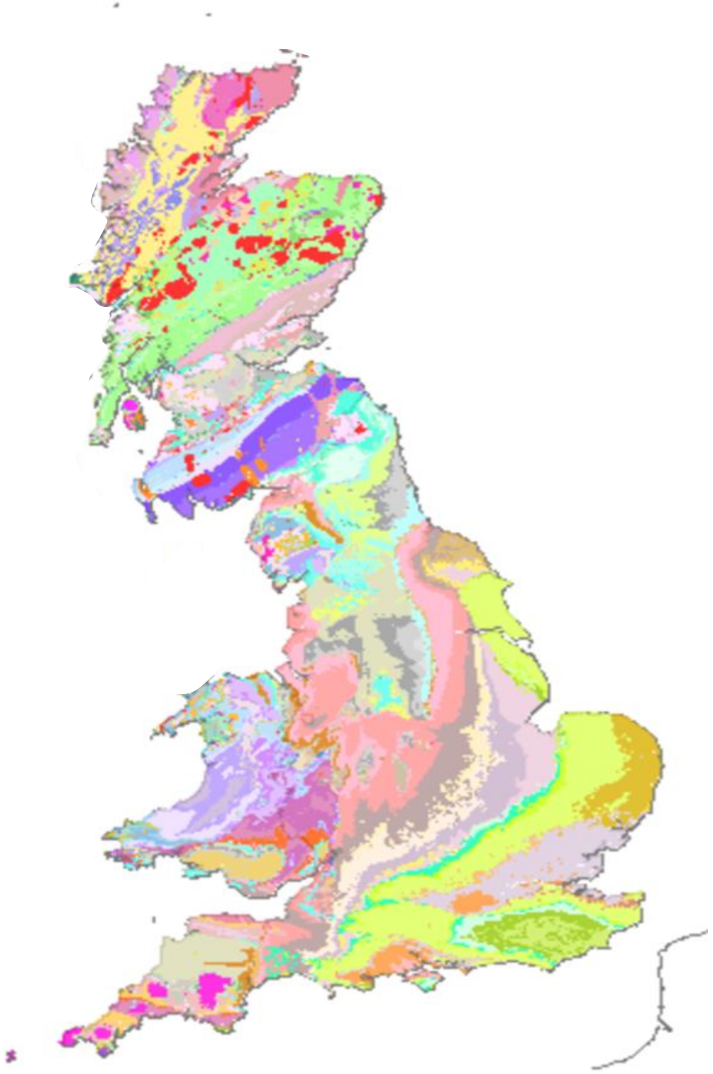
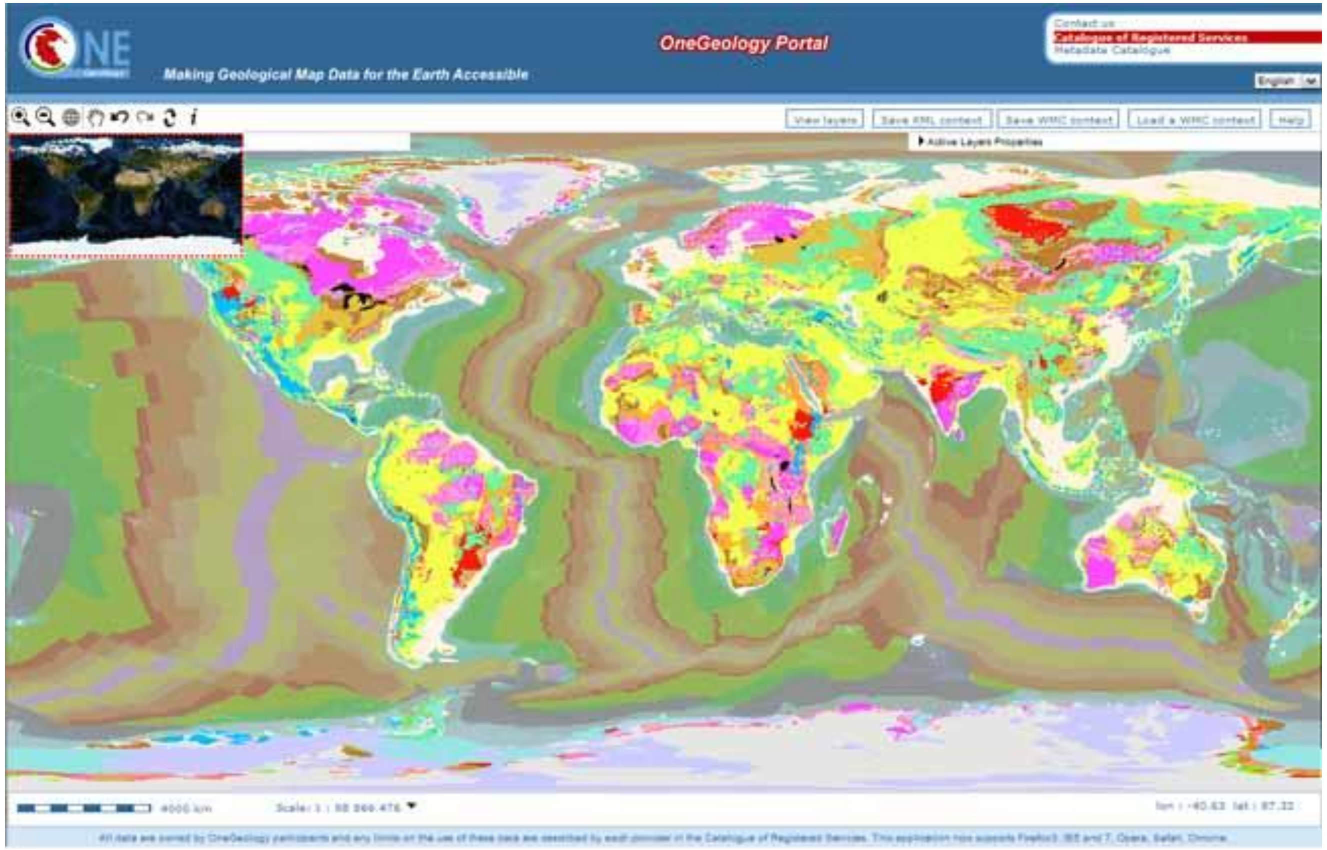
Modelling groundwater at the British mainland scale - so far so good? A summary of the current progress and the challenges to come

