Transporting Stratospheric Water Vapor in the GMI Combo Model

David B. Considine
NASA Langley Research Center

GMI Science Team Meeting
March 17, 2007

Motivation:

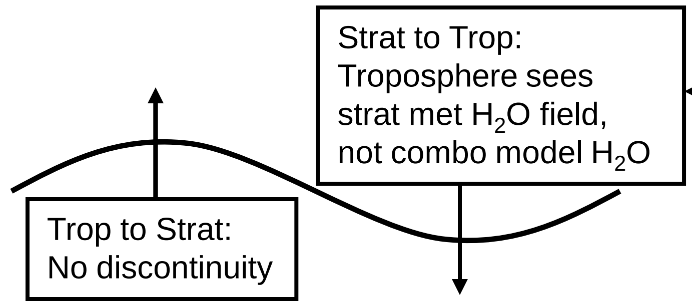
Stratospheric water vapor in the current Combo model is climatological, and accounting for PSC processes as well as changes in CH_4 emissions is clumsy. Can we improve this by transporting water in the stratosphere?

Methodology

1. Advection
2. Convection
3. Deposition
4. Add Trop Water
5. Chemistry

Currently A = 1, meaning Met H_2O replaces transported water below tropopause at every time step

$$H_2O(t+dt) = H_2O(t) + A \times (MetH_2O(t) - H_2O(t))$$



Might be a problem, depending on what strat metH2O is

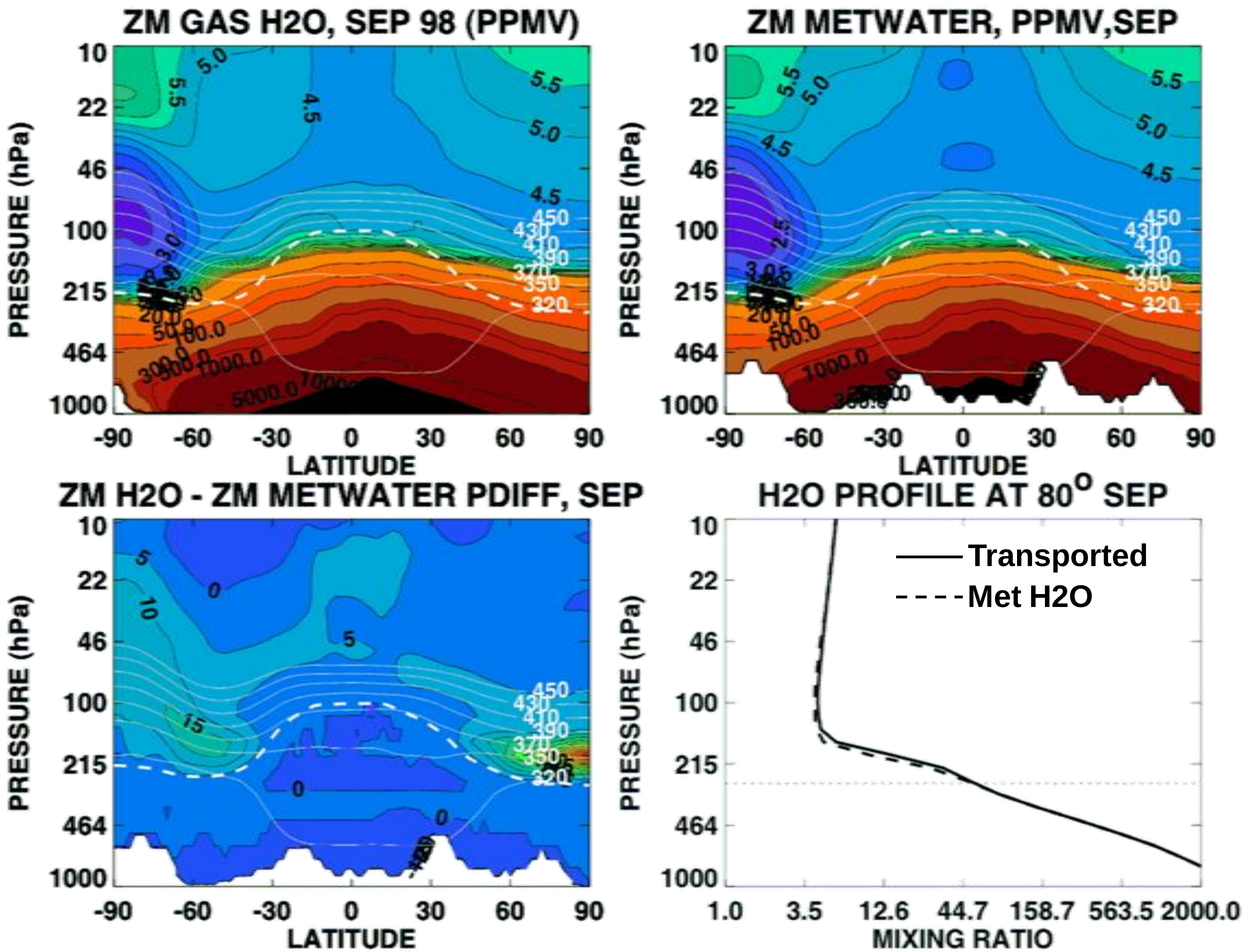
Independently Transported Species:

H2O
H2OCOND
HNO3
HNO3COND

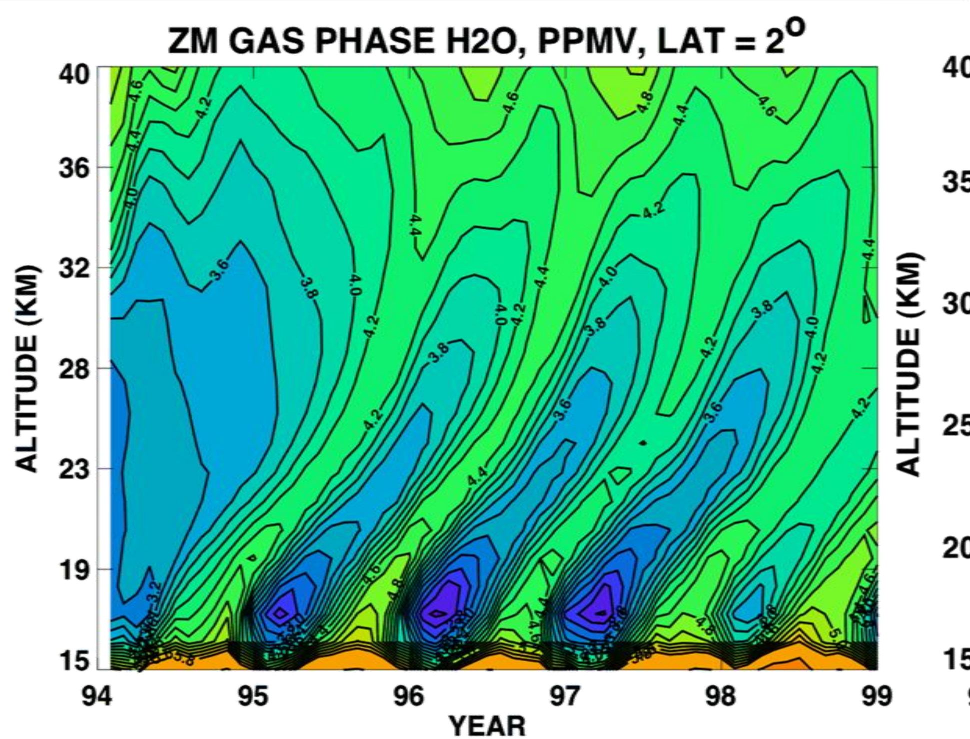
Need to transport separately to allow for separate nucleation and evaporation temperatures

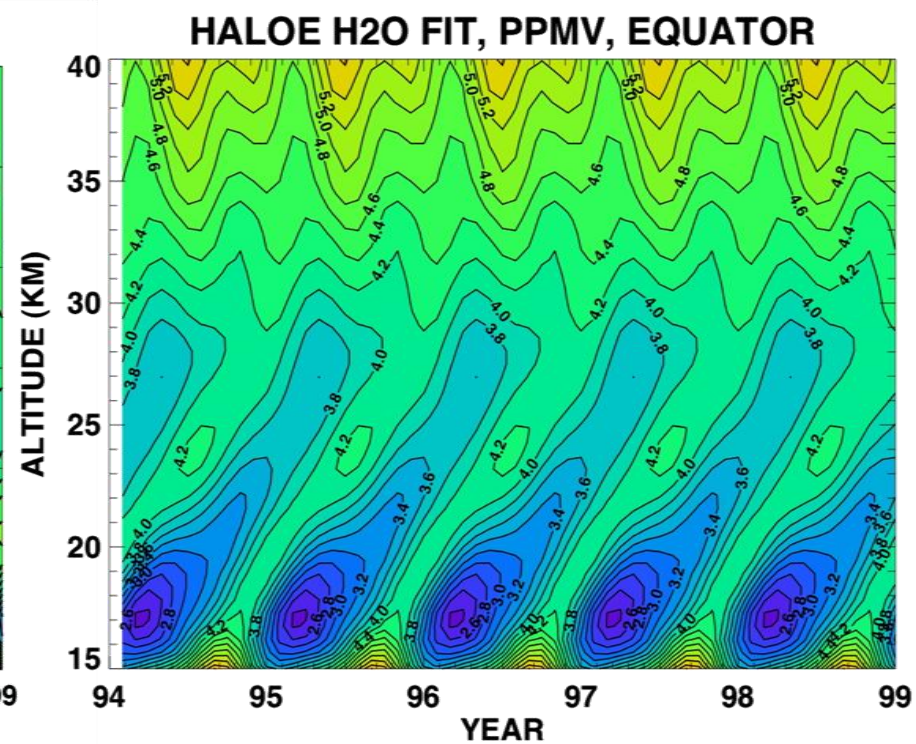
Run Description

- 5 year run.
- GEOS4 AGCM with 1994 - 1998 SSTs data set.
- 2 x 2.5 resolution.
- Combo model is modified version of 10/31/07 download.
- 1st 4 years run with bad “ilat” specification, resulting in PSC scheme only being called at pressures lower than 120 hPa, with max pressure specification at high SH lats being sometimes as low as 36 hPa.
- Reran last year several times (~4 days/year @ 64 nodes); best results with latitudinally-invariant pmax of 300 hPa. (Operationally probably best to set lower bound as tropopause.)
- Also ran 1 year of GEOS 4 DAS winds (year 2004), initialized from December 1998 of AGCM run.



