→ SUPPORT TO SCIENCE ELEMENT | STSE

A pathfinder for innovation in Earth observation

Report 2008–2012

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European Space Agency

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Support To Science Element (STSE)

In the years to come, Earth observation from space will enter into a new era, characterised by a growing number of increasingly advanced and sophisticated satellite missions. They will provide scientists and other data users with an unprecedented capacity to observe and monitor the Earth system and its dynamics, from local to global scales, with different new and complementary techniques.

From the ESA perspective, this new era has already started with the successful launch of the first three Earth Explorer missions (GOCE, SMOS and CryoSat), which deliver new and unique data to the scientific community. The coming Global Monitoring for Environment and Security (GMES) Sentinel satellites will not only complement existing monitoring missions, providing operational long-term data to establish critical information services for Europe, but will also represent a major source of data for scientists world-wide.

The full exploitation of this growing capacity in terms of enhanced and new observations represents both a major scientific challenge and a unique opportunity for innovation and science. It will enable huge synergies offered by this multi-mission observational potential together with the continuous advances in Earth system models and in-situ observation networks.

Anticipating this opportunity, ESA launched in 2008 a new element of its Earth Observation Envelope Programme (EOEP), the Support To Science Element (STSE). Its main ambition is to provide an efficient, flexible and dynamic mechanism to support scientists and industry in Member States to innovate and explore opportunities and challenges in terms of novel observations, new algorithms, enhanced products and new Earth science results.

To achieve this overarching objective, the programme has been articulated across four major pillars that respond to an end-to-end approach to science:

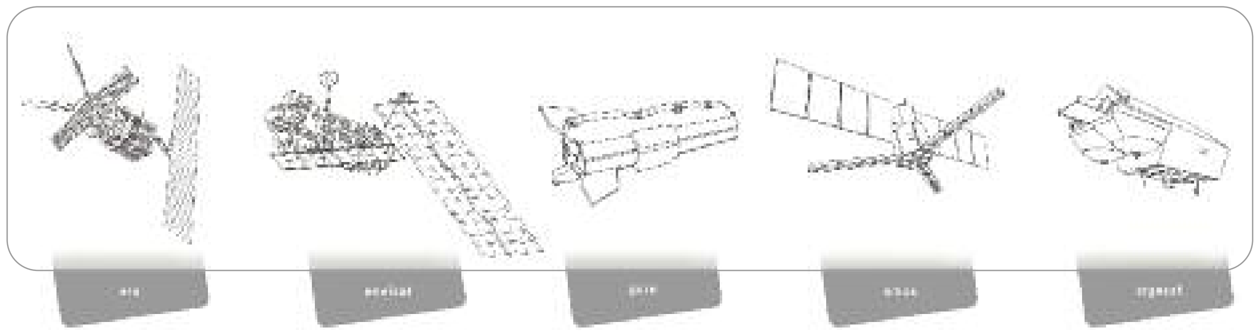
- **Science support to novel mission concepts:** Exploring and advancing the scientific basis of novel mission concepts and novel observational principles in preparation for the next generation of European scientific Earth Observation (EO) satellites;
- **Novel algorithms and products:** Developing and validating of advanced and innovative methods, algorithms and products that may exploit the increasing ESA Earth observation capacity, opening the doors to new scientific results and novel applications;
- **Reinforcing ESA contribution to major global Earth science programmes:** Fostering the scientific exploitation of ESA EO data in collaboration with major international scientific programmes addressing key open questions in Earth system science;
- **Supporting the next generation of European Earth observation scientists:** Supporting young European scientists to undertake leading edge research activities maximising the scientific return of ESA missions while advancing towards the achievement of the scientific challenges of the ESA Earth observation science strategy.

Looking for the next generation of European Earth science missions

Over the last decades, understanding the Earth's system and its climate has raised interest in the international political arena. This interest has augmented the demand for increasingly accurate and reliable observations being able to characterise the dynamics of critical variables and processes that govern the different components of the Earth system. In this context, STSE has initiated a number of activities focusing on three main priorities:

- Addressing current observational gaps exploring new mission concepts that may provide answers to major scientific needs;
- Investigate the potential evolution of current Earth Explorer missions;
- Advancing the scientific basis of immature but promising Earth Explorer mission proposals following the recommendations of the ESA Earth Science Advisory Committee.

These activities are also complemented by implementing a number of software packages, simulation tools and experimental data sets. These will endow the scientific community with the necessary elements to advance the scientific background for preparing the future exploitation of emerging concepts.



A pathfinder for innovation in the exploitation of ESA Earth observation data

In the years to come, the increasing number of Earth observation missions available for scientific and operational use will provide a range of opportunities to develop novel methods, algorithms and products that may open the door to new science results and applications. In the last few years, almost 20 projects have been launched aiming at maximising the scientific return of ESA missions in line with the following three priorities:

- Supporting the exploitation of the Earth Explorer series with special focus on novel products and innovative applications beyond the baseline mission objectives;
- Preparing the development of advanced methods and products that fully exploit the novel features and synergies of the Sentinel series in preparation for their scientific exploitation;
- Developing and validating innovative multi-mission based methods and novel products that may exploit the synergies provided by the increasing number of EO missions.

A significant effort has been dedicated to promoting the exploitation of the first Earth Explorer missions as well as to exploring their full capacity beyond their primary scientific targets. To this end, a dedicated initiative, the 'Explorer Plus' project series, was launched including more than 10 parallel activities fostering new applications of GOCE, CryoSat and SMOS data. Through these projects, STSE leads to new applications of the Earth Explorers like atmospheric density mapping with GOCE, sea ice thickness retrievals with SMOS and innovative land applications for CryoSat. Moreover, it also enlarges the user base beyond their original science community and promotes new scientific results and discoveries demonstrating the value of these types of missions as precursors for potential future operational satellites.

Ensuring ESA contribution to major international scientific efforts

International coordinated scientific efforts have always been one of the main catalysts for discoveries and progress in scientific knowledge. Major international scientific programmes and initiatives such as the World Climate Research Programme (WCRP), the International Geosphere-Biosphere Programme (IGBP) or the joint projects of the Earth System Science Partnership (ESSP), among others, provide a coordinated framework for international scientific collaboration in Earth System Science and Climate research, involving thousands of scientists worldwide.

Since 2009, STSE has initiated a number of collaborative research and development activities to face key open questions in Earth system science where data from ESA satellites can play a fundamental role. These activities bring together Earth observation experts, modellers and Earth system scientists to jointly address current global scientific challenges. It also allows for a dialogue among communities to explore, facilitate and promote the integration of Earth observation-based information into advanced Earth system models.

These activities not only aim to ensure ESA data contribution to major international scientific efforts, but also try to foster the use of Earth observation data among extended Earth science communities that, in some cases, may not be familiar with the use of such data.

So far, active collaborations have been established with the cryosphere, water cycle and stratospheric science projects of the WCRP (CliC, GEWEX and SPARC), the land-atmosphere interactions project of IGBP (iLEAPS) and the international ocean-atmosphere interactions project (SOLAS).

The partnerships are implemented through dedicated STSE research projects, joint international conferences and publications. These are effective tools to maximise scientific return of ESA missions, while ensuring the programmatic coordination and alignment of STSE initiatives with the main scientific priorities.

Supporting the next generation of European scientists

In 2006 ESA published 'The Changing Earth' (ESA SP-1304), which represents the ESA EO science strategy. The document highlights a list of 25 scientific challenges related to the different elements of the Earth system where EO technology and ESA data may play a key role. Addressing these challenges will require a long-term effort and support to science including dedicated actions in support of the young generation of Earth scientists.

In this context, STSE launched in 2008 'The Changing Earth Science Network', a dedicated initiative to support young scientists at post-doctoral level in ESA Member States to undertake leading edge research activities addressing the 25 challenges of the ESA science strategy, while maximising the use of ESA EO data.

Distribution of the participants at the Changing Earth Science Network

The main objectives of the initiative are:

- Contribute to consolidate a critical mass of young scientists in Europe with a deep practical knowledge of ESA EO data and missions fostering the scientific use of ESA space assets;
- Maximise the scientific return of ESA data by stimulating leading edge research activities addressing the 25 challenges of the Living Planet Programme;
- Contribute to enhance the interactions between ESA and Earth science labs, research centres and universities in Member States;

After a first call for proposals, a set of 10 young scientists from 7 Member States were selected in 2009. A second call in 2010 resulted in another group of 10 projects enlarging the geographical distribution of the projects to 9 countries. These projects address all the different areas of Earth science including major open questions and important topics such as the global study of CO_2 and methane dynamics, the use of Envisat data to enhance the characterisation of ocean-atmosphere fluxes, the development of novel methods to monitor glacier dynamics in Greenland and the improvement of fire characterisation.

This initiative will not only maximise the scientific return of ESA missions, but will also consolidate a critical mass of young scientists in Europe with a deep practical knowledge of ESA Earth observation data. At the same time it will improve the interactions between ESA and the next generation of scientists. To facilitate this process, young scientists participating to the initiative also have the opportunity to carry out part of their projects in an ESA establishment as a visiting scientist working together with ESA experts.

A significant effort is dedicated to disseminate the scientific results obtained by STSE projects and promoting EO within new Earth science communities. This involves the publication of special issues, proceedings of conferences, dedicated books and multi-media material.

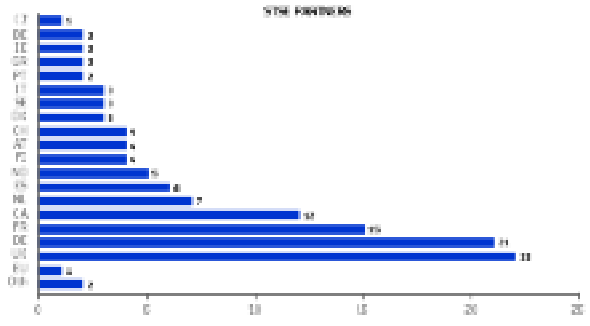
STSE in figures

STSE has been funded with approximately 17 Million Euro for development activities covering a period of 5 years (2008-2012). From 2008 to December 2011, STSE has started almost 60 projects involving more than 120 scientific institutions and industrial partners covering 19 ESA Member States (see the figure on the top right).

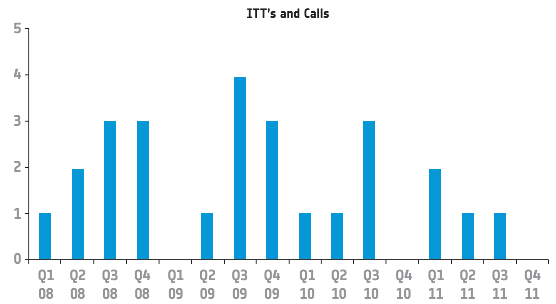
The size and nature of the activities funded through the programme range from small scale feasibility studies (approx. 100 KEuro) up to a maximum budget of 500 KEuro for larger scientific projects. In this context, STSE provides a continuous flow of opportunities offering a highly dynamic and flexible mechanism for scientists and industry to innovate and advance in the scientific exploitation of ESA data.

The figure on the right provides the number of Invitations To Tender (ITTs) issued in each quarter since 2008. As a result, on average, more than 15 contracts have been awarded per year to industry and scientific institutions in Member States (it should be noted that one ITT may result in several contracts).

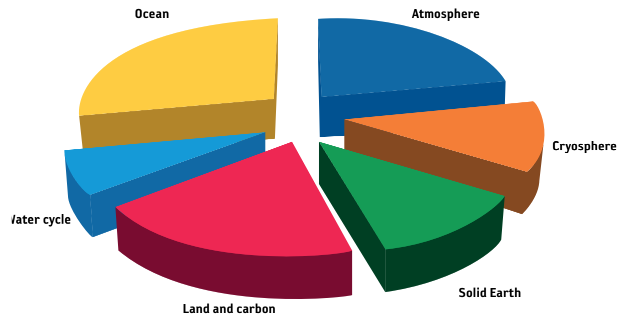
This diversification of activities allows both covering a significant range of key topics (e.g., the bottom right figure provides an overview of the distribution of themes within the programme) and scientific priorities, while, at the same time, mitigating unavoidable risks associated to the exploratory nature of the activities carried out by this programme line. Successful activities may be then extended or supported for continuation within STSE or other more suitable ESA programmes depending on the level of scientific maturity reached.



Number of institutions involved in STSE activities per country.



Number of Invitations To Tender (ITTs) per quarter.



Distribution of STSE activities per thematic area.

INTRODUCTION

A scientific consultation process

The STSE scientific agenda is mainly based on a continuous consultation process with the scientific community. This is done through the existing consultation and advisory mechanism of the Agency and dedicated scientific workshops and conferences. In this context, STSE promotes a series of dedicated scientific consultation workshops and international conferences to identify and define the specific scientific requirements that represent the core of STSE activities. In this context, more than 20 dedicated workshops, international conferences and special sessions in major scientific symposia have been organised, involving more than 1000 scientists worldwide.

ESA-GEWEX Water Cycle Multi-mission Observation Needs Vienna University of Technology, Vienna, Austria	14 April 2008
Scientific Requirements Definition for the ESA-iLEAPS Atmosphere-Land Interactions Study Austrian Academy of Sciences, Vienna, Austria	20 April 2009
ESA-CliC Earth Observation for Cryosphere Science Institute for Meteorology and Geophysics, University of Innsbruck, Austria	17 June 2009
Remote Sensing of 3D-Vegetation Structures Institute of Chemistry and Dynamics of the Geosphere, Forschungszentrum Jülich GmbH, Germany	2 July 2009
ESA-SOLAS Consultation Session SOLAS Open Science Conference, Barcelona, Spain	16 November 2009
ESA-GEWEX-EGU Joint Topical Conference Earth Observation and Water Cycle Science ESA-ESRIN, Frascati, Italy	18-20 November 2009
ESA-SOLAS Consultation Meeting Laboratoire d'Etudes en Geophysique et Oceanographie Spatiales, Toulouse, France	30-31 March 2010
ESA-iLEAPS-EGU Joint Topical Conference Earth Observation for Land-Atmosphere Interaction Science ESA-ESRIN, Frascati, Italy	3-5 November 2010
ESA-SOLAS-EGU Earth Observation for Ocean-Atmosphere Interaction Science ESA-ESRIN, Frascati, Italy	29 Nov - 2 Dec 2011
SPARC Science Requirements Workshop ETH Zürich, Switzerland	20-21 October 2010
ALANIS Final Workshop Alfred Wegener Institute, Potsdam, Germany	14 February 2012
SMOSIce User Workshop Institute of Oceanography, KlimaCampus, University of Hamburg, Hamburg, Germany	17 February 2012
2012 International Workshop on Polar Lows CIENS Resource Centre, Oslo, Norway	21 - 22 May 2012
ESA-CliC-EGU Joint Topical Conference Earth Observation and Cryosphere Science ESA-ESRIN, Frascati, Italy	13-16 November 2012

Some of the main conferences and workshops organised within the context of STSE activities. Also several dedicated sessions in major international scientific conferences have been organised.

NOVEL MISSION CONCEPTS

IRDAS

irdas
support to science element

Project team
University of York (UK)
Danish Meteorological Institute (DK)
Wegener Center for Climate and Global Change (AT)

Status
Completed

During the last years the agency has developed a sound scientific and industrial expertise in the field of limb sounding in Europe, which led to fly instruments such as GOMOS or GRAS. To further consolidate this position, it is desirable to expand our expertise to the SWIR spectral region and the usage of dedicated signal sources.

The observational conditions in the SWIR spectral range are excellent due to an atmospheric window between the visible radiation from the Sun and the thermal infrared irradiation from the Earth. All major greenhouse gases comprise spectral features (vibrational and rotational-vibrational structures) in that band which can be exploited for quantitative observations. ESA's Earth Science Advisory Committee recommended further studies and research of this novel observation approach, as the performance and impact of a dedicated mission depends on the spectroscopic properties of selected lines and broadband atmospheric effects.

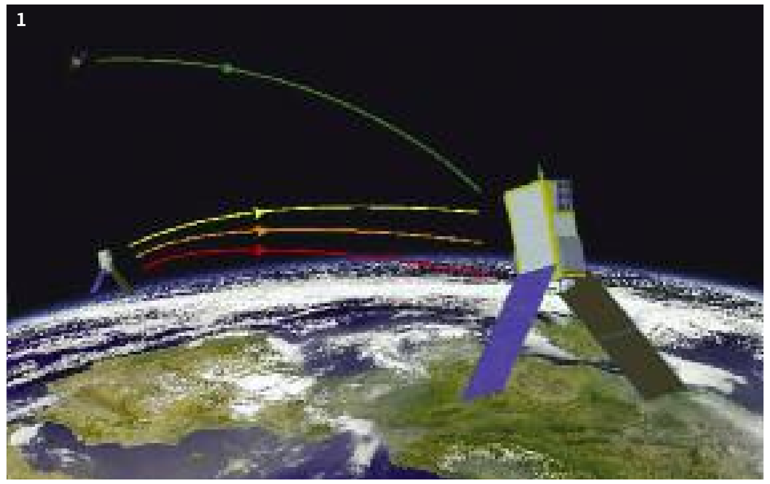
The main objective of the IRDAS study was to establish a sound scientific base-line for active occultation in the SWIR spectral region by application of the differential absorption method in limb sounding geometry in the 2.0 – 2.5 µm spectral band.

The work has been successfully concluded. The team addressed three major areas:

- During the project the team has further refined both the scientific requirements of the mission and the respective geophysical parameter requirements in a way which can be traced back to e.g. WMO requirements. Based on those findings mission analyses scenarios were derived to study the impact of possible constellations, which resulted in a preferred baseline. The potential complementarities with IASI and PREMIER were also assessed.
- Concerning the spectroscopy, the most suitable spectral lines have been selected. Those lines were assessed concerning the uncertainty of their line parameters in the HITRAN2008 database. The conclusion drawn is that, if retrieval should be conducted with around 1% uncertainty, the line parameters have to be known to a higher degree of accuracy. A conclusion shared with recent findings in the area of passive optical remote sensing.
- Broadband atmospheric effects were compiled and studied in detail. Based on the above findings a software tool (ALPS) was developed to conduct performance simulations. The results were validated by a comparison with MKIV balloon data from JPL and ACE (Atmospheric Chemistry Experiment) data. Simulations and real data showed a good agreement. The final software is available to the scientific community in order to support further research activities in this particular field.

Based on the findings of the IRDAS study a field campaign (IRDAS-EXP) has been designed and implemented to test the theory.

1- Schematic picture of an occultation link between two low-orbit satellites.
Credits: WegCenter/Uni. Graz/Alcatel/ NASA 2005.



IRDAS-EXP

irdas-exp
support to science element

Project team
Wegener Center for Climate and Global Change (AT)
University of York (UK)
University of Manchester (UK)

Status
Completed

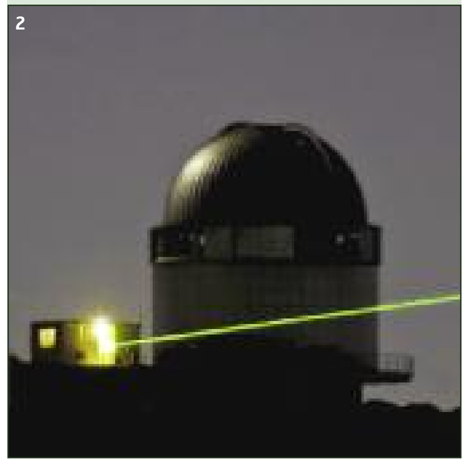
The main objective of the IRDAS-EXP project was to develop the first dedicated dataset for the validation of Differential Absorption Spectroscopy (DAS) performance models and their respective error formulations in the 2.0 – 2.5 µm spectral band by implementing a unique ground-based experimental setup at representative wavelengths.

The experiment was successfully implemented during a two-week field campaign in June 2011.

The experiment, based on state-of-the-art detectors and laser diode technology, was implemented in a way allowing one to tune basic parameters like power or beam divergence angle to mimic different realistic observational scenarios. As optimal locations, the Observatorio del Roque de los Muchachos (Island of La Palma) and the Observatorio del Teide (Island of Tenerife) have been identified, which offered the necessary infrastructure and a baseline distance of ~144 km at an altitude of ~3.4 km. The ESA's Optical Ground Station (OGS) at Teide Mountain was used as receiver unit with the possibility to mount the detector inside, using an optical bench already used in similar ESA projects. The baseline setup consisted of four laser diodes emitting signals at ~2.1 µm and ~2.3 µm allowing to probe the atmospheric content of CO_2 and H_2O. The derived concentrations are being validated against in situ measurements taken at the transmitter and receiver locations using flasks and cavity ring-down spectrometers.

The recorded dataset comprises a unique set of observations and is currently being evaluated and processed. A last-minute add-on experiment used the green guidance laser to monitor and record atmospheric turbulence, complementing the data set in an ideal manner. This activity provides a realistic baseline for active remote sensing in the SWIR band based on the differential absorption technique. The dataset gathered during this activity helps to establish a reliable performance envelope and helps to quantify inherent limitations due to the measurement principle. The observations will allow deriving valuable information concerning effects of atmospheric turbulence as well as other factors limiting the accuracy of the chosen remote sensing approach. It will serve to validate and improve the performance models currently in use in terms of signal propagation, retrieval methodology and error formulations.

1- The link between the two observatories, the NOT observatory at La Palma and the ESA's optical ground station at Tenerife.
2- The intense green guidance laser launched from the NOT observatory at La Palma.
Credits: ESA and IRDAS-EXP team.



DAME

dame
support to science element

Project team:
McGill University (CA)
University of Bonn (DE)
DEIMOS Space S.A. (ES)

Status:
Completed

Clouds and precipitation play one of the most fundamental roles in the Earth's climate. They are key to the global water cycle and energy transport in the atmosphere and very important for the atmospheric influence on the Earth radiation budget. Due to their high variability in space, time and water and ice content, they are particularly difficult to represent or parameterise in atmospheric circulation models. Observations of clouds should ideally include ice crystal and liquid water content and crystal/droplet sizes along with motion vectors. Furthermore, temperature, pressure and aerosol concentrations are critical observables for the understanding of cloud genesis and life cycles. Adequate global data sets are currently not available.

Doppler observations using ground-based radar are being routinely and widely used by weather observatories around the globe. The retrieval of vertical motion along the radar beam direction is based on the radar signal reflection on the moving particles (e.g., ice crystals in clouds) and the analysis of the phase shift of the backscattered radar signal (Doppler effect). During the preparatory work for EarthCARE, techniques have been developed in Japan to model the Doppler shift of a space-borne cloud radar in the W-band from line-of-sight particle velocities. However, the retrieval of effective (or average) particle velocities (as tracers for the wind inside the cloud) from measured Doppler shifts is much more complex and presently not developed. It has not only to consider the instrument transmitter and receiver details (pulse repetition frequency, pulse length and shape, detector characteristics, etc), but also complex effects within the clouds, such as motion in homogeneities within the radar field-of-view and the assumed fall-speed relationship for individual cloud particles of different types, particle size distributions and multiple scattering effects.

During DAME, three models have been developed that are fundamental for the exploitation of space-borne Doppler radars: (1) an instrument model, (2) a forward model for the propagation of the radar (Doppler) signal through the atmosphere and clouds, (3) a Doppler signal retrieval model to correct for velocity unfolding and non-uniform beam filling. Amongst the various difficulties in correctly interpreting Doppler measurements, non-uniform beam filling and multiple-scattering were identified as particularly critical.

The results of the activity and algorithms developed are directly applicable to Doppler retrievals of EarthCARE observations and for the assessment of space-borne Doppler missions that might be considered in the future. It has furthermore provided test scenes suitable for EarthCARE algorithm testing. The activity has significantly advanced European and Canadian expertise in the scientific preparation and exploitation of space-borne Doppler instruments.

1- The plot is an output of the 'forward model' developed in DAME, showing the two most important geophysical parameters for Doppler radars, the radar reflectivity and the Doppler velocity.
Credits: DAME team.

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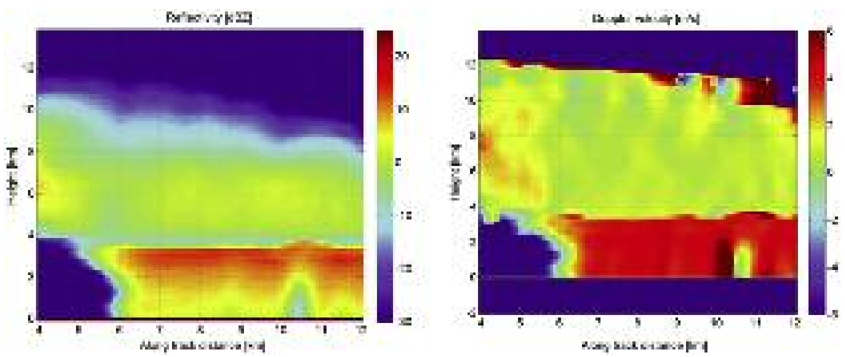

ICAROHS

icarohs
support to science element

Project team:
Deutschen Zentrums für Luft- und Raumfahrt (DLR) (DE)
Leibniz Institut für Troposphärenforschung (IFT) (DE)
Meteorologisches Institut der LMU (MIM) (DE)
Royal Netherlands Meteorological Institute (KNMI) (NL)

Status:
Completed

Aerosols are considered the largest source of error in the direct radiative forcing budget of the climate system, while clouds can contribute with the largest uncertainty on the representation of radiative feedbacks that can either enhance or reduce the sensitivity of climate to that forcing. Anthropogenic aerosol and aerosol precursor emissions are likely to vary in time and space over the coming decades, and it is essential to develop tools for evaluating to what extent passive measurements can monitor the associated forcing. Most present observations by passive sensors of global aerosol properties are limited to optical depth, Ångström exponent and/or a crude estimate of particle size distribution. This is unsatisfactory, since the knowledge of their chemical composition and optical (scattering/absorbing) properties is required together with their vertical and geographical distribution.

ADM-Aeolus and EarthCARE will embark the first ever High Spectral Resolution Lidar (HSRL) space-borne system, albeit with a single wavelength only. The advantage of the HSRL Lidar with respect to a backscatter Lidar is that the separation of the backscattered signal from the molecules and from the particles is possible. As additional information, cross polarisation channels will provide information about the shape of ice particles and aerosols. Furthermore, adding the Lidar ratio one can distinguish between the ice particles and aerosols and also between natural and anthropogenic aerosols.

The purpose of this activity is to contribute to develop a solid scientific basis to advance from today's monochromatic HSRL (EarthCARE) to a potentially more accurate multi-wavelength HSRL system. For this purpose, the activity has combined aerosol measurements of airborne HSRL lidar with ground-based lidar measurements. These data sets have been used to develop and improve algorithms for the retrieval of aerosol profiles from HSRL measurements for future space-borne HSRL instruments.

This database of actual Lidar measurements covers different aerosol types (e.g., continental aerosol, fresh and aged mineral dust, biomass smoke, and continental and marine aerosol), including HSRL aircraft observations of fresh volcanic ash of Iceland's Eyjafjallajökull eruption in 2010. The data have been used to construct simulated atmosphere scenes using the existing EarthCARE simulator ECSIM for implementation and testing of retrieval algorithms against real measurements. The results of the study are furthermore instrumental for the determination of suitable aerosol classification schemes for EarthCARE.

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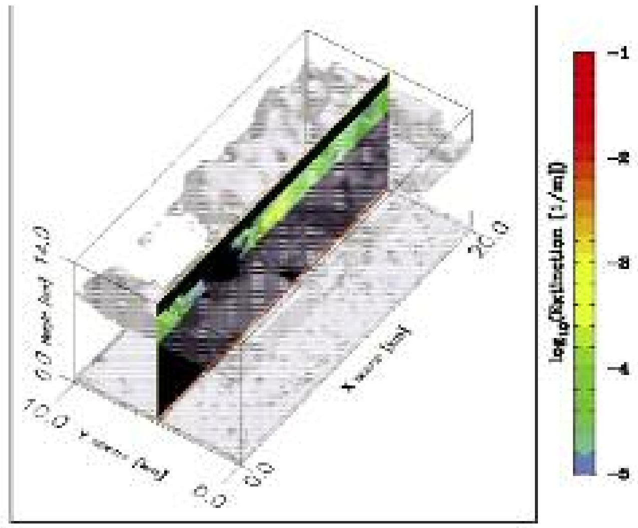

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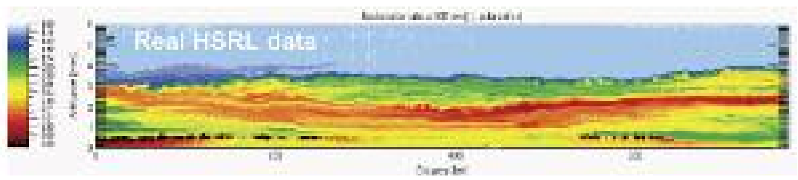


1- ECSIM cloud scene from model data
2- ECSIM aerosol scene from airborne HSRL and ground-based lidar data
Credits: ICAROHS team.

