorithm. Recent upgrades of the algorithm will be presented as well, showing some examples using Sentinel-1 SAR data.

The flood hazard mapping application combines the generation of high-resolution flood maps from large collections of SAR remote sensing-derived flood inundation maps with 30 years of daily flood extent simulations provided by the global ECMWF model. Here, starting from the information provided by ECMWF model at high temporal (i.e. daily) and coarse spatial resolution (i.e. 1 by 1 km), we generate the global flood hazard maps using stacks of historic flood maps derived from SAR imagery. The flood hazard mapping method is applied to test sites characterized by frequent flooding: Severn River (UK) and Lower Zambezi River (Mozambique).

Estimation of Secchi Disk Depth From MERIS Satellite Data using a Linear Mixed Effect Model Over Lake Erie, Canada

Zolfaghari, Kiana; Duguay, Claude R.

Interdisciplinary Centre on Climate Change (IC3), University of Waterloo, Canada

Lake ecosystems provide humans with different services such as tourism, recreation, and biodiversity conservation. Providing these benefits is significantly influenced by lake water quality status. Lake management strategies are established to monitor water quality parameters. Effective water quality monitoring requires accurate knowledge of lake state in the past and present. Ground-based monitoring of water quality factors is sparse in space and time and considering the declining network of in situ measurements and availability of datasets across the globe, alternatives to conventional water quality measurements are necessary. Satellite remote sensing provides capabilities for effective, accurate and more efficient water quality measurements to retrieve parameters related to lake optical properties for many lakes over large areas and with frequent temporal coverage. This study utilized MEdium Resolution Imaging Spectrometer (MERIS) and in-situ data to assess water quality of Lake Erie, Canada, by specifically looking at Secchi Disk depth (SDD). The increasing phosphorus concentration in Lake Erie stimulates occasional algal blooms. Anthropogenic eutrophication in Lake Erie, especially in the western basin, has adverse impacts on the ecosystem and economy in that region. Hence, monitoring water quality status in the lake is

necessary. MERIS spectral bands at shorter wavelengths were utilized in algorithms for deriving SDD. These wavelengths can penetrate beyond the water surface to measure optical visibility of water body. A Linear Mixed Effect (LME) model was used as the regression method. LME model considers the correlation in the repeated measurements of in-situ data collected in space and time. This method is developed between the logarithmic scale of SDD and individual band of B5:560 with r-squared value of 0.78. Cross validation was performed to test the performance of the model and resulted in RMSE of 0.15 for log10SDD. Therefore, the model was found to be reliable for time series application over Lake Erie from 2004 to 2008 to investigate the spatial and temporal variation of the water quality factor. The eastern part of the lake, followed by the central basin, is the least turbid section of the lake. During summer, elevated values of SDD were observed for the lake. The western basin is the most turbid region, with highest and lowest average SDD values in summer and spring.

Advanced Synthetic Aperture Radar (ASAR) image analysis for detecting water cover changes influenced by seasonal variations in Chapala Lake, western Mexico

López-Caloca, Alejandra A. [1]; González-Morán, Tomás [2]

1: Centro de Investigación en Geografía y Geomatica “Ing. Jorge L. Tamayo” A.C., Mexico; 2: Instituto de Geofísica, Universidad Nacional Autonoma de Mexico

The Chapala Lake is the largest shallow water body of the Country and the main supplier of drinking water for the metropolitan area of Guadalajara (about 60%), as well as coastal populations It is located at the western end of the Transmexican Volcanic Belt geological province. The Chapala Lake has presented a series of important water level variations throughout time, which can cause landscape motion surrounding the Lake. The present study shows the advances to detect and measure lake extent variations, and water level changes. Inter-yearly and seasonal changes were examined, detecting water variations of Chapala levels, in satellite image time series (ENVISAT SAR data) from 2002 to 2004. On July 2002 the lake presented a drastic reduction of the covered area, which almost reached the historical minimum. However in summer- autumn of the following year due outstanding (unusual) rains the lake was recovered covering areas used for agriculture. We also examined the possibility of using the radar backscatter variability to differentiate water from land. During the period study aquatic vegetation presented different gradients in the soil moisture on the sediment border’s of the lake. Wind effect (Bragg backscattering mechanisms) and other characteristics which emerged through the water’s surface indicate disturbances and variations in the backscatter signal. To optimize the digital image processing and enhanced the lake shoreline a classifier fusion technique was implemented. The results show the estimated water prevalence and the cover surface obtained from the time series analysis. Currently the ENVISAR ASAR image resource is provided by ESA data (Project C1F.22731) (WInSAR)

Monitoring Wetlands of Lebanon: Use of Space Observations for Better ManagementApproaches

Shaban, Amin [1]; Stephan, Raya [2]; Faour, Ghaleb [1]; Hamze, Mouin [1]

1: National Council for Scientific Research, Lebanon; 2: UNESCO, HIP, Paris

As remarkable geomorphologic landscapes, wetlands are common landforms in Lebanon. They own different dimensions ranges from several hundreds of square meters up to few square kilometres. These typical landforms are viewed mainly from the frequent existence of water bodies and the saturated terrain domains, and thus creating unique ecosystems for flora (e.g. pollens) and fauna (e.g. soaring birds), and this implies terrestrial and marine environments. The aspects of the existing wetlands are found in regions with defined geomorphology and the mechanism of water-bearing is governed mainly by the geological setting. Lately, these wetlands have been subjected to physical and anthropogenic stresses that made them under real threat, notably that water feeding becomes crucial, and this makes some wetlands losing their hydrologic criteria (e.g. Cliffs of Ras Chekka). Hence, monitoring wetlands becomes a priority, and therefore they are investigated by processing satellite images of previous dates (e.g. IRS, Aster) with newly lunched high-resolution satellites (i.e. Sentinel-1) to deduce the timing of water retention and configuring water distribution on terrain surfaces as well as to monitor the changing patterns and volume of water. This will help proposing new management approaches and legislation reform to meet the requirements of international instruments in view of preserving these unique hydrologic systems and their sustainable development.

Determination of Surface water area using multitemporal SAR imagery

Gahlaut, Shakti [1]; Štych, Přemysl [2]; Elmi, Omid [3]; Sneeuw, Nico [4]; Tourian, Mohammad J. [5]

1: Charles University in Prague, Czech Republic; 2: Charles University in Prague, Czech Republic; 3: University of Stuttgart, Institute of Geodesy, Germany; 4: University of Stuttgart, Institute of Geodesy, Germany; 5: University of Stuttgart, Institute o

Inland water and freshwater constitutes a valuable natural resource in economic, cultural, scientic and educational terms. Their conservation and management are critical to the interests of all humans, nations and governments. In many regions this precious heritage is in crisis. Spaceborne sensors provide a number of novel ways to monitor the water changes interannualy. The main focus of this research is to investigate the capability of multi-temporal ENVISAT ASAR imagery to extract water surface and assess the water surface area variations of lake Poyang in the basin of Yangtze river, the largest freshwater lake in China. Nevertheless, the lake has been in a critical situation in recent years due to a decrease of surface water caused by climate change and human activities.

Firstly SAR images were pre-processed using NEST software (ESA). In order to classify water and land areas and to achieve the temporal change of water surface area from ASAR images during the period 2006-2011, the image segmentation technique by Chow and Kaneko (1972) was implemented. In a second step, the time series for this method is derived from the estimated water surface areas.

The results indicate an intense decreasing trend in Poyang Lake surface area during the period 2006-2011. Especially between 2010 and 2011, the lake signicantly lost its surface area as compared to the year 2006. These results illustrate the effectiveness of the locally adaptive thresholding method (Chow and Kaneko, 1972) to detect water surface change. A continuous monitoring of water surface change would lead to long term time series, which is definitely beneficial to the water management purposes.

Mapping Water Bodies and Wetlands from Multi-spectral Optical Satellite Images

Gumbricht, Thomas Robert

Karttur AB, Sweden

The favored source for mapping surface wetness and water bodies from satellite sensors is microwave data. Optical satellite data has a higher spatial resolution compared to microwave data, and a variety of Normalized Difference indexes combining Short-Wave Infra-Red (SWIR) and visible (VIS) wavelengths have been suggested for mapping water bodies and wetlands. Optical satellite images, however present several obstacles for retrieval of surface wetness, including; minimal surface penetration, cloud and cloud shadow contamination, atmospheric attenuation at different wave-lengths, and the vegetation influence on the signal. To overcome some of the limitations in using optical images for mapping surface wetness, I developed the Transformed Wetness Index (TWI). TWI makes use of all available spectral bands transforming the reflectance data to fixed biophysical vectors using a unitary (orthogonal) matrix, optimized for separating wet and dry areas. The biophysical vectors representing the soil line and water are then combined in a non-linear normalized difference index, while the biophysical vectors representing photosynthetic and non-photosynthetic biomass are both omitted. The derived index is translated to actual surface wetness using a linear-power equation. TWI was designed to capture the full range of surface water content, from desert dry to deep open water. For non-inundated soils, TWI soil moisture estimates derived from Moderate-resolution imaging spectroradiometer (MODIS) data has a globally estimated Random Mean Square Error (RMSE) of approximately 14.0 %, and a bias of 2.5 % which reduces to an RMSE of 11.6 % (bias: -0.4 %) when compared to only non-forested in situ data. These results match the performances of the standard soil moisture products from the Advanced Multichannel Scanning Radiometer (AMSR-E) and the Soil Moisture Ocean Salinity (SMOS) sensors.

This study presents the ability of TWI to capture open water bodies and wetlands. The study compares TWI derived from MODIS and the Operational Land Imager (OLI) flown on Landsat 8. The mapping of coast-lines, inland water bodies and wetlands are evaluated compared to antecedent maps representing tropical, sub-tropical and temperate regions. TWI overestimates the surface wetness in dense (needleleaf) forests leading to overestimations of inland water bodies in forested regions, especially in the temperate region. For tropical regions, water bodies and wetlands covered with dense stands of aquatic vegetation (e.g. papyrus and reed) are under-estimated. Soil moisture content and inundation is better captured with Short-Wave Infra-Red (SWIR) compared to VIS and near-infrared (NIR) wavelengths. The Bidirectional Reflection Distribution Function (BRDF) corrected MODIS data has a higher quality than the OLI data used in this study, and MODIS also has a better SWIR resolution compared to OLI. The maps derived from MODIS data are more consistent, but the higher spatial resolution of OLI data allows a more accurate mapping of boundaries between wet and dry land.

