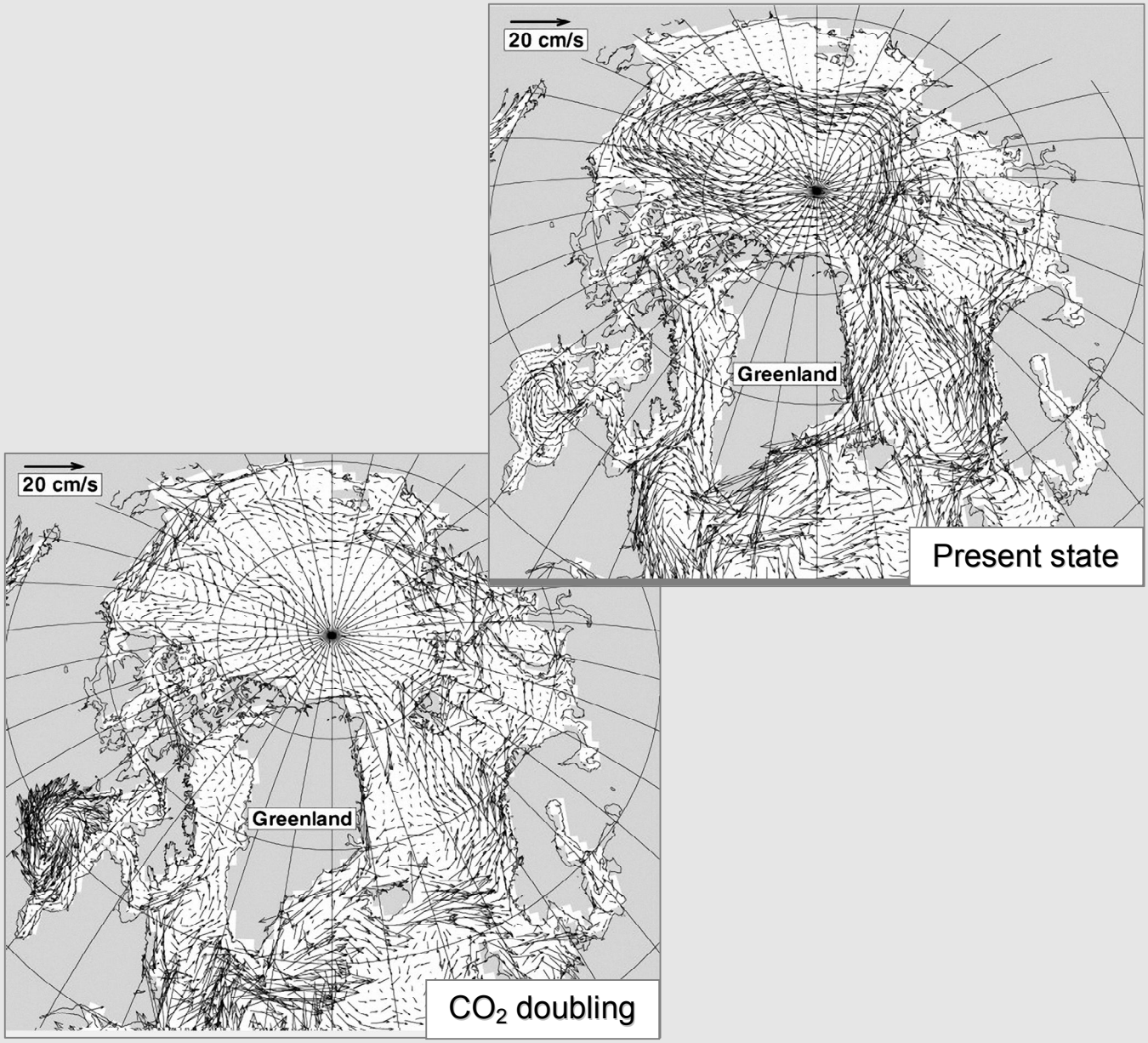
Annual Report 2009

Nansen International Environmental and Remote Sensing Centre

St. Petersburg, Russia

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

Founded in 1992



The Arctic Ocean circulation: substantial weakening projected

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Report from the General Meeting of Founders

Vision and Strategy

The Scientific Foundation "Nansen International Environmental and Remote Sensing Centre" (Nansen Centre, NIERSC) vision is to understand, monitor and predict climate and environmental changes in the high northern latitudes for serving the Society.

The overall strategy of NIERSC has been always targeted at a challenging task to develop the Nansen Centre to be a significant national and international contributor to the studies of climate and environmental changes in the high northern latitudes.

Major Research Areas

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

Organization

NIERSC is an independent non-profit international research foundation established by Russian, Norwegian and German research organizations. NIERSC 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 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 legislation on Non-Commercial Organizations of the Russian Federation.

NIERSC got a license for conducting meteorological and oceanographic observations from Roshydromet in 2006.

In 2008 Nansen Centre received also a license from Roscosmos for conducting the space-related research activities.

Staff

At the end of 2009 the Nansen Centre staff incorporated 25 employees comprising core scientists, including two full Doctors of Science and six with a PhD degree, part-time researchers, and administrative personnel. In addition, 10 Nansen Fellowship PhD-students are supervised and supported financially.

Production

During the year 2009, totally 48 publications were published including one book contribution, 7 papers in peer reviewed journals, 5 papers in other journals and 35 conference proceedings(the full list of publications is at the end of this report).

Workshops

Indo-Russian Workshop on Regional Climate Change was organized and held at Cochin, Kerala, India during October 8-9 2009 in collaboration with Nansen Environmental Research Centre, India (NERCI).

