Soil NO_x emissions in CESM2: Implications for atmospheric chemistry

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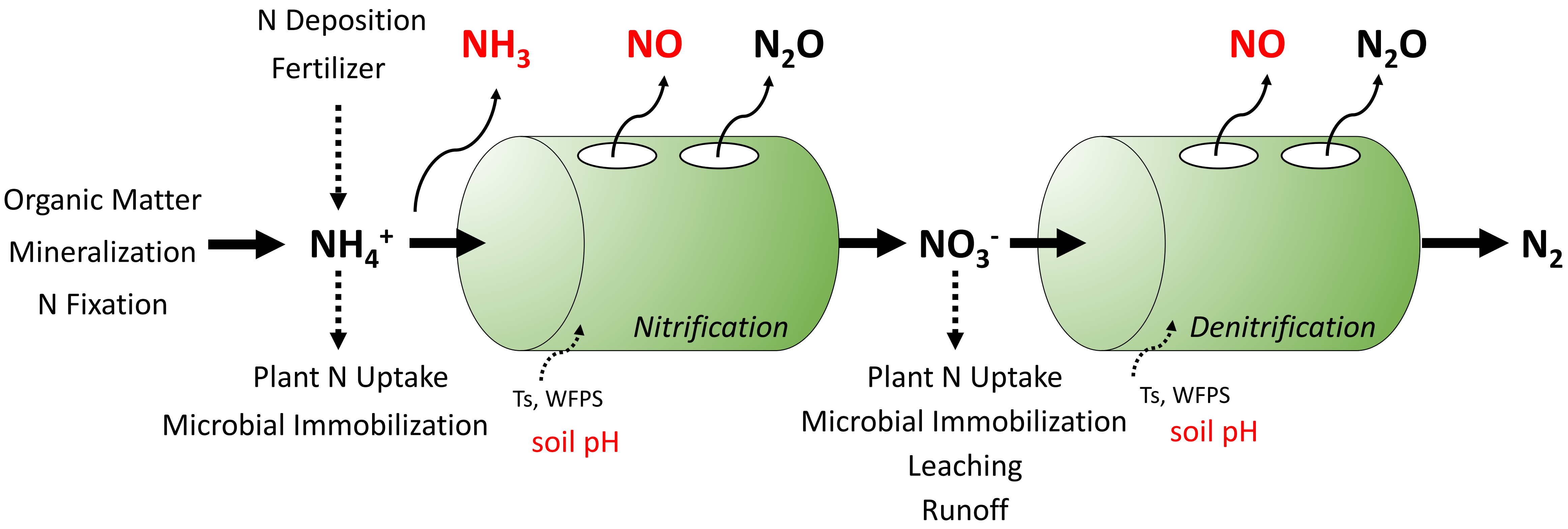
Atmosphere, Chemistry Climate and Whole Atmosphere Working Group Meeting
February 13, 2024

LEVERHULME TRUST

Updated N cycling in CLM5 (CESM2)

Nitrogen Scheme in a "Holes-in-a-Pipe" Concept



Soil nitrogen implementations in CLM5

Biogeosciences, 19, 1635–1655, 2022
https://doi.org/10.5194/bg-19-1635-2022

Biogeosciences
Open Access EGU

Modeling the interinfluence of fertilizer-induced NH_3 emission, nitrogen deposition, and aerosol radiative effects using modified CESM2

Ka Ming Fung[1,a], Maria Val Martin[2], and Amos P. K. Tai[1,3]

- Soil NH_3 volatilization- DeNitrification-DeComposition biogeochemical model
  - canopy reduction

Geosci. Model Dev., 16, 5783–5801, 2023
https://doi.org/10.5194/gmd-16-5783-2023

Geoscientific
Model Development
Open Access EGU

Improving nitrogen cycling in a land surface model (CLM5) to quantify soil N_2O, NO, and NH_3 emissions from enhanced rock weathering with croplands

Maria Val Martin[1], Elena Blanc-Betes[2,3], Ka Ming Fung[4], Euripides P. Kantzas[1], Ilsa B. Kantola[2,3], Isabella Chiaravalloti[5], Lyla L. Taylor[1], Louisa K. Emmons[6], William R. Wieder[6,7], Noah J. Planavsky[5], Michael D. Masters[2,3], Evan H. DeLucia[2,3,8], Amos P. K. Tai[4,9], and David J. Beerling[1]

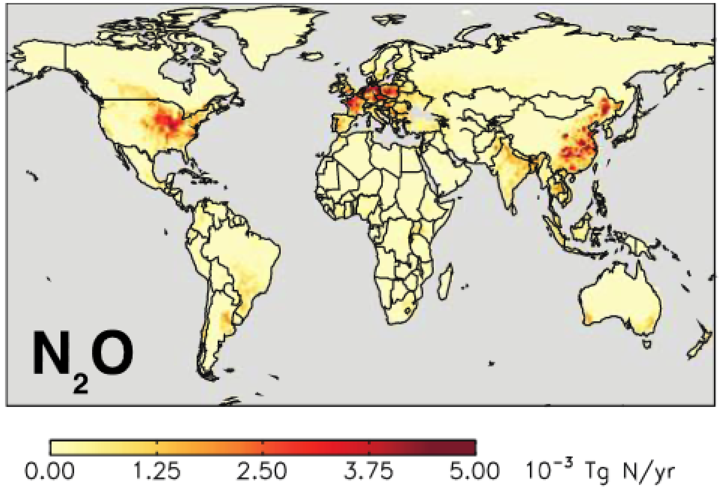
- Linked soil N_2O to soil pH (Blanc-Betes et al., 2020)
- Soil NO (Parton et al., 2001)
  - canopy reduction (CRF)
  - Rain pulses in nitrification (P)

