Transport of CO from the Asian surface layer to the troposphere and lower stratosphere

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Introduction

Carbon monoxide (CO) is mainly produced by incomplete combustion of carbon-based fuels and biomass burning at the surface and by oxidation of methane and non-methane hydrocarbons in the troposphere. CO is widely used to study the transport of polluted air masses due to its relatively long lifetime. Asian boundary layer has become one of the most polluted regions in recent years due to rapid economic growth. This study investigates the transport of CO from the boundary layers above South Asia (SA), East Asia (EA), South-east Asia (SEA), and central-west Asia (CWA) into the global troposphere and lower stratosphere using the numerical global atmosphere-chemistry model EMAC.

Data and methods

EMAC Model: 2010-2012

Emissions: Biomass burning, anthropogenic activities, agricultural wastes, ship

Source Region: South Asia (SA: 0-37N, 60-95E)
East Asia (EA: 23-53N, 95-150E)
South-east Asia (SEA: 10S-23N, 95-150N)
Central-west Asia (CWA: 13-43N, 30-60E; 37-53N, 60-95E)

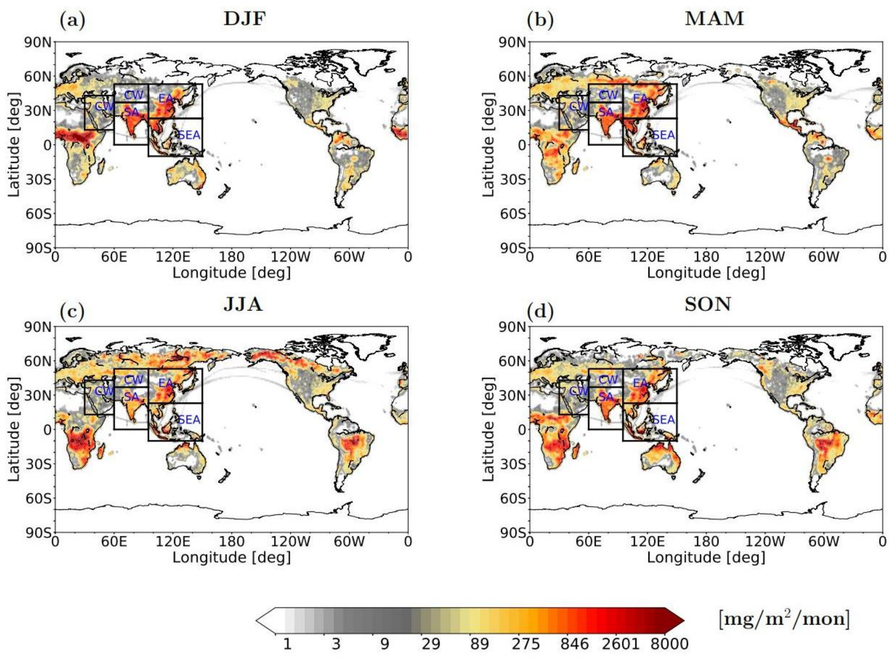
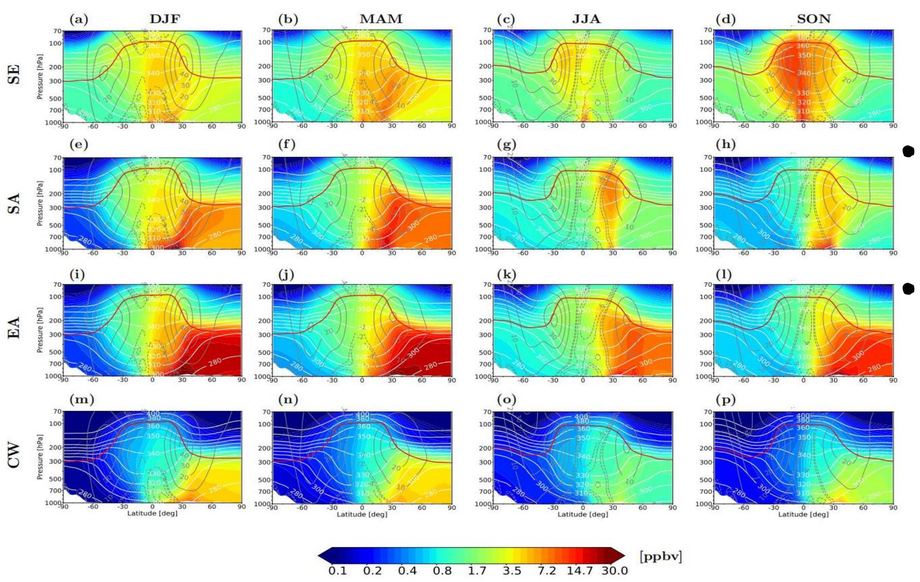


