Ice Sheets and Sea Level Rise

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December 14, 2008

There currently exists an enormous reservoir of ice on Earth which is stored in the great ice sheets of Greenland and Antarctica. These sheets were created as ice accumulated over long periods of time. Eventually, the ice volume on land reached an overall balance with accumulation of snowfall on the ice sheet surface balancing ice loss, through processes such as surface and basal melting, and iceberg calving. The total volume of ice in the sheets has fluctuated in an almost periodic fashion in approximate synchronization with regular changes in Earth's orbit around the Sun.

Periods of large ice sheet volume, known as ice ages or glacials, have been cold enough to draw enough water from the global ocean and deposit it as snowfall on land so as to produce a global drop in sea level approximately 300 feet lower than present. During periods of relative minimum ice sheet volume, such as today's present interglacial, the climate has been warm enough to reduce the ice sheet to their present-day size. But even now, the ice sheets still contain vast amounts of ice that hold the potential for even further sea-level rise, well beyond that of the present level. This raises the concern that in a changing global climate these sheets could undergo further substantial ice loss and thus significantly raise future global sea level.

Over the last few decades, a wealth of knowledge on the ice sheets has been gained through a diverse range of studies. Collection of ice cores from the surface of the ice sheet to the base has revealed the history of Earth's climate over the last million years, clearly showing the periodic warming and cooling of the climate. Cores takes from the sea floor, and related measurements, have shown that global sea level has gone up and done in step with the cooling and warming of the climate. Prior to the modern satellite instrumentation era it was generally thought that the change in ice sheets was a very slow process, and certainly something that would not be of immediate concern. However, satellite observation over the last decade have shown that the periphery of the ice sheets, where the ice sheets meet the ocean, have fast dynamical responses. At the periphery, the land ice is driven seaward by gravity and spreads out over the ocean. This floating ice, known as ice shelves, has the potential for rapidly melting, and thus to be replaced by inland ice, if it comes in contact with warming air or ocean waters. Satellite observations have shown catastrophic breakup of several Greenland and Antarctic ice shelves in recent times, and in each case, a warming of the air or ocean can be associated with the change.

An obvious next question is what will happen to the ice sheets over the present century and beyond. Scientists have yet to develop an appropriate model that provides society with such a predictive capability. One basic reason underlying this shortcoming is the inadequacies in observations of the ice sheets, largely owing to the harsh environmental conditions. A second reason relates to the enormous computational demands of properly simulating the fine-scale physical processes that govern ice sheet behavior and its interaction with the rest of the climate system. While the atmospheric and oceanic components of climate models have been well developed over the last few decades, the ice sheet component has not been developed. To overcome this we are going to require innovative mathematical and numerical techniques that allow a realistic representation of ice sheets in global climate models.

One area in particular need of further development is that of adaptive meshes which are able to have both areas of coarse and fine resolution and change the location of the fine resolution areas over time. Fine resolution is required in some parts of the ice sheet where it is either streaming very fast or is transiting from streaming to floating. Such fine resolution cannot be used at all locations in an ice sheet, as the computational burden would be too large. The geographical locations of these streaming and transition zones in the ice sheets evolve significantly over time and so the adaptive meshes need to be able to migrate geographically as these zones change location through time, and do so accurately.

Further Information on Antarctica, Greenland, and ice sheets and sea level change is found here:

http://www.coolantarctica.com/index.html

http://www.geographia.com/denmark/greenland.html

http://www.nasa.gov/vision/earth/environment/ice_sheets.html

http://tidesandcurrents.noaa.gov/sltrends/

http://www.sciencedaily.com/releases/2006/10/061019162746.htm

http://pubs.usgs.gov/fs/fs2-00/

Current configurations of the Greenland Ice Sheet (left image) and the Antarctic Ice Sheet (right image). Each sheet is surrounding by ocean waters, which are partially covered by sea ice. Images from www.NASA.gov.