ARCTIC REGIONAL OCEAN OBSERVING SYSTEM: ARCTIC ROOS

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ABSTRACT

The main objective of Arctic ROOS is to promote, develop and maintain operational monitoring and forecasting of ocean circulation, water masses, ocean surface conditions, sea ice and biological/chemical constituents at high latitudes. This information can only be achieved by close integration of data from in situ observations (ships, moorings, buoys, floats), remote sensing (satellite, aircraft, land based), and from numerical models using data assimilation techniques [1]. During the International Polar Year (IPY) 2007 – 2009 there were enhanced observational efforts of the Arctic and sub-Arctic seas, with testing and implementation of new instruments and platforms for data collection and data transmission. These efforts have resulted in increased amounts of data from the Arctic seas, and Arctic ROOS members are making significant contribution to dissemination of these data and building up know knowledge about the Arctic.

INTRODUCTION

The Arctic Regional Ocean Observing System (Arctic ROOS) has been established by 15 institutions[1] from nine European countries working actively with ocean observation and modelling systems in Arctic and sub-Arctic seas. The main components of Arctic ROOS are (1) satellite observations from polar orbiting satellites using active and passive microwave, optical and infrared instruments, (2) numerical modelling including data assimilation, nowcasting, short term forecasting, model comparison and validation, and (3) In situ observation systems based on ship-borne instruments, moored instruments, ice buoys, floats and drifters. Satellite observations of seas ice, wind, waves, oil spills and ocean colour parameters have been developed extensively in recent years with support from GMES projects[2] funded by European Space Agency (ESA) and EU as well as national programmes. Modelling and forecasting systems have been developed through several EU-funded projects, in particular MERSEA IP, which is completed in 2008 (http://www.mersea.eu.org/) and MyOcean going from 2009 to 2012 (http://www.myocean.eu/). The in situ component of the Arctic ocean observing system is the least developed. In a few places, such as the Fram Strait, moorings have been deployed for more that ten years, measuring ocean and sea ice parameters. Hydrographical surveys from ships have been performed in ice-free waters for many years, but the ice-covered ocean is not observed by ship-mounted systems, except during expeditions taking place mainly in the summer period. During IPY 2007 – 2009[3] there are, however, several research projects developing new observing systems for ice-covered areas [2]. It is expected that several types of ice-platforms providing oceanographical and sea ice data will be operated in the coming years. Several EU projects are contributing to Arctic ROOS, in particular DAMOCLES[4] funded by FP6, MyOcean and ACOBAR[5] funded by FP7. Arctic ROOS is a contribution to the IPY project no. 379: "IPY Operational Oceanography for the Arctic Ocean and adjacent seas" coordinated by Prof. Ola M. Johannessen.

SATELLITE OBSERVATIONS

Satellite observation of sea ice using passive microwave, scatterometer, SAR and infrared/IR data is now available from several operational services, as shown on www.arctic-roos.org. Ice concentration, ice area and extent is produced daily, showing seasonal and interannual variability in all Arctic and Antarctic regions [3]. The record low ice extent in September 2007, which was documented by satellite observations, caused extensive debates on climate change and melting of the Arctic sea ice. The record low ice extent was associated with a strong Transpolar Drift observed by the polar ship Tara, drifting across the Arctic from Laptev Sea to the Fram Strait [4]. This strong drift was caused by dominant wind forcing combined with already thinned ice from the previous year and relatively high air temperatures in the Arctic.

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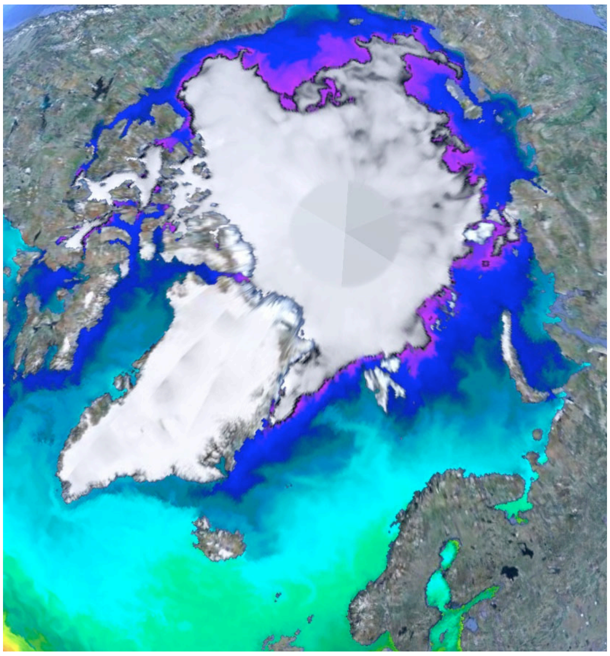
[1] See list of member institutions in Appendix 1.