Nansen Fellowship PhD Programme

The main objective of the Nansen Fellowship Program at NIERSC is support of PhD-students at St. Petersburg University and other Russian educational and research institutions, including Russian State Hydrometeorological University, Arctic and Antarctic Research Institute. Its research areas are climate and environmental change and satellite remote sensing, including 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:

- Russian and international scientific supervision
- financial fellowship

Cover: Simulated Arctic Ocean surface circulation under present climate conditions and the CO_2 doubling global warming scenario. From: Johannessen et al. Radioactivity and pollution in the Nordic Seas and Arctic Region. Observations, modeling, and simulations. Springer–Praxis, ISBN: 978-3-540-24232, 2010

- efficient working conditions at the Nansen Centre
- training and research visits to international research institutions within the Nansen Group and beyond
- involvement into international research projects.

The postgraduate student activity is supervised by at least one Russian and one international senior scientist. All Nansen Fellowship PhD-students must publish their scientific results in the international refereed journals and make presentations at the international scientific symposia and conferences.

On 18 June 2009 Natalia Zakhvatkina (Piotrovskaya) defended her PhD thesis *"Arctic sea ice classification using satellite SAR data"* at the Arctic and Antarctic Research Institute; supervisors: Prof. Ivan Ye. Frolov, Dr. Vitaly Yu. Alexandrov, Prof. Ola M. Johannessen (see thesis summary in the Scientific Report).

20 young Russian Ph-students have since 1997 got their doctoral degree under the Nansen Fellowship Program.

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, Russian State Hydrometeorological University, Voeikov Main Geophysical Observatory, Murmansk Marine Biological Institute, Research Centre of Operational Earth Monitoring and other, 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 Centre in Bergen. Most of scientific results described below are achieved within the joint research activities of both Nansen Centres, in St. Petersburg and Bergen, and cooperating partners

Research Projects

Below is the list of the research projects implemented at NIERSC in 2009. Most of them were implemented in close cooperation with other national and international scientific institutions.

Completed 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)

Monitoring the marine environment in Russia, Ukraine and Kazakhstan using Synthetic Aperture Radar (MONRUK, EU FP6, 2007-2009)

Ocean color (IFREMER, 2008-2009)

SAR-ocean (IFREMER, 2008-2009)

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

Satellite water quality products for Kaspian and Azov seas (NTsOMZ/Roscosmos, Federal Russian Budget, 2009)

Modeling the dynamics of consumer goods production and business cycles in MADIAMS (Multi-Actor Dynamic Integrated Assessment Model System) (Nansen Scientific Society, 2009)

Modeling the climate dynamics of St. Petersburg in 21st century in a coupled climate-socioeconomic integrated assessment model (St. Petersburg City Administration, 2009)

On-going projects

Developing Arctic Modeling and Observing Capabilities for Long-term Environment Studies (DAMOCLES, EU FP6, 2006-2010)

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

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

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)

New projects

MyOcean (EU FP7 GMES, 2009-2012)

Assessing the Sensitivity of Arctic Coastal Dynamics to Change (Helmholtz Gemeinschaft, 2009-2012)

New research topics

In 2009 several new research topics were established at NIERSC:

- Climate change related socioeconomic research. Establishment of the "Climate-socioeconomic Group".
- Permafrost studies:
  - Modelling methane emission from thawing of permafrost. Positive climate feedback.
  - Permafrost studies using remote sensing from satellites.
- Arctic polar low studies using satellite monitoring and climatology.

Prospects for 2010

In 2010 the NIERSC staff is encouraged to further increase the number of publications in peer reviewed journals. Much attention will be paid to timely and detailed publications of results from PhD-students in Russian and at the international peer-reviewed journals.

While continuing the intense research work in the framework of international projects, NIERSC staff also faces the challenge to become involved more actively in research activities at the national level.

St.Petersburg, 13th April 2010

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Ola M. Johannessen, NERSC *Guardian Board, Chair*
Leonid P. Bobylev,*Director*

SCIENTIFIC REPORT

Multi-year ice in the Arctic – present state

Dr. Elena V. Shalina

Prof. Stein Sandven, NERSC

Satellite passive microwave data available for the period since October 1978 provide an efficient tool for monitoring sea ice in the Arctic. At NIERSC sea ice concentrations are generated from these data using the NORSEX algorithm.

In recent years, a large amount of change has been observed in the Arctic sea ice cover. One of the most important changes is the decrease of the area and volume of multiyear (MY) ice.

The main limitation of passive microwave algorithms for retrieval of MY ice concentrations is a number of pixels erroneously classified as MY ice that multiply throughout the winter season. QuikSCAT scatterometer data helps to correct the instances where passive microwave algorithm incorrectly classifies first year (FY) ice as MY ice owing to persistent contrast in scatterometer data between FY and MY ice during the winter. QuikSCAT data is available starting from July 1999 until November 2009. Our estimation of the MY ice area change over the passive microwave observations era gives the decrease of 12.7 ± 1.8% per decade, which makes about 40% decrease over the 30 years period of satellite observations. This estimation is made basing on November MY ice concentrations that contain minimum erroneously classified MY ice. Joint processing of passive microwave and scatterometer data provides us with the details of MY ice changes during the winter. The most remarkable alterations occurred in 2007, during which year the Arctic lost a large amount of MY sea ice. This, together with minimum replenishment of MY by FY ice during the end of the melt season, contributed to the record-low extent of MY ice in 2007. It was not possible for MY ice to restore in two next years after that loss.

Concerning summer ice, while 2009 September minimum ice extent was greater than in 2007 and 2008, it was still significantly below the long-term average. Remarkably that thin first- or second-year ice, rather than thicker matured ice, dominated in the 2009 September ice cover (see Fig. 1).

This study is published in Shalina (2009) – for this and other references see the List of Publications on pp. 10-11.

Enhancing techniques for mesoscale low studies using satellite data

Dr. Elizaveta V. Zabolotskikh

Dr. Leonid P. Bobylev

Intensive mesoscale cyclones at high latitudes, also known as polar lows, represent short-living intensive mesoscale atmospheric low pressure weather systems, developing poleward of the main baroclinic zone and associated with high surface wind speeds. Polar lows can be observed in both hemispheres, but the Arctic polar lows are significantly more intensive than their southern counterparts. But it was only with the general availability of imagery from the polar orbiting weather satellites from the 1960s that it was realized that these phenomena were quite common. Polar lows (PLs) are characterized by the wind speed exceeding gale force (17 m/s); and their size is usually of the order of less than a few hundred kilometres.

