# MLS and TES data for tropical tropospheric ozone: a revealing test of vertical transport in GEOS-5 meteorological fields.

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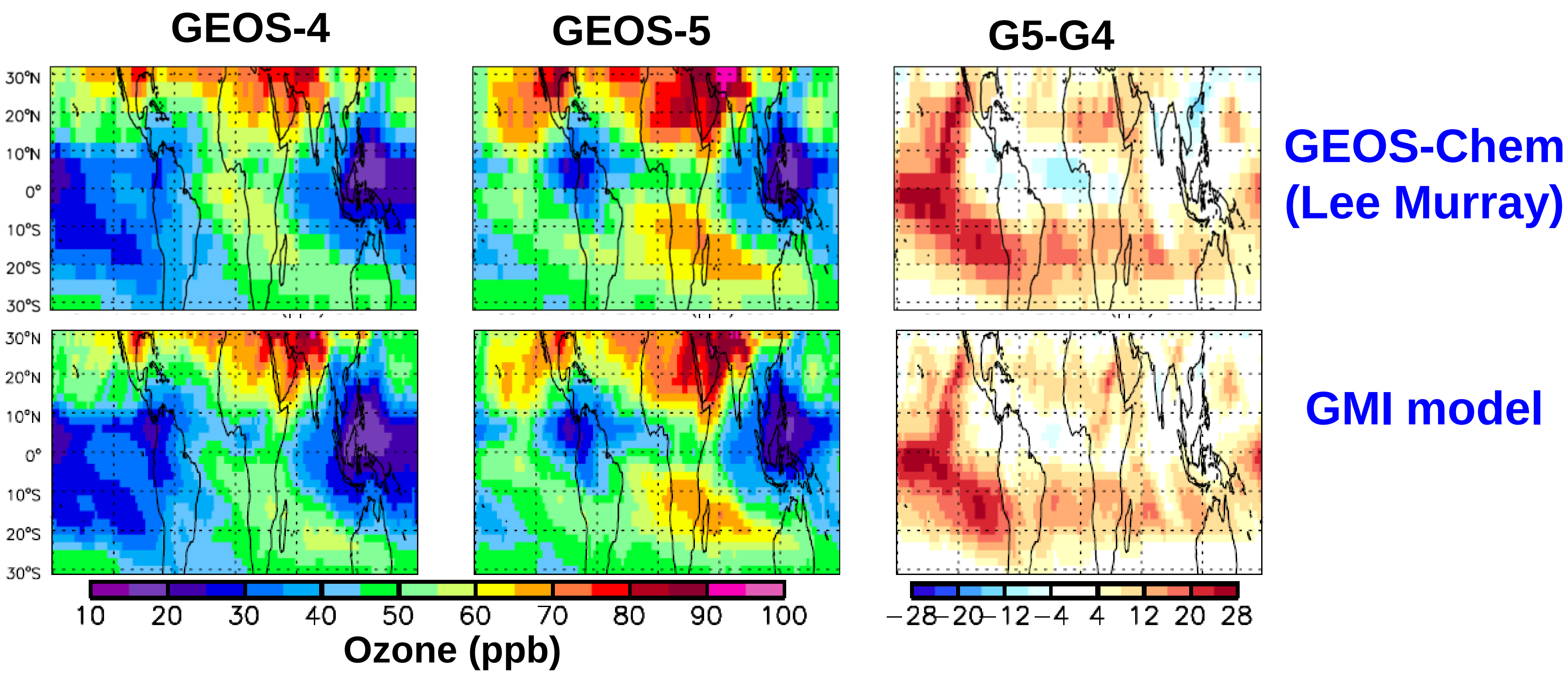
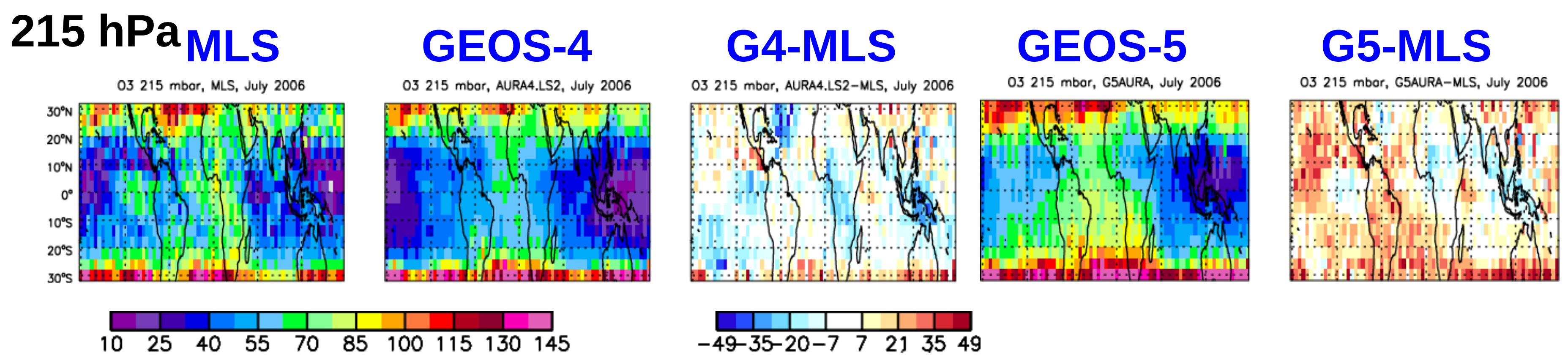
**Vertical transport is different in GEOS-5 and GEOS-4 because the convection schemes are different:**