Andrew Hughes and the Hydro-JULES sub-surface team

Heterogeneity





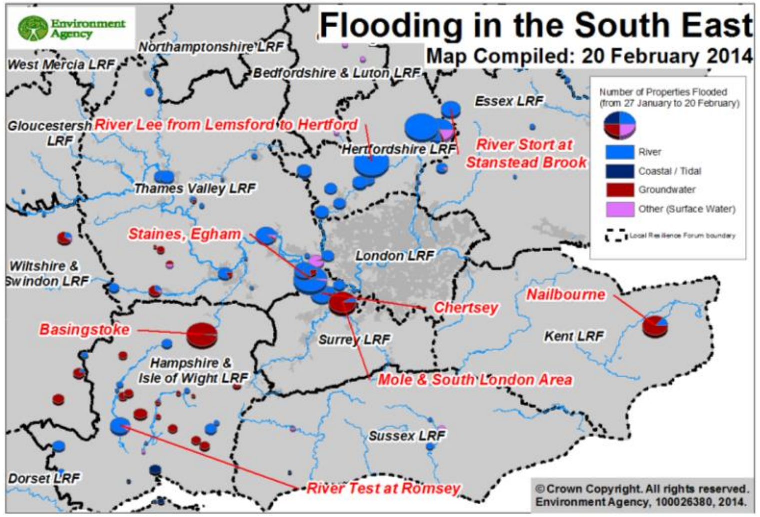
Questions…

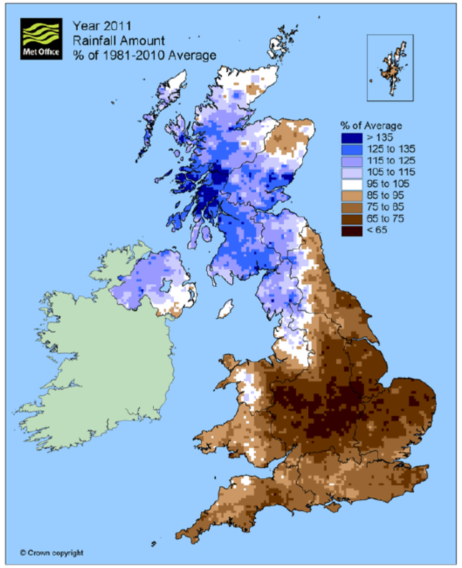
…make the modelling work go round!

We have two main ones:

- How can an integrated approach improve the simulation of major flooding events such as the 2013/4 floods?

- How can a holistic approach be undertaken to assess water resources under drought conditions?





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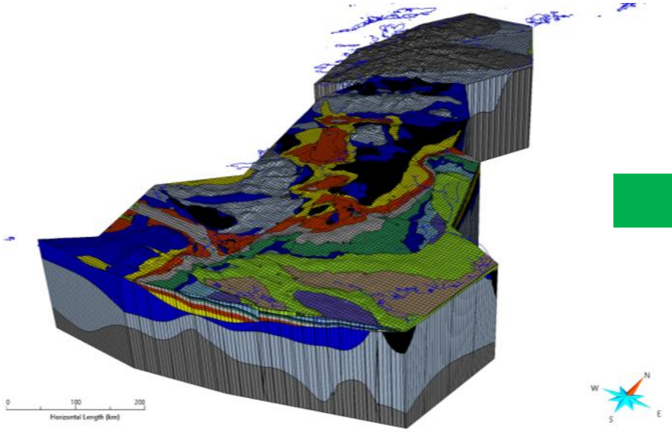
Horizontal Length (km)
0
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200
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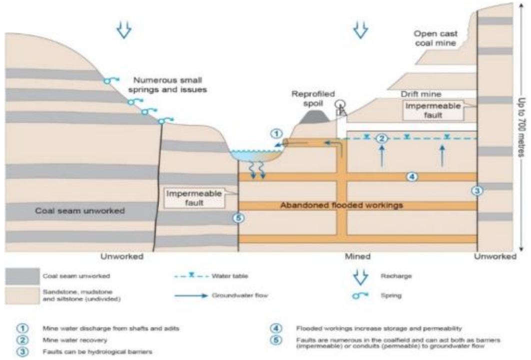
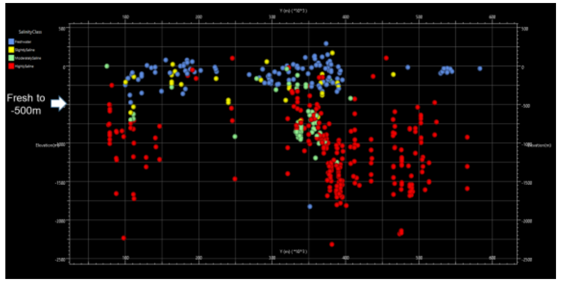
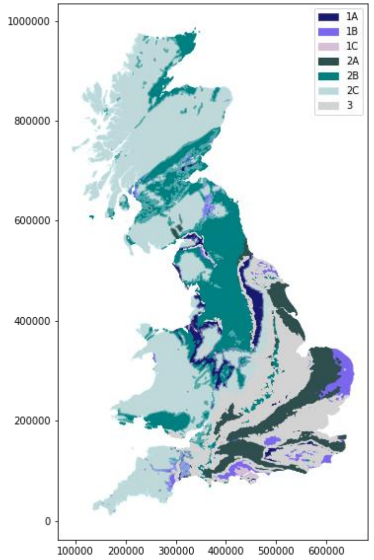
S


