River Basin Management at GEUS: Hydrological Modelling, Satellite Remote Sensing and Machine Learning

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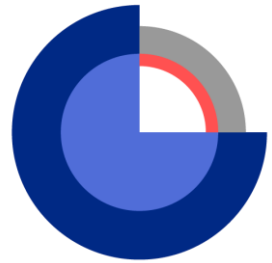


3RD TECHNICAL WORKSHOP on Drought and River Basin Management
DANISH CONSULATE, ISTANBUL
25/March/2021

G E U S

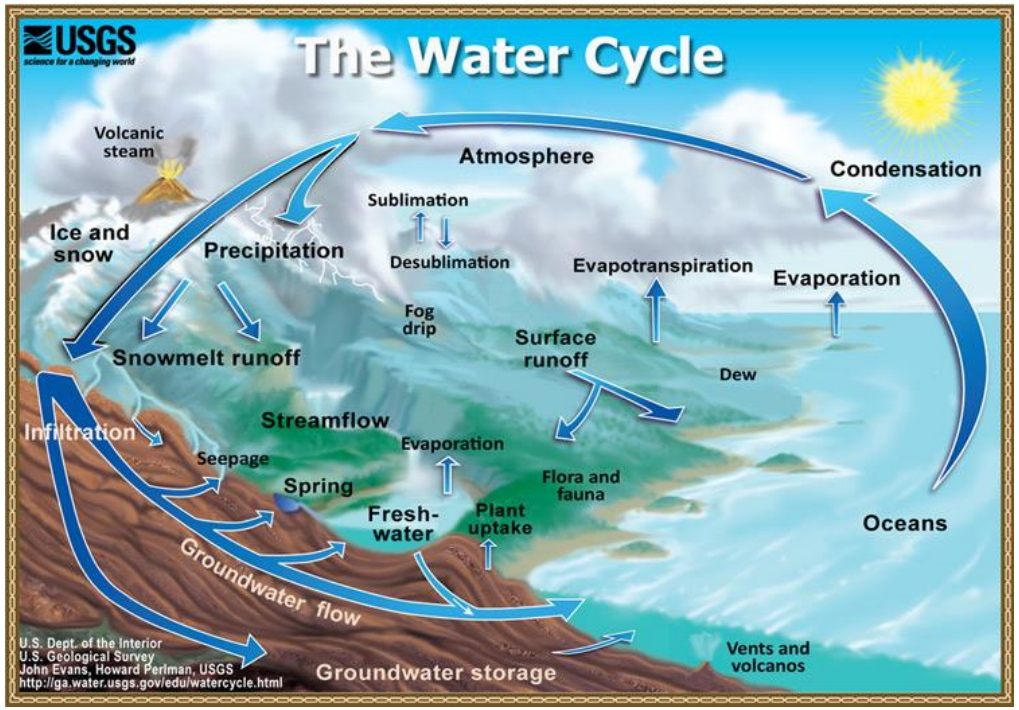
We conduct research on an international level, advise authorities and industry, as well as map the geology and the resources of the earth.

What is GEUS?

- An independent research and advisory institution under the Danish Ministry of Climate, Energy and Utilities
- Geological data centre and national well database
- Partner in Geocenter Denmark – a formalised cooperation with University of Copenhagen and Aarhus
- Member of EuroGeoSurveys
- Denmark's largest geoscience research community and employs approx. 350 people

GEUS

3 Departments



Water Resources

GEUS builds knowledge to optimise the management and protection of Danish water resources and the public's drinking water supply as well as the groundwater's impact on Danish nature and the environment

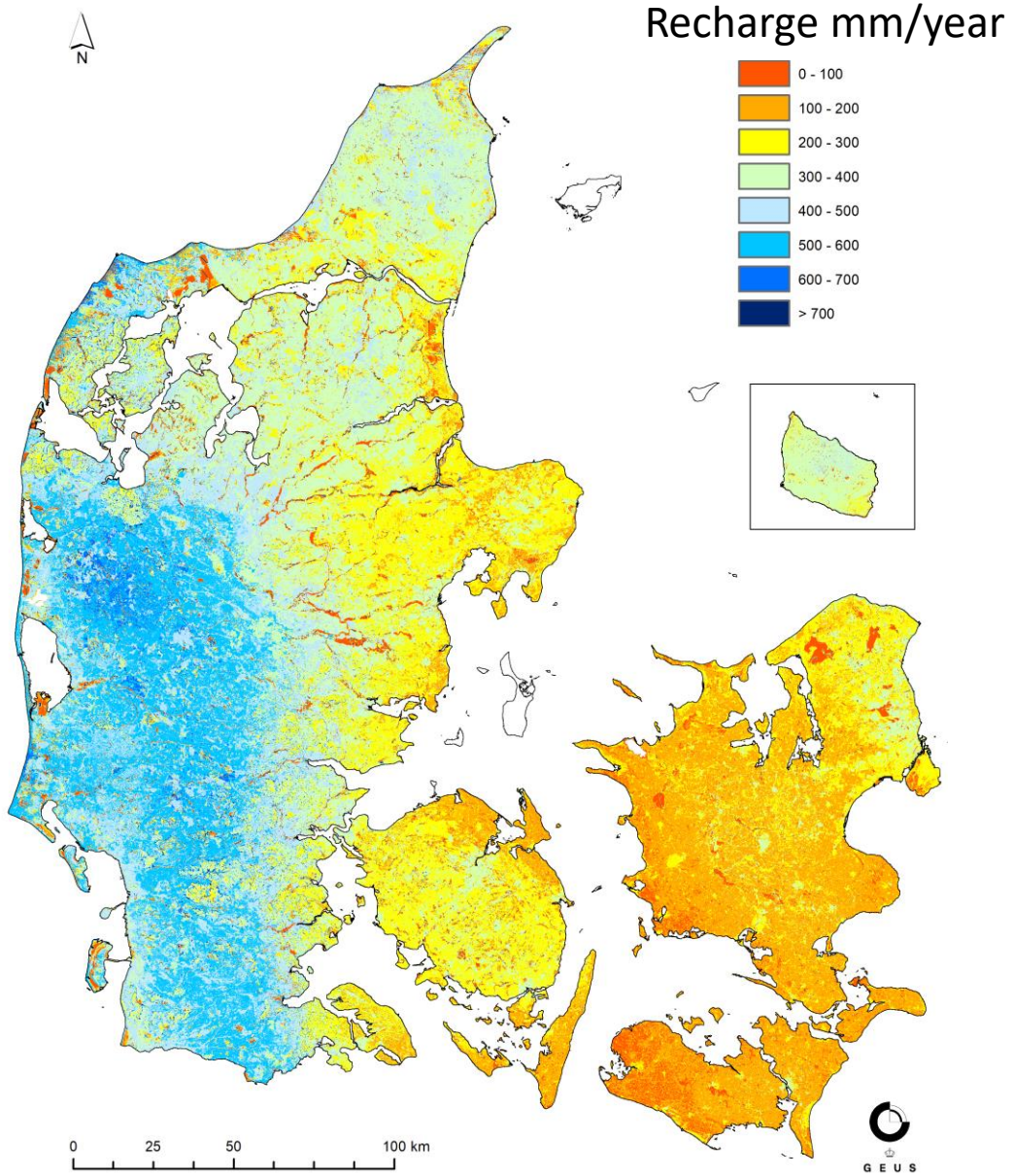
- We map, monitor and conduct research in groundwater and the water cycle
- We supply knowledge and data on water in Denmark

Challenges and Applications:

- Climate Change Impact (flood & drought)
- Groundwatwer Quality (pesticide leaching)

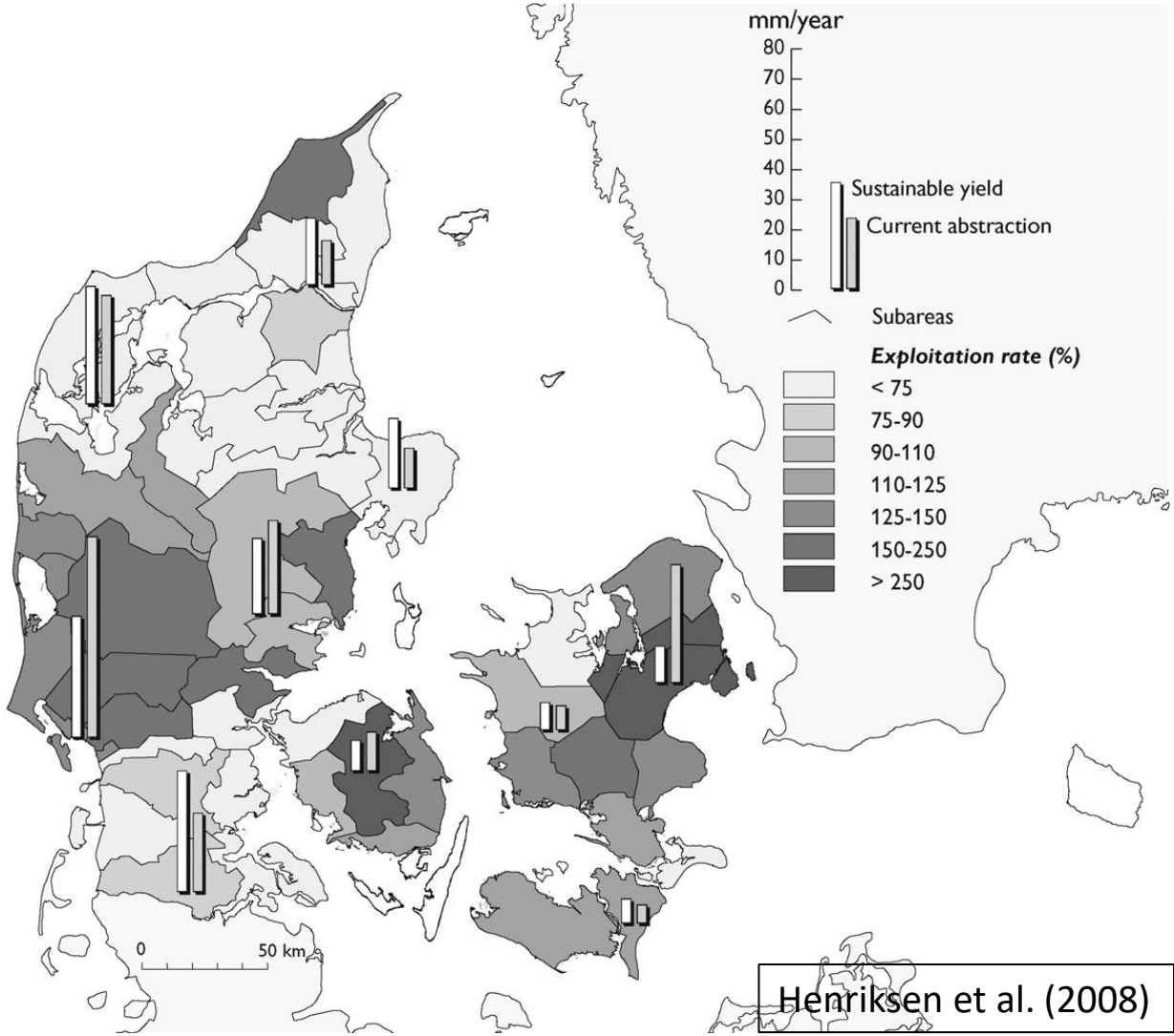
Water Resources in DK

- Land area of ~43,000 km2
- 60% agricultural land
- Temperate Climate
- Precipitation: ~800 mm/year
- Recharge: ~300 mm/year
- 99% of water supply from groundwater for all water uses
- Decentralised water supply (2,500 water utilities + 50,000 private wells) with simple treatment
- Simple treatment requires high groundwater quality ➔ protection required
- National infrastructure – crucial
  - Collection of new field data – for common use
  - Good national databases (mandatory to upload data, public access)
  - National monitoring program
  - National water resources model



Water Resources in DK

- How to quantify sustainable groundwater abstraction?
- Impacts of groundwater pumping on
  - Aquifers water quantity
  - Streamflow depletion (environmental flow)
- Focus on ecological conditions
- Sustainable GW use: Abstraction relative to natural recharge (30%)
- Integrated modelling necessary to make assessments



Henriksen et al. (2008)

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DK Model: The Danish National Water Resources Model

