Atmospheric Chemistry-Composition in GFDL Models

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Atmospheric Chemistry and Composition in GFDL's 4th Generation Models

Dictated by Varied Scientific Needs and Resources

ESM2M/ESM2G

Prescribed O_3 + Aerosols + CO_2 BGC

Fastest simulation of physical climate

AM3/CM3

"Full" Trop+Strat Chemistry

Improved variability, air quality, stratosphere

Increasing Computational Cost
(tracers, vertical levels, horizontal resolution)

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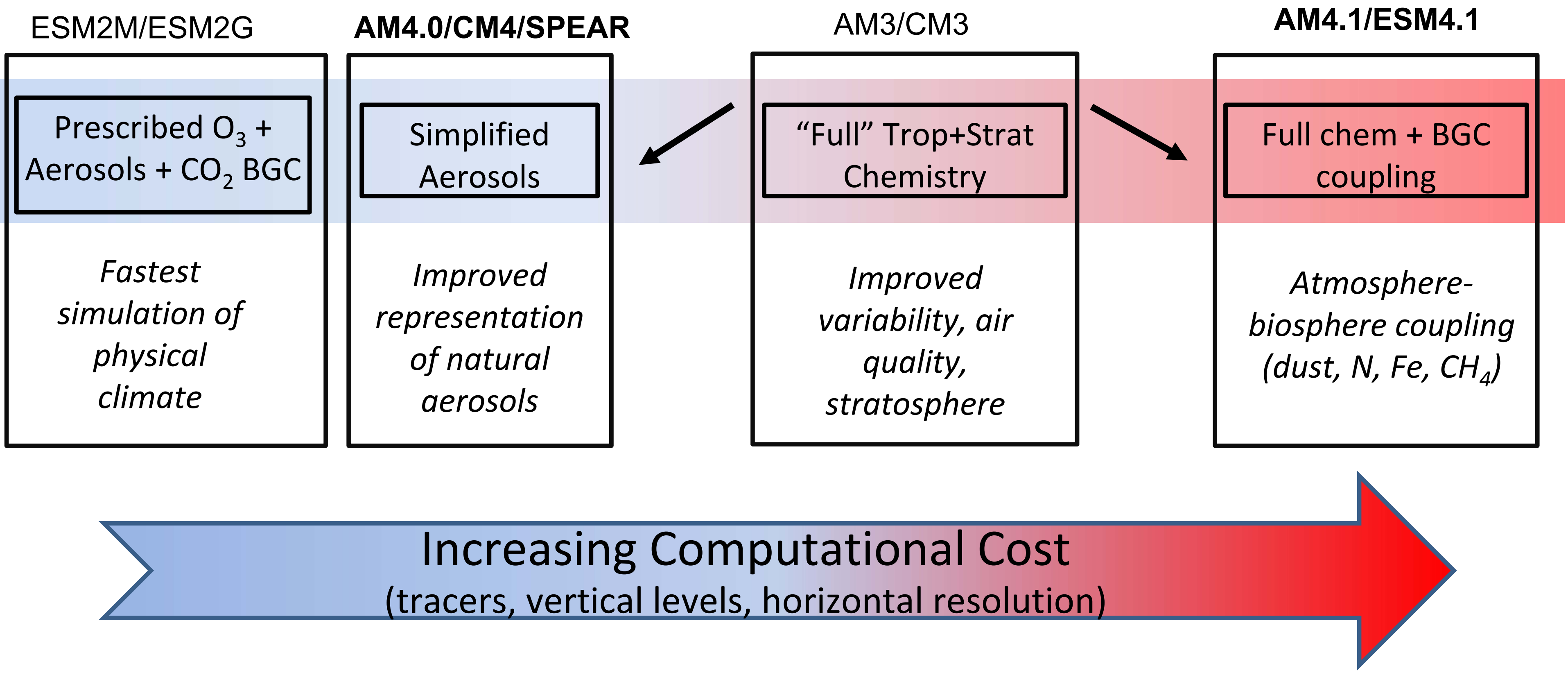
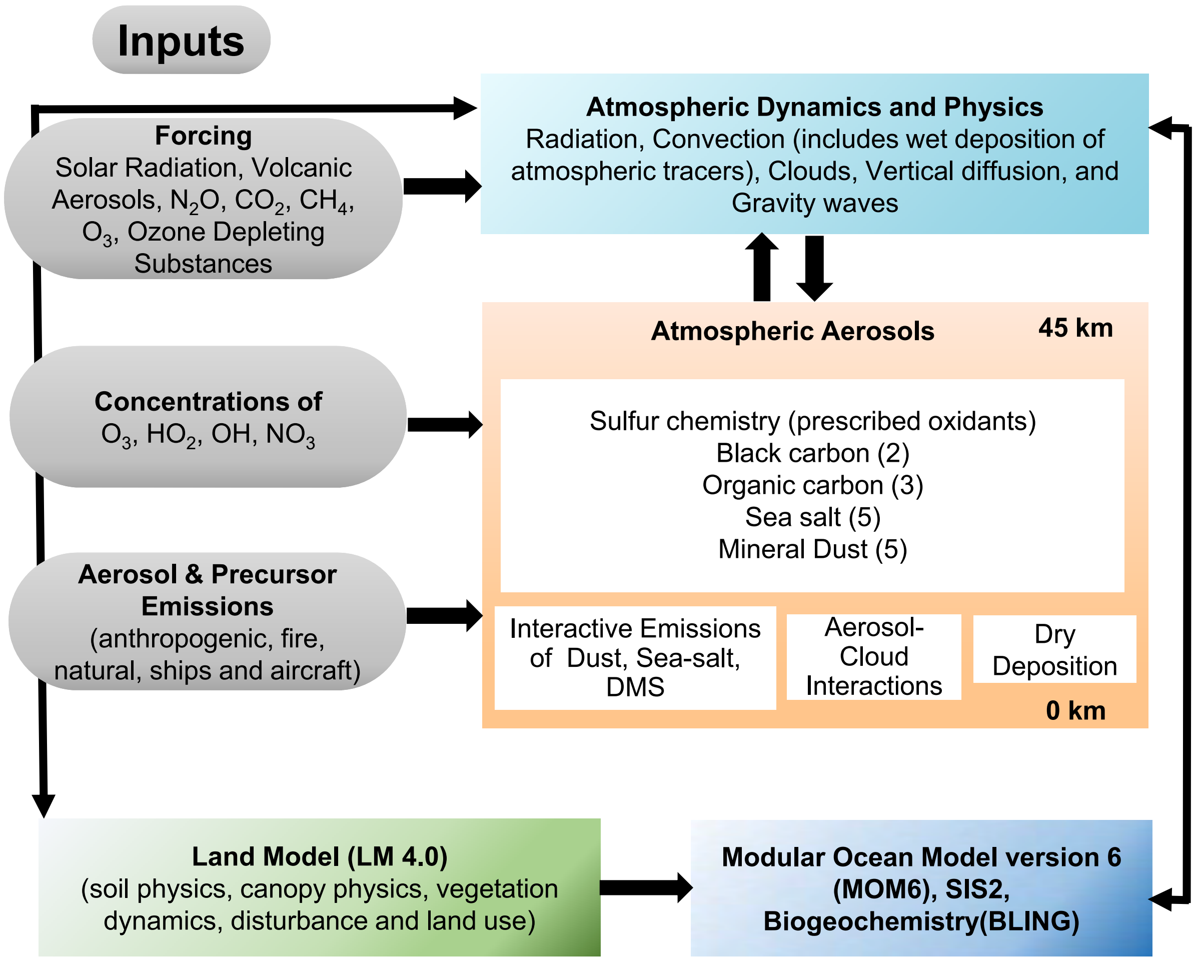


