Reduction of scenario uncertainties through climate models (REDUKLIM)

3. URS Workshop – 24th October 2023

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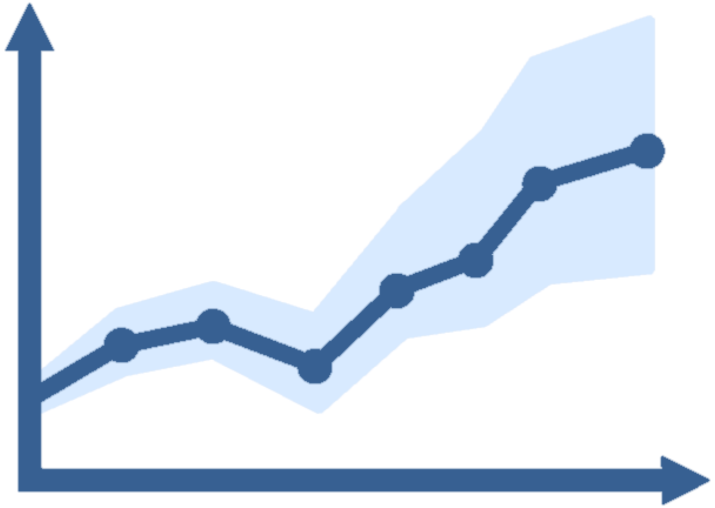
REDUKLIM - Research questions and aims

How can **future climate developments** be taken into account in the context of **long-term safety** and which **uncertainties** do this developments have?

- Assessment period of one million years (EndSiAnfV § 3)
- Consideration of the geological and climatic situation
    - Developing a better understanding of potential future climate developments
    - Linking of climate modelling and groundwater processes for the safety assessment
- Consideration of uncertainties in the context of the site selection
- Create additional confidence in the site selection



Categories of uncertainties

Parameter uncertainties

- Missing data
- Reliability of the data
- Applicability of the data
- Error ranges
- Spatial and temporal variability

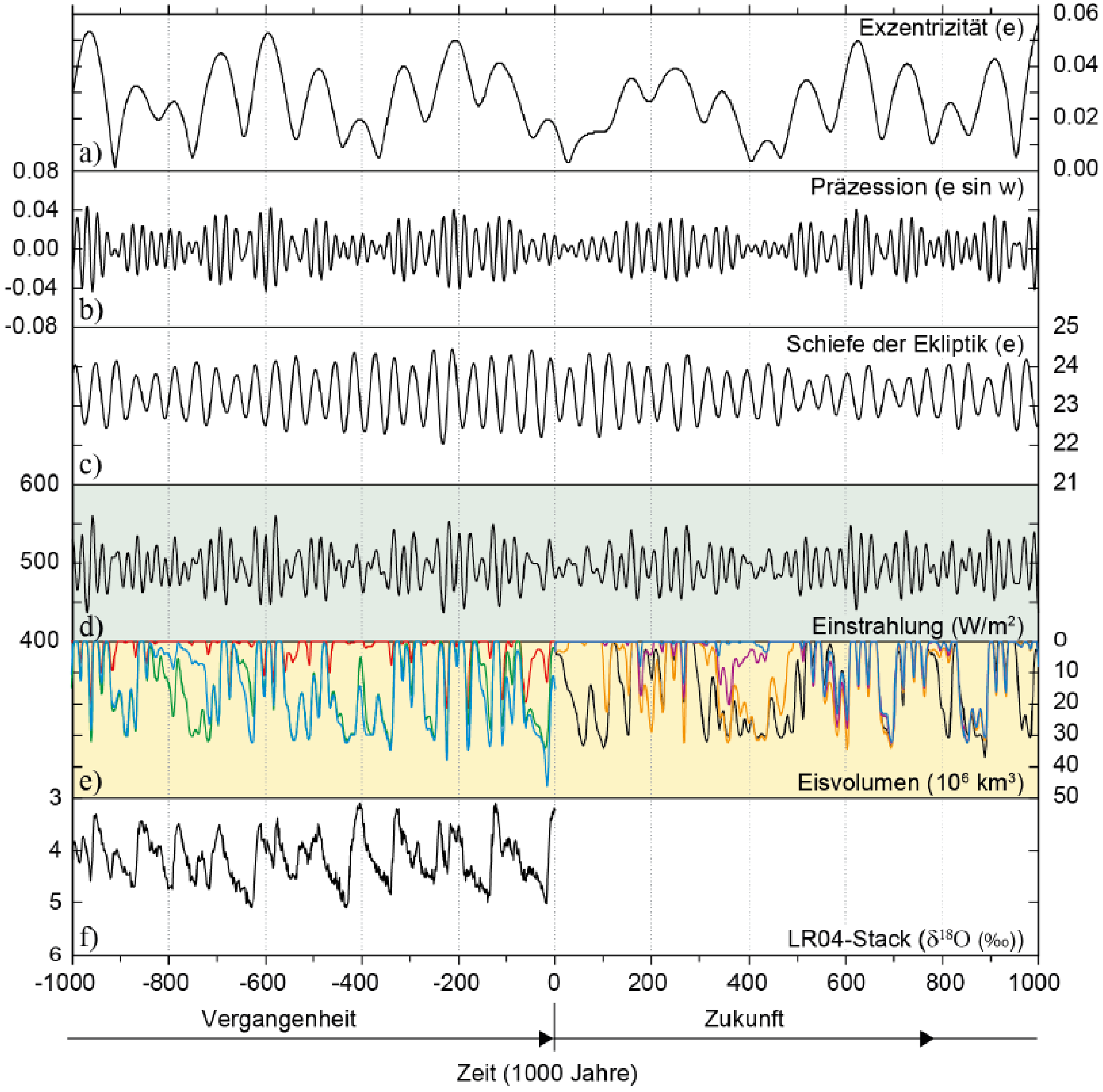
Model uncertainties

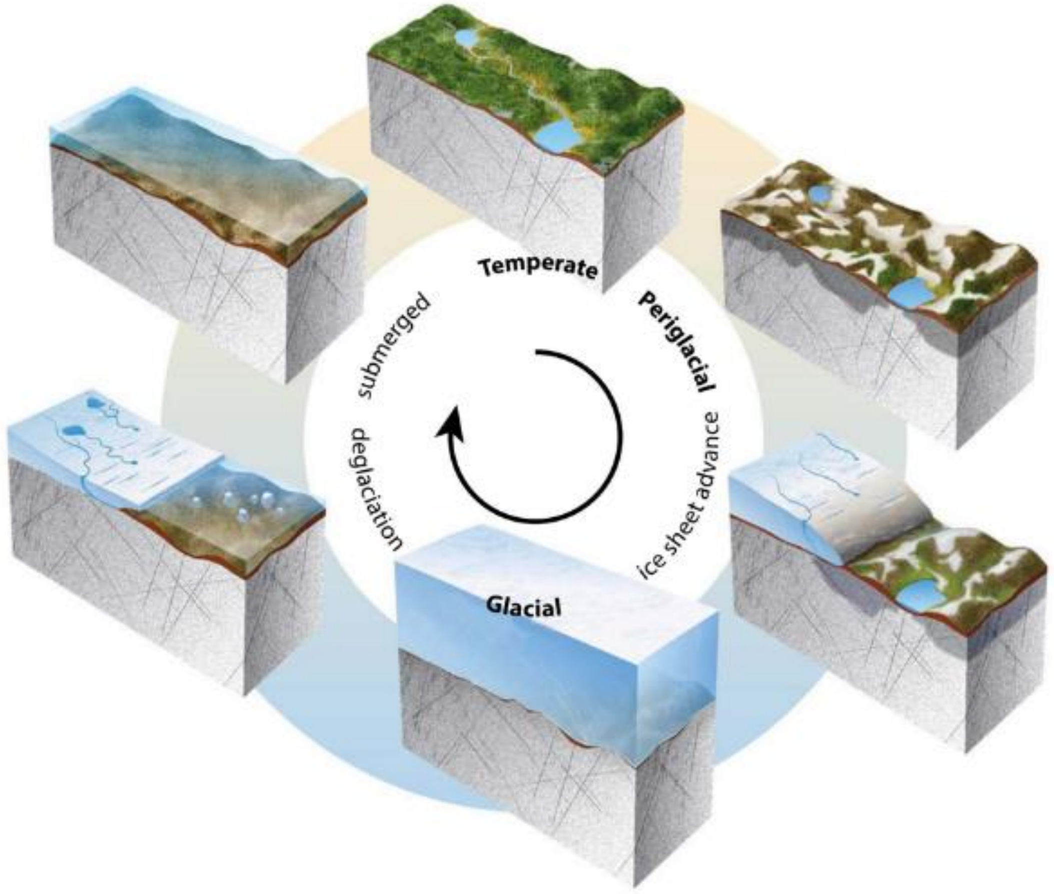
- System understanding
- Simplifications
- Model assumptions
- Model boundaries

