Strong Correlation between Cirrus Ice, Water Vapor and Temperature in the Tropical Tropopause Layer as observed by CALIPSO and MLS

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1. Summary

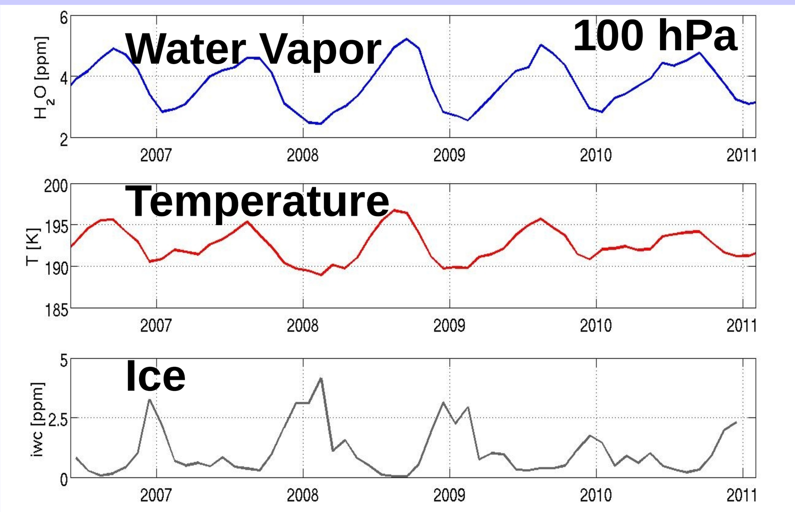
NASA A-train satellite measurements by CALIPSO and MLS show that the tropical 100 hPa temperature controls water vapor and cirrus clouds and regulates the partitioning of water between ice and vapor. As a consequence the total water in the tropical tropopause layer (TTL) stays roughly constant throughout the year. A fact that is not well represented in current global circulation models! But it is important for climate scenarios since water vapor and ice have opposite effects on global climate.

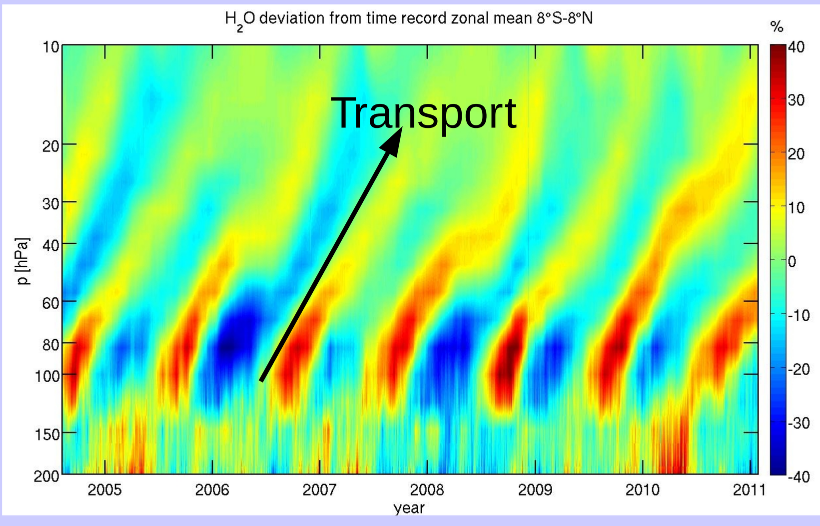
2. Seasonal cycle in the tropics

Tropical water vapor (H_2O) at 100 hPa has a clear seasonal cycle. The signal is transported upward and visible up to 10 hPa (→ famous atmospheric "*tape recorder*").

The seasonal cycle of temperature is in phase with H_2O and shows maxima at the end of northern hemisphere (NH) summer.

The ice water content of cirrus clouds at 100 hPa shows an opposite seasonal cycle which peaks during NH winter.

