Analysis of ozone in the GMI Combo model driven by GEOS-4 and GEOS-5

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GMI Combo model

GMI Combo model

- **Driven by the GEOS-4 and GEOS-5 assimilated meteorological fields**
  - Comparisons of two runs with lightning NO_x treated the same way (local scaling to OTD/LIS) - gmic_aura4Light2 for GEOS-4

Convection schemes

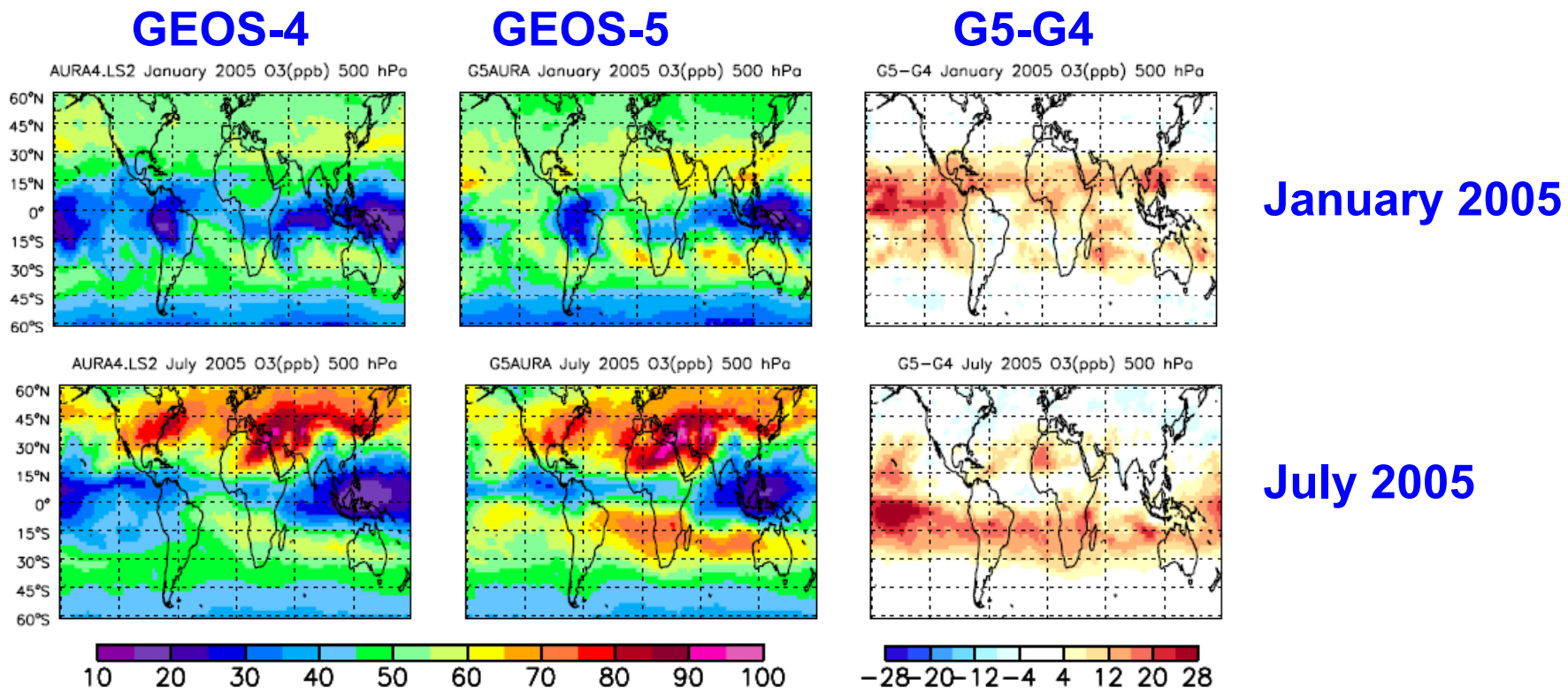
- **GEOS-4 – Zhang and McFarland (1995) (deep) and Hack et al. (1994) (shallow)**
- **GEOS-5 – a version of the Relaxed Arakawa Schubert scheme (Moorthi and Suarez, 1992)**

  (plus many other improvements in GEOS-5)

Outline

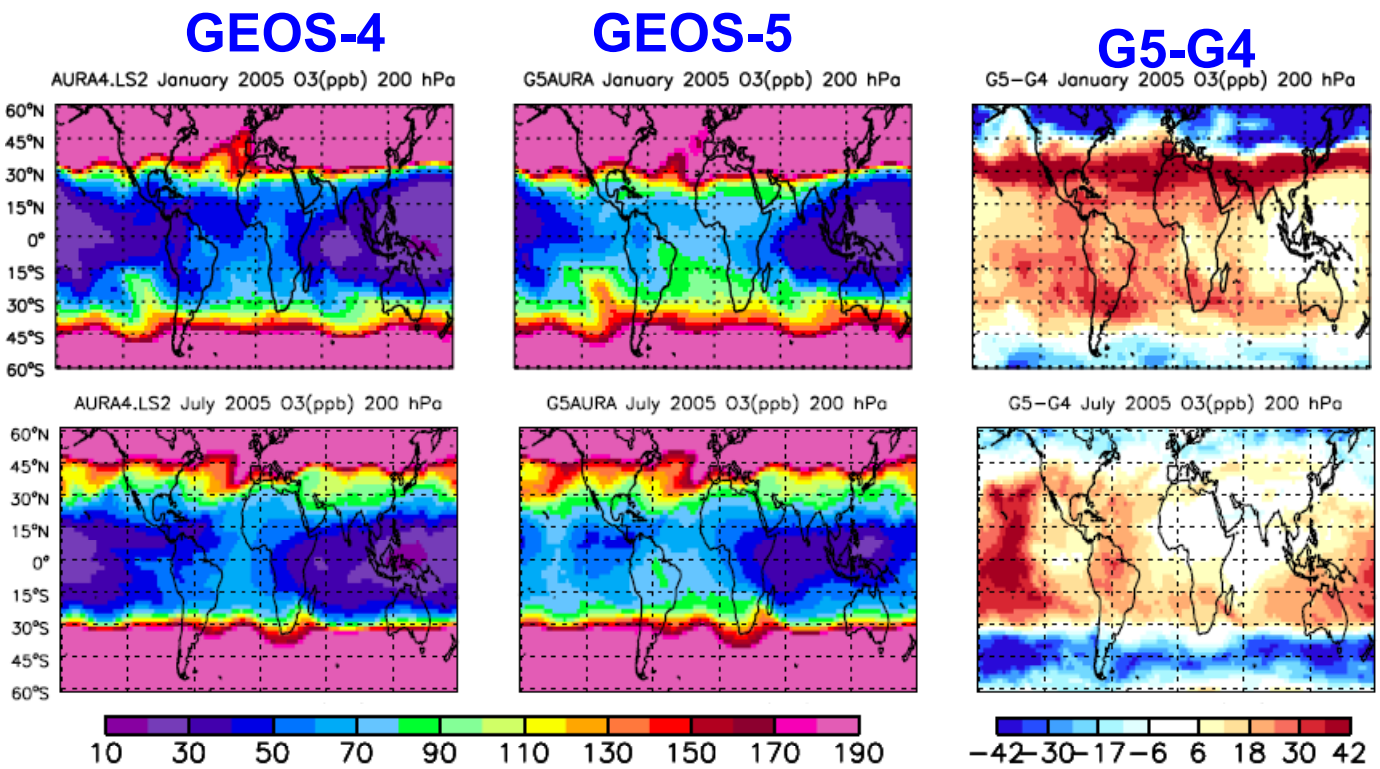
- Analysis of the causes of discrepancies between models and ozone in the tropics (GMI model)
  - Extratropics
  - Tropics, with a focus on understanding effects of differences in vertical transport in GEOS-5 and GEOS-4
- In-situ, TES, and MLS data used for model evaluation

Ozone at 500 hPa in GEOS-4 and GEOS-5.



- Differences are largest in the tropics.
- Which matches observations better?
- Why are the model results different from each other?

Ozone at 200 hPa in GEOS-4 and GEOS-5.

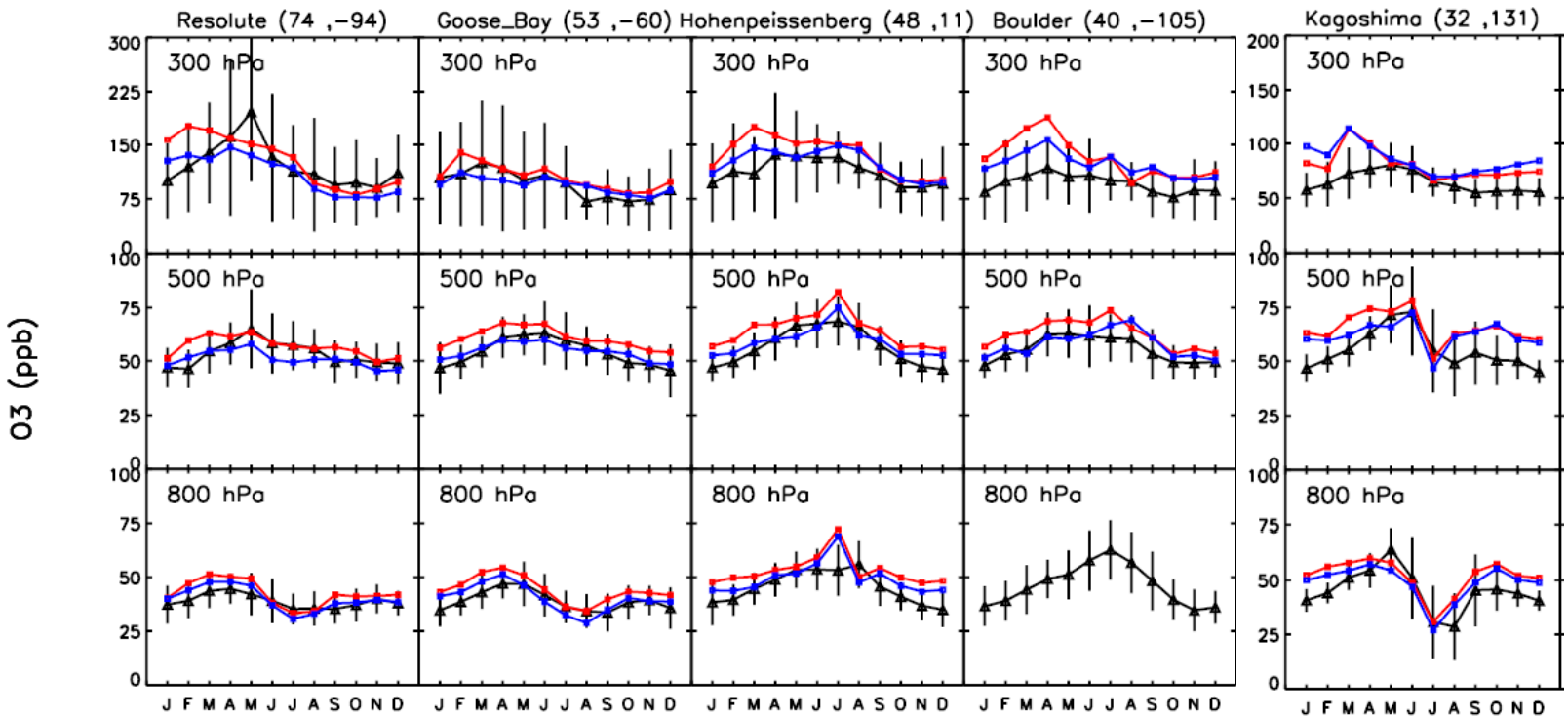


January 2005

July 2005

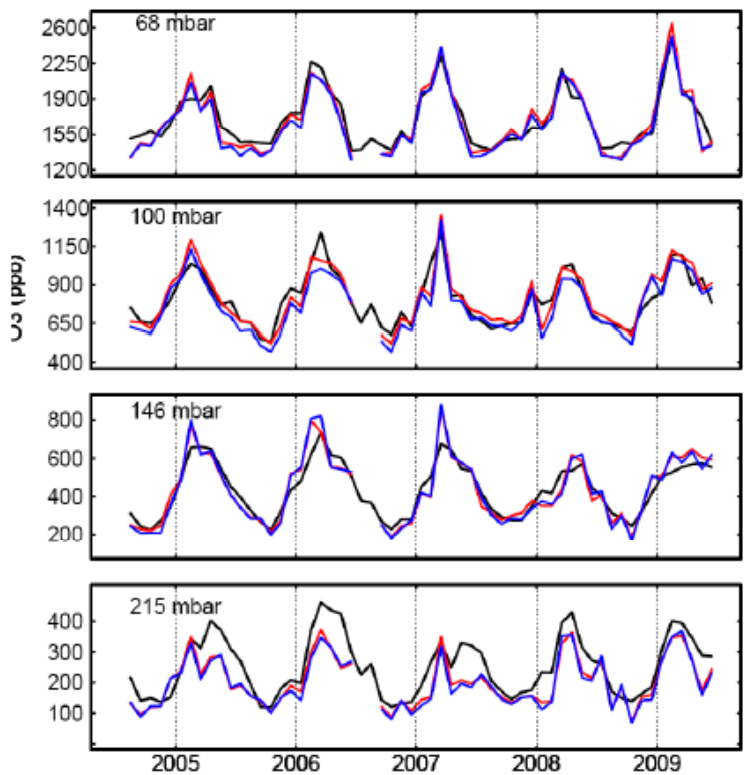
- Differences are largest in the tropics.
- Which matches observations better?
- Why are the model results different from each other?

