The Impact of ENSO on Trace Gas Composition in the Upper Troposphere to Lower Stratosphere

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El Niño Southern Oscillation (ENSO) Variability

- The El Niño Southern Oscillation (ENSO) is the dominant mode of tropical tropospheric interannual variability (Philander, 1989).

- ENSO has been long known to cause significant perturbations to the coupled oceanic and atmospheric circulations (Bjerknes, 1969; Enfield, 1989) and also influences constituent distributions.

- Changes in SST in the Pacific Ocean impact the Walker Circulation as well as the position of the SPCZ

- Satellite observations of atmospheric composition are enabling us to look at this variability in greater detail than ever before.

- An improved quantification of natural climate variations in observations is needed in order to detect and quantify anthropogenic climate trends.

Observations and Simulations

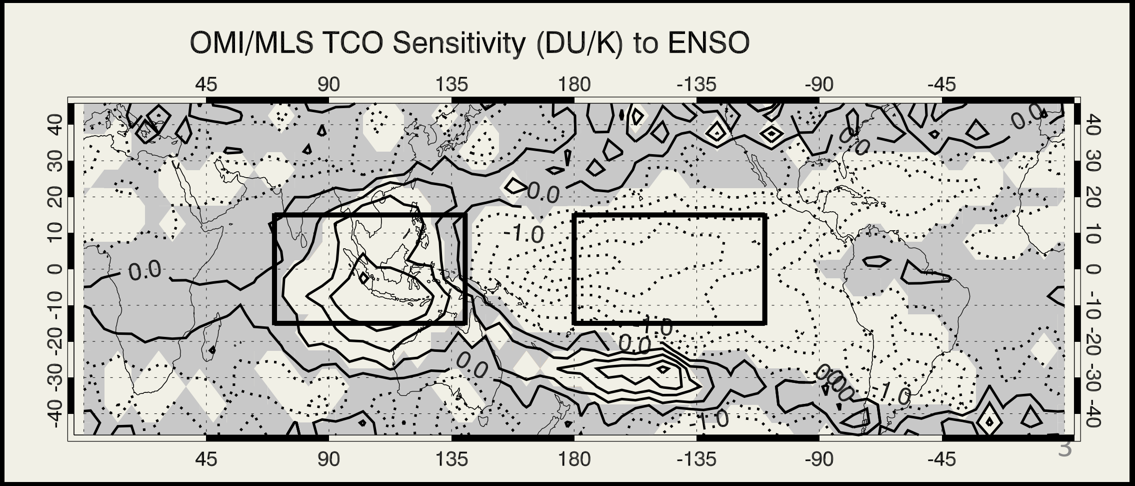
Aura Satellite measurements:
Microwave Limb Sounder (MLS) Level 2 Version 4.2 Aug. 2004 – Mar. 2016
Tropospheric Emission Spectrometer (TES) L3 V2 Sept. 2004 – Dec. 2009
Ozone Monitoring Instrument (OMI) L2 V8.5 Oct. 2004 – Dec. 2015
Aqua Satellite measurements:
Atmospheric Infrared Sounder (AIRS) L3 V6 Sept. 2002 – Dec. 2015

