Lessons learned in CMIP5: aerosols

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With inputs from Jean-Louis Dufresne, Marie-Alice Foujols, Michael Schulz & Piers Forster
CMIP3: forcing vs sensitivity

Kiehl, Twentieth century climate model response and climate sensitivity, GRL, 2007
From CMIP3 to CMIP5

Forster et al., JGR, 2013
Warming due to decreasing aerosols in RCP45

Cooling due to anthropogenic aerosols in historical

Anthropogenic aerosols fixed at 2005 values

No anthropogenic aerosols

IPSL-CM5A-LR climate model

Temperature change due to aerosols - IPSL-CM5A-LR

Temperature change due to aerosols - IPSR-CM5A-LR
AEROCOM / ACCMIP / literature ➔ Chapters 7&8 AR5
IPCC Chapter 7 ERF estimates
**CMIP5 aerosols ➔ Chapters 9 and above**

**Figure 9.29**: Time series of global oceanic-mean AOD from individual CMIP5 models’ historical (1850–2005) and RCP4.5 (2006–2010) simulations, corrected MODIS satellite observations by Shi et al. (2011) and Zhang et al. (2008), and the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP) simulations for the 1850s by Shindell et al. (2013).
Issues and lessons learned

• CMIP5 aerosol schemes are generally not state-of-the-art (aerosols ≠ sulfate + BC) as compared to AEROCOM and ACCMIP models

• Less than half of CMIP5 models diagnosed aerosol forcings (ERF from an sstClim simulation, only present-day)

• All CMIP5 models and simulations use the same historical aerosol emissions, hence have the same time profiles for aerosol variations => issue for understanding past variations

• Some D&A runs group aerosols and O₃, others don’t

• Not enough focus on volcanic stratospheric aerosols

• Not much spread in short-lived climate forcers in RCP scenarios => is it an issue for decadal prediction?
Science questions we could possibly answer with CMIP5

• What circulation changes can be attributed to aerosols?
• Can we learn something from the climate response to volcanic stratospheric aerosols in the CMIP5 runs?

Science questions for CMIP6

• How much sophistication / spatial resolution in aerosol physics/chemistry is needed in climate models to represent aerosol RF & climate response to a sufficient accuracy?
• ERF aerosol-radiation and aerosol-cloud interactions (especially BC)
• D&A of climate response to aerosols, especially at the regional scale
• Can we bound uncertainties in future climate change that is due to aerosols (scenarios + RF + climate response)?
• Are aerosol biogeochemical feedbacks really small?
• Do aerosol influence the statistics of climate extremes?
Need for higher resolution

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Variability in yearly ERF diagnosed in sstClim experiments
Idealised experiments: Easyaerosol, GeoMIP

Zonal AOD=0.2 at 550 nm centred 35°N with s.d. 25°

Angström=1
g=0.7
SCA=(ssa=1) & ABS=(ssa=0.5)

SCA-REF

ABS-REF
Short-lived climate forcers in CMIP6

Jean-François Lamarque (With input from many others)

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Issues with RCPs

1. Emissions not capturing range

SRES scenarios

Van Vuuren et al., 2011

2. Cannot isolate the impact of SLCFs

5-95% range
Recent focus on CH$_4$ and BC as win-win

Shindell et al., Science, 2012
Focus on CH$_4$ and BC: win-win

Obama climate action plan (6/25/13): Leverages new opportunities to reduce pollution of highly-potent greenhouse gases known as hydrofluorocarbons; directs agencies to develop a comprehensive methane strategy; and commits to protect our forests and critical landscapes.

Shindell et al., Science, 2012
Proposal for CMIP6 climate-study scenarios

Goal – be able to identify/quantify a specific alternate (mitigation) pathway that separates two scenarios: e.g.
   – Switching coal power plants to natural gas
   – Policy/regulation on transportation or air quality

1. Define a Reference Scenario and associated emissions. Based primarily on current trajectory of emissions and regulations.

2. Quantify the delta(emissions) associated with change in pathway (specific actions) for each of the IAMs (e.g., actions to keep <2°C). Treat this as a climate model ensemble. Look for agreement global/regional, check for consensus, define ensemble mean emissions/land-use change if possible

3. Perform climate simulations with reference and a single perturbed emissions case (allows calculation of climate sensitivity for specific action)
Proposal for AQ studies

• The main target is to understand the role of climate change on atmospheric composition (change in T, H2O + precip, ...)

• Key assessment is (i) how is background changing from climate and global/regional emissions, and (ii) how is this changing the efficiency of local emissions to produce local pollution.
  – Start from reference case (which must have significant emissions of AQ precursors over the whole simulation period)
  – Use a separate scenario with a large enough climate signal but keep the same precursor emissions as reference.
Diagnosis of forcing

• Very little information in CMIP5
• Estimates from ACCMIP
• ERF (Effective Radiative Forcing) most closely related to climate impact
• Requires additional simulation->for aerosols: rerun historical with prescribed SSTs and PI aerosols
Idealized experiments: specified heating profile for BC

Teng et al., GRL, 2012
Response to regional forcing: idealized experiment

- Temperature and precipitation response to regional aerosol forcing
  - > heating profile for BC
  - > regional solar constant reduction for sulfate
JJA impact: 10x US SO$_2$

Temperature (K)

Precipitation (mm/day)

AOD (x10)

Shortwave cloud forcing (W/m$^2$)

-1.5 -1 -0.5 -0.1 0 0.1 0.5 1 1.5
Annual impact of US emissions

Leibensperger et al., 2012; all aerosols

mm/day
Top of the atmosphere shortwave forcing

Annual Mean

W/m²

US perturbation only