GEOS-4 and GEOS-5 vs. sondes, 32-75 N



- GEOS-4 > GEOS-5 in extratropics by a few ppb
- GEOS-5 agrees better with sonde and MOZAIC in mid-latitudes
- GEOS-5 matches the amplitude of annual cycle better

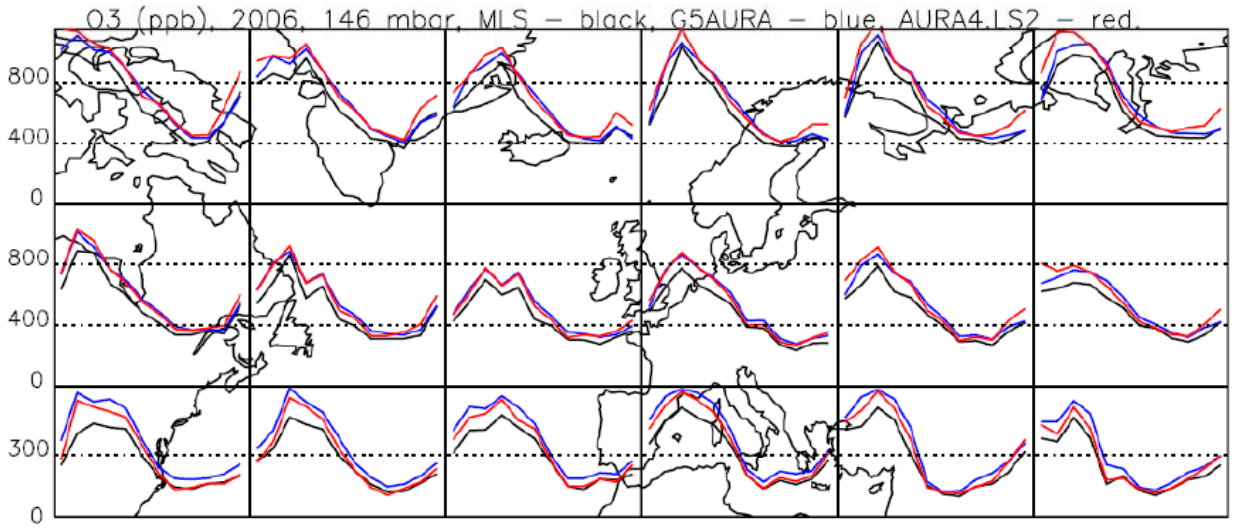
MLS data in the extratropics – comparison with sondes over Europe

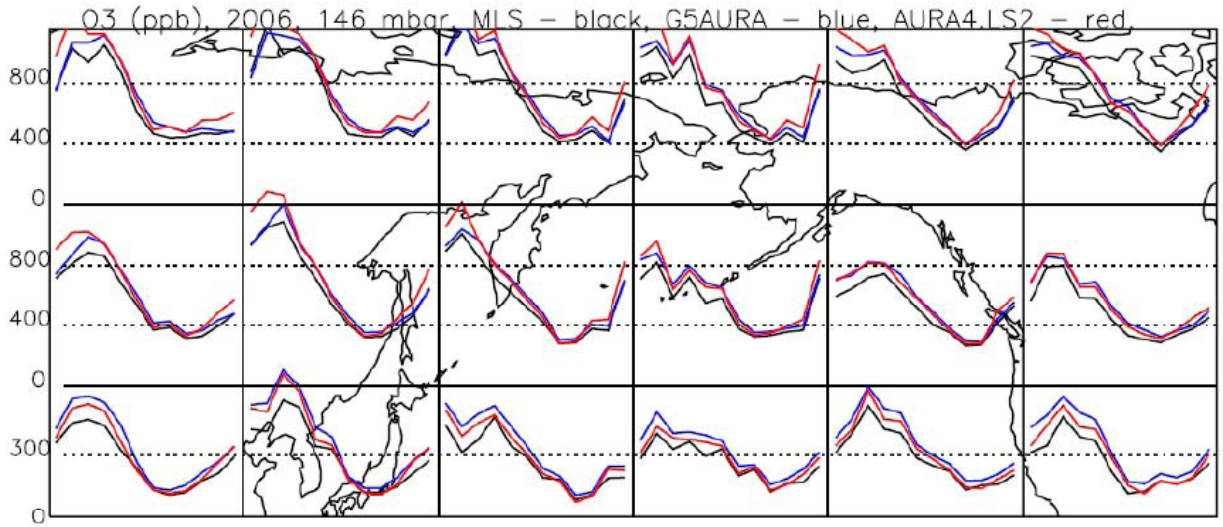


MLS
Sonde data
Sonde data with AK

MLS and sondes show excellent agreement down to 146 hPa in the extratropics.

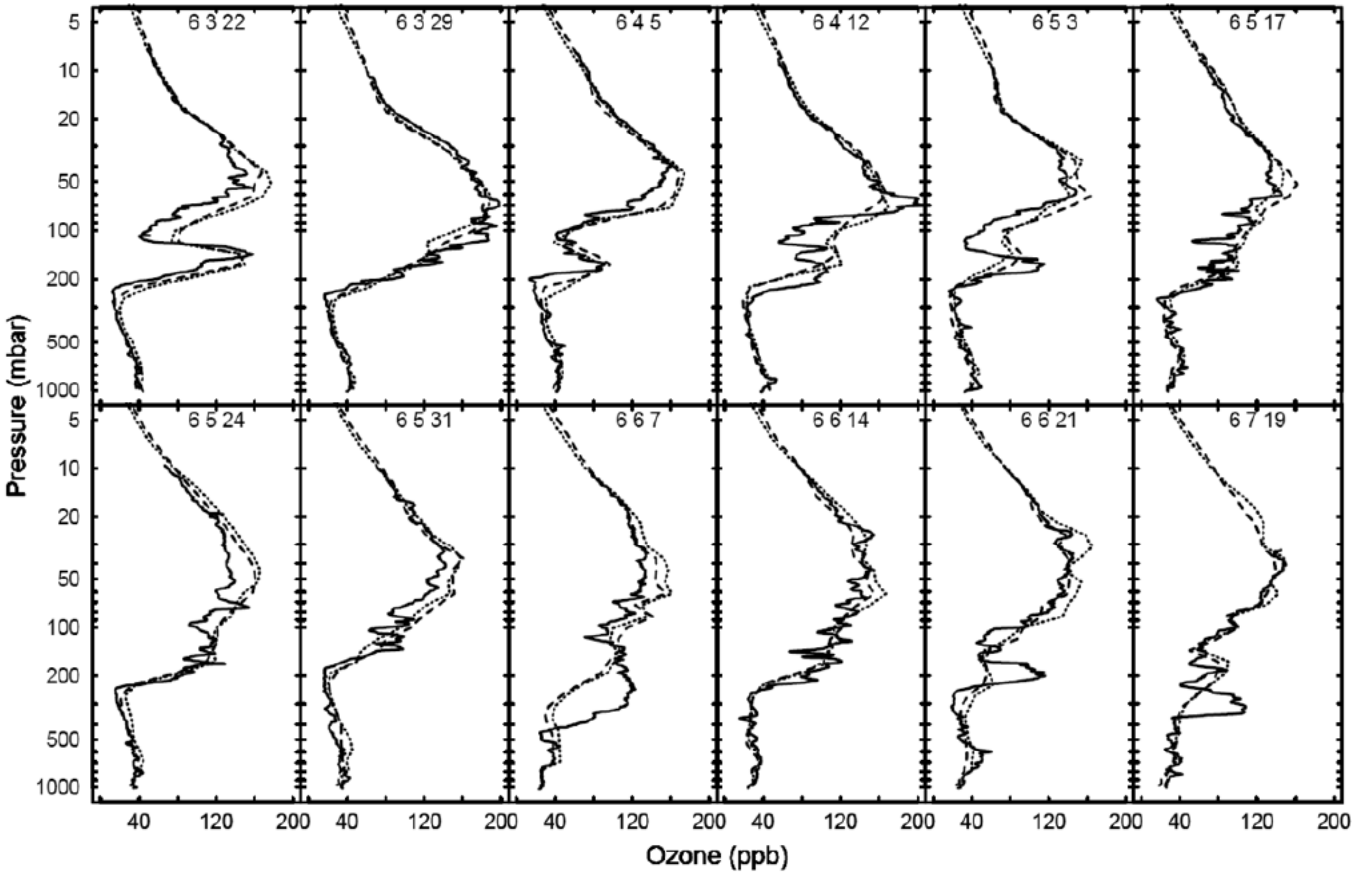
MLS, GEOS-4 and GEOS-5 ozone at 146 hPa in 2006





GEOS-4 and GEOS-5 match spatial and temporal patterns in MLS data very well

Comparison of models to sonde profiles from Goose Bay



Sondes – solid

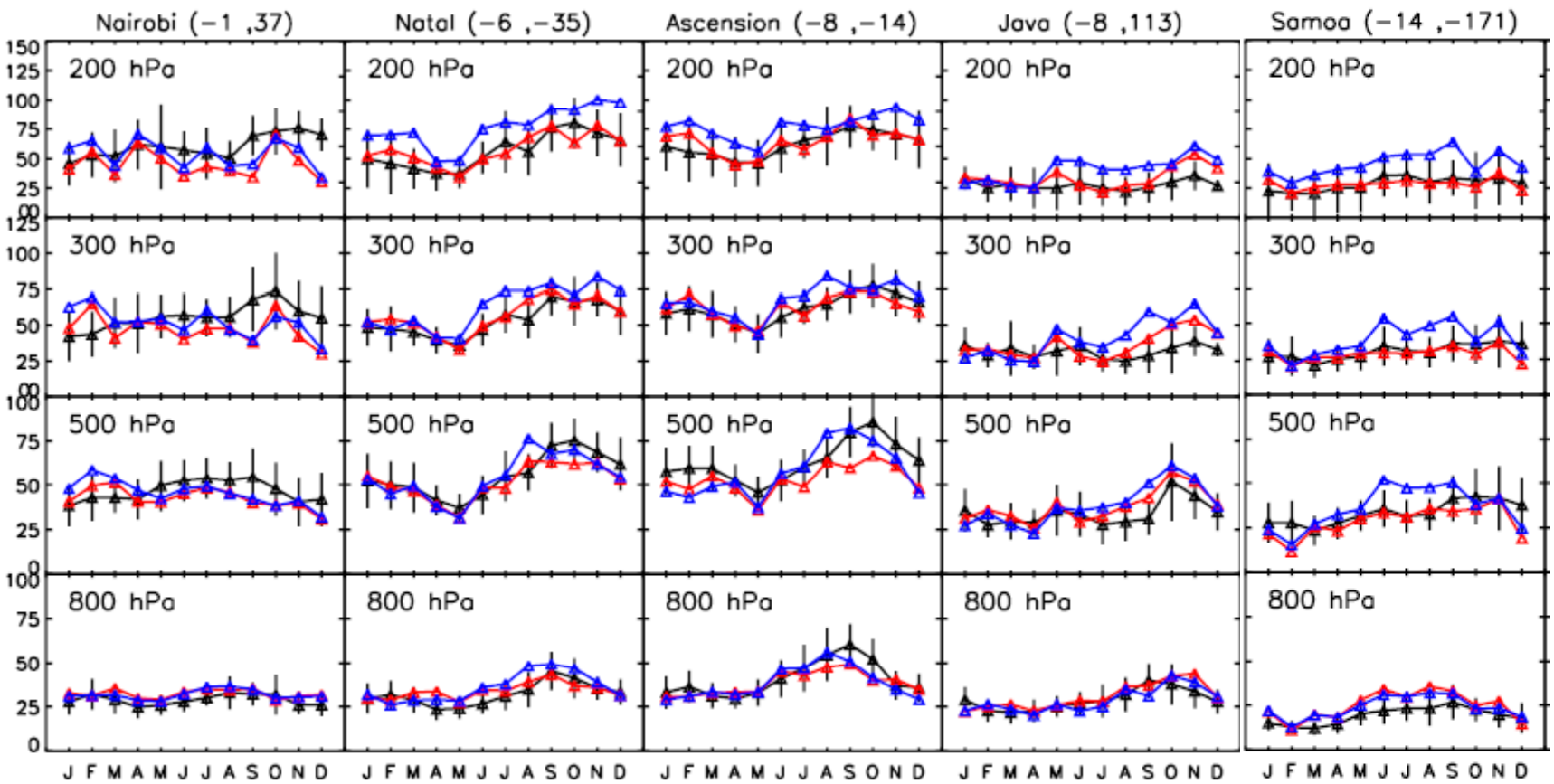
The models capture much of the observed variability of ozone in the lowermost stratosphere on a day-to-day basis

