Ny Viden om Nitratreduktion i Undergrunden

ATV Vintermøde om jord- og grundvandsforurening

15th August 2023

Hyojin Kim
Rasmus Jakobsen, Jens Aamand, and Birgitte Hansen

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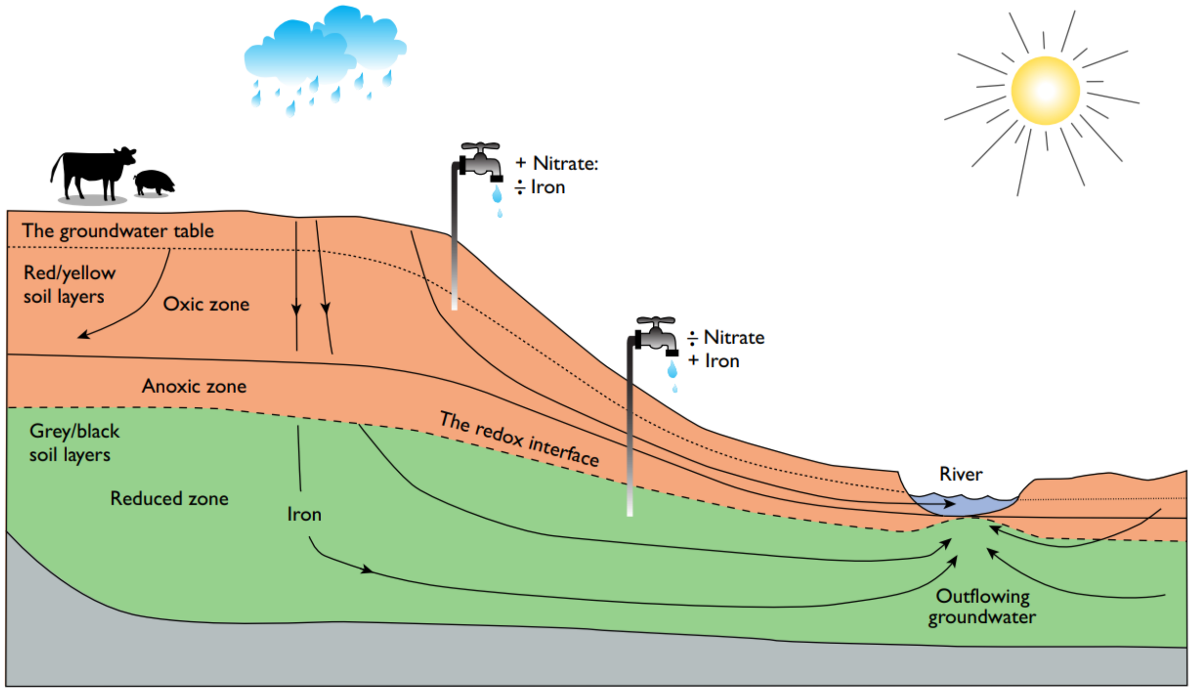
GEUS

What we already know about the nitrate reduction in the subsurface

- Nitrate is reduced only after oxygen is depleted.



Hansen et al. (2012)

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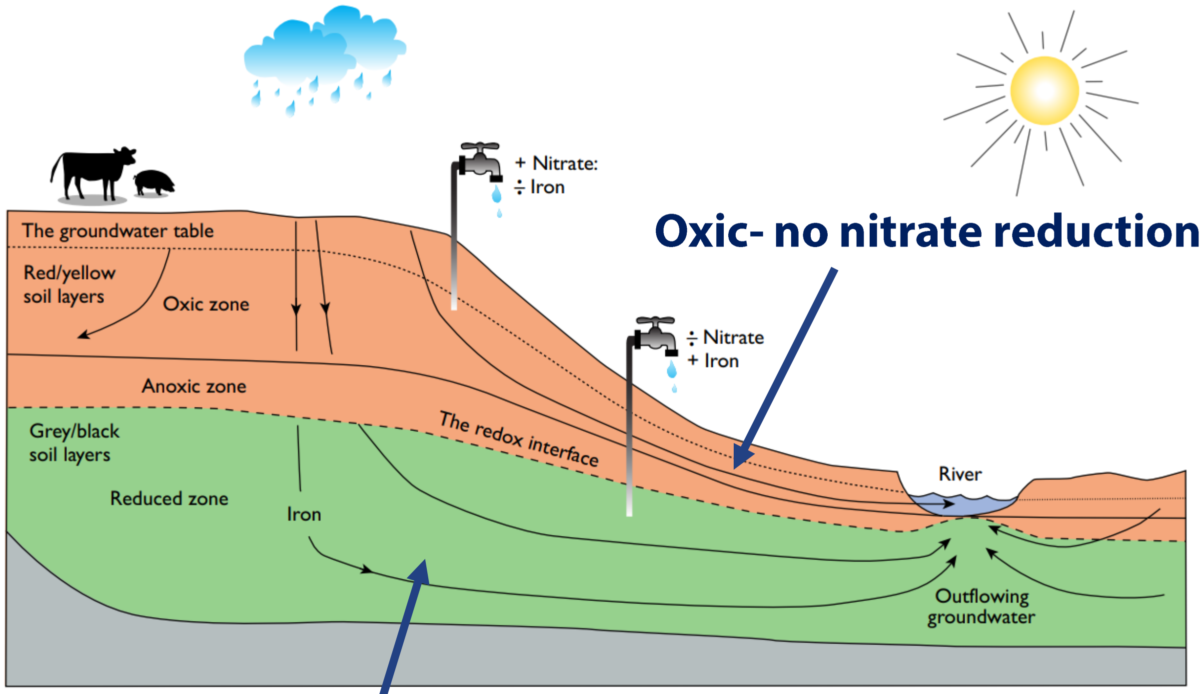

Oxic- no nitrate reduction

Reduced- nitrate reduction

Hansen et al. (2012)

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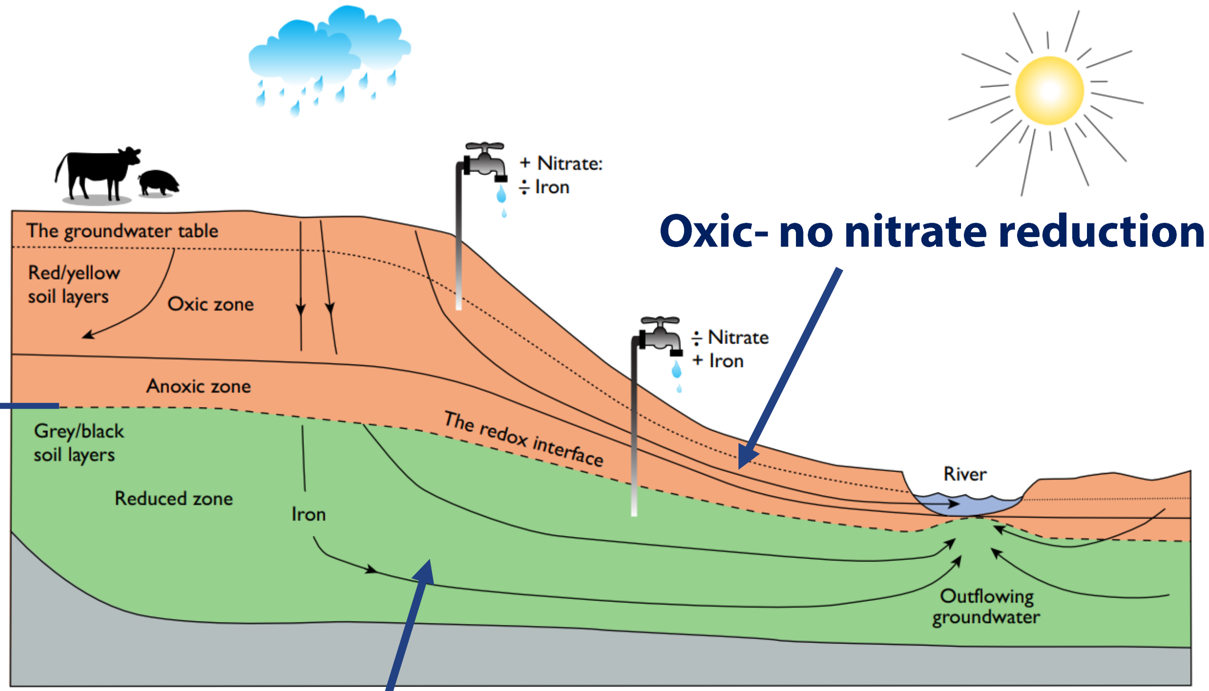
Redox boundary

Oxic- no nitrate reduction



Reduced- nitrate reduction

Hansen et al. (2012)

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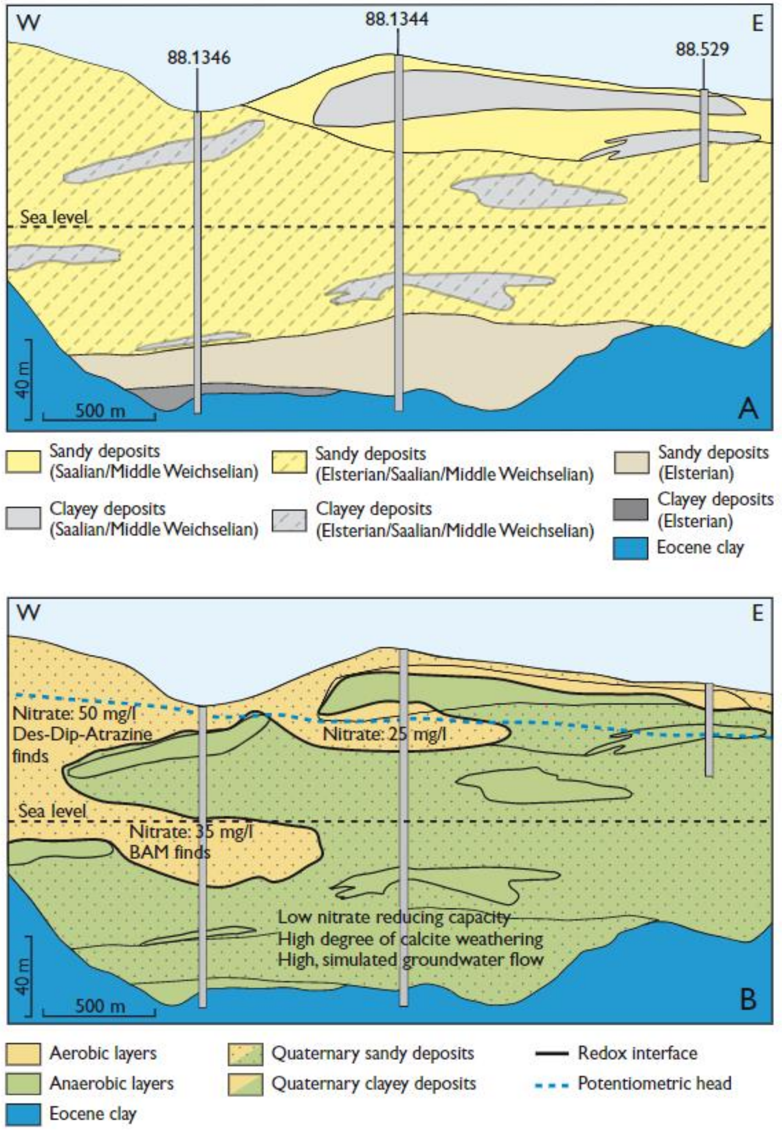
What we already know about the nitrate reduction in the subsurface

- Nitrate is reduced only after oxygen is depleted.
- Nitrate concentrations in groundwater can be highly heterogeneous in space.



Hansen and Thorling (2008)

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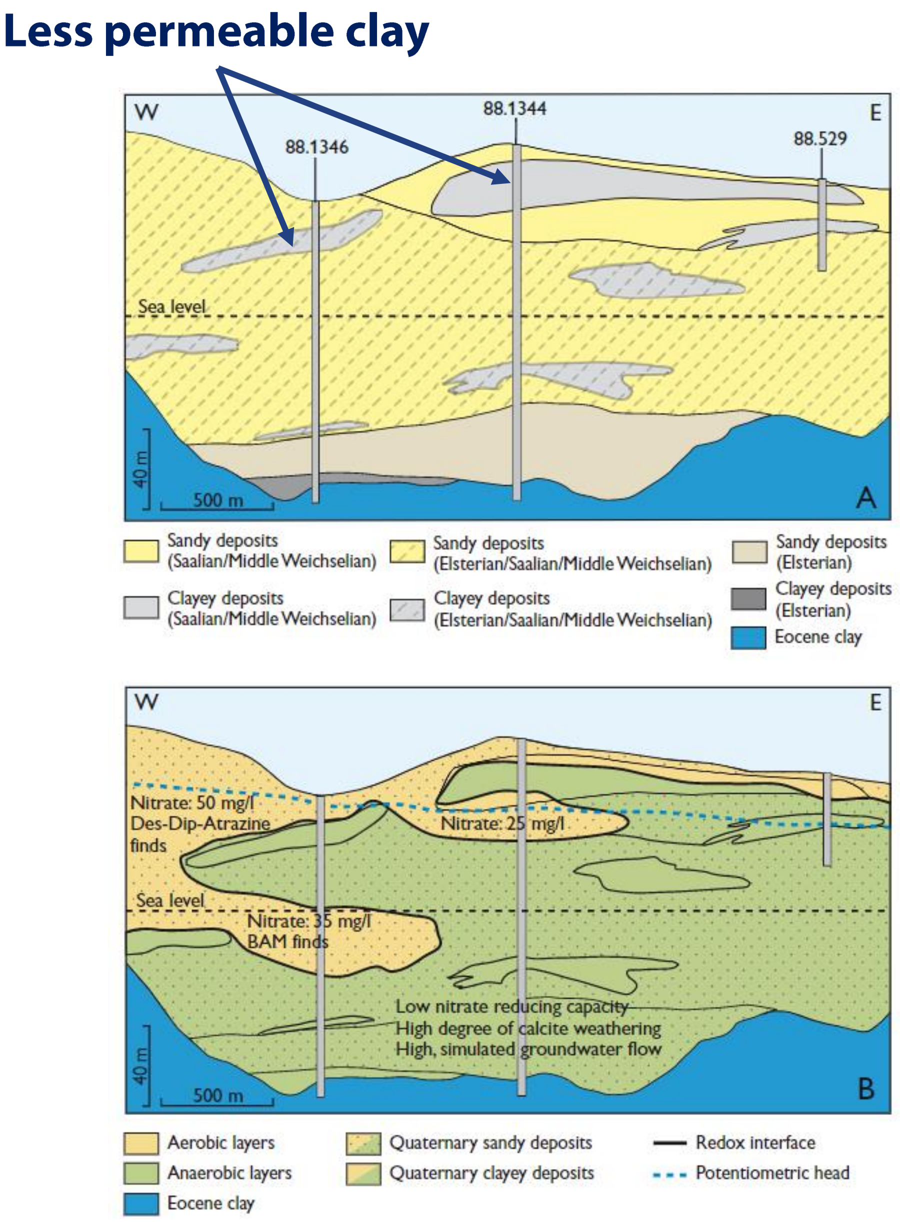

