THE OFFICIAL MAGAZINE OF THE OCEANOGRAPHY SOCIETY

Oceanography

CITATION

Crane, K., and A. Ostrovskiy. 2015. Introduction to the special issue: Russian-American Long-term Census of the Arctic (RUSALCA). *Oceanography* 28(3):18–23, http://dx.doi.org/10.5670/oceanog.2015.54.

DOI

http://dx.doi.org/10.5670/oceanog.2015.54

Russian-American Long-term Census of the Arctic

RUSALCA

By Kathleen Crane and Aleksey Ostrovskiy

Photo credit: RAS-NOAA

Photo credit: RAS-NOAA

July 23, 2004, was a historic day in Arctic research and exploration as well as in Russian-US scientific relations. On this day, the Russian research vessel *Professor Khromov* left Vladivostok, Russia, packed with 52 US- and Russian-funded scientists to begin a 45-day collaborative journey to obtain climate and ecosystem observations in the Pacific Arctic Ocean—a region where summer sea ice cover was declining dramatically. Until that point, the Chukchi Sea, and the life within it, were poorly mapped.

The Cold War negatively affected Soviet and US cooperation, especially in the Bering Strait region, the only Pacific gateway to the Arctic Ocean. Because the United States and the Soviet Union were the gatekeepers of this strait, the region was heavily fortified by the military. It was very difficult for oceanographers to break through this stranglehold on one of the most ecologically and climatologically critical regions in the Arctic.

Toward the end of the Cold War, the door for cooperation between the nascent Russian Federation and US scientific communities was opened, and the Arctic nations rose together to develop an environmental protection strategy. Building upon a US-USSR Environmental Agreement, the US Fish and Wildlife Service developed a bilateral project in 1991 called "The Ecology and Dynamics of Arctic Marine Ecosystems." Because the study area included the Bering and Chukchi Seas and the North Pacific Ocean, the project became known as BERPAC. This program focused on the study of the status and dynamics of Arctic marine ecosystems as affected by humans and potential climate changes (key components of the Arctic Environmental Protection Strategy).

In comparison with other international oceanographic expeditions, BERPAC offered several notable advantages:

- Long-term series of surveys (two decades)
- Repeat sampling of the same areas of the Bering and Chukchi Seas
- Interdisciplinary approach
- Regular expeditions
- Bilateral publications and symposia (Smith et al., 2000)

The last BERPAC expedition took place in 1993. Over a decade would pass before permission was sought *and* granted for both Russian and US scientists to again survey changes in the Chukchi Sea's climate and ecosystem—and to examine what was becoming a dramatic loss of sea ice cover.

TRANSITIONS TO RUSALCA

During the latter part of the 1990s, the US and USSR Agreement on Cooperation in Studies of the World Ocean, signed by US Secretary of State William Rogers and Russian Foreign Minister Andrei Gromyko in 1972, lay dormant. The National Oceanic and Atmospheric Administration (NOAA), which had been the signatory of this agreement on behalf of the US government, sought to reconnect with the Russian Academy of Sciences. The objective was to rebuild cooperation not only in the world ocean but also in the Arctic because the Pacific Arctic seas (especially the Bering and the Chukchi) were areas governed by both our nations. We, the Mission Coordinators, were pleased to be able to stimulate the conversation about Arctic collaboration on a government-to-government level.

Many avenues for progress were considered, and even though they did not result in a renewed Studies of the World Ocean Agreement, they did lead to a new 2003 Memorandum of Understanding between the Russian Federation and the United States for World Ocean and Polar Region Studies. It would sit under the still-functioning 1993 Science and Technology Agreement between the United States and the Russian Federation.

