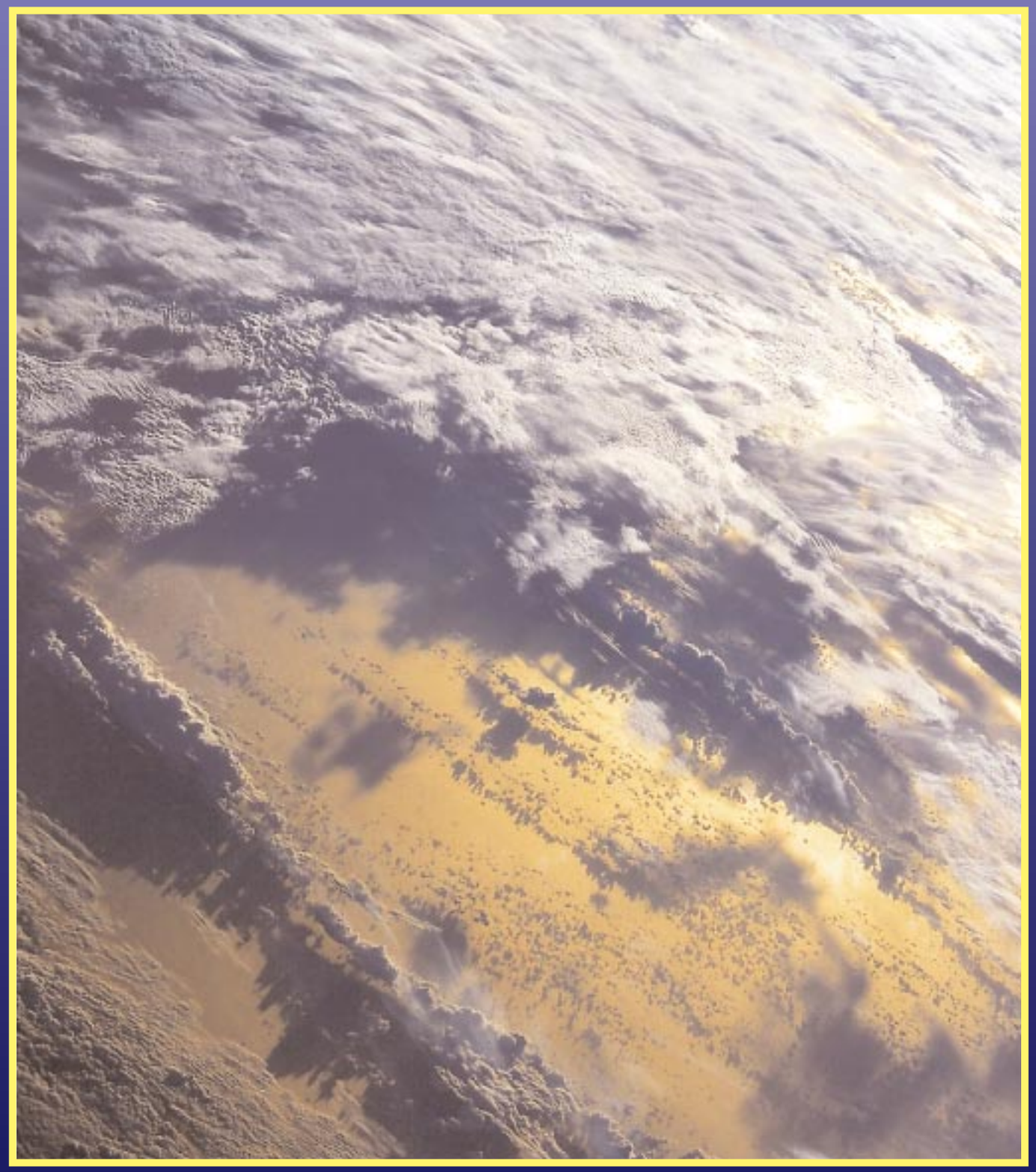
EARTH OBSERVING SYSTEM



EOS

Cloud Radiative Effects

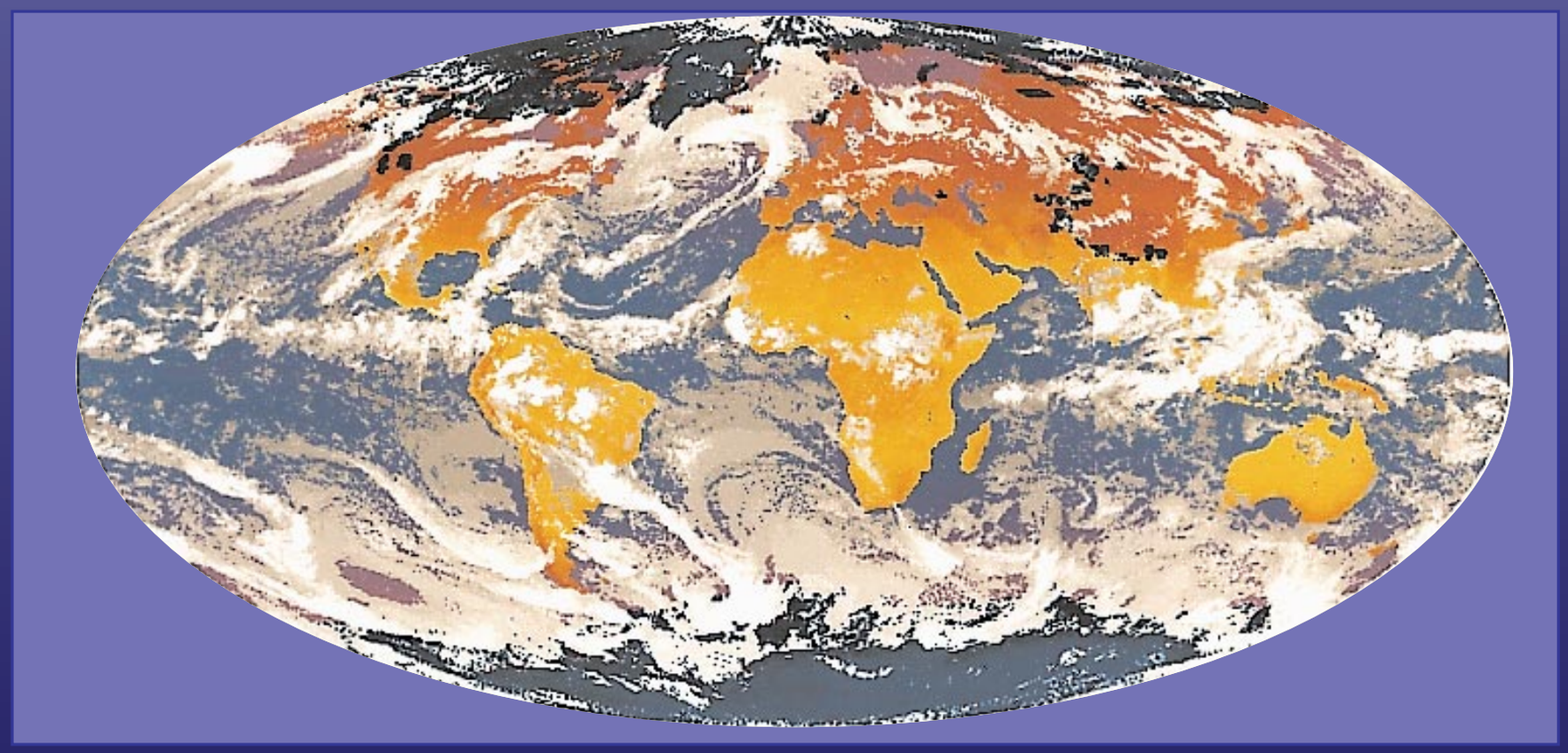
CLOUDS OVER THE ATLANTIC OCEAN
Sunrise viewed from Space Shuttle STS–51G (June 1985). The bronze hue is caused by particles in the atmosphere from a dust storm in West Africa.

National Aeronautics and Space Administration

Cloud Radiative Effects

EARTH OBSERVING SYSTEM

Global cloud observations assist scientists in determining which of the cloud radiative effects—net heating or net cooling—dominates the planet's radiative budget that largely determines global climate.



CLOUD COVER for October 1, 1983 from the International Satellite Cloud Climatology Project, Goddard Institute for Space Studies.

National Aeronautics and Space Administration

EOS

Cloud Radiative Effects

EARTH OBSERVING SYSTEM

HIGH CLOUDS

CIRRUS CLOUDS over the western United States. Cirrus clouds warm Earth's surface by trapping out-going longwave radiation.

LOW CLOUDS

MARINE CLOSED-CELL STRATOCUMULUS CLOUDS over the western North Pacific viewed from Space Shuttle STS–44 (November 1991). Stratocumulus clouds cool Earth's surface by reflecting incoming solar radiation back to space.

Cloud Radiative Effects

EARTH OBSERVING SYSTEM

EOS INSTRUMENTS

NASA's Earth Observing System will contribute continuous measurements of clouds, radiation, and other elements of the atmospheric hydrologic cycle to provide data on Earth's radiative budget.

MODIS will provide simultaneous, congruent observations of cloud cover and cloud properties characterized by cloud droplet phase, optical thickness, droplet size, cloud-top pressure and emissivity. These data will be used to identify trends in atmospheric contamination, as well as to provide models of radiative transfer.

CERES will permit retrieval of the longwave and shortwave components of Earth's radiation budget, both at the top of the atmosphere and at Earth's surface. These data together with MODIS observations will increase our understanding of cloud radiative forcing and hence the impact of clouds on climate.

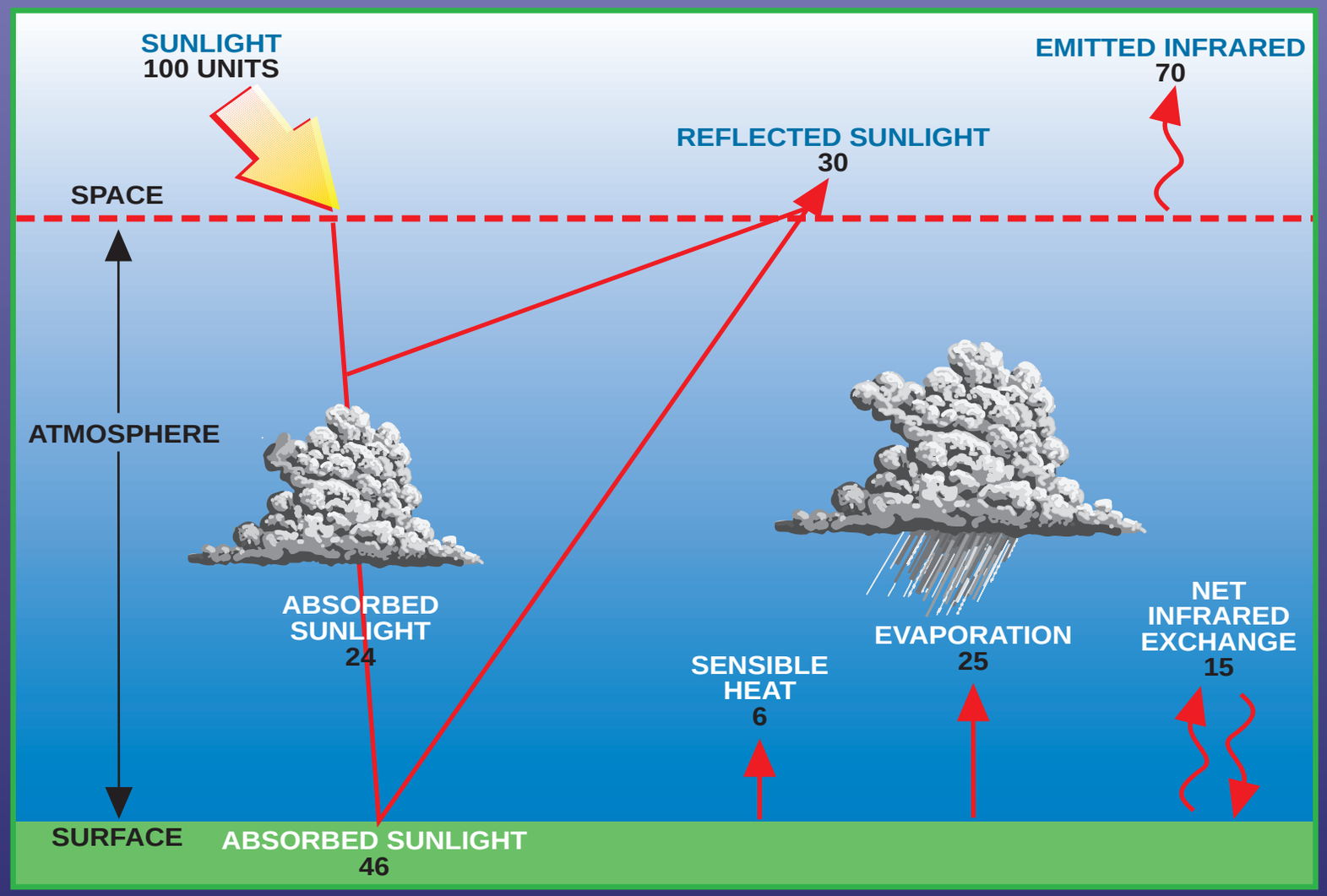
ACRIM III will provide long-term, highly accurate and precise measurements of the total solar irradiance reaching Earth.

AMSR will provide data on cloud water content, atmospheric water vapor, and precipitation.

GLAS will use lidar altimetry to determine the altitude and thickness of thin cirrus clouds and, where feasible, determine altitudes and thicknesses of multi-layer clouds as well.

Cloud Radiative Effects

EARTH OBSERVING SYSTEM



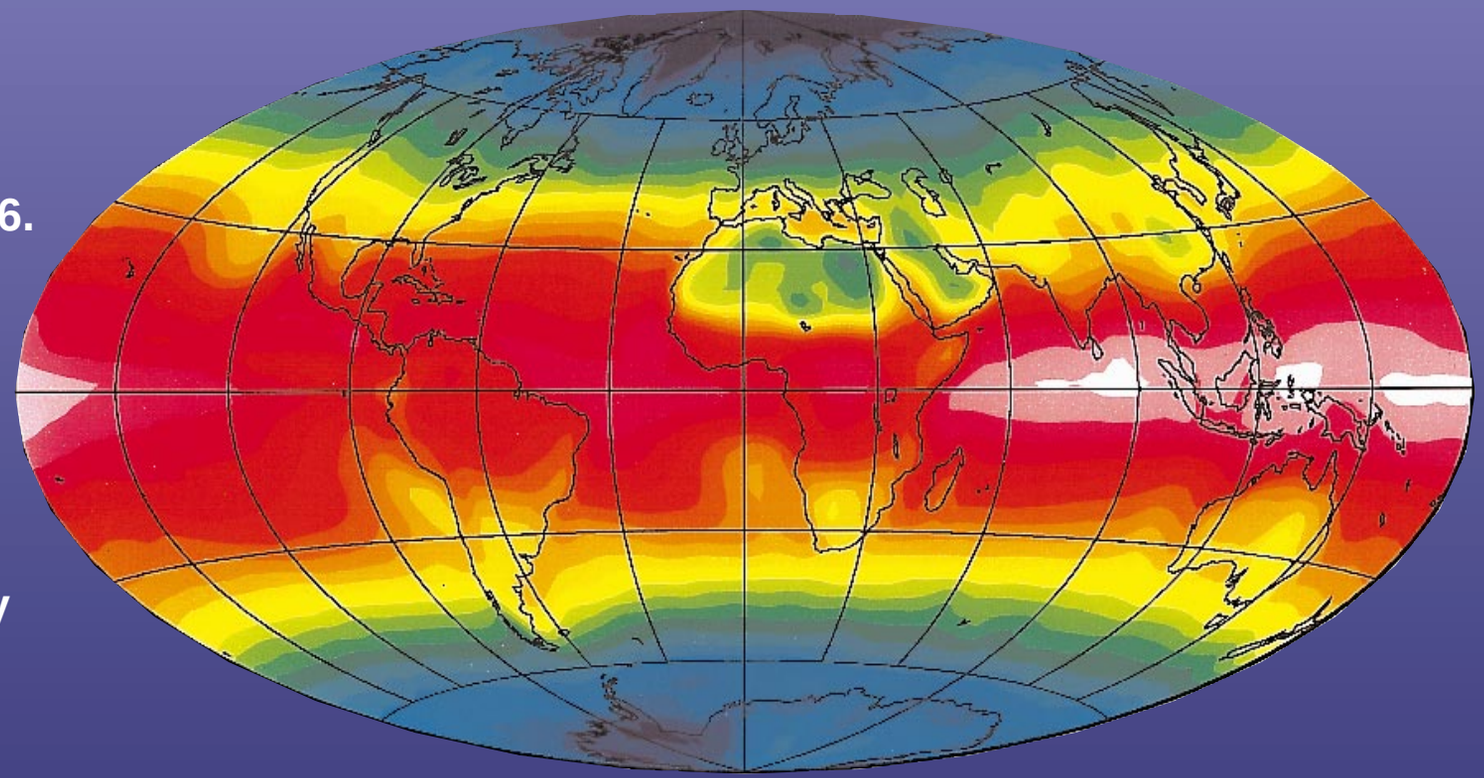
GLOBAL ENERGY BALANCE

GLOBAL ENERGY BALANCE FOR ANNUAL MEAN CONDITIONS. 100 units of incoming sunlight are balanced by 30 units of outgoing reflected sunlight and 70 units of outgoing emitted infrared radiation. Surface absorption of 46 units of sunlight is balanced by 6 units of sensible heat, 25 units of evaporation of water vapor (latent heat), and 15 units of net infrared radiative exchange, lost from the surface to the atmosphere. The 3 latter quantities plus the 24 units of sunlight absorbed by the atmosphere are balanced by 70 units of emitted infrared radiation lost to space.

