Water Vapor, Clouds, and Supersaturation in the Tropical Tropopause Transition Layer

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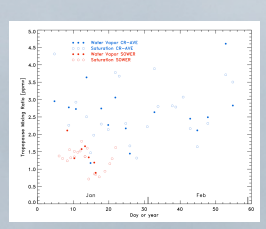
Regional differences: Western Pacific vs. Central America:

In January/February 2006 two balloon campaigns to measure water vapor and ozone in the tropical Tropopause Transition Layer (TTL) took place at Biak, Indonesia (SOWER) and at Heredia, Costa Rica (CR-AVE).

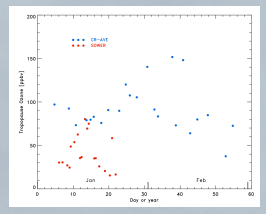
Water Vapor and Saturation:

The Western Pacific site shows colder tropopause temperatures and lower water vapor mixing ratios. All Biak soundings show a water vapor minimum of less than 1.5 ppmv, the Costa Rica soundings generally between 2 and 3 ppmv.



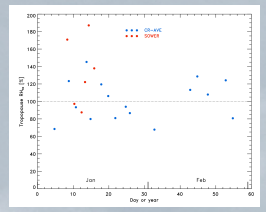
Ozone:

Ozone at the tropopause is significantly lower at Biak compared to Costa Rica. This is a result of the lower tropospheric concentration and the stronger convective activity at Biak during this season.



Relative Humidity Over Ice:

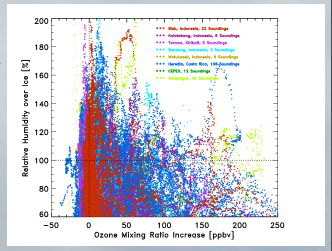
RH_{ice} is similar for both regions, however, the extreme values are only observed at Biak as a result of equatorial waves interacting with deep convection. This indicates similar processes at both locations controlling RH.



Relative Humidity Over Ice vs. Ozone Increase:

The ozone increase over the mean tropospheric ozone concentration (taken here as the average mixing ratio between 5 km and 12 km) shows the largest RH values in air with the smallest ozone increase in the TTL, indicating a recent injection of this air into the TTL partly due to convection.

In a second mode high RH values are found in air with large ozone concentrations (50 to 150 ppbv above tropospheric values). All of these high RH layers may be related to equatorial waves creating supersaturated conditions above the average tropopause height.
This mode, which would correspond to a cold trap mechanism, is less frequent.

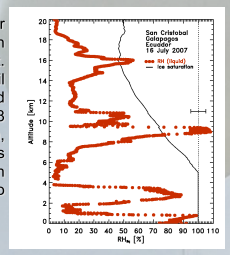


Key points:

- There are strong zonal difference in water vapor and ozone in the TTL, but not in RH_{ice}.
- Highest RH_{ice} values at occur mostly but not always at tropospheric ozone concentrations.
- Cloud free air in the upper troposphere and TTL can be saturated with respect to liquid water.
- Large Supersaturation in the TTL can exist inside long living cirrus clouds
- Supersaturation in the TTL can exceed Murphy and Koop parameterization
- The uncertainty of CFH water vapor measurements is less than 10%.

Supersaturation and balloon contrail formation:

RH profile for the balloon contrail event. The contrail formed between 8.8 and 9.4 km, within air that is saturated with respect to liquid.

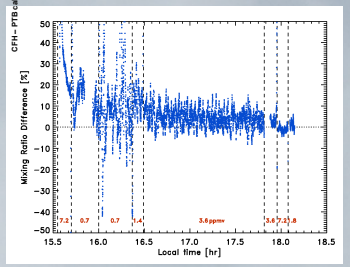


The image shows the first ever recorded balloon contrail, which was created in air supersaturated with respect to ice (140% = liquid saturation). The evaporation of the cryogenic liquid of the CFH cools the air around the instrument, forcing an additional increase in supersaturation and subsequent condensation. Emission of particles is not suspected to play a role.

The sounding was launched shortly before sunset and the picture was taken after sunset, but with the contrail and the balloon still in sunlight. The morphology of the contrail generally matches the vertical structure of the supersaturation profile.

Accuracy of CFH water vapor measurements:

In October of 2007 a large scale intercomparison campaign (AquaVIT) of water vapor instruments took place at the AIDA facility of the Forschungszentrum Karlsruhe. As part of this, an intercomparison took place between a calibrated water vapor source of the German metrology standards institute (PTB) and the CFH. Including some outgassing during this test, the average difference between CFH and calibrator was 10% or less. This is in agreement with the overall comparison during AquaVIT and no systematic biases of the CFH could be found.

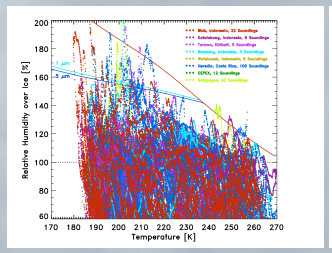


Relative Humidity Over Ice vs. Temperature:

Relative humidity over ice as a function of temperature shows large supersaturations, which are increasing with decreasing temperature. Peak values reaching 190% are observed. All observations are consistent with liquid saturation as upper limit of supersaturation; however, some observations exceed the freezing threshold for liquid aerosols, where rapid ice particle formation is expected. This threshold appears to be exceeded both in the absence and presence of particles.

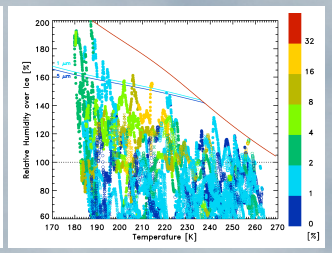
All observations:

RH_{ice} as a function of temperature for all tropical soundings. These soundings only provide water vapor data, with no additional information about the presence of clouds.



Biak observations with lidar (Jan 2006, 2007, 2008):

The color coding on these data indicates the backscatter ratio that was observed in simultaneous lidar observations. These data indicate high supersaturations in the presence of ice clouds.

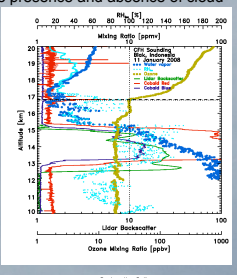


Relative Humidity Over Ice and Cloud Particles:

High supersaturations were observed both in the presence and absence of cloud particles.

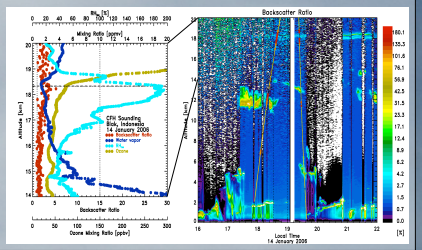
In situ observations of particles:

A Cobald sonde as part of the CFH shows evidence for significant supersaturation inside a cirrus cloud as well as the presence of thin layers at the cold point in just saturated air. The thick cirrus results are consistent with lidar observations; however, the lidar lacks signal at the cold point layers.



Deep convection:

This sounding showed an extremely cold tropopause (180 K), with RH_{ice} reaching 190 % and initial stages of a cirrus cloud.



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Background Image: CFH/ozone sonde launch during TCSP at Alajuela, Costa Rica, July 2005.