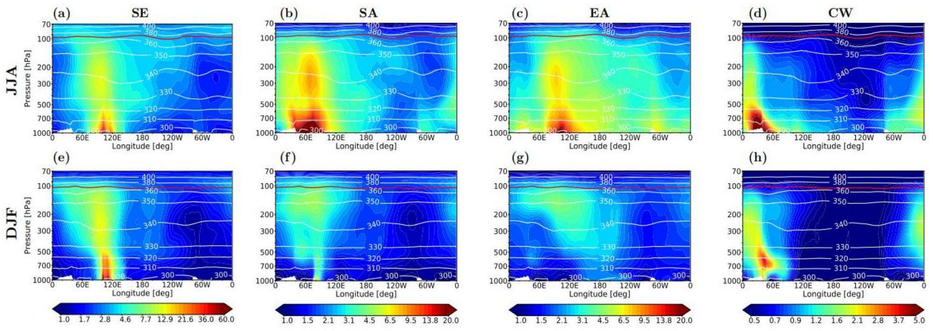
Figure 1. CO emissions from different source regions over Asia used in the model setup during 2010-2012.

Seasonality of transport



- EA contributes most to the NH troposphere.
- SEA contributes most to the SH and tropics.

Figure 2. Climatological (2011–2012) zonal mean CO originated from different source regions



- Two pathways into the tropics:
  - boundary layer in DJF.
  - UTLS in JJA.

Figure 3. Longitude-pressure cross-section over the tropics [15◦ S–15◦ N] of seasonal mean CO

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Transport budget

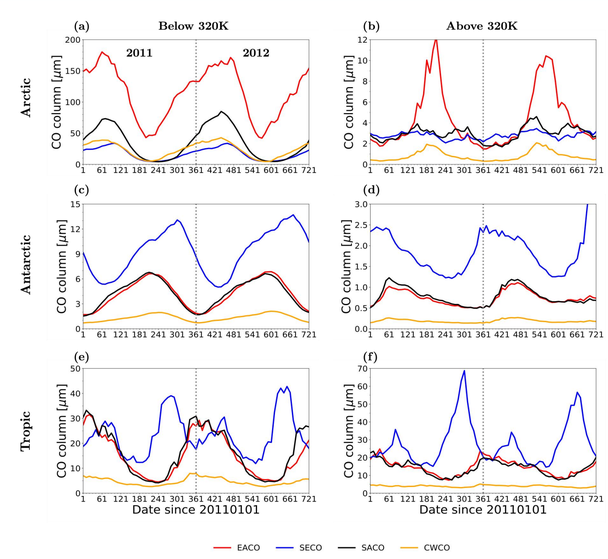

Figure 4. CO column diagnosed in Arctic [60−90N], Antarctic [60−90S], and Tropics [15S−15N]

