Workshop

Near-slope observations in the Eurasian and Makarov Basins of the Arctic Ocean


REPORT

Organizer

International Arctic Research Center, University of Alaska Fairbanks, USA
Preamble: This workshop was held to coordinate scientific activities and future field experiments (including coordination of plans for ships, manpower, scientific instrumentation, and targeted regions) in the near-slope area of the Eurasian and Makarov Basins (EMB) of the Arctic Ocean. This area is critical for the further development of the scientific and political understanding of the Arctic that is so important to the global community. In this time of rapid environmental and political changes, there are urgent needs for enhancing international cooperation and interdisciplinary dialog. The meeting was sponsored by the National Science Foundation.

Motivation

The overarching goal of our observational program, itself an element of the Arctic Observing Network (AON), is to compile a cohesive picture of climatic changes in the EMB of the Arctic Ocean, with particular focus on understanding changes in upper ocean and near-slope areas. Sea ice and ocean stratification, as well as ocean circulation, show a distinctly different regime in the EMB than in the Canadian Basin (CB), raising the need for a study of the two differing regimes. While many measurements have been made in the CB, observations in the EMB are limited, lacking specific studies of along-slope Atlantic Water (AW) transport by boundary currents; interactions between AW branches and shelf waters, the deep-basin interior, and the upper ocean; and EMB changes in upper-ocean circulation. Thus, this program has provided critical information for understanding other large-scale changes occurring in the Arctic Ocean (Figure 1).

The goal of this meeting was to discuss the progress of the program after its first 2013 field season, and to coordinate future efforts in preparation for a 2015 expedition. Following these general goals, the proposed Workshop’s Objectives were formulated thusly:

• Summarize the major results of the 2013 field expedition, with particular focus on problems and unresolved issues, which must be addressed in order to enhance the observational capabilities of the program.

• Develop a plan for the 2015 expedition, including logistics, timelines, international cooperation strategies, and management approaches.

• Develop approaches for coordination of proposed activities with the wider Arctic science community. Identify the needs of international communities for observational data collected by the program. Develop a plan for engagement of young scientists in project activities.
Expectations for this workshop also included a path for enhanced international partnership and field experimental strategy for several years forthcoming, in coordination together with broad U.S. and international Arctic community involvement.

Our one-and-a-half day meeting opened with a welcome address by Dr. Igor Polyakov (leader of NABOS, the Nansen and Amundsen Basins Observational System). The following sessions consisted of first-day 2013 field season reports, followed by the development of plans and strategies for the 2015 field season and beyond, during the afternoon session of the first day and the morning session of the second day.

I. 2013 field season reports

Program Overview. Igor Polyakov (IARC/UAF) presented the fourteen-year-long history of the NABOS project. Scientific results produced by the project have been essential for understanding ongoing changes in high-latitude regions, particularly in the reduction of Arctic ice. Some important milestones of the observational program have included the following. In 2003–04, NABOS observations captured the exceptional warming entering the Eurasian Basin from 1999 (Figure 2), and observations from 2007 documented strong warming of the very uppermost layer in the ice-free area of the eastern Eurasian and Makarov basins. The magnitude of this warming is unprecedented in the history of regional instrumental observations. The unique strength and spatial distribution of this warm surface anomaly suggest an important role of oceanic heat in shaping this summer’s substantially reduced Arctic Ocean ice cover. Mooring-based NABOS observations were instrumental in detecting a
strong seasonal signal in the Arctic Ocean interior. Oceanographic cross-sections and drifters were used to demonstrate propagation of AW heat through the halocline. NABOS has become an important element of the IPY by enhancing international cooperation, resulting in shared research infrastructure, updated databases, and fostering of synergy and interdisciplinary dialog. NABOS was also instrumental in the extensive biochemistry and turbulence observations carried out by our partners in previously inaccessible areas of the Arctic Ocean.

**Figure 2.** Pulse of warm intermediate Atlantic Water in the 2000s was 0.24 °C warmer than the analogous pulse of the 1990s. Vertical cross-sections of water temperature (°C) from the Arctic Ocean and these five series of cascaded plots show temperatures measured by yellow lines on the map. In each section, the horizontal axis shows distance (km), and the vertical axis shows depth (m).
2013 CRUISE OVERVIEW. Vladimir Ivanov (IARC/AARI) was Chief Scientist of the August-September 2013 NABOS expedition, aboard the icebreaker Akademik Fedorov. This expedition was conducted jointly by the International Arctic Research Center (IARC) of the University of Alaska Fairbanks in the US, and the Arctic and Antarctic Research Institute (AARI) in St.-Petersburg, Russia. One significant feature of this cruise was that it took place under conditions of substantially reduced summer ice cover. Documenting changes in atmosphere, ice, and ocean was the main objective of the 2013 NABOS cruise. With participants from ten counties, this cruise had true multidisciplinary status. Another important component of the cruise was the Summer School (see report by the School Director V. Alexeev) outreach program.

Our 2013 NABOS cruise program was fulfilled successfully (see Figure 3). 116 CTD stations and 49 XCTD and 47 XBT casts were completed. Nine deep-water moorings were successfully deployed. An important technological novelty for this cruise was the deployment of a cluster of moorings along 126°E, a cluster covering AW flow in this area at a 250-m to 3800-m depth range, allowing accurate calculation of transports of water, heat, and salt. Five ITP, one O-Buoy, 17 meteo buoys, three UpTempO buoys, and one IMB buoy were deployed. A glider was also launched in the eastern Nansen Basin. Although the glider operated for a short time before its signal was lost, the information provided by this instrument was unique. An extensive list of hydrochemical sampling carried out during the cruise became possible thanks to lab facilities provided onboard the R/V Akademik Fedorov. Complex studies of ocean-air interactions were carried out around the clock, with a variety of advanced
technological devices. Unique data on turbulent heat fluxes, structure of the atmospheric boundary layer, aerosol composition, methane fluxes etc. were collected in the MIZ area. Ice observations during the cruise allowed precise mapping of ice cover properties along the route and appeared to be crucially important for efficient ice navigation and for finding locations for ice buoy deployments.