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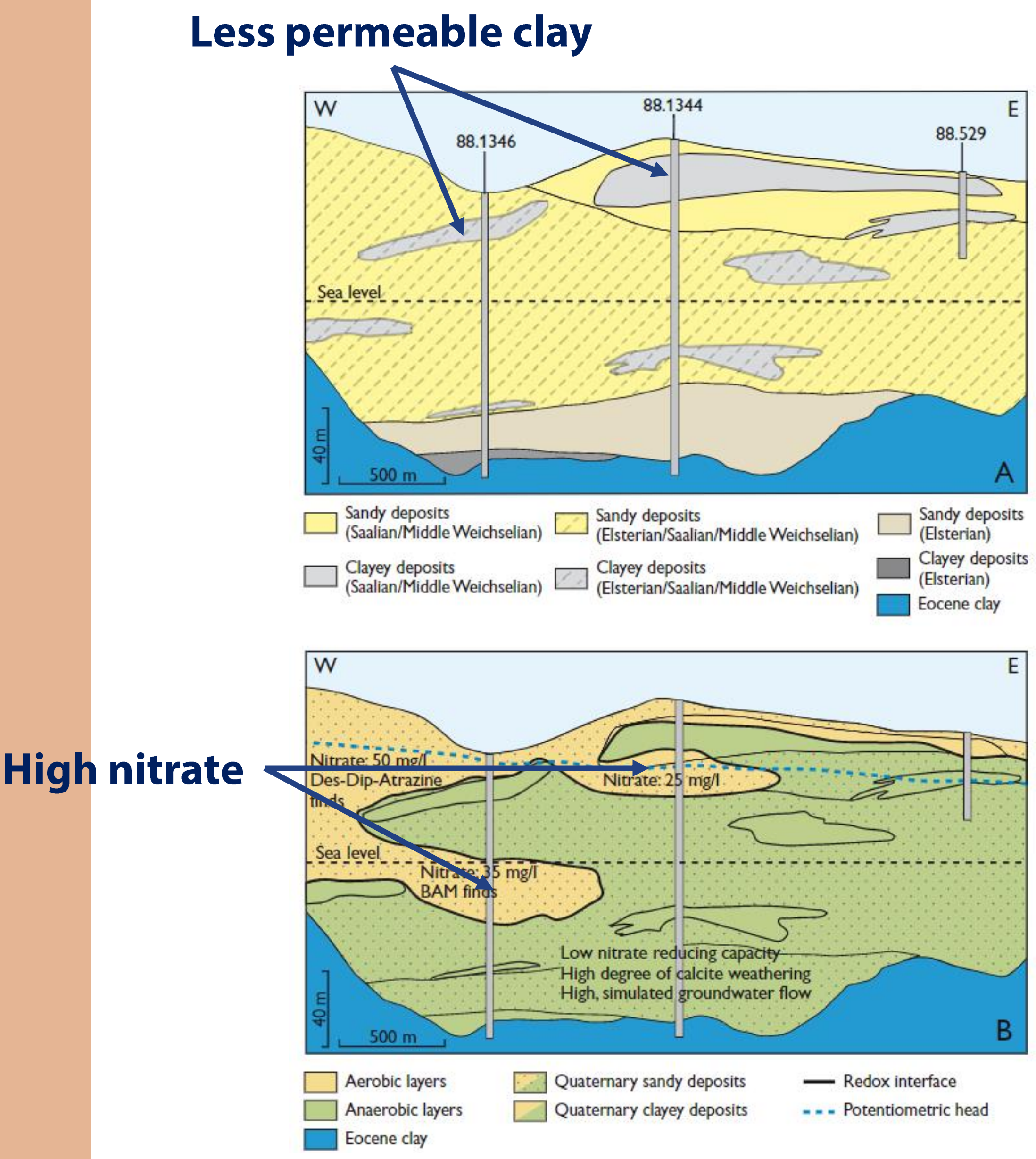

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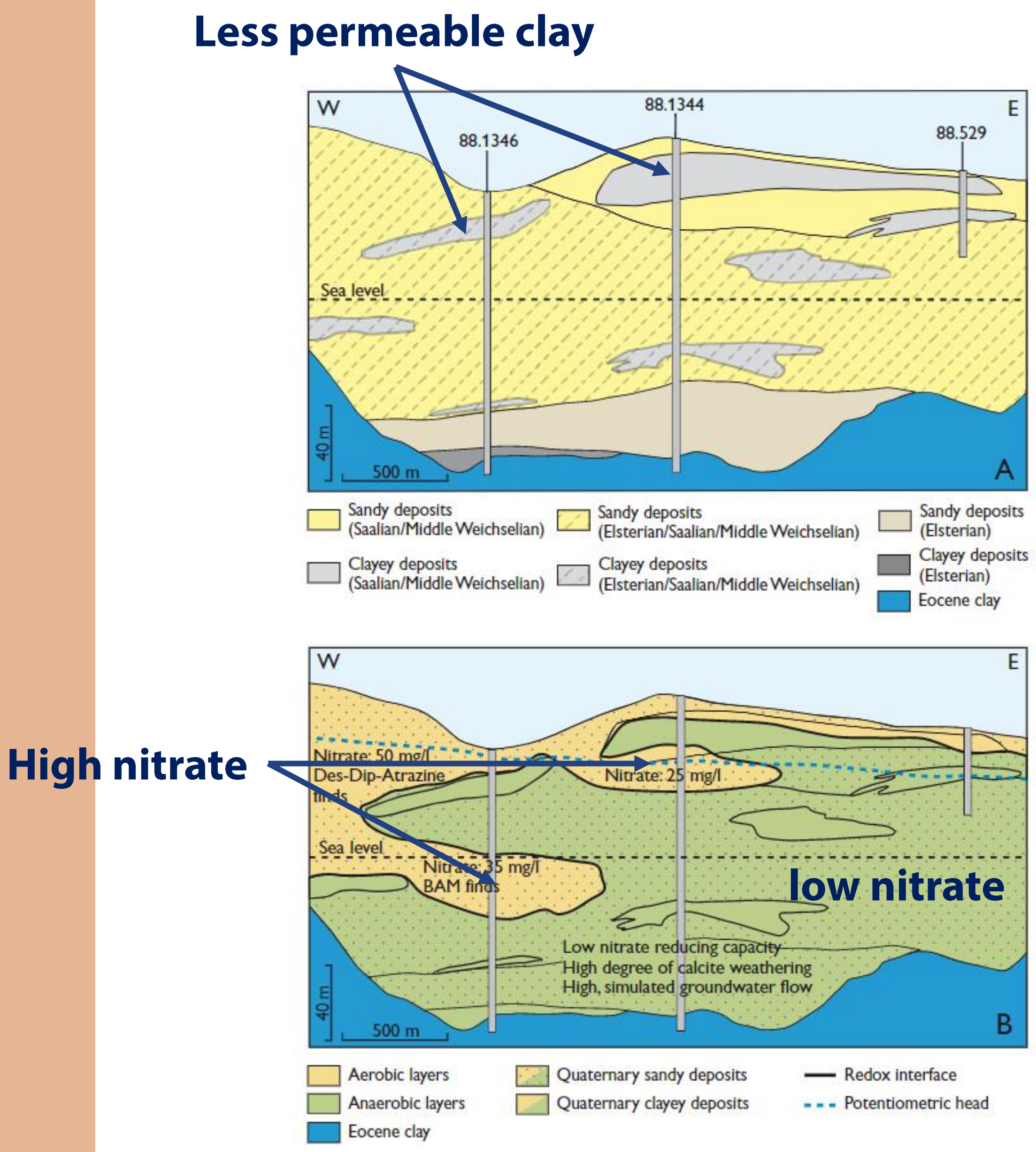

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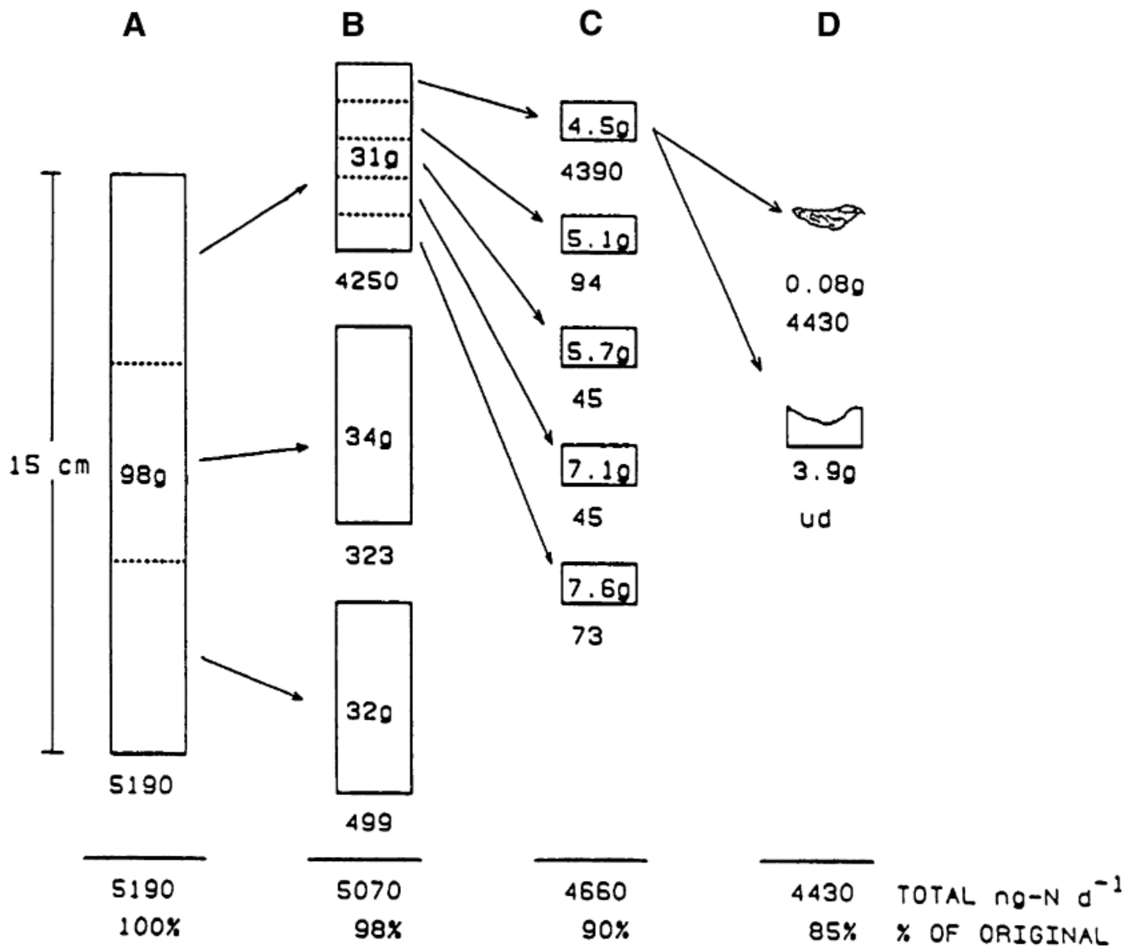

Parkin (1987)

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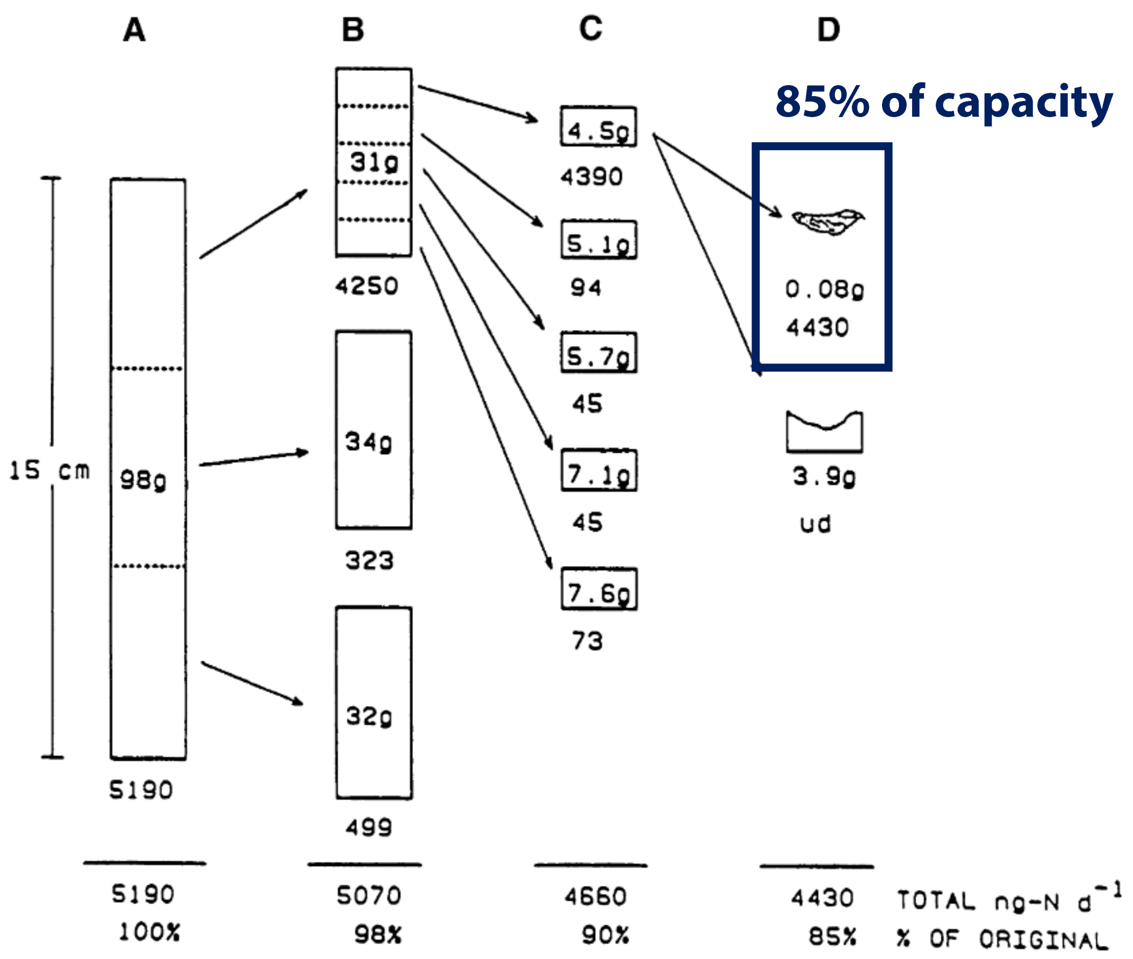

