2. An Urgent Need for Observations in the Changing Arctic

On 16 August 2007, satellite passive microwave monitoring of Arctic sea ice extent revealed that it had equaled the record minimum that had been achieved only two years earlier on 20 September 2005. Subsequently, on 16 September 2007, a new record minimum sea ice extent of 4.13 million square kilometers occurred (NSIDC, 2007; Figure 2). National Snow and Ice Data Center (NSIDC) scientists described the September 2007 ice extent as "quite astounding", and, having "completely shattered that old record", the ice is in a "strong spiral of decline".

On 2 October 2007, Polyakov et al. (2007) described a mooring-based observing system that shows the continued transition of the Arctic Ocean to a warmer state (Figure 3), and suggested that the lowest sea ice extent has yet to be seen. While it is reasonable to predict that continued warming of the Arctic Ocean will cause further loss of sea ice, the ice loss in 2007 was attributed to atmospheric influences, particularly a persistent high pressure system that promoted clear skies and warm, southerly air flow that combined to increase ice melting and movement away from the Siberian shore (NSIDC, 2007). Clearly, continued monitoring of the ocean and atmosphere are vital for determination of their relative influence on the sea ice cover.

The 2007 sea ice extent observations mean that the annual rate of sea ice loss continues to exceed even the most aggressive model predictions from the Intergovernmental Panel on Climate Change Fourth Assessment (IPCC, 2007). The latter currently predict that the sea ice will diminish to zero during summer as early as 2050 or as late the early 22nd

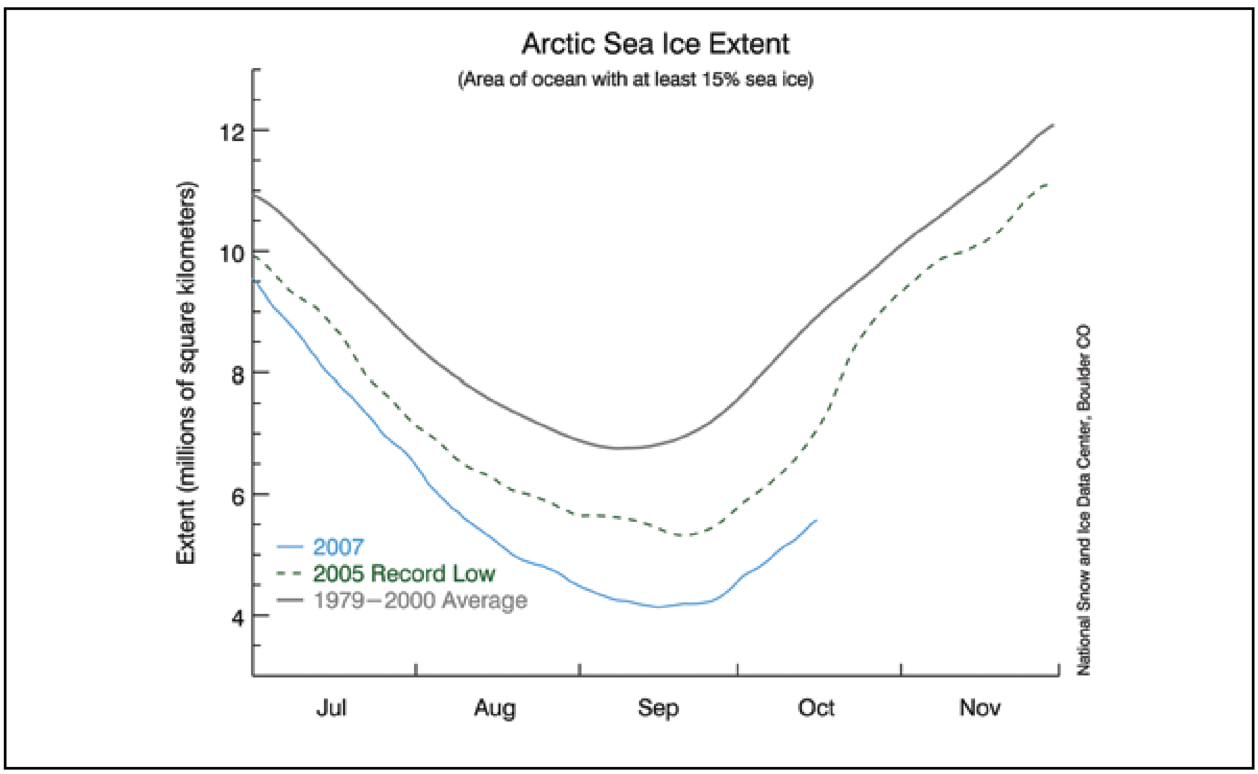

Figure 2. Arctic sea ice extent on 16 September 2007 was 23% lower than the previous record minimum in August 2005, and 39% lower than the long-term, 1979-2000, average. Source: NSIDC.

