



Acceleration of a  
natural process to mitigate  
the greenhouse effect

# CO<sub>2</sub> OCEAN RELEASE



Annual Report 2000  
Nansen Environmental and  
Remote Sensing Center  
Bergen - Norway  
Affiliated with the University of Bergen

# Report from the board

## **Vision**

The Nansen Center's vision is to make a significant contribution to the understanding, monitoring and forecasting of the world's environment and climate on regional and global scale.

## **Strategy**

The Nansen Center research strategy is to integrate the use of remote sensing and field observations with numerical modelling through the use of advanced data assimilation techniques.

## **Organisation**

The Nansen Center is an independent non-profit research foundation affiliated with the University of Bergen, Norway.

The Nansen Center conducts basic and applied environmental research funded by research councils, space agencies, national and international governmental agencies and industry.

## **Staff**

At the end of 2000 the Nansen Center employed a staff of 50 persons. Professor Ola M. Johannessen, The Founding Director, also holds a full chair in oceanography/remote sensing at the Geophysical Institute, University of Bergen (UoB).

Dr. Geir Evensen has a part time professorship at the Mathematical Institute, UoB, and Dr. Johnny A. Johannessen was in August 2000 appointed to a part time professorship to the Geophysical Institute, UoB.

Professor Eystein Jansen from the Geological Institute, UoB, and Dr. Leonid Bobylev the Director of the Nansen Center in St. Petersburg, Russia, both hold a part time position at the Nansen Center in Bergen. Professor Lennart Bengtsson, the previous Director of Max Planck Institute for Meteorology in Hamburg, was in October 2000 also appointed to a part time position at the Nansen Center.

Several visiting scientists from Russia and India as well as students from different countries have worked at the Nansen Center in Bergen during periods from 3-12 months. The staff includes 12 Dr. Scient. Candidates and an administrative staff of six.

## **Production**

During the year 2000, 19 papers were published in international refereed journals, which were eight more than in 1999. Furthermore 45 proceeding papers were

published in addition to 29 technical and other reports to our clients.

The Founding Director was also one of the 131 contributing authors to chapter 2 "Observed Climate Variability and Change" of the IPCC Third Assessment Report.

Public outreach has been done through newspaper interviews at national and international level, including participation in several TV programs. Popular scientific lectures for school children, students and the public have been given in the Nansen Center's small adventure center "Arctica".

## **Doctoral thesis**

Dominique Durand from France, who held a EU Maria Curie Fellowship at the Nansen Center, completed his Dr. thesis, "Monitoring and simulation of water quality in coastal waters by modelling and remote sensing", at the University of Nice, Sophia Antipolis, France.

## **Award**

In early 2000 the University of Bergen, announced for the first time a competition for an outstanding paper in marine science published in 1999 by the University of Bergen staff. The paper "Satellite Evidence for an Arctic Sea Ice Cover in Transformation" by Ola M. Johannessen, Elena V. Shalina and Martin Miles, published in *Science*, vol 286, pp 1937-1939, 1999, won this prize.

## **International Activities**

At the end of 2000, the Nansen Center participated in 25 EU projects and is the co-ordinator of 11 of these projects.

The Nansen Center also co-ordinate three INTAS (International Association for the promotion of co-operation with scientists from the New Independent State of the former Soviet Union) projects with participation from Russia and Ukraine.

The Nansen International Center in St. Petersburg was founded in 1992. The center employs a staff of 30, including 15 Ph.D students. 10 Ph.D students are also supported by the University of Bergen at St. Petersburg University through the Nansen Fellowship Program. In addition, 20 scientists from co-operating institutes in Russia are associate staff. The staff at the center has taken part in several international research programs and is now starting to be well integrated into the international scientific community. The Nansen Center in Bergen is actively co-operating with the Nansen International Center in St. Petersburg and other Russian partners, focusing on global change prob-

lems at high latitude. We are now transferring the center in St. Petersburg into a foundation with seven founders. These are; The State University of St. Petersburg, Russia, St. Petersburg Scientific Research Center of Ecological Safety of Russian Academy of Science, Russia, Northern Water Problems Institute of Russian Academy of Science, Petrozavodsk, Karelia, Russia, Nansen Environmental and Remote Sensing Center, Norway, Bergen University Research Foundation, Norway, Environmental Research Institute of Michigan, USA, Max-Planck-Gesellschaft Forderung der Wissenschaften e.V. with Max Planck Institute for Meteorology in Hamburg, Germany.

