Participatory early warning and monitoring of groundwater flooding in Denmark and Copenhagen

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Societal challenges of climate change for Northern European freshwater cycles

- More wet in winter
- More dry in summer
- More extreme weather
- Increased shallow groundwater levels
- More groundwater, river, cloudburst and stormsurge floodings in rural and urban areas

NORDRESS WP 4.3 approach (participatory early warning and monitoring)

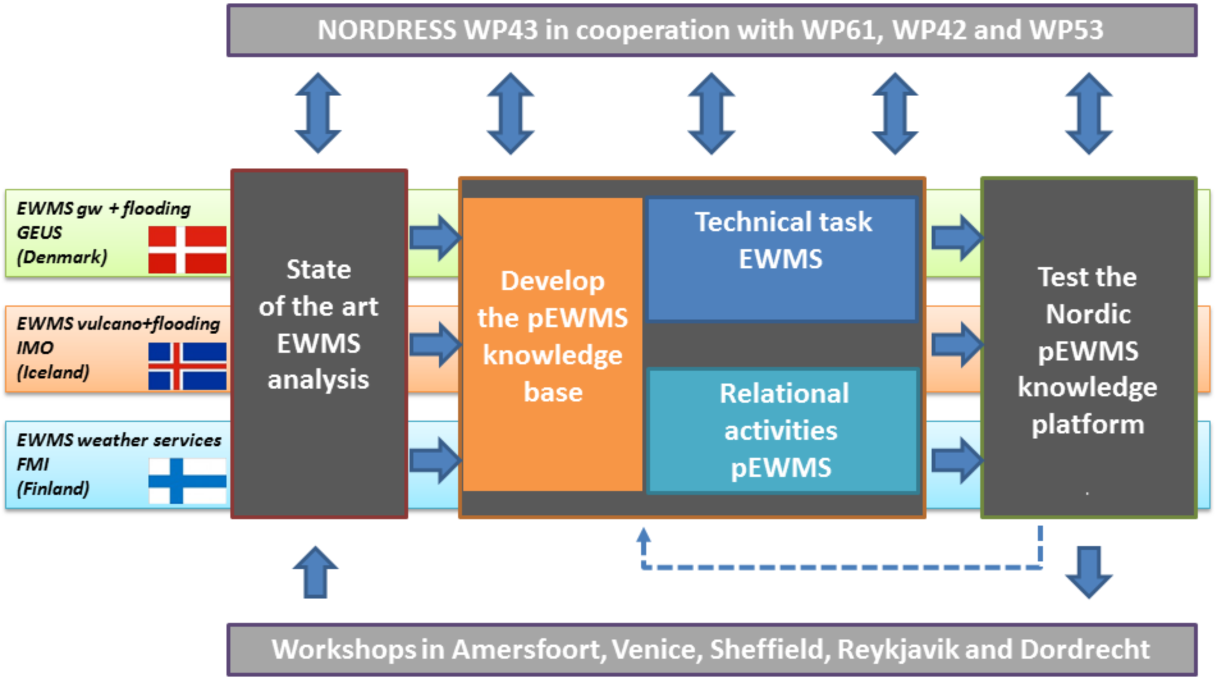


Figure 1 Methodological approach. State of the art analysis in Denmark (Geological Survey of Denmark and Greenland, GEUS), Iceland (Islandic Meteorological Organisation) and Finland (Finnish Meteorological Institute) combined with exploratory workshops in European cities

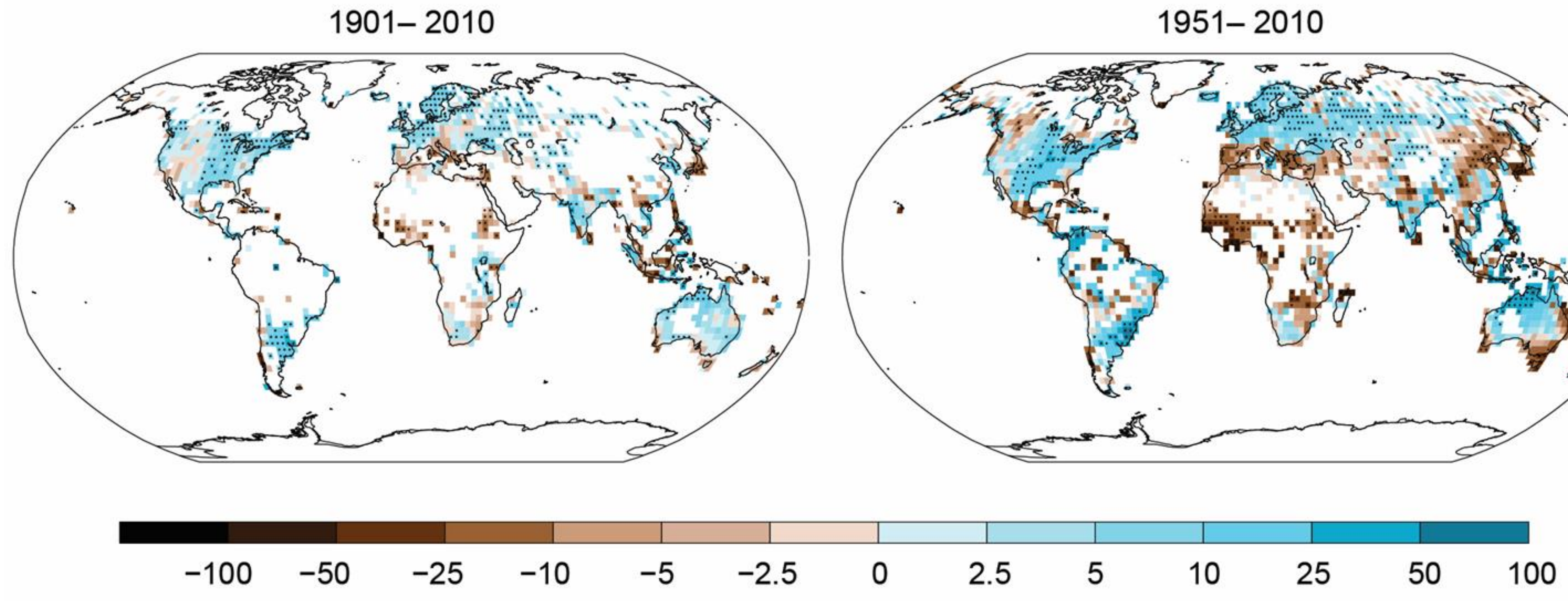
EXAMPLE WP4.3: 2019

- Participated in ECCA 2019 | CCB, Lisbon | 28–31 May | 4th European Climate Change Adaptation conference | *Working together to prepare for change.*
- Coordinated proposal accepted for ECCA2019: **CASES OF THE NORDIC COUNTRIES AND SOUTHERN PORTUGAL REGION**
- Three oral presentations by WP4.3 at ECCA 2019 was given:
  - *Urban flooding and monitoring shallow groundwater: Nature-based solutions in Copenhagen* Peter van der Keur and Hans-Jørgen Henriksen, GEUS.
  - *The incorporation of public observations in Icelandic Meteorological Office monitoring system* Matthew James Roberts, David Egilson, IMO and
  - *The experience in public observations through the mobile Weather app* Karoliina Pilli-Sihvola, Atte Harjanne FMI.

Danmark er blevet vådere?