ENSO used here is the Niño 3.4 Index

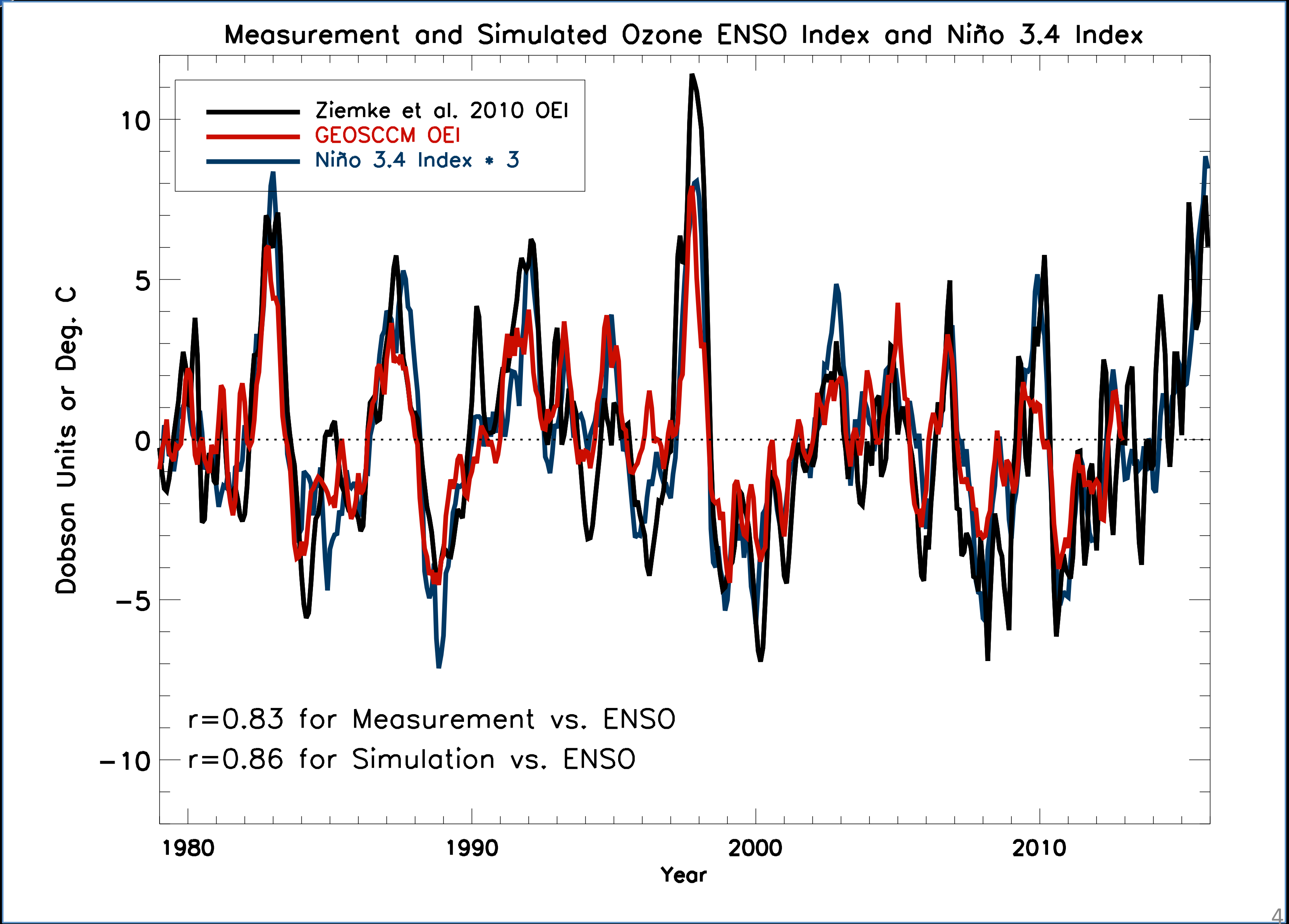
Goddard Earth Observing System Chemistry-Climate Model (GEOSCCM)
Using the combined GMI stratosphere-troposphere chemical mechanism
Analysis of several CCMs contributing to CCMI was also done both free running and with specified dynamics

