Model study of the cross-tropopause transport of biomass burning pollution*

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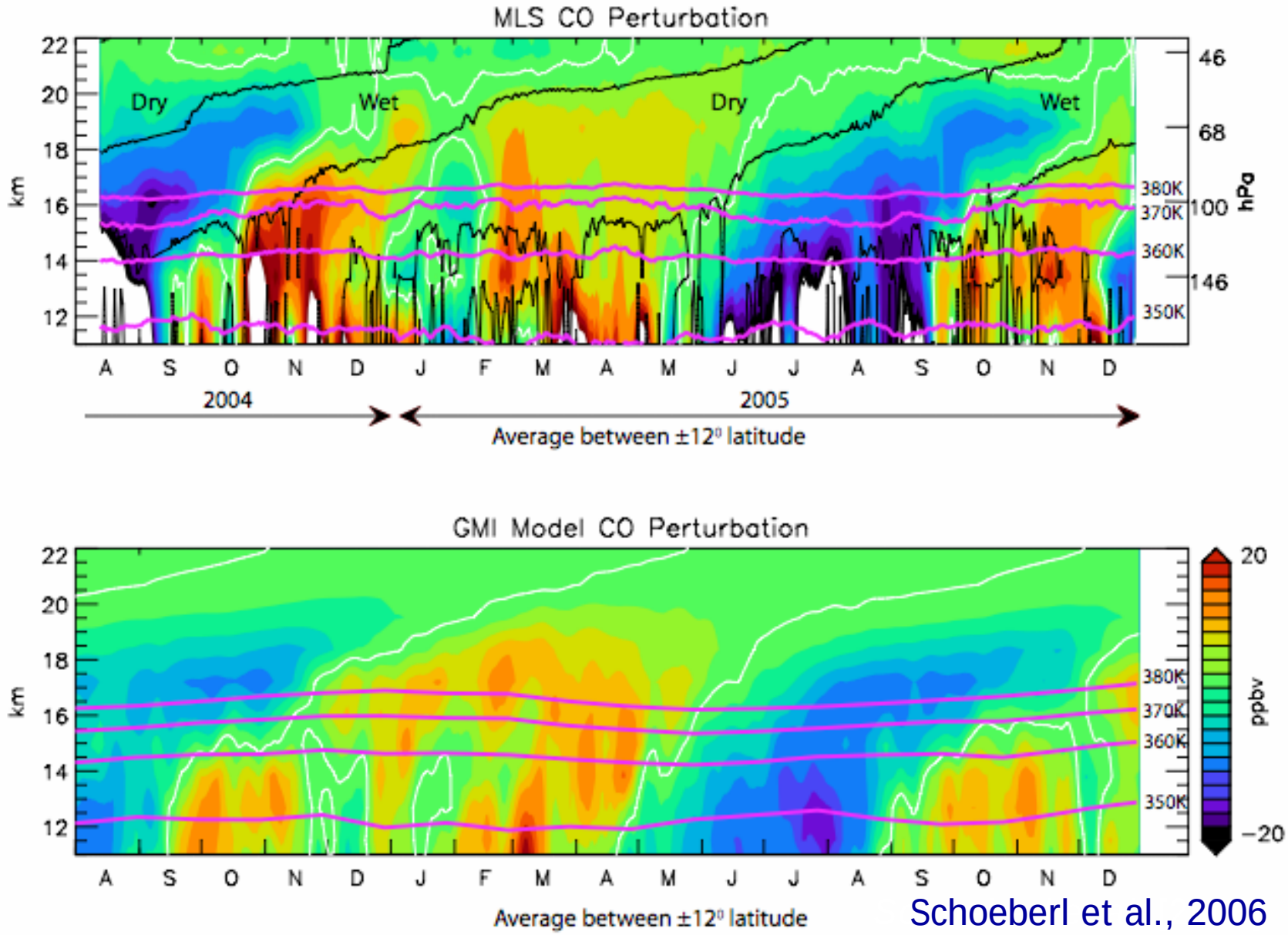
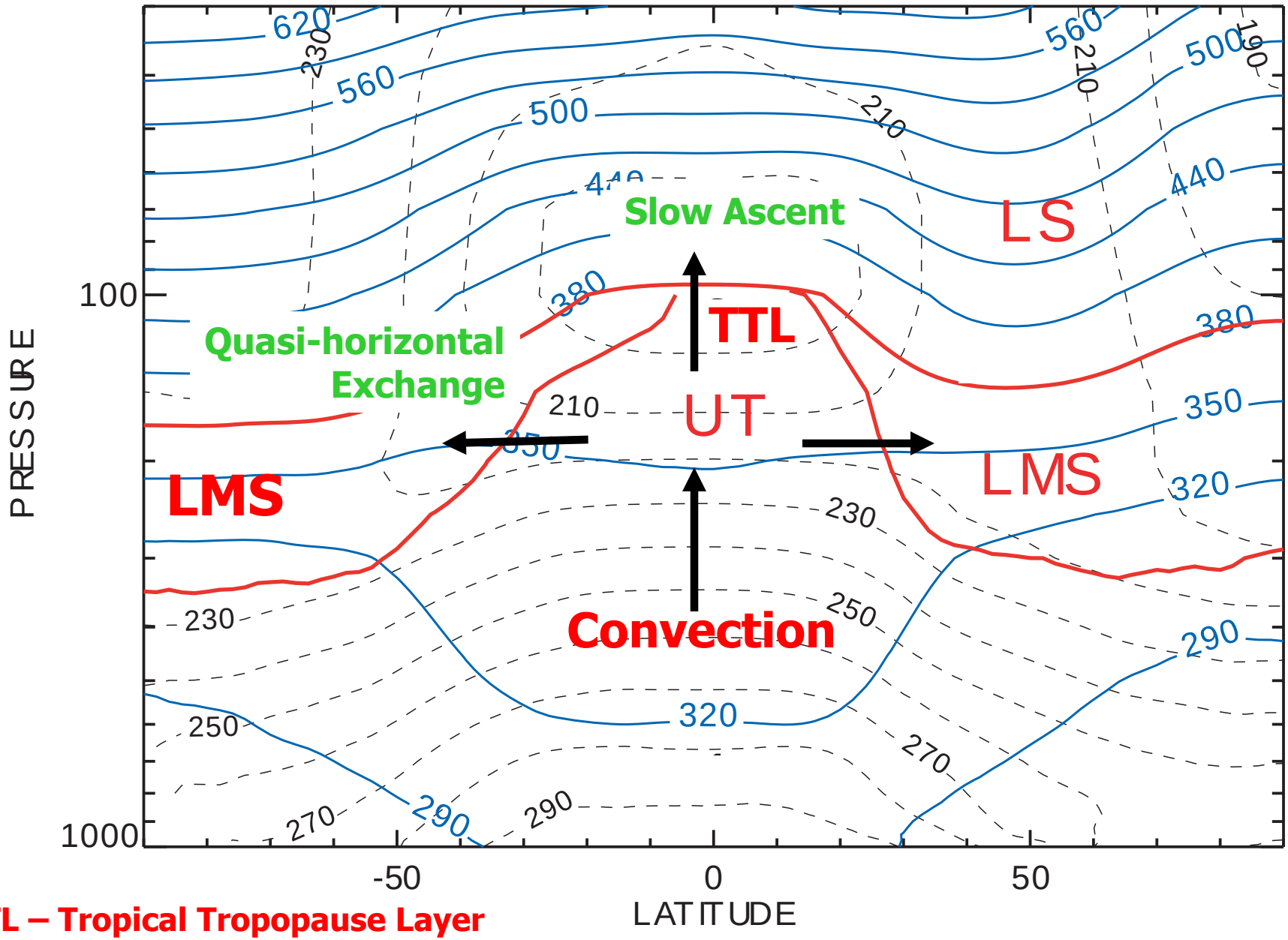
***Plus pollution from other sources too!**

