Aerosol, Clouds, and Water Vapor Transport Across the Tropopause

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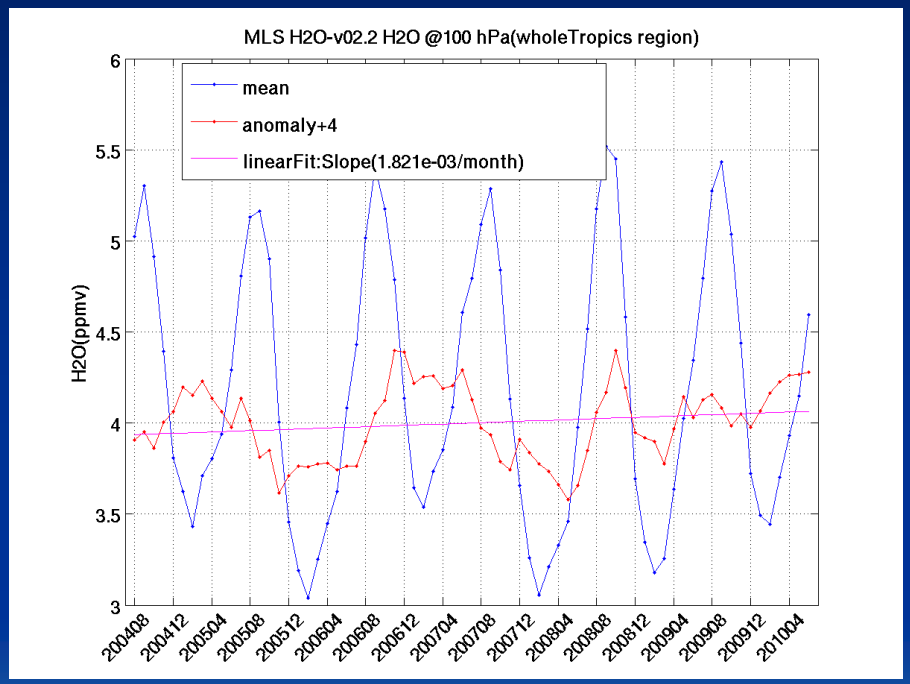
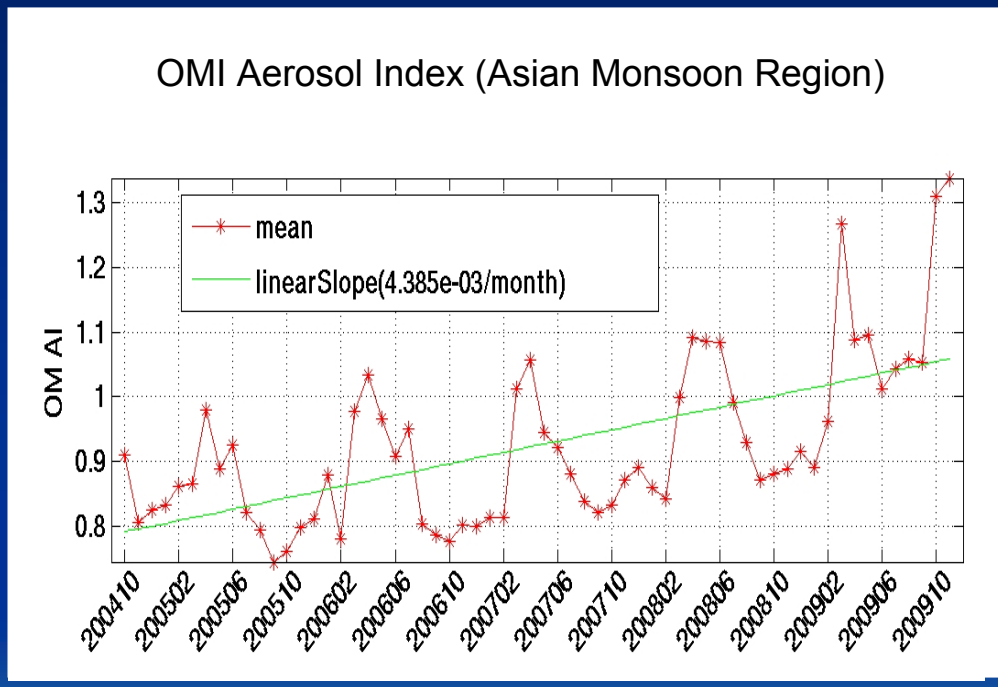
Introduction

