

# **MOPITT Data Validation: Strategy, Plan and Pre-Launch Activities**

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# **The MOPITT Correlative Team:**

- **Mark Smith, NCAR/ACD**
- **Paul Novelli, NOAA/CMDL**
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- **Frank Murcray, University of Denver**
- **Henry Reichle, North Carolina State University**
- **Wallace Mcmillan, University of Maryland/Baltimore County**
- **Nikita Pougatchev, Christopher Newport University**
- **Leonid Yurganov, University of Toronto**
- **Boyd Tolton, University of Toronto**
- **Eamonn McKernan, University of Toronto**

**Note:** The listed investigators are participants in the Pre-launch MOPITT Validation Exercise (Pre-MOVE) who are either NCAR & Toronto MOPITT instrument team members or investigators funded by NASA EOS Validation Office (Drs. David Starr and Tim Suttles) for MOPITT data validation. Each investigator also has co-investigators from the international community.

**-> The MOPITT instrument team and correlative team welcome collaborations in MOPITT data validation and science investigation from any research groups or programs involved in the measurements of tropospheric carbon monoxide (CO) and methane (CH<sub>4</sub>).**



# MOPITT Standard Data Products



- **Standard MOPITT scientific products**
  - **Level 1 data products**
    - **Calibrated and geo-located radiance.**
  - **Level 2 data products**
    - **Tropospheric CO profile. CO mixing ratio at 7 tropospheric pressure levels with a nominal horizontal resolution of 22kmx22km: surface, 850 mb, 700 mb, 500 mb, 350 mb, 250 mb, 150 mb.**
    - **CO total column.**
    - **CH<sub>4</sub> total column.**
  - **Level 3 data products (experimental at launch)**
    - **Gridded global CO distribution (global maps).**
    - **Gridded global CH<sub>4</sub> distribution (global maps).**



# Pre-launch Validation Exercise



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- **Pre-Launch MOPITT Validation Exercise**

- **The first Pre-launch MOPITT Validation Exercise(Pre-MOVE I) was conducted from **March 2-6, 1998** at the Department of Energy(DOE) ARM site.**



## Pre-Launch MOPITT Validation Exercise (Pre-MOVE I)



- **Objectives**

- > Better understanding of correlative measurement techniques and associated data processing algorithms.
- > Intercomparison of correlative measurement results.
- > Test of the readiness of correlative measurements for MOPITT launch.

- **Site Selection**

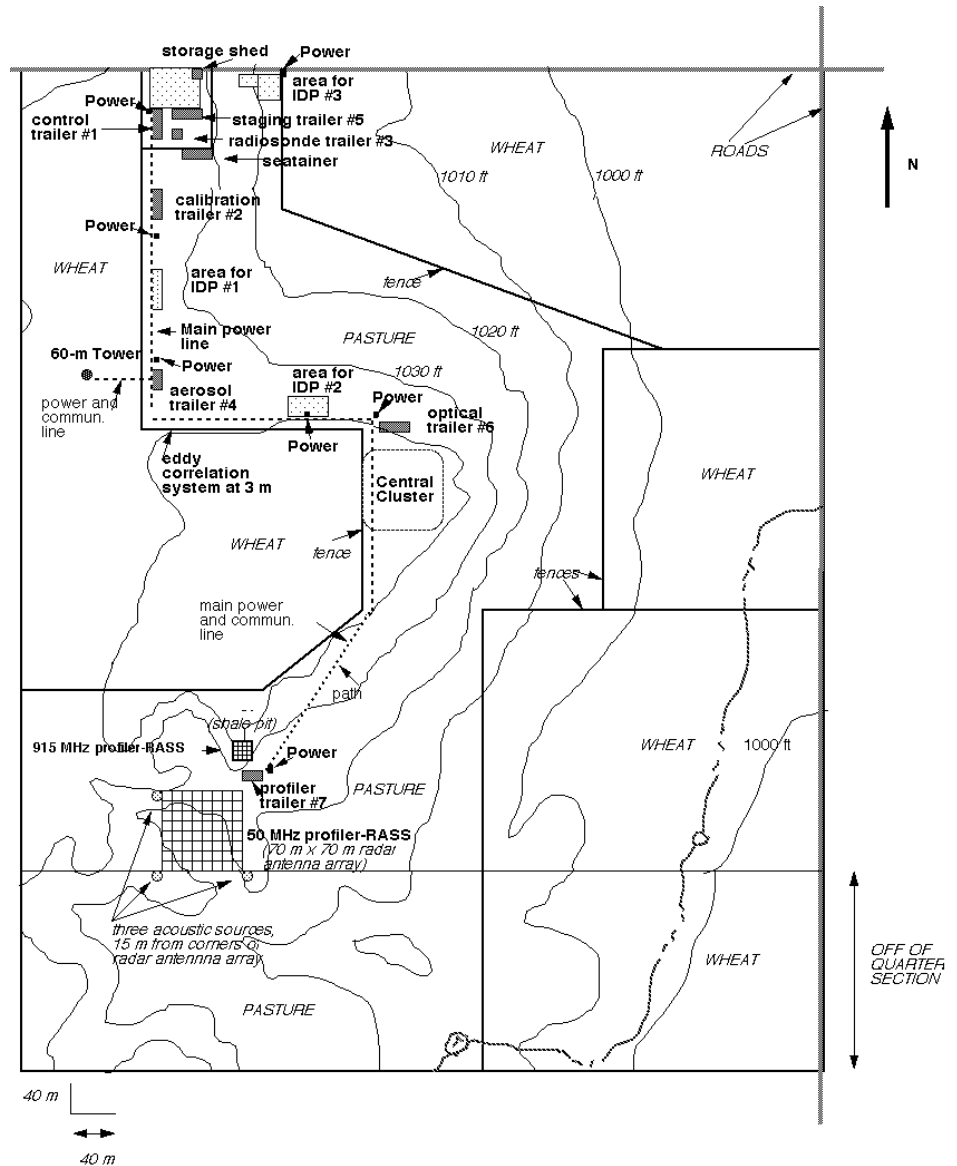
- > DOE/ARM CART site is a heavily instrumented site resulting in good characterization of surface and atmosphere column.
- > Availability of SORTI, AERI, lidar, and radiosonde data.
- > Excellent logistic support.