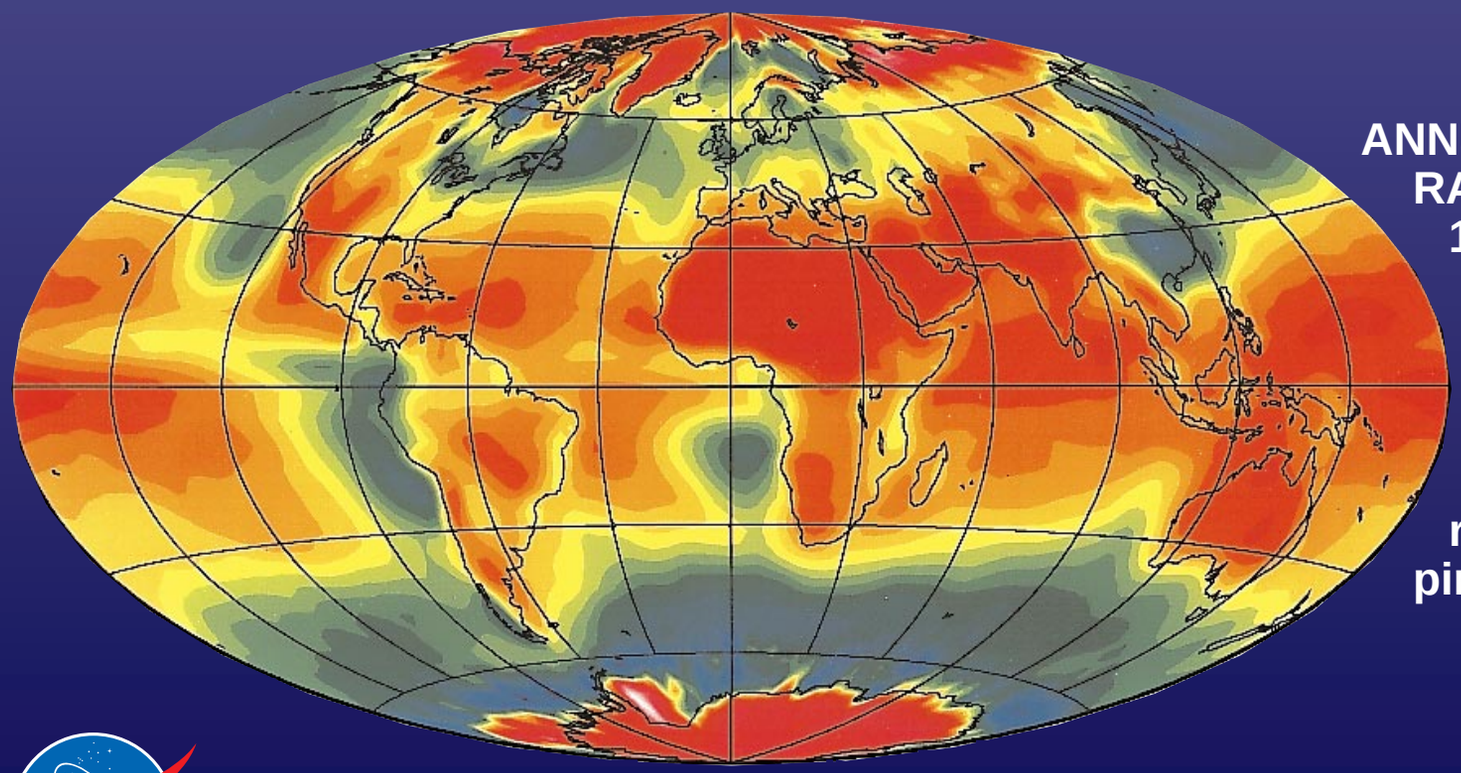
Cloud Radiative Effects

EARTH OBSERVING SYSTEM

CLOUD FORCING



ANNUAL AVERAGE NET RADIATION—1985 to 1986. Net radiation is generally positive at low latitudes (increases in heating represented by oranges, reds, and pinks) and negative at high latitudes (increases in cooling represented by greens and blues).



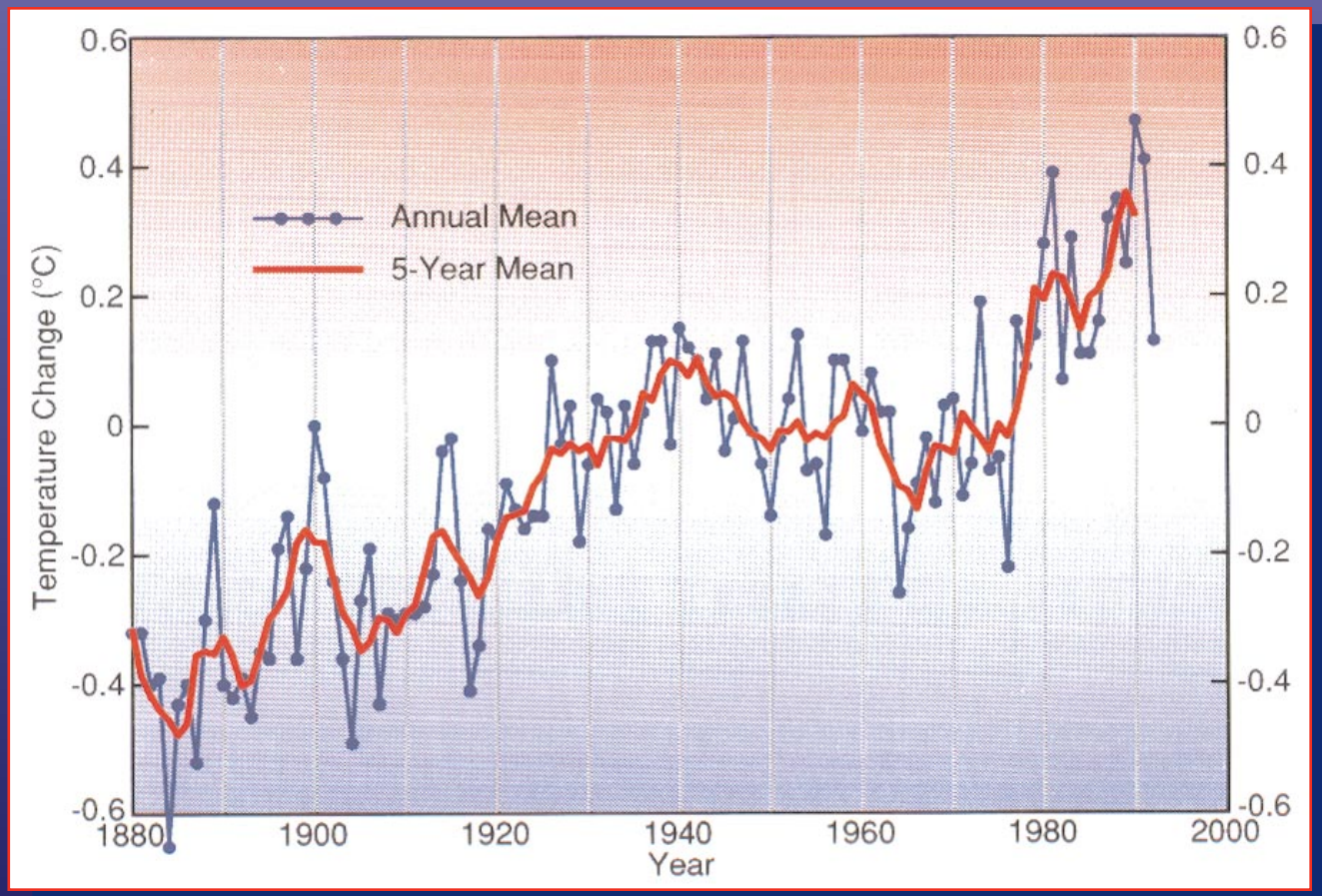
ANNUAL AVERAGE NET CLOUD RADIATIVE FORCING—1985 to 1986. Areas where cooling is the greatest are represented by colors ranging from yellow to green to blue. In some areas clouds produce warming as shown by colors ranging from orange to red to pink.

National Aeronautics and Space Administration

EOS

EARTH OBSERVING SYSTEM

Greenhouse Effect



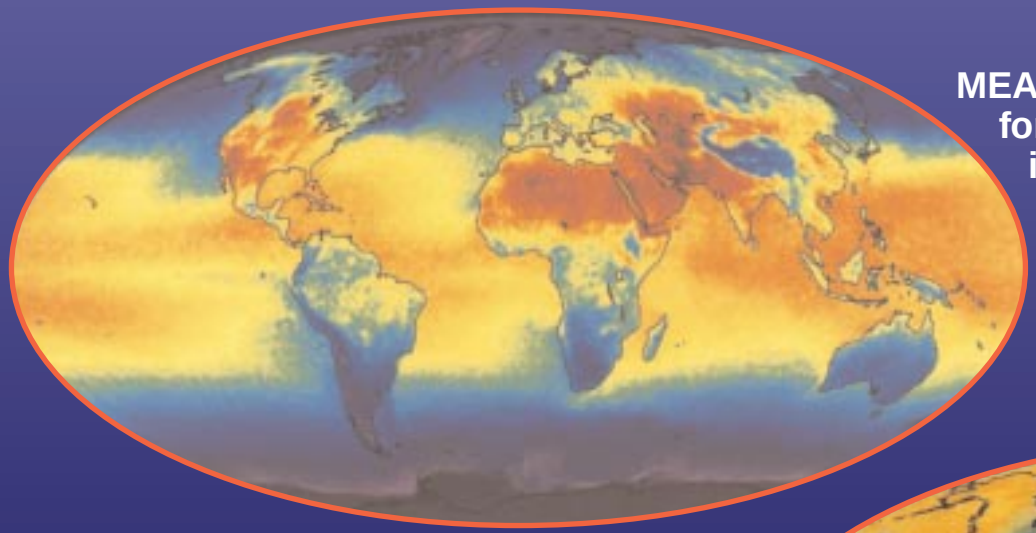
GLOBAL AIR TEMPERATURE CHANGE, showing an increase of about 0.8°C at Earth's surface during the past century. Blue dots indicate annual means; the red curve was constructed from 5-year running means.

National Aeronautics and Space Administration

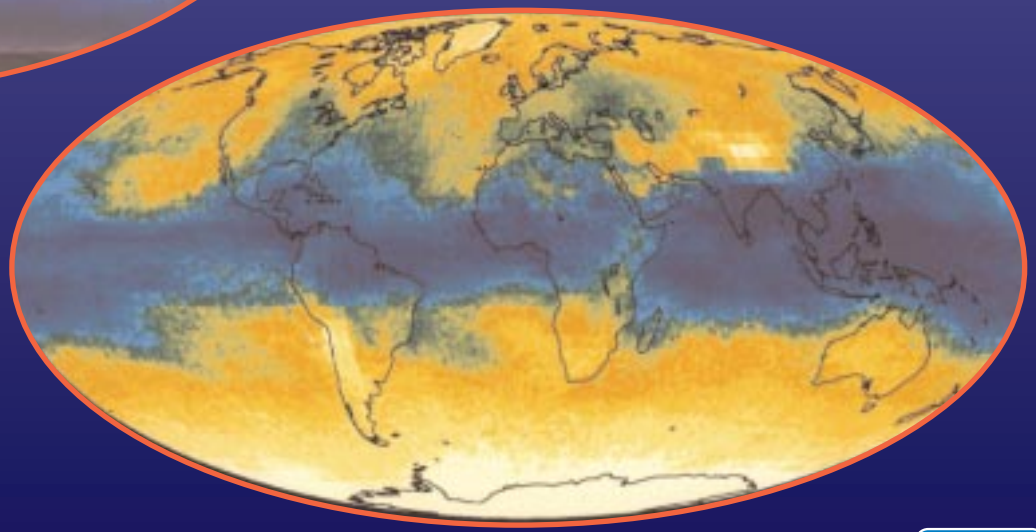
Greenhouse Effect

EARTH OBSERVING SYSTEM

Greenhouse gases such as carbon dioxide, methane, and chlorofluorocarbons have been increasing steadily in the atmosphere. These gases block Earth's heat, preventing it from escaping into space.



MEAN GLOBAL SURFACE TEMPERATURES for June 1988. Warmest temperatures indicated by reds; cooler temperatures indicated by yellows, greens, blues, and purples, in descending order.



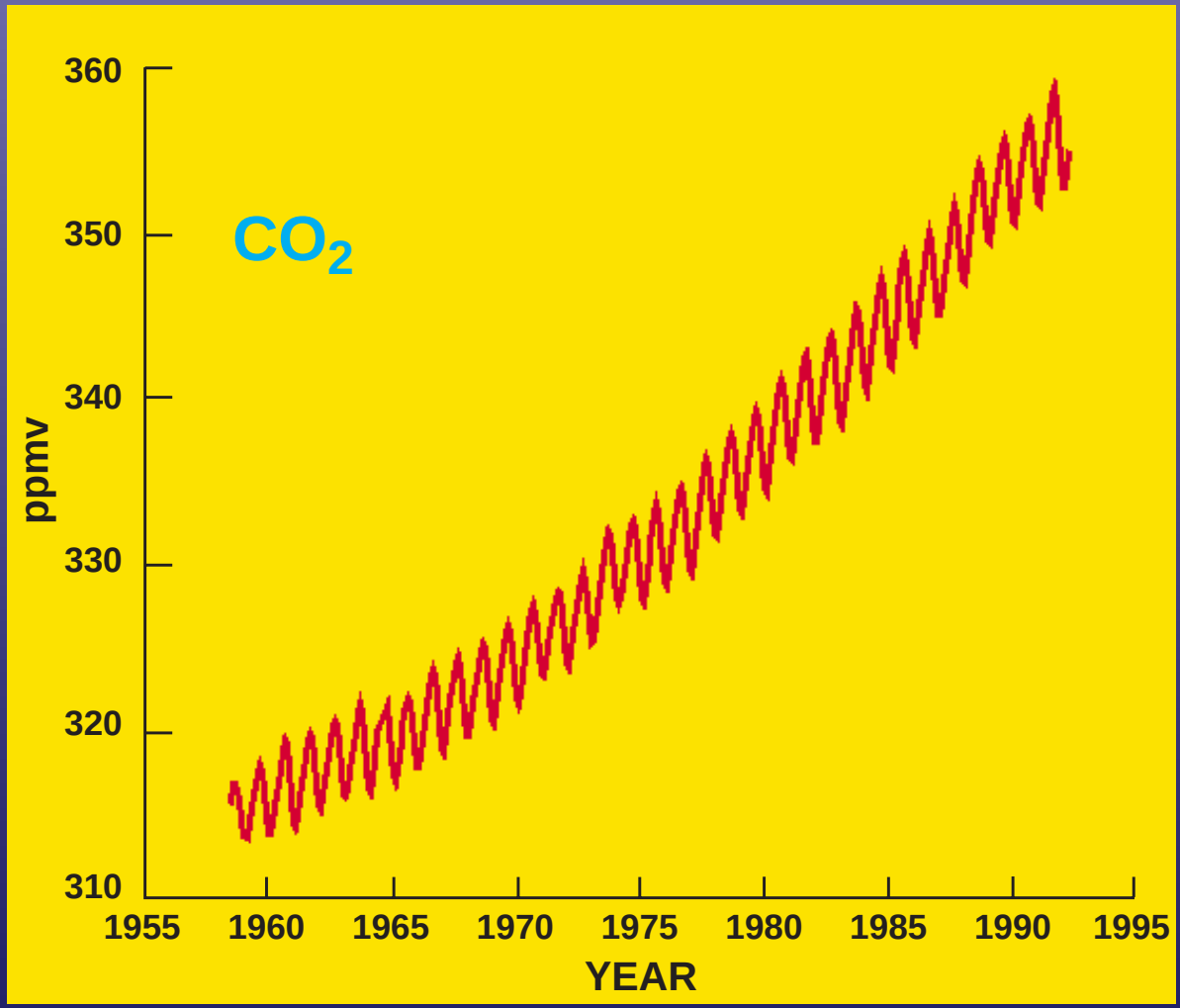
MEAN GLOBAL WATER VAPOR DISTRIBUTION for June 1988.

CARBON DIOXIDE

BURNING OF TROPICAL RAIN FORESTS by humans contributes significantly to the release of CO_2 into the atmosphere, adding further to the global greenhouse effect.

