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Fertilizer NH_3 Emission Estimates for 2017 National Emissions Inventory Using an Agricultural Ecosystem Model and an Air Quality Model

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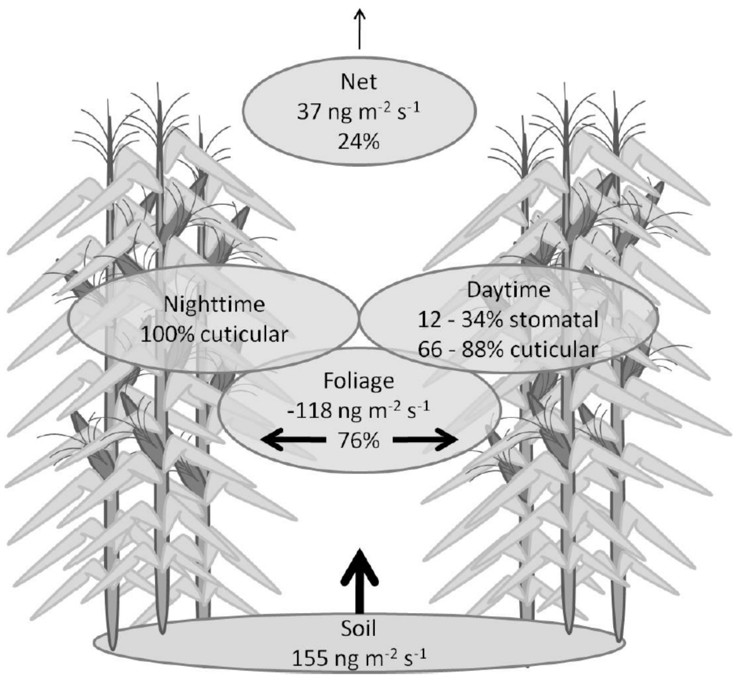
NH_3 Fertilizer Emissions

- Source Classification Code (SCC) 2801700099
  - Used by EPA to classify different activities that generate emissions
- EPA was able to leverage work done in an EPA/ORD and USDA Agriculture Research Service (ARS) collaboration
  - Develop the methodology to run the USDA's Environmental Policy Integrated Climate (EPIC) field scale model on a continental domain
- EPIC output is used by US EPA's CMAQ model to estimate NH_3 emissions from fertilizer considering bidirectional exchange
  - CMAQ uses EPIC for initial conditions and soil NH_4 inputs from fertilization and mineralization

NH_3 Bidirectional Exchange

- Measurements show that NH_3 can deposit or emit
  - Depending on meteorology and soil, plant nitrogen status, and ambient NH_3 concentration
- Traditionally emissions and deposition have been modeled separately in regional and global scale models
- NH_3 bidirectional exchange has been incorporated into the Community Multiscale Air Quality (CMAQ) Modeling system
  - Consistent representation of NH_3 emissions and deposition

