Analysing drain flow modelling

How can representation of nitrate drainage transport be improved in catchment scale models?

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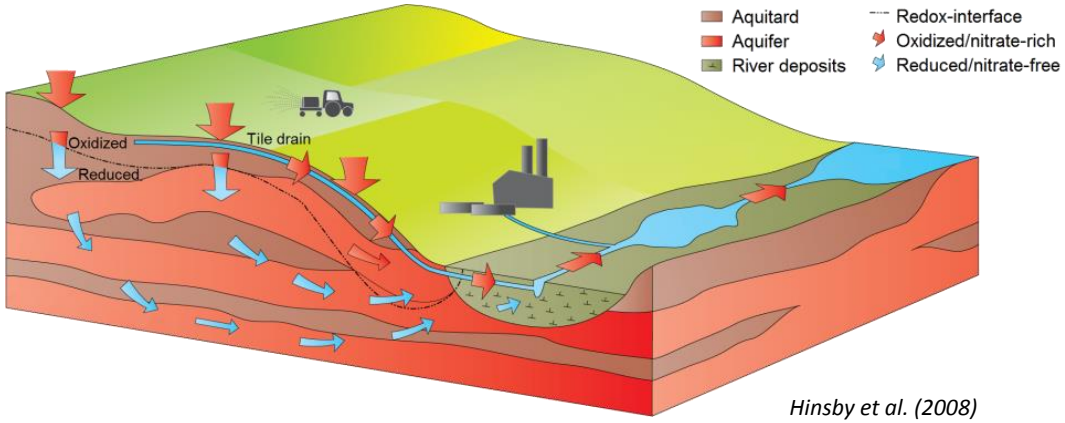
TReNDS

Transport and Reduction of Nitrate in Danish Landscapes at various Scales

Background: Nitrate leaching in Denmark

- Nitrate is an important part of optimization of crop yield
- It is applied as manure or artificial fertilizer
- More than 50% of nitrate leaching in Danish catchments are removed by degradation in the saturated zone

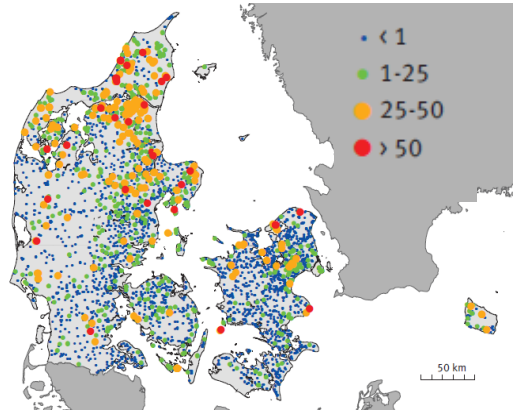


Hinsby et al. (2008)

Environmental risks

Eutrophication of surface water bodies

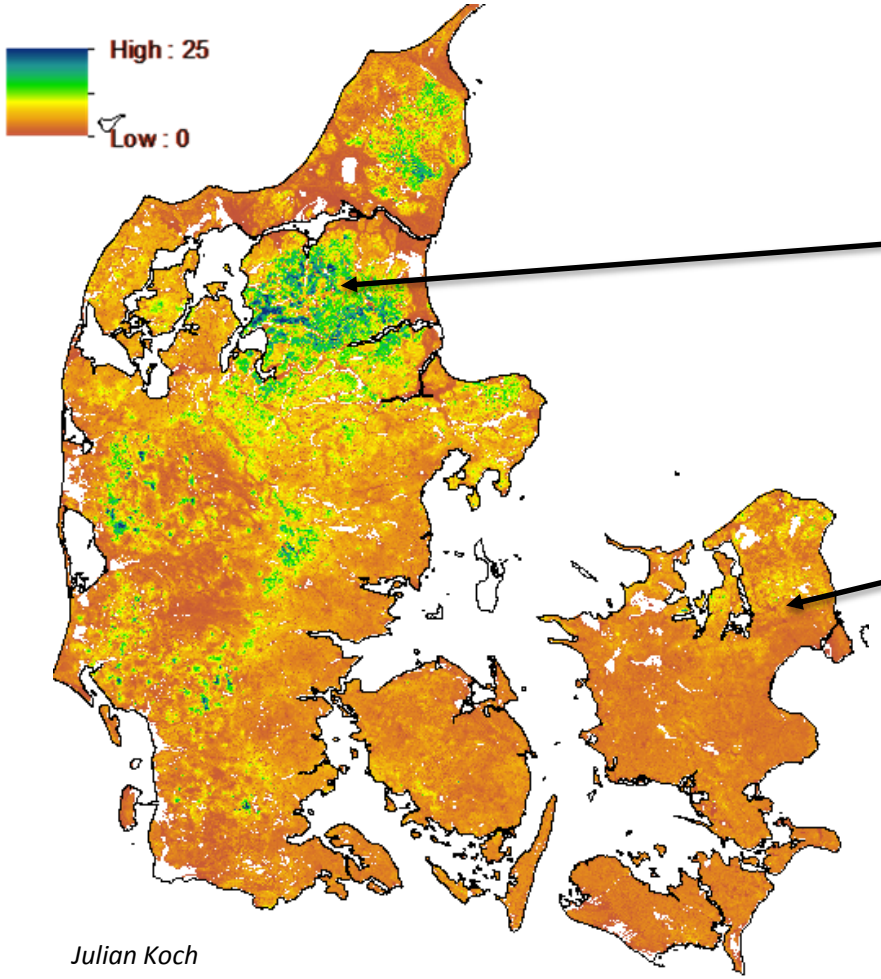
Health risks



Geoviden 2014

Contamination of groundwater (driking water reserve)

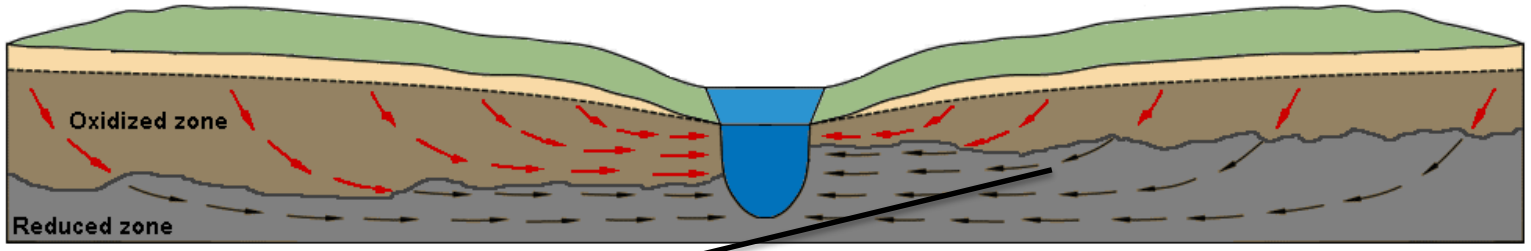
Background: The importance of drain flow



Julian Koch

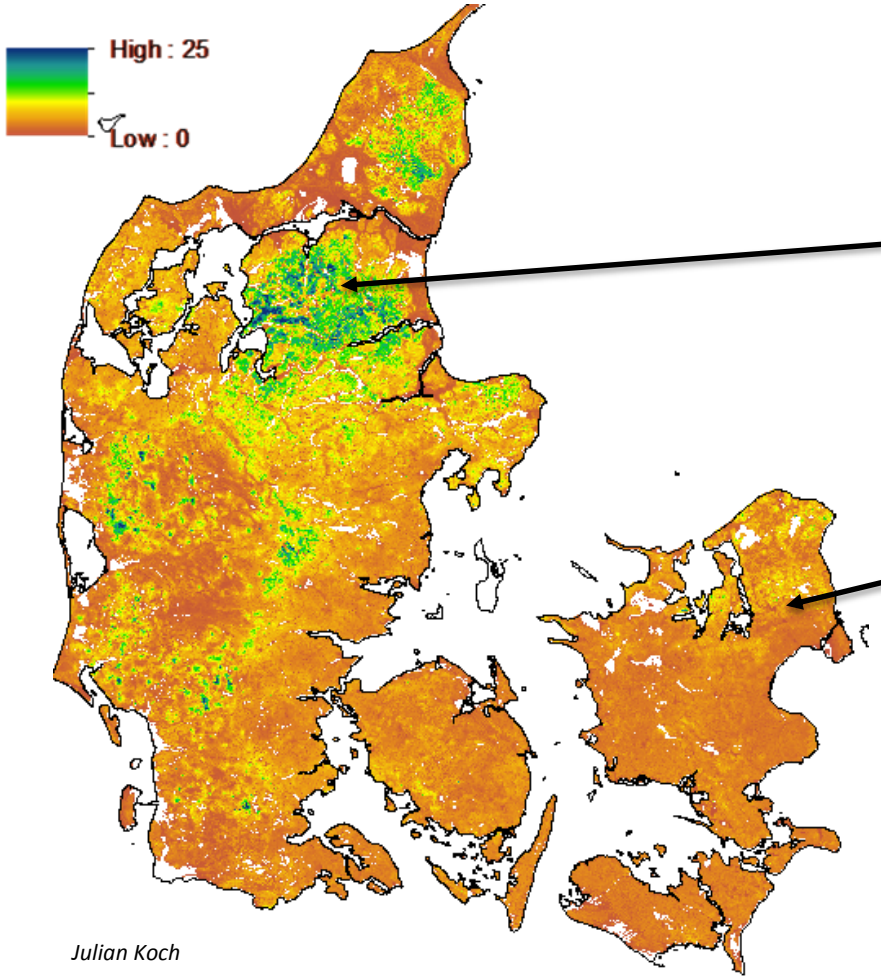
Low reduction potential

High reduction potential



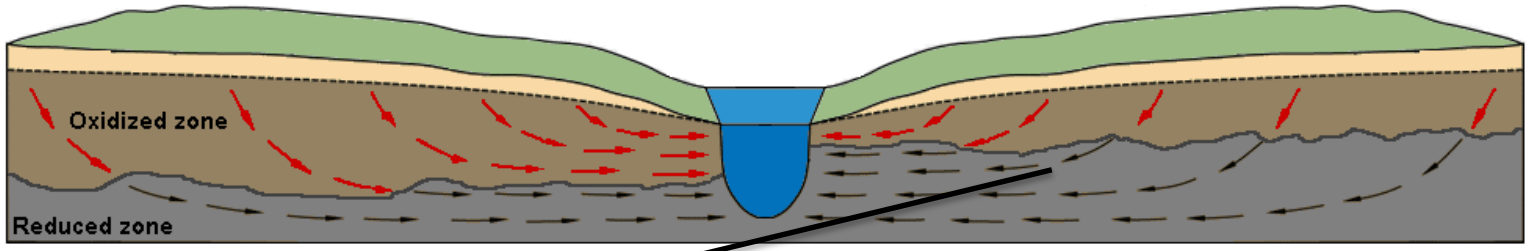
Anne Hansen, 2014

Background: The importance of drain flow



Julian Koch

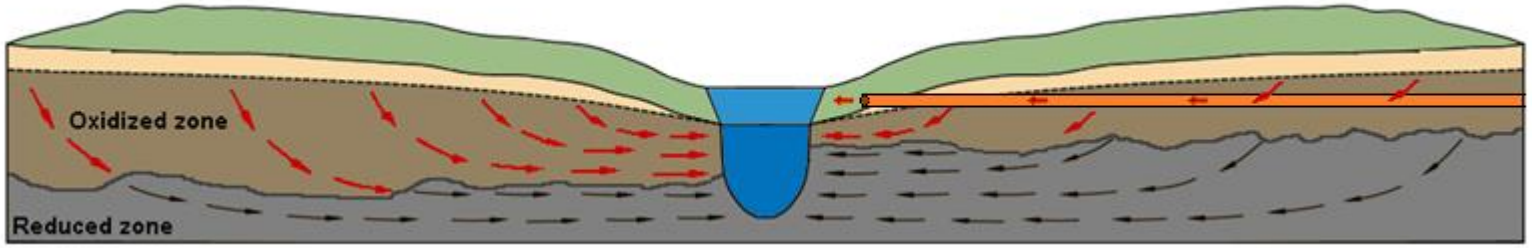
Low reduction potential **High reduction potential**



Anne Hansen, 2014

What happens in tile drained areas?

