OCEAN SCIENCE

Whither Antarctic Sea Ice?

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To an observer from space, the growth and retreat of the white ring of sea ice around Antarctica would be one of the clearest signs that Earth's climate varies on seasonal and longer time scales. However, the record of satellite observations is too short to assess whether there have been climate-related trends in sea ice extent.

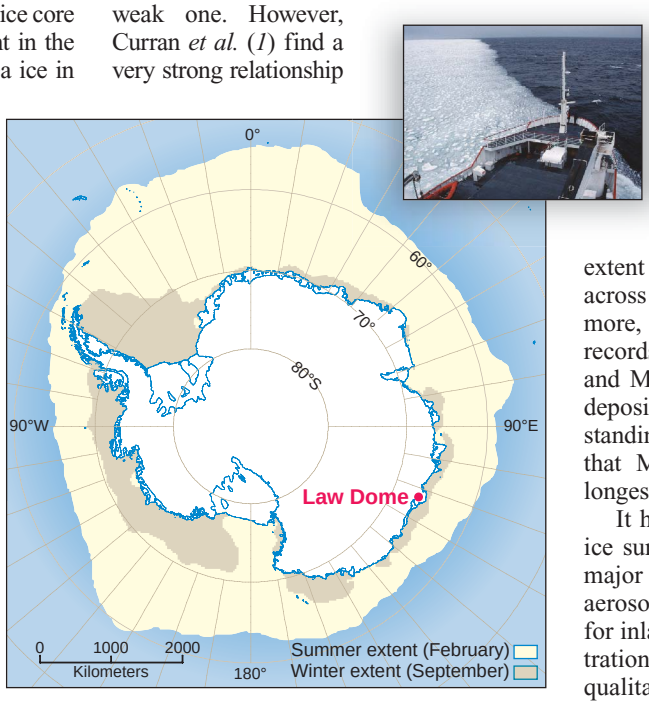
On page 1203 of this issue, Curran *et al.* (*1*) show that a chemical (methanesulfonic acid, MSA) measured in an Antarctic ice core may respond chiefly to sea ice extent in the nearby ocean. They conclude that sea ice in that part of the ocean was stable from 1840 to 1950, but has decreased sharply since then.

Sea ice should be a sensitive indicator of climatic change, declining in response to warmer atmospheric and oceanic temperatures. It also plays several other important roles in the climate system. First, because of its high albedo, sea ice loss should amplify polar climate change. Second, sea ice production leads to Antarctic bottom-water formation, which influences global ocean circulation. Finally, decreasing sea ice extent in the Southern Ocean may have contributed to the increase in CO_2 concentrations between the Last Glacial Maximum and the Holocene (*2*).

For all these reasons, climate scientists need reliable estimates of past sea ice extent. Unfortunately, the instrumental record from satellite passive microwave measurements is only 30 years long (*3*). Within this period, only the sector west of the Antarctic Peninsula, a region with strong regional warming (*4*), shows a statistically significant decreasing trend.

MSA concentrations in ice cores might offer a way of extending the record (*5*). MSA is an oxidation product of dimethylsulfide (DMS), which is produced by marine phytoplankton in the sea ice zone. The link between regional DMS production and ice core MSA is likely to be complicated: It depends on sea-air exchange, the proportion of DMS that is oxidized to MSA, and the atmospheric transport to the ice core site. The area covered by sea ice during the winter is believed to be primed for high DMS production in the following summer. Therefore, if all other factors remain steady, MSA in an ice core is a measure of winter sea ice extent.

The results of previous calibrations of MSA concentrations against the instrumental record have been unconvincing, showing no relationship or only a weak one. However, Curran *et al.* (*1*) find a very strong relationship between MSA in the coastal Law Dome ice core, and sea ice extent in the sector from 80°E to 140°E as determined by satellite. Extending the MSA record back to 1840, they show that sea ice extent in this sector is at a historical low: The ice edge has retreated by more than 1° of latitude since 1950.



Map of Antarctica showing the present-day sea ice extent. The map is based on averages for 1978 to 1997. The winter extent near Law Dome (marked) may have been more than 1° further north for the century before 1950 (*1*). (**Inset**) Edge of Antarctic sea ice from HMS *Endurance* during the 2001/2002 field season.

This is a striking but surprising finding, because it does not seem to echo any clear temperature trend from meteorological stations in this region. A small warming trend (1958 to 2001) at Casey, the station nearest to Law Dome, is not statistically significant. The two other coastal stations in the 80°E to 140°E sector show an even smaller trend (*4*).

Curran *et al.* suggest (*1*) that the MSA concentrations at Law Dome are correlated with sea ice extent around the entire continent and that sea ice may have declined around Antarctica as a whole. This suggestion is difficult to substantiate, because a record from a single site cannot distinguish between a continent-wide decline and a redistribution of ice from one sector to another—a process that can certainly occur on multiannual time scales. Only a suite of ice core records from around Antarctica, each calibrated convincingly against the instrumental record, can resolve this question.

Reconstructions of sea ice extent over glacial-interglacial time scales are also needed. Diatom assemblages in marine sediment cores indicate sea ice presence or absence at single sites, and the sea ice edge can be estimated from networks of such sites (*6*). Could ice cores provide a large-scale view of sea ice extent over long time scales?

Unfortunately, the answer, at least for MSA, is probably no. The processes other than sea ice extent that affect MSA are likely to vary across major climatic changes. Furthermore, at the ice core sites with the longest records, snow accumulation is very low, and MSA is lost from the snowpack after deposition (*7*). With our present understanding of these processes, it is unlikely that MSA can be used reliably for the longest time scales.

It has recently been shown that the sea ice surface, rather than open water, is the major source of sea salt to coastal Antarctic aerosol and ice cores (*8*). It this is also true for inland Antarctica, then sea salt concentrations in ice cores might act as a new qualitative proxy of past sea ice production. It is likely that a combination of marine and ice core records will eventually provide the necessary data sets.

Meanwhile, the findings reported by Curran *et al.* provide intriguing evidence for recent climate change. The sea ice change is a signal that regional climate is well outside the range it occupied for 100 years before 1950. The results demand rapid replication at other locations around Antarctica.

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CREDIT: MAP: BRITISH ANTARCTIC SURVEY; PHOTO: J. SMELLIE/BRITISH ANTARCTIC SURVEY