Effects of the Changing Climate and Emissions on the Air Quality in the U.S. National Parks

Maria Val Martin (CSU) and Colette L. Heald (MIT)

J-F Lamarque, S. Tilmes
and L. Emmons (NCAR)

Thanks to the National Park Service for funding

Effect of Climate and AQ on Forest Systems

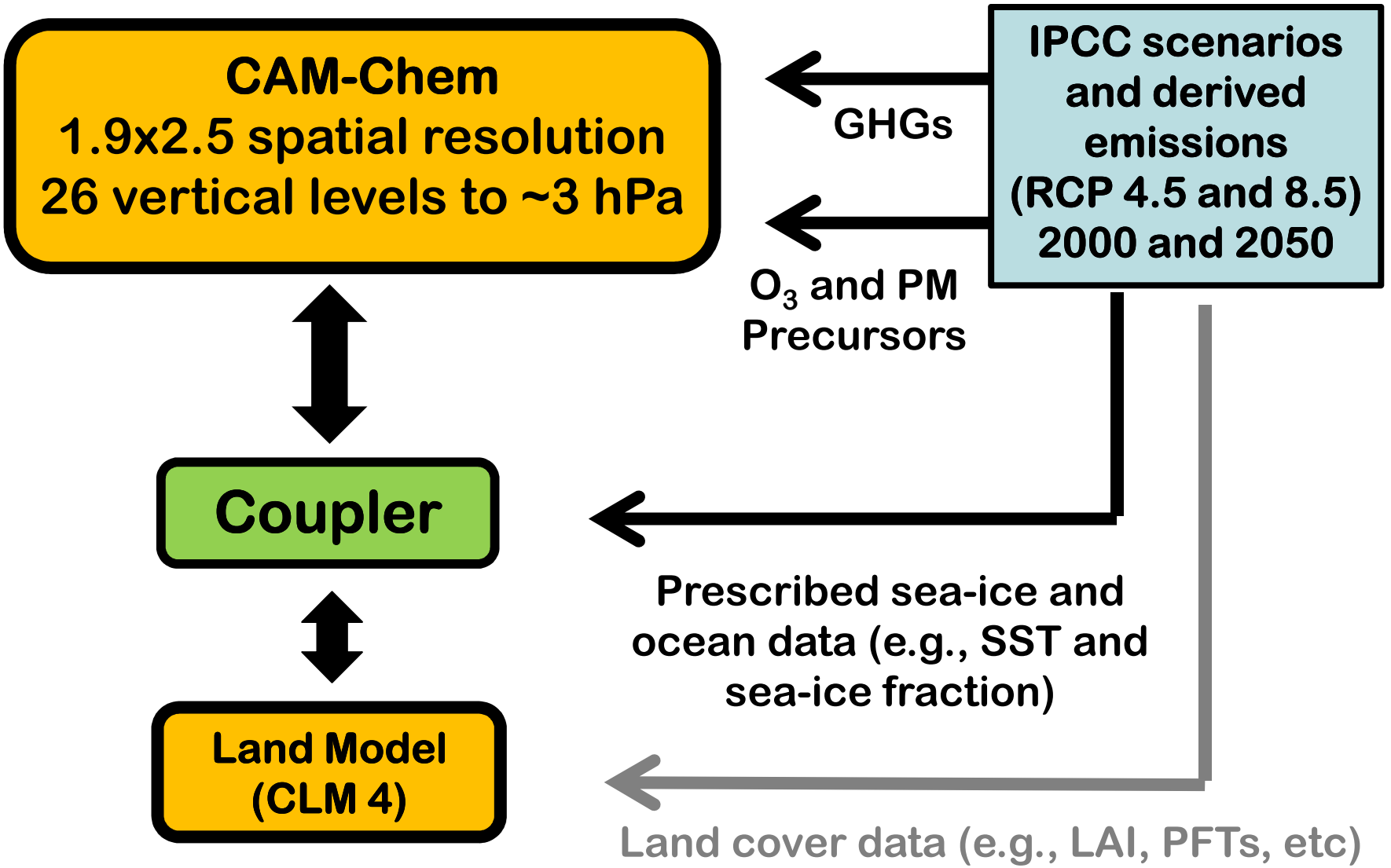
Rocky Mountain NP affected by Haze

http://www.nature.nps.gov/

- High O_3 levels injure O_3 sensitive plants, and impact the health of park visitors and employees.
- Fine particles create haze in the park, affecting visibility.
- N deposition produces loss in biodiversity.

About 50% of forests will be exposed to damaging O_3 by 2100; and 20% will exceed critical loads from S and N deposition by 2050 [FAO, 2007]

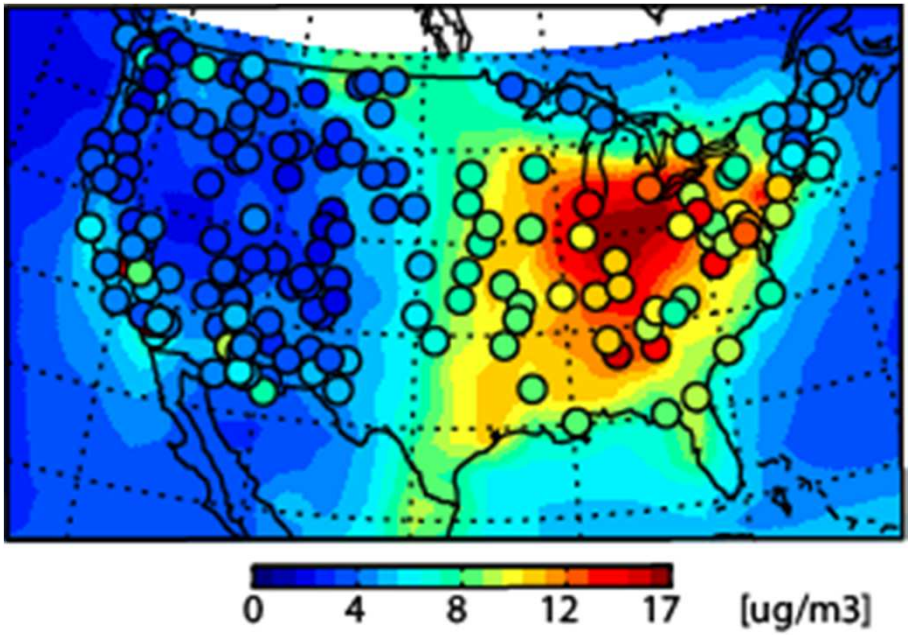
NCAR Community Earth System Model (CESM 1.0.3)