GMI Meeting, Greenbelt, June 13-15, 2007

Inspiration ⇒ *CO "Tape Recorder" in Aura MLS*



Schoeberl et al., 2006



TTL – Tropical Tropopause Layer

LMS – Lowermost Stratosphere **LS – Lower Stratosphere** **UT – Upper Troposphere**

Who Cares?

⇒ **Lifetimes of Trace Gases in Tropical Tropopause Layer (TTL)* impacted by:**

CO + OH

***Air resides in TTL several weeks before crossing the tropopause.**

⇒ **Radiation Budget – Dynamics in TTL**

ozone and aerosols

At October '06 meeting

1) Biomass burning pollution can impact the composition (e.g., OH, ozone, CO) of the UT/LS significantly.

2) There are two* main cross-tropopause transport pathways of biomass burning pollution:

   a) Quasi-horizontal, quasi-isentropic exchange.

   b) Slow ascent in TTL.

** Convection does not penetrate the tropical tropopause in CTM. Liu & Zipser (2005) and Rossow & Pearl (2007) say ~ 1% or less penetrate tropical tropopause and ~ 2% or less enter TTL.*

Since October meeting

1) Seasonal variations in timing of both CO sources and transport conspire to create a quasi-annual oscillation in the CO composition in the TTL that evolves into an annual oscillation in transit to the tropical LS.

2) There are two main sources of interannual variability (IAV) in the composition of the tropical UT/LS:

   a) locations of deep convection, especially ENSO, in relation to sources

   b) biomass burning

Two Simulations:

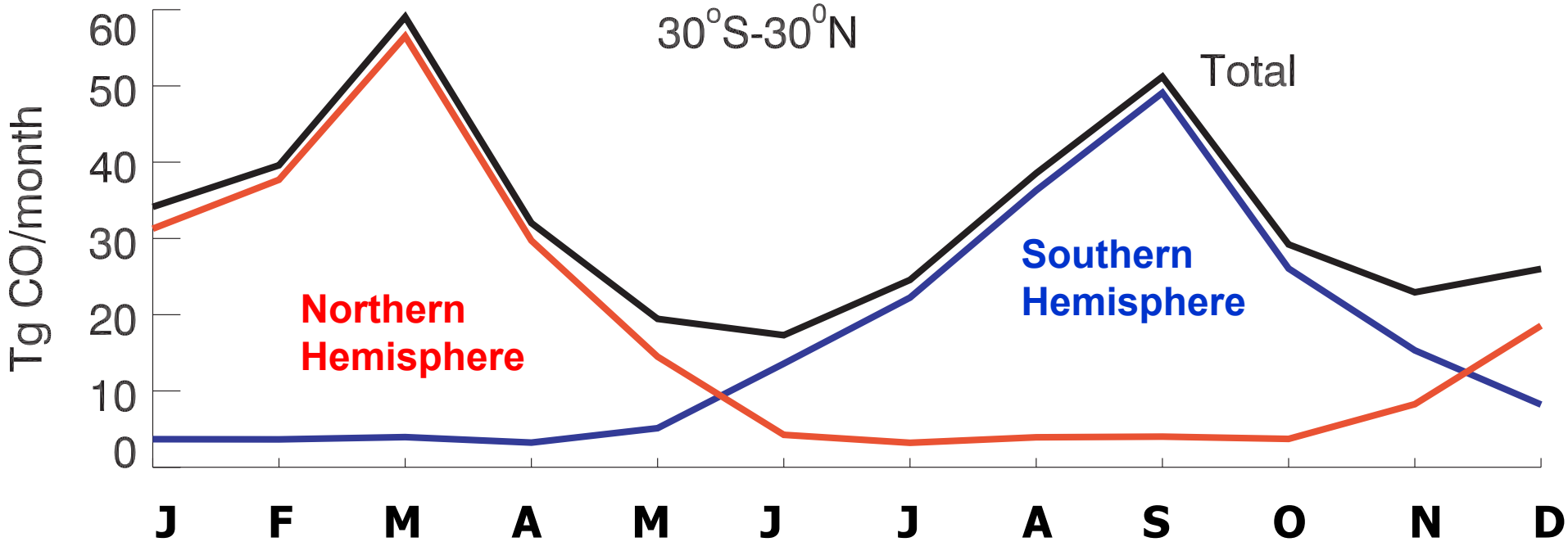
1) Tagged CO : CO from various sources are treated as separate tracers.