MICROWAT

microwat
support to science element

Project team:
Astrium SAS (FR)
ASTRIUM Ltd (UK)
HARP Technologies (FI)
IFREMER (FR)
RS-consult (DK)
ESTELLUS (FR)
Meteo France (FR)
Laboratiore d'Astrophysique of the Observotoire Midi Pyrenees (FR)

Status:
On-going

Sea Surface Temperature (SST) and Ocean Vector Winds (OVW) are fundamental variables for understanding, monitoring and predicting the general circulation of the ocean and atmosphere. OVW drive ocean currents and ocean vorticity through the transfer of energy to the ocean as frictional coupling at the atmosphere-ocean interface (the momentum flux expressed as drag force per unit area). The dynamic patterns of SST and OVW are important predictors of global climate with far reaching consequences for the global economy and security of life and property. Changes in the patterns of SST reveal the dynamic structure of surface currents and other OVW driven features such as tropical instability waves and the magnificent western boundary currents of the global ocean. While current satellite instrument technologies provide passive microwave observations of SST and OVW/wind-stress, these data are limited in resolution and geographic coverage. Ideally, a higher spatial resolution (~10 km) all weather SST and OWV dataset that can observe globally including the coastal and ice infested water is required.

Starting from agreed scientific user requirements, a baseline instrument design has been developed during the project. The proposed instrument is a passive microwave conical scaning (at 53 deg incidence) total power radiometer. It uses a large reflector antenna to achieve 15 km of spatial resolution at 6.9 GHz. Compared to existing instruments (e.g., AMSR-E having a 74x43 km IFOV, 56 km mean spatial resolution @ 6.9 GHz) Microwat is almost 4 times better. The Microwat instrument sensitivity is double that of current instruments due to a larger bandwidth and a longer measurement integration time. Microwat is RFI resistant and includes specific digital hardware for RFI detection and mitigation using both temporal and frequency segmentation of measurments. Microwat will measure wind vector using polarimetric channels at 6.9 & 18.7 GHz. The mission has been developed to fly in tandem with MetOp ASCAT providing complementary surface wind information at high wind speeds (where scatterometer are not ideal due to suppression of Bragg scatterers) across the full swath and will fill the 'ASCAT gap'. Microwat calibration is based on internal targets (Matched load, Active Cold Load and Noise Diode) and external reference targets. High frequency channels (such as 89 GHz for sea ice detection) could be added to the design as the centre part of the reflector is solid with high stiffness and a highly reflective coating. The project is now investigating momentum compensation of the rotating antenna subsystem.

1- Artists impression of the Microwat Mission concept.
Credits: Microwat team.

1

EO-CONVOY

Over the next few years a number of new long-term operational Earth Observation (EO) satellites will be launched by Europe. These missions include the Global Monitoring for Environment and Security (GMES) Sentinel spacecrafts and EUMETSAT operated MetOp satellite series. These missions will provide global, continuous and long-term European capability for systematic observation of numerous Earth system parameters.

If additional cost-effective missions could be flown together with these operational missions, then the possibilities for meeting new Earth science and application objectives could be far-reaching e.g. fulfilling observational gaps, multipoint measurements of Earth system phenomena, etc.

Three studies have been identified (known as the EO-Convoy studies: Ocean and Ice; Land; Atmosphere). The aim of these studies is two-fold:

- To identify scientific and operational objectives and needs which would benefit from additional in-orbit support.
- To identify and develop a number of cost-effective mission concepts to meet these identified objectives and needs.

Each study is based on a comprehensive user needs assessment of Earth science applications and identification of novel data products. From this analysis, a number of preliminary mission concepts are derived together with possible formation and constellation options. Up to three mission concepts per theme are then selected for detailed analysis including a roadmap for development.

From the Ocean and Ice study, three concepts have been selected for further analysis:

- Passive C-band SAR flying with Sentinel-1x for the production of topographic maps and the precise mapping of glacial elevation changes as well as the observation of ocean current circulation and fast moving sea ice drift.
- Laser altimeter flying with Sentinel-3 to measure surface topography (ice sheets, ice caps, large glaciers and sea-ice) and to support the estimation of mass balance. For the ocean domain this concept would be also useful for the measurement of mean dynamic topography, supporting absolute surface current retrieval and characterising upper layer dynamics.
- Ku-band scatterometer flying with MetOp SG to measure ice sheet snow accumulation, the measurement of land snow mass at medium/low spatial resolutions and characterisation of the soil freeze/thaw cycle.

For the Land project, scientific and operational user needs were captured via a dedicated land surface user consultation workshop. The workshop resulted in a number of preliminary convoy concepts presently under consideration including a longer wavelength SAR satellite flying with Sentinel-1, a multi-angle optical satellite flying with Sentinel-2 and a high-resolution thermal infrared imager flying with either Sentinel-2 or -3.

The atmosphere theme project has started at the time this report was prepared.

eo convoy
support to science element

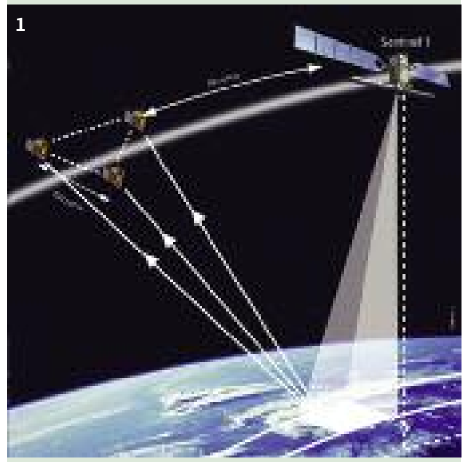
Ocean and Ice team:
EADS / Astrium Ltd (UK)
Environmental Earth Observation IT GmbH (ENVEO IT) (AT)
Polar Imaging Ltd (UK)
Nansen Environmental and Remote Sensing Center (NO)

Land team:
Surrey Satellite Technology Ltd (SSTL) (UK)
University of Leicester (UK)
EADS / Astrium Ltd (UK)

Atmosphere team:
EADS Astrium (UK)
University of Leicester (UK)
KNMI (NL)

Status:
On-going

1



1- Passive C-band SAR with Sentinel-1.
Credits: EADS Astrium.

NOVEL ALGORITHMS AND PRODUCTS

COASTALT-GNSS

This project contributed to the definition, specification, development and validation of a new pulse-limited coastal zone radar altimetry product which is intended to become operationally processed, including the reprocessing of the ESA Radar Altimetry archive (ERS-1, ERS-2, Envisat).

In particular, this project focused on the development of an innovative method for computing the wet tropospheric correction for altimetry measurements in the coastal regions from GNSS derived tropospheric delays, the so-called GNSS derived Path Delay (GPD) approach. In addition, a backup approach is also proposed, the Dynamically-linked method (Dlm), to be used whenever GPD is not available.

Dynamically-linked method (Dlm): This is a simple and easy to implement procedure that requires only data from the altimeter Geophysical Data Records (GDR) with optional information from a distance-to-land global grid and can be implemented globally for any satellite. DLM takes full advantage of the two types of wet tropospheric correction that are present on the GDR: the Microwave Radiometer (MWR) derived correction and a large-scale atmospheric reanalysis Numeric Weather Model (NWM) derived correction such as that from the European Centre for Medium-Range Weather Forecast (ECMWF). The method consists in replacing, in the coastal regions, the invalid MWR-derived correction by the ECMWF correction, somehow dynamically linked to the closest points with valid MWR field, to ensure continuity. This approach is quite different from the use of the model correction everywhere, since it significantly reduces the well-known large-scale errors of most NWM wet tropospheric corrections.

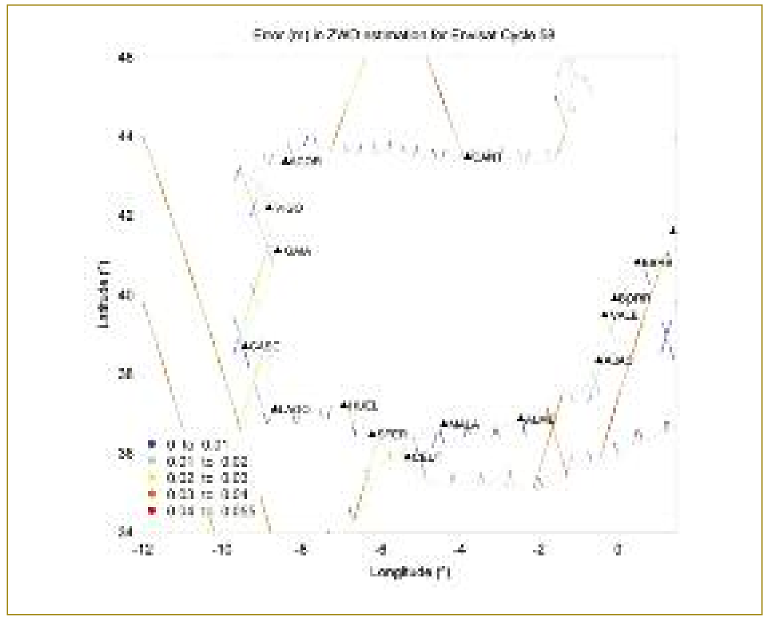
GNSS derived Path Delay (GPD): The method is based on GNSS derived Zenith Wet Delays (ZWD) determined at a network of coastal stations and off-shore platforms or buoys equipped with dual frequency GNSS receivers, further combined with valid MWR measurements and ZWD values from a NWM (e.g. ECMWF). A methodology for computing the wet tropospheric correction at each altimeter point with invalid MWR measurement is implemented by using a linear space-time objective analysis technique. The statistical technique interpolates the wet correction measurements at each altimeter ground-track point with invalid MWR measurements from the nearby (in space and time) valid MWR, ECMWF and GNSS derived independent measurements, and takes into account the accuracy of each dataset.

coastalt-gnss
support to science element

Project team:
Universidade do Porto, Faculdade de Ciências (PT)
HIDROMOD Modelação em Engenharia Lda (PT)

Status:
Completed

1



1- Standard deviation (m) of the GPD estimates for all invalid MWR measurements present in Envisat cycle 58. Black triangles: GNSS stations used in the computation.
Credits: COASTALT-GNSS team.

SMALT

smalt
support to science element

Project team:
De Montfort University (UK)
Starlab (ES)
Technische Universität Wien (AT)

Status:
On-going

The soil moisture plays a crucial role in a multitude of hydrology applications such as water-flow forecasting, soil conservation, soil erosion, infiltration control, flood prediction, and its distribution knowledge is critical even for meteorology, climate change and agriculture.

So far, soil moisture retrievals have been attempted mostly from scatterometer/radiometer/SAR data neglecting that even the radar altimeters detect the backscattering coefficient along the overflown track and also provide nadir measurements that allow to minimize the incidence angle effect and are less sensitive to surface roughness. Furthermore, the next generation SAR altimeters are going to provide high along-track spatial resolution, overcoming the previous spatial limit of pulse-limited altimetry.

This project is developing a novel methodology to generate soil moisture estimates in arid and semi-arid regions from multi-mission satellite radar altimetry. Prior to the SMOS mission these areas were extremely hard to measure remotely.

Key to this approach is the development of DRy EArth ModelS (DREAMS) which encapsulate the detailed and intricate surface brightness variations over the Earth's land surface resulting from changes in surface roughness and composition. These models are made by cross-calibrating and reconciling multi-mission altimeter sigma0 measurements from ERS-1, ERS-2, Envisat and Jason2. This is possible because altimeters are nadir-pointing, and most of the available radar altimeter datasets are from instruments operating in Ku band. These DREAMS are complicated to build and require multiple stages of processing and human intervention. They require fusing ERS-1 Geodetic Mission recalculated sigma0 values with ERS-2 repeat arc data and hence creating models. This is a multi-stage process with 6 separate stages, with manual intervention at each stage. However, this approach obviates the requirement for detailed ground truth to populate theoretical models, facilitating derivation of surface soil moisture estimates over arid regions, where detailed survey data are generally not available.

Results for altimeter derived soil moisture, from a second generation model, have been validated for the Simpson desert, assessed against the Queensland Climate Change Centre AussieGRASS model outputs, with a good agreement between the two datasets. Other test areas are the Sahara desert and the Kalahari desert. Currently, both areas are characterised by a first generation model and a more refined second generation model is expected in the following months.

The initial results used ERS-2 data, it is now intended to apply this technique to Envisat Ku-band sigma0 to generate comparison data for SMOS over a number of different desert and semi-arid regions.

1- Result of the sigma0 model over the Simpson desert.
Credits: SMALT team.

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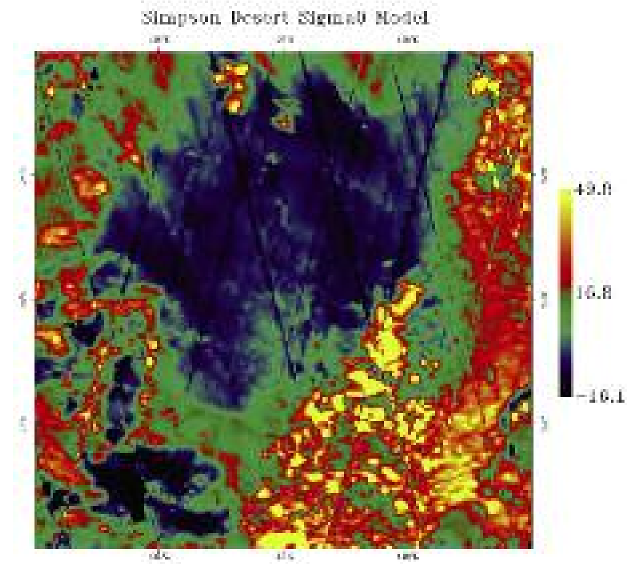

BIOMASAR

The amount and spatial distribution of forest resources in the boreal zone are highly debated because they are often roughly quantified and seldom verified. Gaps and errors in available datasets of growing stock volume (GSV) or aboveground biomass imply that carbon stocks assessments can suffer from substantial uncertainties.

Satellite remote sensing supports mapping and monitoring of forest resources on a large scale because of its synoptic view, frequent revisit capability, relatively low cost and sensitivity of the observable to either biophysical or structural properties of forests. For the boreal zone, observations of the radar backscatter by Envisat ASAR ScanSAR are available with an almost daily frequency and are systematically available to the scientific community. Despite the short wavelength, it is possible to retrieve forest growing stock volume using a multi-temporal approach, which reduces the retrieval error substantially when compared to an estimate based on a single measurement of the radar backscatter.

Scope of this project was the validation of a fully automated approach for the retrieval of GSV starting from a hyper-temporal set of Envisat ASAR ScanSAR backscatter measurements (BIOMASAR algorithm) and its application to generate a pan-boreal map of GSV for the year 2010 at 1 km spatial resolution. Validation at local sites showed that the retrieval error is on the order of 40%, decreasing to 25% when averaging over at least 100 pixels (e.g. from 1 km to 10 km). The pan-boreal map has been produced from 65,000 ASAR data strips using the computing resources of the Grid Processing on Demand (G-POD) platform. In total, 565 Gbyte of SAR data were used to generate the final estimate of GSV. The pan-boreal estimates of GSV will be used for the initialization of global carbon/biosphere models in view of more accurate modelling of the land-atmosphere CO2 exchange compared to the current approaches implemented in these models.

biomasar
support to science element

Project team:
University of Jena (DE)
Gamma Remote Sensing (CH)
Max-Planck-Institute for Biogeochemistry Jena (DE)

Status:
On-going

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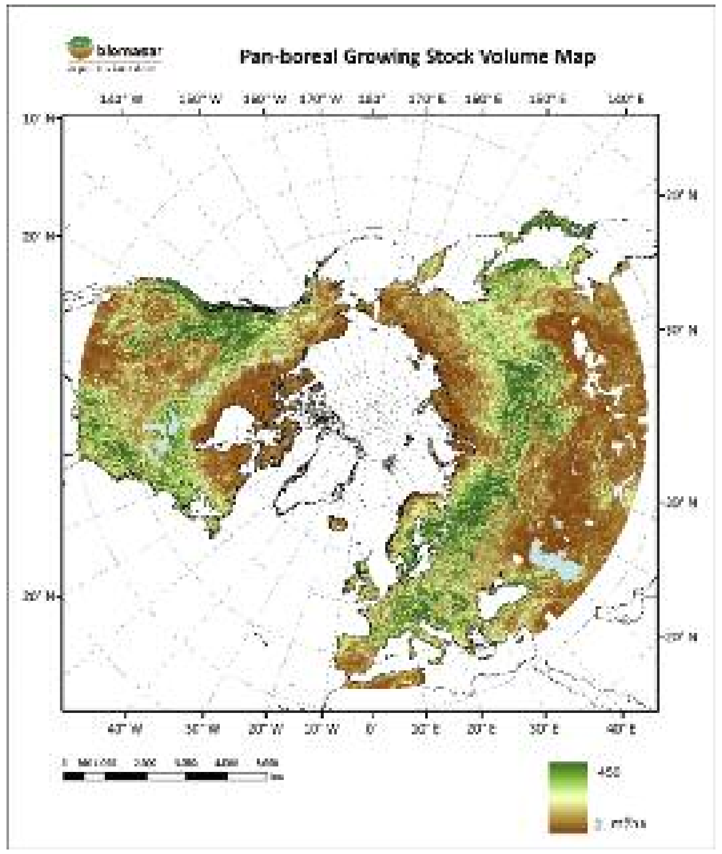

1- Pan-boreal forest growing stock volume (GSV) map obtained with the BIOMASAR algorithm using Envisat Advanced Synthetic Aperture Radar (ASAR) ScanSAR images acquired between October 2009 and February 2011 (for Japan, between March 2011 and March 2012). To enhance contrast, GSV is represented between 0 and 350 m3/ha. The maximum estimate GSV is 900 m3/ha. The GlobCover Land Cover map was used as background for non-forested areas.
Credits: BIOMASAR team.

STARS

stars
support to science element

Project team:
Norwegian Meteorological Institute (NO)

Status:
On-going

Intense meso-scale cyclones known as polar lows are frequently observed in the Arctic sector of the North Atlantic Ocean. During winter, cold-air outbreaks may be triggered by the large scale atmospheric flow exposing dry and very cold air to the relatively warm ocean surface. One of the ocean areas mostly favored for polar low development is between the Norwegian mainland and the Svalbard island. Due to the presence of the North Atlantic Current (NAC), the waters in this area may be warmer than 6°C in January. The large air-sea temperature differences experienced during cold-air outbreaks result in the formations of atmospheric fronts, large heat fluxes and sometimes the development of polar lows.

The main scientific questions addressed by the STARS project are:

- Can satellite IR observations in combination with altimeter be used to detect possible sea-surface warming caused by strong winds under polar low events?
- Can we identify a polar low indicator based on satellite data that could be a useful tool for polar low forecasting?
- Can the forecasting of polar lows be improved by introducing coupled atmosphere ocean models?
- Does the strong turbulent mixing induced by polar lows have an anomalously strong impact on the cooling of the North Atlantic Current?

The project is now in phase-II and has prepared an extensive database of EO data for polar low cases in the Norwegian Sea. These data have been used to derive a climatological study of polar lows in the Nordic Seas (Noer et al, 2011). A polar low indicator has been developed and tested at the Norwegian Meteorological Office Polar Low Forecasting Centre. The project is also investigating the application of SAR data to better understand surface wind fields in and around polar lows. Ocean models are being used to evaluate how the ocean adjusts and re-stratifies after polar low events. An international workshop for polar lows organised by the project team, held in Oslo in May 2012, brought the polar low community together to discuss the results of field studies, new theoretical investigations and develop the polar-low community awareness of new EO data sets.

1- Example from the STAR.DAT system showing a polar low event.
Credits: STARS team.

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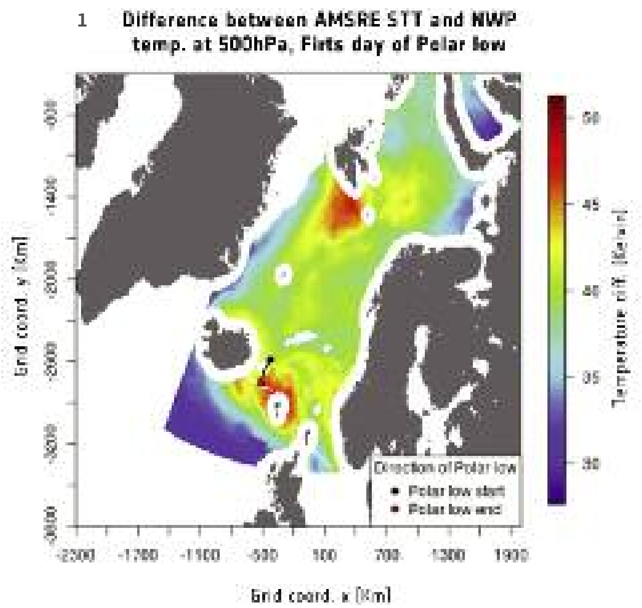

EO-LDAS

Earth Observation (EO) data have great potential to contribute to land surface monitoring, providing consistent global coverage with historical archives to document changes. The increasing number of EO missions is opening new opportunities to users to access a larger number of data products derived from different sensors providing estimates of the same geo-physical or climate variables.

To go beyond description of the Earth modelling and understanding requires land surface properties to be quantified, but inconsistencies in the assumptions used to generate products make it difficult to integrate products from more than one sensor system into modelling assimilation schemes. EO-LDAS aims to overcome these difficulties by developing a scheme to directly assimilate radiance fields, instead of higher level data products.

EO-LDAS approaches the estimation of state variables (properties of the land surface) from remote radiometric measurements as an optimisation problem with multiple constraints. It provides the most reliable estimate of state vector elements in space/time with associated uncertainties, given our current understanding of processes (encoded as models) and Earth observation data. The scheme comprises two main components: 1) a set of constraints contributing to an additive cost function and 2) the assimilation scheme that minimises the cost function based on the set constraints.

Validation of the prototype was undertaken to ensure the correct operation of the software and to demonstrate the utility of the approach. Synthetic data experiments undertaken with simulated Sentinel-2 data showed that a reduction in uncertainty in Leaf Area Index (LAI) retrieval of a factor of around 2 might generally be achieved compared to traditional retrieval techniques, even when there are large data gaps and 50% of the samples lost due to cloud cover.

Experiments using EO and field data showed that the prototype was capable of estimating top-of-canopy LAI with good agreement with field data and that the system could forward model top-of-atmosphere MERIS observations based upon land surface parameters estimated from MODIS data. Experiments in the spatial domain showed that the prototype could reconstruct a simple synthetic scene with good fidelity, even with quite large 'cloud' gaps, and was able to combine datasets at different resolutions to obtain the best estimate of original scene.

The EO-LDAS scheme shows highly encouraging results and offers a promising future as the basis for future operational systems to estimate land surface properties from EO data. A number of future enhancements have been proposed as the next steps towards a more operational implementation, including extensions to the system functionality and improvements in its computational efficiency.

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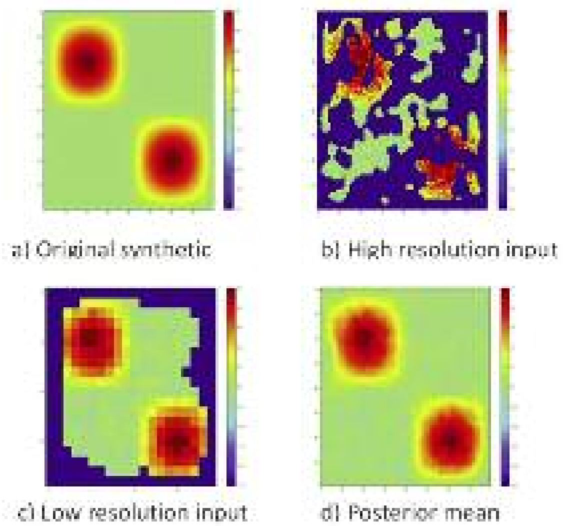

eo-ldas
support to science element

Project team:
FastOpt (DE)
Friedrich-Schiller-Universität Jena (DE)
Joint Research Centre (EU)
National Centre for Earth Observation (UK)
SciSys Ltd. (UK)

Status:
Completed

1- The Figure shows the results of a spatial data assimilation experiment. The original synthetic dataset (a) has noise of sigma 0.15 added. The high resolution dataset (b) has 2/3 of the samples removed and the low resolution version (c) 1/3 removed. The posterior mean after EOLDAS, d) shows very few artefacts of "blockiness" from the low resolution data.
Credits: EO-LDAS team.

SAR ICECONSTELLATION

sar iceconstellation
support to science element

Project team:
C-CORE (CA)
Centre for Earth Observation Science (CA)
Canadian Ice Service (CA)
eOsphere Ltd. (UK)
Polar Imaging Ltd. (UK)

Status:
Completed

Synthetic Aperture Radar (SAR) satellites such as ESA's future Sentinel-1 mission often represent the only reliable source of information on sea ice conditions in the Arctic and Antarctic. Their all-weather day-and-night medium to high resolution imaging capabilities are especially useful in the harsh polar environments which severely limit alternative sources of information based on optical or in-situ measurements. As a result, monitoring sea ice zones and the Arctic environment is one of the major application areas supported by Sentinel-1.

In addition to Sentinel-1, other space-borne SAR missions, often operating at different wavelengths and imaging modes, developed by partner agencies and commercial entities, are expected to operate concurrently with Sentinel-1. This SAR mission constellation anchored by Sentinel-1 is expected to offer unique enhanced scientific and operational capacity for sea ice mapping products compared to a single SAR mission. For example, certain ice types can be more easily identified when using coincident images acquired from two different satellites operating at two different frequencies.

In this context, this STSE project focuses on the potential future SAR constellations for the operational and scientific monitoring of sea ice conditions. Within the study, major efforts were made to assemble a unique and highly valuable database of measurements from a variety of past and current SAR missions and sensors. This database was then incorporated into a software simulation tool which, for the first time, provides quantitative predictions of: a) sea ice radar signal as a function of the ice type, condition and of sensor and/or mission, and b) the accuracy of SAR-constellation based sea ice maps. Through the STSE activity the ice radar software simulation tool will be made available to the user community. It is expected to play an important role in the training of sea ice analysts, support new and enhanced sea ice mapping activities and contribute to Agency end-user dialogue in the design and implementation of future SAR missions.

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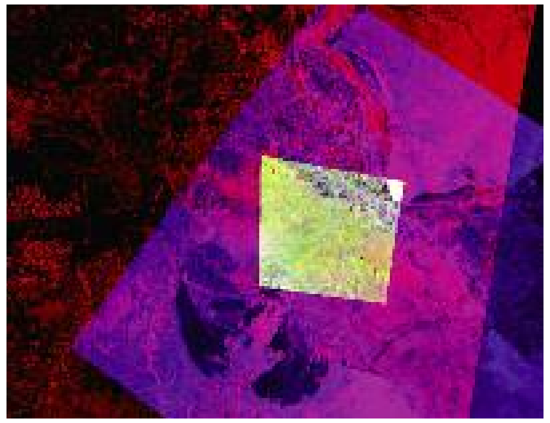

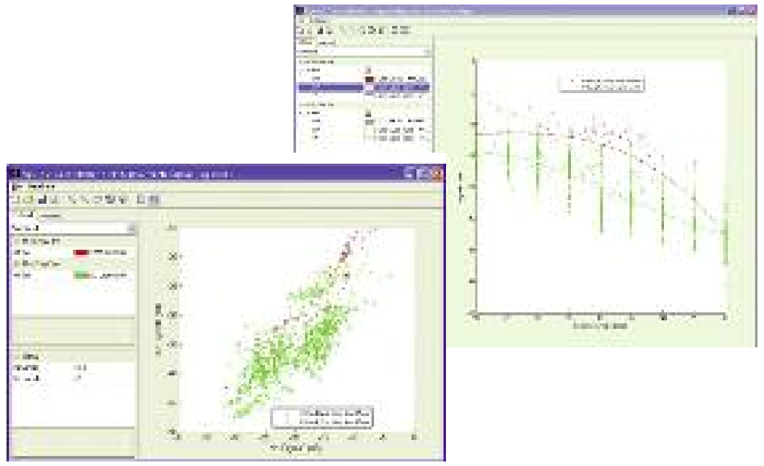

1- The SAR IceConstellation Software package allows the investigation of the benefits provided by the synergetic use of different SAR frequencies and polarisations. The top image shows different scenes acquired at L-, C- and X-band on the same ice in Northern Canada at the same time and overlayed to illustrate the concept of the study (ALOS PalSAR = blue, R2 = red and TerraSAR-X = green). It is a rather unique combination. The botton images illustrate some of the tool functionalities.
Credits: SAR IceConstellation team.

