TTL cooling and drying during the January 2013 Stratospheric Sudden Warming

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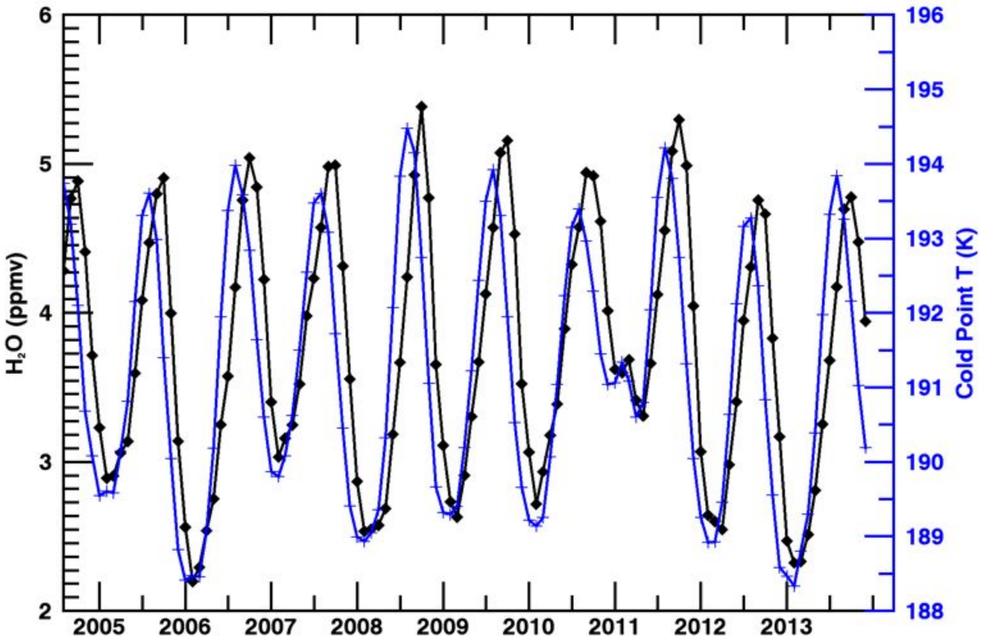
MLS 82 hPa Water vapor and GPS CPT (15S-15N)



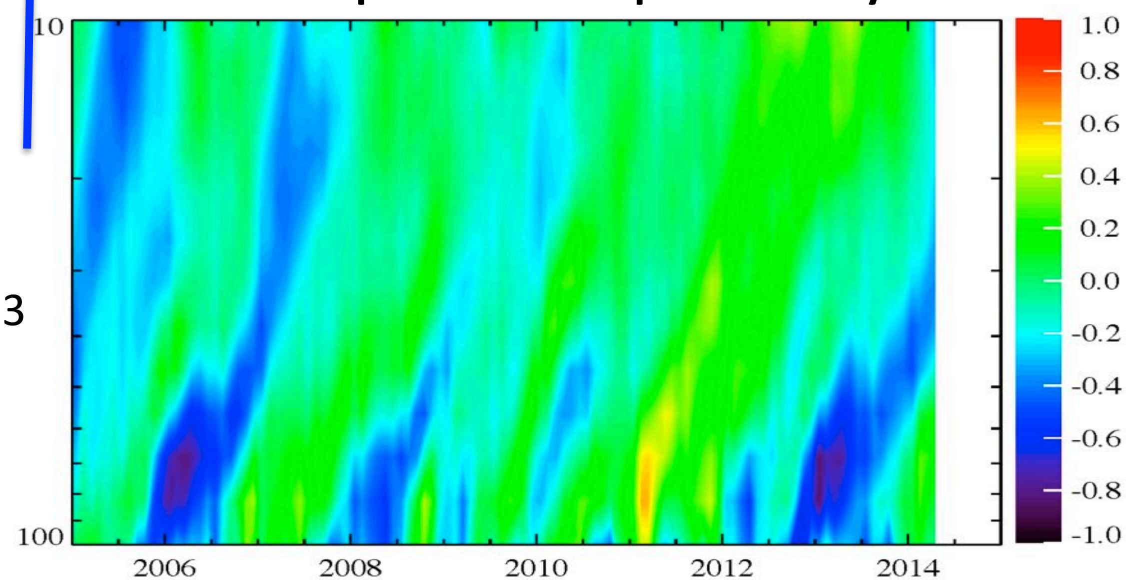
Processes that can impact stratospheric water vapor:

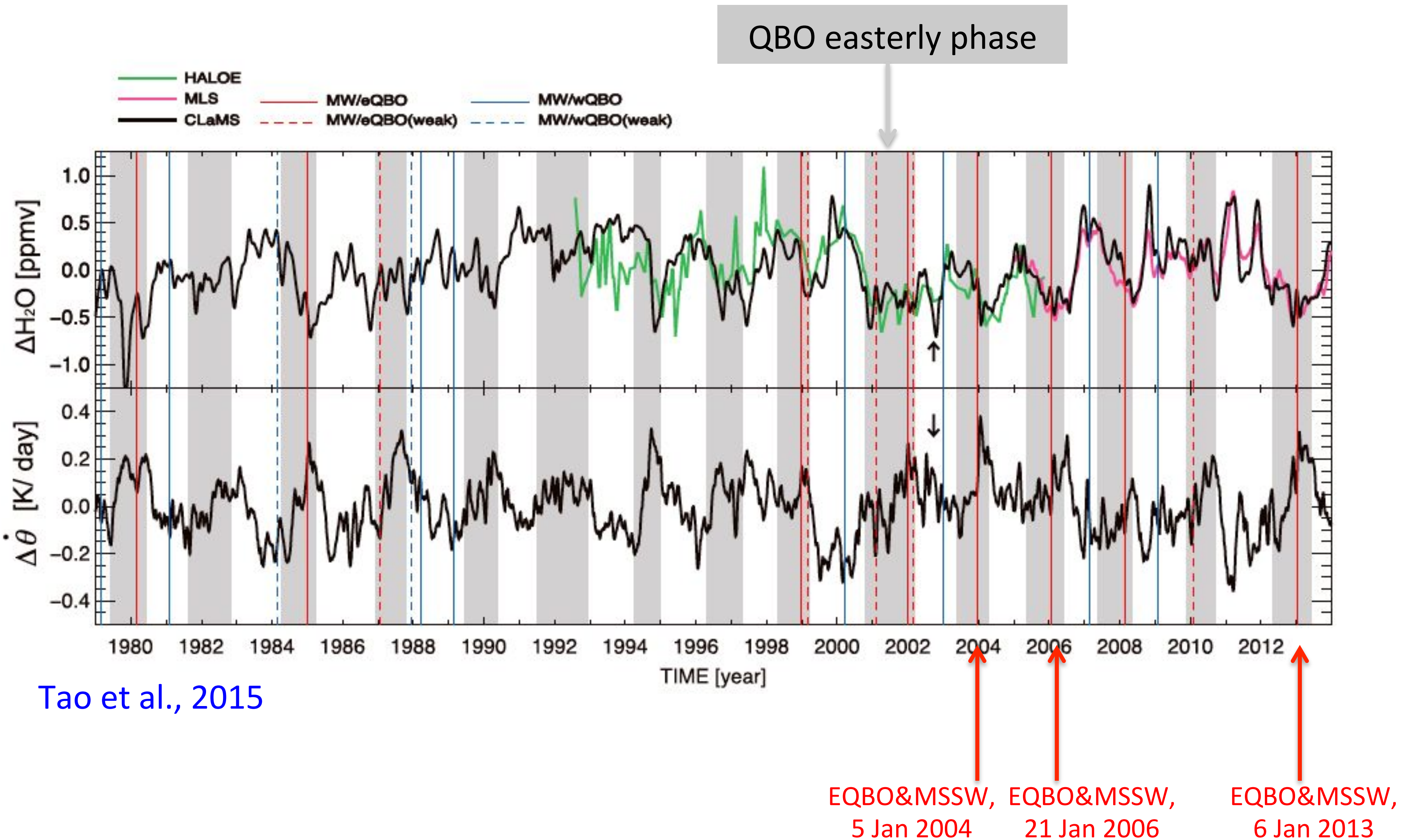
1) Tropical cold point variations
2) Variations in the strength of the tropical upwelling

Influence of QBO, SSW and convection ?

