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Arctic Sea Ice Extent Plummets in 2007

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Arctic sea ice declined rapidly to unprecedented low extents in the summer of 2007, raising concern that the Arctic may be on the verge of a fundamental transition toward a seasonal ice cover.

Arctic sea ice extent typically attains a seasonal maximum in March and minimum in September. Over the course of the modern satellite record (1979 to present), sea ice extent has declined significantly in all months, with the decline being most pronounced in September. By mid-July 2007, it was clear that a new record low would be set during the summer of 2007.

Monthly ice extent for September 2007 was a mere 4.28×10^6 square kilometers, 23% smaller than the previous benchmark of 5.56×10^6 square kilometers set in September 2005. This ice loss relative to September 2005 equates to an area the size of Texas and California combined. Including September 2007, the linear trend in ice extent over the satellite record now stands at -10.7% per decade. Even the August mean of 5.32×10^6 square kilometers broke the previous record of September 2005.

On the basis of an extended time series from the Met Office Hadley Centre [*Rayner et al.*, 2002], we calculated that ice extent in September 2007 was 50% lower than conditions in the 1950s to the 1970s (Figure 1). While ice is now growing in response to autumn and winter cooling, ice extent remains far below normal.

Understanding Sea Ice Loss

Key factors behind this record ice loss include thinning of the pack ice in recent decades [*Nghiem et al.*, 2007a; *Maslanik et al.*, 2007b], making large areas prone to becoming ice-free during the summer melt season, coupled with an unusual pattern of atmospheric circulation.

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The ice pack contains a mixture of first-year ice and multiyear ice (ice that has survived for one or more melt seasons). In general, older ice is thicker than younger ice. On the basis of an ice-tracking algorithm, we estimated that the area of ice exceeding 5 years in age decreased by 56% between 1982 and 2007 [*Maslanik et al.*, 2007b]. Within the central Arctic Ocean, the coverage of old ice over this period declined by 88% and ice that is at least 9 years old essentially disappeared. This change toward younger ice translates to a decrease in mean thickness of ice over the Arctic Ocean from 2.6 meters in March 1987 to 2.0 meters in 2007 (Figure 2). While the loss of old ice was accentuated in the 1990s by anomalous wind patterns over the Arctic Ocean that led to increased ice export through Fram Strait, recent loss in the central Arctic is due to old ice failing to survive westward transport north of the Alaskan and eastern Siberian coasts (e.g., through the Beaufort Gyre).

While this thinning set the stage for pronounced summer ice loss, its effects were compounded by a favorable pattern of atmospheric circulation. An anticyclonic pattern over the central Arctic Ocean that formed in early June persisted for 3 months and was coupled with low pressures over central and western Siberia. Satellite data reveal that skies under the anticyclone were predominantly clear, fostering strong melt. Persistent southerly winds between the high- and low-pressure centers gave rise to above-average air temperatures north of Siberia that promoted melt and also transported ice away from the Siberian coast. While this basic pressure pattern has become more frequent in recent years, helping to reduce sea ice cover in the western Arctic [*Maslanik et al.*, 2007a], it was unusually persistent in 2007.

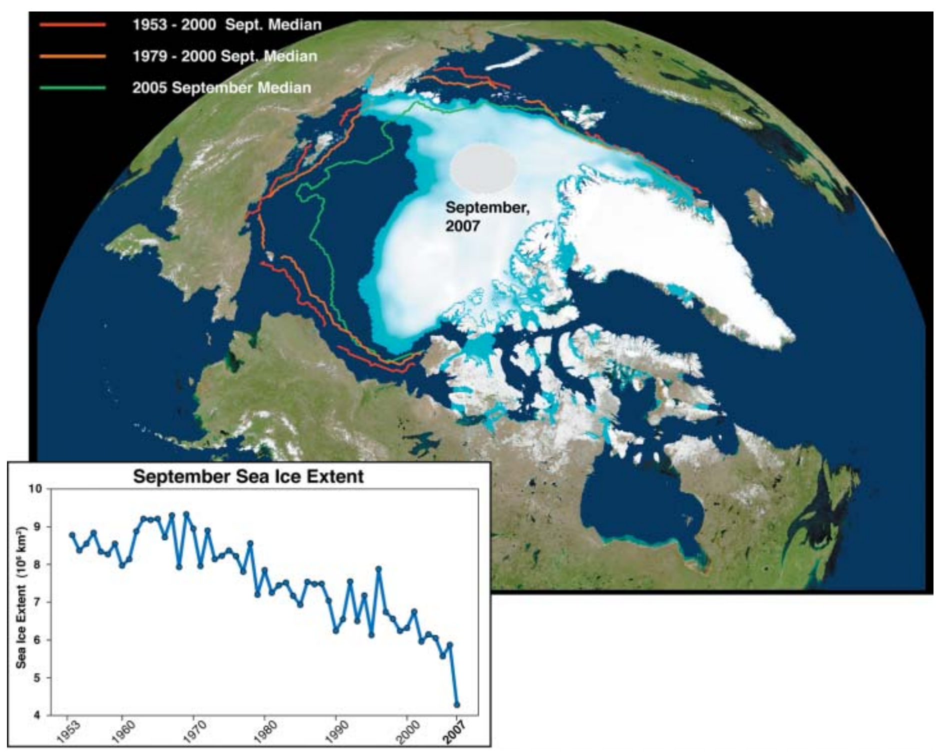

Fig. 1. Sea ice concentration for September 2007, along with Arctic Ocean median extent from 1953 to 2000 (red curve), from 1979 to 2000 (orange curve), and for September 2005 (green curve). September ice extent time series from 1953 to 2007 is shown at the bottom.

