Polar Comparisons: Summary of 2012 Yeosu Workshop

by Kenneth Drinkwater, George Hunt, Eugene Murphy and Jinping Zhao

A 1-day workshop on "*Effects of climate change on advective fluxes in high latitude regions*" was held on May 14, 2012, prior to the 2nd International Symposium on "*Effects of Climate Change on the World's Oceans*" in Yeosu, Korea. Co-sponsored by ESSAS (Ecosystem Studies of Sub-Arctic Seas) and ICED (Integrating Climate and Ecosystem Dynamics in the Southern Ocean), both regional programs under IMBER (Integrated Marine Biogeochemistry and Ecosystem Research), the workshop was co-chaired by the authors of this article, and attended by 32 scientists from 10 different countries, with another 20 scientists contributing to the workshop presentations. The aim of the workshop was to review the advection of water masses within and between polar and subpolar regions, examine their forcing mechanisms, and consider what their role is on the ecology of these high latitude regions. This included the direct advection of heat, salt and nutrient fluxes, as well as direct and indirect effects on the flora and fauna. For higher trophic levels, such as marine mammals and seabirds, the effects of advection were indirect. New insights were sought through comparisons between the Arctic and Antarctic regions. Recent ecological changes and their links to climate variability were investigated, and in keeping with the major theme of the Symposium, the workshop also focused upon likely scenarios for the advective fluxes and their possible changes under future anthropogenic climate change. The workshop included 11 commissioned disciplinary presentations by teams consisting of experts from both the Arctic and Antarctic. They covered atmospheric climate, physical oceanography, biogeochemistry, microbes, ice biota, phytoplankton, zooplankton, benthic pelagic coupling, fish, marine mammals and seabirds. These teams put together presentations on the climate as well as effects on organisms, with special emphasis on the role of advective fluxes. Two presentations were also given based on submitted abstracts. After the presentations, three participants provided their thoughts on what they considered to be highlights of the workshop and what future research was needed as a lead-in to a general discussion. Prior to the end of the workshop, a discussion was held on writing up the results of the presentations and whether a working group should be formed under IMBER to carry forward the comparative studies of the Arctic and Antarctic.

Following the introduction to the workshop, the first disciplinary presentation was on atmospheric changes. Air temperatures have been warming over the Arctic but they have cooled slightly over most of the Antarctic. The polar vortex around Antarctica has strengthened in recent decades, resulting in stronger anticyclonic (clockwise) winds which, in turn, has led to the continent becoming more isolated atmospherically from the rest of the southern hemisphere. This change is related to an increase in the atmospheric pressure gradient between the Antarctic and the mid-latitudes and is linked to the Ozone Hole. In contrast, the Arctic vortex has weakened, resulting in winter outbreaks delivering cold Arctic air masses southwards to the United States and into Europe. The weakening of the Arctic vortex is related to the warming of the Arctic, which has reduced latitudinal atmospheric pressure gradients. Thus, we have the surprising result that warming in the north has caused extreme cold events over the northern continents.

Winds and currents play important roles in the advection of heat and salt, both into and out of the Arctic and clockwise around Antarctica. In the Arctic, the ocean has warmed through increased advection of warm waters from the south, as well as air-sea heat fluxes. This warming has led to significant reductions in both the areal coverage of sea ice and in the amount of multi-year ice (Fig. 1). With thinner ice and lower ice concentrations, it has been easier for the winds to move the ice around, and currents in the Arctic have been observed to have sped up in recent years. In the Antarctic, the sea-ice decline has been less, with the major reduction around the Western Antarctic Peninsula being offset by some regions where ice coverage has been increasing. In future, the Antarctic and Arctic waters are expected to become warmer, resulting in further reductions in sea-ice extent.

Fig. 1 Sea ice in the Arctic is disappearing at a rapid rate due to recent warming.

