ESF projekts „Starpnozaru zinātnieku grupas un modeļu sistēmas izveide pazemes ūdeņu pētījumiem”

Modelling the influence of the Pleistocene glaciatiations on the groundwater flow in the Baltic Basin

Pleistocēna ledāju ietekmes uz pazemes ūdeņu plūsmu Baltijas artēziskajā baseinā modelēšana

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EIROPAS SAVIENĪBA

LATVIJAS UNIVERSITATE ANNO 1919

IEGULDĪJUMS TAVĀ NĀKOTNĒ

Līguma Nr. 2009/0212/1DP/1.1.1.2.0/09/APIA/VIAA/060

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- Meltwater flow beneath the ice sheet
- Modelling scenarious and boundary conditions
- Results
- Discussion
- Conclusions

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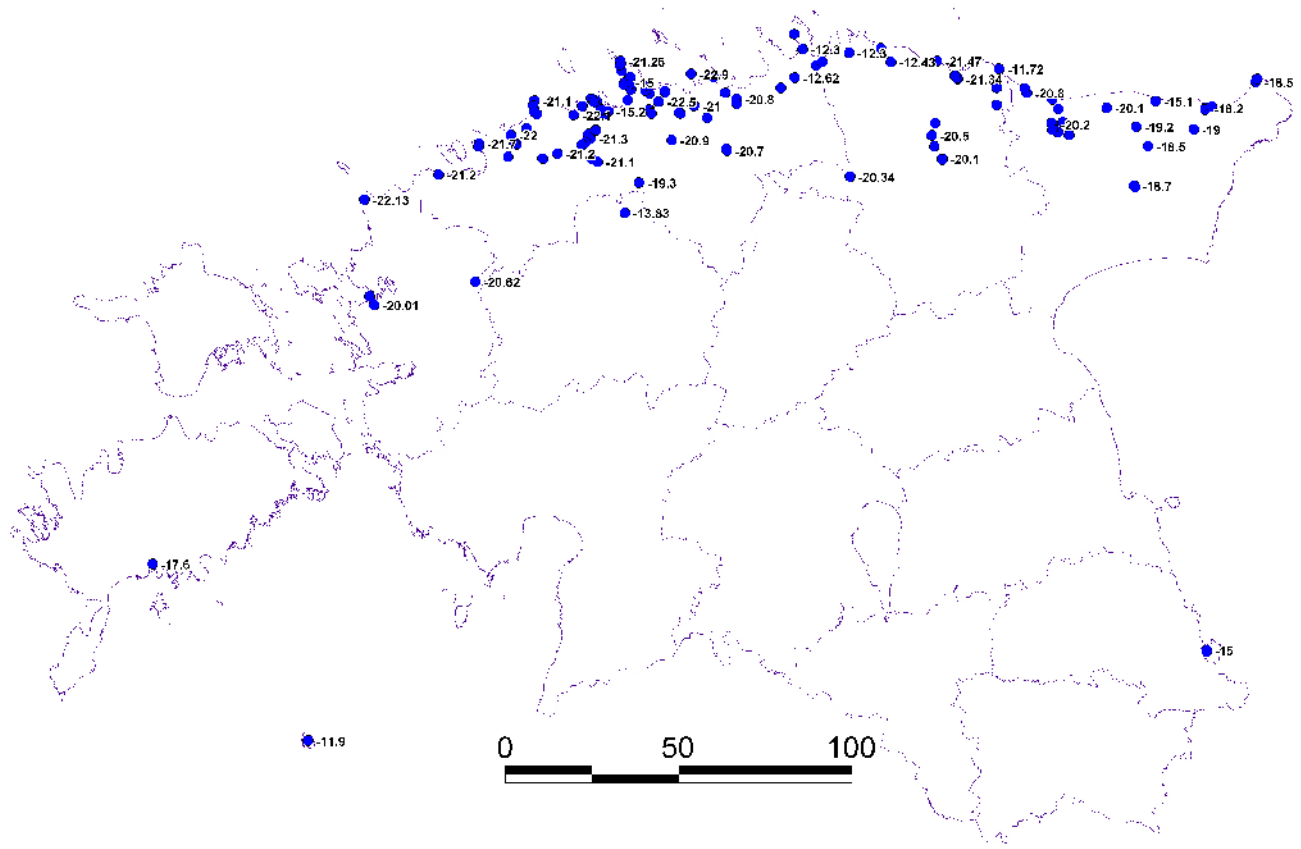
The age of the groundwater in the Baltic Basin

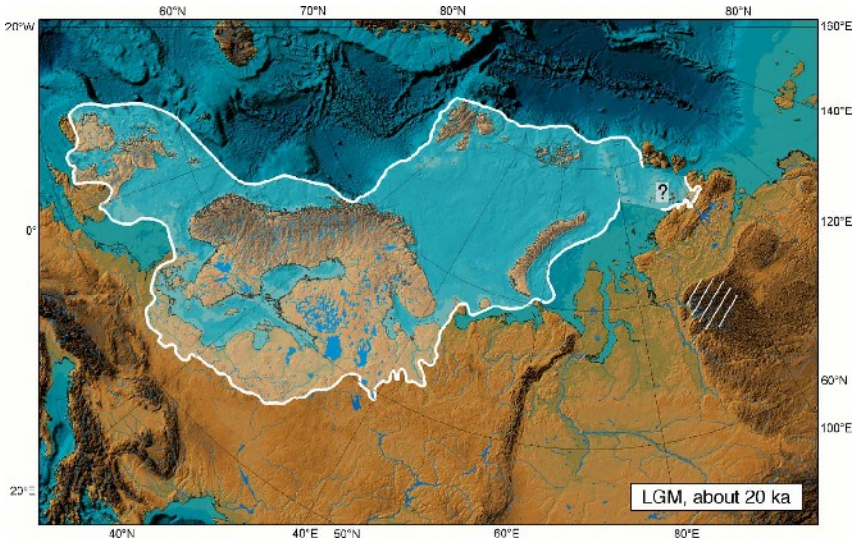
- Groundwater, based on its chemical and isotopical composition can be subdivided into broad 3 groups:
  - "Contemporary" (Last 10 th. y.)
  - Pleistocene (glacial and interglacial)
  - "Ancient" - Prequaternary groundwater

Pazemes ūdens vecums



- Distribution of the dO^{18}‰ in the Vendian – Cambrian aquifer system (after Radla, 2010).