In 1999, the Nansen Center established the Nansen Environmental Research Center in India in Kochin in the coastal State of Kerala. The focus of research applications is on coastal zone and Indian Ocean circulation. At present a manager, Thomas Mathew, and two scientists, Dr Ajith Joseph and Dr. Felix Jose, have been recruited.

The co-operation with the Institute of Atmospheric Physics at the Chinese Academy of Science, Beijing is continuing with expansion into polar problems in co-operation with Professor Deng Yi Gao.

Several Announcement of Opportunity (AO) projects from the European Space Agency (ESA) for the new ENVISAT satellite due to be launched during summer 2001 were also approved, as well as several AO from NASA and the Canadian Space Agency. Stein Sandven, the vice-director, is a member of the ESA CRYOSAT Science Advisory Group. Johnny A. Johannessen is a member of the ESA GOCE Mission Advisory Group and Lasse H. Pettersson is a member of the Science Advisory Group for MERIS/ENVISAT.

The Nansen Center is a major partner in the EuroGOOS activities. Ola M. Johannessen is a member of the Board, Stein Sandven is the chairman of the Arctic task team, Johnny A. Johannessen is a member of the Space Panel, and Lasse H. Pettersson is the co-chairman of the Product Group.

Several ocean modelling projects for international consortiums of oil companies are underway and one of these projects, NWAG, is dealing with ocean current modelling in the region north west of UK under the leadership of Prof. Geir Evensen.

## **G. C. Rieber Climate Institute**

The G. C. Rieber Climate Institute is a part of the Nansen Center, and is led by Dr. Helge Drange. The institute employs

five scientists, three Dr. Scient candidates and one Cand. Scient. student.

The main activity of the institute is devoted to the stability and the dynamic properties of the North Atlantic and Arctic climate system. This work is performed by both ice-ocean models and fully coupled, global atmosphere-sea ice-ocean models. The latter activity is in collaboration with the Geophysical Institute, UoB. Here the Norwegian Research Council project Reg-Clim is an important contributor to the work.

The institute is a major partner in the newly established Bjerknes Co-operation in Climate Research between the University of Bergen, the Institute of Marine Research in Bergen and the Nansen Center. Helge Drange is a member of the leader-team of the Bjerknes Co-operation and Ola M. Johannessen is a member of the board.

Helge Drange is also a member of the Joint Global Ocean Fluxes Study (JGOFS) of the World Climate Research Program.

Other important topics, of the institute program, are modelling of natural cycling of carbon and plant nutrient in ocean, and ocean storage of greenhouse gas CO<sub>2</sub>. The CO<sub>2</sub> ocean storage program is headed by Dr. Guttorm Alendal, who is also a member of the technical committee in the international "CO<sub>2</sub> ocean sequestration field experiment" of the CTI program, Climate Technology Initiative of Japan, USA and Norway.

The G. C. Rieber trusts support the institute with NOK 0,47 mill. on an annual basis for recruiting Master students to climate research in Norway.

#### **Terra Orbit AS / COTO AS**

The Nansen Center is the owner of these companies. The purpose is to commercialise some of the research products which are developed by the Nansen Center in Bergen, in St. Petersburg and in Kochin, India. Terra Orbit is focusing on environmental IT products and COTO on CO<sub>2</sub> mitigation from industrial sources.

These companies are also "know-how" companies giving advice and consultant services to industry and governmental agencies. The manager is Geir Jevne.

