Special Session (SS-1-2)

Global water-climate-human nexus modeling based on process upscaling

Warming may offset impact of precipitation changes on riverine nitrogen loading

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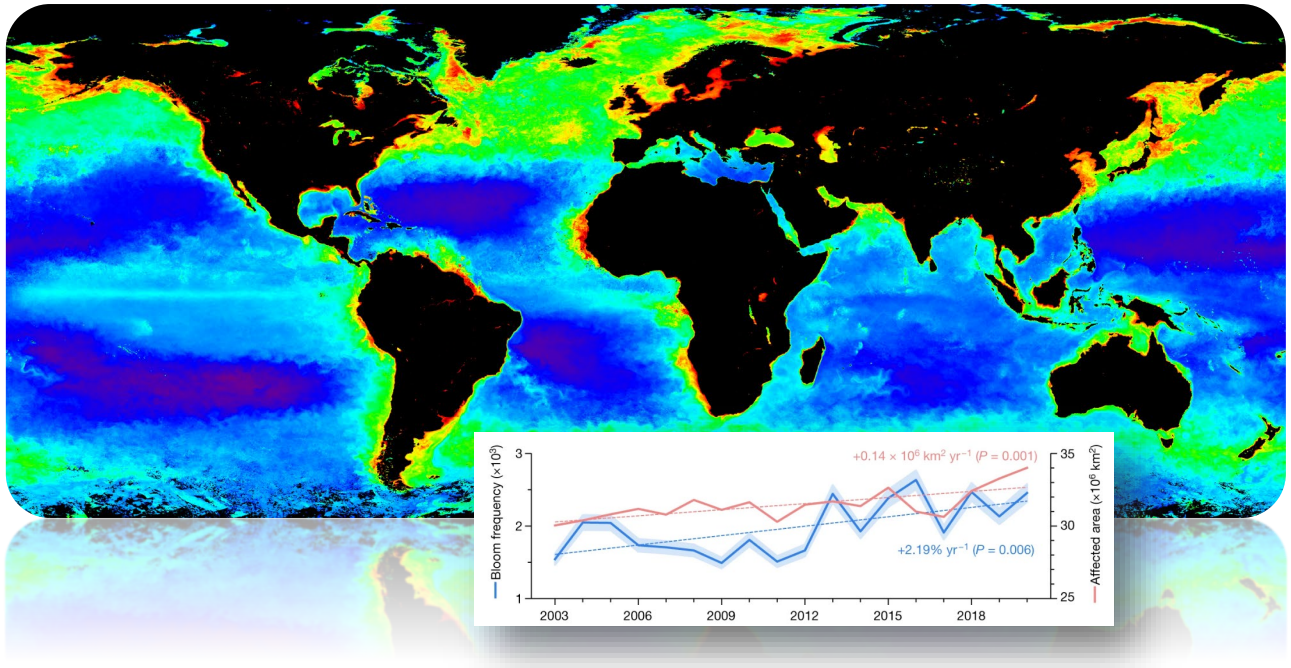
Sept 14, 2023

Outline

- **Background**
  - Coastal eutrophication, nitrogen export, climate change
- **Methods**
  - Geostatistical modeling, nonlinear sensitivity
- **Results and discussion**
  - Tradeoff between precipitation and temperature
  - Future changes in nitrogen export
- **Conclusion**

Eutrophication and nitrogen

- **High risk of eutrophication for global coastal regions**
- **The major reason is inland nitrogen export**



(Increasing) eutrophication risks for global coastal regions

(Credit: Aqua Ocean Color, Dai et al., Nature 2023)

Eutrophication caused by nutrients enrichment. But is it Nitrogen (N) or Phosphorus (P)?

