Evaluation of GMI simulations with TES ozone and CO data, and in situ data.

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Harvard University and NASA/GFSC

GMI Science Team Meeting, March 17, 2008

Updates since last GMi Meeting

Aura3 run

- Includes lightning related to convection, scaled by OTD/LIS (Allen, 2006)
- GFED2 fire emissions available for 2006
- Analysis done on Aura3 run

Aura4 run (available March 12th)

- Megan emissions for isoprene
- Seasonal CO and NOx emissions from China
- Different vertical distribution for lightning NOx
- Some comparisons of Aura4 and Aura3.

Strategy for indirect validation of TES CO and ozone

- **By evaluating the model with in-situ data, we learn where the model does well and where there are deficiencies.**

  Ozone profile data available for ~50 locations (sondes and MOZAIC), CO profile data for ~12 (MOZAIC, NOAA/GMD)

- **Having "calibrated" the model performance, evaluate model performance with TES CO and ozone.**

- **If the model and TES agree where we know the model does well, we are confident that the discrepancies in other regions are "real".**

- **Explore the causes of these discrepancies**

Validation:

- **For the in-situ data (sondes and MOZAIC) we are comparing a multi-year mean and one year of the model, so interannual variability could be an issue.**
  - For cases studies, we can compare data from the same days as the sondes.

- **Plots of (model –TES) apply the AKs to the model, but the (model –in-situ) is at a single pressure level.**

Model evaluation:

- **Simultaneous global data for CO and ozone**

TES data

- **Focus on data after July 2005**
- **TES data much sparser before July 2005, before routine limb soundings were dropped.**
- **The CO data quality is much better after Dec. 2005, due to warm-up of optical bench. CO data not reliable for lat. >60º**
- **Ozone validation with ~1600 sondes shows TES is biased high by ~5 ppb at 500 hPa, ~10 ppb in winter (Nassar et al., Richards et al).**
- **CO validation with INTEX-B data and Ave data – TES within 15% - relatively few comparisons (Luo et al., Lopez et al.)**

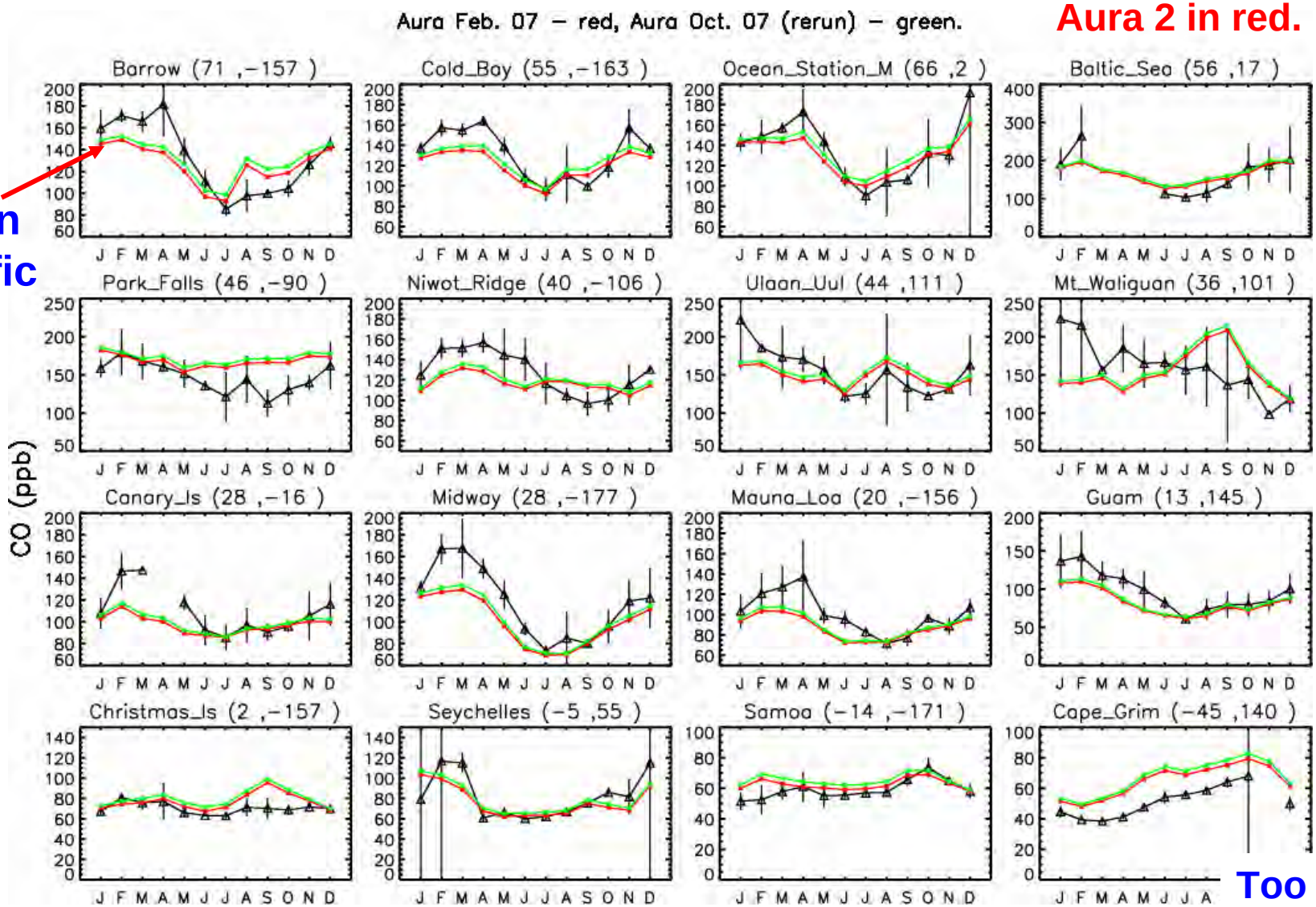
TES –model comparisons

- **Model sampled at TES profile locations on same day, and AKs and prior applied.**
- **TES prior from MOZART model**
- **Results gridded on 4ºx5º grid (TES data 1.6º apart along orbit)**
- **TES data selection used for ozone**
  - Data quality flag
  - Emission layer flag
  - Omit profile if effective cloud optical depth > 2 above layer
  - Filtered on value of AK diagonal (omit <0.02, 18N-18S, or <0.01)
- **Difference [(model with AK) –TES] removes prior**
- **If TES retrieval is mostly the prior, we are comparing the Combo model and MOZART. Not a problem in tropics.**

CO at GMD surface stations – Combo/Aura3 in green.

Aura 2 in red.

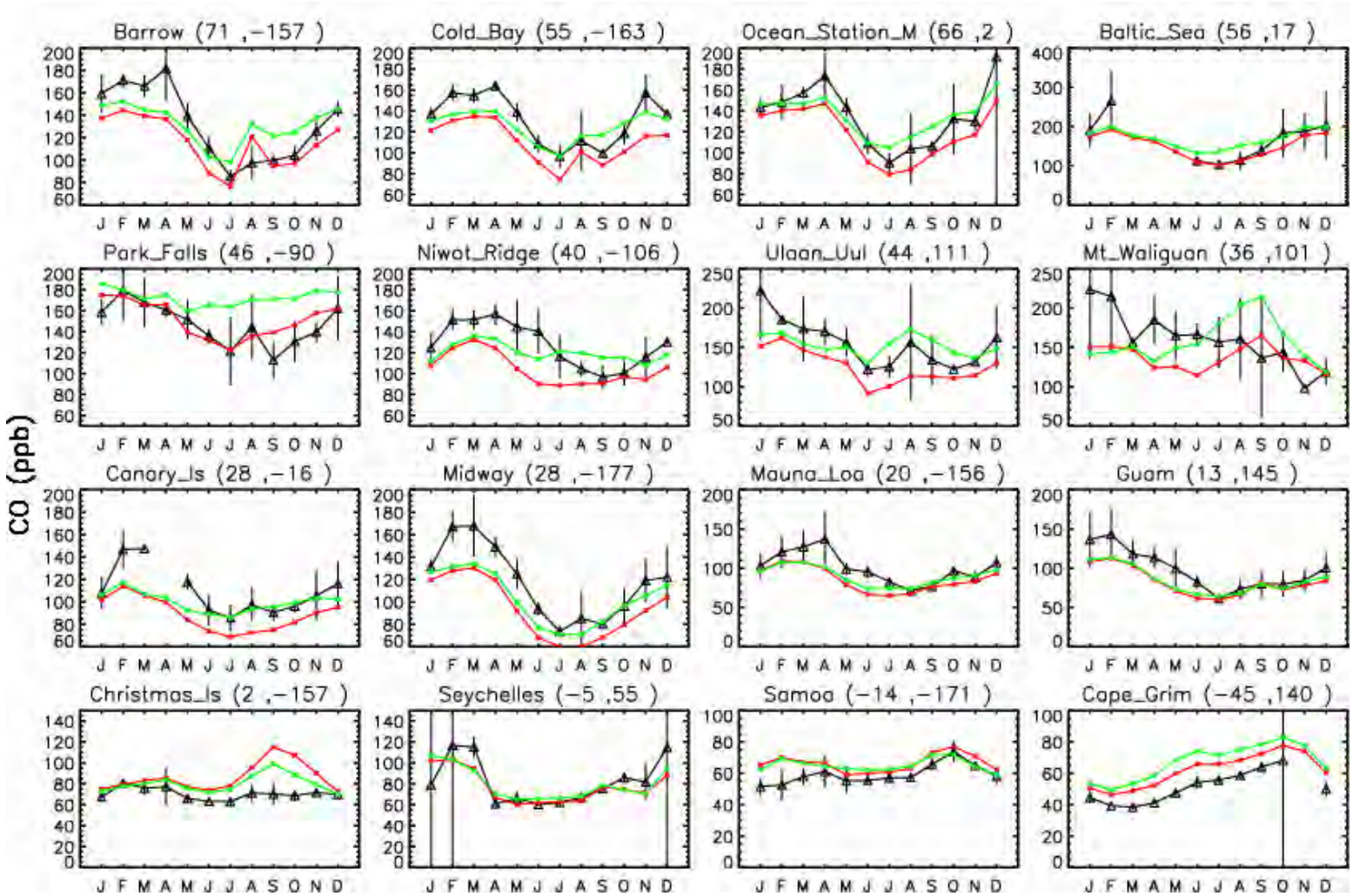
Too low in Pacific



Too high in SH

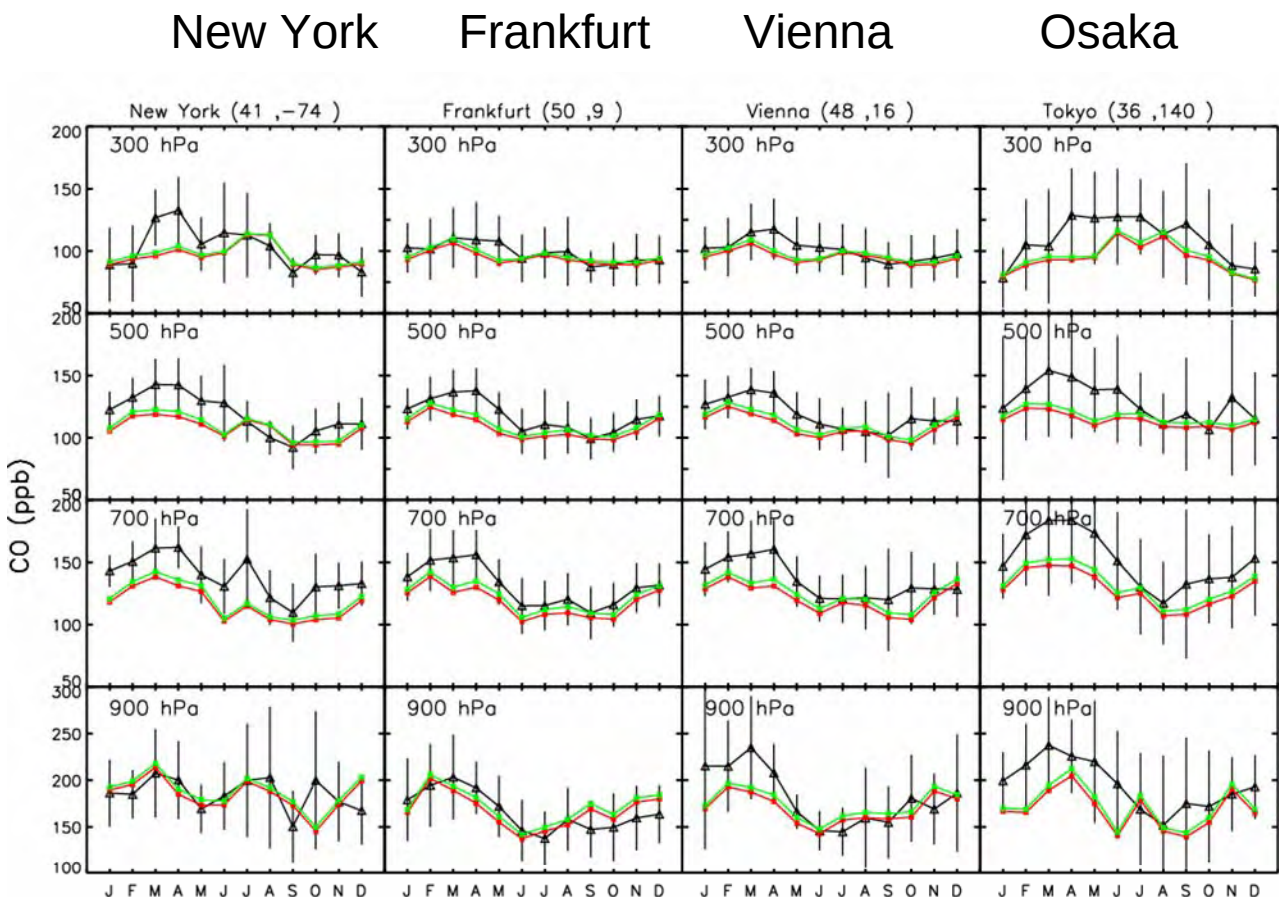
CO surface data for 2005 (FF emissions for 2000).

Aura4 in red, Aura3 in green.



Aura4 is lower in summer in NH – mostly because of MEGAN, also because of seasonality of Chinese emissions. Better fit to amplitude in NH.

CO seasonal cycle, MOZAIC data – back to Aura3.