- **Experiment time**

- > The experiment was conducted on 2-6 March 1998 at the DOE ARM CART site in Lamont, Oklahoma.



# Pre-Launch MOPITT Validation Exercise (Site Characteristics)





## Pre-Launch MOPITT Validation Exercise (Pre-MOVE)



### • Instruments and Measurements

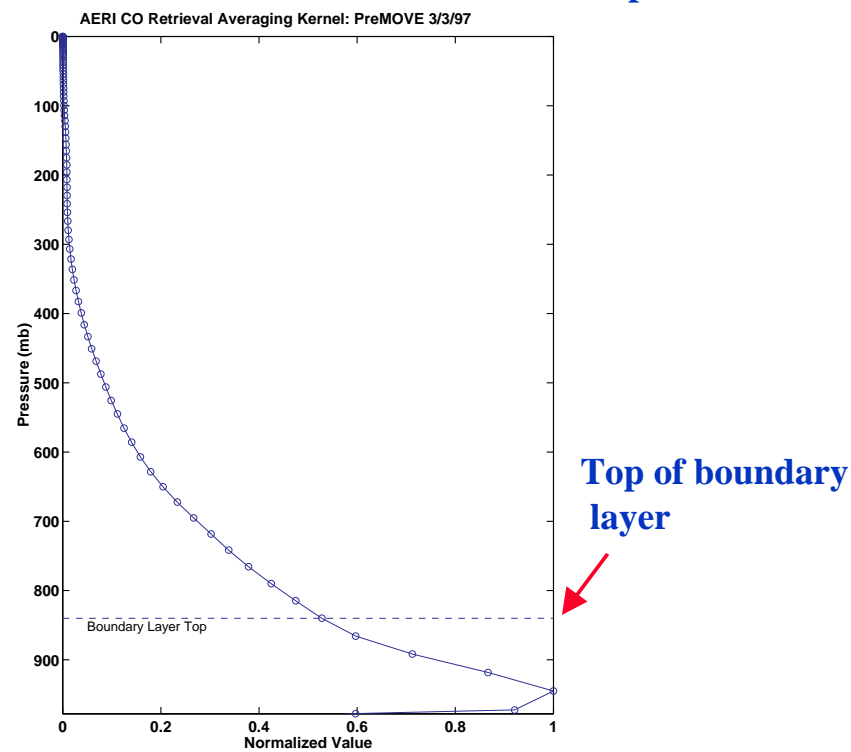
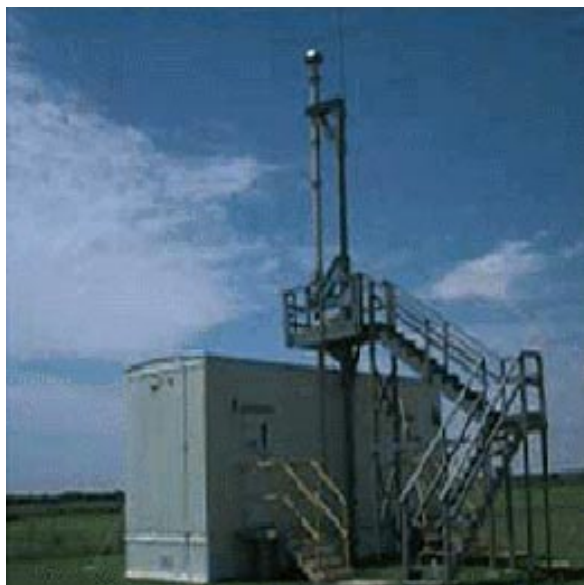
- > MATR from NCAR. MATR was fitted on the Citation aircraft. It flew over the CART site at ~ 39,000 ft. for about 2 hours on March 2, March 3, and March 6, 1998.
- > Automated flask sampling system from NOAA/CMDL. CO, CH<sub>4</sub> and CO<sub>2</sub> profiles were obtained from 1 km to 8 km (~3000 to 26,000 ft.) at a vertical resolution of ~ 0.3 km on March 6, 1998.
- > University of Toronto (UT) ground-based grating spectrometer. Fairly large number of solar absorption spectra were collected on March 3, 1998.
- > ARM ground-based solar absorption FTIR (SORTI) [<http://www.arm.gov/docs/instruments/static/sorti.html>]
- > ARM ground-based thermal emission FTIR (AERI) [<http://www.arm.gov/docs/instruments/static/aeri.html>]
- > Meteorological information by radiosonde and NOAA satellites. ARM program launches radiosonde 3 times per day at 7:00 AM, 12:00 noon and 6:00 PM local time. One extra radiosonde launch were made each day from March 2 to March 6, 1998 to support Pre-MOVE.



