WACCM6 !?*@ 

Gettelman, Mills, Polvani

& The WACCM ‘Team’

Thanks to:

Kinnison, Smith, Garcia, Richter, Bardeen, Tilmes, Vitt, Liu
Outline

• Logistics
• State of WACCM
• WACCM6 overview
• WACCM6 configurations
• Beyond WACCM6 (discussion)
  • WACCM6 Configurations
  • WACCM6 for CMIP6, MIPS
  • Future plans
Logistics

- WACCM-WG: This AM (Break @ 10:30a)
- Joint meeting with AMWG/CHEM: 1 PM main seminar room
State of WACCM

• CESM2 (WACCM6)
  • ‘Almost done’: we think final tuning
  • WACCM historical simulations with near-current complete
  • WACCM6 forcing being used for CESM2...

• WACCM6 forcing for CESM2
  1. Run FW1850 20 years: SSTs from B1850 coupled run [Done]
  2. Run B1850 100 years with forcing [Iterating: Final tuning]
  3. Re-run FW1850 for 20 years
  4. B1850 for another 200-300 years
  5. BW1850 for 250 years (WACCM6-CMIP6 Control)
WACCM6 major advancements

• Updated (and unified) chemistry
  • Better ozone hole evolution
  • Combined tropospheric and stratospheric chemistry

• Prognostic Stratospheric Aerosols
  • Better prediction of response to volcanic eruptions

• WACCM6 matches CAM6 physical parameterizations
  • Aerosol and Cloud adjustments made to CAM6 for WACCM6

• WACCM-X with interactive thermosphere
  • Simulations of the upper atmosphere
  • WACCM4 Physics

• Improved stratospheric variability
  • Internally generated QBO
  • SSW climatology improved
<table>
<thead>
<tr>
<th>Process</th>
<th>CESM1 (WACCM4) CCMI</th>
<th>CESM2 (WACCM6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Resolution</td>
<td>1.9°x2.5°</td>
<td>0.95°x1.25°</td>
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<tr>
<td>Vertical Layers</td>
<td>26/66/88</td>
<td>32/70/88</td>
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<tr>
<td>Boundary Layer</td>
<td>HB</td>
<td>CLUBB</td>
</tr>
<tr>
<td>Shallow Convection</td>
<td>Hack</td>
<td>CLUBB</td>
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<td>Deep Convection</td>
<td>ZM</td>
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<td>Microphysics</td>
<td>R&amp;K</td>
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<td>Radiation</td>
<td>CAMRT</td>
<td>RRTMG</td>
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<tr>
<td>Aerosols</td>
<td>Bulk</td>
<td>MAM4</td>
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<tr>
<td>QBO</td>
<td>Nudged to Observations</td>
<td>Interactive</td>
</tr>
<tr>
<td>Chemical Mechanism</td>
<td>180 species</td>
<td>228 Species</td>
</tr>
<tr>
<td>Chemical rates</td>
<td>JPL-11</td>
<td>JPL-15</td>
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<tr>
<td>Sulfate SAD</td>
<td>Prescribed (CCMI)</td>
<td>Interactive (MAM)</td>
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<tr>
<td>ICE SAD</td>
<td>Bulk Scheme</td>
<td>MG 2.0</td>
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<tr>
<td>Solar Variability / ETF</td>
<td>Lean</td>
<td>Lean (updated)</td>
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<td>GHG abundances</td>
<td>Meinshausen, 2011</td>
<td>Meinshausen, 2016</td>
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<td>Halogens</td>
<td>WMO, 2010</td>
<td>Meinshausen, 2016</td>
</tr>
</tbody>
</table>
Prognostic Stratospheric Volcanoes

Prognostic Stratospheric Sulfur in WACCM: AOD compares well to observations

Mills et al. 2016
Prognostic Stratospheric Volcanoes

Temperature anomalies due to volcanoes are improved with Prognostic Treatment over CCSM4/CESM1

Mills et al 2016
WACCM-X in CESM2: Now with an ionosphere (750km)

Ionosphere F-region Peak Electron Density Height

- WACCM-X in CESM2 interactive ionosphere
  - Ionospheric electrodynamics, ion transport and ion temp
- Image ionosphere peak electron density height matches COSMIC obs
  - Measure of ionosphere electrodynamics
- Runs with WACCM4 Physics
- 7 Papers submitted: 2 published
WACCM6 Climatology
“262” configuration

