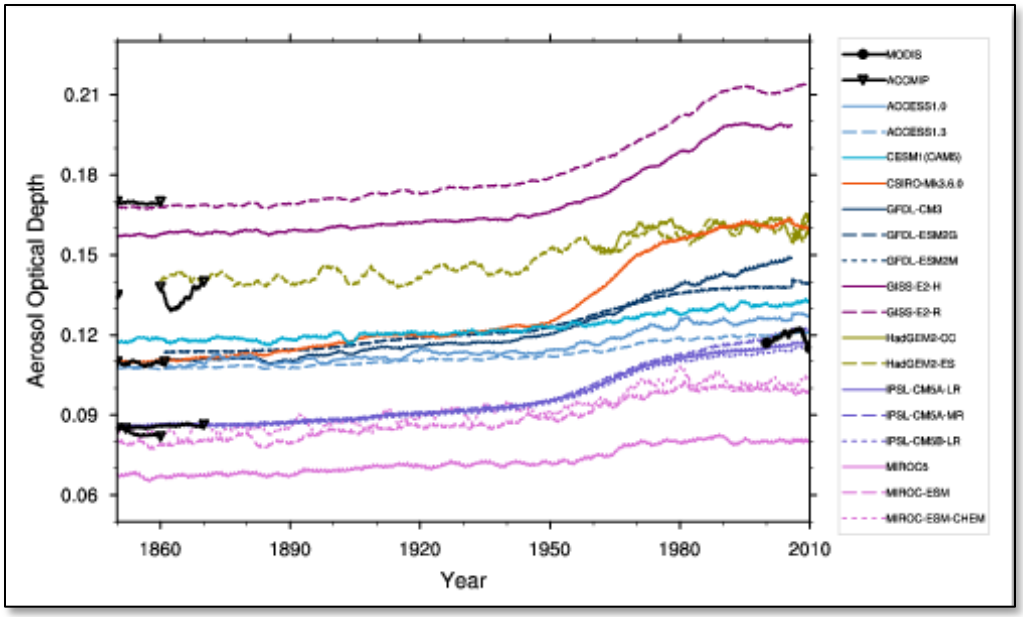
Diagnostics from the Radiative Forcing Model Intercomparison Project

13th International AeroCom Workshop

October 2, 2014

Daniel Feldman, Robert Pincus, Bill Collins,
V. Ramaswamy, David Paynter, Eli Mlawer, Piers Forster

