Connecting surface emissions, convective uplifting, and long-range transport of CO in the upper-troposphere: New observations from the Aura Microwave Limb Sounder

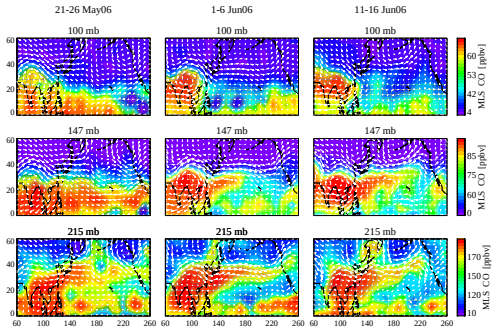
Jonathan H. Jiang[1], Nathaniel Livesey[1], Hui Su[1], Lori Neary[2], John C. McConnell[2], Nigel Richards[3]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, U.S.A.
[2]Department of Earth and Space Science and Engineering, York University, Toronto, Canada; [3]Institute for Atmospheric Science, University of Leeds, United Kingdom

Abstract

Two years of observations of upper tropospheric (UT) carbon monoxide (CO) from the Aura Microwave Limb Sounder are analyzed; in combination with the CO surface emission climatology and data from the NCEP analyses. It is shown that spatial distribution, temporal variation and long-range transport of UT CO are closely related to the surface emissions, deep-convection and horizontal winds. Over the Asian monsoon region, surface emission of CO peaks in boreal spring due to high biomass burning in addition to anthropogenic emission. However, the UT CO peaks in summer when convection is strongest and surface emission of CO is dominated by anthropogenic source. The long-range transport of CO from Southeast Asia across the Pacific to North America, which occurs most frequently during boreal summer, is thus a clear imprint of Asian anthropogenic pollution influencing global air quality.

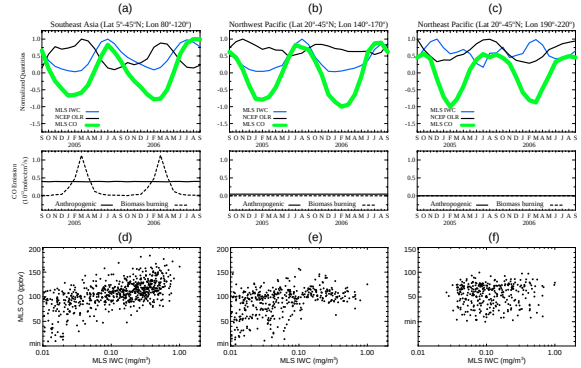
Sporadic long-range transport of CO in the upper troposphere



- The CO distribution varies with height; Plumes of CO episodically extend from South Asia across the Pacific reaching the U.S. west coast following the strong westerly winds.
- At 100 mb, the enhanced CO is mostly concentrated over the Tibetan Plateau due to a strong "trapping effect" of the Asian summer monsoon anticyclone.
- At 147 mb and 215 mb, outflow of CO-rich air is observed to emanate from South Asia, following the mid-latitude westerly jet across the North Pacific and eventually reaching the western United States.

Figure 1. MLS measured CO (V1.5) mean mixing ratios for 21-26 May, 1-6 June and 11-16 June 2006 at three upper tropospheric pressure levels. The white arrows are the mean NCEP vector winds (U,V) at the same pressure levels.

Seasonality of long-range transport in the upper-troposphere



- Southeast Asia: The variability of upper-tropospheric CO closely follows the seasonal cycle of deep-convection, which reaches maximum in July, when CO is mostly from anthropogenic emissions.
- Northwest Pacific: Little CO emission, smaller variation in convection. CO and cirrus amount change in the same phase as those over the Southeast Asia, indicating the outflow of CO rich air and the detrainment of cirrus clouds from South Asia.
- Northeast Pacific: Zero CO emission and changes of CO do not follow variation of convection in the region. The seasonal variation of CO is likely controlled by the long-range transport from Southeast Asia.

Figure 3. Top-panels: Time evolution of monthly mean 147 hPa MLS CO anomaly (thick green-line), 147 hPa MLS IWC (blue-line), and NCEP OLR above 240 W/m2 (black-line). Mid-panels: Time evolution of monthly mean CO emissions from biomass burning (dashed-line) and anthropogenic (solid-line) sources. Lower-panels: Scatter plots of MLS CO versus IWCs at 147 hPa. Panels moving from left to right are for regions of Southeast Asia, Northwest Pacific and Northeast Pacific. All data are 8° × 4° (longitude by latitude) gridded averages. The scatter plots consist 25 monthly mean data from September 2004 to September 2006.

