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Multi-model assessment of climate and emission projections on atmospheric nitrogen loading to the Chesapeake Bay

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Motivation

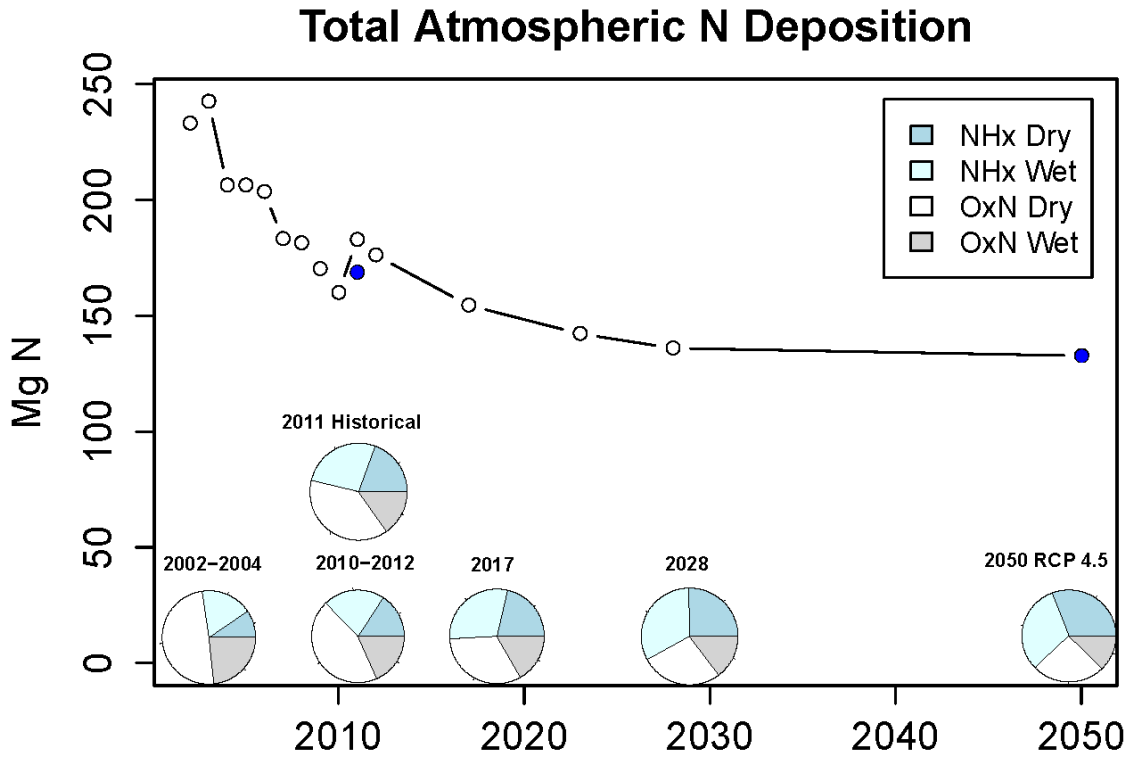
- Atmospheric deposition is one of the largest sources of nitrogen loading to the Chesapeake Bay Watershed
- Emission reductions due to the Clean Air Act have resulted in a large reduction in atmospheric nitrogen deposition to the Chesapeake Bay Watershed
- How will climate change impact atmospheric nitrogen loading to the Bay?
  - Will it offset emission reductions?
  - Explored using multi model simulations for RCP 4.5 and 8.5 scenarios

Methods

- WRF 3.6 dynamical downscaling of NOAA's Coupled Climate Model version 3 and NCAR's Community Earth Systems Model for RCP 8.5
  - Uses large scale forcing from global circulation models and uses WRF model physics parameterizations for fine scales
  - Hourly meteorology output at 36 km resolution
- 2011 emission estimates for historical period and 2040 forecast emissions for 2100
- CMAQ v5.3 beta simulations to estimate air quality and deposition

