GEUS

Uncertainty assessment of spatially distributed nitrate reduction in groundwater using multiple geological realizations

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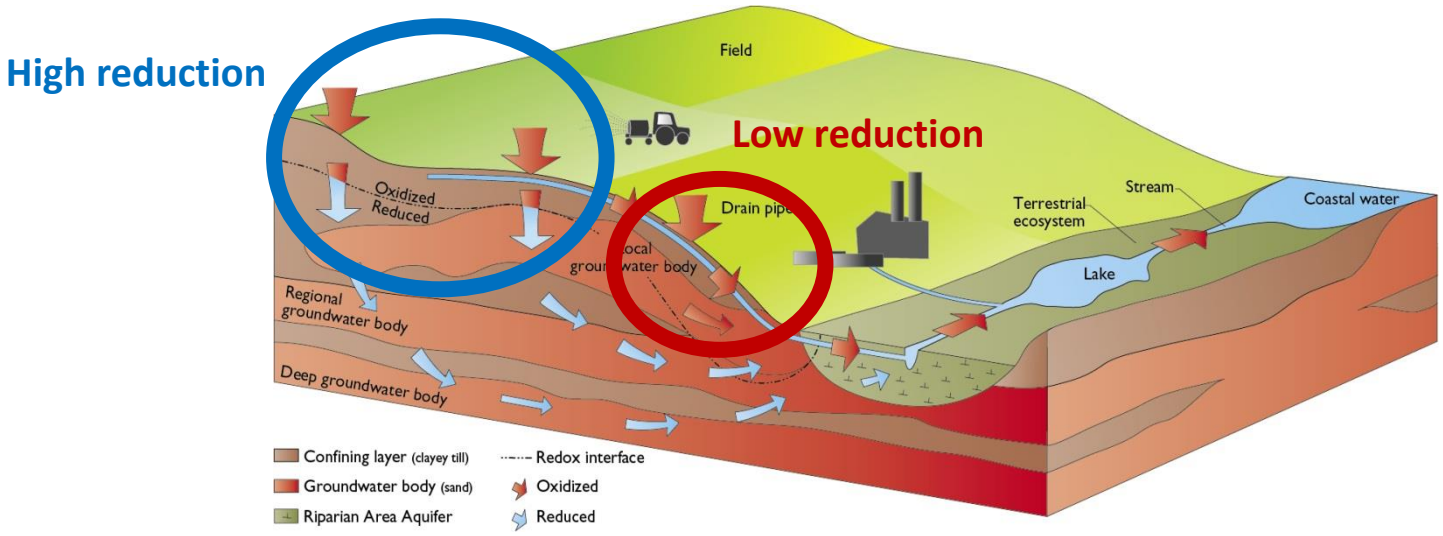
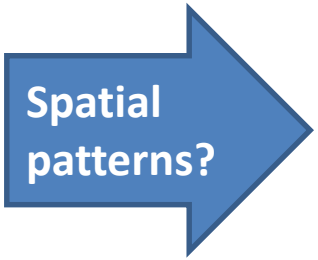
Spatially differentiated regulation

- In many **Danish catchments** more than **50%** of **nitrate leaching** is **reduced** in the **saturated zone**
- **Heterogeneity** in subsurface conditions ➡ **spatial variation** in amount of **nitrate reduction** within a catchment
- A **spatially differentiated regulation** with **focus** on lowering nitrate leaching on **areas with low reduction** would be more efficient



Estimating spatially distributed nitrate reduction in groundwater

- **Tool:** Distributed hydrological model
- **Challenge:**
  - Data quantity
  - Data quality



Large uncertainty on model results on **grid scale!**

- **Key question:** At what scale can the model results be used?