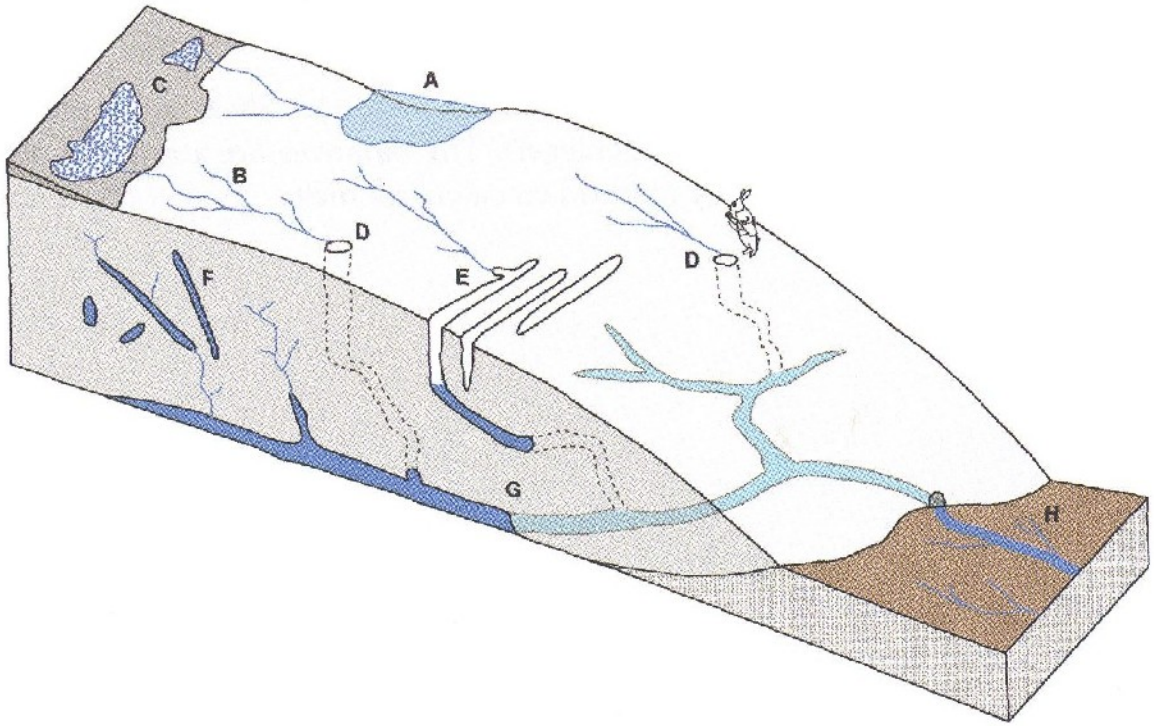
Glacial history of the Baltic Basin



After Svedsen et al 2004

- The Baltic Basin has been covered by the Scandinavian ice sheets at least 4 times
- The last Late Weichselian glaciation was present in the Baltic Basin territory for at least 19 thousand years

Subglacial water flow



A – Supraglacial lake;

B – Surface streams;

C – Swamp zones near the edge of the firn;

D – Moulins;

E – Crevasses

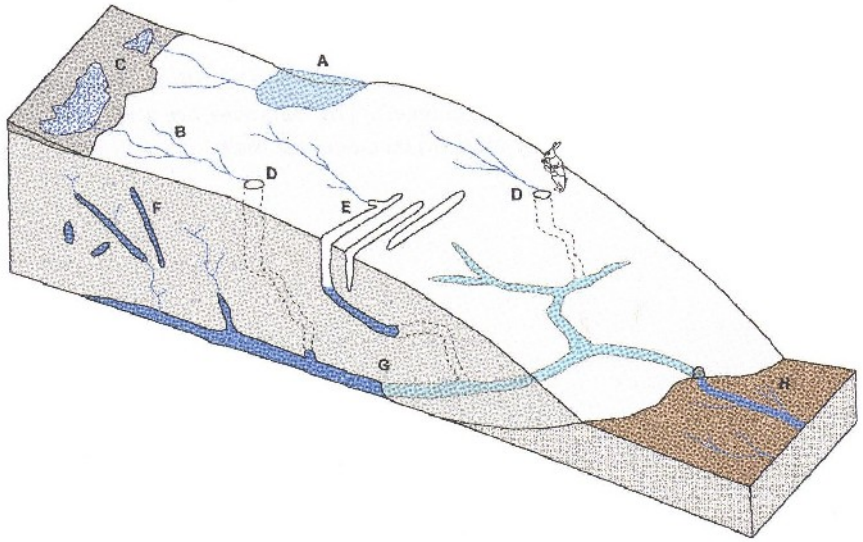
F – Water filled fractures

G – Subglacial tunnels

H – Runoff from the glacier

- The water intrudes the glacier base via network of conduits connecting supraglacial water bodies and the glacier base

Subglacial water flow



A – Supraglacial lake;

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G – Subglacial tunnels

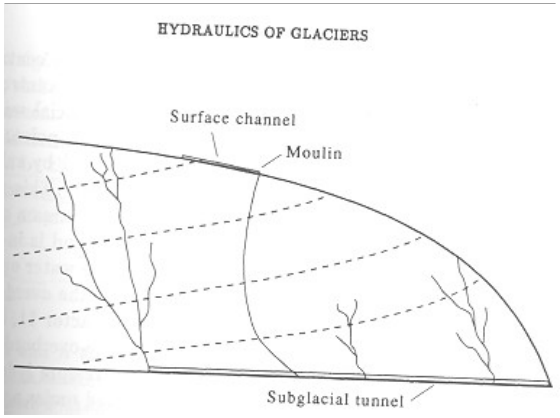
H – Runoff from the glacier

- For ideally plastic glacier ice water pressure at the base of the glacier is equal to the weight of the glacier (Patterson, 1994)
- Surface of the glacier determines the direction of the flow at the glacier base

$$\alpha=-11\beta$$

Subglacial water flow

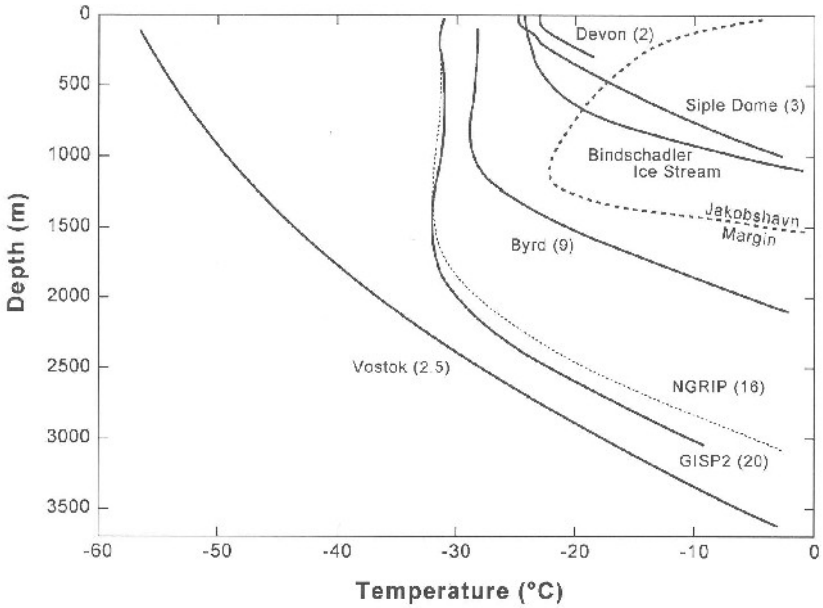
- Most of the water is drained along the ice/bed interface
  - Through R channels
  - Through N channels
  - Through cavity system



