Validation of MOPITT Retrievals of Carbon Monoxide

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Abstract*-Validation of the MOPITT retrievals of carbon monoxide (CO) has been performed with a varied set of correlative data. These include *in situ* observations from a regular program of aircraft observations at 5 sites. Additional *in situ* profiles are available from several short-term research campaigns. These *in situ* profiles are critical for the validation of the retrieved CO mixing ratio profiles from MOPITT. Ground-based spectroscopic measurements are compared to MOPITT CO total column densities to validate the observed seasonal cycles. The current validation results indicate good quantitative agreement between MOPITT and *in situ* profiles, with an average bias less than 20 ppbv. The same seasonal cycles are see in MOPITT and the ground-based spectroscopic data. These validation comparisons provide critical assessments of the retrievals, and continuing improvements to the retrieval algorithms are reducing the validation biases.

MOPITT OBSERVATIONS AND RETRIEVAL PRODUCTS

The Measurements of Pollution in The Troposphere (MOPITT) instrument, onboard the EOS/Terra satellite, makes nadir observations of carbon monoxide (CO) and methane (CH_4) using gas-correlation radiometry [1]. Mixing ratios of CO are retrieved for 7 pressure levels, from the surface to 150 hPa. Total column densities are also retrieved independently. Retrievals are performed using the optimal estimation technique [2].

PROFILE VALIDATION

When comparing the MOPITT retrievals with *in situ* data, it is necessary to account for the sensitivity of the retrieval to the true observed profiles. The *in situ* profiles must be convolved with the averaging kernels and *a priori* profile for a proper comparison:

$$x' = x_a + A(x - x_a)$$

where x is the "true" *in situ* profile, x_a is the *a priori* profile, and A is the averaging kernel matrix.

A set of typical averaging kernels for the CO profiles is shown in Fig. 1. The shape and magnitude of the averaging kernels depends strongly on the surface temperature, so will vary for different locations on the globe.

Fig. 2 shows an example of the effect of convolving an *in situ* profile with the averaging kernels and a priori profile. This figure illustrates how the averaging kernels smooth the *in situ* profile. The *a priori* profile also shifts the transformed profile from the mean of the observations. In this case MOPITT is about 10 ppbv higher than the in situ data in the lower troposphere, with the bias decreasing at higher altitudes.

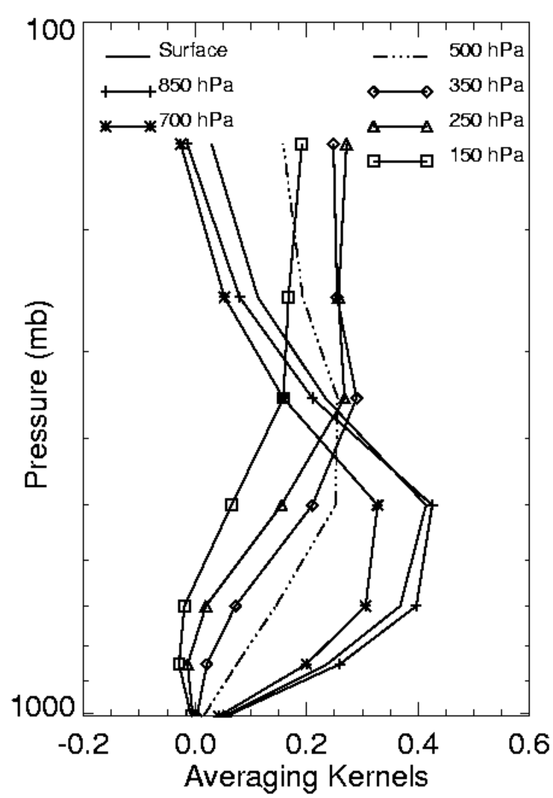

Fig. 1. Typical averaging kernels for MOPITT CO profiles.

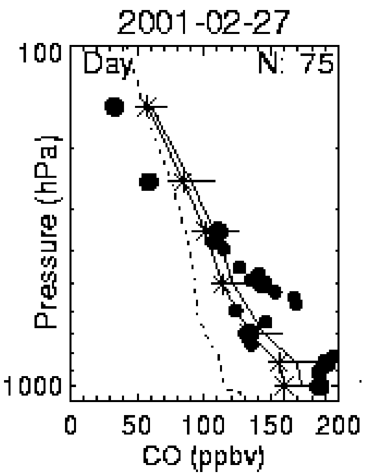

Fig. 2. Transformation (*) of an in situ profile (circles) in comparison with MOPITT retrieval (solid line). The a priori profile is shown as the dashed line.

