NIVA and the ENVISAT project

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The Norwegian Institute for Water Research (NIVA) participat in the geophysical validation of the products from one of the ENVISAT sensors. NIVA contributes in the validation of the MERIS sensor (Medium Resolution Imaging Spectrometer) and takes part in the MERIS and AATSR Validation Team (MAVT). The project "Validation of MERIS data products for long term monitoring of water quality" is based on a response to the European Space Agency (ESA) announcement of the opportunity to conduct scientific research and application development in Earth Observation.

Main objective and future goal

The main objective of the project is to evaluate MERIS data products and to perform investigations of the optical properties in our coastal and open sea areas to support validation of the bio-optical algorithms. The longterm goal is to develop powerful data products to be used for monitoring open sea and coastal areas and to implement such methods and data in the long-term environmental monitoring programs.

Kai Sørensen has a B.Sc. in chemistry with training experience in marine optics and has more than 10 years experience in using satellite data for monitoring water quality in fjords and coastal areas. He has conducted several remote sensing projects regarding validation of optical space and airborne sensors. He is also member of a Science Advisory Group in the European Space Agency for the MERIS sensor, and in the MAVT as principal investigator for this project.

Due to heavy utilization and environmental impact by fishing, industrial and agricultural pollution, tourism and traffic, the need for environmental monitoring is obvious. Many of the coastal waters are highly dynamic systems with strong variability in topography and currents creating the mixing of fresh and salt water. Areas with a mixing of pollution such as nutrients, organic and inorganic material can stimulate algal grown , and during the last decade several harmful algal blooms have occurred in Nordic coastal waters.

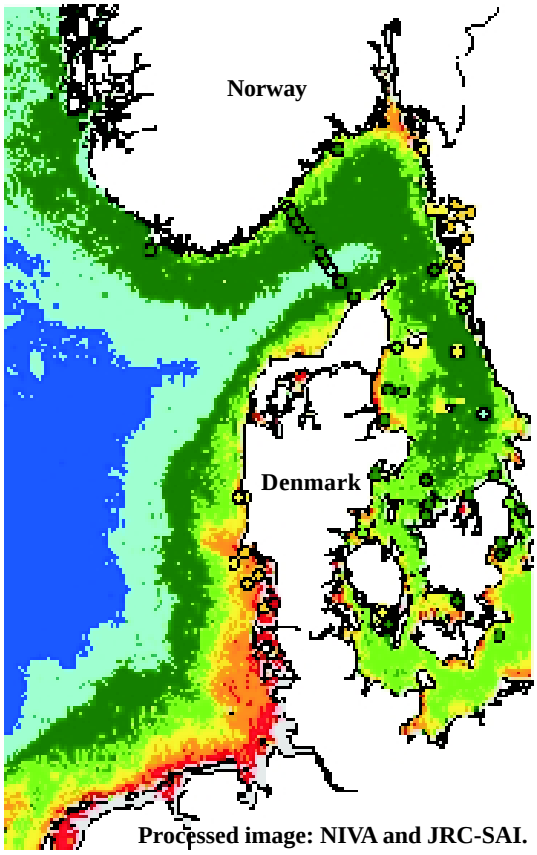
The present use of satellite remote sensing for monitoring coastal water quality is limited in Norway, mainly due to the fact that the present available sensors do not possess the proper accuracy. With new satellite sensors, an increasing interest in using such technology has developed. The information that can be extracted from satellite data within an area is undoubtedly of high importance.

Project team and international collaboration

The project will be co-ordinated by NIVA with scientific personnel from the Department of Geophysics at the University of Oslo, the Institute of Marine Research, Arendal and GKSS Research Center, Germany. The team has the necessary instrumentation, laboratories and resources to perform the validation.

The Department of Geophysics has conducted investigations in marine optics for more than 25 years. Institute of Marine Research (IMR) has conducted monitoring of the Skagerrak area for many decades and is together with NIVA running the Norwegian coastal monitoring programme for the State Pollution Control Authority. NIVA and IMR have the necessary experience to develop useful value-added products to be implemented into long term monitoring programmes. GKSS has extensive experience in marine optics, algorithm development and validation of different remote sensing sensors.

The project will collaborate with the other calibration/validation projects within the MAVT; especially the groups working in the waters of the Baltic and North Seas are of great interest. The water masses from these areas are transported into the Skagerrak and will influence the optical properties of the surface water in our area.



Processed image: NIVA and JRC-SAI.

Example of end products from MERIS showing a Chlorophyll-a map from the Skagerrak area in 1999. The map shows summer mean values of Chlorophyll-a based on all SeaWIFS data from May to September. *In situ* data are presented as points and represent mean value of more than 5 observations in the same period. The image is processed by JRC-SAI and NIVA to evaluate the use of SeaWIFS data in a study of eutrophication in marinee and coastal waters.

Monitoring water quality from space

The success of estimating the water quality from a passive satellite remote sensor depends on the relation between the water-leaving radiance and the water variables. Two optical processes determine the signal – absorption and scattering of light. The value of the water-leaving radiance is regulated by the seven optical factors:

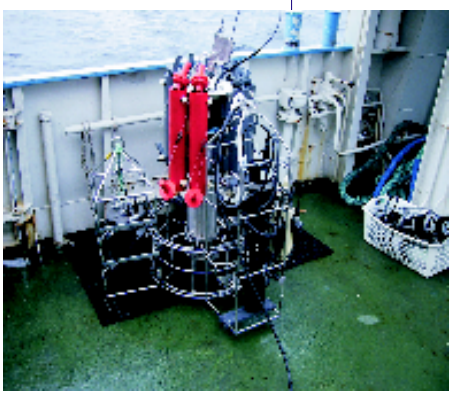
- Absorption from the water itself
- Absorption from phytoplankton, mainly the pigments
- Absorption from inorganic particles
- Absorption from coloured dissolved organic material
- Scattering from the water itself
- Scattering from phytoplankton and associated debris
- Scattering from inorganic particles

The three water constituents, i.e. phytoplankton measured as Chlorophyll-a, total suspended material containing both phytoplankton and inorganic particles, and coloured dissolved organic material quantified by its absorption coefficient, are then the main water quality variables regulating these factors. In coastal waters with high and variable contents of coloured dissolved organic material and suspended material the traditional algorithms are difficult to use. Besides, the in-water optical processes and also the atmosphere will strongly influence the water-leaving radiance, hence the accuracy of the satellite end products will depend strongly on the applied atmospheric correction.