After Cuffey&Patterson, 2010

Intrusion of the meltwater

- Intrusion of the glacier water is controlled
  - by the water conductivity of the sediments at the glacier base
  - the permarfost
  - Groundwater pressure in the aquifer

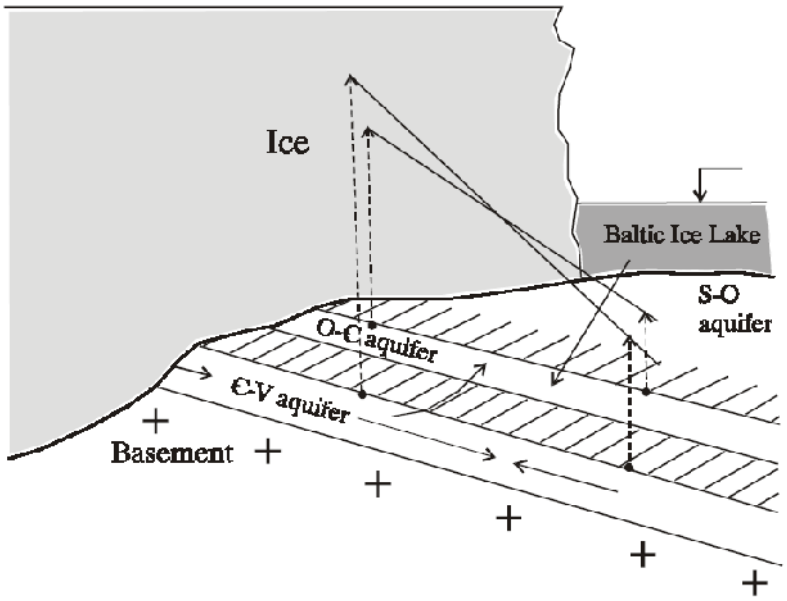


After Cuffey&Patterson 2010

Intrusion of the glacier water

- Timing of the intrusion
  - During the Middle Weichselian Baltic sea basin (~53ka – ~26ka) (Saks et al in press)
  - Subglacial conditions (12 – 28 t.g.)
  - Baltic Ice Lake(12-10 t.g.)

Intrusion of the glacier water



After Mokrik & Mažeika, 2002

- During the Baltic Ice Lake stage as an intrusion through the taliks in permafrost (Mokrik&Mažeika, 2002)
- During the Middle Weichselian from the Baltic basin

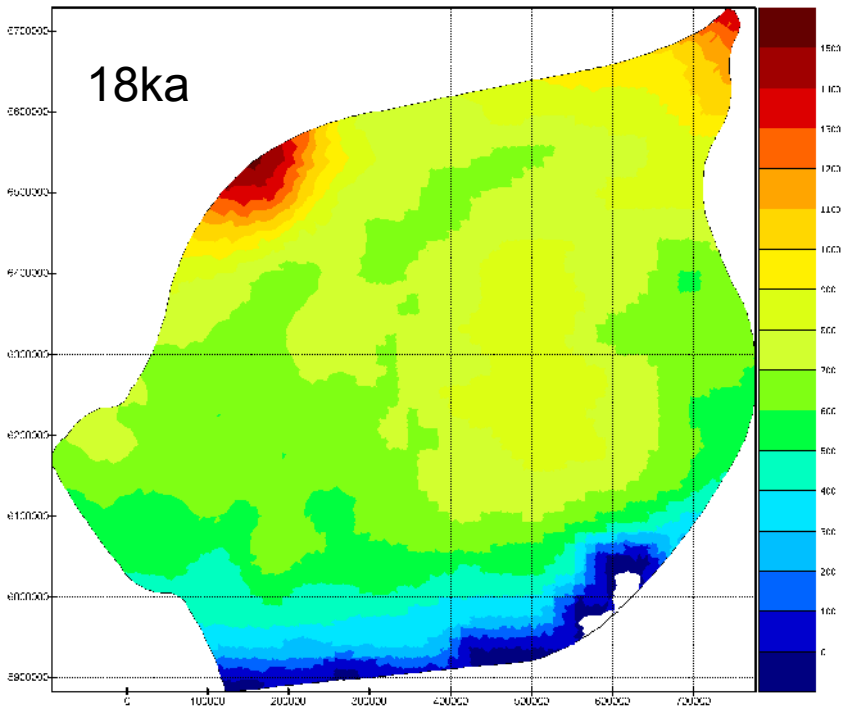
Intrusion of the glacier water

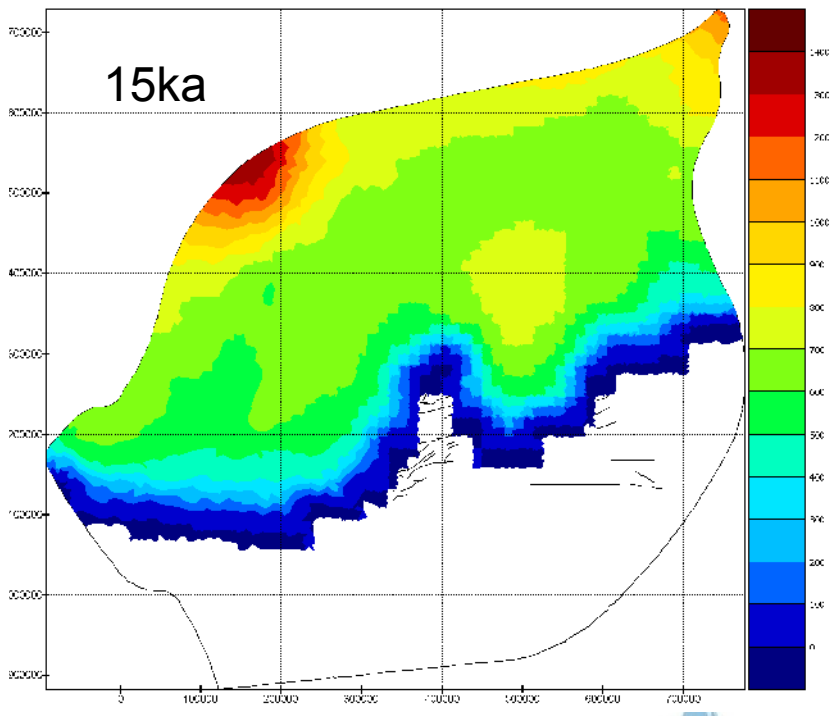
- Intrusion of the meltwater from the glacier is favored, because:
  - Most of the glacier bed is expected to be at the temperate conditions in the ablation zone
  - Permafrost is expected to be thawed
  - Very large pressure gradients existed

