Analysis of GMI tropospheric Simulations and the Combo Simulation

Jennifer A. Logan

Harvard University

with thanks to the Bryan Duncan and the GSFC core team

Inna Megretskaia

GMI Science Team Meeting, January 11-13, 2006

Topics

- Analysis of some key differences among the 3 trop. runs
- Evaluation of stratospheric ozone in the combo run using ozonesonde data
- Comparison of the Combo and Trop. runs using the same year of FVGCM winds

- One minor change to trop. runs since last meeting: use of seasonal fossil fuel emissions
  - very small changes to CO, imperceptible changes to ozone
  - checked out using FVGCM
  - unfortunately, the new DAO and GISS runs were not run for long enough (oops), since corrected (last weekend)

Review - and naming convention

Tropospheric simulations with three sets of meteorological fields:

- FVGCM
- GEOS-STRAT for 1997-1998 - called “DAO” here
- GISS

The GEOS-4-AGCM (FVGCM) met. fields have been run for the with a combined chemical mechanism for stratosphere and troposphere - the “COMBO” run.

- The chemical mechanism and the j-values are different in the combo and in the Trop. FVGCM
- Ozone columns for J-values?

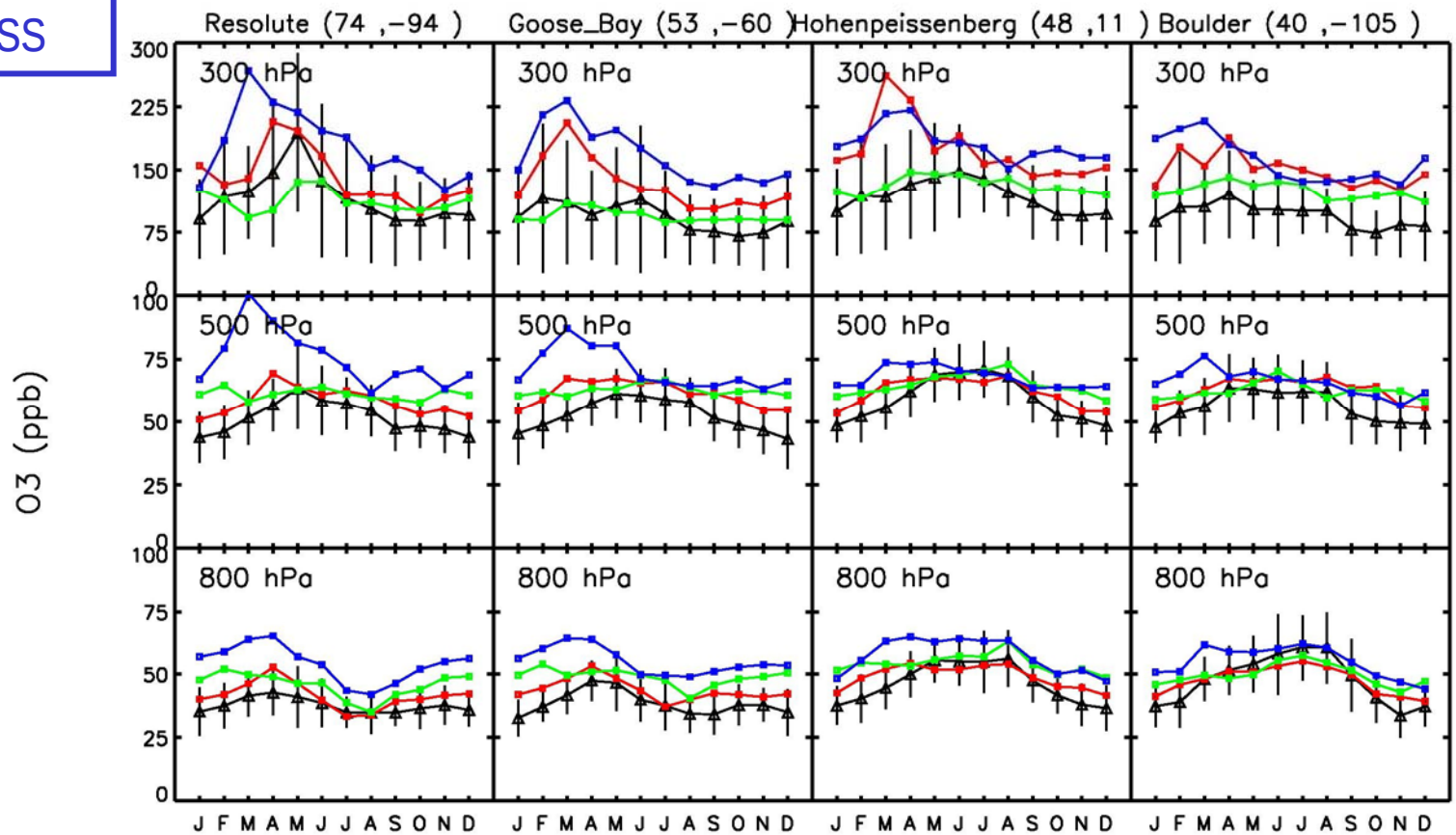
Outline

- Role of stratospheric input into troposphere, using runs with the SYNOZ flux omitted (and zero ozone in the stratosphere)
- Evaluation of the Combo run for stratospheric ozone
- Comparison of the Combo and Trop. FVGCM runs in the troposphere

- Analysis of differences in ozone in July in the sub-tropics among the three trop. runs.

Ozone at mid-high latitudes

FVGCM
DAO
GISS



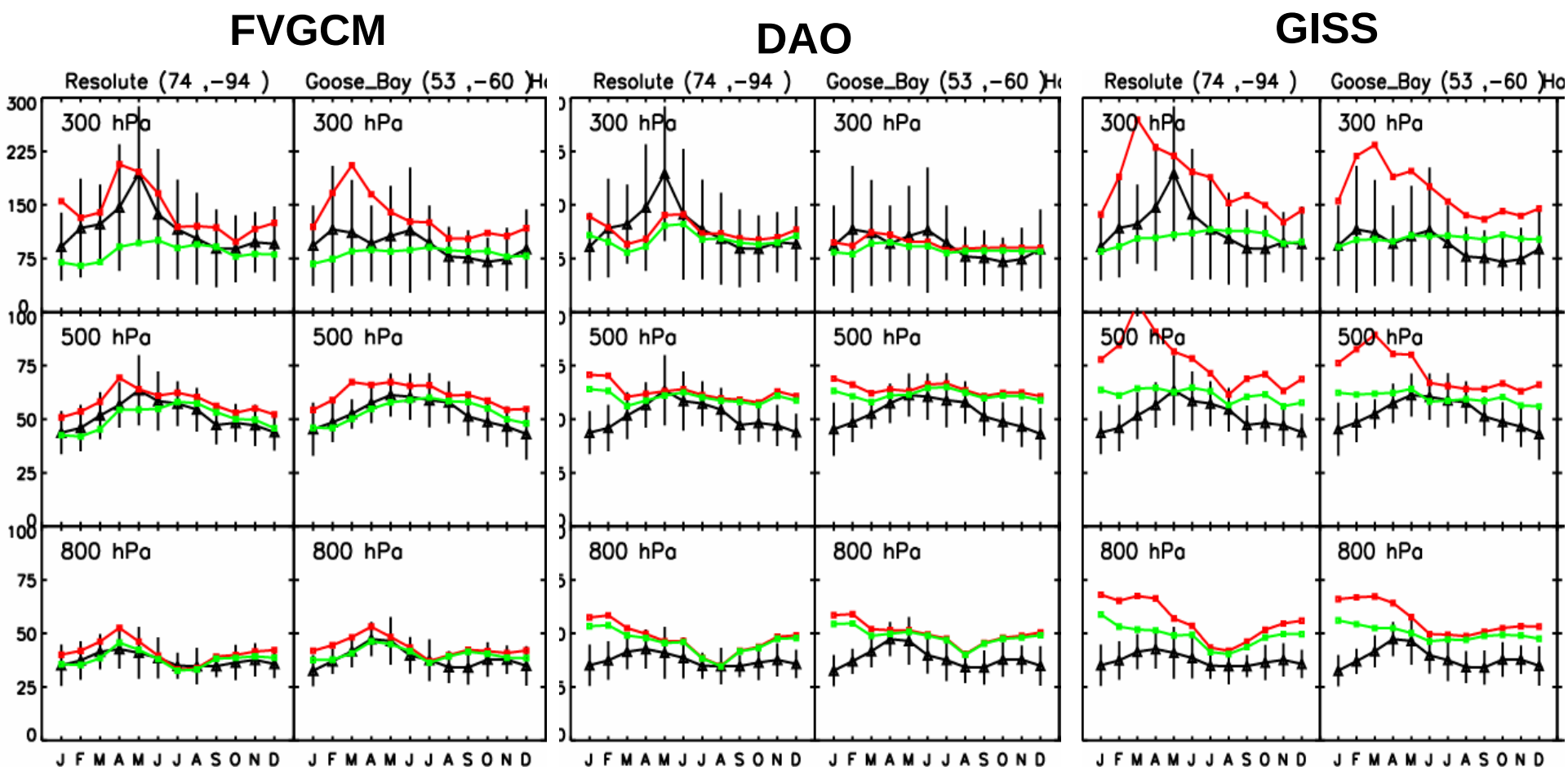
GISS: too much ozone from the strat. at high latitudes, affecting ozone at 500 hPa as well as 300 hPa.

FVGCM: too much ozone at 300 hPa at mid-latitudes, but 500 hPa is reasonable

DAO: damped seasonal cycle at 500 hPa.

Effect of stratospheric ozone at mid-high latitudes

RED: Standard run (but not converged for DAO, GISS, Jan-Mar. too high)
GREEN: Same run without SYNOZ

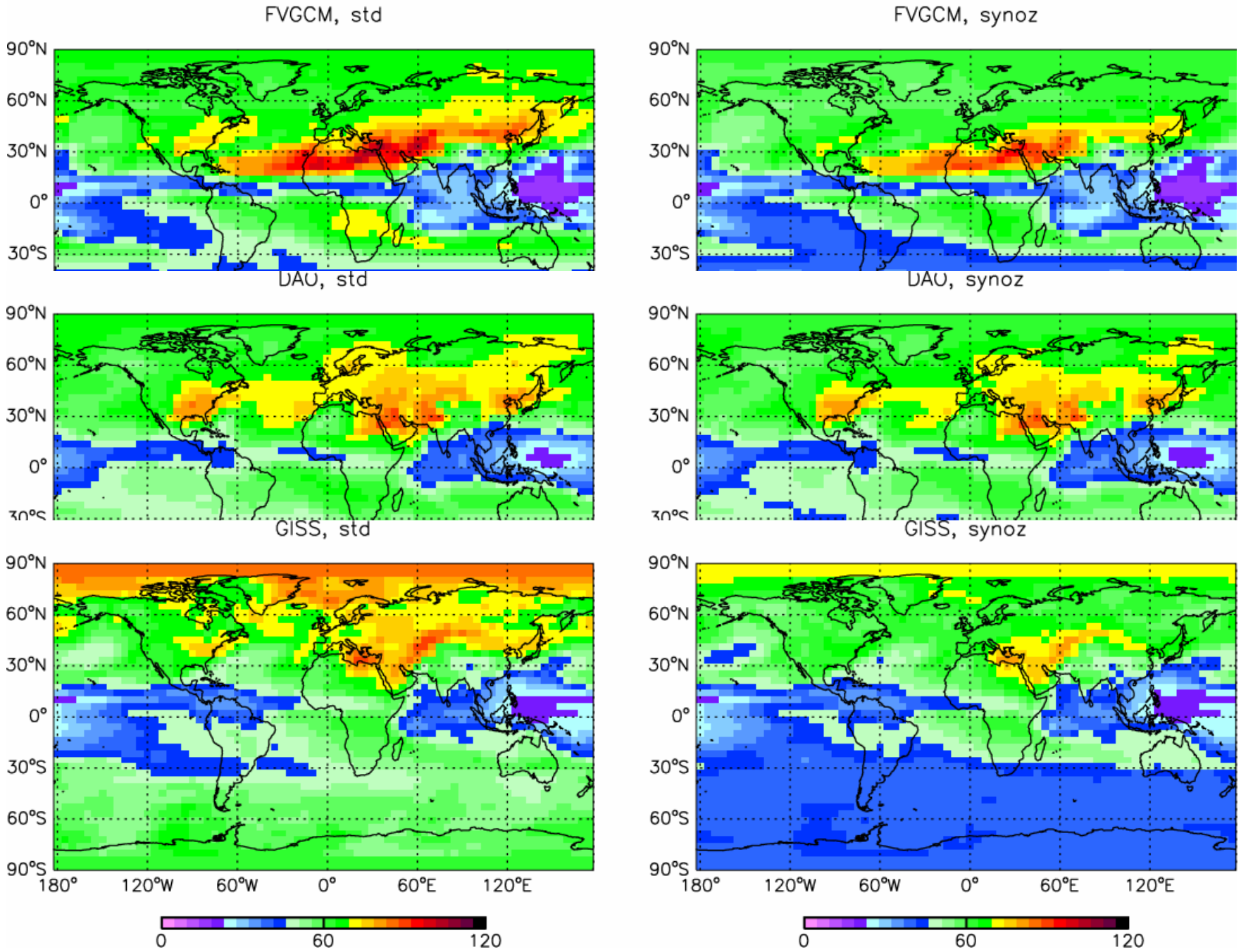


Strat. source has largest effect in GISS, smallest in DAO
Evaluation with all sonde data shows that FVCGM is most realistic

