A Process-based Ammonia Emission Model for Agricultural Soils

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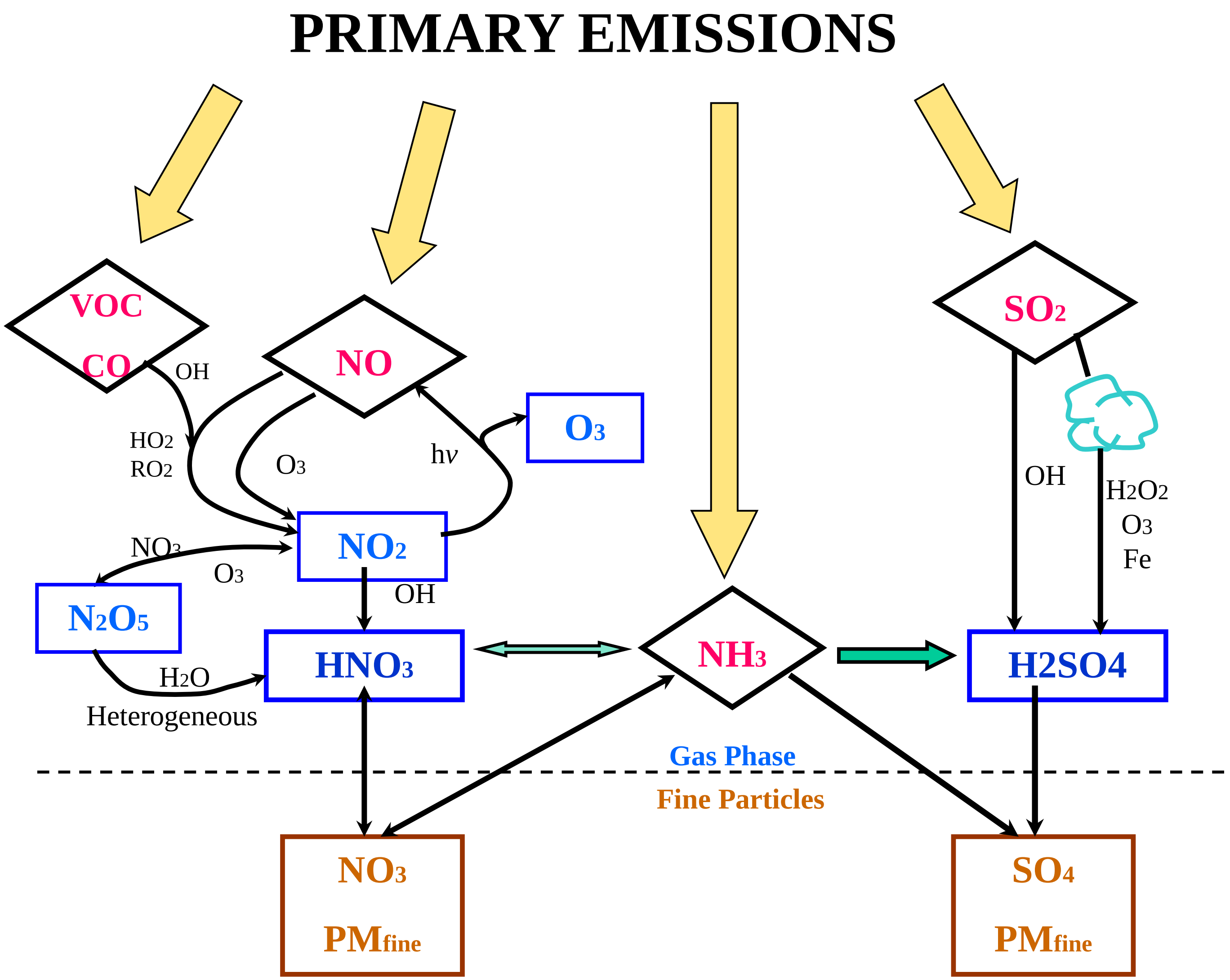
Presented to
NADP Annual Meeting and Scientific Symposium
October 8, 2009

Ammonia in a “one-atmosphere” model



The majority (~85%) of CONUS ammonia emissions are from agricultural sources

- ~51% of agricultural ammonia emissions come from livestock agriculture (NEI 2002af)
  - Animal feeding operations
    - Production
    - Finishing
  - Animal Waste
    - Dry manure management
    - Wet manure management
    - Lagoons

- ~35% of agricultural ammonia emissions come from agricultural soils (NEI 2002af)

- ~14% other agricultural sources

Research Goals

- Improve temporal and, if possible, spatial characterization of soil ammonia emissions from fertilizer.

