Future Climate Scenarios, Atmospheric Deposition and Precipitation Uncertainty

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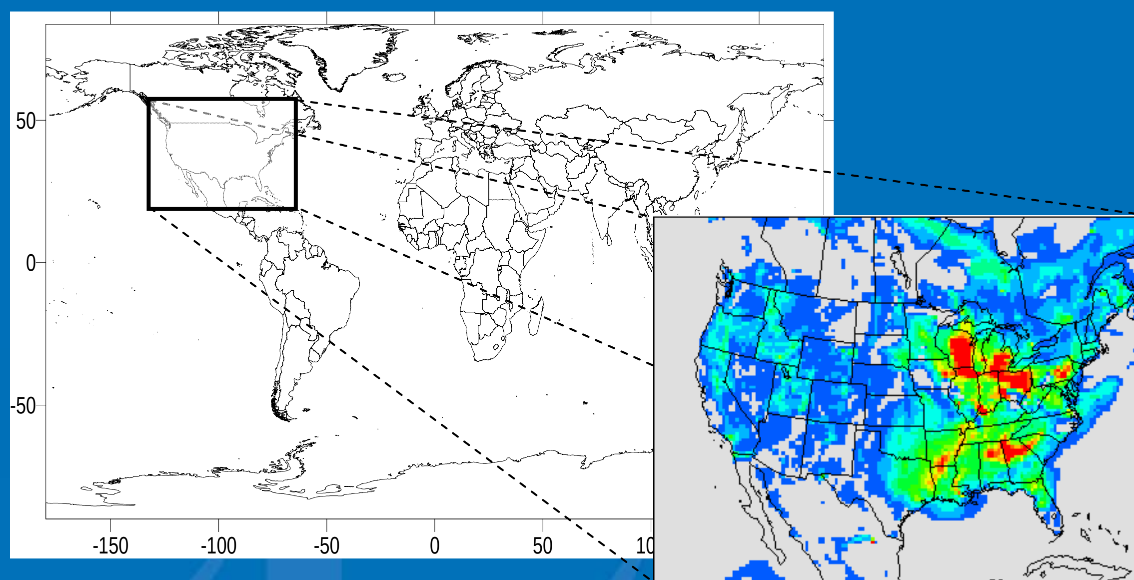


Future Climate and Atmospheric Deposition?

- Precipitation changes are fundamental to modeling climate impacts on wet deposition of aerosols
- Yet, future precipitation changes are more uncertain than trends in temperature (see IPCC Fourth Assessment Report)
- How do regional climate scenarios vary for future precipitation?
- Compare 2 existing model datasets available for this presentation
  1. Regional downscaling climate scenario used in the EPA/ORD/NERL "CIRAQ" air quality simulations
     - 1 of 6 climate and air quality simulations in EPA/ORD interim assessment report: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=181744
  2. NOAA Geophysical Fluid Dynamics Laboratory (GFDL) CM2.1 global climate model "timeslice" @ 50km grid resolution
     - North American Regional Climate Change Assessment Program (NARCCAP): http://www.narccap.ucar.edu/
- Compare to NADP and PRISM precipitation data (http://www.prism.oregonstate.edu/)

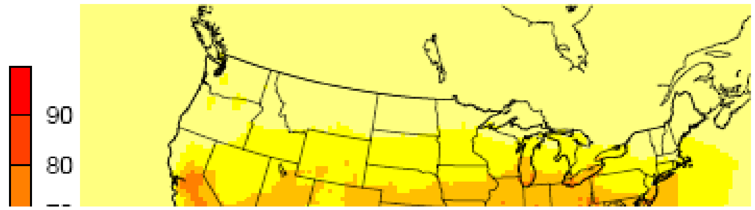
Background Information for CIRAQ Scenarios

- Regional Downscaling Climate Scenarios developed by PNNL
  - MM5 regional simulations: Leung and Gustafson, *GRL*, 2004; Gustafson and Leung, *BAMS*, 2005
  - NASA GISS II' simulations provided initial and boundary conditions, GHGs: Mickley et al., 2004
  - IPCC SRES A1B GHG scenario

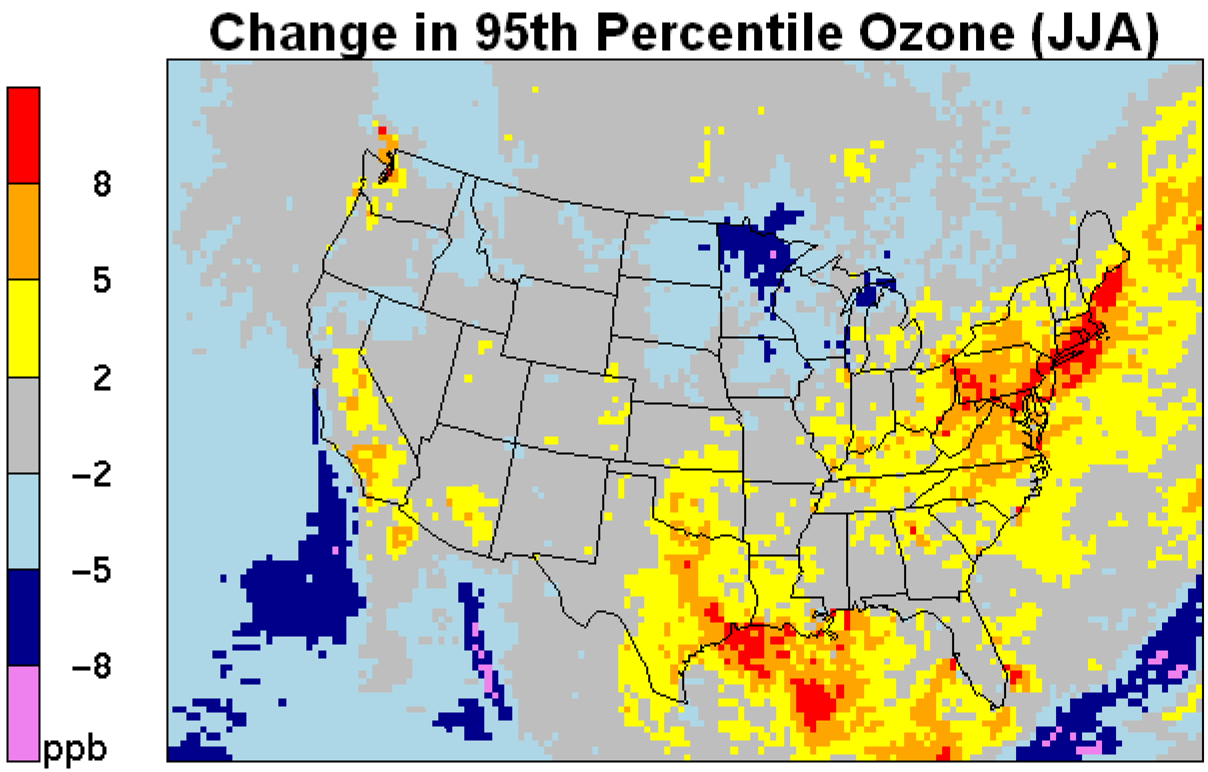
- USEPA/ORD/NERL developed regional air quality simulations using these regional climate scenarios
  - Community Multiscale Air Quality model simulations: Nolte et al., *JGR Atm.*, 2008
  - Given the large uncertainties in future precipitation and climate change, focus has been on ozone impacts from climate
  - Next slide shows example of the results from this study

