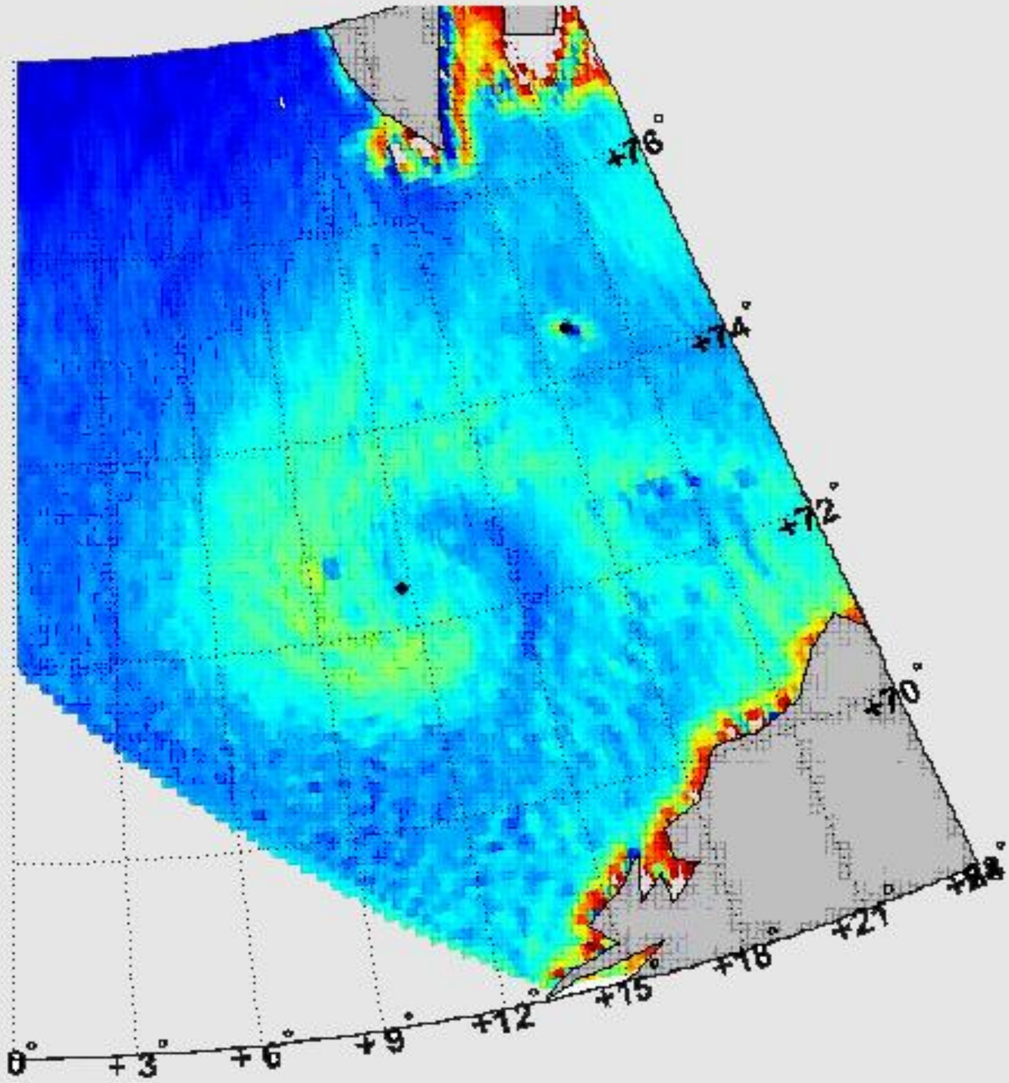
Annual Report 2008

Nansen International Environmental and Remote Sensing Centre
St. Petersburg, Russia

a non-profit international research institute for Environmental and Climate research

Founded in 1992



Polar lows – a challenge for modern meteorology

Founders of the Nansen Centre

Nansen Environmental and Remote Sensing Center
Bergen, Norway

Scientific Research Centre for Ecological Safety of the Russian Academy of Sciences
Saint-Petersburg, Russia

Northern Water Problems Institute of the Russian Academy of Science, Karelian Research Centre
Petrozavodsk, Republic of Karelia, Russia

Saint-Petersburg State University
Saint-Petersburg, Russia

Max Planck Society *Munich, Germany*

Bergen University Research Foundation (UNIFOB)
Bergen, Norway

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Dr. Leonid P. Bobylev

NIERSC Leader Team

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Head of Climate Group

Dr. Dmitry V. Kovalevsky, Research Director,
Head of Socioeconomic Group

Prof. Vladimir N. Kudryavtsev, Research Director,
Head of Atmosphere-Ocean Interaction Group

Prof. Dmitry V. Pozdnyakov, Research Director,
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Mr. Kaare Rommetveit
Bergen, Norway

Cover: Polar low in the Norwegian Sea manifesting in the atmospheric columnar water vapour field retrieved from Aqua AMSR-E data

Report from the Founders

NIERSC Vision

To understand, monitor and predict climate and environmental changes in the high northern latitudes for serving the Society.

Major Research Areas

- Climate Variability and Change in High Northern Latitudes
- Atmosphere-Ocean Interactions
- Aquatic Ecosystems in Response to Global Change
- Applied Meteorological and Oceanographic Research for Industrial Activities
- Socioeconomic Impact of Climate Change

Organization

The Scientific Foundation "Nansen International Environmental and Remote Sensing Centre" (Nansen Centre, NIERSC) is an independent non-profit international research institution founded by Russian, Norwegian and German organizations. It conducts basic and applied environmental and climate research funded by the national and international governmental agencies, research councils, space agencies and industry. Additionally, the Nansen Centre receives basic funding from its Founders and the Nansen Scientific Society.

NIERSC was founded in 1992 and re-registered at the St. Petersburg Administration Registration Chamber into a non-profit scientific foundation in 2001. The Centre got an accreditation at the Ministry of Industry, Science and Technology of the Russian Federation as a scientific institution in 2002 and was re-registered in 2006 according to a new legilation on Non-Commercial Organizations of the Russian Federation.

A new research group on socioeconomic impact of climate change *(Socioeconomic Group)* was established in 2008. The strategic objective of the group is to understand qualitatively and quantitatively the dynamics of the coupled climate/environment-socioeconomic system at the level allowing providing for decision-makers with a policy-relevant information.