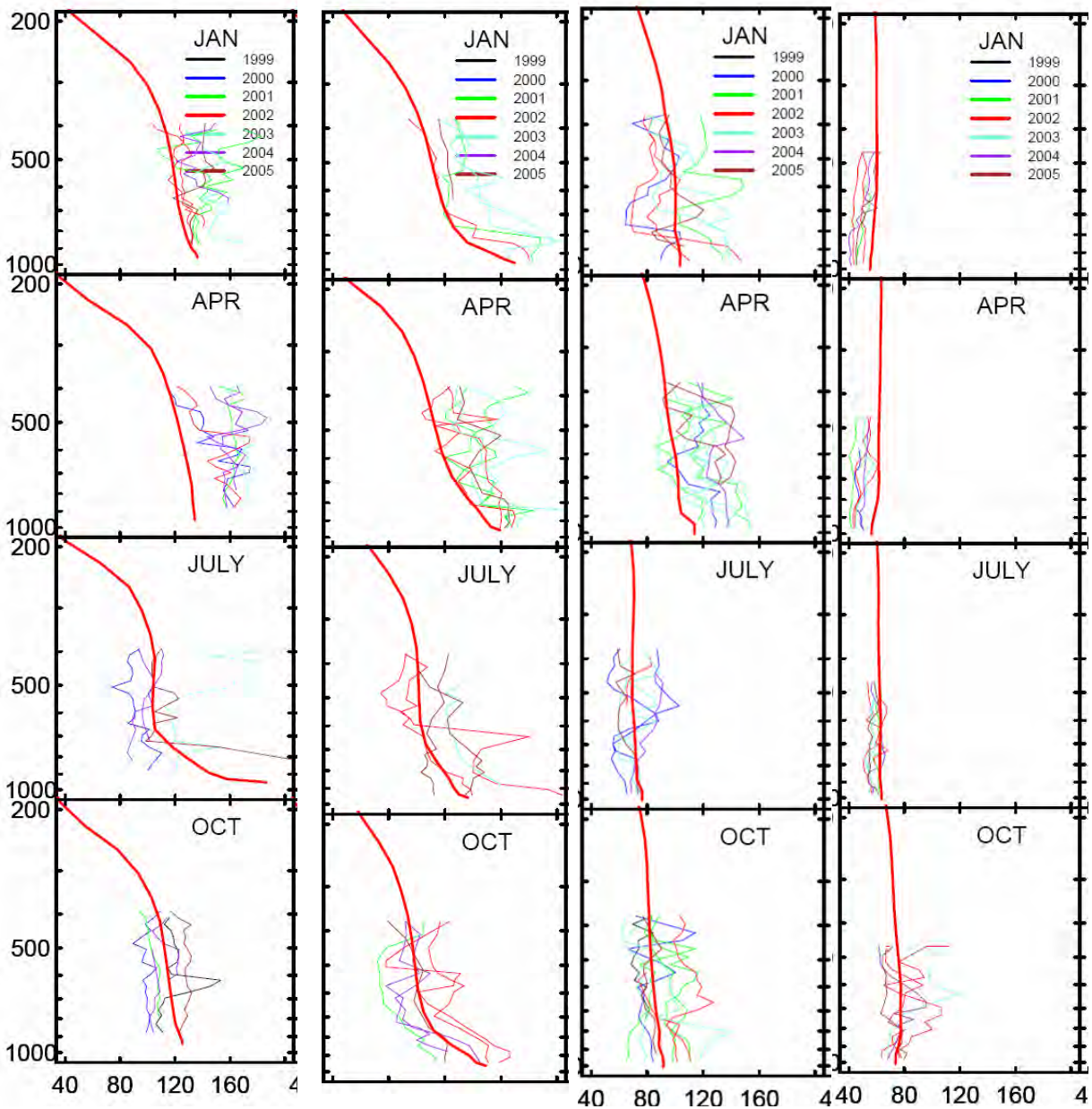


Aura3 is too low in the first part of the year at 500 hPa.

The amplitude of the seasonal cycle is too low in the mid-trop – similar to MOPITT comparisons of Prasad.
Is this seen in TES?

Model does not capture long. gradient in CO.

Poker Flats Alaska **Harvard For. Mass.** **Molokai Is Hawaii** **Raratonga 21 S**



Data from NOAA/ESRL/GMD.

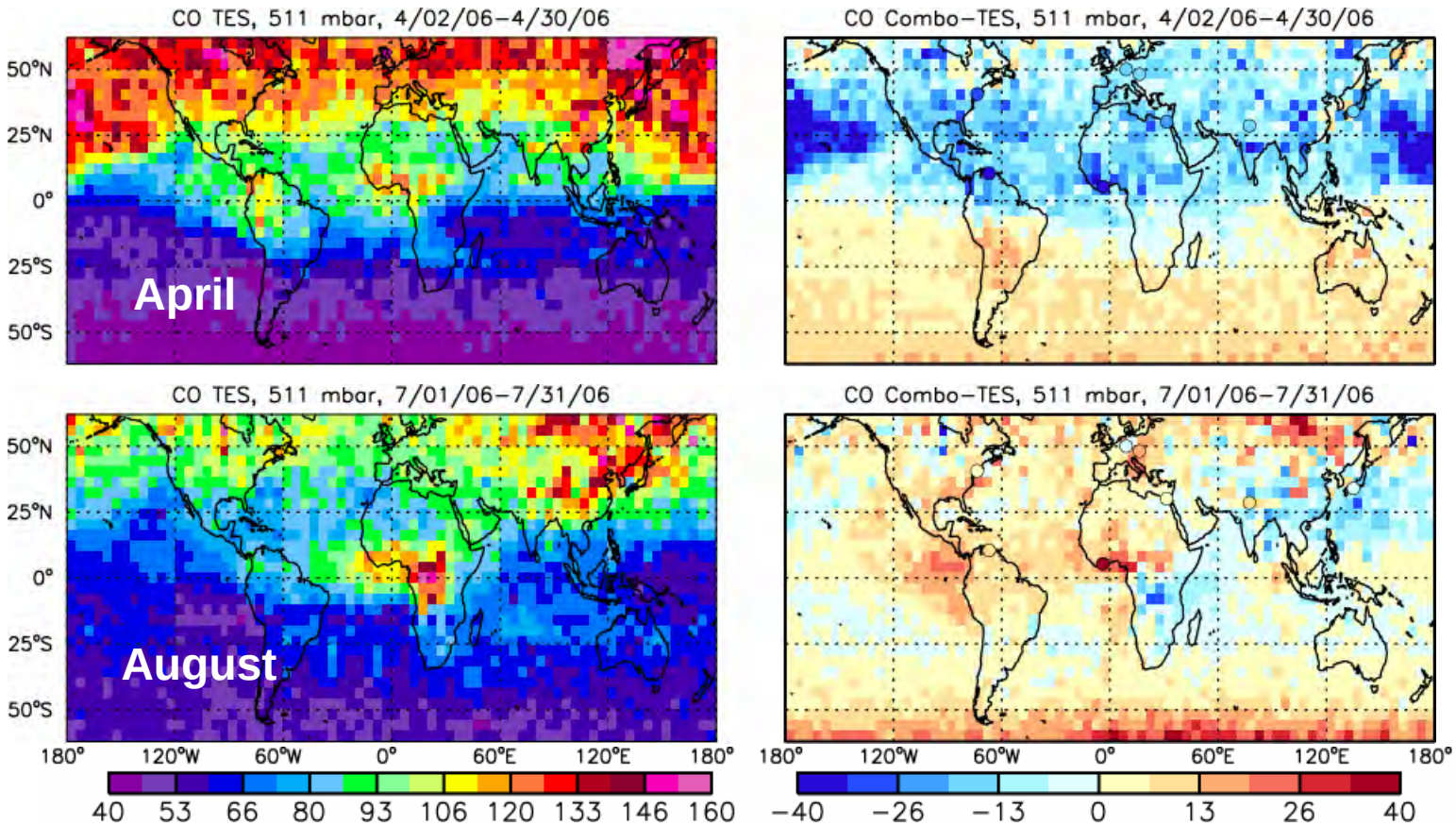
Not many profiles

In NH, consistent with surface data, MOZAIC, model too low in spring.

At Raratonga, similar to Samoa (14 S)

TES CO at 511 hPa and Aura3 run

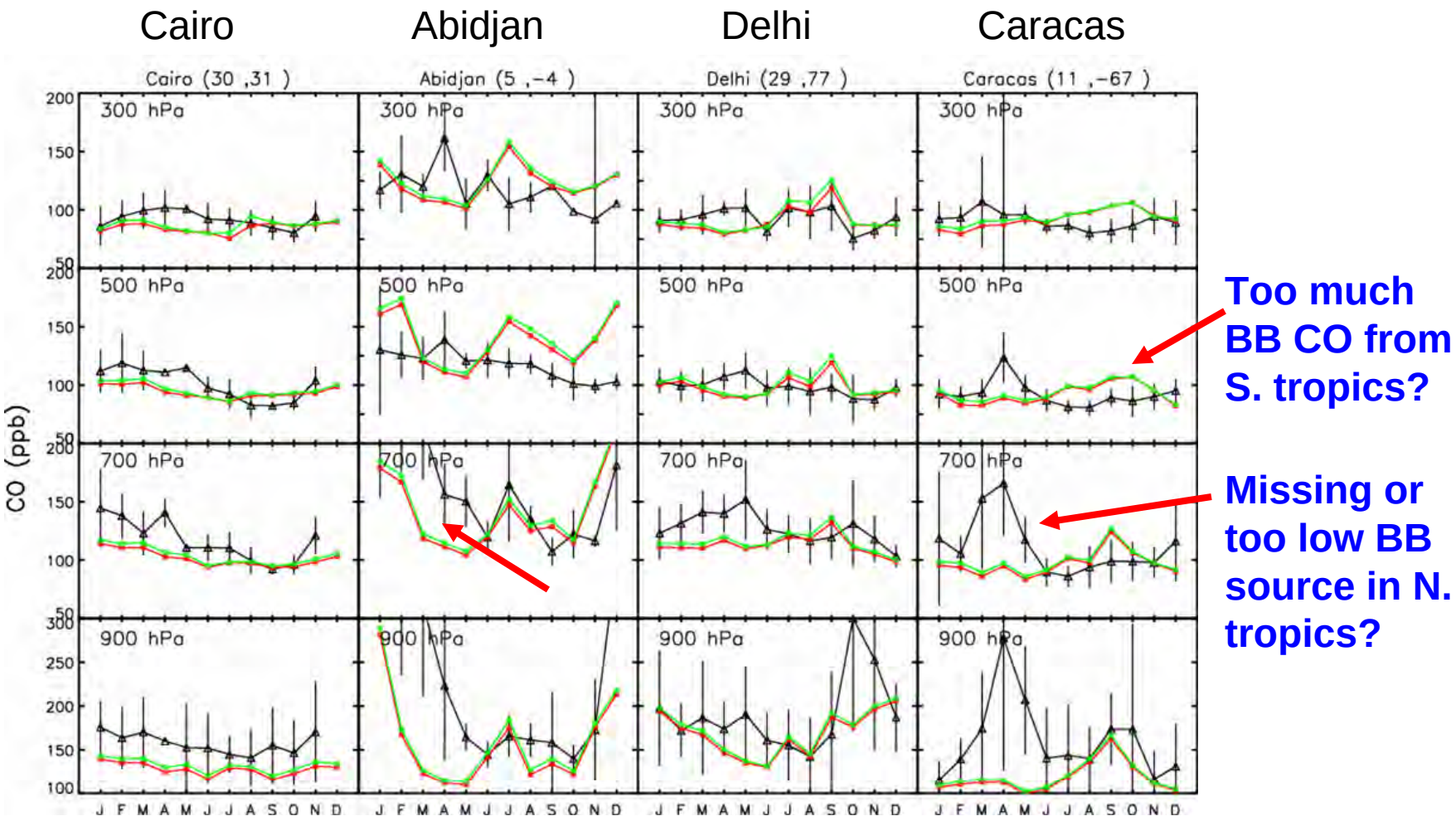
TES | Aura3 – TES, Aura3-MOZAIC (circles)



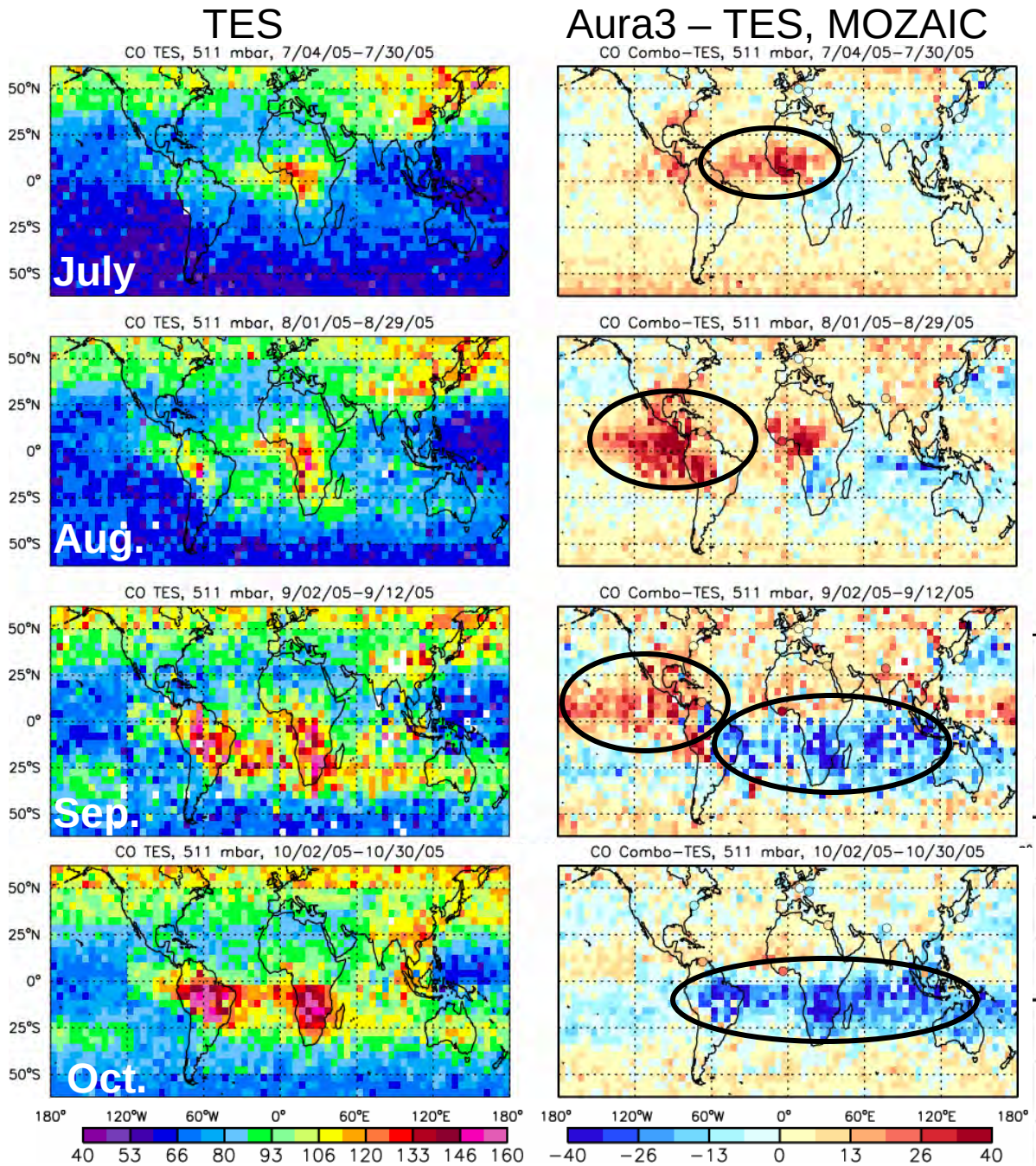
April: Model is too low in N. extratropics, esp. over N. Pacific; too high in SH.
August: Model is about right in N. extratropics, except too high in Siberia

TES and MOZAIC differences are self-consistent. Surface data show same patterns.

