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Future Directions and the Importance of Scale in Estimating Atmospheric Nitrogen Loading to the Next Generation Chesapeake Bay Model

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Motivation

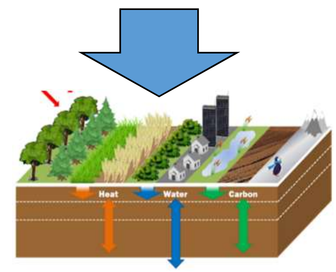
- Atmospheric nitrogen deposition contributes to surface water eutrophication and biodiversity loss
- Air quality models typically have a base resolution on the order of 1-36 km
  - Simulations at finer resolution are problematic due to bulk atmospheric physics parameterizations
- The next generation of distributed watershed models have a resolution in the tens of meters
  - Can we leverage sub-grid scale data to better match atmospheric loading to watershed models?

CMAQ v5.3

Deposition Updates

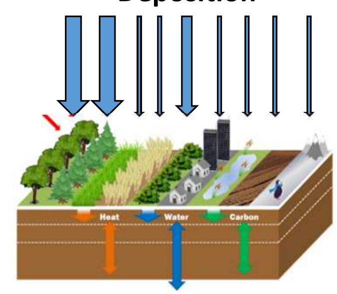
- Option to output land use specific deposition
  - Deposition fluxes estimated for each land use type
  - Land use based aggregation to the grid cell (NLCD or MODIS)
- More comprehensive parameterization of organic nitrogen chemistry and deposition
- Correction to coarse aerosol dry deposition

Grid Cell Average Dry Deposition



Earlier versions of CMAQ

LU Specific Dry Deposition



CMAQ v5.3+

Wet Deposition Updates

- Annual 2016 model simulation
- CMAQ v5.3.1 precipitation was biased low compared to NADP/NTN observations in the summer months when deposition is usually the highest
- Model improvements due to updates to coarse aerosol treatment

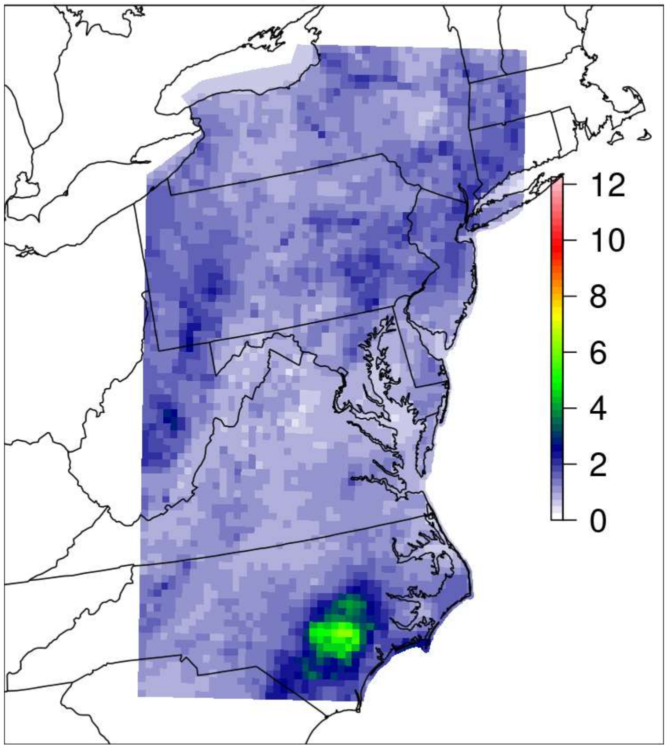
Species	CMAQ v5.2.1 NMB	CMAQ v5.3.1 NMB
NO_3 Wet Deposition	-14.8%	-9.1%
NH_x Wet Deposition	-50.0%	-43.7%
SO_4 Wet Deposition	-28.5%	-22.4%
Precipitation	5.0%	-9.6%

Planned simulations

- Dry deposition by land use planned for 2002-2017
  - CMAQ v5.3.2 simulations
  - MODIS 250 m base resolution
  - 12 km grid resolution
- Air Quality Modelling Evaluation International Initiative (AQMEII) Phase 4
  - Dry deposition intercomparison project (primarily for ozone) including simulations for 2010 and 2016 as well as box model comparisons with field data
  - CMAQ v5.3 deposition will be well evaluated
- Potential 1990 simulation being scoped

How can we leverage sub-grid cell data?