Phytoplankton production in both Polar Regions is strongly seasonal and controlled largely by light availability. In the Antarctic, iron is in short supply and therefore, represents another limiting factor on the total amount of primary production in the Southern Ocean. In contrast, there is sufficient iron in the Arctic. There, melting ice provides the vertical stratification necessary for initiation of the spring bloom, but once the nutrients are used up, primary production is limited because strong stratification limits the amount of new nutrients that can be mixed into the euphotic zone. Decreasing sea-ice coverage in the future is expected to result in higher light levels and a longer production period, resulting in higher primary production. Advection also plays a prominent role in primary production. For example, transport of deep water onto the West Antarctic Peninsula shelf brings nutrient-rich waters shoreward, contributing to the high phytoplankton production in these regions. In the Arctic, currents passing through the Bering Strait from the Pacific carry high nutrients and phytoplankton from the Bering Sea into the Chukchi Sea, resulting in higher production than would otherwise be the case. With the warming in the Arctic, large-sized phytoplankton are being replaced by smaller plankton, a process that is expected to continue with increased warming. The reduction in sea ice will mean a decline in the sea-ice associated algae and phytoplankton, which has been estimated to represent upwards of 50% of the total primary production in the deep Arctic Ocean.

Pelagic/benthic coupling is more important within the Arctic than the Antarctic because of the much greater area of shallow seas. In those regions with seasonal ice coverage, primary production occurs mostly in a very intense spring bloom, and a large percentage sinks to the sea floor. Some changes in benthic production have been observed, *e.g.* in the Chirikov Basin in the northern Bering Sea. There is evidence of reduced carbon supply to the benthos and a shift in bivalve species. This has the potential to affect seabirds such as eider ducks which feed on the bivalves. Where there is a likelihood of greater stratification over some of the shelf areas of the Arctic, a weakening of pelagic/benthic coupling is expected. Changes in the zooplankton community may also lead to changes in the coupling, depending on what the zooplankton feed upon and their fecal pellet production and sinking rates.

There are indications that krill (*Euphausia superba*), the dominant zooplankton species in Antarctic waters, have been declining during recent years. Concurrent with this decrease has been a rise in salps in some areas. The change in the ecosystem structure from krill to salps, or to other smaller zooplankton (*e.g.* copepods), results in a less energy-efficient ecosystem, with less energy available for higher trophic levels. Krill are ice-associated organisms. Many of those produced around the Antarctic Peninsula are transported by local currents to the area around South Georgia, an important breeding area for both marine mammals and seabirds, several species of which forage primarily on krill. The loss of sea ice off the Western Peninsula may have contributed to a decline in krill and, consequently, less krill may have been transported towards South Georgia in recent years.

In the subarctic, increased advection of Atlantic waters farther north, for example off Iceland, has resulted in a corresponding increase in zooplankton biomass in recent years. Direct advection of zooplankton into the Arctic also occurs. Indeed, during summer, the Chukchi Sea zooplankton community is dominated by Bering Sea fauna, which has been advected through the Bering Strait. Little is known about zooplankton variability in the central Arctic Ocean due to a lack of data.

Some fish species may move into the Arctic under future warming, mostly through the movement of adults from the Atlantic Ocean. Which species will be able to survive and become resident populations is unclear at this time. Larval transport may contribute to the movement of fish as well, but whether these larvae will be able to grow and survive in the Arctic is unknown. Ice-dependent fish, such as polar cod, are expected to decline in abundance in parallel with the disappearance of the sea ice.

Ice-dependent marine mammals, such as some seals, walrus and polar bears, and seabirds, including penguins, have been stressed by the loss of ice, with significant declines in abundance of certain species in both the Arctic and the Antarctic. These declines are caused by a combination of an absence of sea ice for hauling out, foraging, or mating encounters, or shifts in prey abundance or availability. Further reductions in sea ice are expected to lead to greater population losses of those affected species.