MOZAIC CO, Middle East and tropics (sparse data)

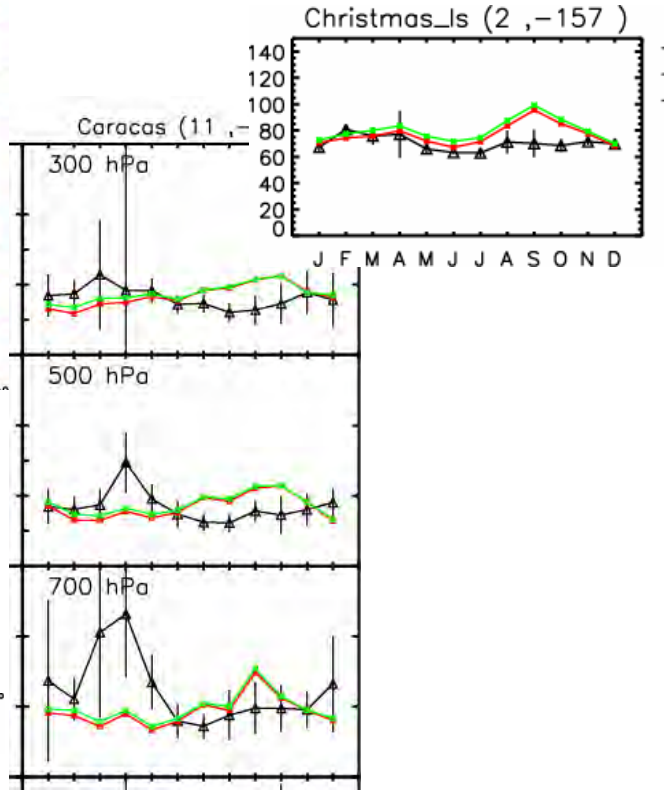


TES CO and Aura3-TES July-Oct., 2005

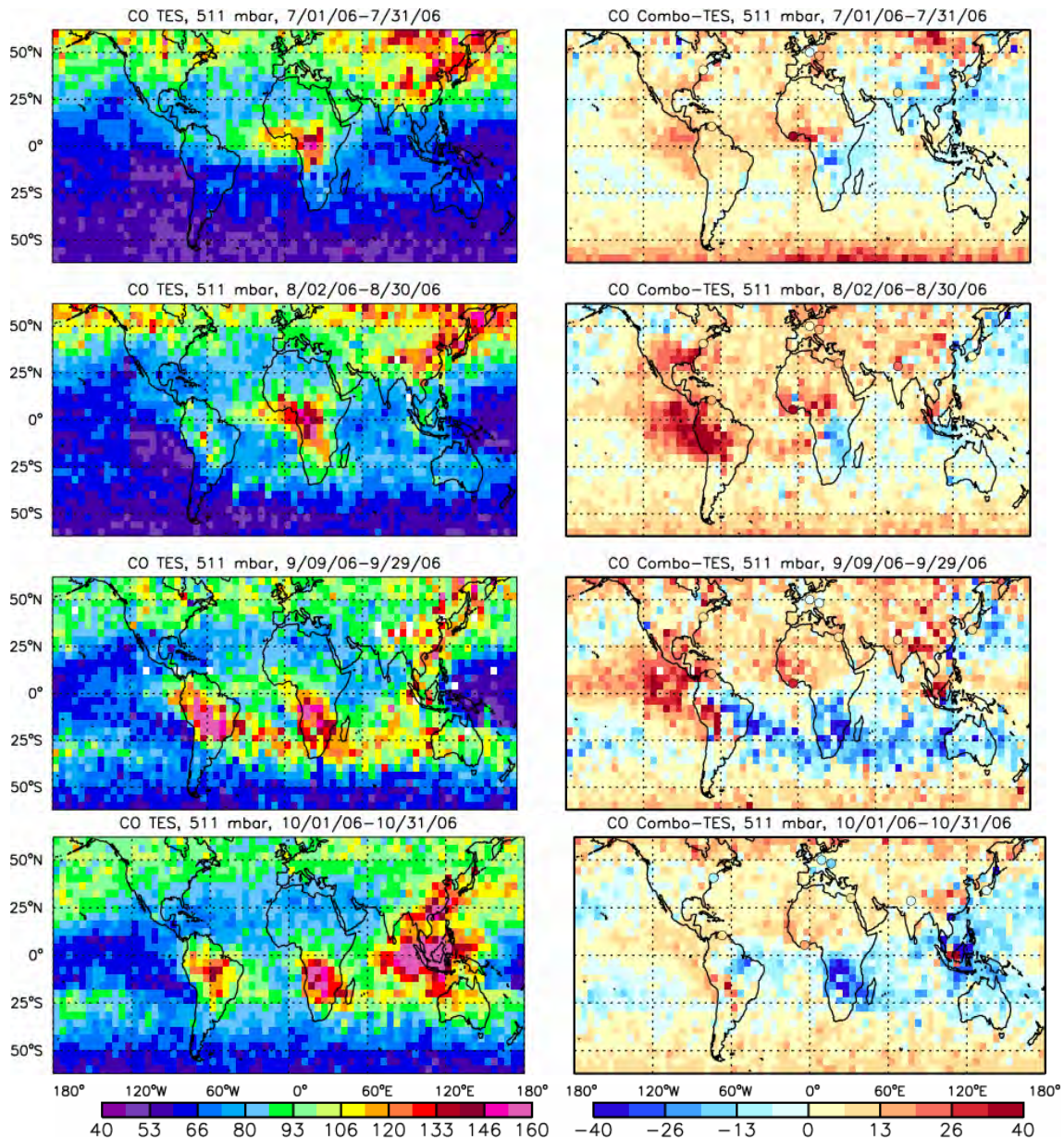


Model too high in E. Pacific in August-Sept., too low in Atlantic/Indian Ocean region in Sept.-Nov.

How does this relate to fire emissions?



TES CO and (Aura3-TES), July-October, 2006

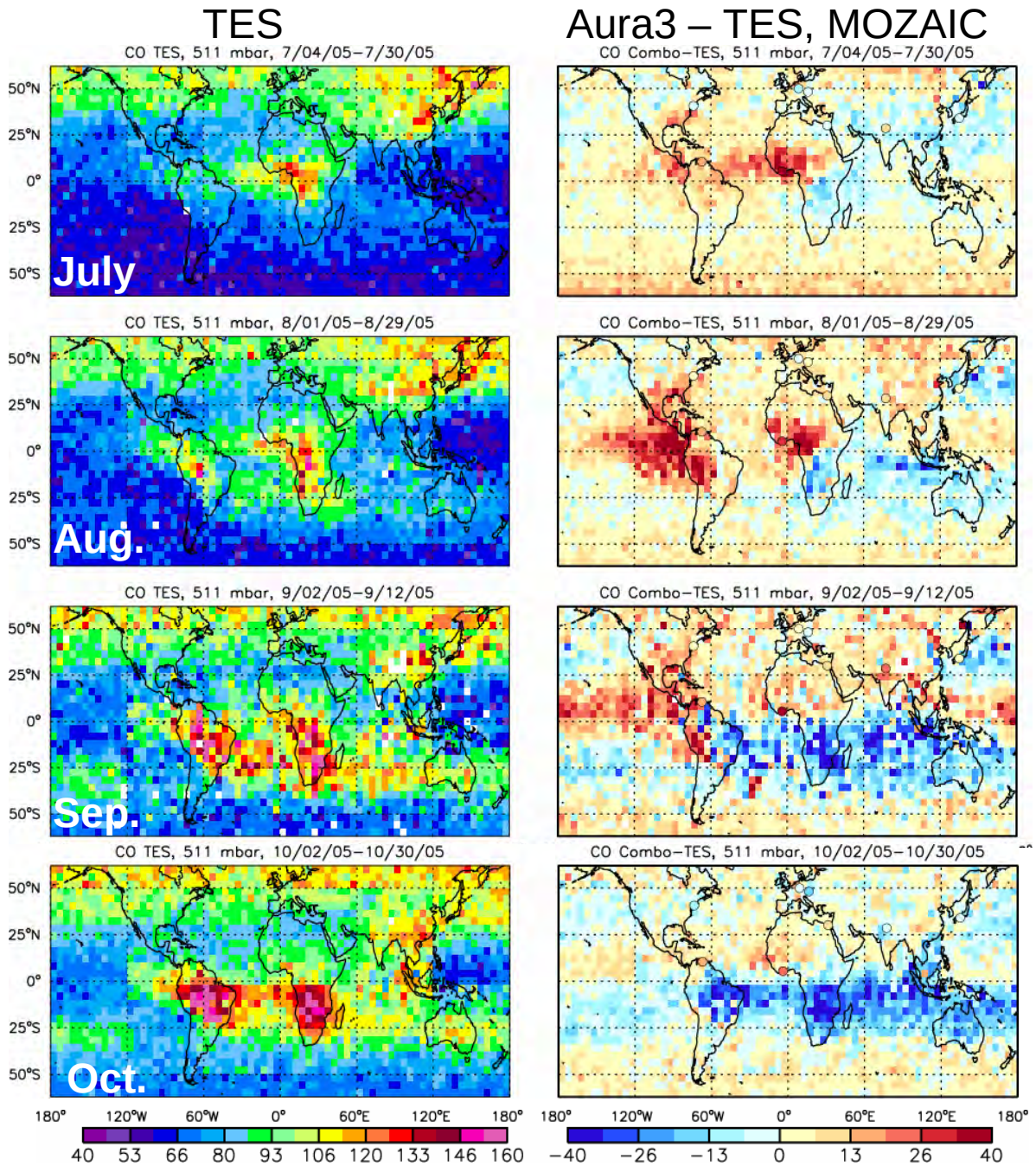


Same problems as 2005 over E. Pacific, but much smaller underestimate in Sep./Oct. in Atlantic region.

Emissions from S. America in 2006 were half those in 2005.

Emissions in Africa were about the same each year.

El Nino in 2006.

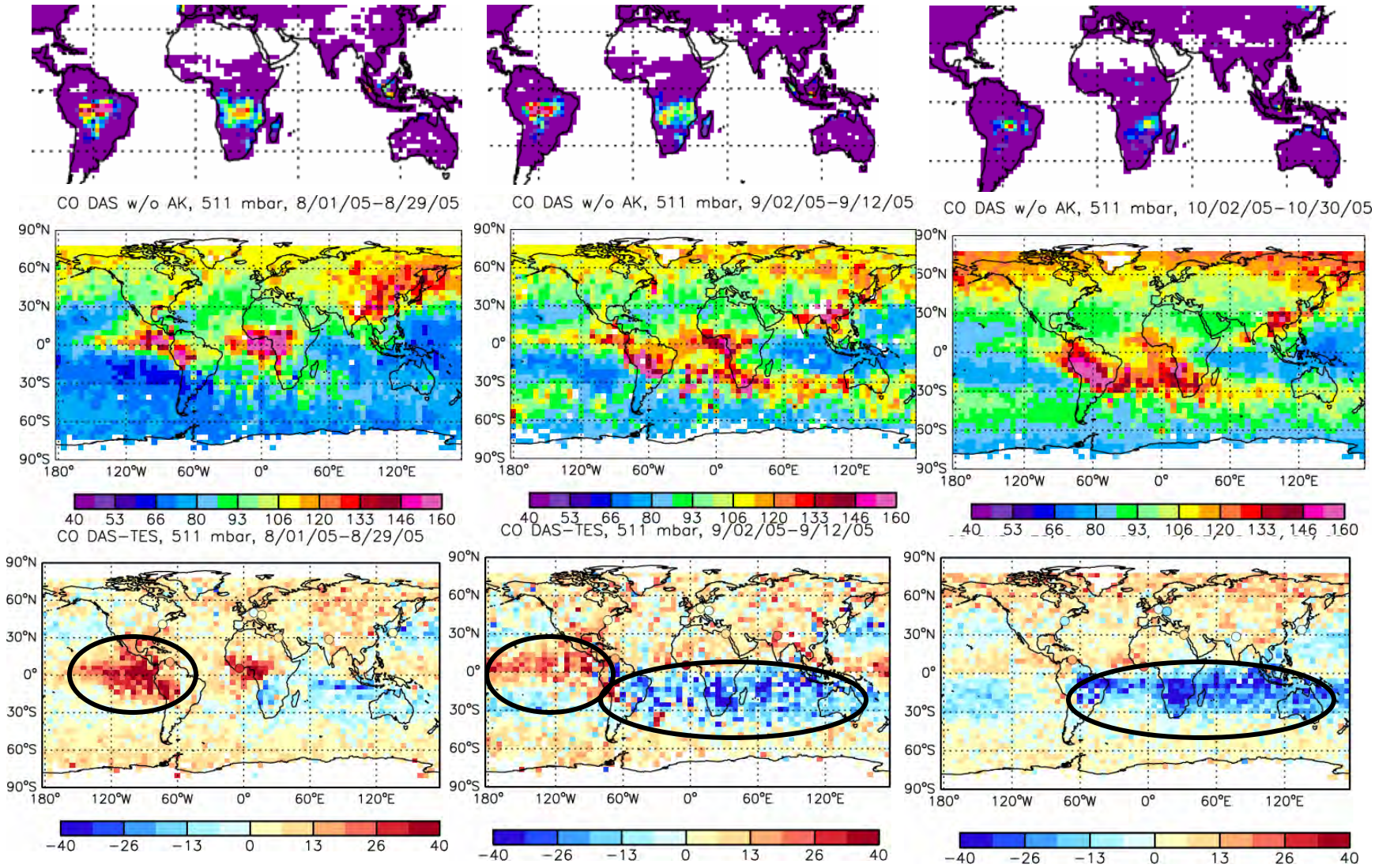


July-October, 2005

Fire emissions (top), Aura3 CO (middle), Aura3–TES (bottom)

