Effects of Climate, Emissions and Land Cover Changes on Air Quality in the U.S. National Parks

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

J-F Lamarque, S. Tilmes
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Thanks to the National Park Service for funding

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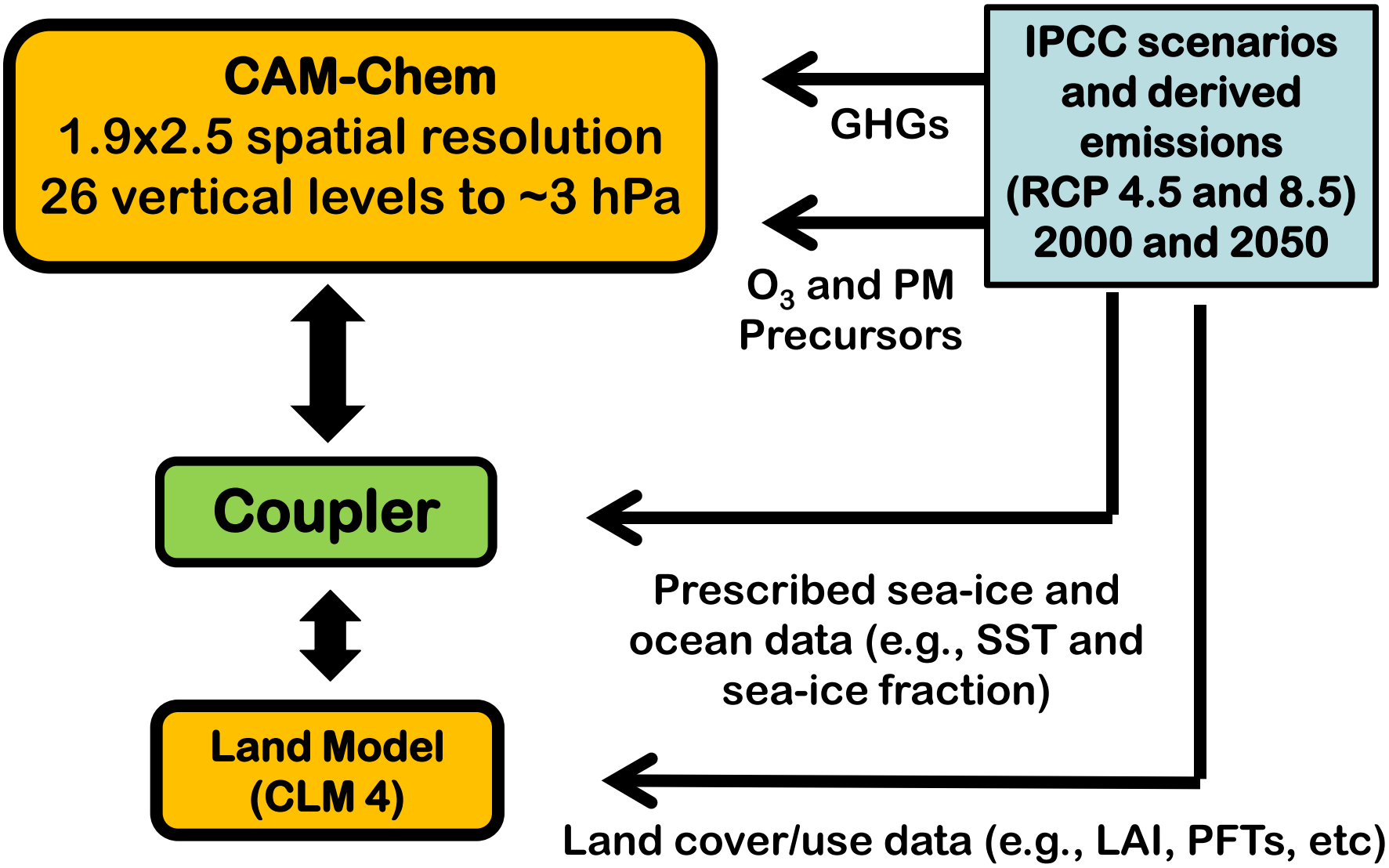
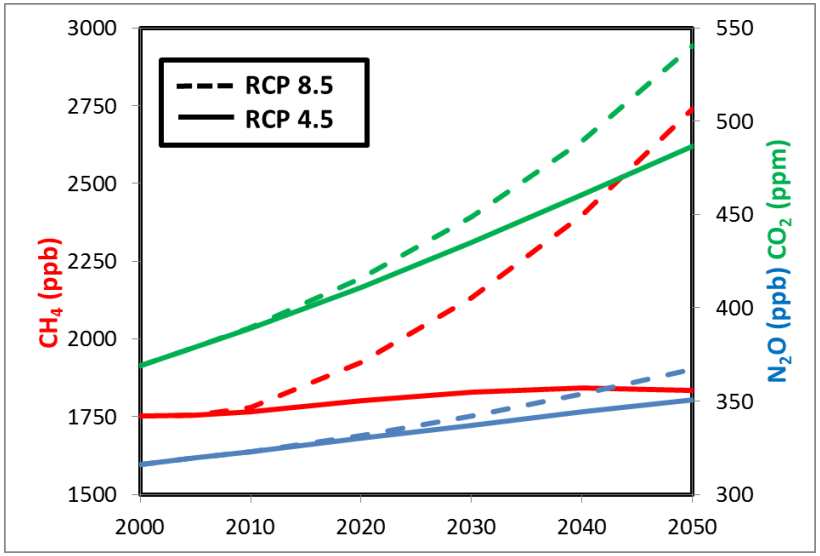
About 50% of forests will be exposed to damaging O_3 by 2100; and 20% will exceed critical loads from S and N deposition by 2050 [FAO, 2007]

NCAR Community Earth System Model (CESM 1.1_alpha12b)



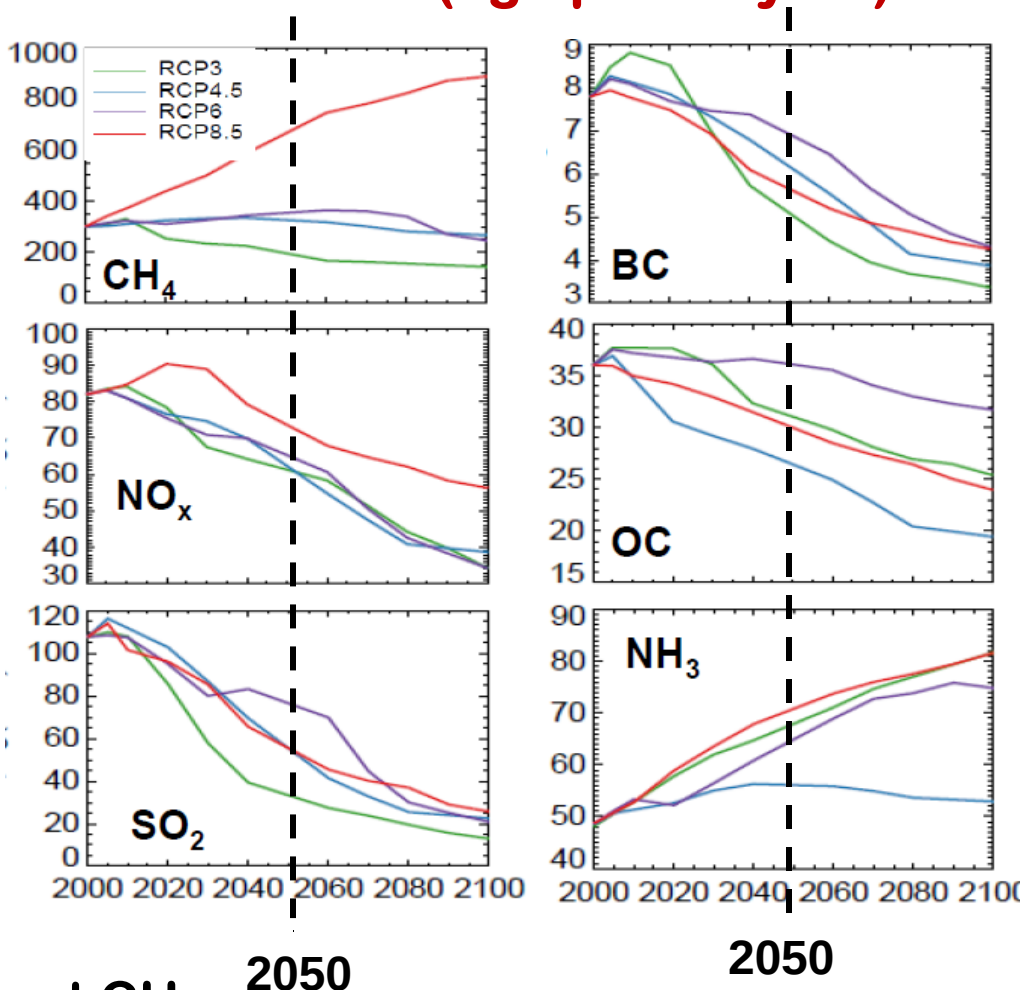
Projections of global AQ-relevant emissions

