



***Interannual and decadal variations of water
vapor in the extratropical lower stratosphere and
underlying causes***

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**Aura 10th Year Anniversary Science Team
Meeting
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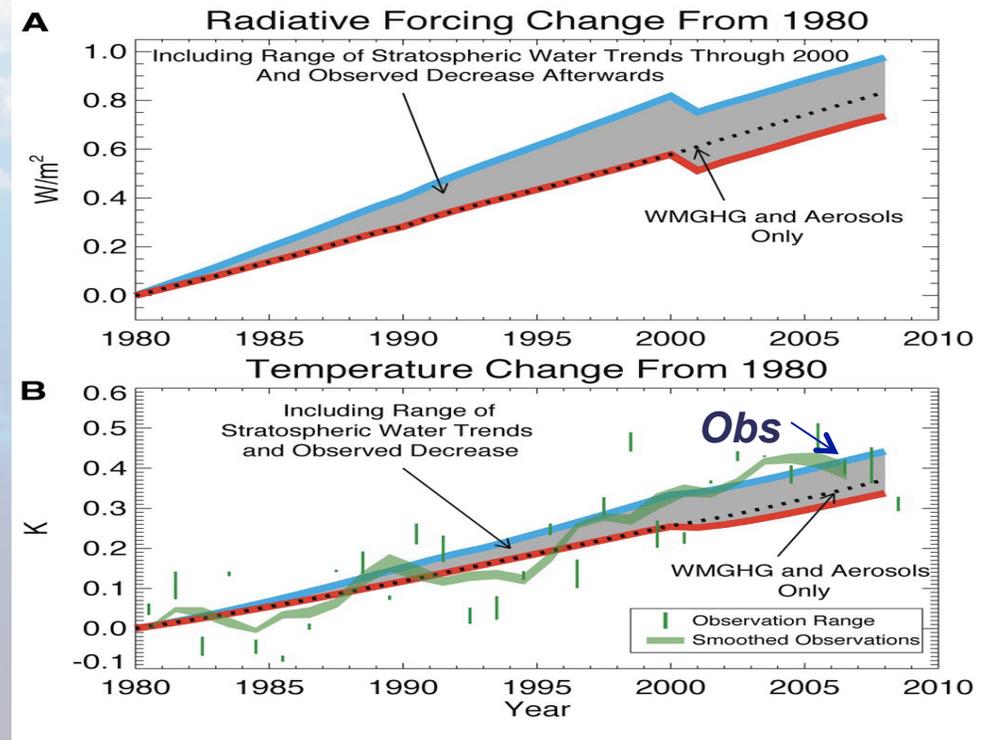
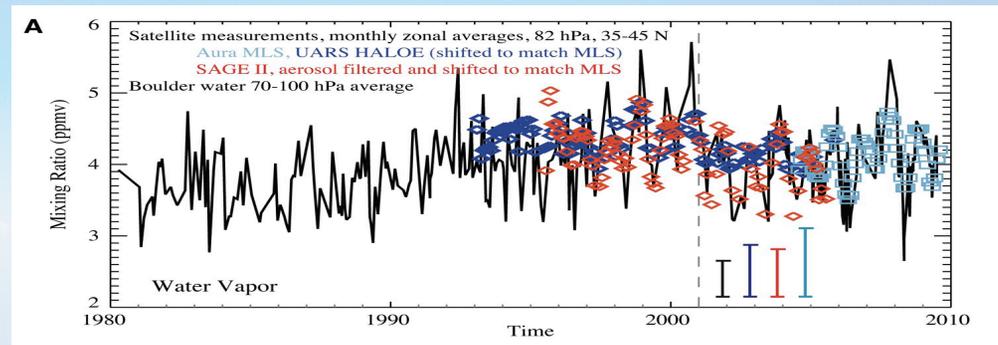
Influence of extratropical stratosphere water vapor on global climate

Solomon et al. 2010, Science:

- An increase of water vapor during 1980-2000 could have increased global warming by 30%, whereas a decrease of stratospheric water vapor have slowed the warming by 25% since 2000.

