Monitoring the Norwegian Coastal Zone Environment (MONCOZE)

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Introduction

The Norwegian marine coastal environment is characterized by the interaction of complex and coupled physical and biochemical upper-ocean and atmospheric boundary layer processes at spatial and temporal scales ranging from meters to hundreds of kilometers and seconds to seasons. In addition, the coastal zone is strongly affected by terrestrial influences such as freshwater runoff and waste effluents, the major sources of which are found in the Baltic Sea and the southern North Sea (Johannessen et al., 1993).

The Norwegian Coastal Current (NCC) is the most prominent feature of the coastal zone. It acts as the highway for transporting nearly all the pelagic chemical and biochemical material entering the North Sea, and spreads it from the Skagerrak to the Barents Sea. As such, it strongly influences the near-coast water quality, which is of major importance for the rapidly increasing fish farming industry. Blooms of harmful algae, such as the *Chrysocromulina polylepis* toxic bloom in 1988 (Dundas et al., 1989; Johannessen et al., 1988), have clearly demonstrated that this major industry is highly vulnerable. In the future, it is likely that there will be increasing demand for quality flags which document that marine food comes from a "clean" environment.

Over the past two decades, the means to observe and model the Norwegian coastal zone, including the Norwegian Coastal Current, have gradually improved through a) developments of *in situ* and remote sensing observational technologies; b) advances in numerical simulation and high performance computing; and c) new methods for assimilation of heterogenic, time-dependent atmospheric, oceanic and chemical data. Despite these developments there are still major deficiencies in our ability to understand and describe the variability of the NCC and its influence on the marine environment and ecology, locally as well as downstream. These deficiencies arise from lack of regular observations as well as from gaps in our knowledge of the many processes involved. Closely allied with these is the need to fully integrate an adequate hierarchical set of properly

validated models capable of assimilating the heterogenic data and simulating the state and evolution of the system with its large range of underlying components.

Aims

The aim of the MONCOZE project is to develop, test and demonstrate a pilot system for monitoring and prediction of the Norwegian marine coastal environment with particular focus on dominant physical and coupled physical-biochemical interactive processes within the Norwegian Coastal Current and along its open boundaries. It is a nationally funded 5-year (2001-2005) cooperative project involving the Nansen Environmental and Remote Sensing Center (NERSC), the Institute of Marine Research (IMR) and the Norwegian Meteorological Institute (met.no). Within this time frame, the pilot system is aimed at four specific themes:

1. *Norwegian Coastal Current variability*. Advance the understanding and description of the mesoscale and sub-mesoscale variability, including the formation, propagation and decay of eddies, the generation and decay of convergent (divergent) zones in frontal regions, and the strength and extent of episodic upwelling.

2. *Algal blooms*. Develop and demonstrate methods to combine multiple data sources, heterogenic in time and space, for consistent and reliable analysis and estimation of algal blooms, including location of source area and its spatial distribution according to dominant oceanic processes and transport characteristics. In particular, the environmental conditions of toxic-versus non-toxic blooms will be examined and characterized for subsequent formulations in algal process models.

3. *Contaminant exposure time*. Develop a method for the combined estimation of contaminant and plankton/fish larvae distribution to be able to integrate the total contaminant exposure time on specific populations.

4. *Extreme events*. Provide monitoring and warnings of extreme and potential harmful events in water properties, such as for instance associated with anomalously cold water outbreaks impacting aquaculture, and river floods affecting salinity and turbidity.

MONCOZE will not provide definitive and final solutions to all of these issues, but it aims at making significant contributions to each of them.

Means

MONCOZE will rely on the combination of *in situ* measurements, satellite observations and numerical models. High-accuracy *in situ* measurements are essential in order to obtain sub-surface observations, as well as for the calibration and validation of satellite data and models. Satellite observations provide wide area (in some cases regular) quantitative information on surface variables, which in some cases may be related to upper layer phenomena. Via systematic combination of these observing methods, a 3-D picture of the ocean state may be drawn and used for validation of models. Ultimately, combining well-validated numerical models with observations by means of data assimilation techniques may provide a tool that can realistically describe, and eventually forecast, the state of the marine coastal environment.

It is essential that the information gathered from the observing systems and from model predictions be combined with other/prior knowledge and offered to users in tailored forms. An important

element in MONCOZE is therefore the definition and development of suitable user products. These may include automatically produced results from observations and from models, as well as analyses and interpretation by scientific experts.

Approach

The MONCOZE approach is a combination of existing capabilities, incremental advances in technology and scientific research. It consists of three development elements:

Observations: - combine different satellite data in order to improve the sampling requirement in time and space; - access near real-time (NRT) satellite data in order to ensure possibility for operational monitoring and to guide research vessels into areas of interesting image expressions for validation and combination with models; - make some of the *in situ* observations available in NRT for operational monitoring purposes; - implement data from new *in situ* observing platforms as they become available.

Models and assimilation: - validate existing, state-of-the-art prediction models for hydrodynamics and ecosystems; - implement data assimilation in coastal and shelf models and demonstrate benefits; - obtain best possible forcing data for regional, shelf and coastal models.