Mid-latitude summary:

- **The GEOS-5 simulation looks great, suggesting the GMI model is well suited for a hindcast.**

- **There are some areas of disagreement with observations, but these discrepancies are much smaller than those in the tropics.**

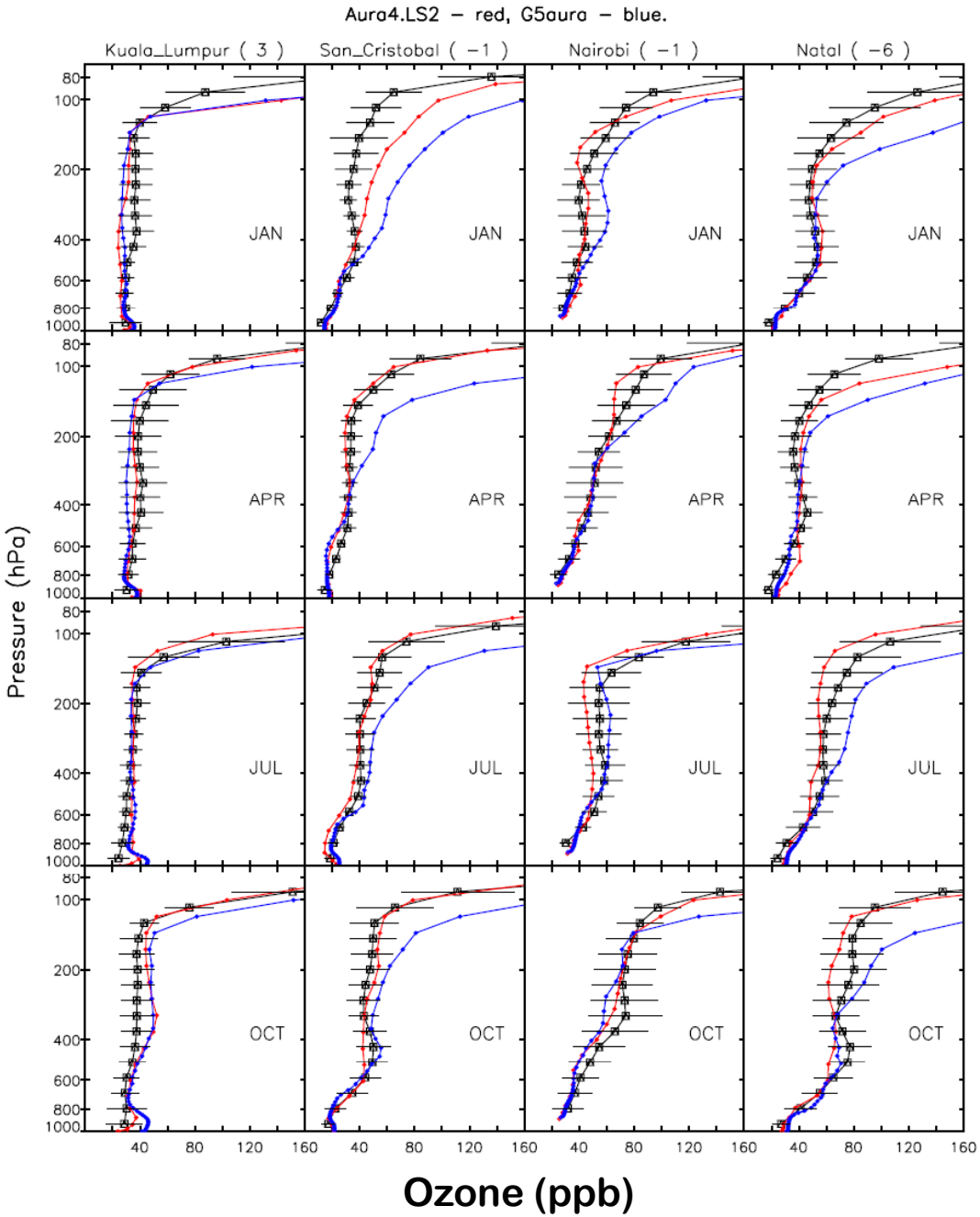
GEOS-4 and GEOS-5 vs. sondes, tropics



----- sonde
----- GEOS-4
----- GEOS-5

GEOS-5 often higher than GEOS-4, and higher than data, in UT

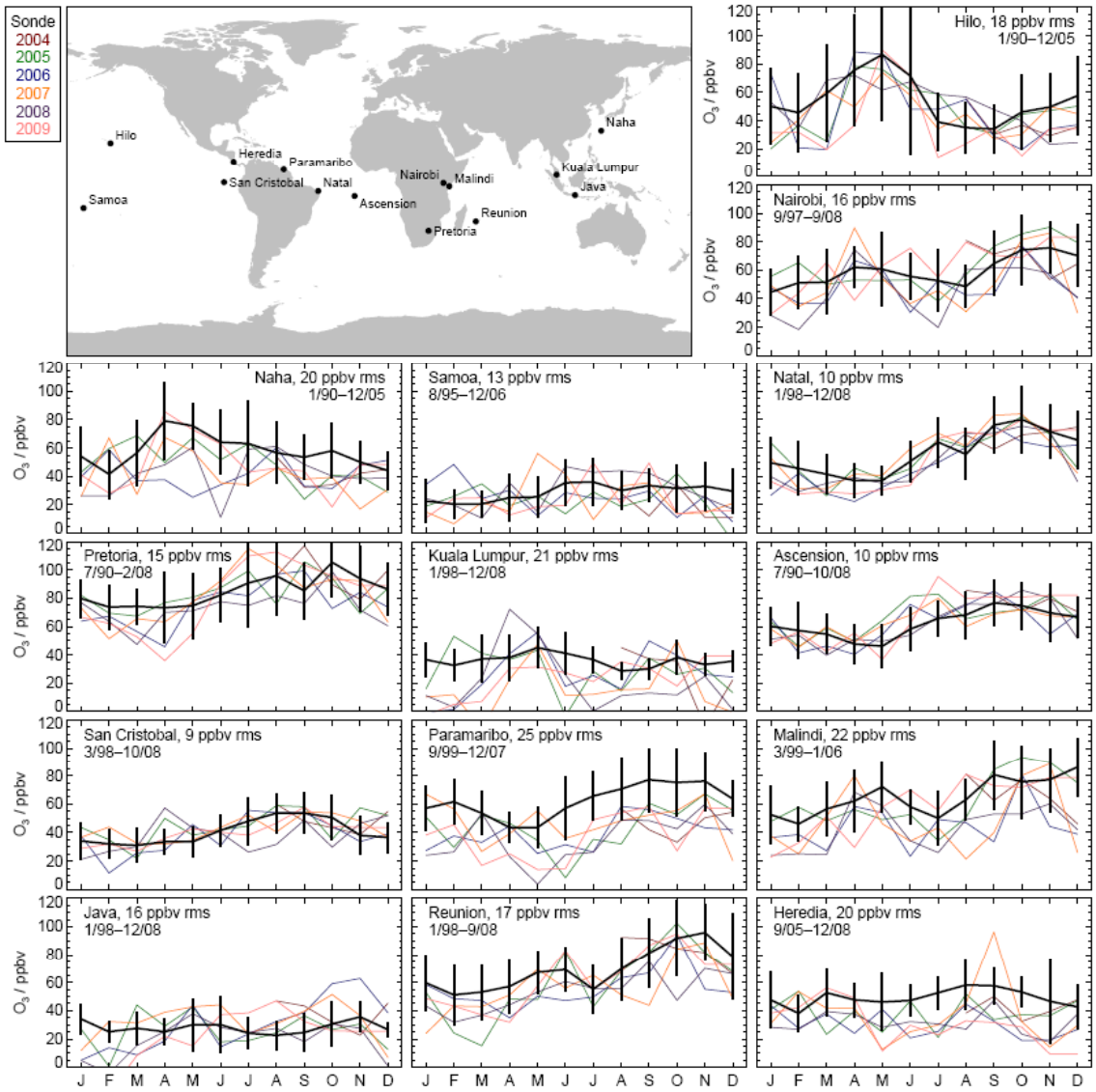
GEOS-4 usually agrees better with data



GEOS-4 usually matches data better than GEOS-5 in UT, except where active convection – e.g., Kuala Lumpur

----- sonde
----- GEOS-4
----- GEOS-5

MLS and sondes at 215 hPa



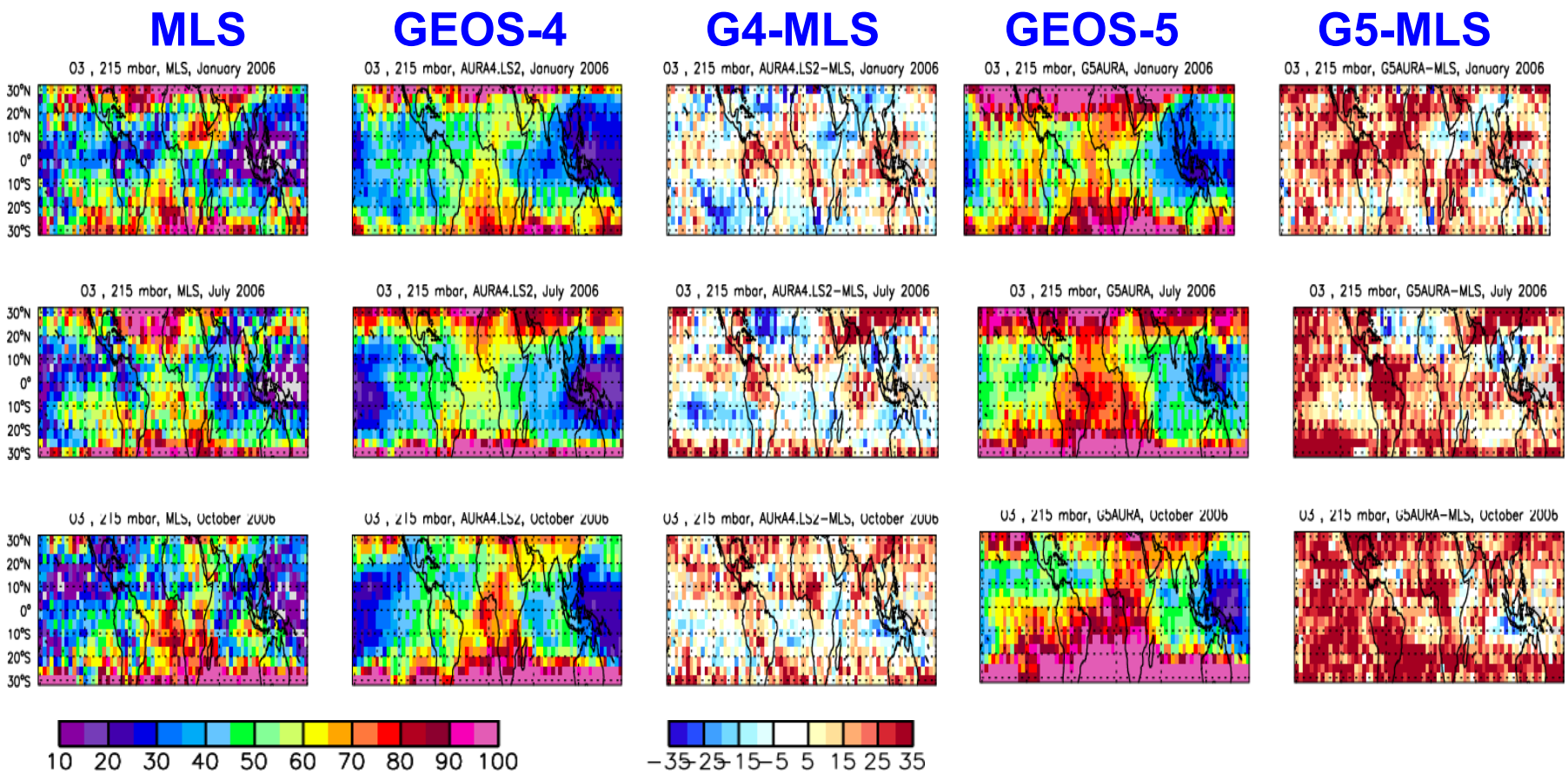
Thin lines are different years of MLS data sampled around each sonde site.

