Trends in Nitrogen Deposition to the Chesapeake Bay Watershed 2002-2012

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Outline

- Review of advancements in the CMAQ modeling system
- Trends in N deposition to Chesapeake Bay Watershed
- What is causing these changes?
  - Emissions
  - Atmospheric chemistry
- Deposition budget 2002-2004 versus 2010-2012
- Future outlook and conclusions

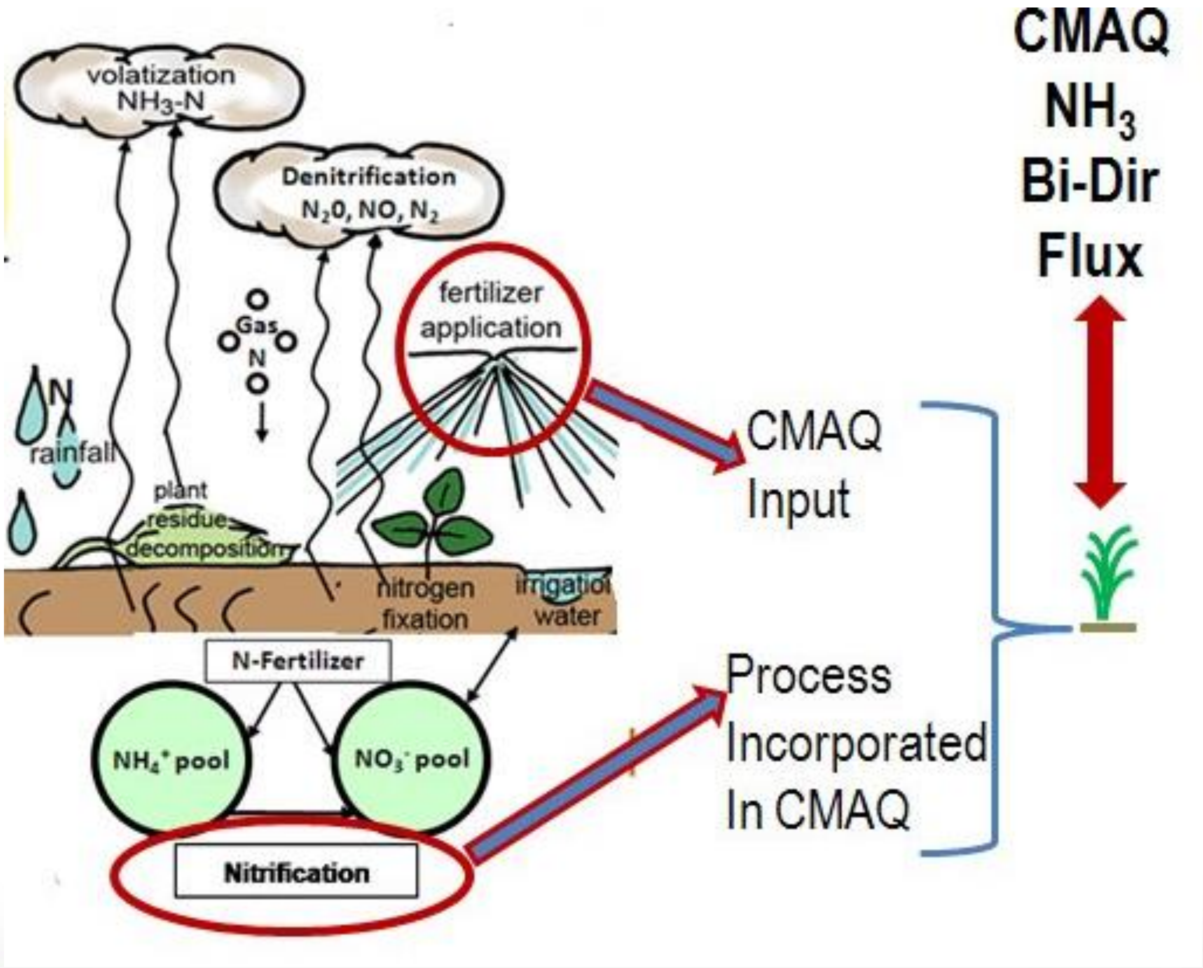
Reduced N in the Environment

- **NH_3 is the primary atmospheric base**
  - **Precursor to atmospheric particulate matter formation**
    - **Deleterious to human respiratory and cardiovascular systems**
    - **Short term climate forcer**
- **Reduced nitrogen deposition accounts for ~35% of the total nitrogen deposition in the U.S.**
  - **Contributes to excess nitrogen in ecosystems**
    - **Surface water eutrophication and terrestrial biodiversity loss**
  - **Contributes to soil and surface water acidification**
- **NH_3 air-surface exchange is bi-directional**
  - **Can be emitted (evasion) or deposited**
  - **Depends on land use, environmental variables, ambient NH_3 concentration and land management practices**

Advancements in CMAQ

- Bidirectional exchange
  - Coupled Agro-ecosystem model to the chemical transport model
    - Environmental Policy Integrated Climate (EPIC) model
  - Couples agricultural cropping management and soil geochemical processes with CMAQ
  - Dynamic NH_3 emissions from fertilizer application
    - Dependent on fertilizer composition, weather, soil conditions, crop, application method, etc.
- Temporal CAFO NH_3 emissions
  - Applies physical constraints for hourly emissions estimates from annual totals submitted by the states
- Improvements in modeled convective precipitation
  - Reduces the overestimate of precipitation in the summer months.