Low reduction potential **High reduction potential?**



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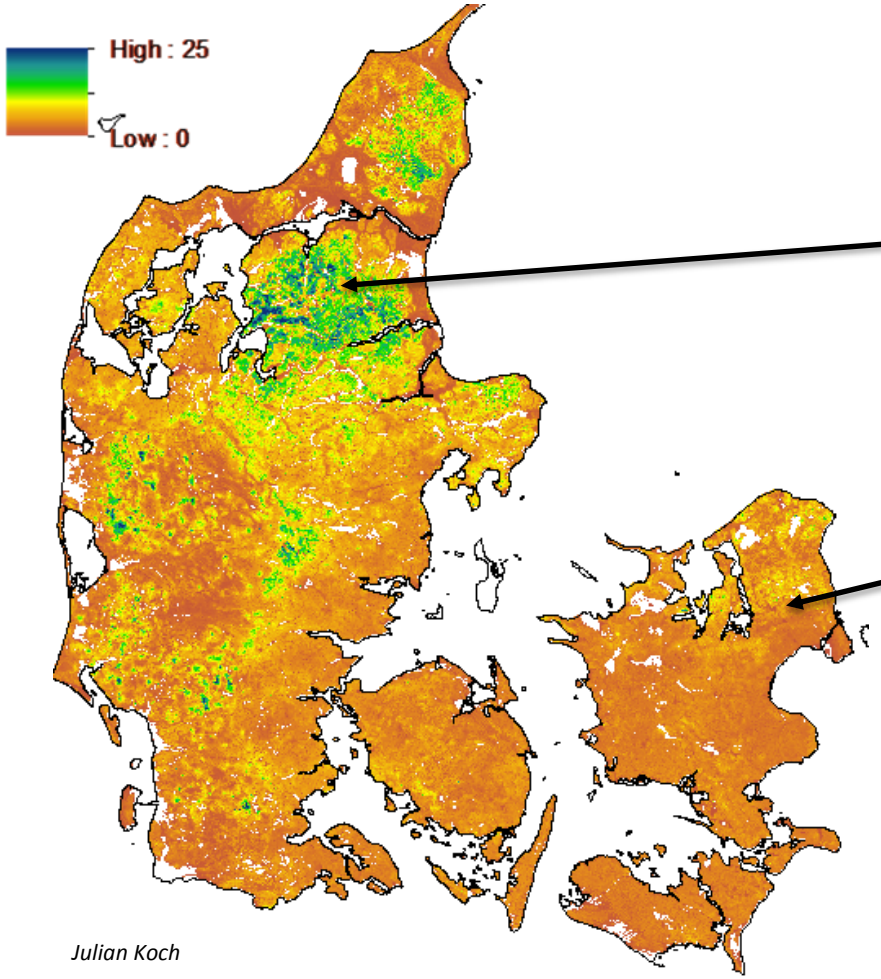

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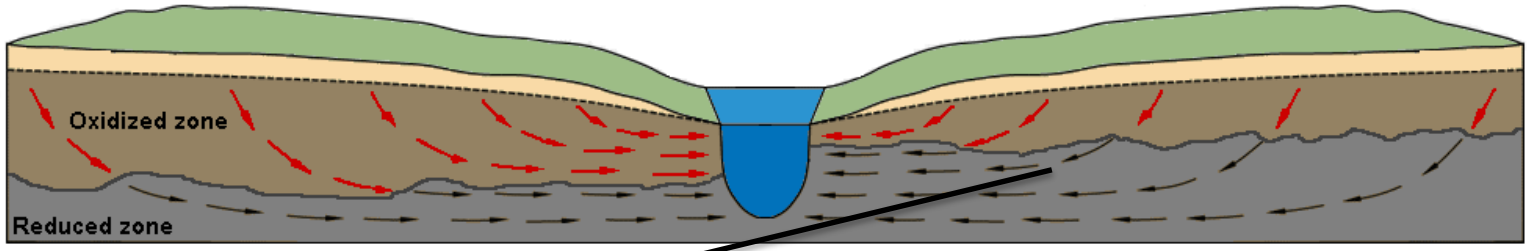
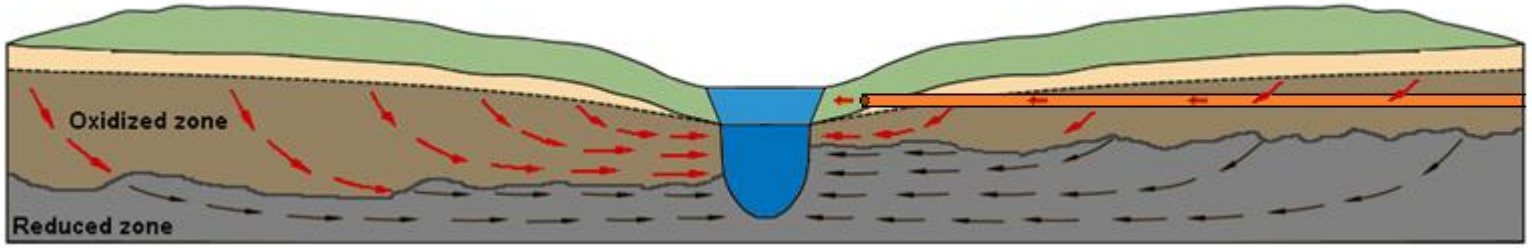


Anne Hansen, 2014

Approximately 50% of the agricultural land is tile drained

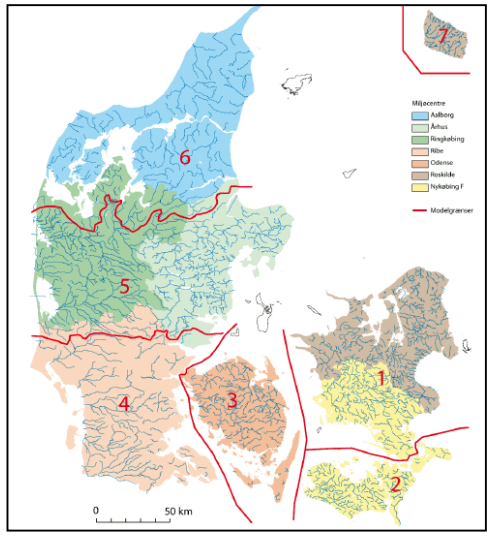
Low reductio

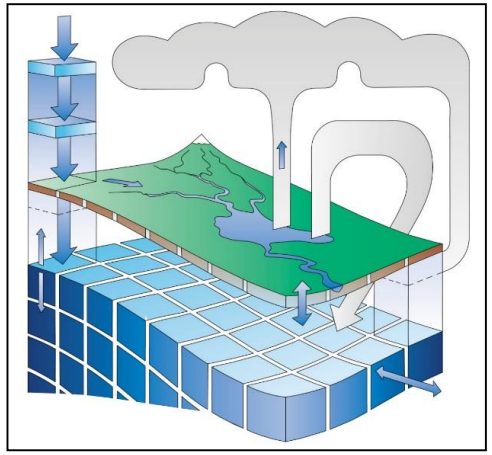
potential?



Background: Motivation for this study

Troldborg et al. 2010





The Danish National Water Resources model, the DK-model, covers all Denmark

» MIKE SHE model framework »7 model domains » 500 x 500 m grid cells

- Used for assess the national exploitable groundwater resource, and quantitative assessment and regulation at national and regional levels, climate change adaption strategies, supporting the national regulation on nitrogen
- More cost-effective regulation of nitrate use requires information on effective and non-effective degradation areas.

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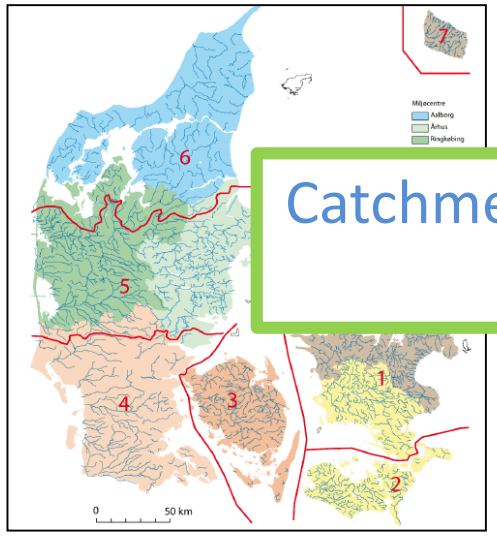

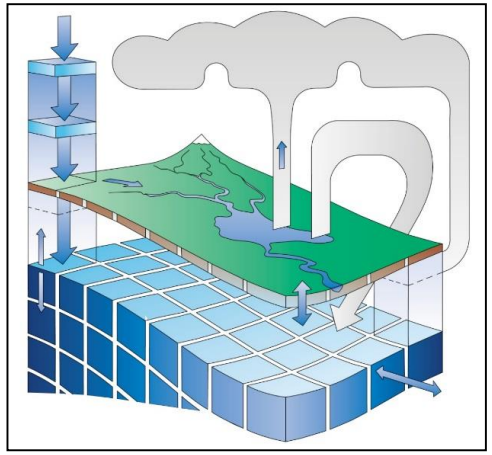

The Danish National Water Resources model, the DK-model, covers all Denmark

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Catchment scale models are generally not very good at capturing the local scale drainage flow

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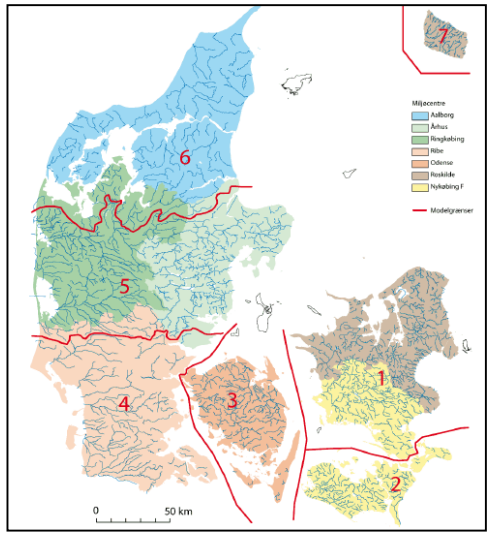