CMDL Profile Comparisons

In situ observations of CO and CH_4 are obtained on regular aircraft flights at five sampling sites operated by CMDL (see Table 1). These data have provided consistent and reliable data with which to perform validation of MOPITT retrievals. Additional profiles have been obtained as part of other field campaigns (SAFARI-2000, MOVE, PICO3, TRACE-P). Prior to performing the validation, the *in situ* profiles are extended to 150 hPa using results from the NCAR global chemical transport model MOZART. This introduces some uncertainty into the validation, particularly at the higher altitudes. The lower altitudes are also affected, as indicated by the averaging kernels in Fig. 1.

The results of the validation comparison for the CMDL data at the 5 anchor sites and during the SAFARI-2000 and MOVE campaigns are shown in Fig.3. Each symbol indicates the difference for each validation profile and MOPITT overpass. The lines are the average of all daytime (solid) and nighttime (dashed) MOPITT overpasses. The average difference at each site is approximately 10 ppbv, but there is up to 50 ppbv (or more, at Carr) difference on individual days.

Table 1. CMDL Regular Sampling Sites and Campaigns

Site	Location
Carr, CO	40.9 N, 104.8 W
Harvard Forest, MA	42.5 N, 72.2 W
Poker Flats, AK	65.1 N, 147.3 W
Hawaii	21.2 N, 158.9 W
Rarotonga	21.2 S, 159.8 W
SAFARI-2000 (Aug-Sep 2000)	South Africa
MOVE (Oct 2000)	Colorado, California

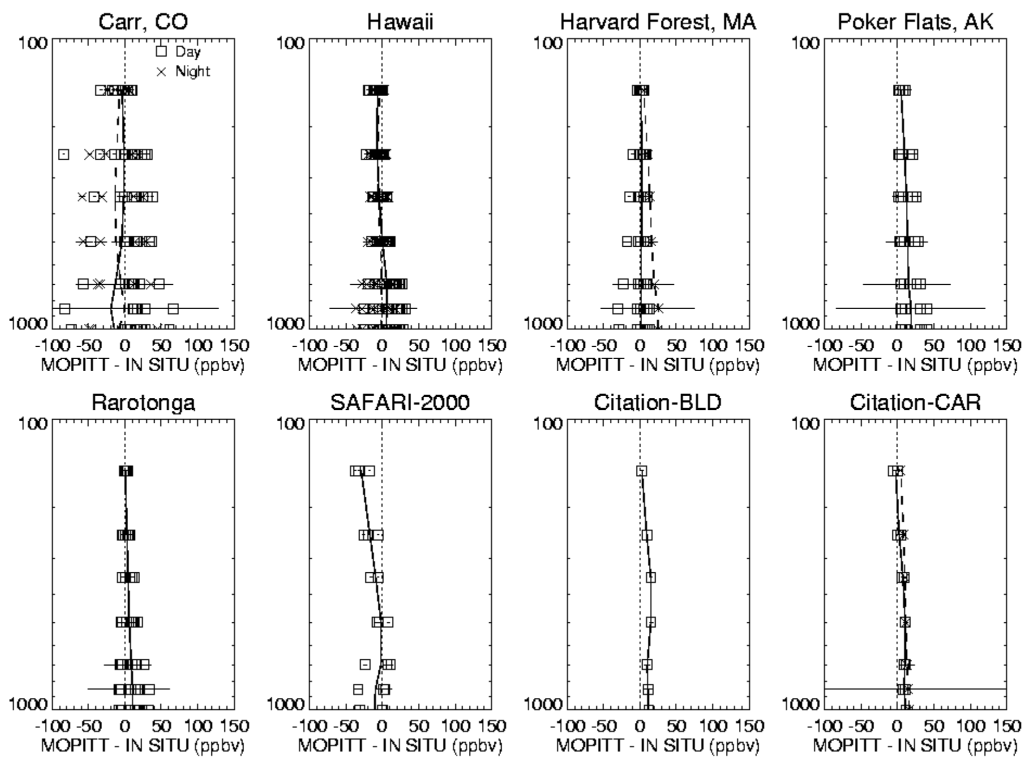

Fig. 3. Difference between MOPITT and CMDL *in situ* profiles.