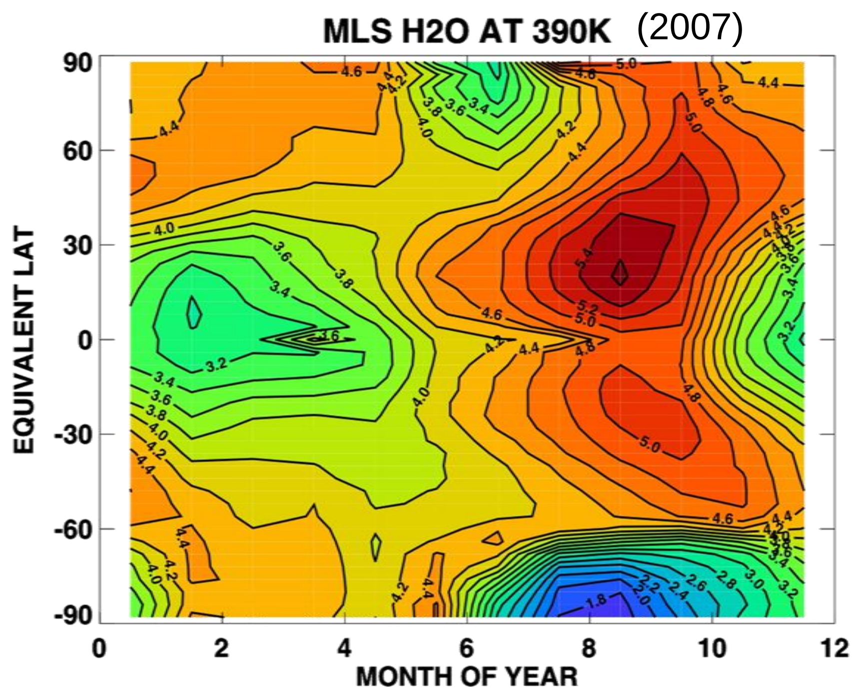
MetH2O stratosphere is HALOE/MLS climatology. Transported H_2O in stratosphere agrees pretty well overall. Transported H_2O tends to be higher just above tropopause at mid-to-high lats. Diffs could also be due to interannual variability.

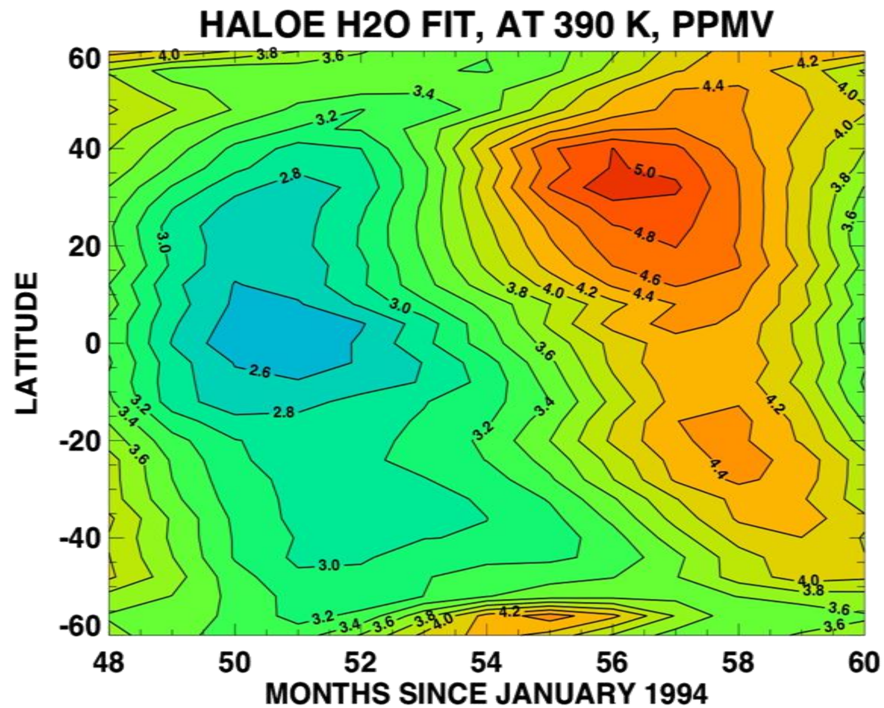


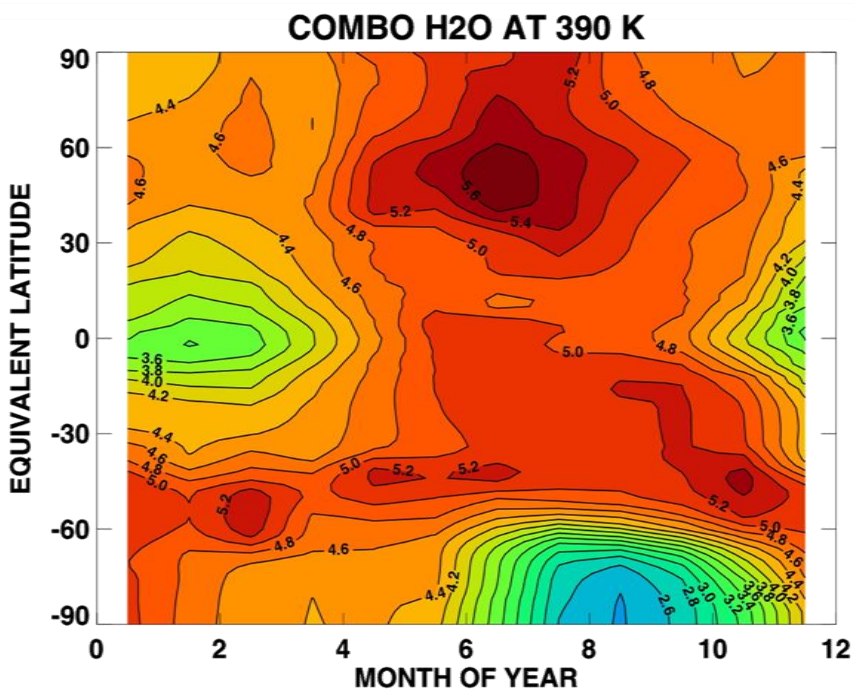


Model exhibits lower stratospheric ascent rate of ~ 0.3 mm/s, consistent with HALOE obs, with ascent rates increasing above 20 - 25 km as observed. Tape recorder signal remains coherent to higher altitudes (> 30 km) than observed, due to lack of QBO and perhaps a weak SAO. US values are slightly smaller than HALOE observation, and there may be a small decreasing trend. Lower stratospheric minima and maxima agree well with obs.

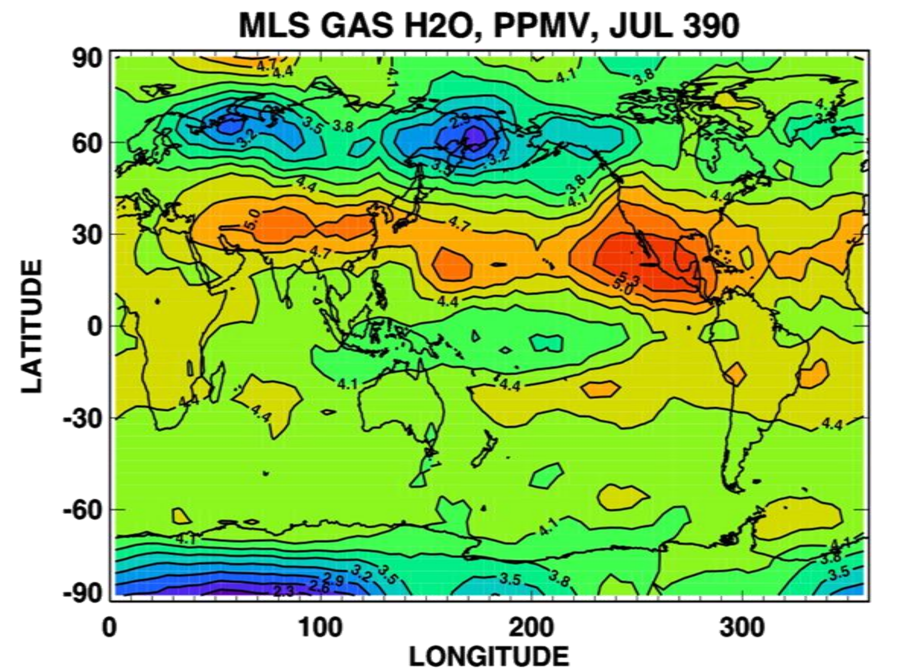
HALOE v19 H2O data, 1994 - 1998, 4° latitude bins, at equator, regressed to annual and semiannual harmonics only, as in Randel et al. [2001].