Monitoring system: - set up a practical framework for combining observations, results from assimilating models and other information (statistics, knowledge, etc.); - systematize the methods and procedures for interpreting diverse and heterogenic pieces of information; – make products available, in a timely manner, to users, who in turn provide critical feedback that can lead to improvement and further development.

A sketch of the pilot monitoring system concept is shown in Figure 1. It consists of three main modules: 1) Observation In-basket, which takes care of acquiring, handling, archiving and disseminating observations as they become available; 2) Hindcast/analysis module, in which numerical hydrodynamic and ecosystem models are run to produce hindcasts, nowcasts and forecasts; and 3) Value added module, in which the data products from the other two modules are analyzed and presented together with other information and knowledge to create information products for users. Figure 1 is a schematic for an operational system (routine, robust, highly automated) that may be applied at a range of time scales, e.g. daily nowcasts, annual assessments.
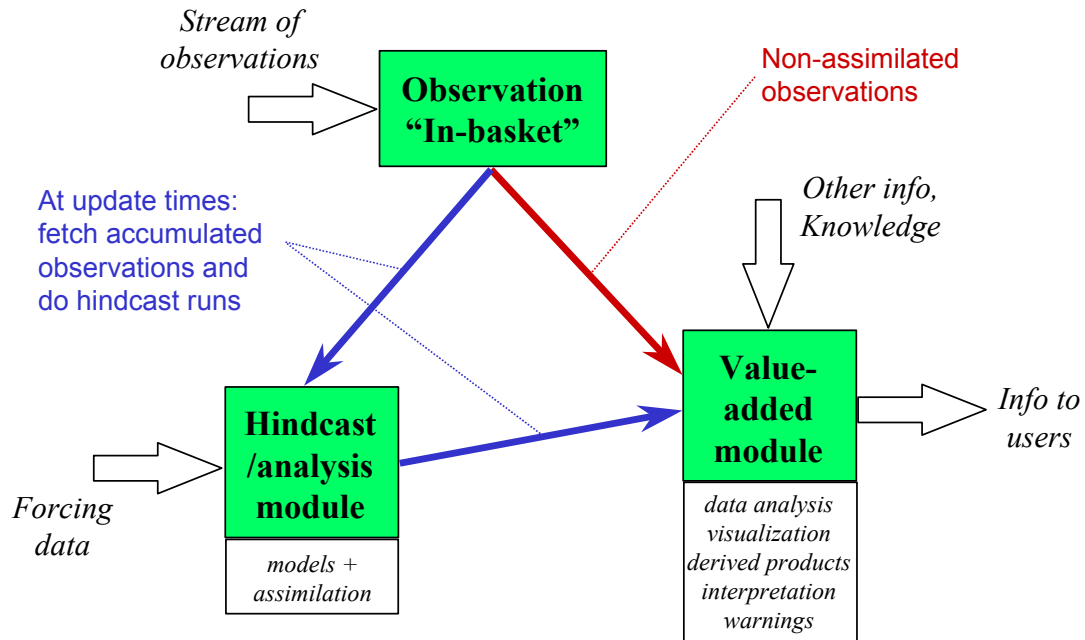
Stream of observations

Observation "In-basket"

Non-assimilated observations

Other info, Knowledge

At update times: fetch accumulated observations and do hindcast runs

Value-added module

data analysis
visualization
derived products
interpretation
warnings

Info to users

Hindcast /analysis module

models + assimilation

Forcing data

Figure 1: Modules and integrated operations of the pilot monitoring system which will be delivered at the end of the project.

The project is organized into tasks dealing with a) development of observation products, models and assimilation techniques for the coastal zone, b) model validation and interpretation of model and observational information, and c) construction and demonstration of the operational monitoring system.

Features of the system

Observational information

The observational element aims to combine all available sources of observation that are operational: ships; drifting buoys (ARGO); satellites; coastal radar. Development focuses on synergetic analysis of various types of observation. Figure 2 shows two key satellite data products that may be further associated with other concurrent observations, e.g., *in situ* measurements from buoys.
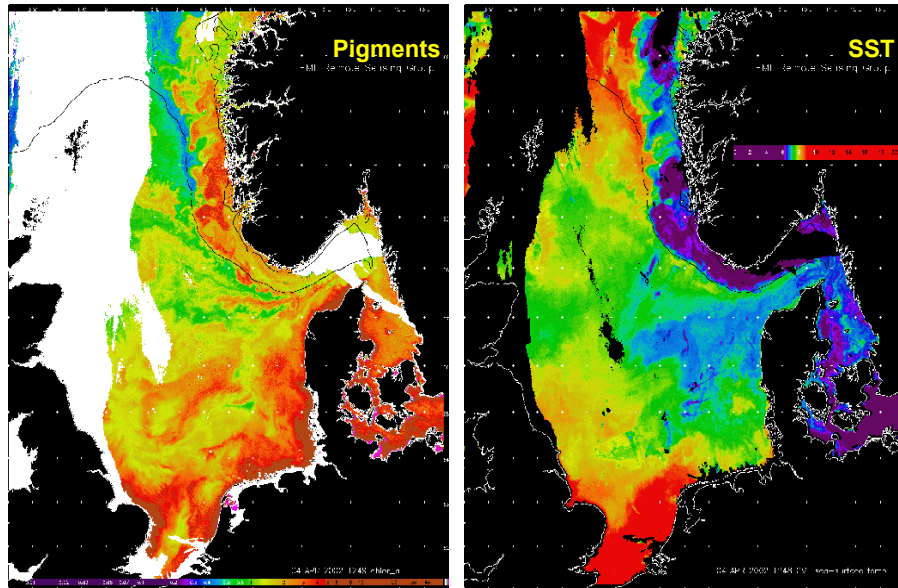
Figure 2: Example of synergetic analysis of concurrent satellite images, in this case SST from AVHRR (at right) and ocean color from SeaWIFS (at left).

