A joint initiative of

AerChemMIP

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Motivation for having AerChemMIP

- Address shortcomings of CMIP5 with respect to documenting composition changes (mostly aerosols and ozone)
- Define combined metrics and diagnostics for composition evaluation
- Identify science questions of relevance to CMIP6 and define the associated simulations
- Single entity to interact with other CMIP6 contributors, including emissions and forcing estimates.
- Chemistry and aerosol model components are tightly linked in many climate models
Shortcomings in CMIP5 in relation to SLCFs

- Scenarios (RCPs) are too similar in their projected emissions of short-lived climate forcers (aerosols and tropospheric ozone)
- No straightforward way of identifying the costs/benefits of air quality measures (including health impacts)
- No detailed analysis/evaluation of composition from CMIP5 models (output data mostly unavailable)
- No CMIP5-integrated calculation of radiative forcings from aerosols or homogeneous diagnostics wrt to aerosols and chemical composition
- Attribution to aerosol effects difficult
- Limited study of chemistry-climate interactions
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Levy et al., JGR, 2013
AerChemMIP in support of CMIP6

- Interest in having scenarios to look at impacts of SLCFs. (i.e. differential scenario pairs)
- Define other scenarios of interest, e.g. Natural gas/methane for power generation?
- Understand trends in composition
- Role of natural aerosols, aerosol-chemistry coupling, other feedbacks (Organic Aerosols, Fires, Dust & Seasalt, OH, Radiation, Dynamics)
- Usage of observational constraints to bracket projections (current processes)
- Stratospheric impacts on climate (strat-trop coupled system)
- Identify relationship between regional forcing and climate response
- Documentation of composition, forcings and feedbacks in CMIP6
- Provide link to detailed modeling in CCMIP & AeroCom
- Propose aerosol and ozone climatology fields for high resolution climate modeling
- Environmental surface (ozone, PM, nitrogen/sulfur deposition) impacts (diagnostics/evaluation) connection with scenarios (population, landuse,...)
AerChemMIP in support of CMIP6

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Small Interannual Variability of Global Atmospheric Hydroxyl

S. A. Montzka, M. Krol, E. Dlugokencky, B. Hall, P. Jöckel, J. Lelieveld

Fig. 1. Methane lifetime due to oxidation by tropospheric OH ($\tau_{CH_4 \times OH}$) simulated by each CTM (solid lines) and reconstructed from the 5-parameter model (dashed lines). The parameters are air temperature, water vapor, ozone column, lightning NOx emission, and biomass burning emission. Parameter values for each CTM are
Air Quality Extreme (AQX) events [red 1x1 cells], when identified as 97%ile form mega-episodes, => matched by global model hindcast.

TODAY bad years have:
(1) most AQX events
(2) largest AQX episodes
(3) highest mean O₃.

Will this get better or worse in future climate?

AerChemMIP:
Model surface O₃ extremes. Will they change with climate?

Measurements of surface AQ over US

Schnell ++, 2014 ACPD (current)
ACCMIP hourly surface $O_3$ diagnostics: Model tests with full EU/US surface sites
from J. Schnell et al 2014 ACP, UC Irvine
Taylor diagrams for surface AQ:

Summer (JJA) diurnal cycle

Winter (DJF) diurnal cycle

Seasonal cycle

AQ extreme events /month
Seasonal Cycle

W. N.Am.  

E. N.Am.  

Europe
ACCMIP model biases:

EU summer (JJA) 50th %ile

UCI CTM treated here as ‘climate’ model, but as a hindcast, it can look different!
Cumulative probability distribution of $O_3$ (MDA8, ppb) for the US in Summer (JJA)

**Observations binned** at every 5$^{th}$ percentile

**CTM-hindcast binned for exact-day** matches w/observations (concurrent)

**CTM-climate binned independently** of the observations
Historic Data For Anthropogenic Emissions

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AGCI

August, 2014
Historical Emissions for CMIP6

The community (funders + scientists) needs to make a choice

- Are MIPs idealized exercises to compare models?
  - If so, then any “reasonable” emissions can be used for the models since the key goal is to have the same inputs for all models

- However, if the model results are meant to be compared to observations, then emissions should:
  - Be a “best estimate” of actual emissions, 2) have consistent trends over time
  - Contain uncertainty estimates (otherwise, how do you compare with observational data?)

- If the model results are meant to be have some policy relevance for atmospheric chemistry
  - Then emissions should be based on country inventory data where those are judged (by the scientific community) to be adequate

This can be done, but it requires a dedicated effort.