2) Uniform Tracer : uniform emissions over globe with 25-day lifetime.

Uniform Tracer ≈ Dynamical Tracer

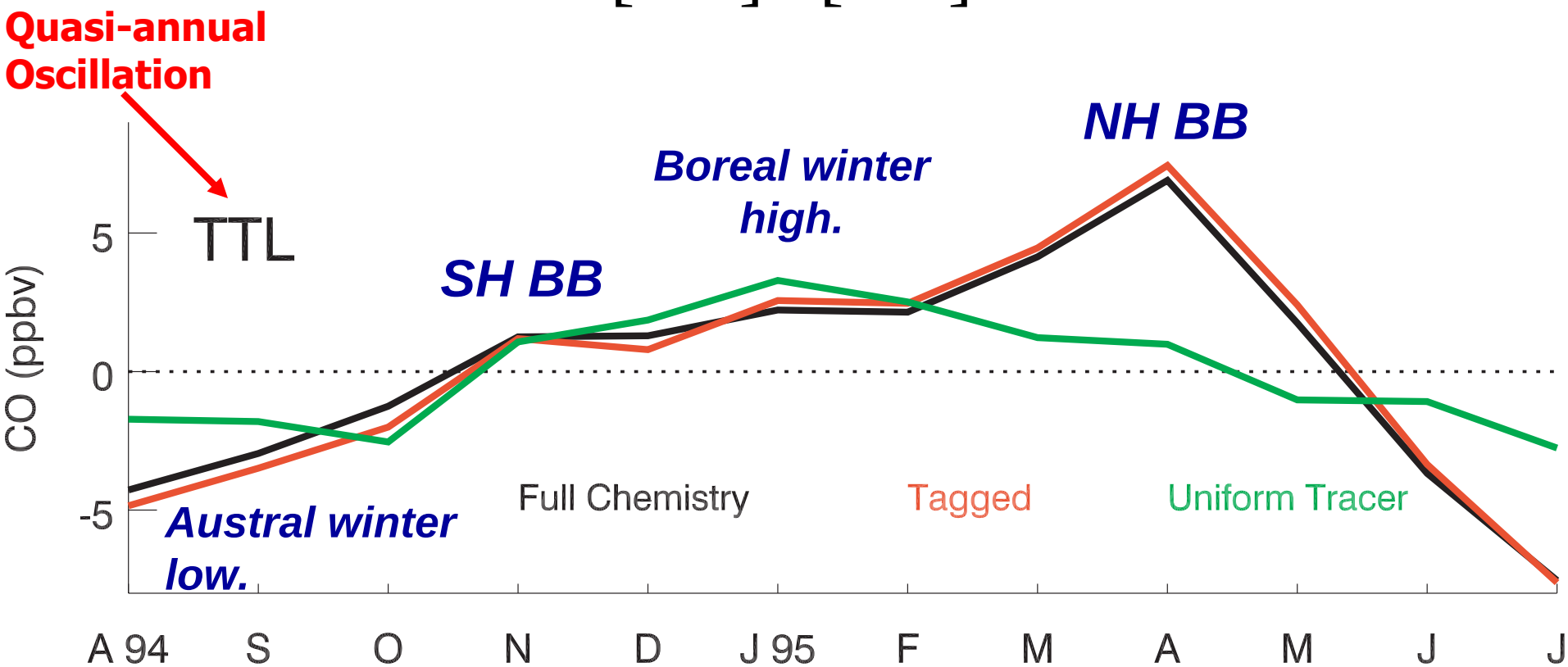
These simulations allow us to deconvolve the impact of the variation of transport on CO in the UT/LS from the impact of the variation of sources.

