Simulating ozone in the near-tropopause region with the GMI combined model of the stratosphere and troposphere

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Study Goals:

- Evaluate capability of combined strat/trop CTM to reproduce observed near tropopause ozone distributions
- Evaluate model physicochemical processes regulating near-tropopause ozone distributions

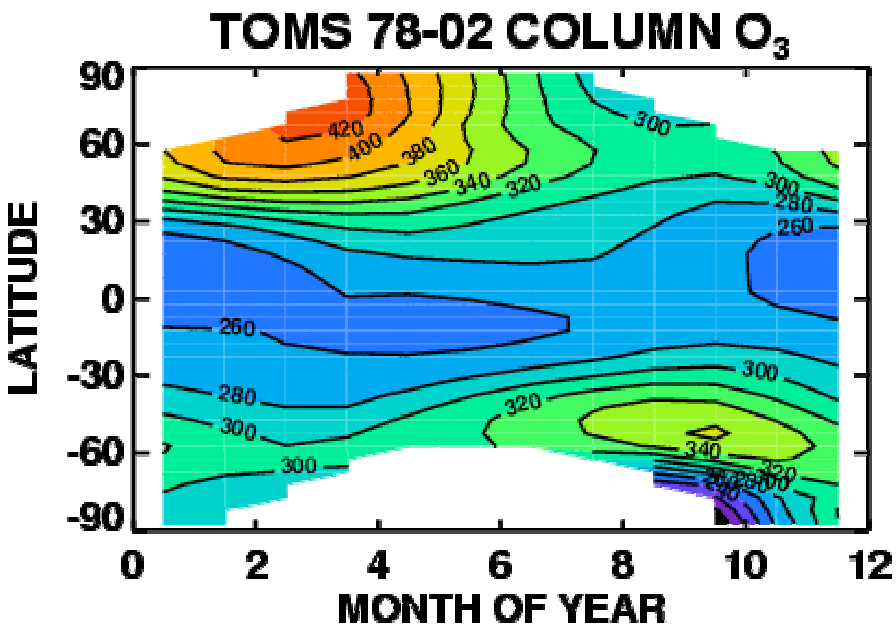
Logan Ozonesonde Climatology

- Monthly averaged ozone profiles referenced to thermal tropopause (lapse rate, not cold point tropopause)
- Profiles interpolated to1 km resolution before averaging
- Range: -6 km to +6 km (sometimes +12 km)
- Includes standard deviation and number of soundings for each monthly average
- Sonde data from 24 sites: 8 tropical, 11 midlatitude, 5 high latitude
- Sondes accumulated between 1978 and 2002, but stations differ in time periods and number of sondes in average

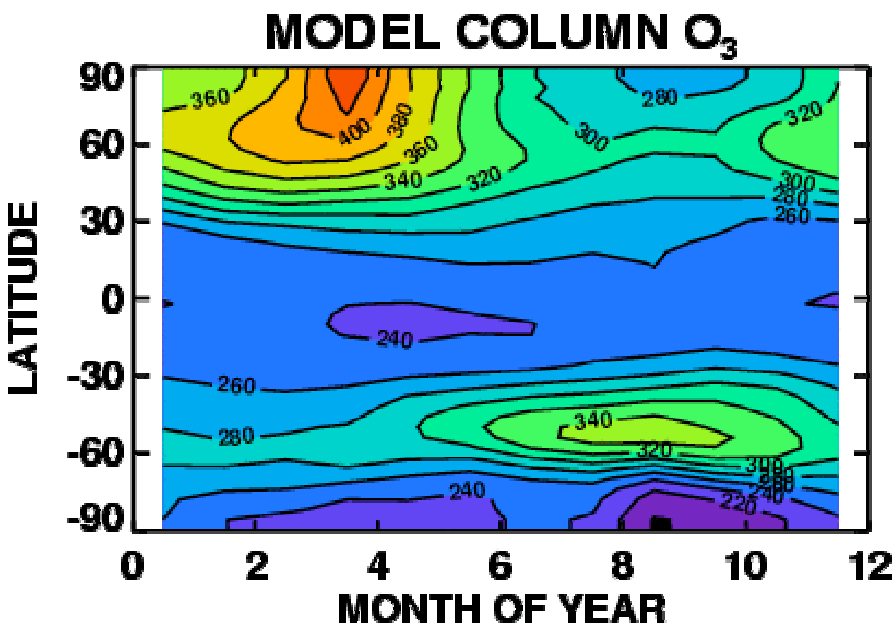
- Reference: Logan, J., An analysis of ozonesonde data for the troposphere: Recommendations for testing 3-D models and development of a gridded climatology for tropospheric ozone, JGR 104, 16,115-16,149, 1999.

GMI combined strat/trop model description

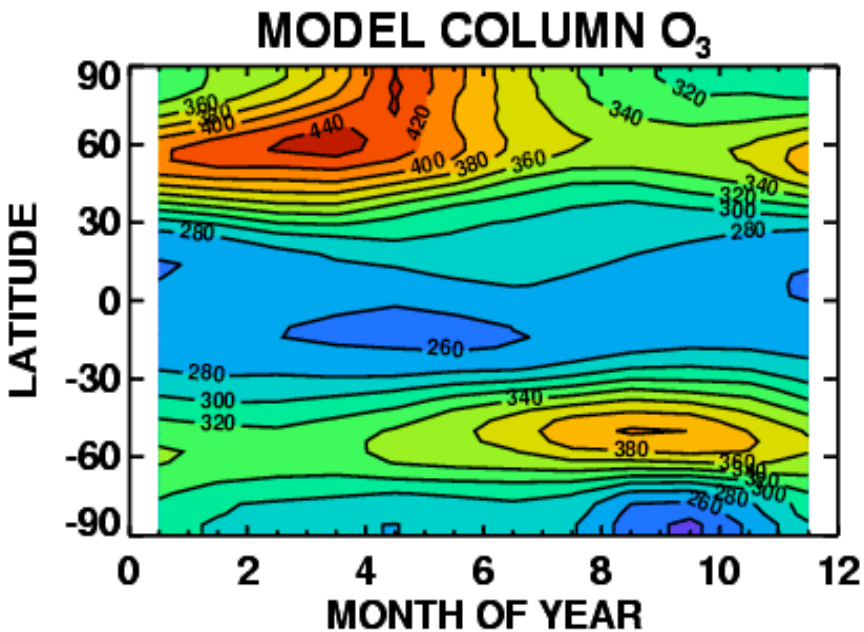
- Chemistry and transport model
- NASA FVGCM (GEOS-4 AGCM) meteorological data
  - Reasonable STE/Strat residual circulation
- 5° lon x 4° lat x 42 hybrid _-P levels, .01 hPa top
- Vertical resolution ~ 1 km at tropopause
- Wet and dry deposition, and convective scavenging params
- Lin and Rood flux-form semi-Lagrangian advection
- 125 species combined strat/trop chemical mechanism
  including inorganic chlorine & bromine, NMHCs,
  322 thermal reactions, 82 photolytic decompositions,
  Type Ia (NAT) and II (ice) PSCs, & background LBS
- SMVGEAR II chemical solver
- Fastj-x photolysis scheme
- Climatological water vapor in strat, met field water vapor in trop
- Model run for a number of years, last year analyzed



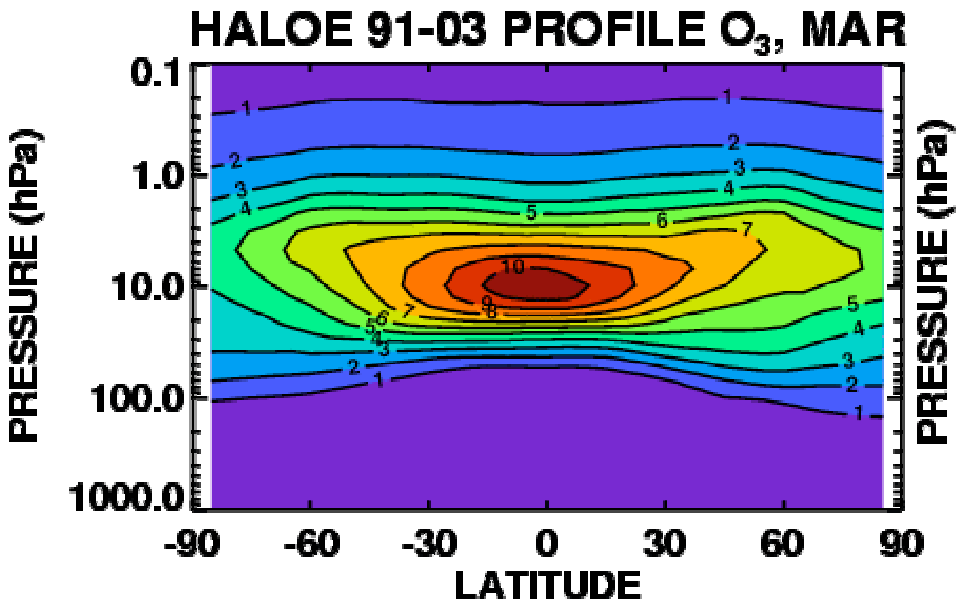
FVGCM run agrees well with TOMS total ozone climatology.