Present-Day Aerosol Optical Depth



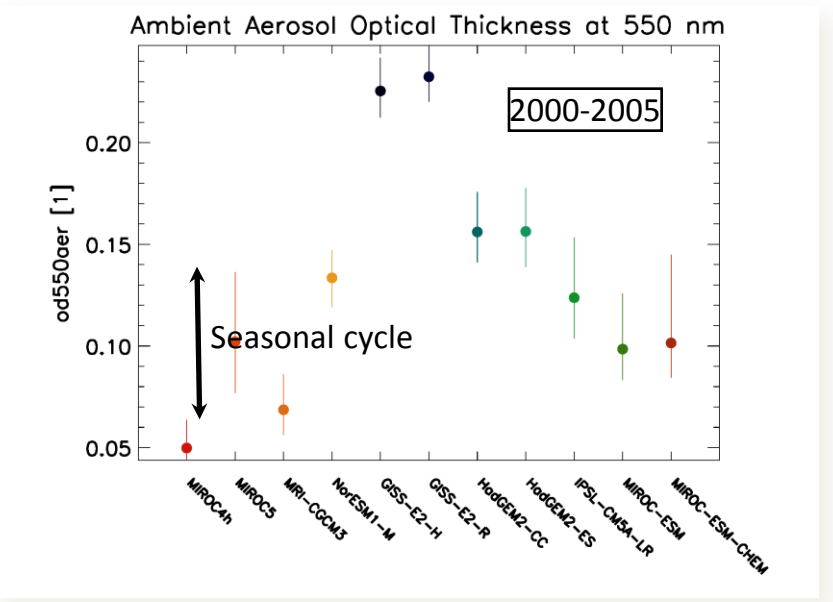
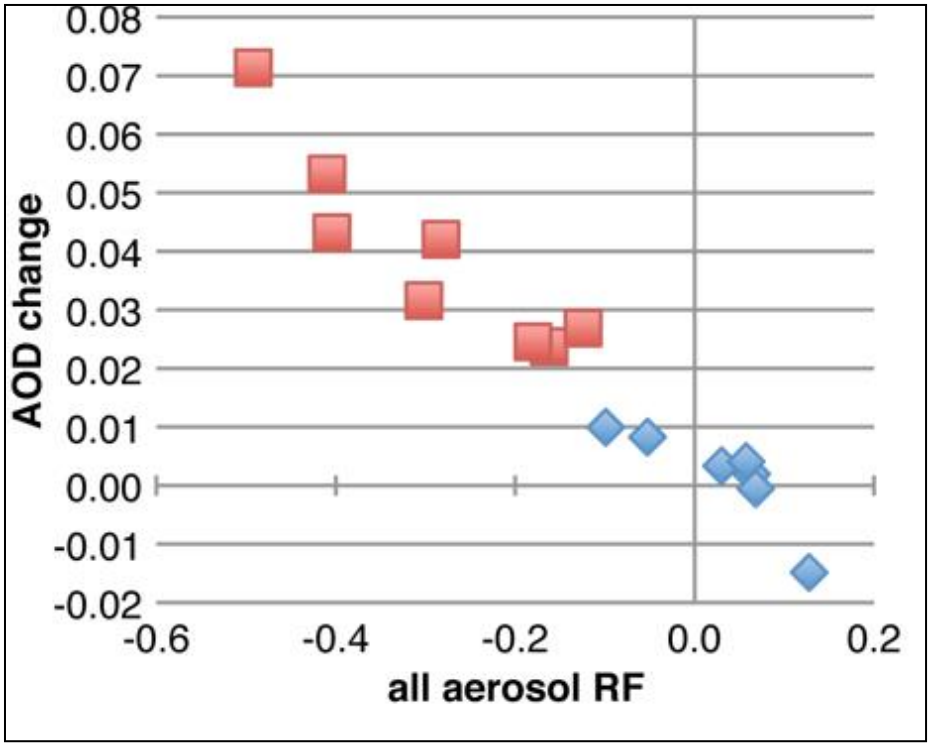