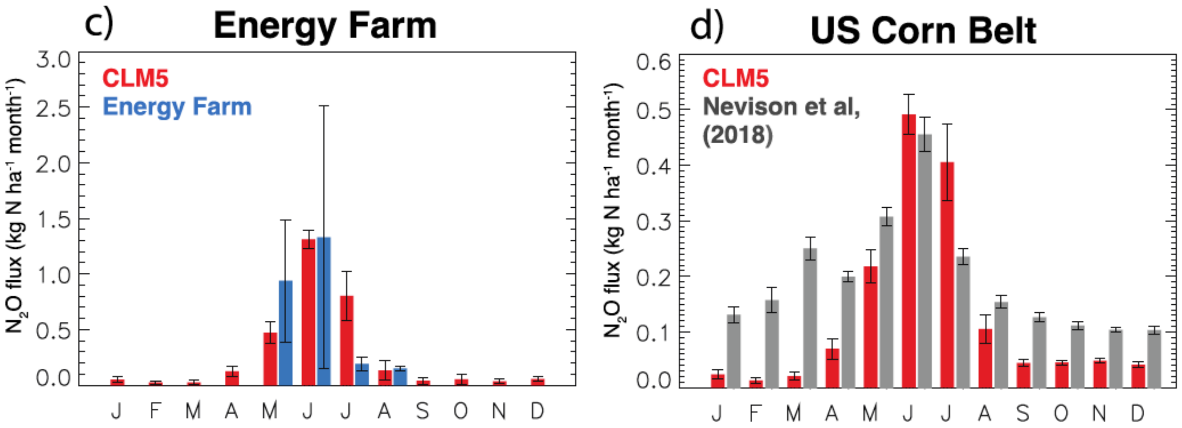
$$\text{Soil NO}_{\text{soil}} = N_2O_{\text{denit}} \times R_{NO:N_2O} + N_2O_{\text{nit}} \times R_{NO:N_2O} \times P$$

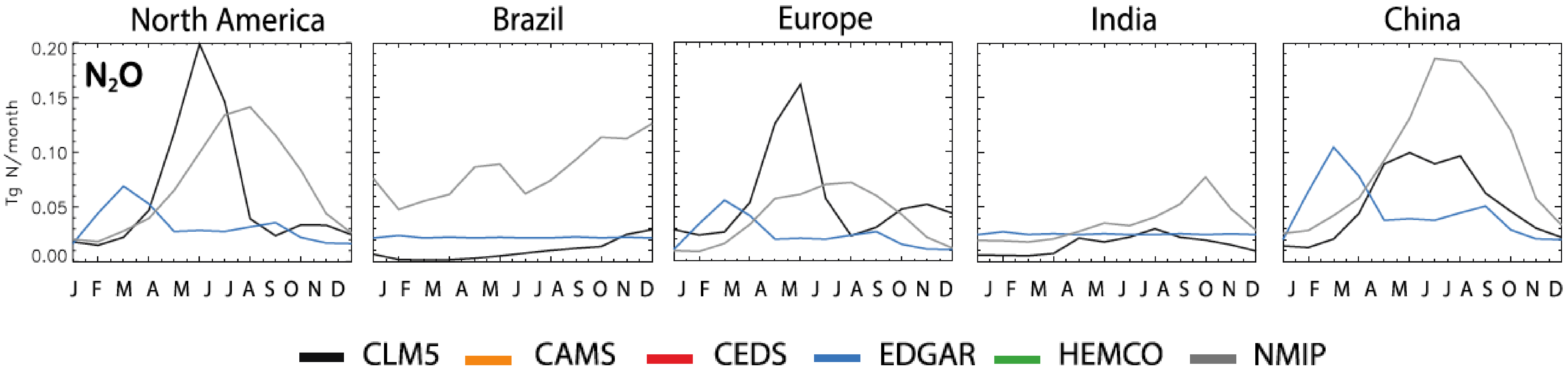
$$\text{Soil NO}_{\text{above-canopy}} = \text{Soil NO}_{\text{soil}} \times \text{CRF}$$