NIERSC started the study of polar lows from satellites using multi-sensor approach in 2008. Basically this study was based on the use of retrieved from Special Sensor Microwave/Imager measurements water vapour fields, revealing vortex structure associated with polar low development. In 2009 the methodology for mesoscale cyclone studies was further enhanced with much attraction of other data, including all available data sources.

Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) data have better (almost twice) resolution than those of SSM/I. This allows identification of much more detailed structures of water vapour fields inside polar lows. Moreover, sometimes the cyclones, not identified by SSM/I instrumentation, can be seen on AMSR-E retrieved water vapour fields, as for example, presented on Fig. 2.

To use this invaluable source of data the algorithms for atmospheric water vapour content and cloud liquid water content should have been tuned and calibrated for AMSR-E data. This work is still under development since AMSR-E measurement data do not have such stable in-orbit calibration as SSM/I. The calibration process includes further enhancement of the geophysical model used for brightness temperature calculation during numerical experiment used for the algorithm development. Such an enhancement is needed since new

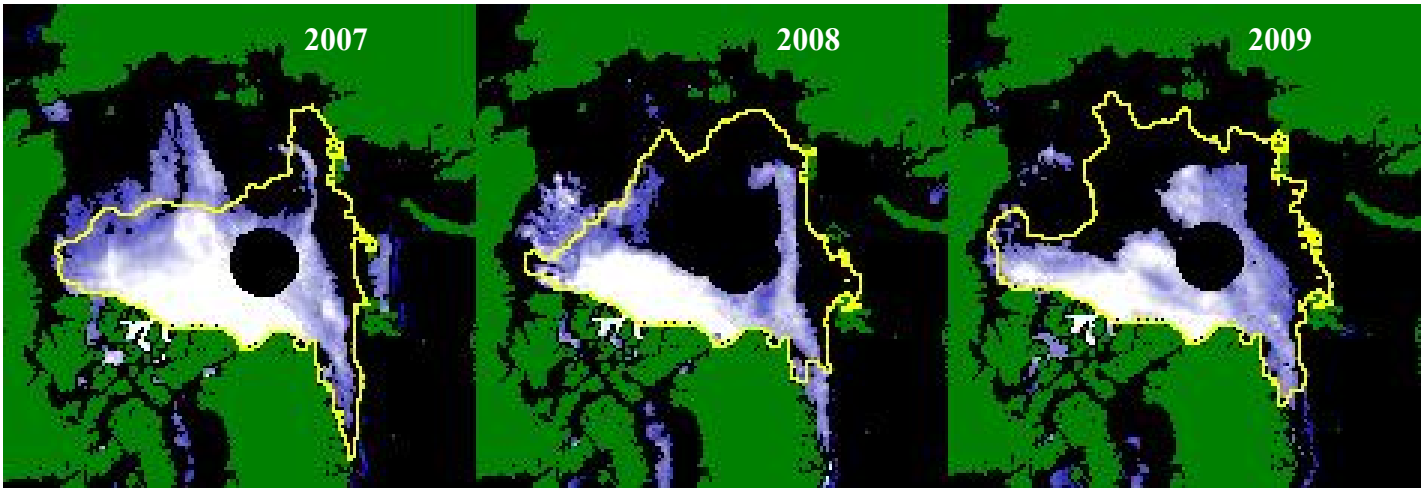

Fig. 1. Multi-year ice extent at the end of March (approximately the end of winter) and the total sea ice cover in September at the end of melting period (yellow line). Note that some MY ice drifts out or possibly melts between March and September.

research results appeared in the scientific community concerning the models of the electromagnetic radiation interaction with the Atmosphere-Ocean System (AOS). Also the database of simultaneous in-situ meteorological and hydrological observation data is needed for the calibration of AOS geophysical model, bringing it into accordance with measured AMSR-E brightness temperatures. This work on the algorithm calibration for AMSR-E instrument is not finished. In parallel in 2009 further processing of Envisat ASAR archive images for the Nordic seas was fulfilled aiming at the identification of the new polar lows. CMOD-4 model function was used for wind speed retrievals inside polar lows. Additional QuikSCAT- wind fields retrieved with the same model were also used since QuikSCAT data are distinguished by their free availability and regularity, especially in the high latitude region, in comparison with expensive and rare SAR data. The usage of active microwave instruments in the study of the polar lows has the limitation of the saturation of the backscatter signal in the area of high wind speed values. This limitation is planned to be overcome by using passive microwave instrument for wind speed retrievals and development of special wind speed retrieval algorithm for AMSR-E instrument.

This study is published in Bobylev et al. (2010) in IEEE Transactions on Geoscience and Remote Sensing.

Permafrost thermal regime and soil gases transport simulation

Mr. Ivan A. Sudakov, PhD-student

Dr. Leonid P. Bobylev

Prof. Ola M. Johannessen, NERSC

A large fraction of the frozen soil carbon stocks of the northern latitudes are prone to disappear in a future warmer world, following permafrost thawing. If the frozen Arctic carbon pools would thaw extensively, it would lead to massive emissions of greenhouse gases to the atmosphere, acting as a strong positive feedback on climate change in the next centuries.

The goal of this study is to propose new methods for describing the thermal regime of permafrost and transport of soil gases to be used in models of permafrost carbon cycle.