Scenario uncertainties

- System understanding
- Uncertainty of future developments

Milankovic-cycles





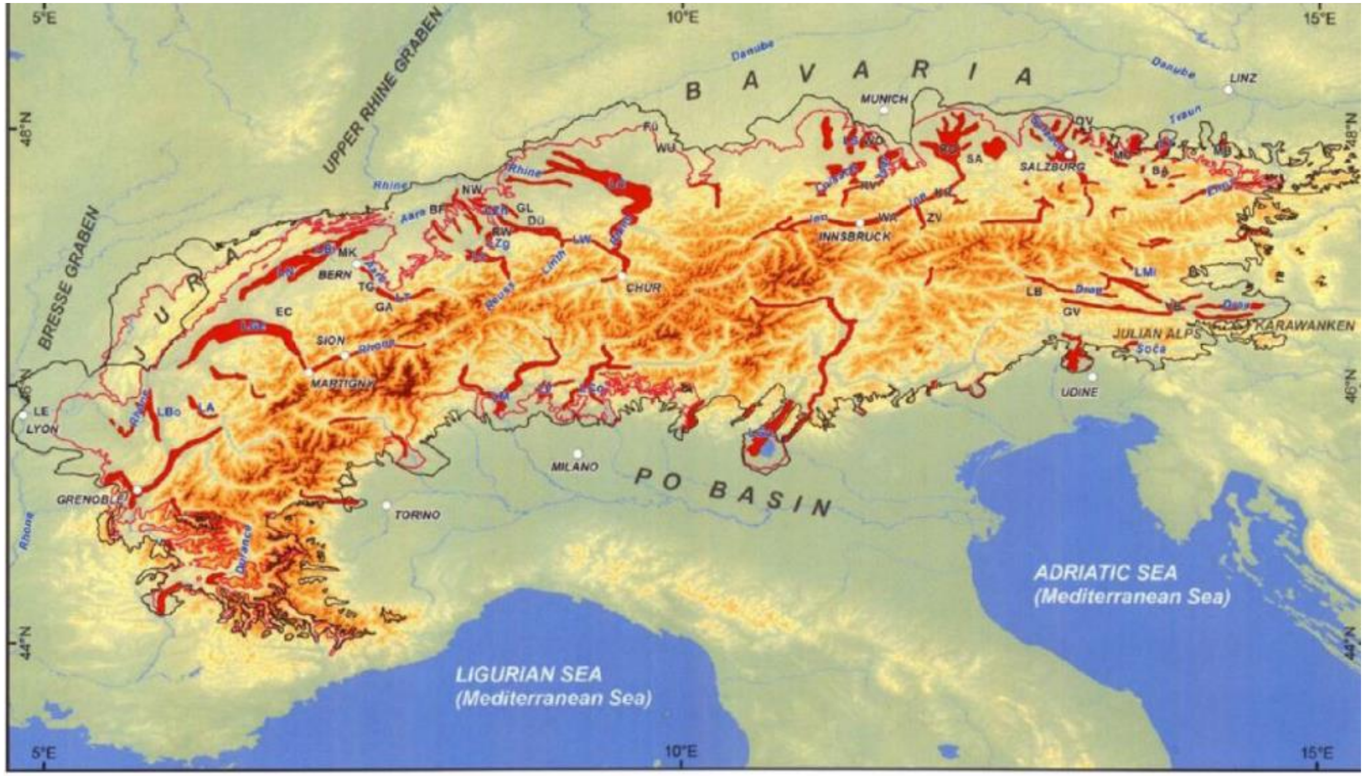
Brandefelt et al. 2019 /SKB TR-19-04

CO_2-Konzentration Vergangenheit (Berger et al. 1999)
- ME (330 ppmv vor 3 Mio Jahren → 200 ppmv heute)
- L01 (const. 220 ppmv)
- L02 (const. 280 ppmv)

CO_2-Konzentration Zukunft (Bioclim 2003)
- A3 (natürl. Szenario kalt)
- A4a (natürl. Szenario alternativ)
- B4 (anthrop. Szenario A4a++)
- B3 (anthrop. Szenario A4a+)

Schnellmann et al. 2014
(NAGRA NAB 14-25)

Past climate development in Germany



Stark 2014 (BGR - AnSichT Süd)

Ice advances in the alps area

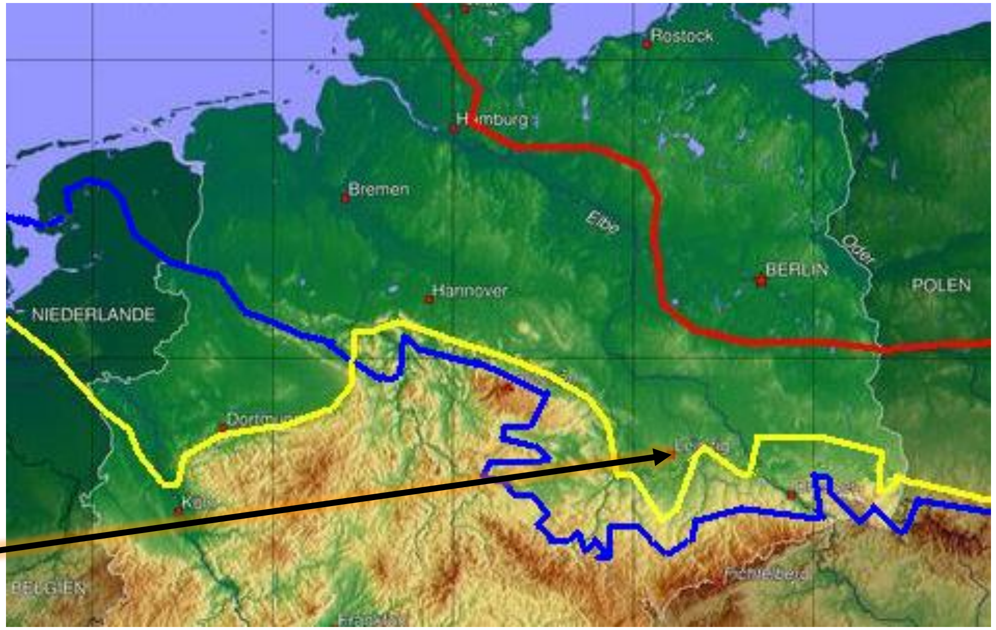
- overdeepened valleys
- − last ice advance
- − max. ice advance in Pleistocene

Classification of most important ice advances in northern Germany and the alps area

Stufe/Alter	Norddeutschland	Nordwestliches Alpenvorland	Nordöstliches Alpenvorland
Oberpleistozän	Weichsel-Kaltzeit	Würm-Komplex	Würm-Kaltzeit
Mittelpleistozän	Saale-Komplex	Riss-Komplex	Riss-Komplex
	Elster-Kaltzeit	Hoßkirch-Komplex	Haslach-Mindel-Komplex

