Sea Ice: Implications of changes in arctic sea ice

"Are sea ice conditions changing in the Arctic, and if so what changes are occurring, how do they vary regionally, and what are the effects on people?"

Background

The research initiative on Human Dimensions of the Arctic System (HARC) of the National Science Foundation (NSF) began in 1999. Since then, HARC has funded several projects that have examined various aspects of the ways in which humans affect and are effected by the arctic system. In an effort to promote interest in the initiative, NSF has sponsored a Science Management Office (SMO) for the HARC initiative. The workshop on sea ice is the third in a series of online workshops designed to stimulate discussion about topics related to HARC and to inspire researchers to submit proposals to the initiative.

Introduction

Sea ice in the Arctic profoundly influences arctic ecosystems, global climate and circulation of oceans and atmosphere in the north. A great deal has been learned about the properties of sea ice, its role in ocean circulation and ecology, and its implications for a range of human activities, but much more remains to be discovered. Examining the ways in which sea ice affects the physical, biological, and human systems of the Arctic is by nature a complex, interdisciplinary undertaking. To involve natural scientists, social scientists, and arctic residents in discussions of these topics, the HARC SMO organized an online workshop on the topic of sea ice and its implications. The text of the discussions is available online at http://arcus.zeroforum.com, and the participants list and further information about HARC and the workshop can be found at http://www.arcus.org/harc.

This report highlights research ideas and opportunities from the online workshop. These ideas are neither exhaustive nor exclusive. We hope readers and participants will use this report and other workshop materials as resources for developing proposals to the HARC initiative. Some of the ideas described are worthy of further attention but do not fit easily within the scope of HARC. Those interested in proposing to HARC should visit the HARC website for further information at http://www.arcus.org/harc. Future online workshops will be used to collect ideas and information about other potential HARC research topics. The SMO welcomes ideas for additional workshops or other ways of promoting collaborative discussions about human dimensions of the arctic system.

Physical Characteristics and Role of Sea Ice

Changes in the extent, thickness, and other properties of arctic sea ice are important topics of current research. There is considerable evidence of striking changes in ice extent, thickness, and type, but with signficant regional variability. The precise causes of these changes, including the role of the Arctic Oscillation and other cyclical factors, are unclear. The extent to which observed changes in ice thickness are due to overall thinning versus shifts in distribution of ice within different areas of the Arctic Basin needs further study.

Monitoring sea ice for large-scale changes requires remote sensing, but the interpretation of satellite and other data can be difficult. Considerable advances have been made in recent years, but more must be done to distinguish with confidence different kinds of ice, to determine ice thickness, and to measure or monitor other key parameters of sea ice with sufficiently high resolution and accuracy. This is particularly true for shorefast ice and newly formed ice, for which existing remote sensing techniques and data are less well suited than is the case for pack ice. To overcome these difficulties, the combined use of several sensing techniques, including the local observations and knowledge of arctic residents, is needed to provide the best understanding possible.

The ability to distinguish the role of oscillations versus trends in forcing the observed changes in sea ice is critical to climate change research. The Arctic Oscillation exerts a powerful influence, with changes

in the prevalence of oscillation modes appearing to have resulted in substantial changes in ice conditions. A switch from its current state may change sea ice characteristics dramatically, perhaps leading to greater extent and thickness of ice. Such a switch would not disprove a long-term decrease in ice, although identifying the trend within the oscillation would be challenging.

Improving our understanding of the interactions between ice, wind, snow, and oceanic conditions is important for determining the climate feedbacks that govern ice and that produce its great interannual variability. The relative importance of multi-year, first-year, and land-fast ice, and snow cover to the persistence of summer ice cover and quality of biological habitat is not well known. The relative roles of air temperature and oceanographic changes need to be determined to understand the mechanisms underlying changes in sea ice extent, thickness, and seasonality. Furthermore, it is important to study the significance of open water leads and polynyas to oceanographic and ecological conditions.

Using Historical and Archeological Sources

Direct measurements of sea ice from historical sources such as ships' logs and trading post records offer observations of sea ice extent, timing, and other characteristics. In some areas, such as the Barents Sea, these records extend two or more centuries into the past. The records also point the way to significant influences on sea ice, for example the role of storms in the break-up of shorefast ice in Labrador and consequent impacts to seals and hunters. Experiences of local hunters and travelers are also important resources for reconstructing the patterns of sea ice.

Both historical and archeological sources offer proxy indicators of sea ice extent and timing over centuries and millennia, although interpreting these records is not a simple task. Faunal remains, for example, can yield a great deal of information on the condition of prey animals and the availability or selections made by hunters, but only if these sources of data are recovered when sites are excavated. Social and technological changes—in the past as well as in recent decades—may greatly alter patterns of living and resource utilization, making extrapolations to environmental conditions tentative. Nonetheless, sources of this kind are a valuable addition to other paleo-environmental records.