Trop. simulation, July

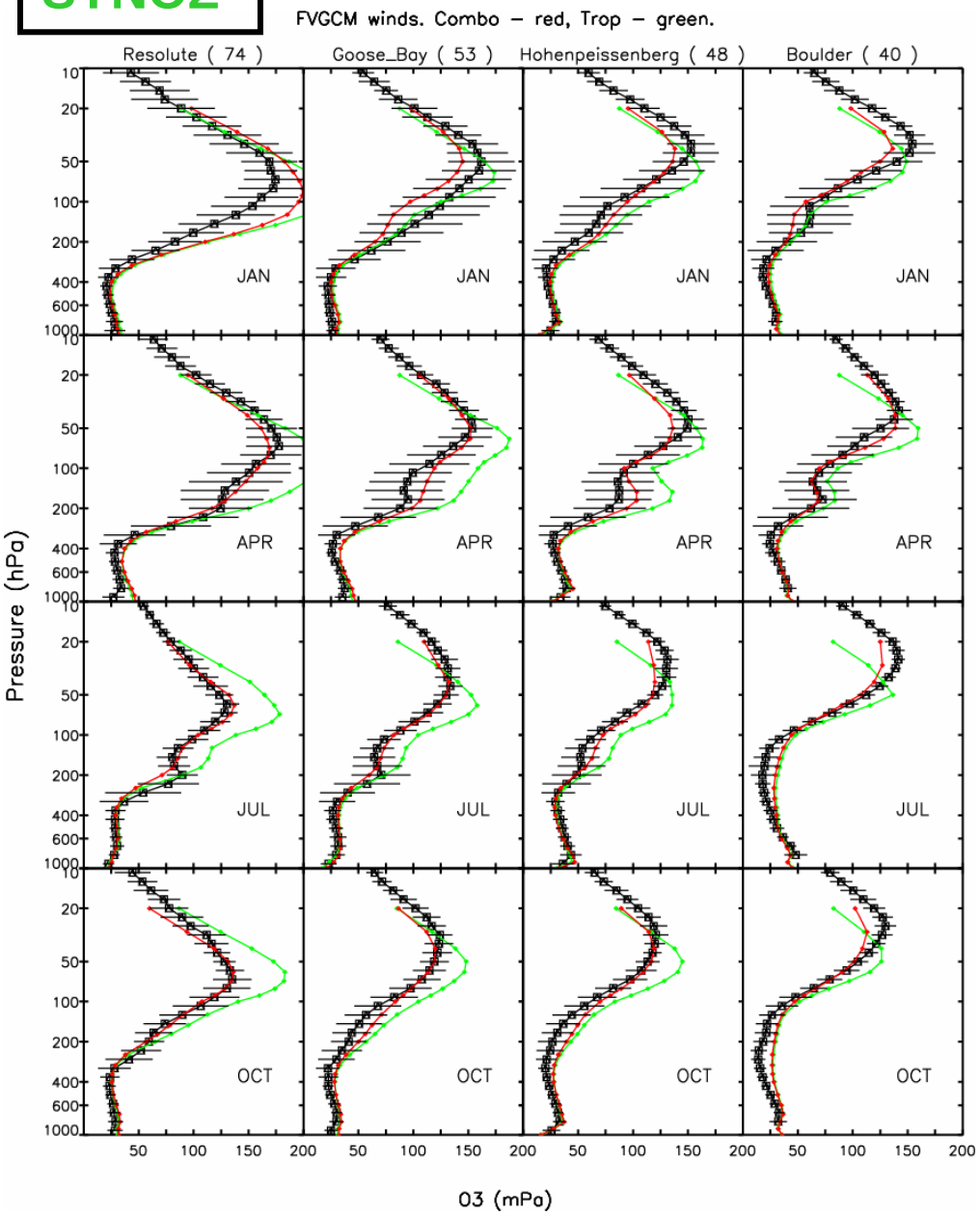
Ozone at 500 mbar

No SYNOZ



COMBO
SYNOZ

Combo vs. ozone sonde data, mid-high lats



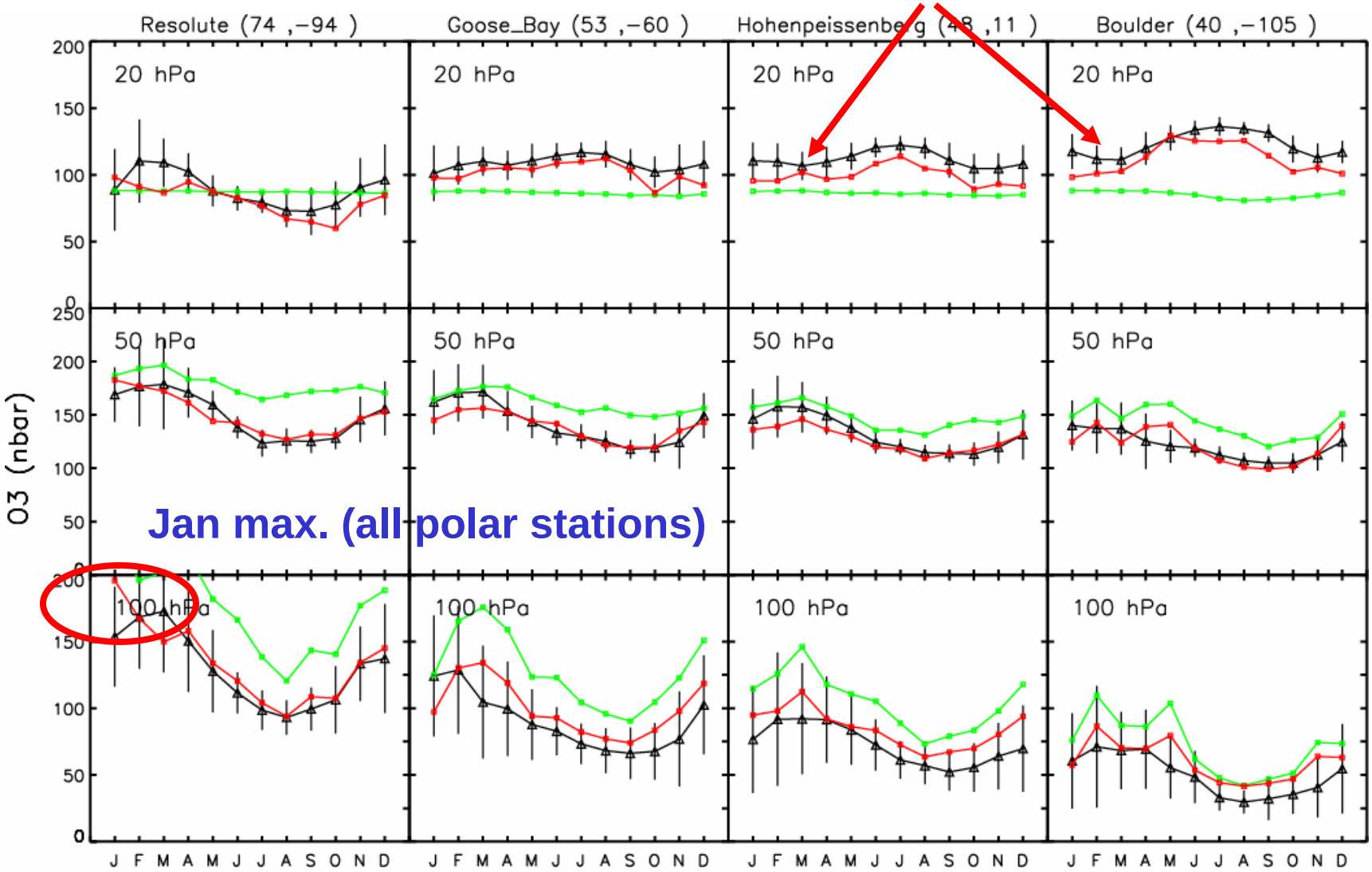
4x5 Combo

- The model looks very like the observations.
  - e.g., annual cycle
  - latitudinal gradients
  - spatial patterns
  - secondary max. in LS
  - ozone hole
- Minor issues:
  - ozone peaks in Jan, not March, at high latitudes
  - model too low at 20 hPa in winter, 30-50 N
  - too much ozone over Japan, lowermost strat.

COMBO
SYNOZ

Annual cycle, mid-high latitudes

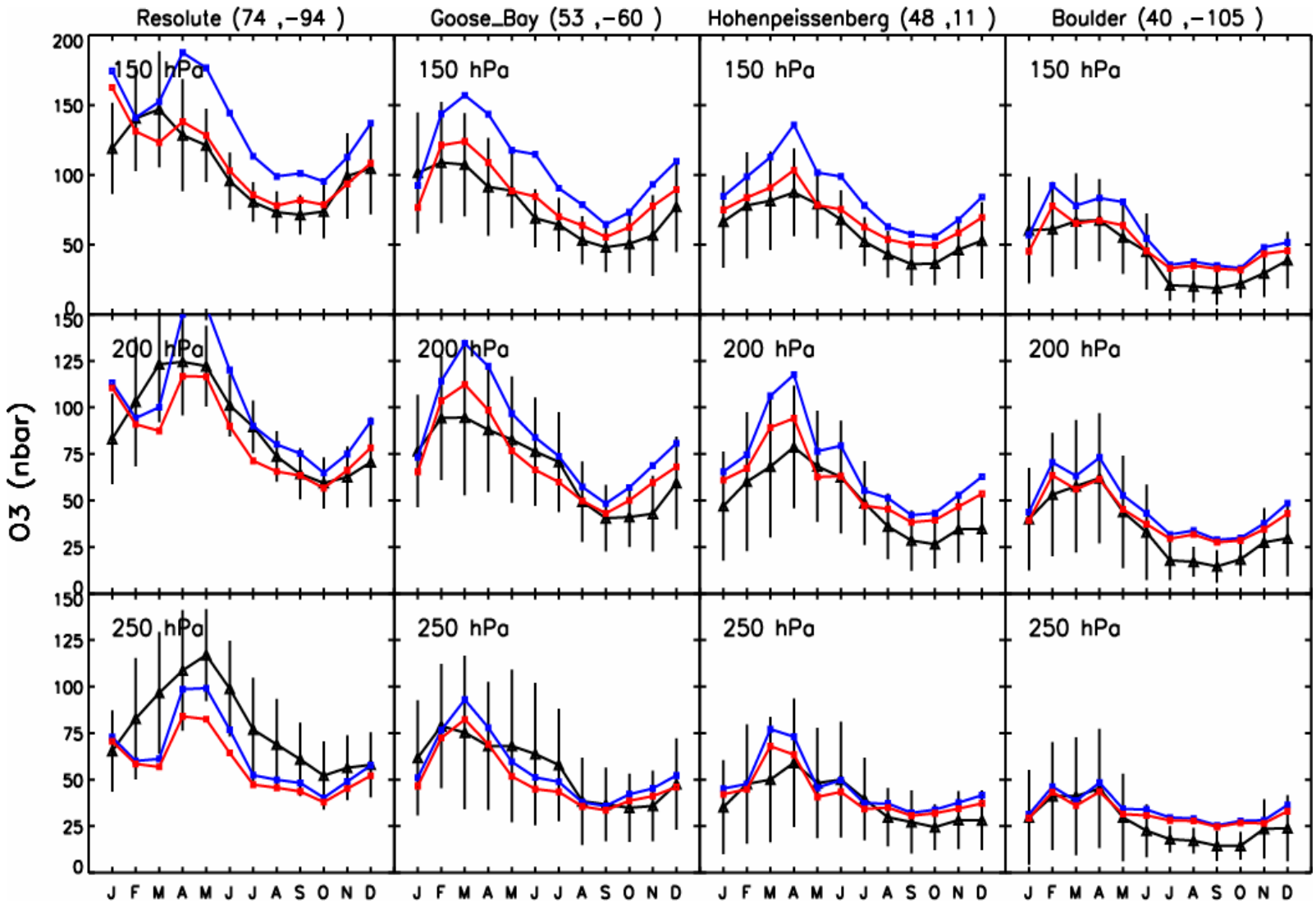
too low



Jan max. (all polar stations)

COMBO
SYNOZ

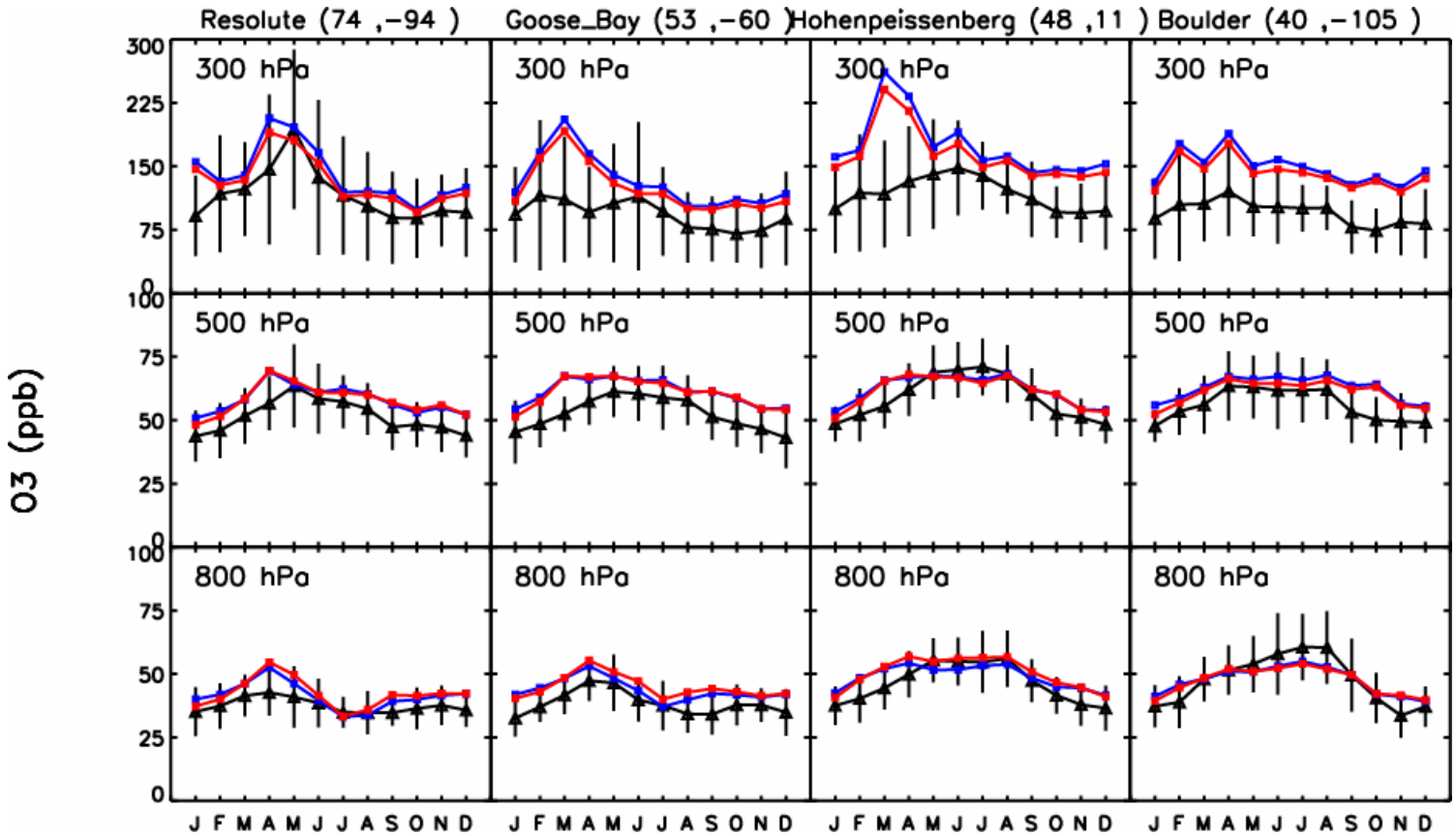
Mid-high latitudes, lowermost stratosphere



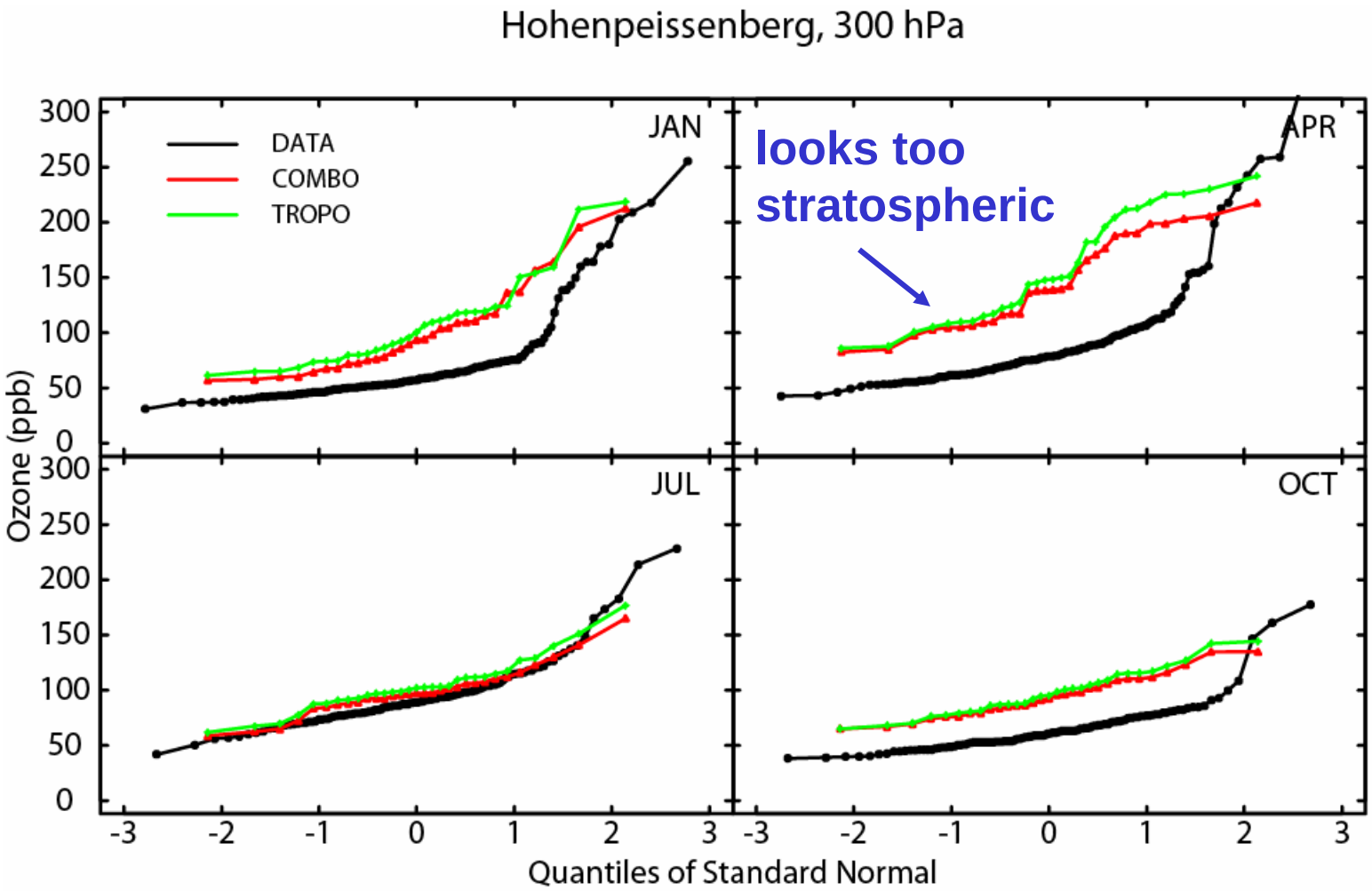
Results of Combo and Trop. are very similar in the troposphere for ozone

COMBO
SYNOZ

Both are high at 300 hPa, near the tropopause



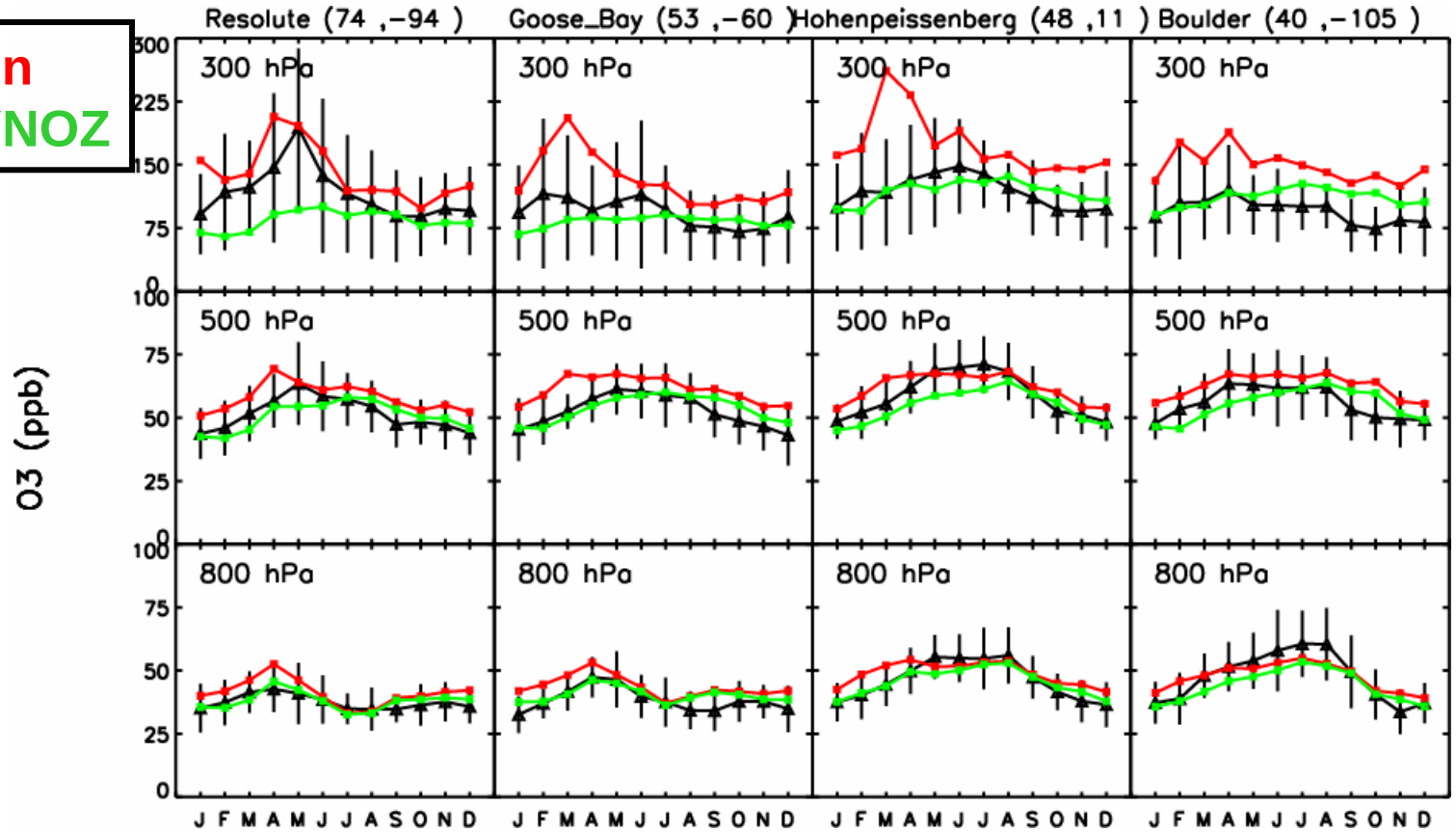
Probability distribution of ozone at 300 hPa