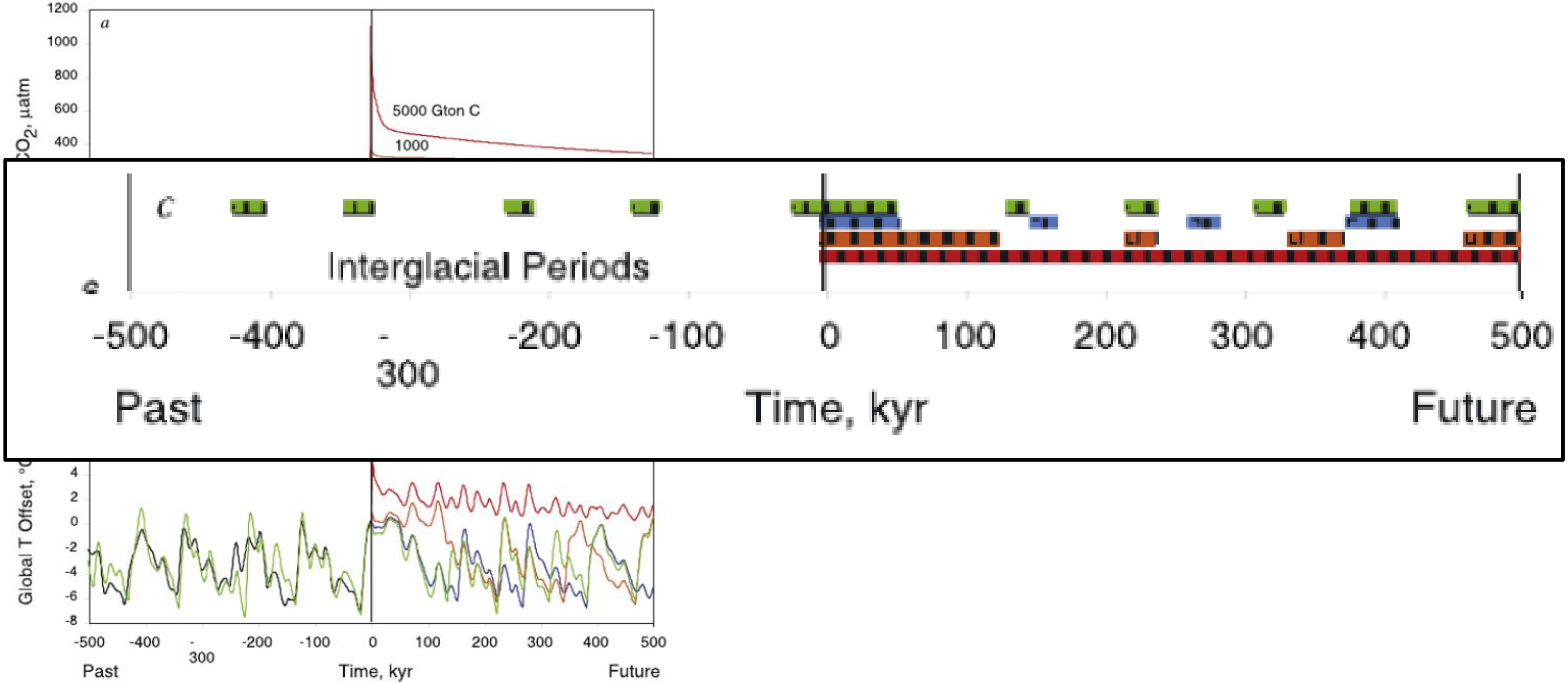
Stark 2014 (BGR - AnSichT Süd)

Leipzig



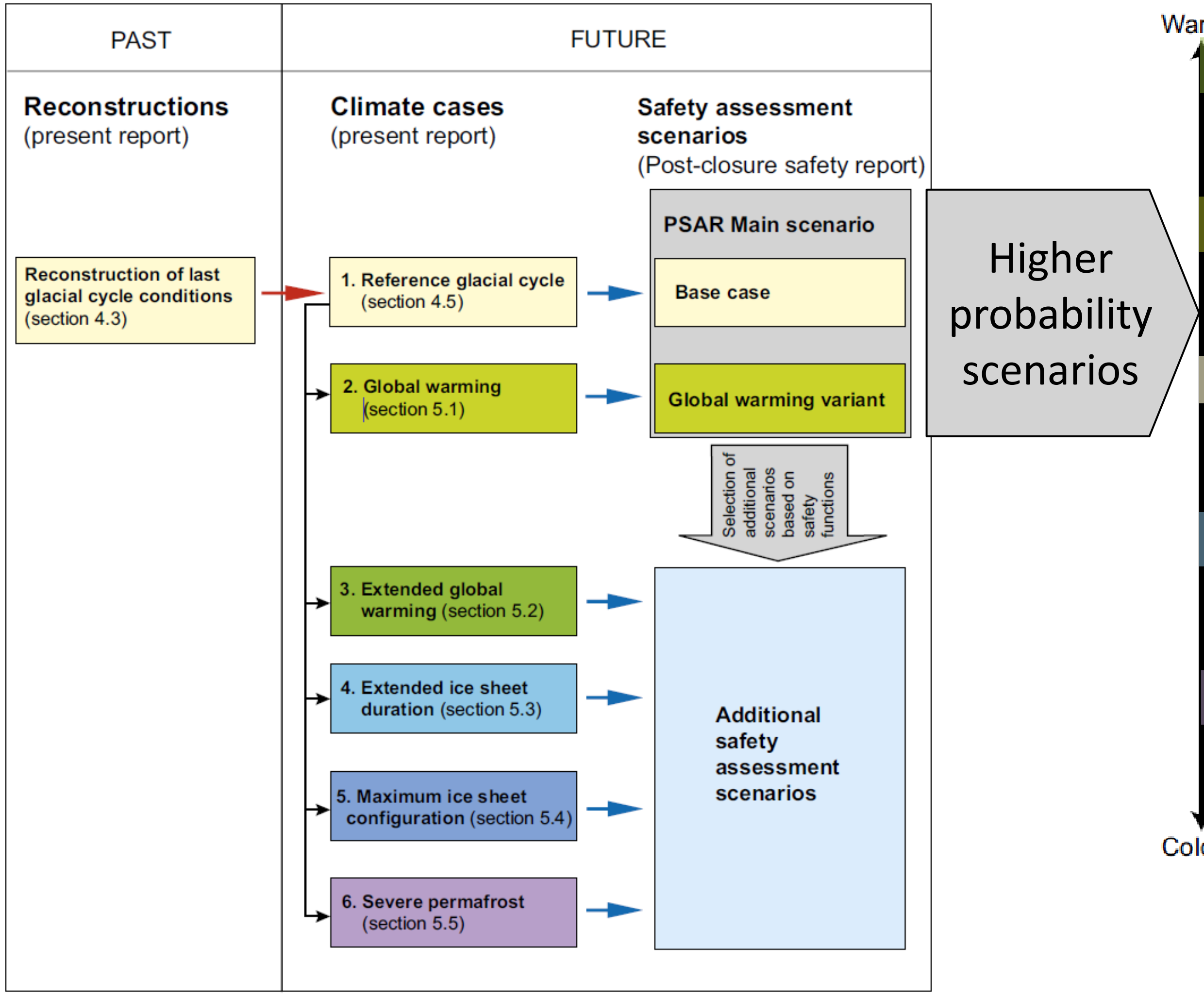
Ice margins after Wagenbreth & Steiner 1990, Walther 2007, WWU-M 2007