Main GHGs



www.iiasa.ac.at

Emissions (Tg Species/year)



- Similar GHGs projections, except CH_4
- The RCP scenarios project large decreases for all emissions, except NH_3 and CH_4 in RCP 8.5

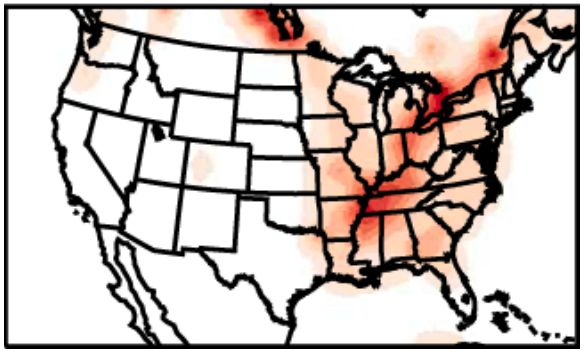
Projections of land cover/land use changes

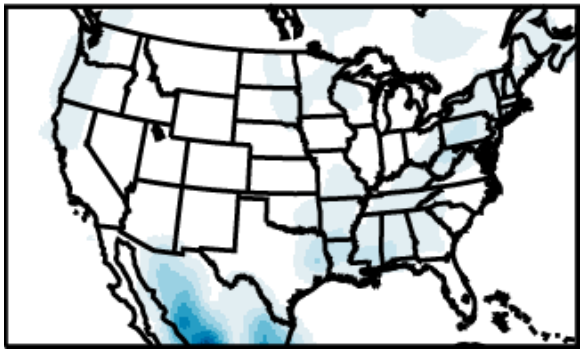
RCP 4.5

RCP 8.5

% Trees

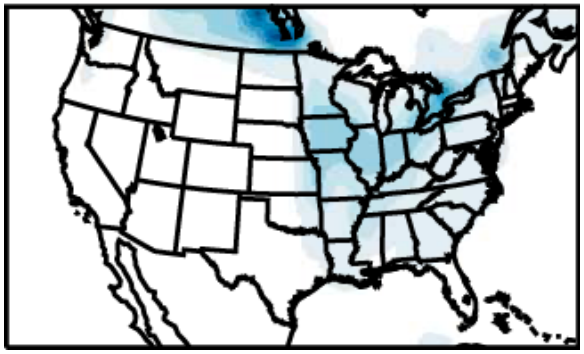
-25 -8 8 25

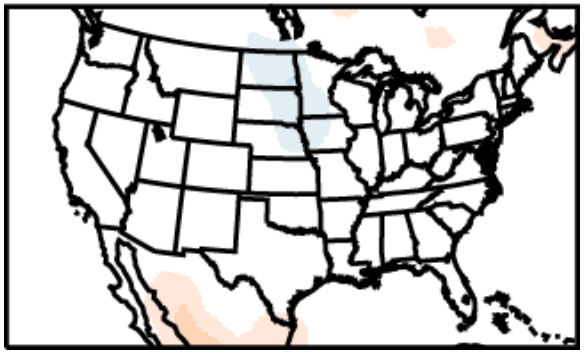




% Crops

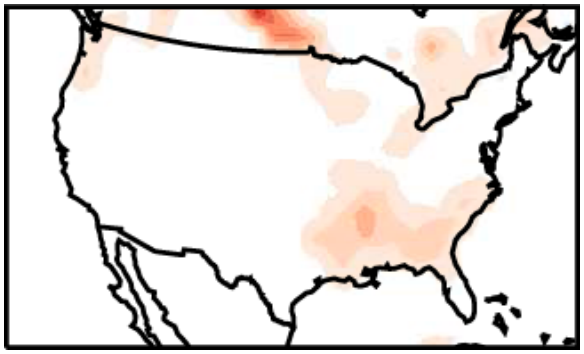
-40 -13 13 40

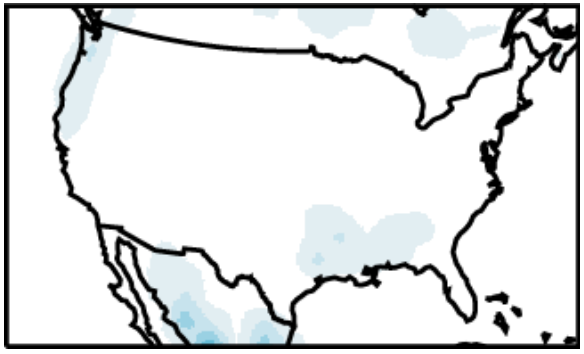




LAI

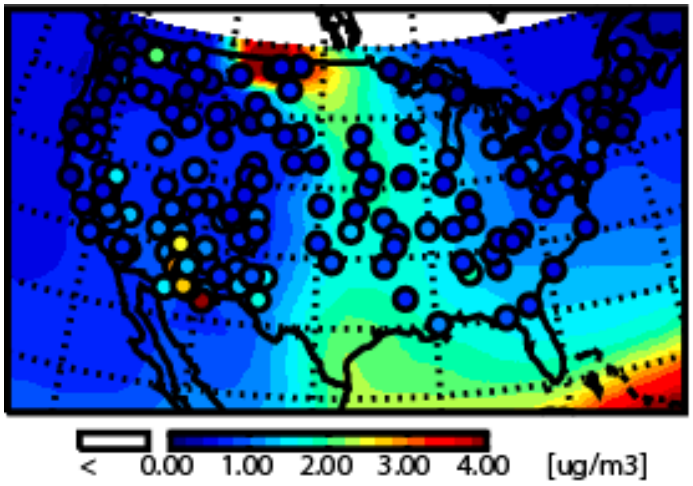
-0.40 -0.13 0.13 0.40

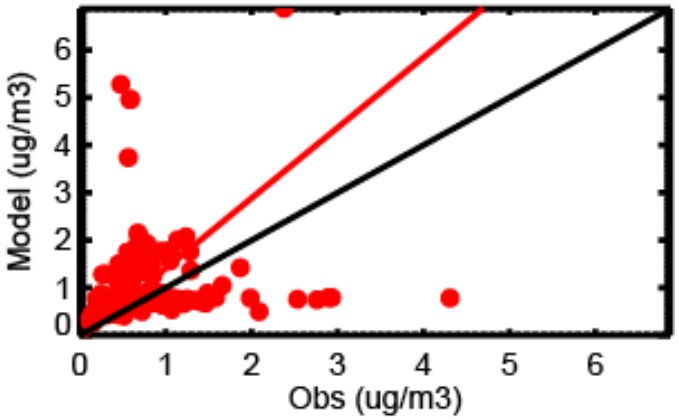




Fine Dust and Seasalt were adjusted to match IMPROVE observations

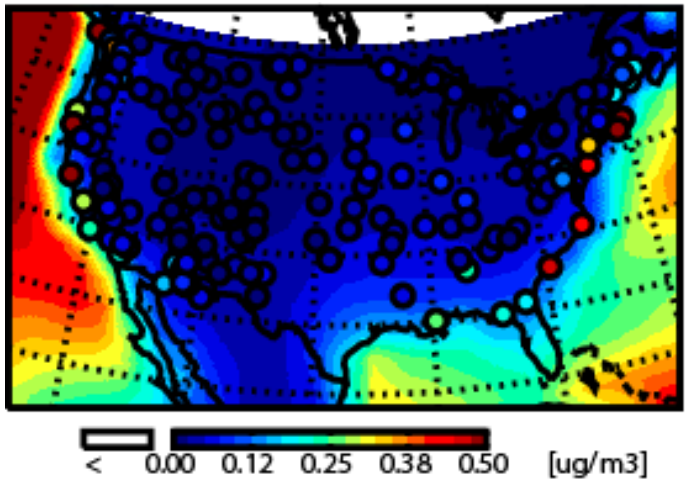
Dust

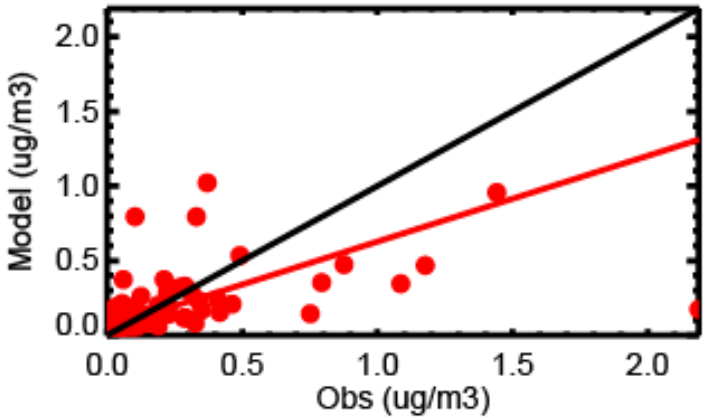




