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ENVISAT FOR SCHOOL: THE SATELLITE EYE FOR THE GALATHEA 3 EXPEDITION

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ABSTRACT

The Galathea 3 expedition started 11 August 2006 and re-entered Copenhagen on 25 April 2007. The cruise was available for science and education internationally, which constituted a unique opportunity as the ship circumnavigated the globe. The ship was comprehensively equipped with modern *in situ* sensors and during the cruise measurements and parameters were available at high time and space resolution from satellites with coverage along the ship's track. Thanks to the educational AO-project accepted by the European Space Agency (ESA), acquisition requests for Envisat covered the entire cruise, and at many occasions also the exact locations at the time the ship passed. The satellite data was available in near real-time.

The project has developed an easy data access via Google Earth, allowing qualitative analyses of all satellite data. Based on a Java applet, another catalogue is also available permitting on-line display and analysis together with the ability to download the data in full resolution. The ship carries a 1.5 Mbits/second communication connection, so position and in-situ data were received every 5 minutes and plotted in near-real-time in both data access locations. Of primary interest both for scientific and educational projects were MERIS, AATSR and ASAR satellite data, but other sensors for ozone, cloud coverage, ice concentration and sea surface height were also acquired and published. Furthermore third party mission data from SPOT and PROBA were used for educational purposes to demonstrate to schools the changes in time of the harbour cities called during the cruise (comparing present images and images of the past decades).

Schools were offered many opportunities to work with satellite data. The web sites were available for everyone to browse and follow the expedition, but in addition we offered so-called running projects and case studies. Experienced teachers together with scientists have developed exercises to analyse Envisat data (SST, Chlorophyll content, surface-phenomena observed with ASAR) along the route. Furthermore enhanced educational material (case studies) include different themes, such as the Gulf Stream, the different issues related to harbours visited, the trace gases in the atmosphere and many others. All the education material is also accessible via school web sites such as the ESA-EDUSPACE. It is the intention that the material will be integrated to become an activity within the already existing module "Envisat for Schools" in EDUSPACE. The educational material including a series of images taken from satellite and photographs by people on-board will be used to produce a special Atlas to document the scientific results comprehensive for secondary schools.

1. BACKGROUND

Within ESA's educational Earth observation website for secondary schools EDUSPACE a special module for Envisat has been generated. It not only describes the mission and its purposes and provides access to a number of images but also offers to teachers and students of secondary school level opportunities to learn and work

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with data in a variety of application exercises. The most recent one invites schools to follow a scientific cruise around the world: the Galathea 3 expedition.

One purpose of Galathea 1 (1845-47) was planned to study among other things the Nicobar Islands in order "to perform scientific Survey of the natural Products of this Group of Islands and their use for Cultivation and Trade." The voyage was tough: 20 Danish sailors died in the course of the voyage, some discharged during the voyage, and Captain Steen Bille's discipline was harsh. He did not hesitate to punish crewmembers with the whip!

A little more than 100 years later, from 1950 to 1952, Galathea 2 went on an expedition to explore the deep seas, and the scientific results produced by this voyage in many ways exceeded the expectations. The activities on Galathea 2 also included ethnographic surveys.

The idea of launching a third Galathea expedition was suggested from a number of quarters. It was the daily newspaper Morgenavisen Jyllands-Posten which picked up the baton and developed the concept of Galathea 3 as a floating platform on which to gather and combine research activities, exploration and dissemination of scientific research information. The project was presented to the Danish Government, and has since developed into a national project with the participation of some of Denmark's strongest research environments and actors in the field of dissemination of scientific research. Some 50 research projects was accepted for participation, including disciplines from Geophysics, Geography, Geology, Biology, , Culture and History, and Climate and Environmental Sciences.

The cruise had a strong educational component and it was in this context a small team of scientists and school teachers got into collaboration with ESA, seeking for Earth observation data along the route. The project offers to schools an access to teaching and learning material produced from the Galathea 3 datasets and gives a unique opportunity to stimulate young people's interest in science and technology in Denmark and Europe. Our generation is the first that is able to continuously view our globe from space, using the eyes of the never sleeping satellites. They provide fantastic images of land, sea surface, ocean winds, sea ice, atmospheric trace gases and particle transport.