Tropospheric Column Ozone Response to ENSO from OMI/MLS residual

OEI = West – East Region



Ozone ENSO Index

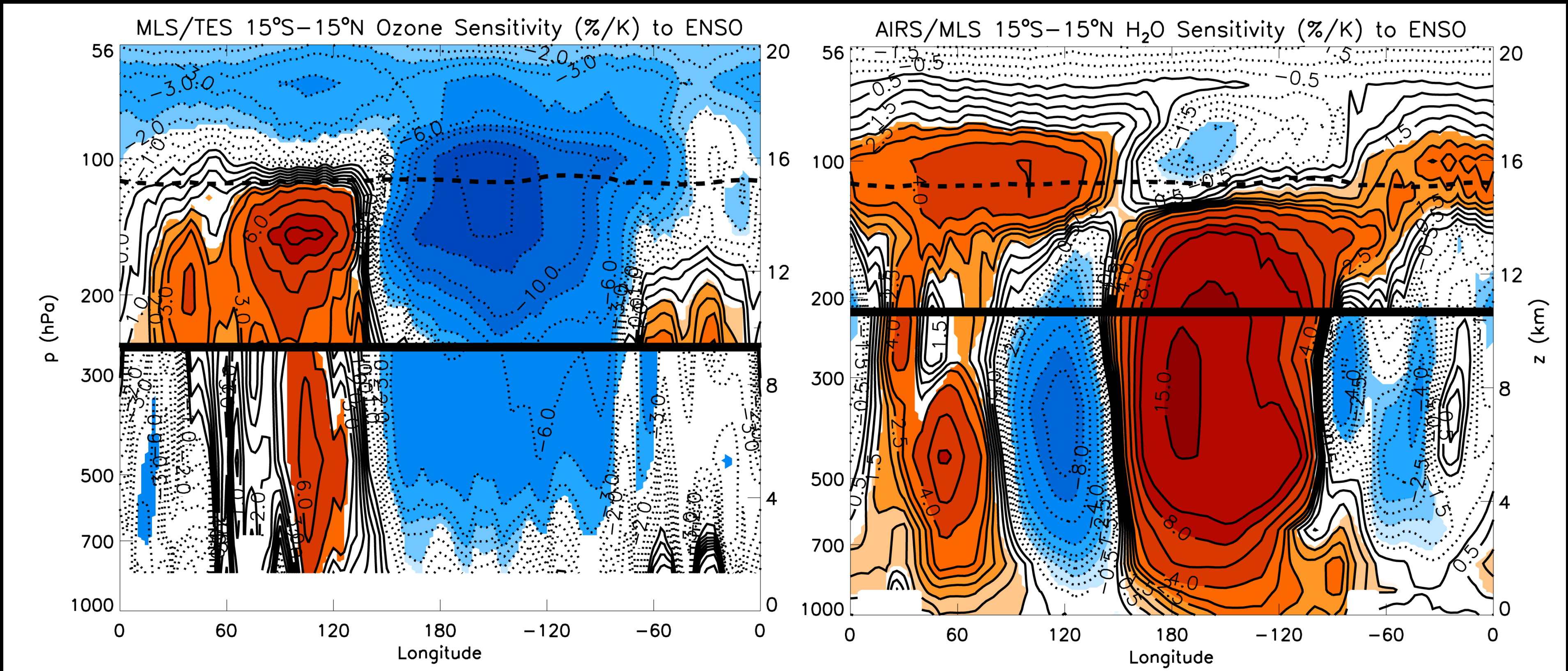


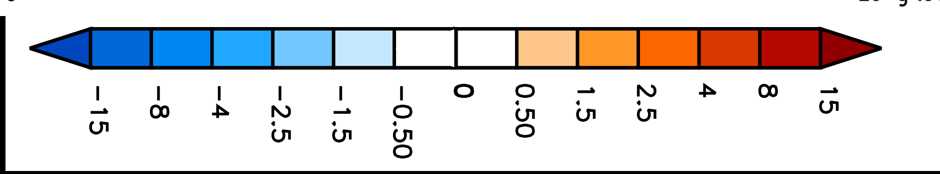
A Tale of Two Tracers

MLS/TES Ozone and MLS/AIRS H_2O sensitivity avg. over the tropics

Negative ozone and positive H_2O sensitivities are seen over the eastern and central tropical Pacific troposphere, in the stratosphere decreases in O_3