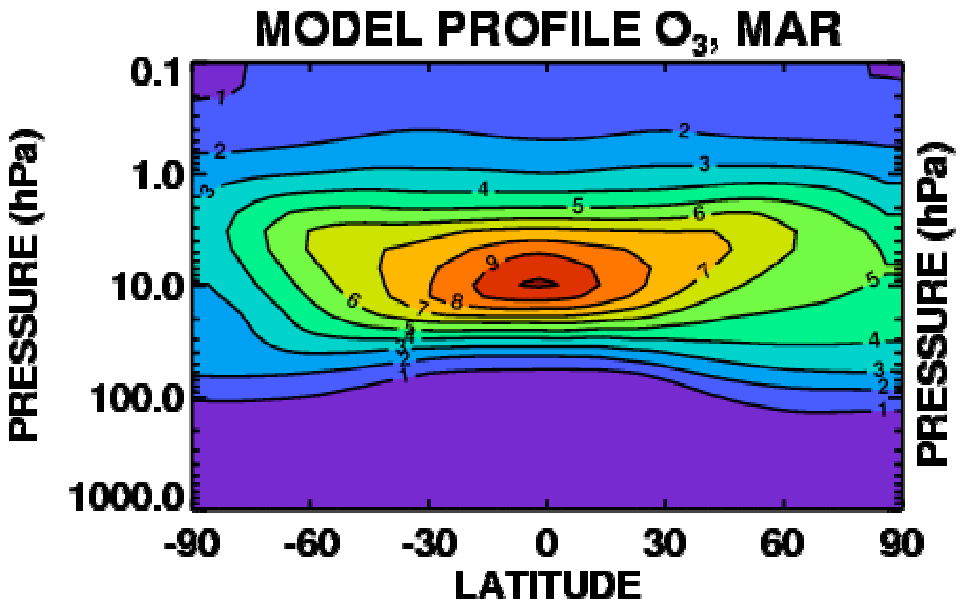


GMI/FVGCM

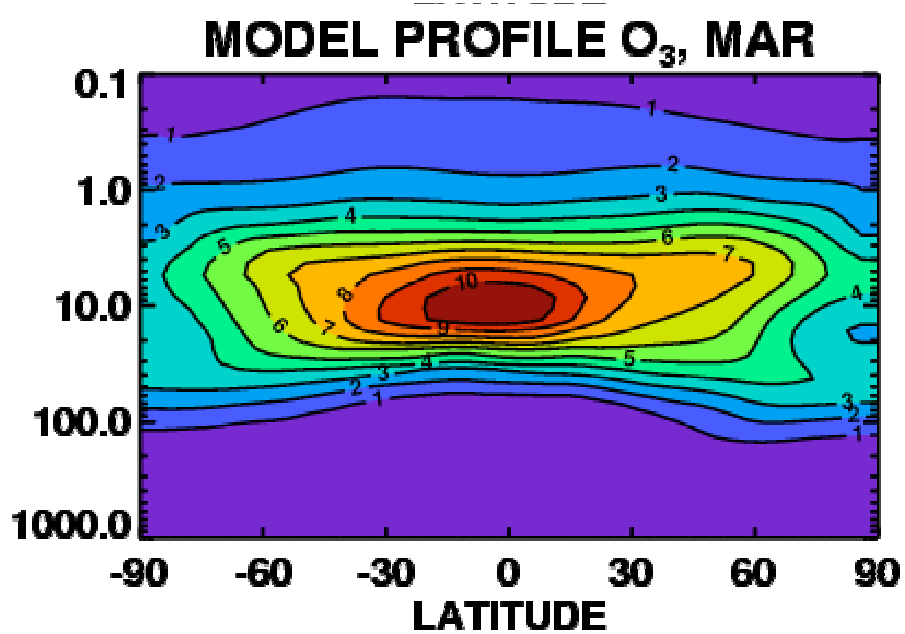


GMI/MACCM3

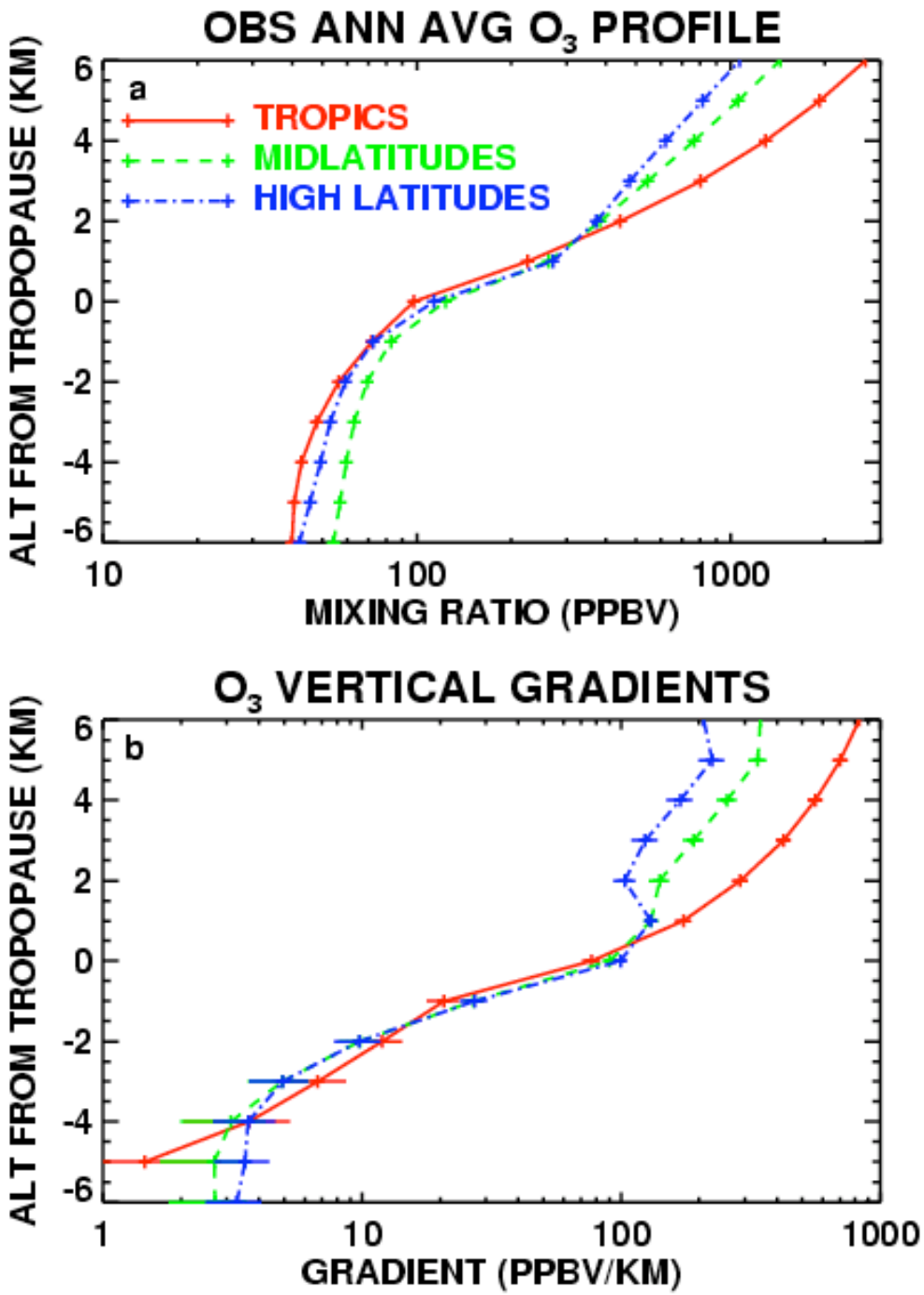




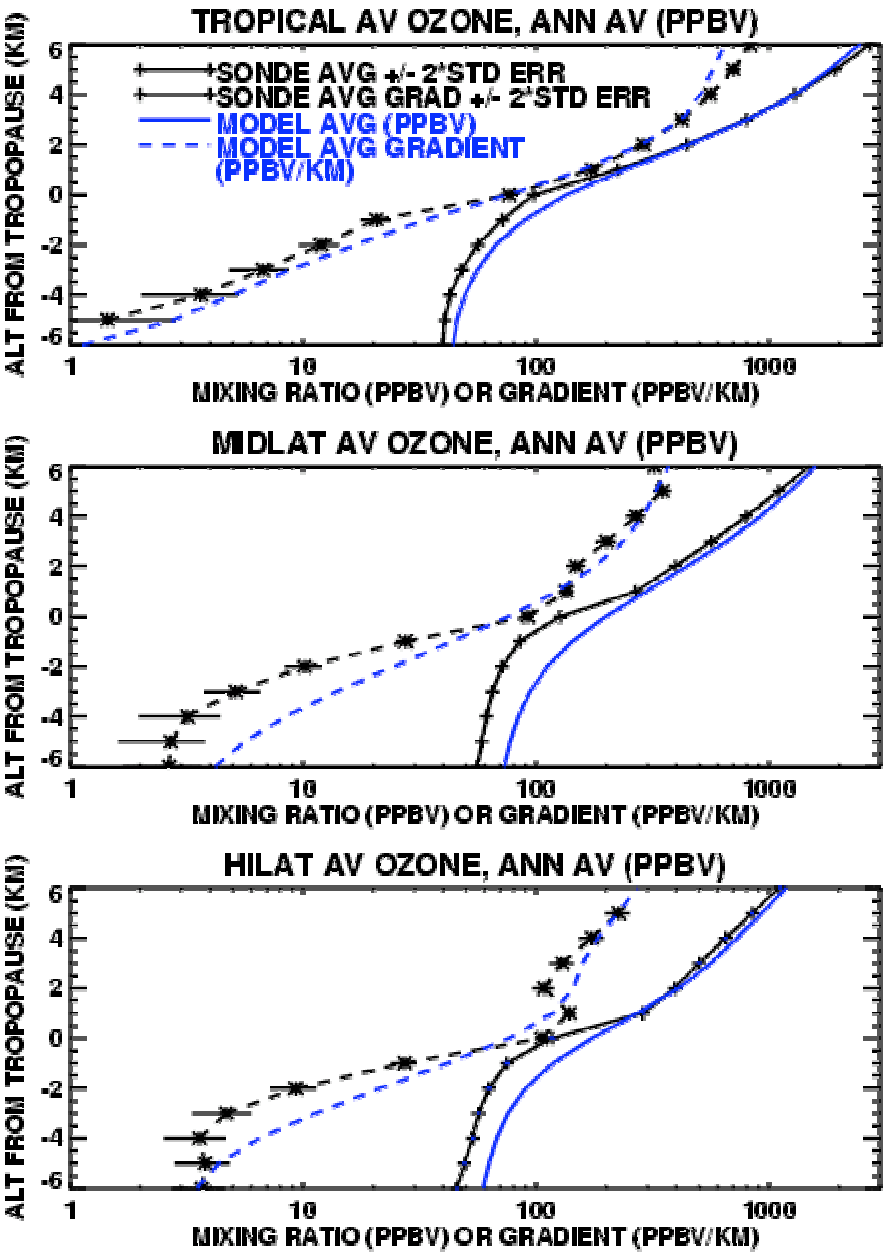
GMI/FVGCM



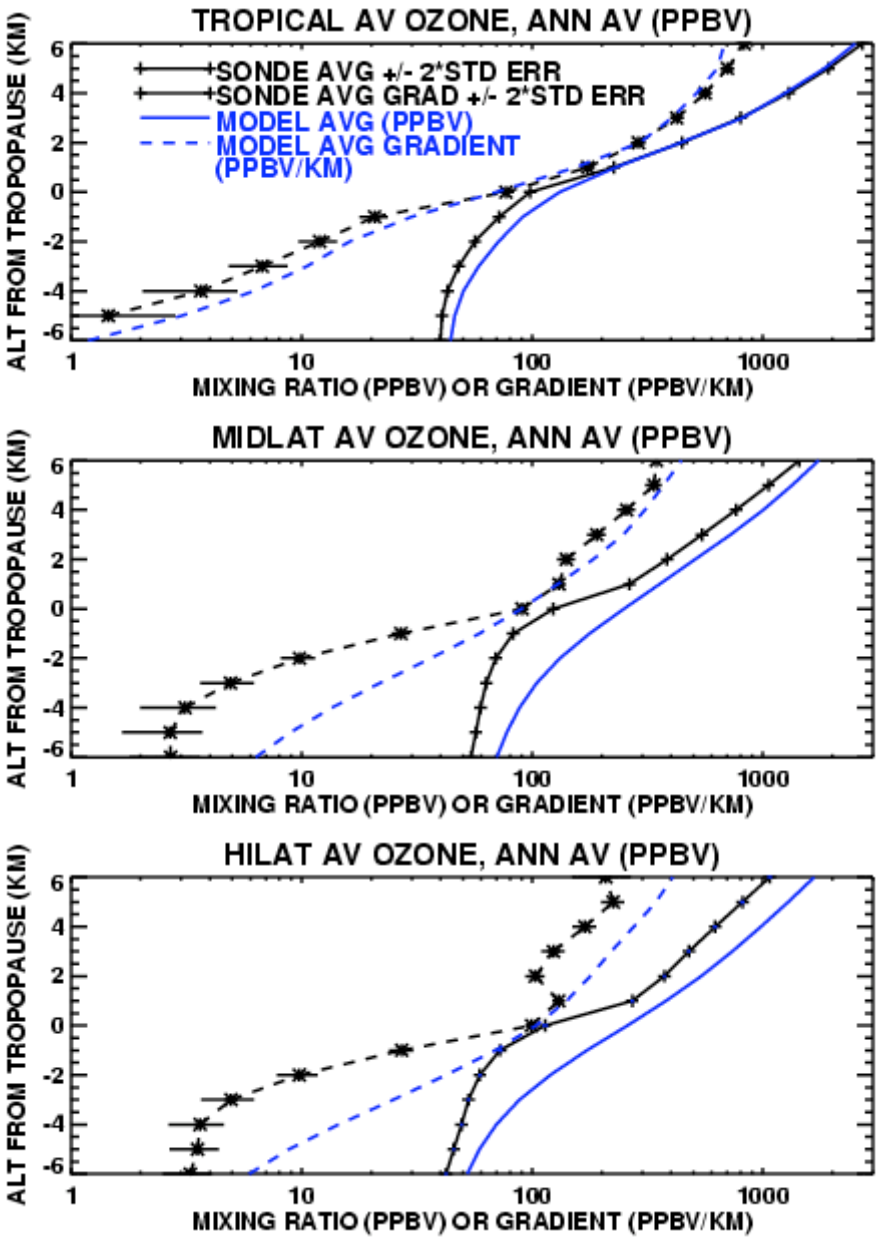
GMI/MACCM3



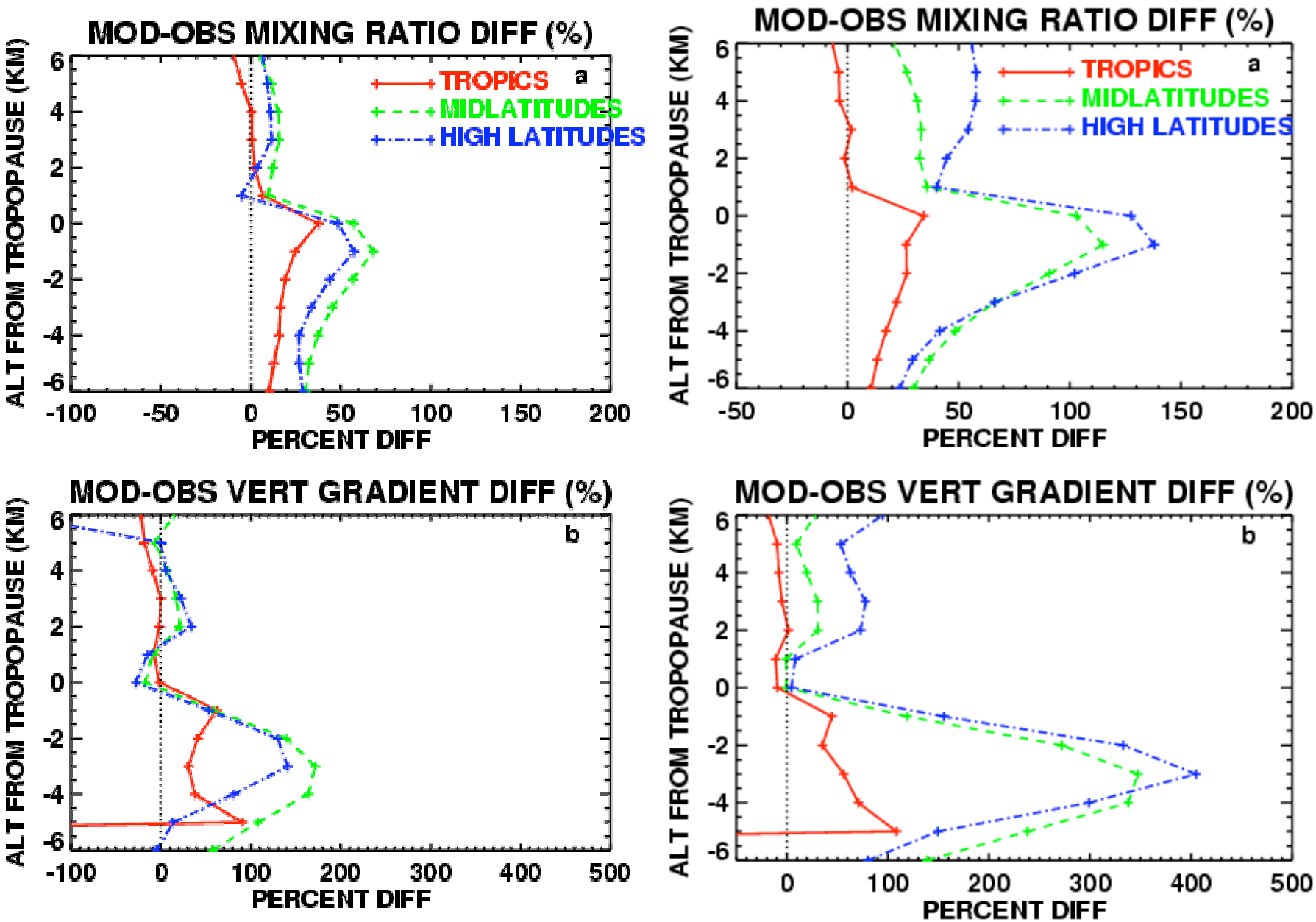
Mixing ratio and vertical gradient profiles from Logan ozonesonde climatology, averaged into tropical, midlatitude, and high latitude bins.



GMI/FVGCM

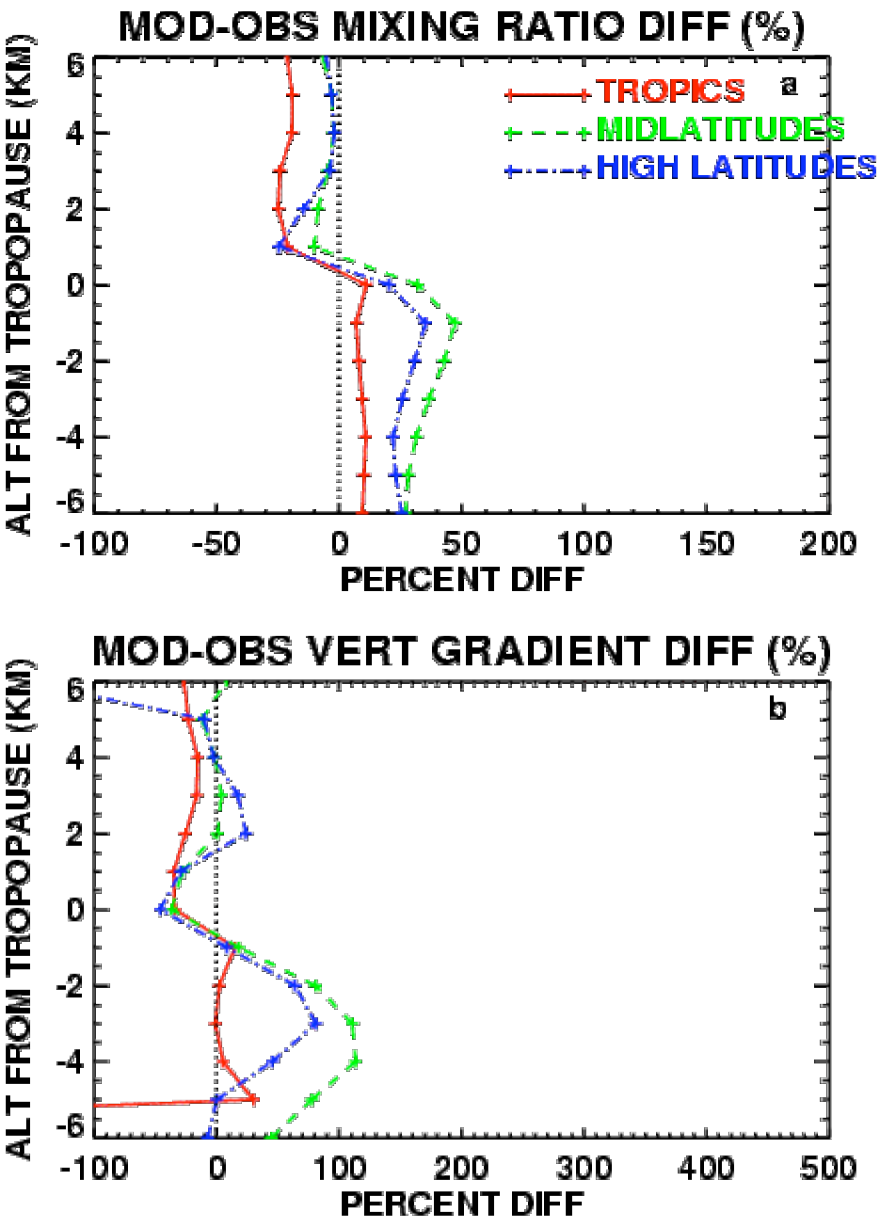