Emissions reduced by a factor of 2 and used an improved soil erodibility map

SeaSalt



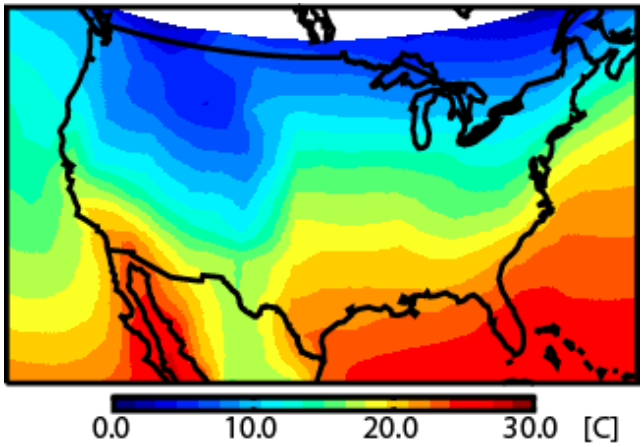


Emissions reduced by a factor of 10

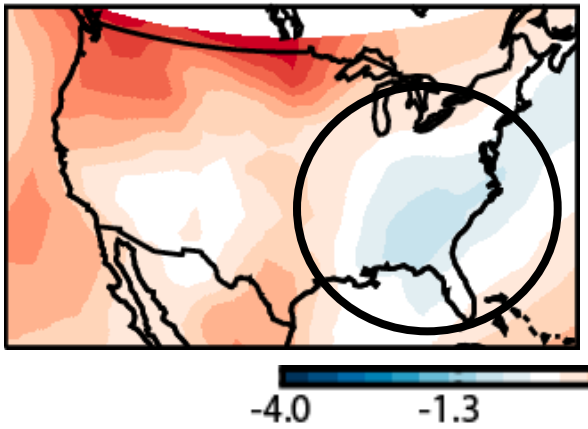
Effects on changes in climate alone

Temperature

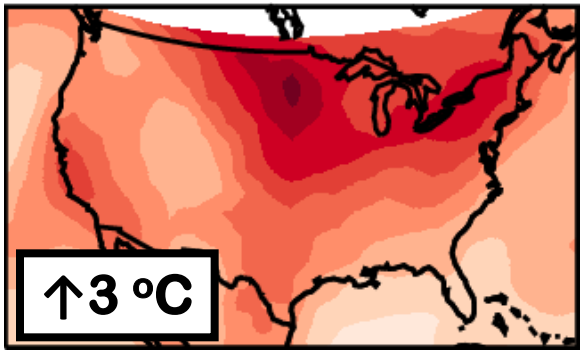
Annual Average in 2000



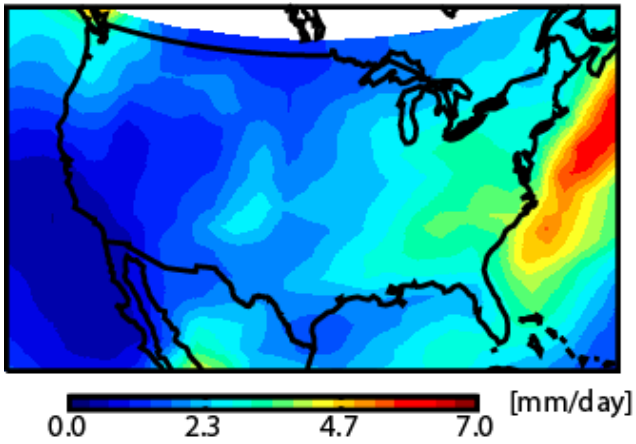
2050 RCP 4.5 - 2000

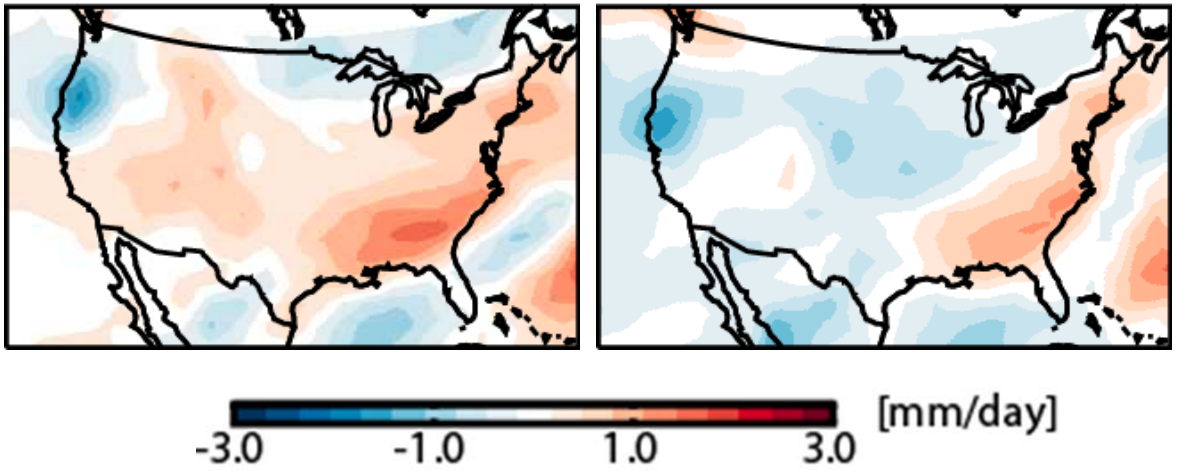


2050 RCP 8.5 - 2000



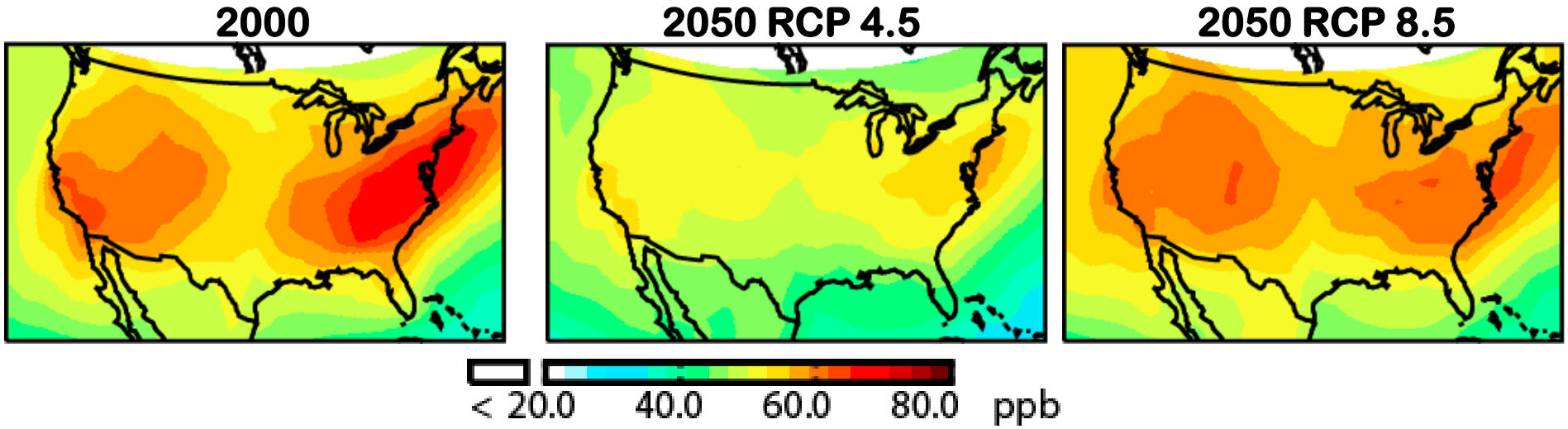
Precipitation



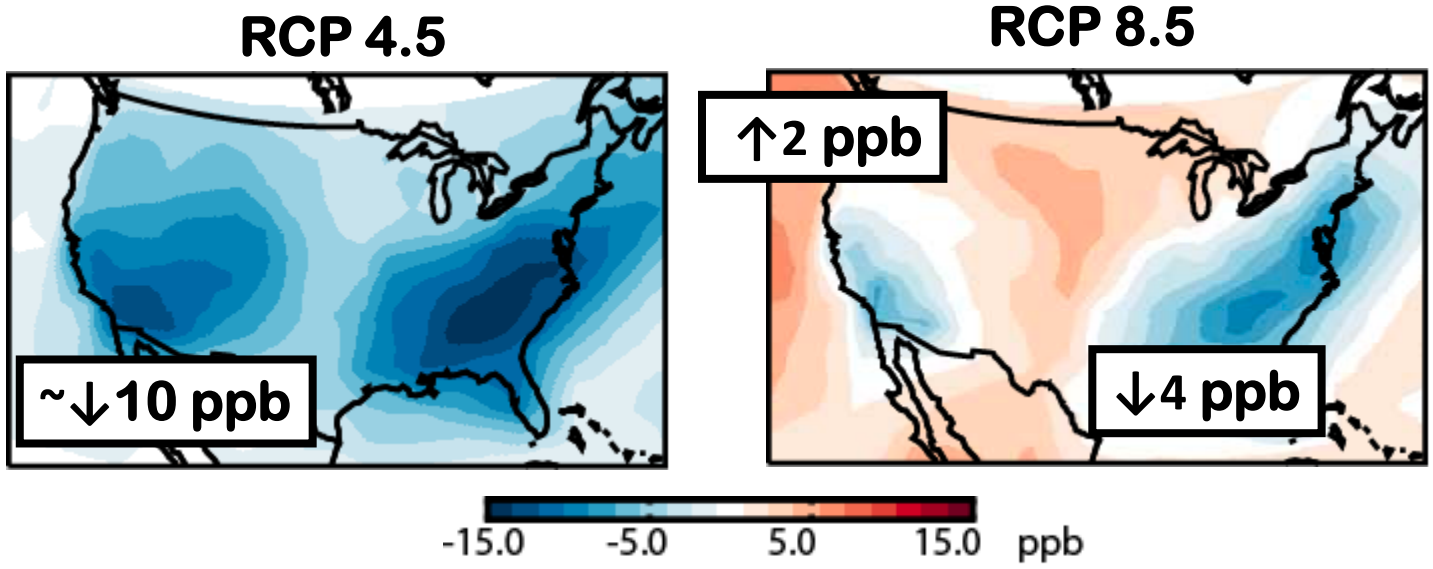


Effects of overall change on ozone

Summer Daily Max 8-hr Avg Surface O_3

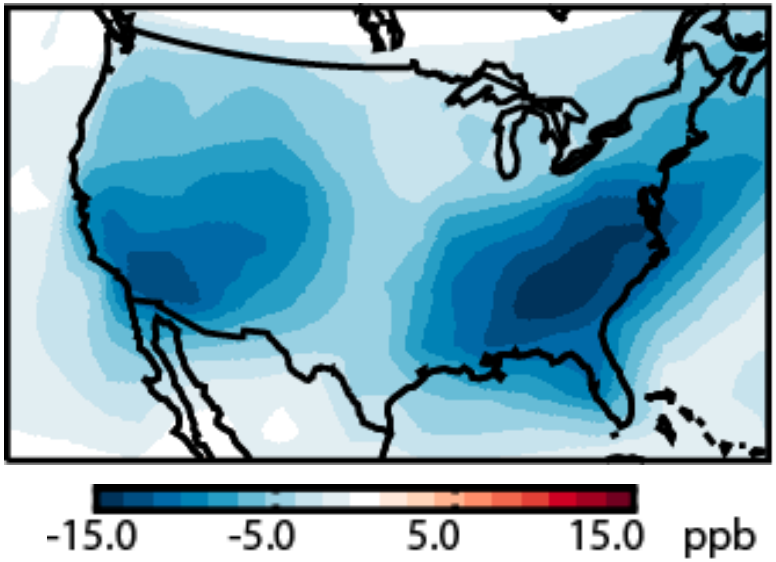


ΔTotal = 2050-2000



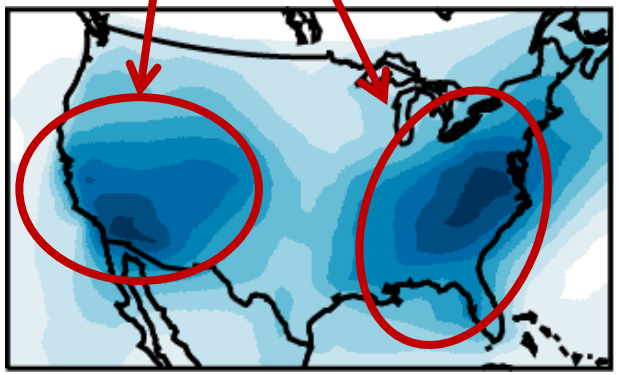
RCP4.5 projects an important O_3 reduction from decreased anthropogenic emissions