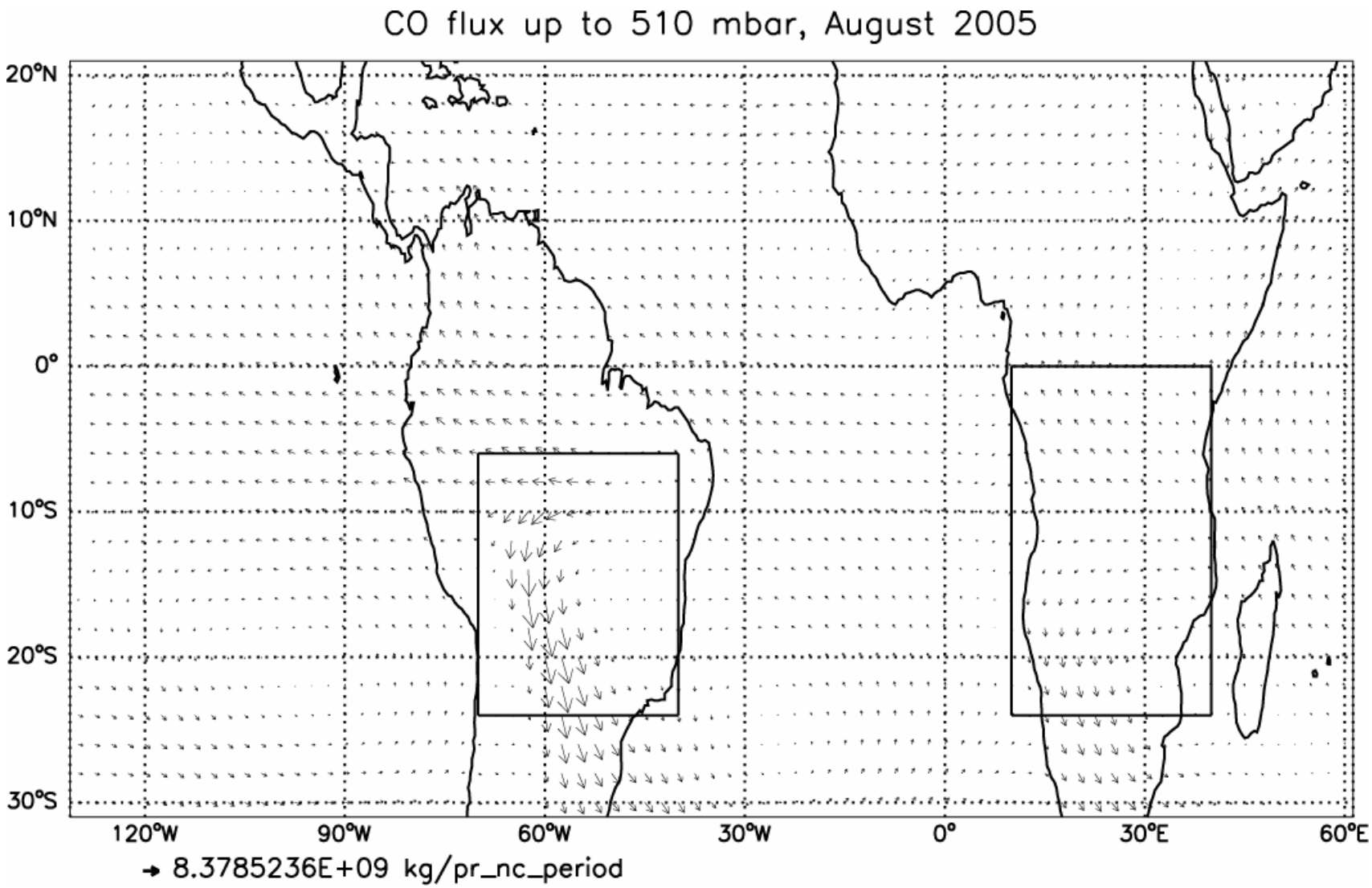
2005

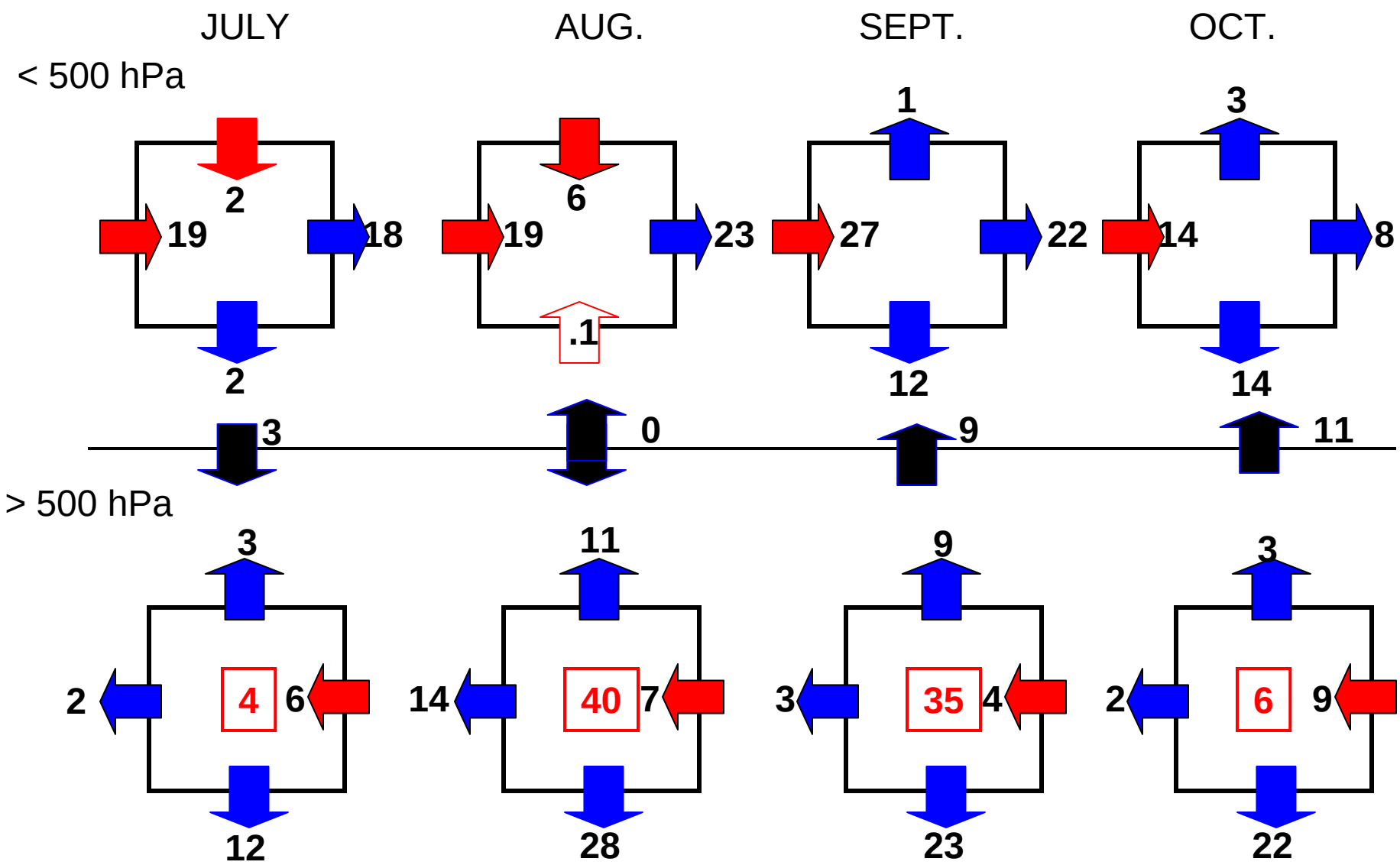
August **September** **October**



In Aug., CO is displaced to NE by easterlies; in Oct. CO circulates over S. Atlantic and to Indian Ocean

CO flux from the surface up to ~ 500 hPa





S. America Budget

n = Biomass Burning Emissions, Fossil Fuel + Biofuel = 1.2 Tg/mo.
P-L (CO) ~= 4-5.6 Tg/mo Horizontal fluxes in blue/red. All in Tg CO/mo.

Issues with CO simulation in the S. tropics

- The model exports too much CO from S. America to the eastern Pacific in August and September – problems with met. data, Andes not providing a barrier? Or are emissions just too high in August – more likely.

- Does this export to the NE contribute to the underestimate of CO over S. America in Sept./Oct?

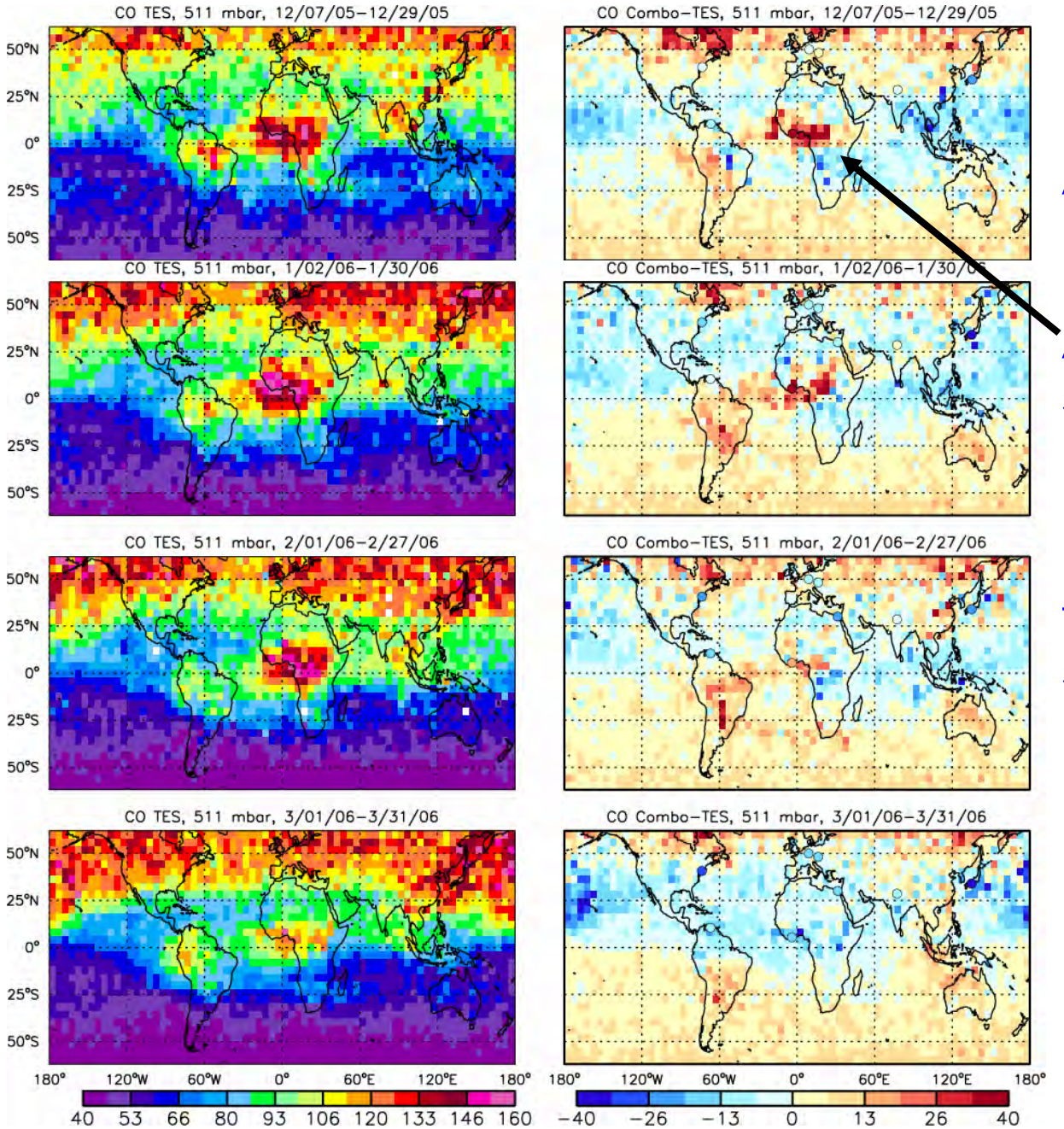
- CO is highest over S. America in Oct. when fire emissions are low. So either emissions (based on fire counts) stop too soon, or else CO is exported too efficiently. CO over the source region is not an OH problem. (Same problem over southern Africa in Sept./Oct.)

- There remains the conundrum that CO is too low over the SH tropics/subtropics in Sept./Oct. compared to TES and MOPITT, and too high in the extratropics in the surface data. (MOPITT discussed at Dec. 06 AGU by P. Kasibhatla).

- **Similar problems with seasonality of BB emissions in SH with GFED (V1) emissions in 2001 in inversions study with GEOS-Chem (Arellano et al., 2005), and in MOZART study (Petron et al., 2001).**

- **Emissions based on fire counts are too high early in the season and too low later in the season.**

CO in N. Tropics burning season, Dec. 05 - Mar. 06

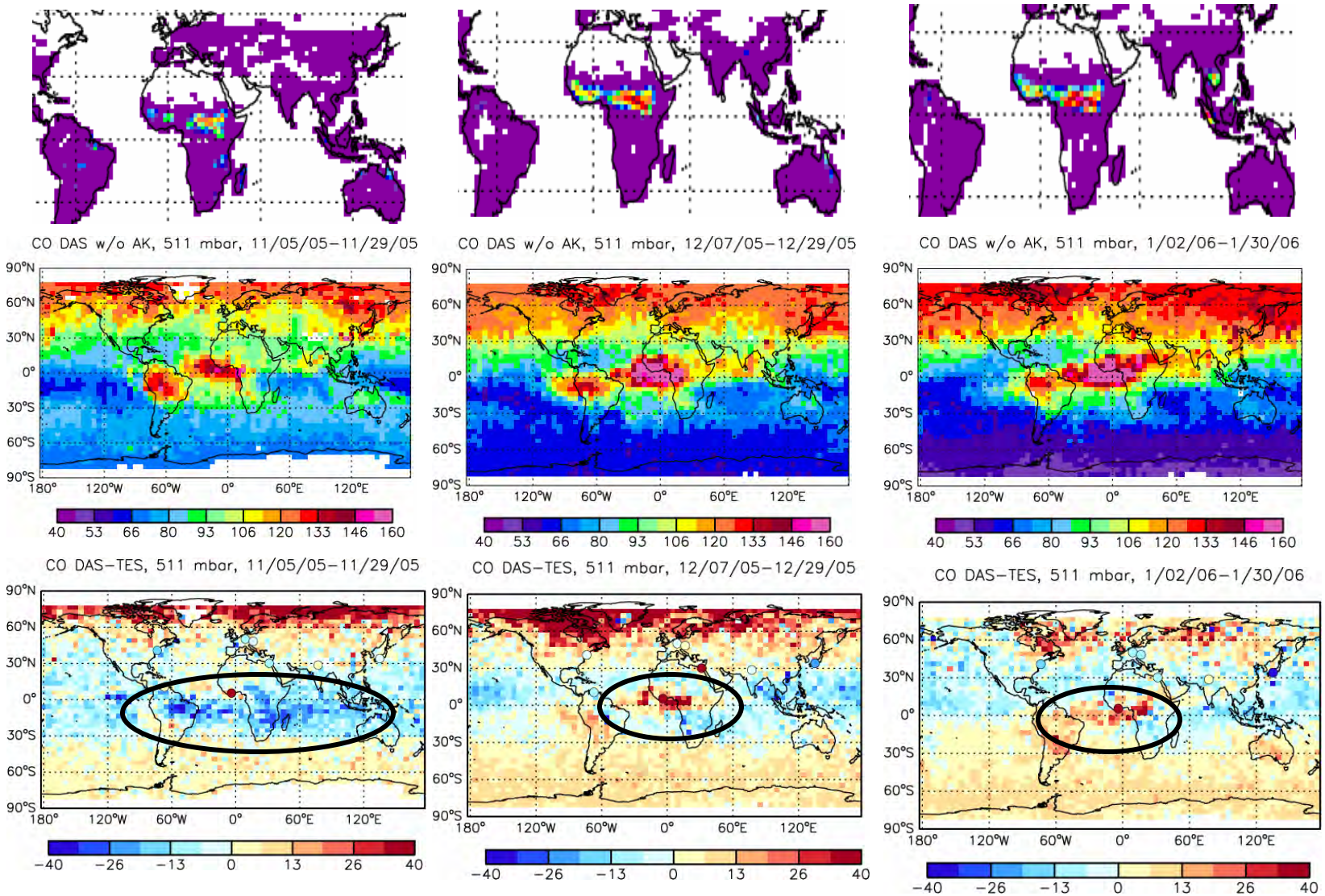


Better consistency between TES and Aura3 run.

Model high over W. Africa at peak of fire season. But low in BL??

Model high in S. extra-tropics, consistent with surface data, and low in NH in spring.

