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

Dale Hurst[1,2], Sean Davis[1,3], Karen Rosenlof[3], Emrys Hall[1,2], and Allen Jordan[1,2]

[1] CIRES, University of Colorado, Boulder
[2] NOAA ESRL Global Monitoring Division, Boulder
[3] NOAA ESRL Chemical Sciences Division, Boulder

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 $W \cdot m^{-2}$

Jensen 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:

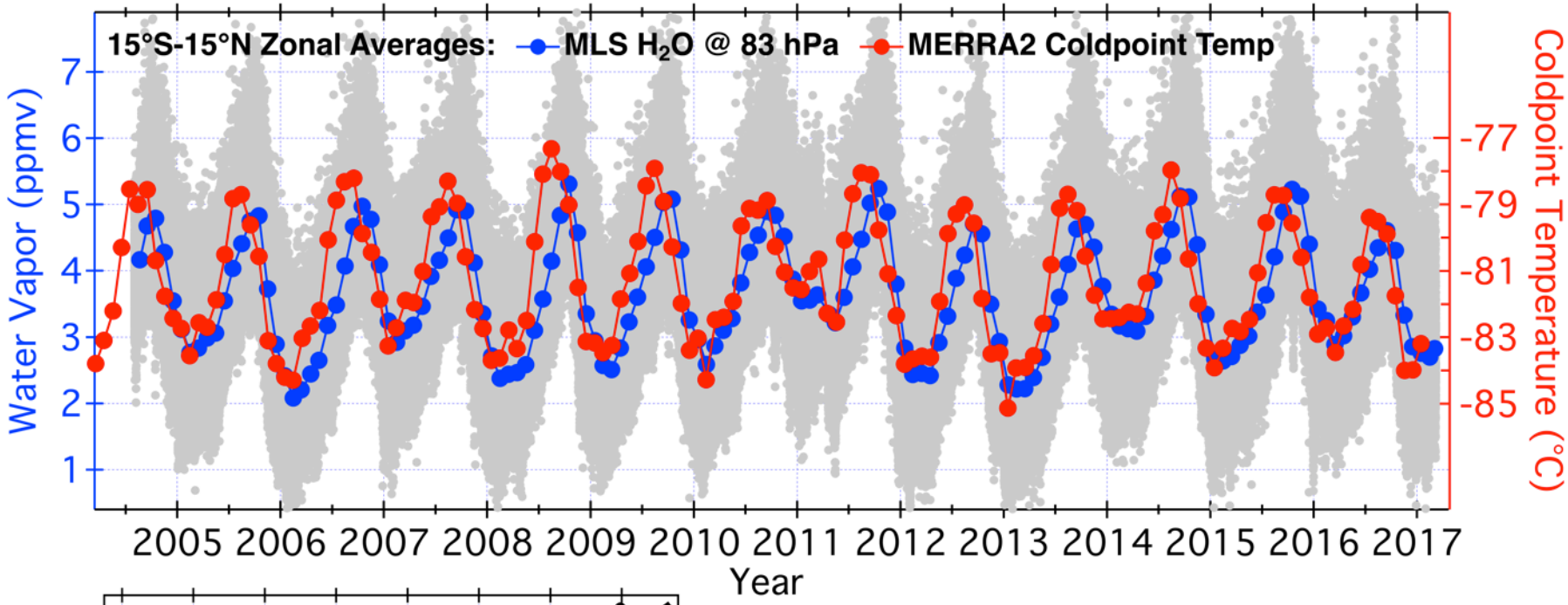
Stratospheric ozone chemistry

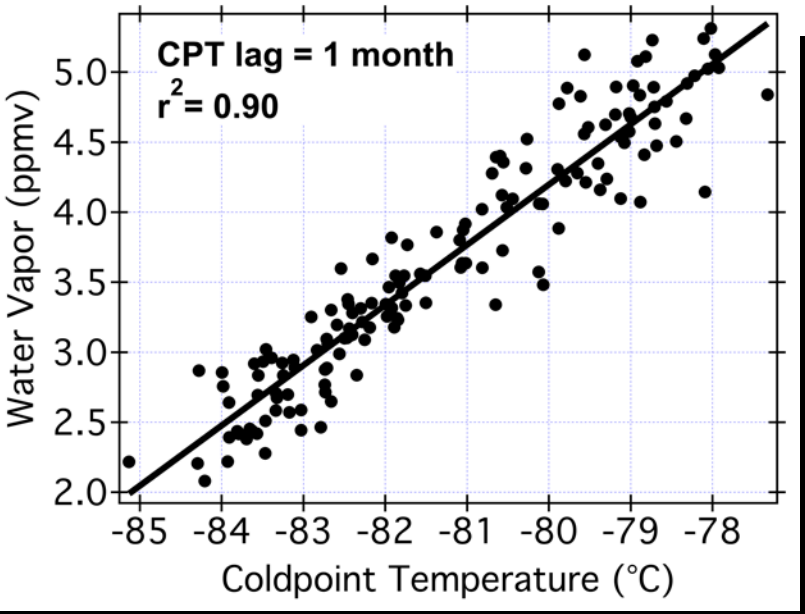
- halogen activation (HOx), O_3 reaction rates, polar O_3 chemistry (PSCs)

Lifetimes of greenhouse and ozone-depleting gases (OH, T)

Cirrus cloud formation

What controls the amount of WV entering the stratosphere?