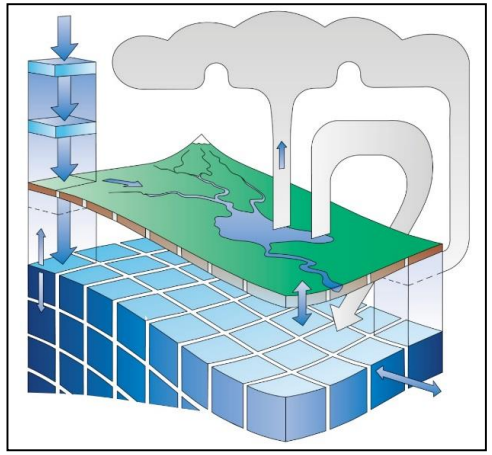

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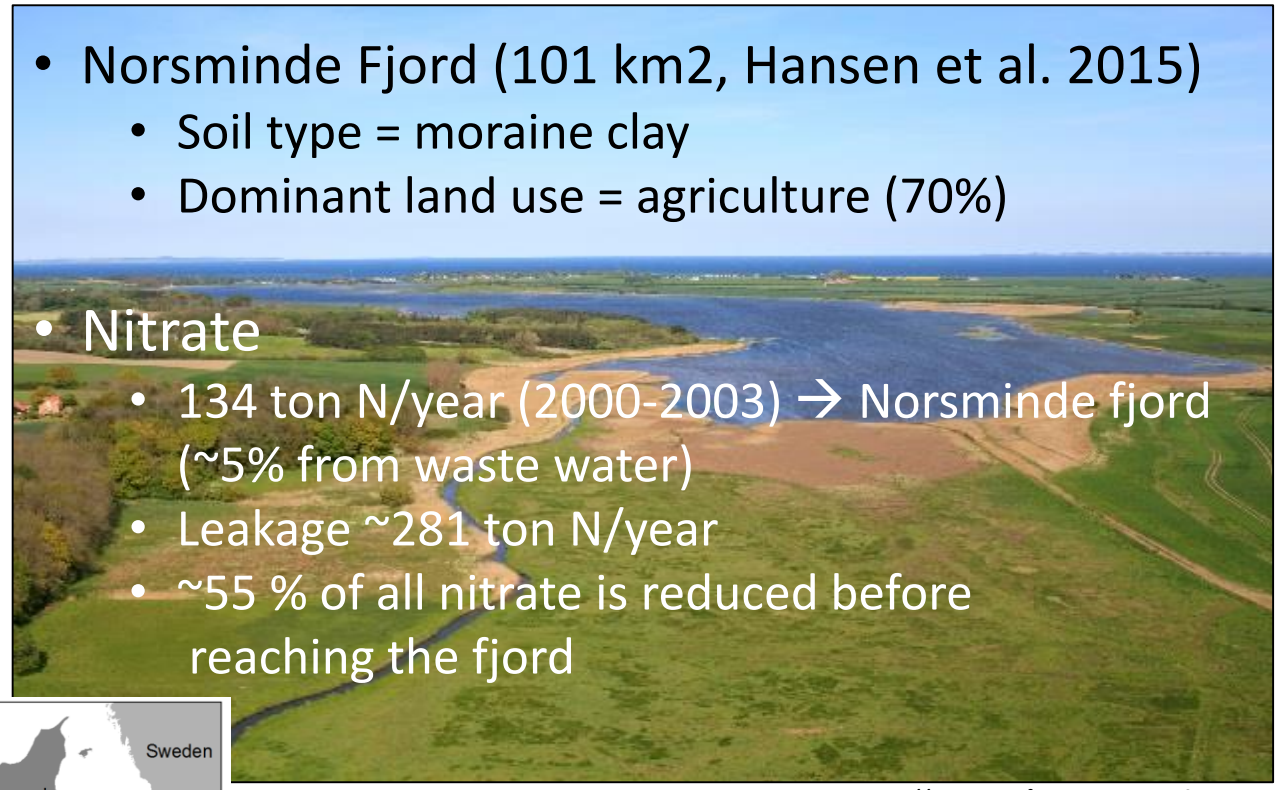
- More cost-effective regulation of nitrate use requires information on effective and non-effective degradation areas.

Current drain concept - Drain formulation in MIKE SHE

- Drain flow is produced when groundwater levels rise above the drain level
- Uniform drains (same depth and time constants)
- Drains represent different drain ”types”

Study site and model



- Norsminde Fjord (101 km2, Hansen et al. 2015)
  - Soil type = moraine clay
  - Dominant land use = agriculture (70%)
- Nitrate
  - 134 ton N/year (2000-2003) → Norsminde fjord (~5% from waste water)
  - Leakage ~281 ton N/year
  - ~55 % of all nitrate is reduced before reaching the fjord

http://oplandsråd-norsminde-fjord.dk

Hansen et al. (2015)

Geological model (Hansen et al. 2014 & He et al. 2015)

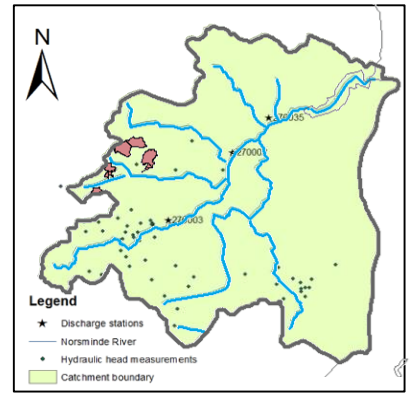
- 11 hydrogeological units
- Based on borehole data from Jupiter and geophysical data from Mini-SkyTEM

Hydrological model

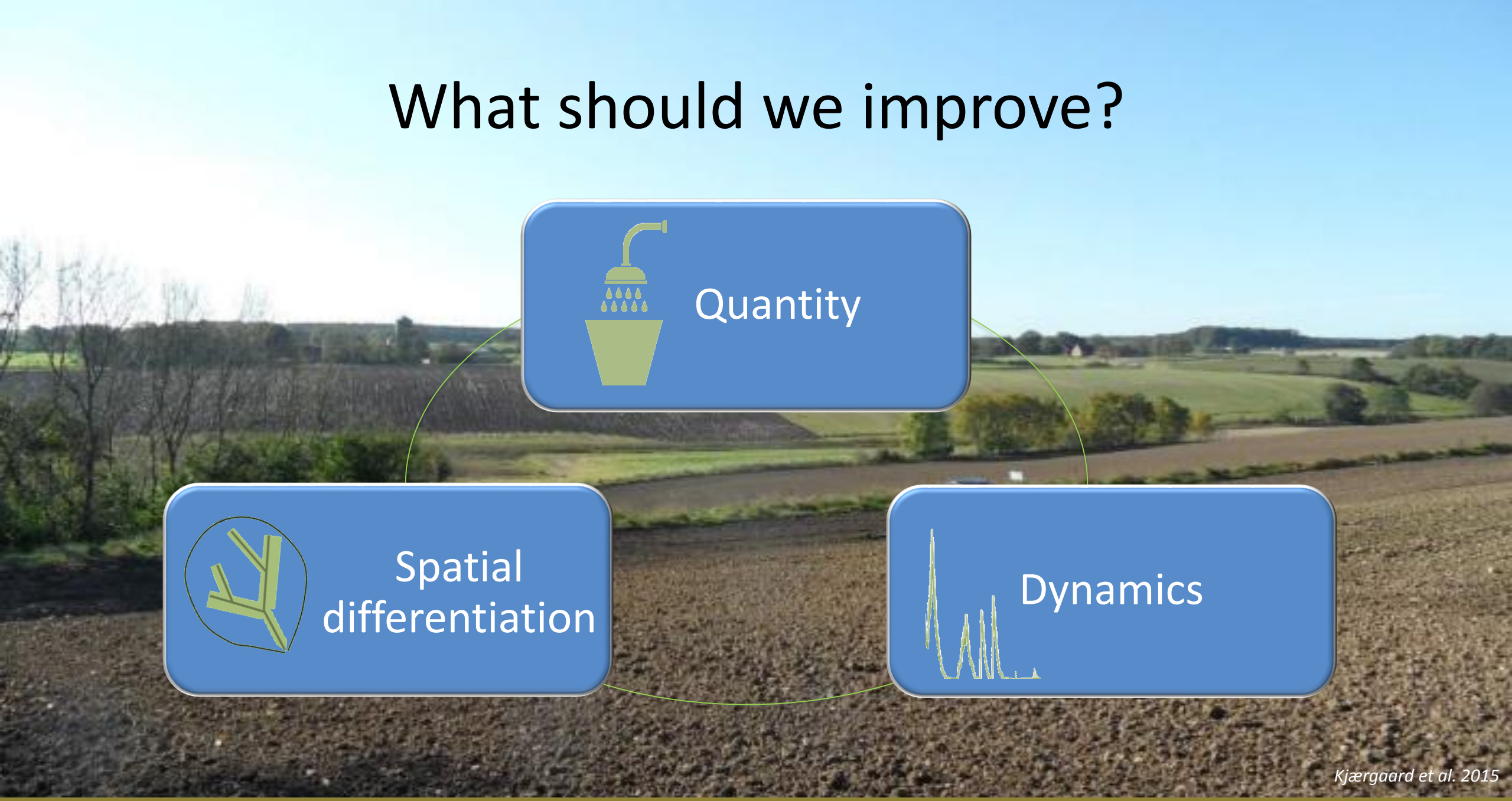
- MIKE SHE/MIKE 11
- 3D groundwater flow, 2D overland flow, 1D unsaturated zone
- 100*100 m grid cells

Objective function

- 4 discharge stations
- 62 Hydraulic head wells
- **8 Drainage discharge (IDræn)**



What should we improve?

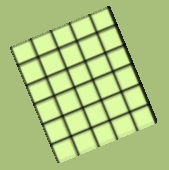


Kjærgaard et al. 2015

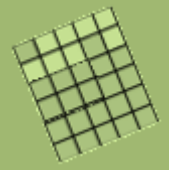
Knowledge to help us improve

Previous studies using MIKE SHE have shown better dynamics with higher resolution for stream flow – could this be applicable for drainage?

Knowledge to help us improve



Resolution



Distributed parameters

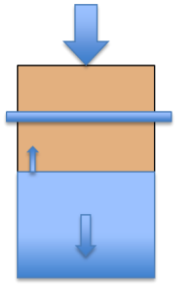
Previous studies using MIKE SHE have shown better dynamics with higher resolution for stream flow – could this be applicable for drainage?

