Improvement of the Retrievals of Carbon Monoxide in the Planetary Boundary Layers using Combined Infrared and Solar Measurements : A Simulation Study

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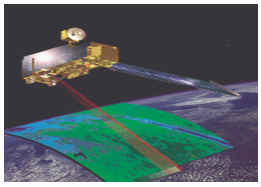
Objective

- Tropospheric carbon monoxide (CO) is produced primarily from anthropogenic emissions related to incomplete combustion, and makes an excellent indicator of poor air quality and a tracer of pollution transport.
- Retrievals of CO from the Measurement Of Pollution In The Troposphere (MOPITT) instrument aboard the low Earth orbit (LEO) EOS-Terra satellite launched in December of 1999 now provide the first global record of the recent inter-annual variability of this important pollutant.
- However, due to instrument noise issue, only infrared measurements are used for MOPITT CO retrievals.
- Because MOPITT infrared measurements are not sensitive to CO information in the lower atmosphere, the retrieved MOPITT CO results in the planetary boundary layer (PBL) are mainly from the background a priori CO profile. The accurate description of CO concentration from MOPITT measurements in the PBL is still not available.

- In this study, we present a simulation study that combines both infrared and reflected near infrared measurements from a MOPITT-like instrument to provide the CO retrievals in the PBL.
- We defined an optimal channel in 2.2 μm CO band that is used together with infrared channels for a retrieval strategy to provide independent sensitivity to CO vertical profiles in both the PBL and free troposphere.
- The cases of strong CO emission due to wild fire over CA and city scale CO pollution near Boston are simulated. The retrieval results using the proposed retrieval strategy are presented.



The Optimal Solar Channel Selections

- MOPITT is a Gas correlation Radiometry, which uses infrared radiances measured near 4.7 μm and solar radiances near 2.2 μm to detect tropospheric CO information.

- Two MOPITT signals are possible:
  Average Signal: Sensitive primarily to thermal emission from the surface. Difference Signal: Sensitive to both thermal emissions from the surface and target gas absorption and emission for different vertical levels.

- By modulating the cell length (Length modulation cell-LMC) or the pressure in the same cell (pressure modulation cell-PMC) in front of a detector, we can control the CO amount in the total atmosphere path and affect the strength of CO absorption line.

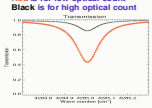
- We have twelve different combinations of LMC and PMC (Table 1).

- Since Case 2 gives us the strongest Weighting Function (WF) among all cases, we use case 2 as the configuration for our solar channel.

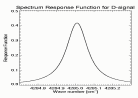
1.	200 mb (cell pressure)	0.4-2cm (cell length)
2.	800 mb	0.4-2cm
3.	100 mb	0.4-2cm
4.	400 mb	0.4-2cm
5.	100-400mb	0.4 cm
6.	100-400mb	2 cm
7.	200-800mb	0.4 cm
8.	200-800mb	2 cm
9.	400-1600mb	0.4 cm
10.	400-1600mb	2 cm
11.	0-400mb	0.4 cm
12.	0-400mb	2 cm

Table 1

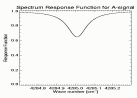
Solar channel transmission for case 2.
Red is for low optical count
Black is for high optical count



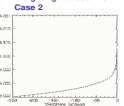
Spectrum Response function For D-signal for case 2



Spectrum Response function For A-signal for case 2

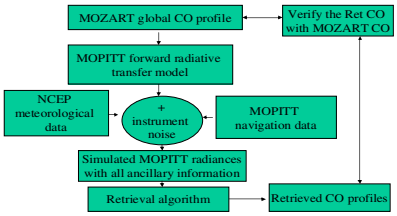


Solar Channel Weighting Function for Case 2

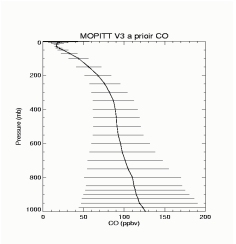


Construction of a MOPITT Simulator

- To represent different measurement characteristics of the MOPITT-like instrument and quantitatively estimate the performance from various observation strategies, we need to construct a MOPITT simulator.
- We use MOZART global CO profiles as the true CO profiles and used as inputs for MOPITT fast model to compute the simulated MOPITT radiances;
- Random measurement noises are added to each computed radiance;
- Using global fixed a priori profile and background covariance matrix;
- Using the current MOPITT V3 Maximum Likelihood (ML) retrieval algorithm.