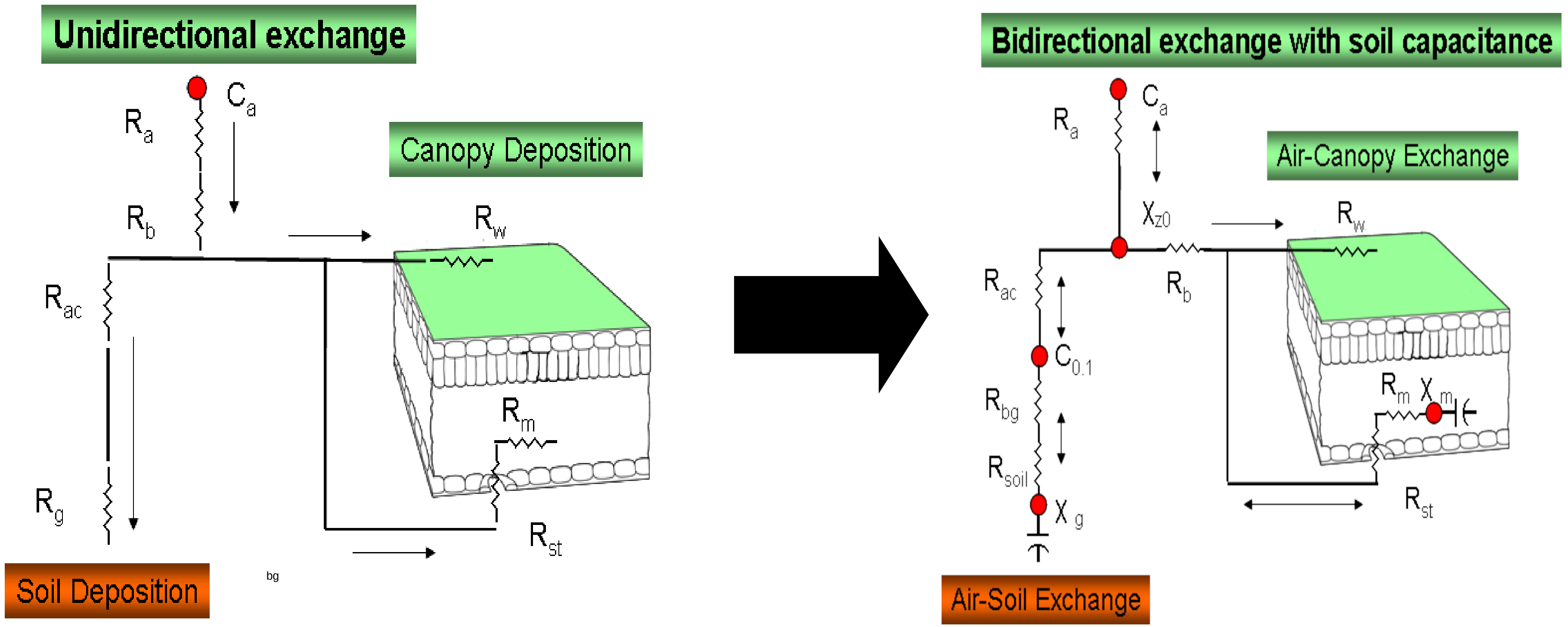
- Enhance CMAQ’s process-based parameterization of air-surface exchange and its ability to respond to emerging issues.

Emerging Issues with Implications for Ammonia Emissions

- Land use and land cover changes
  - Population
  - Economy
- Climate change and variability
- New legislated initiatives, e.g., EISA
  - Agricultural management changes
  - Conservation practices
  - Crop Reserve Program (CRP)

To meet these goals, air-soil and air- canopy exchange in CMAQ are being characterized using a bidirectional, compensation point approach.