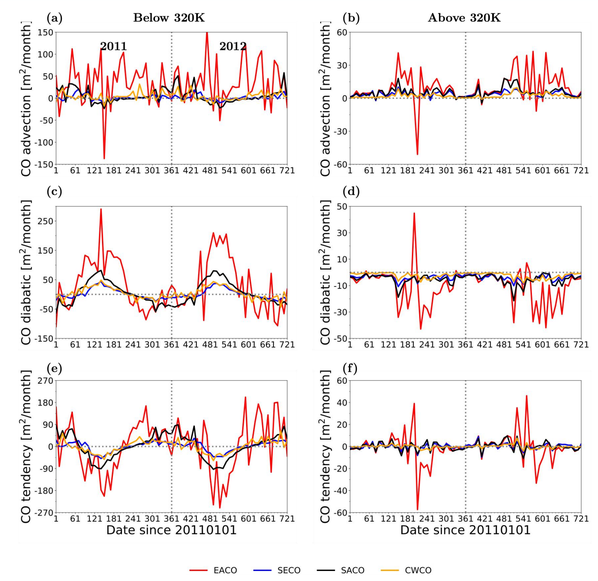

Figure 5. Meridional advection, vertical advection, and tendency of CO averaged over the Arctic

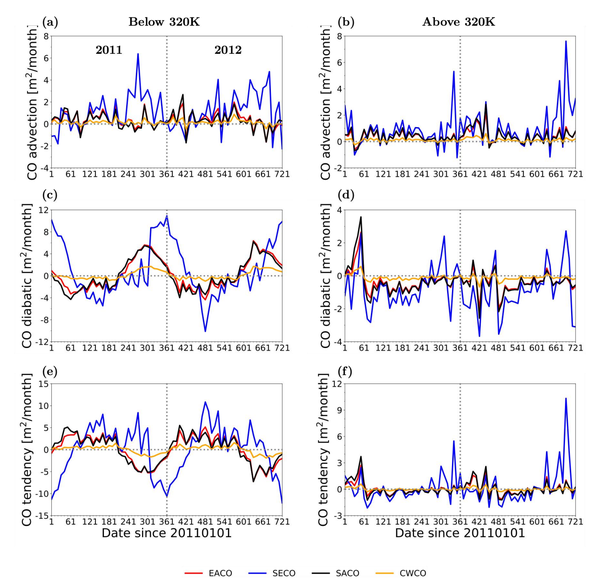

Figure 6. Same as Figure 5, but for the Antarctic

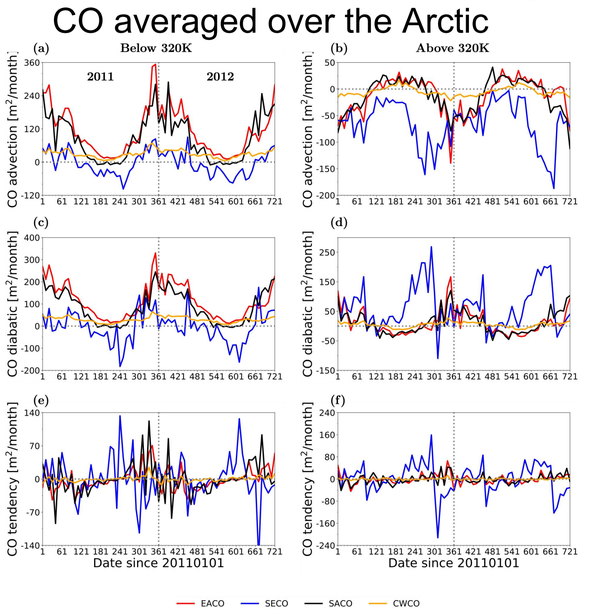

Figure 7. Same as Figure 5, but for the Tropics

Transport into the Arctic

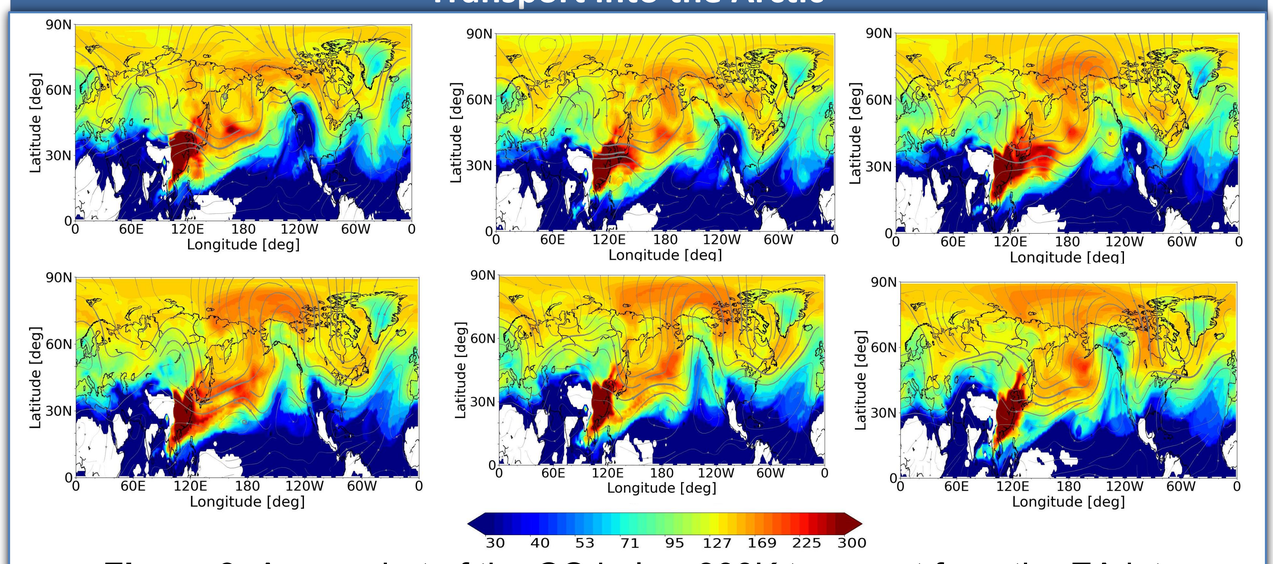

Figure 9. A snapshot of the CO below 300K transport from the EA into the Arctic during 27 Jan-1Feb, 2011. Streamlines show horizontal winds.

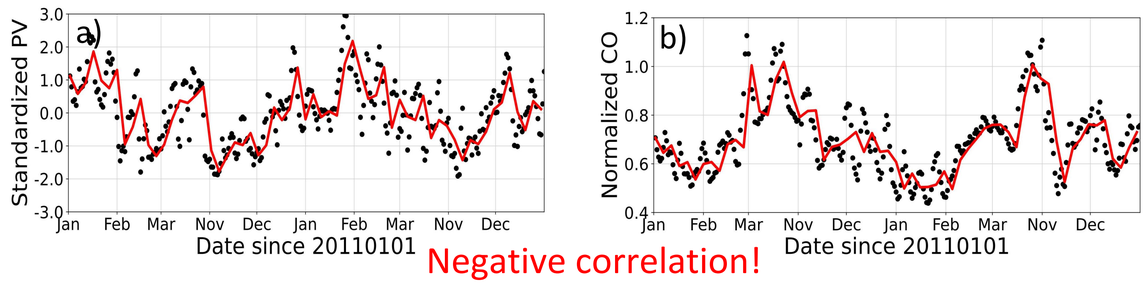

Figure 10. (a) Standardized PV from EA, (b) CO into the Northern Pacific normalized by the EA emissions

Conclusions

- Among the four source regions, CO originating from EA contributes most to the northern hemisphere (NH), while CO originating from SEA contributes most to the southern hemisphere (SH) and tropics.
- There are two different transport pathways from SA and EA to the tropics in winter and summer. Horizontal near-surface transport is the main pathway during winter, while deep convection and the Asian summer monsoon circulation dominate transport during summer.
- Both meridional and vertical advection in the tropics show distinct seasonality, while meridional advection into the polar regions is relatively constant year-round. Meridional advection from EA into the Arctic troposphere is much larger than that from other source regions.
- The transport from EA into the Arctic is mainly through the northern Pacific sector. These contributions are significantly anti-correlated with the strength of the East Asian winter monsoon.