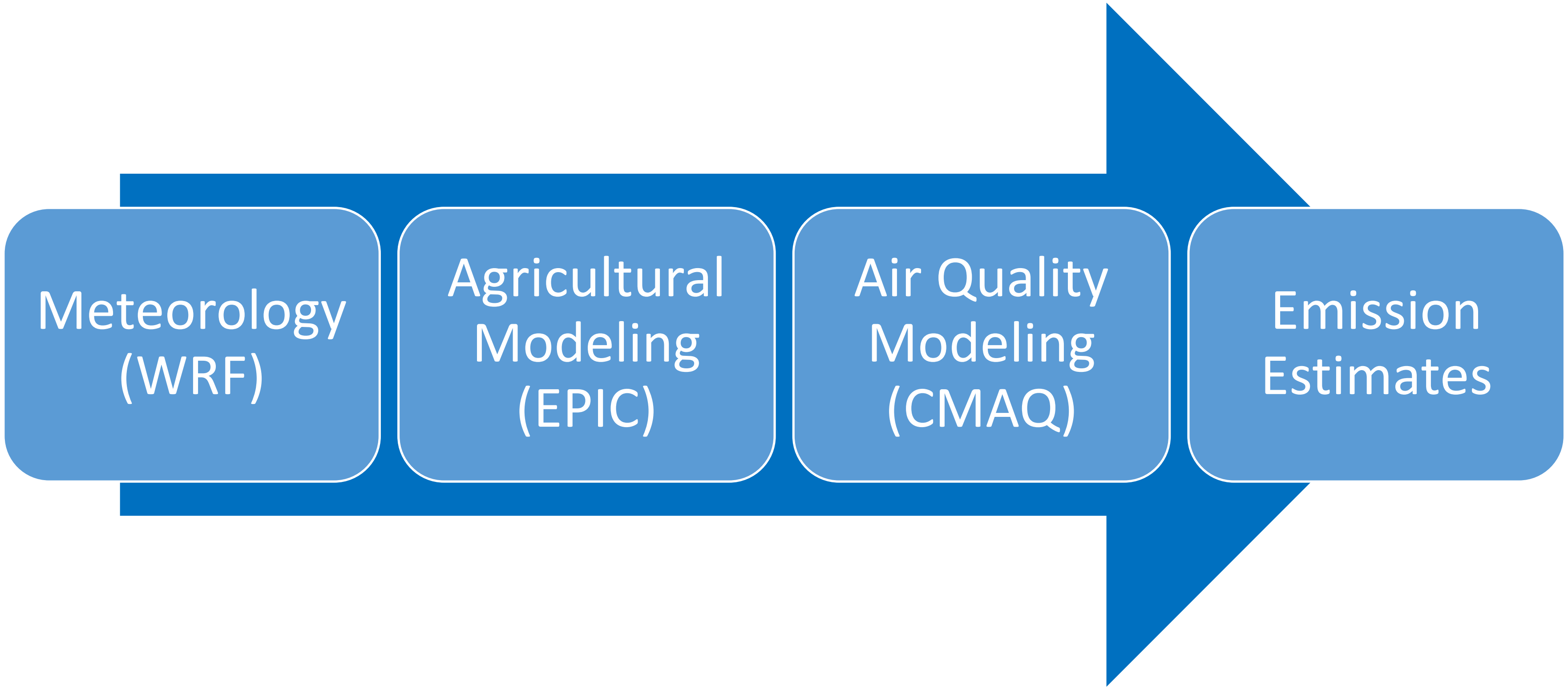


Walker et al 2013

Meteorological Factors Affecting Emissions

- Temperature – ↑ temperature, ↑ emissions
  - Higher temperature reduces the soil equilibrium ammonium concentration
- Wind speed – ↑ wind speed, ↑ emissions
  - Higher wind speed decreases surface resistance
- Precipitation – ↑ precipitation, ↓ emissions
  - Precipitation dilutes the ammonium available for evasion in the soil
- Soil pH – ↑ pH, ↑ emissions
  - Higher soil pH favors reduces the soil equilibrium ammonium concentration

Modeling of NH_3 Emissions in CMAQ



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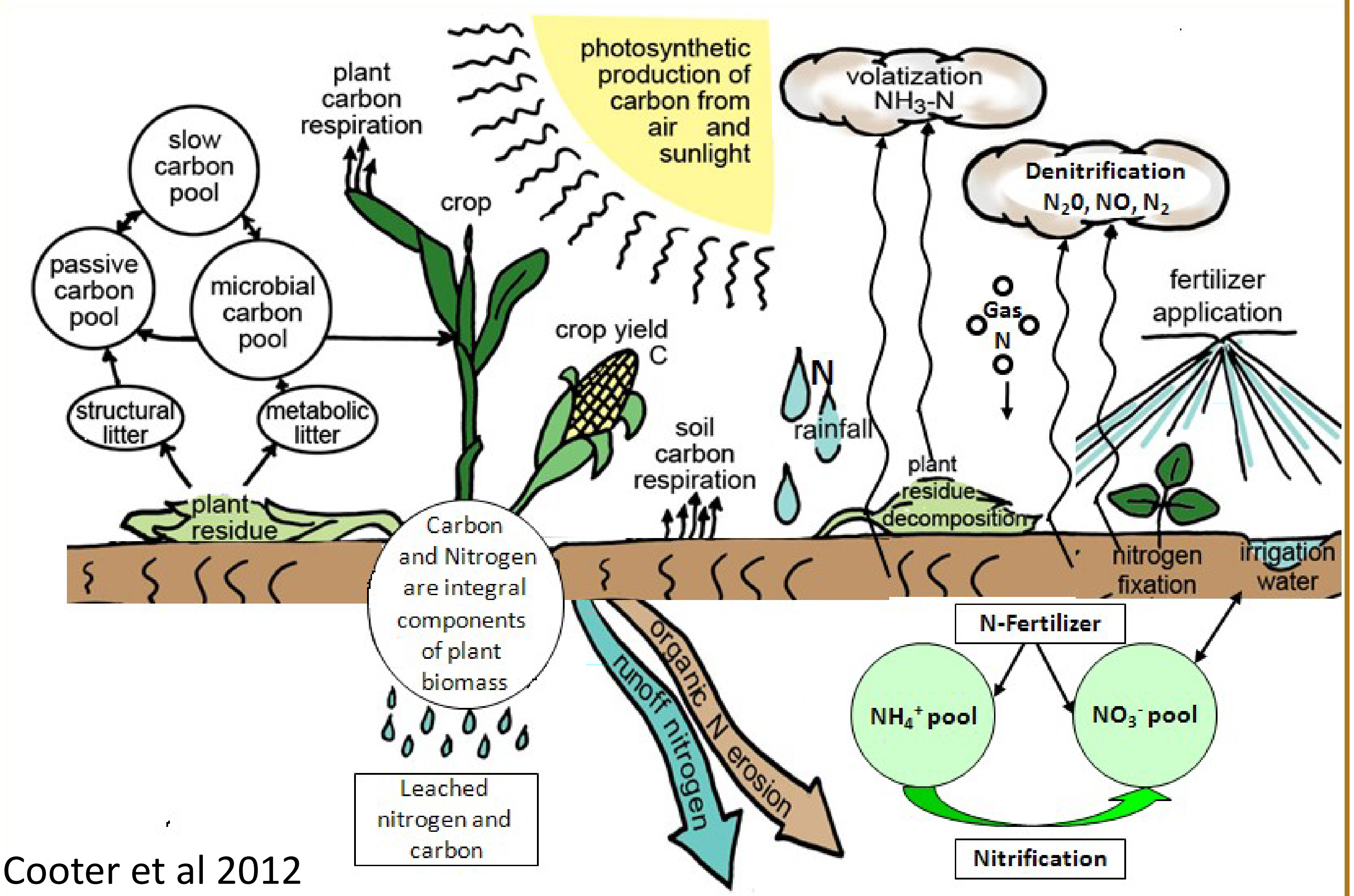
USDA EPIC Model