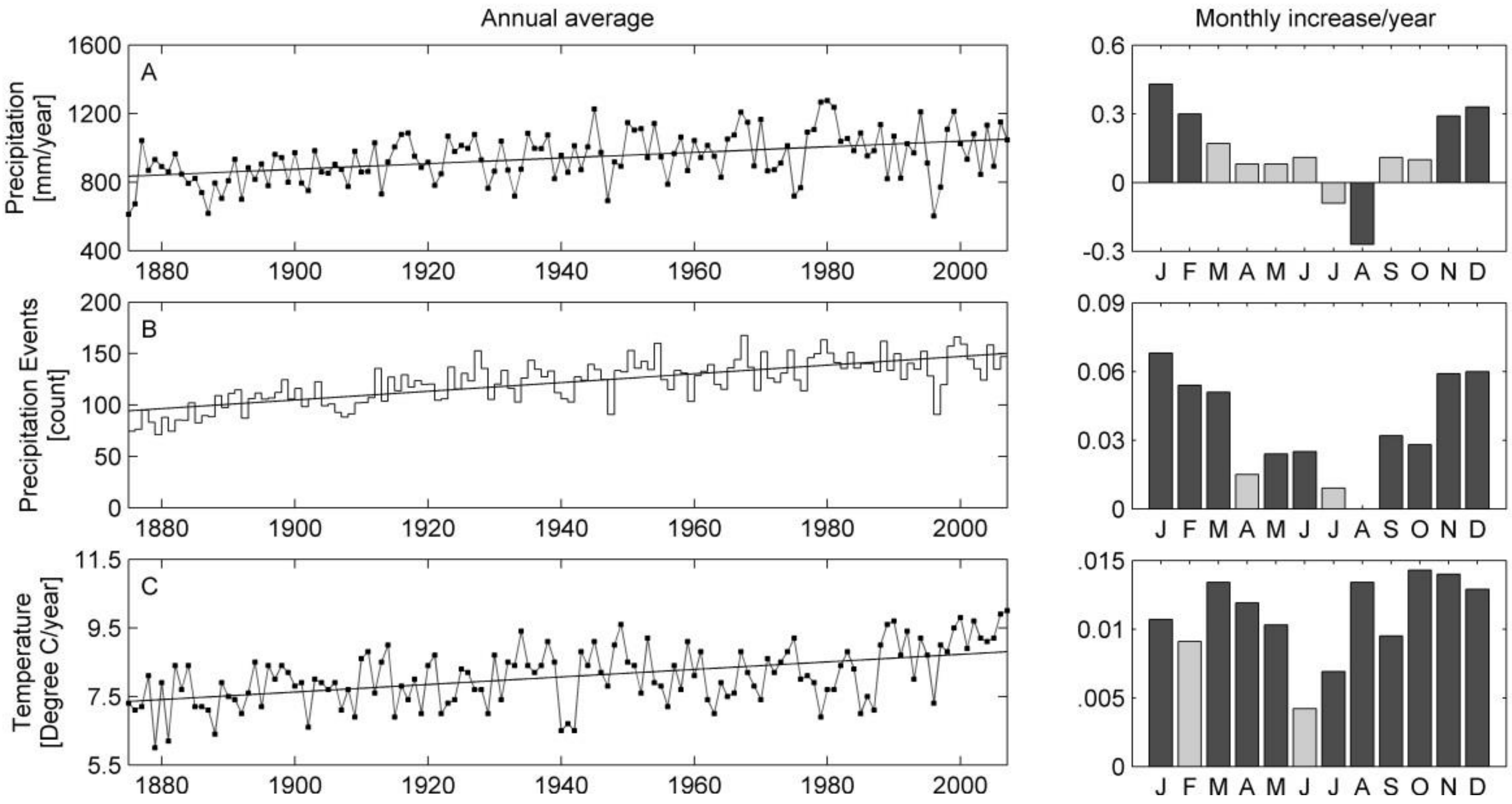
Observed precipitation change 1901-2010

Observeret change in yearly precipitation over land areas



mm / decade

Trend in precipitation, number of days with rain and temperature



Precipitation

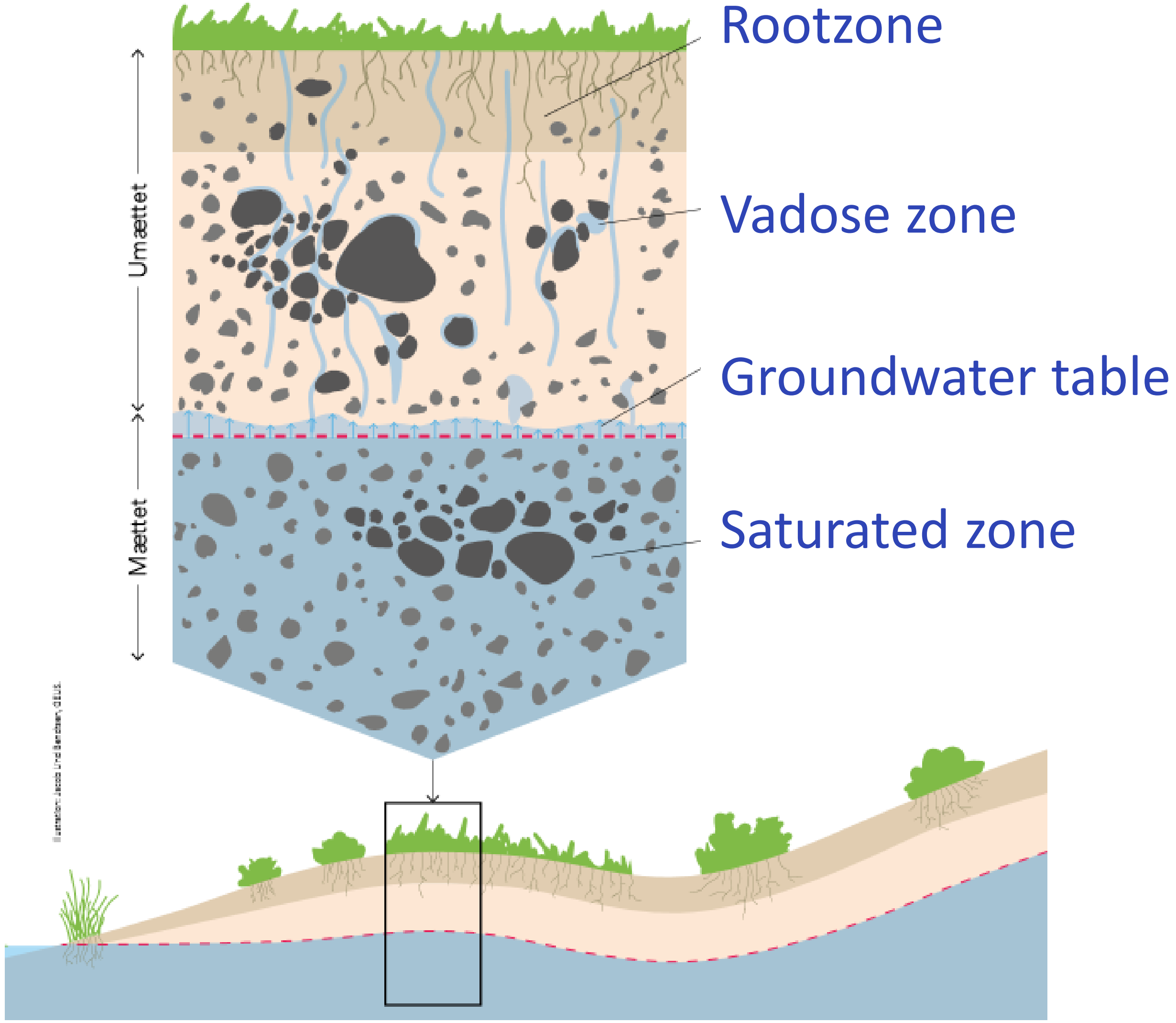
Number of days with precipitation

Temperature

Karlsson et al. (2014)

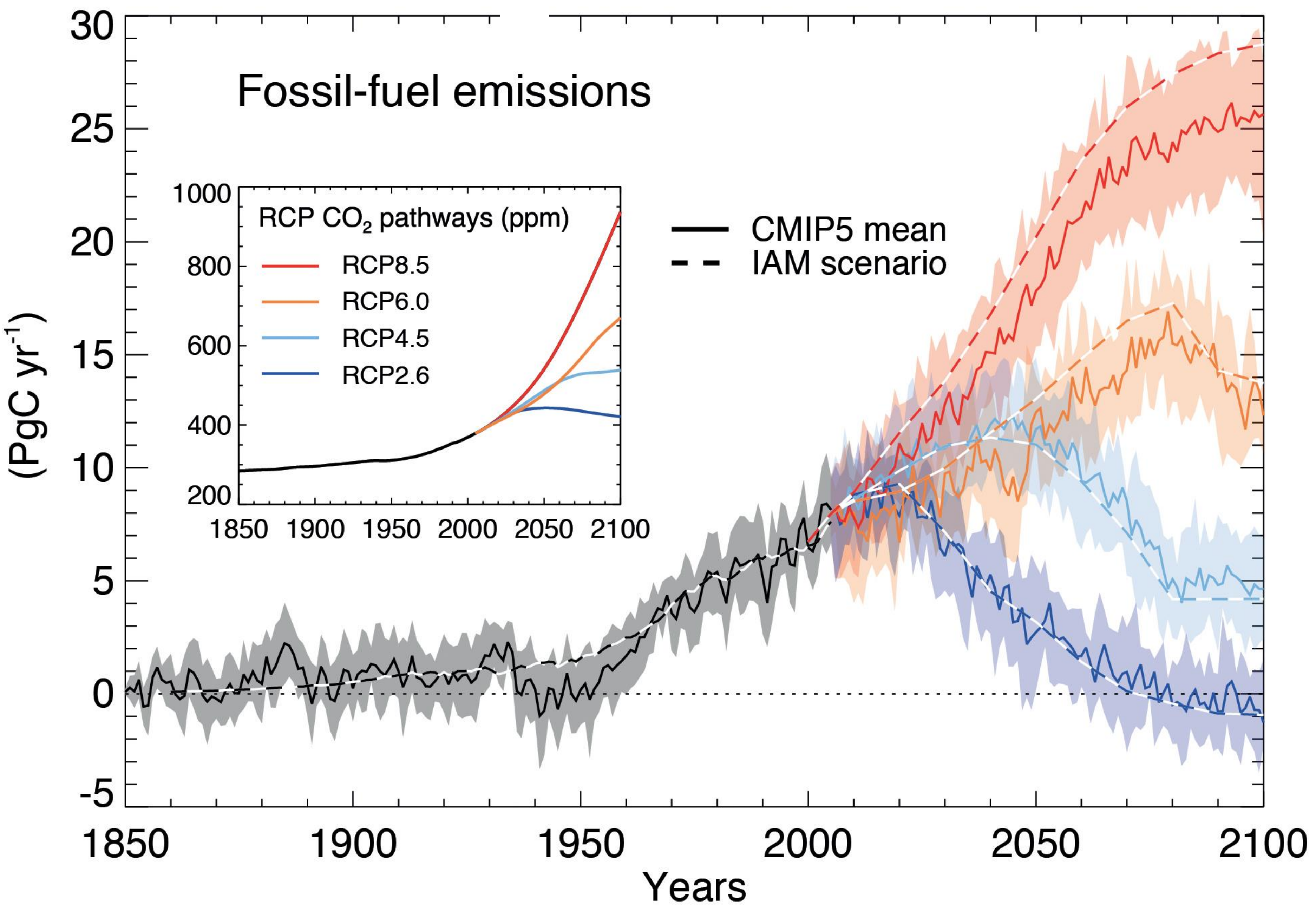
What do we understand by shallow groundwater?