Positive ozone and negative H_2O sensitivities over Indonesia, except in UT H_2O



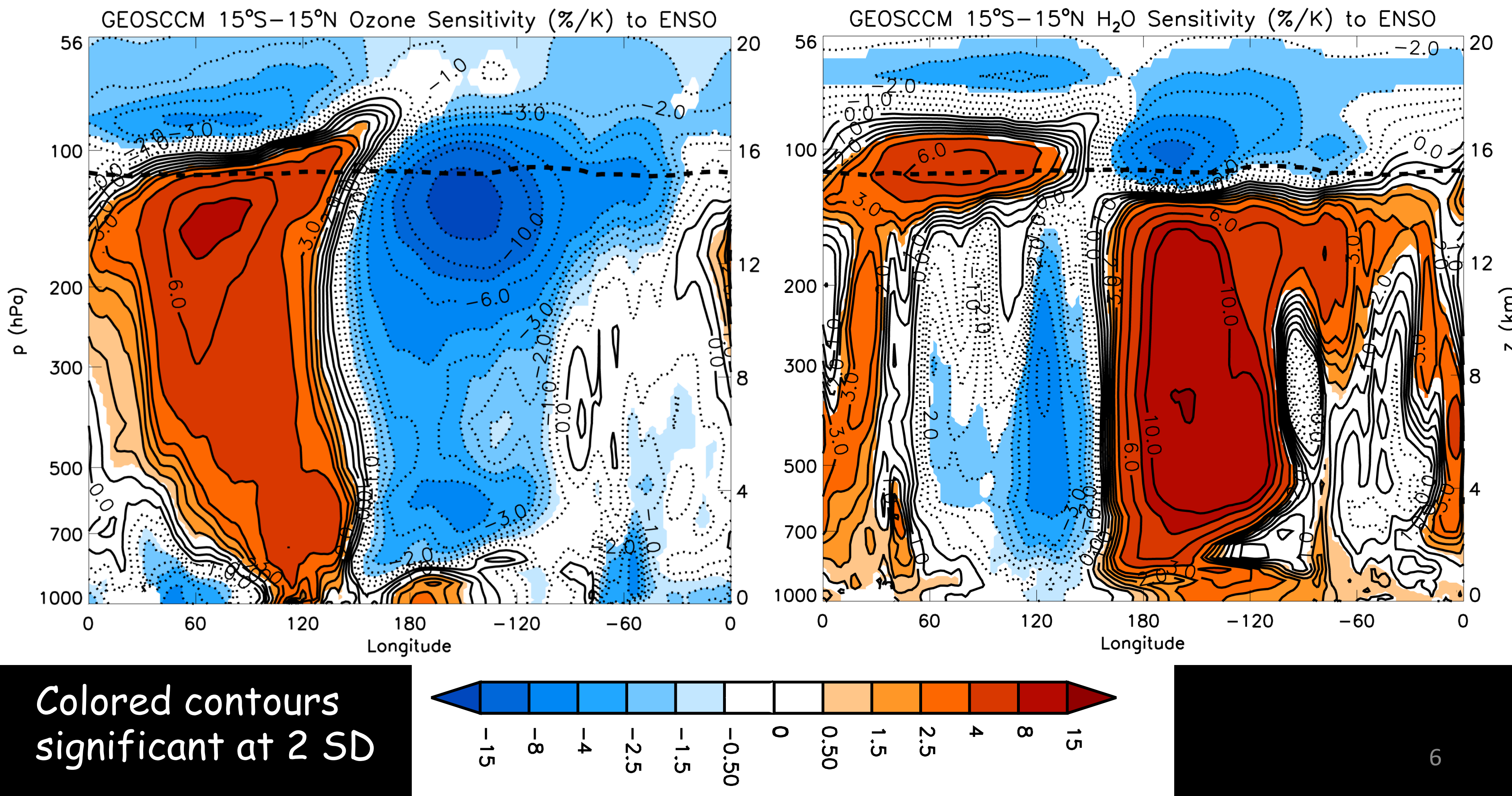


Colored contours significant at 2 SD

GEOSCCM model response to ENSO

The modeled response compares well to the observed response.

Some differences are seen in water vapor response over the western Indian Ocean and over South America



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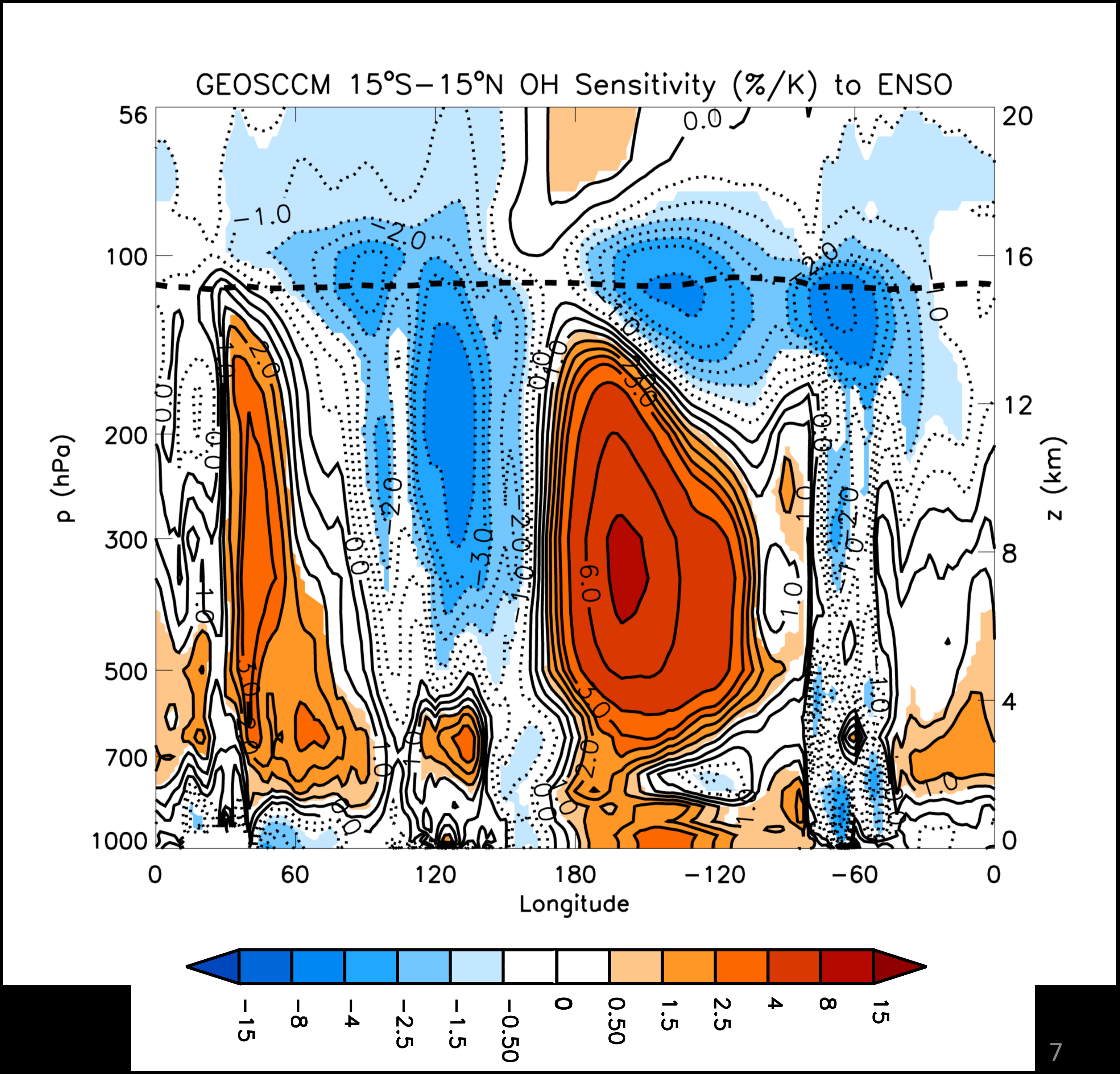
GEOSCCM OH Response to ENSO