## Pre-Launch MOPITT Validation Exercise (ARM AERI Instrument)



- Atmospheric Emitted Radiance Interferometer (AERI)
  - Based on the Bomem MB-100 Fourier transform interferometer
  - Spectral range:  $500 - 3300 \text{ cm}^{-1}$  ( $20 - 3 \mu\text{m}$ )
  - Spectral resolution:  $0.1 \text{ cm}^{-1}$
  - Instrument FOV: 1.3 degrees
  - It generates a calibrated radiance spectrum every 10 minutes.
- CO total column retrieval from AERI spectra.







## Pre-Launch MOPITT Validation Exercise (ARM SORTI Instrument)



- **Solar Radiance Transmission Interferometer (SORTI)**
  - Broker model 120M high resolution FTIR
  - Sun tracker (built at DU)
  - Spectral ranges: 620-1350  $\text{cm}^{-1}$ , 1500-2050  $\text{cm}^{-1}$ , 2020-2550  $\text{cm}^{-1}$ , 2420-3080  $\text{cm}^{-1}$ , 3010-3830  $\text{cm}^{-1}$ , 4020-4300  $\text{cm}^{-1}$ .
  - Spectral resolution: 0.0035  $\text{cm}^{-1}$
  - FOV: 0.3 degree.



- **CO column and profile retrieval from SORTI spectra**
  - Non-linear least square (NLLS) fitting to spectral lines in the 2020-2550  $\text{cm}^{-1}$  region.

Sun tracker



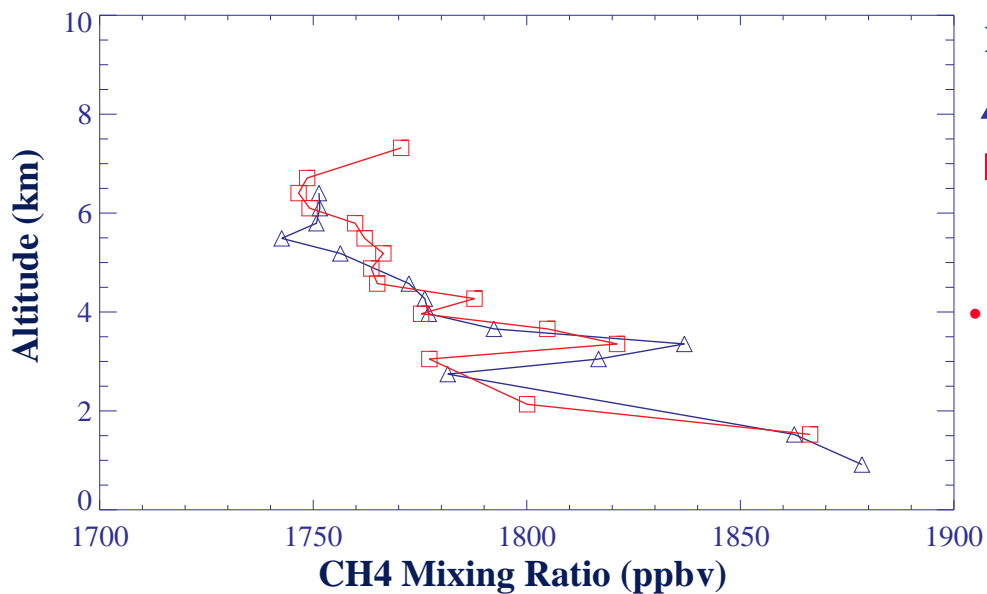
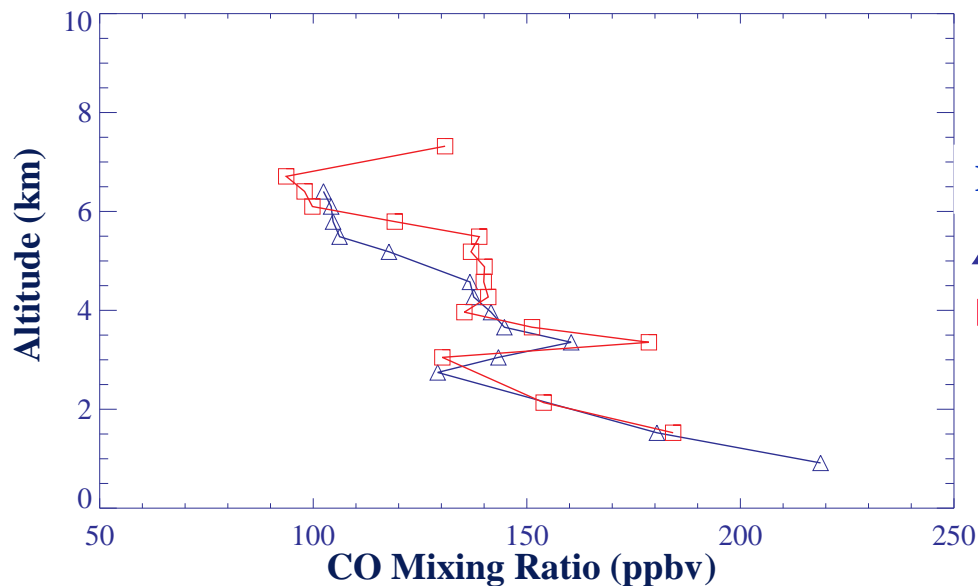
## Pre-Launch MOPITT Validation Exercise (Balloon-Borne Sounding System)