Open cast coal mine
Numerous small springs and issues
Reprofiled spoil
Drift mine
Impermeable fault
Impermeable fault
Coal seam unworked
Abandoned flooded workings
Unworked
Mined
Unworked
Up to 700 metres


Fresh to -500m


1A
1B
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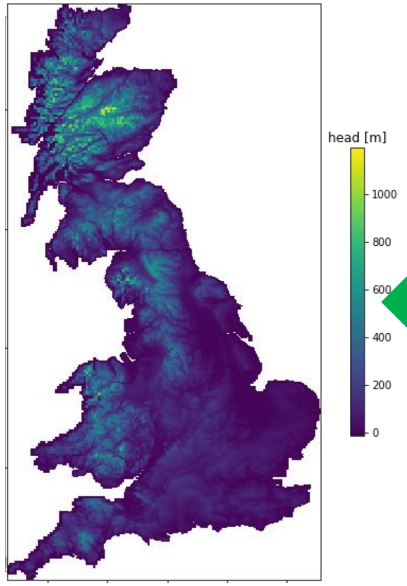
head [m]
1000
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600
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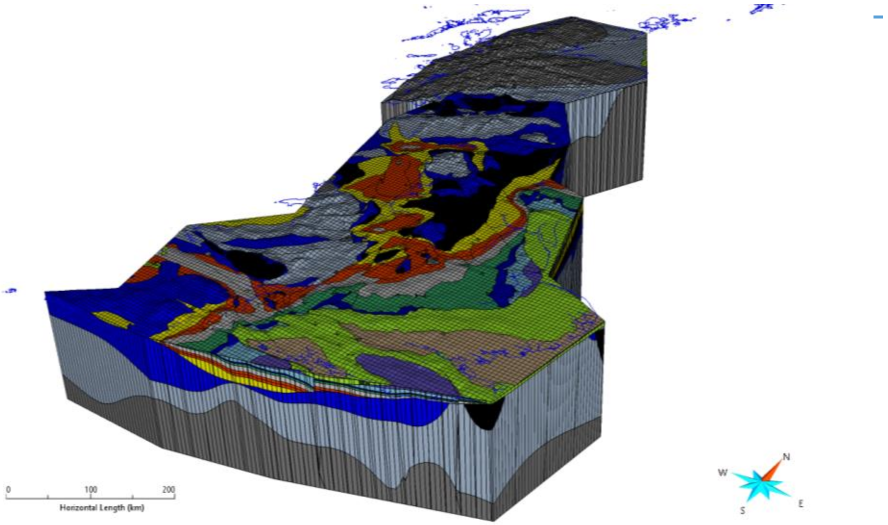
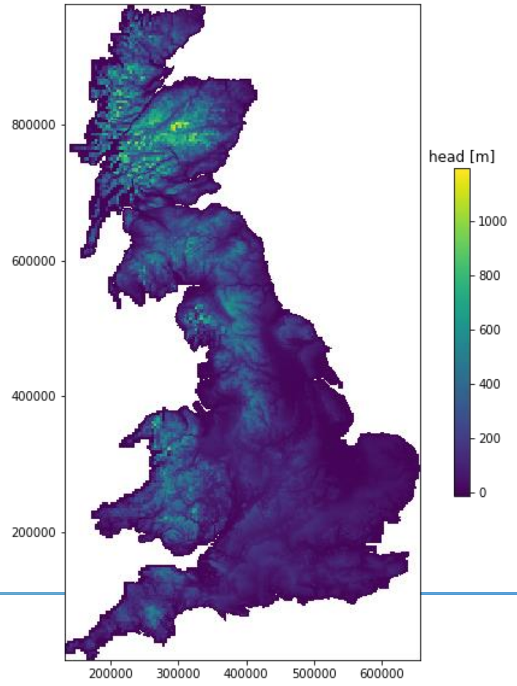
British mainland

