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Long term trends of Carbon Monoxide (CO) in the Upper Troposphere Lower Stratosphere (UTLS) using MLS Measurements from 2004 to 2023

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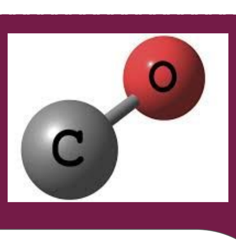
Introduction



Carbon Monoxide

Sources
- Direct surface emissions from fuel combustion, biomass burning and forest fires
- Secondary chemical oxidation of methane and other hydrocarbons in the troposphere
- Photochemical lifetime of 2-3 months

Characteristics
- Important precursor for tropospheric ozone production
- Excellent tracer for transport of transport of atmospheric pollutants
- Major sink of CO through oxidation by OH
- Stratosphere-troposphere exchange

CO profiles in the UTLS provide information on the transport pathways. Analyzing long term trends (2004-2023) with MLS dataset can improve our understanding of atmospheric variation of CO and the impact of human activities on the climate.

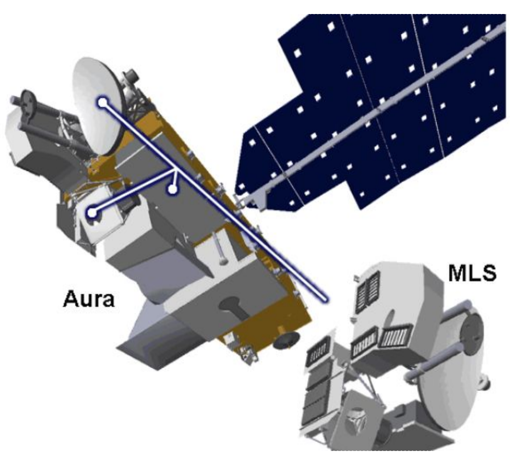
Research Objectives

- To observe long term trends and annual and seasonal variability of CO in the UTLS over the years from 2004 to 2023 through MLS dataset
- To explore potential correlations between the observed CO trends and known climatic factors or events that might influence CO concentrations

Methodology

Microwave Limb Sounder (MLS)

- One of four instruments onboard NASA's Aura spacecraft launched on 15 July 2004
- A single day of MLS observations consists of 3495 scans across the Earth's limband



Dataset

- MLS/Aura Level 3 Monthly Binned Carbon Monoxide (CO) Mixing Ratio on Assorted Grids V005 (ML3MBCO)
- Refined data range: 2004-08-02 to 2023-12-31
- Spatial coverage - near-global (-82 to +82 degrees latitude)
- Spatial resolution - 4° latitude by 5° longitude
- Vertical resolution - 6 km
- Useful vertical range -between 215 and 0.00464 hPa

Linear regression and distributional mapping are applied to analyze the MLS dataset.