First inventory of optical lake types in the permafrost landscapes of the central Lena River Delta and central Yamal - case studies of Coloured Dissolved Organic Matter (cDOM) and turbidity regimes

Heim, Birgit [1]; Bartsch, Annett [2,3,4]; Dvornikov, Yuri [5,1]; Leibman, Marina [5]; Fedorova, Irina [6,7]; Widhalm, Barbara [4]; Morgenstern, Anne [1]; Eulenburg, Antje [1]; Stettner, Samuel [1]; Chetverova, Antonia [6,7]

1: Alfred Wegener Institute for Polar and Marine Research AWI, Germany; 2: Zentralanstalt für Meteorologie und Geodynamik, ZAMG, Austria; 3: Austrian Polar Institute, Austria; 4: Vienna University of Technology, Vienna, Austria; 5: Earth Cryosphere Instit

We provide a first field-based & satellite-based inventory of optical lake types in the permafrost landscapes of the central Lena River Delta (Arctic Siberia) and central Yamal (Western Arctic Siberia) using field investigations and multi-sensor satellite data. Within the thematic network between our groups we seek to investigate how we may link:

- multi-sensor remote sensing analysis (optical and radar)
- tachymmetrical and satellite-based stereographical analysis
- geochemical and hydrodynamical ground investigations

in the thermokarst- and thermoerosional-influenced landscape types in the central Lena Delta and the Yamal region in Siberia.

We are investigating the turbidity regimes of the lakes and the catchment characteristics (vegetation, geomorphology, topography) using satellite-derived information from optical and radar sensors. For some of the lakes in Yamal and the central Lena River Delta we were able to sample for Dissolved Organic Carbon, DOC, and coloured dissolved organic matter, cDOM (the absorbing fraction of the DOC pool). The sediment sources for turbidity spatial patterns are provided by the large subaquatic sedimentary banks and lake cliffs. The cDOM regimes influence the transparency of the different lake types. However, turbidity seems to play the dominant role in providing the water colour of thermokarst lake types.

A Remote Sensing based Inventory of East African Wetlands

Amler, Esther Eva

University of Bonn, Remote Sensing Research Group, Germany

Project Background:

The 'GlobE Wetlands' project is a research cooperation between East African and German partners (www.wetlands-africa.de). 20 partnering institutions from Kenya, Rwanda, Tanzania, Uganda and Germany work in an interdisciplinary partnership. The team aims to reconcile future food production with environmental protection by learning more about and promoting the wise use of wetlands among decision makers and stakeholders in the East African region.

Research abstract:

The 'Millenium Ecosystem Assessment Report on Wetlands and Water' makes it clear that wetlands are important in multiple dimensions e.g. by providing essential freshwater and energy resources, regulating hydrological regimes and climatic processes and controlling soil erosion. Especially inland wetlands are vital for food supply by agricultural production and fisheries. This is of particular importance in the East African region, which has long been a hotspot of food security crises. One dimension of food security is food production, to which wetlands can and do contribute. The year-round water availability and associated fertile soil properties of wetlands provide an excellent resource for local farmers. But wetlands are endangered, e.g. by land conversion, water withdrawals, and overuses. It is estimated that globally more than 50% of wetlands have been lost over the twentieth century.

To balance human claims to wetlands and their protection, spatial explicit information is vital. Institutional stakeholders need systematic spatial knowledge. The transboundary regional focus is useful: mechanisms to share information, including a common definition of wetlands supports stakeholders in monitoring these endangered ecosystems. Also to extrapolate findings from studies on the local level, harmonized knowledge about regional wetland distribution is necessary. Internationally, for example for future improved implementation of the Ramsar convention, remote sensing experts claim a better collaboration between countries to strengthen mechanisms to share information for wetland inventories and monitoring. A review of literature shows that many remote sensing based wetland studies omit a definition of the surveyed land cover and the issue of a standardized wetland definition remains unsolved. On a global scale, wetland extent is likely to be strongly underestimated: Land Use/ Land Cover classification systems do not depict wetlands very well and global wetland inventories are not sufficiently precise, mostly due to their coarse scale. While African wetland inventories are either outdated or only available as estimation bases for wetland extent, an East African regional inventory does not exist. National inventories are differing strongly in quality, methodology and availability.

The motivation of the research study is to provide a regionally harmonized wetland inventory for East Africa by remote sensing data analysis. Basic requirements for a regional binary wetland map are (i) cross-boundary harmonization to avoid discontinuities, (ii) completeness (with the constraint of spatial resolution), including a (iii) well-documented methodology and (iv) validation.

The approach to be developed will focus on time series data analysis of multiple satellite data sets. It is promising in the sense that wetlands can be expected to have a specific temporal signature of surface reflectance compared to the surrounding uplands. To derive a wetland map layer for the 'GlobE Wetland' project region, different active and passive satellite data and a medium resolution time series of satellite data will be combined. A decision tree classification of derivable phenological indicators will support identification of wetlands. Available on-ground data from four test-sites, representing typical wetlands of the region and collected by researchers from different disciplines will contribute to the dataset and are expected to significantly improve the final product's quality validation. In line with the project framework the result will be publicly available not only to researchers but to all

those working in the field of sustainable wetland management. As East Africa covers environmental gradients from semi-arid to sub-humid, valuable methodological insight for other regional and global scale inventories can be expected to be gained.

A talk at the 'ESA DUE Mapping Water Bodies from Space' presents the 'GlobE Wetlands' research activities that contribute to wetland mapping, the outcomes of an extensive literature research on wetland inventories as well as future research activities. Critical feedback and inspiration from experts in water body mapping are valuable for future research on wetland mapping. The thematic closeness to the 'ESA DUE GlobWetland Africa' can be useful for both projects, and a knowledge exchange as well as clear thematic differentiation is necessary.

Multi-sensor Monitoring for Water Resources Management in Dryland NE Brazil

Foerster, Saskia [1]; Brosinsky, Arlena [1]; Zhang, Shuping [1]; Heim, Birgit [2]; Medeiros, Pedro [3]; Mamede, George [4]; Farias, Christine [5]; Schramm, Leonardo [5]; de Araújo, José Carlos [5]

1: German Research Center for Geosciences (GFZ), Potsdam, Germany; 2: Alfred Wegener Institute for Polar and Marine Research (AWI), Potsdam, Germany; 3: Federal Institute of Education, Science and Technology of Ceará (IFCE), Maracanaú, Brazil; 4: Universi

The North East of Brazil is characterized by a high spatial, seasonal and inter-annual variability of rainfall. The climate is semiarid with pronounced wet and dry seasons. For the dry season, water supply is ensured by the construction of reservoirs of various sizes. The stored water is essential for the local population in terms of drinking and irrigation usage. However, the region regularly experiences drought spells when low rainfall rates during the wet season result in insufficient refill of reservoirs, inducing a need for effective and integrated water resource management. In recent years, an increasing growth of macrophytes has been observed indicating an increase in eutrophication of the reservoirs that in turn is related to changes in land use. Particularly direct access of cattle to the reservoirs and the degradation of the natural Caatinga vegetation are supposed to be major causes of increased nutrient inflow. Given the large number of reservoirs, the complex dynamics of water storage and quality and the remoteness of the area, multi-sensor satellite remote sensing is believed to be an ideal source to assist monitoring of water resources as a basis for a sustainable water resources management.

Specific objectives of the presented work are to [1] derive bathymetric information of the reservoirs to estimate height-area-volume curves, [2] monitor the effective water storage dynamics from water surface delineation and derived storage curves, [3] monitor water quality, [4] identify macrophyte types and monitor their spatial and temporal dynamics, and [5] detect land use changes over the past ten years and relate it to the observed eutrophication dynamics and macrophyte growth. We are currently acquiring a multi-sensor satellite image data base comprising of RapidEye time-series and TerraSAR-X time-series complemented by data sets from CHRIS/Proba, Hyperion EO-1 and TanDEM-X. The remote sensing approach is supported by an extensive ground-truthing programme to calibrate and validate image analysis as well as to identify processes on site.

The proposed multi-sensor approach will be tested in the Madalena basin (124 km²) located in the centre of the federal state of Ceará, Brazil. The basin is controlled by the Marengo reservoir (16 million m³) built in 1934, whose main purpose is to supply water for the local population, for animal supply, for fishing and for small irrigation projects. The climate is typical of the Brazilian semi-arid zone, with annual average rainfall of 600 mm, potential annual evaporation of 2,100 mm and high inter-annual rainfall variability. The vegetation consists of a secondary degraded Caatinga dry forest. The area, which had formerly been a large farm with traditional land use, has been more intensively occupied since 1985, when the Federal Government accomplished a land reform, benefiting almost 500 rural families. However, most agricultural and livestock practices remained, leading to a substantial

increase in reservoir eutrophication. The presentation will give an introduction into the overall concept and objectives of the cooperation project. Furthermore, running field data collection and satellite image acquisition as well as first results will be presented.

Submesoscale Eddy Activity in the Mediterranean Sea Seen by Envisat ASAR imagery

Svetlana Karimova[1], Martin Gade[2]

1: Helmholtz-Zentrum Geesthacht, Germany; 2: Universität Hamburg, D-20146 Hamburg, Germany

Despite the fact that spiral eddies on the sea surface were first seen from space more than 40 years ago, there is still a lot of uncertainties concerning their origin, lifetime, participation in the energy cascades, etc. Nowadays many efforts are being undertaken to study this type of ocean stirring through laboratory experiments and numerical modeling, as well as via satellite, high frequency (HF), and in-situ observations.

Due to their high spatial resolution, wide swath of view, and independence on cloud cover and sunlight conditions, satellite-borne synthetic aperture radar (SAR) sensors are an effective tool to gain more information on submesoscale eddies in almost any part of the World Ocean. In the present study, SAR imagery was used to derive statistics on submesoscale eddies in the Mediterranean Sea. The dataset used consists of about 3000 medium resolution wide swath Envisat ASAR images obtained in 2009-2011. The images were inspected visually and eddy manifestations of two types were fixed. The first type is due to surfactant films ("black" eddies) and the second, due to wave/current interaction ("white" eddies).

The collected dataset of eddy manifestations was further processed providing a comprehensive analysis of spatial and temporal distribution of the eddies. The schemes of eddies' spatial distribution revealed that in general "black" eddies tend to be located in the near-coastal area (presumably due to influence of lateral friction), while "white" eddies, in the open sea areas where stronger currents can be encountered. For gaining further details, observed distribution of eddies was compared with distribution of other hydrophysical and meteorological parameters retrieved from satellite data.

The analysis of the temporal variability of the eddy appearance revealed its strong seasonality, whose main reasons were suggested to be the seasonal variability of the wind speed, amount of surfactant films, and stratification of the surface waters.

The material collected can be also interesting for investigating spatial distribution and seasonality of surfactant films presenting on the water surface, because the number of "black" eddies detected in the imagery can be used as a proxy of the area covered by surfactant films.

The SAR data were obtained under the grant of the European Space Agency # 14120 "Spiral eddy statistical analyses for the Mediterranean Sea using Envisat ASAR Imagery (SESAMeSEA)".