Licensing

NIERSC got a license for conducting meteorological and oceanographic observations from Roshydromet on 3 July 2006.

On 5 November 2008 Nansen Centre received also a license from Roscosmos for conducting the space-related activities.

Staff

At the end of 2008 the Nansen Centre staff incorporated 33 employees comprising core scientists, including two full Doctors of Science and nine with a PhD degree, part-time researchers, administrative personnel and 10 Nansen Fellowship PhD-students.

A bereavement for the whole NIERSC staff and its Founders is the loss of **Dr. Dmitry Akimov**, a highly gifted young researcher and a brilliant computer administrator who passed away on 25 May 2008.

Production

During the year 2008, totally 52 publications were published including one monograph, 3 book contributions, 6 papers in refereed journals, 8 papers in other journals and 34 conference proceedings (the full list of publications is at the end of the Report)

Awards and Degrees

Prof. Ola M. Johannessen, the former President and current Chair of the Guardian Board was in 2008 appointed by His Majesty King Harald V of Norway to Officer of The Royal Norwegian Order of St. Olav, Knight of 1st class, for his outstanding efforts in climate and polar research.

Prof. Nickolay Filatov, Director of NWPI RAS, one of the NIERSC Founders, was elected as a Corresponding Member of the Russian Academy of Science in spring 2008.

In 2008 **Prof. Dmitry Pozdnayakov** and **Dr. Anton Korosov** received the Chandelr-Misener Award for the most notable paper published in the *Journal of the Great Lakes Research* during 2007. International Association for Great Lakes Research (IAGLR) recognized the research presented in the paper by *R. Schuchman, **A. Korosov,** C. Hatt, **D. Pozdnyakov,** J. Means, and G. Meadows:*

"Verification and application of a bio-optical algorithm for Lake Michigan using SeaWiFS: a 7-year inter-annual analysis", as a very useful for predicting changes in the Lake Michigan water quality under a set of climate change scenarios.

PhD-student **Ivan Sudakov** received award for the best presentation at the conference of young researchers in the frames of the 3rd International Polar Year, Russian State Hydro-meteorological University, St. Petersburg, 12-13 November 2008.

Nansen Fellowship Programme

The main objective of the Nansen Fellowship Programme at NIERSC is support of PhD-students at St. Petersburg University and other Russian educational and research institutions in their research in the area of climate and environmental change and satellite remote sensing. The Nansen Fellowship shall result in the completion of PhD theses with their subsequent defense. The emphasis is placed on the integrated use of satellite Earth observation techniques in combination with supporting *in situ* observations and numerical modeling for studies of the Earth system.

The Nansen Fellowship provides the PhD-students with:

- conditions at the Nansen Centre sufficient for the successful work
- fellowships and scientific supervision
- training and research visits to international research institutions
- involvement into international research projects.

The postgraduate student activity is supervised by at least one Russian and one West European senior scientist. All Nansen Fellowship PhD-students are strongly encouraged to publish and present their scientific results in the international refereed journals and at international scientific symposia and conferences.

In 2008 two PhD-students within Nansen Fellowship defended their thesis:

Alexei Chaika defended PhD thesis *"Stratospheric aerosol microstructure parameter retrieval from SAGE III measurements"* at St. Petersburg State University on 29 May 2008;

Natalia Ivanova defended PhD thesis *"Radar imaging of the sea surface contaminations from space: Model investigations and some applications"* at the Russian State Hydrometeorological University in St. Petersburg on 19 June 2008.

19 young Russian Ph-students have been defended their Nansen Fellowship degrees since 1997.

National and International Activities

NIERSC has a long-lasting cooperation with Russian organisations such as St. Petersburg State University, institutions of the Russian Academy of Science, Federal Space Agency, Federal Service for Hydrometeorology and Environmental Monitoring including the Northern Water Problems Institute, Scientific Research Centre for Ecological Safety, Arctic and Antarctic Research Institute, Voeikov Main Geophysical Observatory, Murmansk Marine Biological Institute, Research Centre of Operational Earth Monitoring and others, totally about 40 institutions.

Fruitful relations are established also with a number of foreign and international organizations, universities and institutions including Max-Planck Institute for Meteorology, GKSS Research Centre, Friedrich-Schiller-University in Jena, Germany, Finnish Institute of Marine Research, Institut Français de recherche pour l'exploitation de la mer (IFREMER) in Brest, France, European Climate Forum, and especially with the NIERSC founders. Close cooperation is established with the Nansen Center in Bergen. Most of scientific results described below are achieved within the joint research activities of both Nansen Centres, in St. Petersburg and Bergen.

As a part of NIERSC cooperation with the European Climate Forum the international workshop on climate change and socioeconomic issues was held at NIERSC on 19 November 2008.

Research Projects

Below is the list of the research projects implemented at NIERSC in 2008. Most of them were implemented in close cooperation with other national and international scientific institutions.

Completed projects

Russian - Norwegian Program on High Latitude Environment and Climate (Ministry of Education and Research of Norway, 2006-2008)

Irkutsk Regional Information System for Environmental protection (IRIS, EU FP6 SSA, 2006-2008)

Algorithm development for atmospheric water vapor, cloud liquid water and sea surface wind speed retrieval for MTVZ microwave radiometer (NITs Planeta, Roshydromet, 2007-2008)

SAR-sea interaction and Ocean color research (IFREMER, 2007-2008)

Further development of MADIAM (Multi-Actor Dynamic Integrated Assessment Model) to include inter-regional and stochastic aspects (PIK/MPIM, 2008)

Climate change in St. Petersburg (St. Petersburg City Administration, 2008)

Long-Term Options for Russian Climate Policy (German Ministry of Environment, 2008)

The White Sea water exchange by EO (NWPI, 2008)

On-going projects

Development of marine oil spills/slicks satellite monitoring system elements targeting the Black/Caspian/Kara/Barents Seas (INTAS-ESA DEMOSSS, 2007-2009)

MERIS-based assessment of carbon supply into the Arctic Ocean by river runoff (INTAS-ESA MACRO, 2007-2009)

Developing Arctic Modeling and Observing Capabilities for Long-term Environment Studies (DAMOCLES, EU FP6, 2006-2009)

Monitoring the marine environment in Russia, Ukraine and Kazakhstan using Synthetic Aperture Radar (MONRUK, EU FP6, 2006-2009)

Arctic and sub-Arctic climate system and ecological response to the early 20th century warming (ARCWARM, Research Council of Norway, 2007-2011)

Descartes Program (EU Descartes award fund, 2007-2011)

New projects

Maritime resources of the Barents sea: satellite data driven monitoring in the context of increase of commercial efficiency of the fishery (MAREBASE, Research Council of Norway, 2008-2010)

Ocean color (IFREMER, 2008-2009)

SAR-ocean (IFREMER, 2008-2009)

Sea ice and iceberg monitoring system overview (Shtokman Development AG, 2008-2009)

Atmospheric water vapor retrieval by satellite passive microwaves (RSHMU/RF Federal Program "World Ocean", 2008).

