Canadian Space Agency   Agence spatiale canadienne

MOPITT

Measurements Of Pollution In The Troposphere

National Aeronautics and Space Administration

NASA's Earth Observing System

Life on earth depends on the atmosphere. It provides oxygen for respiration, transports gases around the globe and protects life from harmful ultraviolet radiation. With a human population of over 6 billion, the quality of this life-sustaining envelope is vital to our continued survival. The Canadian Space Agency's Measurements Of Pollution In The Troposphere (MOPITT) instrument is designed to monitor from space the health of this thin layer of atmosphere, and give an early warning of unexpected changes.

Cover: *Biomass burning—from both human activities and natural causes—is a major source of pollution in the troposphere.*

The Canadian Space Agency's Measurements of Pollution in The Troposphere (MOPITT) instrument will fly aboard NASA's Terra satellite and monitor the troposphere from space, providing scientists with a greater understanding of the atmosphere's most chemically complex and dynamic region.

While large metropolitan areas have long battled air quality issues, it is now apparent that rural areas are also threatened by damage to crops and forests caused by atmospheric pollutants. Increasing populations and industrial activities continue to erode air quality. In addition, climate change can influence air quality, and in turn, climate is affected by changing atmospheric compositions.

The impact of storms on the atmosphere and ocean, the burning of forests and lightning strikes are all significant issues affecting measurements of the troposphere

In order to understand complex relationships among Earth systems, a combination of measurements and models must be applied. In weather forecasting, the global models currently used assume a relatively constant composition for most atmospheric constituents.

Increases in population, size of cities, and industrial activity all threaten to further erode air quality

Although the accuracy of weather forecasting has increased significantly over the last twenty years with enhanced data collection and modeling methods, the new challenge is to further enhance global climate and meteorological models by gaining extensive knowledge of atmospheric composition.

For more than 30 years, remote sensing from space has been a highly successful tool used to monitor and study the stratosphere. However, scientists' understanding of the troposphere is considerably less evolved. Challenges arise due to the greater variability of the troposphere. Highly dynamic factors such as storms, biomass burning, and lightning are all significant issues that contribute to the region's complexity.

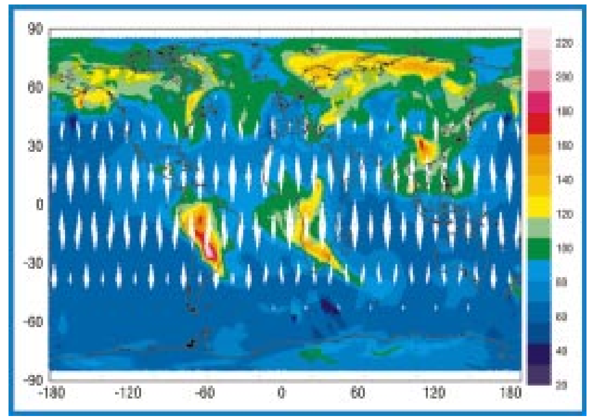
Clouds obscure part of the planet at all times

There are currently few measurement sets of tropospheric chemical components. Because of the strong connection between atmospheric composition and global air quality, attention is being focused on understanding tropospheric chemical processes. Partial ground-based data sets exist, but because of the atmospheric region's great variability, incomplete data sets offer little help for comprehensive modeling studies. Only with space-based measurements can a spatially and temporally extensive data set of tropospheric constituents be collected and evaluated.

MOPITT

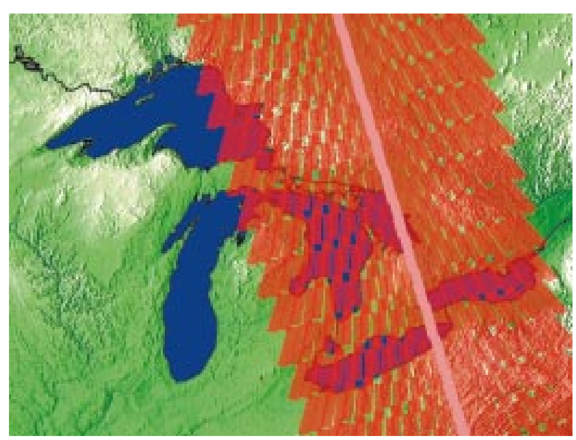
The Canadian Measurements Of Pollution In The Troposphere (MOPITT) instrument will be the first instrument to simultaneously monitor two important atmospheric chemical species, carbon monoxide (CO) and methane (CH_4). MOPITT will fly on board NASA's newest spacecraft, EOS Terra (formerly EOS AM-1), and collect data over the entire globe for at least five years. Combined with concerted modeling efforts, MOPITT will help create the first global and long-term picture of the composition of the lower atmosphere.