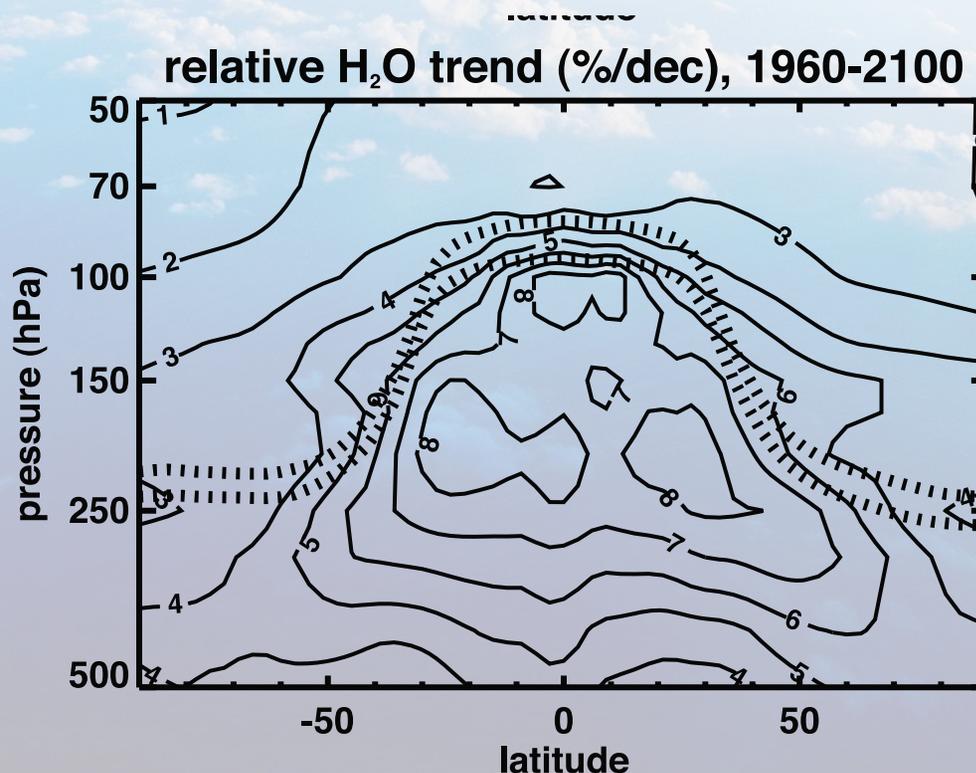
Dessler et al. 2013: PNAS

- Stratospheric water vapor feedbacks contributes $\sim 0.3 \text{ W}/(\text{m}^2\text{K})$, 1/3 from increase of water vapor entering the stratosphere in the tropics; 2/3 from that entering the stratosphere from the extra tropics.



Gettleman et al. 2010:

- **18 Coupled Chemistry-climate models project an increase of stratospheric water vapor in both tropics and extratropics (0.5-1 ppmv/century due to 1 K/century increase in cold point temperature (CPT) .**
- **Many models and the multi- model mean can now broadly reproduce recently observed decreases in (tropical) lower stratospheric water vapor, likely related to SST variability.**