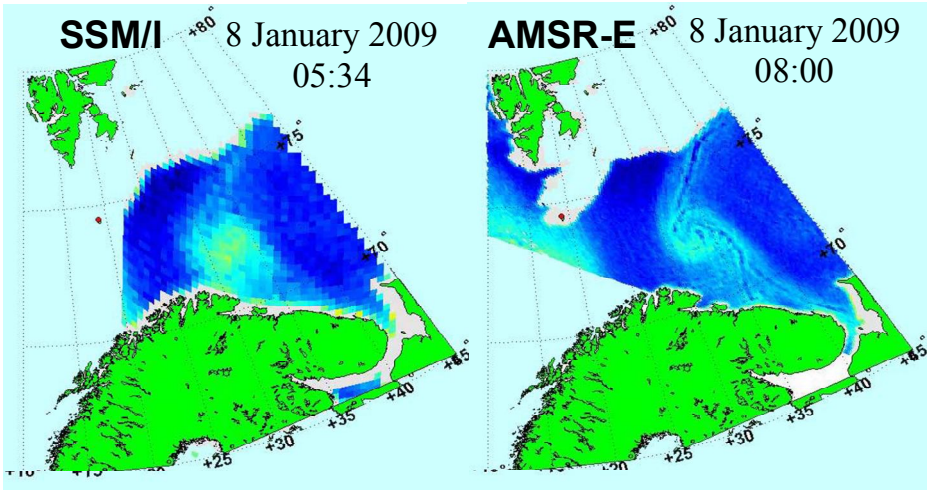

Fig. 2. SSM/I (on the left) and AMSR-E (on the right) retrieved water vapour fields inside the polar low developed in the Barents Sea on 8 January 2009.

They are as follows: 1) simulation of abiogenous methane emission from permafrost using new permafrost thermal regime model; 2) simulation of soil gases diffusion in the aerobic zone of permafrost using the Monte Carlo method.

For the study of abiogenous methane emission from permafrost we proposed to use 1D model of permafrost thermal regime and abiogenous methane emission – TRAME 2.0 model *(Sudakov et al, 2008)*. In this model: 1) permafrost is a monophase system with constant effective thermal characteristics; 2) the non-stationary equation of heat conductivity is used for the description of permafrost thermal regime; 3) improved algorithm CONDUCT *(Patankar, 2003)*is used for numerical simulations of permafrost thermal regime; 4) temperature of ground surface is taken from general circulation model ECHAM 5. Calculation using TRAME 2.0 model showed that abiogenous methane emissions can increase by a factor of 2.5 by the end of 21st century (Fig. 3).

Using the Monte Carlo method we showed that the diffusive transport of methane in thawing permafrost is

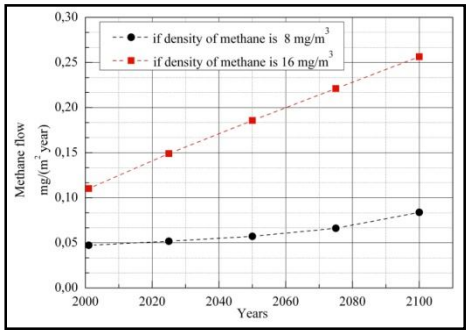

Fig. 3.Abiogenous methane flow through an ever-frozen layer (for Yamal Peninsula, Russia).

significantly less intensive than other types of transport.

This study is accepted for publication inHerald of St. Petersburg University, 2010.

Atmosphere-ocean interaction studies

Prof. Vladimir N. Kudryavtsev

Mr. Alexander G. Myasoedov, PhD-student

Mr. Igor E. Kozlov, PhD-student

Prof. Johnny A. Johannessen, NERSC

The primary activities during 2009 include:

- Studies of the air-sea interaction at high wind conditions and effects of non-linear interactions on formation of short wind wave spectrum.
- Development of a new innovative approach for synergetic analysis of SAR and optical images for investigations of the ocean circulation phenomenon.
- Investigation of SAR signature of the upwelling in the sea.

These investigations were carried out within the frame of following projects lead by the group: FP6 MONRUK Project, MAREBAS Project funded by Research Council of Norway, and a contract with IFREMER

Generation of sea spray

A theoretical model of the spume sea spray generation is suggested. The model is based on arguments that most of spume droplets are generated by breaking of the equilibrium range wind waves.

Spume droplets being torn from an individual breaking wave are injected into the airflow at the altitude of a breaking wave crest. The pulverization of water/foam into droplets takes place in a thin turbulent boundary layer adjacent to a breaking wave crest. Adopting Kolmogorov's [1949] ideas it is shown that the distribution of droplets over radii is proportional to the radius to the power 2. The equilibrium range waves are strongly modulated by dominant wind waves that leads to the enhancement of their breaking, so that the production of spume droplets occurs in the vicinity of the dominant wind waves crests, where from they are injected into the airflow. Solving equation for the droplets concentration the spray generation function can be obtained and compared with empirical functions. Few empirical functions were selected for the comparison and a reasonable agreement in the spectral level, integral flux and shape of the spray generation function is found.

This study is published in Kudryavtsev, Makin (2009)in Geophys. Res. Lett.

Generation mechanisms of capillary-gravity wind wave spectra

This study is aimed on investigation of the role of different generation mechanisms in formation of capillary-gravity wind wave spectra. The following governing mechanisms are considered: 3-wave resonant interaction, viscous dissipation, wind input, non-linear dissipation, and generation of parasitic capillaries. 3-wave interactions are taken into account in the "exact" formulation, – as a collision integral. It is shown that action of 3-wave interaction results in instability of the wave spectra unless a non-linear dissipation is included in the energy balance. In gravity range this dissipation is associated with micro-scale wave breaking, while in the capillary range – with a non-linear limitation of the capillary waves slopes if they are approaching a threshold steepness. Model simulations shows that impact of 3-wave interactions on spectral shape is only important in the very vicinity of k corresponding to the minimum of phase velocity. Above and below this band, the role of the resonant wave-wave interactions is minor, and wind forcing, non-linear dissipation and generation of parasitic capillaries dominate the spectral balance. Improved spectrum of short wind waves can further be implemented in SAR studies.