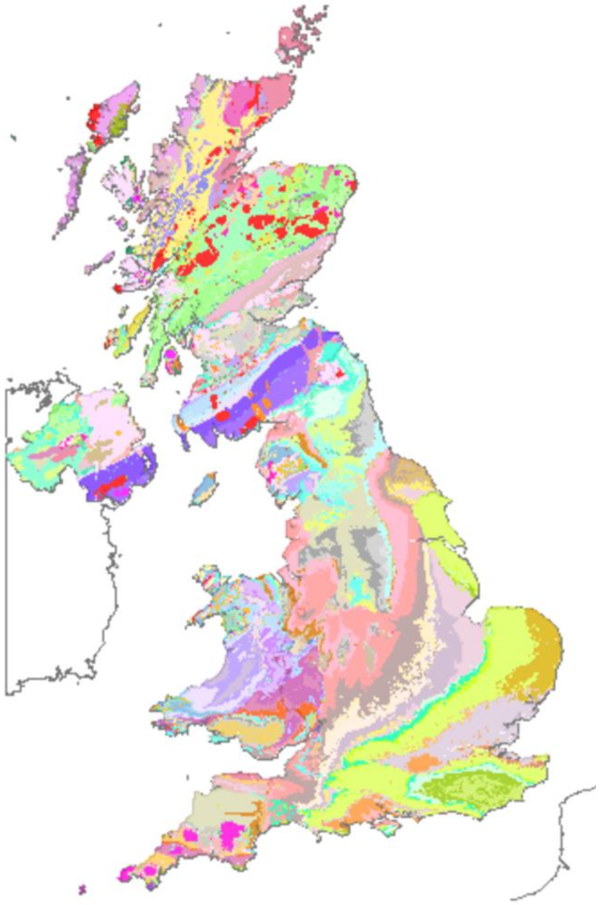
- Geology model – providing basis for conceptualisation, parameterisation and groundwater flow model geometry
- Conceptualisation of groundwater flow – 14 units identified and detailed work on characterising them ongoing
- Parameterisation – Bulk parametrisation undertaken. chalk work ongoing / investigating transferability to other aquifer units
- Unsaturated zone processes – metamodeling approach
- Groundwater flow modelling – MODFLOW6





Defined 14 hydrostratigraphic units:

1	**Quaternary**
2	Neogene and Palaeogene
3	**Chalk**
4	**Upper Greensand to Lower Greensand**
5	Wealden
6	Purbeck Group to Ampthill Clay Formation
7	Corallian Group
8	Oxford Clay
9	**Great and Inferior Oolite groups (mid-Jurassic)**
10	Lias Group
11	Mercia Mudstone Group
12	**Sherwood Sandstone Group**
13	Permo-Triassic
14	Carboniferous
15	Devonian
16	Silurian, Ordovician, Cambrian
17	Precambrian & Igneous