Theme: Water circulation

Remote Sensing of Lakes on the Tibetan Plateau

Hochschild, Volker [1]; Kropacek, Jan [2]; Hoerz, Sebastian [3]

1: University of Tuebingen, Germany; 2: University of Tuebingen, Germany; 3: University of Tuebingen, Germany

Climate change and its potential effects are of global interest. Lake ice and snow coverage act as effective indicators of climate change due to their sensitivity to climate elements (like air temperature in the case of the lake ice), and can be observed on a large-scale with the help of remote sensing. The lakes on the Tibetan Plateau are important indicators for the development of the high mountain ecosystems facing the impacts of future climatic warming on runoff from snow and ice. Many of these Tibetan lakes are remote and hard to access, so multisensoral remote sensing is a valuable tool to generate hydrological relevant information as modeling input (land cover, soil moisture, trends in mountain lake ice cover, etc.) or validation base (lake level changes). For the monitoring of the lake ice, the first and the last day of the partial ice cover and the period of total ice cover are defined on the basis of temporal high resolution MODIS data. The larger lakes were compared and put into regional groups in order to delineate and define different local trends. For obtaining a better spatial resolution for the calculation of the ice covered area, additional medium and high resolution optical and microwave data (ERS-1, ERS-2, ENVISAT A-SAR, LANDSAT, Kompsat-2, RapidEye) are being considered, which at the same time, have a smaller temporal resolution. By means of correlating the different data, the respective advantages of each data type are merged and then used for the exact iced surface area calculation. The study is enhanced by the use of passive microwave data (SSM/I, AMSR-E) which provides very high temporal resolution information as validation input. Simultaneously TerraSAR-X ScanSAR data was analysed for the whole winter period 2011 (December until April) in order to derive the spatial distribution of different ice types. The snow cover is an important intermediate storage of water and plays a crucial role in the water budget of the Tibetan endorheic lakes since their contribution to runoff is mostly unknown as well as the loss through sublimation. It is observed by multitemporal MODIS 8-day snow cover composites, which were split into three different seasons and displayed as RGB synthesis of snow distribution (RSD, Kropacek et al. 2010). The different colors indicate the spatial distribution of the dominant precipitation mechanism within the large Tibetan Plateau. Further multisensoral remote sensing analysis include the observation of lake level alterations by satellite altimetry as well as the investigation of the ice thickness or the glaciated area inside the basins with time series of IceSat data. The study was financed by the German Research Association (DFG) within the priority program 1372 (TiP) “Tibetan Plateau: Formation – Climate – Ecosystems” as well as from the German Ministry of Research (BMBF) within the WET (Variability and Trends of water balance components in benchmark-catchments of the Tibetan Plateau) scientific cooperation.

Commercial Multi-Resolution Water Quality Monitoring Services

Heege, Thomas; Schenk, Karin

EOMAP GmbH & Co.KG, Germany

Mapping status information of water bodies from space meet a wide range of governmental and water industries needs for a huge number of freshwater bodies globally. Required are independent information products, consistent spatially and temporally on a wide range of resolutions.

EOMAP invested respectively in commercial water quality monitoring services. Services base on state-of-the-art analysis technology in operational, scalable production environments for a range of different multispectral satellite sensors. The processing technology includes sensor-independent modules for adjacency correction, fully coupled retrieval of atmospheric- and in-water optical parameters for a wide range of optical conditions. The processors deliver harmonized measures in different analysis and aggregation levels. For an economic and scalable daily production on large data volumes, the processors are imbedded in automated workflow orchestration system, installed in various ground segments located in different continents as well as in commercial cloud provider infrastructures. Currently services are operational for Landsat 5,7,8, MODIS 500m, Worldview 2&3, and prepared for Sentinel 2&3. Quality controls include automated pixelwise quality measures, features such as cloud shadow masking, and a service quality control team. Distribution and access to the products is organized through various commercial portals, customized web applications as well as free demo apps for marketing.

Further technical service improvements such as retrieval in optical shallow waters, infrastructure investments for the Sentinel 2&3 satellites, as well as interactions of ESA programs and free market services shall be discussed.

A Global Map of Open Water Bodies at 300 m Spatial Resolution

Lamarche, Celine [1]; Bontemps, Sophie [1]; Chini, Marco [3]; Giustarini, Laura [3]; Santoro, Maurizio [2]; Van Bogaert, Eric [1]; Wandera, Loise [3]; Defourny, Pierre [1]; Arino, Olivier [4]

1: Université catholique de Louvain, Earth and Life Institute, Belgium; 2: GAMMA Remote Sensing AG, Switzerland; 3: CRP-GL, Luxembourg; 4: ESA-ESRIN, Italy

The increasing pressure on water resources from climate change and population growth will increase the need of accurate estimation of the world water resources (Vorosmarty, 2000). Global and accurate surface water mask is also of paramount importance for satellite dataset processing and for hydrological and climate modelling. It allows selecting the appropriate aerosol algorithms and to share a common coastline map. The retrieval of evaporation, water/land surface temperature and energy balance are key variables for modelling. In the ESA Land Cover Climate Change Initiative (LC_CCI) project supported by the European Space Agency, climate users expressed the needs for a global land/water mask that could be used consistently across Essential Climate Variables (ECVs) for satellite data processing and climate modelling. In this study, we aim at building such a global water mask combining inland water bodies and coastline delineation for the entire globe.

Datasets dedicated to surface water bodies exist at a medium resolution but they are not necessarily global or up-to-date. The Shuttle Radar Topography Mission Water Body Data set (SWBD) depicts water bodies at 90 m spatial resolution but only covers 54°S to 60°N. This is a snapshot of the surface water corresponding to eleven days in February 2000 (NASA/NGA, 2003). The Global Raster Water Mask at 250 m (MOD44W) combined the SWBD data to MODIS optical data to create a global land/water mask but remaining issues exist in the North (Carroll et al., 2009). Santoro et al. (2013) developed an algorithm based on ENVISAT ASAR time series metrics to map open inland water bodies between 84°N and 60°S. Wide Swath Mode data (WSM) at 150 m were primarily used and complemented with imagery in Image Medium Mode (75 m) and Global Monitoring Mode (500 m) from 2005-

2010. Very high accuracy is achieved especially in the Northern Hemisphere where ASAR WSM time series are very dense.

Thanks to their spatial complementarity, the integration between SWBD and the ASAR WSM classification set the basis for building a global and up-to-date CCI map of water bodies, processed at 150 m and delivered at 300 m for the sake of consistency with the global land cover maps. Below 60°S the precise Antarctic coastline complete the global coverage.

An accuracy analysis, focusing on ambiguous areas with regards to water mapping was carried out independently from the production team. A final database of 1844 footprints evaluated against very high resolution imagery and compared to the LC_CCI-WB map demonstrated an overall accuracy reaching 96%. Under-detection of water is more frequent than over-detection.

The LC_CCI-WB is available as a stand-alone product of the 2014 release of global data sets produced by the CCI_Land Cover project and has been already actively downloaded from the following website http://maps.elie.ucl.ac.be/CCI/viewer/. The fitness for use of this product is currently being evaluated amongst the different components of the ESA Climate Change Initiative. An updated product will be released by March 2015 at a higher spatial resolution, with the goal of an equivalent overall accuracy and matching the users' feedbacks.

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Exploitation of the Sentinel missions for the Environmental Monitoring of Lake Victoria

Mangin, Antoine [1,2]; Syed, Aneeqa [3]; Serra, Romain [2]; Dean, Andy [3]; Hembise Fanton d'Andon, Odile [1]

1: ACRI-ST, France; 2: ACRI-HE, France; 3: Hatfield Consulting, Canada

Lake Victoria is the most important fresh water reservoir in Africa and the second one in the world. It is supporting a very large number of human activities either directly through an intensive aquaculture sector, or indirectly, through the development of agriculture around in order to support the ever growing population living in this area. Due to increase of anthropic pressure of many kinds, the water quality of the lake is getting worse, leading to large phytoplankton blooms and presenting eutrophication risks. On top of that, the accidental introduction of water hyacinth in the lake in the 90th has resulted in a recurrent proliferation of this plant, causing troubles to human activities (especially navigation). The water hyacinth can either be fixed to the lake bottom, or being released as a floating material during stormy event and propagated again toward other parts of the lake. It is one of the missions of the Lake Victoria Environmental Monitoring Program (LVEMP) to monitor this proliferation and to assess the effect of remediation that is presently put in place. We will present here the results of a project co-supported by the World Bank and ESA to provide an Earth Observation -response to this need for monitoring. In particular the whole set of data available from Sentinel-1, 2 and 3 has been investigated to test novel capabilities offered by the three sensors independently and together. Joint use of Sentinel-2 (here Landsat-8 has been used, waiting for Sentinel-2 availability) and of real Sentinel-1 data has proven to be very efficient in term of quality and repetitivness for the detection of water hyacinth extent. OLCI aboard Sentinel-3 is also expected to provide useful information for water biological content, although the atmosphere over the Lake is often cloudy. An automatic service has been derived where all resulting products are processed in NRT and are available through a WebGIS. Methods and results will be presented at the workshop.

Impact of Satellite Derived Bathymetry *(SDB)* to the Production and Updating of National Chart Series

Laporte, Jean; Hedley, John; Martin-Lauzer, Francois-Regis; Mouscardes, Pierre

ARGANS Ltd., United Kingdom

Since the early empirical attempts to calculate depths from optical imagery in the 1980s, use of Satellite Derived Bathymetry (SDB) has until recently been limited to terrain models for the promotion of Earth Observation, R&D usage by academics or to provide ancillary data for conservation efforts, civil engineering and advanced Hydrographic Offices. SDB is now coming of ages, thanks to new constellations of High Resolution satellites, improved scientific algorithms and greater interaction between interested parties. The increased involvement of Mapping Agencies and the cartography community with EO laboratories and scientists was demonstrated at the fifth Extraordinary International Hydrographic Conference of October 2014. SDB is now a competent member of the mapping toolbox.

Our contribution in the evolution of SDB has been in the development of methods for depth estimation, and calibration and validation procedures, both specific to SDB, and for general EO quality assurance – work conducted under a range of ESA initiatives. SDB physics-based inversion methods now enable hydrographers not only to calculate depths in shallow waters with an acceptable precision -at least when the environment is not too murky- but further determine the error bars and the cut-off depths beyond which optical methods can no longer guarantee the safety of navigation.

Apart from the production and updating of IHO-compliant international chart series, the new SDB method, which was very recently selected and adopted by a European Hydrographic Office, has already found applications in the

fields of Maritime Protected Areas, tourism, charting of developing countries and last of all, Maritime Delimitations in a settlement submitted to the International Tribunal for the law of the Sea (ITLOS).

On the eve of the International Hydrographic Organisation's World Hydrography Day (21 June 2015), focused on "Our seas and waterways - yet to be fully explored and charted", the latest achievements of this technique let us envisage an end to the blanks of the charts and make the coastal surveyors enter fully in the Age of Satellite.