Aim of the modelling

- The aim of the modelling was to establish:
  - Was the pressure gradient sufficient enough to reverse the groundwaterr flow direction in the CM-V system
  - Groundwater flow direction
  - Groundwater flow velocities
  - Volume of the meltwater intruded

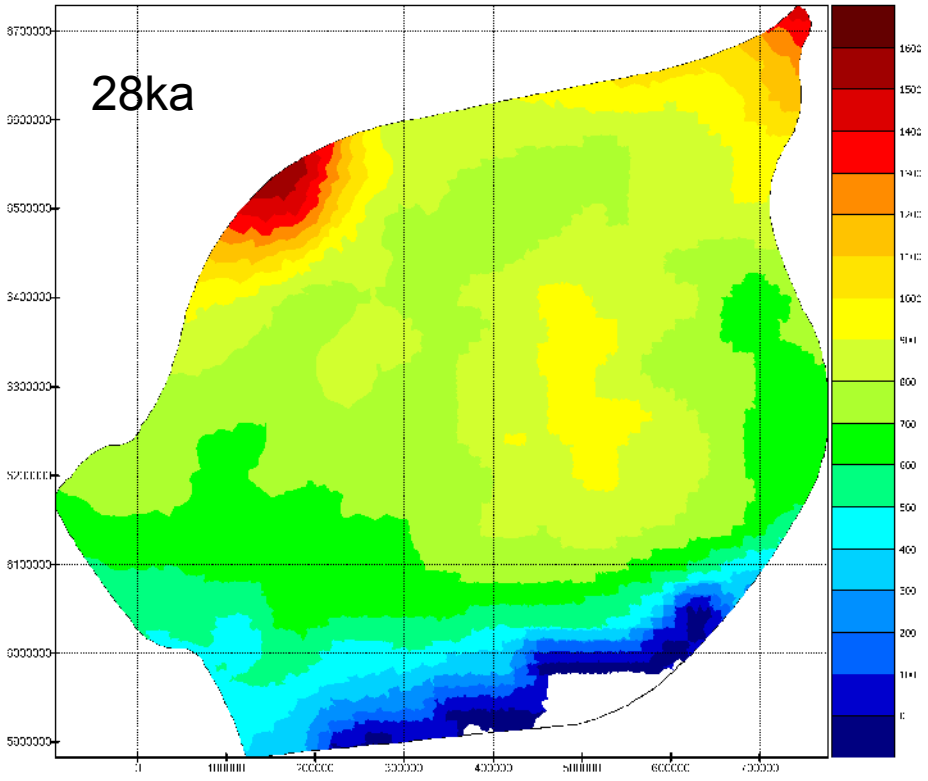
Input data

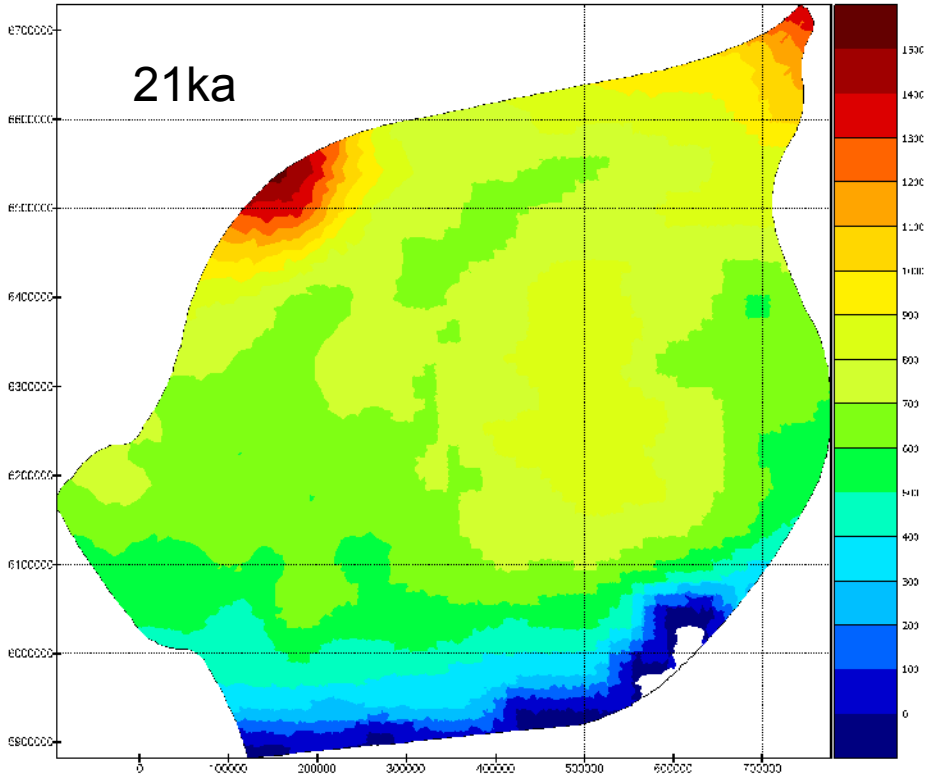




- Ice thickness data 10 – 28ka (After Argus&Peltier, 2010)

Input data





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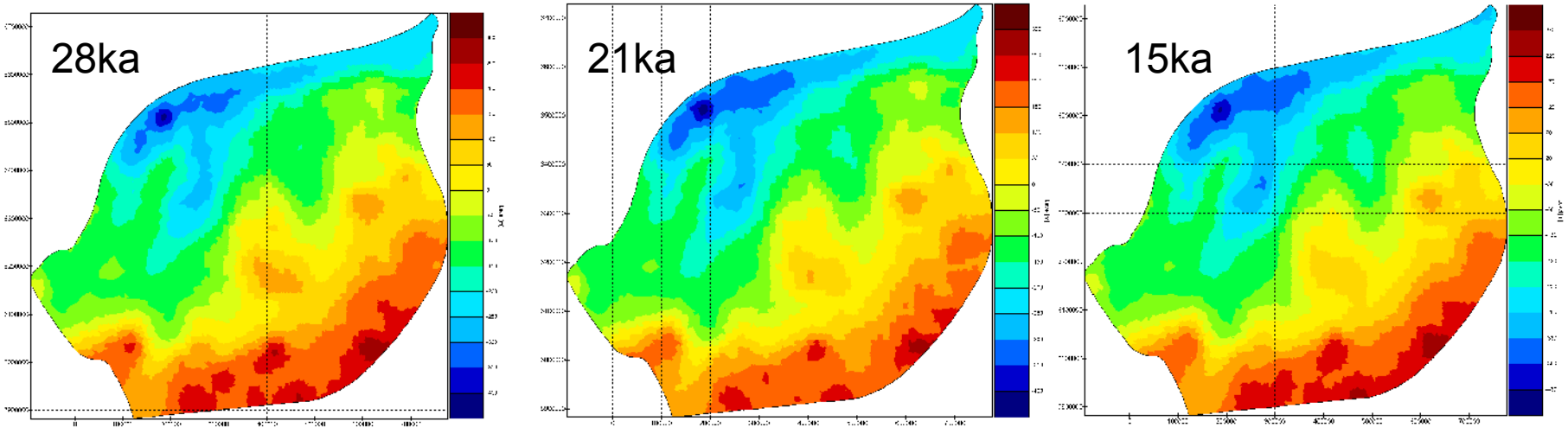


