Analysis of the TTL Cirrus and Their Convective Origin - A Water Perspective

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Abstract:

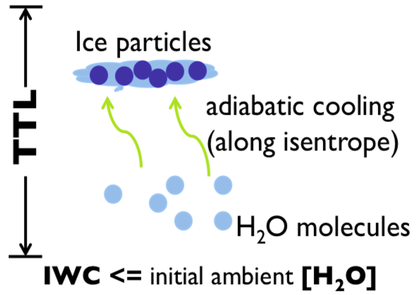
Cirrus in the tropical tropopause layer (TTL) play a significant role in the transport of trace constituents, particularly water vapor, into the stratosphere.

TTL cirrus can arise via two mechanisms:
• In situ
• Convective (detrainment from deep convective anvils)

By analyzing ice water content (IWC) and water vapor (H_2O), we identify TTL cirrus that contain too much ice to have been formed in situ — and therefore must be of convective origin. We find that during 2008-2010, at least 18.3% of cirrus are definitively of convective origin.

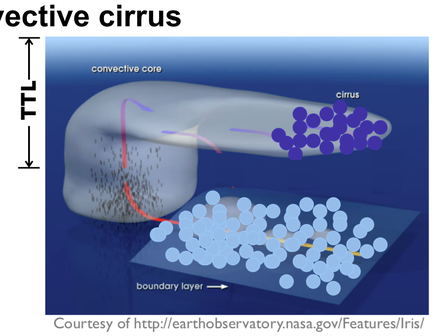
Basic Idea:

- **In situ cirrus**



Cirrus IWC is limited by H_2O availability in the ambient TTL air.

- **Convective cirrus**



Courtesy of http://earthobservatory.nasa.gov/Features/Iris/

No upper limits of IWC

Cirrus IWC come directly from H_2O-abundant boundary layer. No explicit upper limits of IWC for convective cirrus.

- **Strategy**

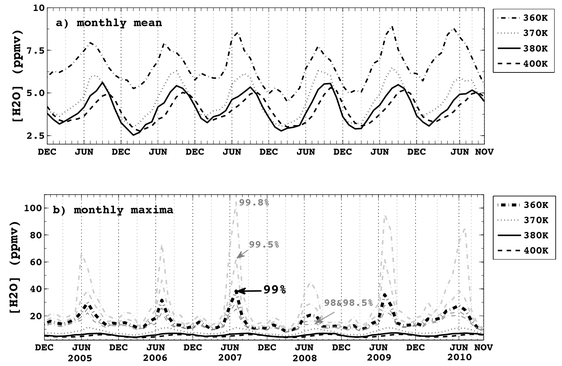
Find the maximum amount of limited H_2O in the TTL, which determines the upper limit for IWC within in situ cirrus. Then, cirrus with IWC beyond this threshold must come from convection.

Data:

• MLS Version 3.3 Level 2 datasets from Dec. 2004 to Nov. 2010, providing water vapor concentration[H_2O].

• CALIPSO version 3.1 Level 2 Cloud Profile 5-km datasets from Dec. 2007 to Nov. 2010. It provides Ice Water Content (IWC), cloud types and cloud thermodynamic phase.

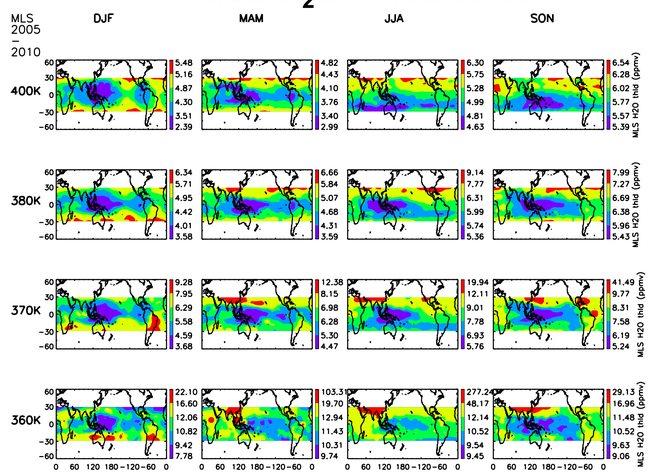
Thresholds from MLS cloud-free H_2O:



360 K: bottom of TTL
380 K: near the tropopause
370 K: halfway between TTL bottom and tropopause
400 K: near the top of TTL

We take greater than 99% of MLS cloud-free [H_2O] as a simple estimate of the maximum amount of vapor available for condensation, and the top 1% as statistical outliers and non-physical retrievals.

