Nitrogen Source Apportionment in the Chesapeake Bay Watershed

July Modeling Workgroup Quarterly

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EPA United States Environmental Protection Agency

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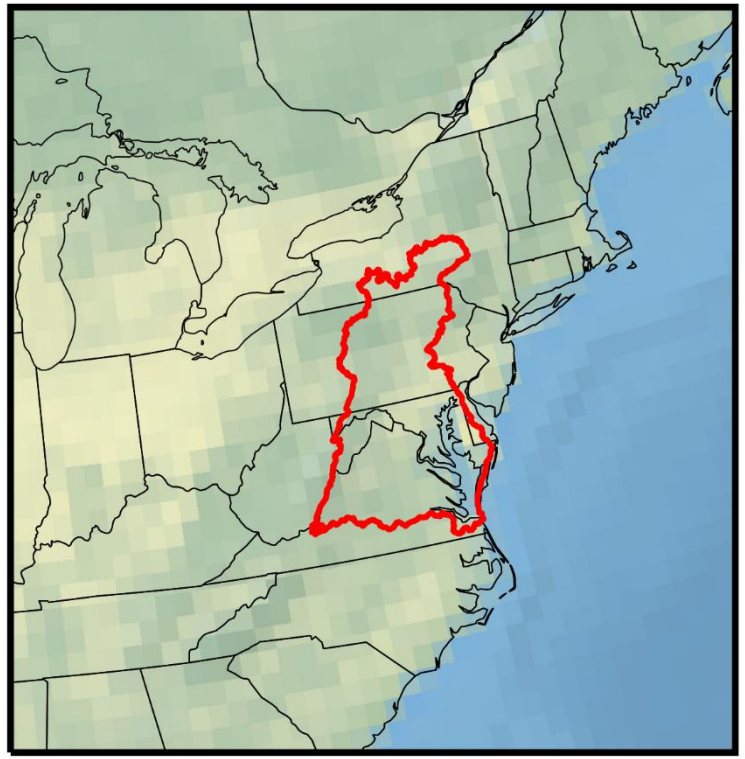
- Atmospheric deposition is important nitrogen source to the Chesapeake Bay watershed and was dominant source from about 1960 to 2000.
- Despite declines in deposition due to air quality regulations, atmospheric nitrogen deposition still contributes ~25% of the annual nitrogen load to the Chesapeake Bay watershed (Burns et al., 2021).
- Chemical transport models, like CMAQ, can extend deposition estimates from limited ground networks to understand atmospheric deposition:
  - Given recent improvements in CMAQ, how do new estimates of deposition compare to observations and previous long-term simulations?
  - What are the important emission sources and source regions contributing to nitrogen deposition in the Chesapeake Bay watershed?
  - The analysis centers on the question, “For a nitrogen emission source from different regions in the Chesapeake watershed, what is the fraction that is deposited to a particular region or point?”

Model
- CMAQv5.3.2

Time Period
- January-December 2016*

Grid
- 12 km windowed domain

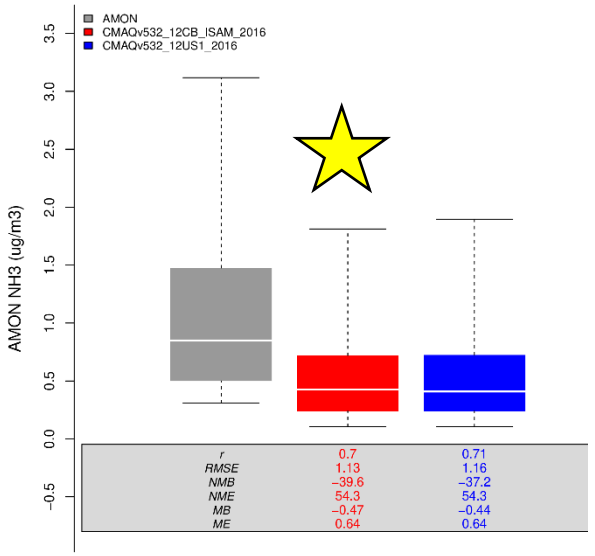


ISAM=Integrated Source Apportionment Method

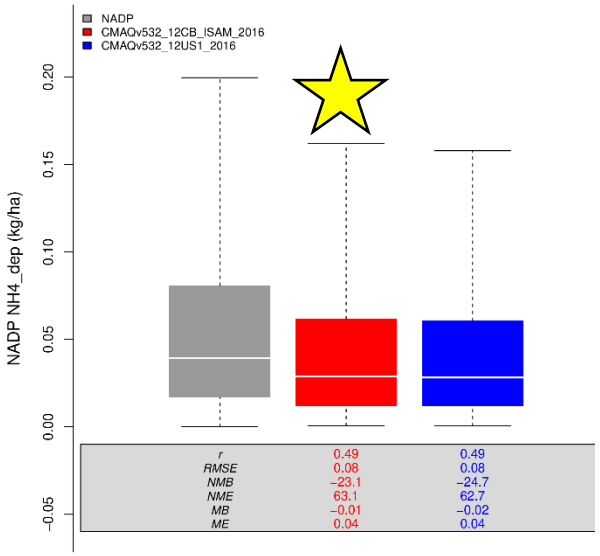
	12US1_2016 (EQUATES)	12CB_2016
Domain	**Full Domain**	**Windowed**
Model	CMAQv5.3.2	CMAQv5.3.2
Date Range	2016 (2002-2017 also available)	2016
Resolution	108 km N Hemisphere+ 12 km CONUS	12 km Windowed domain over the Chesapeake Bay Watershed
Meteorology	WRFv4.1.1	WRFv4.1.1
Emissions	2017 NEI as primary base year; consistent methods used for each sector to avoid artificial step changes	Same
Boundary Conditions	N Hemisphere CMAQv5.3.2	Combination of 12 km EQUATES and 108 km N Hemisphere

Windowed Versus Full Domain Results

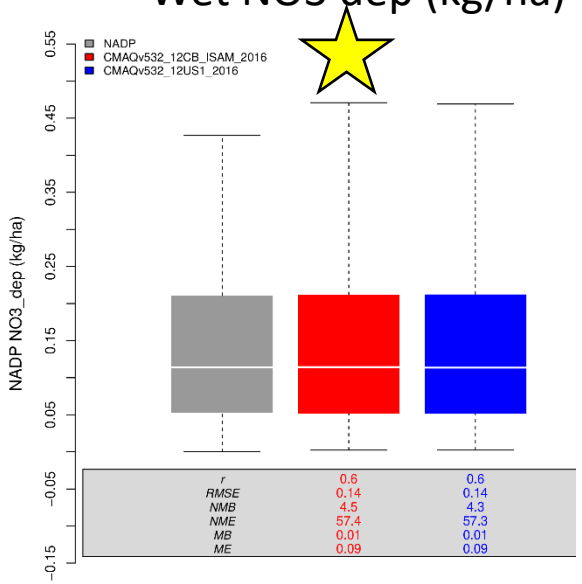
NH3 (µg/m3)



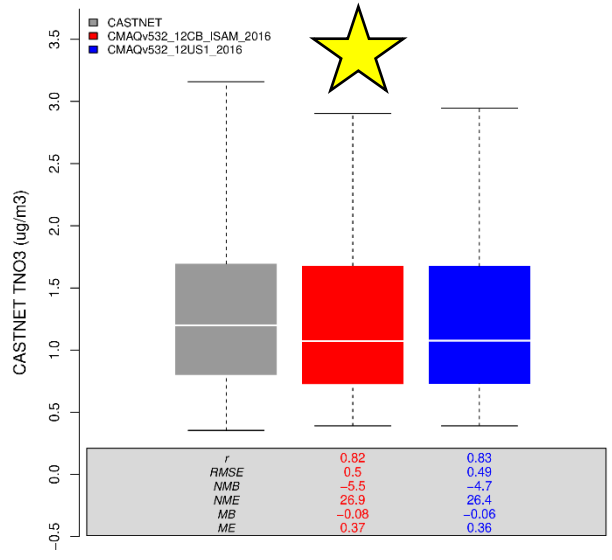
Wet NH4 dep (kg/ha)



Wet NO3 dep (kg/ha)



TNO3 (µg/m3)



- Annual 12CB domain simulation was completed to evaluate potential evaluation differences
- NH_3 and TNO_3 ambient concentrations and NH_4 and NO_3 wet deposition totals are largely similar
- Model to model evaluations of dry and wet deposition of N species were compared and the differences were on the same order as the evaluation against observations
- Model differences due to the windowing of the domain are on the order of 1-2% and are consistent with EQUATES simulation results

Source Apportionment: ISAM

Quantifies the contributions of various emissions **(source sectors and geographic regions)** to pollutant levels in the domain, tracking concentration and deposition with near perfect mass closure.

Can calculate source attribution of a large number of sources directly in the model in one simulation.

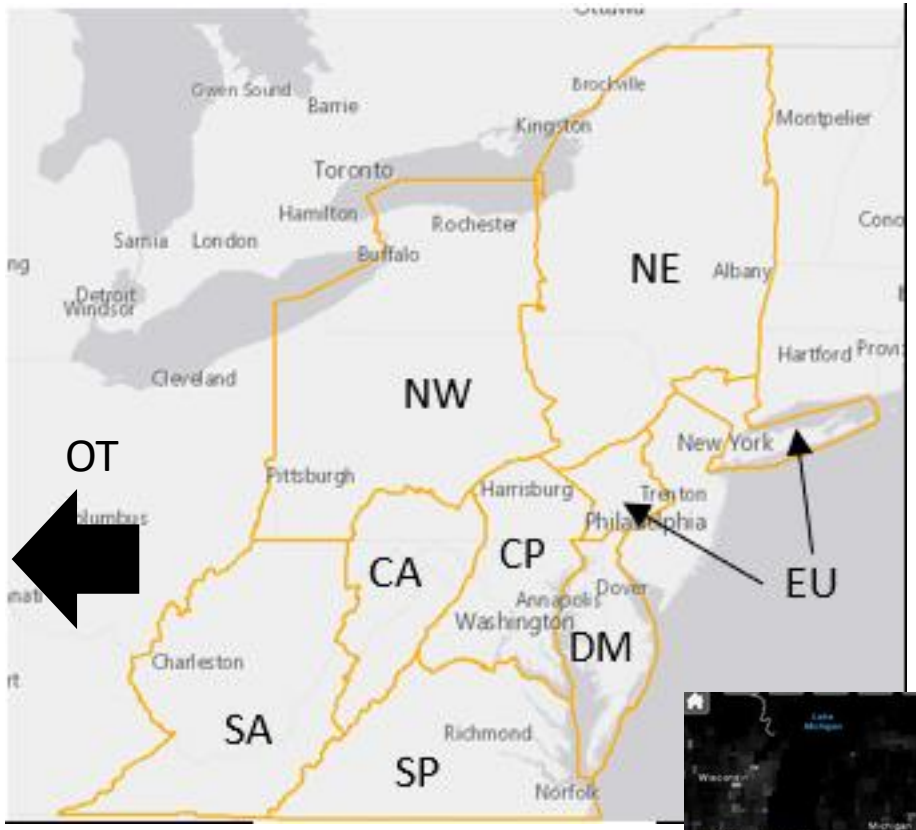
For each species, the production and loss terms from each chemical reaction is tracked (generalized for the available mechanisms) and propagate changes to tags based on stoichiometry and production/loss rates of the precursors.