Future vs. Current CMAQ Max. Daily 8hr O_3(MDA8) : June – August Mean

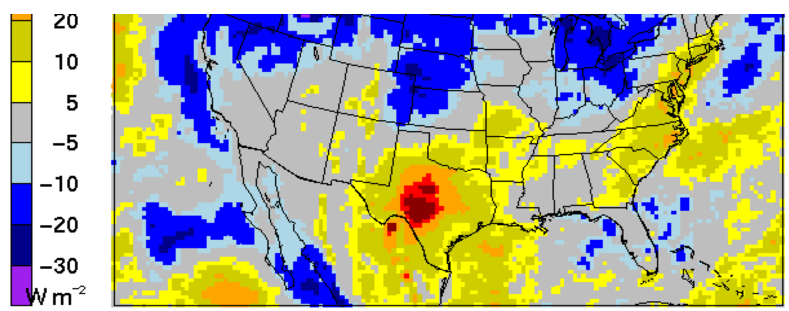
Mean MDA8 O3 (ppb),
Jun-Aug “1999-2003”
(Current)



Change (futu
mean Jun-Au
Future =
- **“2048-52” A**
- **2001 anthro**
emissions



ppb increase
X, eastern
.;
parable
reases in
west, PNW

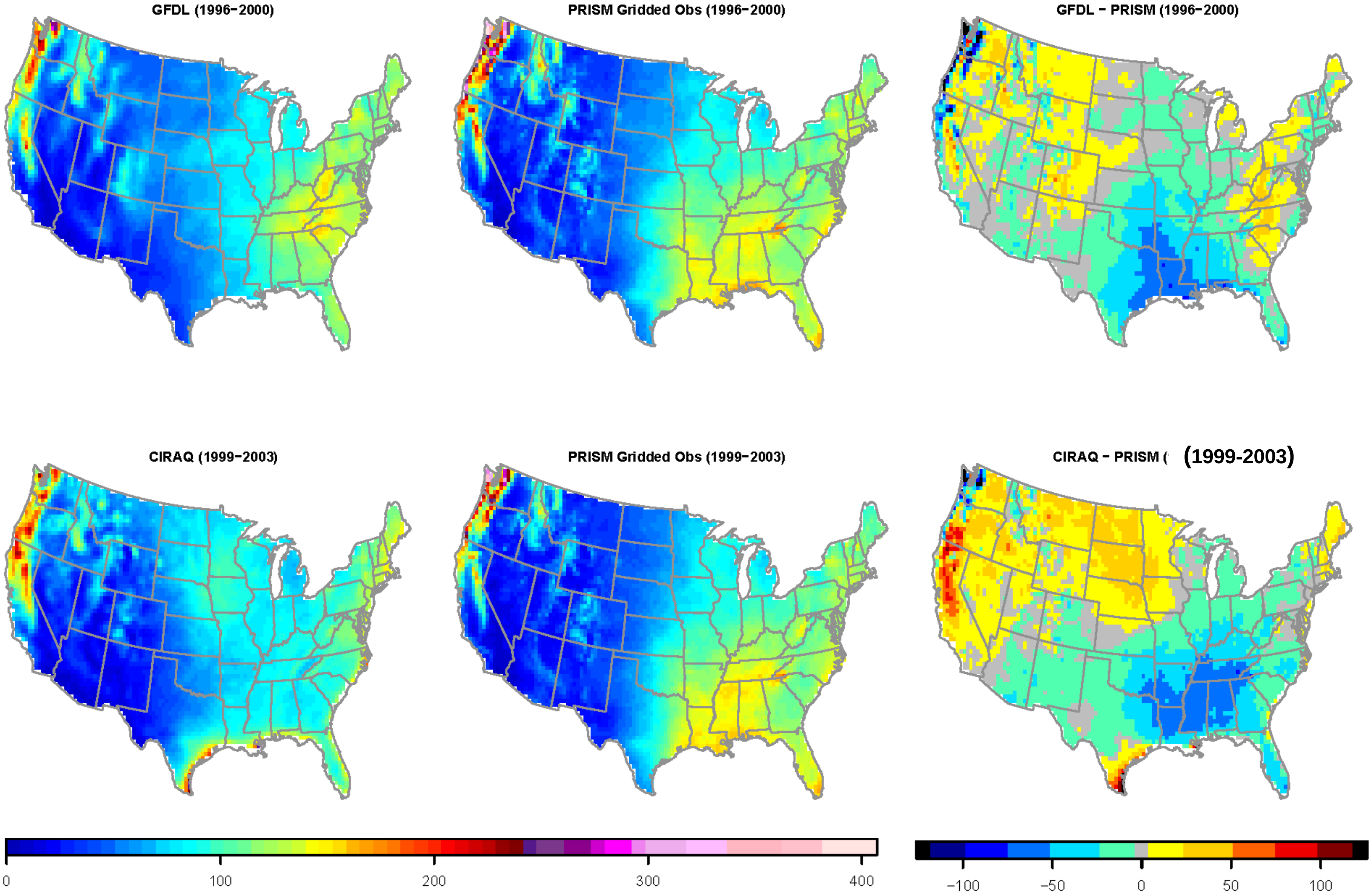


Nolte, Gilliland, Hogrefe, and Mickley, J. Geophys. Res., 2008.

Background Information for GFDL Scenarios

- NOAA Geophysical Fluid Dynamics Laboratory (GFDL) CM2.1 global climate model "timeslice" developed as part of the North American Regional Climate Change Assessment Program (NARCCAP)
- GFDL CM2.1 "timeslice" used $2^{o} \times 2.5^{o}$ CM2.1 GCM simulation and "nested" a 50km ×50km resolution global simulation for 1996-2000 and 2046-2050.
- A series of regional climate simulations using mesoscale models (e.g., WRF) are under development
- All "timeslice" and regional downscaling experiments are relying on the IPCC SRES A2 scenario
- Using GFDL "timeslice" results available now from NARCCAP, next slide compares precipitation from GFDL, CIRAQ, and observations under current climate

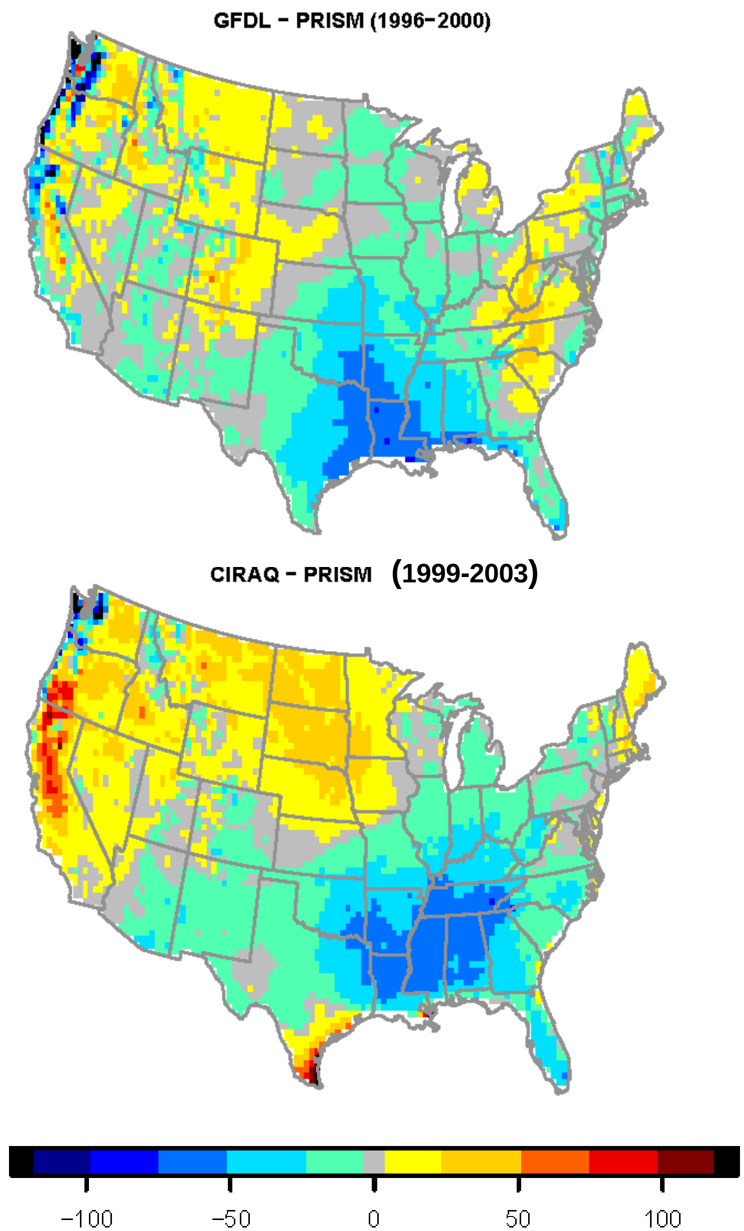
5 Year Annual Average Accumulated Precipitation (cm)