EARTH OBSERVING SYSTEM

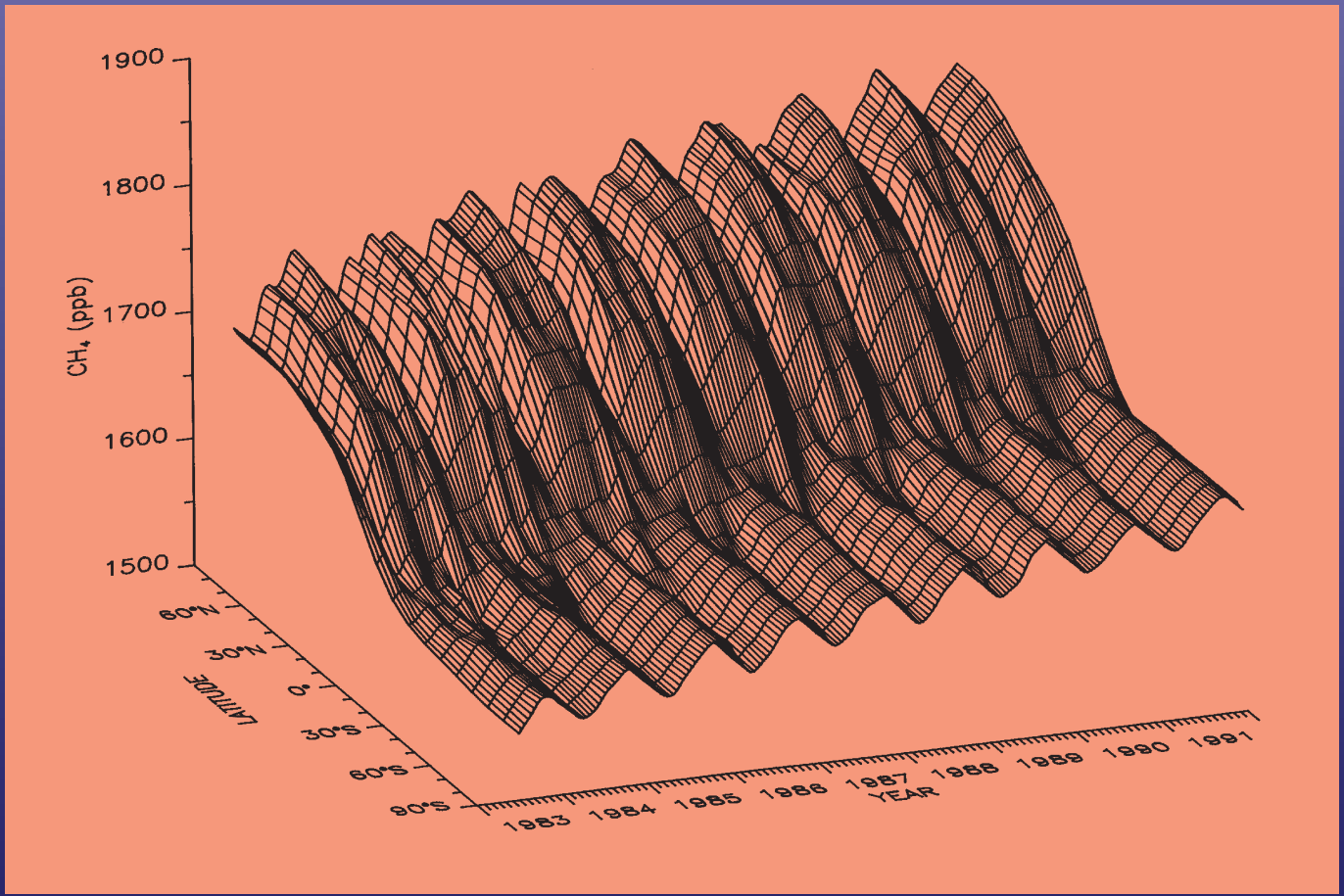
CARBON DIOXIDE



AVERAGE CARBON DIOXIDE (CO_2) concentration in parts per million by volume (ppmv), observed continuously at Mauna Loa, Hawaii.

EARTH OBSERVING SYSTEM

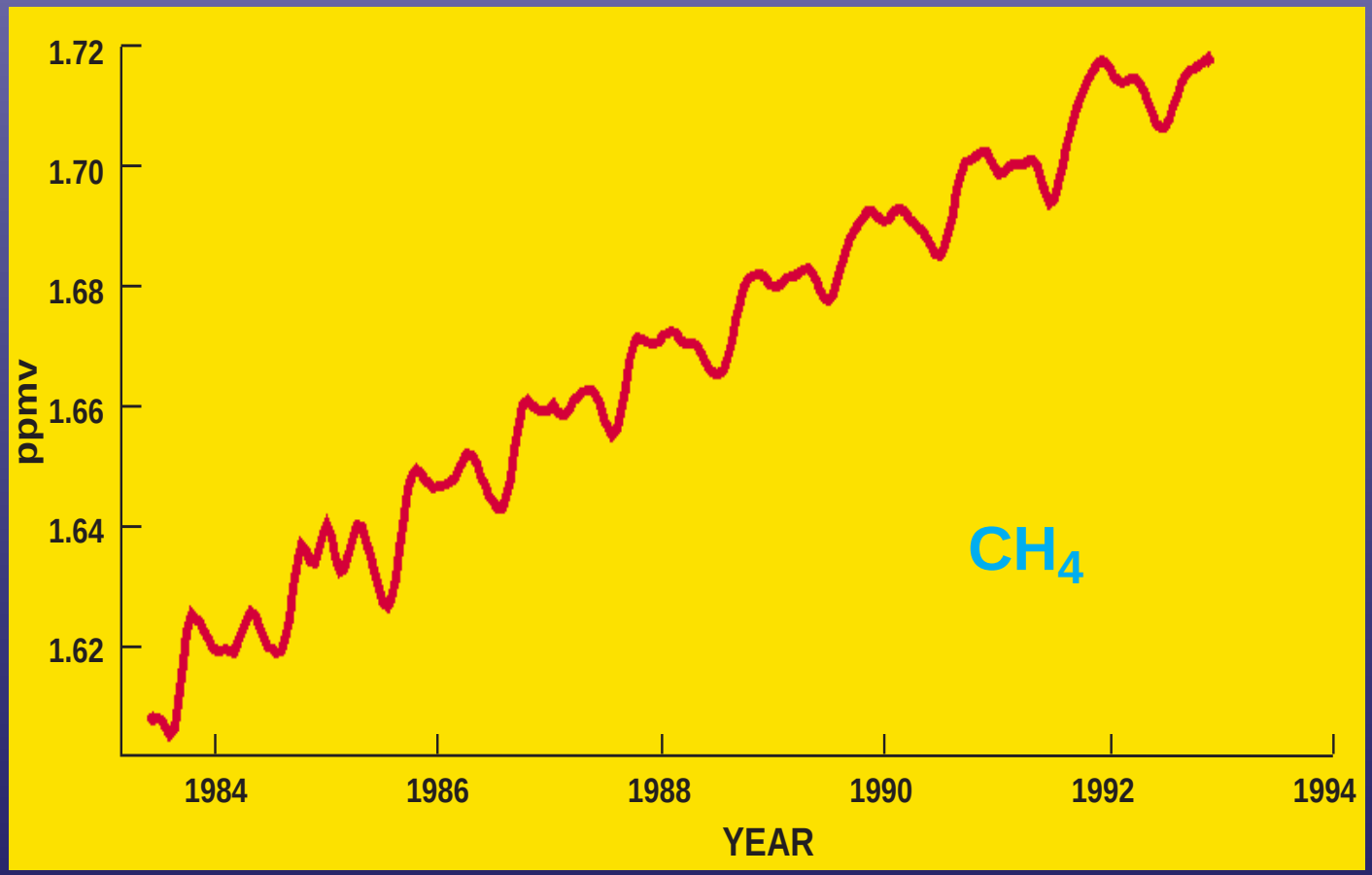
METHANE



GLOBAL DISTRIBUTION OF ATMOSPHERIC METHANE (CH_4) in the marine boundary layer, represented three dimensionally.

EARTH OBSERVING SYSTEM

METHANE



GLOBAL AVERAGE METHANE (CH_4) concentration in parts per million by volume (ppmv).

EOS MEASUREMENTS

ntensive research using computer models and satellite data from NASA's Earth Observing System will enhance scientific understanding of the physical processes affecting trends in temperature, humidity, clouds, and ice/snow cover, and will help scientists assess the potential impact of greenhouse gases on global climate.

AIRS/AMSU-A/HSB will provide temperature and humidity profiles for the world's atmosphere and contribute to the detection of greenhouse gases and their effects.

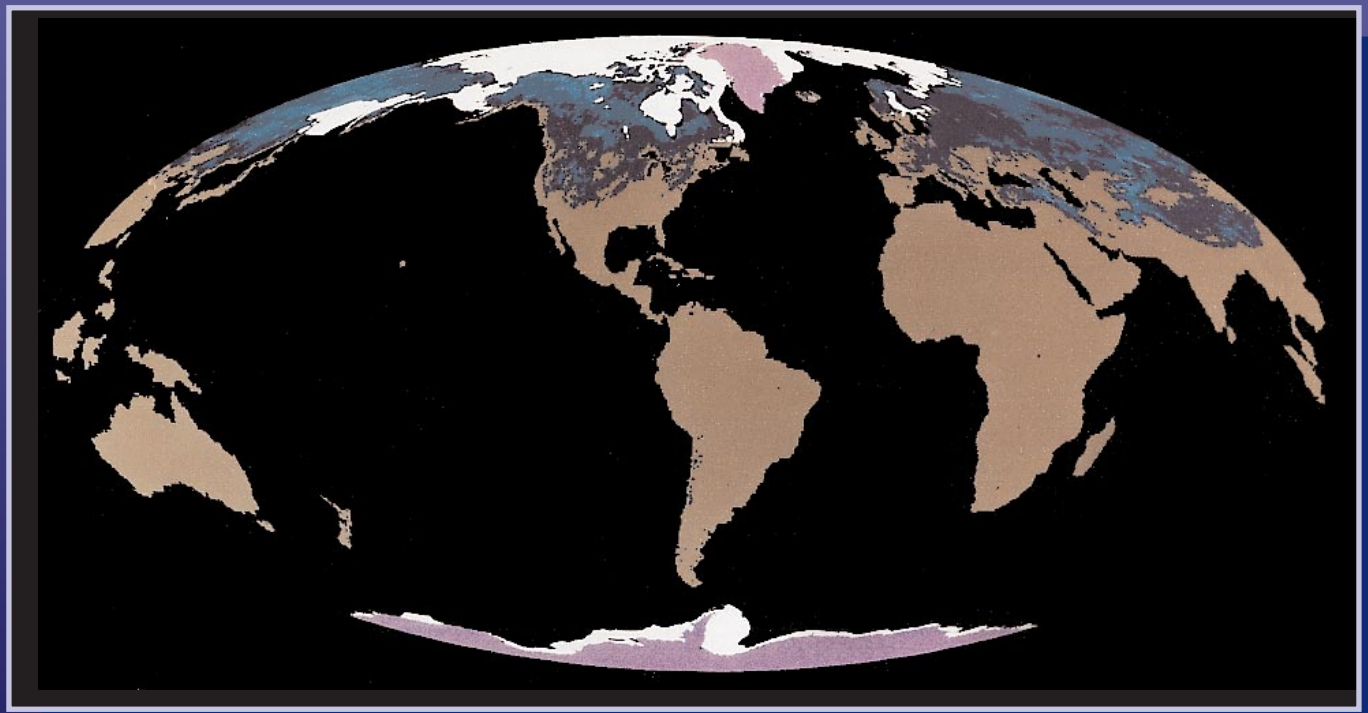
MOPITT will measure total column methane, an important greenhouse gas that is increasing annually.

AMSR will measure the key natural greenhouse gas, water vapor, as well as such indicators of possible climate change as soil moisture, global ice and snow cover, and sea-surface temperature.

TES will measure concentrations of many minor gases in the troposphere, along with the concurrent temperature and humidity profiles, to determine their effects on the global radiative balance.

EARTH OBSERVING SYSTEM

Global Ice & Sea Level Changes



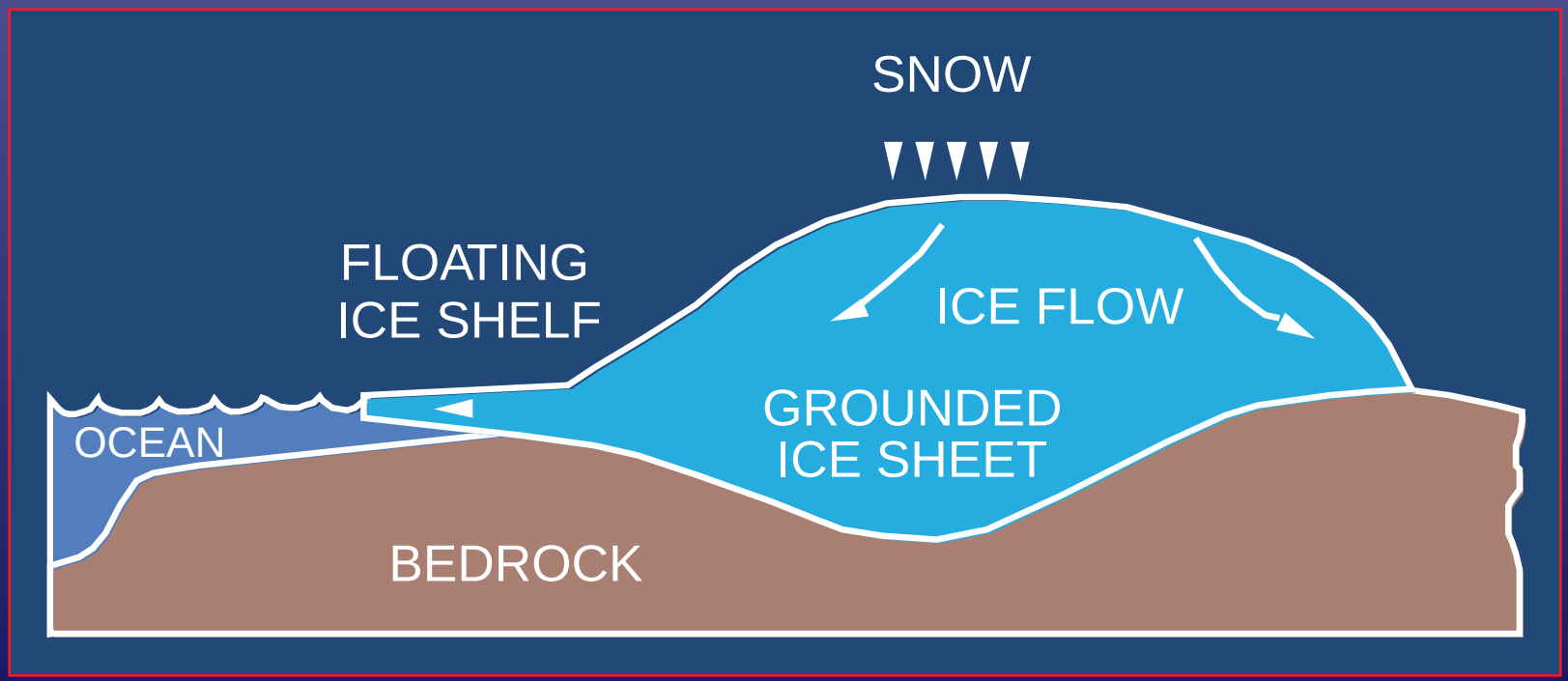
GLOBAL ICE AND SNOW COVER (February 1979). Sea ice is indicated by white, ice sheets by purple, and seasonal snow by various shades of blue representing different snow depths.

National Aeronautics and Space Administration

Global Ice & Sea Level Changes

EARTH OBSERVING SYSTEM

Earth's glacier ice, including the major ice sheets of Greenland and Antarctica, dozens of smaller ice caps, and thousands of mountain glaciers, contains 77 percent of the world's fresh water. Over the last century, many mountain glaciers and ice caps have been retreating, contributing to rising sea level. Scientists have not determined if major ice sheets have been growing or shrinking. Even small changes in their volume could seriously affect global sea level.