GMI/MACCM3

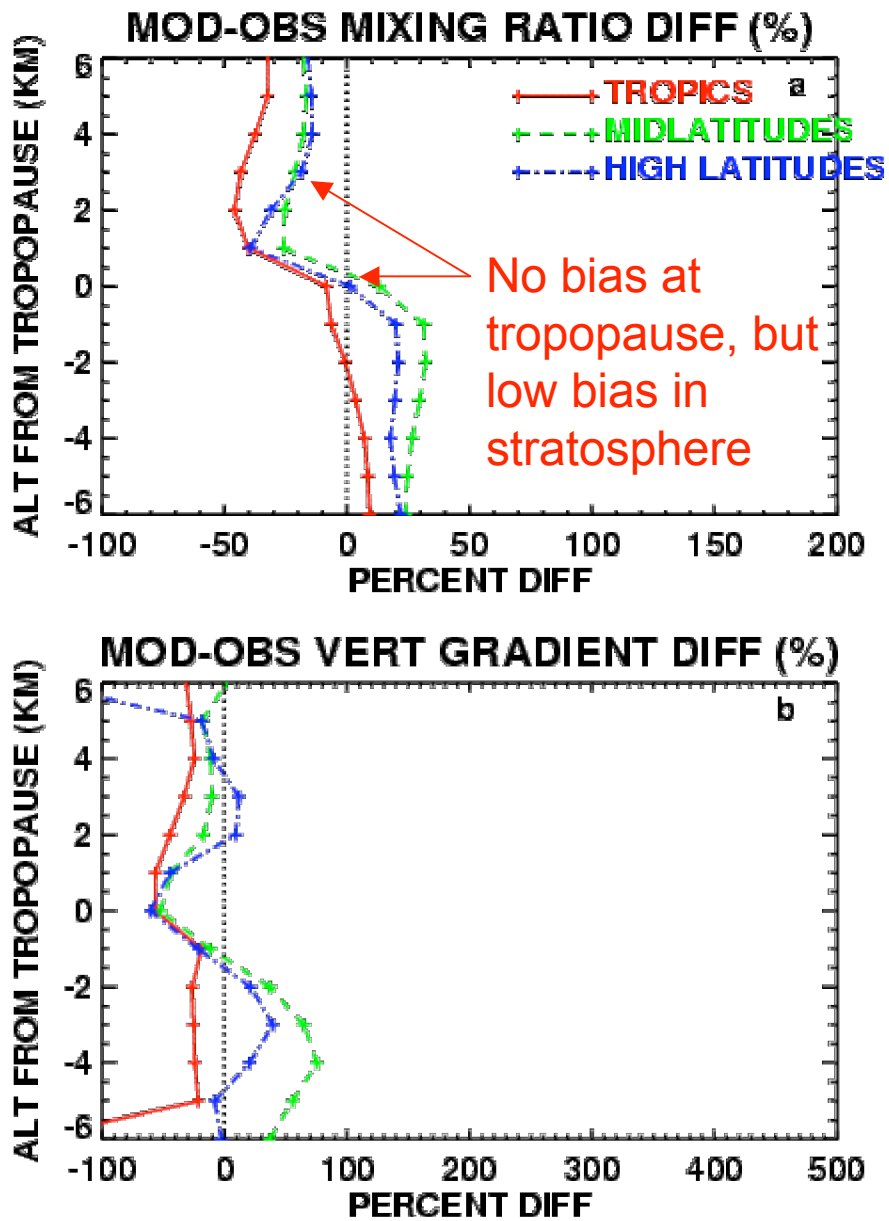


GMI/FVGCM

GMI/MACCM3



Assuming model tropopause height is 0.5 km below calculated value

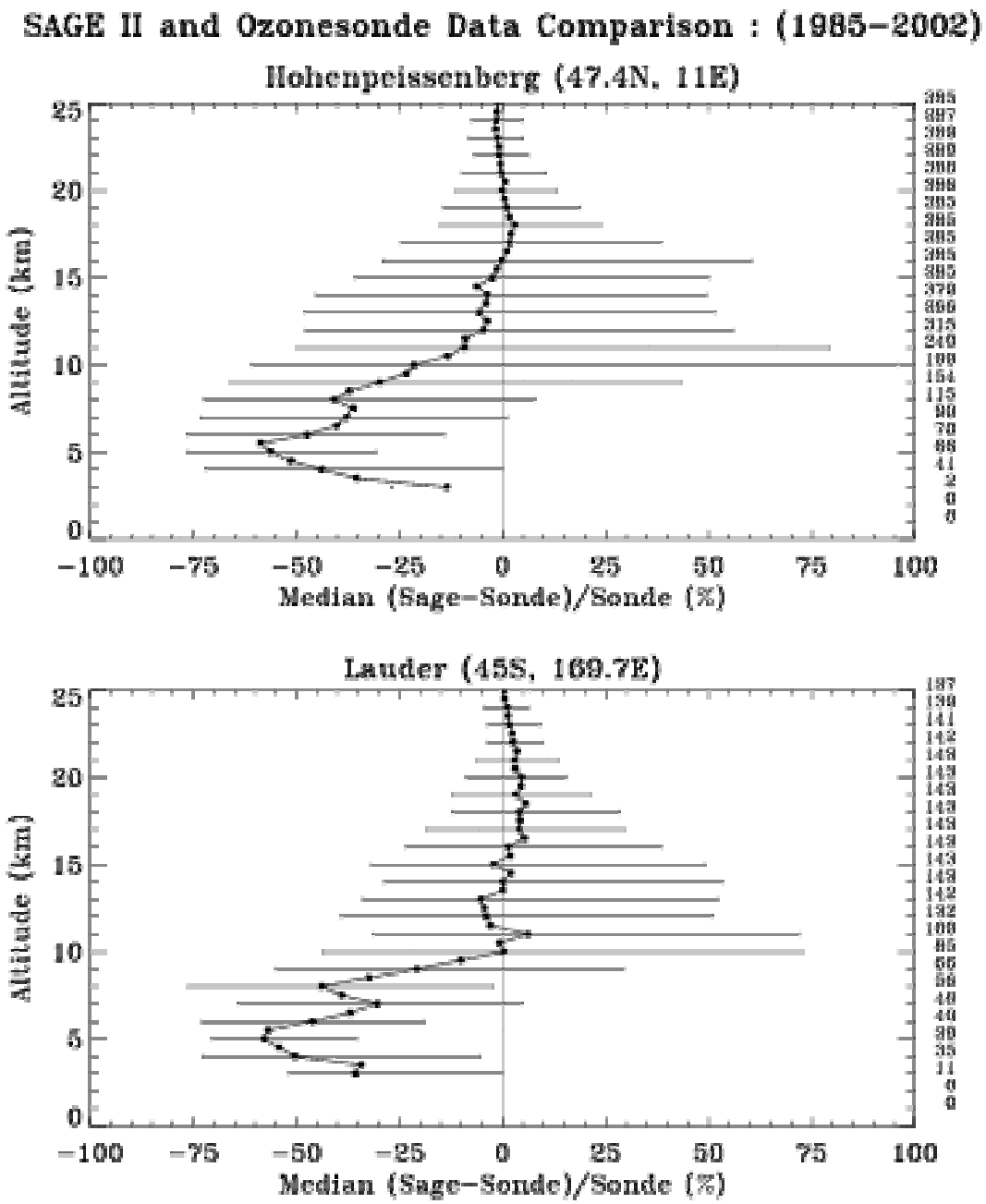


Assuming model tropopause height is 1.0 km below calculated value

SAGE II Ozone Climatology

- SAGE II V 6.2 ozone retrievals, 1985 - 2002
- 6.5 - 20 km, 0.5-km vertical resolution
- 25° - 65°, 5° resolution, NH and SH
- Monthly zonal median climatology
- Tropopause is used as base altitude for calculating medians