PRISM data information: http://www.prism.oregonstate.edu/

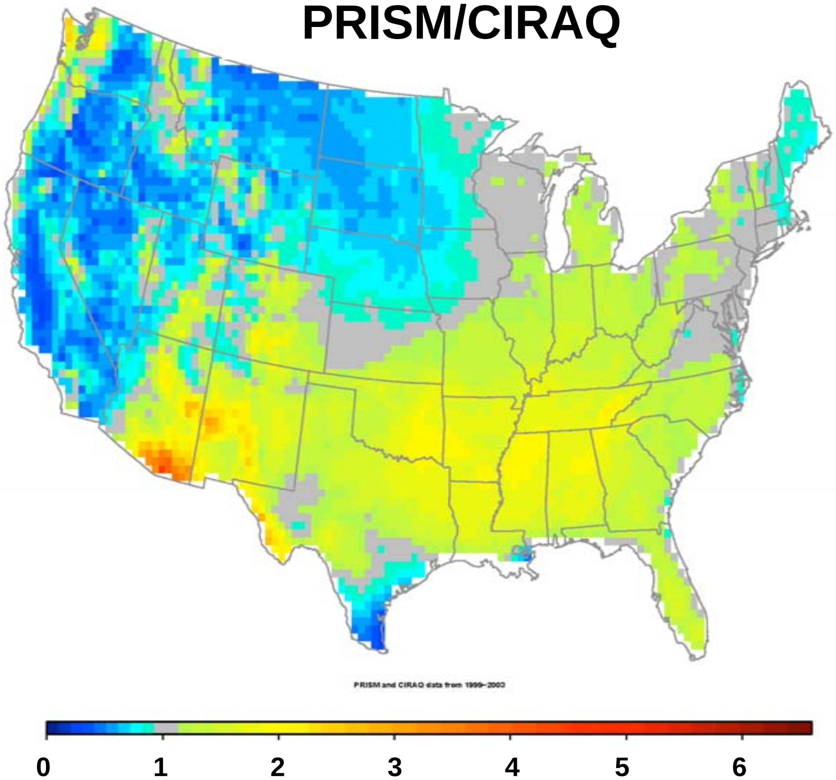
Regional Climate Scenarios – PRISM Observations Differences in 5 year accumulated precipitation (cm)

- CIRAQ regional climate scenarios have larger biases in Southeast and Western Coast than GFDL "timeslices"
- Large overpredictions west coast primarily occur in winter months
- Underprediction biases in southeast primarily occur in summer months
- How would wet deposition estimates from CIRAQ study have changed with different precipitation (current climate)?

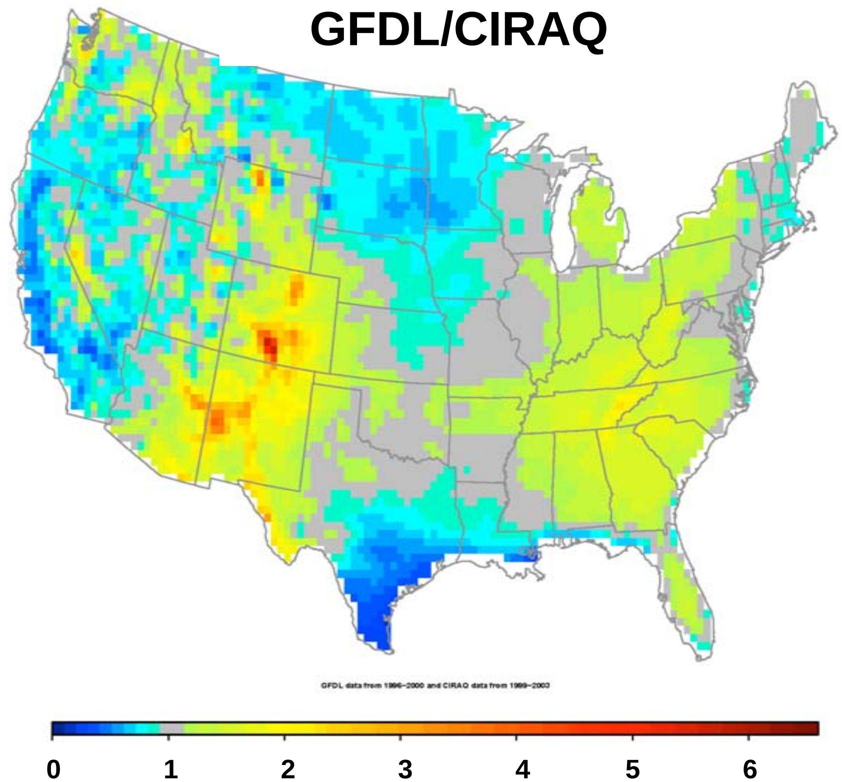


Adjustment of SO_4 Wet Deposition as function of Precipitation

Precipitation Ratio: PRISM/CIRAQ



Precipitation Ratio: GFDL/CIRAQ



- Simple adjustment: [5-yr accumulated SO_4 deposition * Precipitation Ratio]
- Compare to NADP SO_4 wet deposition measurements
- Use precipitation adjustment ratio from both PRISM and also GFDL
    - GFDL “timeslice” evaluated better against PRISM
    - Crude estimate wet deposition under different future climate scenarios
- Could help to select regional climate scenarios for air quality modeling

(cm)

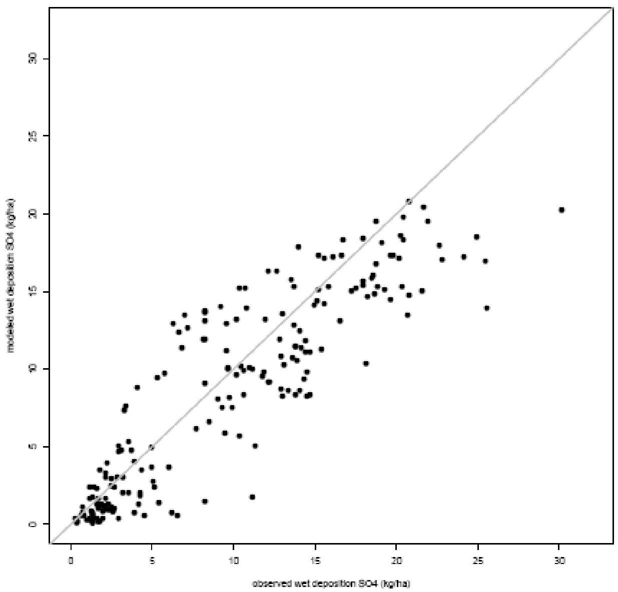
0 100 200 300 400

(kg/ha)