November **December** **January 2006**

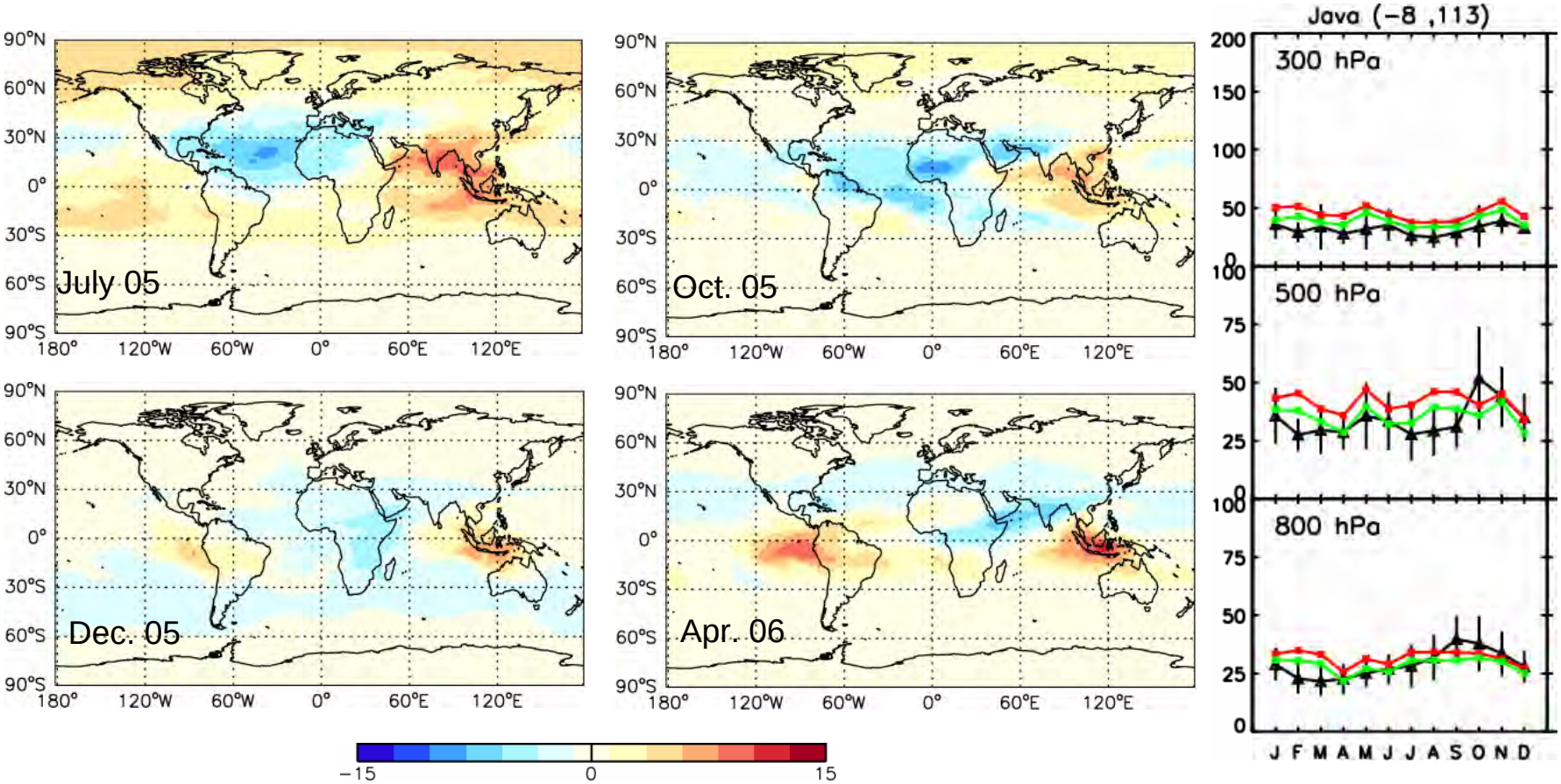


From SH BB **From NH BB**

Ozone

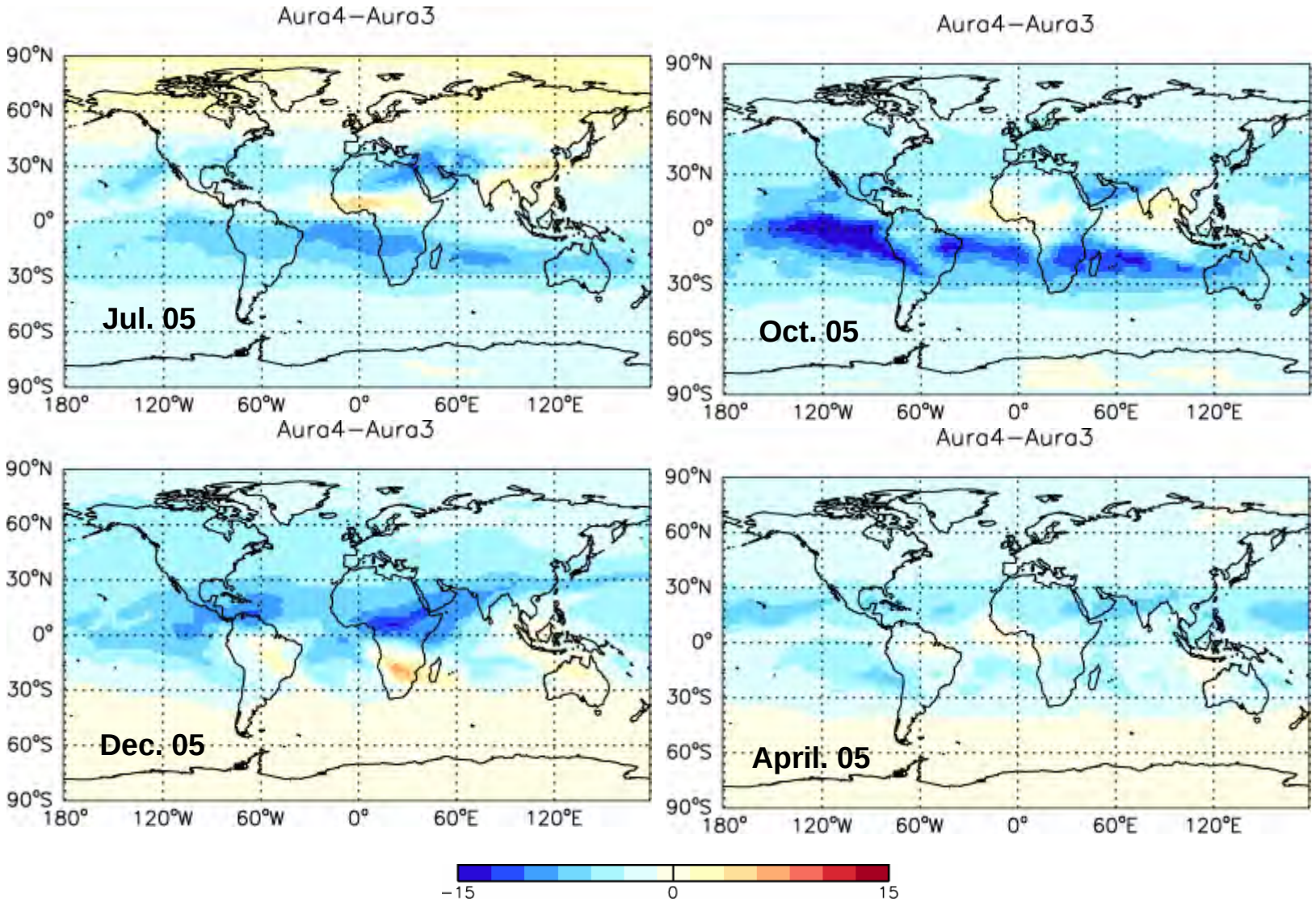
- **Aura2 vs. Aura3**
  - Climatological lightning vs. OTD/LIS spatial distribution
- **Aura3 vs. Aura4**
  - Vertical distribution of lightning, other changes (?)
  - Aura4 includes MEGAN inventory for isoprene, but not much effect on ozone in GEOS-Chem
- **Indirect validation using in-situ data (sondes + MOZAIC, 50 sites) and model evaluation.**

Ozone difference in ppb at 500 hPa, Aura 2 – Aura3



Largest differences over maritime continent, S. Asia. Aura3 led to improvement in model at Java, Bangkok, and Madras. Aura3 in green, Aura2 in red.
Differences also in N. Africa, Atlantic, lead to improvement compared to TES.

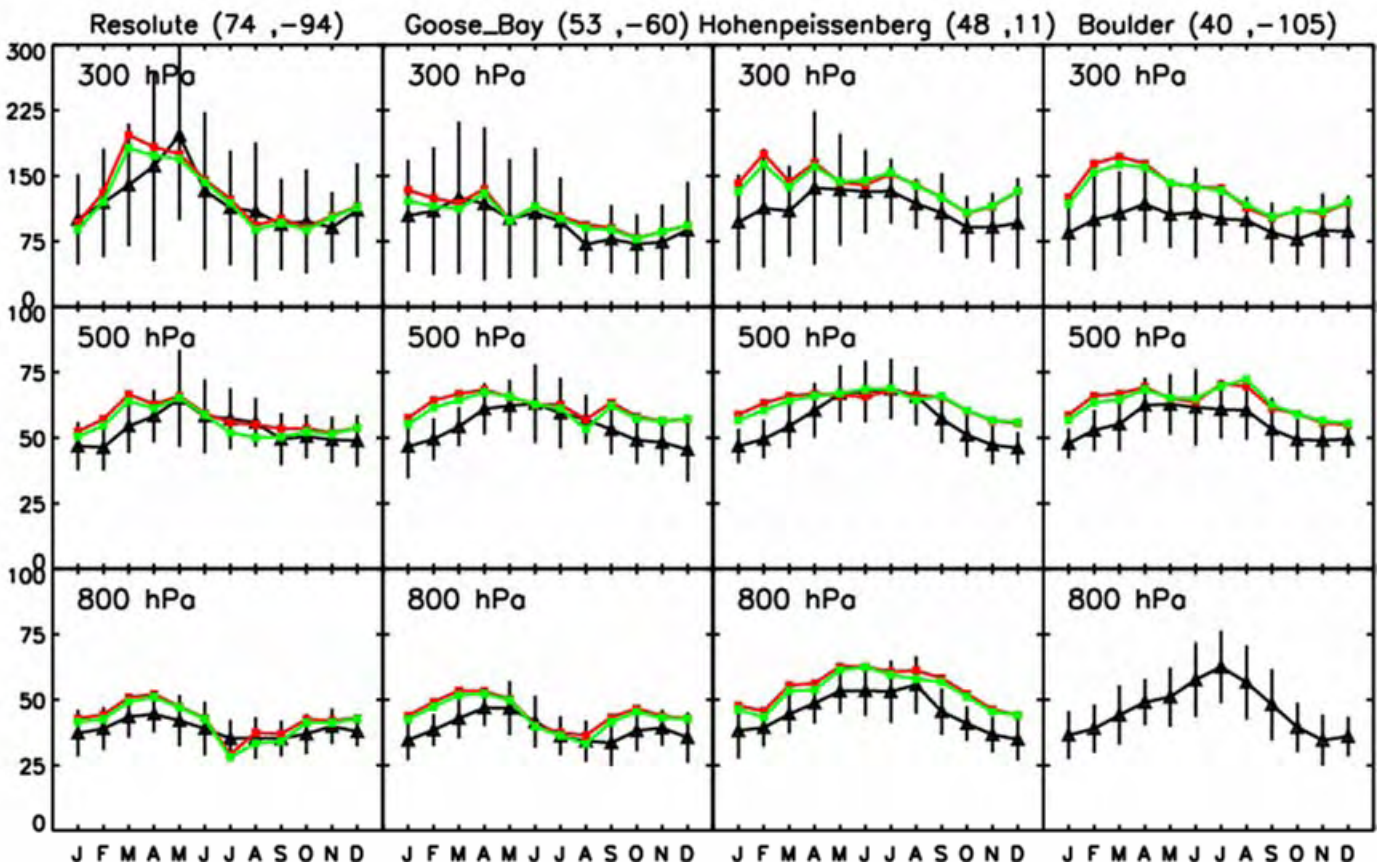
Aura4 – Aura3, ozone at 500 hPa.



Aura 4 generally has lower ozone, especially in the S. tropics BB season.

Ozone at N. extratropics, Aura3, and N. extratropics

Model is too high at 500 hPa except in summer



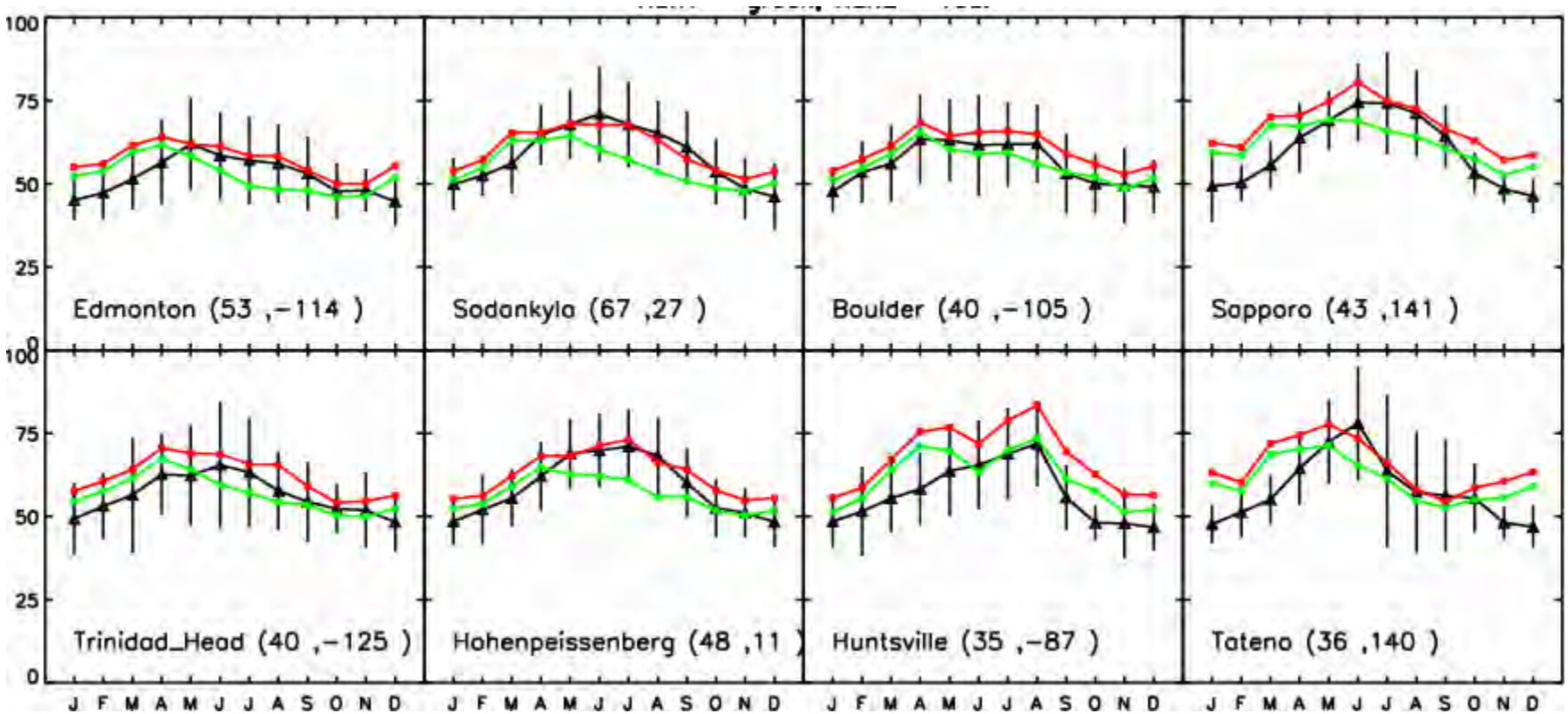
Green: scaled lightning

Red: climo. lightning, not connected to local convection

The Combo model appears to bring too much ozone down from the strat. Note that the seasonal amplitude is too low in mid-trop.