Soil agriculture N_2O emissions are captured reasonably well in CLM5

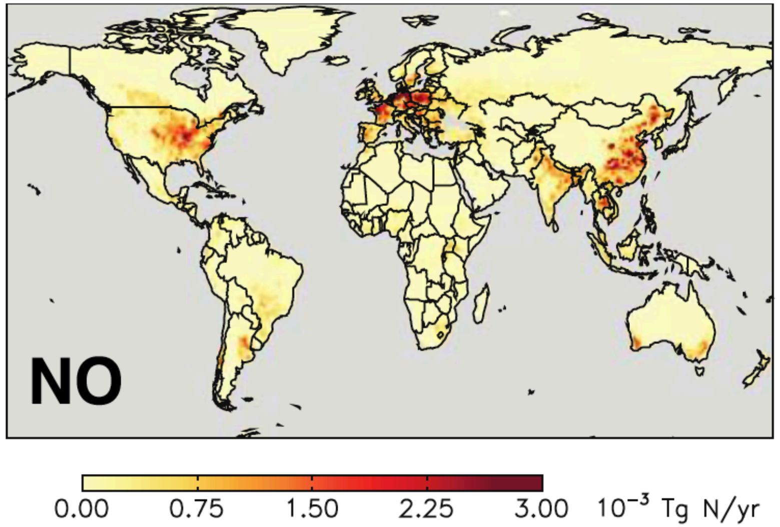
Annual N_2O fluxes in croplands

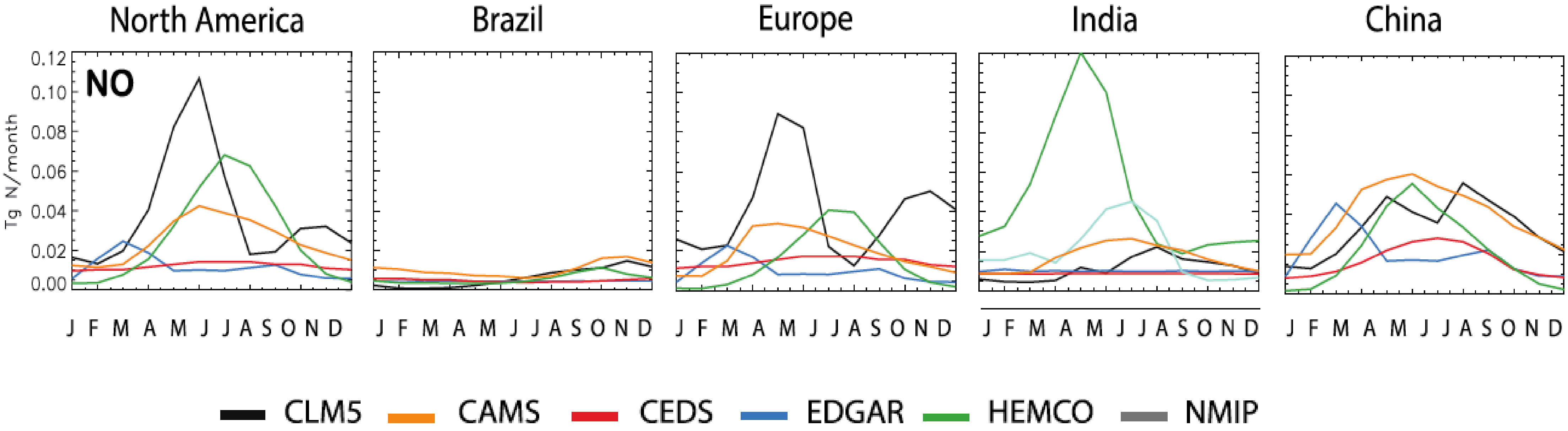




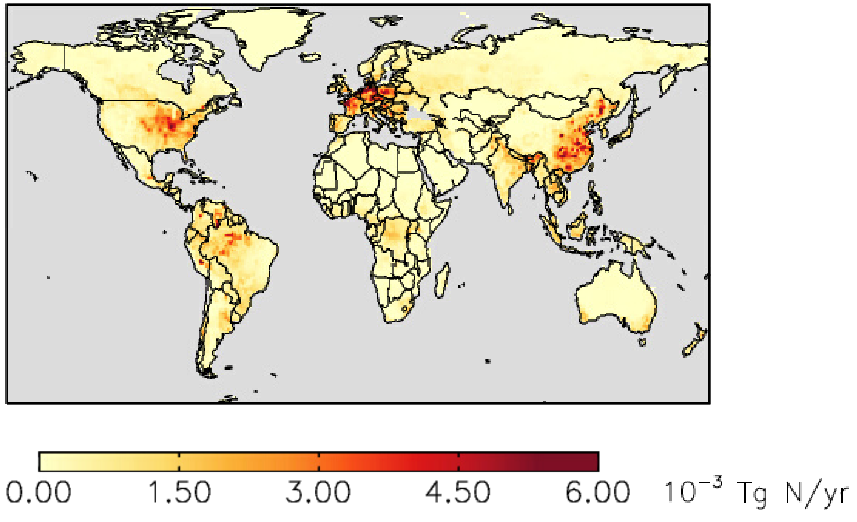


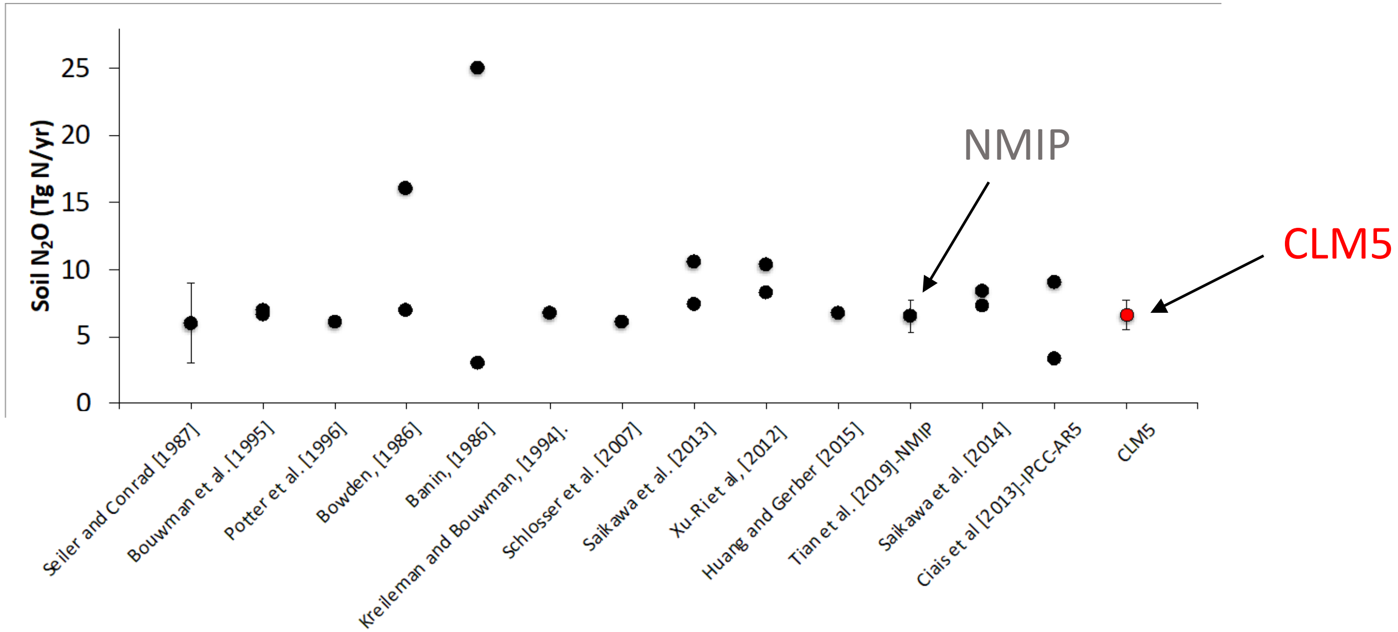
Also, soil agriculture NO_x emissions ….