Bidirectional NH_3 Exchange



Improvements in CAFO Emissions

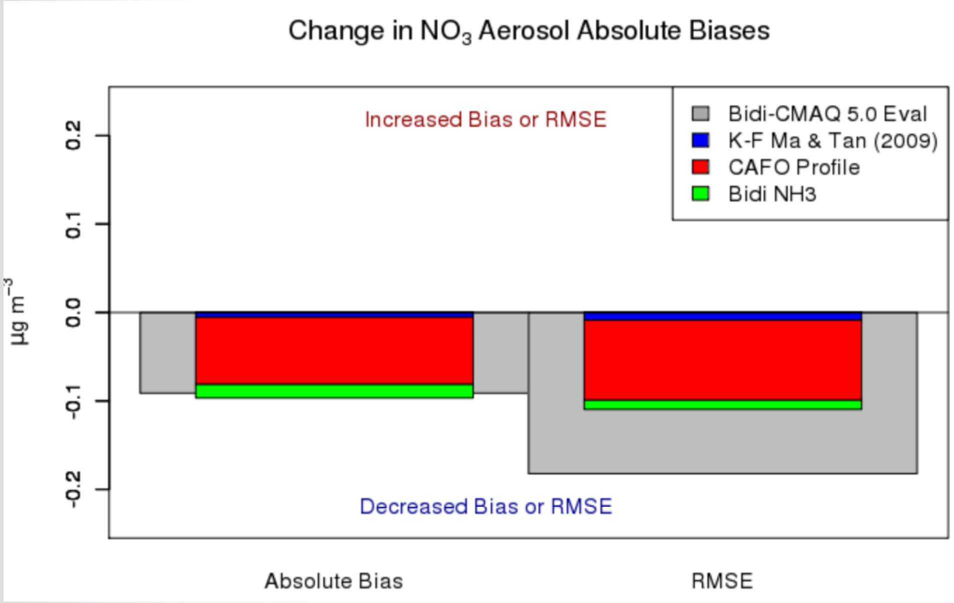
R_a ↑

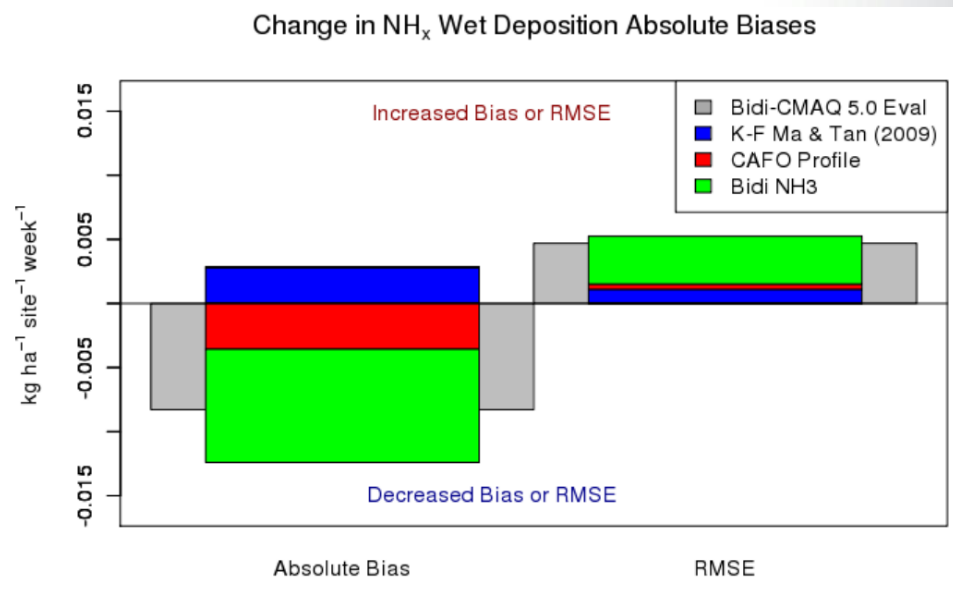
$R_{management}$ ↑

- Use a resistance model approach
- Assume NH_3 at the source is >> that in atmosphere
- Assume NH_3 emissions originate from an aqueous pool
- Key parameters are atmospheric resistance and $NH_4^+{}_{(aq)} \leftrightarrow NH_{3(g)}$ equilibrium