Generally we see opposite signed responses from water vapor and ozone contributing in opposing directions to changes in OH

GEOSCCM indicates that the water vapor change dominates over the ozone changes



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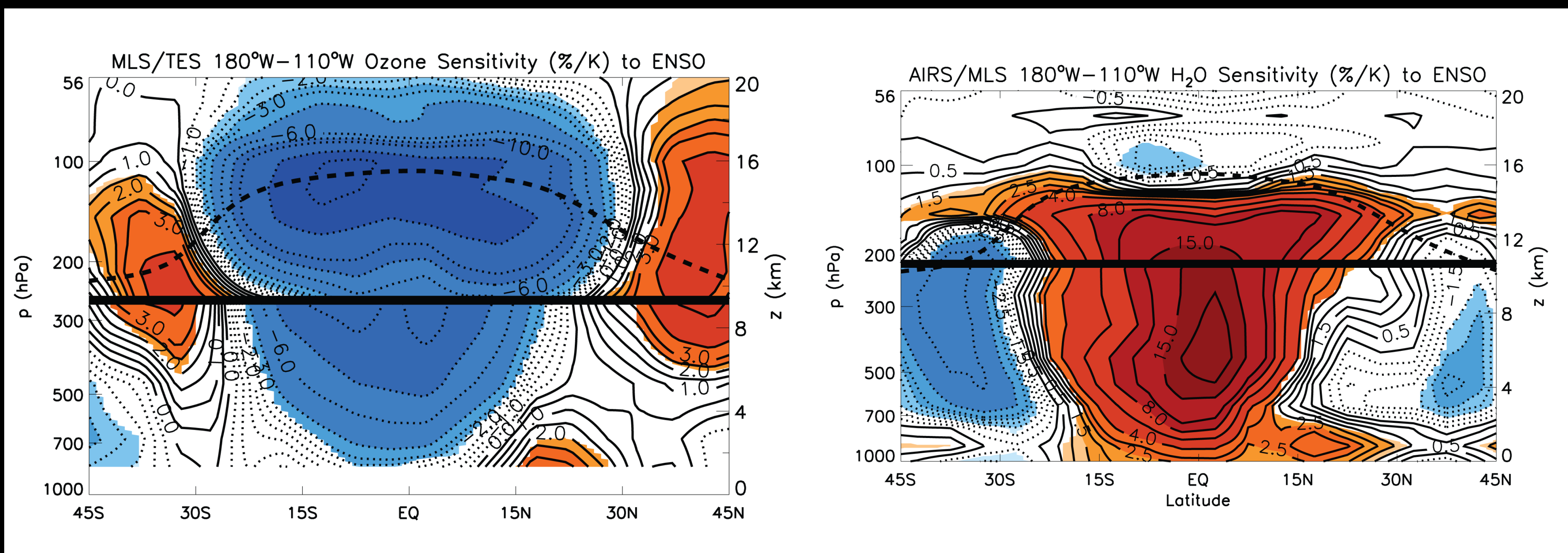
MLS/TES Ozone and MLS/AIRS H_2O sensitivity to ENSO averaged over Eastern and Central Pacific Region

In the deep tropical troposphere Ozone decreases and H_2O increases occur

In the midlatitudes increases in ozone in the UT/LS which continue into the troposphere in the subtropics, H_2O decreases with a larger response in the SH

