Abstract Book

Advances in Geological Remote Sensing

(Including the Oil and Gas Earth Observation Group Workshop)

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ESA/ESRIN, Frascati,

Organised by:

GRSG / OGEO

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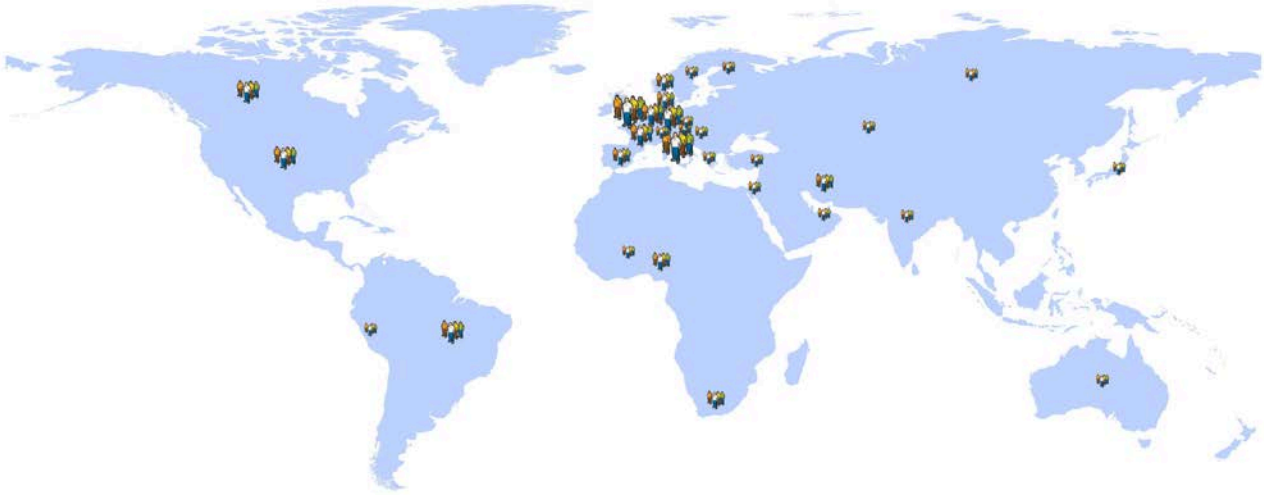
1. WELCOME FROM THE GRSG

Dear OGEO/GRSG workshop participants,

Welcome to the annual meeting of the GRSG, and to a new venue, with thanks to our hosts, the European Space Agency. Whether you were drawn to Frascati for the GRSG content, for the OGEO workshop, or by the location, I hope you enjoy the meeting. If you haven't done so already, I encourage you to pick up a copy of the GRSG newsletter. New members are always welcome, as are those of you who are renewing your membership.

I'm pleased that this year we have a strong focus on oil and gas applications, in addition to a wide range of geological remote sensing presentations. The GRSG and OGEO committees have worked hard to deliver a packed and varied programme. Session chairs will be working to keep everyone to time, so please don't be offended if the enthusiasm of presenters has to be managed, or time for questions is limited. There will be plenty of opportunities for informal discussion during breaks, and at the various social events generously supported by our sponsors. If you aren't able to attend a particular social event do return the ticket and someone else will be able to attend. Please do take the time to visit the various sponsors in the Magellan room and look at the posters in the main meeting room.

The GRSG is becoming increasingly active internationally and you can get an impression of the distribution of participants from the map below.



As ever, this will be a great opportunity to see old friends and meet new friends and colleagues. If you haven't been to a GRSG meeting before, I hope we'll see you again next year, at the meetings planned in North America, Paris and London.

Dr Richard Eyers
GRSG Chairman, Spatial Energy
chairman@grsg.org.uk

2. WELCOME FROM THE OGEO GROUP

Dear OGEO/GRSG workshop participants,

OGEO is an informal working group, established in 2009 and initiated by ESA. Representatives from the Oil & Gas industry as well as service providers with an interest in Remote Sensing came together to facilitate increased awareness and open communication on RS issues and applications in the industry. In the last few years the Oil and Gas industry has started to embrace these 'new' remote sensing technologies and not only in the classical field of exploration, where remote sensing was taken up by the geologists very early in the game. Met-Ocean engineers and environmental scientists, for example, have discovered the powerful information, which can be derived from remotely sensed data, either from satellite or airborne platforms. And it is these remote sensing derived, value added products, which excite us now rather than having a colourful picture from space as a backdrop for our company brochure. From long-term monitoring to short notice emergency response activities, remote sensing provides a range of tools, which will advance and improve the way the industry is doing its business. Minimizing our environmental footprint, increasing the safety performance, allowing improved security assessments and lowering the health risks are the noble goals in all our companies HSSE policies. Remote sensing can contribute to a fair number of them and has already been demonstrated in some of the papers we will hear from in the 2011 workshop.

This workshop will also create an opportunity for an exchange between two industries: Minerals and Oil & Gas. It is rare that subject matter experts, with a common background, come together to discuss cross industry issues and interests on related topics. Please use this workshop as an opportunity to have good communication amongst your PEERS and between industry and service providers. Ask your colleagues from the minerals industry and build a bridge to the different applications in the oil and gas industry. Sharing knowledge, communicating best practise and addressing the needs of future activities is an outcome we seek to achieve during this workshop.

A big 'THANK YOU' to ESA on behalf of the OGEO group for their generosity and hosting the event again in 2011 after the very successful inaugural 2010 event.

Dr. Peter Hausknecht, Woodside Energy - Australia

Chairman of the OGEO group, Dec. 2011

3. ABSTRACTS

Abstracts are arranged in the order of the technical programme.

3.1. A Pan European Approach to Geological Remote Sensing

Geological Remote Sensing: Past, Present and Future

Professor Stuart Marsh
Head of Geoscience Technologies, British Geological Survey

Corresponding Author e-mail: shm@gbs.ac.uk

Geological remote sensing has come a long way from its early days of photo-interpretation. Although those skills remain important, these days they are as likely to be allied to high end analytical, modelling and visualisations skills. The Earth Observing system still includes aerial photography, but that is only a small part of the total system, which includes many different satellites, un-piloted airborne vehicles and numerous ground-based and marine sensors. These cover not just optical wavelengths, but also thermal, not to mention the many radar sensors now in use by geologists. Their applications still include baseline geological mapping – in fact digital field data capture makes this as relevant today as ever – but over the past three decades they have expanded to include exploration for oil, gas, minerals and groundwater, the mitigation of landslide, earthquake, volcanic and subsidence hazards and detection and monitoring of pollution. Future issues that will come under remote sensing's unwavering eye will likely include carbon capture and storage, integrated Earth System monitoring and modelling and assessing potential changes within that Earth System through geo-engineering for climate change mitigation. Rapid advances in 3D, property and process modelling coupled with new immersive visualisation systems will change the way in which geologists go about their work. Similarly, there are changes to the observing system on the horizon, not only in terms of new sensors on board satellites like the Sentinel series but also with respect to a more integrated observing system of systems. The author will take the audience through some of the key issues and milestones in this exciting story. He has been involved in geological remote sensing for over 20 years, including periods as both Chairman of the GRSG and Head of Remote Sensing at the British Geological Survey. In the UK, he has also Chaired the Natural Environment Research Council's Earth Observation Director's Advisory Board. He continues to have significant involvement in the geological aspects of the EC and ESA initiative Global Monitoring for Environment and Security (GMES), intergovernmental Group on Earth Observations (GEO) and many related EC Framework 7 projects; he will use these as examples to illustrate his talk and assess where the future might lie for our subject area.

Monitoring the Environmental and Societal Impacts of Mining – the EO-MINERS project -

Stéphane Chevrel*
Christian Fischer
Christoph Ehrler
Derek Rogge
Gregoire Kerr
Eyal Ben Dor
Simon Adar
Veronika Kopackova
Jan Misurec
Danel van Tonder
Colm Jordan

The EO-MINERS Team

Corresponding Author e-mail: s.chevrel@brgm.fr

Modern mineral resources management requires up-to-date information technologies throughout the life cycle of mining operations. It is vital that the geo-spatial information is produced with appropriate accuracy for different demands and that it can be replicated by several organizations. To fulfill obligations from exploration to remediation with different stakeholders, remote sensing data plays an important role for updating geo-spatial information. Nowadays spaceborne and airborne sensor systems exist and a variety of applications have been developed and presented that show the usefulness of passive and active sensors products for assessing, mapping and monitoring the mining environment. Nevertheless, it appears that there are only a few applications accepted by mining industry and relevant stakeholders (mining authorities, legal offices, stakeholder, public). To overcome this limitation a documented and agreed framework for technical standards and protocols has to be developed.

The EO-MINERS project (*Earth Observation for Monitoring and Observing Environmental and Societal Impacts of Mineral Resources Exploration and Exploitation*) is an EU-funded Research and Technological Development FP7 project. One important aim of the project is to bring together EO-based methods and tools to facilitate and improve interaction between the mineral extractive industry and society in view of its sustainable development while improving its societal acceptability. The anticipated technological developments are being tested over three demonstration sites: the Sokolov lignite open cast (Czech Republic), the Witbank coalfield (South Africa) and the Makmal gold mine (Kyrgyzstan). The project is currently 18 months into its 36 month life and substantial EO datasets (both remote and in situ) have been acquired over the three sites and conceptual source/pathway/receptor models have been produced. A list of macro and micro environmental/societal indicators has been drawn up by the project experts in conjunction with stakeholder input, and these will be integrated to develop products that respond to the stakeholders needs.

Based on two different hyperspectral surveys in 2009 and 2010 over Sokolov using the airborne HyMAP sensor system, standardized pre-processing routines for geometric and atmospheric correction as well as for corresponding quality information (QI) and thematic output have been tested and are currently under further development and at different implementation stages. This involves in turn the establishment of geo-data compliant with international standards (CEO, EN/ISO, INSPIRE, etc). Thematic investigations on the Sokolov site include accuracy assessments of the obtained results and show possible impacts when efforts for high quality reference data are not carefully undertaken. Based on these comprehensive investigations geo-spatial information for an environmental assessment of acid mine drainage related pollution sources, pathways and pollution receptors as well as for vegetation mapping and change detection approaches are currently under development. The presentation will also include a brief outline of ongoing work in South Africa and Kyrgyzstan.

Monitoring Mining-related Environmental Impact (IMPACTMIN); Examples from Russia, Bosnia & Herzegovina, Romania and Sweden

Marc. A. Goossens

On behalf of the ImpactMin project Consortium

Corresponding Author e-mail: goossens@geosense.nl

IMPACTMIN is an EU-FP7 project running from January 2010-December 2013. Aim of the project is to develop tools and methodologies for cost-effective and efficient monitoring of environmental impact as a result of mining activities, using a combination of Remote Sensing data from Satellites, manned aircraft, unmanned aircraft, and ground data collection.

The ImpactMin project is carried out in four different project areas:

1) Christineberg mining area, Sweden
2) Rosia Montana, Roumania
3) Vihovici mine, Bosnia-Herzegovina
4) Karabas and Mednogorsk mining and smelter areas, Urals, Russia

We will demonstrate how we zoom in from regional scalesatellite information to very detailed airborne and ground data and evaluate the different types of data that are being used, the different aircraft (both manned and unmanned), ground data collected during the field visits and initial results of processing and integration.

* Consortium members are:

- Geonardo Environmental Technologies, Hungary
- Geosense, the Netherlands
- University of Exeter, UK
- Lulea Tekniska Institut, Swede
- Photon d.o.o; Croatia
- University of Mostar, Bosnia&Herzegovina
- Russian Academy of sciences, Institute of Mineralogy, Urals Branch, Russia
- University Babes Bolyai, Roumania
- Ukrainan Land and Resource Management Center, Ukraine
- DMT GmbH, Germany
- Vlaamse Instelling voor Technologisch Onderzoek, Belgium

PanGeo: Enabling Access to Geological Information in Support of GMES

Ren Capes

Project Coordinator

Corresponding Author e-mail: r.capes@fugro-npa.com

PanGeo is a 3-year Collaborative project that started 1st February 2011 with the objective of **enabling free and open access to geohazard information in support of GMES.** This will be achieved by providing an INSPIRE-compliant, free, online geohazard information service for 52 of the largest towns in Europe covering approximately 13% of the population.
The geohazard information will be served in a standard format by the 27 EU national Geological Surveys via a modified version of the 'shared access' infrastructure as devised for the DG ISM project *One-Geology Europe*. The information to be served (a new *ground stability data-layer* and accompanying interpretation) will be made by each Survey. These products will be compiled from integrations of:

- Satellite Persistent Scatterer InSAR processing, providing measurements of terrain-motion. Half of these are existing datasets coming from the ESA GMES Service Element project *Terrafirma*.
- Geological and geohazard information already held by national Geological Surveys, together with their expertise.
- The polygonal landcover and landuse data contained within the GMES Land Theme's *Urban Atlas*.

Upon user enquiry, a PanGeo web-portal will automatically integrate the ground stability layer with the Urban Atlas to highlight landcover polygons influenced. Clicking on polygons will hyperlink to interpretative reports. User input to design is facilitated by the 27 national Geological Surveys contracted into the project and a core group of Local Authority representatives.
It is trusted that sustainability of PanGeo will be achieved by attracting a proportion of the remaining 253 Urban Atlas towns to procure the PanGeo service for their towns. The service that will already be provided in their country will form the basis of the required promotional activity.
The key users of PanGeo are anticipated as:

- Local Authority planners and regulators who are concerned with managing development risk,
- National geological surveys and geoscience institutes who collect and disseminate geohazard data for public benefit,
- Policy-makers concerned with assessing and comparing European geological risk, much as the Urban Atlas data is used to compare the landcover/use status of European towns.
- The public.

The provision of an open-access, standardised information service on geohazards will enable policy-makers, regulators, and the public to:

- Systematically assess geohazards in each of the 52 towns involved.
- Gain understanding of the geohazards themselves.
- Know who to talk to for more information.
- Statistically analyse and cross-compare geohazard phenomena across EU countries.
- Gain a better understanding of the socio-economic costs involved.
- Make more informed decisions, e.g. on civil defence, planning controls.
- Have confidence that the information provided is robust and reliable.