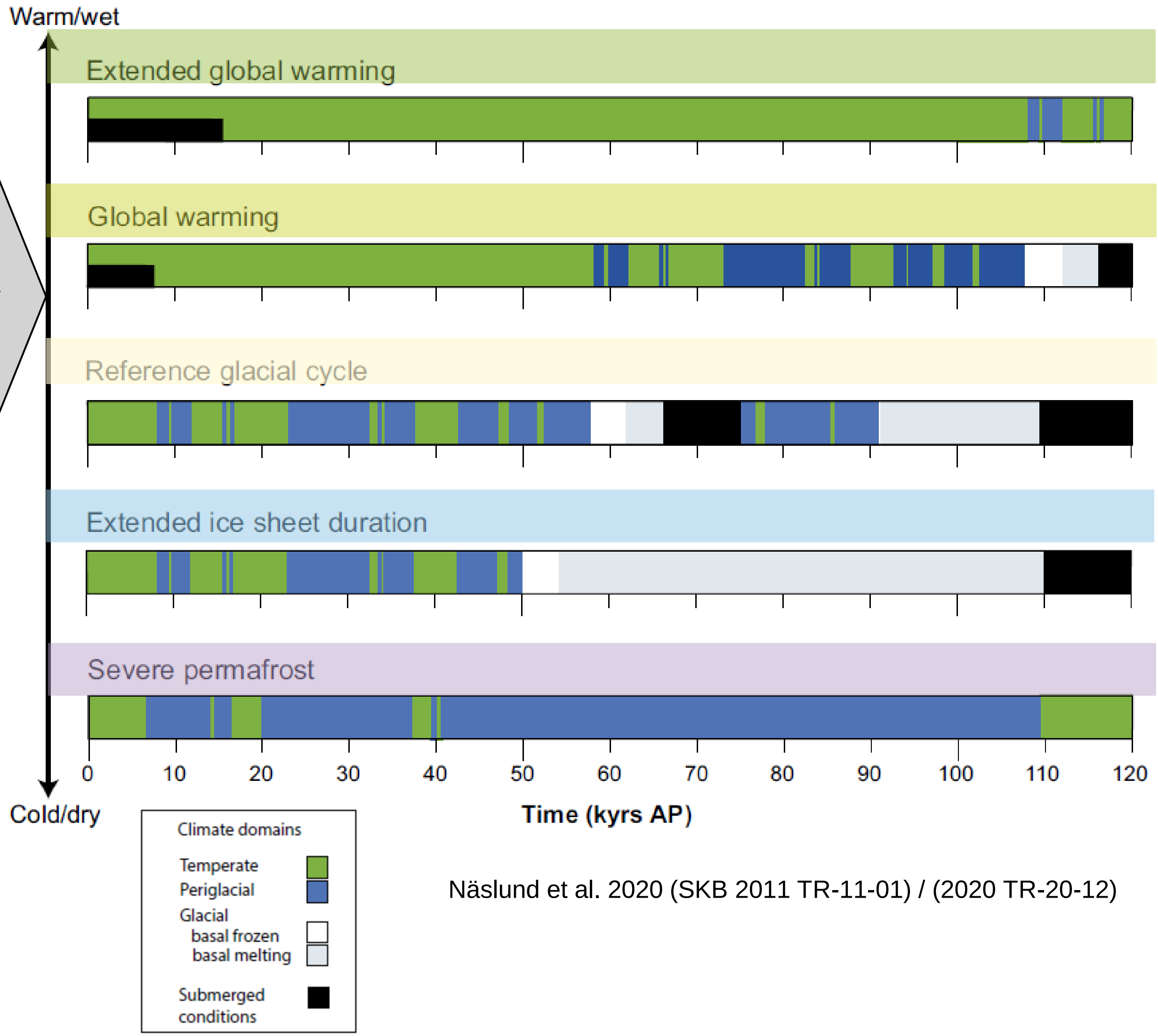
Influence of (anthropogenic) CO_2



Archer & Ganopolski 2005

Climate scenarios – example SKB (Sweden)





Näslund et al. 2020 (SKB 2011 TR-11-01) / (2020 TR-20-12)

Implementation of climate developments – d³f++

d³f++

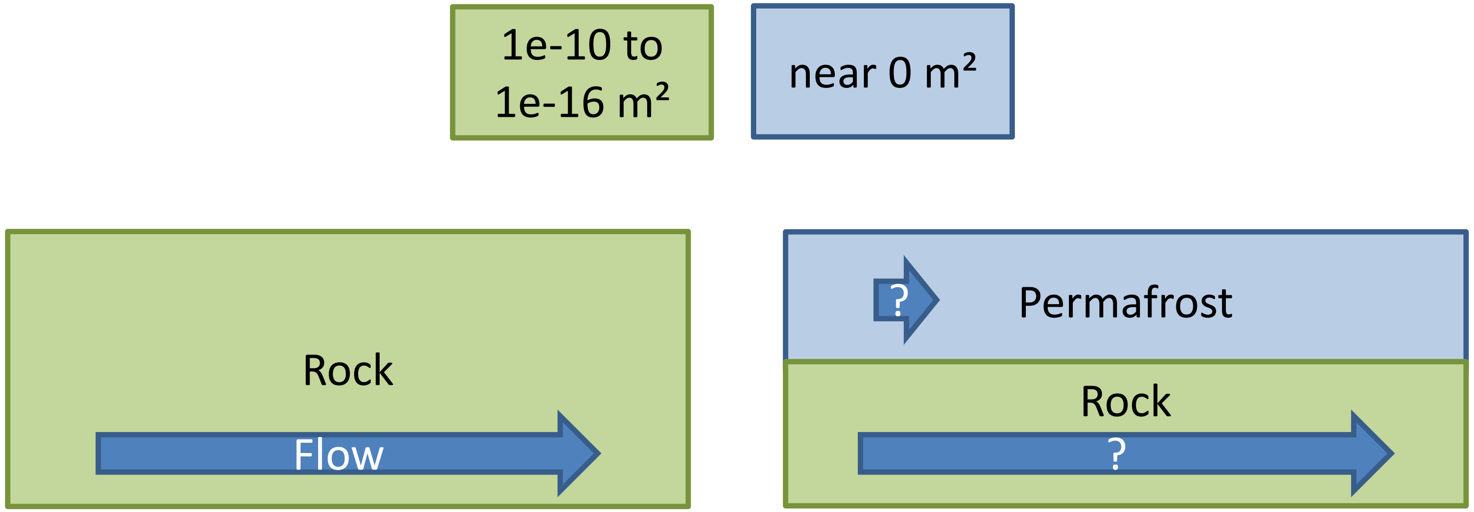
- No change of model geometry possible
- Change of parameters stepwise or with time functions

- Modelling different possible climate developments
  - Permafrost
  - Glacier/ ice sheet
  - Sea level changes
  - Erosion
- Conditions are represented by changed boundary conditions in the groundwater model
- ➢ Evaluate effects of climate conditions

Permafrost

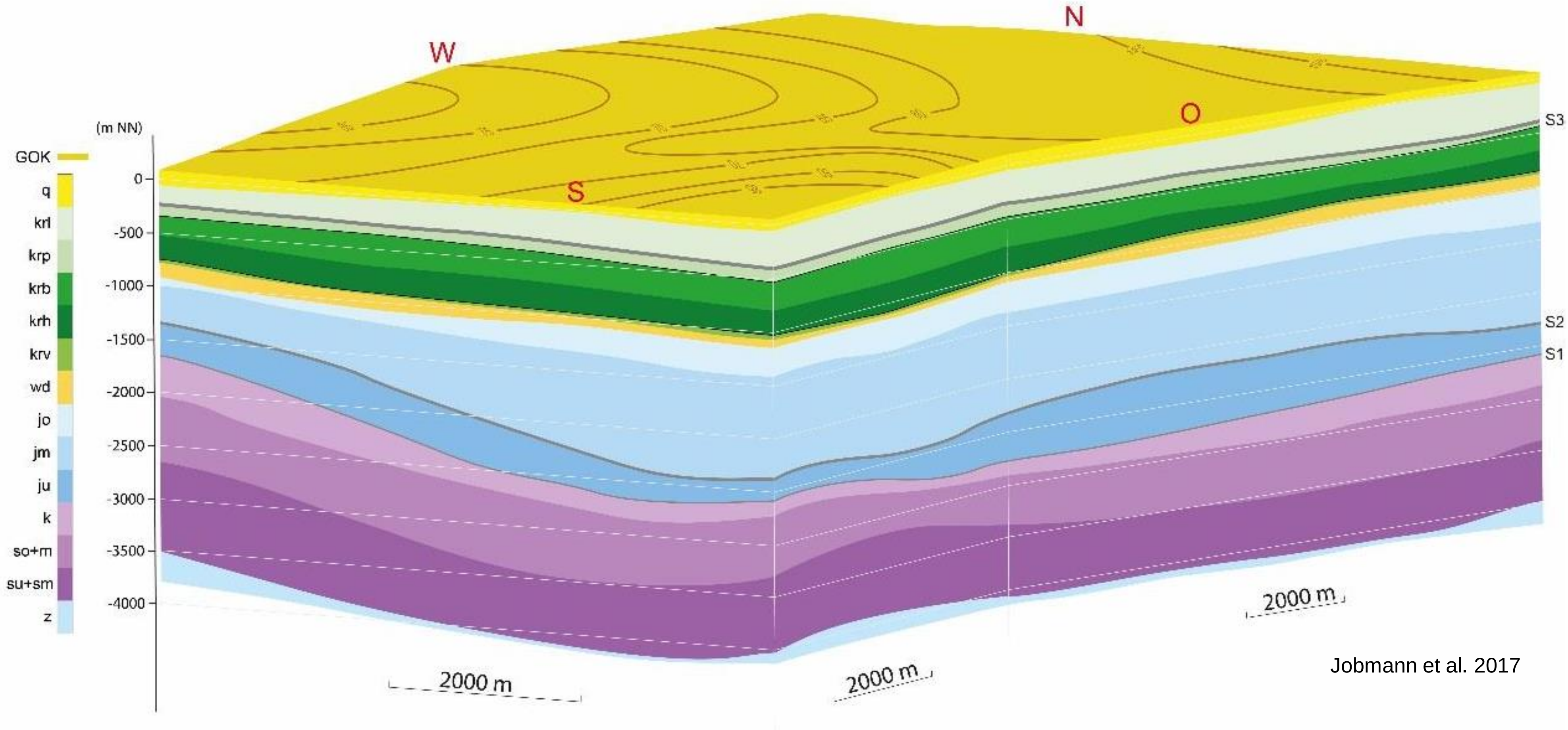
- Subsoil whose temperature is continuously below 0°C for at least two years
- Water in the pore space is frozen and thus reduces permeability
- Reduction of permeability in the affected model area
- ➢ No groundwater recharge in permafrost areas