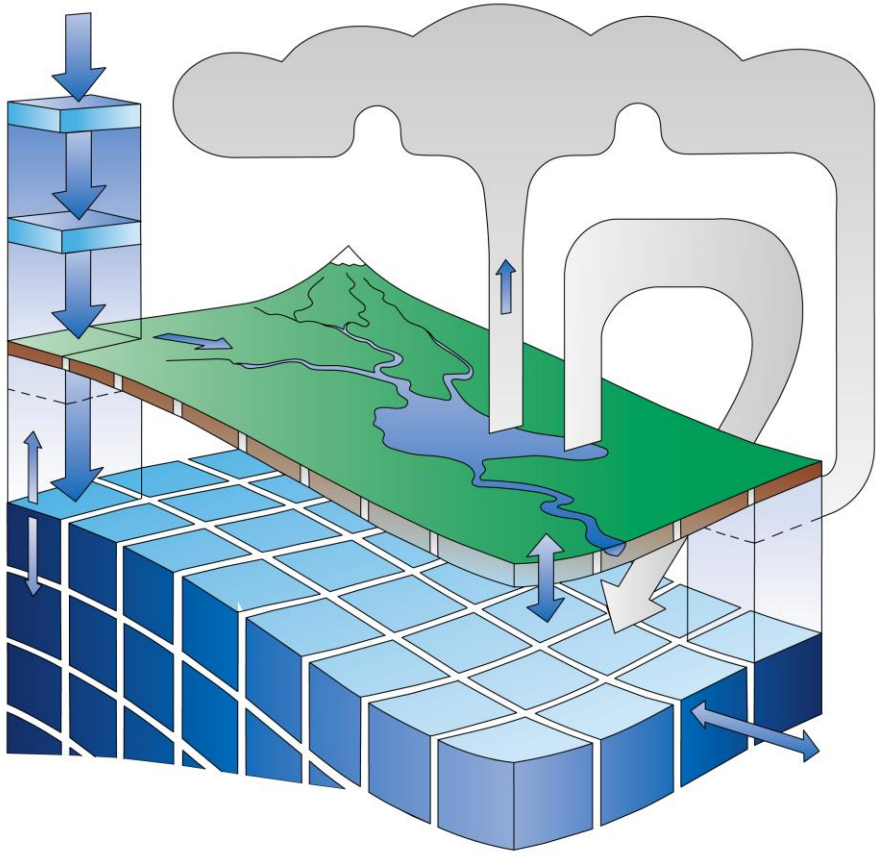
Modelling system – MIKE SHE/MIKE11

- Physically-based integrated model (surface, subsurface)
- Horizontal discretization: 500 x 500 m grid (100 m grid version developed 2020)
- Data rich model

25 years of development

Key Points

- Consistent water balance across the whole country
- Combines several national databases and data sources
- Acts as a national database for all available data relevant for quantitative water resources assessments



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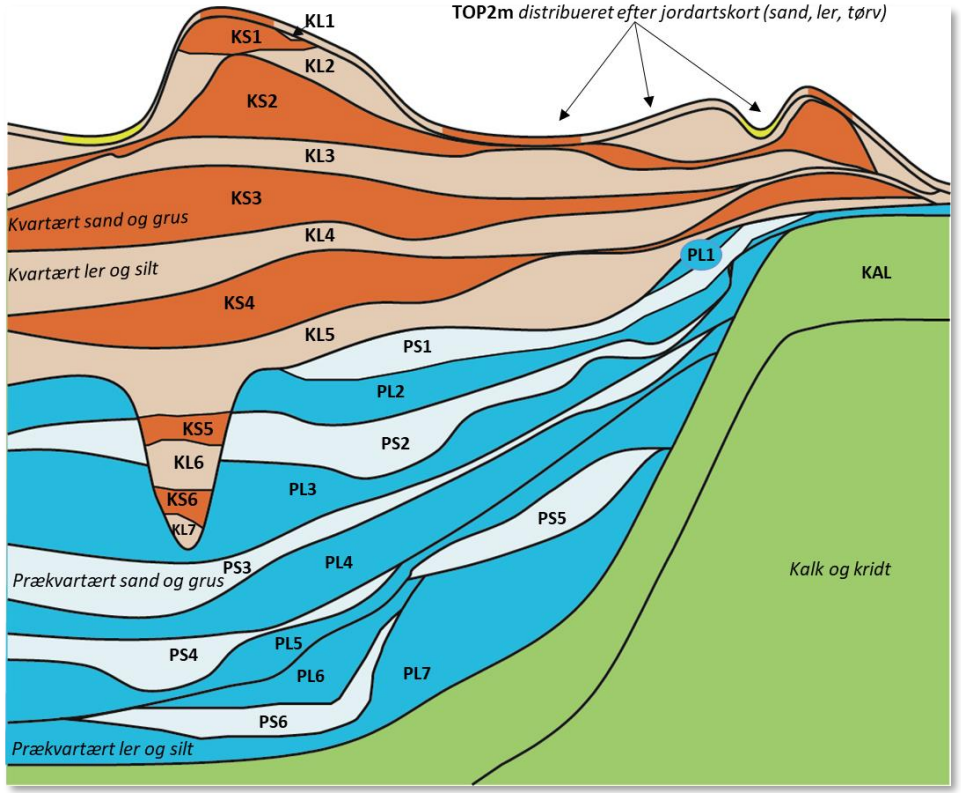
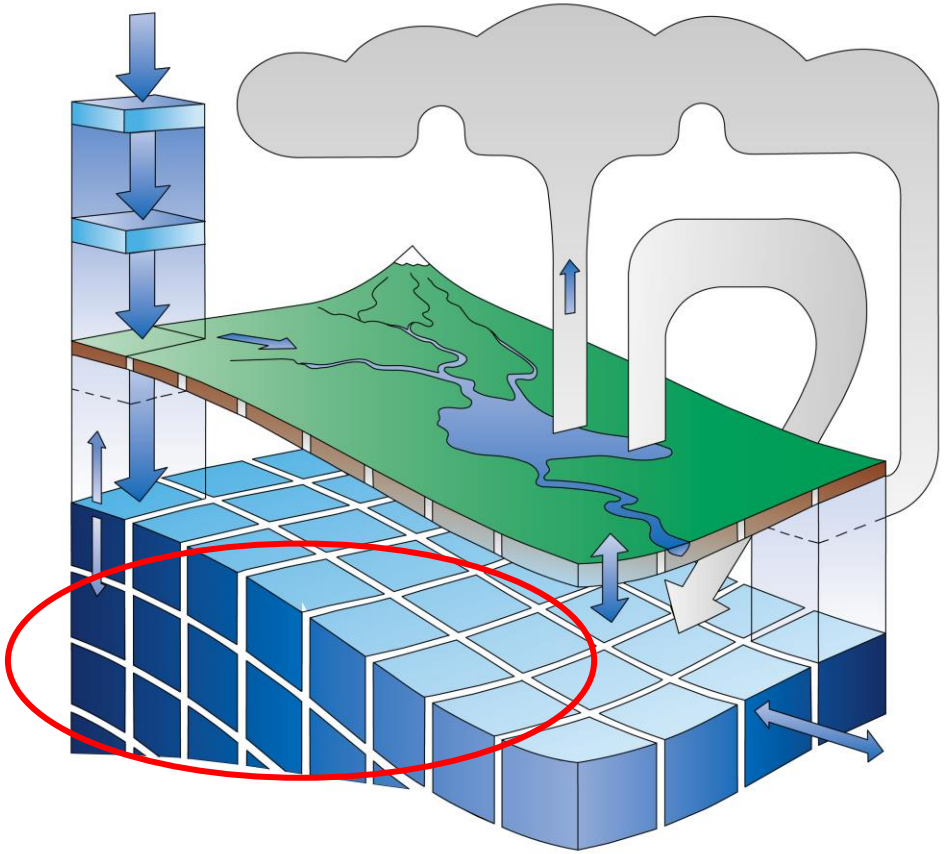
DK Model: Subsurface – 3D Hydrostratigraphy

3D model

- 200,000 boreholes
- Airborne geophysics





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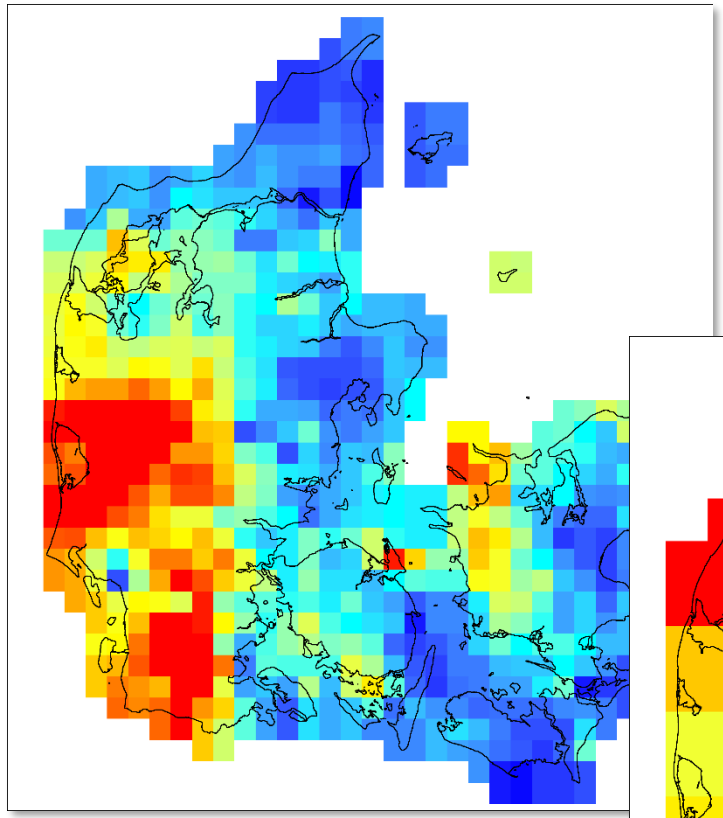
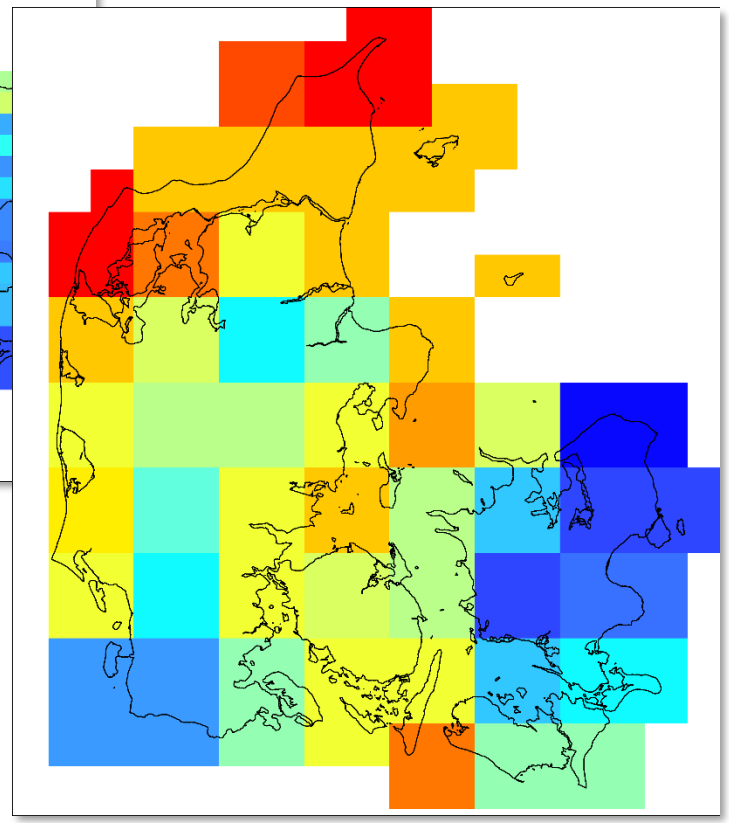
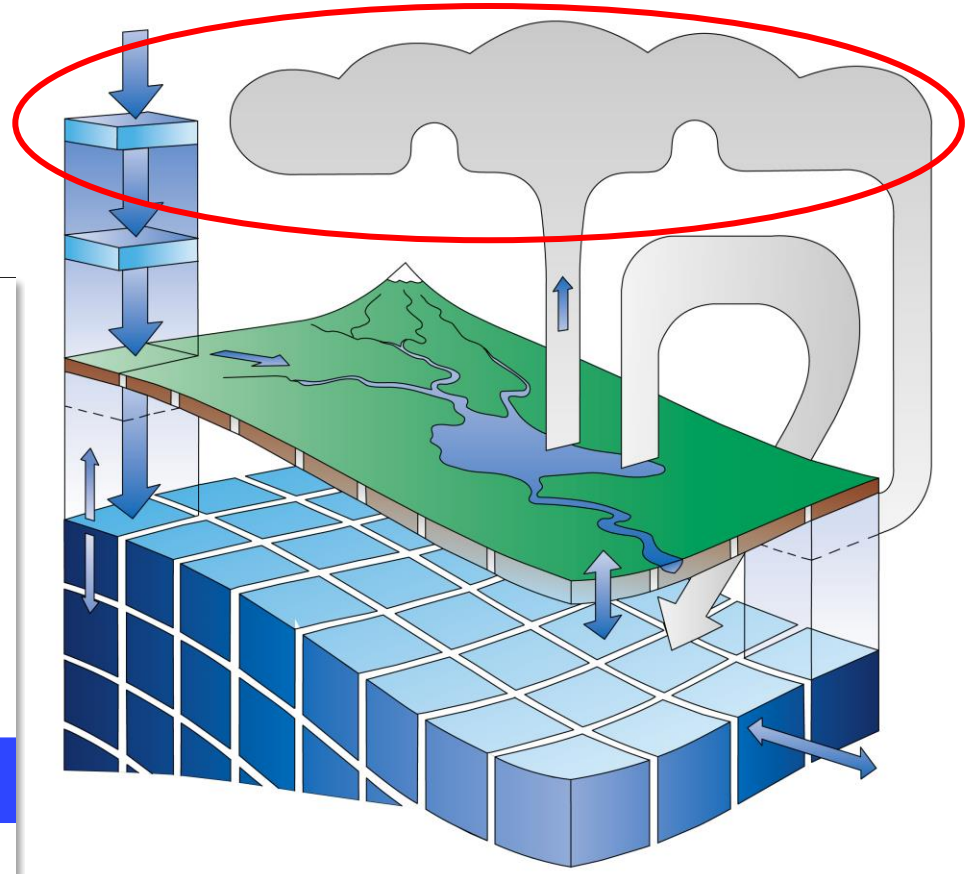
DK Model: Climate Data