The project "Satellite Eye for Galathea 3" was accepted for full funding by Egmont Fonden. It was therefore with great interest that ESA has followed this project and provided a large amount of data from Envisat in near real time. Furthermore archived data and new acquisitions from PROBA as well as from third party missions SPOT and LANDSAT were kindly provided. Scenes from QUICKBIRD and data from NASA, NOAA and JAXA satellites were also used.

2. A NEAR REAL-TIME UPDATED DATA BASE

A data archiving and distribution system for Polar Regions developed at DTU has been expanded to handle the mid- and tropical latitudes as well. This task included development of interfaces and processing systems for new data types and new data sources as well as development of the necessary extension to new map projections etc.

JAVA technology is used to provide platform independent world wide interactive access (through the Internet) to the Galathea 3 satellite image database for scientists as well as for students. The processing and visualization system enables a unified access to a large variety of data types providing a near real time view of the region around Galathea 3. For ingest of Envisat data the open-source BEAM software of ESA has been used and interlinked.

In addition to the JAVA-based data bank, the already very popular platform of Google Earth (GE) is used to display most of the data collected from satellite and from ground. The support offered by GE makes it possible to swiftly overlap and display both satellite imagery and ship route, but as well the recorded environmental data pertinent to any ship position. A slider also allows comparing the overlaid information with the available space images, which especially for the harbour areas is very interesting.

In this way a multitude of satellite data are processed and made available in near real time through both, the JAVA based and the Google Earth based data bank. The scientists and educators have access also to original data while high-school students and teachers (and other people interested, including the media) were able to follow the expedition from day to day with the latest specially processed and partly commented satellite images and relevant auxiliary data. The necessary technology to provide this information has been developed based on previous experience at Danish Technical University, Danish Meteorological Institute and Eduspace/ESA.

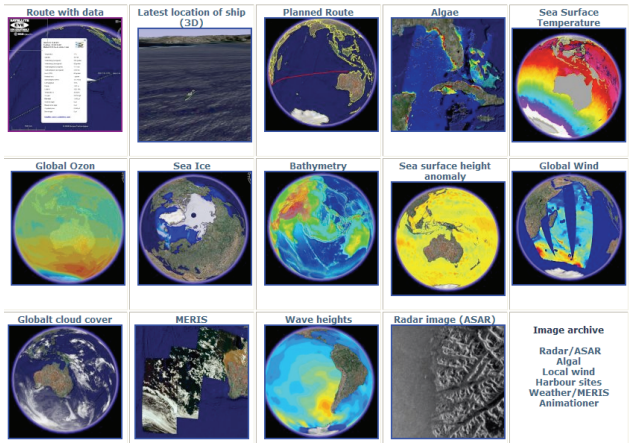

Figure 1. Access to the ship route and related Satellite data based on Google Earth internet access

The data sources in the meta-database of 'Satellite Eye for Galathea 3' include:

- Ship route with real-time in-situ environmental data
- Latest location of the ship (3D)
- Planned route
- Chlorophyll measured by MERIS on Envisat
- Thermal Infrared satellite images for Sea Surface Temperature (SST) from ESA's AATSR instrument on Envisat along with other SST data.
- Atmospheric Chemistry in form of global concentrations of ozone, from instruments such as GOME, SCIAMACHY on Envisat
- Sea Ice (Microwave radiometer data from various NASA/JAXAs AMSR-E instruments)
- Global wind (Microwave scatterometer satellite data from NASA's QuikSCAT satellite)
- Cloud coverage from the geostationary weather satellites (ESA-Meteosat, etc)
- MERIS natural colour and false Infrared colour images
- Sea Surface Height (Microwave altimeter satellite data)
- Synthetic Aperture Radar satellite images from ESA's ASAR instrument on the Envisat
- ASAR derived wind data – near-real-time computation
- Harbour sites (geographical search)
- Animations of SST, Ozone and Sea Ice (timely updated)