CMAQ 4.7 begins this transition….



Parameterized Bidirectional Compensation Point Model

$$\chi = \frac{A}{T} 10^{-B/T_L} \Gamma$$

Where:

X = media compensation point for NH_3

A,B = constants associated with the temperature adjusted Henry's Law coefficient

T= media temperature (K)

Γ = dimensionless emission potential (gamma)

$$\Gamma = \frac{[NH_4^+]}{[H^+]}$$

For soil, when $X_{soil} > C_{air}$ => emission

when $X_{soil} < C_{air}$ => deposition

- To compute compensation point we need to calculate gamma (emission potential).
- How do we estimate gamma across a national domain?

Proposition

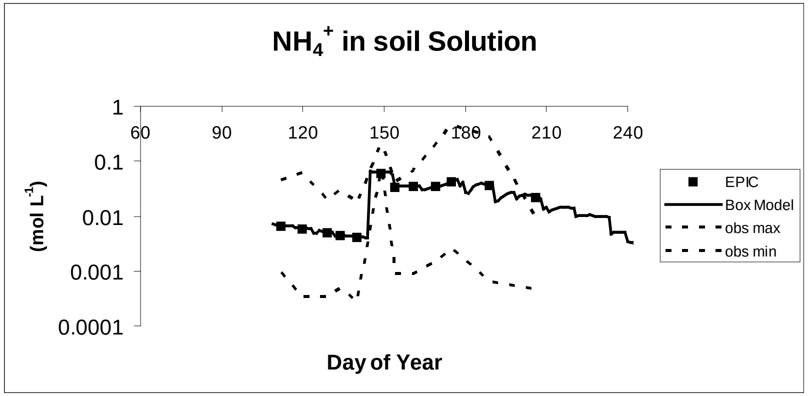
Build NH_4^+ and H^+ budget components from algorithms in the USDA Environmental Policy Integrated Climate (EPIC) model

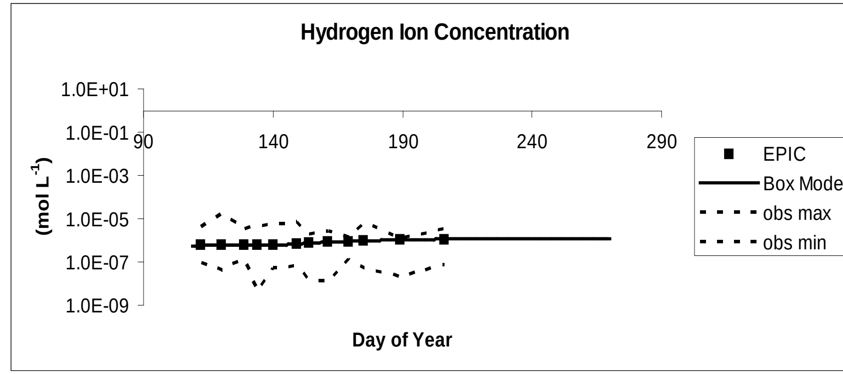
- Developed in early 1980's to assess the effect of erosion on productivity (Williams, et al., 1984).
- Subsequently has been refined to simulate many processes important to agricultural management (Sharpley and Williams, 1990; Williams, 1995).
- Operates on a daily time-step and simulates time periods up to 100 years.
- Drainage area is generally field-size, up to 100ha.
- Applied across the continental U.S. to assess soil loss, nutrient loss and change in soil organic carbon associated with crop production (Potter et.al., 2006; FAPRI, 2007)

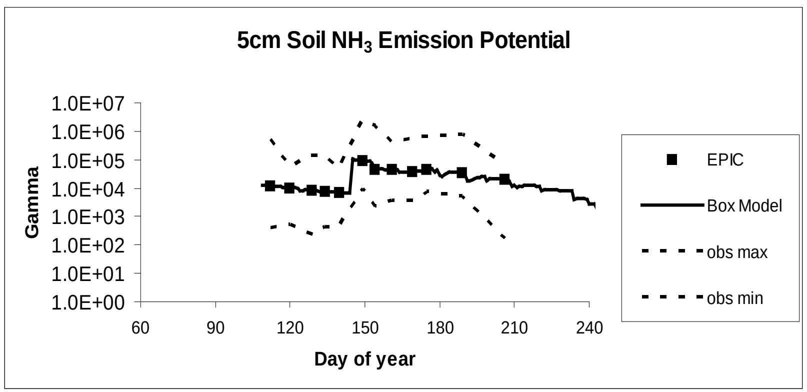
Soil Gamma (and Compensation Point) Model Development Process