”Shallow groundwater is defined as the first free water table we can localize from the top”



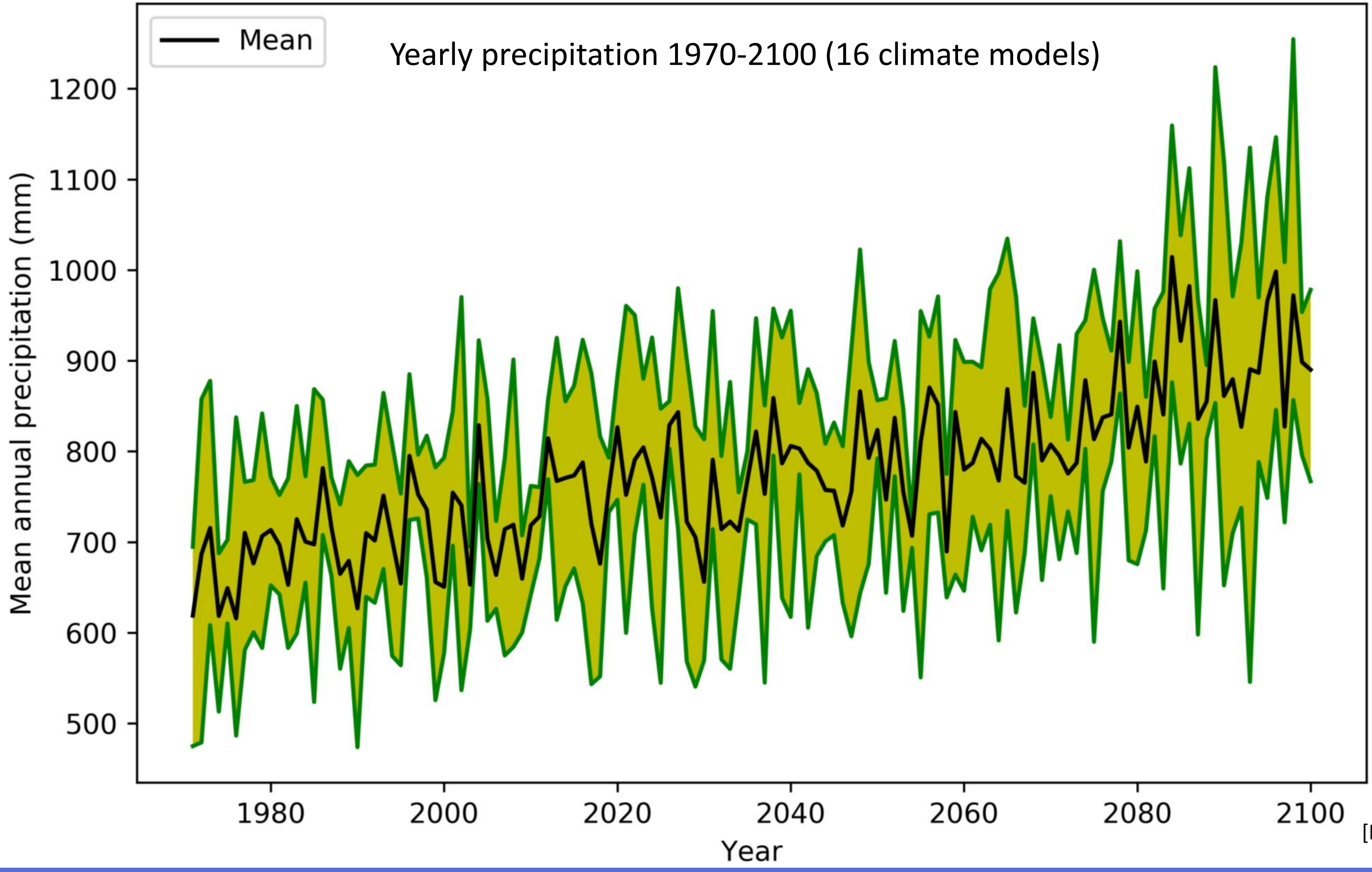
IPCC's Climate projections

Representative Concentration Pathways (RCPs)



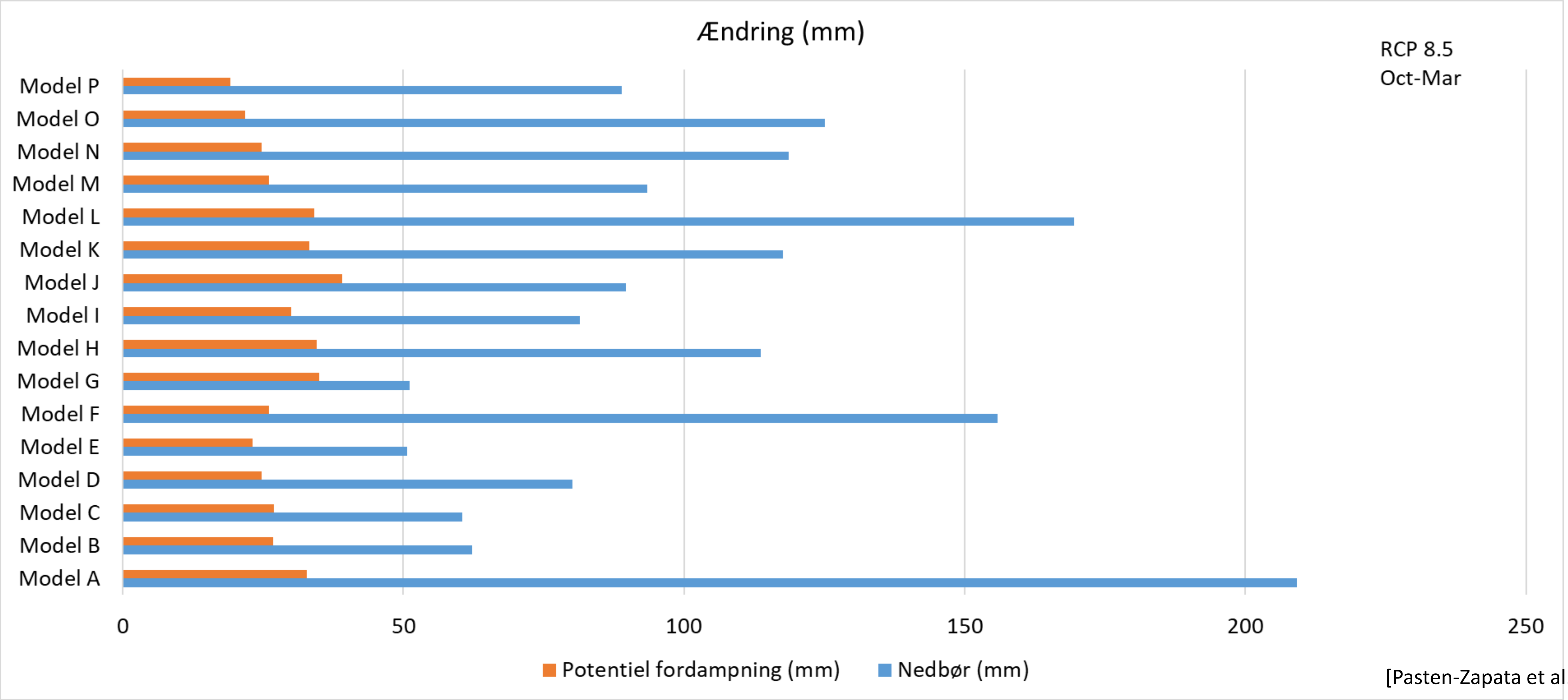
IPCC – AR5 (2014)

Projection of precipitation (RCP8.5)



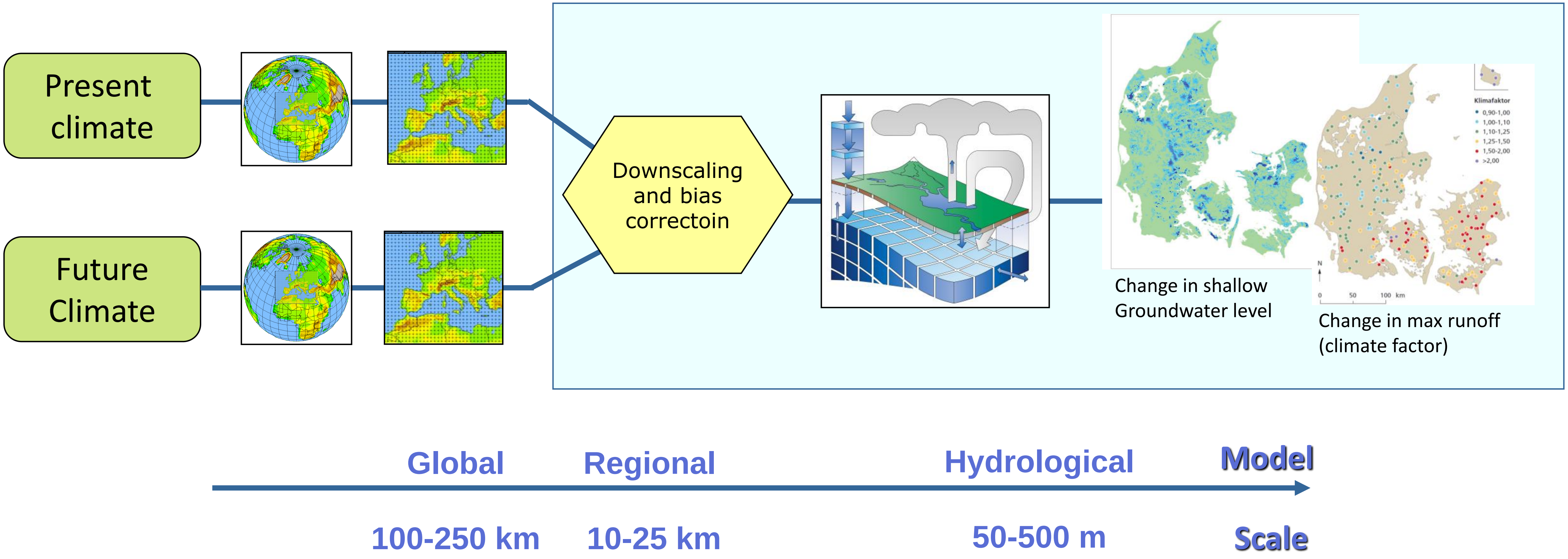
[Pasten-Zapata et al. 2019]