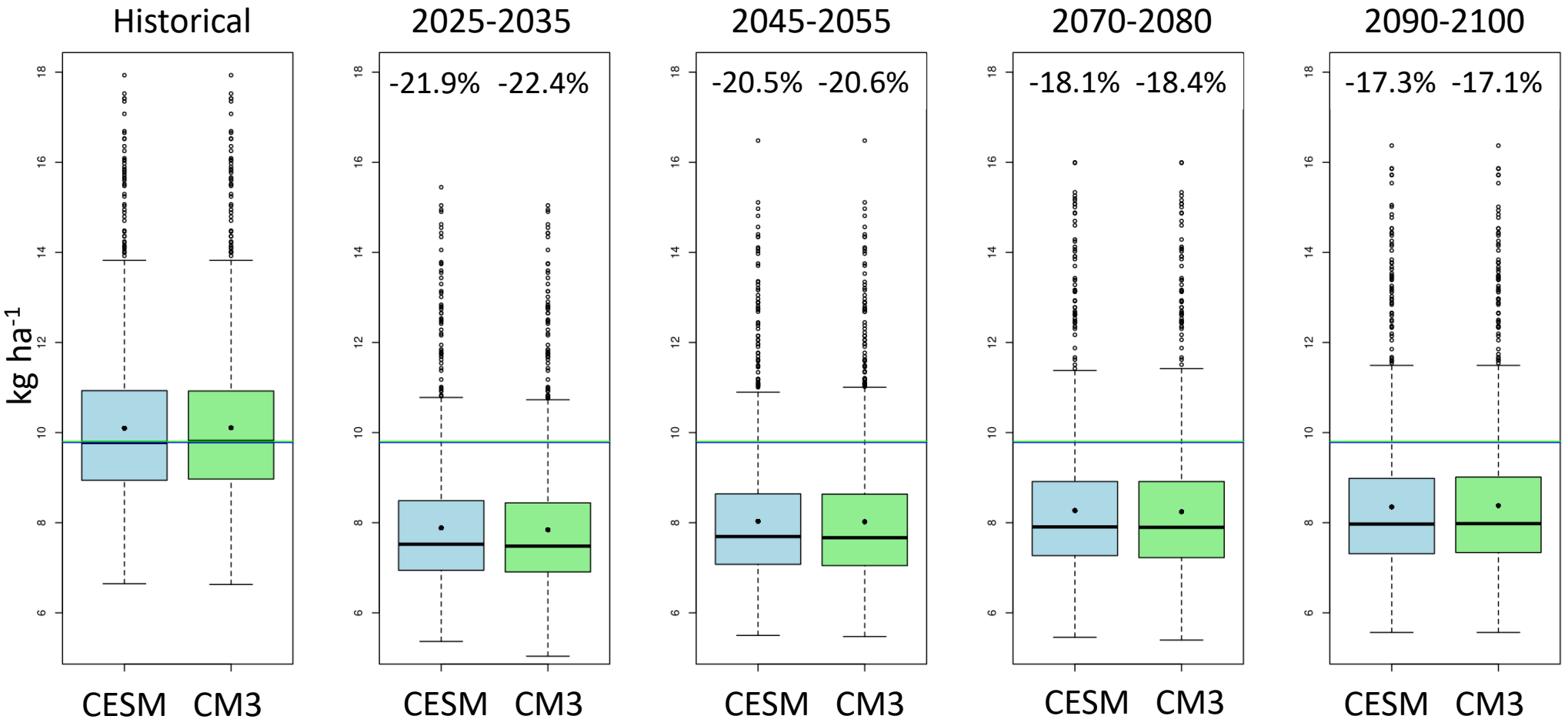
Effect of Emissions Reductions on N Deposition

- Fraction of reduced nitrogen increases as NOx decreases
- Nitrogen deposition projected to decrease by 21% from a 2011 baseline
- Climate change offsets this reduction by approximately 4%
  - Is this consistent across GCM and RCP scenarios?