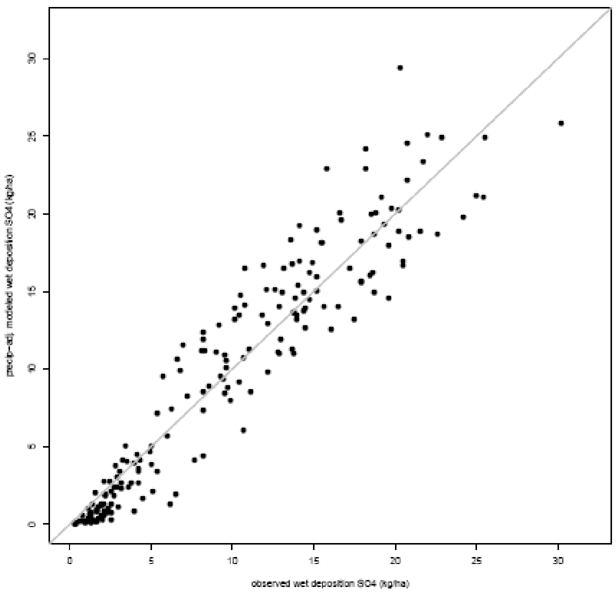
0 5 10 15 20 25 30 35

How do these 3 compare against NADP SO_4 wet deposition?

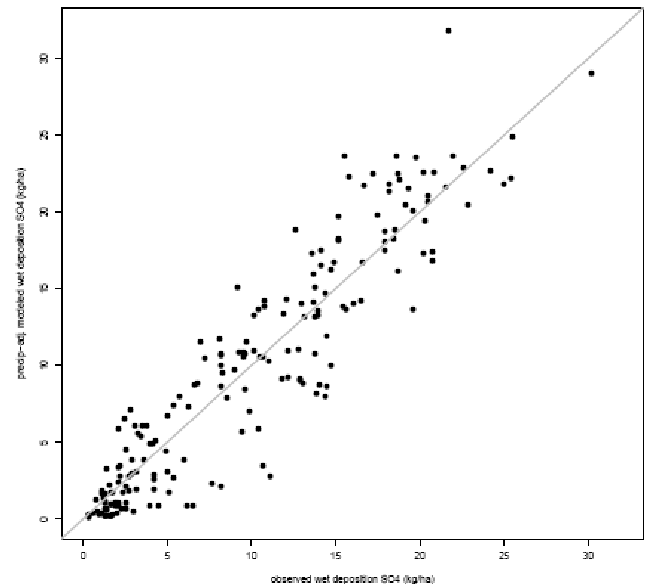
NADP vs CIRAQ SO_4



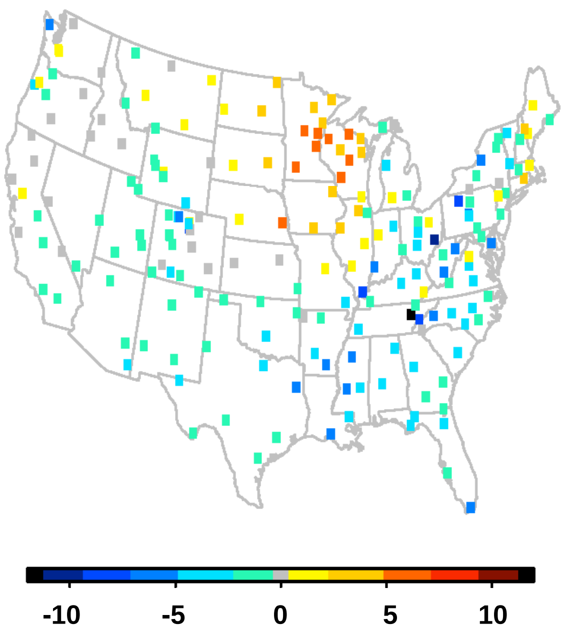
NADP vs NADP/CIRAQ Precip. Adjusted SO_4

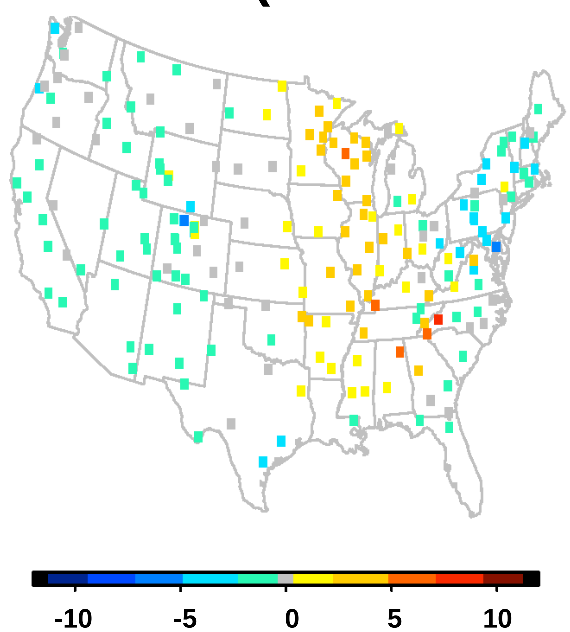


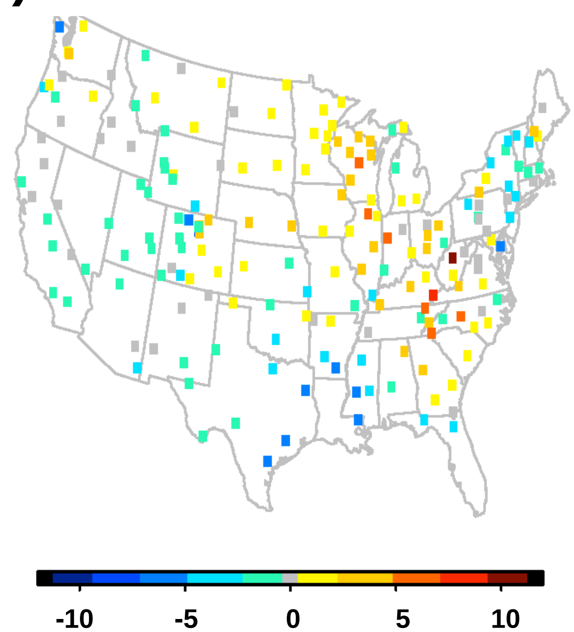
NADP vs GFDL/CIRAQ Precip. Adjusted SO_4



Difference (NADP – Model)







