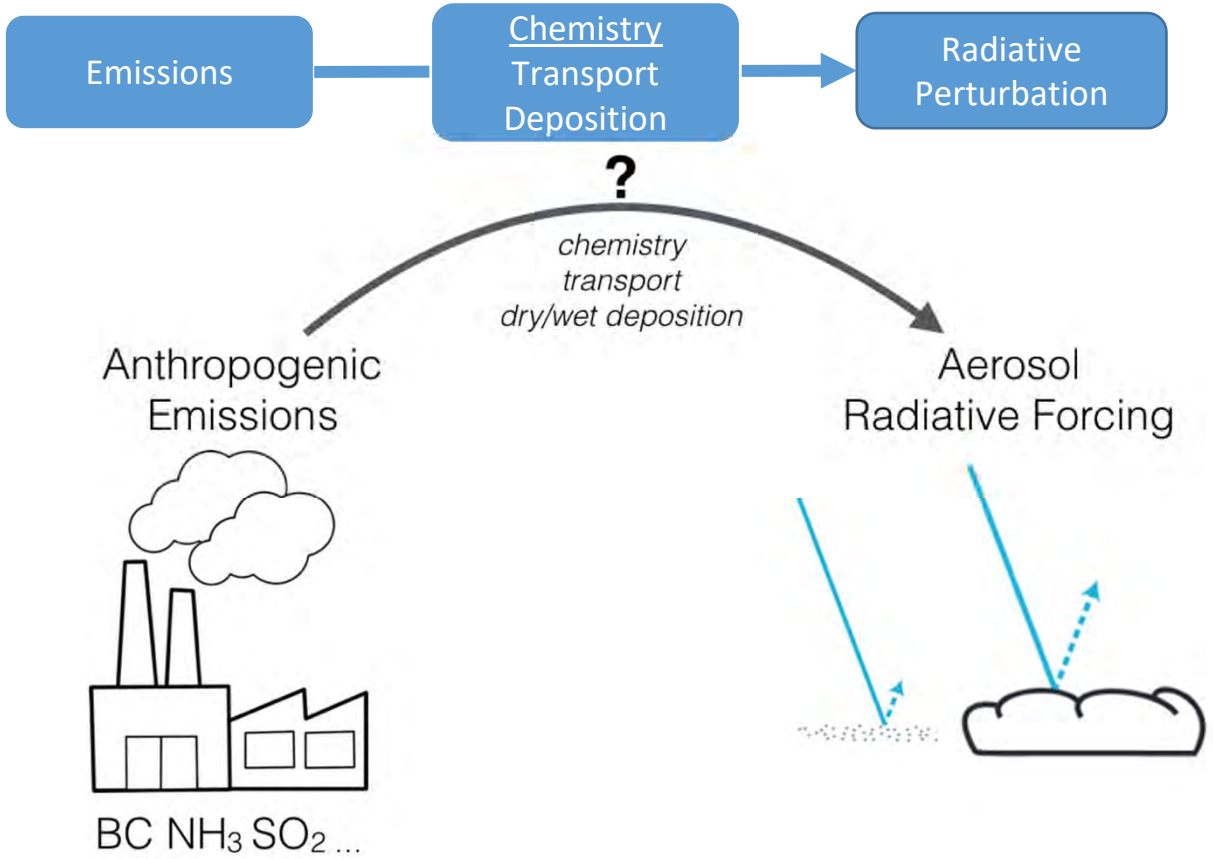
Chemistry Climate Interactions

aulot

Laboratory Review

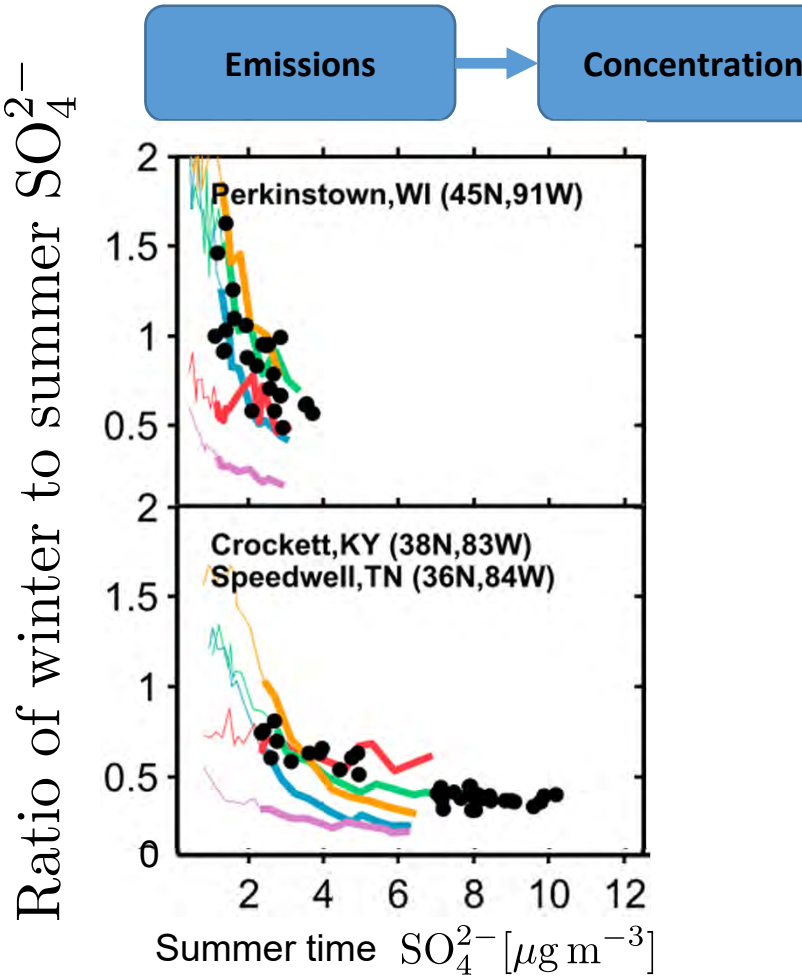
2019

Going from emissions to climate impact: a chemical detour



- Leverage long-term observations to constrain relationship between emissions and concentration/radiative effects
- Develop chemical mechanisms that can provide robust estimates under a wide range of emission conditions

Observed non-linearity in the response of sulfate



Observations

Base + Transition Metals

Dynamic cloud pH

Base model - seasonal NH_3 emissions

Constant cloud pH

Base model with PI NH_3

- SO_2 emissions have decreased by ~70% in the last 30 years. Long-term observations of sulfate in the US show **faster decrease in summer than in winter**
- **Mechanism**