The PanGeo team comprises 13 'core' partners, as well as all 27 EU national geological surveys: Core Team partners are: Fugro NPA Ltd (UK - Project Coordinator), British Geological Survey (UK), Landmark Information Group (UK), TNO (N), SIRS (F), Institute of Geomatics (E), BRGM (F), EuroGeoSurveys (B), AB Consulting Ltd (UK), European Federation of Geologists (B), Tele-Rilevamento Europa (I), Altamira Information (E), Gamma Remote Sensing (S).

SubCoast. Using earth observation for Floods?

Stephan Gruijters

TNO

Corresponding Author e-mail: stephan.gruijters@tno.nl

Coastal lowland areas are widely recognised as highly vulnerable to the impacts of climate change, particularly sea-level rise and changes in runoff, as well as being subject to stresses imposed by human modification of catchment and delta plain land use. Utilisation of the coast increased dramatically during the 20th century, a trend that seems certain to continue through the 21st century. The shallow subsurface in deltaic areas often hold compressible soils (peat, clay) that may cause subsidence as a result of human activities (urbanization, groundwater extraction). But also human intervention in deeper geological layers for extraction of (energy) reserves may result in subsidence at surface level. The combination of sea level rise and subsidence in these areas makes them extra vulnerable to potential inundation, coastal erosion, habitat disruption and salt water intrusion.

Using Persistent Scatter interferometry to quantify historical surface movement over the last two decades helps in evaluating the order of magnitude of subsidence. Furthermore, the combination of PSI with other spatial information on soil composition (geology) and land use may provide a starting point to predict future subsidence scenario's.

In SubCoast (FP7) and TerraFirma (ESA) the added value of PSI in combination with other spatial data is evaluated on different scales, ranging from detailed analysis on flood defence structures to regional and even national subsidence maps. SubCoast will create a webportal where the areal extent of existing PSI products from both projects can be viewed, and the results of the pilot studies can be viewed and downloaded. This will enhance the visibility and usability of PSI data and stimulate the use of flood related downstream GMES services.

3.2. InSAR Applications for Ground Deformation

InSAR ground motions in the Northumberland region of the UK Luke Bateson

British Geological Survey

Corresponding Author e-mail: lbateson@bgs.ac.uk

The Northumberland and Durham area in the North East of the UK is a region with a long history of coal mining. As such the UK Coal Authority is interested in investigating techniques for the verification of mining-related subsidence claims in this area. The Terrafirma study area extends for 50km from Durham in the south to Ashington in the north; it is 20km wide and includes Newcastle Upon Tyne, Sunderland, Gateshead and South Shields.

The geological sequence of interest includes bedrock of Carboniferous strata, including the Westphalian Coal Measures, and Permian strata comprising the basal Permian Yellow Sands Formation and overlying Zechstein Group. The Carboniferous rocks dip gently eastwards and are overlain unconformably by the Permian rocks. The continuity of the outcrops of these units is interrupted by a number of normal faults. Quaternary (drift) deposits mantle almost the entire district and, except in a few places, conceal the bedrock. The coal-bearing strata dip gently to the east, part of the coalfield being concealed beneath the Permian strata to the south of the River Tyne and the coalfield extends beneath the sea. The coalfield has a working history dating back to Roman times. Over twenty coal seams have been mined underground and the coalfield has been one of the major sources of opencast (surface-mined) coal in Britain. The geological structure of the area determined the development of the coalfield with faults, in particular, serving to divide the area into zones of 'take'. The working of deeper and deeper coal seams, including those beneath the Permian, led to the need to pump mine water.

PSI data were retrieved for two radar datasets; 50 ERS descending images from track 137 between the April 1995 and December 2000 produced 115 555 PS points. 21 descending ENVISAT scenes from December 2002 to October 2008 produced 71 899 PS points. Ascending data from ERS and ENVISAT were found to be unsuitable for PSI analysis therefore DifSAR processing was carried out. ERS PSI data cover approximately 50% of the processed area; the ENVISAT data produced fewer points for the same area and therefore has a lower density.

PSI data were checked for geocoding accuracy, residual orbital trends, and the location of the reference points before the data were loaded in to the project GIS. PSI data were integrated with all data available to BGS such as geological mapping, borehole data, coal mining records, other mining records, GeoSure ground stability data, topographic maps and aerial photography. Overall trends in both the ERS and ENVISAT data were analysed and compared to the geology. No direct relationship was found to the bedrock geology although the geological structure of the area was found to relate to several areas of motion. Relationships were also found between areas of thick superficial deposits and motions in the ERS PSI data. A comparison between ERS and ENVISAT PSI datasets was carried out; large differences in the average motion rate were found to occur, these differences appear to be constrained by the faulting.

Several areas were then chosen to carry out more detailed case studies. The Team Valley illustrates the relationship between areas of thick superficial deposits, the compression of these deposits and de-watering through surface sealing and water abstraction and the occurrence of subsidence. The Houghton-Le-Spring and Ryhope areas illustrate that a complex relationship appears to exist within the time frame of the ERS PSI data. It is possible that remnant mining collapse and ground water level changes are leading to ground motion; this motion is accommodated through faults and fissures in the area.

Motions observed in the Envisat PSI data appear to be more regional in both extent and reason; the interpretation of this wide area uplift is unclear but thought to be related to ground water level change.

Application of satellite InSAR data for landslide risk evaluation and hydrocarbon reservoir monitoring

A. Belson, S. Cespa, A. Ferretti, A. Tamburini

TRE (Tele-Rilevamento Europa – T.R.E. Srl), Milano, Italy

Corresponding Author e-mail:

Satellite mounted radar sensors are capable of detecting millimetric changes in surface displacement. Ground deformation can result from a number of geological phenomena or anthropological activities and the ability to monitor the extent and temporal evolution of surface displacement to millimetric accuracy has significantly increased the range of potential applications.

The basic idea is to compare successive satellite images, measuring the sensor-ground point distance, with the objective of measuring ground displacement. Depending on the acquiring satellite, images can be acquired up to every 4 days, creating a tool for measuring and characterising ground deformation due to varying phenomena such as: landslides, hydrocarbon exploration, CO_2 sequestration activities, geothermal fields, construction and infrastructure monitoring.

SqueeSAR™ (the latest multi-interferogram algorithm) processes a series of radar images acquired in the same geometry over a fixed area. The algorithm identifies pixels that exhibit a consistent electromagnetic behaviour in all analysed images – referred to as permanent scatterers (PS) and distributed scatterers (DS), which result from natural or manmade objects already present on the ground. SqueeSAR™ is a quantitative tool for measuring point-wise ground displacements, similar to a GPS network, where the density of ground points and vertical precision is significantly higher, and each datum for a PS or DS corresponds to a single satellite acquisition.

By detecting millimetric displacements over long time periods and large areas, this technology is complementary to conventional geological and geomorphological studies for the determination of landslide inventories at regional scales and supports early monitoring systems at local scales. SqueeSAR™ has been already used to this end as a standard tool by the Italian Ministry of the Environment, aimed at creating the first database of interferometric information on a national level for mapping unstable areas.

Surface deformation monitoring can also provide valuable constraints on the dynamic behaviour of a hydrocarbon reservoirs enabling the evaluation of volumetric changes in the reservoir through time. Depending on depth and reservoir/overburden rheology, volumetric changes in the reservoir due to fluid extraction and injection can induce surface subsidence or uplift which could trigger fault reactivation and threaten well integrity. A number of projects has been already carried out worldwide for monitoring worked hydrocarbon fields and calibrating reservoir models for EOR (enhanced oil recovery), CCS (carbon capture and sequestration) and UGS (underground gas storage). Indeed, in projects involving fracking for UNG (Unconventional Natural Gas) exploitation and steam injection in SAGD (Steam Assisted Gravity Drainage) and CSS (Cyclic Steam Stimulation), there has been a growing interest for new technologies that can be applied in order to estimate the location of the injected fluids and optimize the recovery factor.

High Resolution Ground Deformations Monitoring By Cosmo-Skymed Psp Sar Interferometry

Mario Costantini, Salvatore Falco, Fabio Malvarosa,
Federico Minati, Francesco Trillo, Francesco Vecchioli

e-GEOS - an ASI/Telespazio Company

Corresponding Author e-mail: mario.costantini@e-geos.it

Synthetic aperture radar (SAR) interferometry is a powerful technology for measuring slow terrain movements due to landslides, subsidence, and volcanic or seismic phenomena. Extraction of this information is a complex task, because the phase of the signal is measured only modulo 2p and is affected by random noise and systematic disturbances.

We have developed an advanced interferometric processing system for COSMO-SkyMed high resolution data, characterized by innovative algorithms that can be applied also to other satellites data. In particular, our system is characterized by a new approach, named persistent scatterer pairs (PSP), for the identification of persistent scatterers (PS) in series of full resolution SAR images, and the retrieval of the corresponding terrain height and displacement velocity. The PSP approach differs from standard persistent scatterer interferometry (PSI) methods in that it overcomes problems related to the presence of atmospheric and orbital artifacts in the signal by exploiting their spatial correlation, thus removing the need for model-based interpolations starting from a preliminary set of measurements obtained by radiometric or low resolution analyses. It does not require data calibration or pre-selection of radiometrically stable points, thus not being affected by errors in the pre-selection or by the density of pre-selected points. The PSP method is characterized by the exploitation of redundant information, which makes for a very good robustness to noise. Another qualifying characteristic of our interferometric processing system is a new method for robust phase unwrapping and finite difference integration, which are key problems for reconstruction of elevations and ground displacements from interferometric SAR data. The proposed approach includes standard phase unwrapping techniques (e.g., minimum cost flow and least squares phase unwrapping) as special cases, but allows obtaining a robust and accurate solution by exploiting redundant information, obtained working with differences between not only nearest neighboring pixels. Moreover, the proposed formulation allows to exploit multi-dimensional information (multitemporal, multi-frequency, multi-baseline, etc.), and to integrate external information if available (e.g. GPS). In all cases the solution can be efficiently obtained by solving a linear or a quadratic programming (LP or QP) problem.

Our processing system was successfully validated and used also in massive productions, for analysis and monitoring of ground deformations from satellite SAR data, in particular from the high resolution COSMOSkyMed SAR images. In this work, after analyzing the qualifying characteristics of our processing system, we will show many examples of applications taken from operational projects for analysis and monitoring of subsidence, landslide, volcanic and earthquake phenomena in several contexts. We will finally show the validation tests performed by comparing the ground deformation measurements obtained by PSP SAR interferometry with optical leveling measurements.

The many operational productions and the validation tests performed confirm the validity of the PSP approach and demonstrate the dramatic improvement brought in ground displacement measurements by high resolution COSMO-SkyMed data with respect to low resolution SAR data. In particular, not only the density of PS measurements increases, by two orders of magnitudes, but also the accuracy of PS measurements increases by about an order of magnitude. While the higher PS density is very important for monitoring of buildings and infrastructures, the higher accuracy of ground deformation measurements guaranteed by the high resolution COSMO-SkyMed data allows observing smaller ground deformations and with a shorter observation time. In addition, the COSMO-SkyMed constellation can provide an unprecedented frequency of observations, which allows monitoring also faster movements.

Displacement monitoring by Terrestrial SAR Interferometry: real cases and data dissemination

Francesca Bozzano[1,2,3]
Ivan Cipriani[1,3]
Paolo Mazzanti [1,2,3]
Alberto Prestininzi[2,3]
Alfredo Rocca[1,3]

1)NHAZCA s.r.l., spin-off of “Sapienza” Università di Roma, via Cori s.n.c., 00177, Rome, Italy

2) CERI, Research Centre on Prevention, Prediction of Control of Geological Risks, “Sapienza” Università di Roma, Piazza U. Pilozzi 9, 00038, Valmontone (RM), Italy

3)Department of Earth Sciences, “Sapienza” Università di Roma, p.le Aldo Moro 5, 00185, Rome, Italy

Corresponding Author e-mail: paolo.mazzanti@nhazca.com

Terrestrial SAR Interferometry (TInSAR) is a ground based remote sensing monitoring technique based on the same operational principles of Spaceborne SAR Interferometry (SInSAR) (Mazzanti, 2011). TInSAR allows to monitor widespread areas (up to 10 km2) with high data-sampling rate (few minutes) in any weather and lighting conditions in a completely remote (targets or sensors are not required in the monitoring area). Terrestrial SAR images are obtained by a radar sensor moving along a rail (whose length is usually on the order of a couple of meters). By computing the phase difference of each pixel of SAR images collected at different times we obtain 2D images of displacement; furthermore, in case of continuous and high sampling rate monitoring detailed time series of displacement can be obtained. Thanks to the above mentioned features TInSAR is a very effective monitoring solution in several cases such as: landslides, subsidences, volcanoes, glaciers and structural deformations. Recent successful applications of TInSAR of our research group range from the continuous long term (4 years) monitoring of an unstable slope to the short term (one month) monitoring of a civil building in an urban context. In what following a brief description of some key application is presented:

i) monitoring an Alpine slope facing a large artificial dam in the southern part of French. Several months monitoring by TInSAR allowed to identify and map the unstable zones of the slope with an accuracy of few mm at a distance up to 4 km from the monitoring platform;

ii) continuous monitoring of a small size mudflow interacting with a pipeline in the central part of Italy for civil protection purposes. Displacements up to several tens of centimeters per day was recognized and the most active area mapped thus supporting civil protection actions;

iii) 4 years continuous monitoring of an unstable slope affected by excavation activities for the realization of a major communication road. Continuous collection of displacement images of the entire slope allowed to identify different types of instability conditions thus representing a key support for designers (Bozzano et al, 2011b);

iv) long term discontinuous monitoring of a rock cliffs suitable for identifying the most susceptible sectors (Mazzanti & Brunetti, 2010);

v) few days monitoring for the identification of the unstable areas and the rate of displacement of a landslide interacting with a small village;

vi) identification of sectors of buildings affected by the METRO C underground excavation in the city of Rome (Mazzanti & Cipriani, 2011).