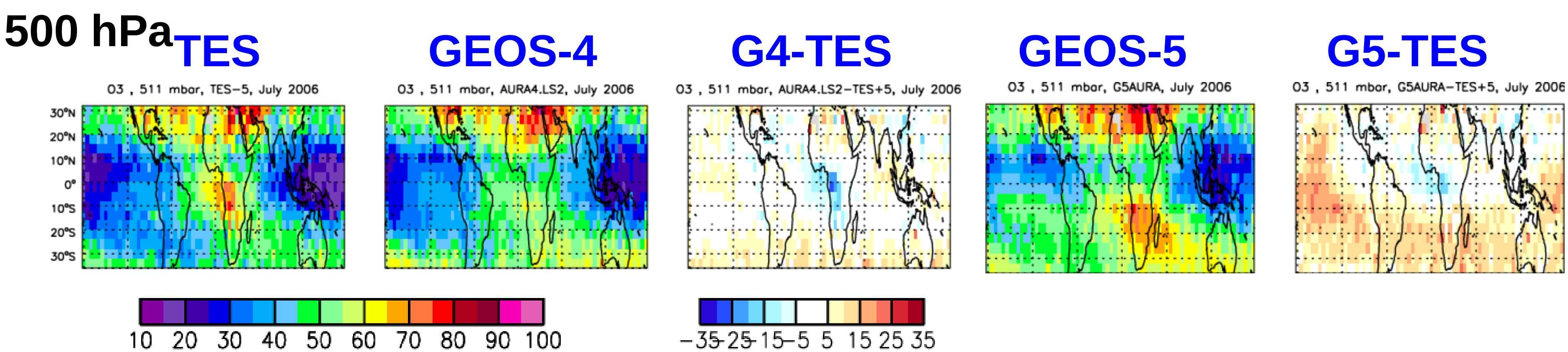
- **GEOS-4 – Zhang and McFarland (1995) (deep) and Hack et al. (1994) (shallow)**
- **GEOS-5 – a version of the Relaxed Arakawa Schubert scheme (Moorthi and Suarez, 1992)**

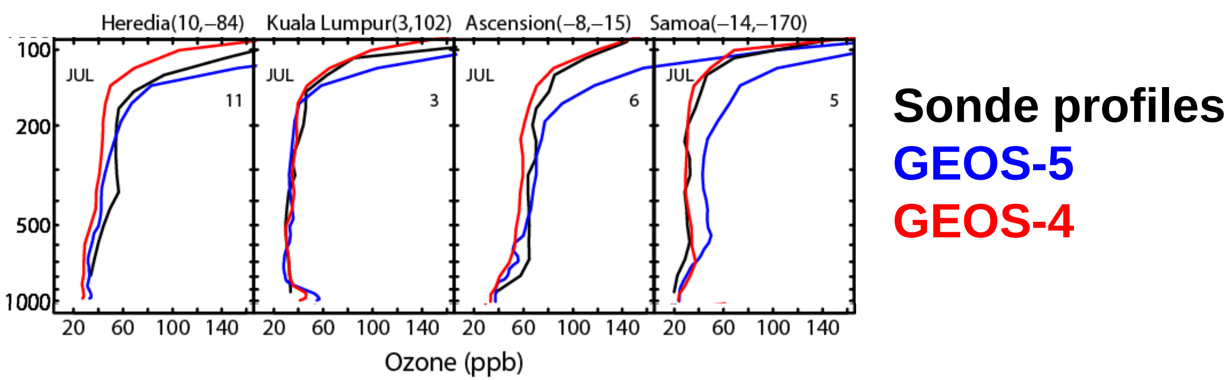
**Ozone in the tropics at 500 hPa in June, 2005**