Simplified Aerosols in AM4.0/CM4/SPEAR

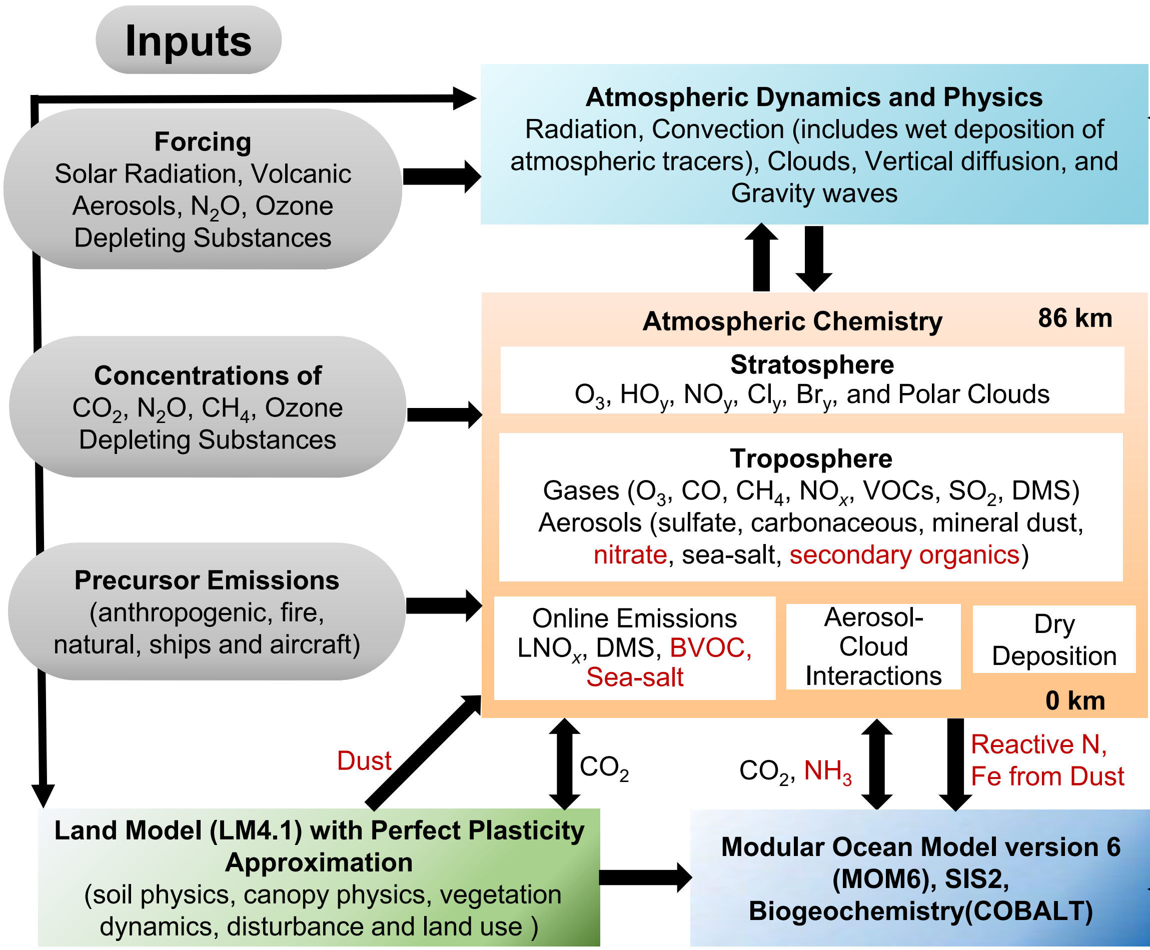


- Aerosol distributions from emissions
- Improved wet removal of aerosols by convection and by frozen precipitation
- Aerosol-cloud interactions

17 aerosol + 4 gas tracers; 50 or 100 km horizontal resolution with ¼° Ocean