#### **Ocean Numerics Ltd**

A joint company, Ocean Numerics Ltd., has been formed by the Nansen Center and Fugro GEOS Ltd. in UK. Its main aim is to provide regional metocean services throughout the world's oceans. The services use advanced numerical models and forecasting techniques, validated and tested with oceanographic field measurement that have been designed and col-

lected specifically for this purpose. The equal share joint company combines the commercial oceanographic measurement capabilities of Fugro GEOS and the modelling and analytical expertise of the Nansen Center. The two companies had already formed a close working relationship while participating in the Atlantic Margin Metocean Project (AMMP), a combined measurement and modelling project covering the northeast Atlantic Ocean.

Ocean Numerics Ltd. is registered in UK and the chairman of the board is Prof. Ola M. Johannessen with Prof. Geir Evensen as a member of the board.

#### **Arctica**

"Arctica" is a small public adventure center at the Nansen Center. Among the attractions are a wide-screen movie "Svalbard – Arctic Seasons", a slide exhibition on Fridtjof Nansen and an exhibition in the "Science Room".

#### **Financial situation**

The Nansen Center is an independent non-profit research institute without basic public funding. The income in 2000 amounted to NOK 25,4 mill. – an increase of 0,7 mill. compared to 1999. The 2000 project income has mainly come from the European Communities (EU), The Research Council of Norway, oil companies, European Space Agency, the Norwegian Space Center and INTAS. Financial support has also been received from G. C. Rieber trusts.

The annual net income for 2000 totalled to 1,292 mill. NOK of which 0,894 mill. NOK came from financial income. This is a slight improvement compared to 1999 – where these numbers were 1,008 mill. NOK and 0,813 mill. NOK respectively. The equity capital amounts to 17,6 mill. NOK out of a total balance of NOK 33.6 mill.

#### **Prospects for 2001**

We are not expecting an expansion of our research activities in 2001 primarily due to limited funding level in Norway set by the Norwegian Parliament.

Bergen 29.03.2001

Bjørn J. Landmark (Chairman)  
Bjart Nygaard (Vice-Chairman)  
Eirik Sundvor  
Anton Kjelaas  
Lasse H. Pettersson  
Ola M. Johannessen (Director)

#### **Leader Team**

##### *Founding Director*

Professor Ola M. Johannessen

Also chair in Remote Sensing/ Oceanography at Geophysical Institute, University of Bergen.

##### *Applied Remote Sensing*

Vice-Director Stein Sandven

##### *Remote Sensing Research*

Research Dir. Dr Johnny A. Johannessen

Also Professor II at Geophysical Institute, University of Bergen.

##### *Modeling and Data Assimilation*

Research Dir. Dr. Geir Evensen

Also Professor II at Department of Mathematics, University of Bergen.

##### *G.C. Rieber Climate Institute*

Director Dr. Helge Drange

##### *International Relations & Marketing*

Director Lasse H. Pettersson

##### *Administration*

Director Bente E. Johannessen

##### *Economy*

Manager Lars Gunnar Veland

#### **The Board**

Prof. Dr. Bjørn J. Landmark, Chairman

Director Bjart Nygaard, Rieber Eiendom, Vice Chairman

Professor Eirik Sundvor, University of Bergen

Dr. Anton Kjelaas, UNIFOB

Lasse H. Pettersson, Representative of employees

Professor Ola M. Johannessen, Director

#### **The Scientific Council**

Professor Dr. Arnfinn Graue, University of Bergen, Chairman

Director Robert Barton, Spectra Resources Inc., Houston, U.S.A.

Chief Engineer Lars Ingolf Eide, Norsk Hydro A/S

Prof. Dr. Hartmut Graßl, Director Max Planck Institute for Meteorology, Hamburg, Germany

Professor Dr. Einar Hope, Norwegian School of Economics and Business Administration

Dr. Edward Josberger, US Geological Survey, Tacoma, U.S.A.