Effect of the stratospheric source on trop. ozone in FVGCM

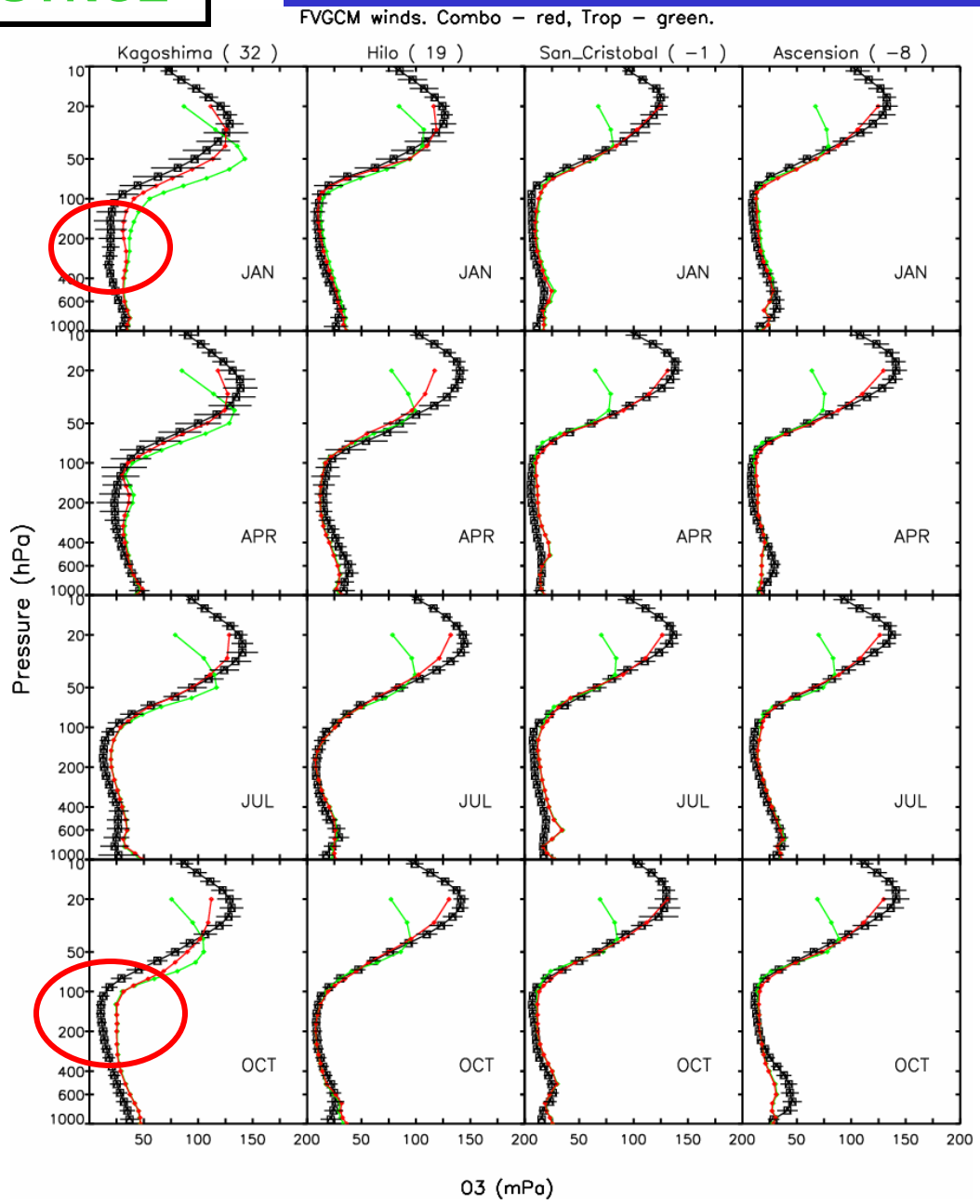
- The Trop. run with a SYNOZ flux of zero shows the effect of the stratospheric source on tropospheric ozone
- Since the Combo and Trop runs are very similar, this should separate the strat. and trop. sources of ozone for the Combo also

Trop. run
Zero SYNOZ



COMBO
SYNOZ

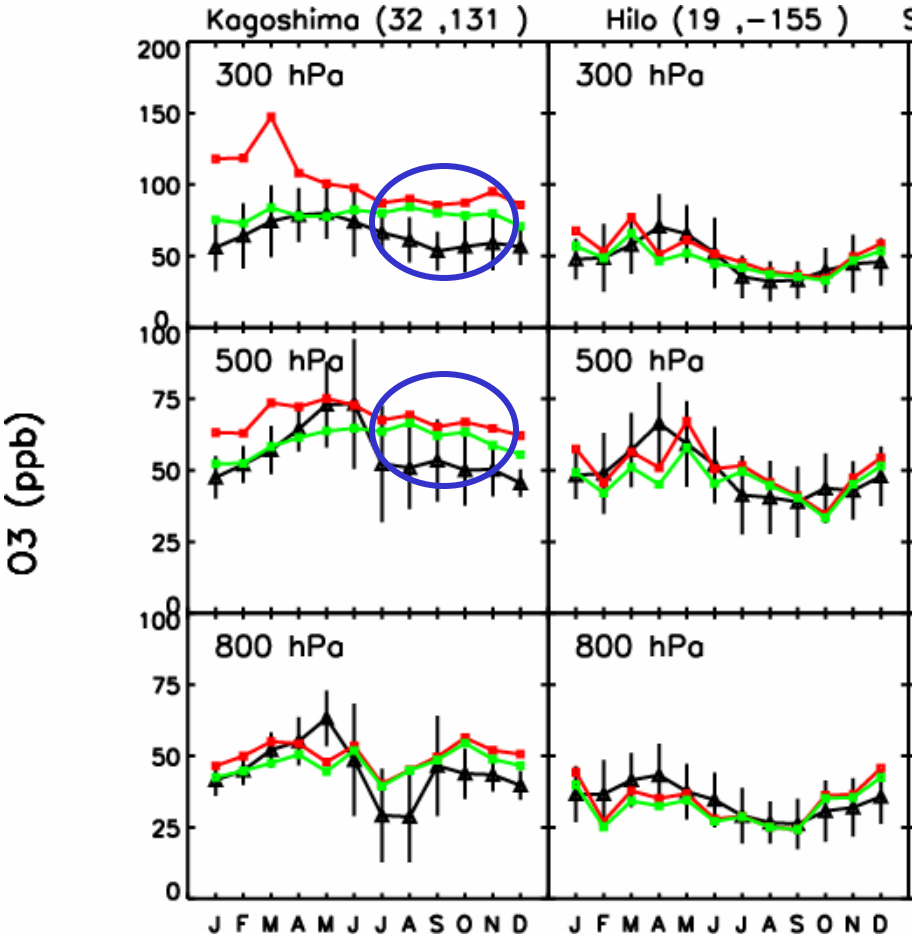
Sub-tropics and tropics - stratosphere



- Note problem over S. Japan, discussed by David Considine
- This is a problem with tropospheric ozone in the runs

FVGCM - Japan

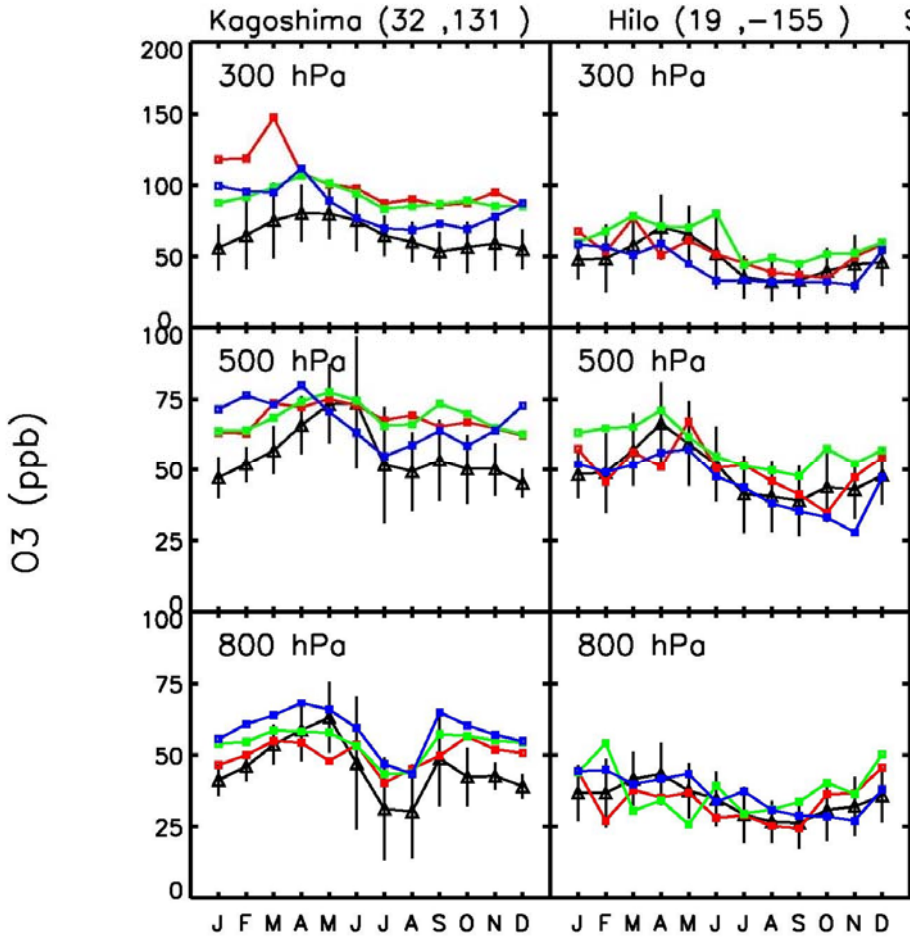
Trop. run
Zero SYNOZ



- **Overestimate in S. Japan is a problem with the <u>tropospheric</u> simulation in fall**
- **The overestimate at 300 and 500 hPa at Tateno (36 N) and Sapporo (43 N) in Jan.-Mar. may be caused by too large a <u>strat. source</u>**

None of the met. fields simulate this region well

FVGCM
DAO
GISS



1. FVGCM has too much ozone over Japan in Jan-Mar. - from strat. (see Kagoshima, 30 N)

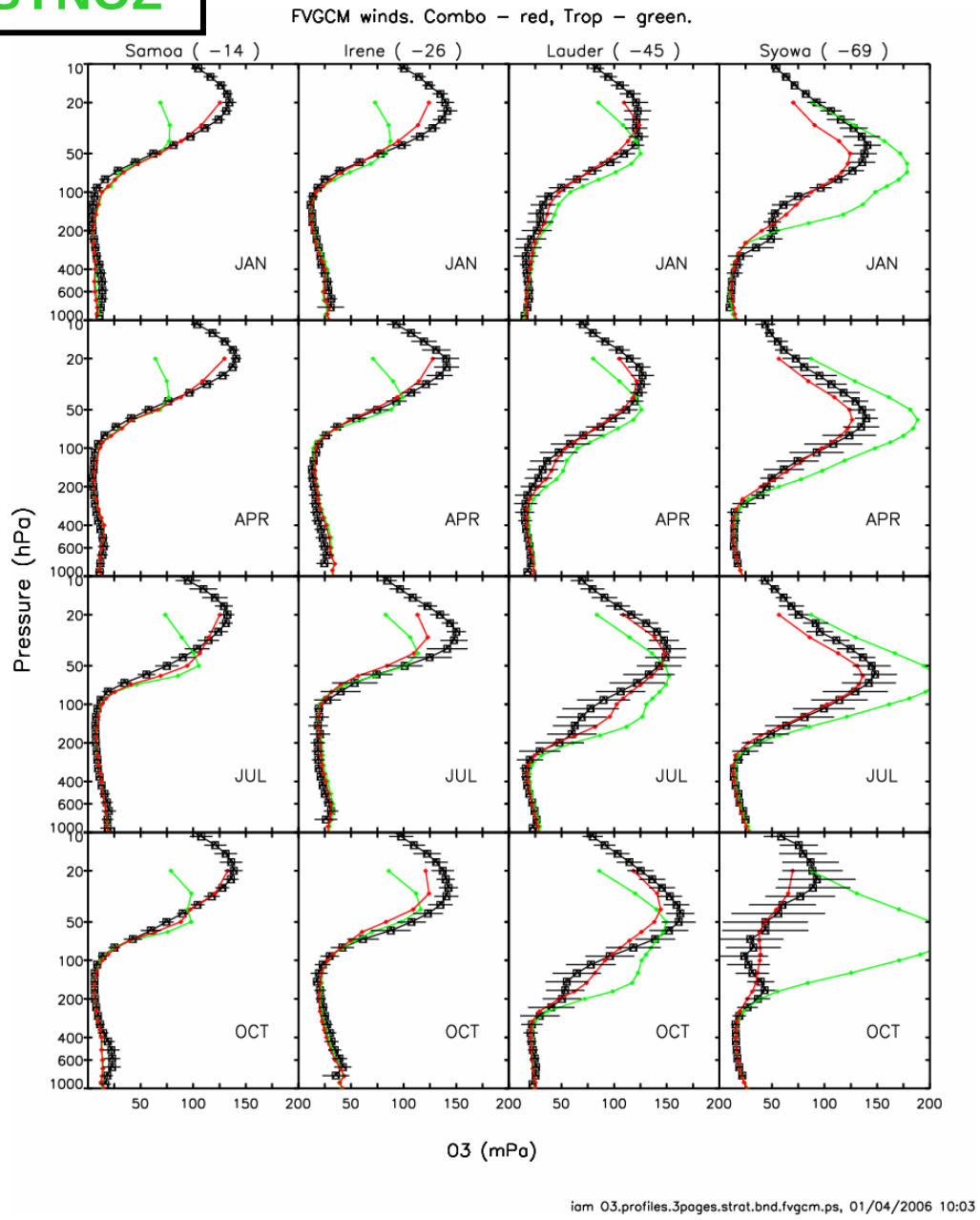
2. Observations show a steep drop from June to July at all sonde and MOZAIC sites in E. Asia.

None of the models do this very well.

FVGCM looks good at Hilo.

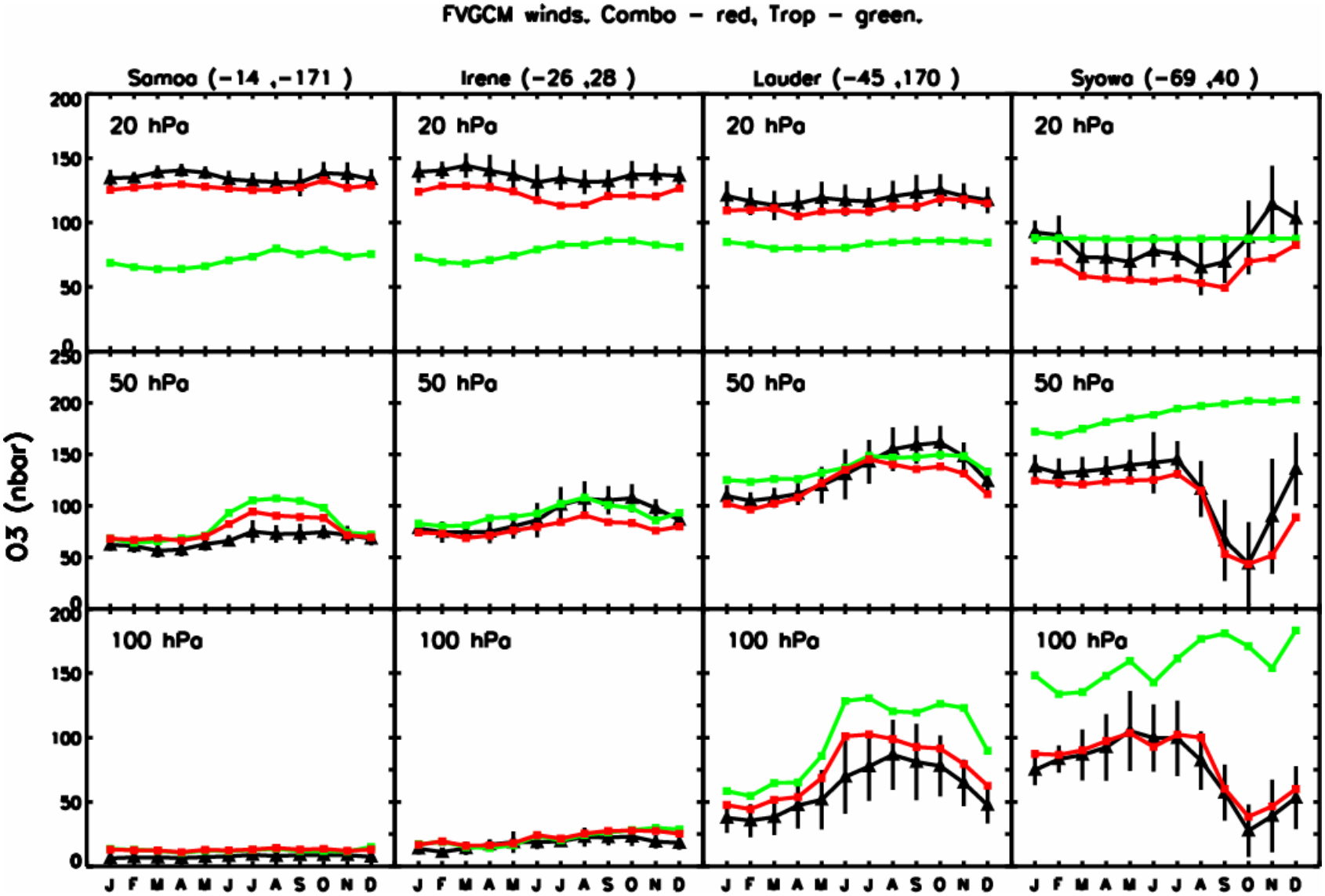
COMBO
SYNOZ

Southern hemisphere - stratosphere



- **The ozone hole is reasonably well reproduced**

Ozone hole in Combo - Wow!

