Cold Trap Dehydration in the TTL
Characterized by SOWER
Observations in the Tropical Pacific

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SOWER Project

Soundings of Ozone and Water in the Equatorial Region

- Radiosonde Observations of Ozone and Water Vapor
- ECC Ozonesonde and Chilled-Mirror Hygrometer
- East-West Contrast Along the Equator in the Pacific Region

- Fujiwara et al. GRL 2001: Dehydration by Kelvin waves
- Fujiwara et al. JTECH 2003: Performance of Snow White hygrometer
- Fujiwara et al. JGR 2003: Upper tropospheric inversion
- Vömel et al. JTECH 2003: Behavior of Snow White
- Eguchi and Shiotani JGR 2004: Role of intraseasonal variations
- Hasebe et al. ACP 2007: Observed ‘cold trap’ dehydration
- Shibata et al. JGR 2007: Cirrus and supersaturation
- Takashima and Shiotani JGR 2007: Ozone over Christmas Island
- Vömel et al. JGR 2007: Validation of Aura/MLS
Current Focus

- Observational study on TTL dehydration
  - In situ observations of ‘cold trap’ dehydration
  - Chilled-mirror hygrometers, ozonesondes and lidars
- Water profiles with the estimates of uncertainties
  - Difference in the response time in $T$ and $T_f$
  - Observational evidence of supersaturation in the TTL
- Lagrangian description of dehydration processes
  - ECMWF analyses on model levels
  - Look-up $T_{bb}$ along the trajectories
  - Observed water mixing ratio (OMR) vs. minimum saturation mixing ratio along the trajectories ($SMR_{\text{min}}$)
  - Estimation of dehydration efficiency by water vapor ‘match’
- Long-term changes in water entering the stratosphere
- Assimilation of observations in GCM-CTMs
Analysis of water vapor sonde data

- **Raw data**
  - Smoothing of $T_f(p)$ to reduce noise
  - Estimation of confidence interval $\Delta T_f(p)$ using fluctuations around mean profile

- **Interpolation to isentropes**
  - The law of propagation of errors; $\chi(\theta), \Delta \chi(\theta)$

- **Compensation for the phase delay**
  - Response time for the frost on the mirror

\[
q(t) = \frac{1}{\tau} \int_0^t p(s) e^{-\frac{t-s}{\tau}} \, ds \quad \left( t - \frac{t}{\tau} \gg 1 \right)
\]

\[
\frac{dq}{dt} = \frac{1}{\tau} (p(t) - q(t))
\]
Trajectory Analyses

- Ensemble of trajectories to represent air parcels
  - Initialization at 10 points/deg. in 1.0 deg.-radius lat/lon circle
  - Estimation of uncertainties in $\text{SMR}_{\text{min}}$
- ECMWF analyses on model levels
  - 6 hour interval, L60/L91, 1.0 (1.125) deg. lat/lon grid
- Estimation of cloud top height referring to $T_{bb}$
  - 20 pixels/deg.
Meteorological Interpretation

- Covered by S midlatitude air mass.
- Intrusion from N midlatitudes ~360K
  - ‘Cold trap’ dehydration for a few days before arrival at Biak
  - Warm/dry layer (356~364K; 15.4 ~ 16.1km)
- 350~354 K (13.1~15.2 km)
  - Supersaturation (<25%)
  - Cirrus
    - ‘Cobald’ BSR<sub>blue</sub> Max 12.8 (351K)
    - Lidar: Ice Crystal (Dp ~ 40%)

http://weather.is.kochi-u.ac.jp
Meteorological Interpretation

http://weather.is.kochi-u.ac.jp
January

350K: Both \( \text{SMR}_{\text{min}} \) and \( \text{OMR} \) strongly depend on the regional convective activity (\( \text{TR} > \text{BI} > \text{KT} > \text{SJ} \)).

360K: In the midst of ‘cold trap’ dehydration. Air parcels usually retain more water than \( \text{SMR}_{\text{min}} \).

380K: Close to the final stage of the ‘cold trap’ dehydration. Dehydration efficiency in W Pacific (\( \text{BI}, \text{KT} \)) is much reduced in 2007 as compared to that in 2008.

400K: The ‘cold trap’ dehydration is almost complete. The range of \( \text{OMR} \) decreases due probably to mixing. The tape recorder signal begins to be established on this isentrope.

\( T - T_{bb} < -10 \text{K} \): These features remain qualitatively the same.
Definition of Water Vapor Match

- The same air mass is sampled twice or more by sondes:
  - Search for a common set of ‘dots’ included in a certain range of sounding radius
- Screening of identified match pairs:
  - Representativeness of an air mass
  - Irreversible mixing due to wind shear and divergence
  - Penetration of deep convection
  - Consistency of sonde data with analysis field
  - Violation of adiabatic condition
  - Conservation of ozone mixing ratio
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\[ \text{O}_3 \]

\[ \text{H}_2\text{O} \]
Summary

- The analyses of water vapor sonde data and corresponding trajectories have been improved.
- Meteorological analyses provide interesting view on the ‘cold trap’ dehydration.
- The statistical relationship between OMR and SMR_{min} on isentropes illustrates the progress of ‘cold trap’ dehydration.
- Water vapor ‘match’ is being developed with the aid of extensive screening procedure.
- Analyses will be extended to the assimilated GCM/CTM fields in the future.