Frequently Asked Questions

FAQ 4.1 | How Is Sea Ice Changing in the Arctic and Antarctic?

The sea ice covers on the Arctic Ocean and on the Southern Ocean around Antarctica have quite different characteristics, and are showing different changes with time. Over the past 34 years (1979–2012), there has been a downward trend of 3.8% per decade in the annual average extent of sea ice in the Arctic. The average winter thickness of Arctic Ocean sea ice has thinned by approximately 1.8 m between 1978 and 2008, and the total volume (mass) of Arctic sea ice has decreased at all times of year. The more rapid decrease in the extent of sea ice at the summer minimum is a consequence of these trends. In contrast, over the same 34-year period, the total extent of Antarctic sea ice shows a small increase of 1.5% per decade, but there are strong regional differences in the changes around the Antarctic. Measurements of Antarctic sea ice thickness are too few to be able to judge whether its total volume (mass) is decreasing, steady, or increasing.

A large part of the total Arctic sea ice cover lies above 60°N (FAQ 4.1, Figure 1) and is surrounded by land to the south with openings to the Canadian Arctic Archipelago, and the Bering, Barents and Greenland seas. Some of the ice within the Arctic Basin survives for several seasons, growing in thickness by freezing of seawater at the base and by deformation (ridging and rafting). Seasonal sea ice grows to only ~2 m in thickness but sea ice that is more than 1 year old (perennial ice) can be several metres thicker. Arctic sea ice drifts within the basin, driven by wind and ocean currents: the mean drift pattern is dominated by a clockwise circulation pattern in the western Arctic and a Transpolar Drift Stream that transports Siberian sea ice across the Arctic and exports it from the basin through the Fram Strait.

Satellites with the capability to distinguish ice and open water have provided a picture of the sea ice cover changes. Since 1979, the annual average extent of ice in the Arctic has decreased by 3.8% per decade. The decline in extent at the end of summer (in late September) has been even greater at 11% per decade, reaching a record minimum in 2012. The decadal average extent of the September minimum Arctic ice cover has decreased for each decade since satellite records began. Submarine and satellite records suggest that the thickness of Arctic ice, and hence the total volume, is also decreasing. Changes in the relative amounts of perennial and seasonal ice are contributing to the reduction in ice volume. Over the 34-year record, approximately 17% of this type of sea ice per decade has been lost to melt and export out of the basin since 1979 and 40% since 1999. Although the area of Arctic sea ice coverage can fluctuate from year to year because of variable seasonal production, the proportion of thick perennial ice, and the total sea ice volume, can recover only slowly.

Unlike the Arctic, the sea ice cover around Antarctica is constrained to latitudes north of 78°S because of the presence of the continental land mass. The Antarctic sea ice cover is largely seasonal, with an average thickness of only ~1 m at the time of maximum extent in September. Only a small fraction of the ice cover survives the summer minimum in February, and very little Antarctic sea ice is more than 2 years old. The ice edge is exposed to the open ocean and the snowfall rate over Antarctic sea ice is higher than in the Arctic. When the snow load from snowfall is sufficient to depress the ice surface below sea level, seawater infiltrates the base of the snow pack and snow-ice is formed when the resultant slush freezes. Consequently, snow-to-ice conversion (as well as basal freezing as in the Arctic) contributes to the seasonal growth in ice thickness and total ice volume in the Antarctic. Snow-ice formation is sensitive to changes in precipitation and thus changes in regional climate. The consequence of changes in precipitation on Antarctic sea ice thickness and volume remains a focus for research.

Unconstrained by land boundaries, the latitudinal extent of the Antarctic sea ice cover is highly variable. Near the Antarctic coast, sea ice drift is predominantly from east to west, but further north, it is from west to east and highly divergent. Distinct clockwise circulation patterns that transport ice northward can be found in the Weddell and Ross seas, while the circulation is more variable around East Antarctica. The northward extent of the sea ice cover is controlled in part by the divergent drift that is conducive in winter months to new ice formation in persistent open water areas (polynyas) along the coastlines. These zones of ice formation result in saltier and thus denser ocean water and become one of the primary sources of the deepest water found in the global oceans.