GEOS-Chem – effect of increased lightning in extratropics (from 0.4 Tg to 1.6 Tg)

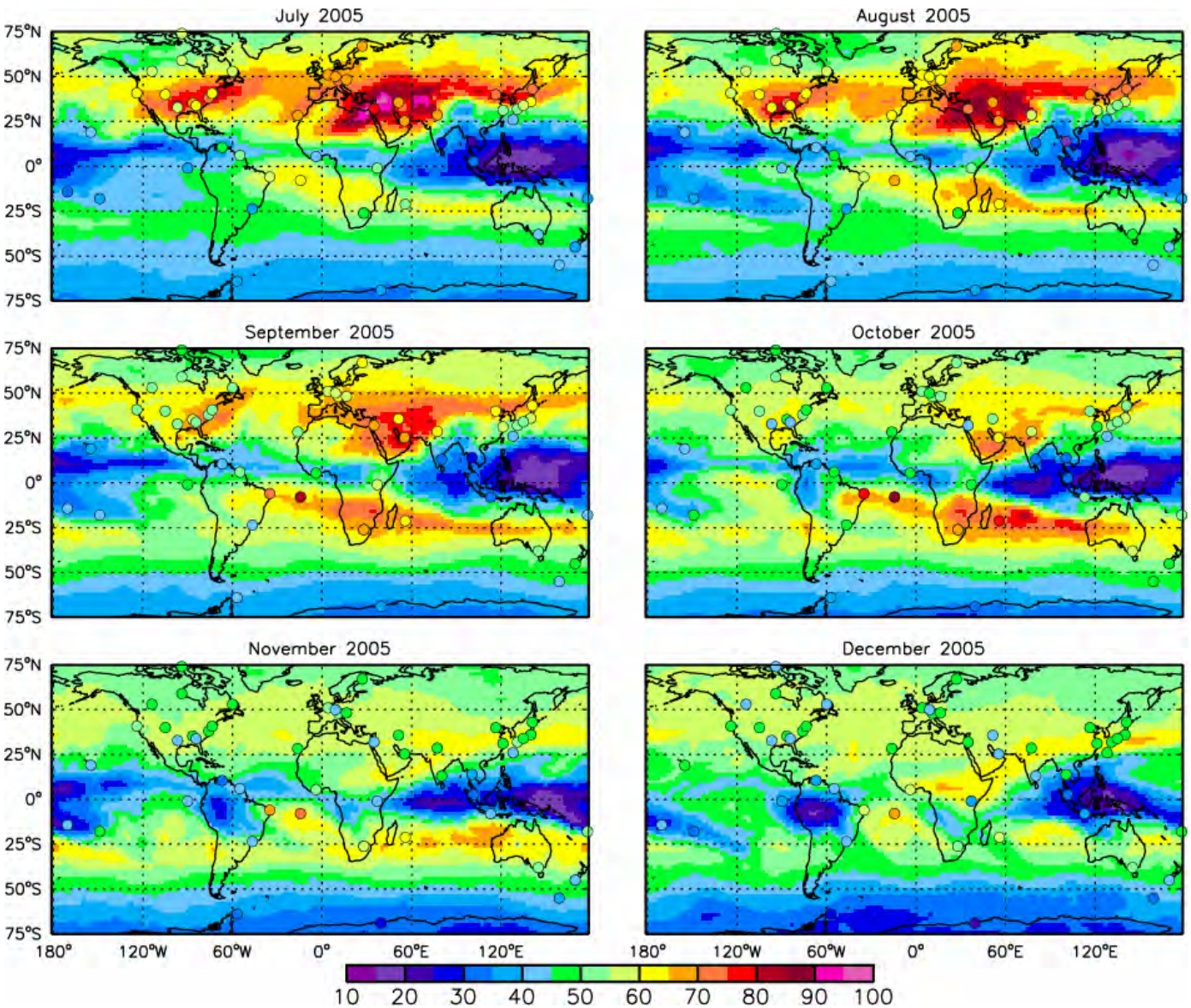
Green – 0.4 Tg
Red – 1.6 Tg



GEOS-Chem, with SYNOZ, does not have quite such high ozone at mid-lat. in winter.
Higher lightning gives more realistic amplitude, but causes some problems

Ozone at 500 hPa, Aura3, compared to in-situ data

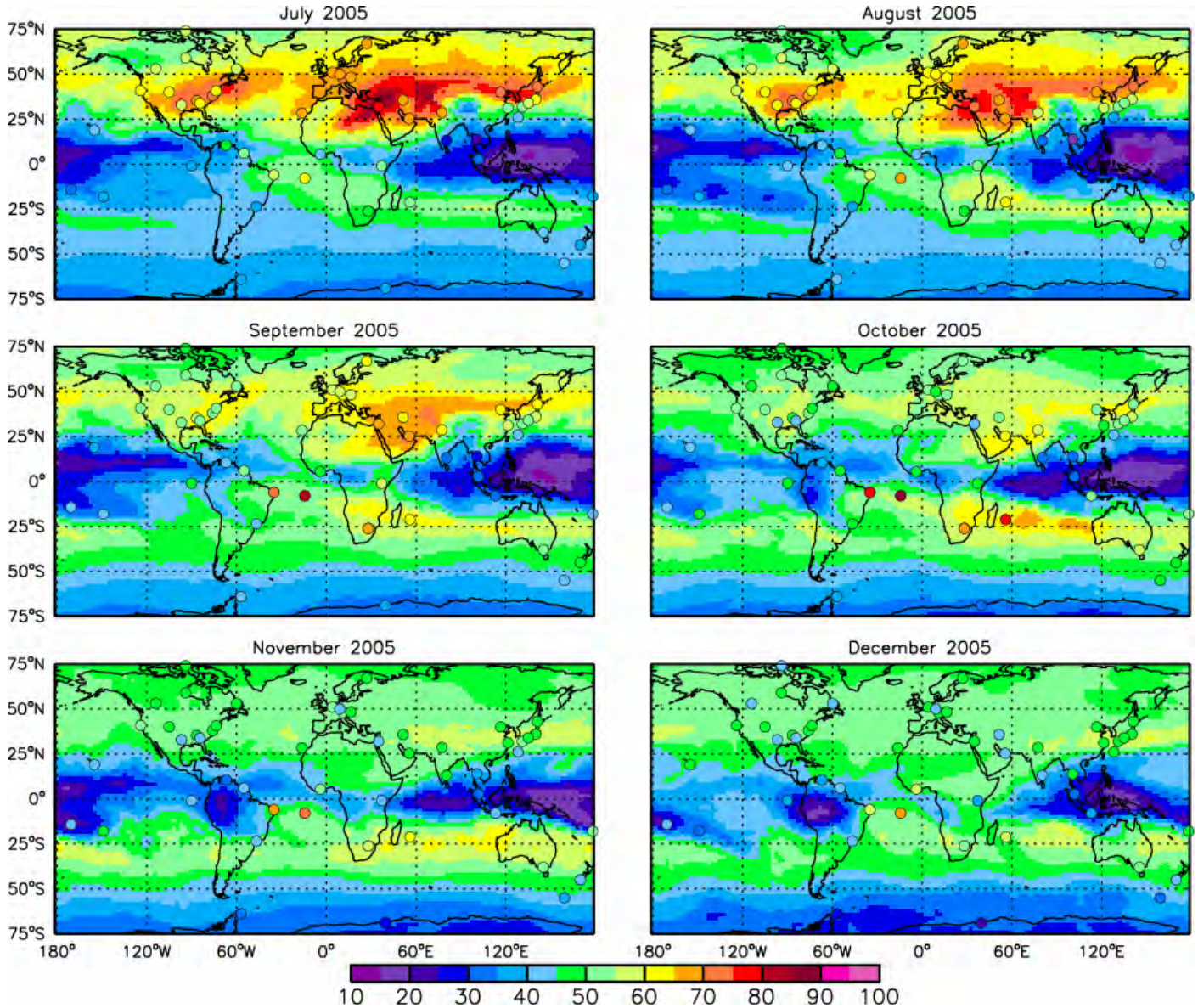
Aura3 too high over S. US in summer, OK over Europe



Model too low over S. Atlantic in Aug-Nov. – O_3 highest over Indian Ocean

Ozone at 500 hPa, Aura4, compared to in-situ data

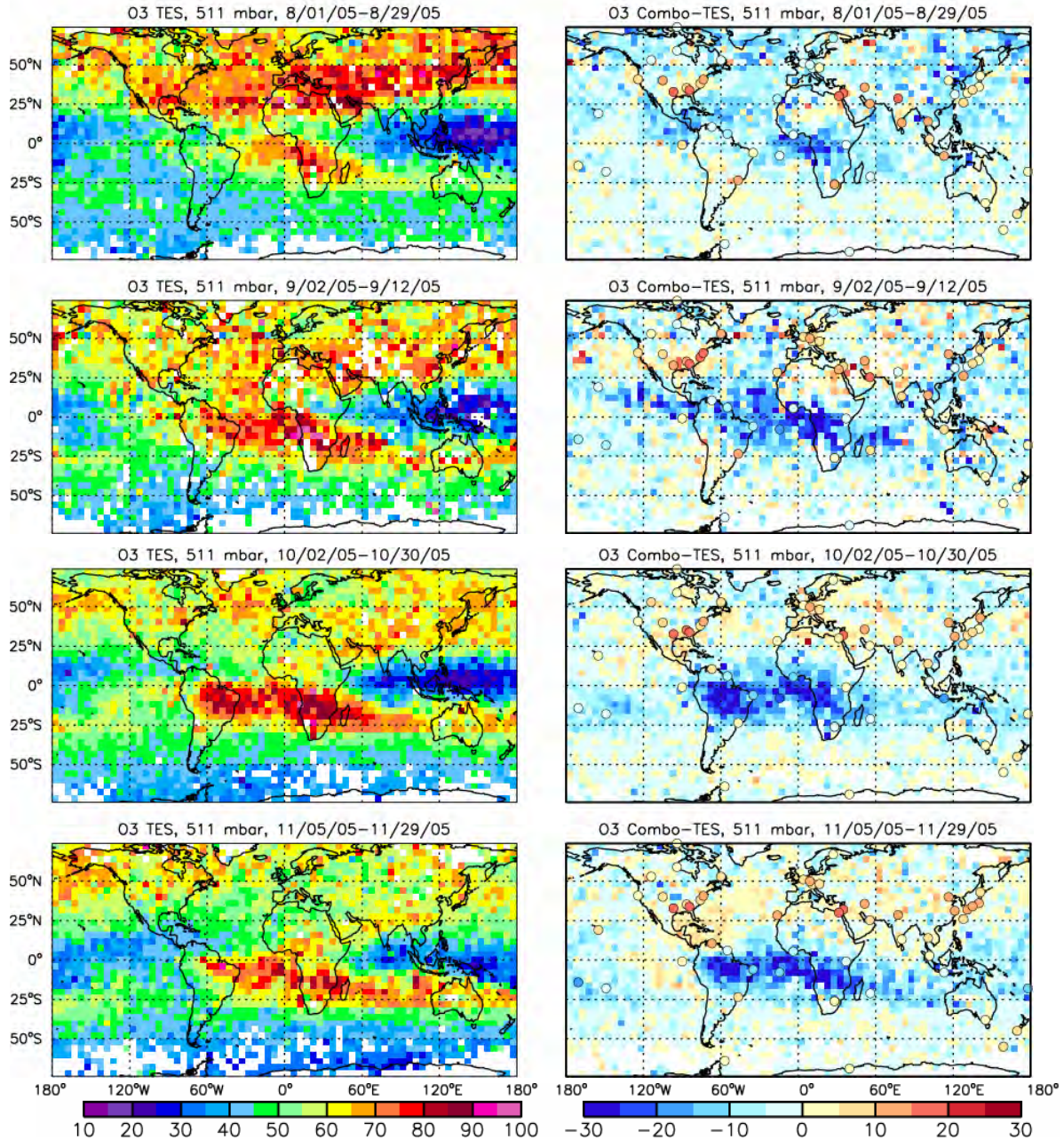
Aura4 lower over US



Aura4 is even lower over S. Atlantic in Aug-Nov.

TES and (Aura3-TES), August – November, 2005

OZONE



TES ozone highest over the S. Atlantic region in Sept.-Oct.

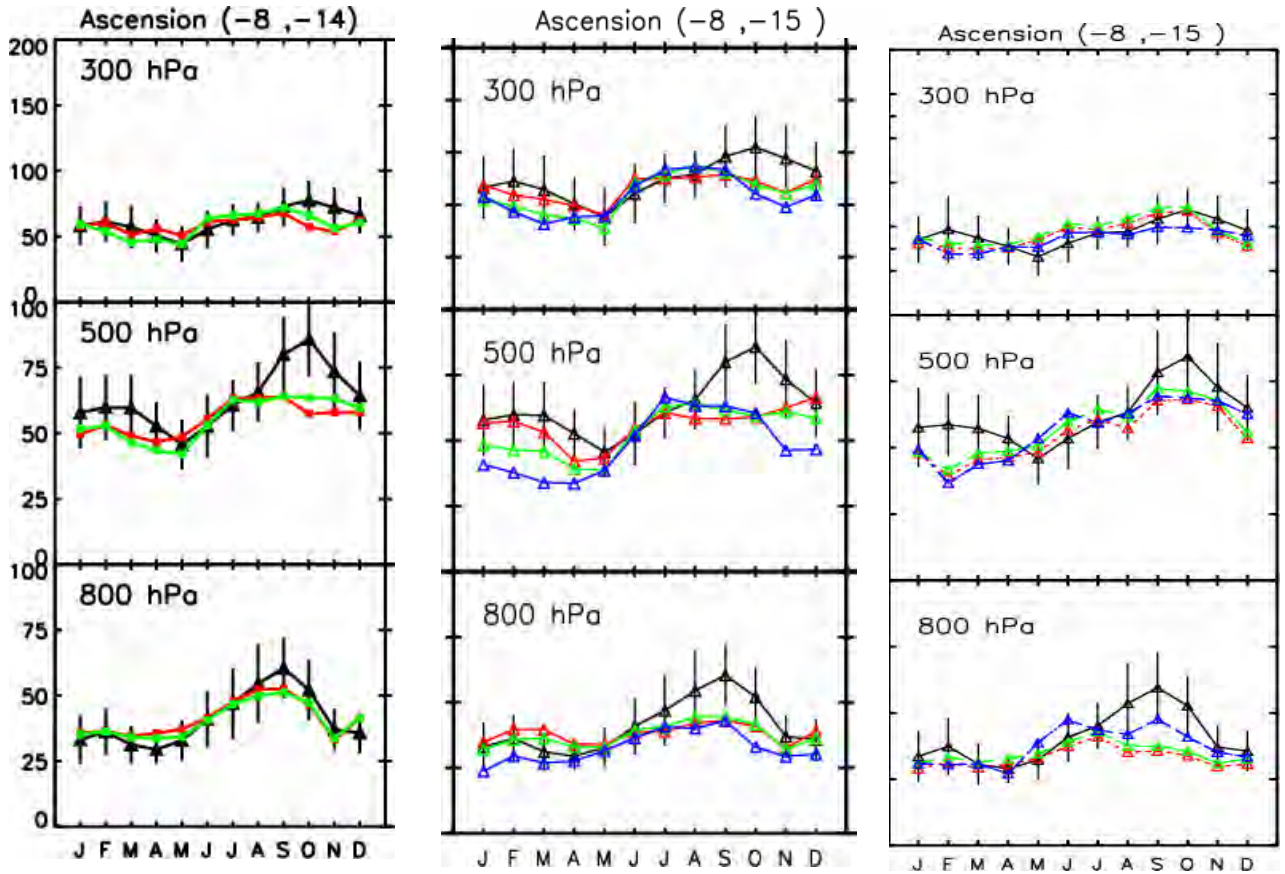
Model is highest over Africa and Indian Ocean.