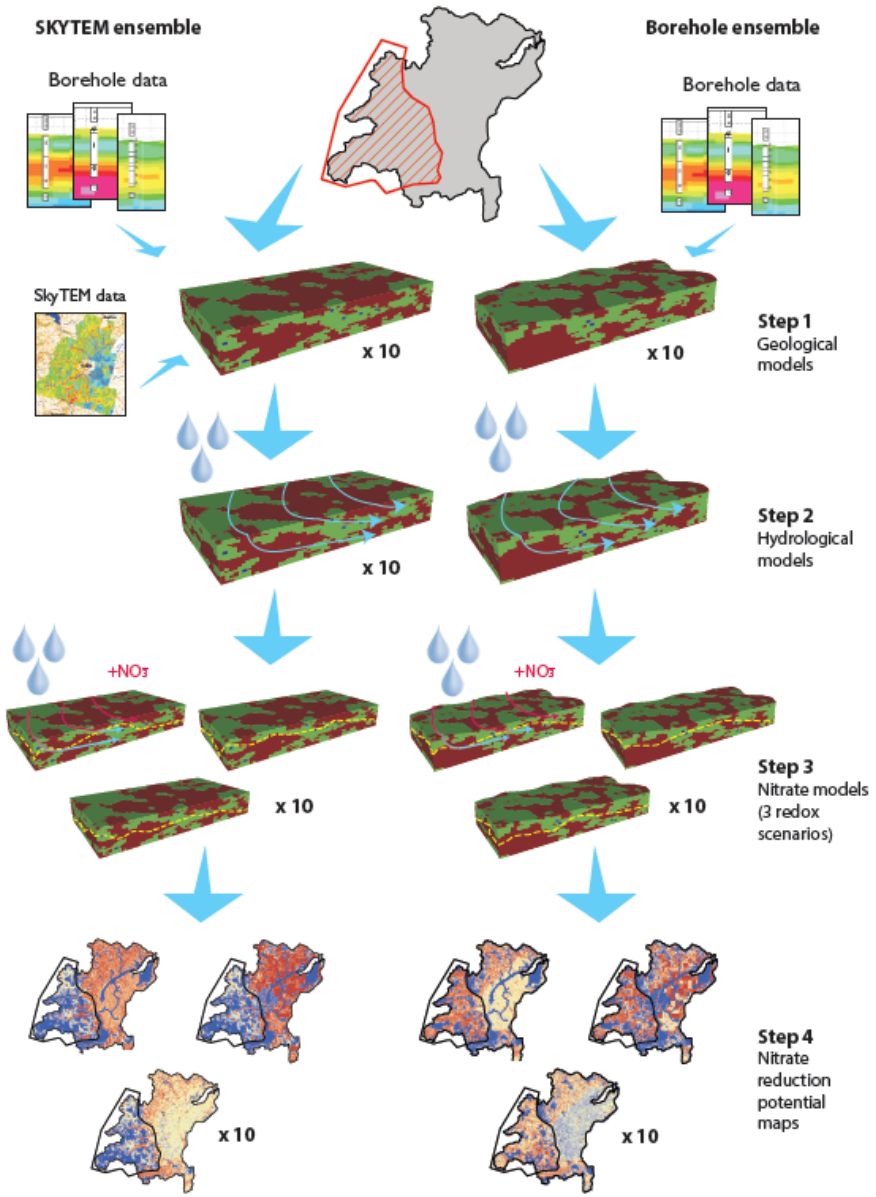
Objectives

- Estimate the **uncertainty** on spatially distributed **nitrate reduction** due to **geological uncertainty**
- Analyze how the **uncertainty** on nitrate reduction **changes with scale**
- Evaluate on the **predictive scale (RES) of the model**
  - **Representative Elementary Scale (RES):**

    *"The RES is the **minimum scale** at which a model, at best, has **predictive capability** corresponding to a **given accuracy**"*
    (Refsgaard et al., 2014)

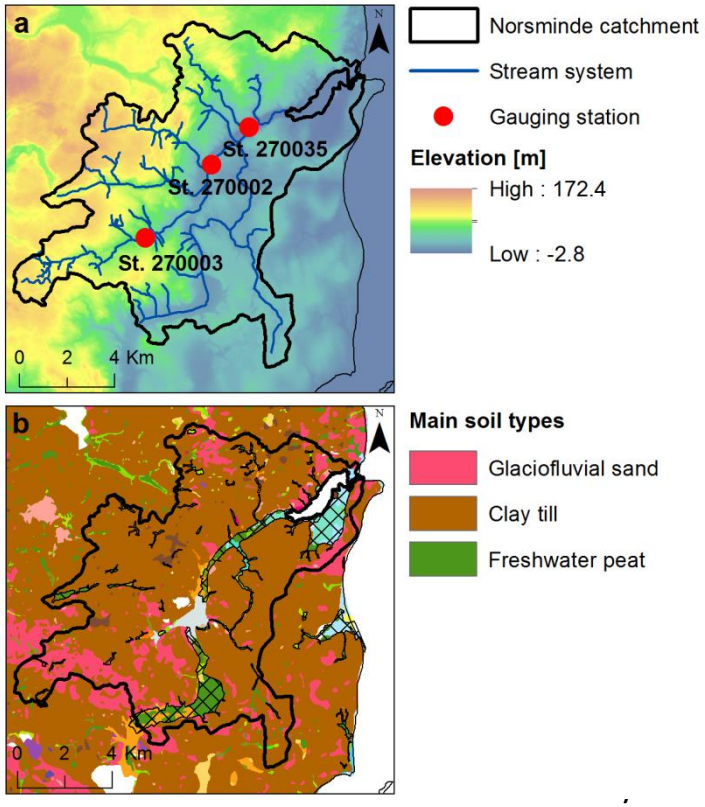
Methodology

1. **Geological models** (2x10)
2. **Hydrological models** (2x10)
3. **Nitrate models** (3x2x10)
4. **Nitrate reduction maps** (60)
5. **Uncertainty and scale analysis**



Norsminde fjord catchment

- **Catchment area:** 101 km^2
- **Soil type:** Clay till
- **Land use:** 70% agriculture

