Nitrous Oxide in the Asian Summer Monsoon

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Background

Nitrous oxide (N_2O) and carbon monoxide (CO) were measured during the ACCLIP campaign with the Carbon mOnoxide Measurement from Ames (COMA) instrument. N_2O is a long-lived (123 years) anthropogenic greenhouse gas, with 300 times the warming power of carbon dioxide. In the stratosphere, N_2O is one of the main ozone-depleting substances.

Global N_2O budget is very sensitive to anthropogenic activities in Asia, due to increased fertilizer use and industrial emissions. N_2O is released from the surface with no chemical sources in the atmosphere, and as such has a fairly constant tropospheric value of 335 ppb (NOAA, 2022).

N2O-CO relation

In the stratosphere, CO is produced from methane oxidation and degraded by OH oxidation. Without the influence of air masses being transported from the troposphere, an equilibrium between production and destruction of CO is reached. Due to the tropospheric background of N2O and the stratospheric equilibrium of CO, the N2O–CO relation can be used to investigate mixing processes and the troposphere and stratosphere.

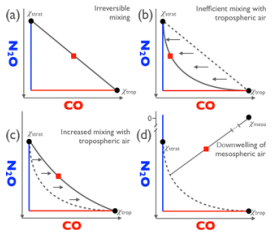


Fig. 1. Tracer correlations of N2O and CO, with the N2O axis reversed. (from Krause et al. 2018),

Depicts efficient mixing (linear relation) and inefficient mixing (curved relation). Horizontal red line indicates tropospheric N2O background while blue vertical line indicates CO equilibrium in the stratosphere.

a) Shows fast mixing.
b) b) inefficient mixing compared to chemical lifetime of CO
c) c) change in curvature depending on mixing strength.

N20 and CO for all flights

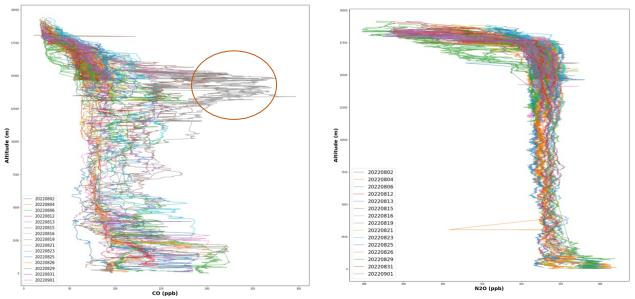


Fig. 2. N2O and CO vs altitude
Tropospheric measurements have high N2O values (> 320 ppb) along with high CO values, while stratospheric measurements have N2O < 320 ppb.

Troposphere: high N2O, variable CO

Stratosphere: low CO, variable N2O

N2O-CO Relation; 8-06-2022 RF3 Example

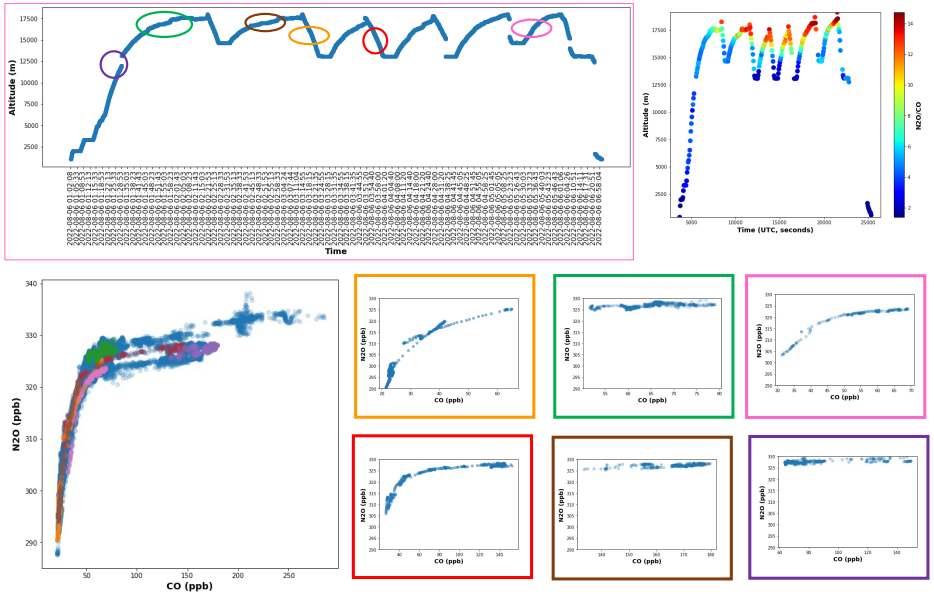


Fig 3. N20-CO relation throughout RF3.
The shape of the curve indicates mixing of the trace gases. If the relation is linear, then air masses are mixing quickly. If relation is curved as in the sections of the flight marked in orange, pink, and red, the air masses are inefficiently mixing. A horizontal line, as in the flight section marked in purple, represents tropospheric background.

CO Source from GEOS

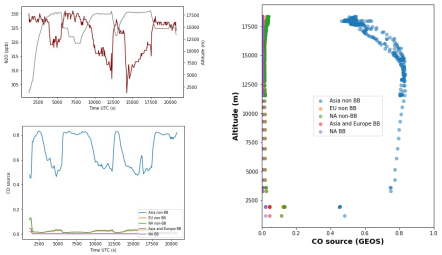


Fig. 4. August 19th, 2022 flight, showing relation with altitude, N_2O, CO, and CO sources from GEOS. Asian non-biomass burning is the largest CO source according to GEOS.

Interpretation

N_2O in boundary layer is enhanced due to agricultural emissions. Drops mid troposphere. Variation in troposphere (325-330 ppb) may be due to instrument variability.

CO is high and variable in BL, drops off mid troposphere, and enhanced in tropopause perhaps due to transport from other regions.

According to the GEOS model, Asian non-BB burning highest contributor to CO in the troposphere, and while it drops in the stratosphere still the largest CO contributor.

N2O-CO relation can be used to see how air masses are mixed between stratosphere and troposphere.

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References

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NOAA: Combined Nitrous Oxide data from the NOAA/ESRL Global Monitoring Division, available at: https://www.esrl.noaa.gov/gmd/hats/combined/N2O.html, 10 November 2022.