Flood detection using radar altimetry backscattering coefficients: examples over West Africa

Frappart, Frédéric [1]; Fatras, Christophe [1,2]; Mougin, Eric [1]; Marieu, Vincent [3]; Diepkilé, Adama Telly [4]; Blarel, Fabien [1]; Borderies, Pierre [2]; Grippa, Manuela [1]

1: Observatoire Midi-Pyrénées; 2: ONERA; 3: EPOC; 4: LOSSA

Backscattering coefficients acquired at Ka, Ku, C and S bands from ERS-1 to SARAL present a wide a range of spatio-temporal variations over West Africa that can be related to the spatio-temporal changes in roughness and dielectric constant of the upper soil surface. Presence of water modifies these two parameters causing large increases in the surface backscattering at nadir incidences. We present several examples illustrating the capability of radar altimetry to detect water using the backscattering coefficients over West Africa. We will focus on two specific environments: the Inner Niger Delta in Sahel and temporarilly inundated forests in the tropical regions.

In the Inner Niger Delta, temporal variations of the backscattering coefficients are related to the flood regime over temporarily inundated areas and to SSM over non-inundated areas. Variations in backscattering greater than 25 dB were found between high and low water periods in the inundated areas and over the Niger River . Considering the differences between frequency (C and Ku with Jason-2 and S and Ku with ENVISAT), it also appears that bare and dry soils exhibit higher backscattering responses (> 3dB) than inundated areas and wet soils and/or covered with vegetation.

In temporarily flooded tropical evergreen forests, the presence of water below the canopy during the flood causes a huge change of the ground reflectivity. An increase in backscattering coefficients at all the bands during the flood season show the capability of radar altimetry to detect water under the canopy, and account for the monitoring of water levels in forested wetlands temporarily or permanently inundated.

Generation of the new River & Lake high-resolution mask

Lucas, Bruno [1]; Smith, Richard [2]; Berry, Philippa [3]; Benveniste, Jerome [4]

1: Deimos/ESRIN, Frascati, Italy; 2: De Montfort University, UK; 3: Newcastle University, UK; 4: European Space Agency, Frascati, Italy

The ESA River & Lake (RL) system developed by De Montfort University (UK) produces accurate river and lake height estimates from ERS-2, Envisat and Jason-2 satellite altimeters. Data are freely available to the scientific community from http://earth.esa.int/riverandlake as both historical and Near-Real-Time products.

In order to produce time-series over an individual inland water target, the RL system utilises a mask to delineate those areas of open water where good results can be achieved. The system uses this mask as a filter to determine whether an echo should processed or discarded.

The previous generation of masks used in the RL system were derived from the Global Land Characterisation Coverage (GLCC) dataset, developed by NOAA from AVHRR data. The GLCC dataset is extensive but not always 100% accurate (often due to vegetation cover), which can allow incorrect delineation of water targets, and thus allow non-optimal results to be generated.

The technique selected to derive the new mask used in the RL project was to utilise an underlying DEM to determine the path of steepest descent over the topography, where water would flow over the landscape. The selected DEM selected was ACE2, which was created by fusing the SRTM with multi-mission satellite radar altimetry. The ILWIS software suite was used to: 1) Fill in DEM sinks; 2) Calculate flow direction; 3) Calculate flow accumulation; 4) Extract Drainage Network.

This approach delineates where the water would theoretically flow, rather than where water currently does flow. In order to remove any contamination from paleo-hydrologic features, a comparison with the Digital Chart of the World took place to remove any clear dry river courses.

As the ILWIS derived mask did not determine lake boundaries, only flow direction through the lake, a mask was created using the existing GLCC dataset that contained only representations of lakes. This lake mask was then combined with the ILWIS mask to produce a new NRT mask.

The mask was validated by comparison with two different datasets, one the old GLCC mask and another using a mask derived from GLOBCOVER (based on MERIS data). The results were assessed over the following test areas: the Amazon, Niger River, Syr Darya and Amur river (for the old mask) and Brahmaputra, Amazon and Zambezi (for the GLOBCOVER based mask).

The new generation of high-resolution altimeters, such as CryoSat-2 and AltiKa (already flying) or to Sentinel-3, to be launched by the end of 2015, will need high-resolution accurate masks of inland water bodies, in order to increase significantly the monitoring capabilities.

The reported ILWIS derived technique could be used to produce these high-resolution masks, depicting all tributaries of a river not just the major stream.

On evaluating the potential of Envisat Individual echoes to retrieve water in small inland water bodies

Vignudelli, Stefano [1]; Scozzari, Andrea [2]; Abileah, Ron [3]

1: Consiglio Nazionale delle Ricerche (CNR-IBF), Italy; 2: Consiglio Nazionale delle Ricerche (CNR-ISTI), Italy; 3: jOmegak, USA

Water bodies narrow in width and shallow in depth are usually challenging targets for satellite remote sensing. In particular, there is a growing interest today in monitoring water heights.Satellite radar altimetry, although designed with oceans in mind, can provide historical and homogenous timeseries of water heights (within satellite track constraints) with a global coverage. Also, radar altimetry is an alternative to the irregular sampling offered by sparse single measurements made with water gauges, and provides access to remote or difficult to reach locations.Generally, the water heights derived from satellite radar altimetry are calculated from an incoherent average of the waveforms received from a large number of echoes reflected back from the surface. However, if the footprint includes non-water targets (e.g. because it touches the shoreline), the reflected echo may be contaminated with some effect on the averaged results. Here we propose the use of individual echoes (IEs)to monitor small inland water bodies (lakes ~200 m diameter, rivers ~200 m or less wide). A large number of IE data packets (each formed by a 1984 x 128 complex data array) have been collected by Envisat during its ten years of service. The inland water body waveforms are seen to vary from specular to moderate Brown, according to the peculiarities of the target, i.e., size, nature of the surrounding land, water surface, etc. Examples generated by extracting all the IE tracks in the vicinity of selected water bodies will be shown and discussed in terms of their echo characteristics, potential accuracy of the measured water height and implications for future inland water altimetry.

Mapping Fresh Water Macrophytes and Shallow Water Bathymetry – a Case Study with Landsat 8 and Sneak Preview of Sentinel-2

Dörnhöfer, Katja [1]; Liekefett, Maike [1]; Fritz, Christine [2]; Oppelt, Natascha [1]

1: Christian-Albrechts-Universität Kiel, Germany; 2: Technische Universität München, Germany

Benthic macrophytes constitute important elements of fresh water ecosystems. Within the European Water Framework Directive they therefore serve as indicators for the assessment of the ecological state of water bodies. Today, monitoring macrophytes is still based on in situ mappings which cannot capture temporal dynamic or spatially large areas. Owing to their improved radiometric and spectral resolution and signal-to-noise ratio (SNR) the new sensor Landsat 8 and the upcoming Sentinel-2 offer a great potential to detect benthic macrophytes. In optically shallow water various factors affect the water leaving radiance, e. g. the bottom substrate, water depth and water constituents. Bio-optical models present a possibility to calculate a best fit of these factors in optically shallow waters. Within the project LAKESAT we tested the potential of Landsat 8 for mapping benthic macrophytes in a test site in Northern Germany. We applied the bio-optical model WASI to a scene acquired on 19th July 2014 at Lake Kummerow (53.808° N, 12.856° E). Concurrently taken water samples and submersible spectroradiometer measurements served to set up the shallow water model in WASI. Inverse modelling of the Landsat 8 reflectance spectra allowed deriving bathymetry and fractional coverage of bottom substrate via spectral endmembers, i.e. sediment and dominant macrophyte species in the optically shallow parts of the lake. Fractional coverages of endmembers were validated on a qualitative basis due to the absence of benthos mappings; quantitative validation by means of a bathymetric chart was possible for water depths. The derived maps based on Landsat 8 data showed reasonable results.

Compared to Landsat 8, Sentinel-2 offers additional spectral information; therefore, its suitability to analyse optically shallow waters is expected. To give an outlook for Sentinel-2, we conducted a modelling analysis for the

sensor. Using WASI in the forward mode, sets of shallow water reflectance spectra (400 to 900 nm, 1 nm intervals) were modelled for different water depths with known input parameters: water constituent concentrations were fixed with constant values; fractional coverages of endmembers (sediment and macrophyte species) varied in 0.05 intervals from 0.0 to 1.0. The modelled spectral dataset was resampled to the Sentinel-2 sensor configurations including spectral response curves and SNR. Afterwards, the resampled spectral data sets were analysed through model inversion to reconstruct the fractional coverages of benthic endmembers. Original and reconstructed endmember coverages were compared to emphasize the possibilities and limits of benthic mapping with Sentinel-2.

Monitoring Freezing and Break-up of Rivers and Shallow Lakes with Dual-Polarized TerraSAR-X Data

Roth, Achim [1]; Schmitt, Andreas [1]; Gauthier, Yves [2]; Grosse, Guido [3]

1: DLR-DFD, Germany; 2: Institute National de la Recherche Scientifique (INRS), Canada; 3: Alfred Wegener Institute for Polar and Marine Research (AWI) , Potsdam

About one-quarter of the lakes on Earth are located in the Arctic. Permafrost thaw lakes are important and widespread landscape elements affected by climate change. Furthermore, thermokarst lakes are critical components of Arctic terrestrial ecosystems. Feedbacks from changing lakes will affect permafrost, hydrology, vegetation, land-atmosphere energy exchanges, carbon cycling, and many other processes.

Objective of the presented work is to test the applicability of higher level products of polarimetric SAR data for monitoring of river and lake ice cover. Based on these SAR products an automized and transferable technique is developed. A time series of dual polarimetric TerraSAR-X data of several test sites was processed and analysed. A Kennaugh decomposition was applied. The TerraSAR-X data were radiometrically and geometrically calibrated. Time series of different rivers and lakes where acquired, that cover at least one complete freezing and thawing period.

Comparison of Efficiency of Optical and Radar Data for Mapping Different Kind of Water Bodies

Surek, Gyorgy; Nador, Gizella; Friedl, Zoltán; Rotterné Kulcsár, Anikó; Gera, David Akos; Tar-Andrási, Agnes; Torok, Cecilia

The Institute of Geodesy, Cartography and Remote Sensing (FÖMI), Hungary

We have shown in the course of an earlier work, that radar polarimetry is suitable for identification of geometrical structural changes due to damages in agriculture parcels. The main aim of the present study is to examine the contribution of radar polarimetry for distinguishing different kind of water bodies since these categories show unique spectral and geometrical structural characteristics. For this purpose a study area was selected near the lake Tisza, in Hungary, having complex characteristics and sensitivity to waterlog. Comparative analysis was carried out focused on the efficiency in distinguishing different type of water bodies by using various type of optical and radar satellite images for classification. Several types of spectral indices were derived from optical satellite images. Polarimetric descriptors were generated from various types of radar images. We established a very effective feature selection methodology-based statistical evaluation of the created polarimetric descriptors. This paper is devoted to present our initial results. The present project demonstrates the potential of integrated usage of polarimetric radar and optical satellite images for identification and classification of water bodies with different characteristics. Our

results contribute to serve water inundation monitoring assessment independent from weather conditions and facilitate to establish an objective and reliable damage mitigation system.