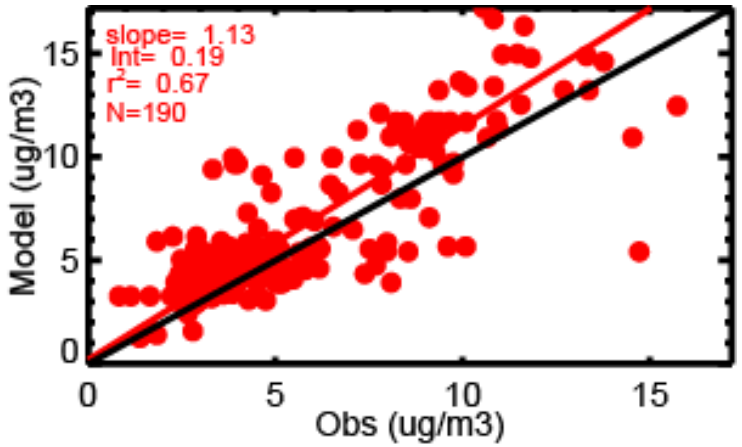


Model Evaluation: PM2.5 (=SO_4+NH_4NO_3+BC+2xOC+Fine DST+SSLT)

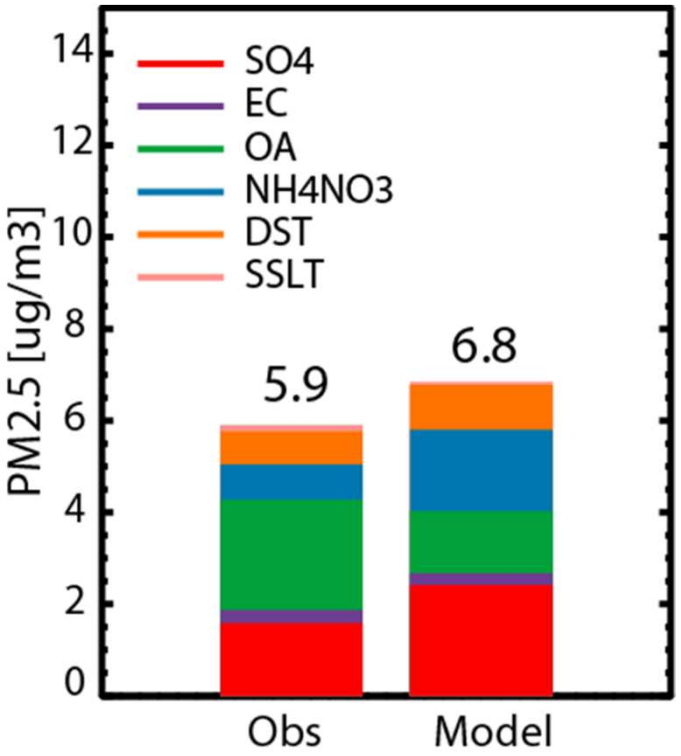
Model 2000 with IMPROVE observations (1998-2010)

Annual average





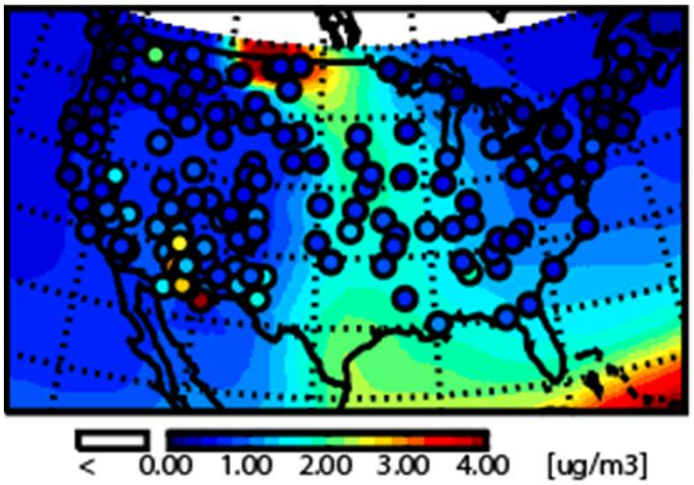
Chemical Speciation

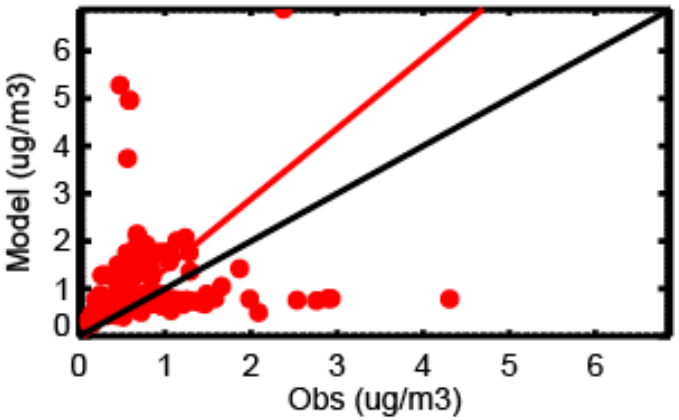


Overall, model captures the magnitude and spatial gradient of much of the IMPROVE PM2.5 observations

