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

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Special thanks to Thomas Peter for providing ‘COBALD’

SOWER Project

Soundings of Ozone and Water in the Equatorial Region

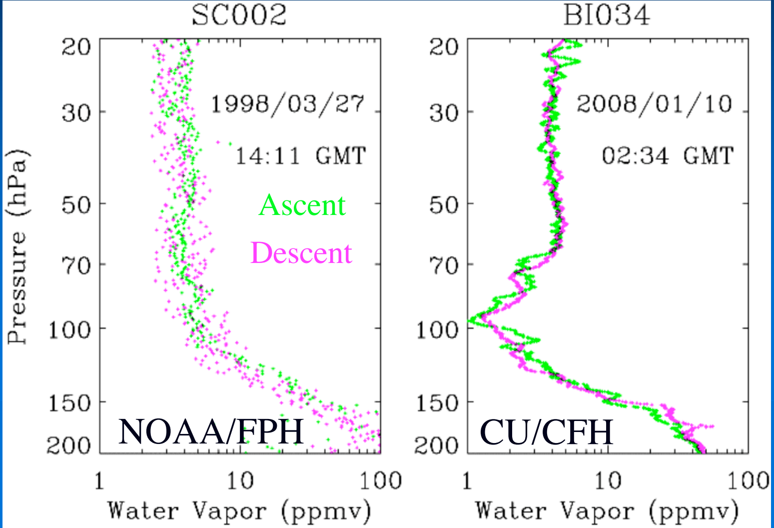
- **Radiosonde Observations of Ozone and Water Vapor**
- **ECC Ozonesonde and Chilled-Mirror Hygrometer**
- **East-West Contrast Along the Equator in the Pacific Region**

- **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**

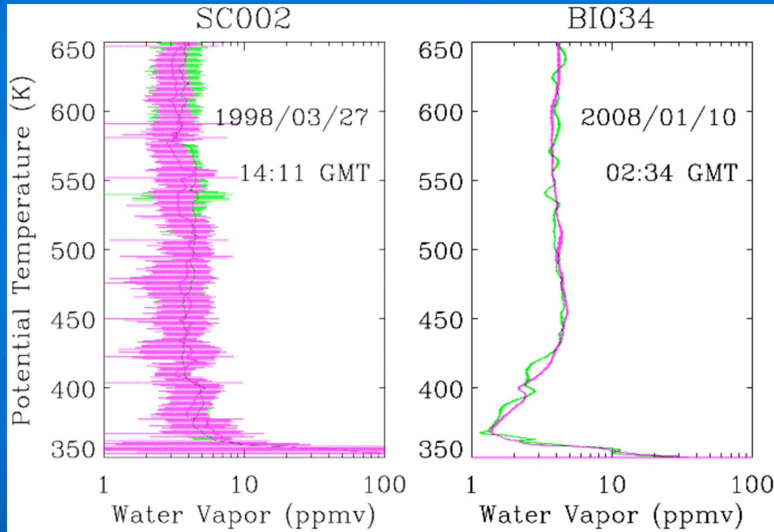
Current Focus

- 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_{min})
  - Estimation of dehydration efficiency by water vapor ‘match’
- Long-term changes in water entering the stratosphere
- Assimilation of observations in GCM-CTMs

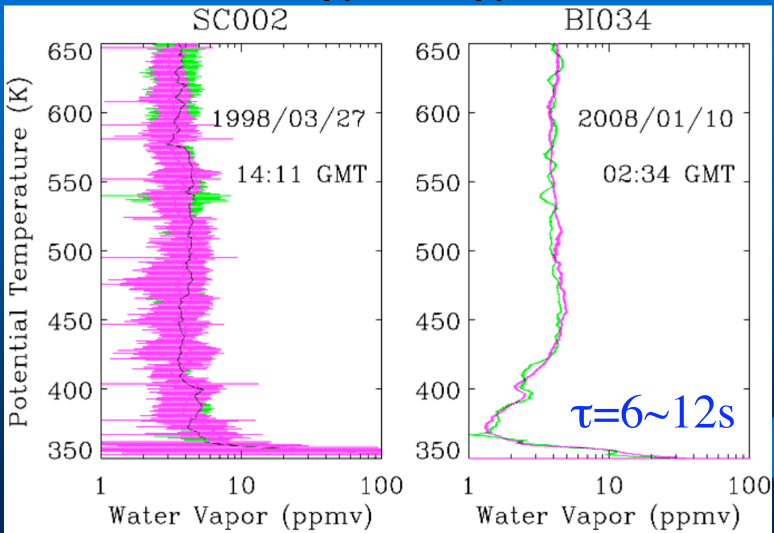
Analysis of water vapor sonde data



- 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; $\chi(\theta)$, $\Delta\chi(\theta)$