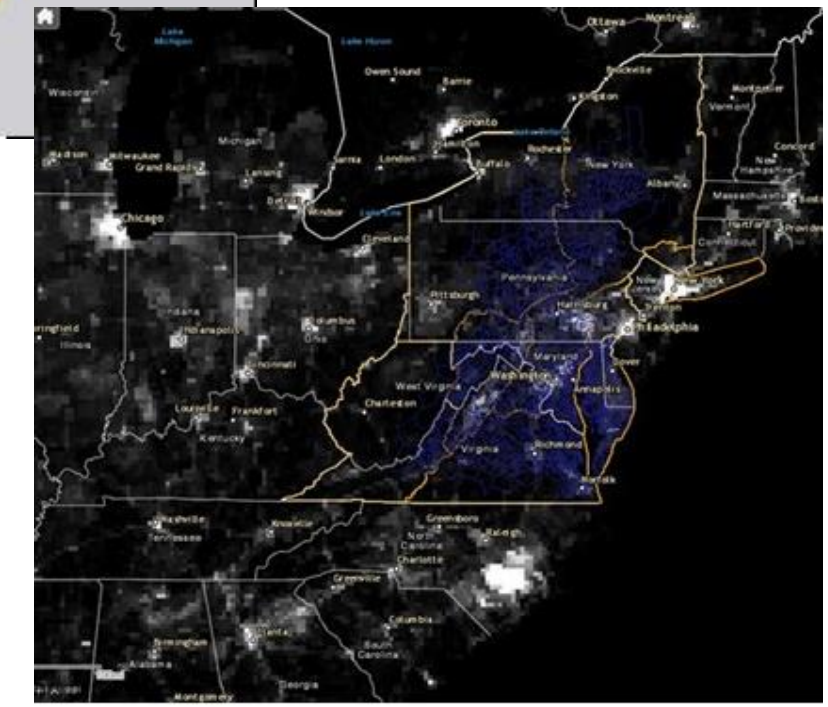
Tag Class	Model species
Sulfate	SO_2, H_2SO_4, SO_4^{2-}
Nitrate	HNO_3, HNO_2, NO_3^-, NO_3, NO_2, NO, Organic Nitrates
Ammonium	NH_3, NH_4^+
EC	Elemental Carbon Aerosols
OC	Organic Carbon Aerosols
VOC	Volatile Organic Aerosols
PM25_IONS	Cl, Na, Mg, K, Al, Si, Mn, and other aerosol cations
CO	CO
Ozone	All Nitrate species + all VOC species

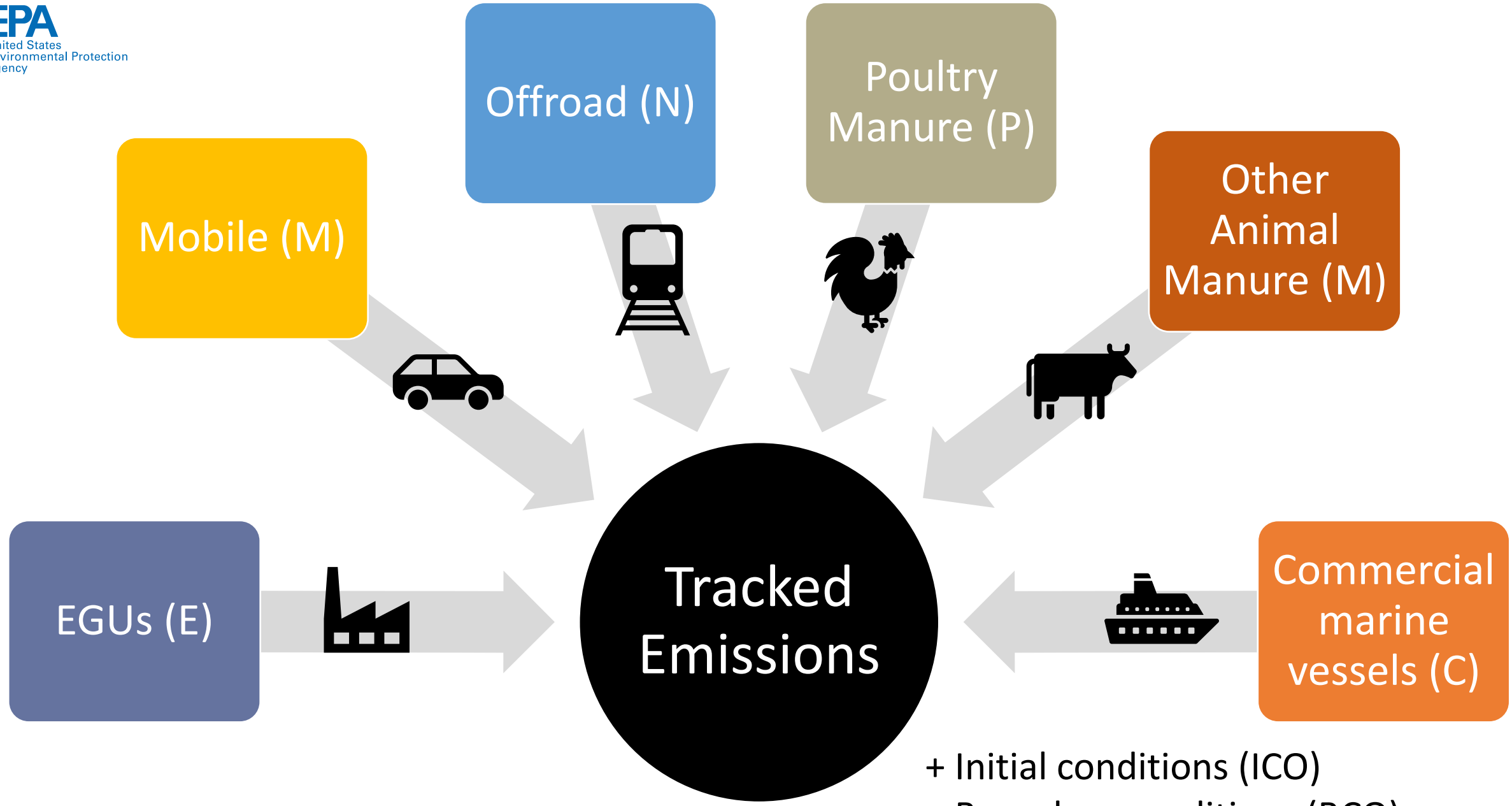
ISAM=Integrated Source Apportionment Method

Source Regions

Tag	Strawman Name
CP	Central Coastal Plain and Piedmont Region
EU	Eastern Urban Region
CA	Central Appalachian-Ridge and Valley Region
DM	Delmarva Coastal Plain Region
NE	Northeast Appalachian Highland Region
NW	Northwest Appalachian Highland Region
SP	South Coastal Plain and Piedmont Region
SA	Southwest Appalachian Region
OT	All other locations