- Subglacial topography data 10 – 28ka (After Argus&Peltier, 2010)

Boundary conditions

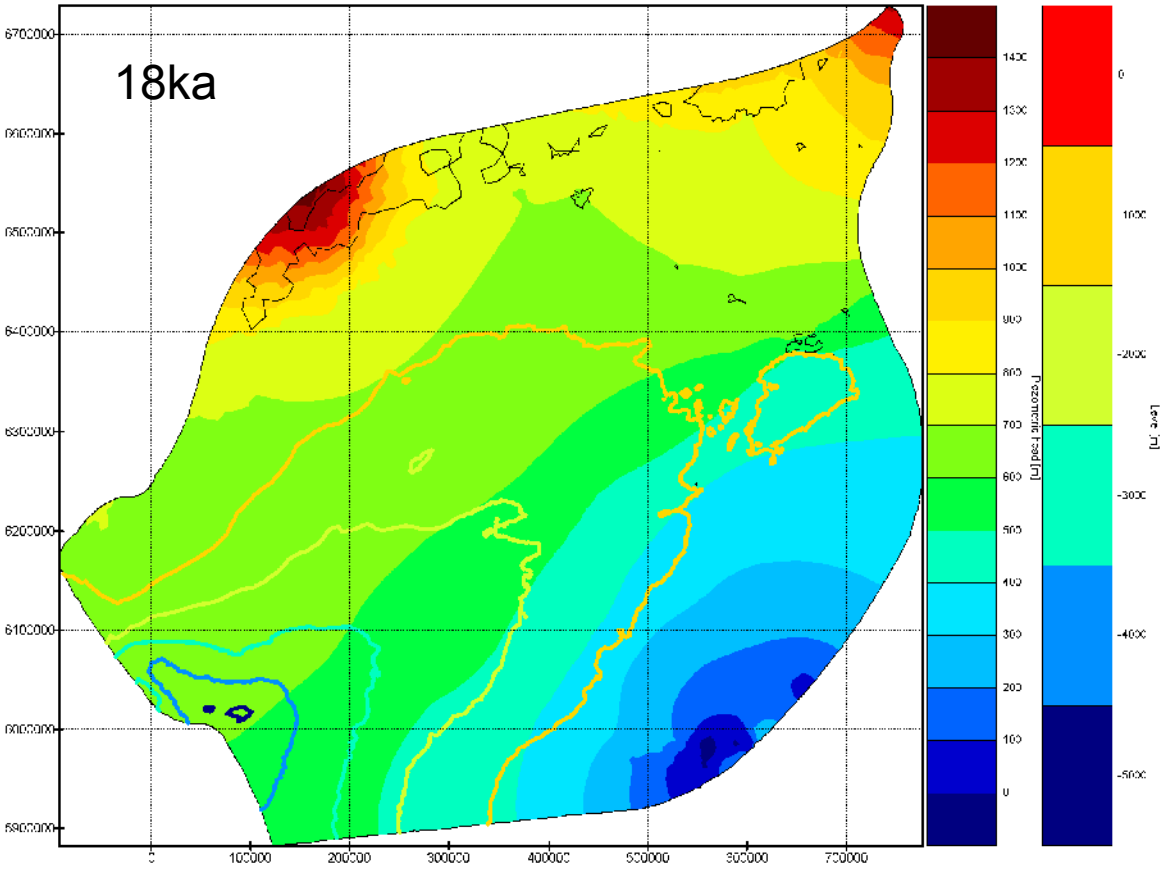
- On the Baltic Basin surface constant pressure boundary condition was applied:

```
InterpolateFromRaster(MeshIn="BAB_BaseCut.meb",
    RasterIn="IceT_Layer19.tif",ZvalOut="Ledus_biezums_19.z")
ZFileOp(OutFile="tophead_19.z",OperationList=["Ledus_biezums_19.z",lambda
    z1:z1*0.917])

#Aprekinat spiedienu
Calculate(MeshIn="paleo_19.str", HeadIn="",
    HeadOut="calc/Head_paleo_19_1.p",
                    TopHead="tophead_19.z", Infiltration="infilt.ez)

Calculate(MeshIn="paleo_19.str", HeadIn="calc/Head_paleo_19_1.p",
    HeadOut="calc/Head_paleo_19_2.p",
                    TopHead="tophead_19.z", Infiltration="infilt.ez)
```

Results

- Groundwater flow under the Scandinavian Ice sheet in the Baltic Basin was calculated for 19 ice advance and retreat scanarious spanning the time from 10 – 28ka BP