Precip: 10 x 10 km^2 grids



Temp, PET: 20 x 20 km2 grids



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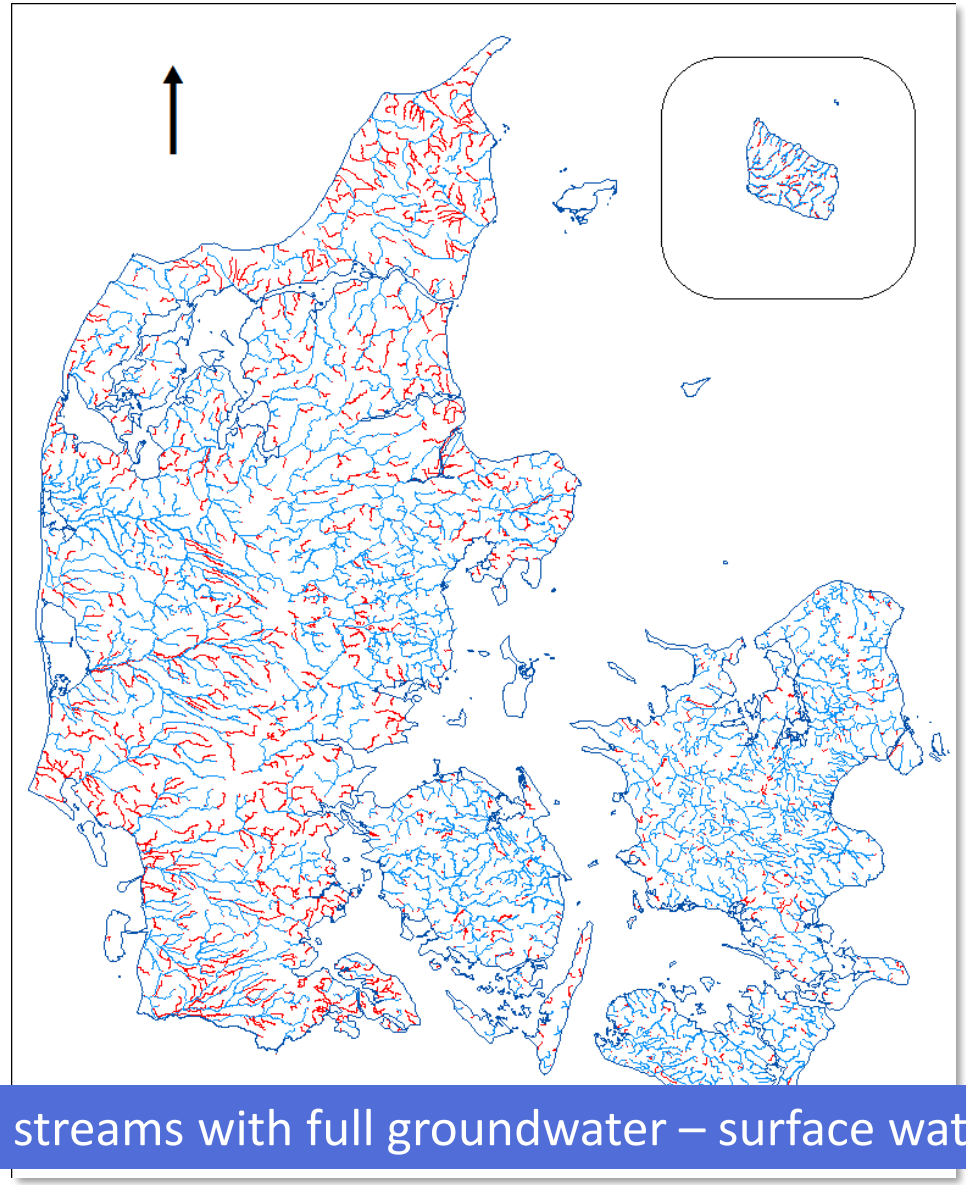
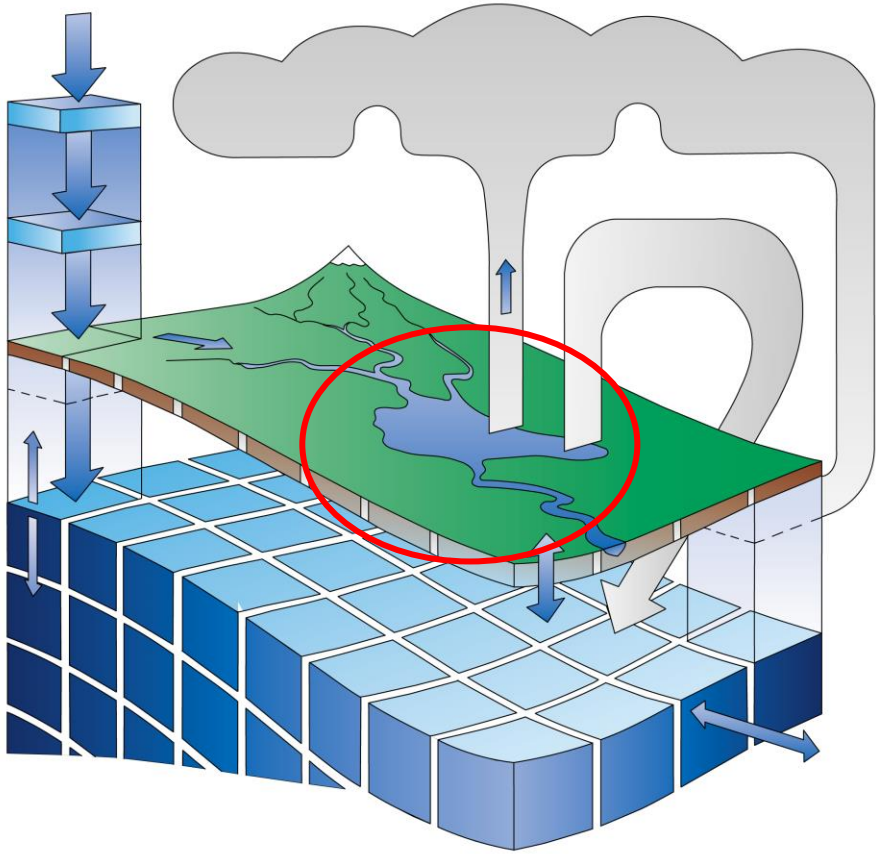
DK Model: Stream Network





~16.000 km streams with full groundwater – surface water coupling

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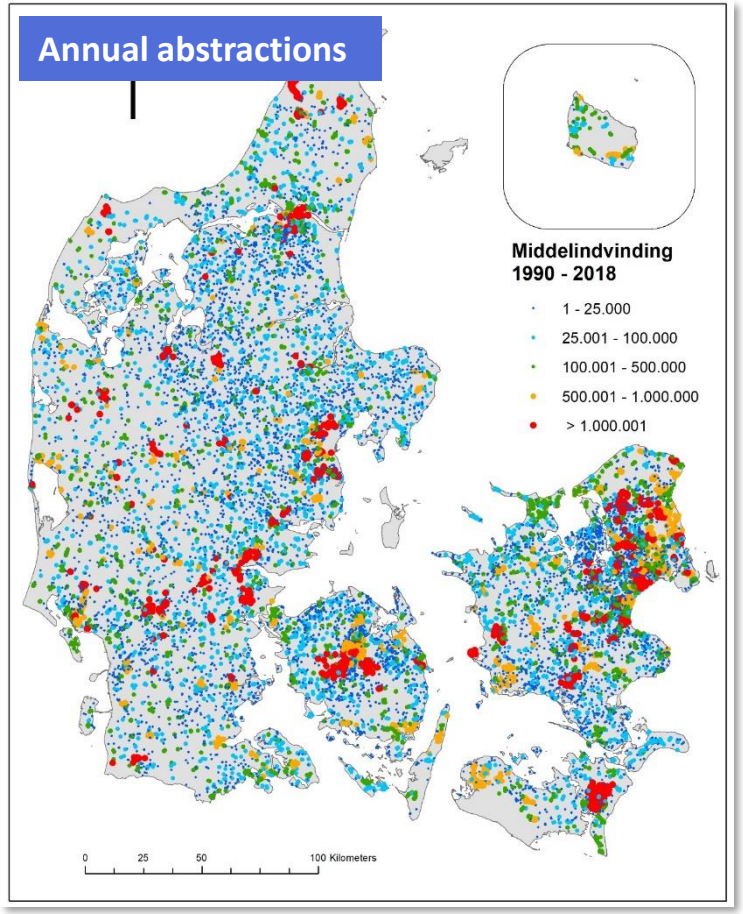
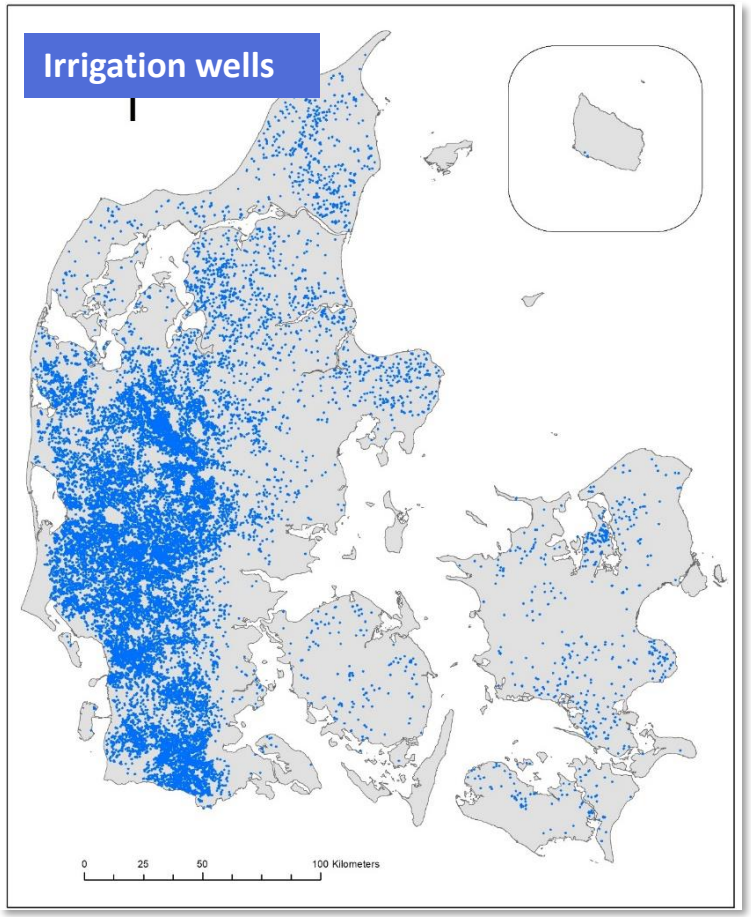
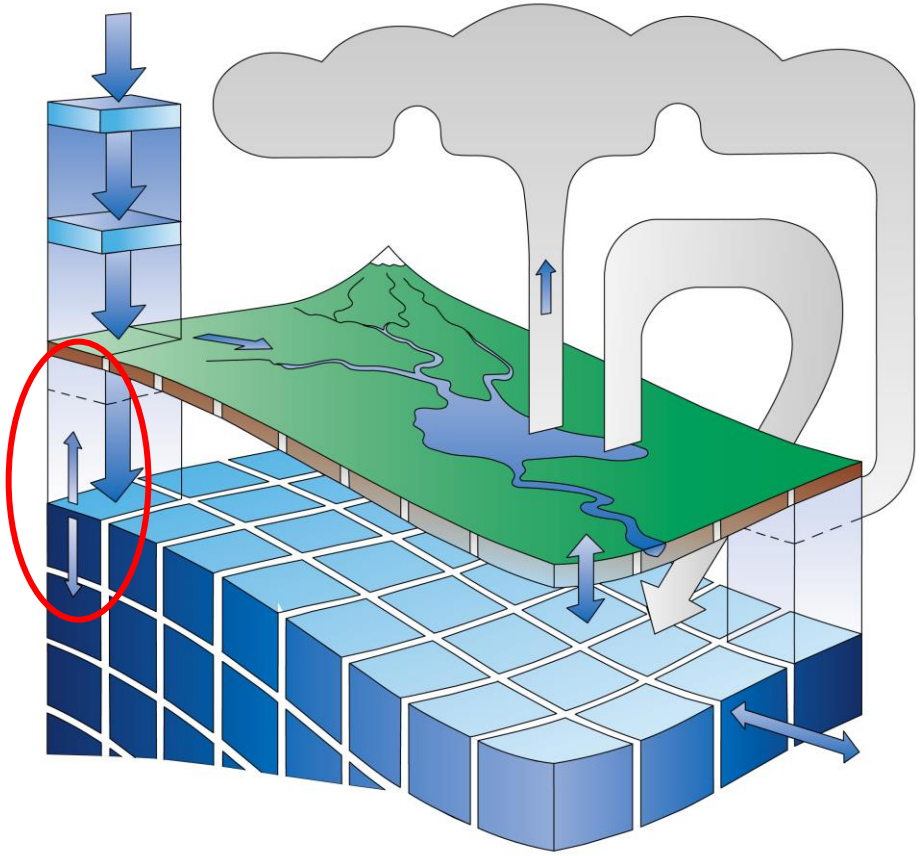
DK Model: Groundwater Abstractions







