Rapid Desiccation of the Stratosphere in 2016: Connection to an Anomalous Change in the QBO

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Why is stratospheric water vapor important?

<1% of atmospheric water vapor resides in the stratosphere.

How can changes in stratospheric WV affect climate?

The flux of outgoing longwave radiation (OLR) is very sensitive to changes in WV abundance near the tropopause.

A 10% increase in water vapor near the tropopause reduces the OLR flux by approximately 1 W•m\(^{-2}\).

\[ Jsen et al. (1999) \]

~1 ppmv increase (~25%) in stratospheric WV between 1980 and 2000 would have enhanced the rate of surface warming in the 1990s by ~30%.

\[ Solomon et al. (2010) \]

Stratospheric WV also influences:

- Stratospheric ozone chemistry
  - halogen activation (HOx), \(O_3\) reaction rates, polar \(O_3\) chemistry (PSCs)
- Lifetimes of greenhouse and ozone-depleting gases (OH, T)
- Cirrus cloud formation
What controls the amount of WV entering the stratosphere?

**Other Contributors**
- Transport through tropopause breaks
- Ice lofting by deep convection
- Asian Monsoon (?)

**In Situ Production**
- Oxidation of stratospheric CH$_4$ and H$_2$
Annual Cycles and Anomalies, 15°S-15°N Zonal Means

- MLS H$_2$O, 83 hPa
  - 2005-2015 Mean
  - 2016

- Coldpoint Temperature
  - MERRA2
  - 2004-2015 Mean
  - 2016

- ∆H$_2$O = -1.9 ppmv
- ∆CPT = -2.5 °C
Quasi-Biennial Oscillation (QBO)

Downward propagating zonal wind shift in the tropical stratosphere

Avg Period 28 months

27 Cycles 1953-2015
**Water Vapor Anomalies and QBO Index**

- **QBO Index (U_{50}-U_{70})** is a gauge of the shear in zonal winds in the tropical stratosphere.
- The QBO is typically zonally uniform.
- 6 distinct QBO cycles 2004-2016.
Water Vapor Anomalies, QBO cycles 1-6

Cycle 6 $\Delta H2O_{anom}$ -1.9 ppmv in 1 yr ~50% of burden!
WV anomalies are zonally asymmetric!

Largest changes in the E Hemisphere
MERRA2 Coldpoint Temperature Anomaly Maps

December 2015

- SST
- Upwelling
+ CPT

Strong El Niño
- SST
- Upwelling
+ CPT

November 2016

Weak La Niña
+ SST
+ Upwelling
- CPT
Meridional WV Anomalies, QBO cycles 1-6

(A) 0°-90°E
- Mean Cycles 1-5
- Cycle 6 (2016)

(B) 90°E-180°
- Mean of Cycles 1-5
- Cycle 6 (2016)

(C) 180°-90°W
- Mean of Cycles 1-5
- Cycle 6 (2016)

(D) 90°W-0°
- Mean of Cycles 1-5
- Cycle 6 (2016)
Meridional WV Anomalies, QBO cycles 1-6
Tropical lower stratospheric WV closely follows tropical CPTs

Zonal average anomalies dropped 1.9 ppmv and 2.5°C in only 11 months (Dec 2015 - Nov 2016)

The anomalous behavior of the 2015-16 QBO cooled the tropical tropopause earlier than normal seasonal cooling.

The 2016 changes in WV and CPTs were not zonally uniform:
  • Transition from strong El Niño to weak La Niña

Lower stratospheric WV anomalies over the E Hemisphere tropics dropped 2.7 ppmv in 11 months!!!
That's all Folks!
MLS WV 83 hPa and MERRA2 CPT Anomaly Maps

December 2015
MLS WV 83 hPa and MERRA2 CPT Anomaly Maps

December 2016

November 2016