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

Luke Oman\textsuperscript{1}, Anne Douglass\textsuperscript{1}, Jerry Ziemke\textsuperscript{1,2}, and Darryn Waugh\textsuperscript{3}

\textsuperscript{1} NASA/GSFC, MD, USA
\textsuperscript{2} Morgan State University, MD, USA
\textsuperscript{3} Johns Hopkins University, MD, USA

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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:

Aqua Satellite measurements:

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

Measurement and Simulated Ozone ENSO Index and Niño 3.4 Index

- Ziemke et al. 2010 OEI
- GEOSCCM OEI
- Niño 3.4 Index * 3

$r=0.83$ for Measurement vs. ENSO
$r=0.86$ for Simulation vs. ENSO
A Tale of Two Tracers
MLS/TES Ozone and MLS/AIRS H$_2$O sensitivity avg. over the tropics

Negative ozone and positive H$_2$O sensitivities are seen over the eastern and central tropical Pacific troposphere, in the stratosphere decreases in O$_3$

Positive ozone and negative H$_2$O sensitivities over Indonesia, except in UT H$_2$O

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.
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.

Colored contours significant at 2 SD.
In the deep tropical troposphere Ozone decreases and \( \text{H}_2\text{O} \) increases occur.

In the midlatitudes increases in ozone in the UT/LS which continue into the troposphere in the subtropics, \( \text{H}_2\text{O} \) decreases with a larger response in the SH.

In the tropical LS ozone decreases but \( \text{H}_2\text{O} \) responses are marginally significant.

Colored contours significant at 2 SD.
GEOSSCCM 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.
MLS/TES Ozone and MLS/AIRS H$_2$O sensitivity to ENSO averaged over Indonesia and Indian Ocean Region

Ozone generally increases in the tropical troposphere but decreases in the LS. H$_2$O decreases in the tropical mid troposphere and increase in the TTL.

There is a hemispheric asymmetry to the response in Ozone and H$_2$O.
Horizontal Ozone and H$_2$O 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$_2$O 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 H₂O 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.

(Contact info: luke.d.oman@nasa.gov)

References