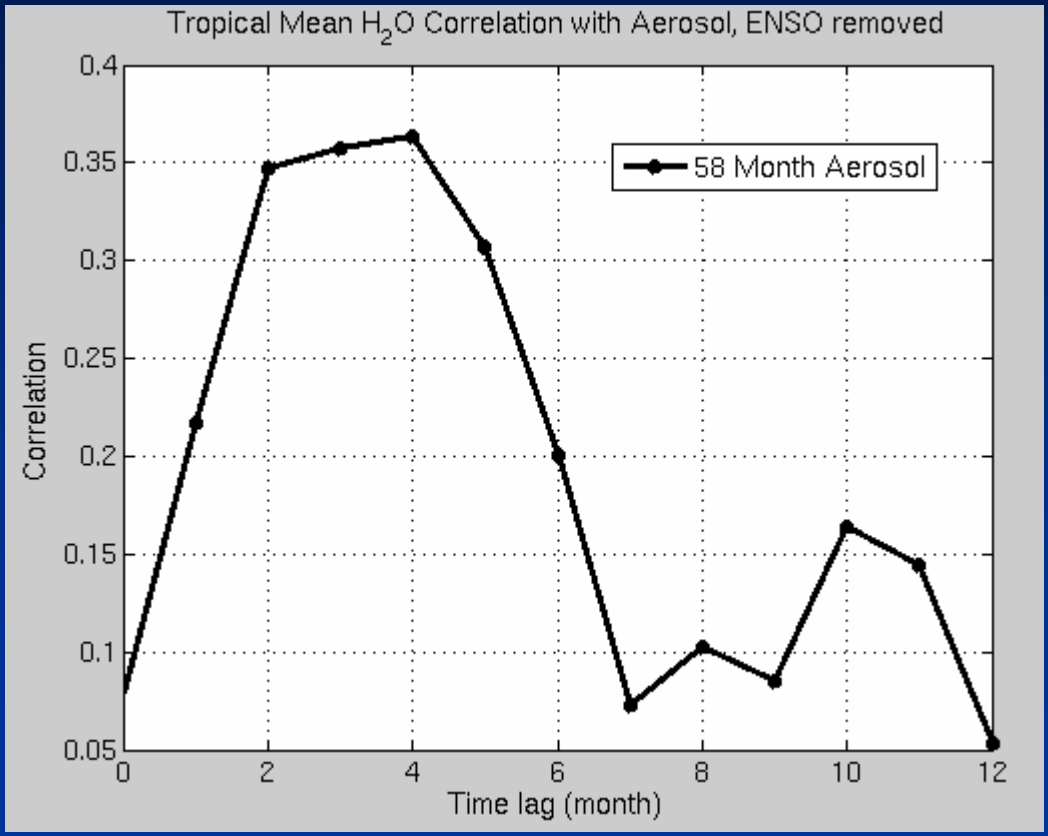
- Stratospheric water vapor (SWV) is important for global radiation and ozone chemistry.
- The trend of SWV has been a puzzling problem for years.
- It was postulated that aerosols may play a role in the SWV trend (Sherwood 2002).





- The tropical-mean 100 hPa H_2O shows a slightly increasing trend from August 2004 to June 2010.
- The Asian aerosol amount also shows an increasing trend since 2004.

Correlations of H_2O with Asian Aerosol



- The tropical-mean 100 hPa H_2O is positively correlated with Asian aerosol with the maximum correlation at 2-4 months lag when ENSO signal is removed.

Questions to be Answered

- Does Asian aerosol pollution affect the water vapor transport from the troposphere to the stratosphere?
- What are the physical mechanisms for the aerosol effect on the water vapor transport across the tropopause?