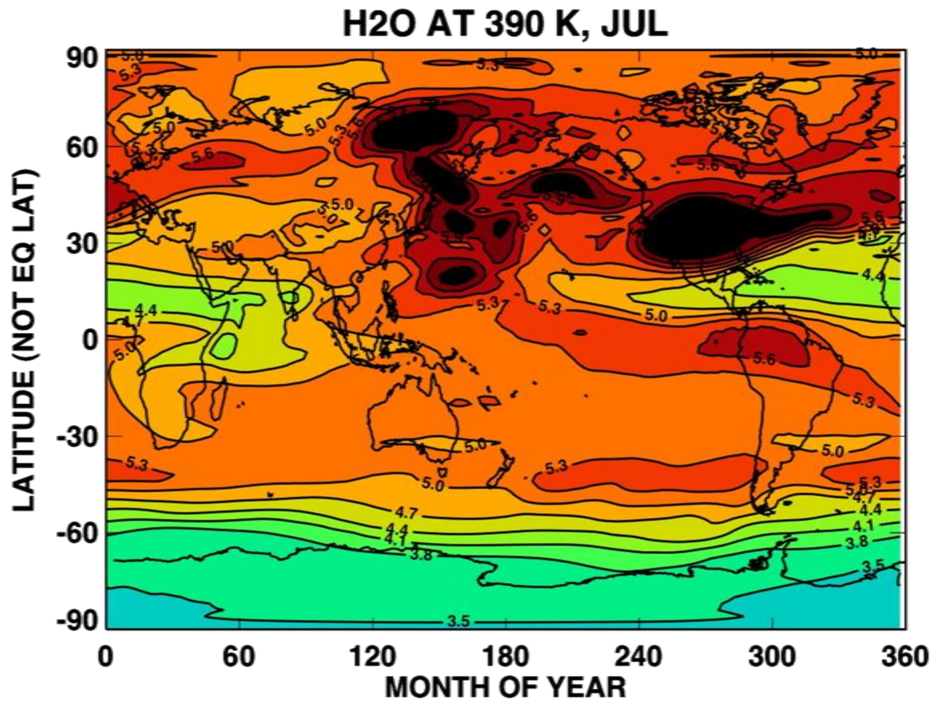


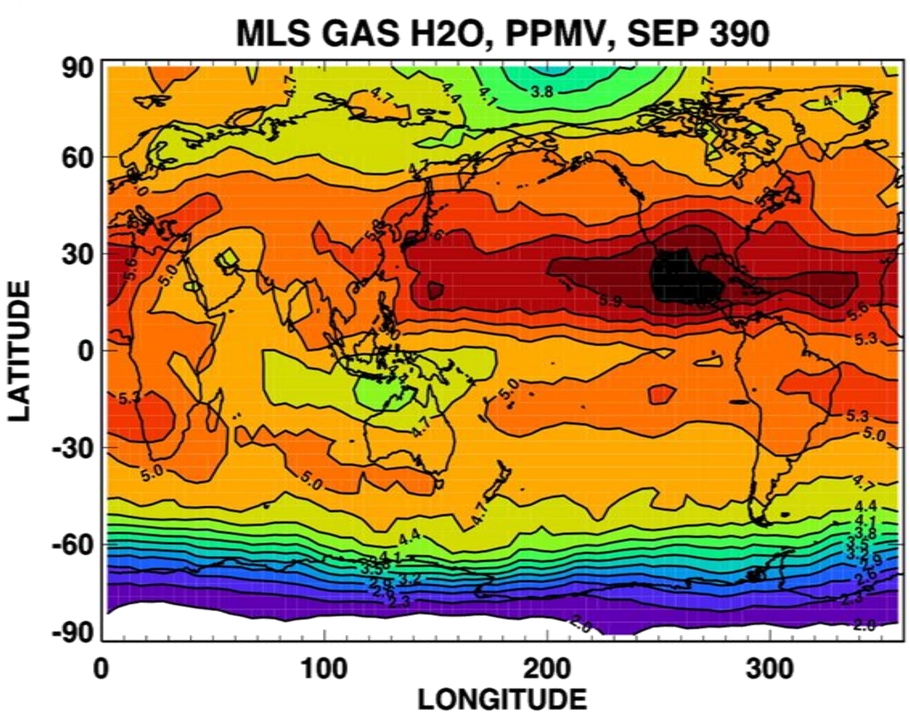




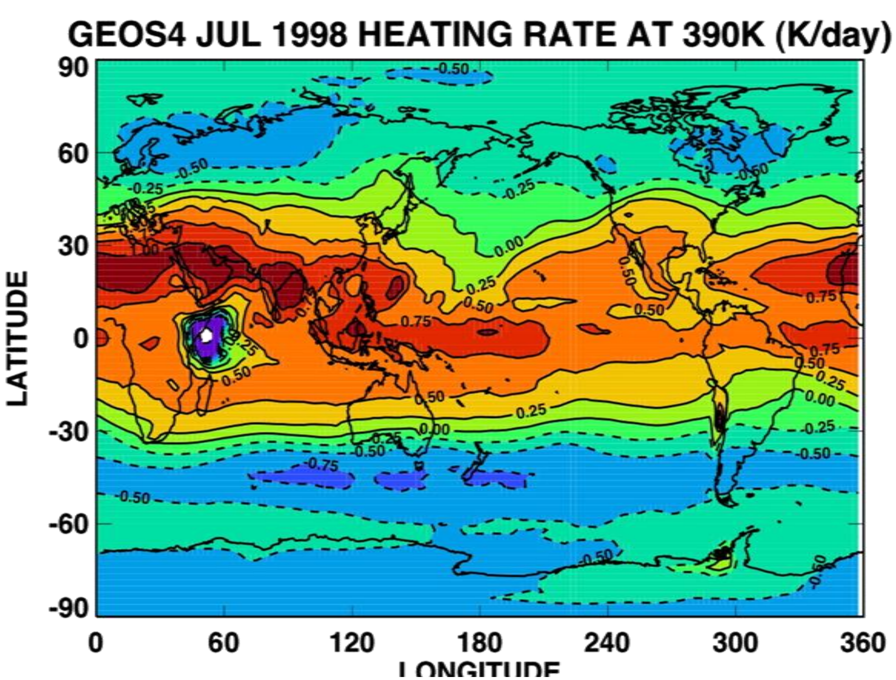
At base of overworld, GMI transported H_2O shares similarities with MLS H_2O. Evidence of poleward transport extending from tropical minimum in February is weak. NH H_2O Max (associated with NH summer monsoon in atmosphere) is right magnitude, but occurs 2 months too early and ~20^o poleward of observed position. SH H_2O max in model occurs too late. Model exhibits high H_2O along stormtracks in SH, which is not observed. SH polar minima are higher than observed in MLS, perhaps due to interannual variability, but timing is correct.