Total N Deposition 12 km



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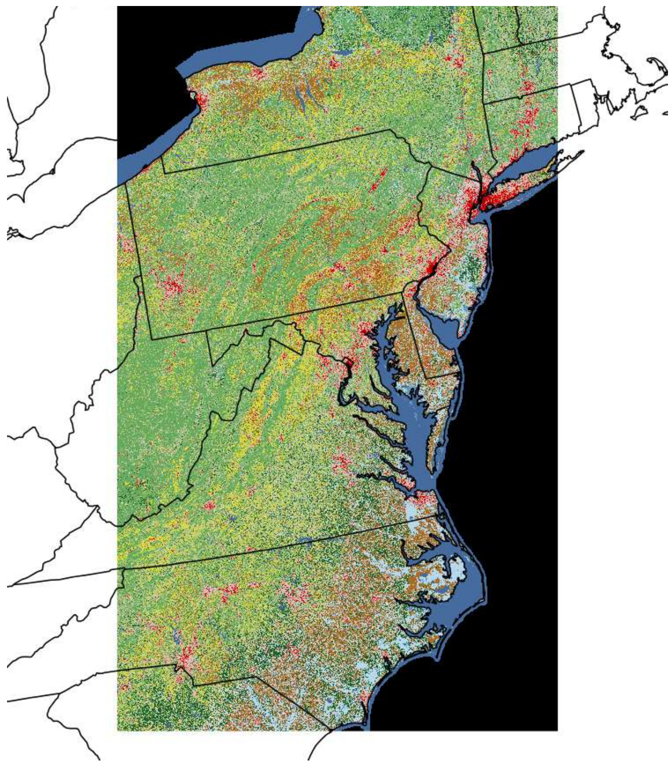
NLCD 30 m Land Use



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Disaggregating flux estimates