Photo credit: Katrin Iken

Photo credit: Christine Patrick

Photo credit: RAS-NOAA

Photo credit: Maria Pisareva

Photo credit: RAS-NOAA

Photo credit: Christine Patrick

Photo credit: Aleksey Ostrovskiy

Photo credit: Bodil Bluhm

THE MECHANISMS

The Russian-American Long-term Census of the Arctic (RUSALCA) program stemmed from the 2003 Memorandum of Understanding between NOAA and the Russian Academy of Sciences (Figure 1). As Mission Coordinators, we realized that we would have to create a new model for cooperation and expand partnerships among multiple agencies in both the Russian Federation and the United States. This would involve matching scientists from both countries to carry out the multidisciplinary research and observations needed to build a long-term climate and ecosystem observing network in the Pacific Arctic (Figure 2). Scientific proposals for cooperation were accepted in both countries. Leadership in Russia was centered on the private-public partnership "Alliance Group," and in the United States, the Arctic Research Office (ARO) of NOAA. NOAA's cooperative Institute for Arctic Research (CIFAR) assisted the ARO with many of the decisions on the US side.

In November 2003, a RUSALCA planning workshop was held in Moscow, Russia, to outline the atmospheric, biological, geological, chemical, and physical oceanographic sampling strategies to be pursued in the Bering Strait and the Chukchi Sea. The initial expedition to the Bering and Chukchi Seas (Arctic Ocean) was conducted July 23–September 6, 2004. This expedition was a collaborative US-Russian Federation oceanographic mission to the Pacific Arctic seas supported by the Russian Academy of Sciences; the Russian Ministries of Natural Resources; Roshydromet, the research arm of the Russian Navy; NOAA's Arctic Research Office and Office of Ocean Exploration; and the US National Science Foundation Office of Polar Programs. Critical information gathered in preparation for placement of a climate-ecosystem monitoring network included characterizing the region's fluxes of freshwater and saltwater and establishing benchmarks for the distribution and migration patterns of life in these seas.

THE EXPEDITIONS

Because of the visibility of the RUSALCA program, we felt it was necessary to design a new template for running the program on land and at sea. The area of observations lay in a militarily sensitive region, and thus we invited the Russian Naval Research Laboratory (GNINGI)

We would like to dedicate this issue to the memory of Admiral Sergey P. Alekseev, a tireless supporter of the RUSALCA mission.

to take part as "Chief of Expeditions" to ensure that all Russian national laws were upheld and to pave the way for the science that we needed to carry out. GNINGI's director, Admiral Sergei Alekseev, was a major supporter of the civilian RUSALCA mission within the military structure of Russia.

Under the GNINGI leadership, there were government-to-government leads from NOAA in the United States and from the Alliance Group in Russia. Each appointed a RUSALCA Mission Coordinator tasked with building cooperation at the government-to-government and scientist-to-scientist levels. At sea, two chief scientists, one from Russia and one from the United States, were charged with facilitating cooperation between the science teams. By the end of the first decade of operation, we had built very close cooperation among all the scientists up the chain to the top of the RUSALCA infrastructure.

Following the initial expedition in 2004, the RUSALCA mission conducted two more long research programs in the Chukchi Sea and north to the Chukchi Plateau in 2009 and 2012. Annually, RUSALCA has deployed and serviced a complete Bering Strait mooring array—a joint US-Russian Federation initiative to monitor the flux of heat, freshwater, and nutrients from the Bering Sea into the Arctic Ocean.

OVERVIEW OF THIS SPECIAL ISSUE

The articles in this issue offer a sample of how bilateral cooperation can advance our understanding of a rapidly changing ocean. **Wood et al.** elucidate the RUSALCA decade of accelerated climate change. The rapid loss of sea ice during the period 2004 to 2013 is the most noticeable characteristic of the emerging "new Arctic" climate (e.g., Wang et al., 2009; Overland et al., 2012; Wood et al., 2015; Carmack et al., 2015)

Recognizing that rapid sea ice loss must have a significant impact on fisheries led **Mecklenburg and Steinke** to compile all known information on the composition, geographic ranges, and characteristics of Pacific Arctic fish. The mission for icthyological investigations in the RUSALCA program has been to provide information necessary to construct zoogeographic and taxonomic baselines against which change may be detected in the future. RUSALCA fish trawling in 2009 when ice was diminished to the north of the Chukchi Plateau revealed that many rare species of fish live in this Pacific Arctic environment. These species were only previously known to survive in the Atlantic Arctic. Whether or not these fish migrated along the warming pulse of intermediate Atlantic water from the Atlantic toward the Pacific Arctic is not known (Chernova, 2009; Norcross et al., 2010).