Satellite infrared observations provide accurate, high-resolution sea surface temperature data. These observations, however, are limited by clouds. To account for gaps in the satellite SST observations, an adaptive multiplatform 3-d optimal interpolation routine has been designed for providing interpolated high-resolution (~5 km) sea surface temperature observations, for a set of regions following the Galathea 3 expedition. The scheme uses locally varying statistics, and the development of the scheme includes empirically estimated spatial and temporal correlations, based on a data set covering at least one year. The operational scheme uses 1 km AATSR data provided by GODAE's (Global Ocean Data Assimilation Experiment) High Resolution Sea Surface Temperature Pilot Project (GHRSST-PP). NOAA satellite SST data are also integrated in the scheme. DMI (Danish Meteorological Institute) is presently providing daily operational SST fields for the North Sea and Baltic Sea and the adaptive Optimal Interpolation scheme has been developed from the already existing code to cover the track of Galathea 3. Local spatial and temporal statistics are calculated for all areas where interpolated SST fields are required.

3. EDUCATIONAL MATERIAL

Satellite Eye for Galathea 3 combines observations from the expedition with satellite image information for use in education. Through this we can demonstrate that working with physical science subjects are exciting and attractive. The databank at DTU is the basis for a series of educationally reworked and well-introduced lessons and exercises that were prepared jointly by a scientist in collaboration with a teacher. In this way it is ensured that the content is of very high quality with respect to physical sciences. At the same time it is being presented by teachers well aware of the situation in the classrooms. There are two types of material, mainly:

- Running projects that offer activity all along the expedition route, and
- Case studies that focus on specific and particularly interesting themes at distinct places en route.

3.1. Running projects

Running projects are of more general character and can be used by teachers throughout the cruise. This means that satellite images and related in situ observations are put on-line daily and can be viewed on the web immediately through Google-Earth. The themes include the sea surface temperature, algae concentration, Radar images of sea surface, atmospheric pollution, wind and weather and the gravity of the earth.

This allows also the introduction of complex themes such as the ASAR radar instrument, from which a nearly complete coverage along the route was provided. The teacher or student find an introduction how to read and interpret the images and stimulate the student to discover and hunt for particular features such as foot prints of clouds, oil slicks and sea ice which are well visible. The introductory text is followed always by exercises where related images can be downloaded and interpreted either using a printout or using the educational image processing software LEOWorks, (www.eduspace.esa.int). The exercises also encourage students to browse the image data bank from specific areas visited by the expedition or to look at the most recent images in order to judge e.g. the weather situation. In fact several times during the cruise the ship itself is clearly visible in the ASAR wide-swath images and its white dot midst of the ocean can be well correlated with the navigational data on-line. Particularly during the cruise in the Antarctic waters the access to up-to-date ASAR images was of paramount importance for the expedition. Luckily due to the low concentration of ice the scientific program only needed minor alterations.

MERIS images were used to highlight the concentration of chlorophyll in the vicinity of the ship and at the same time the measurements carried out onboard can be visualized (in the Google Earth data bank). Since the satellite images were also displayed onboard in near-real time, the scientists used the information as well to plan the on-going experiments. On several occasions they have requested to change the route of the ship, in order to reach an area of particular interest seen in the satellite images.

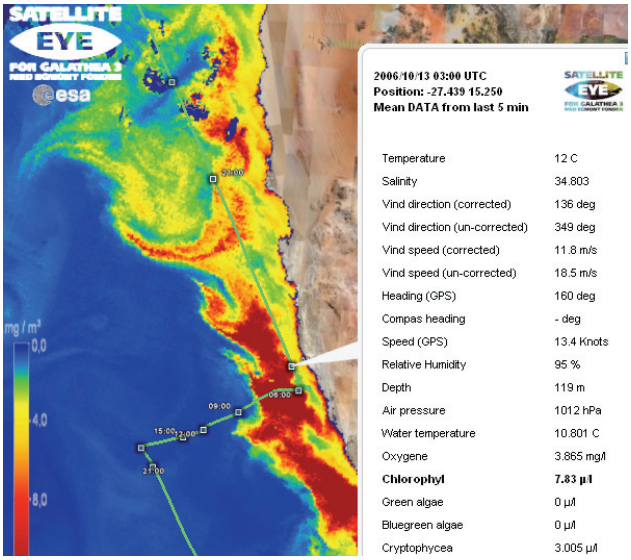

Figure 2. SW-Africa coastal chlorophyll from MERIS and simultaneous data registration on board (right)