Preliminary analysis of the unique scientific data collected along the Eurasian continental margin in summer 2013 shows that the intermediate Atlantic Water was warmer relative to 1950-1990 climatology, even though not as warm as in 2006-2007. An outstanding feature of the summer 2013 thermohaline structure was a strong near-surface temperature maximum in areas where ice-free conditions were observed for sufficient time.

**LOGISTICS: ACCOMPLISHMENTS AND CHALLENGES.** Rob Rember (IARC/UAF) reported that the first year of this project involved a number of logistical challenges, including the procurement of a ship for use in the Russian EEZ, purchasing and shipping new CTD rosette and 911plus tools, and designing and purchasing all equipment associated with nine new moorings. In addition to these challenges, we also had to outfit our winch and capstan for the selected ship.

Work began in mid-2013 to identify a ship, as this selection formed the basis for all other decisions. Over several months, it became apparent that previous ships would not be available, but that the scientific vessel the *Akademik Fedorov* (AARI) appeared a strong possibility. AARI was amenable to making necessary modifications to accommodate our winch, and agreed to rebuild their sampling van. After a number of inspections, we were able to secure the ship.

We were also able to secure our two primary mooring technicians for the duration of the project. In addition, with the deployment of the ITPs and O-buoys, we gained additional expertise in deck work and mooring deployments. These agreements provided us with enough personnel for mooring work.

Purchasing began as we narrowed on the ships available. Due to the nature of the project, the new CTD system was designed for availability to fit any ship. Winch mount drawings were sent to AARI, and the new winch platform was built. Our LEBUS winch was shipped to the manufacturer and refurbished and retrofitted with slip-rings, to accommodate our new CTD system. Orders with vendors for mooring gear were placed a minimum of six months in advance. Most orders were ready for delivery prior to finalizing the ship. The decision was made to ship all equipment to Fairbanks. After all gear was received, our instrument technician travelled to Fairbanks, and we checked and assembled all equipment prior to shipment to Kirkenes. The 15-ton, 33-pallet shipment left Fairbanks on May 20 and arrived in Kirkenes on August 8.

Ian Waddington, Peter Keen, and Rob Rember arrived in Kirkenes on August 10. During the 10 days prior to the cruise, all mooring gear and the new CTD system were assembled and tested. Any problems encountered with instrumentation were resolved prior to the cruise. The ship arrived on August 19 and was loaded on the 20.

**OUTREACH COMPONENT.** Vladimir Alexeev (IARC/UAF) reported about the summer school conducted during the 2014 IARC expedition to the Arctic Ocean, as part of another NSF funded project (NABOS, Nansen and Amundsen Basins Observational Program). This school was co-organized with the Obukhov Institute for Atmospheric Science (IFA) of the Russian
academy of science, and the Russian foundation for fundamental research (RFFR), which contributed funding for both instructors and students. NSF funded eleven of the twenty student participants and three of five instructors; all other funding was provided by RFFR and IFA.

Lindsay Bartholomew, an outreach specialist from the Miami science museum (MSM) joined the cruise with her own funding to provide coverage of the summer school and expedition. In particular, Lindsay was responsible for the blog on the MSM’s website: http://www.miamisci.org/lindsayintheArctic/.

This summer school program consisted of every-day lectures on current problems in Arctic research, as well as practical sessions consisting of both participation in a measurements program and work on science projects under the guidance of summer school instructors.

Summer school statistics:
- 55 lectures on various aspects of climate change,
- 8 separate student projects, including at least 2 undergoing preparation for the publication of outcomes/results
- 176 blog posts
- 42 blog posts written by scientists
- 22,684 blog views
- 1,115 public comments
- 89 countries viewing the blog (on 6 continents)

Managing Data. Igor Polyakov (IARC/UAF) presented the current status of the data management of the project as an element of the Arctic Observing Network (AON). CTD data have been processed and located on the project’s new web page, http://research.iarc.uaf.edu/NABOS2/technology.php, in addition to other external data depositories. Data access via the new project web page was explained. Interested users may find metadata describing observations conducted during the 2013 summer cruise. Chemical data require much longer processing times, which are currently on-going. This data will be located in open access data repositories as soon as processing is completed.

Multidisciplinary Component. Rob Rember (IARC/UAF) discussed an enhanced chemical component of the NABOS program which is a key for providing a better understanding of the interaction of AW branches with shelf water, the deep basin interior, and the upper ocean in the Eurasian Basin. Some chemical observations were a part of the earlier NABOS program, though these components were not necessarily collected during the same year and were never integrated into the program.