Woodgate et al. identify large temporal and spatial variability in fluxes through Bering Strait during the period from 1990 to 2011. RUSALCA's first decade of observations registered noticeable increases in the annual mean volumes of heat (by 50%) and freshwater fluxes northward into the Arctic Ocean. Tantalizing results also suggest that these increases contributed to the triggering of summer sea ice melting north of the Chukchi Sea (Woodgate et al., 2005, 2010; Polyakov et al., 2012).

First results from year-round bio-optics, nitrate, and ocean acidification sensors indicate a significant seasonal and spatial change possibly driven by spring phytoplankton blooms. These Pacific waters are important sources of nutrients for Arctic ecosystems (Walsh et al., 1997), and they provide about one-third of the freshwater entering the Arctic (Aagaard and Carmack, 1989). The broad impacts of the Bering Strait throughflow are important to monitor because they affect both local and global environmental and climate studies.

Woodgate et al. also suggest that the use of only three moorings in US waters is sufficient to determine physical oceanographic properties through the strait (Woodgate et al., 2006, 2007). In contrast, **Pisareva et al.** provide evidence to suggest that a proper understanding of Bering Strait flow through to Herald Canyon requires information from Russian territorial water moorings, which the RUSALCA program has continued to support.

Data from the Bering Strait mooring array also provide much needed information about the changing state of nutrients

FIGURE 1. The 2003 US and Russian Federation Memorandum of Understanding team. Back row, left to right: Josh Foster, Kathleen Crane, Rene Eppi, Yuri Shiyan, Doso Jang, and Susan Ware Harris. Bottom row, left to right: Richard Spinrad, Vice Admiral Lautenbacher, Academician Nikolai Laverov, and Aleksey Ostrovskiy.

and the migration of upper trophic level animals such as marine mammals and seabirds. Changes in marine mammal occurrence can be detected both visually and acoustically by recording underwater sounds. From September to December since 2009, sub-Arctic species of humpback, fin, and killer whales were detected (**Woodgate et al.**). Marine mammals are sentinels of Arctic ecosystem changes (Moore et al., 2014), and understanding the physical drivers of these shifts, and how they vary on a range of time scales, requires long-term monitoring.

Bates illustrates why it is important to measure CO_2 fluxes across the entire Chukchi and East Siberian Seas to gain an understanding of the variability of the ocean carbon cycle, air-sea CO_2 gas exchange, and ocean acidification variability. Summertime surface waters in the western regions of the Chukchi Sea and the East Siberian Sea mostly exhibited low $p$$CO_2$ (<100–400 µatm) during the sea ice retreat. Earlier studies in the eastern Chukchi Sea show a strong potential for ocean uptake of atmospheric CO_2, with saturation states for calcium carbonate minerals having values generally greater than two, thereby facilitating $CaCO_3$ production. In contrast, waters near the Russian coast and nearly 70% of waters next to the seafloor were corrosive to $CaCO_3$ minerals. The decade-long observations suggest that the exposure of benthic communities to a lower pH ocean is progressing faster than typical global open-ocean changes in ocean chemistry (Semiletov et al., 2007; Bates and Mathis, 2009; Bates et al., 2009).

Some important discoveries were also made about the temporal and spatial variability of lower trophic level organisms. **Ershova et al.** examine historical data sets on zooplankton communities in the central Chukchi Sea during the time period spanning 1946 to 2012. Analysis is confounded by differences between years in terms of spatial coverage, seasonal variability, and methodology. Nonetheless, trends remain detectable when a sufficient number of study years are compiled. In addition to high levels of interannual variability, these authors demonstrate that there have been significant increases in zooplankton biomass and abundance in recent years compared to historical studies, as well as shifting distribution ranges for several key species. This signal is most pronounced in copepods, particularly *Calanus glacialis*, which appears to be benefiting from warming of the region. While summer zooplankton communities of the Chukchi Sea have been primarily Bering-Pacific in character for as long as records exist, continuing warming and ice loss are increasing the influence of Bering-Pacific fauna in the Chukchi region. Predators of these zooplankton may also be migrating northward in search of more abundant food sources.