⇩

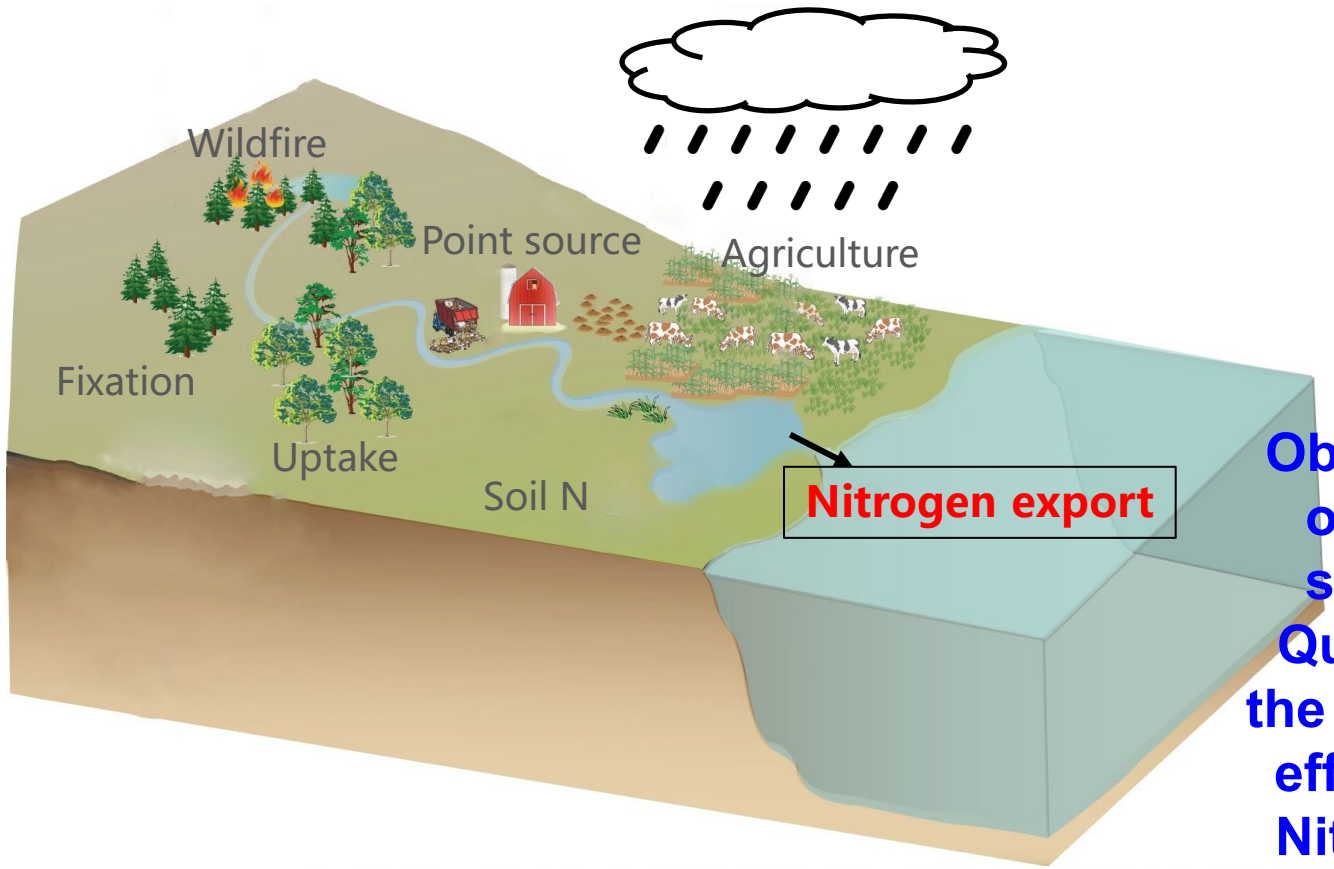
Global oceans are limited by N
- **N:P < 16 (Redfield Ratio)**
- **Denitrification rate > N_2 fixation**

⇩

Coastal eutrophication is largely attributed to inland nitrogen export

Nitrogen export processes

- **Nitrogen export is originated from human input (e.g., Fertilizer)**
- **But it is regulated by climate effect**



Objective of this study: Quantify the climate effect on Nitrogen

Nitrogen input
Fertilizer, biological fixation, atmospheric deposition

Climate effect

- **Precipitation**
  Nitrogen transport
  Flashing rate, sediment
- **Temperature**
  Nitrogen transformation
  Plant uptake, mineralization, nitrification, denitrification

Nitrogen export

Previous studies

- The effect of either precipitation and temperature has been reported using different approaches
- But their combined effect under climate change has not been investigated!

Larger precipitation generally increases nitrogen export

- ✓ Has been confirmed by observations (Howarth et al. 2006), process-based modeling (Actor et al. 2022), and statistical modeling (Sinha et al. Science 2017)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HOME > SCIENCE > VOL. 357, NO. 6349 > EUTROPHICATION WILL INCREASE DURING THE 21ST CENTURY AS A RESULT OF PRECIPITATION CHANGES

