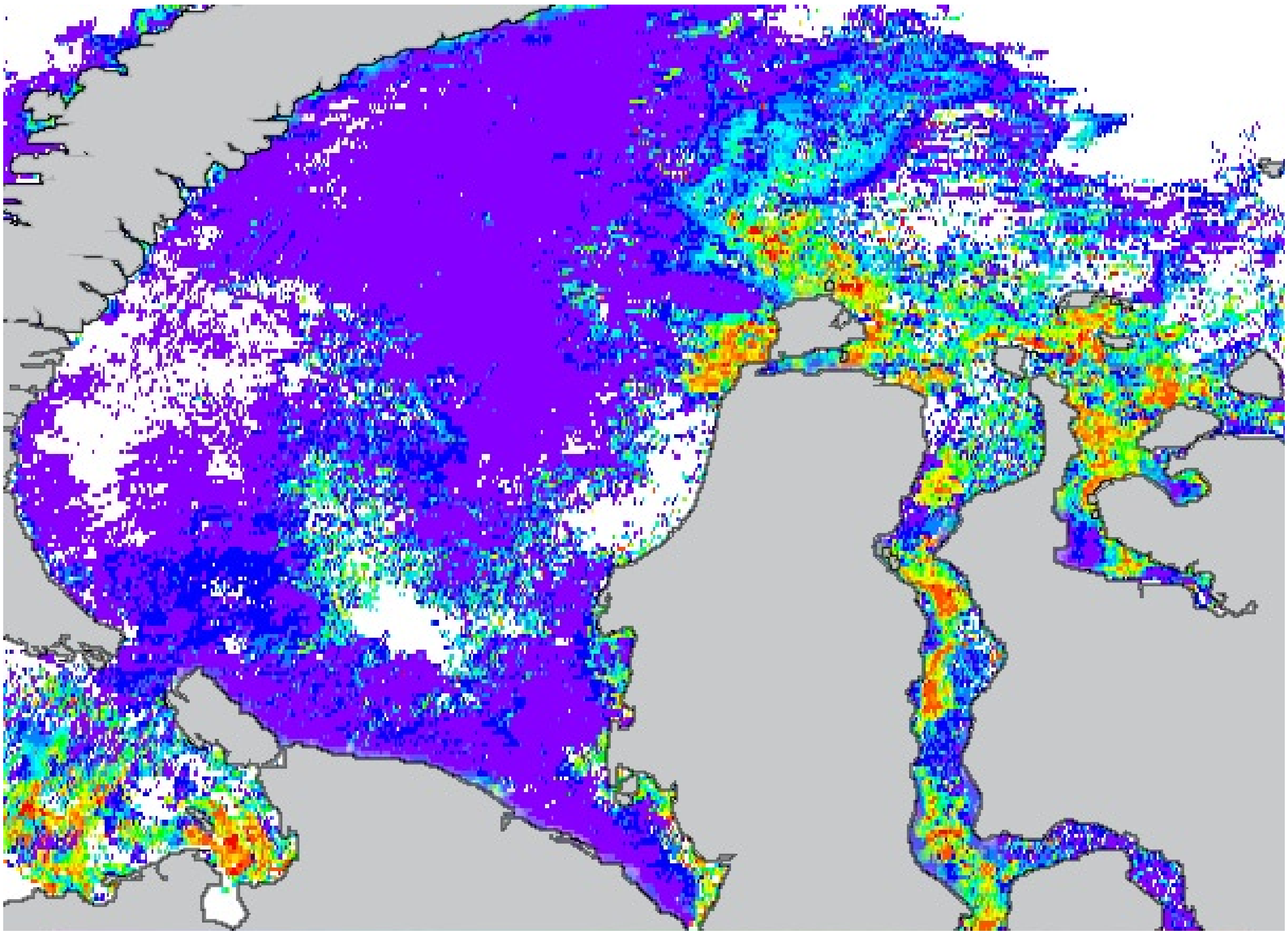
THE SCIENTIFIC FOUNDATION

NANSEN INTERNATIONAL ENVIRONMENTAL AND REMOTE SENSING CENTRE

a Non-Profit International Institute for Environmental and Climate Research in St. Petersburg, Russia founded in 1992



Biennial Report 2003-2004

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Bergen University Research Foundation (UNIFOB), *Bergen, Norway*

Max Planck Society *Munich, Germany*

Nansen Environmental and Remote Sensing Center *Bergen, Norway*

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Academician Kirill Ya. Kondratyev

Activity Report 2003-2004

Vision

Make a scientific contribution to the observations, understanding and predictions of Global Change and Environmental Processes at High Northern Latitudes.