Parkin (1987)

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What we already know about the nitrate reduction in the subsurface

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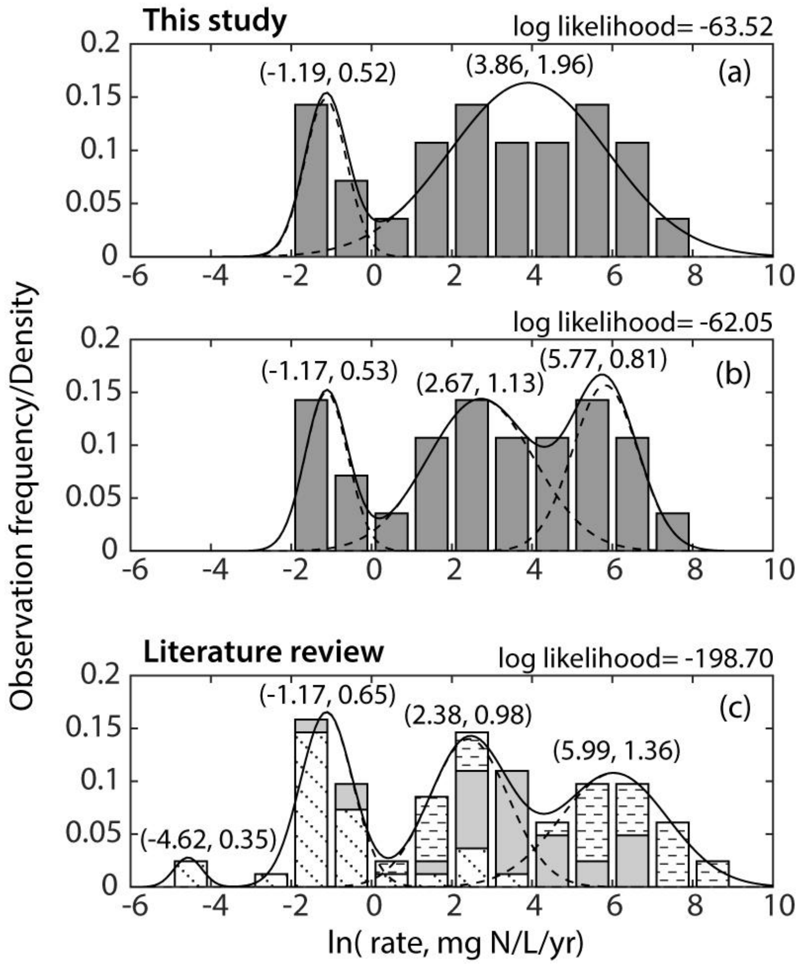
- Hotspots of denitrification result in the high variability of denitrification and widely varying rates.



Kim et al. (2021b)

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What we already know about the nitrate reduction in the subsurface

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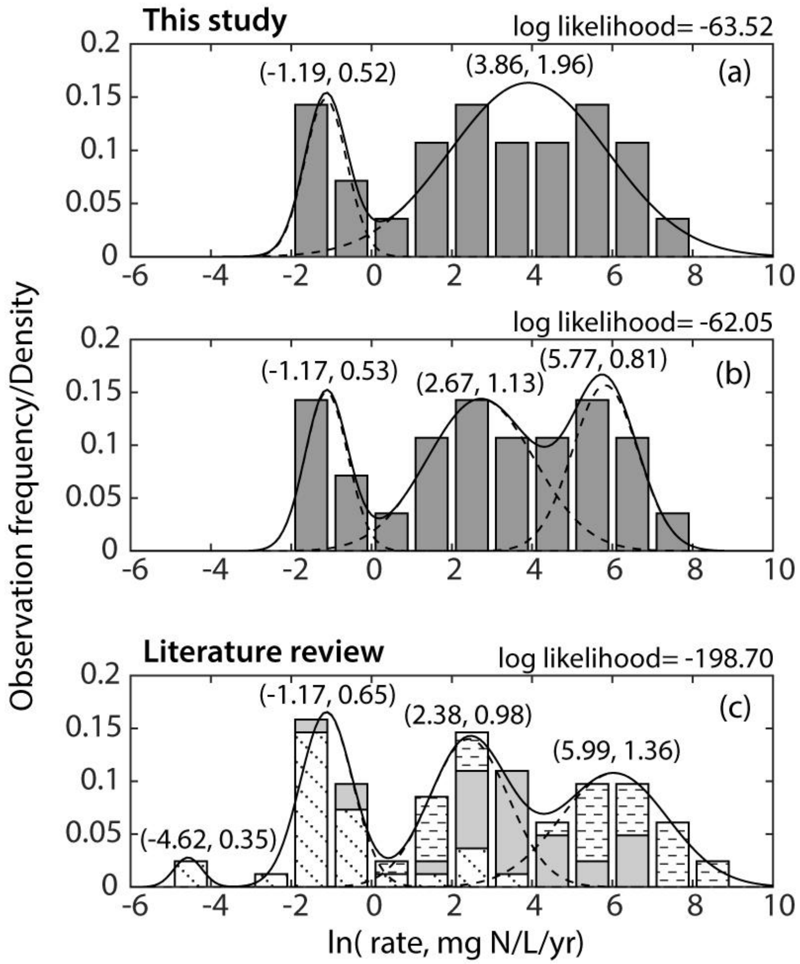
How could we upscale point-scale geochemical information to the catchment or larger scale?



Kim et al. (2021a)

What we already know about the nitrate reduction in the subsurface

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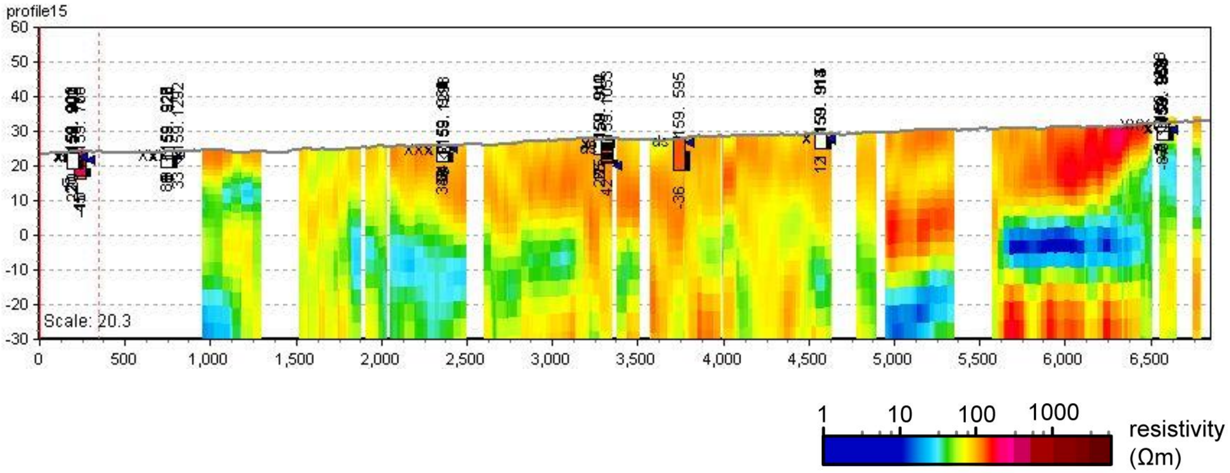
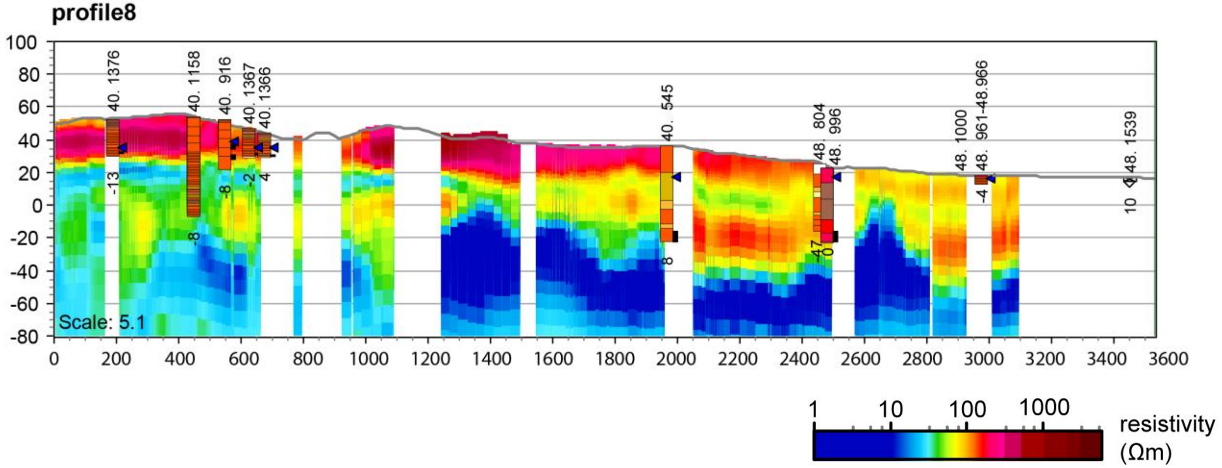
How could we upscale point-scale geochemical information to the catchment or larger scale?
: Using geophysical information





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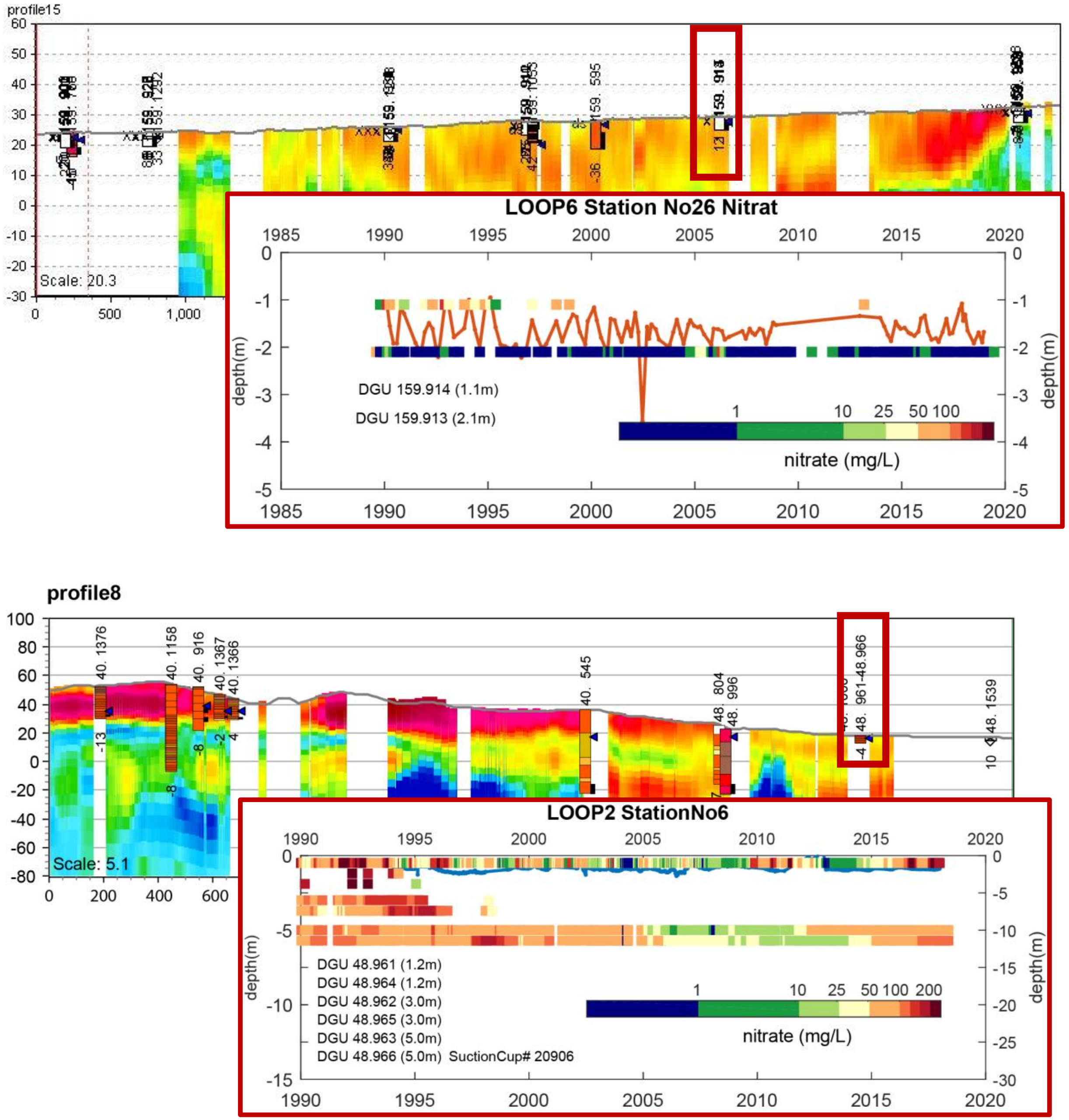
What we already know about the nitrate reduction in the subsurface

- Nitrate is reduced only after oxygen is depleted.