In the tropical LS ozone decreases but H_2O responses are marginally significant



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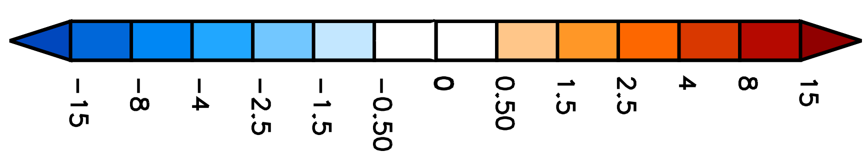
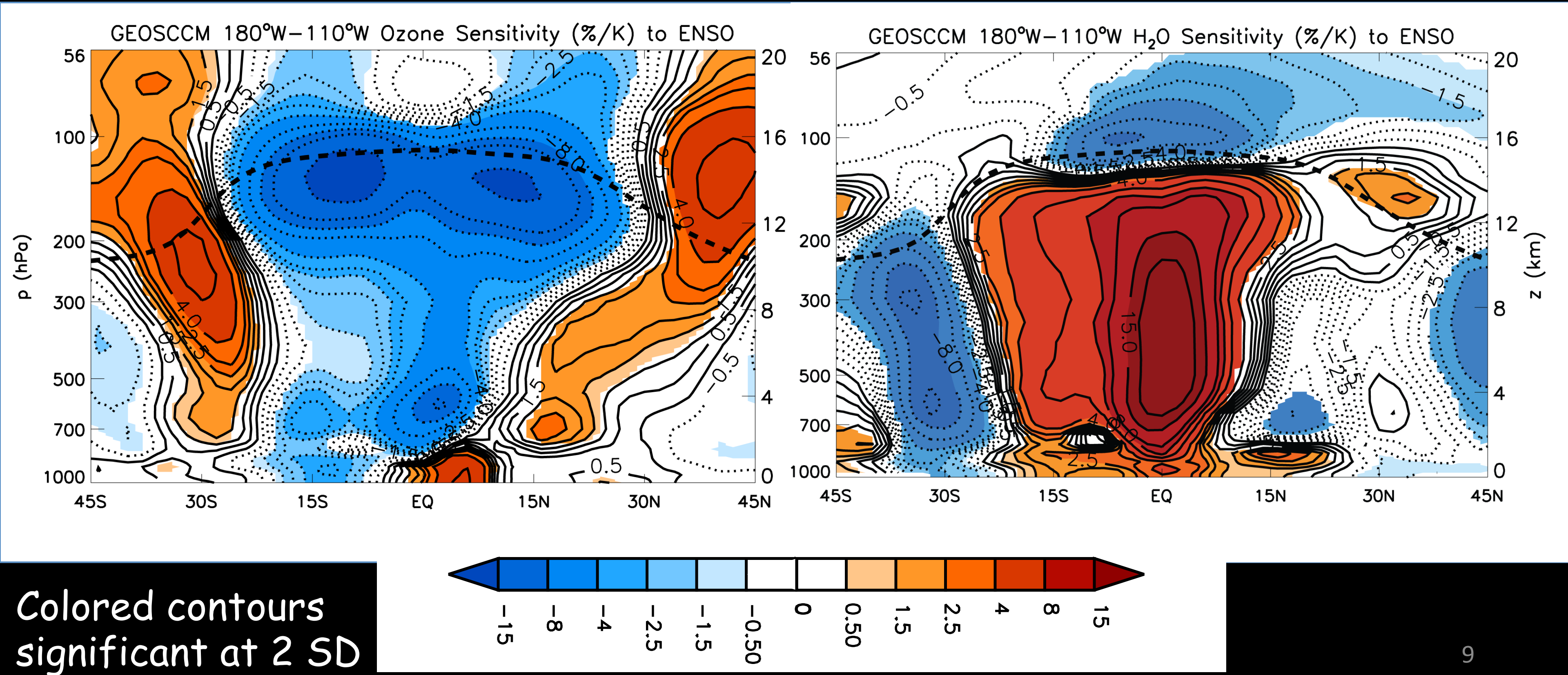


GEOSCCM model response over the Eastern and Central Pacific Region

- The same general pattern is present in the model as the observations
- Water Vapor also shows a clear response of the SPCZ with a northward migration during an El Nino
- LS water vapor tends to decrease in response to El Nino



