Measurements Of Pollution In The Troposphere (MOPITT) NASA Langley ASDC Data Collection Guide

Summary:

The MOPITT data sets are designed to measure carbon monoxide (CO) and methane (CH_4) concentrations in the troposphere. For CO, the objective is to obtain profiles with a resolution of 22 km horizontally, 4 km vertically and with an accuracy of 10% throughout the troposphere. For CH_4, the objective is to measure the column in the troposphere to a precision of better than 1% with a similar spatial resolution to that of the CO measurement. The methane column measurements will only be available on the sunlit side of the orbit.

These profiles are then used in a parallel modeling effort to advance our understanding of global tropospheric chemistry. The results of this project will be global maps of carbon monoxide and column methane distribution in the troposphere and an increased knowledge of tropospheric chemistry resulting from the analysis by 3-D models.

MOPITT was provided to NASA by the Canadian Space Agency (CSA). The University of Toronto directed its development. Data reduction software was developed, and the data processed, at the National Center for Atmospheric Research (NCAR) with NASA support. It is part of the NASA's first Earth Observing System spacecraft, the *Terra* spacecraft, which was launched into polar orbit from Vandenberg Air Force Base on December 18, 1999.

More detailed information on this project may be found at the MOPITT Web Site.

Acknowledgement:

The requested form of acknowledgment for any publication in which these data are used is: "*These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center.*"

Table of Contents:

1. Collection Overview:

Collection Contents:

MOP01 - Measurements Of Pollution In The Troposphere (MOPITT) Level 1 Radiances HDF file

The MOPITT Level 1 data product consists of the geolocated, calibrated earth scene radiances, associated instrument engineering data summaries, and inflight calibration information. Data granules are one day in duration and limited to the earth scenes observed within the midnight to midnight period. Data from calibration sequences are included in the MOPCH files. Instrument performance statistics are presented in the MOP01ES files.

MOP01ES - Measurements Of Pollution In The Troposphere (MOPITT) Level 1 Engineering Summary File Data

This MOPITT data product presents the high, low, mean, and standard deviation of the engineering parameters monitored on the instrument. A record is also made of the number of occurrences yellow and red limits were exceeded, rendering the data invalid during

that segment of the orbit.

MOP01QE - Measurements Of Pollution In The Troposphere (MOPITT) Level 1 Engineering Exception Log
This MOPITT data product consists of Level 1 exception logs.

MOP02 - Measurements Of Pollution In The Troposphere (MOPITT) Level 2 Derived CO and CH_4
The MOPITT Level 2 data product consists of the geolocated, retrieved carbon monoxide profiles and total column amounts for carbon monoxide and methane. Ancillary data concerning surface properties and cloud conditions at the locations of the retrieved parameters are also included. Each retrieval is accompanied by an estimated error and covariance matrix, quantifying how the errors are correlated. The averaging kernels, which allow users to determine the relative contributions of CO into each level, are provided. The methane product is only processed on the daylight half of the orbit.

MOP02Q - Measurements Of Pollution In The Troposphere (MOPITT) Level 2 Quality Control Data
This MOPITT data product contains the log of the processor. It can be used to deduce processing history and data quality. Processing errors are also recorded.

MOPCH - Measurements Of Pollution In The Troposphere (MOPITT) Calibration History File
This MOPITT data product contains the signals from the internal blackbody (hot, warm, and tepid) and space views. MOPITT views space approximately every two minutes and views the warm calibration source approximately every five minutes. The calibration source is heated to the hot setting once every few months. Calibration events from all four optical trains are stored within this file.

Related Data Collections:

Tropospheric Carbon Monoxide Distribution from the Space Shuttle MAPS Experiment. This data set is available from the National Space Science Data Center (NSSDC).

Title of Investigation:

Measurements Of Pollution In The Troposphere (MOPITT)

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2. Applications and Derivation:

MOPITT data will provide unique global observations of Methane and Carbon Monoxide abundance.

Usage:

MOPITT will provide important information about the atmospheric carbon budget. Observations will be assimilated into global atmospheric chemistry models. The models will be able to track the transport and chemical interactions of the atmosphere. The data will also be used to determine the sources and extent of air pollution.

Theory of Measurements:

Drummond (1992) has outlined the MOPITT instrument concept. MOPITT, on the Terra platform, measures upwelling thermal emission from the atmosphere and surface in the long-wave channels, and solar radiation that has passed through the atmosphere, been reflected at the surface, and transmitted back up through the atmosphere in the short-wave channels. Total atmospheric transmittance derived from reflected sunlight measurements is a convenient way to determine the total column amount of a trace gas. This technique requires that the target gas has a spectral band in a region with large solar radiance, and the total optical depth along such a path is not too large. Methane has an overtone band near 2.2 micrometers which provide a measurable but not too large total absorption for such a path. For carbon monoxide, the first overtone band, at 2.3 micrometers,is suitable for a total column measurement.