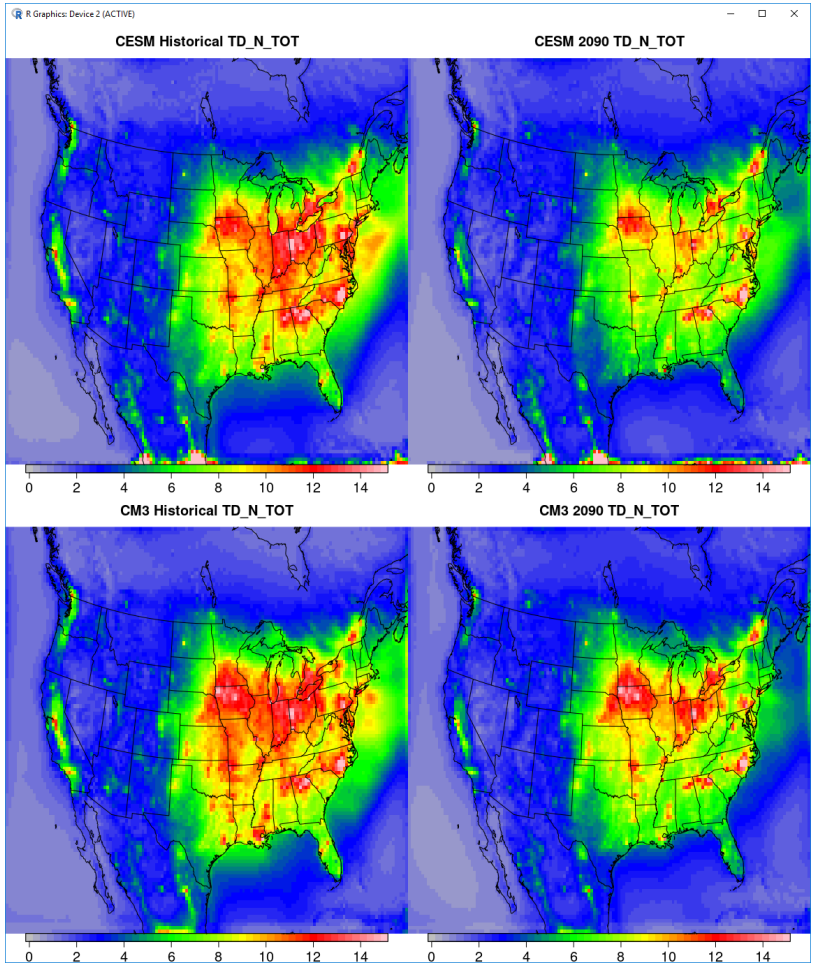


Campbell et al. 2019

Emission Reductions: Total N Deposition

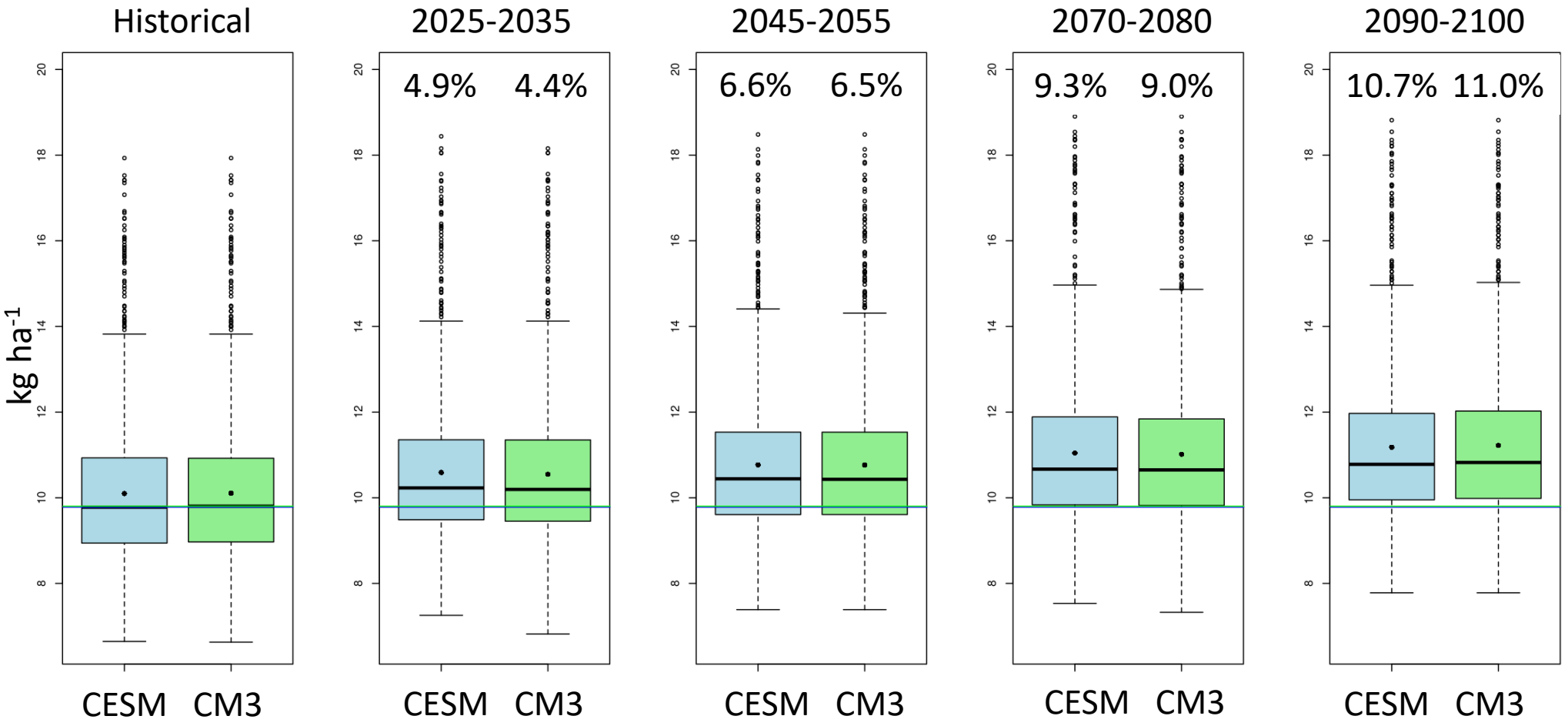


Emission Reductions: Total N Deposition

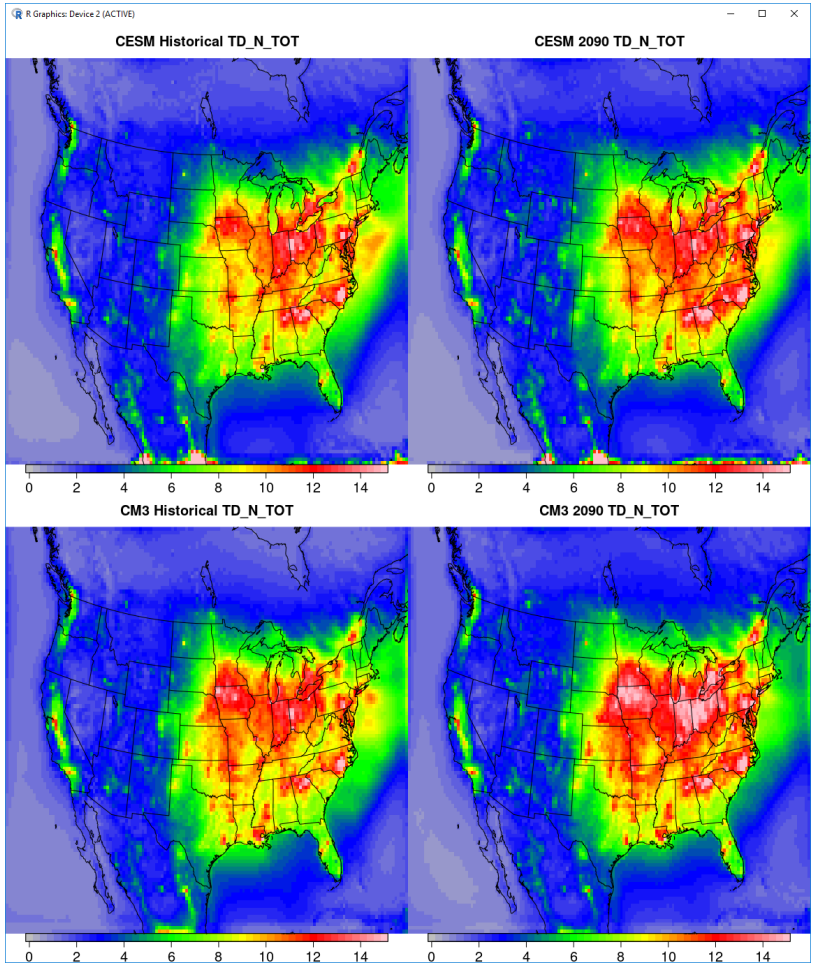


- Emission reductions remain the dominant factor in the atmospheric nitrogen deposition to the Chesapeake Bay
- Relative reductions are similar between CM3 and CESM on the continental scale
  - Absolute reductions are similar for the Bay Watershed