Keywords: Agriculture, Land cover, waterlog assessment, polarimetric descriptors, spectral indices

The Water Quality Assesment of Kızılırmak River of Turkey

Gürsoy, Önder [1]; Birdal, Anil Can [1]; Özyonar, Fuat [3]; Kasaka, Ergün [2]

1: Cumhuriyet University, Turkey, Deparment of Geomatics Engineering; 2: Cumhuriyet University, Turkey, Deparment of Environmental Engineering; 3: Cumhuriyet University, Turkey, Deparment of Biology

Water resources are getting more and more important with each passing day in case of survival of humanity. For this reason, assessing water resources' quality and also monitoring them have attracted lots of attention in the recent years. Remote sensing has been growing widely in the last decade and its resources are very usable when it comes to water resources management. In this study, by using remote sensing technology, satellite images that have 350 to 1050 nanometers wavelength band sensors (e.g. CHRIS Proba) are used to determine the quality of the Kizilirmak River's water. Kizilirmak River is born and also pours out to sea in country limits of Turkey. It is the longest river of the country by the length of 1355 kilometers. Through the river's resources, ground based spectral measurements are made to identify the quality differences of the water at the test spots that have been determined before. In this context, at Kizildağ, where the river is born, and at Imranli, where the river contacts civilization for the first time, which are both located in Sivas city of Turkey, samples are gathered in order to do ground based spectroradiometer measurements. These samples are gathered simultaneously with the image acquiring time of CHRIS Proba satellite. Spectral signatures that are obtained from ground measurements are used as reference data in order to classify CHRIS Proba satellite's hyperspectral images over the study area. Satellite images are classified based on suspended solids and chlorophyl-a attributes. As a result, interpretation obtained from classified CHRIS Proba satellite hyperspectral images of the study area are presented.

On the Use of the Doppler Centroid Anomaly for the Detection of Water Bodies under the Severe Wind Conditions

Dostalova, Alena [1]; Hansen, Morten Wergeland [2]; Wagner, Wolfgang [1]; Doubkova, Marcela [1]

1: Vienna University of Technology, Austria; 2: Nansen Environmental and Remote Sensing Center, Norway

Majority of the today available methods for the water surface retrieval based on the synthetic aperture radar (SAR) imagery have restrictions over rough water surfaces caused by high wind conditions. The wind induced capillary waves cause the so-called Bragg resonance effect which enhances the normalized radar cross-section (NRCS) values above the water surface and thus reduces the contrast between land and water areas. The study of Doppler centroid anomaly was therefore performed over land areas to assess its potential for the detection of water bodies under severe wind conditions.

The Doppler centroid value is dependent on a relative speed of the satellite and Earth surface towards or from each other. It is computed within the SAR data processing ('measured' Doppler centroid) and it can also be predicted with the help of precise orbit and attitude information of the satellite ('modeled' Doppler centroid). The difference between these two values (Doppler centroid anomaly) is expected to be close to 0 for any stable Earth surface. For the moving surface, such as water surface influenced by surface currents and winds, the anomaly values are dependent on the relative speed of the water surface in the sensor line-of-sight direction.

The radial surface velocities based on the Doppler centroid anomalies were successfully used – together with the NRCS data – for wind vector retrievals over oceans [1]. The presented study concentrates on the radial surface velocity values over land. 18 radial surface velocity images from Envisat Advanced Synthetic Aperture Radar (ASAR) Wide Swath (WS) mode were analyzed over central Europe. The retrieval accuracy over land was assessed together with the relationship between wind speed in the radar line-of-sight direction and radial surface velocity over inland water bodies.

Pearson correlation coefficient of 0.79 between radial surface velocity values and ERA-Interim modeled wind speed in the radar line-of-sight direction was found over pixels covered fully by inland water. However, the low retrieval accuracy over land (root mean square error of 42 cm/s at the incidence angle of 35°) in combination with relatively low wind speed values over inland water areas as well as coarse spatial resolution (8 km in azimuth and 3.5 to 9 km in range direction) prevents the use of the currently available ASAR WS data. Both the spatial resolution and the retrieval accuracy are expected to improve in case of the radial surface velocity data derived from the Sentinel-1 satellite.

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VecBorn – Earth Observation products and services for Vector Borne diseases

Weise, Kathrin [1]; Pluschke, Gerd [2]; Niedrig, Matthias [3]; Koetz, Benjamin [4]

1: Jena-Optronik GmbH, Germany; 2: Swiss Tropical and Public Health Institute, Switzerland; 3: Matthias Niedrig, Robert Koch-Institute, Germany; 4: Benjamin Koetz, ESA-ESRIN, Italy

The objective of ESA's DUE project "Vecborn" is to develop satellite based methods for the delineation of risk areas and to support the development of disease control measures for 2 important vector borne diseases, for Tick Borne Encephalitis and for the skin disease Buruli Ulcer. The spread and incidence of both diseases is increasing and thousands of people become infected and die every year.

Since both diseases are related to environmental condition, in particular water and soil moisture, the remote sensing based service of VecBorn could be a breakthrough for the development of warning and protection measures and help to reduce the infection incidence and morbidity rate. The service demonstration areas are highly endemic for both diseases.

Tick-borne encephalitis is an important cause of viral infections of the central nervous system in eastern, central and northern Europe, in northern China, Mongolia, and Russia. Approximately 10000–12000 clinical cases of tick-borne encephalitis are reported each year, but this figure is believed to be significantly lower than the actual total. As the incidence of tick-borne illnesses increases, the geographic areas expand, and in some cases there is no possibility to help and recover infected humans completely. Therefore it becomes increasingly important to develop warning systems, map risk areas and install public health measures to reduce infection risks.

Each tick species has preferred environmental conditions and biotopes that determine the geographic distribution of the ticks and, consequently, the risk areas for tick-borne diseases. As environmental data can be obtained from satellites it might be possible to evaluate relevant parameters of vector distribution by analysing satellite data and determine the relevance by correlating satellite derived information with ground measurements.

Presently the distribution of ticks based on collection and determination of ticks by individual studies gives just a very sporadic picture of the real situation. The distribution of TBE is even based on the registration of single TBE cases reported from endemic areas.

Buruli ulcer is one of the 17 neglected tropical diseases prioritized by the WHO. The exact mode of transmission is still unknown and therefore preventive measures cannot be applied.

Buruli ulcer is caused by infection with Mycobacterium ulcerans, an organism which belongs to the family of bacteria that causes tuberculosis and leprosy. Infection leads to destruction of the skin and subcutaneous soft tissue leading to the development of large ulcers mostly located on the legs or arms. Early diagnosis and treatment are the only ways to minimize morbidity and prevent disability. Buruli ulcer cases have been reported from more than 30 countries with tropical, subtropical and temperate climate. Between 5000–6000 cases are reported annually from 15 of the 33 countries. The disease occurs in Africa, South America, Asia and the Western Pacific regions. Most patients are children under 15. In endemic areas Buruli ulcer is a severe health problem and a major burden for families and the public health system. West African countries, including Cameroon carry most of the burden of Buruli ulcer disease. Currently no strategy or approach exists to identify preventable risks and to reduce the risk of infection for the local population. Therefore Buruli ulcer control relies currently only on awareness campaigns, case detection and treatment, but not on prevention.

Over 50 years of experience have established the fact that Buruli ulcer is acquired through exposure to the environment, particularly through exposure to slow-moving or stagnant bodies of water. Although environmental factors play a key role, their impact is not well understood. Satellite derived information would support the identification of preventable risk factors and VecBorn could be an important contribution to reduce the risk of infection for the local, particular rural populations.

Man-made environmental changes, in particular clearings, dam construction and the resulting changes of water body and wetland distribution will be assessed within VecBorn. Results of epidemiological studies (spatial pattern of Buruli ulcer cases and of M. ulcerans DNA in environmental samples) will be correlated with earth observation data to reveal the association of the disease with different types of water bodies.

VecBorn will make full use of the potential of the new Sentinel 1 and 2 satellites and develop new methods to exploit the full advantages of the Sentinels, in particular the high repetition rate and the high spatial and radiometric resolution. The radar data of S1 in addition to S2 data will help to support the development of reliable methods and repeatable products for the test sites in areas like Berlin, where it is very often rainy, and the tropical rain forested area in Cameroon.

Health mapping targets a user community that is not yet well acquainted with the use of Earth Observation Applications. ESA supported with its DUE project EPIDEMIO and within RESPOND first activities to test and demonstrate the potential of earth observation in epidemiology. Both projects have shown that the potential of earth observation in epidemiology and the need of support from space to fight against diseases is very high. VecBorn will continue activities and, through a close partnership with key user organisations, prepare the ground for a broad involvement of users.

Both user organisations, the RKI for Tick Borne Diseases and the Swiss THP for Buruli Ulcer are leading organisations in Europe and worldwide for the development of infectious disease control measures. Both organisations collaborate very closely with WHO and ECDC on the one hand and local organisations and decision makers on the other hand and support evidence-based decision making for disease control measures.

Health investigations very often are based just on clinical data. Such clinical data can give only very rough estimations about the real local origin of a disease and the environmental conditions relevant for vector distribution and risk of infection. Both End-User institutes can provide data on the spatio-temporal distribution of cases, the distribution of vectors (for TBE) and on contamination of environmental samples. Statistical correlations between

health and Earth observation data have therefore great potential to give deep and valuable insight into the role of environmental factors for the spreading of the two infectious diseases investigated.

Monitoring of Inland Water Quality over Rivers and Lakes using MODIS Data

Martinez, Jean Michel [1]; Roig, Henrique [2]; Filizola, Naziano [3]; Piscoya, Rita [4]; Ventura, Dhalton [4]; Cochonneau, Gérard [1]; Espinoza, Raul [5]; Pinet, Sylvain [1]

1: IRD, France; 2: Brasilia University, Brazil; 3: Manaus Federal University, Brazil; 4: Brazil Water Agency, Brazil; 5: San Marcos University, Peru

The use of satellite imagery to assess inland water quality is reviewed in the context of large rivers and reservoirs. An operational processing chain is presented for Brazil. Satellite sensors measure water color that can be related to the presence of inorganic particular material (sediment), organic particular material (alga) and organic dissolved matter. In this study we show that current space borne sensors such as MODIS, by joining fine spectral resolution, high temporal resolution (up to 2 images a day) and medium spatial resolution (250 meters) may be used for the monitoring of the water quality of the largest rivers of the world.