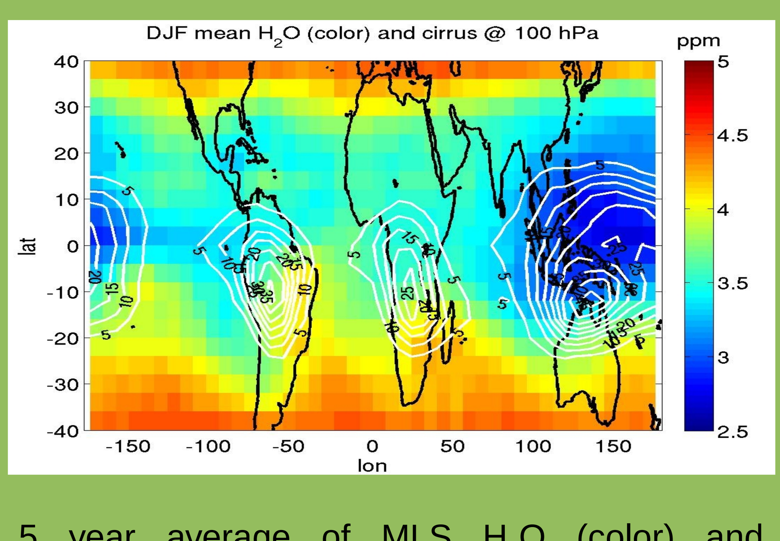




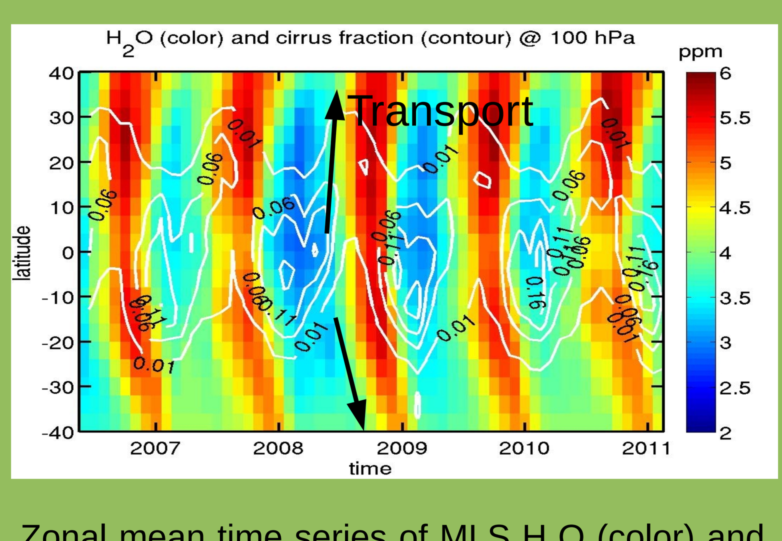
Time series of tropical (8˚S-8˚N) zonal mean water vapor and temperature from MLS and ice water content from CALIPSO at 100 hPa. The H_2O tape recorder is on the right which shows the relative seasonal cycle at 100 hPa. The variations are slowly (~0.3mm/s) transported upward (arrow) towards 10 hPa.

3. Negative correlation of water vapor and cirrus

Tropical H_2O is lowest in NH winter with minima over Indonesia due to low temperatures. The occurrence of cirrus clouds at 100 hPa peaks in the same season (Dec-Jan-Feb). The anticorrelation of cirrus cloud fraction and H_2O can also be seen in the zonal mean time series where transport of H_2O from low to high latitudes is evident.

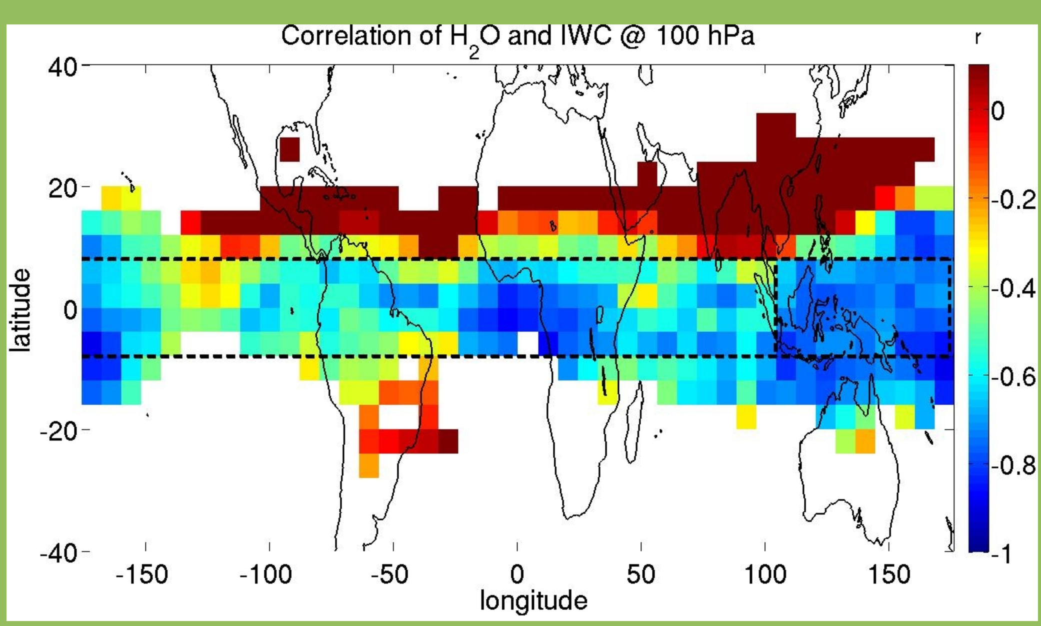


5 year average of MLS H_2O (color) and CALIPSO cirrus cloud fraction (contour) at 100 hPa for Dec-Jan-Feb. Low H_2O corresponds with high cirrus occurrence.