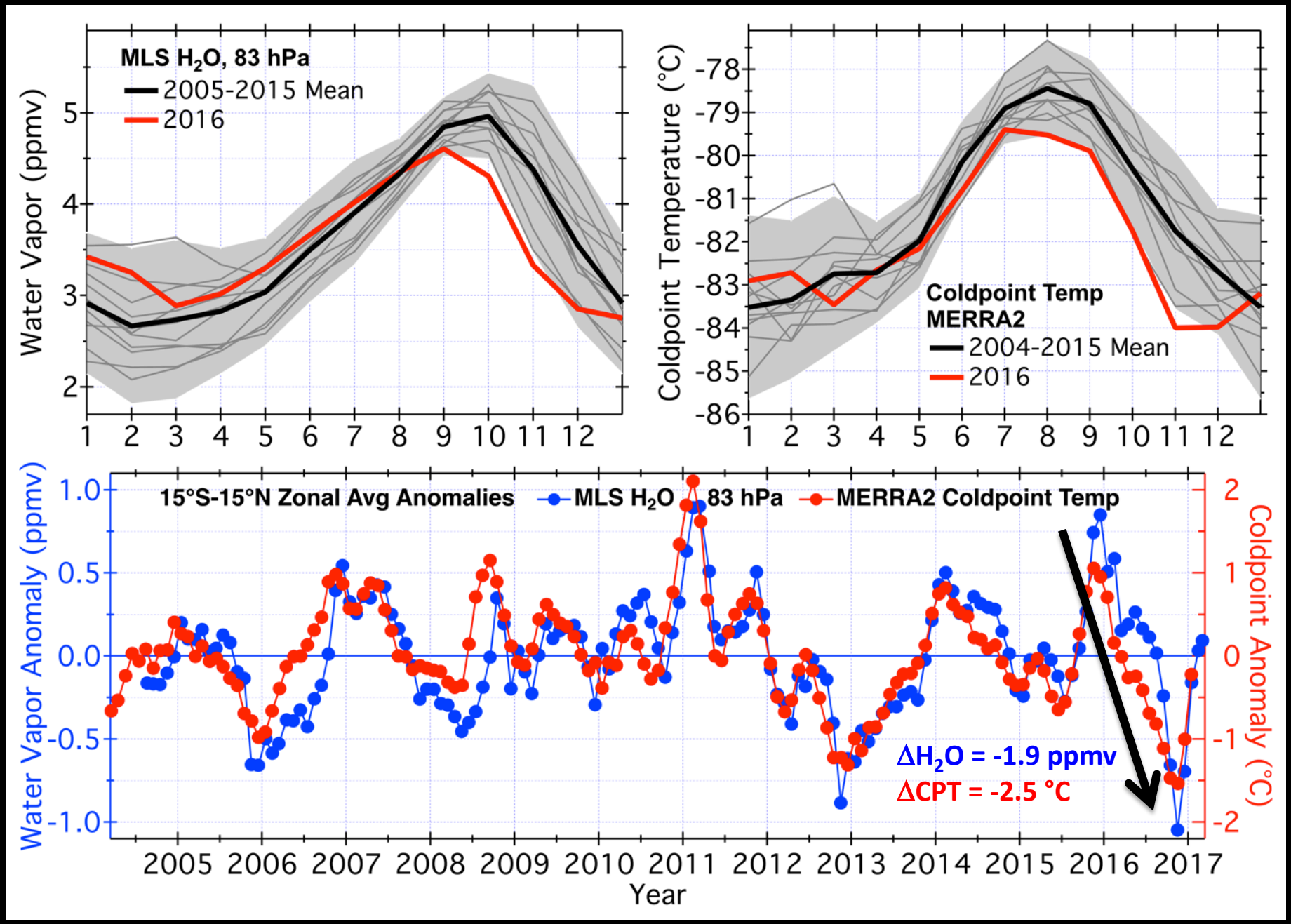
Other Contributors

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

In Situ Production

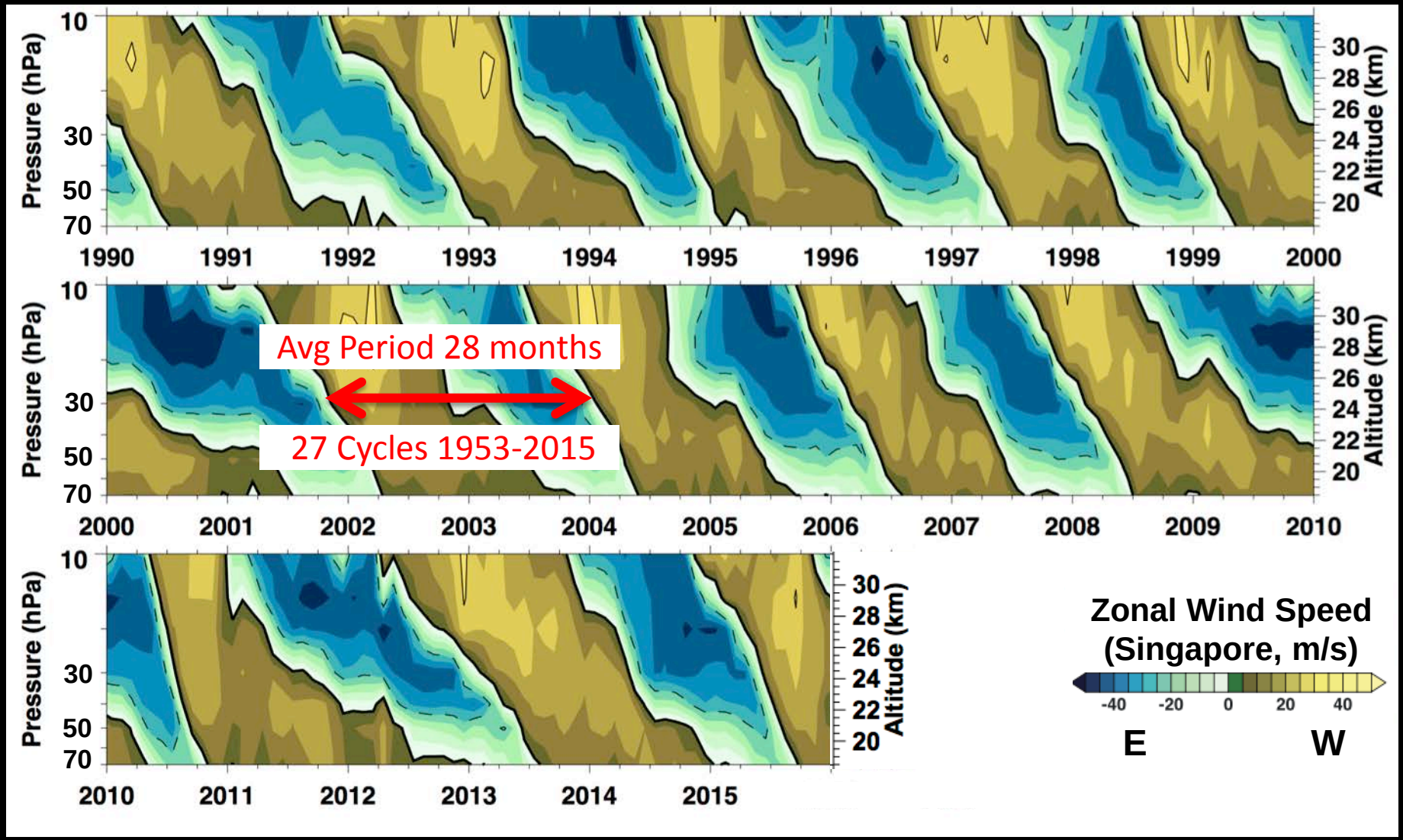
- Oxidation of stratospheric CH_4 and H_2