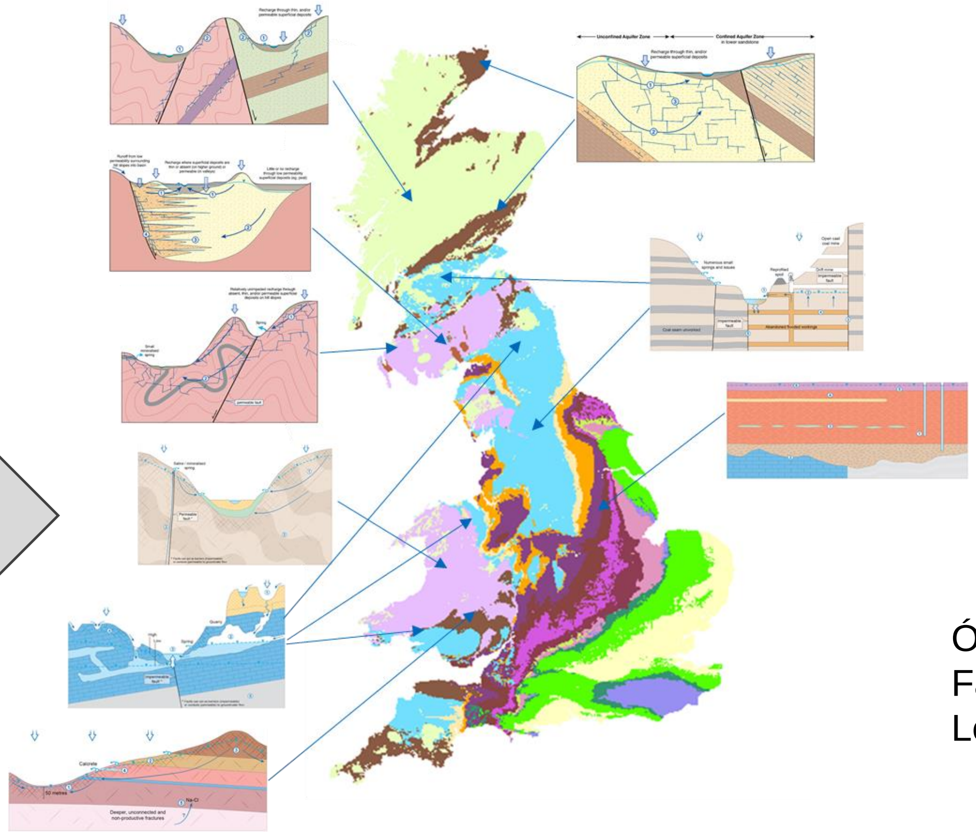
Most productive aquifers

Less productive aquifers or unproductive

Testing of MODFLOW 6 for BM mainland: Parameterisation