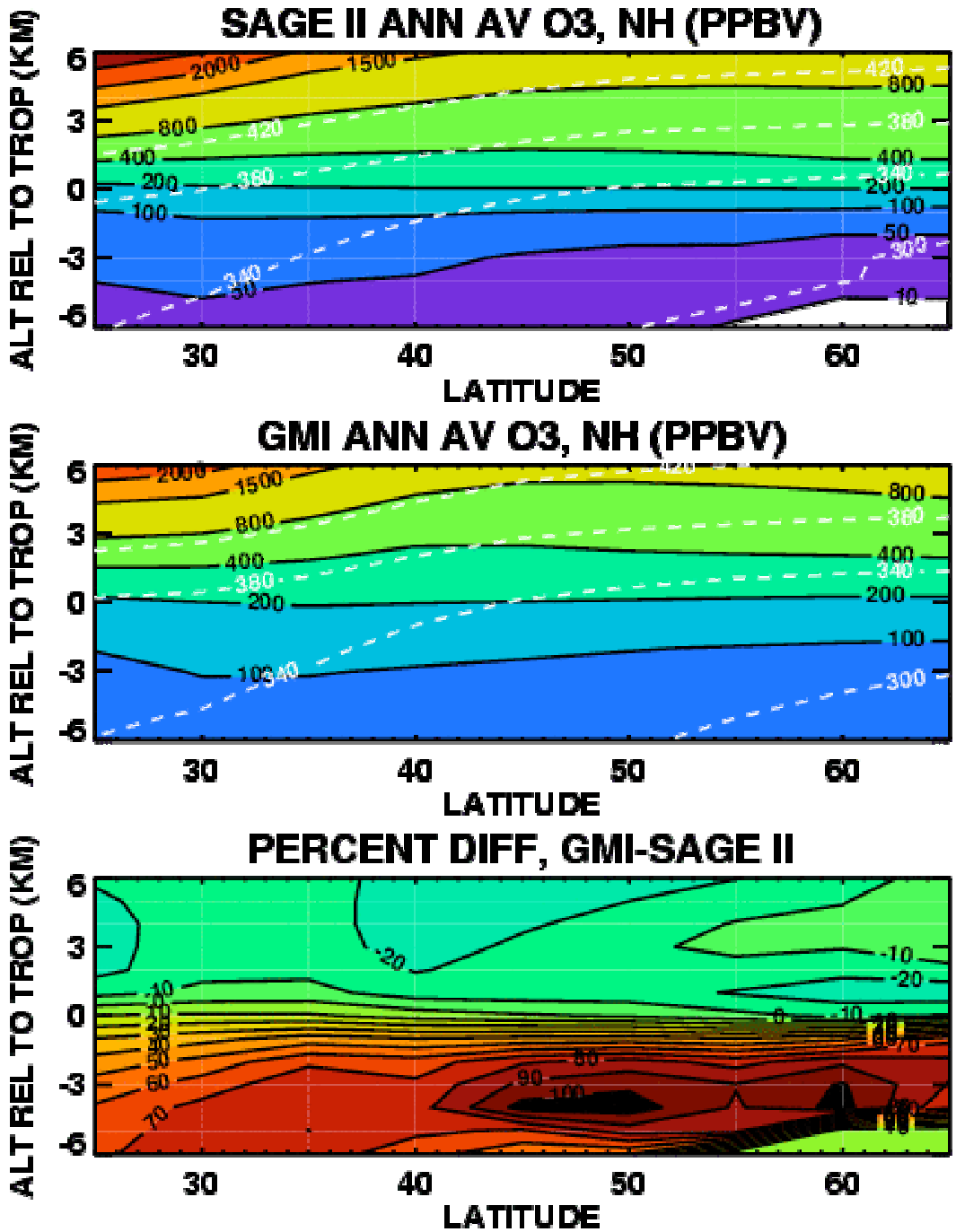
- P. H. Wang, et al., Ozone variability in the midlatitude UT/LS diagnosed from a monthly SAGE II Climatology JGR, submitted, 2005.



SAGE II Climatology is biased low compared to sondes - ~10% at 10 km (~2-3 km below tropopause); ~50% at 6 km (~6-7 km below tropopause)

Annually averaged NH ozone within 6 km of thermal tropopause. Model ~20% lower than SAGE II climatology above tropopause.

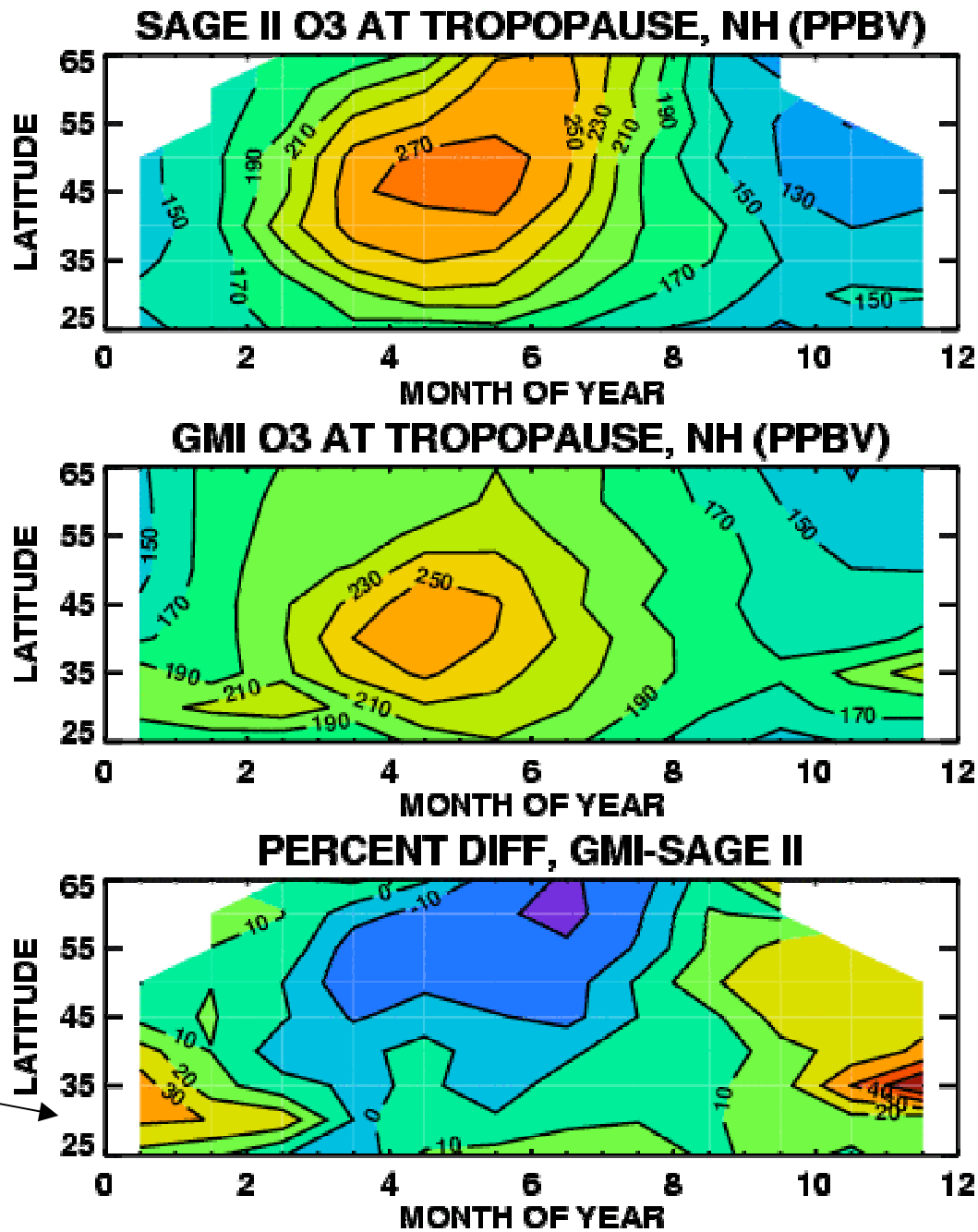
Model is high-biased below tropopause by up to 100%.



Seasonal cycle of O3 at tropopause is weaker than in SAGE II climatology. Peak mixing ratios ~5° equatorward of obs.

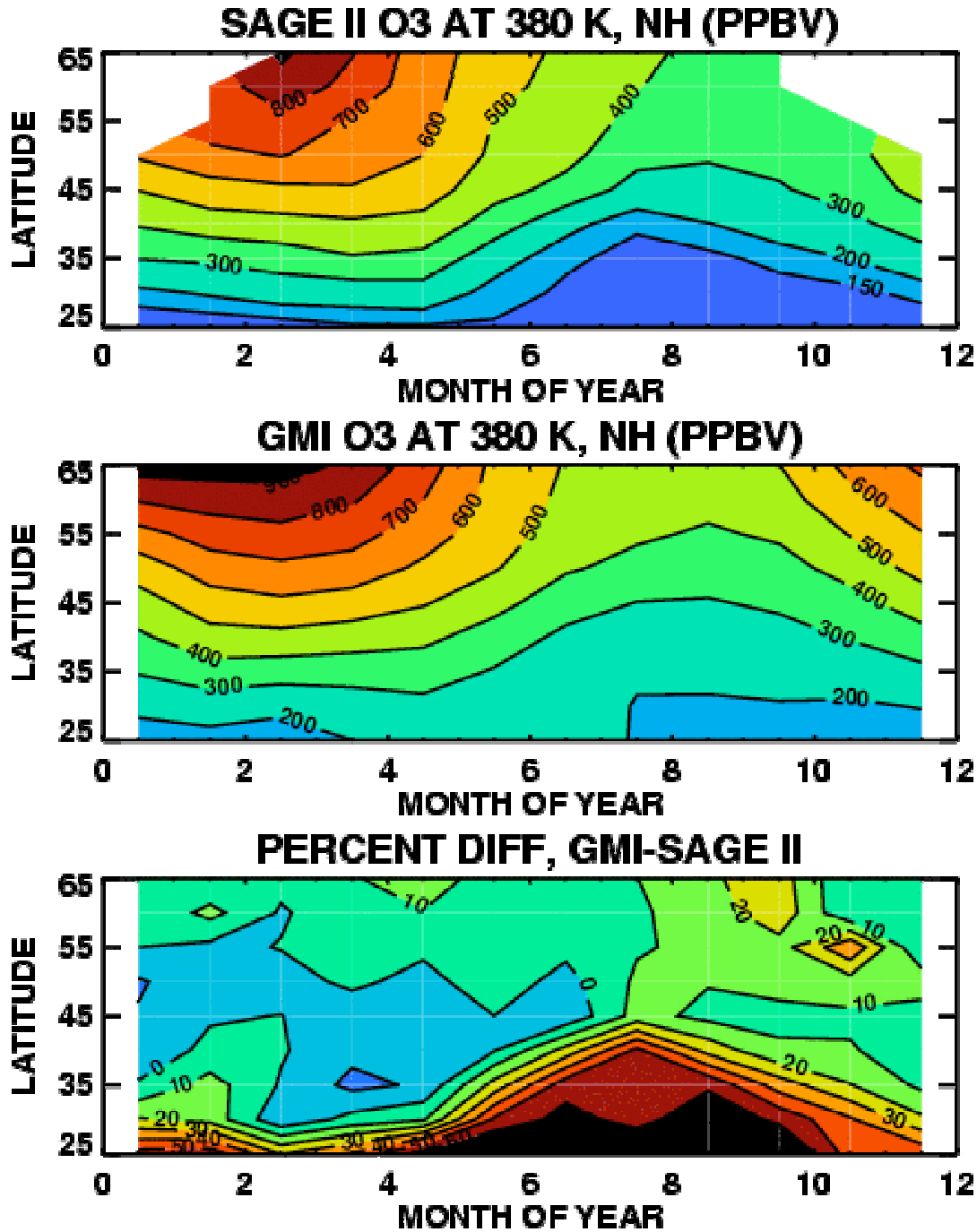
Model is low-biased in summer at higher lats. High-biased in winter, peaking around 35N between 30-40%