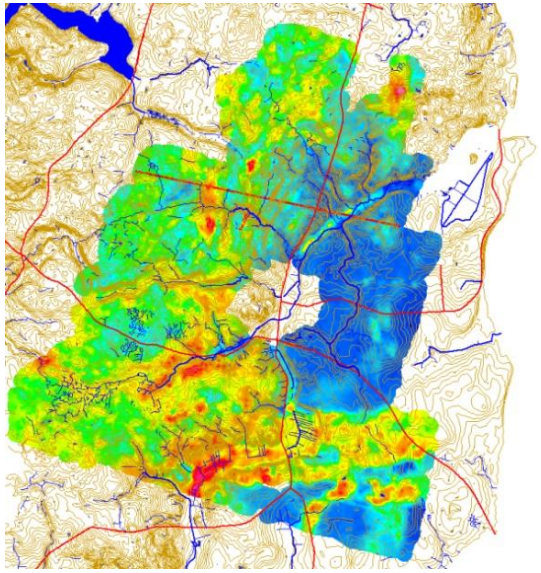


Geophysical mapping in Norsminde

- **Mini-SkyTEM** (SkyTEM101)
  - Airborne TEM
  - High near-surface resolution
- Nearly 2000 line kilometers
- Distance between lines: 50 – 100 m

SkyTEM survey

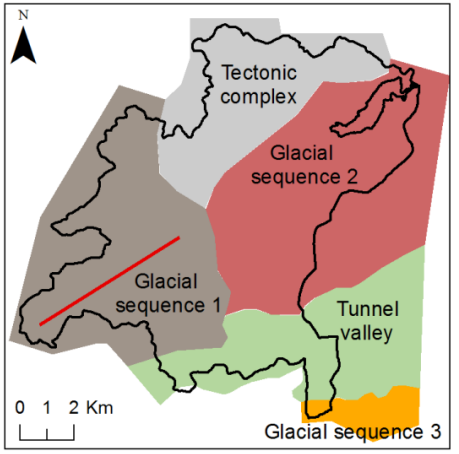
Resistivity data from SkyTEM



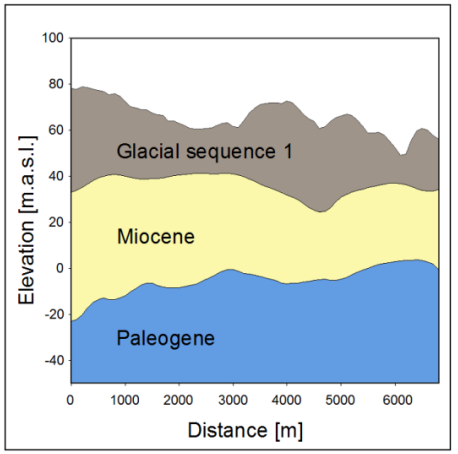
Geological models

- Delineation of **7 large scale geological structures**
- **Stochastic simulations** for **glacial sequence 1**
  - Geology: Clayey till with sand lenses
  - Software: TProGS
  - Borehole data (10 realizations)
  - Borehole data + SkyTEM data (10 realizations)
- **Deterministic geology** for the other **geological structures** based on **SkyTEM data**