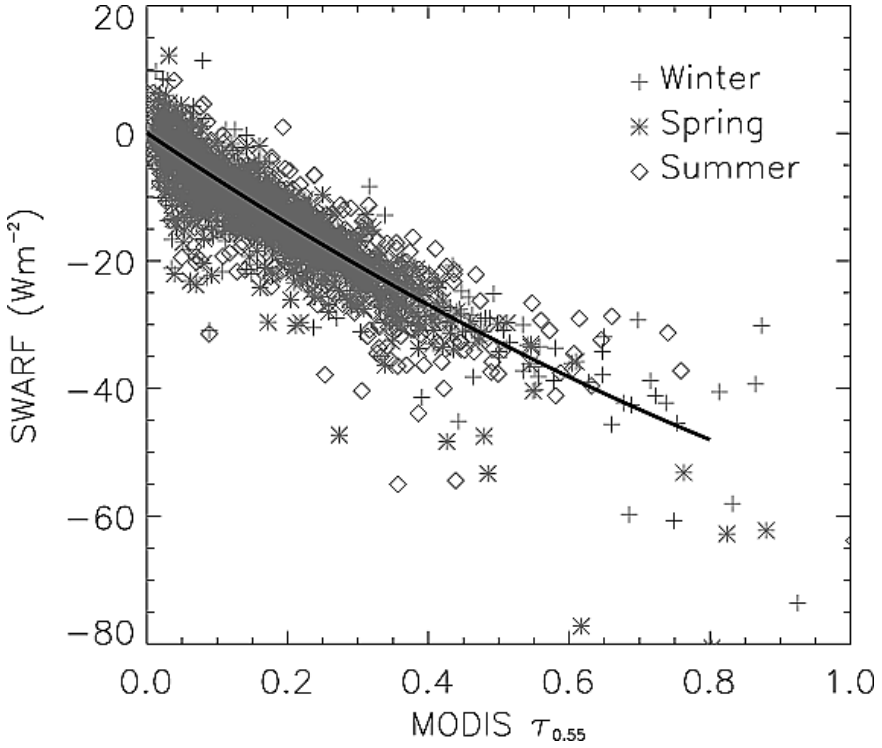
Fig. 9.29, AR5, 2013

- AOD for all species has differed since start of simulations in 1850.
- Historical and Present-Day AODs vary across ensemble by factor of >4.