- Environmental Policy Integrated Climate (EPIC) Model
  - Assess the effect of soil erosion on productivity
  - Predict the effects of management decisions on:
    - Soil, water, nutrient, pesticide movements, soil loss, water quality, and crop yields for areas with homogeneous soils and management
- We have developed an interface to run EPIC for CMAQ applications
  - Fertilizer Emission Scenario Tool for CMAQ (FEST-C)
    - Available at https://www.cmascenter.org/fest-c/
  - Includes EPIC and data needed to run for the contiguous US



Cooter et al 2012
doi:10.5194/bg-9-4023-2012

Processes considered in CMAQ coupled to the USDA Environmental Policy Integrated Climate (EPIC) model

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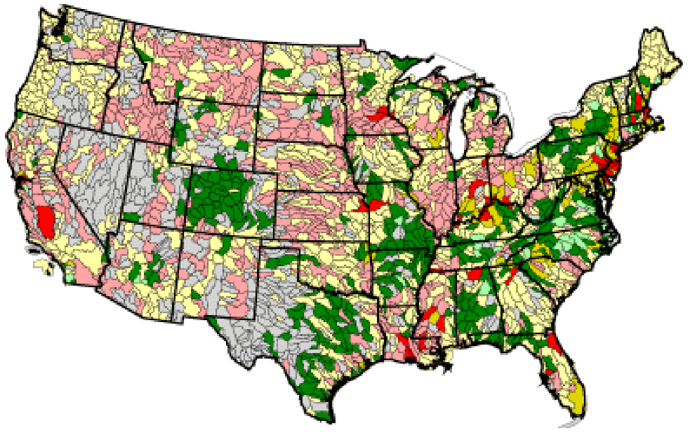
EPIC Inputs

- Soil hydrological properties, type and pH
  - USDA National Resources Inventory agricultural soil survey data
- Crop Type and area
  - 2012 census of agriculture survey data
- Crop management
  - USDA Farm Production Regions based on census of agriculture data
- Meteorological data
  - Weather Research and Forecast (WRF) precipitation, wind speed, min and max daily temperature