Horizontal view

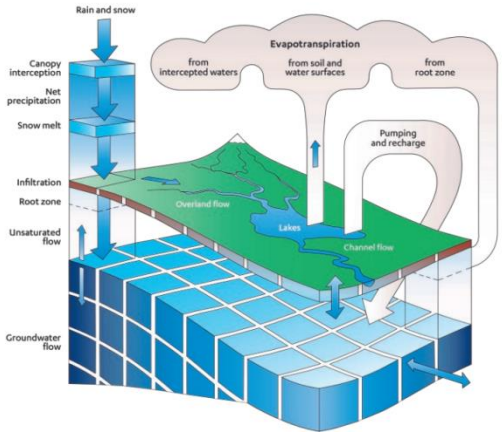


Vertical view

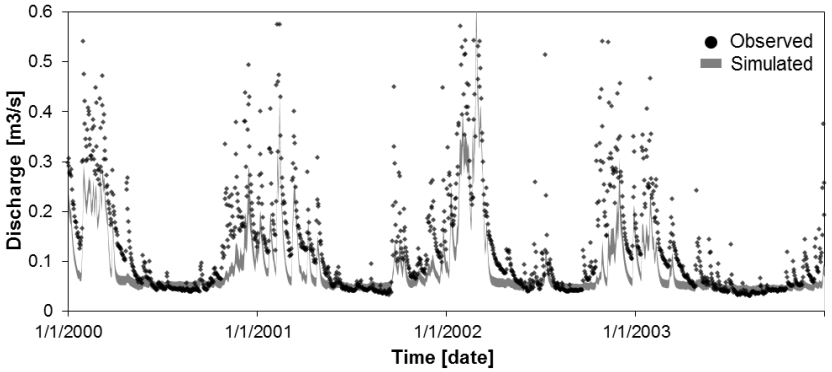


Hydrological models

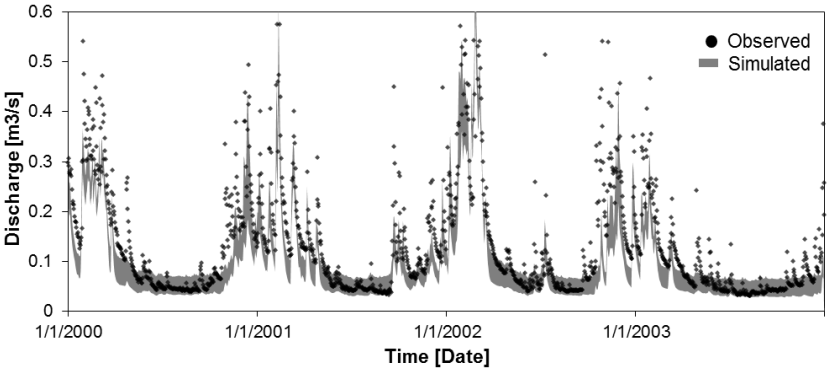
- **Model framework:** MIKE SHE
- **Grid scale:** 100x100 m
- All hydrological processes included
- **Constant parameters** within geological units
- All 2x10 model individually **calibrated** using **PEST**



SkyTEM geology

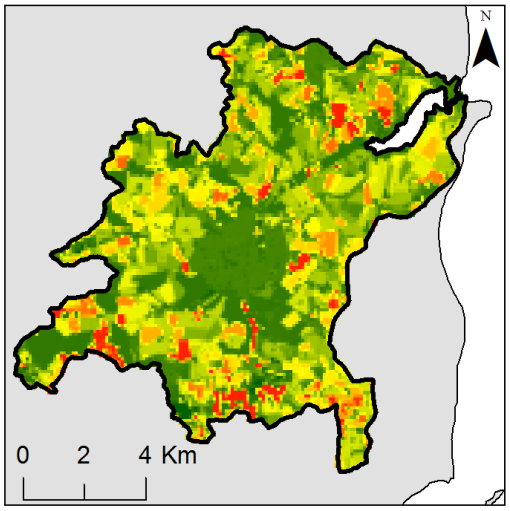


Borehole geology



Nitrate models

- **Model framework:** MIKE SHE - Particle tracking
- **Simulation period:** 2000-2003 with N-input, additional 4 years without N-input
- **Nitrate input:** Daily N-leaching from root zone
- **Nitrate reduction:** Instantaneous reduction at redox interface
- **Redox interface**:
  - 3 scenarios for spatial pattern
  - Actual location calibrated
- **Calibration target**
  - Nitrate arrival % (NAP) = $\frac{\text{N transport to fjord}}{\text{Total N leaching}}$ = 45%