During the MLS record, the lowest monthly mean values occurred during boreal winters 2006 and 2013

MLS tropical water vapor anomaly



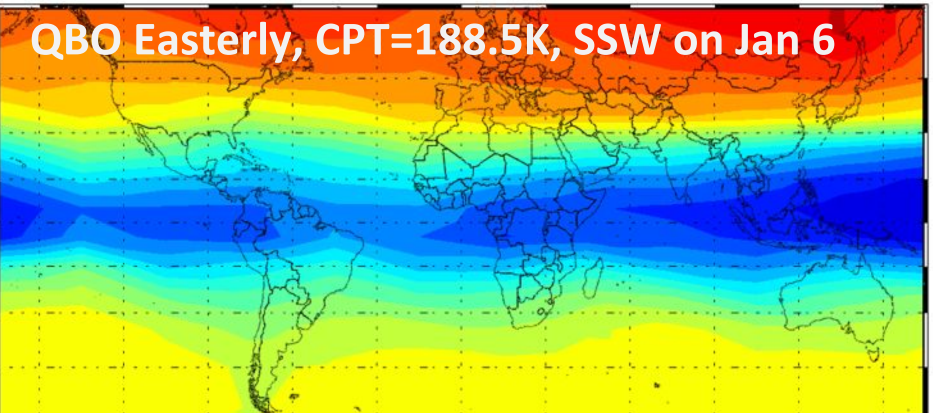


Tao et al., 2015

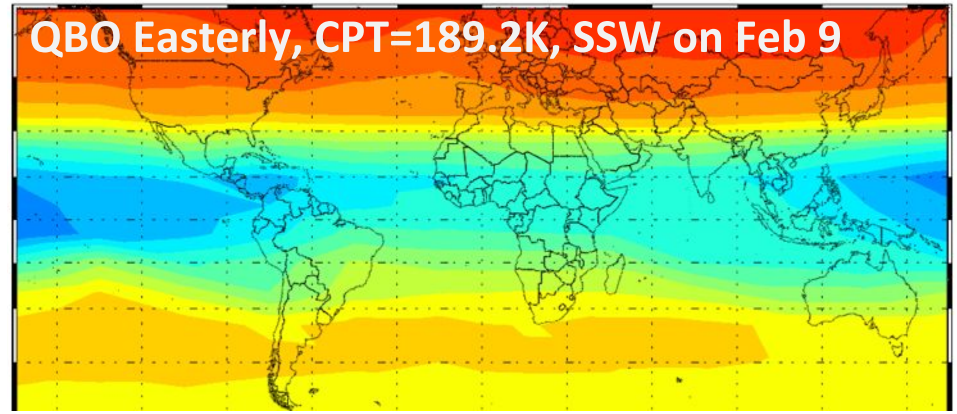
Many water vapor drops and mean tropical upwelling increases follow major SSWs almost simultaneously.

Contrasting 2013 with other years with QBO easterly phase using gridded MLS water vapor at 82 mb. **Note: Jan 2006 is similar to Jan 2013**