Change in precipitation and potential evapotranspiration in winter for RCP8.5 toward 2100



[Pasten-Zapata et al. 2019]

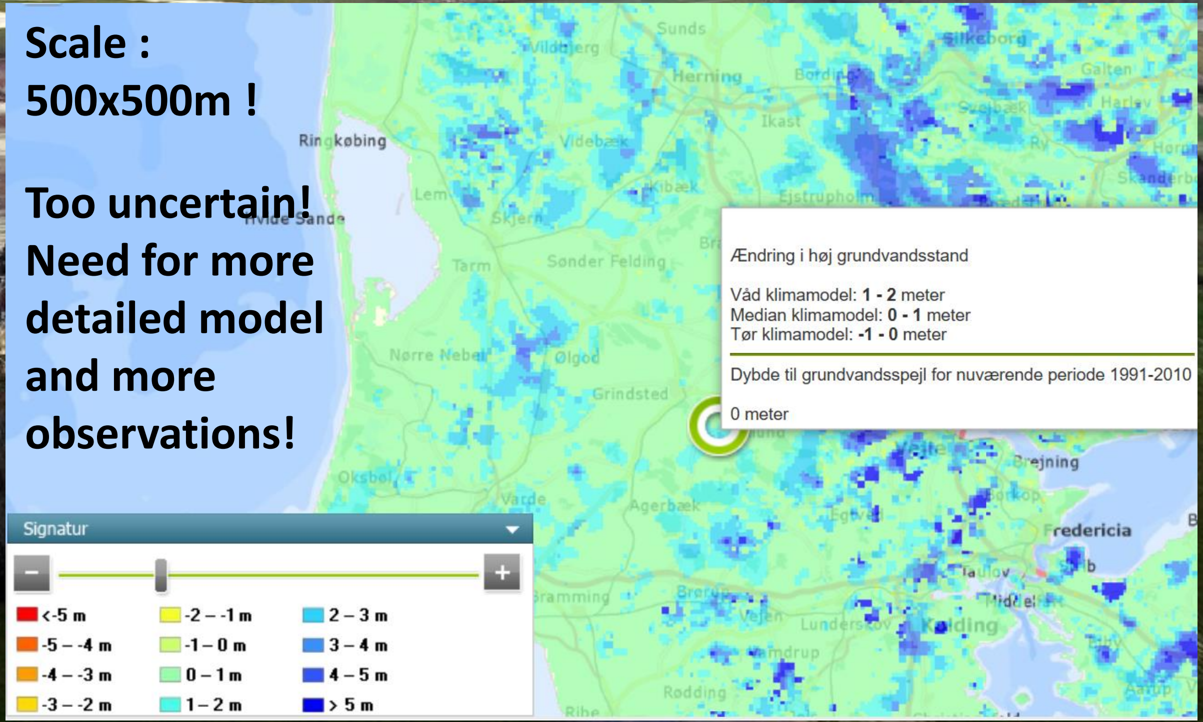
From climate models to impact on hydrology and groundwater



Klimatilpasning.dk

Scale :
500x500m !

Too uncertain!
Need for more detailed model and more observations!

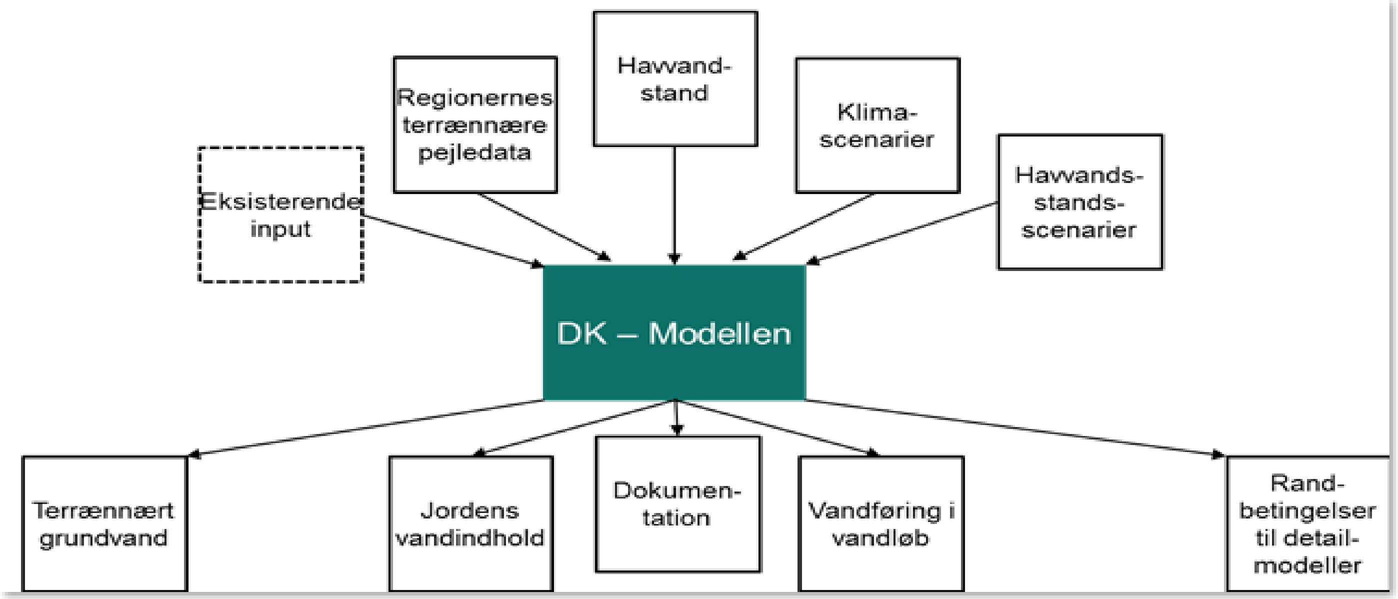


How can we improve early warning and preparedness?

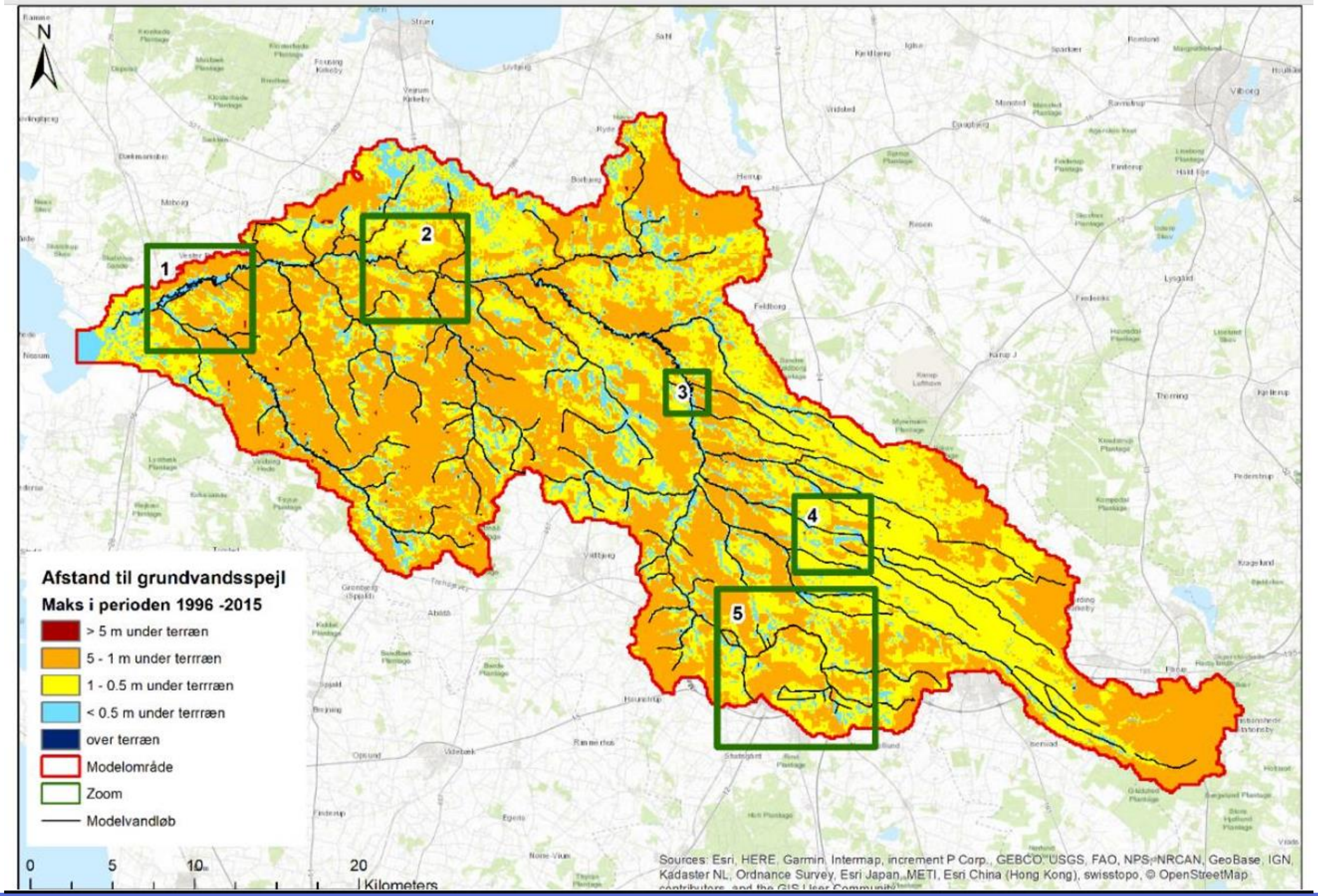
- Reduce uncertainty on climate model projections (*AquaClew.eu project*)
- Reduce uncertainty on hydrological model (*collection of monitoring data, more detailed model - from 500m today to 100m in 2020*)
- Improve access to data and model results *(HIP)*
- Utilization of artificial intelligence and Machine Learning for more detailed outputs (*from 100m to 10 m)*
- We need a real time model with prognoses