To better understand the interaction of AW with surrounding water masses, we concentrated our sampling on the upper water column (Figure 4). Samples were collected at 10-m intervals from the surface down to 150 m (the bottom of the halocline). Samples collected below those depths were spaced at regular intervals. The primary variables of interest included dissolved oxygen, salinity, barium and d18O, nutrients, chlorophyll, and dissolved inorganic carbon. In addition, a submersible ultraviolet nitrate analyzer (SUNA) was used to collect nitrate concentrations on 71 casts. These data will be combined with dissolved oxygen measurements collected on the same cast, to better understand NO
distribution throughout the water column. Salinity, oxygen isotope measurements, and barium will be used to understand the distribution of fresh water throughout the upper water column. Nutrient data suggest that this region is limited by nitrate, and calculated values for N* and N** suggest that the AW entering through Fram Strait has been modified with water having undergone significant denitrification. Additional samples were collected for isotopes of nitrate. Preliminary results from these analyses suggest that Fram Strait AW and modified Barents Sea AW have significantly different values, further suggesting this may provide an additional tracer for the mixing of water masses within the Eurasian Basin. Preliminary dissolved organic carbon data suggest that waters entering the basin from shelves are characterized by low pCO₂, whereas Fram Strait AW shows significantly higher pCO₂, lower pH, and undersaturation with respect to aragonite.

![Figure 4. Rosette (including CTD sensors, right) used in summer 2013 cruise for water sampling.](image)

Analyses are ongoing for nutrients, barium, and oxygen isotopes. We expect analyses to be completed by the end of the summer 2014. The RV *Akademik Fedorov* was an upgraded platform for the NABOS project, including a sampling van, ample laboratory space, and an experienced crew.

**Engagement of Young Scientists.** Andrey Pnyushkov (IARC/UAF), a postdoc working for the NABOS project, described a wide range of possibilities available for young scientists in the project. NABOS has provided excellent opportunities for young scientists’ involvement in scientific research, expedition activities, operations of state-of-the-art instruments and new technologies, and participation in scientific conferences and workshops. Particular attention has been paid to the major results of our scientific studies, based on observations collected at NABOS moorings and cruises, including amplification of tidal currents over the Laptev Sea slope in ice-free conditions (Figure 5), an analysis of structure and variability of the boundary current in the Eurasian Basin of the Arctic Ocean, and a preliminary assessment of mesoscale eddies over the Eurasian Basin continental slope.
PROJECT TARGETS IN FOCUS. Igor Polyakov (IARC/UAF) presented the overarching goal of the 2012-2017 AON project, which is to compile a cohesive picture of climatic changes in the EMB of the Arctic Ocean, with particular focus on understanding three major observational targets:

Target #1: Along-slope Atlantic Water (AW) transport by boundary currents.
Target #2: Interaction between AW branches and shelf waters, the deep basin interior, and the upper ocean.
Target #3: EMB indications of changes in upper-ocean circulation.

Dr. Polyakov gave several examples of how the observational system in place can address these targets. As one of several examples, the scheme of deployed 2013 moorings was demonstrated, with the 125°E mooring section highlighted (Figure 6). Data provided by this section will be instrumental for analysis of water, heat, and salt along-slope transports by the boundary current (Target 1). Our overall conclusion was that this observational system is capable of addressing all observational targets.

Figure 5. Amplification of tidal currents (red), in response to seasonal changes in sea ice (blue) at the M1 mooring (78°26'N, 125°40'E). From Pnyushkov and Polyakov, 2012.

Figure 6. Scheme of moorings currently in the water after 2013 NABOS deployments. Red circles show locations of current moorings.
USING MODERN TECHNOLOGIES. As part of the 2013 NABOS campaign, Luc Rainville (APL/UW) deployed an autonomous Seaglider, which sampled temperature and salinity in the St. Anna Trough (Fig. 7) and along the shelf break, collecting 176 profiles (88 dives) over a total horizontal distance of ~230 km. This glider was also equipped with temperature microstructure sensors, providing direct estimates of turbulent dissipation rates for the entire mission duration [Rainville, manuscript in prep.].

![Temperature and Rate of Dissipation of Thermal Variance](image1)

**Figure 7.** Records of water temperature and the rate of dissipation of thermal variance provided by the glider deployed in St. Anna region by L. Rainville (APL/UW) during summer 2013 NABOS expedition. Figure provided by Luc Rainville, APL/UW.

US PARTNERSHIPS: THE ICE-TETHERED PROFILER PROGRAM: MAKING A CONTRIBUTION TO THE OCEAN OBSERVING SYSTEM AT POLAR LATITUDES. Rick Krishfield (in collaboration with John Toole, Andrey Proshutinsky, Mary-Louise Timmermans, and John Kemp) presented an overview of their ITP program.

In the first ten years since the first prototype Ice-Tethered Profiler was deployed in 2014, the ensemble of 74 ITPs fielded by researchers from six countries have returned more than 55,000 upper-ocean temperature and salinity profiles from the central Arctic, significantly increasing the number of high-quality upper-ocean water property observations available from the central Arctic (Toole et al., 2010, updated). This ITP system consists of three main components: a surface instrument package, which typically sits atop an ice floe (but can float...
in open water); a weighted, wire-rope tether of arbitrary length (up to 800 m), suspended from the surface package; and an instrumented underwater unit that travels up and down the wire tether, transporting a sensor package through the water column (Krishfield et al., 2008). Full-resolution data are telemetered to shore, making the instruments expendable. The base profiler unit is typically outfitted with a CTD (which may also include dissolved oxygen), though prototypes have been successfully fielded that include bio-optical packages (including turbidity, fluorometry, CDOM, and PAR) and MAVS current probes. Fixed sensor packages, such as microcat CTDs and SAMI CO₂, and pH instruments have also been incorporated on ITP tethers just below the ice. As frequently as possible, ITPs are deployed together with other autonomous buoy systems to sample a wide range of variables characterizing the Arctic ocean-ice-atmosphere ecosystem. ITP data are available online (Figure 8) and contribute to the Arctic Observing Network, as well as having been used in a wide range of investigations, from local processes that influence the atmosphere-ice-ocean boundary layer systems to basin-scale variability studies (e.g., Rabe et al., 2010; Timmermans et al., 2011; Cole et al., 2014; Laney et al., 2014).