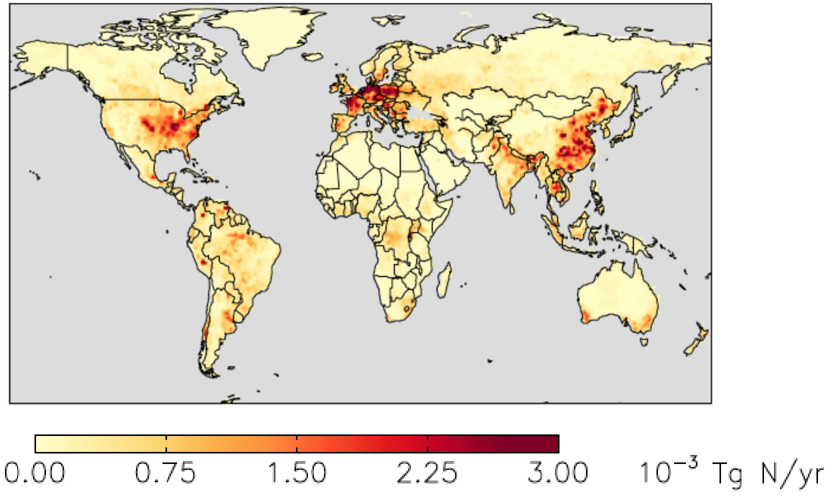


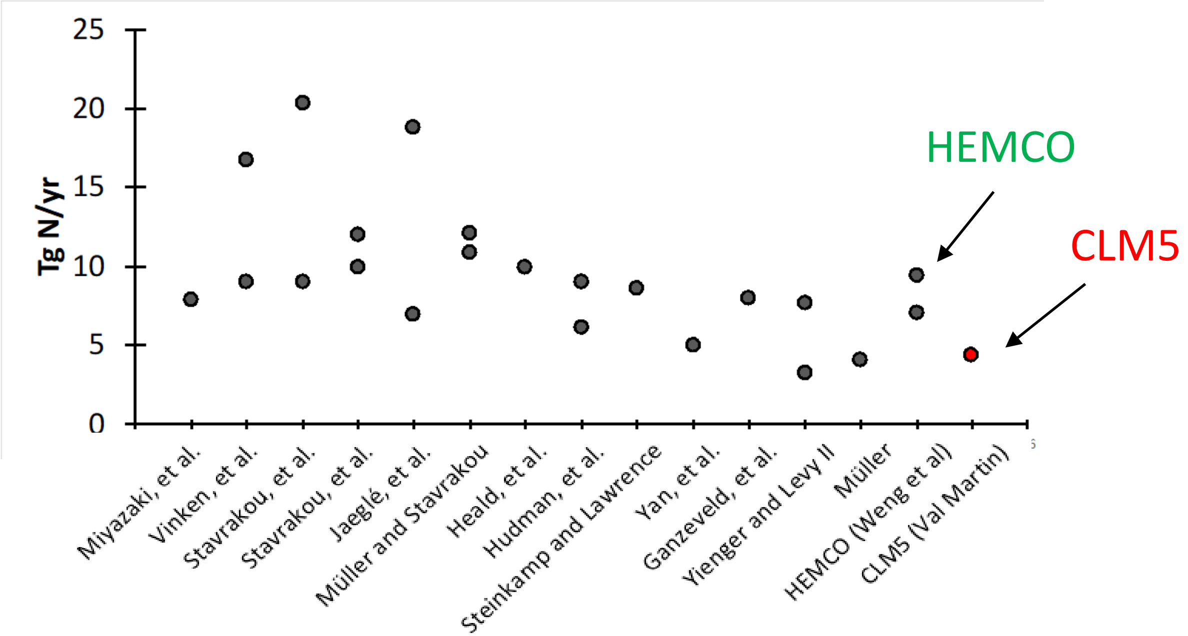


Total global N_2O and NO emissions are on the lower bound

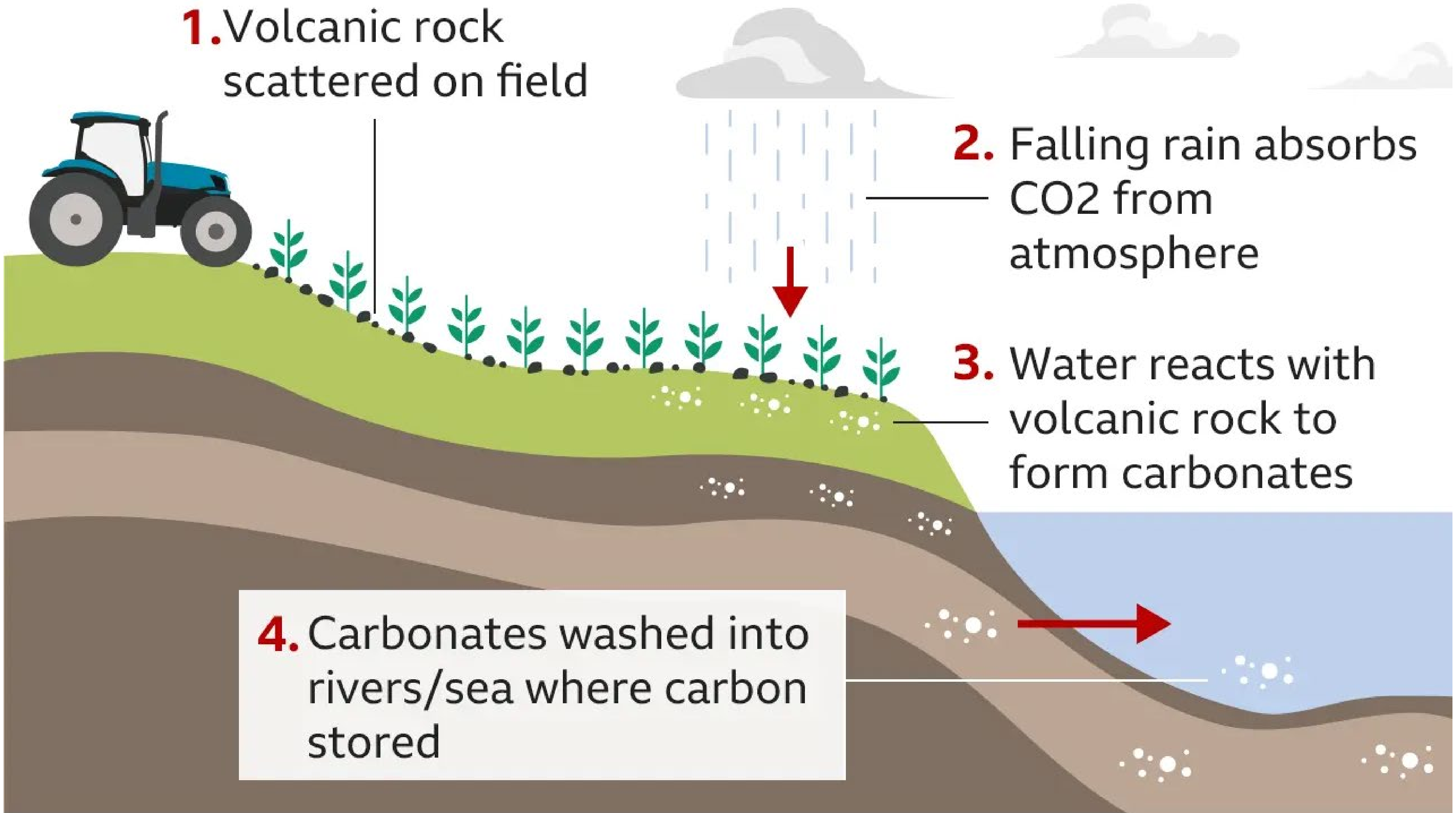








Importance of soil NO_x on atmospheric chemistry: Enhanced weathering (EW) in managed cropland soils