Zhao et al. *JAMES* (2018a,b); Held et al. in press *JAMES* (2019); Delworth et al. (*submitted to JAMES*, 2019)

Comprehensive Chemistry-Climate Interactions in AM4.1/ESM4.1



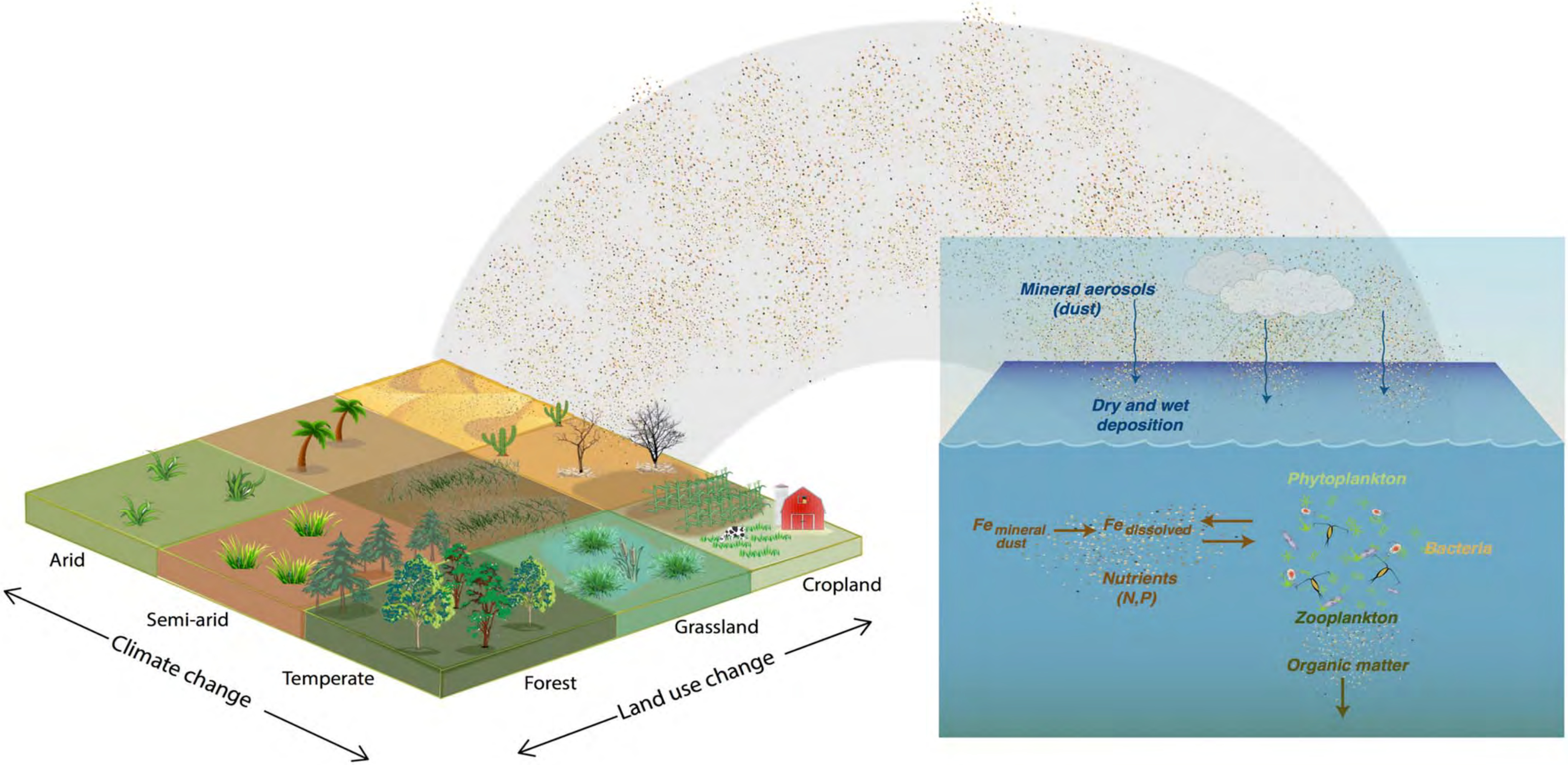
~130 chemical tracers; 250 reactions; 100 km horizontal resolution