MOPITT will divide the globe into approximately 1,000,000 individual cells, or "pixels," and make a measurement over each one every four days. Each pixel is about 22 kilometers square, small enough so that emissions from individual cities can be measured.

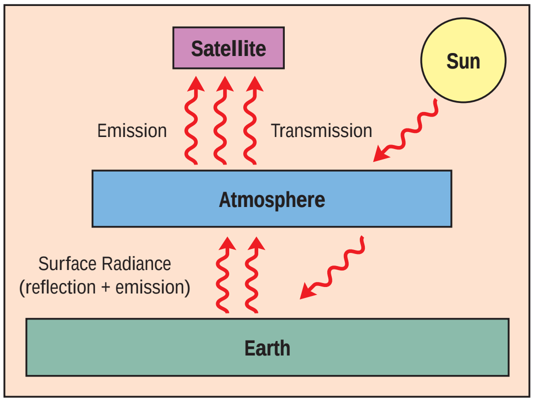


Two-day simulation of MOPITT data for mid tropospheric CO in October (ignoring clouds)

MOPITT will make measurements of infrared radiation originating from the surface of the planet and isolate the energy being radiated from CO and CH_4 molecules by using a technique called gas correlation spectroscopy. Because it measures infrared radiation, MOPITT will be able to collect data during the night



Simulation of two minutes of data collection over the Great Lakes region, showing the 320 km scanning area on both sides of the spacecraft track



MOPITT looks at emitted and reflected infrared radiation

as well as throughout the day. However, MOPITT cannot "see" through clouds, a limitation that will cause a gap in data for cloud-covered areas. Sophisticated models will be used to estimate values where there are data gaps due to cloud cover.

MOPITT measurements will be analyzed and converted into maps of atmospheric composition for use by the MOPITT science team and other scientists. These maps will be produced on weekly, monthly, and annual time scales so that effects due to weather, seasons, and long-term changes can be studied and interpreted.

The Earth Observing System

As a major component of NASA's Earth Science Enterprise, the Earth Observing System (EOS) is the first of its kind designed to offer integrated measurements of the Earth's processes. While gathering a continuous stream of data over the next 18 years, EOS will enable research scientists to gain a better understanding of how our Earth works as an integrated system, and to determine the effects of natural and human-induced changes on its environment.

The Terra spacecraft, the flagship in the EOS series, is scheduled for launch in 1999. Terra will fly in a sun-synchronous polar orbit, crossing the equator at 10:30 in the morning, when cloud cover over land is at a minimum. It will be followed by a series of satellites to be launched by NASA and its interagency and international partners through the year 2012. In addition to MOPITT, Terra will carry four other instruments: ASTER, MISR, and MODIS, which will measure surface radiances, digital elevations, and aerosols; and CERES, which will measure cloud radiative forcing. The measurements provided from these instruments will be used to help interpret the data from the MOPITT experiment.

In addition to satellite measurements, other observational programs from the ground, aircraft, and balloons will be implemented to ensure that data of the highest quality are produced. These measurements will be combined with modeling studies to provide an analysis of possible changes that might be occurring in the atmosphere and what activity, natural or human-induced, might be causing them.