Lends confidence to the use of MLS at 215 hPa in the tropics.

Livesey et al. draft ms

Comparison with MLS at 215 hPa

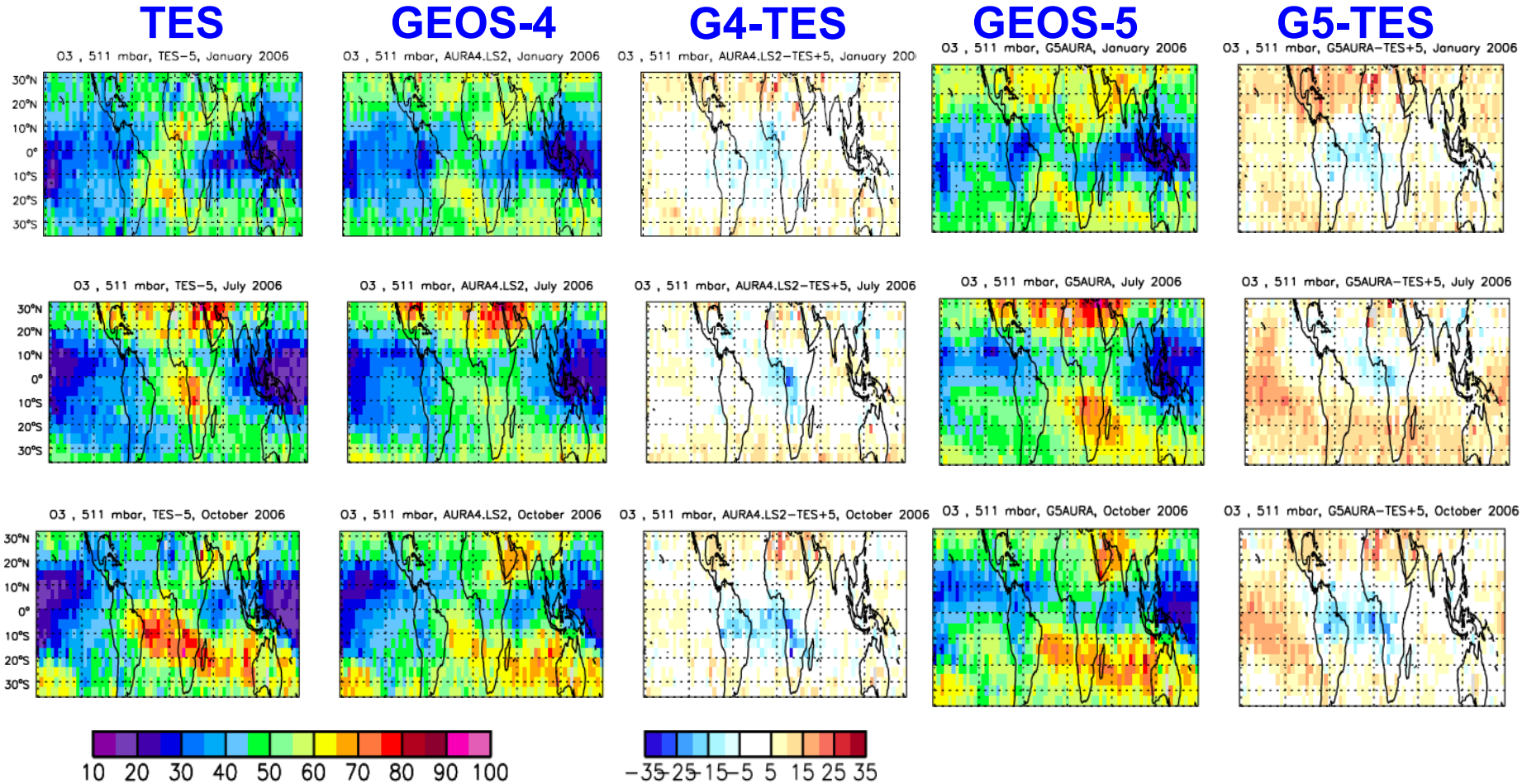
January, July, October, 2006



GEOS-5 ozone > GEOS-4 in much of the tropics
GEOS-4 agrees better with MLS

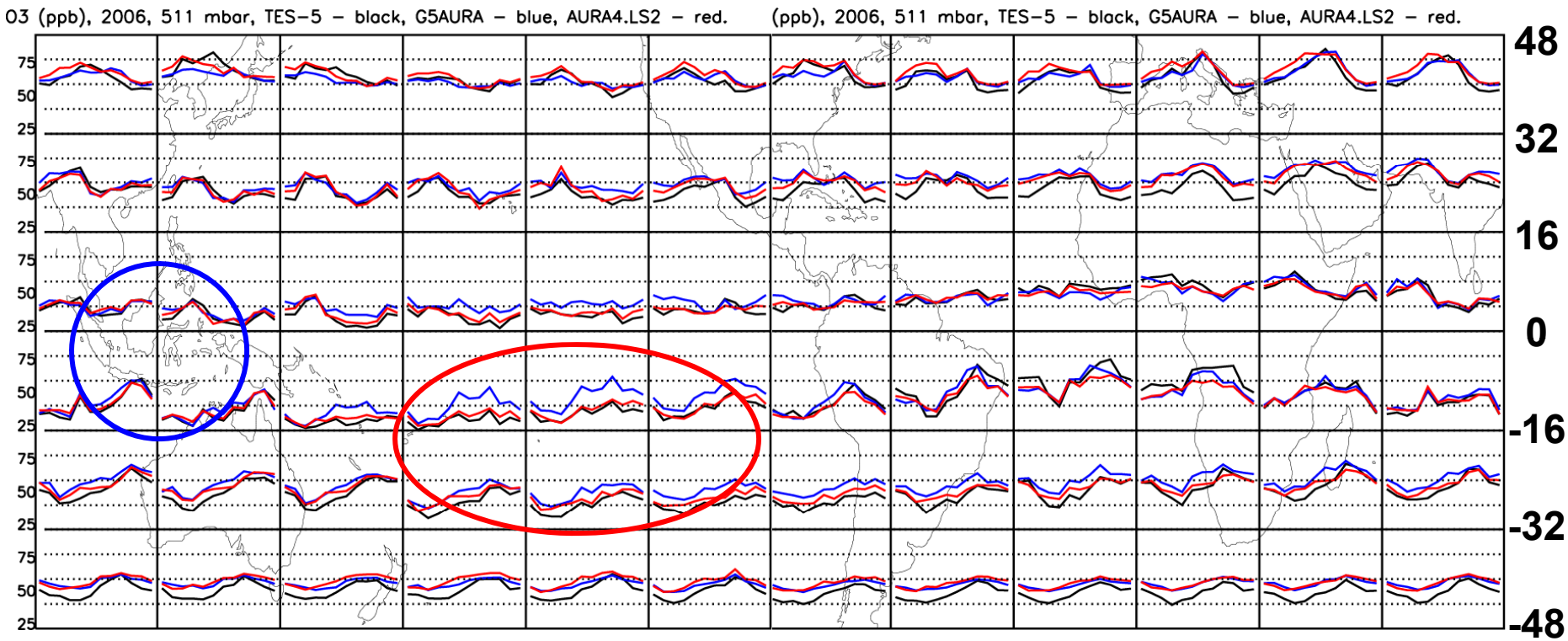
Comparison with TES at 500 hPa

Jan., July, Oct. 2006



GEOS-5 ozone > GEOS-4 in much of the tropics
GEOS-4 agrees better with TES

TES ozone at 511 hPa in 2006 – a global view.



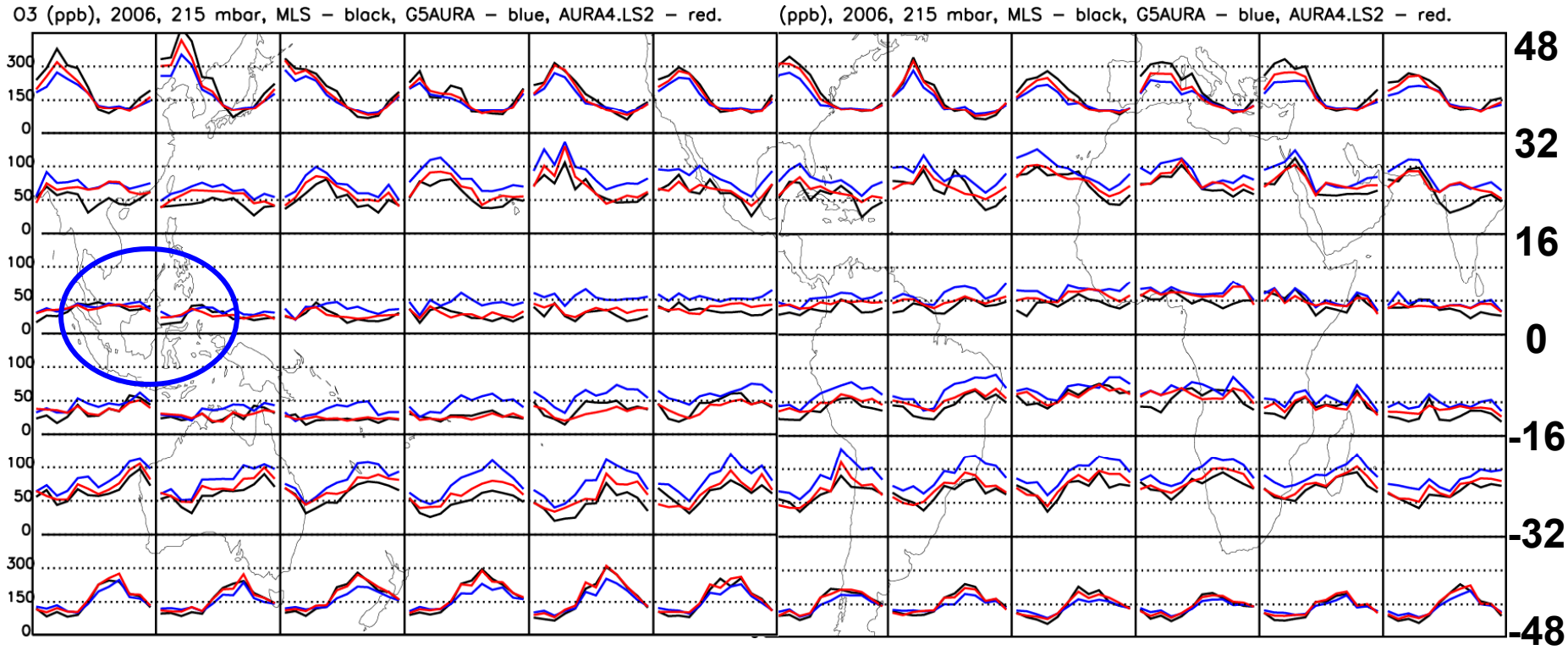
Remarkable fidelity in matching month-month variability of ozone

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

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

GEOS-5 < GEOS-4 in extratropics

MLS ozone at 215 hPa in 2006 – a global view.