Annual Cycles and Anomalies, 15°S-15°N Zonal Means

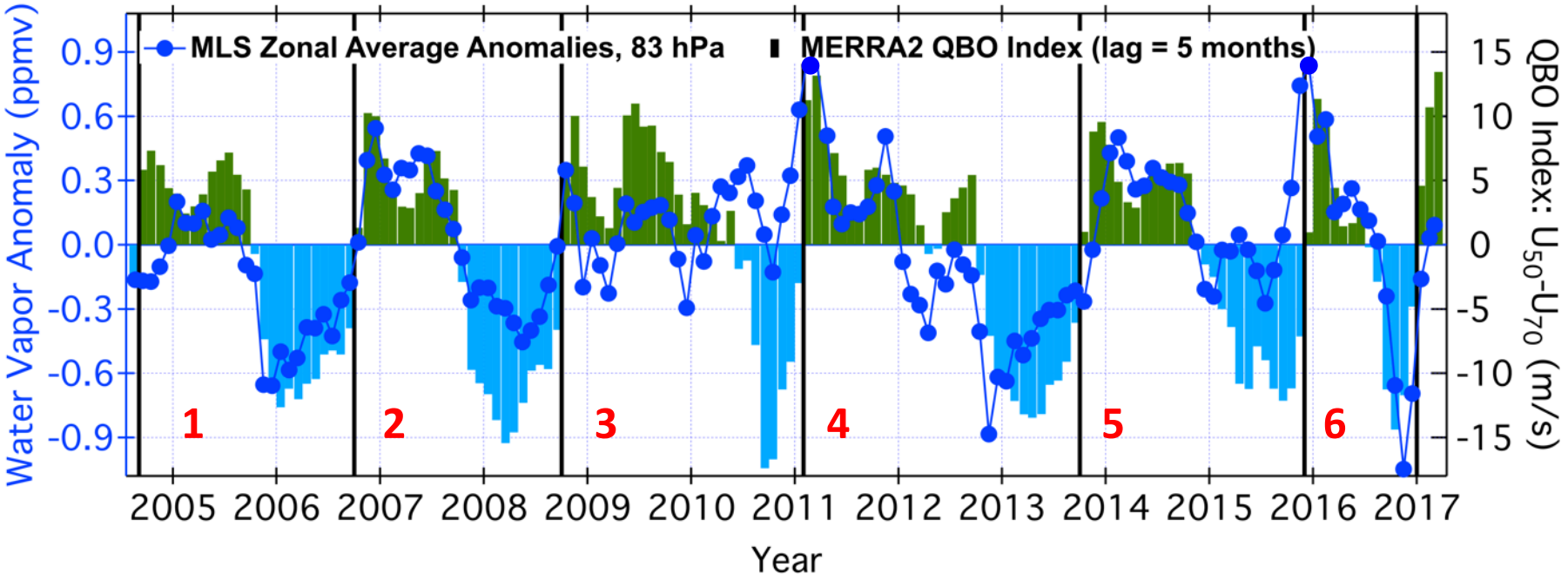


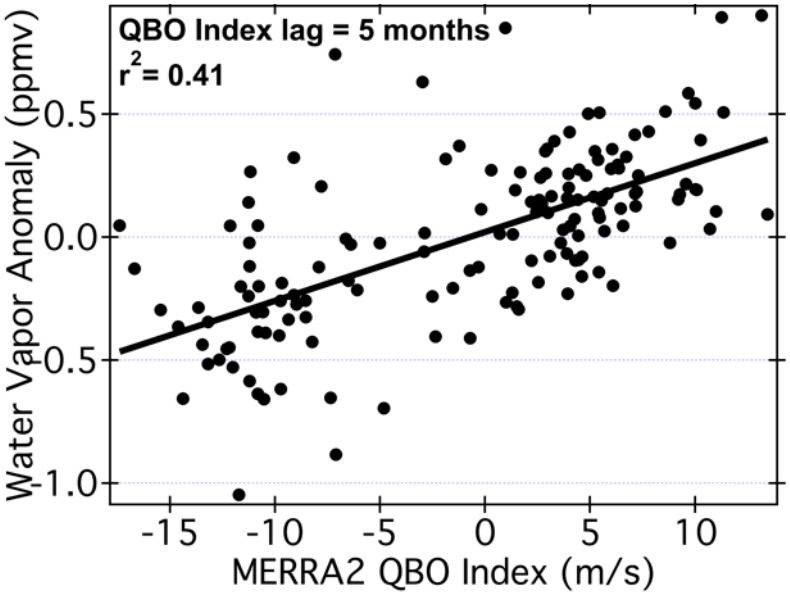
Quasi-Biennial Oscillation (QBO)

