POLAR ICE

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Polar ice consists of sea ice formed from the freezing of sea water, and ice sheets and glaciers formed from the accumulation and compaction of falling snow. Both types of ice extend over vast areas of the polar regions. Global sea-ice coverage averages approximately 25 million square km, the area of the North American continent, whereas ice sheets and glaciers cover approximately 15 million square km, roughly 10% of the Earth's land surface area.

Effects on Energy Exchange

Ice, both on land and in the sea, affects the exchange of energy continuously taking place at the Earth's surface. Ice and snow are amongst the most reflective of naturally occurring Earth surfaces. In particular, sea ice is much more reflective than the surrounding ocean, so that if it were to increase in extent, for instance because of large-scale cooling, then more solar energy would be reflected back to space and less would be absorbed at the surface. This would tend to cool the local region further, with the likelihood that more ice would be formed and still more cooling would occur.

On the other hand, if global warming occurs, then more ice would be expected to melt, reducing the energy reflected back to space and increasing the energy absorbed at the surface. The affected portions of the Earth would become still warmer. Scientists refer to this kind of reinforcing process as a "positive feedback."

Global observations are needed in order to make our theoretical and computer models as correct as feasible and to ensure that they include the major relevant phenomena for understanding the ice and other components of the

Earth’s climate. Generally, these can be obtained systematically only from space-based satellites. In the U.S., missions conducted by NASA, NOAA, and the Department of Defense are all contributing to our knowledge of polar ice on a global basis.

Global Warming and Land Ice

Over the past century, sea level has slowly been rising. This is in part due to the addition of water to the oceans through either the melting of or the “calving” off of icebergs from the world’s land ice. Many individual mountain glaciers and ice caps are known to have been retreating, contributing to the rising sea levels. It is uncertain, however, whether the world’s two major ice sheets—Greenland and Antarctica—have been growing or diminishing. This is of particular importance because of the huge size of these ice sheets, with their great potential for changing sea level. Together, Greenland and Antarctica contain about 75% of the world’s fresh water, enough to raise sea level by over 75 meters, if all the ice were returned to the oceans. Measurements of ice elevations are now being made by satellite radar altimeters for a portion of the polar ice sheets, and in the future they will be made by a laser altimeter as part of NASA’s Earth Observing System (EOS), which will provide much-more-accurate measurements over a wider area.

Where ice sheets extend outward to the ocean, the ice tends to move out over the surrounding water, forming “ice shelves.” There is a concern that, with global warming, the water under the ice shelves would be warmer and cause them to break up more readily, forming very large icebergs. If the ice shelves of West Antarctica were to break up, this would release more inland ice in an irreversible process, leading to sea level rises of several meters.

The Greenland ice sheet is warmer than the Antarctic ice sheet. As a result, global warming could produce serious melting on Greenland while having less effect in the Antarctic. In the Antarctic, temperatures are far enough below freezing that even with global warming, temperatures could remain sufficiently cold to prevent extensive melting.

In addition to increasing the amount of melting, global warming would also be expected to increase the amount of precipitation in the polar regions. There are two reasons for this: 1) warmer air can carry more moisture than colder air; and 2) lessened sea ice would lead to more evaporation from the ocean, as more ocean area would be exposed directly to the atmosphere. Global warming could therefore be expected initially to increase both melting and snowfall. Depending on which increase dominates, the early result could be either an overall decay or an overall growth of the ice sheets.

Global Warming Detection and Sea Ice

The melting and growth of sea ice, in contrast to land ice, does not affect sea level, because the sea ice is floating on the ocean already and is in equilibrium with it. Still, sea ice is important in the context of climate change. Sea ice, with its high reflectance and the insulation it provides between the polar atmospheres and oceans, is a key part of the climate machine. Furthermore, sea ice responds to changes in the atmosphere and oceans, and hence changes in it could be a clue to broader climate change such as global warming. However, the record to date is not clear enough to make any definitive conclusions about long-term climate trends based on the sea-ice observations alone. Sea ice varies significantly from season to season and from year to year, and the extent of its natural variability is not fully known.