![ITP 74 CTD data](image.png)

**Figure 8.** An example of WHOI’s ITP web page.

To date, seven ITPs have been deployed in collaboration with the NABOS project (two in 2009, five in 2013). These systems have been installed in the Laptev and East Siberian Seas, and positioned to drift the length of the Transpolar Drift. The first two were deployed in open water near the marginal ice zone, with one (ITP 37) acquiring profiles for over sixteen months.
across the greater part of the Eurasian Basin, measurements that were then used to estimate winter heat loss from the subsurface cold halocline and upper pycnocline layers (Polyakov et al., 2013). Another ITP deployed during the 2013 NABOS expedition (ITP 74) has largely transected the same path as ITP 37, and qualitatively appears to reinforce the results. Continuing this collaboration with NABOS into the future, at least two ITPs are planned for deployment during the 2015 and 2017 expeditions.

**US PARTNERSHIP (O-BUOYS).** Patricia Matrai reported that, as part of the O-Buoy Network of Chemical Sensors in the Arctic Ocean, OB-9 was deployed at approx. 80°N, 120°E during the 2013 NABOS campaign (Figure 9). Meteorological variables including air temperature, pressure, relative humidity, wind speed, and direction were measured on a continuous basis; and atmospheric chemical variables including CO₂ and O₃ concentrations were measured continuously year-round. BrO concentration was measured seasonally, except in darkness. In addition, latitude, longitude, speed, azimuth, pitch, and roll were also reported continuously. Pictures were taken every twenty minutes year-round, except in darkness; pictures were looped into movies. Finally, a variety of internal, buoy-specific parameters (e.g., battery characteristics, instrument loads, computer variables and Iridium signal strength) were monitored continuously. All preliminary data can be seen in real time at http://obuoy.datatransport.org/monitor#overview/gpstracks. Additional information can be obtained at http://www.o-buoy.org/. Data are regularly submitted to ACADIS (www.acadis.org). NSF PLR AON funding is gratefully acknowledged (ARC-1022834_Bigelow, 1022773_MBARI, 1023221_CRREL, 1023393_Purdue, 1023118_UAF).

![Figure 9. O-Buoy observations in 2013-2014.](image)

Left, from top to bottom: GPS latitude, air temperature, DOAS exposure, O₃ mixing ratio, CO₂ instrument temperature. Right: O-buoy deployed as a part of cluster with other buoys.
**US Partnership (SVP Buoy).** Mike Steele reported about the deployment of his SVP (UpTempO) buoys. Each of these buoys consists of a flotation device with several meteorological sensors and a thermistor chain for monitoring the thermal state of the ocean in the upper 60-m layer. Three such buoys were deployed in 2013, during the NABOS expedition. These buoys are still functional and transmitting data from the Arctic. An example of the record from one of these buoys is shown in Figure 10. It shows the development and deepening of the Near Surface Temperature Maximum (red signal shown at ~30m depth, at the beginning of the record) as well as pulses of warmth coming from below the surface mixed layer (SML); the only source of heat in this part of the Arctic Ocean is AW heat. Thus, this buoy gives an example of the thermal communication between the ocean interior and the SML, an important finding.

![Figure 10. Observations of Eurasian Basin Near-Surface Temperature Maximum and interaction of the upper layer with the Atlantic Water layer. Shown is water temperature (color) and sea level pressure (red isoline, mb) as measured by the UpTempO buoy deployed in 2013.](image)

**US Partnership (Meteo Buoy).** Curtis Reinking, Pablo Clemente-Colón, and Ignatius Rigor presented results from the International Arctic Buoy Programme (IABP), as well as meteorological observations in the Eurasian Arctic as a part of the IABP. The goal of this program is to observe air, sea, and ice using drifting buoys. US IABP coordinates US contributions to the IABP, which has 34 participants from ten different countries, including the WCRP and EUMETNET. IABP observations are used for both operations (WMO GTS) and research, including:

- forecasting weather and ice conditions,
- validation and forcing of climate models,
- validation of satellite data,
- assimilation into reanalysis fields (e.g. NCEP/NCAR), and
- aiding studies of climate change.
II. Strengthening science and logistical strategies for 2015 field season and beyond

**ENHANCING ATMOSPHERIC COMPONENT.** Irina Repina described the objectives for the atmospheric measurements of the Russian team during NABOS expeditions, including the design of field experiments and the choice of instrumentation. These objectives are to

- Calculate the surface heat budget using direct measurements of turbulent fluxes (latent and sensible heat fluxes, momentum fluxes; see Figure 12) and radiative fluxes in the subsurface layer of the atmosphere under different stability conditions.
- Analyze air temperature and characteristics (structure) of the air-ocean interface, as well as its impact on the atmospheric boundary layer. Validate satellite-derived surface temperatures using observations of the oceanic thermal skin layer.
Improve satellite measurements of surface temperature in the infrared and the microwave range.

- Validate exchange coefficients in aerodynamic bulk formulas and the surface roughness parameter with respect to the type of surface and meteorological conditions.
- Estimate Arctic cloud radiative forcing.
- Measure CH$_4$ and CO$_2$ concentrations along the Arctic continental shelf, where methane hydrate deposits are predicted; validate satellite methane data.
- Investigate time-space variability of atmospheric ozone and aerosols including optical, microphysical, and chemical properties of Arctic aerosols.