SNOW RADIANCE

snow radiance
support to science element

Project team:
Brockmann Consult (DE)
Finnish Meteorological Institute (FI)
University of Bremen (DE)
Free University of Berlin (DE)

Status:
Completed

Monitoring of snow covered land areas and sea ice is today recognized as of primary importance in the climate change context. In the near future, the novel capacities of Sentinel-3 and other optical missions (e.g., Sentinel-2) will open the door for enhanced observations and novel global data sets beyond the existing and planned ESA products. In this context, SnowRadiance provided support the scientific community to advance in the modelling of the spectral (in the UV to TIR spectral range) and bi-directional properties of snow/ice in preparation of the next generation of snow/ice products. The project also focused on prototyping and validating novel snow/ice products using ESA optical data (MERIS/AATSR).

The new algorithms, based on radiative transfer models, use the two comprehensive radiative transfer codes SCIATRAN (from the University of Bremen) and MOMO (from the Free University of Berlin). With these models the snow radiative properties were calculated in the visible and the thermal IR. The radiative transfer calculations include databases of atmospheric optical properties (phase matrix, extinction and scattering coefficients), atmospheric absorption characteristics (gases, aerosols), underlying surface properties (vegetation, bare soil, snow) and account for their arbitrary vertical distributions.

Snow grain size can be retrieved from MERIS measurements at 865 nm by applying pre-calculated look up tables (LUTs). The physics behind this is that the reflectivity of snow at 865 nm depends on the snow single scattering albedo, which is lower for larger grains due to larger absorption. Snow temperature retrievals are based on LUTs at 11 and 12 micron channels of AATSR. Optionally, the 443 nm wavelength can be used for the estimation of the soot concentration. Snow is essentially a white object at 443 nm with a high level of reflectivity (90-100% depending on the geometry). If the snow is polluted, e.g. by soot, the snow brightness is reduced considerably.

The new SnowRadiance algorithms have been implemented in the BEAM toolbox. They will enable a detailed monitoring in the regions of mountain glaciers, the ice sheets on Greenland and Antarctica, the glaciers of the Antarctic Peninsula or the Arctic. They are flexible in that they can be applied to observations from future missions as well. A sensitivity analysis of the snow grain size retrieval already indicated that the measured signal is at maximum around 1020 nm being available at OLCI/Sentinel-3. This implies that the new algorithm will provide excellent results for the future ESA OLCI sensor.

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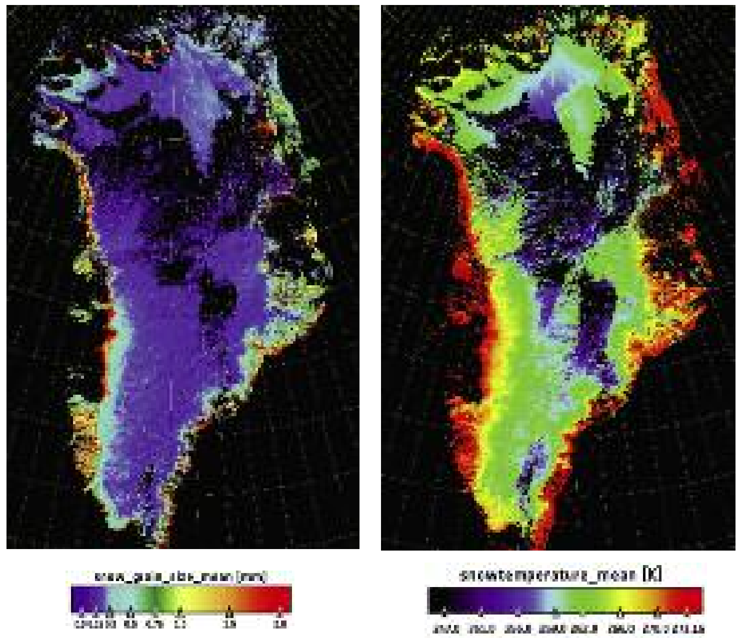

1- Monthly mean snow grain size and snow temperature derived from MERIS and AATSR over Greenland. May 2004.
Credits: Snow Radiance team.

→ WATER RADIANCE

water radiance
support to science element

Project team:
Helmholtz-Zentrum Geesthacht (DE)
Freie Universität Berlin (DE)
Brockmann Consult (DE)
Argans Limited (UK)
University of Strathclyde (UK)
Bio Optika (UK)

Status:
Completed

The remote sensing of natural water constituents such as phytoplankton chlorophyll, its detritus or the mineral matter in suspension, relies on the interpretation of the water leaving radiances measured just above the water surface. Such measurements are available from satellite (after atmospheric correction of the top-of-atmosphere measurements). The interpretation of these water leaving radiances into the natural water inherent optical properties generally requires accurate knowledge of the optical properties of pure water taken alone. The pure water optical properties are namely its absorption, its scattering and its refractive index. Pure water optical properties are a prerequisite to disentangle the optical contribution from the additional water constituents present in natural waters.

The capability of modelling the radiative transfer in the water column is also key to the quantitative interpretation of the water leaving radiances into water constituent concentrations or into water inherent optical properties.

The main objective of the STSE Water Radiance activity was to both improve our understanding of the radiative transfer in natural waters and to improve the characterisation of pure water optical properties. Such understanding is required when exploiting optical remote sensing data of ocean as delivered by Envisat/MERIS and, in the near future, Sentinel-3/OLCI.

The activity aimed more specifically at:

1) improving the characterisation of the optical properties of pure water from the ultra violet to the thermal infrared, with particular emphasis being placed on the sensitivity of these optical properties to temperature and salinity variations;
2) developing a radiative transfer model capable of simulating the radiative transfer of light in the water column, in a coupled ocean-atmosphere system, including the simulation of the polarized components of light, the effects of in-water Raman scattering and of a wind driven air-sea interface;
3) developing a retrieval scheme applicable to MERIS and OLCI capable of retrieving the IOPs of natural waters from the measurement of water leaving radiances provided by space missions.

1- The Total Suspended Matter concentration over the Baltic Sea as retrieved from Envisat/MERIS data by the prototype Water Radiance retrieval algorithm. The salinity of the Baltic Sea is below 10 PSU which is much lower than global ocean salinity and makes it a perfect test case for testing the impact of salinity on optical water properties. In the photo, The PSICAM used at the Helmholtz-Zentrum in Geesthacht (Germany) to perform pure water absorption measurements.
Credits: Water Radiance team.

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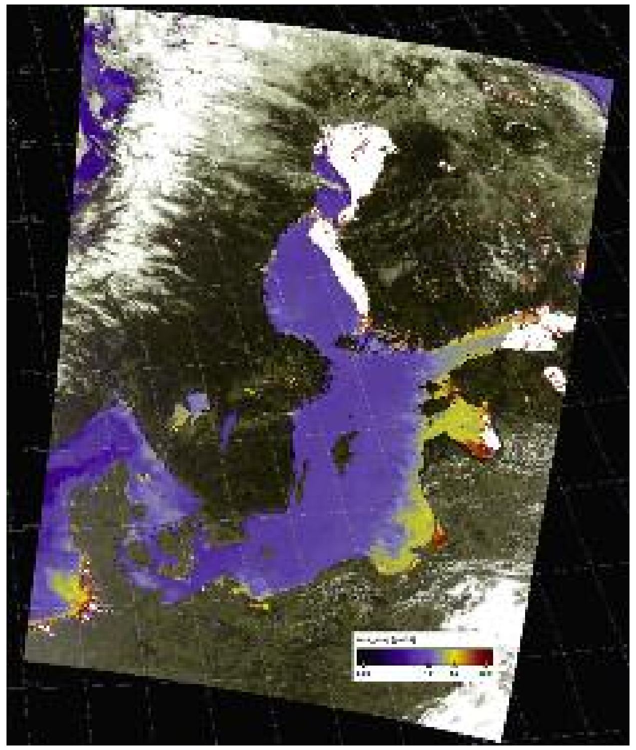


→ SEN4SCI

sen4sci
support to science element

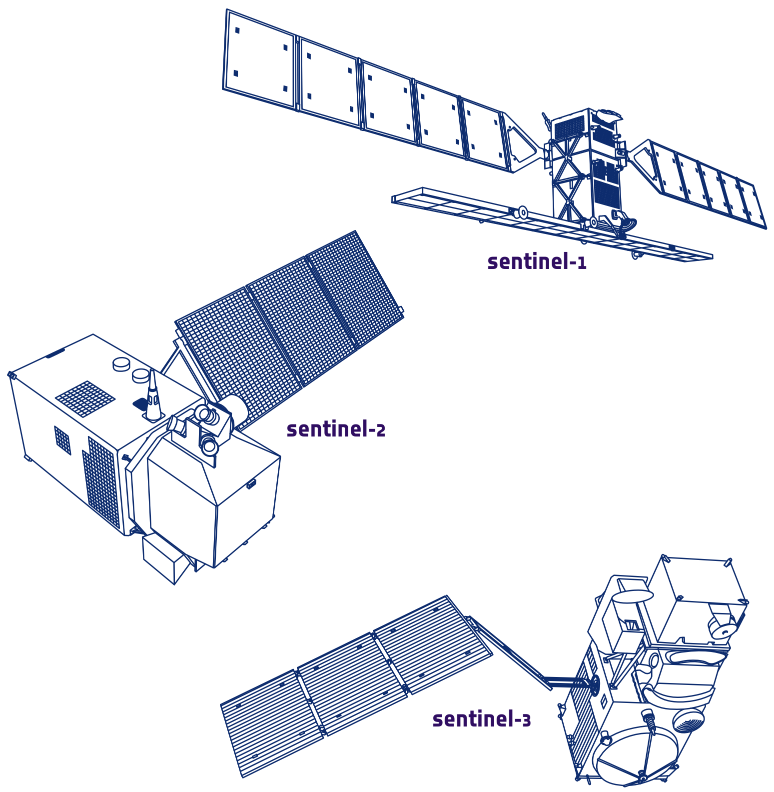
Project team:
Environmental Earth Observation IT GmbH (ENVEO IT) (AT)
Remote Sensing Laboratories (RSL) (CH)
ZEMKON Inc (CA)

Status:
On-going

Today, a new age in the ESA Earth Observation (EO) programme is becoming a reality with the launch of the Earth Explorers, the continuity of well established meteorological missions and the development of the space component for the GMES (Global Monitoring for Environment and Security), namely the Sentinels, which will not only provide data for operational services but will also open the door to new and enhanced scientific applications. These planned missions together with the Third Party Missions (TPM) will provide ESA with an unprecedented observation capacity to support the scientific community to address the key challenges of the Living Planet Programme and the priorities of the major international scientific organisations and programmes.

The Sentinel missions are driven by operational services and their particular requirements. However, as widely recognised, operational missions also bear a wealth of information for scientific exploration in different scientific disciplines. This is in particular true considering the high temporal revisit provided by the planned constellations of satellites, the novel instrumentation covering different spatial and spectral scales and the long-term commitment. Data access for scientific use is currently being favoured in the GMES data access principles. Considering the above, it is getting high time to establish a strategy for the scientific exploitation of the Sentinel missions.

In this context, this study is preparing the scientific exploitation of the Sentinel missions. The improved observational capacities of the Sentinel missions shall be analysed and their potential to contribute to achieve the major challenges in Earth science shall be explored. To this end, the project will support the development of a scientific roadmap identifying major scientific requirements in terms of new products and novel retrieval methods. Requirements of the science community shall be analysed beyond the product portfolios of the GMES operational services.



3D VEGETATION LAB

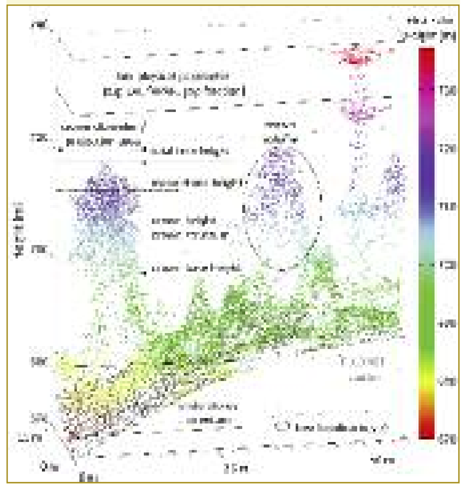
3d vegetation lab
support to science element

Project team:
Remote Sensing Laboratories UZH (CH)
Technische Universität Wien (AT)
University College London (UK)
Netcetera (CH)
Centre d'Etudes Spatiales de la Biosphère (CESBIO) (FR)
Technische Universität Dresden (DE)

Status:
On-going

1


1- 3D scan of a coniferous branch performed in the laboratory characterizing the canopy structure at shoot level.
2- Point cloud of two airborne LiDAR campaigns (under leaf on and off conditions) close to Lägeren fluxtower, Switzerland. Variables to be derived from the LiDAR data describing the canopy structure at stand and tree level are shown in the graphic.
3- Range image produced by the terrestrial laser scanner of the forest stand at the Lägeren site. The color coding represents the horizontal distance to the laser scanner.
Credits: 3D VegetationLab team.

2


The coming generation of ESA operational missions – the Sentinels – will enhance the capability to observe and monitor the global vegetation dynamics. The enhanced accuracy, coverage and resolution in space and time will provide operational institutions and the scientific community with an excellent tool to improve the monitoring of the global vegetation. Nevertheless, the quantitative interpretation of the Earth Observation (EO) signal is a challenging task because vegetation is a complex and dynamic medium. Effects of horizontal and vertical heterogeneities and asymmetrical structures of vegetation as well as their high temporal dynamics are often neglected in algorithm development, calibration and validation procedures.

To better understand the scientific basis as well as the potential of future and upcoming missions we need detailed knowledge about the observed medium and the processes governing the radiative transfer. The combination of a realistic description of the medium in high detail together with a validated radiative transfer model can create a virtual lab simulating reality, which is capable to assess the potential of novel observation systems as well as to develop new algorithms and understand scaling issues from point measurements to the landscape.

The 3D-Vegetation Lab aims to establish a novel reference site concept, accounting for current field site deficiencies by fully describing a site using structural, physical and biochemical measurements simultaneously in combination with the two established canopy radiative transfer models librat and DART. In particular, the combination of airborne and terrestrial LiDAR observations allows describing and reconstructing complete forest stands (up to several hundred metres) in 3D from single trees down to the leaf/shoot level. The newly developed reference site concept is being developed and demonstrated initially over two FLUXNET sites (Lägeren, Switzerland and Tharandt, Germany), which will further include a multi-scale and multi-temporal data set of airborne and EO data over each site.

The 3D radiative transfer models parameterized by the realistic representation of the canopy structure are integrated in an open source software toolbox, which allows the simulation of current and future optical missions in a controlled but realistic environment. The development of such a benchmarking tool for a number of different reference sites will represent an excellent platform to stimulate innovative research, algorithm development and support EO product validation in view of maximizing the scientific exploitation of the novel capacities offered by the coming ESA missions such as the Sentinels.

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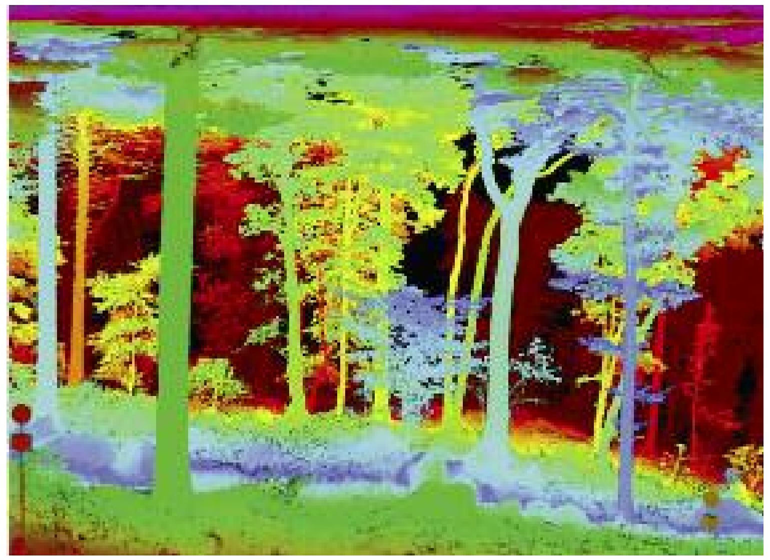

SMOS ICE

Sea ice is one of the key parameters quantifying the exchange of energy and water between the ocean and the atmosphere. Accurate knowledge about its state is valuable for many applications including climate research, weather forecasting and operational oceanography. In particular, sea ice thickness is one of the most important climate change indicators.

Passive microwave observations have been used for the retrieval of sea ice parameters for more than 30 years. Retrieval algorithms for fractional ice coverage, multi- and first-year ice and ice extent are based on measurements in a spectral domain from 19 GHz to 85 GHz. ESA's Soil Moisture and Ocean Salinity (SMOS) mission provides observations at 1.4 GHz. At this frequency, the atmosphere is almost transparent and atmospheric water vapour and cloud liquid water have only a small effect on the measured brightness temperatures. Due to the relatively high penetration depth at L-band, information about sea ice thickness can be obtained for thin sea ice.

Within the study, a retrieval algorithm for ice thickness has been developed based on a simplified semi-empirical microwave emission model. A data pre-processing chain has been implemented to generate brightness temperature intensities on a fixed polar-stereographic grid. The algorithm has been used to produce global maps of ice thickness. An initial validation has been performed using observations from Baltic Sea campaigns, MODIS imagery and computations from numerical ice growth models. It has been found that ice thicknesses of up to 0.5 m can be retrieved with an acceptable accuracy. Consequently, a future SMOS derived sea ice thickness data set would complement the sea ice information provided through the CryoSat-2 mission. Currently, the sea ice algorithm is being further validated and revised. Special emphasis has been put on the information provided through angular measurements of the full Stokes vector.

In the future, it is planned to produce sea ice thickness data operationally. The new Level-3 ice product will be computed and disseminated through the University of Hamburg together with the underlying pre-processed and quality controlled brightness temperatures. An ice data set with a reduced latency based on Near-Real-Time brightness temperatures is also under consideration.

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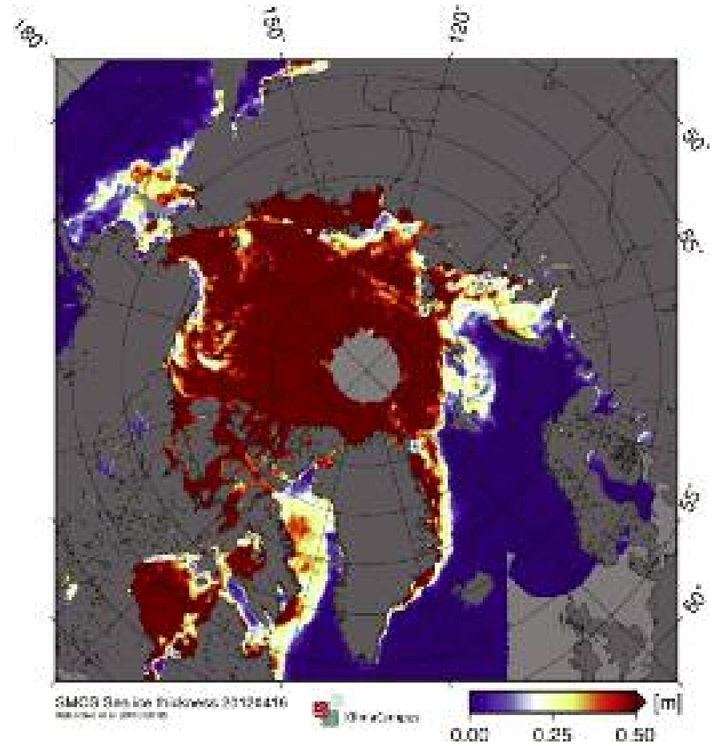

smos ice
support to science element

Project team:
University of Hamburg (DE)
University of Bremen (DE)
Alfred Wegener Institute (DE)
Finnish Meteorological Institute (FI)
Danish Meteorological Institute (DK)

Status:
On-going

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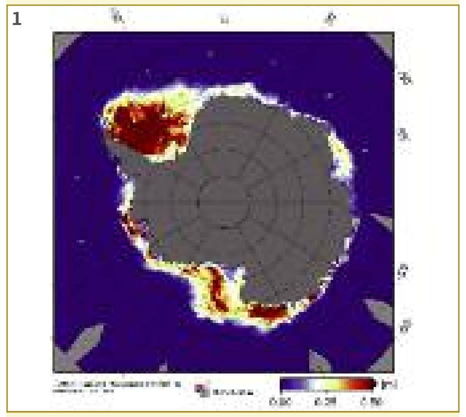

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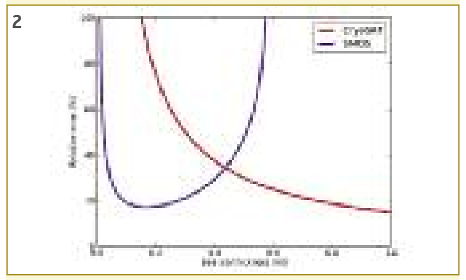

1- Sea ice thickness (up to 0.5 m) over the Antarctic in April 2012. Credits: SMOSIce team.
2- Relative error in sea ice thickness for both SMOS and CryoSat-2 demonstrating their complementarity. Credits: Kaleschke et al., TCD, 2009).
3- Sea ice thickness (up to 0.5 m) derived from SMOS over the Arctic in April 2012. Credits: SMOSIce team.

→ CRYOSAT-SAMOSA

cryosat-samosa
support to science element

Project team:
Satellite Oceanographic Consultants Ltd (SatOC) (UK)
National Oceanography Centre, Southampton (NOCS) (UK)
National Space Institute (DTU Space) (DK)
Starlab (ES)

Status:
Completed

The application of Synthetic Aperture Radar (SAR) techniques to nadir-pointing radar altimetry offers the potential to significantly enhance Earth surface mapping. The Sentinel–3 Surface Topography Mission altimeter will be able to operate in SAR mode over the ocean, and will aim to achieve high–resolution high–accuracy altimetric mapping over the ocean in regions of high mesoscale variability, in coastal areas, and also over inland waters.

The SAMOSA project was initiated in 2007 to investigate the improvements that SAR Mode (SARM) altimetry can offer over ocean, coastal and inland water surfaces, developing practical implementation of new theoretical models for the SAR echo waveform as part of this process. The team, led by SatOC (UK), brings in expertise from NOC and DMU in the UK, STARLAB in Spain and DTU-Space in Denmark. The team was also strongly supported by Dr Keith Raney of JHU (USA) – a highly regarded international expert in the field of Delay Doppler altimetry.

The project team succeeded in defining two novel retracking techniques for SAR Mode altimeter echoes over water surfaces and in evaluating the performance of SARM altimetry compared to conventional pulse-limited altimetry (LRM). SAMOSA confirmed earlier expectations of improvement in range retrieval accuracy (2 fold) and finer along-track spatial resolution. Results also indicated that retrieval of significant wave height is at least as good for SARM as for LRM. The performance of SARM in terms of range retrieval accuracy was analysed by retracking simulated CryoSat data, airborne data and real CryoSat-2 data.

The SAMOSA1 SAR ocean retracker was documented in a Detailed Processing Model (DPM) in support of the Sentinel-3 mission. The DPM was based on the original SAMOSA1 formulation. An update of the DPM is being currently done based on SAMOSA3, the successor of the SAMOSA2 model.

A technique for the reduction of SARM data to emulate LRM and implemented in the 'RDSAR' software was also developed.

The 'Berry Expert System' (BEST) was applied to simulated data over complex inland water scenarios to assess SARM performance over lakes, estuarine and wetlands. Simulated LRM and SARM data were obtained also for scenarios representing inland waters, including a lake scenario, an estuarine scenario and a wetland scenario. These were processed with BEST and successful retracking of the SAR waveforms (more than 62% for the wetland, and up to 85% for the lake scenario) and recovery of small-scale topographic features was demonstrated.

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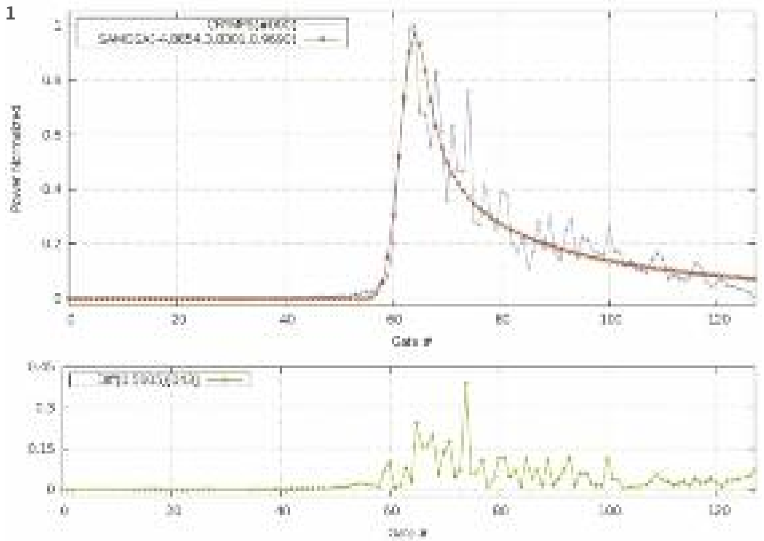

1- Simulated waveform with fitting model overlapped. It shows the outcome from a retracker run; the input Significant Wave Height (SWH) vary between 1 and 3 m (pink line) whereas the blue line is the retracker\output.
Credits: Cryosat-SAMOSA team.

→ GOCE+ HUG

The ESA GOCE mission will allow the determination of geoid heights with an accuracy of 1-2 cm and spatial resolution of about 100 km. An important application that will benefit from this is the global unification of the (over 100) existing height systems. GOCE will provide three important components of height unification:

- highly accurate potential differences (geo-potential numbers),
- a global geoid- or quasi-geoid-based reference surface for elevations that will be independent of inaccuracies and inconsistencies of local and regional data,
- a consistent way to refer to the same datum all the relevant gravimetric, topographic and oceanographic data.

The overall objective of the GOCE+ Height System Unification (HUG) with GOCE project is to demonstrate the feasibility of calculating heights and connecting height systems with GOCE products. There are nine objectives to be addressed in this study:

- To collect information and review the state-of-the-art in height systems and local/regional/global initiatives to unify height systems.
- To quantify the currently known differences (without a precise GOCE geoid) between height systems in Europe and other parts of the world based on available literature and existing results.
- To review, evaluate and improve methodology and/or existing algorithms for height determination and height system unification.
- To attempt global height unification and tide gauge unification for those parts of the world where the data sets are available.
- To select two test regions for height system unification and to demonstrate the benefit of using GOCE data for this purpose (to the resolution and accuracy of the new data).
- To assess the impact of a unified height system on local gravity information (systematic errors in local gravity anomalies and alike) and topographic heights and vice versa.
- To geophysically interpret height differences (compared to the GOCE geoid) at one or more tide gauges in terms of ocean dynamic topography and currents and to compare the results to altimetry.
- To involve local/national organisations maintaining height systems.
- To provide a roadmap for future work required to define a world height system and vertical datum exploiting GOCE data.

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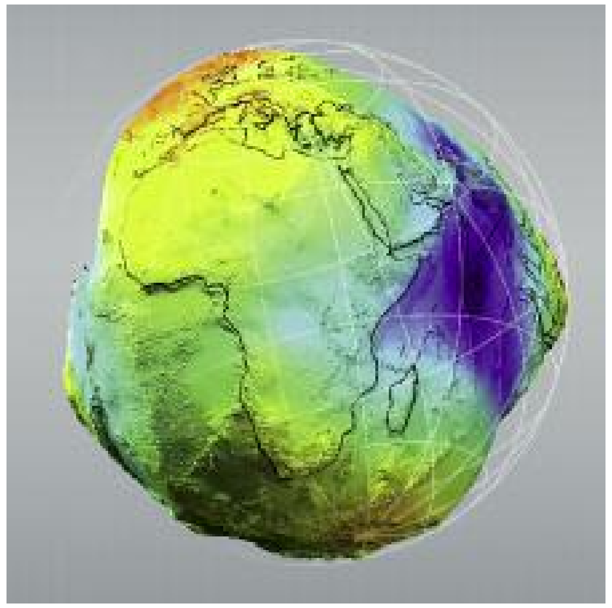


goce+
hug
support to science element

Project team:
Institute of Astronomical and Physical Geodesy, Technische Universität Munich (DE)
Bundesamt für Kartographie und Geodäsie (DE)
University of Calgary (CA)
National Oceanographic Centre (UK)

Status:
On-going

1- The World Height System is an integrated product that comprises numerous inputs.
Credits: ESA.