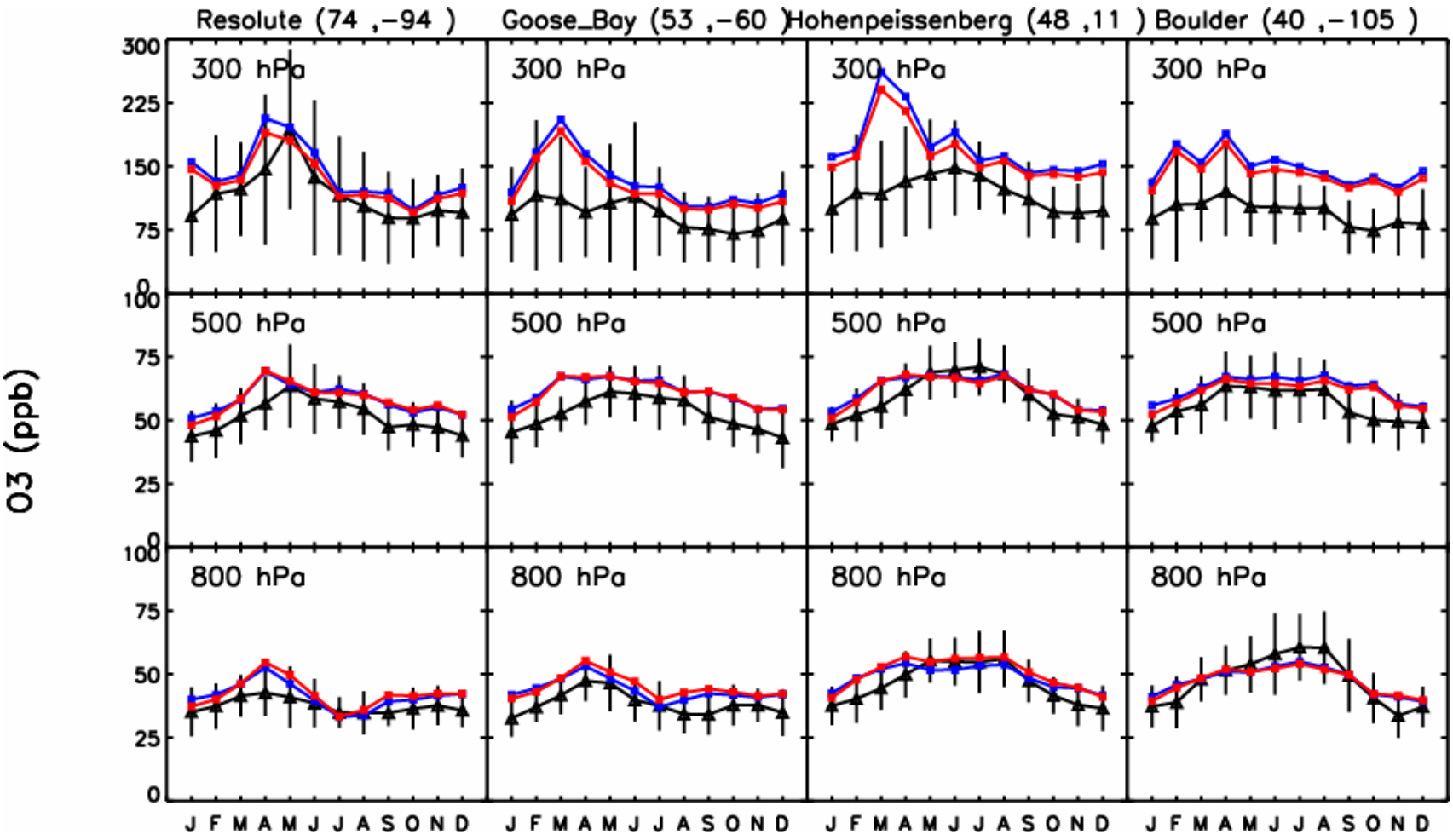


Trop. vs. Combo in the troposphere

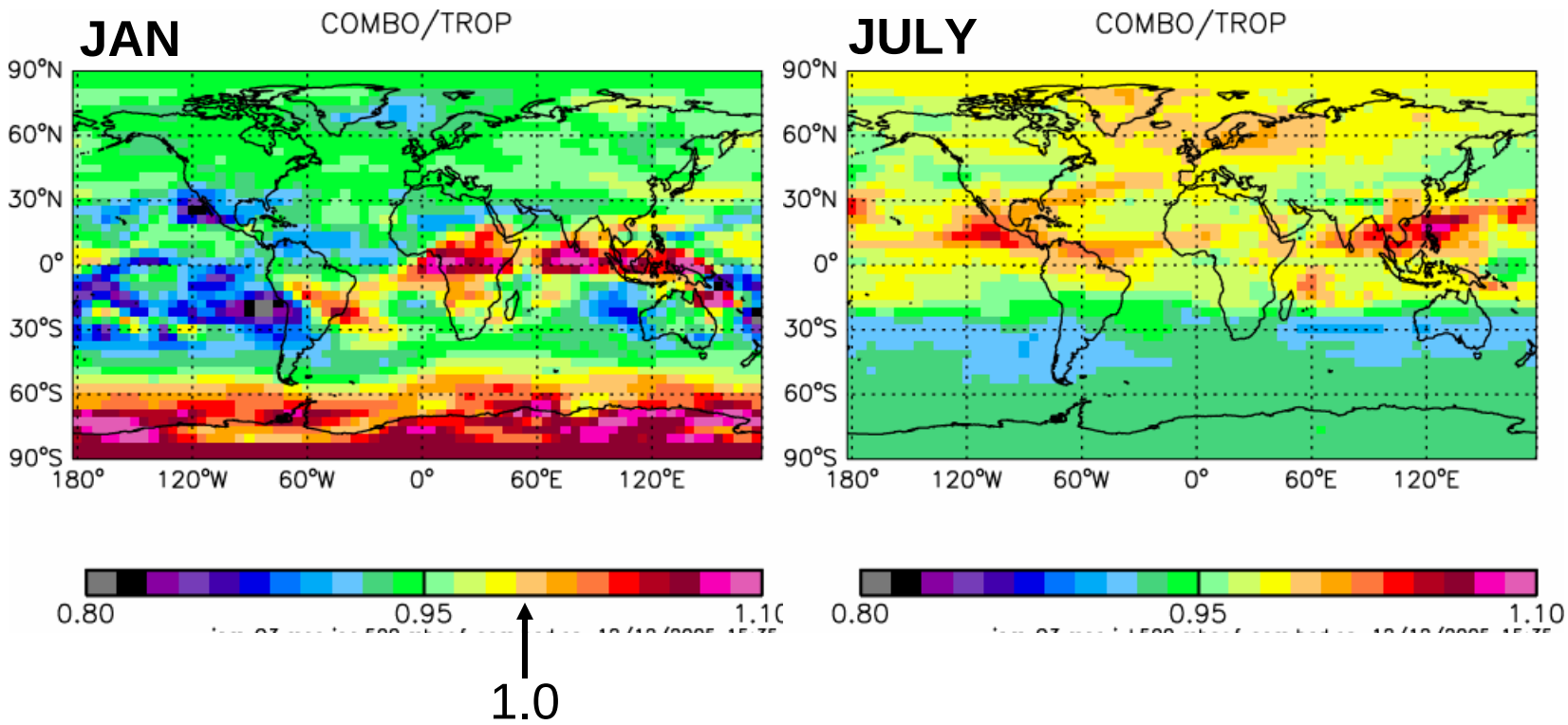
- Ozone, CO, OH, NOx

Comparisons made to observations and model-model comparisons.

Ozone - again


Resolute (74 ,−94)
Goose_Bay (53 ,−60)
Hohenpeissenberg (48 ,11)
Boulder (40 ,−105)
300 hPa
500 hPa
800 hPa
O3 (ppb)
J F M A M J J A S O N D

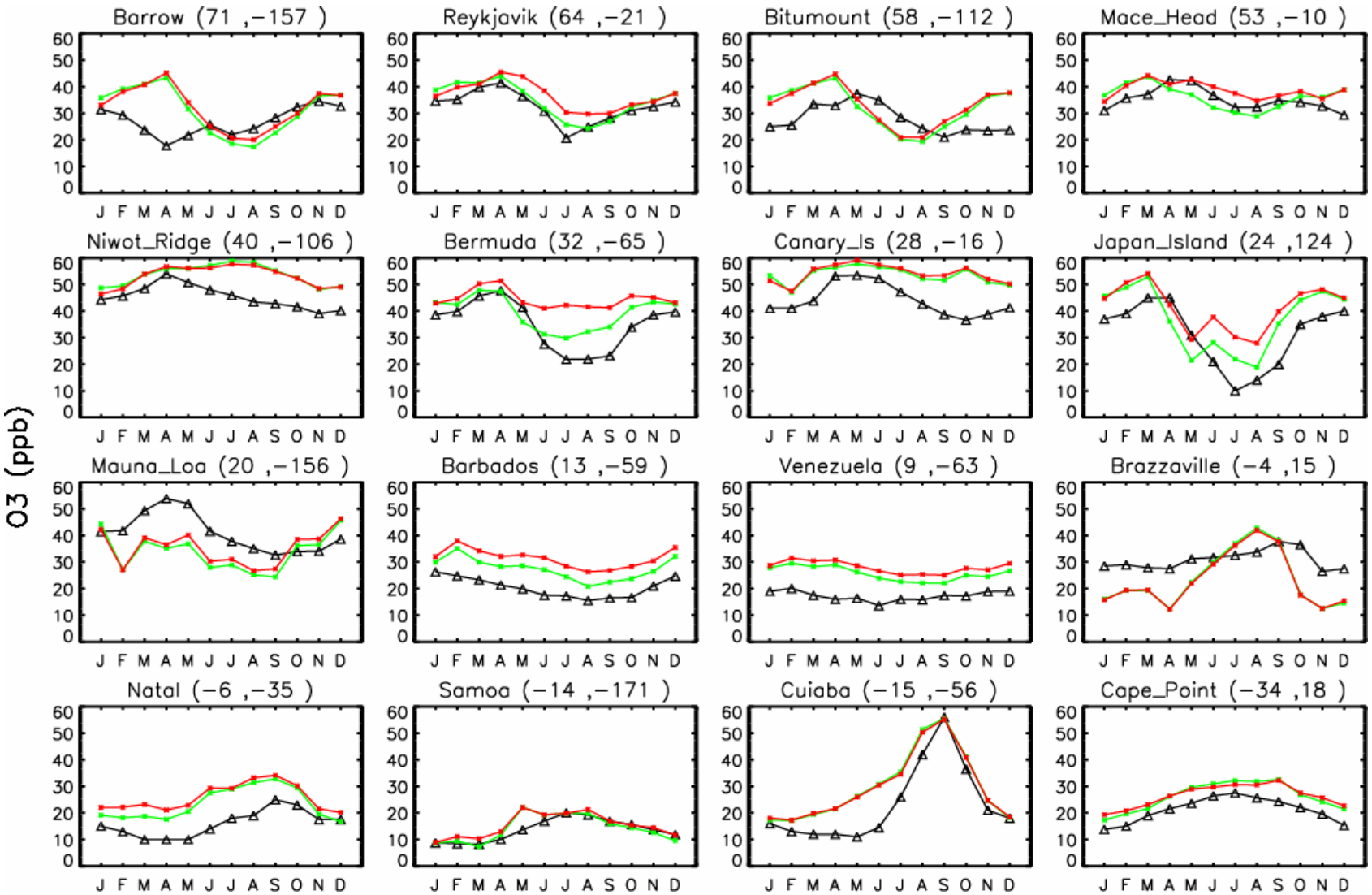
Trop. vs. Combo, Ozone at 500 hPa



- Differences in trop. ozone between Combo and Trop. run are small, <10%
- Combo smaller than Trop.
- Differences larger in January than in other months, initialization?
- Differences larger at 300 hPa at mid-high latitudes