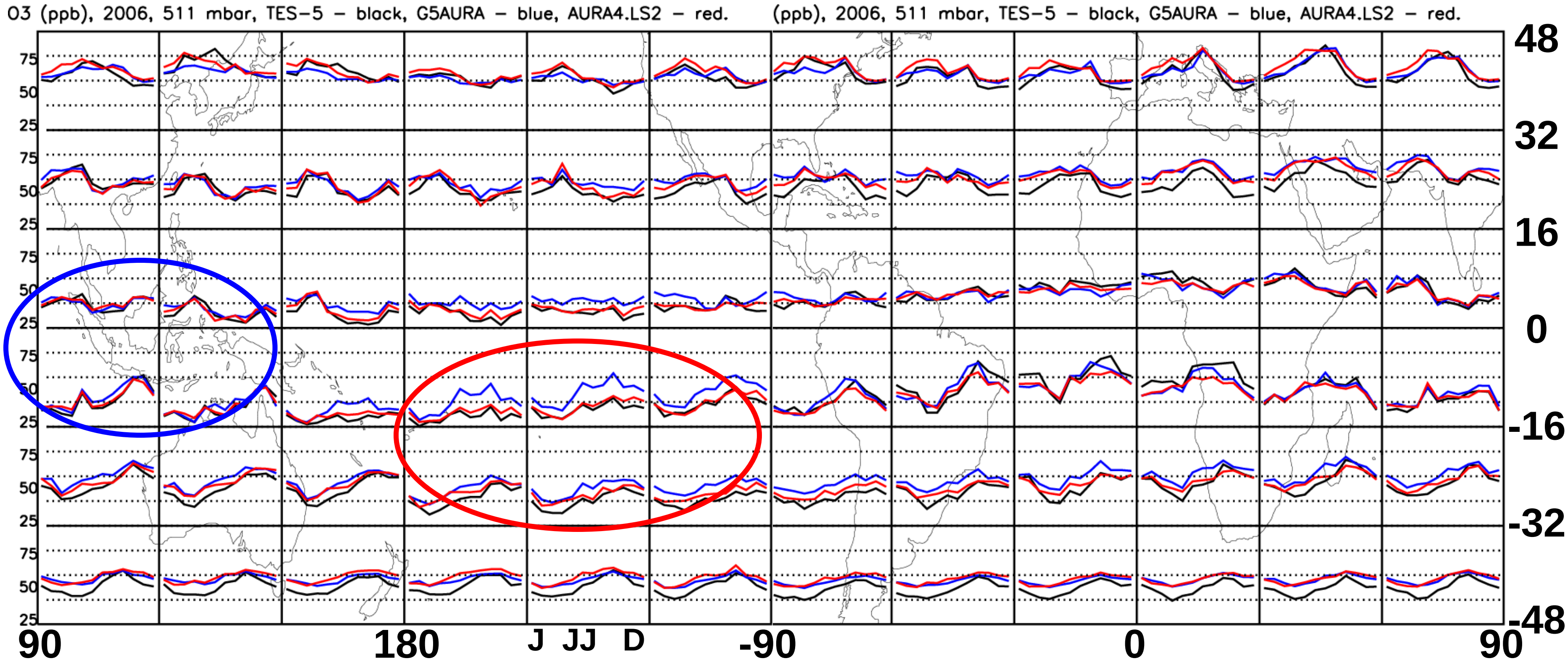
# MLS, TES, and sondes show that tropical ozone in GEOS-4 is more realistic than in GEOS-5 (example for July 2006)