Zonal mean time series of MLS H_2O (color) and CALIPSO cirrus cloud fraction (contour) at 100 hPa. Anticorrelation of H_2O and cirrus as well as poleward transport (arrows) of H_2O is evident.

Water vapor and cirrus ice at 100 hPa are strongly anticorrelated as shown in the following map. Correlation is strongest over Indonesia and Africa where cirrus clouds are most abundant.



Correlation calculated with 19 seasonal data points of MLS H_2O and CALIPSO IWC at 100 hPa. White indicates no IWC. Anticorrelation is close to -1 over Indonesia (highlighted box) and high all over the tropics (inside dashed lines).

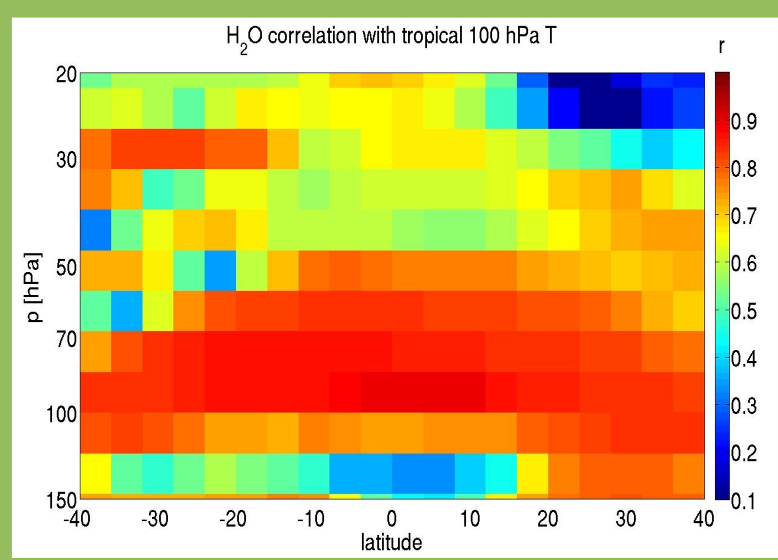
Correlation Coefficients

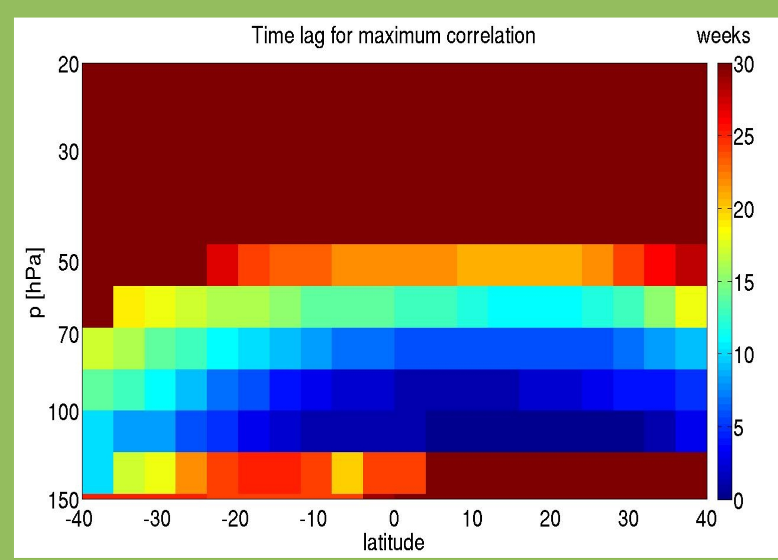
Region @ 100 hPa	T, H_2O	T, IWC
Tropics	0.94	-0.91
Indonesia	0.95	-0.84

Correlation coefficients of tropical zonal mean temperature with H_2O and with IWC at 100 hPa (8˚S-8˚N). The high correlation coefficients underline the important role of T in partitioning water between vapor and ice in the TTL.

4. Temperature controls water vapor

Strong correlation of H_2O with the tropical 100 hPa temperature shows that tropical and midlatitude lower stratospheric H_2O is determined in the tropics. Correlation decreases with altitude due to the formation of H_2O by oxidation of methane (CH_4). The time lag calculated for maximum correlation at each altitude and latitude shows that transport by the Brewer-Dobson circulation is faster towards the northern hemisphere and happens within a few weeks.