For vertical profiling, the requirement is that significant and measurable portions of the signal must originate in different atmospheric layers, which means that there must be a few values of different but appreciable opacity in the atmosphere, and that there must also be a source of radiation in the atmosphere. Thermal emission is a radiation source, and the CO fundamental band at 4.7 micrometers has enough opacity to determine atmospheric amounts, as demonstrated by Reichle et al. (1986, 1990).

All three of these bands are in regions of the spectrum with other gas bands, and the lines of interest are mixed with those of interfering species. In principle it is possible to measure total emission or transmission in a spectral band, and then correct for the contributions of the interfering species to arrive at a measurement of the species of interest. However, the contributions of the other species are considerably larger than those of the gases of interest, and their amounts are often not known with sufficient accuracy. The uncertainties of the corrections may significantly degrade, or even mask, the detection of changes in the gas of interest.

MOPITT is designed to meet this challenge by enhancing the sensitivity of the instrument to the gas of interest. Since all gases in the atmosphere are emitting/absorbing simultaneously it is essential that the effect of the gas of interest be separated out from the general radiation field. Further, since the information from the vertical distribution of the gases is contained within the shape of an individual absorption/emission line, it is necessary to be able to resolve the line shape, which generally requires high spectral resolution. High spectral resolution leads to low signal to noise, which means low instrument sensitivity. Therefore, high sensitivity and high spectral resolution requirements for tropospheric trace species remote sensing are difficult to implement with conventional dispersing instruments.

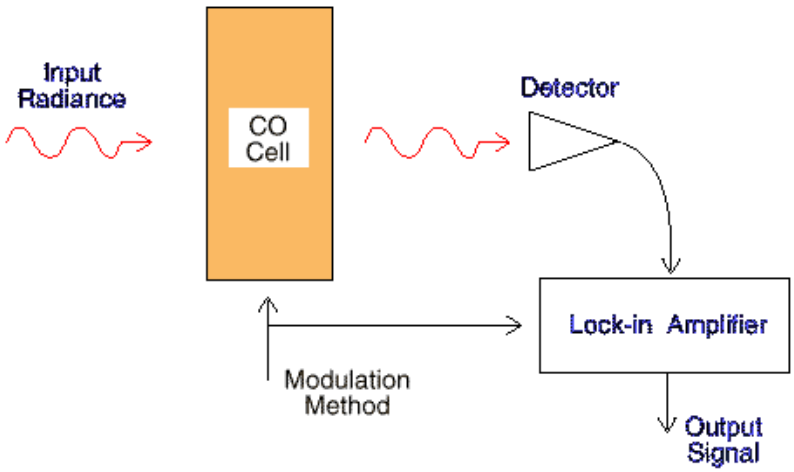


Figure 1. Schematic of a typical Correlation Radiometer (CR).

Correlation Radiometry (CR), a non-dispersing spectroscopy technique, offers the opportunity for high spectral resolution as well as high signal to noise. The fundamental techniques of correlation radiometry are illustrated using the apparatus illustrated in Figure 1. The cell contains a sample of the gas under consideration. If radiation enters from the left and is detected by the system on the right then the output as a function of spectral frequency for a single line is shown in Figure 2 for two different amounts of gas in the absorption cell. By cycling the amount of gas in the absorption cell between the two states, the detector will be alternately looking through two different filters. If the difference of the two signals is taken, this signal will be identical to the output of a system in which the gas cell and it's modulator are replaced by an optical filter of profile shown by the Effective Difference Transmission (EDT) curve in Figure 3.

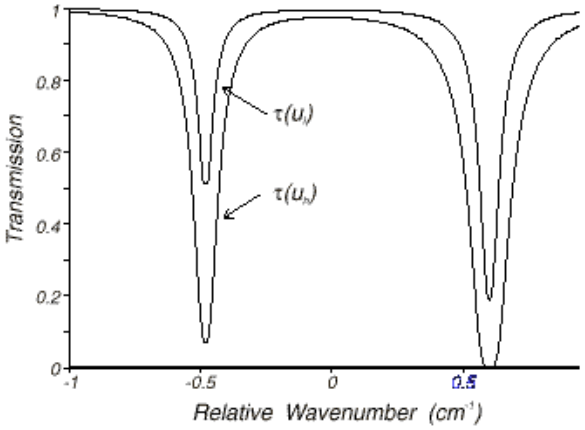


Figure 2. Transmission through a cell with two distinct amounts of the absorbing molecule in the path.

