Stratospheric drain over Indonesia and dehydration within the tropical tropopause layer (TTL) diagnosed by air parcel trajectories

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Outline

• Introduction
  - Stratospheric drain (observation, AGCM)
• Causes of the drain
• Trajectories using AGCM simulation
  [Sprinkler mechanism for dehydration]
• Role of disturbances
• Interannual variation related to ENSO
CCSR/NIES AGCM

- T42L50 (Surface - 0.4 hPa)
- Radiation [Nakajima et al., 1995]
- Cumulus [Arakawa & Schubert, 1974; Moorthi and Suarez, 1992]
- Cloud water [Le Treut and Li, 1991]
- No overshooting cloud are included.

- 44-year run using observed SST [1956-1999]
Hatsushika and Yamazaki (2001, GRL)

Tropopause Temperature (DJF) [1956-1999]

Hatsushika and Yamazaki (2001, GRL)
Figure 2. Map of DJF $\omega$ at 85 hPa. Solid contours indicate descent, dashed contours ascent; contour interval 0.5 hPa/day. Shaded (dotted) areas are greater (less) than zero by at least one standard error; areas where standard error is greater than 1.0 hPa/day are left blank. JJA map (not shown) is similar.
cumulus overshooting?

Figure 4. Illustration of the diabatic mean flow (arrows) and its relationship to the locations of deep convection and convective outflows.
at 85hPa simulated by AGCM

Omega (hPa/day) at 85 hPa

DJF 1985-1998
heat budget: Indonesia & C. Pacific

- Cooling due to horizontal advection
- Warming due to downward motion
- Small diabatic heating
P.T. (θ) & (u, w) along the Equator

AGCM

ECMWF data [2000-2002]
Conclusion 1 (Stratospheric drain)

- The AGCM reveals downward motions in the upper part of the TTL over Indonesia, representing the stratospheric drain.
- In the TTL, strong easterlies prevail and the cold ascent region tilts eastward. A down-slope flow over the upward-bulging isentropic surface produces the downward p-velocity over Indonesia.
- In addition, reduction of long-wave heating over deep convection suppresses the upward motion.
Trajectory calculation

• CCSR/NIES AGCM
  1. 紹介
  2. 紹介

• 東京大学
  1. 東京大学
  2. 東京大学
Number density for parcel’s initial locations.

$350K \rightarrow 390K$
Number density of the minimum SMR locations
350K $\rightarrow$ 390K
SMR & (u,w) at the equator

SMR & streamline
Blue: DRY
Red: WET

La Niña JAN. 350K–390K
La Nina DJF  350K→390K
DJF-mean wind: 350K → 385K
La Niña JAN. 350K–375K steady state
La Nina DJF 355K → 375K
Steady winds
Path of the tropospheric air into the stratosphere

Indonesia and western Pacific
90-hPa
10S-10N
VMR, entering number and the ENSO signal

- El Nino (HighPass)
- El Nino (LowPass)
- La Nina (HighPass)
- La Nina (LowPass)
- El Nino (ALL)
- La Nina (ALL)

VMR (ppmv) vs. Total number
Conclusion 2 (dehydration –sprinkler-)

• Tropospheric air parcels are advected upward to the bottom of the TTL mainly from the stratospheric fountain region.

• A pair of anticyclonic circulations in the tropical western Pacific entrains air parcels, which then pass through the equatorial cold region several times during the slow ascent in the TTL.

• This slow spirally ascending motion brings about low humidity in the stratosphere despite the local downward motion over Indonesia.

• Transient disturbances, particularly low-frequency disturbances, contribute to effective dehydration.
El Nino and La Nina
In El Nino years, the main entry shift eastward, the mean SMR is 15% higher than in La Nina years.

The number of initial locations of parcels that entered the stratosphere and their SMRs for each longitudinal range.
Backward trajectories from 90 hPa

La Nina

El Nino

90hPa

Variance

100E-160E

La Nina, VMR, DJF, 1mon back traj.
Conclusion 3  (interannual variability)

• The interannual variation in the water vapor mixing ratio into the tropical lower stratosphere with the ENSO cycle is also estimated.

• In La Nina years, air is more dehydrated.

Wake up?
90-hPa
10S-10N
Figure 4. Composite $\omega$ (hPa/day) at 90 hPa in DJF. The La Niña years (top) and the El Niño years (bottom). A 9-point smoothing is applied in zonal and meridional directions. Positive value means downward motion.
Figure 5. Latitudinal mean (9.77°S-9.77°N) composite of difference in $\omega$ (hPa/day) for the AGCM simulation between El Niño and La Niña, in DJF. The line with open circles denotes $\omega$ at 120 hPa (below the tropopause) and the line with closed circles denotes $\omega$ at 70 hPa (above the tropopause).

Hatsushika and Yamazaki (2001, GRL)