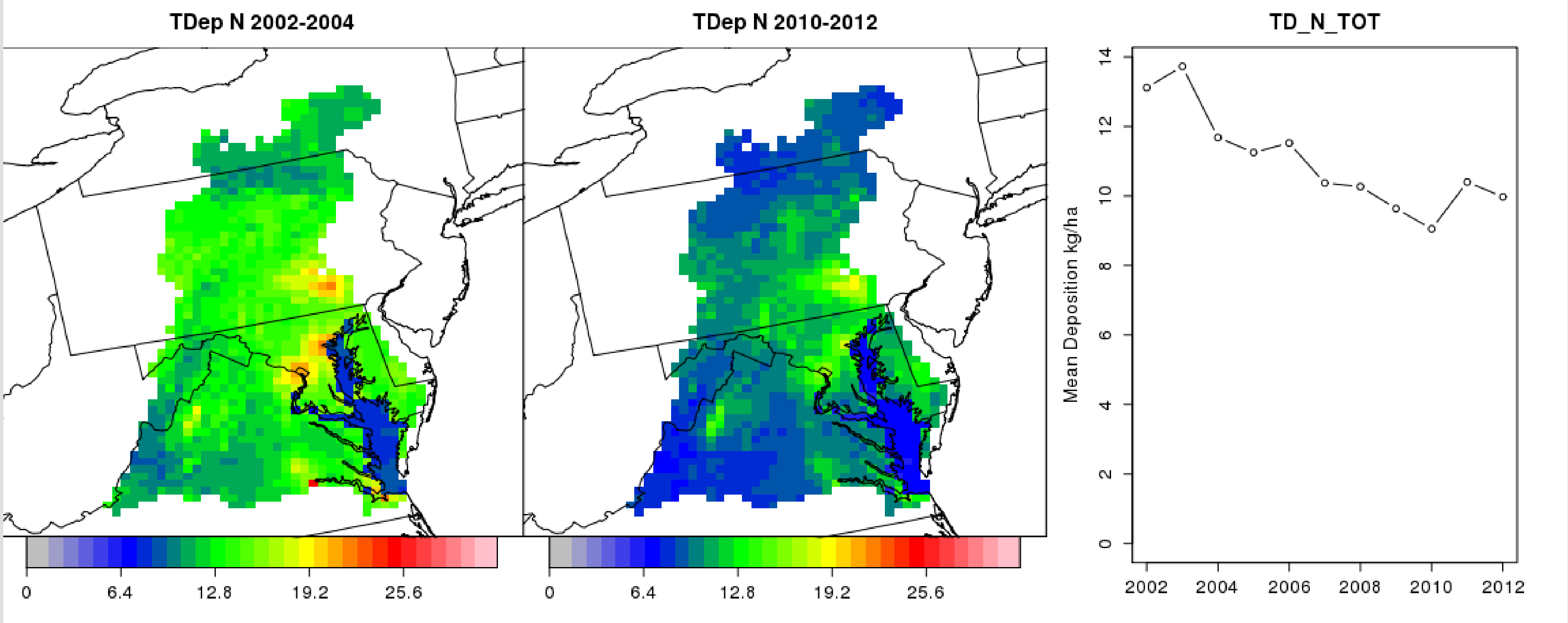
CMAQ Improvements

- **Bidirectional exchange and CAFO updates significantly improve model evaluations against NHx wet deposition and NO_3 ambient aerosol observations**
- **Further evaluation in the next presentation by Robin Dennis**