Constant 2011 Emissions: Total N Deposition

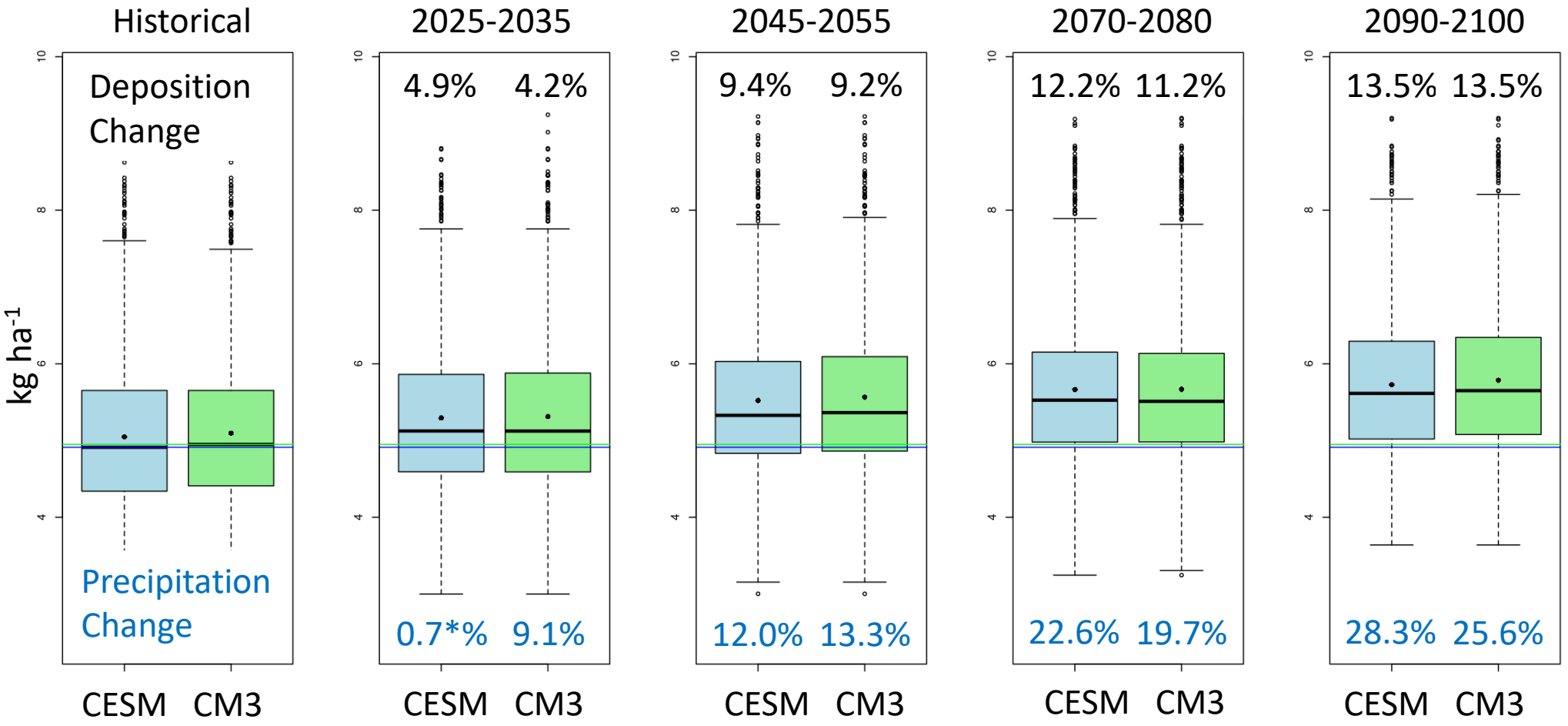


Constant 2011 Emissions Total N Deposition

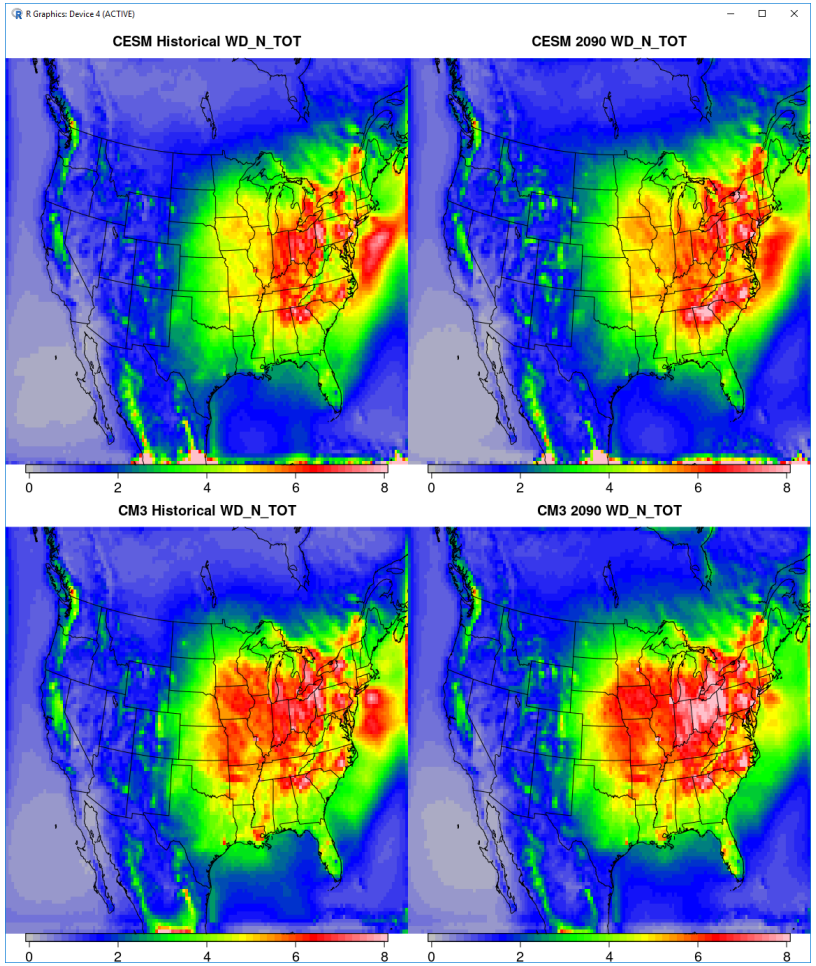


- At 2095 mean 4-6% increase in nitrogen deposition
  - 11% for the Chesapeake Bay Watershed
- CM3 has a larger increase in nitrogen deposition in the Ohio Valley than CESM downscaled results

