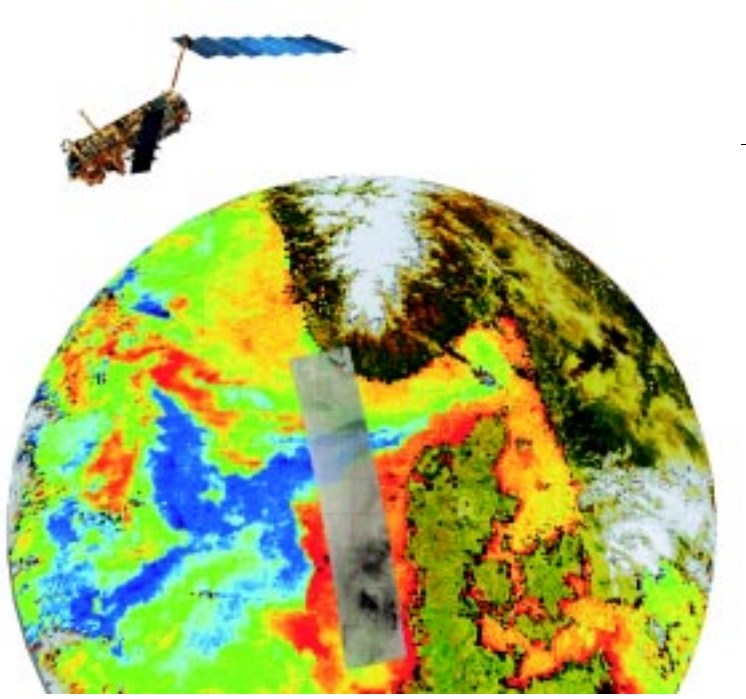

Lasse H. Pettersson

Nansen Environmental and Remote Sensing Center
Edv. Griegsv. 3A
N-5059 Bergen,
Norway

Tel:+47 55297288
Fax: +47 55200050
E-mail:
lasse.pettersson@nrsc.no
www.nrsc.no

ENVISAT will overload us with data – are we prepared to cope with it?

The largest ever Earth observation satellite to be launched in to space will be the European Envisat satellite due for launch at the earliest by Ariane 5 on March 1. Its suite of ten Earth observation sensors will allow the scientific community to simultaneously map the land, oceans and atmosphere of our planet with instrumentation covering a wide range of the electromagnetic spectrum and mapping technologies. Synergetic retrieval of information about the Earth from these sensors is a key word for efficient utilisation of this huge collector of environmental and global change data about the Earth system.

Lasse H. Pettersson is a research leader at the Nansen Center responsible for optical remote sensing research and applications. His is a physical oceanographer of training and has worked within various fields of marine Earth observations since 1984.

Many Earth observation satellites are currently in orbit providing a wide range of data about the Earth system. These Earth observation data are acquired for daily operational use, monitoring and for scientific applications. In the context of the European Space Agency the ERS-1 & 2 satellites, launched in respectively 1991 and 1995, have been the core “working horses” within Earth observations.

In view of the various Earth observation systems in orbit, will then Envisat just be another vehicle for data collection and not provide us with any new information and knowledge? Definitely not! The suite of sensors onboard Envisat is complex, but designed to provide us with complementary data in order to obtain a more holistic information of the Earth surface and its dynamical processes. The technologies used are based on the experiences and breakthroughs achieved through design, operations and use of the past and current ERS sensors as well as new innovative sensor concepts. The Envisat sensors have been selected and designed in order to retrieve data about the atmosphere, the land surface, the oceans and other aquatic regions of the Earth. The scientific community is providing the tools to convert what will be a huge stream of data into useful information for the society.