# Models match month-month variability of TES ozone at 500 hPa

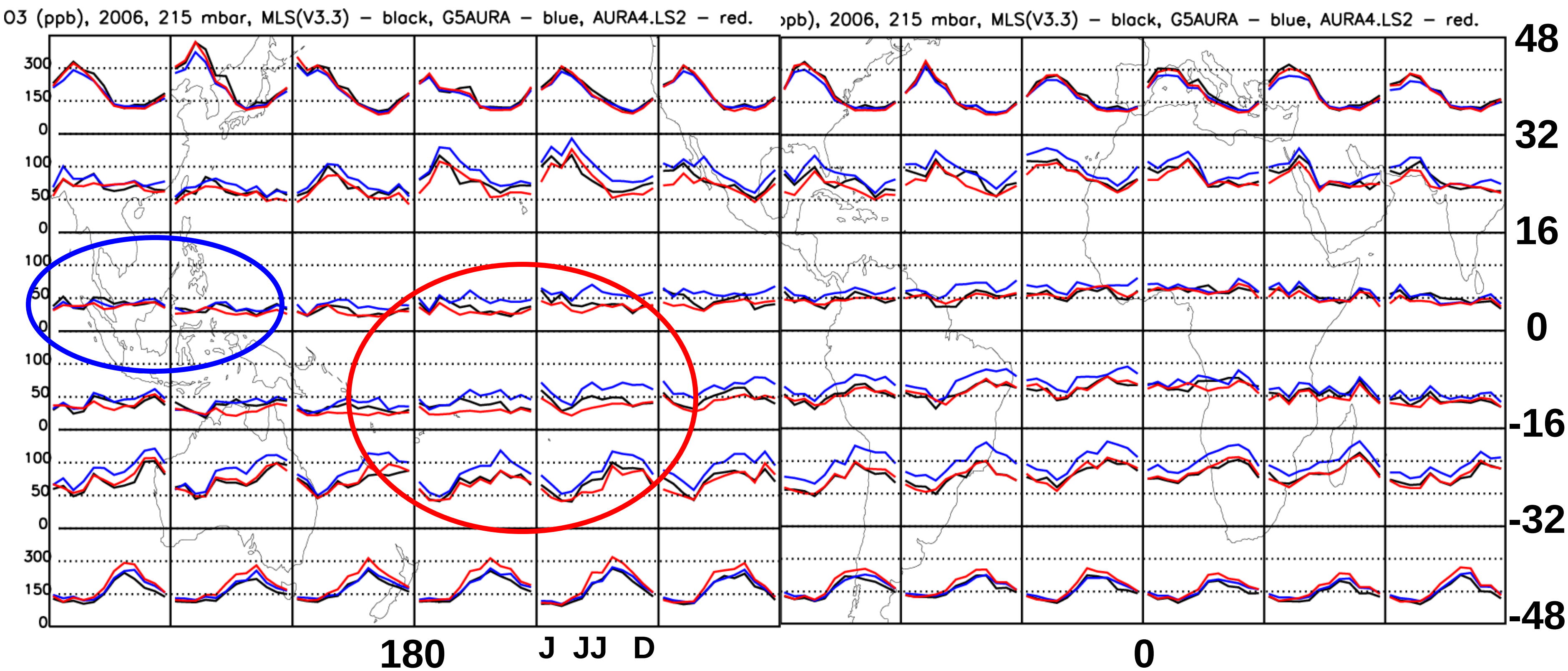



Each panel shows ozone for Jan. to Dec. from TES, GEOS-4 and GEOS-5

TES (minus 5 ppb)
GEOS-4
GEOS-5

GEOS-5 > GEOS-4 mid-year, mid-Pacific
GEOS-5 ≈ GEOS-4, maritime continent

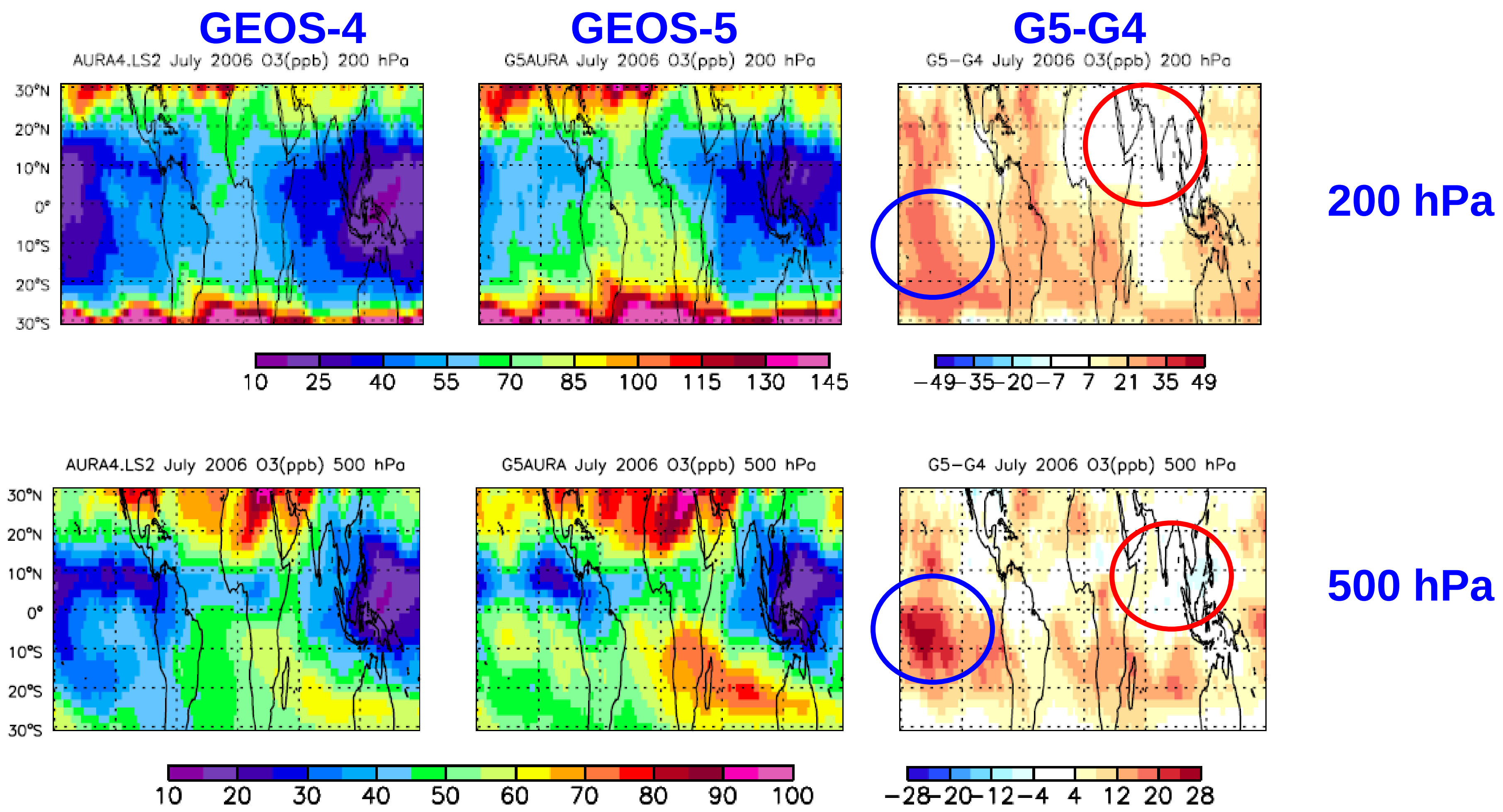
# Models match month-month variability of MLS ozone at 215 hPa