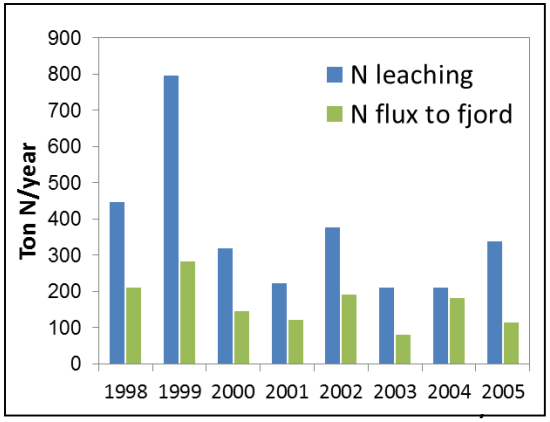


Avg. N leaching 2000-2003

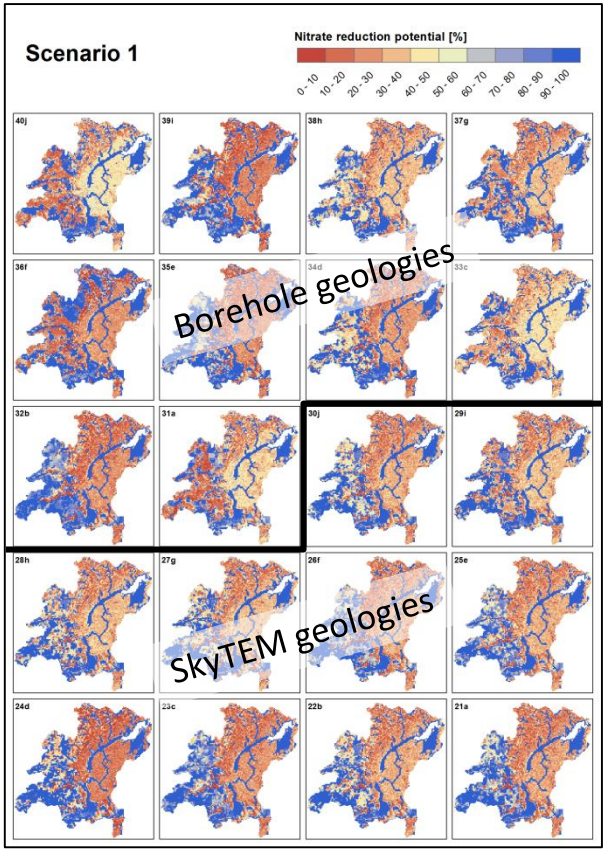
High: 180 kg/ha/yr

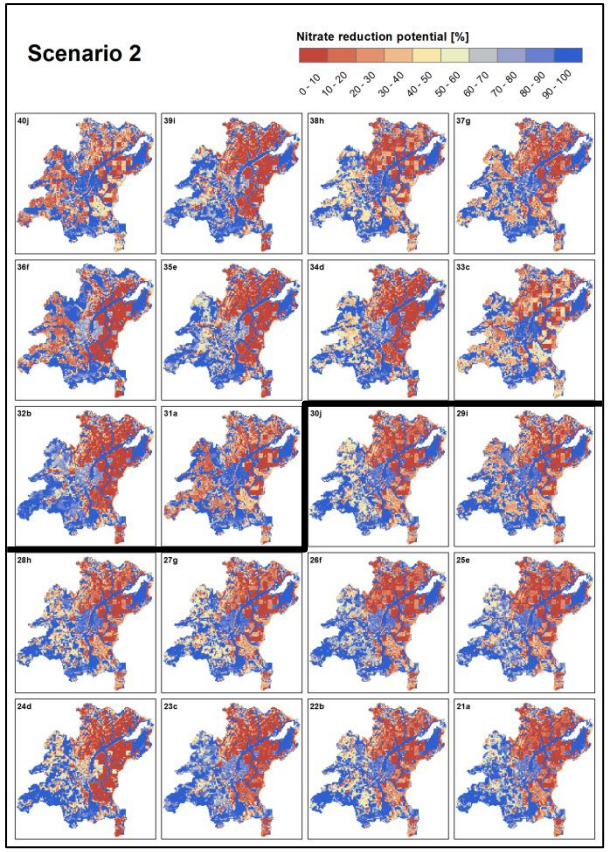
Low: 2 kg/ha/yr

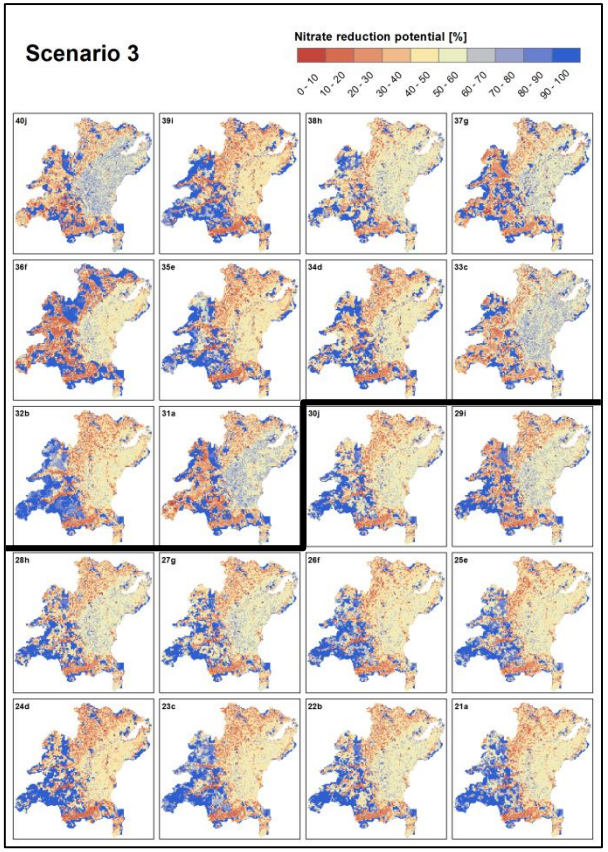
Mean: 25 kg/ha/yr



Nitrate reduction maps