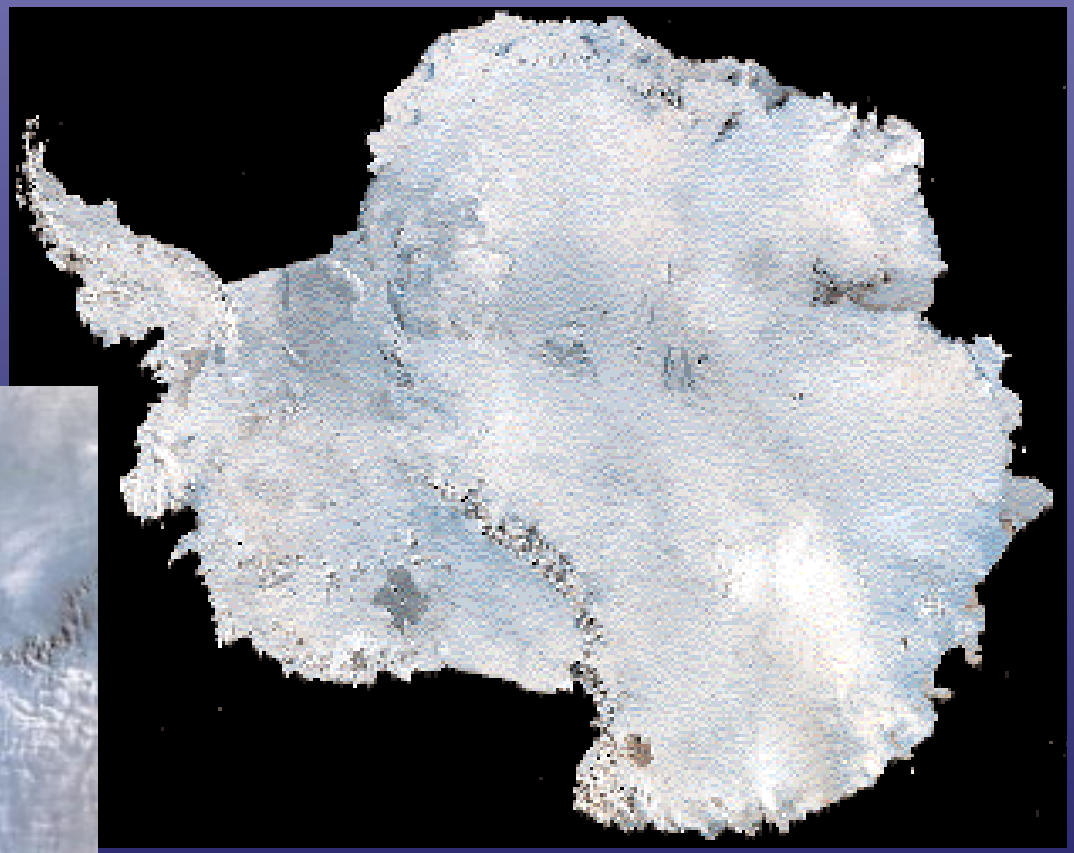


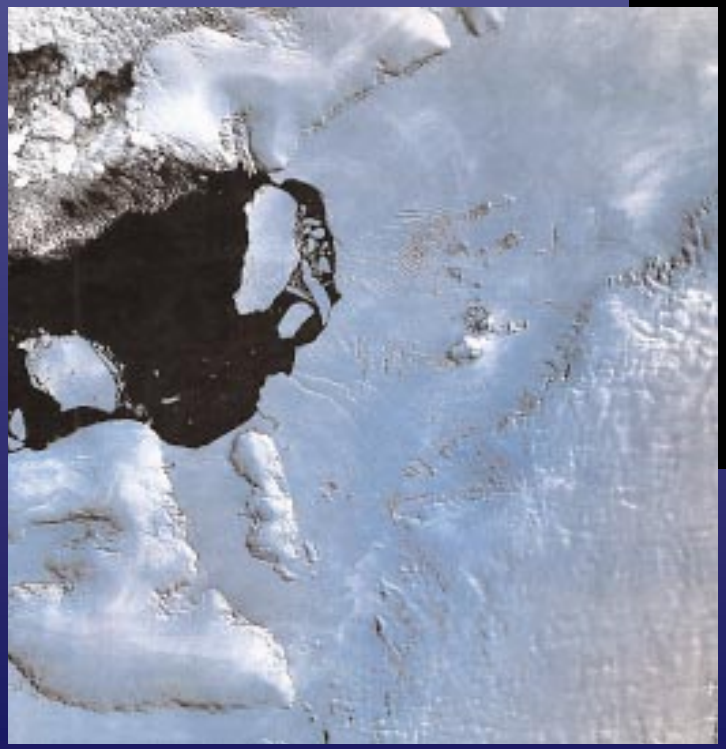
Global Ice & Sea Level Changes

EARTH OBSERVING SYSTEM

ANTARCTICA

ANTARCTICA. Shades of blue and pink correspond to colder and warmer regions, respectively.





ICEBERGS BREAKING OFF FROM THE WEST ANTARCTIC ICE SHEET. The largest iceberg shown has a length of 32 km.

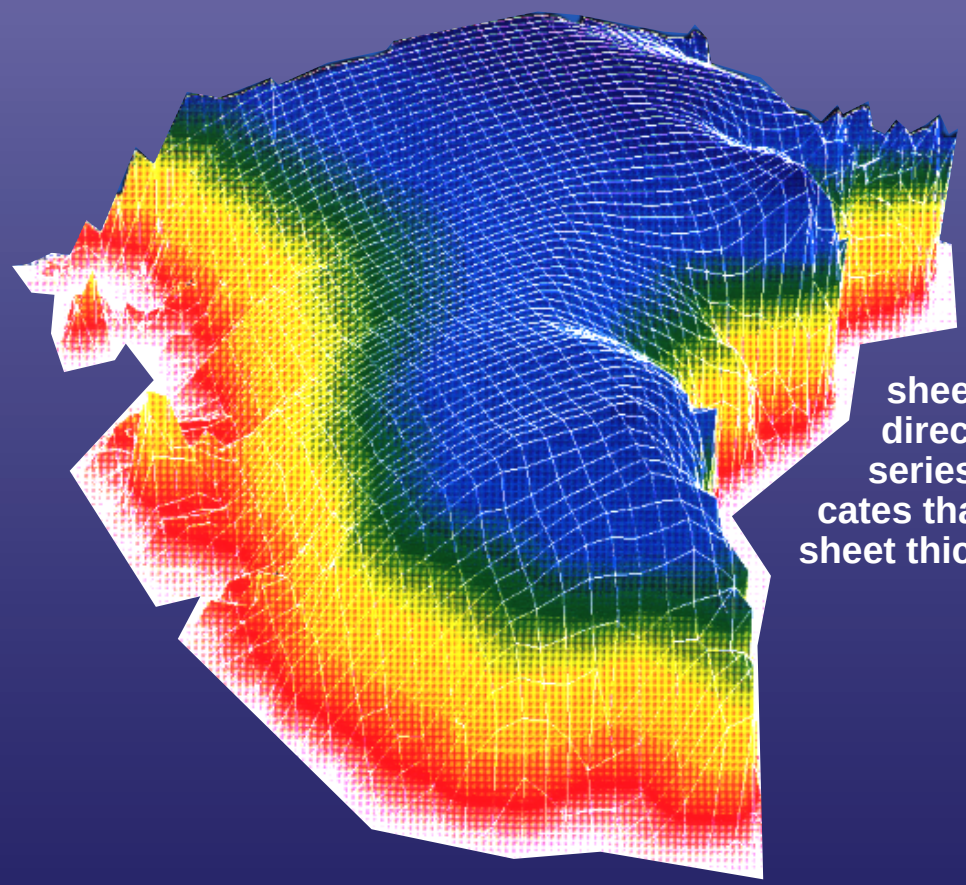
National Aeronautics and Space Administration

EOS

Global Ice & Sea Level Changes

EARTH OBSERVING SYSTEM

SOUTHERN GREENLAND



THREE-DIMENSIONAL SURFACE-ELEVATION MAP OF SOUTHERN GREENLAND (60°N to 72°N). The north central part of the map is near the 3200-meter crest of the ice sheet. The surface slope indicates the direction of glacier flow. Analysis of time series of Geosat and Seasat data indicates that the southern portion of the ice sheet thickened between 1978 and 1985.

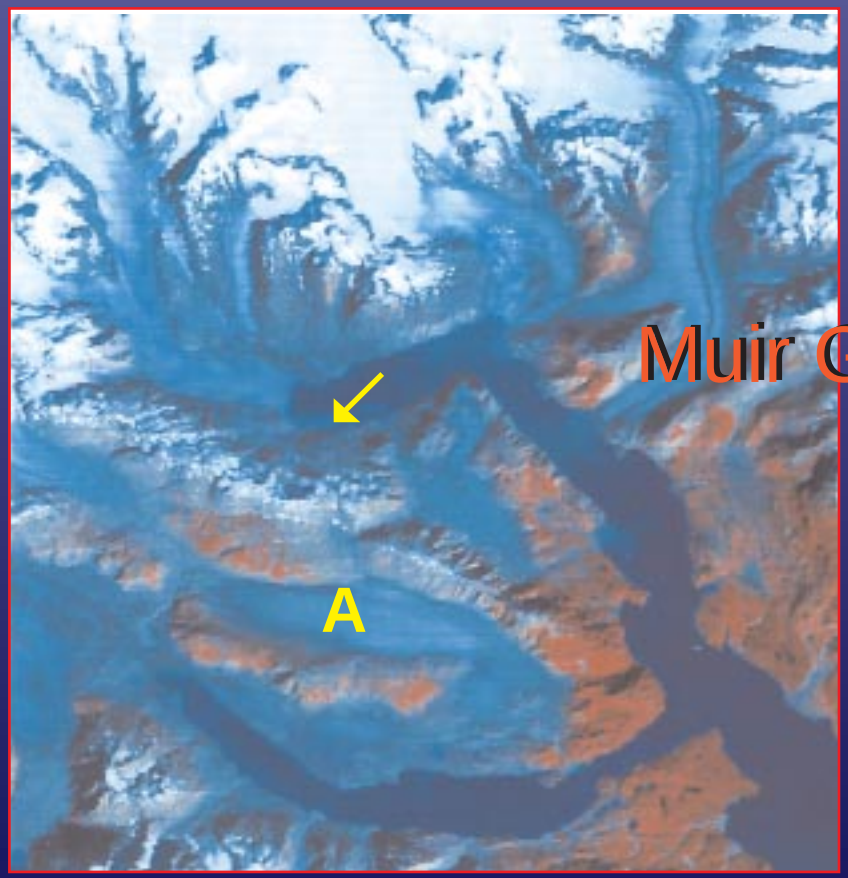
Global Ice & Sea Level Changes

EARTH OBSERVING SYSTEM

ALASKA

RETREAT OF THE MUIR GLACIER in southeastern Alaska from September 12, 1973, to September 6, 1986, during which the glacier retreated more than 7 km. By 1986, the Burroughs Glacier (A) had become a melting ice field. Vegetation is shown in red.

1973



1986

Muir Glacier

National Aeronautics and Space Administration

EOS

Global Ice & Sea Level Changes

EARTH OBSERVING SYSTEM

EOS MEASUREMENTS

NASA's Earth Observing System will use laser and radar altimeters, along with visible, near-infrared, and microwave sensors, to provide new data for better understanding of the role that polar ice plays in Earth's climate. The new data will include information on continental snow cover and polar sea ice as well as information on ice volume changes and their relevance to sea level rise.

GLAS will provide data on ice-sheet topography through laser altimetry.

AMSR will provide data on global distribution of ice and snow cover.

MODIS will provide information on global distribution of ice and snow cover.

EARTH OBSERVING SYSTEM

Ocean Processes

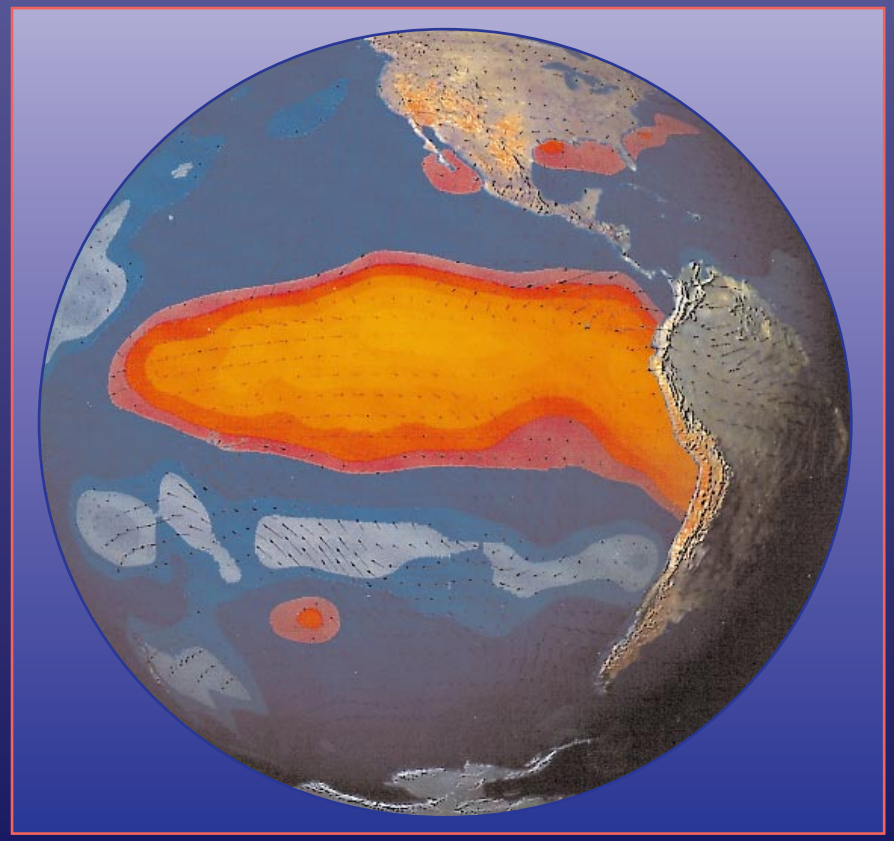
OCEAN TEMPERATURES IN THE NORTH ATLANTIC. Reds are warmest, blues and violet coolest. The large swirls are eddies in the Gulf Stream.

National Aeronautics and Space Administration

Ocean Processes

EARTH OBSERVING SYSTEM

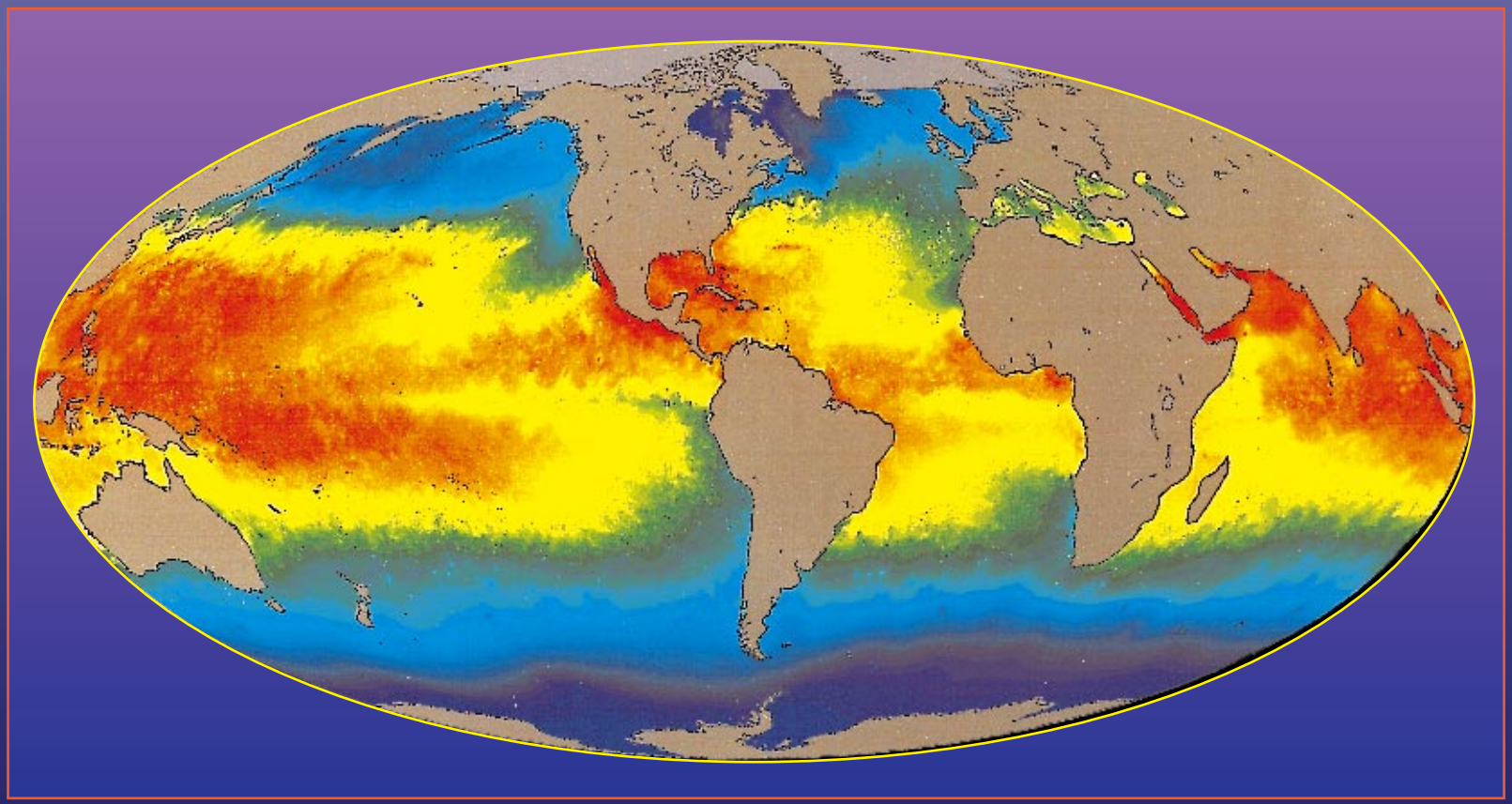
The study of oceanic processes is vital to climate change research because oceans cover 70 percent of the planet and contribute to global heat transport and global meteorological phenomena (such as El Niño).



1982 EL NIÑO. Sea surface temperature anomalies during the December 1982 El Niño. Temperature anomalies range from -4.0˚C to 4.0˚C as colors go from gray to blue, pink, and orange. Arrows depict the force of the winds driving the ocean surface waves and surface currents.