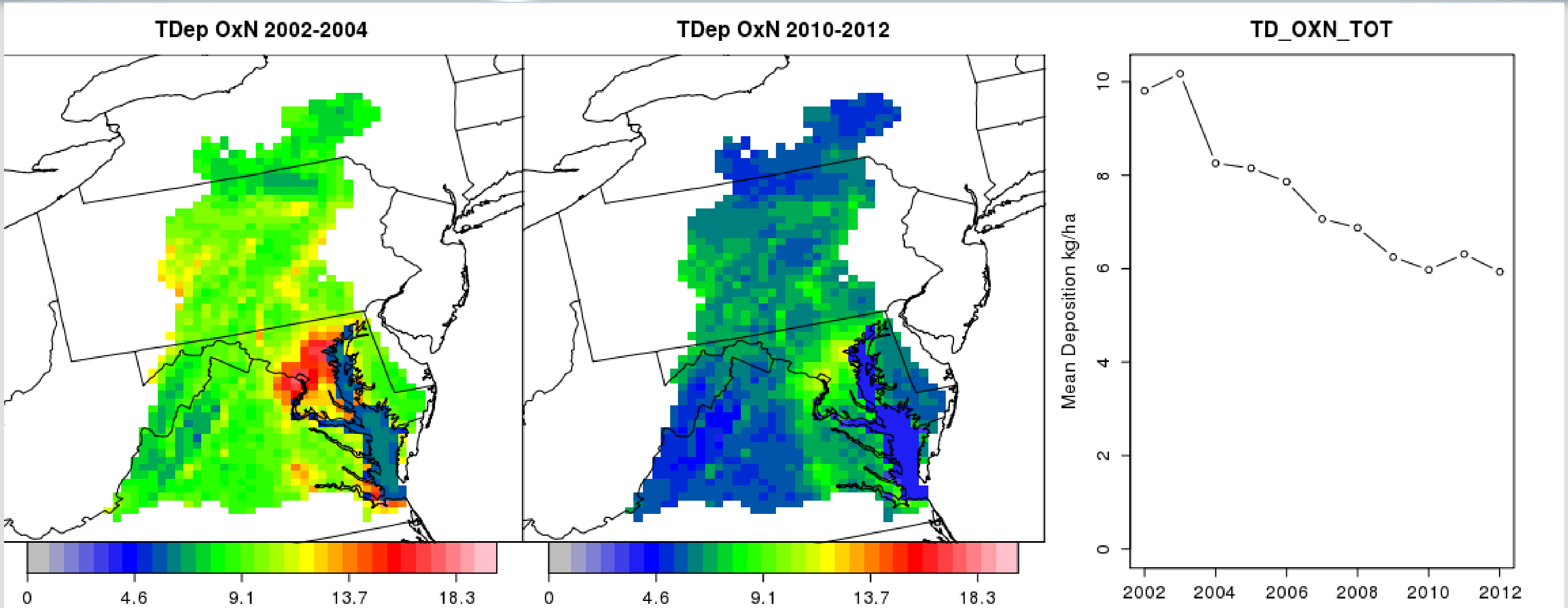


Nitrogen Total Deposition



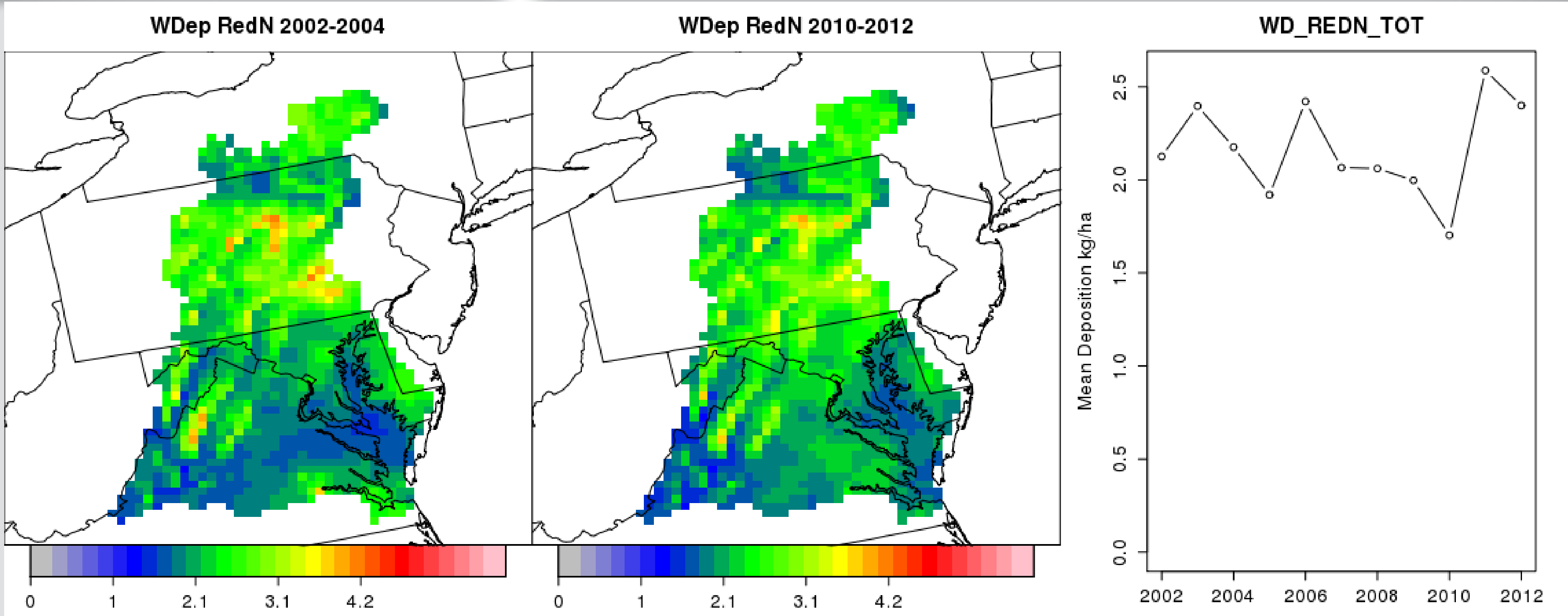
- 24% reduction in total nitrogen atmospheric deposition
- Clear benefits from air-quality regulations