↓ SO_2 ≈ oxidants ↑ oxidation

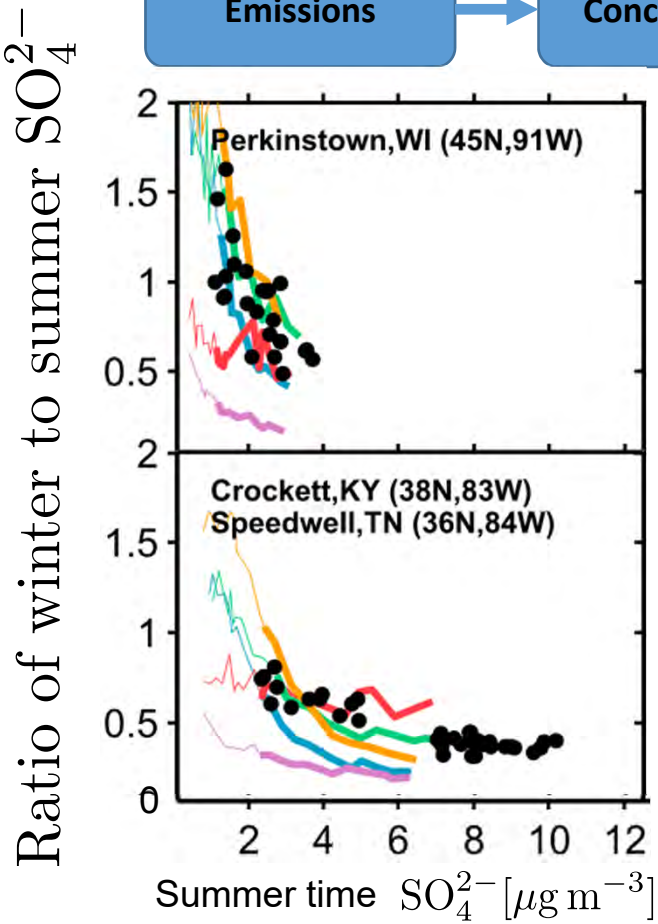
↓ SO_2 ↑ cloud pH ↑↑ oxidation by ozone

most important under low oxidant levels (winter)

Paulot et al. (GRL, 2017)

Observed non-linearity in the response of sulfate

Emissions → Concentration → Radiative Perturbation → Climate



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- **Mechanism**

  ↓ **SO_2** ≈ **oxidants** ↑ **oxidation**

  ↓ **SO_2** ↑ **cloud pH** ↑↑ **oxidation by ozone**

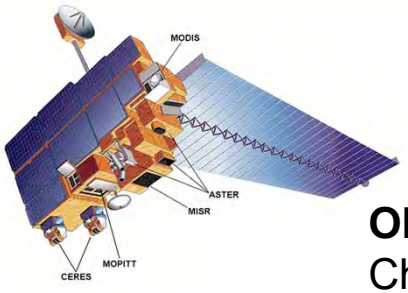
  most important under low oxidant levels (winter)
- **Implications**

  A) high sensitivity to NH_3 emissions

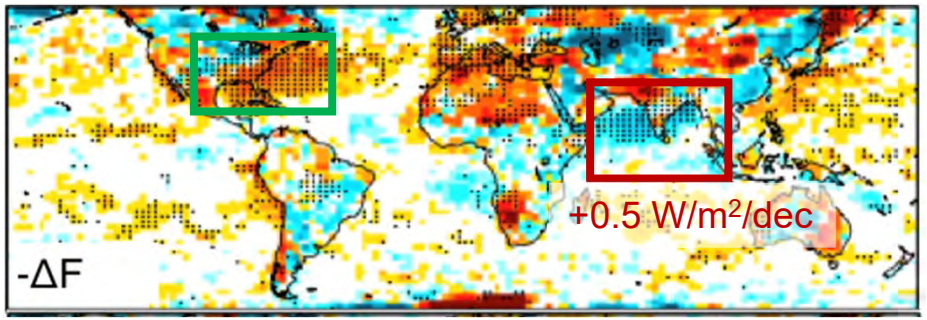
  B) SO_4 forcing does not follow SO_2 emissions

Paulot et al. (GRL, 2017)

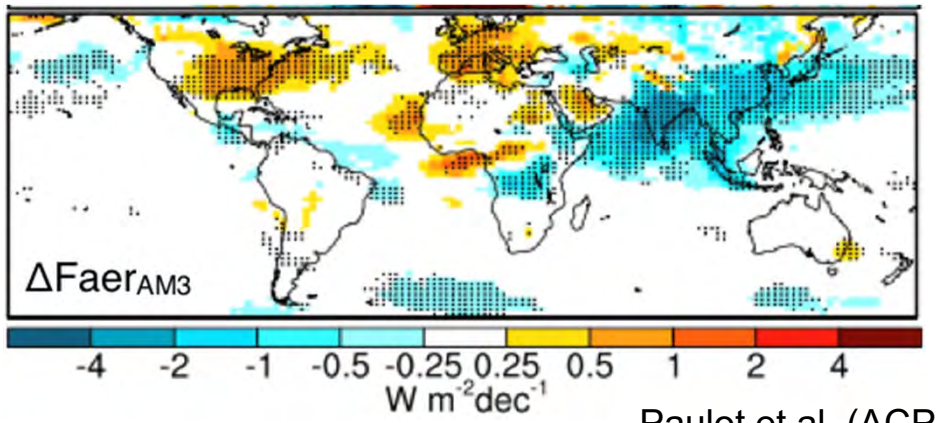
Extracting changes in aerosol effect from CERES