3.2. Case Studies

The case studies include themes in connection with port calls of the expedition, but also problem-areas of the world such as the Sahel, or of interest to the different disciplines such as the Inter Tropical Convergence Zone, the Peru and the North Atlantic Currents or the Panama Canal. There is also a case prepared to follow Sea Turtles and a documentary concerning facts and in situ observations from the Galapagos Island.

We also present sea ice distribution from satellite images around Greenland and Antarctica. Related questions are treated, such as: What does it mean for shipping? Where does the sea ice come from? What effect does global warming have on sea ice? What are the consequences for the Polar regions?

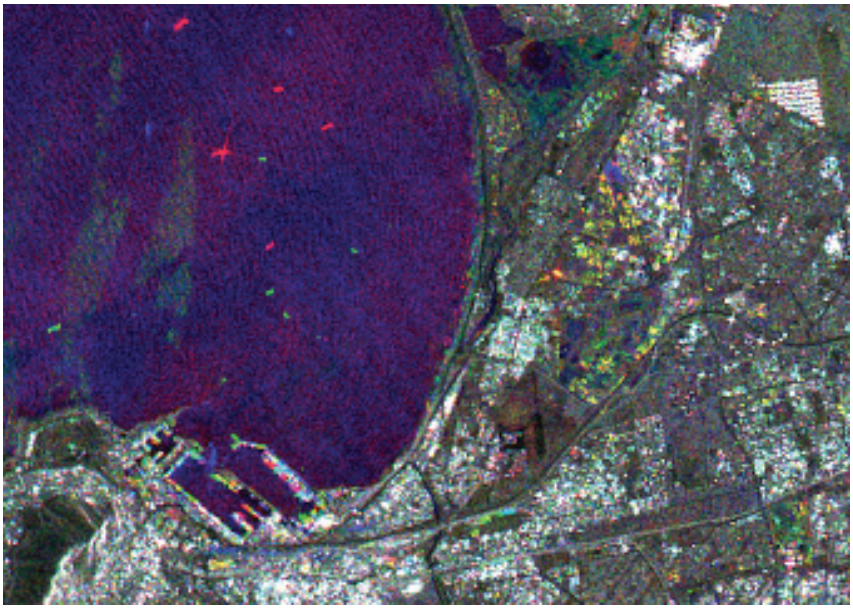

Figure 3. Mulitemporal Ers-SAR image of Capetown. Colours reveal the changes between 2001 and 1996

Case Studies are in general built in the same way as the Running Projects. They consist of a background section, of exercises and related links. The exercises include downloads of satellite images that can be printed and analyzed on paper or further processed using the image processing software LEOWorks. For novices a tutorial give instructions step-by-step how to improve and interpret and classify satellite images, and advanced students find suggestions to even use GIS-technology in connection with images of different kind in terms of spatial and spectral resolution.

3.3. Image of the Week

Once a week, an image was published on the project web site highlighting the area where the ship was operating with respect to a particular theme. It consists of a mostly colourful image with an exhaustive description helping students understand the content of the image and at the same time triggering their curiosity for the matter.