Connection between surface emission, deep-convection and upper tropospheric CO

- Surface Emission: The anthropogenic emission is approximately unchanged throughout year; Bio-mass burning in South Asia usually peaks in spring and weakens in summer and fall.
- Convection in the South Asia, as indicated by the MLS IWC and NCEP OLR, is the strongest in summer, associated with Asian monsoon, and lasts until early fall.
- Upper-tropospheric CO loading, as observed by MLS, maximizes in summer, resulted from convective transport of surface emitted CO (mostly from anthropogenic sources) into the upper-troposphere.

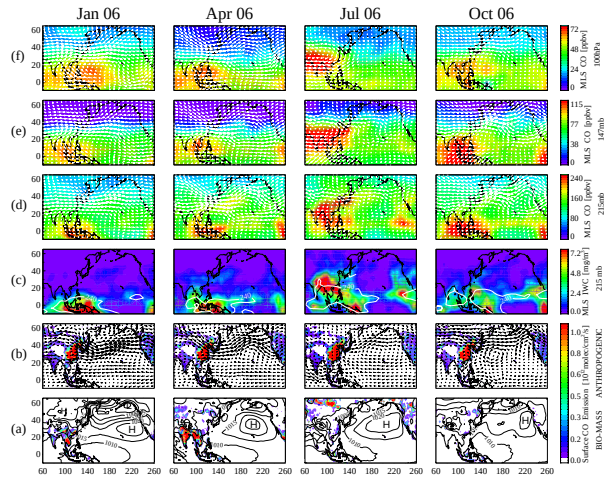


Figure 2. From left to right columns are monthly mean values (January, April, July, October 2006) averaged on 8°×4° longitude by latitude grids. From bottom panel and up: (a) Bio-mass burning emissions of CO (color-filled contour) and NCEP sea-level-pressures (line-contour); (b) Anthropogenic CO emissions (color-filled contour) and the 700 hPa vector winds (U,V) from NCEP analysis; (c) MLS measured IWC at 215 hPa and the 240 W/m^2 OLR contours in white line contours for the tropical region from NCEP (low OLR in the high-latitude are not shown); (d), (e) and (f) are MLS measured CO mixing ratios at 215hPa, 147hPa, and 100hPa pressure levels, respectively, over plotted by NCEP vector winds at same pressures levels.

Typical transport regimes of upper-troposphere CO

- **The distribution of CO in the upper troposphere is controlled by a combination of surface emissions, deep convection, and winds.**

Typical regimes:

I Strong deep convection deposits surface CO emissions into the upper troposphere.
II Convection is strong but surface emissions low; observed high CO arises from convective lofting of CO transported from another area.
III No convection, low emissions; CO enhancements arise from long-range transport of CO-rich air.
IV Large surface emissions but no convection or horizontal transport.

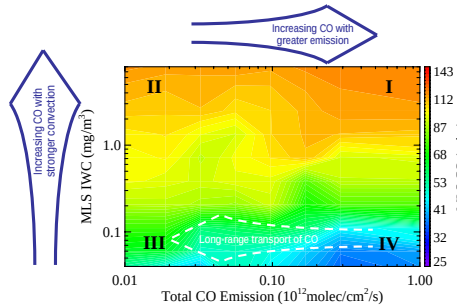


Figure 4. Contour plots of MLS CO mixing ratio at 147 hPa binned according to the total surface emission and MLS IWC amount at same pressure. All data are monthly mean values from September 2004 to September 2006 on 8°×4° longitude by latitude grids.

ACKERKNOWLEDGEMENTS

This work was performed at Jet Propulsion Laboratory (JPL), California Institute of Technology, under contract with NASA. We are grateful to the Aura MLS project and wish to thank useful comments from Mark Shoeberl, Steve Massie, Chuntao Liu, Qinbin Li, Joe Waters, Michelle Santee, Rong Fu, and Mijeong Park. JHJ and HS also wish to thank Phil DeCola, Rangasayi Halthore, Ernest Hilsenrath and the NASA Atmospheric Composition program for support. LN and LCM wish to thank the Canadian Foundation for Climate and Atmospheric Science MAQNet grant.