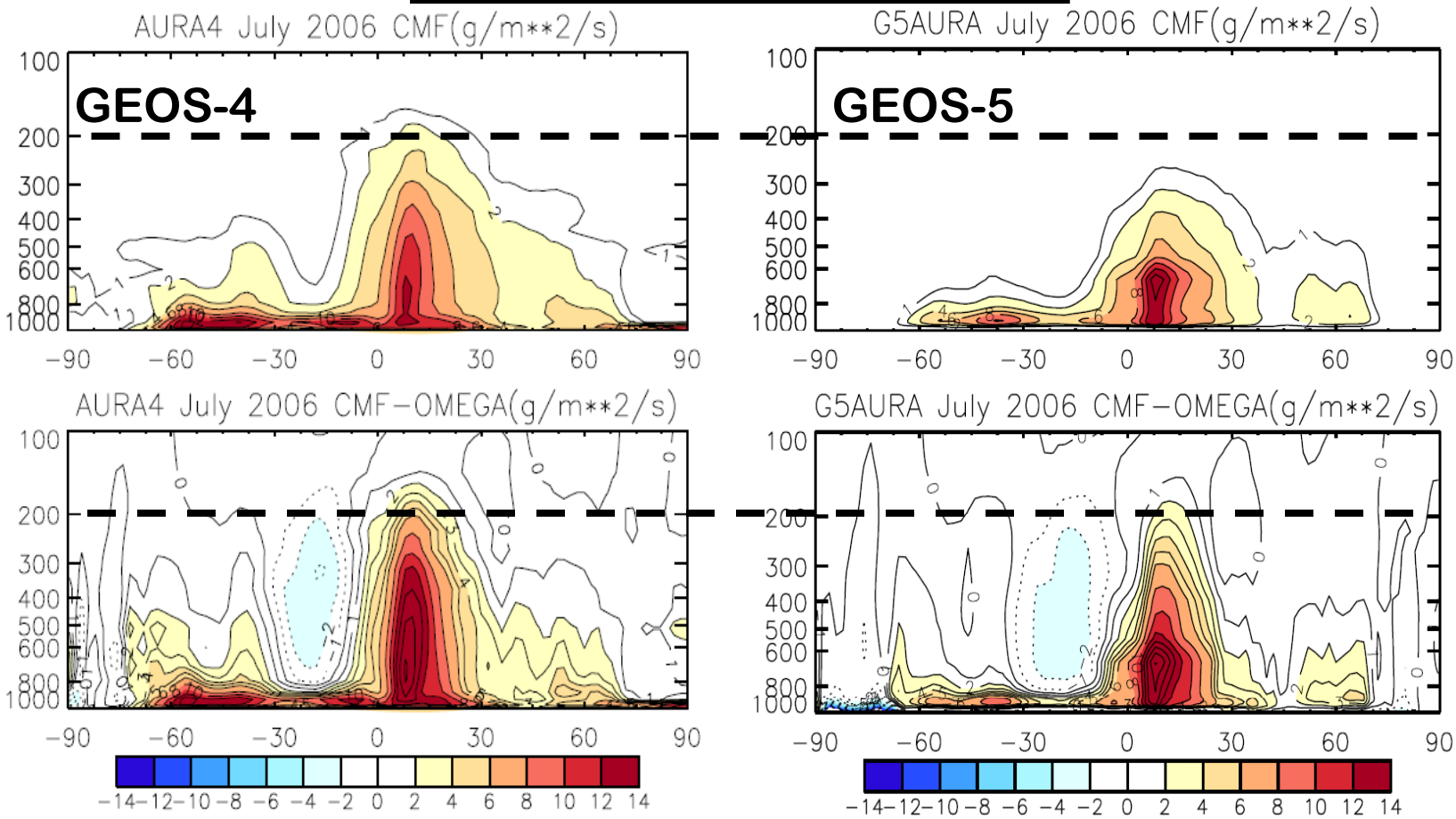


MLS
GEOS-4
GEOS-5

GEOS-5 > GEOS-4 in most of S. tropics and in N. sub-tropics
GEOS-5 ≈ GEOS-4 in maritime continent
GEOS-5 < GEOS-4 in extratropics

Vertical transport of air in GEOS-4 and GEOS-5: July 2006

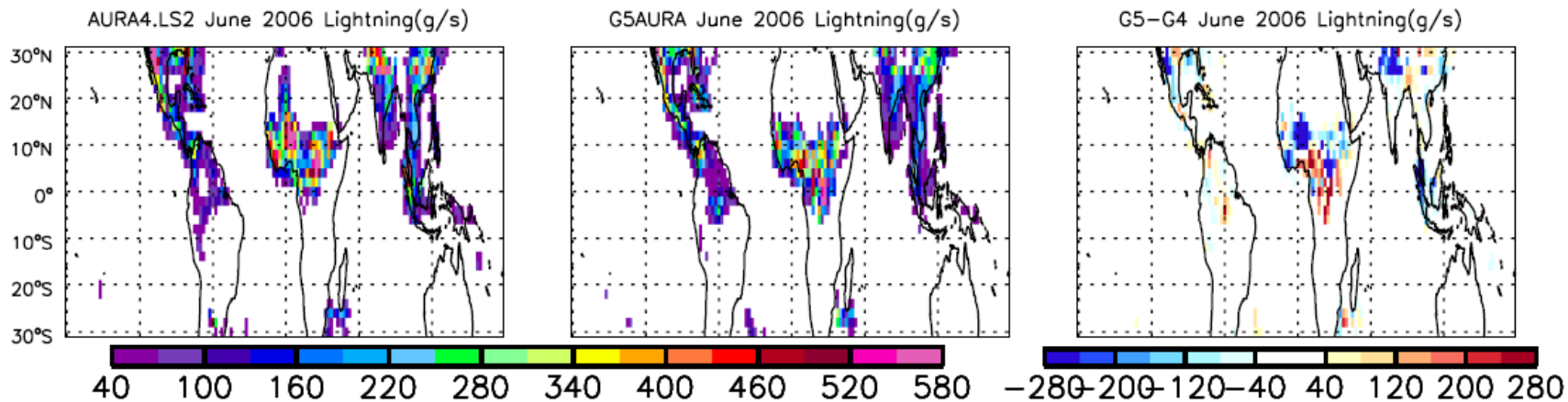
Top: Convective mass flux



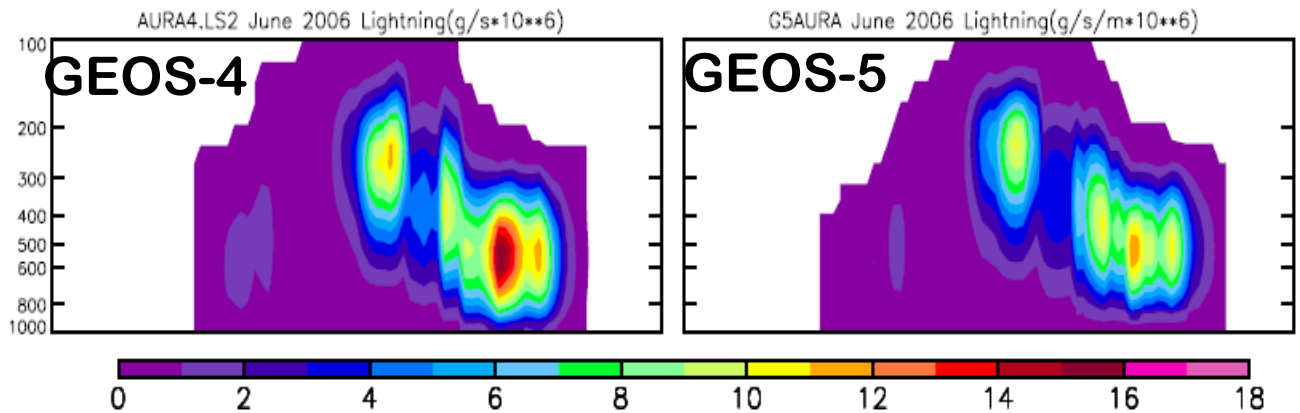
Bottom: vertical flux due to convection plus advection

Red = upward flux, blue = subsidence

Lightning NOx in GEOS4 and GEOS-5

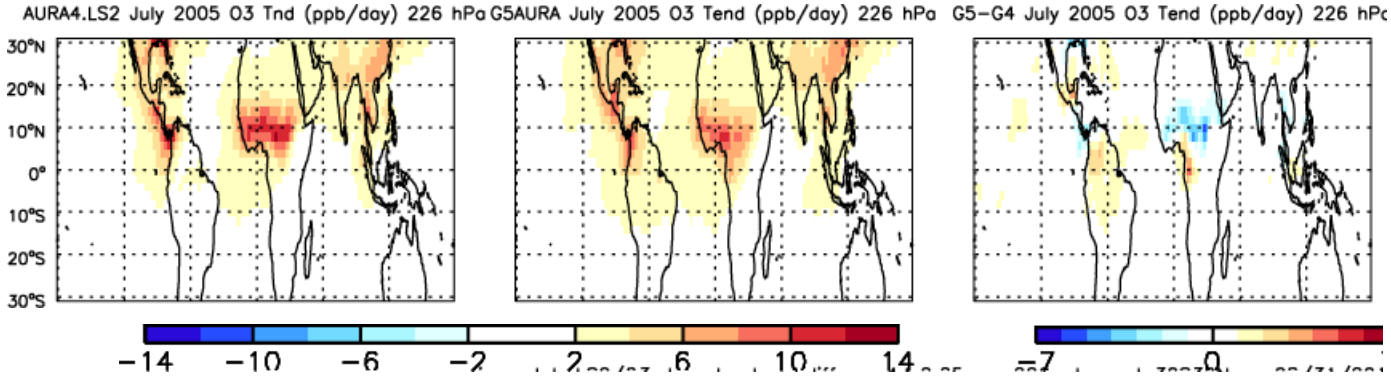


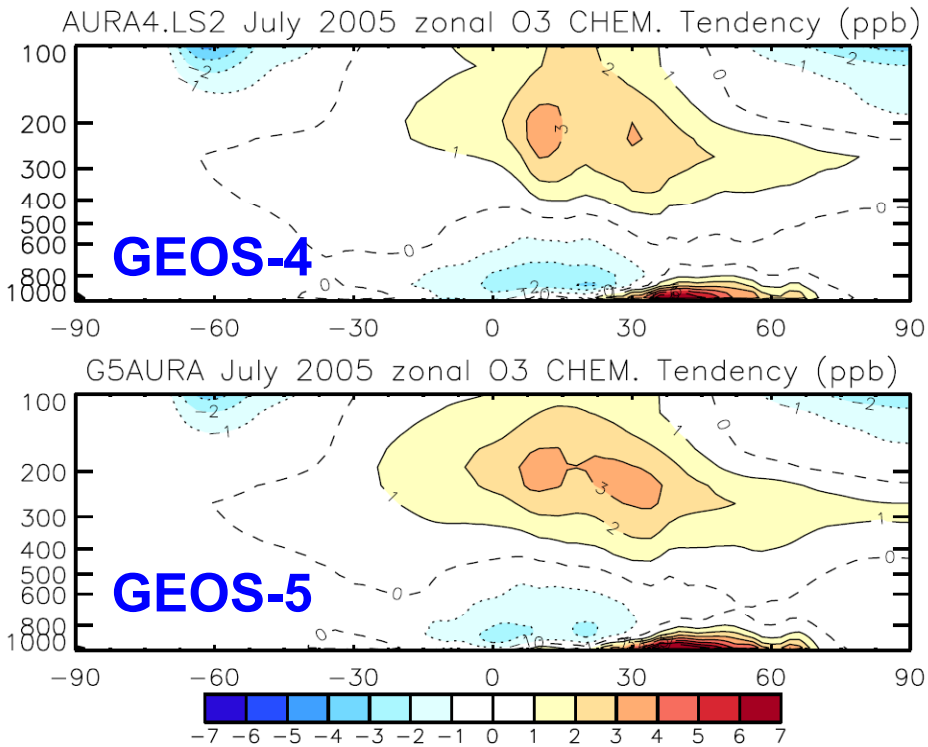
Spatial patterns are similar – true for all months



Vertical profiles of lightning NOx are similar.
The top of the LNOx profile is determined by the top-most altitude with any detrainment – similar in GEOS-4 and GEOS-5.