This study by Kosnik, Dulov and Kudryavtsev is accepted for publication inIzvestiya RAN, Physics of Atmosphere and Ocean, 2009.

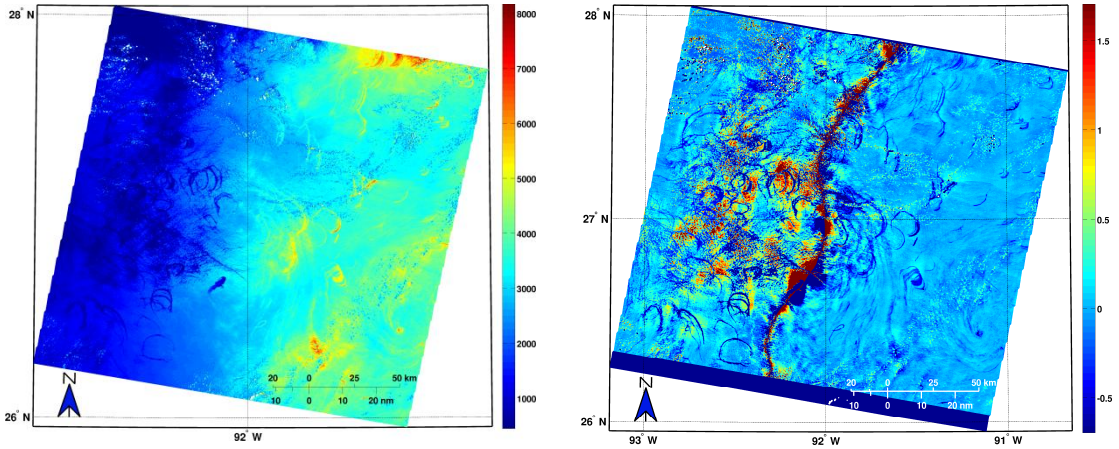

Fig. 4. Left: fragment of the MODIS image in red channel 645nm of the Gulf of Mexico with sunglint signatures of natural oil seeps; right: retrieved MSS contrast caused by natural oil seeps.

Sun glitter imagery of the ocean surface phenomena

This activity is targeted on development of an advanced synergistic approach for analysis of SAR and optical scanner data for detection of oil spills and mesoscale ocean dynamics and its surface signatures.

The space optical scanners (e.g. MERIS, MODIS) produce almost daily worldwide coverage which results in a large volume of imagery that has sunglint. In this context the optical sensors can be considered as the instruments complementary to the SAR that may potentially be used for the oceanic surface phenomena survey on a near-global scale. In spite of numerous efforts, the physics of SAR imaging of the ocean phenomena is not properly investigated and the mechanisms leading to manifestation of the ocean phenomena on the sea surface are still poorly understood. In order to better understand physics of surface manifestation, a new "SAR-independent" data source on the surface signatures is desirable. Sunglint imagery opens such an opportunity. In this case, there is a possibility to analyse surface signatures in terms of fundamental

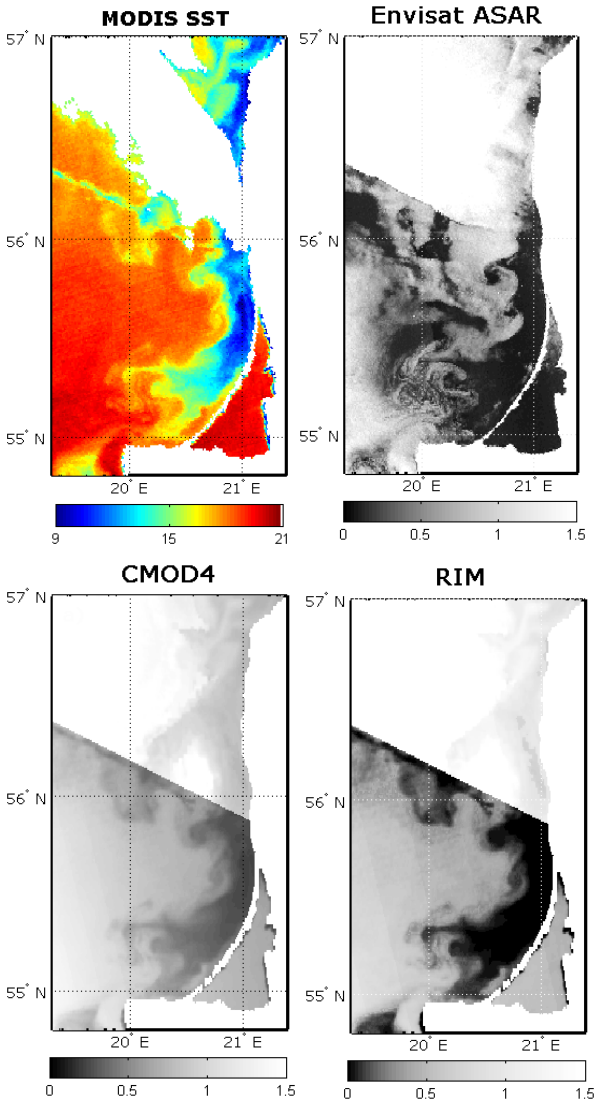

Fig. 5.Coastal upwelling signatures in the southeastern Baltic Sea on MODIS SST at 20:10 UTC (upper left) and Envisat ASAR at 20:11 UTC (upper right) on 19 July 2006.Modeled NRCS from CMOD4 (bottom left) and RIM (bottom right).

parameter of the sea surface roughness, - its mean square slope (MSS).

The goals of the present study are to develop a method for quantification of the surface signatures in terms of the MSS anomalies, and to demonstrate ability of the proposed method for quantitative estimates of the MSS signatures of the oil slicks, meso-scale currents and internal waves. Fig. 4illustrates the ability of developed approach. In this Figure the MODIS images of the Gulf of Mexico possessing well visible sunglint brightness features related to the natural oil spills are presented. Analysis of these data gives us values of the oil slicks contrasts in MSS and their dependence on wind speed. It is anticipated that synergy of these and SAR data provides a possibility to discriminate oil slicks from biogenic origin.