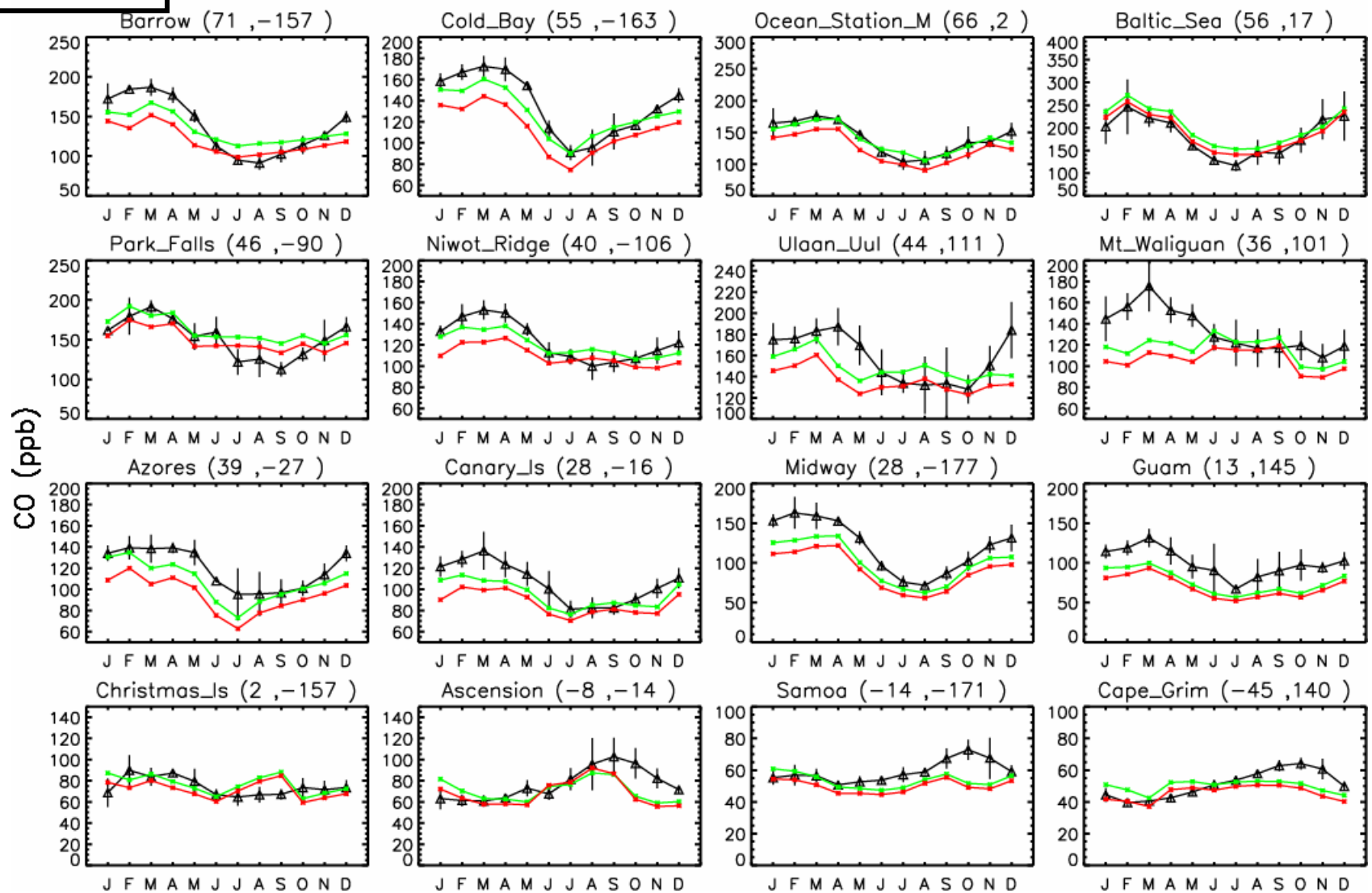
COMBO
TROP

Surface ozone in the Combo is now more realistic

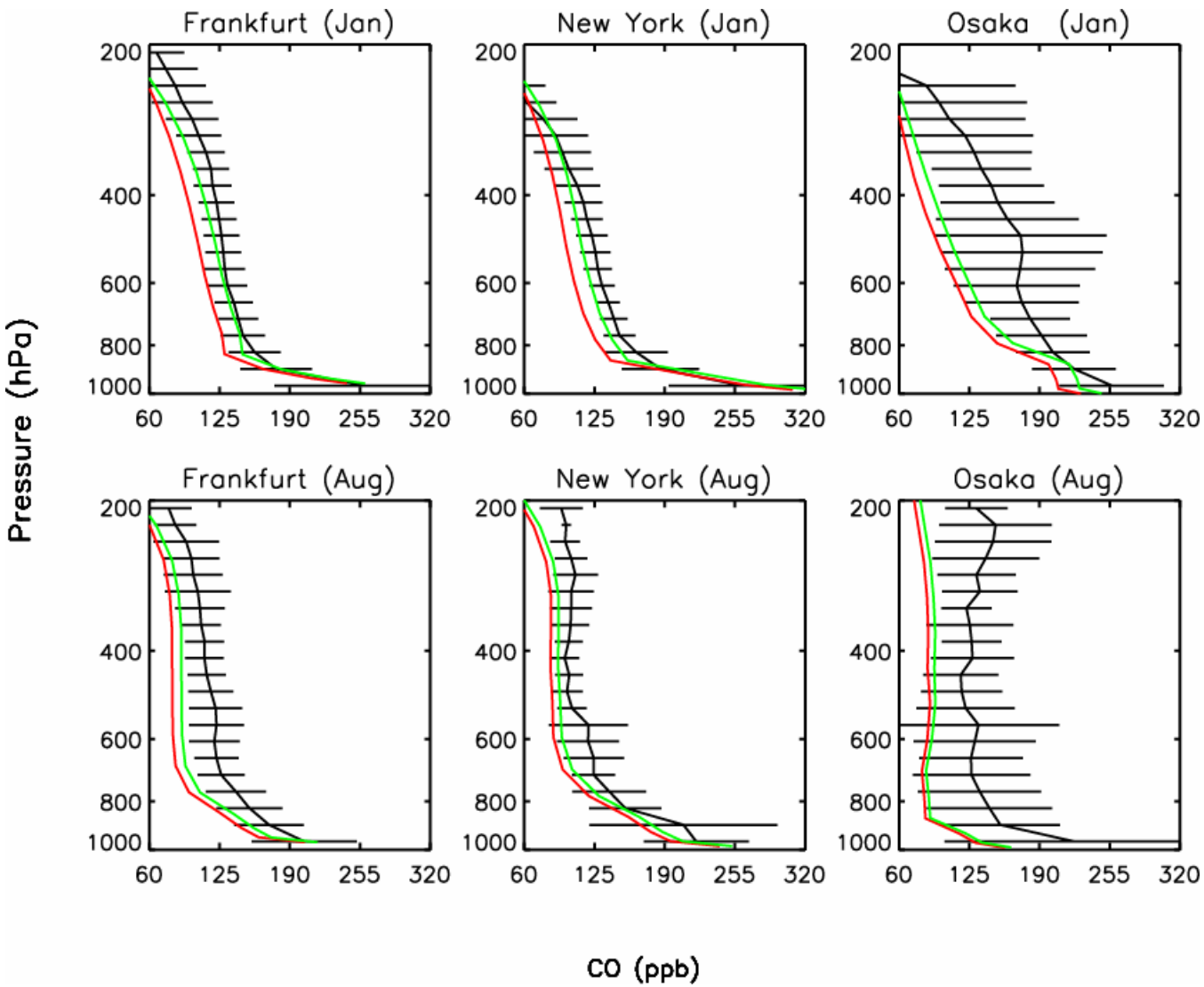


COMBO
TROP

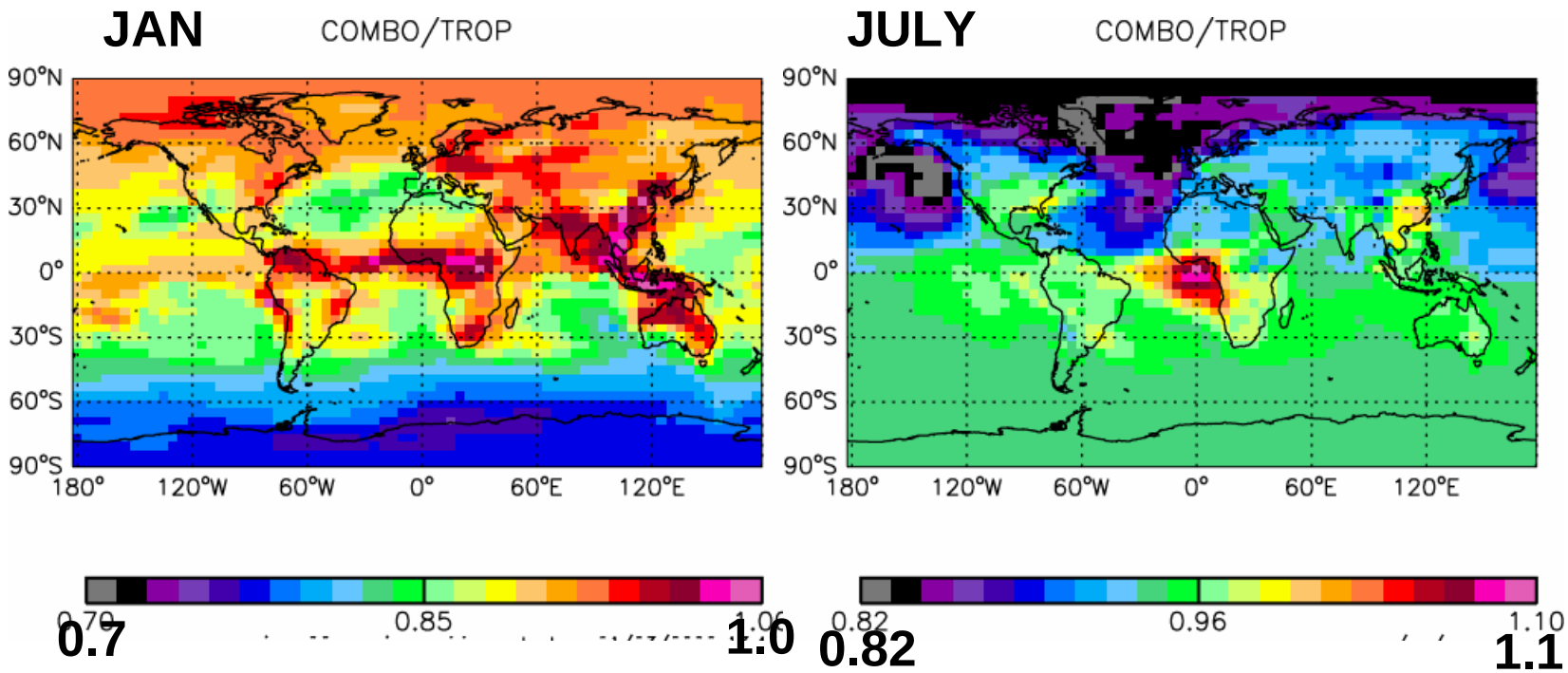
Surface CO: Combo lower than Trop



Combo lower than trop. at all altitudes

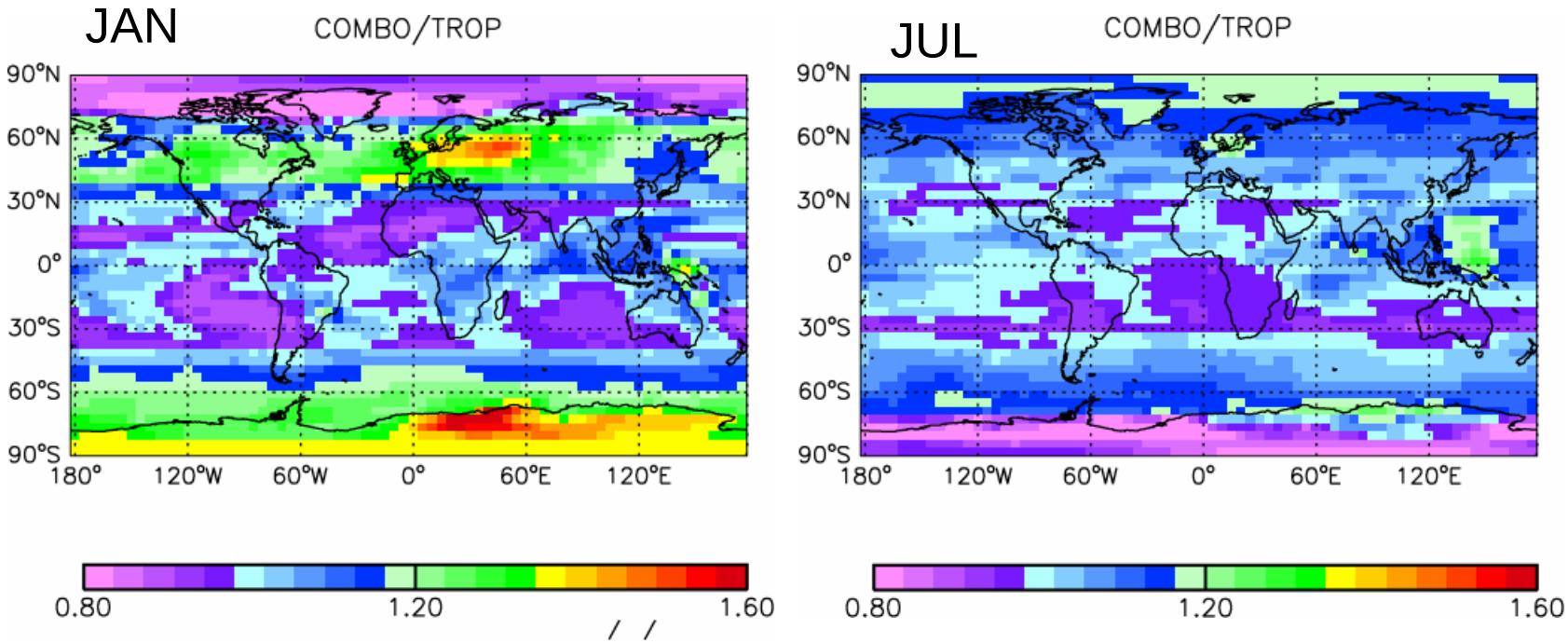


Surface CO lower in Combo than in Trop.



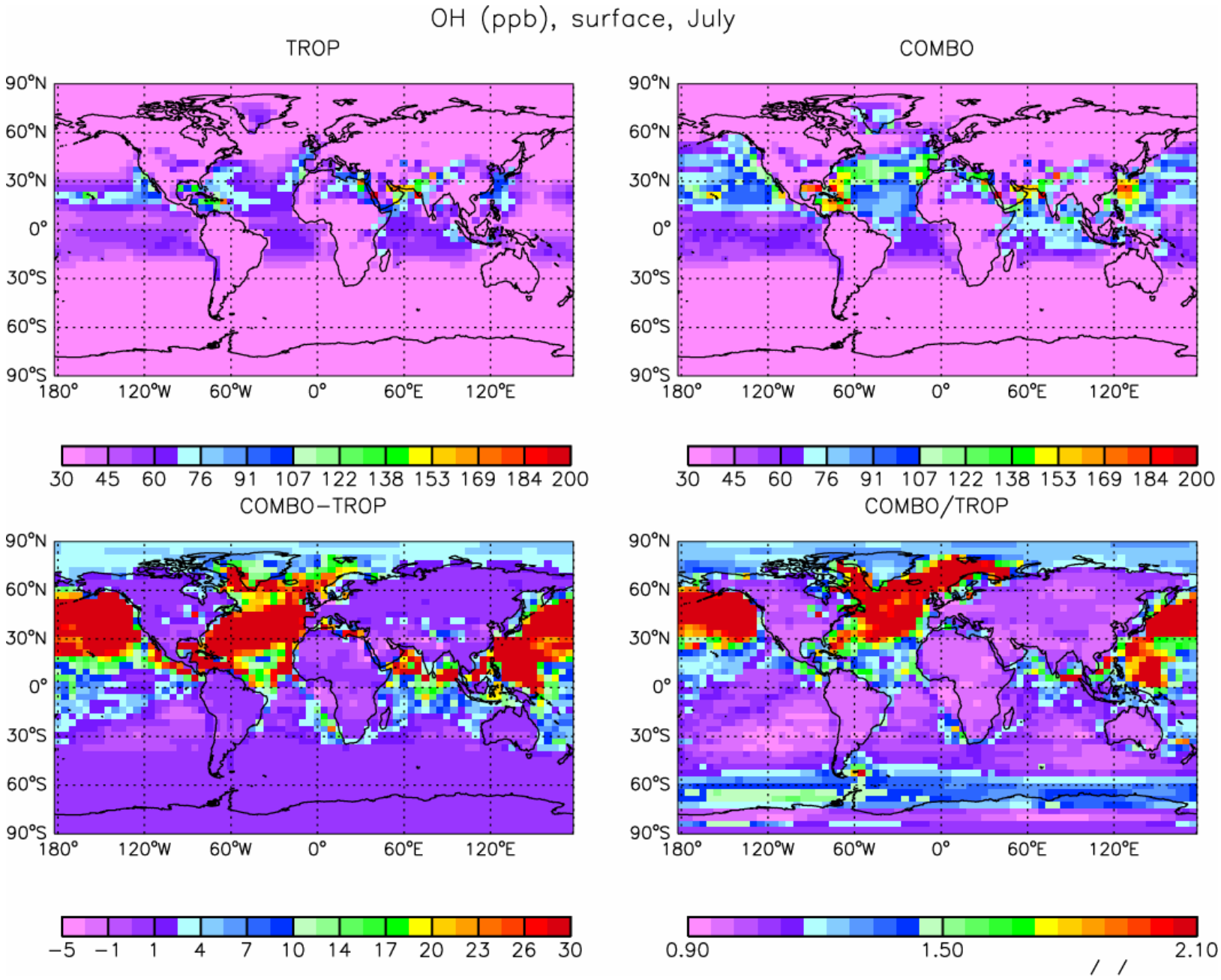
- Combo smaller than Trop.
- Differences of up to 20% at the surface in the summer hemisphere
- Similar differences at 500 hPa

OH ratios, 500 hPa



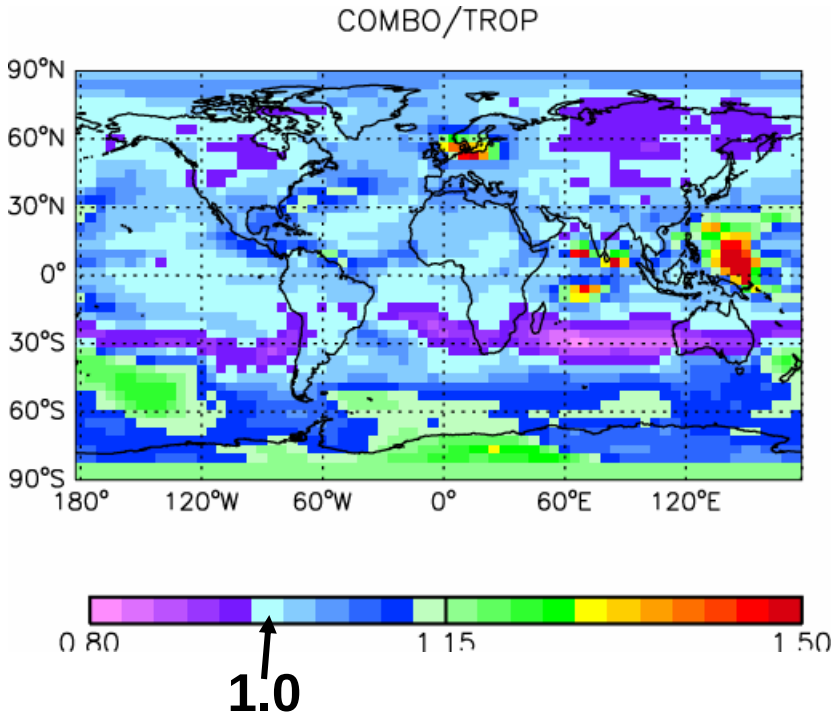
- **OH differences of ±20% in July, some <10%**
- **Combo larger than Trop. in summer hemisphere**
- **Larger differences in January, up to 60% at higher latitudes, ±20% in tropics**
- **Need to check lifetime for CH_3CCl_3**

Mean OH, Combo. vs. Trop, surface



NOx in Combo vs. Trop.

NOx at 500 hPa, July



- **In NH, combo is slightly larger, up to 10%.**
- **Ratios for NOx are largest when NOx is smallest**
- **Very large ratios <u>at the surface</u> over the N. oceans (5-10), much smaller ratios over land**
- **Surface needs further investigation**

Summary of Combo - Trop Comparisons

- Ozone is very similar, generally within 5%
- CO differences larger, and are consistent with higher OH.
- Not clear if differences in OH can account for differences in CO
- Causes of higher OH require investigation

Case study

The largest differences among the three trop. runs in the summer hemisphere are:

- **The Middle East ozone maximum**
- **Ozone over the S.E. United States**

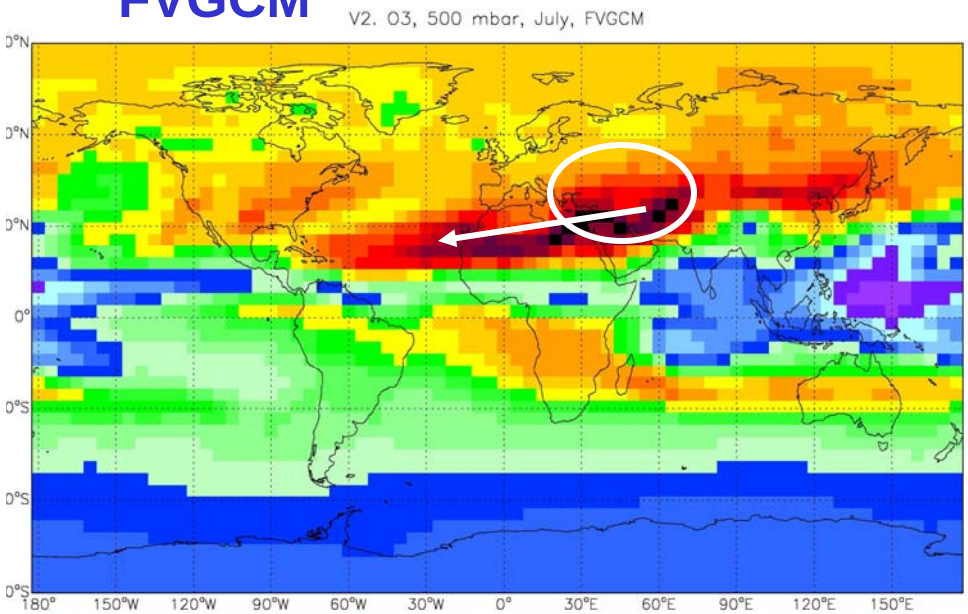
Ozone at 500 hPa in July

Note extended region of enhanced ozone in the sub-tropics in FVGCM - not just in the Middle East

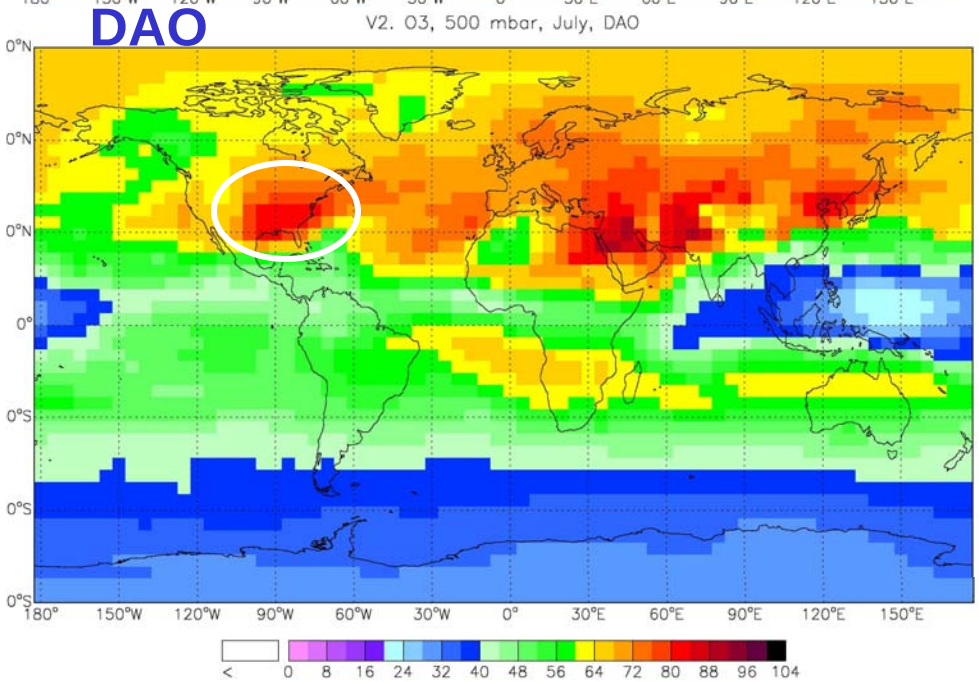
DAO highest over SE U.S.

These do not agree with obs.