However, reanalysis, satellite and in situ data have shown rather large discrepancies in variability of the water vapor in the extratropical lower stratosphere:

NH (20-70N):

- **Boulder balloon sound, ERA-I and WCAM show an increase of water vapor, also IPCC AR5 shows 1.0 ± 0.2 ppm over 16-26Km for 1980-2011.**
- **Combined satellite data: no-trend.**

SH water vapor

- **ERA-I: increasing water vapor**
- **Merged satellite data: decreasing trend**

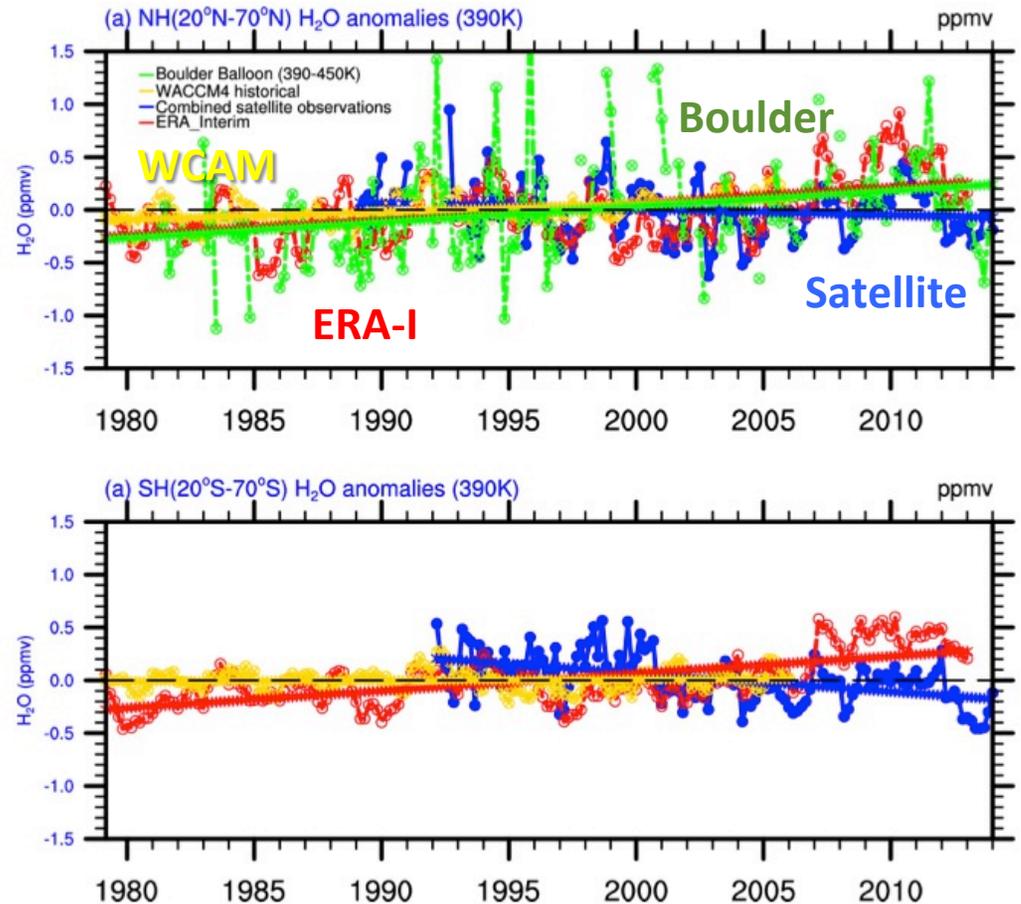
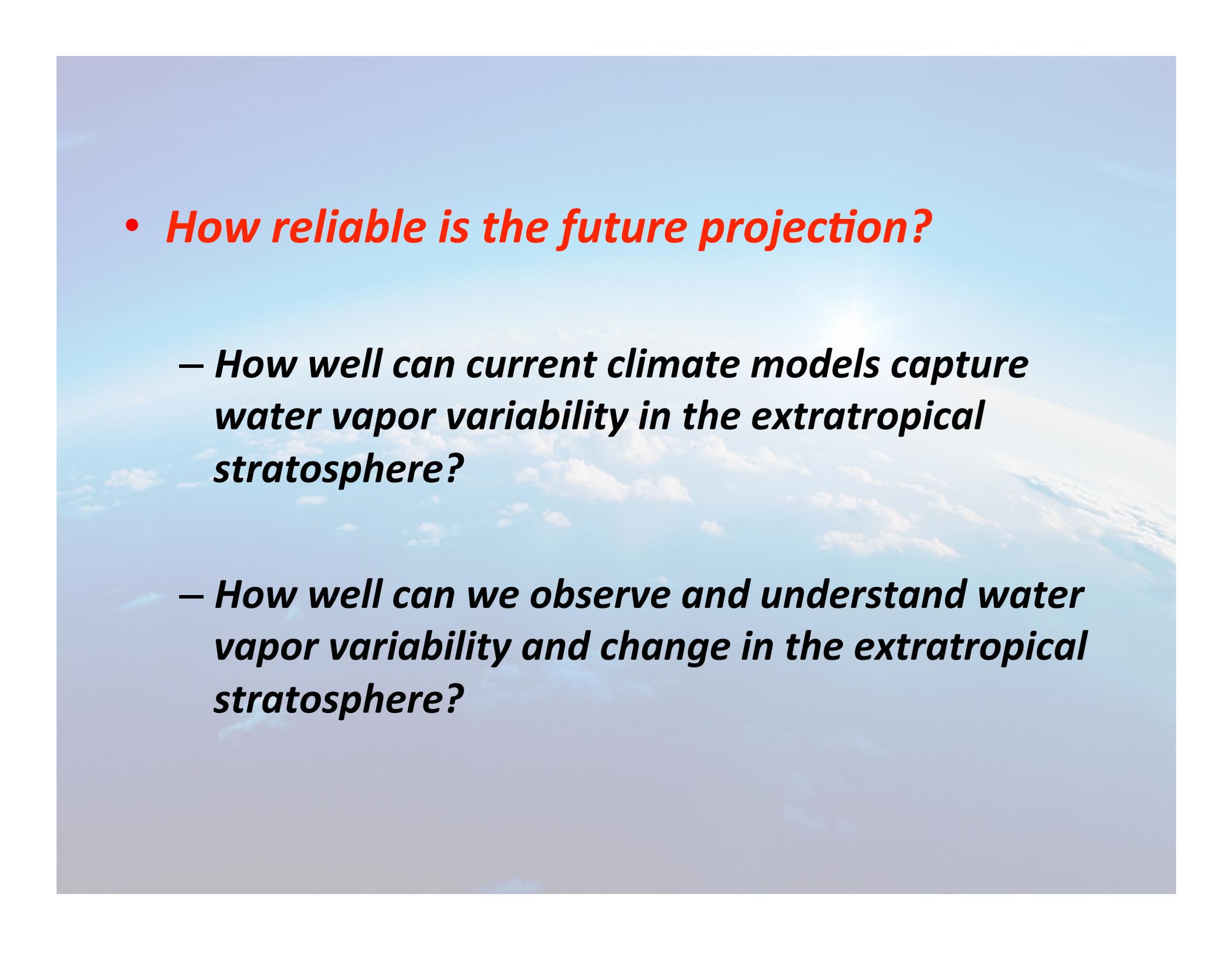