The improvement of conventional water quality monitoring capacity (mainly through more intensive water sampling) would necessarily raise significantly the operational cost of any hydrological network. However, it is seen as crucial due to water resources importance for both environmental and economical issues in most countries. As a result, alternative techniques to conventional monitoring methods based on field measurement should be evaluated. Recently, the Brazilian Water Agency ANA and the French Institute for the Development (IRD) have developed the MEG-HIBAM project that aims to incorporate the spatial remote sensing into a global monitoring strategy for hydrosedimentary processes. The project seeks to integrate both altimetric and water color data for river level and water quality monitoring.

A website is hosted by the ANA (www.ana.gov.br/hidrosat) and provides remote sensing-based hydrological data at different locations. For the water quality monitoring, MODIS (MOD09Q1 product) were considered due to their preprocessing technique robustness and their near-daily revisit frequency. Due to the MODIS coarse resolution, only large rivers and lakes are considered in the Hidrosat website.

During the presentation, three main points will be discussed :

1- Is water color a reliable estimator of some key water quality parameters (Suspended Particulate Matter - SPM, Chlorophyll-a - Chl-a) ?

To assess this issue, the team involved realized hundred of field radiometric data in several catchments (Amazon River, Sao Francisco River, Parana River) located either in tropical or semi arid conditions in South America. The field measurements confirm that the remote sensing reflectance is robust enough to promote satellite-based operational monitoring of inland water quality. For example, over the Amazon catchment, more than 300 measurements collected during 6 years are used to assess the reflectance / SPM relationship ($r2 = 0.81$)

2- Is it possible to exploit long time series of satellite data for quantitative monitoring ?

We will show the main features of an automatic processing chain based on MODIS 250-meter and 500-meter products (MOD3R algorithm). 15-year time series are evaluated versus conventional monitoring stations (10-day water samplings) showing the remarkable stability and accuracy of MODIS preprocessing and MOD3R postprocessing ($r = 0.79$ - $N = 282$).

3-•What is the accuracy of the technique ?

Different case studies over different rivers (Amazon, Madeira Rivers) and reservoirs (Paranapanema, Tres Marias and Armando Ribeiro lakes) will be presented to assess the accuracy of the SPM and Chl-a retrieval and for derivation of hydrological derived parameters such as river sediment discharge or lake eutrophication level. We show that retrieval performance is consistent with both SPM (about 30% RMSE in relation to field measurements) and Chl-a (about 40 % RMSE).

Finally, we will conclude on the need to integrate spatial hydrology techniques (inland water) and conventional monitoring to developed operational solutions with end-users such as water agencies.

Monitoring Water in Private Pools and Small Ponds with Deimos-2 satellite

Petit, David [1]; Ramos, Jose-Julio [1]; Marti, Paula [1]; Moclan, Cristina [3]; Romo, Alfredo [3]; González Abeytua, José Antonio [2]

1: Deimos-space, United Kingdom; 2: Deimos-Space, Spain; 3: Deimos-Imaging, Spain

This work studies the possibility to use sub-meter resolution optical satellites like Deimos 2, to detect small water bodies (private pools and small ponds) and define their quality. The challenge of detecting the swimming pools is fairly addressed in the literature, therefore this work is focusing on the issue to know if there is water in it or not and if it is a maintained pool or not (Chlorophyll level). Applications are: water-saving policies enforcement during drought season for local authorities, dynamic knowledge of improvised reservoirs for firemen, detection of potential habitats for mosquitos...

We propose a short survey of the studies which have been already performed to detect private pools using Earth Observation. Some are using aerial imagery: Rodriguez et al [2014] is combining high resolution RBG images and Lidar data in a Dempster-Shafer algorithm, Fitzsimmons et al [2012] is using an airborne multispectral camera with ENVI's Spectral Angle Mapper tools. Galindo et al [2009] is one the first to have tried to do that with satellite imagery (Quickbird) using a color-space projection for detection and a snake algorithm to find the shape. But this is with the availability of better sensors, that the "state" of a swimming pool could have been investigated. Thompson et al [2013] uses airborne multispectral AVIRIS sensor and Normalized Difference Water Index and compares the interesting results obtained by Kim et al [2011] with an equivalent NDWI for GeoEye satellite (0.40cm resolution in panchromatic).

Our work is carried out on satellite data acquired since summer 2014. The method is using a random forest algorithm and the 5 bands of Deimos 2 satellite (4 visible bands + 1 Near Infra-Red) at a sub-meter resolution (0.75 cm for the panchromatic band) to classify the small water bodies and their current state (dynamic mapping) regarding the "inspired" EAGLE methodology. For a subset of samples, we assume that the possible location of water bodies is known by using existing local GIS information then we analyse the performance of the classification (empty, full, clear water, turbid water...). The quality is assessed using approaches that we have previously developed with Deimos-1, Landsat and Modis, for large water bodies. The validation is based on a manual classification and further work is intended to be done in summer 2015 with ground truths.

Mapping Water Bodies at Submetric Resolution in a Regional Monitoring Context

d'Andrimont, Raphaël; Marlier, Catherine; Defourny, Pierre

Université catholique de Louvain, Belgium

In the coming years the European Common Agricultural Policy will be modified though the introduction of a Greening Payment. A significant share of the subsidy will in future be linked to rewarding farmers for the provision of environmental public goods. In particular, the European farmers will be subjects to maintain "ecological focus area" across their farms. As reservoir of biodiversity, water bodies are one of the natural resource targeted by this measure. Members' states need therefore a very high resolution mapping of water bodies to monitor precisely their extent variation. Furthermore these accurate water bodies maps can be use as validation to support larger scale mapping. However, detecting the water bodies extent at a submetric resolution is a new challenge to address. Indeed, due to the submetric resolution of the imagery, specific difficulties are encountered as the water bodies are frequently spectrally similar to shadows caused by topography and anthropic or natural features. Actually, at this scale, confusion with features not problematic at lower resolution could lead to false detection.

The objective of this research is to update an existing water bodies' dataset thanks to aerial or satellite multispectral image at a submetric spatial resolution over the Walloon Region (Belgium). The method was developed first using orthoimages at 25 cm and then tested on PLEIADES multispectral images at 50 cm. The method proceeds in two steps. The first step of the method is to rely on the already existing information about water bodies to confirm their existence and give information about their current state and extent. A method based on indices calculation is proposed for this part. In a second step, the detection of new water bodies not included in the database is carried out though a supervised classification using the cleanest training dataset obtained in the first step. A dedicated validation scheme was defined to take into account the specificities of the acquisition (acquisition angle, acquisition date and sun angle).

The paper presents the results of an enhanced method for water bodies detection dedicated to a submetric resolution and describes the advantages, the limitations and the challenges related to the water bodies detection' at this scale.

Aquatic Plants Spectral Signature Database in support of Bio-Optical Model Inversion based on Satellite Data

Fritz, Christine Gloria; Schneider, Thomas; Geist, Jürgen

Aquatic Systems Biology Unit, Limnological Research Station, Department of Ecology and Ecosystem Management, Technische Universität München, Hofmark 1-3, D-82393 Iffeldorf

Macrophytes have important functions in lake ecosystems. They can be used as long-term indicators to characterize the trophic state of freshwater lakes. Monitoring aquatic plants is currently still based on in situ mappings. These routine monitoring cycles in response to the requirements of the European Water Framework Directive are repeated every three years. Supervising the abundance of aquatic plants relies on estimating the effect of their expansion on a lake as well as on ecosystem. Even in a stable system, different proportions of sediment and macrophyte coverage across a vegetation period, greatly affect the reflectance signal. Presently, high invasion dynamics are observed for some submersed species, superimposing the seasonality effect. All these observations suggest monitoring at a higher frequency.

The presented research deals with a subtask of an integral concept for a remote sensing based inventory and monitoring system for freshwater lakes. Components of this system are combined growth and reflection models based on in situ data collections and bio-optical model inversion. The model inversion is derived from satellite data parameters. For initializing the bio-optical models, prior information from the integrated growth and reflection

models is used. The “clear sky” precondition for data to be integrated in phenological spectral databases, as required for such a system, is a limiting factor for continuous measurement series throughout the vegetation period. Therefore, an interpolation model to calculate the remote sensing reflection intensities for submersed macrophytes was developed. Presently, spectral signatures of four macrophyte species, the thermophilic invasive species Najas marina and Elodea nuttallii, as well as Potamogeton perfoliatus and several species of Characae, summarized as Chara spp., are integrated. The the presently integrated spectra are from the study sites, Lake Starnberg and Lake Tegernsee, both situated in the south of Germany. To collect the species-specific remote sensing reflectance of the selected macrophytes in situ mappings with a submersible RAMSES spectroradiometer were done in shallow water. Based on these systematic in situ measurements an interpolation model was computed. In this model the intensity of the remote sensing reflection of each day can be simulated for each macrophyte species separately. Therefore, two different interpolation methods, a linear and bicubic interpolation of the statistic software R, were tested and compared. As a result species-specific reflection intensities over the complete vegetation period were created. At the same time, remote sensing reflectance spectra with wavelengths from 400 to 700nm in 1nm intervals can be calculated for each day throughout the vegetation period. Furthermore, the variable solar altitude is considered in the interpolation model.

Within the project LAKESAT, funded by the Federal Ministry for Economic Affairs and Energy (No. 50EE1340) via the Space Directorate of the German Aerospace Centre, spectra from additional macrophytes, lake bottom sediments and study sites will be integrated.

Water Surface and Volume Monitoring with the Future SWOT Mission: Generation and Use of DEM.

Laurence FRUTEAU[2], Claire HUBERT[1], Mathias STUDER[1], Denis Blumstein[3], Henri GIRAUD[1], Jean-François CRETAUX[3], Olivier THEPAUT[4], Hervé YESOU[1]

[1] SERTIT, [2] PhD Research student (LEGOS – SERTIT – CS-SI), [3] LEGOS, [4] CS-SI

SWOT is a groundbreaking mission which will provide the first comprehensive view of Earth’s freshwater bodies from space and will allow scientists to determine the height and area of fresh water across the global at an unprecedented resolution. The SWOT satellite mission with its wide-swath altimetry technology, KaRIN, will provide an inventory of water bodies but also water elevation: a key for a better understanding of wetlands and floodplains hydrological functioning.

In order to prepare this mission, CNES and JPL are jointly developing a SWOT simulator. This simulator needs some inputs data such as high resolution DEM, water bodies extent and landcover description to create a virtual interferogram scene and inverse the water height in order to generate, track by track, SWOT simulated data (elevation point cloud data).

First request for this is the availability of a high resolution DEM which was generated exploiting 11 TanDEM-X products. On the resulting DEM there are resulting artefact such as outliers on water bodies due to a loss of coherence of SAR signal on water. in order to resolve these outliers, a watermask, containing 250 000 water bodies corresponding to lakes, pounds, reservoirs, paddy field and river courses has been extracted from the magnitude image using a threshold technique. The final DEM is obtained by subtracting the water elements to the DEM and providing an arbitrary height value to these water bodies.