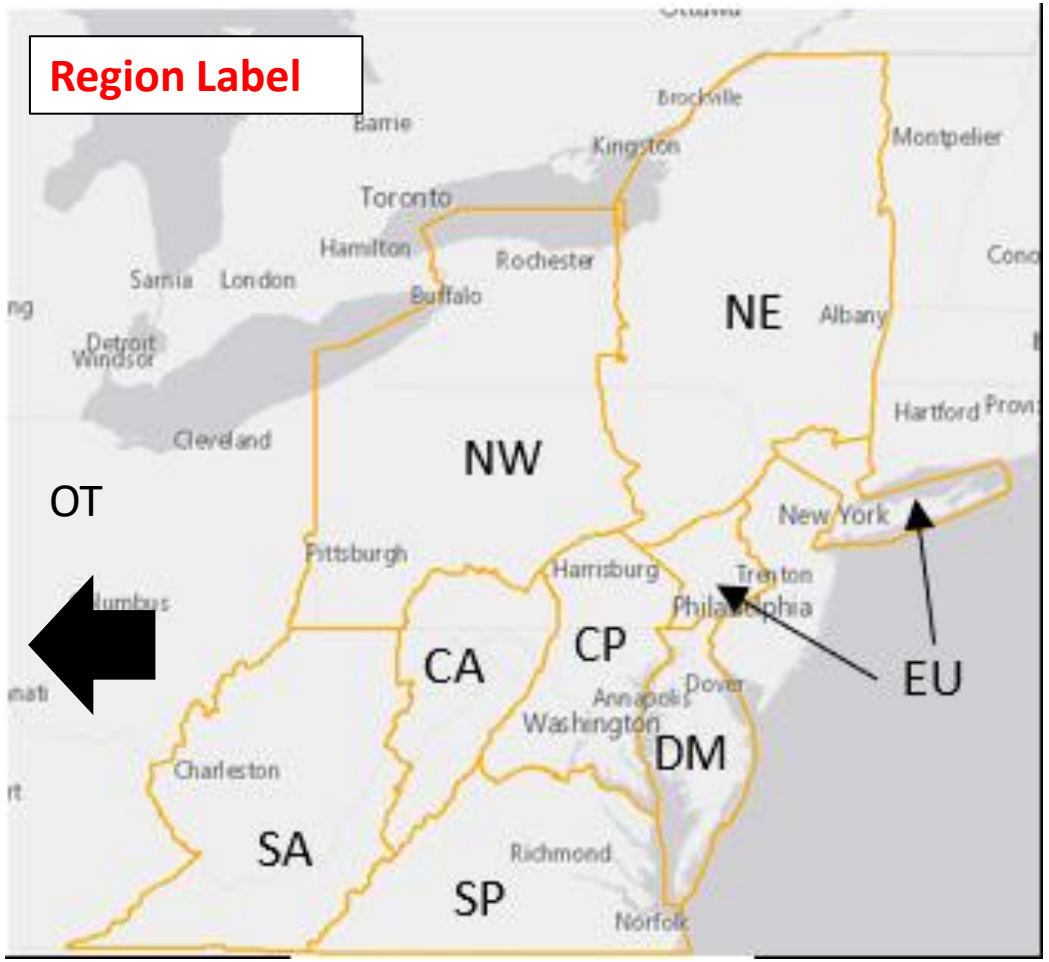






ISAM=Integrated Source Apportionment Method

Tag Name=2 letter Region Label+1 letter Emission Label

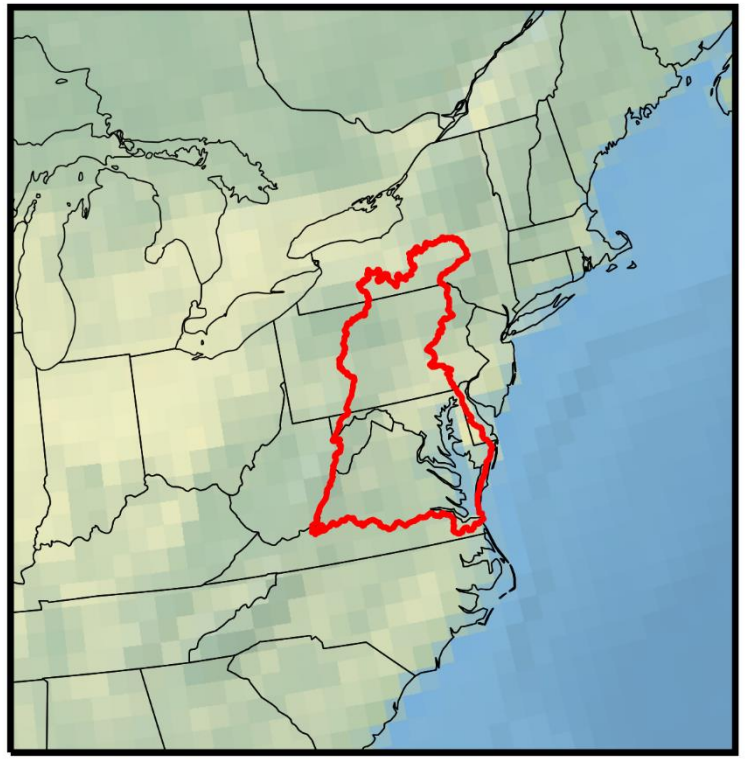


+

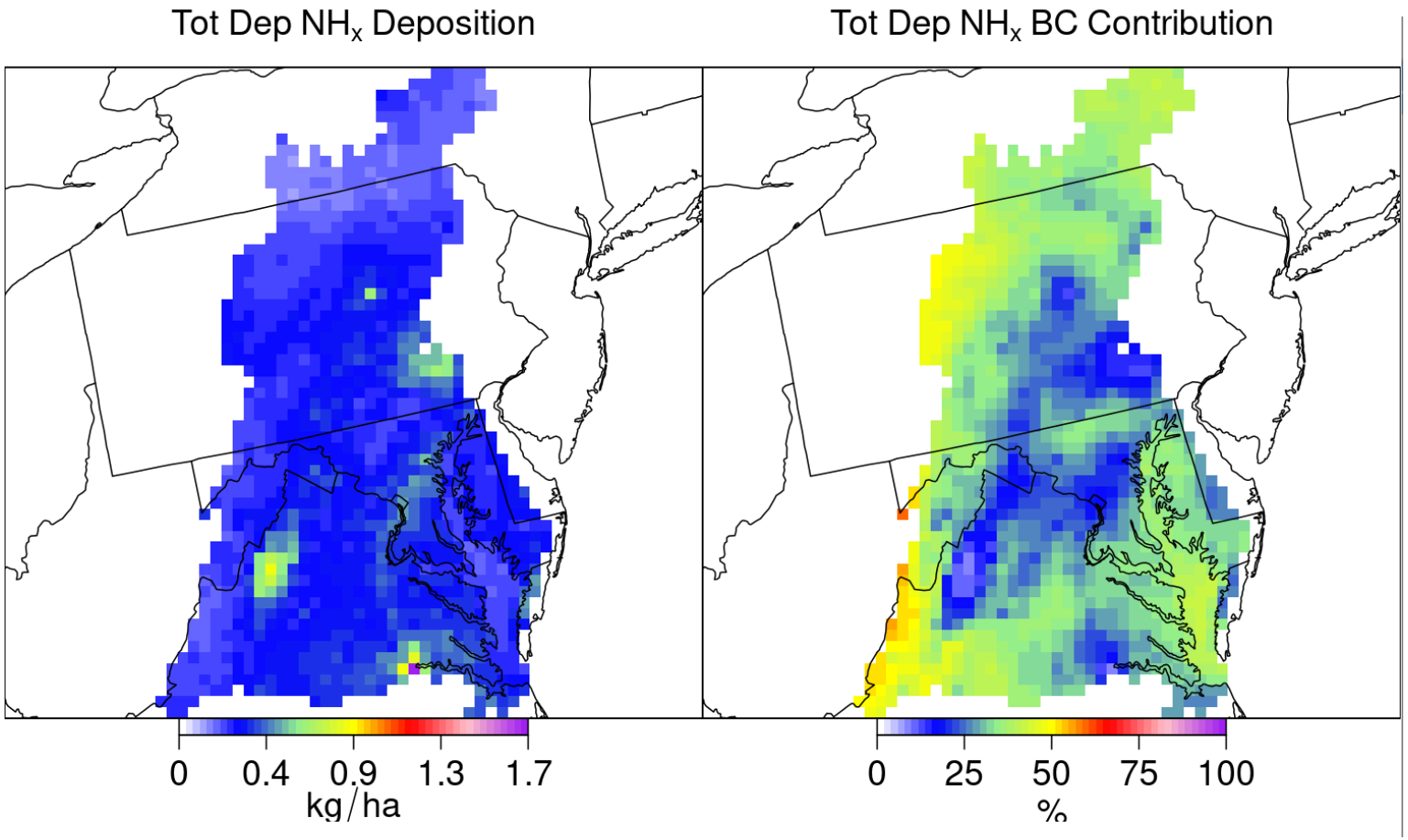
Emission Label	Emission Name
E	EGU
P	Poultry Manure
A	Other Animal Manure
C	Commercial Marine Vessels
N	Nonroad
M	Mobile

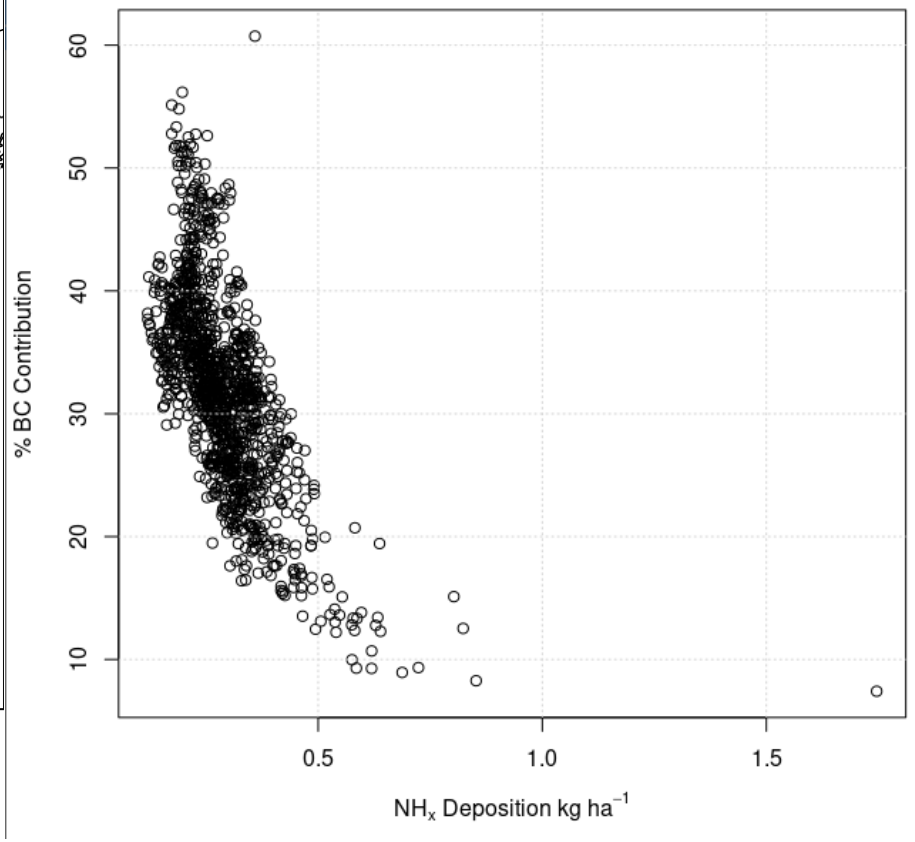
BCO=Boundary Conditions
OTH=Other

- Model is still running!
- Preliminary Results from January through March 2016 only
- Time of year when deposition is usually the lowest
- Some minor species are not tracked in ISAM
  - Coarse mode aerosol deposition and some organic nitrates
  - Minor components, typically less than 1% of NO_y, total oxidized N, deposition