GOCE+ GEOEXPLORE

goce+ geo explore
support to science element

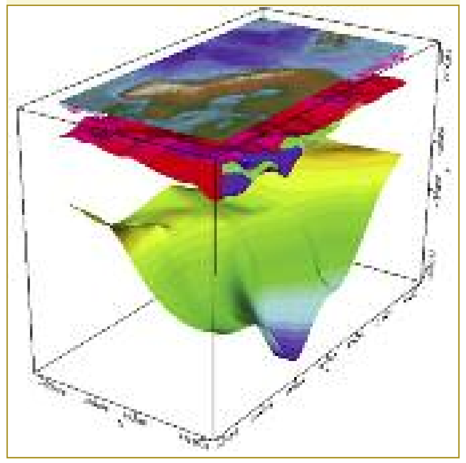
goce+ geo explore II
support to science element

GOCE+ GeoExplore Team:
Deutsches Geodätisches Forschungsinstitut (DGFI) (DE)
Norwegian Geological Union (NO)
Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (TNO) (NL)

GOCE+ GeoExplore II Team:
University of West Bohemia (CZ)
Aristotle University of Thessaloniki (GR)
Dublin Institute for Advanced Studies (IE)
AAS (AT)
GIS (DE)
Delft University of Technology (NL)

Status:
On-going

GOCE gravity gradient data may improve modelling of the Earth's lithosphere and mantle composition and thereby contribute to a better understanding of the Earth's dynamic processes and geo-resources exploration.
Credits: GOCE+ GeoExplore team.



GOCE data may improve the understanding and modelling of the Earth's interior and its dynamic processes, contributing to gain new insights into the geodynamics associated with the lithosphere, mantle composition and rheology, uplift and subduction processes. However, to achieve this challenging target, GOCE should be used in combination with additional data sources: e.g. magnetic, gravity and seismology in situ, airborne and satellite data sets. In this context two parallel studies have been launched addressing this challenging scientific problem:

GOCE+ GEOEXPLORE:

The overall objective of the study is to combine GOCE gravity gradients with other satellite and in situ gravity information to arrive at a combined set of gravity gradients complementing (near)-surface data sets spanning all together scales from global down to 5 km. This is useful for various geophysical applications and demonstrate their utility to complement additional data sources (e.g., magnetic, seismic) to enhance geophysical modelling and exploration.

The GOCE gravity gradient data sets and regional gravity fields will be used for the North East Atlantic Margin for modelling of the lithosphere and upper mantle. In addition, the gravity data sets will be used for the southern part of the Arabian Peninsula (Rub' al Khali) to improve modelling for exploration geophysical purposes. The North East Atlantic Margin is a well-studied area and the knowledge acquired for this region will be translated to the frontier Rub' al Khali area.

GOCE gravity gradients will be used in their original form, but they will also be combined with existing global gravity field models to improve the long wavelengths. In addition, terrestrial gravity data will be added to improve the resolution and to add additional constraints that may aid in the iterative forward modelling and inverse modelling to improve the geophysical model.

GOCE+ GEOEXPLORE II:

This project complements the GOCE+ GeoExplore activity with additional scientific efforts and test cases. To this end, the team of 6 European institutes investigates applications of GOCE gravity gradients in order to improve geophysical models in two different geographical areas.

The first area, the Reykjanes Ridge close to Iceland, covers a mid-ocean ridge that plays a key role for creation of a new crust and for generation of ridge push driving partly plate motion. Combined GOCE gravity gradients from study team I will be used for refined local density modelling that cannot uniquely be achieved through seismic measurements.

In Africa, the second test area of the project, GOCE gravity gradients from team I will be combined with seismic tomographic models of the continental lithospheric mantle (upper 200 km or so of the Earth's mantle that lies beneath the thin crustal layer) in order to refine an initial density model derived by 3-D modelling programs.

To achieve these goals, GOCE gravity gradients from team I will be used in combination with other available data sources such as ground and marine gravity, altimetry, terrain elevation and density models, seismic tomographic and mantle flow models and crustal thickness models. However, the main target for the project is to demonstrate in particular the benefits of GOCE gravity gradients for geophysical applications and interpretations.

GOCE+ AIR DENSITY

GOCE is the first of a family of Earth Explorer satellites designed to study our planet and its environment in order to enhance our knowledge and understanding of Earth-system processes and their evolution, to enable us to address the challenges of global change. The main goal of the GOCE mission is to determine the Earth's stationary gravity field with unprecedented accuracy and resolution. Applications are expected in the area of marine geoid determination, a better understanding of the Earth's interior, global height datum unification and the estimation of mass and thickness of polar ice sheets.

In addition to addressing the primary objectives, GOCE data can also be used in a number of other applications. Neutral density in the thermosphere is one of the most important variables to model for applications in satellite orbit determination and solar-terrestrial physics.

The main objective of this study is to derive algorithms to retrieve thermospheric density and winds using GOCE common-mode accelerations and DFAC data. Furthermore, the algorithms shall be used to generate air density and wind products along the GOCE orbit and on grids.

The data processing and the resulting data set are unique in several ways: GOCE uses an ion thruster to compensate for thermospheric drag, in order to maintain its orbit at a very low mean altitude of 270 km. This means that the most important acceleration data source for density retrieval is the thruster activation data. This information is combined with cross-track accelerometer measurements from GOCE's Electrostatic Gravity Gradiometer instrument to derive crosswind speeds. The nearly sun-synchronous dawn-dusk orientation of the orbit is also unique for high-resolution acceleration-derived thermosphere measurements. The resulting data on the thermosphere will complement and extend existing thermosphere datasets, such as those derived from CHAMP and GRACE data.

The density and wind retrieval algorithm to be developed in this activity is based on the principle that the observed and modelled aerodynamic acceleration vectors should match both in direction and length. First, the relative velocity direction is rotated, so that the resulting modelled aerodynamic acceleration matches the observed one. The difference in relative velocity is the crosswind observation. Subsequently, the neutral density is adjusted so that the modelled aerodynamic acceleration also matches with the observed one in terms of the vector magnitude.

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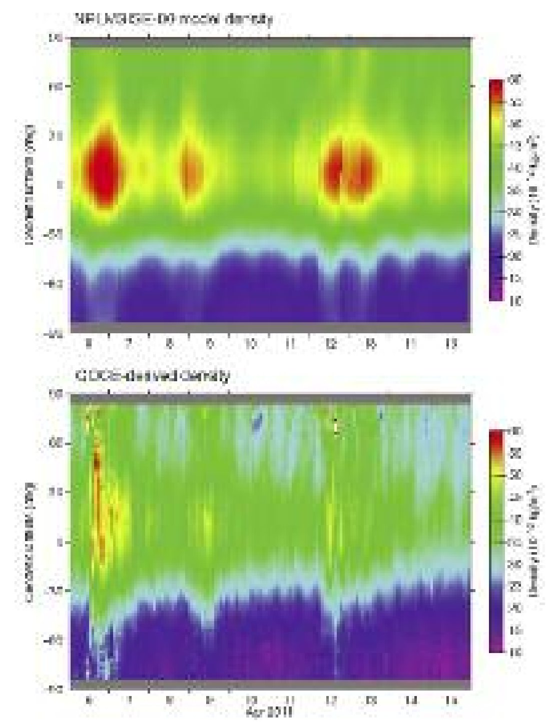


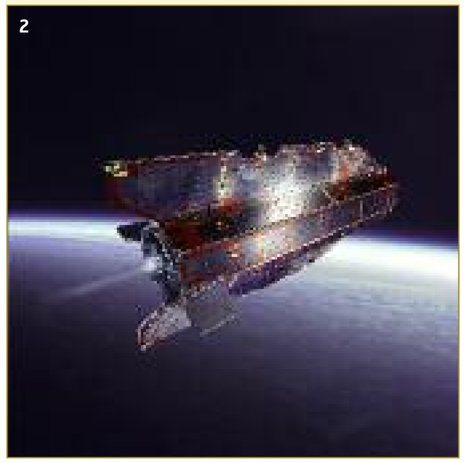
goce+ air density
support to science element

Project team:
Delft University of Technology (NL)
Centre National d'Etudes Spatiales (FR)
Hyperschall Technologie Göttingen (DE)

Status:
On-going

1- The GOCE satellite (below) uses a drag-free control system which keeps the mean altitude fixed at about 270 km (top panel), well below most other satellites. The plot shows a sample of the first GOCE derived density observations, compared with equivalent NRLM-SISE-00 model observations. The GOCE data shows the sharply delineated responses of the thermosphere to several moderate fluctuations in geomagnetic activity. Credits: (1) GOCE+ AirDensity team. (2) ESA.

2



→ GOCE+ TIME VARIATIONS

goce+ time variations
support to science element

Project team:
Deutsches Geodätisches Forschungsinstitut (DGFI) (DE)
Delft University of Technology (NL)

Status:
On-going

The main goal of the GOCE mission is to determine the Earth's stationary gravity field with unprecedented accuracy and resolution. Applications are expected in the area of marine geoid determination, a better understanding of the Earth's interior, global height datum unification and the estimation of mass and thickness of polar ice sheets. To do so, the nominal mission lifetime is about two years with originally two measurement phases of six months and a hibernation phase of 5 months. However, due to the currently low solar activity and the lower than expected effect of drag on GOCE a hibernation phase is not necessary and probably GOCE can stay at one mean altitude for the entire mission lifetime. This opens the innovative possibility to study the feasibility of investigating the Earth's time-varying gravity field in the GOCE data.

The idea is that on the one hand the GOCE data may add additional information to what GRACE observes because GOCE is in a lower orbit than GRACE and the GOCE ground track pattern is regular instead of irregular for GRACE. The combination of GOCE and GRACE data may stabilize the GRACE only solution and may lead to a reduction of the well-known 'stripes' in the GRACE solution. On the other hand, it appears that the GOCE gradiometer provides very accurate gravity gradient information, which may allow detecting very large earthquakes. Whereas GRACE and terrestrial gravity data provide mostly 1D information on the gravity field, the GOCE gravity gradients provide 3D information, which may yield improved geophysical understanding.

The overall objective of the study is to investigate and explore at feasibility level the potential of GOCE data in the context of the Earth's time-variable gravity field. In particular:

- Regional gravity field solutions will be computed for Greenland from a combination of GRACE and GOCE data;
- It is studied whether the signal of the Chile-Maule February 2010 and Japan-Tohoku March 2011 earthquakes are detectable with GOCE.

On the one hand, the expected gravity signal of the earthquakes and the ice mass variations are modelled using geophysical models. Some forward modelling results are shown here.

On the other hand, the GOCE gravity gradient errors are assessed, regional gravity field solutions are computed from GOCE and/or GRACE and gravity gradients before and after the earthquakes are analyzed. In the next step, the results of the gravity analysis will be compared with the forward model results.

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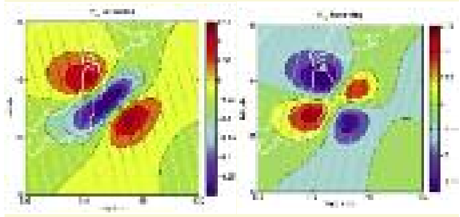
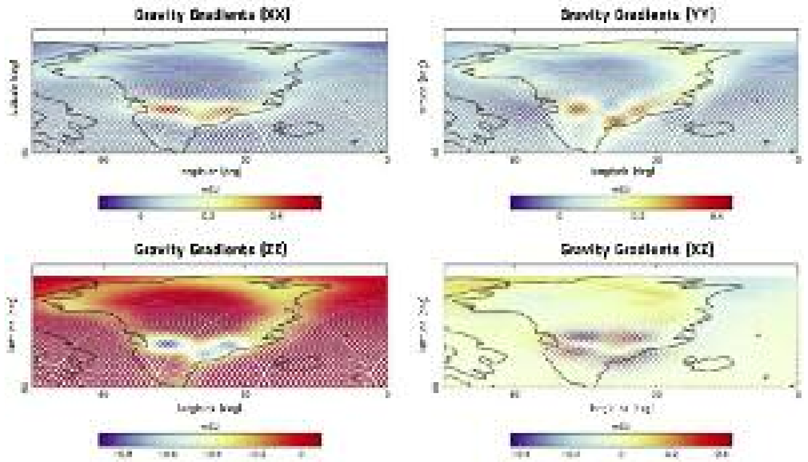


1- Gravity gradients due do the Japan earthquake as they could have been measured along the GOCE orbit.
2- Residents check the damage done on a road and house in Sukagawa city, Fukushima prefecture, in northern Japan.
Credits: (1) GOCE+ TimeVariation team. (2) ESA

2

3



3- Modelled cumulative gravity gradient changes due to a 7-yr ice mass loss along a typical GOCE orbit. These would be the changes observed between two over-flights with a time interval of 7 yr.
Credits: GOCE+ TimeVariation team.

→ SMOS+ HYDROLOGY

smos+ hydrology
support to science element

Project team:
University of Gent (BE)
Centre d'Etudes Spatiales de la Biosphère (CESBIO) (FR)
Princeton University (US)
Monash University (AU)

Status:
On-going

ESA's SMOS mission is part of the ESA's Living Planet Programme and carries the first-ever, polar-orbiting, space-borne, 2-D interferometric radiometer providing observations at 1.4 GHz. From the Level 1 brightness temperatures we derive the Level-2 data products, namely surface soil moisture (over land) and salinity (over oceans). A Near Real Time (NRT) product containing brightness temperatures similar to those delivered as Level-1C is generated on a regular basis for operational applications.

The dynamics of surface soil moisture are an important source of uncertainty in flood forecasting models and a key parameter for the generation of floods. In fact, soil moisture determines how much water can be stored in the soil before runoff and flooding starts. In addition, soil moisture determines the infiltration capacity and the moment when runoff starts. Consequently, SMOS observations can potentially improve run-off and flood forecasting systems in two ways: (1) through data assimilation and more accurate initial conditions and (2) through verification and subsequently improved models. Within this study, robust end-to-end methodologies (from data acquisition to data assimilation approaches) enabling the effective exploitation of SMOS data including L1 brightness temperatures and L2 soil moisture into hydrological models will be developed. The capabilities of this system will be studied based on a number of suitable test cases.

To make optimal use of the SMOS data, large catchments have to be studied in areas where Radio Frequency Interference (RFI) does not contaminate the observations. Moreover, land cover conditions in these test sites should allow a relatively accurate retrieval of the surface soil moisture conditions. Therefore, the SMOS+ Hydrology study will focus on the Upper Mississippi River Basin in the US Northern Midwest and the Murray Darling Basin in Victoria, Australia. Another advantage of both catchments is the relatively frequent occurrence of floods; these floods are often influenced by the initial soil moisture conditions.

The flood prediction analysis system has been built around the Variable Infiltration Capacity model (VIC), the Community Microwave Emission Model (CMEM) and an Ensemble Kalman Filter. The observation database for the two catchments has been assembled and provides information on soils and vegetation, meteorological forcing data and in situ measurements for the model calibration and validation.

1

1- SMOS satellite.
Credits: ESA.

➔ SMOS+ PERMAFROST

smos+ permafrost
support to science element

Project team:
Finnish Meteorological Institute (FI)
Gamma Remote Sensing (CH)

Status:
On-going

Soil freezing, wintertime evolution of soil frost and thawing are important characteristics influencing hydrological and climate processes at the regions of seasonal frost and permafrost, which include major land areas of North America and northern Eurasia. Changes in the seasonal behavior of frost have a major effect on the surface energy balance, as well as on the intensity of CO_2 and CH_4 fluxes. Space-borne L-band radiometers, such as SMOS, provide a unique opportunity to monitor soil freezing and thawing processes on a global scale, covering regions of seasonal soil frost and sporadic / continuous permafrost.

The objective of the SMOS+ Permafrost activity is to improve existing methods and develop new algorithms for the detection and monitoring of soil freezing / thawing processes using L-band passive microwave data. Radiative transfer modelling and algorithm development will be based on observations from the ELBARA-II SMOS reference radiometer data together with extensive in situ information available for the Sodankylä - Pallas region in northern Finland. First results obtained from the Sodankylä test site show that the L-band passive signature tends to saturate for the winter period after the soil frost depth has reached a depth of 25 - 35 cm; the maximum seasonal soil frost in this area typically extends to about 1.5 - 3 metres depending on the year.

For the interpretation of SMOS observations detailed information on the land cover and soil type is required, since the microwave emissivity from barren mountain regions, bogs and forests can vary substantially. In addition, the contribution from open and ice covered water bodies have to be taken into account. For the whole of Northern Finland land cover and soil type information is available in 25 x 25 m resolution. First SMOS-based frost depth estimates have been derived for Northern Europe for 2010 and 2011 (see figures). The examples for 26 November 2010 and 2011 show the late onset of winter in the Northern European areas in 2011. The results are currently being validated using frost tubes installed in the Northern part of Finland. Within the activity it is planned to produce a demonstration data set for the Northern Hemisphere.

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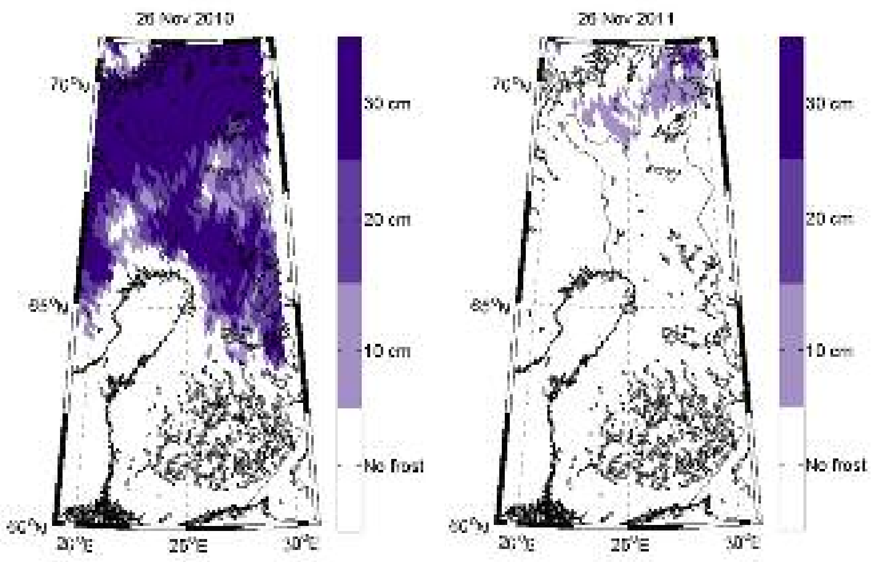

1- SMOS derived soil frost depth on 26 / 11 / 2010 (left) and 26 / 11 / 2011 (right).
Credits: SMOS+ Permafrost team.

➔ SMOS+ STORMS

smos+ storms
support to science element

Project team:
Institut Français pour la Recherche et l'Exploitation de la MER (IFREMER) (FR)
Collecte Localisation Satellites (CLS) (FR)

Status:
On-going

The SMOS mission currently provides multi-angular L-band (1.4 GHz) brightness temperature snapshots of the Earth, originally designed to monitor moisture content over land and sea surface salinity over the oceans. Nevertheless, because upwelling radiation at 1.4 GHz is significantly less affected by rain and atmospheric constituents (compared to higher microwave frequencies), these new SMOS measurements offer also a unique opportunity to complement existing satellite ocean observations at very high winds, which are often erroneous in these extreme conditions.

The objective of this project is to exploit the identified capability of SMOS L1 brightness temperatures to monitor wind speed and whitecap statistical properties beneath hurricanes and severe storms. Such new capability at the core of the project was recently demonstrated by analysing SMOS data over several category-4 hurricanes. Without correcting for rain effects, the wind-induced components of SMOS ocean surface brightness temperatures were co-located and compared to observed and modelled surface wind speed products. The evolution of the maximum surface wind speed and the radii of 34-, 50- and 64-knots surface wind speeds retrieved from SMOS were shown to be consistent with hurricane model solutions and observation analyses (figure below). This feature is being extensively verified in other cases, with the aim of producing a SMOS-derived storm catalogue. The SMOS sensor is thus closer to a true all-weather ocean wind sensor with the capability of providing quantitative and complementary surface wind information of added value for operational hurricane intensity forecasts.

As a further application, the evaluation of SMOS salinity measurements and additional surface parameters response in the wake of hurricanes, especially in freshwater major river plumes, is under study. In a wider context, it is envisaged to use SMOS Sea Surface Salinity (SSS) measurements as a tracking-predictive tool for assessing hurricanes strength intensification or mitigation.

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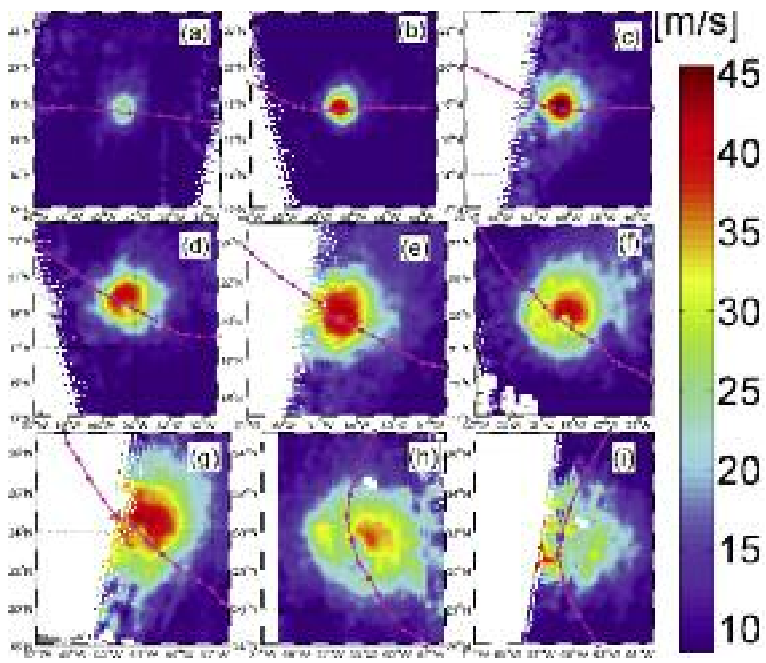

1- Sea Surface Wind Speed fields (m/s) retrieved from SMOS data over the Saffir–Simpson category-4 hurricane Igor that developed in the North Atlantic ocean from 11 (a) to 19 (i) September 2010. The magenta curve is showing the hurricane eye track.
Credits: N. Reul, Ifremer and J. Tenerelli, CLS.

→ SMOS+ POLARIMETRY

smos+ polarimetry
support to science element

Project team:
ACRI-ST (FR)
Institut de Recherche en Astrophysique et Planétologie (IRAP) (UPS) (FR)
University Politécnica de Cataluña (ES)

Status:
On-going

The SMOS satellite has been designed to observe soil moisture over land and salinity over oceans. For this purpose, SMOS takes on board a two-dimensional interferometric radiometer called MIRAS (Microwave Imaging Radiometer using Aperture Synthesis).

MIRAS is a passive instrument operating at a single frequency of 1.4 GHz. At this frequency, the main source of emission is the Earth surface (Planck law) and the emissivity of water. The brightness temperatures (TB) depend on the reflectivity and the viewing conditions (Fresnel equations). Therefore, surface water content drives the emission over land and emissivity of water depends on salt concentration over sea.

This study focuses on the fact that brightness temperature biases have been detected during the commissioning phase. The main objectives of this project are:

- To discriminate instrumental biases from the geophysical signal for different polarizations, specifically for A3 and A4 (third and fourth Stokes parameters);
- To develop and test correction algorithms.

These objectives need a requirement definition:

- Diagnosis definition which will be partially based on the studies already performed by the teams involved in the SMOS phase E programme (L1 and L2 teams). More specifically, the techniques implemented for the analysis of X and Y residues could be adapted to A3 and A4 analysis. New approaches will be proposed, including analyses at the visibility level.
- Correction definition. The limits of the L2 correction implemented in the current L2OS processor will be investigated (OTT). Other solutions will be investigated such as multi-polarization correction or using the whole polarizations at the same time. Criteria of acceptance will be defined (bias on corrected TBs, validity domain of the corrections, etc.).
- The project also includes a global overview of the polarised signal over all surface types in order to identify polarisation signals over all surface types, and to discriminate the part due to a real geophysical signal and the one which is most probably due to an instrument/L1 issue. The outcome being not only corrections of the L1 short comings, but also identification of areas of interest for research exploiting the full polarisation capability of SMOS (specifically for A3 and A4 polarisations).

All these activities will be analysed from an instrumental point of view in order to better understand and to improve the reconstruction algorithms.

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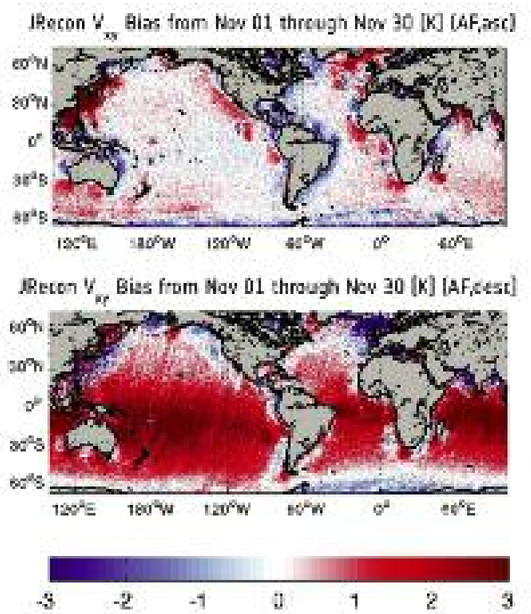

1- A4 biases (average on the alias free FOV) after OTT correction (OTT is obtained from one ascending orbit). Top: ascending orbits; Bottom: descending orbits. The residues are not the same for ascending and descending orbit. The global bias is close to 0 from ascending orbit. For descending orbit, the global bias shows a large positive value. (Source: SMOS QWG#4, March 7-9, "Global biases in the dwell-line mean Stokes parameters from SMOS for November 2010").
bottom: SMOS satellite.
Credits: (1) SMOS+ Polarimetry team and (2) ESA.

2

→ SMOS+ NEURAL NETWORK

smos+ neural net
support to science element

Project team:
Centre d'Etudes Spatiales de la Biosphère (CESBIO) (FR)
ESTELLUS (FR)
Array Systems Computing Inc. (CA)

Status:
On-going

The SMOS Level 2 soil moisture algorithm is based on a radiative transfer model coupled to an iterative inversion scheme. It minimizes a cost function for the difference between the actual observed data and modelled brightness temperatures by adjusting iteratively the state variables. This operational algorithm has provided reliable soil moisture estimates thanks to the high sensitivity of L-band observations to soil moisture and vegetation opacity or vegetation water content. However, the corresponding processor is rather complex and relies on a large number of auxiliary data, which are mainly provided through the European Centre for Medium-range Weather Forecasts (ECMWF), introducing a data latency substantially exceeding the 3-hour Near-Real-Time window. However, this model-based retrieval approach facilitated a Level 2 data production and dissemination service right from the beginning of mission operations in 2009.

Now, with more than two years of harmonized and quality controlled SMOS brightness temperature data available, statistical methods can be exploited. Within this study the potential of Neural Networks (NN) for the soil moisture retrieval will be analyzed. A NN can offer the following advantages: (1) Once trained, a NN is computationally efficient and very quick to apply, (2) NN can handle non-linearities, which may affect the soil moisture retrieval under saturated land surface conditions, and (3) NN are well adapted to make use of different observation types. Therefore, a NN-based retrieval could offer the opportunity for a Near-Real-Time Level 2 soil moisture product, which has often be requested by the hydrological community. In addition, NN retrievals offer the possibility of an efficient re-processing or even a continuous production of SMOS-based soil moisture re-analyses with minimum data latency. Therefore, statistical algorithms can become a very efficient tool for mission performance evaluation. From a more scientific point of view, the NN retrieval would facilitate a soil moisture retrieval combining ASCAT and SMOS observations.

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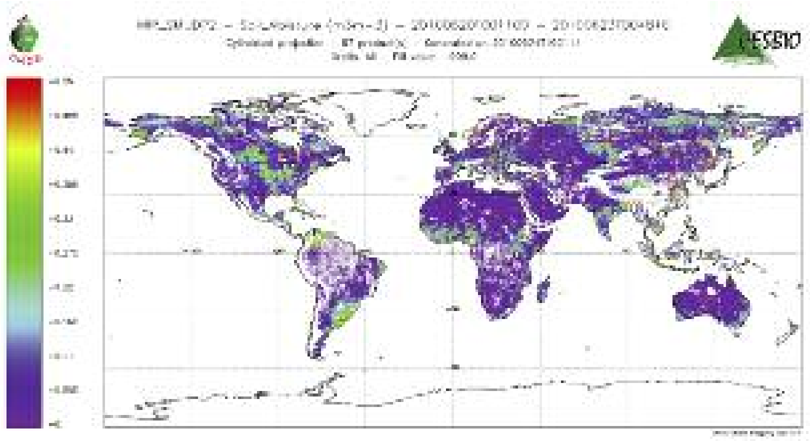


1- First global soil moisture map from SMOS.
Credits: CESBIO.