For the simulation the Water Bodies extent has been derived from multi-sensors and multi-resolutions optical and SAR data, in order to optimize the enrichment of the database on the test site. Simulations are realized on Yangtze intermediate watershed, PR of China, more precisely over Poyang Lake, a large wide monsoon lakes connected to

the Yangtze River and will be extended to Dongting Lake, Three Gorge reservoir, as well as smaller disconnected lakes of the Anhui province.

Estimating Volumes Stored in Water Reservoirs from Space. A Mutli Source Analysis in the Valle D'aosta (Italy) Test Site

Cenci, Luca [1,2]; Gardella, Fabio [2]; Pulvirenti, Luca [2]; Squicciarino, Giuseppe [2]; Boni, Giorgio [2,3]

1: WRR Programme, UME School, IUSS-Pavia, Italy; 2: CIMA Research Foundation, Savona, Italy; 3: DIBRIS, University of Genoa, Genoa, Italy

The estimation of the degree of filling of reservoirs (e.g. the percentage of water volume stored in a reservoir compared to the maximum storage capacity) is particularly useful for hydrological and emergency management purposes. In fact both water resources and emergency managers can benefit from this information that, coupled with rainfall forecasts (both medium and long-range), can be exploited for planning hydroelectric power production or for flood forecasts. In many cases water volume data are not available because not shared by operators for use in real time or due to the lack of reliable, real-time monitoring networks. Remote sensing may allow overcoming these limitations for applications on large spatial scales. It allows the near real-time extraction of the shorelines of water bodies that, if merged with accurate topographic information, can help to estimate the volume of water stored. In order to achieve this objective the accuracy of the mapping procedure must satisfy high standards because errors higher of 10 m in the delimitation of the shoreline can produce substantial errors in the hydrological modelling. The increasing number of satellite observations currently available can allow the estimation from different sensors, at different times. Therefore, it is necessary to evaluate the quality of the estimates from the different sources.

The aim of this work is to map the shoreline of some reservoirs located in Valle d'Aosta (Northern Italy), by applying a semi-automatic method able to detect water surfaces, and to estimate the stored volume of water. The algorithm is based on both image segmentation and thresholding techniques. Images acquired by different satellites (i.e. Cosmo SkyMed, Sentinel 1 and Landsat) are analysed in order to assess the impact of different spatial, spectral and radiometric resolutions on the final estimation (namely, the exact quantification of the water volume). Despite the study area presents a mountainous environment that can add noise to the data due to the presence of clouds, relieves and vegetation, it was selected as test site because Valle d'Aosta is an alpine region with many artificial water reservoirs, with known bathymetry, constantly and accurately monitored. These characteristics makes the area particularly interesting for calibrating and validating the methodology described beforehand. In fact the abundance of reliable "ground-truth" information allows the comparison with the results based on remotely sensed data and the assessment of the errors. As final remark, it must be said that this multi-sensor analysis is also important to evaluate the compatibility of the aforementioned satellite products in order to assess their interchangeability. Compatibility is here intended as similar range of error with respect to the reference data. The availability of different, interchangeable data can be particularly useful if these analyses are applied in data scarce environments in which ground-truths are not available. In this last case, also efficient methodologies able to generate reliable bathymetries, starting from cartographic/topographic data, must be implemented.

Identification of changes of inland waterways of Karachi using Satellite Remote sensing

Zafar, Sumaira

Institute of Space Technology, Pakistan

As the time passes waterways of urban areas changed and encroached by settlements and other commercial activities which results flash flooding and blockages of drainages. Karachi is the metropolitan city with almost 20 million population. Due to pavements in urban areas percolation rate of rain water is slow or almost near to zero that's why surface runoff increases and cause destruction in urban areas. Satellite remote sensing made it possible to identify the major changes of land areas. For this study old drainage network were extracted from topographic maps of 1950s, recent drainage network extracted from Landsat 8 resolution merged images at 15 meter resolution and with the help of Google earth satellite images. Digital elevation model also used to check the accuracy of drainage network. Landcover map of the study area also prepared to identify the landuse which encroached the waterways. An inventory of blockages were prepared to share with the organizations whom are responsible for the disaster management and drainage maintenance.

Key words: Topographich maps, DEM, Blockages, Remote sensing

Wetland Monitoring in Semi-arid African Regions Using MODIS Time Series

Moser, Linda; Voigt, Stefan; Schoepfer, Elisabeth

German Aerospace Center (DLR), Germany

Monitoring of wetlands and water bodies in semi-arid African regions is of high importance for the local population and for wetland ecology. The study area is situated in Burkina Faso, West Africa, and extends over an area of 500 km north-southwards, ranging from Sahelien to Savannah climates, and showing a gradient of different rainfall and land use characteristics. Surface water is an important resource for different livelihoods such as farmers or herders, as well as for water extraction by the local population, and can be scarce particularly in seasons of drought.

This study demonstrates the applicability of time series of optical remote sensing data for dynamic water body mapping on a high temporal and medium resolution spatial scale. The main dataset is a 15-year time series (2000-2014) from the Moderate Resolution Imaging Spectrometer (MODIS) with temporal intervals of eight days and 250 m spatial resolution bands in the red and near infrared range (MOD09Q1 product), supported by further information from the 500 m resolution MOD09A1 product, and the digital elevation model (DEM) of the Shuttle Radar Topography Mission (SRTM). RapidEye and Landsat high resolution optical images are available for different seasons in different years, and serve for exploring trends on a higher resolution scale, as well as for validation of the results derived from MODIS.

Spatio-temporal dynamics of water covered areas have been obtained, showing intra-annual variations as well as dynamics throughout the 15-year time series. Trends reveal changing flooding regimes in terms of larger water coverage while the flooding duration decreased. These findings correspond to information gained during field work, and is connected to siltation on the bottom of the water bodies. Caused by dam constructions 21 newly created water bodies larger than 0.5 km², and a number of smaller water bodies were discovered, as well as a few water bodies that have vanished. Secondary applications such as detecting irrigation trends around wetlands from MODIS vegetation indices could be verified using high resolution RapidEye and Landsat data, and vegetation indices can aid for wetland delineation of vegetation covered wetlands. The negative anomalies of both, surface water dynamics of wetlands and vegetation of the environment, were found to coincide with the occurrence of drought seasons (2000-01, 2004-05 and 2011-12). Possibilities and limitations for extending this approach over larger areas are

discussed, and challenges such as mapping sediment rich waters, vegetation covered waters, or misclassifications due to cloud shadows or burnt areas are addressed.

This study demonstrates the potential to detect and monitor water bodies and wetlands in semi-arid African regions, and contributes to the understanding of inter- and intra-yearly dynamics, based on a time series of medium resolution MODIS data. Additionally, the role of wetland monitoring for both, estimating water availability and indicating drought in semi-arid areas is discussed. An outlook on an adapted concept using Sentinel-3 data is presented. The study shows that the use of remote sensing time series is a suitable tool to monitor wetlands in semi-arid regions.

Discovering Optically Shallow Water

Brockmann, Carsten [1]; Odermatt, Daniel [1,2]; Stelzer, Kerstin [1]; Ruescas, Ana [1]

1: Brockmann Consult GmbH, Germany; 2: Odermatt & Brockmann GmbH, Switzerland

Optically shallow water are characterised by visibility of the bottom. In this case mapping of the substrate (different types of vegetation, sediments, bedrock or corals) is possible and also a determination of the bathymetry. Benthic light availability determines habitats for specific aquatic and benthic species, and therefore it is important to know the extent and location of optically shallow water. In contrast, optically deep waters are those where practically all light emerging from the water body origins from within the water column, a prerequisite commonly assumed when remotely sensing the concentration of water constituents

Several algorithms were developed to estimate bathymetry and map benthic substrates (Bierwirth et al, 1993; Dierssen et al, 2003), classify seabed habitats (Kenny et al., 2003; Louchard et al., 2003) or to correct benthic reflectance for water constituent retrieval (Cannizzaro and Carder, 2006; Giardino et al., 2012) in optically shallow waters. On the other hand, many algorithms facilitate estimation of water constituent concentrations in optically deep waters (e.g. forward models by Lyzenga, 1978, 1981; Maritorena et al., 1994; Lee et al., 1998, 1999). Each of these algorithms implicitly assumes either optically shallow or deep conditions. However, almost no algorithms are published on the separation of optically shallow and deep water, be it for delineating habitats, or as guidance for the right subsequent algorithm retrieval.

In the framework of the ESA DUE Diversity II project it was necessary to develop an algorithm to identify and flag pixels that are affected by bottom reflection, as these are potentially important areas for biological diversity, but also to avoid inappropriate water constituent retrieval. The biggest challenge is to distinguish between very similar signals from benthic and suspended sediment, or from vegetated bottoms and moderate phytoplankon concentrations. A further challenge is the fact that bottom reflection can disturb the atmospheric correction significantly and hence detection should ideally work on a top-of-atmosphere signal, or on Rayleigh corrected reflectances. Our approach is loosely based on the band arithmetic bottom reflectance indicator suggested by Cannizzaro and Carder (2006). We evaluate similar expressions for TOA radiances and found that

ratio_490 = radiance_3* radiance_7/(radiance_5 * radiance_5)

is the most effective indicator for shallow water. However, this still identifies many cases of either high sediment load or high chlorophyll concentration. We solved this problem by applying the ratio to a longer time series, assuming that bottom reflection remains temporally stable whereas spectrally similar water columns vary with time. The assessment of different temporal aggregation approaches revealed that the average of several ratio_490 images is a suitable indicator of shallow water, and an appropriate threshold was derived by comparison with bathymetry maps. The new algorithm was evaluated for all 340 lakes considered in Diversity II. It revealed several cases of reliably retrieved optically shallow waters, predominantly in relatively clear waters, and only small areas around the

origin of turbid river plumes remain ambiguous. In this presentation we will detail the algorithm, demonstrate its application and how we validated it.

Satellite-based water quality monitoring products: Global user requirements and potential solutions

Saile, Philipp [1]; Odermatt, Daniel [2]; Brockmann, Carsten [3]

1: Bundesanstalt für Gewässerkunde; 2: Odermatt & Brockmann GmbH; 3: Brockmann Consult GmbH

Anthropogenic deterioration of the quality of water resources is an emerging problem in many parts of the world that often affects already water-scarce areas further reducing water security. Reliable data of sufficient spatial and temporal coverage is the prerequisite to determine hotspots of pollution. The UNEP Global Environment Monitoring System (GEMS) Water Programme aims at improving the knowledge on inland water quality issues by increasing the water quality monitoring capacities in participating countries as well as collecting in-situ water quality data from both national agencies and scientific institutes all over the world to support regional and large-scale water quality assessments. However, many countries deem water resources monitoring data strategic information not to be shared with the international community. In conjunction with existing gaps in national monitoring systems this severely limits the level of detail and soundness of most supranational water quality assessment nowadays.