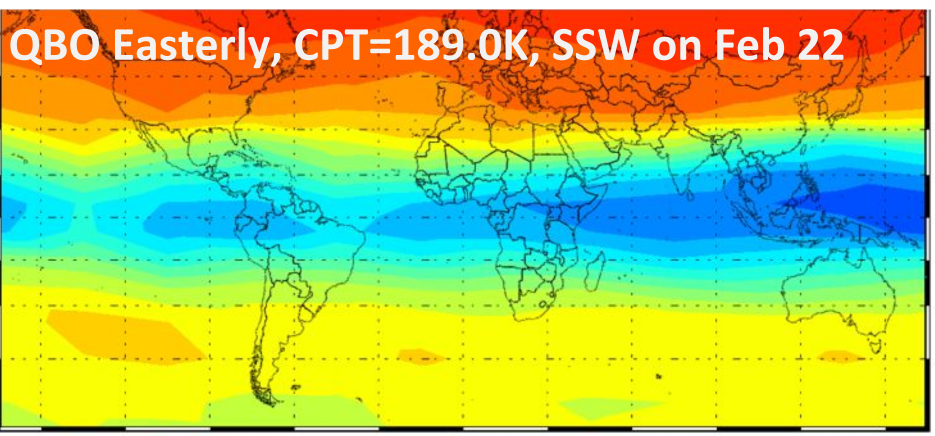
MLS 82 hPa Water vapor, Jan 2013



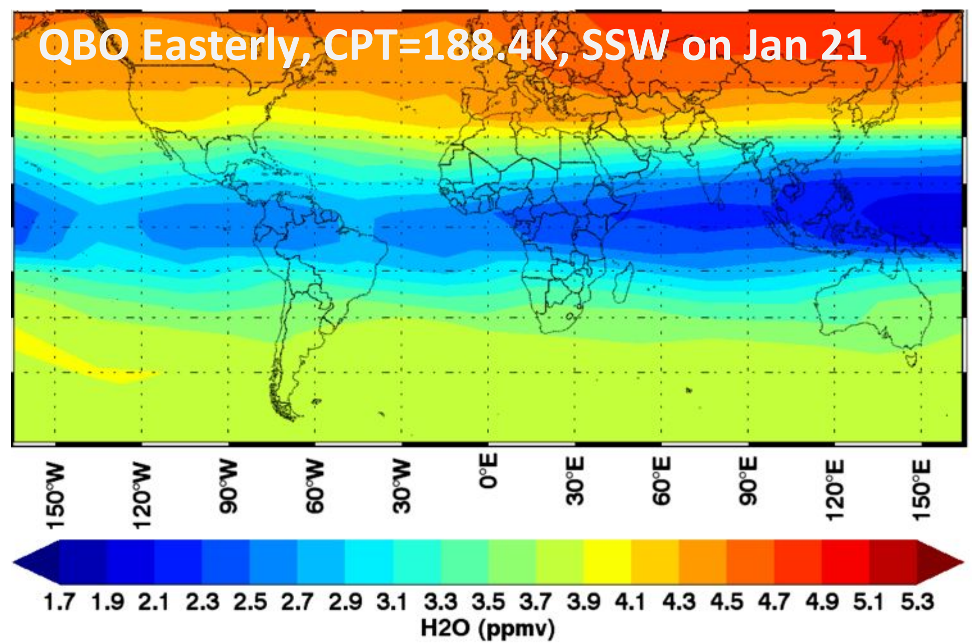
MLS 82 hPa Water vapor, Jan 2010



MLS 82 hPa Water vapor, Jan 2008

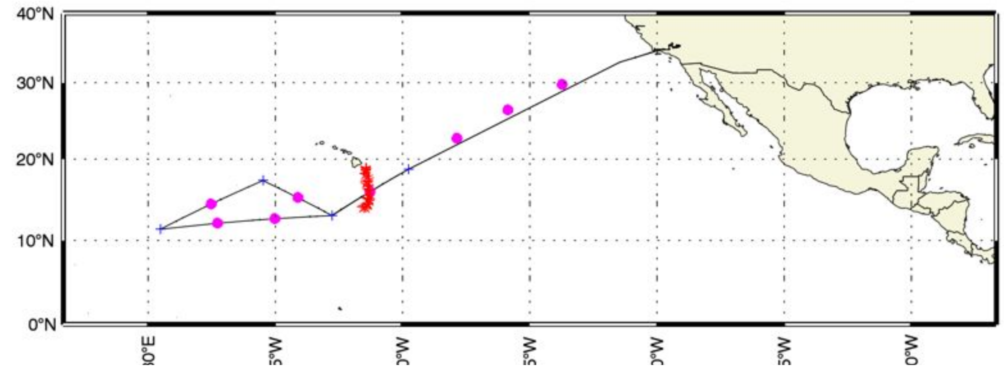


MLS 82 hPa Water vapor, Jan 2006

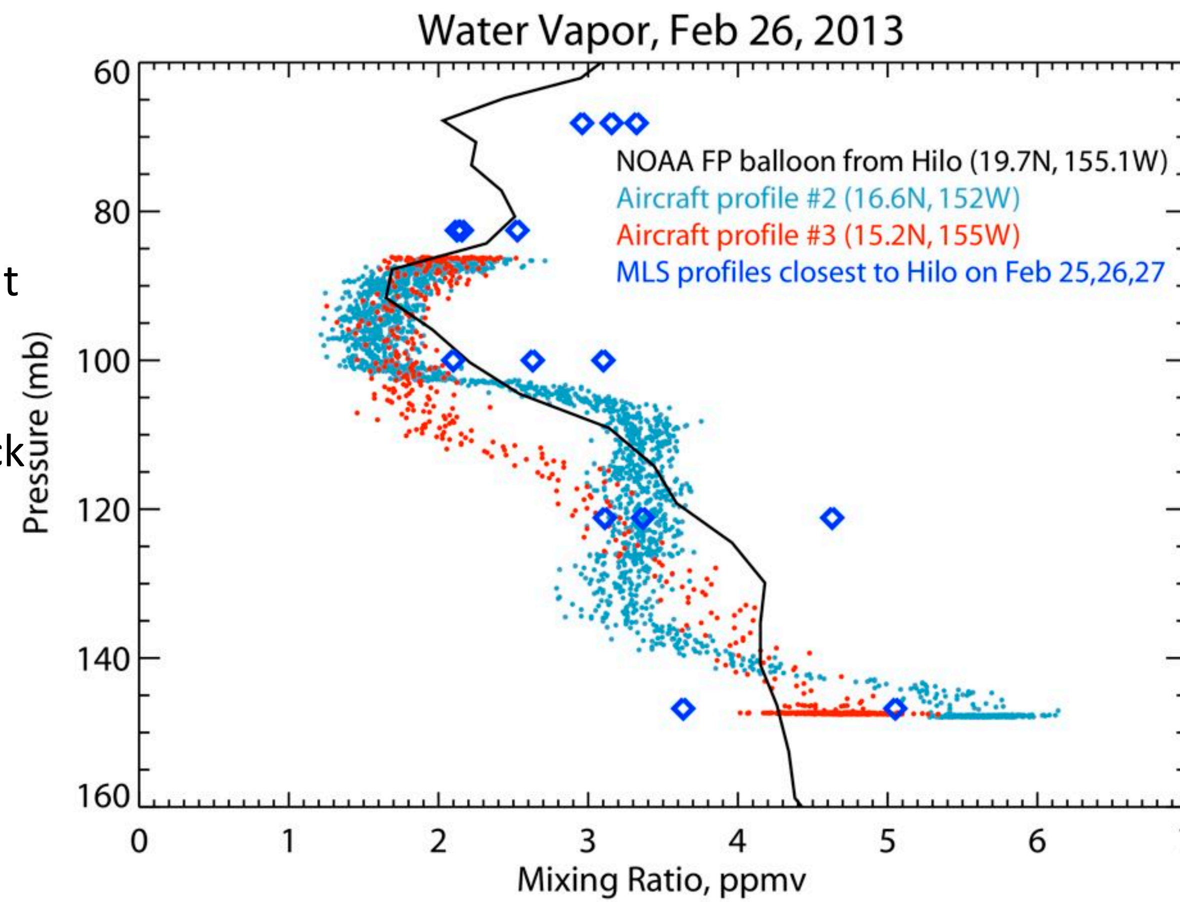


MLS data from SWOOSH dataset, S. Davis, http://www.esrl.noaa.gov/csd/groups/csd8/swoosh/

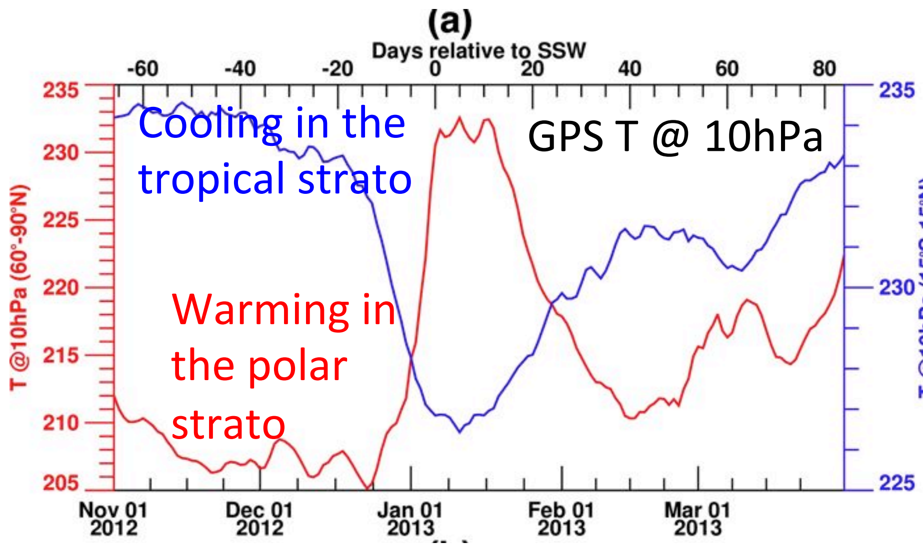
The Hilo FPH launch on 26 February 2013 was done in coordination with the ATTREX flight.

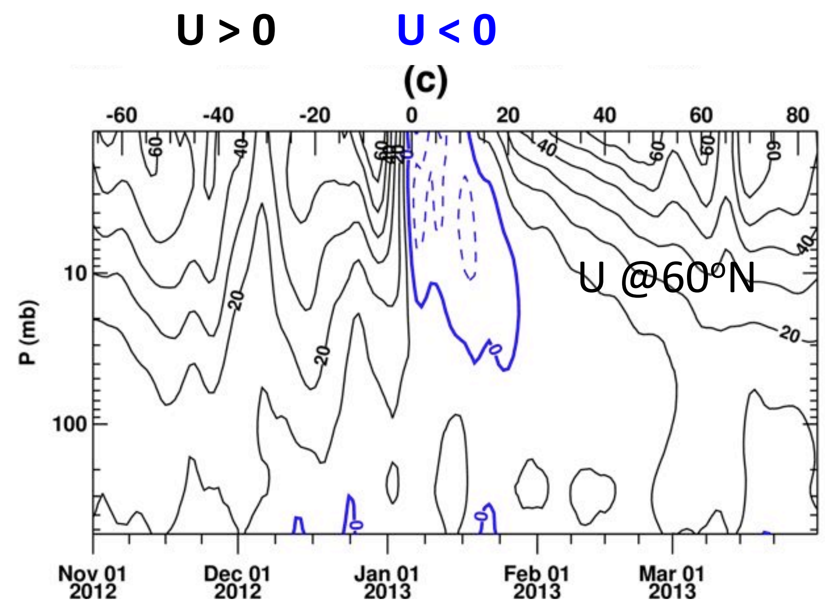


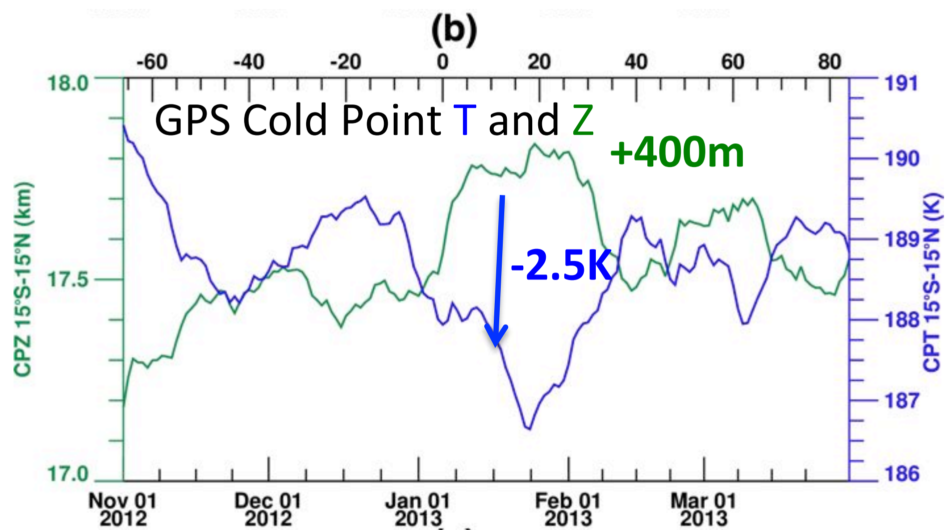
The 2013 case was a strong event that impacted zonally averaged water vapor, and, conveniently with aircraft and FPH data to back up the satellite observations of very low stratospheric water vapor.