Climatological Biomass Burning



⇒ **Semi-annual oscillation in biomass burning source.**

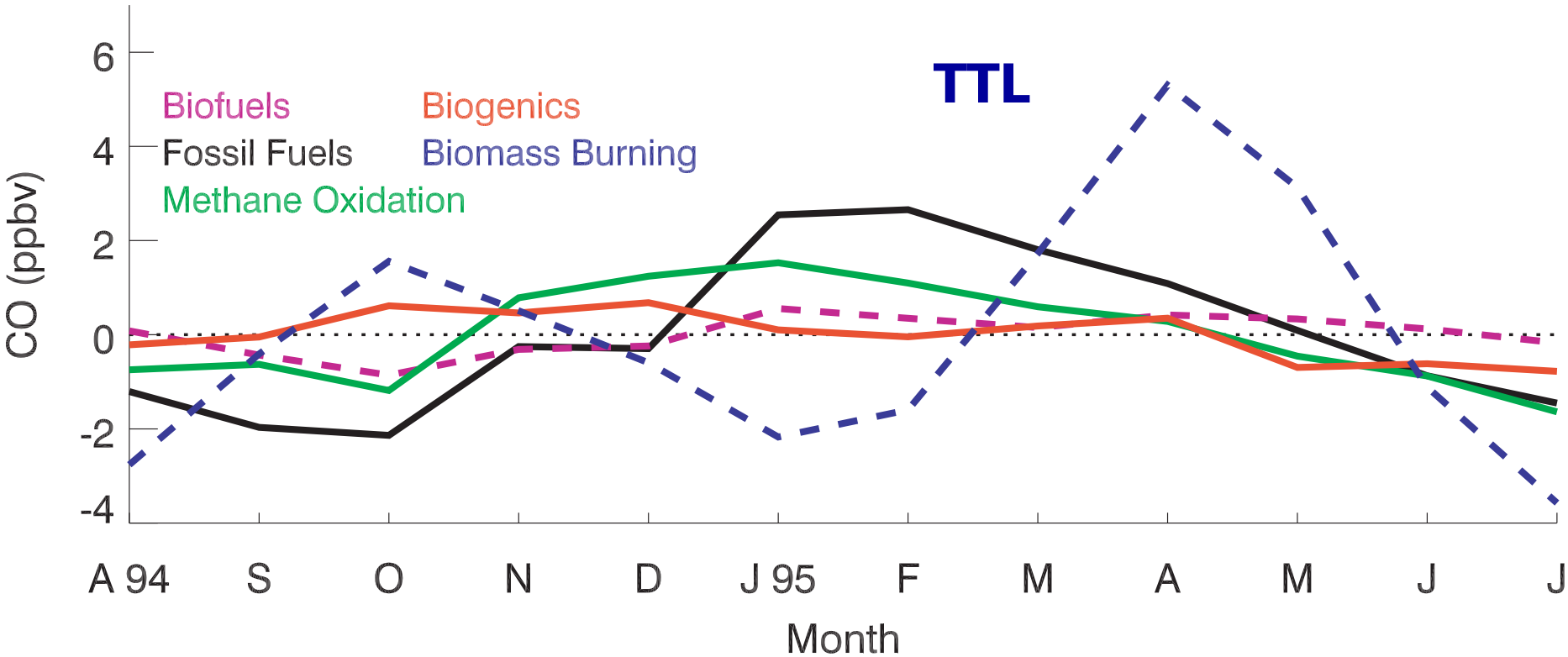
$$[CO]-[\overline{CO}]$$



⇒**Seasonal variation in biomass burning plays a role, but …**

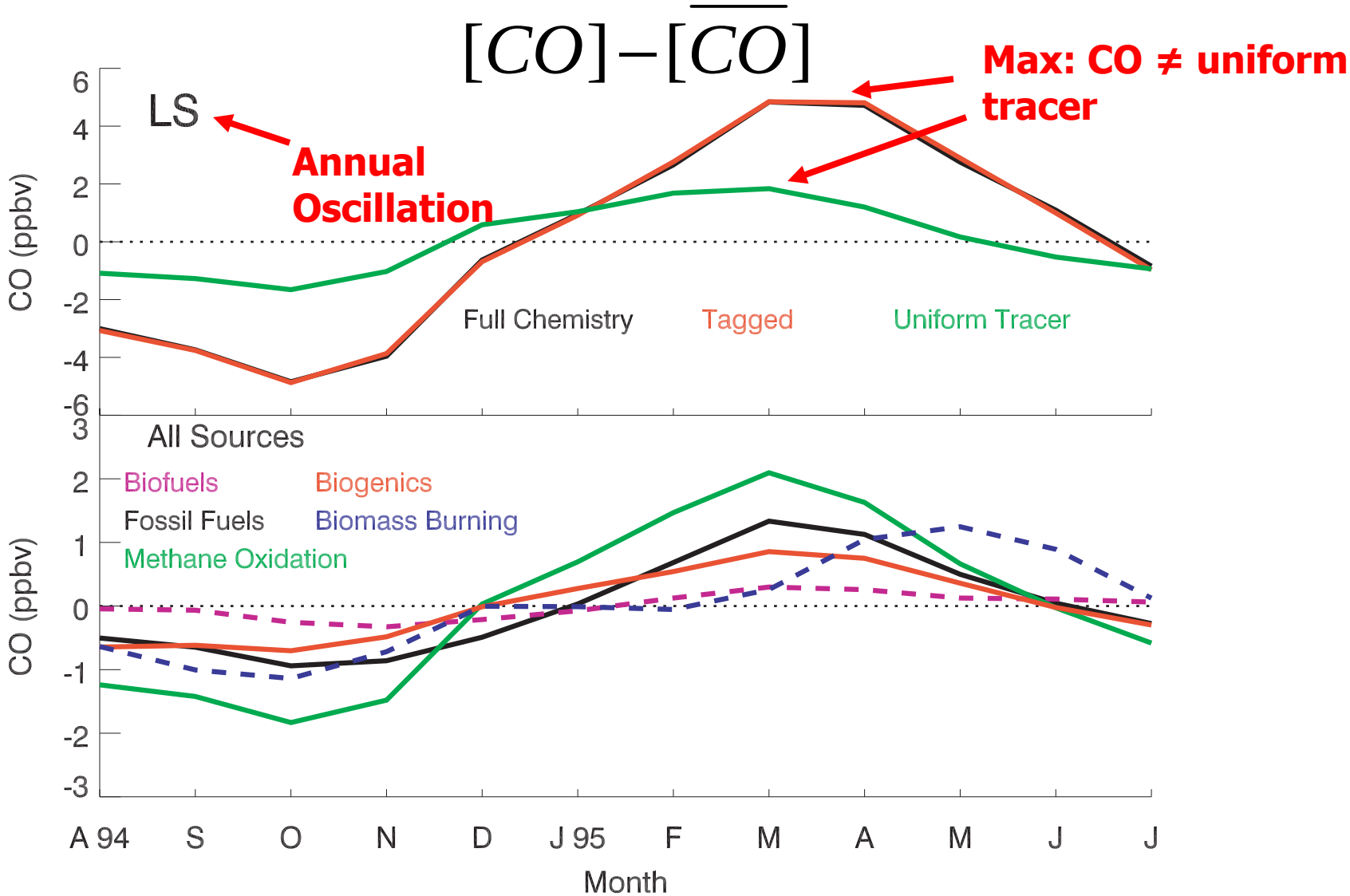
⇒**Seasonal variation in dynamics also plays a role, but ….**

$$[CO]-[\overline{CO}]$$



NH winter: **Seasonally high transport and seasonally high CO conspire to "fill in" minimum in "biomass burning" CO.**

SH winter: **Seasonally low transport and seasonally low CO conspire to "deepen" minimum – S. Asian monsoon lofts Indian pollution > 15°N.**



⇒ **Methane higher : 3-d "fresh" source v. surface emissions only depleted.**

⇒ **Dynamics can either enhance or damp a source's impact on LS (e.g., SH vs NH BB CO).**