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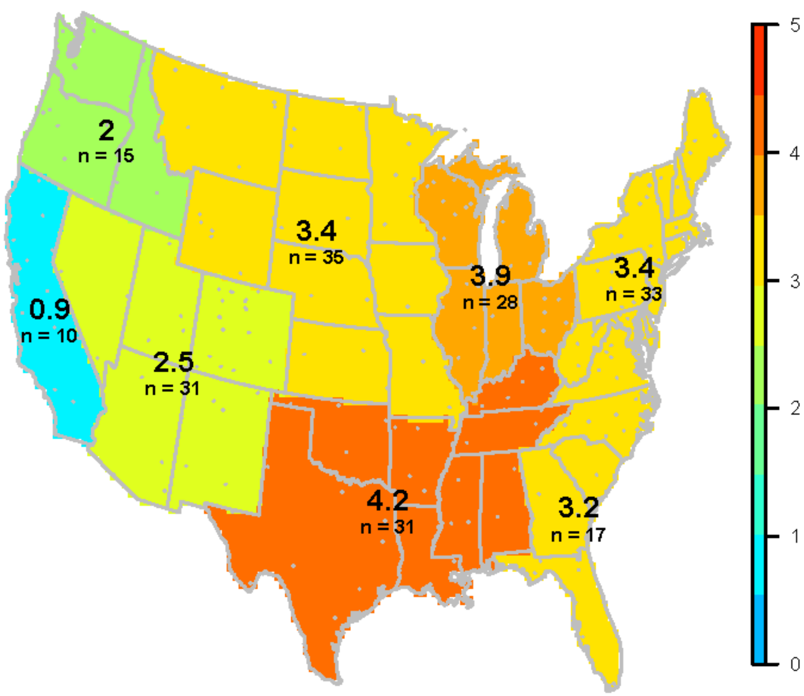
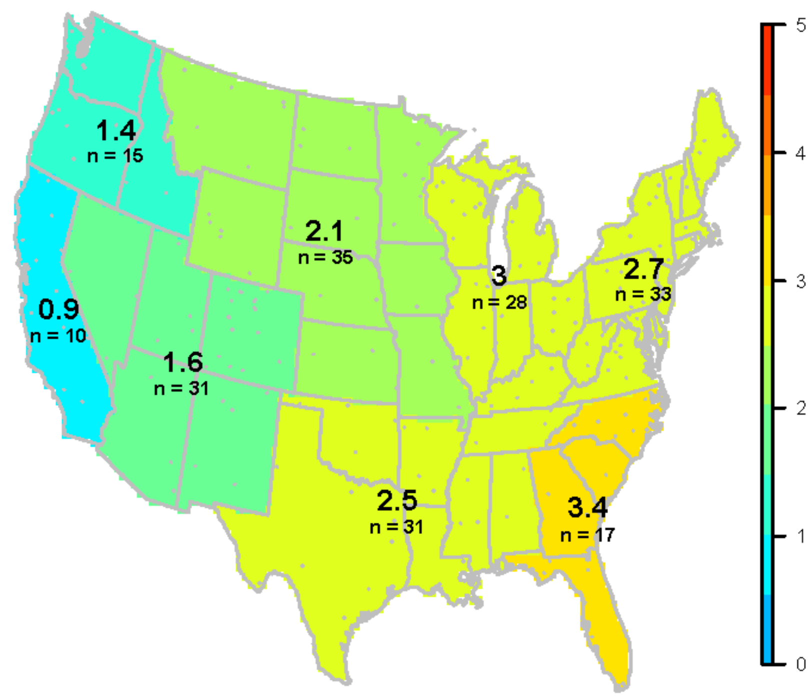
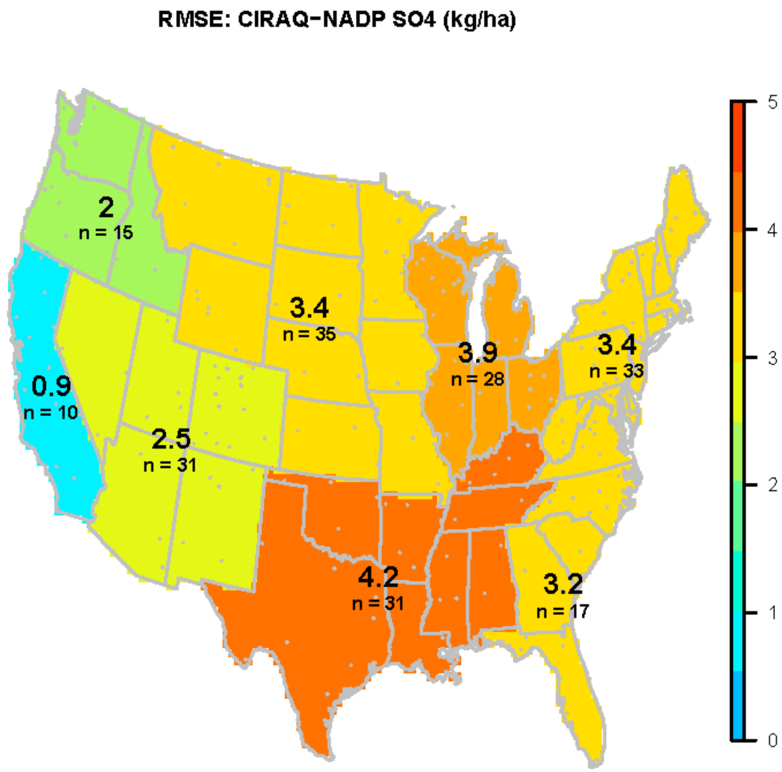
RMSE for CIRAQ - NADP Wet Deposition SO4 (1999-2003)

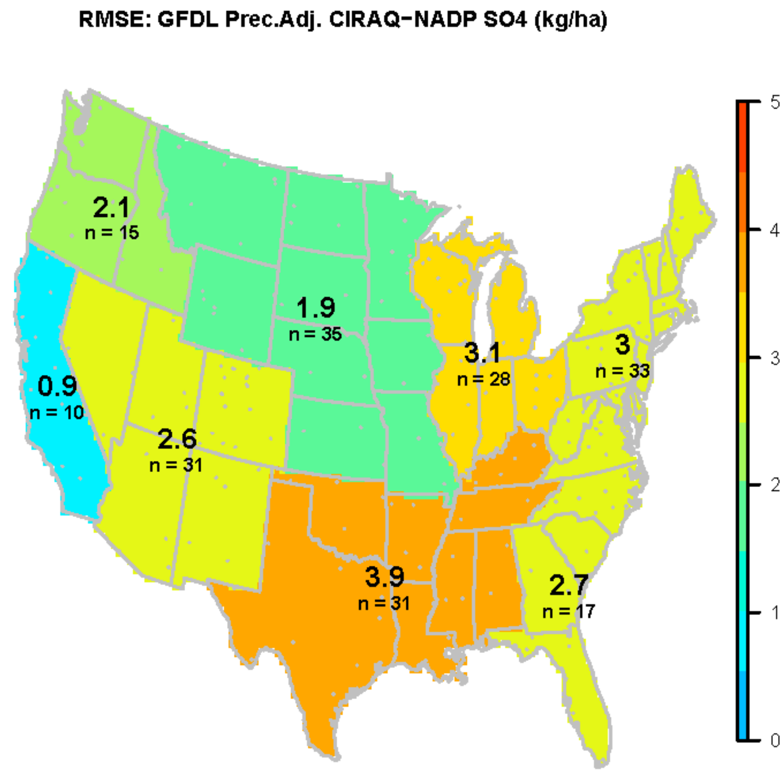


RMSE for Precip. Adjusted CIRAQ - NADP Wet Deposition SO4 (1999-2003)