- **PRESSURE**  
Type: Capacitive aneroid  
Range: 1060 hPa to 3 hPa  
Resolution: 0.1 hPa  
Accuracy: 0.5 hPa
- **TEMPERATURE**  
Type: Capacitive bead  
Range: +60 degC to -90 degC  
Resolution: 0.1 degC  
Accuracy: 0.2 degC  
Lag: <2.5 s (6 m/s flow at 1000 hPa)
- **HUMIDITY**  
Type: H-HUMICAP thin film capacitor  
Range: 0 to 100 %RH  
Resolution: 1 %RH  
Accuracy: 2 %RH (0 to 80 %RH)  
3 %RH (80 to 100 %RH)  
Lag: 1 s (6 m/s flow at 1000 hPa, +20 degC)

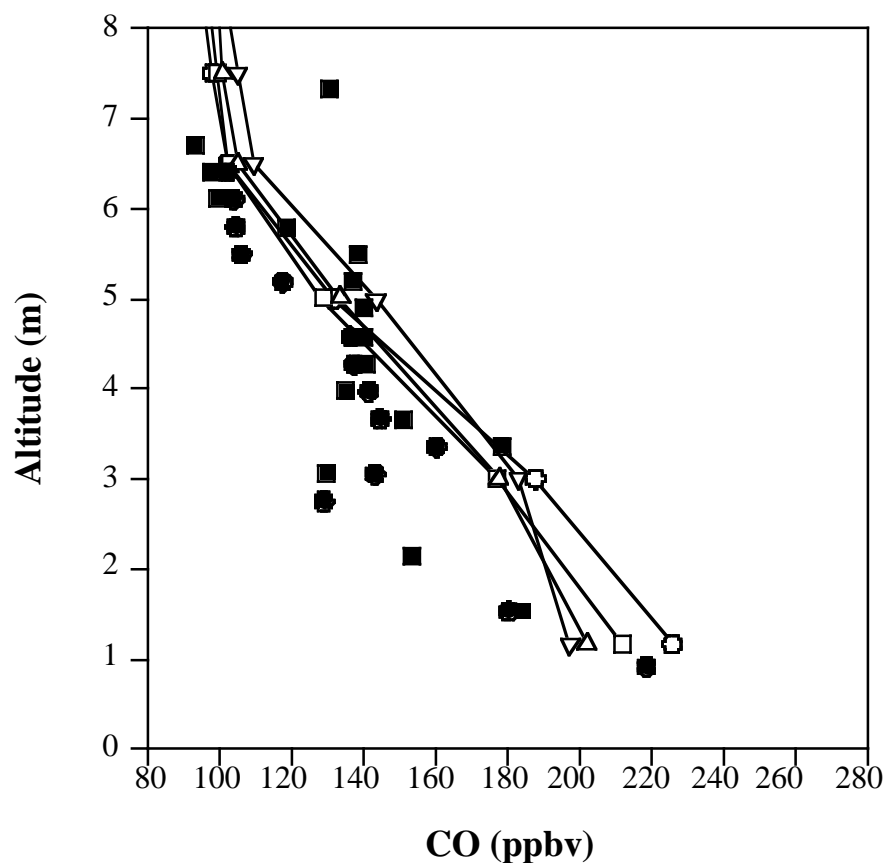


# NOAA/CMDL Aircraft Sampling Measurements (March 6, 1998)





## Preliminary Results from Pre-MOVE: Comparison Between Sampling and Interferometer

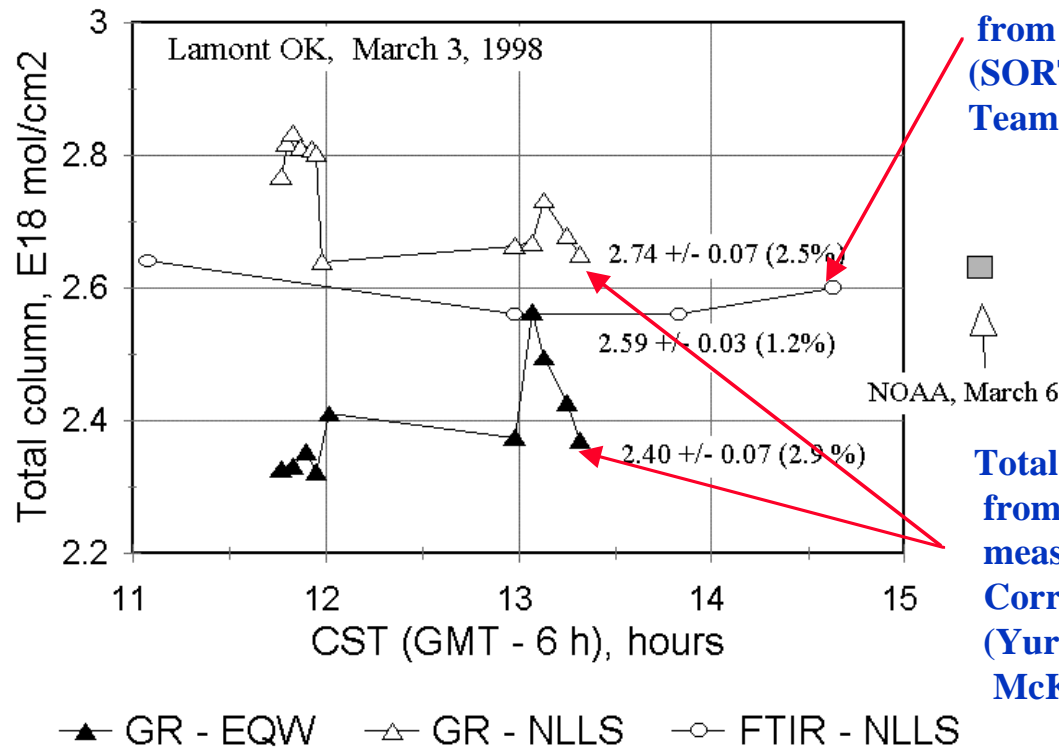


- In-situ CO profile on the morning of 6 March 1998 by NOAA/CMDL automated flask system.