Observation (CERES)
Change in outgoing clear-sky SW radiation (2001-2015)

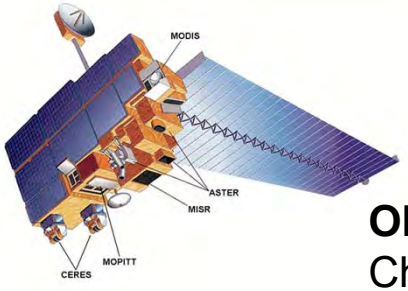


Simulated change in aerosol effect (AM3)



Paulot et al. (ACP, 2018)

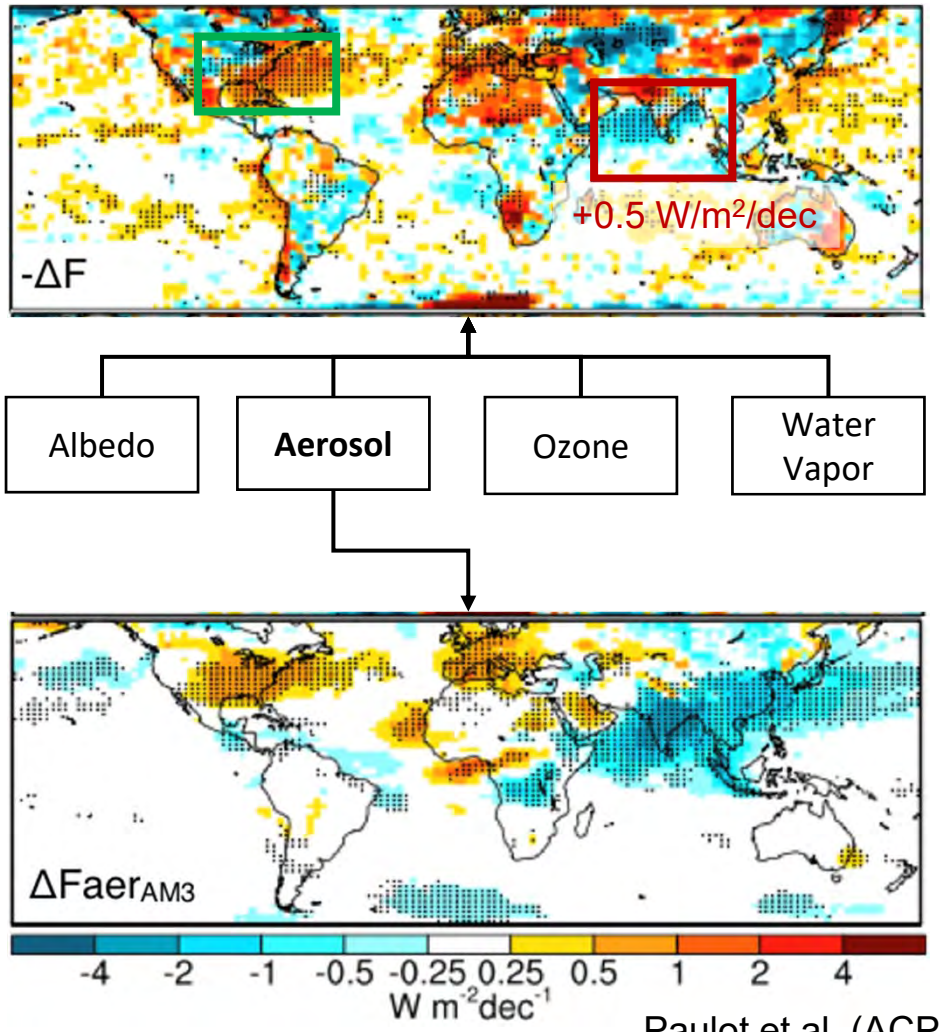
Extracting changes in aerosol effect from CERES