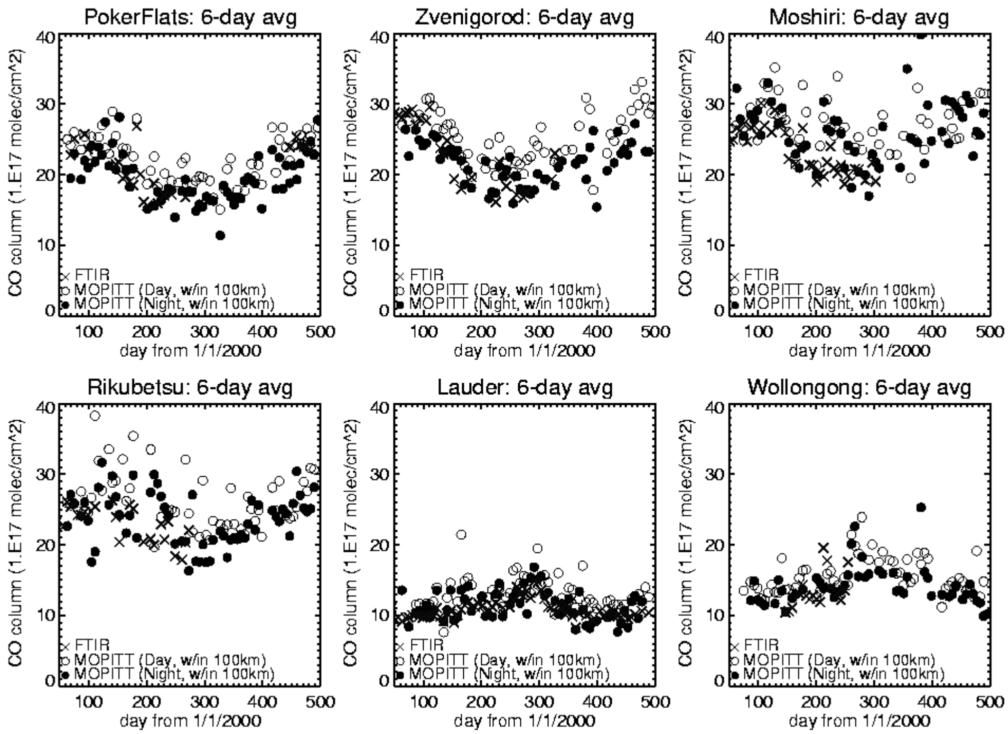

Fig. 4. Comparison of ground-based FTIR and grating spectrometer observations with MOPITT CO columns within 100 km of ground site. Data are shown for Mar 2000-Mar 2001.

TABLE 2. SPECTROSCOPIC SITES SHOWN IN FIG. 4

Site	Investigator	Spectrometer
Poker Flats, Alaska (65N, 148W)	U. Denver	FTIR
Zvenigorod, Russia (55N, 36E)	Inst. Atm. Physics	Grating
Moshiri, Japan (44N, 142E)	U. Nagoya	FTIR
Rikubetsu, Japan (43N, 144E)	U. Nagoya	FTIR
Lauder, New Zealand (45S, 170E)	NIWA	FTIR
Wollongong, Australia (34S, 151E)	U. Wollongong	FTIR

SEASONAL VARIATION

The ground-based spectroscopic observations of column CO from six sites (identified in Table 2) are shown in Fig. 4. It is difficult to perform a quantitative validation between MOPITT and ground-based observations, as the two types of instruments are sensitive to different parts of the atmosphere, and therefore have different averaging kernels. Without knowing the true profile distribution, it is not possible to precisely apply the two different averaging kernels to calculate a directly comparable quantity from the two instruments. However, since the ground-based measurements are essentially continuous, it is possible to qualitatively validate the seasonal cycle as seen by MOPITT.

In Fig. 4, daytime and nighttime MOPITT overpasses within 100 km of the ground site are plotted separately with the spectroscopic data. Daytime data is generally higher than nighttime over polluted land regions, where CO concentrations are high near the surface. This is due to the daytime retrievals having a greater sensitivity to the lower atmosphere due to warmer surface temperatures. Averages were made over 6 days to reduce the scatter in the data, and reduce differences due to a lack of coincidence in time.

The first 4 panels show similar seasonal variation for these Northern Hemisphere sites (Alaska, Russia and Japan). CO is highest in winter when photochemistry is least active, and drops in summer when OH concentrations increase. At the two Southern Hemisphere sites, the average column densities are much lower, reflecting the much cleaner troposphere there due to fewer pollution sources. A distinct increase in the column amounts can be seen in September-October when biomass burning in southern Africa and South America is at a maximum.

REFERENCES

[1] Drummond, James R. and G.S. Mand, The Measurements of Pollution in the Troposphere (MOPITT) Instrument: Overall Performance and Calibration Requirements, *Journal of Atmospheric and Oceanic Technology*, **13**, 314, 1996.

[2] Pan, Liwen, John C. Gille, David P. Edwards, Paul L. Bailey, and Clive D. Rodgers, Retrieval of tropospheric carbon monoxide for the MOPITT experiment, *J. Geophys. Res.*, **103**, 32,277, 1998.