A Multi-Model Study of (Aerosol) Sensitivity to Emission Characteristics

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Outline

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The National Aeronautics and Space Administration's Atmospheric Composition: Modeling and Analysis Program (ACMAP)

Background: Why Focus on Emission Data?

Model inter-comparison experiments have often used common datasets for anthropogenic (and natural) emissions of reactive and primary aerosol species.

Model results will be impacted by uncertainties in emission data, which means:

- Multi-model means may be biased
- Uncertainties, as measured by multi-model spread, are underestimated
- "Auxiliary" emissions characteristics will have unknown effects
  - Either no assumptions or default assumptions (such as AeroCom specifications) are often used for "auxiliary" characteristics such as seasonality, emission injection height, etc.

The importance of these factors has not been systematically quantified

- ***This means that we do not know where to focus emission inventory development efforts to better improve emissions data.***

We have proposed a multi-model comparison study to quantify the impact of uncertain emission characteristics.

Background: Emission Data Uncertainties

Emission Data have a number of uncertainties. In addition to global annual emission rates and long-term trends:

- **Emission Rate Uncertainties in specific regions and times**
  - Mid-20th century SO_2 emissions in N America/Europe
- **Temporal Distribution: Seasonality, Diurnal & Weekly Patterns**
  - Impacts aerosol formation and transport, chemical reaction rates
- **Injection Height and Characteristics**
  - Effective Injection Height = stack height + plume rise (v, T, W)
  - Plume processing (e.g. fraction of SO_2 injected as SO_4)
- **Spatial Distribution (and changes over time)**
  - Shifts within US emissions over 20th century (China, Canada, Russia?)
  - Atlantic vs Pacific distribution of 20th century International Shipping SO_2

- Some of this information is in regional datasets, but requires work to incorporate into long-term global data.
- Other uncertainties could be substantially reduced, but also requires effort

Motivation: Anthropogenic Differences CMIP6 vs CMIP5 Emissions

Some CMIP6 modelers have reported that their historical simulation results are different using the latest emissions as compared to the data used in CMIP5.

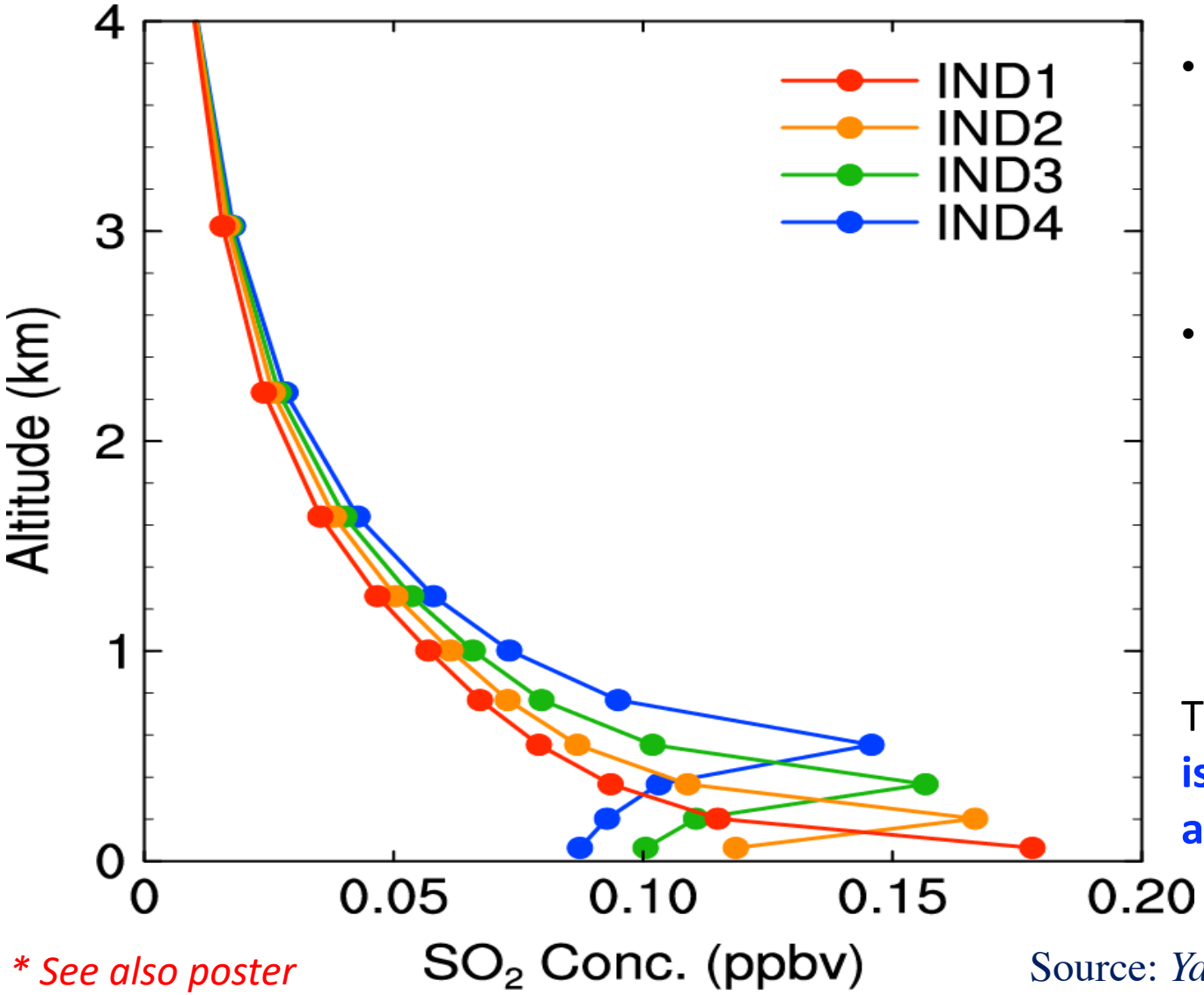
Differences/New Features in Hoesly et al (2018) CEDS data used in CMIP6

