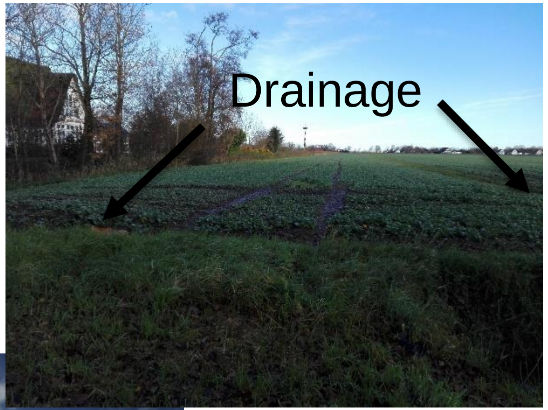
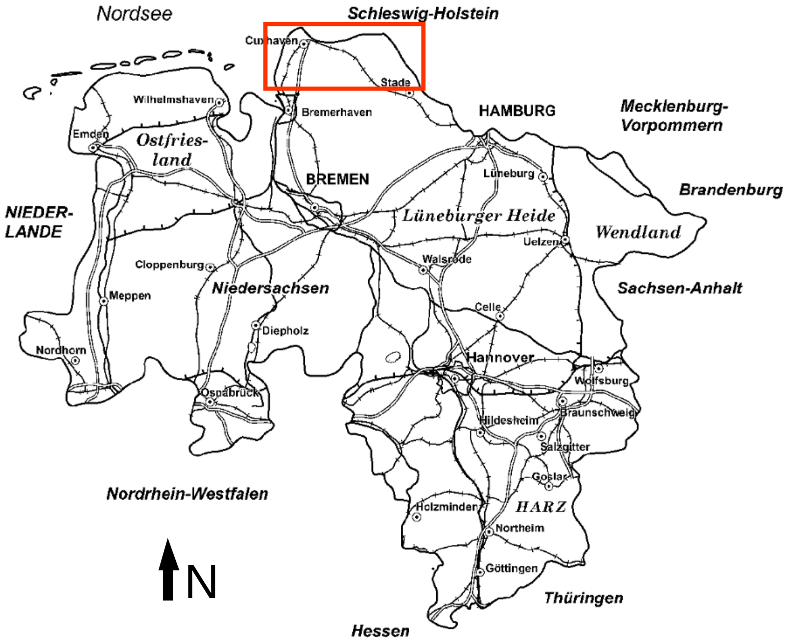
Pilot area GE 2:

- **Effects of climate change on the salt-/fresh water distribution in coastal aquifers of Lower Saxony**





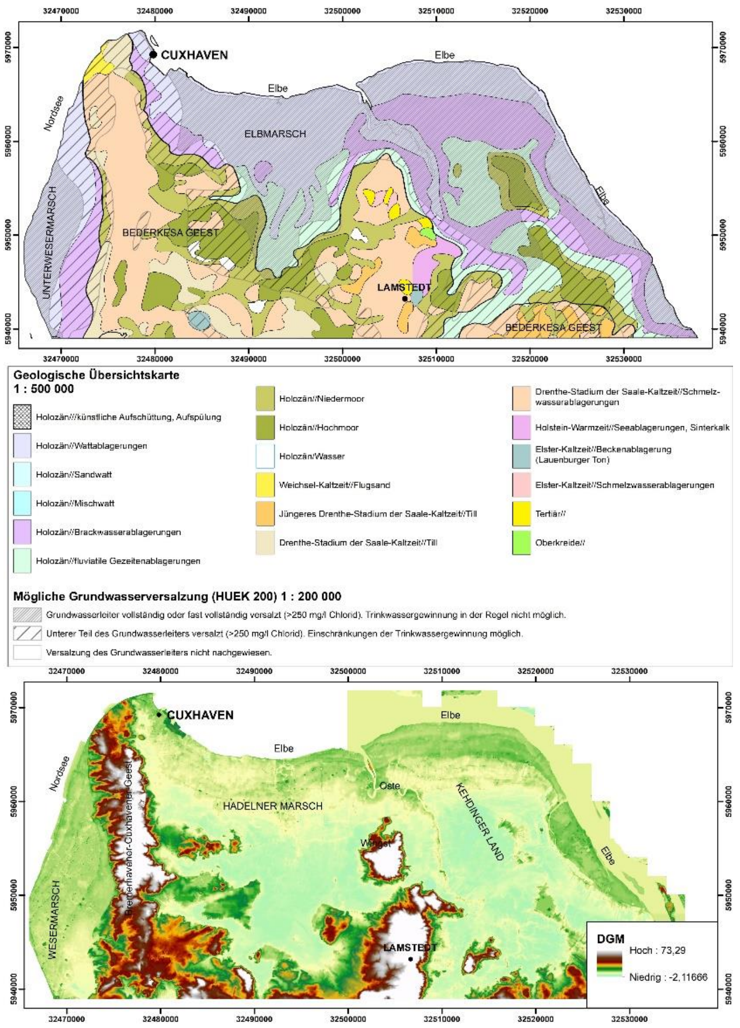
Nico Deus

State Authority for Mining, Energy and Geology

Pilot area GE-2

Challenges:

- ➢ Seawater intrusion due to climate change
- ➢ Increasing water demands
- ➢ Buffering of freshwater for dry periods



Marsh area

- ➢ low groundwater recharge,
- ➢ Groundwater level between -1 & 1m NHN
- ➢ Extensive drainage,

Moraine area

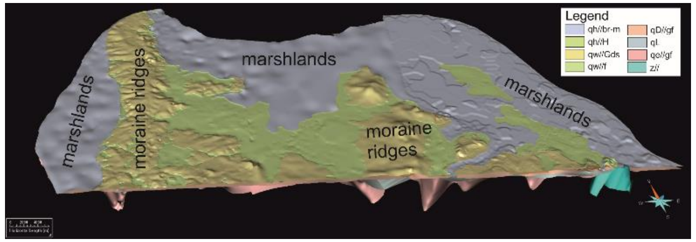
- ➢ High groundwater recharge,
- ➢ Groundwater level between 5 to 15m NHN

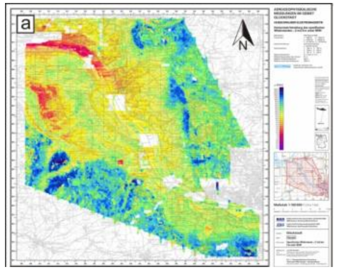
Landesamt für Bergbau, Energie und Geologie
GEOZENTRUM HANNOVER

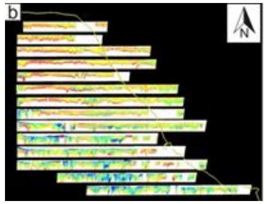
Niedersachsen. Klar.

