Radiative Impacts of Aerosol & Greenhouse Gases

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Introduction

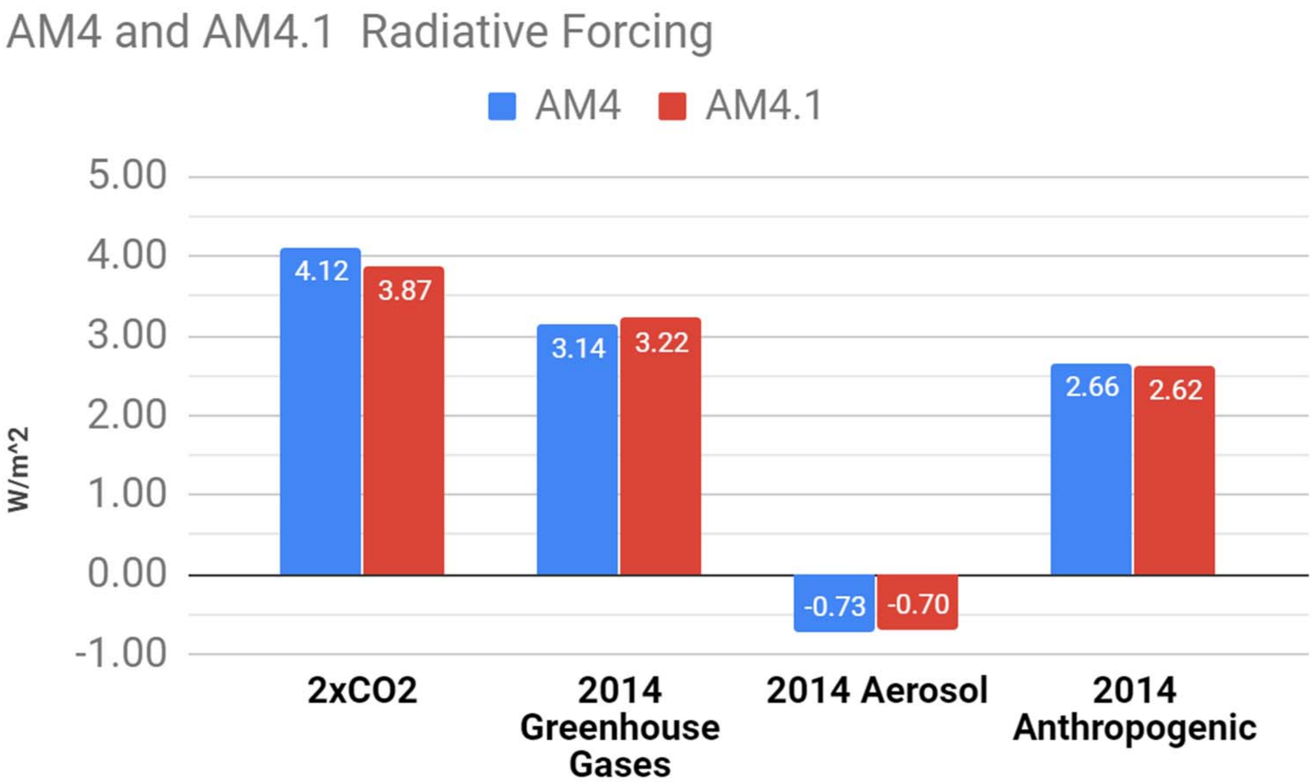
Scope:

Using GFDL radiative transfer codes to better quantify and understand models and observations

- Evaluating the Effective Radiative Forcing in GFDL AM4.0 and AM4.1 with RFMIP experiments and estimating the radiative contribution from fast adjustments
- Recent trends in the clear-sky greenhouse effect in models and observations (*Raghuraman et al.* 2019**)**
- How radiative feedbacks are altered by evolving SST patterns in GFDL ESM2M,CM3 and CM4 (Paynter et al. 2018)
- Model and observed trends in clear-sky aerosol radiative effect (Paulot et al. 2018)
- Similarities and differences in the feedbacks, heat uptake and temperature change due to aerosol and greenhouse gas forcing (Paynter et al. 2015,Persad et al. 2018)
- Improving the longwave and shortwave radiative transfer for the GFDL AM4.0/4.1 radiation code (Zhao et al. 2018)
- Providing benchmark calculations for RFMIP-IRF with a new GPU based line-by-line radiation code.
- The accuracy of aerosol radiative transfer calculations in CMIP GCMS (Jones et al. 2018)

Radiative Forcing of GFDL AM4.0 & AM 4.1

GFDL is partaking in the Radiative Forcing Model Intercomparison Project (**RFMIP**).
This includes a series of experiments designed to quantify the present-day Effective Radiative Forcing (ERF).