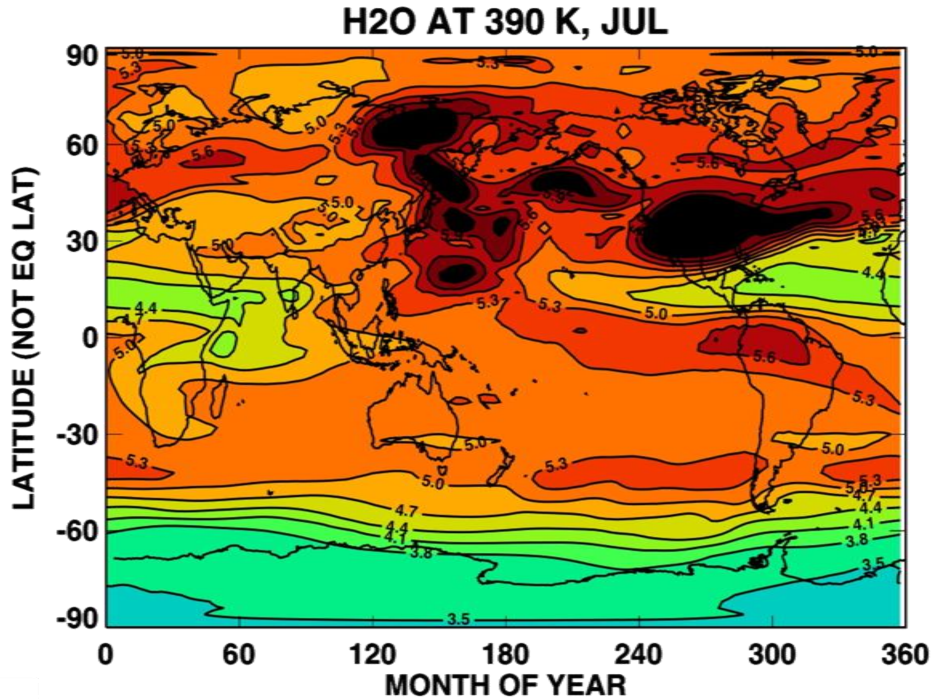


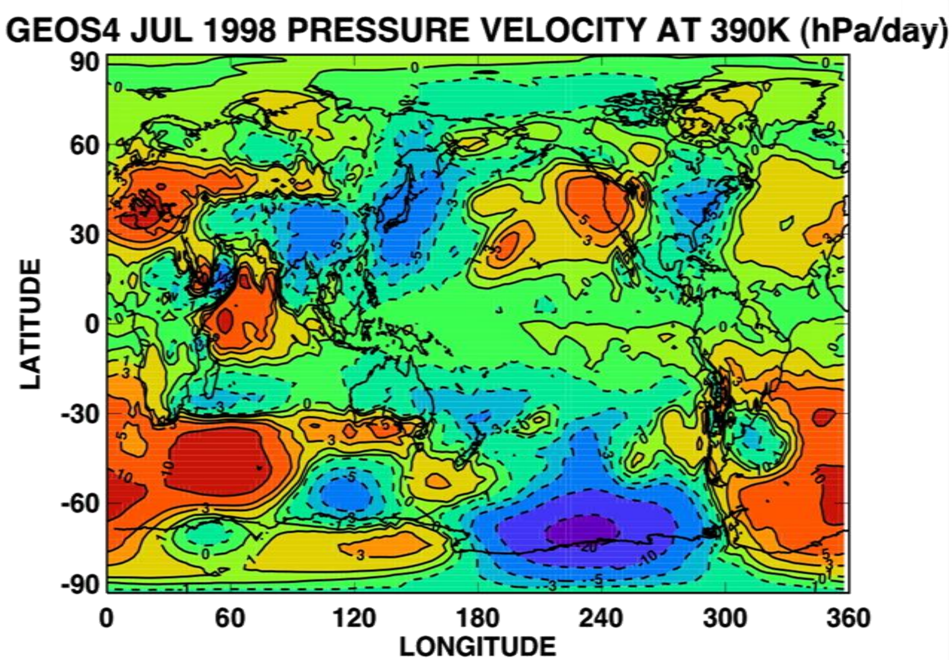




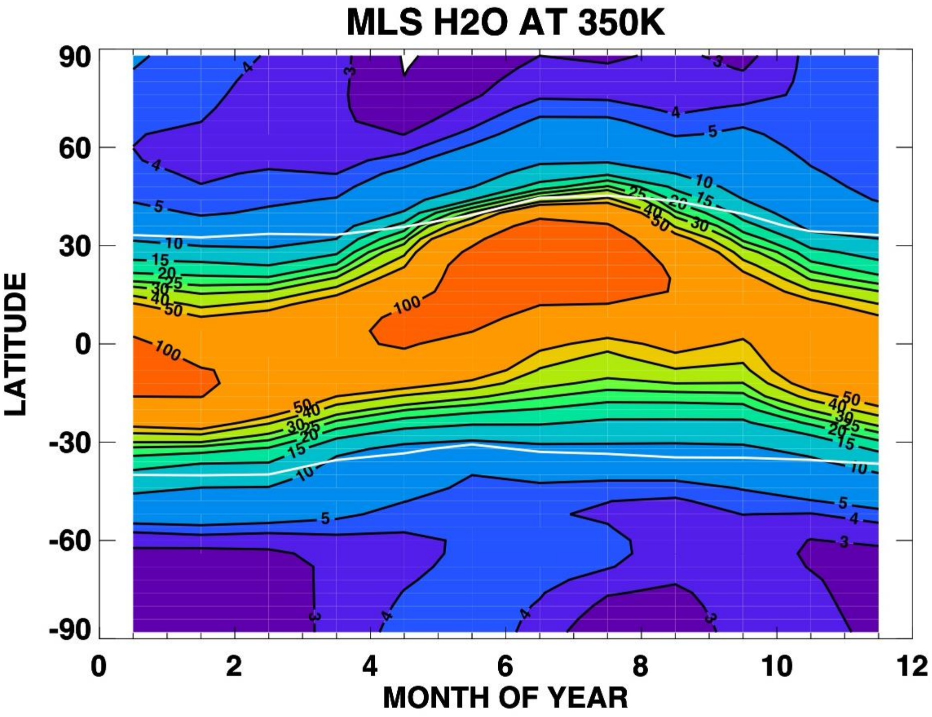
In July, MLS H2O maxima occur over Central America, western Pacific and Tibetan plateau. Model has larger maxima over CONUS and western Pacific as far north as 70º. The MLS Central American maximum is stronger in September and is apparently responsible for annual cycle peak.

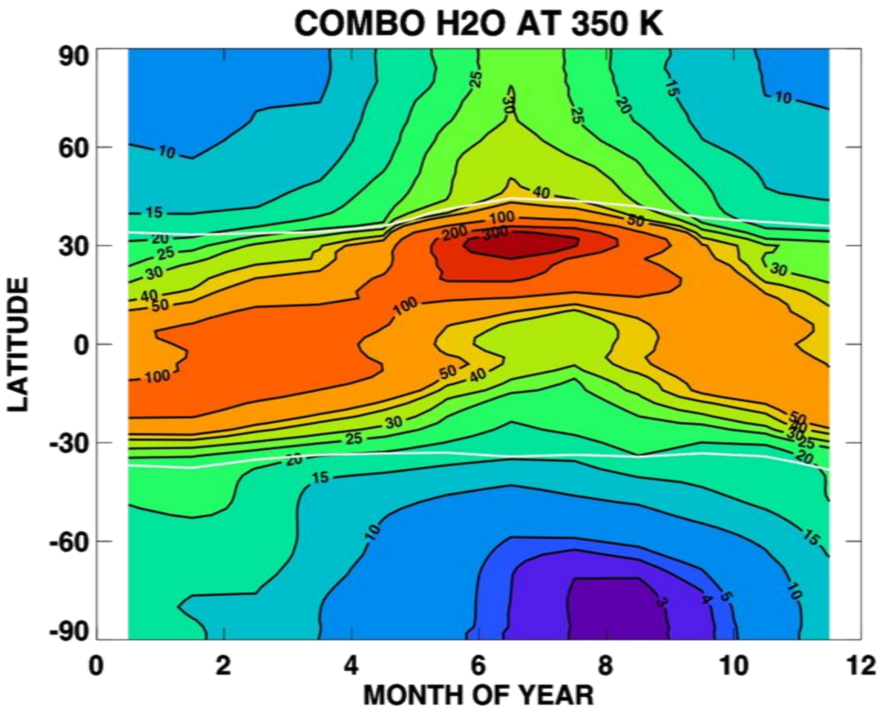




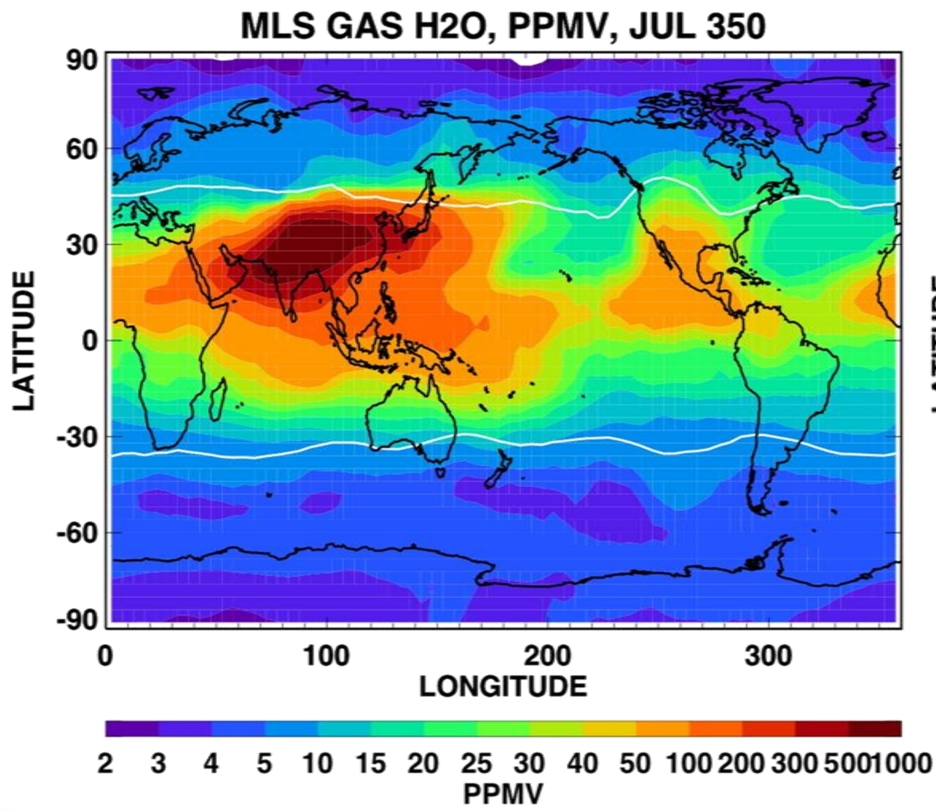


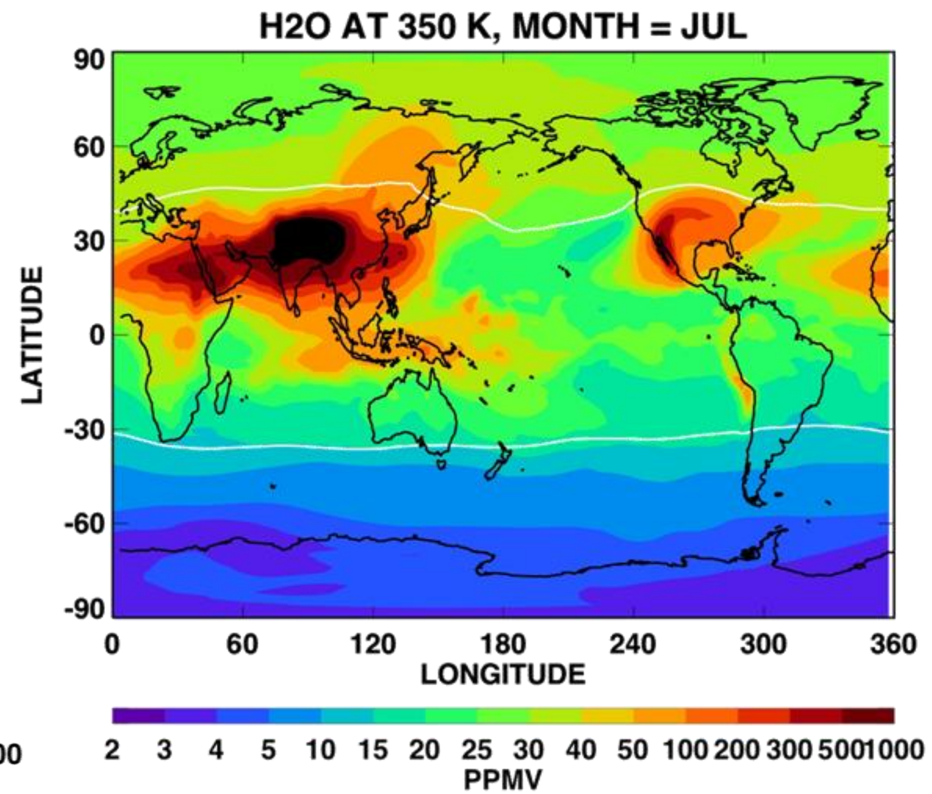
GEOS 4 Heating rates at 390K are positive between ~ (30S - 40N), and negative poleward. Morphology of high H2O values does not reflect heating rates. Vertical pressure velocities are generally negative (i.e. upwelling) in NH where 390K H2O mixing ratios are large.