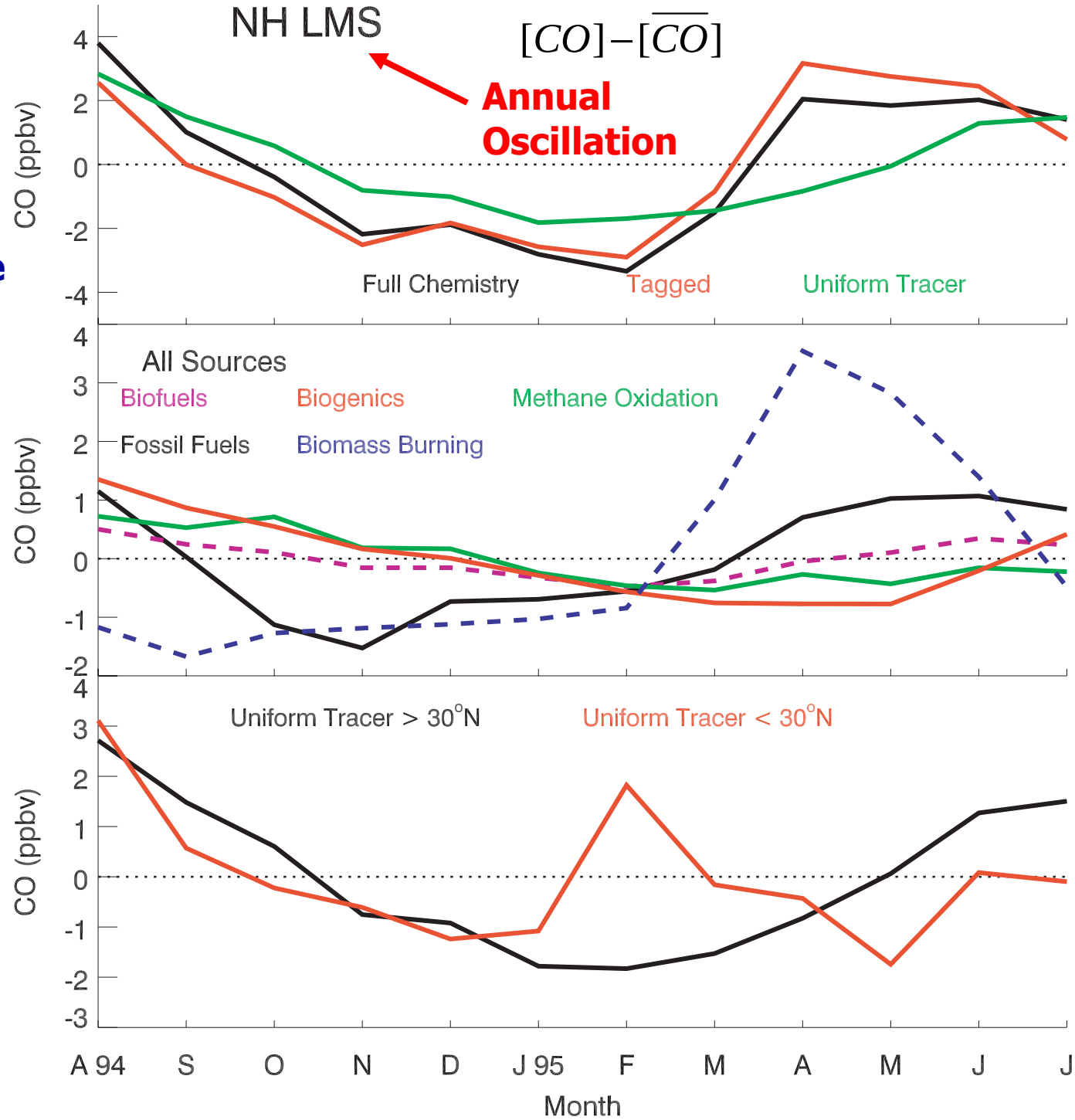
Lowermost Stratosphere - NH

⇒ **LMS does not contribute to CO tape recorder.**

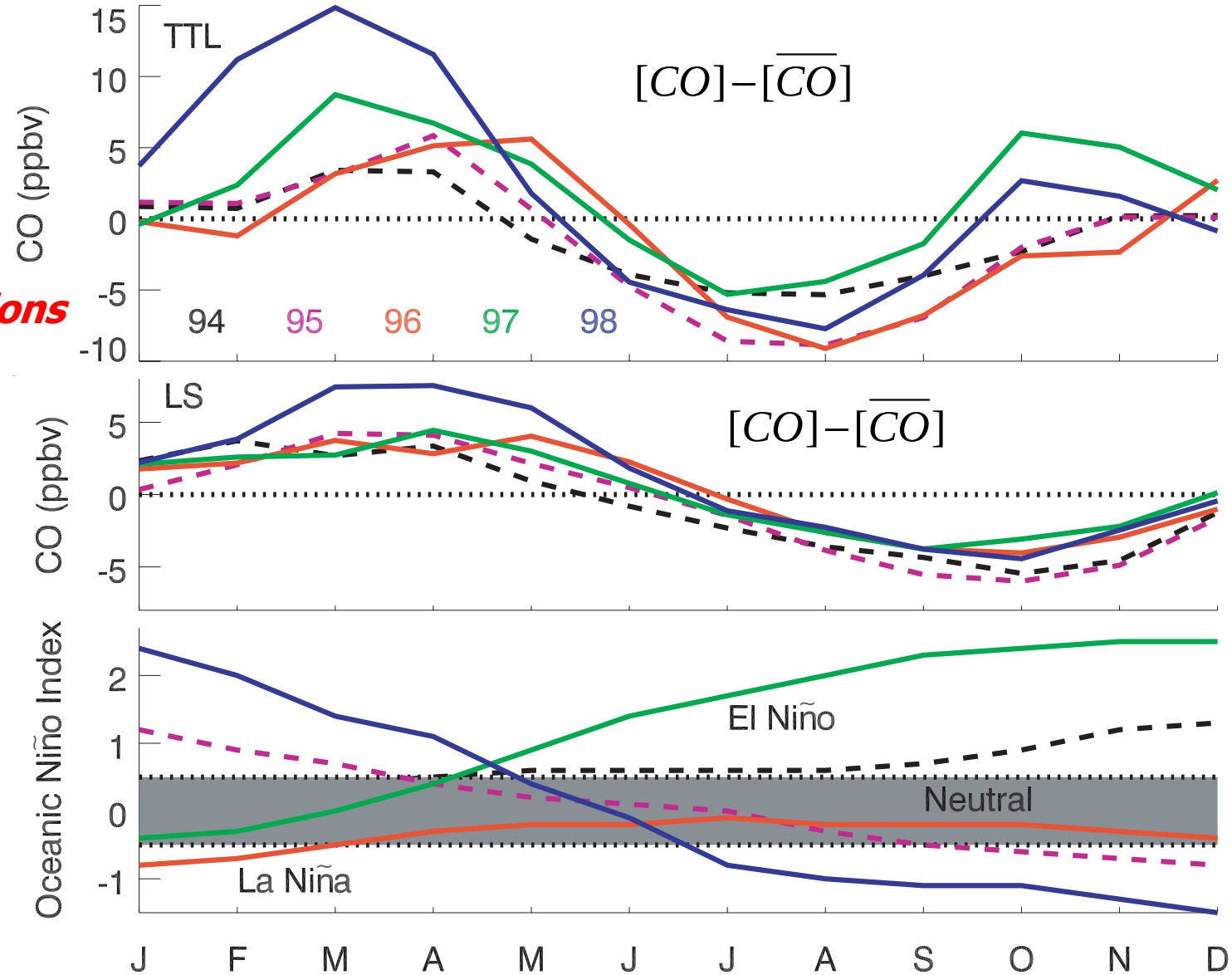
⇒ **Biomass burning from SE Asia dominates.**