Global network field-scale pilot demonstrations

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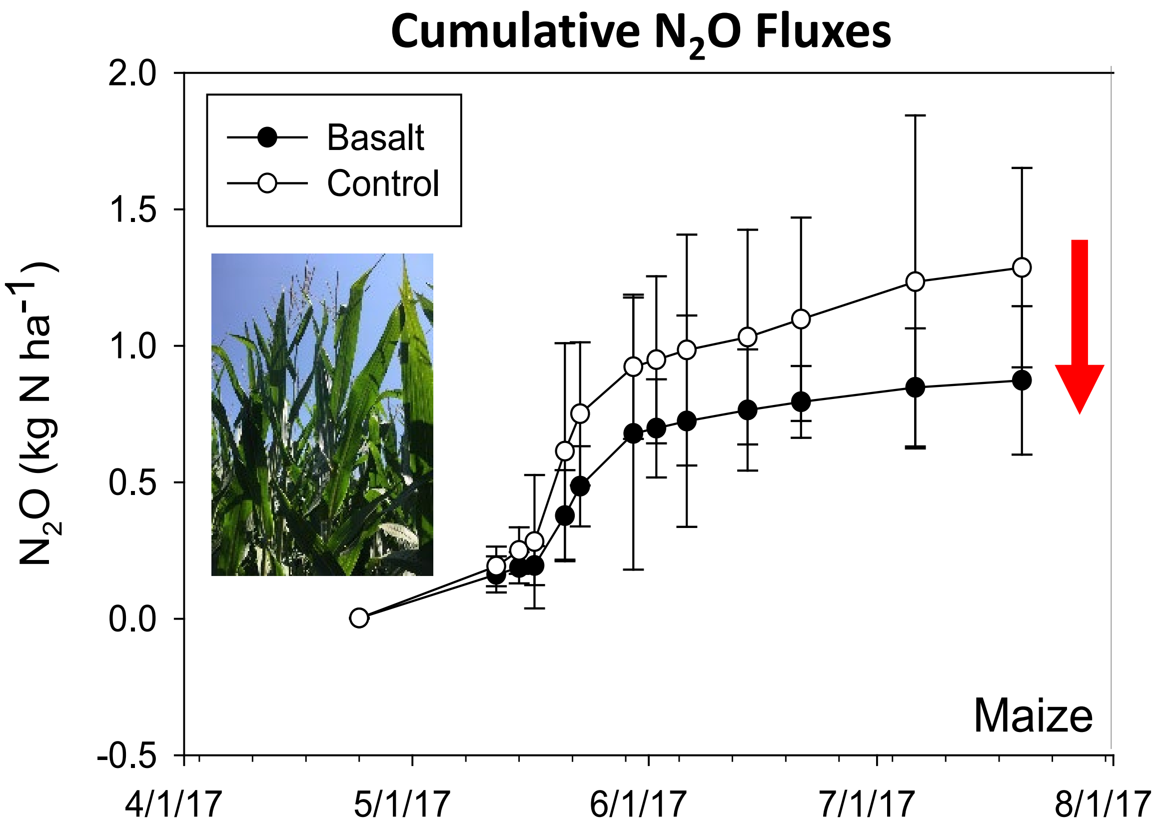
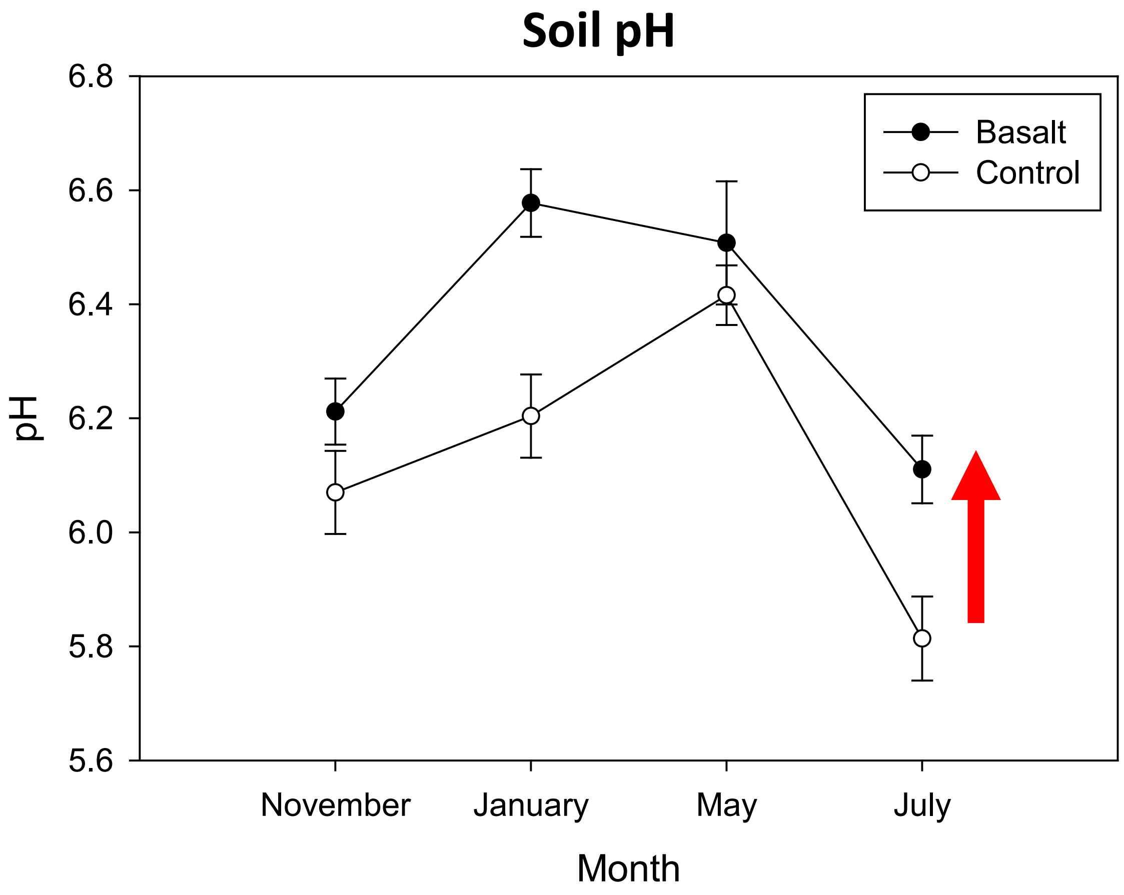
Basalt treatment reduces N_2O emissions from maize plots linked to increases in soil pH





