Combined effect of the ENSO and 11-year solar cycle signals in the NH polar stratosphere.

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Motivation:

ENSO effects on the polar stratosphere

WACCM1, no solar cycle, no QBO (Garcia-Herrera et al., 2006)
Motivation:

**QBO effects on the polar stratosphere** (Holton and Tan 1980, 1982)

Modeling results from MAECHAM5 with climatological SSTs (Calvo et al., 2007)
Motivation:

Solar effects on the polar stratosphere (Labitzke, Matthes)

At high latitudes, a solar cycle signal is found only if the data are separated according to the phase of the QBO (Labitzke and van Loon, 1988; Gray et al., 2001)

Camp and Tung (2007) did not find reversal of the Solar signal from wQBO to eQBO in NCEP/NCAR reanalysis. (Same signal for Smax-eQBO than Smax-wQBO and Smin-eQBO)

Motivation:

Holton and Tan relationship

Gray et al., (2004): Holton and Tan relationship disrupted or reverse from Smax to Smin? Depending on the month of the winter and the level where the QBO is defined. Significance. (ERA-40 data)

Wei et al., (2007), Calvo et al., (2009): weaker or even reversed Holton and Tan relationship during warm ENSOs in observations and models.

**ENSO/QBO effects** Calvo et al., (2009), Garfinkel and Hartman (2007)
Motivation:

There are ‘strange’ effects when ENSO and QBO are combined when QBO and Solar are combined.

What about the combined effect of the 11year solar cycle signal and the ENSO signal??
WACCM3

Version 3.1.9

**Resolution:**
- **Horizontal:** 1.9° x 2.5° (lat x lon)
- **Vertical:** 60 levels 0-140km
  - ~ 1.0 km in UTLS
  - 1-2 km mid-upper stratosphere
  - 3 km in MLT

**REF1:** Retrospective simulation of the 20th century (1950-2004)
- Observed SST, GHG and CFCs
- 3 realizations
detrended, deseasonalized, monthly-mean REF1 data

- WACCM3 does not produce a QBO spontaneously. **No QBO** was included in the simulations discussed here
- Interactive chemistry (MOZART, 57 species)

Composites

**ENSO stratification:** N3.4 higher or lower than 0.8

**Solar cycle stratification:** f10.7 higher than 150 or lower than 100

Analysis from 1950 to 2004 in February

<table>
<thead>
<tr>
<th></th>
<th>Smax</th>
<th>Smin</th>
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<tbody>
<tr>
<td>wENSO</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>cENSO</td>
<td>9</td>
<td>12</td>
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</tbody>
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Results

Calvo and Marsh (submitted to GRL)
Results

Calvo and Marsh (submitted to GRL)
Results

50hPa anom T wave 10hPa

W (a) Smin-wEN
C (b) Smin-cEN

Calvo and Marsh (submitted to GRL)
During **Smin conditions**, the NH polar stratosphere responds to ENSO in the same way as reported in literature (warm ENSO leads to weaker polar vortex and warmer polar stratosphere)

During **Smax**, the response is opposite. Strong cooling during warm ENSOs.

In both Solar conditions, anomalies reach up to 3-4K.

The **solar cycle effect** also changes sign depending on the ENSO conditions. It is largest and significant during strong warm ENSO events (up to -6 K)

These changes are mainly related to the state of the atmosphere during **Smax-wEN conditions**, when two forcings act together. In this case, the planetary wave activity observed during Smin conditions and extreme ENSO events is inhibited and thus, the pole becomes very stable and cold.

Need to stratify with respect to ENSO and solar conditions.

**Compared to Observations??**
Conclusions

Compared to Observations??

Kuroda (2007): ENSO modulation on the solar cycle signal on NAO

They did not find a reverse but a weaker solar (ENSO) response for different ENSO (solar) conditions.

\[ \text{Smax (wEN-cEN)} \quad \text{Smin (wEN-cEN)} \]

Differences related to QBO effects?

Non linear behavior
Non additive response

From Kryjov and Park (2007)