St. Petersburg, 1st April 2009

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Valentin Meleshko, VMGO, *co-President*
Hartmut Grassl, Max-Plank Society, *co-Vicepresident*
Lasse H. Pettersson, NERSC, *co-Vicepresident*
Valery Astakhov, SPbSU
Vladislav Donchenko, SRCES RAS
Nickolay Filatov, NWPI RAS
Ola M. Johannessen, NERSC *Guardian Board, Chair*
Leonid P. Bobylev, *Director*

Scientific Report

Arctic sea ice transformation from satellite and modelling

Dr. Svetlana I. Kuzmina
Dr. Leonid P. Bobylev
Prof. Ola M. Johannessen

Shrinking sea ice cover in the Northern Hemisphere observed since 1980s is a clear indicator of the climate warming in the high northern latitudes. Sea ice changes in the 20th century and till now were retrieved from satellite passive microwave measurements using SMMR and SSM/I sensors. Future changes of the sea ice were estimated using the ensemble of IPCC AR4 global climate models.

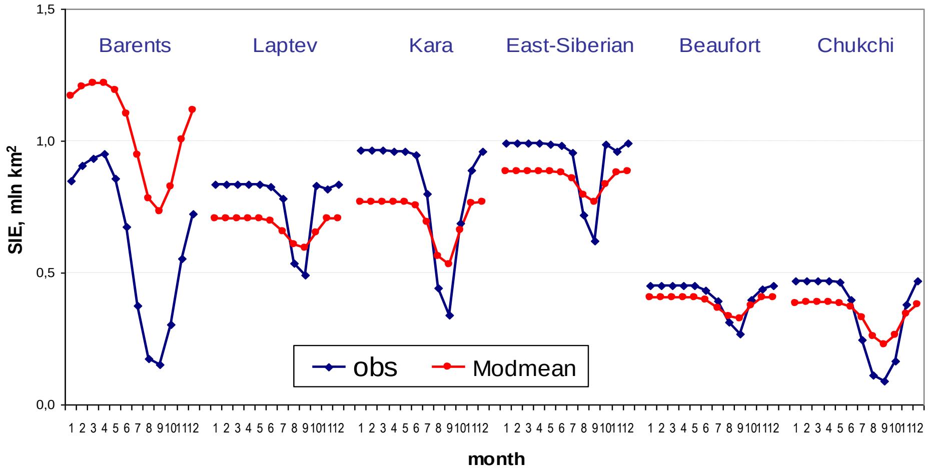


Fig.1. Comparison of the annual cycle of sea ice extent (SIE) in the Arctic seas from IPCC AR4 models and satellite measurements averaged for the years 1979-2005

Satellite observations of the Arctic sea ice showed its retreat over the last three decades (1979-2008) with the rate ~4.6 % per decade for the total ice area. Summer sea ice was shrinking much more drastically with acceleration starting from the beginning of this century.

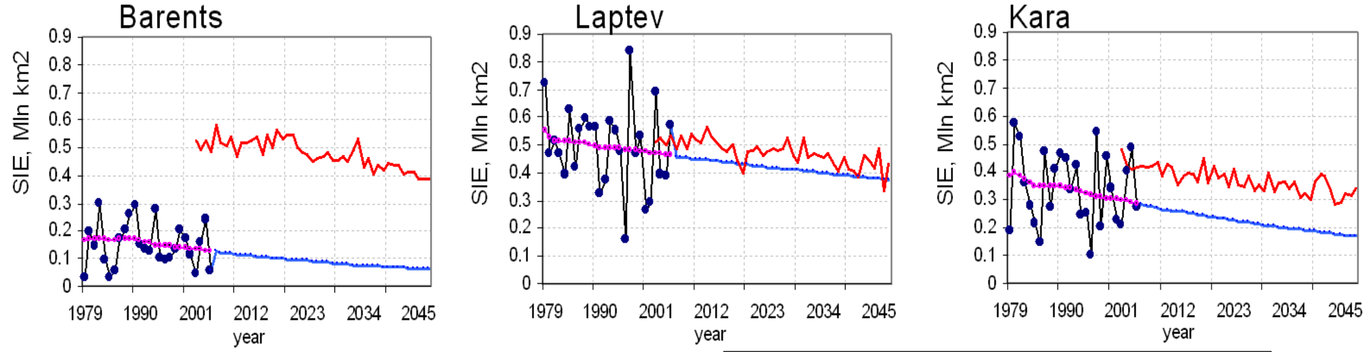
Unprecedented minimum summer ice cover occurred in 2007 and with both the North East and West passages ice-free in September 2008. The ice area came down to 4.1 million km^2 being 23 percent lower the previous record observed in 2005. Thus, the summer sea, which by definition is the multi-year ice, was decreasing with the rate 9.3% per decade, twice faster than the total sea ice area.

In all Arctic seas, the negative trend in the sea ice concentration was observed. For winter and spring the largest negative trends have been recorded in the Greenland and Barents Seas. For the whole Barents Sea the winter trend was about -13.6% per decade. In summer and fall the greatest decline was observed in Beaufort and Chukchi Seas (from June to November), as well as in East Siberian, Laptev and Kara Seas (from June to October). The highest trend in this period was observed in the Beaufort Sea in September: 15.6% loss of ice concentration per decade.

When considering the climate projections one of the important issues is how well models reproduce variability and change of the main climate parameters, one of which is the sea ice concentration. Generally the IPPC AR 4 models seem to overestimate the sea ice extent in the Arctic. Observed sea ice decreases faster than forecasted. Biases in main climate parameters derived from observations and models are most pronounced over the Russian Arctic seas. Figure 1 shows a comparison of observed and modeled annual cycle of sea ice extent for six Arctic seas. For the Barents Sea models overestimate sea ice during the whole year. For other seas models overestimate sea ice extent only for summer and early fall. For all other seasons they underestimate Arctic sea ice. The difference between observed and modeled sea ice is quite big, especially for Barents, Kara, Laptev and East-Siberian Seas.