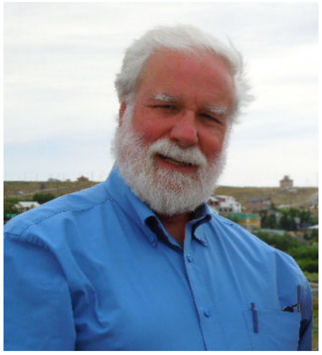
Advection plays an important role in terms of generating hotspots which attract marine mammals and seabirds to feed. Examples of a few significant feeding hotspots include Unimak Pass in the Aleutian Islands (Fig. 2), canyons in the Beaufort, Chukchi, Bering and Barents seas, and Margarite Bay off the West Antarctic Peninsula. It is not only the concentration of prey in these hotspots that is important but also the quality of the prey.

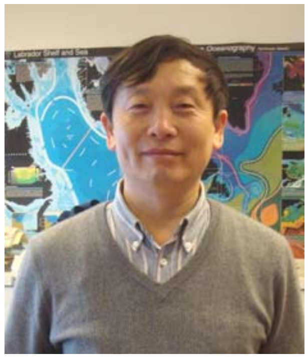
Fig. 2 Shearwaters and whales feeding near Unimak Pass in the Aleutians. Photo by Mike Britton, North Gulf Oceanic Society (NGOS), copyright Mike Brittain.

In addition to the requested disciplinary contributions, there were two submitted papers presented at the workshop. The first focused on estimates of new primary production (NPP) from satellite imagery and showed a positive relationship of NPP with SST (sea surface temperature) in both the Arctic and the Antarctic. This suggests that under future warming, there is likely to be a slight increase in NPP in the two areas. The other presentation compared copepod collections in 1964 and 2004 during the austral summer in the sub-Antarctic region of the western Indian Ocean. An increase in the carnivorous components in recent years suggests the possibility of an altered trophic structure.

One feature that differentiates the Arctic and the Antarctic is that the former is mostly a closed system while the latter is entirely open. Another feature is the difference in the connectivity or residence times, with relatively rapid connectivity around the Antarctic (scale of years) whereas in the Arctic it is much longer (decades to a century or longer). It is clear that large changes in the polar and subpolar regions are expected under anthropogenic climate change. Many participants stressed the need for increased observations and time series from these crucial areas.

At the end of the workshop the possibility of writing a paper or papers on the workshop results was discussed. No definite decision was made but the co-convenors will survey all those involved in the disciplinary groups to determine their interest in pursuing journal publications. A Working Group under IMBER will be formed to continue the comparisons of Arctic and Antarctic ecosystems, and those involved in the writing of any papers will be the initial members of such a working group.



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Dr. George Hunt (geohunt2@uw.edu) is Research Professor in the School of Aquatic and Fishery Sciences at the University of Washington. In 2005 he retired from the University of California, Irvine, after teaching and doing research there for 35 years. Now, he divides his time between Seattle and Friday Harbor, Washington. George began his career studying the behavioral and reproductive ecology of gulls in southern California and British Columbia. This work led to studies of seabird reproductive ecology on the Pribilof Islands and of the foraging ecology of seabirds in the Bering Sea, the Barents Sea, the North Water Polynya, and the Southern Ocean. More recently, he has participated in ecosystem-level studies of the southeastern Bering Sea, the Aleutian Archipelago, and in studies comparing the Barents Sea with the Bering Sea and the Chukchi Sea. George was the Chairman of the Scientific Steering Committee (SSC) of BEST (Bering Ecosystem Study) and Co-Chairman of the SSC of the IMBER Regional Program ESSAS (Ecosystem Studies of Sub-Arctic Seas). In PICES, he led Working Group 11 on Prey Consumption by Marine Mammals and Seabirds in the PICES Area, was founding Chairman of the Advisory Panel on Marine Birds and Mammals, and was a member of the CFAME (Climate Forcing and Marine Ecosystem Response) Task Team.

Dr. Eugene Murphy (ejmu@bas.ac.uk) is an ecological modeler with the British Antarctic Survey in Cambridge, UK. His main research interests include krill ecology, the general structure and function of the Southern Ocean ecosystems, and responses to physical oceanographic and climate forcing. Eugene is presently the chair of the ICED (Integrating Climate and Ecosystem Dynamics in the Southern Ocean) regional program of IMBER that focuses upon the Southern Ocean and is on the SSC of IMBER.

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