Recent developments consist in the prediction of landslide time of failure by TInSAR monitoring. During four years continuous and high sampling rate monitoring of an unstable slope the pre-failure displacement time series were collected thus allowing the efficacy of existing forecasting methods to be assessed and new methods to be developed (Mazzanti et al., 2011a; Bozzano et al., 2011a). For such a purpose the high accuracy, high sampling rate and the widespread monitoring capabilities of TInSAR demonstrated to be very effective. However, even if TInSAR can be considered a self-sustained technique for deformation monitoring, in several cases can be still more effective if integrated with other techniques. For example, a new method for the combination of radar images and 3D cloud-points derived by Terrestrial Laser Scanner (named

LARAM) has been recently developed by some of the authors (fig. 1). Furthermore, TInSAR data could represent a precious opportunity for integrating and cross-checking Satellite InSAR data. As a matter of fact, thanks to its view from the ground, TInSAR is very effective for monitoring high steep and vertical slope and structures that are not visible from the satellite. Also in case of complex slope and structures or objects by a complex dynamics different direction of movements can be derived from the combined Satellite and Terrestrial InSAR monitoring. Furthermore, Terrestrial InSAR can be very useful when higher temporal and spatial resolution is required (difficult to be achieved by satellite data having a sampling rate of some weeks. Nevertheless, archives of satellite SAR data collected since 1992 all around the world from several National and International Space Agencies, are still today a unique opportunity to gather information of past processes. Indeed, TInSAR is a future oriented monitoring method, since only after the installation of the equipment on site, the collection of data could start. Hence, integration of Satellite and Terrestrial InSAR data seems to be very promising opportunity for dealing with landslide hazards (Mazzanti et al., 2011b). In this perspective, a first attempt of integration has being carried out in the frame of the GENESI-DEC project, carried out by several partners including ESA (European Space Agency) (http://portal.genesi-dec.eu/). GENESI-DEC (Digital Earth Community) is a web-based platform for open data and services access, that allows European and worldwide Digital Earth Communities to seamlessly access, produce and share data, information, products and knowledge. A dedicated tool for the integration of TInSAR data in GENESI has been recently developed and tested thus improving also the efficacy in TInSAR data dissemination. Rendering TInSAR data in a geographical (not-local) system, dramatically simplifies its diffusion, while the perspective of web-based data storage necessarily improve the free access to information for end-users.

3.3. ADVANCES IN HYPERSPECTRAL REMOTE SENSING

The White Reference Tour –Concept and Results

András Jung
Cornelia Gläßer
Christian Götze
Michael Denk

Martin Luther University Halle, Germany

Institute of Geoscience, Department of Remote Sensing

Corresponding Author e-mail: cornelia.glaesser@geo.uni-halle.de

Spectral libraries play significant role in archiving spectral information. The documentation of spectral signatures has different tradition, structure and aims. Even the signatures self have their unique history and origin depending on data collection methods or techniques. There are many well structured and organized meta-databases provided by state of the arte data management technologies. Valuable solutions and good practices were recommended and implemented by many researchers. The scope and architecture of a library depend on application and requirements of the user and standards on how to build a spectral library were not introduced yet.

The theory of an appropriate measurement with its geometrical, radiometrical and technical aspects has been widely investigated in the literature and has a long history. But less attention has been paid to see and to monitor the present reality of the spectral measurements and their practical consequences. However this fact is of high importance for the spectral libraries and it directly affects the quality of the spectrum and throughout the usability and comparability of the spectral products.

We do have an increase about the type and number of field spectrometers in the research institutes and industry. More and more groups with different background are working in this field and will increase in the future. It is well known, how many parameters are influencing the spectral signal, from the type, age and calibration status of the equipment, over the geometry and illumination of the samples to subjective human factors.

The German Society for Photogrammetry, Remote Sensing and Geoinformation and the Martin Luther University Halle-Wittenberg (MLU) initiated a project, called *White Reference Tour*. The objective of this project is to investigate and document the daily measurement routines, equipments, general attitudes and first of all about the spectral products. We do have included now 30 labs from 8 countries. Every lab got from the Halle University the same rock sample and different calibrated reference targets. The labs have to document the measurement routine in the lab in a protocol and by photos. All differences of equipment, missing calibration and so on are included in the results- like in the normal measurement routine.

The presentation will show the results of the spectral mineral measurement in relation to different influencing parameters. The experiences from this project are important for education in remote sensing science and beginners in HRS. It is very helpful for improving good measurement protocols and metadata base. Finally the project helps to improve networking and communication between the groups. The project will continue and more groups are invited to participate.

Examination of spaceborne imaging spectroscopy data utility for stratigraphic and lithologic mapping

Alon Dadon[1]
Eyal Ben-Dor[2]
Michael Beyth[3]
Arnon Karnieli[1]

1) The Remote Sensing Laboratory, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede-Boker Campus 84990, Israel

2) The Remote Sensing and GIS laboratory, Geography and Human Environment Department, Tel-Aviv University, Israel

3) Geological Survey of Israel, Jerusalem, Israel

Corresponding Author e-mails: karnieli@bgu.ac.il, bendor@post.tau.ac.il, mbeyth@gsi.gov.il

Due to the increasing development of image spectroscopy techniques, airborne and spaceborne hyperspectral images have in recent years become readily available for use in geological applications. One of the prominent advantages of imaging spectroscopy is its high spectral resolution, producing detailed spectral information in each pixel. The current study aims at exploring the feasibility of the Earth-Observing-1 Hyperion imaging spectrometer to map the geology arena over the Dana Geology National Park, Jordan. After overcoming the common preprocessing difficulties (e.g., smile effect), a classification scheme of two levels was applied. The first level resulted in a stratigraphic classification product of 11 classes and the second level in a lithologic classification product of 6 classes. The overall accuracy of the stratigraphic product was 57%, while that of the lithologic product was 79%. Mismatches in classification were mostly related to terrestrial cover of the lower topography formation by rock and sand debris. In addition, low accuracy values can be attributed to Hyperion's high sensitivity, leading to recognition of different mineral compositions as different classes within a rock formation, while the conventional geology-stratigraphic map generalizes these different classes into one formation. The methods practiced in the current research can advance the Hyperion's classification capabilities and therefore can be applied in different geological settings and additional disciplines such as penology, agriculture, ecology, forestry, urban, and other environmental studies.

Microscopic remote sensing as a scale-integrated tool in mineral exploration

T.J. Roache[1]
J.L. Walshe[1]
J.F. Huntington[2]
M.A. Quigley[2]
K. Yang[2]
B.W. Bil[3]
K.L. Blake[4]
T. Hyvärinen[5]

1) CSIRO Earth Science & Resource Engineering, 26 Dick Perry Avenue, Kensington, WA, 6151, Australia.

2) CSIRO Earth Science & Resource Engineering, 11 Julius Avenue, North Ryde, NSW, 2113, Australia.

3) AGH-University of Science and Technology, A. Mickiewicza 30 Ave, Krakow, 30-059, Poland.

4) James Cook University, Advanced Analytical Centre, Townsville, QLD, 4811, Australia.

5) SPECIM, Spectral Imaging Ltd., Teknologiantie 18 A, FI-90590 Oulu, Finland.

Corresponding Author e-mail: tony.roache@csiro.au

A method has been developed that incorporates micron-scale hyperspectral imaging, petrography and mineral chemistry as key components in the mineralogical characterization of a hydrothermal system. The spatial integration of mineral chemistry, textures and hyperspectral images validates the assignment of mineralogy from hyperspectral indices, as well as maintains the geological context between hyperspectral datasets collected at varying scales from microscopic to exploration camp. A newly-defined hyperspectral index has been characterized from this process that acts as a proxy for composition of the epidote–clinozoisite solid solution. A combination of the wavelength position and depth of the 1550 nm absorption was used to characterise the solid solution series spectrally. The epidote–clinozoisite hyperspectral index[1] is designed to supplement and support data derived from other hyperspectral indices that target gold mineralisation within the lithologically diverse mafic sequences of the Eastern Yilgarn Craton, Western Australia.

Spectral interpretation and index creation within The Spectral Geologist (TSG-Core™) software focussed on those minerals associated with most or all of the seven studied deposits. Indices were tested using a combination of visual validation via the spatially referenced spectra and drill-core image facility within TSG-Core, and correlation plots involving EPMA compositions and proxy compositions derived from SWIR spectra. SWIR spectra were collected from an Analytical Spectral Devices (ASD) FieldSpec-3 spectrometer, either attached to a HyChips™ system or by stand-alone handheld probe. HyChips, developed by CSIRO, integrates an Analytical Spectral Devices (ASD) FieldSpec-3 spectrometer with fibre-optic probe into a translation table with associated lighting, calibration standards and other instruments (0.2 mm resolution visible imaging from Basler and laser depth profiling). The ASD spectrometer has a spectral range of 350–2500 nm and a spectral resolution of about 8 nm. The sample carriage is on a robotic-controlled X–Y table large enough to carry a full one-metre-long diamond-drill-core tray. Associated software (CSIRO-developed HyChips control software, Labspec) drives the X-Y table, and captures the ASD spectra and other data. Additional spectra were collected from samples containing multi-phase epidote and clinozoisite using a spectral-imaging camera (SisuCHEMA™) for the purpose of obtaining a fine spatial resolution to detect micron-scale variability in mineral phases. The SisuCHEMA is a high-speed push-broom hyperspectral imager with a spectral range of 1000–2500 nm, spectral sampling/pixel of 6.3 nm, spectral resolution of 10 nm and 320 spatial pixels/line. Pixel sizes used in this study were 0.31 mm and 30 □m. Image data are calibrated to reflectance through measurement of an internal reference target before each sample scan.

Correlation between the epidote–clinozoisite index and mineral chemistry was enhanced significantly by the hyperspectral imager where both epidote and clinozoisite were microscopically-intergrown; a trait common within samples of intermediate epidote composition. Textural studies found genetic links between epidote and Mg-chlorite, and between clinozoisite and Fe-chlorite, with each mineral combination part of separate, diagnostic hydrothermal assemblages. The hyperspectral imager helped resolve potential conflict in interpretation by demonstrating that spectra from epidote–clinozoisite-dominated veins showed that shifts in the 2250 nm absorption correlate with epidote–clinozoisite composition and not with chlorite composition, and that coexisting amphibole phases have a closer compositional tie with epidote–clinozoisite than chlorite in the given samples. The genetic affiliation yet compositional discordance between co-existing epidote–clinozoisite and chlorite suggests that the compositional spectral index associated with each are wholly independent, but in combination are diagnostic for the mapping of separate hydrothermal assemblages at the mine- to camp-scale.

[1] Roache T.J., Walshe J.L., Huntington J.F., Quigley M.A., Yang K., Bil B.W., Blake K.L. & Hyvärinen T. (2011): Epidote–clinozoisite as a hyperspectral tool in exploration for Archean gold, *Australian Journal of Earth Sciences* **58:7**, 813-822.

Exploring the Geological Value of LWIR Drillcore Imaging

Phil Harris[1]
Rainer Bars[2]
Neil Pendock[3]
Paul Linton[4]
Harri Karjalainen[2]
Mike Buxton[5]

1) GSI Consulting

2) Specim, Spectral Imaging Ltd

3) PicoImages

4) AngloGold Ashanti Ltd

5) TU -Delft

Corresponding Author e-mail: philharris@mweb.co.za

Previous investigations into the potential of the long wave infrared (LWIR) have reviewed the potential of drillcore imaging (Harris *et al*., 2009). These investigations involved the use of low spectral resolution imaging sensors, but clearly demonstrated that the data contained significant geological information. This subsequent investigation focuses on demonstrating the geological value of the LWIR for drillcore imaging by comparing LWIR data with other infrared data.

In this investigation we review:

The geological information that can be obtained in the LWIR,
The influence of spectral resolution and SNR on mineral detection,
Geological information derived from LWIR compared with data obtainable from other infrared wavelength ranges.

The LWIR (7-14µm) has long been recognised for its importance in detection of minerals that are poorly detected in the near infrared (0.5-2.5µm). LWIR has the ability to detect many fundamental rock forming silicate minerals (i.e. quartz, feldspar, garnet). Understanding the nature of the information obtained from the LWIR aids in the processing and interpretation of the data. There are many challenges in the interpretation of combined infrared wavelength data on rocks. These have been previously highlighted by Green and Schodlok (2010). The greater variability encountered in the LWIR measurements complicates data interpretation. For this study, data have been obtained on the same pieces of drillcore from several different sensors measuring across similar, and different, wavelength ranges. These datasets allow a review of what information is possible to extract from the LWIR for these rock types. They also allow different wavelength ranges to be reviewed in terms of their geological content. These results confirm the complementary and supplementary nature of wavelength ranges of the infrared. The minerals and their associated assemblages have a significant influence on the sensor resolution requirements.

Further developments need to consider different rock types and other geological problems where the LWIR may be considered valuable. There are still many questions that need to be answered before the LWIR can be considered as a developed infrared drillcore imaging technology. Some of these questions relate to methods for extraction of geological information from the data, how to integrate this data with other infrared wavelength ranges, and what information is required to provide answers to the geological questions proposed. None the less, we see the LWIR as an important strategic dataset in many future drillcore imaging applications.

References

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Harris, P., Buxton, M., Linton, P., Holma, H., Bars, R., and Karjalainen, H. (2009) Longwave Infrared Imaging of Drillcore: Is it Possible and Practical? GRSG Conference Presentation, London, December 2009.