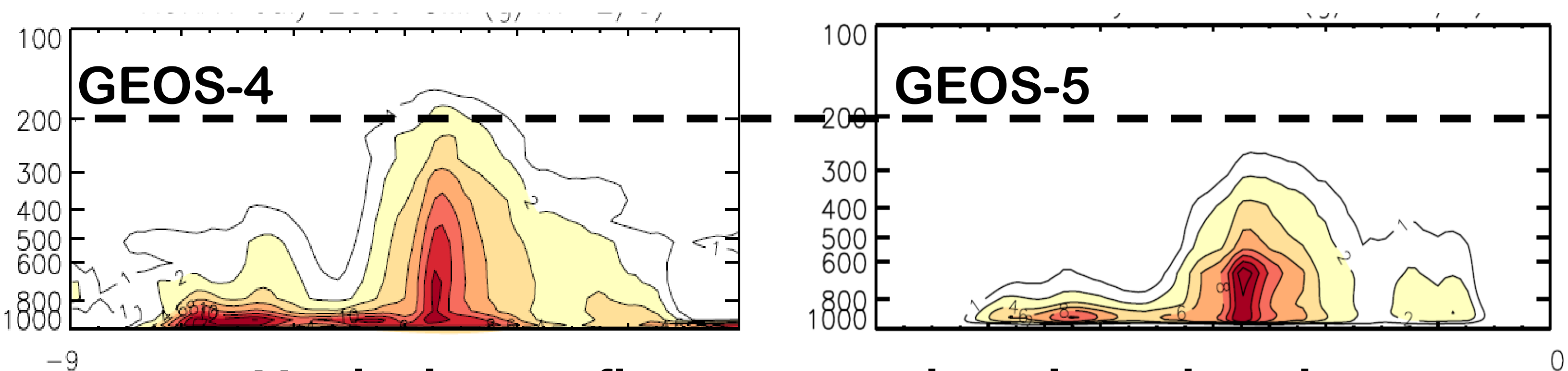
GEOS-5 > GEOS-4 in much of the tropics
GEOS-5 ≈ GEOS-4 in maritime continent
GEOS-4 is usually closer to the MLS observations