Figure 1. Time series of H₂O anomalies (unit: ppmv) in the NH (20-70N) and SH (20-70S) at 390K; Boulder Balloon observations (390-450K average).



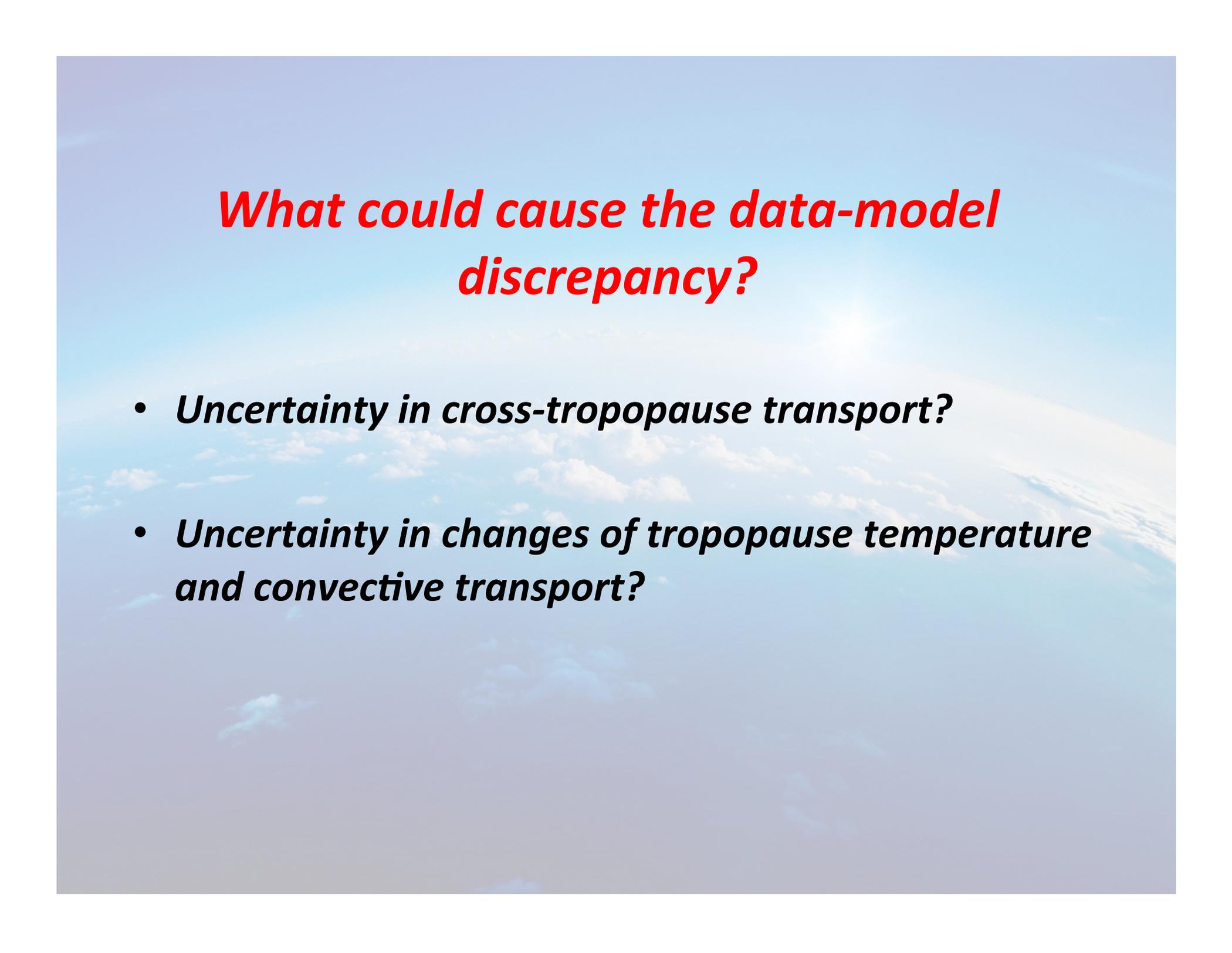
- ***How reliable is the future projection?***