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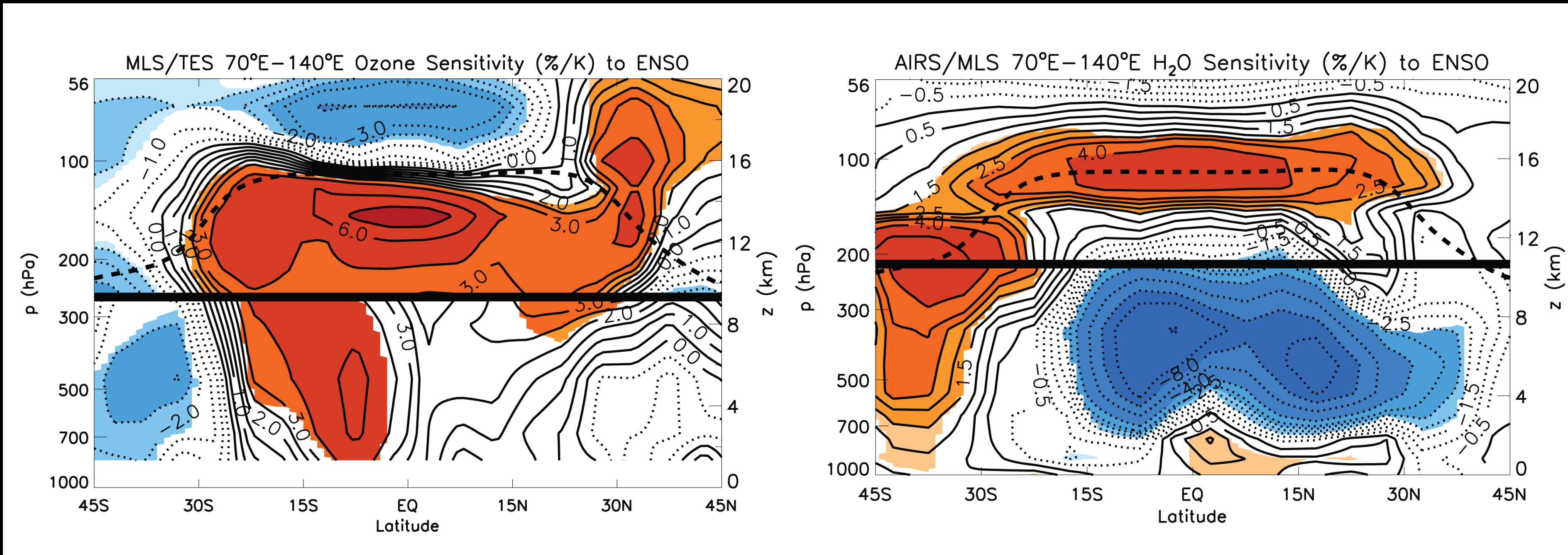
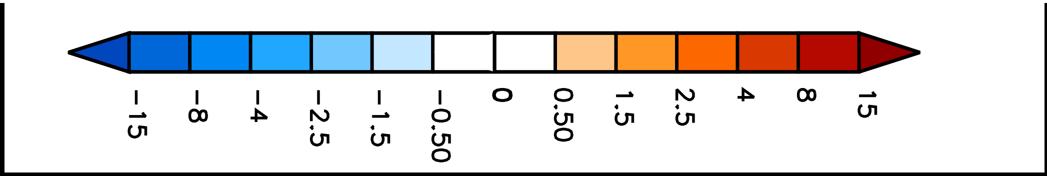
MLS/TES Ozone and MLS/AIRS H_2O sensitivity to ENSO averaged over Indonesia and Indian Ocean Region

Ozone generally increases in the tropical troposphere but decreases in the LS.
H_2O decreases in the tropical mid troposphere and increase in the TTL.

There is a hemispheric asymmetry to the response in Ozone and H_2O.