Benthic ecosystem observations also recorded local biomass hotspots. **Grebmeier et al.**, **Cooper et al.**, **N. Denisenko and Grebmeier**, and **S. Denisenko et al.** all report changes in habitat over a period of several decades

Russian-American Long-term Census of the Arctic (RUSALCA) Goals

1. Take observations where Arctic sea ice reduction is a maximum
2. Monitor freshwater, heat, and nutrient fluxes and transport pathways through the Pacific Gateway to the Arctic
3. Monitor ecosystem indicators of climate change in the Pacific Arctic
4. Monitor changes in ecosystems and Arctic-wide physical systems that impact global climate and ecosystem stability
5. Improve Russian-US Arctic science relations
6. Explore the unknown Arctic

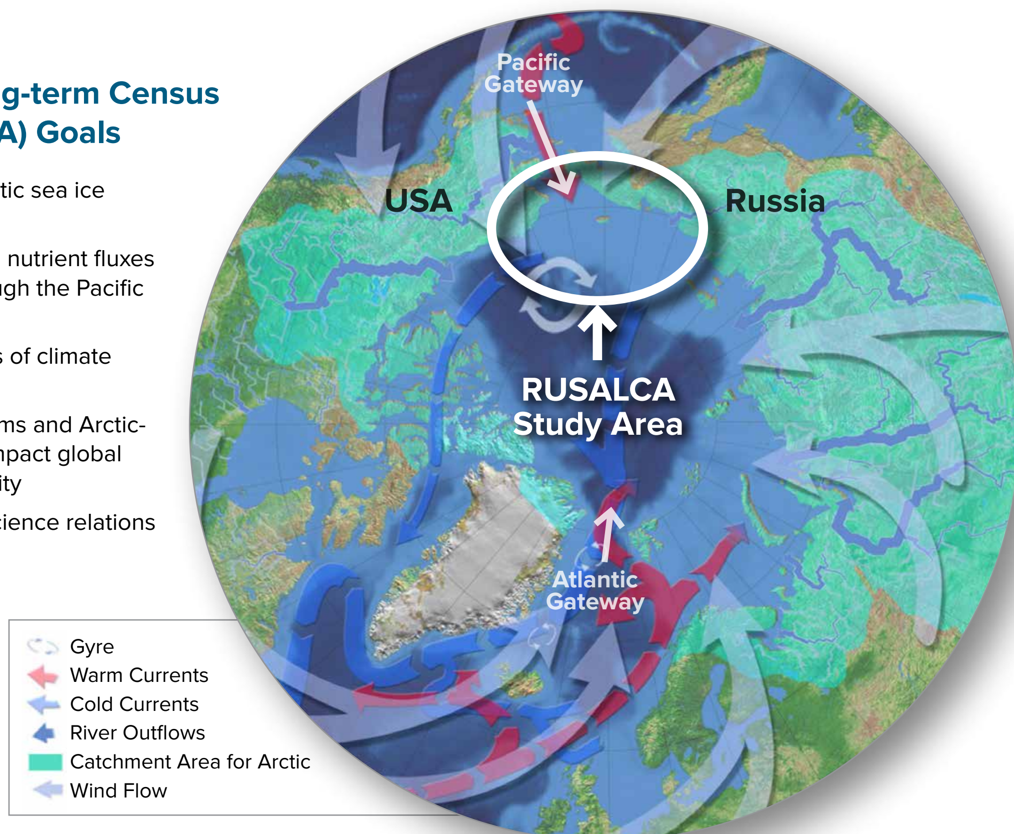

FIGURE 2. Goals of the RUSALCA program.