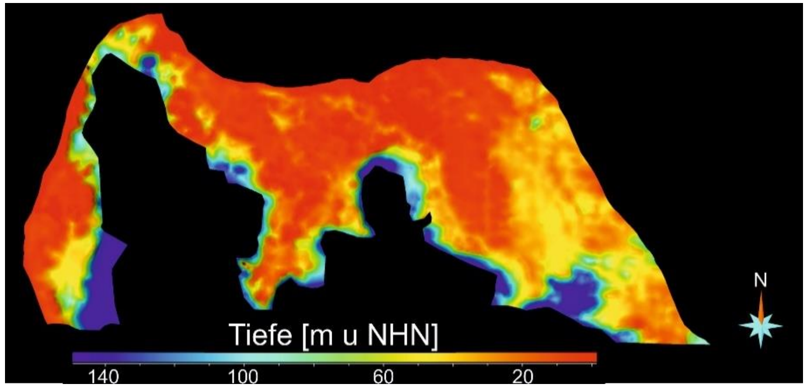
Pilot area GE 2:

Effects of climate change on the salt-/fresh water distribution in coastal aquifers of Lower Saxony**?**





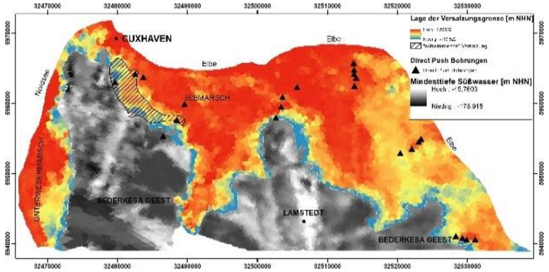




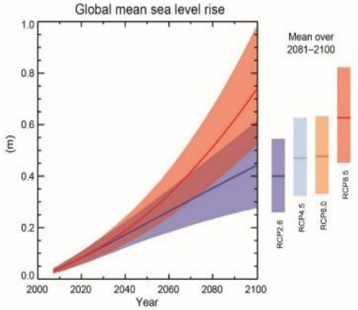
Deducing the distribution of Salt- & fresh water as input for the flow model

Modeling the impact of climate change on the salt-/fresh water distribution

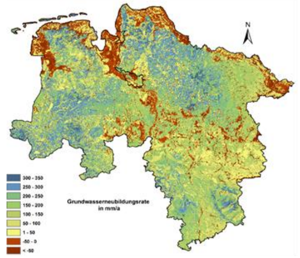
Modelling the climate change induced variations in salt-/freshwater distribution

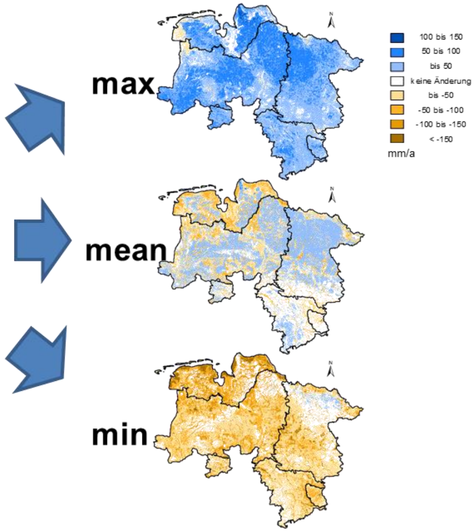


Status quo



Sealevel rise



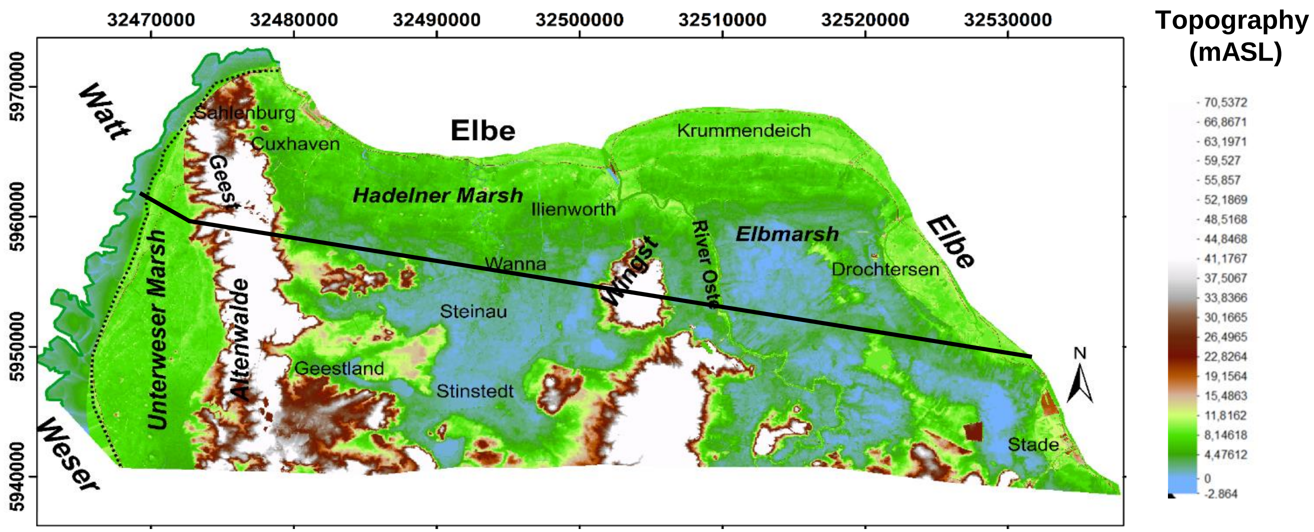


Changes of simulated groundwater recharge rates from mGROWA18 for the period 2071 - 2100

- Extraction rates
- Drainage
- Groundwater level
- Groundwater characteristics
- Chloride concentrations from HEM data