Fine Dust and Seasalt were adjusted to match observations

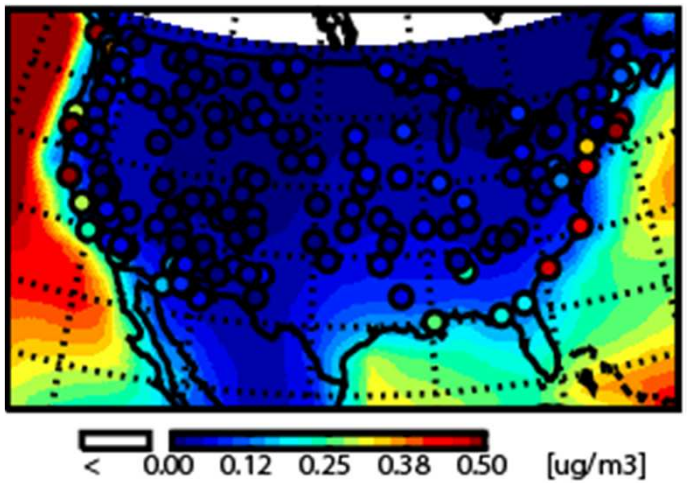
Dust

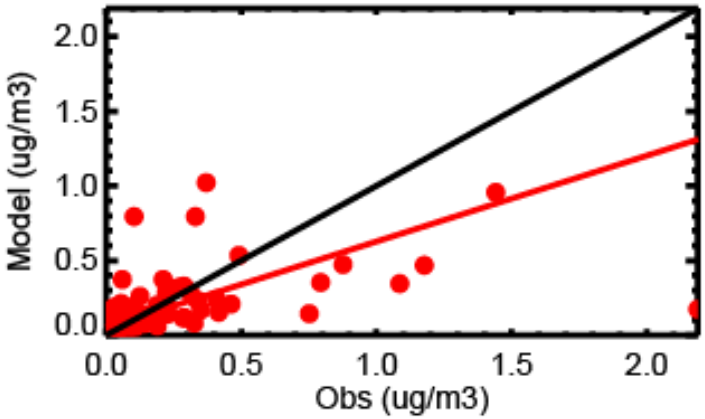




Emissions reduced by a factor of 2 and used an improved soil erodibility map

SeaSalt



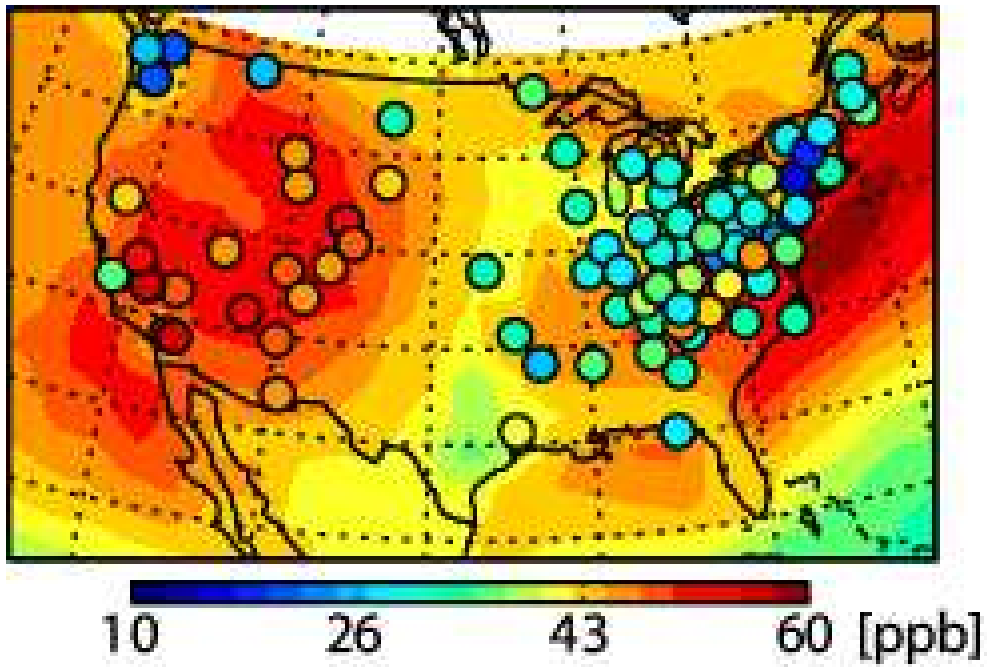


Emissions reduced by a factor of 10

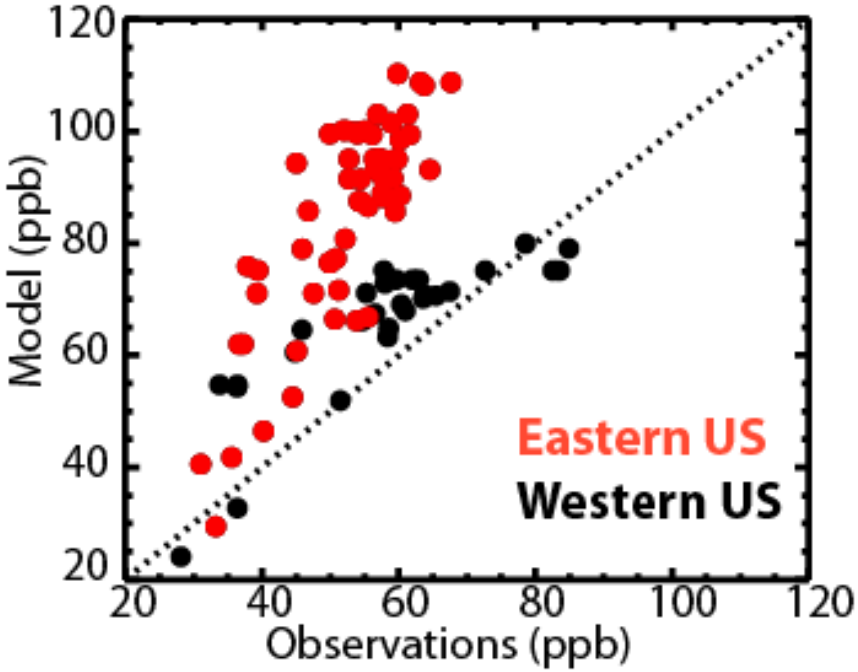
Further Model Evaluation: Ozone

Model 2000 with CASTNET Observations (1995-2005)