based on data assembled from prior Russian oceanographic expeditions in this region and the more current RUSALCA missions. A zone of large biomass productivity in the Bering Strait region, discovered during the earlier BERPAC missions, was found to have greatly increased productivity in 2009 compared with 2004. Carbon-to-nitrogen ratios have increased since 2004 at productive sites in this region, suggesting changes in organic material deposition. Other indicators studied on some or all of the decadal series of joint Russia-US cruises include sediment oxygen demand, the nitrogen isotopic composition of organic matter, sediment grain size, chlorophyll content in surface sediments, and elemental ratios of carbon and nitrogen in surface sediments. These process measurements support interpretations that the ecosystem shows strong coupling between bacterial and primary production and the underlying benthos (Savvichev et al., 2007; Sirenko and Gagaev, 2007; Lein et al., 2007; Mathis et al., 2014; Grebmeier et al., 2015).

N. Denisenko and Grebmeier observed a significant relationship between bryozoan faunal richness and large water column temperature gradients within various geographic regions of the Chukchi Sea. Their observations led to the conclusion that the Pacific Ocean water mass strongly influences the health of the bryozoan fauna. Of the 204 registered bryozoan species, about 30% are of Pacific origin. Bryozoans mapped in the southern and eastern parts of the Chukchi Sea are most closely related to those in the more southerly Bering Sea. Analysis of variable species composition over the Chukchi Sea confirms the existence of a transitional zone between the Arctic and Pacific high boreal biogeographic regions in the western and northern areas of the sea. The boundary between boreal and Arctic species extends from Cape Serdtse-Kamen' in the western Chukchi Sea northward to Point Franklin (68°30'N) in the eastern Chukchi Sea and then declines in the northwestern direction from Icy Cape.

S. Denisenko et al. show that there were changing domains of the total standing stock and the spatial biomass distributions of key macrofaunal species, as well as the main taxonomic and trophic groups of zoobenthos, in Chukchi Sea collections over the period 1986 to 2012. The dominant species, ranked by biomass, are: the bivalves *Macoma calcarea, Ennucula tenuis*, *Astarte borealis*, *Nuculana radiata*, *and Yoldia hyperborea*; the sipunculid *Golfingia margaritacea*; the polychaete *Maldane sarsi*; and the sea cucumber *Psolus peroni*. The authors interpret these distributions as a function of the influence of bottom sediments and water masses on the zoobenthos, and they consider various mechanisms that could facilitate the very high benthic biomass in the southern eutrophic Chukchi Sea.

Pisareva et al. investigate aspects in which the benthic fauna, sediment structure, and zooplankton in the Chukchi Sea are related to the hydrographic conditions on the shelf and the circulation patterns. For the most part, benthic epifaunal and macrofaunal suspension feeders are found in high flow regimes, while deposit feeders are located in regions of weaker flow. The major exceptions are in Bering Strait and in Herald Canyon. Sediment grain size is also largely consistent with variations in flow speed on the shelf. Data from the 2004, 2009, and 2012 RUSALCA biophysical surveys of the Chukchi Sea also reveal close relationships between the water masses on the shelf and zooplankton communities. Variations in atmospheric forcing (**Wood et al.**), particularly wind, during the main RUSALCA expeditions caused significant changes in the lateral and vertical distributions of the summer and winter water masses. This in turn was reflected in the amounts and species of zooplankton observed throughout the shelf in each survey.

Matveeva et al. discuss methane release in the RUSALCA region of the Arctic environment. Warmed relict seafloor permafrost on the shallow Arctic shelves of the Chukchi and East Siberian Seas can easily thaw over a relatively short time period. Very few data about the sources of methane in the Chukchi Sea were available prior to RUSALCA. This article illustrates for the first time the role of methane turnover and net transport in organic-rich environments within western Chukchi Sea. The study corroborates historical observations, new data obtained during the RUSALCA program, and modeling results, providing important insights into contemporary methane dynamics in the western Chukchi Sea. The results of their studies indicate that the Southern Chukchi Basin is one important source of atmospheric CH_4; further work is required to accurately quantify this flux (Shakhova et al., 2010).