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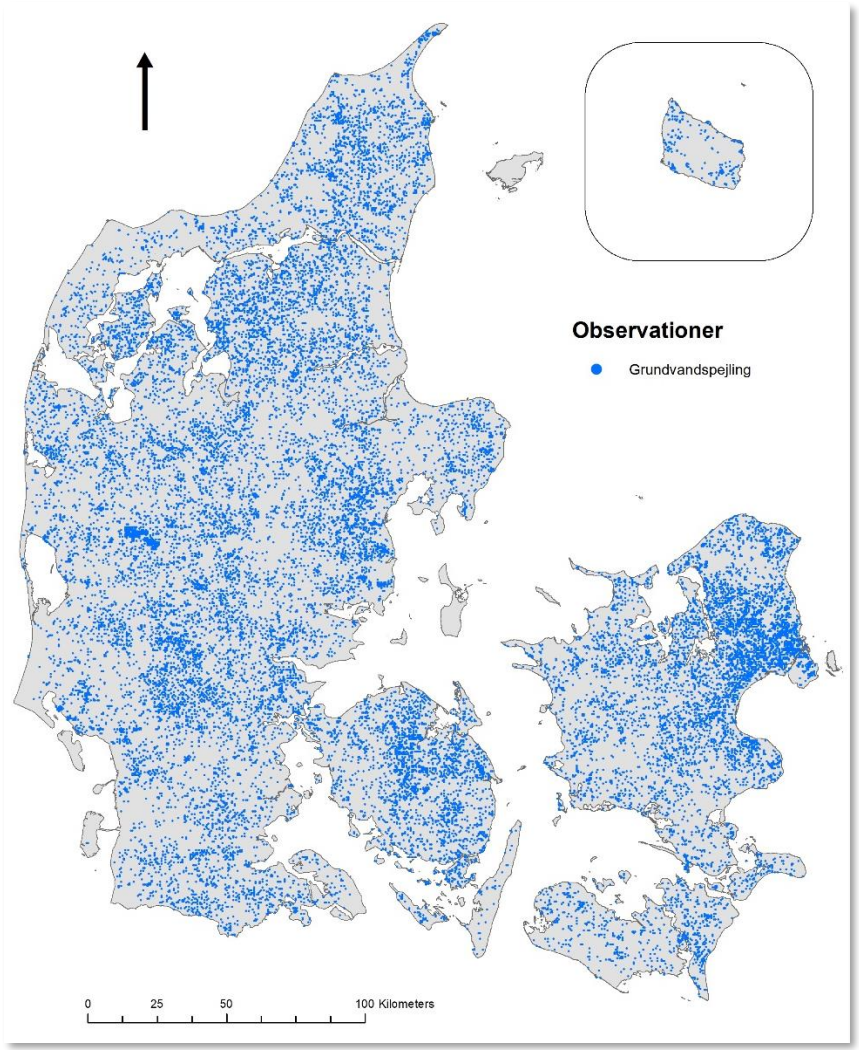
DK Model: Observations

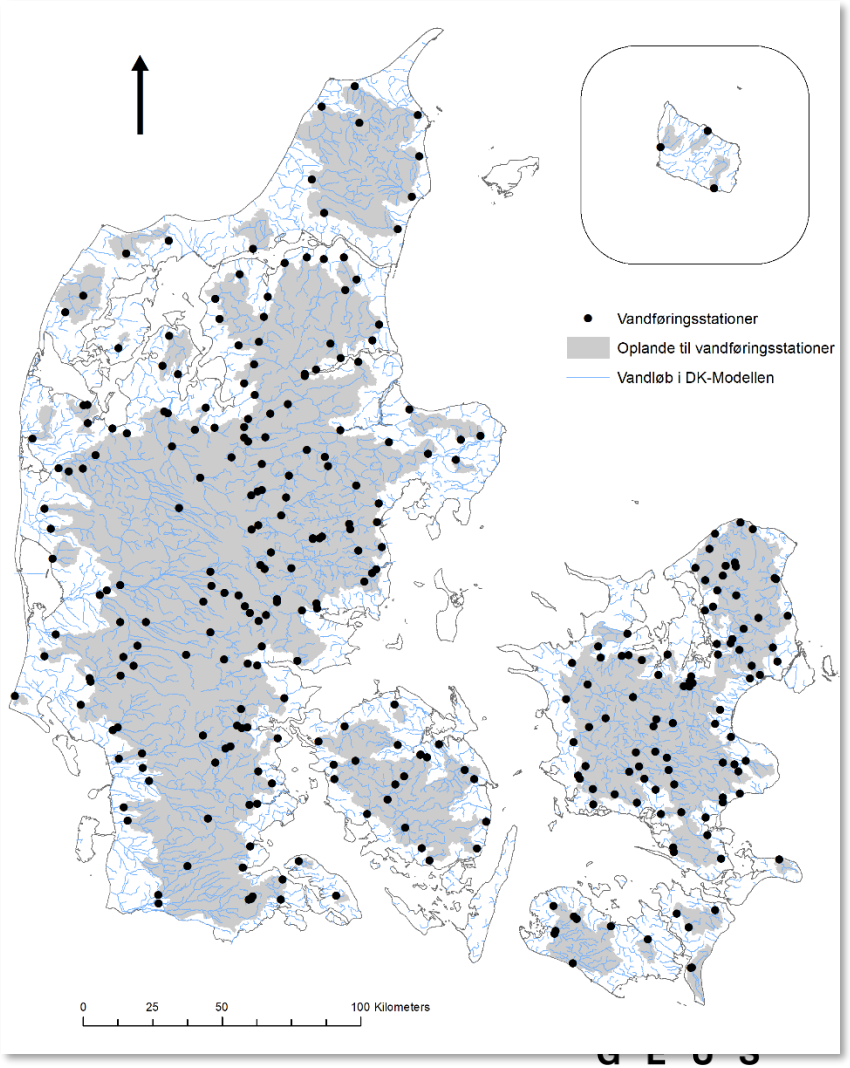


Groundwater levels

- Selected from Jupiter (well database)
- ~29.000 intakes

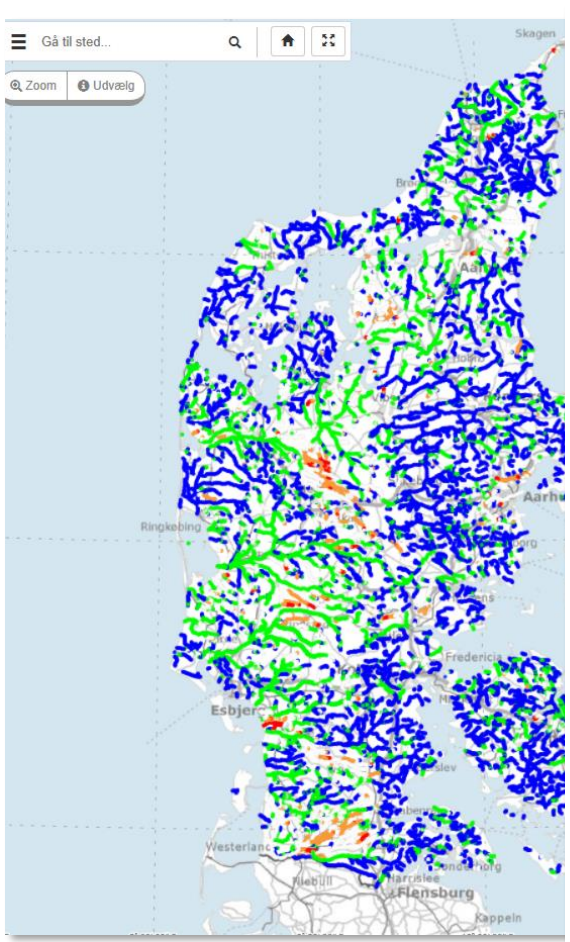
Streamflow

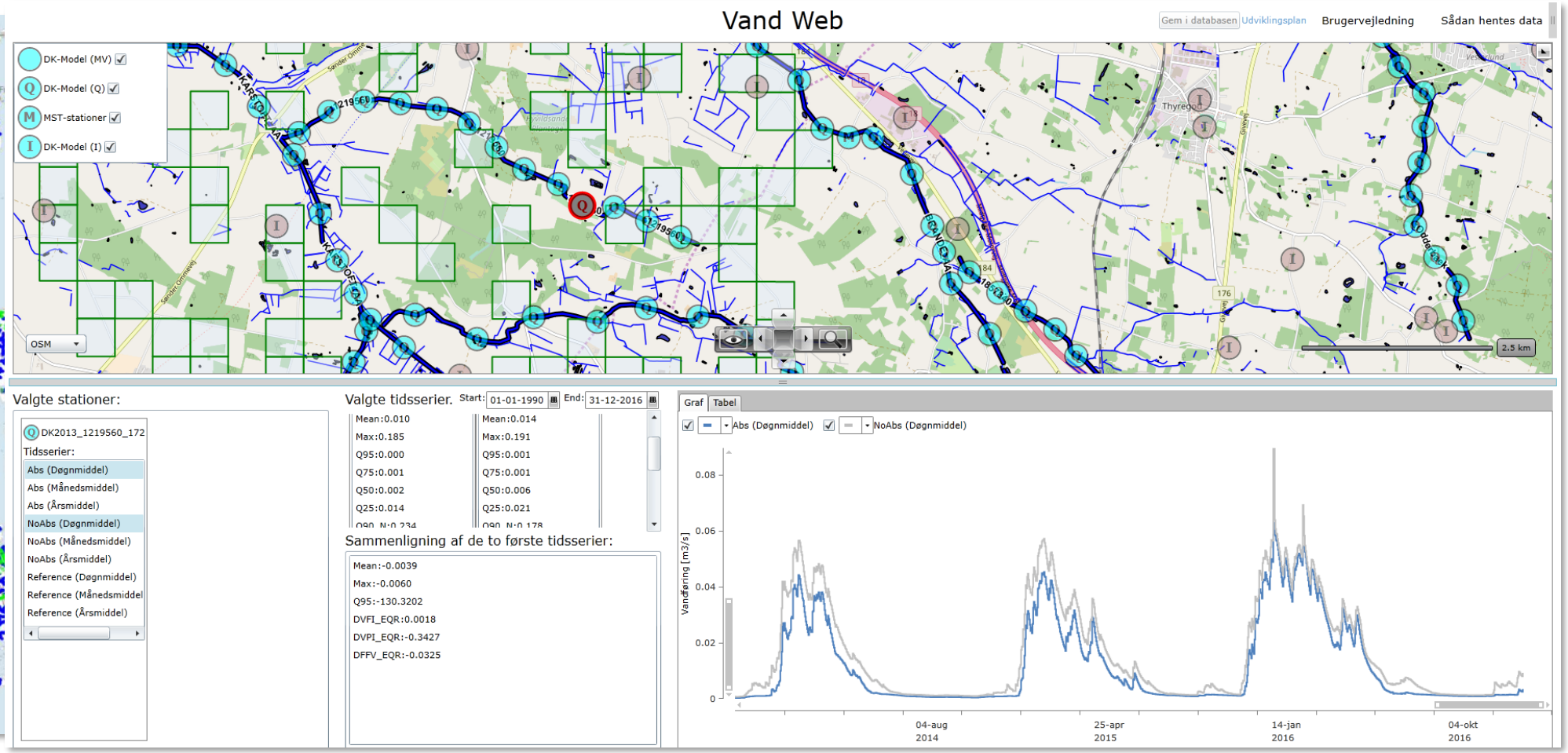
- ~305 stations



DK Model: Application

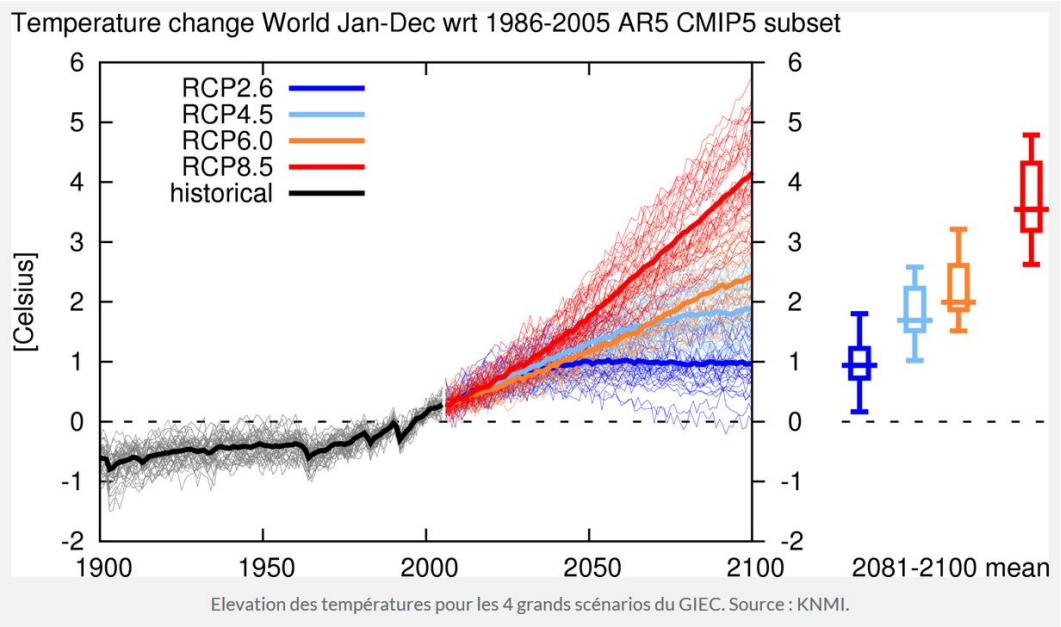
- Water management – Effect of abstraction