Annual average



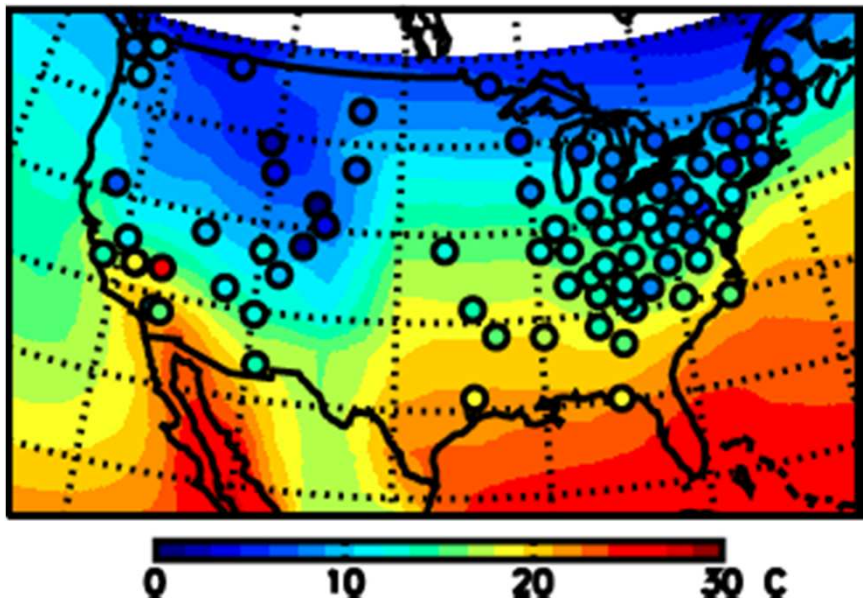
Summer Daily Max 8-hr Avg Surface O_3



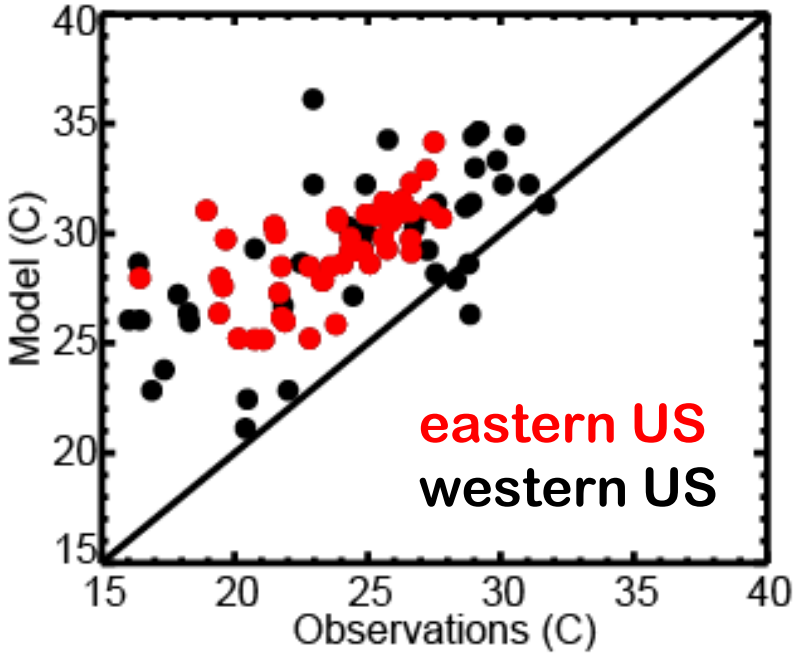
- O_3 is simulated well over western US, and overestimated over eastern US (~20 ppb).
- This strong positive bias in CESM and other models is well know [e.g., Fiore et al, 2008, Brown-Steiner and Hess, 2011].