This study is published by Kudryavtsev et al. in Proceedings of the SeaSAR-2010 Workshop.

Investigation of SAR signature of the upwelling in the sea

In this work SAR signatures of coastal upwelling event in the southeastern Baltic Sea are investigated. Observed upwelling signatures (Fig. 5, upper right) were analyzed within the frame of the model approach accounting for the effect of atmospheric stratification only. The model spatial distribution of the surface wind stress over the SST front (Fig. 5, upper left) was used for radar backscatter calculations on CMOD4 and RIM models.

It was found that impact of varying SST field on wind stress via stratification factor is the primary mechanism responsible for upwelling manifestation in SAR imagery. Model calculations are in qualitative agreement with the observations. Calculations of NRCS on CMOD4 and RIM models showed a good overall agreement with observed SAR signatures. At the same time both models demonstrated some under- and over-estimations of NRCS, which presumably resulted from uncertainties in specification of geostrophic wind field as input parameter for model calculations.

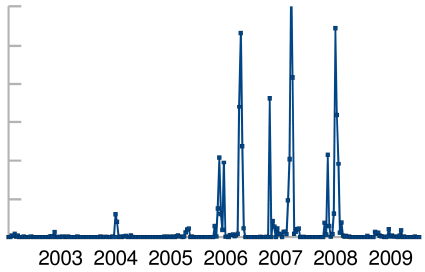

Fig. 6. Dynamics of the L. chlorophorum blooming events in the D'Iroise Sea as established from MODIS-Aqua observations

This study is published in Proceedings of the SeaSAR-2010 Workshop.

Aquatic ecosystems in response to global change studies

Prof. Dmitry V. Pozdnyakov

Dr. Anton A. Korosov

Mr. Eugeny A. Morozov, PhD-student

Dr. Olga G. Aniskina

Mr. Dmitry A. Petrenko, PhD-student

Mr. Lasse H. Pettersson, NERSC

Investigation of the *Lepidodinium chrlorophorum* blooming phenomenon in the Biscay Bay

Satellite identification and surveillance of the spatio-temporal dynamics of blooming of harmful algae –is a topical challenge for contemporary remote sensing of the world's oceans. The main impediment for the problem solution is development of appropriate algorithmic tools. Marine microalga *L.chlorophorum*was described in the literature only recently (in 1996!), the data on this species are extremely scarce, and the perception that it belongs to HABs came only several years ago.

Under a bilateral IFREMER-NIERSC Agreement, we developed two original bio-optical algorithms for *L.chlorophorum*intended for processing MODIS-Aqua data. Based on the techniques of neural networks and fuzzy logic of *c*-means, the algorithms are mutually independent, based on and intended for an ensemble application in order to enhance the reliability of the developed algorithm.

The developed ensemble approach has been applied to the Biscay Bay waters. It permitted to objectively identify the bloomings of this species as well as the dynamics of the phenomenon occurrence. Fig. 6 indicates that *L.chlorophorum* blooming in the D'Iroise Sea had not been occurring until 2006; onwards, there was a series of annual outbursts of this species. Possibly, this indicates that they are somehow related to the dynamics of

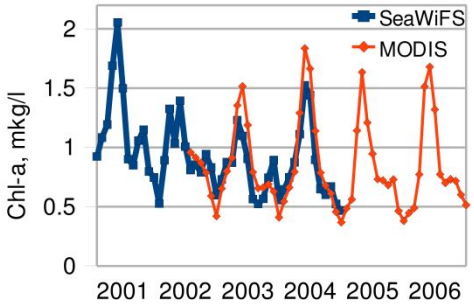

Fig. 7. Coastal zone-averaged SeaWiFS – MODIS bridged data on the Bay of Biscay obtained with the NIERSC methodology

ongoing global changes. Importantly, the new approach is not marine area specific and is widely applicable.

This study is accepted for publication inEarth Observation and Remote Sensing, 2010..

Assessment of compatibility of satellite ocean colour data and investigation of phytoplankton growth dynamics in the coastal zone of the Bay of Biscay

Merging/bridging of data from ocean colour satellite sensors, such as SeaWiFS and MODIS-Aqua is an important task within the framework of investigation of the spatio-temporal dynamics of biogeochemical processes in the world's oceans. Assessment of compatibility of data from two ocean colour sensors is particularly challenging when dealing with case-2 waters (e.g. inland and marine coastal waters).

Under the bilateral IFREMER-NIERSC Agreement, we conducted such a study for the Bay of Biscay. Employing a very large databank of shipborne/in situ measurements we developed dedicated algorithms for the retrieval of water quality parameters in the bay's coastal zone from, respectively, SeaWiFS and MODIS-Aqua data. Our retrievals have shown that both sensors yield very close results and identically reflect the seasonal dynamics of the phytoplankton growth within the coastal zone. The developed algorithmic approach permitted to define the temporal boundaries of such phenomena annually occurring in the Bay of Biscay as resuspension of bottom sediments or else analyze the temporal dynamics in the onset, duration and intensity of blooming events of phytoplankton (including calcifying alga *Emilianiahuxleyi*) over a long time period. The merged data (partially exemplified in Fig. 7) indicate that in period from 2005 to 2009, in the target waters there occurred a significant enhancement of

