The constraint of denitrification and leaching in the CLM5.1

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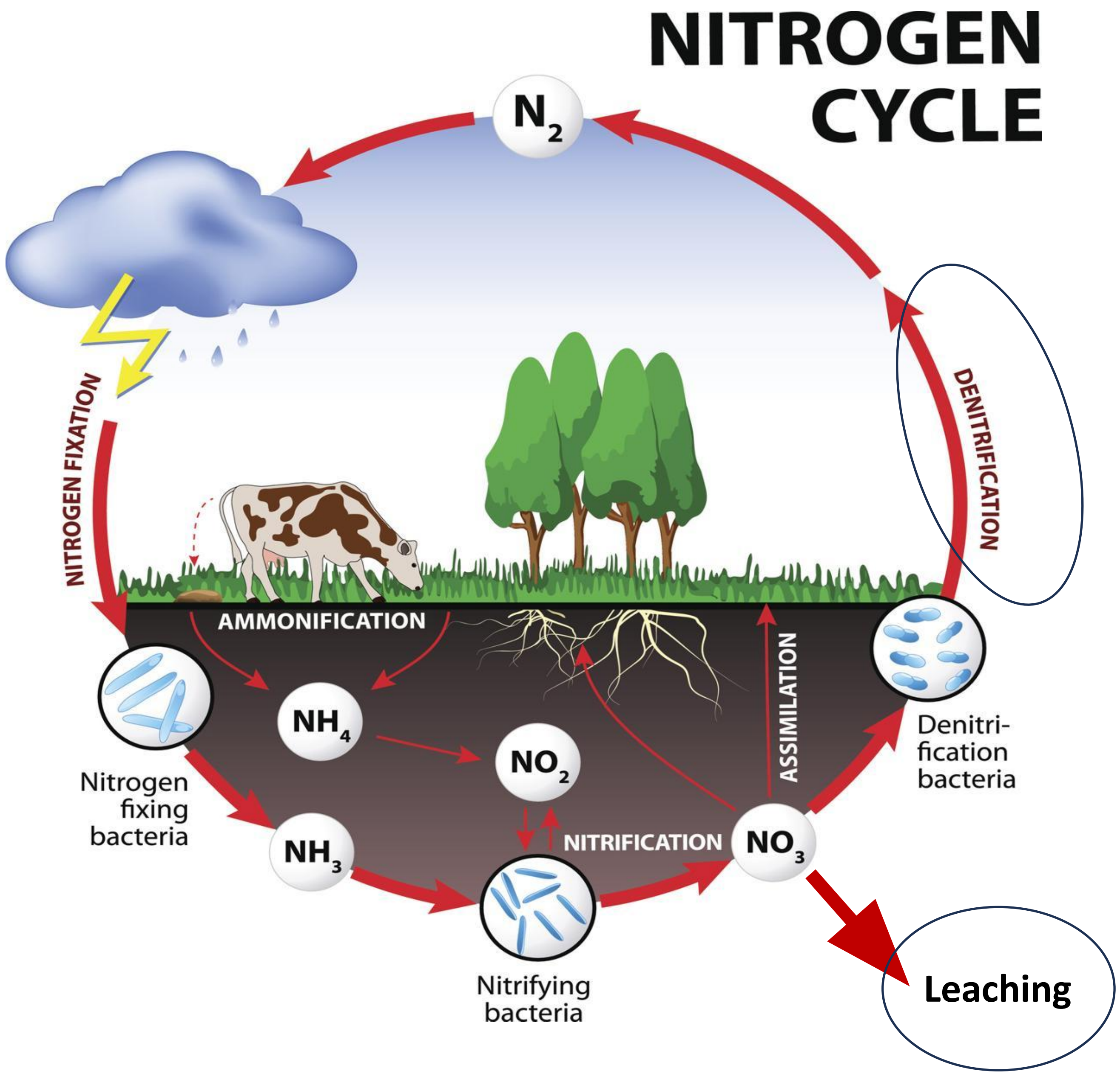
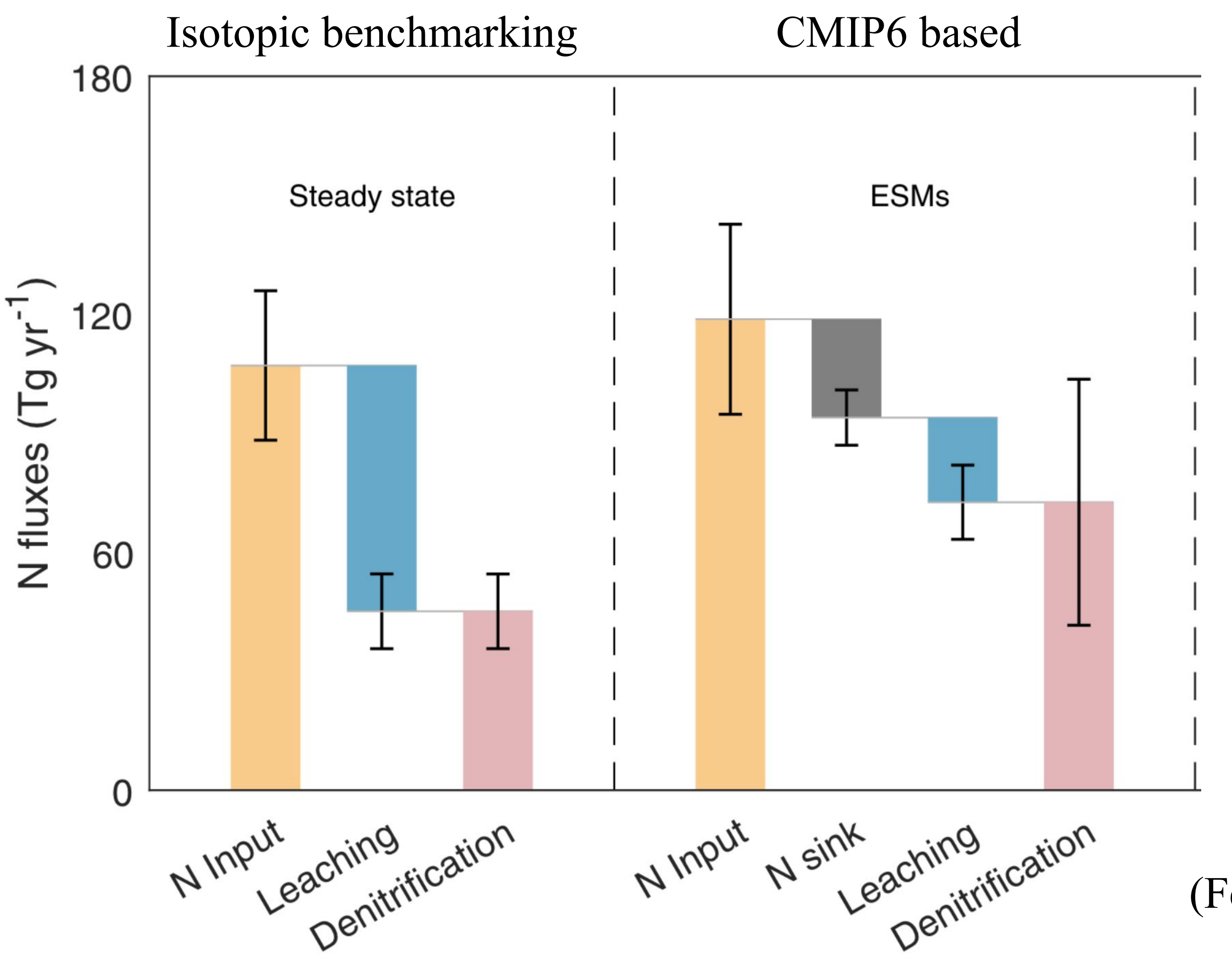


Leaching and **denitrification** are the two major pathways for nitrogen leaving the soil.

https://www.onlinebiologynotes.com/nitrogen-cycle-steps-of-nitrogen-cycle/

Overestimated denitrification and **small** leaching compared to isotopic inferred budget



- Overestimation of denitrification in 13 ESMs from CMIP6 is almost a factor of two larger than that estimated from isotopic benchmarking over natural soil.

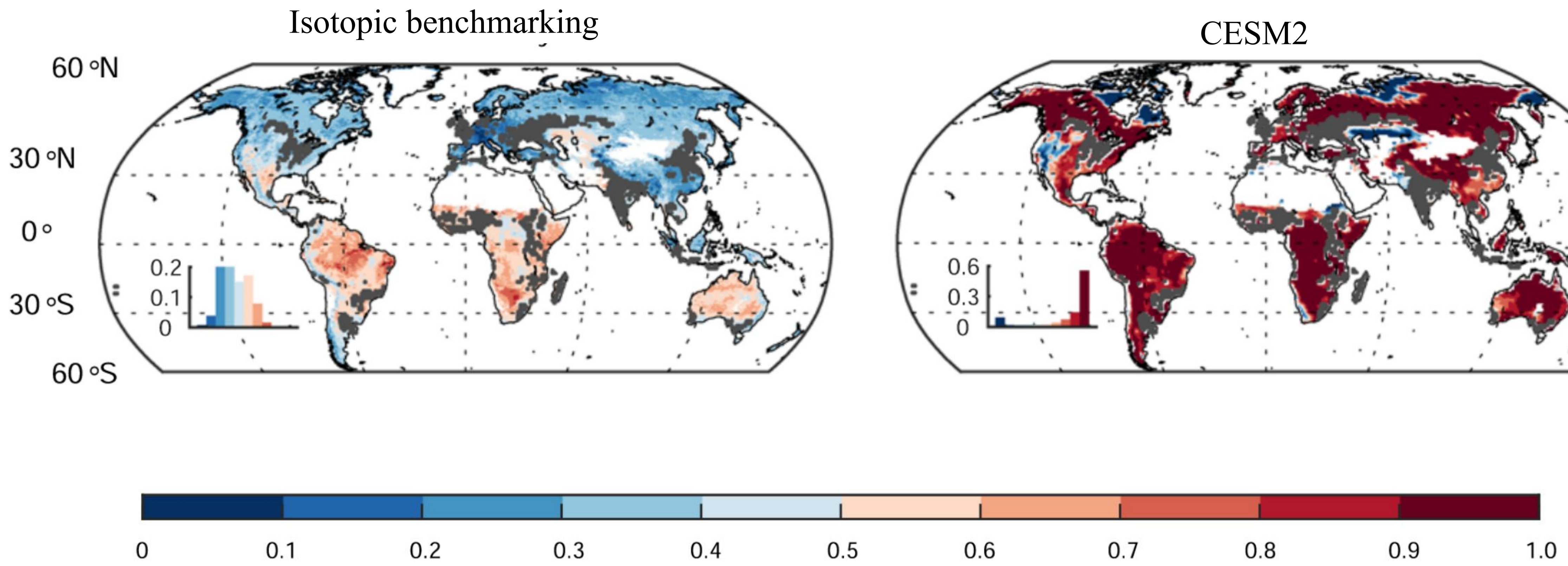
- Denitrification in CMIP6, 73 ± 31 Tg N yr^{-1} , **Isotopic benchmarking** estimated denitrification is 38 ± 11 Tg N yr^{-1}

- Leaching/denitrification

ESMs:	**0.3**
Isotopic benchmarking	**1.4**

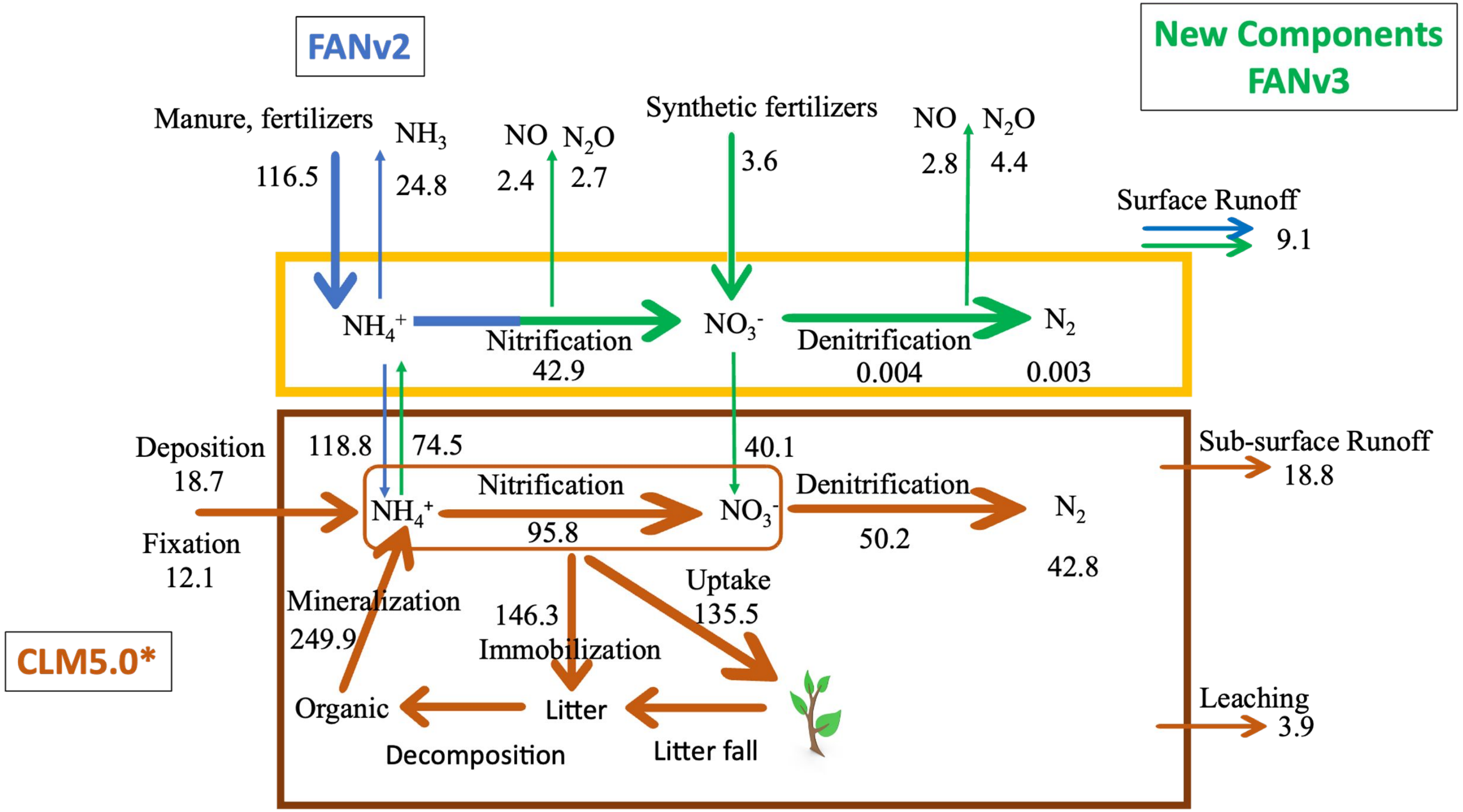
(Feng et al., 2022).

Fraction of denitrification N loss simulated by CESM2 compared to isotopic inferred fraction



Feng et al., 2022

Flow of Agricultural Nitrogen (FANv3)



- FANv2 diagnoses NH_3 emissions from agriculture from manure and fertilizer inputs. It explicitly models NH_3 flows and transformations in top layer of CLM. (Vira et al., 2020, 2022).
- FANv3 extends FANv2 by coupling FANv2 to the CLM5.1 and the hole-in-the-pipe model.
- FANv3 changes the leaching, nitrification, and denitrification in CLM.

Mesocosm measurements (agricultural site)

What it measured.

- Fertilizer usage
- NO_x, N_2O emissions
- Harvest N
- Inorganic N runoff
- NO_3^-, NH_4^+ in soils
- Soil properties

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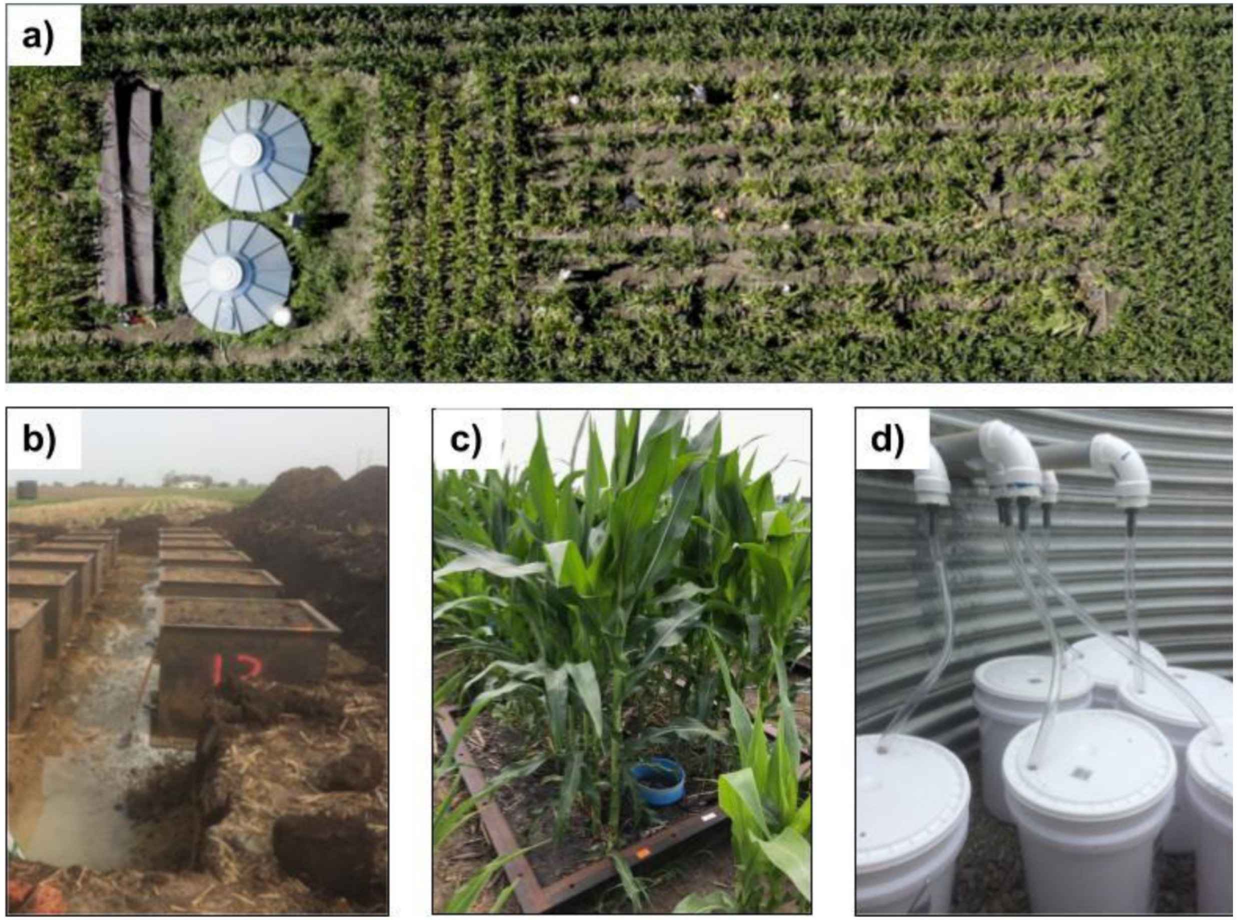
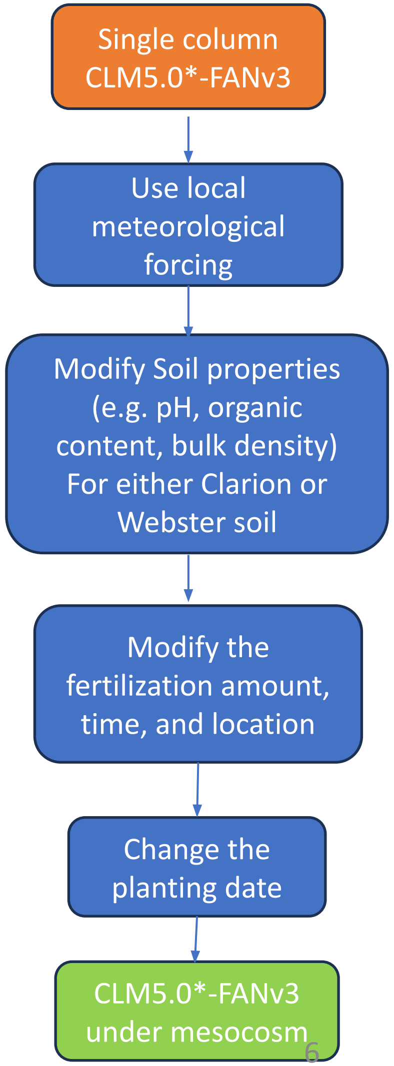
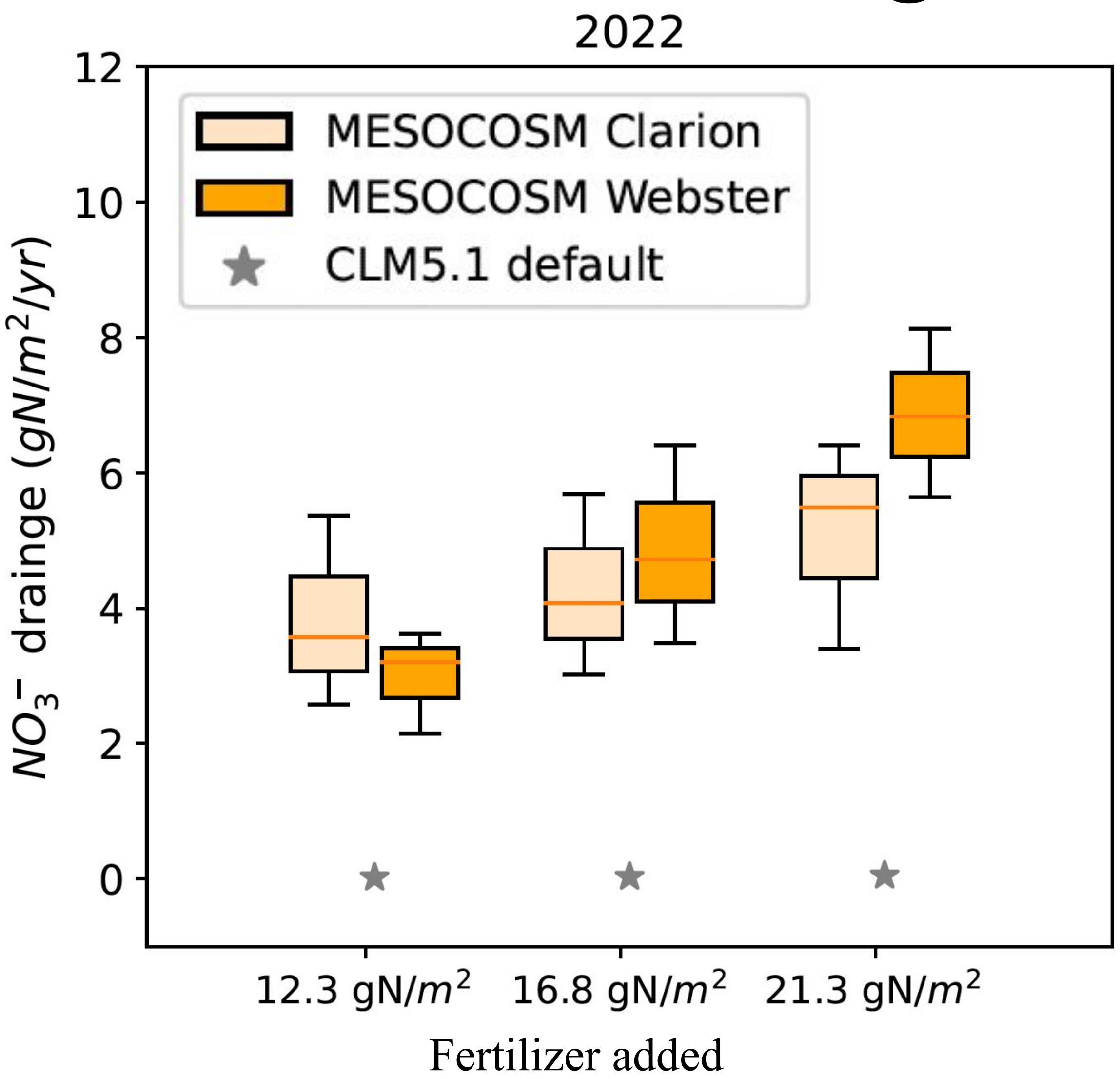
These unique observations give us a chance to further evaluate the model.





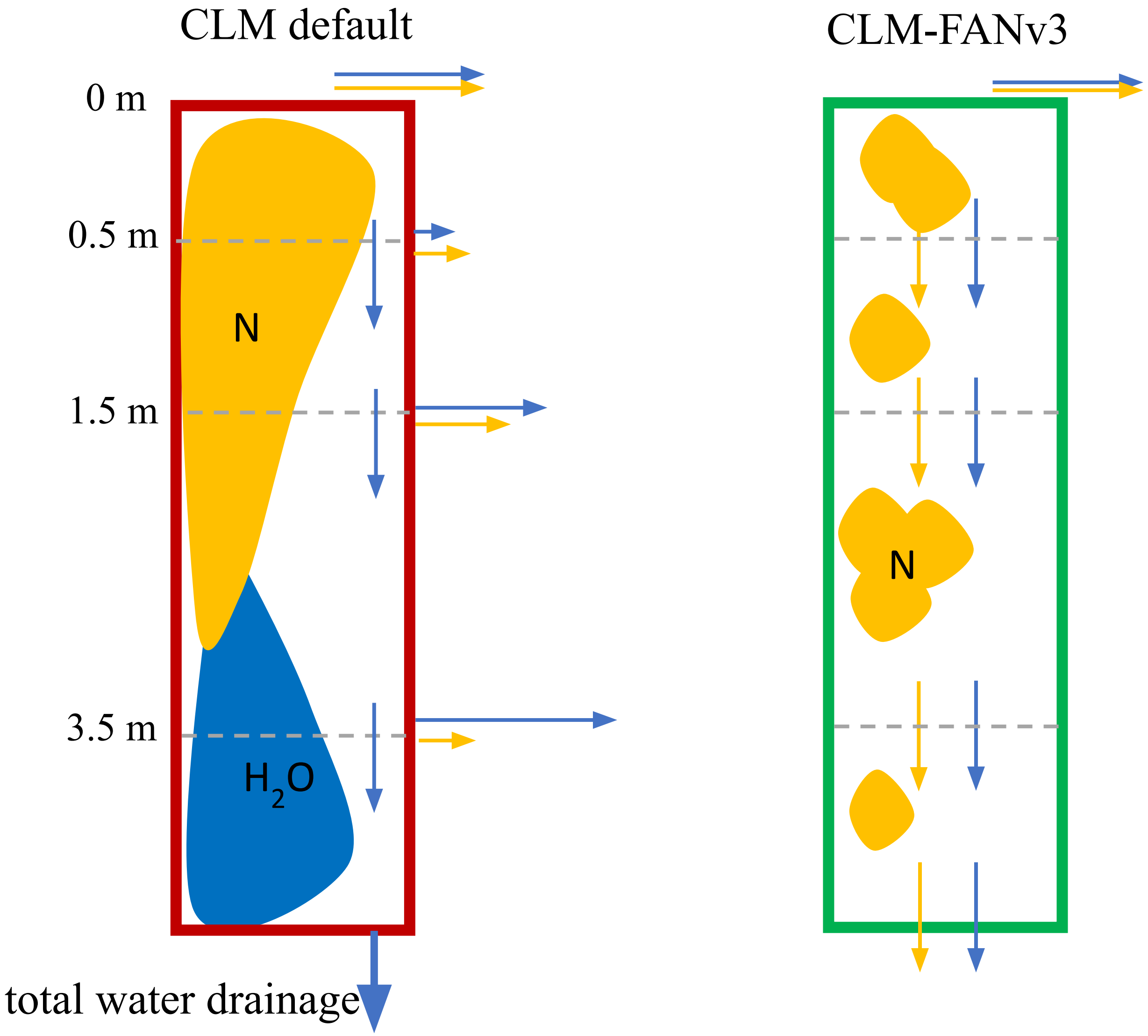
CLM5.1 Simulates Low Leaching in the Agricultural Site



- CLM5.1 predicts small leaching for 2022 (a high leaching year).
- Clarion and Webster are different soil types
- Three fertilization experiments are set up in the Mesocosm measurements

Solutions: Vertical transport of nitrate

$$\frac{\partial C_{soil}}{\partial t} = \frac{\partial J}{\partial z} + S$$



CLM5.1 default

(1) Nitrogen doesn't move with water vertically (remains at a fixed profile)
(2) CLM predicts the total water drainage but redistributes the drained water back to different layers based on the soil moisture profile.
(3)N leaching is evaluated in different layers from the redistributed drained water.

CLM-FANv3

(1) Nitrogen moves downward with soil water
(2) Leached nitrogen is taken out at the bottom of the column.

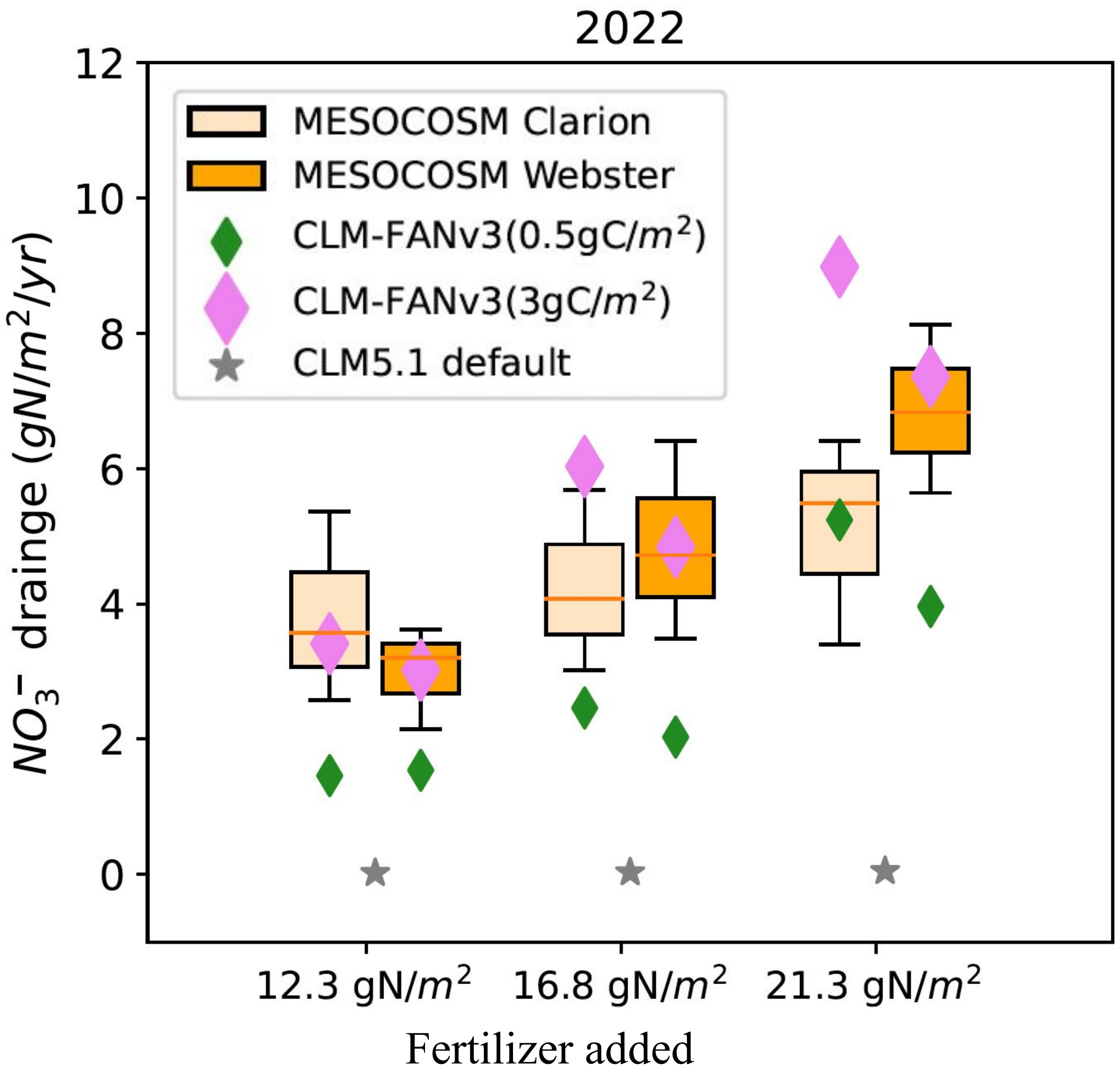
Vertical transport of nitrate

CLM5.1 default

CLM5.1-FANv3

Luo et al (to be submitted)

After incorporating our leaching method



- CLM-FANv3 performance is better than CLM5.1 default for all soil types and fertilization experiments.
- Different initial seeding densities could affect the leaching (0.5 gC/m^2 or 3gC/m^2)

Luo et al (to be submitted)

Comparison of different denitrification limited functions

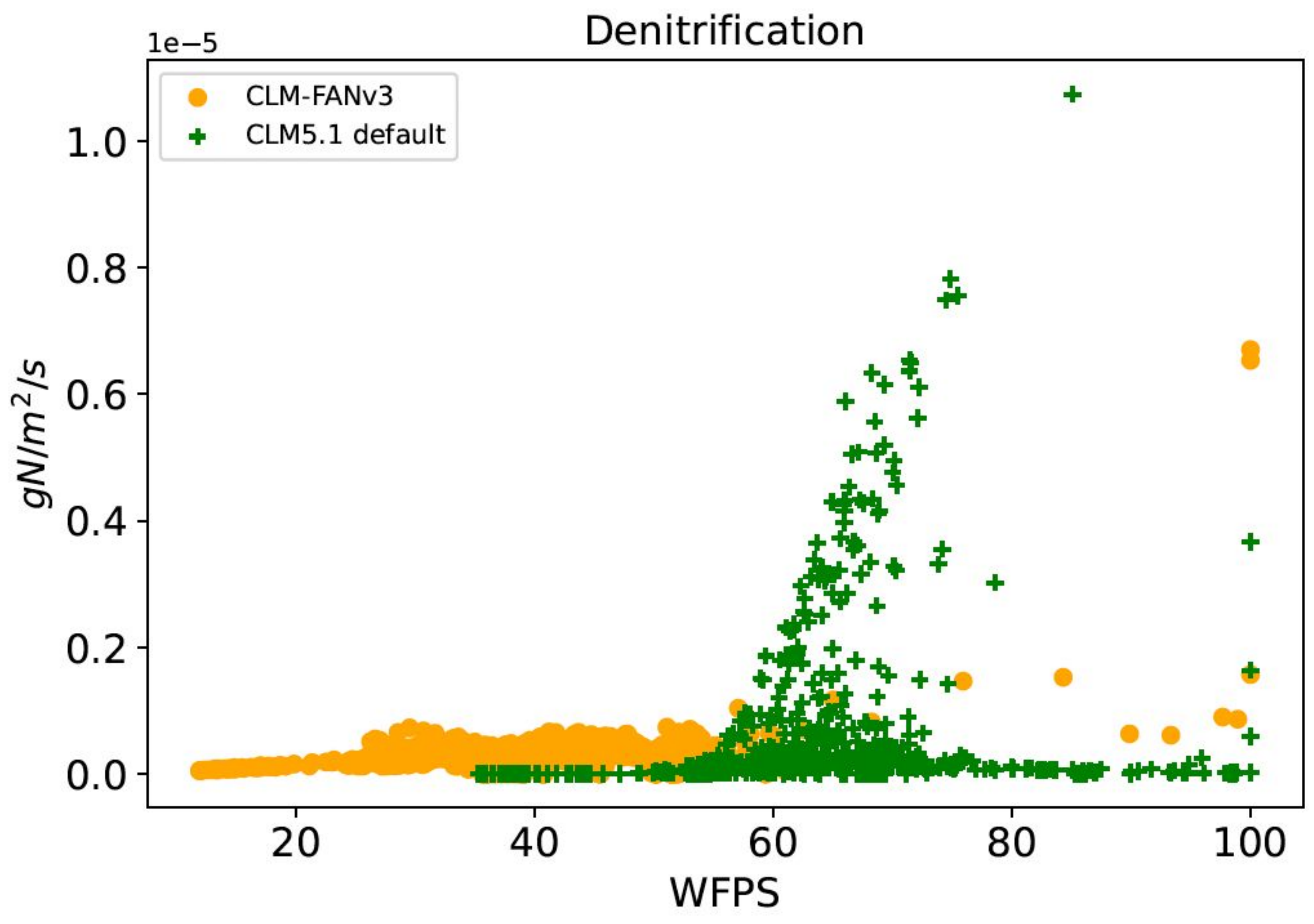
CENTURY (Parton et al., 2000)

CLM5.0 (Riley and Matson 2000)

Most of site research suggest no denitrification happen under 55% WFPS

Luo et al (to be submitted)

Why denitrification flux is large in CLM?



Water filled pore space (WFPS) %

- Basing denitrification on the **anaerobic fraction** in CLM5.1 gives significant denitrification at moderate WFPS.
- Basing denitrification on WFPS in CLM-FANv3 gives the highest denitrification at higher WFPS.

Luo et al (to be submitted)

Simulated nitrogen budgets

	Leaching/Denitrification
CLM5.1:	0.014
CLM-FANv3:	1.7
CMIP6:	0.3
Isotopic benchmarking:	1.4

Luo et al (to be submitted)

Conclusions

(1)A more physical leaching method in CLM-FANv3 improves CLM performance in high-leaching years.

(2) The **anaerobic fraction function** used in the denitrification module partially explains why CESM2 has larger denitrification than isotopic observations suggested.

(3) Changes in CLM-FANv3 modify the ratio of leaching/denitrification from 0.014 (in CLM5.1) to 1.7 (in CLM-FANv3) more in line with expectations and Mesocosm measurements.