The interdependency of sea ice and ice shelves

P.J. Langhorne

University of Otago, Dunedin, New Zealand

Global climate models are not able to reproduce both the trend and the mean of Antarctic sea ice extent. Further there are large variations between model predictions of sea ice coverage, some of which arise because of differences in representation of the relative importance of heat from the atmosphere versus heat from the ocean. It is very well known that Antarctic coastal waters are conditioned by interaction with ice shelves, but the pervasiveness of the influence of this water on sea ice formation is poorly documented. Not only does proximity to an ice shelf alter sea ice growth, there is mechanical coupling between an ice shelf and the sea ice at its edge that probably buffers the shelf from the ravages of the ocean. Here we focus on observations of the physical processes involved in the interaction between ice shelf-conditioned waters and sea ice formation, with the ultimate aim of guiding model development.

Close to an ice shelf, sea ice often grows in water that has been supercooled by interacting with the ice shelf at depth. An important consequence is that the sea ice loses heat to the ocean as well as to the atmosphere. This "negative" ocean heat flux causes the sea ice to grow thicker than it would without the ice shelf. The thermal deficit also means there are tiny frazil crystals in the water column. While they sometimes accumulate and grow on any object suspended in the near-surface ocean, they also accumulate under the sea ice where they form a porous layer of crystals in an evolving state of consolidation. This consolidation results in a modified crystallographic structure that leaves a detectable signature frozen into the sea ice cover through the formation of incorporated platelet ice.

Here we use new results to extend some of the longest available Antarctic ice-ocean observational records that were initiated a century ago near the combined Ross and McMurdo Ice Shelves in southern McMurdo Sound. Over that time there has been no discernable change in the temperature of the upper ocean. This surface water is held just below its freezing point as it enters the Sound, probably because of the regulating influence of basal melting deep in the ice shelf cavity. We use the ability of sea ice to integrate the effect of ocean heat flux over its annual growth to interpret crystallographic records from a historical time series of sea ice cores. This information is supplemented by airborne and satellite remote sensing of sea ice thickness and modeling at a range of scales. The distribution of platelet ice (and hence negative ocean heat flux) appears to be strongly linked to the circulation in McMurdo Sound although its abundance varies from year to year. These multiple sources of data, contextualized within the relatively long time series, are extended around coastal Antarctica to provide estimates of the influence of ice shelf-conditioned surface water on sea ice. These data may also enable indices of the ice shelf "health" to be constructed.