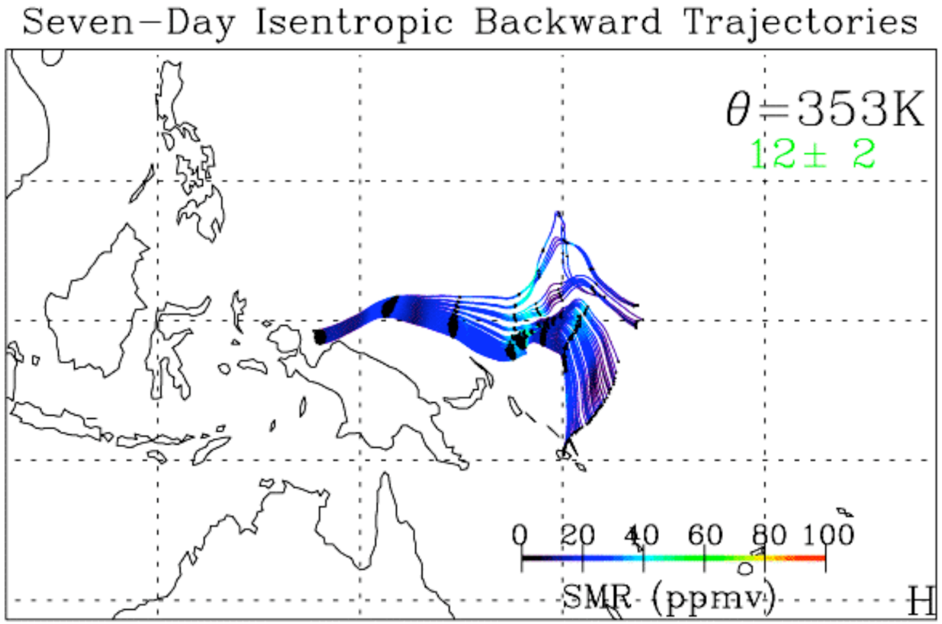
- Compensation for the phase delay
  - Response time for the frost on the mirror

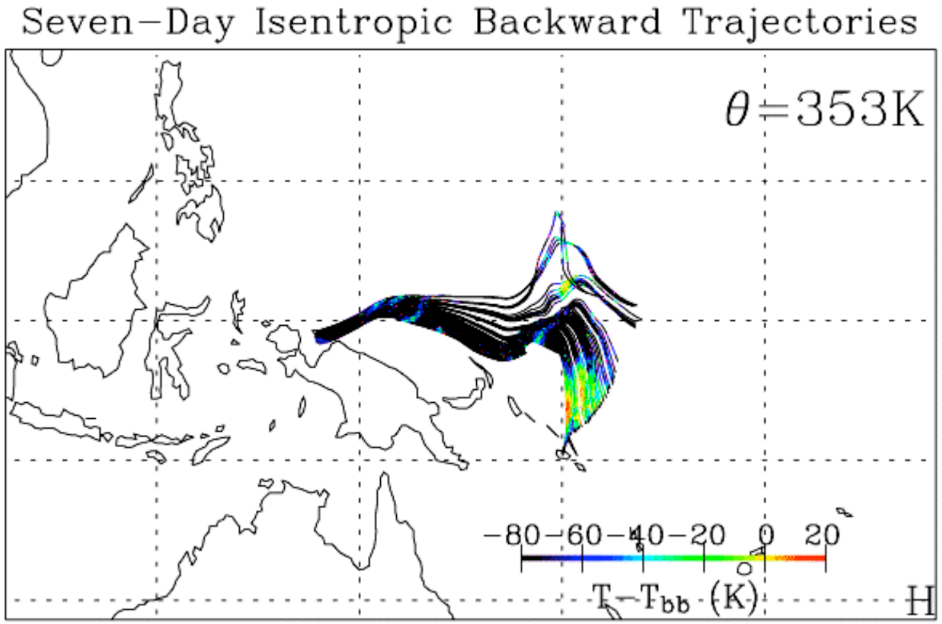
$$q(t) = \frac{1}{\tau}\int_0^t p(s)\, e^{-\frac{t-s}{\tau}} ds \quad \left(\frac{t}{\tau} \gg 1\right)$$