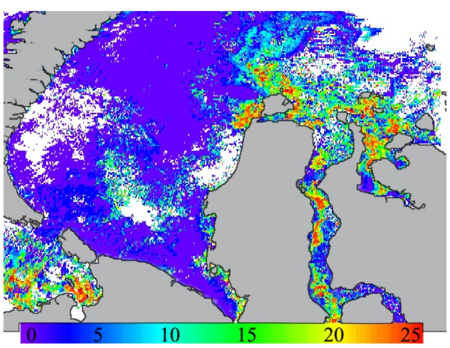
Organization

The Scientific Foundation "Nansen International Environmental and Remote Sensing Centre" (NIERSC) is a non-profit international research institution for environmental and climate research. It was founded in 1992. The major foci of the Centre are studies of Global Climate Change in the Arctic as well as Arctic environmental processes using satellite remote sensing, *in situ* data and numerical modelling. These foci include also applied research aimed on the use of remote sensing for support of service development including navigation and offshore oil and gas operation in ice covered areas.

NIERSC was officially registered as a Scientific Foundation according to Russian legislation on 2nd July 2001. This was accompanied by enlargement of the body of co-founders of the Centre to seven co-founders. The scientific and educational mission and foci of the Centre remained unchanged in this process.

NIERSC got accreditation at the Ministry of Industry, Science and Technology of Russian Federation as a scientific institution on 26th December 2002.

In January 2003 NIERSC has passed through a renewed registration and received from the local Tax Inspection a certificate, which validated its official status and allowed further normal functioning of the Centre as a legal entity of the Russian Federation.



Cover picture: *The averaged distribution of chlorophyll (µg/l) as retrieved from the MODIS images over the Kara Sea, August 2003 (Pozdnyakov, unpubl. data).*

Major events

Within the framework of "the Week of Hamburg" in St. Petersburg a Russian-German Symposium entitled "Environmental Changes in High Northern Latitudes" was conducted in commemoration of the 300th anniversary of the city of St. Petersburg in September 2003. The symposium was jointly organized by the Max-Planck Institute for Meteorology in Hamburg, Germany, St. Petersburg State University and Nansen International Environmental and Remote Sensing Centre. Chaired by Prof. Hartmut Grassl, Director of the Max-Planck Institute for Meteorology, the Symposium assembled about one hundred participants encompassing both renowned scientists of Russia and Germany and a group of young Russian Ph.D. students awarded the Nansen Fellowship. The Symposium highlighted the major accomplishments in the climate-related research areas and defined the pressing challenges facing the scientific community, and the humanity as a whole in the future.

The year of 2004 was distinguished by an important decision taken by the Nansen Environmental and remote Sensing Center in Bergen, which purchased new office premises (285 m^2) for NIERSC in a newly-built Business Centre on Vasilievsky Island close to St. Petersburg State University. NIERSC is scheduled to move to the new premises by fall 2005.

The 31st International Symposium on Remote Sensing of Environment (ISRSE): "*Global Monitoring for Sustainability and Security*" will take place for first time in Russia on June 19th to 24th, 2005. Since August 2003 NIERSC has been thoroughly involved in the planning and organisation of the 31st ISRSE in St. Petersburg. The symposium, with a tradition dating back to 1960, is expected to provide a forum for around 500 participants during the plenary and technical sessions as well as a number of dedicated workshops, including the Strategic Scientific Workshop granted by INTAS and hosted by NIERSC. NIERSC is the local organizer of this Symposium, which from Russia is co-hosted by RosCosmos, St. Petersburg State University and NIERSC.

Through the period 2003 to 2004, NIERSC scientists took part in 19 international project meetings, of which 11 meetings were hosted by NIERSC in St. Petersburg.

Scientific output

14 peer review papers were published in international referee journals during the period. Two papers were selected as respectively editorial choice in Science and as EOS highlights. The two books "*Arctic Environment Variability in the Context of Global Change*" and "*Colour of Inland and Coastal Waters: A Methodology for Its Interpretation*" - were published by Springer-Praxis Publishing House in the Nansen Centers Polar Series. 26 papers were published in conference proceedings during the period.

Staff

The staff of the Centre incorporates about 30 employees comprising core scientists (including three full Doctor of Science and eleven with a Ph.D. degree), associated staff, Ph.D. students and administrative personnel. The Centre is divided into two main scientific groups: Climate Research Group and Environmental Remote Sensing Group.

The Nansen Fellowship Programme

The main objective of the Nansen Fellowship Programme is to develop education and expertise in environmental and climate change research for young Russian Ph.D. students at the St. Petersburg State University and other Russian higher education institutions. The scientific emphasis is placed on integrated use of satellite Earth observation techniques in combination with supporting *in situ* observations and numerical modelling techniques for studies of the Earth's system.

The Nansen Fellowship Programme is being supported by the NIERSC founding institutions, the Research Council of Norway, Nordic Council of Ministers, INTAS and private donations.

During the reporting period 12 Ph.D. students have been supervised, supported and have carried out their Ph.D. studies at NIERSC under the Nansen Fellowship Programme. In addition during 2003 and in 2004 twenty Ph.D. students at St. Petersburg State University have, on an annual competitive base, been awarded the Nansen Grant funded by the University of Bergen.

An extensive programme of exchange visits of Ph.D. students to the co-founding and other institutions is pursued. Six Ph.D. students conducted international research visits mainly to Norway and Germany, totally about 20 person-months.