What does the drains in the model represent
- Tile drains → Agriculture
- Natural drains, small streams/ditches → Forest
- Wetlands → Wetlands
- Urban sewer systems → Urban areas

Knowledge to help us improve

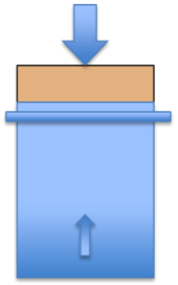
- Resolution
- Distributed parameters
- Local factors

If we want the correct local partitioning of drain and groundwater flow, we need to make sure the model represents the local scale mechanisms



Recharge rate > natural drainage of soil

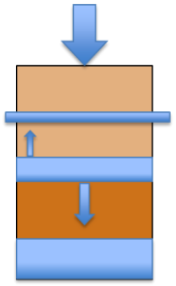
Natural drainage controlled by **regional geology**



Recharge rate > natural drainage of soil

Discharge areas

Controlled by **geology and topography**



Perched water table

Controlled by **local geology**

Knowledge to help us improve

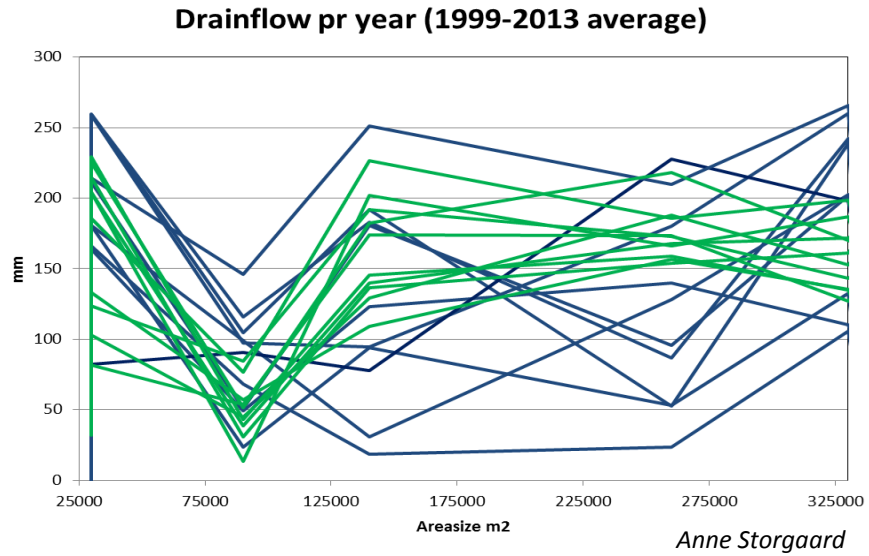
- Resolution
- Distributed parameters
- Local factors
- Spatial calibration

Simulated drainflow in six fields (in Norsminde)

20 different stochastic realisation of geology based on

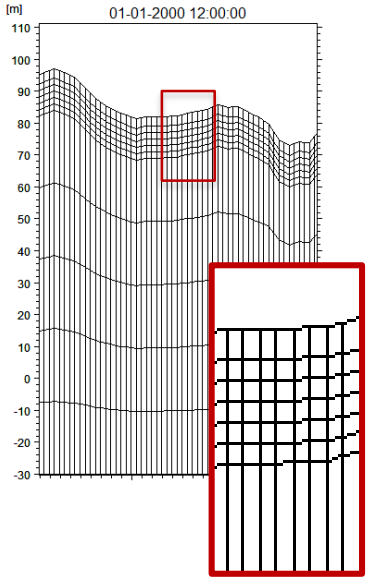
- Boreholes only (blue)
- Boreholes & SkyTEM (green)

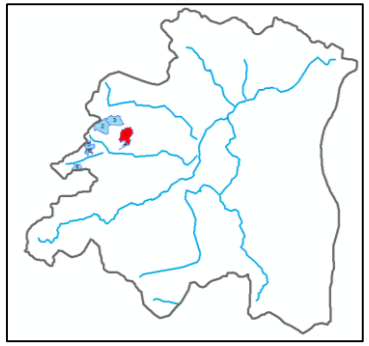
NOTE: Geology in top 3m is the same in all models

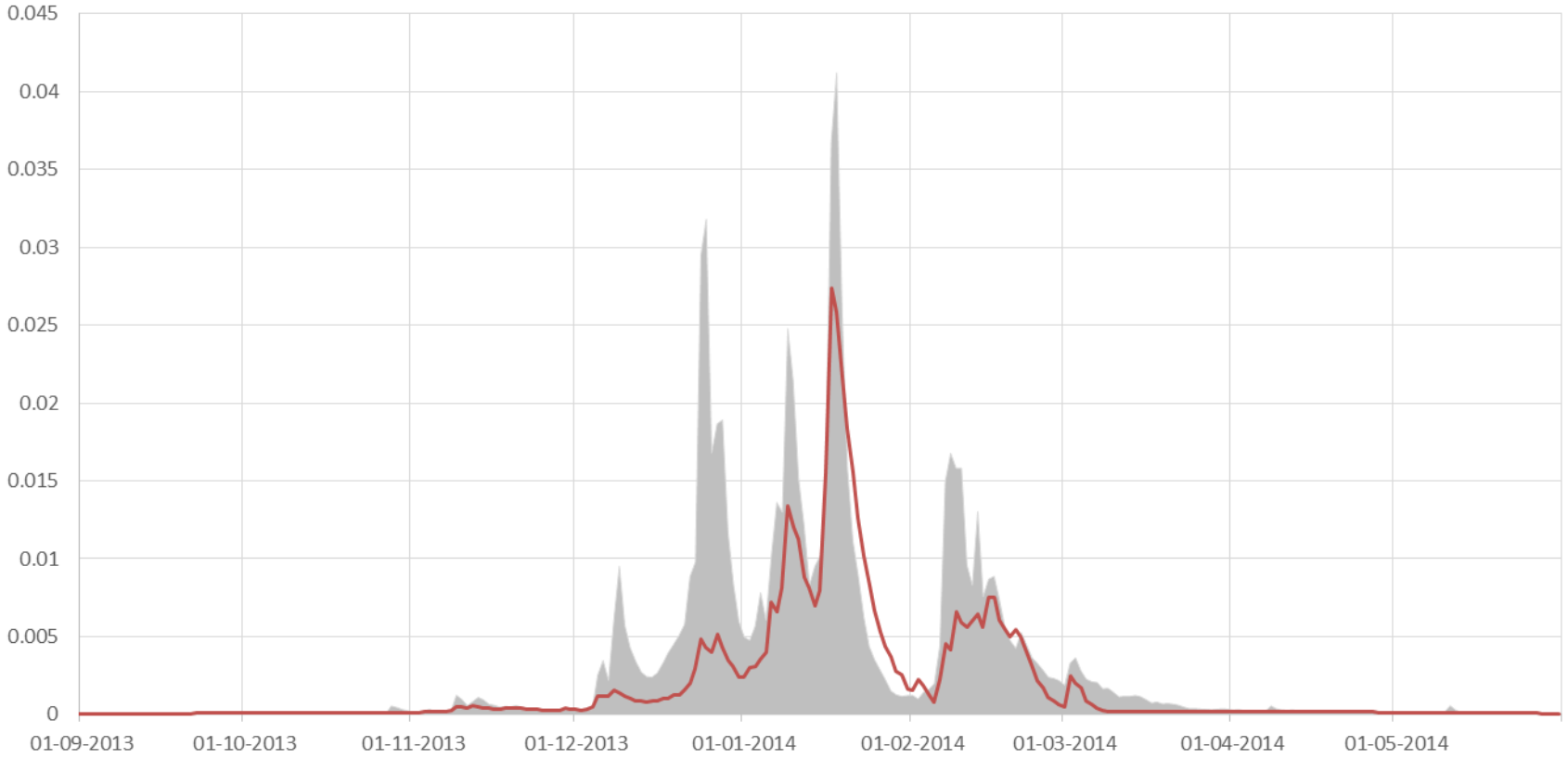


Anne Storgaard

Resolution of upper simulation layers







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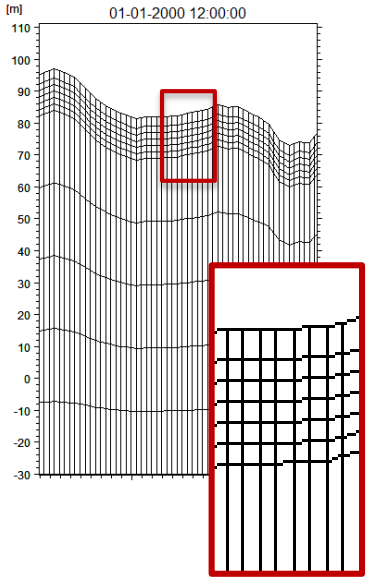