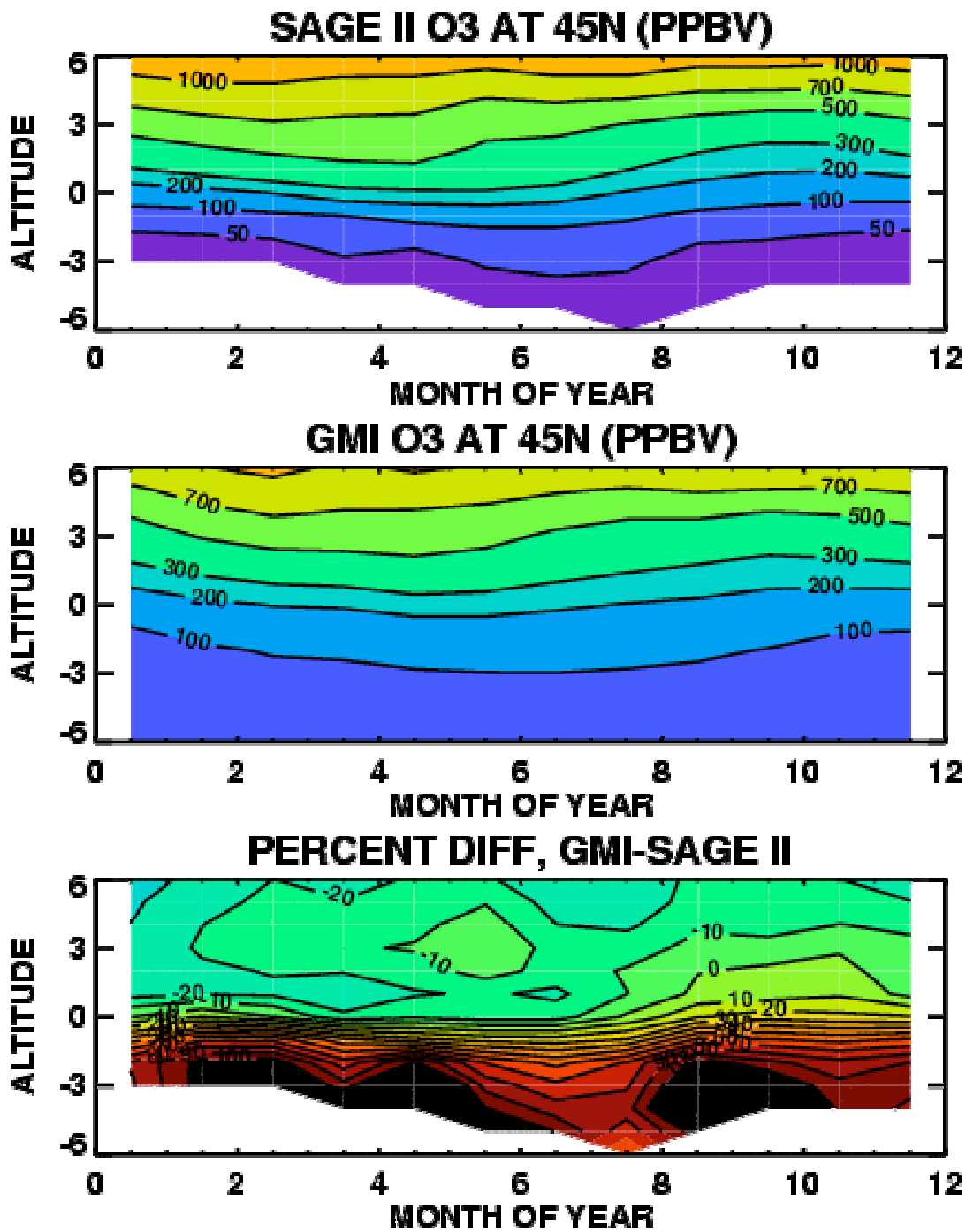
Suggests diabatic STE will be overestimated during winter, pretty good in spring and early summer.

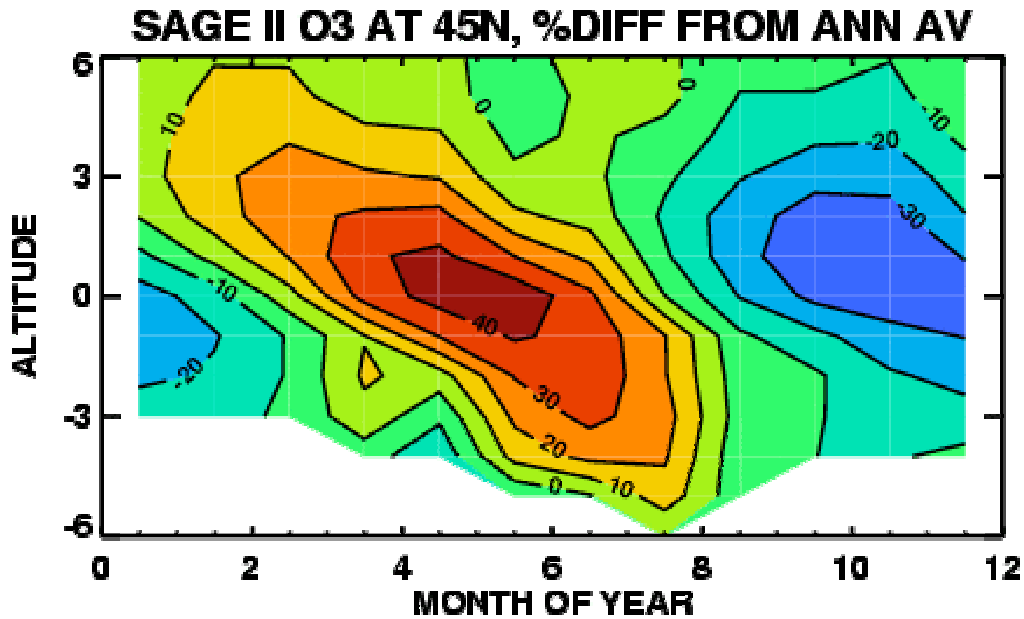


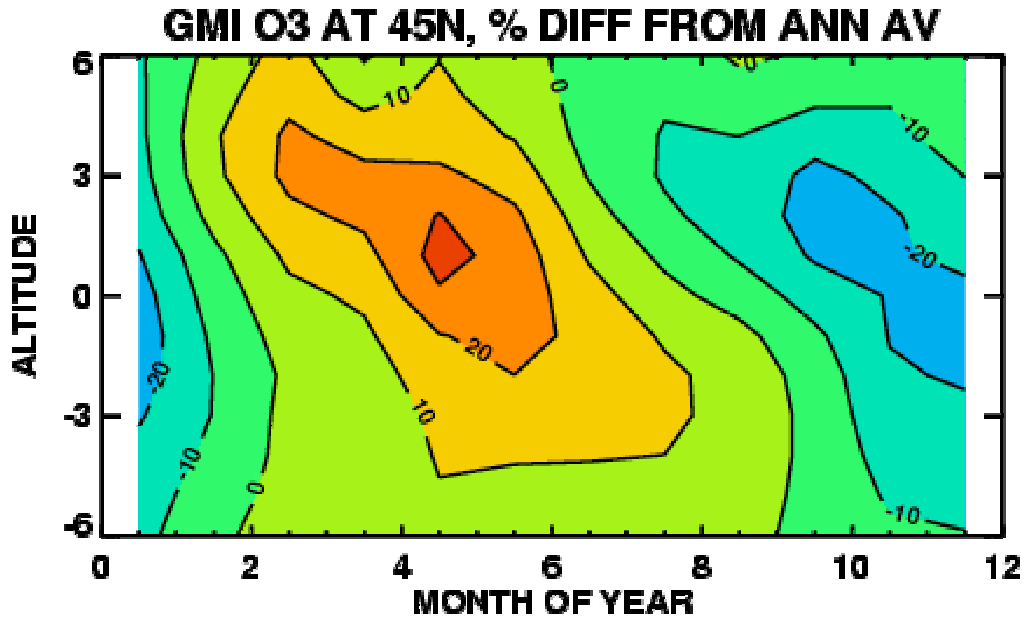
Good agreement on 380 K surface (top of middleworld) at mid to high latitudes throughout year.

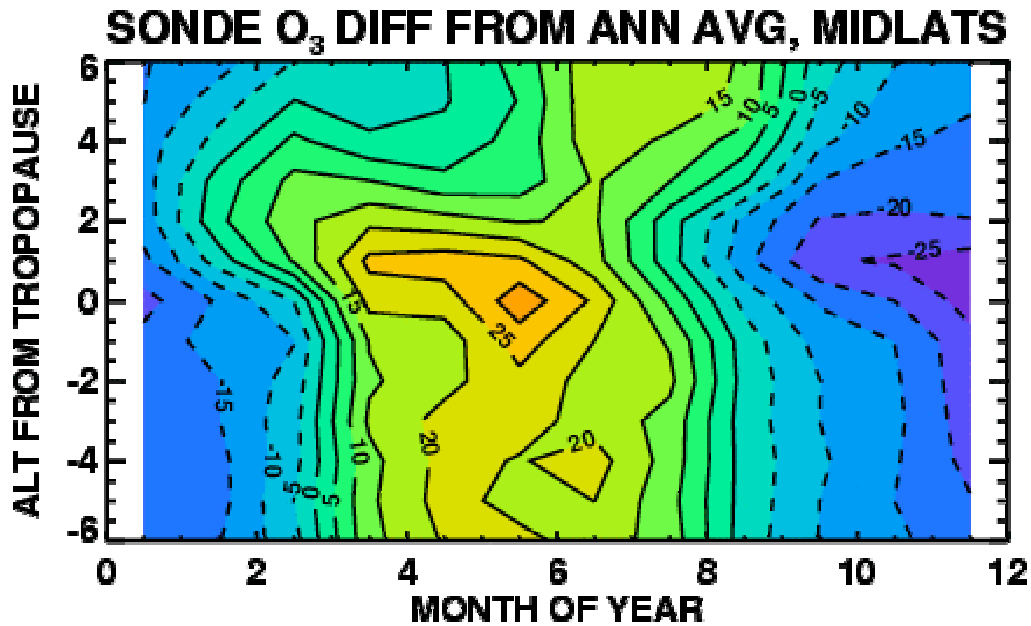
Over 60% overestimate in subtropics/low midlats during summer/fall season.

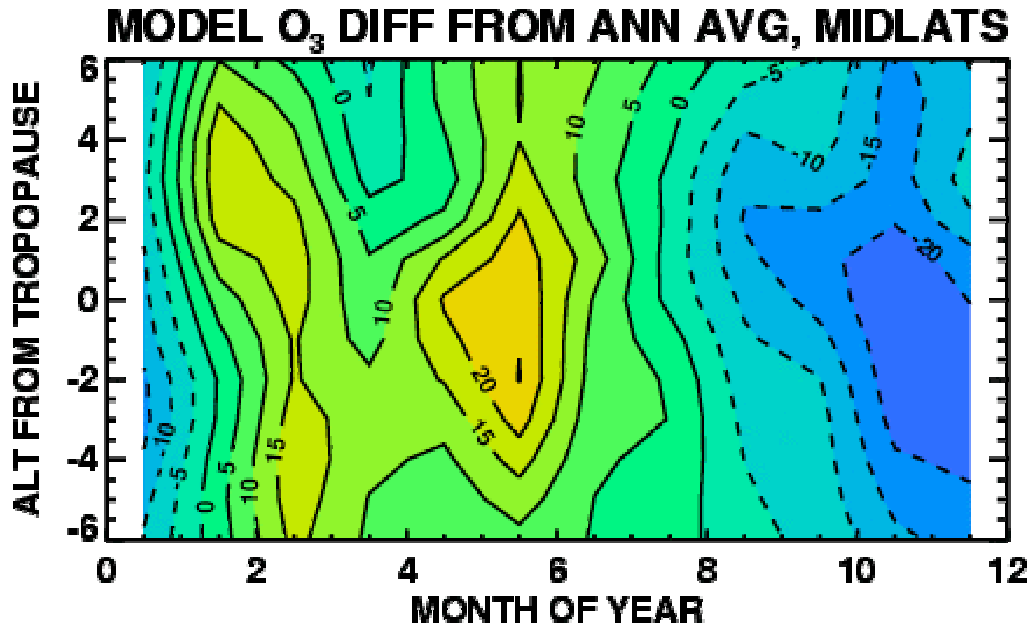



SAGE II O3 AT 45N (PPBV)
ALTITUDE
MONTH OF YEAR
1000
700
500
300
200
100
50
GMI O3 AT 45N (PPBV)
ALTITUDE
MONTH OF YEAR
700
500
300
200
100
PERCENT DIFF, GMI-SAGE II
ALTITUDE
MONTH OF YEAR
-20
-10
0
10
20


SAGE II O3 AT 45N, %DIFF FROM ANN AV
ALTITUDE
MONTH OF YEAR
6
3
0
-3
-6
0
2
4
6
8
10
12
10
0
0
-10
-20
-30
-10
-20
40
30
20
0
10


GMI O3 AT 45N, % DIFF FROM ANN AV
ALTITUDE
MONTH OF YEAR
6
3
0
-3
-6
0
2
4
6
8
10
12
10
0
-10
-20
20
10
-20
-10
0
-10


SONDE O_3 DIFF FROM ANN AVG, MIDLATS
ALT FROM TROPOPAUSE
MONTH OF YEAR


MODEL O_3 DIFF FROM ANN AVG, MIDLATS
ALT FROM TROPOPAUSE
MONTH OF YEAR

Conclusions

1. GMI combined model driven by fvgcm agrees with sonde ozone mixing ratios in 6 km region above tropopause to within 20%, and vertical gradients within 50%.

