Modeling the Downward Influence of Stratospheric Final Warming events

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Research supported by the NSF: Climate and Largescale Dynamics Program
Observed stratospheric final warming in NH (NCEP reanalysis daily climatology)

[u] 75°N

[T] 75°N

From website of the NOAA Climate Diagnostics Center
## Stratospheric sudden & final warmings

<table>
<thead>
<tr>
<th></th>
<th><strong>Stratospheric Sudden Warming (SSW)</strong></th>
<th><strong>Stratospheric Final warming (SFW)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Similarity</strong></td>
<td>Polar T increases, high latitude [u] weakens, reverses</td>
<td></td>
</tr>
<tr>
<td><strong>Difference 1: timing</strong></td>
<td>Mid/late-winter, ~ every 2nd year</td>
<td>Spring, every year</td>
</tr>
<tr>
<td><strong>Difference 2: characteristic</strong></td>
<td>[u] reverses, then recovers</td>
<td>[u] reverses “permanently”</td>
</tr>
<tr>
<td><strong>Difference 3: mechanism</strong></td>
<td>Planetary waves</td>
<td>Solar radiation</td>
</tr>
</tbody>
</table>
Observed final warmings in the Northern and Southern Hemispheres

Black et. al., 2006, *J. Climate*

Numerical experiments - dynamic core GCM

GFDL spectral GCM (Held and Suarez, 1994)

- Newtonian relaxation of temperature field to zonally symmetric radiative-equilibrium $T$ ($T_{eq}$)
- Rayleigh friction for low-level winds to parameterize surface drag
- Vertical levels and $T_{eq}$ similar to Scinocca and Haynes (1998)
- R30 truncation, 30 levels
- Dry
Simulations of final warmings

1) Begin seasonal transition at different days of long winter run

2) 180 day transition from winter to summer state $Teq$
   $$Teq = Teq_{winter} + \sin^2(\pi \frac{t}{360\text{day}}) (Teq_{summer} - Teq_{winter})$$

3) Summer $Teq$ continues 120 days

Winter and summer have the same tropospheric $Teq$

Only the stratosphere undergoes seasonal transition
Final warming in zonally symmetric model

In zonally symmetric model, tropospheric $[u]$ is unchanged across warming.
Composite analysis of final warmings

1) Identify final warming events based on the \([u]\) transition at 50 hPa, 70° (Black et al. 2006)

2) Composite \([u]\) transition during final warmings

3) Construct climatological \([u]\) transition based on mean onset time

4) Calculate the composite \([u]\) anomaly & test for significance
Final warmings with and w/o topography

Topography
• “NH”
• 2 mountains. 3km and 5km, to represent Rockies and Himalayas
• Equilibrium stratospheric jet ~120m/s

Non-topography
• “SH”
• Equilibrium stratospheric jet ~150m/s

Two “spring” hemispheres in non-topo runs, only one spring hemisphere for topo runs
2*40=80 non-topo events - 40 topo events
Wintertime mean flow and variability
Onset dates

- **Non-topography SFW events**

- **Topography SFW events**

Number of days after radiative transition begins
<table>
<thead>
<tr>
<th></th>
<th>Simulation average onset date</th>
<th>Observation average onset date</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH</td>
<td>Day 162</td>
<td>Dec 4 (day 163)</td>
</tr>
<tr>
<td>NH</td>
<td>Day 152</td>
<td>April 14 (day 113)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Simulation onset standard deviation</th>
<th>Observation onset standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH</td>
<td>19 days</td>
<td>13 days</td>
</tr>
<tr>
<td>NH</td>
<td>26 days</td>
<td>N/A (&gt;18 days)</td>
</tr>
</tbody>
</table>
[u] evolution for non-topography final warmings
[u] evolution for topography final warmings
Composite \([u]\) anomaly for non-topography final warmings
Composite \([u]\) anomaly evolution for topography final warmings
Non-topography composite \([u]\) anomaly and upward E-P flux anomaly
Topography composite [u] anomaly and upward E-P flux anomaly
Tropospheric circulation changes

NH observations

Black et al., 2006, *J. Climate*
Summary

• Salient features of final warming obtained when seasonal transition is imposed *only* from the stratosphere
  • Including stronger zonal wind anomalies in NH
  • Suggests tropospheric “response” to final warming is truly that
  • Implies influence of stratospheric final warming on springtime transition is significant, especially in NH

• Precursor events in EP flux and zonal wind
  • Immediate precursors required by dynamical consistency
  • Earlier precursors (also in obs) remain a puzzle
Questions

Mechanism for downward influence?
  • Topo/non-topo difference suggests big role for planetary waves (cf. Song and Robinson, 2004)

Mechanism for precursors?
  • Wintertime variability does not appear to be periodic
  • Change in dynamical regime as stratospheric circulation weakens?

Predictability across spring transition?