- In-situ CO profile on the afternoon of 6 March 1998 by NOAA/CMDL automated flask system.
- Retrieved CO profile using ground-based solar absorption FTIR measurements (SORTI) by MOPITT Correlative Team member Pougatchev.

- SORTI spectra were provided by MOPITT Correlative Team members Frank Murcay and Thomas Stephen.



## Preliminary Results from Pre-MOVE: Interferometer, Grating Spectrometer and Sampling

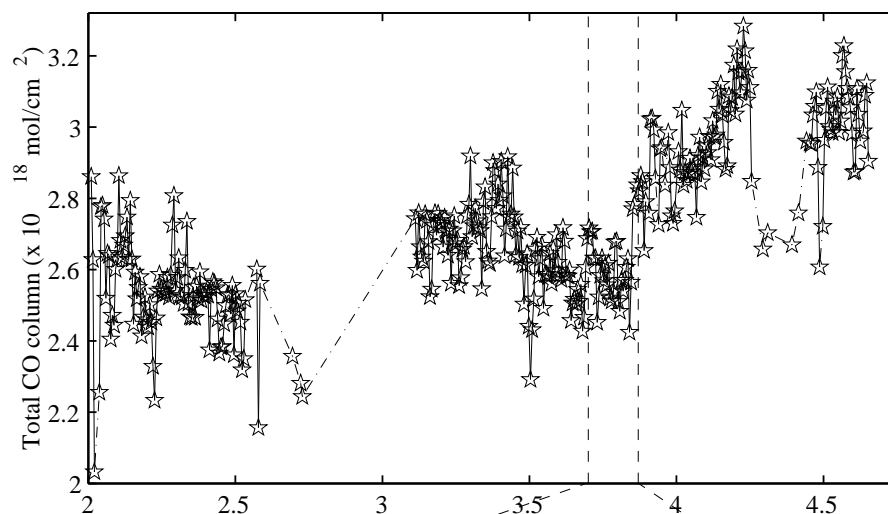


Total CO column retrieved from interferometer spectra (SORTI) by MOPITT Correlative Team member Pougatchev.

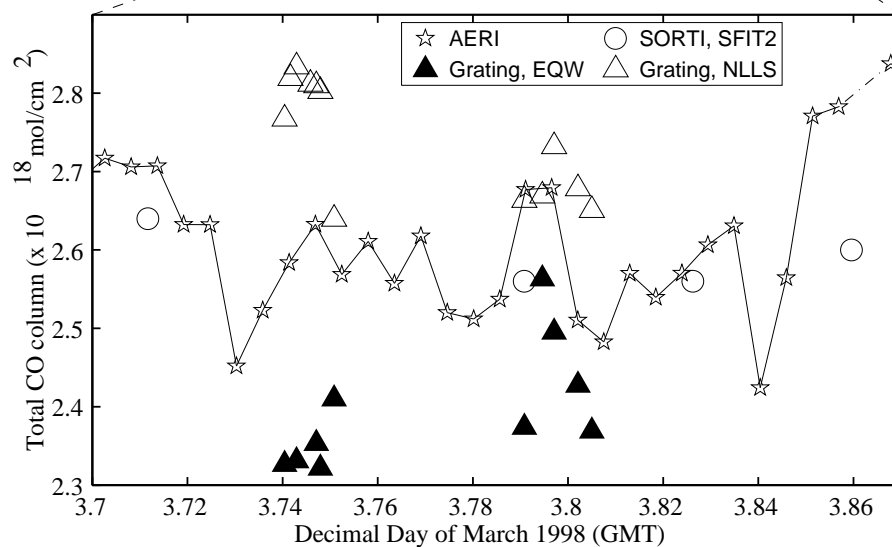
Total CO column retrieved from grating spectrometer measurement by MOPITT Correlative Team members (Yurganov, Tolton and McKernan).