NH_x Total Deposition: Boundary Condition Contributions





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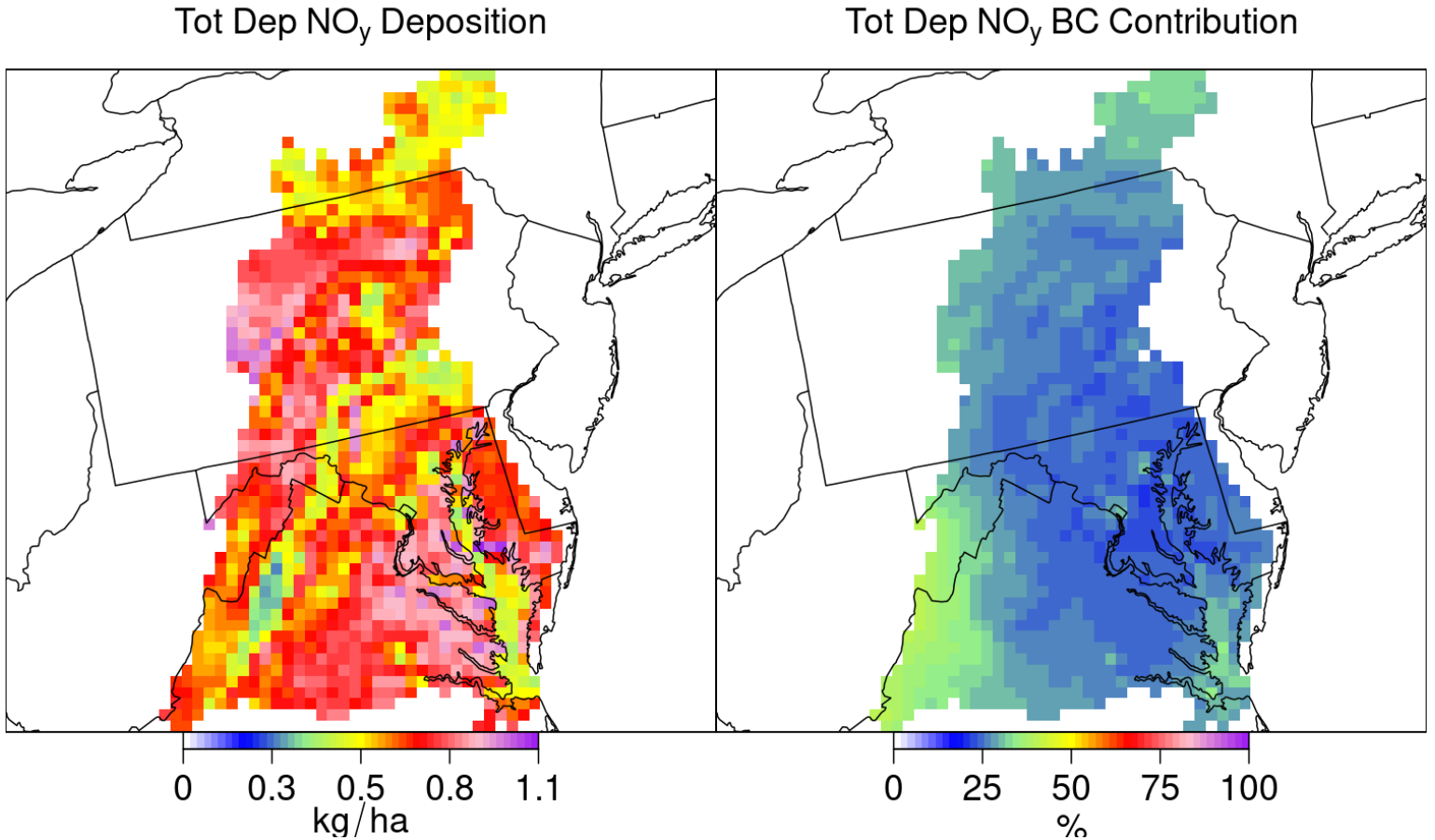
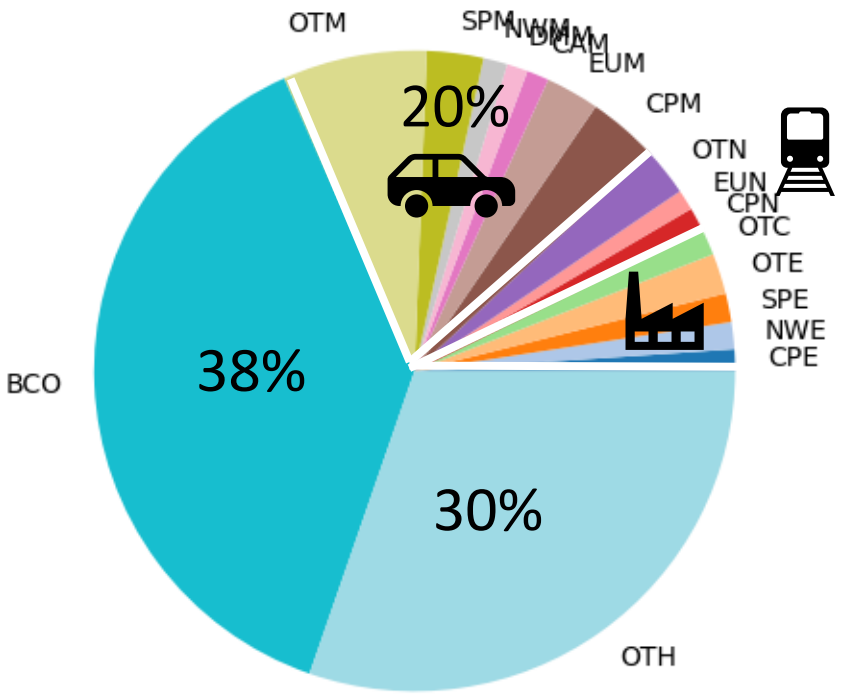


- Boundary conditions contributed to 30% of NH_x and 27% of NOy total deposition
- Areas of high NH_x deposition had low boundary conditions contributions
  - High NH_x deposition is estimated to be from local sources and likely dominated by NH_3
- NO_y boundary condition contributions are more uniform
  - Likely due to the secondary atmospheric formation of major deposition species, e.g. HNO_3.

Wet N Deposition (Jan-March)

Oxidized



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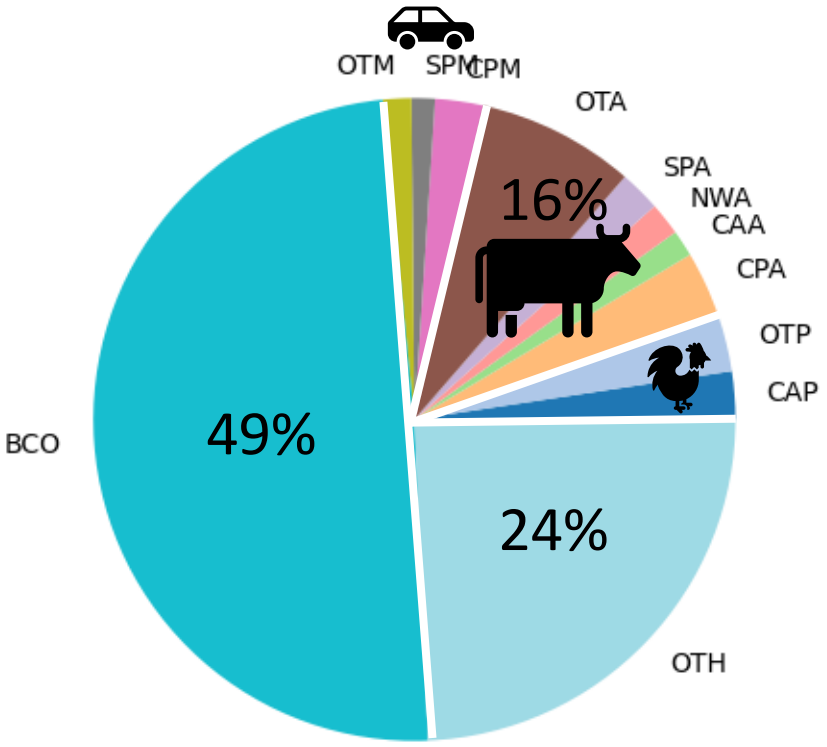

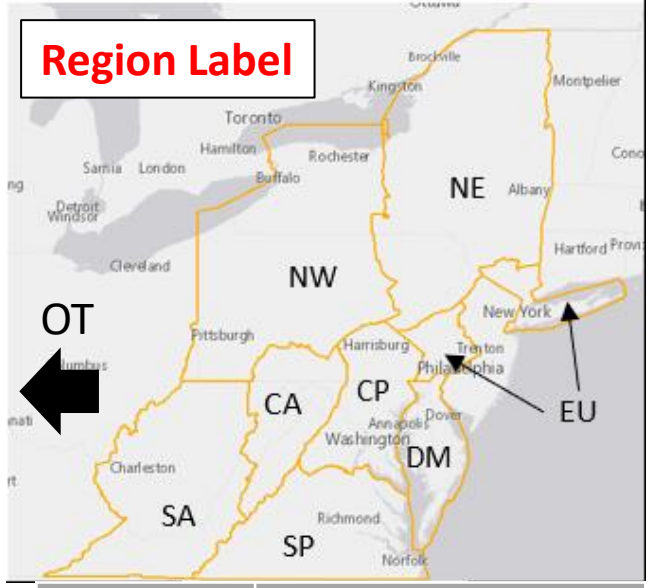

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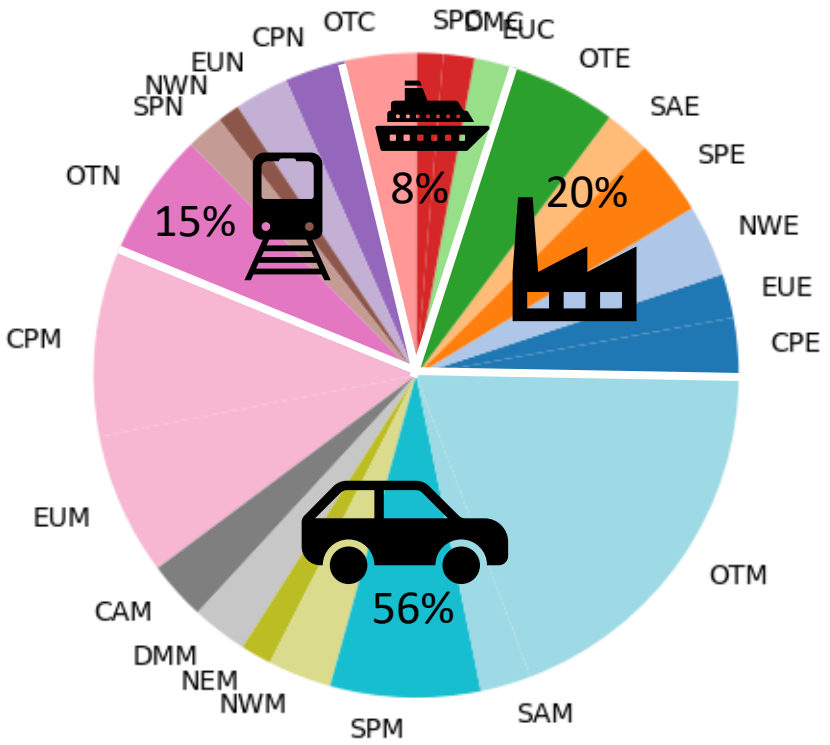

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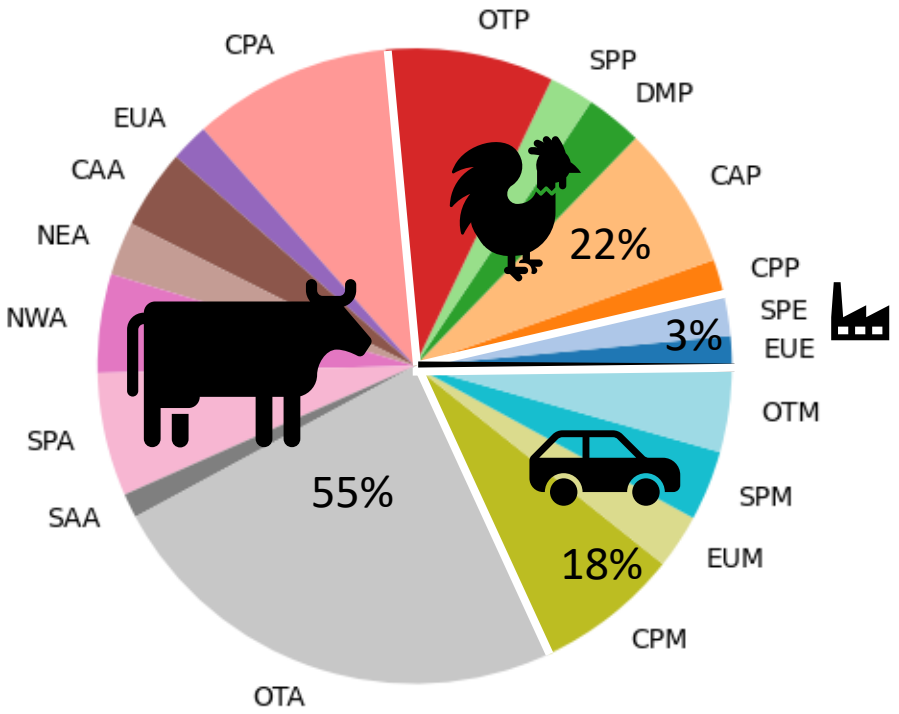