The capabilities of Envisat to map the surface of the Earth are primarily related to four of its ten sensor systems, namely the Advanced Synthetic Aperture Radar (ASAR), the Medium Resolution Imaging Spectrometer (MERIS), the Radar Altimeter (RA-2) and the Advanced Along Tracking Scanning

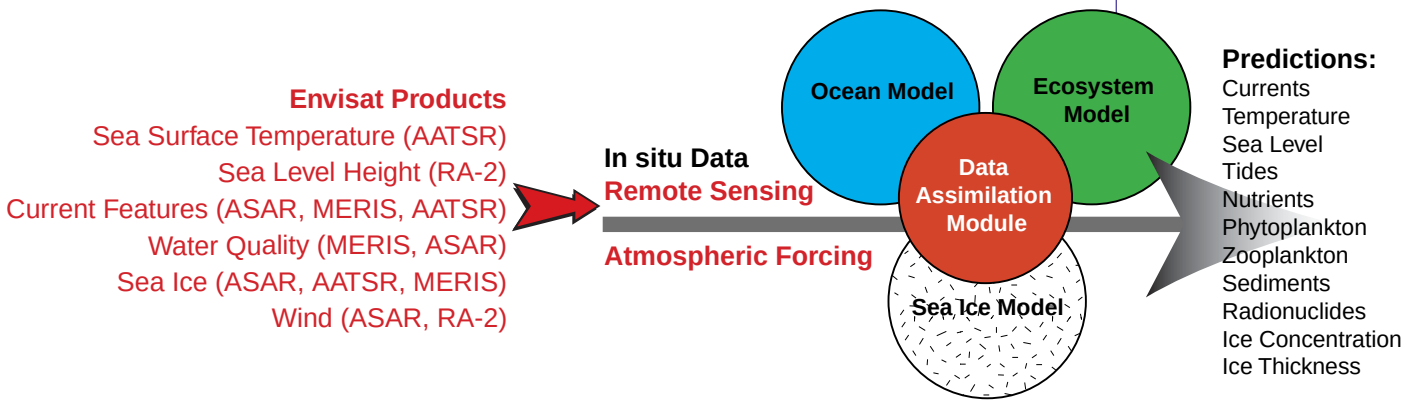

Figure 1:
The research strategy of the Nansen Center combines integrated use of remote sensing and field observations with numerical modelling through the use of advanced data assimilation techniques in order to generate information and predictions. The Envisat data products suits well into this research strategy.

radiometer (AATSR). Three sensors are allocated to observations of the atmosphere and the last three providing auxiliary information used in the generation of information products. Through the efforts of the science advisory groups (SAG´s) and industrial contracts, the European Space Agency (ESA) will be able to deliver 50 information products where information about the Earth system is generated from the data flow from Envisat sensors. The majority (38) of these information products originates from the four above-mentioned sensors and from the ASAR (22) in particular. These information products will assist the scientific community and other users to better answer the questions about the current state of the environment and to study the global change processes on the Earth.

From Norway NORUT, NDRE, NIVA and Nansen Center have contributed through ESA contracts or SAG participation to the development of the MERIS and ASAR product algorithms.

The Nansen Center – an integrated approach

The scientists at Nansen Environmental and Remote Sensing Center in Bergen are primary engaged with research related to the oceans and sea ice covered areas of the Earth. Remotely sensed and *in situ* field data are essential and used for retrieval of information for applications within operational oceanography, ship navigation and routing, fisheries research and management, coastal management and global change research. A key word in the research their strategy is the integrated use of information from several sources, including data from satellite Earth observation sensors (figure 1). In this context the ASAR instrument will at a high spatial resolution provide information related to the sea ice in the Arctic, oil pollution and surfactants at sea, internal waves, coastal current features and surface wind fields. The MERIS sensor will be the key source of information related to the phytoplankton and other water quality parameters in marine and coastal waters, as well as providing information on the ocean current fields and sea ice in combination with the AATSR sensor, which also resolves the sea surface temperature. The RA-2 sensor will operationally supply data for retrieval of the ocean currents through the sea surface height measurements and the surface winds as regular input to operational met-ocean modelling. Accordingly, from a single spaceborne platform the Envisat satellite will provide electromagnetic measurements to derive huge amounts of information about the earth system at various spatial and temporal scales. A challenge is then to integrate these Envisat products with other sources of information to produce new knowledge about the state and processes on the Earth.

The research strategy of the Nansen Center is well suited to cope with the information flow from the suite of Envisat sensors.