Artist's concept of NASA's Terra spacecraft in orbit

Forest fires destroy resources and cause serious pollution

Carbon Monoxide In The Atmosphere

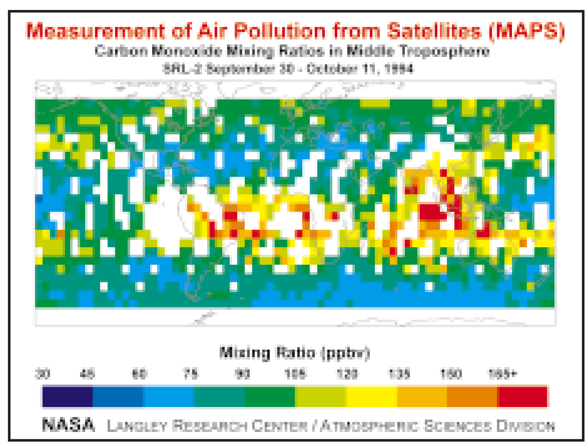
Carbon monoxide is a colorless, odorless gas that is present in the lower atmosphere at a concentration of about one hundred parts per billion depending on the geographic location. “Clean” areas may show concentrations as low as 50 parts per billion, whereas polluted areas may have much higher concentrations. At very high levels, CO is poisonous.

Carbon monoxide is produced by a number of processes, almost all of which happen at or near the ground. Some of these sources are natural and some, such as fossil fuel consumption and biomass burning, are connected with human activity. Total planetary production of CO is estimated at between two and five gigatons per year. The major loss, or “sink” of carbon monoxide occurs through its reaction with the hydroxyl (OH) radical.

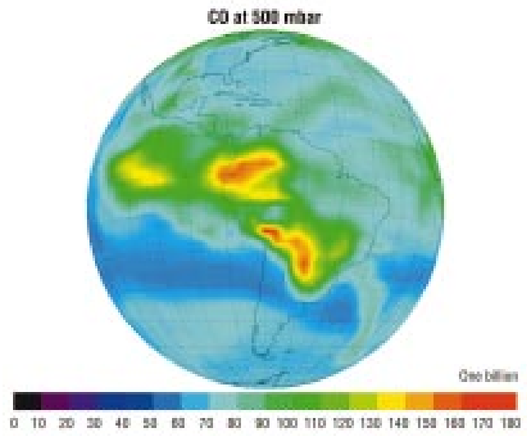
The OH radical is one of the most important chemicals in the troposphere and is intimately connected with atmosphere’s ability to control pollutants. Changes in OH concentration indicate changes in pollution levels that can have beneficial or detrimental effects. Since tropospheric OH can’t be measured from space, monitoring CO gives scientists a “window” into the chemical processes occurring in the atmosphere’s lowest layer.

The average life cycle of a CO molecule is on the order of several months. Since it takes much longer than that for a chemical to completely mix throughout the lower atmosphere, the distribution of CO concentrations show the locations of respective sources and sinks. Thus, using advanced mathematical models it is possible not only to locate the sources of CO, but also to estimate their distribution. In addition, by monitoring how the patterns of CO concentration change with time, we can build up an understanding of how the atmosphere transports this and other chemicals from one area of the planet to another.

Global measurements of CO have been made over short periods of time by the shuttle-based Measurement of Air Pollution from Satellites (MAPS) instrument, which has flown a number of times during the past twenty years. MAPS has provided some intriguing snapshots of the CO distribution in the middle of the troposphere as a function of time and, in so doing, the effects of human activity have been observed. In the figure, the increased mixing ratios around the equator are undoubtedly due to biomass burning in South America, Equatorial Africa, and Indonesia.



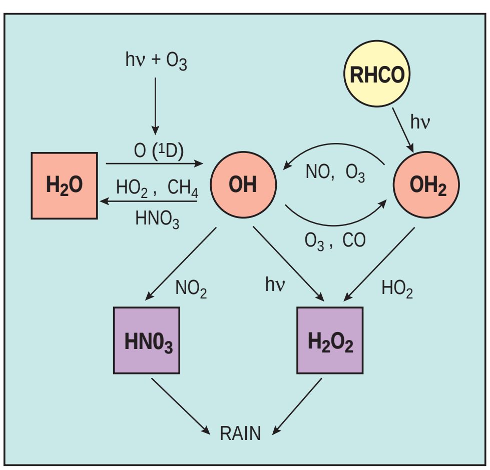
We know, however, that this picture changes with the seasons, and there remain serious gaps in the coverage of CO measurements, both in space and time. MOPITT will enormously expand our knowledge of



Model distribution of CO over South America in September. High values are from burning during forest clearing and the transport of CO over the Pacific by easterly winds at the Equator. The color scale corresponds to a mixing ratio of CO in parts per billion.

this important gas by providing high-resolution global maps twice a week.