# Case study:  Ozone in July

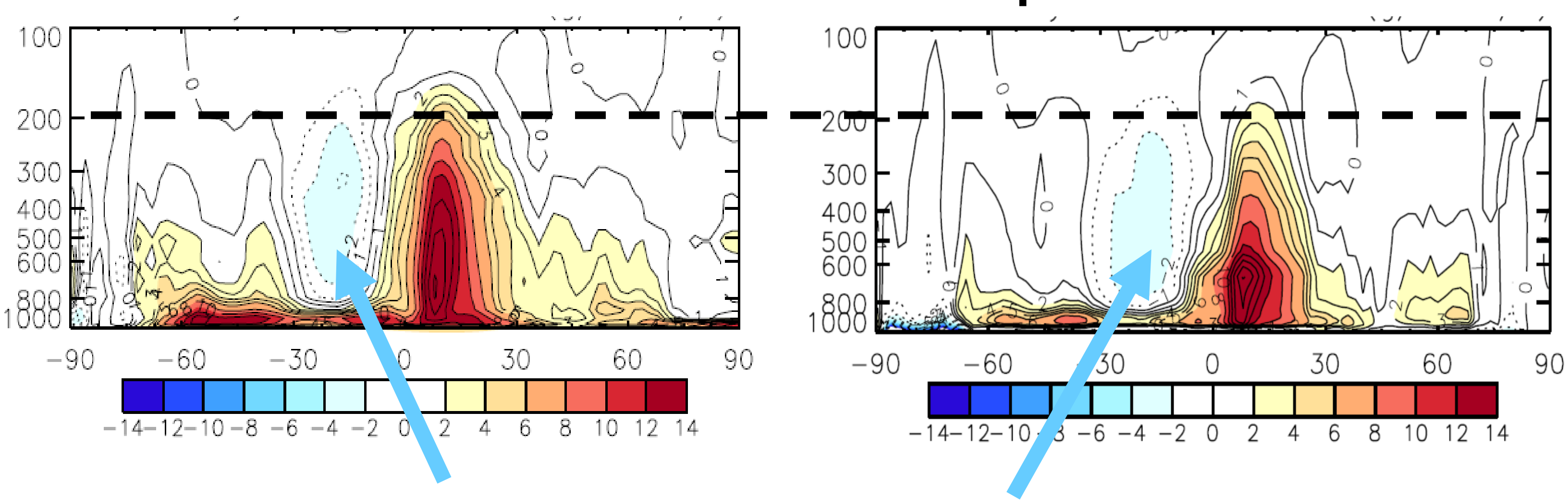


# Vertical transport of air, zonal mean, July 2006

## Convective mass flux (g/m$^2$/sec)



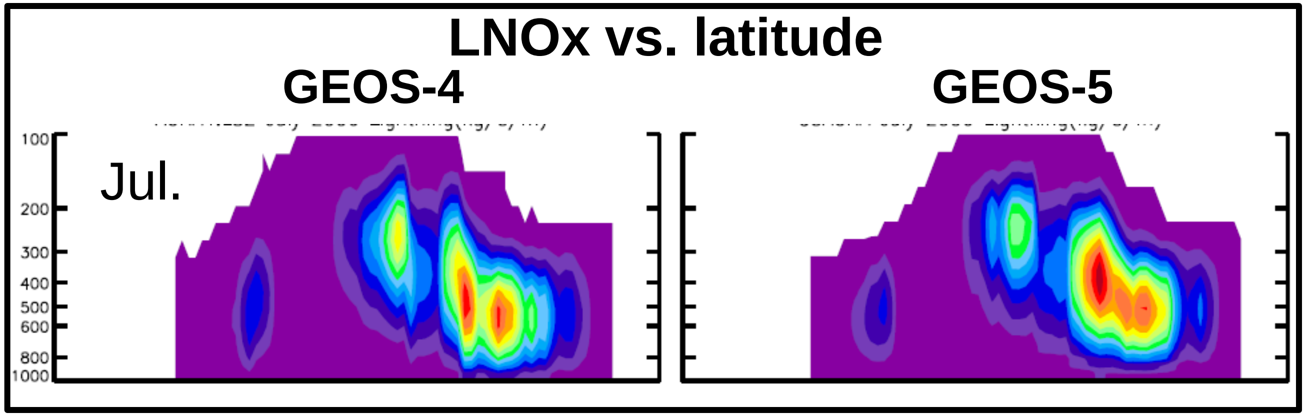

## Vertical mass flux: convection plus advection

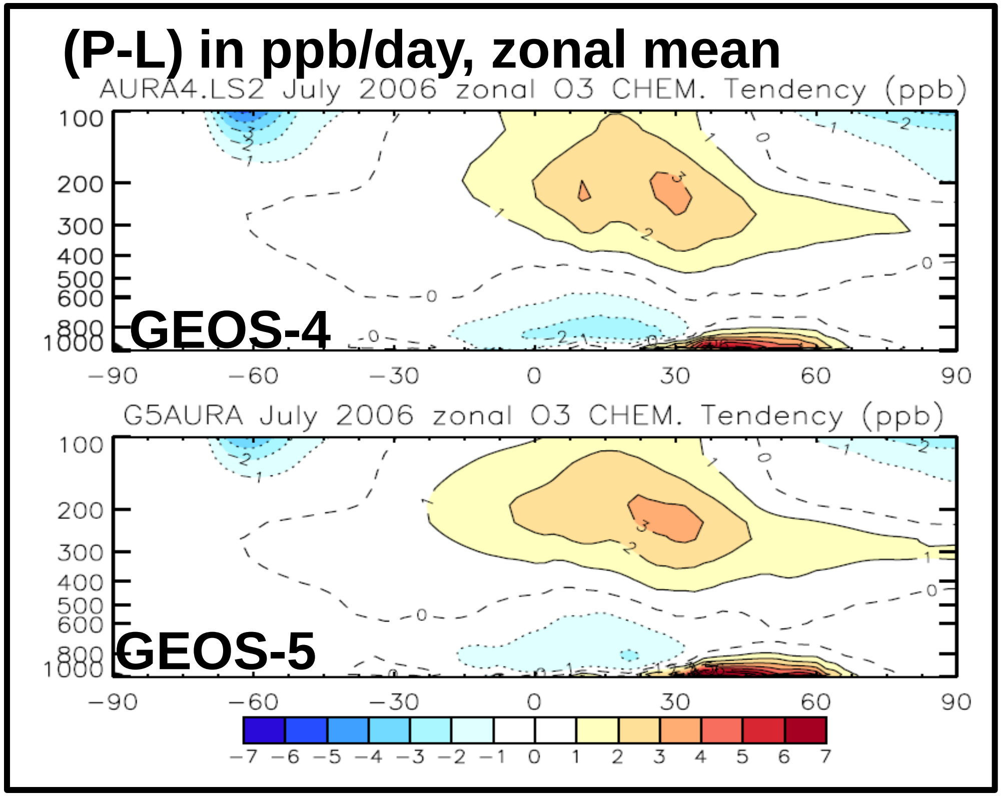



**Subsidence in southern sub-tropics (Hadley cell)**

**Red = upward flux, blue = subsidence**

# Lightning NOx (LNOx) emissions and (P-L) are similar




LNOx emissions have a similar vertical profile even though the mass fluxes peak at a lower altitude in GEOS-5.

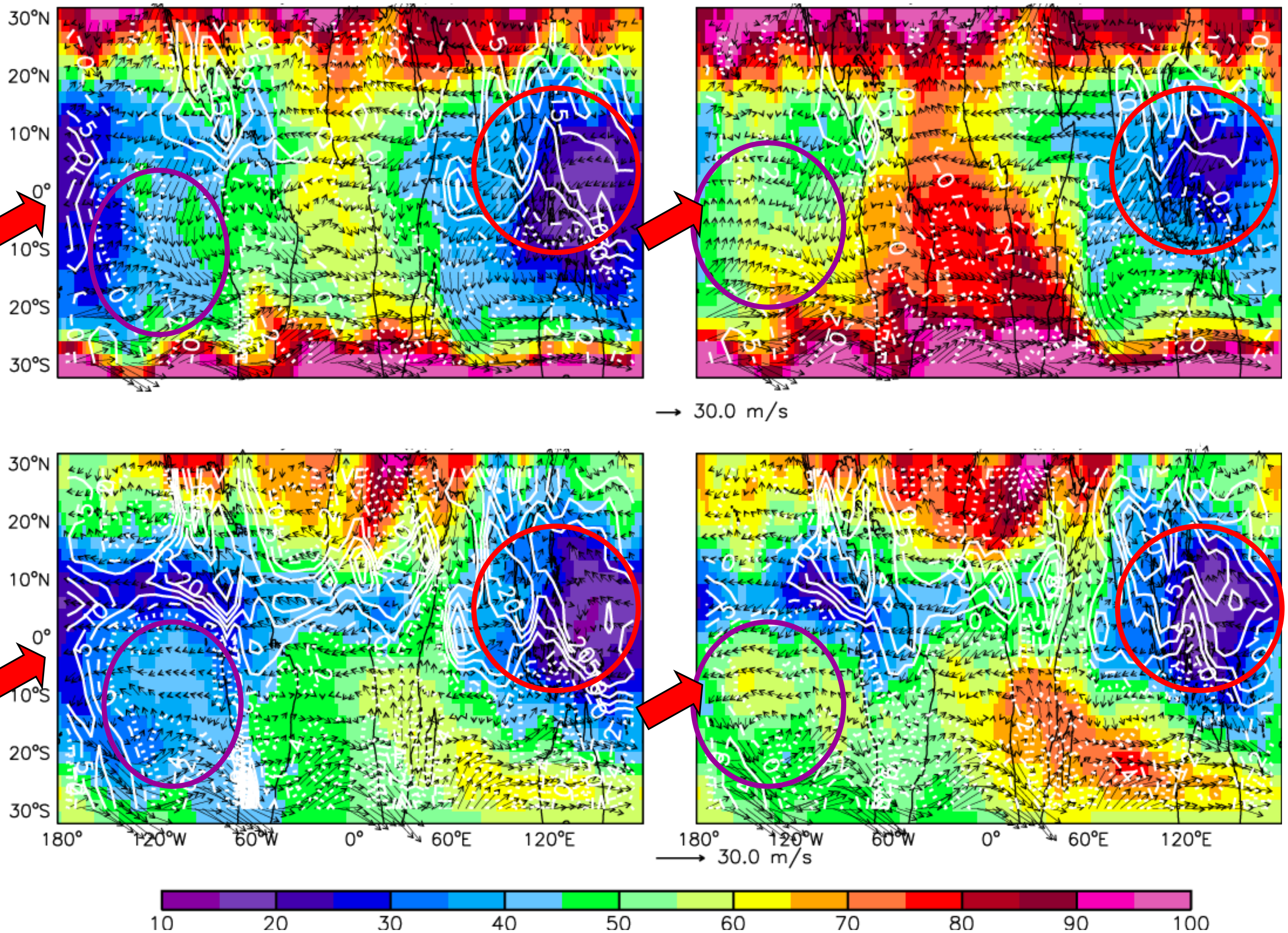
The top of the LNOx profile is determined from the top level with any cloud mass flux (or detrainment) – an extrema