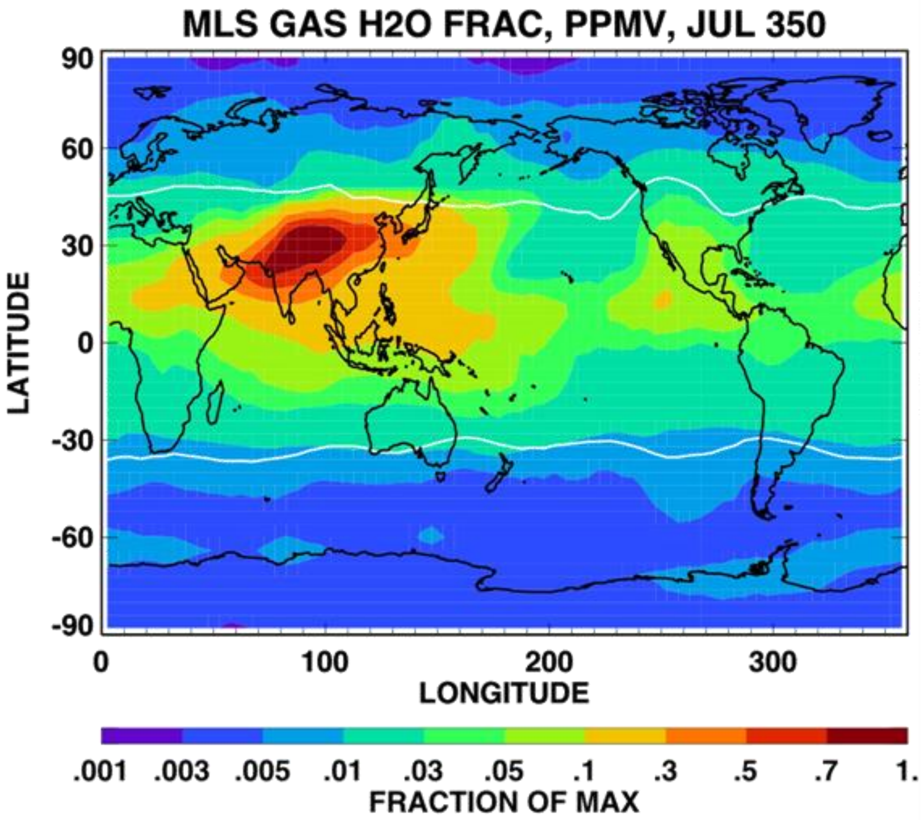


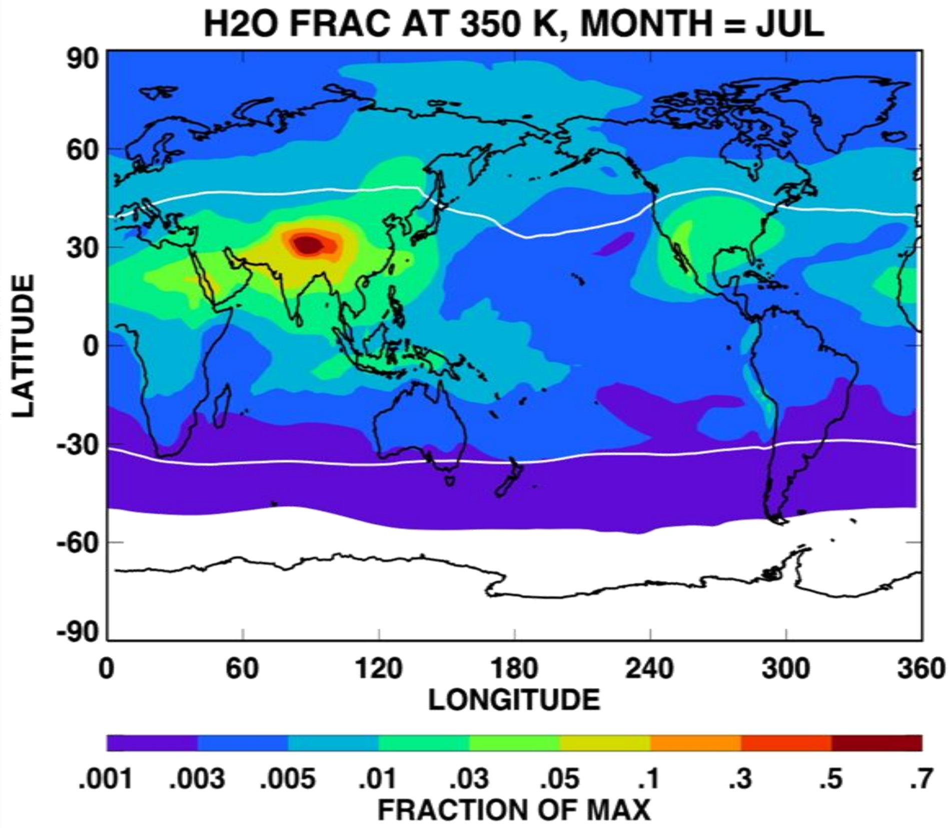
The 350 K surface is approximately coincident with the 215 hPa surface, and crosses from the tropical UT into the lowermost stratosphere poleward of the tropopause. Model H_2O is higher than observed in tropics, where water vapor is met water field, and shows substantially higher values than observed by MLS in the LMS.
MLS values are extremely low, lower
even than at the tropical cold point from which they are supposed to have been transported.



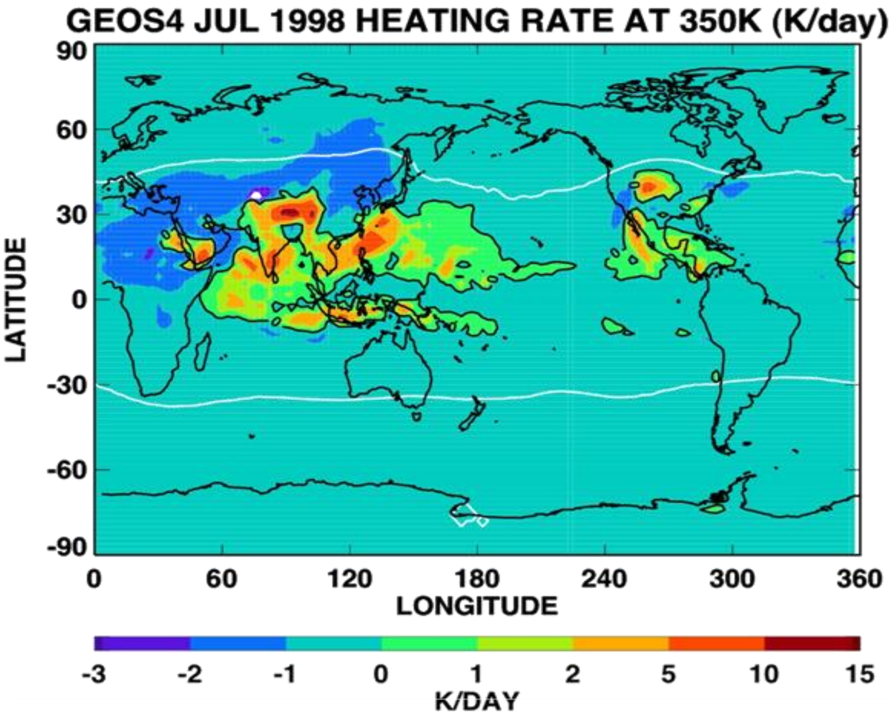


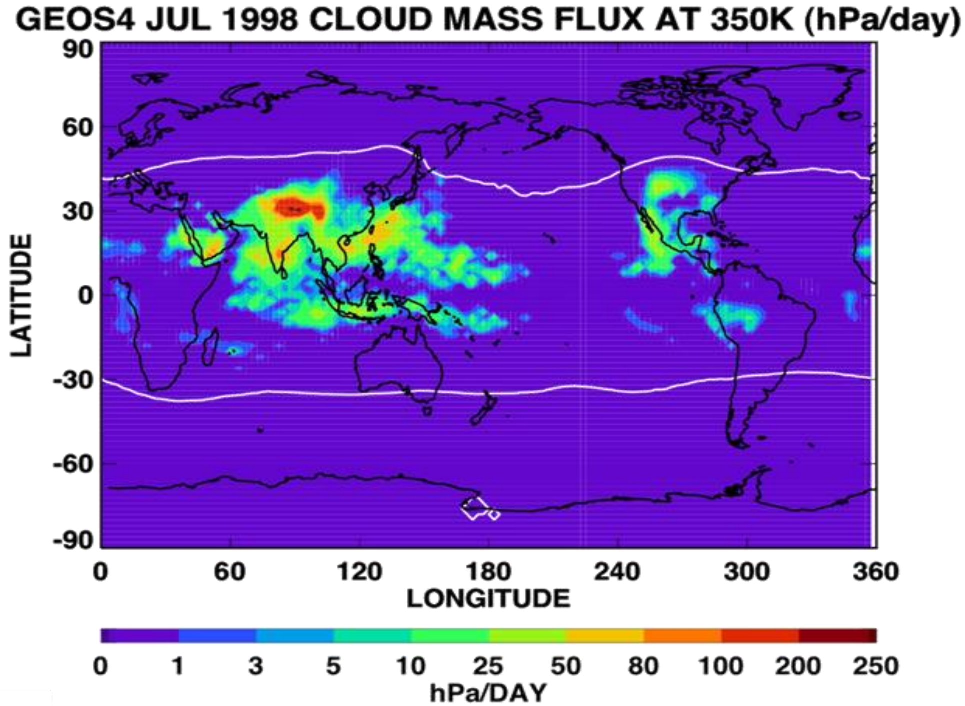
In NH LMS, MLS mixing ratios are < 15 ppmv. Combo model H_2O mixing ratios range from 25 - 100 ppmv in LMS. Model H_2O in LMS appears to have been transported from maximum over northern India and Tibetan plateau, with secondary contribution from west coast of northern and central America. Model shows ridge of high H_2O running along west coast of South America that is not observed.