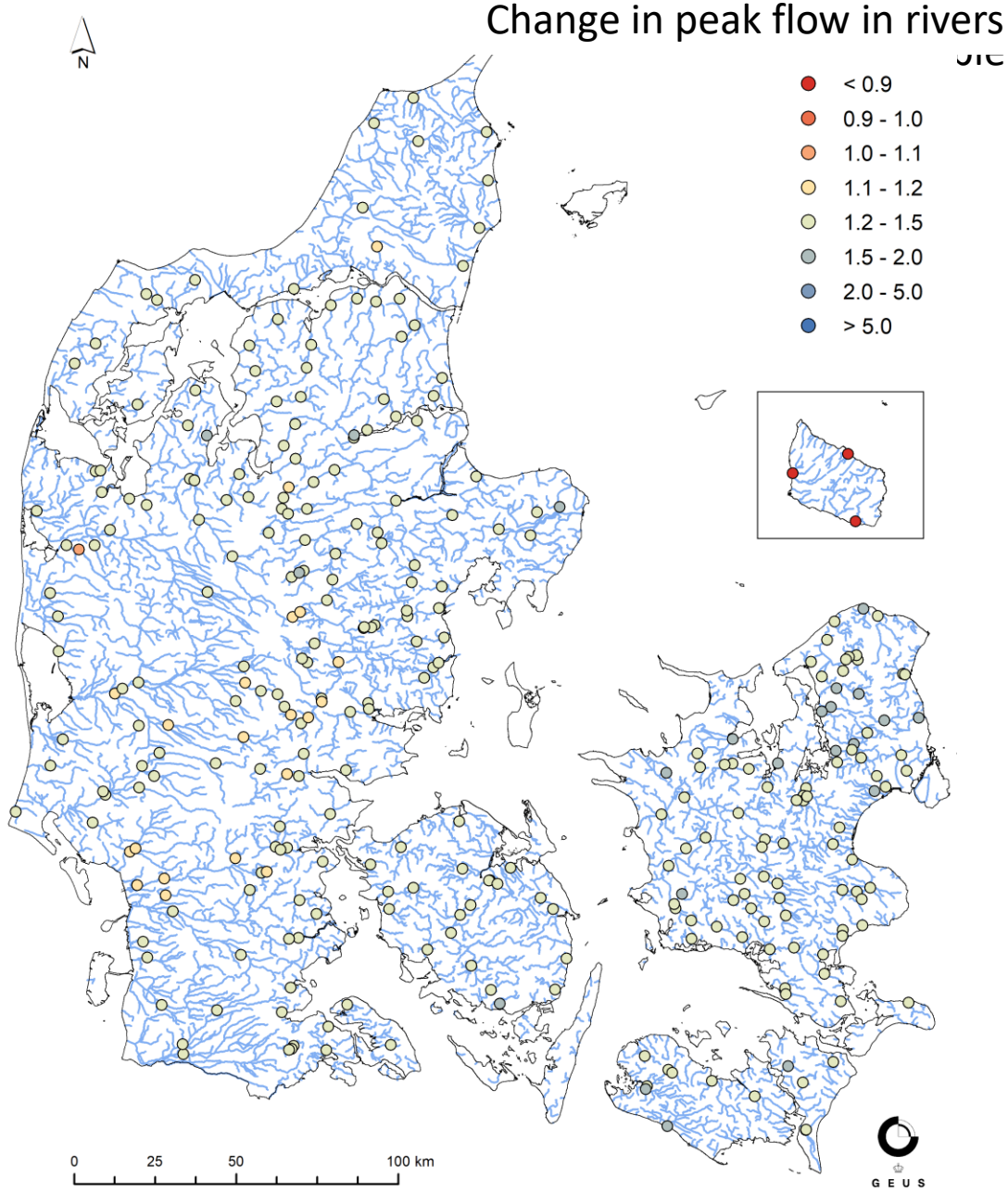


DK Model: Application

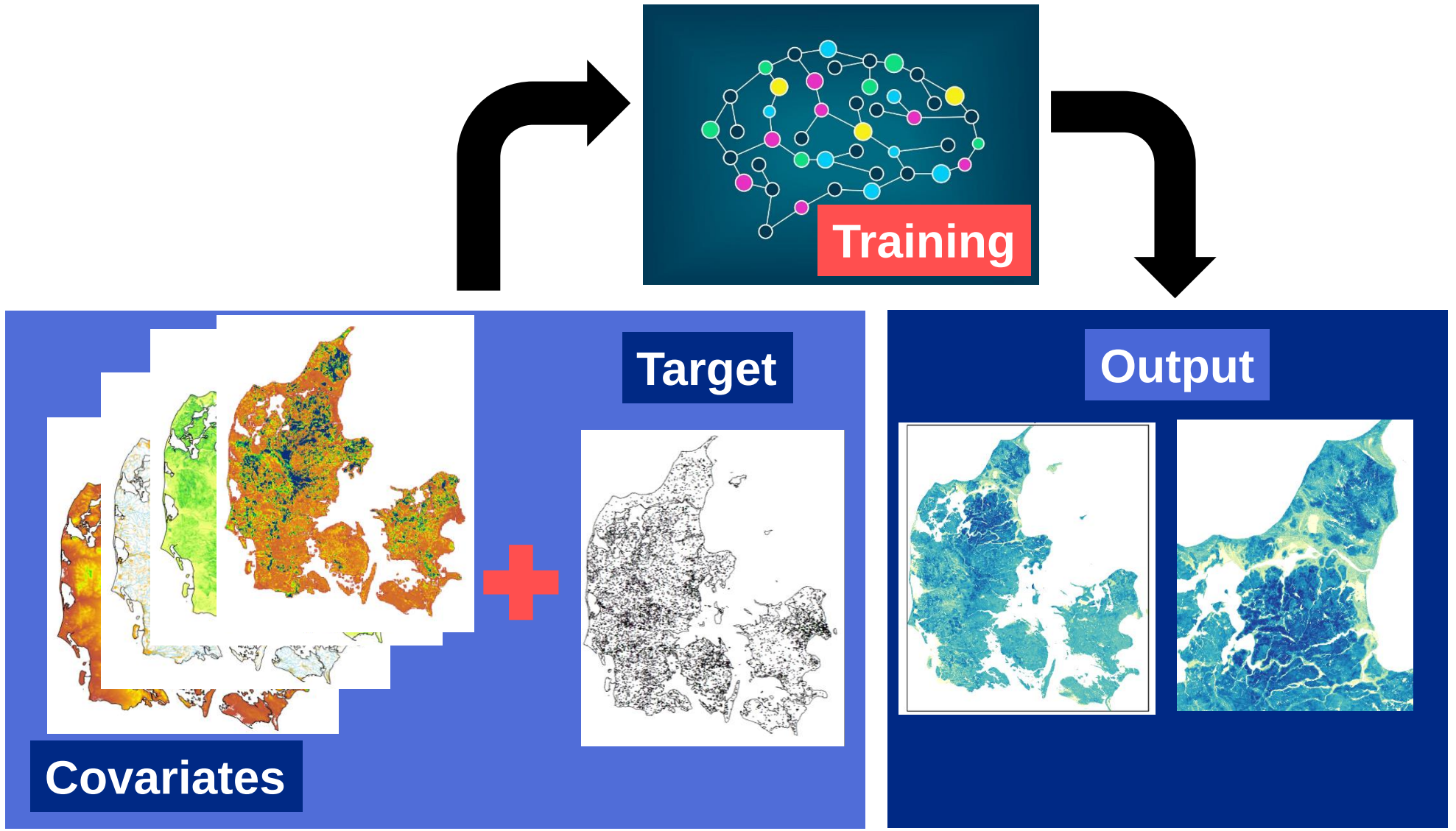
- Climate Change Impact Analysis on water resources
- Propagate climate change uncertainty via ensemble modelling



Elevation des températures pour les 4 grands scénarios du GIEC. Source : KNMI.



Machine Learning for high resolution models



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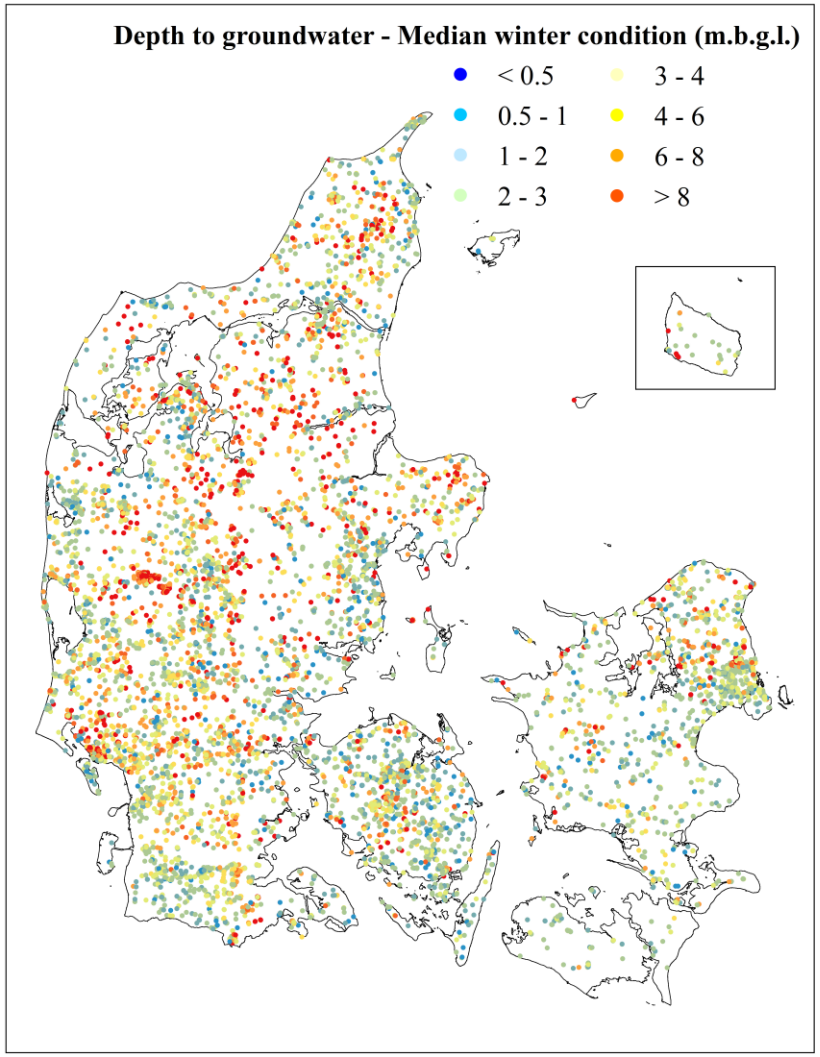
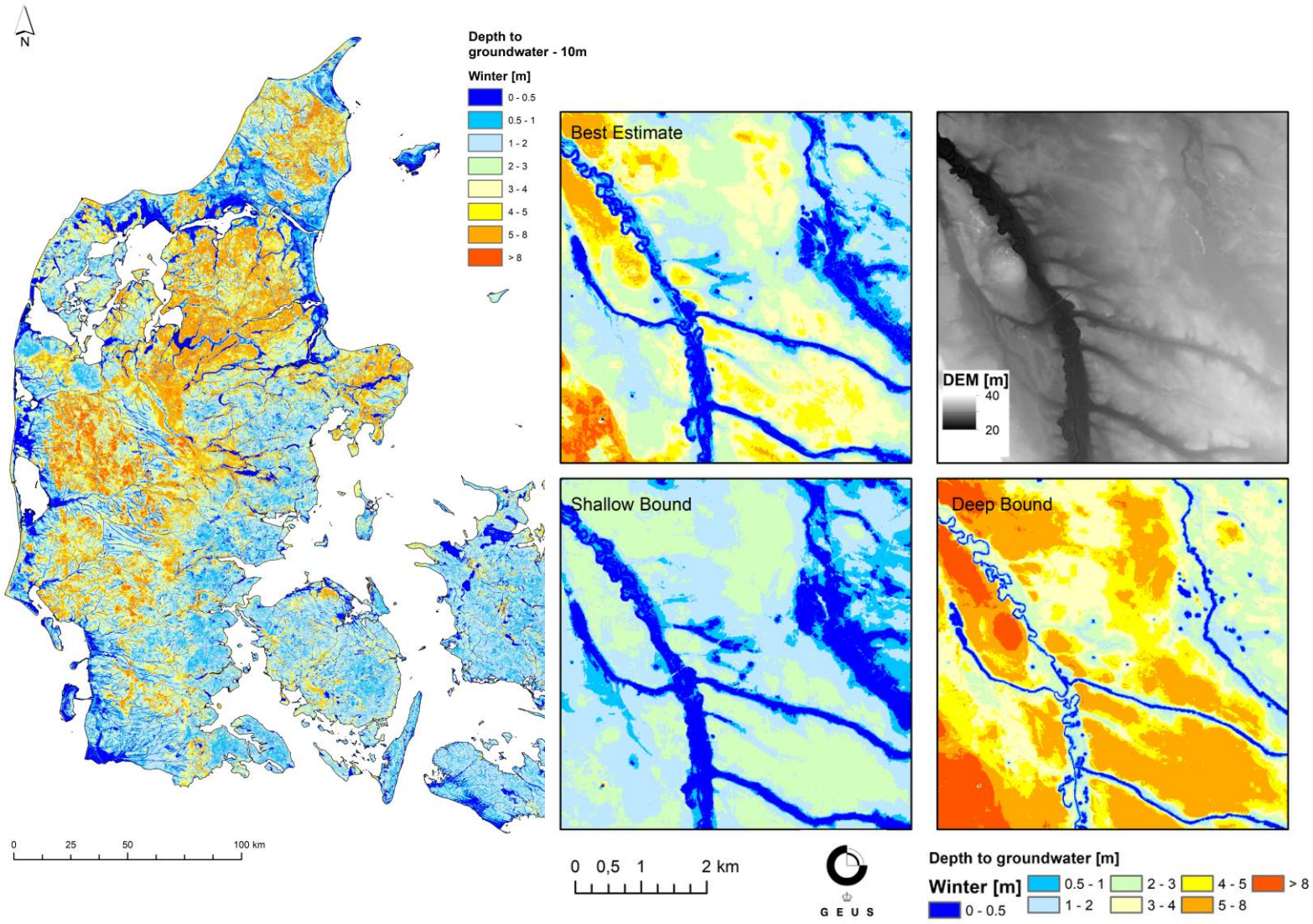
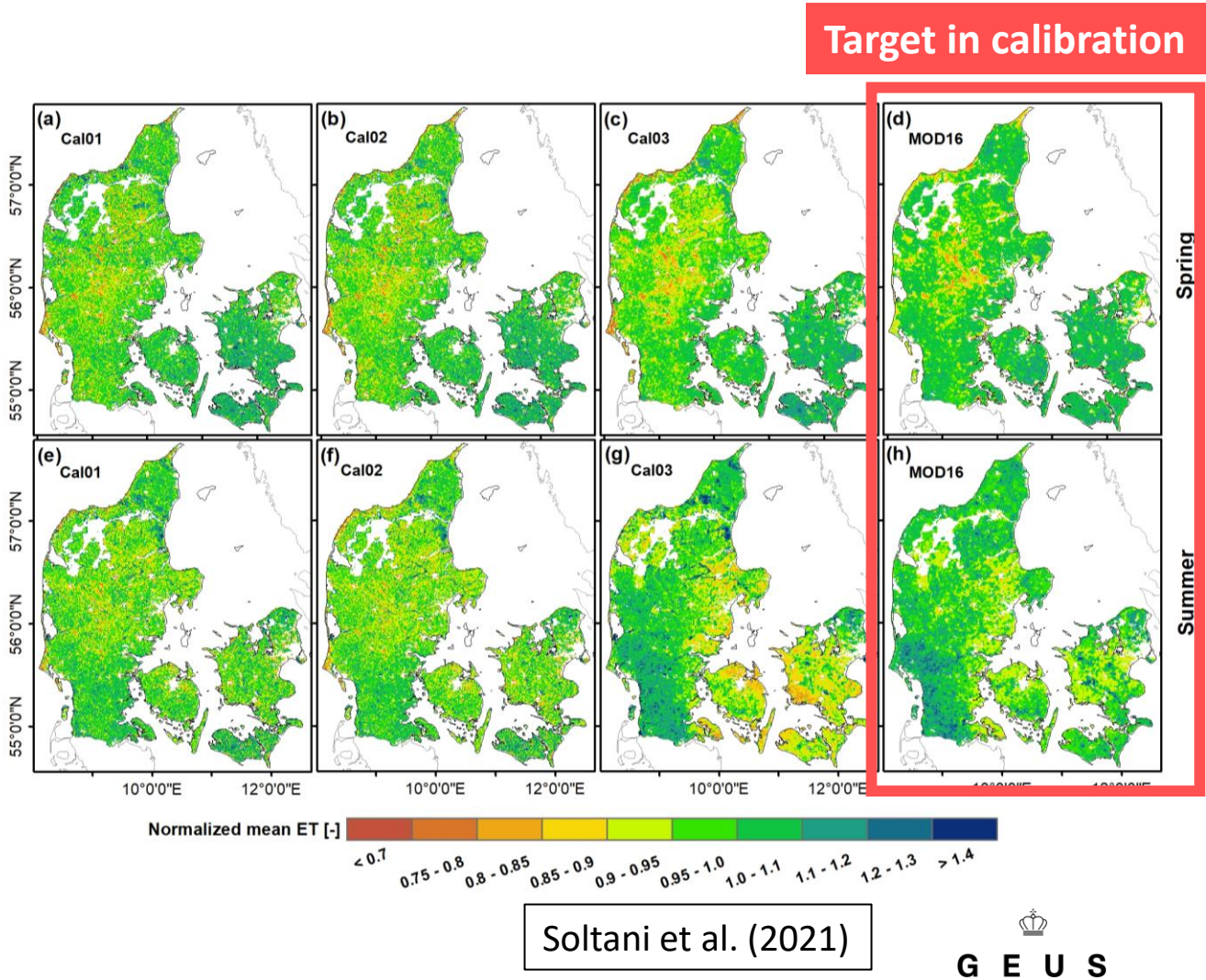
Machine Learning for high resolution models