New satellite sensors onboard the ENVISAT satellite, and in particular the Medium Resolution Imaging Spectrometer (MERIS), have improved qualities. The better spectral resolution due to the 9 bio-optical bands of the MERIS sensor, as well as the better spatial resolution will improve the remote sensing of coastal waters. MERIS will also be the first satellite to allow the determination of the sunlight stimulated fluorescence from chlorophyll. This can be important for the development of new remote sensing products.

The phytoplankton concentration measured as Chlorophyll-a in the coastal waters of Southern Norway varies in the range between 0.1 and 30 µg/l, but in most of the time (90 %) the concentrations are low (<3.5 µg/l). The satellite data product should then have a power of resolution of <0.5 µg/l in order to be acceptable for long term monitoring. In parts of the Skagerrak area the other optical constituents also vary considerably, and the values of coloured dissolved organic material sometimes strongly exceed values typical for the German Bight and the Baltic Sea, due to local river input to the Oslofjord. This will reduce the upward radiance in the blue part of the spectrum to very low values, thus making use of the more traditional algorithms difficult.

Public concern about the conditions of marine waters has increased after numerous environmental “accidents”. Most likely an increase in the eutrophication is responsible for these accidents, and satellite maps of chlorophyll in the surface waters will therefore help in assessing the spatial magnitude of the eutrophication. Hopefully the MERIS with its higher spectral resolution and more dedicated bio-optical algorithms will improve the retrieval of water quality products for coastal water.



The validation will include numerous *in situ* measurements and water sampling during the field campaigns. Measurement of the inherent optical properties will be performed to determine the optical quantities and validate the water quality products from MERIS.

The validation exercise and field campaigns

The Skagerrak is the main validation area for the NIVA project. Field measurements and validation campaigns will start about 10 weeks after the launch of the ENVISAT, hopefully in March 2002. They will then continue for a six-month period. Research vessels from the University of Oslo and the Institute of Marine Research will perform validation cruises several times per month where optical measurements and water sampling will be performed. The data will be processed and delivered to the NILU (the Norwegian Institute for Air Research) database to be used by the members in the MAVT and ESA.

In addition to the research vessels, the ferry between Oslo and Hirtshals will also be used during the validation period. This will be carried out in collaboration with another NIVA project funded by the Norwegian Research Council. Physical and optical sensors placed onboard the ferry record the temperature, salinity, chlorophyll-a fluorescence, turbidity, and incident daylight. Together with exact positions from the ship navigation system a plot of the concentrations of chlorophyll and total suspended matter can easily be obtained. The data are automatically transferred to NIVA via the web system, and a water-sampling unit can be performed after a fixed plan based on positions or remotely triggered from NIVA if interesting situations are discovered.

Measurement of the downwelling and upwelling irradiance as well as the upwelling radiance must be performed to validate the geophysical MERIS products.

The validation follows agreed protocols, which are necessary to execute a successful validation. The measuring protocols are based on the former protocols of SeaWIFS and tuned to fit the scope of the MERIS algorithm. The aim of the field measurements will be to collect data for comparison with the MERIS retrieved concentrations. The optical measurements are needed to explain eventual discrepancies between *in situ* data and MERIS data products.

The project is built up around the following work packages:

- Intercalibrate optical field methods and water analysis
- Perform field measurements, water sampling and analysis
- Deliver validation data to the NILU data base
- Validate MERIS standard data products
- Suggest improvements to ESA

The intercalibration exercise will include all groups involved in the ground truth measurements, and include necessary preparations for the validation campaigns. Such campaigns have already been executed and the final preparations are ongoing. The validation programme will include measurements of all the necessary optical quantities for the description of the radiative transfer into the atmosphere, and analyses of all the necessary water quality variables. Methods that will be used, and of which some have to be intercalibrated, are listed below:

Field measurements of:

- Upwelling radiance
- Downwelling and upwelling irradiance
- Absorption and scattering properties of water and particles
- Temperature and salinity
- Vertical distribution of the phytoplankton, measured as Chlorophyll-a fluorescence
- Wind, weather, wave heights
- Other phenomena at the sea surface, e.g. white caps, red tide (algal bloom).

Laboratory analysis of:

- Phytoplankton pigment concentration, measured as Chlorophyll-a
- Phytoplankton pigment detritus absorption
- Suspended material
- Coloured dissolved organic material
- Phytoplankton species

It is also planned that NIVA will host an intercomparison exercise for the analysis Cloro-phyll-a and the detritus absorbtion measurement.

The NIVA-project will be sponsored from the PRODEX-programme of the European Space Agency and Norwegian Space Centre, and the Norwegian Institute for Water Research and the other partners in the project.

New Projects

Already a follow-up project has been planned, and NIVA as well as the other partners will participate in a three-year EU-project, – Regional Validations of MERIS Products - REVAMP, which will start early 2002. Eight European partners will participate in this project that will focus on regional validation ending up in products to be used in future monitoring.