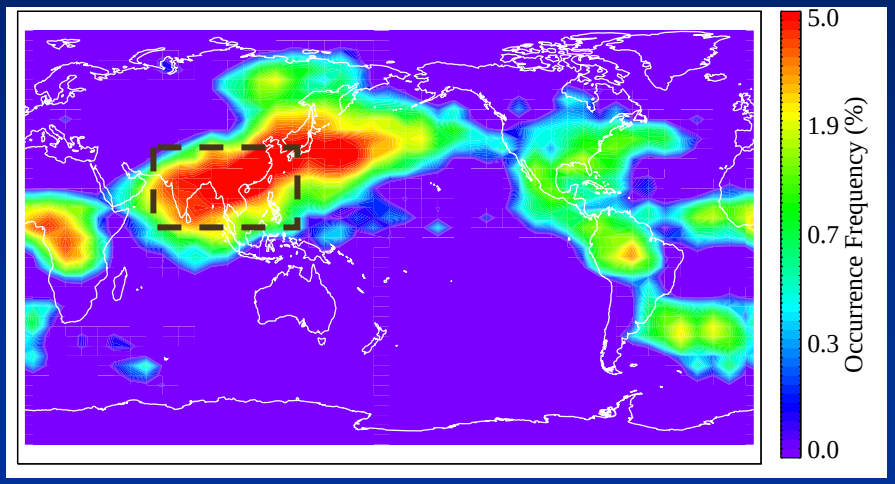
A Combined Multi-Satellite Data Analysis and Modeling Study

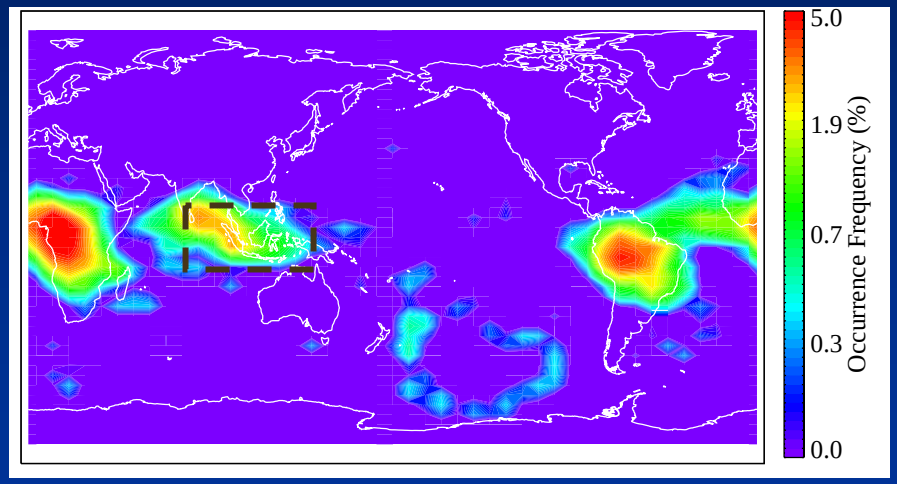
Define Polluted and Clean Clouds by Aura MLS CO at 215 hPa