Aura3 is too low in S. Atlantic region in Sept.-Nov.

(Aura3 - TES) is similar to (Aura3 - in situ), allowing for TES high bias of ~5 ppb, with a few exceptions.

Ozone in the south Atlantic:
TES and sonde data - ozone increases from May to Oct.
Combo/Aura3 and GEOS-Chem – increase stops in July.
GEOS-Chem has been getting worse, in small increments.

1. Combo model **2. G-Chem in 2007** **3. G-Chem in 2005**



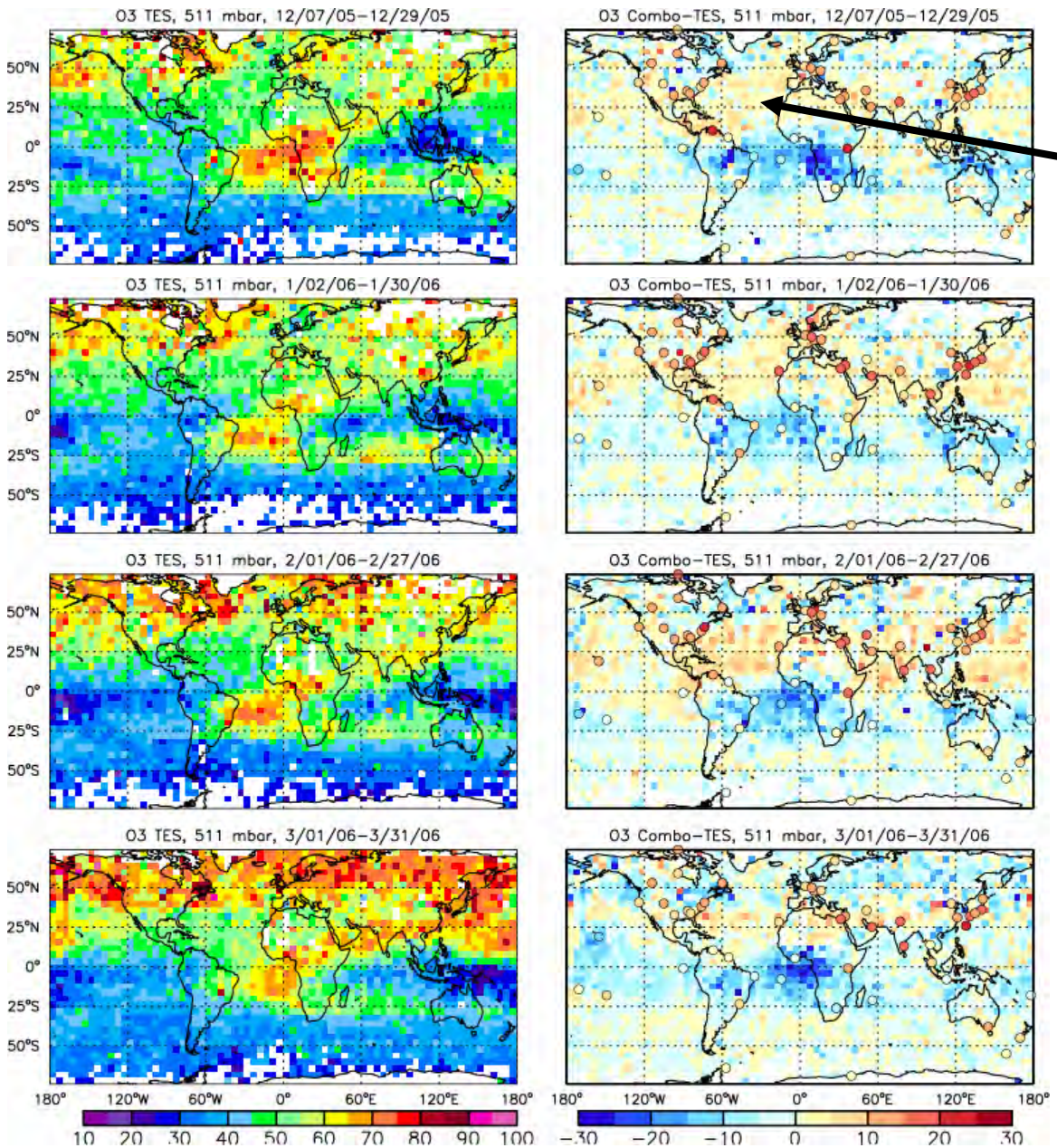
Model has always underestimated Atlantic max. since Bey et al. (2001).

Adding more lightning in Sep-Oct would help, but what about issues with convection?

2. Red: v7−04−12−Run2 (2005); Green: v7−04−13−Run (2005). Blue: v8−01−01−geos5 (2005)

3. Red: v5−07−08 (2001); Green: v7−02−03.geos3 (2001); Blue: v7−02−03.geos4 (2001)

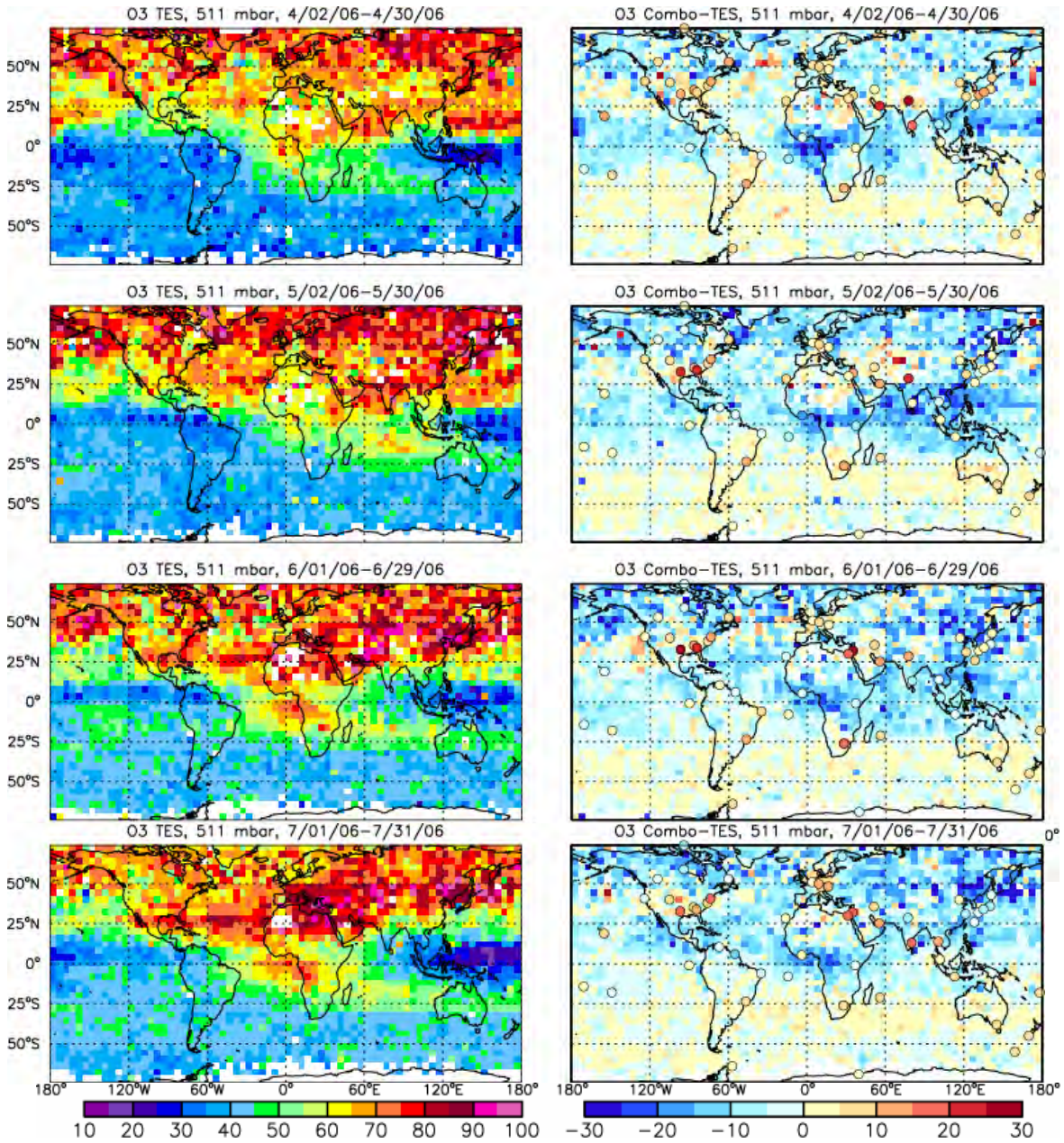
TES and (Aura3-TES), Dec. 2005 – March, 2006



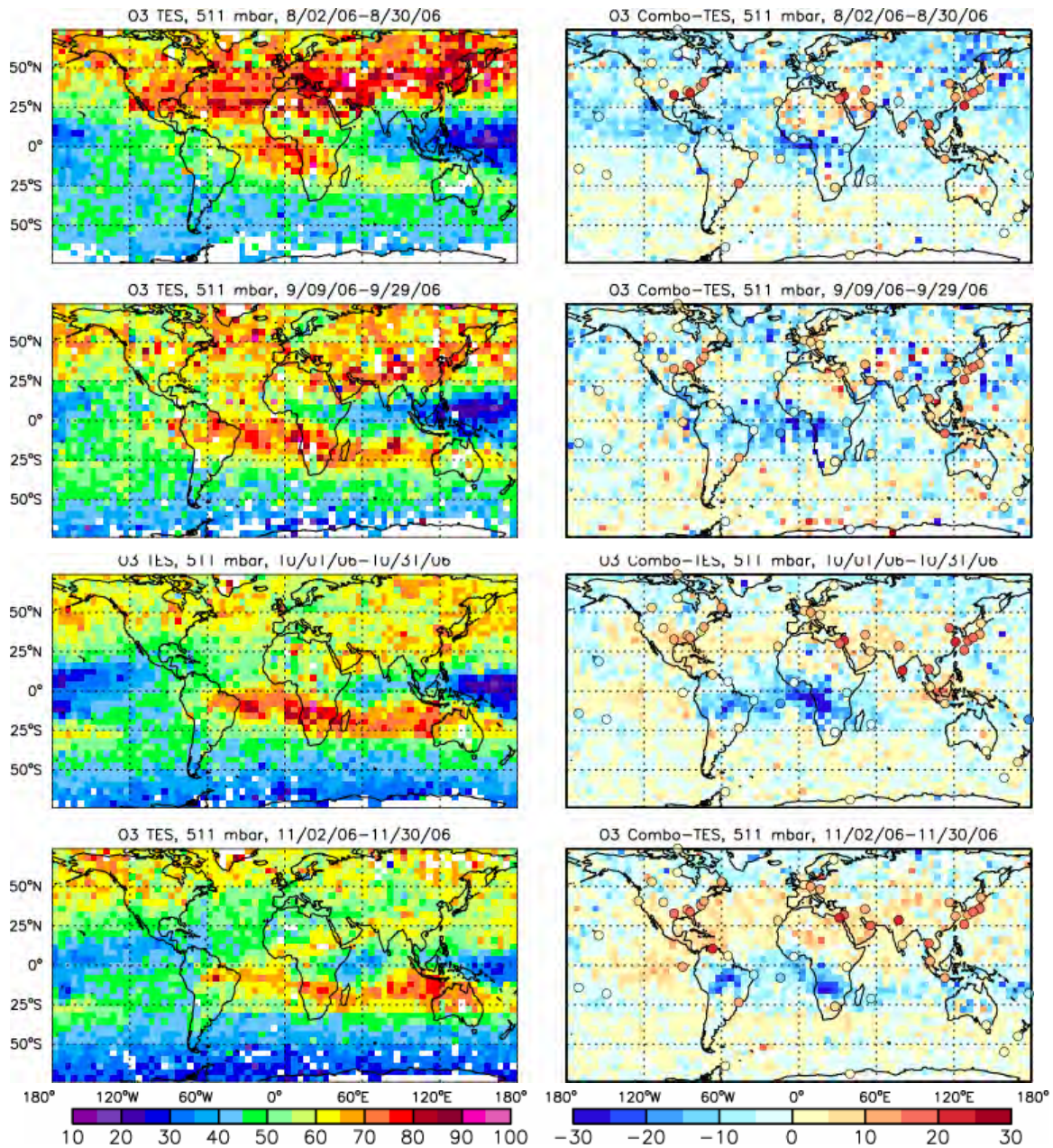
In-situ data show model too high in winter, if TES bias (~10 ppb) allowed for.