IPCC AR4 climate model projections show that the Arctic seas may be ice-free in summer to the end of this century. However, as was mentioned earlier, retreats projected by models are not consistent with trends in observed sea ice coverage during past decades. Figure 2 shows the comparison of extrapolated, by means of "Caterpillar" method, observed September sea ice extent with climate model projections for Barents, Laptev and Kara Seas for the first part of the 21st century. There is a good coincidence of modeled sea ice extent values with extrapolated observed values only for Laptev Sea. For Barents and Kara Seas there is significant discrepancy between these two types of forecast. Thus, extrapolated observed data show that already to the middle of this century Barents Sea may be free of ice, significantly earlier than the models project. The same is obtained for Chukchi and Beaufort Seas (not shown in Figure 2).

Revealed discrepancies between simulated and observed variability of sea ice will help in improvements of the climate models and improving the understanding of the interaction between sea ice and climate. This study is published in *Bobylev et al (2008), in AARI transactions*.



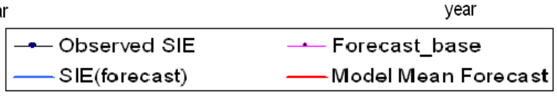


Fig. 2 September sea ice extent (SIE) for the Arctic seas: observed, extrapolated and modeled.

Multi-year ice concentration retrieval using passive and active microwave satellite data

Dr. Elena V. Shalina

Prof. Stein Sandven

At present, changes of the spatial coverage of sea ice in the Arctic for the satellite passive microwave data are well described. However, present algorithms for observing Arctic sea ice are not accurate enough in calculation of the multi-year (MY) fraction, which is a significant shortcoming of the present system of global ice monitoring considering the fact that MY ice is one of the key indicators of the Arctic climate change. A number of studies demonstrated problems of retrieving MY ice concentrations from passive microwave data. Those problems are manifested mainly by growth of MY ice coverage, calculated with passive microwave

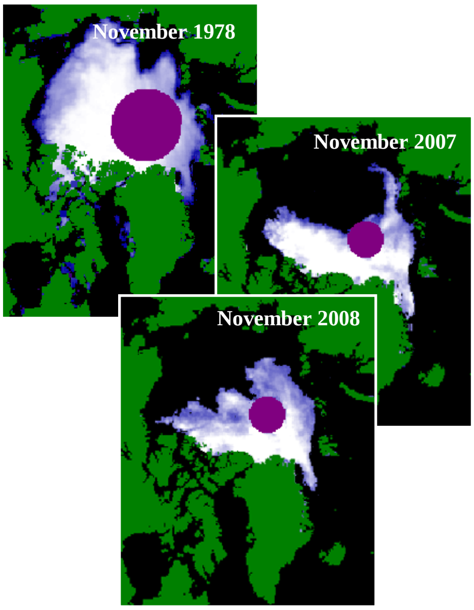


Fig. 3. Change of the multi-year ice coverage from the beginning of satellite passive microwave observations to two consecutive minimums in 2007 (the lowest area) and 2008 (the second-lowest area)

algorithms, in the course of the winter season.

This study has been conducted in the frame of the EU FP6 DAMOCLES Project. The study is an extension of the research published by Johannessen et al. (1999). The improvement of MY sea ice fraction calculations, based on the NORSEX algorithm, is achieved by adding active microwave satellite data to the calculation procedure. QuikSCAT scatterometer data are used as a complementary source of information that assists in separating first-year (FY) and MY ice. Sea ice backscatter maps help to correct the cases where passive microwave algorithms incorrectly classify FY ice as a MY ice. They also allow describing MY ice extent changes when passive microwave retrievals cannot provide reliable results.

In 2007, we observed the most remarkable reduction of the ice that was present in the Arctic by the end of the summer season. Accordingly, during the following winter (2007/2008) the MY ice cover reached its absolute minimum over the period of satellite observations. Our calculations showed that in winter 2008/2009 multi-year ice cover has not recovered: in November 2008 the area of MY ice was only 1% larger than one year earlier (Figure 3). This study is published in *Shalina et al, in Proceedings of MICRORAD 2008.*

Surface Air Temperature variability in the Arctic

Dr. Svetlana I. Kuzmina

Prof. Ola M. Johannessen

Dr. Olga G. Aniskina

Dr. Leonid P. Bobylev

In the framework of the *Arctic and sub-Arctic climate system and ecological response to the early 20th century warming - ARCWARM* project, funded by the Research Council of Norway, a new objectively analyzed (OA) gridded surface air temperature (SAT) dataset – the NansenSAT, was created. The data set covers area north of 40°N and the period from 1900 to 2006 and is available at: http://www.niersc.spb.ru/NANSEN_SAT_gridded.rar.

The main advantage of the new dataset is its enhanced spatial coverage that provides a better SAT representation for the Arctic, especially for the first half of the 20th century, when observations were scarce. This is achieved by: 1) the involvement of additional data used in

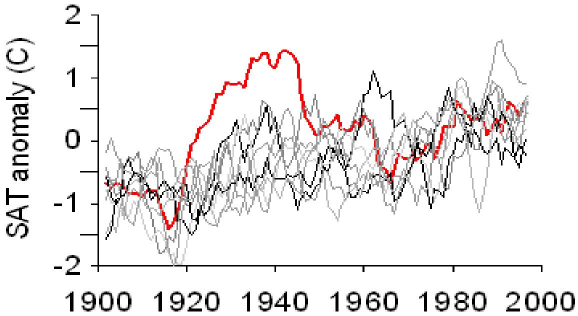


Fig. 4. Time evolution of the 20th century winter SAT anomalies averaged for 60-90ºN. Red–NansenSAT; black–nine GISS-ER model individual realizations.

the NansenSAT dataset; 2) the implementation of the enhanced OA technique that allows the optimal use of the data outside the current grid cell, if the information is scarce.