Temperature does not explain the O_3 bias over the eastern US

Annual Average



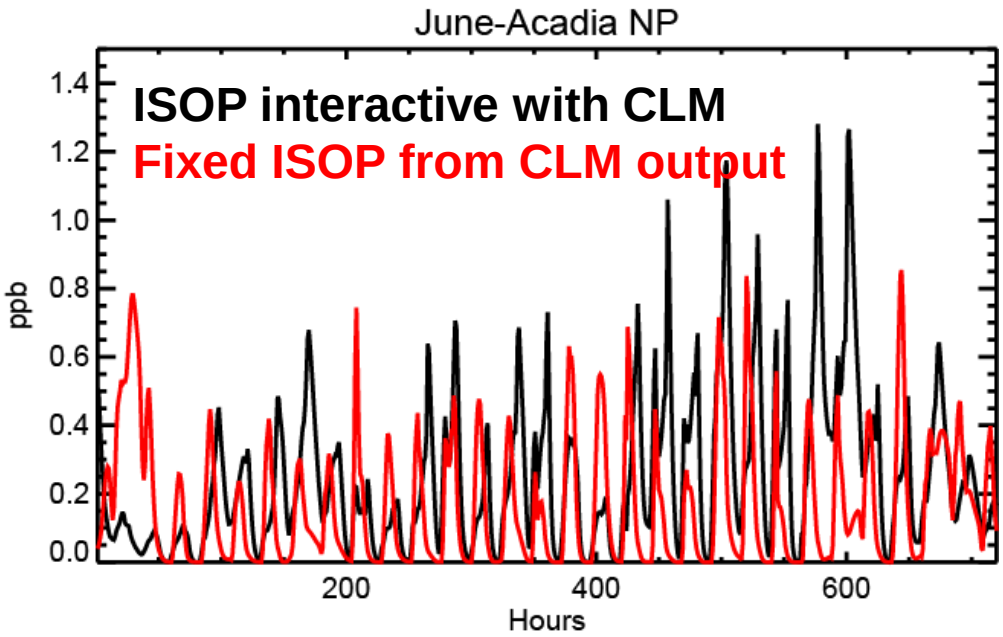
Summer Afternoon (13:00-15:00) Average



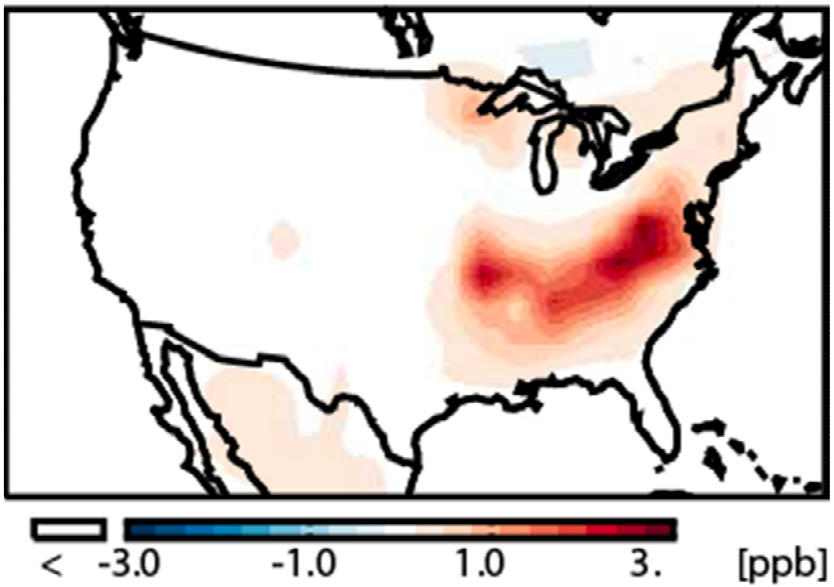
- On an average, model captures the magnitude and spatial gradient of much of the temperature
- Summer afternoon temperature is slightly overestimated