Hydrological Information and Prognosis system (HIP 4 PLUS)

(FODS 6.1 Strategy on climate, terrain and water
The Danish Digital Strategy 2016-2020

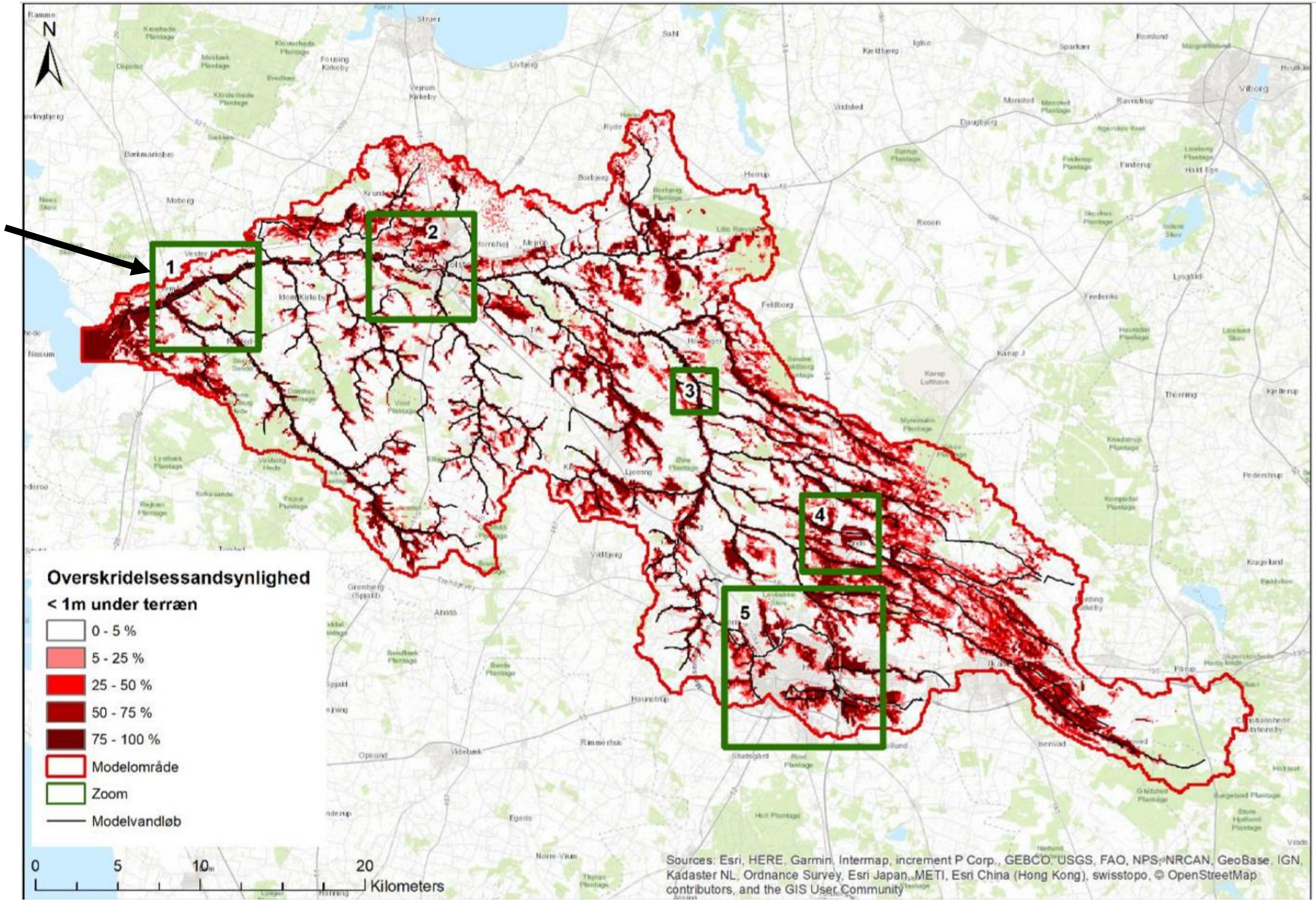


Example of simulated depth to shallow gw (high gw level 1996-2015)



Exceedance probability for shallow gw < 1m below terrain

ZOOM 1

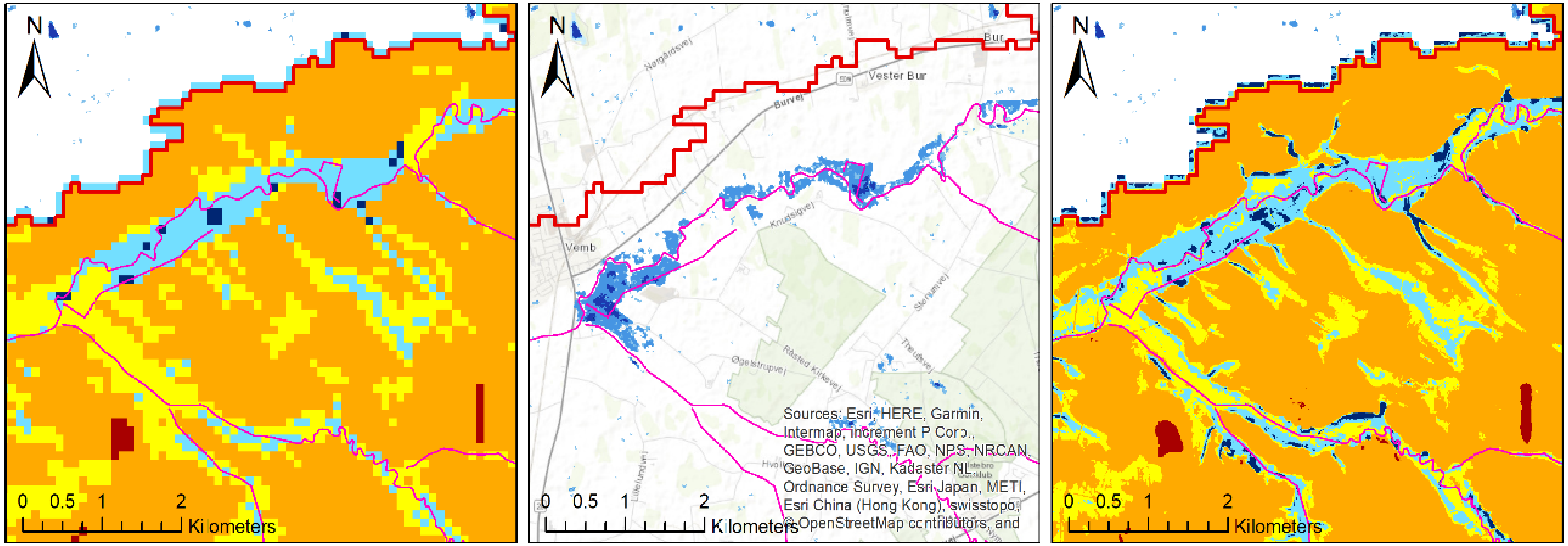


Example of depth to shallow groundwater simulated with hydrological model 100 m – left and topographical downscaled to 10 m – right (in the middle observed RS data)

Afstand til grundvandsspejl
100m model

Observation
Satelitdata DHI/GRAS 09dec2015

Afstand til grundvandsspejl
Nedskaleret



Simuleret afstand til grundvandsspejl

- > 5 m under terræn
- 5 - 1 m under terrræn
- 1 - 0.5 m under terrræn
- < 0.5 m under terrræn
- over terræn