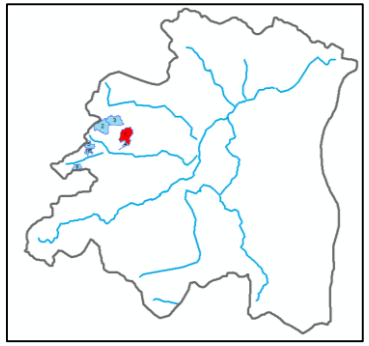

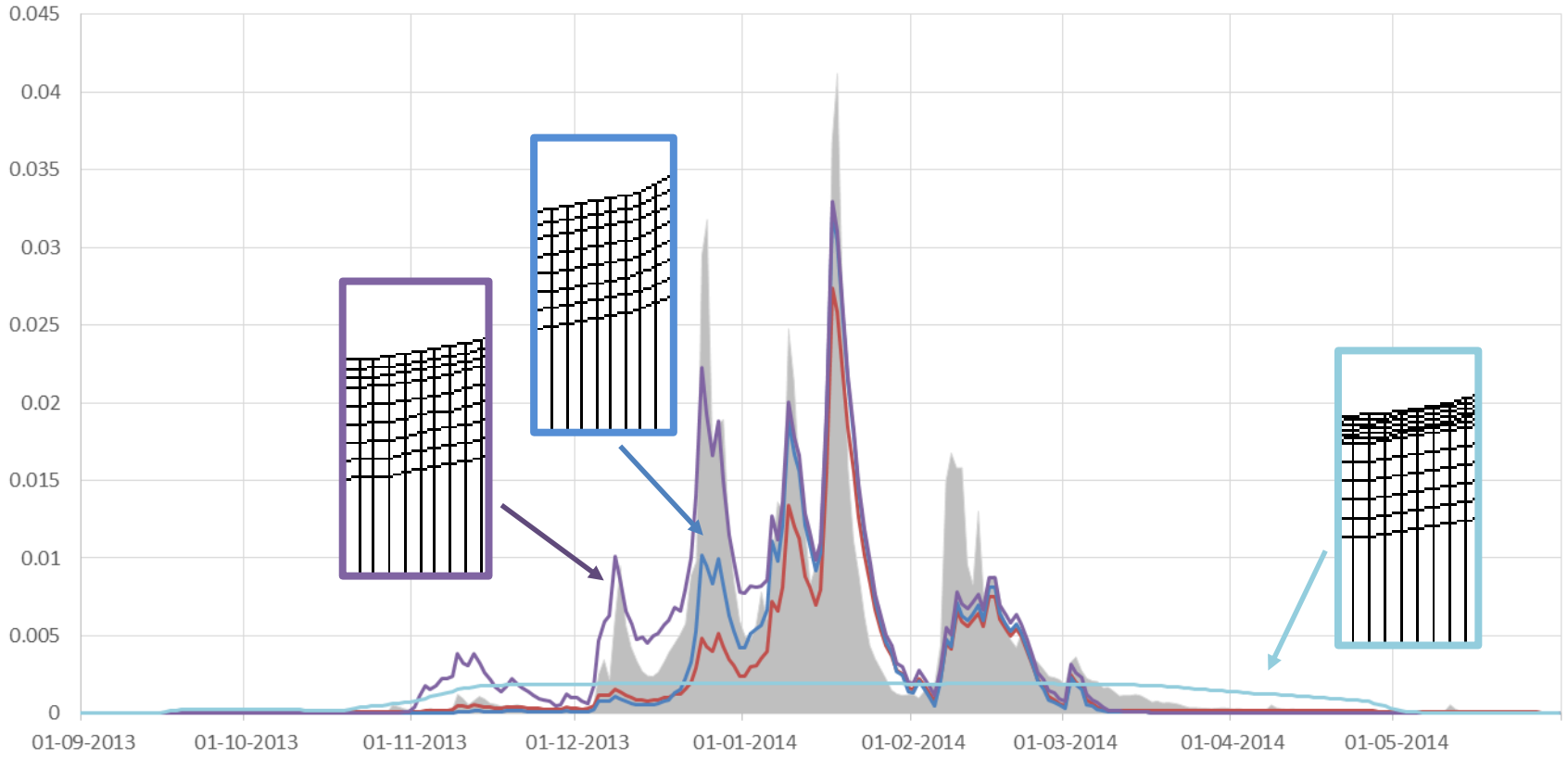

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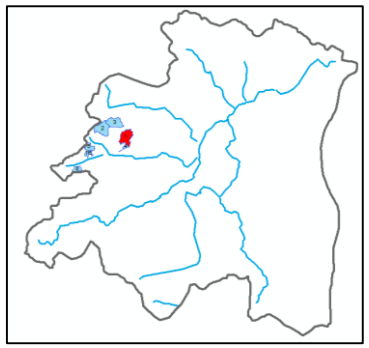
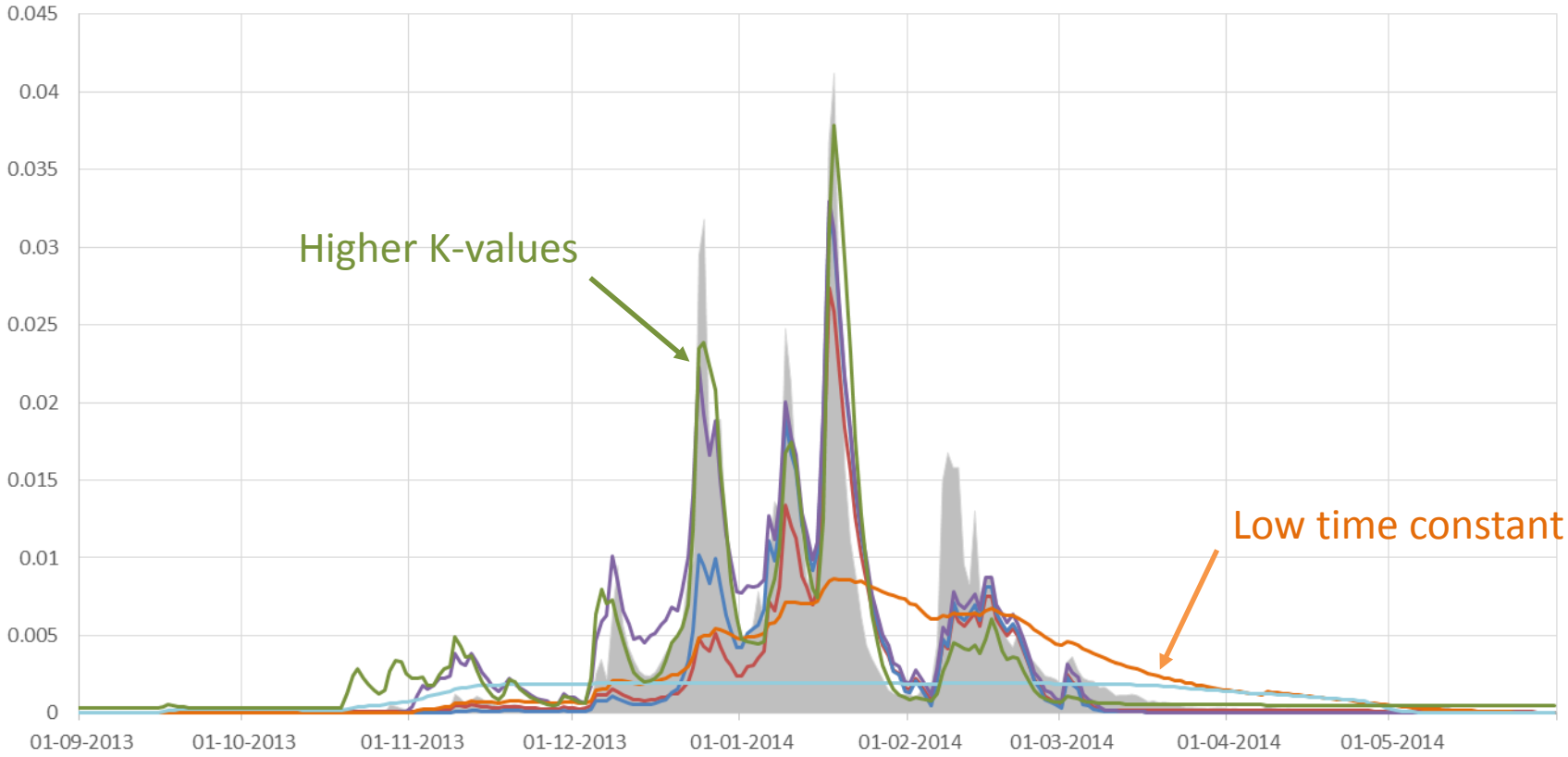




Distributed drainage parameters

What does the drains in the model represent

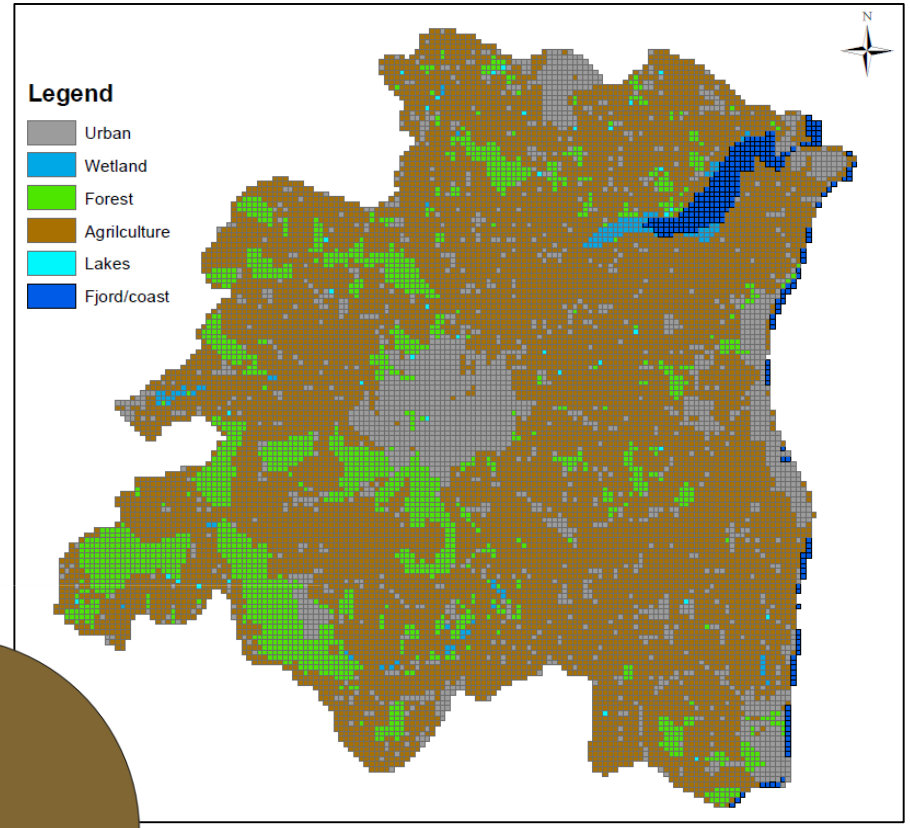
- Tile drains → Agriculture
- Natural drains, small streams/ditches → Forest
- Wetlands → Wetlands
- Urban sewer systems → Urban areas

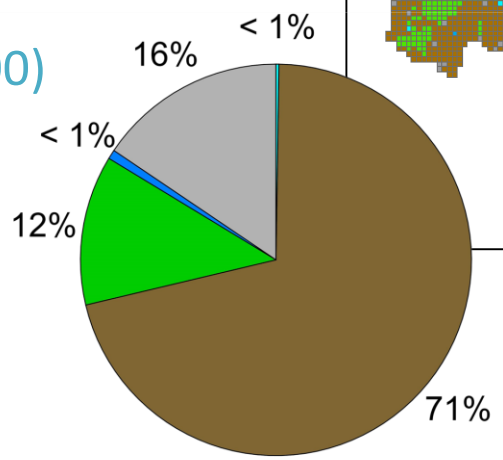
Forest → lower drain time constant (factor 5-10)

Wetlands → lower drain time constant (factor 10-100)

Wetlands → shallower drain depth (0.25 to 0.5 m)

Urban → higher drain time constant (factor 10-100)