Doctoral Dissertations

Four Nansen Fellowship Ph.D. students have defended dissertations and obtained their Doctoral degree during the period:

Dmitry B. Akimov "*Modelling satellite radar signatures of ocean fronts and comparison with field observations*", on 13. March 2003.

Andrey N. Filatov "*Method of barriers zones identification by system of ecometric indicators (rivers Neva and Chupa as an examples)*", 25. December 2003.

Kirill S. Khvorostovsky "*Spatio-temporal Greenland Ice Sheet elevation changes from satellite radar altimeter data*", 27. May 2004.

Julia B. Rosanova "*Satellite ice concentration data assimilation by numerical modelling of the sea ice cover of the Arctic*", 16. December 2004.

Drs. Akimov and Khvorostovsky are now employed as scientists at NIERSC.

Funding

The co-founders provide the basic funding for the Centre. The operations of the Centre are based on competitive project funding. Project in the period has been funded by INTAS (The International Association for the Promotion of Co-operation with Scientists from the New Independent States of the Former Soviet Union), European Commission, Research Council of Norway, European Space Agency (ESA), Russian Agency of science and innovation as well as the co-founding institutions.

National and International Activities

NIERSC has long-lasting national cooperation with several institutions of the Russian Academy of Sciences (RAS), the Ministry of Industry, Science and Technologies of the Russian Federation, the Russian Federal Space Agency (ROSCOSMOS) as well as with a number of Russian institutions including the Arctic and Antarctic Research Institute, Voiekov Main Geophysical Observatory and others, totally about 40 institutions.

Fruitful relations are established with both several Russian and European Universities as well as institutions and agencies located in Egypt, England, Finland, France, Germany, Italy, Norway, USA and other countries. NIERSC staff participates in several research projects funded by INTAS, European Commission, European Space Agency (ESA), Research Council of Norway and other Russian and European agencies.

NIERSC has been awarded and acted as the official "INTAS Information Desk" for the St. Petersburg, Novgorod and Pskov regions.

Since its foundation, NIERSC maintains very close scientific co-operation with its co-founding institutions. The NIERSC activities resulted in numerous jont scientific publications of fundamental and applied nature in several Russian and international refereed journals, as well as books published by international publishing houses.

Some scientific partners

- Alfred Wegner Institute, Bremerhaven, Germany
- ALTARUM Institute, Ann Arbor, MI, USA
- Arctic and Antarctic Research Institute – AARI, St. Petersburg, Russia
- Bergen University Research Foundation -- UNIFOB, Bergen, Norway
- Finnish Institute of Marine Research – FIMR, Helsinki, Finland
- Friedrich-Schiller-University, Jena, Germany
- GKSS Research Centre, Geesthacht, Germany
- Institute of Geography, Russian Academy of Sciences – IG RAS, Moscow, Russia
- Institute of Mathematical Machine and System Problems – IMMSP, Kiev, Ukraine
- Institutes Francais de Recherche pour l'Exploitation de la mer – IFREMER, France
- Karelian Scientific Center of the Russian Academy of Sciences – NWPI, Petrozavodsk, Karelia, Russia
- Marine Hydrophysical Institute of the National Academy of Sciences of Ukraine – MHI, Sevastopol, Ukraine
- Max Planck Institute for Meteorology – MPIM, Hamburg, Germany
- Murmansk Marine Biological Institute, Russia
- Murmansk Shipping Company, Russia
- Nansen Environmental and Remote Sensing Center - NERSC, Bergen, Norway
- Royal Netherlands Meteorological Institute - KNMI, The Netherlands
- Scientific Center for Earth Operative Monitoring, RosCosmos, Moscow, Russia
- Scientific Research Centre of Ecological Safety, Russian Academy of Sciences – SRCES RAS, St. Petersburg, Russia
- St. Petersburg State University – SpbSU, St Petersburg, Russia
- University of Bergen, Norway
- University of Oslo, Norway
- Voeikov Main Geophysical Observatory, St. Petersburg, Russia

Science Report

Arctic Environment and Climate Change Studies

***Dr. Leonid P. Bobylev**, Director*

The NIERSC is organized in two research units: ***Climate Research Group*** and ***Environmental Remote Sensing Group***. The NIERSC scientific objectives include five major areas of activities:

- Collection and analysis of past and present data relating to climate and marine ecosystem parameters of the Arctic and sub-Arctic,
- Analysis of the results of coupled general circulation models (GCM) together with observational data in order to estimate the climate variation modes and related temperature and sea ice vaiability in the Arctic and sub-Arctic,
- Analysis of marine and lake water bodies based on a synergistic approach developed for combining remote sensing data obtained in different spectral ranges,
- Investigation of the Greenland Ice Sheets mass balance and its contribution to the sea level rise,
- Assessment of natural and anthropogenic components in past and future climate and marine ecosystem changes in the Arctic.

