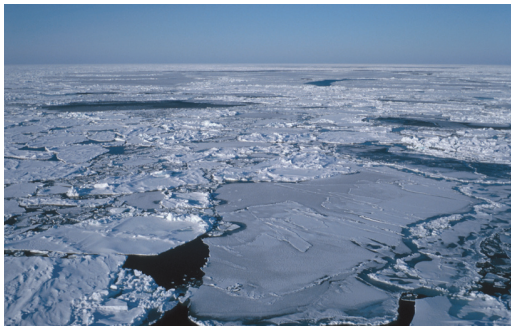
Foreword
Sea ice extent and the global climate system

Sea ice is a remarkable component of the global climate system. It can form over up to about 10% of the global ocean area, and creates an insulating barrier between the relatively warm seawater and the cold atmosphere, allowing a temperature difference that may be tens of degrees over only a couple of metres. It reduces evaporation from the ocean, leading to a drier atmosphere than would otherwise exist. Sea ice modifies the radiation balance at the Earth's surface because it supports snow (the most reflective of the Earth's natural surfaces, with an albedo of up to approximately 0.8), where otherwise there would be seawater (the least reflective, with an albedo of about 0.07). As sea ice forms it excludes brine, deepening the ocean surface mixed layer and influencing the formation of deep and bottom water. As it melts, it releases relatively fresh water, stratifying the upper layers of the ocean. Through these processes sea ice exerts an enormous influence on the atmospheric and oceanic circulation in cold regions and indeed the climate of the rest of the globe.

In the Northern Hemisphere the area covered by sea ice doubles between summer and winter, while in the Southern Hemisphere there is a five-fold difference between the seasons. The extent of ice in any one year is influenced by many factors, including prevailing winds and ocean currents, as well as surface air temperature. The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report notes that the extent of sea ice in the Northern Hemisphere has decreased by about 10 - 15% since the 1950s. Sea ice thickness may also have decreased significantly in the Arctic, leading to speculation that the Arctic Ocean may become seasonally free of ice within the present century. In contrast, the IPCC notes that no significant trends in Antarctic sea ice are apparent. Unlike the Arctic, changes in Southern Hemisphere sea ice extent do not seem to be related to Antarctic temperatures.

How well are these changes in sea ice extent understood? Do Arctic changes indicate a long-term trend, or are they merely part of a cycle? Are Antarctic observations



Ice floes move over the ocean surface, driven by wind and currents. Sea ice can cover up to about 10% of the global ocean, reducing heat and moisture transfer from the oceans to the atmosphere. (Photo at left by H. Bäsemann, at right by S. Gerland. Photos courtesy of Norwegian Polar Institute Picture Library.)

sufficient to characterize the state of sea ice extent in the Southern Hemisphere? Can we model changes in sea ice extent and relate them to changes in climate? Are our historical records of sea ice extent adequate for model validation?

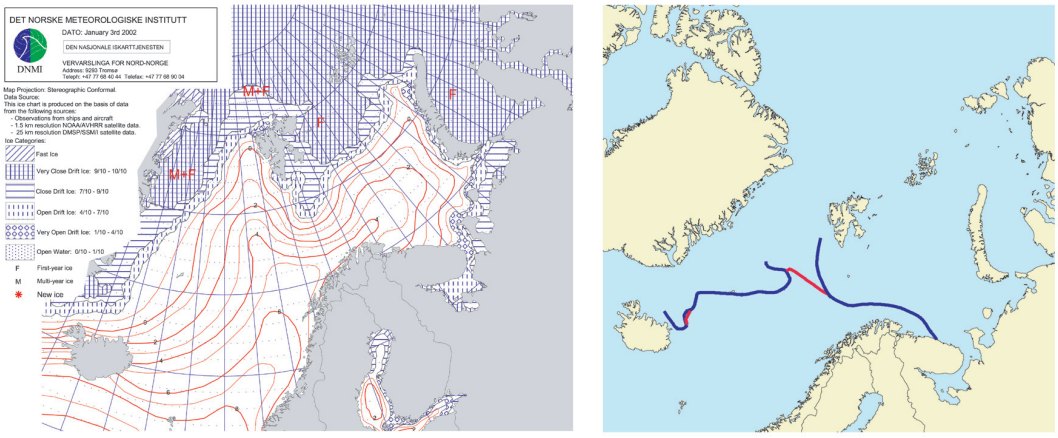
To attempt to answer some of these questions, a workshop entitled *Sea ice extent and the global climate system* was convened under the auspices of the World Climate Research Programme (WCRP) Arctic Climate System Study (ACSYS) and Climate and Cryosphere (CliC) projects. These projects seek to improve understanding of the role of the Arctic region and of the cryosphere in global climate variability and change, and sea ice obviously forms one major component of both the Arctic climate system and of the cryosphere.