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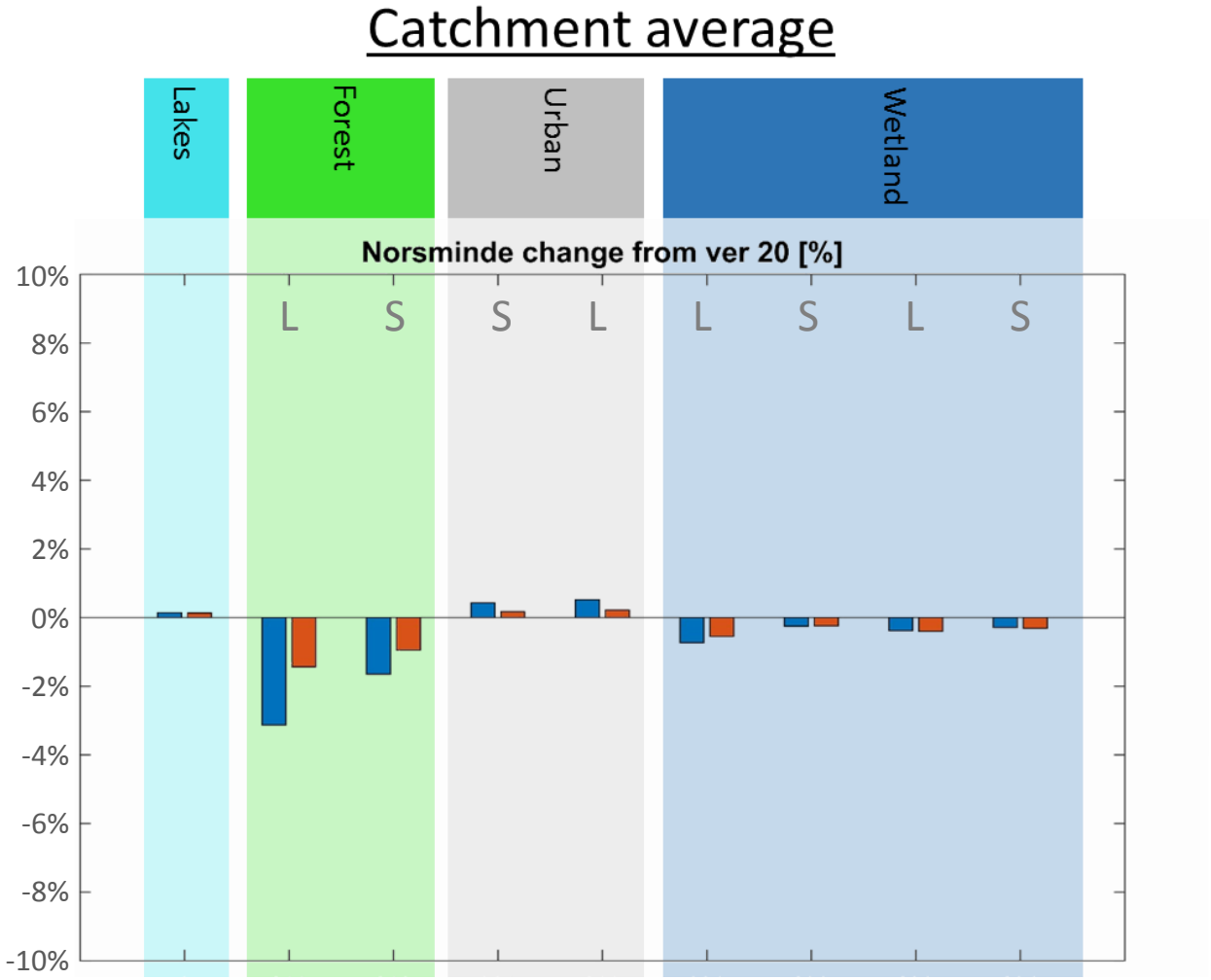
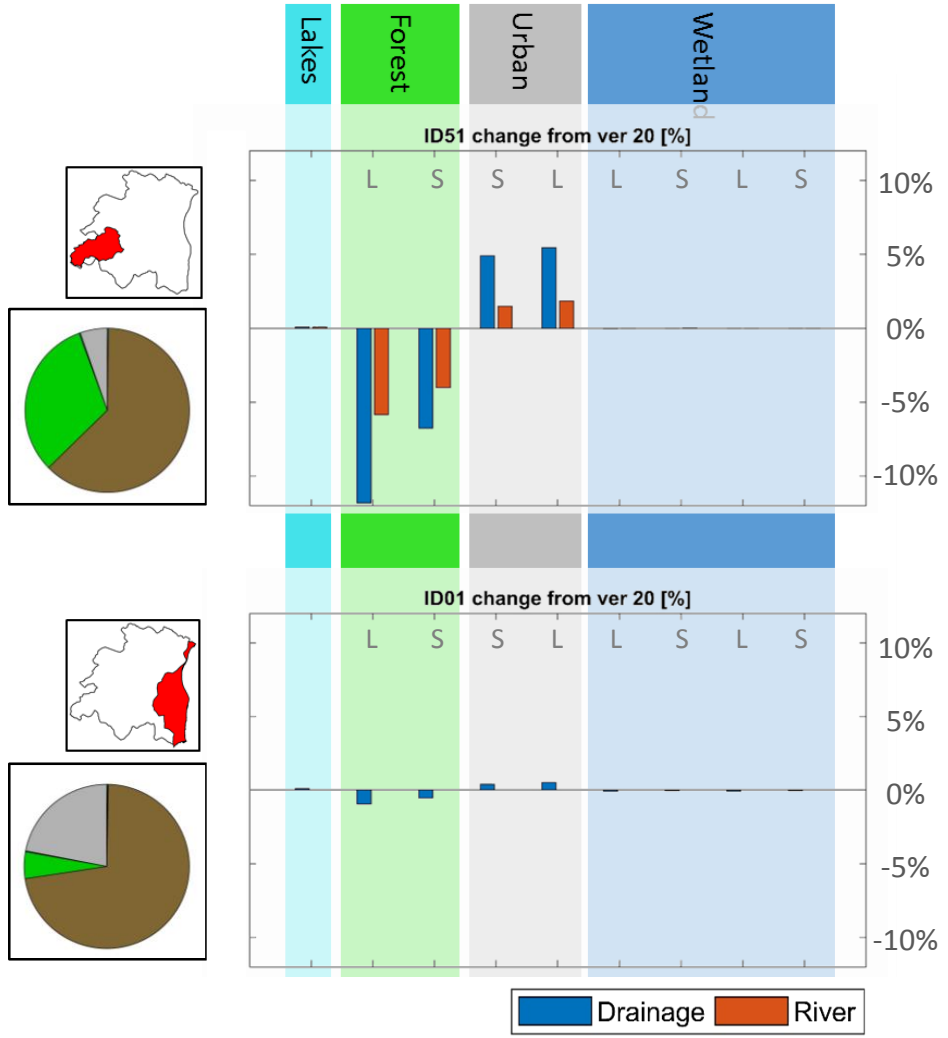
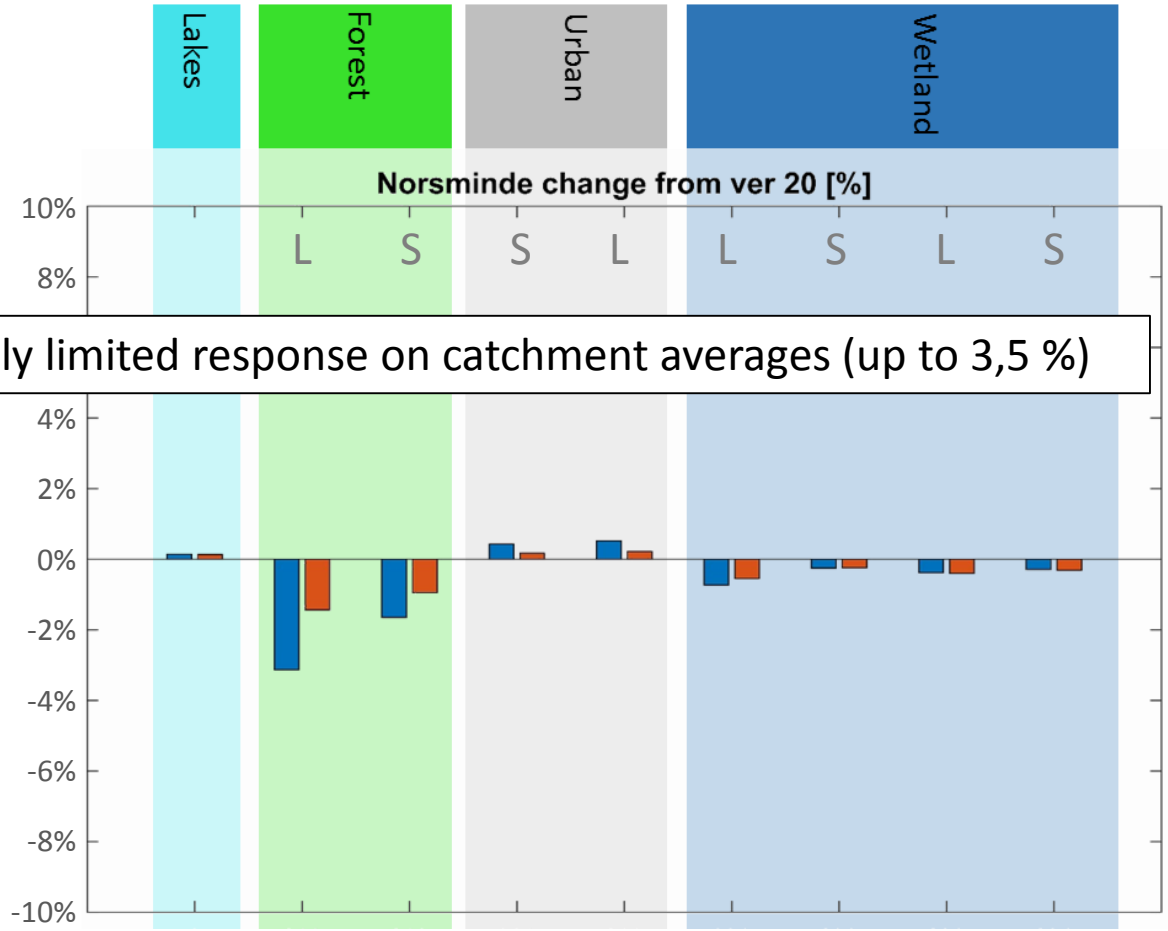