The focus is on quantifying the cryosphere/climate relationship, linkages between climate sensitive sea-ice variables (ice extent, ice area, first-year and multi-year ice fractions, ice thickness etc.), atmospheric parameters (surface air temperature), sea level pressure and circulation indices as North Atlantic Oscillation (NAO), Arctic Oscillation (AO) using an ensemble of comprehensive state-of-art data sets spanning up to a century long.

In order to contribute to the five major research areas of NIERSC participated in the projects "*Marine Climate and Ecosystems in the Seasonal Ice Zone – MACESIZ*", "*Material fluxes from the Russian Rivers Ob' and Yenisey: Interactions with climate and Effects on Arctic Seas - MAREAS*", "*Integrating modelling and remote sensing for algae bloom monitoring in Norwegian waters – MORAN"*; all three funded by the Research Council of Norway, the "*Arctic Ice Cover Simulation Experiment-AICSEX*", the "*Sea Ice Thickness Observation System – SITHOS*" both funded by European Commission, the ESA Project "*SAR ice monitoring for climate research, environmental management, resource exploitation and marine operation safety in polar regions – ICEMON*"; several INTAS projects, which addressed problems of climate change in the Arctic; the "*Climate Data Access System – CLIMAS*", "*Nordic Seas In The Global Climate System*", as well as "*Synergistic satellite remote sensing of biotic and abiotic processes in marine and large fresh water bodies: development of a methodology and application to some European seas and large lakes*".

Study of the processes determining Arctic climate variability and change

***Dr. Svetlana I. Kuzmina**, Senior Scientist*

Collection and analysis of historical and modern observational data

In the framework of the INTAS project "*Climate Data Access System – CLIMAS*" an electronic data access system was created. This system contains high latitude digital climate data, climate analysis, major climate events and numerical simulations of future climate change scenarios. The system is available for use by the public sector, governmental agencies, industry, media and the academic sector including education at http://nwpi.krc.karelia.ru/climas/index.htm. Understanding of the uncertainties and biases of the temperature records is a necessary condition for any definitive conclusion regarding the nature of temperature variability and identification of anthropogenic or other physical forcing that may affect the temperature record. The comparison of high latitude temperature datasets, which are widely used now in climate research studies has been performed in order to demonstrate the regional differences between the data sets and to explain part of the reasons for these differences.

Observed and modelled air temperature and sea ice variability

In the framework of EU AICSEX and research council of Norway MACESIZ Projects a new set of century and multi-decadal scale observational data of surface air temperature and sea ice was analyzed in combination with ECHAM4 and HadCM3 coupled atmosphere–ice– ocean global model simulations in order to better determine and understand Arctic climate variability. It was concluded that two pronounced twentieth-century warming events, both amplified in the Arctic, were linked to sea-ice variability. Surface air temperature (SAT) observations and model simulations indicate that the nature of the Arctic warming in the last two decades is distinct from the early twentieth-century warm period (fig. 1). It is suggested strongly that the earlier warming was natural internal climate-system variability, whereas the recent SAT changes are a response to anthropogenic forcing. The area of Arctic sea ice is furthermore observed to have decreased ~$8*10^5$ km^2 (7.4%) in the past quarter century, with record-low summer ice coverage in September 2002. A set of model predictions is used to quantify changes in the ice cover through the twenty-first century, with greater reductions expected in summer than during winter season. In summer, a predominantly sea-ice-free Arctic is predicted by the end of this century. These results were published in *Tellus* (Vol. 56A, No. 4, pp. 328-341) and also selected as Editorial Choice in *Science*.

The North Atlantic Oscillation and greenhouse-gas forcing

The results of 12 coupled global climate

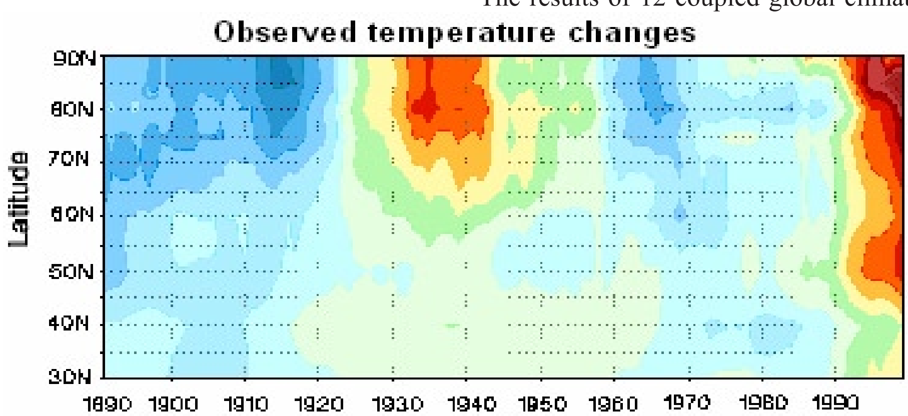


***Fig. 1**: Zonally averaged surface air temperature (°K). Johannessen et al., 2004.*

models participating in the "*Coupled Model Intercomparison Project - CMIP2*" were compared together with observational data in order to investigate:

1) How the current generation of climate models reproduce the major features of the winter North Atlantic Oscillation (NAO), and
2) How the NAO intensity and variability may change in response to increasing atmospheric CO_2 concentration.