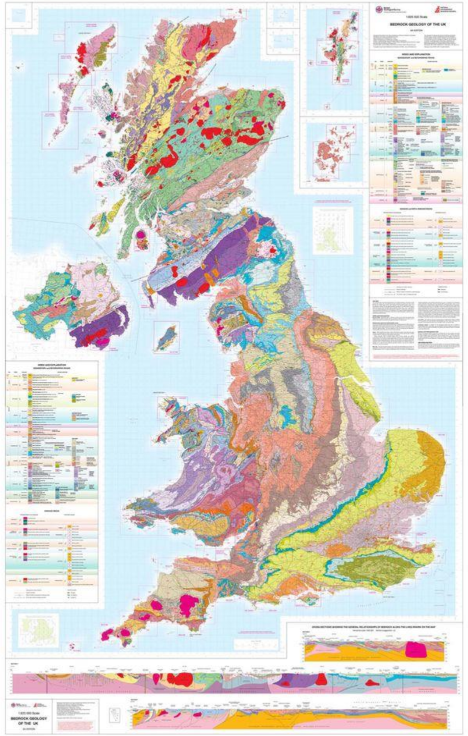
Surface bedrock geology

Regional groundwater conceptual models

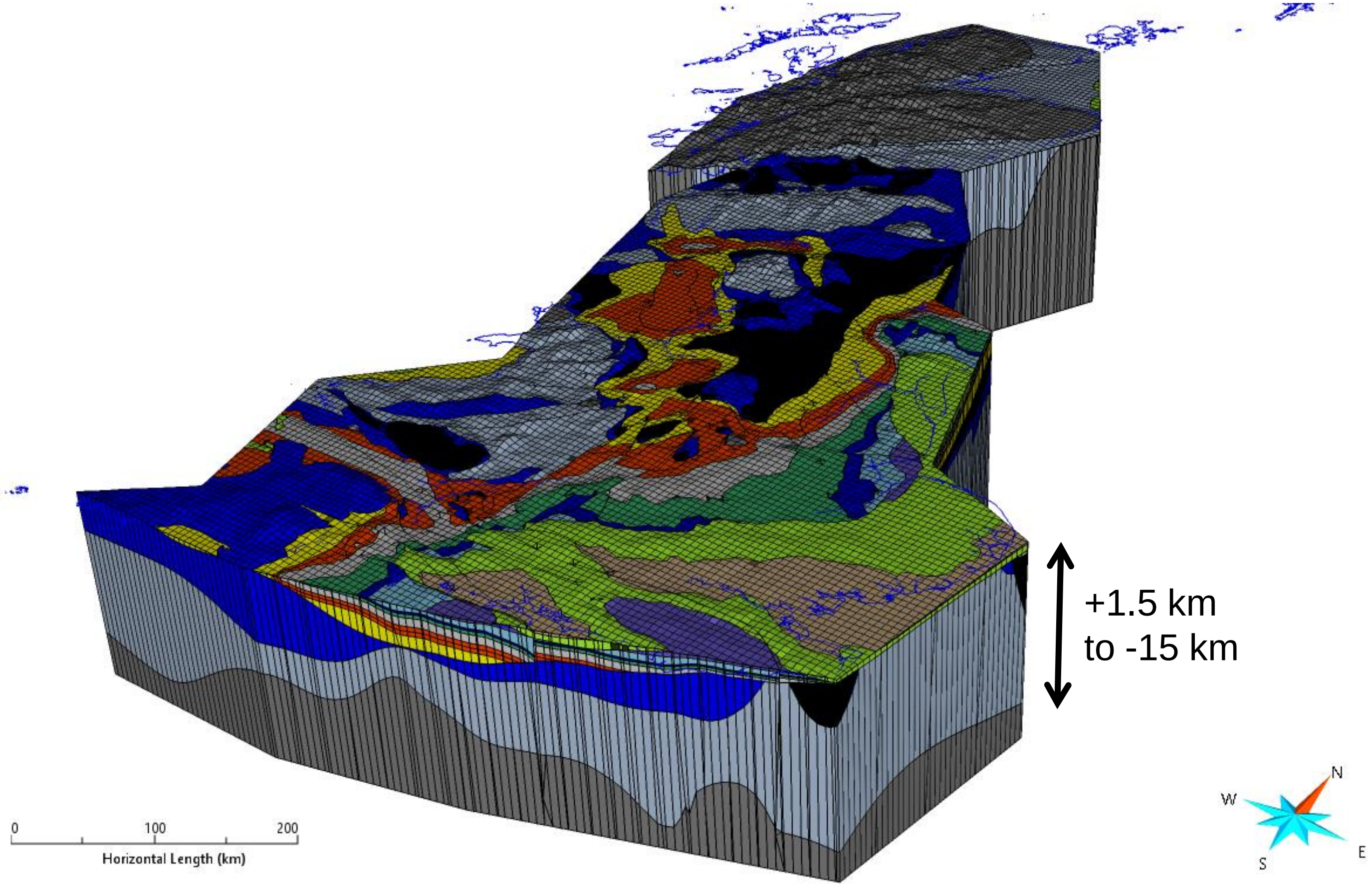


Ó Dochartaigh,
Farr,
Lewis