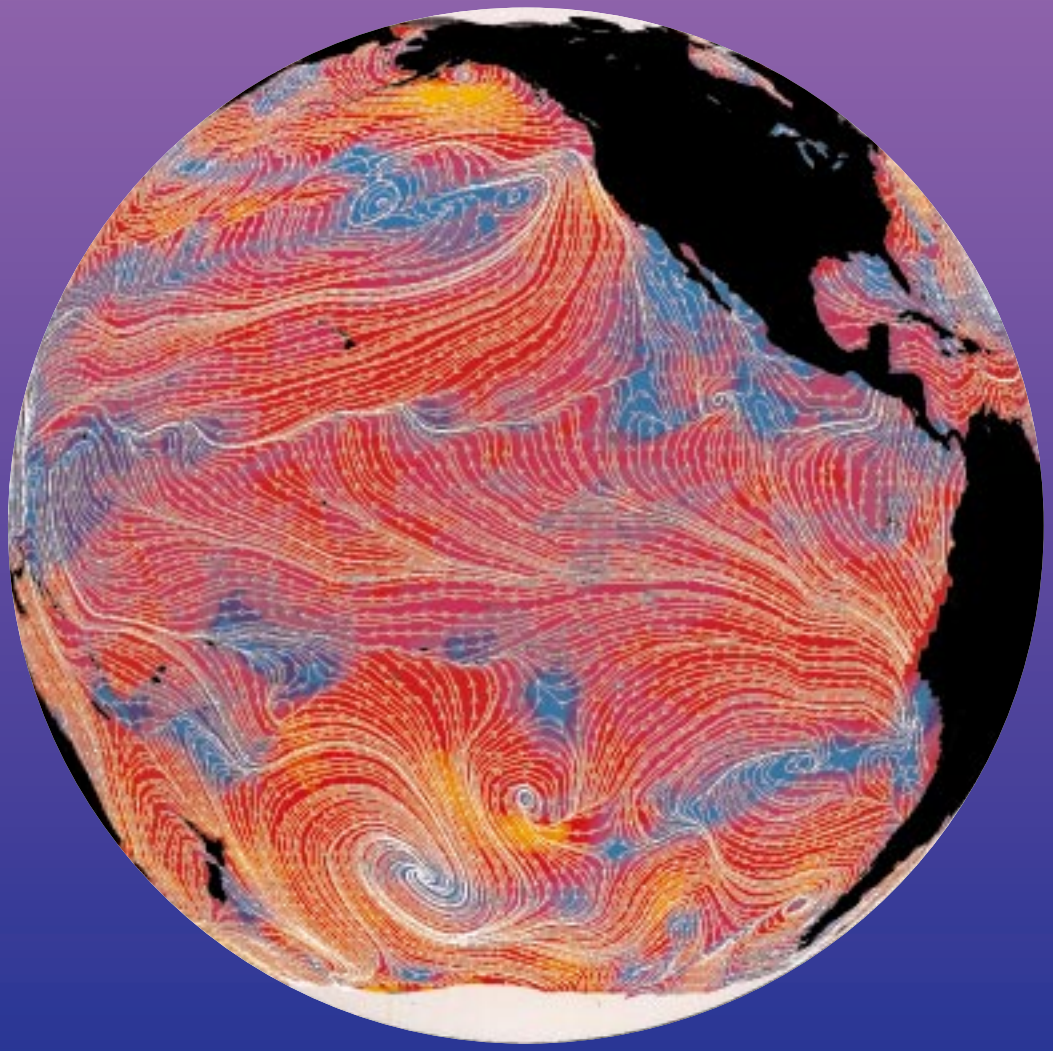
EARTH OBSERVING SYSTEM

TEMPERATURES



SEA SURFACE TEMPERATURES from satellite measurements. Warmest temperatures indicated by red tones, coolest by dark blue.

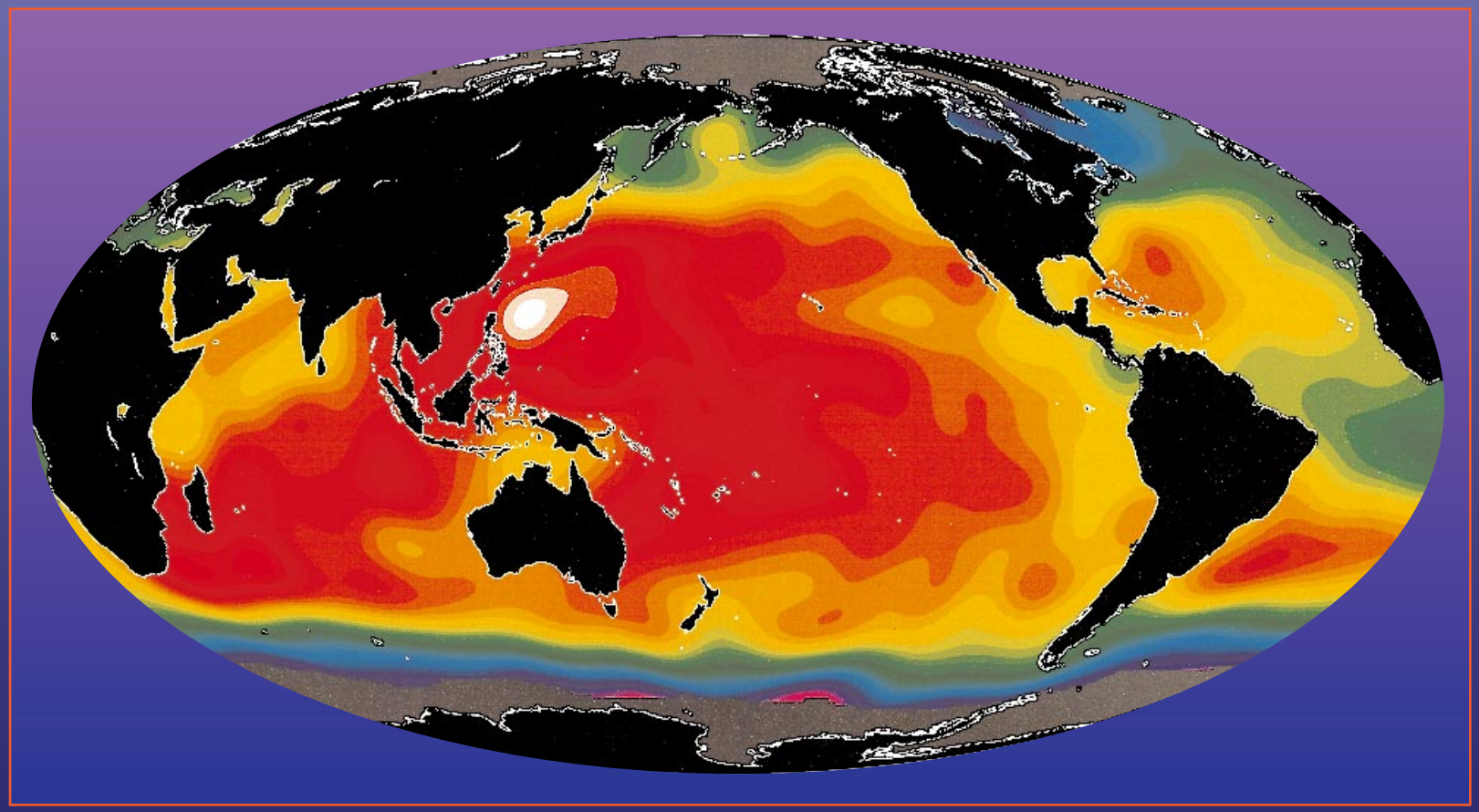
WINDS



WINDS OVER THE PACIFIC OCEAN. Wind speed increases as colors change from blue-purple to yellow-orange, with the strongest winds at 20 meters per second. Arrows show the directions of wind flow.

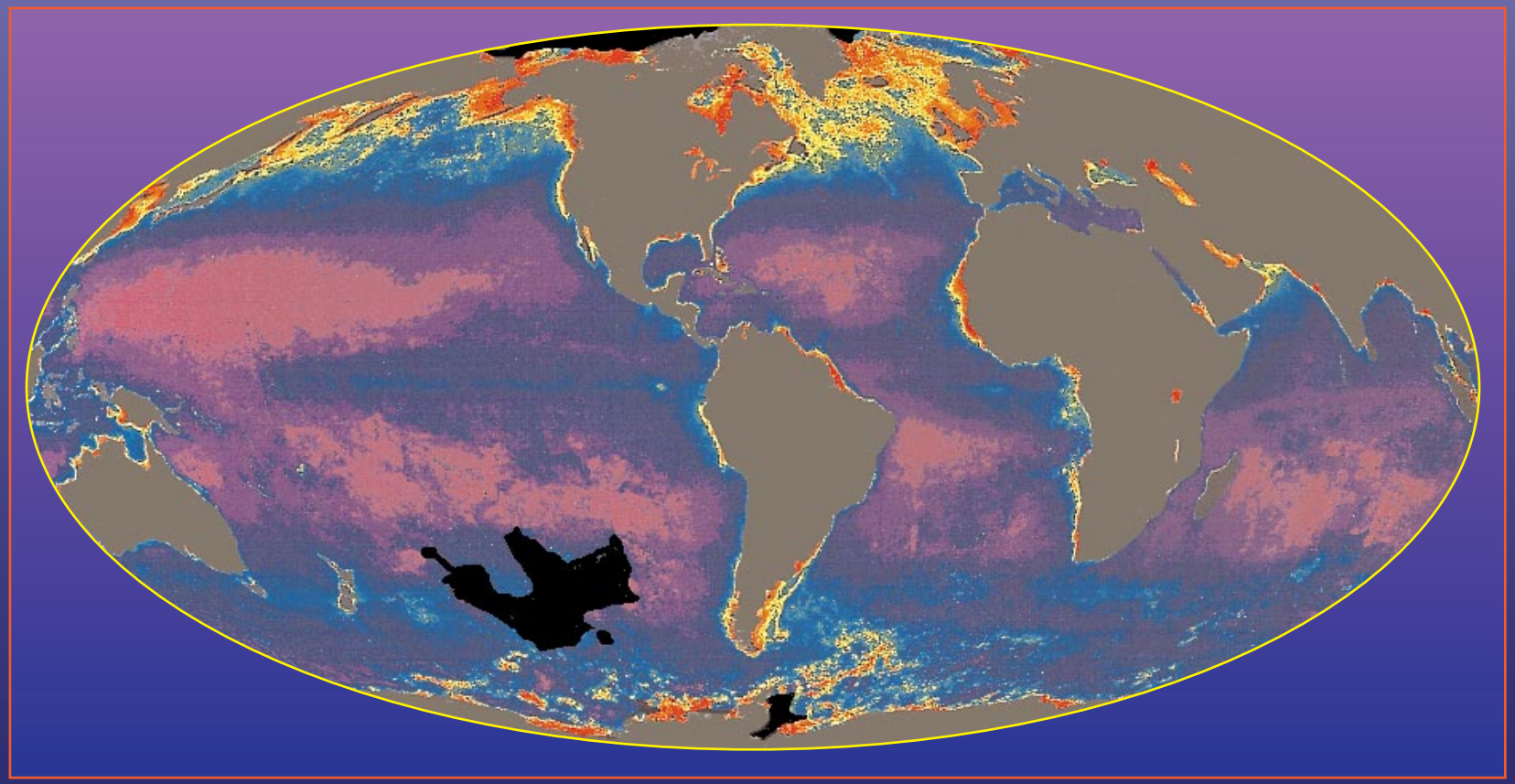
EARTH OBSERVING SYSTEM

TOPOGRAPHY



OCEAN SURFACE TOPOGRAPHY. The maximum sea level is located in the western Pacific Ocean (white) and the minimum is shown around Antarctica (blue and purple).

PHYTOPLANKTON



MEAN GLOBAL DISTRIBUTION OF PHYTOPLANKTON CONCENTRATION as determined from measurements obtained by the Coastal Zone Color Scanner. Important features in the global pattern of phytoplankton are the high concentration (red and yellow) at high latitudes in the Northern Hemisphere, the relatively low concentration in the Southern Hemisphere, and the very low concentration (purple and blue) in mid-latitudes.

EARTH OBSERVING SYSTEM

EOS MEASUREMENTS

NASA's Earth Observing System will use remote sensing observations to improve understanding of the role of oceans in the climate system.

MODIS will measure sea-surface temperatures, ocean color, chlorophyll concentration, and sea-ice cover and reflectance.

AMSR will provide data for studies of heat exchange across the air-sea surface. MIMR will provide the necessary measurements of sea surface temperature, wind, and atmospheric humidity in the ocean boundary layer.

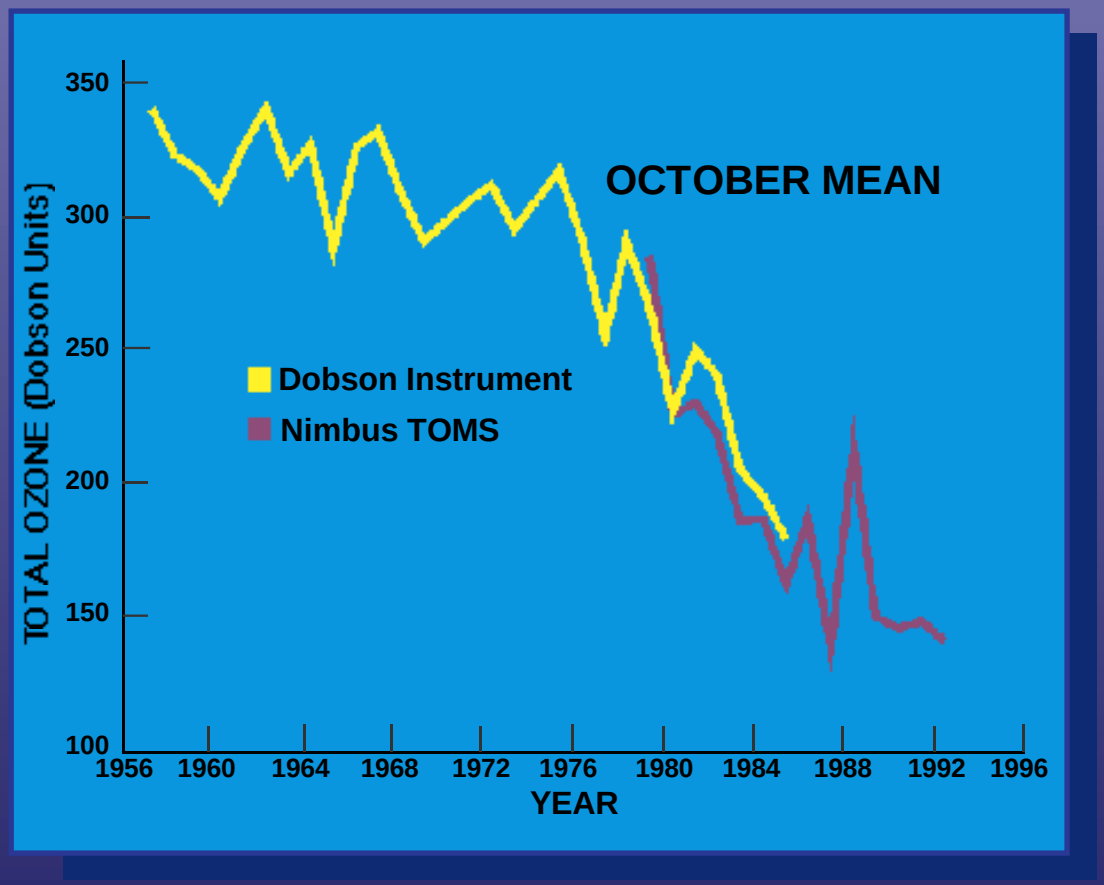
SeaWinds will measure near-surface vector winds over the ice-free global oceans.

JMR/Poseidon-2/DORIS maps the topography of the sea surface and polar ice sheets, measures ocean wave height and wind speed, and provides information on the ocean surface current velocity.

EARTH OBSERVING SYSTEM

EOS

Ozone Depletion



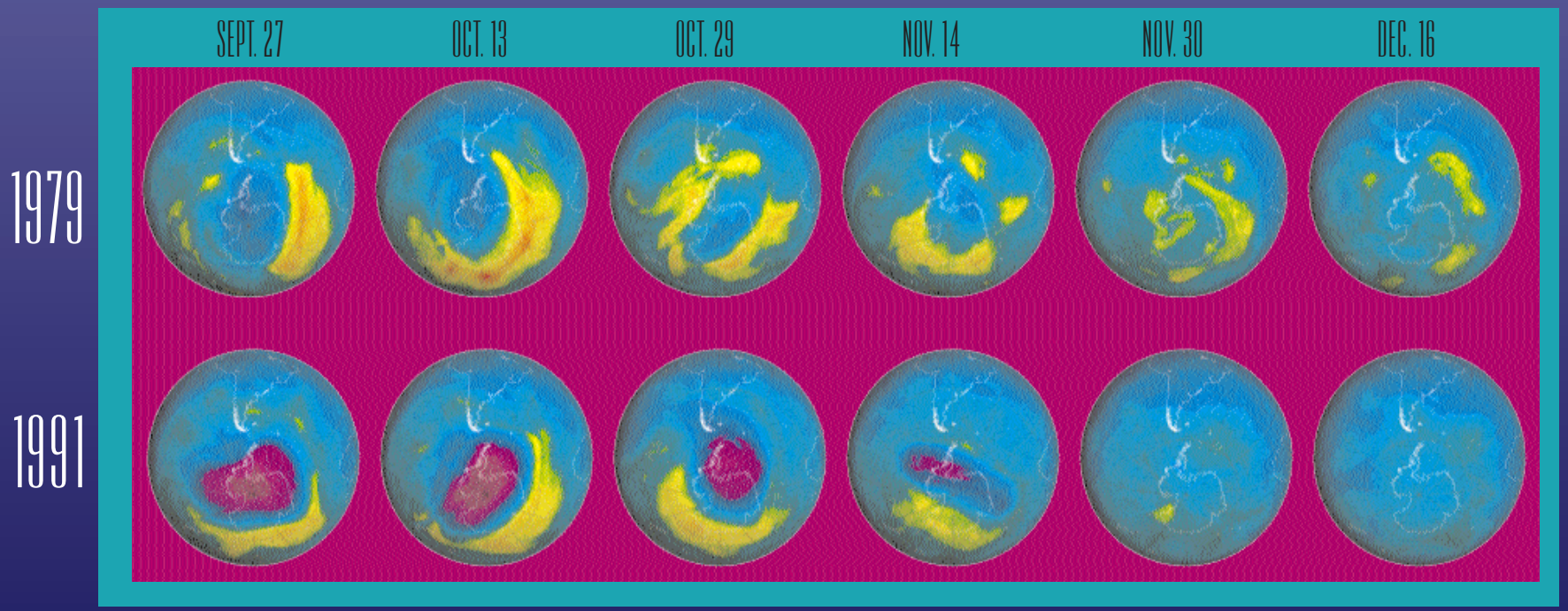
OZONE HOLE OVER ANTARCTICA. The development of the Antarctic ozone hole has been confirmed both by satellite (Total Ozone Mapping Spectrometer) and ground-based measurements (Dobson instrument).