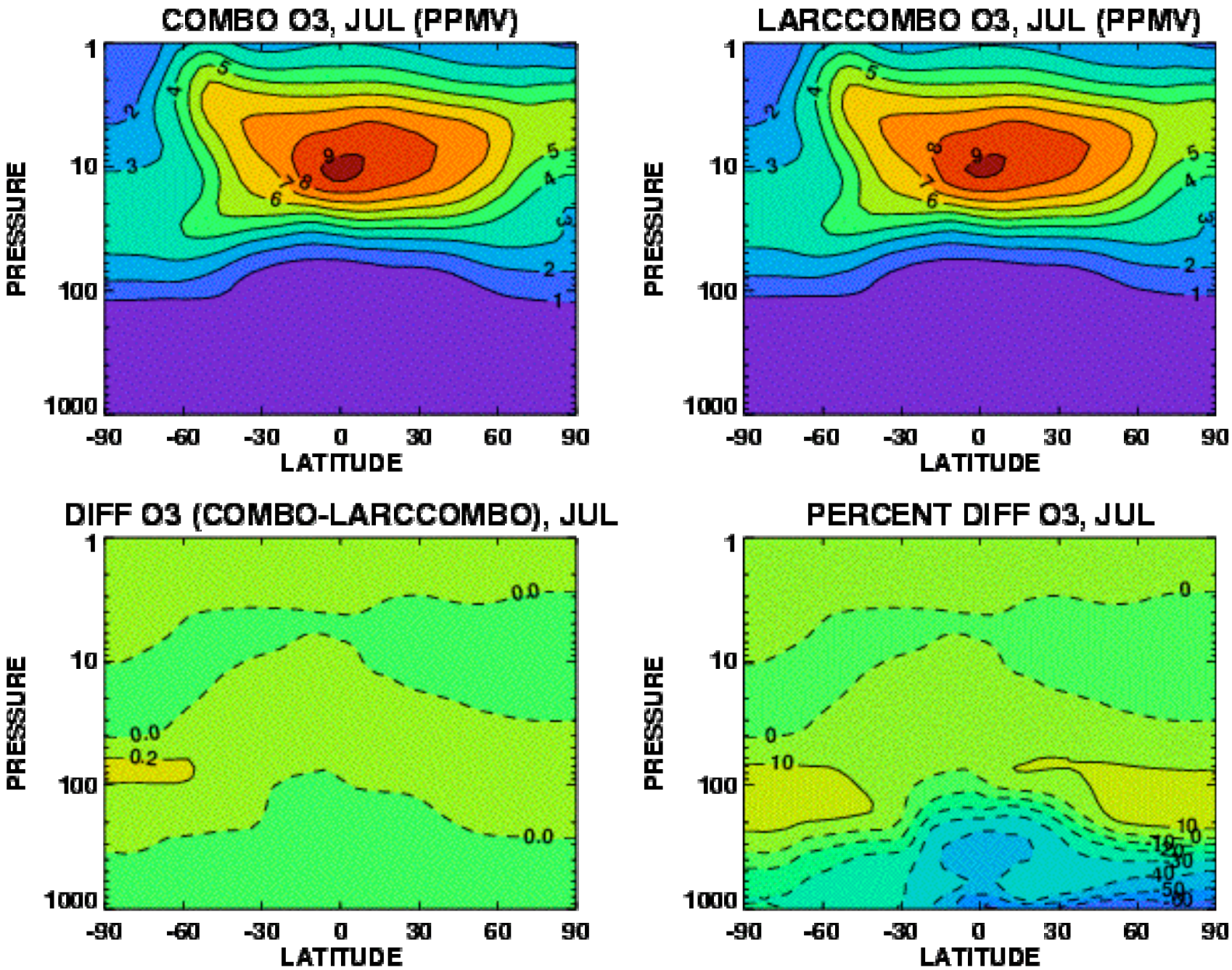
2. In 6 km region below tropopause, model mixing ratios are high-biased compared to sondes by ~50%. Model vertical gradients high-biased by ~150%.

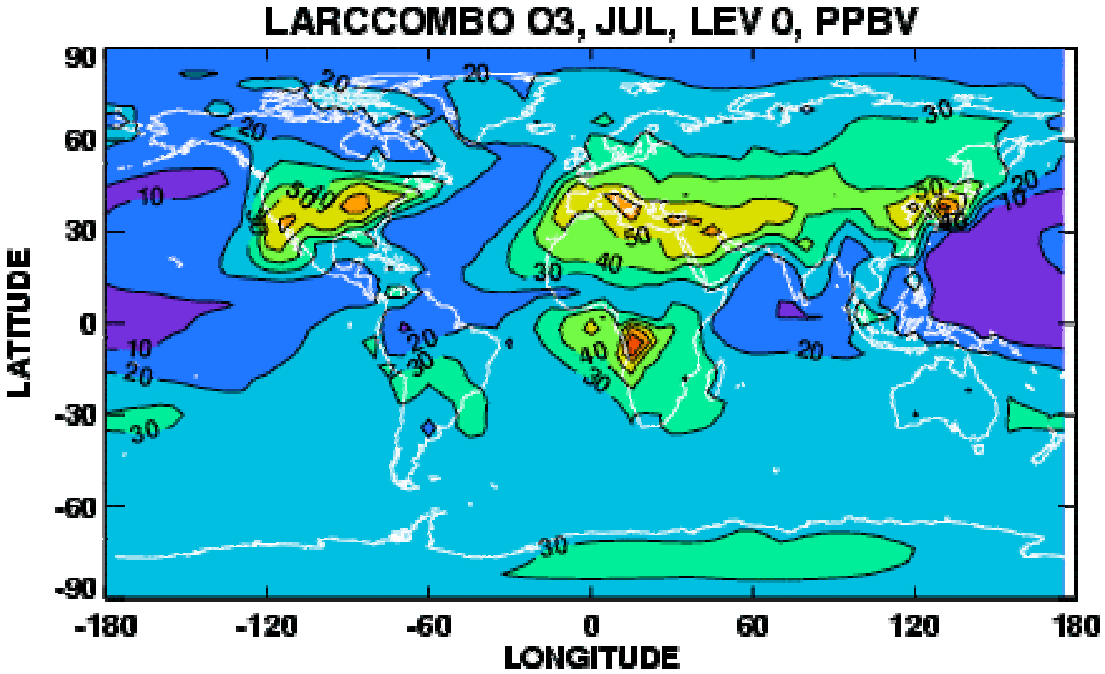
3. Model seasonal cycle phasing as function of altitude is similar to obs. Peak seasonal cycle amplitude occurs at tropopause, as observed. Amplitude of model seasonal cycle of ozone at midlatitudes (as % of annual average value) is weaker than observed.

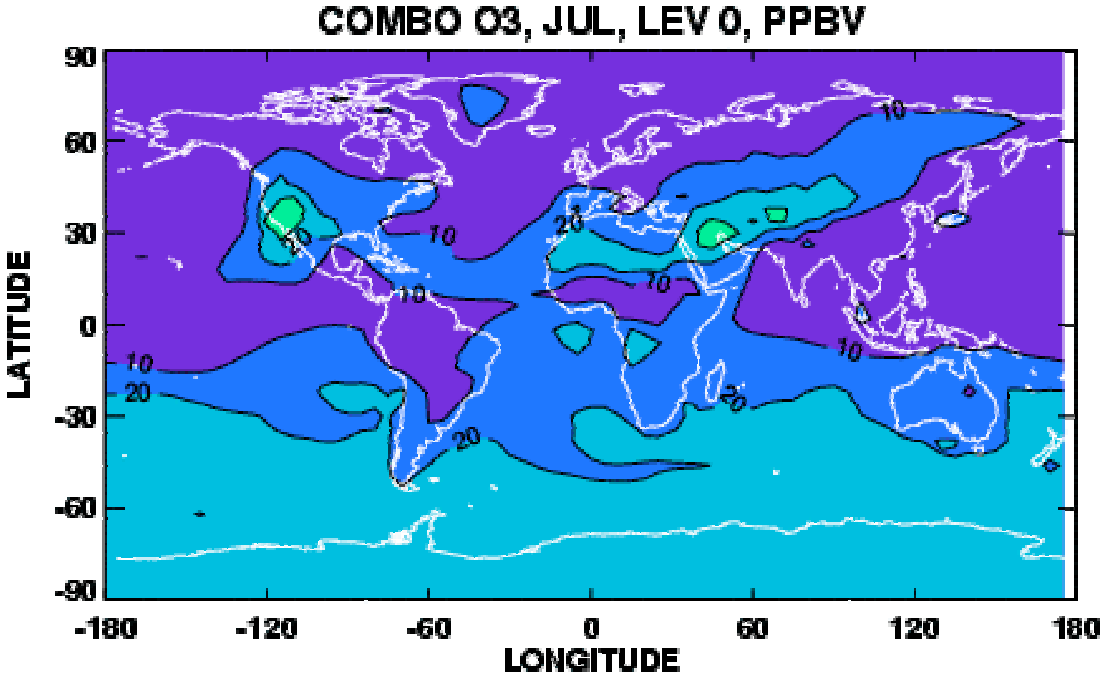
4. High model bias at tropopause suggests that model estimates of strat-to-trop transport could be high-biased by up to 50%, *presuming* mass fluxes are correct.