REPORT

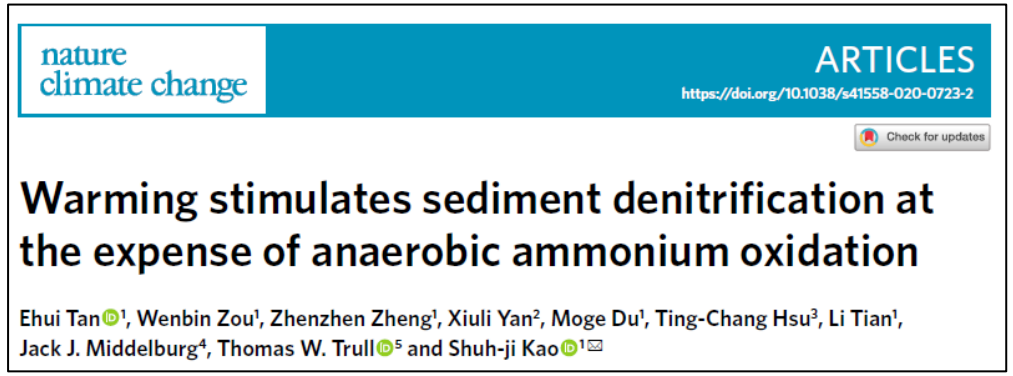
Eutrophication will increase during the 21st century as a result of precipitation changes

E. SINHA, A. M. MICHALAK, AND V. BALAJI Authors Info & Affiliations

SCIENCE · 28 Jul 2017 · Vol 357, Issue 6349 · pp. 405-408 · DOI: 10.1126/science.aan2409

Temperature likely reduces nitrogen export due to denitrification

- ✓ Reported by lab experiments (Tan et al. NCC 2020; Yu et al. NCC 2022; Velthuis and Veraart. 2022)


nature climate change

ARTICLES

https://doi.org/10.1038/s41558-020-0723-2

Check for updates

Warming stimulates sediment denitrification at the expense of anaerobic ammonium oxidation

Ehui Tan[1], Wenbin Zou[1], Zhenzhen Zheng[1], Xiuli Yan[2], Moge Du[1], Ting-Chang Hsu[3], Li Tian[1], Jack J. Middelburg[4], Thomas W. Trull[5] and Shuh-ji Kao[1]✉

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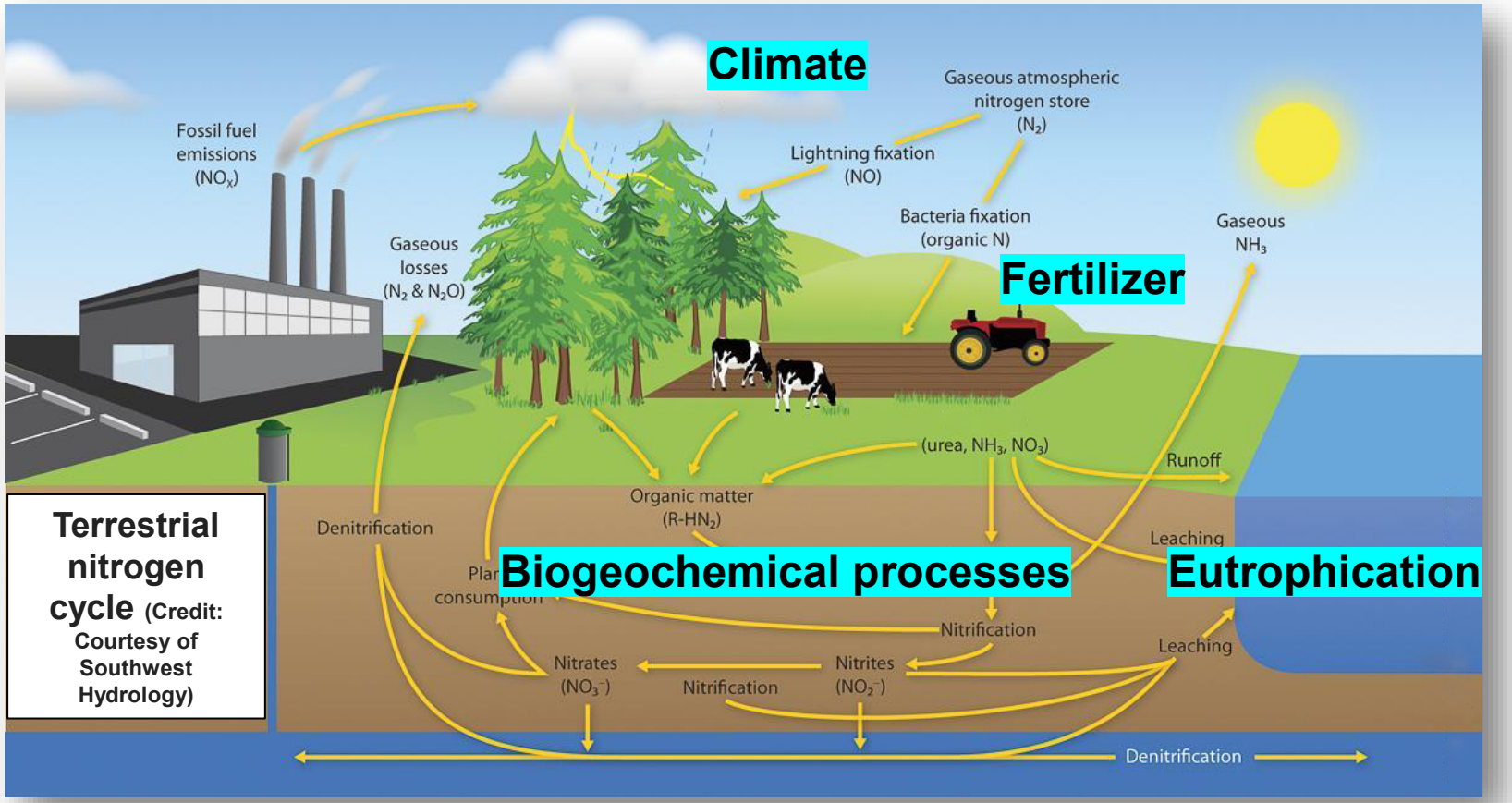
Modeling nitrogen export