$$\frac{dq}{dt} = \frac{1}{\tau}(p(t) - q(t))$$

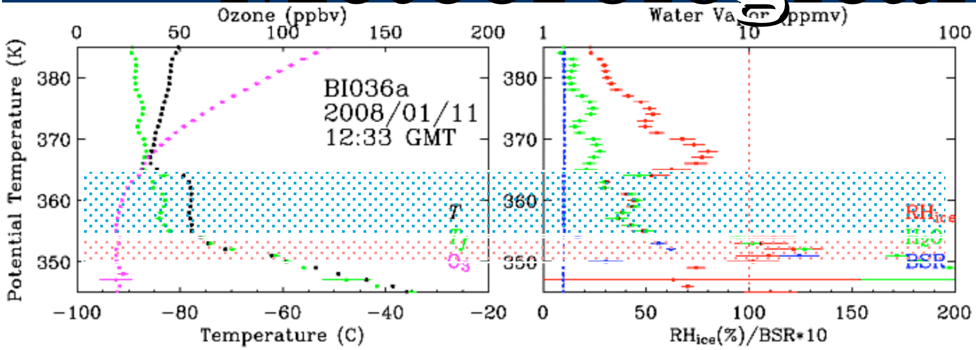
Trajectory Analyses

- Ensemble of trajectories to represent air parcels
  - Initialization at 10 points/deg. in 1.0 deg.-radius lat/lon circle
  - Estimation of uncertainties in SMR_{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.