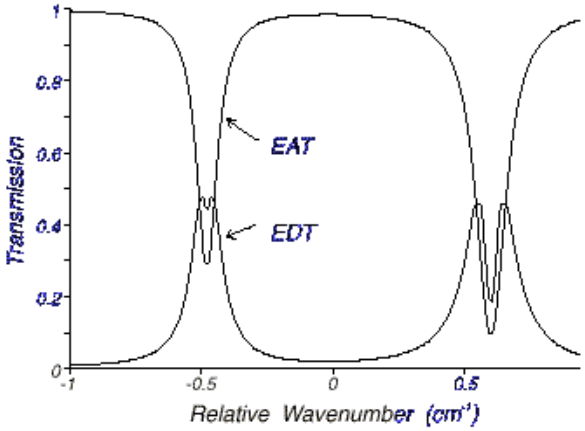


Figure 3. The Equivalent Average Transmission (EAT) and Equivalent Difference Transmission (EDT) of the signals passed through a long and short path of an absorbing molecule.

For each modulator, the correlation radiometry technique then yields both 'Difference' and 'Average' signals. For the retrievals of carbon monoxide, Difference and Average signals from four different modulators (each sensitive to a different atmospheric layer) are used as the basis of the 'retrieval' of the target gas. The general mathematical technique used to calculate the statistically most probable atmospheric profile of the target gas from the measured signals is known as the maximum likelihood method. This technique is heavily based on a radiative transfer model which calculates theoretical instrument radiances for a given atmospheric state (i.e. temperature, water vapor, and target-gas profiles), given surface conditions (surface temperature and emissivity) and given geometrical parameters (solar and satellite zenith angles). Unfortunately, the problem of retrieving the target gas profile (or even the target gas total column) solely from the measured signals is underconstrained, meaning that there is no unique target gas profile which can be inferred from the signals alone. (This is actually true of many remote sensing applications.) The maximum likelihood technique therefore incorporates 'a priori' information (i.e. statistical information about the known patterns of variability of the target gas) to compensate for the fact that the measured signals simply do not contain sufficient information to unambiguously determine the target gas profile (or total column value). (Rodgers, 1976)

Derivation Techniques and Algorithms:

Formulae:

See Theory of Measurements. Additional information is in the MOPITT Algorithm Theoretical Basis Document (ATBD).

Processing Steps:

Processing is divided into several steps.

1. **Level 0 to Level 1B**
    1. Observations are sorted by whether they are views of the Earth or of calibration targets.
    2. Views of the calibration targets are used to compute the gain and instrument noise.
    3. Earth views are geo-located.
    4. Geo-located signals are calibrated into radiances (using the gain computed from the calibration views).
    5. Geo-located radiances are written to MOP01 data files.
2. **Level 1B to Level 2**

1. Level 1B data is read in.
2. Atmospheric data, such as water vapor and temperature profiles, are interpolated to the same times and locations as the MOPITT observations.
3. MOPITT observations are compared with radiation model calculations in order to detect clouds.
4. Cloudy pixels are not processed further at this time.
5. Cloud-free pixels are sent to the retrieval section of the processor where the amounts of CO and CH_4 are deduced using the "maximum likelihood" method.
6. The results of the retrieval are written to the MOP02 level 2 files.

Processing Changes:

MOPITT is a pioneering instrument. Validation and calibration are expected to take several years. There will be many revisions and reprocessing steps, but no major changes are anticipated.

Special Corrections/Adjustments:

None.

Calculated Variables:

MOPITT provides CO at seven pressure levels and total column abundance. Total column CH_4 is also determined.

Graphs and Plots:

To be submitted.

3. Data Description and Access:

Information about the MOPITT data products, including the User's Guide and Data Quality documents, may be found on the MOPITT Data Products page.

Format:

MOP01 - Hierarchical Data Format (HDF)
MOP01ES - Text
MOP01QE - Text
MOP02 - Hierarchical Data Format (HDF)
MOP02Q - Text
MOPCH - Hierarchical Data Format (HDF)

Data Organization:

Data Granularity:

The general description of data granularity as it applies to the IMS is: "The smallest aggregation of data which is independently managed (i.e., described, inventoried, retrievable). Granules may be managed as logical granules and/or physical granules.".

MOPITT files (i.e. granules) are daily.

Volume:

MOP01 files are approximately 80MB.
MOP02 files are approximately 67MB, depending on the cloudiness of the day.