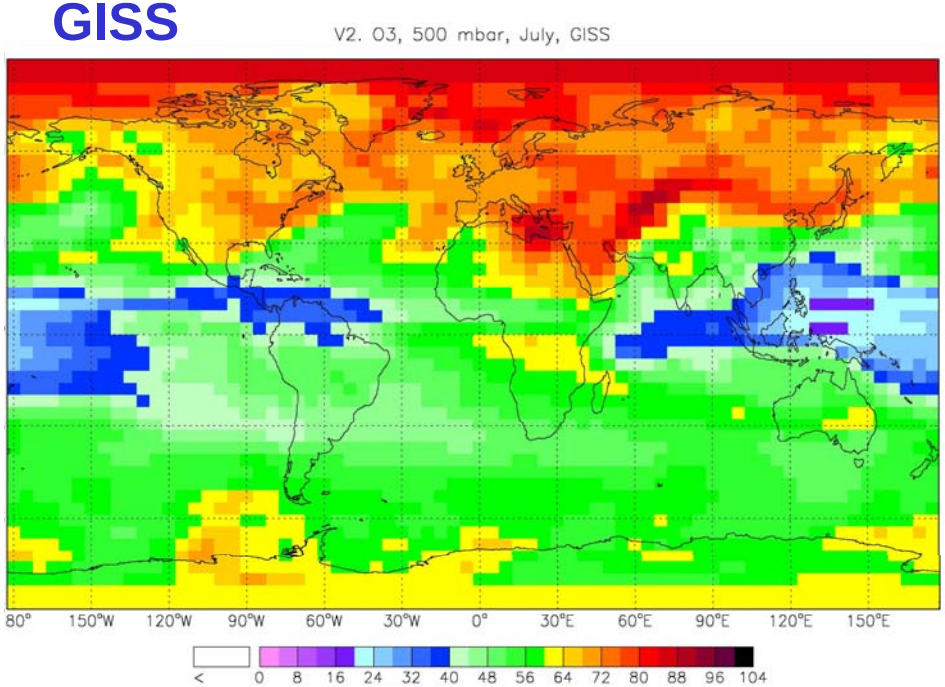
FVGCM



DAO



GISS

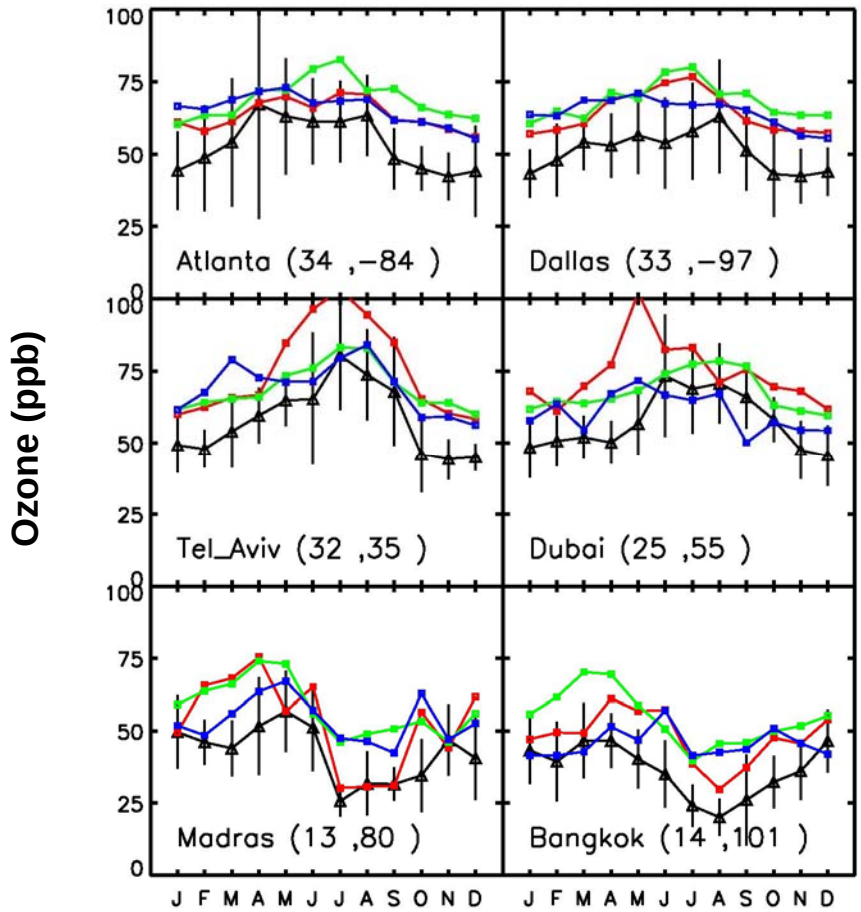


FVGCM
DAO
GISS

Ozone in the sub-tropical US and Middle East

Ozone at 500 hPa

MOZAIC data



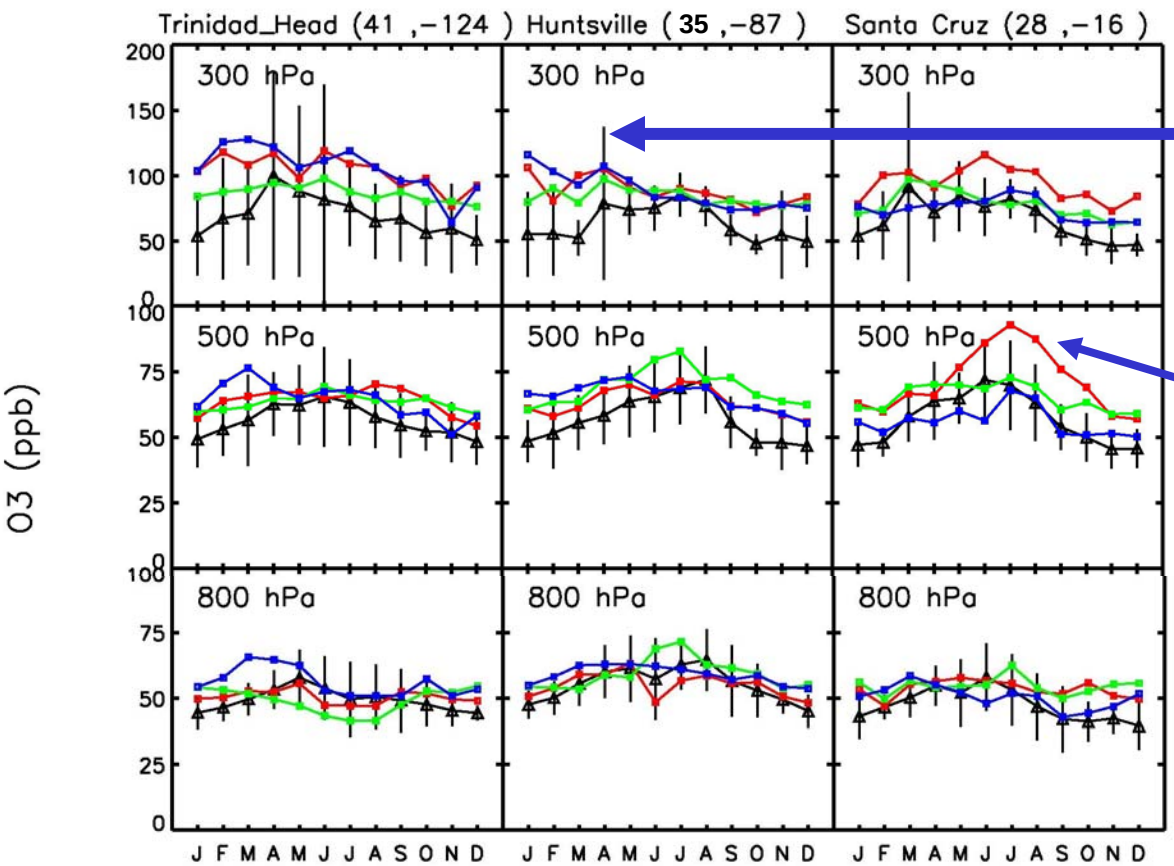
All too high in summer over southern US

FVGCM much too high for Middle East summer maximum.

FVGCM best in S. Asia during the monsoon, but too high in N. spring (along with DAO)

Note: problem with Middle East ozone not seen using GEOS-4 data GEOS-CHEM.

New sonde stations - the U.S. and Canary Islands



Note that 300 hPa is not yet completely "tropospheric" in simulations at 300 hPa at 35 N.

Excessive summer max. in FVGCM extends to E. Atlantic.

Middle East ozone max. Why do the models differ?

Li et al. showed the Middle East max. was caused by

- **high ozone production over N. India, E. Asia (lightning, pollution)**
- **anti-cyclonic circulation over Middle East brings**
  - **mid-lat. pollution in westerly sub-tropical jet**
  - **E. Asian pollution from Easterly tropical jet**
  - **subsidence over the region**

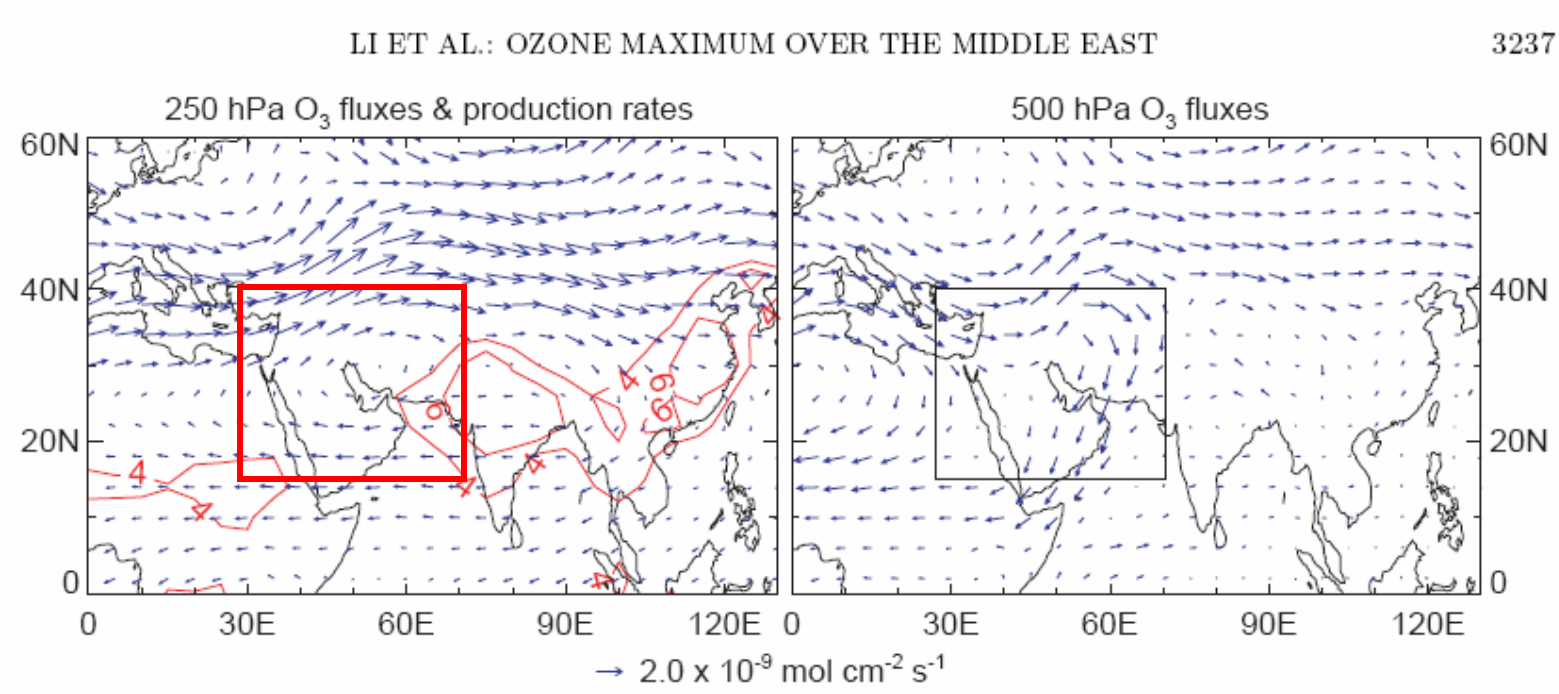
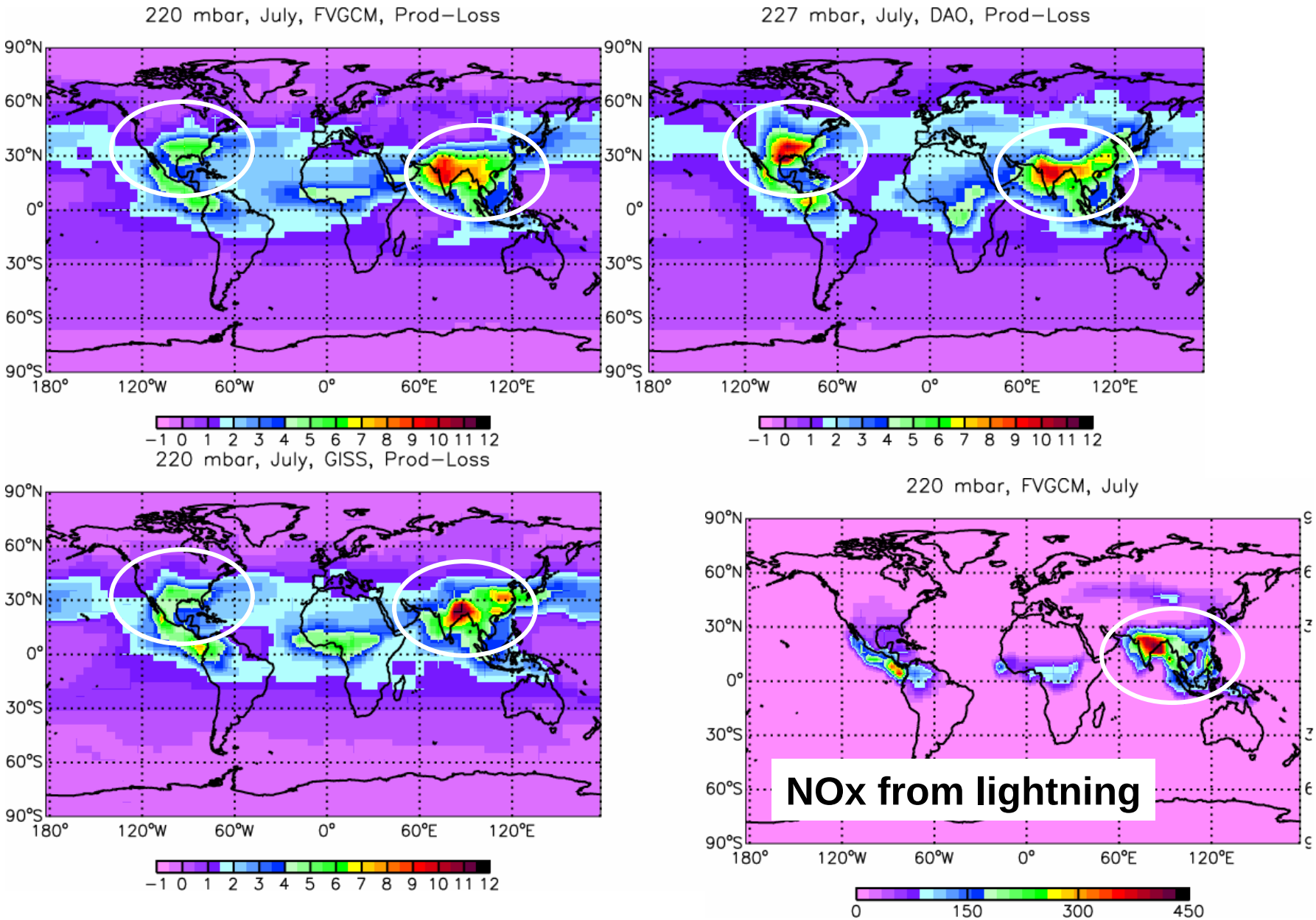
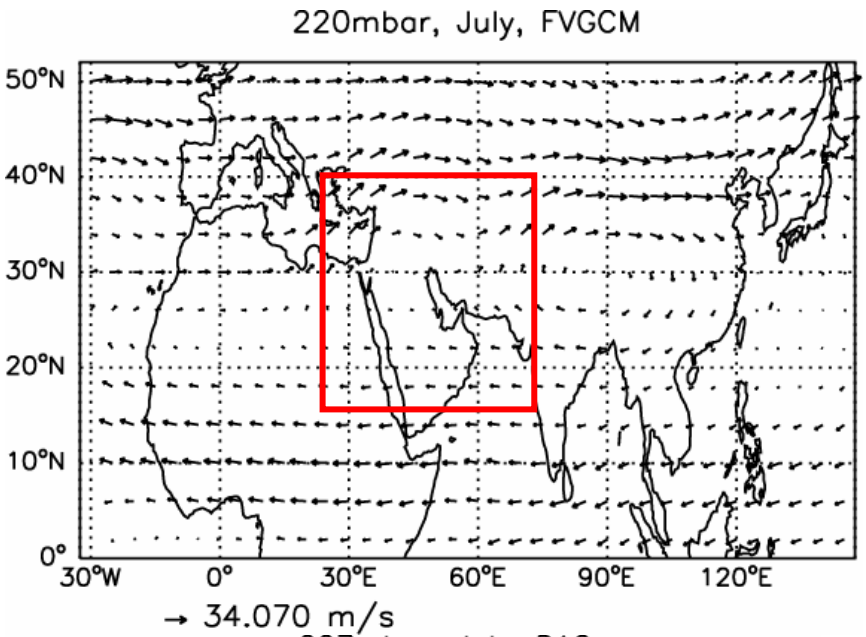


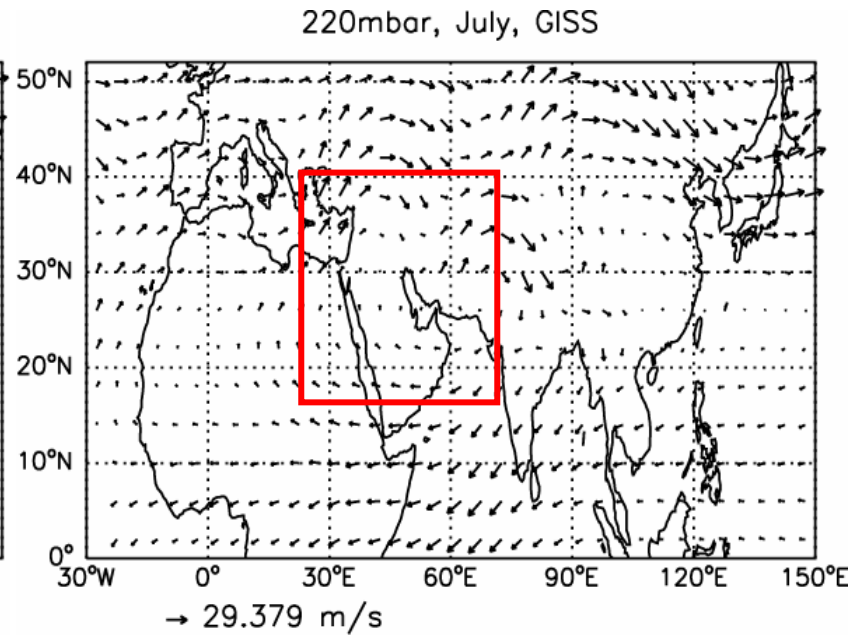
Figure 3. Simulated horizontal O_3 fluxes (arrows) and net chemical O_3 production rates (contours, $> 4\,\mathrm{ppb\,day^{-1}}$) at 250 hPa (left panel) and horizontal O_3 fluxes at 500 hPa (right panel). Values are model monthly means for July 1997. The rectangle in the right panel indicates the Middle East region used for budget analysis.