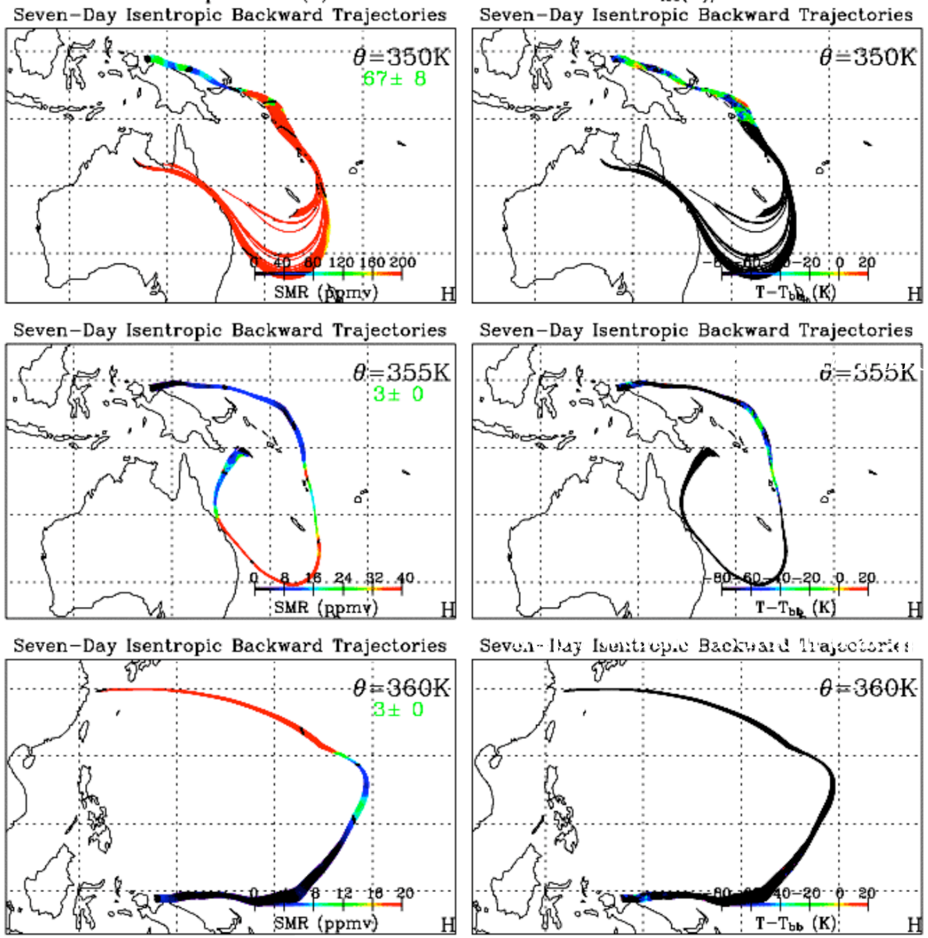


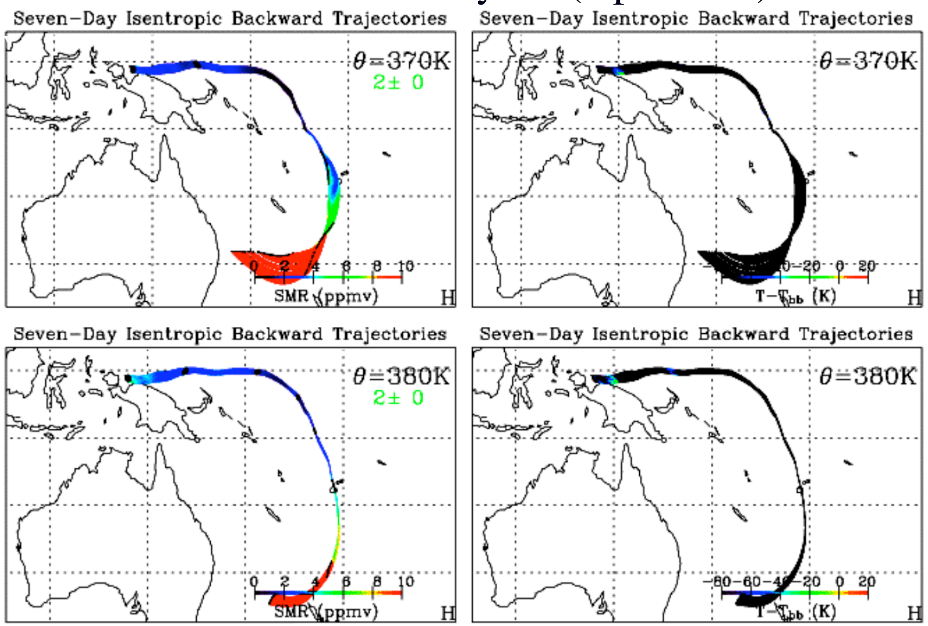


Meteorological Interpretation

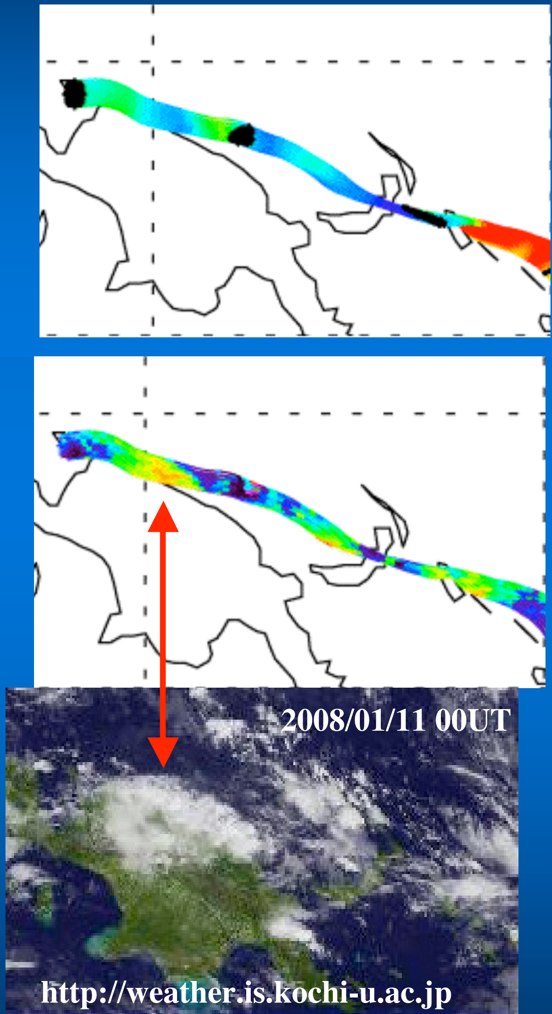


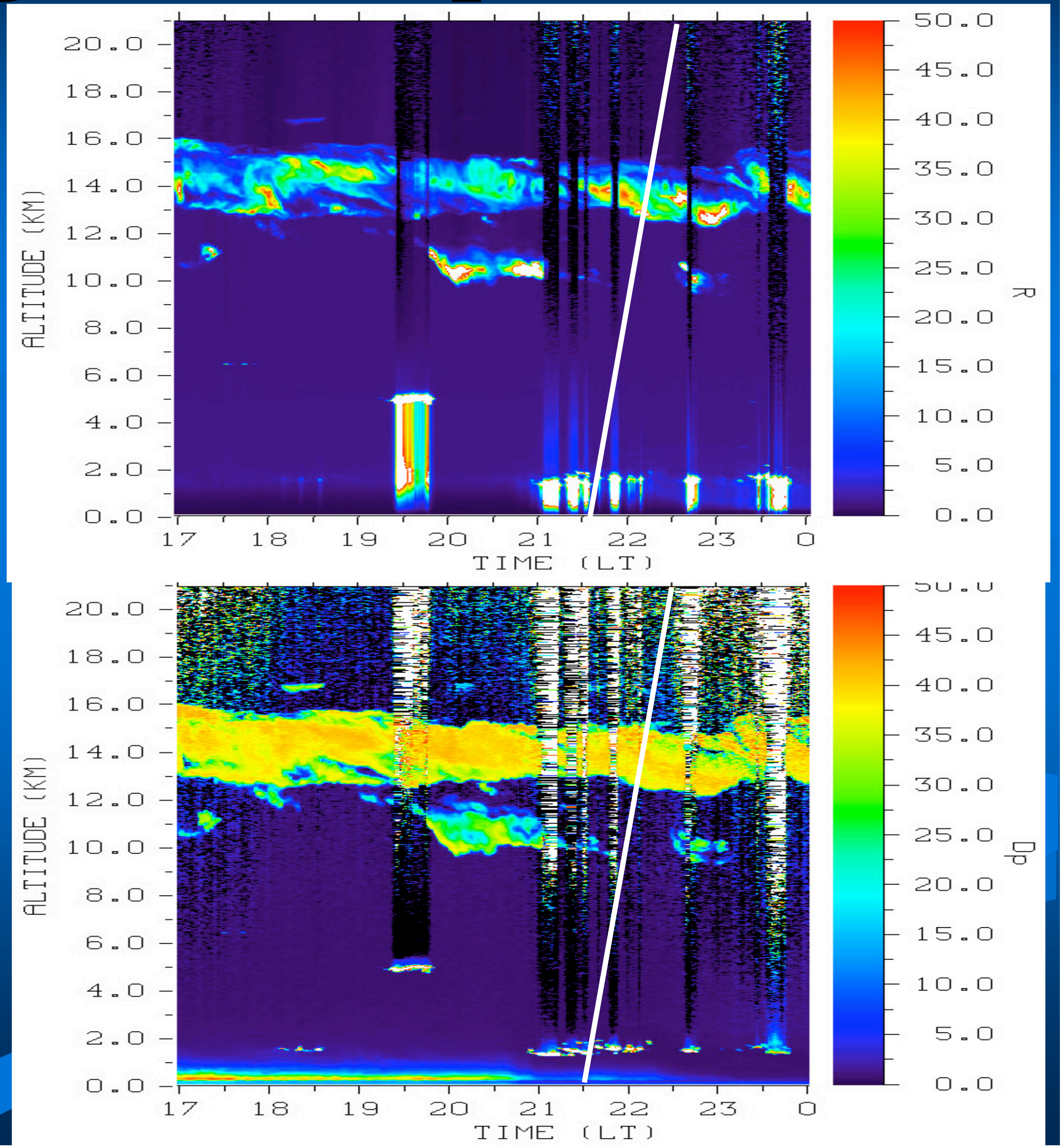
- Covered by S midlatitude air mass.
- Intrusion from N midlatitudes ~360K
  - ‘Cold trap’ dehydration for a few days before arrival at Biak
  - Warm/dry layer (356~364K; 15.4 ~ 16.1km)
- 350~354 K (13.1~15.2 km)
  - Supersaturation (<25%)
  - Cirrus
    - ‘Cobald’ BSR_{blue} Max 12.8 (351K)
    - Lidar: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