Numerical models

The model component includes two alternative systems, based on differing hydrodynamical and ecological models: the hydrodynamical models are based on the POM (Princeton Ocean Model; Blumberg and Mellor, 1987; Martinsen et al., 1997) and the HYCOM (Bleck, 2002) codes. A large-scale Atlantic version of HYCOM supplies far-field forcing for the nested regional models. Figure 3 shows a proposed configuration of nested model domains. The largest domain (30 km HYCOM) actually extends from about 20º S to the Arctic. Both HYCOM and POM codes are run on the high-resolution nested domains.
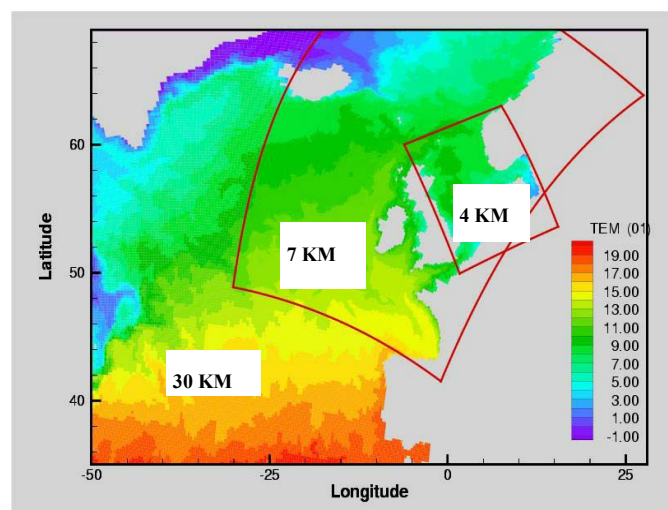

Figure 3: Proposed configuration of nested model domains for use in MONCOZE. The target area for MONCOZE is the northern North Sea and the Skagerrak.

Data assimilation

Assimilation of satellite altimeter and SST data is presently carried out in the large-scale model component (HYCOM/DIADEM), and the influence of the observations is propagated into the nested coastal models through nesting. A key area of development in the project is methods for assimilation of SST and ocean color at shelf and coastal scales.

Product development

It is expected that the primary users of the monitoring system will be public authorities responsible for coastal zone management (e.g., fisheries, pollution, ship traffic) and the marine scientific community. Close cooperation with users is necessary to develop and refine suitable products from the diverse data sources within the system. Figure 4 shows an example of a forecast product tuned to the request of a specific user. In this case the user is interested in a quickly scanned estimate of today's state and the expected change over the next 5 days.
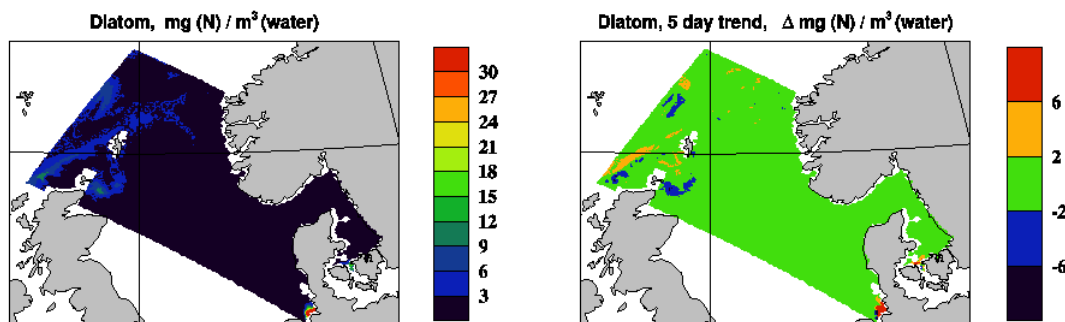

Figure 4: Example of user-defined numerical forecast product. Diatom concentration at the surface (at left) and the change in concentration 5 days hence.

Monitoring system

The operational system will provide real-time updating of standard monitoring products and facilities for dissemination to users. Pilot demonstrations of the system will be carried out in 2003 and 2004 for the coast of southern Norway.

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