• FWHIST Historical Simulation
  • Prescribed SSTs, historical emissions
  • 1955-2010
  • Based on 262 Code base: Latest – sea ice tuning

• Some samples of Climatology
  • Ozone, Polar Temperature, Winds, Tropical Temperature and Water vapor.
CESM2-WACCM6 Ozone Hole Simulations

Halley Station, Antarctica (75ºS, 26ºW) Total Column Ozone

From: D. Kinnison

CESM2 (WACCM6) better represents both December and January Ozone loss over the historical record compared to CESM1 (WACCM4). Updated from Garcia et al., JAS, 2017.
SH Polar Cap T v. MERRA
1980-2010
Polar Cap T @ 85hPa v. MERRA

\[ T(k) \]


blue: \( \Delta T \) not significant at 95%
SH Polar Cap, October Timeseries

Total Ozone

Temperature

Sulfate SAD

October, South Polar Cap Average

Column O3 (DU)

Temperature (K) at 85 hPa

SAD_SULFC (um2/cm2) at 85 hPa
Subpolar U v. MERRA
1980-2010
NH SSW Frequency

model winter frequency: 0.581; MERRA 1980–2010 winter frequency: 0.580
concat_tem_diag_mg17.262a_1979–2011.nc (19800101–20101231)
source: f.e20.FWHIST.f09_f09_mg17.262a.cam.h6*
Tropical Temp v. MERRA

Tropopause temp within 1K of MERRA for most months
H2O Tape Recorder v. MLS

H₂O within ±0.5ppmv of MLS
WACCM6 Configurations

• ‘Full’ WACCM (WACCM6) 1°
  • 70L, full chemistry, 140km lid
  • FW2000, FWHIST, BWHIST, BW1850

• WACCM6-SC 1°
  • 70L, fixed ozone and oxidants, 140km lid
  • FWHISTSC

• WACCM-X 2.0 (2°)
  • 126L, 750km lid, WACCM4 physics
  • Ionospheric Physics, Transport
  • FWX Comp Set

• Other options (not full scientific support):
  • High vertical resolution: L110 Initial condition
  • Reduced Chemistry: Middle atmosphere mechanism exists
  • Will also have 2° versions
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WACCM For CMIP6
’DECK’ Experiments

• WACCM6 will create forcing for CESM2
  1. Run FW1850 20 years with SSTs from B1850 coupled run. *(Already done, will redo with final code)*
  2. Run B1850 100 years with forcing
  3. Re-run FW1850 for 20 years
  4. B1850 for another 200-300 years
  5. BW1850 for 250 years (WACCM6-CMIP6 Control)

• WACCM6 Deck
  • BW1850 (#5 above)
  • 1%/yr, 4xCO2, AMIP (1979-2014), 20th Century (x3)

• ScenarioMIP: SSP5-8.5, SSP3-7, SSP2-4.5, SSP1-2.6
CESM2 Timeline

**CESM2-WACCM6**
- CAM: 30 sypd (1°, 32L)
- WACCM: 6 sypd (1°, 70L, 228 sp.)
- Ocean only: 100 sypd
- Land only: 150 sypd

**CESM2-CAM6**
- WACCM (fixed SSTs, 20 years)
- CAM (coupled, 100 years)
- WACCM (fixed SSTs)
- CAM coupled (100 years)
- Ocean only (2500 years)
- Land only (1200 years)
- WACCM coupled (150 years)
- CAM coupled (500 years)

Days

Tasks:
- Task 1
- Task 2A
- Task 2B
- Task 2C
- Task 3A
- Task 3B
- Task 3C
- Task 3D
- Task 4

LENs 402
WACCM6: MIP, MIP, MIP

- QBOi (Richter)
- Solar Variability (Marsh)
- Dyn Var (Marsh, Simpson)
- VolMIP (Mills)
- ISA-MIP (interactive stratospheric aerosols: Mills)
- AerChemMIP (Lamarque/Emmons)
- GeoMIP (Tilmes)
Beyond WACCM6/CESM2

• Exploring further GW tuning
• WACCM-X $\rightarrow$ WACCM6X (merge up to WACCM6)
• Global Electric Circuit
• High vertical resolution (SAO, QBO)
• Heterogeneous Chemistry Updates
• FAST-J or TUV
• Other emerging science issues?