## Preliminary Results from Pre-MOVE: Interferometers and Grating Spectrometer



- Total CO column densities retrieved from AERI spectra during Pre-MOVE, March 2-5 1998 by MOPITT Correlative Team members (McMillan and He) are presented in the upper panel. Dot-dash lines connect retrievals interrupted by cloudy sky scenes while solid lines connect continuous data points.



- The bottom panel shows an expanded view of the time period on 3 March 1998 (GMT) and compares the CO columns retrieved from AERI spectra to those retrieved from coincident ground-based SORTI and UT spectrometer measurement. We are very encouraged by the initial agreement of all these retrievals to +/- 10%.



# Post-launch Activities



## Major components of post-launch MOPITT data validation activities:

- > Airborne in-situ and sampling measurements.
- > Airborne remote sensing measurements.
- > Ground-based spectroscopic measurements.
- > Surface measurements.
- > Satellite measurements.



## Airborne In-Situ and Sampling



- **Aircraft in-situ CO and CH<sub>4</sub> profiling.**

(1) Long-term A/C CO and CH<sub>4</sub> profiling at selected sites (Validation AO selection).

- | <b>-&gt; Site</b>               | <b>Location</b>  | <b>Environment</b>                              |
|---------------------------------|------------------|---|
| Harvard Forest<br>Massachusetts | 42.54 N/72.18 W  | Continental polluted<br>forest regions          |
| Barrow, Alaska                  | 71.32 N/156.6 W  | High northern latitude<br>pollution from Europe |
| Carr, Colorado                  | 40.15 N/104.13 W | Continental, northern<br>plains                 |
| Mauna Loa, Hawaii               | 19.53 N/155.58 W | Oceanic, northern<br>central Pacific            |
| American Samoa                  | 14.57 S/170.57   | Oceanic, southern<br>eastern Pacific            |
- > Biweekly (i.e. every 2 weeks) measurements of CO and CH<sub>4</sub> profiles at 5 carefully selected sites.
  - > Samples collected at predefined altitudes (approximately 500 m intervals over an altitude range of 0.3 to 8-9 km) using portable, automated equipment aboard small aircraft.
  - > Collaborators(NASA AO): Paul Novelli *et al.*, NOAA/CMDL





## Airborne In-Situ and Sampling



- **Aircraft In-situ CO and CH<sub>4</sub> profiling (continued).**

(2) **A/C CO and CH<sub>4</sub> in-situ profiling during campaigns in Africa (SAFARI-2000). Funded by the Validation Office.**