Oversvømmelse 09. december 2015

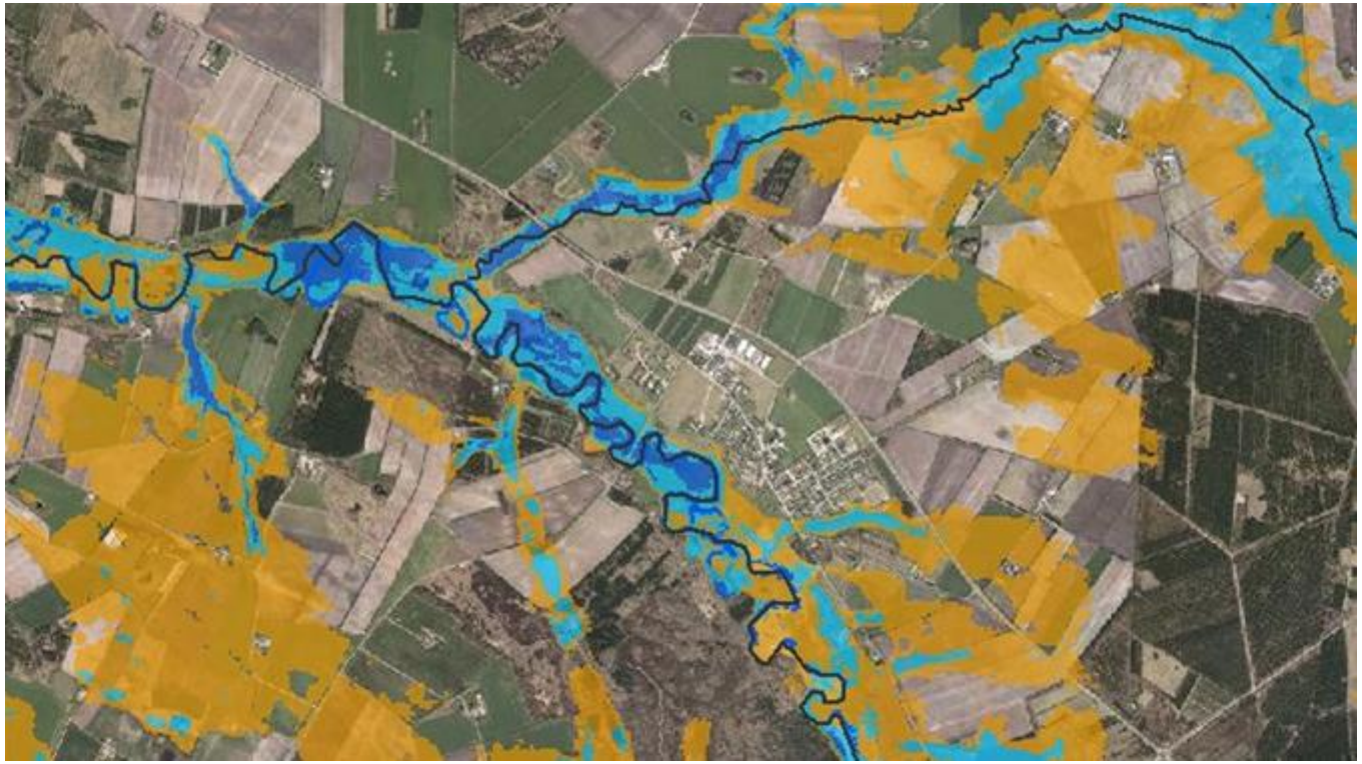
Baseret på Sentinel 1

- Lav sandsynlighed for oversvøm og ikke i reference
- Høj sandsynlighed for oversvøm og ikke i reference
- Lav sandsynlighed for oversvøm og åben vand i reference
- Altid åben vand
- Kun oversvøm i reference

- Modelområde
- Modelvandløb

GEUS 2018 FODS 6.1

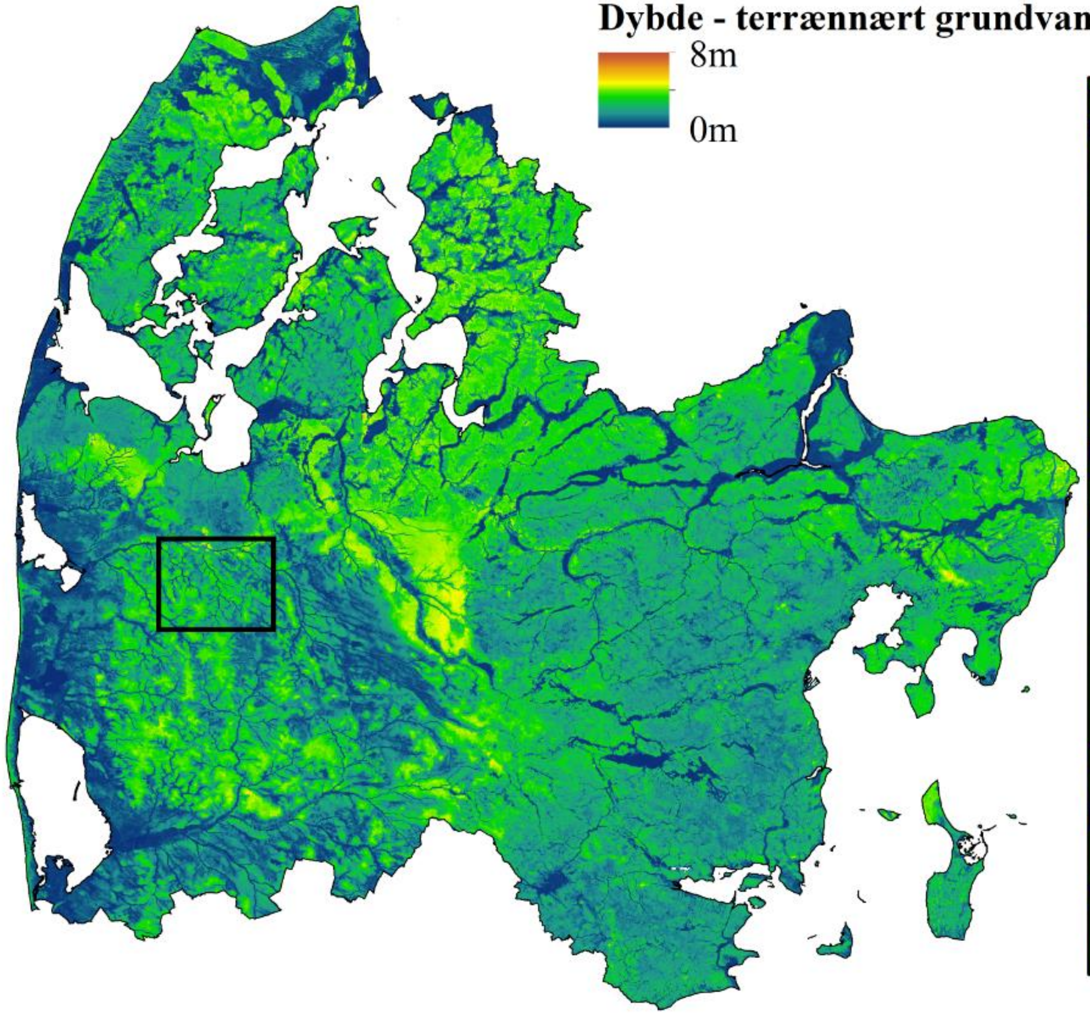
Hydrologic Information and Prognosis (HIP) System – to sumarize



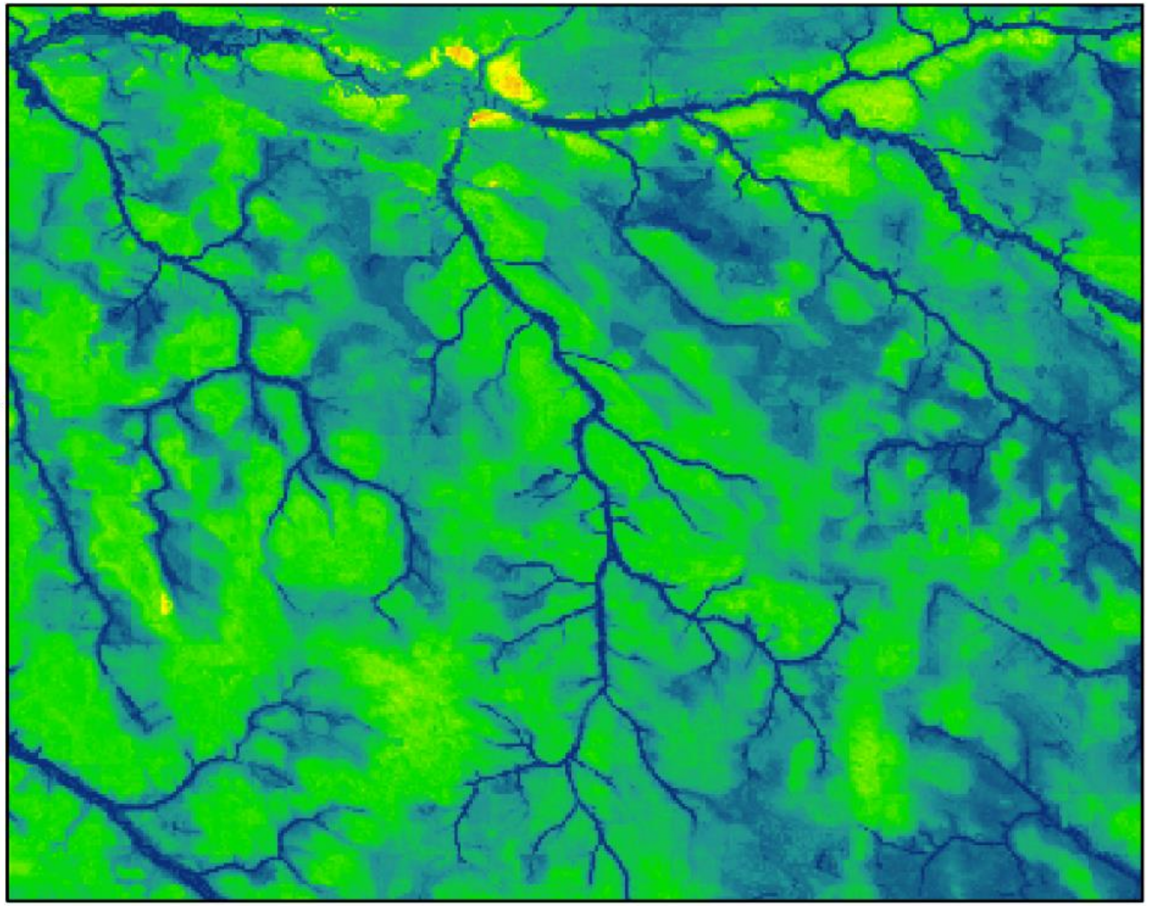
HIP combine and couple data on terrain, climate and water and simulates shallow groundwater under current conditions and under future climate change