Permeability values:



Model region – ANSICHT North

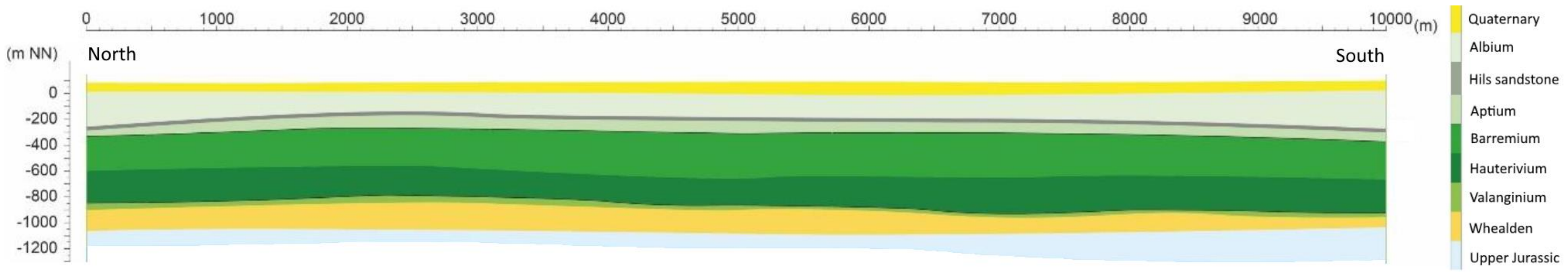
- Generic geological site model with relation to geological units which are investigated in Germany



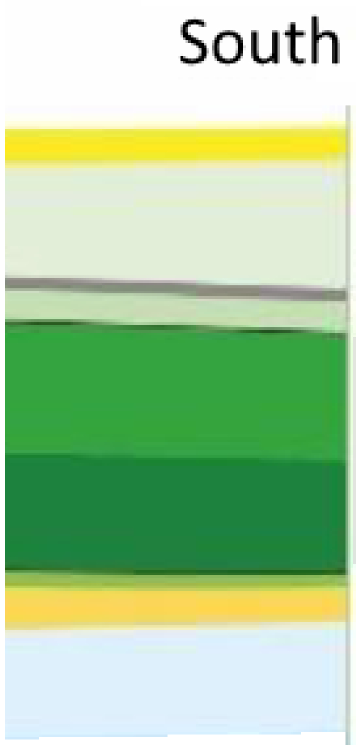
Jobmann et al. 2017

Model region – ANSICHT North

- Model area with smaller amount of lithostratigraphic units
  - Upper Jurassic as lowest unit
    - No further influence from underlying units
    - ➢Reducing computer simulation capacity
- 9 lithostratigraphic units with different characteristics (permeability, porosity)
- The dimensions of the model area are approximately 10 km in width by up to 1400 m in height.



Model region – ANSICHT North



	Permeability [m²]	Effective porosity [-]
Quaternary	$1\cdot10^{-14}$	0,2
Albium	$1\cdot10^{-18}$	0,05
Hils sandstone	$1\cdot10^{-14}$	0,1
Aptium	$1\cdot10^{-18}$	0,05
Barremium	$1\cdot10^{-19}$*	0,05
Hauterivium	$1\cdot10^{-19}$*	0,05
Valanginium	$1\cdot10^{-16}$	0,05
Whealden	$1\cdot10^{-14}$	0,075
Upper Jurassic	$1\cdot10^{-15}$	0,01

Einschlusswirksamer Gebirgsbereich (ewG)
containment providing rock zone (CRZ)

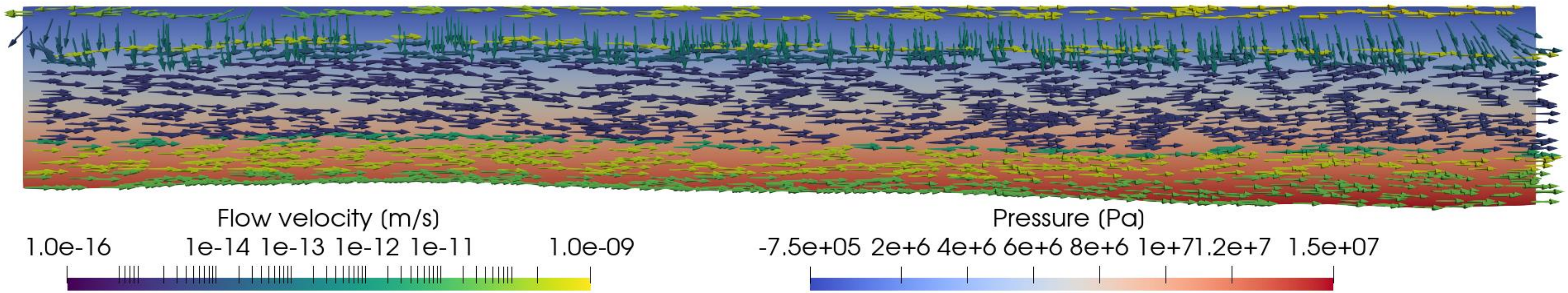
*vertical $1\cdot10^{-20}$ [m²]

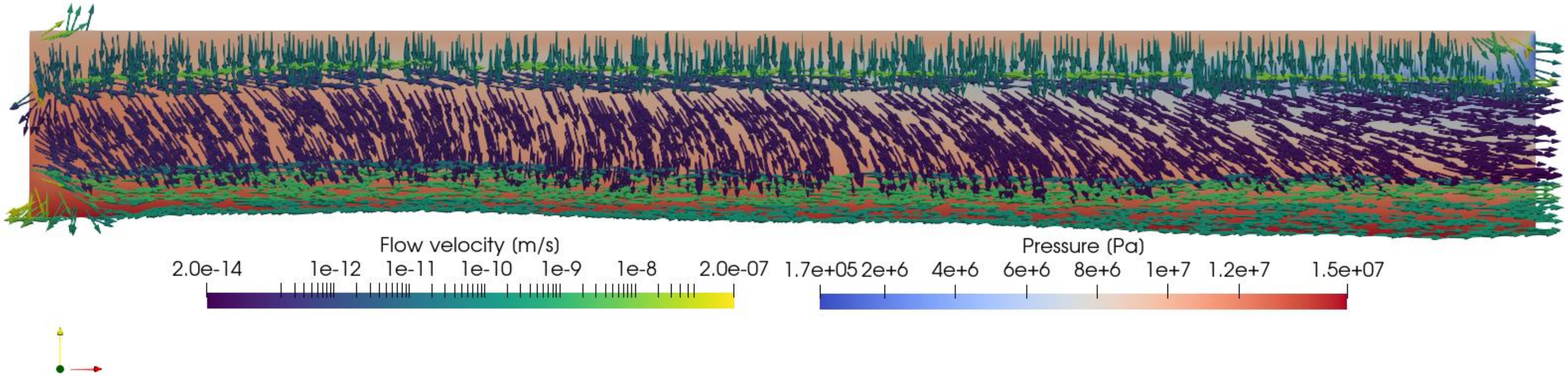
Simulation cases

- ANSICHT
  Parameters ("Base case")
  - Parameter variations
    - Flow
      - Permeability
      - Porosity
    - Transport
      - Diffusion
      - Dispersion
  - Climate developments
    - Steady climate states
      - Permafrost
      - Glaciation
      - Sea level changes
      - Erosion
    - Transient climate developments
      - Likely German climate scenario