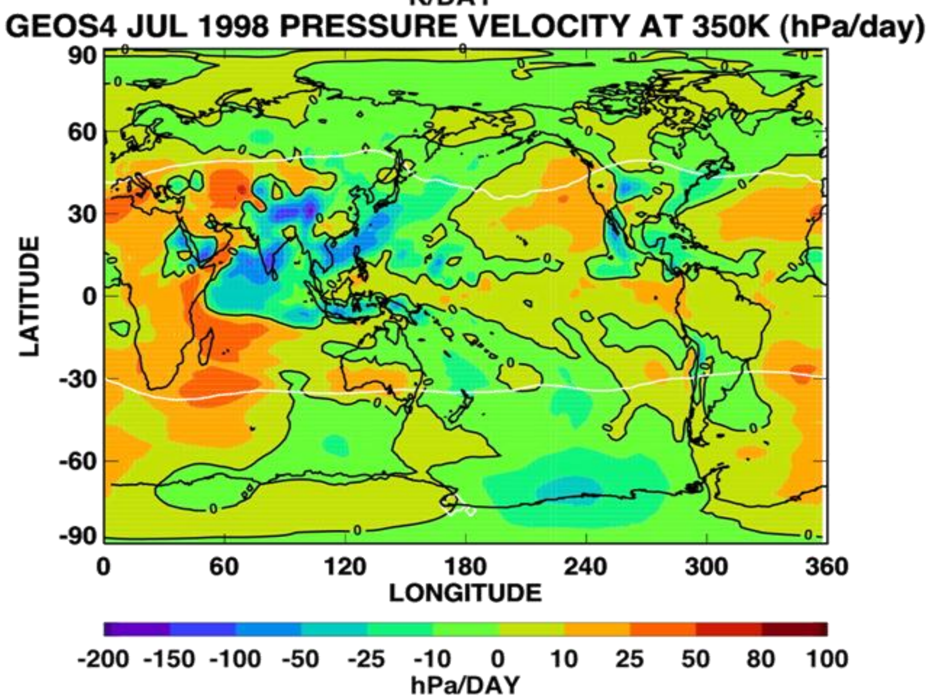




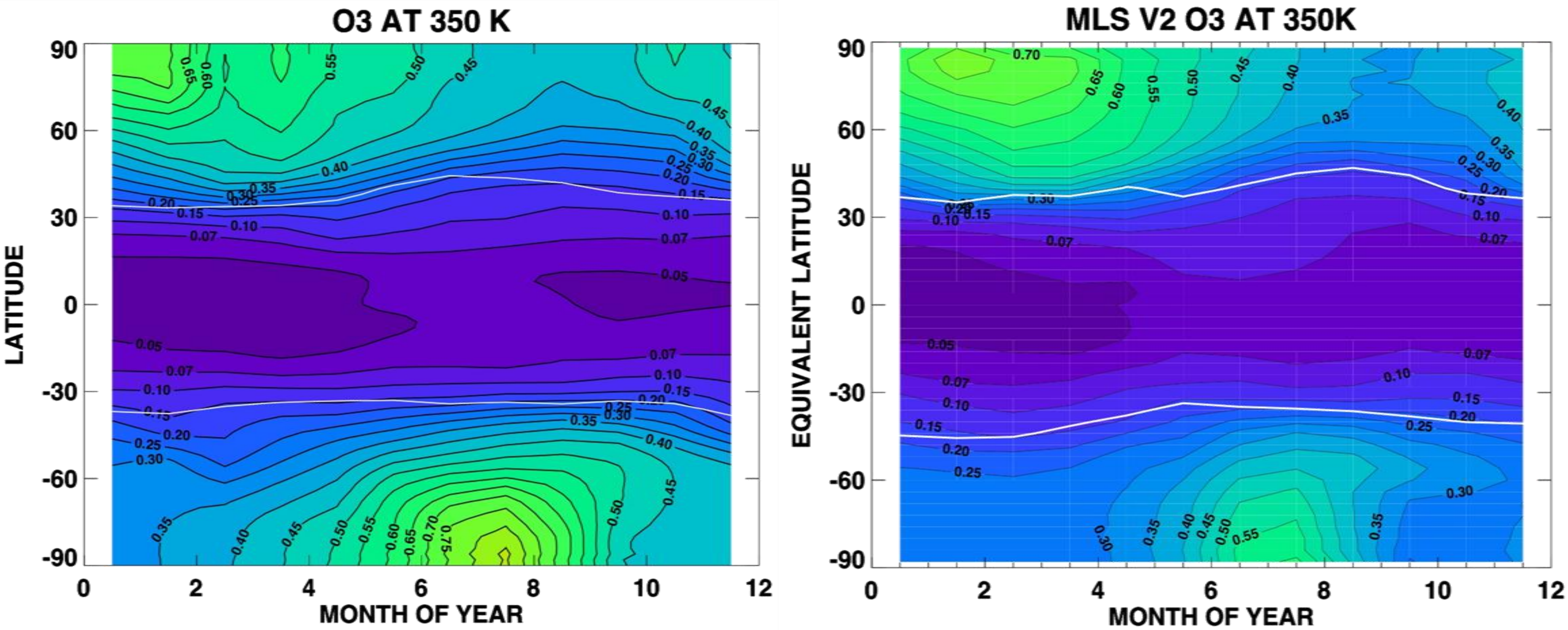
Plotting fraction of H_2O maximum on 350 K surface shows that Combo model distribution is more sharply peaked than observed by MLS. In NH LMS, model H_2O fraction is smaller than seen in MLS. This indicates that model tropopause transport barrier may be fine, and that excessive H_2O in the LMS is due to excessive vertical transport of H_2O in tropics over Tibetan plateau.



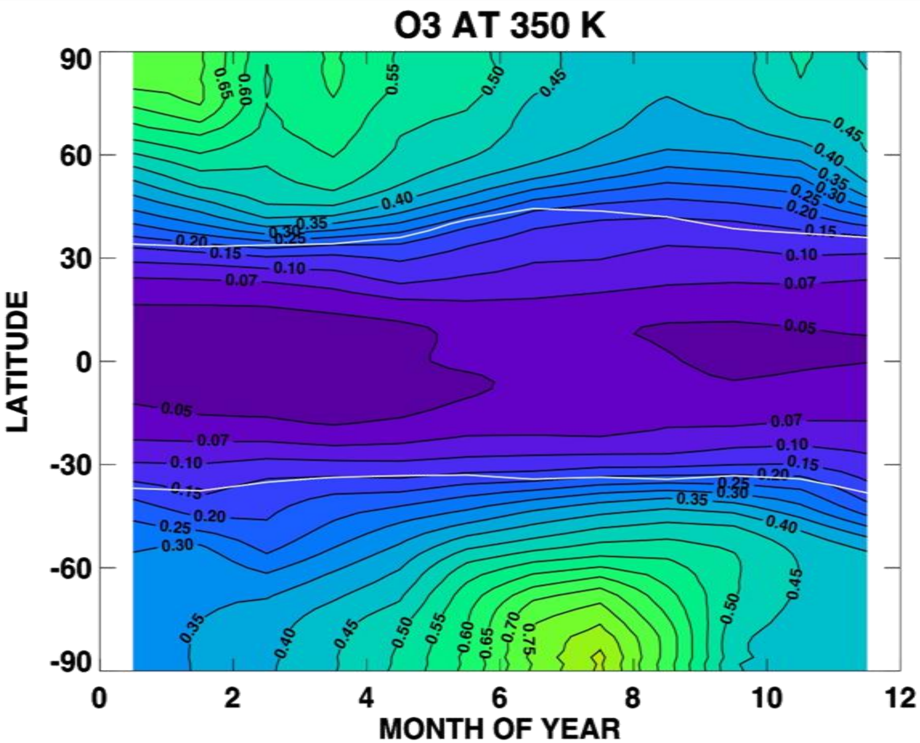


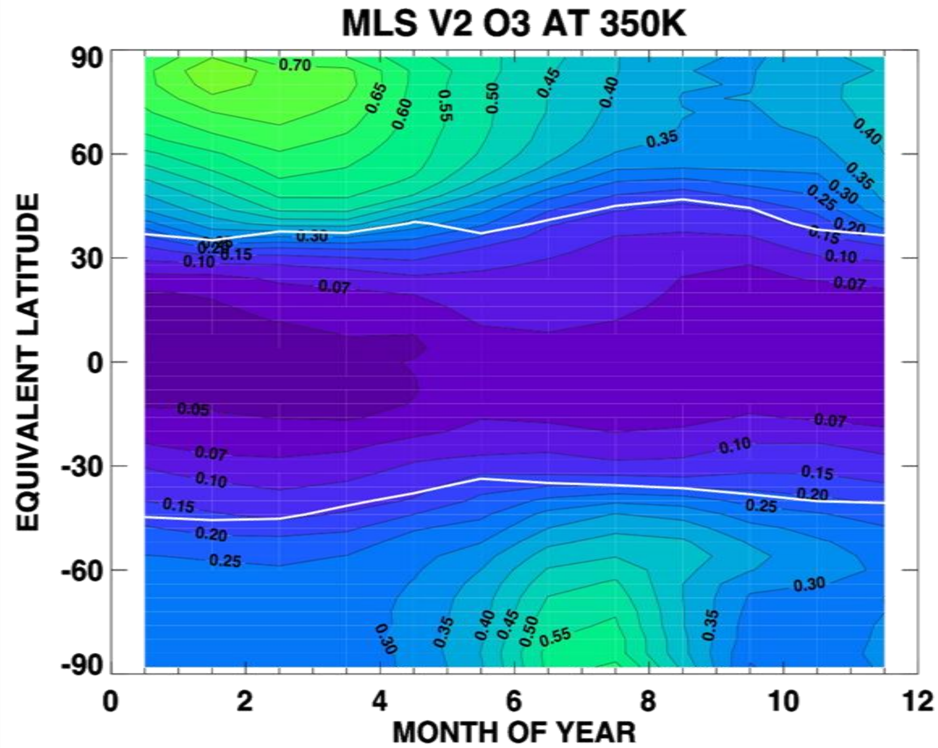


Convective heating rates, cloud mass fluxes and negative pressure velocities maximize over Tibetan plateau & southeast Asia, indicating both large-scale and convective contributions to vertical transport to 350 K isentrope. In LMS, negative heating rates and zero convective mass fluxes indicate any transport from below which might contribute to high water vapor mixing ratios is anomalous.