National Aeronautics and Space Administration

Ozone Depletion

EARTH OBSERVING SYSTEM

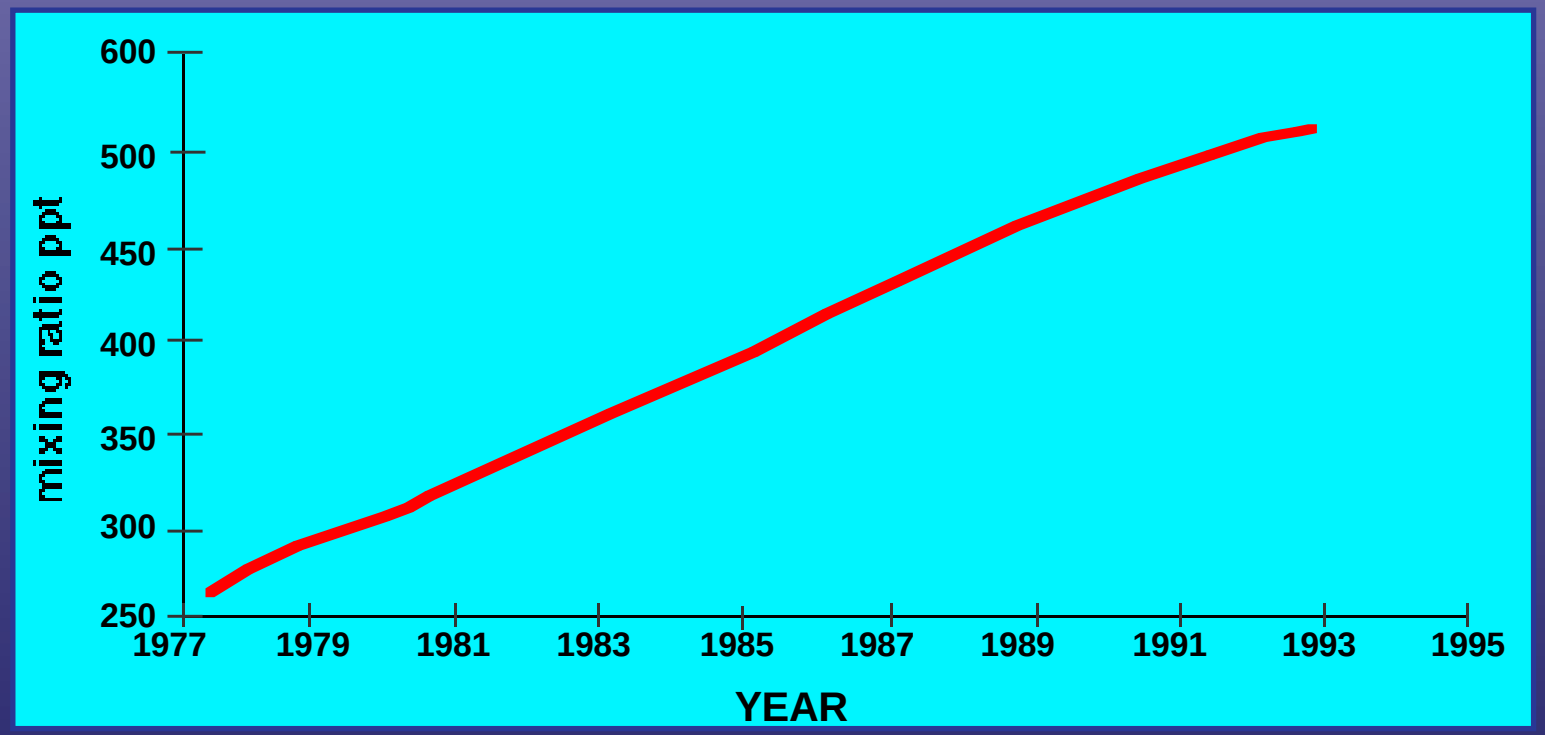
Natural and human activities impact the global environment, including the decrease in ozone in the stratosphere.



OZONE DEPLETION OVER ANTARCTICA. Total column ozone in Dobson units ranges from 100 (purple) through blue, green, and yellow to 500 (red).

EARTH OBSERVING SYSTEM

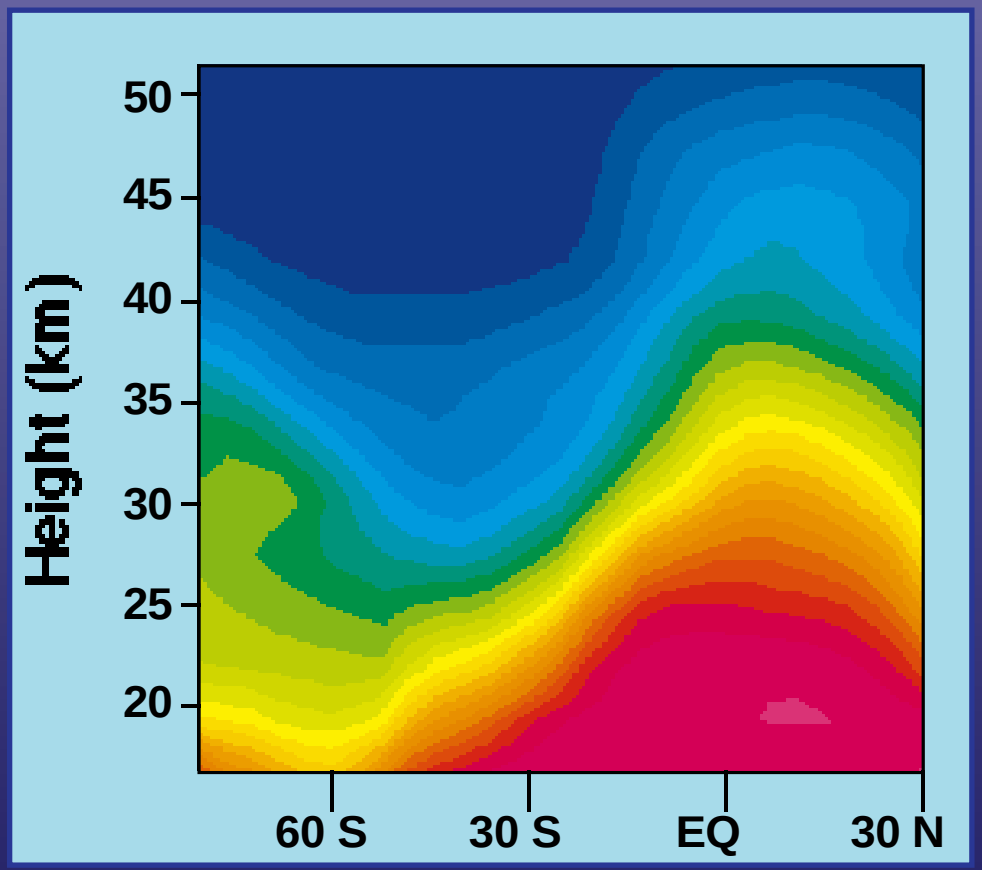
CHLOROFLUOROCARBONS (CFCs)



THE STEADY INCREASE OF CHLOROFLUOROCARBONS (CFCs) in the atmosphere from 1978 to 1984 (CFC 12 is shown).

EARTH OBSERVING SYSTEM

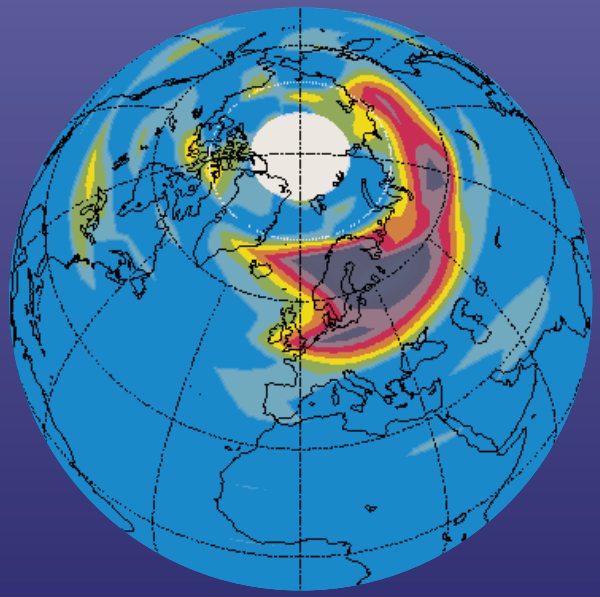
CHLOROFLUOROCARBONS (CFCs)



MEASUREMENT OF CFC 12 (August 27, 1992) in the mid-to-upper stratosphere. Scale ranges from 0 to 500 parts per trillion of CFC 12 as colors change from blue to pink.

EARTH OBSERVING SYSTEM

CHLORINE MONOXIDE (CLO)



Northern Hemisphere

ClO, the dominant ozone-destroying chlorine molecule, in the stratosphere on January 11, 1992. ClO increases as colors go from blue to green, yellow, red, and dark purple.

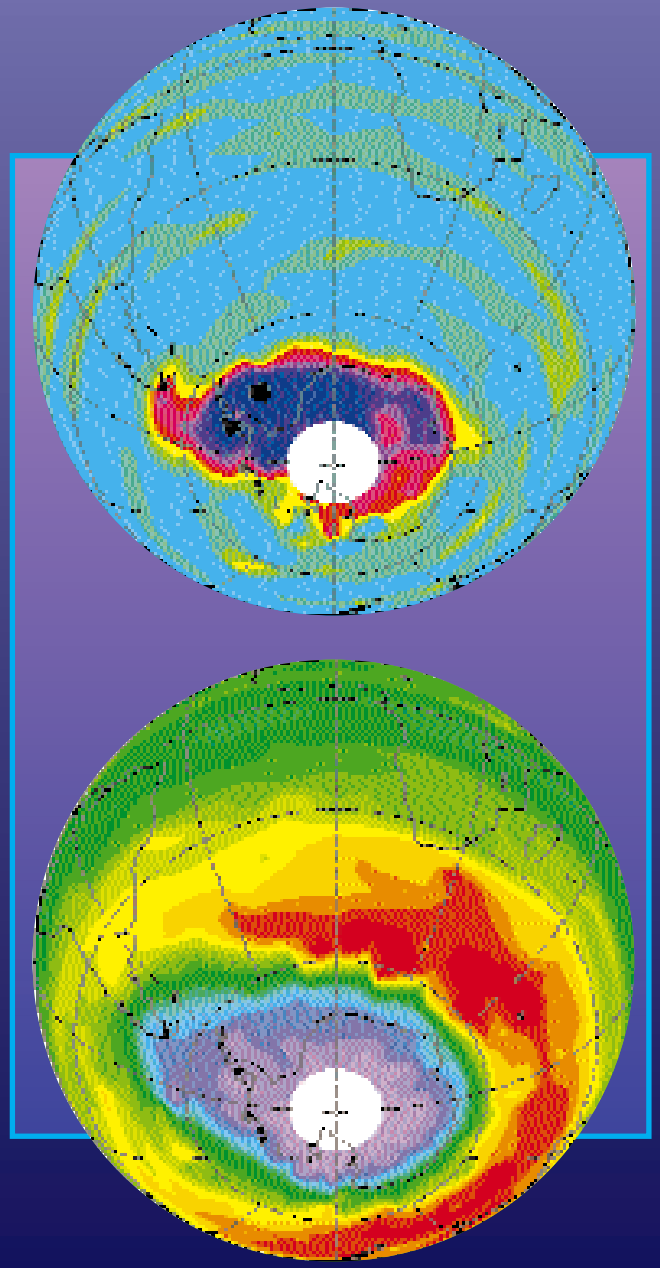
Ozone Depletion

EARTH OBSERVING SYSTEM

CHLORINE MONOXIDE (CLO)

Southern Hemisphere

ClO in the stratosphere on September 21, 1991 (top). Red and purple areas represent large amounts of ClO. Decreased amounts of ozone (bottom) are shown by green and purple areas.



National Aeronautics and Space Administration

EOS

EOS MEASUREMENTS

NASA's Earth Observing System will provide data needed needed to model current ozone levels as well as to predict future ozone levels.

HIRDLS measures the global distribution of ozone and many other trace species that affect ozone concentrations.

SAGE III measures the global distribution of atmospheric aerosols and stratospheric ozone.

MLS measures the global distribution of ozone-destroying chlorine monoxide.

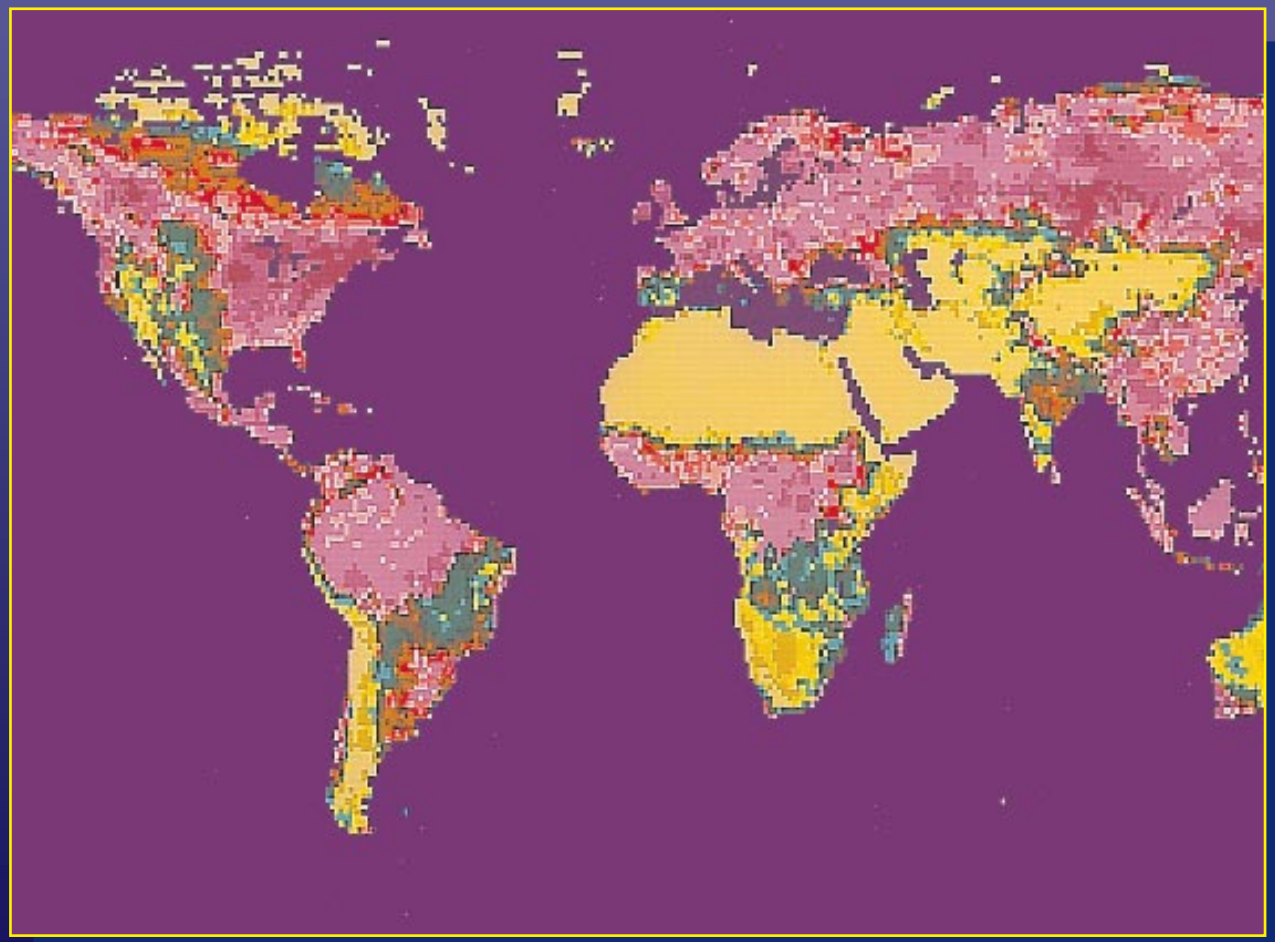
TOMS provides high-resolution global mapping of total ozone on a daily basis.

EARTH OBSERVING SYSTEM

Vegetation & Hydrology

EOS

VEGETATION TYPE. Seasonal variations in the NDVI as observed by NOAA AVHRR. Purple and green areas represent dense vegetation, tan areas represent sparse vegetation.