Finally, **Astakhov et al.** examine Chukchi Sea sediment geochemistry and diatom distribution to investigate climate changes over space and time. Sediment cores are the most continuous archives available for paleoenvironmental reconstructions. Such reconstructions for the shelf of the East Siberian and Chukchi Seas are complicated because of the paucity and poor preservation of biological remains, including the carbonates usually used for paleoproductivity and paleoenvironment studies in deeper parts of the Arctic Ocean (Polyak et al., 2004; de Vernal et al., 2005). Therefore, the main goal of the RUSALCA paleoceanography team was to analyze the sedimentary indicators of climate change based on both investigation of biogenic elements produced by phytoplankton in the Chukchi Sea sediments and study of the chemical composition of the sediments. The species compositions of diatom assemblages in the sediments were also analyzed in detail to enable environmental reconstructions of the changing climate in the Pacific Arctic (Tsoy et al., 2009). Notable discoveries from this work include the reconstruction of paleo-transport pathways of warm Pacific water within the Chukchi Sea.

These articles illustrate the breadth of science carried out by RUSALCA in a previously poorly observed region of the Arctic. We, as RUSALCA Mission Coordinators, designed the sampling strategy to overlap as much as possible with previous Soviet and US expedition transects in the region. Scientists from the Russian Federation, the United States, South Korea, and Norway collaborated to collect Arctic atmospheric, marine chemistry, physics, geology, and biology-ecosystem observations with the goal of capturing the changes in this environmentally sensitive region at a critical stage in its evolution from an ice-covered marginal sea to a predominately ice-free summer state.

It is our hope that the RUSALCA mission will continue to collect a sustained suite of observations and provide baseline information about changes in the Pacific Arctic in the decades to come. The data gathered over the last 10 years already constitute a major contribution from both the Russian Federation and the United States to the Arctic Council's Conservation of Arctic Flora and Fauna working group on pan-Arctic Marine Biodiversity Monitoring (CBMP-Marine; http://www.CAFF.is).

It has been our pleasure as the Russian and US Mission Coordinators to lead this group of very talented investigators from both of our countries. We look forward to decades of collaboration to come.

REFERENCES

Aagaard, K., and E.C. Carmack. 1989. The role of sea ice and other fresh water in the Arctic circulation. *Journal of Geophysical Research* 94(C10):14,485–14,498, http://dx.doi.org/10.1029/JC094iC10p14485.

Bates, N.R., and J.T. Mathis. 2009. The Arctic Ocean marine carbon cycle: Evaluation of air-sea CO_2 exchanges, ocean acidification impacts and potential feedbacks. *Biogeosciences* 6(11):2,433–2,459, http://dx.doi.org/10.5194/bg-6-2433-2009.

Bates, N.R., J.T. Mathis, and L.W. Cooper. 2009. Ocean acidification and biologically induced seasonality of carbonate mineral saturation states in the western Arctic Ocean. *Journal of Geophysical Research* 114, C11007, http://dx.doi.org/10.1029/2008jc004862.

Carmack, E., I. Polyakov, L. Padman, I. Fer, E. Hunke, J. Hutchings, J. Jackson, D. Kelley, R. Kwok, C. Layton, and others. 2015. Towards quantifying the increasing role of oceanic heat in sea ice loss in the new Arctic. *Bulletin of the American Meteorological Society*, http://dx.doi.org/10.1175/BAMS-D-13-00177.1.

Chernova, N.V. 2009. Review of fish fauna of the Chukchi Sea. P. 19 in *13th European Congress of Ichthyology, 6–12 September, 2009.* Klaipeda, Lithuania.

de Vernal, A., C. Hillaire-Marcel, and D.A. Darby. 2005. Variability of sea ice cover in the Chukchi Sea (western Arctic Ocean) during the Holocene. *Paleoceanography* 20, PA4018, http://dx.doi.org/10.1029/2005PA001157.