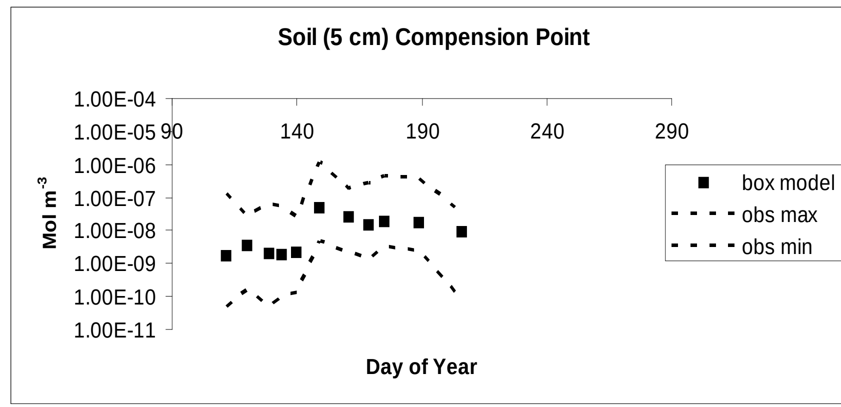
- Participation in a collaborative field study during 2007 at Lillington, NC
- Calibration of the EPIC model to the Lillington site.
- Extraction of the relevant EPIC algorithms into a compensation point box model (i.e., outside CMAQ).
- Verification of the box model against the calibrated EPIC model results