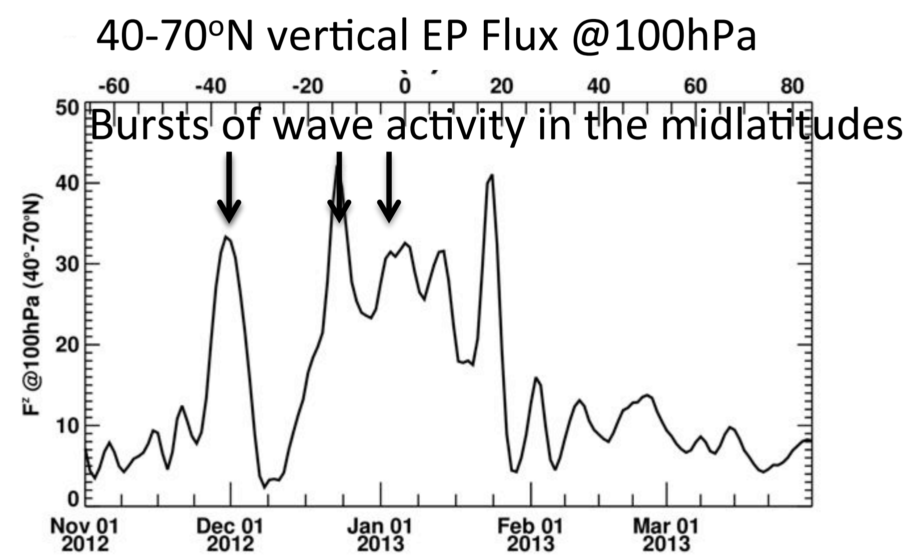


Aircraft data: from NOAA Water (Thornberry, Rollins, Gao)
Balloon data: NOAA FPH, launched from Hilo (Hurst)









Day 0 = Jan 6, 2013

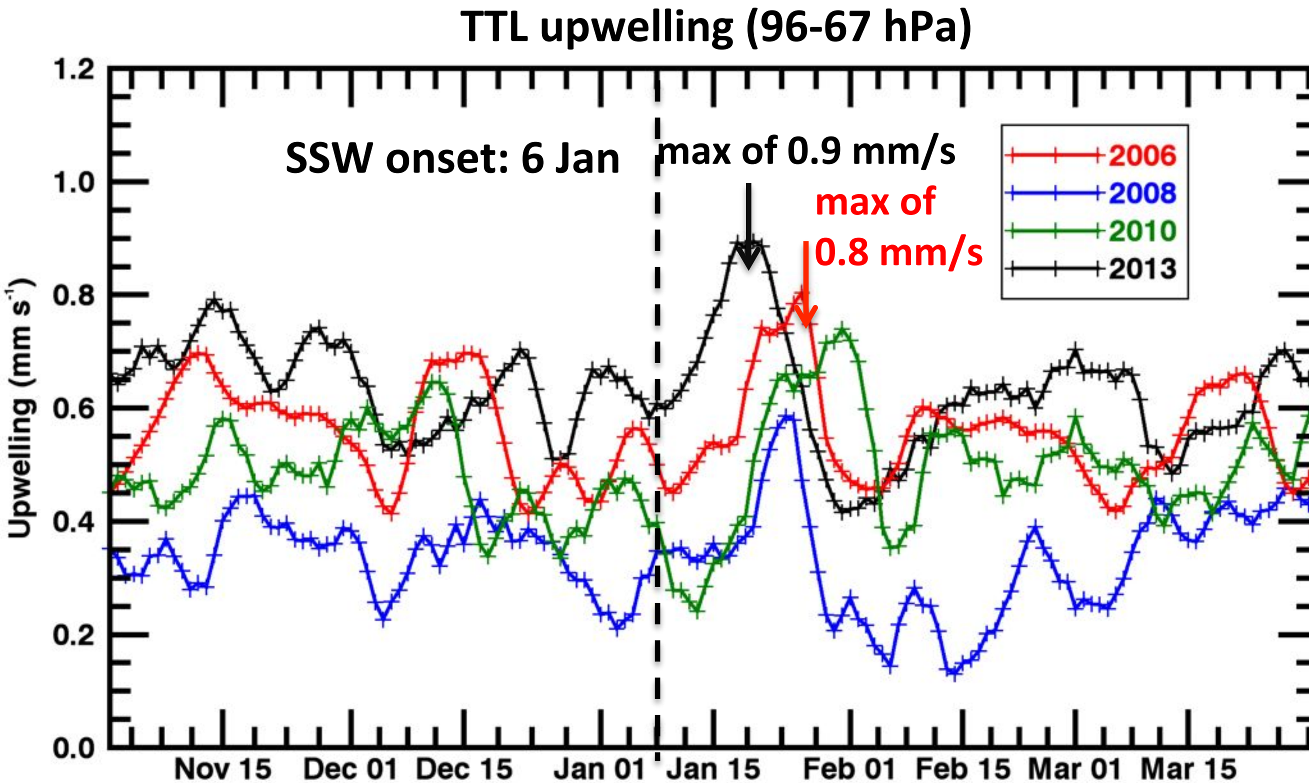
TTL upwelling (96-67 hPa) computed from residual mass stream function using ERA-Interim 6-hourly data on model levels.