Downward propagating zonal wind shift in the tropical stratosphere



Water Vapor Anomalies and QBO Index



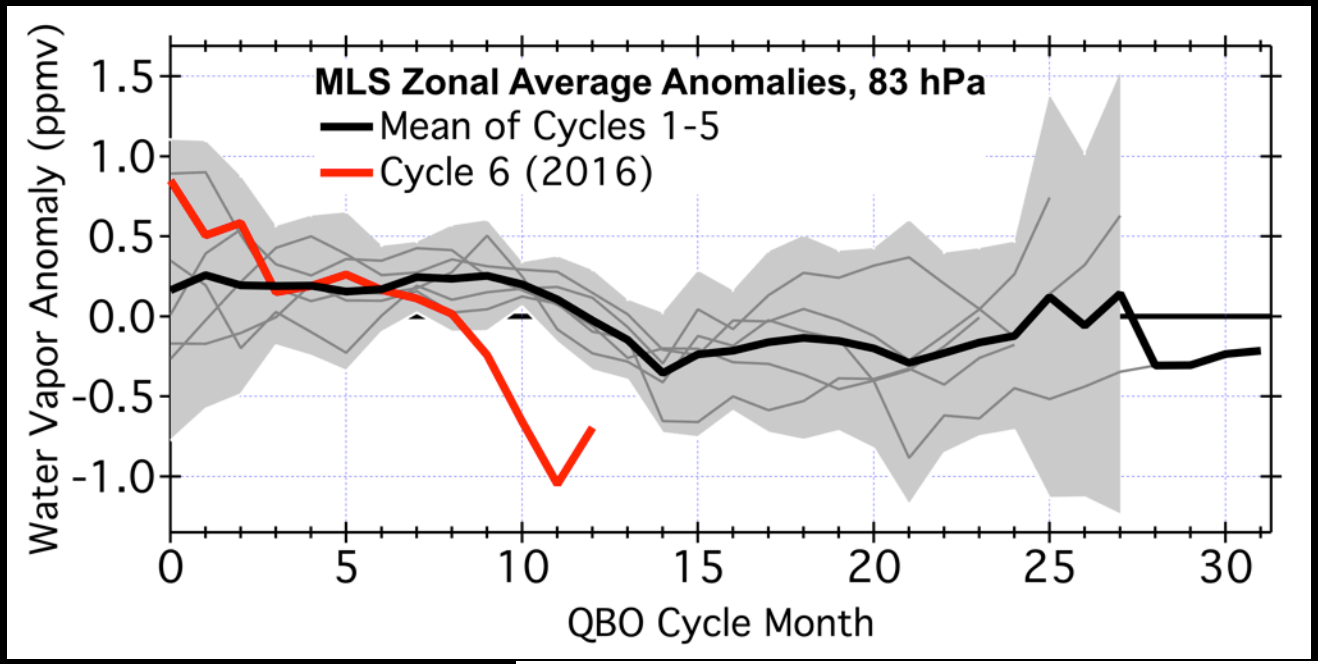


QBO Index (U_{50}-U_{70}) is a gauge of the shear in zonal winds in the tropical stratosphere.

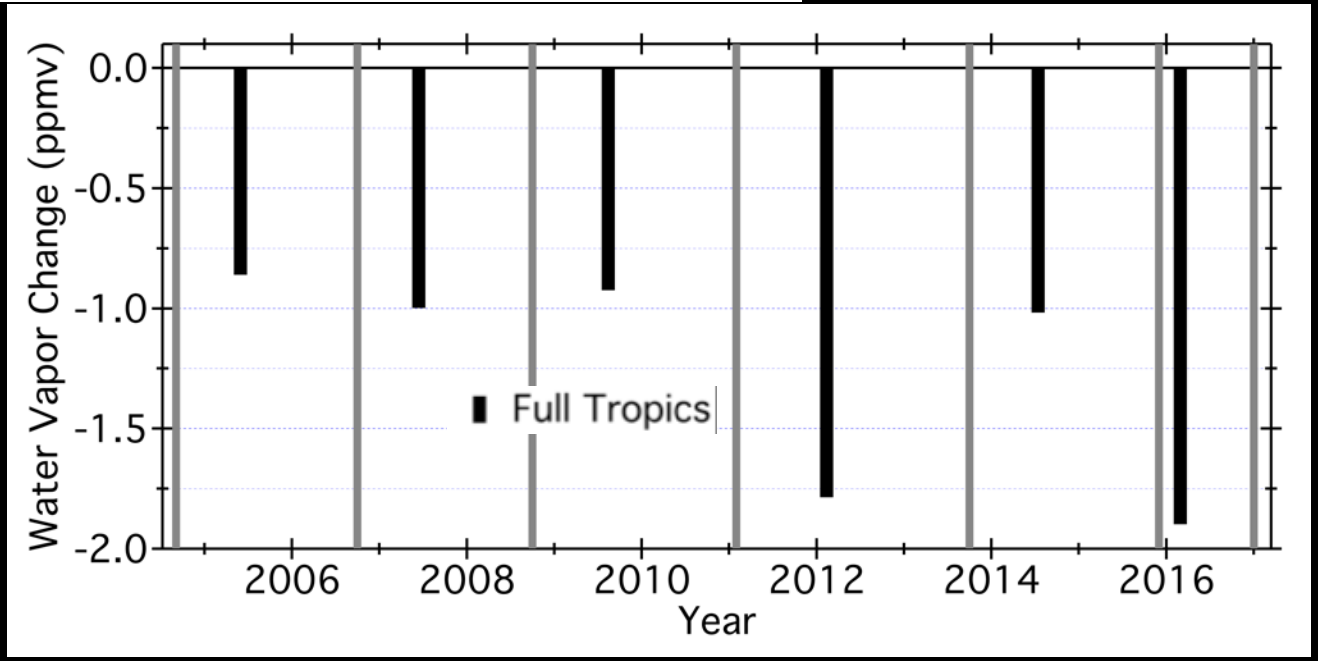
The QBO is typically zonally uniform.