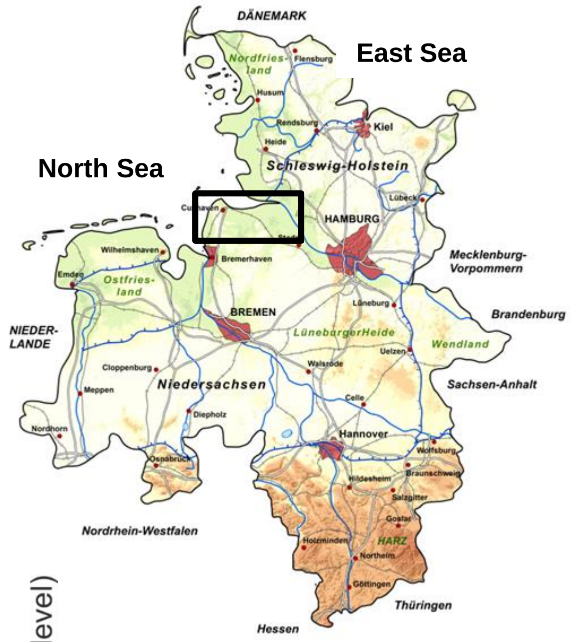
Climate szenario: RCP 8.5 (IPCC report, 2013)

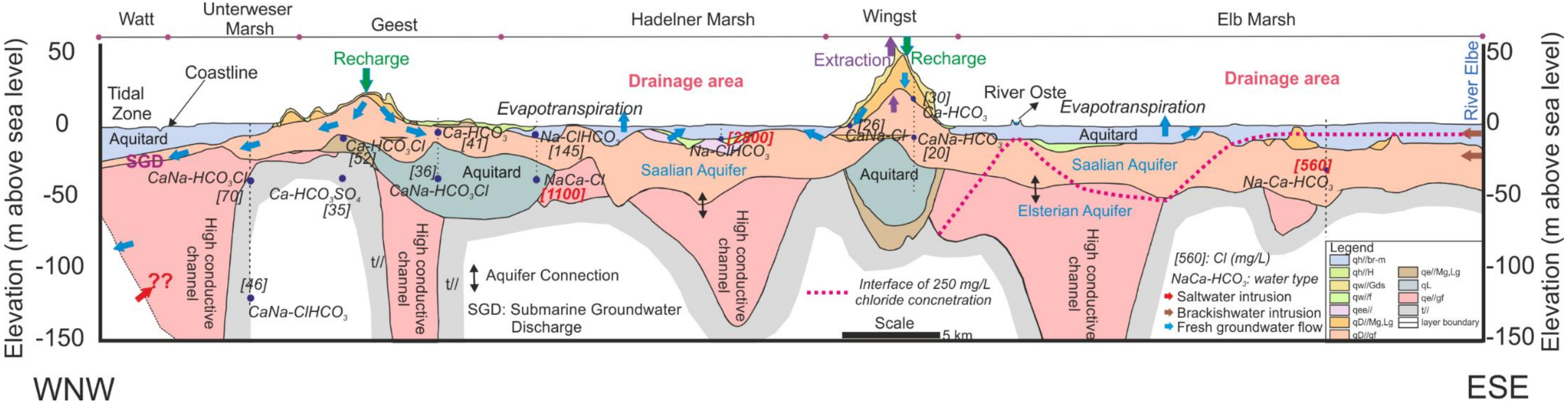
Conceptual model



Boundary between land and sea

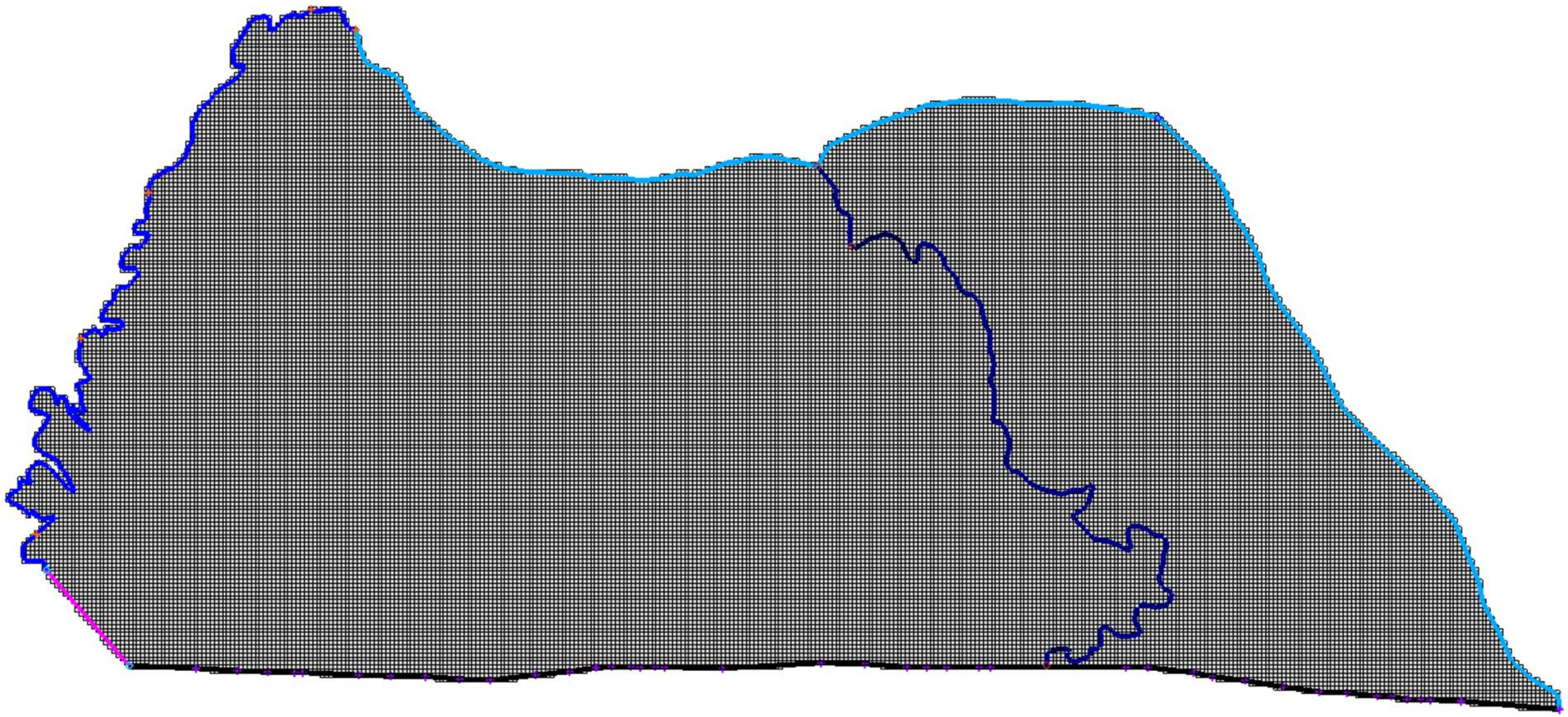
2D profile line (conceptual model)