RCP4.5

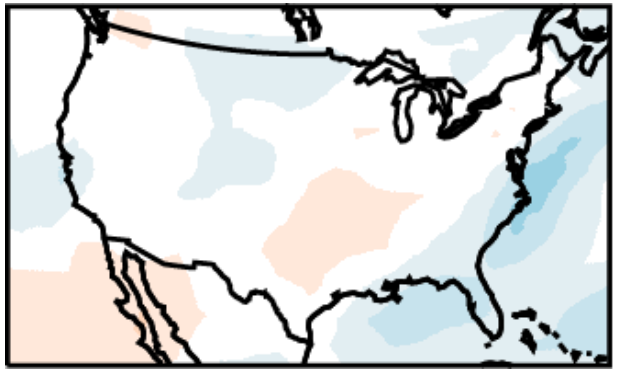


Important decrease in NO_x emissions

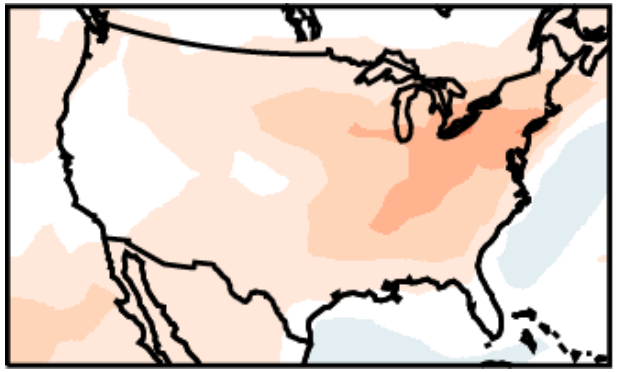
ΔAnthro Emissions



ΔClimate

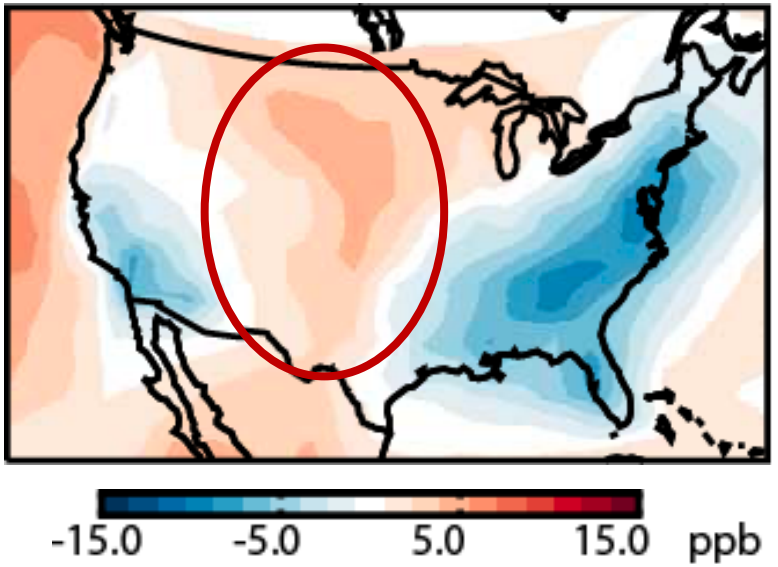


ΔLand Cover/Use

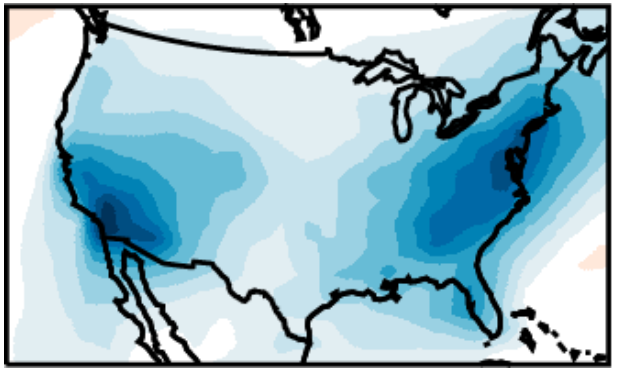


In RCP8.5, climate and land cover changes offset benefits from emission reductions