- For CMIP5, we got lucky. By coincidence, several individuals were able to devote quite a lot of time, building off of current projects, to put together a historical dataset. That won’t happen this time.
What is “Plan B”

What can be done without a dedicated historical emissions effort for anthropogenic emissions in general

   - Grids not consistent over time.
   - Not most recent years.
   - Country level, emissions should be somewhat, consistent.
   - No seasonality.

2) Use EDGAR v4.3 (1970-2010) + RCP before 1970
   - Annual resolution from 1970 - 2010
   - Won’t contain the most recent years.
   - Consistent from 1970, but break to 1960.
   - Not consistent with country inventories (or RCP). Large differences with literature “best estimate” are possible.
   - No seasonality.

The historical land-use community also needs guidance on what is needed, and by when.
A Solution: Proposed Community Emissions Data System

Timely estimates for emissions of aerosol (BC, OC) and aerosol precursor compounds (SO$_2$, NO$_x$, NH$_3$, CH$_4$, CO, NMVOC) are key inputs for aerosol research and Earth System Models

_Needed for historical and future simulations, validation/comparisons with observations, historical attribution, uncertainty quantification, IAM calibration and validation, and economic/policy analysis._

Instead of this

Produced using an open-source data system to increase data transparency and facilitate research advancements.

Uncertainty essential if extended to more recent years.
A Solution

Have proposed the development of an open-source Community Emissions Data System

- Annual estimates of all chemically reactive species and CO$_2$ over the entire industrial era (as reference). Updated every year.
- Emissions estimated at level of country, sector/sub-sector, and fuel.
  - Have proposed greater spatial detail (state/province) for large countries
- Uncertainty estimated at the same level (Country, fuel, sector)
- Seasonal cycle (monthly)
- Aggregate NMVOCs by sector/sub-sector
- Annual updates up to latest full calendar year.
- Gridded emissions (0.1°) w/ sub-national resolution for large countries

Goals

- Consistent extrapolation over time (prevent spurious discontinuities)
- Community data review: aggregate (country, sector, ...) & gridded
- Facilitate cross-country comparison (EF consistency, trends)
- Transparent emission results (assumptions -> emissions)
CMIP6 Timing

New (higher resolution & seasonal) **pre-industrial** emissions could be made available by Spring 2015, if full project starts fall 2014.

A tested, gridded data set for the **industrial era** could be made available Spring 2016.

If substantial work could start relatively soon we could still get close to this timeline. Some (but not many) short-cuts may be possible.

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**A CMIP6 Deliverable Timeline**

- **1750-1850** Pre-industrial Anthro Emissions
- "Emissions Data Available" (Mehel et al. 2014)
- **1900-2014** Anthro Em (Test/Validation)
- **1900-2010** Anthro Emissions Data
- **2010-2015** Anthro Em (Cont Rel) + Future (?)

Red = Data Release
Tan = Testing/Validation Release

Have built in time for testing/validation.
ADDITIONAL SLIDES
System Diagram

Fuel consumption and other drivers
(1750 or 1850) - 20xx

Emissions Factors
or Emissions by fuel and sector
Key Years

Emissions inventory estimates where available

Default emissions by year, country, fuel, and sector

Emissions factor interpolation, extrapolation

Uncertainty Estimates

Final emissions by country, year, fuel, process, and sector

Other bottom-up estimates: (smelting, international shipping ...)

Spatial Proxy & Emissions Data

Emissions Gridding
Uncertainty Estimates

Overall Approach

All bottom-up emission uncertainty estimates contain a substantial element of expert judgment

- Guide assumptions with literature & comparisons between inventories
- Reduce dimensionality by a “tiered” approach to group assumptions
  
  Otherwise: ~10 sectors X 200+ countries X 5 fuels X ~10 emissions

- Consider correlations across sectors and countries
- Result: consistent uncertainty across emissions and regions

Uncertainty For Most Recent Years

It is critical that emissions for recent years are coupled with uncertainty estimates

- The additional uncertainty in the most recent years can be rigorously assessed by applying the extension methodologies to past data
  
  Although “past uncertainty does not guarantee future uncertainty”
Issues II

- Emissions gridding
  - Many gridding processes rely on proprietary data that cannot be released and that would be difficult for users to obtain.
  - Goal is for the community data system would produce gridded data
  - Produce only on basis of broad sectoral grids? (e.g. RCP sectors)
  - Globally consistent proxies (e.g., EDGAR) or use regionally detailed data (e.g. most recent HTAP)

- NMVOC speciation
  - Are there specific sectors that should be explicitly detailed in order to facilitate NMVOC speciation?
  - Perhaps the greater sectoral detail of EDGAR can be used where needed for sub-sector speciation detail?

- Special sectors/sub-sectors
  - Updates to shipping and aircraft emissions? Bricks? Others?

- Coordination with Open burning emissions
  - Temporal resolution (annual?). Speciation? Other?
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