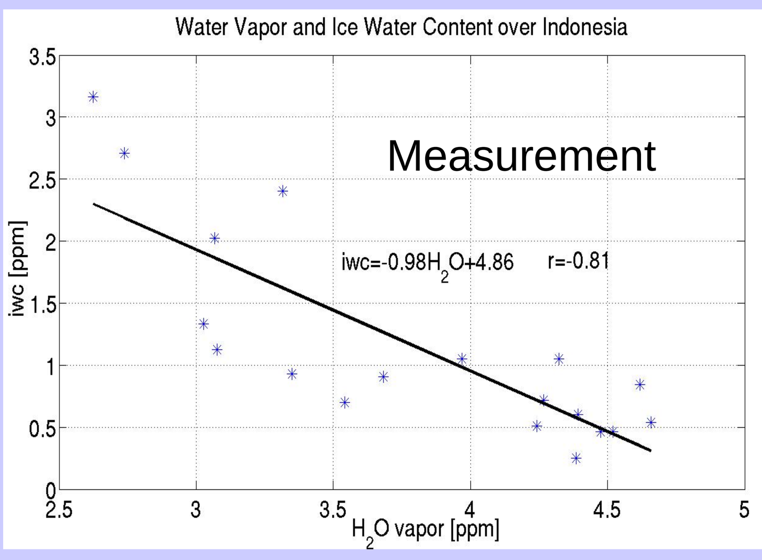




Correlation of daily tropical 100 hPa T with local H_2O on the left and the corresponding time lag for maximum correlation. Correlation is high throughout the lower stratosphere up to midlatitudes and transport is faster to the NH.

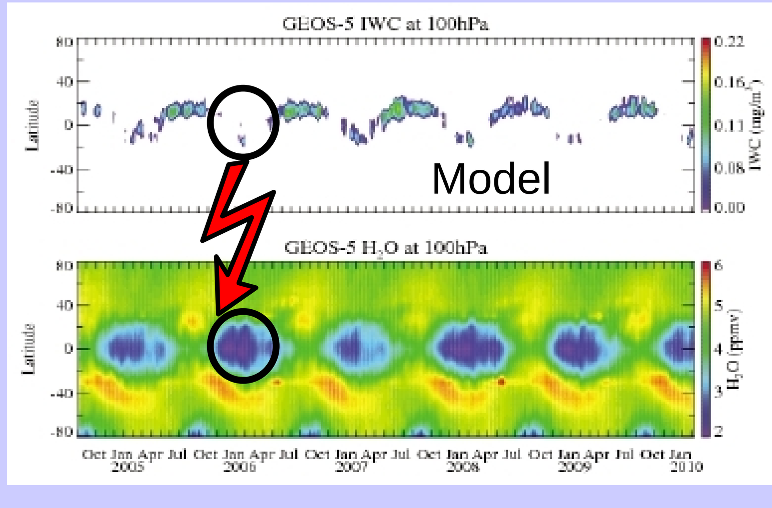
5. Conservation of total water in the TTL

The anticorrelation of water vapor and cirrus ice at 100 hPa suggests that cirrus clouds act as a reservoir for TTL water vapor. Thus the seasonal cycle of water vapor is mainly a manifestation of cirrus formation.



Seasonal mean water vapor H_2O from MLS and ice water content from CALIPSO measured over Indonesia (region of the box displayed in the figure above).

The measurements of ice and water vapor support the hypothesis that total water is constant in the TTL and that temperature acts as regulator for balancing the partition between water vapor and ice in cirrus clouds.



Zonal mean time series of IWC and H_2O at 100 hPa from GEOS-5. There is neither anticorrelation nor conservation of total water inside the tropics.(Figure from Jiang, JGR 09)

The GEOS-5 model does not produce the anticorrelation of IWC and H_2O at 100 hPa. Especially during NH winter with low H_2O a lot of ice would be expected but the model shows no ice at all as pointed out by the circles.

6. Conclusions

- TTL temperature controls water vapor and cirrus clouds
- Total water is roughly constant in the TTL
- Decreasing water vapor in DJF is due to cirrus formation
- GEOS-5 model wrong for the ice-water vapor balance
- Ice-water vapor balance important for climate scenarios

Reference: T. Flury, D. L. Wu, W. G. Read, Correlation among cirrus ice content, water vapor and temperature in the TTL as observed by CALIPSO and Aura/MLS, Atmos. Chem. Phys. Discuss., 11, 2011