Director Jan Petter Myklebust, University of Bergen, International Division

Director Sven Rong, Polar Holding A/S

Vice-President Dr. Robert A. Shuchman, Environmental Research Institute of Michigan, Ann Arbor, U.S.A.

Managing Director Rolf Skår, Norwegian Space Centre

Chief Engineer Per Strass, STATOIL

Professor Ola M. Johannessen, Director

## Modelling and Data Assimilation

### Geir Evensen

The modelling and data assimilation group has over the last few years developed activities built around the three major strategies:

To take a lead in the development of pre-operational monitoring and prediction systems for the world's ocean and marine ecosystem,

To establish the Nansen Center as a world leading center for performing hindcast ocean modelling studies for the off-shore oil industry, and

To establish a competitive process modelling group.

A major highlight has been the establishment of an operational ocean monitoring and prediction system for the North Atlantic, the Nordic Seas and the Arctic Ocean. The system is a culmination of research work and developments carried out within a number of research projects, but the operation and final development has been done through the EU MAST-III DIADEM project co-ordinated by the Nansen Center. The assimilation system currently utilise observed Sea Surface Height, Sea Surface Temperature and Ocean Colour data which are processed in real time by partners in the DIADEM project and which are assimilated into the NERSC model system to make real time predictions for the North Atlantic. Results from the project are available on the web page (<http://www.theyr.is/diadem/rtweb/rtres.html>). From end of 2000 this activity is now carried on with further funding from the EU FPV TOPAZ project also co-ordinated by the Nansen Center.

Another challenge has been the development of a nested ocean model system, which allows for high-resolution simulations in targeted areas and where the model is capable of reproducing the observed water masses and current variability in the ocean. This model development was motivated by demands for current statistics within the oil industry operating in deep waters along the Atlantic Margin north of Scotland. Much of this activity was funded by the North Western Approaches Group (NWAG) which comprises about 16 oil companies. During 2000, the Nansen Center's ocean model system has been upgraded to the Hybrid Co-ordinate Ocean Model (HYCOM), and further validated within the NWAG project. The commercial modelling activities have now been organised through our new company Ocean Numerics Ltd. owned in co-operation with Fuguro Geos Ltd..

A strategy plan for strengthening the proc-

ess studies competence at NERSC has been written and a decision to build a group devoted to process and small scale studies in the ocean was made. The group will focus on small scale non-hydrostatic modelling and will be headed by Guttorm Alendal.

Since 1991 NERSC has studied CO<sub>2</sub> sequestration, as an option for reducing the atmospheric burden of antropogenic CO<sub>2</sub> emission. In 2000 the activities has been to support the technical committee for the international CO<sub>2</sub> ocean sequestration field experiment, also known as the Hawaii experiment (<http://www.co2experiment.org>) in which NERSC is a member. This project is an international joint research effort initiated in December 1997 by Japan, Norway and the USA in the framework of the Climate Technology Initiative (CTI). The CTI was promoted by the 24 member countries of the OECD and IEA in 1995. Later Canada, Australia and ABB Switzerland have become partners in the experiment. The main uncertainty for a successful experiment is the permitting issue. To support the required Environmental Assessment NERSC has contributed through studies of the spatial and temporal extent of reduced pH during the experiment.

In the Norwegian Research Council KLIMATEK project efforts are made to bridge the modelling tools at different spatial scales that are available at NERSC. The objective is to build a generic model system ranging from small to global scale that can be used for efficiency and impact studies at possible injection sites worldwide.