How could we upscale point-scale geochemical information to the catchment or larger scale?
: Using geophysical information. But cannot be directly translated into geochemical information.

: more comprehensive understanding of both geochemical and hydrogeological information is needed.



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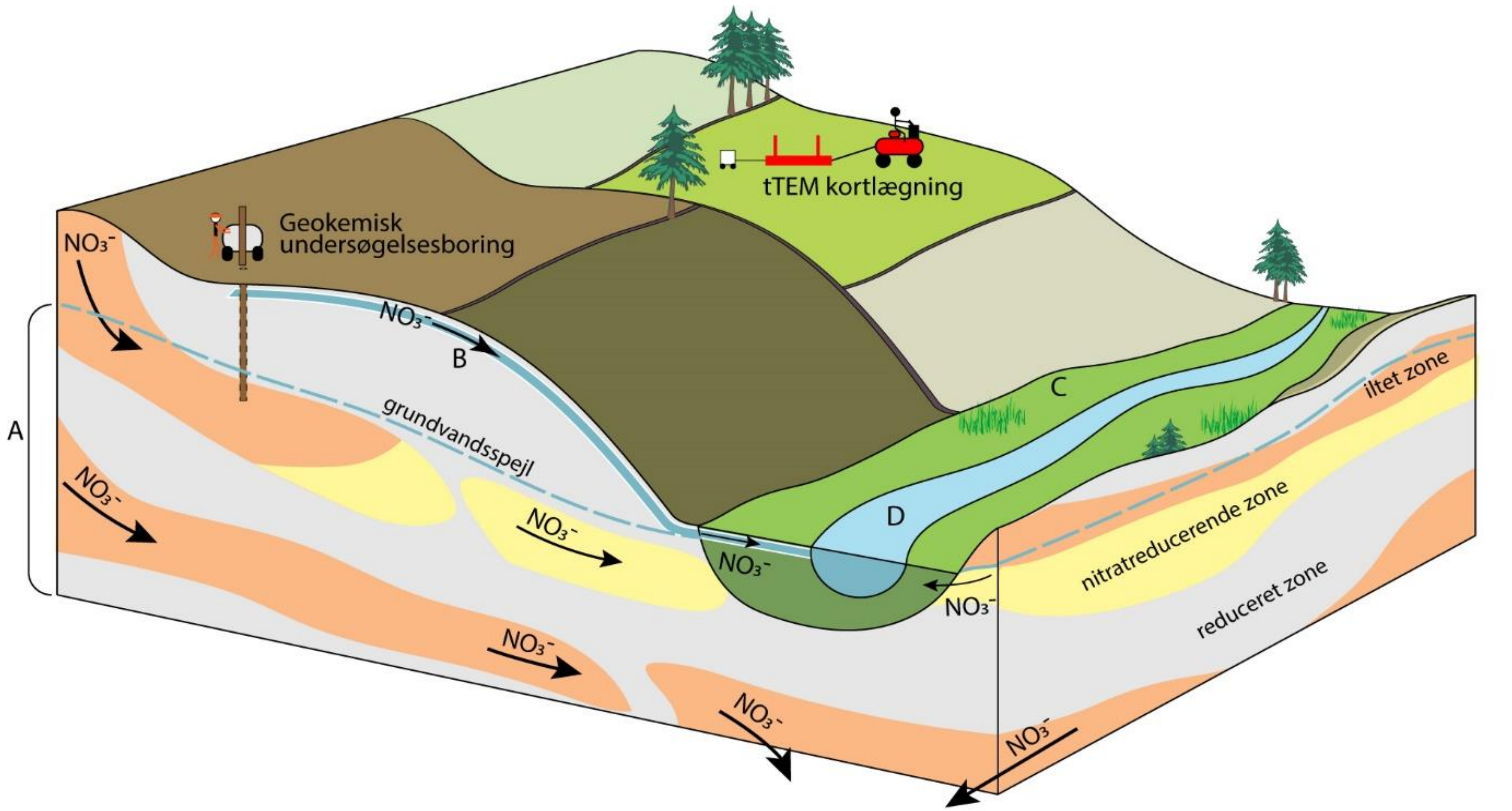
Needs for New Knowledge of Nitrate Retention in the Subsurface

- **New regulations**
  - Spatially targeted N regulations

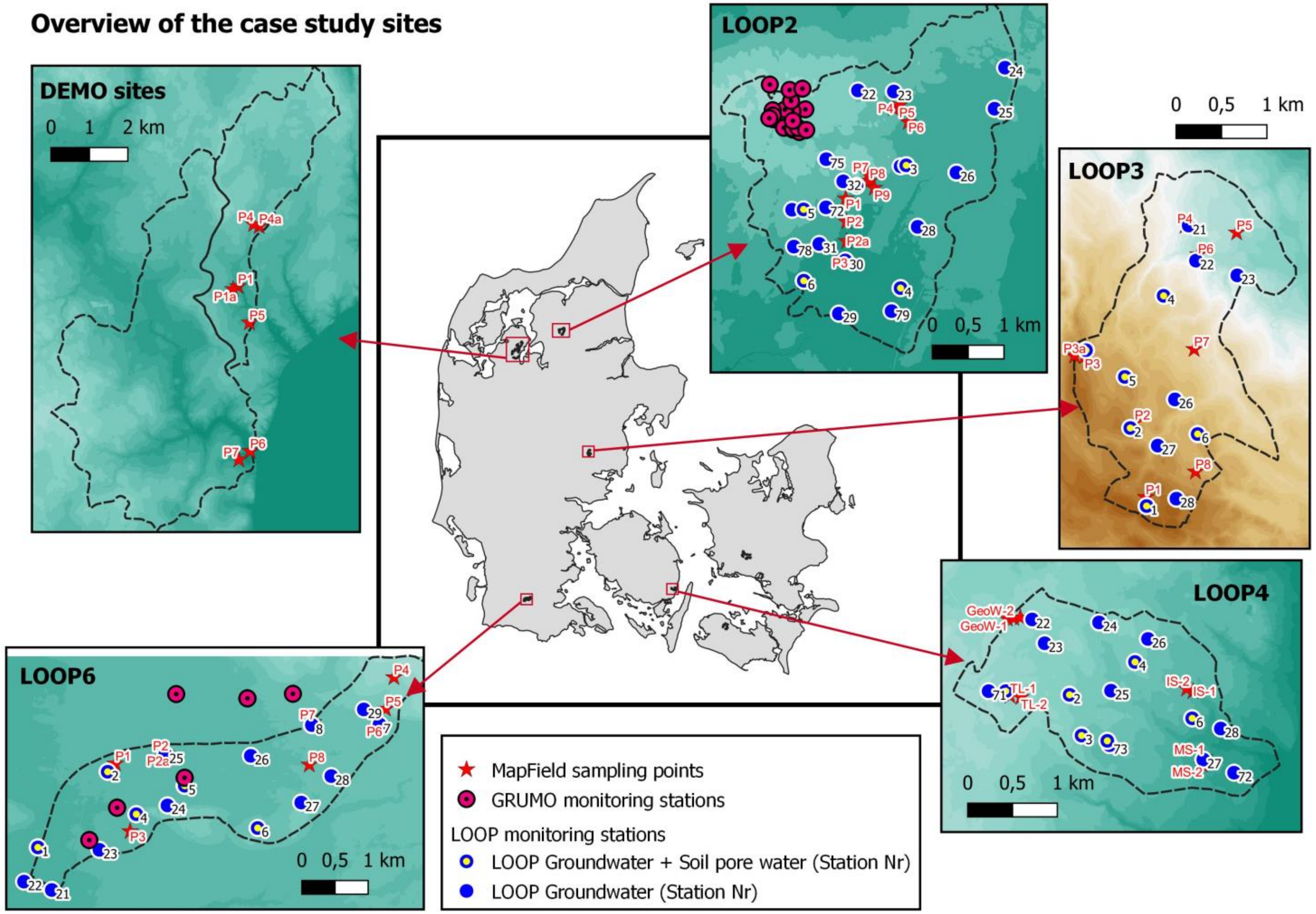
- **New technologies**
  - High-resolution of 3D information of the subsurface structure



Hansen et al. (in prep)

MapField case sites

- Long-term monitoring data of groundwater and stream chemistry
- Subsurface structural information from geophysical and geological investigations
- Sediment color data
- High resolution surface geology map



Innovationsfonden MapField

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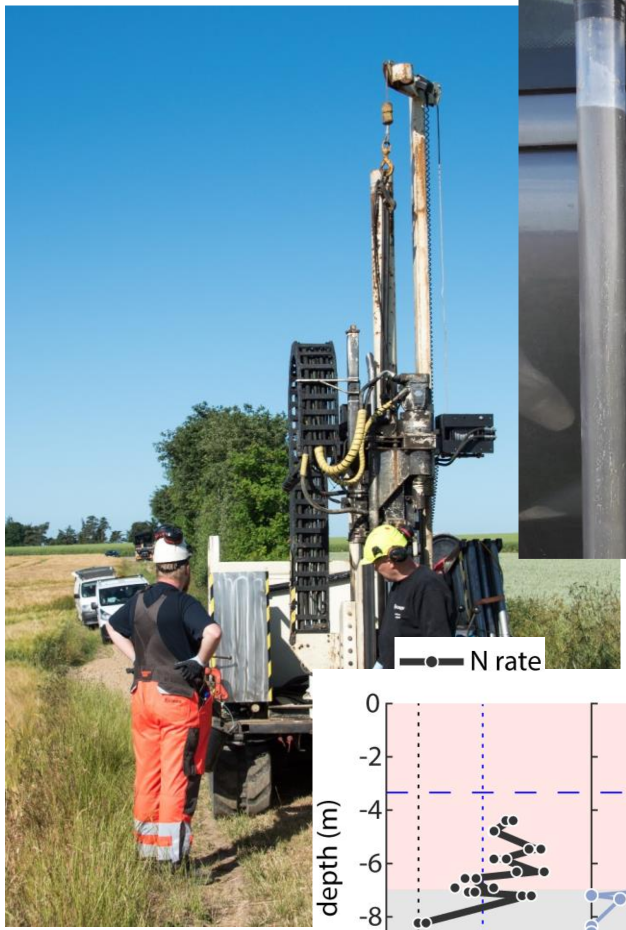