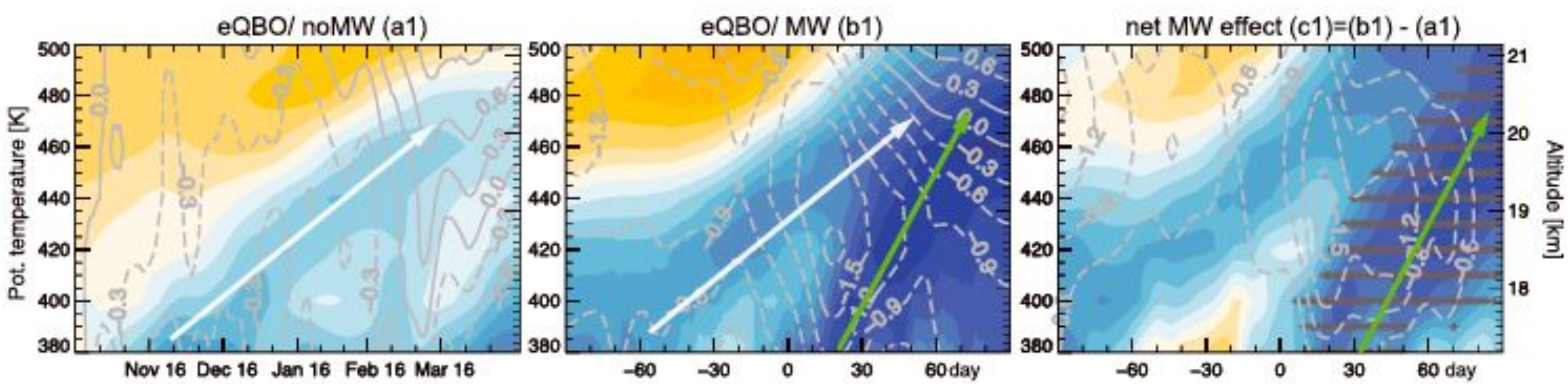
SSW 2006: 21 Jan

SSW 2008: 22 Feb

SSW 2010: 9 Feb

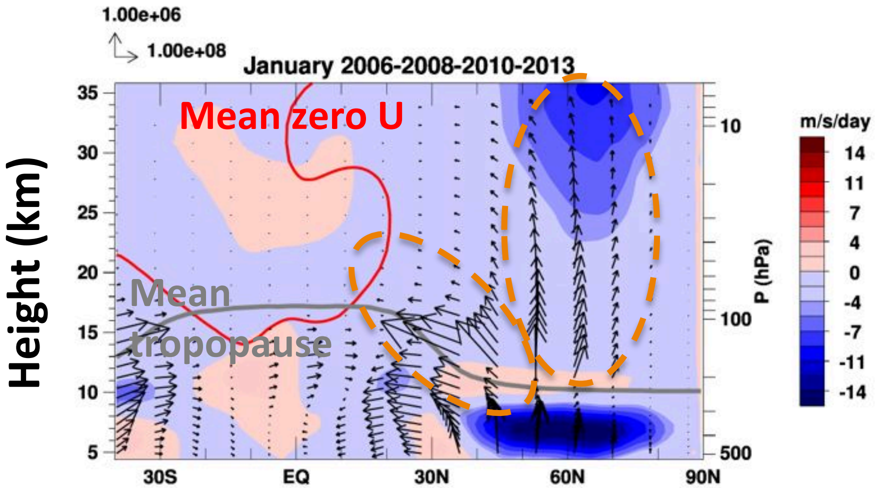
SSW 2013: 6 Jan

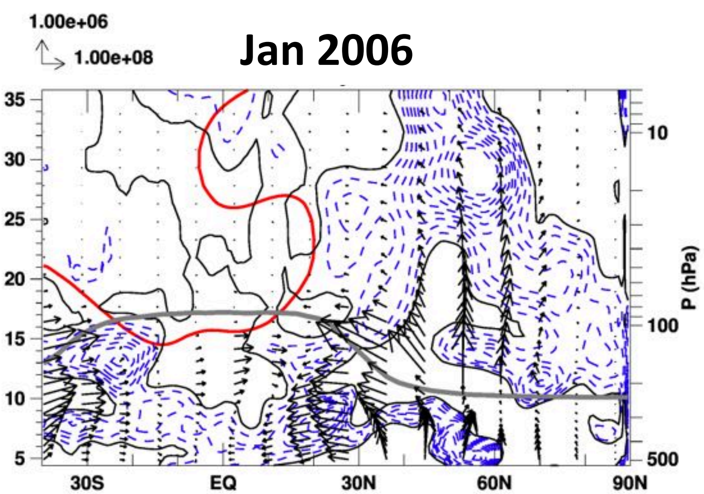


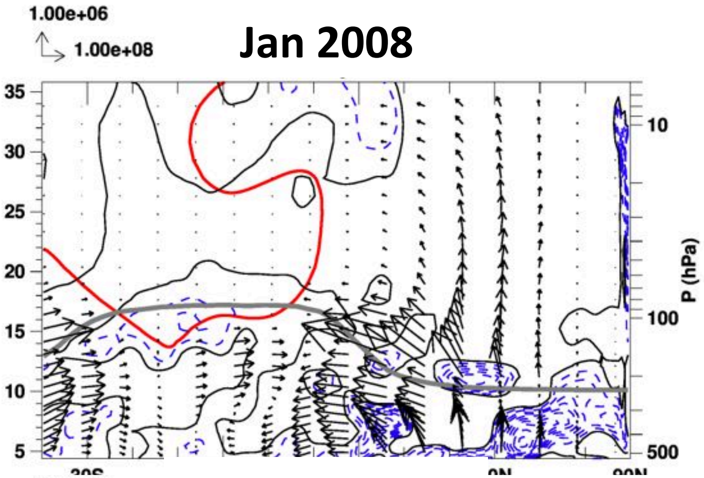


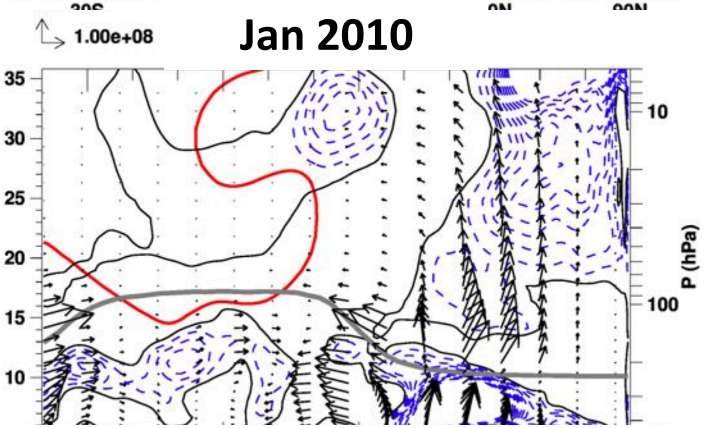
Tao et al. 2015: Increase in upwelling starting in early winter (Nov) and faster upwelling after the SSW

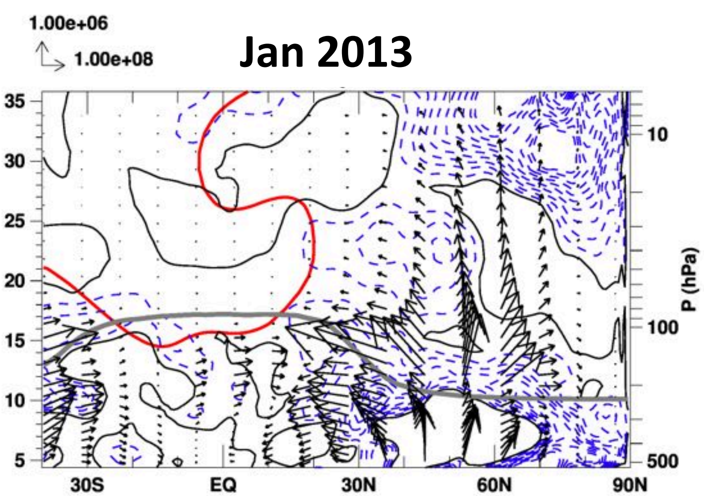
Dynamics of the stratosphere: Zonal mean EP flux divergence and vectors