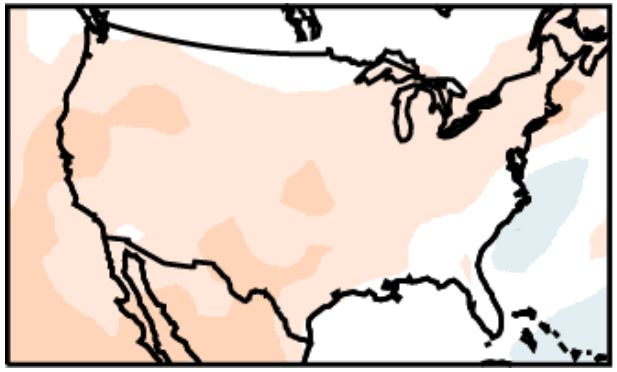
RCP8.5



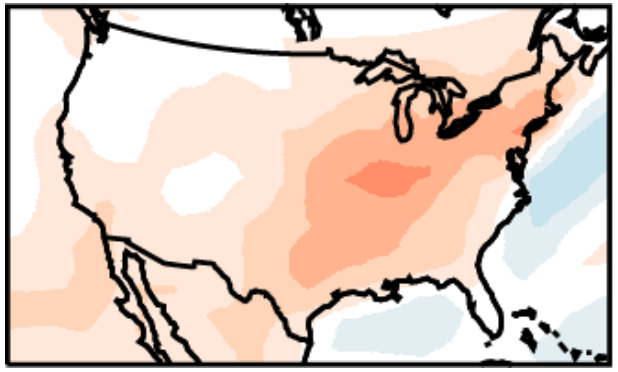
ΔAnthro Emissions



ΔClimate

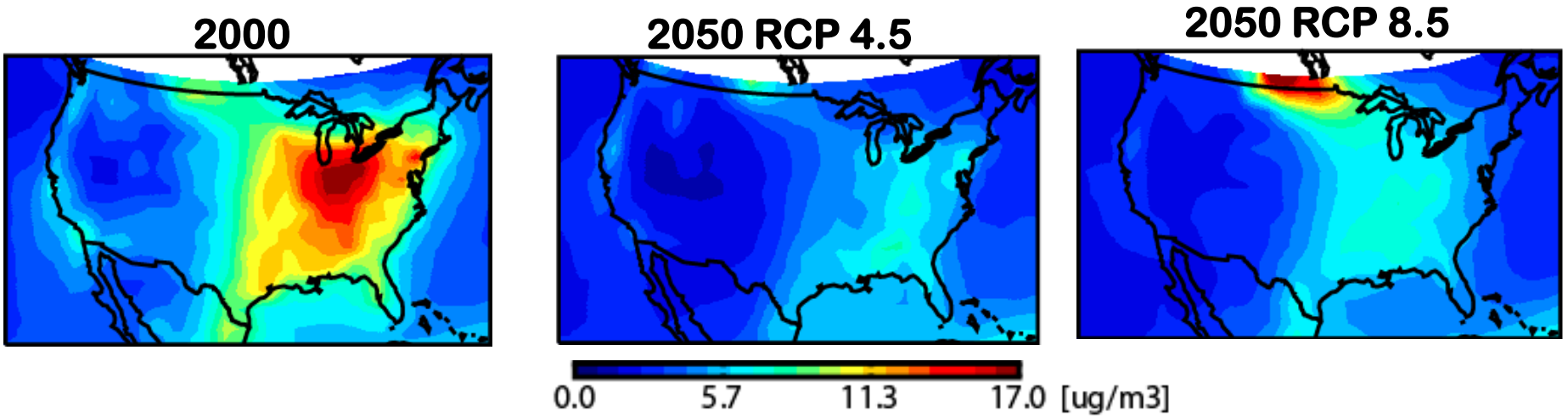


Δ Land Cover/Use



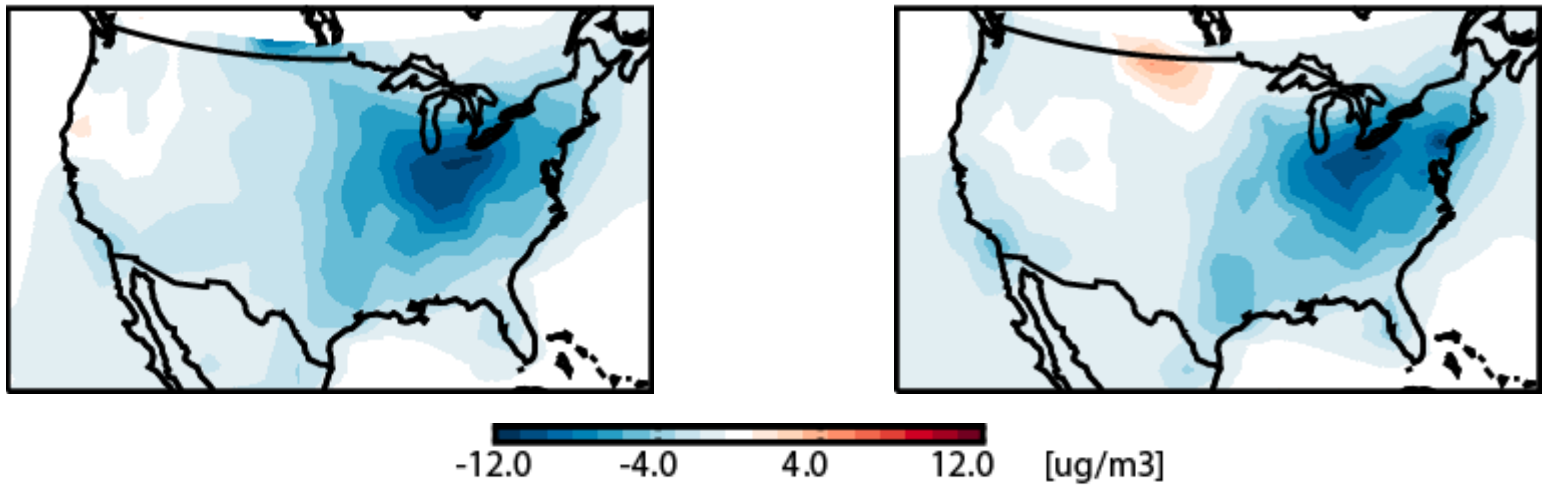
Both RCPs project a decrease in PM2.5

Annual Average PM 2.5



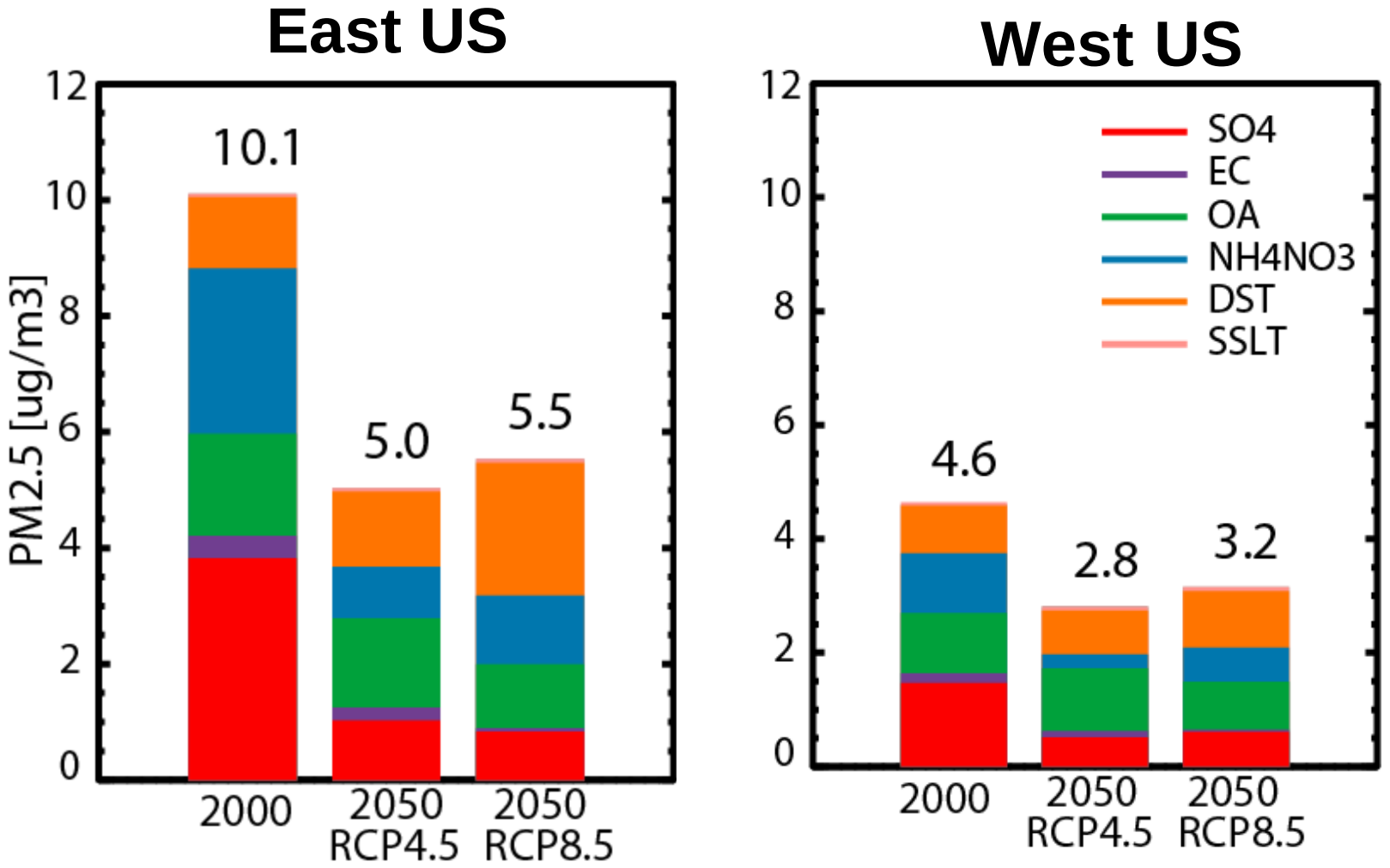
RCP 4.5

RCP8.5



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

Changes in Chemical Speciation



What is next…

Rocky Mountain NP affected by Haze

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

- Study the effect of nitrogen deposition.
- Perform high resolution (0.5x0.5) simulations, and analyze the effect of spatial resolution on the results.