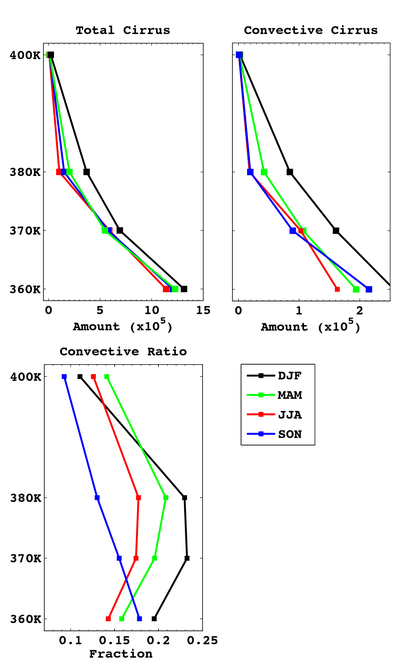
MLS H_2O Thresholds



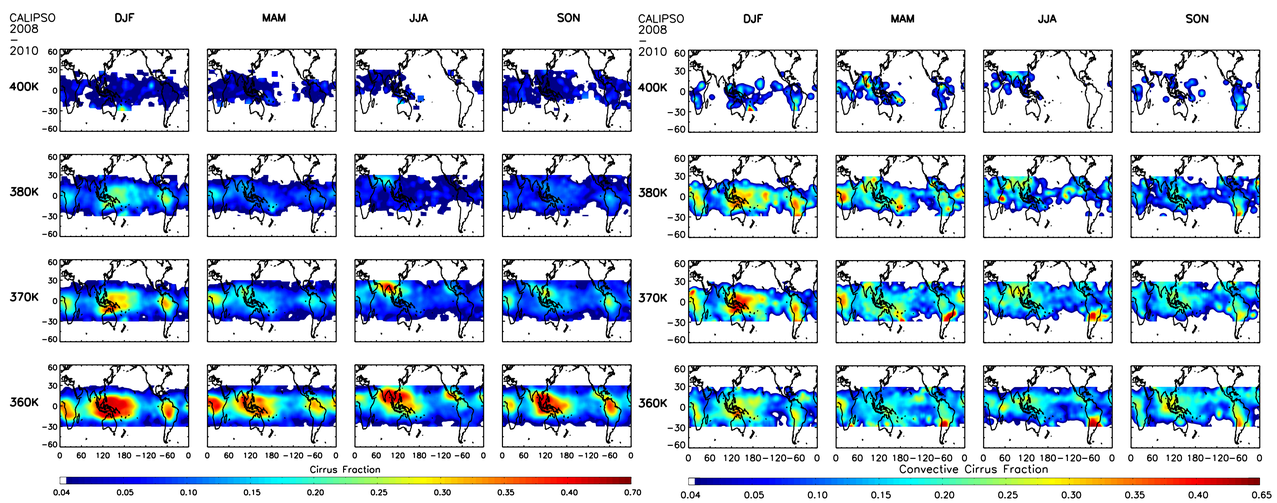
[H_2O] thresholds are obtained for each 4°x2° longitude by latitude grid box.

Results:

Total Cirrus



Convective Cirrus



- Overall, at least 18.3% of TTL cirrus are of convective origin.
- Enhanced regions of convective cirrus distribution follow the distribution of total cirrus.
- A clear modulation by Indian and South Asian monsoon during boreal summer.
- At each level, convective cirrus fractions appear to be higher in DJF and MAM.
- During each season, convective cirrus occur more frequently near the tropopause.

Discussion:

We demonstrated a method to identify TTL cirrus that are of convective origin. To be noted that our approach produces lower fractions because:
1) Our thresholds come from assumption that H_2O would condense 100%;
2) Convective cirrus may be formed from small amount of ice injected into the TTL; and
3) Convective cirrus could have subsequently thinned out due to sedimentation of the largest particles or spreading of clouds by wind shear.

Therefore, convective cirrus fractions are likely to be higher than the values we get, so our values should be considered a lower limit. Even though, the behavior and distribution patterns of convective cirrus we get are still consistent with many previous work, which proves the validity of our method and the importance of them being of cirrus population.

Paper in 2012 JGR (http://geotest.tamu.edu/userfiles/216/Wang2012.pdf)