- Grid cell flux

$$Flux_{Grid} = \sum_{LU} Frac_{LU,Grid} Flux_{LU,Grid}$$

- Land use fraction

$$Frac_{LU,grid} = \frac{\sum_i LU_{i,30m}}{Area_{Grid}}$$

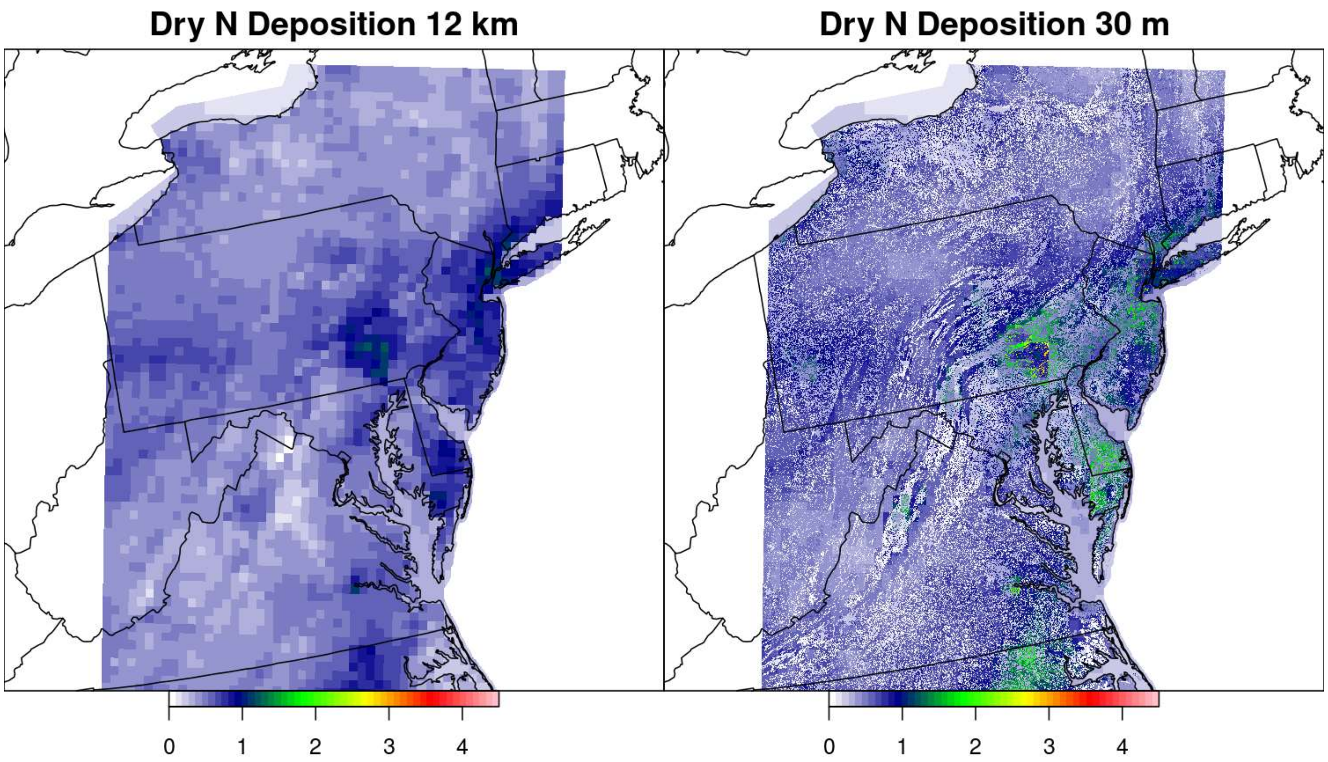
- Disaggregated Flux

$$Flux_{Gri} = \sum_{LU} \left(\frac{\sum_i Flux_{LU,Grid} LU_{i,30m}}{Area_{Grid}} \right)$$

Disaggregating Flux Estimates

- Developed an R script to disaggregate land use specific flux data
- Confirmed that the mass of the 30m disaggregated flux is equivalent to the 12 km grid cell flux
- 30 m fluxes estimated for CMAQ 5.3 July 2014 simulations at a 12 and 4 km resolution over the Chesapeake Bay Watershed
    - ~10 hours of processing time on one core for an annual simulation
    - Viable for production runs
    - Not exactly an exact comparison
        - 4 km used CMAQ v5.3 beta and 12km used CMAQ v5.3.1