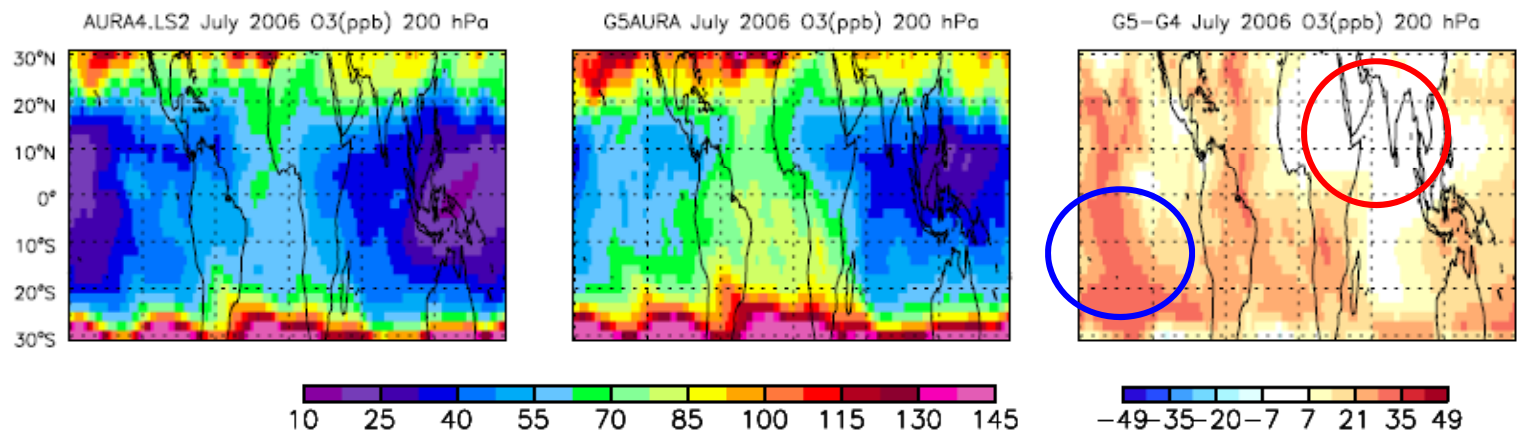
Chemical tendency: (P-L) for ozone (ppb/day)



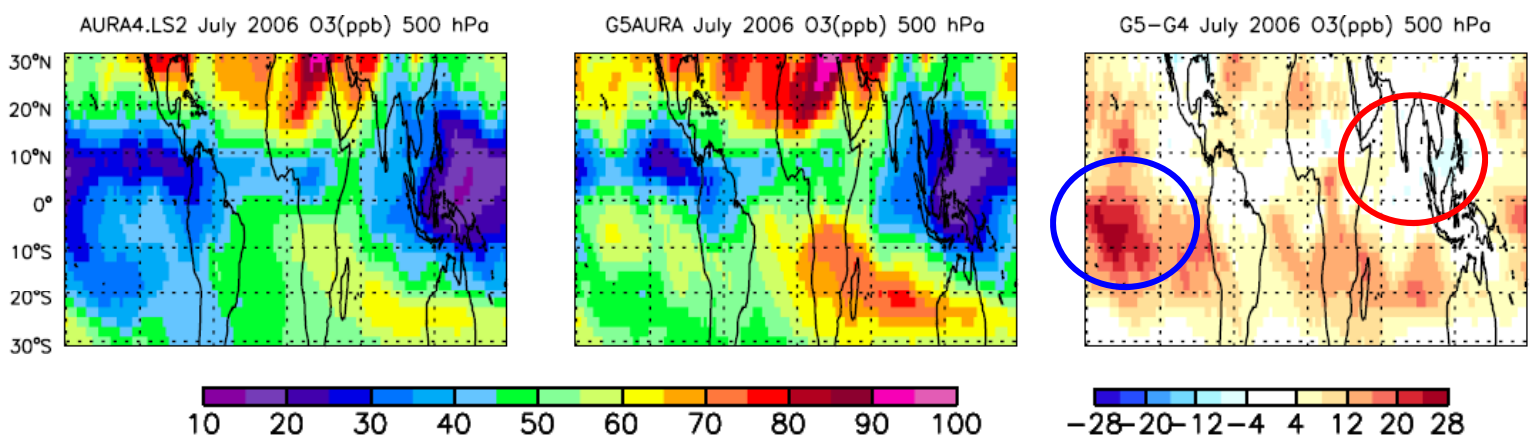


Similar in GEOS-4 and GEOS-5

Ozone, GEOS-5 minus GEOS-4, July 2006

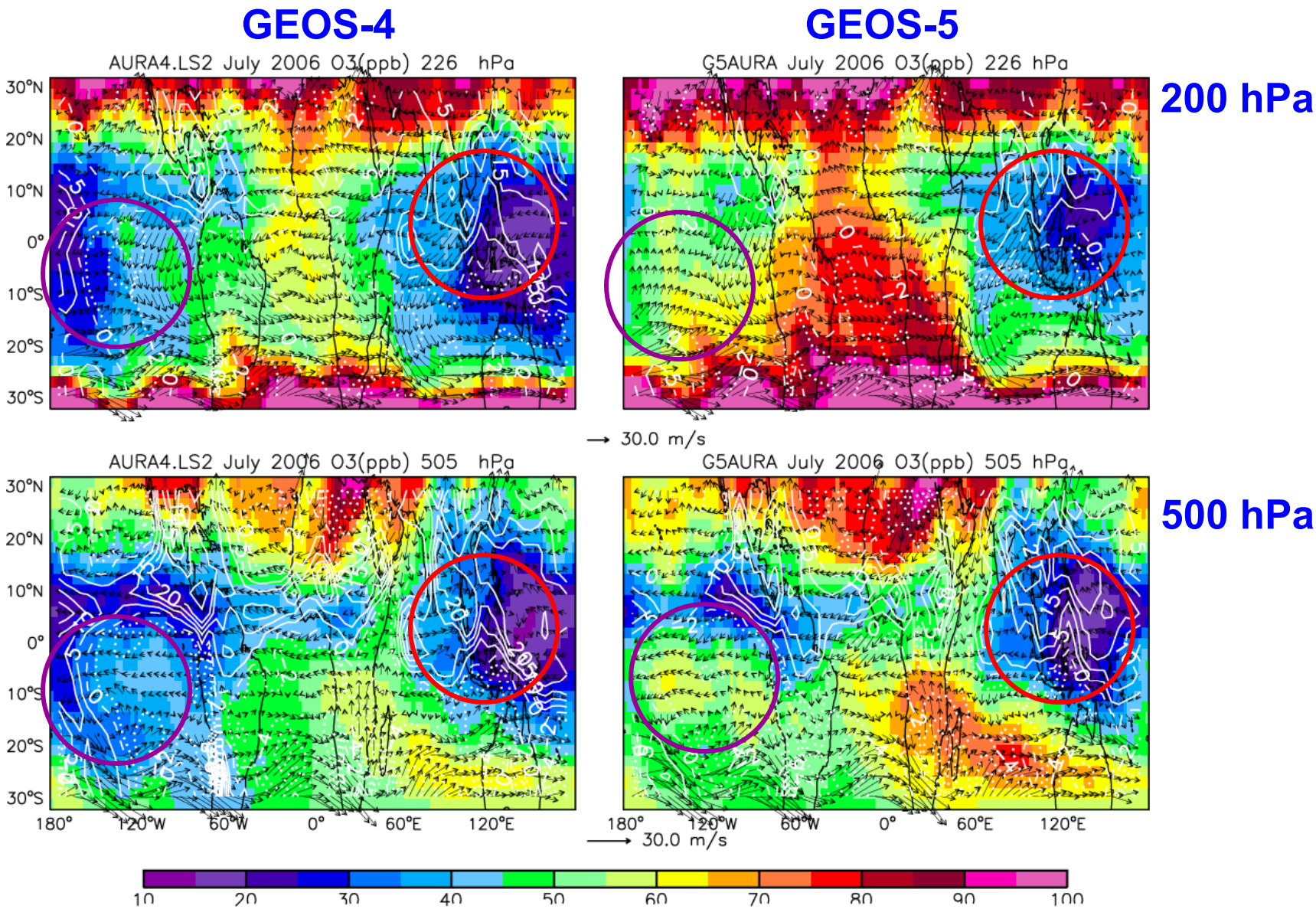


200 hPa



500 hPa

Ozone, winds, and air mass flux, July 2006



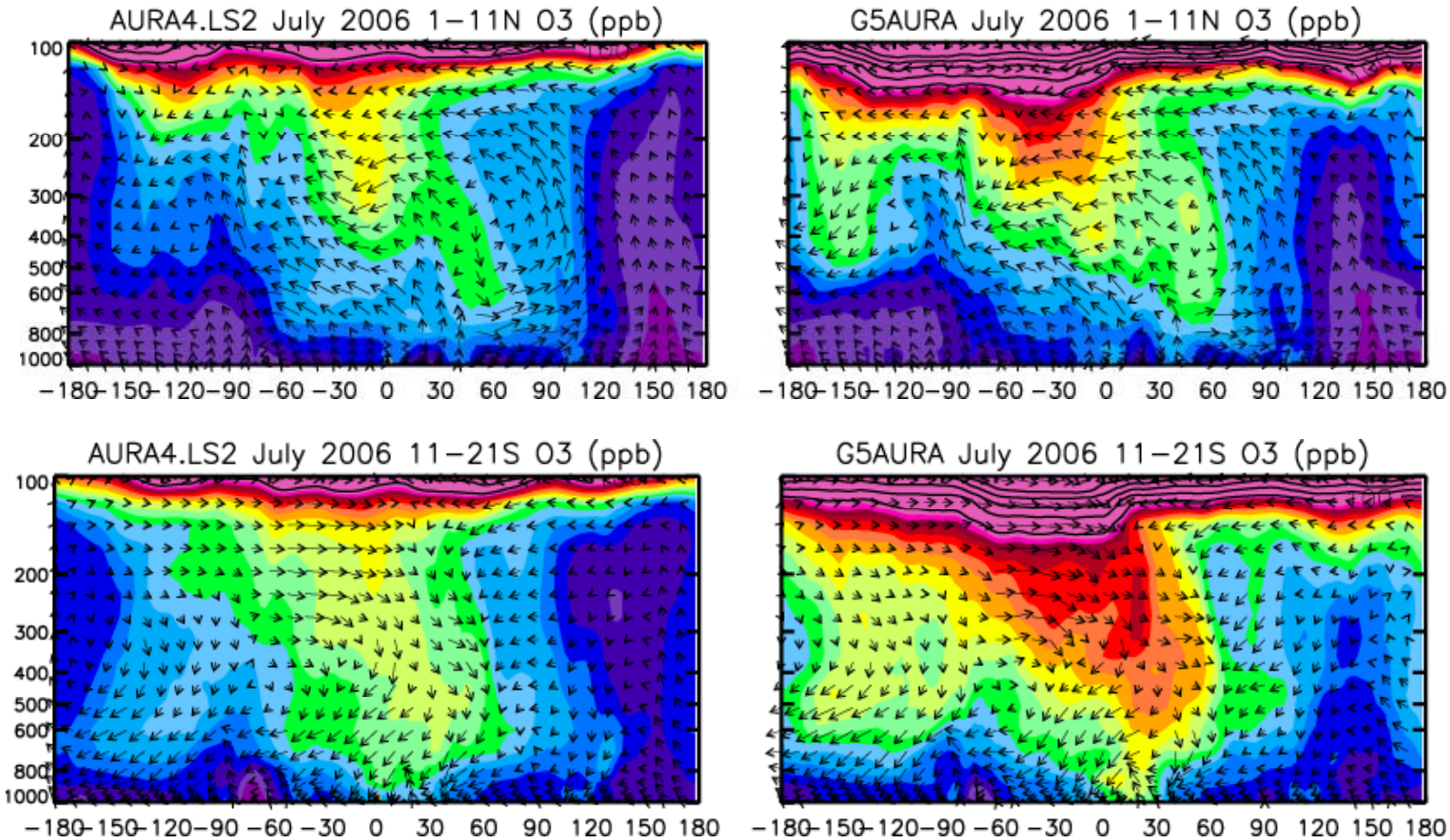
White lines: air mass flux, solid=up, dotted=down; arrows are winds

Ozone and vertical transport

- Ozone is most similar within and downwind of regions of convection
- It is most different in regions of strong subsidence