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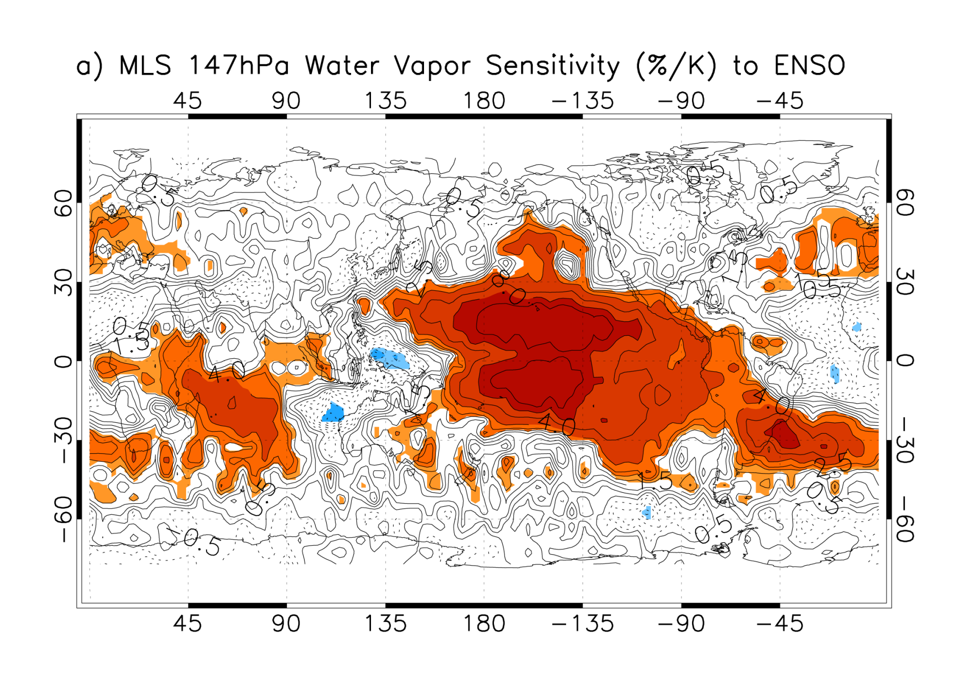
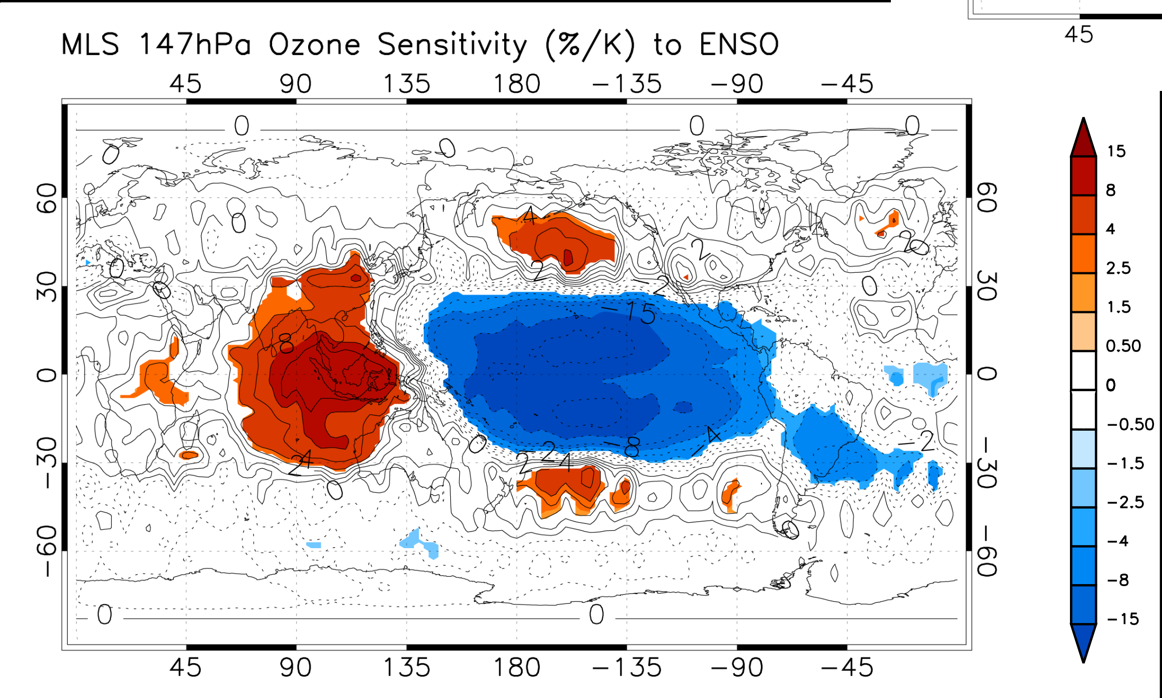
Horizontal Ozone and H_2O Sensitivity to ENSO at 147 hPa

Strong negative ozone sensitivity over much of the tropical Pacific

Water Vapor increases over much of the troposphere especially in the tropics





Positive ozone sensitivity over Indonesia and tropical Indian Ocean with a mixed H_2O response

Colored contours significant at 2 SD

Conclusions

- ENSO variations are important drivers of tropical composition variability that can be quantified using satellite measurements.

- We can use information from multiple instruments MLS and TES for ozone and multiple satellites Aura (MLS) and Aqua (AIRS) for H_2O measurements to derive the response from the troposphere into the stratosphere.

- They provide a natural experiment to test a models representation of trace gas responses to ENSO.

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References

Oman, L. D., A. R. Douglass, J. R. Ziemke, J. M. Rodriguez, D. W. Waugh, and J. E. Nielsen, 2013: The ozone response to ENSO in Aura satellite measurements and a chemistry climate model, J. Geophys Res., 118,-976, doi:10.1029/2012JD018546.

Oman, L. D., J. R. Ziemke, A. R. Douglass, D. W. Waugh, C. Lang, J. M. Rodriguez, J. E. Nielsen, 2011: The Response of Tropical Tropospheric Ozone to ENSO, *Geophys. Res. Lett.,* 38, doi: 10.1029/2011GL047865.

Ziemke, J. R., S. Chandra, L. D. Oman, and P. K. Bhartia, 2010: A new ENSO index derived from satellite measurements of column ozone, *Atm. Chem. Phys.,* 10, 3711-3721.