CAM-Chem returns higher isoprene when interacting with CLM

Example of diurnal variability of isoprene



2000 with interactive ISOP – 2000 FIXED ISOP from CLM output

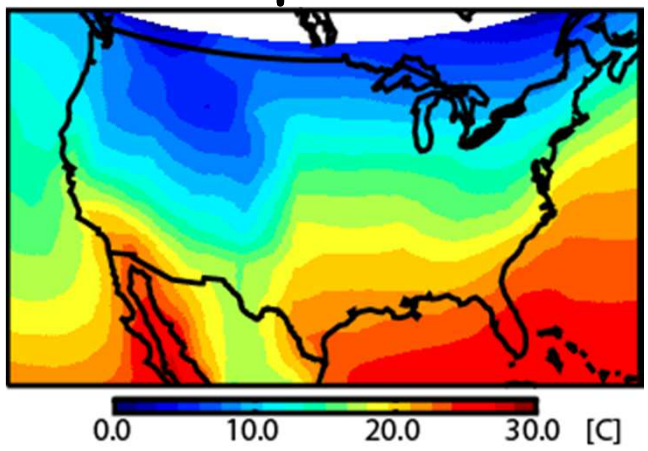


Important effect on the quantification of O_3 changes in the future

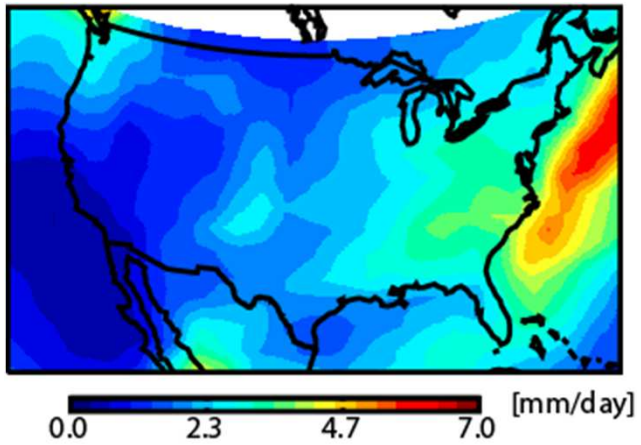
Effects on Changes in Climate Alone

Annual Average in 2000

Temperature

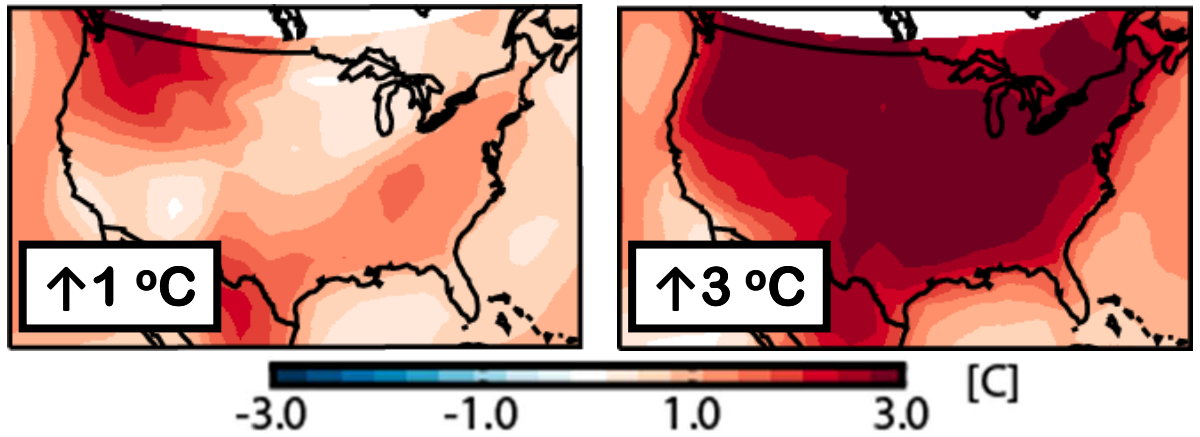


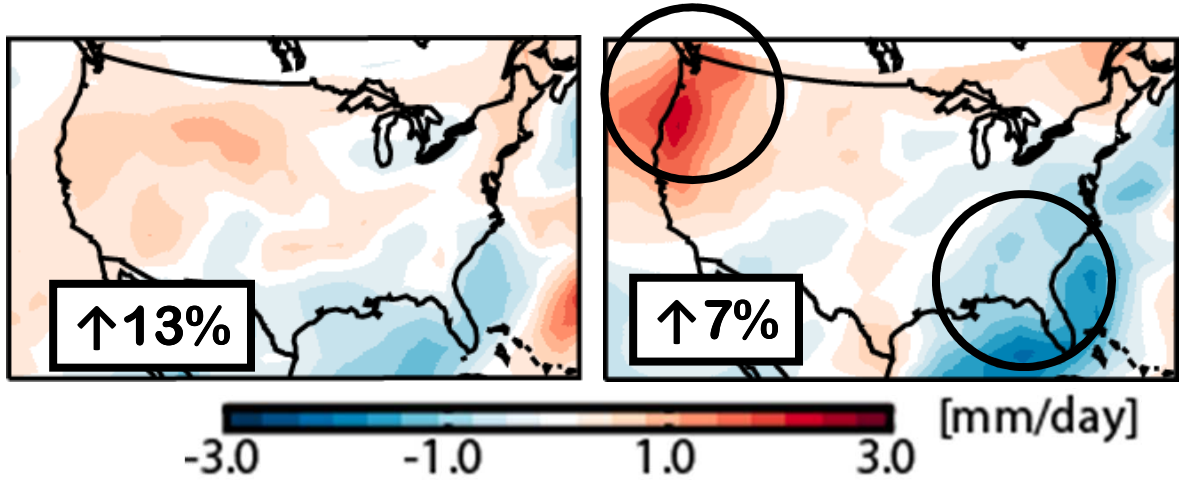
Precipitation



2050 RCP 4.5 - 2000

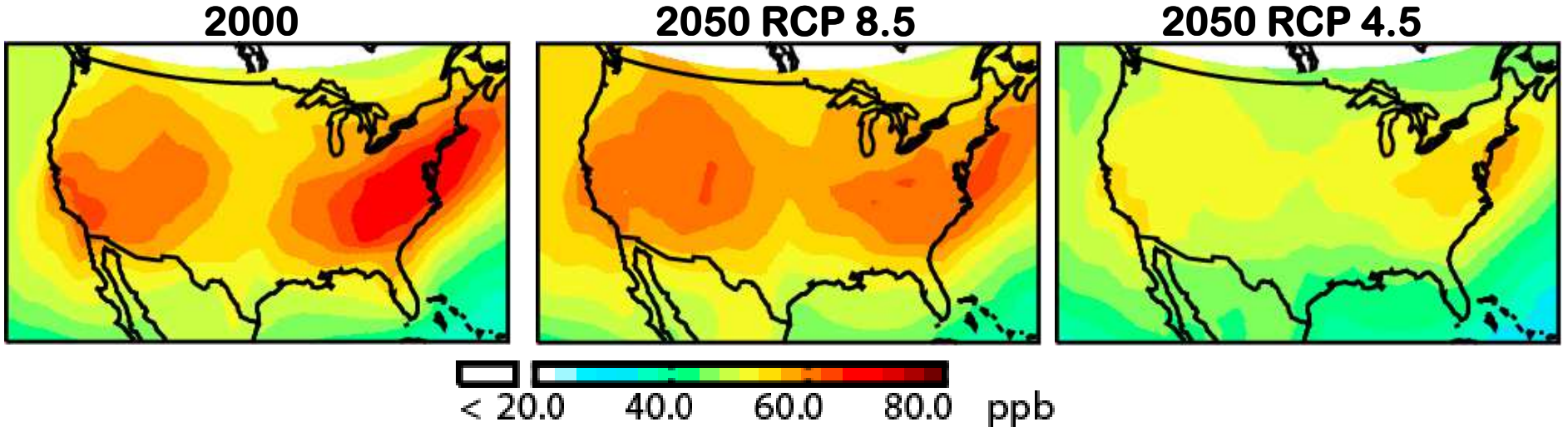
2050 RCP 8.5 - 2000