Despite the different chemistry schemes, overall AM4.0 and AM4.1 have similar radiative forcing values in 2014.

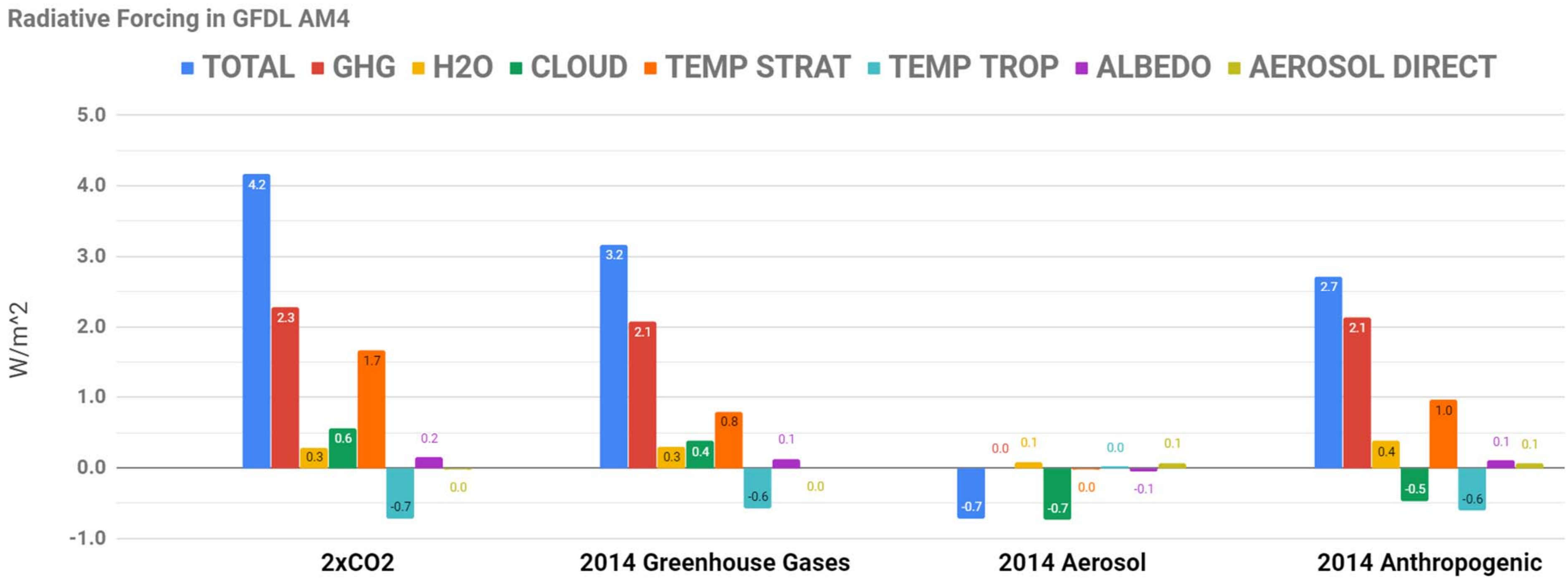
AM4.0 has a stronger 2xCO_2 forcing. This is due to reduced stratospheric cooling because of interactive ozone. This accounts for ~0.3 K of the difference in ECS between ESM4 and CM4.

Notes: 2xCO2 scaled from actual 4xCO2 run
2014 anthropogenic excludes land-use

D. Paynter, R. Menzel, A. Jones, S. Freidenreich M.D. Schwarzkopf, P. Lin, V.Ramaswamy,

Drivers of Radiative Forcing in AM4.0

- Partial Radiative Perturbation (PRP) method allows for a detailed understanding of the drivers behind the ERF values. It also provides more accurate estimates than radiative kernels.
- The PRP method works by running a **full offline version of the GFDL radiation code** and perturbing one physical variable at a time.



- The direct radiative forcing due to greenhouse gases (red bar) only accounts for half to two-thirds the total forcing (blue bar) in the case of 2xCO2 and 2014 Greenhouse Gases.
- For 2014 aerosol forcing, almost all change comes from cloud, with a near zero aerosol direct effect.