Model setup

Software: GMS 10.3.7
based on Modflow



Grid: 200 m X 200 m

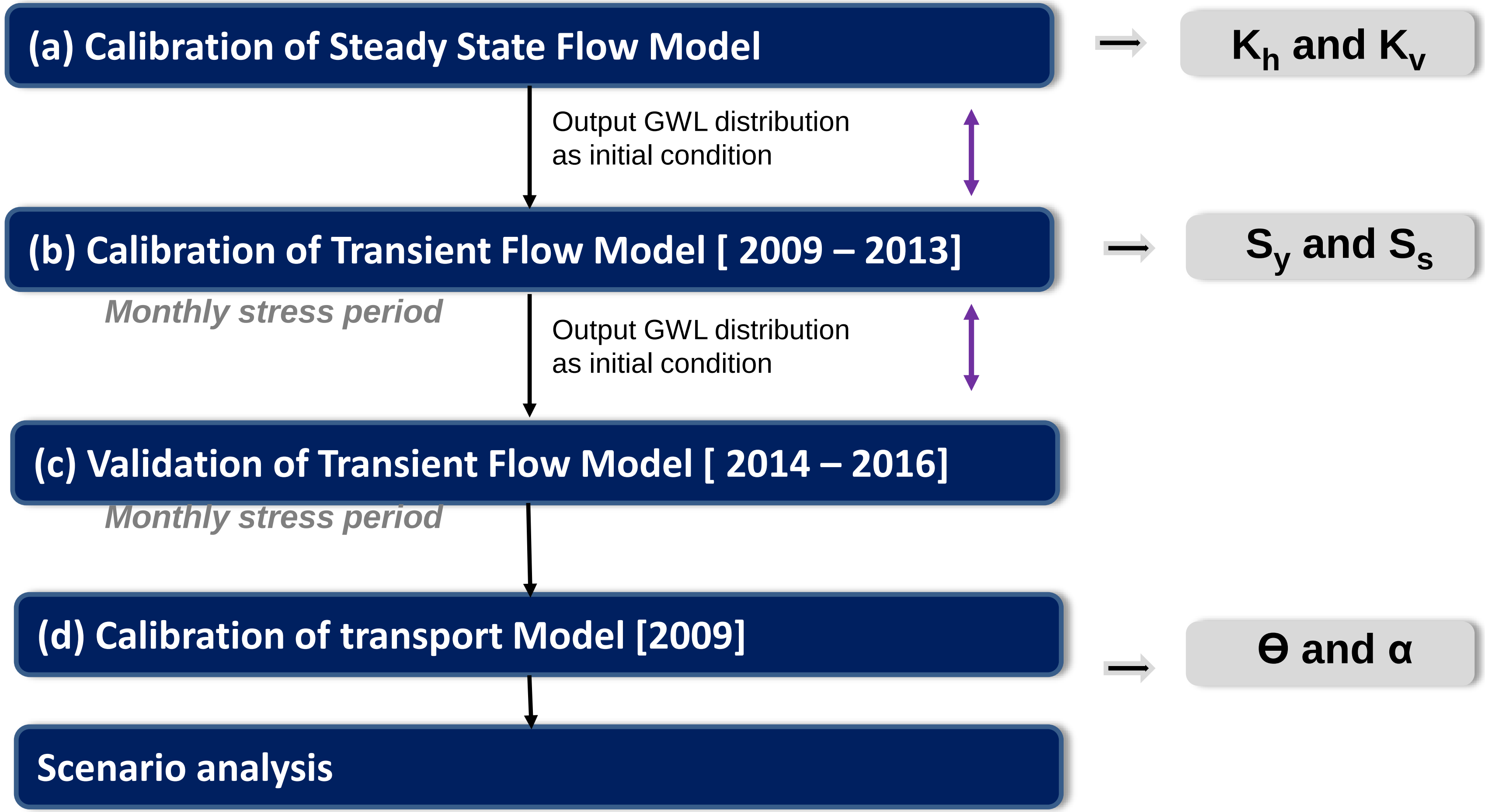
405 Columns

193 Rows

42,448 active cells

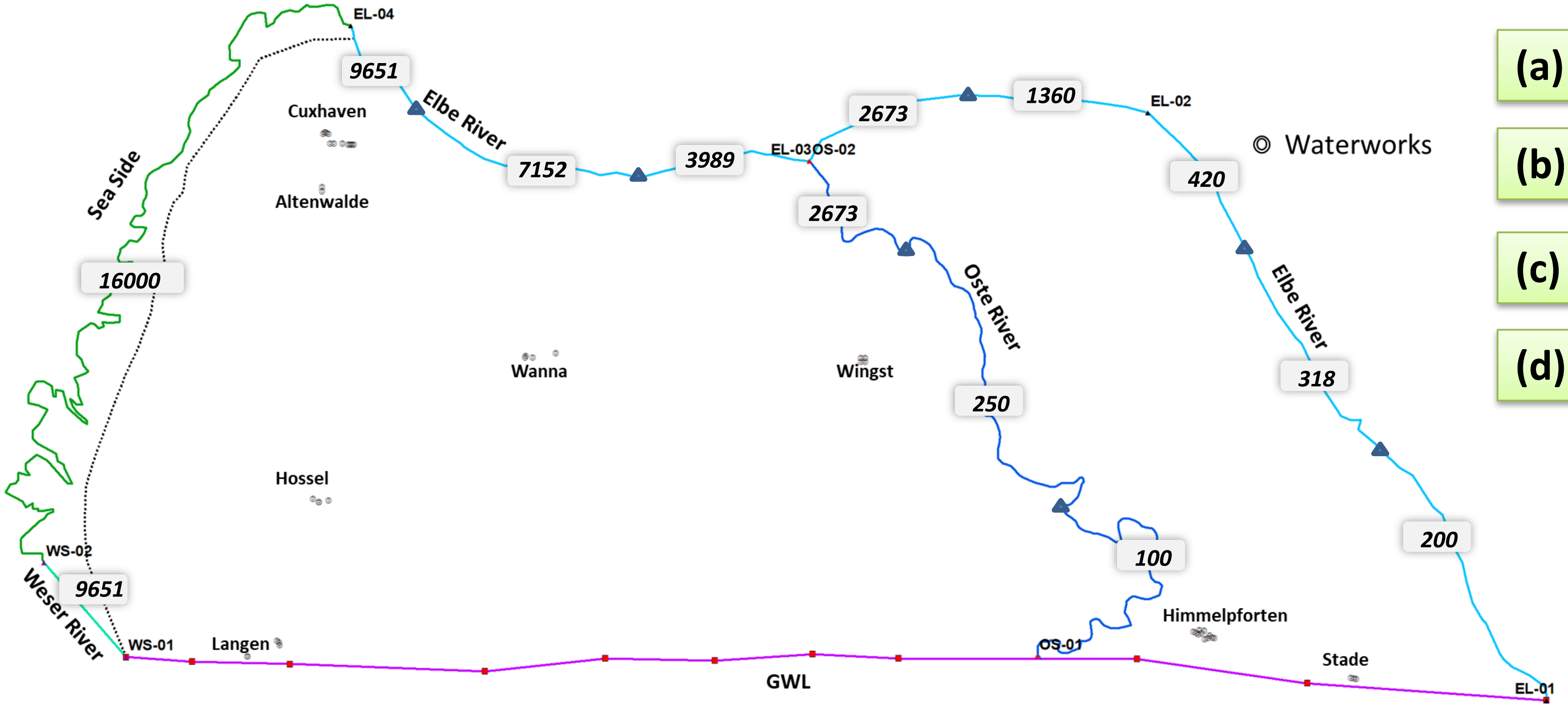
8 layer flow model
and 55 layer
transport model