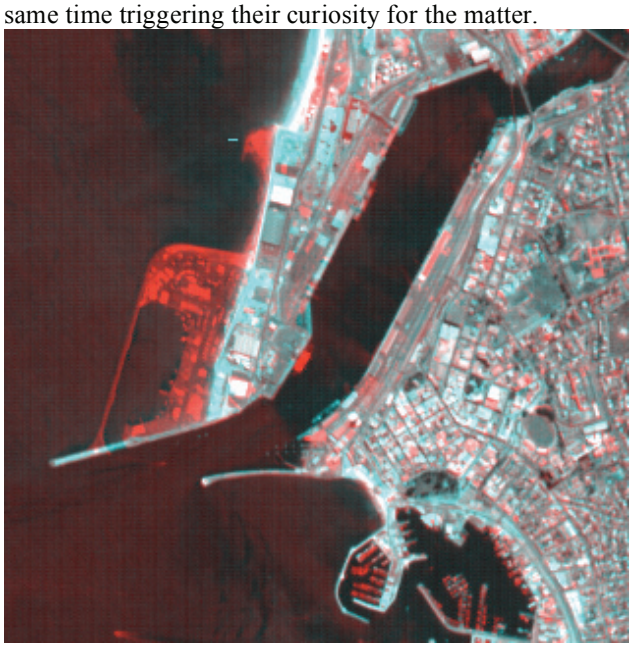

Figure 4. Image of week 46 showing the changes between 1986 and 2004: new habour (red) but also coastal erosion (cyan) at Freemantle/Perth, copyright SPOT and ESA

4. PREPARATION OF TEACHERS AND STUDENTS

Prior to the expedition, a number of competitions in Danish higher secondary schools took place, and the best projects were selected for realization. The ones including satellite data applications were concerned with dinoflagelates, oxygen production of the ocean, botanical mapping on the Galapagos and the land cover and social changes due to the tsunami. The respective school classes were visited by a "Satellite Eye project" team member and instructed how to use satellite data and how to process them. Two students and a teacher of each project spent some time on board doing in situ experiments, while the reminder of the class did similar work at home.

5. COOPERATION WITH SCIENTIFIC PROJECTS

The Satellite Eye for Galathea 3 project was contacted by 18 out of the 50 scientific projects who declared interest in satellite images. We have provided mainly Envisat images to these projects, but also higher spatial resolution images provided by the project. Among the projects are several ocean and atmosphere related projects dealing with the mercury contamination, the carbon cycle, the oxygen production in the ocean, dissolved organic matter, plankton, eel breeding and sea turtle migration. The list also includes land based projects looking after the land cover change and wild life habitat on the Solomon and St. Croix Island. Under AO-3917 runs the research for CO_2 and wind along Galathea. It produced for this conference the poster/paper 4P15.2, The Marine Carbon Cycle from North to South along the Galathea 3 Route. Authors are: Christiansen, Merete Bruun; Soerensen, Lise Lotte; Nissen, Jesper; Hasager, Charlotte Bay

6. OUTLOOK

The expedition ended with the arrival of the expedition ship "Vaedderen" in Copenhagen on 25th April 2007. A vast amount of satellite data has been collected. Learning and teaching material in the form of small projects have been generated. A part of these study cases are still in production, since some data became available only recently. The three year "Satellite Eye" project also includes an evaluation and archiving phase which will cover the time up to the end of 2008. All the satellite data will be archived in a unique data base together with the scientific observations from the different projects performed on the ship during the cruise. These data will be made available to the scientific world and where appropriate also to the public and hence also to schools.

The educational material has been designed in such a way as to become easily integrated in the ESA Earth observation web site for schools EDUSPACE. From there a link to the image data base will be established.

For the use in schools an illustrated Atlas describing the overall results of the expedition will be issued. It

will contain a great number of satellite images from the “Satellite Eye” project. A DVD with five themes demonstrating the use of “Satellite Eye for Galathea 3” is in the works and will be distributed to the Danish schools.

7. RELATED LINKS

- Web-site of the “Satellite Eye for Galathea 3” project
http://www.satelliteeye.dk/index_uk.htm
- General information about the Galathea 3 expedition
http://www.galathea3.dk/uk
- Site of the image data base of “Satellite Eye for Galathea 3”
http://www.satelliteeye.dk/databank_uk.htm
- Site of the educational material of “Satellite Eye for Galathea 3”
http://galathea3.emu.dk/satelliteeye/index_uk.html
- ESA Earth observation web site for secondary schools
http://www.eduspace.esa.int/

8. ACKNOWLEDGEMENTS

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