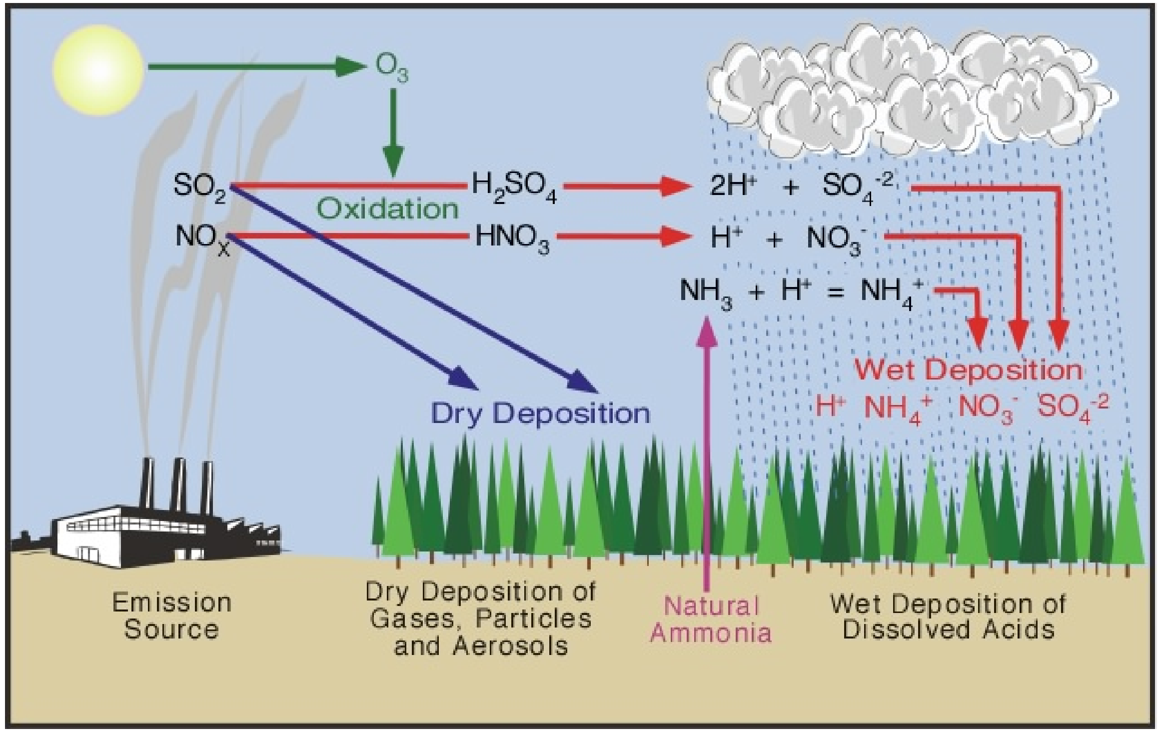


EPIC Crops Modeled for CMAQ Applications

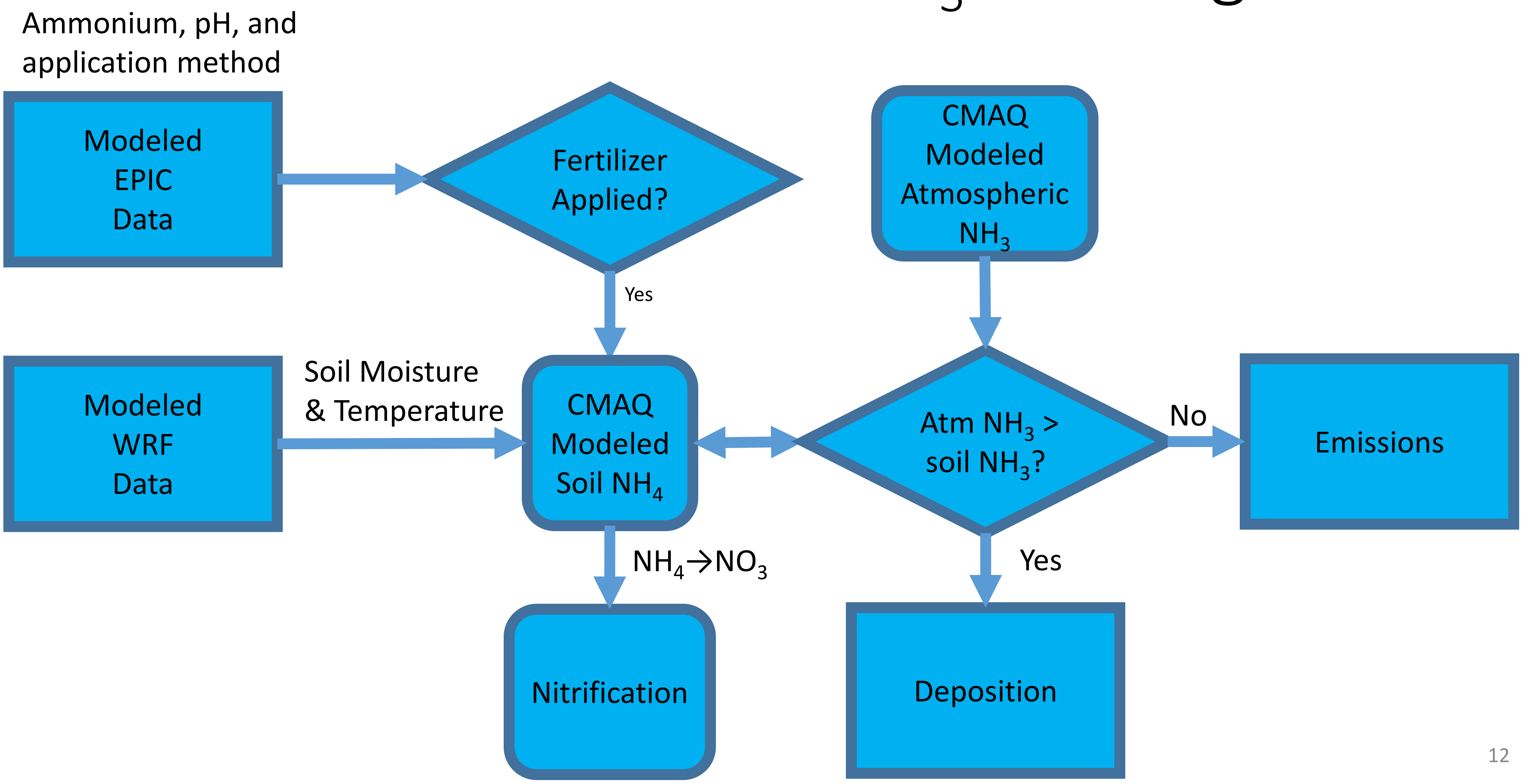
- Fertilizer Emission Scenario Tool for CMAQ (FEST-C)
  - Interface to run EPIC on the contiguous US domain and formats EPIC output for CMAQ
  - Includes USDA survey data for farm practices and crops grown
    - Mapped to CMAQ domain
- Set up to model 21 crops
  - Hay, Alfalfa, Grass, Barley, Beans Edible, Corn Grain, Corn Silage, Cotton, Oats, Peanuts, Potatoes, Rice, Rye, Sorghum Grain, Sorghum Silage, Soybean, Spring Wheat, Winter Wheat, Canola, Beans, Other Crops
  - Other crops modeled as corn
  - Crop rotation is modeled
  - Biogenic nitrogen fixation and mineralization of organic material are modeled