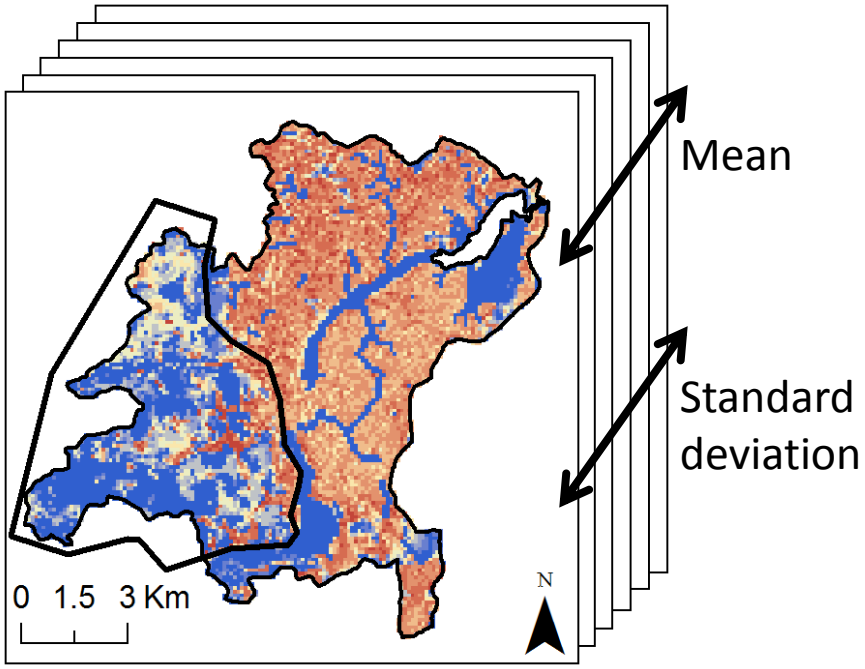




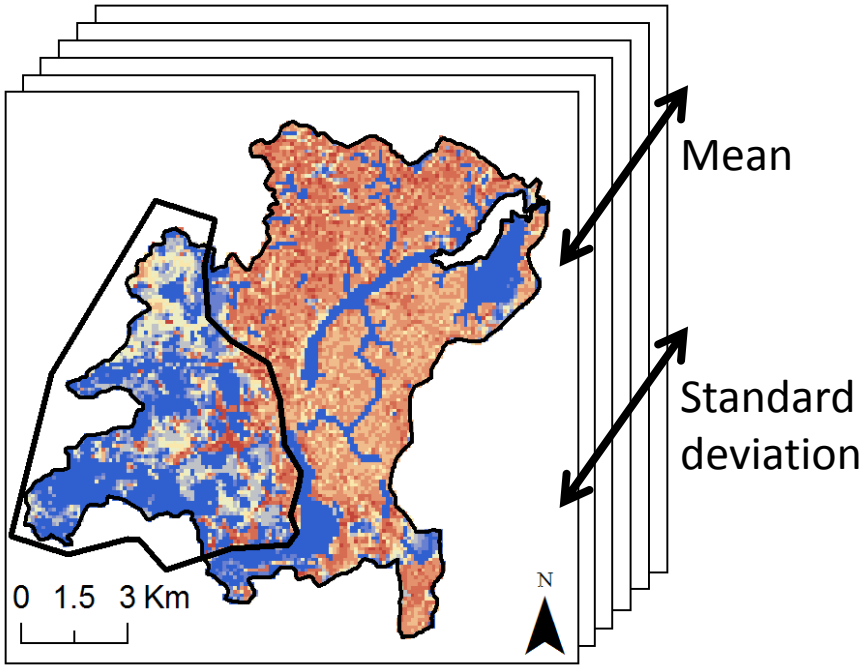
All **60 nitrate models** can be **calibrated** to a **NAP = 45%**, but result in rather **different nitrate reduction maps**

Mean nitrate reduction and standard deviation

Borehole geology (30 maps)

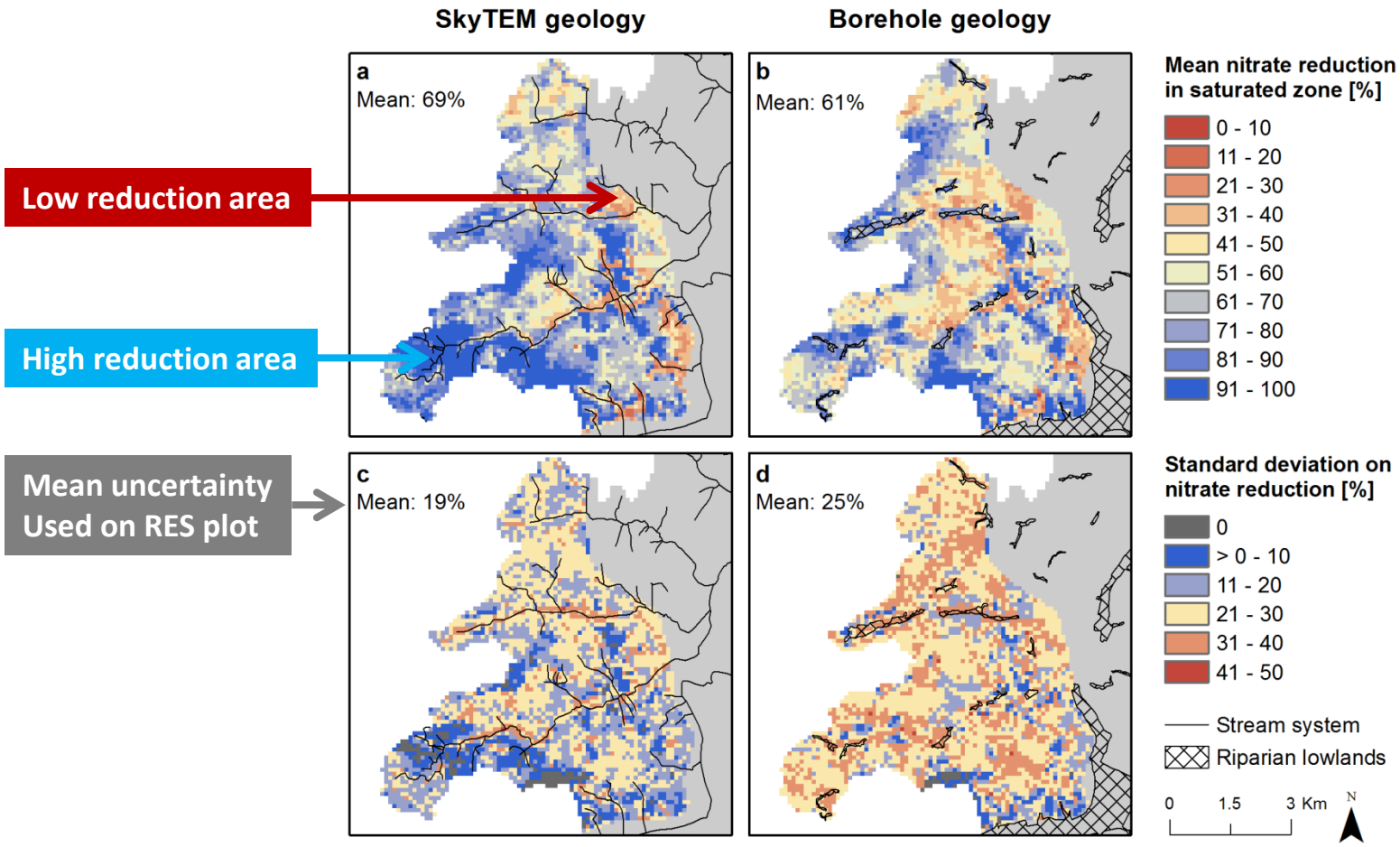


SkyTEM geology (30 maps)