**Figure 12.** Sensible (left) and latent (right) heat fluxes (W/m$^2$) measured during the NABOS 2013 cruise.

**Ola Persson** stressed that regular standard radiosonde observations, complemented by measurements of surface heat fluxes, should be an essential component of an Arctic observational program, including NABOS. Measurements of boundary layer parameters and gas concentrations would also benefit the program.

**Enhancing Ice Component.** **Igor Polyakov** stressed the potential link between measurements of ice thickness, drift, and sea level conducted by NABOS and similar information derived from satellite measurements. **John Kemp** and **Rob Pinkel** suggested a closer association between the Russian team of ice observers aboard of the ship and the US team. **Don Perovich** and **Irina Repina** mentioned the possibility of a joint analysis of IMB measurements and atmospheric heat flux measurements from the ship.

**Geomar Laptev Sea Program** was described by **Heidi Kassens**. Heidi presented an overview of the Russian-German research project „Laptev Sea System: the Transpolar System of the Arctic Ocean" which aims to assess how climate change will affect the highly sensitive Arctic environment and in how far the changes will be of consequence for Europe. Research areas are the Laptev Sea as the most important area of sea-ice production and the Fram Strait as the only deepwater and intermediate water connection between the Arctic Ocean and the Atlantic Ocean (Figure 13). The Transpolar Drift connects both regions. At the same time, the Russian partner institution, the State Scientific Center of the Russian Federation the Arctic and Antarctic Research Institute, St. Petersburg, implements multidisciplinary investigations in the
Central Arctic Ocean as the key research topic of their research program „Arctic Basin Cluster”.

She presented some scientific highlights of the TRANSDRIFT expeditions to the Laptev Sea and she informed about the upcoming expedition TRANSDRIFT XXII onboard Viktor Buynitskiy in August and September 2014. She is proposing a NABOS/System-Laptev-Sea workshop in 2015 to merge the results of the projects.

**Figure 13**: Station map of TRANSDRIFT XXI (22.8. – 20.9.2013)

**AWI ARCTIC OCEAN PROGRAM.** Markus Janout reported that the System Laptev Sea program is a ~20 year ongoing collaboration between different German (such as the Alfred-Wegener-Institute, AWI) and Russian Institutions, with a focus on the Laptev Sea shelf (Figure 14). The Laptev Sea shelf work has a clear overlap with the NABOS program (see Figures 14 and 2), and a joint data analysis may be beneficial for both programs. In his presentation, Janout provided an overview of different ongoing oceanographic activities in the Arctic carried out by AWI scientists, centered mainly around work aboard the German research icebreaker RV Polarstern. Further, he presented highlights from the 2013 German-Russian Laptev Sea expedition TRANSDRIFT-21.
Norwegian Observational Program. Arild Sunfjord reported that in September 2012, a survey and mooring deployment was carried out in the vicinity of Svalbard (Figure 15). Total nine moorings forming a section were deployed. In September 2013, the survey was repeated and the moorings were recovered. Four moorings were redeployed (Figure 15). Analysis of data includes wind driven upwelling events, cross-slope fluxes, shelf-slope exchange, tidal analysis, up-/downward propagating energy, internal wave activity. Potential collaboration with NABOS includes comparison with downstream moorings, particularly looking at time lags and along-flow changes in volume flux, changes in AW core depth, T and S, calculate vertical heat loss and (to extent possible) lateral exchanges with shelves and deep basin. Future plans: August 2014: mooring and survey cruises, 5-6 moorings; August/September 2015: mooring cruise. 2017 Joint cruise with NABOS?
RUSSIAN OBSERVATIONAL PROGRAMS. Alexander Danilov reported that during recent years, there had been an increase in Arctic expedition activities conducted by AARI (Arctic and Antarctic Research Institute, St.-Petersburg, Russia). In 2013, AARI researchers organized, conducted, and/or took part in eighteen expeditions in the vast area spreading from Svalbard to the Novosibirskiye Islands. In particular, the AVLAP-NABOS expedition onboard the RV *Akademik Fedorov* in 2013 was essential for their study of the Arctic Ocean. Expedition participants noted that the ship was well equipped and the crew qualifications were high.

Since 2012, in addition to the RV *Akademik Fedorov*, the AARI has owned another RV, the *Akademik Treshnikov* (Figure 16). These two ships have similar technical characteristics. RV *Akademik Treshnikov* was tested during voyages to Antarctica; there are also plans for the use of this ship for summer observations in the Arctic Ocean—particularly in summer 2014. Thus, AARI has the capability to use either RV *Akademik Fedorov* or *Treshnikov* for the next AVLAP-NABOS expeditions.

![Figure 16. (Top) New AARI RV *Akademik Treshnikov* (Bottom left) RV *Professor Molchanov*. (Bottom right) Oceanographic stations carried out in 2013 using RV *Professor Molchanov*.](image)

Over recent years, regular expeditions were conducted in the White, Barents, and Kara seas as a part of the Arctic Floating University program aboard the RV *Professor Molchanov* belonging to the Northern Branch of RosHydroMet. In 2013, there were two expeditions using RV *Professor Molchanov* (Figure 16). The program for these expeditions included both educational and research components. As part of the research component, oceanographic
observations along sections of the Barents, Greenland, and Kara seas were carried out. These observations were complemented by measurements of meteorological, CO₂, and O₃, as well as several other important measurements. It appears reasonable to consider a possible extension to the ongoing Russian-US NABOS-AVLAP collaboration, with the potential of such a program as the RV *Professor Molchanov*’s Floating University. In that case, the two programs might be coordinated in a more cooperative fashion, producing additional information regarding analyses of transport and transformation of Atlantic waters entering into the Arctic Ocean not only through Fram Strait, but also via the Barents Sea, through St. Anna Trough.