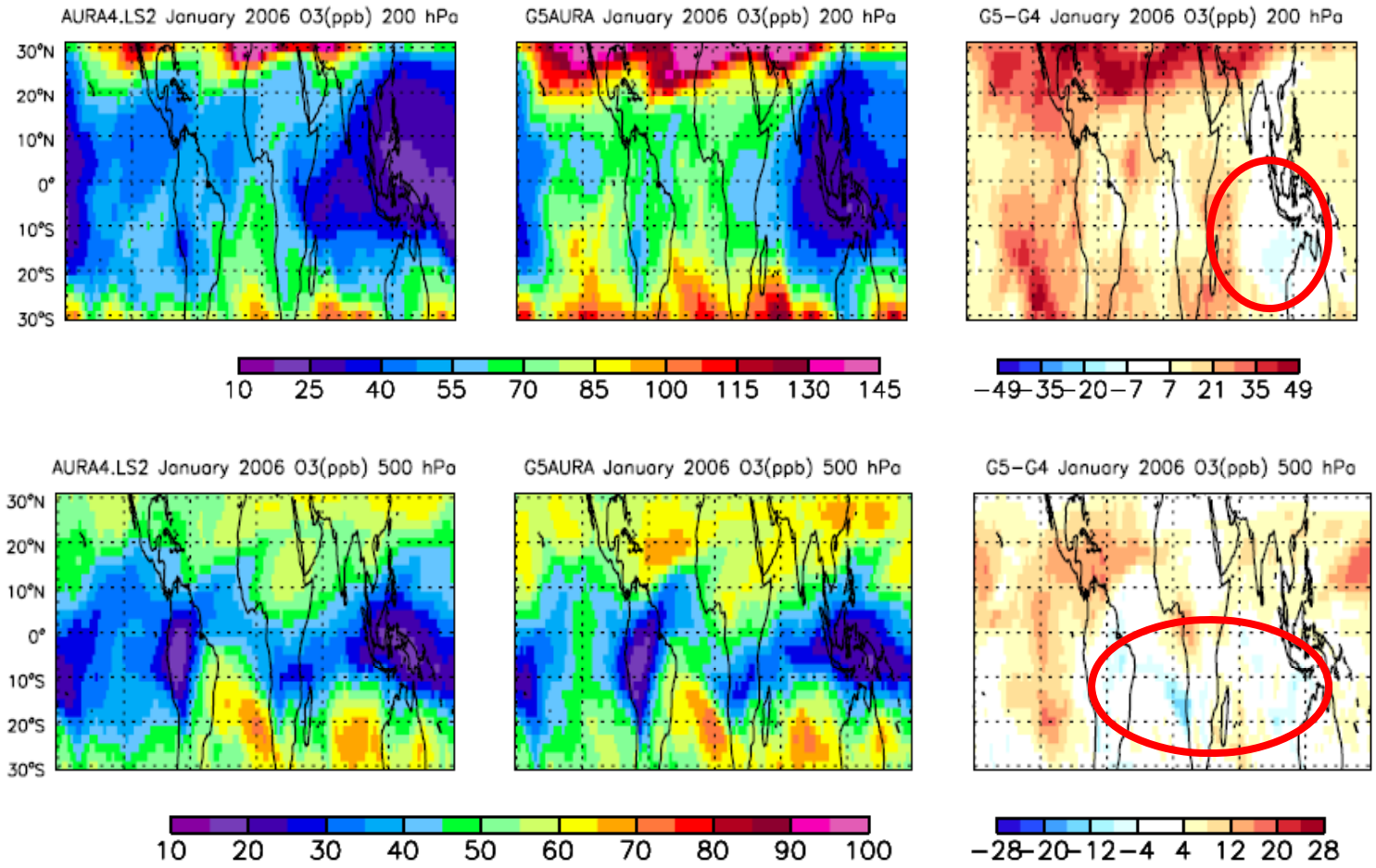
- Lifetime of ozone with respect to chemical loss is weeks-months in UT and MT
- Vertical transport controls lifetime
- Faster overturning of the atmosphere => lower ozone in GEOS-4