- ***How well can current climate models capture water vapor variability in the extratropical stratosphere?***

- ***How well can we observe and understand water vapor variability and change in the extratropical stratosphere?***

Observations, reanalysis and models:

- ***SWOOSH (monthly, 1984-present, water vapor data from the SAGE II, UARS HALOE, UARS MLS, and Aura MLS satellite instruments);***
- ***Boulder Balloon (40N, 1980-present);***
- ***Reanalysis: ERA-Interim (1979-present), MERRA (1979-present)***
- ***Models: WACCM4, GISS ModelE historical simulations***



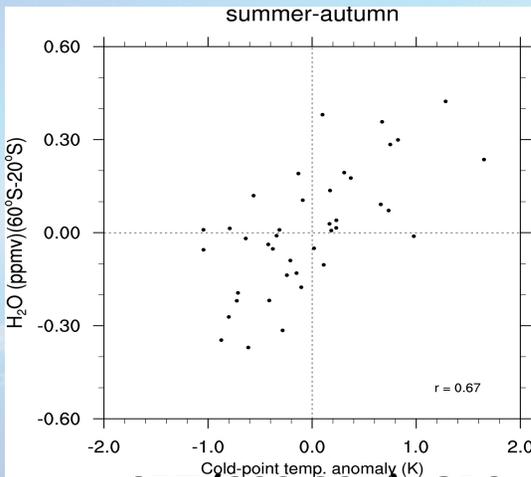
What could cause the data-model discrepancy?

- ***Uncertainty in cross-tropopause transport?***
- ***Uncertainty in changes of tropopause temperature and convective transport?***

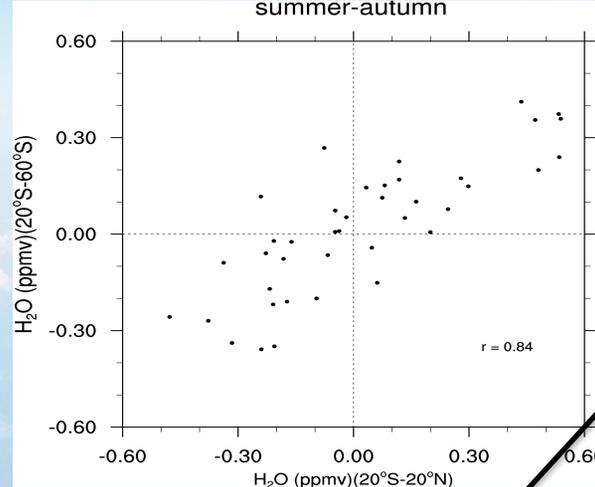
SH extratropical LS water vapor variations is controlled by the local cold points and water vapor variability in the tropics.