Long-term changes in the intensity and spatial position of the NAO nodes (Icelandic low (IL) and Azores high (AH)) are investigated, and different definitions of the NAO index and the Arctic oscillation (AO) are considered (fig. 2). The observations indicate that the IL and AH comprise a unified system varying synchronously – their centers simultaneously shift position along a southwest–northeast axis, with a northeastward shift occurring during maximum sea level pressure gradient (i.e., strong NAO^+). Most of the model runs also exhibit this tendency to shift position. The observed temporal trend in the NAO in recent decades lies beyond the natural variability found in the model control runs. For the majority of the models, there is a significant increase in the NAO trend in the forced runs relative to the control runs, suggesting that the NAO may intensify with further increases in greenhouse-gas concentra-tions. That, in turn, may lead to temperature and precipitation increase in the European region. These results were published in ***Geophysical Research Letters*** and in EOS highlights in 2005.

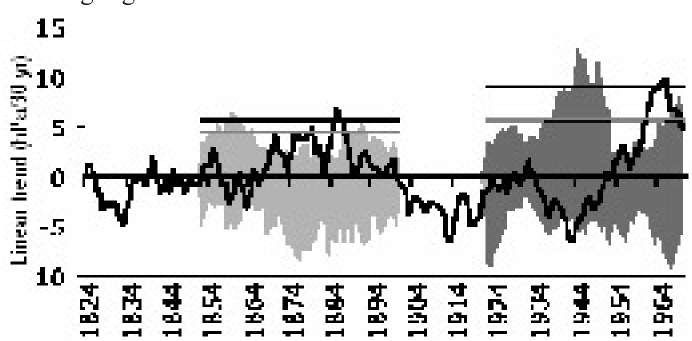


Fig.2: *30-yr linear NAO trends for observations (black curve) and CMIP2 control and forced runs (light and dark gray shading). Kuzmina et al, GRL, Vol. 32, No. 4., 2005.*

Sea-ice change and its connection with climate change in the Arctic

The two-dimensional distribution of mean and intermodel spread of Arctic sea ice at the time of CO_2 doubling and its connection with the climate change was analyzed using the simulations from the CMIP2 Project. Arctic surface warming at the time of CO_2 doubling is found to be not evenly distributed and ranges from 1^o to 5°C. The intermodel spread is pronounced in the Arctic Ocean, particularly in the Barents Sea. Reduction of sea-ice thickness (SIT) is in the range 0.3–1.8 m and mainly appears in the Greenland-Barents Seas. Meanwhile, sea-ice concentrations (SIC) decrease more than 10% in most regions of the Arctic Ocean. The simulated mean and intermodel spread patterns of surface air temperature (SAT) change are similar to those of SIT and sea level pressure changes. This implies that projected Arctic climate changes are influenced by the interaction between sea ice and the atmosphere. Both SIT and SIC are sensitive to the increase in greenhouse gas concentrations, and are connected with SAT and SLP changes in the Arctic. The average of all model simulations indicates that the north-south SLP gradient and the mean westerly winds are enhanced by CO_2 doubling.

Changes in the Arctic Ocean sea ice cover

***Dr. Elena V. Shalina**, Senior Scientist*
***Dr. Vitaly Yu. Alexandrov**, Senior Scientist*
***Dr. E. Zabolotskikh**, Senior Scientist*
***Ms. Olga I. Babina**, Ph.D. Student*

The sea ice cover is an important component of the global climate system. It is predicted that global warming should be amplified in the Arctic due to feedback processes within the atmosphere - ocean - ice climate system. The amplified warming suggests a drastic reduction of the sea ice cover, which is perennial in the Arctic Ocean and at least seasonal in its marginal seas. The most consistent, quantitative means to monitor the Arctic sea ice cover is satellite-borne passive microwave sensors. The merged inter-calibrated SMMR-SSM/I time series of sea ice concentration, produced for the period 1979 - 2004 using NORSEX algorithm revealed shrinking of the total Arctic sea ice cover of about 3% per decade. The reductions have been mostly pronounced in the European sector during winter and the Siberian-Alaskan sector during the summer, with the record of low Arctic ice cover minima in the 1990s and 2002. The pronounced summer reductions imply changes in the character of the ice cover i.e., reduced amount of perennial, multi-year (MY) ice. The negative trend in MY ice area analysis is often cited as evidence of a substantial change in the ice cover. However, capabilities and limitations of passive microwave algorithms to estimate the relative coverage of first year (FY) and MY ice have not been quantitatively established. Therefore the validation of the NORSEX algorithm is being conducted by means of comparison of SSM/I-derived MY-ice areas with synthetic aperture radars (SAR) image expert interpreted sea ice data. For this purpose RADARSAT ScanSAR images covering the whole Arctic in November 1997 and March 1998 are used. Development of a new algorithm based on the neural networks approach is suggested for MY ice concentration retrievals from passive microwave satellite Earth observation data. For this purpose Neural Networks can be trained using SAR images data converted into sea ice concentration data with help of an expert interpretation and automatic classification algorithm.