Grebmeier, J.M., B.A. Bluhm, L.W. Cooper, S. Danielson, K.R. Arrigo, A.L. Blanchard, J.T. Clark, R.H. Day, K.E. Frey, R.R. Gradinger, and others. 2015. Ecosystem characteristics and processes facilitating persistent macrobenthic biomass hotspots and associated benthivory in the Pacific Arctic. *Progress in Oceanography* 136:92–114, http://dx.doi.org/10.1016/j.pocean.2015.05.006.

Lein, A.Y., A.S. Savvichev, I.I. Rusanov, G.A. Pavlova, N.A. Belyaev, K. Crane, N.V. Pimenov, and M.V. Ivanov. 2007. Biogeochemical processes in the Chukchi Sea. *Lithology and Mineral Resources* 42(3):221–239, http://dx.doi.org/10.1134/S0024490207030029.

Mathis, J.T., J.M. Grebmeier, D.A. Hansell, R.R. Hopcroft, D. Kirchman, S.H. Lee, and S.B. Moran. 2014. Carbon biogeochemistry of the Western Arctic: Production, export and ocean acidification. Pp. 223–268 in *The Pacific Arctic Region: Ecosystem Status and Trends in a Rapidly Changing Environment.* J. Grebmeier and W. Maslowski, eds, Springer, Dordrecht.

Moore, S.E., E. Logerwell, L. Eisner, E.V. Farley Jr., L.A. Harwood, K. Kuletz, J. Lovvorn, J.R. Murphy, and L.T. Quakenbush. 2014. Marine fishes, birds and mammals as sentinels of ecosystem variability and reorganization in the Pacific Arctic region. Pp. 337–392 in *The Pacific Arctic Region: Ecosystem Status and Trends in a Rapidly Changing Environment*. J.M. Grebmeier and W. Maslowski, eds, Springer.

Norcross, B.L., B.A. Holladay, M.S. Busby, and K.L. Mier. 2010. Demersal and larval fish assemblages in the Chukchi Sea. *Deep-Sea Research Part II* 57(1–2):57–70, http://dx.doi.org/10.1016/j.dsr2.2009.08.006.

Overland, J.E., J.A. Francis, E. Hanna, and M. Wang. 2012. The recent shift in early summer Arctic atmospheric circulation. *Geophysical Research Letters* 39, L19804, http://dx.doi.org/10.1029/2012GL053268.

Polyak, L., W.B. Curry, D.A. Darby, J. Bischof, and T.M. Cronin. 2004. Contrasting glacial/interglacial regimes in the western Arctic Ocean as exemplified by a sedimentary record from the Mendeleev Ridge. *Palaeogeography, Palaeoclimatology, Palaeoecology* 203:73–93, http://dx.doi.org/10.1016/S0031-0182(03)00661-8.

Polyakov, I.V., J.E. Walsh, and R. Kwok. 2012. Recent changes of Arctic multiyear sea ice coverage and the likely causes. *Bulletin of the American Meteorological Society* 93(2):145–151, http://dx.doi.org/10.1175/BAMS-D-11-00070.1.

Savvichev, A.S., I.I. Rusanov, N.V. Pimenov, E.E. Zakharova, E.F. Veslopolova, A.Y. Lein, K. Crane, and M.V. Ivanov. 2007. Microbial processes of the carbon and sulfur cycles in the Chukchi Sea. *Microbiology* 76(5):603–613, http://dx.doi.org/10.1134/S0026261707050141.

Semiletov, I., I. Pipko, I. Repina, and N.E. Shakhova. 2007. Carbonate chemistry dynamics and carbon dioxide fluxes across the atmosphere-ice-water interfaces in the Arctic Ocean: Pacific sector of the Arctic. *Journal of Marine Systems* 66:204–226, http://dx.doi.org/10.1016/j.jmarsys.2006.05.012.

Shakhova, N., I. Semiletov, A. Salyuk, V. Yusupov, D. Kosmach, and Ö. Gustafsson. 2010. Extensive methane venting to the atmosphere from sediments of the East Siberian Arctic shelf. *Science* 327:1,246–1,250, http://dx.doi.org/10.1126/science.1182221.