- Updated chemical mechanism and online photolysis (FAST-JX scheme)
- Improved wet removal of aerosols by convection and by frozen precipitation
- Treatment of nitrate aerosols (ammonium-sulfate-nitrate thermodynamic equilibrium)
- Online biogenic secondary organic aerosol source (fixed yield from online BVOC emissions-MEGAN)
- Stronger temperature-dependence of sea salt emissions (Jaeglé et al., 2011)
- Enhanced interactions between chemistry and radiation via methane
- Interactive land dust source and bidirectional oceanic exchange of ammonia (NH_3)

Horowitz et al. *(in preparation)*

Dust Lifecycle in ESM4.1

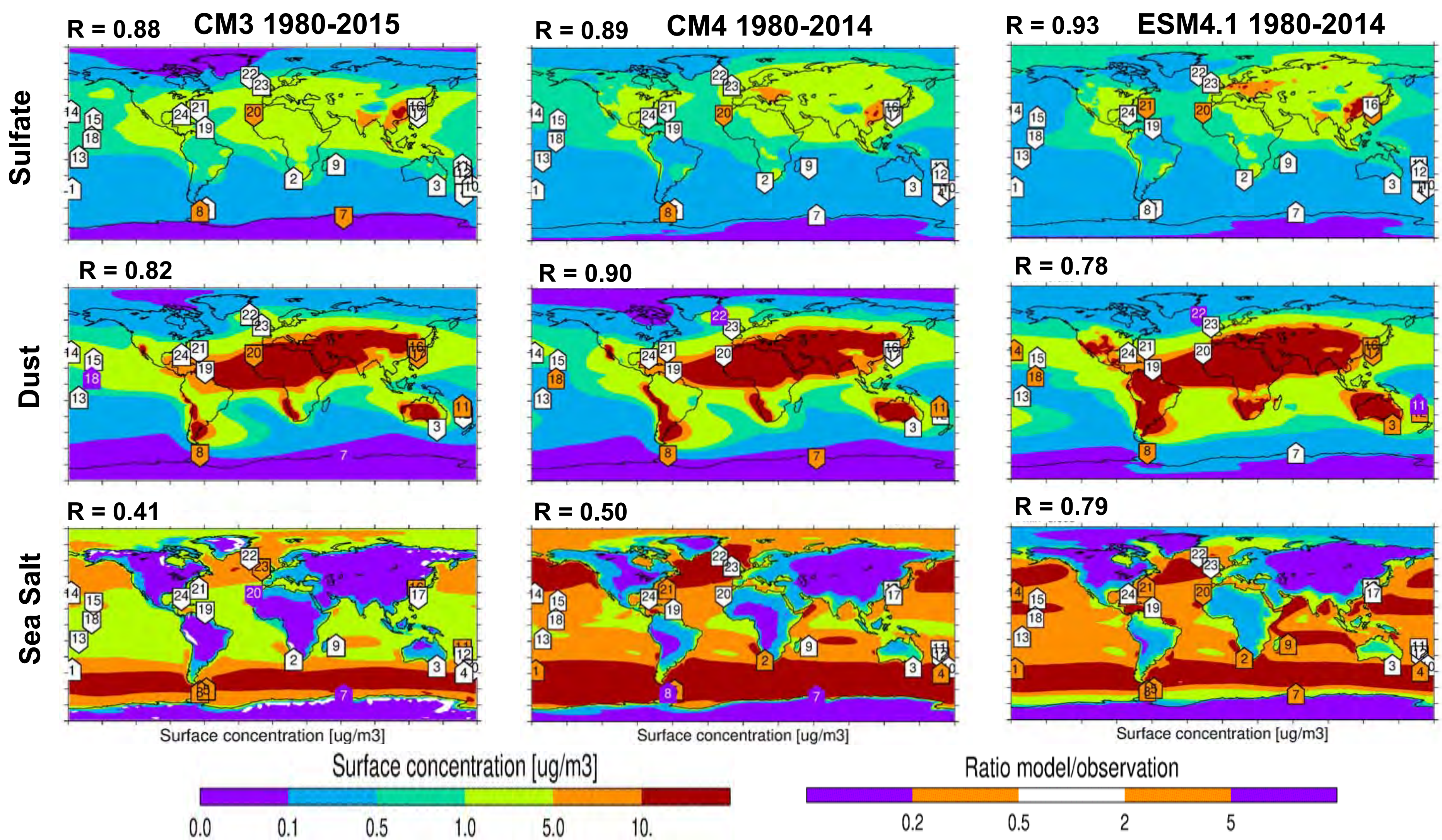
- Dust emissions from LM4.1 dynamic vegetation – only from bare, dry, snow-free, and windy areas
- Dust deposition supplies soluble iron to marine ecosystem (COBALT)