6 distinct QBO cycles 2004-2016

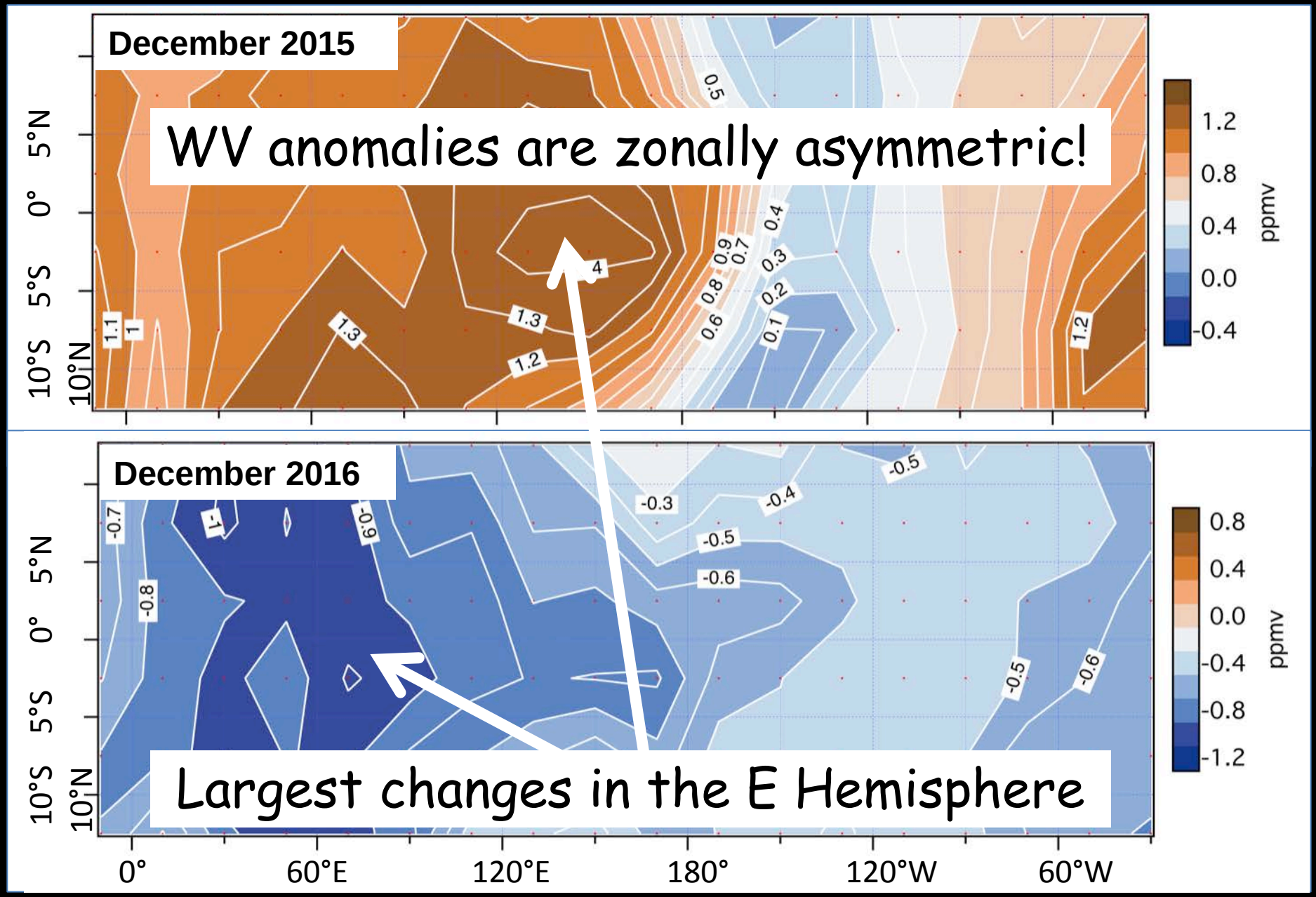
Water Vapor Anomalies, QBO cycles 1-6



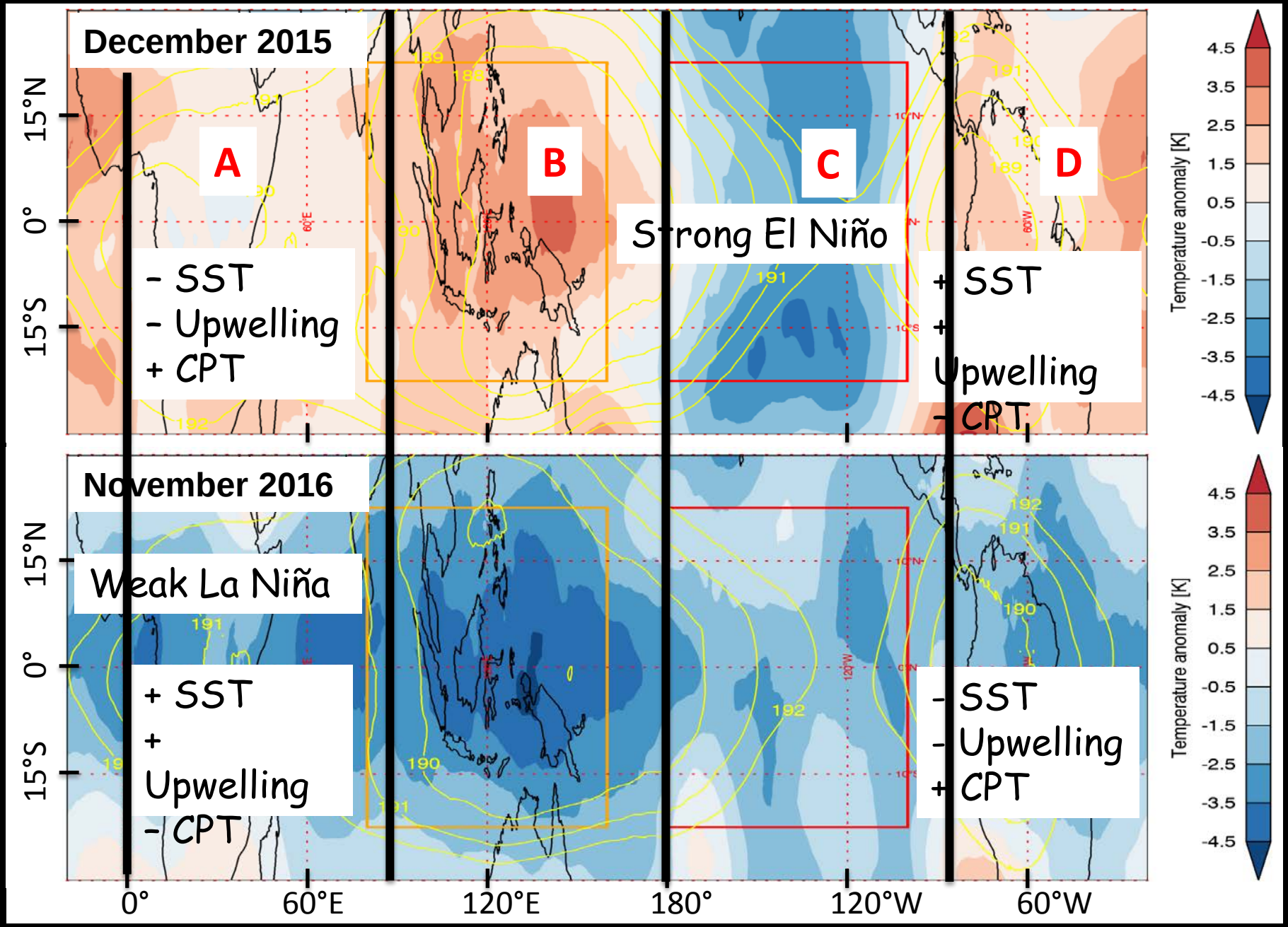