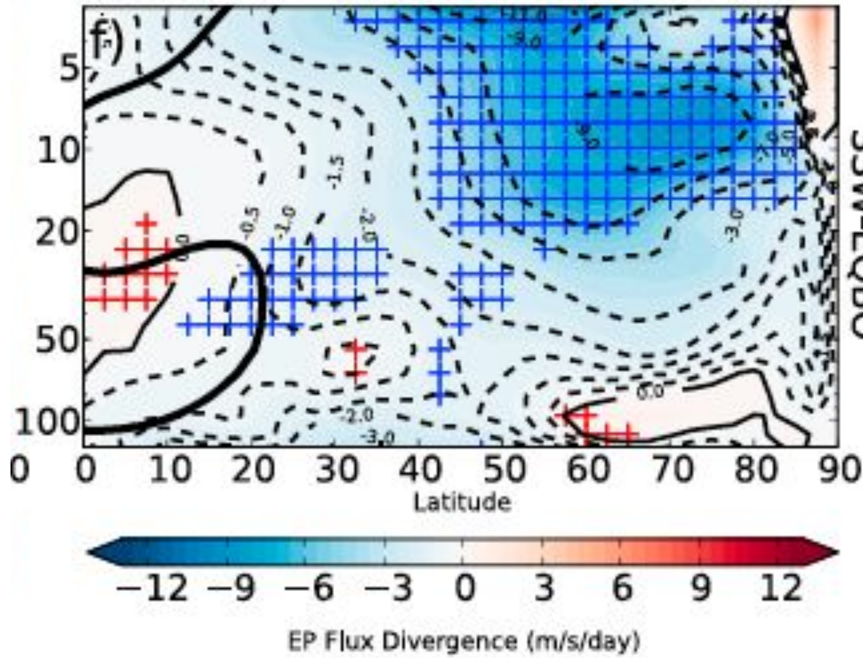




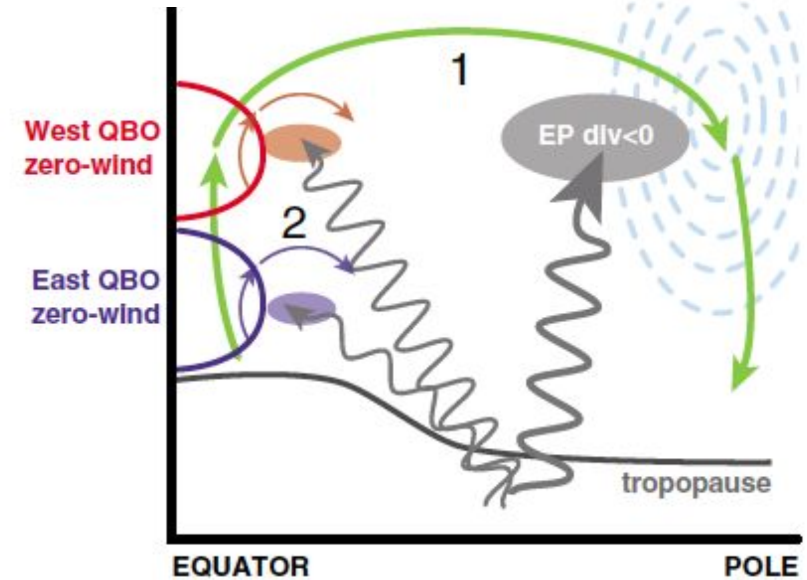


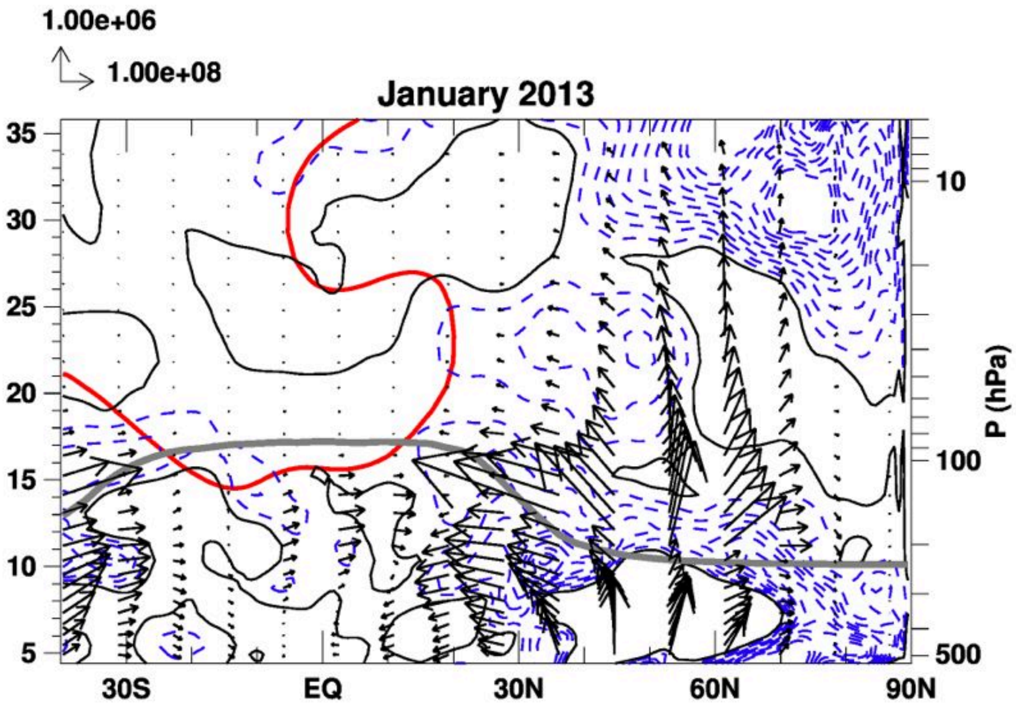






Gomez-Escolar et al., 2014

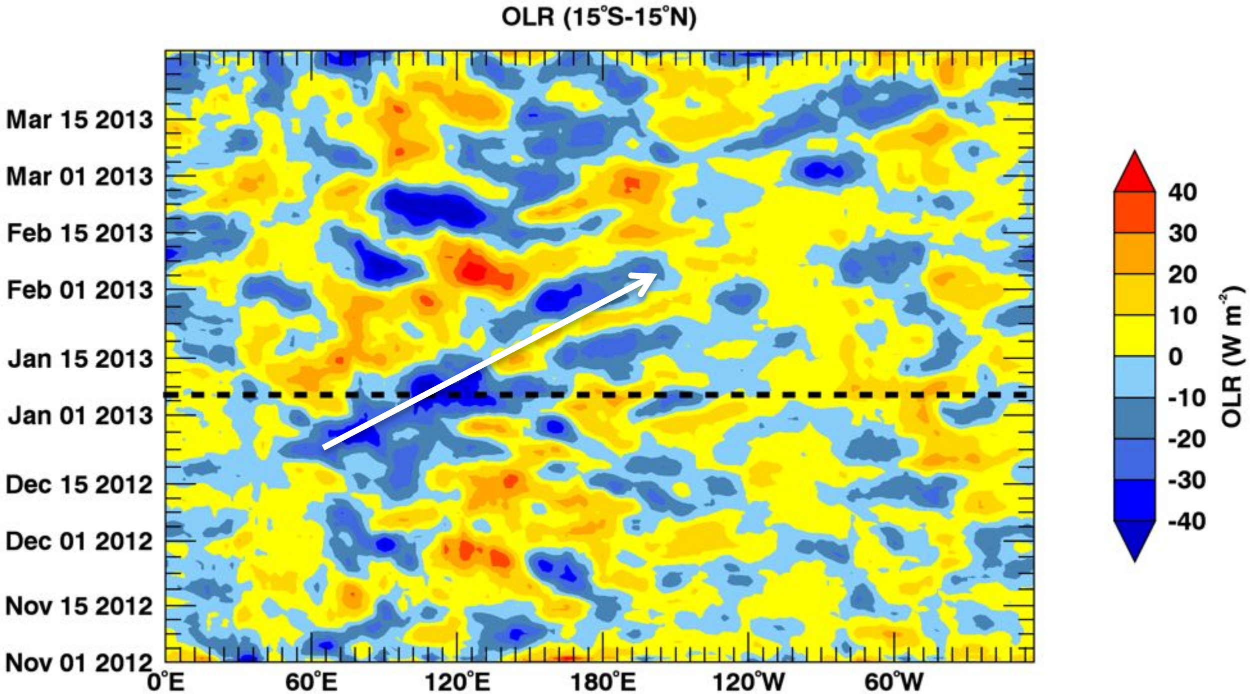


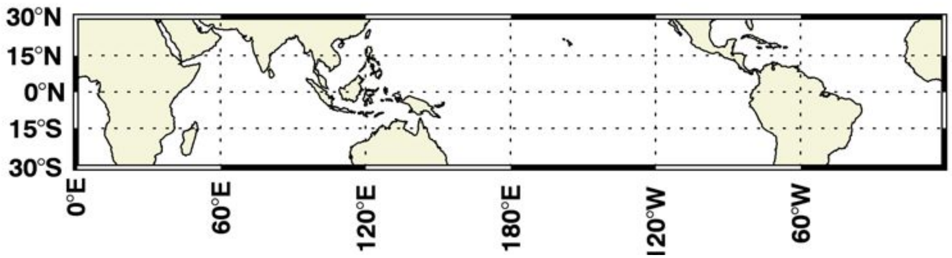


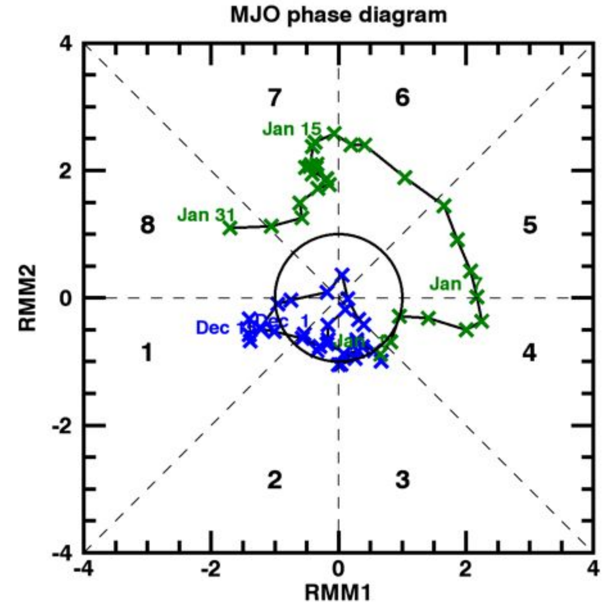
Preceding the SSW:

- **Planetary waves intensify in the stratosphere**
- **Upper stratospheric wave breaking triggers the SSW and accelerates the deep branch of the BDC**
- **Wave breaking in the subtropical lower stratosphere accelerates the shallow branch of the BDC**
- **During QBO easterly, the zero-wind line is much lower (~30hPa)=more subtropical wave dissipation at low latitudes than during QBO westerly**