What is done:



K_h: Horizontal hydraulic conductivity; K_v: Vertical hydraulic conductivity; S_y: Specific yield; S_s: Specific storage, ϴ = Eff. Porosity, α = Dispersivity

Boundary conditions



(a) West : Sea Side (Eq.FWH) [Type 1]

(b) North & East : River Stage [Type 2]

(c) West : River Stage (Weser) [Type 2]

(d) South : GWL [Type 1]

Boundary type

Type 1: Dirichlet (h = constant)

Type 2: Neumann (dh/dx = constant)

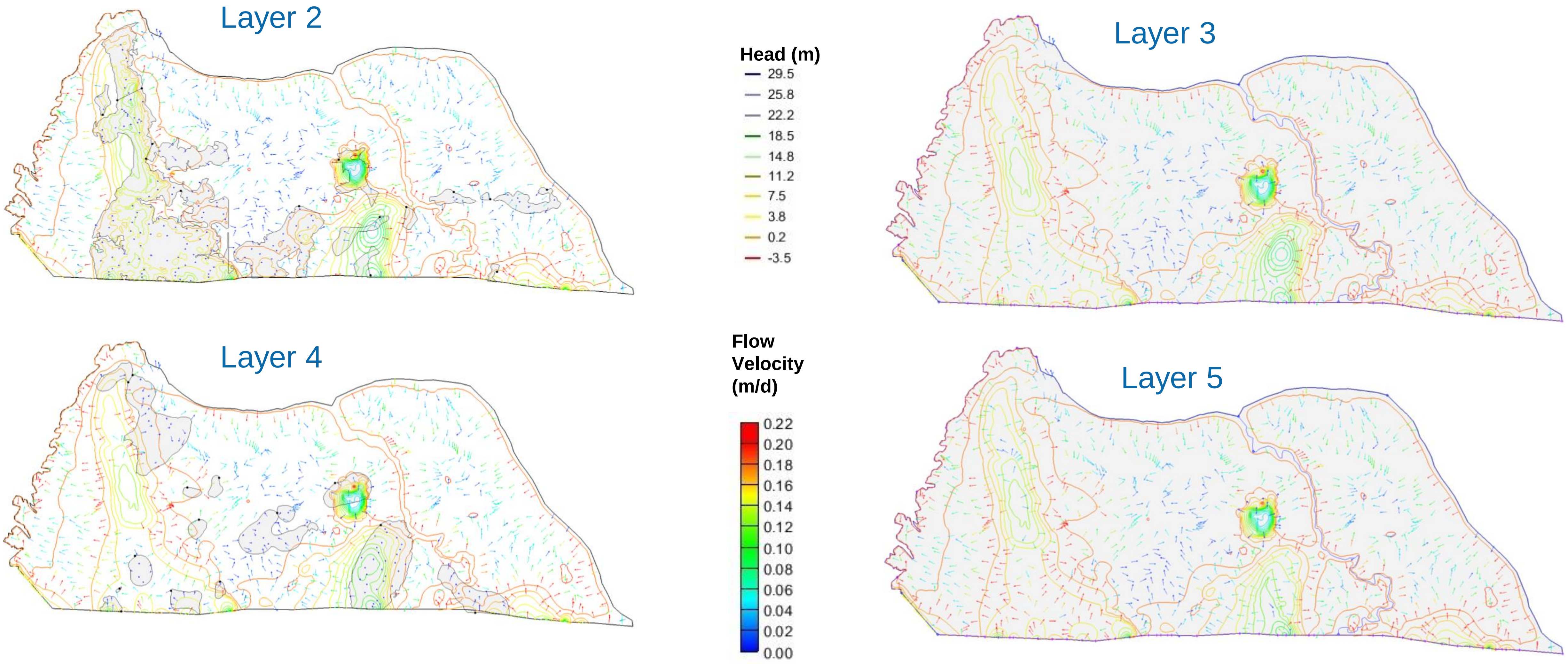
Eq FWH: Equivalent freshwater head

Chloride boundary segments (mg/l)

Flow Initial condition : Interpolated heads for December 2008

Transport Initial condition : Helicopter borne Electromagnetic chloride distribution.