Cycle 6 $\Delta H2O_{anom}$
-1.9 ppmv in 1 yr
~50% of burden!



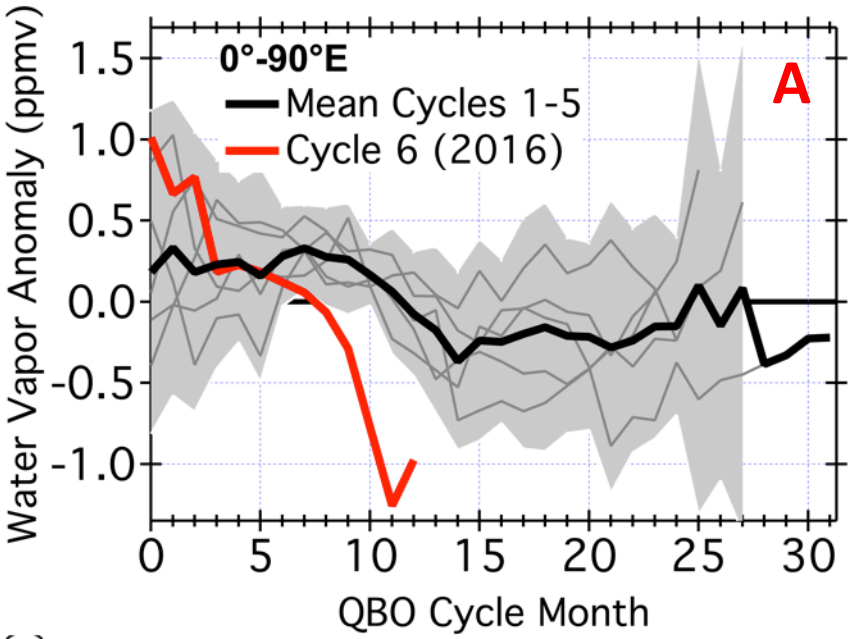
Tropical Water Vapor Anomaly Maps, 83 hPa