Evolution of the MJO during Dec-Jan 2012/2013

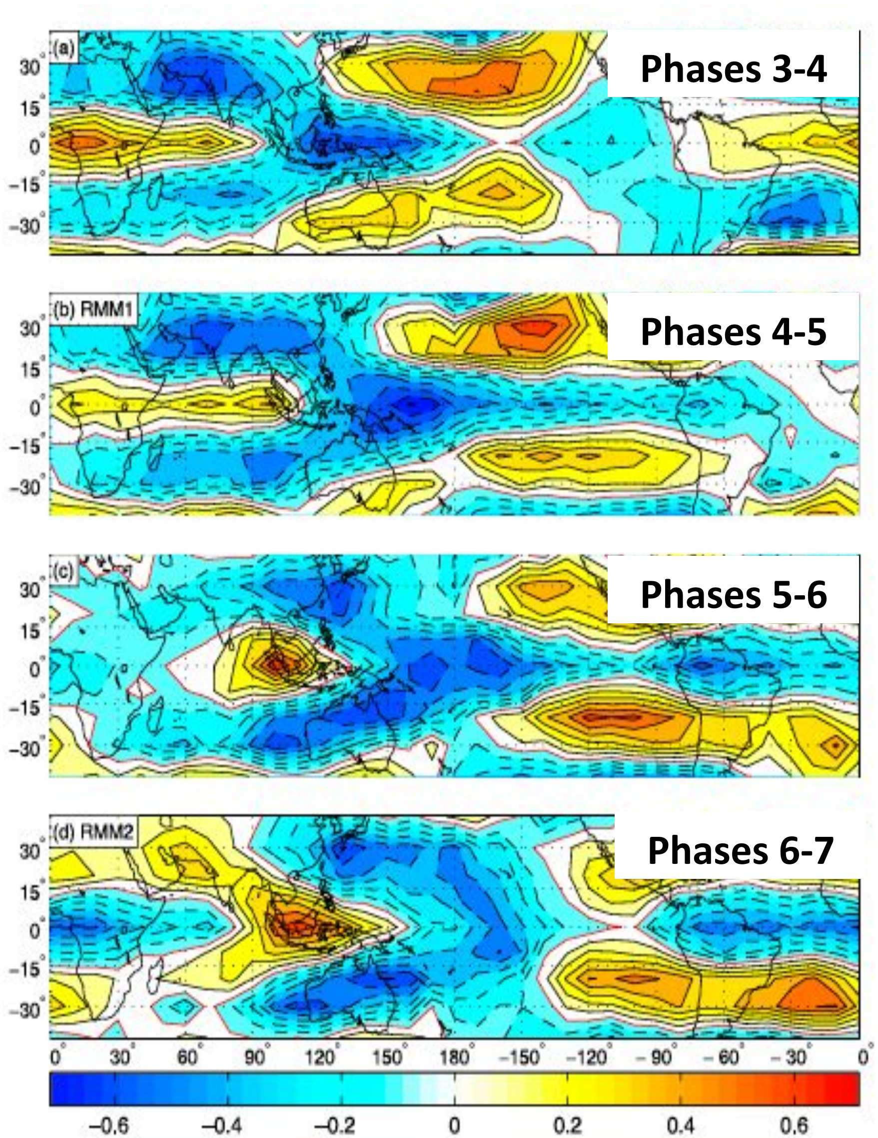




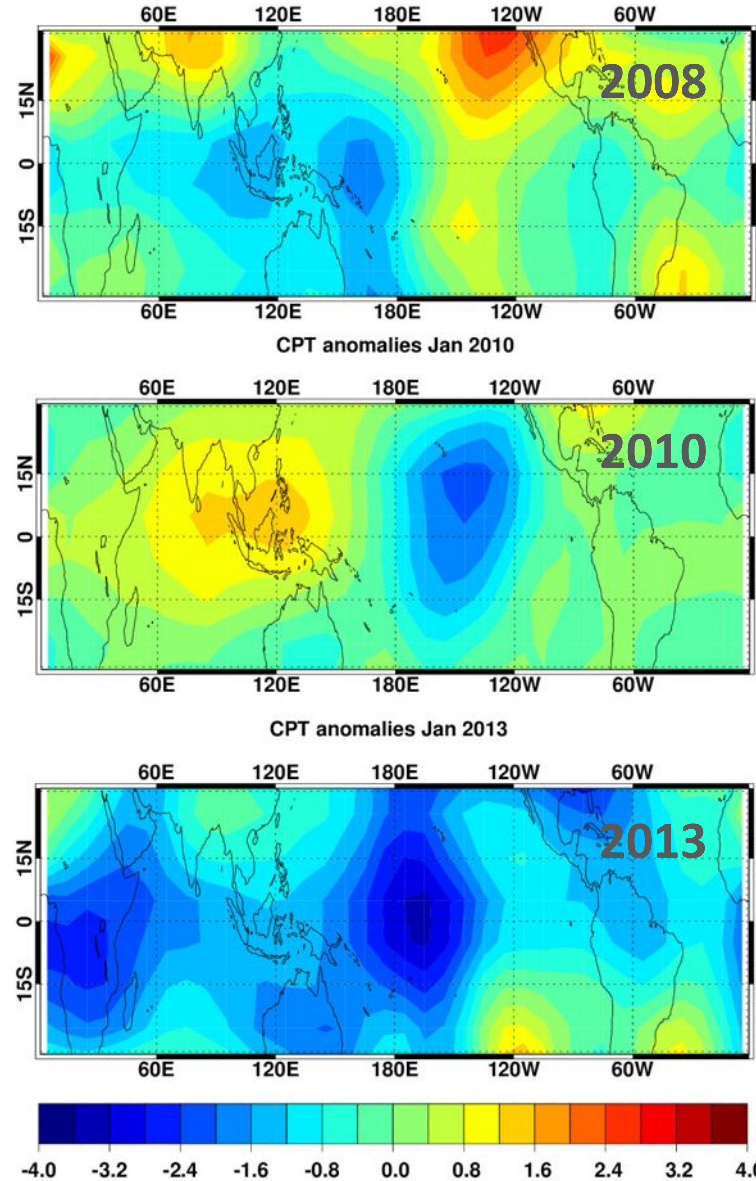


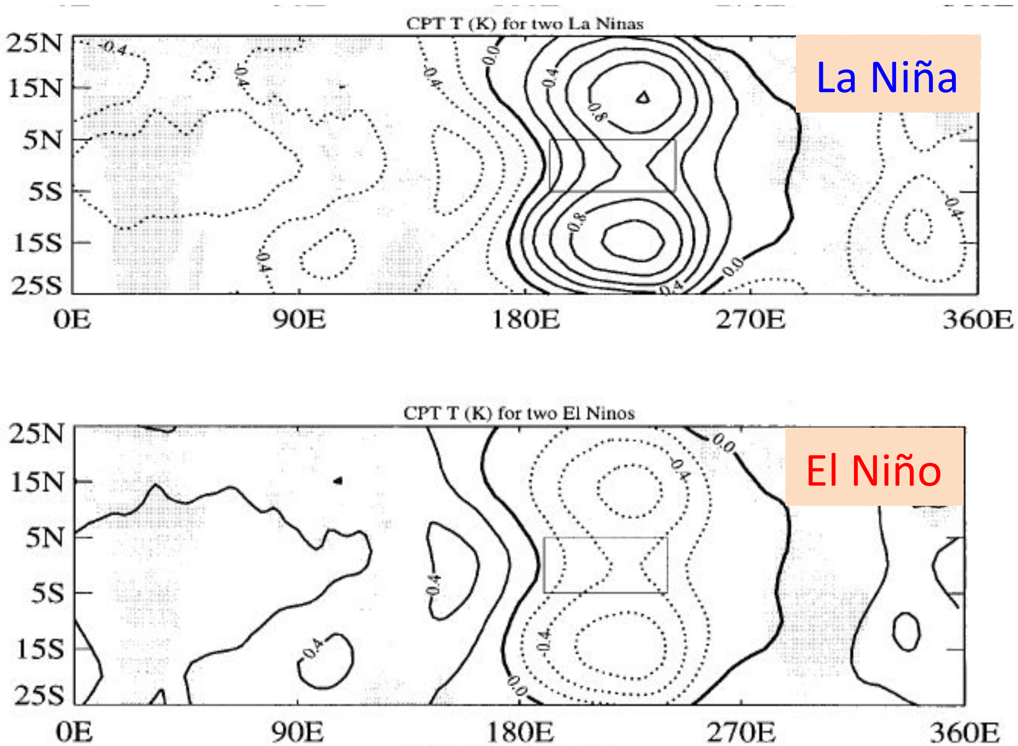
MJO phase diagram corresponding to RMM1 & RMM2 based on EOF analysis of (15S-15N) zonal winds and OLR