- **Fine-scale** nitrogen-related processes are very **complex**, thus need to **upscale** to large scales



How to upscale?

Option 1: Process-based model

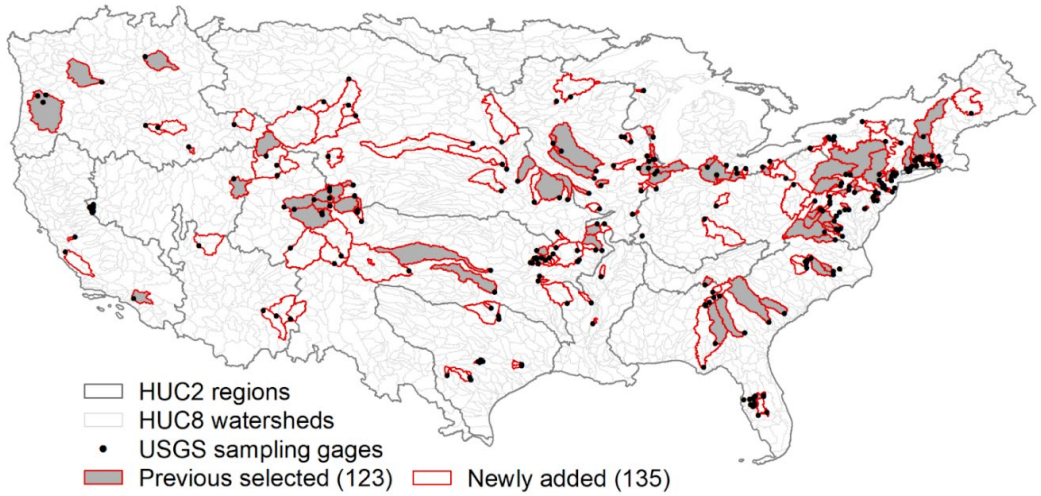
- **Appropriate for processes with clear understanding**

Option 2: Statistical model

- **Appropriate for processes that lacks understanding**
- **Especially good for interactive multi-processes**
- **Can benefit process-based modeling**

Modeling nitrogen export

- **Generalized additive model (GAM) to model the nonlinear correlation of multi-spatiotemporal data**



