Downward coupling in CESM1(WACCM)

Dan Marsh, Mike Mills, Doug Kinnison, Jean-Francois Lamarque, Natalia Calvo, and Lorenzo Polvani
Outline

• Review important differences between WACCM and CCSM4

• Compare CCSM4 and WACCM in two areas where downward coupling is important:
  
  • NH winter

  • Influence of the antarctic ozone hole
Important differences from CCSM4 used for CMIP5

• Model top at ~140 km (66 levels) vs. ~40 km (26 levels)

• Horizontal (lat x lon) resolution: 1.9° x 2.5° vs. 0.94° x 1.25°

• Fully-interactive chemistry

• Nudged Quasi-Biennial Oscillation (QBO)

• Forced with daily varying spectral irradiance rather than annual mean TSI

• Thermospheric processes - aurora, ion chemistry, molecular diffusion

• Additional parameterization for gravity waves from convection and fronts (same orographic parameterization)

• “Turbulent mountain stress” (TMS) turned on
How then to investigate the influence of a ‘high-top’?

- Parallel simulations of CCSM4 configured in a similar manner to WACCM
  - Horizontal (lat x lon) resolution: 1.9° x 2.5°
  - Daily TSI
  - TMS turned on
- We term this model CCSM4-WSET
- Note: all simulations (WACCM, CCSM4 1°, and CCSM4-WSET) run with the same POP2 active ocean at 1°

<table>
<thead>
<tr>
<th>Model name</th>
<th>horizontal resolution</th>
<th>model top (hPa)</th>
<th># levels</th>
<th>TMS</th>
<th>QBO</th>
<th>Interactive chemistry</th>
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</thead>
<tbody>
<tr>
<td>WACCM</td>
<td>1.9° x 2.5°</td>
<td>5.96 x 10^{-6}</td>
<td>66</td>
<td>ON</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>WACCM NO-TMS</td>
<td>1.9° x 2.5°</td>
<td>5.96 x 10^{-6}</td>
<td>66</td>
<td>OFF</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>CCSM4</td>
<td>0.95° x 1.25°</td>
<td>3.54</td>
<td>26</td>
<td>OFF</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>CCSM4-WSET</td>
<td>1.9° x 2.5°</td>
<td>3.54</td>
<td>26</td>
<td>ON</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>
NH variability
SSW counts in CMIP5 models

WACCM 3.3-5.3 / decade (4.6 on average)

A. Charlton-Perez et al., JGR, 2013
Stratospheric Sudden Warmings
1960 to 2004
Stratospheric Sudden Warmings
1960 to 2004

AMWG/ WAWG Joint Session - 11 February 2013
NAM index composite for winters with SSWs

Fig. 4. NAM index composite constructed from winters with major SSWs for the ensemble of (a) WACCM and (b) CCSM4-WSET simulations. Day 0 is the central date of each SSW. Contours every 0.5. Blue is negative, yellow positive.
CCSM4 Sea level pressure bias (de Boer et al., 2013)
CCSM4 Sea level pressure bias (de Boer et al., 2013)
DJF Sea Level Pressure

![Graph showing DJF Sea Level Pressure comparison between WACCM and CCSM4 models. The graph displays sea-level pressure (millibars) on the y-axis and latitude on the x-axis. The WACCM model is represented by a red solid line, while the CCSM4 model is represented by a blue dashed line.]
DJF Sea Level Pressure

WACCM

CCSM4

WACCM-CCSM4-WSET
Sea level pressure change PI to present
Precipitation change PI to present over Europe
Climate change projections and stratosphere–troposphere interaction

Adam A. Scaife · Thomas Spangehl · David R. Fereday · Ulrich Cubasch · Ulrike Langematz · Hideharu Akiyoshi · Slimane Bekki · Peter Braesicke · Neal Butchart · Martyn P. Chipperfield · Andrew Gettelman · Steven C. Hardiman · Martine Michou · Eugene Rozanov · Theodore G. Shepherd

Winter Mean Rainfall
(4 x CO₂)-(1 x CO₂)
Precipitation change PI to present
SH response to the development of the stratospheric ozone hole
Total Column Ozone - Halley Bay
SH polar cap temperature trends (K/decade)
DJF zonal mean wind trends (m/s/decade)
DJF zonal wind (m/s)

Lines: 1960-79 average.
By specifying ozone and greenhouse gas forcings independently, and performing long, time-slice integrations, it is shown that the impacts of ozone depletion are roughly 2–3 times larger than those associated with increased greenhouse gases, for the Southern Hemisphere tropospheric summer circulation.

“...ozone contributed about 50% more than GHG toward the jet shift...”
Trend reverses going into the future

Hurrell et al., BAMS, 2013
Zonal wind and precipitation trends 1975-1995

(a) DJF zonal mean U trend

(b) DJF precipitation trend
Polvani et al., 2011

b: zonal wind response

a: P – E response
Antarctic Sea Ice Extent

SIE (10^6 km^2)

% change from PI
Summary

- SSWs are practically absent in standard CCSM4 - there is no NAM signal propagating into the troposphere.

- TMS leads to a reasonable SSW occurrence in WACCM and a substantial increase (~50% obs.) in CCSM4. NH polar SLP bias reduced. It also improves N3.4 power amplitude (not shown).

- PI to present change in NH European SLP and precip. are different between WACCM and CCSM4 - pattern remarkably consistent with prior studies.

- Correct ozone changes in the stratosphere are critical to getting trends correct there. These trends lead to differences in surface winds and precip.

- WACCM and CCSM4 show an acceleration of SEI loss with the development of the ozone hole - contrary to observations, which show flat or slightly positive trends.