Diversity of AOD

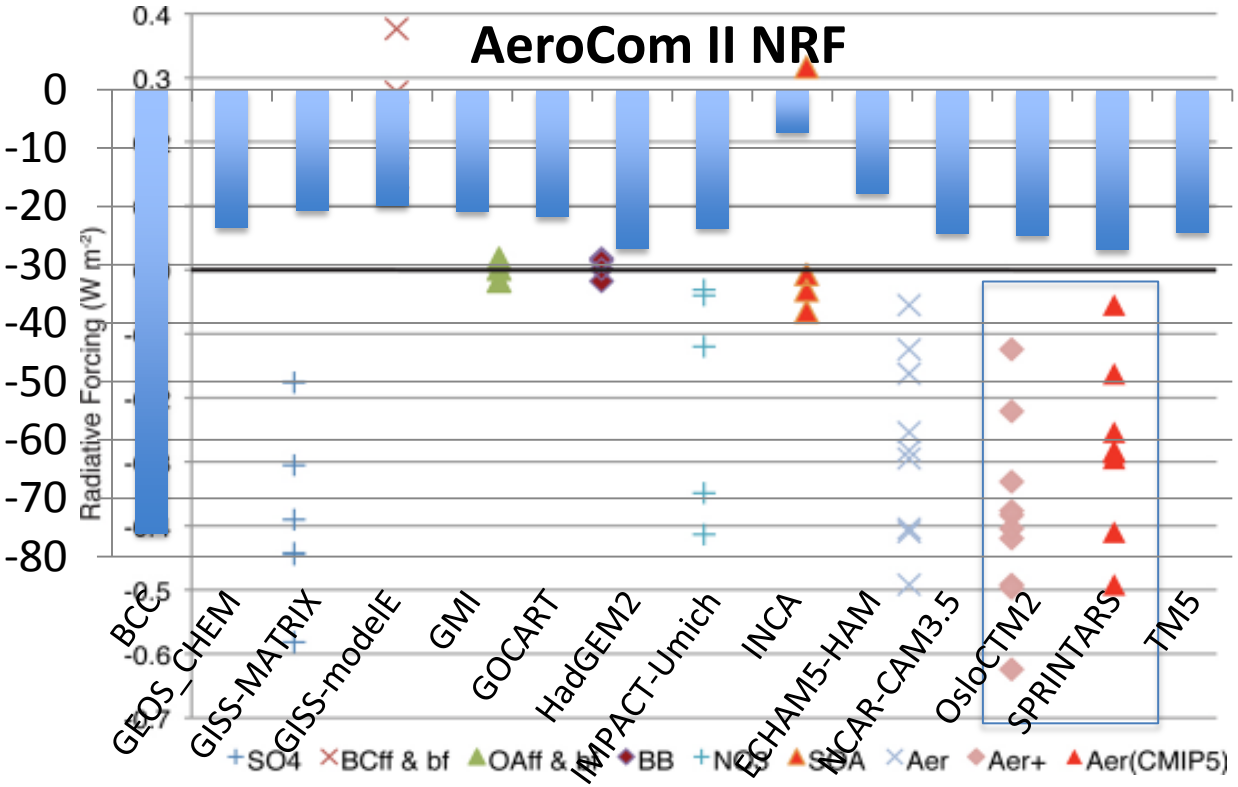


Shindell et al 2013



Zhang et al, 2005

Range in Aerosol DRF



Shindell et al 2013

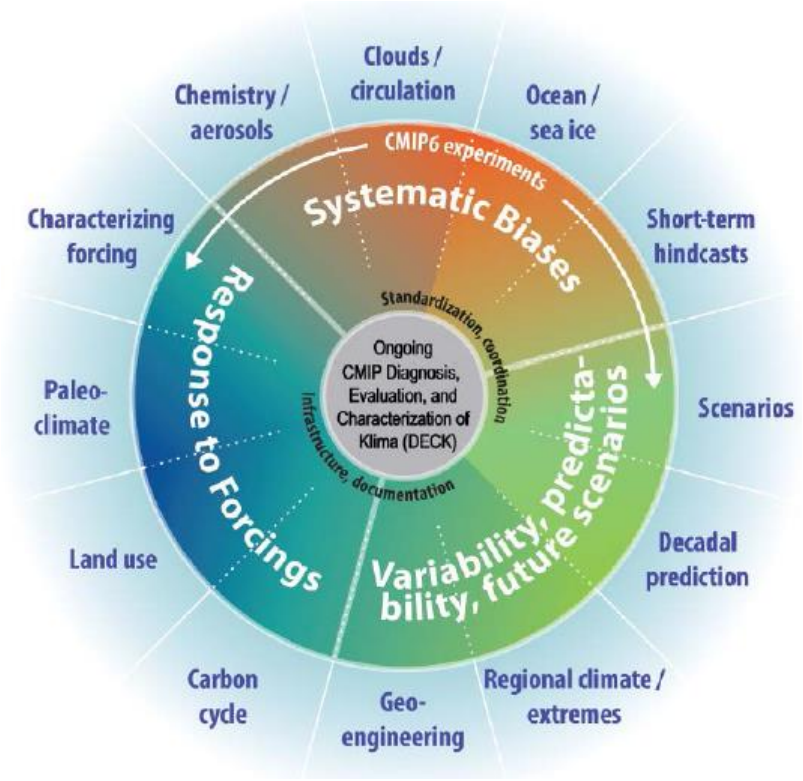
- Small forcing exhibited by models relative to AOD change PD-PI, both total and broken down by species.
- However, the results of AeroCom II indicate some members exhibit normalized radiative forcing values that are consistent with obs.

Open Questions on Aerosol DRF

- The results from CMIP5 are puzzling with respect to radiative forcing, particularly from aerosols.
- How are the large ranges in AOD and Δ(AOD), consistent with the small range in DRF required to match the historical record?
  - What led to 4x range in AOD in historical simulations (Shindell et al, ACP 2013)?
  - Range in direct forcing is about 0.5 W/m^2 --- much smaller than should occur with range in AOD if we are considering mostly conservatively scattering aerosols.

Background on RFMIP

- The CMIP5 experimental design sought to compare model response to prescribed forcings.
- RFMIP, funded through DOE's SciDAC/RGCM, aims to diagnose and quantify potentially-variable contributions to CMIP RF terms.
- Three components:
  - Characterize GHG RF for a range of atmospheric thermodynamic states.
  - Diagnose model discrepancies in burdens, AOD, and aerosol RF.
  - Characterize model differences in effective RF.