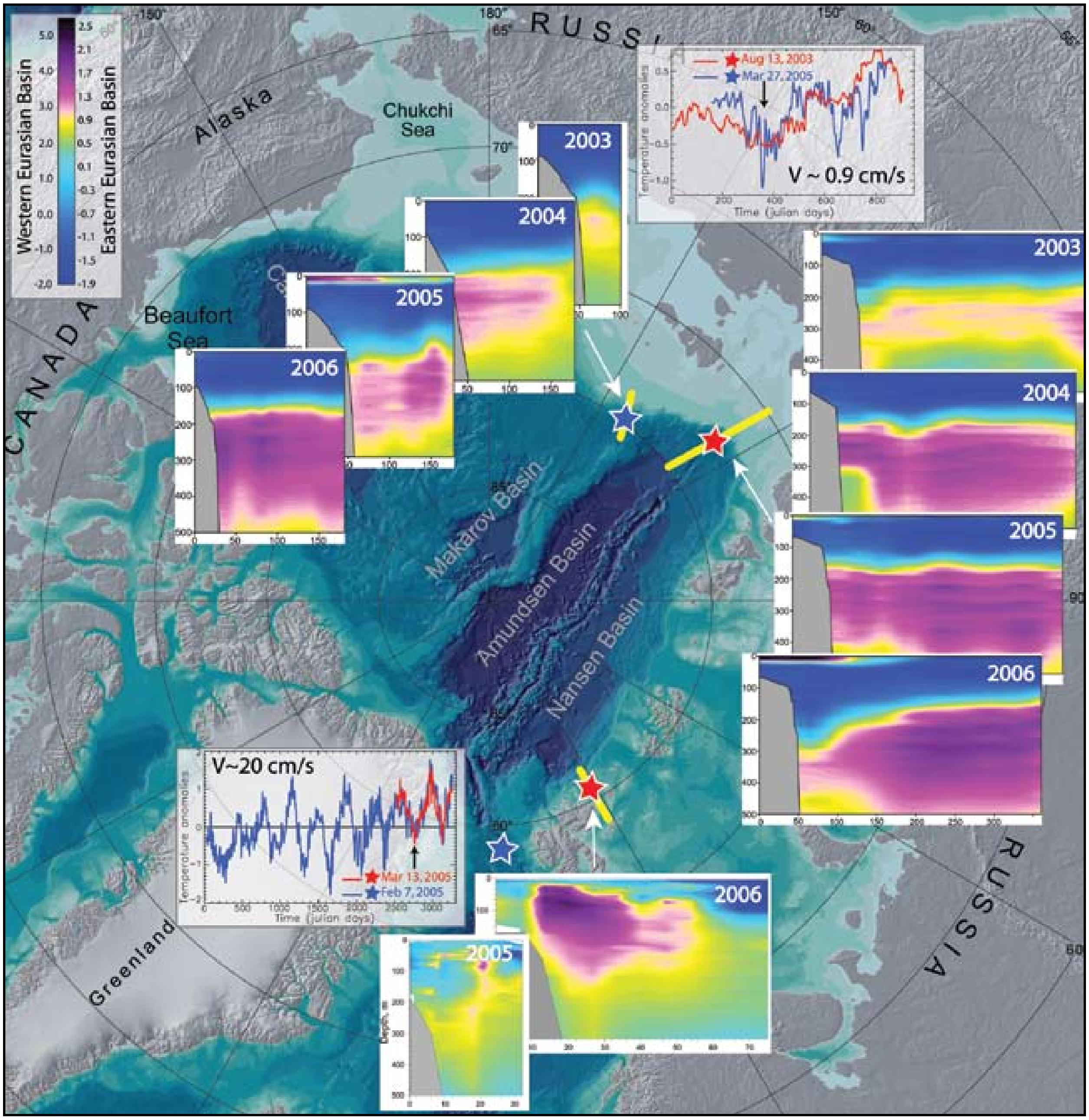

Figure 3. Water temperature as a function of depth, and time series of water temperature anomalies (°C) on the Laptev Sea slope and in the vicinity of Svalbard. Maximum lagged correlation is used to define anomaly propagation speed (V). These results are from the Nansen and Amundsen Basin Observing System (NABOS) sites, and were provided by I. Polyakov, International Arctic Research Center (IARC).