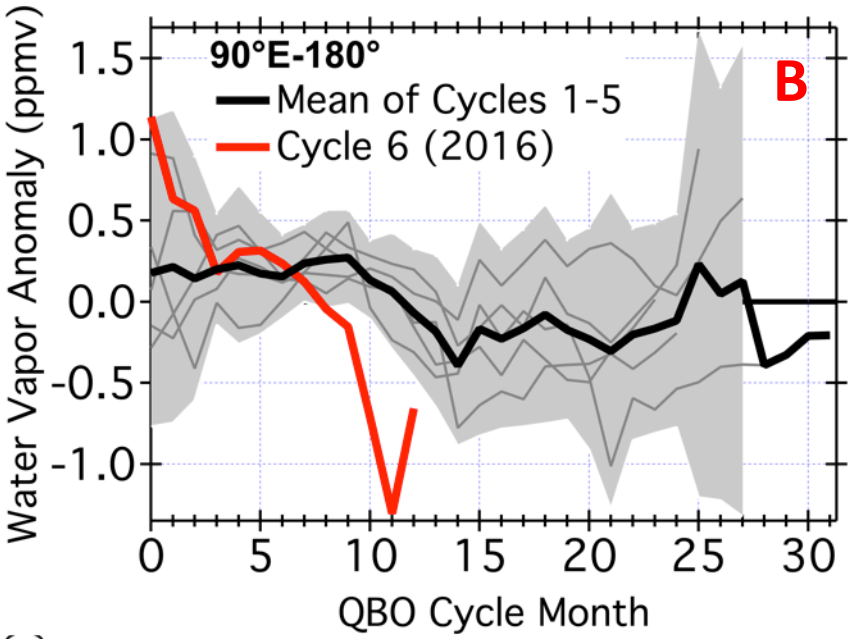


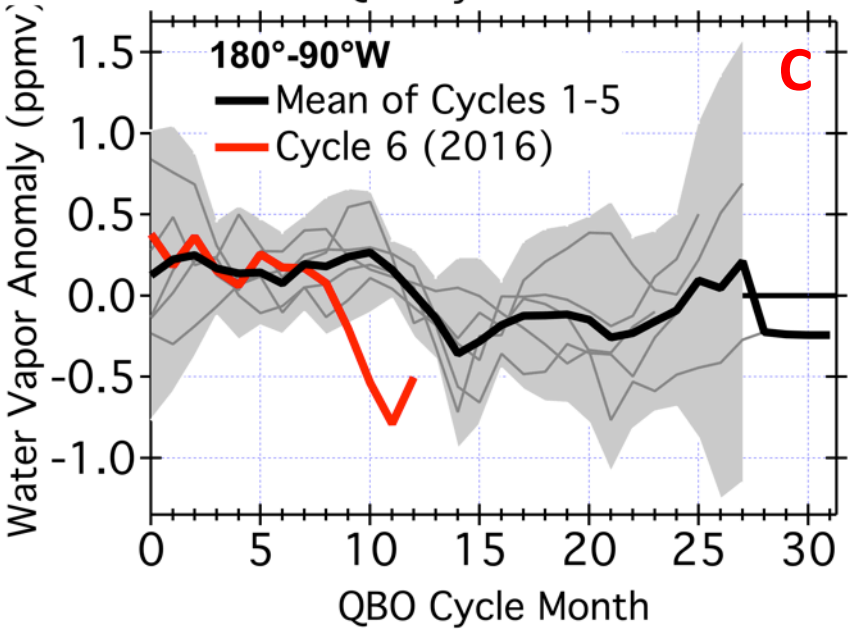
MERRA2 Coldpoint Temperature Anomaly Maps

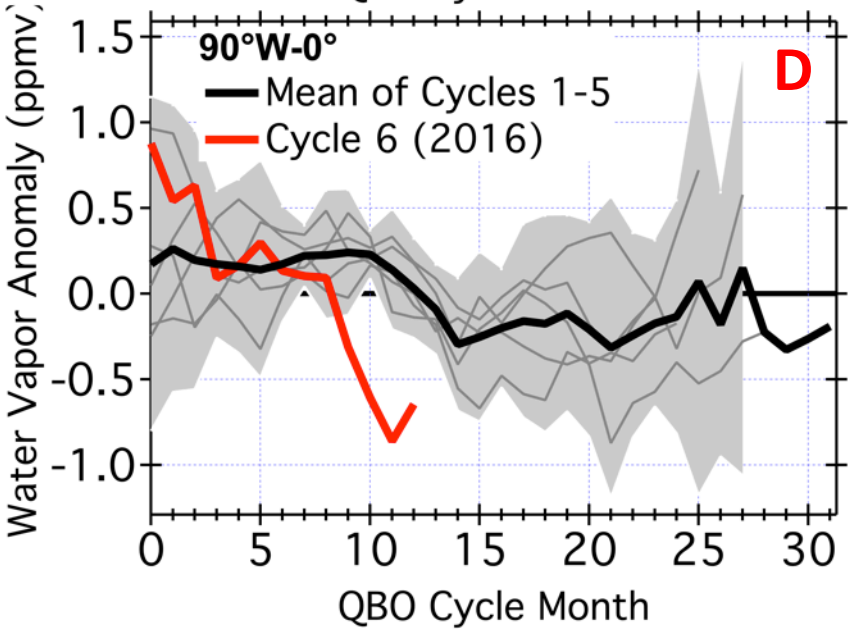


Meridional WV Anomalies, QBO cycles 1-6









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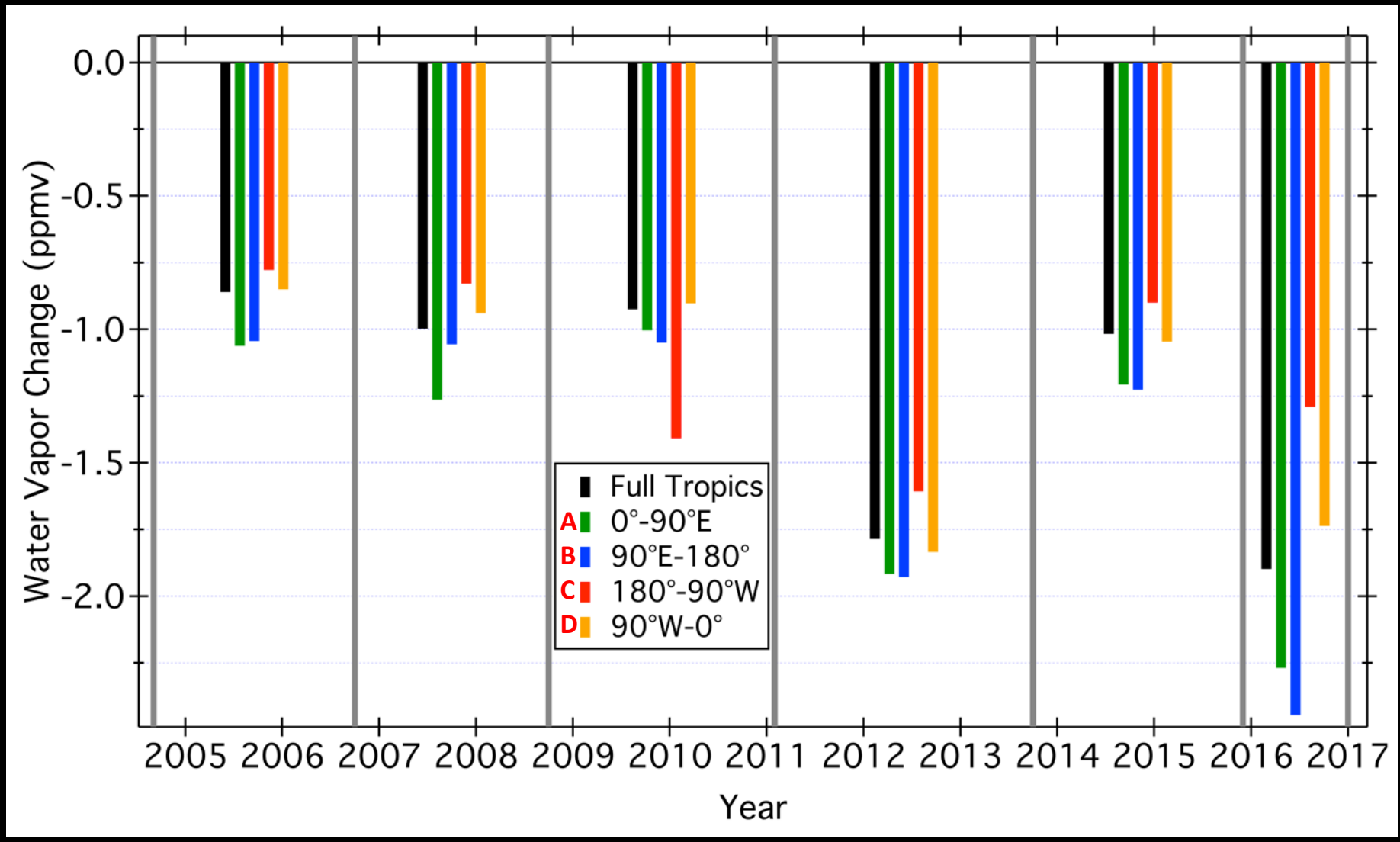