EARTHCARE ASSIMILATION

earthcare assimilation
support to science element

Project team:
European Centre for Medium-Range Weather Forecasts (ECMWF) (UK)

Status:
On-going

The EarthCARE mission, selected for implementation together with the Japan Aerospace Exploration Agency, JAXA, is a process-oriented Earth Explorer research mission with a very strong operational potential. The mission will carry four instruments for measuring clouds and aerosols simultaneously with outgoing broad-band radiances. The two core instruments are a cloud radar and a cloud-aerosol lidar for vertical profiling along the satellite nadir track.

The data from the EarthCARE mission will present an unprecedented resource for information on cloud-radiation feedbacks useful for Numerical Weather Prediction (NWP), climate model improvements and for directly constraining cloud physical state through data assimilation.

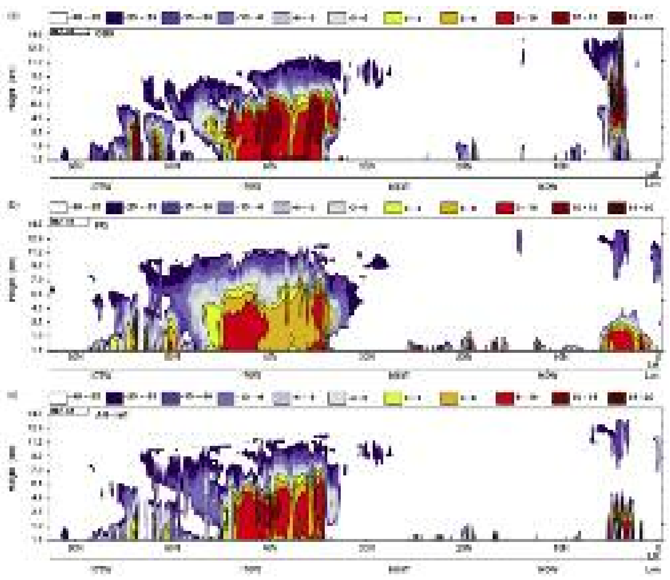
The objective of the study is the development of an off-line data assimilation and monitoring system to exploit combined EarthCARE lidar and radar data for the assimilation of cloud data into an existing NWP model. This will also include the assimilation/monitoring system preparations as well as further improvements to the radar observation operator and the corresponding development of a new lidar operator.

Exploiting EarthCARE-type data through assimilation and monitoring will not only be beneficial for the NWP community by performing the necessary developments and scientific testing, but would furthermore demonstrate the operational potential for space-borne cloud radars and cloud/aerosol lidar missions.

The off-line systems for assimilation and monitoring developed during this project will allow extended research studies beneficial for future applications of EarthCARE radar and lidar data once available on the global scale. To accomplish this objective the following technical developments are required: (1) improvement of the radar observation operator, (2) development of the lidar observation operator, (3) generation of representativeness error statistics, (4) development of a bias correction, (5) construction of data selection tools (quality control and data screening). Furthermore, all developments required for the cloud radar and lidar data ingestion by the ECMWF system and the adaptation of the variational data assimilation framework must be performed.

The testing of the system and the analysis of its performance through case studies will use data of NASA's CloudSat and CALIPSO satellite missions since these are currently the only available real data of similar type with global coverage.

1



1- An example of such retrievals is presented in the figure showing along-track cloud radar reflectivities derived from the CloudSat 94 GHz cloud radar on 23 January 2007 over the northern part of the Pacific ocean together with the model equivalent to the observations (model first guess, FG) and 1D-Var analysis (AN).
2- EarthCARE satellite.
Credits: (1) ECMWF and (2) ESA.

2

SEN4LST

sen4lst
support to science element

Project team:
University of Valencia (ES)
Brockmann Consult (DE)
Swansea University (UK)

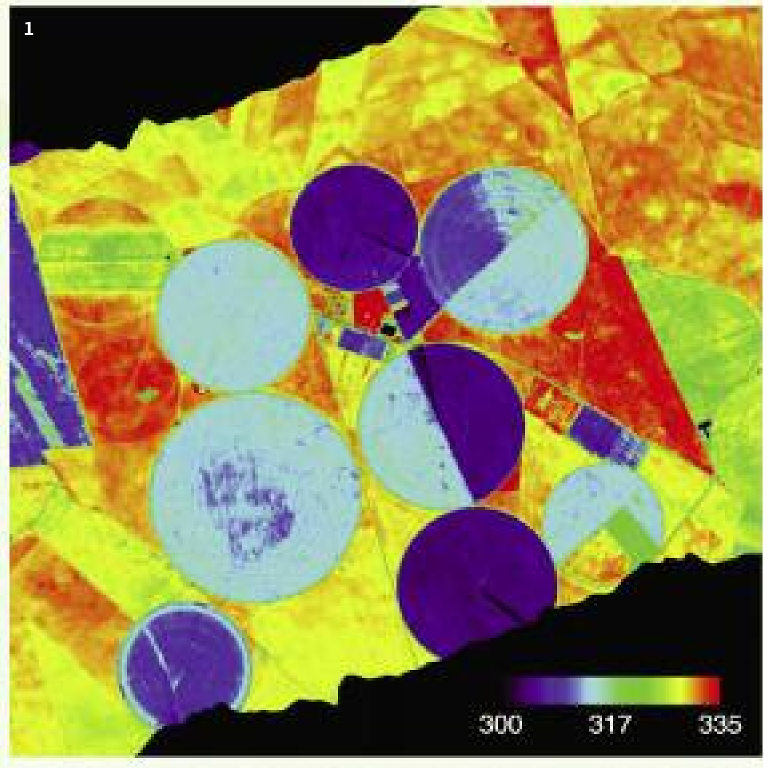
Status:
On-going

Land Surface Temperature (LST) is a key variable for studying global or regional land surface processes and interactions with the atmosphere, and has important applications in various areas such as fire monitoring, urban heat island monitoring, volcanoes monitoring, irrigation management and climate change studies.

LST can be deferred from remote sensing brightness temperature (TB) observations e.g. in the Thermal Infrared (TIR) region, if the emissivity of the material is known. However, the unknown emissivity which not only depends on the surface type but also on its physical condition imposing additional large temporal changes, make the retrieval of LST a complex undertaking, often prone to large varying and inconsistent accuracies. In addition, the atmosphere contributes and alters the TB observed by the satellite instrument. Therefore, cloud screening and atmospheric corrections are important requisites. Consequently, the synergistic use of observations which allow an improved cloud screening and atmospheric correction in addition to an improved estimate of the emissivity and their temporal changes from land cover and their bio/geochemical and physical conditions potentially will provide higher accuracy and temporal consistent LST estimates.

The SEN4LST study aims at analysing the potential synergies of the Sentinel-2 and Sentinel-3 optical and TIR instruments for improving the LST estimates. Special emphasis shall be put on the temporal, spatial and spectral characteristics of these missions. Pros and cons of the retrieval concept shall be demonstrated by using simulated Sentinel-2 and Sentinel-3 data sets from suitable campaign data sets over different sites with different surface conditions. The demonstration shall be based on a detailed analysis of the spectral, spatial and temporal synergistic information content. Furthermore, the retrieval concept shall be adapted to Envisat MERIS and AATSR data, and implemented into the BEAM toolbox. Using this toolbox add-on, synergistic LST time series starting with beginning of 2003 until the end of 2009 shall be produced and compared with the standard AATSR LST product for a selected area. LST anomalies shall be analysed in detail outlining the pros and cons of the improved retrieval concept.

1



1- LST obtained from the SEN4LST algorithm using one AHS image acquired on 12-July-2005 (SEN2FLEX, with a spatial resolution of 3 m).
2- Artists impression of Sentinel-3.
Credits: SEN4LST team (1) and ESA (2).

2

➔ CRYOSAT+ OCEAN

cryosat+ ocean

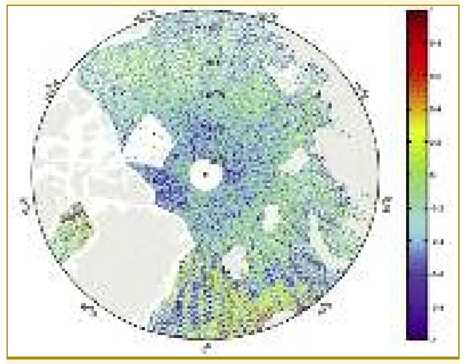
support to science element

Project team:

SATOC (UK)
DTU Space (DK)
isardSAT (ES)
NOC (UK)
Noveltis (FR)
STARLAB (ES)
TU Delft (NL)
University of Porto (PT)
In collaboration with CLS (FR)

Status:

On-going



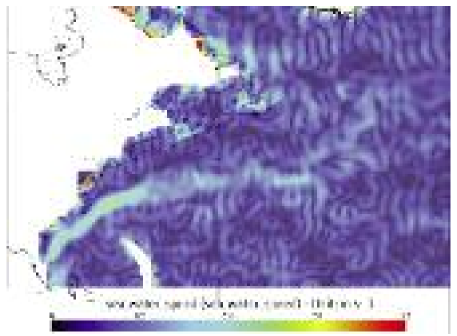
1- CryoSat Sea Level Anomaly over the Arctic from SAR and LRM L2 Data: The coverage is extended till 88 deg and SAR mode allows to retrieve the sea surface height in the leads between floes but discontinuities in boundaries of change mode are visible.
2- Gulf Stream Speed from CryoSat L2 LRM Sea Surface Height using GOCE Geoid. In the CryoSat+ project, the purpose is to provide such maps with less noise and at global scale.
3- Absolute Dynamic Topography from L2 LRM Sea Surface Height using GOCE Geoid in the Gulf Stream area. In the CryoSat+ project, the purpose is to provide such maps at global scale and with more details.
Credits: CryoSat+ Ocean team.

In order to understand fully how climate change is affecting these remote but sensitive regions, there remains an urgent need to determine exactly how the thickness of the ice, both on land and floating in the sea, is changing. By addressing this challenge, the data delivered by the CryoSat mission will complete the picture and lead to a better understanding of the role ice plays in the Earth system. In spite of this major scientific objective, CryoSat data will not only be acquired over sea ice and ice sheets but also over the ocean and land areas opening unique opportunities to explore the full potential of this novel technology for innovative science and applications beyond the mission primary objectives.

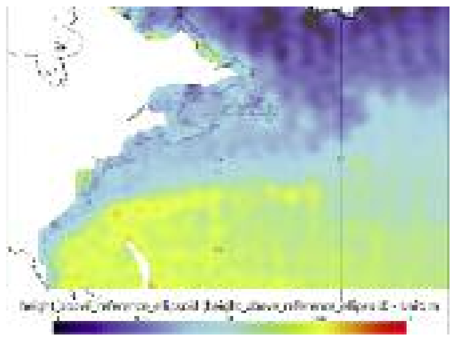
In this context, the ultimate target of CryoSat+ Ocean is to create a solid scientific basis for innovative science and new applications and to develop and validate novel algorithms and products that may fully exploit the novel capabilities of the CryoSat mission in the context of oceanography. In particular four priorities will be addressed:

- Open Ocean Altimetry: Combining GOCE Geoid model with CryoSat Oceanographic LRM products for the retrieval of CryoSat MSS/MDT model over open ocean surfaces and for analysis of mesoscale and large scale prominent open ocean features. Under this priority the project will also foster the exploitation of the finer resolution and higher SNR of novel CryoSat SAR data to detect short spatial scale open ocean features.
- High Resolution Polar Ocean Altimetry: Combination of GOCE Geoid model with CryoSat Oceanographic SAR products over polar oceans for the retrieval of CryoSat MSS/MDT and currents circulations system improving the polar tides models and studying the coupling between blowing wind and current pattern.
- High Resolution Coastal Zone Altimetry: Exploitation of the finer resolution and higher SNR of novel CryoSat SAR data to get the radar altimetry closer to the shore exploiting the SARIn mode for the discrimination of off-nadir land targets (e.g. steep cliffs) in the radar footprint from nadir sea return .
- High Resolution Sea-Floor Altimetry: Exploitation of the finer resolution and higher SNR of novel CryoSat SAR data to resolve the weak short-wavelength sea surface signals caused by sea-floor topography elements and to map uncharted sea-mounts/trenches.

2



3



➔ CRYOSAT+ LAND / INLAND WATER

Applications of CryoSat SAR data can be attempted with success in novel investigation areas such as inland water and land surface: these are all areas where the conventional altimetry encounters severe difficulties to be applied due to the very short scale nature of the quantities involved and to contamination by off-nadir targets. Now, thanks to SAR altimetry, it shall be finally possible to profile the land surfaces and measure with accuracy their geophysical features (scattering qualities, soil moisture, biomass, vegetation index) and to monitor the small lakes/rivers basins that up to now are missed out from standard River&Lake observation systems. This project addresses these two main priorities. In particular:

- High Resolution Inland Water Altimetry: In principle, the operation in SAR mode should permit the resolution of signals from smaller water targets and the signal is expected to possess higher SNR. But it has to be kept in mind how the across track resolution is unaltered with respect to conventional altimetry and hence the strong off-nadir returns from steep river/lake banks in across track direction may still contaminate (up to hiding it totally) the nadir echo waveform from the water body. In this scope, the SARIn mode can become helpful and provide the means to identify the origin direction of the major return power and hence to discriminate between clutters and proper signals. With SAR altimetry, a new quantity, useful for the assessment of the water discharge, could be retrieved: the water body surface local slope. Thanks to the finer resolution, whenever CryoSat is overflying a river or lake target, multiple measurements of the water body surface height can be differentiated to estimate the surface slope. Hydrological modelling will be applied to estimate the water discharge in some special cases.
- High Resolution Land Surface Altimetry: The high-resolution land altimetry will render possible the improvement of the existing altimetry-corrected DEMs such as ACE2. The difference between interferometric imaging SAR data and altimetry SAR data consists in that the latter can deliver second-ary products such as the height of the trees and in conclusion the biomass content of forested areas. The test-bed against which to validate the new retrieved heights and estimate the performances is the current 'state of art' DEM: ACE2. One of the final results of this activity is expected to provide significant enhancement of the Sentinel-3 OLTC DEM (on-board range tracking data). The secondary products of the land altimetry are related to the backscattering assessment. The backscattering coefficient over land is the final effect of many interconnected factors: vegetation, surface geometry and soil moisture content. The usage of altimetry SAR data is expected to make more robust and efficient the soil moisture retrieval problem. Now, since it is envisaged that the SAR altimetry signal shall have higher SNR and twice better precision than conventional altimetry, this will ease also the inversion of the altimetric data in order to recover the soil moisture.

cryosat+ land

support to science element

Project team:

De Montfort University / EAPRS (UK)
Technical University of Denmark (DK)
University of Newcastle-Upon-Tyne (UK)

Status:

On-going

1- Artists impression of CryoSat satellite.
Credits: ESA

1

→ CRYOSAT+ CRYOSPHERE

cryosat+ cryosphere
support to science element

Status:
To be started (2012)

The main target of CryoSat+ Cryosphere is to contribute to fully exploit the potential of the CryoSat mission to advance towards novel scientific results, novel retrieval methods and prototype products for cryosphere science. In this context, this project will focus on two main thematic areas:

- CryoSat-airborne high resolution thickness at grounding line locations: Ice sheet mass balance is strongly modulated by variations in ice stream dynamics, grounding line ice thickness and grounding line migration. One of the principal uncertainties in ice mass flux across grounding lines – and thus ice sheet contribution to sea level – is the cross section of the ice stream channel (i.e. bed profile) at artificial flux gate locations which are located at the grounding line. The objective of the theme is twofold: 1) to find an optimal combination of CryoSat, airborne and other datasets (ASAID, IceBridge, SPIRIT, POLARIS, in-situ) and suitable processing methodologies that may be exploited in a synergetic manner the complementary information provided by the use of new satellite, airborne, and in situ data at basin and sub-basin scale and 2) to develop a methodology using CryoSat high along-track resolution elevation data to identify grounding line location and the accompanying elevation/thickness of ice to identify methods for computing elevation at grounding line location over time.
- CryoSat-GOCE elastic rebound and glacial isostatic uplift: One of the principal limitations to contemporary altimeter or gravimetric estimates of ice sheet mass balance is the need to correct the estimates for the impact of glacial isostatic adjustment (GIA) and spatial variability in the rates of vertical uplift. Pre-launch research on the benefits of GOCE satellite gradiometry indicate the ability of GOCE to capture high-order harmonics in lithospheric uplift due to contemporary ice sheet melt and patterns of ice sheet unloading (due to crustal low-viscosity zone). The projected errors in vertical rate due to this effect may be of the order of centimetres in height perturbation, depending on how the upper mantle and lithosphere react to the pattern of contemporary ice unloading. Meanwhile, this vertical rate affects the ability to quantify and correct for GIA in elevation rates of change of CryoSat and mass exchange and subsequent net mass balance estimates. The objectives of this theme are: 1) to constrain properties of Crustal Low Viscosity Zone (CLVZ) in GIA models with GOCE data and estimate GIA with greater regional detail in uplift and 2) to identify synergetic data processing methods for use on CryoSat data with GOCE, GRACE and GIA models to establish a robust method for correcting vertical elevation/topographic change due to GIA.

1- CryoSat satellite.
Credits: ESA.

1


→ SMOS+ OCEAN

smos+ ocean
support to science element

Status:
To be started (2012)

Salinity is a key variable describing the characteristics of the ocean and plays a fundamental role in the density-driven global ocean circulation, the water cycle and climate. The average salinity of the global ocean mixed-layer (0-50 m depth) is 35 psm (typical range <16 to ~38) but is highly variable spatially, temporally and vertically due the dynamic fluxes of the water cycle. Freshwater inputs (F) from precipitation, river discharge, spring snowmelt and melting sea ice cause dilution of the SSS in the surface ocean. Evaporation (E) at the ocean surface occurs at the diffusive boundary between the ocean and atmosphere driven predominantly by the temperature and humidity difference across the air-sea interface and the surface wind stress that provides turbulent energy. The development of sea ice also removes freshwater from the surface ocean leading to an increase in SSS and in some areas significant vertical ocean circulation (deep water formation). In addition to the horizontal time-space variability due to the E-F balance, vertical stratification of SSS in the upper ocean layers lead to a halocline with characteristic horizontal time-space and vertical dimensions depending on the local water-cycle and turbulent state of local ocean. Thus, the complex balance between evaporative and freshwater fluxes at the air-sea interface and the turbulent state of the ocean defines the state of the SSS at any given time and location.

The Soil Moisture and Ocean Salinity (SMOS) and the Aquarius-SAC-D missions are now providing estimates of SSS from space using L-band (~1.4 GHz) passive microwave radiometers. The challenging nature of SSS retrievals from SMOS coupled with the complex relationship between the vertical SSS structure in the upper ocean require further study to demonstrate the performance and utility of SMOS Sea Surface Salinity data products. A better understanding of the relationship between satellite derived SSS and the SSS at depth may yield more robust accuracy and uncertainty estimates.

The aim of the SMOS+ Ocean SOS project is to demonstrate the performance and utility of SMOS Sea Surface Salinity (SSS) data products using well-defined case studies incorporating synergy analysis and complementary data. Can case study examples demonstrate the challenges and best scientific approach to SMOS SSS validation and demonstrate improved uncertainty estimates? How does the salinity measurement made by SMOS relate to the salinity at several meters depth? How do we project SSS signals measured by SMOS down into upper ocean layers? What is the accuracy and uncertainty of SMOS SSS? What are the new oceanographic processes we can study with SMOS SSS? What do we gain from using SMOS and Aquarius-SAC-D mission data in synergy? These are some of the challenges for the SMOS+ Ocean project.

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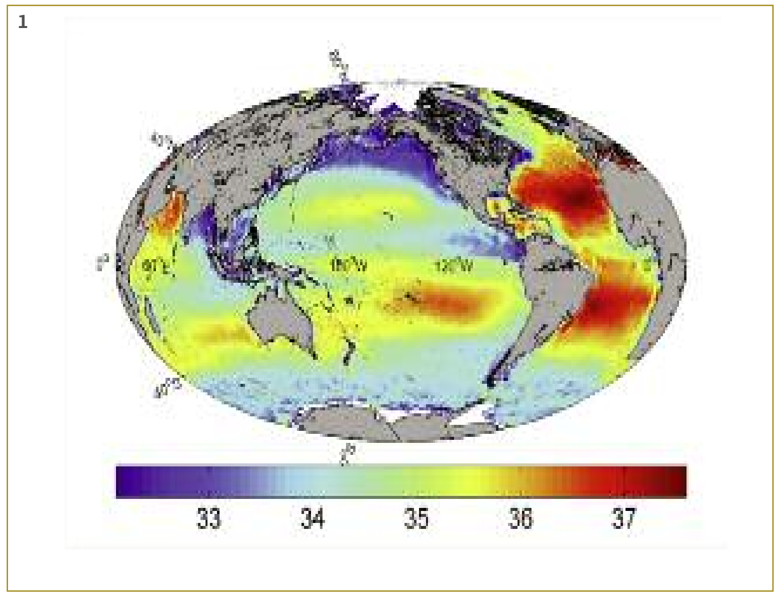


1- Annual average Sea Surface Salinity map (scale in psu) at 0.25°x0.25° resolution derived from SMOS satellite data for 2010 processed at Cersat Salinity Center.
Credits: IFREMER.

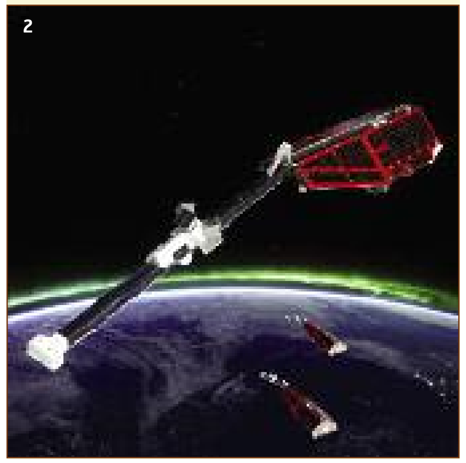
SWARM-CLUSTER Tandem

swarm-cluster tandem
support to science element

Project team:
Technical University of Denmark (DTU) (DK)
GeoForschungsZentrum, Potsdam (GFZ) (DE)
Institut de Recherche en Astrophysique et Planetologie, IRAP (FR)
Swedish Institute of Space Physics (IRFU) (SW)
Space Science and Technology Department, (RAL) (UK)

Status:
On-going

CLUSTER (1) and SWARM (2) satellites. Credits: ESA



The primary focus is here on the ionospheric conductances and convection maps and the coupling between ionosphere and magnetosphere. The second part of the activity is a generation and elaboration of ideas for new opportunities arising from joint analysis of Swarm and Cluster data when operating at the same time.

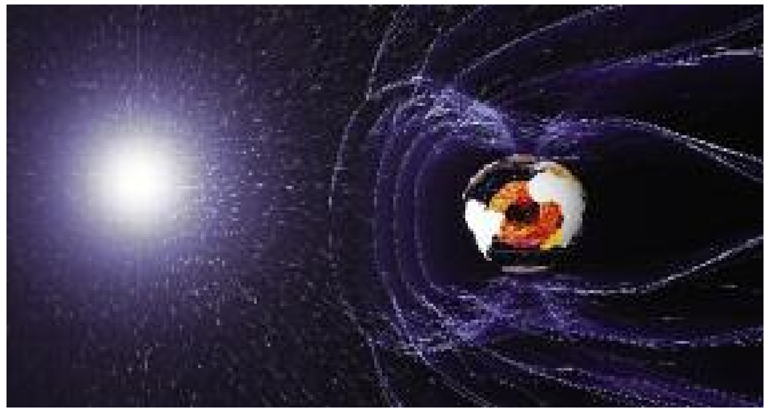
Swarm is the fifth of a family of Earth Explorer satellites designed to study our planet and its environment in order to enhance our knowledge and understanding of Earth-system processes and their evolution, to enable us to address the challenges of global change. In particular, Swarm will measure the specific characteristics of the changing magnetic field of the Earth and the influence of the Sun on this field manifest in near-Earth current systems and radiation belts. This analysis can be performed based upon data from a constellation of three satellites each with a suite of instruments to measure features of the magnetic field, the electric field and the atmospheric composition and temperature.

Cluster, a space science mission, is a constellation of four spacecraft flying in formation around Earth. They are making the most detailed investigation yet of how the Sun and Earth interact beyond sunlight alone. The four Cluster spacecraft work together collecting three-dimensional information about how the perpetual stream of subatomic particles given out by the Sun, the solar wind, interacts with Earth's natural cloak of magnetism, the magnetosphere. Each spacecraft carries an identical set of 11 instruments to investigate electrical and magnetic fields, and charged particles. These were built by European and American teams of scientists and engineers led by Principal Investigators.

The determination of ionospheric conductances and convection maps from the satellite data and a better understanding of the ionospheric-magnetospheric coupling can help to significantly improve the quality of current density estimates which rely today on model corrections. Present day data from CHAMP, Cluster and simulated data from Swarm can be used to study this topic in detail and prepare for the Swarm operational phase.

The expected benefits from the study are:

- Improved understanding of the ionosphere-magnetosphere coupling in relation to conductivity in the ionosphere;
- Deriving conductances and convection maps from CHAMP/Cluster data in preparation of Swarm data analysis, including validation of the results;
- Elaboration of the Swarm case and simulations for the expected constellation of the Swarm and Cluster satellites together;
- Collection of science ideas for the analysis of data jointly obtained from Swarm and Cluster during the Swarm mission lifetime coinciding with the expected Cluster extension.



THE CHANGING EARTH SCIENCE NETWORK

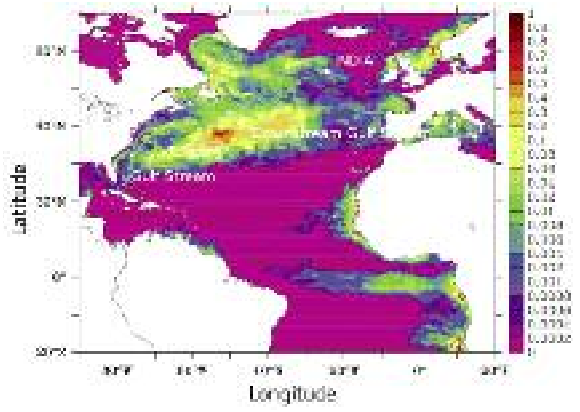
→ ASSOCO

ASSOCO:
Assimilation of ocean colour satellite data to monitor the biogeochemical state of oceans and estimate its variability

PI:
Maeva Doron, Laboratoire des Ecoulements Géophysiques et Industriels, MEOM-LEGI, Grenoble (FR)

Status:
Completed

The oceans account for around 50% of the primary production and play a major role in the carbon cycle through the capture of atmospheric CO2 and sequestration of carbon in sediments. However, ocean's physical and biogeochemical properties are largely under-sampled and modelling activities are necessary to improve the quantification of the processes. Coupled physical-biogeochemical models are now comparable to satellite observations and data assimilation is a powerful approach to do such systematic comparisons and assessments. Robust assimilation techniques have been developed, principally for physical oceanography, and this project will extend these capabilities to primary production models coupled to ocean circulation models. It has been proven that simple models can be efficient if they are properly calibrated, and the main objective of ASSOCO is to use data assimilation of ocean colour MERIS data to perform this calibration.



Standard deviation ensemble for surface phytoplankton concentration after 1 day calculated with a 200-member ensemble with regionally perturbed parameters of the biogeochemical model.
Credits: Maeva Doron.

→ DECPHY

DECPHY:
Global ocean analysis of decadal covariability in phytoplankton and physical forcings through satellite remote sensing, in-situ measurements and upper ocean modelling

PI:
Elodie Martinez, Laboratoire d'Océanographie de Villefranche (LOV-OOV), Villefranche sur Mer (FR)

Status:
Completed

The main aim of this project is to provide new elements to understand the global response of phytoplankton to climate change through its physical forcing, to better understand and forecast phytoplankton evolution in future. A first objective of DECPHY is to extend the recent analysis (1979-2002) till 2009 exploiting Envisat data, and confirm (or not) the role played by the natural basin-scale decadal oscillations over the last three decades. Secondly, the Envisat time series extension over the last ten years allow comparisons with other relevant remote sensing and in situ physical parameters which may be physical forcing to Chl variability (satellite derived wind, sea level anomaly, surface current, SST and in situ mixed layer depth). Finally, to go further in the understanding of the dynamics that rule the upper ocean mixed layer (ML) and which is therefore responsible, through its depth variability, for the amount of nutrient inputs and productivity, a 1-dimensional model of the ML has been run locally following the results obtained above, and its outputs investigated.