Nitrogen Wet Deposition

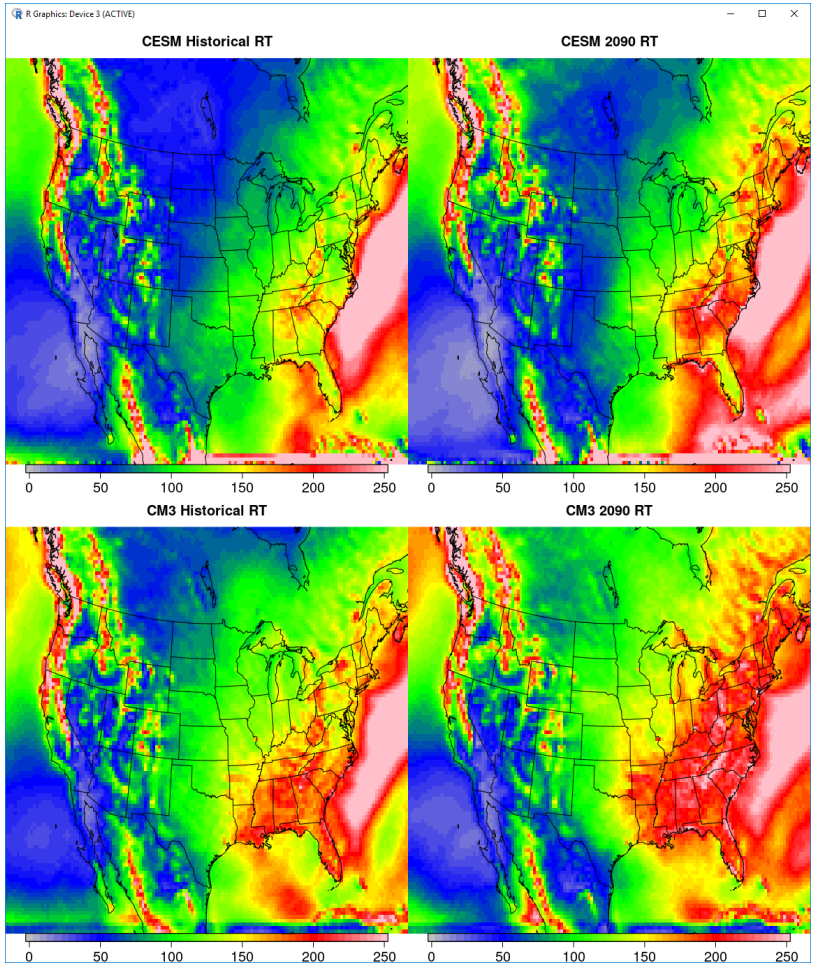


Nitrogen Wet Deposition



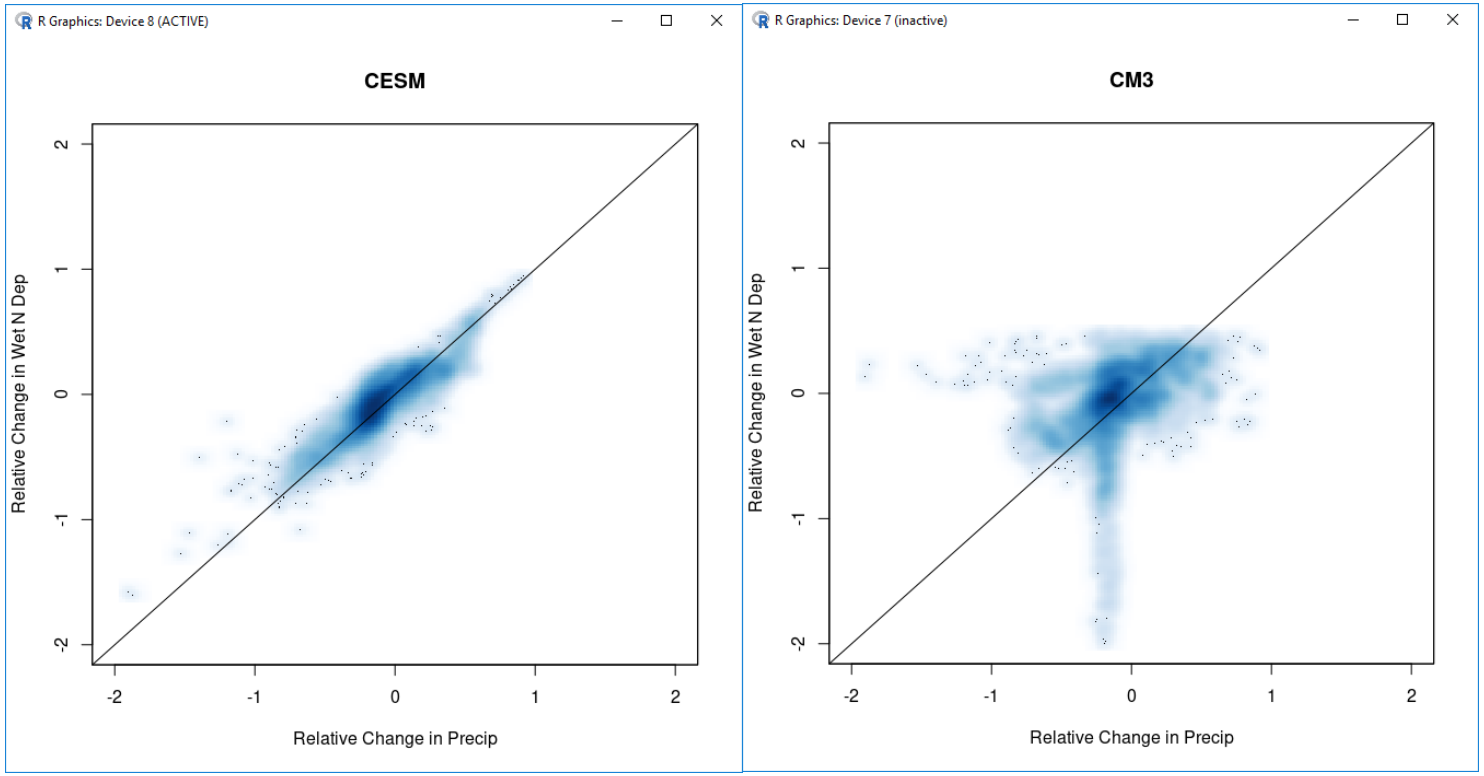
- At 2095 a mean 3-6% increase in nitrogen wet deposition
  - 14% for the Chesapeake Bay Watershed
- CM3 has a larger increase in nitrogen wet deposition in the Ohio Valley and lower increase in deposition for the Chesapeake Bay Watershed