Ocean Monitoring and Prediction

Operational oceanography is defined as the “weather forecasting” of the oceans. Like in the atmosphere, but at different temporal and spatial scales, both high and low pressure systems (eddies) are formed in the oceans. These circulation features govern much of the processes taking place in the oceans and are of concern to those operating at sea. In order to make predictions of the physical and bio-chemical state of the oceans numerical circulation and ecosystem model systems have been developed. Through simulations of the physical processes of the ocean and sea ice dynamics, predictions of its development can be made for the world oceans. Such model predictions are essential for many applications such as in shipping, fisheries and aquaculture, pollution monitoring and in global

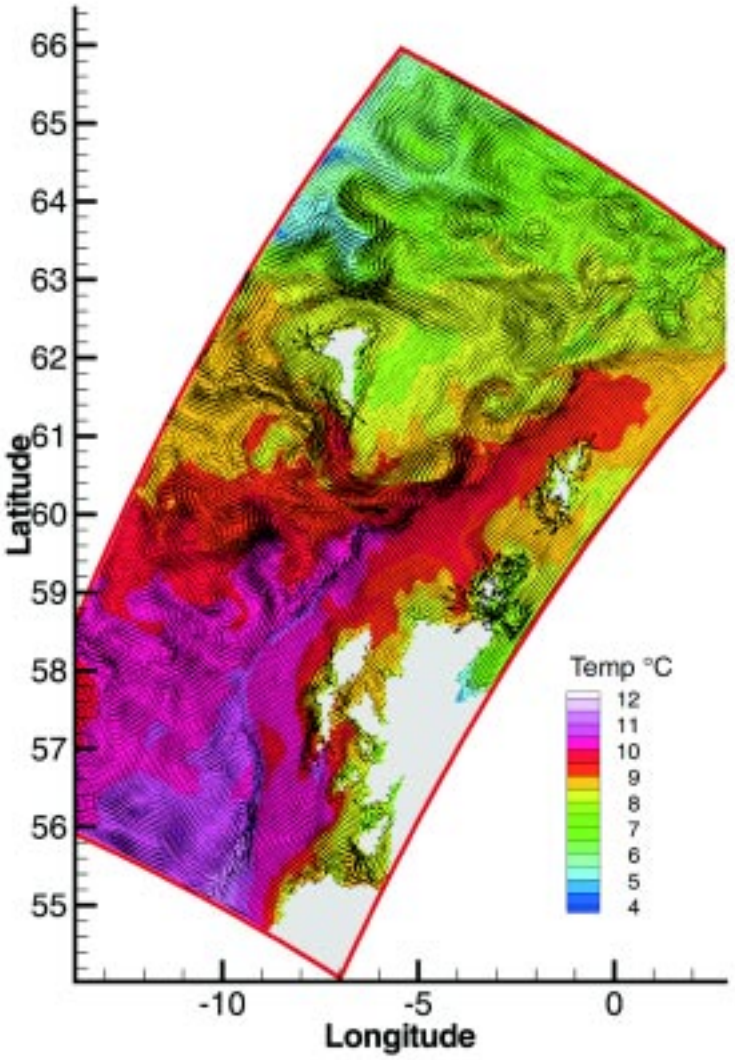

Figure 2:
Model prediction of the ocean currents and sea surface temperature west of Scotland. Satellite based information on the sea surface temperature and ocean circulation fields are assimilated in to the ocean model, resolving the meso-scale ocean circulation structures.

change studies. The ocean dynamics are to a large extent governed by the atmosphere. Information from the weather services on the surface winds and pressure are hence essential to correctly force the physical ocean models. Much of this information for the world oceans is based on data from EO satellites.