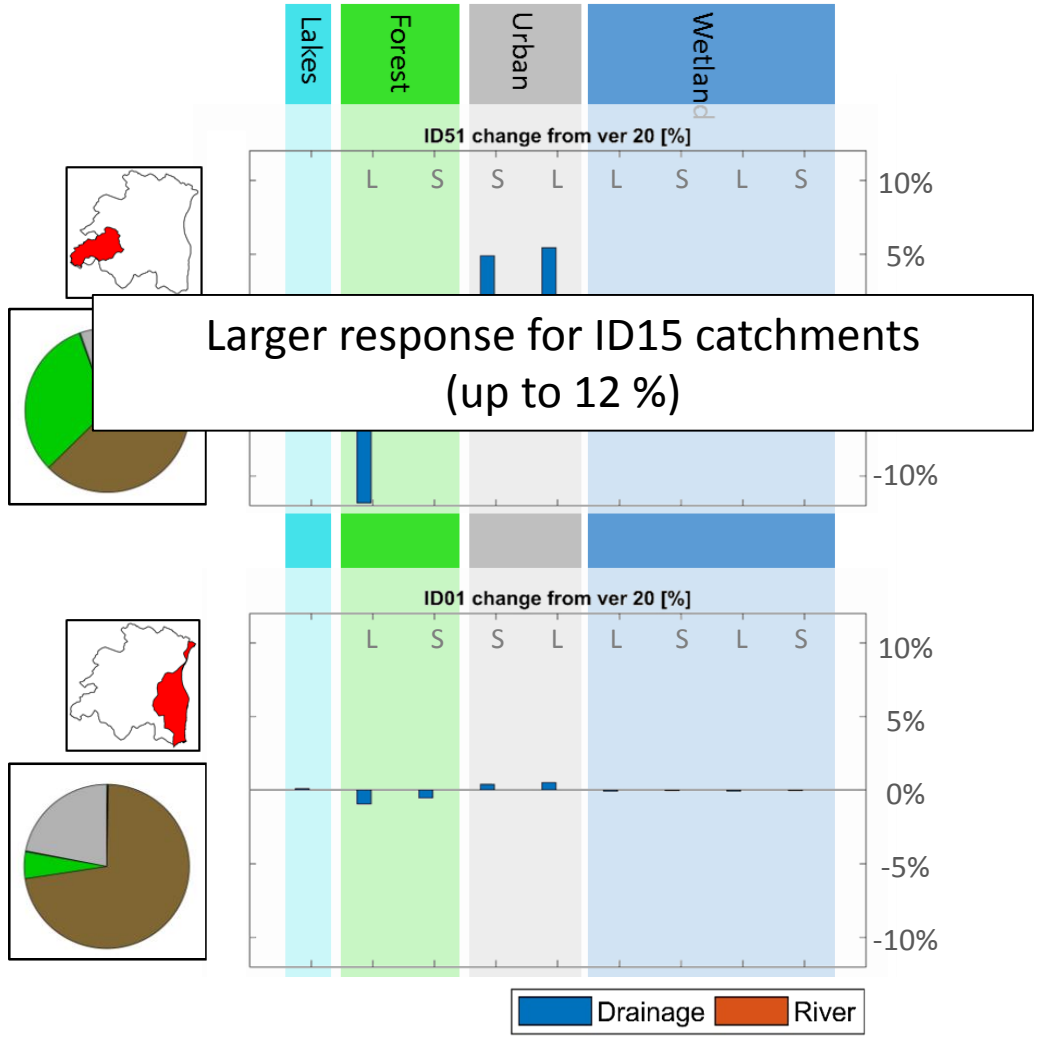


Distributed drainage parameters

Catchment average

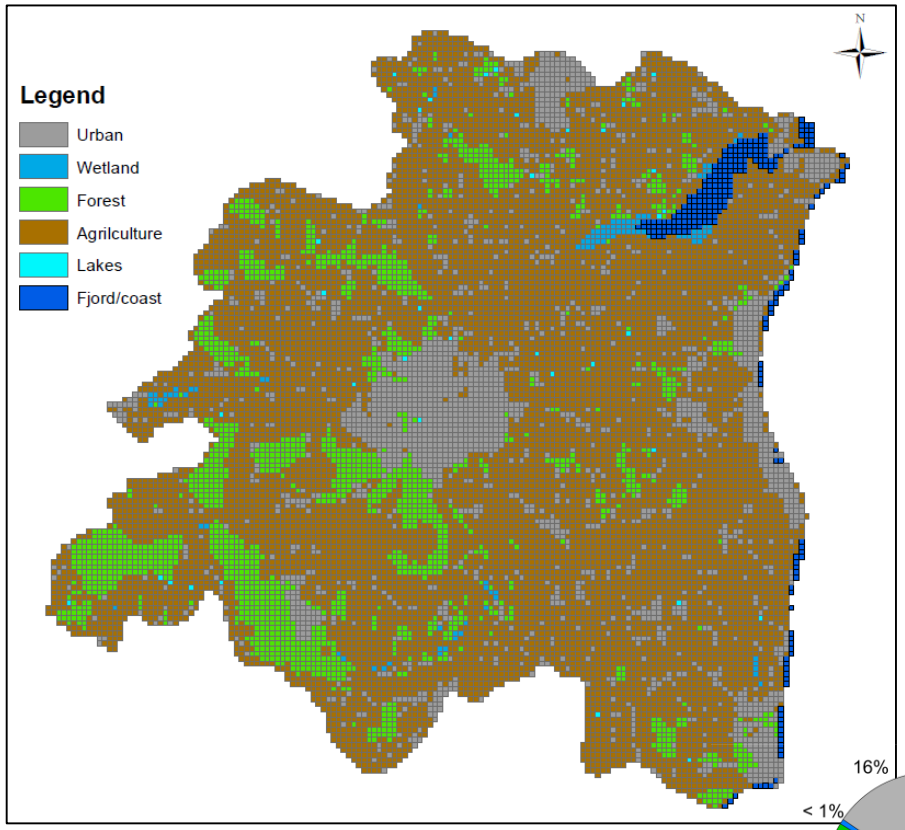


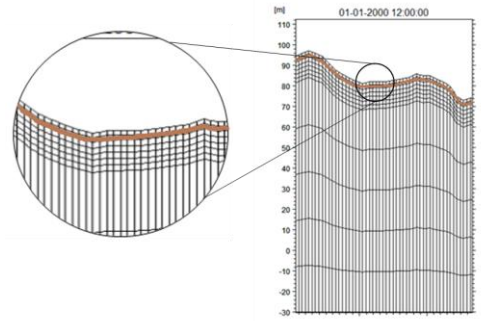
Only limited response on catchment averages (up to 3,5 %)

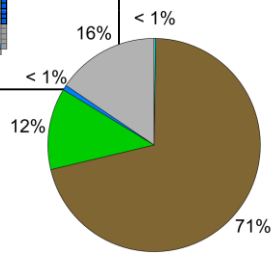


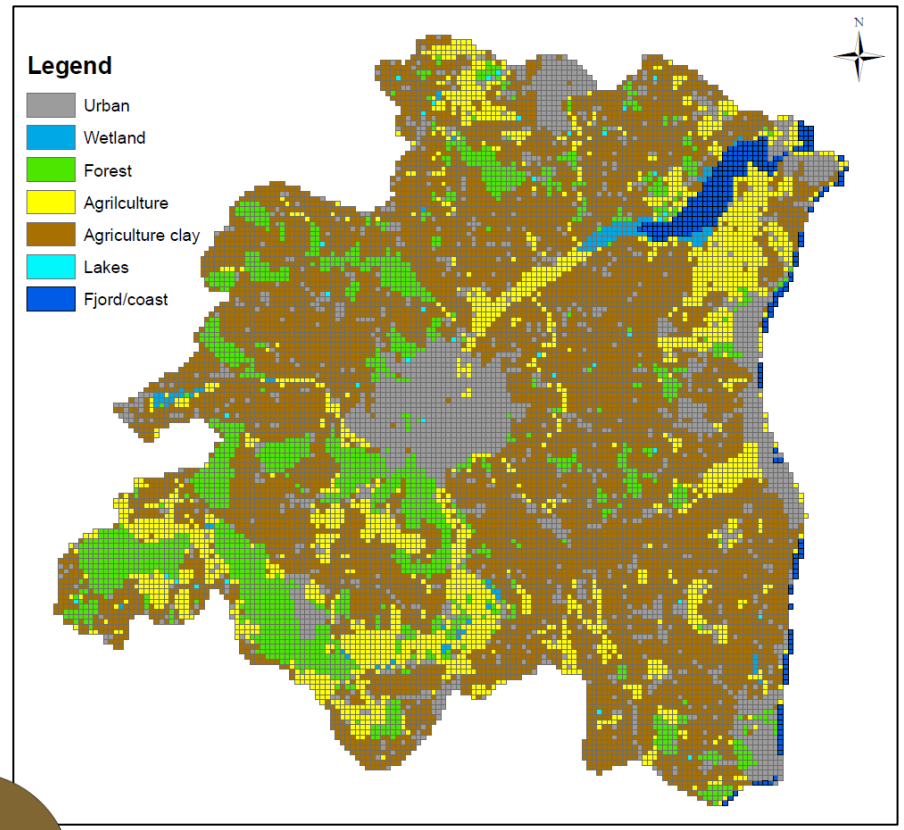
Larger response for ID15 catchments (up to 12 %)

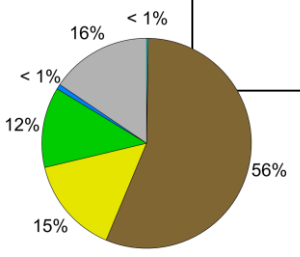
Improving local scale drainage flow (low K-layer)