Sirenko, B.I., and S.Y. Gagaev. 2007. Unusual abundance of macrobenthos and biological invasions in the Chukchi Sea. *Biologia morja* 33(6):399–407, http://dx.doi.org/10.1134/S1063074007060016.

Smith, G., J.M. Grebmeier, S. Kohl, and A.V. Tsyban. 2000. BERPAC: A long-term ecological research program of the Bering and Chukchi Seas and Pacific Ocean. ARCUS Annual Meeting and Arctic Forum Abstracts.

Tsoy, I.B., M.S. Obrezkova, and A.V. Artemova. 2009. Diatoms in surface sediments of the Sea of Okhotsk and the Northwest Pacific. *Oceanology* 49:130–139, http://dx.doi.org/10.1134/S0001437009010159.

Walsh, J.J., D.A. Dieterle, F.E. Muller-Karger, K. Aagaard, A.T. Roach, T.E. Whitledge, and D. Stockwell. 1997. CO_2 cycling in the coastal ocean: Part II. Seasonal organic loading of the Arctic Ocean from source waters in the Bering Sea. *Continental Shelf Research* 17:1–36, http://dx.doi.org/10.1016/0278-4343(96)00021-0.

Wang, J., J. Zhang, E. Watanabe, M. Ikeda, K. Mizobata, J.E. Walsh, X. Bai, and B. Wu. 2009. Is the Dipole Anomaly a major driver to record lows in Arctic summer sea ice extent? *Geophysical Research Letters* 36, L05706, http://dx.doi.org/10.1029/2008GL036706.

Wood, K.R., N.A. Bond, S.L. Danielson, J.E. Overland, S.A. Salo, P. Stabeno, and J. Whitefield. 2015. A decade of environmental change in the Pacific Arctic region. *Progress in Oceanography* 136:12–31, http://dx.doi.org/10.1016/j.pocean.2015.05.005.

Woodgate, R.A., K. Aagaard, and T.J. Weingartner. 2005. A year in the physical oceanography of the Chukchi Sea: Moored measurements from autumn 1990–1991. *Deep Sea Research Part II* 52:3,116–3,149, http://dx.doi.org/10.1016/j.dsr2.2005.10.016.

Woodgate, R.A., K. Aagaard, and T.J. Weingartner. 2006. Interannual changes in the Bering Strait fluxes of volume, heat and freshwater between 1991 and 2004. *Geophysical Research Letters* 33, L15609, http://dx.doi.org/10.1029/2006GL026931.

Woodgate, R.A., K. Aagaard, and T.J. Weingartner. 2007. *First Steps in Calibrating the Bering Strait Throughflow: Preliminary Study of How Measurements at a Proposed Climate Site (A3) Compare to Measurements within the Two Channels of the Strait (A1 and A2).* University of Washington, 20 pp, http://psc.apl.washington.edu/HLD/Bstrait/A3asclimatesiteAug07.pdf.

Woodgate, R.A., S. Hartz, M. Kong, E. Ershova, V. Sergeeva, and K. Stafford. 2010. *RUSALCA 2010: Bering Strait Mooring Cruise Report, July/August 2010*. University of Washington, 55 pp., http://psc.apl.washington.edu/HLD/Bstrait/CruiseReportKhromov2010wEL_verNov11.pdf.

AUTHORS

Kathleen Crane (kathy.crane@noaa.gov) is US Mission Coordinator, Arctic Research Program, Climate Program Office, National Oceanic and Atmospheric Administration, Silver Spring, MD, USA. **Aleksey Ostrovskiy** is Russian Federation Mission Coordinator, Alliance Group, Russian Federation.

ARTICLE CITATION

Crane, K., and A. Ostrovskiy. 2015. Introduction to the special issue: Russian-American Long-term Census of the Arctic (RUSALCA). *Oceanography* 28(3):18–23, http://dx.doi.org/10.5670/oceanog.2015.54.