Observation (CERES)
Change in outgoing clear-sky SW radiation (2001-2015)

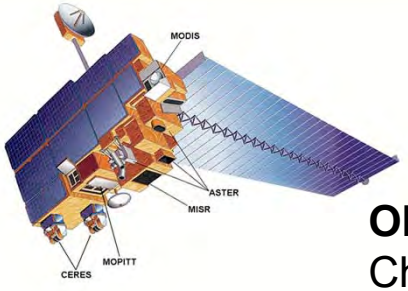
Use **RTM** to correct for changes in albedo, water vapor, and ozone

Simulated change in aerosol effect (AM3)



Paulot et al. (ACP, 2018)

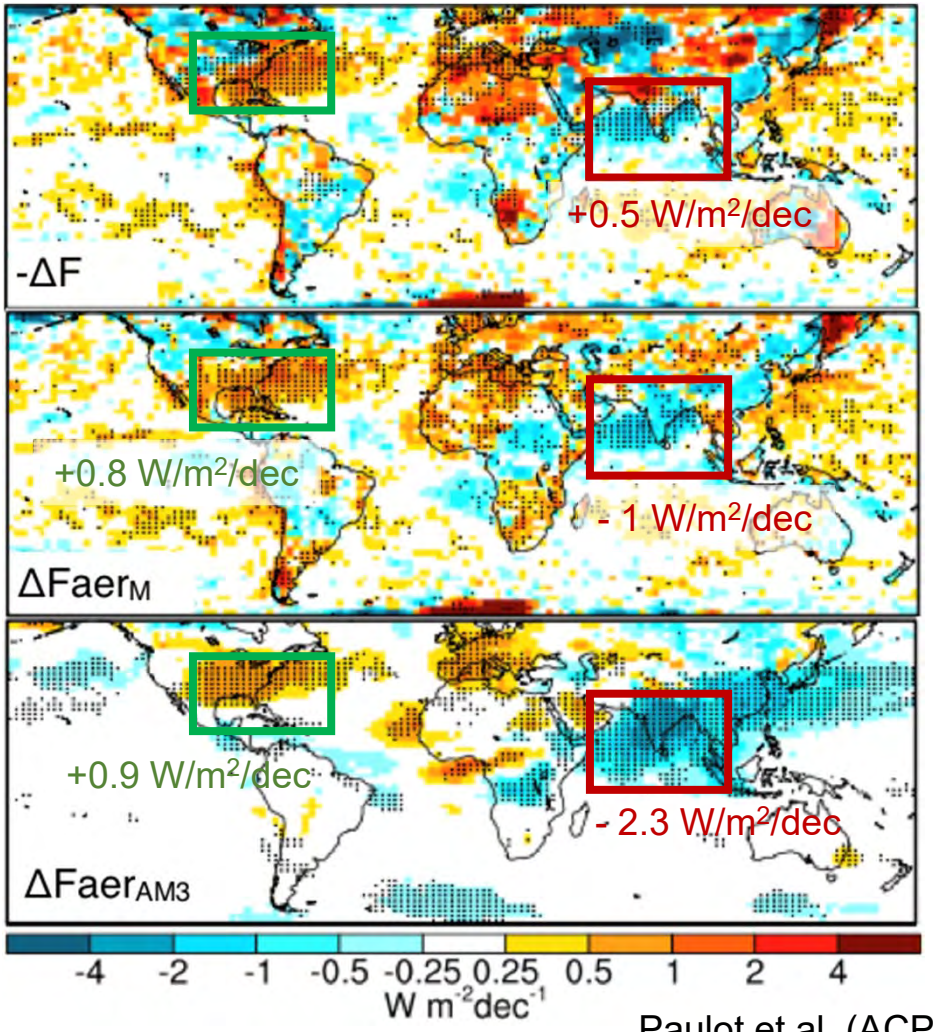
Regional constraints on changes in the aerosol effect