Disaggregating flux estimates 12km



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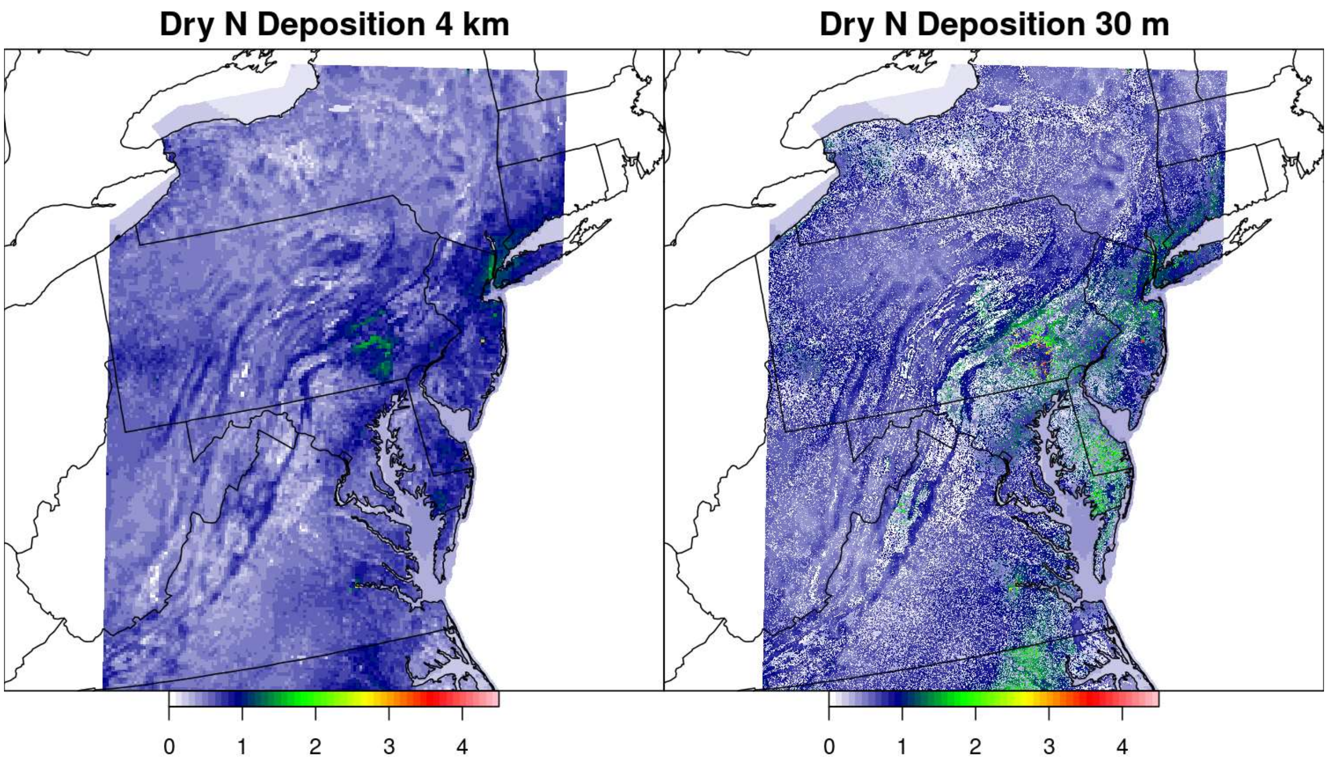