**Pacific Arctic Group’s Plan** was described by Kathy Crane.

**Plans of Chinese Arctic Observation.** Dr. Jinping Zhao (Ocean University of China, OUC) expressed interest regarding the analysis of the vertical structure of the upper ocean (down to 100 m). In the NABOS area, temperature and salinity in the upper ocean differ greatly from those in the Canada Basin. Dr. Zhao and his colleagues plan to deploy two ITPs in 2014 in the Canada Basin, and they have also designed two profilers for temperature and salinity for shallow water (called shallow water ITP) shown in Figure 17, which are also planned for deployment in 2014. A shallow water ITP has several advantages for NABOS observations. First, it can reach areas just under the bottom of sea ice, and can thus better measure the vertical structure of the upper ocean. Secondly, its cable is 120 m long, suiting both shelf and deep ocean depths. Third, it is equipped with air temperature and humidity sensors, and fourth, it is equipped with a wind generator to keep it working during the polar night. Dr. Zhao suggested that the OUC can contribute two shallow water ITPs for the 2015 NABOS cruise. Data collected can be compared with that from the Canada Basin.

![Figure 17. Sketch of profiling process using proposed shallow water ice tethered profiler.](image-url)
III. Summary of recommendations

The following statements summarize the major recommendations made during the meeting:

**Enhancing observational activities**

- A combination of Eulerian measurements (CTD/hydrochemical surveys and mooring observations) and observations provided by various Lagrangian drifters has proven very effective; continue and enhance this approach in NABOS observations. Provide help with future deployments of new types of buoys like the Autonomous Ocean Flux Buoy (AOFB) to monitor and better understand the delicate balance between the upper ocean, sea ice cover, and incoming solar radiation that sustains the perennial ice cover in the Arctic Ocean.

- Enhance atmospheric observational component: radiosonde observations complemented by measurements of surface heat fluxes should become routine NABOS observations. These observations are vital for development reliable atmospheric forecasts and reanalysis products. This activity requires additional funding.

- Enhance ice observation component linking *in situ* and satellite measurements of ice thickness, drift, and sea level. Interagency (e.g. NSF-NASA) approach may be necessary in order to accomplish this objective.

**Enhancing international collaborations**

- **U.S.-Norway:** Develop joint protocol for chemical analyses between US NABOS and Norwegian observations in Svalbard area, in order to enhance comparative analyses of water mass composition in future joint studies. Consider coordination of plans for 2017 for a joint cruise.

- **U.S.-Germany:** Develop joint protocol for chemical analyses between US NABOS and German observations in the Laptev Sea area, in order to enhance comparative analyses of water mass composition in future joint studies. Coordinate efforts for deployment of German moorings off Severnaya Zemlya in 2015. Develop a cohesive plan for joint analysis of tidal currents.

- **U.S.-Russia:** Investigate potential for collaboration between NABOS and AARI’s Arctic Floating University; collaborative effort may result in better understanding of the destiny of the Atlantic Water heat in the polar basins.

- **U.S.-China:** Enhance US-Chinese collaborations using new Chinese technologies recently developed for Arctic exploration; utilize these techniques in joint field experiments.
Motivation

The overarching goal of this program, as an element of the Arctic Observing Network (AON), is to compile a cohesive picture of climatic changes in the Eurasian and Makarov Basins (EMB) of the Arctic Ocean, with particular focus on understanding changes in upper ocean and near-slope areas. Sea ice and ocean stratification, as well as ocean circulation, show a distinctly different regime in the Eurasian and Makarov Basins (EMB), compared to the Canadian Basin (CB), arguing for a study of the two differing regimes. While many measurements have been made in the CB, observations in the EMB are limited, and lack specific studies of along-slope Atlantic Water (AW) transports by boundary currents; interactions between AW branches and shelf waters, the deep-basin interior, and the upper ocean; and EMB changes in upper-ocean circulation. Thus, this program provides information that is critical for understanding other large-scale changes occurring in the Arctic Ocean (Figure 1).

Observations are coordinated with other AON elements such as the North Pole Environmental Observatory (NPEO), the International Arctic Buoy Program (IABP), and the international Ice-Tethered Profiler (ITP) Program. This coordinated network provides vital information about Arctic Ocean changes.

Figure 1. Scheme of originally proposed program observations, including moorings, repeated oceanographic cross-sections, and Lagrangian drifters. We refer to the Amundsen and Nansen Basins collectively as the Eurasian Basin, and as distinct from the Makarov Basin.
The goal of this meeting is to discuss the progress of the NABOS program after its first 2013 field season (Figure 2), and to coordinate future efforts in preparation for a 2015 expedition. Following these general goals, the proposed Workshop’s Objectives are to

- Summarize major results of the 2013 field expedition, with particular focus on problems and unresolved issues that must be addressed in order to enhance observational capabilities of the program.

- Develop a plan for the 2015 expedition, including logistics, timelines, international cooperation strategies, and management approaches.

- Develop approaches for coordination of proposed activities with the wider Arctic science community. Identify needs of international communities for observational data collected by the program. Develop planning for engagement of young scientists in project activities.