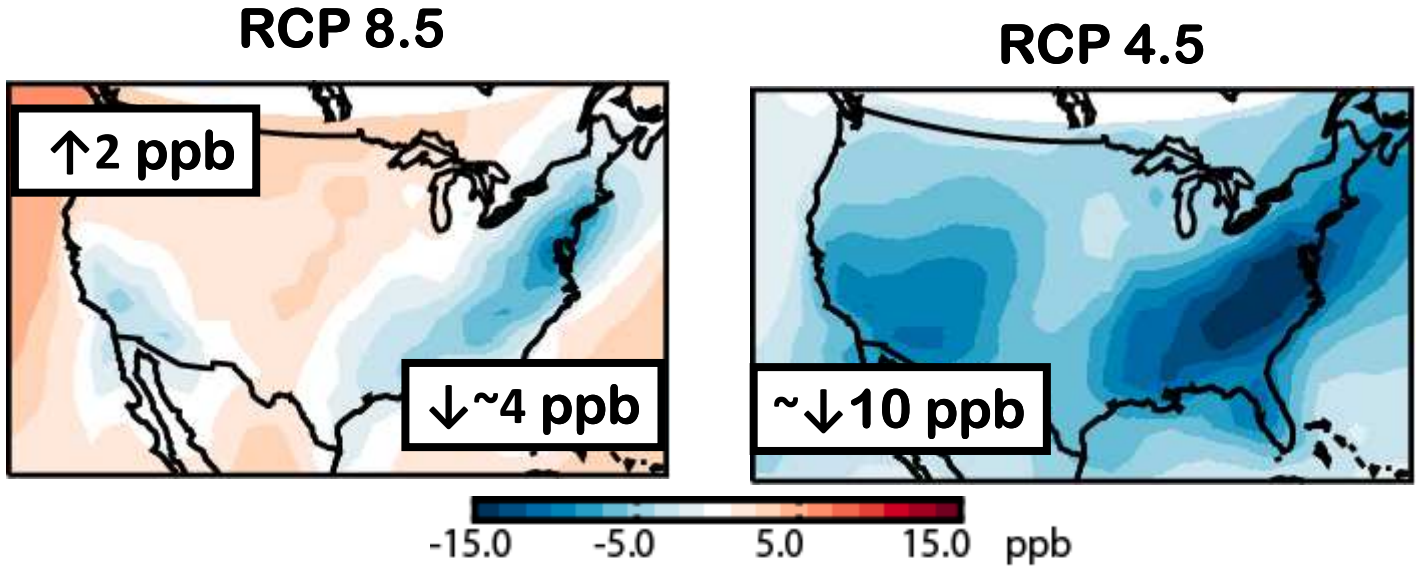


Effects of Global Change on AQ: Ozone

Summer Daily Max 8-hr Avg Surface O_3

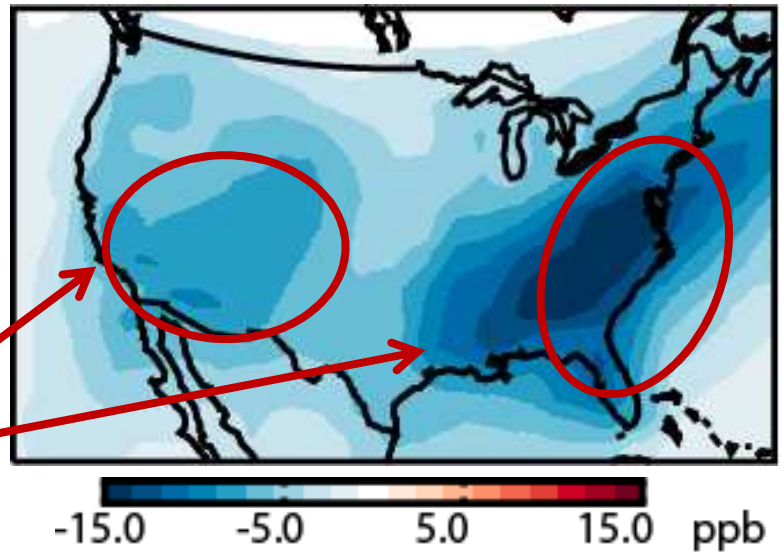


ΔTotal = 2050-2000



Quantifying the change in O_3 due to changing climate and emissions

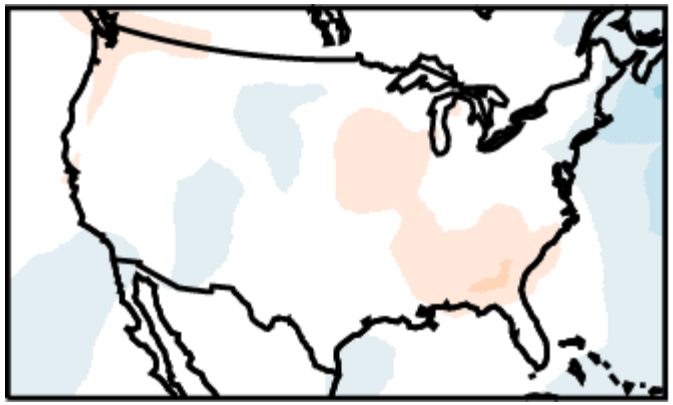
ΔAnthropogenic= 2050 Anthro-2000



RCP4.5

Important decrease in NO_x emissions

ΔClimate= 2050 Clim-2000

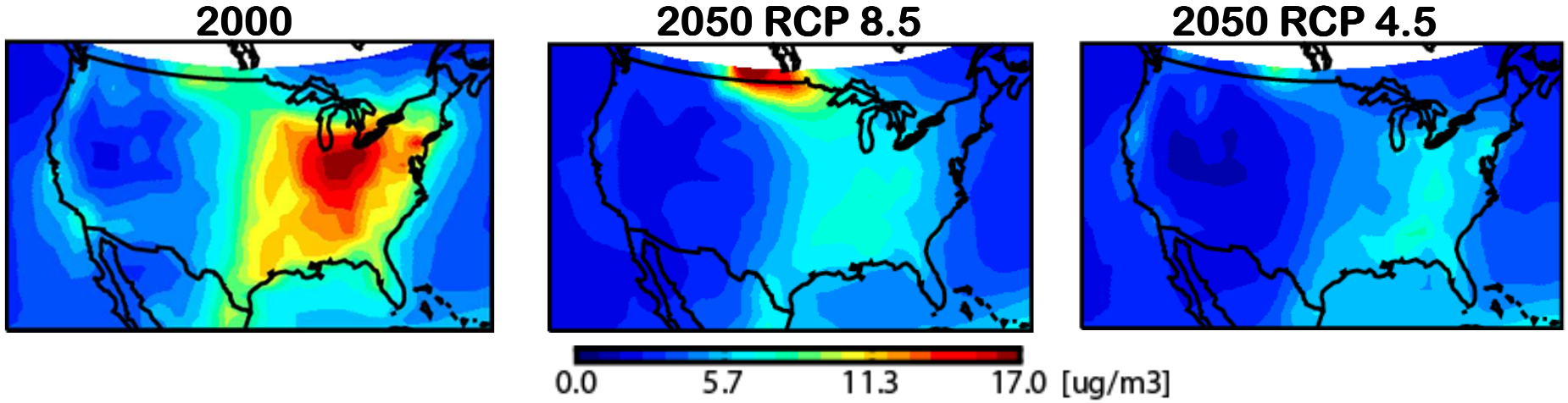


Δ Biogenic= 2050 Nat-2000

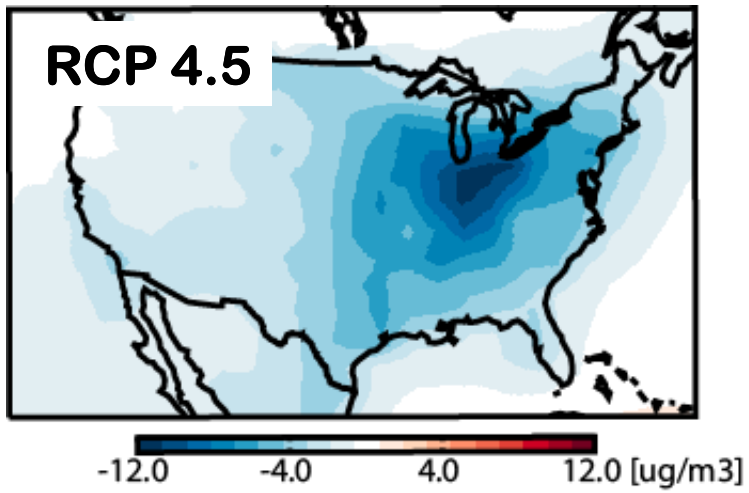
Note: It includes the effect of NOx lightning and Stratospheric O_3 exchange in response to climate

