Summary and Evaluation of Tropospheric Ozone in the NCAR CESM Simulations for CCMII

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The Community Earth System Model (CESM) can be used in multiple configurations, including CAM-chem (Community Atmosphere Model with chemistry) and WACCM (Whole Atmosphere Community Climate Model). CAM-chem is primarily used for tropospheric and climate studies, while WACCM is used for study of the Middle Atmosphere and UT/LS.

Both models have been run for REFC1 (FR: free-running) and REFC1SD (Specified Dynamics).

<table>
<thead>
<tr>
<th>CESM1-CAM4-chem</th>
<th>CESM1-WACCM</th>
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<tbody>
<tr>
<td>Resolution</td>
<td>1.9°x2.5°, SD: 56L, FR: 28L (0-40km)</td>
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<tr>
<td>Chemistry</td>
<td>Troposphere-Stratosphere 157 species; 373 reactions, JPL-2010</td>
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<td>Trop. Aerosols</td>
<td>Bulk Aerosols (BAM), 2-step SOA [Heald et al., 2008]</td>
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<td>Dry Deposition</td>
<td>New DV scheme [Val Martin, 2014]</td>
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<td>Wet Deposition</td>
<td>Neu scheme</td>
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<td>Volcanic Heating</td>
<td>Observed sulfate mass and radius with CAMRT</td>
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<td>Emissions</td>
<td>Biogenic: online MEGAN; Anthro, BB, etc; CCMI MACCity; Lightning NOx ~ 5 Tg N per year</td>
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<td>Lower boundary</td>
<td>CCMI-specified mixing ratios for halogens, CO₂, CH₄, N₂O</td>
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<td>SD</td>
<td>CCMI Stratospheric sulfate SD</td>
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MOPITT CO and OMI O₃ column climatologies

OMI ozone climatology: 2004-2010 [Ziemke et al., 2011]
Model CO low almost everywhere, particularly NH spring (~25%)
Tropospheric O₃ in NH all year, low in SH
Stratospheric O₃ columns high over both poles in winter by ~15%

Ozone time series with sondes
Western Europe – 500 hPa

The CAM-chem and WACCM REFC1 and REFC1SD simulations are compared to the ozonesonde climatology for 1995-2011 [Tilmes et al., 2012]. Shown (at left) are the time series averaged over Western Europe at 500 hPa.
CAM-chem and WACCM are quite similar, and have consistent differences between FR & SD.

In winter and fall, all simulations underestimate the observations.
In spring, the free-running simulations overestimate the sondes by almost 10 ppb, but the SD runs agree well.
In summer, all simulations are within the range of the observations.

Seasonal variation
Western Europe - CAM-chem

Seasonal cycle is reproduced well at all altitudes.
At surface in summer, FR too high by 10 ppb.
Differences will be explored through examination of meteorology and dynamics, as well as chemistry.

Next Steps
Evaluation of ozone precursors is required to fully evaluate simulated ozone.
Comparisons will be made to surface networks of CO and hydrocarbons.
Aircraft campaign climatologies and individual data sets will be used to evaluate a large suite of compounds including NOY species and numerous VOCs.