Groundwater flow direction (transient flow)

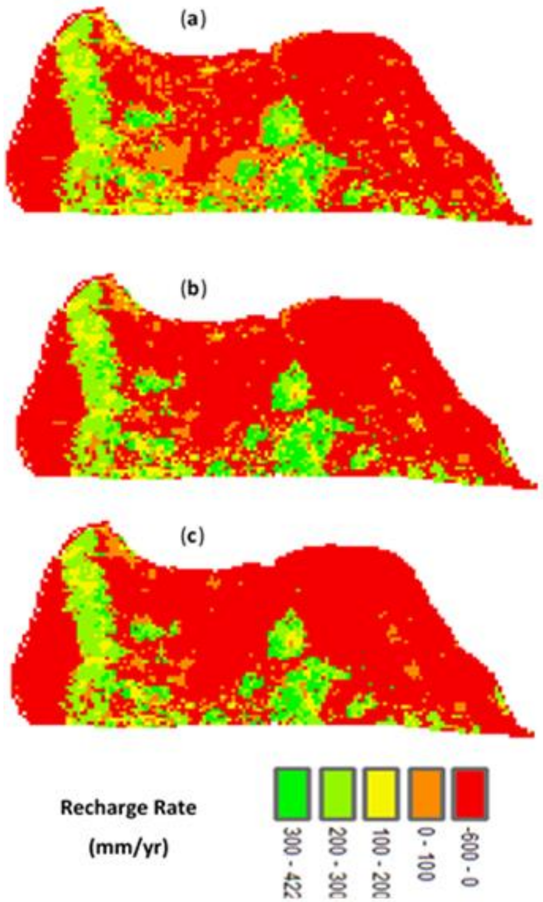


Variations in groundwater recharge

Global mean sea level rise (m)

Year	RCP6.0	**RCP8.5**
2007	0.03 (0.02 to 0.04)	**0.03 (0.02 to 0.04)**
2010	0.04 (0.03 to 0.05)	**0.04 (0.03 to 0.05)**
2020	0.08 (0.06 to 0.10)	**0.08 (0.06 to 0.11)**
2030	0.12 (0.09 to 0.16)	**0.13 (0.10 to 0.17)**
2040	0.17 (0.12 to 0.21)	**0.19 (0.14 to 0.24)**
2050	0.22 (0.16 to 0.28)	**0.25 (0.19 to 0.32)**
2060	0.27 (0.19 to 0.35)	**0.33 (0.24 to 0.42)**
2070	0.33 (0.24 to 0.43)	**0.42 (0.31 to 0.54)**
2080	0.40 (0.28 to 0.53)	**0.51 (0.37 to 0.67)**
2090	0.47 (0.33 to 0.63)	**0.62 (0.45 to 0.81)**
2100	0.55 (0.38 to 0.73)	**0.74 (0.53 to 0.98)**

Szenario from IPCC report 2013



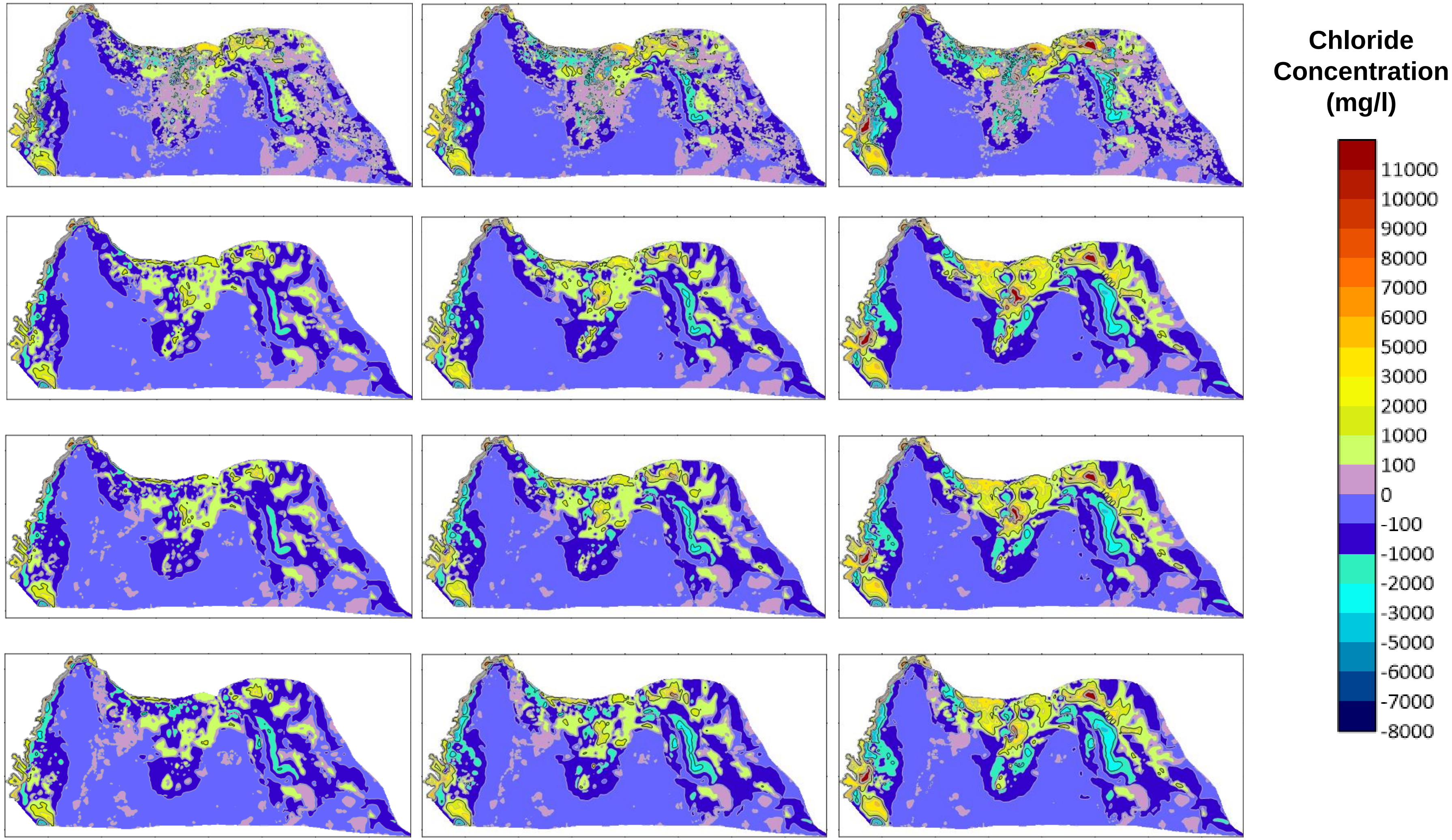
(a) Average recharge from 2010-2040
(b) Average recharge from 2040-2070
(c) Average recharge from 2070-2100

Szenario from water balance model mGrowa18 (LBEG)