## Climate Studies and Modelling

### Helge Drange

The evidence for a change of the global climate system as a result of human induced atmospheric pollution increases. To detect such a global climate change, a trend or a shift in the natural variability of the climate system needs to be identified. A central topic in the climate change research is therefore to better understand the natural variability of the climate system. This topic is the major activity at the G. C. Rieber Climate Institute, and the activity is focusing on the natural variability of the North Atlantic Ocean, the Nordic Seas and the Arctic Ocean on annual to decadal time scales. In these studies, analysis of observed climate parameters over the last 50-100 years and extensive use of process and basin scale sea ice-ocean models, and a coupled, global atmosphere-sea ice-ocean

model (the latter in collaboration with the Dept. of Geophysics at the University of Bergen), are used. The studies are promising in that both the mean state and the many of the well-known and observed anomalies in the ocean and sea ice systems can be simulated in a fairly realistic way. This includes the variability of the Arctic sea ice extent and thickness over the last 20 years, and the hydrography of the North Atlantic-Nordic Seas region for the last 50 years. It is also encouraging that the fully coupled, global atmosphere-sea ice-ocean model is operative in several configurations, and that the simulated, mean climate and variability of this model is in general agreement with observations.

In the near future, the coupled model will be run with increasing concentrations of the atmospheric greenhouse gasses and aerosol particles in an attempt to study the evolution of the climate over the last 150 years, and to generate scenarios for the following 100 years. The activities at the Climate Institute are supported by the G.C. Rieber Funds, the Norwegian Research Council, the Nordic Council of Ministers, and the European Commission.

## Remote Sensing Research

### Johnny A. Johannessen

Three major study projects have been awarded in 2000.

In Monitoring of the Norwegian Coastal Zone Environment (MONCOZE), a five year collaborative project between NERSC, DNMI and IMR has been funded by the Norwegian Research Council. The main objective 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. The study focus on the following specific objectives: to advance the understanding and description of the mesoscale and sub-mesoscale variability of the coastal current including eddies, and episodic upwelling events; to develop and demonstrate methods to combine multiple data sources for analyses and estimation of algal blooms and their spatial resolution according to dominant oceanic processes and transport characteristics; to develop and implement a method for estimation of contaminant exposure time on specific plankton/larvae populations; and to provide monitoring and warnings of extreme and potential

harmful events in water properties.

In Marine SAR Analyses and Interpretation System (MARS AIS), which is funded by EU for three years and coordinated by NERSC the main goal is to design and implement a prototype generic Marine SAR Analysis and Interpretation System (MARS AIS) for specific application to the marine coastal zone. MARS AIS comprises a consistent, homogeneous and user friendly data base to be generated primarily based on existing, new, multi-satellite and multi-sensor data and the most effective proven processing schemes and retrieval algorithms, scattering models and ocean interaction models. These tools shall be combined and merged into a state-of-the-art toolkit of SAR analyses and interpretation system. Candidate users are invited and stimulated to assist in the development and refinement of this MARS AIS toolkit and its products through testing, validation and evaluation of the capabilities of the SAR ocean interaction models and algorithms.

Study of Impact and Relevance of ESA's mission for Operational oceanography and Climate change monitoring (SIREOC) is a two year project funded by the European Space Agency. The main focus is to assess and quantify the relative impact of different Earth Observation data types for climate research and monitoring and for operational ocean prediction systems. The impact will be examined in light of availability of satellite observations of physical oceanographic variables, sea ice variables and marine ecosystem variables. In so doing model simulations will be conducted with specific focus on: assessing the impact of applying existing and planned (simulated) remotely sensed data sets to simulate the mean state and variability in a state-of-the-art coupled ocean-sea ice model for climate research and monitoring; and assessing and quantifying the relative impact of different Earth Observation data types (existing and simulated) in an operational prediction system.

## Applied Remote Sensing

**Stein Sandven**

The three year framework project, supported by the Norwegian Space Centre, to develop satellite remote sensing in climate and marine monitoring continued with focus on development of a generic SAR analysis system, 2) optical remote sensing of Norwegian waters, and 3) assimilation of satellite data in climate models at high latitudes.

The Norwegian Space Centre is also sup-

porting a joint project between the Nansen Center, Norwegian Polar Institute and NORUT IT to develop use of satellite data to observe sea ice parameters of importance to polarbear migration. ARGOS and GPS tracking data of polarbears are used to compare with sea ice conditions in the Svalbard area observed from SAR and other satellite data.