Results and Discussion

Horizontal Distributions

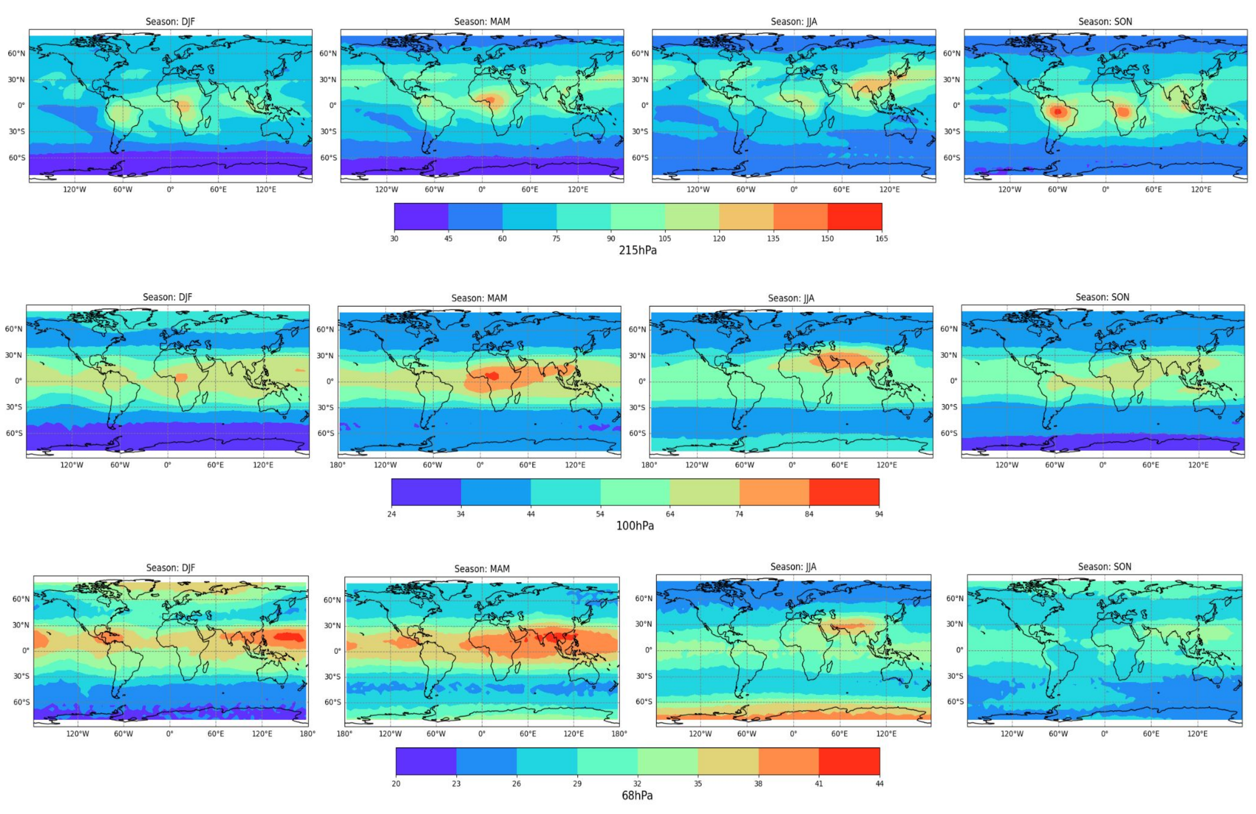


Fig 1. Horizontal distributions of CO in the UTLS averaged from 2004 to 2023

High CO mainly located in the tropics in the UTLS →
- Tropics are characterized by intense and frequent convective activity such as cyclones

Highly elevated CO region observed in Africa →
- Signature of northern hemisphere harmattan intense burning in DJF
- Peaks in April and Sep due to agricultural burning months
- Highest in DJF and MAM, lowest in SON in northern hemisphere
- Gradual increase of 2.3 Mhayr-1 of burned area in Africa since 2000

Significant CO peaks during DJF and MAM in South East Asia →
- Due to significant biomass burning in those dry seasons

Results and Discussion

Annual variations in specific regions

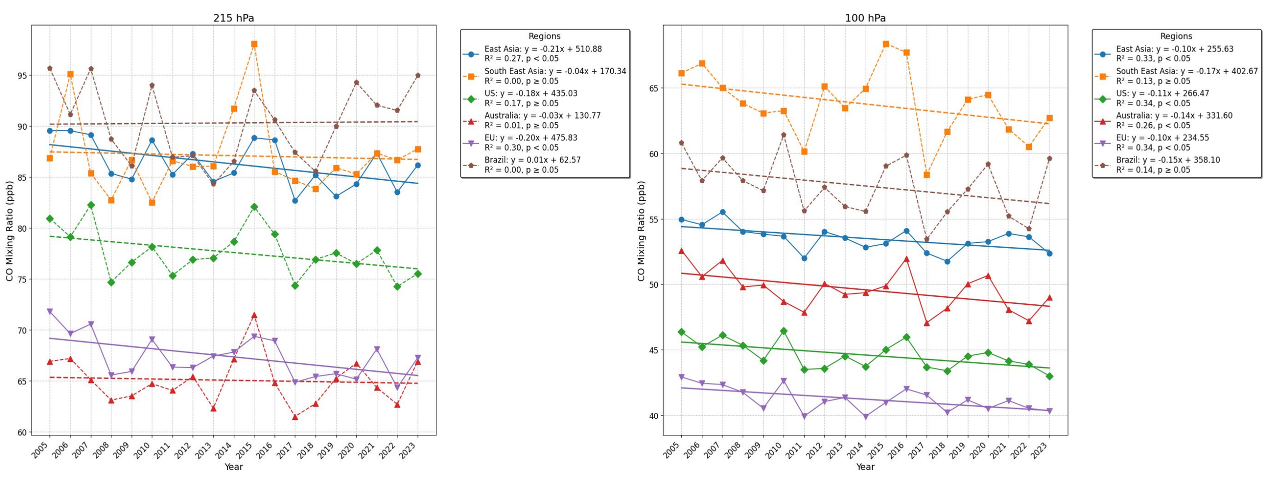


Fig 2. Annual variations of CO for specific regions

- Negative trends of CO concentrations are observed over many regions of the world.
- Gradual decreasing trends are observed in Australia, US and EU at both 215 hPa and 100 hPa.