Courtesy Paul Ginoux

Improvements in Surface Aerosol Distribution :CM3→CM4 & ESM4.1

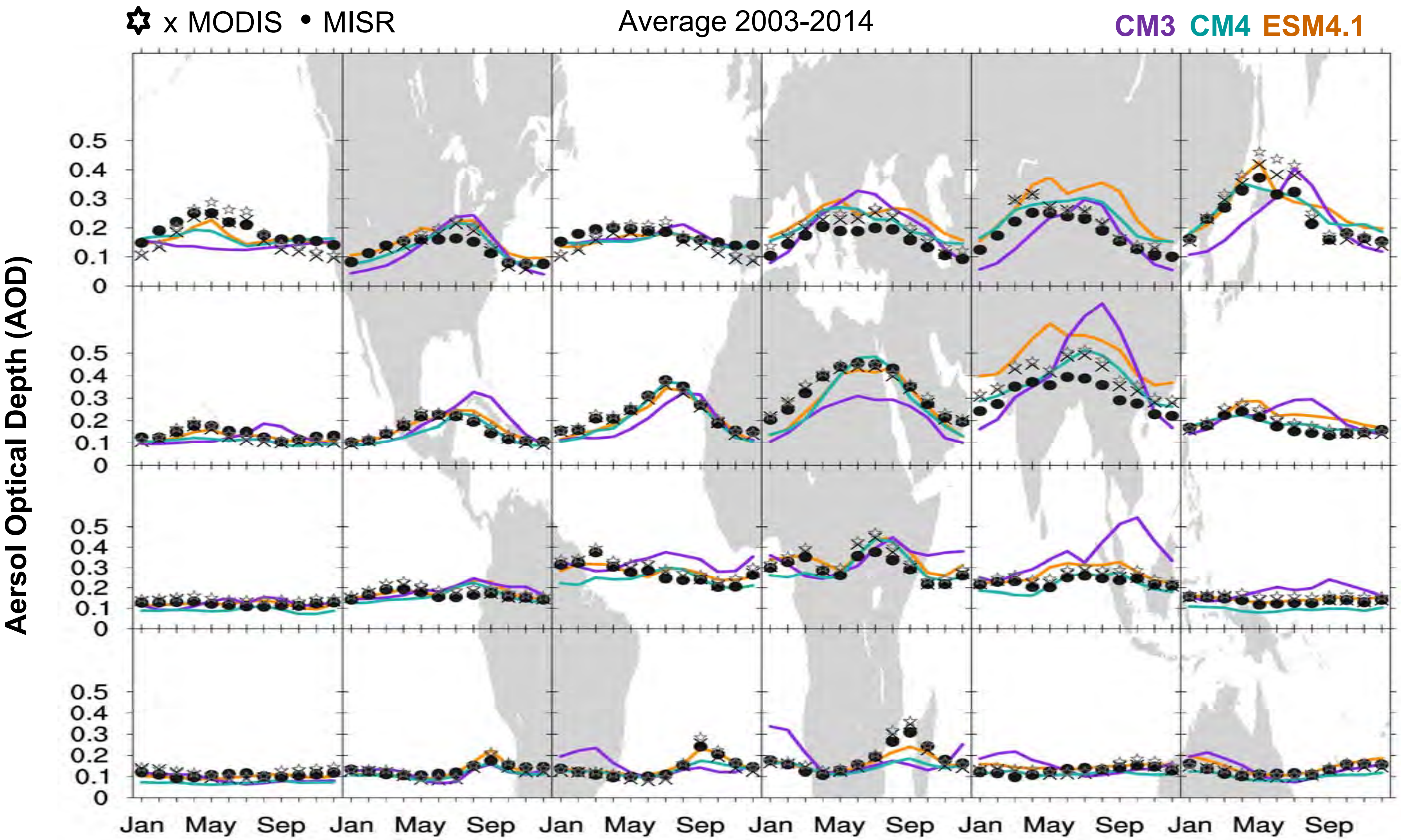
Comparison with surface concentration on islands collected by University of Miami