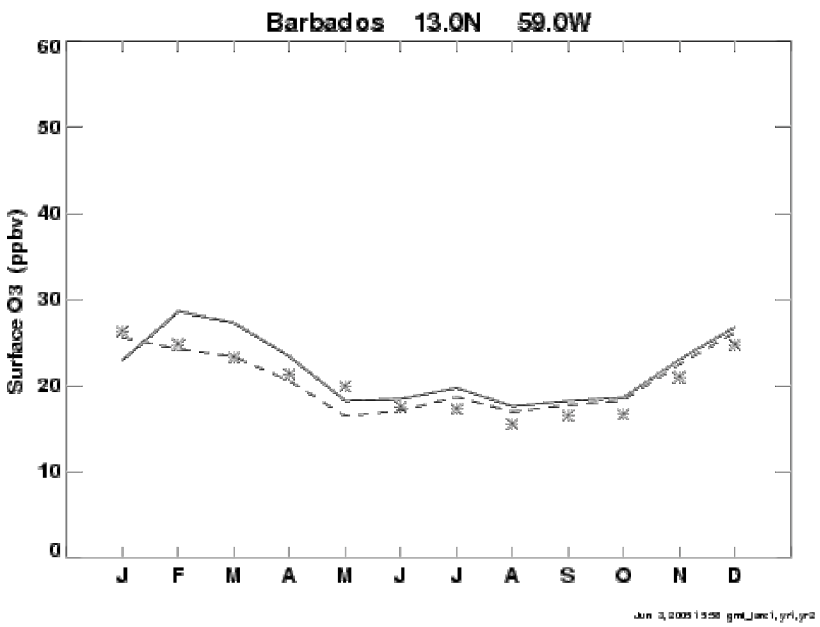
Larccombo model update

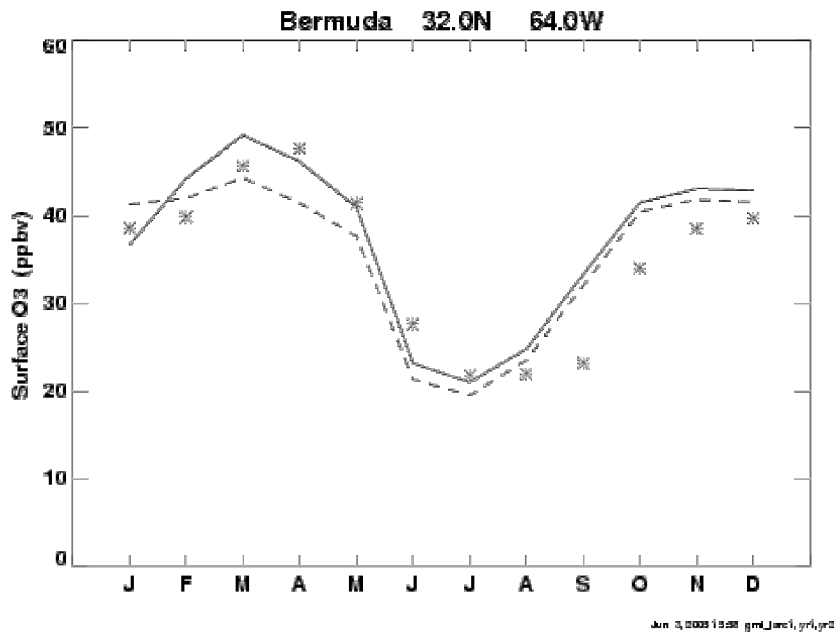
- SMVGEAR II implementation of LaRC combined chemical mechanism developed using Connell's KMG software and implemented into GMI combined model.
- First "Larccombo" model integration on 4/15/05
    - MACCM3 met data
    - 85 species mechanism, 81 species transported
    - 219 thermal reactions, including 24 het rxns
    - 52 photolytic decompositions
    - Connell "family groups" for Cly, Bry species
    - Fastj-x photolysis scheme
    - Initialization developed from LaRC IMPACT GCM
    - Model run for 2 yrs past initialization
- Integration time ~2 hrs/month on 64 halem nodes (Std combo ~ 3 hrs)
- Currently in debug/evaluation phase
- Current CH3CCl3 lifetime = 3.9 years, clear sky (OH is biased high, don't have an estimate of how much.)

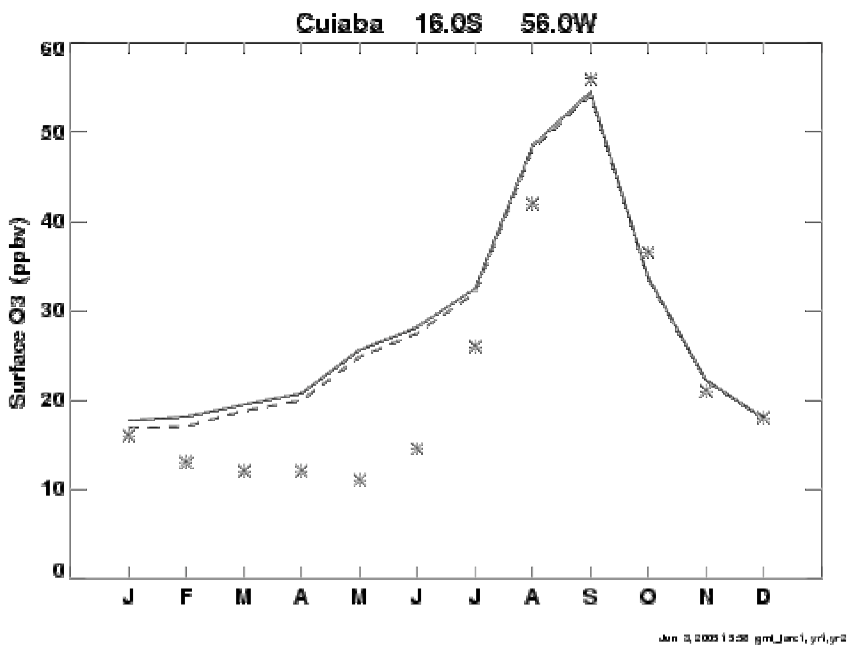

COMBO O3, JUL (PPMV)
LARCCOMBO O3, JUL (PPMV)
DIFF O3 (COMBO-LARCCOMBO), JUL
PERCENT DIFF O3, JUL
PRESSURE
LATITUDE
1
10
100
1000
-90
-60
-30
0
30
60
90

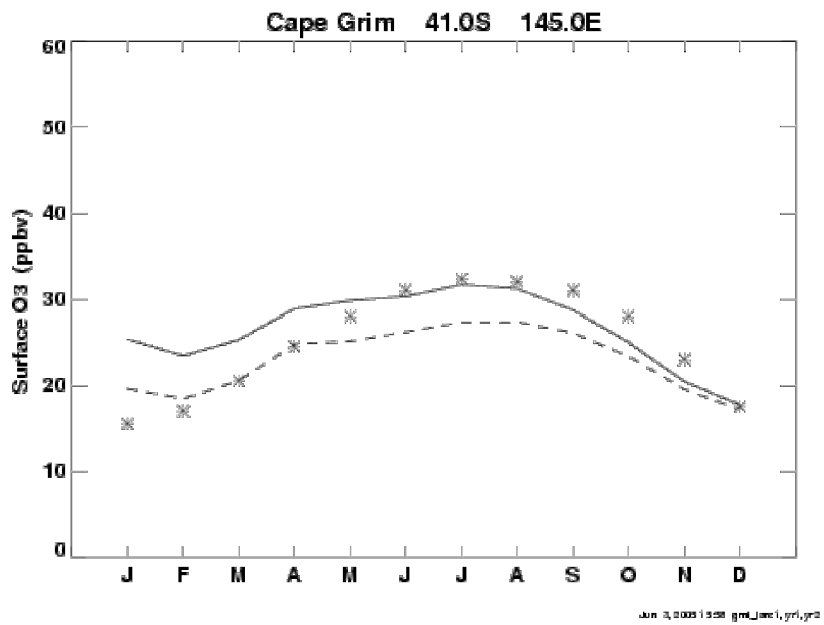

LARCCOMBO O3, JUL, LEV 0, PPBV
LATITUDE
LONGITUDE
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180

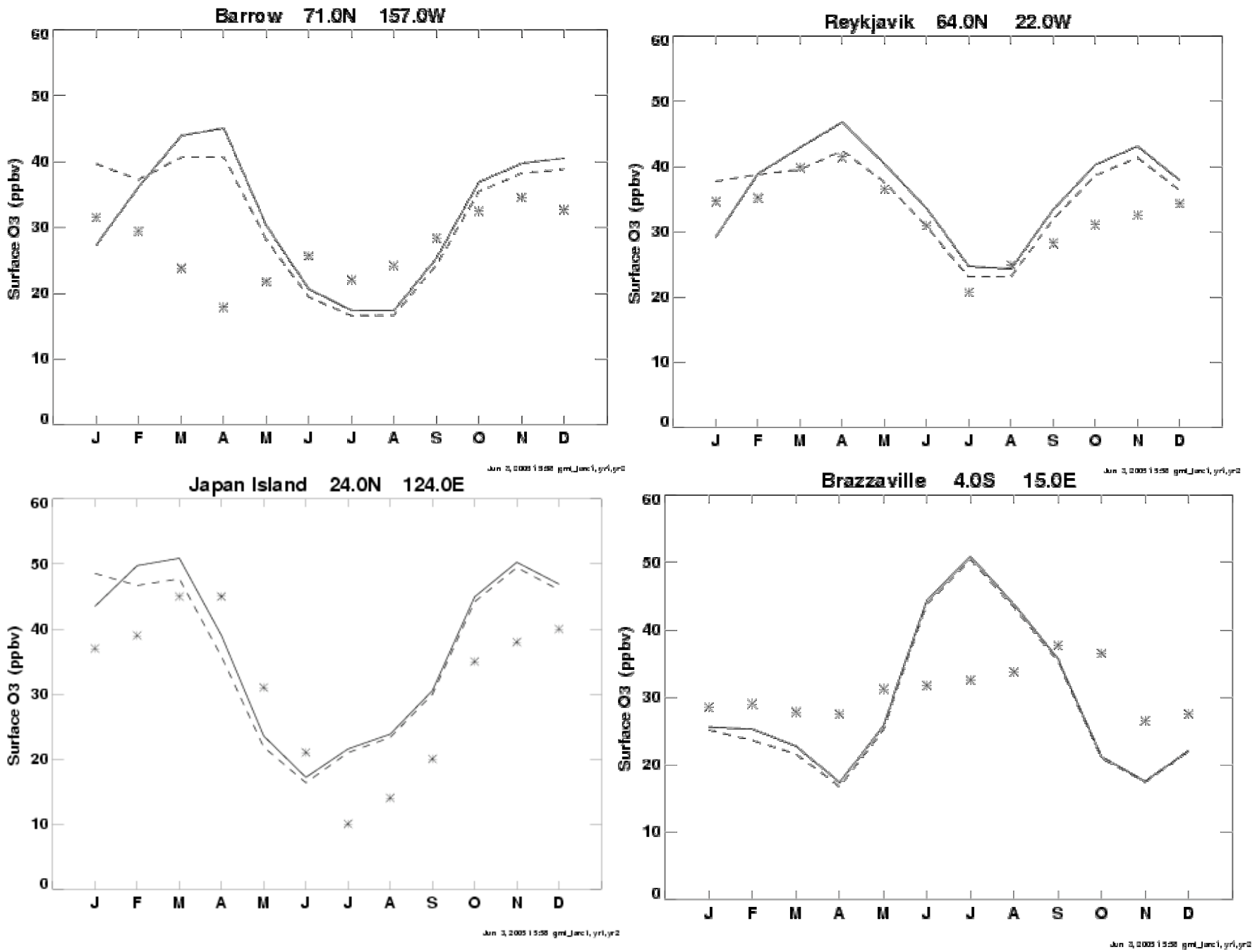

COMBO O3, JUL, LEV 0, PPBV
LATITUDE
LONGITUDE
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180

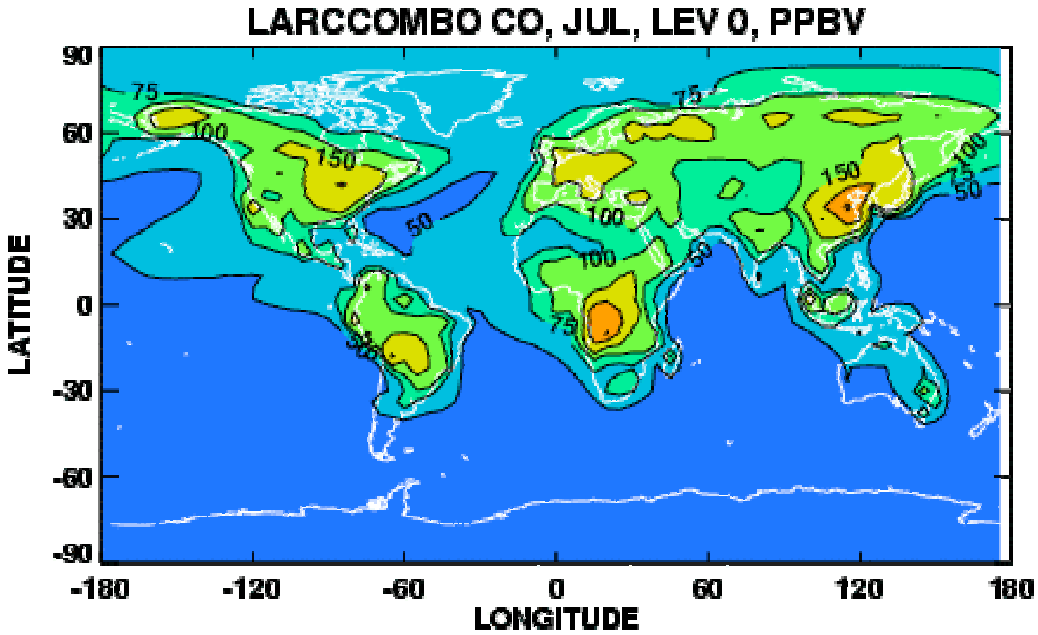

Barbados 13.0N 59.0W
Surface O3 (ppbv)
0
10
20
30
40
50
60
J F M A M J J A S O N D