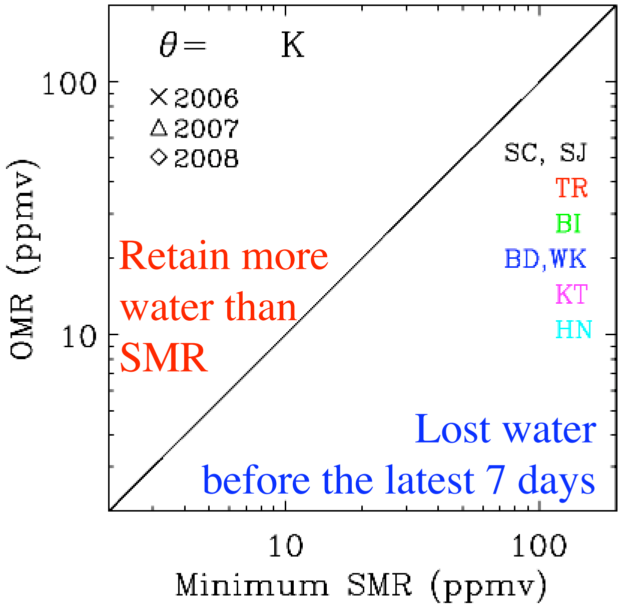


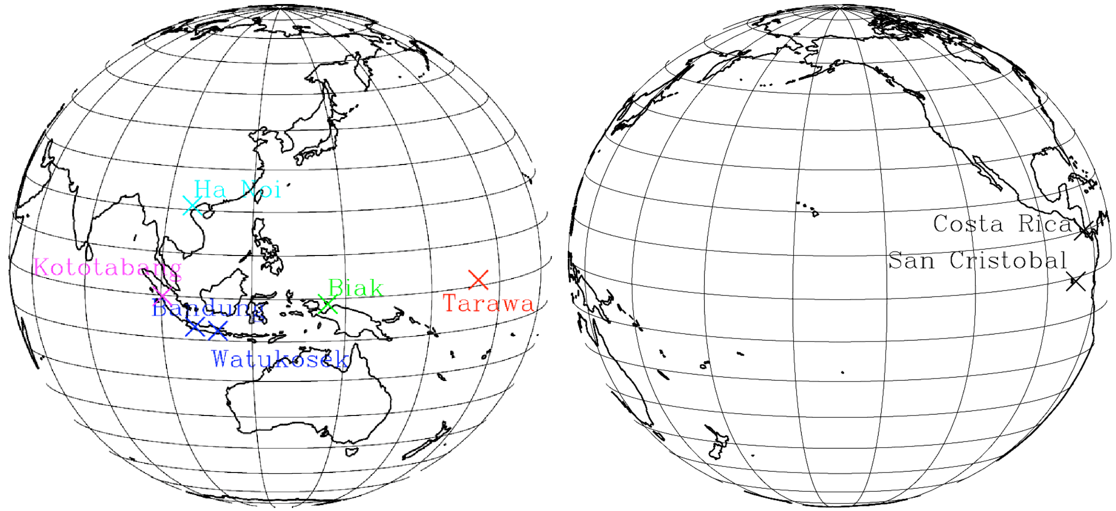
Meteorological Interpretation

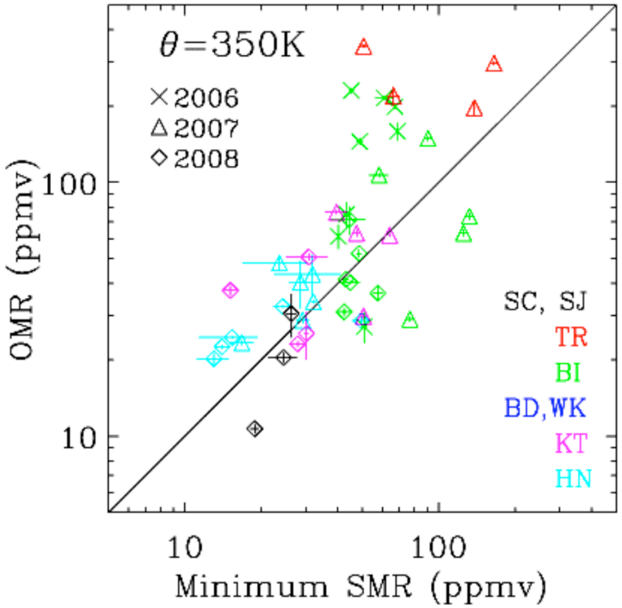




January







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

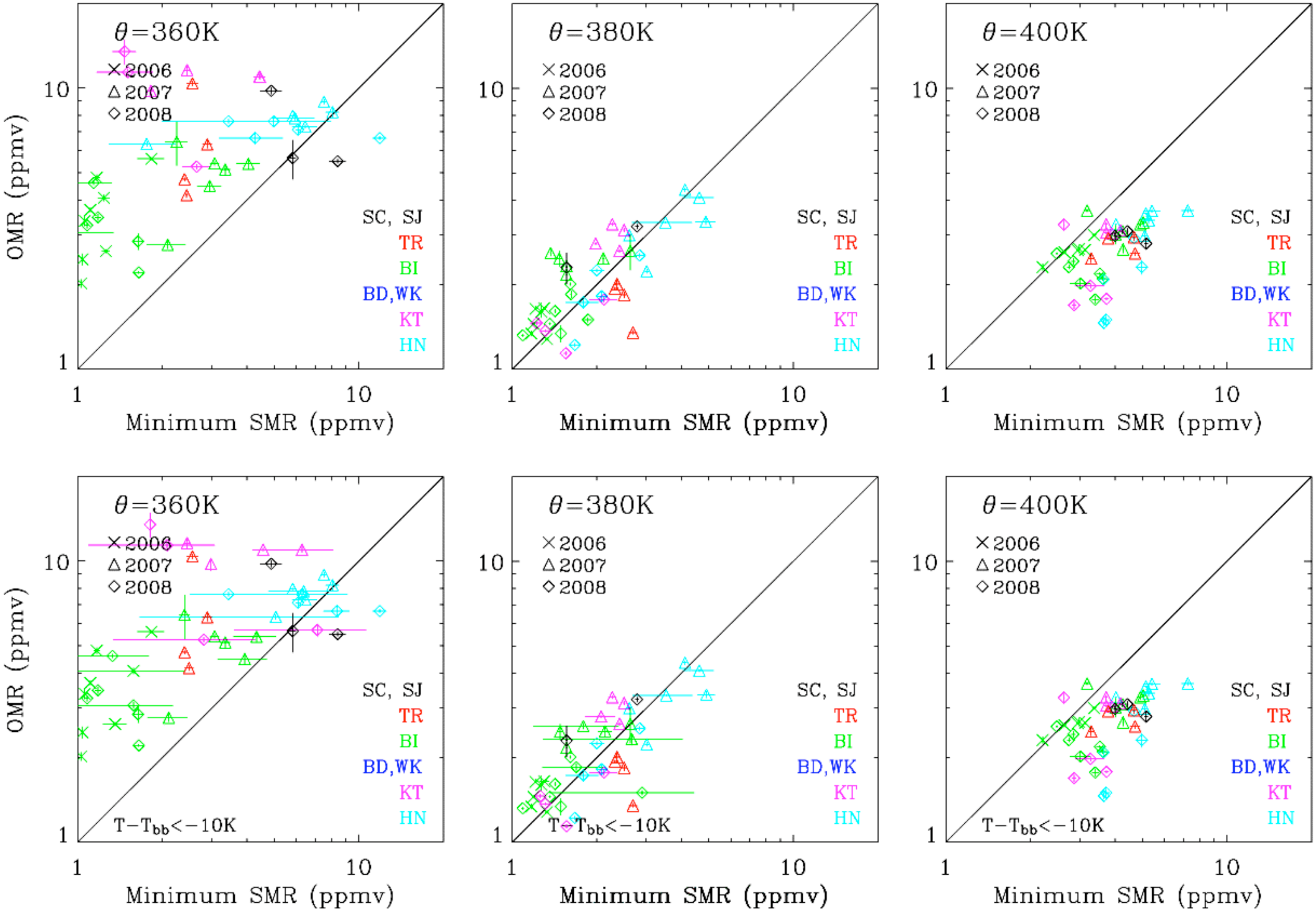
360K: In the midst of 'cold trap' dehydration. Air parcels usually retain more water than SMR_{min}.

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

400K: The 'cold trap' dehydration is almost complete. The range of OMR decreases due probably to mixing. The tape recorder signal begins to be established on this isentrope.