Courtesy Paul Ginoux

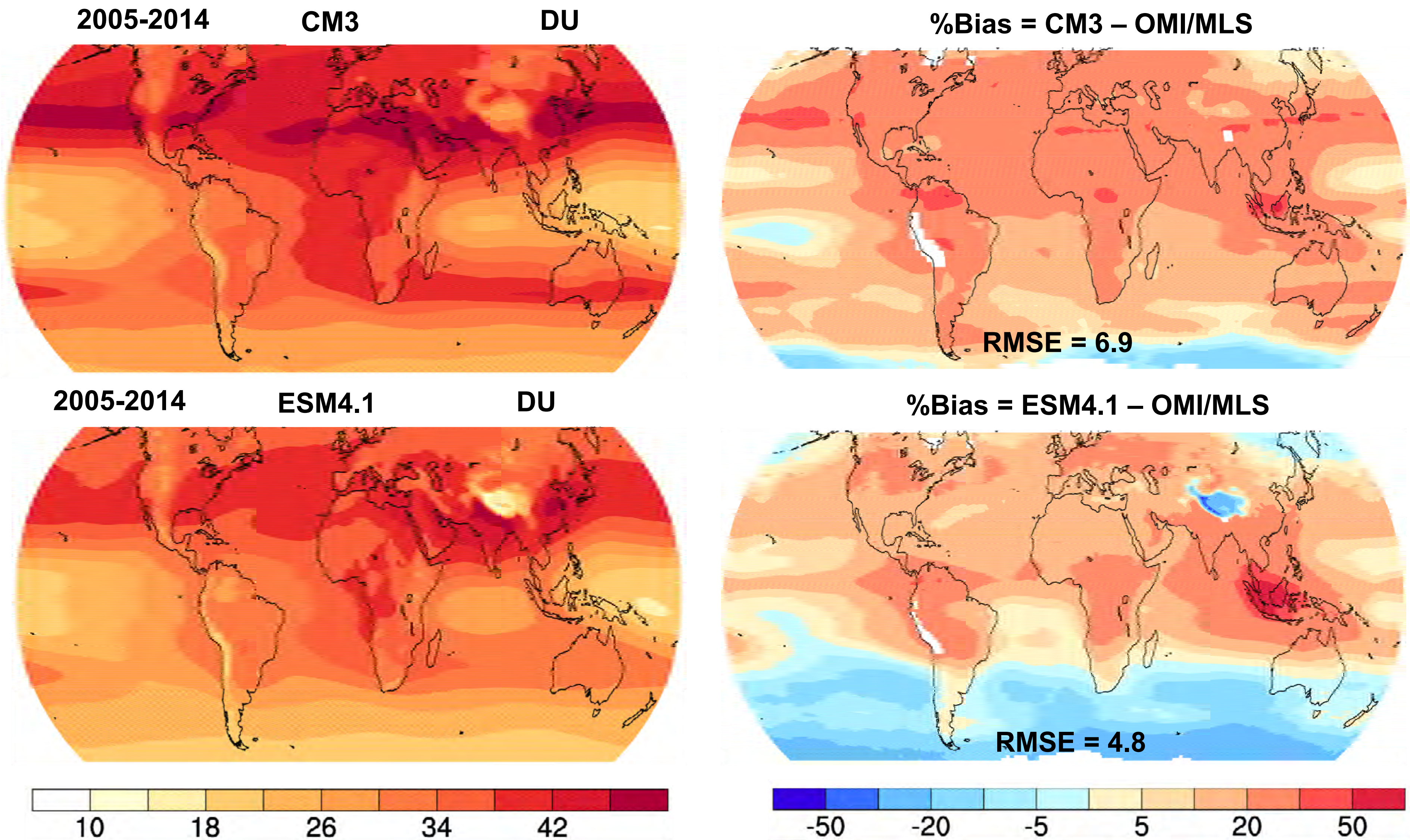
Reduced Summertime Biases in Aerosol Optical Depth (AOD) in CM4 & ESM4.1

Comparison with AOD from MODIS (Remer et al., 2008) and MISR (Kahn et al., 2009) satellites