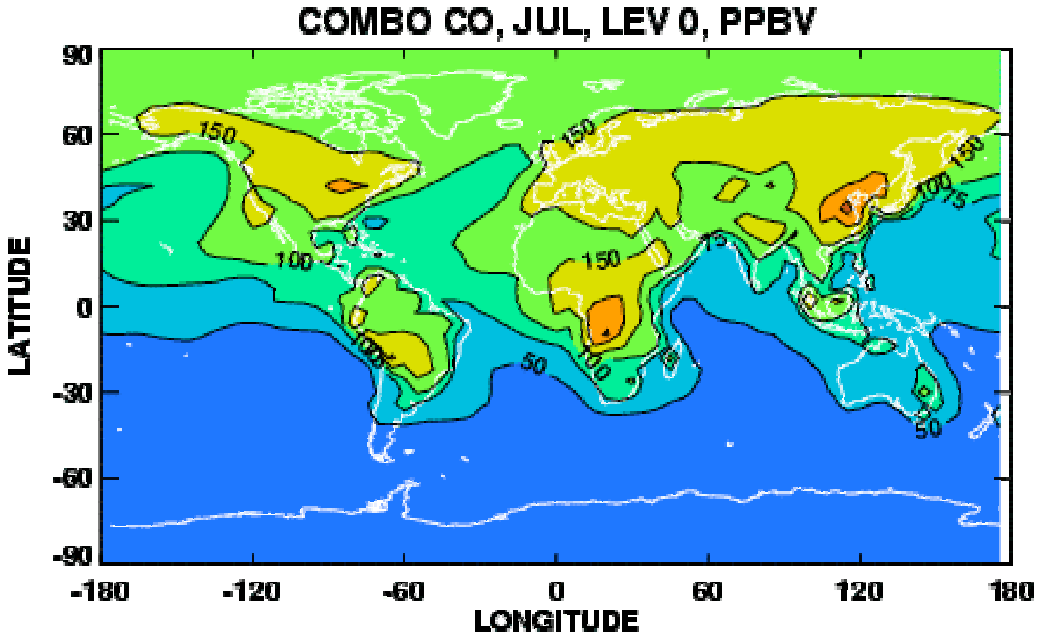

Bermuda 32.0N 64.0W
Surface O3 (ppbv)
0
10
20
30
40
50
60
J F M A M J J A S O N D

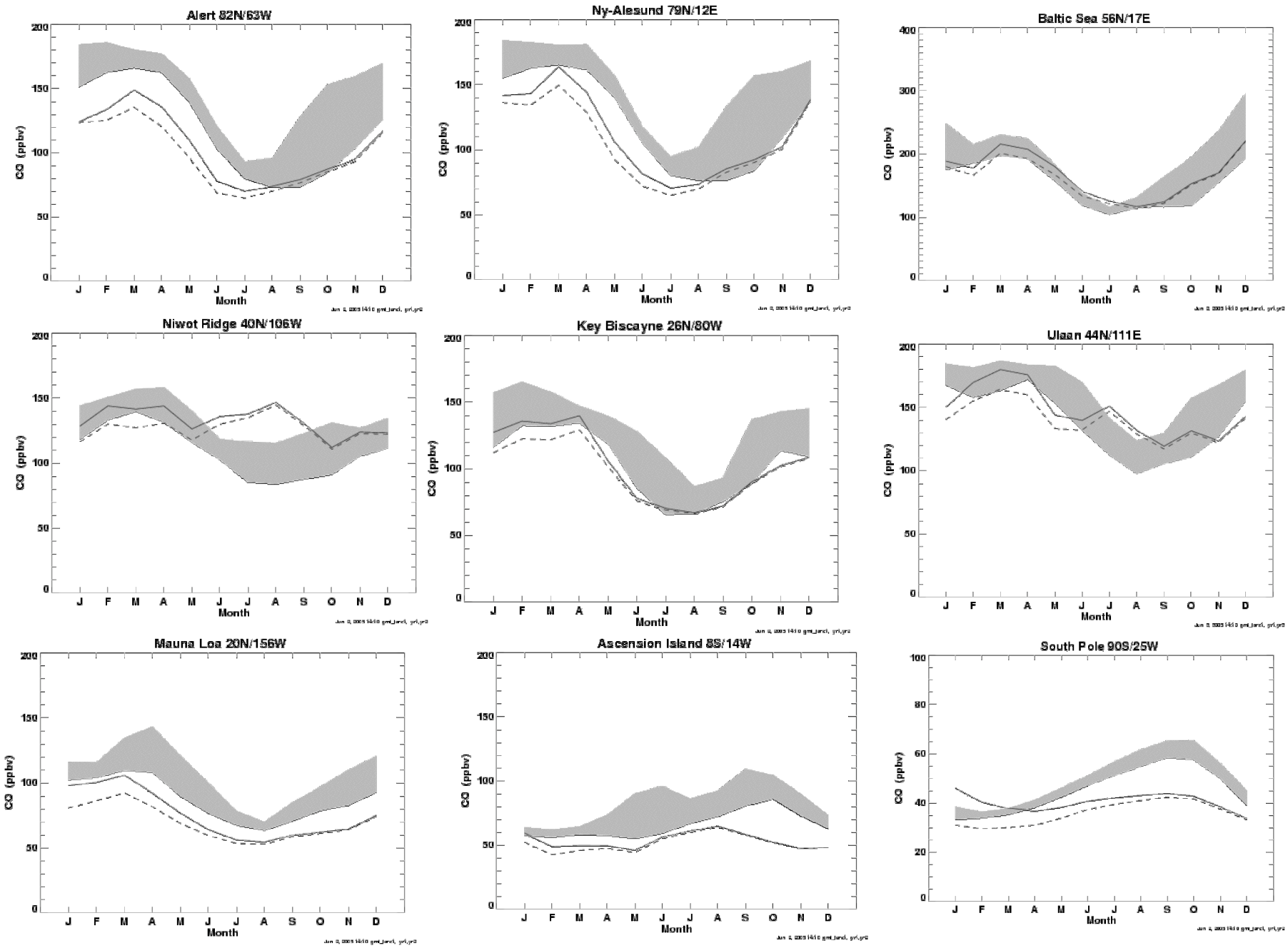

Cuiaba 16.0S 56.0W
Surface O3 (ppbv)
0
10
20
30
40
50
60
J F M A M J J A S O N D

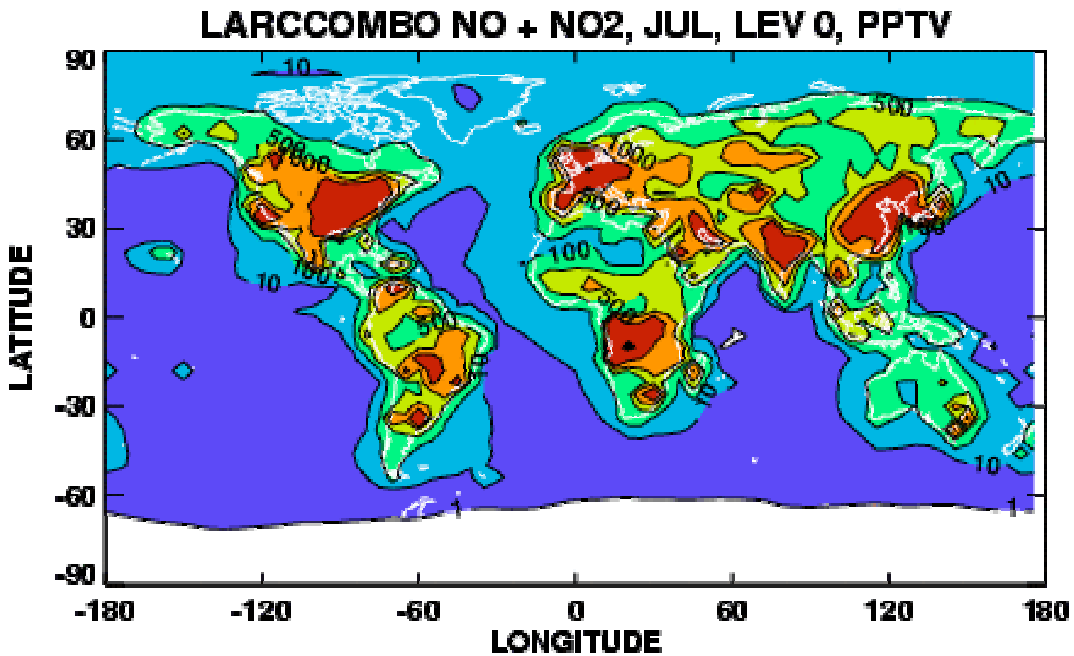

Cape Grim 41.0S 145.0E
Surface O3 (ppbv)
0
10
20
30
40
50
60
J F M A M J J A S O N D

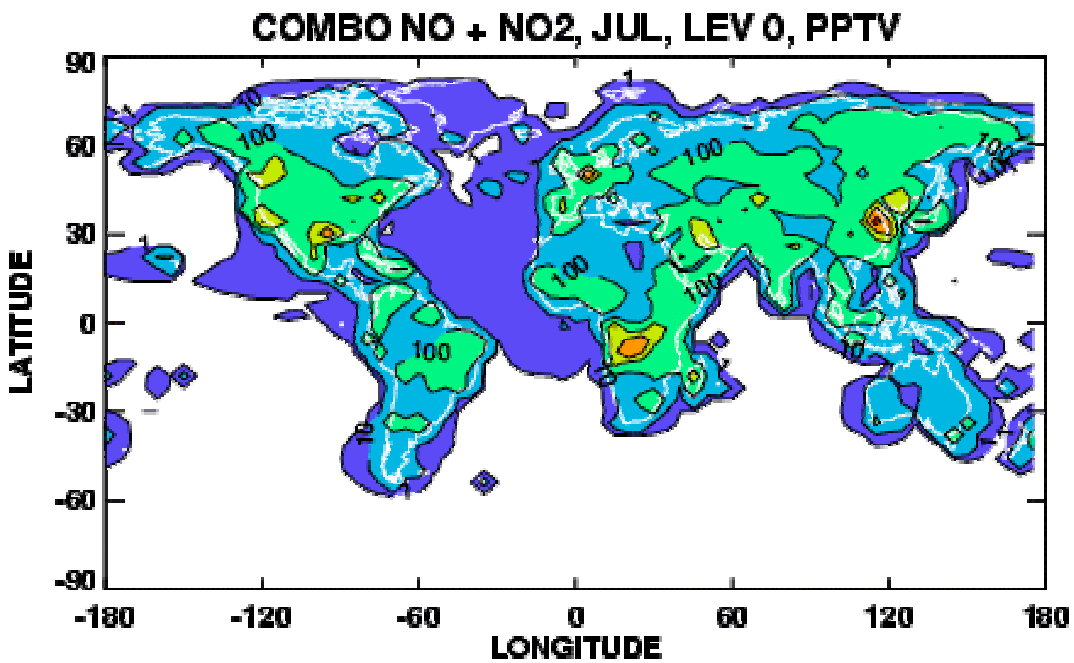

Barrow 71.0N 157.0W
Reykjavik 64.0N 22.0W
Japan Island 24.0N 124.0E
Brazzaville 4.0S 15.0E
Surface O3 (ppbv)
0
10
20
30
40
50
60
J F M A M J J A S O N D


LARCCOMBO CO, JUL, LEV 0, PPBV
LATITUDE
LONGITUDE
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180
75
100
150
50


COMBO CO, JUL, LEV 0, PPBV
LATITUDE
LONGITUDE
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180
150
100
75
50


Alert 82N/63W
Ny-Alesund 79N/12E
Baltic Sea 56N/17E
Niwot Ridge 40N/106W
Key Biscayne 26N/80W
Ulaan 44N/111E
Mauna Loa 20N/156W
Ascension Island 8S/14W
South Pole 90S/25W
CO (ppbv)
Month
J F M A M J J A S O N D


LARCCOMBO NO + NO2, JUL, LEV 0, PPTV
LATITUDE
LONGITUDE
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180


COMBO NO + NO2, JUL, LEV 0, PPTV
LATITUDE
LONGITUDE
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180

Larccombo conclusions/issues

- Neither combo model nor larccombo model has been vetted against observations or compared to tropo model (need common met field).
- Compared to combo, larccombo has
  - higher surface O3 concentrations,
  - lower surface CO
  - higher surface NOx
  - higher surface OH
  - other significant differences

- Compared to surface obs, larccombo O3 looks to be in good general agreement, CO looks to be low. Situation will change when OH is fixed.
- Do not as yet know whether differences are due to mechanism differences, incorrect coding, bugs, or initialization

- PAR species (> C3 alkanes) lifetime too short due to bug in isoprene oxidation mechanism - solution determined but not implemented