Geographic and Seasonal Distributions of CO Transport Pathways and Their Roles in Determining CO Centers in the Upper Troposphere

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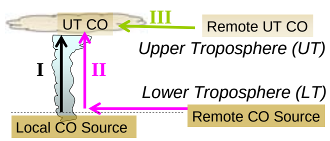
1. Introduction

Carbon monoxide (CO) :

- important role in atmospheric chemistry and radiation balance
- produced by incomplete combustion of carbon-based fuels
- lifetime of 1-2 months in the troposphere, used as a good tracer

UT CO Transport pathway:



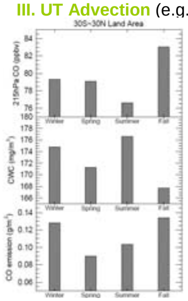
What are the roles and relative importance of these transport pathways in determining the locations and seasonality of the UT CO centers?

Three pathways for transporting biomass burning generated CO to the upper troposphere (UT) CO center:

I. Local convection (e.g., Thompson et al. 1996)

II. LT advection → convection (e.g., Folkins et al. 1997)

III. UT Advection (e.g., Ray et al. 2004)



- CO emissions at the surface peak during boreal fall and winter, while convective activity peaks during boreal summer and winter.
- UT CO peaks during boreal fall, and is higher during boreal spring than during summer.
- The lack of correlations among peaks in UT CO and peaks in surface emission and convective activity highlights the potential importance of transport pathways.

2. Data and Methodology

Aura TES L2 CO: 5.3 × 8.3 km (3.2-15.4 µm)

Aura MLS L2 CO: 300-400 × 4km (240 GHz)

Cloudsat CWC: 1.3 km × 1.7 km × 240m (94 GHz)

GFED v2.1: 1° × 1° gridded, derived from MODIS fire counts

- **Local convection pathway:** CO emission, deep convection and increase of CO in the UT are simultaneously detected during an 8-day period.
- **LT Advection → convection pathway:** deep convection and increase of CO in the UT are simultaneously detected without co-located surface CO emission during an 8-day period. .
- **UT advection pathway:** increase of CO in the UT is detected in the absence of co-located deep convection during an 8-day period.
- The influence of transport fluxes on UT CO concentration is diagnosed by evaluating the change in mean CO concentrations at 215 hPa between two consecutive 8-day periods.
- Vertically integrated CloudSat cloud water content (CWC) above 6 km is used to represent the strength of deep convective activity during the 8-day period.

➢ The threshold of UT CO increase is 10 ppbv.

➢ The threshold of CWC to determine deep convection is 100 mg m^{-3}.

➢ The threshold of fire counts is 10 1km × 1km fire pixels within each 8° × 4° grid box.

3. Two Case Studies

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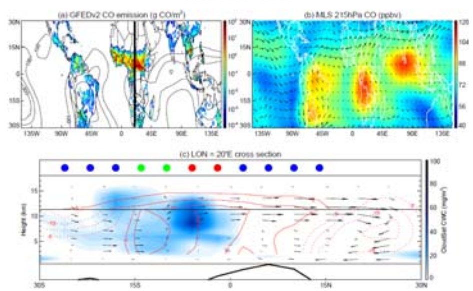

Grid Box	Identified Pathway	TrjFrac
28°S–24°S	UT advection	100%
24°S–20°S	UT advection	94%
20°S–16°S	UT advection	41%
16°S–12°S	LT advection → convection	79%
12°S–8°S	LT advection → convection	86%
8°S–4°S	local convection	67%
4°S–0°	local convection	44%
0°–4°N	UT advection	93%
4°N–8°N	UT advection	100%
8°N–12°N	UT advection	100%
12°N–16°N	UT advection	100%

Over Central Africa, CO appears to be transported to the UT via the “LT advection → convection” and “local convection” pathways. Over northern Africa, CO is transported via the “UT advection” pathway.

The automated detection method captures these pathways and the results are in good agreement with those of trajectory simulations.