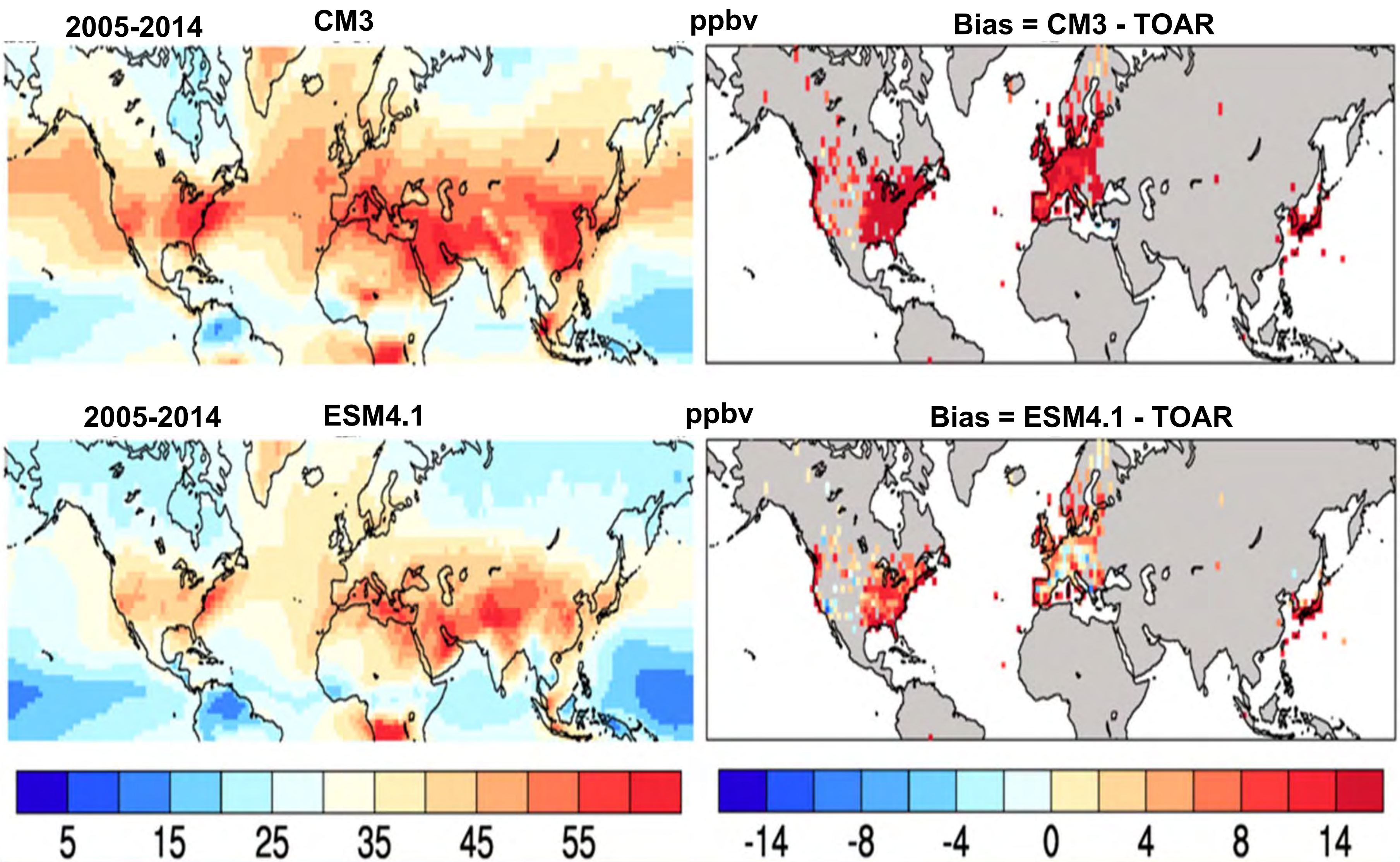
Reduced Biases in Tropospheric Ozone in ESM4.1

Comparison with OMI/MLS satellite Tropospheric Ozone Column (Ziemke et al., 2019)

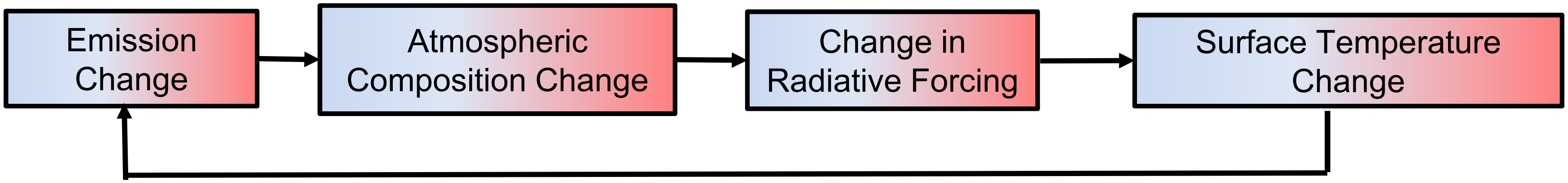


Reduced Biases in Summertime Surface Ozone in ESM4.1

Comparison with Tropospheric Ozone Assessment Report (TOAR) database of surface ozone (Schultz et al., 2017)