SH H2O vs. tropical CPT June-Nov SH H2O vs. tropical H2O

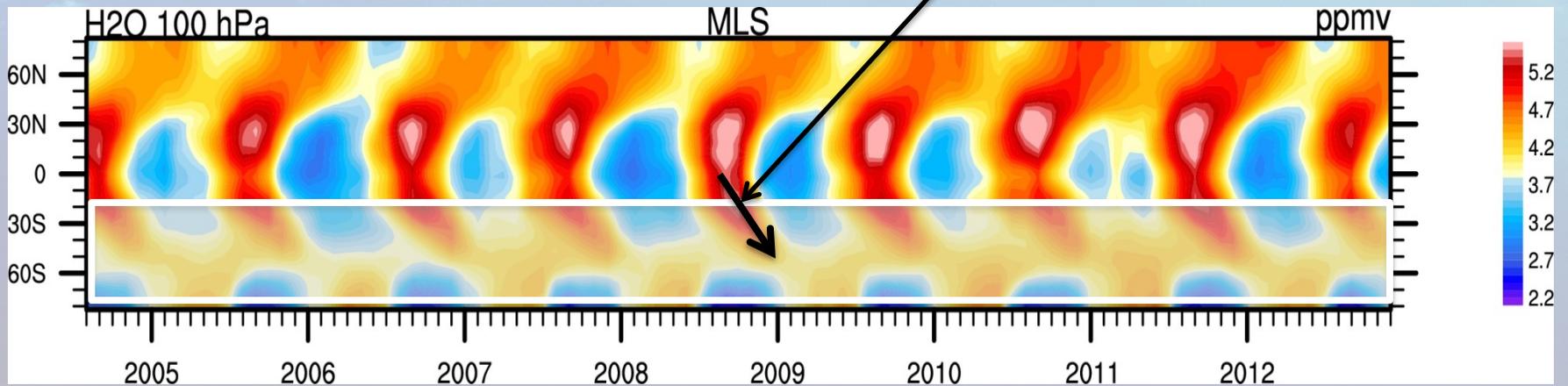
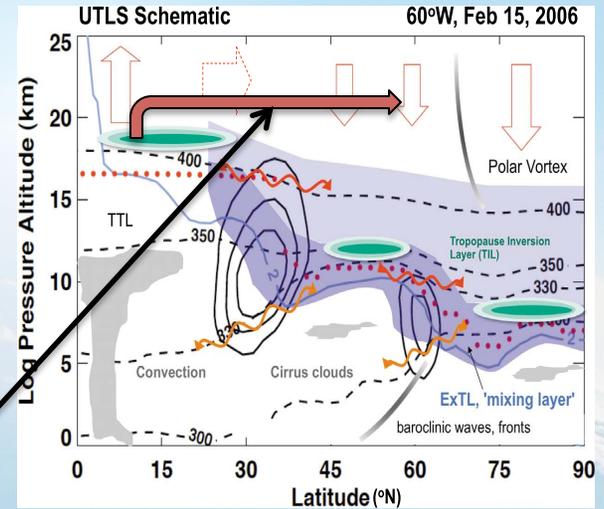
SH H2O 390K, SWOOSH



CPT (20S-20N), GPS



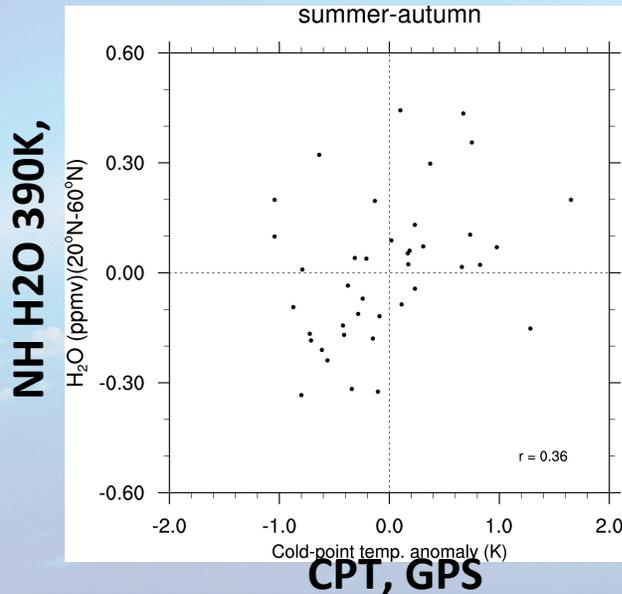
TROP H2O, 390K



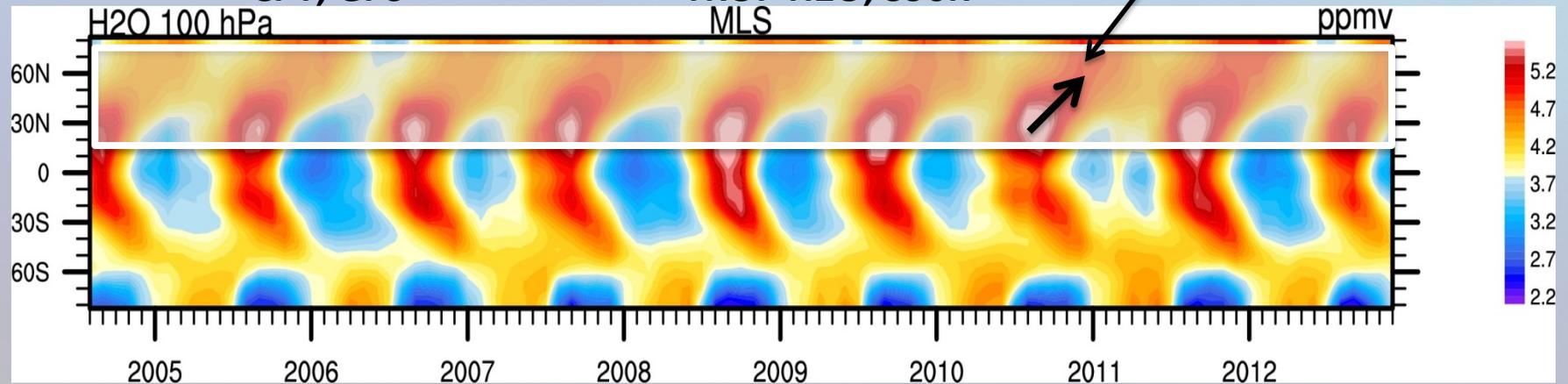
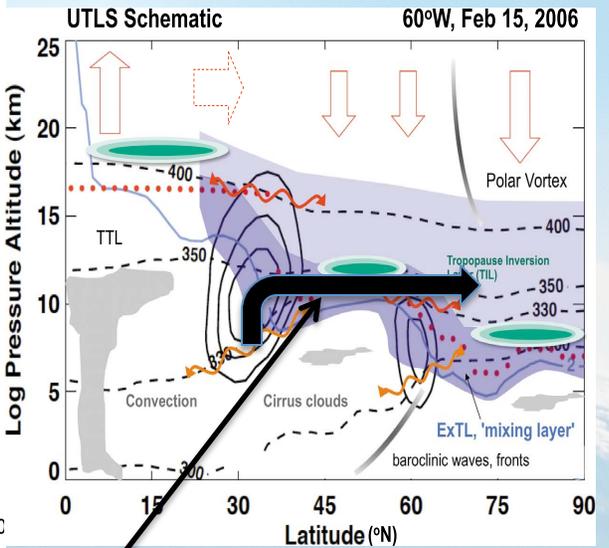
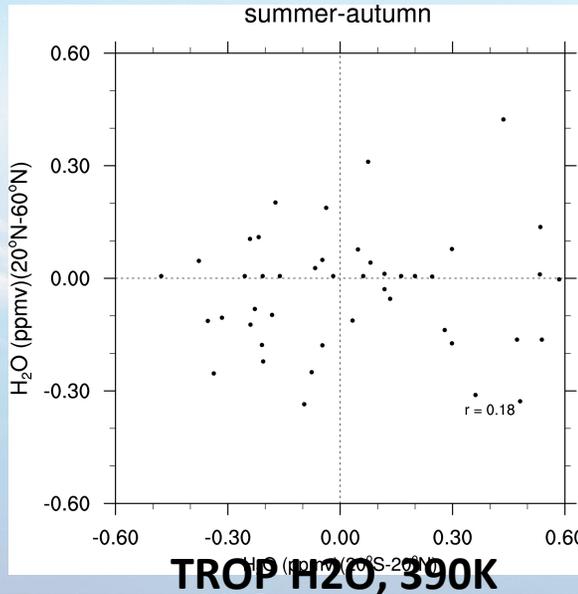
Reproduced by MLS follow Randel 2002?