Spatio-temporal Greenland Ice Sheet elevation changes

***Dr. Kirill S. Khvorostovsky**, Scientist*

Investigation of the Greenland Ice Sheet mass balance is important for understanding its current state with regard to climate change and contribution to the sea level rise. Satellite radar altimeter measurements of ice sheet surface elevation change allow to determine directly the changes in ice volume and therefore mass balance of the ice sheets. Studying of Greenland Ice Sheet elevation changes have been earlier performed using Seasat and Geosat satellite radar altimeter data and only related to the southern part of Greenland.

The objective of our work was a study of the Greenland Ice Sheet elevation changes using altimeter data from ERS-1 (1992-1996) and ERS-2 (1995-2003) satellites. The use of data from both satellites allowed us to assess the elevation change of the whole Greenland Ice Sheet.

The following specific tasks were addressed: 1) to collect ERS-1 and ERS-2 radar altimeter data and create databases needed for Greenland Ice Sheet elevation change study; 2) to assess the bias between ERS-1 and ERS-2 radar altimeter measurements over Greenland Ice Sheet for joint data analysis obtained from both satellites; 3) to estimate the Greenland Ice Sheet elevation change rate and to analyze its spatial distribution; 4) to investigate temporal elevation variations within different Greenland Ice Sheet regions; 5) to analyze the dependence of Greenland Ice Sheet elevation from climate and glaciological factors.

The approach taken in this study is based on the crossover analysis using the differences in radar altimeter measurements at crossing points of the satellite orbit ground tracks. All measurements were corrected for the range measurement errors, as well as the orbit, instrument, atmospheric and tide errors. A database of all available crossover points was created for performing a comprehensive analysis of the spatial and temporal variations of the Greenland Ice Sheet elevation changes. Two methods of elevation change calculations were used. The first is based on the consideration of all available crossovers, allowed estimation of the elevation change rate over the whole time period considered. Another method is based on creating a time series of seasonally averaged elevation change. Additional algorithm for determination of the bias between radar altimeter measurements from ERS-1 and ERS-2 satellites was developed. It allowed to study the elevation change over the whole period 1992 - 2003 and to improve considerably the accuracy of elevation change estimates.

The major result of this study is that Greenland Ice Sheet elevation was growing from 1992 to 2003 at the rate of 5,4 cm/year (fig. 3). If an isostatic uplift of underlying bedrock is taking into account, which is expected as a delayed response to a decrease in the mass of the ice sheet during the Holocene, then the ice thickness increase amounts to approximately 5 cm/year. Positive values are found over most of the high-elevation areas, while over low-elevations decreases are revealed. Seasonally averaged time series of elevation changes showed that this decreasing is mostly pronounced since 2000 and mostly caused by elevation decreasing in summer, i.e. may be attributed to increased snow melting

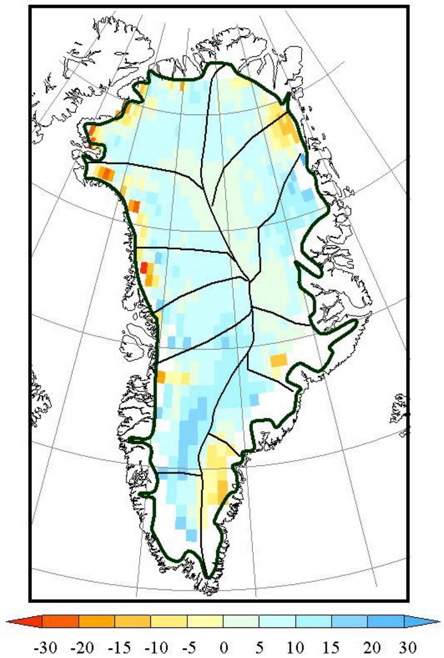


Fig. 3: *Greenland Ice Sheet Elevation change (cm/year) Khvorostovsky, unpubl. data.*

during this period. Over the southern area of Greenland, the considerable elevation decrease from 1992 to 1995 changed to significant elevation grows from 1995 to 2003. At the same time over most parts of the interior region of the northern Greenland an insignificant but stable growth of elevation was revealed.

A good agreement between the Greenland Ice Sheet surface elevation change and snow accumulation rate was established. It was shown that the main factor of elevation change is the location of the Icelandic Low especially during the winter season.