A project for ESA with title "Study on the Quantification of the Importance of the Sea Ice Budget in the Climate System" has started as a joint effort with the University College London. The project is focusing on sea ice thickness observed from satellite altimetry, in situ data and model simulations using coupled ice-ocean models at the Nansen Center. The project will assess the importance of assimilating sea ice thickness data from CRYSAT, scheduled for launch in 2003, into ice-ocean climate models.

The first year of the IWICOS project was completed ( Integrated Weather. Ice and Ocean System Service) funded by EU under the IST programme. The main focus of this project is to develop a prototype marine information system which will provide a single-entry access to meteorological, sea ice and oceanographic (met-ice-ocean) data and products in electronic form for use by operational centres, fishing vessels and other marine operators.

AMETHYST, which is a two-year project to study sea ice and glaciers by satellite remote sensing in the Russian Arctic, started with funding from EU's INCO-COPERNICUS programme. The project is coordinated by Joanneum Research in Austria with the Nansen Centers in Bergen and St. Petersburg as partners.

ENVIREF – Environmental Monitoring of Refugee Camps using High-Resolution Satellite Images continued in its second year with funding from both EU and Norwegian Research Council. The project demonstrated for the first time how very high resolution IKONOS images (1 m pixel size) can be used to map individual buildings and infrastructure in refugee camps. IKONOS images can also be valuable to complement and validate other satellite images (Landsat, IRS) with respect to environmental parameters such as vegetation, land cover change and hydrology. The ARSGISIP project funded by EU was completed, demonstrating the benefit of using optical satellite data, in combination with GIS, for estimation of parameters which are important for hydrological modelling. These parameters, which are related to vegetation, soil, topography, geology and land use change, were inves-

tigated in a test area in Østerdalen and can potentially be used to improve models for flood forecasting.

## The Director's Research Group

**Ola M. Johannessen and Lasse H. Pettersson**

The project AMOC – Acoustic Monitoring of Ocean Climate in the Arctic Ocean – was completed with funding from EU and the Norwegian Research Council. AMOC has demonstrated, through a series of model simulations and comparison with observations, that it is feasible to monitor ocean temperature, sea ice thickness and currents by using arrays of acoustic sources and receivers. Dr. Hanne Sagen is the co-principal scientist.

Another EU-funded project started in 2000: WEMSAR, which will develop SAR wind energy mapping for wind turbine industry. The project will investigate, validate and demonstrate the potential of satellite-based synthetic aperture radar (SAR) to map wind energy in offshore and near-coastal regions for potential wind turbine siting. SAR data in combination with in situ wind measurements have been obtained and analysed for three coastal test sites in Norway, Denmark and Italy. Dr. Heidi Espedal is the co-principal scientist.

Other EU projects in the group are: Arctic ice cover simulation experiment (AICSEX), Simulation scenarios for potential radioactive spreading in the 21st century from rivers and external sources in the Russian arctic coastal zone (RADARC), Sustainable management of the marine ecosystem and living resources of the White Sea (WHITESEA), Estimation of primary production for fisheries management (PROOF) in addition to several INTAS projects, e.g.: Detection and modelling of greenhouse warming in the Arctic and sub-Arctic; Developing methods for boreal forest mapping and monitoring by combined using SPOT and SAR satellite data; and Study of influence of land-based sources of radio nuclides on radioactive contamination of Kara Sea through Ob and Yenisey river system. Furthermore Ola M. Johannessen coordinates Norwegian Research Council projects, e.g., The Nansen Fellowship Program, a Scientific and Educational Program for Ecological Studies of North Western Russia. Lasse H. Pettersson is the co-principal scientist of these projects.

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Fridtjof Nansen (1861-1930) on the ice pack during the FRAM-expedition (1893-96). For three years they drifted, with their vessel FRAM, frozen in the ice, across the Arctic Ocean. The results from the expedition laid the foundation for currently important research in the Arctic Ocean, where today's focus is on understanding the role of the polar oceans in the global climate system.

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