⇒ **Semi-annual oscillation < 30°N**

⇒ **Annual oscillation > 30°N**

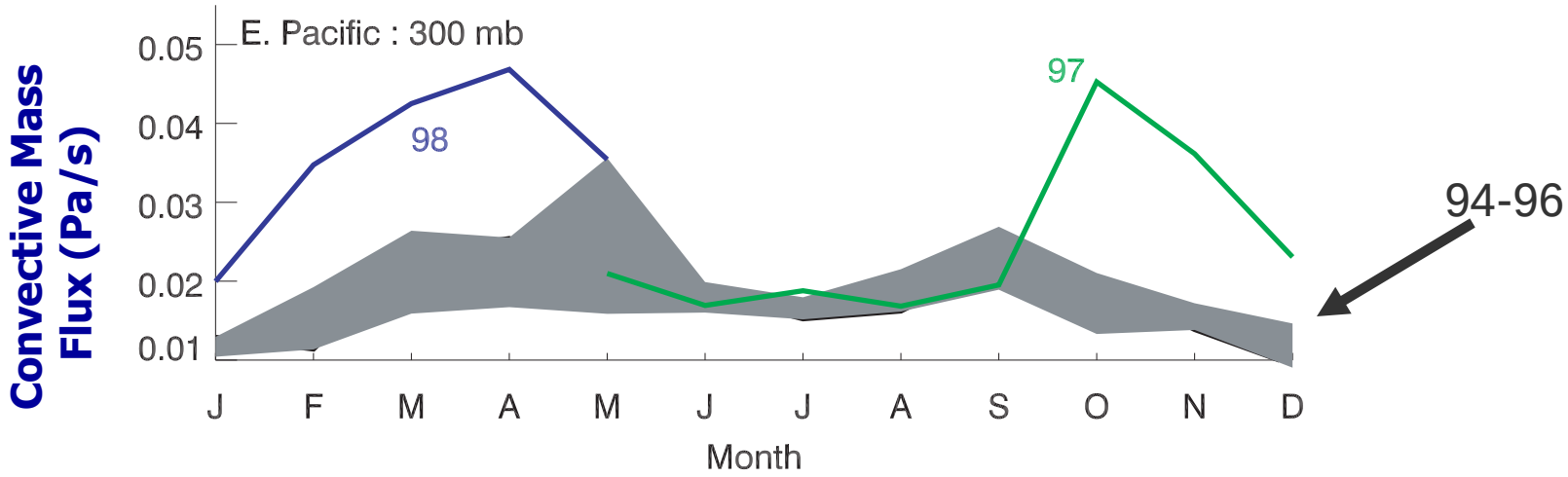


Interannual Variability*

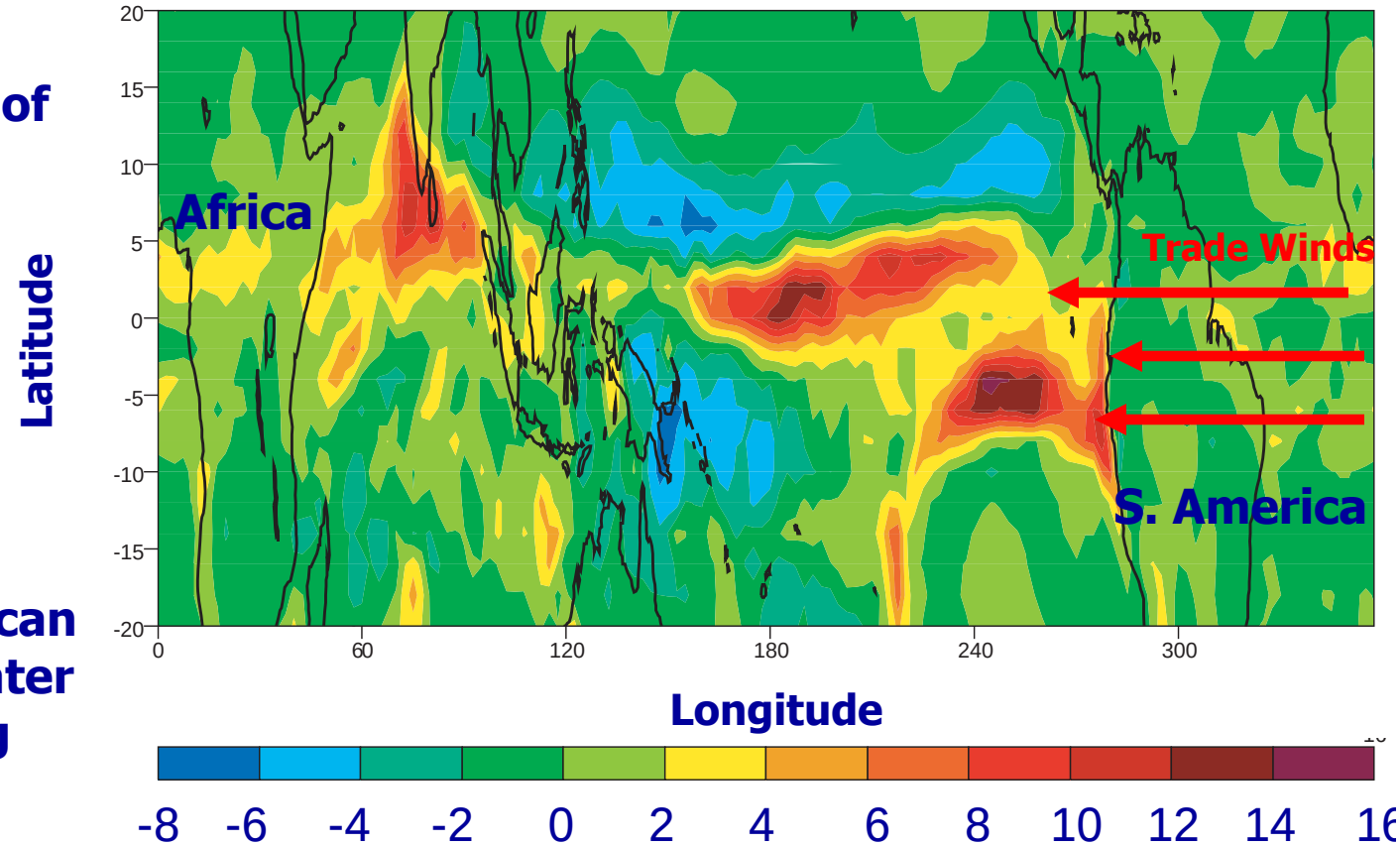


Seasonal emissions same each year.

⇒ Convective mass flux at 300 mb ~10% higher in 97-98, but …



Tropical Convection Perturbation (mm/d) : March 1998



⇒ **<u>IMPORTANT</u>: IAV of the locations of convection in relation to sources.**

⇒**S. American & African surface sources greater impact (2-3x) during this El Niño event.**

Conclusions

1) Biomass burning pollution regularly & significantly impacts UT/LS ($CO\uparrow$, $OH\downarrow$, $O_3\uparrow$, aerosols?).