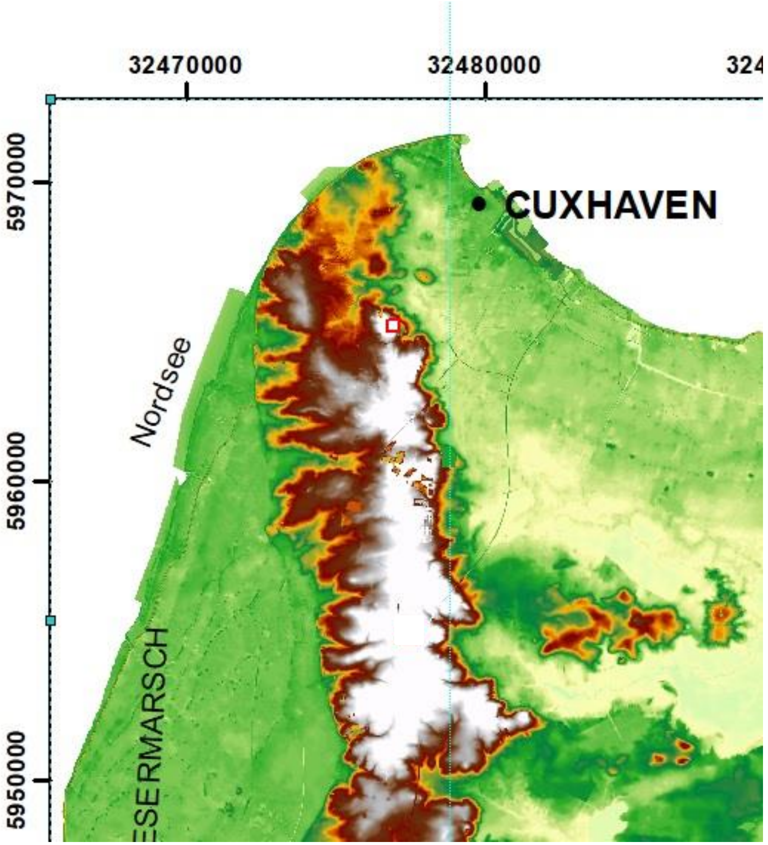
Chloride concentration difference maps – Average

2040-2010 | 2070-2010 | 2100-2010

0 m ASL
-20 m ASL
-40 m ASL
-60 m ASL



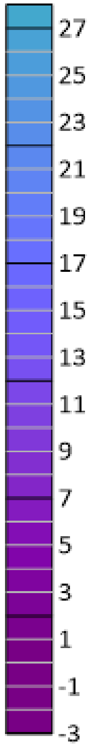
Managed Aquifer Recharge



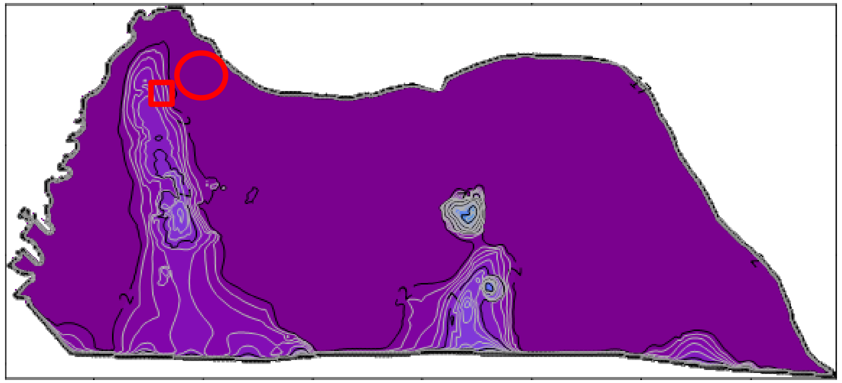
- *Calibrated model (2009-2013)*
- *All boundaries are kept constant*
- *Recharge was changed to consider effect of climate change*
- *Average recharge 2010-2040.*
- *20 Mio m³ per year water recharge by MAR*

Possible locations (min. 400 x 400 m)

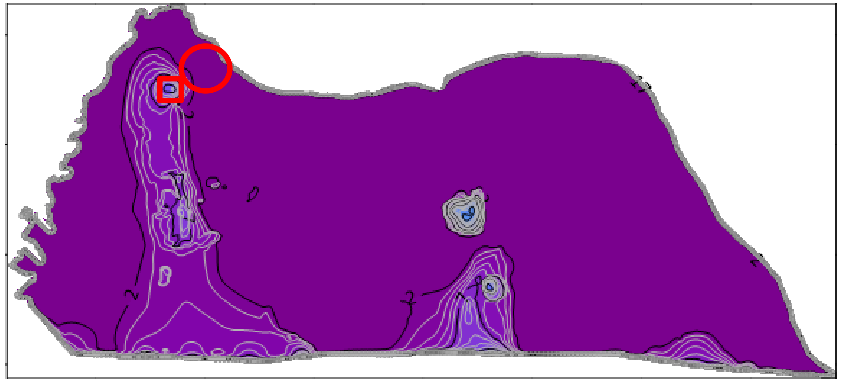
Managed Aquifer Recharge



Head at -20 m ASL without MAR

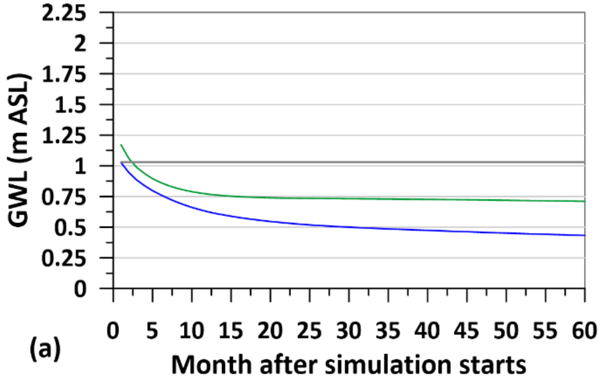


Head at -20 m ASL with MAR

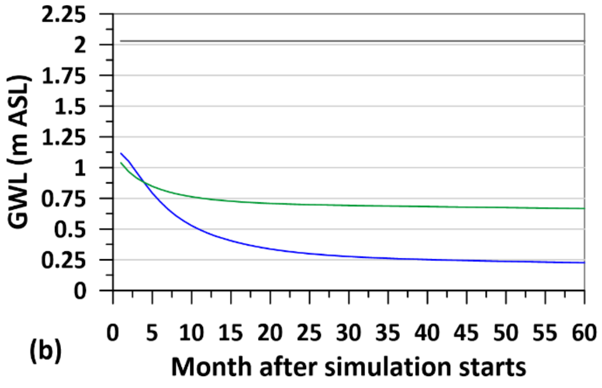


After 2 years

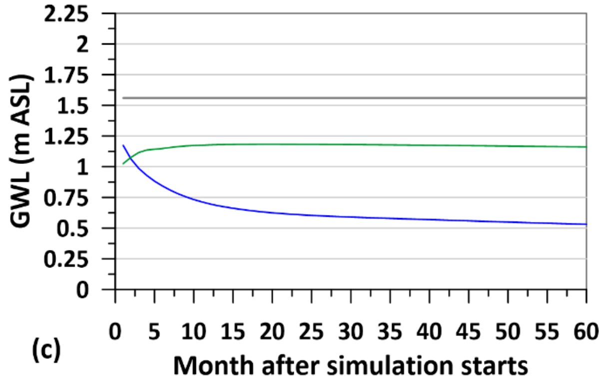
3 observation points



(a)