- **Seasonality for all emissions**
  - All emissions now have seasonality.
- **Annual instead of decadal values**
  - Will make some difference in periods of large inter-annual variability.
- **Different spatial proxies were used**
  - Gridded country profiles (mostly from EDGAR) applied by gridding sector
  - Western US SO_2 emissions are too high in all years (~12% of USA em)
- **There are regional differences (even if similar global trends)**
  - Time trend and spatial distribution of shipping emissions are different

We do not know which of these factors might be important

Motivation: Injection Height Sensitivity

Vertical Profile of SO2 Concentration over Land for Injection Into Model Layers 1-4



- Emission height has a large influence on SO_2 vertical profile in CESM (Yang et al. 2018, in revision).
- These differences will impact model evaluation when comparing with observations (either surface or satellite)

This raises the question: **is this sensitivity similar across models?**

** See also poster*

Source: *Yang et al. 2018, in revision*

Proposed Project Structure

Phase 1

Suite of ~decadal length, atmosphere-only (proscribed ocean and sea-ice) model runs

- Should include CTMs as well as atmospheric components of GCMs

First order evaluation of inter-model differences, and magnitude of effects on radiative forcing and concentrations

Phase 2

Ensembles of fully coupled model experiments over longer periods (20-50 years) to test sensitivity in the interactive system.

- Aim to branch from CMIP6 DECK/historical runs

Data Logistics

- Use CMIP6 input and output data format specifications
- Public data and protocols to allow for replication and extension

Proposed Experiments: Phase 1

Initial Proposed Suite of Phase 1 Sensitivity Experiments

Property	Reference State	Contrast Case
SO_2 Emission Height	Surface Emissions	Emissions at a specified height
SO_2 Seasonality	CMIP6 (CEDS) seasonality	No seasonality
BC Seasonality	CMIP6 (CEDS) seasonality	No seasonality
International Ship SO_2 Emission - 1950	CMIP6 distribution	CMIP5 distribution
International Ship SO_2 Emission - 1920	CMIP6 distribution	CMIP5 distribution
% SO_2 emitted as SO_4	x% as SO_4	0%, 2%, 4%, 8% as SO_4
Regional SO_2 Emissions Sensitivity	Latest Europe and N American CEDS 1950s emissions	Emissions adjusted up or down by max estimated uncertainty

Others?

Project Status

- ***Proposal is in review***
  - *Timing: Hoping to start early 2019*
- PNNL (and GISS) taking lead for data analysis
- A number of modeling groups have committed in principle to participate: PNNL (E3SM), GISS, GFDL, NCAR and HadGEM-UKCA.
- **Call For Participation. Additional groups welcome.**
  - CTMs can participate in phase 1
  - Having a variety of models would add to the value of the results
- **Open design.**
  - Participating groups could propose additional sensitivity tests (if they commit to analyzing output, and enough models agree to do runs)
  - The initially proposed tests focus on aerosols, but there are atmospheric chemistry-focused questions that could benefit from similar set of sensitivity experiments.

END