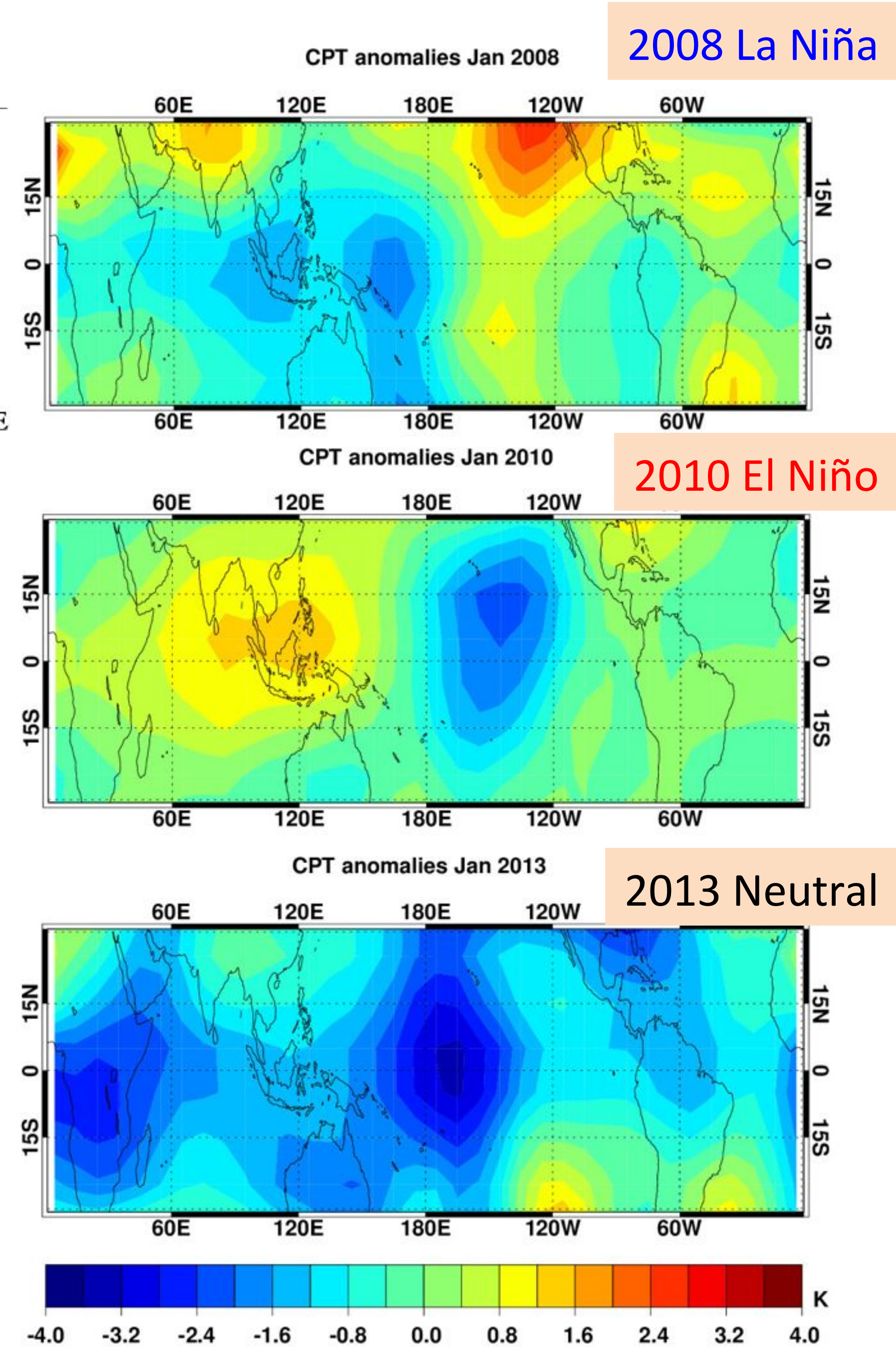
Virts and Wallace (2014) quantify MJO impact on CPT temperature for each MJO phase using ERA-Interim and COSMIC temperature data.



COSMIC CPT anomalies for Jan







Zhou et al., 2001

- January 2008, La Niña: north-south dumbbell of positive CPT anomalies over the central Pacific and cold anomalies over the WP
- January 2010, El Niño: opposite pattern
- January 2013, ENSO neutral: strong zonally symmetric CPT cooling

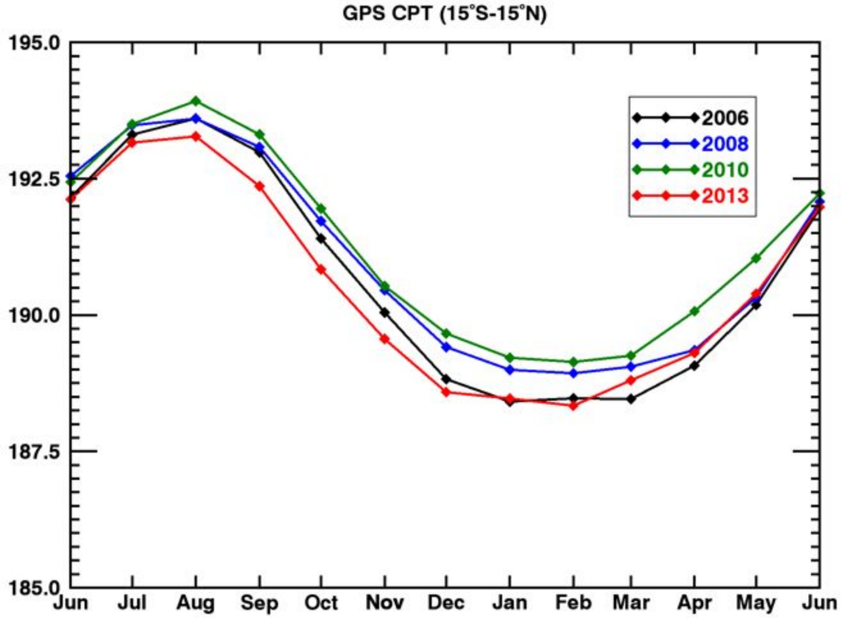
Summary

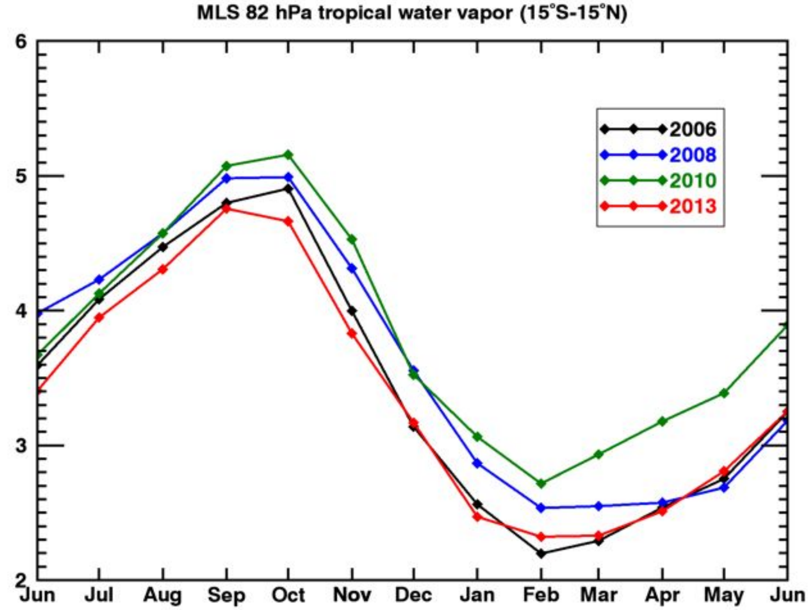
- February 2013 monthly-mean value of MLS water vapor at 82hPa was one of the lowest during the MLS record, in situ measurements of water vapor indicate dry values (~1.5ppmv) in the TTL over the Eastern Pacific
- COSMIC and MLS data indicate cooling and drying with a strong zonally symmetric component.
- The phase of QBO and active MJO can explain part of the cold values but the SSW played a significant role as well.

Major SSW=more wave activity in the midlatitudes →

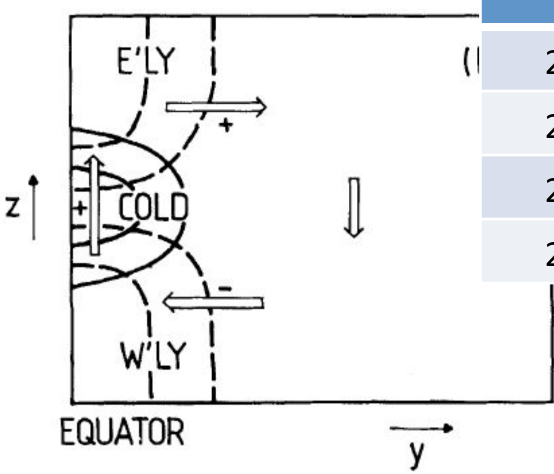
Easterly QBO=more dissipation in the subtropical lower stratosphere →

Acceleration of the shallow branch of the BDC → Strong tropopause Cooling → **“Extra” dehydration**





Plumb and Bell, 1982



Winters	QBO (U50-U100hPa)	ONI	SSW date	CPT T	Water anomaly @82hPa
2006	-10m/s	-0.9 (Neutral)	21 Jan	188.4K	-0.5ppmv
2008	-10m/s	-1.8 (La Niña)	22 Feb	189.0K	-0.2ppmv
2010	-6m/s	1.6 (El Niño)	9 Feb	189.2K	-0.1ppmv
2013	-10m/s	-0.6 (Neutral)	6 Jan	188.5K	-0.5ppmv

Composites of OLR anomalies for the MJO events of DJF 2006-2008-2010-2013: