Nitrogen losses in agriculture: coupling the updated FAN ammonia model with CLM

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FAN: Flow of Agricultural Nitrogen

- Reduced nitrogen (NH4+NH3) is subject to losses due to volatilization and leaching
- Atmospheric emissions of ammonia have an important role in aerosol formation
- Aiming to evaluate ammonia emissions consistently with CLM land use, nitrogen cycle and atmospheric forcing
- Riddick et al. (2016): FAN, this presentation: FAN2

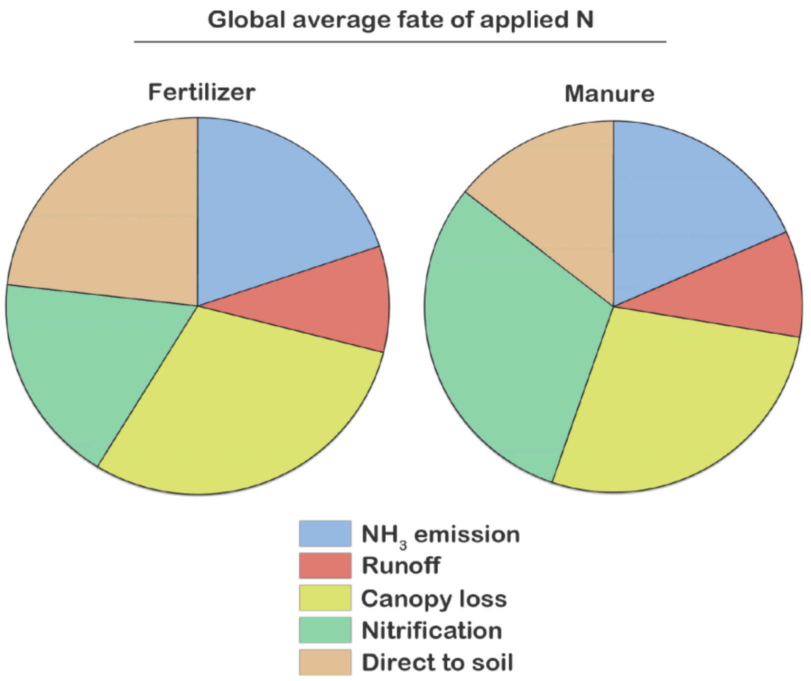
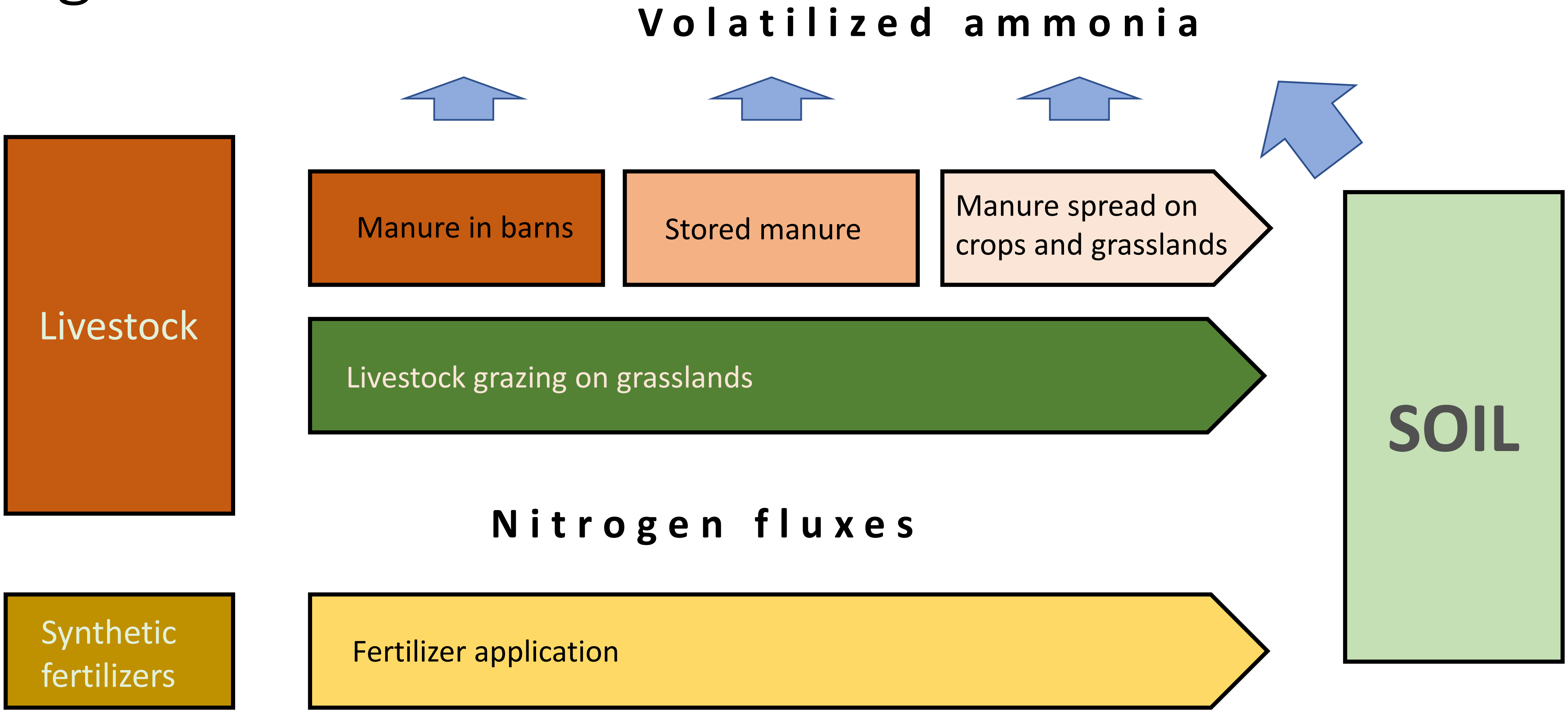


Figure 9. Global fate of TAN Nr applied as synthetic fertilizer **(a)** or as manure **(b)**. NH_3 emissions are split between those to the atmosphere and those captured by the canopy.

Ammonia volatilization in agriculture



Agriculture processes in FAN2

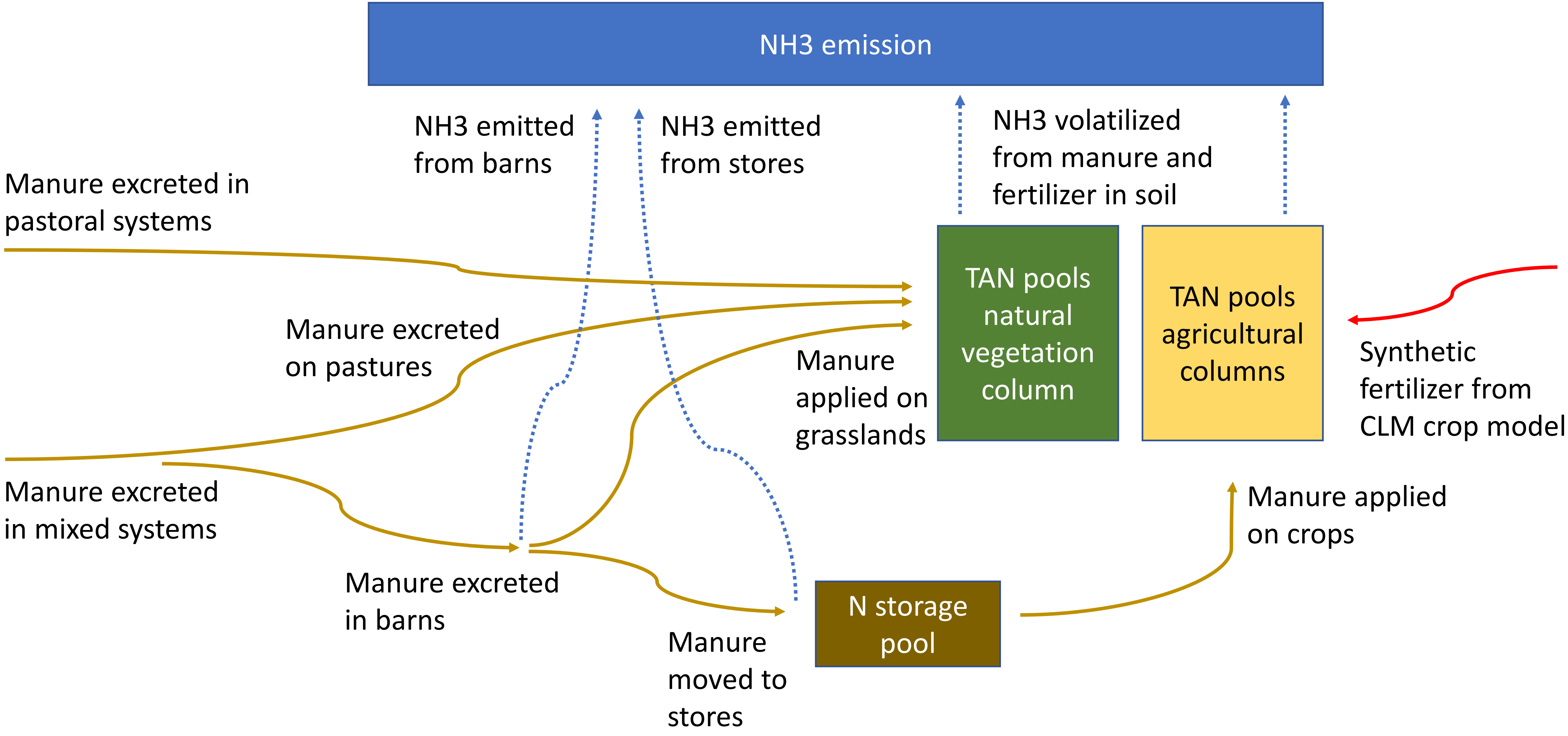
Fertilizers
- Consider only urea
- Broadcast application
- Assumed to dissolve in the existing soil water

Grazing animals
- Ammonicial nitrogen mostly within urine
- Volatilization affected by water content
- Infiltration assumed instant

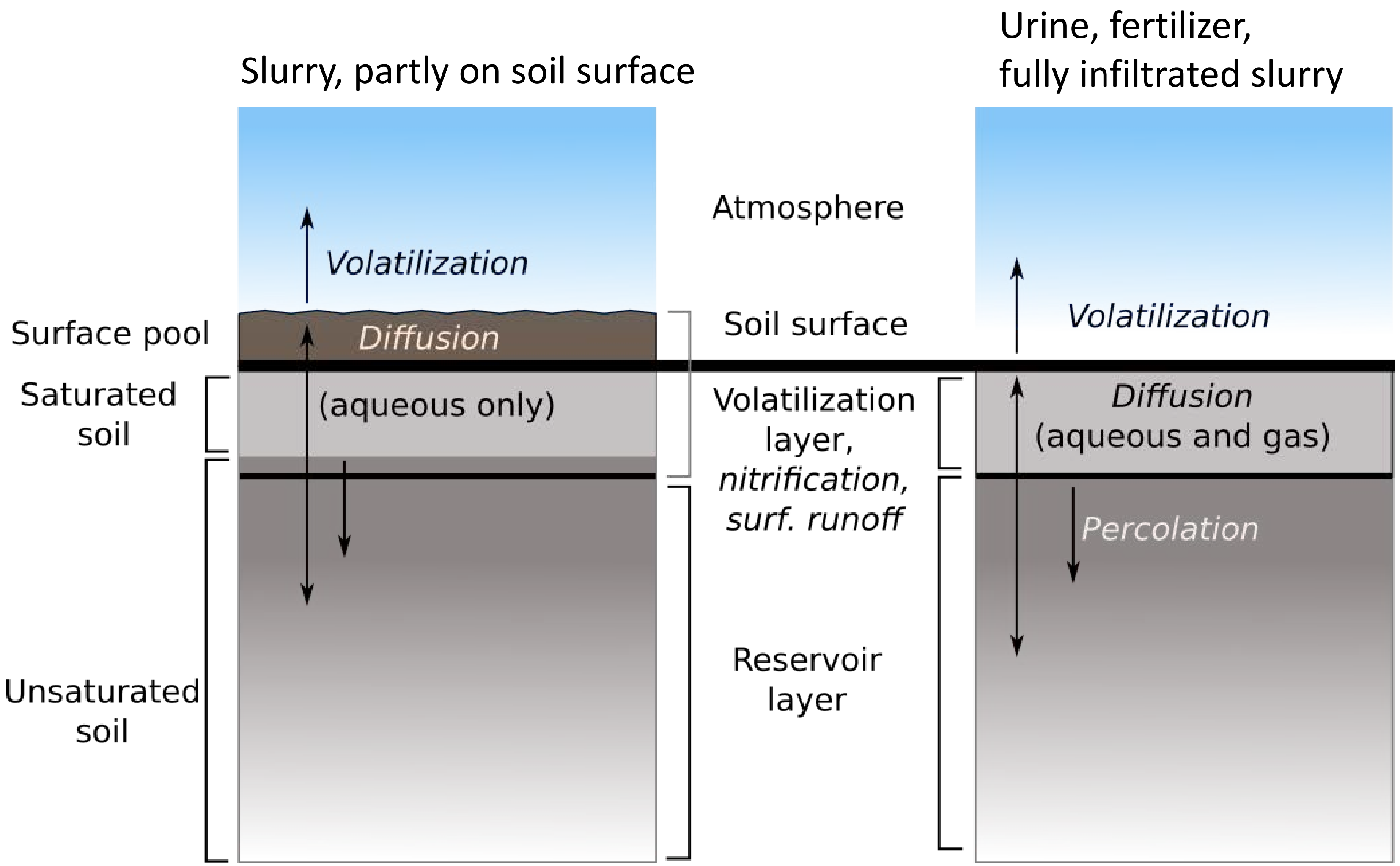
Manure application
- Consider only slurry
- Broadcast application
- Slow infiltration to soil

Barns and storage
- Volatilization rates based on the empirical approach of Gyldenkærne et al. (2005)
- Representative of cattle in naturally ventilated barns and manure stored in lagoons

Flows of fertilizer and manure nitrogen



Volatilization from soil



Volatilization:
- chemical + Henry equilibrium,
- Prescribed pH

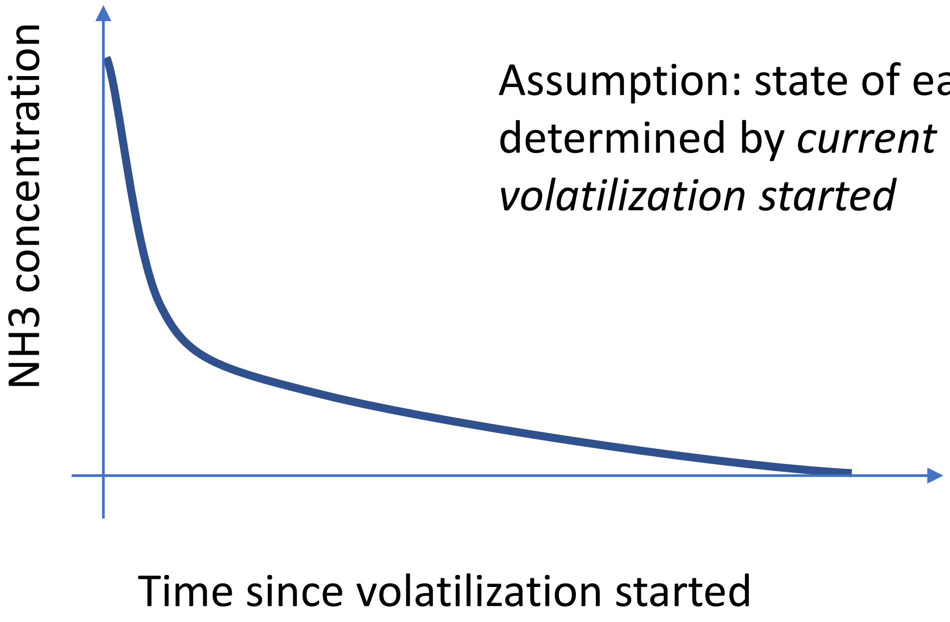
Diffusion:
- Simultaneous gas and aqueous phase diffusion
- Diffusivity much higher in the slurry remaining on surface

Percolation (leaching to soil)
- Due to precip and the water content in manure
- Diagnosed from the water budget

Nitrification and runoff evaluated as in Riddick et al. (2016)

Upscaling the volatilization model

- Manure or fertilizer is not applied evenly over a soil column, but in spots
- Each spot is ongoing volatilization but in varying stages with different pH, and water content



Assumption: state of each ”sub-patch” is determined by *current time* and *time since volatilization started*

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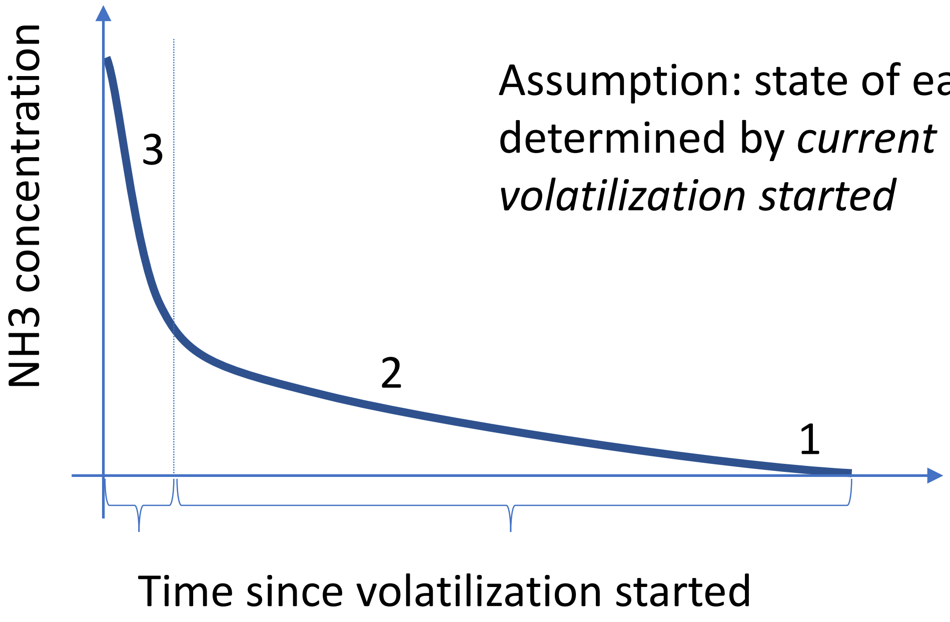

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FAN2 Soil nitrogen pools

TAN transferred from pool to pool as the patches become older
Volatilization evaluated from each pool

TAN produced from decomposing manure organic matter input to S2 and P2

Slurry

S0: partly infiltrated slurry
- Partly on surface
- Higher evaporation rate
- Higher volatilization rate

→

S1: fresh slurry
- pH = 8.0
- Water content relaxing towards background

→

S2: aged slurry
- pH = 8.0
- Water content and fluxes as in background soil

Pasture

No surface pooling for urine and fertilizers

P1: fresh urine patches
- Similar processes as in S1
- pH = 8.5

→

P2: aged urine + fecal matter
- pH = 8
- Otherwise as S2

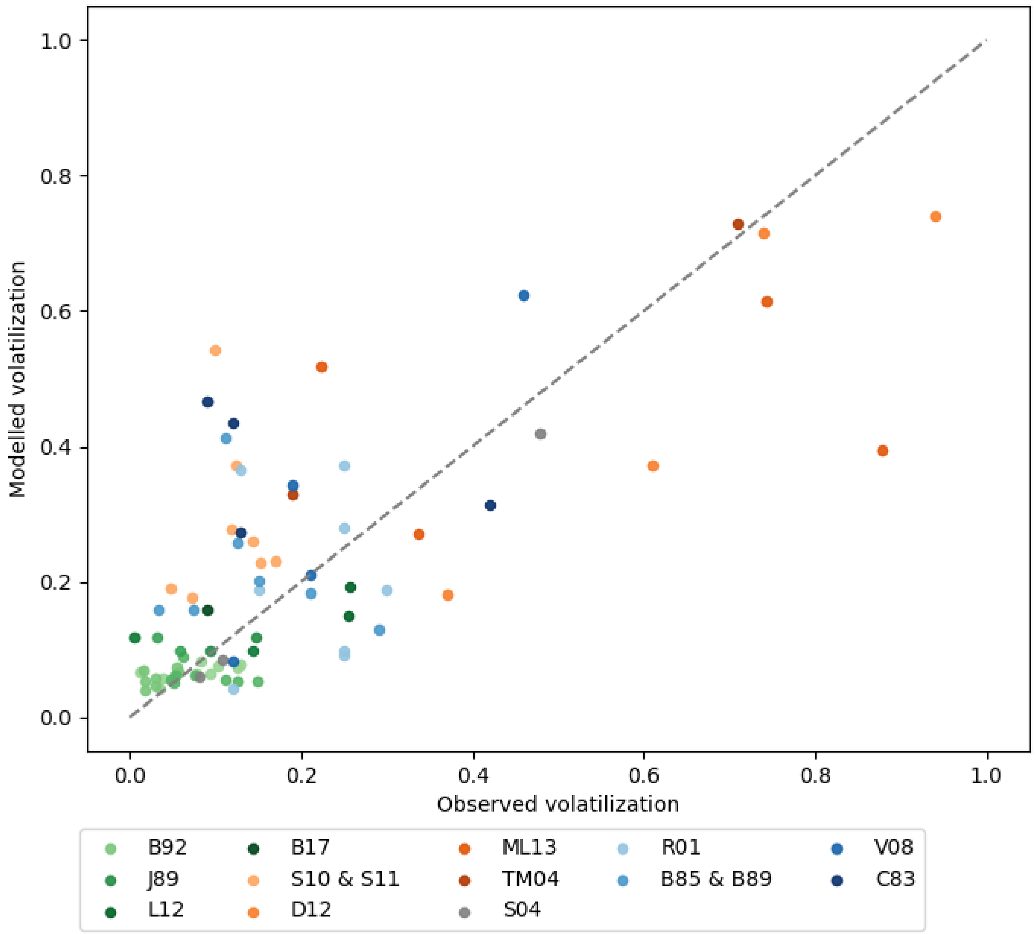
Fertilizer

F1: freshly fertilized
- pH = 8.5
- No perturbation to soil water

→

F2: aged fertilizer
- Same features as P2
- For accounting only

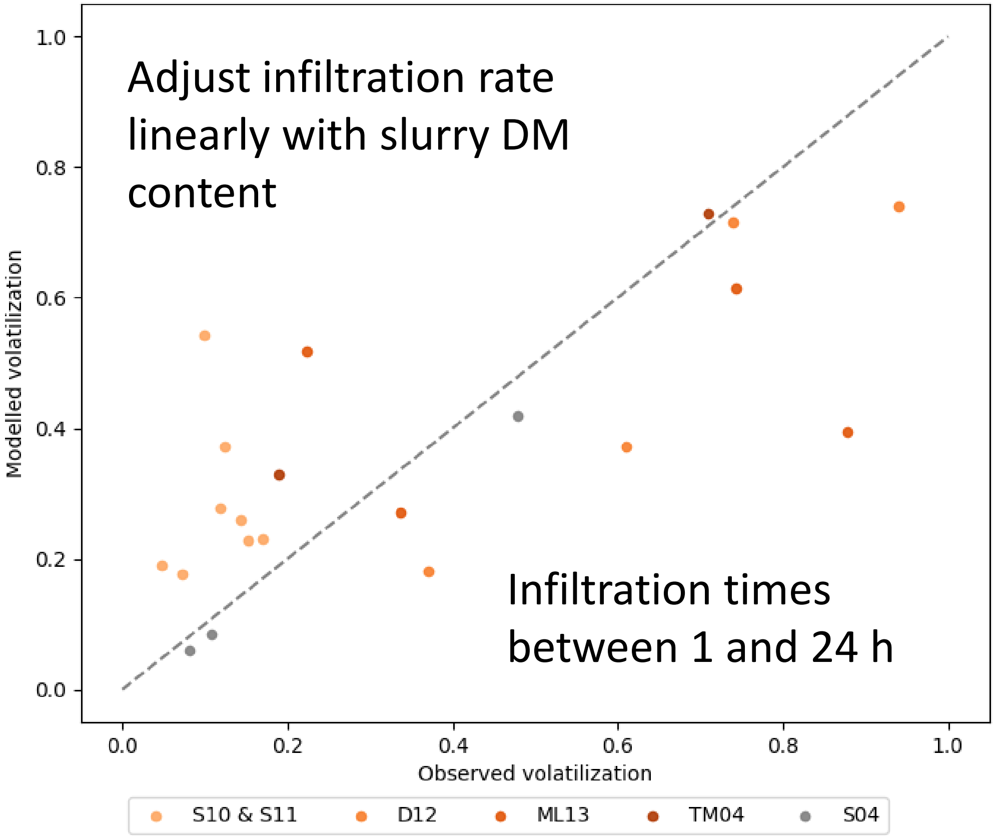
Comparison to field observations

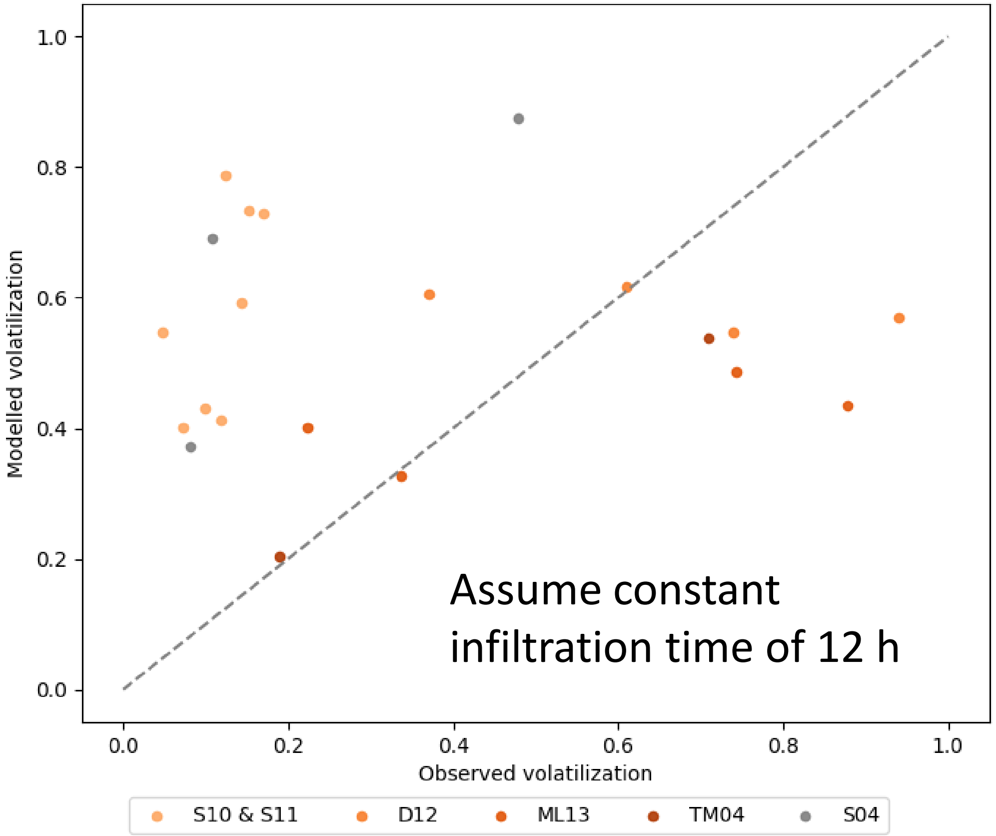


- Compare with 15 field experiments
- CLM point simulation at each location with the CRUNCEP* forcing
- Pasture, slurry, fertilizer, poultry litter

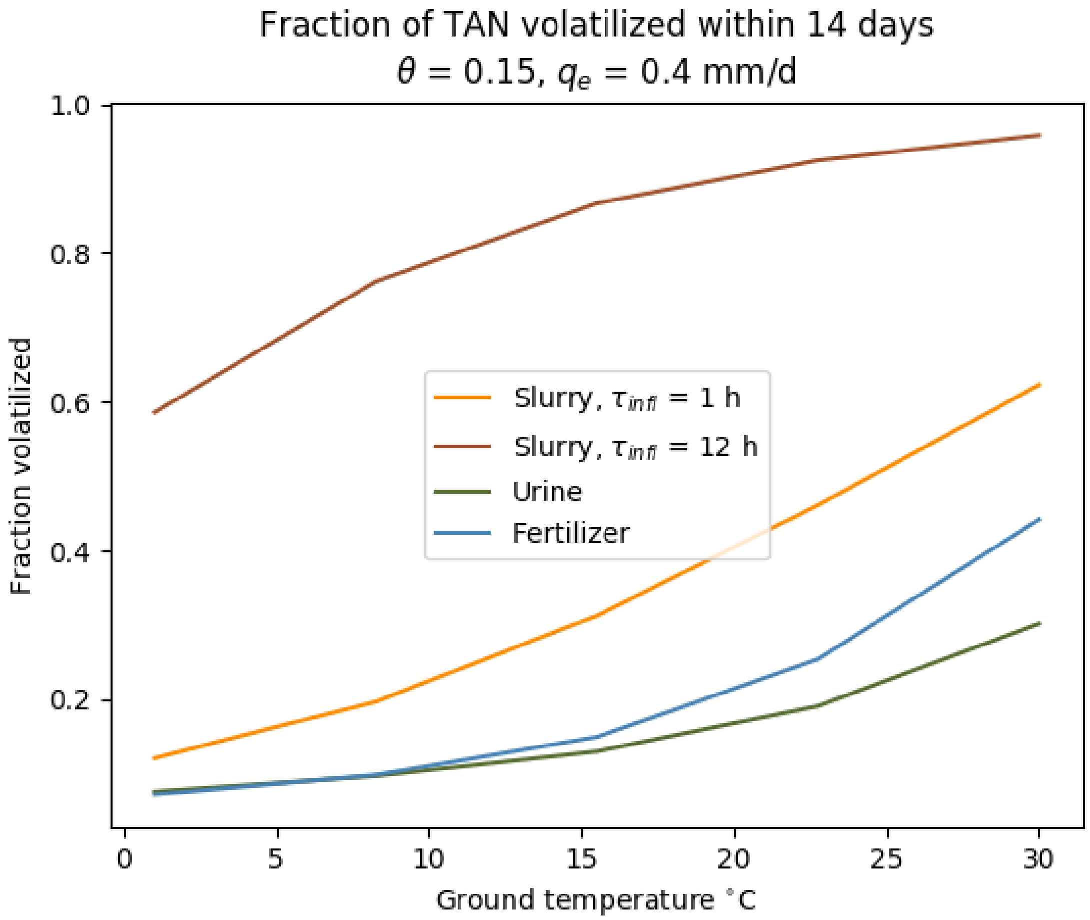
*In-situ observed precipitation used when available

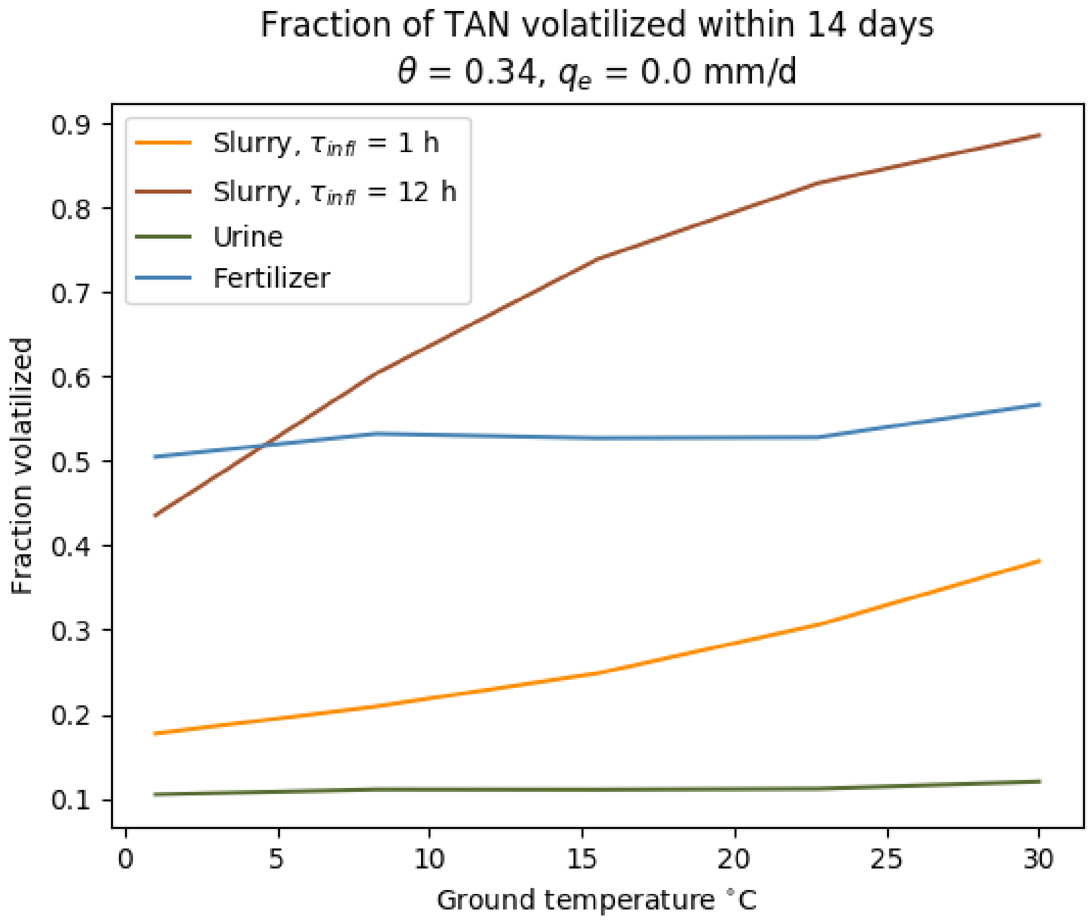
More on slurry: effect of infiltration rate



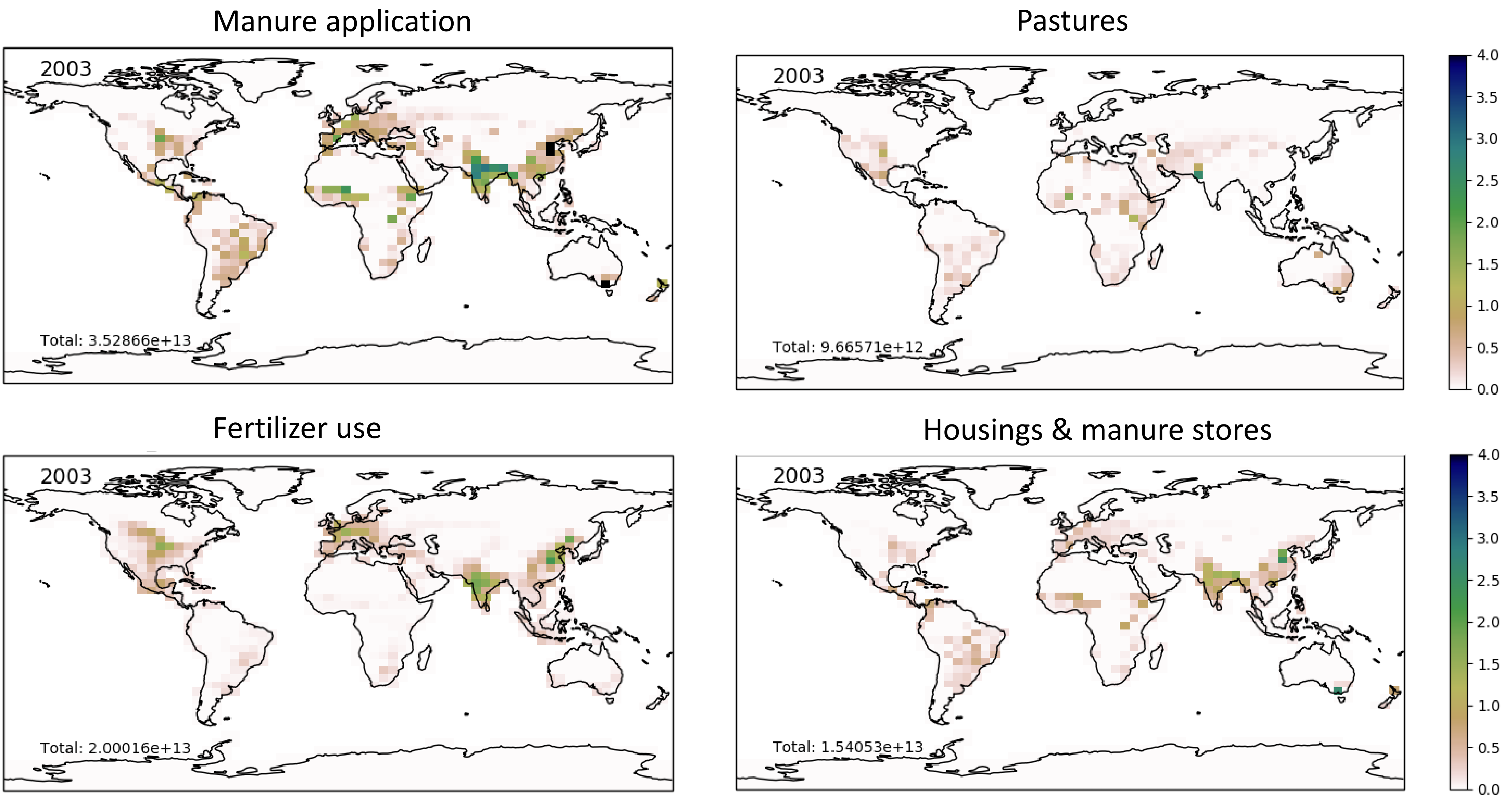


Response to temperature and moisture





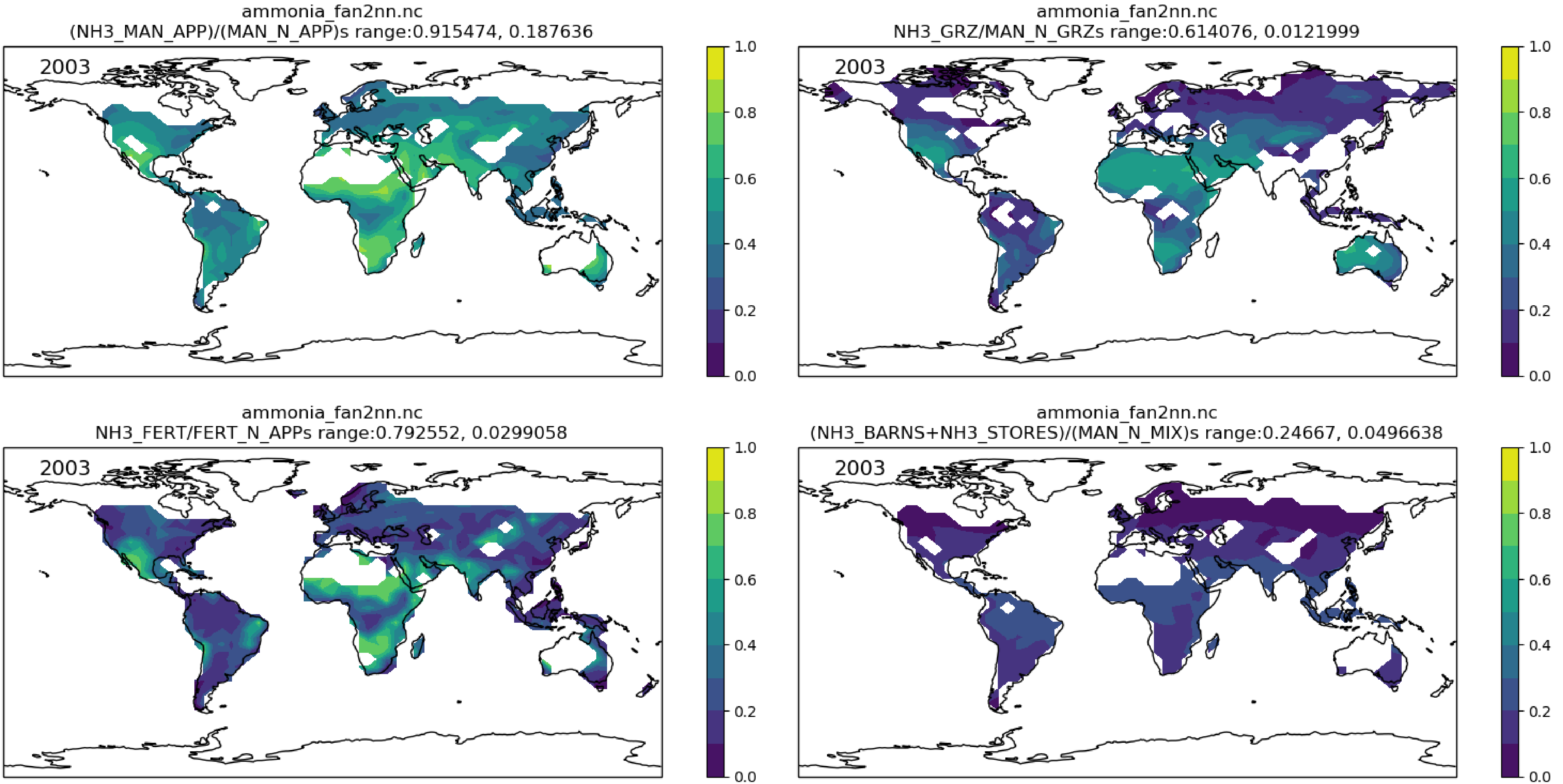
First FAN2 simulations: NH3 emissions, gN m^{-2} yr^{-1}



Future

- In near future, couple FAN2 with CAM to evaluate the impacts on atmospheric composition using observations of NH_3 and NH_4 in rainwater and air
- Coupling with terrestrial nitrogen cycle in CLM should be developed further
- Further developments for the process model
  - Fertilizers other than urea
  - Agricultural practices not currently covered, e.g. paddy rice

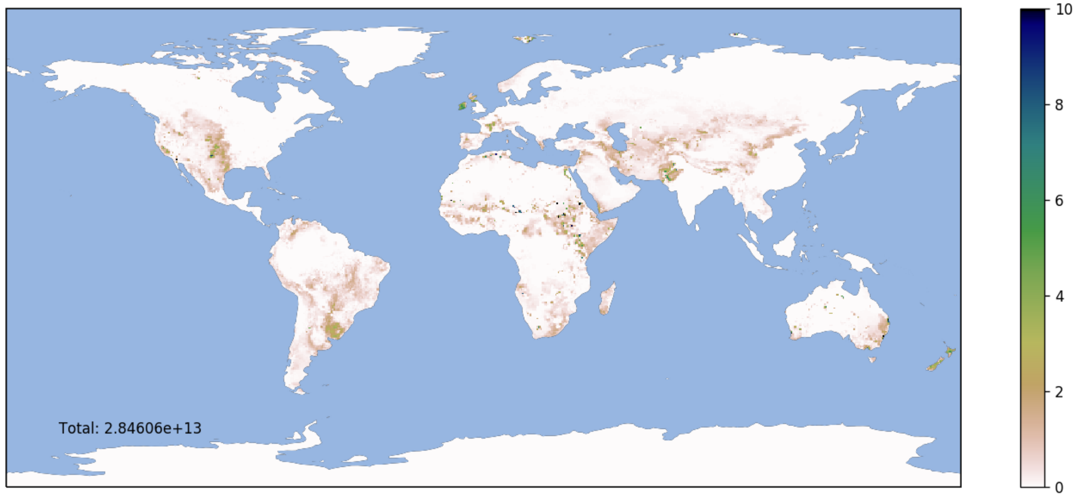
Volatilization rates



Thank you!

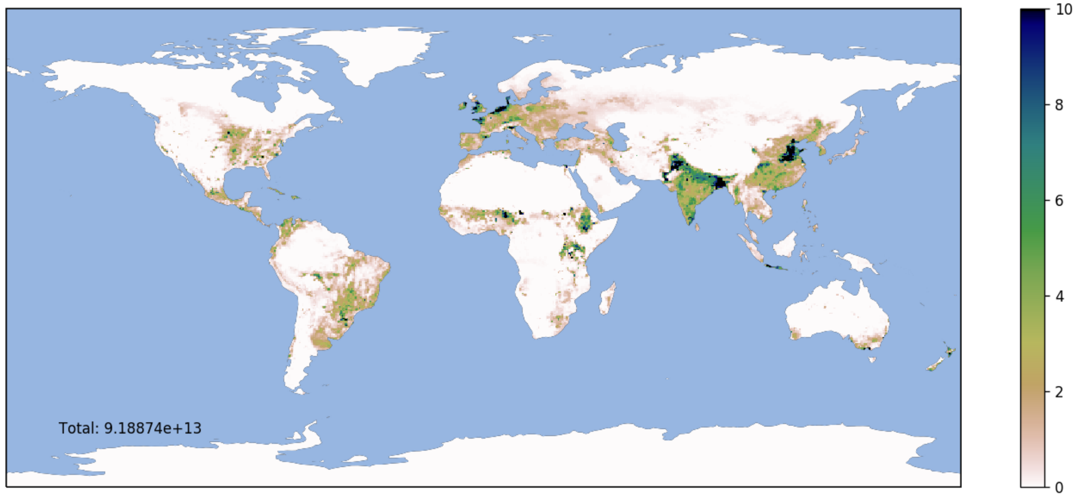
The manure dataset

Manure attributed to pastoral systems, gN/m2/year

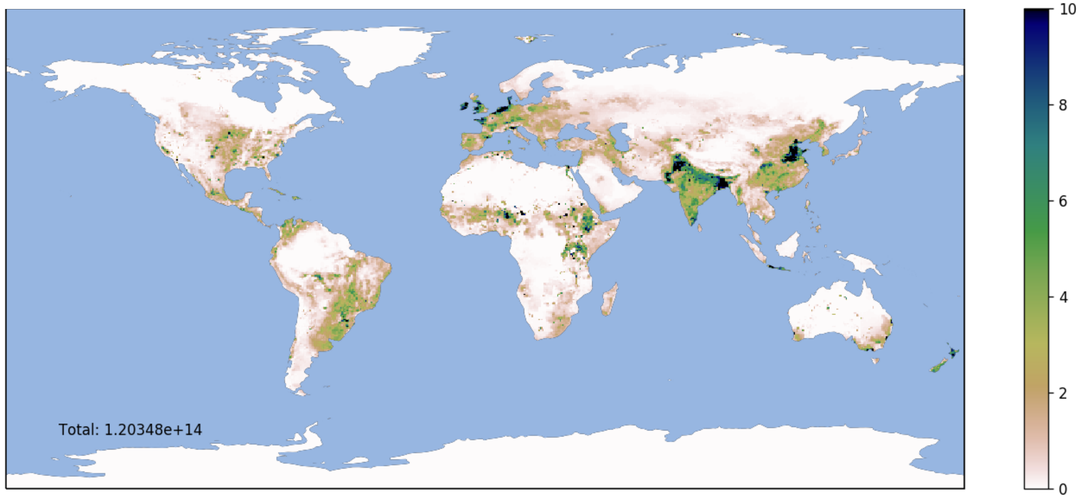


- Global distribution of manure production evaluated using the Gridded Livestock of World database (FAO, 2010)
- Cattle and sheep manure attributed to either pastoral or mixed production systems based on the characterization given in the FAO database
- Global total within 10% from the Potter et al. (2010) dataset used in the Riddick et al. (2016) paper

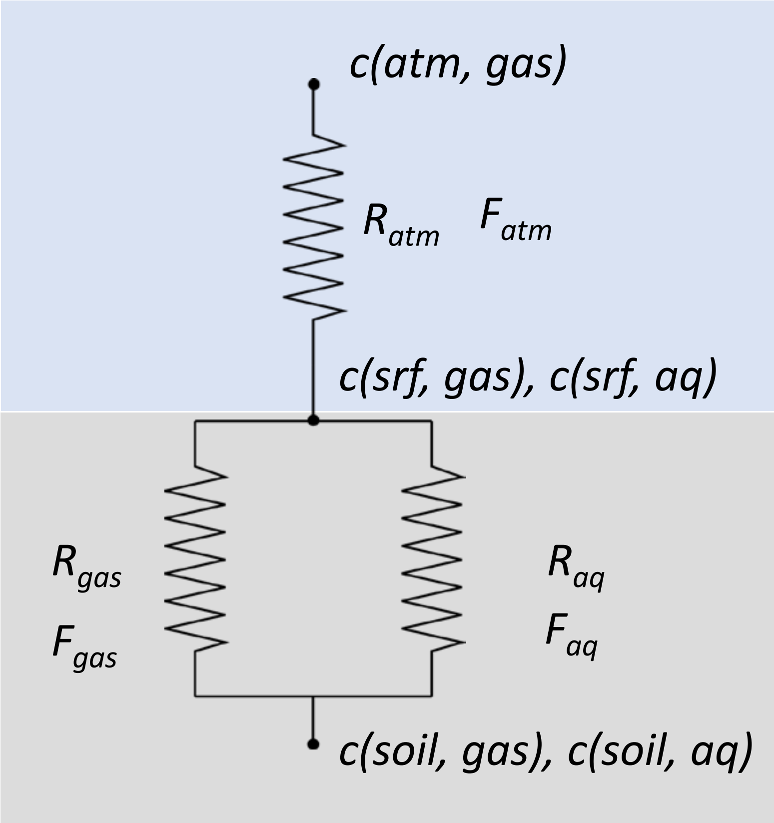
Manure attributed to mixed systems, gN/m2/year



Manure nitrogen, total, gN/m2/year



Resistance analogy to evaluate nitrogen fluxes



$$F(atm) = \frac{c(atm, gas) - c(srf, gas)}{R_{atm}}$$

$$F(aq) = \frac{c(srf, aq) - c(soil, aq)}{R_{aq}}$$

$$F(gas) = \frac{c(srf, gas) - c(soil, gas)}{R_{gas}}$$

N Partitioning in soil and at surface:

$c(gas)=H^*c(aq)$

Setting *F(aq)+F(gas)=F(atm)* and applying the effective Henry constants *H** gives

$$F(atm) = \left(\frac{1}{g_s} + \frac{1}{g_{atm}}\right)^{-1} c(soil, aq)$$

where

$$g_s = \frac{H^*}{R_{sg}} + \frac{1}{R_{sl}}$$

$$g_{atm} = \frac{H^*}{R_{atm}}$$

Riddick model obtained when $g_s \to \infty$