NH extratropical LS water vapor variations is mainly controlled by cross-tropopause transport within extratropics.

NH H2O vs. CPT June-Nov



NH H2O vs. tropical H2O



Relative importance between Asian and N. American monsoon:

- *Partial Least square regression remove the contribution of correlated fields;*
- *Water vapor transport in Asian monsoon dominate the NH extratropical LS water vapor variability.*

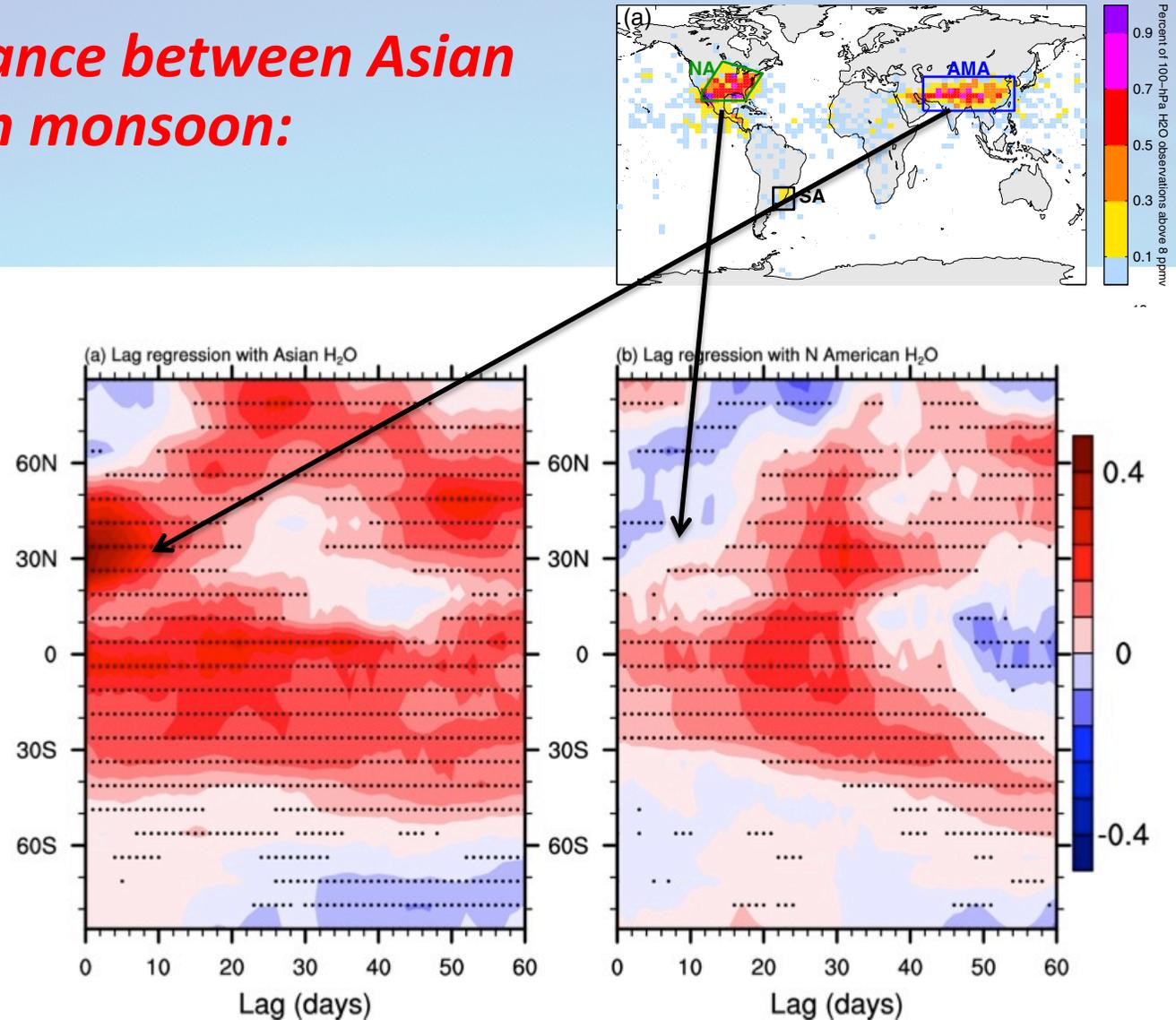
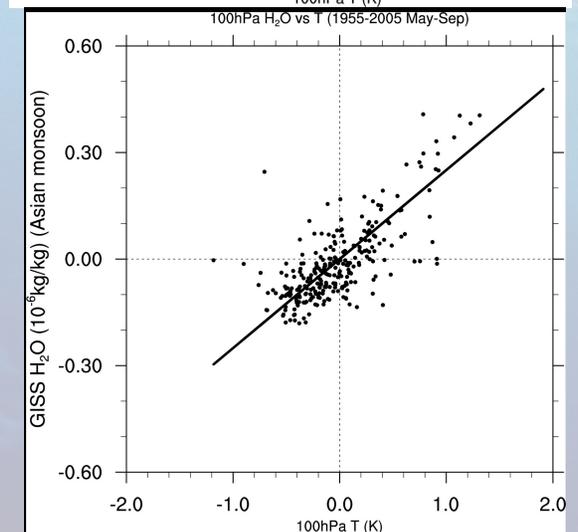
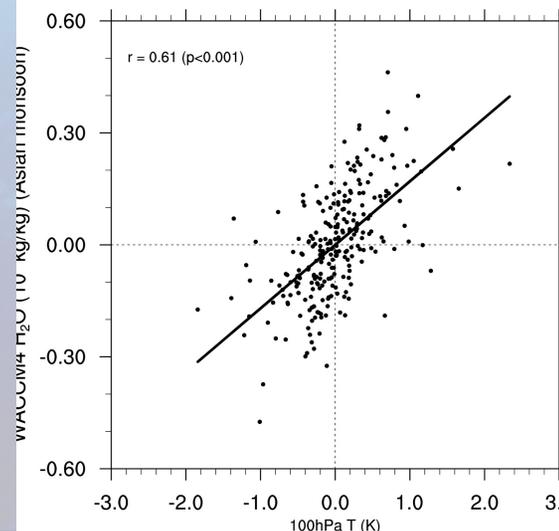
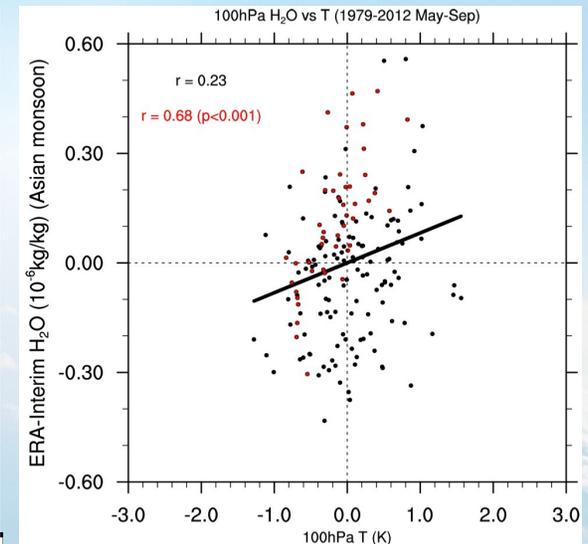
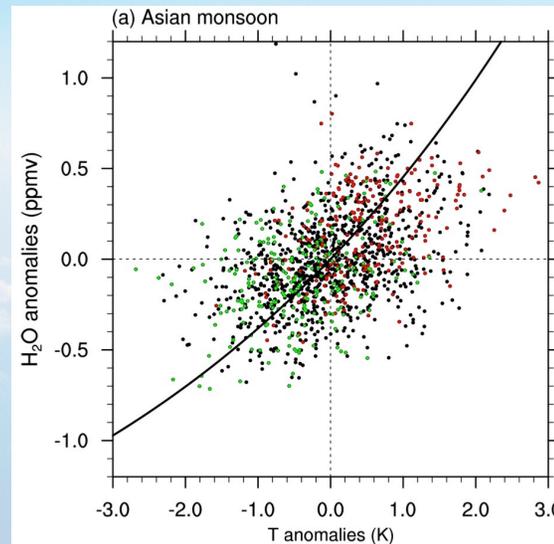


Figure 3. Partial Least Square lagged regression between H₂O anomalies at 390K over Asian monsoon region (left) and North American monsoon region (right) with zonal mean H₂O using MLS daily data from 2005-2013. Black dots represent the correlation is 95% significant using bootstrap calculations.