Satellite Remote Sensing

- Focus on spatial pattern performance of hydrological models
- Evapotranspitaion key flux of the hydrological cycle; depending on soil, vegetation and climate
- Better representation of evapotranspitaion poteitnally yields a better representation of gw rechrage



Soltani et al. (2021)

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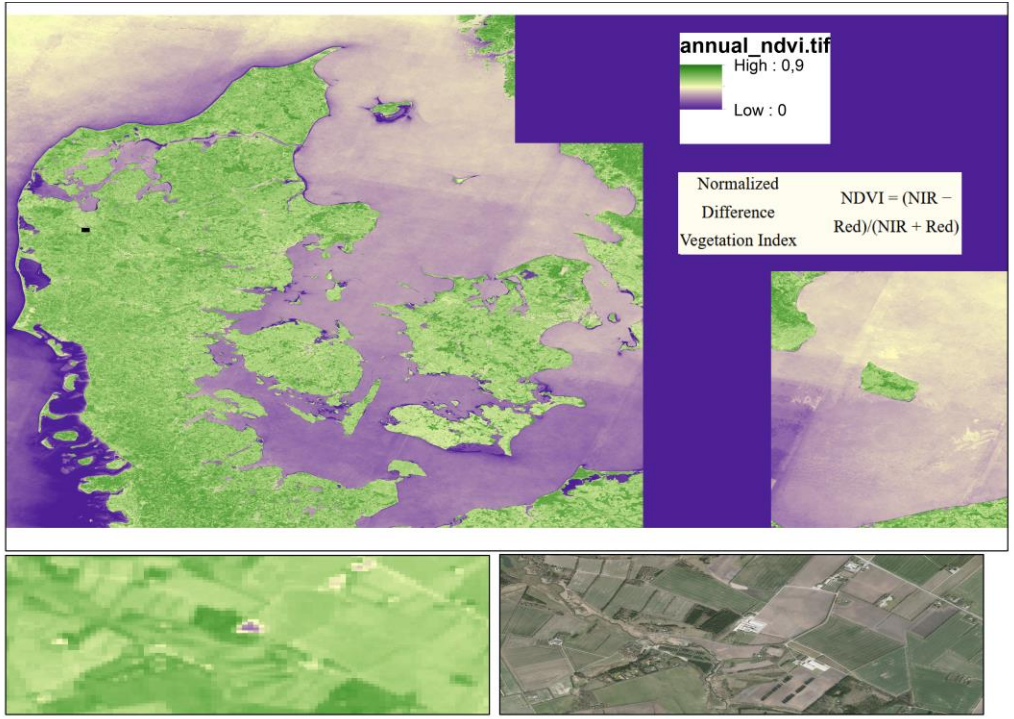
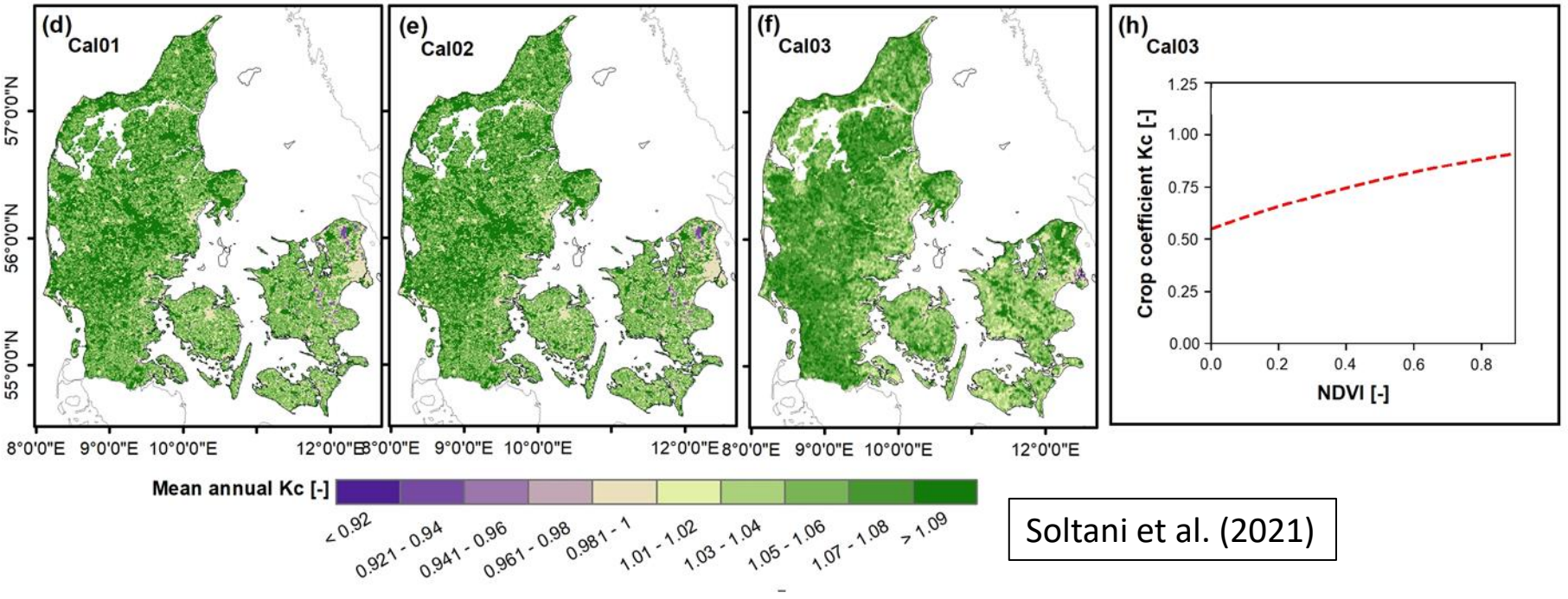
Satellite Remote Sensing

- Unique opportunities to utilize RS data in hydrological modelling for (1) **parametrization** –> seamless physically consistent model inputs





Soltani et al. (2021)

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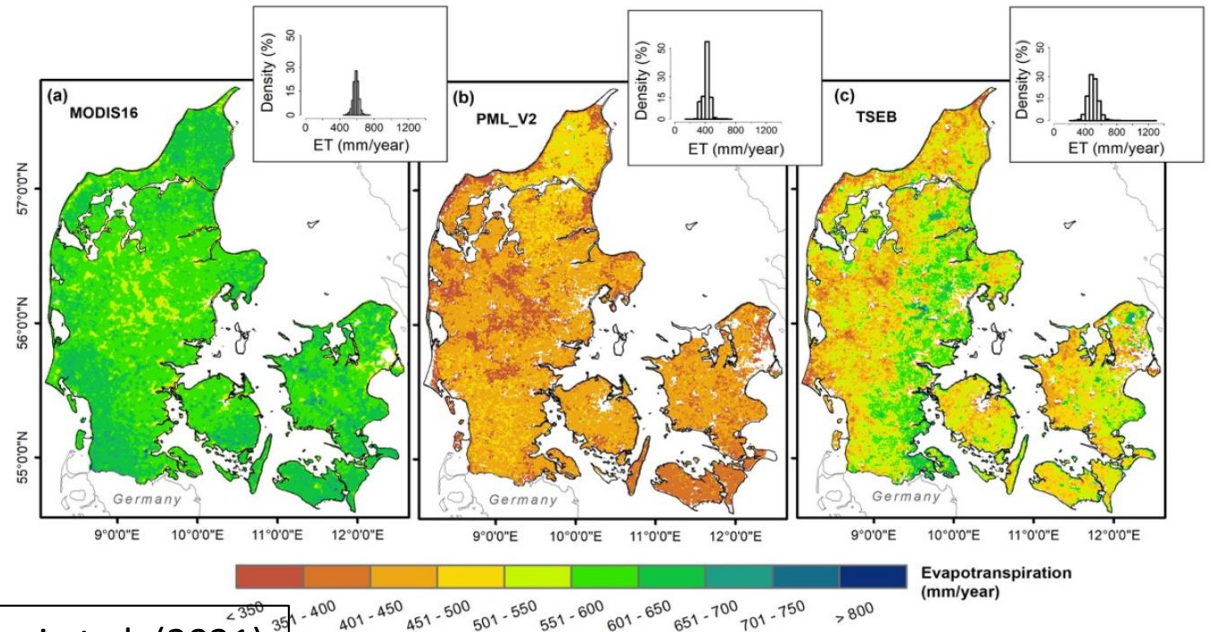
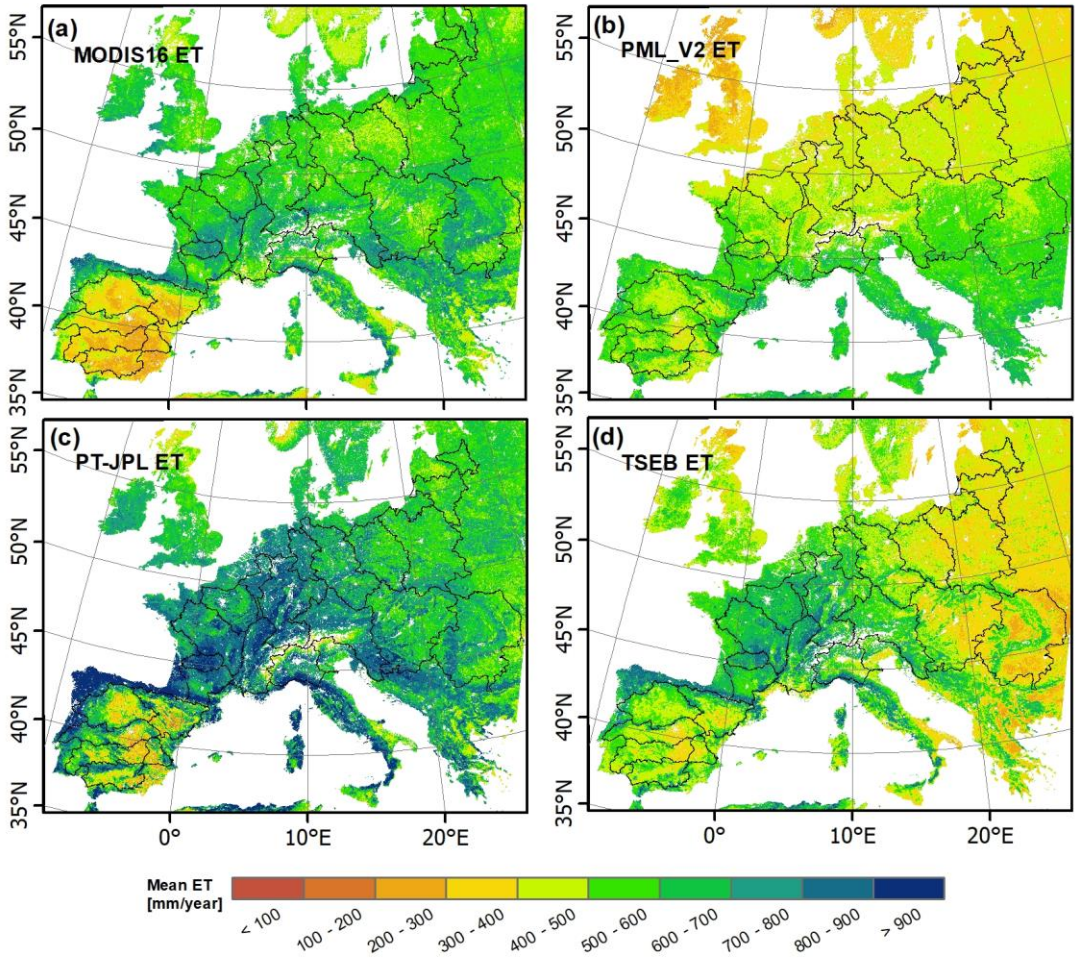
Satellite Remote Sensing