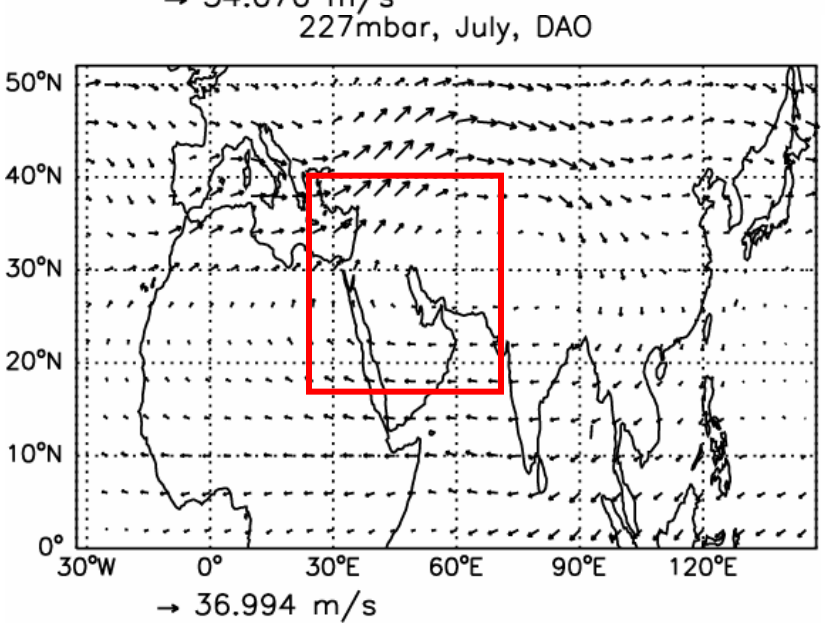
Ozone P-L at ~220 hPa in July: 2 hotspots, Middle East, SE U.S.



Winds at ~220 hPa- no flux diagnostic as yet!



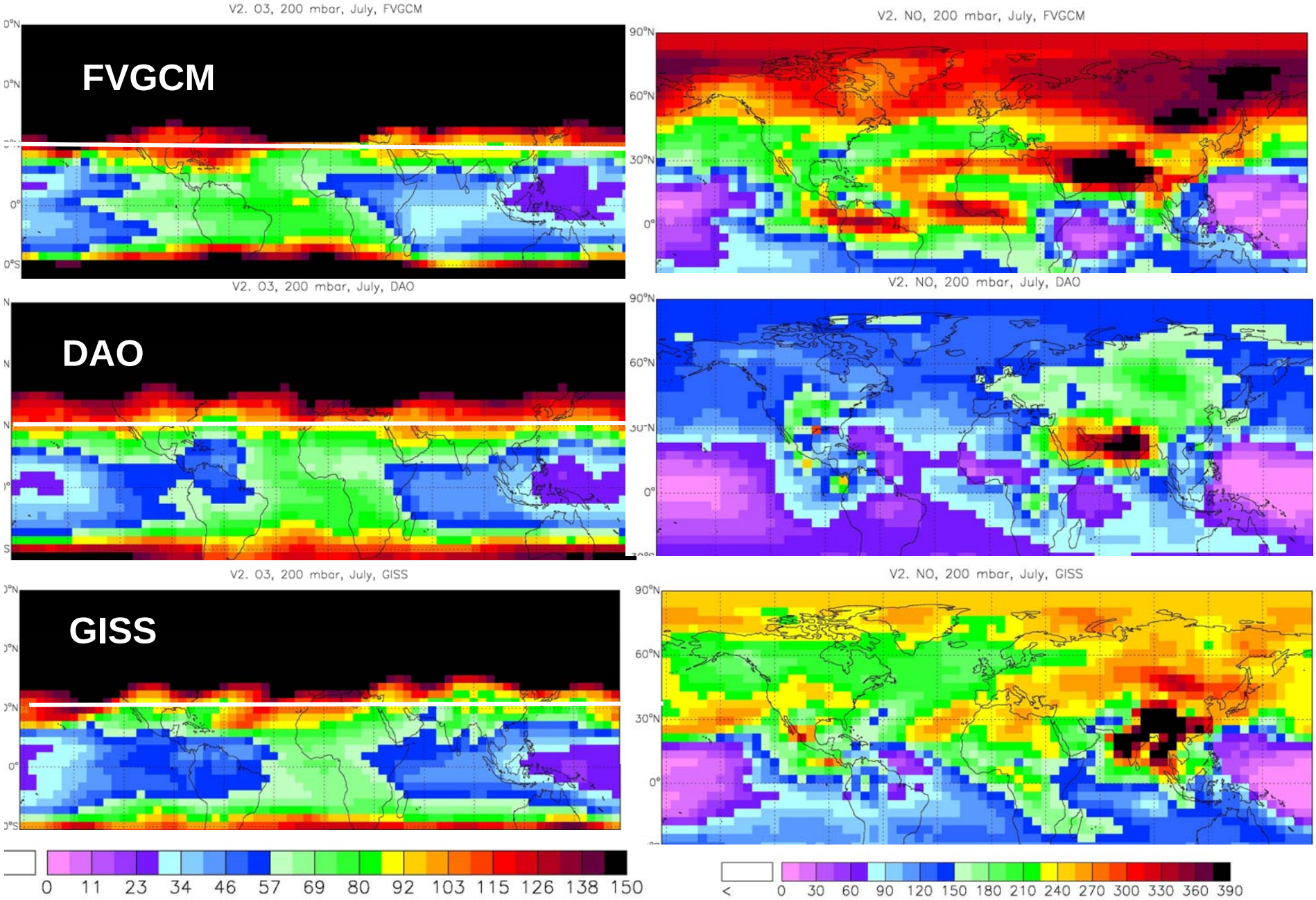




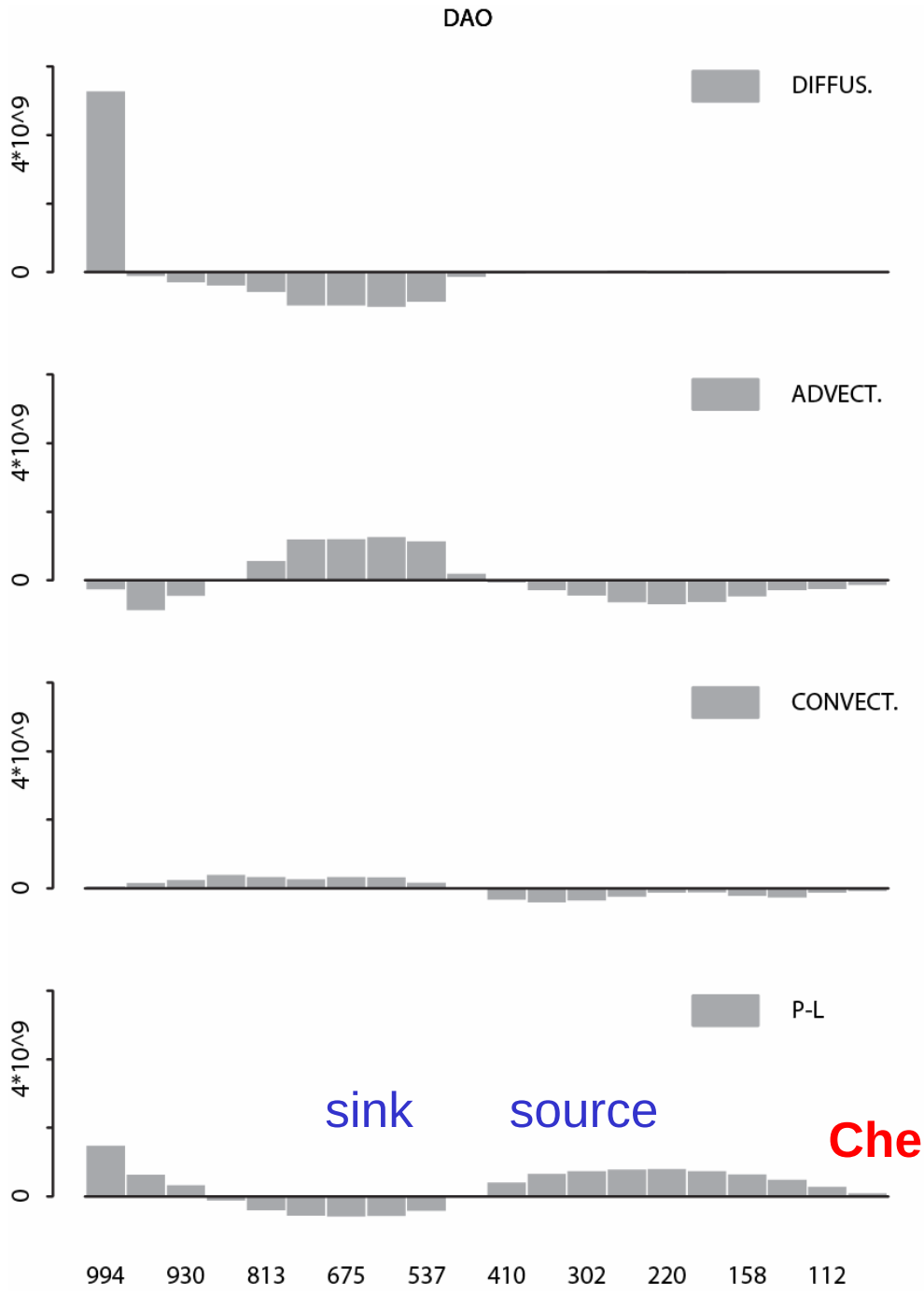
- **Flow in FVGCM more zonal at north of box**
- **Flow appears more anti-cyclonic at lower levels**
- **Winds and higher ozone (next slide) suggest much higher ozone flux into Middle East for FVGCM**

Ozone at 200 hPa in July
FVGCM is more “stratospheric” at 30-40 N

NO at 200 hPa

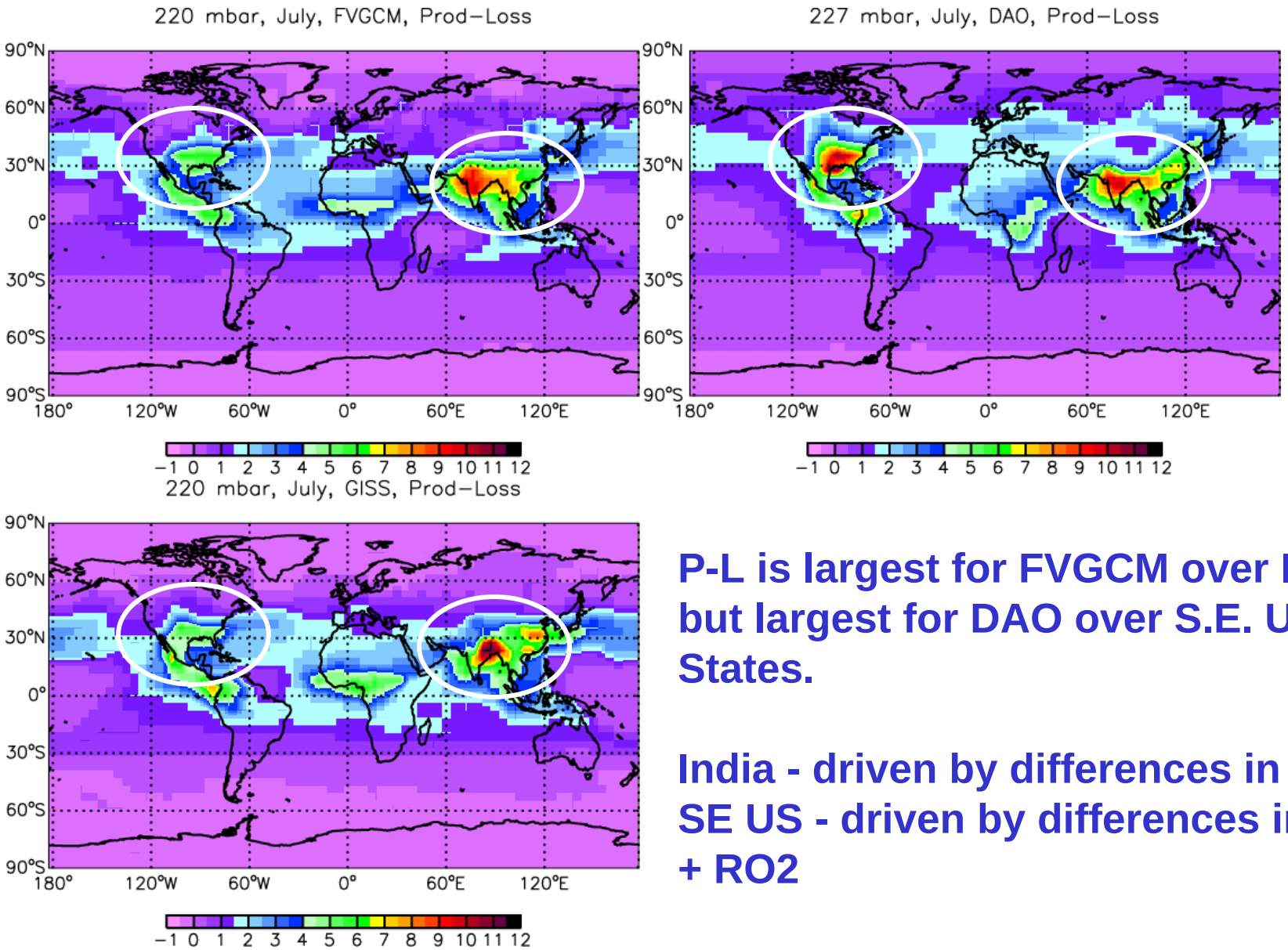


Ozone Tendencies for Middle East box



- **Tendency shown for each model layer, in gm/month**
- **Dry deposition not shown**
- **Largest terms are (P-L) and advection (3-d)**

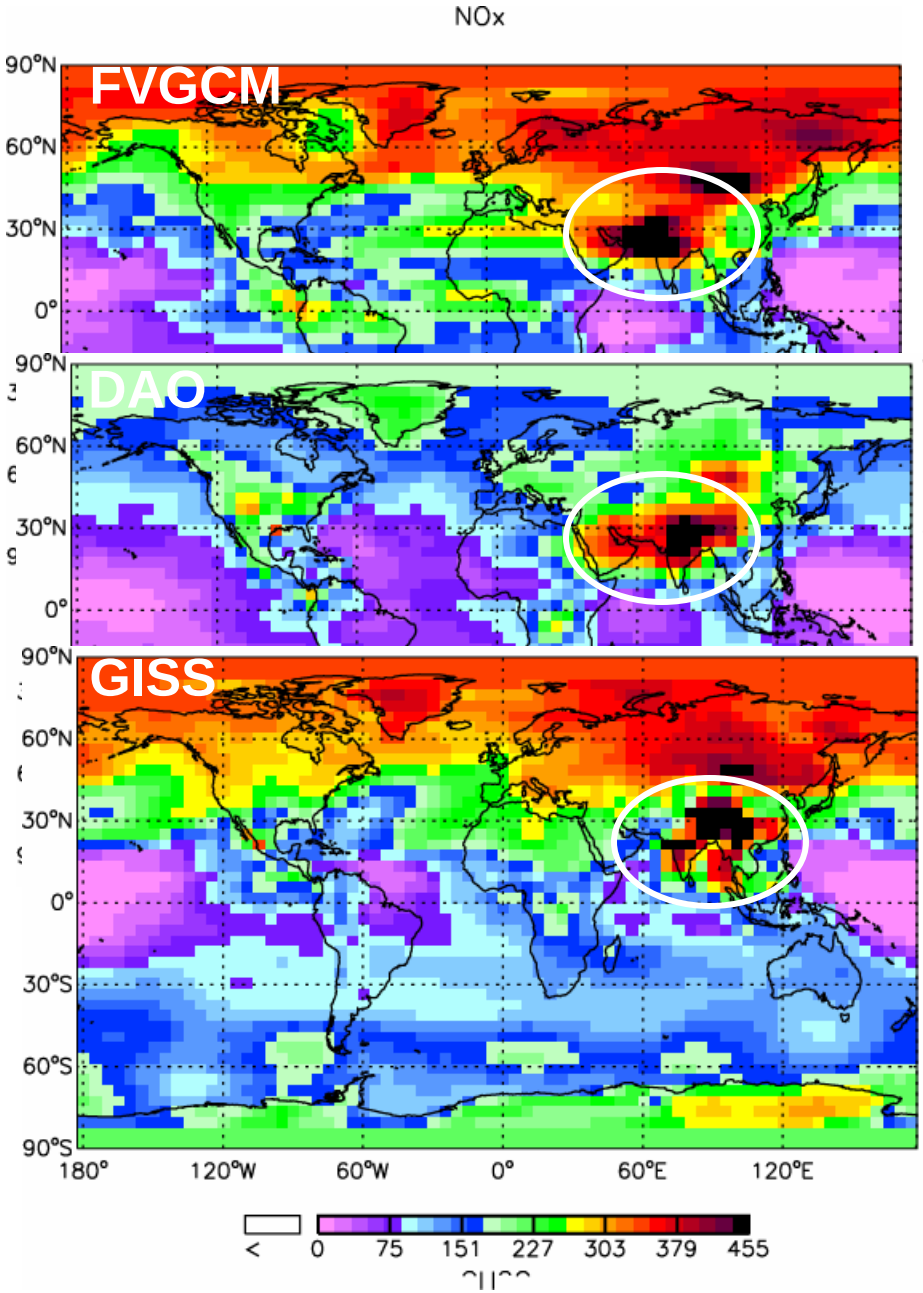
Ozone P-L at ~220 hPa in July: 2 hotspots, Middle East, SE U.S.