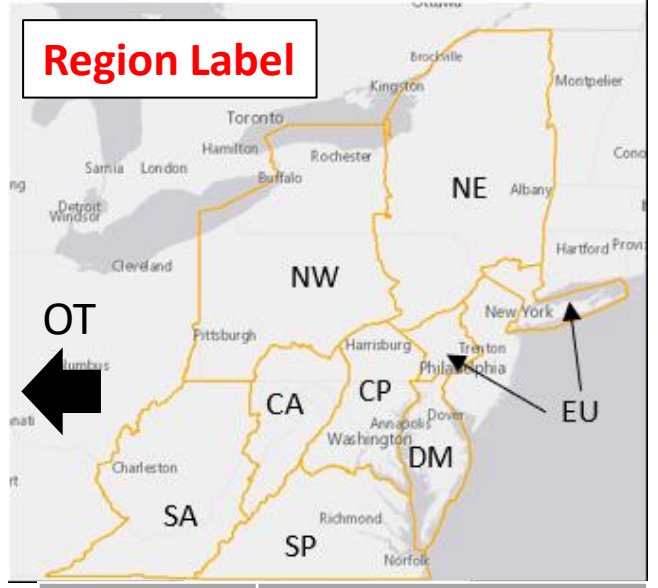

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Total N Deposition (Jan-March)

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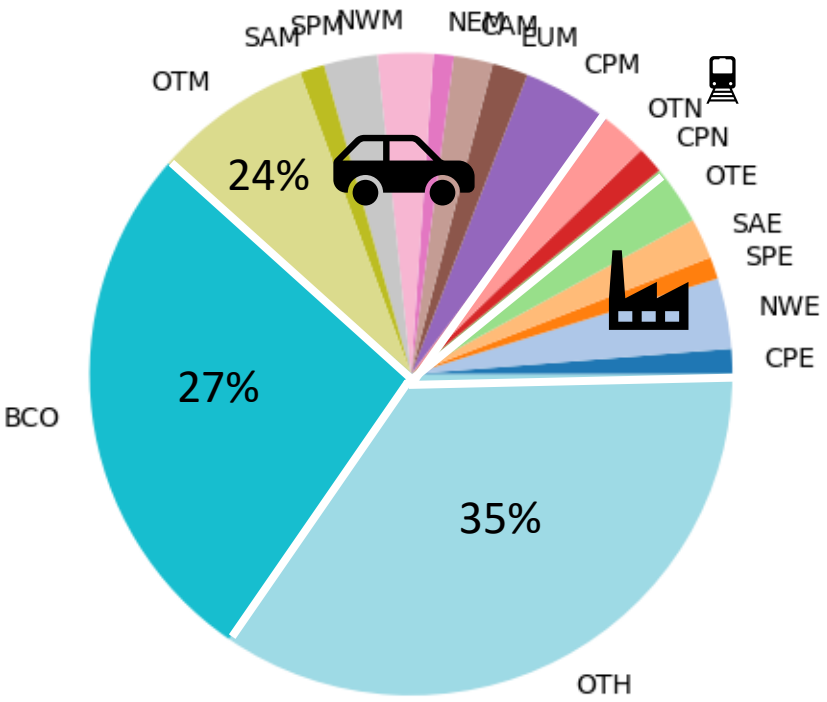

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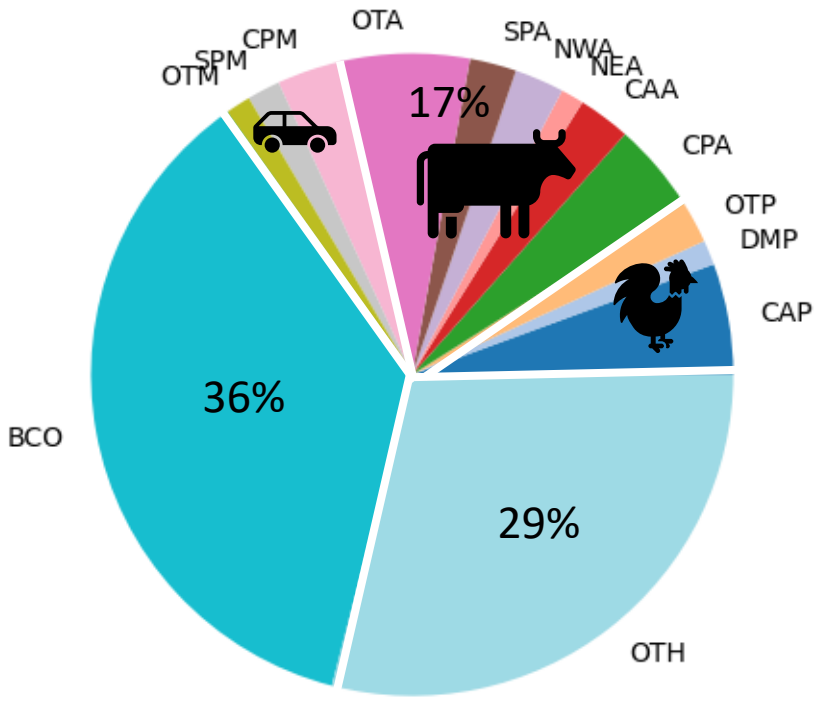

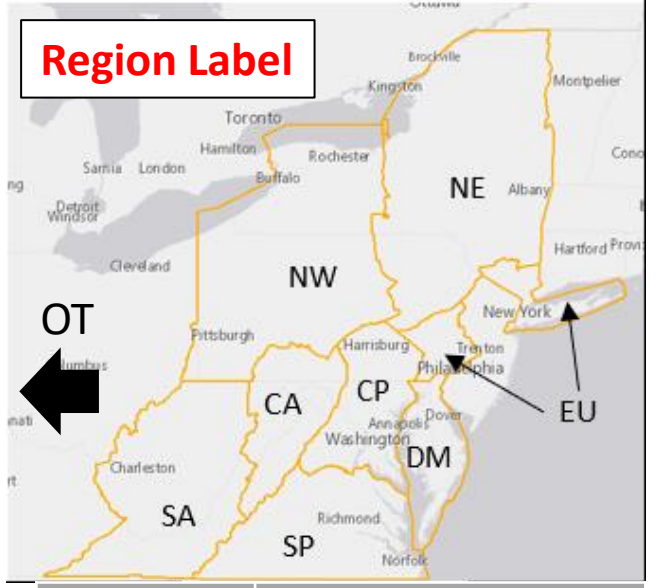

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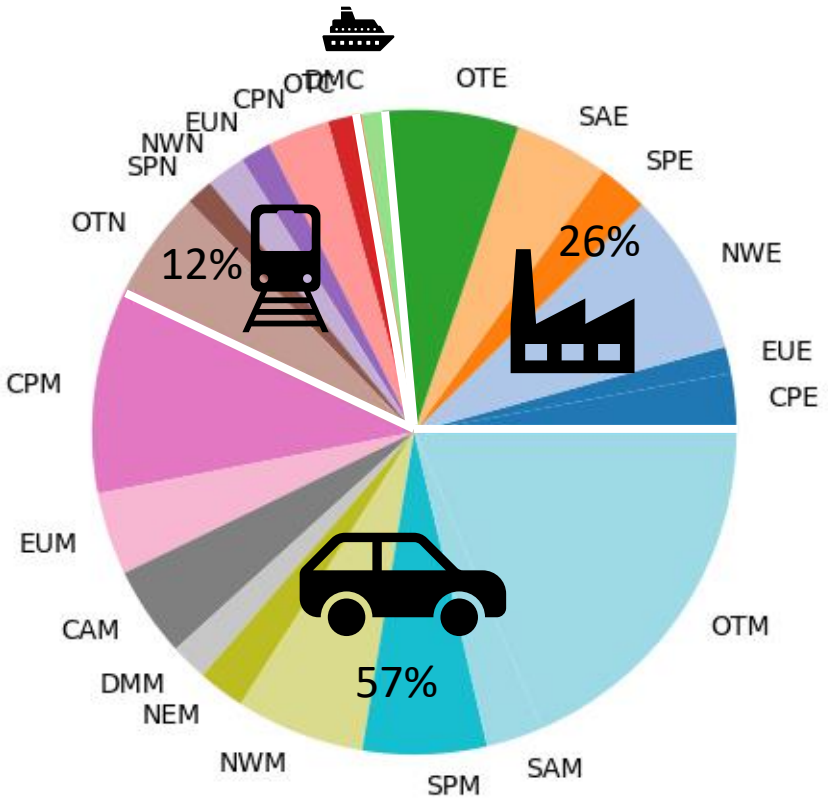

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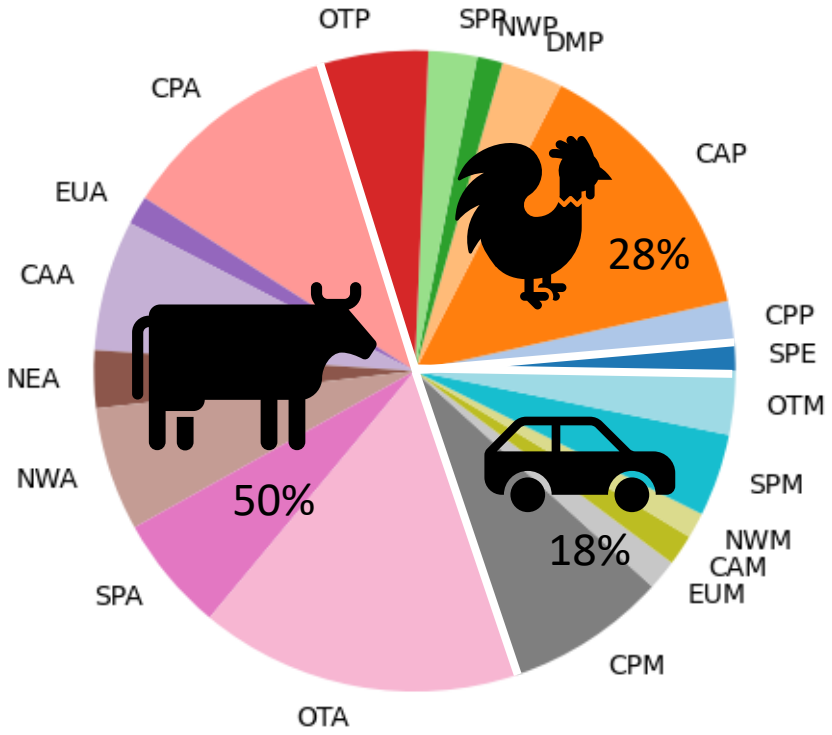

