NASA Facts

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Measurement of Air Pollution from Satellites

MAPS - understanding the chemistry of the atmosphere

What is MAPS?

The MAPS instrument measures the distribution of carbon monoxide in the Earth's lower atmosphere (3 to 10 kilometers above the surface), from latitude 57 degrees North to latitude 57 degrees South.

The MAPS measurements provide scientists with the only near-global database of atmospheric carbon monoxide levels. These unique measurements help scientists understand how well the atmosphere can cleanse itself of pollutants such as carbon monoxide. In addition, the MAPS measurements help scientists better understand both how far pollutants are transported from their source areas and the size of the sources.

What is Carbon Monoxide?

Carbon monoxide (CO) is a colorless and odorless gas produced by the burning of fossil fuels, such as gasoline, and by the burning of forests and grasslands.

World-wide increases in human technological and agricultural activity are causing increasing amounts of carbon monoxide to be released into the air. Once in the atmosphere, carbon monoxide can be transported over long distances, eventually converting to carbon dioxide by reaction with a chemical called the hydroxyl radical (chemical symbol: OH). The OH radical is a key participant in the destruction and removal of greenhouse gases such as methane. Methane itself is important in the chemical cycle of stratospheric ozone.

As the amount of carbon monoxide in the atmosphere increases, its reactions with the OH radical may increase accordingly. This may leave less OH available to break down and remove greenhouse gases. Therefore, increases in carbon monoxide levels may cause subsequent decreases in OH levels, which can have long-term consequences on stratospheric ozone and the levels of various greenhouse gases, potentially influencing the Earth's climate. At present, the size of the various global carbon monoxide sources and their seasonal cycles are not well known.

Previous MAPS missions

The MAPS instrument has flown aboard the Space Shuttle four times: in November 1981 (STS-2), as the first science payload on the Space Shuttle, in October 1984 (STS-41G), and in April 1994 (STS-59) and October 1994 (STS-68).

The November 1981 mission provided surprising results in that the greatest concentrations of carbon monoxide in the lower atmosphere were found over the Earth's tropical regions rather than over the industrialized Northern Hemisphere, as had been expected. The 1981 mission also showed that carbon monoxide concentrations vary greatly from region to region. The October 1984 mission (Fig.1) confirmed the November 1981 finding that the burning of forests in South America and grasslands in Africa are significant sources of global tropospheric carbon monoxide during the Southern Hemisphere dry season.

Results from the April 1994 (STS-59) MAPS mission (Fig. 2) show low carbon monoxide mixing ratios in the Southern Hemisphere (very clean air), with a gradual increase in carbon monoxide levels in the Northern Hemisphere. In October 1994 (STS-68), the data (Fig. 3) revealed that the latitudinal gradient was reversed from the situation observed in April. The highest levels of carbon monoxide were measured over central Brazil, southern Africa, and over Indonesia where extensive fires and smoke plumes were reported by the astronaut crew.

Correlative measurements

The space-based data from the MAPS instrument were correlated with a global network of intercalibrated ground- and aircraft-based measurements. To ensure the accuracy of the ground and aircraft measurements, every instrument was calibrated using the same four gas cylinders. This ensured that all the instruments had the same calibration standard (that they were "intercalibrated") and allowed for the intercomparison of carbon monoxide data measured by dozens of different instruments around the world.

The more than two dozen ground sites during the April and October 1994 missions included locations in the United States, South Africa, Russia, Germany, Bermuda, Ireland, Hong Kong, Australia and New Zealand. The aircraft underflights of the 1994 MAPS missions included the NASA DC-8, and aircraft from INPE, Brazil; CSIRO, Australia; the University of Maryland; and NOAA, Boulder.

The MAPS instrument

The MAPS shuttle flight hardware consists of an optical box, an electronics box, a tape recorder, and an infrared camera, all mounted to a single baseplate. This assembly is mounted to a Multi-Purpose Experiment Support Structure near the forward end of the cargo bay. The instrument is about 36 inches long, 30 inches wide, and 23 inches high. It weighs 203 pounds and consumes about 65 watts of electrical power.

The MAPS instrument is based on a technique called gas filter radiometry. The MAPS instrument determines the COmixing ratio in the atmosphere by comparing the measured thermal energy from the atmosphere to the thermal energy of a known quantity of CO carried aboard the instrument. Heat, or thermal energy, is emitted by the Earth's surface and passes upward through the atmosphere. As the thermal energy passes through the atmosphere, it is absorbed by atmospheric carbon monoxide and retransmitted at a thermal energy frequency unique to CO. The MAPS instrument is designed to be sensitive to the thermal energy at this unique CO frequency. This unique frequency can be thought of as an atmospheric CO "fingerprint."

The thermal energy from the atmosphere enters the MAPS instrument and is split into three beams. One beam is passed through a gas cell containing CO and then falls upon an electronic detector which measures the amount of thermal energy in the filtered beam. The second beam falls directly onto a second electronic detector without passing through any gas filter. The difference in the amount of voltage between the first and second detectors is used to determine the amount of CO present in the atmosphere.