Comparison of the new surface air temperature dataset with that simulated by IPCC AR4 models was performed with special emphasis on the warm temperature anomaly of the first half of the 20th century in high northern latitudes. It was found that all models simulated correctly Arctic warming during the last two decades, but with significant spread in magnitude. However, no one of the IPPC models reproduced the phasing and duration of the early 20th century warming event. Generally, model ensemble underestimate mean SAT for the 20th century, modeled trends are higher than observed (Figure 4). This study is published in *Kuzmina et al (2008), in Tellus and AARI Transactions.*

Studying Arctic polar lows from satellites

Dr. Elizaveta V. Zabolotskikh

Dr. Leonid P. Bobylev

Winter polar mesoscale lows are continuously formed over the Arctic seas. They are associated with heavy precipitation and severe winds causing serious disturbance in the fishery and transport operations in the sea. Polar lows (PLs) are characterized by the wind speed exceeding gale force (17 m/s); their size is usually less than 1000 km but some may span as little as 100 km. PLs are often not reported on the weather charts due to their small scales, short life time (typically between 12 and 36 hrs) and development in remote areas with sparse observations. Accordingly, satellite data is a valuable and unique source of information for detection, tracking and studies of polar lows.

In 2008 NIERSC started the study of polar lows from satellites using multi-sensor approach. While satellite visible, infrared, scatterometer and SAR data were used as a source of the qualitative information, satellite passive microwave measurements were utilized to construct the fields of atmospheric water vapour content and cloud liquid water content inside the PLs.

Thus, a polar low, occurring in the Norwegian Sea on 30-31 January 2008, was detected and tracked using columnar water vapor fields (see cover page) retrieved from SSM/I and AMSR-E passive microwave data. This was carried out by means of a Neural Network based algorithm for retrieval of water vapor for polar conditions developed at NIERSC. NOAA AVHRR, Terra and Aqua

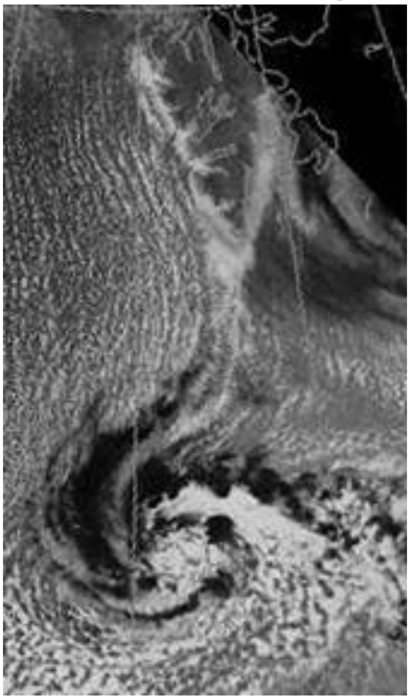


Fig. 5. Polar low in the Norwegian Sea observed in an Aqua MODIS image, 31 January 2008

MODIS images (Figure 5), QuikSCAT-retrieved wind fields, Envisat ASAR images as well as weather maps were used as ancillary information for study of this cyclone.

The trajectory of considered polar low was reconstructed and the total amount of the water vapor content in this PL was estimated for all of the stages of its development. This case study demonstrates the potential of using satellite passive microwave measurements for detection and tracking of polar lows through the retrieval of the atmospheric columnar water vapor fields.

NIERSC is going to improve this towards the general methodology for polar low studies from satellites and apply this to available satellite data in order to create a polar low climatology for the Arctic.

Climate changes in Saint Petersburg in the 20th and 21st centuries and impact on the economy

Dr. Leonid P. Bobylev

Dr. Svetlana I. Kuzmina

Dr. Olga G. Aniskina

In the framework of a project supported by the City Administration of St. Petersburg, past and present climate changes in the region were analyzed.

Future changes of heat and water balance were estimated using the realizations of the IPCC AR4 climate models. Probability of future extreme events and long-term flood risk were assessed and recommendations were developed for the urban planning.

It was found that during the 20th century the largest temperature increase occurred in winter and spring. The largest trends of maximum temperature were registered in March (4.4^{0}C/106 yr) and December (2^{0}C/106 yr). Since 1970s the positive temperature anomalies are prevailing (Figure 6), due to the ongoing global warming. In the same period the snow cover depth is decreasing, in spite of an increase in the precipitation rate about 1.1 cm per year.

The climate projections indicate significant increase of temperature and precipitation towards the end of this century, especially during winter. A 20 % increase in precipitation is projected during summer and 50% during winter. The surface air temperature projection is about three degrees during summer and about nine degrees during winter towards the end of this century.

Statistically significant changes in the flood level since 1703 were not found in the observations. However, significant increases of total flood number (~1.1 floods per year over 300 years) as well as a number of winter floods during last 37 years were registered. Analysis of long-term flood risk up to 2090 showed, that flood frequency will continue to increase and could reach three floods per year.

Thus, the climate in Saint Petersburg later in this century will be warmer and more humid. Projected climate changes will have a positive effect on the reduction of fuel end energy consumption as well as on the agriculture in the region.

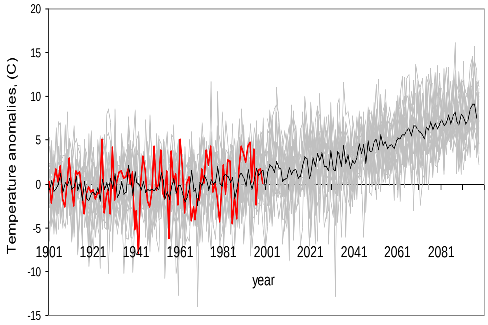


Fig. 6. Time evolution of the winter temperature anomalies in St. Petersburg during 20th and 21st centuries. Red – observations, grey – individual IPCC AR4 model realizations, black – model mean

Atmosphere-Ocean interaction studies

Prof. Vladimir N. Kudryavtsev

Mr. Alexander G. Myasoedov, *PhD-student*

Prof. Johnny A. Johannessen

The primary activity of the Atmosphere-Ocean Interaction Group during 2008 includes:

- Further study of the air-sea interaction at high wind conditions, in particular study and modeling of spume drops. generation by breaking waves
- Development of the model of the sea surface roughness in slicks formed by biogenic and oil films and application of this model for further development of oil spill detection and quantification algorithms based on synergetic analysis of radar and optical data
- Further advancing of Radar Imaging Model in order to simulate Doppler shift in SAR-signal
- Development of a new perspective approach for analysis of optical images targeted on retrieval of the sea surface roughness characteristics and their spatial variations caused by different type of ocean phenomena.

