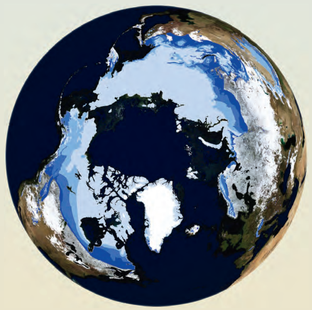
USGS science for a changing world
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Professional Paper 1386–A
The Earth's Dynamic Cryosphere—PLATE 1
Williams, R.S., Jr., and others, 2012

Earth's Cryosphere

The four elements of the Earth's cryosphere: glaciers, snow cover, floating ice, and permafrost. Fractal snowflake diagram designed by James A. Tomberlin, USGS

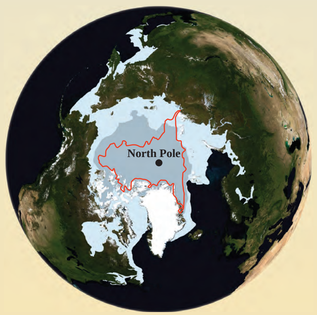


Permafrost in the Northern Hemisphere

The distribution of **permafrost in the Northern Hemisphere,** shown as areas of continuous, discontinuous, sporadic, or isolated patches, is centered in the Arctic regions and extends southward and into the sea floor. The blue colors are superimposed on a polar stereographic projection of the Earth as a mosaic of images of global snow cover (far right-hand panel, center) that NASA's Terra satellite acquired in 2004 using its Moderate-resolution Imaging Spectroradiometer (MODIS). The Greenland ice sheet is bright white (just below the center). Duller gray to white areas indicate snow-covered land.

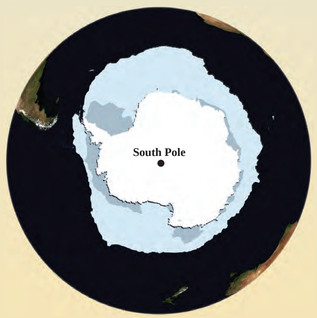
Permafrost concentration, in percent

- Continuous, 90 to 100
- Discontinuous, 50 to 90
- Sporadic, 10 to 50
- Isolated patches, 0 to 10



Northern Hemisphere Sea Ice, Seasonal Maxima and Minima Areas, 2005

- March 2005 (near maximum)
- September 2005 (near minimum)
- 14 September 2007 (minimum)



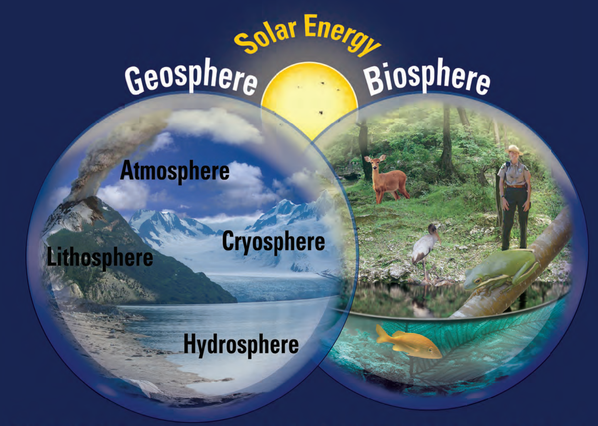
Southern Hemisphere Sea Ice, Seasonal Maxima and Minima Areas, 2005

- September 2005 (near maximum)
- February 2005 (near minimum)

These two maps of sea-ice distributions are derived from passive microwave data and plotted on polar stereographic projections of mosaics of images created from data from the MODIS on NASA's Terra satellite. The white areas shown in the **Northern Hemisphere** indicate the Greenland ice sheet and glaciers in Alaska, Iceland, Norway, and the Arctic islands of Canada and Russia and some seasonal snow cover. The white areas in the **Southern Hemisphere** indicate the Antarctic ice sheet, glaciers in southern South America, and South Island, New Zealand.

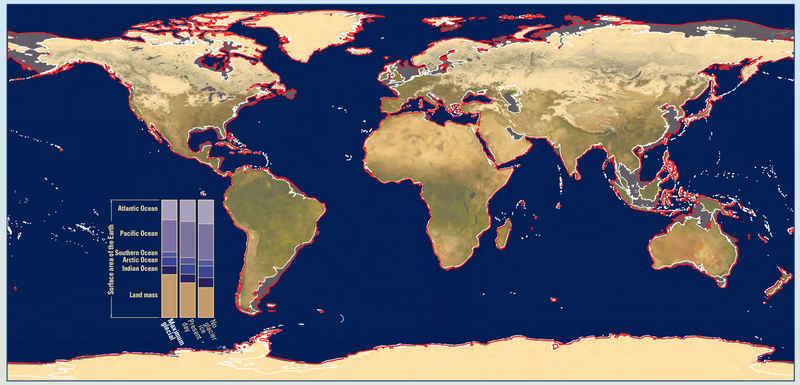
Earth

Astronaut Harrison H. (Jack) Schmitt, geologist, took this photograph during the Apollo 17 flight to the Moon in December 1972 (NASA photograph No. 72-HC-928).