- Focus on the air quality over the US National Parks

EXTRA

Performed (and Planned) Simulations

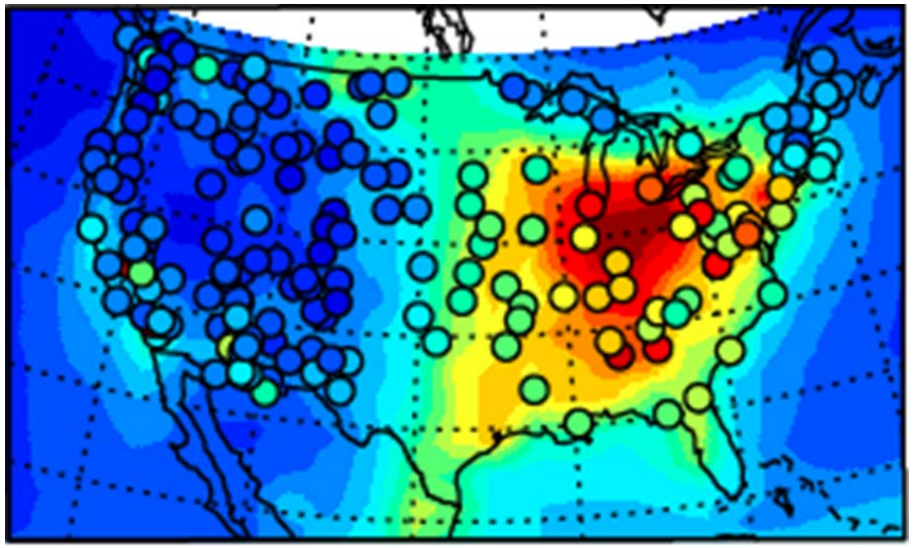
Simulations	2000 Climate	2000 Anthro Emissions	2000 Natural Emissions	2050 Climate	2050 Anthro Emissions	2050 Natural Emissions
1: 2000	X	X	X			
2: 2050				X	X	X
3:2050 Anthro	X		X		X	
4: 2050 Clima		X	X	X		
5:2050 Natur	X	X				X

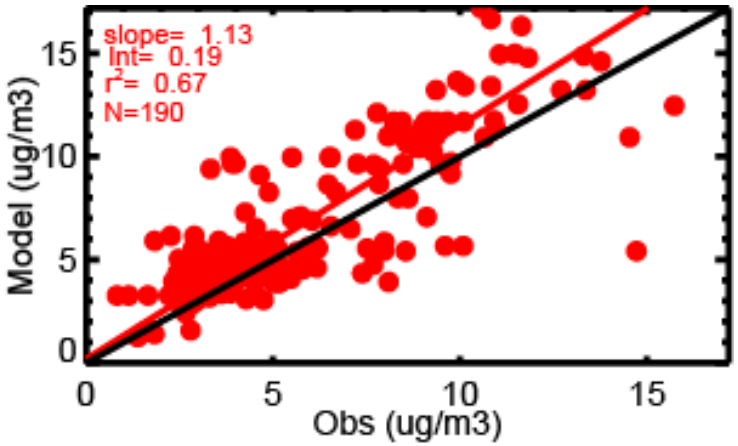
- Future simulations for RCP4.5 and RCP 8.5 scenarios
- We will repeat the runs for 10 different meteorological scenarios to estimate the effect of interannual climate variability.