We hope this workshop will lead to enhanced international partnership and field experiment strategies for several years forthcoming, coordinated together with broad U.S. and international Arctic communities.

Workshop coordinators will develop a draft report summarizing workshop outcomes. This document will be circulated amongst all workshop participants for further comments, before being finalized and located on the project website within the two months following the workshop.

Figure 2. Scheme of 2013 field experiment
April 23, 2014, Wednesday

Morning Coffee: 8.15 – 8.45 (catered)

8:45: Welcome from the Organizing Committee: I Polyakov, R. Rember, V. Ivanov

Morning session: 9.00 – 12.00 (coffee break 10:20 – 10:50).

I. 2013 field season. Chair: Igor Polyakov

1. Overview of the program – Igor Polyakov – 30 min.

Coffee break 10.40 – 11.00

2. Multidisciplinary component – Rob Rember – 20 min
4. Project targets in the focus – Igor Polyakov – 20 min.

Lunch: 12.00 p.m. – 13.00 p.m. (catered)

Afternoon Session: 13.00 – 17.00 p.m. (coffee break 14:50 – 15:30)

I. 2013 field season (Cont). Chair: Robert Rember

2. US partnership (O-buoys) – Patricia Matrai – 20 min.
3. US partnership (SVP buoys) – Mike Steele – 20 min.

Coffee break 14:50 – 15:30

II. Strengthening science and logistical strategies for 2015 field season and beyond

➢ Logistical support of future operations – 50 min :
a. Choice of ship and status of Arctic ice (V. Ivanov, R. Rember, J. Kemp and others)

b. Mooring strategies (I. Polyakov, R. Rember and others)

c. Plans for oceanographic survey, etc. (All participants)

➢ Implementing integrative observation strategies via US/AON cooperation – 40 min:

a. Enhancing coordination among Lagrangian buoy programs (All participants)

b. Enhancing implementation of new technologies (L. Rainville, C. Lee, P. Winsor and others)

c. Strengthening ties with other AON projects (I. Polyakov and others)

➢ Discussion – 30 min.

17:00: Adjourn

April 24, 2014, Thursday

Morning Coffee: 8.15 – 8.50 (catered)

Morning session: 8.50 – 12.00 (Coffee break 10.30 – 10.50)

II. Strengthening science and logistical strategies for 2015 field season and beyond (Cont). Chair: Vladimir Ivanov

➢ Enhancing multidisciplinary approach – 50 min:

a. Enhancing atmospheric component (O. Persson, I. Repina and others)

b. Enhancing ice component (R. Kwok, J. Hutchings, D. Perovich and others)

➢ Coordinating efforts among existing international observational programs – 1hr:

- Geomar Laptev Sea program (Heidi Kassens)

- AWI Arctic Ocean program (Markus Janout)

- Norwegian observational programs (Arild Sundfjord and/or Harald Steen)

- Russian observational programs (Alexander Danilov and/or Igor Ashik)

- Pacific Arctic Group’s plan (Kathy Crane)

- Chinese Arctic observations (Jinping Zhao)

Coffee break 10.30 – 10.50
General discussion including questions, field experiment requirements, output for the meeting etc. – 1hr 10min.

Adjourn by 12:00

Lunch: 12.30 p.m. – 13.30 p.m. (catered)

Dinner (19.00 – 21.00): *Enhancing collaboration via informal discussions.*

Where: F. Scott Fitzgerald A.
## List of participants
### NABOS/Eurasian Basin Ice camp meeting
#### April 23-25, Arlington VA