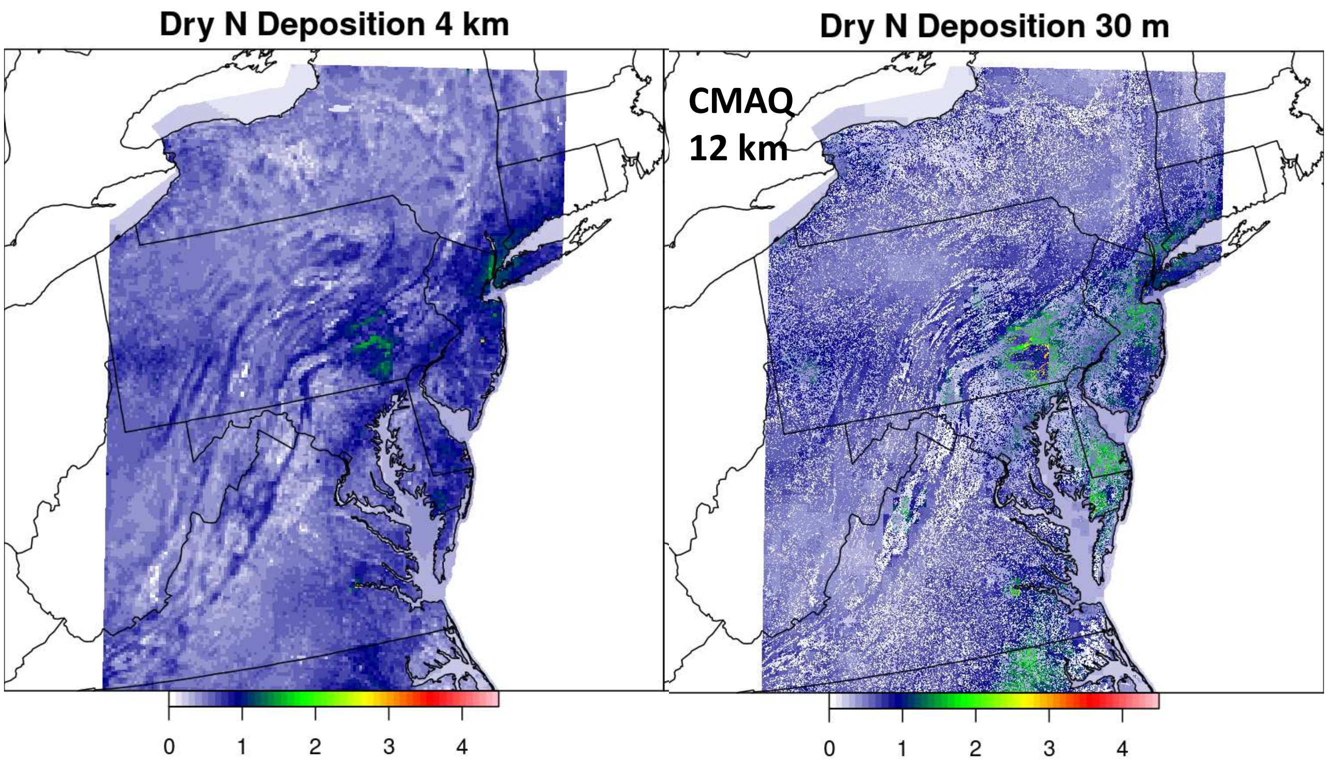
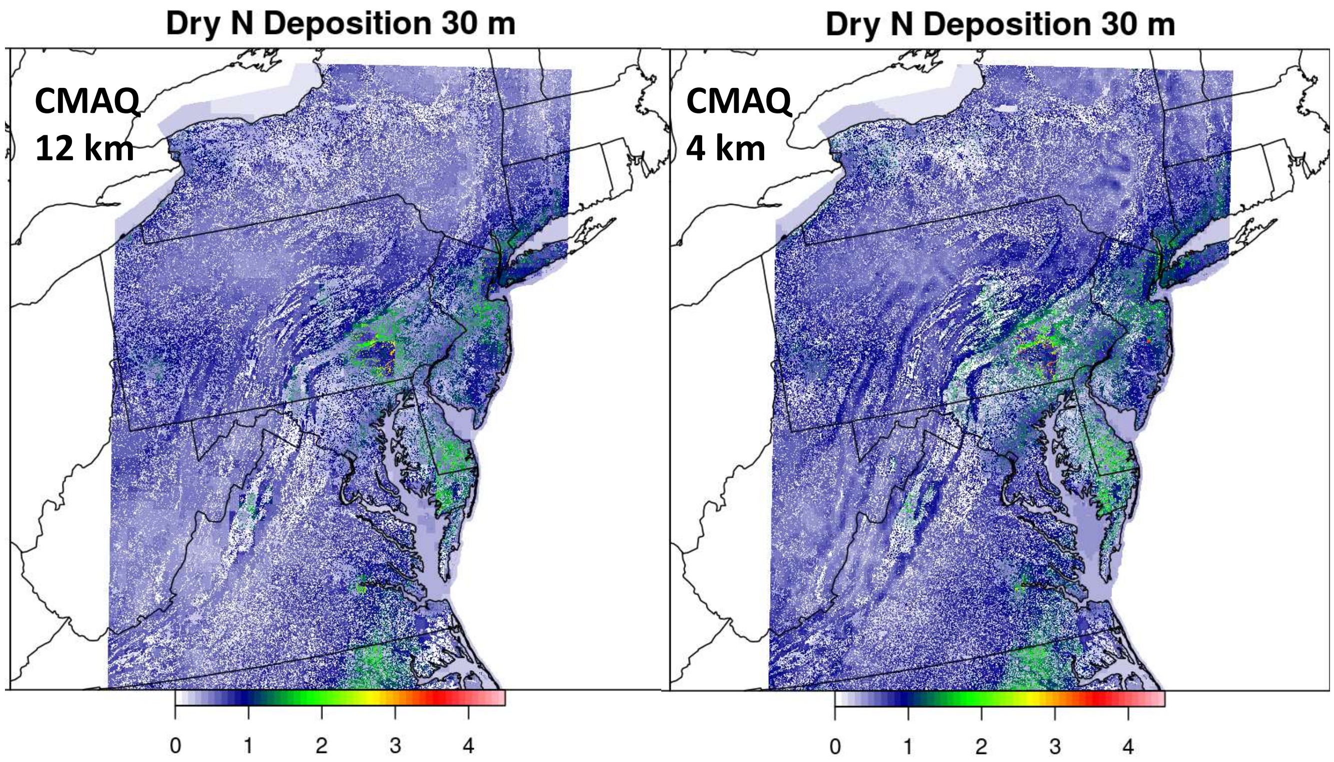
Disaggregating flux estimates 4km