Kantola et al, (submitted)

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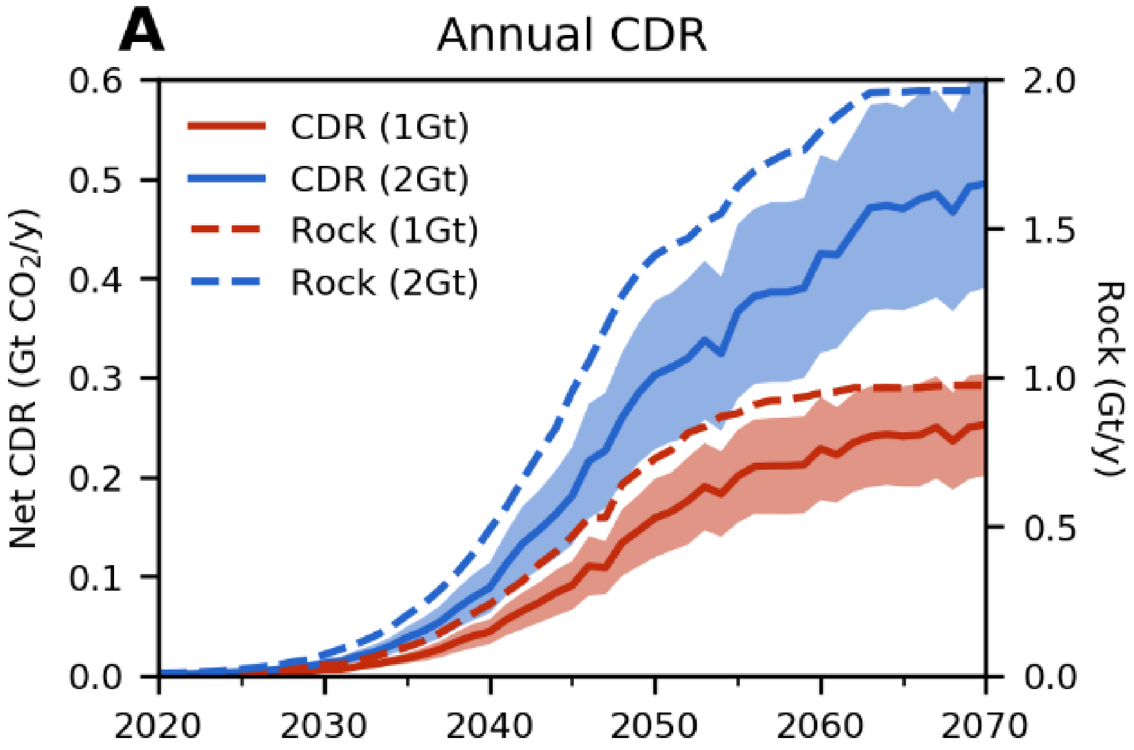
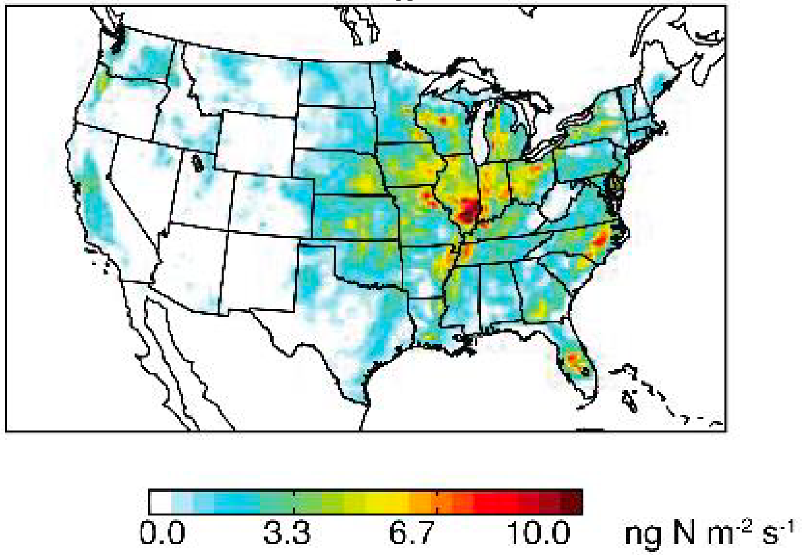
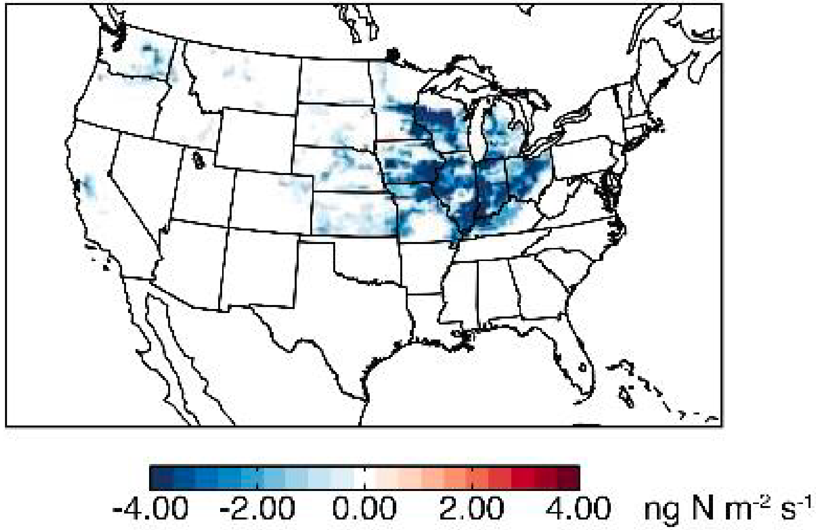
Transforming USA agriculture with EW for CO_2 sequestration