Modeling NH_3 exchange

- CMAQ with bidirectional exchange connects the emission and deposition of NH_3 from cropping systems to ambient concentrations
  - Important for emissions and deposition weeks to months following fertilization
  - Captures the impact that vegetation coverage has on emissions

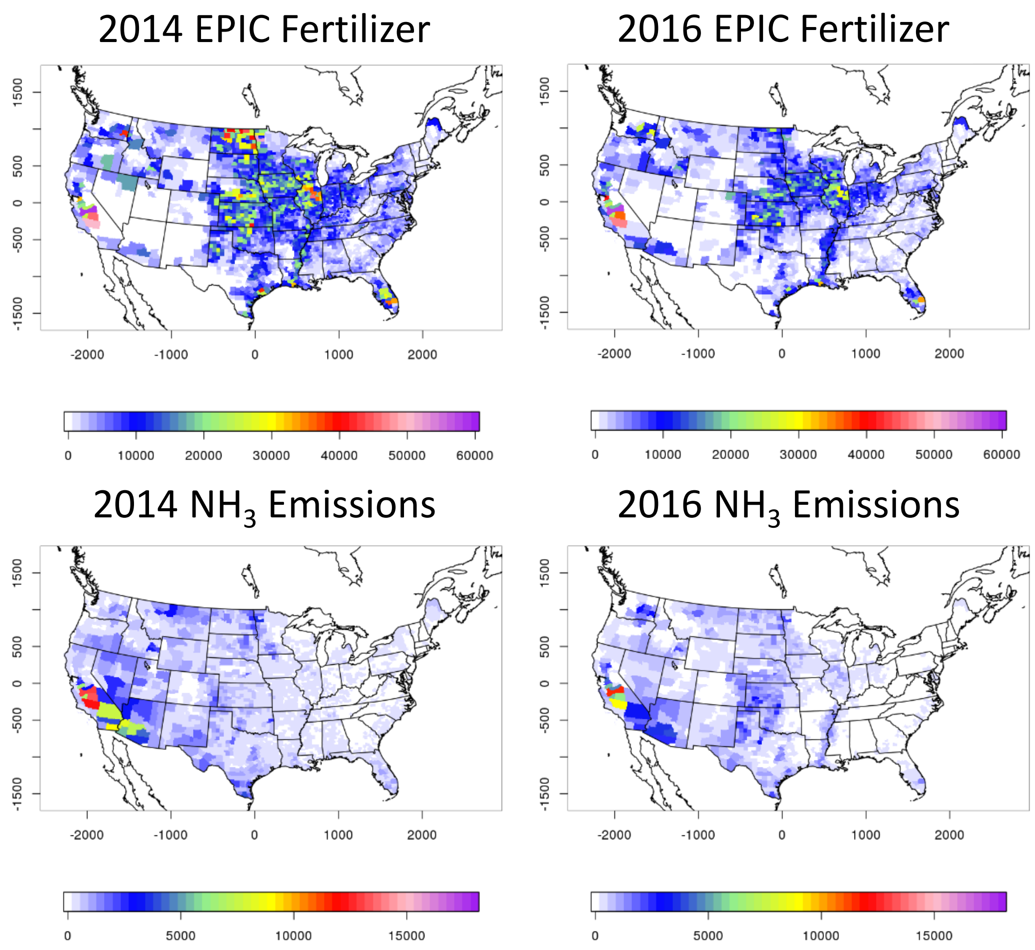


CMAQ with Bidirectional NH_3 Exchange



Draft 2017 Fertilizer NH_3 emissions

- Estimated fertilizer application lower than 2014 NEI due to updates to EPIC model
- CMAQ emissions estimates are similar despite different configuration
- EPIC fertilizer application estimates lower than sales or survey data



2017 Draft emissions

	2017 Updated	2017 Draft	2014 v2	2011 (2014 v1)