Century. Continued observation of sea ice extent, and improved spatial and temporal resolution in the observation of sea ice thickness and albedo will help to improve computer models and their predictions, lead to better understanding of the causes and consequences of the changing sea ice-climate system, and inform natural resource development and maritime transportation in an ice-diminished Arctic. There may be economic advantages in a much-reduced, or even zero, end-of-summer Arctic sea ice cover. For example, it is believed that it would allow increased natural resource exploitation and maritime transportation, with shorter routes between European, Asian and North American markets. In response to the potential for increased shipping in the Arctic, in 2004 the Arctic Council commissioned an Arctic Marine Shipping Assessment (AMSA). Increased access to the Arctic Ocean also raises questions about national security and sovereignty.

Increased ship traffic, however, increases the likelihood of pollution in waters where clean-up, of an oil spill, for example, would be difficult, to say the least. Pollution would compound the stress on marine ecosystems that are under pressure as they adjust to the receding ice cover. The possible consequences of sea ice change on the marine ecosystem are exemplified by the polar bear population, which, according to a US Geological Survey report on 7 September 2007, could be reduced by 66% by the middle of this century (USGS, 2007).

The IPCC4 report (IPCC, 2007) notes that "Understanding and evaluating sea ice feedbacks is complicated by the strong coupling to polar cloud processes and ocean heat and freshwater transport. Scarcity of observations in polar regions also hampers evaluation". IPCC4 stresses the importance of improving atmospheric observation, specifically aerosol and cloud measurements, since the largest uncertainty in climate sensitivity is due to cloud feedbacks, with low clouds making the largest contribution to uncertainty.

Continued observation and improved modeling of the Arctic sea ice-cloud-climate system will not be sufficient to address the issue of marine ecosystem response to Arctic Change. At the higher trophic levels (polar bear, walrus, whales, seals), for example, immediate needs include better observations of populations and their trends, and reproductive rates and feeding ecology. Since changes in the marine ecosystem are likely to affect indigenous communities that see marine living resources as integral to their cultures, such information will contribute to the identification of effective adaptive responses, including better tools for managing marine ecosystems in a changing climate.

The Arctic terrestrial ecosystem is also changing. The greening of the North Slope of Alaska (Figure 4) is consistent with an increase in the biomass of shrubs and climate warming (e.g., Sturm et al., 2001a, 2001b; Jia et al., 2003). Climate warming is also being manifested in rising permafrost temperatures, and even thawing in regions of discontinuous permafrost (e.g., Lachenbruch and Marshall, 1986; Clow and Urban, 2002; Osterkamp et al, 2000; Osterkamp, 2003). This has the potential for large quantities of methane to be emitted into the atmosphere, which would amplify the effects of global warming in the Arctic (Walter et al, 2006). Models will help to improve the understanding of the broader consequences of Arctic terrestrial methane emissions, but that requires the initiation of systematic, long-term measurements in order to quantify the magnitude, variation and trends of emissions in the first place.

Also on land, the area of surface melting on the Greenland ice sheet, the velocity of its outlet glaciers, and iceberg calving have increased, raising concerns about sea level rise and its global consequences. The Gravity Recovery and Climate Experiment (GRACE) observations show that the ice sheet is currently