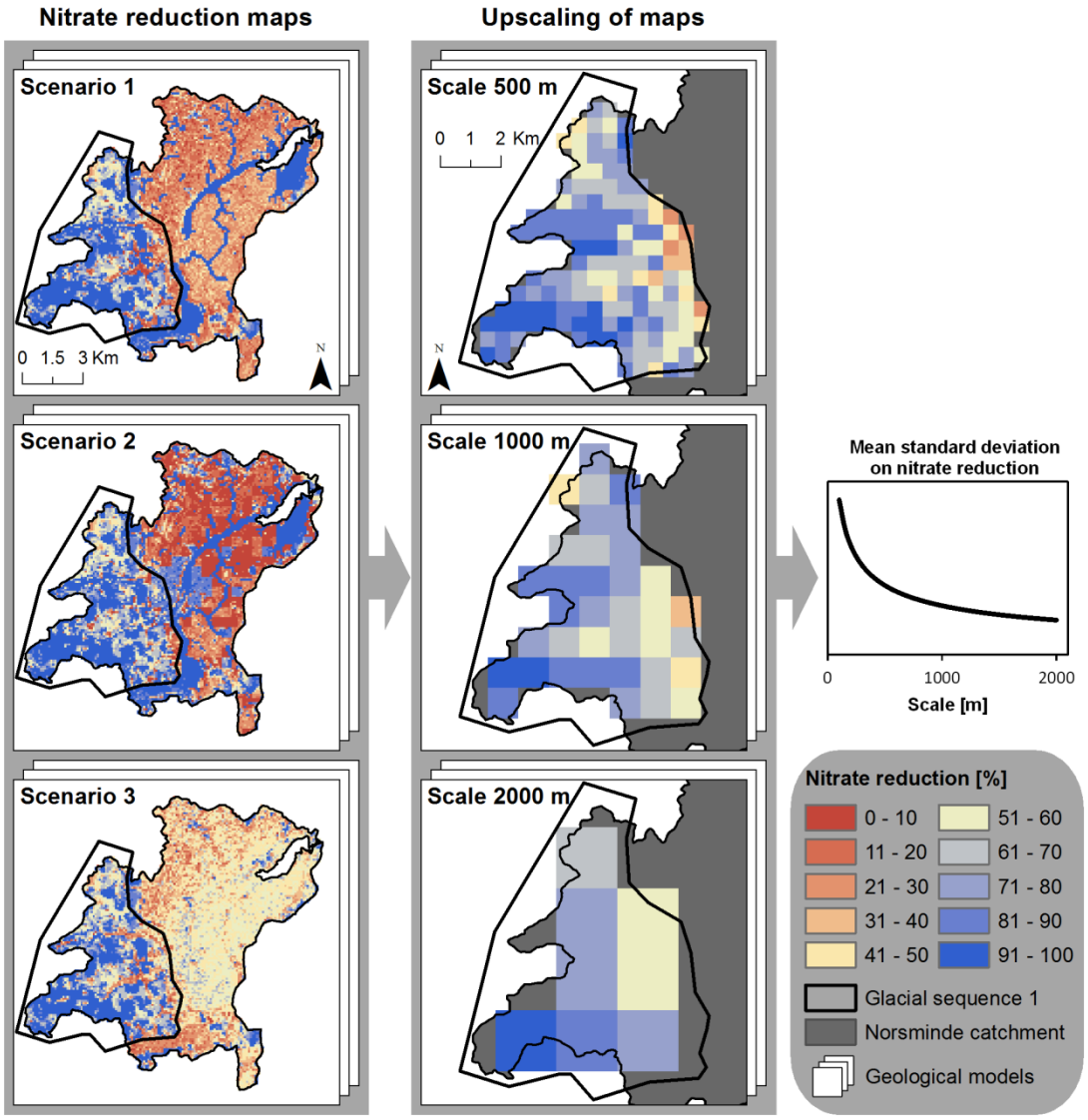


Mean and standard deviation calculated across the maps for each grid cell

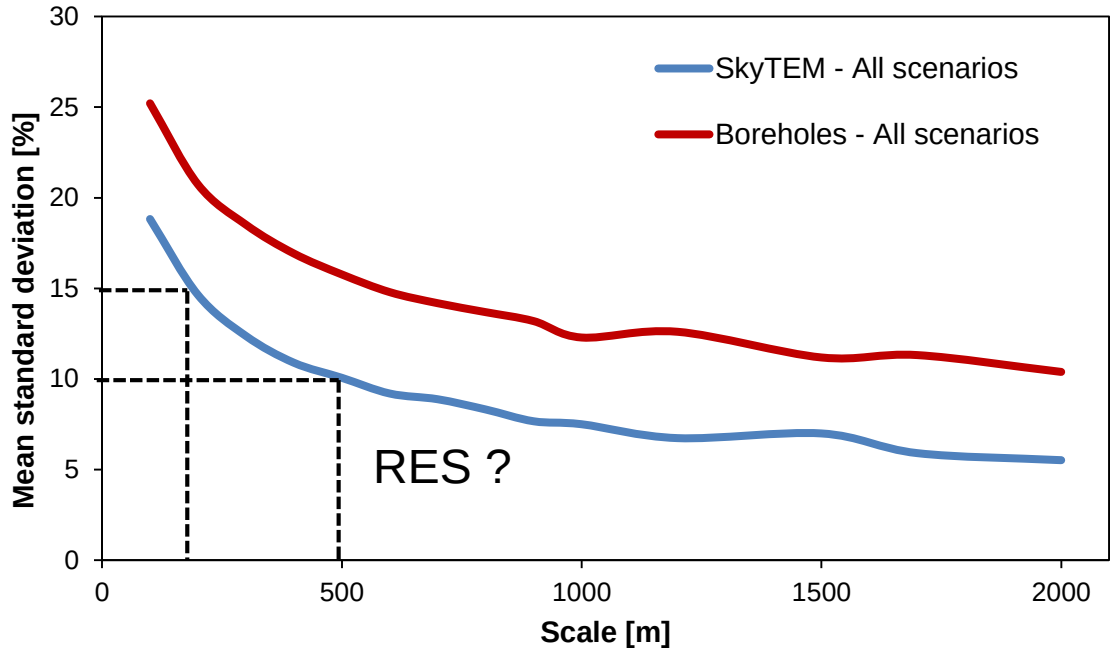
Mean nitrate reduction and standard deviation



Upscaling of nitrate reduction maps



Uncertainty on nitrate reduction as a function of scale



- The **uncertainty decreases** with **increasing scale**
- **Uncertainty lower** for **SkyTEM geologies**
- **Decrease largest 0-500 m** ➔ Mean length of sand units is 500 m
- **RES** is dependent on the **acceptable level** of **uncertainty**

Discussion and conclusions

- **Areas of high and low reduction** can be **predicted** with **distributed hydrological models**
- **Large uncertainty** on **predicted nitrate reduction** at **grid scale**
- **Uncertainty decreases** with **increasing scale**, but the decrease **levels out** with scale
- Using **geophyscial data** in combination with **borehole data** for setting up geological models **lower** the **uncertainty**
- Only **geological uncertainty considered** in study
- **Results** are **conditioned** on the **data** and **models** used → we **ignore bias** on **models** and **data** → **uncertainties underestimated**

Discussion and conclusions

- Important to **evaluate** at what **scale (RES)** the **results can be used**
- **Predictive capability (RES)** of distributed models **constrained** by **spatial resolution** of key input data such as **geology**
- **RES** is **not** a **constant** value but depends on:
  - Chosen level of certainty
  - Characteristics of the area
  - Simulated variable

NiCA Research project
NITRATE REDUCTION IN GEOLOGICALLY HETEROGENEOUS CATCHMENTS

The Danish Council for Strategic Research

Thank you for your attention