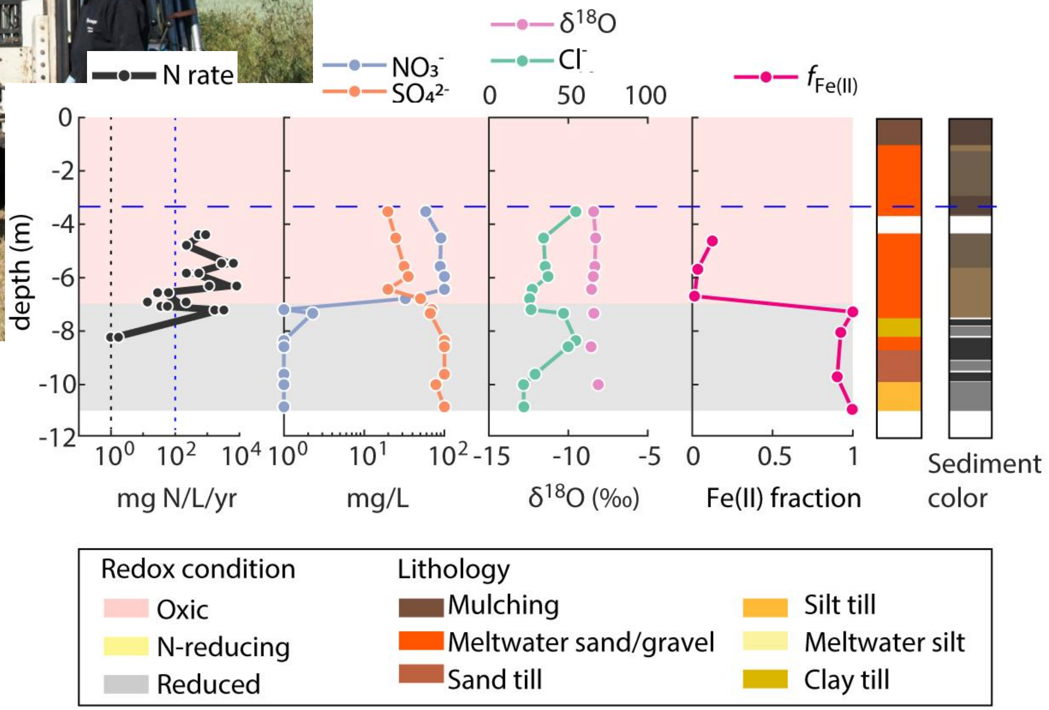

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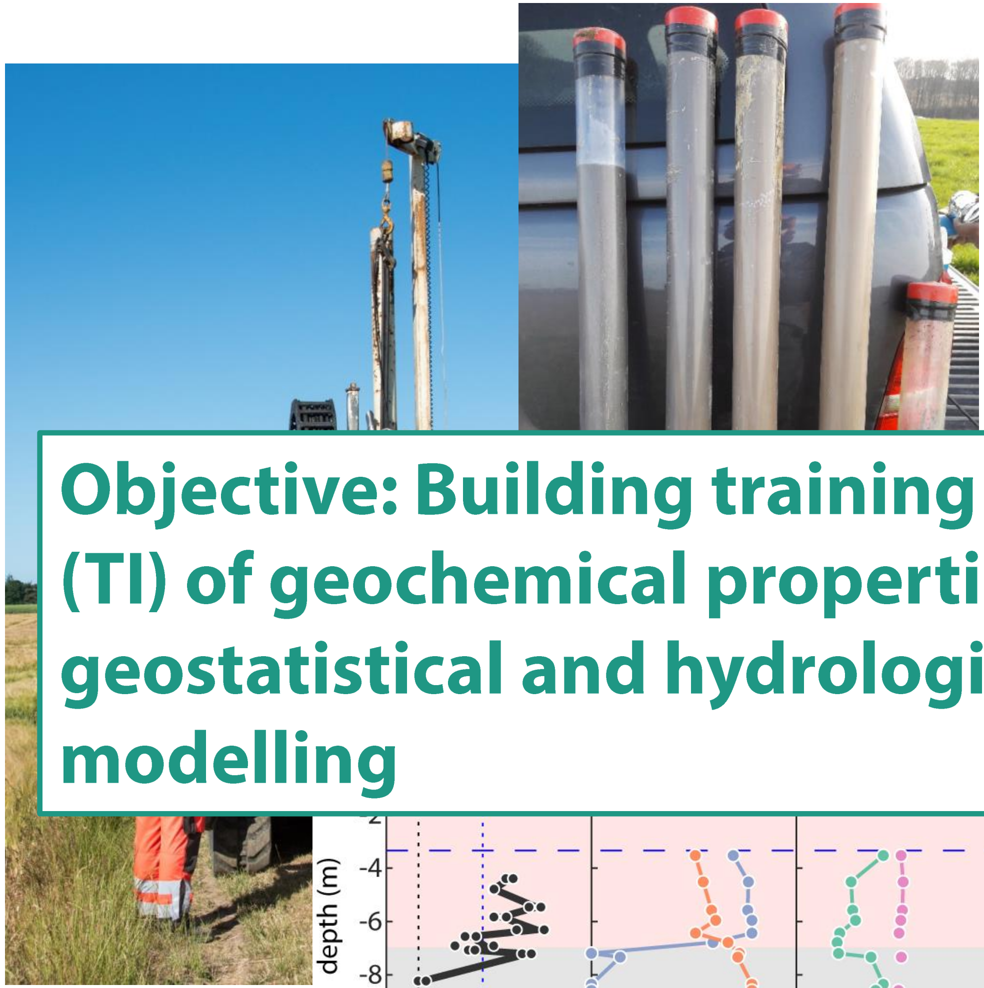
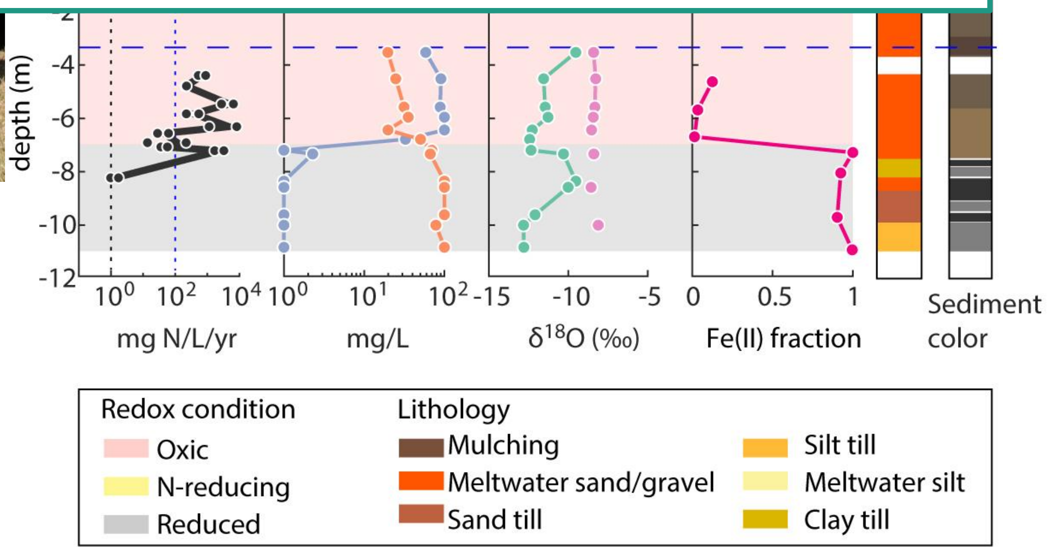


Objective: Building training images (TI) of geochemical properties for geostatistical and hydrological modelling



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Where does denitrification occur in the subsurface at the catchment scale?

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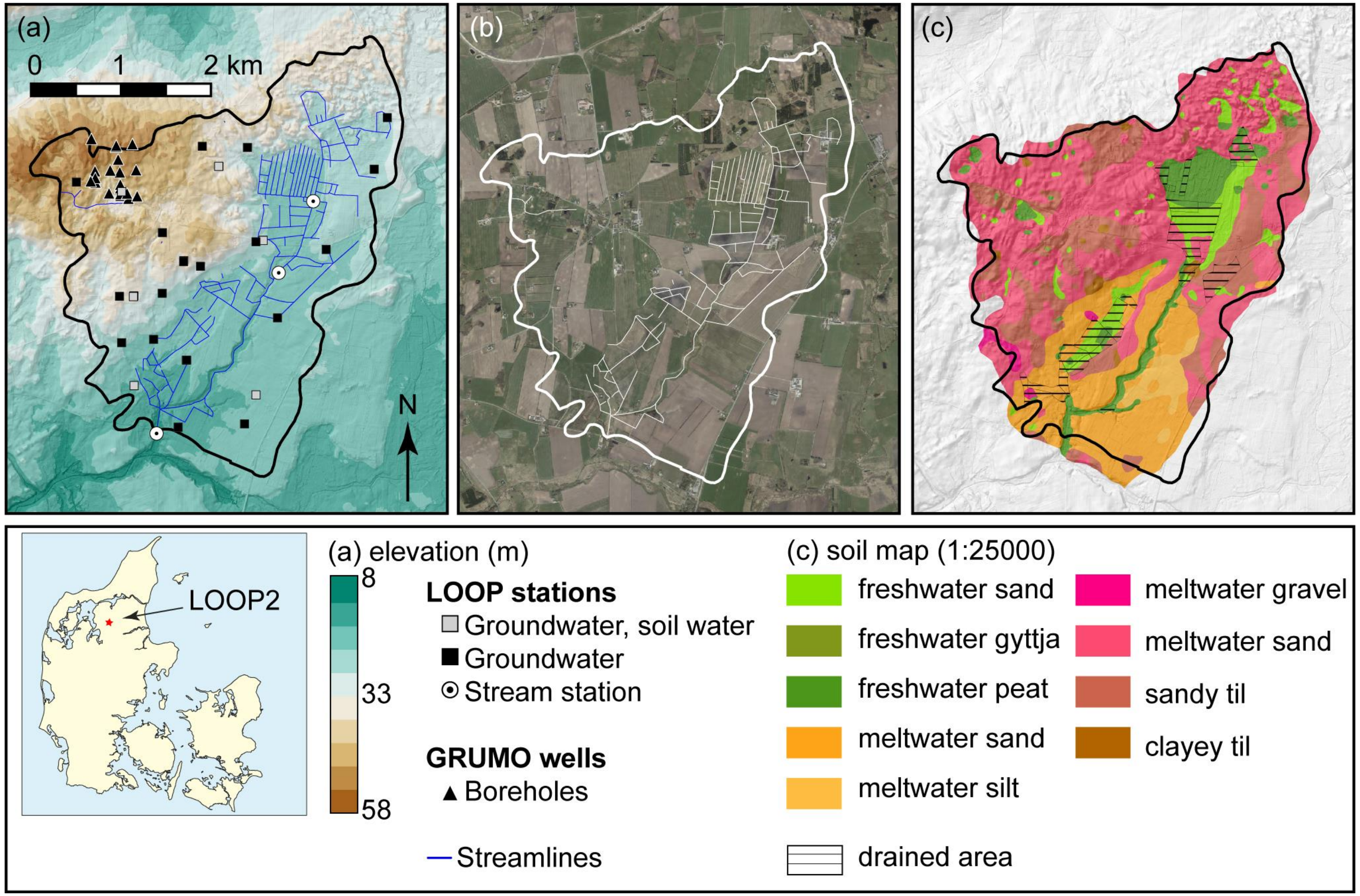
LOOP2 case study site

- Intensively-managed agricultural catchment
- Meltwater sand/gravel dominated surface geology
- Part of the National monitoring program



Kim et al. (2021b)

Where does denitrification occur in the subsurface at the catchment scale?

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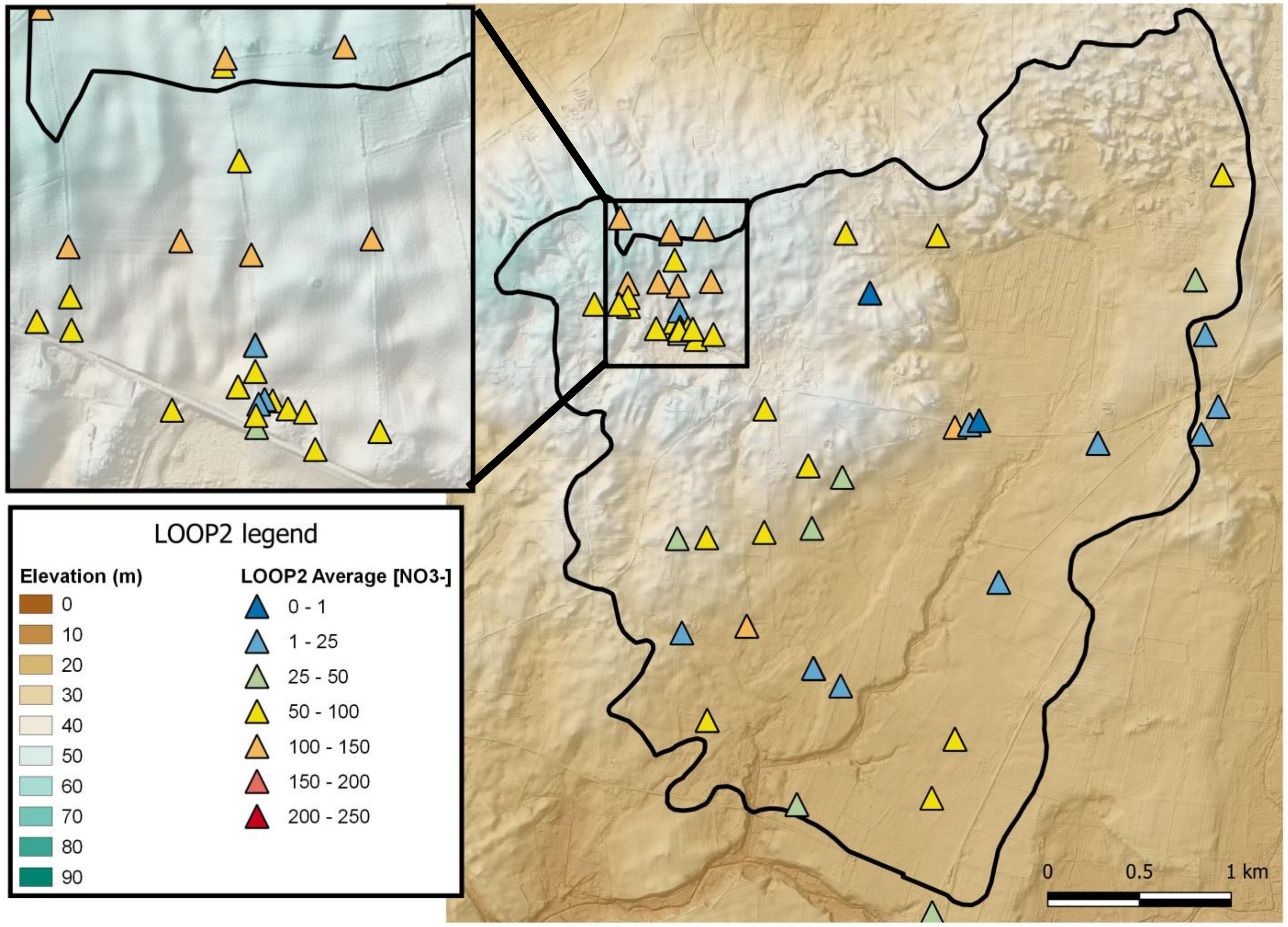
LOOP2 case study site