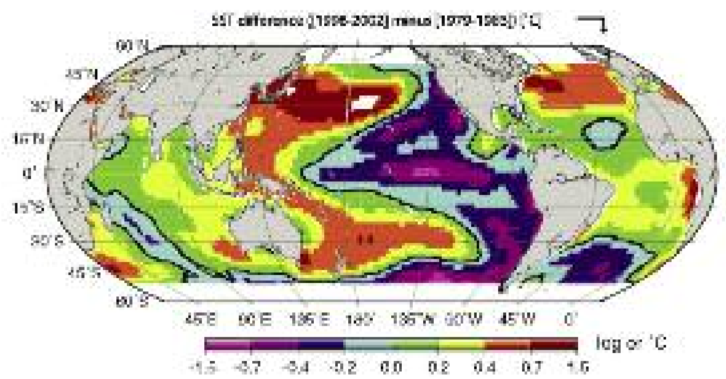


Figure adapted from Martinez et al. (2009): SST difference over the period 1979–1983.
Credits: Elodie Martinez

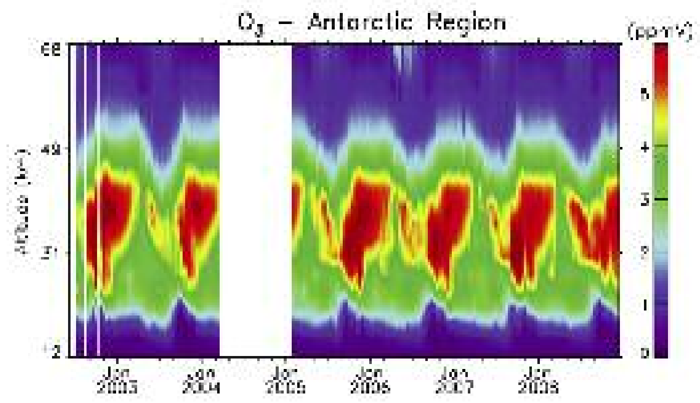
→ OCCURR

This project investigates how the dynamic variability of the UTLS regions can influence the ozone concentration and, on the other hand, to what extent the variability of ozone and other long-lived species can be used as a tracer of the dynamic variability of the UTLS region. For this purpose, measurements acquired with MIPAS and SCIAMACHY and a Chemical Transport Model (CTM) will be used. Satellite missions, having global and multi year coverage, give the possibility to study the physical and chemical quantities of the atmosphere whereas the CTM can complement measurements for the understanding of the chemistry-dynamics coupling of the stratospheric and upper tropospheric circulations.

OCCURR:
Study of the chemistry-climate coupling in the UTLS region with satellite measurements

PI:
Enzo Papandrea, Department of Physics and Inorganic Chemistry, University of Bologna, Bologna (IT)

Status:
Completed



MIPAS Ozone time series from GMTR level 2 analysis.
Credits: Enzo Papandrea.

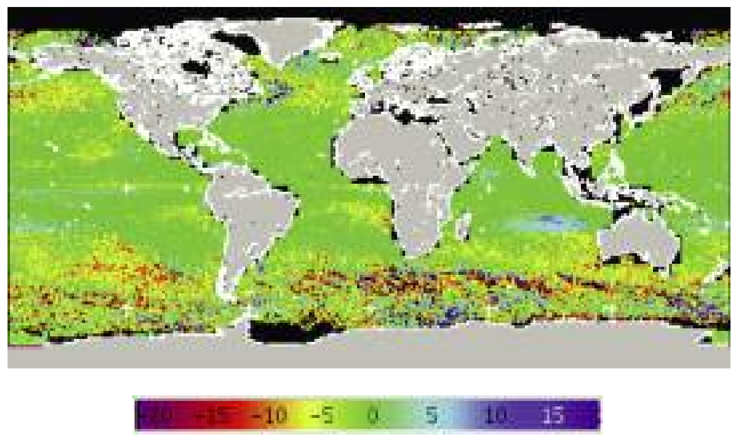
→ OC-FLUX

Earth Observation (EO) is well placed to study and monitor air-sea fluxes. However, there remain large uncertainties in the current parameterisations of EO derived air-sea gas interactions, which can have profound effects on the resulting predictions from global carbon cycle models. OC-flux exploits the synergy of the sensors on board Envisat to investigate the uncertainties in current EO retrievals of air-sea fluxes, studying both open ocean and coastal regions. The knowledge gained will then be used to extend the current methods to the proposed Sentinel-3 suite of sensors, meaning that future missions will be able to monitor fluxes in near-realtime.

OC-Flux:
Open ocean and Coastal CO2 fluxes from Envisat and Sentinel-3 in support of global carbon cycle monitoring

PI:
Jamie Shutler, Plymouth Marine Laboratory, Plymouth (UK)

Status:
Completed



CO2 fluxes analysis derived from coincident Envisat RA2, AATSR and MERIS data. The image shows global errors due to ignoring vertical temperature gradients when estimating air-sea fluxes of CO2. Ignoring vertical temperature gradients can result in errors of ~10% when calculating global net fluxes; localised fluxes can have errors that are greater than 20%.
Credits: Jamie Shutler.

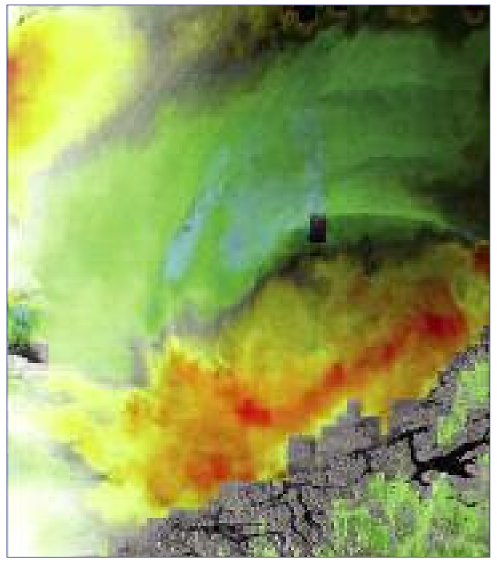
→ INCUSAR

INCUSAR:
INverting consistent surface CUrrent fields from SAR

PI:
Knut-Frode Dagestad, Nansen Environmental and Remote Sensing Center, Bergen (NO)

Status:
Completed

The first part of the study focused on a method to improve the SAR wind retrieval, which benefited the second part dealing with a consistent inversion of wind, waves and the surface current. Novel wind retrieval techniques have been used to improve traditional wind retrieval from SAR. The subsequent inversion of consistent wind, waves and surface current combine both SAR Doppler and roughness measurements, and utilise a complex radar imaging model (forward model) to simulate the radar signatures for given wind, wave and current fields. An iterative approach is attempted to converge to a consistent solution.



right: Doppler Centroid velocity from a SAR scene. Yellow/orange colours indicate ocean velocity (wind/waves motion in this case) away from sensor (towards right), and green/blue colours indicate ocean velocity towards left. The Doppler velocity is an additional resource to the roughness for retrieval of wind speed and direction.
Credits: Knut-Frode Dagestad..

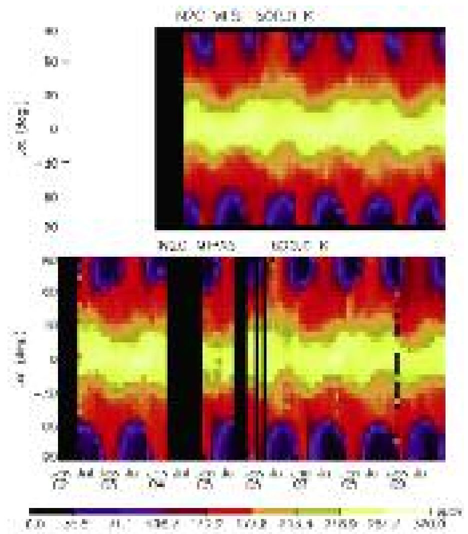
→ DIMITRI

DIMITRI:
DIagnostics of MIxing and TRansport in atmospheric Interfaces

PI:
Elisa Palazzi, Istituto di Scienze dell'Atmosfera e del Clima (ISAC-CNR), Bologna, Italy (IT)

Status:
Completed

This project aims to improve the understanding of the transport processes and their variability in the upper troposphere-lower stratosphere (UT-LS) region and in the lower stratosphere (LS). Globally, the UTLS region is characterized by sharp changes in chemical species gradients across the tropopause, both in the tropics and in the extra-tropics. Transport in the LS involves meridional overturning and mixing, which together represent the Brewer-Dobson circulation. Horizontal mixing in the LS is inhomogeneous, with transport barriers in the subtropics and at the edge of the polar vortex. These aspects of the atmospheric circulations are addressed within DIMITRI, through the use of MIPAS and GOMOS data and the application of diagnostic tools to chemical tracer distributions.



Time-latitude cross section of the N2O mixing ratio concentrations (ppbv) for (top) MLS (2004-2009) and (bottom) MIPAS (2002-2009). MLS data are available through the on-line Mirador data access (http://mirador.gsfc.nasa.gov/);
MIPAS data shown here are generated with the GMTR code (http://www.mbf.fci.unibo.it; http://www.isac.cnr.it/~rss/mipas2d.htm).
Credits: Elisa Palazzi.

→ CHOCOLATE

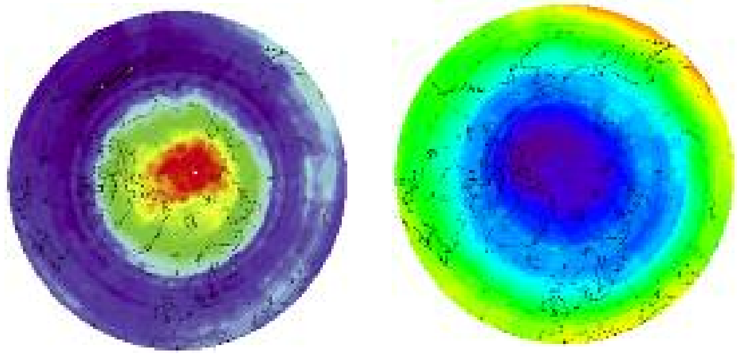
THE CHANGING EARTH SCIENCE NETWORK

Chocolate:
CH4, H2O and CO from Limb middle-ATmosphere Emissions

PI:
Maya Garcia-Comas, Instituto de Astrofisica de Andalucia – CSIC, Granada (ES)

Status:
Completed

Water vapour is a key constituent in the middle atmosphere since it is involved in the ozone chemistry, it is the precursor of polar stratospheric and mesospheric clouds, and it is also an important infrared cooler in the stratosphere. Its precursor in the stratosphere is methane, which is oxidized producing water vapour and carbon monoxide, whose concentration has increased due to human activity. H2O and CH4 are vertically transported up to the mesosphere where their photolysis occurs. CO is there locally produced by photolysis of CO2. Their long lifetime makes these three species excellent middle-atmosphere tracers. Few simultaneous global measurements of H2O, CH4 and CO are currently available in the middle atmosphere for an extended period of time. This project aimed at deriving H2O, CH4 and CO concentrations in the stratosphere and mesosphere from MIPAS spectra around 6.3, 7.6 and 4.7 μm, respectively, measured in its middle atmosphere and upper atmosphere modes using the IMK-IAA processor.



Summer solstice water vapour distribution around the North Pole at 80 km (left) and 85 km (right).
Credits: Maya Garcia-Comas.

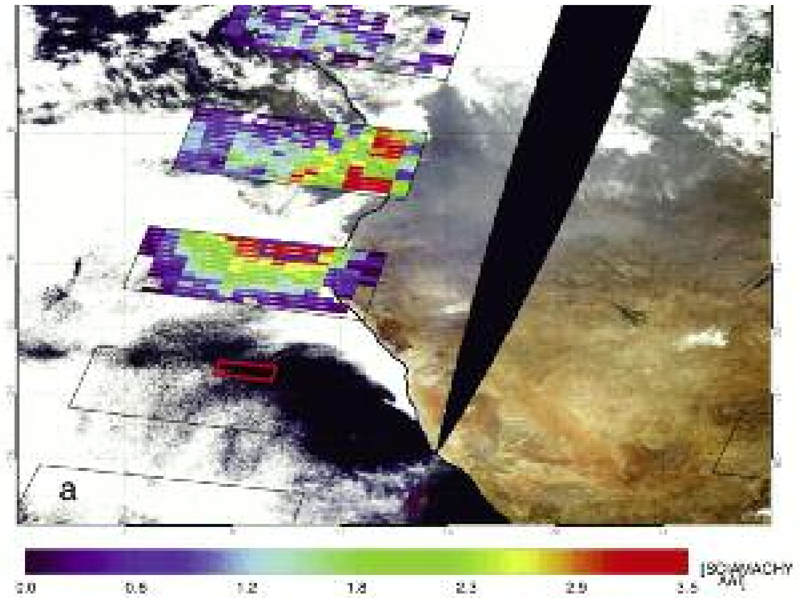
→ CLARIFI

CLARIFI:
Clouds and Aerosol Radiative Interaction and Forcing Investigation: the semi-direct effect

PI:
Martin de Graaf, Royal Netherlands Meteorological Institute (KNMI), De Bilt (NL)

Status:
Completed

Satellite observations are ideally suited to monitor globally the heterogeneous distribution of aerosols. However, most aerosol retrieval techniques rely on cloud masks, hampering aerosol-cloud interaction studies. This project focuses on identifying UV-absorbing aerosols in the cloud scenes using direct space-based radiance SCIAMACHY measurements. The spectra of absorbing aerosol contaminated clouds are skewed in the UV, which can be used to quantify the absorption of solar radiation. The identification and quantification of the absorption of solar radiation by aerosol in clouds can help to understand the radiative feedback mechanisms between clouds and aerosols, and improve our understanding of this important climate effect.



MODIS RGB image of biomass burning on 9 September 2004 over the eastern South Atlantic Ocean overlaid with SCIAMACHY AAI (Absorbing Aerosol Index).
Credits: Martin de Graaf.

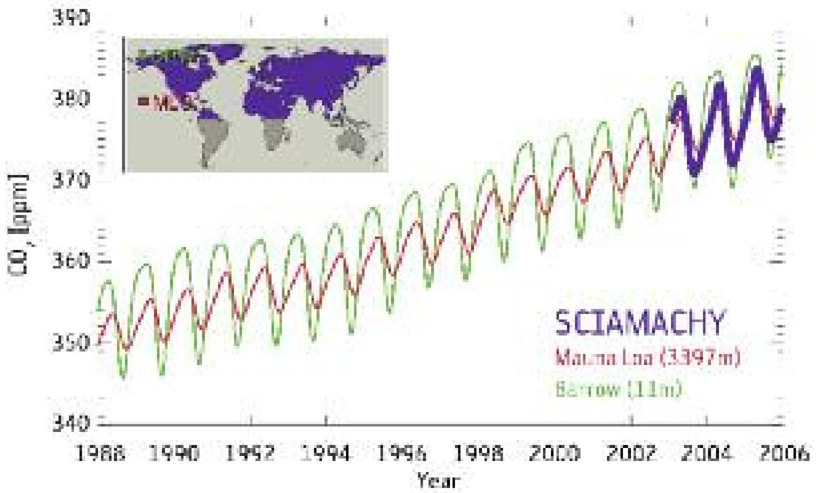
CARBONGASES

CARBONGASES:
Retrieval and analysis of CARBON dioxide and methane greenhouse GAses from SCIAMACHY on Envisat

PI:
Oliver Schneising, Institute of Environmental Physics (IUP), University of Bremen, Bremen (DE)

Status:
Completed

The main objective of CARBONGASES is to make a contribution to fill the significant gaps in our understanding of the global carbon cycle by improving our knowledge about the regional sources and sinks of greenhouse gases. This is done by generating the required global multi-year satellite datasets, namely column-averaged dry air mole fractions of carbon dioxide and methane retrieved from SCIAMACHY on Envisat. The focus of CARBONGASES has been on four years of data (2006-2009).



Comparison of northern hemispheric atmospheric carbon dioxide column-averaged mole fractions retrieved from SCIAMACHY with two NOAA surface stations demonstrating the seasonal cycle and the increased CO_2 over time. The existing SCIAMACHY dataset has been further improved and extended up to 2009 during the CARBONGASES project.
Credits: Oliver Schneising.

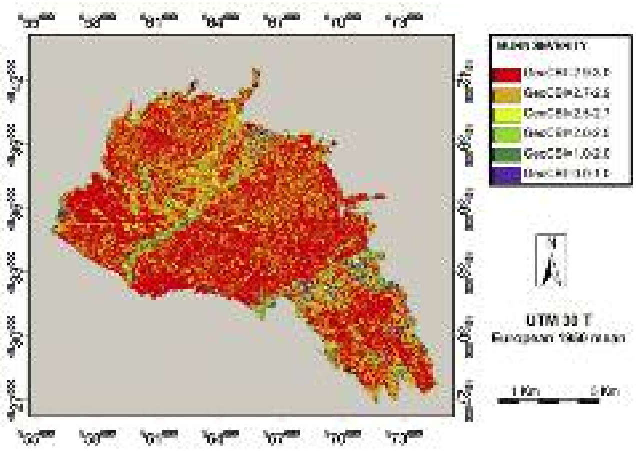
FEMM

FEMM:
Fire Effects Modelling and Mapping

PI:
Patricia Oliva Pavon, Department of Geography, University of Alcalá, Alcalá de Henares, Spain (ES)

Status:
On-going

Accurate estimations of burn severity and its distribution in post fire scenarios are critical for short-term mitigation and rehabilitation treatments. The use of remote sensing techniques, coupled with radiative transfer models (RTMs) can improve the accuracy, precision (in terms of number of classes) and cost-effectiveness of burn severity assessment and ensure a generalization of the methodology. In this project, an improved simulation model to estimate burn severity from MERIS data was tested in European Mediterranean forest fires. The determination of burn severity is based on a new version of the CBI index (named GeoCBI), that takes into account the vegetation fraction cover (FCOV) to compute the burn severity of the total plot. Model inversion results are validated using ground truth data.



Burn severity estimation from Landsat TM images in Guadalajara (Spain). Landsat image RGB-7/4/1 colour composition on the right.
Credits: Patricia Oliva Pavon.

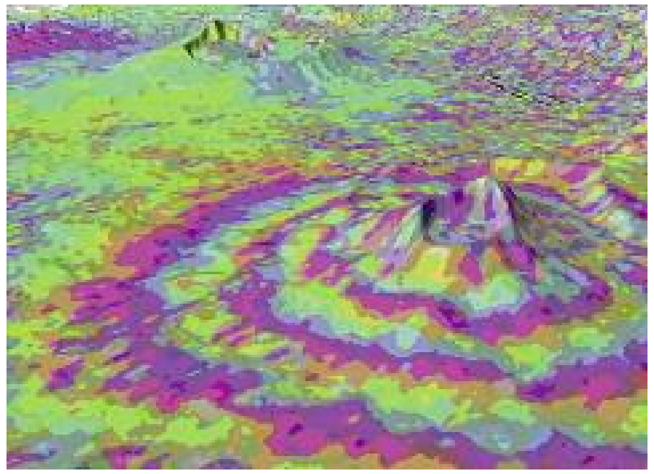
ISMER

The aims of this project are to perform a systematic programme of InSAR observations along the East African Rift using both archived and new data. This project has produced the first geodetic surveys of the Main Ethiopian Rift, the Western Branch of the East African Rift and the Malawian Rift. Together these form the first map of the temporal and spatial distribution of magmatic activity in a developing rift system. This comparison between rift segments at different stages of maturity is the key to understanding the development of rift systems both in East Africa and elsewhere and will act as the basis to test future models of continental rifting. This project has demonstrated the use of InSAR data for hazard monitoring and geothermal exploration in East Africa.

ISMER:
InSAR Survey of the Magmatic Effects on Rift development

PI:
Juliett Biggs, University of Bristol, Bristol (UK)

Status:
Completed



Interferogramme showing land displacements in a volcano over the study area.
Credits: Juliet Biggs.

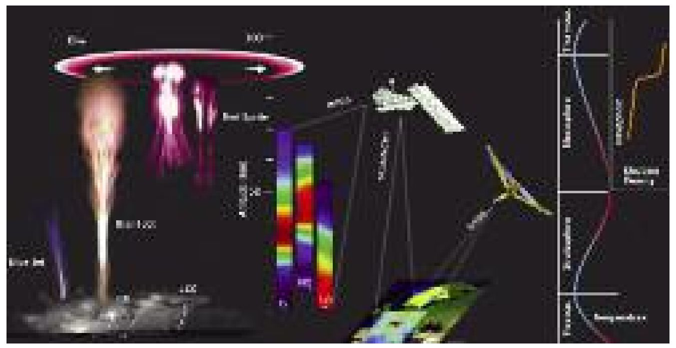
CHIMTEA

The observation of sprites, other transient luminous events and terrestrial gamma-ray flashes shows how the impact of thunderstorms onto the atmosphere extends from the troposphere up to the upper atmosphere and ionosphere. Thunderstorms are responsible for lightning-produced NOx, one of the major sources in the troposphere, and for driving troposphere-stratosphere exchange of atmospheric constituents. They may also be producing NOx in the upper atmosphere above them through upper atmosphere discharges and ionization. The impact on atmospheric chemistry, together with thunderstorm-driven precipitation, severe weather events, lightning-induced wildfires, but also gravity wave drive of upper atmosphere circulation and global electric circuit recharge, make thunderstorms a key player of the atmosphere and climate. The CHIMTEA project merges modelling and satellite measurements of NOx, ozone and other related constituents, from the troposphere to the mesosphere, to quantify thunderstorm-induced changes and explore how to improve their detectability in present measurements and future missions.

CHIMTEA:
CMemical IMpact of Thunderstorms on Earth's Atmosphere

PI:
Enrico Arnone, Institute of Atmospheric Sciences and Climate, CNR, Bologna (IT)

Status:
On-going



Pictorial view of thunderstorm and associated lightning processes in the troposphere and upper atmosphere thought to be a source of nitrogen oxides. Also shown is an indication of the atmospheric vertical structure in terms of temperature, ozone, NO2 and N2O, and a cartoon of observational geometries for the adopted SMOS and Envisat's MIPAS and SCIAMACHY measurements.
Credits: adapted from Neubert et al., 2003, Science, and van der Velde et al., 2011, JGR.

→ GEMMA

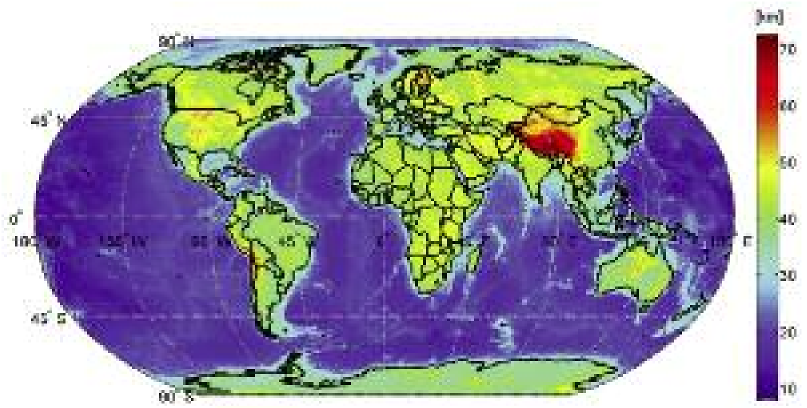
GEMMA:
GOCE Exploitation for Moho Modelling and Applications

PI:
Daniele Sampietro, Laboratorio di Geomatica, Politecnico di Milano, Milano (IT)

Status:
On-going

During the first year of the GEMMA project two different global Moho models have been produced: one has been obtained by inverting gravimetric data reduced according to a very simplified model and should be used as a preliminary information for local refinement. The second one has been estimated by mixing directly gravimetric observations with seismic global Moho model. The result is a new global model consistent with both gravity and seismic observations with a resolution of 1°. Moreover, local models beneath the Himalayas, the Tibetan Plateau, the Alps and the Italian region have been estimated. All the models can be downloaded at:

http://geomatica.como.polimi.it/elab/gemma/



Gemma Moho depth [km].
Credits: Daniele Sampietro.

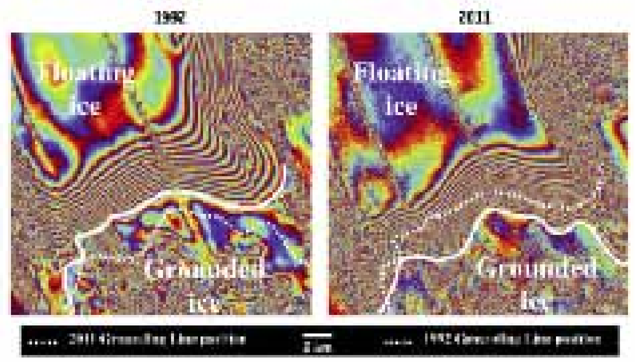
→ GREENSAR

GreenSAR:
Greenland ice sheet mass and velocity trends from CryoSat SARIn and InSAR data

PI:
Noel Gourmelen, School of Earth and Environment, University of Leeds, Leeds (UK)

Status:
On-going

Earth observation satellites provide a way to measure essential climate variables over large areas and with a frequency that allows to understand and quantify the changes affecting the Greenland Ice Sheet (GrIS). Satellites provide, for example, datasets to understand the mechanisms by which mass is being lost and how the GrIS responds to the forcing of heat transport by the atmosphere and the ocean. The purpose of GreenSAR is to quantify the degree of mass imbalance of the GrIS by exploiting Earth Observation datasets from past, present, and future European Space Agency satellite missions. In the frame of GreenSAR, algorithms have been developed to extract fine characteristics of the way glaciers flow in relation with ice melting. It opens new perspectives to study past trends of ice loss and feedback mechanisms between the dynamic of glaciers and climate trends. In the frame of GreenSAR, data from the last phase of ERS-2 mission have been exploited to reveal continuing ice loss at the margin of Greenland (figures below).



Retreat of Petermann glacier grounding line between the year 1992 and 2011.
Credits: Noel Gourmelen.

→ PROGRESSION

PROgRESSion:
PROtotyping the Retrievals of Energy fluxes and Surface Soil moisture

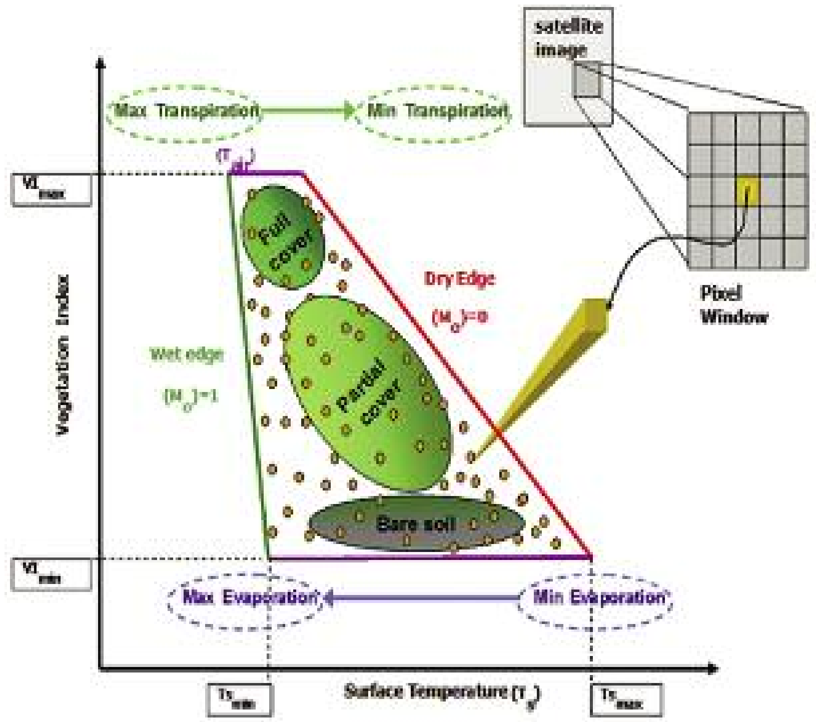
PI:
George P. Petropoulos, Institute of Applied and Computational Mathematics, FORTH, Heraklion (GR)

Status:
On-going

Estimation of the fluxes of heat (H) and moisture (LE) over land as well as the soil surface moisture (Mo) has been of great interest due to their bearing to a large number of Earth's physical processes as well as to the global energy and water cycle.