Oxidized Nitrogen Total Deposition



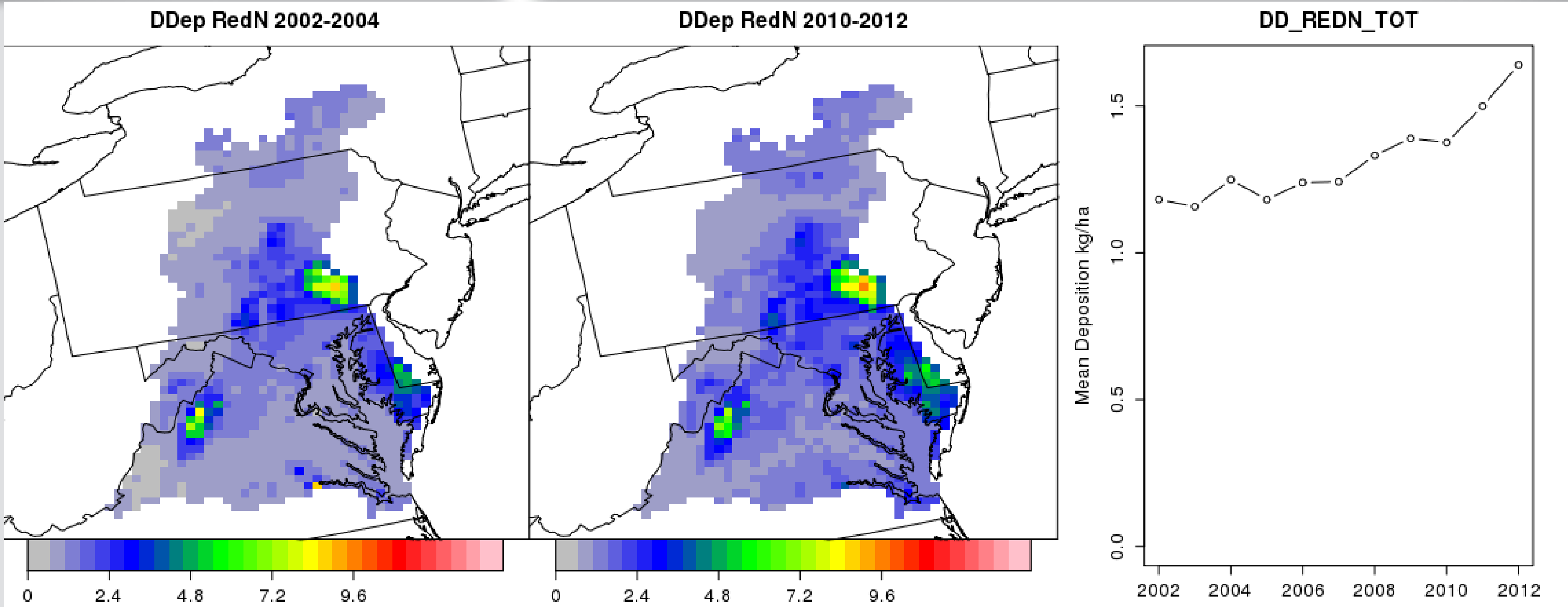
- 35% reduction in oxidized nitrogen atmospheric deposition
- Closely follows NOx emission reductions

Reduced Nitrogen Wet Deposition



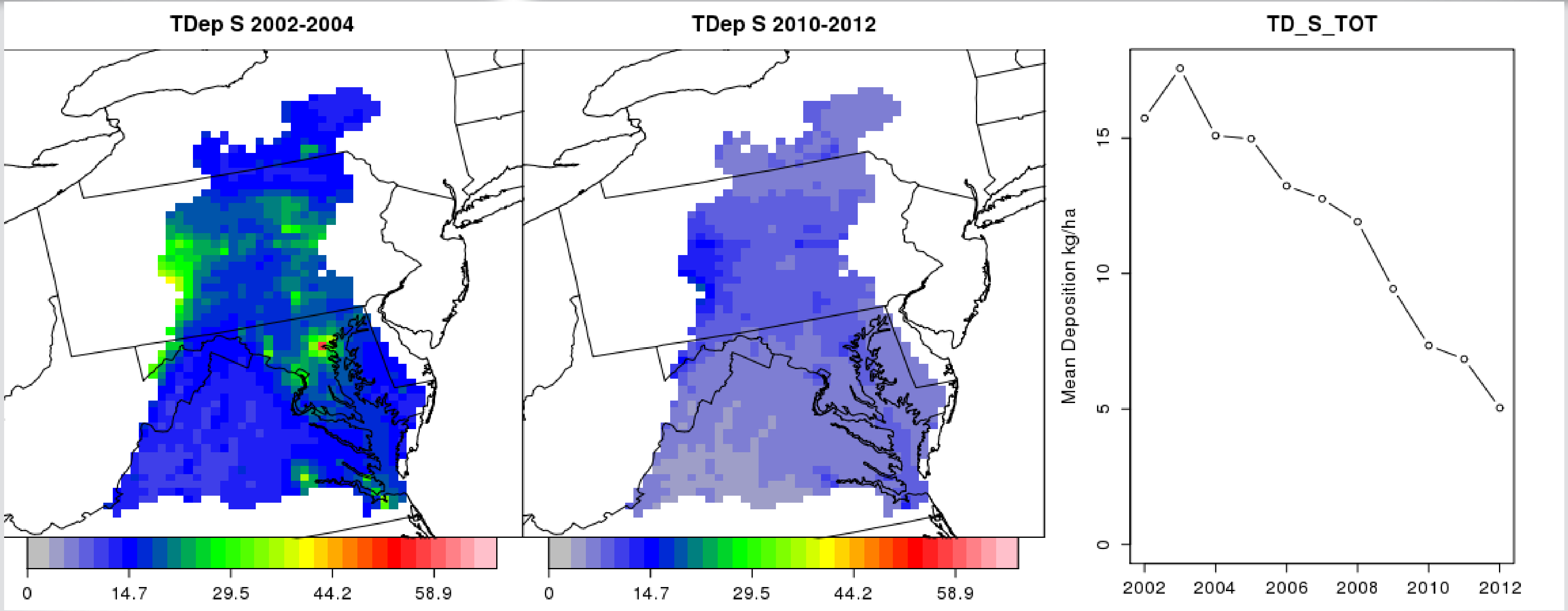
- No trend in reduced nitrogen wet deposition
- No to slightly increasing trend in NH_3 emissions
- Variability driven by precipitation

