Status of CAM -chem  
Chemistry -Climate Working Group

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Louisa Emmons  
ACOM, NCAR  
9 March 2020
Papers describing chemistry and aerosols in CESM2

- MOZART-T1 chemistry (Emmons et al., *JAMES*, in review)
- VBS-SOA (Tilmes et al., *JAMES*, 2019)
- WACCM6 (Gettelman et al., *JGR-Atmos*, 2019)

Implementing for CESM2.2

- Aerosol wet scavenging improvements
- Brown Carbon radiative effects
- MOSAIC-MAM aerosols (includes ammonium, nitrate aerosols)
- NOx-dependent SOA formation
- Online photolysis (TUV) [*Bardeen talk on Tuesday*]
- Online ocean emissions (OASISS) of DMS, VOCs [Siyuan Wang, GRL, 2019]
- MOZART-T2 (expanded isoprene & terpene oxidation) (Schwantes et al., *ACP*, 2020) [*Schwantes talk Tuesday*]
In order to better treat nitrate (NO$_3^-$) aerosols, the Model for Simulating Aerosol Interactions and Chemistry (MOSAIC) module [Zaveri et al., 2008] is coupled with MAM7 and MAM4 in CESM [Zaveri et al., in prep.; Zheng Lu et al., in prep.].

In the version of MAM coupled with MOSAIC, gas-aerosol exchange is treated by MOSAIC. The other processes are handled by MAM.

<table>
<thead>
<tr>
<th>Mode</th>
<th>BC</th>
<th>POM</th>
<th>SOA</th>
<th>SO4</th>
<th>NH4</th>
<th>NO3</th>
<th>Cl</th>
<th>Na</th>
<th>Dst</th>
<th>Ca</th>
<th>CO3</th>
<th>total</th>
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<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>X</td>
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</tbody>
</table>

Red crosses: new aerosol tracers in MAM4-MOSAIC
a1: accumulation
a2: Aitken
a3: coarse
a4: primary carbon
Modeled surface mass concentration of nitrate aerosol in good agreement in E. Asia, including China, U.S. and E.U.
Organic aerosols from biomass and biofuel burning can contribute to shortwave radiation absorption.

**BrC parameterization**

From Saleh et al. (2014):

\[
1.7 (\pm 0.2) + k_{OA}i = 1.7 (\pm 0.2) + k_{OA,550}(550/\lambda)^w i
\]

\[
k_{OA,550} = 0.016*\log_{10}(\text{BC-to-OA}) + 0.04
\]

\[
w = 0.21 / (\text{BC-to-OA} + 0.07)
\]

**modal_aer_opt.F90**

Call the different species optical properties at each mode, level, wavelength, lat/lon

Modify refractive index for *biomass burning* and *biofuel POM* based on BC-to-OA ratio calculated at each timestep, grid cell.

Calculate bulk refractive index for each mode

Brown Carbon Direct Radiative Effect (DRE)

Brown carbon DRE from chemical transport models:

**DRE (w/o bleaching)**
Feng et al., 2013: \(0.04 \text{--} 0.11 \text{ W m}^{-2}\)
Wang et al., 2014: \(0.11 \text{ W m}^{-2}\)
Saleh et al., 2015: \(0.13 \text{ W m}^{-2}\)
Jo et al., 2016: \(0.11 \text{ W m}^{-2}\)

**DRE (w/ bleaching)**
Wang et al., 2018: \(0.05 \text{ W m}^{-2}\)

Based on Brown et al. ACP, 2018
Improved aerosol profile by changing wet removal scheme

Schemes by Yunpeng Shan (S19) and Pengfei Yu (Y19)

**Pacific Ocean**

- 80N-60N,120W-180W
- 60N-20N,120W-180W
- 20N-20S,120W-180W
- 20S-60S,150E-120W
- 60S-70S,60W-180W

**Atlantic Ocean**

- 80N-60N,30W-90W
- 60N-20N,60W-0W
- 20N-20S,60W-0W
- 20S-60S,60W-0W
- 60S-70S,60W-0W

**Legend**

- **S19**
- **Y19_M4BC2**
- **Y19_M4BC1**
- **Y19_M3**
- **CTL**
- **ATom1**
- **HIPPO**
Yunpeng Shan’s scheme in CESM2.1 (Simone Tilmes)

Jan.

HIPPO1 January:

OLD

NEW

Mar-Apr

HIPPO3 March/April 2010 Alt: 1–2km

Aug-Sep

HIPPO5 Aug./Sept. 2011 Alt: 1–2km

HIPPO5 Aug./Sept. 2011 Alt: 4–5km

HIPPO5 Aug./Sept. 2011 Alt: 7–8km

HIPPO1 January:

4-5 km

7-8 km

Improved Aerosol Scavenging for CESM2.2
Surface Ozone evaluation for CMIP6 models

North Pole (10)

North America (149)

Europe (148)

Russia Bel Ukr (4)

Central America (1)

Ocean (8)

South America (2)

South Pole (6)

Southern Africa (1)

East Asia (36)

South East Asia (1)

Pacific AUS NZ (7)

Turnock et al., ACPD, 2020
Surface Ozone evaluation for CMIP6 models

N. America, Europe – WACCM matches model mean, higher than obs in summer (long-time problem for models)

E. Asia – WACCM closer to obs than most models
Surface PM2.5 evaluation for CMIP6 models

Turnock et al., ACPD, 2020
A new model-independent infrastructure, which will enable chemistry and aerosols to be simulated at different resolutions in a coherent fashion.

Tutorial: June 18-19 – Application deadline May 1
https://www2.acom.ucar.edu/workshop/musica-tutorial-2020
MUSICA-V0 (CAM-chem-SE-RR) release in June 2020
Anthropogenic emissions at 0.1 degree horizontal resolution are conservatively regridded to standard CESM 1 degree and SE Regionally Refined approximately 1/8 degree (14 km)
CO urban sources and pollution plumes are more refined in CAMchem-SE-RR than 1-degree.

Slightly higher ozone over Atlantic and Pacific in RR.
- change in chemistry and dynamics (stratospheric contribution)
February 11th

WRF-Chem

WACCM forecast

CESM-RR

CESM-RR with EPA obs

https://www2.acom.ucar.edu/acresp/forecasts-and-near-real-time-nrt-products
• Expanded alkane chemistry [R. Schwantes, paper in prep.]

• VSLS Halogen Chemistry

• Connecting GEOS-Chem module to CESM (MIT & Harvard)

• Connecting HEMCO emissions module to CESM2 (Harvard)

• Simpler chemistry for climate simulations (e.g., reduced HC, MOZART-2) – Discussion on Tuesday AM