Remote sensing and especially high-resolution satellite-based water quality monitoring products can help to overcome these data gaps with respect to turbidity and eutrophication related issues. In the mid-term future, GEMS/Water requires quality-assured remote sensing data products from an operational service. The DUE Innovators III project Spaceborne observations to nourish the GEMS/Water Global Network (SPONGE) aims to develop a pilot service that meets this demand. Water quality indicators such as turbidity, total suspended solids and chlorophyll-a will be derived from Sentinel-2 and Landsat-8 imagery, using state-of-the-art methods. In collaboration with GEMS/Water and several committed National Focal Points, the acquisition of in situ measurements and satellite passes is coordinated. The resulting matchup datasets are used for the calibration of parameter retrieval, and the assessment of the pilot service accuracy. Comparing the service adequacy for existing monitoring sites in geographically, climatically and limnologically different situations will finally allow to estimate the global feasibility and corresponding constraints for GEMS/Water compliant operational water quality monitoring.

This paper will present preliminarly user requirements of GEMS/Water and individual National Focal Points, with respect to satellite-based water quality products and provide a summary of the SPONGE project starting in March 2015.

Improved Performance of new Earth-Observing Satellites for Monitoring Water Quality in Small Inland Water Bodies

Brunclík, Tomáš; Danquah, Kwasi Asare Baffour

University of Pardubice, Czech Republic

This article would deal with image noise, revisit cycle, spatial and radiometric resolution of Earth-observing satellites and influence of these imagery properties on water quality (WQ) monitoring using modeling and retrieval of WQ parameters from satellite imagery. The work would be focused on comparison of Landsat 5,7 TM/ETM+ and the new Landsat 8 OLI sensors performance, with properties of the future Sentinel-2 MSI in mind. The experimental part would illustrate improvements brought by the new generation of sensors on example of satellite data used in project focused on relatively small inland water bodies and multitemporal WQ modeling. The project is carried on in the region near town Pardubice, Czech Republic. The WQ parameters studied are chlorophyll-a, Secchi disk depth, total nitrogen, total carbon and total organic carbon. The water bodies studied are either Middle Ages built fishponds or ponds and lakes created by sand mining in the twentieth century, most of them are used for swimming and fishing.

Relatively small size of these water bodies (typically 10-90 ha) makes spatial resolution 30 m of Landsat satellites a limiting factor, which is further stressed by need of ETM+ image smoothing with 3x3 mean filter to mitigate relatively high noise and low radiometric resolution of previous generation of satellites. The region contains also numerous smaller water bodies and rivers, whose dimensions are too small to include them in the monitoring.

To create the models, atmospherically corrected Landsat images available via USGS EarthExplorer were used. Signal to noise ratios (SNR) example values (computed considering the water area only signal levels in the area of interest) were found to be approximately 12 in blue band and only 6,5-8 in red band for atmospherically corrected Landsat 7 ETM+ images. After image smoothing by 3x3 average filter these values increased to 27-40 and 13-31, respectively. In comparison, pushbroom sensor OLI of Landsat 8 produced images with SNR 34-51 in blue band and 38-81 in red band without smoothing. It was also found, that the provisional Landsat 8 surface reflectance data products available from USGS contain square artifacts of 10x10 pixels in water areas. After removal of these artifacts the SNR values increased slightly further.

Furthermore, the revisit cycle of 16 days (average 8 in the region of satellite path overlap) of Landsat satellites in combination with weather changes brings relatively high risk of missing clear-sky weather conditions, resulting in substantial periods of time, when satellite monitoring of WQ parameters would not be possible. In this regard, the 10 meters spatial and 12 bit radiometric resolution together with 5/10 day revisit time and expected low noise thanks to pushbroom sensor of Sentinel-2 would be important improvement for inland water quality monitoring.

Evaluation of CryoSat-2 SAR and SARin altimetric modes for the mapping of rivers

Bercher, Nicolas; Fabry, Pierre

ALONG-TRACK, France

CryoSat-2 is an ESA mission whose primary objective is the monitoring ice surfaces using nadir radar altimetry. The satellite flies on a geodesic orbit of long repeat period of 369 days and dense spatial coverage, notably over polar regions. Its primary instrument SIRAL is a Ku band altimeter running in three exclusive modes: LRM, SAR and SARin, depending on a geographical modes mask. LRM is conventional Low Resolution Mode altimetry while SAR and SARin both rely on Doppler processing (along-track direction), SARin making additional use of the satellite's two antennas to derive across-track direction angle of tracked surfaces.

Together with its geodesic orbit, characterised by a 7km inter track distance at equator, and its pulse limited footprint of a similar width, CryoSat-2 spatial coverage of Earth is complete between -88° and 88° latitude. These characteristics makes it a unique opportunity for altimetry-derived topographic studies over land surfaces and particularly over surface waters.

Alti-hydrology (of Hydrology from Space) applications usually relies on external water mask derived, for example, from SAR imagery (SRTM/SWBD) or other imagery datasets like Landsat and MODIS. Since the advent of CryoSat-2 and for the first time, several teams around the world working in the field of alti-hydrology seriously envision the possibility to derive, or help to derive, water masks directly from SAR and/or SARin altimetry data.

Actually, the SAR mode of CryoSat-2 (the first implemented on-board altimetry satellite) produces intermediate Multi-Looked Data (MLD, in the shape of radar waveforms matrix) from which statistics can be computed to later build water detection indicators. Despite the fact that MLD are not provided in any known CryoSat-2 product officially distributed, some statistical parameters (1st to 4th momentum) are provided into standard L1-b CryoSat-2 products (Baseline B).

Moreover, the potential of SARin mode for water body localisation has already been highlighted (by our team). In SARin mode, the altimeter is naturally locked on brighter targets, like small-width rivers, e.g. down to ~30 m wide, which are still hard to detect otherwise.

The combination of SAR Doppler processing together with the across-track capability of SARin and the CryoSat-2 geodesic orbit makes it a promising tool.

Finally, while SAR mode is planned to be the mainstream mode for forthcoming and future altimetry missions such as Sentinel-3 and Sentinel-6 (JaconCS), SARin mode is unfortunately not planned to be re-implemented in future altimetry missions. Still, SARin mode has been used since the beginning of the mission (5 years ago) to monitor major basins around the world like the Amazon and Congo basins. In the presented work, we will evaluate and show preliminary results of SAR mode data and SARin mode data used to derive water masks over rivers of various width.

Altimeter and SAR based Assessment of Lake Dynamics in Semi-Arid Regions: case study of Ceará's reservoirs, Brazil

Longépé, Nicolas [1]; Ortega, Christian [2]; Banqué, Xavier [3]; Hajduch, Guillaume [1]; Mercier, Franck [2]; Koudogbo, Fifamè [3]; Martins, Eduardo S. [4]; de Carvalho Júnior, Valdenor Nilo [4]

1: Radar Application Division (DAR), Collecte Localisation Satellites (CLS), Plouzané, France; 2: Space Oceanography Division (DOS), Collecte Localisation Satellites (CLS), Ramonville St Agne, France; 3: Altamira Information, Barcelona, Spain; 4: Ceara's

Semi-arid regions have a short but well-defined wet season (2-3 months) followed by a long dry period. To have continuous access to water, a number of regions rely on hundreds or even thousands of water reservoirs, most of them being not instrumented. The knowledge of available water volume at any given time is of high interest, and especially at the end of the wet season. It is essential to assist agricultural crop management and regulate water use. This study aims to provide to water manager an automatic methodology for water volume estimation for a large set of reservoirs. In fine, it should enable the continuous monitoring of water resources at regional scale.

In this study, water volumes (or its variations) are assessed by the joint use of altimeter, Synthetic Aperture Radar (SAR) and regional geomorphologic HSV modeling (Height Curve, Surface, Volume). The study site is located in the state of Ceará, a dry region in the Northeastern Brazil.

While the altimeter-based estimation provides an accurate mean to monitor water level of large reservoir at medium-continuous temporal scale (see Figure 1), SAR image provide high-resolution spatial capabilities. Beyond the analysis of the dynamics of the water elevation in this region, we analyzed from the comparison between the SAR results and in situ measurements (via HSV modeling) that SAR-derived surfaces are systematically underestimated. A set of ad-hoc corrections on the surface bias are proposed. In addition, improvements linked to the delineation on SAR image are suggested 1) use of dual-polarisation with Sentinel-1 images to ease the discrimination of swamp areas or eutrophication 2) ortho-rectification with DEM consideration, or at least integration of the altitude of lakes with respect to the geoid during the processing the SAR image from L0 to L1. A comparison of segmentation methodologies is provided as well.

Landsat-Based Global Lake Dynamics Products and Quality Assurance and Quality Control (QA/QC)

Sheng, Yongwei; Wang, Jida; Song, Chunqiao; Garibay, Dorian; Woods, Jordan; Lyons, Evan; Te, Gary; Smith, Laurence

University of California, Los Angeles, United States of America

Lakes, important water resources, play a crucial role in the global water cycle and are sensitive to global warming and human activities. There clearly is a pressing need to understand temporal and spatial variations of lakes globally. Our current goal is to produce circa 2000 and circa 2015 high-resolution global lake databases in a systematic way and to provide a comprehensive assessment on lake dynamics between the two episodes at global scales. Mapping dynamics of global lakes is rather challenging due to their high abundance and low accessibility. With its broad spatial coverage and monitoring capability, satellite remote sensing is the only feasible approach to inventory global lake dynamics, but requires tens of thousands of high-resolution satellite images, automated mapping algorithms, and more importantly tedious yet essential quality assurance and quality control (QA/QC) procedures. However, QA/QC procedures are missing from many regional-scale water body mapping projects. In our USGS- and NASA-funded projects, millions of lakes have been mapped out using thousands of Landsat images acquired at appropriate seasons and have gone through intensive QA/QC procedures. The appropriate seasons refer to the period in a typical year when lakes are relatively stable, and are determined spatially using precipitation and temperature datasets. Thousands of cloud-free Landsat images at 30 m resolution have been acquired during lake-stable seasons. Satellite lake mapping succeeds at different levels from place to place and from season to season. A set of highly replicable automated lake mapping methods and tools have been developed to tackle various situations across the entire Earth and to handle such a large volume of satellite data. Even though these effective algorithms are being used, commission and omission errors still exist and some lake boundaries may not be adequately delineated. These errors need to be identified and mitigated through intensive QA/QC processes. However, QA/QC of such a huge quantity of lakes remains a great challenge. We have developed two QA/QC strategies with automation. Automated QA requires mapping the Earth twice in the same seasons for lakes and identifies “inconsistent” lakes for further QA/QC. Other lakes without significant changes are considered quality assured, and labor-intensive QA/QC is only limited to those “inconsistent” lakes. We have also developed semi-automated QC tools to further reduce the workload for manpower. The circa 2000 high-resolution systematically-generated global lake database with adequate QA/QC will be released shortly. The circa 2015 database is being produced using the recently launched Landsat 8 images.