These investigations were carried out within the frame of the following projects led by the group: FP6 MONRUK project, MAREBASE project funded by Research Council of Norway, INTAS-ESA project DEMOSSS, Contract with IFREMER and HURRICANE project funded by the Russian Agency for Science and Innovations.

Wind driven currents and sub-surface turbulence

Vertical structure of the wind driven sea surface currents and role of wind wave breaking in its formation are studied by means of both field experiments and modeling.

Analysis of drifter measurements of surface current in the uppermost 5m layer at wind speeds from 3m/s to 15 m/s is the experimental starting point of our study. The velocity gradients beneath the surface are found to be 2 to 5 times weaker than in the “wall” boundary layer. Surface wind drift (identified via drift of an artificial slick) with respect to 0.5 m depths is about 0.7%, which is less than the velocity defect over the molecular sub-layer in the wall boundary layer at a smooth surface. To interpret the data, a semi-empirical model describing the effect of wave breaking on wind driven current and subsurface turbulence is proposed. The model is based on the idea of direct injection of momentum and energy from wave breaking (including micro-scale breaking) into the water body. Momentum and energy transported by breaking waves into the water enhance significantly the turbulent mixing and decrease velocity shears as compared to the wall boundary layer. No "artificial" surface roughness scale is introduced in the model. From the experimental fact of the existence of the cool temperature skin at the sea surface, we deduce that there is a molecular sub-layer at the water side of the sea surface with a thickness which depends on turbulent velocity beneath the surface. The model predictions are consistent with the reported and other available experimental data. This study is published in *Kudryavtesev at al (2008), in Journal of Physical Oceanography*.

Drag of the sea surface at very short fetches

The specific properties of the turbulent wind stress and the related wind-wave fields are investigated in a dedicated laboratory experiment for a wide range of wind speeds and fetches, and the results are analyzed using the Wind over Wave Coupling (WOWC) model. Compared to long-fetch ocean wave fields, wind wave fields observed at a very short fetches are characterized by higher significant dominant wave steepness, but much smaller macro-scale wave breaking rate. The surface drag dependence on the fetch and wind then follows closely the dominant wave steepness dependence. It is found that the dimensionless roughness length z_0 varies not only with wind forcing (or inverse wave age) but also with fetch. At a fixed fetch, when gravity waves develop, z_0 decreases with wind forcing according to a -1/2 power law.

Taking into account the peculiarities of laboratory wave fields, the WOWC model predicts rather well the measured wind stress values. The relative contributions to the surface drag of the equilibrium range wave-induced stress and the air flow separation stress due to wave breaking remain small, even at high wind speeds. At moderate to strong winds, the form drag due to dominant waves represents the major wind stress component. This study is published in *Caulliez et al (2008), in Journal of Physical Oceanography*.

Ocean surface velocity measurements from space

Previous analysis of Advanced Synthetic Aperture Radar (ASAR) images collected by ESA Envisat satellite has demonstrated that this instrument is a very valuable source of high-resolution information, namely on the line-of-sight velocity of the moving ocean surface. This velocity is estimated from a Doppler frequency shift consistently extracted within the ASAR scenes. The Doppler shift is caused by the combined reasons: action of near surface wind on shorter waves, longer wave motion, wave breaking and surface current. Both cinematic and dynamic properties of the moving ocean surface roughness can therefore be derived from the ASAR observations. These observations are compared with simulations using a Radar Imaging Model extended to include a Doppler shift module. The results are promising. Comparisons with coincident altimetry data suggest that regular account of this combined information would advance the use of SAR in quantitative studies of ocean currents. This study is published in *Johannessen et al (2008), in Geophysical Research Letters.*

Wind wave damping by biogenic and oil surface films

A model for the damping of wind wave spectrum by surface films is proposed. The model takes into account a mechanism of non-linear energy transfer from long waves (not "feeling" a film) to short waves affected by surface films. This mechanism provides small but not infinitesimal energy level in short wave interval. This fact is supported by observations. The model is adopted for analysis of radar observations. It is shown, that within the frame of a composite scattering model, wave breaking (if not affected by films) should play an important role in the forming of radar contrasts. However, as found, such model estimates are not consistent with measurements. This fact presumes that short wave breaking should also be damped by a film. As turned out, a "phenomenological" model accounting for this effect is consistent with radar observations. This study is published in *Kudryavtsev et al. (2008), in IAP RAS Preprint*.

Optical scanners and SAR ocean surface phenomena signatures

This activity is targeted on improvement of our knowledge on optical and SAR imaging mechanisms of ocean phenomena, e.g. mesoscale current features and fronts, internal waves, biogenic and oil slicks etc. It is anticipated that results of this study will be further used for the development of a synergetic approach for detection and quantification of ocean phenomena features by optical sensors and SAR. At the first stage the algorithm and respective software have been developed for processing data received from operational space-born optical scanners (MODIS, MERIS and others) in order to discriminate sea surface from clouds and land, and to retrieve the sea surface roughness parameters from the surface brightness. At the second stage a series of "nice" co-located optical

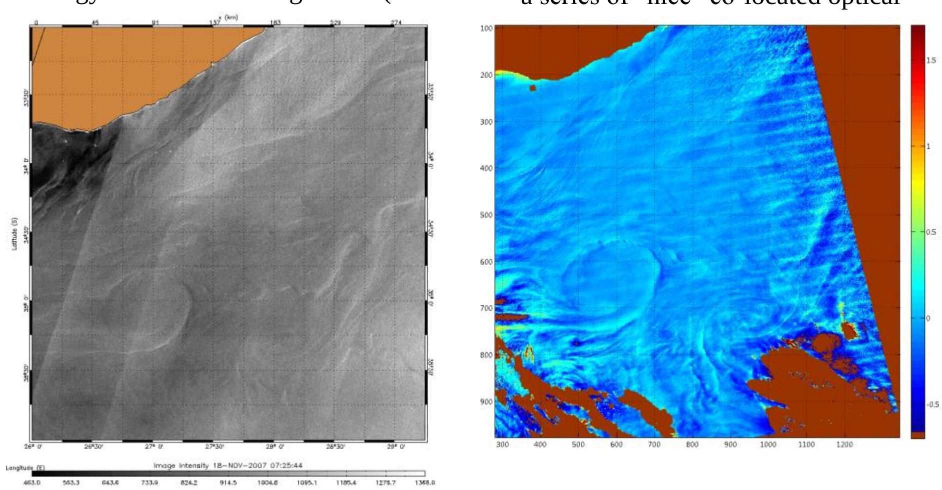


Fig. 7. An example of perfect synergy: comparison of mesoscale structures near Cape Agulhas derived from (a) SAR image 18.11.2006, 07:25 (©BOOST Technologies), and (b) processed MODIS image, representing the mean square slope variations calculated using developed method.

and SAR images possessing apparent surface signatures of variety of the ocean phenomena (current and frontal features, internal waves, surface slicks, wind field features) at different wind/wave and surface illumination conditions was selected. This is an ongoing activity. An example of surface manifestation of ocean eddy in the sea surface roughness derived from sun-glitter and its comparison with co-located SAR image is shown in Figure 7.

