An analysis of SSW & elevated stratopauses generated in WACCM

Amal Chandran, Richard Collins, Rolando Garcia,
Daniel Marsh

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Outline

• Classification of SSW in WACCM
• Dynamics of an elevated stratopause generated in WACCM
• Climatology of SSW in multiple WACCM runs
• Longitudinal variations during an SSW
• Conclusions
Multiple WACCM 3.5 simulations have been analyzed for SSW events (Two 50 year and one 150 year simulation).

Arctic winters have been classified into 4 types:
- Quiet (undisturbed) winters
- Minor SSW winters - Poleward temperature gradient becomes positive but zonal mean wind at 10 hPa does not reverse.
- Major SSW winters - Poleward temperature gradient becomes positive with reversal in zonal mean wind at 10 hPa.
- Major SSW with elevated stratopause winters
Quiet year
1996-1997 NH winter

Minor Warming
1994-1995 NH winter

Major Warming
1992-1993 NH winter

Elevated Stratopause
1997-1998 NH winter

Zonal mean wind at 60 N
A case study of an elevated stratopause generated in WACCM

Chandran et. al. GRL 2011

We analyze and compare the dynamics of the middle atmosphere during an elevated stratopause winter generated in WACCM with a dynamically quiet Arctic winter.
Elevated stratopause in WACCM

Quiet winter

Elevated stratopause winter

Zonal mean EP flux (m/s/d) 55-70 N

Zonal mean U (m/s) 55-70 N
Elevated stratopause in WACCM

Quiet winter

Elevated stratopause winter

(d) Zonal mean GWF (m/s) 55-70 N

(a) Zonal mean V* 55-70 N

(b) Zonal mean W* (cm/s) 75-90 N
Elevated stratopause in WACCM
Summary of Dynamics

- The triggering mechanism for SSW events were strong persistent westward planetary wave forcing in the stratosphere which results in a reversal of the eastward stratospheric jet.
- This reversal of the stratospheric jet then results in a change in GWF from westward to eastward in the mesosphere driven by non-orographic waves as the orographic gravity waves are filtered out at the zero wind line.
- The residual circulation shows strong down-welling in the stratosphere leading to adiabatic warming and upwelling in the upper stratosphere and mesosphere leading to adiabatic cooling of the mesopause region during the SSW event.
- The net forcing in the upper mesosphere becomes eastward due to the eastward GWs which reverses the westward jet and helps in the formation of the elevated stratopause.
- After the formation of the elevated stratopause, the stratopause warms and descends through gravity wave induced diabatic descent.
A New Look at Stratospheric Sudden Warmings. Part I: Climatology and Modeling Benchmarks

ANDREW J. CHARLTON*
Department of Applied Physics and Applied Mathematics, Columbia University, New York, New York
LORENZO M. POLVANI

The frequency and dynamics of stratospheric sudden warmings in the 21st century
A. J. Charlton-Perez,¹ L. M. Polvani,² J. Austin,³,⁴ and F. Li³,⁵

Charlton & Polvani 2007 analyzed the NCEP-NCAR and 40-yr ECMWF Re-Analysis (ERA-40) datasets and identified SSWs based on the zonal mean zonal wind at 60°N and 10 hPa, and classified them into events that do and do not split the stratospheric polar vortex.

Fig. 1. Polar stereographic plot of geopotential height (contours) on the 10 hPa pressure surface. Contour interval is 0.4 km, and shading shows potential vorticity greater than 4.0 × 10⁻⁴ K kg⁻¹ m⁻² s⁻¹. (a) A vortex displacement type warming that occurred in February 1984. (b) A vortex splitting type warming that occurred in February 1979.
Quiet winter

Major SSW winter

Major SSW & elevated stratopause winter

Robust undisplaced Vortex

Vortex displacement event

Vortex Splitting event

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Quiet winter

Major SSW winter

Major SSW & elevated stratopause winter
# Climatology of SSW in WACCM

<table>
<thead>
<tr>
<th>Type of SSW</th>
<th>Realization</th>
<th>Refb 1.1 (1953-06)</th>
<th>Refb 1.4 (1953-06)</th>
<th>Refb 2.3 (1953-2100)</th>
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<tr>
<td>Quiet Year</td>
<td>0.06</td>
<td>0.08</td>
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<tr>
<td>Minor SSW</td>
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<td>0.34</td>
<td>0.41</td>
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<td>Major SSW</td>
<td>0.29</td>
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<tr>
<td>Major SSW with elevated stratopause</td>
<td>0.27</td>
<td>0.29</td>
<td>0.2</td>
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<td>Quiet or minor SSW winter</td>
<td>0.44</td>
<td>0.42</td>
<td>0.49</td>
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<tr>
<td>Major SSW &amp; elevated stratopause winter</td>
<td>0.56</td>
<td>0.58</td>
<td>0.51</td>
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</table>

Charlton & Polvani 2007

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>All SSWs</th>
<th>Vortex displacement</th>
<th>Vortex splitting</th>
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<tbody>
<tr>
<td>1) Frequency (SSWs yr⁻¹)</td>
<td>0.60 (0.10)</td>
<td>0.33 (0.07)</td>
<td>0.27 (0.07)</td>
</tr>
</tbody>
</table>

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Longitudinal Variability

Geopt Ht 10 hPa

MY 1968-69

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Summary & Conclusions

• **WACCM** with the new GW parameterization produces SSW at a realistic occurrence frequency (w.r.t. observations).

• **WACCM** produces elevated stratopauses with characteristics similar to recently recorded events in the Arctic.

• **WACCM** produces both vortex displacement and vortex splitting events.

• Some of the vortex splitting events are associated with the formation of an elevated stratopause.

• During a vortex displacement event, there are vast longitudinal variability in the temperature structure and different ground based locations might observe vastly different winters.

• This study shows that during undisturbed winters the dominant GWF is westward in the mesosphere between 40-65 N. However, during an SSW event, the dominant GWF becomes eastward poleward of 60 N.
The End !! Thank you !!