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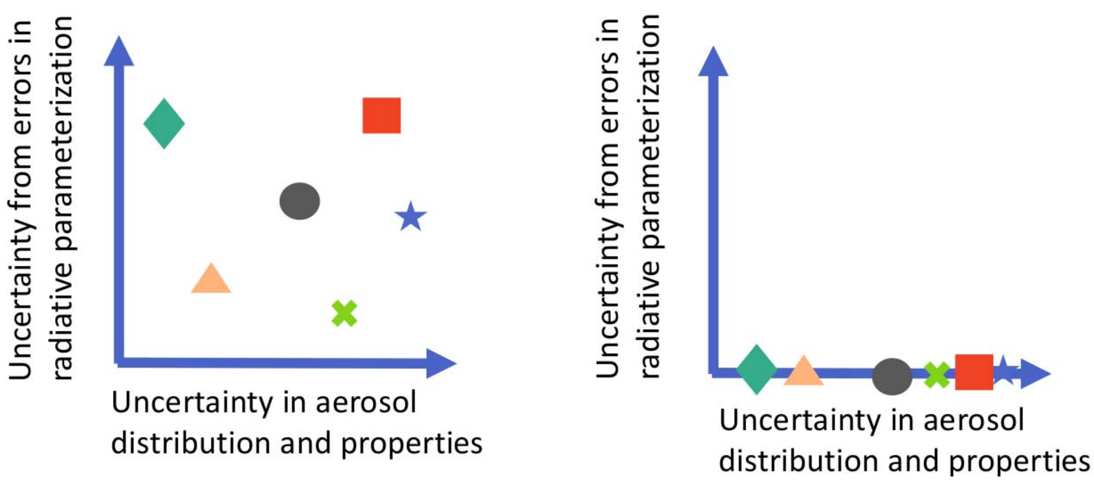
Constraining Clear-Sky Aerosol IRE

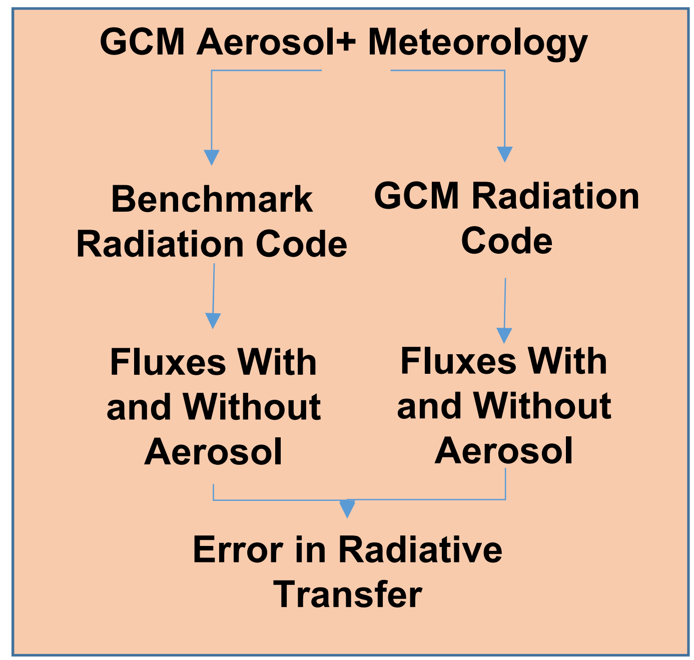
What causes the spread in clear-sky Aerosol Instantaneous Radiative Effect (IRE) Across GCMs?

1) **Different aerosol burdens and optical properties**
2) **Different radiative transfer codes**