Observation (CERES)
Change in outgoing clear-sky SW radiation (2001-2015)

Estimated change in aerosol effect
observation corrected for albedo, water vapor, and ozone using RTM

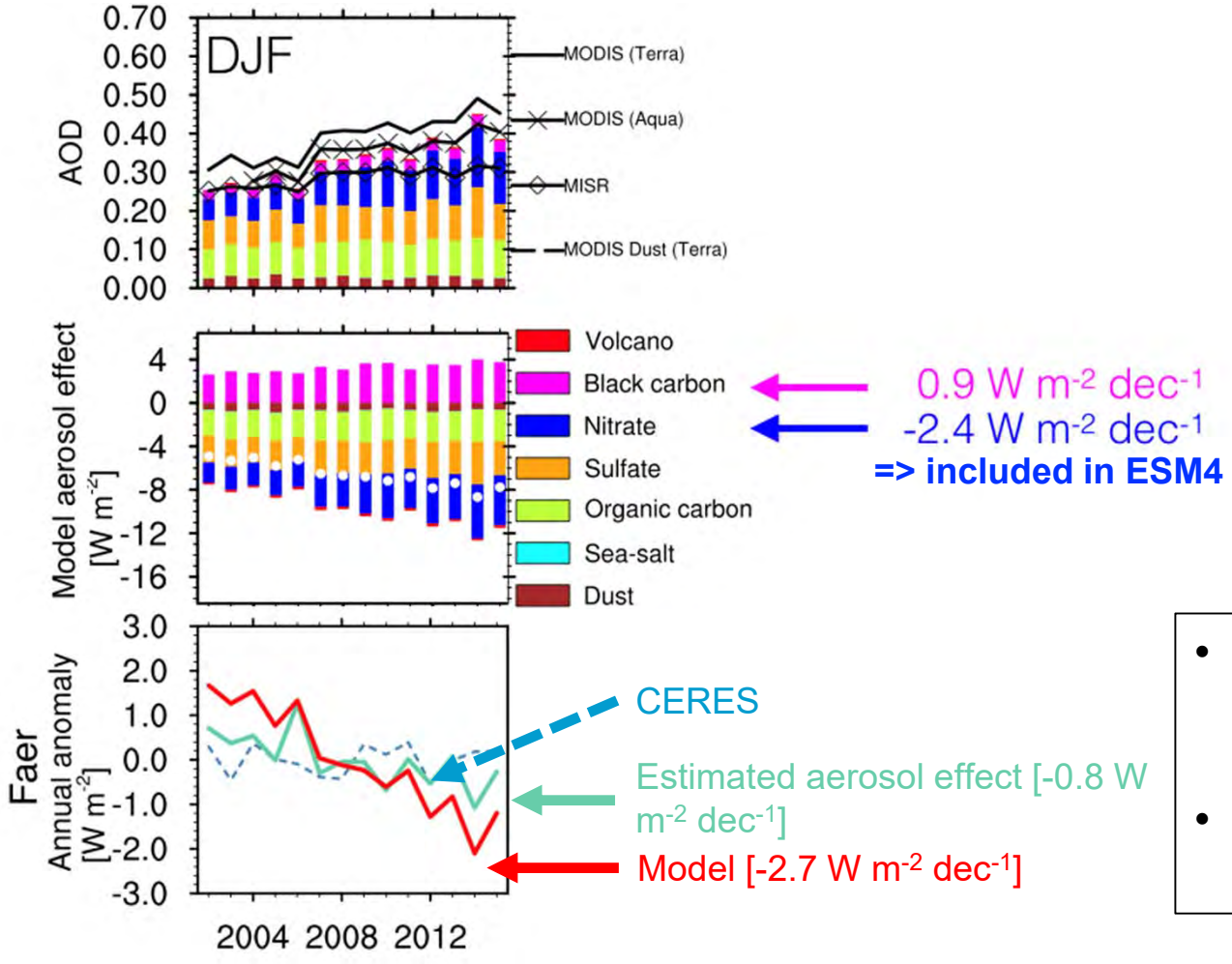
Simulated change in aerosol effect



Paulot et al. (ACP, 2018)