Polluted Clouds

June-July-August

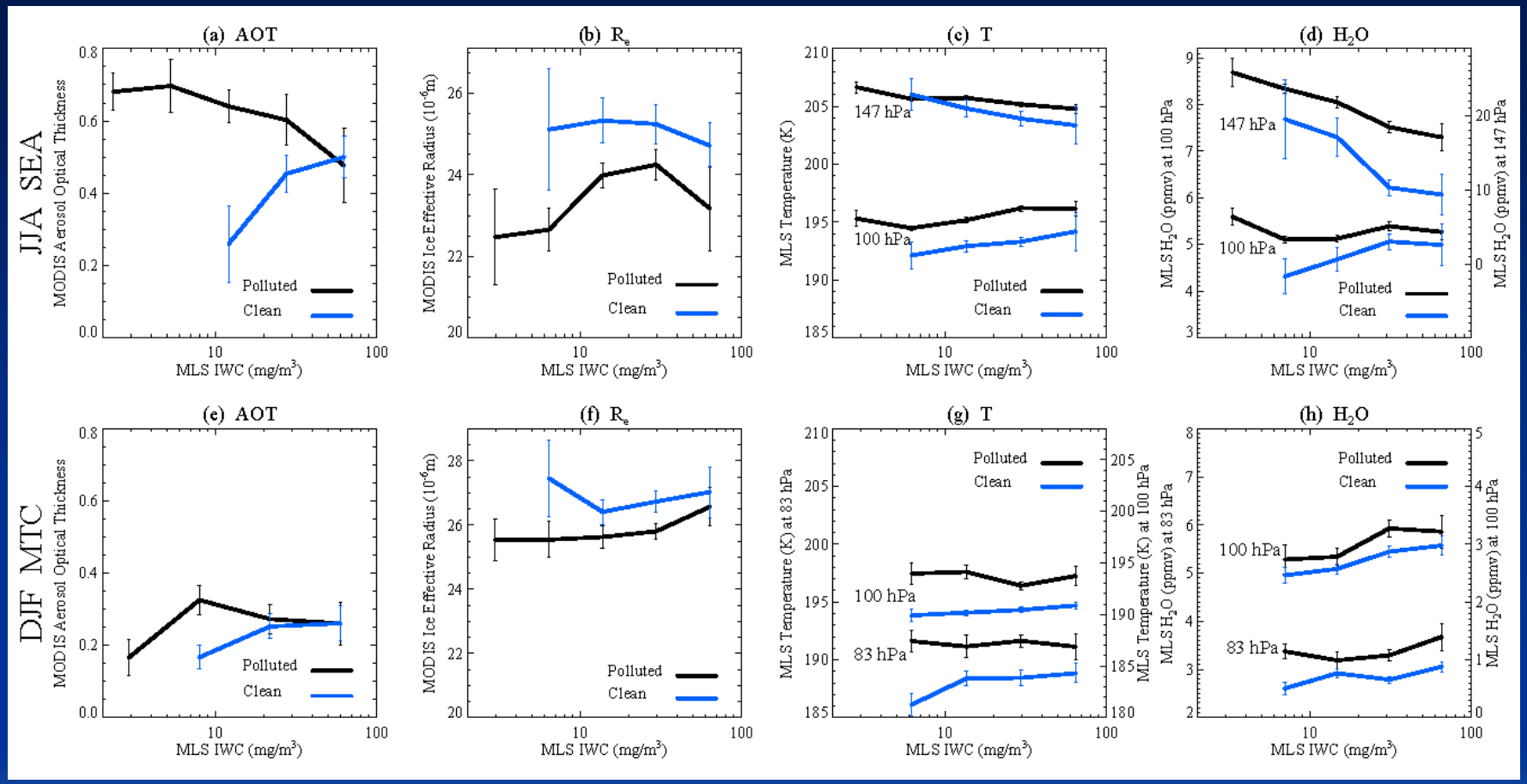
December-January-February





- JJA South-East Asia (SEA) and DJF maritime continent (MTC) have high occurrence frequency of polluted clouds.
- Both regions are important pathways for the mass transport from the troposphere to the stratosphere (e.g., Fu et al., 2006; Randel et al, 2010).