Reduced Nitrogen Dry Deposition



- 26% increase in reduced nitrogen dry deposition
- No to slightly increasing trend in NH_3 emissions
- Trend driven by NOx and SOx emission reductions (aerosol partitioning)

Sulfur Total Deposition

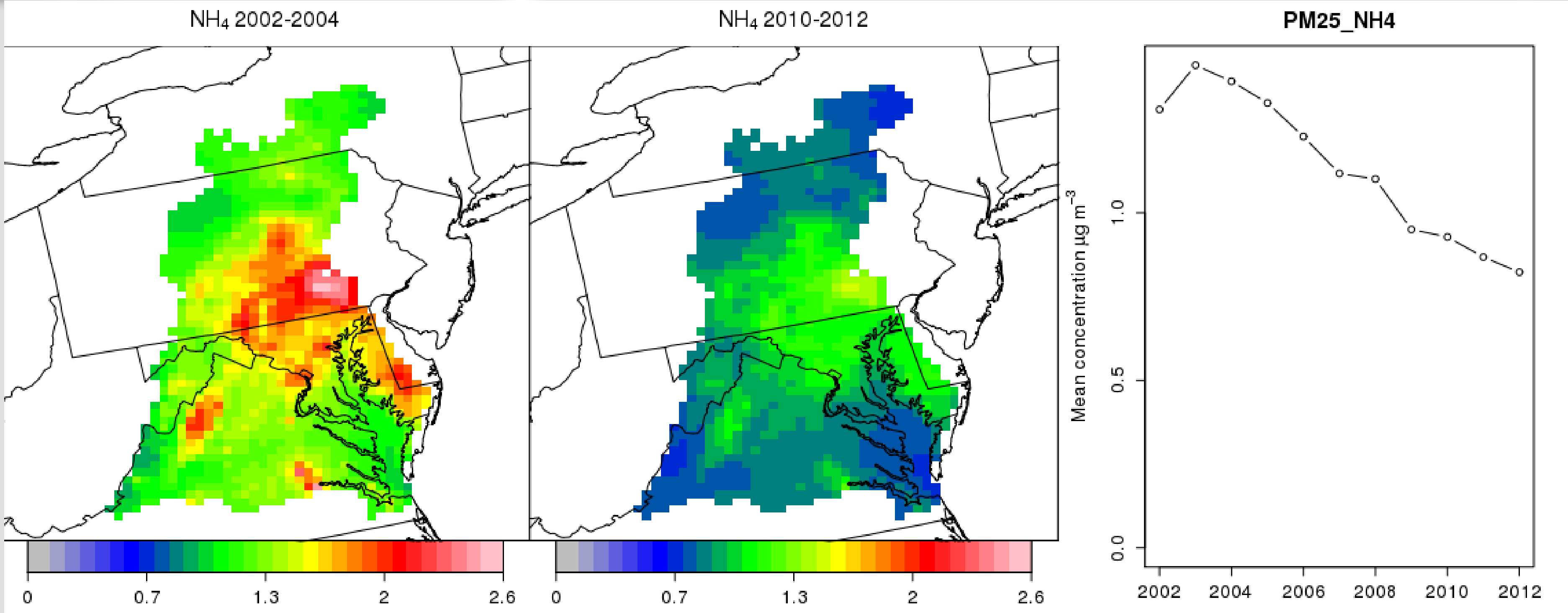


- 60% reduction in sulfur deposition
- Reflects large reductions in SO_2 emissions