12 km versus 4 km fluxes



12 km versus 4 km fluxes



Summary Part 1

- The land use specific fluxes can differ from grid cell fluxes by a factor of two
  - Forested land use types have the largest deposition fluxes
  - Highest deposition rates are where forested landscapes are collocated with high emission sources
- Deposition hot spots are focused around NH_3 emission sources
  - Higher levels of deposition are not seen in the I-95 corridor (a large NOx source)
  - NO_x deposits relatively slowly
  - HNO_3 deposits quickly but is a secondary pollutant (formed downwind from sources)
- 12 km and 4 km simulations resulted in remarkably similar deposition totals over the domain
  - 4 km domain had more variability in deposition

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Summary Part 2

- Improvements in modeled wet deposition when compared to NADP observations
  - Despite larger precipitation biases in the more recent WRF simulations used for the comparison
- Land use specific fluxes can be disaggregated and still maintain the model mass balance
  - Code has been developed to do this disaggregation
- Increased model spatial resolution primarily impacts reduced nitrogen deposition near ammonia emission sources and wet deposition
- Disaggregated 12 km model data captures much of the spatial variability of the 4 km simulations

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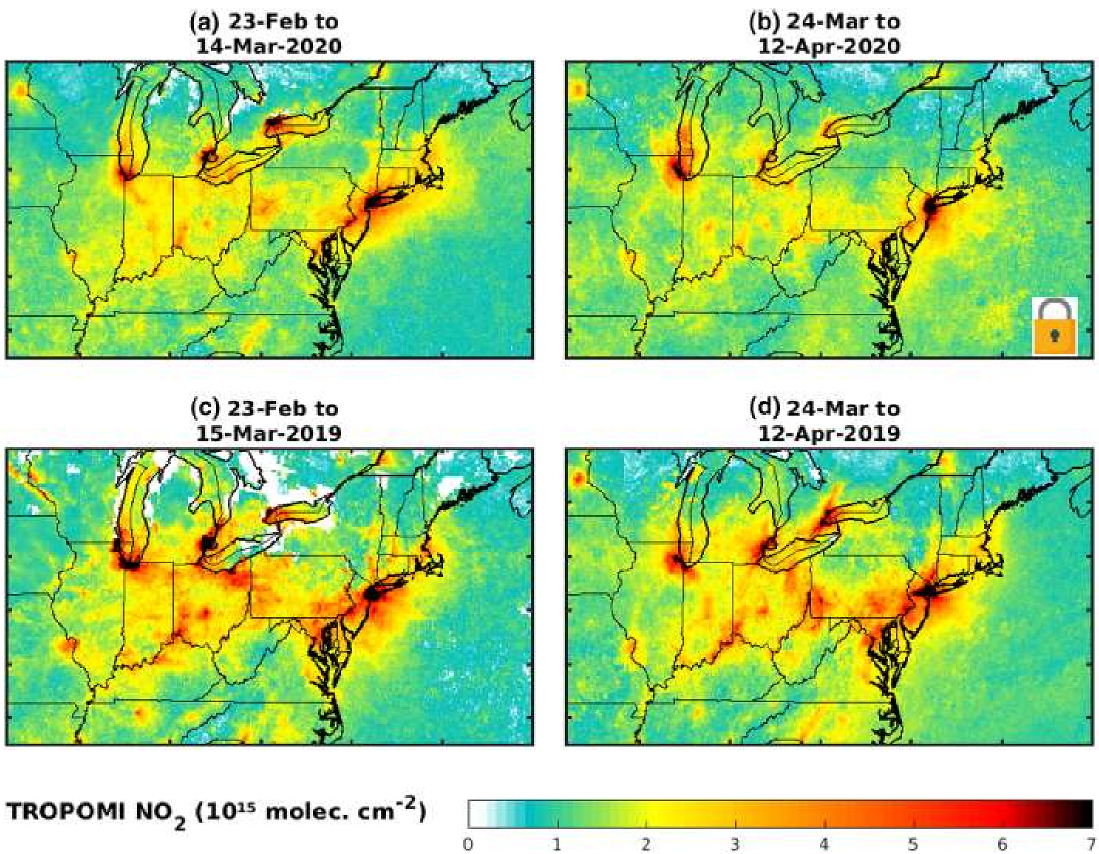
COVID 19 and Air Quality