Coastal Impacts of Ice

Sea ice affects coastal areas in many ways. Bottom ice in shallow water interacts with sub-sea permafrost, which in turn may control erosion and sediment transport. The presence of sea ice prevents waves from eroding coastlines, whereas increases in open water may exacerbate the impacts of severe storms and storm surges. Whether storm tracks and strength of storms are affected by changes in the location and conditions of the ice edge is an unresolved but important question in ocean-ice-atmosphere interactions. The characteristics of near-shore ice are vital in many respects, from the dynamics of ice formation and break up to the safety and speed of over-ice travel by hunters. Break-up of land-fast ice in particular appears to be the result of several interacting factors, making modeling difficult.

Ecological Importance of Ice

Sea ice serves a broad and significant role in arctic ecology, most visibly for the many fish, bird, and mammal species that live in, on, or under sea ice, or are otherwise constrained or aided by its presence. Changing sea ice conditions will impact not only the marine ecosystem, but will have ramifications for terrestrial environments and the wildlife and people found there.

Sea ice both shelters the underlying water column and blocks sunlight, affecting the productivity of the Arctic Ocean that is driven by plankton and algae. Moving ice in shallow water gouges the seabed, disrupting benthic communities while stirring nutrients and sediments into the water column. As a physical platform, sea ice provides the substrate needed by algae, as well as serving as a resting and birthing place for seals, a hunting and breeding ground for polar bears, a foraging ground for arctic fox, seabirds, whales and other animals. Leads in the icepack and polynyas, such as the North Water, are characterized by particular oceanographic and ecological conditions, which may be severely disrupted by changes in climate.

Studies from ice camps and ships frozen in the ice pack have found radical changes in ice-associated species over the past few decades. Harp seal pups in the White Sea suffered catastrophic mortality in 1966 and 2001 as a result of unfavorable winds moving sea ice and affecting the pups' ability to feed. Arctic foxes have been stranded on shore, where they compete

with terrestrial predators instead of migrating onto the ice and beyond.

The oceanographic changes that lead to sea ice changes may force marine invertebrates and their predatotrs to move, perhaps leading to the extinction of some species and sub-species. Certain types of marine invertebrates are expanding their ranges northward, displacing the indigenous forms or species. Many animals depend on marine invertebrates for food, including walrus, eiders, and whales; thus, changes in the composition of marine invertebrates could profoundly affect higher trophic levels.

Many of these changes are perhaps within the variability typical of the Arctic region, but others strongly indicate directional change. Investigating these and other such changes and their implications is critical to understanding the full role of sea ice in arctic ecology.

Humans and Sea Ice

Humans in the Arctic are affected in many ways, directly and indirectly, by sea ice. Marine mammal hunters require access to prey, which is dependent on the distribution, quality and movement of the ice fields, which also affects the ability of the hunters to reach and safely recover the animals that are harvested. Changes in ice distribution may affect both access and timing of harvest, potentially conflicting with other seasonal activities. Reaching the animals may require improvements in transportation or taking greater risks to travel farther or across less stable ice.

Some types of small-scale fishing in the Arctic can be affected by the timing of freeze up. Thin autumn ice is needed as a platform for fishing, and must be in place before the fish runs occur. If freeze up is late, the opportunity is lost. Commercial fishing in subarctic waters can be greatly affected by the oceanographic influences of ice, particularly the influx of fresh water in the North Atlantic from melting ice.

The impacts of sea ice changes can be monitored, retrospectively and prospectively, through changes in harvest patterns of marine mammals. Such studies must take into account the tremendous social and technological changes that have occurred in recent decades throughout the Arctic, as well as changes in marine mammal population levels unconnected to climate. Seals and walrus may be particularly useful indicators. Studies of fishing patterns may be equally informative, particularly in subarctic areas where commercial fisheries take place.

Sea ice has major implications for infrastructure as well. Coastal communities can be severely affected by erosion, in which sea ice can play a substantial role. Shipping, both to Arctic destinations and perhaps trans-shipment from Atlantic to Pacific ports, will be made much easier if sea ice is reduced around the margins of the Arctic Basin. The presence of large cargo ships, particularly in narrow straits in the Northwest Passage and the Northern Sea Route, could have local impacts through noise and chronic pollution. Accidents could cause even greater damage in remote, fragile areas. Offshore development, another source of potential accidents, may be made easier with less or less thick ice. Developing measures of ice severity for areas of high use, as has been done in the Point Barrow, Alaska, area, would be highly worthwhile to assist such activities and reduce the risk of accidents.

Conclusions

Sea ice is a key element of the Arctic environment, directly or indirectly affecting many of the oceanographic, climatic, ecological, and human patterns that characterize the region. Changes in sea ice may have significant implications for the all of these systems. There are many research opportunities in this area, both for HARC and for programs studying other aspects of the Arctic climate system. We hope this report is a helpful starting point for those interested in research of this kind, and that it inspires strong proposals that will extend our understanding of Arctic sea ice and its implications.

Acknowledgments

Jim Maslanik, Igor Krupnik, and Alex Whiting moderated the Sea Ice Workshop, stimulating and facilitating the discussion. Henry Huntington, SMO director, and Renée Crain and Wendy Warnick at ARCUS, worked diligently behind the scenes to make the workshop possible. Funding for the HARC SMO and online workshops is provided by the National Science Foundation Office of Polar Programs, Arctic Section. The HARC SMO and workshop moderators extend sincere appreciatito all those who joined us online and contributed ideas that will help drive the HARC research initiative and further the study of arctic sea ice.