Environmental Remote Sensing

Prof. Dmitry V. Pozdnyakov,
Environmental Remote Sensing Group Leader,
Deputy Director for Research

First Estimations of the Kara Sea Water Quality

Prof. Dmitry V. Pozdnyakov,
Deputy Director for Research
Mr. Anton A. Korosov, *Ph.D. Student*

The Arctic Ocean and in particular its coastal margin is particularly influenced by multifaceted alterations due to the freshwater input fluctuations from the major rivers entering the Artic Basin. In this respect, as a recipient of two largest rivers that flow into the Arctic, the Kara Sea is particularly affected by fresh water fluxes and associated inputs of nutrients and terrogenious matter through the Ob´and Yenisei rivers. The Kara Sea annually receives a record amount of fluvial waters (~1350 km^3), which is equivalent to a 1.52 m fresh water layer if spread throughout the entire area of the Kara Sea. Significant efforts have been undertaken to investigate the riverine impacts on the Kara Sea and ultimately on the adjacent Arctic Ocean interior areas from board research vessels. However, field data collection suffers from undersampling and low spatial-temporal resolution.

Satellite remote sensing in the visible range of the spectrum is known as an efficient mean of retrieving water quality information in coastal and oceanic waters. During cloud free conditions the satellite remote sensing data can be acquired at a significantly higher spatial and temporal resolution than the available ship observations. Remote sensing data provides supplementary information, which in combination with shipborne measurements increases the body of knowledge about the water quality in the Kara Sea and further out in the adjacent areas of the Arctic Ocean.

Within the MAREAS Project, funded by the Research Council of Norway, several hundreds of SeaWiFS and MODIS ocean colour satellite remote sensing data were collected, processed and thematically analyzed for the Kara Sea during the June 1998 and September 2004. However, because of unfavorable weather conditions/heavy cloudiness, the major part of the high quality satellite data falls into the time period August-September each year.

Processing of the satellite images were done using the validated and operational NIERSC bio-optical algorithm based upon combining the Neural Network (NN) and the Levenberg-Marquardt (LM) multivariate procedures. The algorithm can be used for the simultaneous retrieval of the so called colour producing agents (CPAs) encompassing first and foremost chlorophyll (chl), suspended minerals (sm) and dissolved organic matter (doc) in marine waters.

A combination of the LM and NN procedures leads to a fast-operating bio-optical algorithm. With a given accuracy threshold, the developed algorithm is sufficiently robust for data with noise levels up to 15 per cent for certain hydro-optical conditions. To avoid inadequate retrieval results, the algorithm identifies and eventually discards the pixels with inadequate atmospheric correction or water optical properties incompatible with the constraints of the hydro-optical model.

To obtain spatial distributions of the CPAs (i.e. chl, sm and doc) throughout the entire Kara Sea, the results of CPA retrievals were merged and respective composites were generated for each month of remote observations. From thus processed satellite data derived were short-term (1998–2004) trends of CPA concentrations that are, apparently, dictated by a change in the weather (precipitation) pattern in that region. Further spaceborne monitoring will help to thoroughly study the nature of the revealed trends and their relationship to the ongoing environmental changes in the Arctic.

An example of the monthly spatial distribution of chl concentration retrieved by the NIERSC advanced algorithm from MODIS files taken in August 2003 is presented on the cover page of this report (*Pozdnyakov et al.,* IJRS accepted).

A thematic interpretation of the chl concentration distribution in the Kara Sea implies that the predominant winds determined a distinctively eastern spread of river runoff waters, predominantly from the Ob and Yenisey Rivers. Whereas, the northern area of the south-western region of the Kara Sea was fairly devoid of the impact of river waters and proved to be poorly productive.

The comparisons of in situ and retrieved data indicate that the spatial patterns in chl, sm and doc distributions comply very closely with the oceanographic data.

The simultaneously recovered spatial distributions of chl, sm and doc are assumed to be the first trustworthy estimates of water quality parameter fields in the Kara Sea obtained from space. The obtained results document the impact of Ob and Yenisey rivers discharge as well as the Barents Sea and Petchora River discharge on the Kara Sea trophy determining to a great extent productive/destructive processes in the Kara Sea waters (Pozdnyakov et al., 2003). Remote sensing data is explicitly indicative that in many regions the Kara Sea waters are highly productive, which is thought to be very consequential in terms of understanding the pathways of energy and matter transport into the Arctic Basin from its marginal seas and eventually determining the hydrochemical and hydrobiological conditions.