Schematic of multi-model spread in IRE



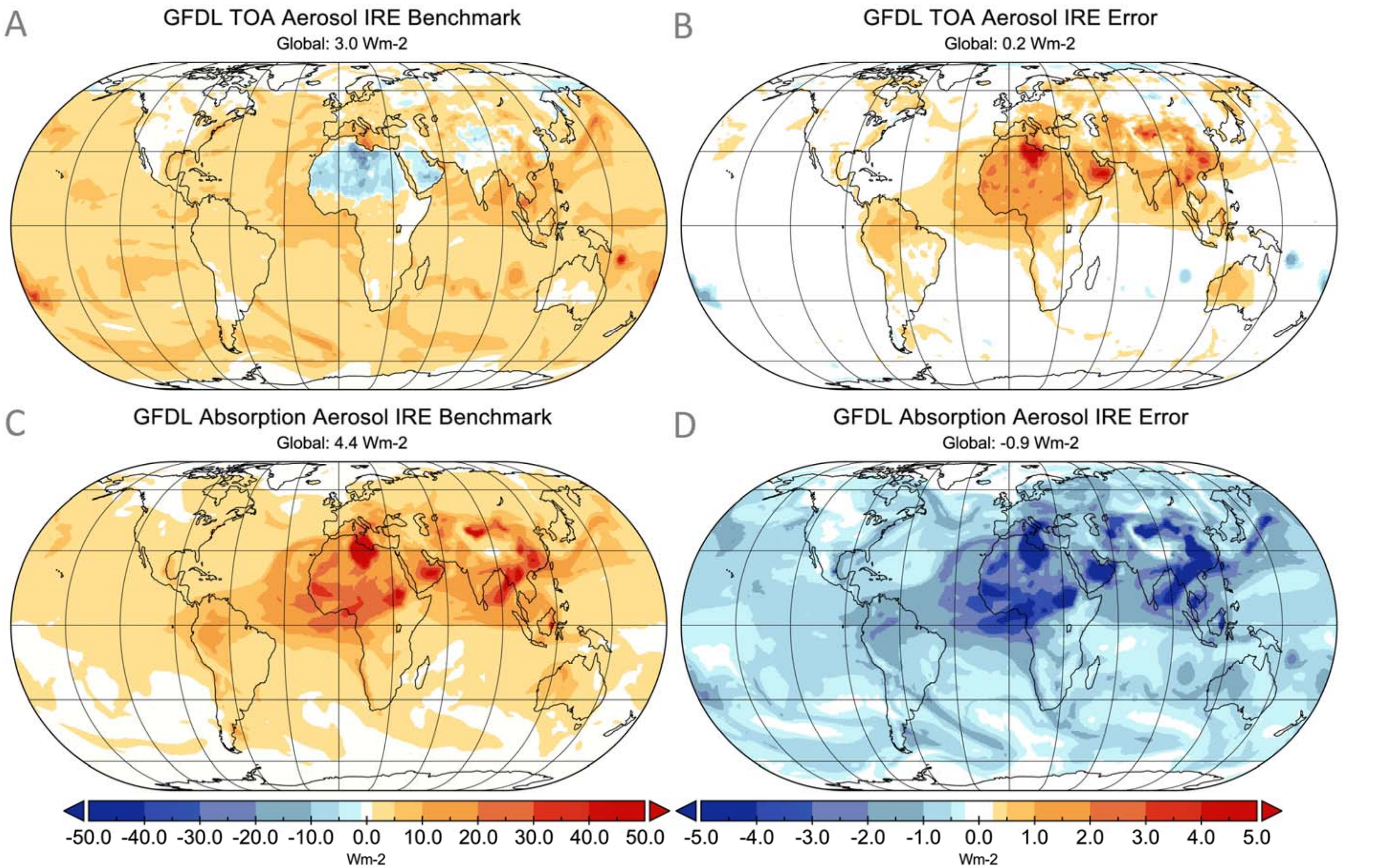
RFMIP-IRE Aerosol Protocol



- Can reduce 2) by running the same **benchmark radiation code on each GCMs native aerosol.**
- Developed a unique HPC Benchmark line-by-line doubling and adding radiation code at GFDL that can run at the **native resolution of a GCM.**
- Code is **~10,000 times more expensive than a GCM radiation code**, but can run for a single day.