Hydrologic measurements can support model simulations. Observed data of depth to shallow groundwater are collected from 5 Regions and 98 Municipalities and stored in GEUS's JUPITER database. GEUS develop nationwide 100m model.

Machine learning (Random Forest) – depth to shallow groundwater

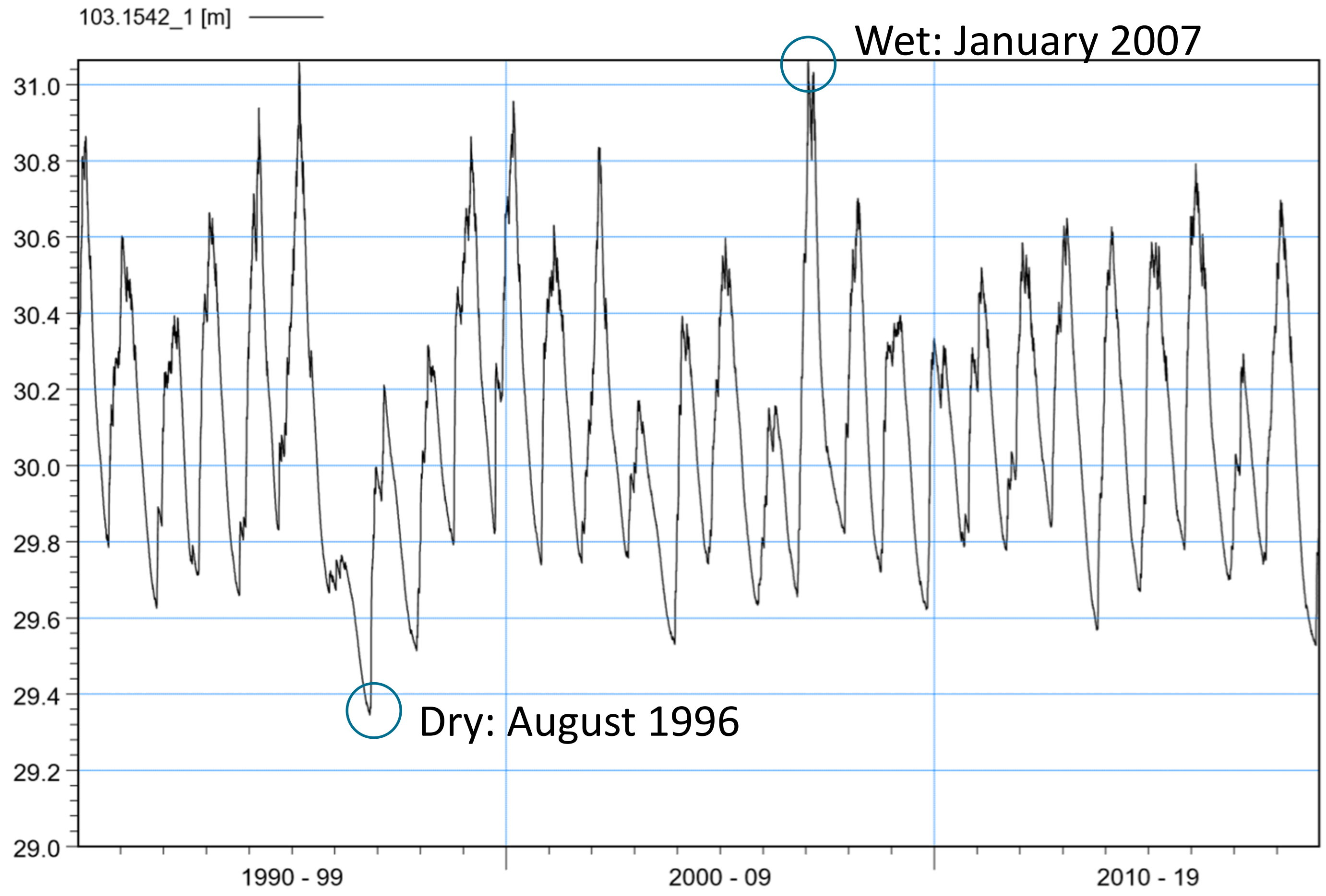


Koch et al. 2019 Hess Journal

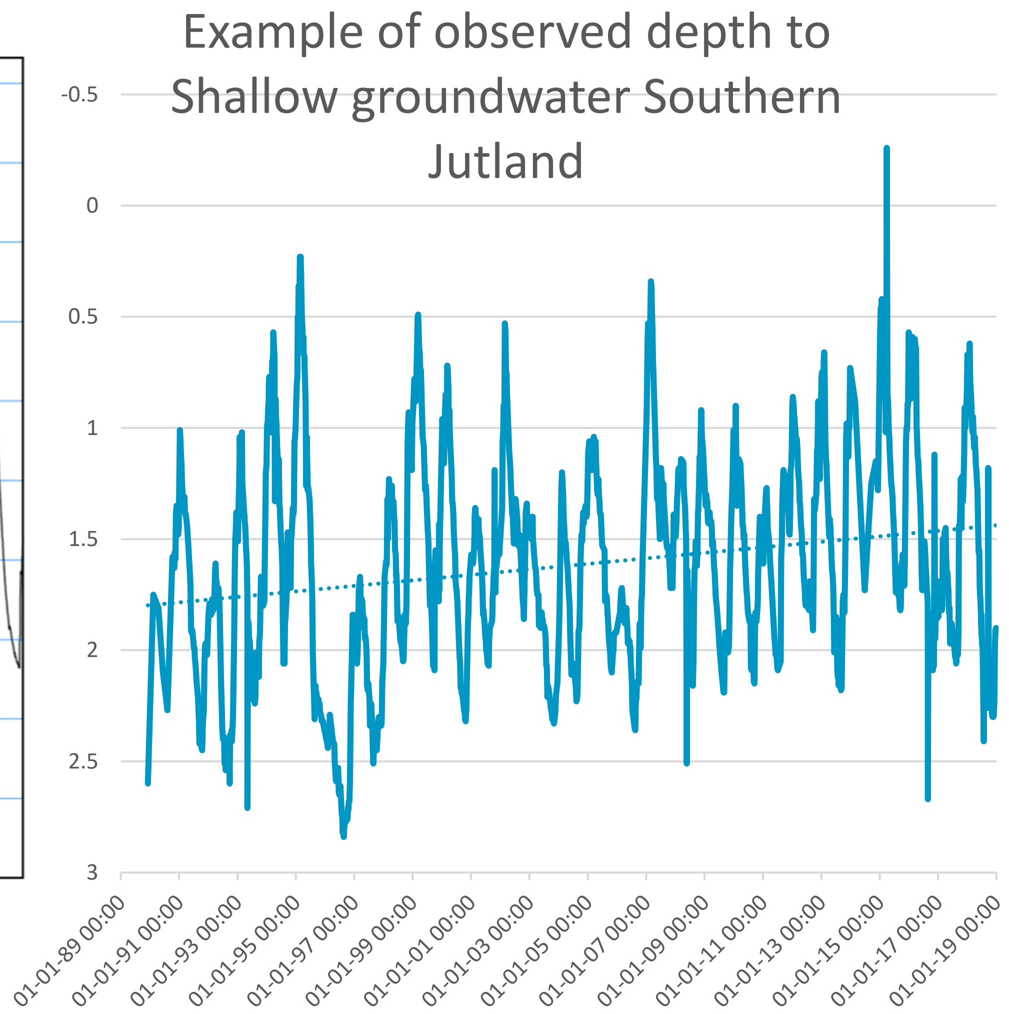


Shallow groundwater table has fluctuations and trend

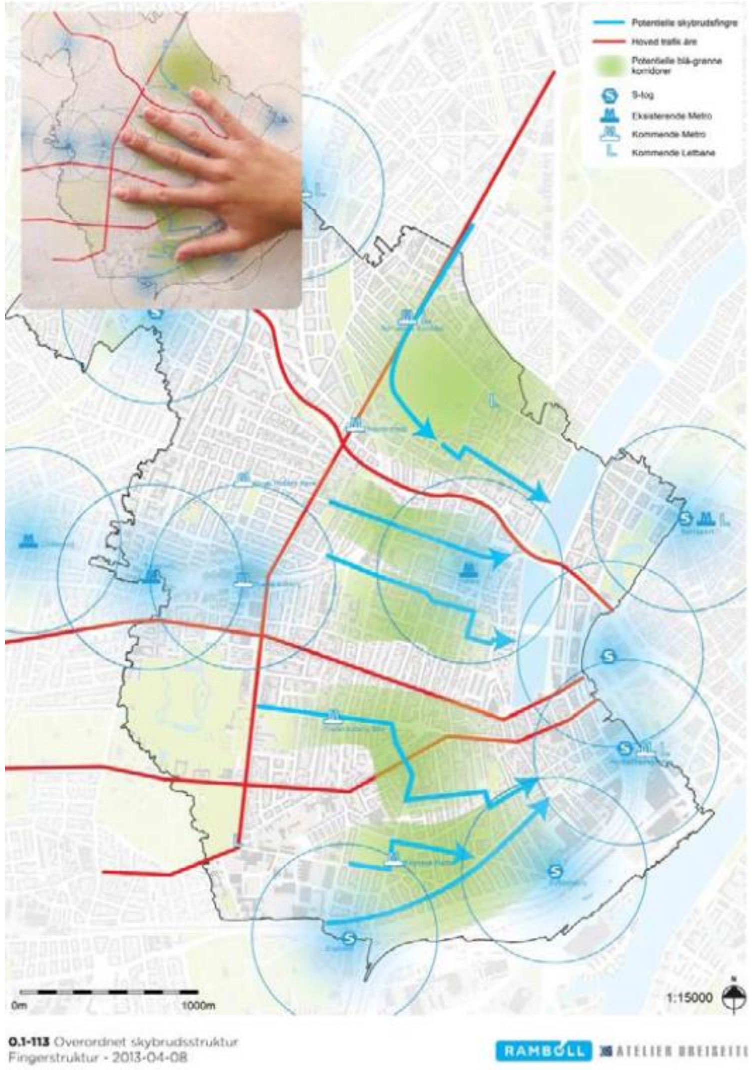
1.1.1990 - 31.12.2018 Vandspejlskote



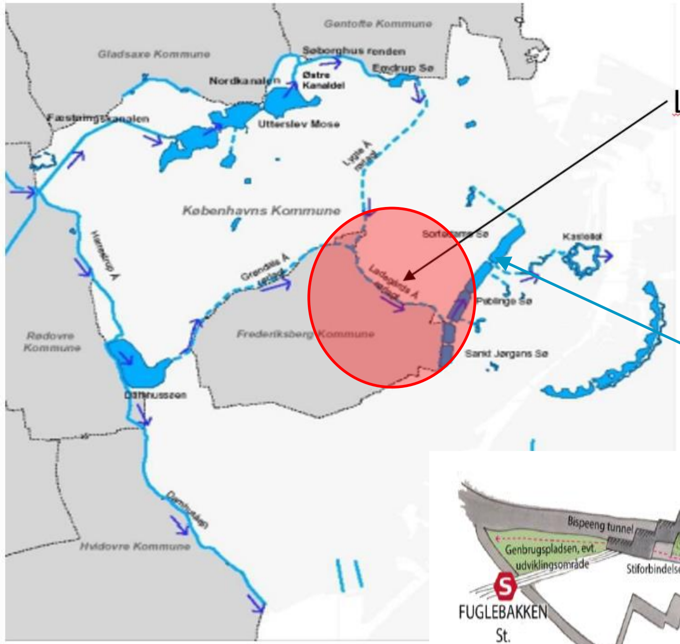
Example of **model simulated shallow groundwater table** (Sdr. Omme plantage – DK model



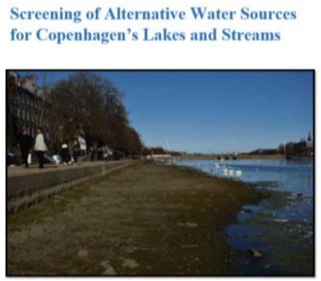
Multiple flooding challenges in Copenhagen (cloudburst, sea level/storm surge and groundwater flooding…



NBS solutions needed !



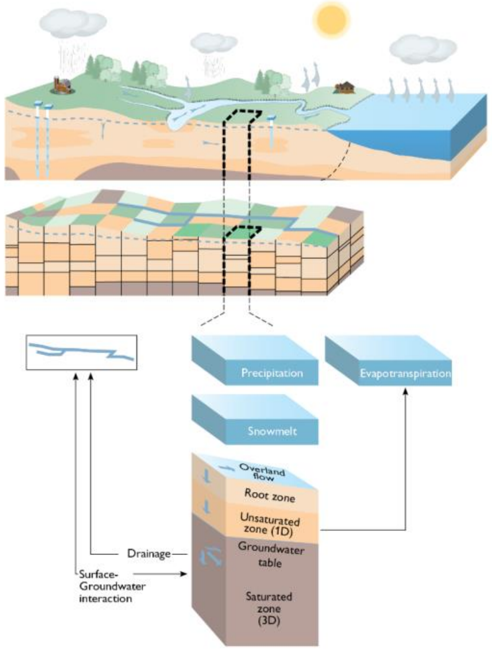
Ladegaardsaa river



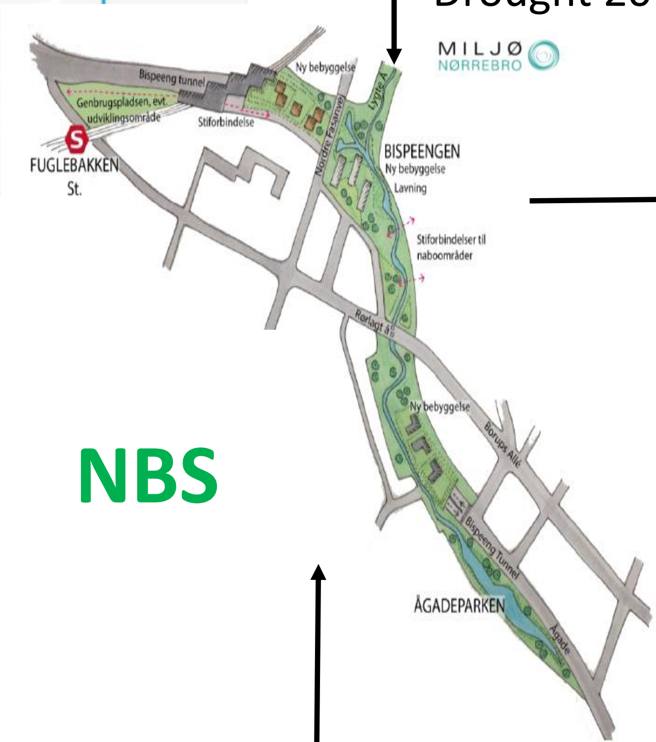
Drought 2018?

MILJØ NØRREBRO

CCA options and Co-benefits for Urban River Restoration Demonstration



NBS



Stakeholder involvement

Hydrological model for urban River area and tributaries

Increased problems with groundwater flooding, but how to handle?

- Management of groundwater level (3. drain/groundwater abstraction)
- Restoring urban rivers and natural drainage systems (increased resilience)
- Blue and green climate change adaptation solutions (lakes, green roofs, trees)
- Avoid local infiltration of rain water in areas with groundwater flooding
- Afforestation and other solutions for increasing evapotranspiration