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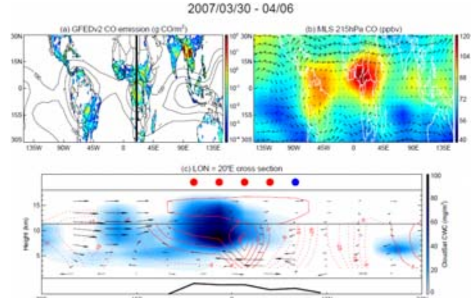
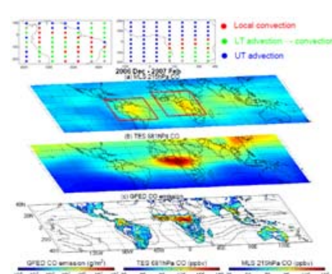


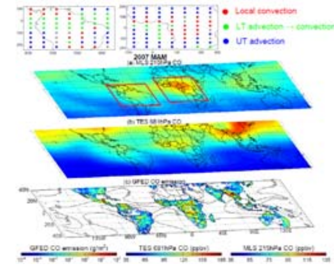
For the boreal spring case, the automated method also successfully diagnosed “local convection” as the dominant CO transport pathway between 8°S and 8°N.

4. Seasonal Distribution of CO Transport Pathways

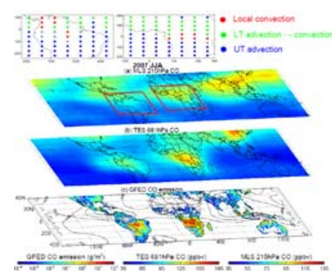


The primary fire regions and the centers of high UT CO were located in opposite hemispheres.

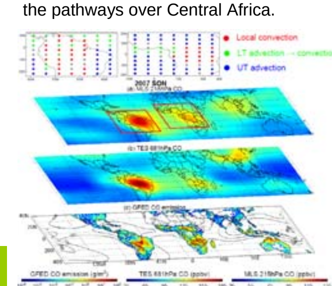
“LT advection → convection” was the dominant pathway for transporting CO to the UT over South America.



The overlap between convective activity and the fire source regions increased the occurrence and spatial coverage of the “local convection” pathway over the tropical African continent relative to boreal winter.



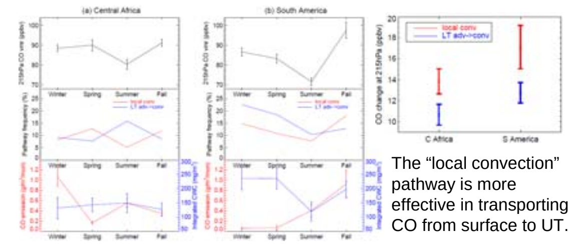
The locations of strongest CO emissions and strongest deep convective activity are in opposite hemispheres relative to boreal winter, which causes a similar reversal in the preferred hemispheric locations of the pathways over Central Africa.



The “local convection” pathway was not as prevalent over Central Africa as over South America, and “UT advection” played a more central role in this region.

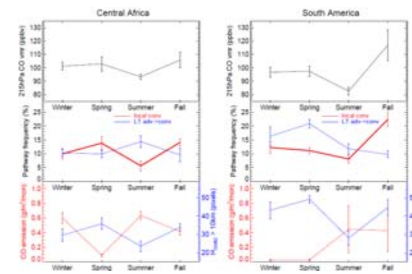
5. Year 2007 Analysis

The seasonality of the UT CO over Central Africa and South America does not follow those of CO surface emission or deep convective activity. Rather, it primarily follows the seasonality of CO transport by the “local convection” pathway.

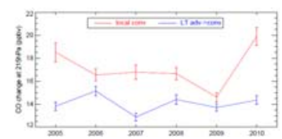


The “local convection” pathway is more effective in transporting CO from surface to UT.

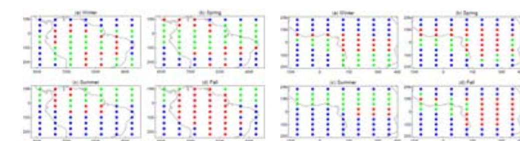
6. Multi-year (2005 - 2010) Analysis



The multi-year analysis also suggested The seasonality of the CO concentration in the tropical UT mainly follows the seasonality of “local convection” transport pathway.



During each year (2005 - 2010), the “local convection” pathway is significantly more effective in transporting CO from surface to UT than the “LT advection → convection” pathway.



7. Conclusions

➢ We have developed a method for detecting UT CO transport pathways on seasonal to interannual scales using Aura MLS, CloudSat and MODIS data.

➢ Dominant UT CO transport pathways vary both geographically and seasonally.

➢ The seasonality of the CO concentration in the tropical UT mainly follows the seasonality of “local convection” transport pathway, because “local convection” pathway is more efficient than “LT advection → convection” pathway.

References

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