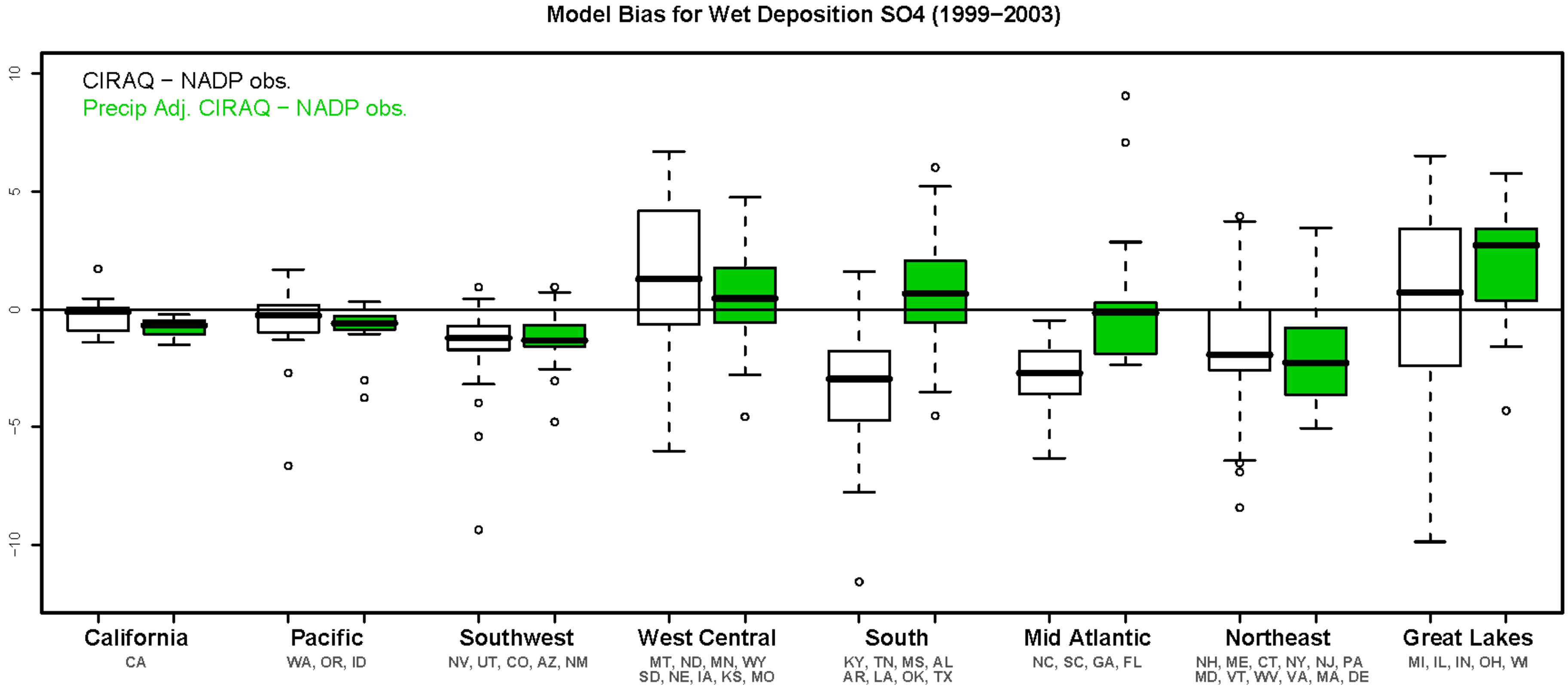


- Using the simple adjustment against PRISM precipitation, SO_4 deposition estimates have lower RMSE in most regions.





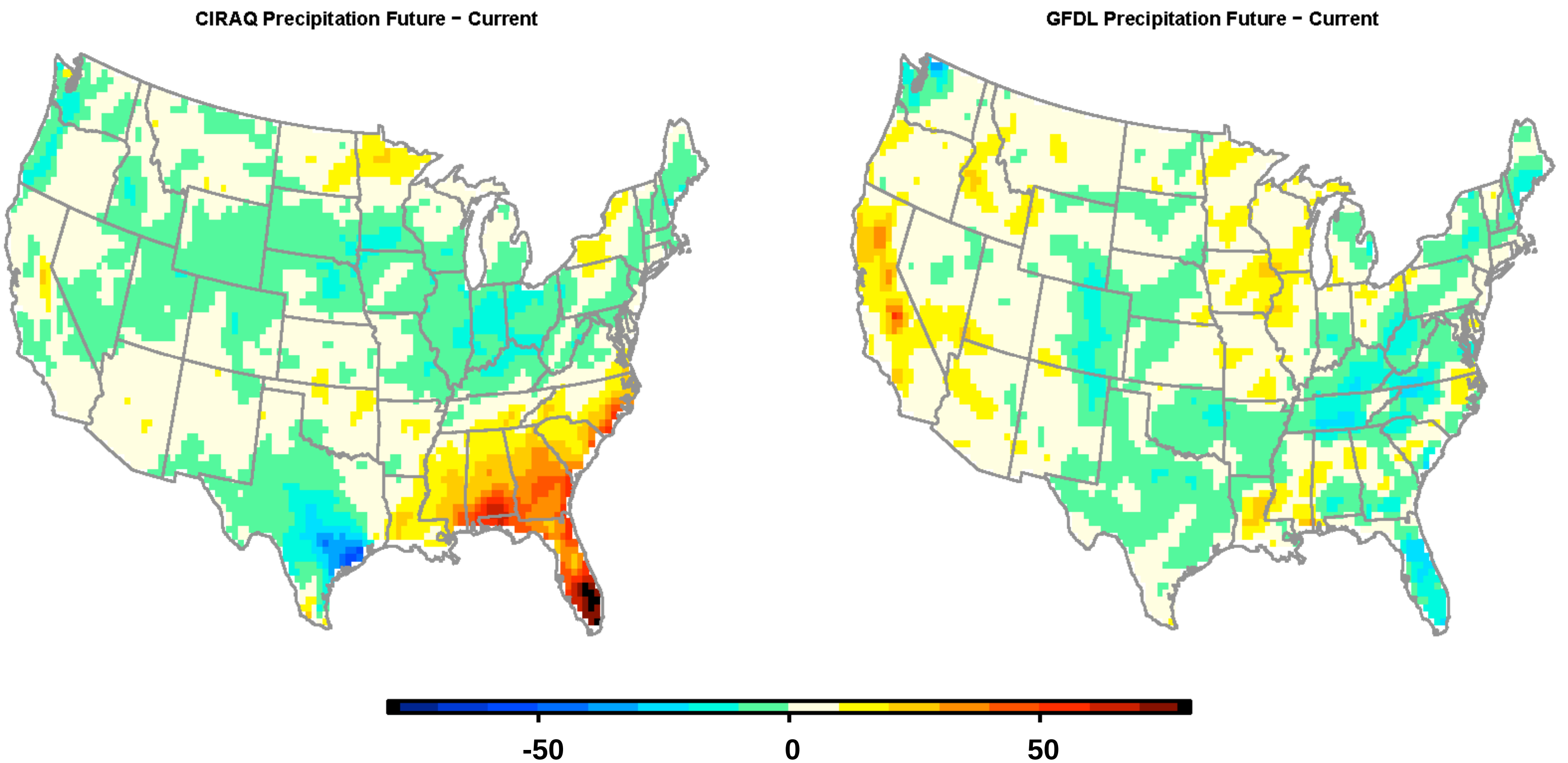
- Using the GFDL 5-year accumulated precipitation (1996-2000) for the precipitation adjustment of SO_4 deposition leads to modestly lower RMSE in most regions.



- The adjustment helps to reduce spread of model-obs differences
- Bias can be larger in some cases after adjustment (Northeast)
- Will apply a similar method for sulfate deposition in current vs. future climate
- Results for NO_3 and NH_4 deposition more mixed; will just focus here on SO_4 5-yr average, annual accumulated totals for now

How do the two Future – Current precipitations compare?