1. Data

Nitrogen export for 258 watersheds from 1981 to 2017

2. Model

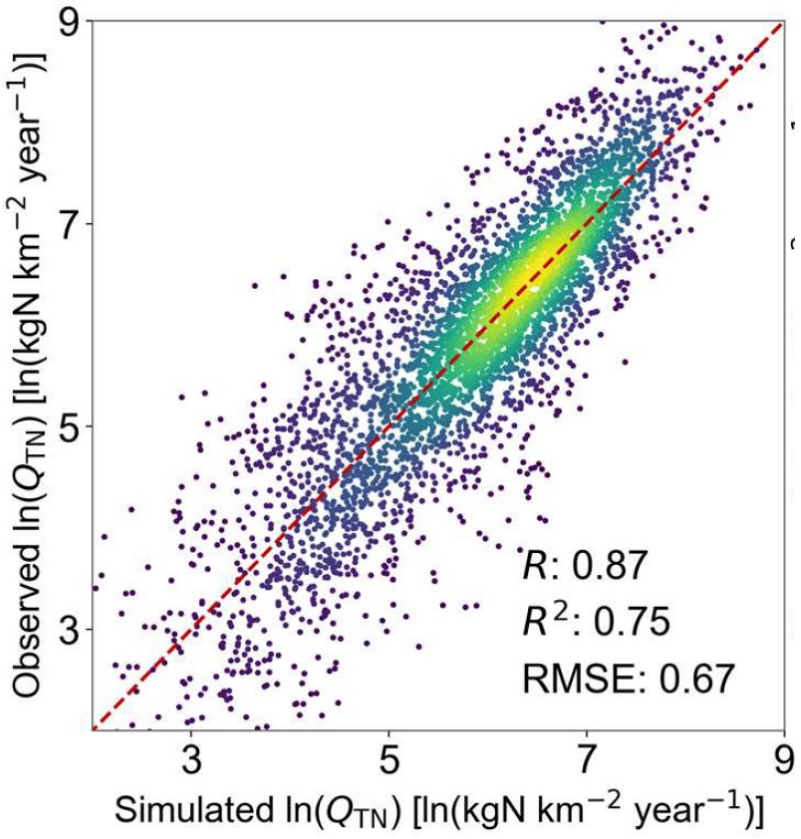
Nitrogen export

$= f(\text{fertilizer}+\text{atm}+\text{fixation}+\text{waster})$ → **Nitrogen Input**

$+ f(\text{precip})+f(\text{extreme precip})+f(\text{temp})$ → **Climate effect**

$+ f(\text{land cover})+f(\text{till drain})$ → **Land cover**

3. Model performance



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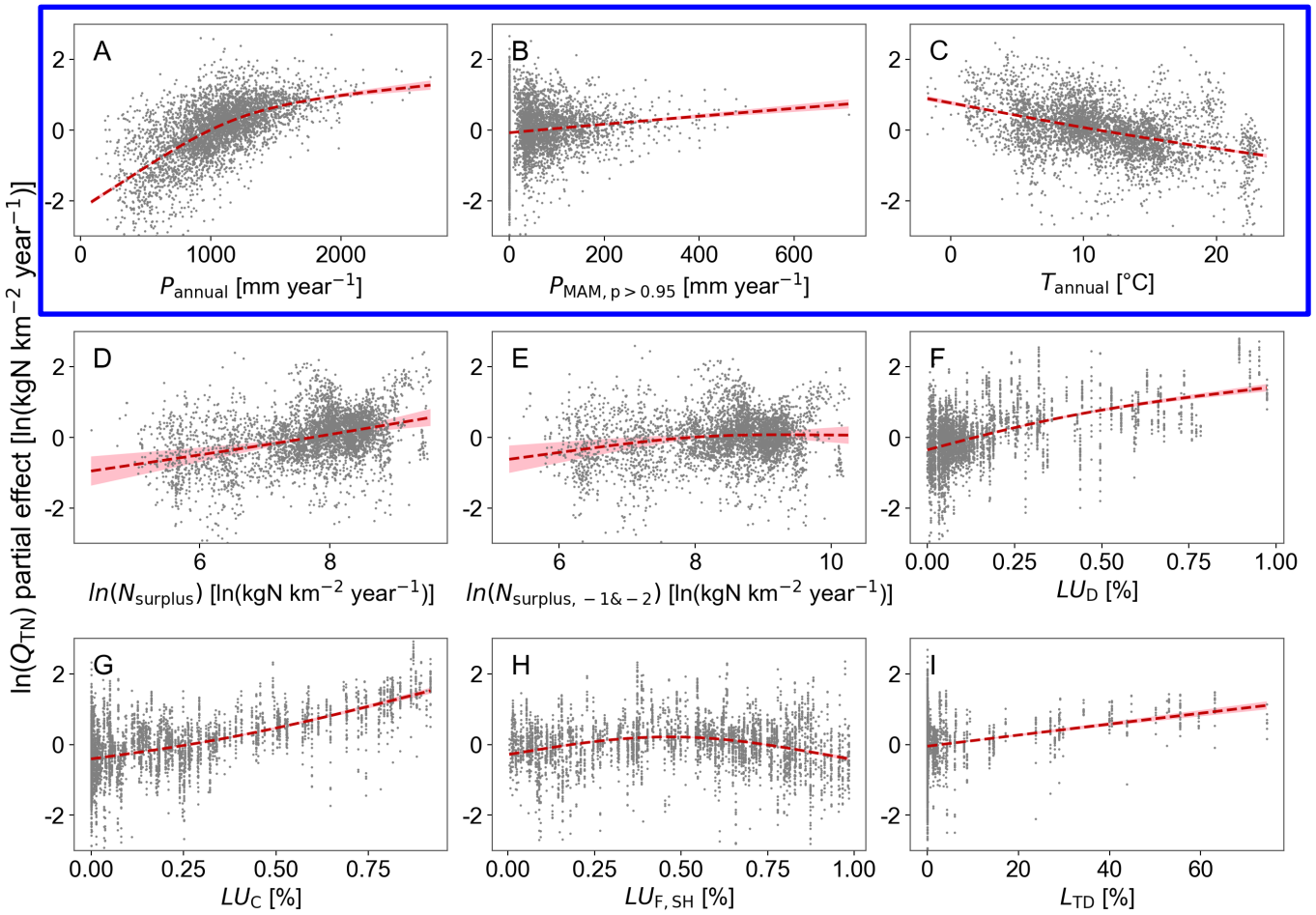
Drivers of nitrogen export

- **Sensitivities of nitrogen export to environmental variables**

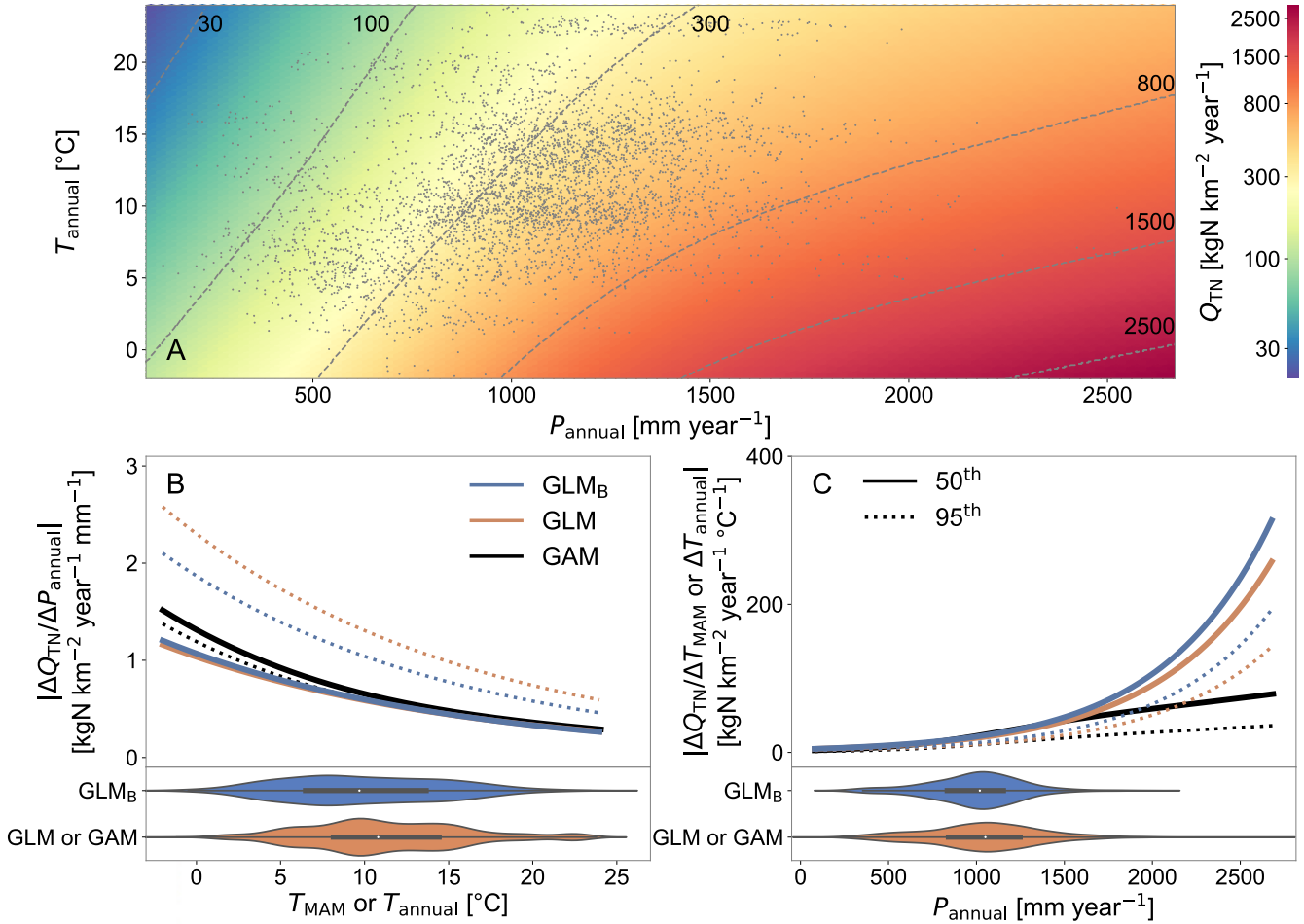


- **Precipitation**
  Increase nitrogen export but nonlinearly
- **Extreme precipitation**
  Increase nitrogen export
- **Temperature**
  Decrease nitrogen export