Effects of Global Change on AQ: PM2.5

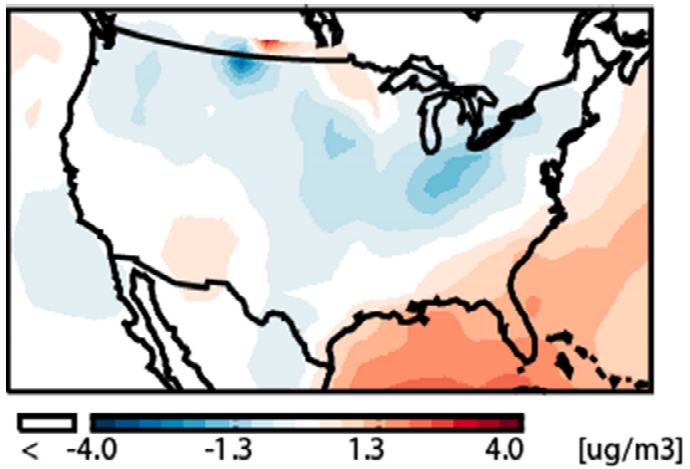
Annual Average PM 2.5



ΔTotal =2050-2000

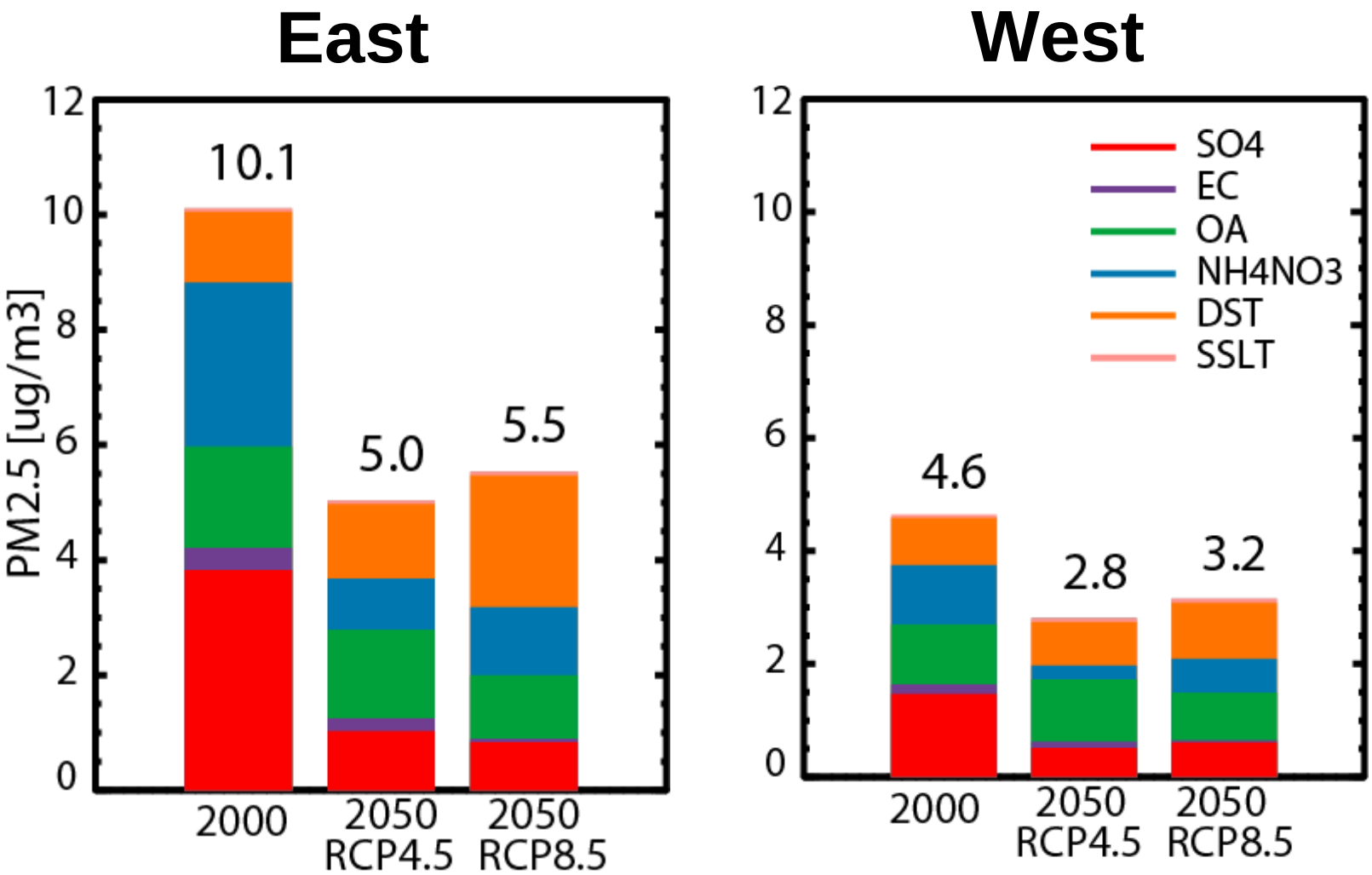


ΔClimate= 2050 Clim-2000



Change in PM2.5 due mainly to SO_4 and NH_4NO_3 emission reduction

Changes in Chemical Speciation



What is next?

- Better quantification of changes resulting from climate, anthropogenic and natural emissions alone.
- Consider the effects of land cover/land changes.
- Study the effect of nitrogen deposition.
- Perform high resolution (1x1 or 0.5x0.5) simulations and analyze the effect of spatial resolution on the results.
- Focus on the air quality over the U.S. NP