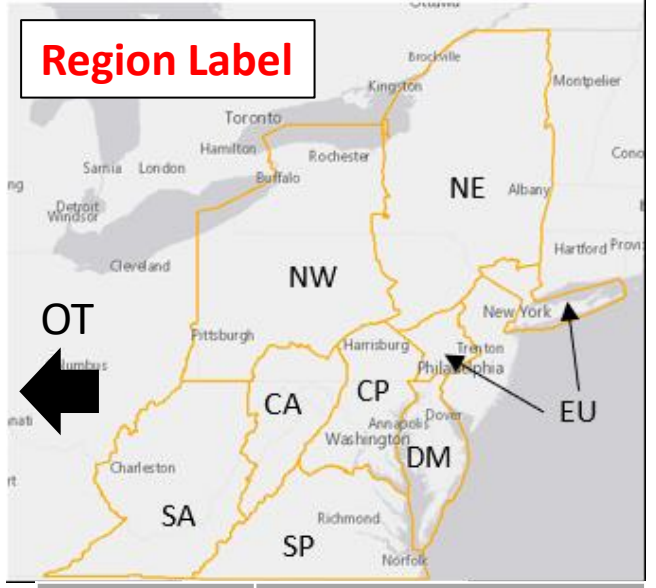

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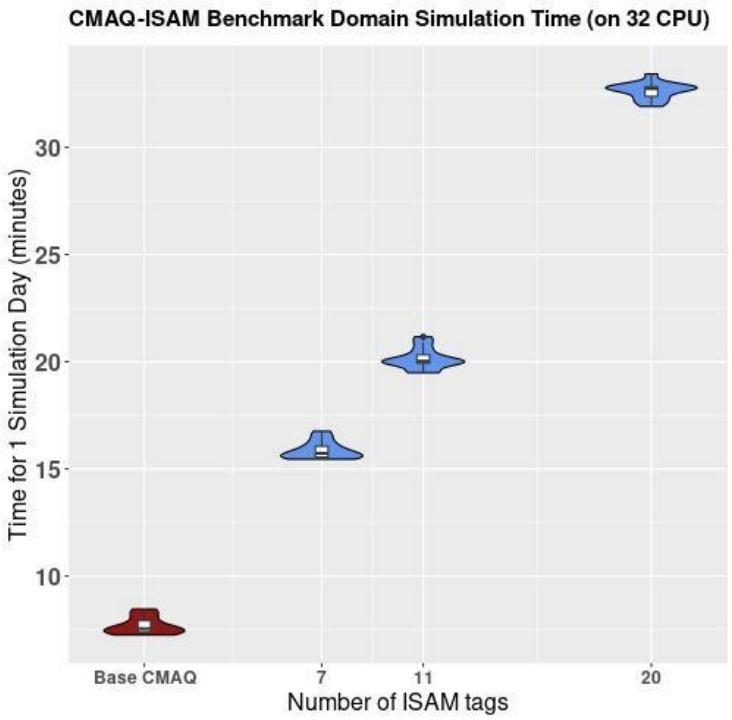
- Assess annual, seasonal source apportionment to Chesapeake Bay Watershed when model is finished running.
- Future simulations will estimate reductions of nitrogen deposition to the Chesapeake watershed and tidal Bay under future conditions of greater penetration of electric vehicles into the existing fleet, greater wind and solar electric generation, and other types of future economic conditions.
  - The next release of CMAQv5.3.3 (release date Fall 2021) with new emissions scaling tools is required to conduct these simulations.



Summary

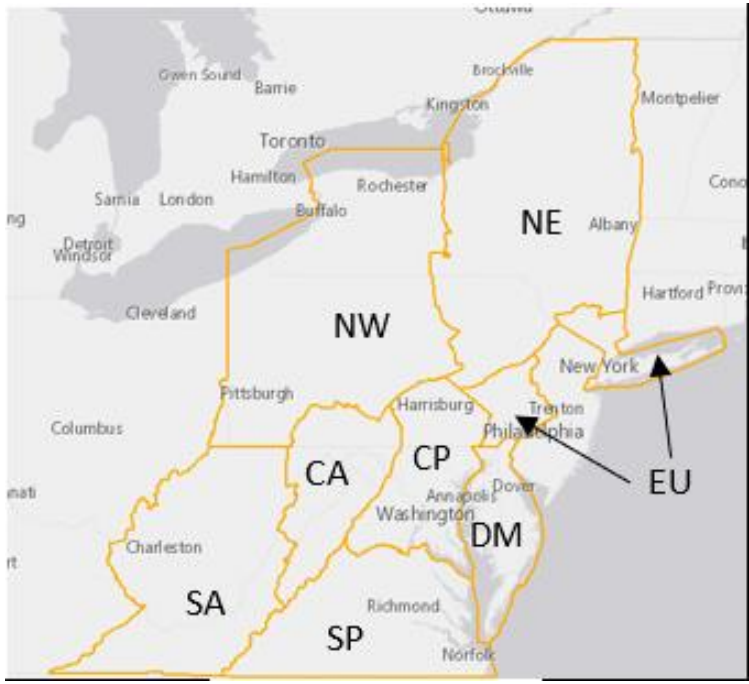
- Model differences due to the windowing of the domain are on the order of 1-2% and are consistent with EQUATES simulation results.
- The model simulations with ISAM are still running and we expect the full year to be completed in a few days.
- Preliminary results over Jan-March 2016 in the Chesapeake Bay Watershed show:
  - Mobile sources are a large contributor to total oxidized nitrogen deposition (~24% of total);
  - Non-poultry animal manure is an important source of total reduced nitrogen deposition (~17%);
  - Regions outside the Watershed are responsible for ~13% of the total oxidized nitrogen deposition, followed by the Northwest Appalachia and Central Coastal Plain (~7% each);
  - The Other and Central Appalachia regions are responsible for ~9% each of the total reduced nitrogen deposition.

EPA United States Environmental Protection Agency

Questions?

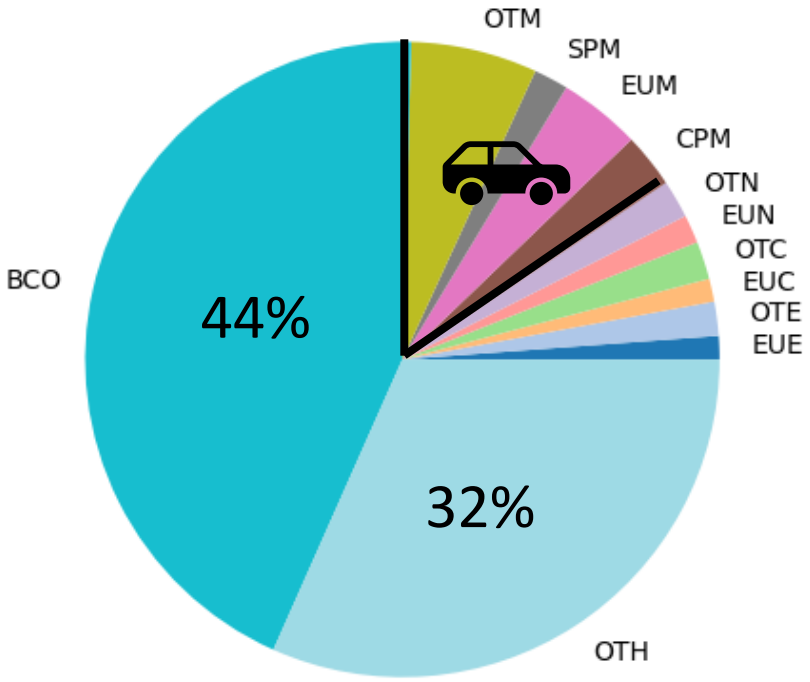
Fraction of Emissions Reaching Chesapeake Bay Watershed

Source Region	EGU	Mobile	Onroad	Poultry Manure	Other Animal Manure	Commercial Marine Vessels
Central Coastal Plain and Piedmont (CP)						
E Urban (EU)						
Central Appalachian-Ridge and Valley (CA)						
Delmarva Coastal Plain (DM)						
NE Appalachian Highland (NE)						
NE Appalachian Highland (NW)						
S Coastal Plain and Piedmont (SP)						
SW Appalachian (SA)						



January Wet Deposition

Oxidized



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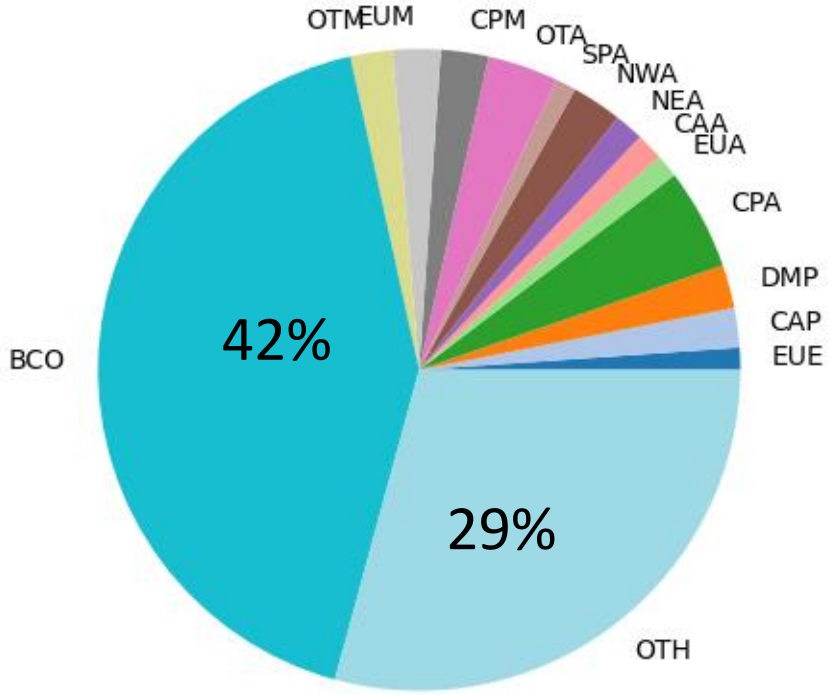