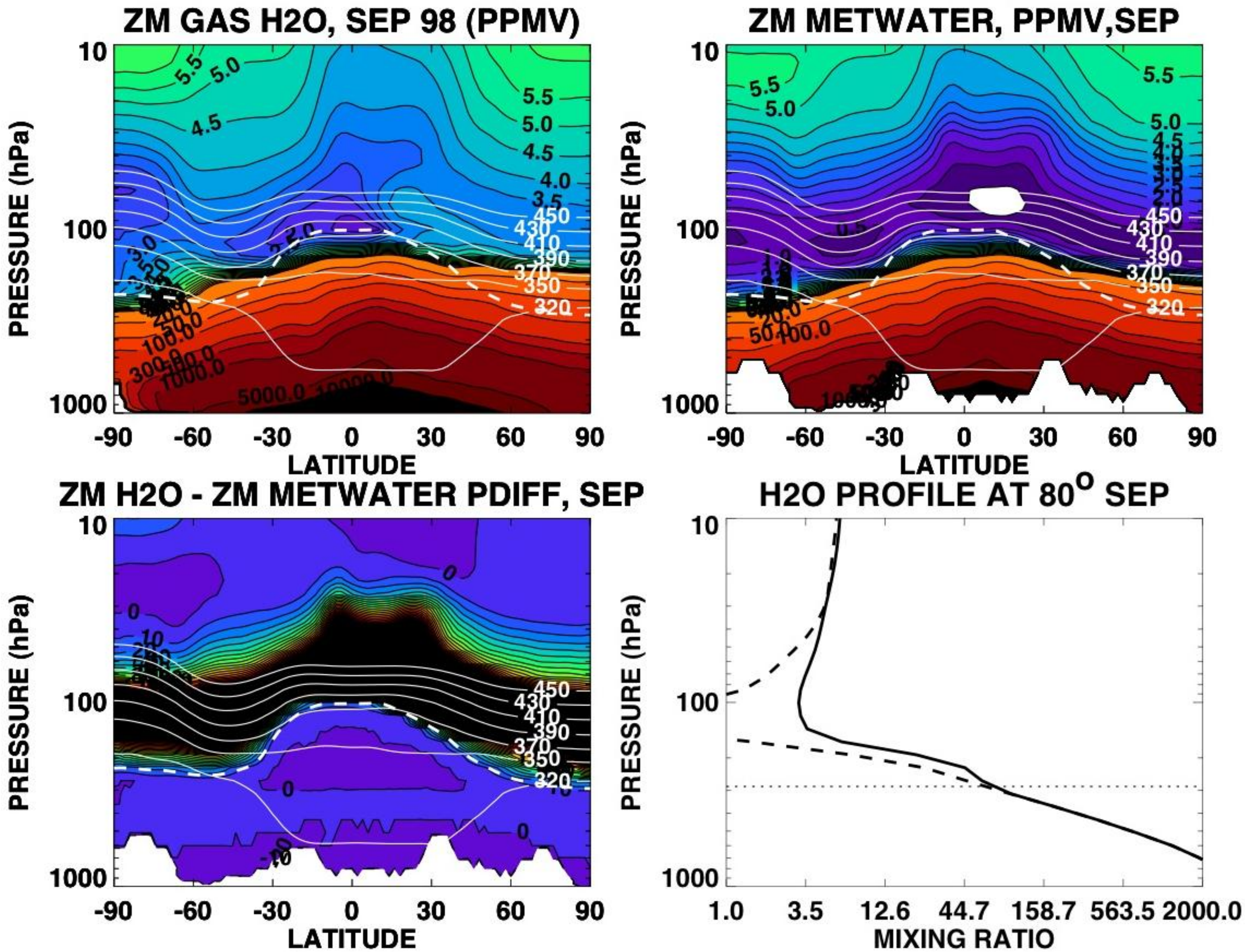
- At 350 K, Combo Model and MLS O_3 are in good agreement at high lats, as shown for v 1.5 MLS data in Strahan et al. [2007]. High lat fall O_3 minimum not as low in Combo model as is observed (Consistent with Strahan et al. [2007].)
- High bias in Combo H_2O at high lats would suggest concurrent low bias in O_3 if purely excessive isentropic transport caused H_2O high biases.
- Summer/fall O_3 high-bias in model may be due to insufficient isentropic transport from lower latitudes.
- Note good agreement in tropics; Strahan et al. [2007] found v 1.5 MLS high-biased with respect to Combo model.



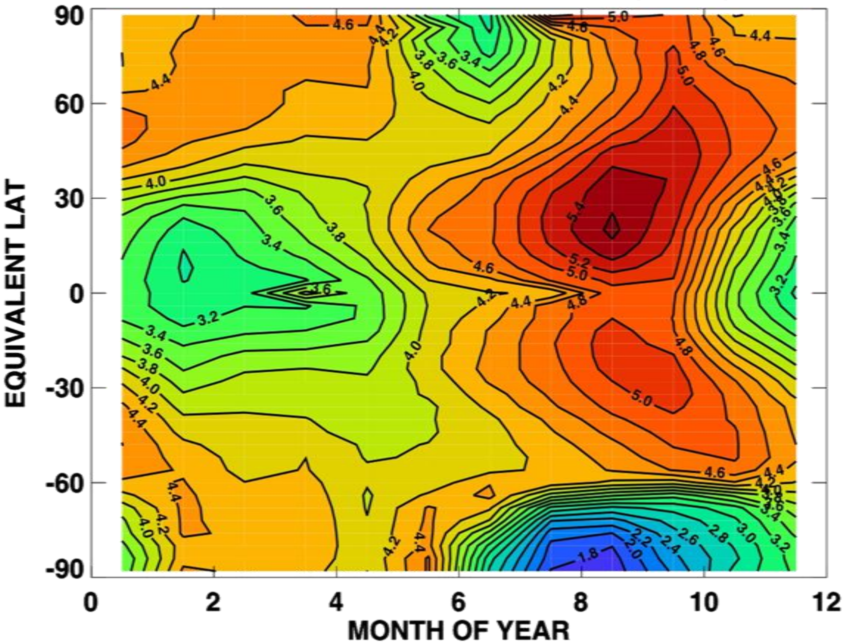


- At 350 K, Combo Model and MLS O_3 are in good agreement at high lats, as shown for v 1.5 MLS data in Strahan et al. [2007]. High lat fall O_3 minimum not as low in Combo model as is observed (Consistent with Strahan et al. [2007].)
- High bias in Combo H_2O at high lats would suggest concurrent low bias in O_3 if purely excessive isentropic transport caused H_2O high biases.
- Summer/fall O_3 high-bias in model may be due to insufficient isentropic transport from lower latitudes.
- Note good agreement in tropics; Strahan et al. [2007] found v 1.5 MLS high-biased with respect to Combo model.

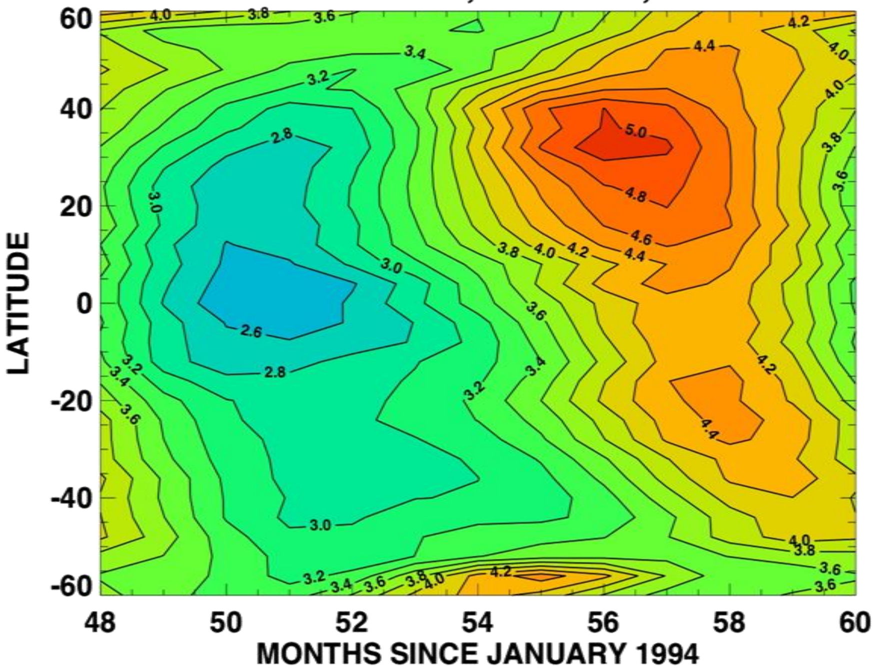
Effects of GEOS 4 DAS met fields. GEOS 4 DAS uses TOVS moisture retrievals above 200 hPa, where it is very dry and there is no information. GEOS 4 DAS cold point temps are lower than GEOS4 AGCM, leading to low water vapor values in tropical lower stratosphere.



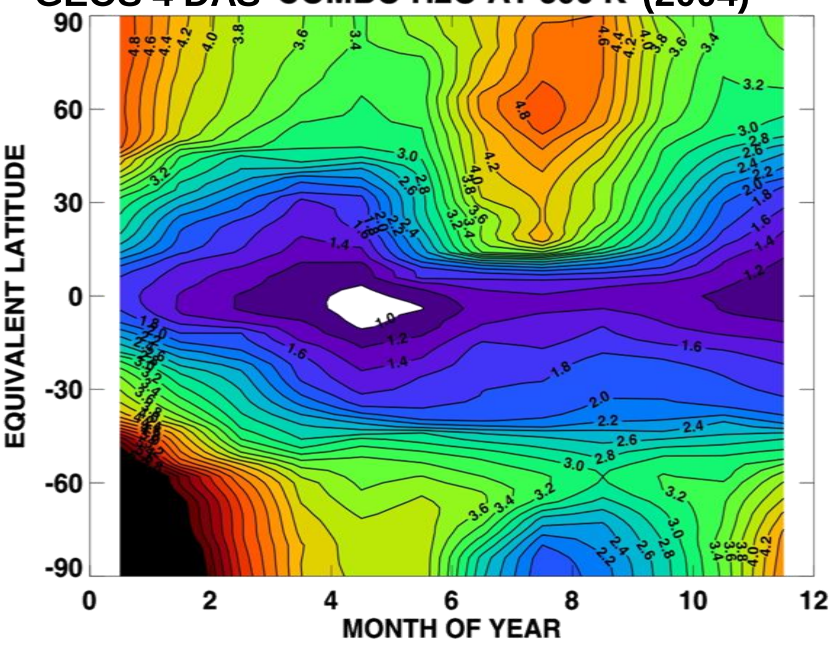
MLS H2O AT 390K (2007)