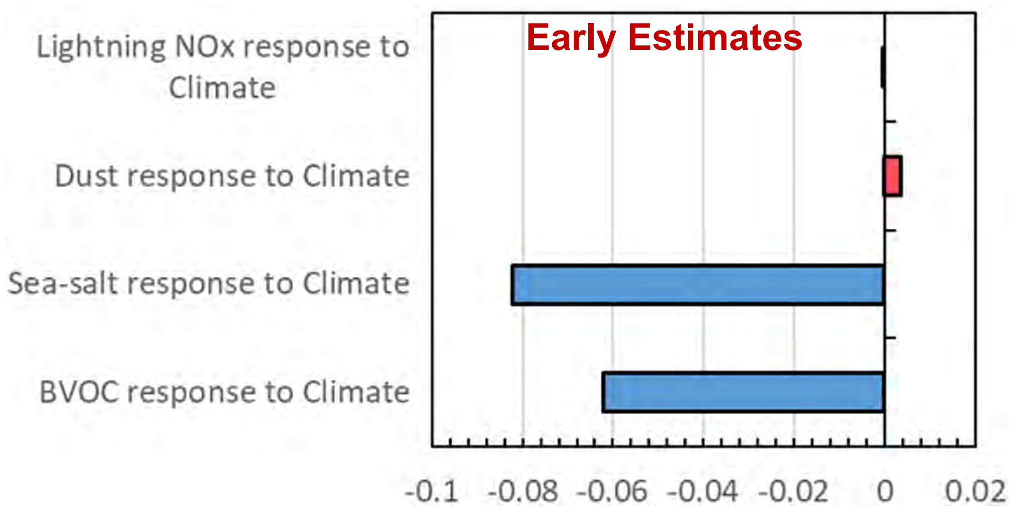


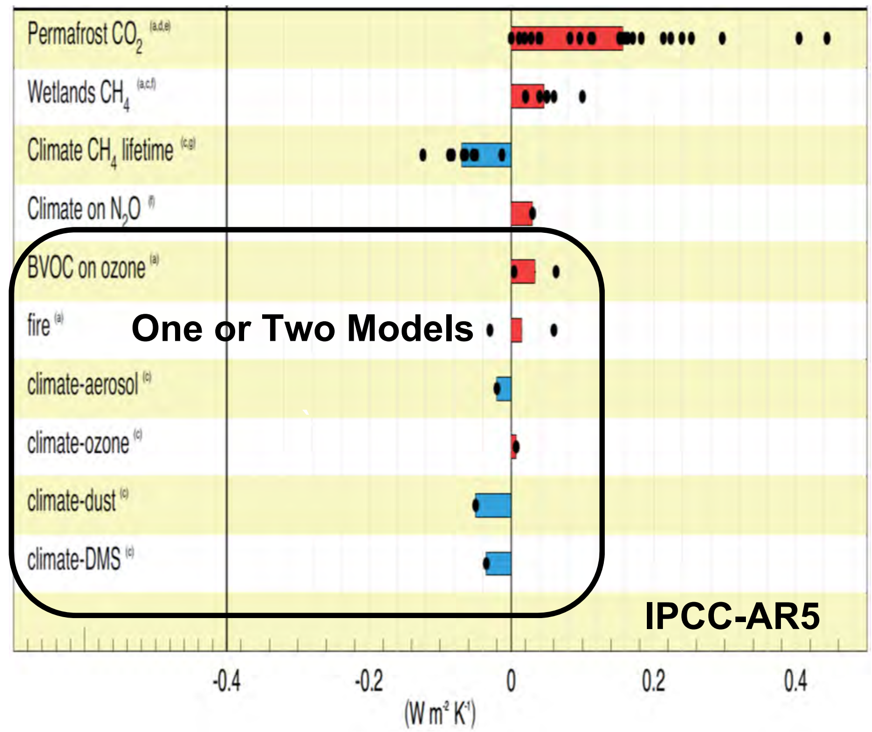
Increased comprehensiveness in ESM4.1 allows quantification of biogeochemical feedbacks on climate



Biogeochemical Feedback Factor (W m^{-2} K^{-1}) =

$$\frac{\Delta RF\ (Wm^{-2})}{\Delta E\ (Tg\ yr^{-1})} \times \frac{\Delta E\ (Tg\ yr^{-1})}{\Delta T\ (K)}$$





ESM4 is participating in the CMIP6-endorsed AerChemMIP – a goal is to quantify the importance of biogeochemical feedbacks

Next Steps

- **Enhance comprehensiveness** of interactions between Earth System components
  - e.g., BVOCs, Fires, Marine organics, Methane

Talk by Meiyun Lin & poster by Jian He

- **Increase resolution** to resolve atmospheric chemistry at exposure relevant scales
  - Analysis and prediction of air-quality and climate extremes

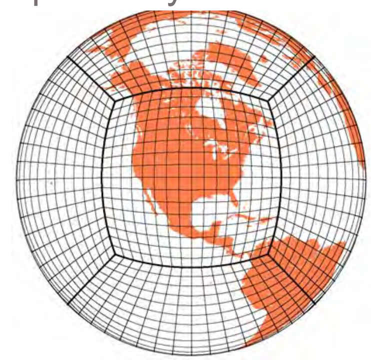
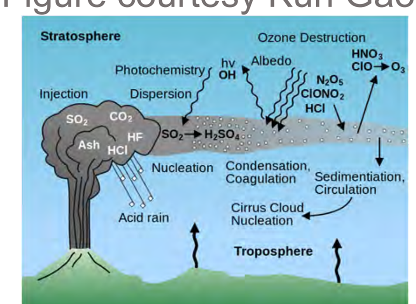


Figure courtesy Kun Gao

- **Improve representation of processes**
  - e.g., stratospheric chemistry and aerosols



McGee et al., 1992

Summary

- **All 4th generation GFDL models (AM4, CM4, SPEAR, ESM4) include atmospheric chemistry**
- **Improvements in chemical and physical processes enhance the skill of our models** in representing the distribution and variability of atmospheric constituents relevant for climate and air quality
- **Comprehensive representation of complex atmosphere-biosphere interactions** advance our ability to understand biogeochemical feedbacks on atmospheric composition, climate, and air quality
- Future plans include **continued push towards increased comprehensiveness, greater resolution, and improvements in process representation** to advance understanding of the changing atmospheric composition and its influence on climate and air quality