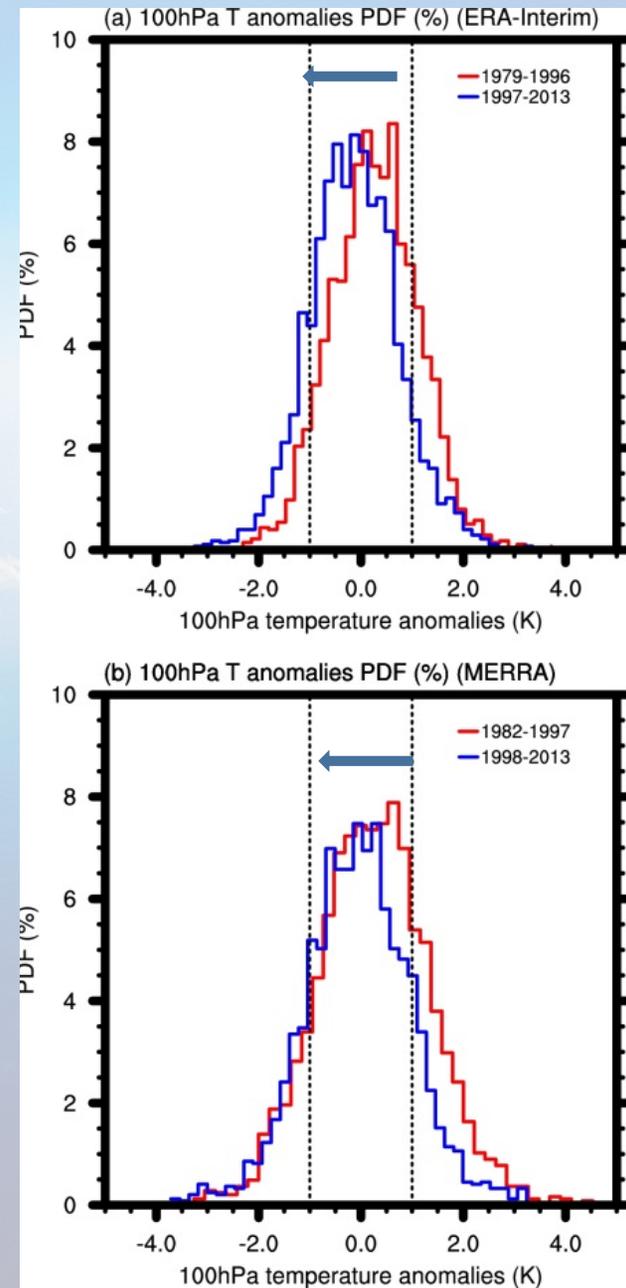
What might cause the discrepancy between observation, reanalysis and models?

- **ERA-I shows too weak correlation between H_2O and tropopause T in the Asian monsoon region.**
- **WCAM and GISS appears to capture the observed relationship between H_2O and tropopause T .**



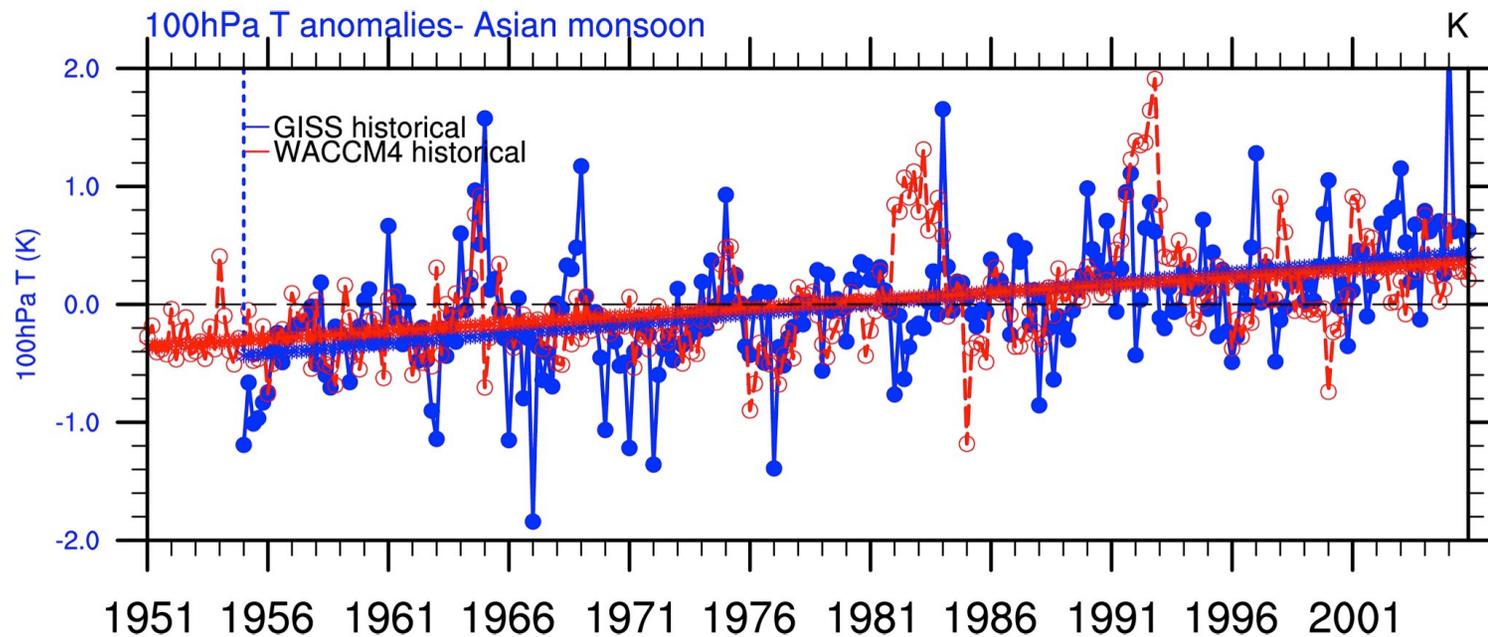
What cause the discrepancy between ERA-I and MERRA reanalysis and merged satellite observations?

- The ERA-I and MERRA would show drying trends in the NH extratropical LS based on the cooling of the tropopause temperatures during the recent decades (1997-2013) relative to earlier decade (1979-1996), if they were able to realistically capture the observed H₂O-T relationship.***



What cause the discrepancy between the models and satellite observations?

- *WCAM and GISS models would simulate drying trends if they were able to capture the cooling of the tropopause temperatures in recent decades.*



Summary

- *Interannual and decadal variations of the NH extratropical LS water vapor appear to be dominated by the tropopause temperature in the Asian monsoon region, whereas those of SH appear to be dominated by tropical tropopause temperature.*
- *In ERA-I and MERRA, the discrepancy of decadal variation of the extratropical LS water vapor with satellite observations appear to be due to weak relationship between water vapor and tropopause temperatures.*
- *In climate models (e.g., WCAM and GISS IE), warmer of the tropopause temperature appear to contribute to perhaps spurious wetting the of the extratropical LS.*