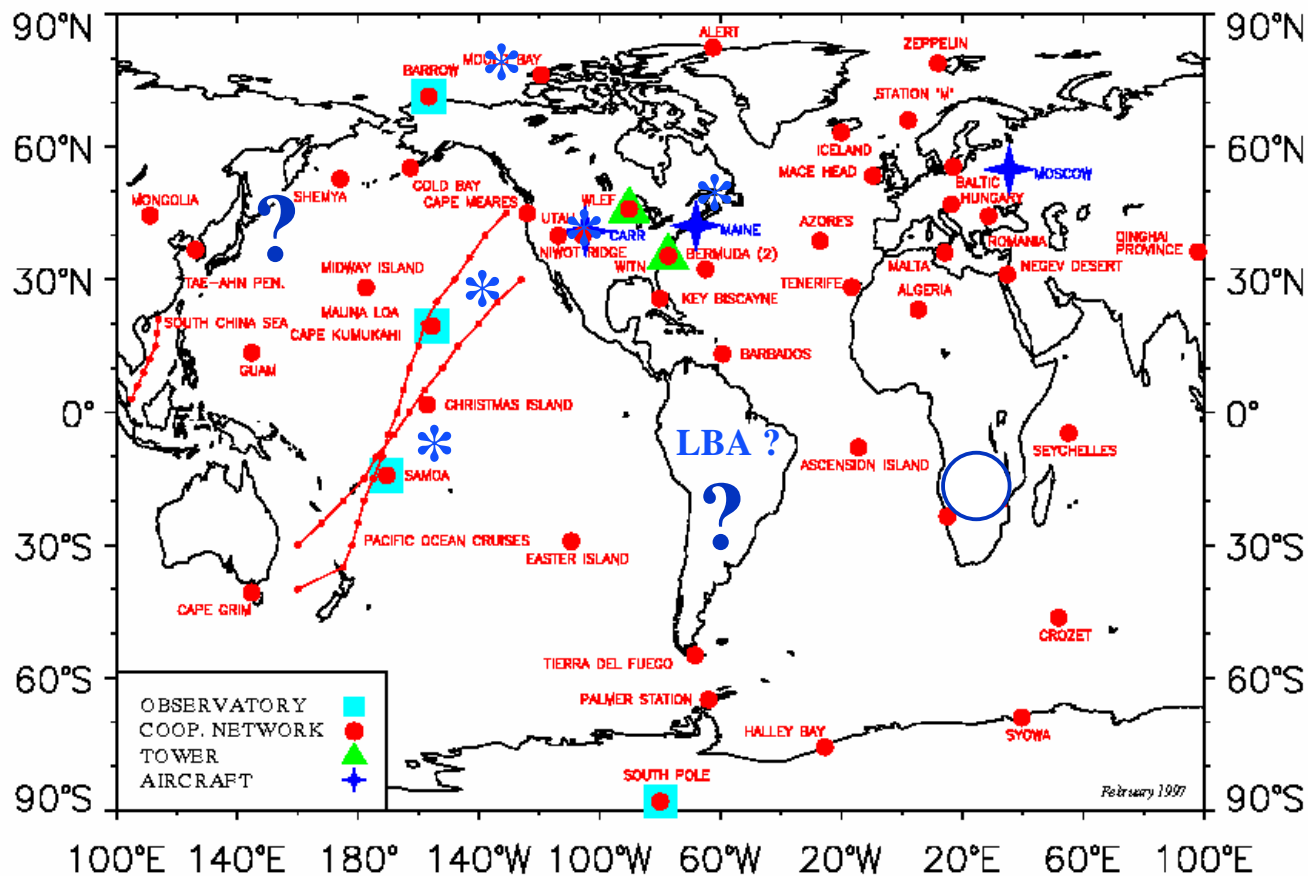
- > **In-situ measurements of CO and CH<sub>4</sub> profiles in South Africa during the wet season (January - February) in 2000.**
- > **In-situ measurements of CO and CH<sub>4</sub> profiles in South Africa during the dry season (August - September) in 2000.**



# Airborne In-Situ Measurement Locations



NOAA CMDL Carbon Cycle Group Measurement Programs



- Only 1-2 surface sampling sites in Africa.
- No profile measurement sites in Asia and South America.

\*: Aircraft in-situ profiling sites selected for MOPITT CO and CH<sub>4</sub> validation.

○: Aircraft in-situ profiling of CO and CH<sub>4</sub> during SAFARI-2000.



# Airborne Remote Sensing



## • Airborne remote sensing measurements.

- (1) **MOPITT Airborne Test Radiometer (MATR) validation campaigns (~ 1-2/year)**
  - U.S. MOPITT team activities.
  - Participated in Pre-MOVE I at the DOE ARM site, March 2-6, 1998.
  
- (2) **MOPITT Airborne Simulator (MOPITT-A) validation campaigns (~ 1-2/year)**
  - Canadian MOPITT team activities.
  - Plan to conduct a test flight on ER-2 in 1999 in collaboration with MODIS team (Yoram Kaufman) during the Fire Experiment.
  - Plan to participate in SAFARI-2000 NASA ER-2 flights in 2000.
  
- (3) **Airborne FTIR**
  - Scanning HIS (SHIS) instrument during SAFARI-2000 campaign in 2000.
  - NAST-I instrument flight on Proteus during SAFARI-2000 campaign (?).
  - Other campaigns (collaboration with NASA/Langley and U. of Wisconsin) (?).



# Ground-based Spectroscopic Measurements



- **Ground-based spectroscopic measurements (spectrometers & FTIRs)**
  - (1) **CO and CH<sub>4</sub> retrievals from FTIR solar absorption measurements at 12 selected sites.**
    - > **List of sites (Eureka, Spitsbergen, Harestua, Zvenigorod, Zugspitze, Jungfrauoch, Moshiri, Egbert, Rikubetsu, Kislovodsk, Kitt Peak, Lauder).**
    - > **Frequency of measurements for MOPITT validation will vary from station to station.**
      - (1) **Routine NDSC measurements (daily or weekly).**
      - (2) **Intensive validation campaigns (2 -3 per year) with daily measurements.**
    - > **Collaborators(NASA AO): Nikita Pougatchev *et. al.*, CNU & NASA Langley.**
  - (2) **CO and CH<sub>4</sub> retrievals from FTIR solar absorption measurements at 6 sites.**
    - > **List of sites (Antarctica, Wollongong, Mauna Loa, 3 DOE ARM sites).**
    - > **Frequency: probably daily**
    - > **Collaborators (NASA AO, NDSC): Frank Murcray *et. al.*, University of Denver.**