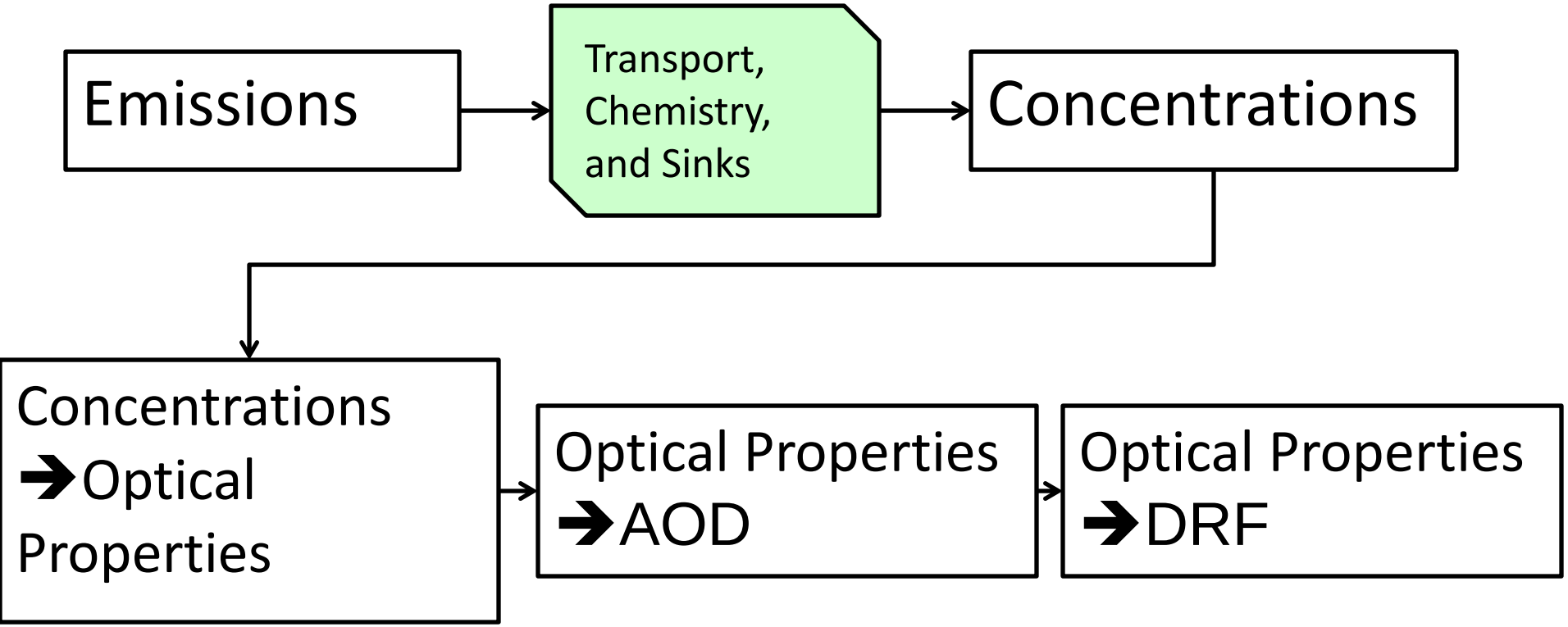


Meehl et al, 2014

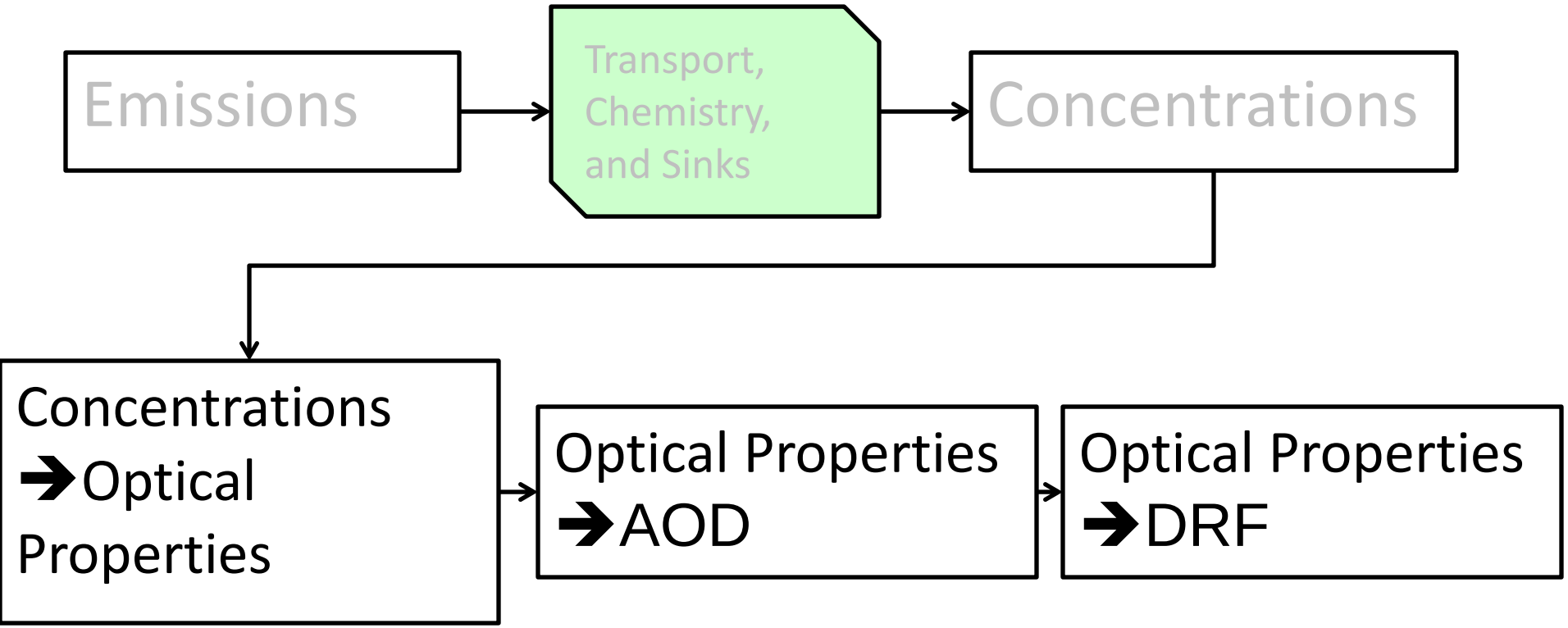
Goals of Our RFMIP Activity

- Determine the relationships among AOD and other aerosol optical properties and DRF for the CMIP6 models
- Determine whether the diversity in the relationships explains the small range in DRF despite the large range in Δ(AOD).
- Determine whether the relationships between burdens, optics, and forcing exhibited by CMIP6 are correct, using a benchmark model.