Precipitation



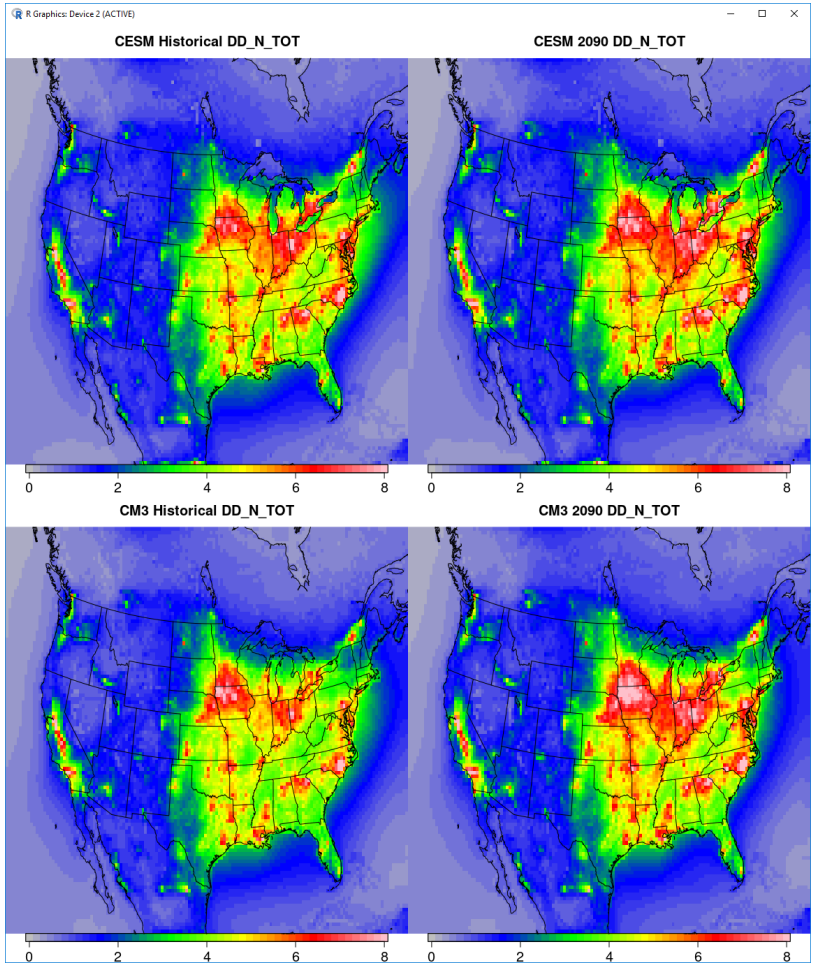
- At 2095 a mean 10% increase in precipitation
  - 26-28% for the Chesapeake Bay Watershed
- Large increases in precipitation inland and in the Ohio Valley
  - May washout reactive nitrogen transported to the Bay

Nitrogen Wet Deposition



- At 2095 the change in deposition is proportional to change in deposition for CESM
  - Slope ~1
  - Similar to NADP observations and earlier 2050 simulations
- Slope for Chesapeake Bay watershed is ~0.5
  - May be due to larger increase in precipitation for the watershed

Nitrogen Dry Deposition



- At 2095 a mean 2-8% increase in nitrogen deposition
  - Smaller than the changes in wet deposition
- It is not yet clear what is driving the difference
  - Potential suspects: longer growing season, increase in transpiration, etc.

Summary

- Projected changes in deposition are most sensitive to emissions
- Downscaled deposition results from CESM and CM3 are similar
  - Differ from RCP 4.5 downscaled CESM
- The majority of emission increases under RCP 4.5 and 8.5 scenarios are associated with wet deposition
  - RCP 4.5 relationship closely matches historical observations at NADP sites

	CESM 4.5	CESM 8.5	CM3 8.5
Climate Impact at 2050	+4.0%	+6.6%	+6.5%
Precip. Change at 2050	+4.0%	+12.0	+13.3
Slope	~1.0	~0.5	~0.5
Climate Impact at 2095	-	10.7%	11.0%
Precip Change at 2095	-	28.3%	25.6%

Future Research

- Leverage climate downscaling meteorological simulations
  - Developing 12km dynamically downscaled meteorology
- Focus on emissions:
- Explore the impact of mobile NH_3 emissions in collaboration with the Office of Transport and Air Quality (OTAQ)
- Source apportionment of emissions
  - What sectors and states are contributing to nutrient deposition?
- Explore future emission sector scenarios, e.g. electrification of mobile fleet, etc., using models like the Global Change Assessment Model (GCAM)
  - Leveraging existing EPA ORD research