Cost:

Currently, there is no charge for the data.

Data Access:

MOPITT data and information is available from the Atmospheric Science Data Center at:
http://eosweb.larc.nasa.gov/project/mopitt/mopitt_table.

Data Archive Center:

Contact for Data Center Access Information:

User and Data Services
Atmospheric Science Data Center
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov
URL: http://eosweb.larc.nasa.gov

Product Availability:

The data are available via FTP from the NASA Langley Atmospheric Science Data Center.

How to Cite the Data Collection:

When data from the Langley Atmospheric Science Data Center are used in a publication, we request the following acknowledgment be included:

> "*These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center.*"

The Langley Data Center requests a reprint of any published papers or reports or a brief description of other uses (e.g., posters, oral presentations, etc.) of data that we have distributed. This will help us determine the use of data that we distribute, which is helpful in optimizing product development. It also helps us to keep our product-related references current.

How to Cite the Guide Document:

Measurements Of Pollution In The Troposphere (MOPITT) Data Langley Data Center Collection Guide, September 2000. Guide document is available on-line. Hampton, VA, USA: NASA Langley Atmospheric Science Data Center (http://eosweb.larc.nasa.gov).

4. Data Characteristics:

Study Area:

MOPITT is particularly sensitive to the abundance of CO in the middle troposphere near 500hPa. The polar regions are currently excluded from MOPITT data because of the difficulty eliminating cloud contamination.

Spatial Coverage:

Spatial Coverage Map:

These data collections consist of coverage at all longitudes from 65°S to 65°N.

Spatial Resolution:

MOPITT pixels are square 22x22km. The swath width is approximately 640km, so it takes about three days to obtain approximately complete global coverage. The vertical resolution is defined by several broad and overlapping weighting functions. CO is output at seven pressure levels.

Projection:

MOPITT data are ungridded. It follows the HDF-EOS Swath data convention.

Grid Description:

MOPITT data are ungridded. It follows the HDF-EOS Swath data convention.

Temporal Coverage:

Temporal Coverage Map:

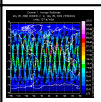
MOPITT began collecting data in the beginning of March, 2000. In May, 2001 a cooler failed, so the mission will continue with only half the channels operational. This should reduce the vertical resolution of the data after the first year. Otherwise, MOPITT is expected to be in near-continuous operation for at least five years.

Temporal Resolution:

MOPITT makes observations every 0.4 seconds. These observations are compiled into daily files.

Parameter or Variable:

Table 1. Summary of Parameters

Parameter	Unit	Source	Range	sample
Radiance	Watts meter^{-2} Sr^{-1}	NCAR	>0	
CO Profile Mixing Ratio	Parts Per Billion Volume (ppbv)	NCAR	>0	
CO Total Column Abundance	molecules cm^{-2}	NCAR	>0	
CH_4 Total Column Abundance	molecules cm^{-2}	NCAR	>0	Not Available Yet

Error Sources:

- Electronic and thermal noise in the instrument
- Scattered light into the detectors during views of cold space, or onto the warm calibration targets
- Insufficient characterization of the pre-launch instrument, e.g. uncertainties in spectral response or co-location.
- Non-uniform surface conditions over the duration of the observation
- Undetected cloud contamination
- Ancillary input data errors
- Radiative transfer model errors
- Surface emissivity and temperature uncertainty

Quality Assessment:

Validation by Source:

Validation is a major effort. The primary validation activities include:

- *In situ* flask samples from aircraft, primarily from NOAA/CMDL
- Ground-based spectroscopy
- Comparisons with MATR (Aircraft instrument similar to MOPITT)
- Comparisons with MOPITT-A (Aircraft based MOPITT engineering qualification model)
- Comparisons with atmospheric chemistry models

Confidence Level or Accuracy Judgment:

After calibration and validation, CO determinations are expected to be within 100f actual CO amounts.

Measurement Error for Parameters:

At this point, while the validation effort is in progress, a definitive characterization of the error is impossible. However, it appears that the Beta release of the data reports CO amounts approximately 20 0gher than independent observations.

Additional Quality Assessments:

Please read the QA metadata included in the *.met files which accompany the data.

Verification by Data Center:

The Langley Data Center performs an inspection process on the data received by the data producer. The Data Center checks to ensure the transfer of the data was completed and that the data were delivered in their entirety.

5. Usage Guidance:

Limitations of the Data:

These data are considered a Beta release. They have not been thoroughly validated yet. It is not recommended for scientific publications.

Known Problems with the Data:

See the

- Level 1 Version 1 Product Quality Statement.
- Level 2 Version 2 Product Quality Statement.