Over the same 34-year satellite record, the annual extent of sea ice in the Antarctic increased at about 1.5% per decade. However, there are regional differences in trends, with decreases seen in the Bellingshausen and Amundsen seas, but a larger increase in sea ice extent in the Ross Sea that dominates the overall trend. Whether the smaller overall increase in Antarctic sea ice extent is meaningful as an indicator of climate is uncertain because the extent

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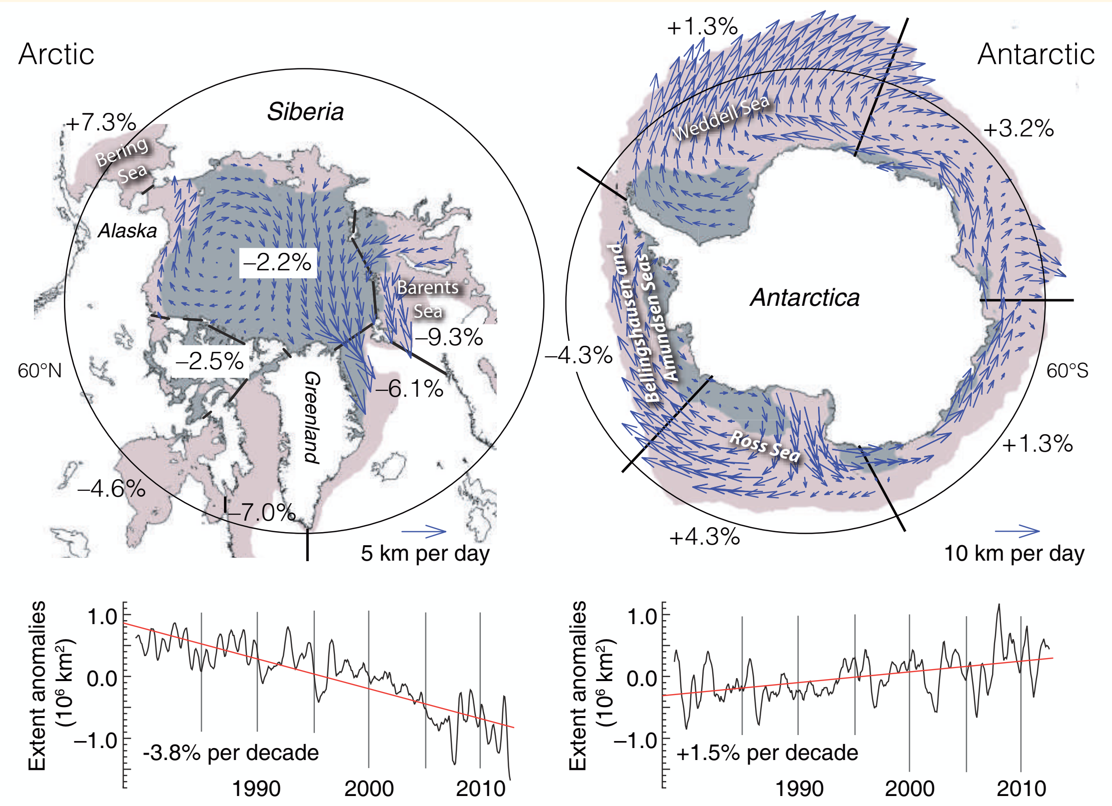
FAQ 4.1 (continued)

varies so much from year to year and from place to place around the continent. Results from a recent study suggest that these contrasting trends in ice coverage may be due to trends in regional wind speed and patterns. Without better ice thickness and ice volume estimates, it is difficult to characterize how Antarctic sea ice cover is responding to changing climate, or which climate parameters are most influential.

There are large differences in the physical environment and processes that affect the state of Arctic and Antarctic sea ice cover and contribute to their dissimilar responses to climate change. The long, and unbroken, record of satellite observations have provided a clear picture of the decline of the Arctic sea ice cover, but available evidence precludes us from making robust statements about overall changes in Antarctic sea ice and their causes.



FAQ 4.1, Figure 1 | The mean circulation pattern of sea ice and the decadal trends (%) in annual anomalies in ice extent (i.e., after removal of the seasonal cycle), in different sectors of the Arctic and Antarctic. Arrows show the average direction and magnitude of ice drift. The average sea ice cover for the period 1979 through 2012, from satellite observations, at maximum (minimum) extent is shown as orange (grey) shading.

trend over the same period. Variability in the ice cover in this region is linked to changes in the Southern Annular Mode (SAM). Between 1974 and 1976, the large Weddell Sea Polynya, which is a sensible heat polynya, was created by the injection of relatively warm deep water into the surface layer due to sustained deep-ocean convection (sensible heat effect) during negative SAM, but since the late 1970s the SAM has been mainly positive, resulting in warmer and wetter condition forestalling any reoccurrence of the Weddell Sea Polynya (Gordon et al., 2007).

4.2.3.6 Antarctic Land-Fast Ice

Land-fast ice forms around the coast of Antarctica, typically in narrow coastal bands of varying width up to 150 km from the coast and in water depths of up to 400 to 500 m. Around East Antarctica, it comprises generally between 5% (winter) and 35% (summer) of the overall sea ice area (Fraser et al., 2012), and a greater fraction of ice volume (Giles et al., 2008a).

Variability in the distribution and extent of land-fast ice is sensitive to processes of ice formation and to processes such as ocean swell and