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

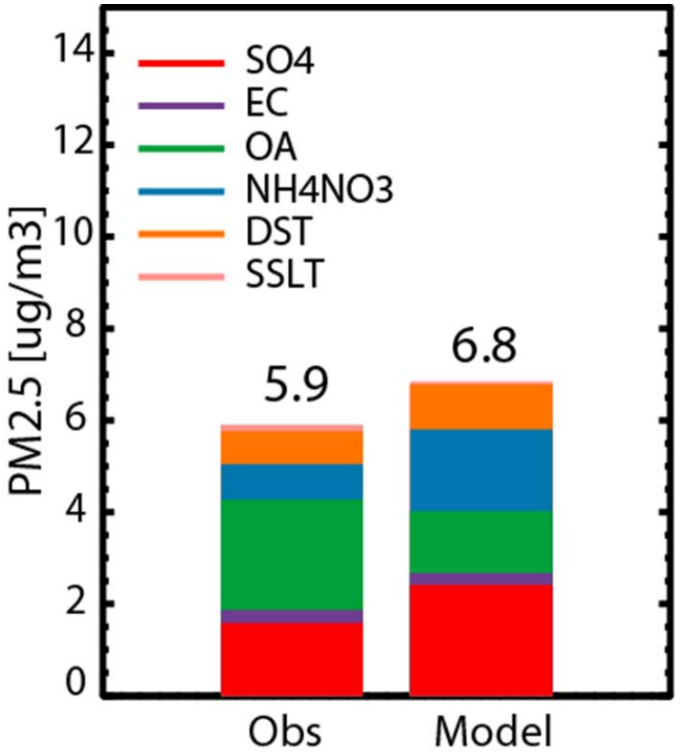
Model 2000 with IMPROVE observations (1998-2010)

Annual average





Chemical Speciation

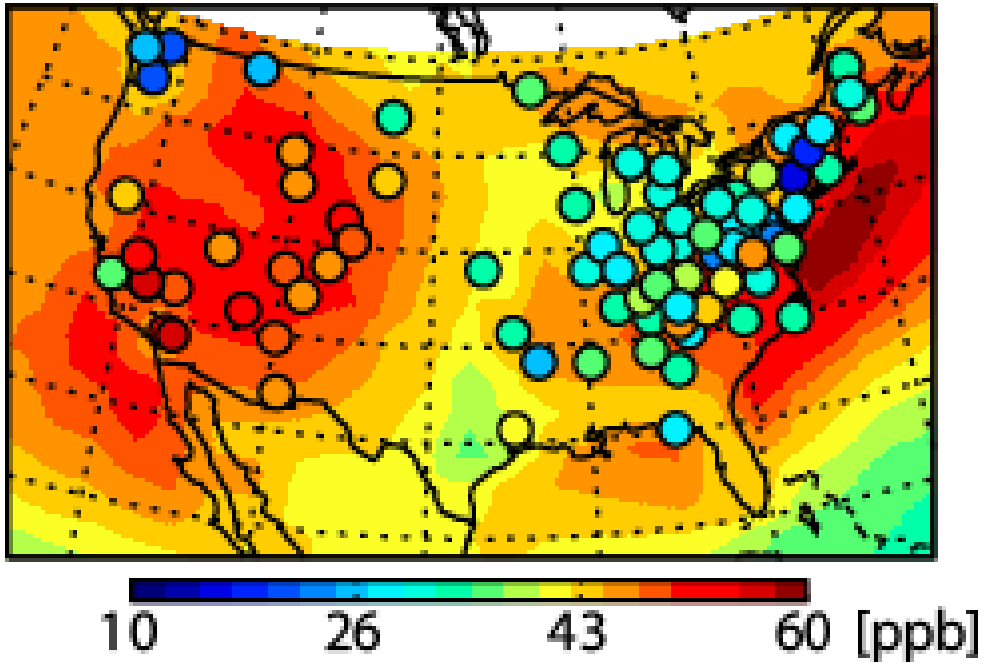


Overall, model captures the magnitude and spatial gradient of much of the IMPROVE PM2.5 observations

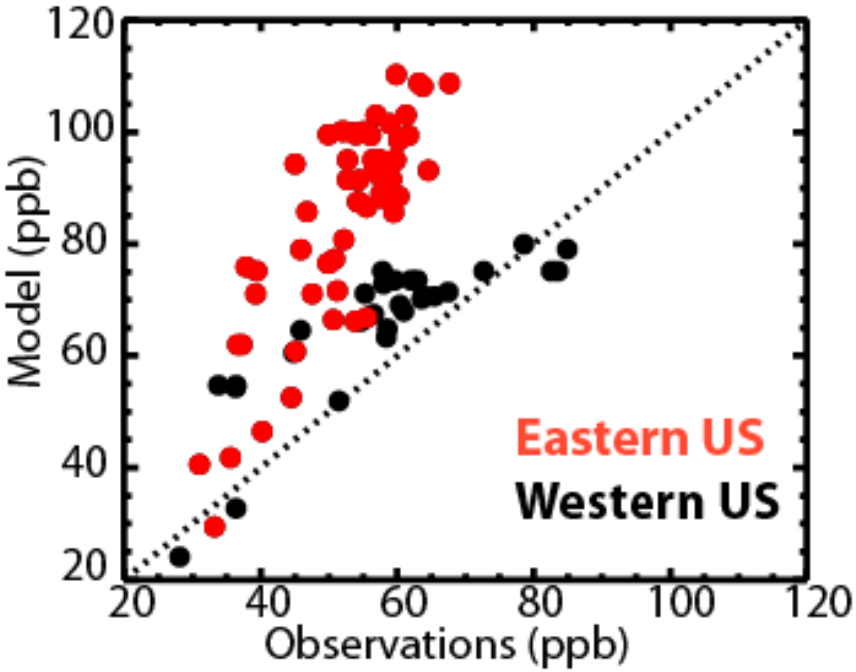
Further Model Evaluation: Ozone

Model 2000 with CASTNET Observations (1995-2005)

Annual average



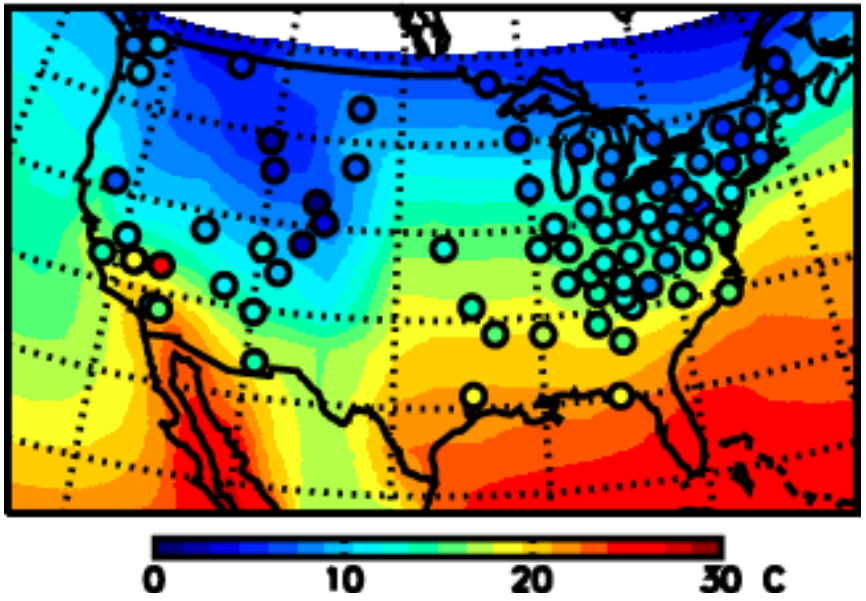
Summer Daily Max 8-hr Avg Surface O_3



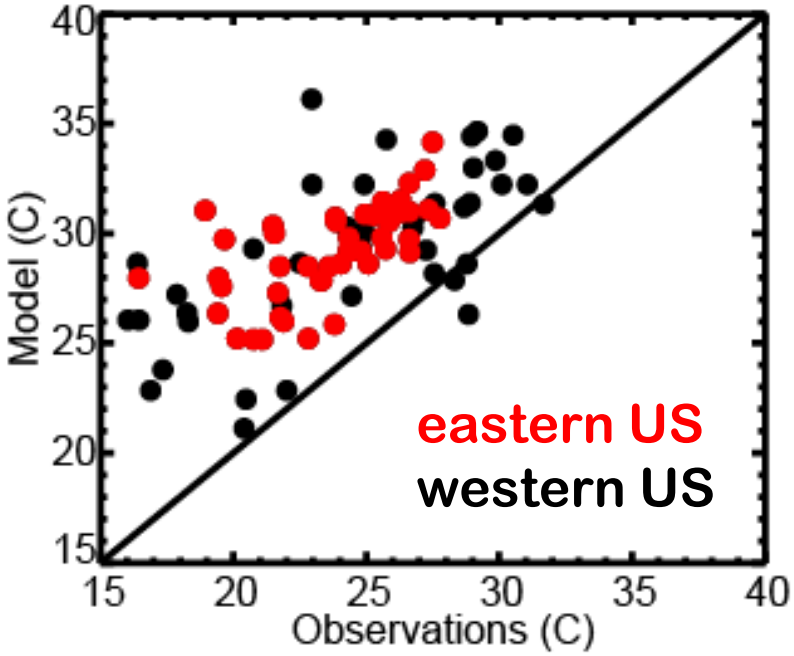
- O_3 is simulated well over western US, and overestimated over eastern US (~20 ppb).
- This strong positive bias in CESM and other models is well known [e.g., Fiore et al, 2008, Brown-Steiner and Hess, 2011].