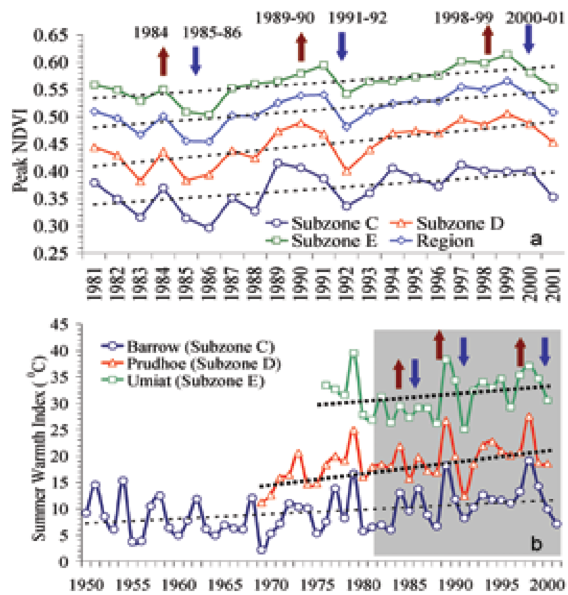

Figure 4. Increase in greenness (a) and summer warmth (b) in different regions of the North Slope of Alaska. Greening is illustrated by Normalized Difference Vegetative Index (NDVI) data derived from the NOAA Advanced Very High Resolution Radiometer. Source: J. Jia, University of Virginia.

losing mass at a rate of about 150 gigatons/year (Luthcke et al., 2006), and in 2007 melting on the ice sheet reached the highest altitudes observed during the satellite observation era (Figure 5; Tedesco, 2007). Improved observing systems, and models that adequately simulate ice sheet dynamics and thermodynamics, and are coupled to Global Circulation Models (GCMs), are needed. Observations and models will help to determine the state of the Greenland ice sheet and whether the global consequences of changes in its mass balance will be manifested over decadal, centennial or millennial time scales.

Arctic Change is not limited to the examples given above. Change is occurring throughout the Arctic environmental system, and current observation systems are not adequate to detect the full suite of changes that are underway, nor the human responses

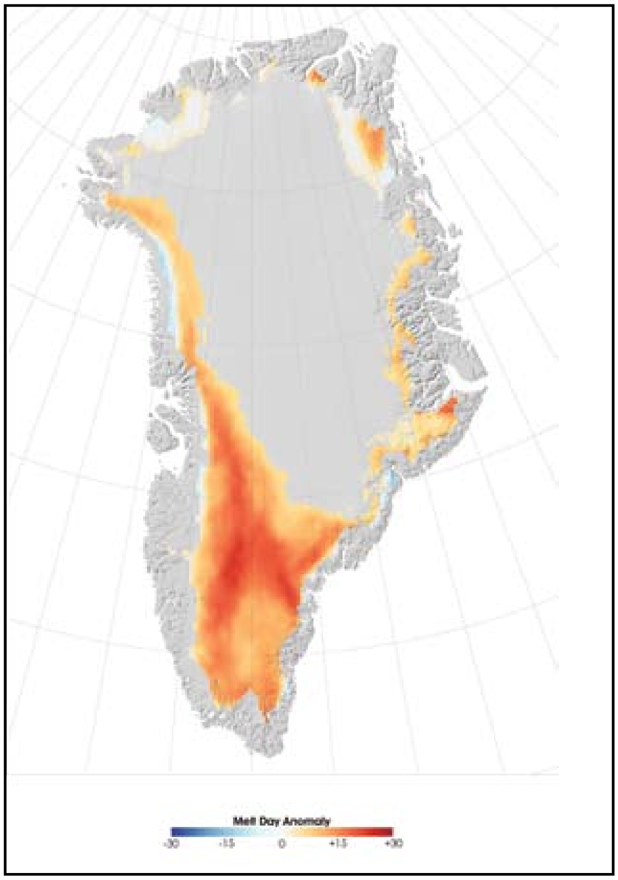

Figure 5. The extent of melting at the surface of the Greenland ice sheet in summer 2007 determined from SSM/I data. Source: M. Tedesco, University of Maryland Baltimore County and NASA Goddard Space Flight Center.

to change. Enhanced, coordinated and sustained observing sites, systems and networks in the Arctic will provide data on the magnitude, variation and rate of current and past environmental change, and for the initialization, calibration and validation of computer models that allow simulation of the Arctic environmental system and its global connections.

The Arctic is integral to the global environmental system, and models enable the Arctic system to be understood in the broader context of the Earth system. Models make it possible to study the interactions and feedbacks that occur within the Arctic system, and between the Arctic and the global, integrated Earth system. Models and modelers need observations, and both are required to (1) document the magnitude, variation and rate of changes that are currently occurring, and place them in the context of past environmental change, (2) understand the regional and global causes and consequences of current changes, (3) predict the magnitude, variation, rate and consequences of future Arctic Change, and (4) identify effective adaptive responses to Arctic Change.