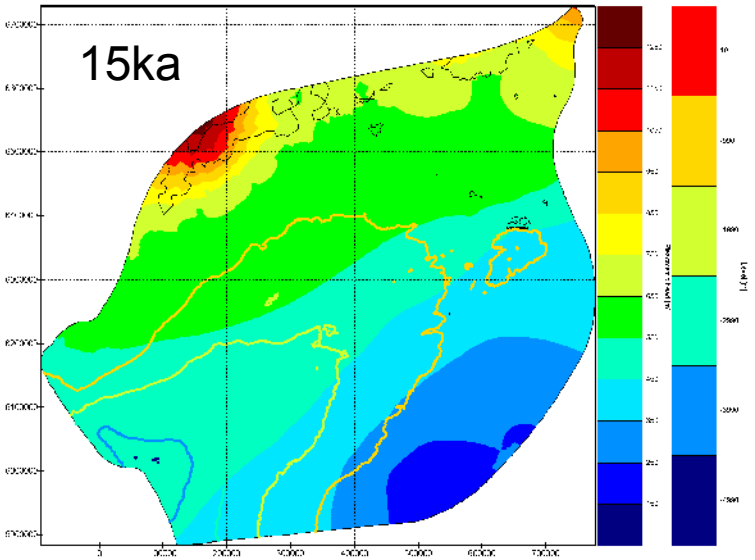
Groundwater flow directions

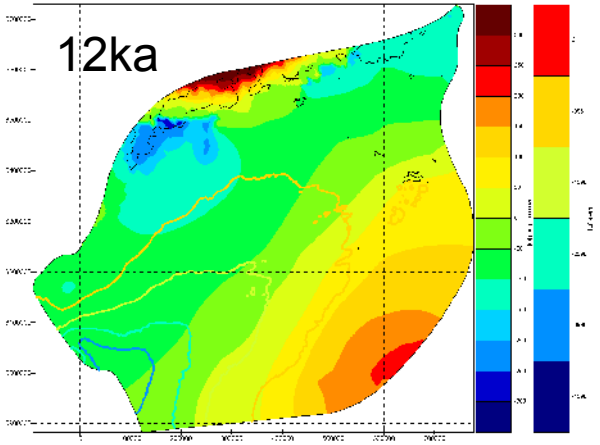


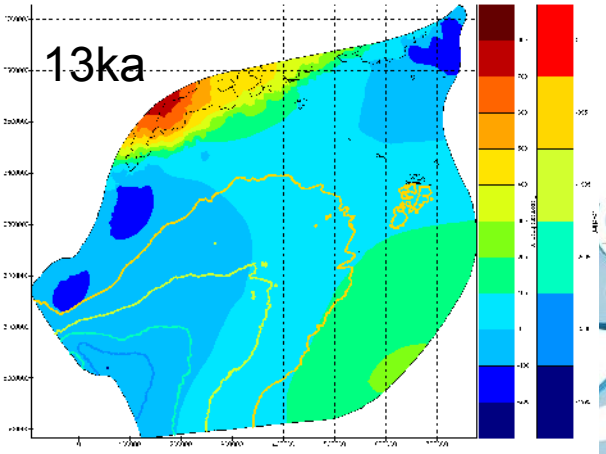
Two main areas of meltwater intrusion into the Cm-V aquifer system

Duration of the glacier induced groundwater flow

- Reversed groundwater flow has been present for at least 14ka

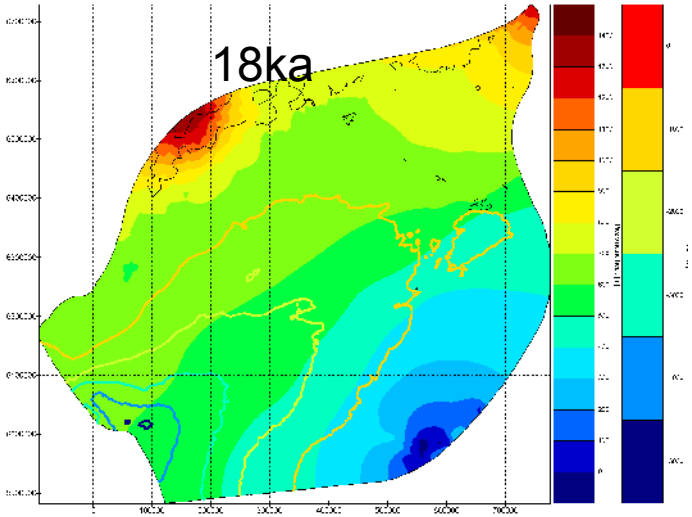


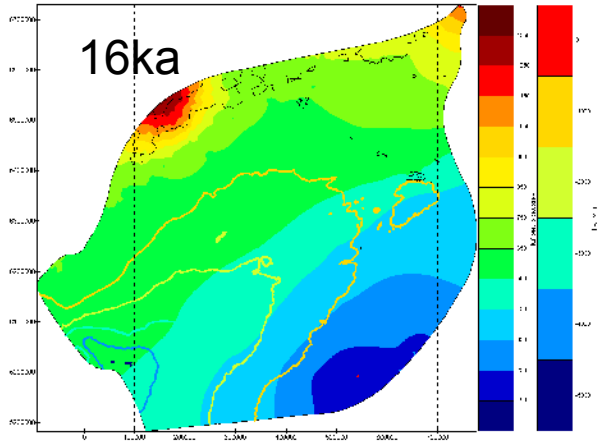


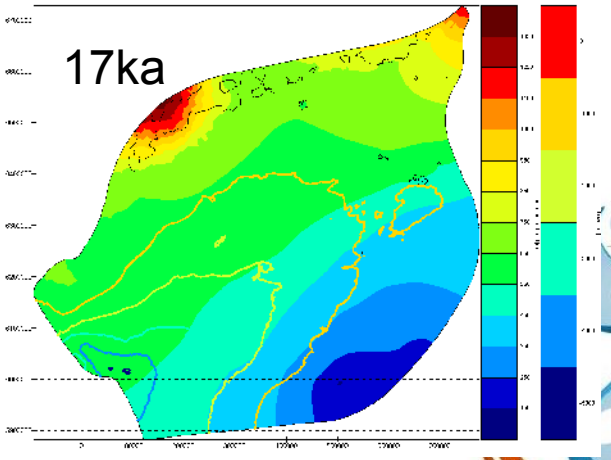


Duration of the glacier induced groundwater flow

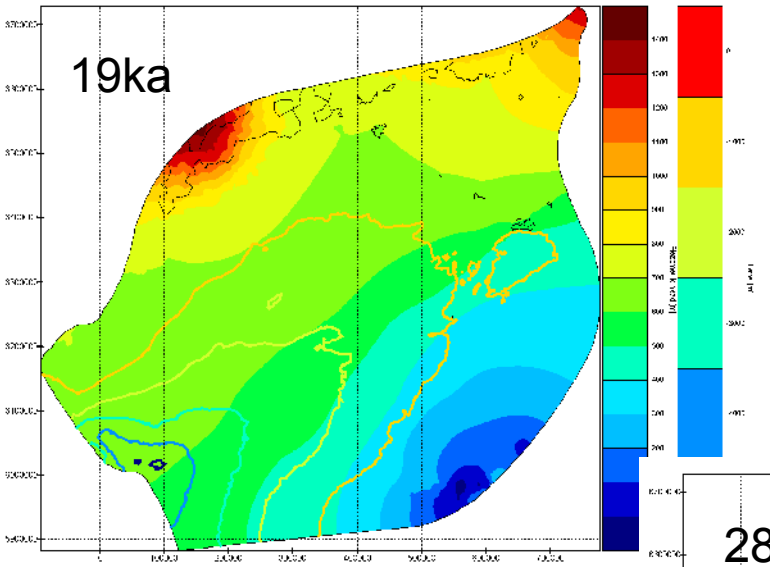
- The westeren intrusion area has been present for longer time periods