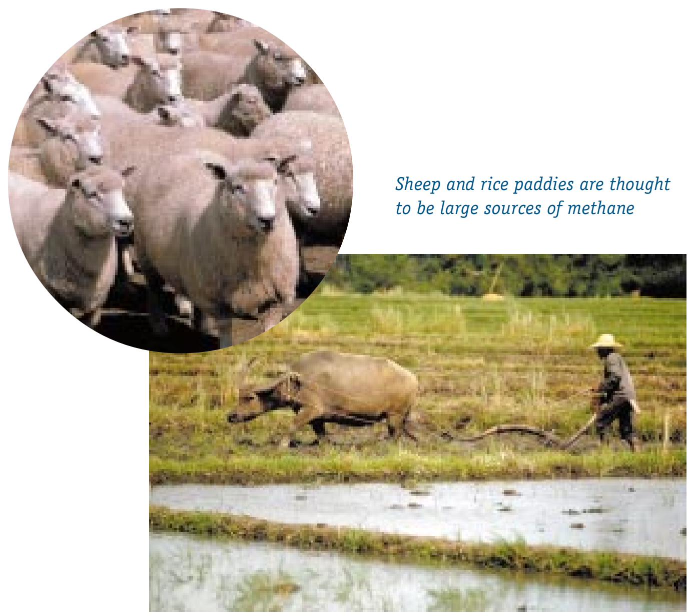
Such maps, together with the individual measurements that comprise the maps, will enable scientists to test and refine their models of lower atmospheric chemistry. The models will be used to display the transport of these chemicals, both horizontally and vertically, and verify our understanding of the chemical processes occurring in the lower atmosphere. They will also be used to test predictions of pollutant concentrations. This will allow the provision of reliable forecasts to the general public, industry and government, eventually leading to informed policy decisions related to our influence on the global environment.



A schematic of tropospheric chemistry

Methane In The Atmosphere

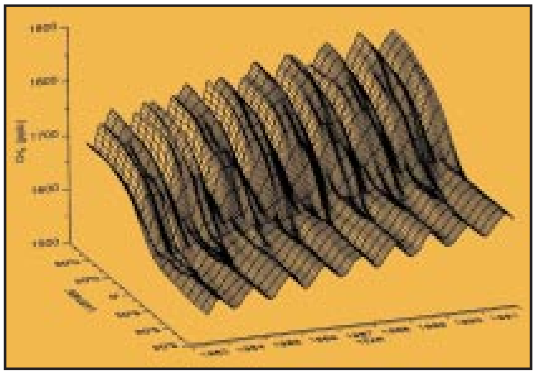
Methane is an important greenhouse gas that is involved in atmospheric chemical processes. Its average concentration is around 1.7 parts per million and, unlike CO, the concentration is very uniform both horizontally and vertically. The main observed variation to date has been a 5% higher concentration in the Northern Hemisphere, as compared to the Southern Hemisphere.



Sheep and rice paddies are thought to be large sources of methane

Most measurements of methane have been made by sampling the concentration at or near the Earth's surface over long periods of time at specific sites. Using the assumption that there is no variation around a circle of latitude, global plots have been constructed.

Methane also has a wide variety of sources, many of which are directly or indirectly affected by human activity. Moist land areas, such as the wetlands of the high northern latitudes and the rice paddies of the subtropical latitudes, are sources of methane. Cows, sheep, and other similar herbivores also produce significant amounts. The total annual production of



A "plot" of global methane with time, taken from a number of fixed ground sites

methane is thought to be about 500 megatons. The main loss mechanism is through reaction with the hydroxyl radical. Because of the strong biological links in methane production, concentrations vary in a noticeable seasonal cycle.

Methane has a very long lifetime in the atmosphere—about 10 years—and therefore is able to become well mixed in both hemispheres. In order to determine the sources and sinks, MOPITT must make very accurate measurements of the concentration of this gas.

Since methane is very efficient at absorbing infrared radiation emitted by the Earth's surface—up to 60 times more efficient than carbon dioxide—there is concern over its increasing concentrations in the atmosphere. Thus, increases in methane concentration, although small in themselves, can have considerable consequences. There is evidence that methane has increased fairly continuously for some time and has doubled in concentration since the beginning of the Industrial Revolution. The recent record is more variable, with individual years showing both increases and decreases. The reasons for these variations are not fully understood.