[2] An overview and description of Global Monitoring for Enviroment and Security (GMES) projects are found at http://gmes.info/180.0.html

[3] International Polar Year 2007 – 2009. http://www.ipy.org

[4] DAMOCLES Integrated Project: Developing Arctic Modeling and Observing Capabilities for Long-term Environmental Studies: http://www.damocles-eu.org

[5] ACOBAR: Acoustic Technology for observing the interior of the Arctic Ocean: http://acobar.nersc.no/



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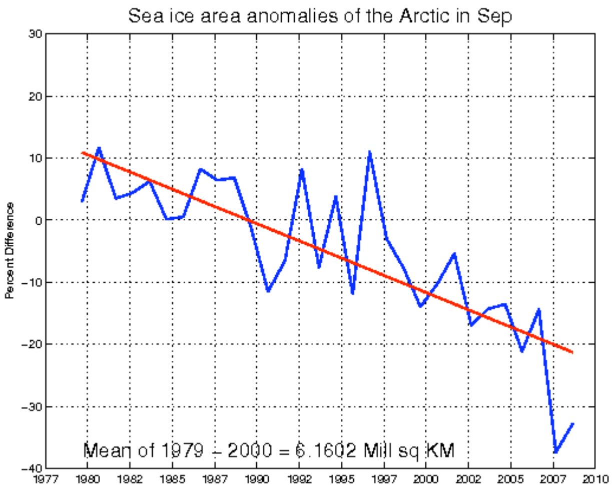

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Figure 1: (a) Ice concentration (graysale) and sea surface temperature (colour) from TOPAZ-3 model simulations, showing ice extent in August 2009; (b) time series of monthly mean Arctic ice area anomaly in percent relative to the mean for September based on satellite data from 1978 to 2008. The reduction in summer sea ice extent has been about 10 % per decade, while the reduction in winter is much smaller, 2 – 3 % per decade (http://arctic-roos.org).

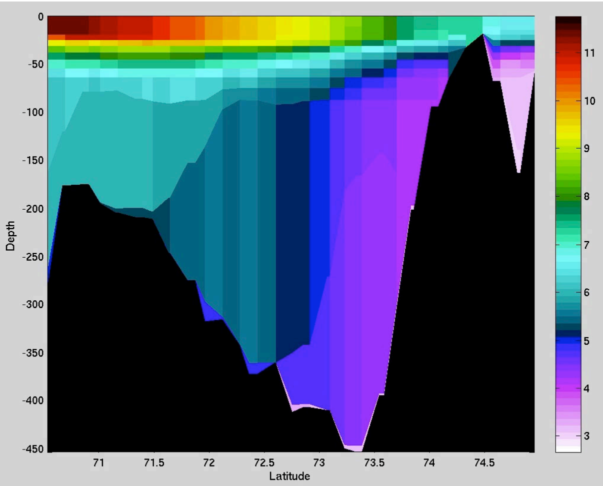
Monitoring of multiyear ice is particularly useful because the reduction of summer ice is directly determining the amount of the multiyear ice in the following winter. In the MERSEA project improved multiyear retrieval has been developed which combine SSM/I data with scatterometer data. Analysis of multiyear ice area since 2002, when QuikSCAT scatterometer data became available, shows a dramatic reduction, especially from 2005 to 2008 [5]. The winter ice area has been reduced much less, implying that a lager part of the ice cover consists of first-year ice that is much thinner than the multiyear ice. This means that the melting in summer will be enhanced and the decrease of the summer ice will continue.

Observation of ice drift from satellite data is progressing with several ice drift products available at www.arctic-roos.org. The amount of multiyear ice is also linked to the export of ice through the Fram Strait. Ice drift from passive microwave and scatterometer is presently available for the whole Arctic, while SAR data can provide scattered ice drift vectors in areas with repeated SAR coverage. In the Fram Strait comparison of ice drift vectors between SAR and other satellite products is conducted to obtain more accurate estimates of the ice area flux [6].