Soil NO_x (2020)



Δ EW-Control (2050)



U.S. projected CDR removal for 2050 is 1 $GtCO_{2(e)}$

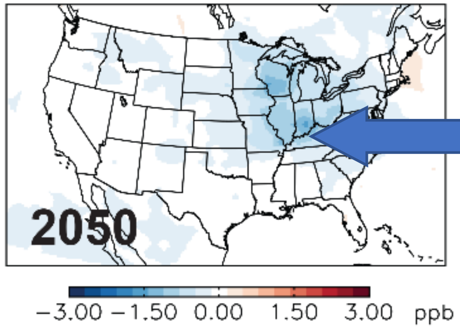
ERW = up to 50%

Beerling et al, in review

ERW implications for future air quality and crop yields in the US

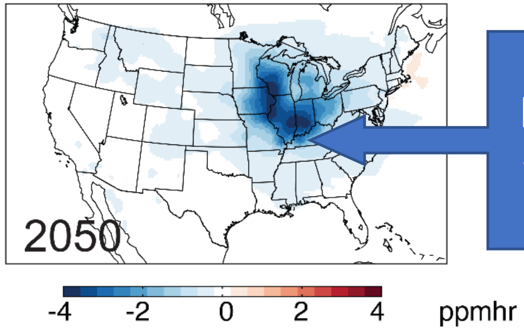
Δ ERW-Control (2050)

Max. daily 8h O_3 average (MDA-8)



Improved human health impacts

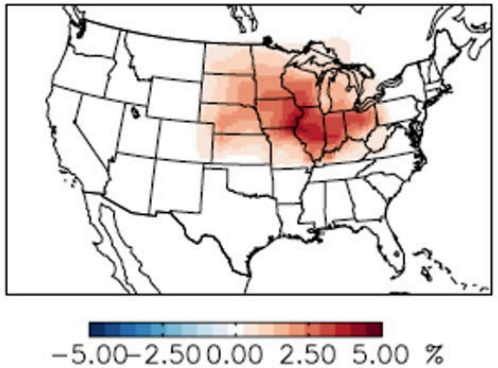
Accumulative O_3 Exposure >40 ppb (AOT40)



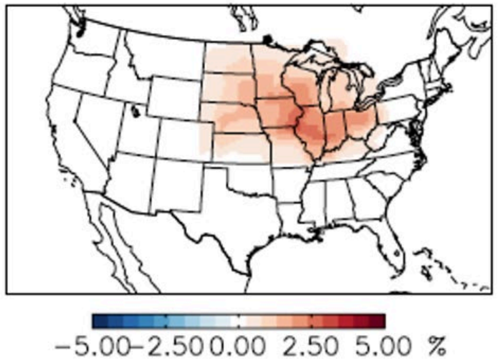
Reduced crop yield damage

Reduced yield damage

Maize yield increase



Soybean yield increase



Average 4% yield increase worth roughly $500 million

Average 3% yield increase worth roughly $200 million

Beerling et al, in review

Conclusions and Next Steps

- It is important to consider a dynamic soil NO_x scheme in CESM2
- Soil NO_x scheme is being implemented in CTSM5.1 dev118 and will be released within CESM3

Code Issues 581 Pull requests 48 Discussions Actions Projects

Add soil NO fluxes into the N cycle. #2290

- There is still room to validate further and improve the soil NO_x scheme

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Potential climate and atmospheric effects of EW applications