Sea ice monitoring in the Northern Sea Route using ENVISAT ASAR images

Dr. Vitaly Yu. Alexandrov, *Senior Scientist*

Supporting icebreaker operations in the Northern Sea Route with satellite Synthetic Aperture Radar (SAR) data is one of the main applied research activities of the Nansen International Center. For more than a decade NIERSC has done investigations and provided SAR data in support of navigation operations in sea ice. In the first half of 2004 ENVISAT ASAR images have been used for this purpose on regular basis. After downloading from Kongsberg Satellite Services in Tromsoe, and preliminary processing at NERSC, Bergen ASAR images were sent by e-mail to Murmansk Shipping Company. The SAR based sea ice information and images were transmitted to the nuclear icebreakers *Yamal*, *Sovetsky Soyuz*, *Arktika*, *Vaygach*, and *Taymyr* via the Russian "Orbita" telecommunication system. All received ASAR images were used for supporting navigation in the sea ice of the Barents and Kara Seas, in the Yenisey estuary and in the northern part of the Ob Gulf. In early February ASAR images were used for identification of possible convoy formation areas in open water, selection of the icebreaker route through the Kara Gate to the north, and for estimating the possibility of ship entering into fast ice in the area of accessible depths. E.g. the images of February 18th 2004 confirmed the difficulties of sailing through the Kara Gate because of strong ice drift from the Kara to the Barents Sea. Further the formation of wide flaw polynya in the Ob-Yenisey region predetermined a selection of the northward sailing route from the Yenisey Gulf to the Arctic Institute and Izvestiy TSIK Islands and further to Cape Zhelaniya. Later during this winter season this route was used for sailing between Yenisey and the Barents Sea until May. ASAR images for late March were used for selection of ship steering route to the Ob Gulf. The passage into the Ob Gulf from the north was quite easy due to ice divergence in its eastern side and because the fast ice in the northern part of the Ob Gulf was in the stage of thin/medium first-year ice. Using ASAR images more optimal new sailing channel was made in the fast ice. Supporting the icebreaker operations in the Northern Sea Route was continued until late June. The icebreaker navigators received all afore-mentioned images and select the easiest ways of sailing through level thin ice and along leads and polynyas with prevailed nilas and grey ice and avoiding large ice floes. As a result the speed of convoy's steering increased for 40-60% on average. Supporting icebreaker operations in the Northern Sea Route was continued in winter 2004/2005.

Modelling satellite radar signatures of ocean fronts

Prof. Vladimir N. Kudryavtsev, *Leading scientist*
Dr. Dmitry B. Akimov, *Scientist*

Research activities have been carried out under the INTAS "*Development of Synthetic Aperture Radar Marine Information System - SARMIS*", the "*Small-scale wind waves and exchange processes at the sea surface – NICOP*", ESA/IAF "*Marine oil spill control: SAR monitoring and model prediction - OSCSAR*" projects.

The overall goal of these projects is to improve our knowledge on the air-sea interaction processes and to develop am improved radar scattering model which can be further adopted in: the wind and wave SAR retrieval algorithms, advanced radar imaging models of the upper ocean dynamics and oil spills control.

An advanced short wind waves model has been proposed accounting for the effect of wave breaking on generation of short waves. A breaking wave crest disturbs the surface and generates sub-surface turbulence. The locally disturbed area further disperses and feeds short wave energy to the surroundings. The total short wave energy results from summing up the effect of wave breaking events randomly distributed over the sea surface. The rate of short wave generation is determined by the frequency of wave breaking events per unit area. The source of short wave energy is isotropic, thus it generates waves at cross and opposite wind directions. The model qualitatively reproduces observed directional property of short wind wave spectra and mean square slope.

Wind stress at low and moderate wind conditions governs the short wind-waves. Thus quality of short wind waves prediction in large extend depends on atmospheric boundary layer model. A model, which describes the impact of swell on the marine atmospheric boundary layer is proposed. The swell-induced momentum and energy fluxes are confined within the inner region. Swell loses energy to the atmosphere and enhances the turbulent kinetic energy in the inner region. The transfer of momentum results in acceleration or deceleration of the airflow near the surface. Following-wind swell accelerates the flow (a swell-driven wind). Opposite-wind swell decelerates the airflow, which for a steep swell could cause the reverse airflow. The sea drag in case of opposite-wind swell is considerably enhanced as compared to following-wind swell case. The model reproduces qualitatively and quantitatively the main experimental finding on the sea drag in the presence of the ocean swell.

A new radar imaging model of oceanic phenomenon of the arbitrary origin is proposed. The model takes into account scattering from "regular" surface and scattering from breaking waves. Description of background wind waves and their transformation in non-uniform medium is based on solution of the wave action conservation equation. Wave breaking play a key role in the radar imaging model. They: (i) scatter radiowaves (thus directly contribute to the radar returns), (ii) provide energy dissipation in wind waves (thus define the wave spectrum of intermediate scale waves), (iii) generate short surface waves (thus affect Bragg scattering). Surface current, surfactants and varying wind surface are considered as the main sources of the medium non-uniformity. The latter can results from transformation of atmospheric boundary layer over the sea surface temperature front. It is shown that modulation of wave breaking significantly influences both radar returns and short wind waves. In the range of short waves related to Ku-, X-, and C-band mechanism of Bragg waves modulation through wave breaking is the governing mechanism. The model is tested against well-controlled experiments JOWIP, SARSEX and CoastWatch-95 field data. A reasonably good agreement between model and observations is obtained.

An application of radar imaging model has been done to simulate radar signatures of meandering fronts, frontal eddies and meso-scale features of the coastal current. To do this the fields of surface temperature and currents derived from two distinct numerical ocean models were adopted. The comparison of simulated images with ERS SAR and Envisat ASAR images is favourable. One may conclude that the new radar imaging model provides promising capabilities for advancing the quantitative interpretation of current features manifested in SAR images.

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