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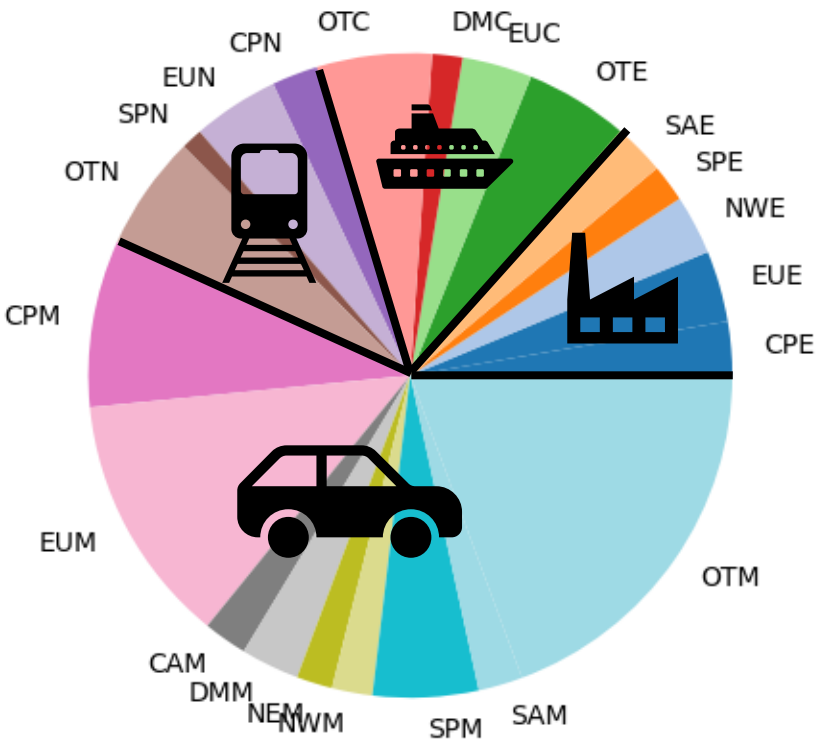

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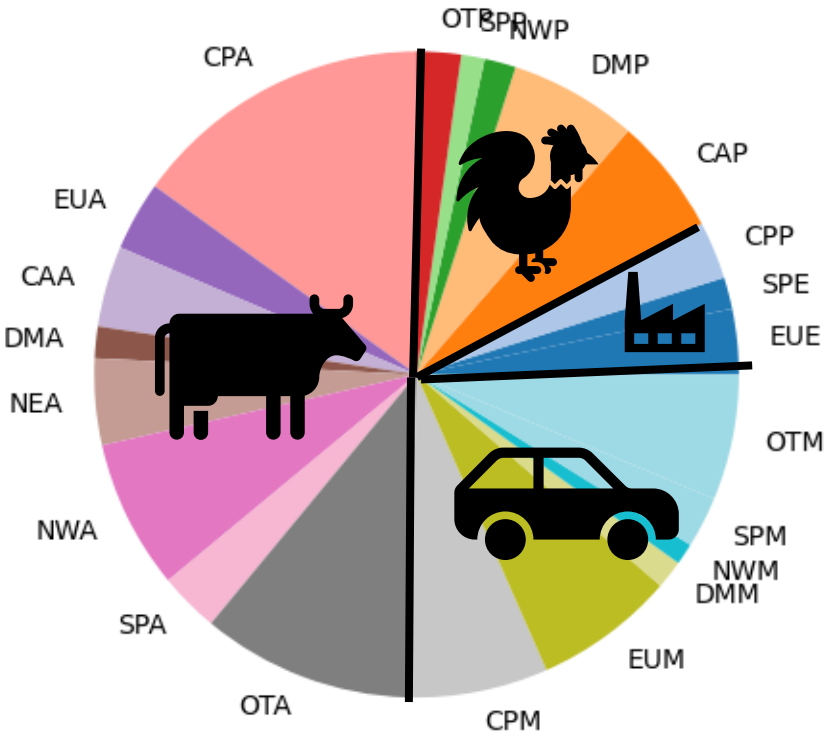

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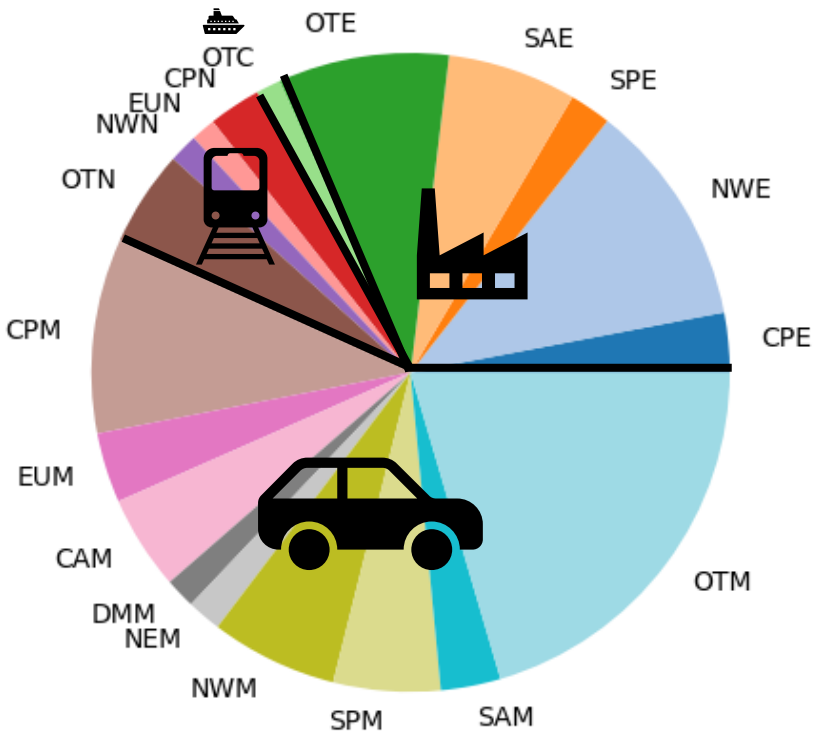
January Total Nitrogen Deposition

Oxidized



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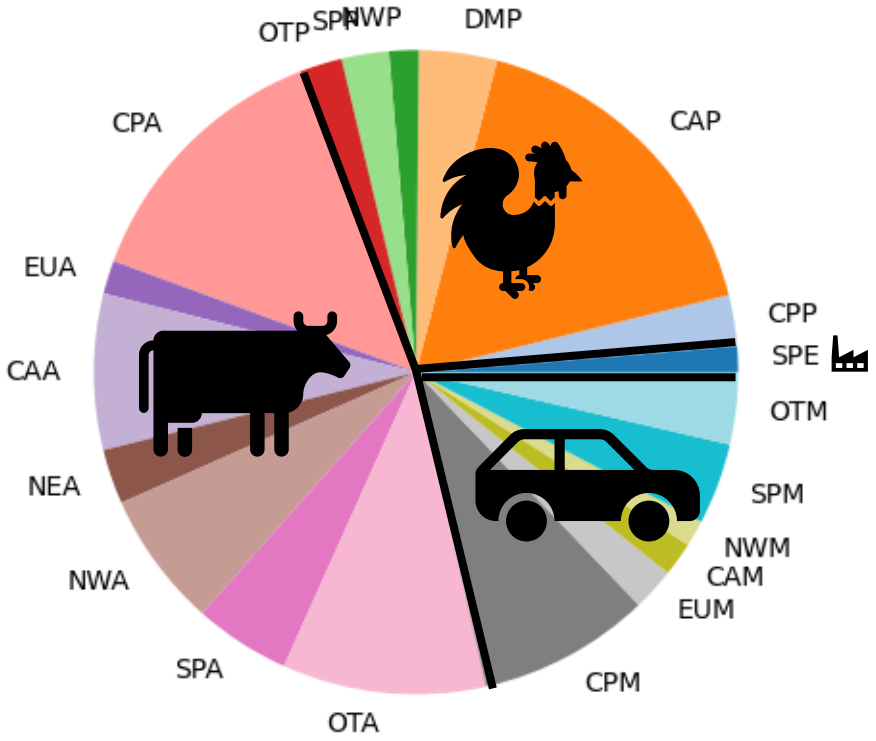

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Chesapeake Bay Watershed Preliminary Results