Ocean colour-based assessment of carbon fluxes and harmful algae blooms

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The main activities of Aquatic Ecosystem research group in 2008 were pursued in two major areas:

- utilization of ocean-color data for quantitative studies of carbon fluxes in marine environments, and
- identification and quantification of harmful algal blooms (HABs).

These studies were conducted under two projects, respectively, the INTAS *MERIS-Based Assessment of Carbon Supply into the Arctic by River RunOff - MACRO* project, and the IFREMER-NIERSC bilateral cooperation on *empirical to semi-analytical algorithms for open and coastal marine waters with a focus on the Bay of Biscay*.

SeaWIFS, MODIS and MERIS data were used and processed with the bio-optical operational algorithm previously developed at NIERSC. Determination of carbon fluxes in the world ocean is important in the

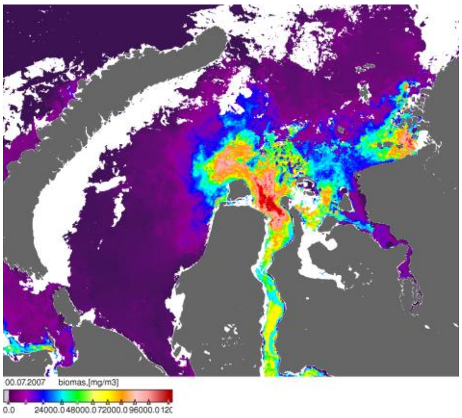

Fig. 8. Spatial distribution of dissolved organic matter across the Kara Sea in August 2008 as retrieved from the MERIS data

context of climate change. Under the INTAS MACRO project, temporal and spatial variations of the monthly dissolved organic carbon *(doc)* across the Kara Sea (KS) was determined for the ice-free period for the years 2002-2008, using a NIERSC developed method for temporal averaging of the data. The *doc* fields thus obtained (Figure 8) were further analyzed and compared with the available historic *in situ* data for verification purposes.

Given the available data on river discharge monthly rates for the years of observations, the allochthonous *doc* fluxes into and out of the KS were assessed and compared with the respective historical ground-based estimations. The comparison revealed a very close correspondence between these two kinds of data. Inasmuch as extensive hydrodynamic and biogeochemical simulations for the KS were also conducted under the MACRO Project, the modeling results of current trajectories and velocities were employed for quantifying the rate of *doc* fluxes out of the KS given the remotely determined riverine *doc* influxes. Such satellite data-driven estimations of *doc* fluxes were obtained for the first time for the KS, and the developed methodology can be employed for other semi-enclosed marine environments affected by significant river discharge, e.g. along the north Siberian coast.

It is recognized that the incidence of HABs events significantly increased over the last decades throughout the world ocean, and an operational space-borne surveillance of this phenomenon is of significant importance. Under the IFREMER-NIERSC cooperation we developed a new methodology for both identification such calcifying harmful algae as coccolithophores (specifically, *Emiliania huxleyi*) and delineating the areas of their proliferation. Remaining within the ideology of the previously developed bio-optical algorithm, and employing the optical characteristics of this specific alga, the algorithm permits quantifying the concentration and areal extent of *E. huxleyi* (Figure 9). The methodology was applied to the Bay of Biscay and the English Channel (*Korosov et al., 2009*). Analysis of the obtained satellite data on monthly variations of *E. huxleyi* blooms showed that they are preceded by a massive growth of diatoms that "prepare" the aquatic environment rendering it favorable for the

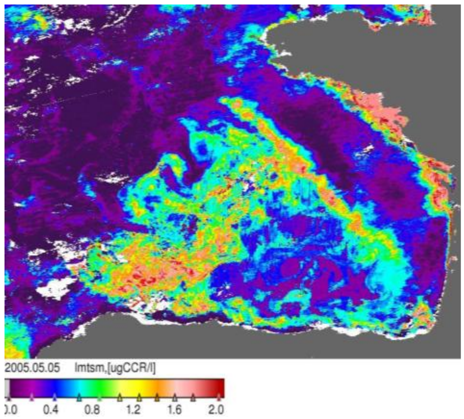

Fig. 9. Spatial distribution of E. huxleyi in the Bay of Biscay in May 2005 obtained from MERIS data.

development of a following *E. huxleyi* bloom.

At least for the last eight years of the MERIS operations, the satellite data indicates that intensity/extent of *E. huxleyi* blooms increased. The satellite data also allowed quantifying the generation of inorganic carbon in the *E. huxleyi* blooms, which is important in the context of studying global carbon cycle and climate change.

A review is published in *Pozdnyakov et al (2008), a book contribution*.

Satellite remote sensing methods for assessment of sea ice conditions, icebergs and stamukhas

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Based on results made during last several years within the NIERSC MetOcean Group, significant progress have been made in methods for assessment of the sea ice conditions as well as identification of icebergs and stamukhas (grounded deformed ice) using satellite remote sensing data. Methods include the following stages:

1) choosing the remote sensing information type according to tasks of the application;
2) correction of images; and
3) analysis of sea ice distribution, and iceberg and stamukha identification.