EPIC Fertilizer Application	13,914,762 tons N fertilizer 122,475 tons Biologically Fixed N	11,451,713 tons N fertilizer 122,475 tons Biologically Fixed N	18,851,866 tons N	20,314,303 tons N
CMAQ Emissions	962,985 tons N	592,218 tons N	883,526 tons N	948,616 tons N
Mean Annual Emissions Factor	6.9% total, 12.6% of urea/NH_4	4.8% total, 8.9% of urea/NH_4	4.7% total, 9.8% of urea/NH_4	4.7% total, 9.1% of urea/NH_4
Fertilizer Use*	Not Available	Not Available	13,295,000 tons N	12,814,000 tons N

* USDA Economic Research Service (https://www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx)

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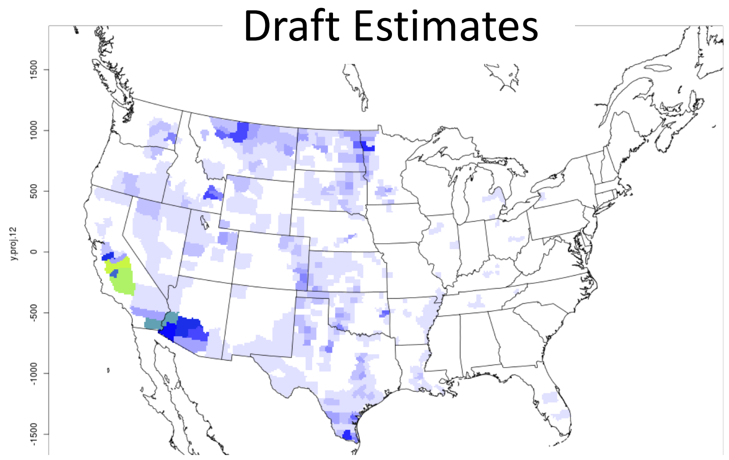
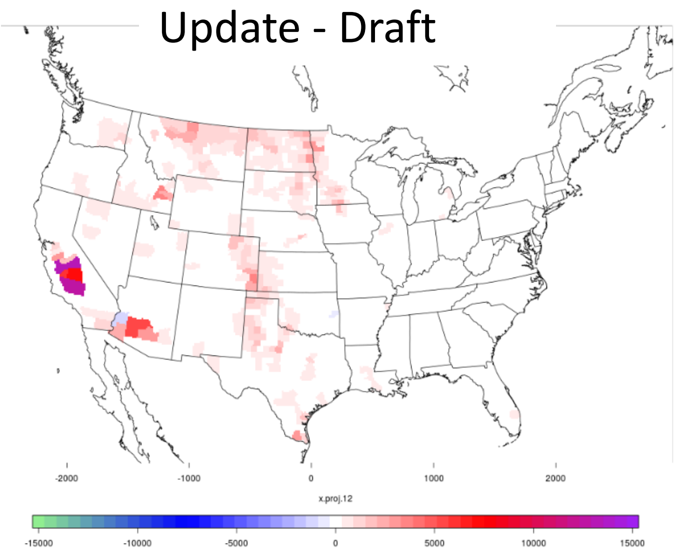
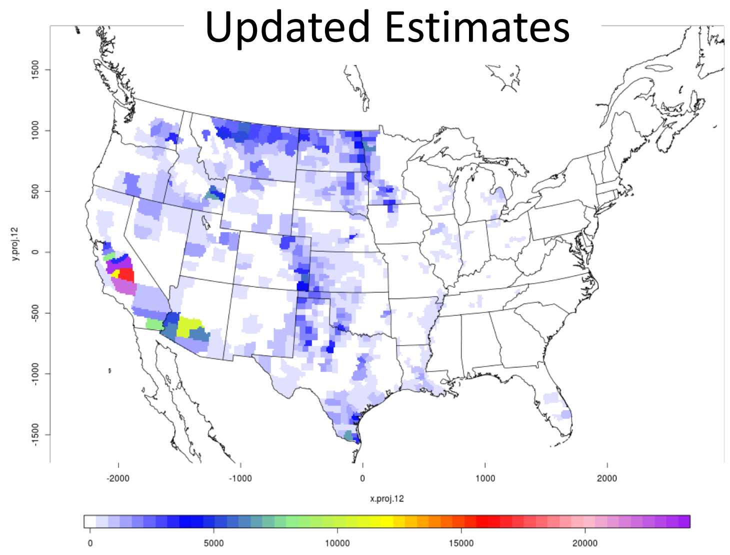
Post Processing EPIC for CMAQ

