Equal frequency of stratospheric sudden warmings in El Nino and La Nina

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Stratospheric Sudden Warmings

- Dramatic reversal of the polar vortex winds during NH wintertime, often followed by anomalies that propagate downward to the troposphere 10-60 days later.
Stratospheric Sudden Warmings

- Can have significant impacts on surface climate in NH winter
- Strong (-) NAO: extreme cold outbreaks, Arctic warming

As in Thompson et al. 2002, updated through 2011

Being able to forecast these events could improve intraseasonal to seasonal prediction!
SO.... What causes them to occur?
Stratospheric Sudden Warmings

- Driven by tropospheric planetary-scale waves propagating vertically into the stratosphere and breaking at high-latitudes

Processes which drive planetary scale waves, like ENSO, may therefore be associated with changes in the frequency of SSWs.

How does ENSO impact the stratosphere?

*Polvani and Waugh 2004*
Presumably, the warmer temps during El Nino are associated with stronger wave driving in the seasonal-mean, which weakens the vortex and warms the stratosphere.
Because El Nino reinforces climatological wave 1, planetary wave driving of the vortex increases. La Nina has the opposite effect, since it’s associated with an anomalous high over the Pacific region. But do extreme wave driving events that lead to SSWs ever occur during La Nina?
Mean winds are weaker during El Nino relative to La Nina, but extreme wind anomalies are similar in each phase.
El Nino and La Nina have equal frequency of SSWs in the historical record.

Why do SSWs occur during La Nina as often as during El Nino if the La Nina teleconnection in the Pacific presumably interferes with wave amplification into the stratosphere?
While El Nino is associated with a trough in the North Pacific, and La Nina is associated with a ridge, both teleconnections are associated with low height anomalies in the SSW precursor region (marked by the square).
Extreme negative anomalies in the SSW precursor region occur nearly equally often in La Nina and El Nino, and less often in neutral ENSO, consistent with SSW frequency.

Can this relationship explain the difference between SSW frequency and ENSO in chemistry climate models as well?
Though El Nino enhances SSW frequency in most models, the impact of La Nina varies wildly- e.g., the SSW freq is enhanced in UMSLIMCAT and CMAM, but reduced in GEOSCCM, UMKCA-METO, and CCSRNIES. Can the location of the ENSO teleconnections in these models explain the SSW frequency response?
SSW frequency is closely related to extreme negative anomalies in precursor region

From Garfinkel et al. 2012, JGR
No relationship between ENSO impact on seasonal mean vortex and SSW frequency

From Garfinkel et al. 2012, JGR

Models/data with a large seasonal mean impact from ENSO do not necessarily have a large SSW response to ENSO, and vice versa
Conclusions

- SSW frequency during different phases of ENSO is related to the subpolar extent of ENSO teleconnections.
- Frequency of extreme negative anomalies in SSW precursor region largely determines SSW frequency for a given dataset/model simulation.
- Response to an external forcing, like ENSO, of the seasonal mean stratospheric vortex may not be indicative of the response of extreme stratospheric events.

SSW frequency during neutral ENSO winters is also tied to negative anomalies in SSW precursor region

From Garfinkel et al. 2012, JGR
Heat flux and ENSO

zonal wavenumber 1

![Graph showing zonal wavenumber 1](image)

zonal wavenumber 2

![Graph showing zonal wavenumber 2](image)

all zonal wavenumbers

![Graph showing all zonal wavenumbers](image)

Legend:
- **Red**: El Nino
- **Blue**: La Nina
- **Black**: Neutral ENSO

(mean $\bar{v'\bar{v}}$ Kms/s)

(mean $\bar{v'\bar{v}}$ > 15Kms/s (days per winter))

(latitude)
• Seasonal mean response is more closely related to strength of teleconnections in Gulf of Alaska.
Split vs displacement frequency is similar in EN and LN.

Slight wave 2 signature during LN in the troposphere.