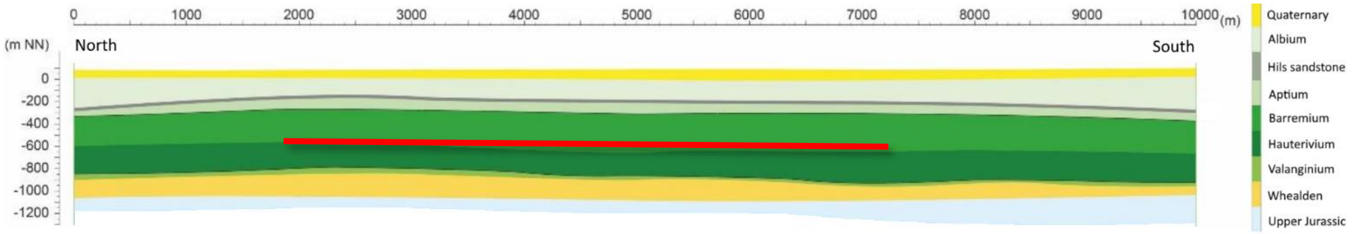
Results – parameter variation

- Present Climate with parameters from Rübel & Gehrke 2022 after the data from the ANSICHT project



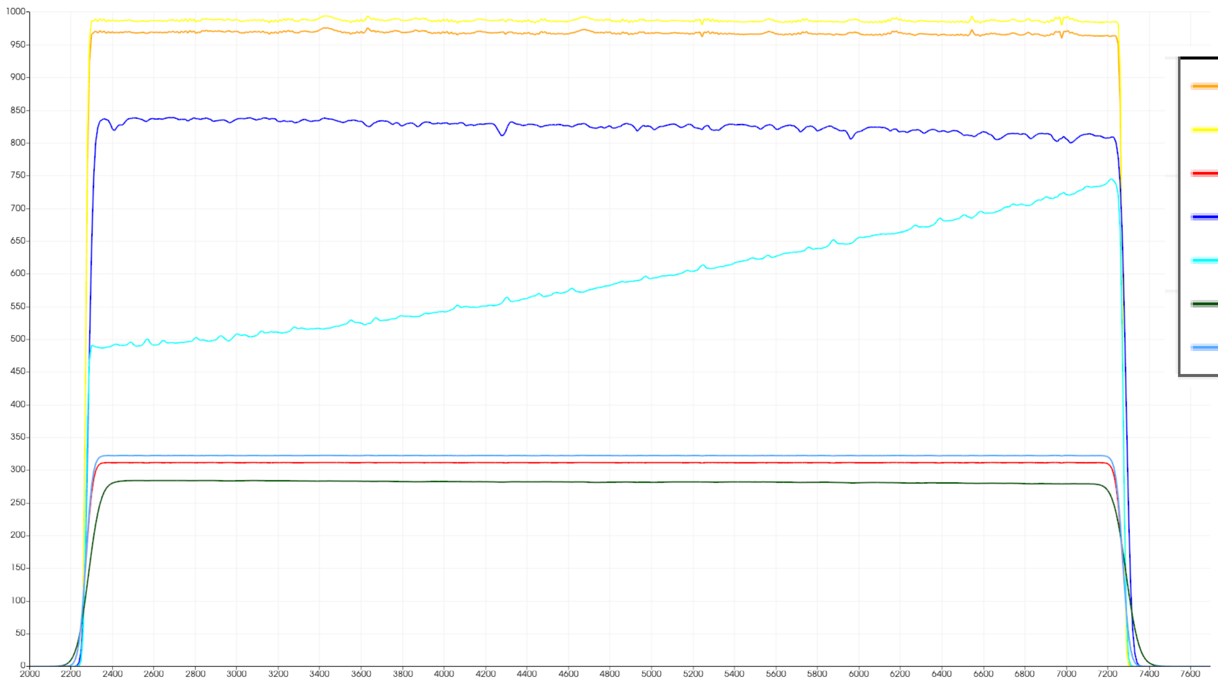


Results – parameter variation

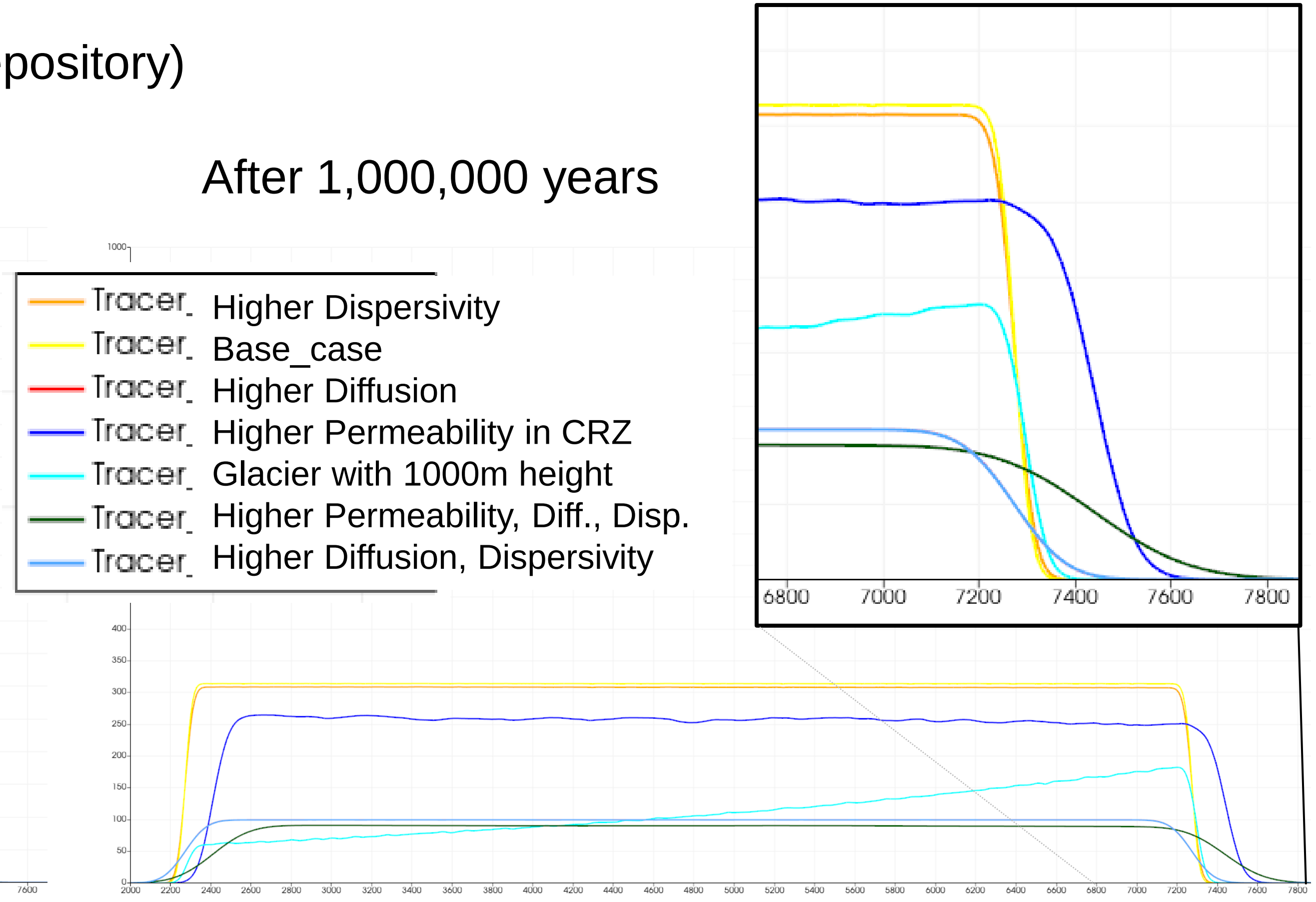


- Cross section from X=0 to X=10080 at Y -622 (repository)