MODELLING AND DATA ASSIMILATION

Operational modelling and forecasting of ice-ocean conditions in the Arctic and subarctic areas is done by the TOPAZ system (http://topaz.nersc.no). The TOPAZ modelling and data assimilation system was developed under the MERSEA project and is now run in the Arctic Marine Forecasting Center as part of the MyOCEAN project, as described in [7., 8]. TOPAZ assimilates ice concentration, sea surface temperature fand sea level anomaly fields from satellite data. The TOPAZ3 model runs at a resolution of 11 – 18 km, which is about a factor of two better than the previous version. For example, TOPAZ3 gives a very realistic representation of the Westspitzbergen Current, which has positive impact on the water mass distribution in the Arctic regions. A major activity in the model development is validation of the TOPAZ output, using several validation schemes. One example of validation is to compare vertical sections of temperature and salinity from model runs with observed fields obtained from CTD sections. The example in Fig. 2 shows that the temperature field from TOPAZ is in good agreement with observations, except for the outflow of cold water south of Bjørnøya (the right side of the plots). TOPAZ provides a stratification with warmer water in the top 50 m, while the observations show uniform, cold water reaching the surface.

Similar validation is done for other sections where hydrographic data are obtained regularly in the Barents, Norwegian and Greenland seas including the Fram Strait. Other validation schemes use satellite-derived ice concentration and ice drift for comparison with ice model results. In the ice-covered seas there are very few regular data available for validation of the ocean model in TOPAZ. One exception is the North Pole Environment Observatory[6], providing CTD profiles for the deep Arctic Ocean. These profiles are used to validate the TOPAZ model results in the interior of the Arctic.



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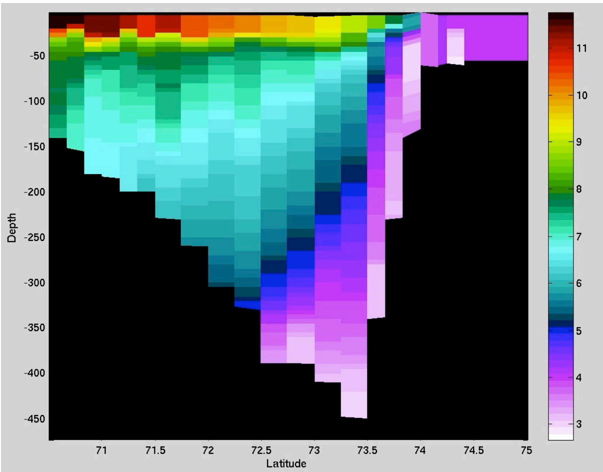

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Figure 2: (a) Vertical section of temperature in the Barents Sea opening (Fugløya-Bjørnøy section, where south is to the left and north to the right) based on TOPAZ-3 model simulations, (b) vertical section of the temperature field from observations, based on CTD data provided by Institute of Marine Research. The comparison is for 17 August 2007, showing that TOPAZ3 is in good agreement with the observations regarding distribution of water masses. Red is warm water and violet is cold water, as shown by the temperature scale in °C.

[6] http://psc.apl.washington.edu/northpole/index.html

IN SITU OBSERVATIONS

There are few regular in situ observations in the Arctic and subarctic seas compared to other European areas. The most important oceanographic data are obtained from ships surveys and bottom-moorings located in strategic positions, such as the Fram Strait. The deployment of ARGO floats[7] in the Norwegian – Greenland Sea is in progress, but ARGO floats cannot be used in the deep Arctic Ocean with ice cover. In the DAMOCLES project, there is extensive testing of new instruments that can drift freely under the ice or be deployed on the ice. These include Ice Tethered Profilers (ITP), Ice Tethered Acoustic Current Profilers (ITAC, Polar Ocean Profiling System (POPS), Arctic Ocean Flux Buoy (AOFB), Ice Mass Balance buoys (IMB) as well as standard met-buoys. More information about these systems is described in [2 and 4]. Hydrographic sections in the Fram Strait and Norwegian Seas are carried out annually by the Arctic-ROOS members Institute of Marine Research in Norway, Norwegian Polar Institute (NPI), Alfred Wegener Institute (AWI) and Institute of Oceanology, Polish Academy of Sciences. Monitoring fluxes of water masses and sea ice in the Fram Strait is an important element of climate studies in the Arctic and the Nordic Seas. AWI and NPI have been operating an array of moorings along approximately 79°N equipped with current meters, some of them are equipped with Upward Looking Sonar (ULS), since 1997.