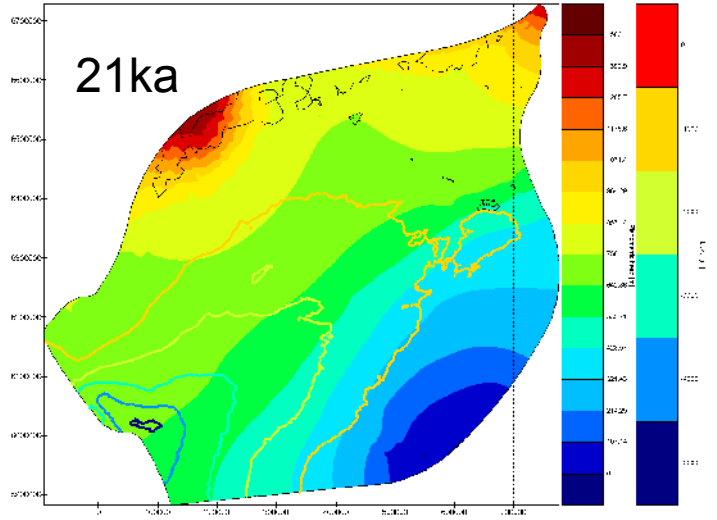


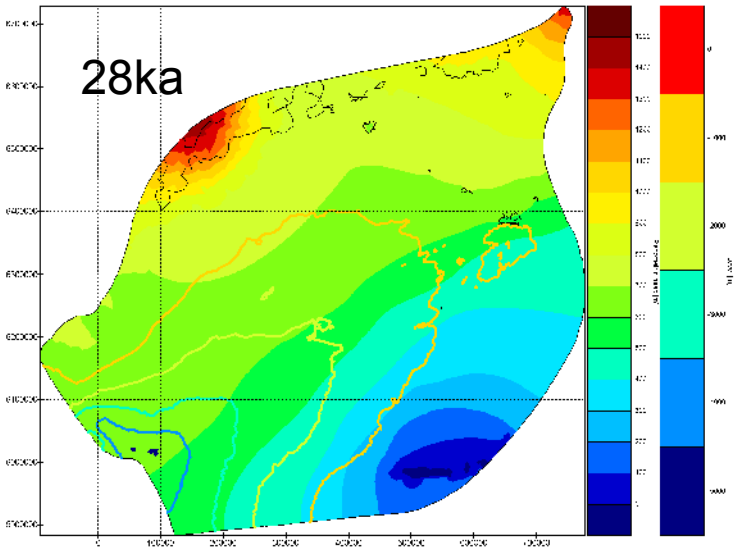




Duration of the glacier induced groundwater flow

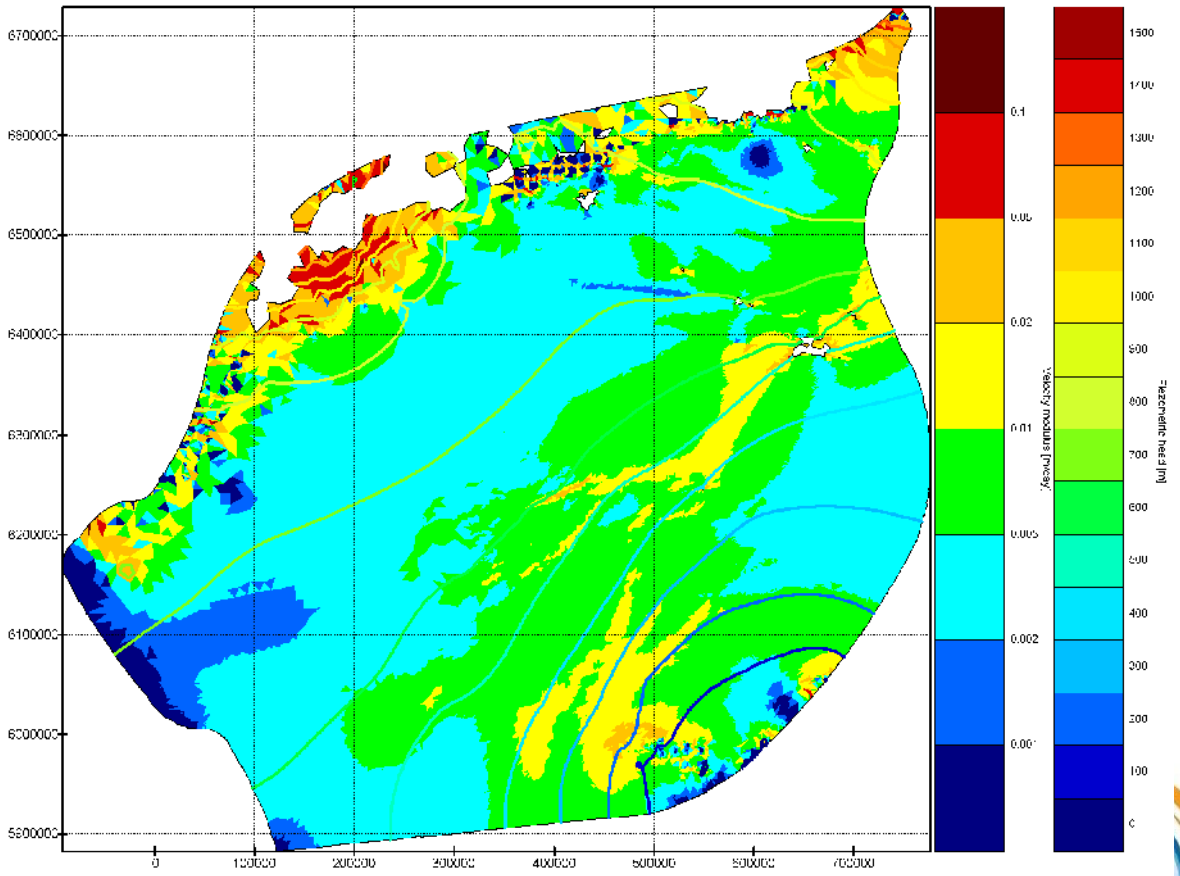






Flow velocities

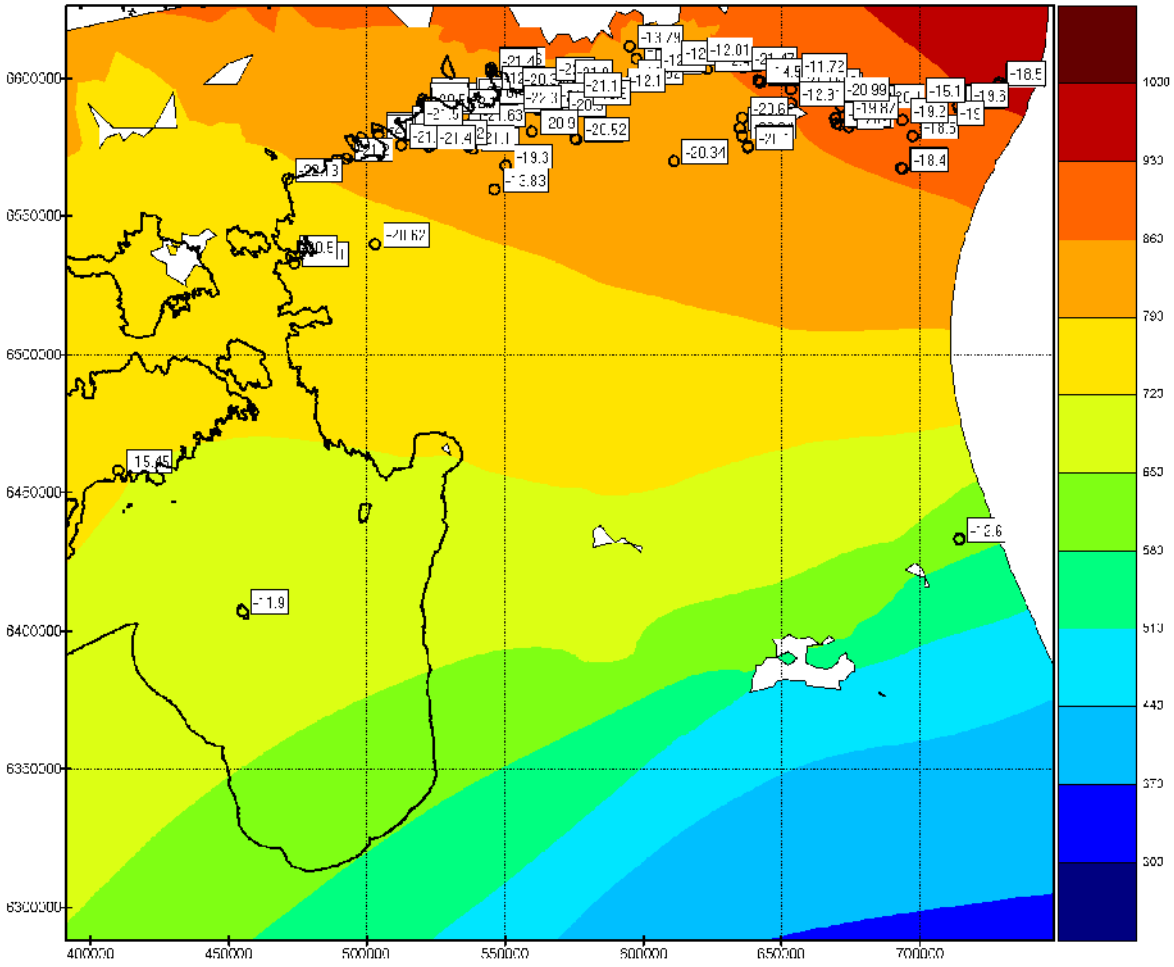
- Maximum velocities near the intrusion
- Velocities XX times higher than during the “normal” flow regime



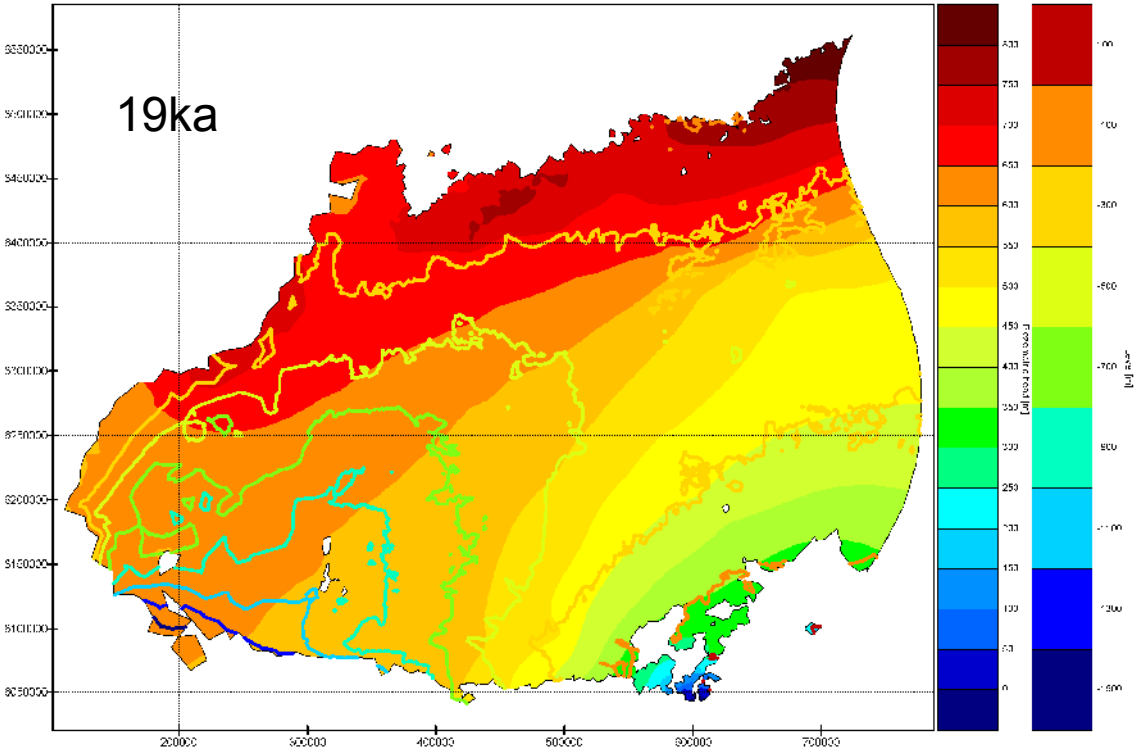
Volume and distance of the meltwater intruded

- Assuming that the width of the Cm-V aquifer system through which meltwater was intruded was ~ 750 km and the mean thickness ~ 150 m the total volume intruded into the Cm-V aquifer system amounts to ~ $2.2*10^{12}$ m^3 during the 14 th years of glaciation
- The distance of the intrusion amounts to ~ 20 km
- Given that the 95% of the meltwater is intruded into 2 aquifers of total thickness ~ 50m, the depth of the intrusion extends to ~ 54 km, corresponding to $2.0*10^{12}$ m^3

Volume and distance of the meltwater intruded



Meltwater intrusion in the lower Devonian aquifer system



- Lower Devonian aquifer system is the likely candidate to contain glacial meltwater

Drawbacks and the future work

- The water conductivity of the subglacial sediments is one of the main factors directly influencing the volume of the meltwater intruded and the flow velocities of the groundwater
  - Till distribution
- Permafrost distribution – unknown
- Buried valleys in Northern Estonia
- Uncertainty of the glacial history

Conclusions

- Two main intrusion areas for the Baltic basin
- Reversed (as to present) groundwater flow direction existed for 14 thousand years?!
- At the present model setup the meltwater intrusion from the glacier can explain most of the glacier water presence in the Cm-V aquifer system

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Paldies par uzmanību!

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