2) Two main cross-tropopause pathways: Slow ascent in TTL, Quasi-horizontal exchange in jets.

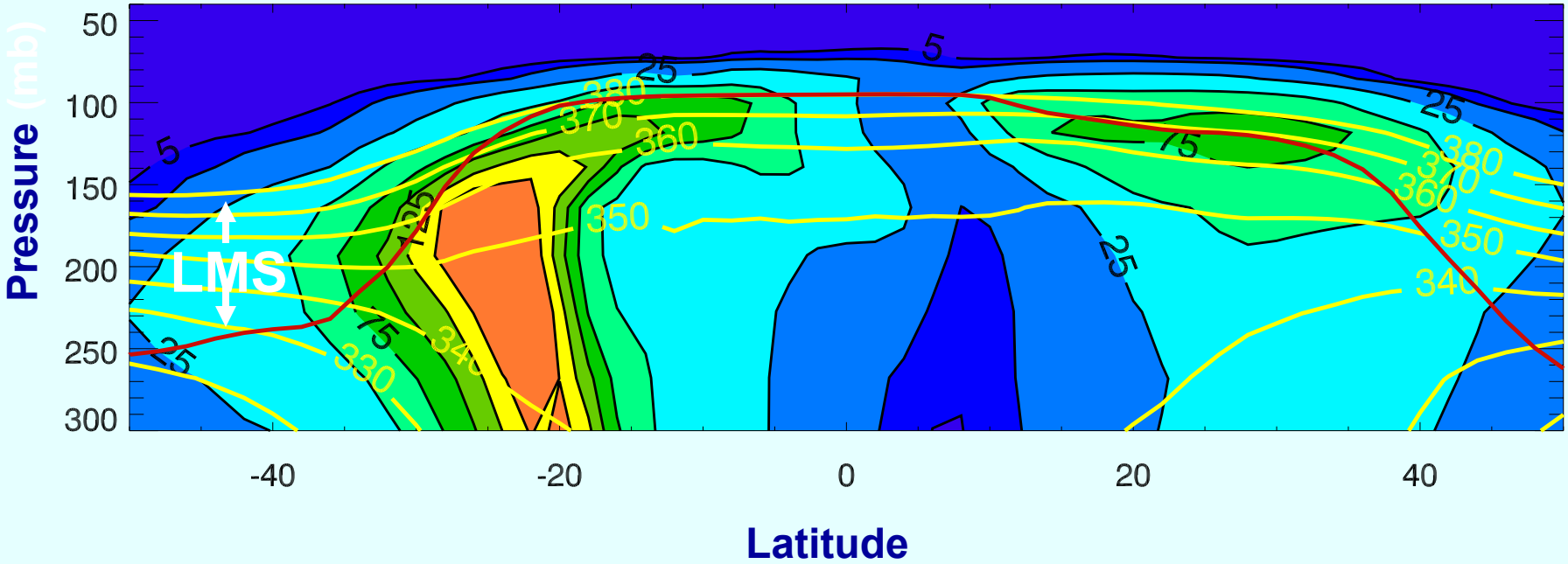
3) Tropopause penetrating convection not needed to explain large-scale features of observations.

4) Seasonal variations in both sources and dynamics important to composition of UT/LS.

5) Dynamical variation can enhance or damp a particular source's impact on composition of UT/LS, depending on timing.

6) Interannual variations in UT/LS composition are mainly due to variations in a) Indonesian biomass burning and b) locations of convection in relation to surface sources.