Hyperspectral Applications in Southern Africa

Alex Fortescue

Southern Mapping

Corresponding Author e-mail: alex@southernmapping.com

This paper will describe how hyperspectral imagery is being applied to real world problems in South Africa. It will include the technologies potential in assisting the Acid Mine Drainage (AMD) problem in Gauteng province South Africa. It will also include results from a recent Southern Mapping/SpecTIR campaign in Southern Africa which include the following Application areas

Asbestos mapping
Hydrocarbon spill assessment
Alien vegetation monitoring (*Acacia Mearnsii* and *Eucalyptus spp*.)
Mine Rehabilitation monitoring
Mineral mapping
Water quality assesment

Using high resolution terrain information from stereo imagery for monitoring and surface analysis

Andy Garratt

Intergraph | ERDAS

Corresponding Author e-mail: andy.garratt@intergraph.com

Sophisticated algorithms within LPS eATE for generating and classifying dense elevation surfaces allow collection of information clouds from stereo imagery with applications such as volumetric extraction from open mines, pipeline monitoring, monitoring geohazards etc. Information clouds can be analysed within powerful new tools developed by ERDAS | Intergraph, turning data into actionable information. The new Solution Builder will Integrate vector operators from Intergraph GeoMedia and raster operators from ERDAS IMAGINE to build a combined powerful analysis capability, supporting Python scripting and web based geo-processing (WPS) with ERDAS APOLLO.

3.4. Posters & Rapidfire Presentations

	Author	Organisation	Title
	Simone Pascucci	(CNR IMAA)	The CNR IMAA airborne TASI-600 hyperspectral thermal spectrometer, a new tool for geological application: first test site results
	Andre Bos	Pims International	Space Assets For Pipeline Integrity Management (Pims)
	Fabrizio Barone	Uni. Of Salerno	Compact Tunable Monolithic Sensors For Very Low Frequency Seismic Noise Monitoring And Sites Characterization
	Federico Raspini	Uni. Of Firenze	Urban Subsidence In The City Of Rome (Italy) Detected By Satellite Radar Interferometry
	Lorenz Wendt	Freie Universitaet Berlin	The Geology Of Mars Using Color & Panchromatic Imagery Together With Hyperspectral Imagery
	Michael Denk	Uni. Halle.	Comparison Of Field Spectra And Hymap Spectra In Terms Of The Detection Of Gypsum – A Case Study In A Small Scale Heterogeneous Environment
	Nasos Argyriou	Uni. Of Portsmouth	Detecting Neotectonic Deformation In Landscapes Using Freely-Available Satellite Data And Geomorphometrics
	Natasha Stephen	Imperial College	Building A Martian-Specific Mineral Database; Using Terrestrial Analogues Alongside The Analysis Of Martian Meteorite Samples To Characterise Individual Mineral Spectra
	Peter Gyuris	Geonardo Ltd.	Monitoring Mining-Related Environmental Impact (Impactmin); Examples From Russia, Bosnia&Herzegovina, Romania And Sweden
	Sam Murphy	University Of Campinas Brazil	A Synergy Of Orbital Sensors For Volcano Monitoring
	Sjef Meekes	TNO	Heterogeneous Gravity Data Combination For Geophysical Exploration Research: Linking Satellite Gravity Gradients To Basin Maturity
	Stefania Amici	INGV	A Thermal Eye On Uas System
	Tony Roache	CSIRO	Application Of Short Wavelength Infrared Spectroscopy For Very Low-Grade Petrology Of Phyllosilicates
	Veraldo Liesenberg	Tu Bergakademie Freiberg	Characterizing Indonesian Peat Swamp Forest Physiognomies With Multiple Remote Sensing Data

3.5. OGEO: Data

Access to EUMETSAT data

Dr. Harald Rothfuss

EUMETSAT

Corresponding Author e-mail: harald.rothfuss@eumetsat.int

EUMETSAT operates a system of meteorological satellites monitoring the atmosphere and ocean and land surfaces which deliver weather and climate-related satellite data, images and products – 24 hours a day, 365 days a year. Key to the EUMETSAT mission is the commitment to the delivery of data originating from these operational weather satellites. To achieve this, efficient processes for the collection, storage, cataloguing and dissemination of the data are in place, and user interfaces available to enable easy access to the data.

EUMETSATs near-realtime data distribution services are provided via EUMETCAst, a satellite-based transmission system using off-the shelf DVB technology and commercial telecommunications satellites. Through trusted partnerships, EUMETSAT is engaged in the exchange of data between Europe, the Americas and Asia-Pacific. Using the GEONETCast network, of which EUMETCast is one component, these data are delivered in near-real-time to users world-wide.

Historical data from EUMETSAT satellites are archived in the EUMETSAT Data Centre and made available through an online ordering system. The Data Centre provides users easy and free access to historical data and products of Meteosat, Metop, Jason-2 and NOAA satellites. These data are delivered via FTP and offline media. As the central node in the existing Archive network with the Satellite Application Facilities (SAF), the EUMETSAT Data Centre hosts a central ordering catalogue, comprising all entries of products generated in the SAF's and the Central Application Facility at EUMETSAT.

The EUMETSAT EO Portal offers a harmonised user interface to all EUMETSAT's near-real-time and on-demand services. The Product Navigator is the central online catalogue listing all data and services provided by EUMETSAT and facilitating the discovery of and access to Earth observation data. It allows product searches according to keywords and provides descriptions and metadata on the products, including information on delivery mechanisms. The EO Portal also allows users to register for all EUMETSAT data services through one single sign-on.

The paper will present an overview of the user related data access mechanism at EUMETSAT with a focus on archived data.

Quality, Standards and Protocols – Working towards certified services based on Earth observation and remote sensing

Andreas Müller
Martin Bachmann
Stefanie Holzwarth

German Aerospace Center (DLR), German Remote Sensing Data Center (DFD

Corresponding Author e-mail: Stefanie.Holzwarth@dlr.de

When working with remote sensing data and derived products from different data providers operating diverse sensors, it is often difficult or even impossible to directly compare the data and to evaluate the quality of the data. Currently, there is a huge heterogeneous pool of remote sensing data available to the user. This includes different ways of handling the processes involved in Earth observation measurements, from sensor calibration, system correction, atmospheric and geometric correction to information extraction and classification. With the advent of operational remote sensing services (e.g., within GMES) there is a strong push towards the introduction of standards and protocols to ensure well documented and standardized data products, and to enable easier exchange and comparison of data. This need is also illustrated by the QA4EO initiative as a contribution to GEOSS (Global Earth Observation System of Systems), and the CalVal activities of the Committee on Earth Observation Satellites (CEOS).

DLR can demonstrate a long-time experience within the field of certifying services for Earth observation (e.g. Ground Station Services, Optical Airborne Remote Sensing Service, Data Information and Management Services), and is also involved in several international initiatives towards standardization and harmonization (e.g. EUFAR). This talk will give a brief overview, how standards can be achieved within a certain field of interest (e.g. remote sensing products for the oil and gas industry). Different options to obtain harmonization at various processing levels will be illustrated. A major focus will be given towards common metadata.

3.6. OGEO: Leveraging EO for Oil Spill Detection, Monitoring & Mitigation

Future needs in the Oil & Gas Industries

Jean-Paul Xavier

TOTAL S.A.

Corresponding Author e-mail: jean-paul.xavier@total.com

For many years, Remote Sensing techniques were well developed in the oil and gas industries. Their interest was concentrated on visualization and morphological analysis of the surface, using the resources of space programs such as Landsat or Spot. The advent of high resolution satellite or the systematic developments of radar sensors combined with a new data policy from space agencies has significantly changed the characteristics of the data and provided easier access to new information or parameter. Thus, many users have used this information and, consequently, new operational requirements have emerged. Various applications are used, now, on the whole process from exploration to production and taking into account environmental constraints. The main need is based on cross-applications due to a large sample of sensor, processing and application and related to dedicated systems that meet specific requirements by mean of radical change in technology. Some needs are listed below:

Environmental needs include precise baseline studies for environmental impact statements and quantification of the effects of oil and gas operations on the environment. Even, parameters in climatology and oceanology are required more frequently and with more precision. A worldwide and real time access is a major issue for the monitoring of installations. The characterization and quantification of the near surface objects is a major target for exploration evolution. New sensors to detect low clues warning the evidence of hydrocarbon is a challenge that Remote Sensing will have to face. Business strategy and organization will have to evolve towards an internal development of business-oriented studies and R&D activities based on short terms operational objectives and, an external need for highly technological companies to outsource the rest.

The presentation will detail these methods concerning petroleum activities and will point out the principal needs for an intensive development of the Remote Sensing techniques.

Satellite Monitoring of Drilling Operations Offshore French Guiana

Martin Insley[1]
Joe Plunkett[2]

1) Tullow Oil, 9 Chiswick Park, 566 Chiswick High Road, London, UK

2) Number 1, Central Park, Leopardstown, Dublin 18, Ireland

Corresponding Author e-mail: Martin.Insley@tullowoil.com

A combination of microwave and optical satellites has been successfully used to monitor Tullow Oil's exploration drilling in the Guiane Maritime License offshore French Guiana. The duration of the monitoring programme was 9 months and involved the acquisition of radar images every 1-3 days and Quickbird optical imagery every 7 days depending on cloud-cover.

In order to achieve better than every third or fourth day coverage of the drilling location a constellation of microwave satellites including Radarsat-2, TerraSAR-X and Cosmo SkyMed were necessary. Microwave sensors ensure reliable imaging of the sea-surface conditions and associated features because of their sensitivity to subtle variations in surface texture. Radar data is therefore routinely used for detecting oil slicks related to pollution or natural seepage from the sea bed. Microwave sensors can acquire imagery both day and night irrespective of cloud cover. The X-band Cosmo SkyMed and TerraSAR-X data was found to be susceptable to poor atmospheric conditions resulting in poorer image quality than the C-band Radarsat-2.

The primary aim was to regularly monitor a 25km radius around the drilling location although images generally cover an area of 10,000 sq km and provide an overview of the regional sea surface and atmospheric conditions as well as monitoring of shipping activities in the area. AIS data from the rig was used to identify vessels in the area. Information on wind speed and direction, wave height, ocean current speed and direction were integrated into the project and used to validate the radar data and interpretation.

This is the first time a satellite based monitoring programme has been implemented for an offshore area by Tullow. The Norweigen company Kongsberg Satellite Services (KSAT) was selected to provide the monitoring service due to their unique position of ground receiving stations and established track record of routine surveillance for oil spills. Notification of the results of each analysed radar image was received via email and text, and via telecom in the event of an anomaly being detected on the radar imagery. Imagery was available to view via a web browser. Delivery times ranged from approximately 30-200 minutes in the case of Radarsat-2; 1.5-9.0 hours for Cosmo SkyMed and 3.0-13.25 hours for TerraSAR-X data. Turn-around time from receipt of data by KSAT was consistently less than 30 minutes.

This paper provides a summary of the results of the monitoring programme including the performance of the individual satellites and respective data providers, as well as contrasting image characteristics depending on data type i.e. wavelength, incidence angle, beam mode and spatial resolution. The project including acquisition of over 110 radar images and 10 optical images and provides an important baseline from which to evaluate the application of the service.

Understanding the phenomenology of liquid and gaseous hydrocarbon detections and its environmental impacts using ProspecTIR and SEBASS imagery

Wilson Oliveira
Carlos Roberto de Souza
Dean Riley
Guilherme Brechbueler de Pinho
Conrad Wright

Corresponding Author e-mail: **conrad@spectir.com**

The presentation contains the research and development undertaken by Petrobras utilizing two hyperspectral data sets for hydrocarbon detection and environmental monitoring. The work, in conjunction with SpecTIR, Fototerra Ltd, and Aerospace Corporation, was undertaken to understand the phenomenology of liquid and gaseous hydrocarbon detections and the environmental impacts of various normal pipeline and facility operations in Brasil with an AISA DUAL sensor operated by SpecTIR LLC and Fototerra Ltd. A second and controlled test at the Rocky Mountain Oil Test Center (RMOTC) in Casper, Wyoming utilized an AISA DUAL sensor, operated by SpecTIR, and SEBASS operated by Aerospace Corporation both co mounted in a single aircraft. Data were taken under controlled and uncontrolled conditions at various spatial resolutions. In the controlled experiment at RMOTC, while measuring various ground and atmospheric conditions, simulated gas leaks at various controlled flow rates were tested for detections as well as liquid hydrocarbon detections against a series of soil substrates. The following presentation aims to show the structure of the experiments, how this may be utilized in ongoing monitoring efforts worldwide, and the detection results considering the various conditions and substrates.

Maritime surveillance – related to oil rig operations

Sigmund Delhi

KSAT

Corresponding Author e-mail: sigmund@ksat.no

In this presentation KSAT will focus on maritime surveillance related to oil rig operations, both from a safety and security point of view.

In addition to present our highly operational and global oil-spill-monitoring services we will discuss why satellite data are a critical factor in supporting oil rig operations with regards to both safety and security. Covering oil rig operations and navigation support in ice-infested waters and vessel detection in piracy-infested areas are areas where use of satellite data are crucial for decision support.

Satellite imagery provides extensive coverage of the earth's surface, and has therefore become one of the most important sensors for operational near real time monitoring of the marine environment.
KSAT provides a fully operational maritime surveillance services and reports to the customer in near-real time.

KSAT provides a 24/7 operational maritime surveillance service world-wide. Synthetic Aperture Radar (SAR) imagery is used as the prime source of information, independent of cloud, fog and light conditions and with rapid delivery. Optical data is used when more detailed information is required.

The KSAT service is the most reliable, available and sustainable monitoring service in the world, due to long experience, number of available satellites, unique locations, highly skilled personnel and state-of-the-art infrastructure. The service has been developed in close cooperation with the users and satellite owners.

Offshore oil pollution preparedness, monitoring and response

Han Wensink
Oliver Muellenhoff
Jean-Paul Lindeboom

BMT ARGOSS

Corresponding Author e-mail: han.wensink@bmtargoss.com

Although many governments have ratified the IMO International Convention on Oil Pollution Preparedness, Response and Cooperation of 1990 (OPRC Convention), governments often have their owns laws and procedures to prepare and respond to oil spills. The industry needs to be fully aware of and compliant with those national laws in order obtain licenses and to limit their liabilities.