Atmospheric NH_3

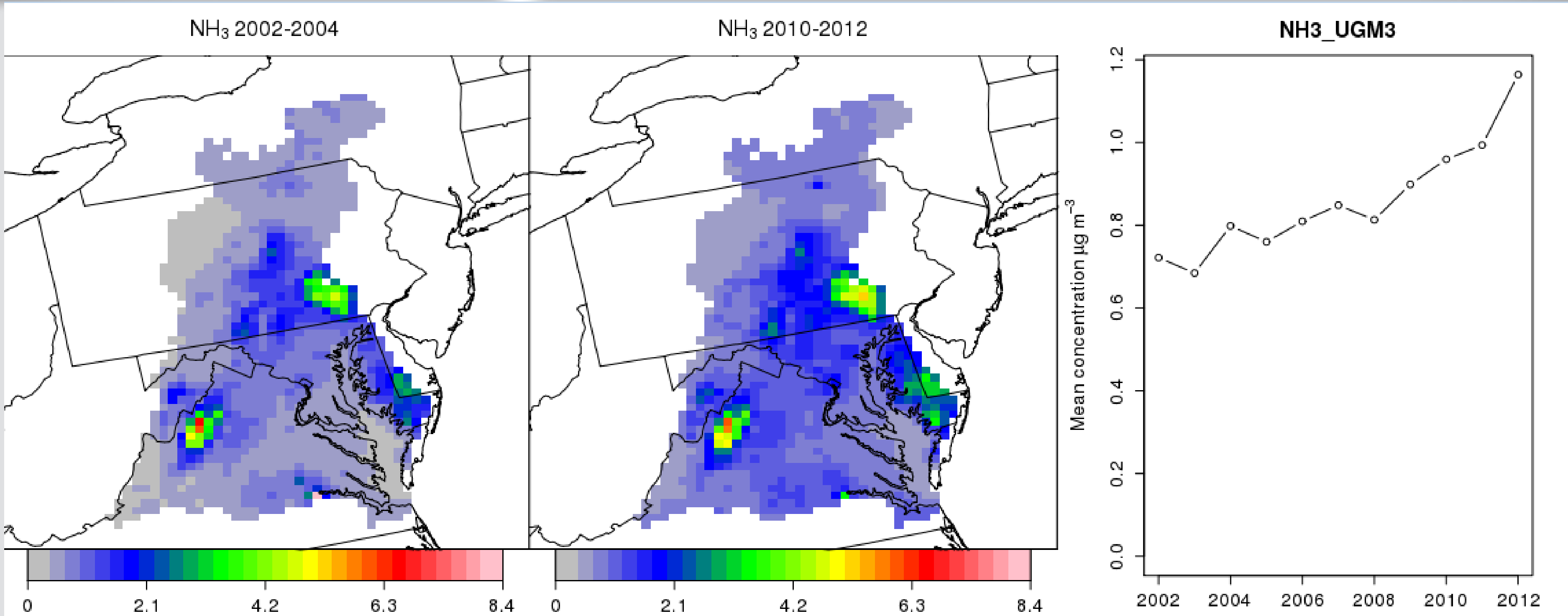
- NH_3 neutralizes SO_4 and NO_3 aerosols to form NH_4 aerosols as ammonium sulfate and ammonium nitrate
- Gaseous NH_3 and aerosol NH_4 behave differently in the atmosphere
  - NH_3 dry deposits more rapidly than NH_4
- NO_x and SO_x emission reductions
  - Lowered SO_4 and NO_3 aerosol concentrations
  - Results in lower NH_4 aerosol concentrations
- Static NH_3 emissions with these reductions results in more ambient gaseous NH_3
  - More local NH_3 deposition
  - Reduction of long range reduced nitrogen transport

Ambient NH_4 Aerosol



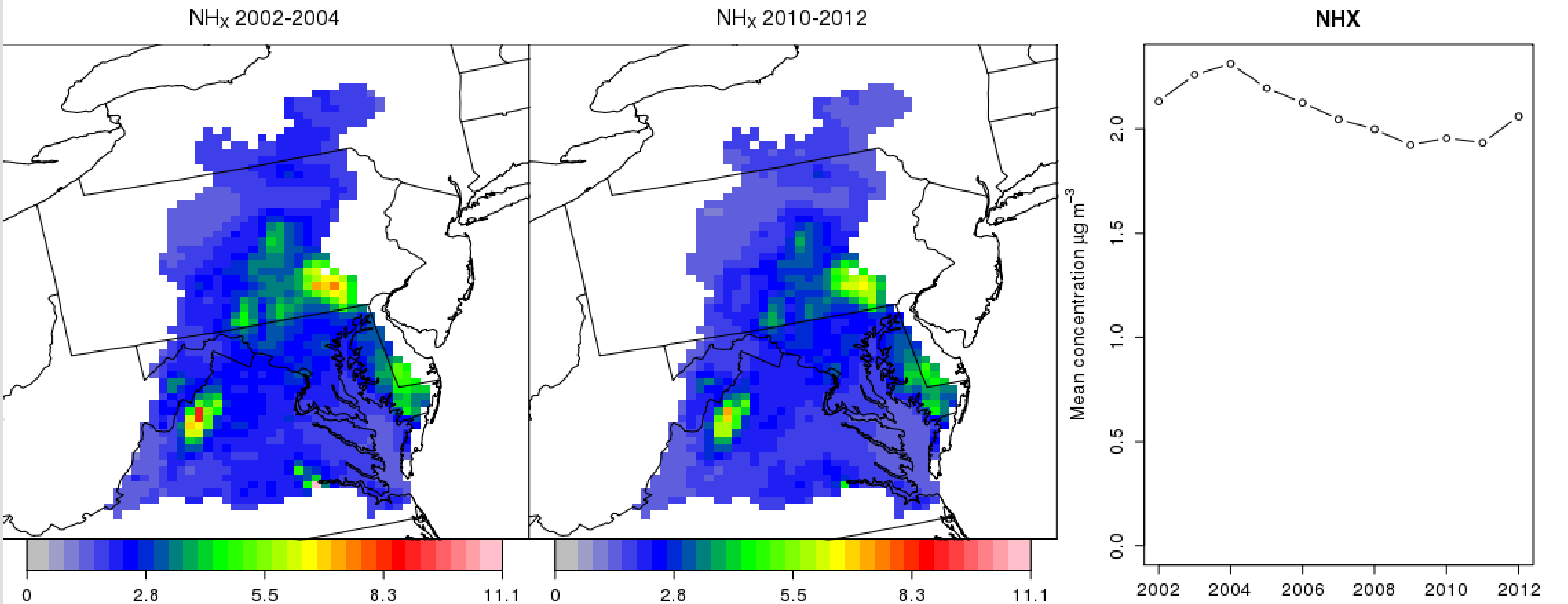
- 37% reduction in ambient NH_4 aerosol concentration
- Reflects reductions in SO_2 and NO_x emissions