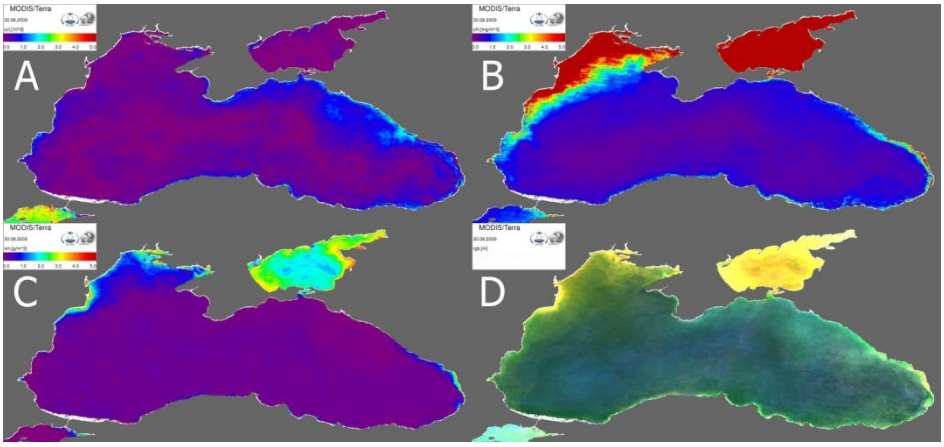

Fig. 8. Concentrations of coccoliths (A), phytoplankton chlorophyll (B) and suspended minerals (C) as well as an RGB composite of channels 2, 5 and 6 as averaged in the Black Sea over the summer time in 2009.

phytoplankton growth, which, like in the case of *L.Chlorophorum*, is possibly a consequence of the ongoing global changes.

This study are summarized in the paper submitted by Morozov et al. to International Journal of Remote Sensing, 2010.

Impact of weather and climate changes on the Arctic coastal zone

An important feature of the Arctic seas is that there is ice beneath the bottom as well as seasonal marine surface ice cover. Erosion of the Arctic seas coastal line is triggered by both the mechanical action of the sea ice, and wave- and thermal-driven degradation/erosion of permafrost seabeds. The joint RFBR-Helmholtz Association project addresses the challenge of a quantitative assessment of the shore line position dynamics. The rate of the coastline erosion drops down with the decrease of the extent, duration and thickness of ice cover (especially fast ice) as well as with the increase of intensity and occurrence frequency of storms, which is typical of climate warming. According to various assessments, the coastline regression within the Euro-Asian part of the Arctic Basin can attain values between 1 and to 10 m per year. The coastal erosion drives a significant enhancement of organic carbon, suspended minerals and nutrients fluxes in the Arctic Seas. In combination with reduction of the sea ice extent (i.e. increase in available photosynthetic solar radiation in the water column during the peak melt season), the transport of nutrients is bound to result in intensification of both phytoplankton growth and bottom-up trophic interaction. Satellite borne ocean colour sensor can detect, survey and quantify the manifestations of the above consequences driven by climate change-driven impacts. SeaWiFS and MODIS data for 1998-2009 are used to reveal the dynamics in remotely-determined parameters. These will further be subjected to analysis together with ground-truth data in order to reach some definite conclusions about the climate-change-driven dynamics of the coastal line.

Development of an operational system of monitoring of water quality in the Black, Azov and Caspian Seas

Under the NIERSC contract with Roscosmos, we developed a system of operational monitoring of the ecological state of the Black, Azov and Caspian Seas making use of the hardware facilities at NTsOMZ. The system uses MODIS-Terra information as input data for the retrieval of: (*i*) concentrations of phytoplankton chlorophyll, mineral suspended matter, dissolved organics, and coccoliths, (*ii*) spectral coefficient of diffuse attenuation, (*iii*) Secchi disc depth and (*iv*) water surface temperature. The satellite data are processed with the NIERSC neural network bio-optical algorithms. Satellite data processing is effected via employing a sub-layer, module approach. This simplifies use of the developed package for different target water bodies as well as for data acquisition from other satellite sensors. Available at http://87.237.43.66:5580, a web-interface is developed for reviewing current and past/archival processed satellite data.
Fig. 8 illustrates the MODIS-Terra data processing results for 2009 obtained over the Black and Azov Seas. Analysis of the retrieved monthly-mean spatial distributions of some of the water quality parameters and further comparison with the relevant reports in the literature indicate that the attained results are of high accuracy and adequately portrait the water quality status throughout the Black Sea.

Development of techniques for sea ice monitoring in the Arctic

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In 2009 Met-Ocean Group continued developing techniques of sea ice monitoring in the Arctic Ocean, interpretation and processing of satellite images of the sea ice. A PhD thesis on elaboration of neural network (NN) approach for classification of sea ice types in SAR images was defended by Dr. Natalia Zakhvatkina. The NN approach for classification of SAR and AMSR-E images for the ice edge region has been developed.

Besides this the Bayesian approach has been implemented for classification of sea ice types in SAR images and retrieval of partial concentration of multiyear ice in the Central Arctic. The range-varying normalization, using empirical dependencies for the multiyear ice was applied in the first stage. After that a decision is made in favor of ice type with a maximum aposteriori probability, which is calculated from conditional probability of sigma-zero (NRCS) and a priori probability for each ice type. Conditional probabilities were derived from calibrated ENVISAT ASAR images. Using this algorithm a series of ENVISAT ASAR WS images, acquired in the region to the north of Greenland, was processed.

The major areas of multiyear ice and leads are classified correctly. Some of the pixels of multiyear ice are erroneously classified as level or deformed first-year ice due to overlapping of their sigma-zero values.