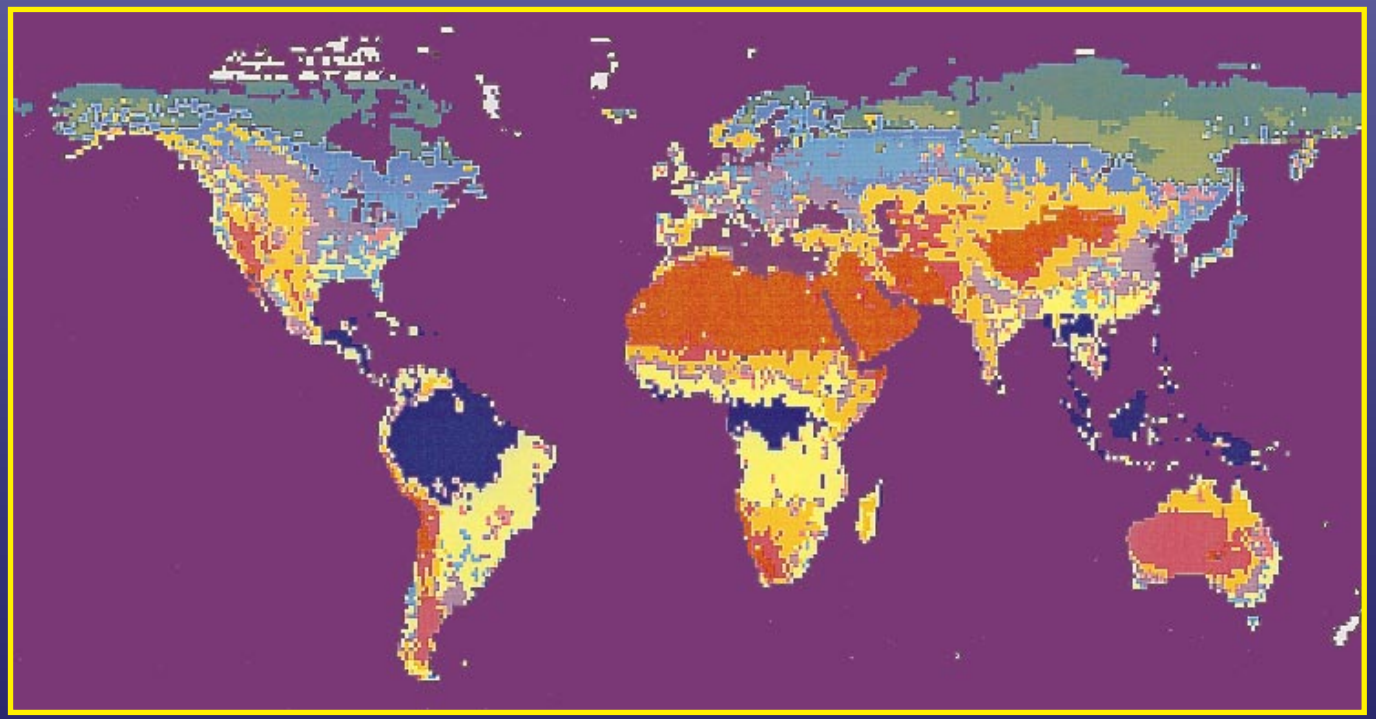


National Aeronautics and Space Administration

Vegetation

EARTH OBSERVING SYSTEM

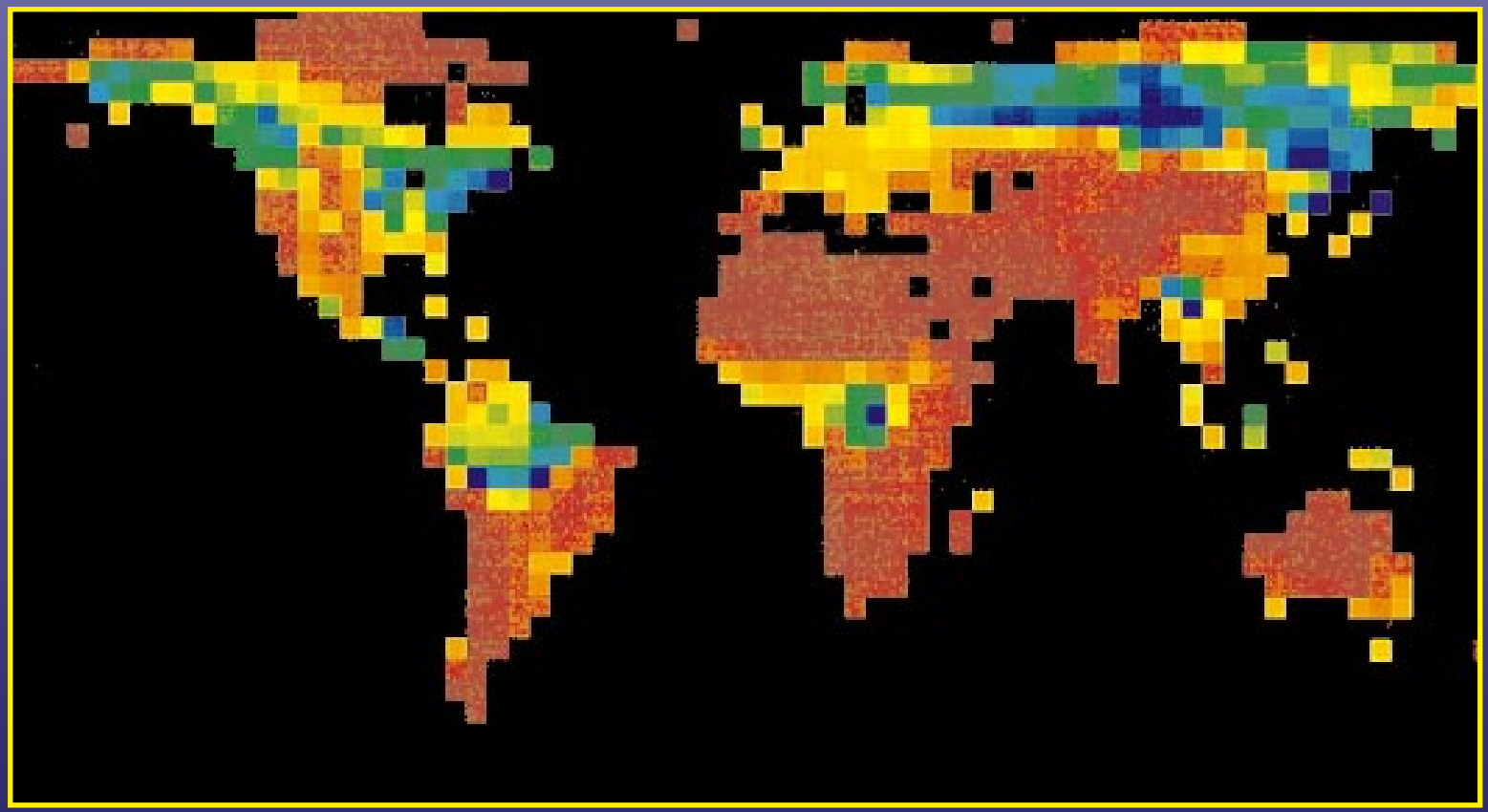
Processes on the land directly affect Earth's energy and water cycles, and influence the balance of atmospheric greenhouse gases.



GLOBAL BIOPHYSICS. NOAA Advanced Very High Resolution Radiometer (AVHRR) data processed into normalized difference vegetation index (NDVI) for August 1987. Dark-blue and green areas represent dense vegetation, pink and dark-red areas represent sparse vegetation.

Vegetation

EARTH OBSERVING SYSTEM



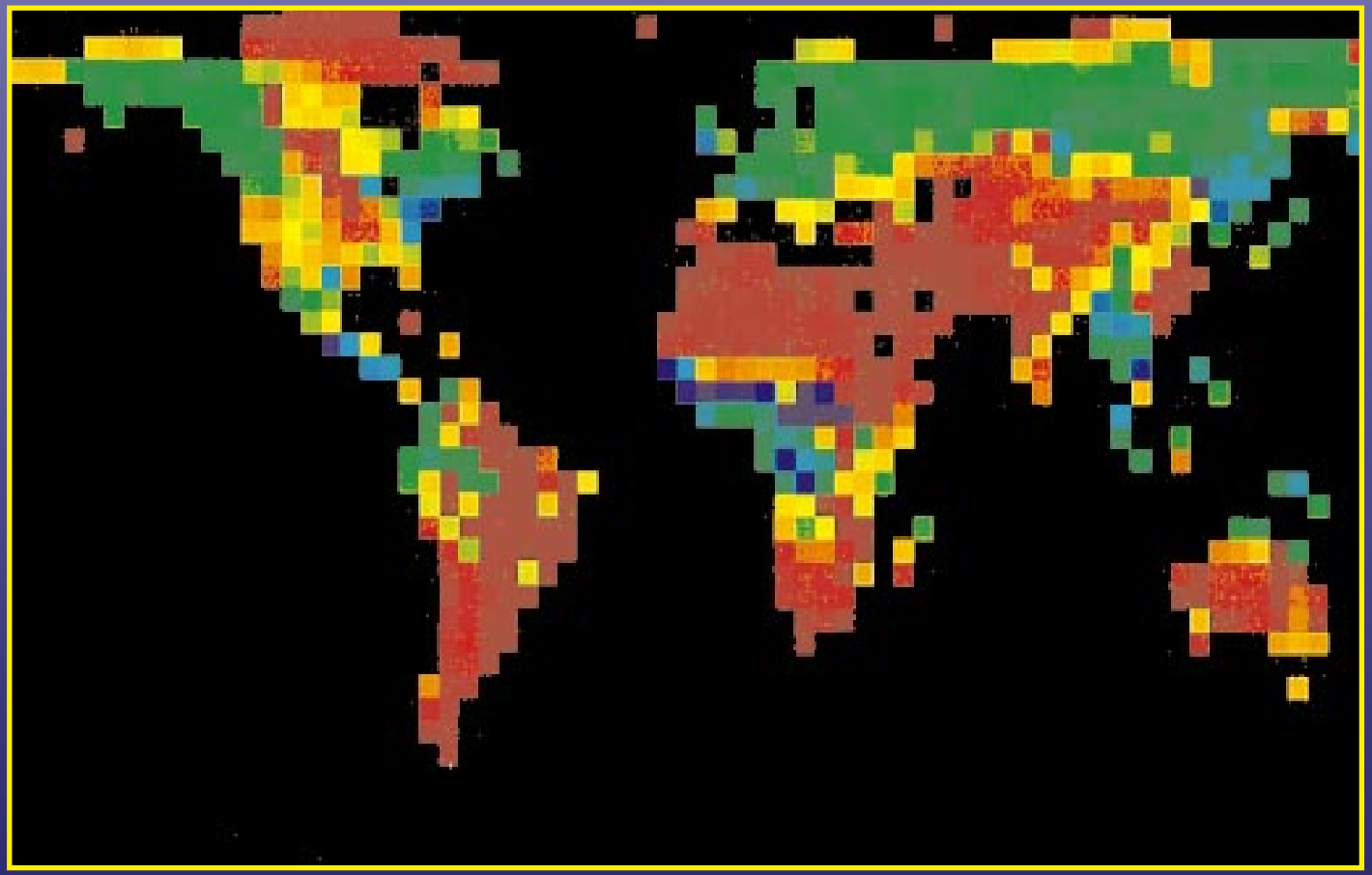
LEAF AREA INDEX. The NDVI data are used to calculate global monthly fields of green leaf area index (square meters of green leaves per square meter of surface). Green represents dense vegetation, while brown indicates desert.

National Aeronautics and Space Administration

EOS

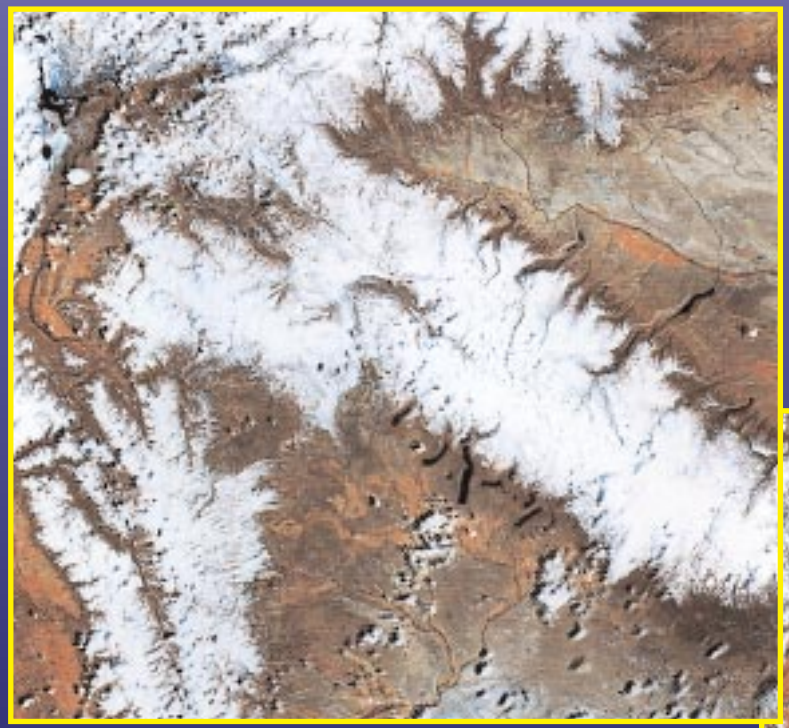
Vegetation

EARTH OBSERVING SYSTEM



GLOBAL TERRESTRIAL PHOTOSYNTHESIS. The leaf area index fields are used within a global biosphere-atmosphere model to calculate global fields of photosynthesis. The satellite data have been used to determine where the green vegetation is, while the climate component of the biosphere-atmosphere model is used to calculate the vegetation's level of photosynthetic activity.

SNOW COVER



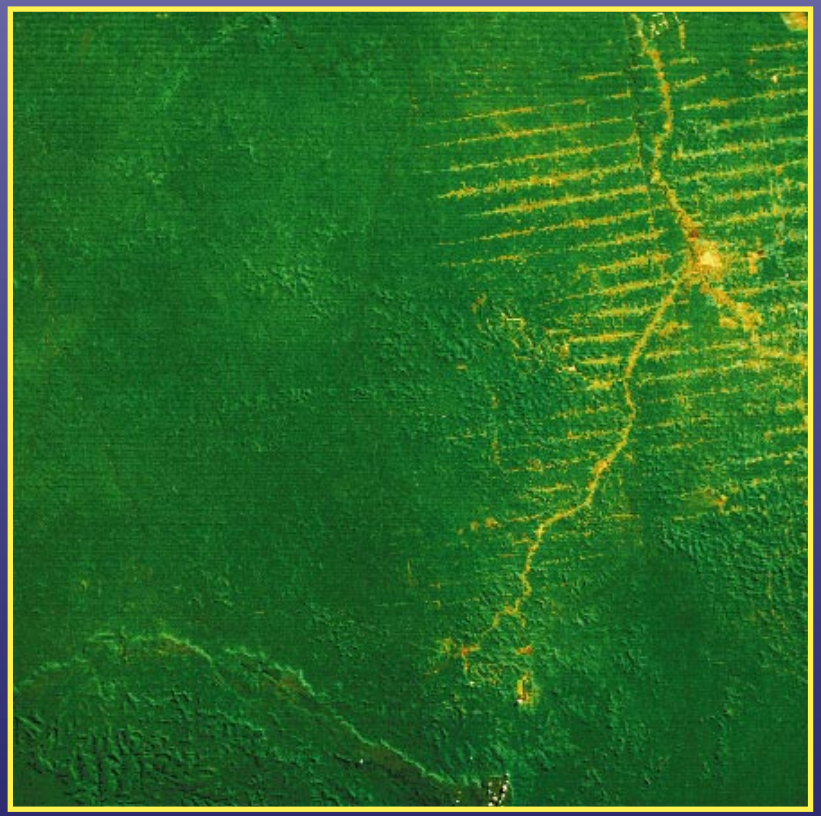
SNOW COVER IN WEST CENTRAL WYOMING, May 16 (top) and June 21 (bottom), 1993. The total snow cover area has been reduced from 90 percent to 55 percent in a month. The bluish cast to portions of the snowpack indicates melting snow or snow that has melted and refrozen.

FLOODING

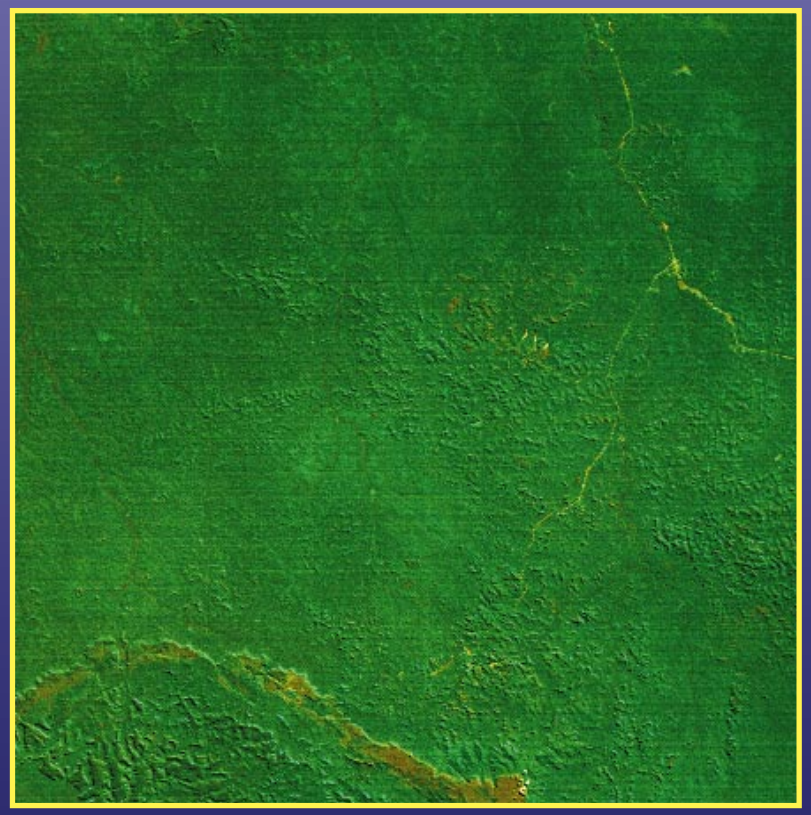
FLOOD WATERS of the Illinois, Mississippi, and Missouri Rivers near St. Louis, Missouri on July 29, 1993.