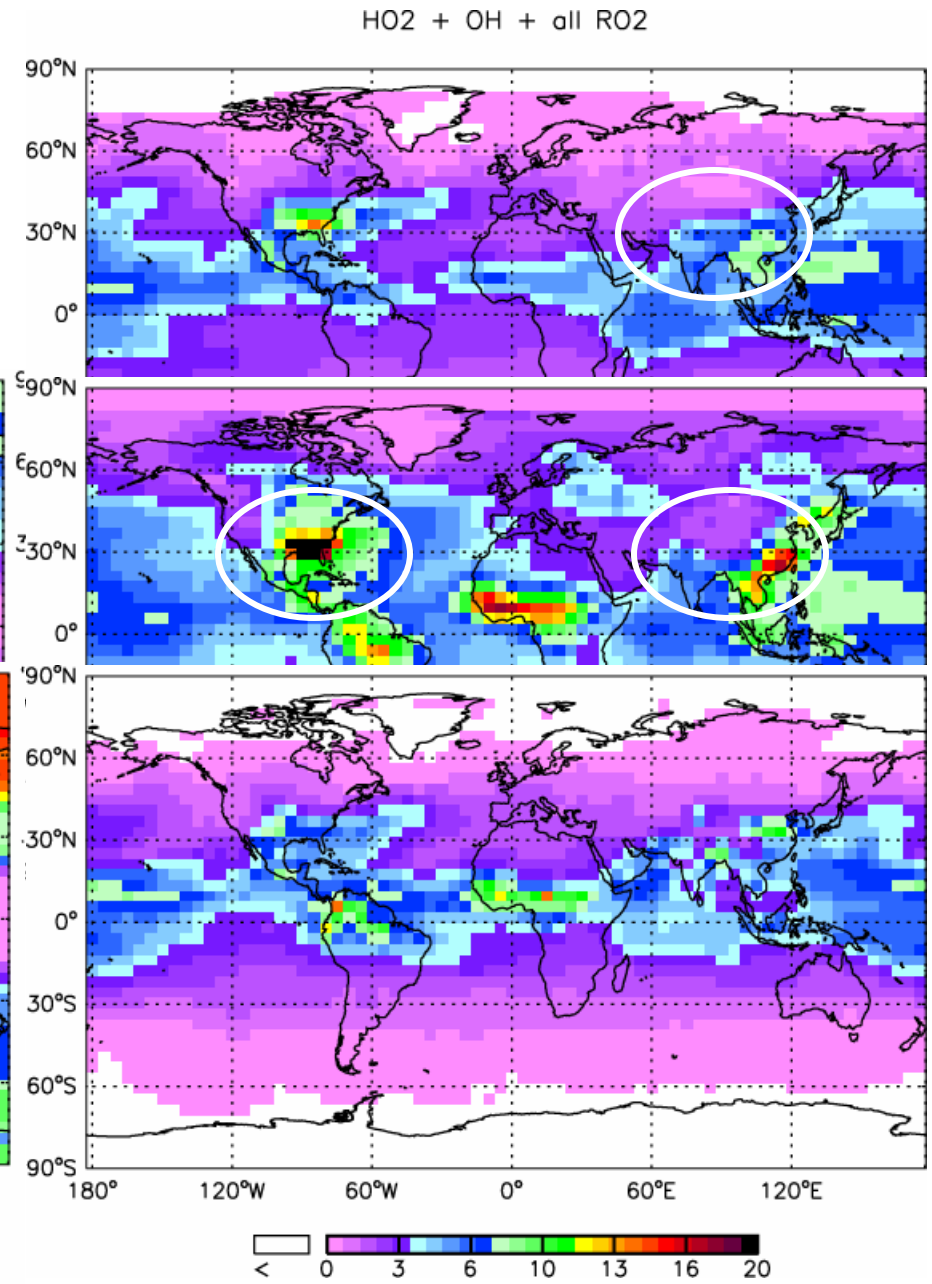
P-L is largest for FVGCM over India but largest for DAO over S.E. United States.

India - driven by differences in NOx
SE US - driven by differences in HO2 + RO2

NOx at 220 hPa

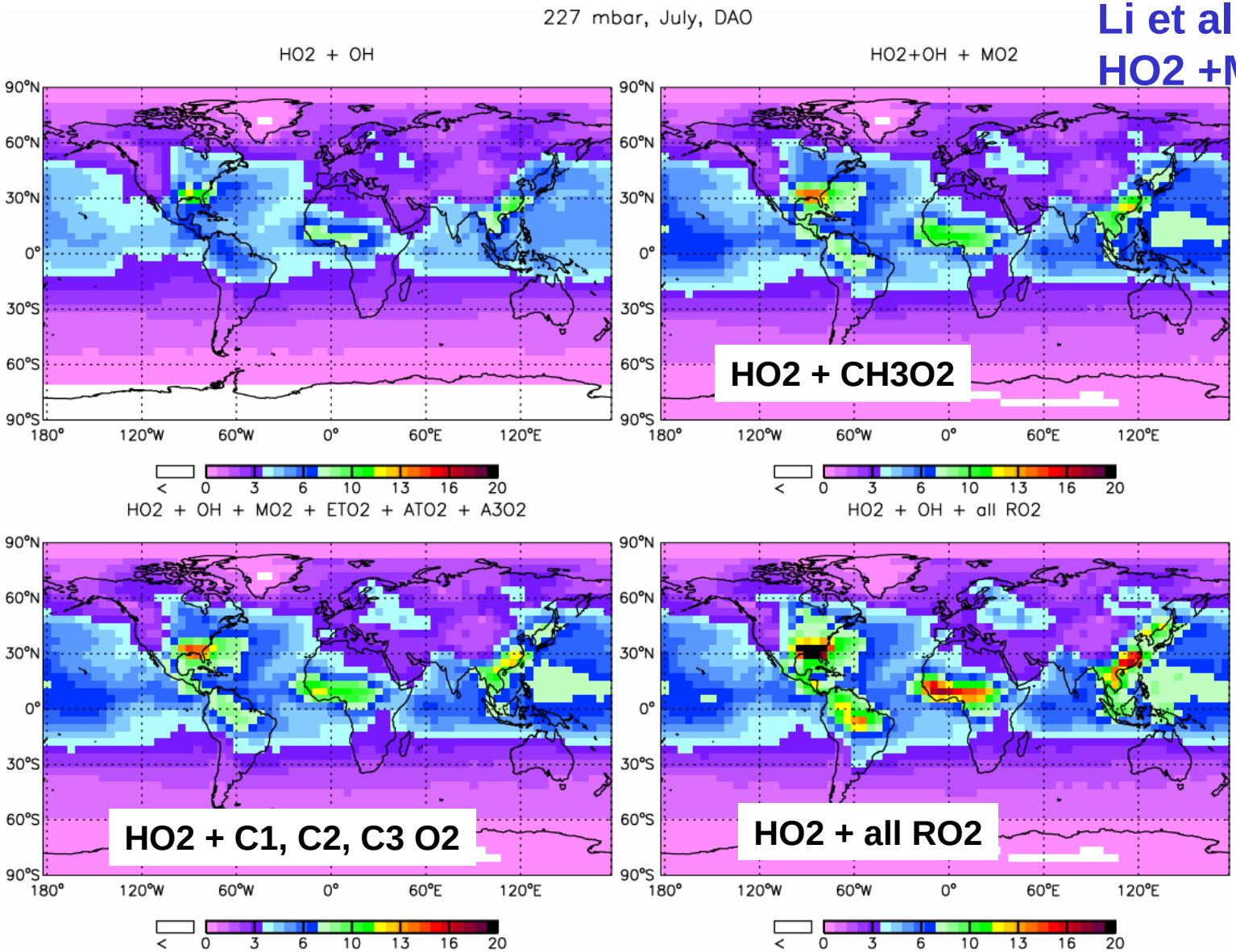


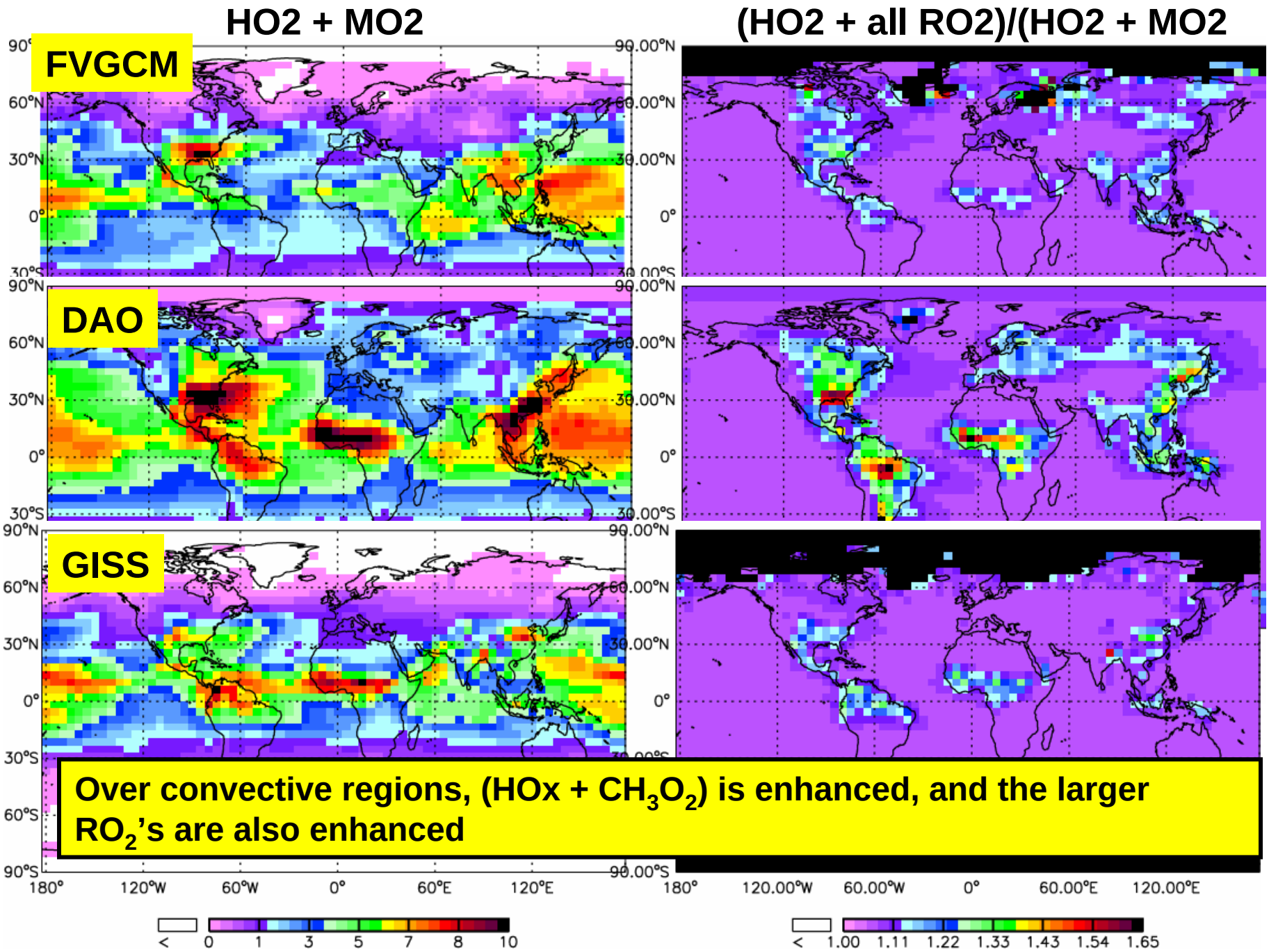
$HO_2 + RO_2$



RO2 species are important in ozone formation over isoprene source regions with active convection (see Li et al. 2004 for SE US)

Li et al. showed HO2 +MO2

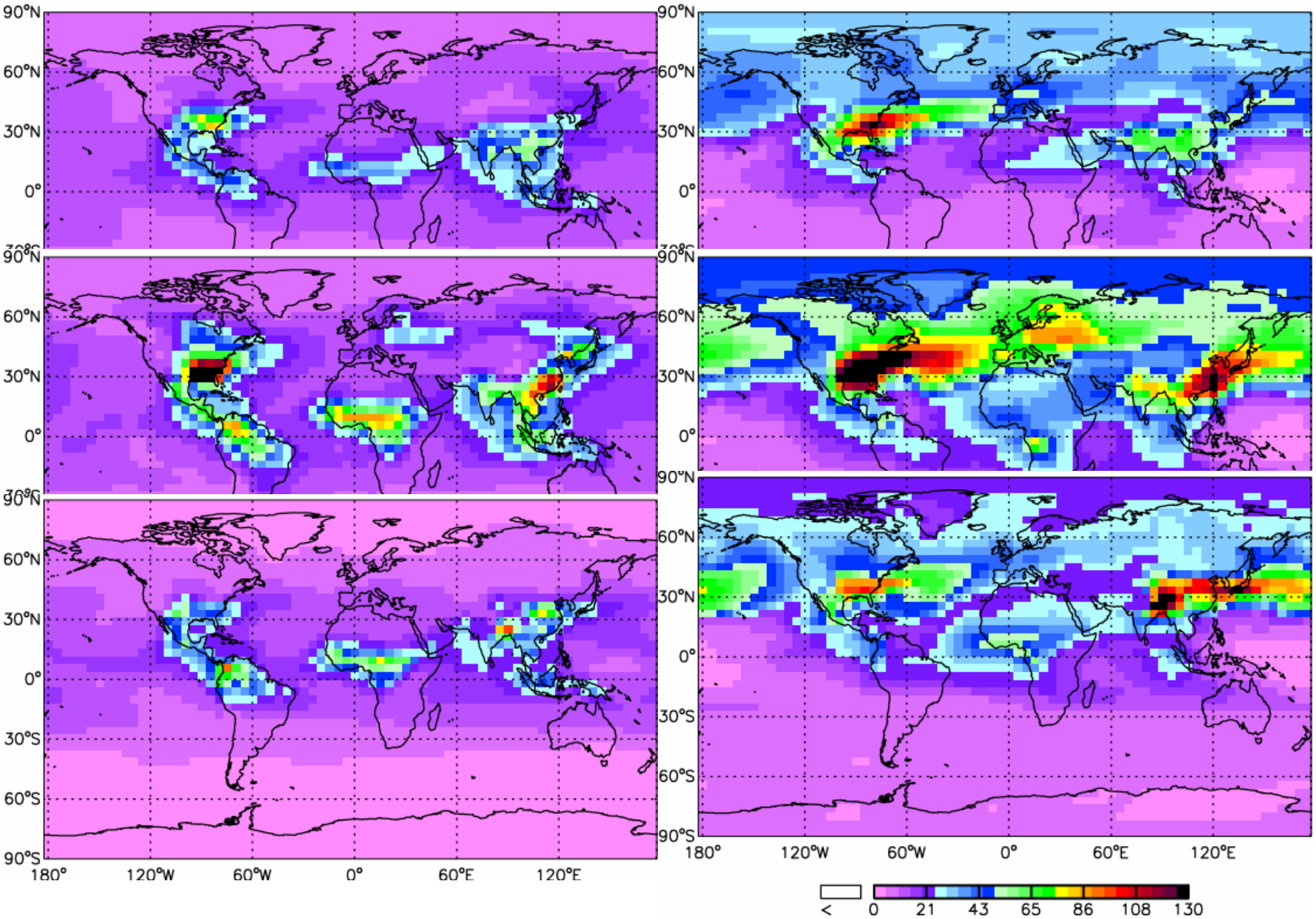




Over convective regions, (HOx + CH_3O_2) is enhanced, and the larger RO_2's are also enhanced

CH2O (from isoprene) C3H8 short-lived pollution tracer

Both show regions of convective influence on these tracers



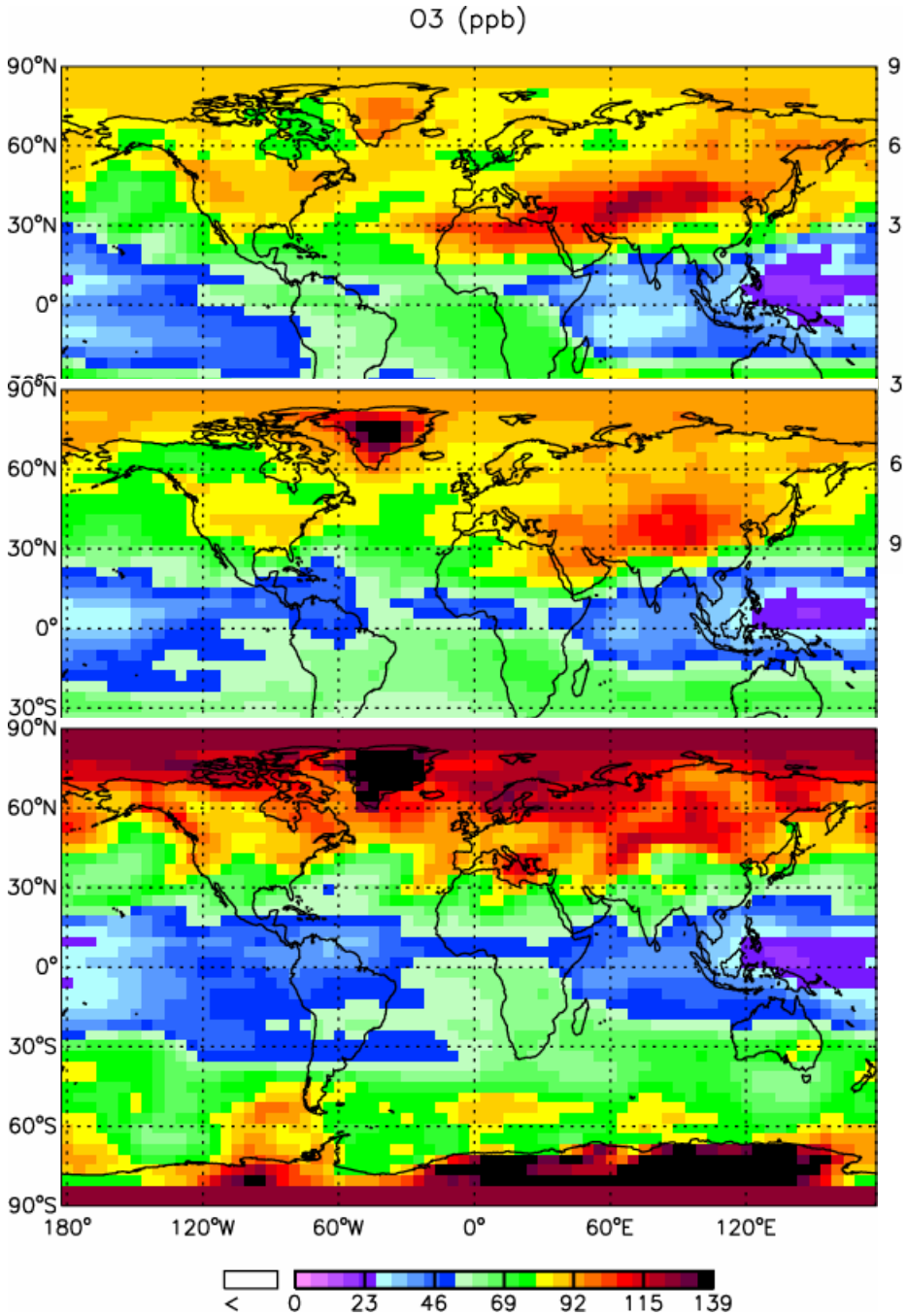
Summary of Case Study

- Higher values over Middle East (and its outflow) in FVGCM appear to be caused by transport differences. Flux diagnostic needed to confirm, and complete regional budget studies.

- HO_2 and RO_2 radicals seem to drive the differences in ozone production over regions of isoprene sources/convection (with common NO_x from lightning)

- The oxidation mechanisms, and rate constants for the RO_2's are not well known, and overestimates of HO_2 + RO_2 may explain the overestimate of ozone over the SE United States in summer

- We know that DAO mixes convection to higher altitudes than FVGCM and DAO (June presentation)

- Need to investigate NO_x budget in sub-tropics and tropics

Ozone at 370 hPa