Based on complementary expertise in oceanography, meteorology, mathematics and computer sciences an integrated ocean and ecosystem model prediction system including the atmosphere, ocean and sea ice has been implemented at the Nansen Center (figure 1). Its optimal utilisation of the available information is assured through the development of advanced data assimilation techniques. In the EU-DIADEM and TOPAZ projects weekly data from several satellite EO sensors provides information about ocean parameters and are assimilated into this ocean and ecosystem model system. The sensors used are the radar altimeter, radiometers such as AVHRR and ATSR, SeaWiFS and scatterometer sensors, providing information on respectively the ocean circulation (sea surface topography), sea surface temperature (SST), chlorophyll concentration and near surface wind speed. With Envisat, much of this information can be retrieved from the sensors on board one single platform, partly covering the same area of the Earth surface.

The model predictions (figure 2) of parameters such as the sea surface temperature, ocean currents, phytoplankton distribution and other marine parameters are weekly updated on the project web-site (http://www.theyr.is/diadem).

Harmful Algae Blooms

The growth of the aquaculture industry along the coast of Norway has been enormous over the last decades. The production of marine living resources through fisheries and aquaculture are envisaged to become Norway's prime national income after the oil and gas era. One has however also experienced over the last years that diseases and harmful algae blooms (HAB) are a threat to the aquaculture industry. Since 1998 the Nansen Center has regularly utilised the US SeaWiFS ocean colour sensor together with other *in situ* and satellite information to study (harmful) algae blooms in coastal waters of interest to Norway. Last time in March 2001 the entire southern coast of Norway (Sørlandet) from the western coast of Sweden to the southern part of Jæren were "invaded" by the algae *Chattonella*. Large amounts of fish, mainly salmon, in the aquaculture cages were killed and the future existence of aquaculture in this part of Norway was debated. This bloom was monitored daily using SeaWiFS and AVHRR satellite data in order to provide information on the chlorophyll concentration, phytoplankton biomass and sea surface temperature (see figure 3). The integrated information were used by the scientists in planning sampling strategy for field data collection as well as providing direct information and advises to the aquaculture owners and the public (http://www.nersc.no/Decide-HAB). Luckily, due to favourable wind conditions, this bloom was trapped in two eddies located around Lindesnes and after about two weeks the bloom culminated. The bloom caused severe losses to the aquaculture sites affected, but the bloom did not move up along the western coast of Norway (Vestlandet) to the regions where the major part of the Norwegian aquaculture industry are located.

Back in 1998 and 2000 similar algae blooms were first detected in satellite images by scientists at the Nansen Center west of Denmark (Jutland). At that time after more dedicated field observations ocean model predictions were initiated to follow the development and decay of these harmful algae bloom events.

The Envisat MERIS sensor should significantly improve the quality of the radiation data from the ocean water in the visible part of the spectrum. Such measurements are the basis in monitoring of algae blooms and other water quality

parameters. After proper correction of the atmospheric part on the measured signal (about 90 %), bio-optical algorithms for retrieval of information about the phytoplankton concentrations are applied. MERIS have 15 spectral channels in the visible and near infrared range, compared to the state-of-art sensors with six to eight channels. This will primarily improve the retrieval of the water constituents including different algae classes in our optically complex coastal waters.

Sea Ice

Operations in the ice-covered waters impose strict constraints on the vessel, crew, icebreaker support and knowledge on the ice conditions. Satellite EO data is an important data source for retrieval of the needed sea ice information. The Nansen Center and its sister organisation in St. Petersburg, Nansen International Environmental and Remote Sensing Center have since 1991 extensively used the ERS SAR data in providing sea ice information in the navigation along the coast of Siberia. The huge oil and gas resources in the eastern Barents and the Kara Seas opens up for future increased shipping activities as well as direct exploration activities in this region. The future needs for sea ice information is hence expected to increase. As a result of the ICEWATCH project, the first co-operative project between the Russian and European Space Agencies within Earth observations, two Envisat ASAR receiving stations are now being installed in Russia in respectively Moscow and Khanty-Mansiysk. ASAR with its wide range of operational modes including up to a 400 kilometre wide swath will facilitate the use of the data in support of tactical ice navigation. The studies of sea ice variability is also essential in the longer term perspectives as a measure of the climatic change in the ice cover of the Arctic.

Envisat ASAR will provide a continuation and extension of the ice observations provided by ERS satellites since 1991.

