Chemistry-Climate WG: Current and planned activities

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ChemClim WG Charter

• The goal of the Chemistry-Climate WG is to continue the development of the representation of chemistry in the CESM and to further our understanding of the interactions between chemistry and climate.

• Scientific motivations include advancing knowledge on past, present and future atmospheric composition, interactions between atmospheric composition and the Earth System, stratosphere-troposphere coupling, and impacts of global composition and climate on air quality.
Participation

United States

• Colorado State University, Fort Collins, CO
• Cornell University, Ithaca, NY
• Jet Propulsion Laboratory, Pasadena, CA
• Lawrence Livermore National Laboratory, Livermore, CA
• Massachusetts Institute of Technology, MA
• NOAA, Boulder, CO
• Pacific Northwest National Laboratory, Richland, WA
• University of Colorado, Boulder, CO
• University of Illinois, Urbana-Champaign, IL

International

• Laboratory for Atmospheric and Climate Science (CIAC), CSIC, Toledo, Spain
• University of Leeds, UK
• University of Oslo, Norway
• University of Toronto, Canada
Chemistry in an Earth System Model

Emissions

Natural

Anthropogenic

Chemical reactions

Removal processes

Radiation

Clouds

Biosphere

Snow/ice

Climate and other feedbacks
CAM-chem: chemistry in CESM

Atmosphere Model version 4

Dynamics
Physics
Chemistry

Coupler

Land Model
Ocean Model
Sea-ice Model

Lamarque et al., GMDD, 2011
CAM-chem: chemistry in CESM

Lamarque et al., GMDD, 2011
Why do we need extensive chemistry?

Ozone from the stratosphere:
1-2x10^{13} moles per year

Ozone + radiation + water = 2 OH
2-4x10^{13} moles per year

CH4 + OH -> products
NMHC + OH -> products

> 10x10^{13} moles per year

Methane + NMHC emissions
(e.g. isoprene)
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Climate benefits from methane reductions

Shindell et al., Science, 2012
Global modeling of CH4 lifetime in IPCC AR5

Figure courtesy of V. Naik, GFDL, 2012
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Byproducts
- Ozone
- SOA

Methane + NMHC emissions
(e.g. isoprene)
Aerosols

Primary:
- dust
- soot
- some organics
- pollen
- metals

Secondary:
- sulfate
- nitrate
- ammonium
- most organics

Mixed:
- most !!
Radiative Forcing of Climate

Incoming solar \( \sim 340 \, \text{W m}^{-2} \)

Changes since 1750:

long-lived gases \( \sim 3 \, \text{W m}^{-2} \)
ozone \( \sim 0.4 \, \text{W m}^{-2} \)
aerosols and clouds \( \sim -1 \, \text{W m}^{-2} \)

Forcing by aerosols is largest uncertainty
Not just climate: air quality and mortality

130,000-240,000 premature deaths per year are attributable to PM2.5 and ozone

Fann et al., Risk Analysis, 2011.
Multi-model mean bias
Multi-model mean bias

CMAQ bias (normalized)

McKeen et al., JGR, 2005
Source-receptor relationships

14 models, including CAM-chem

Wild et al., ACP, 2012
Chemistry-climate coupling: BC

Teng et al., in preparation
Chemistry-Climate coupling: single forcing

Precip (1975-1999)-(1850-1874)

Sulfate

Annual average

Units: mm/season
Summary

• Chemistry capability in CESM
• Surface air quality (health & ozone impact on agricultural yields) research possible but beware of biases
• Source-receptor relationship: surface ozone
• Near-field and far-field climate response to regional emissions
Thank you.
Questions?
How Aerosols Affect Radiative Forcing and Climate

- Scattering & absorption of radiation
- Unperturbed cloud
- Increased CDNC (constant LWC) (Twomey, 1974)
- Drizzle suppression. Increased LWC
- Increased cloud height (Pincus & Baker, 1994)
- Increased cloud lifetime (Albrecht, 1989)

- Top of the atmosphere
- Surface

Direct effects

Cloud albedo effect/ 1st indirect effect/ Twomey effect

Cloud lifetime effect/ 2nd indirect effect/ Albrecht effect

Indirect effect on ice clouds and contrails

Heating causes cloud burn-off (Ackerman et al., 2000)

Semi-direct effect

IPCC, 2007
Climate Models Are Sensitive to Aerosol Forcing

11 models compared, each with different aerosol forcing

Trade off between
- aerosol forcing
- climate sensitivity

Climate sensitivity = $\Delta T_f$