Zonal transport of ozone in July, 2006

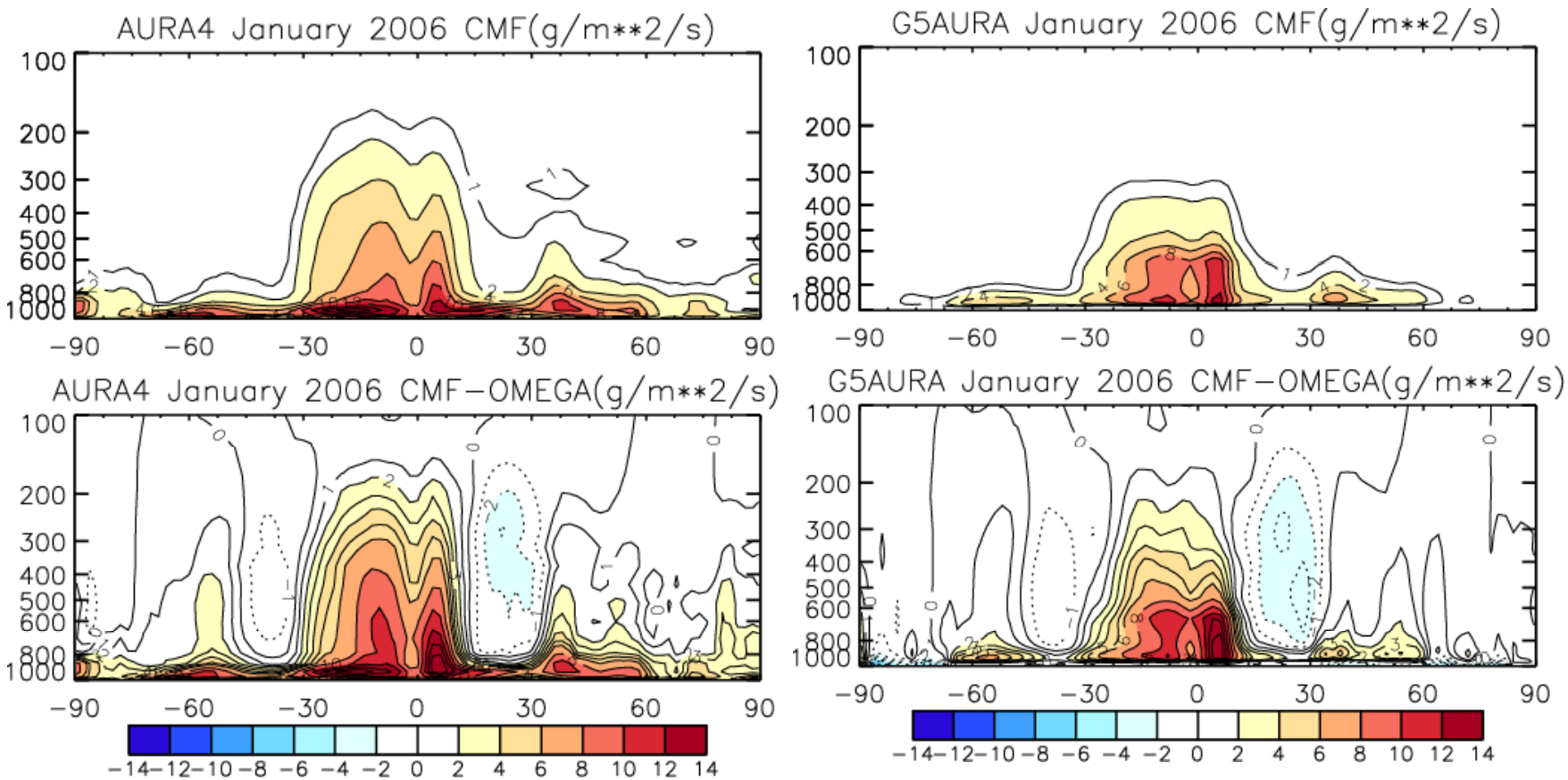


Arrows are the ozone flux

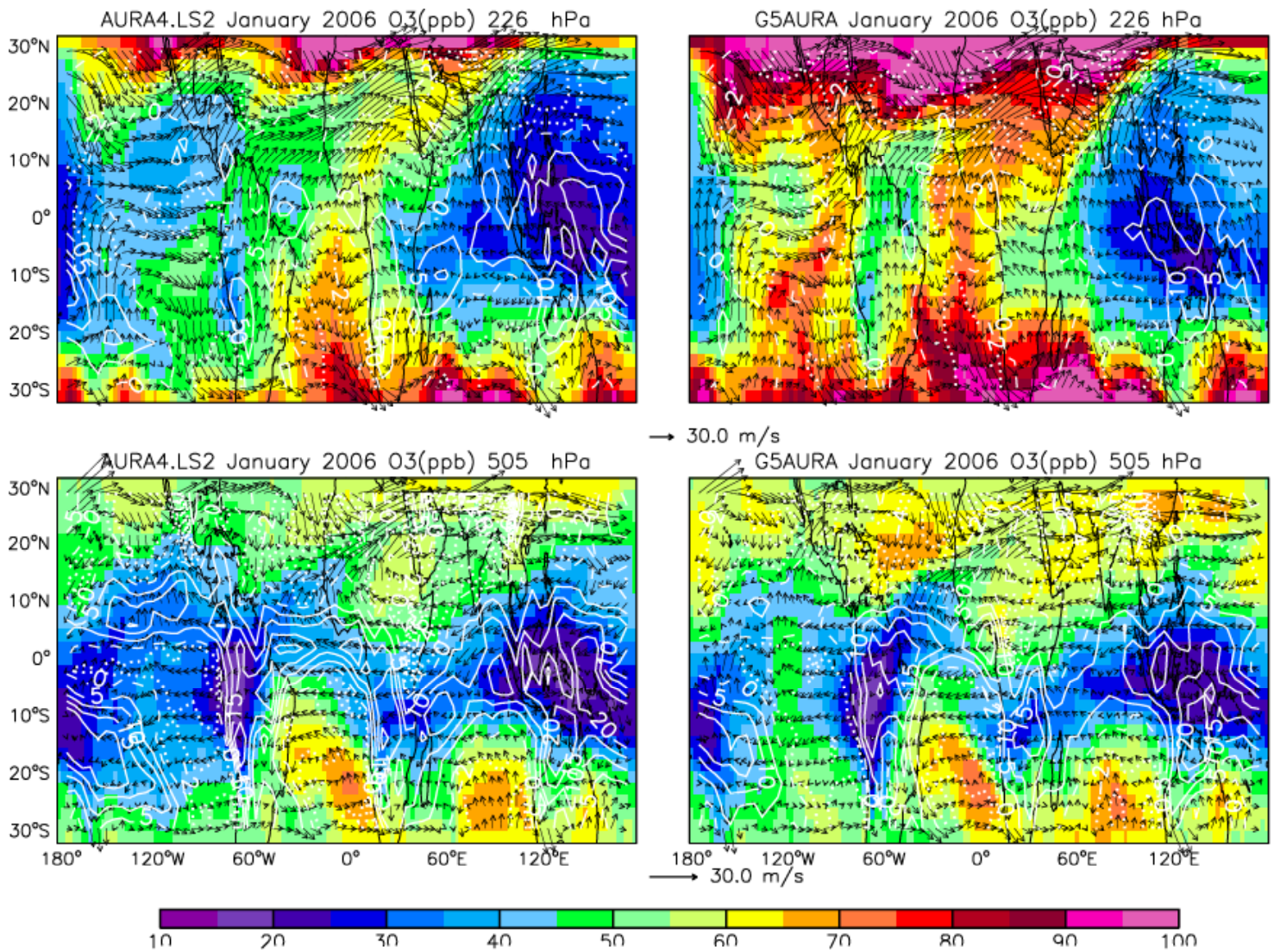
GEOS-4 and GEOS-5 in January, 2006



Vertical air mass flux in GEOS-4 and GEOS-5: January 2006

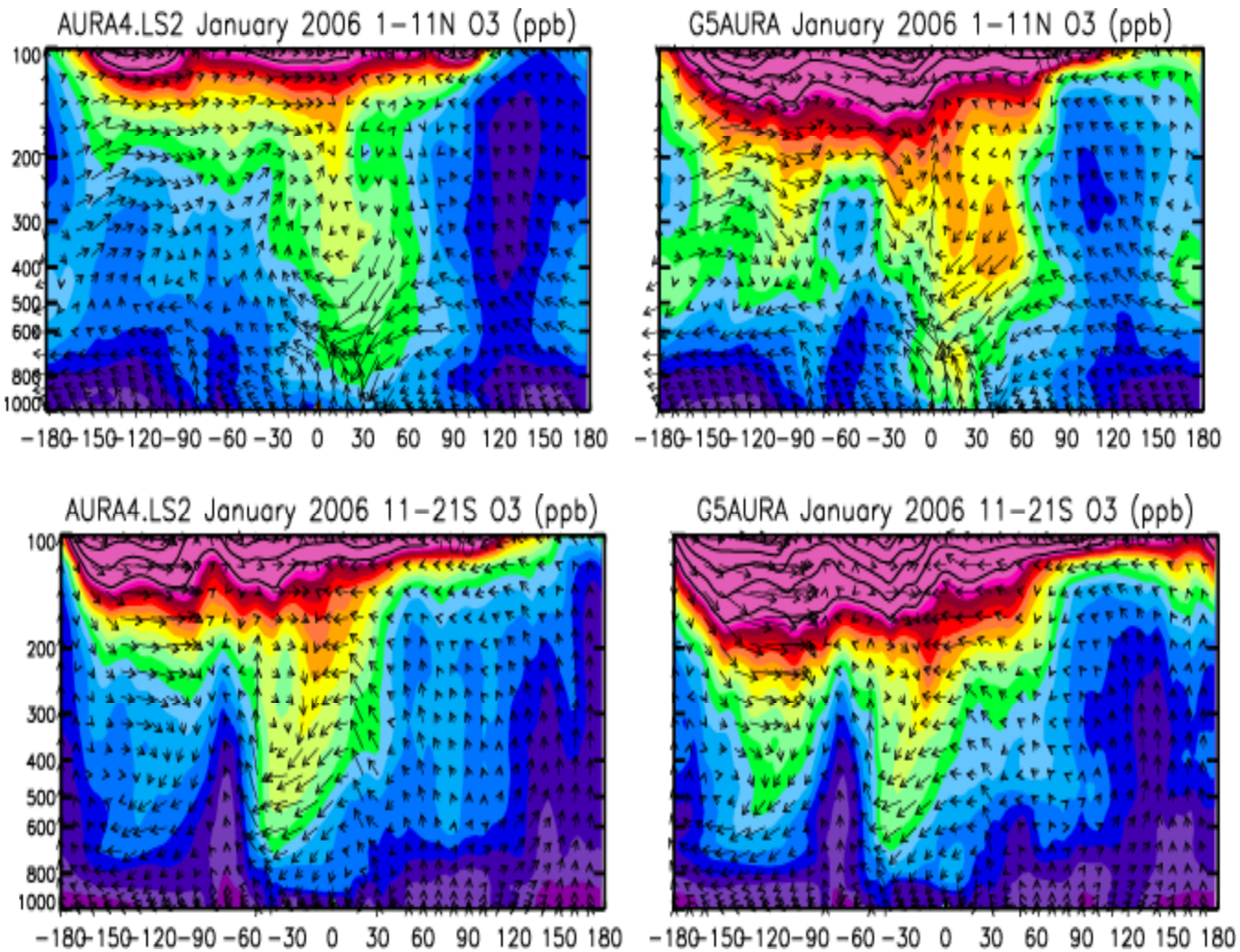


Ozone, winds, and air mass flux, January 2006
ITCZ far south



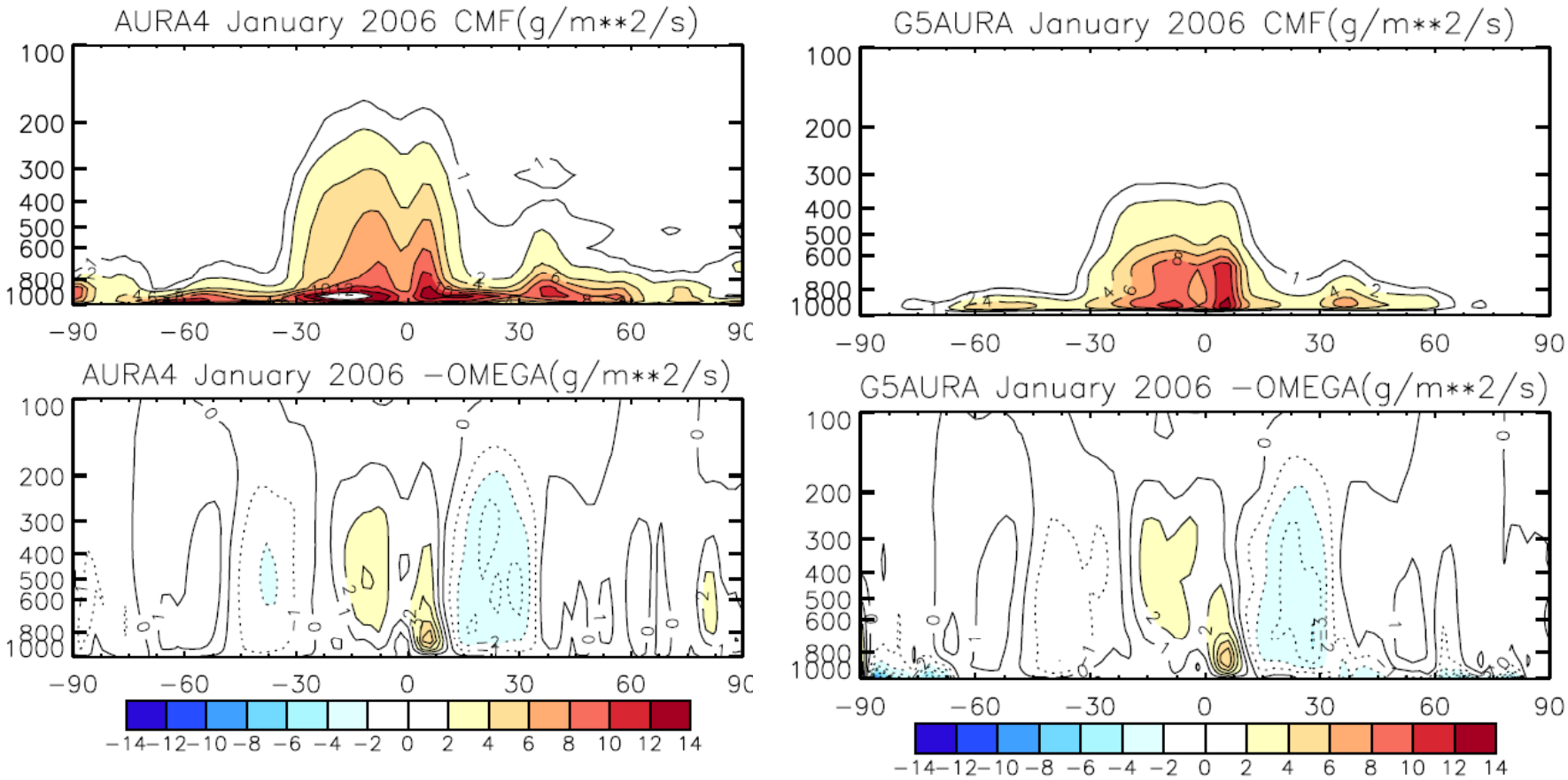
Ozone similar within convective regions at 500 hPa

Zonal transport of ozone in Janaury, 2006



Concluding remarks

- Both GEOS-4 and GEOS-5 simulations look fine in the extra-tropics
- GEOS-4 and GEOS-5 ozone are similar in regions of deep convection, and are most different in regions of subsidence
- TES and MLS data show that vertical transport in GEOS-5 degrades the tropical simulations compared to GEOS-4
- Conventional view that LNOx is the main factor controlling tropical ozone is simplistic – transport rules!
- 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.
- CTM studies often identify problems with model transport – but they don't necessarily lead to improvements in parameterizations inherent in global GCMs – 2 communities. GMAO always working on the next version (GEOS-6).


AURA4 January 2006 CMF(g/m**2/s)
G5AURA January 2006 CMF(g/m**2/s)
AURA4 January 2006 −OMEGA(g/m**2/s)
G5AURA January 2006 −OMEGA(g/m**2/s)
100
200
300
400
500
600
800
1000
−90
−60
−30
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30
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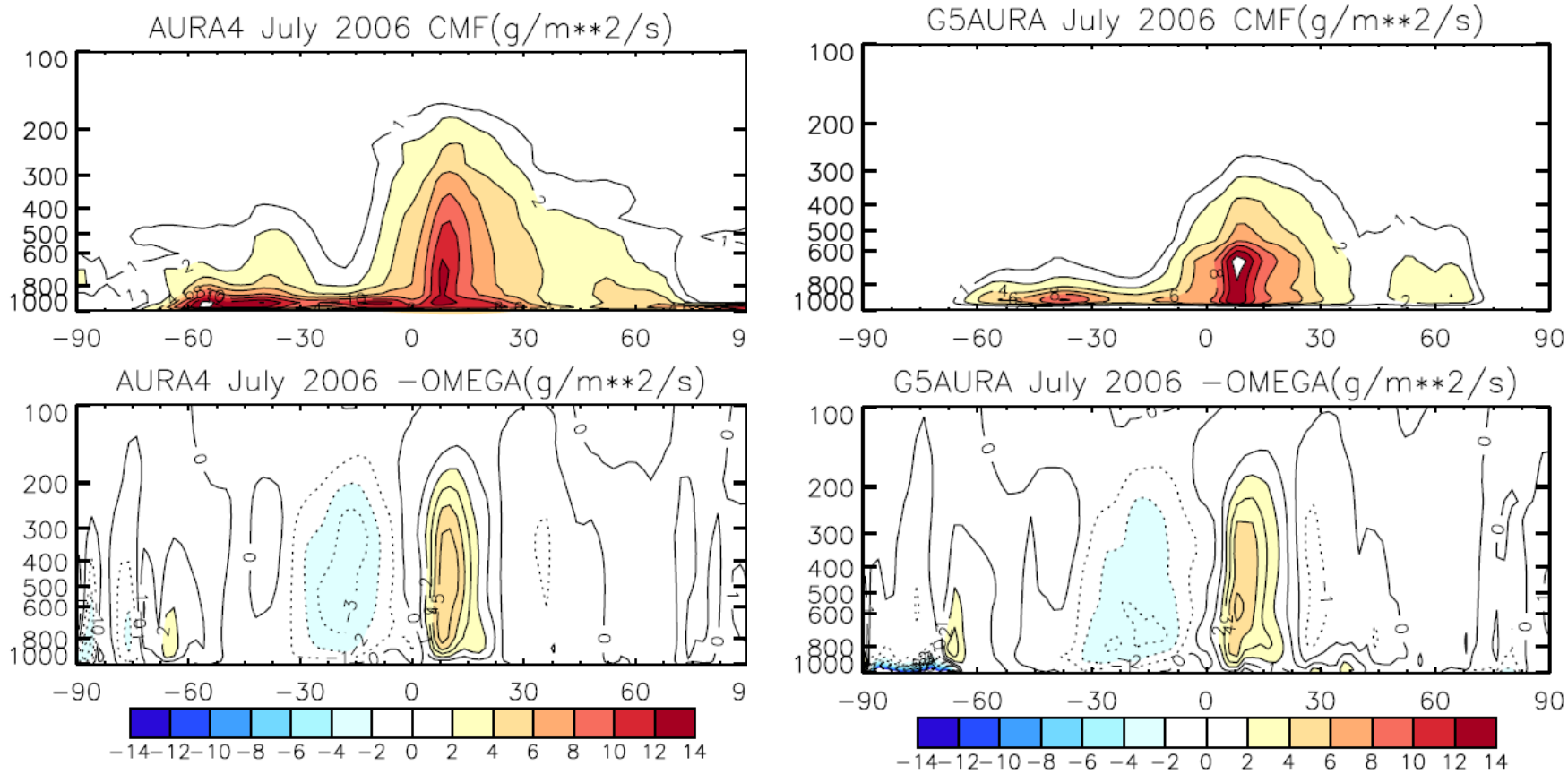
−14 −12 −10 −8 −6 −4 −2 0 2 4 6 8 10 12 14


AURA4 July 2006 CMF(g/m**2/s)
G5AURA July 2006 CMF(g/m**2/s)
AURA4 July 2006 −OMEGA(g/m**2/s)
G5AURA July 2006 −OMEGA(g/m**2/s)
100
200
300
400
500
600
800
1000
−90 −60 −30 0 30 60 90
−14 −12 −10 −8 −6 −4 −2 0 2 4 6 8 10 12 14