The third beam of thermal energy passes through a gas cell containing nitrous oxide then falls upon a third detector. This third beam is used to determine the amount of nitrous oxide in the lower atmosphere. Because the amount of nitrous oxide in the lower atmosphere is relatively constant worldwide, any changes in the levels of nitrous oxide measured by the MAPS instrument indicates that some portion of the atmosphere may have clouds present (the MAPS instrumentcannot measure CO through clouds).

The MAPS data

The MAPS measurements were recorded on a tape recorder aboard the instrument, and were also transmitted to the ground in real-time through the Space Shuttle telemetry system. The real-time data transmissions were processed at the Payload Operations Control Center at the Johnson Space Center to produce "quick look" maps of the measured carbon monoxide distribution. Real-time data analysis by the MAPS operations team and observations by the astronaut crew helped scientists on the ground evaluate the MAPS data and determine those regions where more detailed measurements should be made by the MAPS instrument.

The infrared camera attached to the MAPS instrument photographed sunlit portions of the Earth when the MAPS instrument was operating. Real-time observations by the astronaut crew, and the examination of photographs taken by the astronaut crew and the MAPS camera, played a crucial role in understanding the MAPS measurements. Following the flight, the data recorded on board the instrument and the data transmitted to the ground in real-time were merged, then processed using more sophisticated techniques than used for the preliminary ("quick look") MAPS data.

Internet access to MAPS information via a WWW browser

Information on the MAPS missions is available via the Internet. The information is available via DOS, Macintosh and UNIX platforms.

MAPS information can be accessed through the World Wide Web at URL:

http://stormy.larc.nasa.gov/press.html

The Future of MAPS

MAPS is scheduled to fly aboard the Russian Mir space station in 1997. From the vantage point of Mir, MAPS will gather CO data to examine the seasonal changes in the global distribution of this important tropospheric trace gas.

October 1984 Global Carbon Monoxide Values

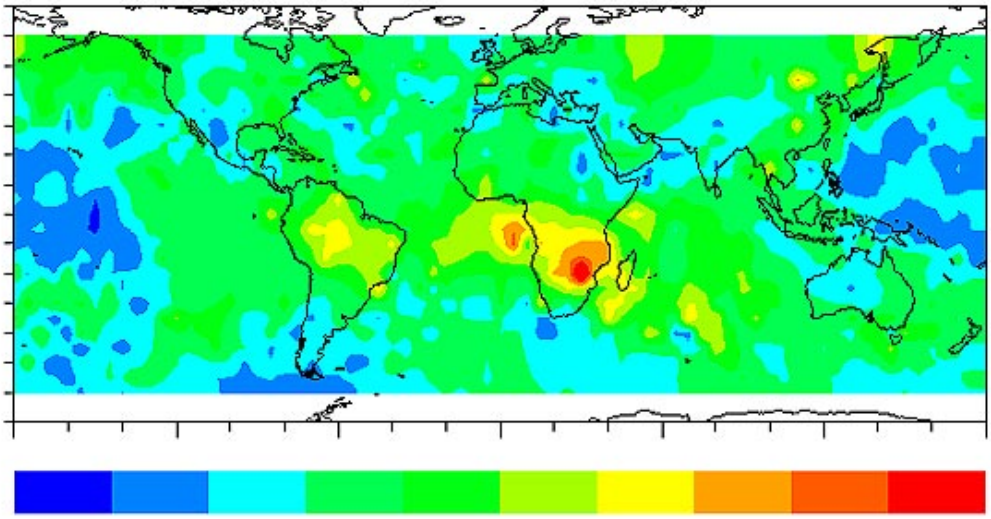

Figure 1

Large concentrations of atmospheric carbon monoxide, caused by biomass burning in South America and southern Africa, can be seen in measurements made by the Measurement of Air Pollution from Satellites (MAPS) instrument. These October 1984 measurements, made from the Space Shuttle Challenger (STS-41G), were the first to show that biomass burning is a very large source of air pollution in the lower atmosphere (3 to 10 kilometers above the surface of the Earth) of the Southern Hemisphere. Carbon monoxide, a colorless and odorless gas, is created by the burning of fossil fuels such gasoline and by the burning of forests and grasslands.

These measurements have been analyzed to show the average carbon monoxide measured over that region from October 5-13, 1984. The shades of blue represent low mixing ratios of carbon monoxide or relatively "clean" air; while the shades of red represent high carbon monoxide mixing ratios or relatively “polluted” or “dirty” air.