Precip: +0.17%/mm
Temp: -6.4%/°C

Climate effect on nitrogen export

- **Nitrogen export is co-regulated by both precipitation and temperature**



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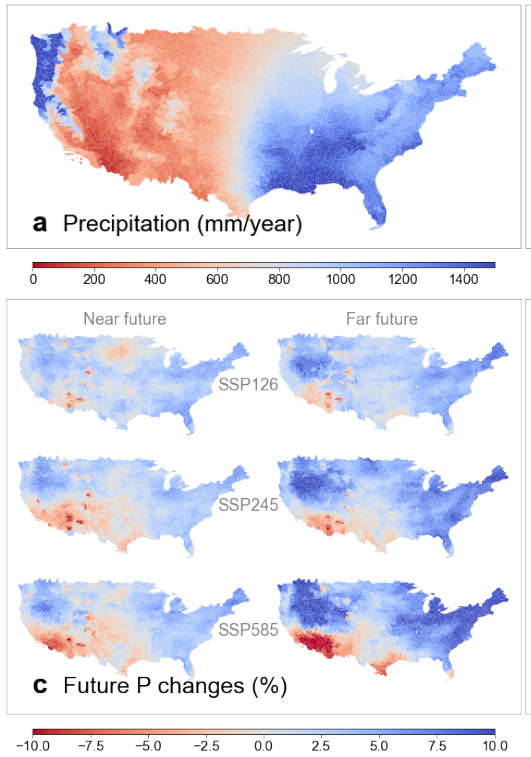
Precip: +0.17%/mm
Temp: -6.4%/°C

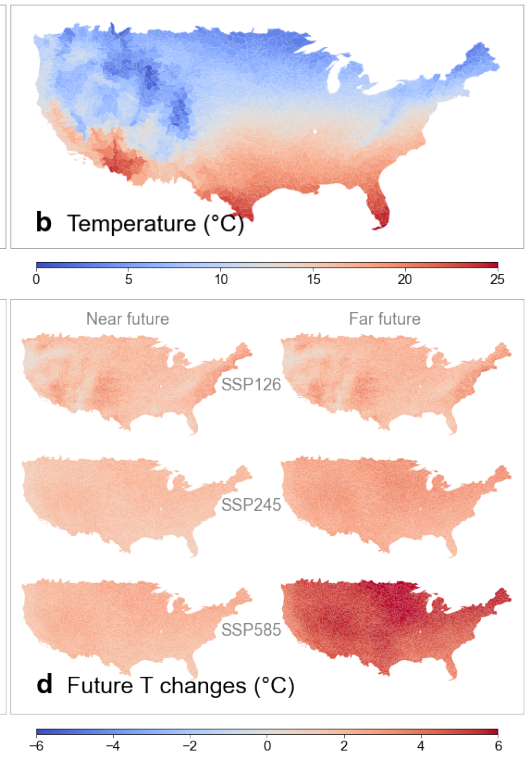
Future changes in nitrogen export

- Future **precipitation** will be **increasing** in a warming world
- However, the **nitrogen export** will be **decreasing**