Bauwens et al. 2020 GRL DOI:10.1029/2020GL087978

- NO_2 OMI and TROPOMI columns 10-12% lower in the US
  - Approximately 28% lower over major Northeastern Cities
- This change in emissions is likely to have an impact on atmospheric N deposition
- How do we translate the observational data into model emissions?
- Similar reductions not seen in $PM_{2.5}$

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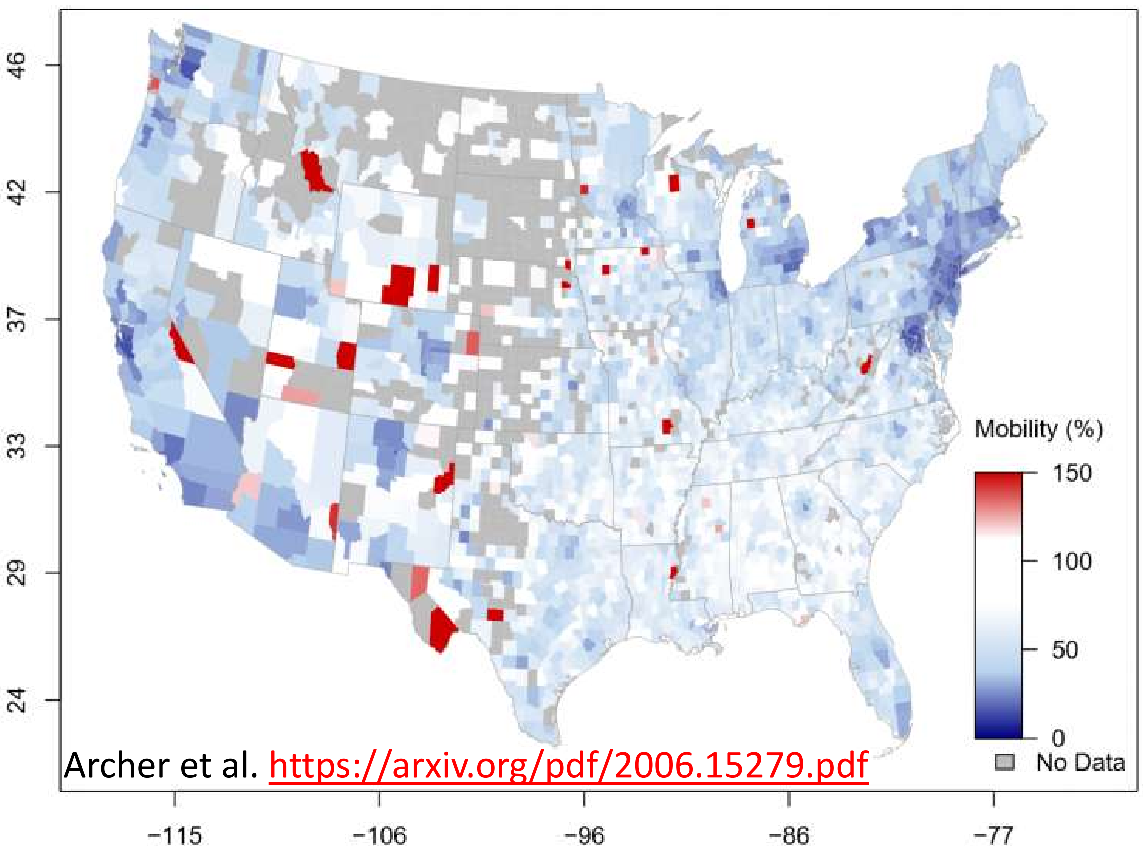
COVID 19 and Emissions Modeling



Archer et al. https://arxiv.org/pdf/2006.15279.pdf

- Where will emissions be reduced
  - Decrease in mobility has been documented
  - Other sectors?
- Likely to impact NO_2 emissions and HNO_3 deposition primarily
- Data is still coming in and being collected
  - Some will be delayed

2020 National Emissions Inventory

- National Emissions Inventories (NEI) are compiled every three years currently
  - 2020 is an NEI year
- Will not be a good base year due to COVID 19 and emission anomalies
- Emission activity data will be arriving late
  - Due to workplace disruptions from COVID 19
  - Typically about 2 years to compile data and estimate emissions for a public release
- Will be collaborating with a COVID modeling team