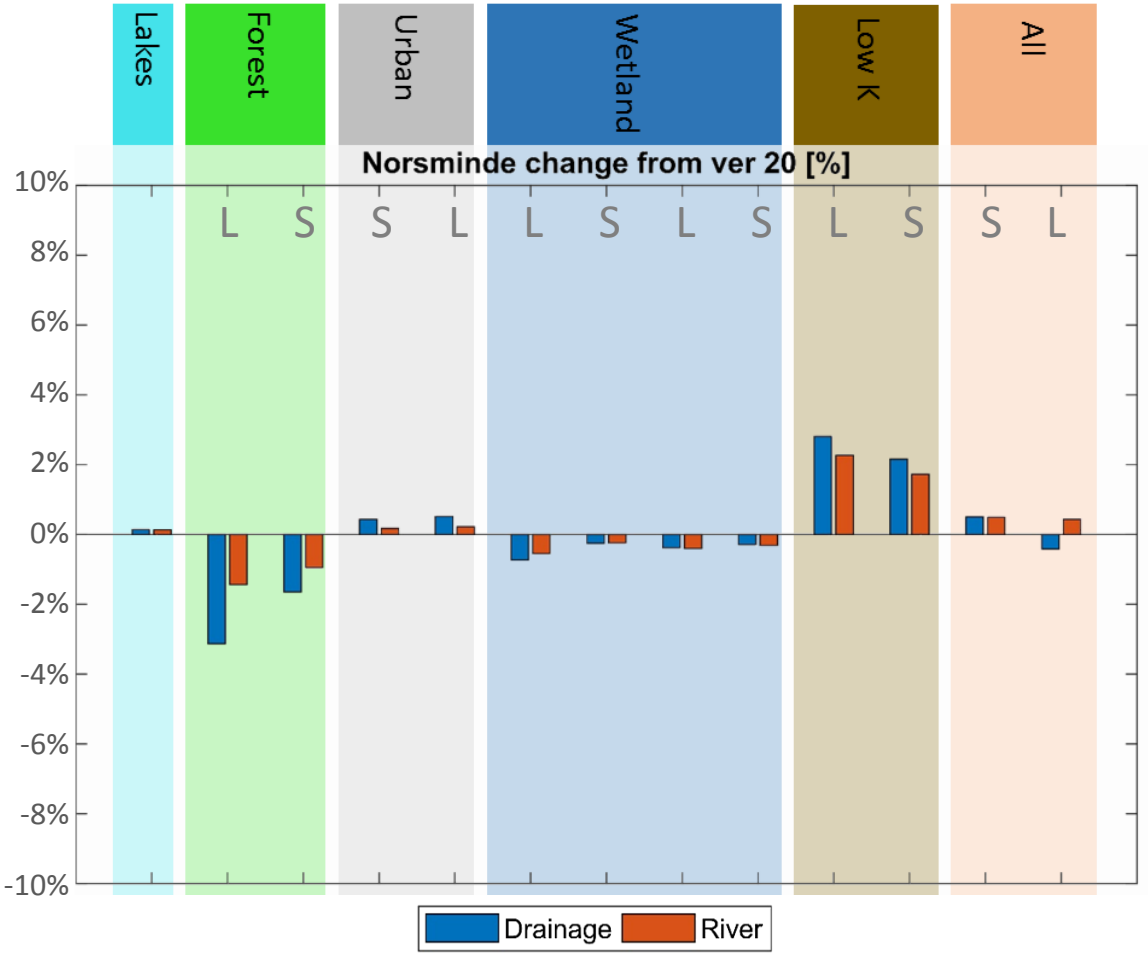


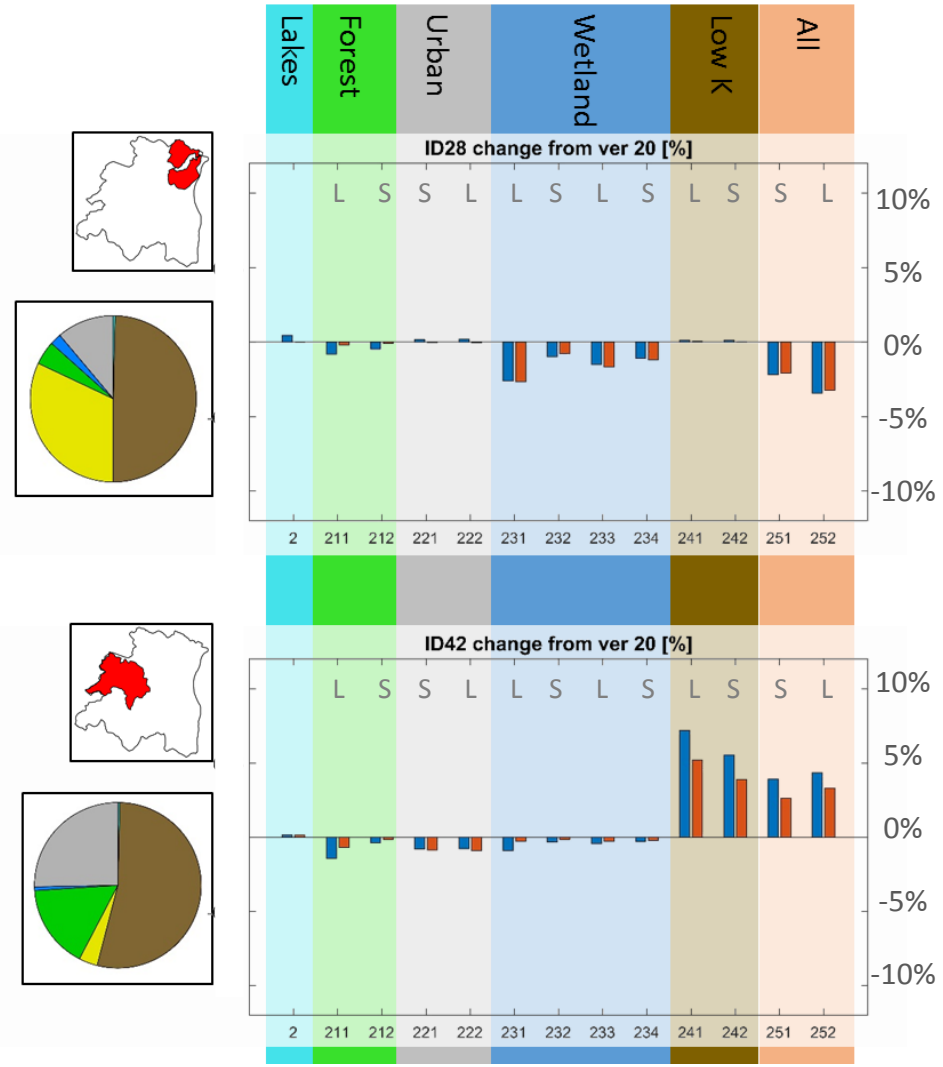




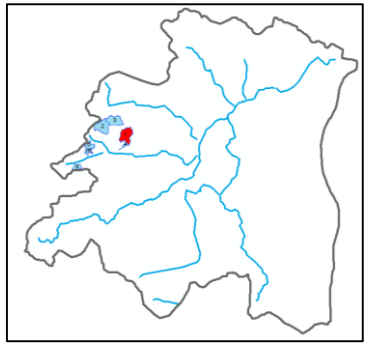
Improving local scale drainage flow (low K-layer)

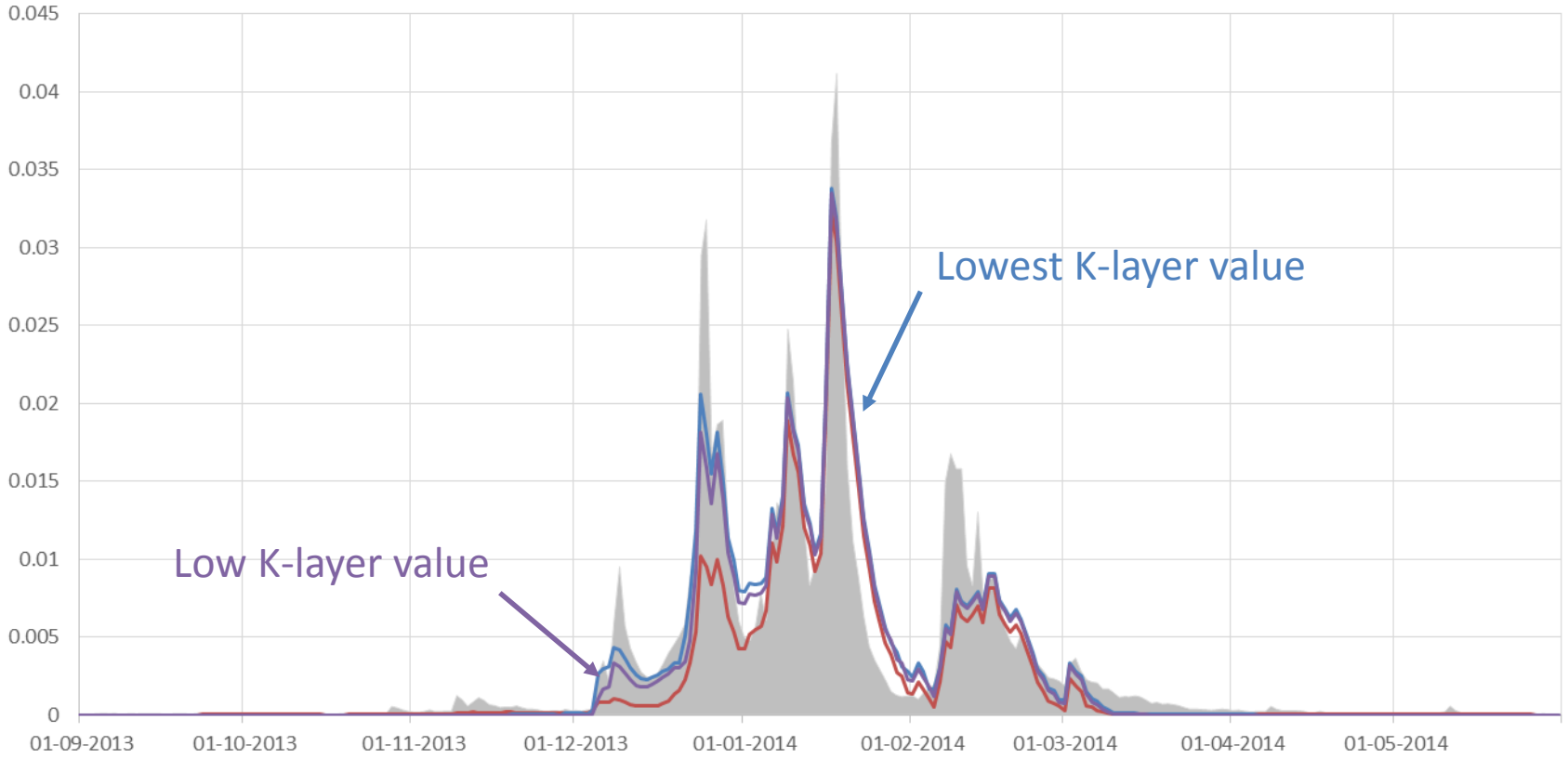
Catchment average





Improving local scale drainage flow (low K-layer)



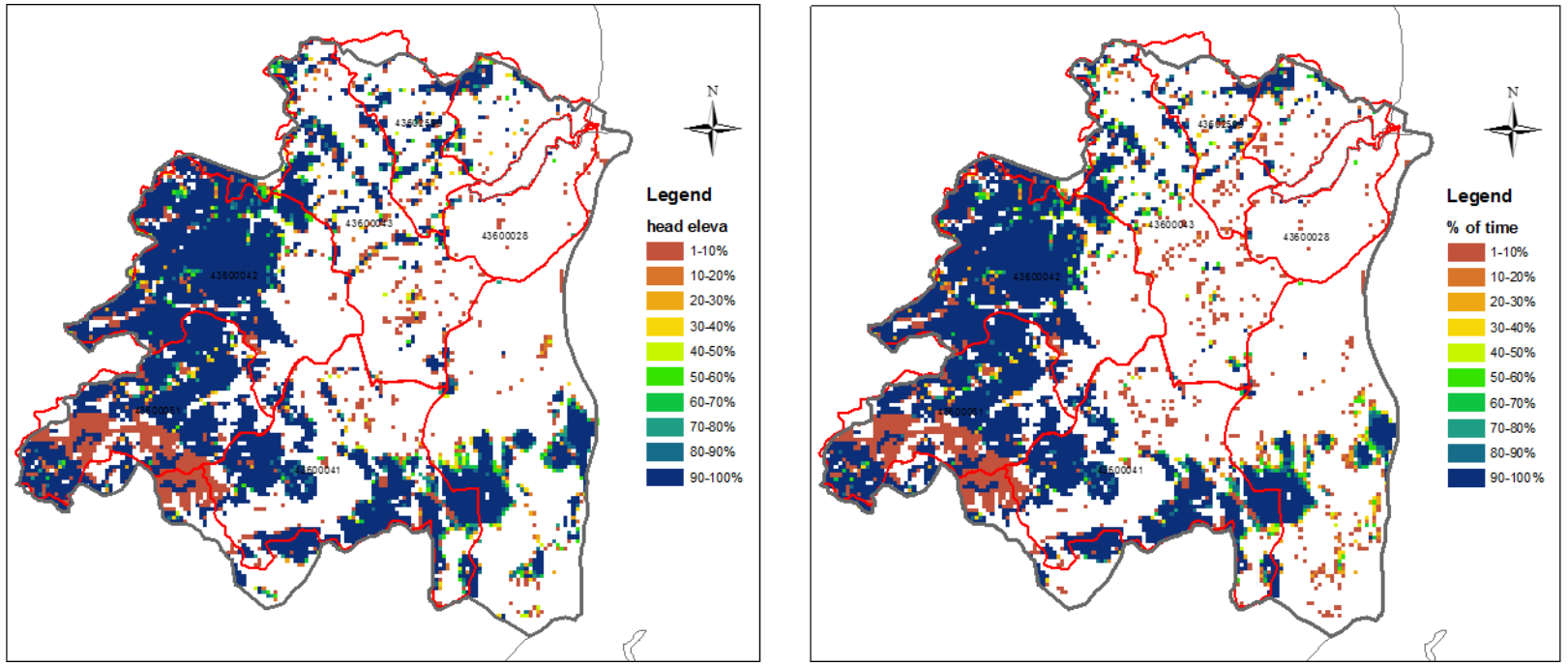


Improving local scale drainage flow (low K-layer)

Not all areas with implemented low K layer has a perched water table occurring

→Other processes dominate

→The dominant process may also change over time



How can representation of nitrate drainage transport be improved in catchment scale models?

Dynamics
Resolution
Local factors

Quantity
Resolution
Local factors

Spatial differentiation
Distributed parameters
Local factors

Spatial calibration

Flemmning Gertz, SEGES

Thank you for your attention!

Innovation Fund Denmark
RESEARCH, TECHNOLOGY & GROWTH