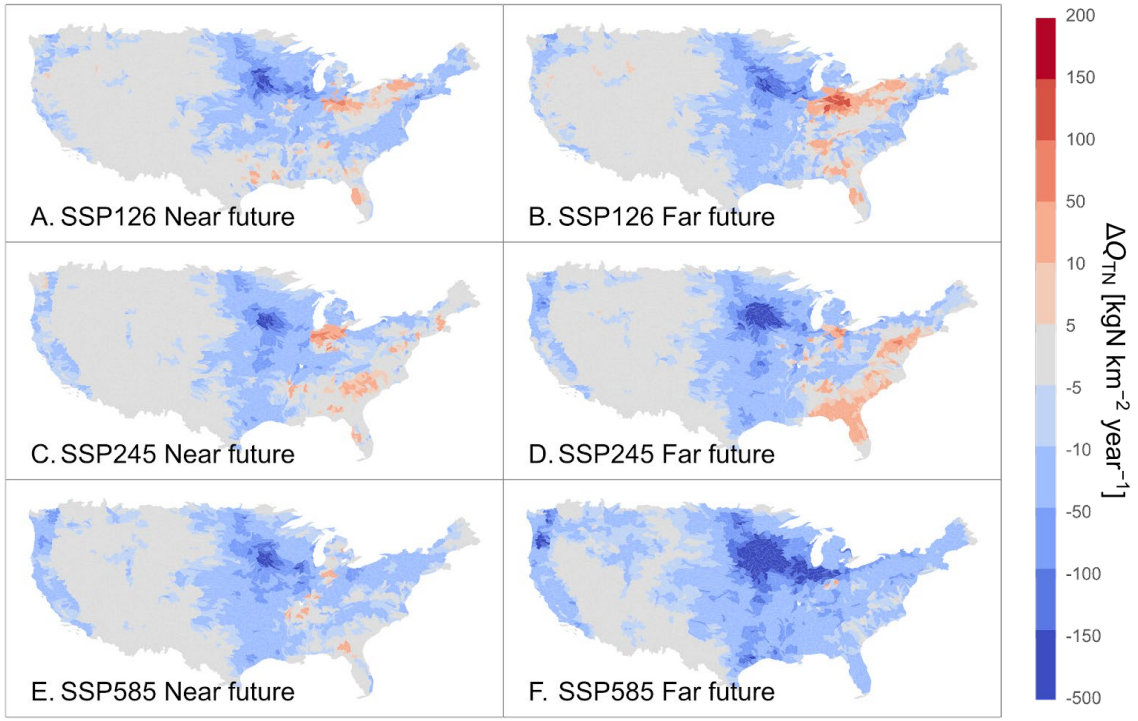
Future precipitation



Future temperature

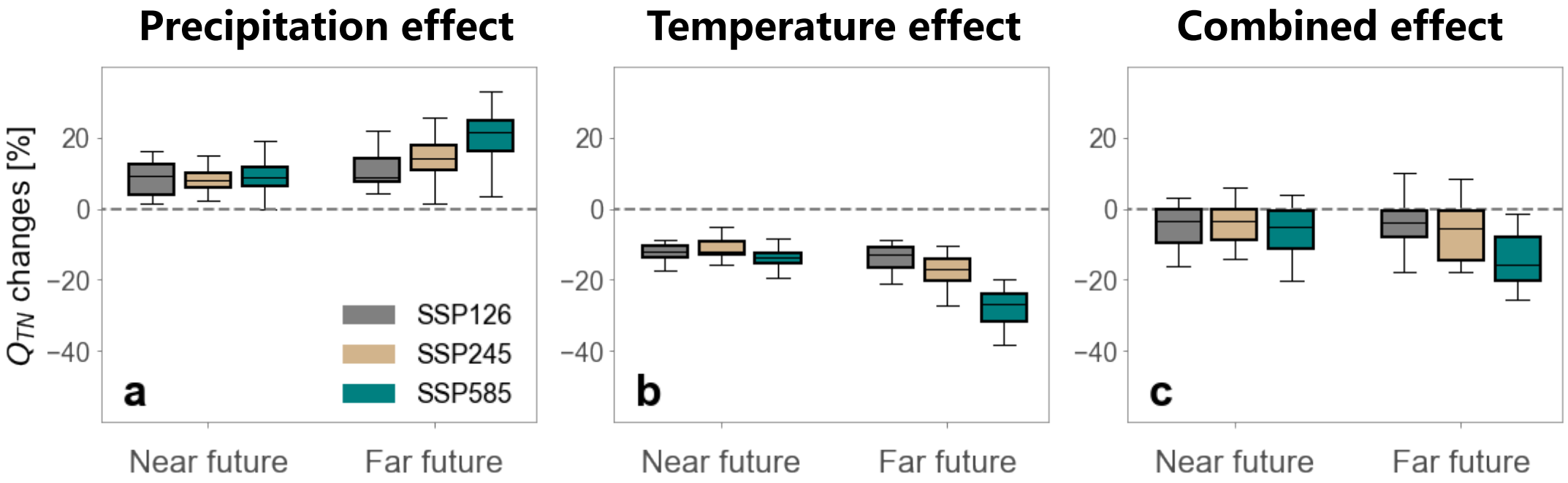


Future nitrogen export



Future changes in nitrogen export

- Precipitation alone will increase nitrogen export
- Temperature alone will reduce nitrogen export
- The effect of temperature is more pronounced, such that it will offset the effect of precipitation on nitrogen export



Zhao et al. (PNAS 2023)

Conclusion

1. **Geostatistical approach** is an effective method to **upscale** fine-scale complex processes to larger scales
2. River nitrogen export is **co-regulated** by precipitation and temperature
3. **Future nitrogen export** is likely to **decrease** largely owing to the enhanced **denitrification** in a warming world
4. More mechanistic understanding is still needed regarding transformation of nitrogen under climate change

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Thank you!