Studies were conducted on developing approach for ice thickness retrieval from radar-altimeter data. Retrieval of

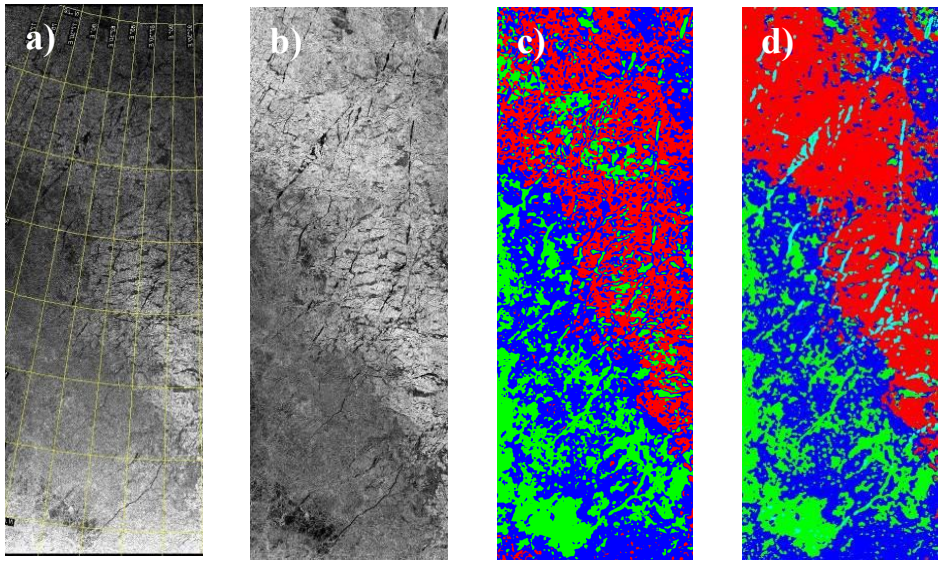

Fig. 9. An example of the application of the developed algorithm for ENVISAT ASAR image classification.18 January 2008, Central Arctic.

a) Raw ASAR WSM image (150-m resolution, the swath width is approximately 400 km).
b) Image corrected using elaborated methodology.
c) ASAR image classification using trained NN for three ice types derivation.
d) ASAR image classification – the result of consecutive application of the two trained NN for four sea ice types.

Colors of classified image (c and d): green – FY level ice, blue – FY deformed ice, red – MY ice, blue – calm open water/nilas.

sea-ice thickness from radar altimeter freeboard data requires surface observational data to determine and understand the relation between the two variables. In this study, extensive *in-situ* ice and snow data from about 680 observation sites obtained during the Russian 'Sever' expeditions have been used to establish a new empirical relation between ice thickness and freeboard. The hydrostatic equilibrium equation to estimate ice thickness as function of ice freeboard, snow depth and snow/ice density. It is found that uncertainties of ice density and freeboard are the major sources of error in ice thickness calculation. The derived relations have been verified by comparing with independent *in-situ* measurements of ice thickness and freeboard, and the average differences between measured and calculated thicknesses of first-year ice are less than 0.2 m. These relations can be used to estimate ice thickness from freeboard measurements from by satellite altimeters such as on CryoSat-2.

An algorithm of sea ice drift retrieval, based on cross-correlation approach, was developed and tested using ENVISAT ASAR images of the Fram Strait and Barents Sea. Its accuracy was estimated by comparison with manually derived ice drift vectors and found reasonable. At present time a technology of obtaining ice drift data from SAR images using this approach is under development. Its aim consists in deriving ice drift data for studies of ice drift conditions in the Arctic seas and ice exchange with the Arctic Basin, verification of dynamic-thermodynamic ice model and also assimilation of ice drift data in this model.

This study is presented in Alexandrov et al. (2009) and in paper submitted to Cryosphere.

Sea ice types identification in the Arctic Ocean using SAR

(Summary of PhD thesis)

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A multilayer feed forward Neural Network (NN) algorithm is developed for the Arctic sea ice classification during the winter period. The algorithm can be applied to ENVISAT Advanced Synthetic Aperture Radar (ASAR) images using extracted backscatter coefficients and image texture features. Based on the visual interpretation of ASAR images, a neural network is trained for the classification of the first year (FY) level or deformed ice and multiyear (MY) ice. The algorithm validation is done using Arctic and Antarctic Research Institution (AARI) ice charts and ice expert visual analysis. Preliminary neural network classification errors are 15% for level first year ice, 17% for deformed first year ice and 20% for multiyear ice (Fig. 9).

The backscatter coefficients for the major sea ice types at HH–polarization and 23° incidence angle, as well as angular dependencies of the backscatter for young, first-year and multiyear ice types are derived from calibrated ENVISAT ASAR Wide Swath Mode (WSM) images. A methodology is developed for the backscatter angular correction for the predetermined incidence angle for obtaining range independent contrast for the same ice types. The backscatter coefficient data sets for various Arctic winter sea ice types at HH–polarization and 23° incidence angle are derived from Envisat ASAR image analysis.

The Alternating Polarisation images from ENVISAT ASAR have been analyzed over sea ice areas for various parts of the Arctic. The most promising results suggest using HH and VV polarisation to discriminate ice and open water at high incidence angles (swath IS5 – IS7). Also classification of multiyear, first year and thin ice types can be improved by the use of polarisation data. Some recommendations are given concerning the combination of co-and cross-polarisation which is optimal for the ice type classification for better detection.

This study is published in Zakhvatkina et al. (2009).

Studies on socioeconomic impact of climate change

Dr. Dmitry V. Kovalevsky

Prof. Valentin P. Meleshko

Dr. Leonid P. Bobylev

Prof. Klaus Hasselmann, MPI-M/ECF

Prof. Carlo Jaeger, PIK/ECF

NIERSC is involved in the development of the Multi-Actor Dynamic Integrated Assessment Model System (MADIAMS) in close cooperation with Prof. Klaus Hasselmann (Max Planck Institute for Meteorology). MADIAMS simulates possible trajectories of the coupled climate-socioeconomic system. In 2009 the main focus was on further developing the socioeconomic module

of MADIAMS, focusing on the treatment of the production of consumer goods and services in a non-equilibrium framework. In parallel, the earlier version of MADIAMS was applied to the studies of St. Petersburg regional climate in the 21st century under different socioeconomic scenarios.

Besides modeling efforts, a qualitative study of contemporary Russian climate policy and options for its further development was performed, and some elements for possible win-win strategy on climate change were suggested.

This study is published in Jaeger et al., ECF Working Paper (2009).

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