The workshop was hosted by Météo-France on their campus in Toulouse in southern France from 15–17 April 2002, with nearly 60 participants from 11 countries taking part. Many participants then took part in the ACSYS/CliC mini-conference on *Long-term variability of the Barents Sea region*, which followed on 18 and 19 April at the same venue, where sea ice and climate were again topics of considerable interest.

The overall goal of the workshop was to examine recent changes in sea ice extent in the context of long-term variability. To achieve this, the workshop sought to bring together numerical modelling and observational scientists from both the research and operational communities. It also sought to provide a forum where experts in the study of ice in both Northern and Southern hemispheres could meet. The format of the workshop was very deliberately designed to promote both individual and group discussion as well as formal oral presentation of invited papers. During the morning sessions, a total of twelve invited scientific talks were given, which covered the themes of:

1) The physics of sea ice cover and its variations;
2) Data on trends and variability; and
3) Modelling of sea ice extent variations.

Posters presented on the first evening of the workshop covered these themes and other



Providing insights into climate variability, modern ice charts (left) can be compared with historical recordss, such as those based on 19th century ships' logbooks (right). For further information see http://acsys.npolar.no/ahica/intro.htm

Study of the sea ice edge presents many challenges to researchers, particularly when in situ measurements are needed. Here, a scientist sets up a spectroradiometer to measure the reflectance of snow- and ice-covered surfaces in Kongsfjorden, Svalbard. (Photo S. Gerland, Norwegian Polar Institute Picture Library.)

aspects of the relationship between sea ice and climate. It is mainly from these talks and posters that the material for this special issue has been drawn.

The working groups (facilitators in parenthesis), which met during the afternoon sessions, were set the task of examining questions of:

1) Model / data interactions (Wieslaw Maslowski and Aike Beckmann);
2) Assessment of historical records of sea ice extent (Astrid Ogilvie and Börge Pflüger); and
3) Archival and enhancement of sea ice observations (Florence Fetterer).

The output from the working groups has been published as a WCRP report (*WCRP Informal Report No. 9/2003*), and is also available through the ACSYS or CliC websites at http://acsys.npolar.no and http://clic.npolar.no.

Whilst the longest records of sea ice characteristics that are available relate to sea ice position (i.e. extent), it quickly became apparent during discussions of sea ice physics and models that the relationship between extent and climate is difficult to understand in isolation. For a full understanding, and even more for a predictive capability, other sea ice parameters such as ice thickness, concentration and motion also become vitally important. The talks and posters presented at the workshop recognized this and covered all of these aspects of sea ice and their relationship to climate. This was reflected in the papers that were submitted for inclusion in this special issue of *Polar Research*. The 13 manuscripts that made it through rigorous peer review to be included in this issue

chiefly address the main theme of sea ice extent, but also tackle issues of other sea ice characteristics, and the relationship of sea ice with oceanic and atmospheric conditions in the cold regions of the world. The papers cover both modelling and observations, including observations made from satellites. It is also gratifying to note that sea ice in both hemispheres is addressed, even if some Northern Hemisphere bias remains due to some extent to the even greater difficulties associated with sea ice studies in the Southern Ocean.

This volume is published during the final year of the WCRP's 10-year ACSYS project. However, this does not mean that WCRP no longer sees Arctic sea ice as important, but is more a reflection on the fact that all sea ice can have a major influence on climate. The influence of both polar oceans on global climate is gaining ever more recognition, and sea ice on regional seas can both be an indicator of, and have a major effect on, regional or even hemispheric climate. With this in mind, WCRP's CliC project has taken "sea ice interactions with climate" as one of its major themes. Efforts will continue to be made to increase our understanding of the role of sea ice in climate, through enhanced observations, process studies and improved models. The participation of the scientists in this workshop is greatly appreciated as a contribution towards the goals of both ACSYS and CliC.

The efforts of the members of the scientific organizing committees for this Toulouse meeting (Roger Colony, Thierry Fichefet, Humfrey Melling, John Walsh, Paul Wassmann and Aleksey Zuyev) are very much appreciated, as is the assistance of the local organizers at Météo-France (Paul Pettré and Isabelle Varin). The WCRP also gratefully acknowledges the support of the meeting co-sponsors: Météo-France, the Norwegian Polar Institute, the Office of Naval Research International Field Office (USA), the National Ice Center/National Oceanic and Atmospheric Administration (USA) and the Arctic Climate Impact Assessment. The support of these people and organizations contributed greatly to the success of the meeting.

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Changes in sea ice extent have impacts on the ecosystems and societies of polar and cold regions —and beyond. (Photo S. Gerland, Norwegian Polar Institute Picture Library.)