The establishment and maintenance of long-term Earth observing programmes, providing temporally and spatially consistent measurements, offers inimitable possibilities for performing a multi-scale and multi-sensor spatial mapping and monitoring of those parameters. Yet, their accurate retrieval is challenging, due to the difficulty in accurately measuring some of the input parameters required for their estimation which exhibit strong spatial and temporal variability. This may also largely explain why operational retrieval of those parameters at a global scale still appears to be somehow at a relative early stage of maturity.

PROgRESSion aims to develop a series of prototype products for the operational retrievals of both LE/H and Mo based on the synergistic use of observations acquired from ESA funded/co-funded missions combined with a land surface process model. Specifically, the synergies between the Envisat's AATSR-MERIS and also between the MIRAS/SMOS-SEVIRI/MSG2 sensors are considered. Products' accuracy is scrutinized by different means of assessment conducted at a range of test sites in Europe representative of different ecosystem and climatic conditions.



Summary of the key descriptors and physical interpretations of the satellite-derived Ts/VI feature space.
Credits: adopted from Petropoulos et al., 2009.

LACRA

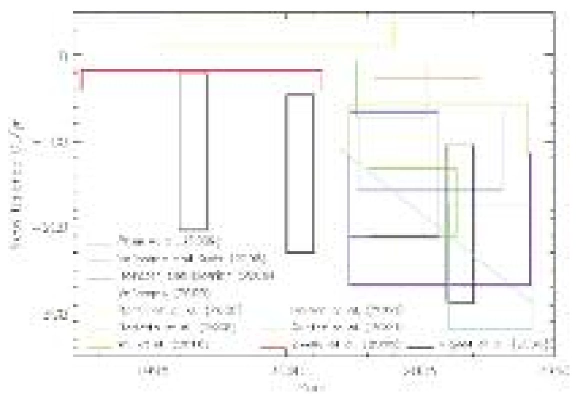
LACRA:
Laser Altimeter Cryosat Radar Altimeter analysis

PI:
Jennifer Griggs, Bristol Glaciology Centre, University of Bristol, Bristol (UK)

Status:
On-going

This project will determine the accuracy with which future measurements of the mass balance of the polar ice sheets will be made. This is needed to assess their potential impact on sea level. There is agreement that the ice sheets are currently losing mass but the range of estimates is larger than the loss. One method of determining ice sheet mass balance is to repeatedly measure the ice sheet surface elevation and determine how it is changing.

CryoSat is a radar altimeter launched by ESA in 2010. It is determining the height of the ice sheet surface with unprecedented accuracy. The radar waves penetrate into the surface of the ice sheet and how far they penetrate and how that changes under different conditions is poorly understood. We will compare CryoSat with similar data from airborne instruments and airborne laser altimeters. The laser instruments do not penetrate into the ice sheet surface and so comparison with these will allow us to determine the penetration depth and its variability.



Recently published mass trend estimates for Antarctica. The height of the bars indicates the quoted uncertainty (usually 1 sigma).
Credits: Jennifer Griggs.

MESO3D

MESO3D:
Sensor Synergies for Studies of Mesoscale and Sub-mesoscale Ocean Dynamics

PI:
Frédéric Nouguier, Laboratoire d'Océanographie Spatiale, IFREMER, Plouzané (FR)

Status:
On-going

Today, sea surface variability is well observed at different scales and it was shown that the smallest ones strongly contribute to important physical and bio-geochemical phenomena (e.g., upwelling of nutriments and their offshore transfer). Because of this, mesoscale and sub-mesoscale variability of the sea surface and its specific signatures on the remote sensed data is of major interest. In this framework, oceanic fronts at the boundary of meandering currents and eddies are observed and models suggest to interpret the modulation of radar backscatter in terms of convergence and divergence zones. A new principle has been developed based on systematic collocation of radar backscatter modulation over oceanic fronts and surface winds highlighting the strong interaction of Ekman current with ageostrophic jet currents along the oceanic front location. Analysis of such backscatter modulation intensity in terms of wind conditions and observation geometry will be performed. Complementary observations of the same principle on MERIS optical glitter derived sea surface roughness are also considered.

Example of ocean front current backscatter modulation observed by ASAR.
Credits: IFREMER.

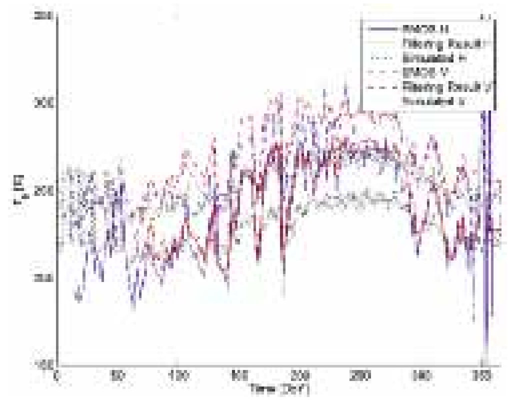
SMASPARES

SMASPARES:
SMos data ASsimilation for PARameter EStimation in hydrological and radiative transfer models

PI:
Carsten Montzka, Forschungszentrum Juelich GmbH, Juelich (DE)

Status:
On-going

The terrestrial part of ESA's Soil Moisture and Ocean Salinity (SMOS) mission is focused on the spatial and temporal dynamics of soil moisture, which will have a large impact on the understanding of climate-related processes and will help to improve the forecasts of climate change, weather and extreme-events.
The accuracy of this soil moisture product can be enhanced by data assimilation techniques. A coupled model system containing a hydrometeorology model as well as a radiative transfer model is integrated into a data assimilation framework using a sequential Monte Carlo algorithm, which is able to update both model states (e.g. soil moisture or brightness temperatures) and model parameters (e.g. surface roughness, vegetation opacity). This study will focus on the estimation of parameters as well as a bias term for the radiative transfer model and their spatiotemporal dynamics by assimilating SMOS brightness temperature and in situ soil moisture observations. The approach of using additional world-wide available in situ observations during the processing may enhance also the accuracy of Level-2+ products from other ESA missions.



TB for the SCAN site Nunn (Colorado, USA) simulated by L-MEB, observed by SMOS and estimated by the data assimilation algorithm, where the bias in TB observations has been eliminated. Simulated and estimated TB are presented for 42.5° incidence angle only, observed Tb are shown for incidence angles between 42° and 43°. Only Ascending node data are presented.
Credits: Carsten Montzka.

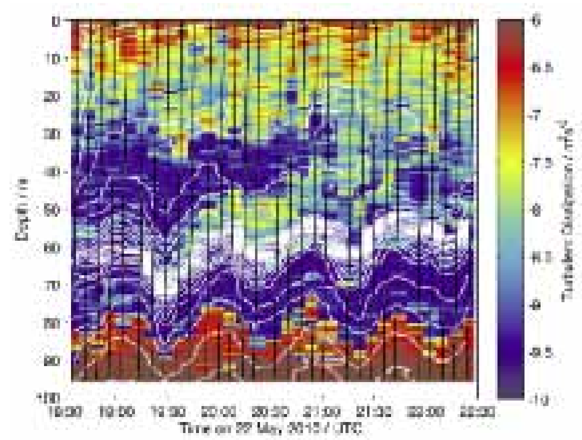
SMOSPROC

SMOSPROC:
Study of ocean surface processes and their impact on the retrievals of salinity from SMOS

PI:
Danielle Wain, National University of Ireland, Galway (IE)

Status:
On-going

Salt and freshwater fluxes in the upper ocean constitute an important element of global hydrological cycle, an integral component of the climate system. Sea surface salinity is currently being measured on a global scale by the ESA Soil Moisture and Ocean Salinity (SMOS) and the Aquarius/SAC-D satellites. The aim of this project is to study the upper ocean with the Air-Sea Interaction Profiler (ASIP), using existing data and new data to be collected during Salinity Processes in the Upper-Ocean Regional Study (SPURS). ASIP is ideally suited to measure high-resolution temperature, salinity, and velocity shear both immediately below the ocean surface and through the mixed layer. From these measurements, the turbulent fluxes of heat and salt can be estimated and the mixing processes responsible for the fluxes can be evaluated. The existing data from the Labrador Sea show intense turbulence at the surface and patches of turbulence at the base of the mixed layer from breaking internal waves.



Turbulent dissipation measured by ASIP in the Labrador Sea, with isopycnals (lines of constant density) drawn in white and the path of ASIP indicated in black. The region of high turbulence at the bottom is from ASIP's thrusters.
Credits: National University of Ireland, Galway.

TIBAGS

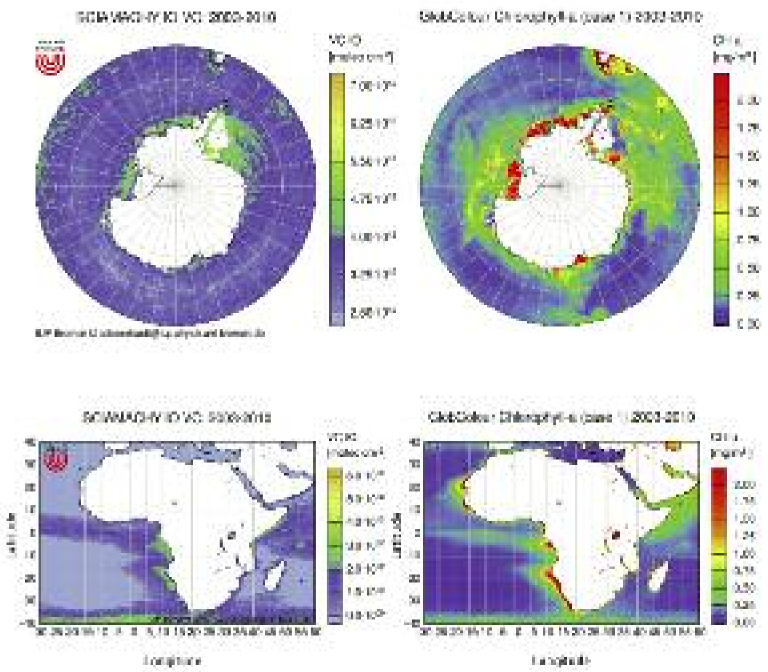
TIBAGS:
Tropospheric Iodine monoxide and its coupling to Biospheric and Atmospheric variables – a Global Satellite Study

PI:
Anja Schönhardt, Institut für Umweltphysik, Universität Bremen, Bremen (DE)

Status:
On-going

TIBAGS investigates atmospheric abundances of iodine monoxide (IO) from space and the relations between IO and selected atmospheric species and biospheric parameters. Through its strong ozone destruction potential, as well as its impact on OH levels and particle formation, iodine may impact on the radiation balance and on life times of relevant trace gases. Iodine in the troposphere is partly of organic origin, however, the sources and emission strengths are not well defined, and inorganic emission pathways may also play a role.

IO column amounts are retrieved from measurements of the SCIAMACHY instrument onboard Envisat. IO observations are compared to selected species including bromine monoxide (BrO) and short-lived biogenic compounds in the atmosphere as well as Chlorophyll-a (chl-a) and phytoplankton types in the ocean. Largest wide spread amounts of IO are detected in Antarctica. Enhanced IO is also present above some oceanic regions. In Antarctica, the IO spatial and temporal distribution is found to be different from that of BrO, arguing for partly different release pathways of iodine and bromine precursors. Above the oceans, some regions reveal a positive relation between IO and chl-a, while other areas rich in chl-a do not show IO enhancements. Further investigations shall improve our knowledge and understanding of surrounding conditions related to IO occurrence.



Spatial distributions of atmospheric iodine monoxide vertical columns (top left) observed by SCIAMACHY and Chlorophyll-a concentrations in case 1 waters (top right) from the GlobColour project above the Antarctic Region and around the African continent (bottom). Data is averaged over eight full years 2003-2010. Above several biologically active regions around Antarctica and above the Benguela current, enhanced IO is present. Other Chlorophyll-a rich locations (such as Lake Victoria, Africa) do not reveal enhanced IO abundances. (GlobColour monthly merged MERIS/MODIS/SeaWiFS product, GSM method. Acknowledgement: ACRI & the GlobColour Team. GlobColour is funded by ESA with data from ESA, NASA and GeoEye).
Credits: Anja Schönhardt.

→ REINFORCING ESA CONTRIBUTION TO MAJOR GLOBAL EARTH SCIENCE PROGRAMMES

→ WACMOS

wacmos
support to science element

Project team:
Technische Universität Wien (AT)
Deutscher Wetterdienst (DE)
International Institute for Geo-Information Science & Earth Observation (ITC) (NL)
Royal Netherlands Meteorological Institute (KNMI) (NL)
Vrije Universiteit Amsterdam (NL)

Status:
Completed

ESA launched WACMOS in collaboration with and as a contribution to the Global Energy and Water Experiment (GEWEX) of the World Climate Research Programme (WCRP). WACMOS focused on four components of the water cycle:

Evapotranspiration: Evaporation from water or soil surfaces and transpiration from plants combine to return available water at the surface layer back to the bulk atmosphere. This process is referred to as evapotranspiration (ET) which represents a direct feedback of moisture to the atmosphere from the land surface. At present, there is an urgent need for validated global EO-based high-resolution ET product, or an algorithm commonly available to the scientific community for estimating this critical variable. WACMOS has developed a novel global evapotranspiration product based on the synergistic use of MERIS, AATSR and other non-ESA data (e.g., MODIS). The applicability of the WACMOS ET product was demonstrated for drought monitoring in Africa.

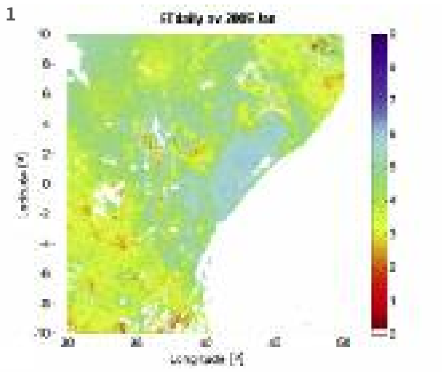
Soil moisture: In the last few years a number of global soil moisture products have been made available by different scientific groups using different EO systems (passive microwave, scatterometers). In this context, WACMOS investigated the potential to exploit these products in a synergistic manner and delivered the first multi-decadal (30+ years) multi-mission soil moisture data set based on the synergistic use of soil moisture products derived from scatterometer data (from ERS-1/2 and MetOp) and passive (e.g., SSM/I, AMSR-E) microwave observations.

Clouds: Clouds play an essential role in the energy budget and hydrological cycle of the Earth. Clouds reflect shortwave (solar) radiation and trap longwave radiation and represent the visible expression of atmospheric condensation processes as the origin of precipitation that is essential for many hydrological processes on land. WACMOS aimed at developing novel and enhanced products at global scale based on synergistic use of SEVIRI and SCIAMACHY data.

Water Vapour: Water vapour is a key variable of the water cycle and the climate of the Earth. WACMOS aims at exploring novel methodologies to deliver enhanced water vapour products that may exploit the synergies among different observation systems providing high vertical resolution (IASI), high temporal sampling (SEVIRI) and high spatial resolution (MERIS). In this context, WACMOS aimed at developing and validating two novel products based on the combination of SEVIRI and IASI observations at 0.25° spatial resolution and SEVIRI and MERIS at 0.025° spatial resolution.

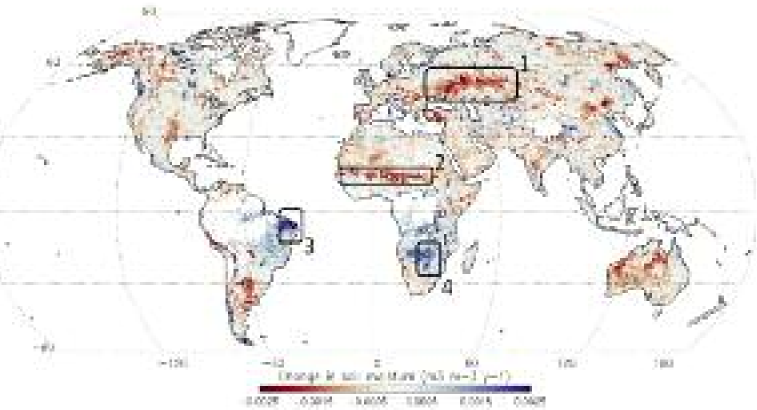
1- Actual Evapotranspiration product at 1km resolution in January 2005 using the SEBS model. The product was generated from AATSR based LST and vegetation and land cover information derived from MERIS data. Credits: WACMOS team/ITC.

1



2- The first trend analysis of the WACMOS soil moisture 30 year dataset revealed subtle soil moisture trends over the entire globe varying from -0.06 m3m-3 to 0.06 m3m-3 over the last 30 years. Credits: WACMOS team/TUW/VUA.

2



The strongest negative trends can be found in Russia and Kazakhstan (1) and the Sahel Region(2). Strong positive trends are found in North East Brazil (3) and Southern Africa (4).

→ ALANIS-METHANE

alanis methane
support to science element

Project team:
Natural Environmental Research Council Centre of Ecology and Hydrology (NERC-CEH) (UK)
Technische Universität Wien (AT)
University of Bremen, Institute of Environmental Physics (IUP) (DE)
ESTELLUS (FR)

Status:
Completed

Boreal Eurasian lakes and wetlands play an important role in the carbon cycle as they represent both the largest natural methane (CH4) source and one of the major carbon sinks in this region. Indeed, the combination of elevated water tables, high productivity and low decomposition has led to significant storage of carbon, which can be transformed into CH4 by methanogens. While most of it is oxidized by methanotrophic bacteria, the remainder is transported to the atmosphere via bubbling and diffusion. Both lake/wetland dynamics and related methane emissions depend on climatological and hydrological factors, leading to potentially significant feedbacks to the global climate. Modelling the natural variability of methane fluxes from boreal Eurasian lakes and wetlands represents an important crosscutting topic. However, the high spatial and temporal variability of the emissions combined with patchy and incomplete information on their geographical dispersion makes it difficult to obtain reliable estimates. This complex scenario represents the framework of the ALANIS methane project (www.alanis-methane.org).

The aim of the ALANIS methane project is to investigate the potential of EO data to reduce current uncertainties in methane emissions from boreal lakes and wetlands through the synergistic use of EO-based products in a coupled land surface-atmosphere model. The project has produced a number of new or extended EO-based products, which are highly relevant to the surface characterization of wetlands and their emissions of methane:

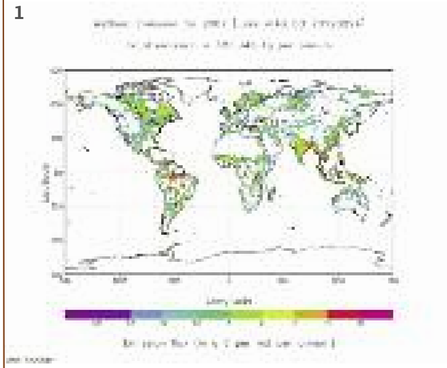
- wetland/inundation dynamics for the boreal domain for the period July 2007 to June 2008 using ASCAT (MetOp-A) and SSM/I (DMSP) data, supplemented with vegetation indices derived from AVHRR data;
- wetland/inundation dynamics at higher spatial resolution for the Northern Eurasia domain (north of 50° N) from ASAR (Envisat) wide swath data for the spring/summer months of 2007 and 2008;
- snowmelt onset/duration/end derived for a circumpolar domain (north of 50°N) from ASCAT (MetOp-A) data for the years 2007-2010;
- atmospheric CH4 columns derived from SCIAMACHY data (Envisat) for the years 2003-2009.

The EO products were then used to validate the JULES land surface model (JULES, the Joint UK Land Environment Simulator, development led by the UK Centre for Ecology and Hydrology). JULES is a state-of-the-art land surface-atmosphere model, which can simulate methane emissions from boreal lakes and wetlands (and wetlands globally). A key parameter in the wetland emission parameterisation is the wetland fraction and the model was driven with the EO-derived value to assess the importance of the EO wetland/inundation products. The JULES land surface model was used to derive a number of wetland emission scenarios for the use in the HadGEM2 Earth-system model (i.e., Hadley Centre Global Environmental Model, developed by UK MetOffice) and the outputs of these runs were compared with the SCIAMACHY atmospheric CH4 columns.

Until now, the wetland emission scheme in JULES had largely been evaluated at specific locations where measurements had been made. This was the first time that the JULES model had been evaluated over a larger spatial domain. The ALANIS methane project has identified a number of limitations in the JULES land surface and HadGEM models, in terms of the treatment of wetland hydrology and biogeochemistry and the atmospheric chemistry and physics. These will need to be addressed to provide confidence in modelling wetlands in land surface and climate models, especially over long time periods.

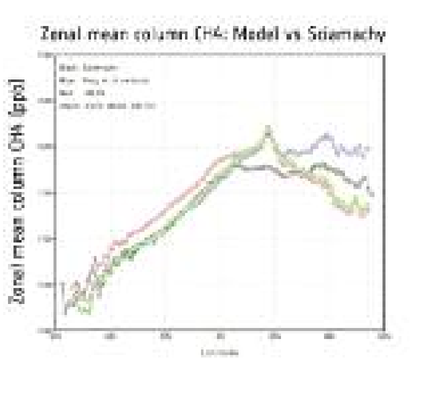
The formal project outputs were (i) datasets of the EO products covering, as a minimum, the boreal Eurasia for the years 2007 and 2008 and (ii) methane emission estimates obtained from the land surface model. The EO datasets have proved to be an important resource for evaluating the performance of the JULES land surface model. These could be used in the future as benchmark datasets to quantify model performance, not only of the JULES model but also of other land surface models.

1



1- Map of the modelled JULES annual emission fluxes of methane from wetlands for 2007 (in g C m-2 yr-1), in which the modelled wetland fraction has been replaced with fractions derived from the EO global inundation product.
2-Zonal mean atmospheric methane columns for 2003-2005 derived from SCIAMACHY (black) and from HadGEM2 runs with different wetland methane emissions: (1) based on Fung et al. (blue); (2) from JULES (red) and (3) from JULES with the modelled wetland fraction replaced with an EO-delived fraction (green). Credits: ALANIS Methane team.

2



ALANIS-SMOKE PLUMES

alanis smokeplumes
support to science element

Project team:
Noveltis (FR)
University of Wageningen UR (NL)
Joint Research Centre (EU)
University College London (UK)
Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS) (FR)

Status:
Completed

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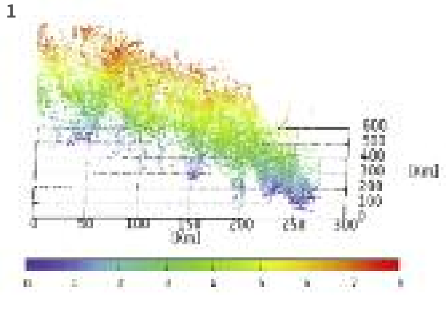

1- 3D view of the new AATSR derived smoke plume height.
2- Modelled CO columns from TM5 integrating the ALANIS EO-based products;
3- Comparison with IASI CO columns.
Credits: ALANIS smoke plumes team.

Generally, most of the fires deposit their emissions into the atmospheric boundary layer (i.e., below about 2 km). However, due to high atmospheric instability and high energy release, emitted greenhouse gases and aerosols at northern high latitudes might be injected to either upper troposphere or lower stratosphere where their effects last longer affecting greater regions. Understanding the impacts of fires on air quality and climate requires the use of transport models, which must be initialized with reliable estimates of smoke plume injection height and validated against plume dispersion measurements over time. Unfortunately, due to the lack of auxiliary data, often rather arbitrary assumptions are used (e.g., fixed vertical injection levels).

Satellite remote sensing provides useful information on the variation and coverage of widespread boreal fires and can be used to monitor regional to global dispersion of fire-related aerosols and trace gases. In this context, and in collaboration with ILEAPS (the Land-Atmosphere Interactions Project of IGBP), the ALANIS Smoke Plumes project aimed at exploiting the complementary capabilities offered by multi-mission Earth Observation (EO) data for improving current large-scale dispersion forecasts of compounds emitted from biomass burning events occurring in boreal Eurasia.

Three main EO-based products have been used to characterize emissions: 1) Burnt areas and fire emission products from MERIS and MODIS data, 2) Smoke-plume mask and injection height products (SPM, SPIH) using stereo retrievals from AATSR and 3) CO columns derived from near-real-time IASI retrievals.

These novel EO-based products have been integrated into the TM5 land-atmosphere coupled model, explicitly simulating the main processes characterizing fire-plume dispersion. A 4D-VAR system was subsequently used to optimize surface CO emissions. Using these optimized emissions, the 3D CO distributions over boreal Eurasia have been calculated.

The added values of the ALANIS EO-based products have been analyzed. Sensitivity analysis for the 2010 Moscow fires showed that the assimilation of the IASI products leads to robust emission estimates, irrespective of the a priori distribution of emissions.

To our knowledge the ALANIS system is the first of its kind that combines global modelling, satellite observations of CO columns, and bottom-up fire emission estimates in a consistent framework. It appears to be feasible to optimize prior emission estimates with daily satellite observations from IASI. A multi-year experimental database was also generated including the aforementioned EO products calculated for a consistent number of fire events which occurred between April 2008 and August 2011 over the whole boreal Eurasia, as well as the corresponding emission dispersion forecasts obtained by employing the optmised TM5 model.

(http://www.alanis-smokeplumes.info).

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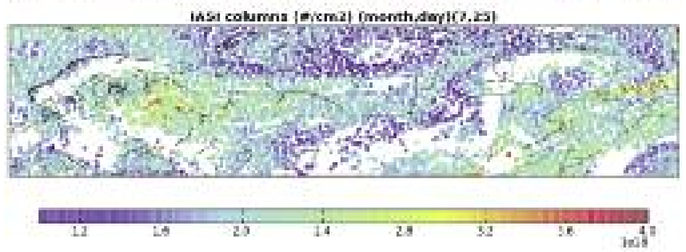

ALANIS-AEROSOLS

alanis aerosols
support to science element

Project team:
University of Helsinki (FI)
Finnish Meteorological Institute (FI)
Lund University (SE)

Status:
Completed

The scientific objective of iLEAPS (the land-atmosphere core project of the International Geosphere-Biosphere Programme, IGBP) is to provide understanding on how interacting physical, chemical and biological processes transport and transform energy and matter through the land-atmosphere interface.

Atmospheric aerosols play a crucial role in climate evolution. In particular, their influence on the Earth's radiative budget is to cool the climate system by directly reflecting sunlight to space, and indirectly by increasing cloud cover and brightness. However, depending on their composition, atmospheric aerosols can also absorb incoming sunlight, thus further cooling the surface but warming the atmosphere. Assessing the effects of aerosols on climate is then of paramount importance and represents a very complex task, as atmospheric aerosols exhibit different chemical compositions resulting in different optical properties.

Aerosols in the atmosphere are composed of particles of both natural (e.g., soil dust, sea salt and sulphates) and anthropogenic (e.g., pollutants by energy production, traffic and industrial activities) origin. However, since their lifetime is comparable to the time scale of intra-continental and intercontinental transport (i.e., 3 to 10 days), anthropogenic aerosols are ubiquitous and the natural background aerosols are difficult to observe and quantify with confidence.

The ALANIS Aerosols project was a feasibility study on the use of existing satellite data for discriminating between natural aerosols emitted by boreal Eurasian forests and long-range transported anthropogenic aerosols. The study used satellite data as primary data source to examine the secondary production of aerosols from their precursor gases. These newly formed particles are initially too small to observe directly with satellite-based optical instruments, but through the use of proxies, information can be obtained on global nucleation mode aerosol concentrations.

Firstly, the activity developed novel algorithms exploiting currently available EO-based products. Second, the project investigated novel strategies for assimilating existing EO data and products into suitable chemical transport models currently available in the literature. This was useful for indirectly characterizing different types of aerosols (e.g., anthropogenic aerosols could be discriminated by identifying the source regions from the analysis of model back-trajectories). Three case studies were conducted: a biomass burning episode, new particle formation and fresh pollution transport.

The ALANIS Aerosols project results demonstrated the feasibility of discriminating long-range transported anthropogenic aerosols from natural aerosols emitted by boreal Eurasian forests with existing multi-mission EO-based products.