October 1997 : CO Perturbation (%): 180° Longitude



Yellow Lines = Isentropes

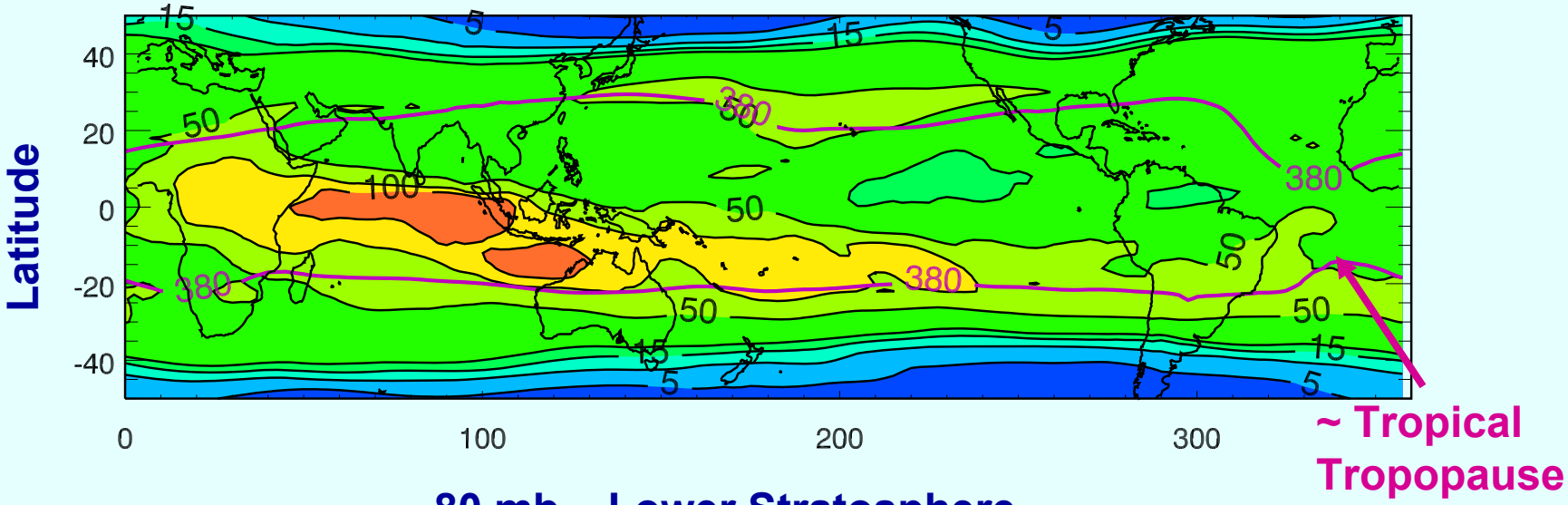
Red Line = Approximate Tropopause

⇒ Troposphere-to-Stratosphere Exchange (TST) via Quasi-horizontal, Quasi-isentropic Exchange

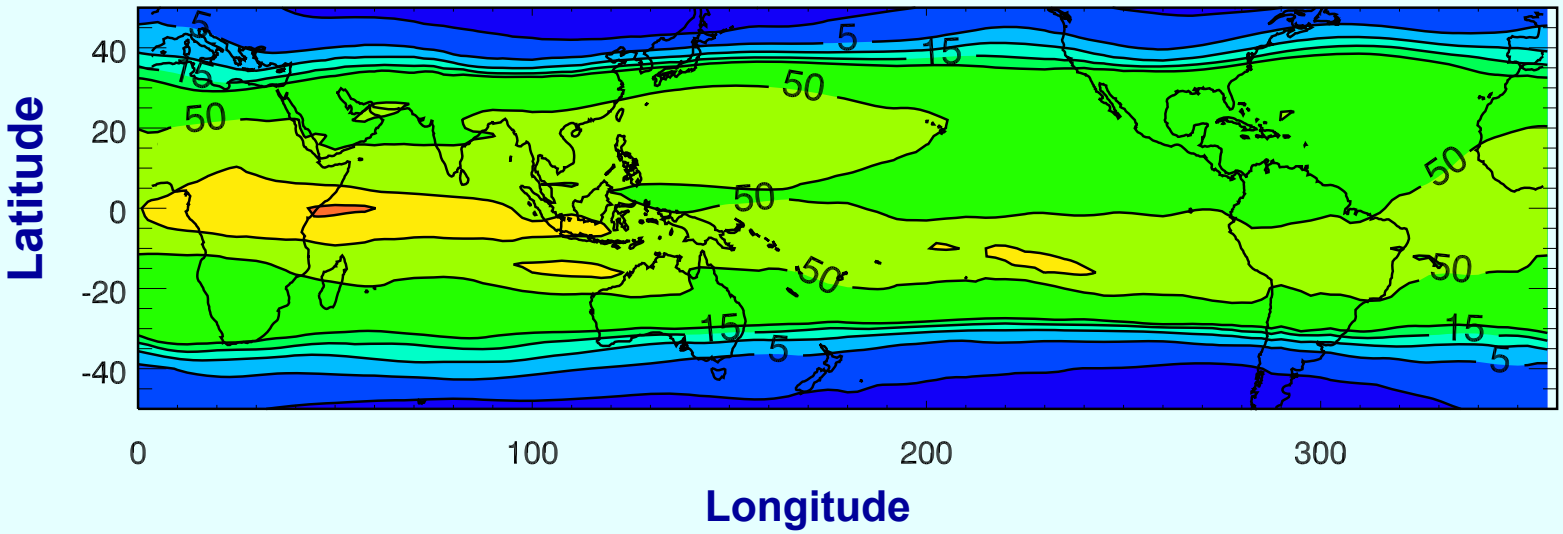
⇒ But, pollution in Lowermost Stratosphere (LMS) returns to troposphere eventually.

November 1997: CO Perturbation (%)

~100 mb – Near Tropical Tropopause



~80 mb – Lower Stratosphere



⇒ **TST via Slow Ascent in Tropical Tropopause Layer (TTL)**