DEFORESTATION

1986



1975



DEFORESTATION IN THE BRAZILIAN RAIN FOREST. Satellite imagery offers a consistent, continuous approach for monitoring the rate of deforestation over wide areas.

DEFORESTATION

BURNING OF TROPICAL RAIN FORESTS (inset). To facilitate agriculture, forests are cut and allowed to dry before being burned to remove the woody material and herbaceous cover. This process is repeated until the land can support only cattle pasture or will be altogether abandoned to low-productivity secondary growth.

EOS MEASUREMENTS

NASA's Earth Observing System will provide data on land use and vegetation patterns, geological and mineralogical formations, snow cover, soil moisture, precipitation, and radiation budgets. With these data, the key radiative, atmospheric, and hydrologic processes can be understood in a global context.

MODIS will provide measurements of vegetation/land surface cover conditions and productivity. It will also provide measurements of snow cover, soil moisture, cloud properties and their distribution, and total precipitable water.

ASTER will provide high-resolution measurements of Earth's surface and of clouds; also stereo mapping of local topography.

AMSR will provide measurements of precipitation, atmospheric moisture, soil moisture, ice and snow cover, and sea-surface temperature.

LIS will provide lightning incidence measurements for use in studying convective storms and the distribution of precipitation, globally.

EARTH OBSERVING SYSTEM

Philippine Institute of Volcanology and Seismology

ERUPTION OF MT. PINATUBO on June 12, 1991.

EOS

Impact of Volcanoes

National Aeronautics and Space Administration

Impact of Volcanoes

EARTH OBSERVING SYSTEM

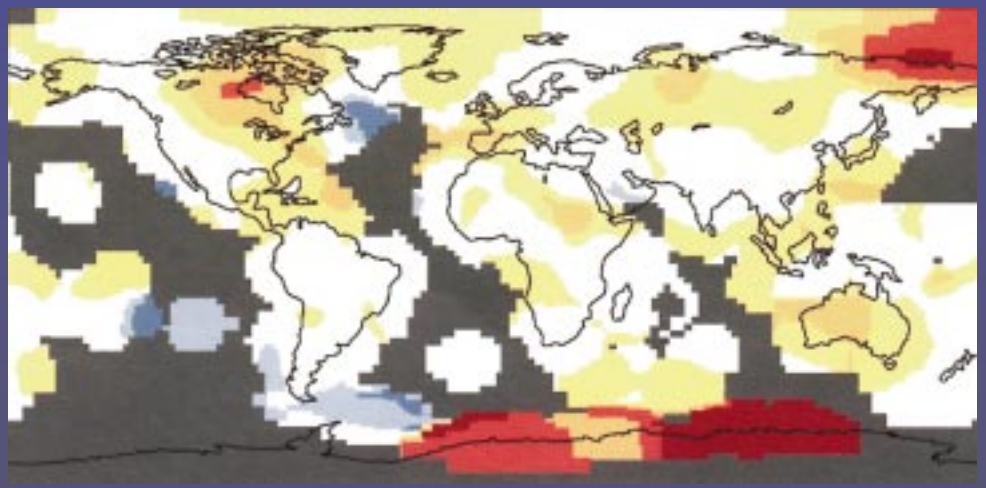
Volcanoes can place so much sulfur dioxide into the stratosphere that global climate is affected. Cooling from eruptions such as Mt. Pinatubo (1991) temporarily slows the pace of greenhouse warming.

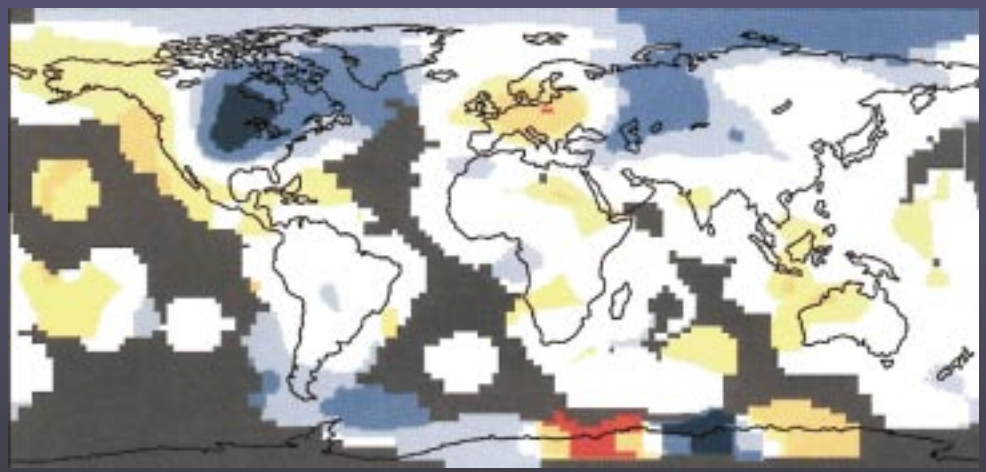
MT. PINATUBO STRATOSPHERIC AEROSOL LAYER as seen from Space Shuttle STS–43 (August 1991).

Impact of Volcanoes

EARTH OBSERVING SYSTEM

WORLD WIDE TEMPERATURES



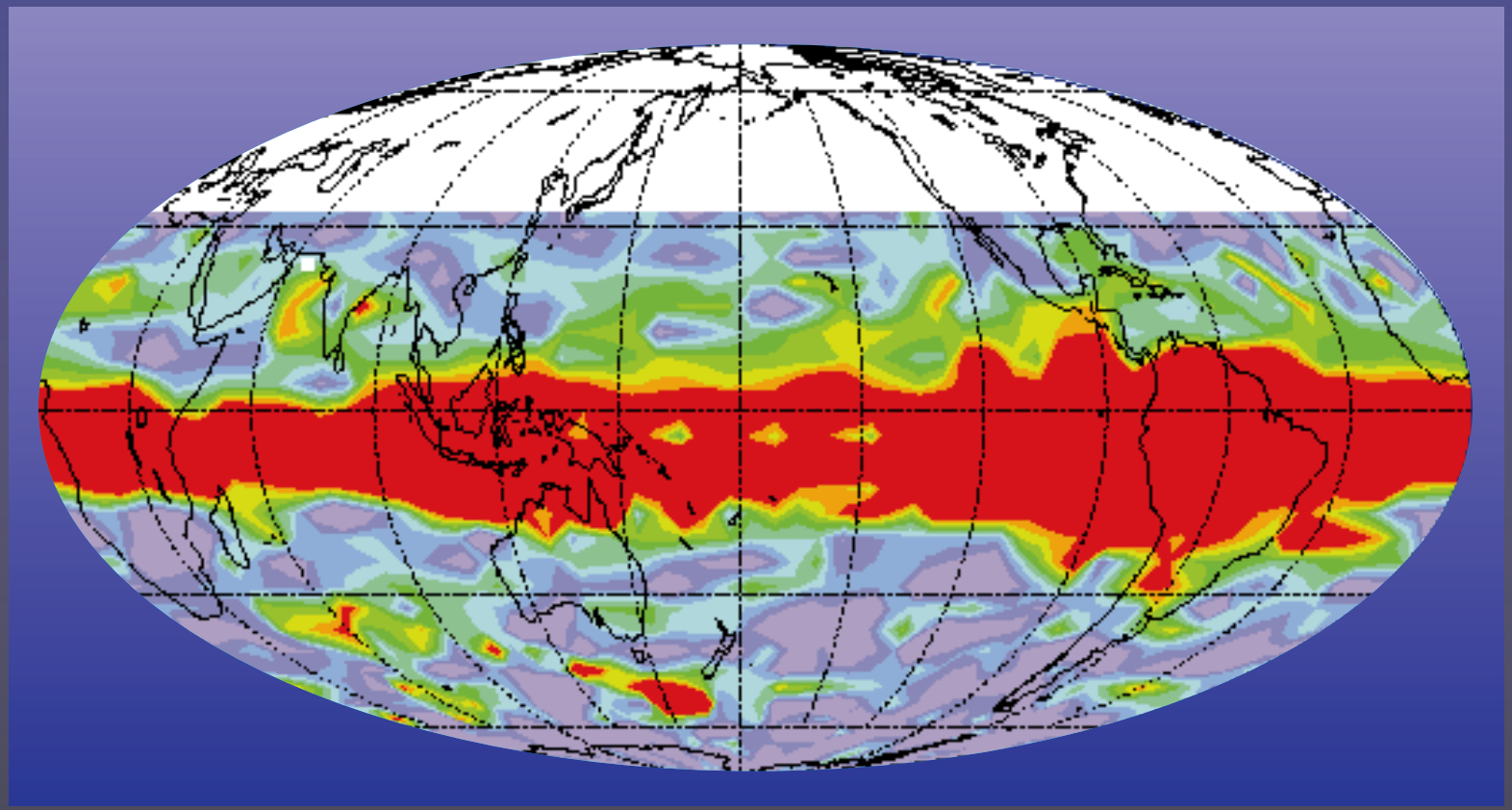


GLOBAL COOLING. Aerosols from Mt. Pinatubo's eruption in 1991 are believed to have caused a 0.5°C drop in average global temperatures by the following summer. In the upper image widespread yellows indicate a slight warming as compared to a 30-year baseline. One year later, as shown in the lower image, when the aerosols had spread around the world, the summertime temperatures showed marked cooling, evidenced, particularly, by the blue areas of 1° to 2° or more, temperature drops.

Impact of Volcanoes

EARTH OBSERVING SYSTEM

SULFUR DIOXIDE GAS

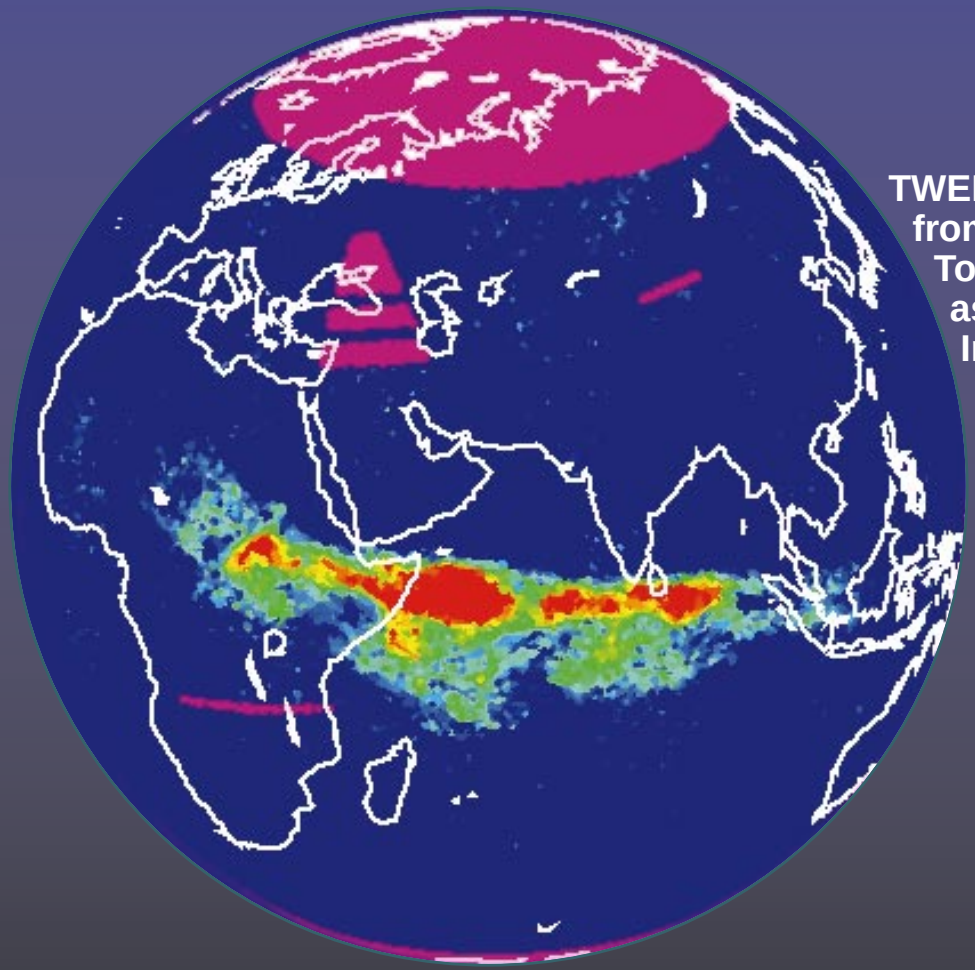


ATMOSPHERIC SULFUR DIOXIDE (September 21, 1991). The colors ranging from light green to bold orange indicate the increase in sulfur dioxide that followed the eruption of Mt. Pinatubo.

Impact of Volcanoes

EARTH OBSERVING SYSTEM

SULFUR DIOXIDE GAS

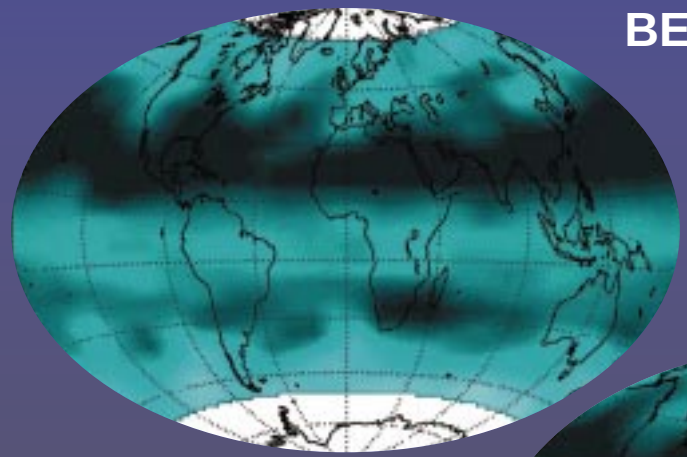


TWENTY MILLION TONS OF SULFUR DIOXIDE from Mt. Pinatubo were measured with the Total Ozone Mapping Spectrometer (TOMS) as the cloud drifted westward across the Indian Ocean on June 23, 1991.

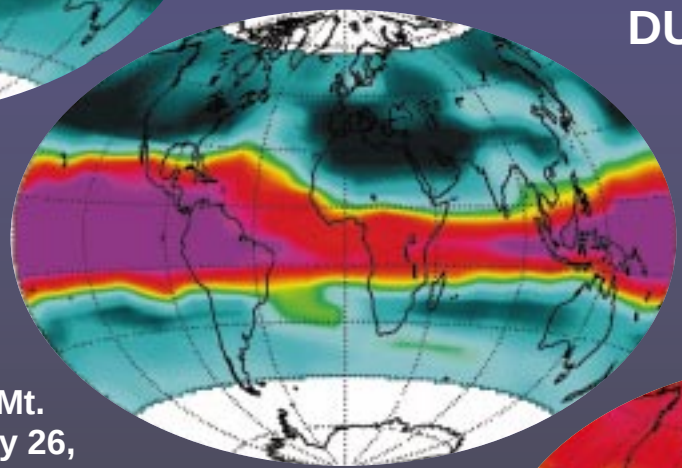
Impact of Volcanoes

EARTH OBSERVING SYSTEM

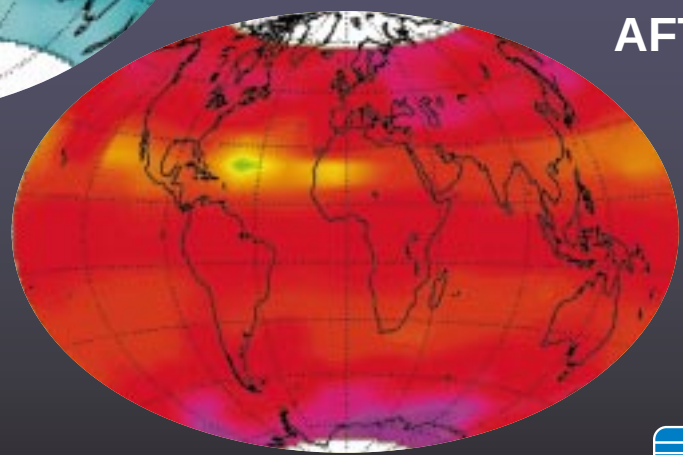
SULFURIC ACID PARTICLES



BEFORE



DURING



AFTER

SULFURIC ACID AEROSOL PARTICLES produced from sulfur dioxide emissions from Mt. Pinatubo (June 14 to July 26, 1991; middle). Also shown are 1 month before the eruption (top) and1 year and 8 months after the eruption (bottom). Very thin pre-eruption levels are shown in blue; very thick levels in red.

Impact of Volcanoes

EARTH OBSERVING SYSTEM

EOS MEASUREMENTS

NASA's Earth Observing System will provide data needed to develop models of volcanic effects so scientists can identify and quantify their impacts on climate.

SAGE III will characterize tropospheric and stratospheric aerosols including those from volcanoes and also quantify their possible effects on ozone.

MLS will provide direct measurements of sulfer dioxide and other gases appearing in volcanic plumes which may affect both climate and ozone.

TOMS will detect and map sulfur dioxide clouds resulting from major volcanic eruptions.

EOSP measurements will be used to retrieve global aerosol distribution and optical thickness in the troposphere and stratosphere, including sulfuric acid aerosols from volcanic emissions.

MISR will monitor trends in radiatively important optical properties of natural and anthropogenic aerosols, including those arising from industrial and volcanic emissions.

MODIS will provide the high-resolution and timely data needed to observe and track plumes from volcanoes at times close to their eruption times and thereafter.