MOPITT Instrument

MOPITT is a multi-channel correlation radiometer and views the Earth looking vertically downwards from the satellite, scanning 320 km on each side of the spacecraft as it orbits the planet. This enables coverage of most of the planet every four days. Measurements are made in a total of 64 channels at the rate of just over two measurements every second. These measurements are combined to give profiles of carbon monoxide and column amounts of methane at a rate of 8 points per second.

MOPITT is designed to operate continuously for a period of five years to permit the science team to observe changes in the concentrations of these chemicals over long periods of time.

A COM DEV technician prepares the MOPITT instrument for flight

MOPITT Data Processing

MOPITT data processing will initially occur at the National Center for Atmospheric Research, Boulder, Colorado. Scientists will receive the raw instrument data on a daily basis and process the readings into distributions of carbon monoxide and methane over the surface of the planet.

After the first eighteen months, when the conversion programs are well understood, processing will be performed at the Distributed Active Archive Center at the NASA Langley Research Center in Hampton, Virginia.

MOPITT Data Products

MOPITT produces two major data products, one for each of the gases that it monitors:

Carbon monoxide (CO)

Profiles in cloud-free conditions at a spatial resolution of about 22 km x 22 km horizontally and an approximate equivalent vertical resolution of 3-5 km. During daylight, reliable information is obtained down to the surface. After dark, the information near the surface becomes less reliable. The measurement accuracy after validation is estimated to be about 10% rms–10 parts per billion in a profile of about 100 parts per billion.

Methane (CH_4)

Total vertical column amounts in cloud-free conditions at a spatial resolution of about 22 km x 22 km. There is no vertical information, only the integrated amount is measured. The methane channels are only active during daylight, thus no information is returned at night. The measurement accuracy is estimated to be about 1% after validation.

MOPITT Facts

Spacecraft:	EOS Terra (AM-1)
Orbit:	705 km; 10:30 am descending node, sun-synchronous, near polar, circular
Size:	1.1m x 0.9m x 0.5m
Mass:	190 kg
Power:	250W
Data Rate:	30 kbps
Spatial Resolution:	22 km x 22 km (nadir)
Detector Temperature:	<100K
Design Life:	5 years
Spectral Bands:	
4.562-4.673 µm 2140-2192 cm^{-1}	CO profiles
2.323-2.345 µm 4265-4305 cm^{-1}	CO column
2.222-2.293 µm 4361-4500 cm^{-1}	CH_4 column

MOPITT is supplied to the EOS program by the Canadian Space Agency. The MOPITT instrument was built by COM DEV International of Cambridge, Ontario, and will be operated by the University of Toronto, both under contract to the Canadian Space Agency. The Principal Investigator is Prof. James R. Drummond of the Department of Physics, University of Toronto. For further information contact Prof. Drummond at (416)-978-4723; jim@atmosp.physics.utoronto.ca

Information on MOPITT is available at:

http://www.atmosp.physics.utoronto.ca/MOPITT/home.html

http://www.eos.ucar.edu/mopitt/home.html

http://www.science.sp-agency.ca/J1-MOPITT(Eng).htm

http://www.science.sp-agency.ca/J1-MOPITT(Fr).htm

Information on the Terra mission is available at:

http://eos-am.gsfc.nasa.gov/

International Collaboration

The Mission Statement of the Canadian Space Agency is to lead the development and application of space knowledge for the benefit of Canadians and humanity. The provision of MOPITT to the EOS program demonstrates Canada's commitment to participate in international missions focused on understanding how changes in our atmosphere affect global climate change. Since atmospheric pollution is a worldwide problem, international teams of scientists on all continents will work closely with MOPITT data.

The Future

The ultimate objective of research in this area is to develop our understanding to a level where our predictions are reliable. This will allow us to manage the environment more effectively and improve the quality of life for the entire biosphere—including humanity.

MOPITT Science Team

The international MOPITT science team has been working for more than a decade to develop both the MOPITT instrument and the algorithms needed to turn MOPITT measurements into maps and profiles of CO and CH_4.

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