Validation

New spaceborne observation systems will require proper calibration and validation to assure that the data used are correct and stable in order to reproduce correct information. A four-week field validation cruise with the R/V Håkon Mosby of the University of Bergen is planned for May- June 2002 in the coastal waters in southern Norway. This cruise will, among other validation activities in Norway and internationally, contribute to confirm if the corrections and retrieval algorithms developed are proper to provide us with accurate information from the data collected by the earth looking sensors onboard Envisat. Through integrated studies and modelling of the coastal waters the information content from the field observations, the satellite sensors and the numerical models can be compared and evaluated.

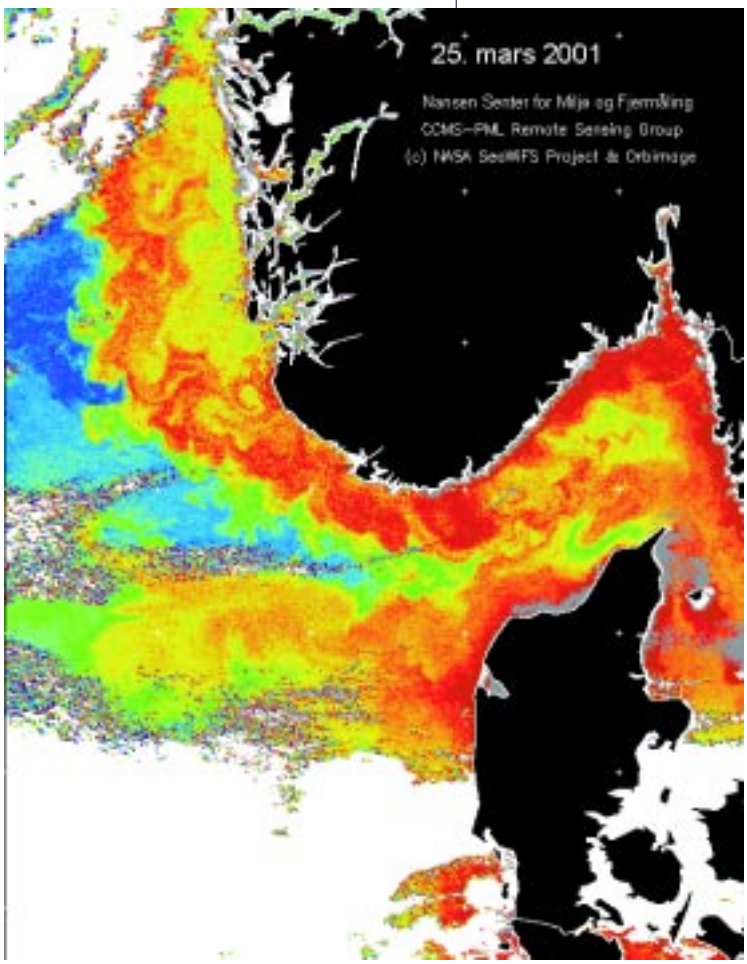

Figure 3: Satellite based concentrations of chlorophyll-*a* pigment on the Skagerrak and North Sea on March 25. 2001 resolving the severe bloom of the harmful algae *Chattonella (high concentrations given in red colour)*. The bloom caused significant losses to the aquaculture industry along the southern coast of Norway.

The Challenges

Timely delivery of accurate information are the practical challenges the ground segment of the European Space Agency (ESA) faces in their preparatory process for the Envisat data and products stream to start in a few months from now. For some applications this means that the information products must be available preferably a few hours after the pass of the satellite above the study area, for others it will be sufficient with information aggregated to weekly products. In global change studies the precision of the information products and hence sensor calibration are more critical than the timely delivery, since often small changes over long periods are the essential signal to identify.

In the real life the experts work more in thematic sectors than the overall information flow from Envisat sensors are designed for and a challenge lies within the provision and communication of integrated information embodies in the data available from synergy of the Envisat sensors.

Given the access to the data acquired from Envisat the scientist and other users have great responsibilities to generate, integrate and utilise the information provided by Envisat in the years to come. ■