## Location of ground-based spectroscopic stations for MOPITT data validation (Pougatchev *et al.*)



<u>Spectroscopic Station</u>	<u>Location(degree)</u>	<u>Elevation(m)</u>	<u>Spectrometer</u>
Atmospheric Environment Service, Eureka, Canada	80.05 N/86.4 W	610	FTIR, Bomem DA8
Alfred Wegner Institute for Polar and Marine Research(Germany) Spitsbergen, Norway	78.90 N/11.9 E	10	FTIR, Bruker 120M
Swedish Environmental Research Institute, <u>Harestua</u> , Sweden	60.00 N/11.0 E	560	FTIR, Bruker 120M
Institute of Atmospheric Physics, Zvenigorod, Russia	55.40 N/36.5 E	200	Grating
Fraunhofer-Institut fuer Atmosphaersche Umweltforschung, Zugspitze, Germany	47.40 N/11.0 E	2964	FTIR, Bruker 120HR
International Scientific Station Jungfrauoch, Switzerland	47.00 N/8.0 E	3580	FTIR
University of Nagoya, Moshiri, Japan	44.36 N/142.3 W	20	FTIR, Bruker 120HR
Atmospheric Environment Service, Egbert, Canada	44.20 N/79.8 W	251	FTIR, Bomem DA8



## Location of ground-based spectroscopic stations for MOPITT data validation (Pougatchev *et al.*)



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<u>Spectroscopic Station</u>	<u>Location(degree)</u>	<u>Elevation(m)</u>	<u>Spectrometer</u>
University of Nagoya, Rikubetsu, Japan	43.50 N/143.8 E	215	FTIR, Bruker 120M
Institute of Atmospheric Physics, Kislovodsk, Russia	43.50 N/42.4 E	2100	Grating
National Solar Observatory, Kitt Peak, USA	32.00 N/111.5 W	2090	FTIR
National Institute of Water and Atmosphere Lauder, New Zealand	45.00 S/169.8 E	370	FTIR



## Location of ground-based spectroscopic stations for MOPITT data validation (Murcray *et al.*)



<u>Spectroscopic Station</u>	<u>Location(degree)</u>	<u>Elevation(m)</u>	<u>Spectrometer</u>
University of Denver & NIWA, Arrival Heights, Antarctica	78.00 S/167.0 E	180	FTIR, Bruker 120M
University of Wollongong, Wollongong, Australia	34.00 S/151.0 E	35	FTIR, Bomem DA8
University of Denver, Mauna Loa, Hawaii	37.00 N/98.0 W	3100	FTIR, Bruker IFS120HR
DOE ARM SGP Site, Lamont, Oklahoma	36.80 N/97.5 W	318	FTIR, Bruker IFS120M
DOE ARM TWP Site, Lamont, Oklahoma	2.06 S/147.4 W	6	FTIR, Bruker IFS120M
DOE ARM NSA Site, Barrow, Alaska or Fairbanks, Alaska	71.32 N/156.6 W  64.83 N/147.7 W	?  150	FTIR  FTIR, Bruker IFS120M



## Surface and Other Satellite Measurements



- **Surface and boundary layer measurement.**
  - > 48 sites operated by NOAA/CMDL & collaborators.
  - > Not critical for level 1 and level 2 data validation.
  - > Useful for level 3 data validation and modeling activities.
  
- **Intercomparison with other satellite measurement.**
  - > Troposphere CO column from SCIAMACHY on ENVISAT-1 to be launched in 2000.
  - > CO and CH<sub>4</sub> measurement (?) from MIPAS on ENVISAT-1 to be launched in 2000.
  - > Free troposphere CO column and CO profiles from TES to be launched in December 2002 on the EOS/CHEM platform.
  - > CH<sub>4</sub> measurement from HIRDLS on EOS/CHEM platform.
  - > IMG II from Japan (?).
  
- **MOPITT and TES CO Retrieval Comparison.**
  - > Using simulated MOPITT data for MOPITT retrieval.
  - > Using simulated TES data for TES retrieval.





# Summary



- A comprehensive MOPITT data validation plan is in place. The MOPITT correlative measurement team has been established with support from EOS Validation Office.
- MOPITT correlative measurements include aircraft in-situ measurements at 5 carefully selected sites and during validation campaigns, airborne remote sensing measurements, ground-based interferometer and spectrometer measurements, and other satellite measurements.
- A Pre-launch validation exercise (Pre-MOVE I) was conducted at the DOE ARM site in Lamont, Oklahoma to inter-compare different correlative measurements. Preliminary results are very encouraging. More intercomparisons are planned.

The MOPITT team welcome collaborations in MOPITT data validation and tropospheric chemistry studies using MOPITT observations. Please contact Jinxue Wang at [jwang@eos.ucar.edu](mailto:jwang@eos.ucar.edu), John Gille at [gille@ucar.edu](mailto:gille@ucar.edu), Jim Drummond at [jim@atmosp.physics.utoronto.ca](mailto:jim@atmosp.physics.utoronto.ca) for MOPITT validation collaborations.

MOPITT Validation Plan Version 4.0 is available at NCAR and NASA Validation web site.

Anonymous MOPITT FTP site: [eos-atm.eos.ucar.edu /pub](ftp://eos-atm.eos.ucar.edu/pub)

NCAR MOPITT Homepage: <http://eos.acd.ucar.edu/mopitt/home.html>

U. of Toronto MOPITT Homepage: <http://www.atmosp.physics.utoronto.ca/MOPITT/home.html>