Leverage seasonal trends to understand source of biases over India: nitrate and BC

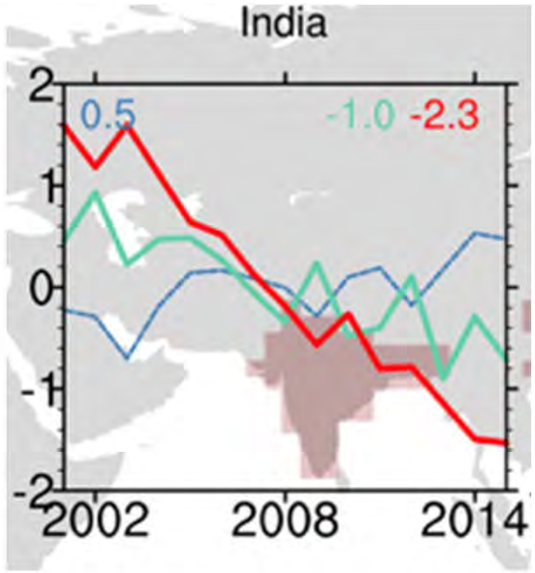
Emissions → **Concentration** → **Radiative Perturbation** → Climate



0.9 W m^{-2} dec^{-1}

-2.4 W m^{-2} dec^{-1}

=> included in ESM4



CERES

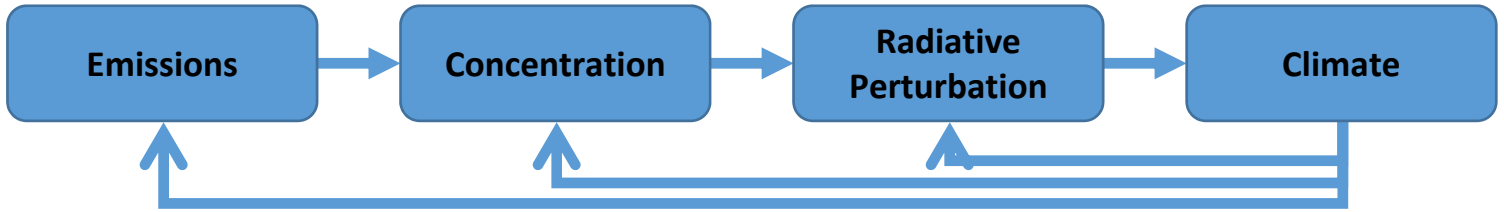
Estimated aerosol effect [-0.8 W m^{-2} dec^{-1}]

Model [-2.7 W m^{-2} dec^{-1}]

- Additional information helps constraints sources of biases
- Changes are not dominated by sulfate