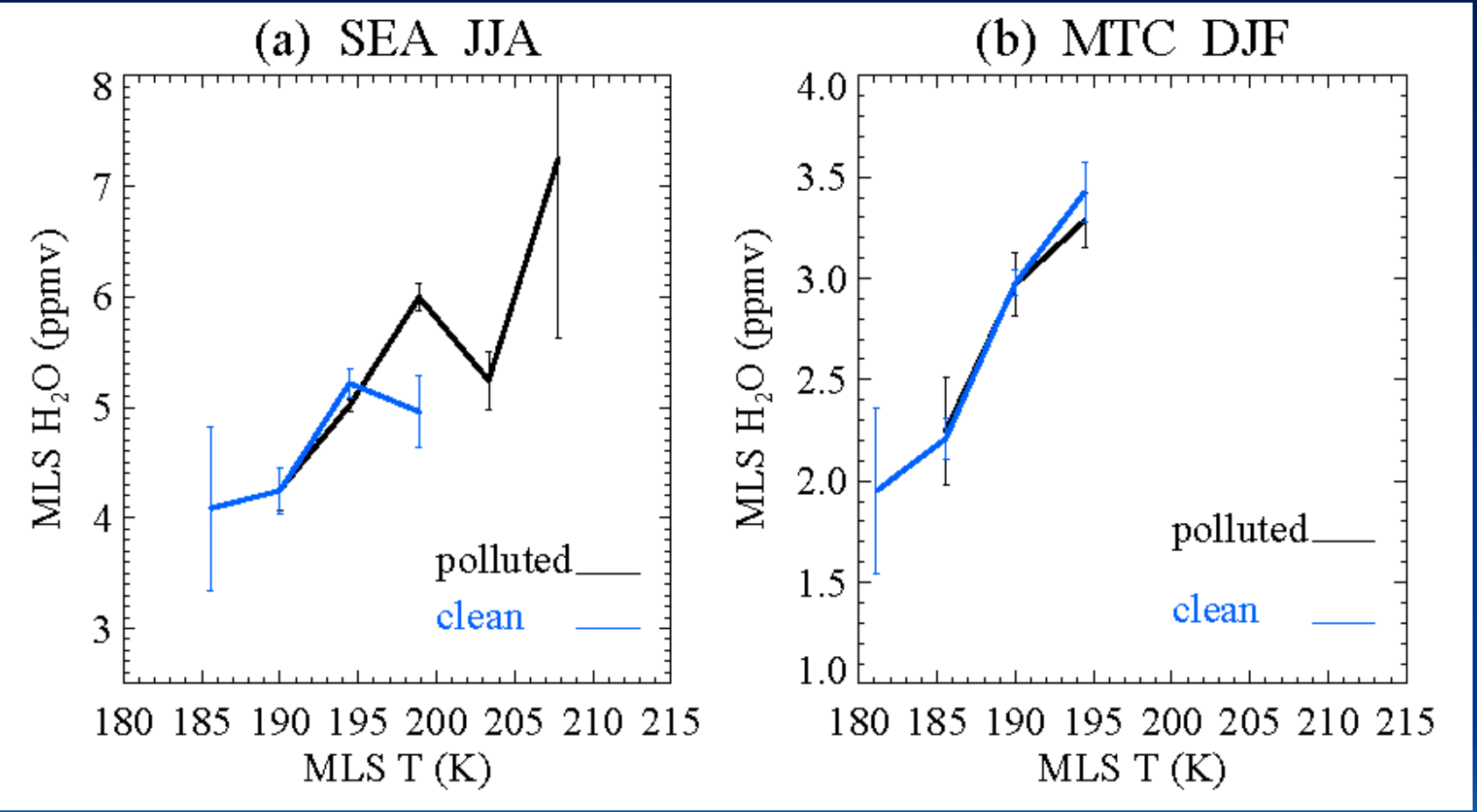
Comparing the Polluted and Clean Ice Clouds



With the same IWC, compared to clean clouds, polluted clouds have:

- Higher aerosol loading
- Smaller ice cloud effective radius
- Higher T in the tropical tropopause layer (TTL)
- Higher H_2O in the TTL