We need to continue to monitor the location and extent of sea ice and its changes seasonally and interannually. We also need additional studies to determine ice thicknesses and reflectivities. This kind of information can be fed into climate models to attempt to simulate future climate conditions. The same information also will serve as a check on models to see if they are properly simulating existing sea-ice amounts and distributions.

NASA Missions to Study Ice

NASA has had missions that collected ice data for many years (see the accompanying table), and ice is among the many variables included in NASA's Pathfinder Program, which is providing research-quality data sets on global change from past and current satellite missions. The Pathfinder Program will lead up to the main initiative of NASA's Mission to Planet Earth, the Earth Observing System (EOS). EOS involves a series of satellites to be launched in 1998 and thereafter, providing coverage of the Earth over a period of fifteen to twenty years. Several sensors on the early satellites in the 1960's and 1970's obtained valuable ice data, especially under cloud-free conditions. However, cloudiness and polar darkness often obscured the observations that were obtained with visible and infrared sensors. A major breakthrough occurred in December 1972 with the launch of the Electrically Scanning Microwave Radiometer (ESMR) on the Nimbus-5 satellite. Taking advantage of the microwave radiation that is emitted from the Earth's surface, ESMR could see through the clouds, providing for the first time detailed data sets of sea-ice distributions for cloudy and cloud-free conditions, and could do this at night as well as during daylight.

Microwave radiation is emitted in varying amounts by everything on the surface of the Earth. The amount of radiation emitted depends on the temperature of the substance and its “emissivity,” which is a measure of the substance’s ability to emit radiation. Because the microwave emissivity of sea ice is markedly greater than that of water, it radiates more microwave energy than the water, even when their temperatures are the same. The greater intensity of the microwave radiation coming from ice allows the ice/water distinction to be made in the satellite data.

The data from Nimbus-5 ESMR and its successor, NASA’s Scanning Multichannel Microwave Radiometer (SMMR), which was launched on Nimbus-7 in 1978, have resulted in three major atlases, giving the history of the Arctic and Antarctic sea-ice covers for the years 1973-76 and 1978-87. NASA’s Seasat satellite also carried a SMMR instrument in 1978, but, unfortunately, a power failure caused data acquisition to cease after 106 days. The Defense Meteorological Satellite Program (DMSP) has flown a Special Sensor Microwave/Imager (SSM/I) since 1987. This instrument is similar to SMMR, and its data are being analyzed and converted to sea-ice concentrations by NASA and other scientists.

Other satellite data have also been used in the study of ice. For instance, high-resolution images from the Landsat series of satellites have been converted into photo maps for parts of the Antarctic and Greenland ice sheets. Landsat images have also been used to measure ice flow rates and the advance and retreat of glacier margins. Radar altimetry data from NASA’s Seasat and the Department of Defense Geosat satellites have been used to determine and map the elevation contours of the southern half of the Greenland ice sheet and a small fraction of northern Antarctica. (The Seasat and Geosat orbits did not allow data collection in the central polar regions.)

The EOS series of satellites will carry several very important instruments for ice studies during the period 1998-2017. Of particular interest are the Geoscience Laser Altimeter System (GLAS), scheduled to fly on the EOS-ALT missions beginning in 2002, and the Multifrequency Imaging Microwave Radiometer (MIMR), which will fly on the EOS-PM missions beginning in 2000. MIMR will obtain sea-ice information with greater spatial detail than earlier microwave radiometers, while GLAS will measure growth or shrinkage of the ice sheets. GLAS will be 100 times more accurate than radar altimeters, which have been designed for ocean measurements, and will be flown in an orbit nearly over the South pole. GLAS measurements of ice melting, changes in snowfall in polar regions, and changes in the ice volume will provide critical data for understanding and predicting sea-level change during the next century. GLAS will also be very useful in the study of individual ice streams and ice shelves in the West Antarctic. Observing these ice streams and shelves is particularly important because of the possibility that they might become unstable under certain conditions of global change.

Analyses of EOS data sets are expected to enhance our knowledge of sea ice and continental ice sheets and their implications for global change as we enter the next century.

Source: NASA