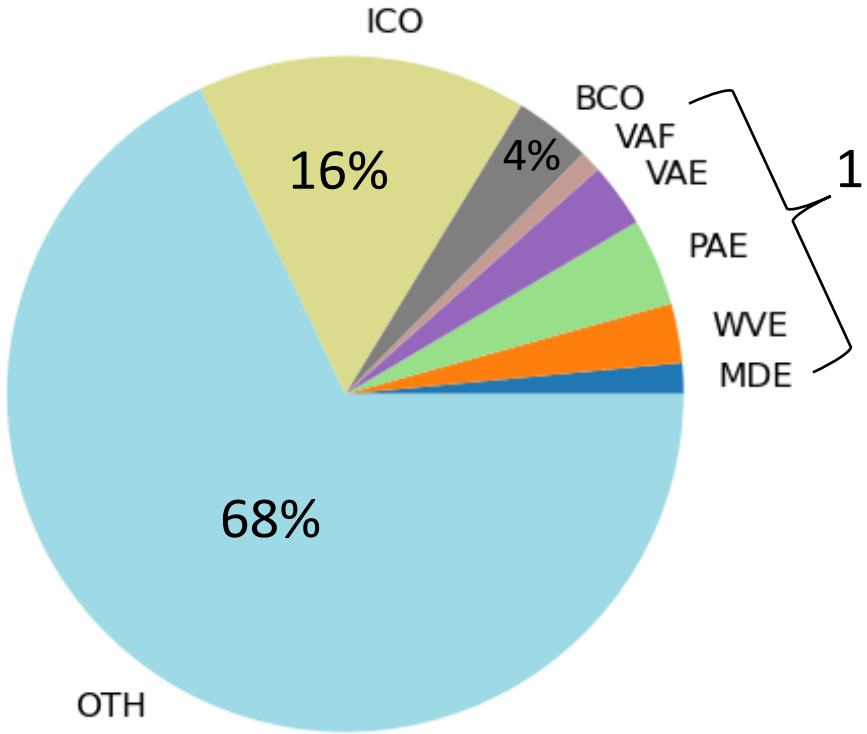
REGIONS

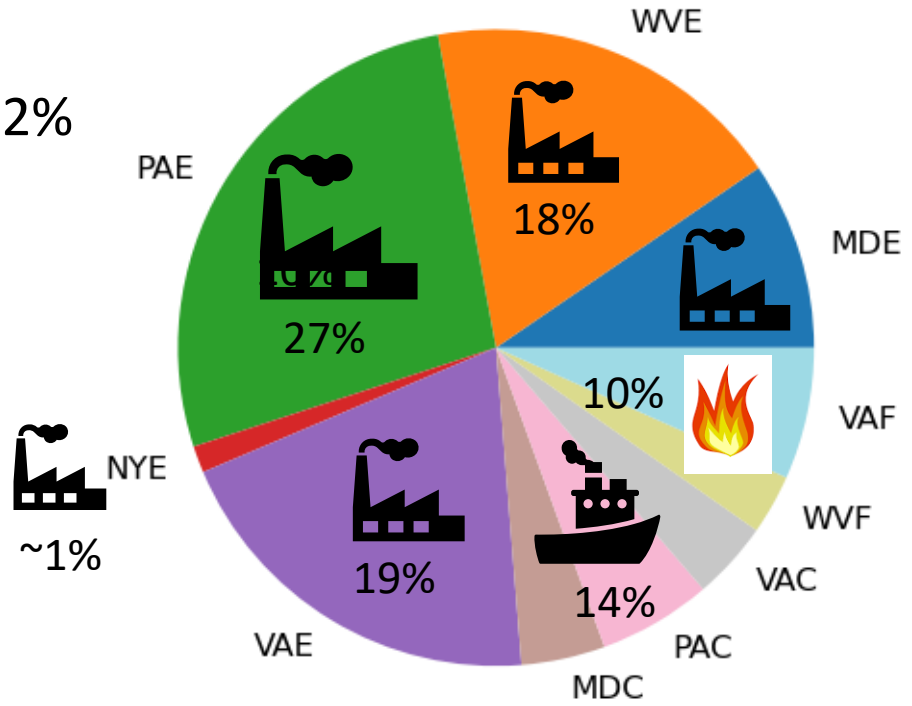
- Maryland (MD)
- West Virginia (WV)
- Pennsylvania (PA)
- New York (NY)
- Virginia (VA)
- Washington, D.C. (DC)

EMIS STREAMS

- EGUs (E)
- Agricultural fires (A)
- Commercial marine vessels (C)
- Fires (F)

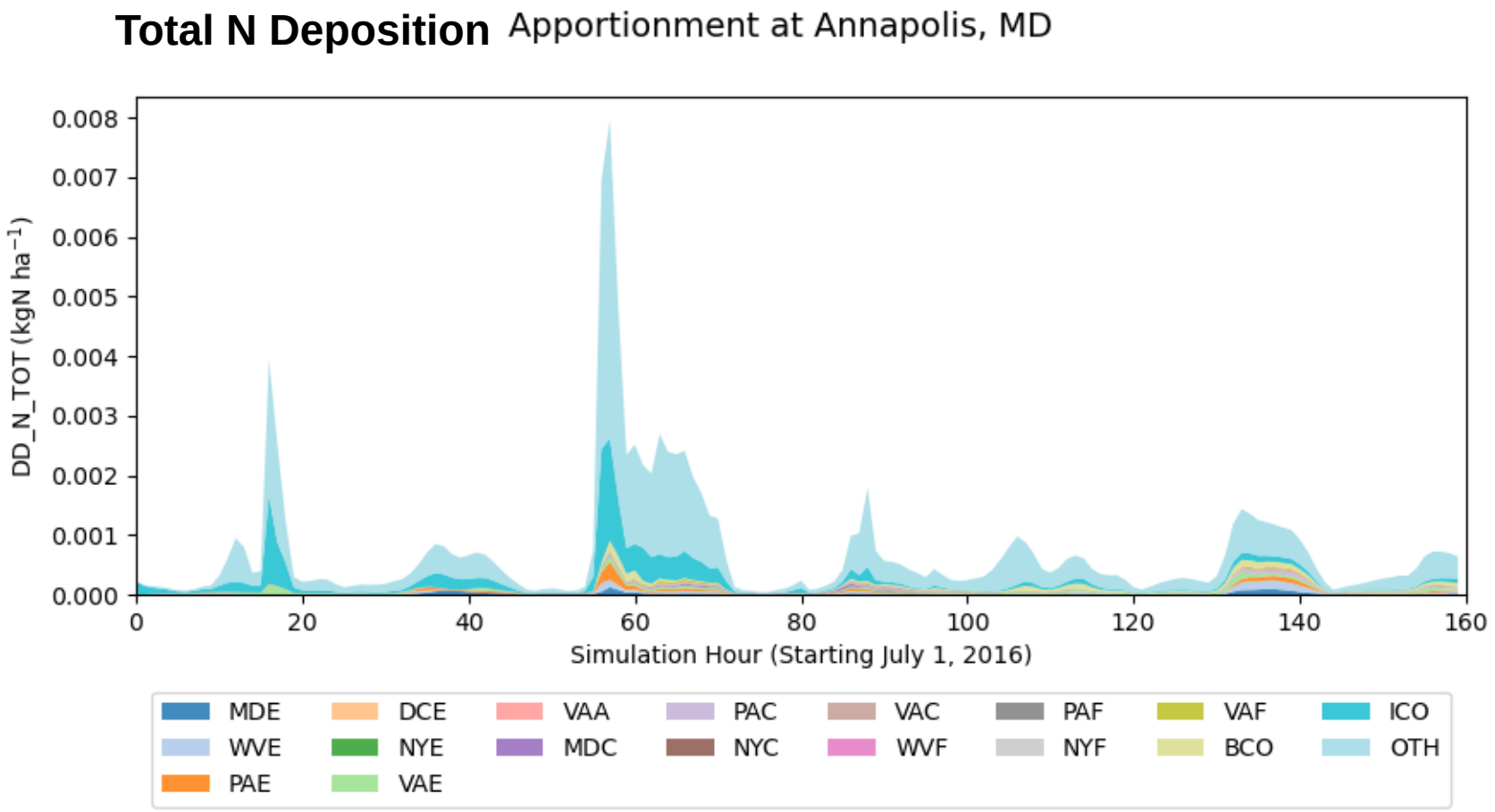
Chesapeake Bay Watershed
July 1-7, 2016





- Large contributions from initial and boundary conditions
- EGUs in PA, WV, VA, and MD are influential
- Smaller contribution from fires, CMV

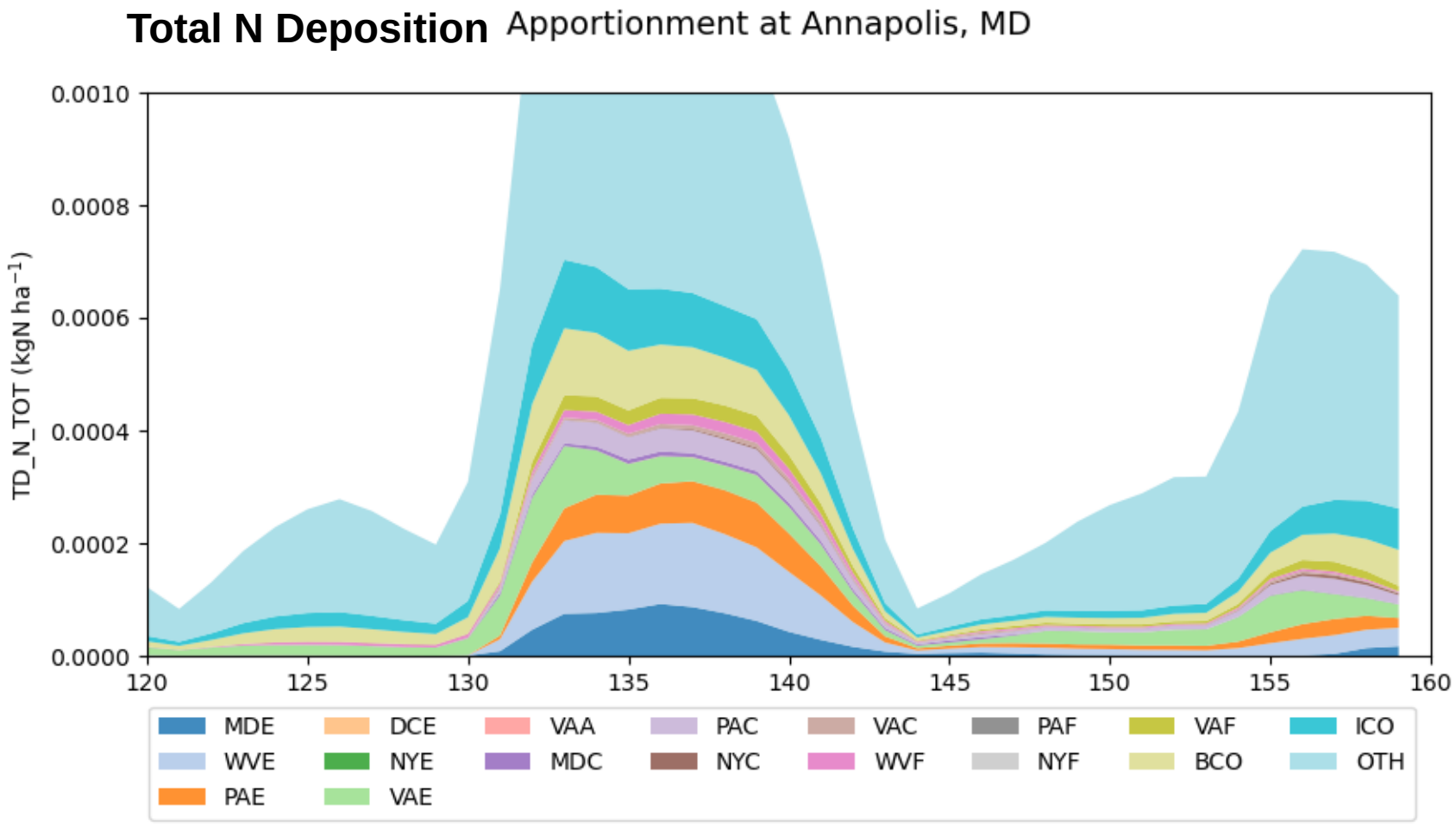
Chesapeake Bay Preliminary Results



TAG ID:
1st two letters: State abbreviation
Last letter:
E=EGU
A=Agricultural fires
C= Commercial marine vessels
F= Fires
BCO=Boundary Conditions
ICO=Initial Conditions
OTH=Other

ICO, OTH dominating total N deposition, especially toward the beginning of the simulation

Chesapeake Bay Preliminary Results



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At the end of the simulation, still see large contribution from OTH, BCO, and ICO, but also from EGUs in MD, WV, PA, and VA