Overshooting convective clouds

Water vapour transport to the stratosphere driven by thunderstorm activity

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Thunderstorm Effects on the Atmosphere-Ionosphere System
Overshooting convective clouds

Outline

Water in the stratosphere

Why is water interesting?

What controls the stratospheric water content?

Overshooting deep convection
  Tropical Stratospheric Clouds
  11 μm climatology (PATMOS-x)
  Model

Phenomenological relation

Ideas and perspectives

Conclusions
Water in the stratosphere

Methane oxidation, triggered by UV

$$\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$$

Water transport

Tropopause 16 km

(Plot from Pommereau and Khaykin)
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Water in the stratosphere

UARS HALOE 2.5- 11 \( \mu \) m
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Water in the stratosphere

H$_2$O+2CH$_4$ anomaly 20S–20N

Randel (2006)
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Water in the stratosphere

Hurst et al. JGR (2011)
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Why is water interesting?

Why is water interesting?

Solomon et. al (2010)
What controls the stratospheric water content?
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What controls the stratospheric water content?

Dehydration at the tropopause

Correlation between tropopause temperature and stratospheric water: 0.81 Fueglistaler (2005)

(Anti) correlation between residual vertical velocity and stratospheric water -0.66. Castanheira (2012 in review ACPD)

Figure 1. Tropical mean (30°S to 30°N) water vapor mixing ratios in the lowermost stratosphere at 400 K \([\text{H}_2\text{O}]_{400}\) and \([\text{H}_2\text{O}]_{t}\). (a) Model results (black) and model results for \([\text{H}_2\text{O}]_{t}\) (grey), (b) Model results (black) and HALOE (red), and (c) Model, HALOE, and MLS. The water vapor data were derived from the HALOE and Aura MLS instruments. Both time series were smoothed by a 5-month running mean and normalized by their respective standard deviations. The time series of the residual vertical velocity loads the water vapor by 5 months. This means that the time series of the residual vertical velocity is shifted five months to the left in the plot.
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what controls the stratospheric water content?

Hydration from overshooting convection
Tropical Stratospheric Clouds

Khaykin et al. (2009)

Nielsen et al. (2007)
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Intensity of clouds with $T_B < 200$ K (OCEAN!)
Overshooting convective clouds

- Overshooting deep convection
- 11 $\mu$m climatology (PATMOS-x)

Intensity of clouds with $T_B < 200$ K (LAND!)
Overshooting convective clouds

Overshooting deep convection

11 $\mu$m climatology (PATMOS-x)

Intensity of clouds with $T_B < T_{\text{tropopause}}$ (LAND!)

![Graph showing the intensity of clouds with $T_B < T_{\text{tropopause}}$ over time and latitude.](image)

- **Latitude (deg.)**: -40, -20, 0, 20, 40
- **TSC frequency**: 0, 0.0005, 0.001, 0.0015, 0.002, 0.0025, 0.003
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Overshooting deep convection

Model

\[ \dot{x} = -k(x - a) + cd(t) \]  

\( x = \text{Water Vapour Mixing Ratio} \)
\( d = \text{Tropical Stratospheric Cloud -frequency} \)
\( a = \text{Mixing ratio of slow ascending air.} \)
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Phenomenological relation

Phenomenological relation

\[ r_C = 0.87 \]

\( \ast \) HALOE 16–17 km

\( \ast \) TSC 4 to 20 deg.
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Phenomenological relation

$r_c = 0.64$

H2O Mixing R.

Time (years)

H2O+2CH4 anomaly 20S–20N

Height (km)

Pressure (hPa)

Year

-0.9 -0.7 -0.5 -0.3 -0.1 0.1 0.3 0.5 0.7 0.9
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Ideas and perspectives

Explain QBO! ← Lightening data / Shumann resonances / PATMOS-x
Explain stratospheric water SWOOSH, 2 decades, (SAGE, HALOE, MLS) (Rosenlof)
Characterize thunderstorms with GNSS RO data. (Biondi 2011)
Conclusions

- Tropical stratospheric clouds correlate well with stratospheric Water Vapour Mixing Ratio
- Still a lot to do

lunch
RHW = exp \left( - \frac{\vec{p} \sigma q}{\varepsilon_0 k_B T} \right).
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Conclusions
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Conclusions

Radiation Transmitted by the Atmosphere

Radiative Forcing Components

(Wikipedia)
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Conclusions

UARS HALOE 2.5- 11 \( \mu m \)
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Conclusions
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Conclusions

$\text{CO}_2$ forcing + natural variability
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Conclusions

Earth with stratosphere