No major discrepancies

TES and (Aura3-TES), April - July, 2006



TES and (Aura3-TES), August-November, 2006

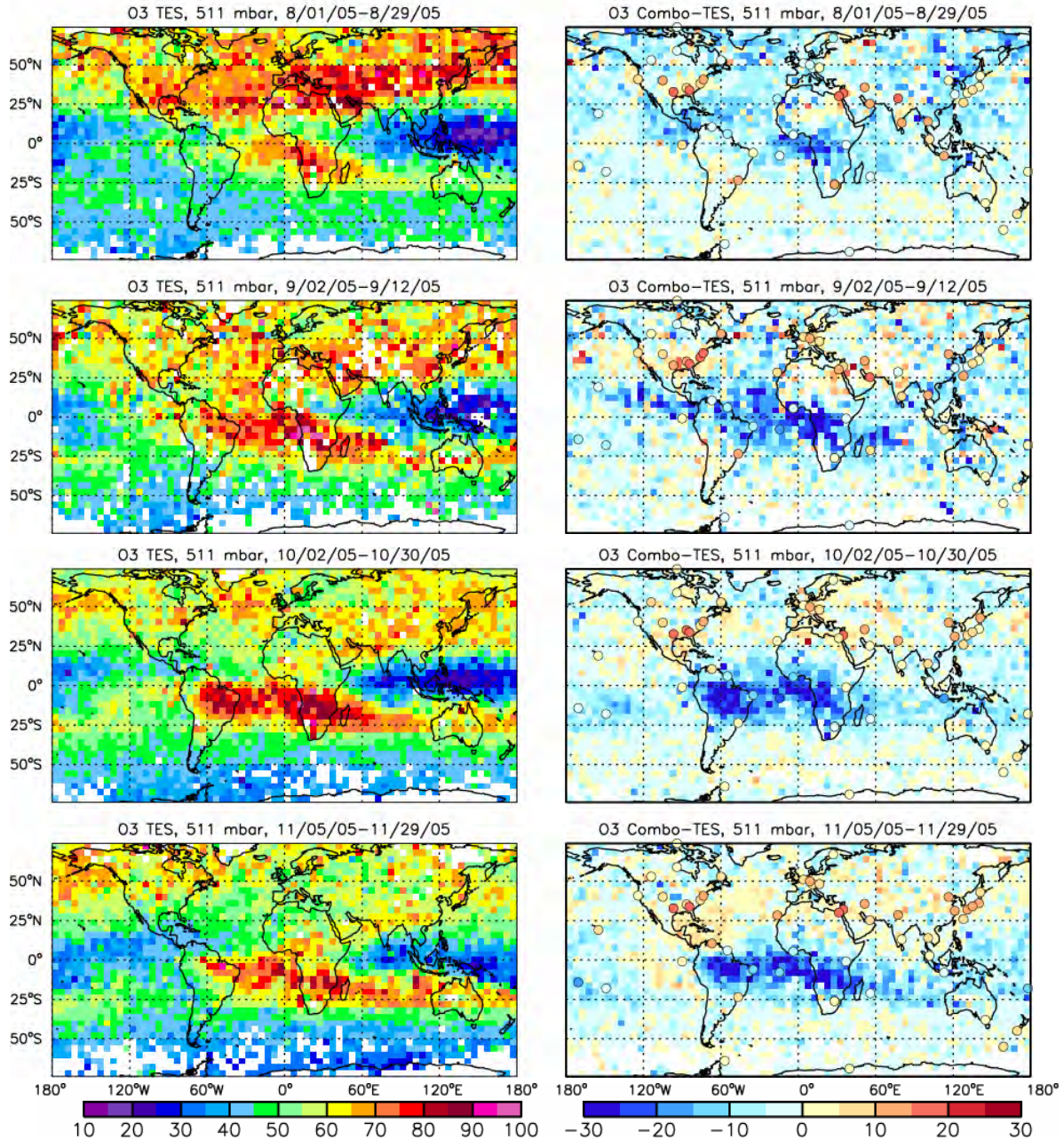


Model-TES discrepancies are smaller in late 2006 than in 2005, as they were for CO.

Ray Nassar using GEOS-Chem to investigate causes of differences in CO and O3 in late 2005 and 2006 – circulation, fire emissions, lightning.

Paper is preparation on 2006 El Nino simulations.

TES and (Aura3-TES), August – November, 2005



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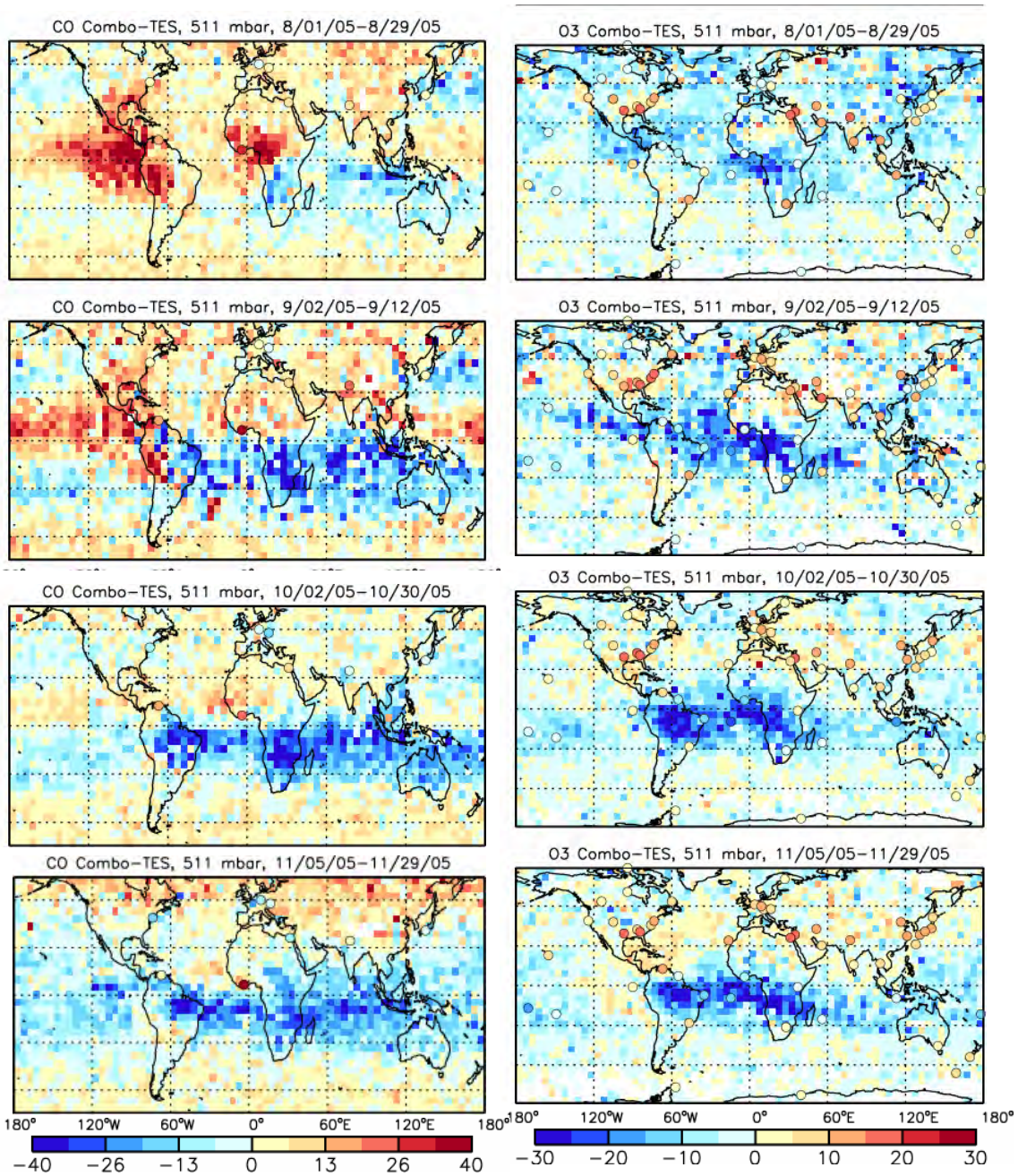
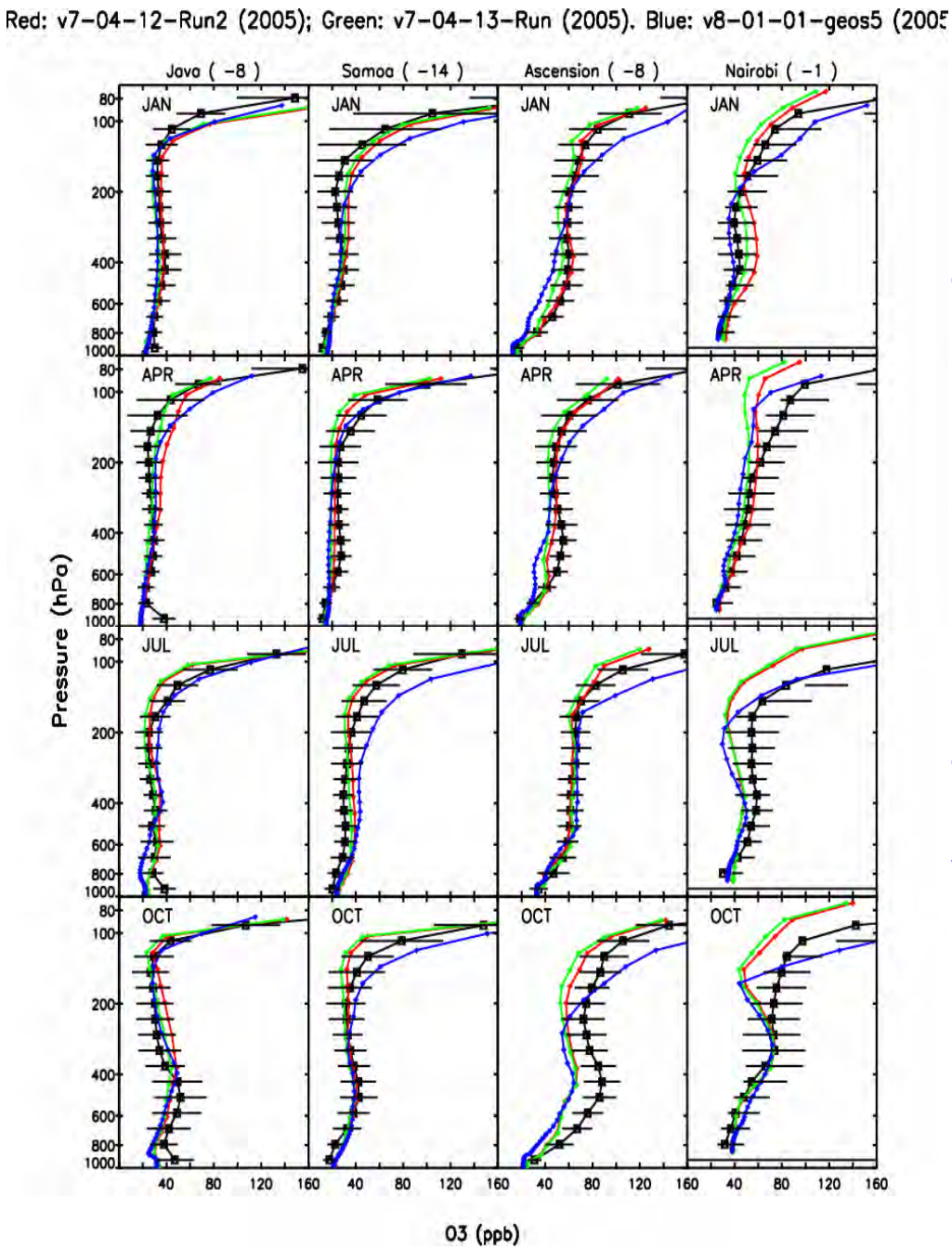
(Aura3 - TES) is similar to (Aura3 - in situ), allowing for TES high bias of ~5 ppb, with a few exceptions.

CO, Aura3-TES O3, Aura3-TES August-November, 2005.



O3 underestimate in Sept.-Oct. May be related to underestimate of fire emissions, as well as to issues with lightning NOx at end of the dry season.



GEOS-4:green
GEOS-5: blue

GEOS-4 and -5 similar in middle trop.

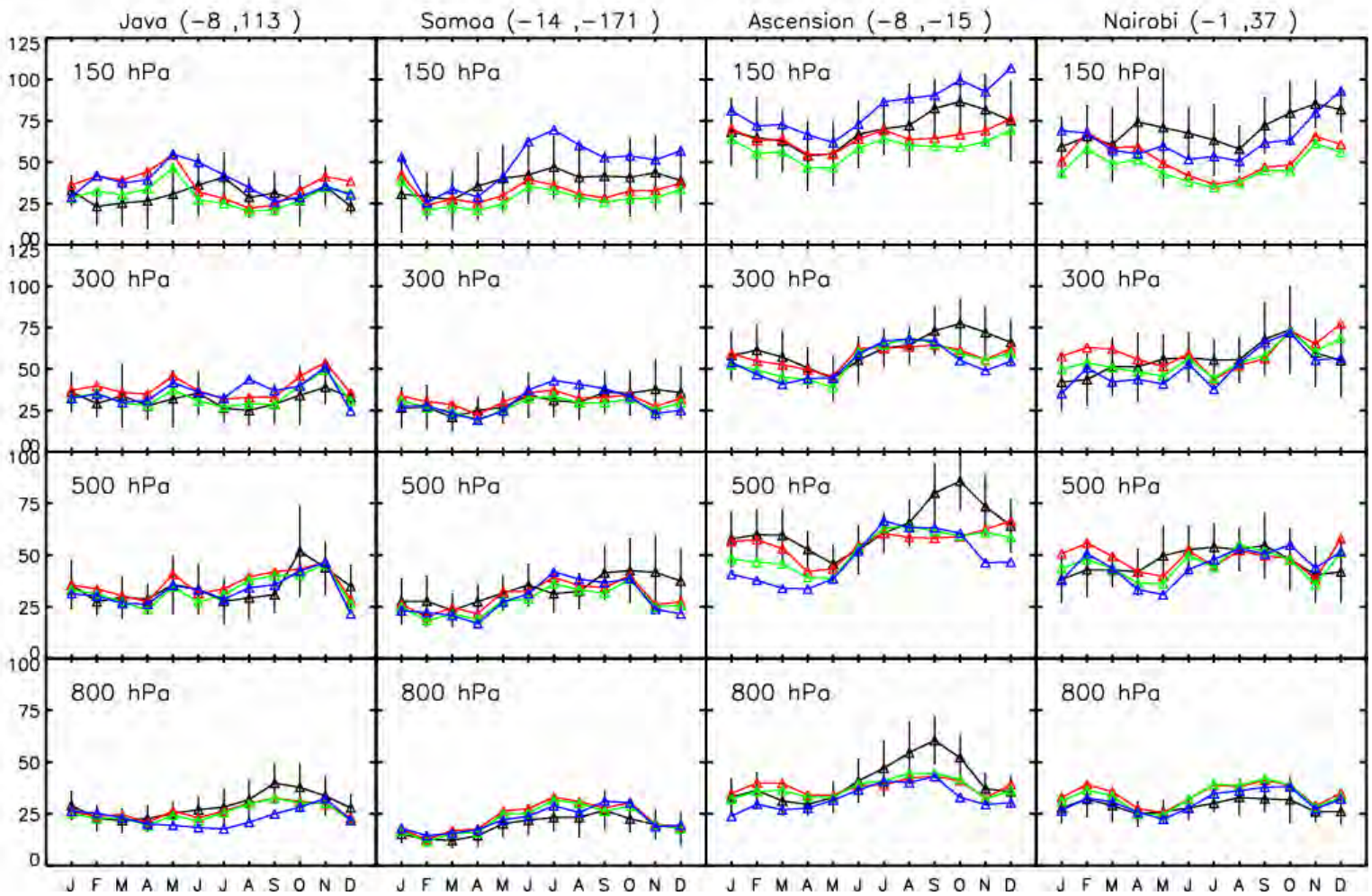
In regions of strong convection GEOS-5 and GEOS-4 similar in UT: Java in Oct., Jan; Samoa in April

Largest differences in ozone profile in UT in regions of weak convection – S. tropics in dry season. GEOS-5 turns over at a lower altitude.

Which agrees better with observations? Depends on region/season. No clear winner.

GEOS-5 usually higher in UT

Red: v7−04−12−Run2 (2005); Green: v7−04−13−Run (2005). Blue: v8−01−01−geos5 (2005)



Other GEOS-5 differences

- CO slightly larger, as OH lower
- Lightning implementation – but this depends on how it’s done.
- Problems with implementation of wet removal – Hongyu talk

Concluding comments – TES/GMI analysis

- Indirect validation generally support quality of TES measurements.
- The Aura3 run is similar to TES and in-situ ozone in most regions, except extratropical winter/spring (model too high), and S. Atlantic maximum (model too low).
- Aura4 appears worse in SH tropics.
- Write up material in this talk. Aura 3 or Aura4? TES version?
- Update with V003 TES data: CO is similar in V002 and V003, but there are differences in ozone in lower trop.
- Problems with fudge for C-shaped ozone profiles
- Investigate use of MLS CO and O3 data in UT as constraint on convection.