East Asia
- Rapid decline of CO at both pressure levels
- 76% of the decrease is due to the emissions control of four source sectors in China, i.e. iron and steel industries, residential sources, gasoline-powered vehicles, and construction materials industries.
- MOPITT and ground-based CO measurements suggest a downward trend in CO over East Asia during 2005–2016

South East Asia
- Peak of annual mean CO in 2015 as a result of 2015-16 El Niño
- An especially dry period from July to October in Indonesia
- Indonesia's 2015 fire season burned more than 2.6 million hectares [NASA] and contributed to a severe fire season and significant carbon and pollution emissions

Seasonal Cycles

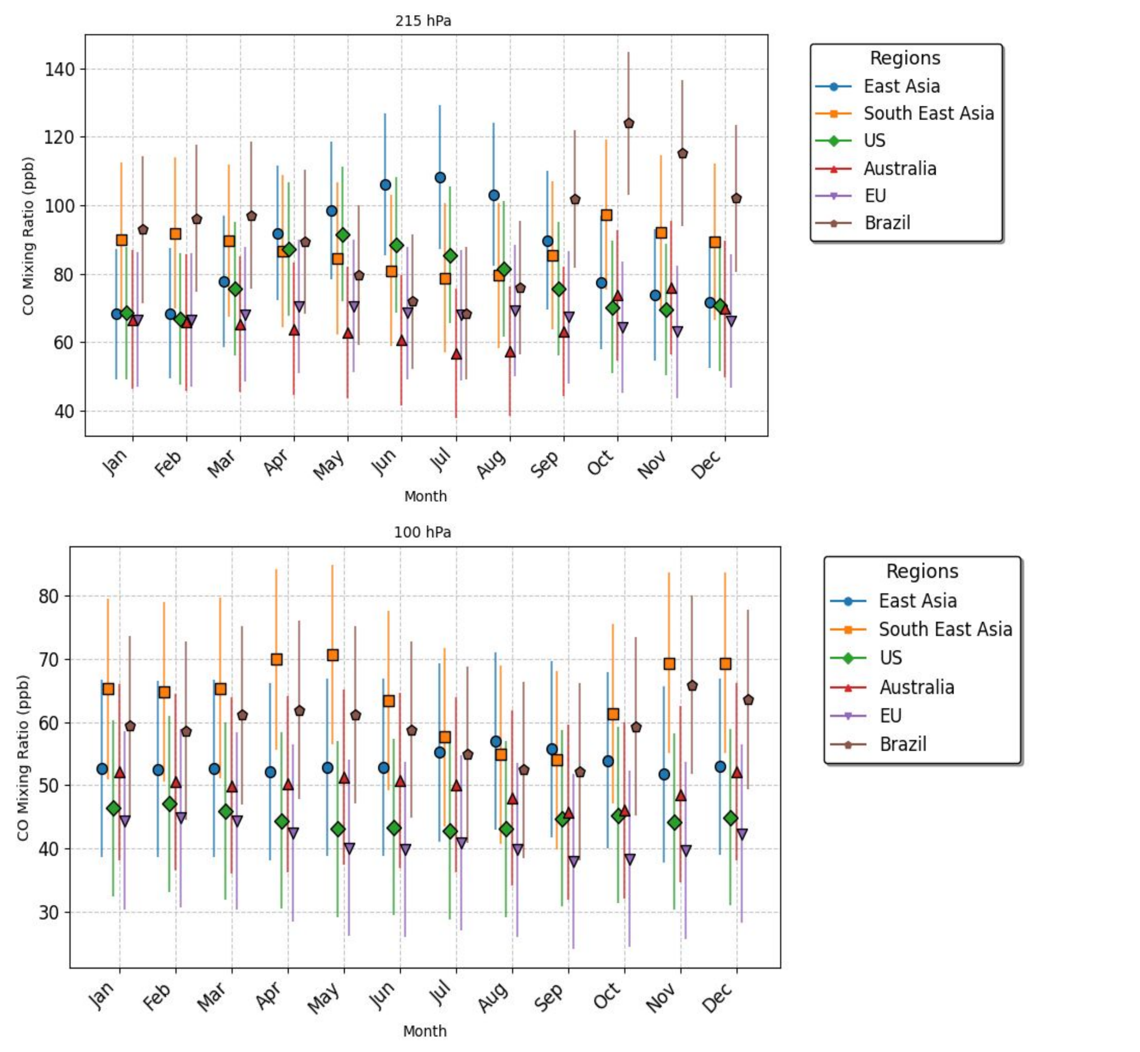


Fig 3. Mean Seasonal Cycles of CO

Brazil
- A significant peak of CO at 215 hPa
- Oct is the peak fire month for 2010 and 2015 in Brazilian Amazon, causing forest fire carbon emissions
- Fire incidence increased by 36% during the 2015 drought compared to the preceding 12 years

South East Asia
- Highly elevated CO at the pressure of 100 hPa in May
- Upward transport of CO by monsoon deep convection, with surface sources from India and Southeast Asia
- Uppermost altitude of the convective transport is ~12 km, near the level of main deep convective outflow

Conclusions

- Peaks in CO profiles are prominently observed in the tropics, particularly in Southeast Asia and Africa, associated with seasonal biomass burning and deep convective systems.
- Other climate events such as El Niño, Asia monsoon and intense forest fires also correspond to the variations of CO.
- Further research could focus on investigating the CO long term trends, comparing with the surface emission datasets such as MOPITT, ACCMIP and RCPs.

Reference

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