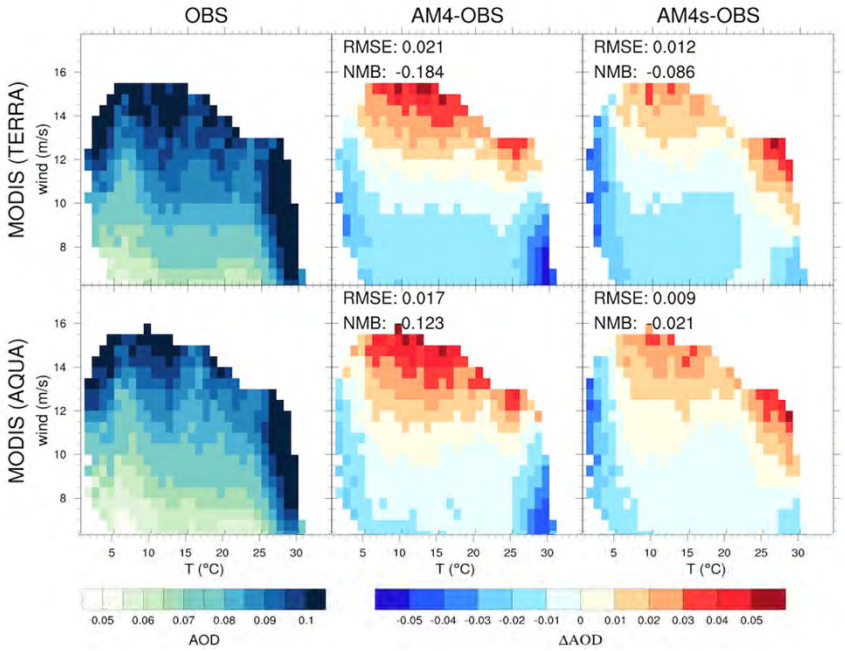
Paulot et al. (ACP, 2018)

Closing the loop: sea salt radiative feedback



Weak response of sea salt to SST

Strong response of sea salt to SST



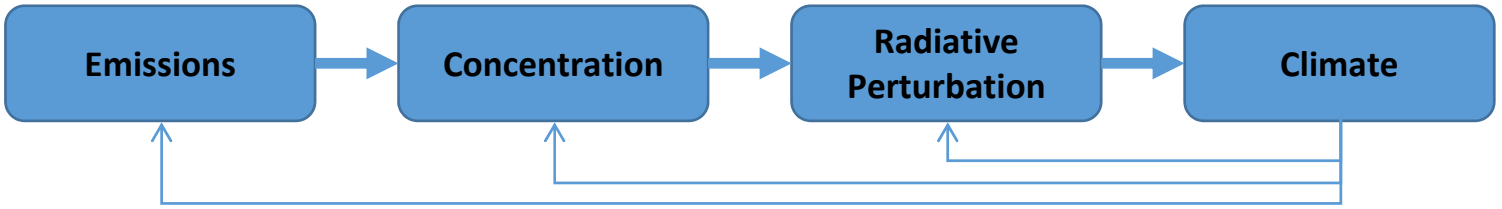
Recent field/lab experiments point to a **sensitivity of sea salt emissions to SST**

Sea salt aerosols – **most important scattering aerosol** in the atmosphere.

Use **nudged configuration to compare simulated and observed relationship between AOD, SST, and wind speed over "pristine" marine regions**

Strong T dependence reduces model bias at high temperature (equatorial/subtropical Pacific)

Closing the loop: natural aerosols feedback



	ECS [°C]
CM4 Weak response of sea salt to SST	5
ESM4 Strong response of sea salt to SST	3.1
CM4s Strong response of sea salt to SST	4.5

- Change in sea salt parameterization contribute ~25% of the difference in climate sensitivity between CM4 and ESM4.
- Other factors include: stratospheric ozone, biogenics, land, …
- **Negative feedback ~-0.08 W m^{-2} K^{-1} AerChemMIP** Considerable uncertainty on the size distribution, temperature sensitivity, and radiative effect of sea salt emissions.
- Highlights uncertainty in the representation of marine chemistry

Summary & Future plans

- High-frequency/long-term observations can provide emerging constraints for the sensitivity of climate forcers to changes in anthropogenic emissions/climate. [Paulot et al. (2017ab GRL), Paulot et al. (2018, ACP), He et al. (2019, ACP)]

- Comprehensive coupling between land/ocean/atmosphere to improve and advance the scientific understanding of the role of biogeochemical feedbacks on climate and air quality
  - Interactive emissions
    - Interactive fire emission (Ginoux et al., in preparation)
    - Agricultural activities (-> Minjin Lee's talk)
    - Natural aerosols (dust (in ESM4), marine aerosols)
  - Interactive deposition (-> Meiyun Lin's talk)