Schematic diagram of the data flow of Geo-MOPITT simulator



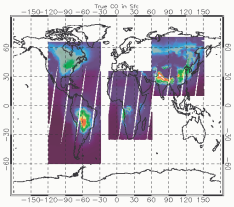
Current MOPITT V3 a priori profile and standard deviation

The Decoupling Method for MOPITT Tropospheric CO Profile Retrieval using Solar and Thermal Channels

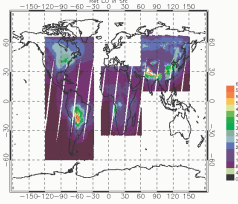
- Although using both MOPITT thermal channels and solar channels, the retrieval results from MOPITT ML method are still highly dependent on the a priori information we used.
- In this study, we explore the use of the Decoupling Retrieval Method for allowing independent sensitivity to CO vertical profiles in both the PBL and free troposphere when using both MOPITT infrared and solar channels.

Decoupling Retrieval Method :

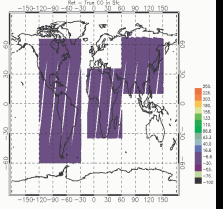
1) Process MOPITT V3 retrievals.
2) Using CO retrievals from 1) as the a priori profile and adjust CO profile below 700 mb, while CO values above 700mb are fixed, until the difference between forward calculated and observed D/A for solar channel are within the instrument noise level.



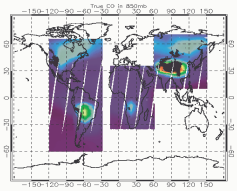
True Sfc CO



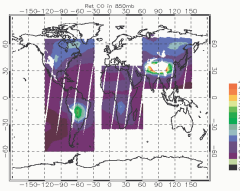
Ret Sfc CO



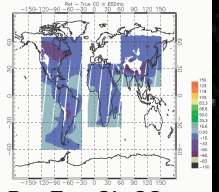
Ret -True Sfc CO
Mean bias = -1.9 ppbv



True 850mb CO



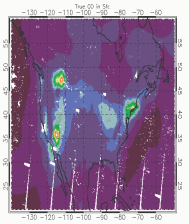
Ret 850mb CO



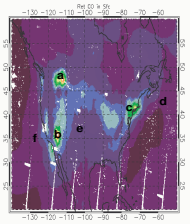
Ret -True Sfc CO
Mean bias = -4.3 ppbv

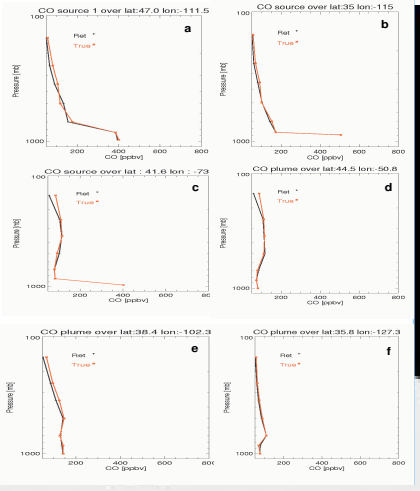
Detection of CO Plumes over North American using the Decoupling Method

True Surface CO



Ret Surface CO





Wild-fire Aug 2000:

- The high CO concentrations caused by wild fires are clearly identified and retrieved. The mean biases between retrieved CO and the true CO at surface and 850 mb are -0.67 ppbv and 0.2 ppbv.

City-scale pollution

- Very shallow industrial/urban emissions over Boston can be identified using the Decoupling Method.

CO concentration in the free troposphere

- High CO values were still found 500 km downwind, eastward and northward of the fires and urban emissions, indicating rapid large-scale transport, which are also be identified using the Decoupling Method.

Conclusions

- The objective of this study is to find an optimal channel in 2.2 μm CO band to combine with MOPITT thermal channels to provide atmospheric CO information from both free troposphere and the PBL.
- To provide independent sensitivity to CO vertical profiles in both the PBL and free troposphere in a local scale using both thermal and solar channels, the Decoupling Method is implemented.
- This method is basically using infrared channels to provide the best CO profiles in the free troposphere and use this retrieved profile as the a priori profile for a further retrieval step. Then we adjust CO profile in the lower atmosphere only until the forward calculated solar radiances match the observed solar radiance within the instrument noise level.
- The CO retrieval results using the decoupling method show excellent agreements with the true MOZART CO profiles at a local scale. The CA wild fire, the wide fires in the North USA and the city-scale pollution near Boston and downwind CO plumes for August 2000 provided from MOZART are clearly identified. The results show that with both MOPITT thermal and solar channels and using the decoupling retrieval algorithm, the independent sensitivity to CO vertical profiles in both the PBL and free troposphere in a local scale can be provided.
- In this study, we have demonstrated the possible capability for a future gas correlation satellite instrument. With the high spatial, temporal and vertical resolution sensing ability, the future MOPITT-like instrument can provide independent sensitivity to CO vertical profiles in both the PBL and free troposphere that may help us to track local city-scale pollution evolutions and may allow us to separate local pollution production from imported pollution.