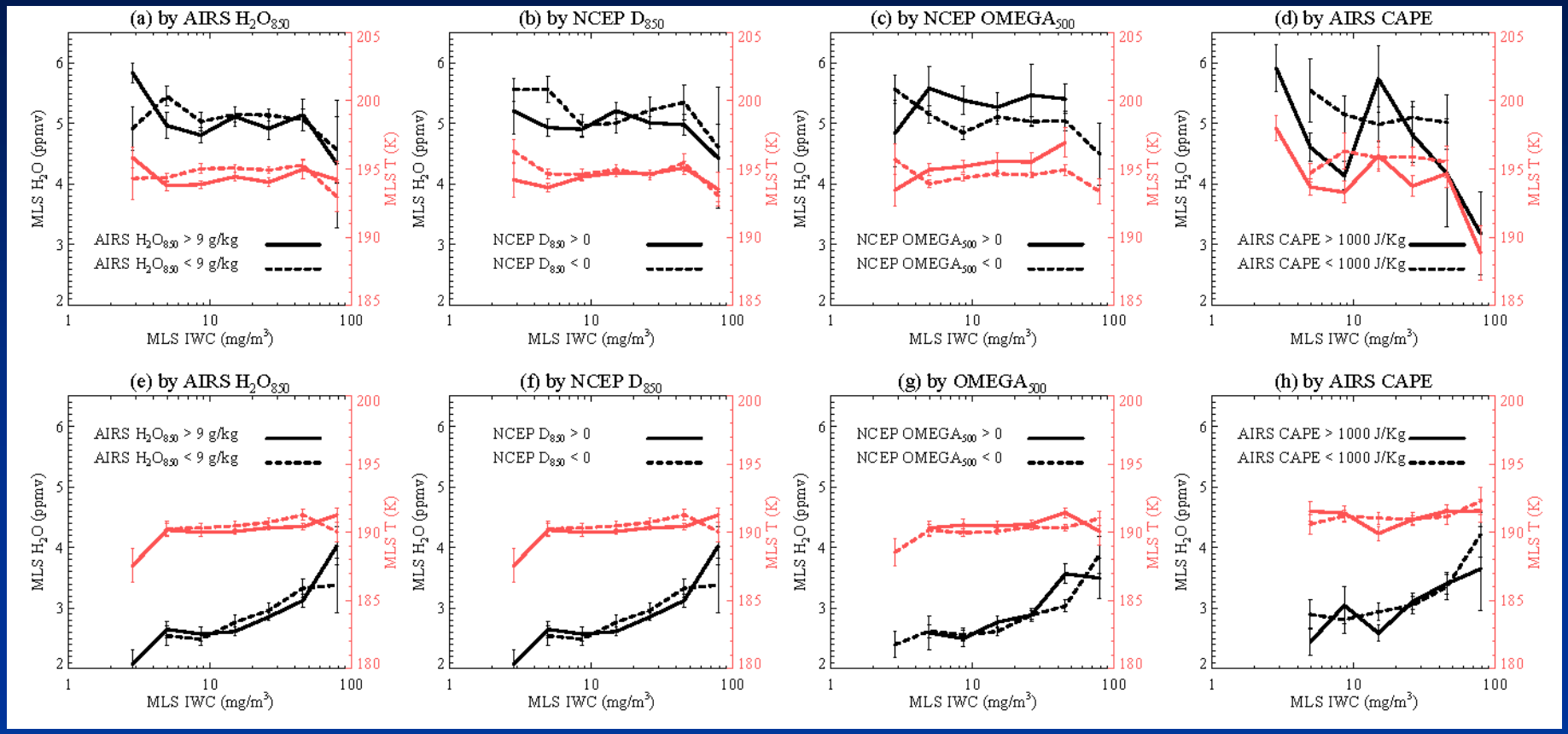
The Role of Temperature



Influence of Meteorological Factors

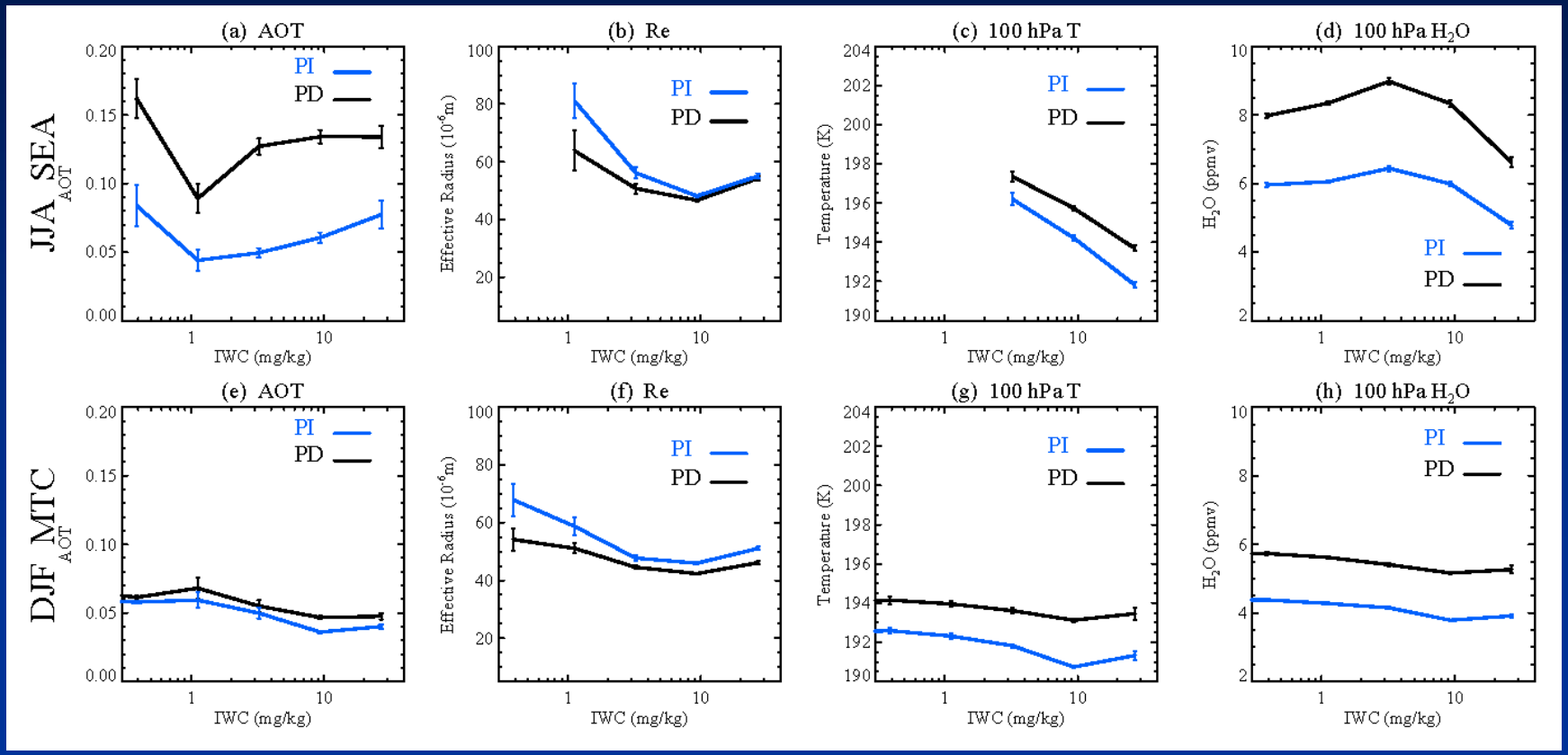
JJA SEA

DJF MTC



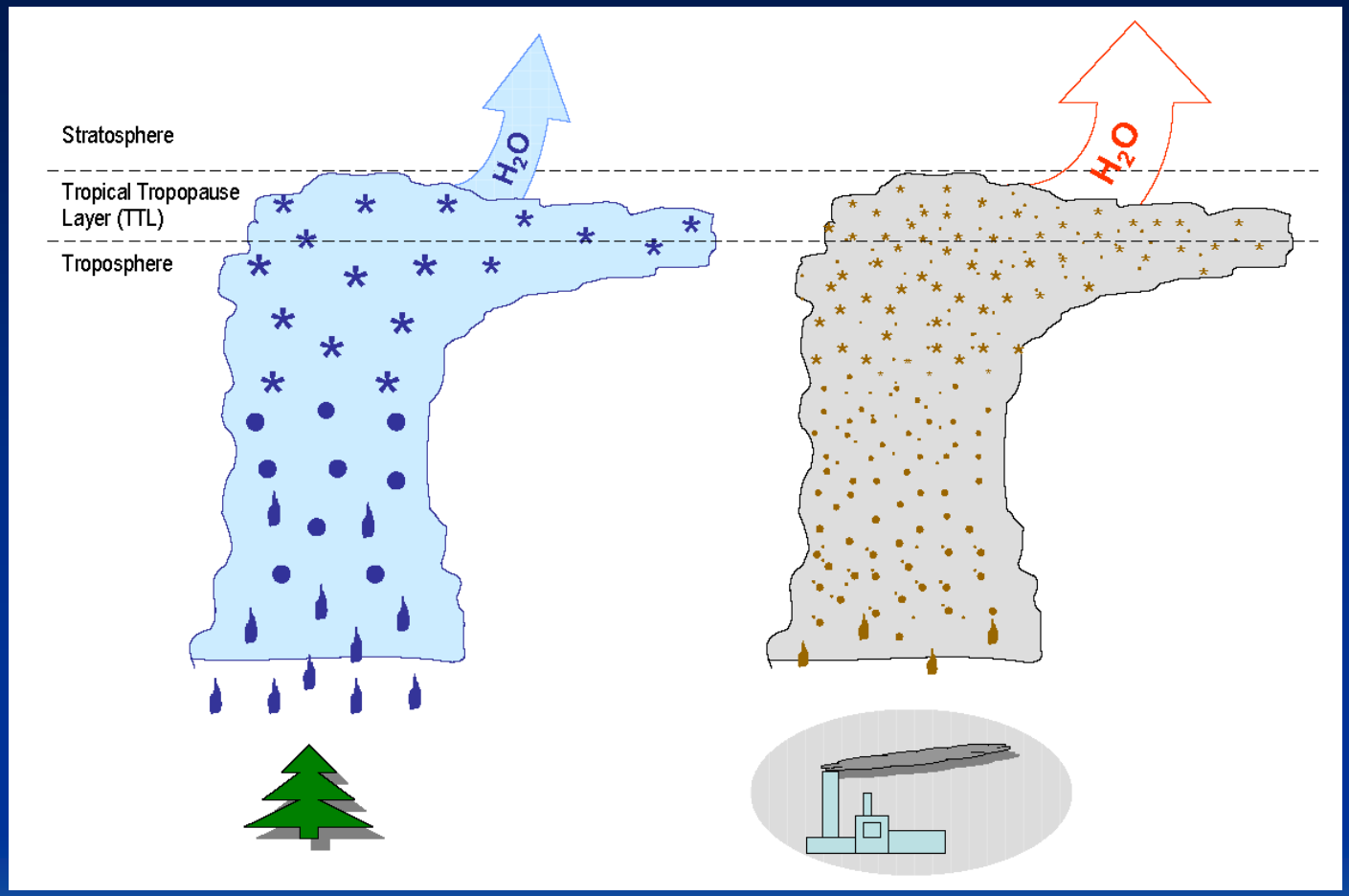
- Air parcels grouped by meteorological parameters do not show clear-cut separation in 100 hPa temperature and water vapor.

Model Results Similar to Observations



- NCAR CAM and IMPACT aerosol model simulations suggest increasing ice nuclei (sulfate and black carbon) can reduce ice cloud particle size and increase 100 hPa T and H_2O. Aerosol direct radiative heating is also at play.

Possible Mechanisms



smaller ice particle size → larger cirrus cloud fraction → increased cloud radiative heating → warmer temperature → higher water vapor

enhanced aerosol → smaller ice particle size

enhanced aerosol → Increased direct aerosol heating → warmer temperature

Conclusions

- Using Aura MLS observed CO at 215 hPa as an index for aerosol pollution loading to classify clouds as “polluted” or “clean”, we find that the polluted clouds are associated with higher water vapor (specific humidity) at 100 hPa than the clean clouds over Asia.
- The increase of 100 hPa H_2O results from the increase of 100 hPa T.
- Differences in the meteorological conditions cannot explain the increased 100 hPa H_2O and T in the polluted clouds.
- Coupled aerosol-climate model simulations demonstrate that increasing aerosols can produce smaller ice cloud effective radius, higher temperature and water vapor in the TTL, suggesting a warming and moistening effect by aerosols.
- The exact pathways for the aerosol effects on the water vapor transport are not yet clear. Further investigation is needed to distinguish the role of dynamics from aerosols.

Su et al, “Enhanced Water Vapor Transport to the Stratosphere by Pollutants in Asia”, *J. Climate*, in revision, 2010. URL: *http://mls.jpl.nasa.gov/publications.php* Email: Hui.Su@jpl.nasa.gov