T-T_{bb}<-10K: These features remain qualitatively the same.

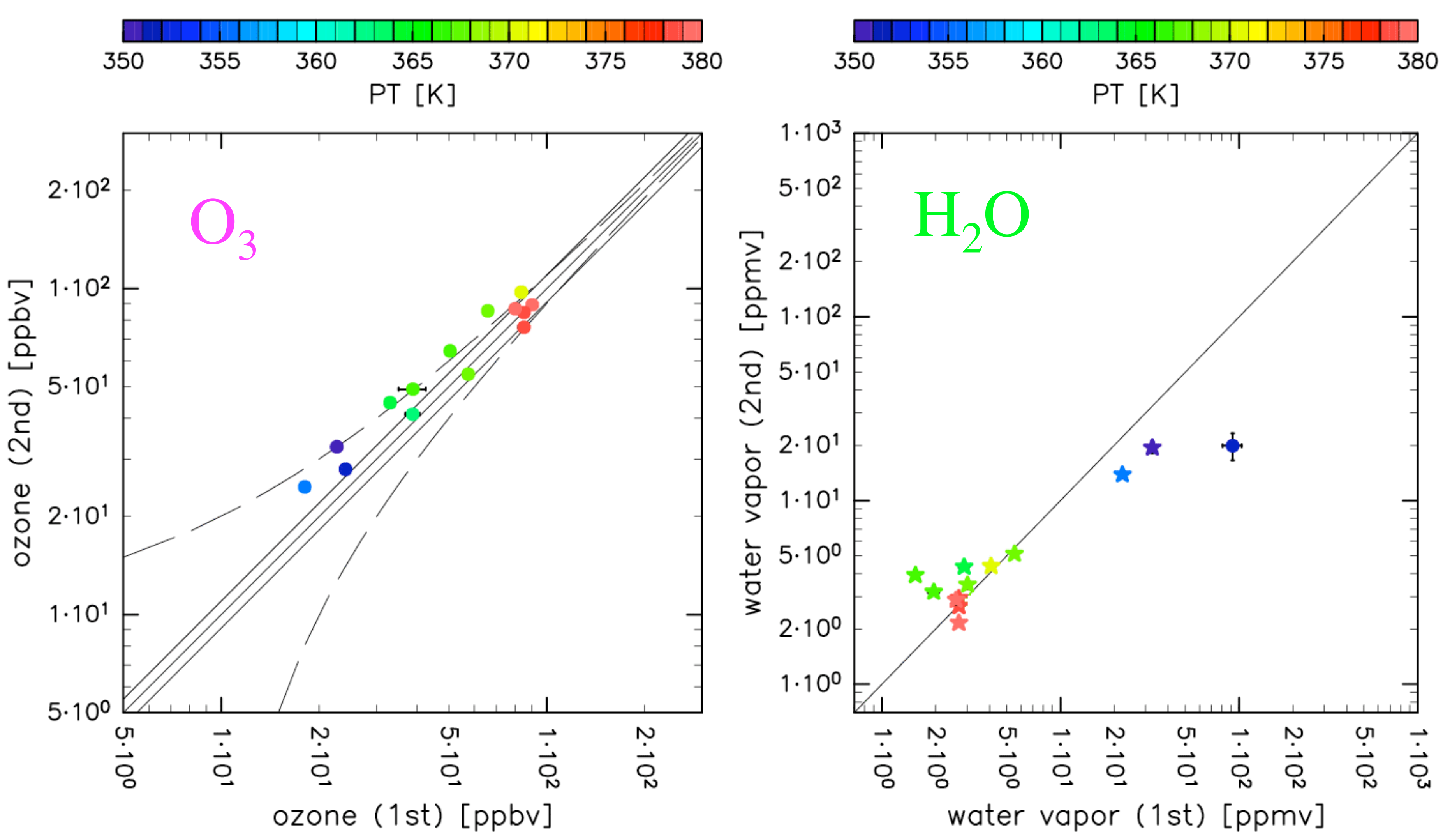
January


θ=360K
×2006
△2007
◇2008
SC, SJ
TR
BI
BD,WK
KT
HN
OMR (ppmv)
Minimum SMR (ppmv)
θ=380K
θ=400K
T−Tbb<−10K

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

Definition of Water Vapor Match



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.