- Unique opportunities to utilize RS data in hydrological modelling for (2) **evaluation** –> spatial pattern of evapotranspiration to better model water fluxes



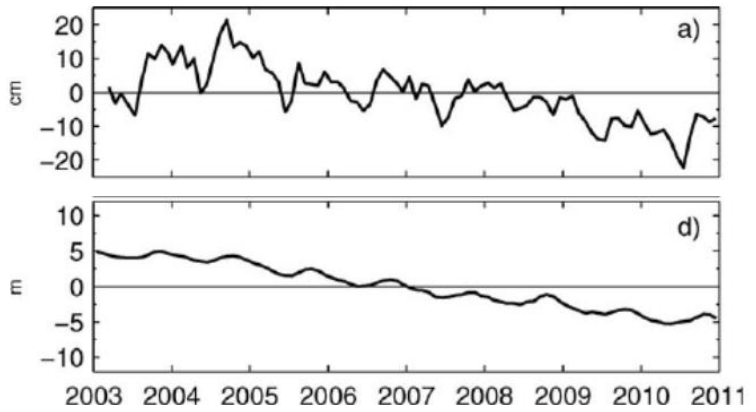
Soltani et al. (2021)



Stisen et al. (2021)

Irrigation Quantification in the China

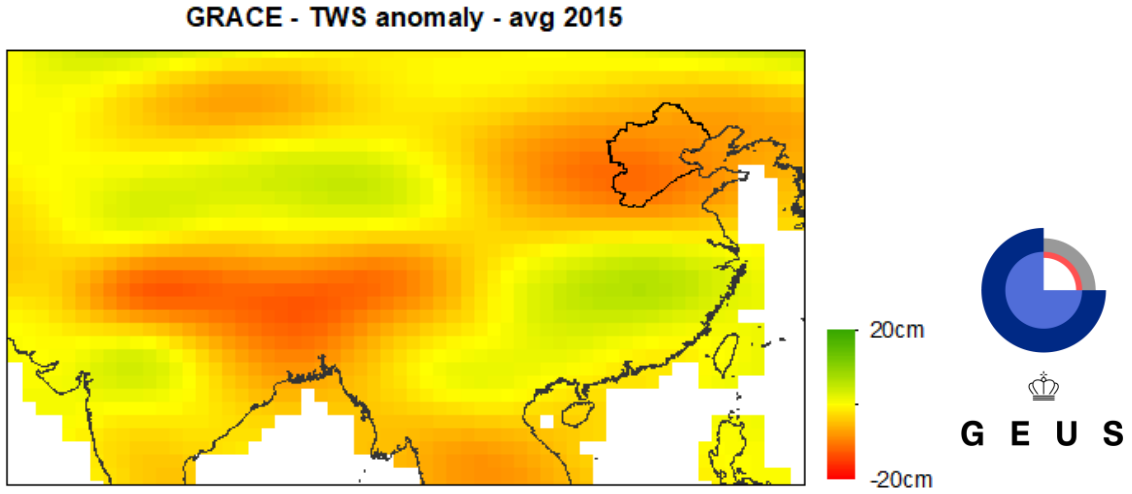
- North China Plain global hotspot for groundwater depletion
- 3 km^3 annual overexploitation
- Agriculture is accountable for 70% of total GW consumption
- Irrigation quantities largely unknown especially its spatio-temporal pattern



Satellite measured stroage

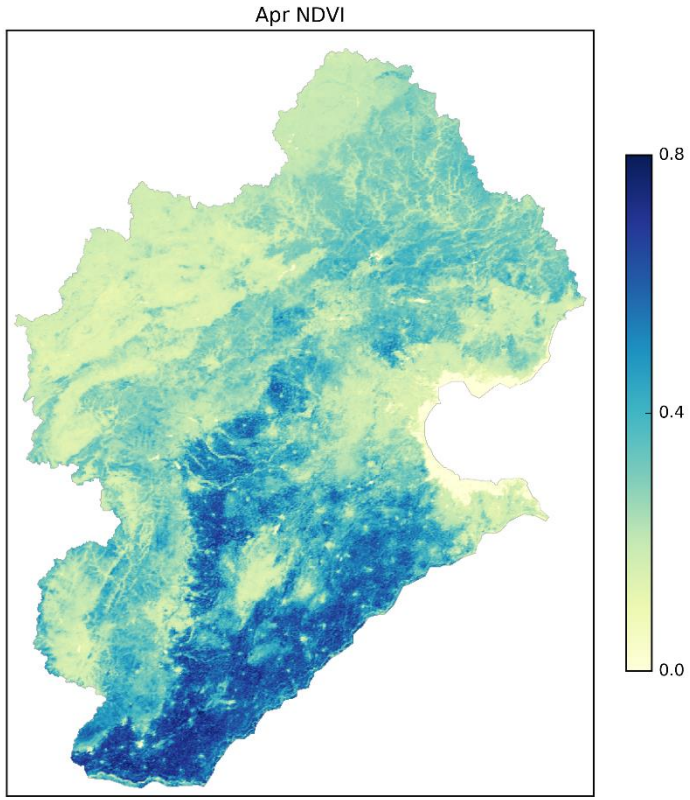
Groundwater wells

Feng et al. (2013)

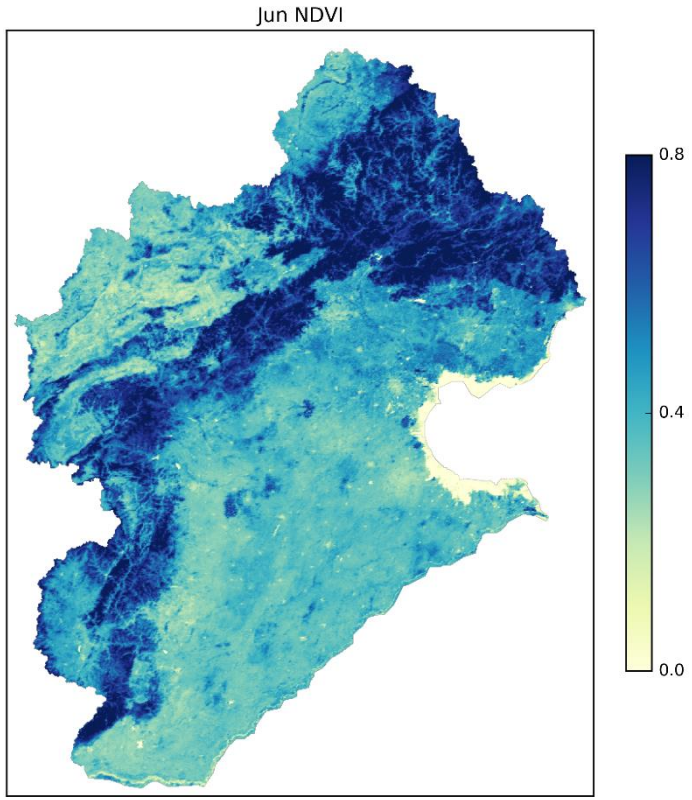


Irrigation Quantification

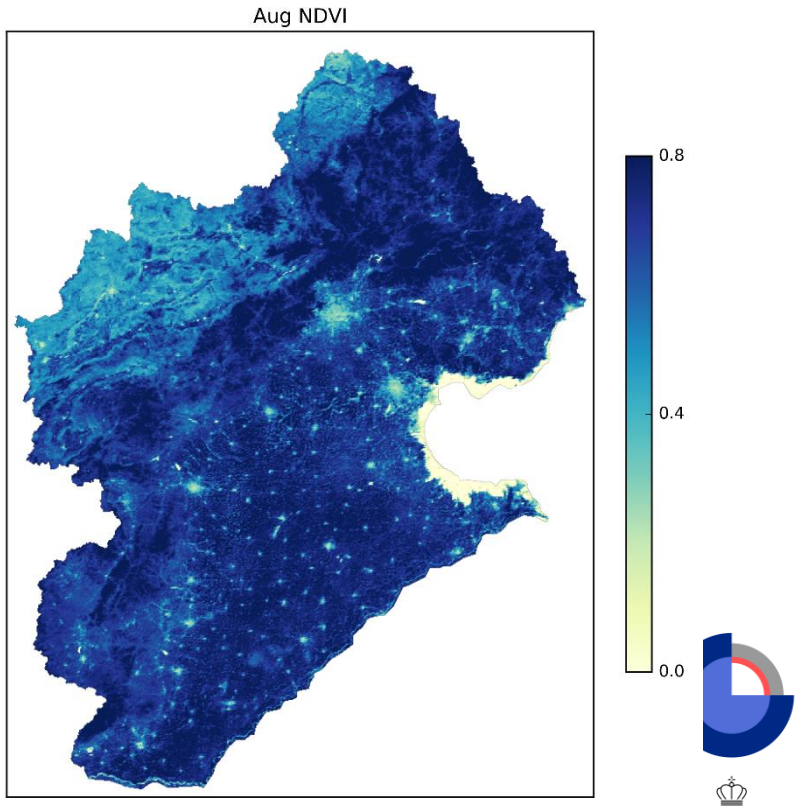
- Vegetation Pattern: normalized difference vegetation index (NDVI)
  - Haihe River Basin (320k km^2) North China Plain (140k m^2)



peak of winter wheat



winter wheat harvested



peak of summer maize

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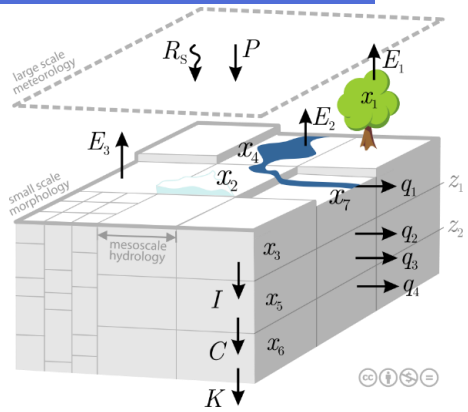
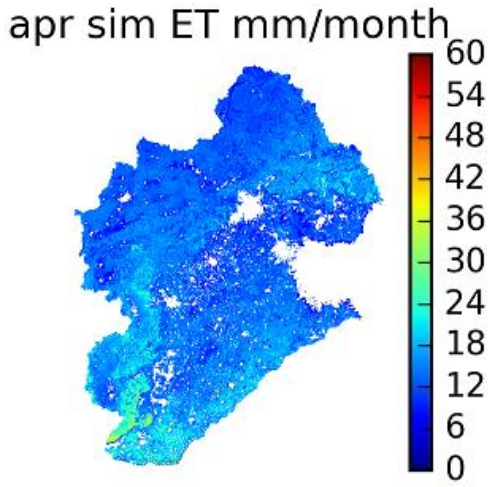
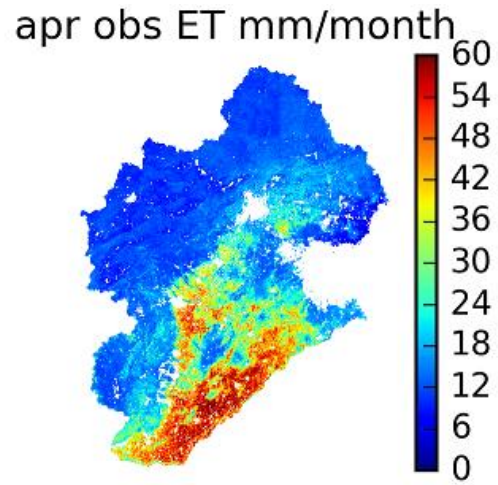
Irrigation Quantification