Other Relevant Information about the Study:

None.

Future Modifications and Plans:

Reprocessing is expected as the algorithm is improved and the data products validated.

6. Acquisition Materials and Methods:

Source or Platform Collection Environment:

Terra Satellite

Source or Platform Mission Objectives:

- Provide global and seasonal quantitative measurements of the Earth's lands, ocean and atmosphere.
- Characterize the human induced changes of the land, ocean and atmosphere.
- Improve understanding and prediction of the Earth's climate including weather events and seasonal and interannual climate change.
- Improve understanding of the timing, location and risk reduction of natural hazards including wildfires, volcanoes, droughts and floods.
- Begin long term monitoring of the state of the health of the Earth.

Source or Platform Program Management:

NASA

Coverage Information:

Terra orbits the Earth in a sun-synchronous orbit. The orbit repeat cycle is approximately every 16 days, or 233 orbits. MOPITT swaths cover the Earth after three days.

Attitude Characteristics:

The orbit is approximately 705km, in a near-polar orbit. The period is about 100 minutes.

Data Collection System:

The data are collected by MOPITT and transmitted through EDOS to the Langley DAAC. The DAAC sends the Level 0 to NCAR, where they are processed to higher level products. The Level 1 and Level 2 products are sent back to DAAC for archive and distribution.

Communication Links:

Consult EDOS.

List of Sensors or Instruments:

- ASTER
- CERES
- MISR
- MODIS
- MOPITT

Ground Segment Information:

Spacecraft control is maintained by the Flight Ops Center at NASA GSFC.

Data Acquisition and Processing:

See Data Collection System.

Latitude Crossing Times:

The equator crossing time of the satellite is approximately 10:45 and 22:45 local time. These will drift earlier as the mission continues.

Sensor or Instrument Description:

See the MOPITT Mission Description Document.

Key Variables:

See the MOPITT Mission Description Document.

Principles of Operation:

See the MOPITT Mission Description Document.

Sensor or Instrument Measurement Geometry:

See the MOPITT Mission Description Document.

Manufacturer of Sensor or Instrument:

ComDev under contract to the Canadian Space Agency (CSA). The work was controlled by the University of Toronto.

Calibration:

MOPITT calibration occurs by positioning the mirror either to space or to an internal blackbody target. The space view is used to evaluate the instrument's response to "zero" radiance (a measure of the system offset). The views of the internal blackbody, at a known temperature, are used to provide a second fixed point. The gain and offset of the system are computed from these non-Earthview observations.

Specifications:

See the MOPITT Mission Description Document.

Tolerance:

Typically, the blackbodies are held at steady temperatures with a daily standard deviation of a few milliKelvins.

Frequency of Calibration:

Cold calibrations (i.e. space views) are done every 10 tracks or approximately every 2 minutes. Warm calibrations (i.e. views at the internal blackbody usually set around 295K) occur approximately every 11 minutes. Hot calibrations are done once every few months. They involve raising the blackbody temperatures up to 460K.

Other Calibration Information:

None.

Data Acquisition Methods:

See the MOPITT Mission Description Document.

Observations:

Data Notes:

None.

Field Notes:

None.

7. References:

- Drummond, J. R., Measurements of Pollution in the Troposphere (MOPITT), in The use of EOS for Studies of Atmospheric Physics, edited by J. C. Gille and G. Visconti, pp. 77-101, North Holland, Amsterdam, 1992.
- Reichle, Jr., H. G., V. S. Connors, J. A. Holland, R. T. Sherrill, H. A. Wallio, J. C. Casas, E. P. Condon, B B. Gormsen, and W. Seiler, The distribution of middle tropospheric carbon monoxide during early October 1984, J. Geophys., Res., 95, 9845-9856, 1990.
- Reichle Jr., H. G. , V. S. Connors, J. A. Holland, W. D. Hypes, H. A. Wallio, J. C. Casas, B. B. Gormsen, M. S. Saylor, and W. D. Hesketh, Middle and upper tropospheric carbon monoxide mixing ratios as measured by a satellite-borne remote sensor during November 1981, J. Geophys. Res., 91, 10865-10887, 1986.
- Rodgers, C. D., Retrieval of Atmospheric Temperature and Composition from Remote Measurements of Thermal Radiation, *Rev. Geophys. and Space Phys.*, **14**,609-624, 1976.

8. Glossary and Acronyms:

EOSDIS Acronyms (PDF).

9. Document Information:

- **Document Revision Date:** Sep 2001; Apr 2003; Nov 2008; June 2010
- **Document Review Date:** June 2010
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