- Overall, high nitrate in high elevation vs. low nitrate in low elevation

- But still, high nitrate cases in low elevation

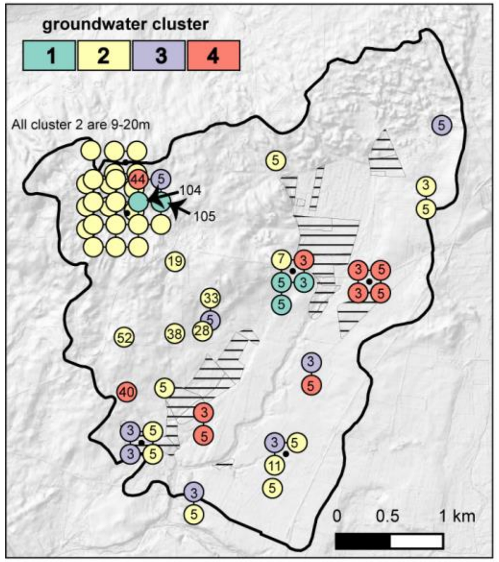


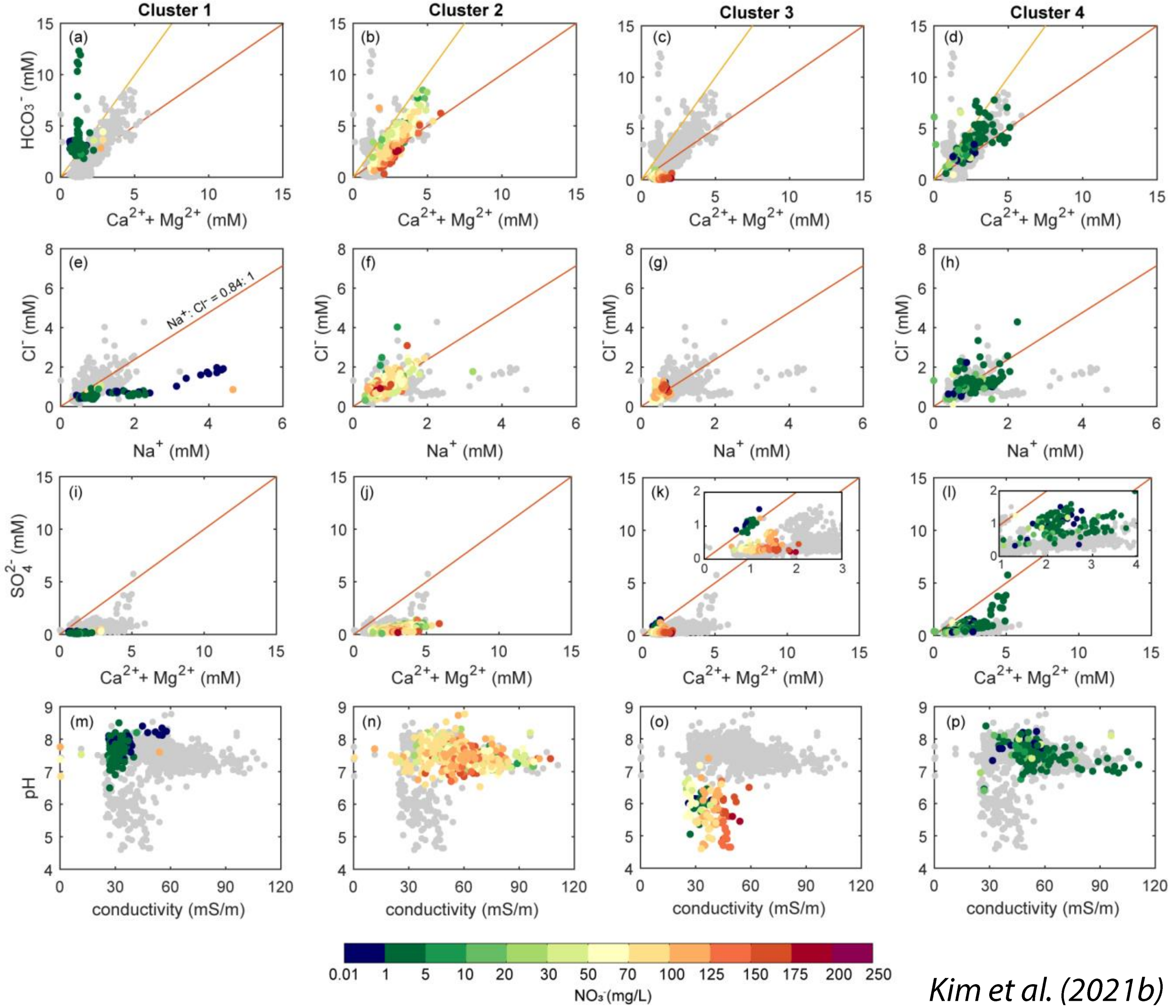
Kim et al. (2021b)

Where does denitrification occur in the subsurface at the catchment scale?

K-means clustering analysis of groundwater chemistry

- Cluster 1
- Cluster 2
- Cluster 3
- Cluster 4





Kim et al. (2021b)

Where does denitrification occur in the subsurface at the catchment scale?

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K-means clustering analysis of groundwater chemistry

- Clu
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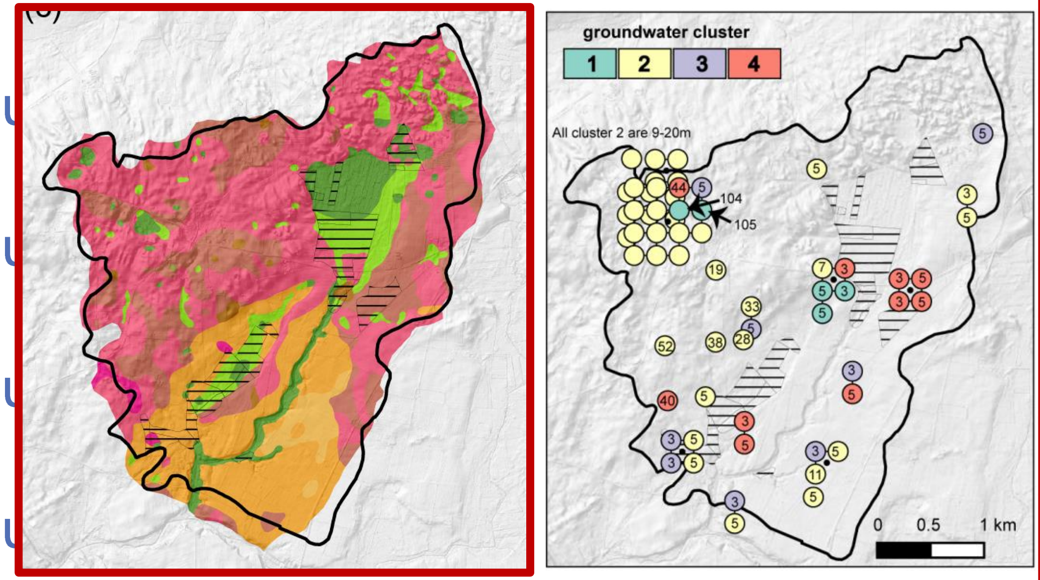
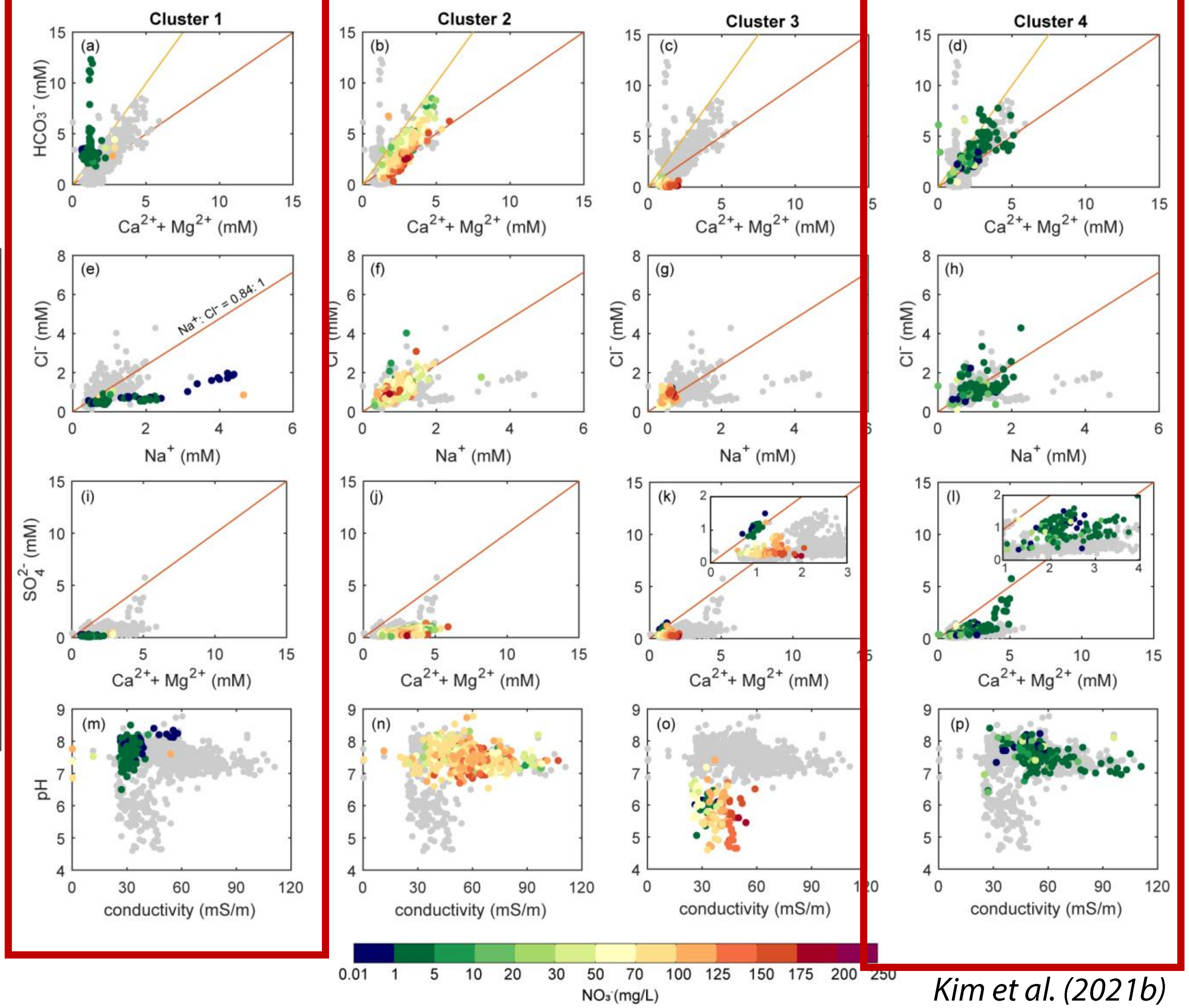


Organic-rich postglacial sediments



Kim et al. (2021b)

Where does denitrification occur in the subsurface at the catchment scale?

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K-means clustering analysis of groundwater chemistry

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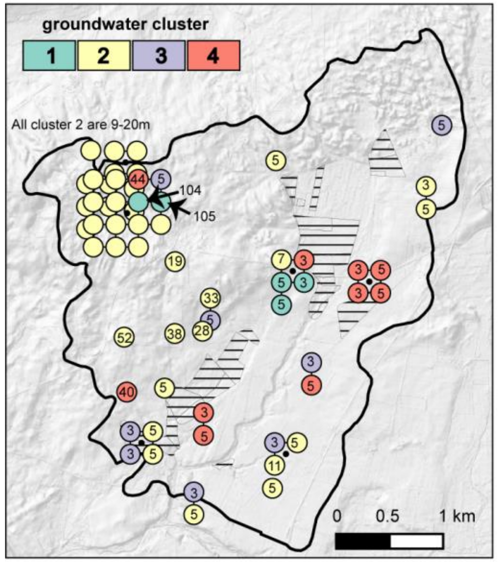
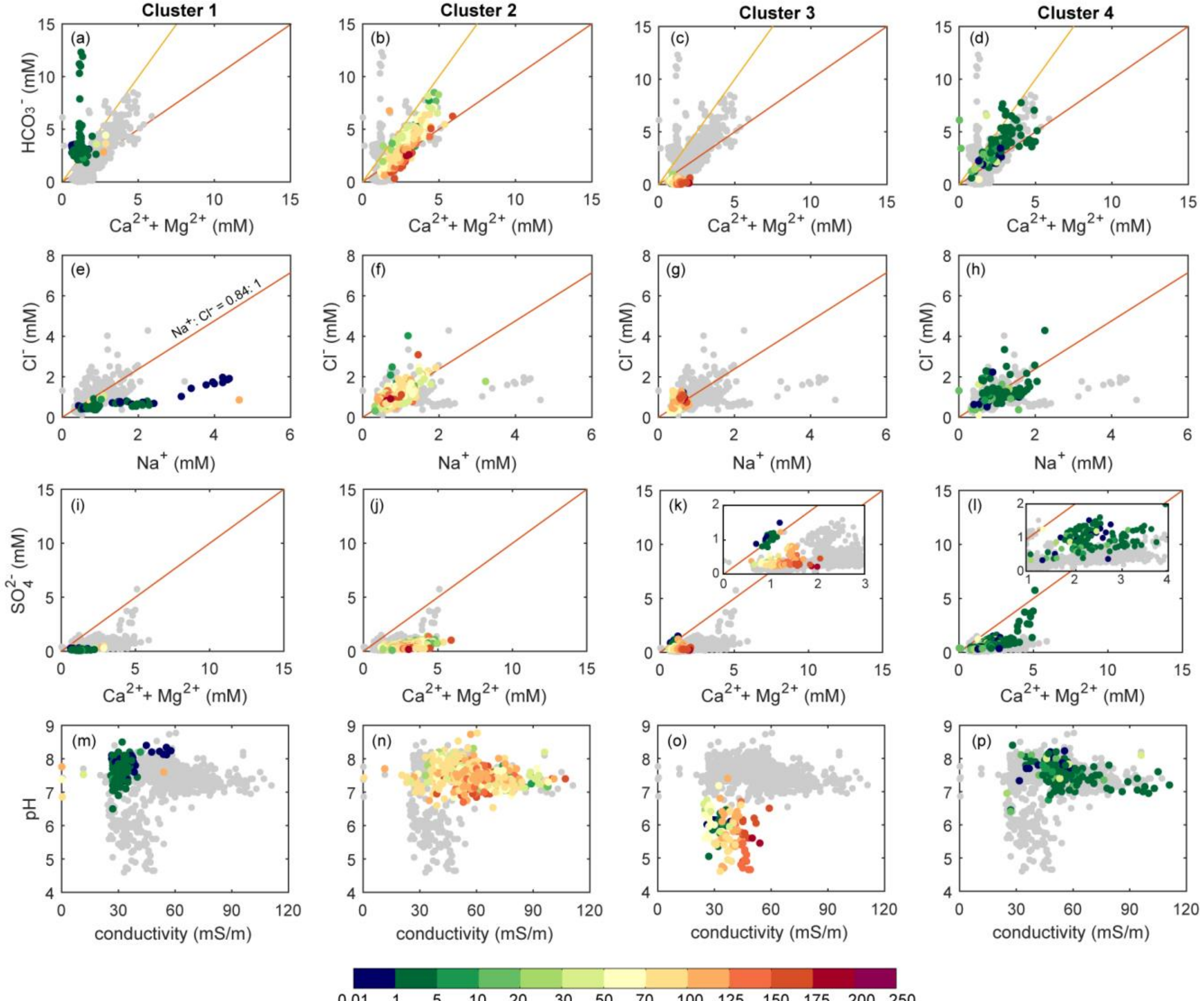