- Nobody is responsible for management of shallow groundwater level
- Participatory groundwater flooding risk management, and local early warning and sub-model/monitoring systems linked to national model (HIP 100m model)
- Think about increasing groundwater as a resources! (liveability/drought/heatwaves)

Thank you for your attention!

Example of ”animated video” from TOPSOIL project (Groundwater):

https://www.youtube.com/watch?v=nk_mK4hduz0&feature=youtu.be

https://northsearegion.eu/topsoil

More information:

- Henriksen HJ, Roberts MJ, van der Keur P, Harjanne A, Egilson D, Alfonso L.(2018). Participatory early warning and monitoring systems: A Nordic framework for web-based flood risk management. International Journal of Disaster Risk Reduction, 31 (2018) 1295–1306. https://doi.org/10.1016/j.ijdrr.2018.01.038

- Simon Stisen, Raphael J.M. Schneider, Maria Ondracek og Hans Jørgen Henriksen. GEUS. 2018. Modellering af terrænnært grundvand, vandstand I vandløb og vand på terræn i Storå og Odense Å. Slutrapport FODS 6.1 fast track metodeudvikling (in Danish). http://dk.vandmodel.dk/media/20174/36-2018-geus.pdf

  (**FODS 6.1 initiative** for water, terrain and climate-Hydrological Information System HIP)

- Koch J, Berger H, Henriksen HJ and Sonnenborg TO 2019. Modelling of the shallow water table at high spatial resolution using random forests. Hydrol. Earth Syst. Sci., 23, 4603–4619, 2019 https://doi.org/10.5194/hess-23-4603-2019

  (C2CCC project Central Region Denmark)

NAIAD www.naiad2020.eu

GEOVIDEN https://www.geocenter.dk/geoviden/grundvand-og-klima/