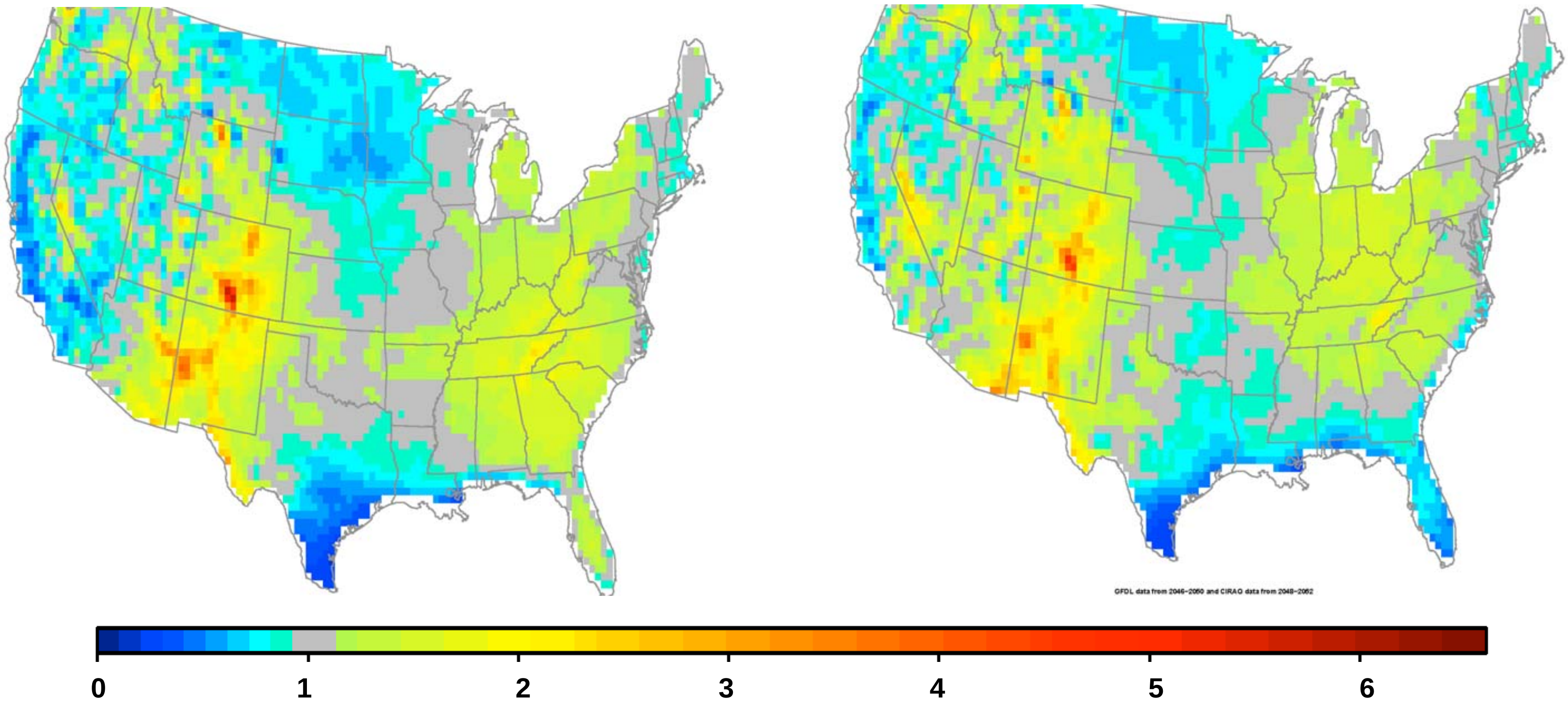
5-yr average of accumulated annual precipitation (cm)



- CIRAQ regional climate scenario has <u>large</u> increases in future precipitation in the Southeast, localized large decrease in southeast TX
- GFDL “timeslice” scenario does not show similar increases in the Southeast, larger increases in precipitation in localized areas of California

Adjustment Ratio
5-yr Current: GFDL/CIRAQ precipitation

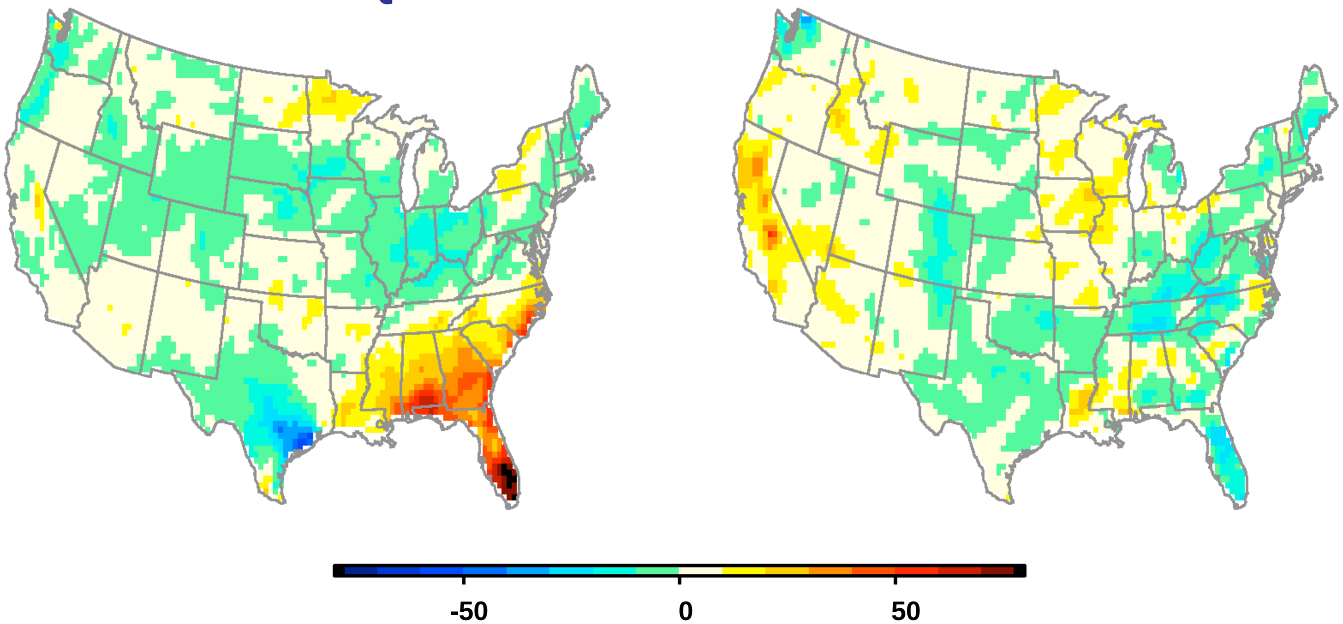
Adjustment Ratio
5-yr Future: GFDL/CIRAQ precipitation