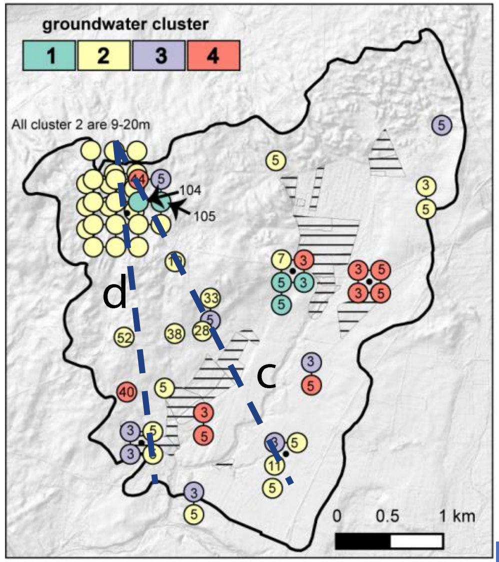


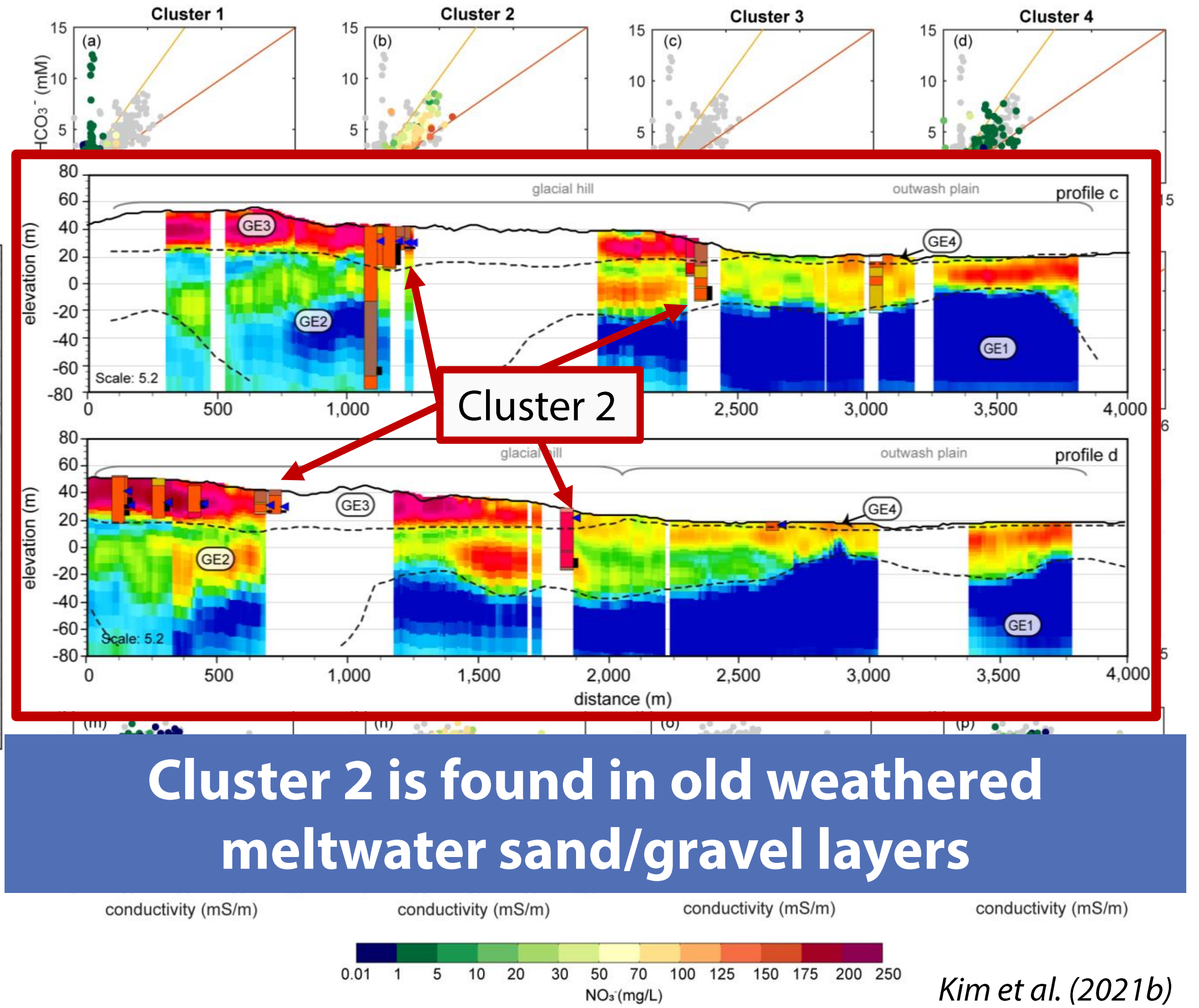
Kim et al. (2021b)

Case I: Where does denitrification occur in the subsurface at the catchment scale?

K-means clustering analysis of groundwater chemistry

- Cluster 1 (reduced)
- Cluster 2 (oxic)
- Cluster 3 (oxic)
- Cluster 4 (reduced)





Cluster 2 is found in old weathered meltwater sand/gravel layers

Kim et al. (2021b)

Case I: Where does denitrification occur in the subsurface at the catchment scale?

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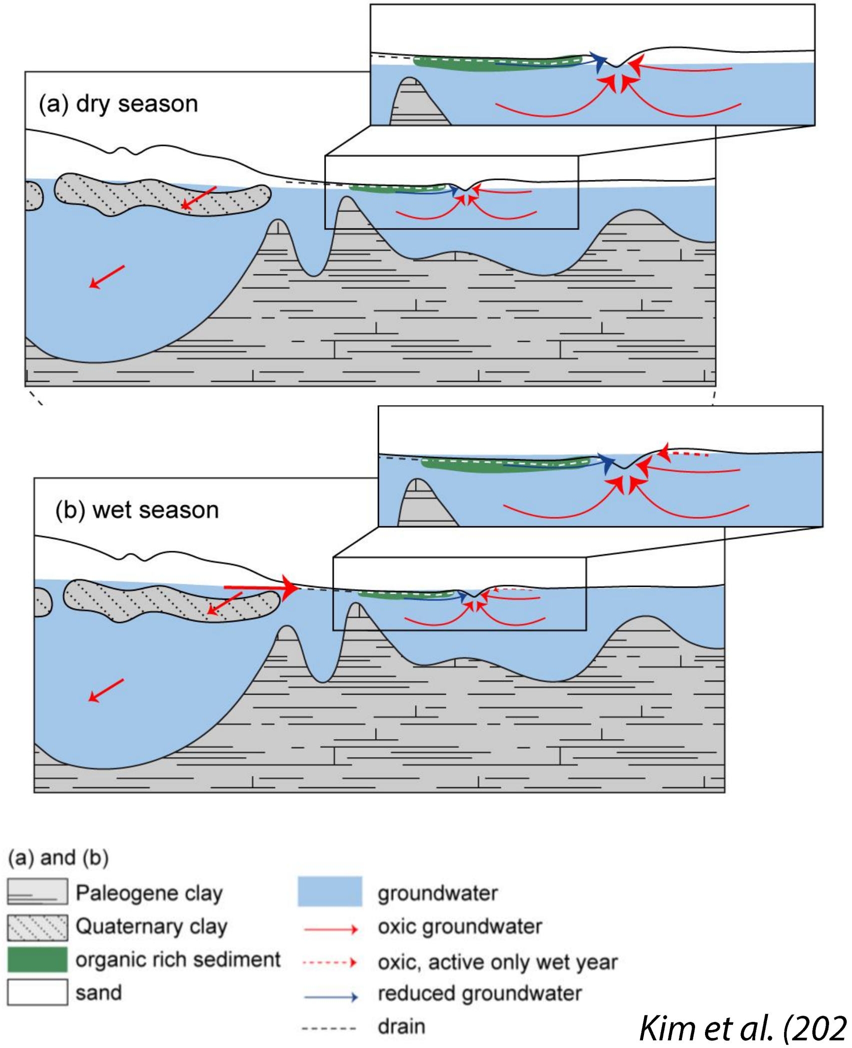
Conceptual model of the distribution of denitrification zone in LOOP2

- Denitrification occurs near the organic-carbon rich postglacial sediments at shallow depth by oxidation of either organic carbon or pyrite.
- Meltwater sand/gravel in LOOP2 is weathered, thus, is depleted with N-reducing material. Thus, denitrification may be extremely slow or does not occur.



Kim et al. (2021b)

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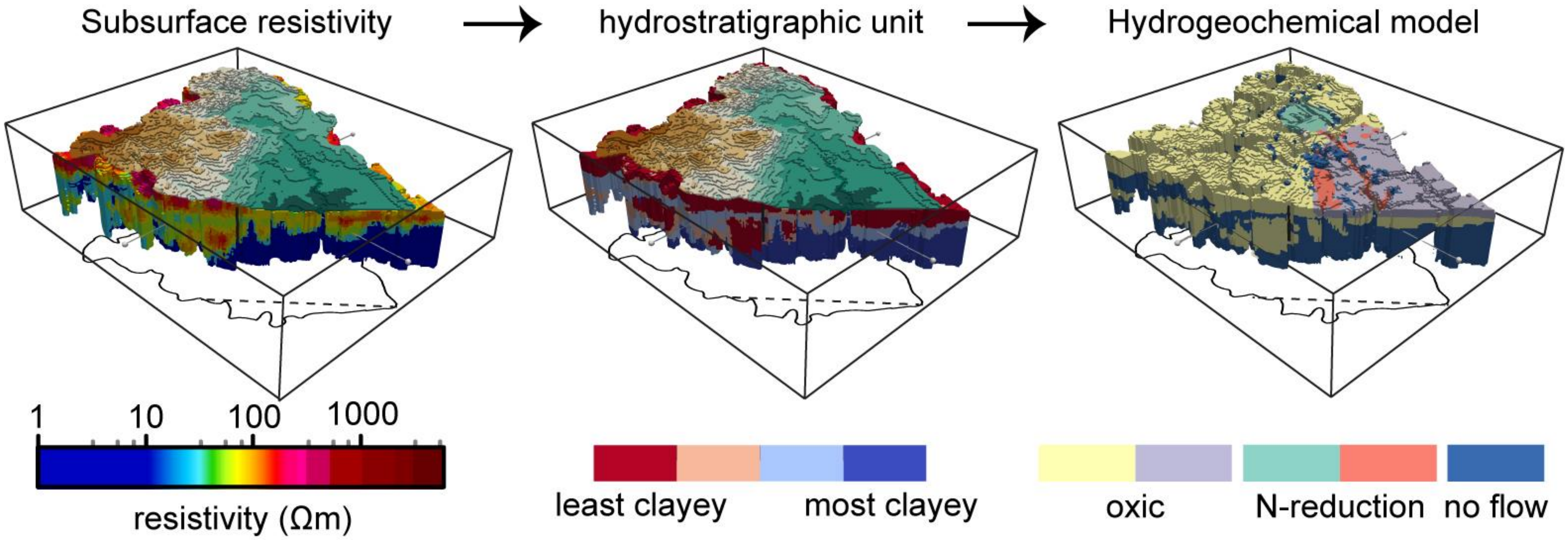

Kim et al. (2021b)

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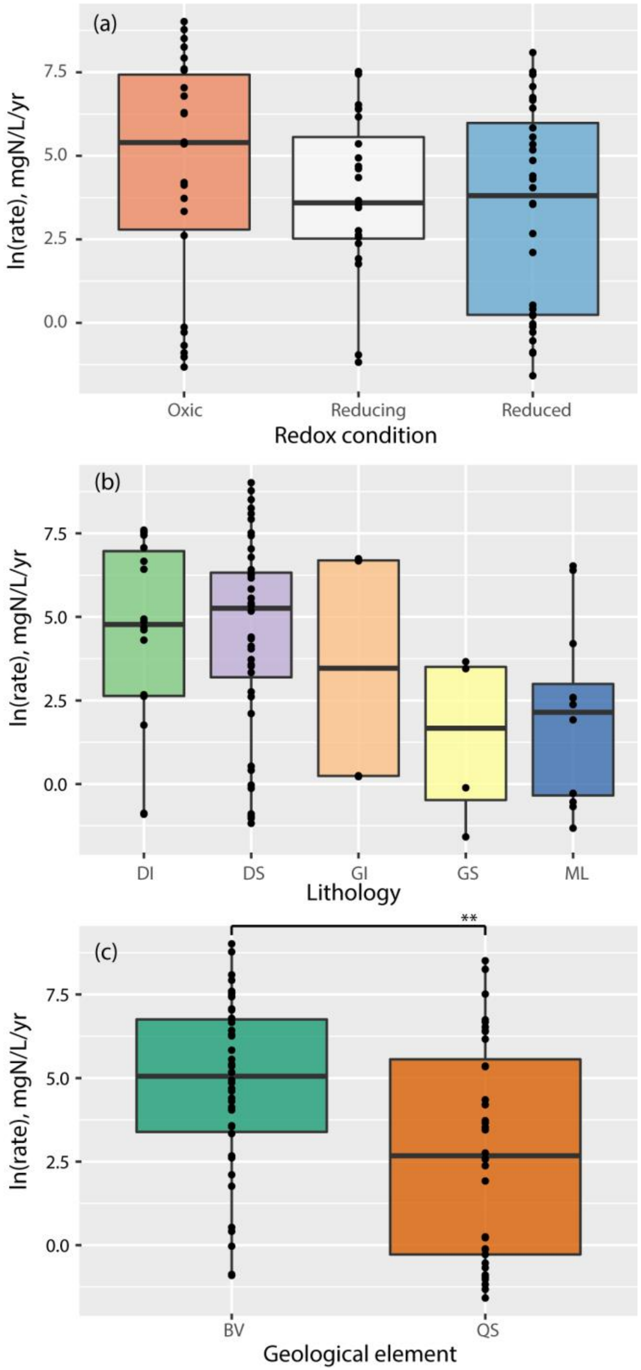
Case study II: Where are the denitrification hotspots?



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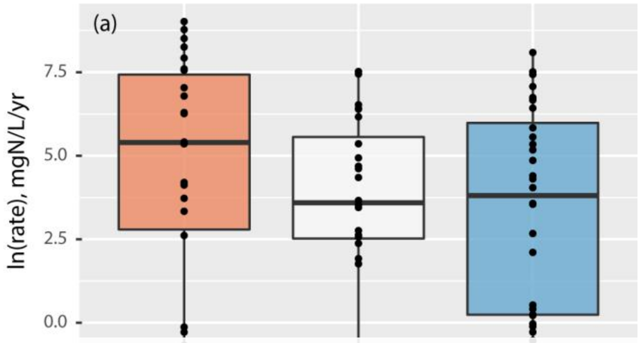
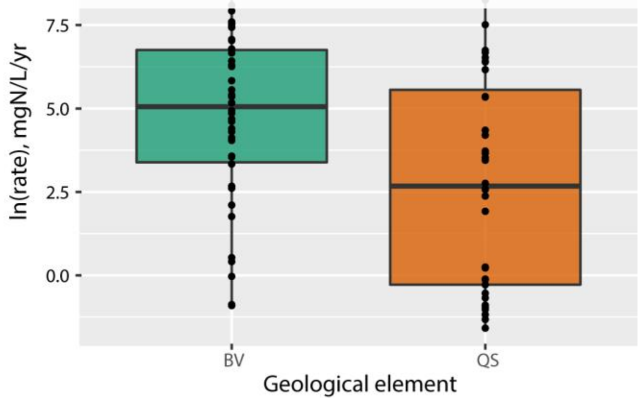
LOOP3



No statistically significant difference among different categories of redox types and lithology.