Hydrological Model mHM

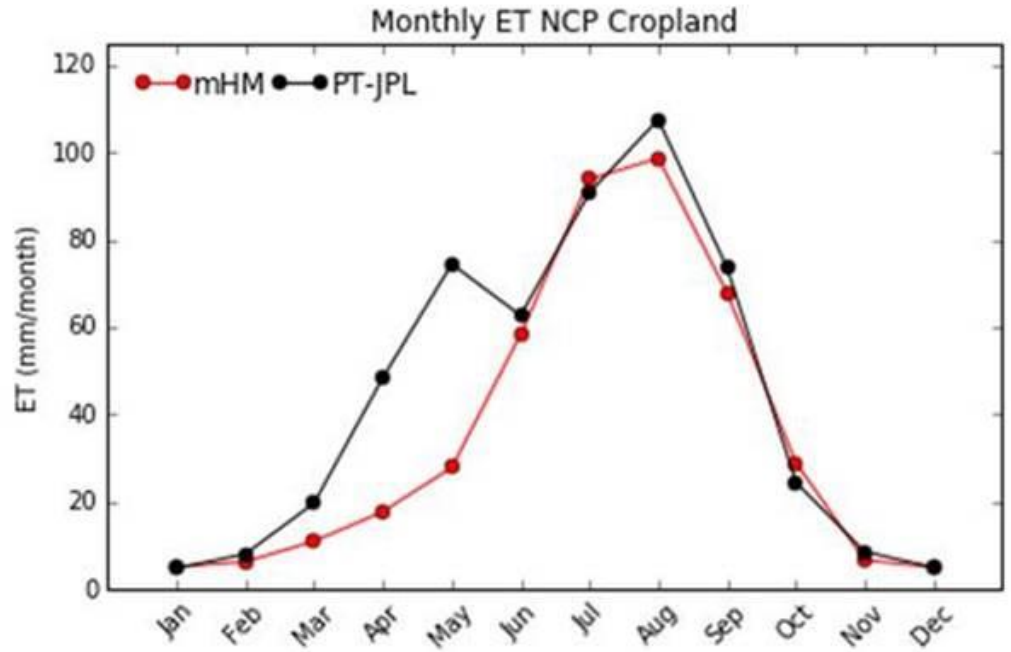


Remote sensing method PT-JPL





Difference: Irrigation loss



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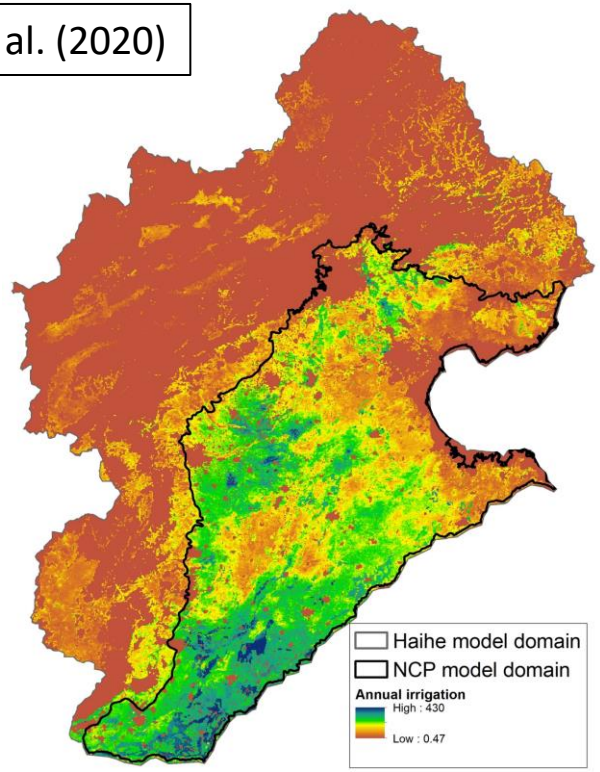
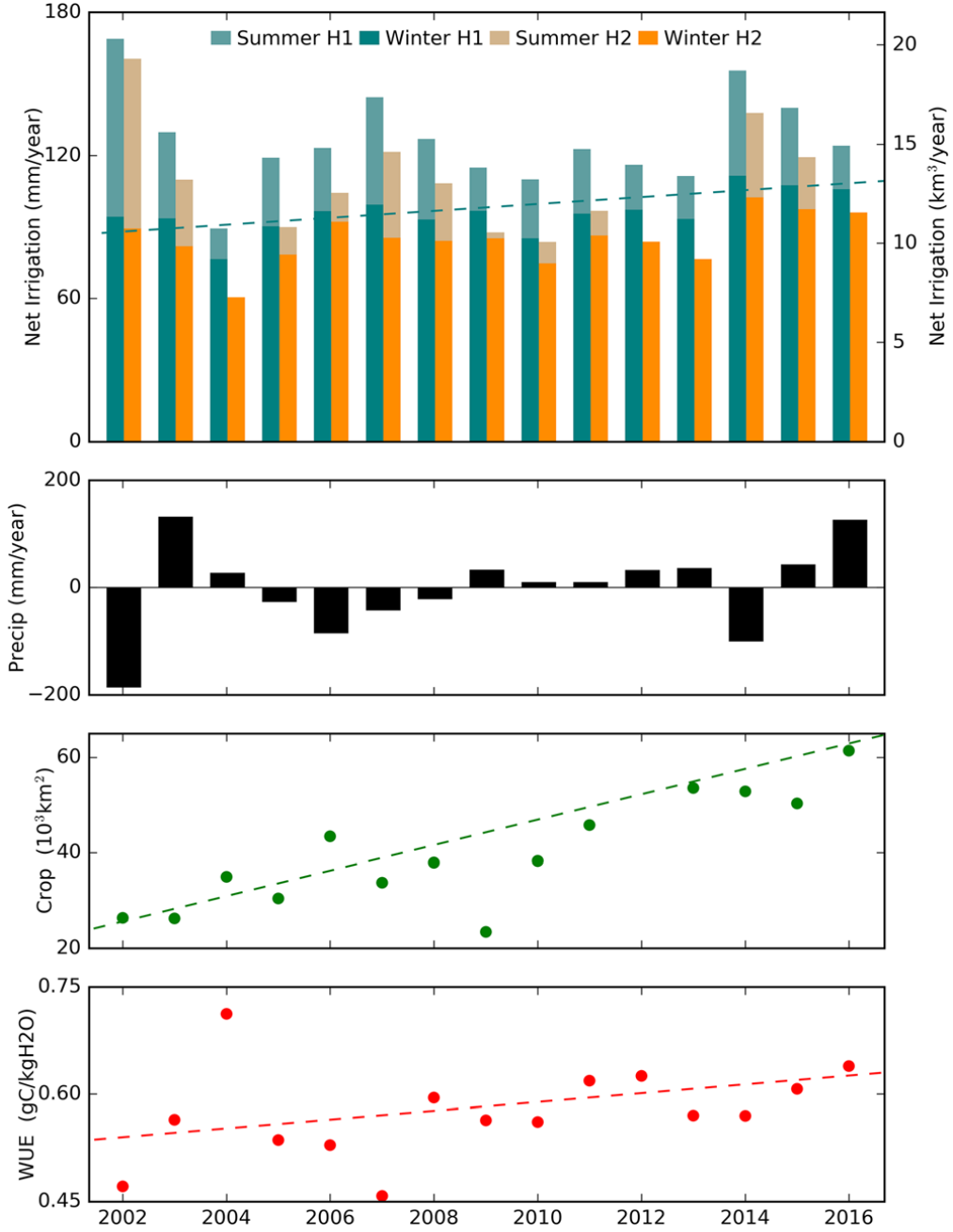
Irrigation Quantification

Koch et al. (2020)

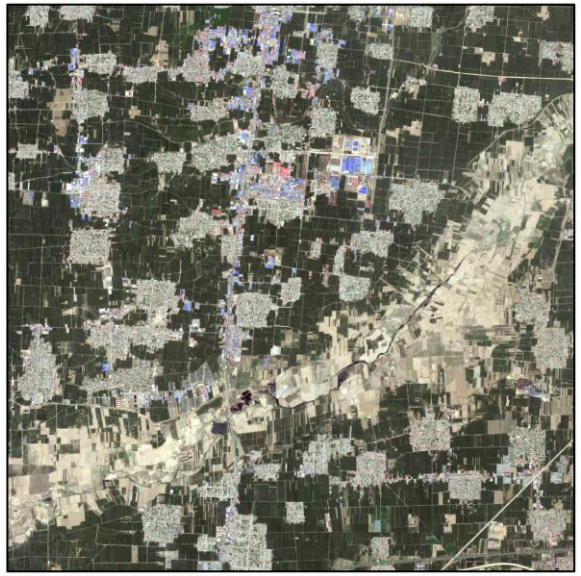


- Knowledge on irrigation crucial for management
- Water saving initiatives in China have led to an increase in water use efficiency.

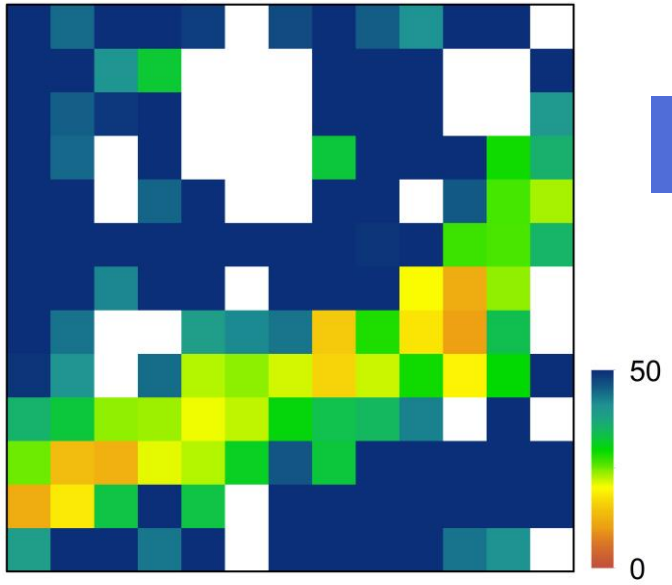


Irrigation Quantification

orthophoto



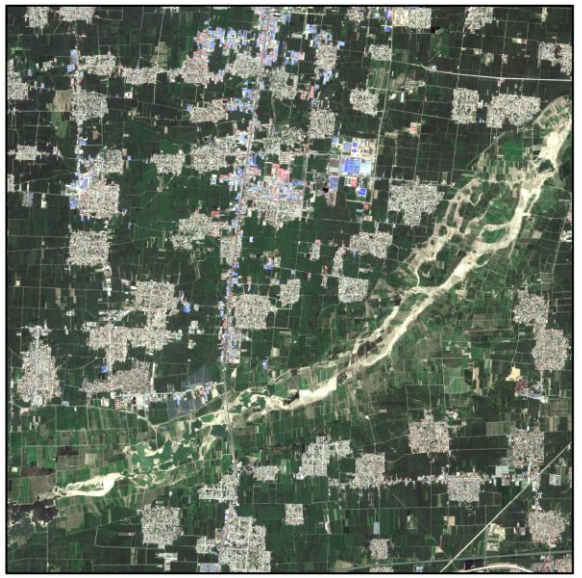
monthly irrigation loss [mm]



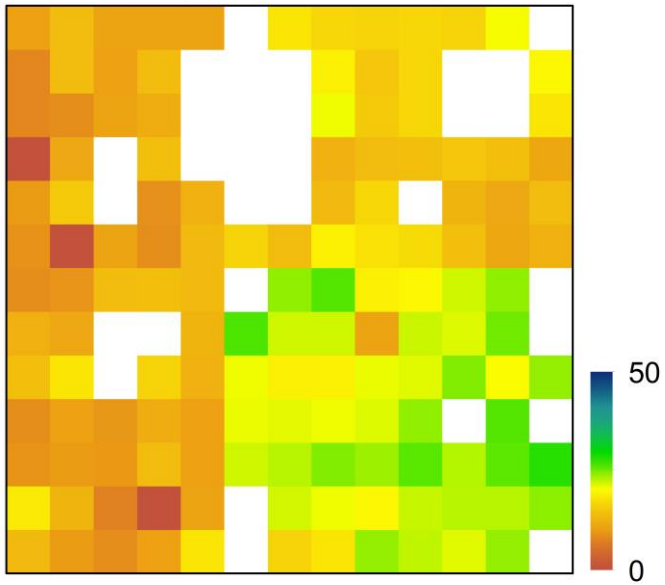
← Extensive irrigation in May (dry month)

Sporadic irrigation in July (wet month) →

orthophoto



monthly irrigation loss [mm]



@hydrokoch

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Final Remarks

- GEUS plays a key role in the national water resources management in Denmark – National Water Resources Model
- National infrastructure of high quality to address sustainable basin management (Data collection, Monitoring, Databases and Models)
- GEUS provides science-based solutions using state-of-the-art (climate change impact analysis, machine learning, satellite remote sensing)
- Integrating model, data and knowledge in novel ways (irrigation quantification)
- Future directions: (1) More data online, easily accessible for users, (2) real-time DK-Model with forecasting (drought and flood), (3) linking groundwater to green house gas emissions

GEUS