Automatic image interpretation

Regular acquisition of high-resolution SAR images over ice-covered waters generates large volumes of data and

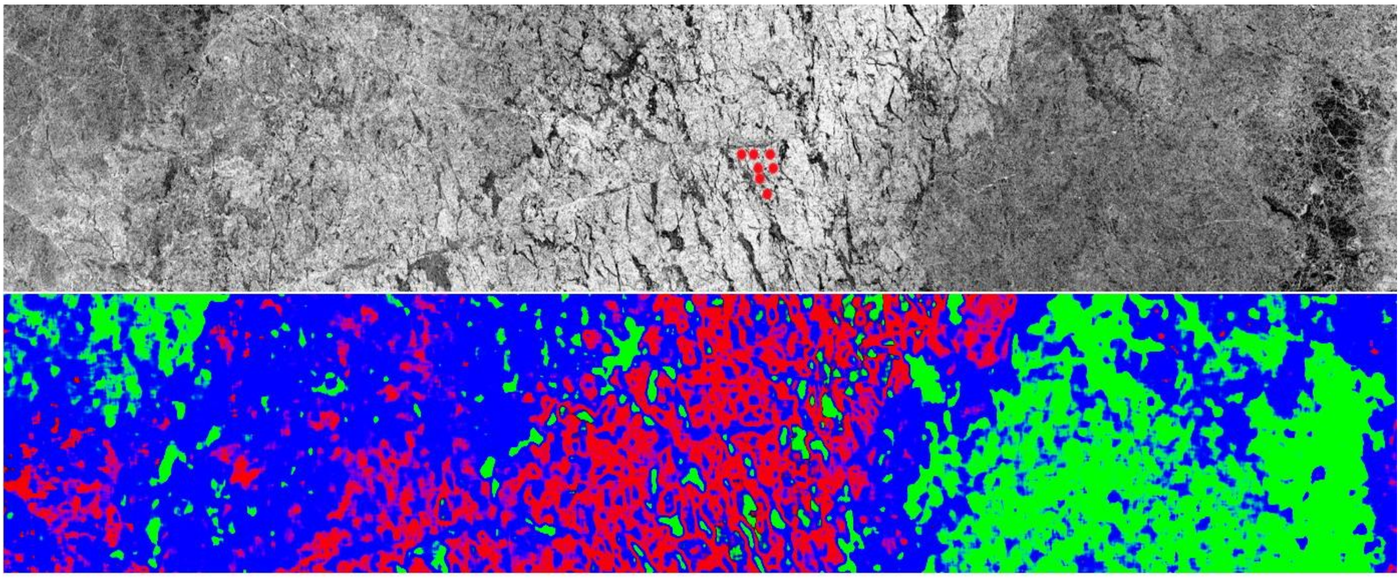

Fig. 10. Upper: ENVISAT ASAR WS image of the Russian Drifting Station North Pole NP-35 location area (04.02.2008). Lower: result of the automatic sea ice classification: green – level first-year ice, blue – deformed first-year ice, red – multiyear ice. Red points – location of NP-35

visual interpretation of these images and retrieval of sea ice parameters becomes laborious. Therefore, significant attention was paid to the development of the algorithms for automatic derivation of the main sea ice parameters. The objective of sea ice classification is to categorize SAR image pixels into several ice type categories. The used ice categories are mainly related to the sea ice development and its surface roughness. Correct classification of sea ice is also an important prerequisite for estimation of other sea ice parameters such as ice concentration, distribution of polynyas and their shapes.

In the stage of pre-processing different artefacts are removed in the images and their absolute calibration is done. For classification of wide swath (WS) Envisat ASAR images it is also necessary to account for the angular dependence of the sea ice backscatter coefficient. To reduce this effect the range-varying normalization, using empirical dependencies for the ice type dominant in the image, is applied. Elaborated methodology of backscatter recalculation to the predetermined incidence angle allows obtaining range independent contrast for the same ice types.

A back-propagation Neural Network algorithm together with expert knowledge was used for sea ice classification in Envisat ASAR WS images. The following image features were used in classification: backscatter coefficient, image texture features including correlation, inertia, cluster prominence, energy, homogeneity, and entropy, as well as 3rd and 4th order central moments computed over the distribution of pixel values within a small computation window. Further development of elaborated algorithm is connected with the analysis of polarimetric SAR information (see Figure 10). This work was published in *Alexandrov and Pritrovskaya (2008), in Earth Observation and Remote Sensing*.

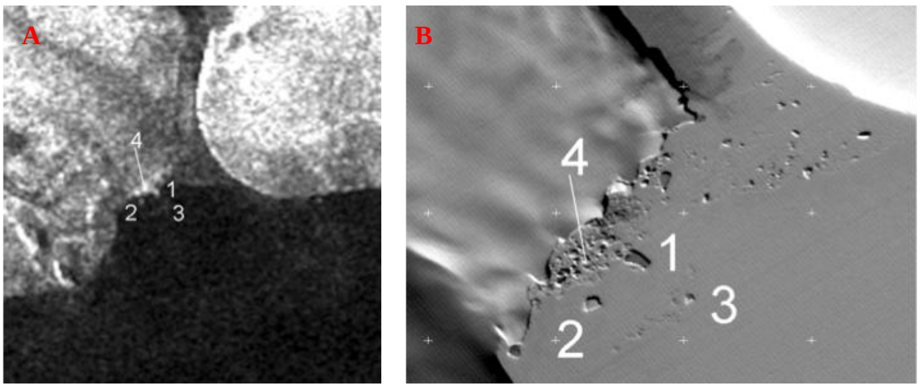

Fig. 11. Envisat ASAR sub-image (A) for April 5, 2006, and "Monitor-E" sub-image (B) for April 7, 2006, covering the area near outlet glacier in Franz Josef Land. Numbers indicate icebergs

Iceberg identification

The methods of identification of Arctic icebergs in visible Landsat, "Monitor_E", Terra, Aqua (ASTER and MODIS) satellite images and Envisat ASAR images has been developed, and features for iceberg detection are determined (Figure 11). Arctic icebergs can be located among open water, fast ice and drifting ice.

The conducted analysis revealed that iceberg monitoring by satellites should be based on using SAR and optical images with resolution of 10 meter or better. The technological scheme of combined use of different types of satellite information depending on ice and hydrometeorological conditions for iceberg identification was elaborated. The methodology consists of following procedures:

- Definition of the area under study
- Determination of iceberg detection conditions (open water, fast ice, drifting ice)
- Selection of image type (coverage and resolution) and search for available image in archive
- Image analysis: estimation of iceberg features and iceberg identification
- Validation of identification results using sequential images
- Combined analysis of identification results from satellite images in different spectral bands
- Composition of iceberg distribution maps
- Supplement of iceberg data base.

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