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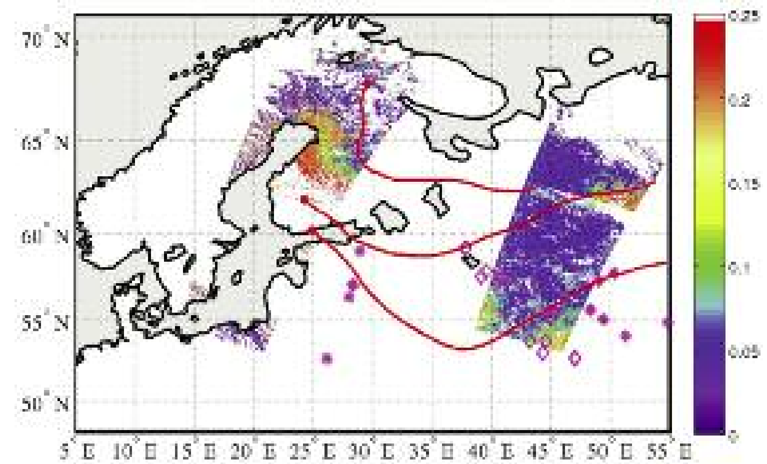

1- AATSR-retrieved AOD at 555 nm over Finland and neighbouring countries the 2nd May 2006. The symbols indicate the presence of forest fires as detected by AATSR on the same day, one day before and two days before. The red lines are the 96-hour back trajectories for air masses arriving in Helsinki, Hyytiälä and Värriö at 12:00 GMT.
Credits: ALANIS Aerosols team.

NORTHHYDROLOGY

north hydrology
support to science element

Project team:
Interdisciplinary Centre on Climate Change, University of Waterloo (CA)
Water & Climate Impacts Research Centre, Environment Canada at University of Victoria (CA)
Environmental Earth Observation IT GmbH (ENVEO IT) (AT)
Finnish Environmental Institute (SYKE) (FI)
Finnish Meteorological Institute (FI)
Institut National de la Recherche Scientifique (INRS), Centre Eau Terre Environment (CA)
Northern Research Institute Tromsø (NORUT) (NO)
Norsk Regnesentral (NO)
Swedish Meteorological and Hydrological Institute (SE)

Status:
On-going

The CliC Project was established in March 2000 by the World Climate Research Programme (WCRP) to stimulate, support and coordinate research into the processes by which the cryosphere interacts with the rest of the Earth system.

In this context, NorthHydrology aims at addressing the scientific priorities of the CliC community and the relevant operational users (e.g., weather services, water authorities, hydrological services) in terms of novel products and applications that may be derived exploiting the increasing multi-mission observational capacity. Priorities have been discussed and defined during a Scientific Consultation Workshop organised jointly by CliC and ESA on 17 June 2009 and hosted by the University of Innsbruck, Austria. In particular, the main thematic area addressed by this activity is the lake and river ice dynamics in the northern hydrology system.

Lake and river ice dynamics represent a key component of climate and creates and controls unique aquatic habitats and related biological productivity and diversity. River and lake ice changes over seasons. The dates of freeze up and break up are useful indicators of climate change and variation. Ice is a seasonal storage of water over the winter. To determine this storage amount, ice extent and thickness data are necessary. Ice thickness can reach up to 2-3 metres in the northern regions. Ice break-up in the arctic watersheds is closely associated with the spring peak floods. River and lake ice condition changes due to climate warming in the cold regions. There are long-term observations of river and lake ice in the northern regions (mainly in Siberia and Northern Europe). However, the observations network is declining in recent decades.

Satellite data have proven to be a key source of information to derive lake ice products at global and regional scales. However, currently available operational products do not provide the sufficient spatial and temporal resolution to match the increasingly demanding user needs (e.g., national agencies have started to incorporate lake parameterisation schemes into numerical weather prediction and regional climate models with an increasing demand for high-resolution information).

In this context, the overall goal of the NorthHydrology is to support the international efforts coordinated by the CliC project of the WCRP to exploit the use of EO technology, models and in situ data to improve the characterisation of river and lake ice processes and their contribution to the northern hydrology system. To this end NorthHydrology aims at developing a portfolio of novel multi-mission geo-information products (maximising the use of ESA data) improving the current characterisation of river and lake ice dynamics to enhance NWP and modelling of key hydrological processes in northern latitudes.

1- Medium resolution lake ice cover product for the Fennoscandia region.
Credits: NorthHydrology team.

1

OCEANFLUX GREENHOUSE GASES

oceanflux ghg
support to science element

Project team:
North Highland College, Scotland (UK)
IFREMER (FR)
Plymouth Marine Laboratory (UK)
National Oceanography Centre (UK)

Status:
On-going

Understanding the CO2 pathways, sources, sinks, their budgets and their impacts on Earth's climate system is essential for monitoring and projecting future climate model scenarios. In-situ measurements of GHG fluxes and related forcing/control parameters of air-sea fluxes remain sparse relative to the global ocean area and will at best provide sufficient information to develop regional relationships through process studies and, at some locations, long term monitoring of key variables. In contrast, EO measurements provide quasi-synoptic, reproducible and well-calibrated data for driving parameterization development and enhancing models of air sea gas transfer. Due to the vast size of the global ocean, EO measurements provide a unique (arguably the only) means to reliably monitor global air-sea fluxes. The combined use of models and EO data enables powerful synergy, but models need to be properly configured to study the detailed processes at the air-sea interface. Further work is required to develop new and innovative EO products for air-sea gas transfer calculations of CO2 and optimize their application using model systems: this is the main focus of the STSE "OceanFlux Greenhouse Gases" project.

The objective of the project, carried out in collaboration with SOLAS, is to improve the quantification of air-sea exchanges of greenhouse gases by exploiting a wide range of ESA EO data sets. The project will develop and validate new and innovative products combining field data, satellite observation and models. The main scientific challenges concern the estimate of the gas transfer velocity parameter and the quantification of the impact of biological slicks, rainfall, sea surface temperature and salinity variability on the air-sea CO2 flux.

At the current state of knowledge it is at least as important to understand the true uncertainty in the fluxes of CO2 as it is to publish a new 'central estimate' of flux and we are designing the architecture to enable a large ensemble of calculations that will elucidate systematic and sampling bias uncertainty.

The expected outputs of the project include:

- New dynamic estimates of GHG air-sea gas transfer on a sub-weekly timescale based on the synergy between EO data, in situ data and models;
- Improved understanding of the spatial and temporal variability in GHG air-sea gas transfer and the underlying processes governing flux rates;
- New multi-sensor EO algorithms and products capitalising on the synergy between complementary EO data sets for use by the SOLAS and air-sea interaction community;
- Enhanced use and uptake of ESA and other Third Party EO Mission data by the SOLAS and air-sea interaction community;
- New NOP model systems tuned to air-sea interaction and the carbon cycle;
- A clear scientific roadmap for future activities to improve the quantitative understanding of the carbon cycle.

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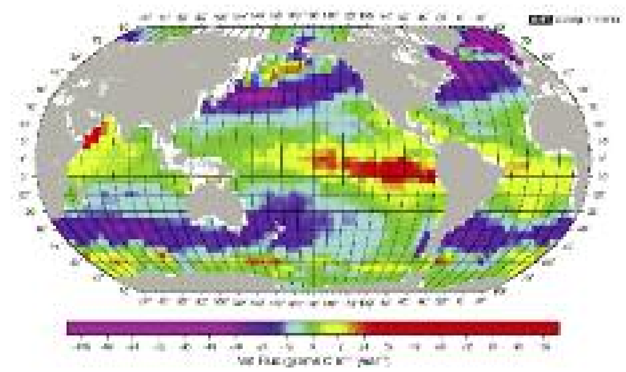

1- Mean CO_2 fluxes for the year 2000, based on 3 million in situ measurements, showing large spatial variations.
Credits: T. Takahashi, Lamont-Doherty Earth Observatory of Columbia University.

→ OCEANFLUX SEA-SPRAY

oceanflux sea spray
support to science element

Project team:

Finnish Meteorological Institute (FI)
National University of Ireland (IE)
Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (TNO) (NL)

Status:

On-going

The action of wind stress on the ocean surface results in the mechanical production of sea-spray aerosol (SSA), consisting of a suspension in air of particles that are directly produced at the sea surface mainly by bursting of whitecap bubbles. SSA differs from sea salt aerosol in the sense that the particles may be enriched by other substances such as organic matter. SSA is the strongest source of natural aerosols in the global climate system, making up between 30-70% of all natural aerosols. SSA also plays a major role in the Earth's radiative budget by scattering incoming solar radiation (the direct aerosol effect) and by the modification of cloud microphysics and radiative properties (the indirect aerosol effect).

SSA is a natural component of atmospheric aerosol, having no direct anthropogenic source. However, it is important to quantify the emission processes and atmospheric burden of SSA in order to understand how SSA may respond to anthropogenic climate change, to put anthropogenic aerosol emissions in context, and to understand the cloud microphysical processes where SSA contributes a major fraction of cloud condensation nuclei.

The sea-spray source function (SSSF) is used to describe the production of the number of aerosol particles per unit surface area and per second. Estimates of global annual mass emission of sea salt with current chemical transport models and global climate models (CTMs and GCMs, respectively), using various parameterizations of the sea-spray source function, range over nearly two orders of magnitude. This large uncertainty has consequences for the evaluation of effects of sea-spray on climate, air quality and atmospheric chemistry. Much of this variation is due both to the parameterizations used and to uncertainties in the input parameters. Satellite observations can help to reduce these uncertainties by providing information on the biophysical conditions of the aerosol source regions, as well as on the optical depth of the resulting aerosol distribution.

Some of this satellite information, such as surface wind speed from scatterometers, is already assimilated operationally in global models to provide accurate global fields of some of the SSSF controlling parameters. The other parameters are either not assimilated at all, or even after assimilation may not be sufficiently well represented in models for the purpose of characterising SSA. Therefore, it is expected that the project will depend on a mix of both satellite and model derived oceanographic information.

The objective of the OceanFlux Sea-Spray is to exploit European multi-mission satellite data to improve the characterization of the SSSF for the purpose of reducing uncertainty in SSA emissions, SSA atmospheric burden and the resulting climatically important direct and indirect radiative effects.

1- Artists impression of ENVISAT satellite.
Credits: ESA.

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→ OCEANFLUX UPWELLING

OceanFlux aims at reinforcing the scientific collaboration with the Surface Ocean-Lower Atmosphere Study (SOLAS), an international research initiative meant to achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and atmosphere.

Within this context, OceanFlux Upwelling aims at exploring the potential and limits of EO technology to characterise the role of ocean upwelling processes as sinks and/or sources of greenhouse gases (GHG), with a distinctive focus on the Eastern Boundary Upwelling Systems (EBUS). The EBUS and the associated OMZs (Oxygen Minimum Zone) contribute very significantly to the gas exchange between the ocean and the atmosphere, notably with respect to GHG. However, from in situ measurements it is estimated that the uncertainty of the global net ocean-atmosphere CO2 fluxes is between 20% and 30%, and could be much higher in the EBUS-OMZ. In this framework, the overarching scientific questions to be answered by OceanFlux Upwelling are: Which is the spatio-temporal variability of the net GHG effect in the EBUS? Are the uptake/release of the most important long-lived radiatively-active gases coupled or decoupled with these upwelling events?

To address these questions, state-of-the art modeling techniques applied to Vertical Column Densities (VCDs) of SCIAMACHY and GOSAT are being used together with image processing techniques for improving the signal-to-noise ratio and extracting fluxes of GHGs from EO data at low spatial resolution.

Through concomitant information on gas solubility (dependent on SST and salinity) and parameterizations of gas transfer velocities (mainly related to wind speed and whitecapping), it will be possible to extract the partial pressure of GHG in the ocean. Nevertheless, for accurately linking sources of GHGs to EBUS and OMZs, the spatial resolution of the source regions needs to be increased. This task develops on new non-linear and multi-scale processing methods for complex signals to infer a higher spatial resolution mapping of the fluxes and the associated sinks/sources. The use of coupled satellite data (e.g. SST and/or Ocean Color) that carry turbulence information associated to ocean dynamics is taken into account at unprecedented level of detail to incorporate turbulence effects in the evaluation of the air-sea fluxes.

These analyses will be linked to a coupled physical bio-geochemical model (ROMS-BioBus) and a comparison of results will be carried out with a wide range of in situ and simulated data over the two main areas of interest: the Peru-Chile and Benguela upwelling systems.

oceanflux upwelling
support to science element

Project team:

University of Heidelberg (DE)
CNRS (FR)

Status:

On-going

1- Mean over two months period (December 2009 - January 2010) of the gas tranfer velocity (KS) with Nightingdale et al., (2000) relationship (left) and solubility constant (KO) (right).
Credits: OceanFlux Upwelling team.

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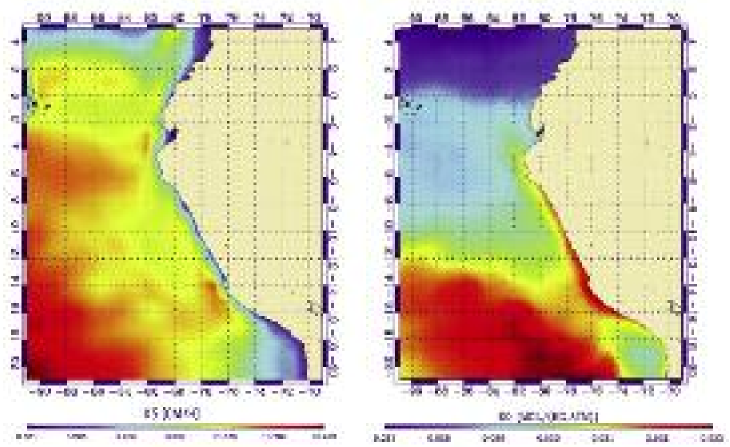

SPIN

spin
support to science element

Project team:
Belgian Institute for Space Aeronomy (BIRA-IASB) (BE)
University of Bremen, Institute of Environmental Physics (IUP) (DE)
Chalmers University of Technology (SE)
Finnish Meteorological Institute (FI)
University of Saskatchewan (CA)
University of Toronto (CA)
Hegglin Scientific (CH)

Status:
On-going

The cornerstone of climate science is generation of climate data records (CDRs) that provide the observed record of climate and its past changes. CDRs are the basis for assessing our current understanding and the attribution of past changes in climate (e.g. the activity of IPCC and UNFCC) and are used, in part, to validate the models used for climate prediction. The most essential characteristic of a CDR is the stability of its uncertainty characteristics over time. While grounded in observations, CDRs are thus much more than the raw observations; rather, they are a synthesis of related observations, often from multiple instruments, taking account of anything that disturbs the homogeneity of the time series: e.g., variations in spatial coverage, orbital drifts, instrument degradation, and inconsistencies between the calibration of different versions of the same instrument.

The SPIN project, carried out in collaboration with SPARC (the Stratosphere science project of the WCRP), aims to improve the characterization of CDRs, and produce new CDRs, for four essential climate variables in the stratosphere (approximately 10-50 km altitude). Where possible, the domain of study will extend into the lower mesosphere (to approximately 65 km altitude). In the stratosphere, space-based measurements are the dominant source of CDRs because of the limited extent of in situ measurements compared with the troposphere and the near-global coverage of space-based measurements. As a result of their pioneering developments in the early phase of the space age, the space-based stratospheric CDRs to date are reliant primarily on US (NOAA or NASA) data. The purpose of this study is to work towards the inclusion of ESA and ESA-TPM data in the stratospheric CDRs used by the stratospheric research community. This is a pressing need because a number of key US-based CDRs ended in 2005/2006: namely the SAGE-based ozone record, the SAGE-based aerosol record, the SSU-based temperature record and the HALOE-based water vapour record. Since the ESA and ESA-TPM vertical profile observation records begin a few years before 2005/2006 and continue to the present, there is a period of overlap which allows for a potential extension in time of the existing CDRs.

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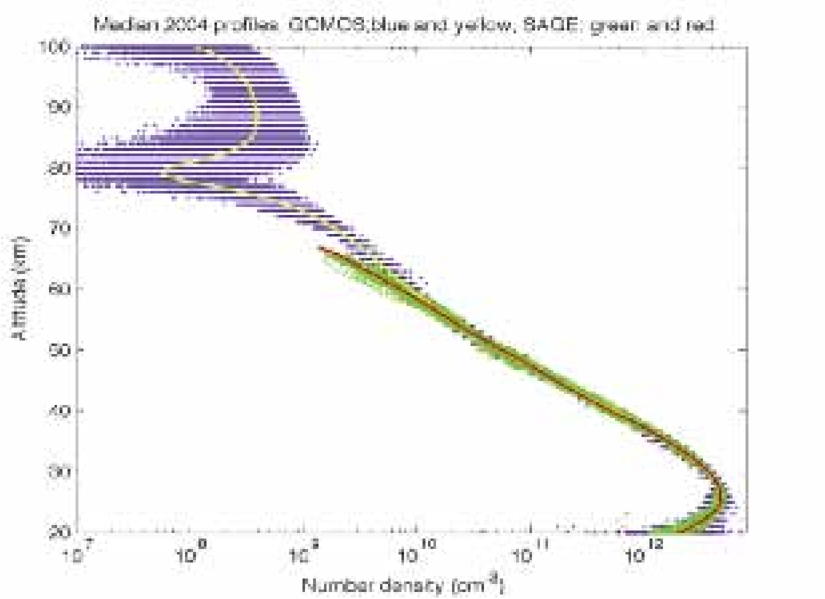

1- GOMOS profiles vs SAGE II profiles at Equator demonstrating compatibility of both satellites to develop a harmonized long-term data series.
Credits: SPIN team.

WACMOS II

wacmos II
support to science element

Project team:
Estellus (FR)
Observatoire de Paris (FR)
University of Bristol (UK)
ETH (CH)
MPI-BGC (DE)
Instituto de Meteorologia (PT)
NILU (NO)
UCL (UK)

Status:
On-going

Evaporation from water or soil surfaces and transpiration from plants combine to return available water at the surface layer back to the bulk atmosphere in a process referred to as evapotranspiration (ET), which is of utmost importance in understanding the terrestrial water and climate systems because it represents a direct feedback of moisture to the atmosphere from the land surface. Thus, the quantification of terrestrial evapotranspiration helps determining the biological environment and its water use efficiency. Evapotranspiration is also of primary interest to water resources management in practice because many end users need ET to estimate the loss of useable water from the soil column and to help determine plant water stress for applications that include drought assessment, agricultural irrigation management and forest fire susceptibility. Knowledge of surface ET helps also in estimating the formation of summertime convective precipitation patterns.

The WACMOS II project is motivated by scientific challenges emerging from the needs to develop a predictive capability for terrestrial evapotranspiration to support both climate research and operational water management and agriculture. In both cases, the need for improving relevant observations and modelling capabilities is mandatory in order to overcome the current drawbacks and limitations faced by the scientific and operational communities. EO provides one of the main sources of information for estimating key water cycle variables at global, regional and even basin scales, including some of the main inputs needed to estimate ET. However, there is still a significant scientific effort required at international level to further advance towards the development of quality datasets and models, which may respond efficiently to some of the key open questions and challenges expressed by the scientific community today. In this context, WACMOS II aims at exploring the potential and fostering the scientific use of EO and in particular ESA EO data to advance towards the development of global and regional evapotranspiration products serving two different communities with different needs: 1) Regional medium resolution (approx. 1 km) land evapotranspiration data set to support agriculture and water management applications and 2) Global low resolution (approx. 10-25 km) multi-decadal land evapotranspiration data set for climate research in line with the objectives of the GEWEX LandFlux project.

→ CARBONFLUX

carbonflux
support to science element

Status:
To be started (2012)

The carbon cycle is central to the Earth system, being inextricably coupled with climate, the water cycle, nutrient cycles and the production of biomass by photosynthesis on land and in the oceans. A proper understanding of the global carbon cycle is critical for understanding the environmental history of our planet and its human inhabitants, and for predicting and guiding their joint future. The challenge to the scientific community (e.g., the Global Carbon Project) is to monitor (quantify), understand (attribute) and predict the evolution of the carbon cycle in the context of the whole Earth system, including its feedbacks with human components. This demands new scientific approaches and syntheses that cross disciplinary and geographic boundaries and place particular emphasis on the carbon cycle as an integral part of the coupled carbon–climate–human system.

In this context, CarbonFlux will contribute to the efforts of the GCP by exploring and quantifying the incremental value of Earth observation products of the biosphere, hydrosphere and atmosphere on the quality of global scale biophysical and biogeochemical models through multiple constraint assimilation studies. Particular emphasize shall be put on a better understanding of the links and feedbacks of the carbon and hydrologic cycles. The Earth observation products to be considered shall be fAPAR or LAI, soil moisture and total column CO2. In particular CarbonFlux shall

- Adopt two independent biogeochemical models to allow multiple observations from the hydrosphere, biosphere and atmosphere to be assimilated with the aim to improve terrestrial carbon cycle predictions and refine the assessment of related uncertainties in scenario analyses;
- Run data assimilation experiments to quantify the incremental value of Earth observation products of the biosphere, hydrosphere and atmosphere on the quality of global scale biophysical and biogeochemical models;
- Interpret the model analysis in terms of feedbacks between the hydrologic and carbon cycles and the vulnerability of the terrestrial carbon sinks and pools;
- Produce a global spatially explicit carbon balance, including its component fluxes in form of regional statistics and maps.

1- The CarbonFlux project will explore the potential of EO-derived soil moisture, CO2 atmospheric total column and vegetation parameters to enhance current carbon flux models. The images show soil moisture from SMOS, atmospheric CO2 from SCIAMACHY and vegetation parameters from MERIS.
Credits: ESA.

1

→ MASS BALANCE

The Intergovernmental Panel on Climate Change (IPCC) has expressed concern that progress will not be made in the run up to the fifth Assessment Report; in their 2010 report on sea level rise and ice sheet instabilities this disagreement was highlighted as a primary emerging topic and the value of inter-comparison projects was explicitly noted. European Space Agency (ESA) and National Aeronautic and Space Administration (NASA) recognised the need to take urgent action and started the Ice sheet Mass Balance Intercomparison Exercise (IMBIE) as an ESA-NASA Inter-Agency framework to deliver improved estimates of ice sheet mass balance. IMBIE aimed to resolve the apparent disagreement between geodetic estimates of ice sheet mass balance through a coordi nated exercise, within which estimates are developed from all three geodetic techniques using a common spatial and temporal reference frame, and a common appreciation of the contributions due to external signals (e.g. fluctuations in Surface Mass Balance (SMB) and Post Glacial Rebound (PGR)). IMBIE brought together the handful of laboratories and space agencies that have been instrumental in developing independent estimates of ice sheet mass balance. The IMBIE project had two key objectives: 1) to provide an understanding as to why geodetic estimates of ice sheet mass differ and 2) to provide a reconciled geodetic estimate of ice sheet mass balance.

A main outcome of the IMBIE project is the finding that there is excellent agreement between estimates of the Greenland Ice Sheet (GrIS) and West Antarctic Ice Sheet (WAIS) mass balance derived from all three satellite geodetic techniques. A second outcome is that there are outstanding challenges to deriving estimates of the regional mass balance of East Antarctic Ice Sheet (EAIS) and the Antarctic Peninsula (AP).

At present the only complete assessment of the AP mass balance have been obtained using gravimetry. However, the low spatial resolution achievable with the GRACE-mission (~300 km to 400 km) means that it is not possible to examine the detailed spatial patterns of mass loss using this technique. Moreover, there are challenges associated with gravity signal leakage from areas adjacent to the AP, because the AP itself is relatively small in area. In contrast, the techniques of altimetry and interferometry are capable of providing estimates of mass balance at the scale of individual glacier drainage basins. However, current estimates of the AP mass balance based on these techniques are based on partial surveys of the region. Combining observations from a series of satellite altimetry and interferometry missions will produce a more comprehensive, fine-resolution survey than possible using a single technique alone. These observations can then be combined with satellite gravimetry measurements from GRACE to provide a complete analysis of the AP mass imbalance.

The objectives of the STSE Mass Balance project are:

- To produce error-characterised time-series of Antarctic Peninsula Mass Balance (APMB) with each of the three satellite geodetic techniques;
- To produce a comprehensive inter-comparison of the APMB results obtained from the individual geodetic techniques, taking full account of variations in the spatial and temporal extent of each individual dataset, and to develop methodologies for optimally combining the three techniques for mass balance estimation;
- To produce a reconciled and comprehensive assessment of the APMB by optimally combining the three techniques;
- To publish the improved APMB estimate in a major scientific journal;
- To assess the open issues in ice sheet mass balance estimation and to produce recommendations to ESA in the form of a Scientific Roadmap.

mass balance
support to science element

Status:
To be started (2012)

→ PARTNER

PARTNER	NATIONALITY
AAS	AT
Environmental Earth Observation IT GmbH (ENVEO IT)	AT
Technische Universität Wien	AT
Wegener Center for Climate and Global Change	AT
Monash University	AU
Belgian Institute for Space Aeronomy (BIRA-IASB)	BE
University of Gent	BE
Array Systems Computing Inc.	CA
Canadian Ice Service	CA
C-CORE	CA
Centre for Earth Observation Science	CA
Institut National de la Recherche Scientifique (INRS), Centre Eau Terre Environment	CA
Interdisciplinary Centre on Climate Change, University of Waterloo	CA
McGill University	CA
University of Calgary	CA
University of Saskatchewan	CA
University of Toronto	CA
Water & Climate Impacts Research Centre, Environment Canada at University of Victoria	CA
ZEMKON Inc	CA
GAMMA Remote Sensing and Consulting AG	CH
Hegglin Scientific	CH
Netcetera	CH
Remote Sensing Laboratories (RSL)	CH
University of West Bohemia (Západočeská Univerzita v Plzni)	CZ
Alfred Wegener Institute for Polar and Marine Research (AWI)	DE
Brockmann Consult	DE
Bundesamt für Kartographieund Geodäsie (BKG)	DE
Deutscher Wetterdienst	DE
Deutsches Geodätisches Forschungsinstitut (DGFI)	DE
Deutsches Zentrum f:ur Luft- und Raumfahrt (DLR)	DE
FastOpt	DE
Forschungszentrum Juelich GmbH	DE
Freie Universität Berlin	DE
Friedrich-Schiller-Universität Jena	DE
GIS	DE
GKSS Research Centre – Institute for Coastal Research	DE
Hyperschall Technologie Göttingen	DE
Leibniz Institut fur Tropospharenforschung (IFT)	DE
Meteorologisches Institut der LMU (MIM)	DE
Ruprecht-Karls-Universität Heidelberg	DE
Technische Universität Dresden	DE

➜ PARTNER

PARTNER	NATIONALITY
Technische Universität Munich	DE
Universität Hamburg	DE
University of Bonn	DE
University of Bremen, Institute of Environmental Physics (IUP)	DE
Danish Meteorological Institute	DK
National Space Institute (DTU Space)	DK
RS-Consult ApS (RSC)	DK
DEIMOS Space S.A.	ES
Instituto de Astrofisica de Andalucia - CSIC	ES
isardSAT	ES
STARLAB	ES
University of Alcalá	ES
University of Valencia	ES
University Politécnica de Cataluña	ES
Joint Research Centre	EU
Finnish Environmental Institute (SYKE)	FI
Finnish Meteorological Institute	FI
Harp Technologies Oy	FI
University of Helsinki (UHEL)	FI
ACRI-ST	FR
Centre de Météorologie Spatiale (CMS) Météo-France	FR
Centre d'Etudes Spatiales de la Biosphère (CESBIO)	FR
Centre National de la Recherche Scientifique-LEGOS	FR
Centre National d'Etudes Spatiales	FR
Collecte Localisation Satellites (CLS)	FR
EADS / Astrium SAS	FR
ESTELLUS	FR
Institut de Recherche en Astrophysique et Planétologie (IRAP) (UPS)	FR
Institut Français pour la Recherche et l'Exploitation de la MER (IFREMER)	FR
Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS)	FR
Laboratoire d'Astrophysique Observatoire Midi-Pyrenees	FR
Laboratoire des Ecoulements Géophysiques et Industriels (LEGI/CNRS)	FR
Laboratoire d'Océanographie de Villefranche	FR
Noveltis	FR
Aristotle University of Thessaloniki	GR
FORTH - Institute of Applied and Computational Mathematics	GR
Dublin Institute for Advanced Studies	IE
National University of Ireland	IE
Istituto di Scienze dell'Atmosfera e del Clima (ISAC-CNR)	IT
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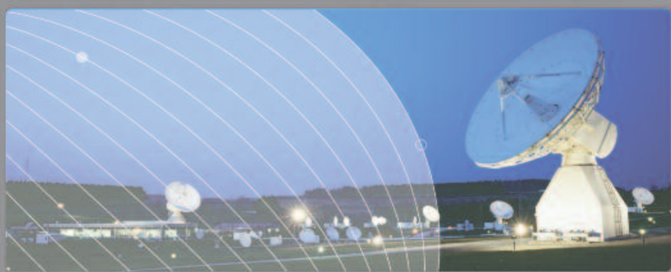

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