HALOE H2O FIT, AT 390 K, PPMV

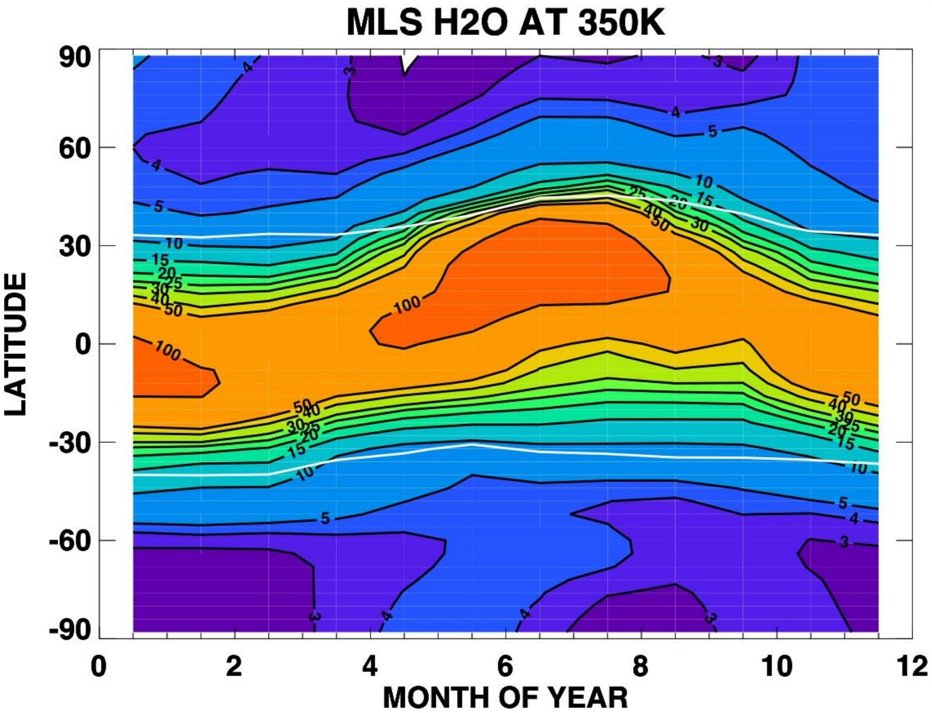


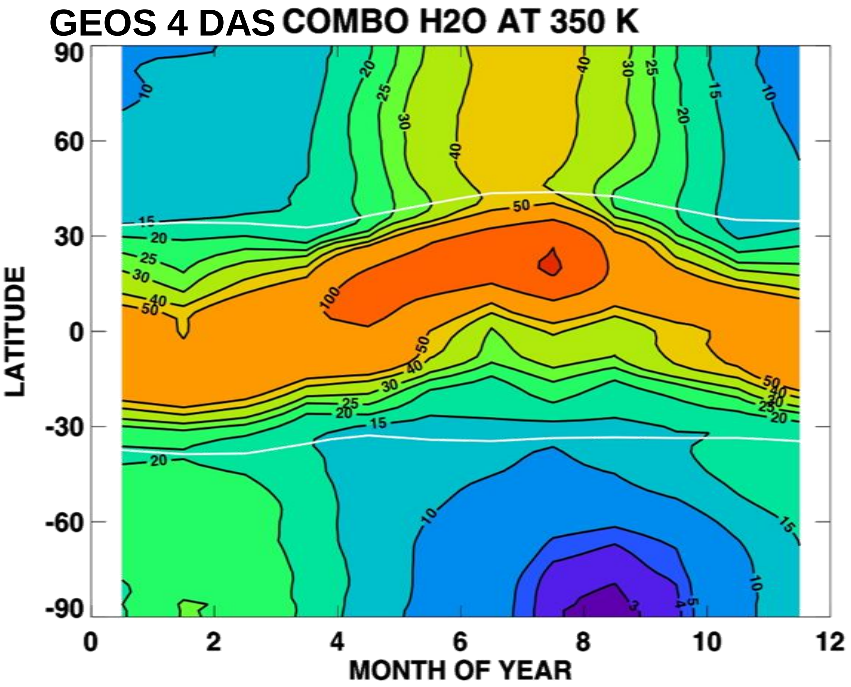
GEOS 4 DAS COMBO H2O AT 390 K (2004)



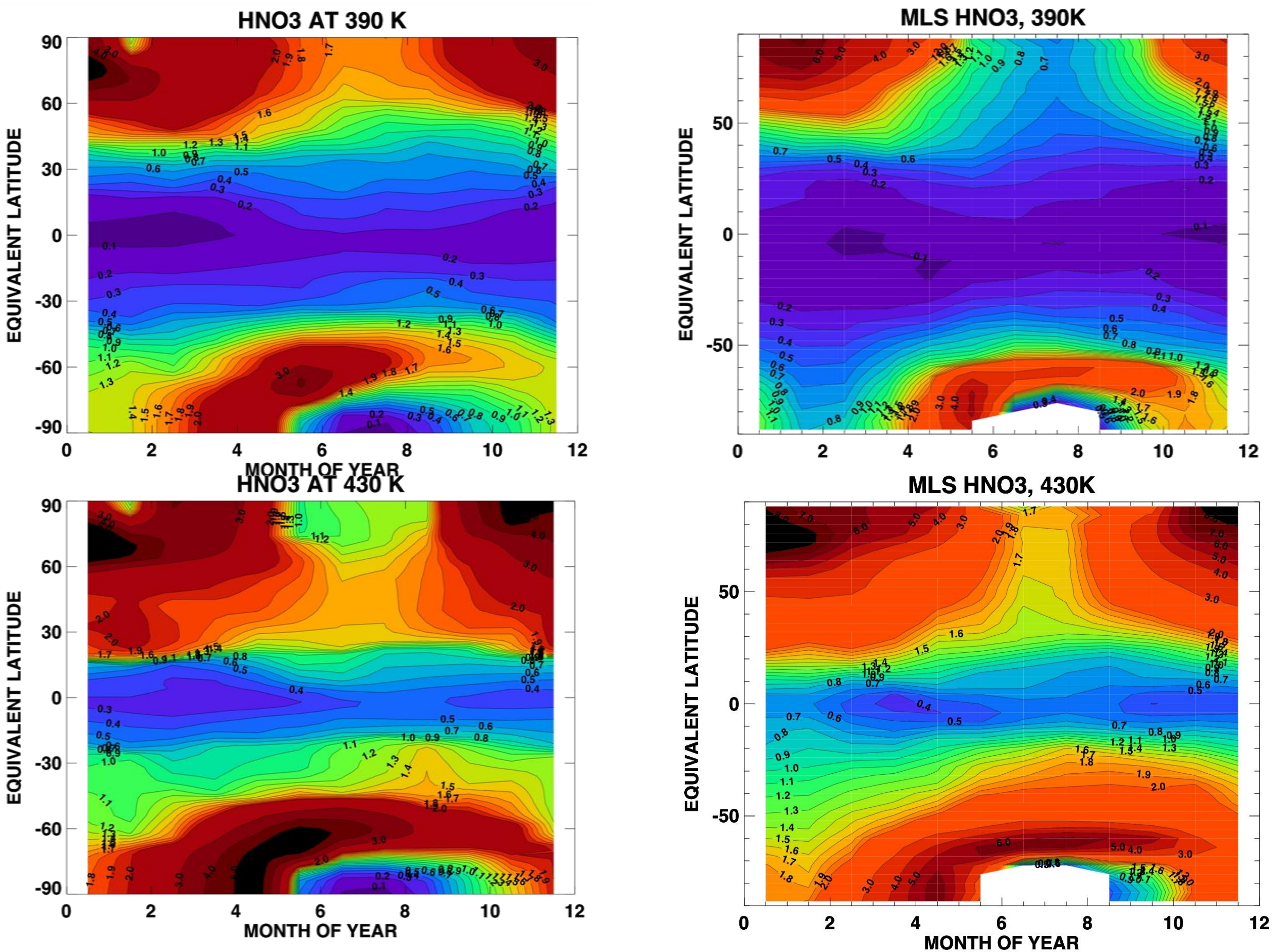
EFFECTS OF GEOS 4 DAS MET DATA

When driven by the GEOS 4 DAS met data, annual cycle of H2O at base of overworld shows much lower than observed mixing ratios in the tropics due to the ~5 degree colder temperatures than seen in GEOS 4 AGCM. This degrades agreement with observations shown above.





GEOS 4 DAS H2O on the 350 K surface agrees better in the tropics with MLS obs than GEOS 4 AGCM. However, There is more H2O in summer extratropics than in GEOS 4 AGCM or seen in MLS observations. Could be excessive isentropic transport or anomalous vertical transport.


HNO3 AT 390 K
MLS HNO3, 390K
HNO3 AT 430 K
MLS HNO3, 430K
EQUIVALENT LATITUDE
MONTH OF YEAR

Conclusions

1. Using G4AGCM met data, good simulation of H_2O in stratospheric overworld.
    - Model generates reasonable polar dehydration.
    - Tape recorder signal is good:
        - Overly coherent signal above 30 km understandable given lack of QBO in met data (what about SAO?)
    - Stratospheric H_2O mixing ratios not bad.
    - Annual cycle of H_2O at base of overworld (390 K) resembles patterns seen in MLS and HALOE obs, but suggestion of weaker isentropic poleward transport than seen in observations.
2. Simulation of H_2O in LMS shows deficiencies.
    - Mixing ratios appear to be too high (but MLS is dry-biased relative to AIRS by 50% at low H2O, so might not be so bad).
    - High H_2O appears to be due to excessive UT H_2O in met H_2O field, rather than excessive isentropic cross-tropopause transport - O_3 is not correspondingly low.
3. HNO3 annual cycle in lower stratosphere compares well to MLS:
    - Polar denitrification in Combo model is reasonable.
    - Summer high lat NH mixing ratios 2x high - why?
4. GEOS 4 DAS LMS more high-biased relative to obs, very low tropical lower stratosphere mixing ratios. Not as good a simulation as GEOS 4 AGCM