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexeev, Vladimir</td>
<td>IARC/UAF, USA</td>
<td><a href="mailto:valexeev@iarc.uaf.edu">valexeev@iarc.uaf.edu</a></td>
</tr>
<tr>
<td>Clemente-Colón, Pablo</td>
<td>NOAA</td>
<td><a href="mailto:Pablo.Clemente-Colon@noaa.gov">Pablo.Clemente-Colon@noaa.gov</a></td>
</tr>
<tr>
<td>Ferriz, Cecilia</td>
<td>APL/UW, USA</td>
<td><a href="mailto:ferriz@apl.washington.edu">ferriz@apl.washington.edu</a></td>
</tr>
<tr>
<td>Granger, Julie</td>
<td>U. Conn, USA</td>
<td><a href="mailto:julie.granger@uconn.edu">julie.granger@uconn.edu</a></td>
</tr>
<tr>
<td>Hutchings, Jenny</td>
<td>OSU, USA</td>
<td><a href="mailto:jhutchin@coas.oregonstate.edu">jhutchin@coas.oregonstate.edu</a></td>
</tr>
<tr>
<td>Kemp, John</td>
<td>WHOI, USA</td>
<td><a href="mailto:jkemp@whoi.edu">jkemp@whoi.edu</a></td>
</tr>
<tr>
<td>Krishfield, Richard</td>
<td>WHOI, USA</td>
<td><a href="mailto:rkrishfield@whoi.edu">rkrishfield@whoi.edu</a></td>
</tr>
<tr>
<td>Kwok, Ronald</td>
<td>JPL, USA</td>
<td><a href="mailto:ronald.kwok@jpl.nasa.gov">ronald.kwok@jpl.nasa.gov</a></td>
</tr>
<tr>
<td>Lee, Craig</td>
<td>APL/UW, USA</td>
<td><a href="mailto:craig@apl.washington.edu">craig@apl.washington.edu</a></td>
</tr>
<tr>
<td>Matrai, Patricia</td>
<td>Bigelow, USA</td>
<td><a href="mailto:PMatrai@bigelow.org">PMatrai@bigelow.org</a></td>
</tr>
<tr>
<td>Nguyen, An T</td>
<td>MIT, USA</td>
<td><a href="mailto:antnguyen13@gmail.com">antnguyen13@gmail.com</a></td>
</tr>
<tr>
<td>Obbard, Rachel W.</td>
<td>Dartmouth U., USA</td>
<td><a href="mailto:Rachel.W.Obbard@dartmouth.edu">Rachel.W.Obbard@dartmouth.edu</a></td>
</tr>
<tr>
<td>Padman, Laurie</td>
<td>ESR, USA</td>
<td><a href="mailto:padman@esr.org">padman@esr.org</a></td>
</tr>
<tr>
<td>Perovich, Don</td>
<td>CRELL, USA</td>
<td><a href="mailto:donald.k.perovich@usace.army.mil">donald.k.perovich@usace.army.mil</a></td>
</tr>
<tr>
<td>Persson, Ola</td>
<td>NOAA, USA</td>
<td><a href="mailto:ola.persson@noaa.gov">ola.persson@noaa.gov</a></td>
</tr>
<tr>
<td>Petty, Alek</td>
<td>ESSIC/NOAA, USA</td>
<td><a href="mailto:alek.petty@noaa.gov">alek.petty@noaa.gov</a></td>
</tr>
<tr>
<td>Pinkel, Robert</td>
<td>SCRIPS, USA</td>
<td><a href="mailto:rpinkel@ucsd.edu">rpinkel@ucsd.edu</a></td>
</tr>
<tr>
<td>Pluedemann, Al</td>
<td>WHOI, USA</td>
<td><a href="mailto:aplueddemann@whoi.edu">aplueddemann@whoi.edu</a></td>
</tr>
<tr>
<td>Pnyushkov, Andrey</td>
<td>IARC/UAF, USA</td>
<td><a href="mailto:andrey@iarc.uaf.edu">andrey@iarc.uaf.edu</a></td>
</tr>
<tr>
<td>Polyakov, Igor</td>
<td>IARC/UAF, USA</td>
<td><a href="mailto:igor@iarc.uaf.edu">igor@iarc.uaf.edu</a></td>
</tr>
<tr>
<td>Rainville, Luc</td>
<td>APL/UW, USA</td>
<td><a href="mailto:rainville@apl.washington.edu">rainville@apl.washington.edu</a></td>
</tr>
<tr>
<td>Reinking, Curtis</td>
<td>NOAA</td>
<td><a href="mailto:curtis.reinking@noaa.gov">curtis.reinking@noaa.gov</a></td>
</tr>
<tr>
<td>Rember, Rob</td>
<td>IARC/UAF, USA</td>
<td><a href="mailto:rob.reember@gmail.com">rob.reember@gmail.com</a></td>
</tr>
<tr>
<td>Stanton, Tim</td>
<td>NPS, USA</td>
<td><a href="mailto:stanton@nps.edu">stanton@nps.edu</a></td>
</tr>
<tr>
<td>Steele, Mike</td>
<td>APL/UW, USA</td>
<td><a href="mailto:mas@apl.washington.edu">mas@apl.washington.edu</a></td>
</tr>
<tr>
<td>Stockwell, Dean</td>
<td>IMS/UA, USA</td>
<td><a href="mailto:dastockwell@alaska.edu">dastockwell@alaska.edu</a></td>
</tr>
<tr>
<td>Wardell, Lois</td>
<td>Arapahoe SciTech</td>
<td><a href="mailto:wardell@arapahost.com">wardell@arapahost.com</a></td>
</tr>
<tr>
<td>Winsor, Peter</td>
<td>IMS/UA, USA</td>
<td><a href="mailto:pwinsor@alaska.edu">pwinsor@alaska.edu</a></td>
</tr>
</tbody>
</table>

### non-USA

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashik, Igor</td>
<td>AARI, Russia</td>
<td><a href="mailto:ashik@aari.ru">ashik@aari.ru</a></td>
</tr>
<tr>
<td>Danilov, Alexander</td>
<td>AARI, Russia</td>
<td><a href="mailto:aid@aari.nw.ru">aid@aari.nw.ru</a></td>
</tr>
</tbody>
</table>
31. Ivanov, Vladimir  AARI, Russia  vivanov@arthur.iarc.uaf.edu
32. Janout, Markus  AWI, Germany  Markus.Janout@awi.de
33. Kassens, Heidi  Geomar, Germany  hkassens@ifm-geomar.de
34. Perrie, William  Bedford Ins., Canada  William.Perrie@dfo-mpo.gc.ca
35. Repina, Irina  IFA, Russia  iar.ifaran@gmail.com
36. Steen, Harald  NPI, Norway  harald.steen@npolar.no
37. Sundfjord, Arild  NPI Norway  arild.sundfjord@npolar.no
38. Zhao, Jinping  OUC, China  jpzhao@ouc.edu.cn

Guests:

Brendan Kelley  Executive Office  of the President  Brendan_P_Kelly@ostp.eop.gov
Erica Key  NSF/AON  ekey@nsf.gov
Kathy Crane  NOAA  Kathy.Crane@noaa.gov
William Wiseman  NSF  wwiseman@nsf.gov
Neil Swanberg  NSF  nswanber@nsf.gov
Simon Stephenson  NSF  sstephen@nsf.gov
Martin Jeffries  ONR  martin.jeffries@navy.mil
Lisa Clough  NSF  lclough@nsf.gov
Rickey Petty  AAF/DOE  rick.petty@science.doe.gov