Ambient Gaseous NH_3



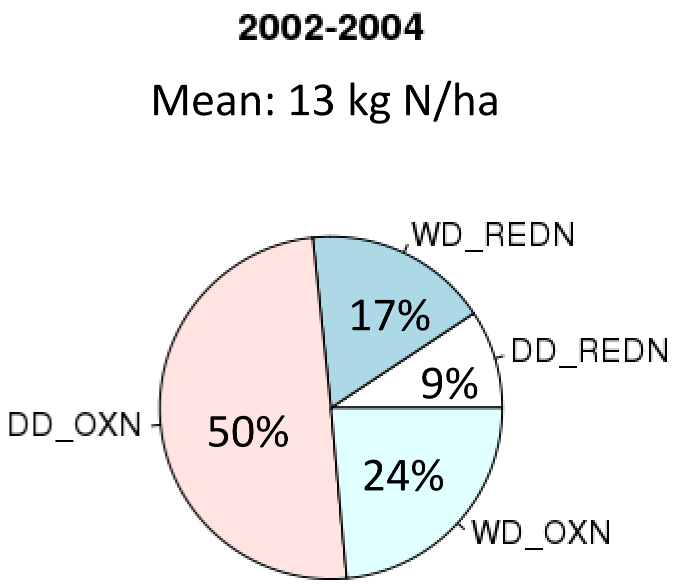
- 41% increase in ambient NH_3 gaseous concentration
- Due to reduction in aerosol partitioning
- Almost the inverse of the NH_4 reduction

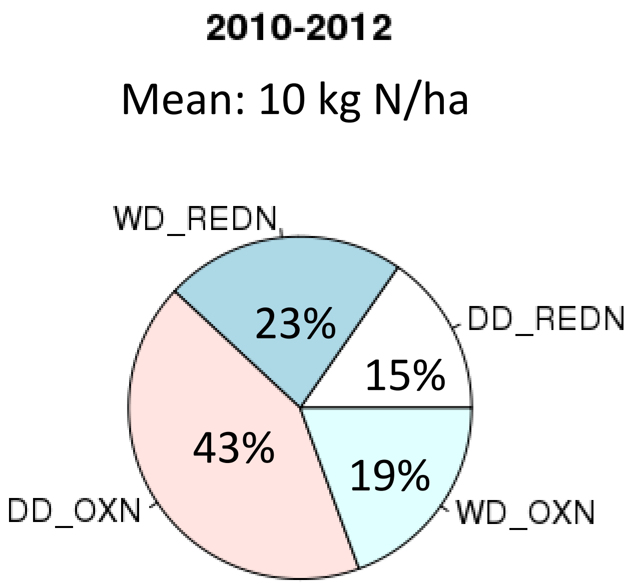
Ambient NH_x (NH_3+NH_4)



- 11% reduction in ambient NH_x
- Static NH_3 emissions
- Reduction is due to increase in NH_3 dry deposition

N Deposition Budget





- Overall N deposition has decreased due to regulations
- Ratio of oxidized to reduced N deposition is changing
- Oxidized N deposition is decreasing
  - Due to controls on combustion sources
- Reduced N deposition is increasing
  - Due to changes in atmospheric composition and a lack of controls on NH_3 emissions

Conclusions and Future Outlook

- CMAQ captures the NOx regulations reductions in N deposition
- Oxidized nitrogen deposition primarily from combustion sources has decreased more rapidly than total N deposition
- Reduced nitrogen deposition primarily from agricultural sources has increased due to atmospheric composition changes
  - Gaseous NH_3 is deposited more rapidly than aerosol NH_4
- Future reductions in NOx will likely plateau
- Reduced N deposition will likely represent a larger portion of the deposition budget
- Mitigating NH_x loading will be tricky
  - Need to consider run off and ground water infiltration
  - A linked agriculture, air-quality, hydrology and water quality modeling system is needed