Mineral oil floating on the sea surface often originates from ships, oil rigs and natural oil seeps as well as from onshore sources like refineries and industrial facilities. Marine oil spills pose a risk to marine habitats and coasts in terms of ecological damage, socio-economic losses and influence on coastal industries.

Consequently, there is a need to set-up operational processes to rapidly and reliably detect, track, monitor and analyze oil spills and to predict their drift. The accidental pollution caused by ships and oil rigs in distress usually catches the imagination of publics and the dramatic consequences environment are widely illustrated and broadcast through mass media like the recent leakages in China's Bohai Bay in June 2011, in the North Sea in August 2011 and in New Zealand's coast in October 2011.

To detect, monitor and forecast oil spills at sea, airborne or Spaceborne Synthetic Aperture Radar in combination with oil spill trajectory models and accurate metocean data are required.

In this presentation a recent development will be shown of a new operational infrastructure where multispectral and SAR data, oil spill modeling and Metocean forecast and hindcast data are integrated into a 24/7 support centre to support tactical assistance in emergency cases and to enhance strategic and tactical decision-making to facilitate rapid oil recovery.

Remote Sensing as a tool in Emergency Preparedness & Response- Developments response industry would like to see to assist in responding to emergency oil spill response situations

Lucy Heathcote

Oil Spill Response Limited

Corresponding Author e-mail: LucyHeathcote@oilspillresponse.com

Oil Spill Response Ltd (OSRL) has been responding to oil spills since 1984. In recent years the quantification of oil on water has become an increasingly more prominent aspect of our operations with demands from regulators to understand accurate volumes to impose appropriate financial penalties and operators wanting to understand the size of the problem they already have and what their worst case may be.
Tools we already use:

Oil Spill Modelling, there are a number of programmes that are avaliable to be used either in the planning phase to identify areas at most risk in the event of an incident or during a spill to predict the most likely areas that will be impacted.

Development needed, the most challenging aspect of oil spill modelling to us is obtaining accurate current data on a worldwide basis especially 3D data.

Aerial Surveillance, used to 'monitor and evaluate' i.e. determine where the oil is and how it is behaving in the environment (naturally dispersing or emulsifying and increasing in volume for example). Aerial surveillance is also key in increasing the effectiveness of other response strategies.

Development needed, applications 'apps' to be able to accurately quantify oil on water.

Satellite Imagery, used to confirm the presence of spilt hydrocarbons in the marine environment (government use such as the 'cleansat') and quantify the amount of oil.

Development needed, the results of satellite imagery easily (for a non-GIS specialist) overlaid with modelling results and aerial surveillance outputs and locations of response assets deployed in field to produce a 'Common Operating Picture', a visual interpretation of the status of the spill within a GIS platform.

The presentation will look at the issues surrounding oil spill response and identify the key areas of opportunity for using remote sensing tools based on response scenarios from real incidents.

3.7. OGEO: EO Applications for the Oil & Gas Industry I

Remote Sensing Products for environmental assessment at offshore platforms and pipelines

Prof. Susanne Lehner
Stefan Brush

DLR – German Aerospace , Remote Sensing Technology Institute

Corresponding Author e-mail: Susanne.Lehner@dlr.de

Oil pollution due to accidental spill disaster and ship, tanker and offshore platform, either in open oceans or in coastal waters may have a severe impact on both the flora and fauna of the polluted area. The environmental damages on the natural resources and on the economy of the area in distress are almost always uncountable. Thus, there is a need to rapidly and effectively detect and monitor such source of pollution as well as predict oil spills drift.

Satellite radar (SAR) data are reliable for support response operations in case of maritime accidents and detecting and deterring illegal discharges from sea-based source. The TerraSAR-X, e.g., the ScanSAR image with swath of 100 km and spatial resolution of 18 m can significantly improve the detection of small spills both from stationary and moving probable source. The possibility to acquire dual-pol (in StripMap (SM) and SpotLight (SL) mode) data in the combination HH/HV, HH/VV and VV/VH gives the opportunity to better discriminate between oil spills and oil look-alikes.

In this work TerraSAR-X in ScanSAR (SC), StripMap (SM) and SpotLight (SL) in a choice of single or dual polarization for oil spill monitoring will be presented.

Application of Remote Sensing Technologies for Engineering for Onshore Pipelines in Active Dune Fields

Jason Manning[1]
Dr Matthew Free[1]
Dr Charlie Bristow[2]

1) Arup, 13 Fitzroy Street, London W1T 4BQ,

2) Birkbeck, University of London, Malet Street, London WC1E 7HX,

Corresponding Author e-mails: jason.manning@arup.com, matthew.free@arup.com, c.bristow@ucl.ac.uk

Remote sensing data and techniques provide essential tools to be utilised at all stages of oil and gas development projects: concept/feasibility; pre-FEED, FEED; detailed design; construction, and; operation/maintenance.

Development of oil and gas infrastructure projects in desert regions requires appropriate solutions to overcome the significant technical, operational and logistical challenges. Desert regions are far from benign and pose a wide range of geohazards that can have significant impact on engineering projects. Hazards include: mobile dunes, flooding, wadi scour erosion, aggressive soils, bedrock, rugged terrain and slope instability
Detailed assessment of these hazards is required to enable quantification of the hazards and allows for risk management measures to be developed, thus reducing project risk.

The mix of medium and high resolution optical imagery in conjunction with DEM datasets are key tools. These are supplemented by other techniques, as appropriate, including multispectral, hyperspectral, radar (SAR/InSAR), aerial survey photography and Lidar. Archive datasets are of significant value, such as Corona, dating back to 1960's, that allows for change detection analysis over more than 50 years (can be typical design life for some structures).

This presentation provides examples of use of different remote sensing techniques for geohazards related to dune fields, with particular emphasis on quantifying the hazard of dune mobility in active dune fields. Integrating variety of investigation techniques allows for development of conceptual geological models and greater understanding of potential hazards. For dune mobility this may include spaceborne radar (SAR/InSAR), ASTER and high resolution imagery, combined with conventional ground truthing, ground investigation and geophysical techniques, that can be used to determine details of internal structure of dunes to help determine geomorphological characteristics and a geological model.

Ground related risks and geohazards have significant impact on development costs, thus need to be carefully assessed in order to reduce risks and assist successful development of the project. Early identification of ground related risks allows for risk appropriate risk management strategies to be implemented in a timely and efficient manner.

Satellite based impact monitoring in coastal and offshore applications: Advantage and examples of harmonized and automated monitoring approaches

Thomas Heege

EOMap

Corresponding Author e-mail: heege@eomap.de

Satellite observations significantly increase the validity of baseline and environmental impact surveys by means of conceivable area wide records, if well resolved in space and time. Such approaches have been time consuming, costly and challenging for the quality assessment when integrating several satellite resources. New standardized, sensor independent, automated approaches decrease costs and the product generation time significantly.

The physics based production technology and the service provision concept is presented, with several application examples to illustrate these advantages.

Examples comprise of multi-sensor water quality mapping e.g. for dredge impact monitoring, oil spill monitorig and bathymetry mapping. Furthermore, baseline, change detection and impact surveys for submerged habitats as well as for onshore construction sites profit from this concept.

Fostering Increased Adoption of Remote Sensing Technology for Sustainable Oil and Gas and Mining Activities in Northern Environments

Dennis Nazarenko
Paul Adlakha

LOOKNorth

Corresponding Author e-mail: dennis.nazarenko@looknorth.org

The challenges of sustainable resource development in Northern environments amid traditional cultures, sensitive environments and increasing concerns about the impact of climate change represent a forum for remote sensing innovation. The process by which appropriate technology is introduced and adopted by industry is frequently more random than intentional.

LOOKNorth is a Canadian designated Centre of Excellence for Commercialization and Research (CECR) that is focused on fostering the adoption of remote sensing applications for sustainable development of Canada's Northern resources. LOOKNorth accomplishes this through an integrated set of programs including sector assessments, outreach, technology validation and R&D initiatives.

LOOKNorth has identified key resource sectors including oil and gas and mining where challenges in exploration, development, and operation are frequently made more complex in cold, remote environments. These challenges exist for the resource industry across the North regardless of national boundaries.

The presentation addresses the process LOOKNorth is pursing and also looks at the synergy with related European efforts to foster broader resource industry adoption of remote sensing technologies.

Finally opportunities for collaboration between Canadian and European initiatives are proposed.

Spectral Responses of Eucalyptus Trees Submitted to Natural Hydrocarbon Seepages: An Integrated Approach from Leaf- to Canopy- Scales

Lucíola Alves Magalhães[1]
Carlos Roberto de Souza Filho[1]
José de Oliviera[2]

1) UNICAMP

2) Petrobras

Corresponding Author e-mail: beto@ige.unicamp.br

The São Francisco Basin, in central Brazil, displays several hydrocarbon (gas) seepages. Among the most intensively investigated in recent years are those located in the Remanso do Fogo area (Minas Gerais State). This area has flat terrain and sandy soils, covered by *Eucalyptus spp*. (*Eucalyptus*) plantations. This paper aims to characterize spectral modifications on leaves induced by hydrocarbons gases using the hyperspectral sensor ProSpecTIR-VS (357 bands from 400 to 2500 nm, 1 m spatial resolution) and the portable, FieldSpec Full Resolution (> 2000 bands, 400 to 2500 nm) spectrometer.

Digital image enhancement allowed the identification of spectrally anomalous areas related to geobotanical anomalies, highlighted by the employment of the chlorophyll a index (R807/R638). Field checking of these anomalies shows that eucalyptus trees in these areas are poorly developed, with foliage loss or simply do not grow. Additionally, the vegetation indices MSI (R1599/R819), SIPI ((R800-R445) / (R800-R680)) and CSE (R694/R760) were tested. A ternary composition R (CSE) G (MSI) B (SIPI) demonstrated a lateral variation in photosynthetic pigments and leaf water content. The eastern portion of the study area is dominated by healthy vegetation in contrast to the western portion, which showed high concentrations of gas and stressed vegetation. An average of 256 pixels in ten points provides spectral signatures used for a comparison with the leaf's signatures collected *in situ*. The results derived at canopy scale were significantly similar to the spectral signatures at leaf scale, excluding the near infrared (NIR) and the end of the shortwave infrared (SWIR). At 676.8 nm (chlorophyll absorption feature) the reflectance of stressed vegetation was 373% higher than the healthy equivalent. Between 1166 to 1172 nm the recorded increase was 12%. Also, there is a reflectance increase between 1441 to 1479 nm (137.5%) and between 1836 to 1937 nm (469%), which comprise water absorption regions. These are the mainly spectral regions that present the greatest variations in canopy reflectance. Leaves spectra recorded an increase of 233% at 676 nm, while no significantly variations were observed in the NIR. At the SWIR, the reflectance increased 18.5% and 78.5% at 1434 nm and 1920 nm, respectively. The ATCOR radiometric calibration of ProSpecTIR applies a linear interpolation in the 691-836.4 nm and a non-linear interpolation in the 880-995 nm, 1103-1178nm, 1335-1491 nm and 1786-1969 nm parts of the spectrum.

Although these bands are mathematically estimated they show high correlation with reflectance value obtained in the field using a portable spectrometer. There was also an increase in reflectance at 1774 nm (3%) (lignin absorption feature), in the triplet between 2275 and 2350, centered at 2307nm (5.5%) and at 2460 nm (7%) (cellulose absorption features). Throughout the SWIR, the increase in reflectance indicates a fall in leaf water content and biochemical compounds (lignin and cellulose) with increasing chlorosis. Canopy spectra were analyzed by principal component analysis (PCA) which allowed the separation of them into five groups using the score plots of PC1 vs PC2. Three groups comprise points located in the western portion of the image, representing stressed vegetation, whereas the other two groups include points located in the eastern portion of the image where there are no gas anomalies. PCA indicates that SWIR (with maximum value at 1894 nm) and visible (with maximum value at 672 nm) bands are key to distinguish between stressed and non-to less-stressed vegetation. These results support the efficient use of vegetation remote sensing in prospecting activities of hydrocarbon seepages.

3.8. OGEO: EO Applications for the Oil & Gas Industry II

TerraSAR-X - A Spaceborne Toolbox for Oil/Gas Exploration and Monitoring

Lutz Petrat
Dr. Gertrud Riegler
Frank Teufel

Astrium GEO-Information Services

Corresponding Author e-mail: lutz.petrat@astrium.eads.net

TerraSAR-X SAR satellite started its operation at the beginning of 2008. Since then, the sensor has demonstrated its suitability in a broad range of applications related to oil- and gas exploration, production and storage. This contribution summarizes some technical principles and examples arising from the experience collected at Astrium GEO-Information Services, so far:

For exploration purposes, TerraSAR-X' capacity for collecting cloud as well as day/night independent information about topography and terrain heights allows a quick provision of background information for planning and scouting of geophysical or geological surveys. These applications are strongly supported by the high reliability of TerraSAR-X data acquisition, high geolocation accuracy as well as its capability to acquire also radargrammetric datasets for the generation of digital surface and - terrain models. This is just the "preparative" step for the upcoming TanDEM-X digital elevation model, which will be globally available off-the-shelf from 2014 on. The high geolocation accuracy of TerraSAR-X is also a unique character which allows the derivation of ground control points in the field - without accessing sometimes remote and difficult terrain. TerraSAR-X ground control points can be used for the establishment of a proper geodata base having contributions also from less precise remote sensing data sources or historic terrestrial data (e.g. seismics).

During production, the sensor is useful for monitoring oil- and gas production, through related surface movements: The high spatial and temporal resolution of TerraSAR-X data in conjunction with reliable data acquisition enables proper monitoring of the production process, especially if used for the improvement of existing geomechanical models. Furthermore, its capability for pipeline and oil-rig monitoring with regards to slicks or environmental risks can be stated. In a potential phase for storing natural gas or CO2 in underground formations - the latter in context with Carbon Capture and Storage (CCS) - TerraSAR-X based radarinterferometry could be used for monitoring the spatial and temporal development of the underground pressure plume.