After 100,000 years

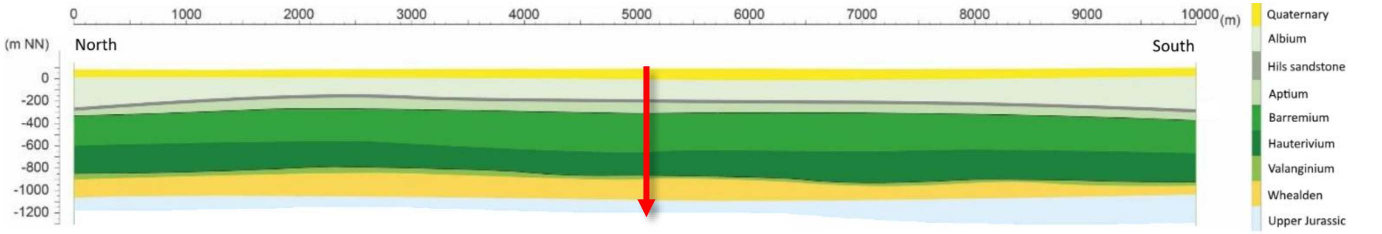


After 1,000,000 years



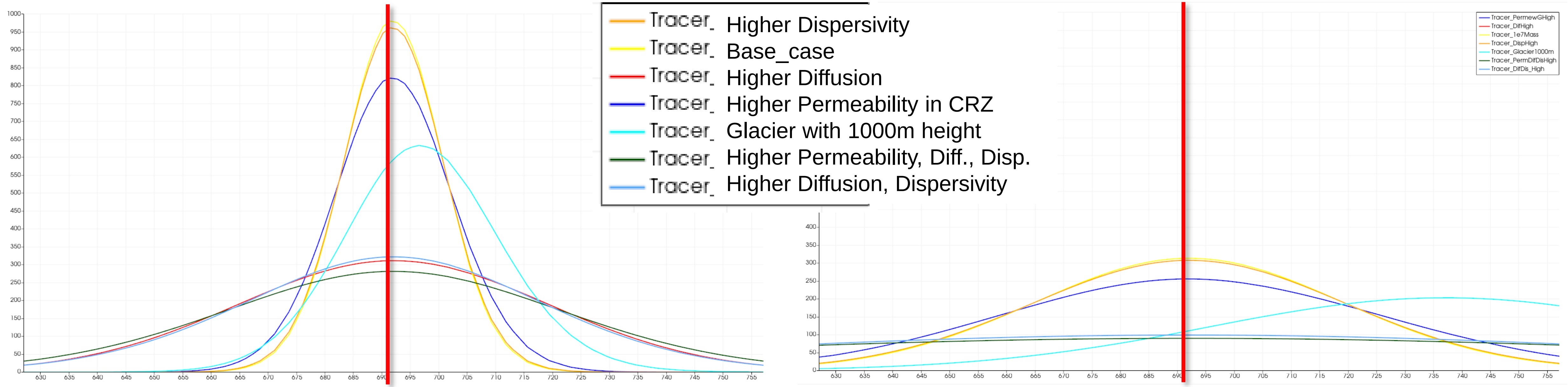
Results – parameter variation

- Cross section from Y=70 to X=1200 at X= 5040

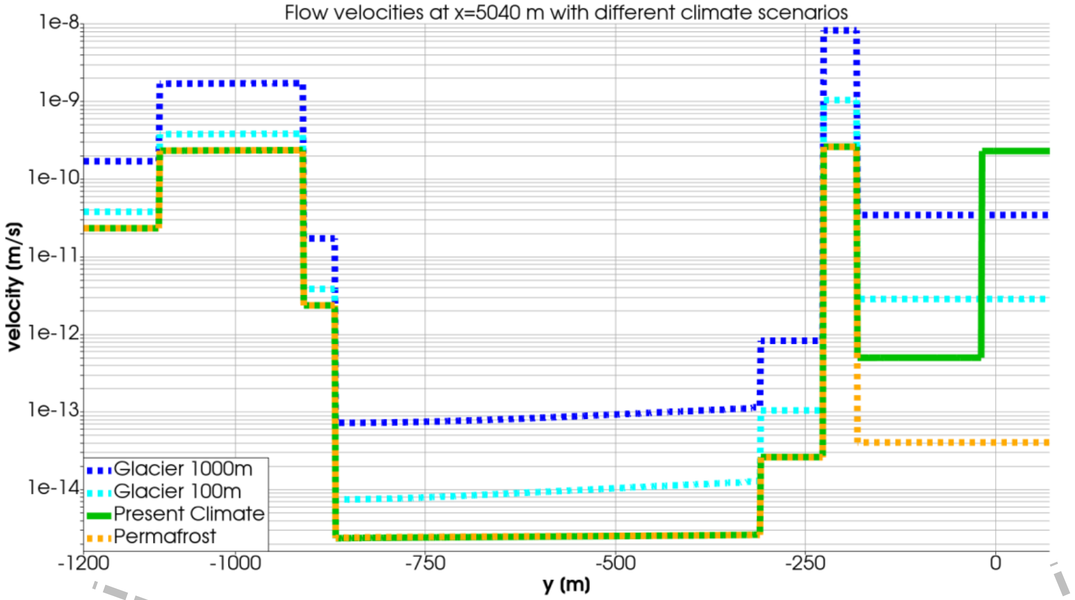


After 100,000 years

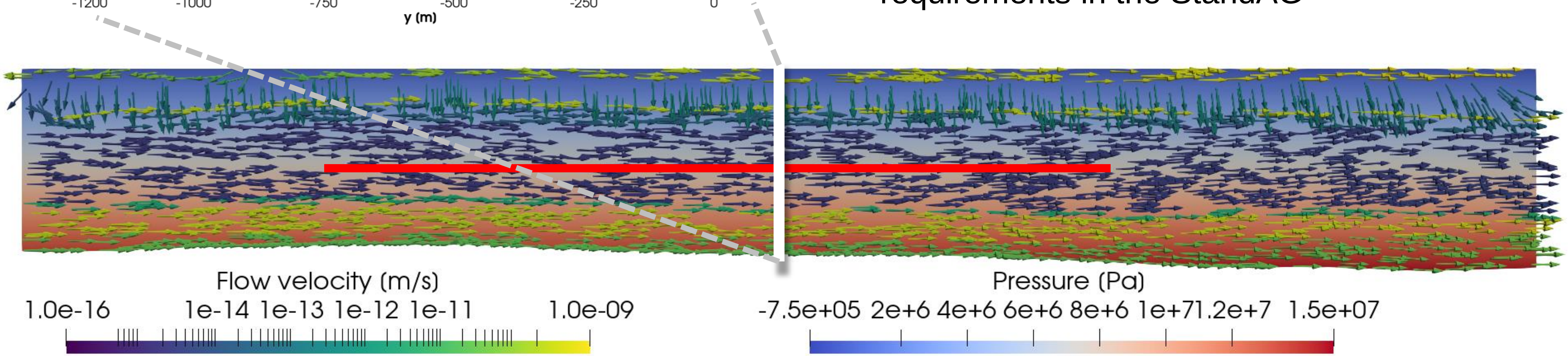
After 1,000,000 years



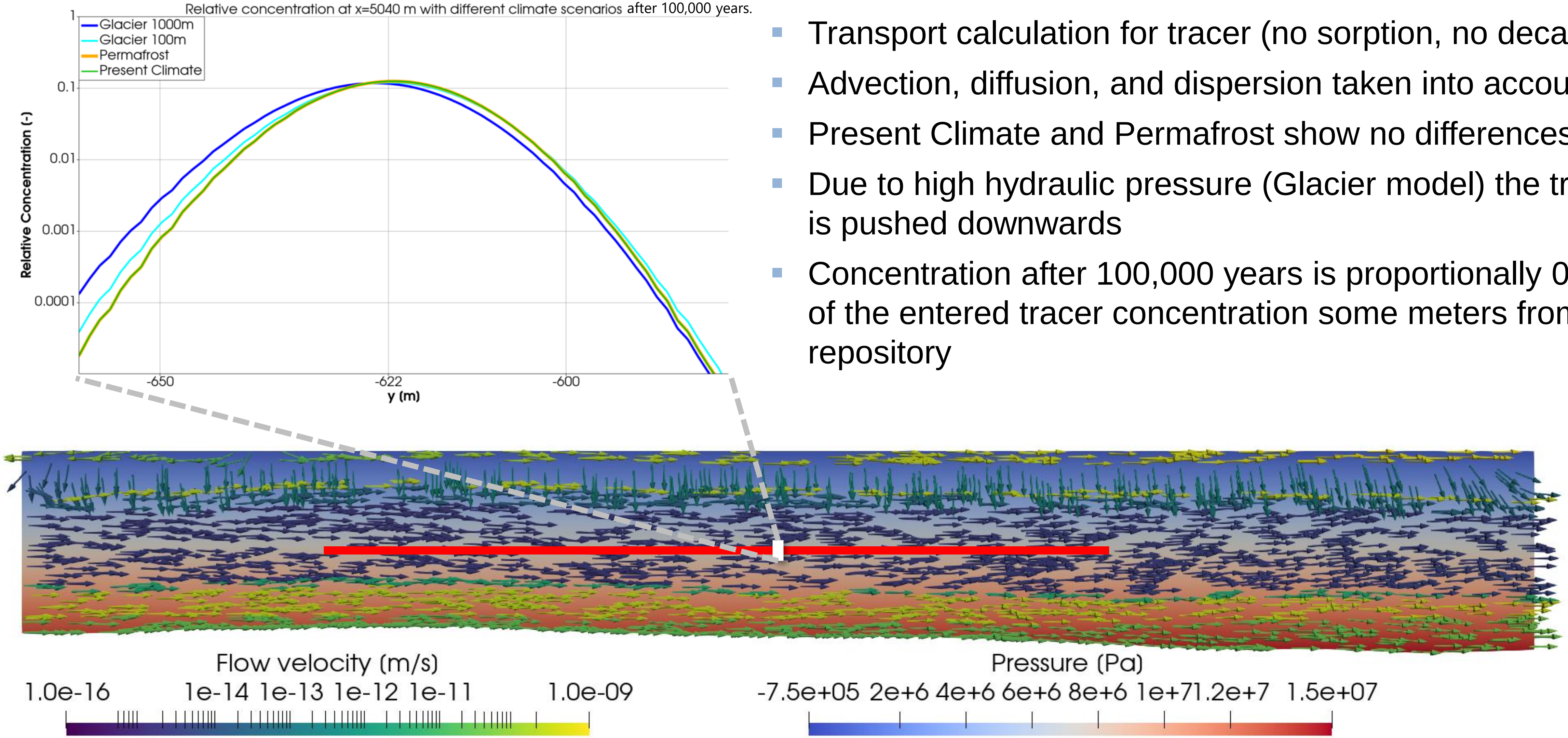
Results – climate states stationary



- 4 climate cases simulated
  - Present climate
  - Permafrost
  - Glacier thickness 1000 m
  - Glacier thickness 100 m
- Variation of flow velocities in different units
- All velocities are favourable after the requirements in the StandAG



Results – climate states stationary – transport



- Transport calculation for tracer (no sorption, no decay)
- Advection, diffusion, and dispersion taken into account
- Present Climate and Permafrost show no differences
- Due to high hydraulic pressure (Glacier model) the tracer is pushed downwards
- Concentration after 100,000 years is proportionally 0.1 % of the entered tracer concentration some meters from the repository

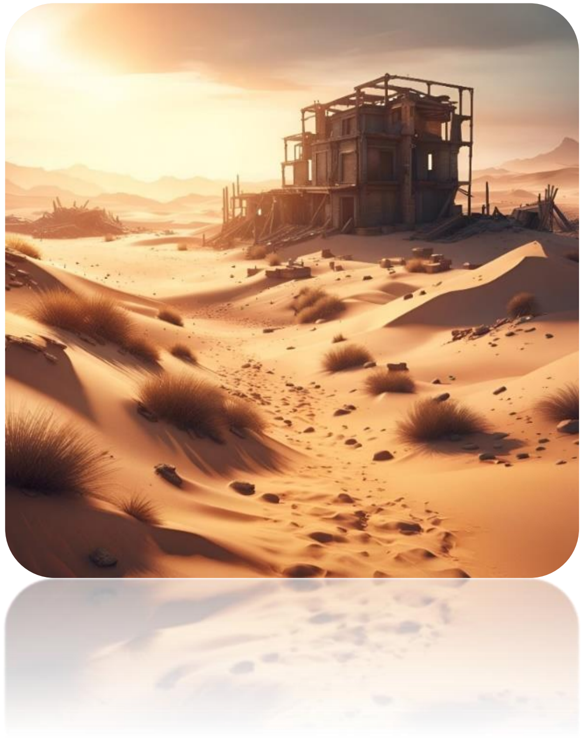
Summary and outlook