(b)



(c)

topographie

Gw level with MAR

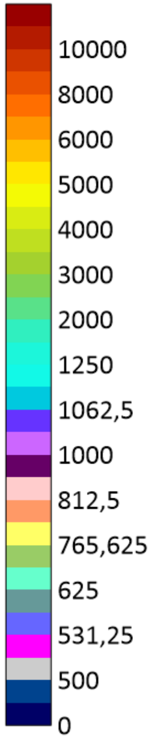
Gw level without MAR

MAR location

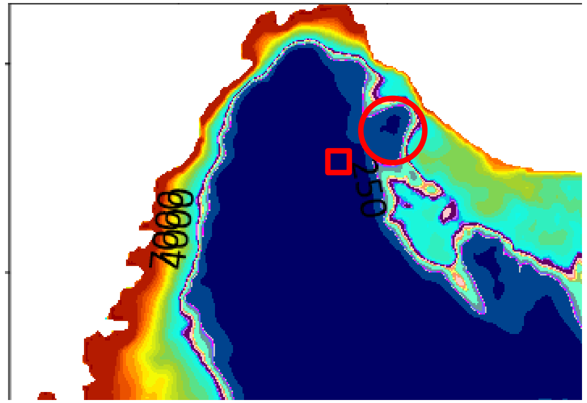
Location observation wells

Managed Aquifer Recharge

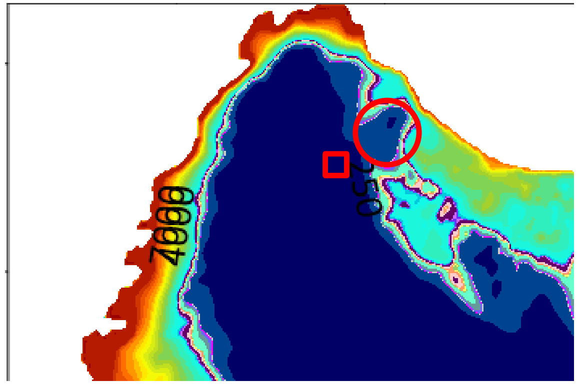
Chloride Concentration (mg/l)



Salinity at -20 m ASL without MAR

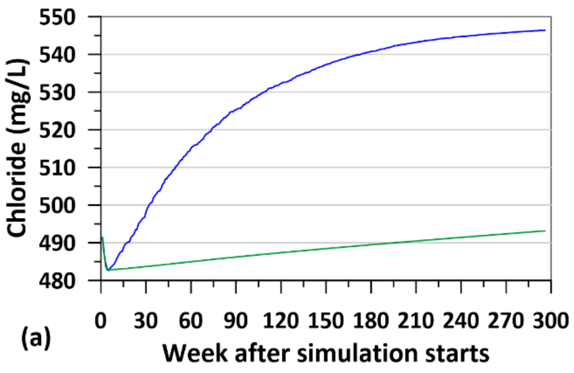


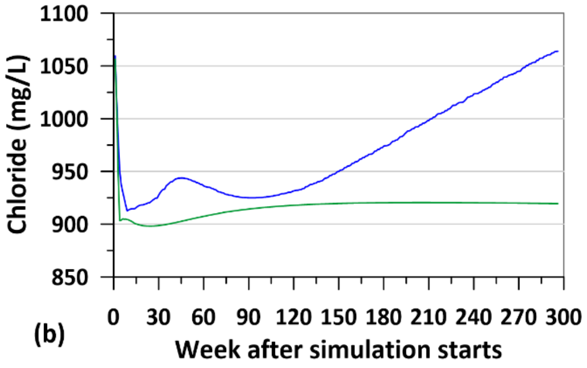
Salinity at -20 mASL with MAR

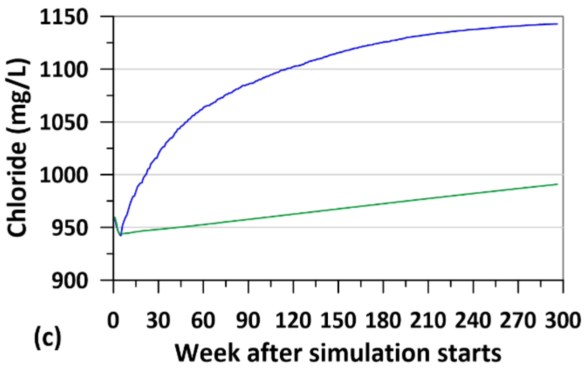


After 2 years

3 observation points







Chloride concentration with MAR

Chloride concentration without MAR

(a) 9 % reduction of chloride
(b) 14 % reduction of chloride
(c) 14 % reduction of chloride

MAR location

Location observation wells

Conclusion and outlook

Regional flow model

- A calibtrated and validated groundwater flow model has been developed
- Recharge and drainage are the main mechanism that control the regional flow and water budget.
- Only very few monitoring wells are located near the Elbe river and the sea.
- Hence, the flow pattern might not be accurately reproduced near the boundaries

Regional transport model

- A calibrated transport model has been developed
- No density effect has been considered
- Due to lack of chloride concentration near the boundaires, the calibration is not well established
- Initial condition for the transport model needs further improvement

Conclusion and outlook

Climate change scenario

- Three scenarios based on RCP 8.5 (Min, Average and Max) have been simulated
- The chloride distribution largely controlled by the recharge
- Chloride distribution changes at the Marsch area and near the sea side
- The model gives a first overview of climate change impact on salinity distribution.
- For water resources planning, the model must be improved with current monitoring data

Groundwater Buffering – managed aquifer recharge

- Managed aquifer recharge can improve the water quality (e.g., chloride) of the aquifer
- Care should be taken to avoid flooding
- Detail fine scale groundwater model should be developed for better understanding of MAR

Many thanks for your kind attention!

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