- USDA ERS and State submitted crop specific fertilizer application is used to adjust EPIC outputs
  - Assumed that EPIC spatial and temporal allocation is reasonable
  - Post processed EPIC data is then input in CMAQ with the STAGE deposition option
  - Maximum fertilization rates used from EPIC







Fertilizer application increased by 21.5%

Corn increased 18%

Cotton increased 154%

Wheat increased 27%

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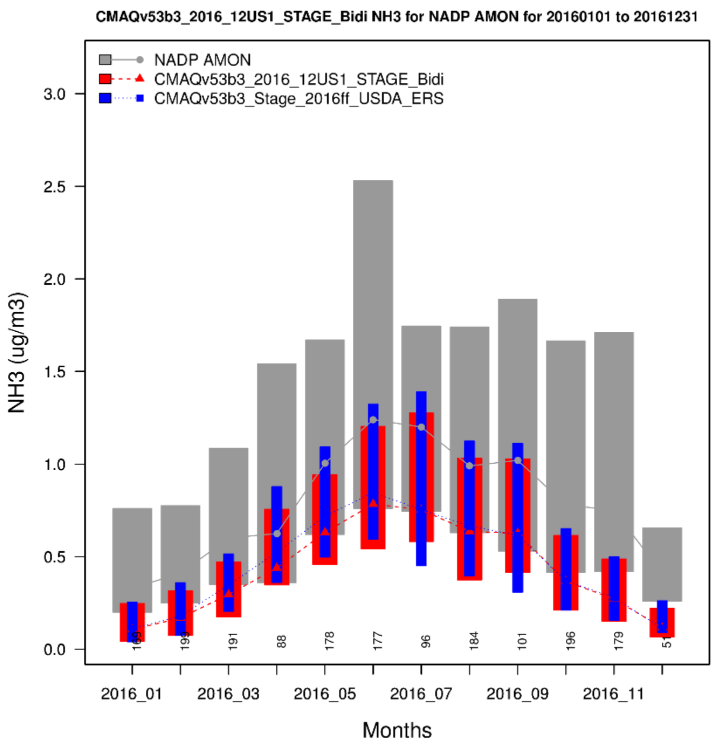
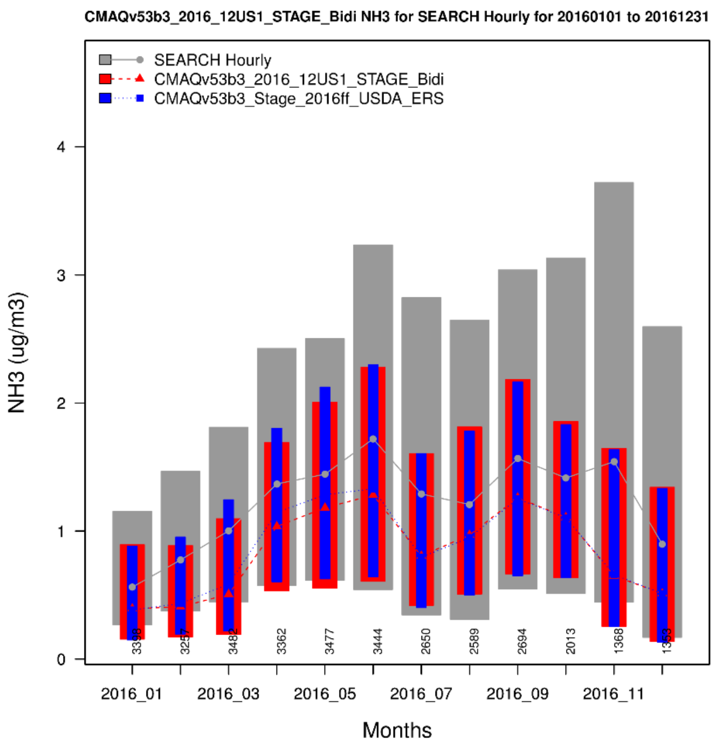
CMAQ Model Evaluation