Temperature does not explain the O_3 bias over the eastern US

Annual Average



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

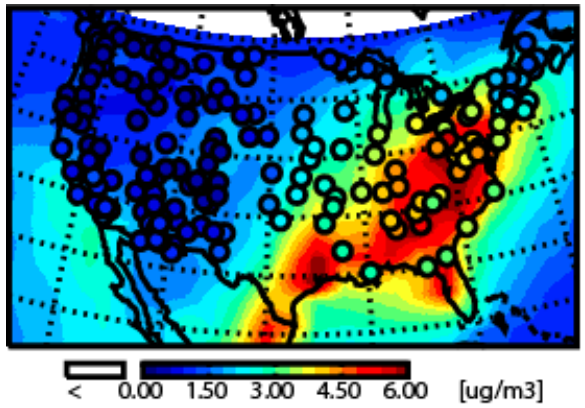


- On an average, model captures the magnitude and spatial gradient of much of the temperature
- Summer afternoon temperature is slightly overestimated

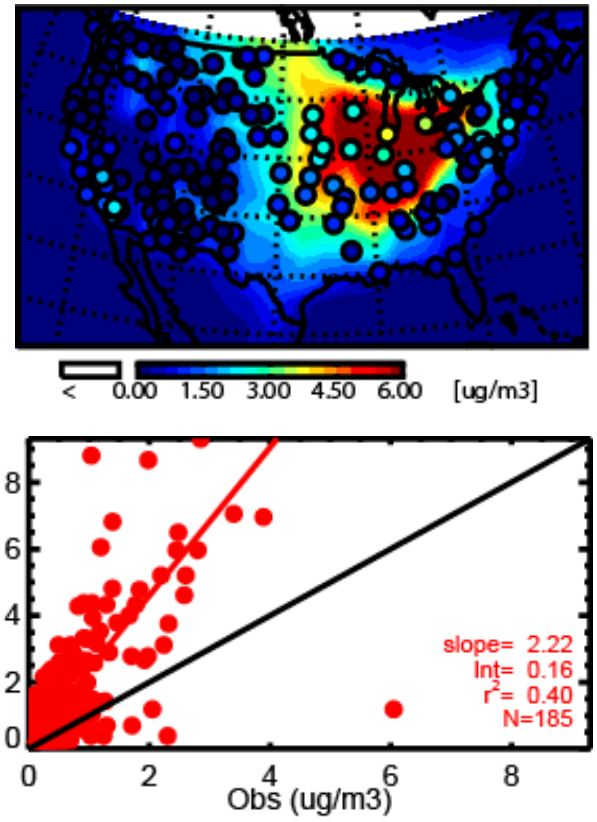
Model Evaluation: Sulfate and Ammonium Nitrate

Model 2000 with IMPROVE observations (1998-2010)

SO_4

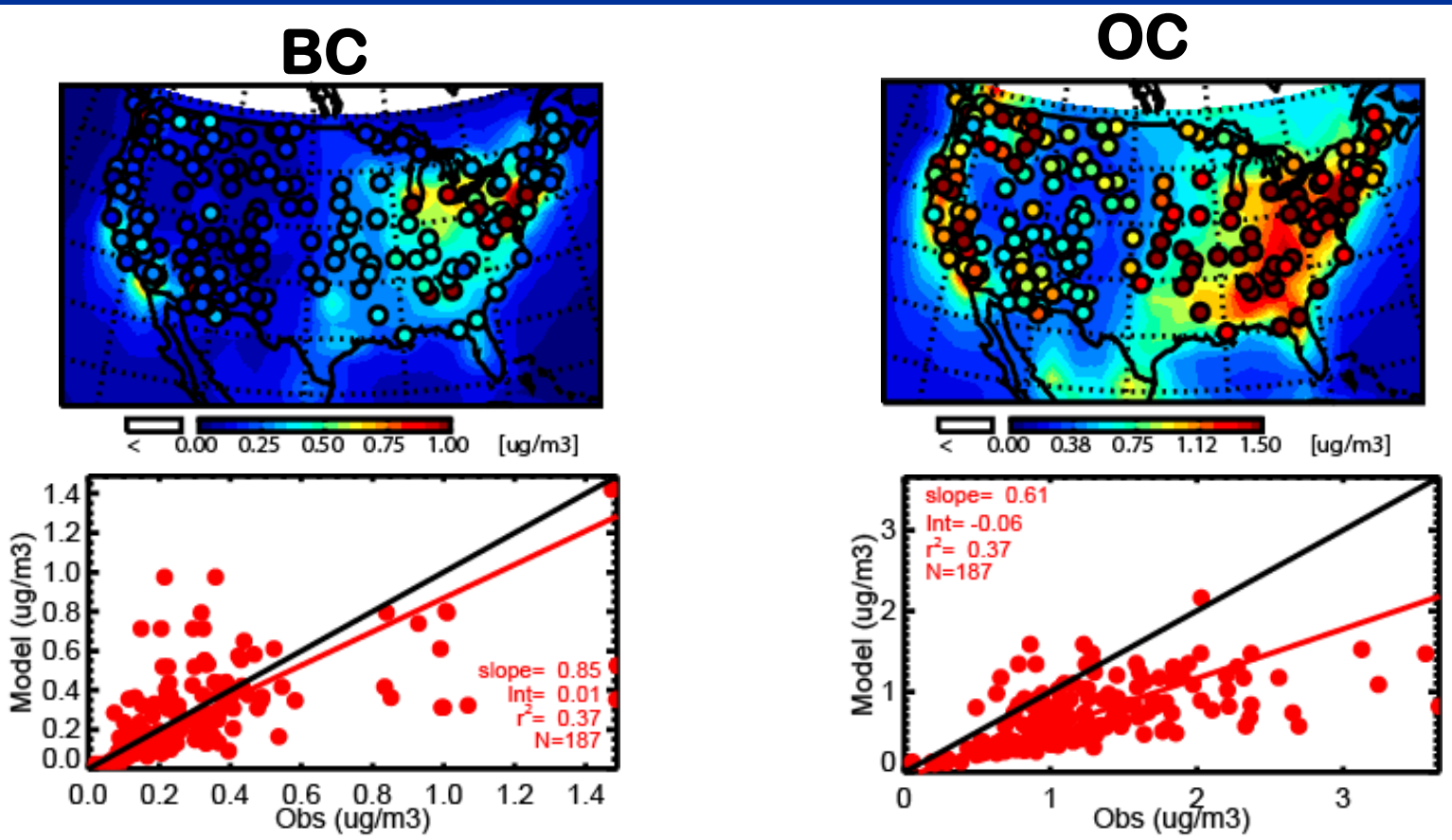


NH_4NO_3



The model captures the spatial gradients of much of the observations. NH_4NO_3 is overestimated in the Midwest.

Model Evaluation: Black Carbon, Organic Carbon, Fine Dust and Seasalt



- The model captures the spatial gradients, but low bias of OC compared to the IMPROVE observations.
- Dust and Seasalt not shown. Fine sea salt and dust emissions were adjusted in the model to match surface observations