In the DAMOCLES project, new observing systems using acoustic tomography and gliders are tested to improve the observation of water masses in the strait (http://acobar.nersc.no). There is also testing of acoustic data transmission from underwater platforms to a surface relay station in order to obtain near-real time data. The International Polar Year (IPY) has been very instrumental in enhancing Arctic ocean and sea ice field campaigns, testing new observing systems and increase data collection. After IPY was completed in 2009, the main challenge will be to sustain the most important components of the new observing systems. Increased collection of in situ data is required for validation of satellite data and models, and to fill gaps where satellite observations cannot provide data.

CONCLUSION AND FURTHER WORK

Arctic ROOS has been formally established with 15 members who are working actively with development and implementation of operational oceanography systems in Arctic. The demand for monitoring and forecasting in the Arctic Ocean and sub-Arctic seas is

[7] http://www.argo.ucsd.edu/index.html

growing as a result of climate change and its impact on environment and human activities. After intense field activities and data collection during IPY, it will be a major challenge to implement, fund and operate long-term observing systems. The Arctic ROOS members will focus on the following activities in the coming years:

- Maintain and develop the field observation activities in order to improve data collection and data dissemination from in situ platforms
- Improve the exploitation of new satellite data covering Arctic marine regions
- Improve ice-ocean forecasting systems including validation by increased use of in situ data and satellite data
- Implement the GMES Marine Core Service project MyOcean under EU FP7 from 2009 to 2012 where the Arctic is one of the focused regions
- Increase the interaction with users of operational oceanography in the Arctic and sub-Arctic regions
- Lobby for funding of long-term in situ observing systems, supplementing satellite observations that are committed for the next decade.

ACKNOWLEDGEMENTS

Establishment of Arctic ROOS is supported by IPY, EuroGOOS, I-GOOS, EU and ESA GMES projects including MERSEA, DAMOCLES and MyOcean and national activities run by the Arctic ROOS members.

REFERENCES

1. Sandven, S., O. M. Johannessen, E. Fahrbach, E. Buch, H. Cattle, L. Toudal Pedersen and T. Vihma. The Arctic Ocean and the Need for an Arctic GOOS. EuroGOOS Publication No. 22, March 2005, 50 pp.
2. Dickson, R. R. (editor). The integrated Arctic Ocean Observing System (iAOOS) in 2007. Report of the Arctic Ocean Science Board (www.aosb.org).
3. Sandven, S. and O. M. Johannessen, Sea ice monitoring by Remote Sensing, chapter 8, pp 241 – 283, in Remote Sensing of the Marine Environment (ed. J. Gower), Manual of Remote Sensing, Third Edition, Volume 6, Published by American Society for Photogrammetry and Remote Sensing, 2006, Maryland, USA, 338 pp.
4. Gascard, J.-C. et al., Exploring Arctic Transpolar Drift During Dramatic Sea Ice Retreat. EOS, Vol. 89, No. 3, pp. 21-23, 15 January 2008
5. Richter-Menge, J. et al., (2008) Arctic Report Card 2008 (http://www.arctic.noaa.gov/reportcard)
6. Sandven, S. Sea ice monitoring in European Arctic Seas using a multisensor approach. Chapter in the book *"Remote Sensing of the European Seas" (Eds. Barale and Gade) Springer Science and Business Media B. V.,* 2008, pp. 487 – 498.
7. Bertino, L., K. A. Lisæter, A. Samuelsen, F. Counillon, C. Hansen, I. Keghouche, G. Zangana. Ice and ocean forecasting with the TOPAZ system. Proceedings of EuroGOOS Conference, 20-22 May 2008.
8. Bertino and Liseter (2008) The TOPAZ monitoring and prediction system for the Atlantic and Arctic Oceans. *J. Operational Oceanogr.*, **1**(2), 15-19.

APPENDIX A: MEMBERS OF ARCTIC ROOS

Nansen Environmental and Remote Sensing Center (NERSC), Norway

Swedish Meteorological and Hydrological Institute (SMHI), Sweden

Institute Français de Recherche pour l'Exploitation de la Mer (Ifremer), France

Institute of Marine Research in Norway (IMR), Norway

Institute of Oceanology, Polish Academy of Sciences (IOPAS), Poland

Norwegian Institute for Water Research (NIVA), Norway

Danish Meteorological Institute (DMI), Denmark

Mercator Océan, France

University of Cambridge, Dept. of Appl. Math. and Theor. Physics (DAMPT), UK

Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI), Germany

Finnish Meteorological Institute (FMI), Finland

University of Bremen, Institute of Environmental Physics (IUP), Germany

Norwegian Meteorological Institute (met.no), Norway

Nansen International Environmental and Remote Sensing Center (NIERSC), Russia

Norwegian Polar Institute (NPI), Norway