Aerosol Uncertainties addressed (and omitted) by RFMIP

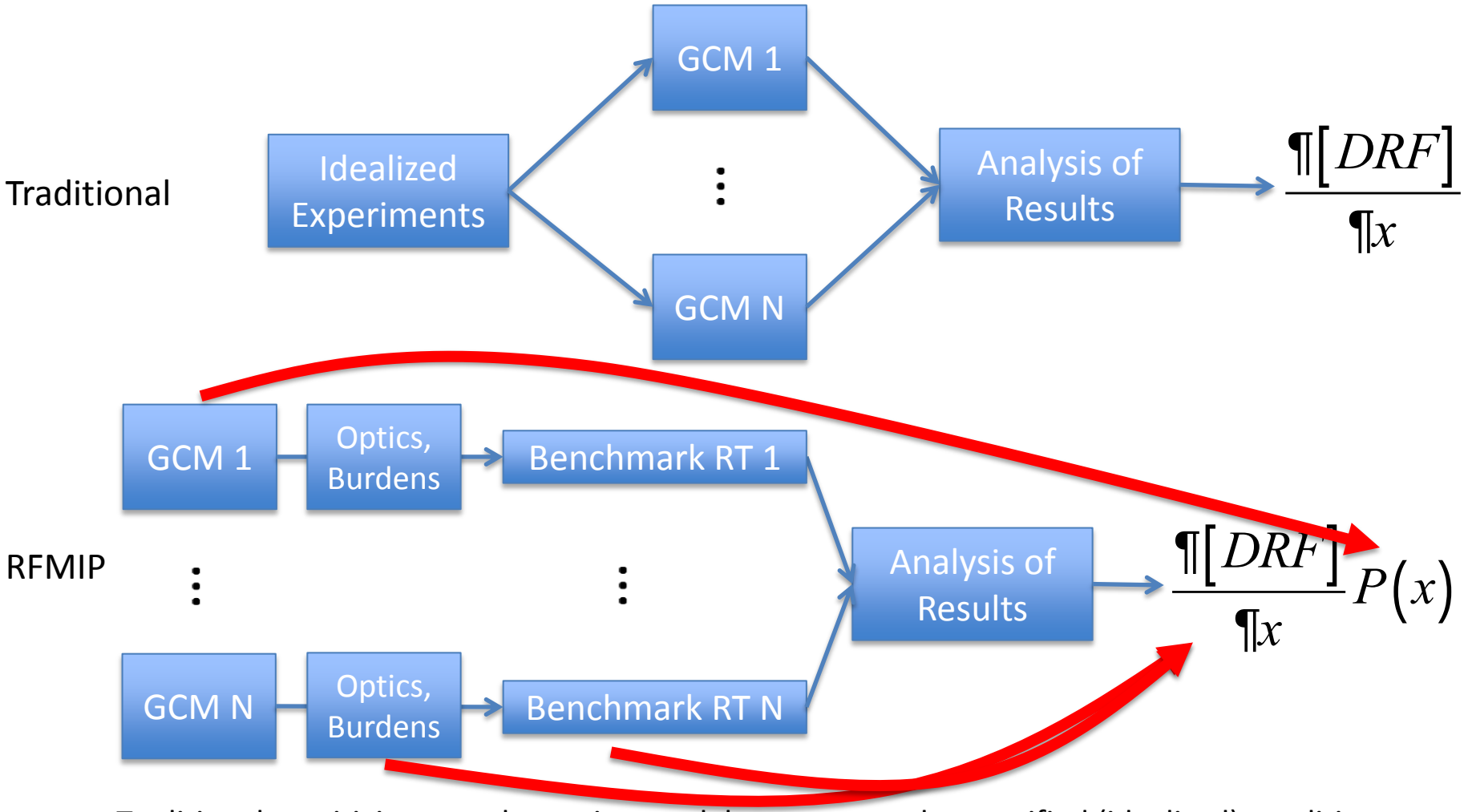


Aerosol Uncertainties addressed (and omitted) by RFMIP



RFMIP does not aim to diagnose indirect effects.
RFMIP does not plan to consider all-sky aerosol RF.

Diagram of experimental design



- Traditional sensitivity tests determine model response under specified (idealized) conditions.
- By comparing models as they are implemented, we aim to establish both model sensitivity factors that affect aerosol DRF and the weights that models assign these factors.

Benchmark Calculations

- Line-by-line RT is essential for radiometric accuracy in translating aerosol burdens and optics into DRF.
  - Critical for overlap between H_2O NIR bands and hygroscopic particles.
- Computational expense is offset by NOAA and DOE computational resources and trivial parallelizability of RT.
- In Phase 1, we will sample the parameter-space of the requested data for consistency between each model's aerosol RF and benchmark results.
- Phase 2 will compare spatial patterns of DRF from model and benchmark for CESM and CM3.

Outcome of RFMIP (what we would learn)

- Evaluation of each model's accuracy in its native translation from aerosol burdens and optics to DRF.
- Sensitivities, probabilities, and spatial patterns of the relationships between burdens, optics, and DRF.
- The formulation of a complete clear-sky error budget from CMIP5 for aerosol RF.
- An explanation of the AOD/RF mystery in CMIP5 and a path for a resolution in CMIP6.

Request to the Centers

- We aim to minimize the barrier to entry for each modeling center.
  - No new experiments will be requested.
- We will request the following for pre-industrial and present-day conditions, at each model grid-point for a single, equinoctal day:
  - Aerosol optical properties.
  - Background atmospheric state.
  - Radiative surface and top-of-atmosphere boundary conditions.
  - Clear-sky model fluxes with and without aerosols.
- The request will enable us to have radiative closure between aerosol optical properties and DRF.

RFMIP-AEROCOM Collaboration

- Requests to the modeling centers must be minimized, so requests from RFMIP and AEROCOM should be coordinated.
- We wish to solicit feedback on the data request that ensures the broadest participation to solve the AOD/RF mystery.
- Ongoing discussions beginning at WCRP have suggested the need for a working group.