Verification of the Compensation Point Box Model



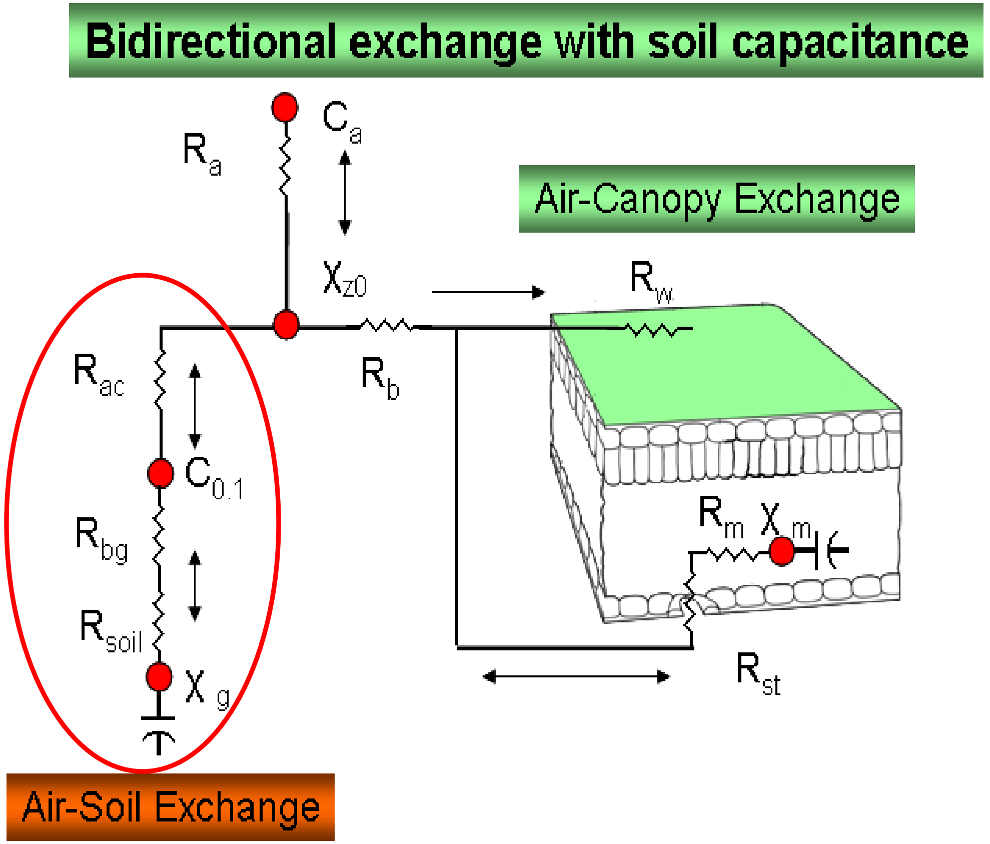






We now have a validated soil compensation point model, but how well does it characterize ammonia soil emissions at the field site?

This requires development of a soil flux model



Soil Flux Model Incorporating a Compensation Point Approach

$$Flux_{soil} = (X_g - C_{0.1})/(R_{ac} + R_{bg} + R_{soil})$$

(positive values indicate emission)

Where:

X_g = ammonia concentration in the soil pore air (soil compensation point)

$C_{.01}$ = ammonia concentration in the air immediately above soil surface

R_{ac} = aerodynamic resistance below the canopy

= $f(u_*$, stability); (assumed zero for emission)

R_{bg}= boundary layer resistance at soil surface

$$= \frac{Scn - \ln(d_0/0.1)}{k u_{stg}}$$

Scn= Schmidt number

u_{stg} = friction velocity at soil surface (Bash et al, 2009)

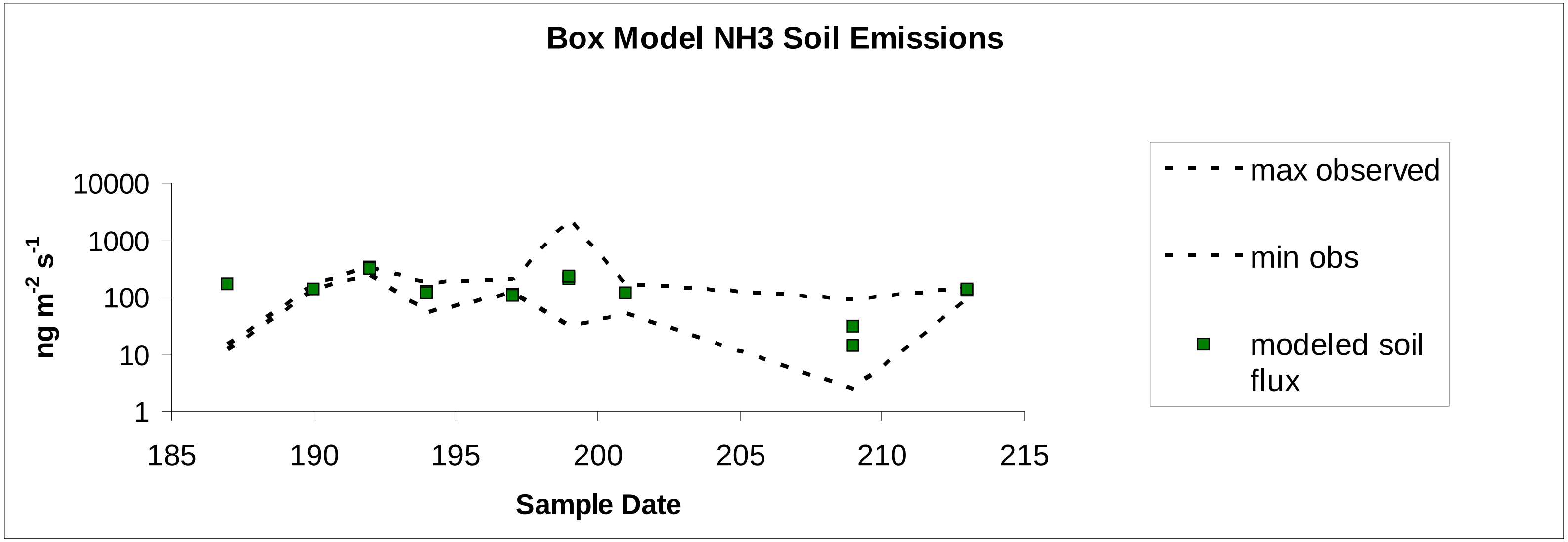
d_0 = laminar layer thickness

R_{soil} = soil resistance = d_l/D_p

d_l = diffusion length adjusted for soil moisture as described in Sakaguchi and Zeng (2009)