Sea surface temperatures (SSTs) over the Chukchi and East Siberian seas have increased since the year 2000. During the summer of 2007, SSTs over parts of these seas reached more than 3.5°C. Increased SSTs and attendant upper ocean warming are consistent with loss of sea ice, allowing for enhancing absorption of solar energy at the ocean surface [*Steele et al.*, 2008]. Increased ocean warmth appears to be inhibiting autumn ice growth. The large summer heat gains in 2007 are likely to be expressed as thinner than normal ice at the start of the 2008 melt season.

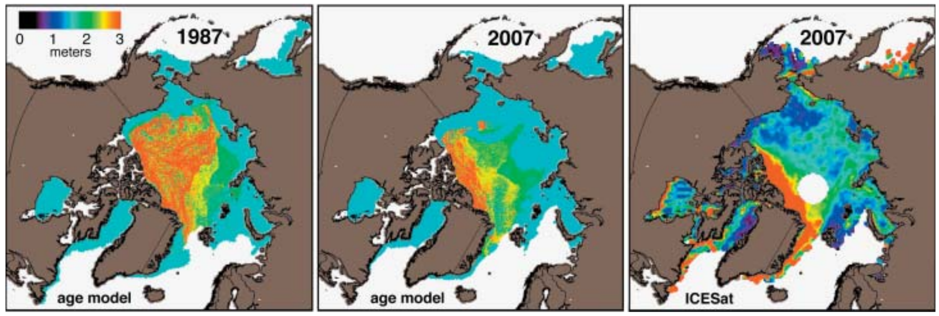

Fig. 2. March sea ice thickness for 1987 and 2007 from Maslanik et al. *[2007b] ice-tracking algorithm, and for March 2007 from ICESat (data provided by D. Yi and J. Zwally, NASA).*

Biogeophysical Implications and Consequences

Even before 2007, ice loss was affecting Arctic residents. Their use of the ice requires detailed knowledge of ice conditions for safety and success in hunting, which is a primary means for providing food and a mainstay of culture and social organization. Dramatic changes described in recent years [*Gearheard et al.,* 2006] include later ice freeze-up and earlier breakup, increased coverage of thin ice over which travel is dangerous, and shifts in the location of the ice edge [e.g., *George et al.*, 2004]. Hunters are responding by altering hunting locations, making greater use of new technologies (e.g., GPS, satellite phones), and avoiding hunting practices that have become too risky [e.g., *Ford et al.*, 2006].

Changing ice conditions are also affecting animal species. Seals and walruses use sea ice for their breeding and pupping grounds. With less ice, seal populations in some areas, such as Canada's Hudson Bay, are decreasing. This affects polar bear populations, who depend on seals for food and use the ice as a platform for hunting them.

Grebmeier et al. [2006] found that a reduction of sea ice, combined with increased air and ocean temperatures, has reduced the summertime extent of the cold pool that maintains food web production in the northern Bering Sea. This has resulted in the northward displacement of fish populations as well as ice-related marine mammals and sea birds, with effects on subsistence harvests and commercial fisheries. *Grebmeier et al.* [2006] argue that similar changes will soon become more widespread.

The extreme conditions of 2007 portend an increased access to the Arctic. Summer 2007 saw the opening of the Northwest Passage, a potential shortcut for shipping between the Atlantic and Pacific oceans. During August and September, the passage was more navigable than at any time since routine monitoring by the Canadian Ice Service began in 1972.

The likelihood of more frequent and longer openings in coming years has raised issues of sovereignty and environmental impacts. The year 2007 saw renewed interest in economically viable oil and gas extraction and efforts by several countries to enhance their seabed economic resource claims of the Arctic Ocean.

The Future of the Sea Ice Cover

Could the summer of 2007 be remembered as the first year of a rapid shift to a seasonally ice-free Arctic Ocean? Simulations from the National Center for Atmospheric Research's Community Climate System Model version 3 (CCSM3), with the middle-range A1B emissions scenario, show that after the ice thins to a more vulnerable state in response to rising greenhouse gas (GHG) concentrations, a reinforcing kick from natural variability may trigger an initial, abrupt ice loss. Rapid decay of the remaining summer ice cover can then ensue due to the albedo feedback mechanism. Other models show similar events [*Holland et al.*, 2006].

Interestingly, data from ICESat (a satellite laser altimeter) show that the record low ice extent seen in September 2007 was preceded by a March ice thickness averaged across the Arctic comparable to the ice thickness preceding the rapid ice loss events in CCSM3. These thickness comparisons raise the intriguing possibility that the stage is now set for rapid loss of the remaining summer ice cover, with the unusual atmospheric circulation of 2007 serving as a trigger.

While natural variability may instead stabilize the ice cover for the next few years, the long-term outlook is disturbing. All models evaluated in the Intergovernmental Panel on Climate Change Fourth Assessment Report show declining September sea ice from 1953 to 2006. While these models point to a role of GHG forcing, as a group they significantly underrepresent the observed trend [*Stroeve et al.*, 2007]. The reasons for this underrepresentation remain to be fully resolved, but overly thick ice in several of the models provides a partial explanation. Given these conservative model results, along with the remarkable events of 2007, our view is that a seasonally ice-free Arctic Ocean might be realized as early as 2030.

Acknowledgments

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