Summary

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

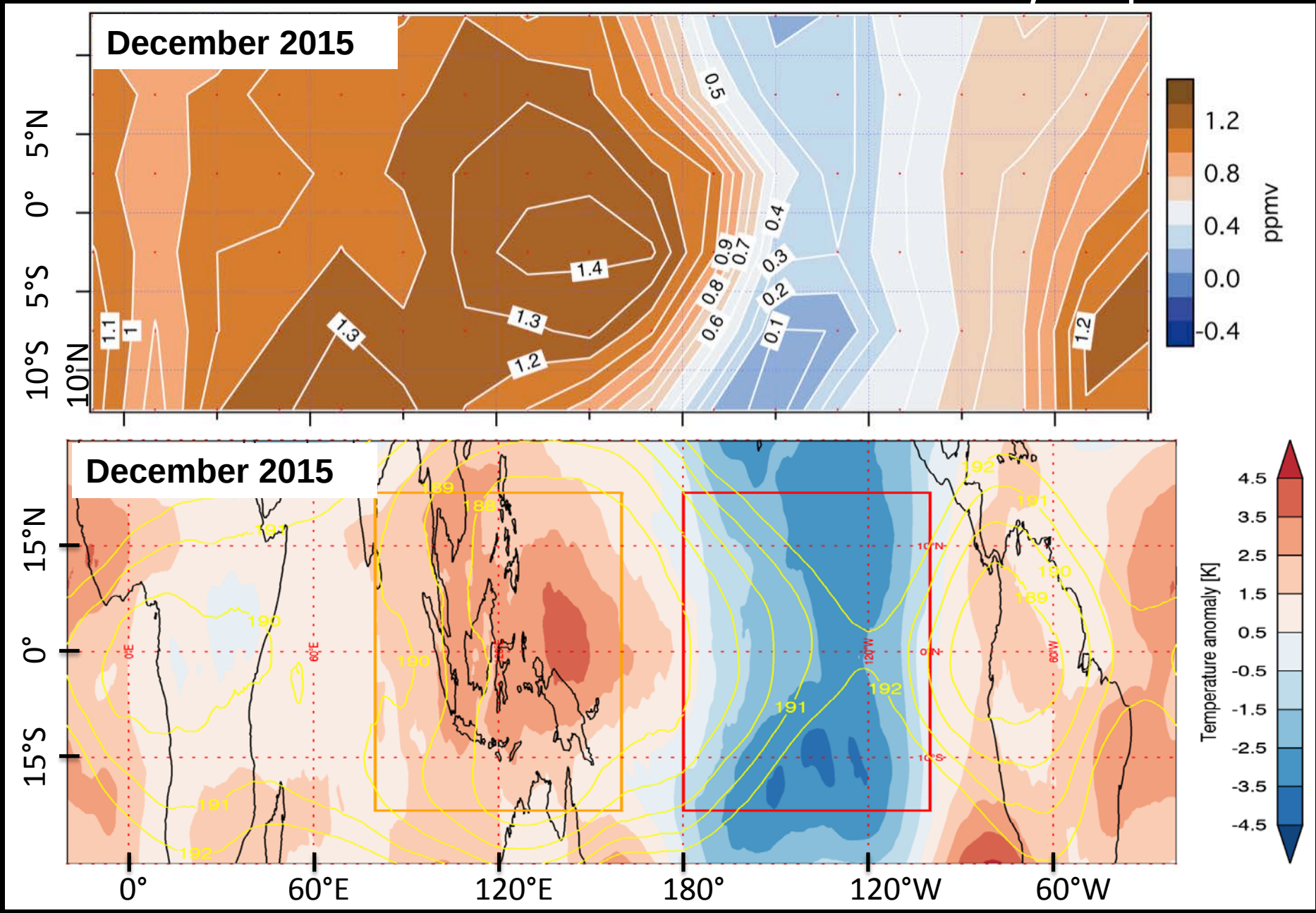
The 2016 changes in WV and CPTs were not zonally uniform
- Transition from strong El Niño to weak La Niña

Lower stratospheric WV anomalies over the E Hemisphere
tropics dropped 2.7 ppmv in 11 months!!!

Photo by Patrick Cullis, CIRES


That's all Folks!

MLS WV 83 hPa and MERRA2 CPT Anomaly Maps



MLS WV 83 hPa and MERRA2 CPT Anomaly Maps