Latest result for a natural gas storage site show, that even the derivation of the gas-water contact in the underground formation is possible, if information about well pressure is available from the site. As such a direct link even to the behaviour of the gas plume is apparently possible and TerraSAR-X can really be considered as geophysical instrument - operated from space.

20 years of oil routes

Serge Riazanoff

VisioTerra

Corresponding Author e-mail: serge.riazanoff@visioterra.fr

To celebrate the 20 years of the launch of ERS-1, the first European satellite carrying a SAR instrument, a very large amount of radar data is being processed to automatically extract oil slicks observed offshore. New algorithms have been developed to enable equidensity rendering of the radar backscattering and to automatically extract and classify oil spills released by tankers, large oil spills from platforms up to small oil seeps.

Operational applications for the Oil and Gas industry measuring ground motion with radar satellites (InSAR)

Alain Arnaud
Johanna Granda
Blanca Payàs

Altamira Information

Corresponding Author e-mail: johanna.granda@altamira-information.com

InSAR (Interferometry for Synthetic Aperture Radar) technology is a spaceborne measurement method that uses radar satellite images to detect and measure ground deformation with millimetric precision. Measurements are taken remotely from space, making this an appropriate tool for measuring ground motion in difficult to reach remote areas and in almost all weather conditions, during day or night.

The Stable Point Network (SPN) is an advanced differential interferometric chain which was developed by Altamira Information in order to process several raw radar images to achieve millimetric ground motion measurements. Ground motion monitoring with radar images can contribute to oil & gas reservoir monitoring in several ways:

For oil & gas extraction areas, InSAR ground motion results support site safety since risk areas can be identified at an early stage.
For Enhanced Oil Recovery, millimetric ground motion monitoring is able to contribute to safety and production efficiency: By mapping ground motion elevation changes over the whole area, InSAR measurements can aid the assessment of whether the pressure of injection is correctly distributed over the area.
For Carbon Capture and Storage (CCS) areas, InSAR technology is used in order to monitor the CO_2 plume. Possible detected abnormal movements might be caused by seismic fault reactivation due to CO_2 injection or production operations. By inverting InSAR measurement results and feeding them with into a geo-mechanical reservoir model, macroscopic flow characteristics such as the pressure location and horizontal permeability anisotropy can be estimated.
Another application for Oil & Gas is the monitoring of infrastructures situated in unstable areas, e.g. coastal areas near the sea. A typical example is the monitoring of LNG terminals, often located in ports. Monitoring of ground motion of LNG terminals can be crucial for the safety of operations.

The different applications will be illustrated with international case studies. The comparison of results in very different regions in the world will present the advantages and also the limitations of InSAR technology. All presented technical applications are already fully operational and currently in use by major oil & gas players.

Joint analysis of PSInSAR and repeated leveling data for monitoring ground motions in the Romashkino oil exploration area (Russia)

V. Mikhailov[1]
Yu. Kuzmin[1]
V. Golubev[1]
P. Dmitriev[1]
E. Kiseleva[1]
E. Smolyaninova[1]
R. Gayatullin[2]
A. Baratov[2]
P. Koshurkin[2]
M. Rahmatullin[2]

1) Schmidt Institute of physics of the Earth, Russian academy of sciences, Moscow, Russia

2) Tatneft Group

Corresponding Author e-mail: mikh@ifz.ru

Romashkino oil fields are situated in the central part of the East-European platform. Extensive continuous exploration activity results here in ground motions and technogenically induced seismicity. Seismological monitoring started here in mid- 80th, repeated leveling profiles were established in 1991. Regional profiles were served in 1992-1993 and during 2001-2006. Measurement campaigns at local profiles were performed at 1992 - 1993, 1995, 1996, 1998 - 2006.

We used ERS and ENVISAT images covering Almetievsk city delivered by ESA under C1P # 9664 project. These images cover periods of 1992 – 1995 and 2003 – 2009 years and permit joint analysis of displacements recovered from satellite and surface data. Displacement fields are very complicated in space and time in result of continuous oil extraction and pumping of fluids. Comparison of surface and satellite data is sophisticated because repeated leveling characterizes vertical displacements in benchmarks which probably move in horizontal direction when SAR data provide displacements of persistent scatterers in LOS direction. The paper presents technique and result of joint analysis of the both sets of data based on mathematical modeling of exploration process.

Quantitative comparison of methods and sensors for monitoring land subsidence phenomena based on satellite SAR interferometric stacking

Paolo Pasquali[1]
Paolo Riccardi[1]
Alessio Cantone[1]
Marco Defilippi[1]
Fumitaka Ogushi[2]
Stefano Gagliano[3]

1) sarmap SA, Cascine di Barico, CH-6989 Purasca

2) ITT Visual Information Solutions K.K., Tokyo, Japan

3) ITT Visual Information Solutions, Italia, Concorezzo, Italy

Corresponding Author e-mail: paolo.pasquali@sarmap.ch

Interferometric stacking techniques emerged in the last decade as methods to obtain very precise measurements of terrain displacements, and in particular subsidence phenomena. In particular, the so-called Persistent Scatterers (Ferretti et al. 2001) and Small BASeline (Berardino et al. 2002) methods can be considered as the two most representative stacking approaches.

In both cases, the exploitation of 20 or more satellite Synthetic Aperture Radar (SAR) acquisitions obtained from the same satellite sensor with similar geometries on the interest area allows to measure displacements with an accuracy in the order of few mm / year, and to derive the full location history of “good” pixels with an accuracy of 1cm or better for every available date. A main difference between the two approaches is the type of objects and land cover that are favoured in the analysis: the PS technique focuses on so-called Point Targets, i.e. objects possibly of small size and with a very well characterized geometry like corner reflectors (e.g. buildings, rocks) and with a high temporal stability of the backscattered signal; the SBAS technique vice-versa is concentrating the analysis on so-called distributed targets, like open fields and not very geometrically characterized objects. The PS approach is then not making any assumption on spatial correlation of the displacement to be measured, but more on its linearity; the SBAS approach vice-versa is more robust in case of spatially correlated displacements, and allows in this case to monitor larger displacement rates.

This paper is performing an extensive analysis and comparison of the results that have been obtained with the two approaches in a same geographical area in Japan, characterized by subsidence due to water and natural gas extraction. The analysis is based on data acquired from the ALOS PALSAR (L-band), ENVISAT ASAR (C-band) and COSMO-Skymed (X-band) satellite instruments, and the validation of the results is based on GPS and leveling measurements.

The analysis allows to draw conclusions on pros and cons of the different approaches and sensors for deriving the displacement measures for monitoring subsidence phenomena. The feasibility of exploiting the same approach in different geographical areas is also discussed. Finally, comments are given on the outcomes of this analysis in view of the exploitation of the data to be available from the forthcoming Sentinel-1 (C-Band) and PALSAR-2 (L-Band) missions.

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Standards and Guidelines for the use of Satellite based ice information in the Oil and Gas Sector

Des Power

C-Core

Corresponding Author e-mail: des.power@c-core.ca

3.9. Geology & Mineralogy

The Potential of Hyperspectral Techniques for Geological Mapping and Mineral exploration

H. Kaufmann
K. Segl
Ch. Rogass
S. Chabrillat
A. Eisele

German Research Centre for Geosciences (GFZ)

Corresponding Author e-mail: charly@gfz-potsdam.de

For the detection and quantification of minerals such as clays, micas and carbonates, to name a few, hyperspectral remote sensing has a tremendous impact in lithological mapping, exploration and discrimination of minerals and their typical assemblages in hydrothermally altered areas (propylitic, argillic, sericitic, potassic). Furthermore, it has the potential to become an efficient and operational tool to monitor both, the effects of environmental hazards and the progress made in the rehabilitation of affected mining sites.

Presently, these tasks are tackled by use of recent operating multispectral satellite systems or by hyperspectral sensors mounted in aircraft carriers. Thus, the possibility of imaging spectroscopy to provide more frequent and better information about the Earth system than given by traditional multispectral instruments is currently not counterbalanced by an equivalent availability of space-borne spectroscopy data.

However, there is a number of super- and hyperspectral instruments proposed or under construction to fill this gap in the future. One of these is "The Environmental Mapping and Analysis Program" (EnMAP), a German hyperspectral satellite scheduled for launch in 2015. EnMAP will sample an area of 150.000 km^2 per day with a ground sampling distance of 30m x 30m, measuring contiguous spectra in the 420-2450 nm range with a sampling rate of 6.5nm (VNIR) to 10nm (SWIR). EnMAP is designed to record physical, bio-chemical and geo-chemical variables on a global basis to allow for a detailed analysis of surface parameters and to increase our understanding of biospheric/geospheric processes and to ensure the sustainability of our resources.

The presentation focuses on the spectral significance of minerals, rocks, soils and hydrocarbons, associated processing and analysis techniques and derived definitions for the sensor parameters of EnMAP.

Discrimination and Mapping Types of Alunita Using ASTER Sensor: Experiences in the Peruvian Andes

Christian Vargas Gonzales
Remote Sensing Geoimage

Corresponding Author e-mail: cvargas@rs-geoimage.com

This paper presents the methodology and results in discrimination and mapping of minerals, with special emphasis on the discrimination of types of alunite.

L1B ASTER images were used. The pre-processing was to make the correction of the crosstalk effect. The orthorectification and the integration of subsystems VNIR and SWIR. The atmospheric correction was done using a proprietary method, which corrects the influence of aerosols and water vapor in the ASTER data.

The reference spectral library was Splib06a of the USGS. The spectral patterns were resampled to the spectral resolution of the ASTER. The spectra of the different types of the alunite are characterized by absorption in the band 5 and presented slightly different reflection in the bands 4, 7 y 8.

The identification of alunite in the ASTER image was made using the Pixel Purity Index technique and using ratios and b7/b5 b4/b5. It was identified and mapped: alunite, natroalunite, K-alunite, ammonioalunite, ammoniojarosite, supergene alunite and other minerals typical of argillic and phyllic alteration. These maps were used to prioritize targets of advanced argillic alteration.

Hyperspectral mapping for the Mexican Geological Survey using ProspecTIR

Israel Hernández Perez[1]
Javier Sanchez Lara[1]
Conrad Wright[2]

1) Servico Geologica Mexico (SGM)

2) SpecTIR

Corresponding Author e-mail: conrad@spectir.com

The Geological Service of Mexico (Servicio Geologia Mexico -- SGM), as part of their natural resource development program, has initiated a robust hyperspectral mapping initiative to produce mineral mapping products, a field spectral database, and related airborne data. The presentation will describe the SGM natural resource program to include all available geophysical databases/products, the airborne hyperspectral solution, a sample of the hyperspectral data/mapping products, the overall goals of the program, and the efforts SGM is taking to ensure a high data quality. The airborne hyperspectral solution, to include technical support and training to SGM has been provided by SpecTIR LLC of Reno, NV USA. The solution presented includes a dedicated Beechcraft King Air 90, a fully integrated SpecTIR AISA DUAL sensor, a customized Ground Processing Unit (GPU), all related software for data processing/exploitation/analysis, and a modular training curriculum for airborne & ground hyperspectral operations, data processing, spectral geology, and data exploitation.

Integrated Remote Sensing, Geochemical and Isotopic Studies for understanding Hydrocarbon-Induced Rock Alterations

Shuhab D. Khan[1]
Ana Petrovic[1]
Allison K. Thurmond[2]

1) Department of Earth & Atmospheric Sciences, University of Houston

2) StatOil, Postboks 7200, NO-5020 Bergen, Norway

Corresponding Author e-mail: sdkhan@uh.edu

Our recent work in the Patrick Draw area of Wyoming and Paradox basin in Utah, identified characteristic rock alterations, mineral assemblages and chemical changes in areas affected by hydrocarbon microseepages. In an attempt to understand the relationship between microseepages and rock alterations, altered and unaltered Wingate Sandstone outcrops in Lisbon Valley, Utah were studied in detail. The Spectral Angle Mapper method was applied on HyMap hyperspectral data to classify the extent of altered and unaltered outcrops, as well as to map the changes in mineral content within the outcrops. The Spectral Feature Fitting method was used to identify lithological changes in the area. Reflectance spectroscopy, thin section studies, major, minor, and trace element analyses, and stable carbon and oxygen studies on both bleached (altered) and unbleached (unaltered) samples were successfully used to delineate areas of similar rock composition and relate changes due to hydrocarbons leaking from underlying petroleum reservoirs. Unbleached Wingate Sandstone samples had higher hematite and feldspar content than bleached Wingate samples, which were characterized by larger amounts of clay, calcite, and pyrite. Some bleached samples also had higher concentrations of elements (U, Mo) characteristic of hydrocarbon-related reducing environments, and were depleted in ^{13}C when compared to the unbleached samples. Based on these results, the following model of chemical reactions is suggested for diagnostic changes within Wingate Sandstone. Hydrocarbon-induced reducing environment caused the transformation of sulfate ion (obtained from groundwater or from oxidation of H_2S) to sulfide ion, resulting in the reduction of hematite to pyrite. The released hydrogen ion from this reaction reacted with available feldspars in the rock, leading to precipitation of kaolinite. These conditions favor the reaction between bicarbonate ion and Ca^{2+} ions that can be obtained from the groundwater, leading to precipitation of calcite in pore spaces left open after the reduction and removal of hematite.