April 1994 Global Carbon Monoxide Values

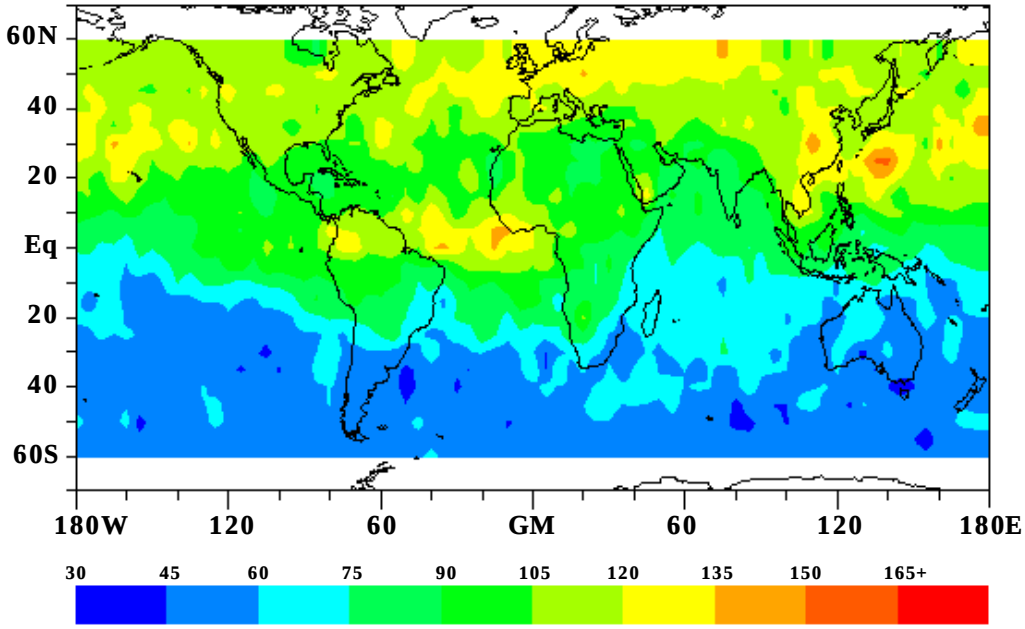

Figure 2

Relatively high concentrations of carbon monoxide over the Northern Hemisphere can be seen in measurements made by the Measurement of Air Pollution from Satellites (MAPS) instrument. These April 1994 measurements, made from the Space Shuttle Endeavour (STS-59), show large sources of air pollution in the lower atmosphere (3 to 10 kilometers above the surface of the Earth) over the industrialized Northern Hemisphere. Carbon monoxide, a colorless and odorless gas, is created by the burning of fossil fuels such as gasoline and by the burning of forests and grasslands. These measurements were made from April 9-19, 1994.

October 1994 Global Carbon Monoxide Values

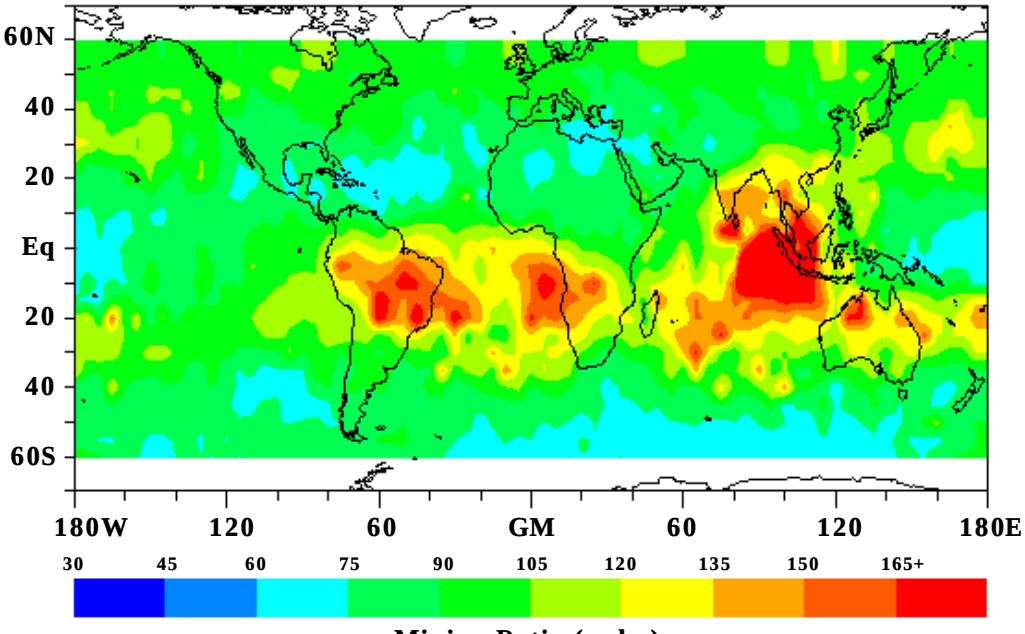

Figure 3

High concentrations of carbon monoxide over the Tropics and Southern Hemisphere can be seen in measurements made by the Measurement of Air Pollution from Satellites (MAPS) instrument. These October 1994 measurements, made from the Space Shuttle Endeavour (STS-68), show large sources of air pollution in the lower atmosphere (3 to 10 kilometers above the surface of the Earth) over the grasslands and savannas in central South America, southern Africa, and over the Indonesian Islands. Carbon monoxide, a colorless and odorless gas, is created by the burning of fossil fuels such as gasoline and by the burning of forests and grasslands. These measurements were made from September 30 - October 11, 1994.