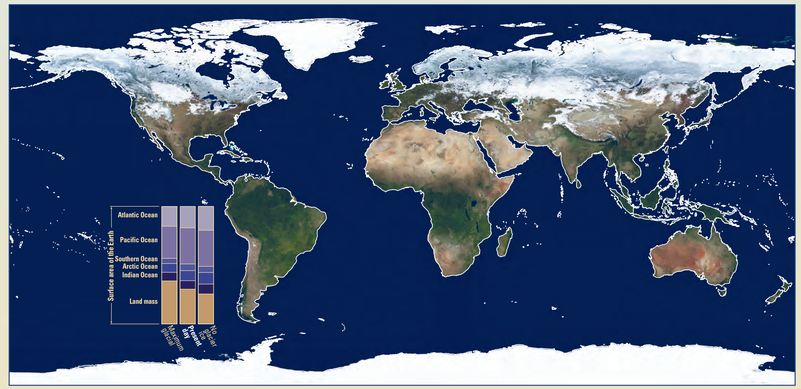
Earth System

The geosphere and the biosphere are the two components of the **Earth System;** the geosphere is the collective name for the lithosphere, the hydrosphere, the cryosphere, and the atmosphere. All parts of the Earth System interact and are interrelated through climatic processes and through the hydrologic cycle and biogeochemical cycles. The Sun is the dominant source of all external energy to the **Earth System.**
Diagram designed by James A. Tomberlin, USGS



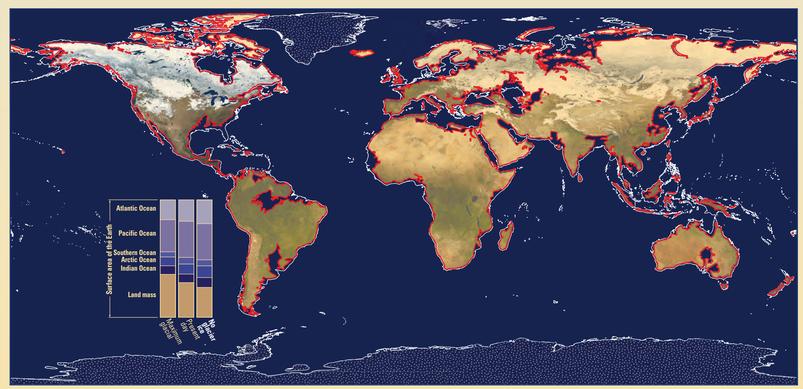
Earth's Coastlines Approximately 20,000 Years before Present

Sea level 20,000 years ago was lower by about 125 meters (about 410 feet) than it is today. The Earth's coastlines therefore extended farther into the oceans than they extend today (2009). The older coastline was drawn from data from The University of California at San Diego's TOPEX/Poseidon Shuttle Radar Topography Mission (SRTM) 30 PLUS archive combined with a bathymetric dataset. Geologists drew outlines (in red) of the older coastlines over a modified version of the 2004 MODerate-resolution Imaging Spectroradiometer (MODIS) image-mosaic map of global snow cover. Snow cover (and glaciers) shown as white on the center graphic is shown here as a pale yellow color. The 2004 MODIS images were acquired by NASA's Terra satellite. Present-day coastlines are delineated in white.



Earth's Present-Day Coastlines

Image-mosaic map of the Earth showing global snow cover in 2004 produced from images acquired by the MODerate-resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite. Present-day coastlines are delineated in white.



Earth's Projected Coastlines if All Glacier Ice on Land Melted into the Ocean

If all glacier ice on land were to melt, glacial meltwater entering the ocean would raise global sea level by more than 75 meters (about 250 feet). The water-covered coastlines worldwide were calculated using data from The University of California at San Diego's TOPEX/Poseidon Shuttle Radar Topography Mission (SRTM) 30 PLUS archive. The retreated coastlines are drawn in red over a modified version of the MODerate-resolution Imaging Spectroradiometer (MODIS) image-mosaic map of the Earth showing global snow cover (above, center). Snow cover shown as white on the center graphic is shown here as a pale yellow color but, under a warmer Earth, would not be present except at high elevations and high latitudes (seasonally). The 2004 MODIS images were acquired by NASA's Terra satellite. Present-day coastlines are delineated in white. Note that the representation of the coastlines of Greenland and Antarctica, from the TOPEX/Poseidon SRTM 30 PLUS archive data, do not account for the extensive subglacial areas of each ice sheet, which are below present-day sea level, nor for the isostatic rebound of the Earth's crust following the loss of overlying ice. Hence, some of the present-day ice-covered Greenland and Antarctica would become ocean (shown schematically by the stipple pattern. Therefore the coastlines of Greenland and Antarctica are not shown for a warmer Earth—with no glacier ice on land.

The Earth's Dynamic Cryosphere and the Earth System (8 Supplemental Cryosphere Notes accompany Plate 1)

1 **The Earth System**
By Richard S. Williams, Jr.[1]

2 **Global Hydrologic Cycle**
By Thomas G. Huntington[12] and Richard S. Williams, Jr.[1]

3 **Glaciers**
By Richard S. Williams, Jr.,[1] Jane G. Ferrigno,[2] Bruce H. Raup,[14] and Jeffrey S. Kargel[15]

4 **Global Snow Cover**
By Dorothy K. Hall[3] and David A. Robinson[4]

5 **Floating Ice** (Sea Ice; Lake Ice and River Ice)

Sea Ice
By Claire L. Parkinson[3] and Donald J. Cavalieri[3]

Lake Ice and River Ice
By Martin O. Jeffries,[5] Kim Morris,[5] and Claude R. Duguay[6]

6 **Permafrost and Periglacial Environments**
By J. Alan Heginbottom,[8] Jerry Brown,[7] Ole Humlum,[9] and Harald Svensson[10]

7 **Glacier Mass Changes and Their Effect on the Earth System (Sea Level)**
By Mark B. Dyurgerov[11] (Deceased, 2009) and Mark F. Meier[11] (Deceased, 2012)

8 **Ice Cores, High-Mountain Glaciers, and Climate**
By Lonnie G. Thompson[13]

Earth's Dynamic Cryosphere

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