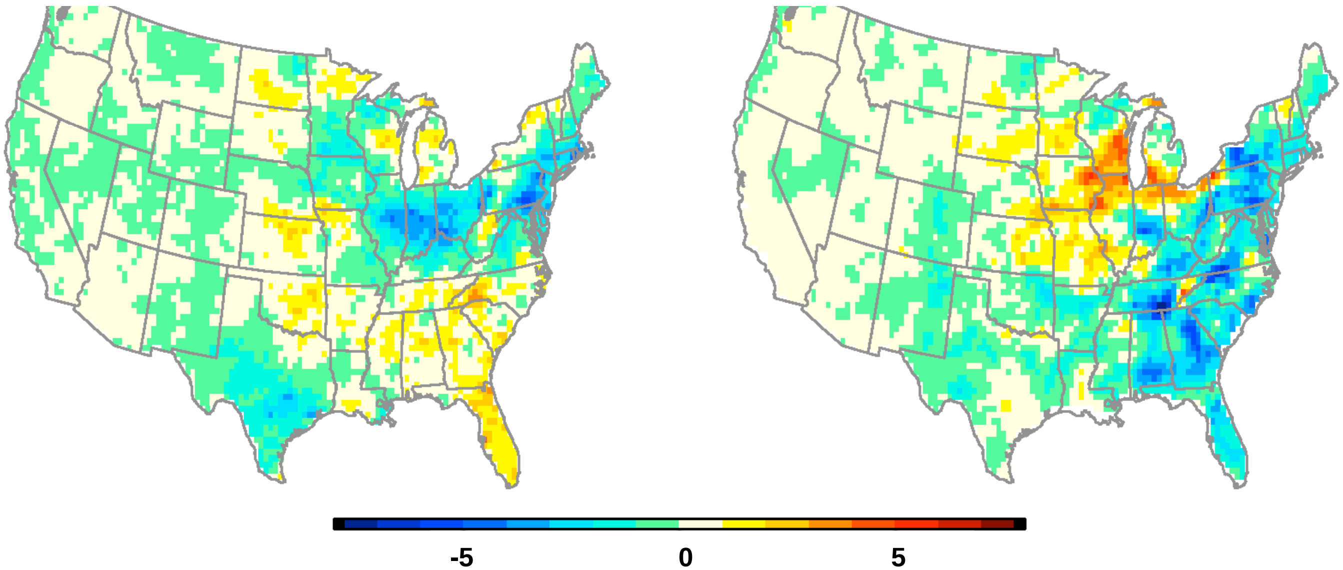
- **GFDL/CIRAQ precipitation ratios are very similar under current and future (2050)**
  - **CIRAQ drier in Eastern US and CO, NM, AZ, WY**
  - **CIRAQ wetter along Gulf coast, CA coast, and upper Midwest**
- **Ratios are applied to CMAQ SO_4 wet deposition for current and future simulations and then compared (future-current)**

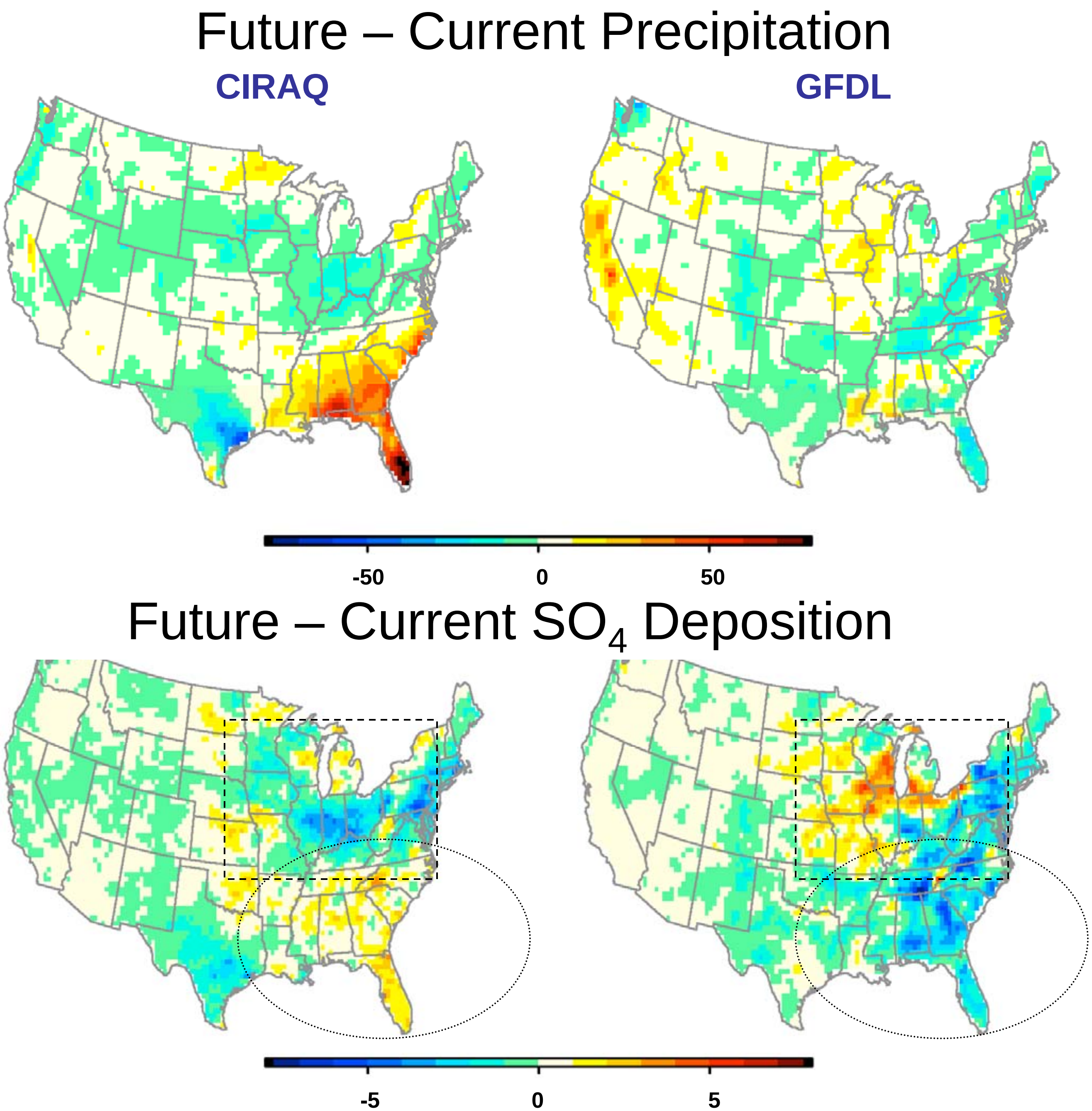
Future – Current Precipitation *(5-yr average, annual accumulated, cm)*

CIRAQ **GFDL**



Future – Current SO_4 Deposition *(5-yr average, annual accumulated, kg/ha)*





Some spatial correlation between changes in precipitation and SO_4 deposition.

Very different patterns in future precipitation change (GFDL vs CIRAQ).

SO_4 deposition changes are drastically different in Southeast and upper Midwest.

Summary and Conclusions

- Predicted precipitation changes are fundamental to model estimates of nutrient wet deposition changes
- Future changes in precipitation (related to climate change) are very uncertain
- To develop more confidence in how future climate may change wet deposition of aerosols, a range of future scenarios is needed
- Ensemble regional-scale climate scenarios (e.g., NARCCAP) can help to assess what precipitation changes may be expected
- Using simple adjustment methods and existing model estimates of sulfate deposition (and other efficiently scavenged species?) can be tested with various future precipitation scenarios
- In parallel, further development and evaluation of regional climate scenarios will continue for air quality and future climate studies

Acknowledgements

- NARCCAP: Seth McGinnis for providing the GFDL timeslice experiments, Isaac Held and Bruce Wyman from GFDL for generating the GFDL "timeslice" simulations
- PNNL: Ruby Leung and Bill Gustafson for generating the CIRAQ regional climate downscaling scenarios.
- Harvard University: Loretta Mickley for generating the GISS II' GCM and ozone chemistry results for the CIRAQ regional downscaling and chemical boundary conditions