Lithological Mapping Of The Sarduiyeh Area, Se Iranian Copper Belt, Using Thermal Bands Of The Aster

Hosseinjani M
Tangestani M.H

Dept. of Earth Sciences, Faculty of Sciences, Shiraz University, 71454 Shiraz, Iran

Corresponding Author e-mails: mh.hosseinjani@gmail.com, tangestani@susc.ac.ir

The study area is situated in the southern part of Central Iranian volcano-sedimentry complex, southeast of Kerman province. The dominant lithological units exposed at the area include felsic and mafic igneous rocks and the carbonate masses as well. The thermal bands of ASTER L1B and the AST- 05 datasets were used to map lithological units. The thermal bands of L1B were atmospherically corrected and converted into the emissivity using Reference Channel, Emissivity Normalization and Alpha Residual algorithms. In order to map lithological units the band ratio and spectral angel mapper (SAM) algorithm were implemented on the L1B calibrated datasets and the AST- 05. The spectra were derived from the image using spectral endmember selection procedure including minimum noise fraction (MNF), pixel purity index (PPI) and n-dimensional visualizer. Results were compared with the geological map of the study area to determine the accuracy of discriminated areas. The output results obtained from the Reference Channel, Emissivity Normalization and AST_05 dataset were similar in discriminating the lithological units of the area, but the output image of the Alpha Residual calibration could not identify the lithological units. The band ratios 13/14, 13/11 and 12/13 could successfully discriminate carbonate, felsic and intermediate-mafic rocks. The Spectral Angle Mapper algorithm shows reliable results and discriminates felsic, intermediate to mafic, carbonates and sandstone units from each other. It is concluded that atmospheric-calibrated thermal infrared bands of ASTER as well as AST_05 dataset can successfully be used for geological mapping at the areas dominant of felsic to mafic rock units.

Structural approach combining ALOS PALSAR linear feature extraction with field structural and geophysical investigations

Veronika Kopačková[1]
Jan Franěk[1]
Kryštof Verner[1]
Karel Martínek[1]
Michal Tesař[2]

1) Czech geological Survey, klárov 3, Prague 1

2) G-IMPULS Praha spol. s r.o., Přístavní 24, 170 00 Prague 7

Corresponding Author e-mail: Veronika.Kopackova@seznam.cz

Mapping geological structures in heavily forested terrains is a difficult and complex task requiring a great knowledge across geological disciplines about a region and synthesis on geological data collected in the field (ground truth). Quality of a map depends on how well and to which extend geologists has explored an area of the interest and, of course, on individual geological experience and knowledge of a mapping expert. In the past geological mapping was much more subjective, thus individual maps had a great degree of information inconsistency that reflected the variability of geological attitude from one geologist to another one and from one geological school to another one as well. At the present time a big emphasis has been put on increasing objectivity in geological mapping and on making the geological interpretation more exact. Fast progress in space technologies brought another expansion and dimension in collecting information about the Earth property including also the geology. At this point Earth Observation (EO) data can significantly contribute in terms of geological map information consistency as giving synoptic, continuous and interdisciplinary information about whole regions and as enabling to interpret structure and geological information in more logical way.

The objective of our work was to develop and validate a technique that employs new computer-based extraction of the information on geological structures (faults, joints, fractures etc.) from radar data (ALOS PALSAR) at a regional scale. The authors assumed that real fractural systems, discontinuity and fault planes appeared in a digital image as spatially structured and oriented systems of small linear features (micro-lineaments). In order to minimize subjectivity in the lineament interpretation the first step was to develop a reliable computer based technique how to automatically extract these features from a satellite image and how to further assess their geospatial pattern. Supplementary, routinely used visual interpretation of DEM was conducted. Lineament features detected by both approaches were further validated and sorted out by analyzing ground truth data sets: structural field data and information resulting from geophysical field profiling. The new method based on ALOS PALSAR processing showed a great accordance with the validating data, especially with the field geophysical investigations.

3.10. Advances in New Technology for the EO Industry

EarthImages: a new satellite image planning and access service tailored for the oil and gas sector

Kim Partington
Felipe-Martin Crespo
Thomas Lefort

EarthImages

Corresponding Author e-mail: kim.partington@polarimaging.co.uk

EarthImages is a integrated web-based satellite image search, ordering and access facility that is under development through a newly established company based at Harwell in the UK. The origin of the service lies in the frustrations of organisations, including oil and gas companies, who find it extremely difficult and complicated to select, order and access imagery from multiple providers. EarthImages combines a powerful proprietary image planning and visualisation technology with a sophisticated image search engine and an image order/access facility. The image planning and visualisation technology provides very precise location and timing of almost the entire range of civilian imaging satellites. The image search engine will be able select images based not only on basic parameters (e.g. time and location), but also on theme (e.g. oil spills) and specific events. In the case of search by themes, optimum image modes and configurations are pre-selected. Search results provide information on total costs as well as technical information and image orders can be automatically generated from the results. In addition, free imagery can be accessed from third party servers. As the service is under development, we are keen to receive suggestions on how we might optimise this service for the oil and gas sector.

Retrieval of volcanic ash particle size, mass, optical depth and mass of sulfur dioxide from multispectral data using neural networks

Alessandro Piscini[1]
Matteo Picchiani[2]
Stefano Corradini[1]
Marco Chini[1]
Luca Merucci[1]
Fabio Del Frate[2]

1) Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy.

2) Earth Observation Laboratory – Tor Vergata University, Rome, Italy.

Corresponding Author e-mail: alessandro.piscini@ingv.it

In the present work, analysis techniques of satellite data in the TIR (Thermal Infrared) are shown, in the framework of volcano monitoring, in particular concerning the estimation of physical quantities related to volcanic ash clouds, ash mass, effective radius, optical thickness at 11 microns (Aerosol Optical Thickness) and the mass of sulfur dioxide, SO_2, at 8.7 microns, present in the atmosphere due to volcanic eruptions. MODIS (Moderate Resolution Imaging Spectroradiometer) multispectral data is analysed, using an inversion model based on Multi Layer Perceptron Neural Networks (MLPNN).

A network was built for each parameter to be retrieved. Additionally, for volcanic ash, a network for the classification of “ash image pixels” was implemented, which was then used to mask the estimates. Several network topologies were compared in terms of their performance. Concerning the training phase and testing of the networks, two MODIS images were selected covering the eruption of the Icelandic volcano Eyjafjallajokull, which took place from April to May 2010 and was one of the most disastrous natural hazards in recent years. In particular, the image acquired on May 8th 2010, at 13:20 was selected for training. The networks obtained were then applied to an image of May 9th, 2010, 12:25 UTC.

The classification NNs were trained with the volcanic ash classification map obtained with the Bright Temperature Difference (BTD) algorithm, assumed to be error free. The neural networks for the quantitative estimation of the parameters associated with volcanic ash, mass, effective radius AOT and SO_2, were instead trained with maps obtained using estimation algorithms based on simulated radiances at the top of the atmosphere (TOA), generated in turn applying a radiative transfer model (RTM) to remote sensing data.

The networks proved very effective in solving the inversion problem related to the estimation of the parameters of the volcanic cloud, settling the crucial issue related to false alarms in the detection of volcanic ash. Furthermore, once the training phase is complete, NNs provide a faster inversion technique, useful for the applications. From this point of view the technique satisfies the need to respond quickly as a result of disastrous natural hazards, such as volcanic eruptions. In addition, the comparison between network topologies revealed that, for a given truth, a network with few inputs, but containing information on the physics, is better able to model nonlinear functional relations, proving more robust and therefore more able to generalize the phenomenon. Instead, a network ingesting all the sensor bands would probably require pruning to improve its ability to generalize.

Future activities include testing the effectiveness of the technique under different lighting conditions (night images) and on other types of multispectral data, such as that provided by high temporal resolution sensors like SEVIRI-MSG, on board the METEOSAT second Generation satellites. The latter would be particularly suitable considering its exceptional quick response characteristics for real-time monitoring of the atmosphere. The use of hyperspectral data, recently used for the estimation of parameters associated with volcanic clouds, is also under consideration for future work.

High resolution stereo satellite mapping is replacing GPS and conventional surveying on resource development projects in the developing world

Gerry Mitchell

PhotoSat

Corresponding Author e-mail: gerry@photosat.ca

Accurate locations of drill hole collars and surface geological features are critical to the correct interpretation of ore deposit geology. Resource development feasibility studies, project planning and construction always require accurate, reliable, 3D mapping of surface features. With improvements in the accuracy and reliability of stereo satellite mapping we are beginning to see stereo satellite mapping replacing GPS and conventional surveying in determining and verifying locations of surface features on resource development projects in the developing world. In the middle of the last decade GPS surveying was almost universally used to establish the location framework and base maps for these projects. The GPS locations were usually considered to be perfectly accurate and any airphoto mapping adjusted to perfectly match the GPS survey data.

The first commercial high resolution stereo satellite photos, one metre stereo IKONOS photos, became available in 2004. In 2005, stereo IKONOS mapping, accurate to 3m in horizontal location and 3m in elevation, required approximately one GPS survey point for each $10km^2$ to $20km^2$ of mapping. With 50cm resolution WorldView and GeoEye stereo satellite photos and new developments in stereo satellite processing systems, better than 50cm in horizontal and vertical accuracy can now be achieved with approximately one ground survey point for each $200km^2$. With this improvement in mapping accuracy, stereo satellite mapping is now being used to replace much of the ground surveying on many projects and to quality control the remaining ground surveying. We will show a number of examples of stereo satellite elevation mapping projects with better than 50cm horizontal and vertical accuracy and the identification of a variety of ground survey errors with stereo satellite mapping.

Airborne Hyperspectral LWIR Imager - AisaOWL

Hannu Holma
Antti-Jussi Mattila
Timo Hyvärinen
Harri Karjalainen

Specim, Spectral Imaging Ltd, Finland

Corresponding Author e-mail: harri.karjalainen@SPECIM.FI

AisaOWL is the first commercial UAV compatible airborne hyperspectral imaging system operating on thermal range. The system operates in pushbroom mode. The main design goals were compact size and easiness of use combined to performance. These goals were achieved with room temperature optics and high sensitivity Mercury Cadmium Telluride FPA. The weight of the sensor is only 13 kg, the size is less than 30 cm in longest dimension and power consumption is less than 200 W. The spectral sensitivity range covers wavelengths from 7.6 to 12.4 micrometers.with 100 spectral bands and 384 spatial samples. The performance in terms of NESR is 18 mW/($m_2$sr⌈m) at 10 ⌈m wavelength for 300 K target. This results an SNR of more than 500. The first flight tests with AisaOWL LWIR hyperspectral imager were performed at the end of February 2011 in Nevada, USA. Some of Cuprite mineral exploration areas were covered to enable comparison with other instrument data and known ground truth. AisaOWL sensor head can be used in large variety of applications ranging from gas detection to mineral mapping.

Airborne Remote Sensing with Microlight and UAV: Towards greater flexibility and lower cost

M.A.Goossens

Ursus-airborne

Corresponding Author e-mail: goossens@geosense.nl

Recent years have seen spectacular developments with respect to miniaturisation of various sensors such as Aerial photography, Lidar, Gammaray, Mag, Hyperspectral, Thermal Infrared, etc.

In the past, these sensors were rather bulky and heavy, and often needed an onboard operator, implying that large and expensive manned aircraft were needed to perform surveys with those instruments. Inherent high cost and complex operational logistics often prohibited the use of these kinds of surveys in projects where they could have been very useful.

Combining those developments with equally spectacular developments on the aviation side: the professionalization of Microlight aircraft and UAV's, undoubtedly adds a completely new dimension to remote sensing.

For example: imagine that you are a field geologist that needs to go out and map a difficult or dangerous area. You take your small UAV out of the boot of your car, lauch it, and 45 minutes later you have an airphotomosaic with 5 cm resolution on your fieldbook.

Or: you want to do a mag-survey as well as a hyperspectral survey over some small remote area. In the traditional way you would need two contractors; prohibitively expensive. But now you have your small helicopter UAV with all the sensors you need packed in a small van that can be driven right into the project area, where you can do your surveys one after another.

In this talk we will present three different aircraft that we are currently operating with diffent kinds of sensors:

1. The Gyrocopter: a microlight aircraft with helicopter properties
2. The Geocopter: an unmanned helicopter with 30 kg of payload
3. The Smartplane fixed wing UAV: a hand-luggage size fixed wing system for aerial photography.

3.11. Remote Sensing of Geohazards

Using ASTER, EO1-Hyperion, and ENVISAT data for rapid assessment of the Tohoku–Oki 2011 earthquake and tsunami effects

Stefania Amici[1]
Marco Chini[1]
Alessandro Piscini[1]
Maria Fabrizia Buongiorno[1]
David Pieri[2]

1) Istituto Nazionale di Geofisica e Vulcanologia, Rome ITALY

2) Jet Propulsion Laboratory, Pasadena, California USA

Corresponding Author e-mail: stefania.amici@ingv.it

On March 11, the northeast coast of Japan was affected by a tsunami triggered by intense earthquakes (M9.0) occurring offshore Hoshu Island. The acquisition of remote sensing data played an important role in a preliminary evaluation of resulting damage by providing timely information relevant for the assessment of the location and degree of destruction. Since the satellite data are often temporally limited by long revisit intervals, and because available ground truth was extremely limited by intense communication infrastructure damage, the independent acquisition of data over the affected area was extremely helpful.

A multispectral thermal image was acquired by ASTER on March 12, and March 19, a hyperspectral data cube was acquired by the EO1-Hyperion on March 13, covering the visible and near infrared spectral range, and a SAR image was acquired by ENVISAT on March 21.

EO1-Hyperion data was used to create a flooding map and a combustion map. The flooding map was created by applying an unsupervised K-mean classification algorithm, and the combustion map was made using SWIR bands. ASTER thermal images and SAR data were used to validate the results. The results of flooding maps derived from EO1-Hyperion 30m resolution data, acquired very close in time to the tsunami event, are in good agreement with the results obtained from analyses of similar SAR data and analyses based on near-simultaneously acquired ASTER images. Likewise, combustion maps, validated by identifying hot spots both in ASTER and Hyperion data, in time-coincident overlapping areas, are consistent in location and intensity in both data sets.

This work was carried out in part at the Jet Propulsion Laboratory, California Institute of Technology under contract to NASA.