D_p = gas diffusion coefficient in soil (Moldrup et al. 2000)

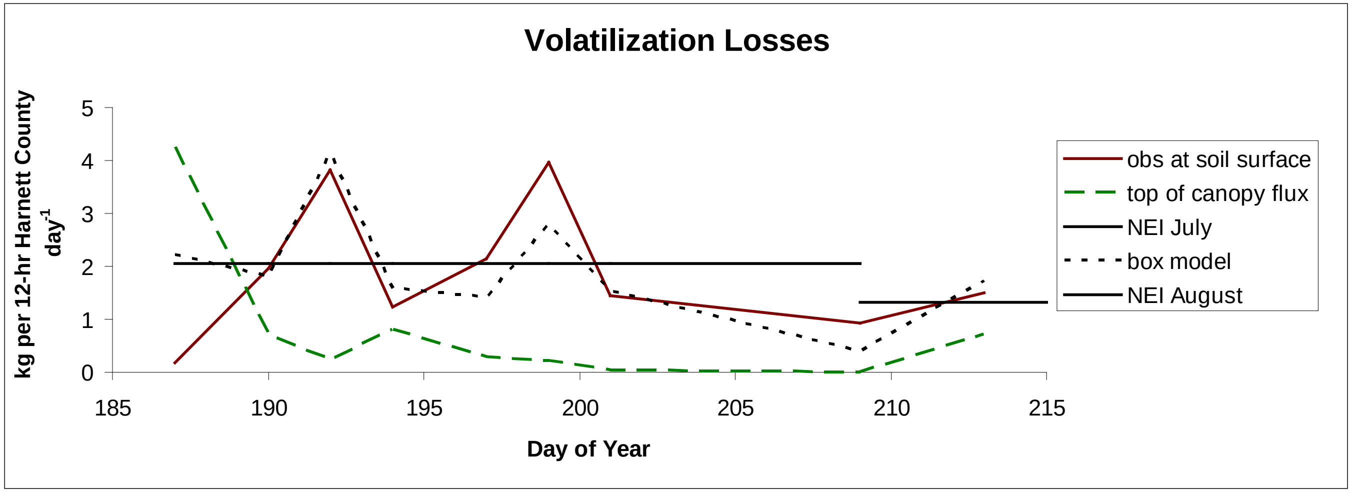
Comparison of Air-Soil Exchange Model to Field Observations



Sample median (ng m^{-2} s^{-1})	Model median (ng m^{-2} s^{-1})	Median daily bias (ng m^{-2} s^{-1})	Normalized mean error	RMSE
127	131	+4.4	41%	106

Parameterization of the soil diffusion length continues to undergo refinement prior to incorporation into CMAQ.

Integrated Agricultural Management and Air Quality Flux



Benefits

- Captures day-to-day variability
- Responds to smaller spatial scale drivers
- Does not rely on historical records
- Highlights the importance of canopy uptake and release
- Will allow us to correct for potential NEI bias with regards to soil ammonia emissions that can result from inverse modeling adjustments dominated by animal emissions

Conclusions

- The soil compensation point model for agricultural soils is a key feature of CMAQ's new ability to address ammonia bi-directional air-surface exchange.

- This research allows CMAQ to develop a more scientifically defensible estimate of ammonia flux, which is known to be bi-directional, for applications such as critical load studies, studies of aquatic and terrestrial impacts from nitrogen, and land use change studies.

- Addressing agricultural soil emissions of ammonia across the continental domain from within CMAQ (i.e., in-line) looks feasible and is currently being developed and tested.

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Thank you
Questions?

This project was supported by National Research Initiative Competitive Grant no.35112 from the USDA Cooperative State Research, Education, and Extension Service Air Quality Program and by US EPA's Office of Research and Development.