Dynamics of warm water intrusions: A Summary of Air-Sea-Ice Interactions in Greenland and Antarctica.

Overview

The melt rate of ice sheets and outlets glaciers is related to interactions between the atmosphere, ocean, and cryosphere. Different processes limit melt in Greenland and Antarctica, respectively: spatial distribution of warm water and fresh water fluxes, in Greenland; and shelf geometry and katabatic winds in Antarctica.
Observational challenges make it difficult to understand what physical processes are in place. However, new experimental techniques and monitoring programs have begun to allow us to study the interaction between the ocean and ice in these regions.

Greenland, by Fiamma Straneo

Ice-ocean interactions are an important part of the global climate system and its study requires an interdisciplinary approach. Glaciologists should be concerned with ocean dynamics because water properties – specifically, temperature and salinity – can strongly affect mass balance, ice flow, grounding line dynamics, and (less directly) sea ice cover. Oceanographers should be interested in ice sheets due to their potential to dramatically change freshwater fluxes in the arctic, and because of their crucial importance for sea level change.

Greenland's glaciers interact with the ocean and atmosphere in a number of different ways. Two mechanisms are particularly important, namely,

i. Ocean currents define the availability of warm waters near fjords, either enabling or limiting the rate of melt;
ii. Sporadic wind events can drive surface heat fluxes and export sea ice, affecting both local ocean conditions and the stability of sea ice in the margin of the fjord.

The intrusion of warm water beneath ice tongues affects their melting rate. Coastal currents around Greenland transport cold and warm water masses near the coast. Complex bathymetry and horizontal boundaries steer the regional currents around Greenland. This leads to a large geographic contrast in the distribution of temperature and salinity. The intrusion of warm water is associated with topographic troughs near the mouth of fjords and the vicinity of these troughs to warm, deep coastal currents.

Extreme wind events occur frequently in the vicinity of Greenland. Katabatic winds, driven by radiative cooling over the ice sheet, flow rapidly offshore. North Atlantic cyclones pass by southern Greenland and interact strongly with Greenland's steep topography, leading to an intensification of surface winds. These events are classified as forward and reverse tip jets, and as barrier winds. Sea ice export and warm water transport are both sensitive to the development of these cyclones and to the katabatic winds.

Ocean conditions inside the fjords are difficult to observe, because ice floes make access to many important regions impossible for the small vessels needed to navigate the narrow channels. Helicopters and marine mammals have now made it possible to take numerous measurements inside the channels.

Antarctica, by Ole Anders Nøst

Within the Antarctic region we see great variability in terms of onshore flow of circumpolar deep water (CDW) underneath the ice shelves. Important factors governing the rate at which heat can be transported into the cavity include bathymetry, katabatic winds, steady alongshore wind forcing, regional oceanography, and ice sheet and shelf geometry.

An example of this spatial variability is the contrast between several Antarctic ice shelves. Dronning Maud Land is characterized by a narrow continental shelf, steady easterly winds offshore, and relatively small ice shelves. In contrast, the Ronne Filchner and Ross Ice Shelves are much larger.

Katabatic winds are relevant as in Greenland, but play a somewhat different role. The strong katabatic flows come in narrow bursts, and are greatly constrained by topography. Additionally, the horizontal length scale is large enough that these winds feel the effect of rotation. The net result is that katabatic wind stresses and induced heat fluxes often occur only in concentrated zones along the much wider Antarctic ice shelves. Thus, topography inland of the shelves is important not only for the dynamics of the ice streams feeding the them, but also for setting the location of wind forcing at the ice-ocean interface.

The easterly winds form the Antarctic Slope Front that controls the input of warm CDW onto the continental shelf. The basic features of the circulation are simple and have been understood for many years (e.g. Sverdrup, 1953) but the observed transport of water across the continental shelf has been puzzling. Diagnostics using a simple box model indicate that eddy transport is important. The fluxes can only be explained by the residual circulation driven by eddies. This is further explored using a simplified and high-resolution model. The model provides some surprising results in that the onshore transport of CDW is highly sensitive to the surface wind stress forcing, with intermediate values producing the greatest flux.

Larger ice sheets contain significant topographic features. These features can direct the flow of dense and warm CDW inside the cavity because the cavity is large enough that the effects of rotation become important. In order to understand and accurately model the subshelf flow, the underlying bathymetry and shelf thickness must be known. Ground penetrating radar and seismic surveys have provided insight into the subshelf geometry, while tagged marine mammals and borehole CTD sections provide information about the water properties, allowing the model results to be verified.