But the difference is statistically significant between geological elements.



Kim et al. (2021b)

Case study II: Where are the denitrification hotspots?

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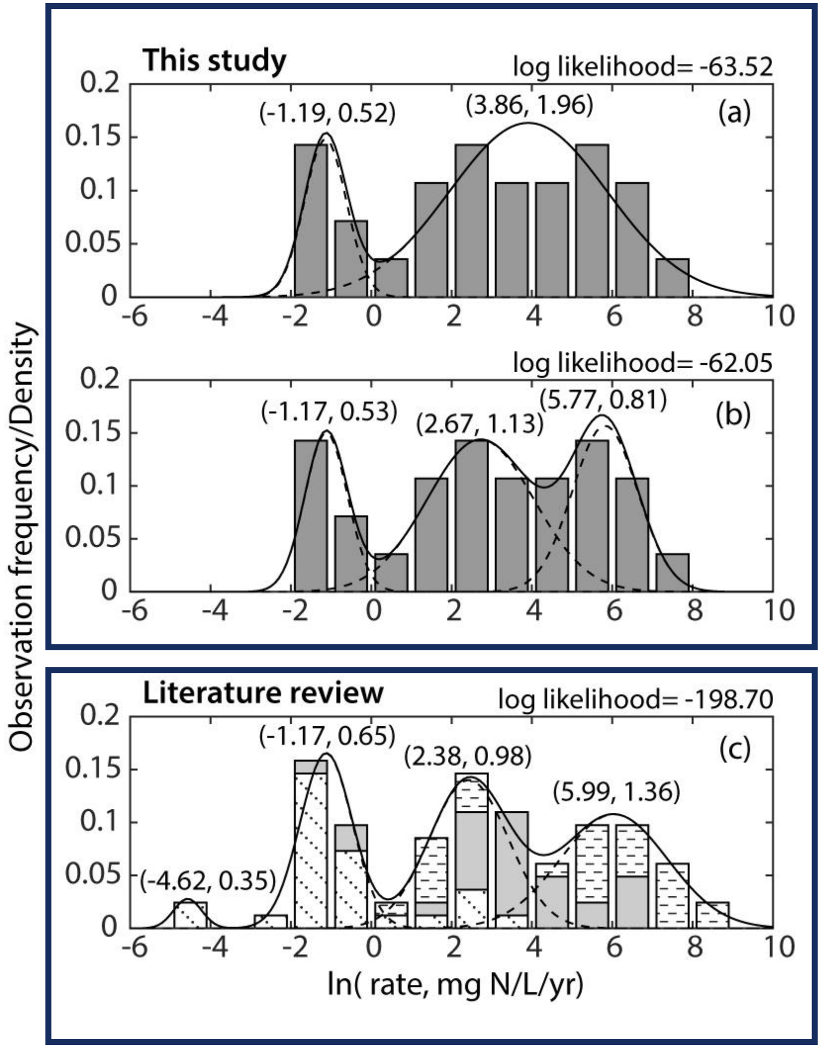
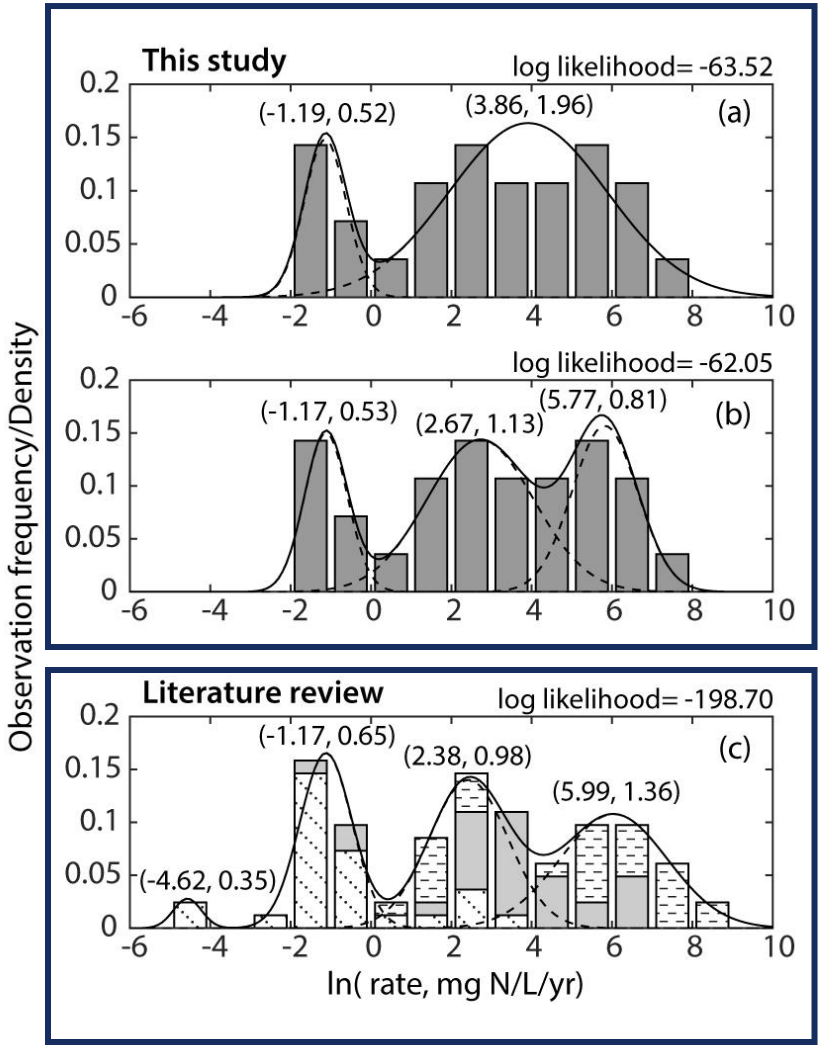


Kim et al. (2021b)

Case study II: Where are the denitrification hotspots?

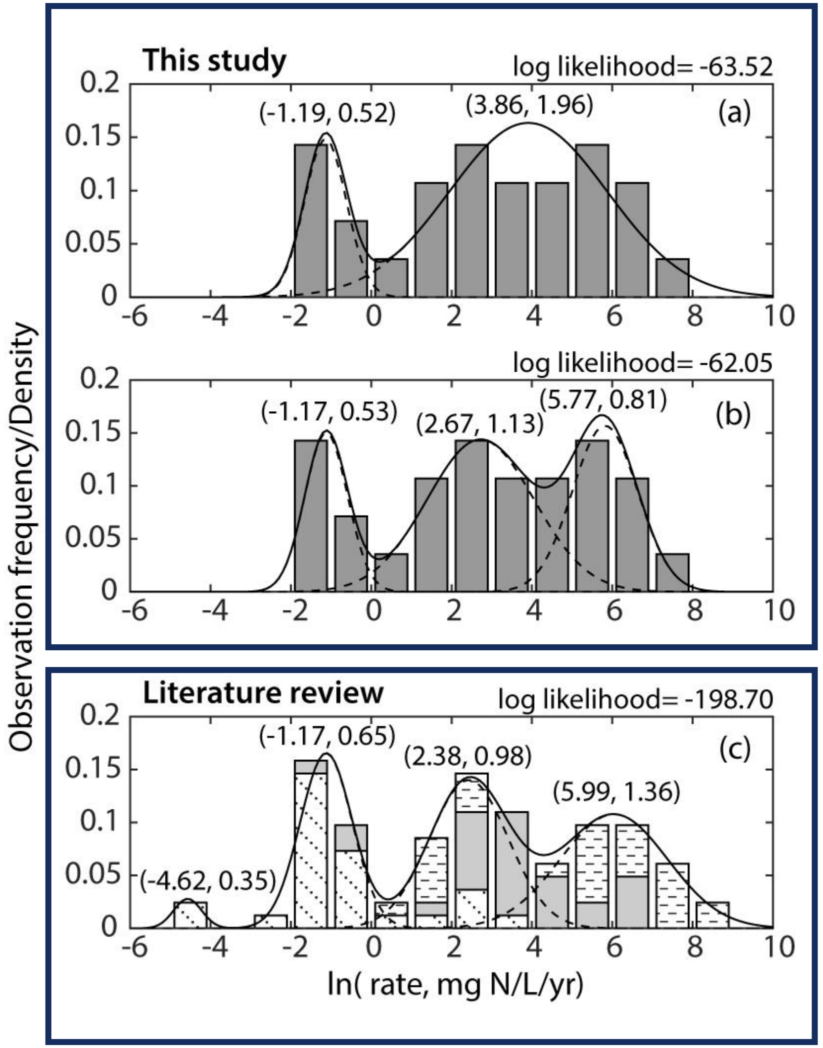
- Multi-modal log-normal distribution
- Literature shows the similar pattern



Kim et al. (2021b)

Case study II: Where are the denitrification hotspots?

- Low-rate zones: Geological window in the recharging areas



Kim et al. (2021b)

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Case study II: Where are the denitrification hotspots?

- Low-rate zones: Geological window in the recharging areas
- High-rate zones: lithologic interface and postglacial sediment in the lowland

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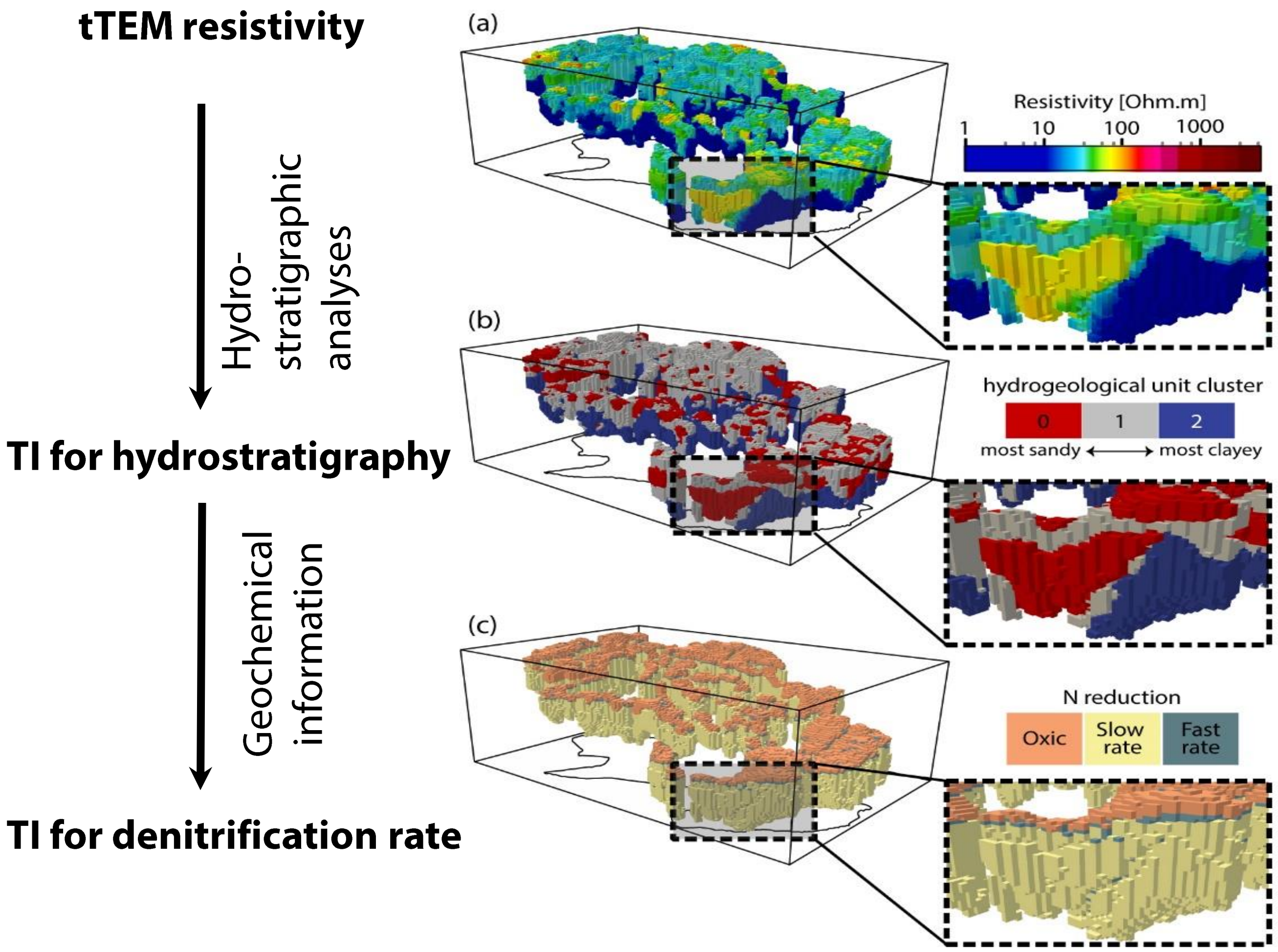

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Training image of denitrification rate as a novel way of deliver the new knowledge of N reduction in the subsurface to modelling framework.

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Summary

- Point-scale geochemical information provides process-based understanding of nitrate transport and fate (where, how, and why).

- Process-based understanding identifies the key controls of the spatial distribution of denitrification zone, and then can be upscaled to the catchment scale by synthesizing geophysical, geological and geochemical information.

- Direct geochemical measurements and process-based understanding of nitrate fate and transport are as important as the high-resolution structure information to obtain the spatial knowledge of denitrification in the subsurface.

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References

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