Exploitation of 20-years SAR data for long-term deformation phenomena analysis: the SBAS-DInSAR approach

P. Berardino,
M. Bonano
F. Calò
R. Castaldo
F. Casu
R. Lanari
M. Manunta
M. Manzo
L. Paglia
A. Pepe
S. Pepe
E. Sansosti
G. Solaro
P. Tizzani
G. Zeni

IREA-CNR, via Diocleziano 328, 80124, Napoli, Italy

Corresponding Author e-mail: manunta.michele@gmail.com

Differential Synthetic Aperture Radar Interferometry (DInSAR) techniques have opened new perspectives in the field of Earth Sciences, with particular regard to environmental hazards, greatly contributing to the assessment and mitigation of the associated risks. The advanced DInSAR technique referred to as Small BAseline Subset (SBAS) algorithm (Berardino et al., 2002) is able to carry out a multi-scale and multi-sensor analysis of surface deformation, providing more insights on the spatial and temporal pattern of the phenomena under investigation. The SBAS approach, in fact, allows analyzing ground deformation at two spatial scales, i.e. the regional and local scale (Lanari et al., 2004). In particular, at the regional scale, the SBAS technique allows analyzing ground displacements relevant to wide areas (several thousands of km^2) by making use of average SAR data at low spatial resolution, while at the local scale we can detect and monitor very localized deformation phenomena by squeezing the full spatial resolution capabilities of the SAR sensors.

Furthermore, the SBAS technique allows a multi-sensor processing of SAR data collected by different radar systems acquiring with the same illumination geometry, as for the case of ERS-1/2 and ENVISAT satellites (Pepe et al., 2005). The multi-sensor SBAS approach has also been extended to the full spatial resolution scale, in order to study localized displacements exploiting huge archives of ERS-1/2 and ENVISAT SAR data (Bonano et al., 2011).

In this work we apply such a comprehensive SBAS approach for investigating several deformation phenomena. Among them, by taking advantage of the 20-years ERS-1/2 and ENVISAT SAR dataset, we analyze, detect and monitor different instability phenomena related to landslides and aquifer exploitation (Central Italy), urbanized area subsidence (Napoli and Roma, Italy), volcanic (Mt. Etna, Italy) and seismic (Tohoku-oki earthquake, Japan) events. To this aim, we effectively exploit the whole ERS-1/2 and ENVISAT SAR datasets collected between 1992 and 2011 thus generating very long-term deformation time-series that allow us to give more insights on the spatial and temporal pattern of such phenomena.
The achieved results show the effectiveness of the SBAS approach for the investigation of complex scenarios involving surface deformation, and suggest as the development of integrated monitoring systems, based on the joint use of ground measurements and DInSAR data, can significantly improve the definition of risk prevention and management strategies; this latter can further benefit by the availability of improved temporal and spatial resolution SAR systems, as the Italian COSMO-SkyMed constellation.

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Flood studies in Greece using Earth Observation data and Geographical Information Systems

Antonios Mouratidis[1]
Melina Nikolaidou[2]
Georgia Doxani[2]
Francesco Sarti[1]
Maria Lampiri[2]
Maria Tsakiri-Strati[2]

1) ESA/ESRIN, Via Galileo Galilei, 00044 Frascati, Italy

2) Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece

Corresponding Author e-mail: antonios.mouratidis@esa.int

Among natural disasters, floods are considered as one of the most important catastrophes, as they affect more population compared to any other natural disaster worldwide. Having drawn increasing attention, floods are presently one of the most significant natural hazards in Europe, posing serious risks for life, properties and infrastructure. Remote Sensing and Geographical Information Systems (GIS) provide safe and cost-effective tools for monitoring, mapping and assessing the evolution and damages caused by flood events.

In Greece, despite the plethora of major and catastrophic events in the country during the last two decades, floods have been poorly documented and Earth Observation (EO) data and GIS have hardly been used in relevant studies.

In this context, the research project entitled ''Earth Observation data and Geographical Information Systems to mapping and managing flood events in Greece'', funded by the Latsis Public Benefit Foundation, is envisaged to be the first attempt on national level that deals with floods from the Remote Sensing - Earth Observation point of view, by simultaneously incorporating GIS techniques and field work for validation purposes.

Starting from the collection of information about the occurrence of floods for the past 20 years and the creation of a database as input to a GIS, to the presentation of specific case studies using satellite imagery and the production of thematic flood-related maps on national level, this paper outlines the concept and presents the preliminary results of the project.

Assessing low-cost geo-informatics for disaster risk applications with focus on coastal regions

Mathias Leidig
Richard Teeuw

School of Earth and Environmental Science, Centre of Applied Geoscience, *Disaster Risk Reduction Group*, University of Portsmouth, UK

Corresponding Author e-mail: richard.teeuw@port.ac.uk

With respect to the growing evidence for global warming, the associated rise in mean sea level, will increase the severity of geo-hazards such as larger and more frequent storms, resulting in a temporal and spatial increases in storm surges, coastal erosion, cliff failures and fluvial flooding. The frequency and severity of disasters is set to increase in coastal regions.

At present 195 countries have a coastline, inhabiting and 60% of the world's population within 100km to the coast. There is a significant tendency for migration towards the coast, accompanied by a strong global urbanisation trend. Consequently the number of coastal residents is likely to increase in the near future. The highest growth of population until 2050 is expected in "developing" countries. Many of those do not have the data or the financial, technological and expert-knowledge sources for complicated, time consuming and expensive risk assessments.

While we will never be able to avoid environmental hazards and associated risks of disasters, there is a need for methods and procedures in the field of disaster preparedness, rather than limiting our response to post-disaster action. The terrible impact of the 2004 Indian Ocean Tsunami and the 2011 Japan Tsunami indicate the value of pre-disaster measures.

It is difficult and time consuming to keep up to date risk maps (for both urban and rural areas) or data on land-use and urbanisation - when depending only on ground based procedures. Here moderate resolution satellite data, which is often available at low-cost or for free, can make a significant contribution and change. The combination of the data existing at reasonable prices (e.g. ASTER) or for free via virtual globes such as Google Earth or Bing Maps, free image processing software, has huge potential applications. At the present this potential is insufficiently used and there are uncertainties about the reliability of the results.

The aim of this ongoing study is to examine the effectiveness of low-cost geo-informatics for analysing and mapping coastal flood hazard features, elements at risk and the potential of disaster at coastal regions, by "translating" existing knowledge and methodologies for the application with free and low-cost software thus make it useable for more communities.

Our approach incorporates free GIS and image processing software and compares them to their commercial counterparts. Particular attention is given to the application of recent developments in remote sensing such as the progressive use of object-based image analysis (OBIA) but by means of freely available software.

Integrated remote sensing and fieldwork in the aftermath of the Japan Tohoku Tsunami

Colm J Jordan[1]
David Tappin[1]
Hannah Evans[1]
Daisuke Suguwara[2]
Kazuhisa Goto[3]

1) British Geological Survey, Keyworth, Nottingham, UK

2) Tohoku University, Japan

3) Chiba Institute of Technology, Japan

Corresponding Author e-mail: cjj@bgs.ac.uk

The 2011 Japan Tohoku tsunami was catastrophic. Whilst the Japanese preparedness for such an event was comprehensive, e.g. 40% of the Japanese coastline is protected with tsunami walls, the scale of the tsunami was a surprise. On the 11th of M*arch a magnitude 9.0 earthquake struck at a depth of 24km off Sendai on the NE coast of Japan. The earthquake warning was effective, for example in Toyko the warning went out* after 60 seconds and the shaking started after 90 seconds. Nevertheless, the impacts of the tsunami were devastating with over 15,000 people killed, nearly 4,000 people missing and a further 300,000 made homeless. 19,000 cars were destroyed in Miyagi prefecture alone; 26,000 fishing boats in the Miyagi, Iwate and Fukashima prefectures were rendered unusable; 26,000 hectares of farmland were damaged and the total material cost is estimated at US$300 billion.

Research into the tsunami is critical to understanding its cause and its impact. BGS expertise in tsunami science, remote sensing and coastal geomorphology formed the basis of a research project that is contributing to a better understanding of the Tohoku tsunami event. A NERC Urgency grant was awarded to BGS to cover two aspects of the research: 1) fieldwork to investigate the tsunami sediments laid down by their type, structure and extent; and 2) the interpretation of remote sensing data to map out the tsunami impact and extent.

Due to the fact that BGS was supporting local counterparts involved with the disaster response, and the fact that we are a trained Project Manager of the International Charter on Space and Major Disasters, we were very fortunate to be granted temporary access to Charter satellite imagery. That imagery, along with others from local sources gave us a unique opportunity to combine data from before, during and after the event. High resolution satellite imagery (Ikonos, Quickbird, WorldView), aerial photography, LiDAR, along with Landsat data, and GEBCO bathymetry were processed prior to the fieldwork when they were utilised on rugged laptops equipped with the BGS•SIGMAmobile digital mapping system in order to derive greatest benefit from the combined data. InSAR data that provided measurements of ground motions were also employed in the project, although they were not processed by BGS in this case.

Working with colleagues from Tohoku University and the Chiba Institute of Technology, the BGS field team mapped the tsunami sediments, flow directions, inundation limits, flow heights, and additional features such as coastal geomorphology. Traverses across the coastal plain at Arahama, Sendai airport and Shichigahama were completed along with spot sampling at locations such as Minamisanriku. These traverses allowed us to identify sediment distributions from the tsunami and to identify pre tsunami earthquake faults and liquefaction and even to identify Jogan tsunami sediments from the Sanriku earthquake that occurred in 869 with an estimated magnitude of 8.6. The satellite imagery, aerial photography and LiDAR were manually interpreted in the office and used in the field on tablet PCs to integrate the sampling regime. Tsunami deposits were mapped up to 4.5 km inland and the maximum wave inundation height of over 11 m. The sediment structure ranged from laminated to massive and their sizes from silt to > boulder (including items such as houses). The presentation will outline the applicability of various forms of imagery to better understanding the tsunami impacts and future modelling projects, and also how geological remote sensing might be better integrated with the work of field investigation teams such as the Earthquake Engineering Field Investigation Team (EEFIT).

Mud Volcanoes in the South Caspian Basin: Activity Inferred From ENVISAT ASAR Images

M. Weinelt
W. Brückman

Leibniz Institute of Marine Sciences (IFM-GEOMAR), Wischhofstrasse 1-3, D 24148 Kiel, Germany

Corresponding Author e-mail: mweinelt@ifm-geomar.de

Mud volcanoes (MV) and their eruptive activity must be regarded as a potential thread in different contexts. The contribution of MVs to the global atmospheric methane budget (a very important greenhouse gas) is under debate, but may be as high as ~10% of all free atmospheric methane (Milkov et al., 2003). More local but not less important hazards are induced by sub-surface soil or rock instabilities caused by MV activity that may affect population, infrastructure and industry investments.

Due to the regional tectonic setting (high vertical compression of oil and gas rich source and reservoir rocks), the South Caspian Basin (SCB) is the most prominent area globally to study occurrence of and processes triggering mud volcano activity and flux rates of gaseous or liquid phases. More than 400 MVs have been counted on-shore alone, more than 180 are already identified at the sea floor of the SCB.

Spotting MVs (and thus potential risks) at the sea floor mainly is done by

- application of geophysical methods,
- sampling of typical sediments or
- physiographic criteria.

Satellite imagery (synthetic aperture radar, SAR) adds to this set of tools: MV eruptions in the SCB can discharge crude oil into the water column that ascents to the sea surface forming slicks of oil that can be discriminated from other oil or biogenic slicks in SAR images.

In a pilot study a first set of ~ 20 ASAR images from the ESA archives where selected and inspected to identify natural oil films on the sea surface that show the typical shape of seafloor seepage induced slicks. These where correlated to known MVs and to potential MV locations identified by geomorphologic features (local, roughly circular shaped highs) as seen in a digital elevation model (DEM) of the South Caspian Basin itself.

These first results are promising, as natural oil slicks in SAR images episodically show up in the vicinity of MV suspects not identified as active MV to date. In a following project we will attempt to intensify the use of SAR imagery in monitoring MV activity, together with on-site geochemical and geophysical observatories.

Assessing tsunamigenic landslide hazard on a tropical volcanic island

Richard Teeuw
Nasos Argyriou
Derek Rust

Centre for Applied Geosciences, University of Portsmouth, UK

Corresponding Author e-mail: richard.teeuw@port.ac.uk

Islands built by explosive strato-volcanoes tend have inherently unstable flanks, due to undercutting by coastal erosion and the ensuing slope over-steepening. When such islands are in tropical settings, this potential slope instability is exacerbated by deep weathering. Add seasonal storms and downpours during the hurricane season and you have the potential for major coastal landslides – and associated tsunami waves. The island of Dominica, in the eastern Caribbean is one such island.....

Potentially tsunamigenic volcano flank instability features have been observed on the north coast of Dominica. Seismic, bathymetric and geomorphological data suggest that this coast is bounded by an active fault structure, with the relatively up-thrown flank displaying evidence of slope instability. Studies during 2007-8 indicated a landslide block of ~1 M tonnes on the seaward margin of the flank instability complex, the collapse of which could generate locally-significant tsunami waves around Dominica and the adjacent Guadeloupe archipelago.

Current research aims to quantify the landslide and associated tsunami hazards. The first stage is examining the nature of the volcano flank instability and preliminary results from recent fieldwork are presented here. The second stage will focus on the tsunami hazard, examining coastal bathymetry along the north flank of Morne aux Diables and looking for evidence of past landslides.

Recent fieldwork used Google Earth and 1:10,000-scale aerial photography as the basis for geomorphological mapping and the selection of survey transects. Most of the transects radiated out from Morne aux Diables crater (600-660 masl), northwards to coastal cliffs that were up to 300 m high; most followed ridges, as these consist of in situ rock, whereas Dominica's valleys have fills of alluvium and slope debris. The transects were sampled by a geomorphological survey (slope steepness, slope morphometry, soil type, soil thickness, rock type, vegetation cover) and a VLF geophysical survey.

Preliminary results indicate many E-W trending zones of structural weakness in the northern flank of the volcanic edifice, with faults extending for hundreds of meters, some forming water-filled voids. Areas of hydrothermal alteration appear to favour landsliding, with large (>100 m high) sub-vertical slab failures dominating in the E-W fault zone and large rotational slides occurring on the NE and NW coasts.