- Flow velocities changes through different considered climate states
- Groundwater models helps to understand the sensitivity of parameters and different climate scenarios
  - In low permeable claystone the concentration front does not reach the top of the CRZ in assessment period with parameters from Ansicht model
  - Higher diffusion coefficient and Glacier load lead to transport in the Lower Cretaceous/Upper Jurassic units
  - Choice of parameters or differences in rock characteristics can have larger influence on model results than different climate states
  - ➢ Choice of parameters and good exploration will be very important in the site selection

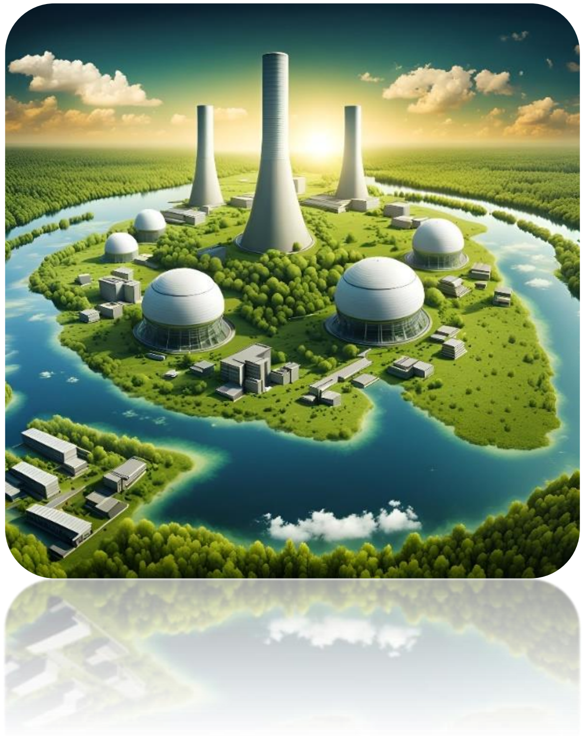
- Running sea level change and erosion models
- Implement transient changes of parameters for climate cycles
- Additional parameter variation simulations

Thank you for your attention!

warm climate?



Temperate climate?



cold climate?

Generated by AI (Nightcafe)

BUNDESGESELLSCHAFT FÜR ENDLAGERUNG

Research order number:
STAFuE-21-4-Klei

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Literature

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