	AMON	SEARCH
Normalized Mean Bias	-37.9%	-30.1%
Normalized Mean Error	60.0%	60.7%
r	0.60	0.40

- CMAQ model under estimates AMoN and SEARCH observations.
- Fertilizer updates reduced model bias by 5% and 2% when compared against AMoN and SEARCH sites respectively
- Existing model biases are expected to be reduced with animal NH_3 emission updates

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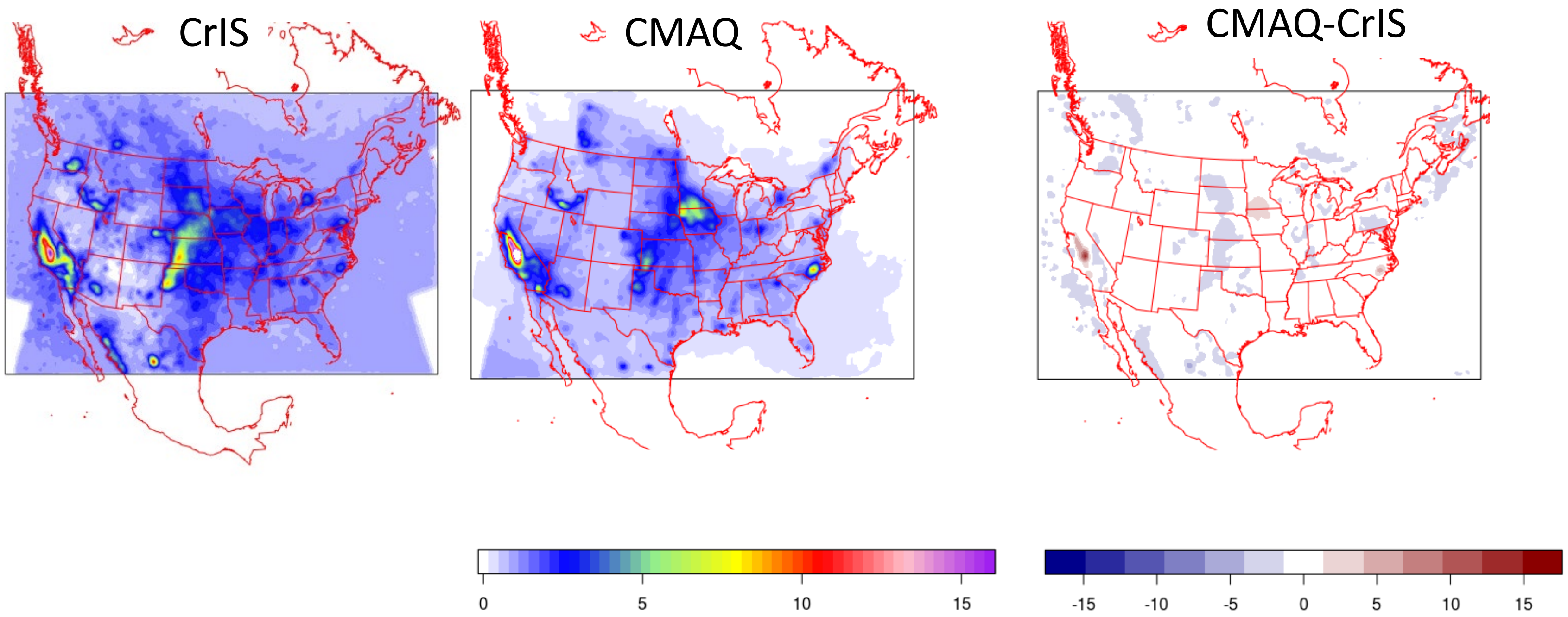
CMAQ Model Evaluation



- Cross Infared Sounder (CrIS) satellite observations using the latest retrieval algorithm v1.5
- CMAQ model simulations capture much of the spatial variability of the satellite observations
- CMAQ values are generally lower than CrIS observations

Summary

- Fertilizer sector emissions were developed using the EPIC/CMAQ modeling system for the 2017 NEI
- A methodology has been developed to address EPIC fertilizer usage estimate biases
  - Using USDA and state submitted data
- CMAQ model results underestimate NH_3 concentrations
  - Likely to improve with animal emission updates
- Spatial and temporal patterns of emissions appear to be reasonable when compared to satellite and surface observations