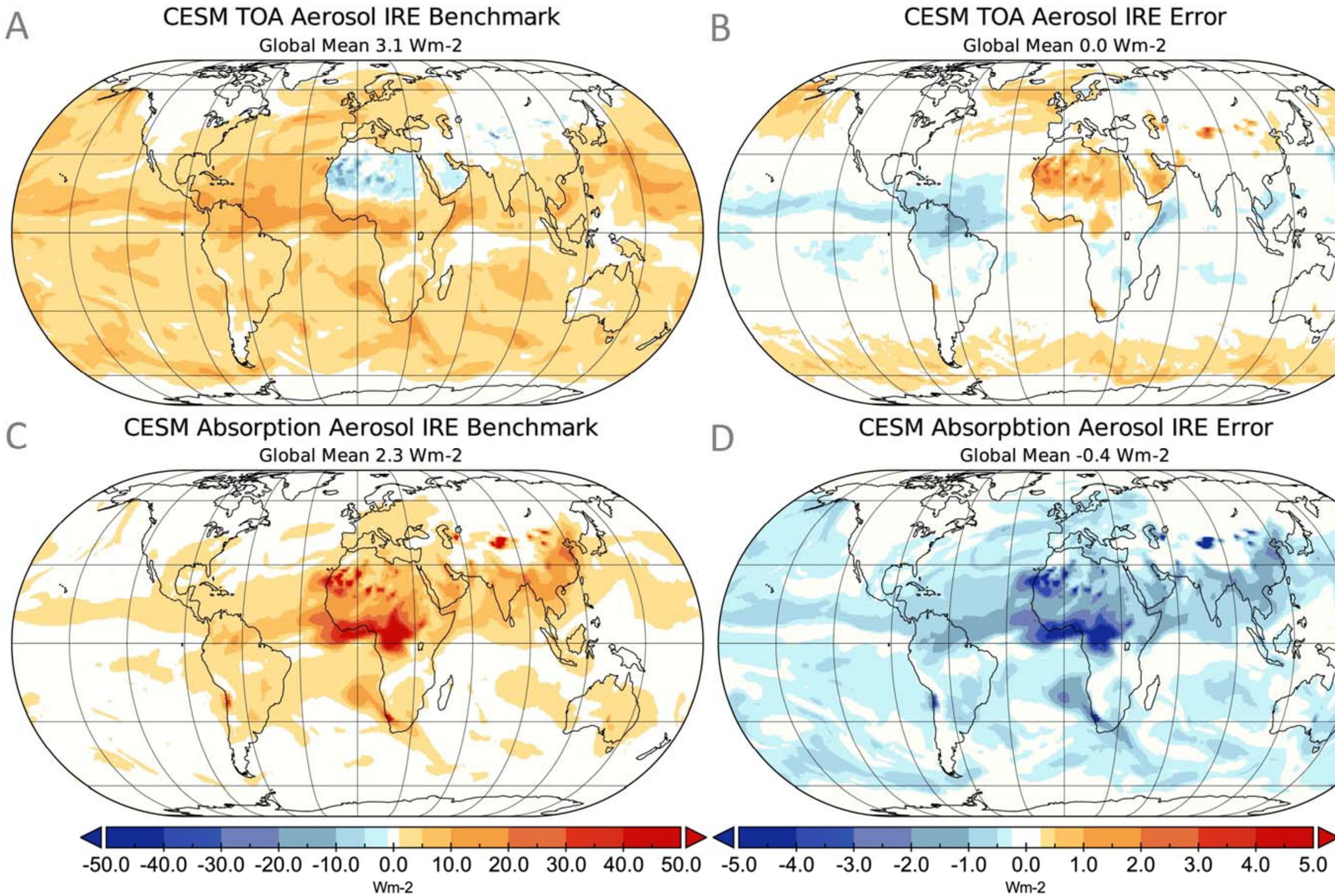
RFMIP-IRE Aerosol data request will allow us to perform these benchmark calculations on CMIP6 models.

RFMIP-IRE Aerosol –GFDL model



Jones et al. 2018

RFMIP-IRE Aerosol –CESM model



Summary and future work

- Effective Radiative Forcing (ERF) in 2014 is similar between AM4.0 and AM4.1, with WMGHG contributing 3.1 Wm^{-2} and aerosol -0.7 Wm^{-2}.

  Future work: Analyze the 1850-2100 forcing time-series for both models and compare to other CMIP6 models

- Applying PRP method to the AM4.0 ERF runs demonstrates the importance of fast adjustments. However, cancellation between adjustments, mean that the instantaneous WMGHG forcing accounts for 80% total 2014 ERF anthropogenic forcing.

  Future work: Perform a similar analysis on AM4.1.

- Benchmark HPC radiation codes developed at GFDL allow for a detailed understanding of radiative transfer errors in GCMs. This aided our AM4 model development.

  Future work: Places codes to run ‘online’ within the GCM.

- Running HPC Benchmark code on a GCMs own aerosol allows for an in-depth understanding of the radiative transfer errors unique to that model. It was demonstrated that both the CESM and GFDL GCM radiation codes underestimate atmospheric absorption by aerosol.

  Future work: Apply protocol to all CMIP6 models partaking in RFMIP Aerosol-IRF