# GEOS-4 vs. GEOS-5 ozone: similar in regions of deep convection, most different in regions of subsidence

**GEOS-4** | **GEOS-5**

**200 hPa**

**500 hPa**

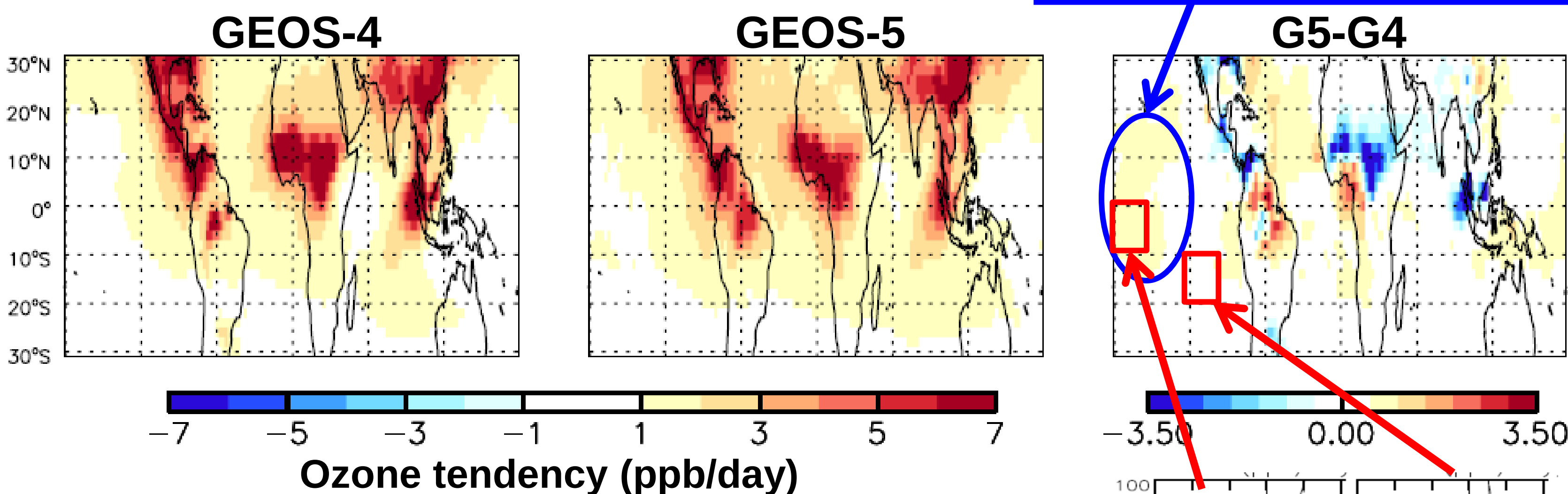



**White lines: air mass flux, solid=up, dotted=down; arrows are winds**

# Ozone chemical tendency (P-L) is higher in GEOS-5 in regions of subsidence at 200 hPa – caused by higher NOx

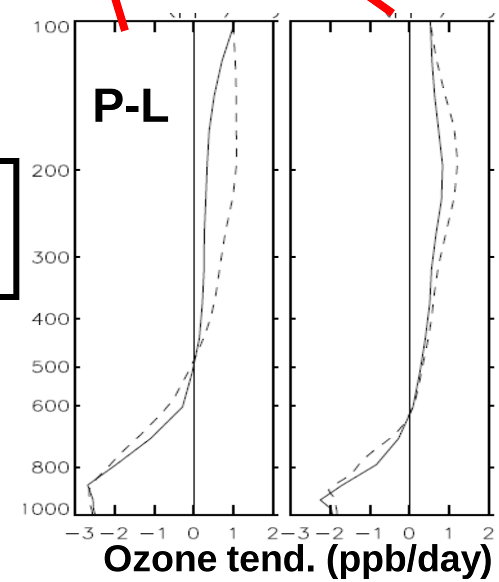
**July 2006, 200 hPa**

**>0.5 ppb/day more ozone formed in GEOS-5**




**Net production of ozone is highest over the lightning source regions - but rapid vertical mixing by convections leads to lower ozone in these regions.**

**GEOS-5: dashed**
**GEOS-4: solid**



# Concluding remarks

- **GEOS-4 and GEOS-5 ozone are similar in regions of deep convection, and are most different in regions of subsidence**

- **TES, MLS, and sonde data show that vertical transport in GEOS-5 degrades the tropical simulations compared to GEOS-4**

- **Conventional view that lightning NOx is the main factor controlling tropical ozone is overly simplistic – transport is also key, affecting ozone and its precursors**

- **What would the effect be of releasing LNOx at lower altitudes (Bousserez study)?? Ozone would increase in the mid-trop.**

- **Do the same problems exist in the GEOS-5 GCM using the same convective scheme? Coupled chemistry-climate models used for projections, so the stakes are high.**

- **What about GEOS-6?**