Improving the geological representation: 3D framework model

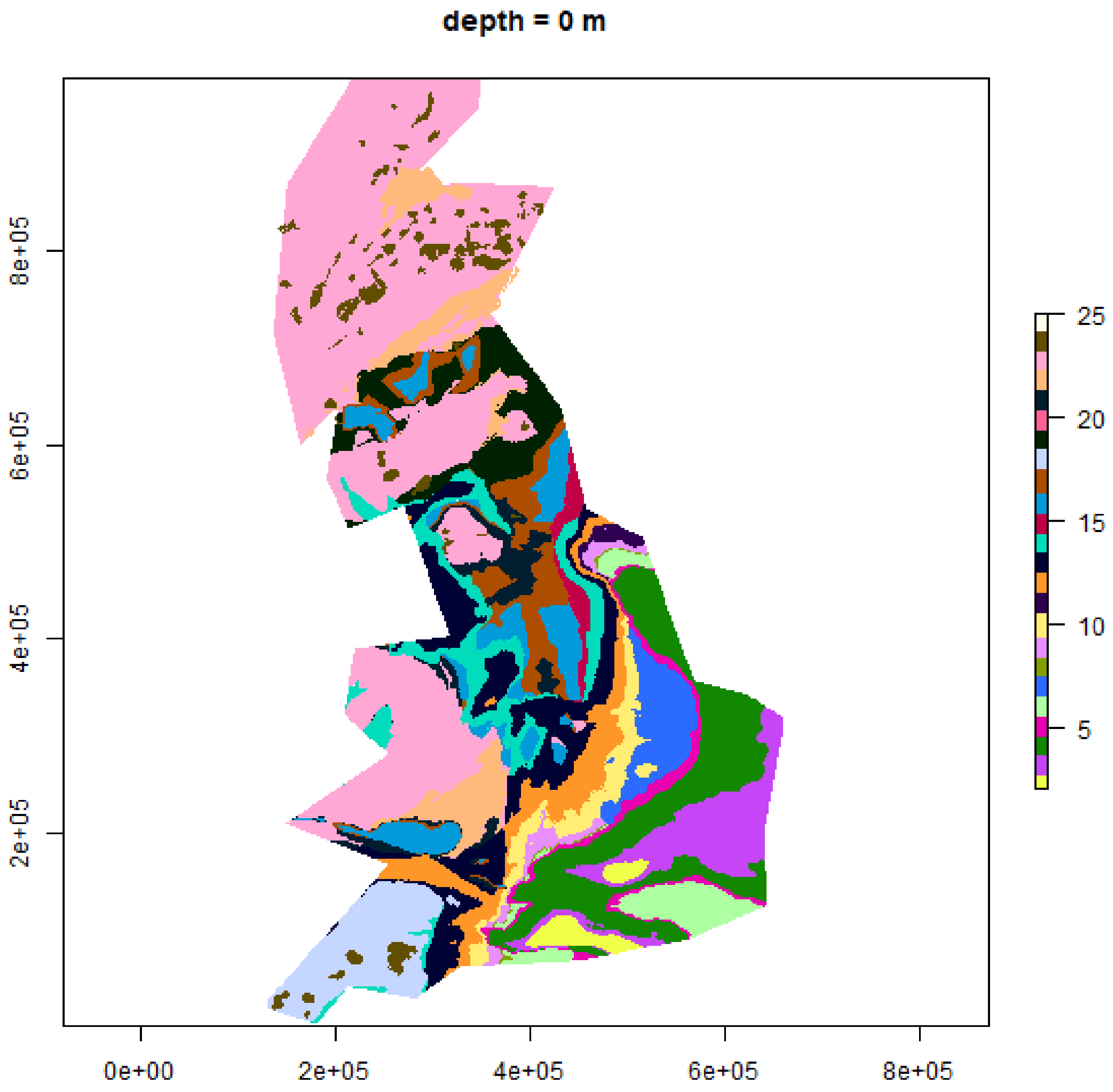


1:625,000 scale mapping

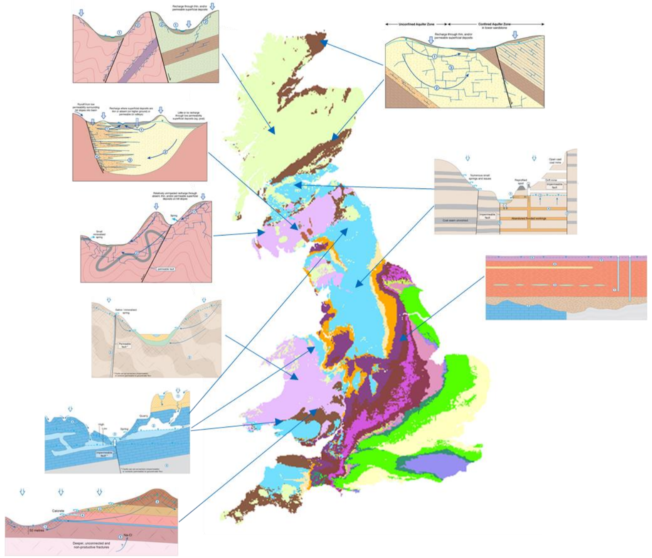


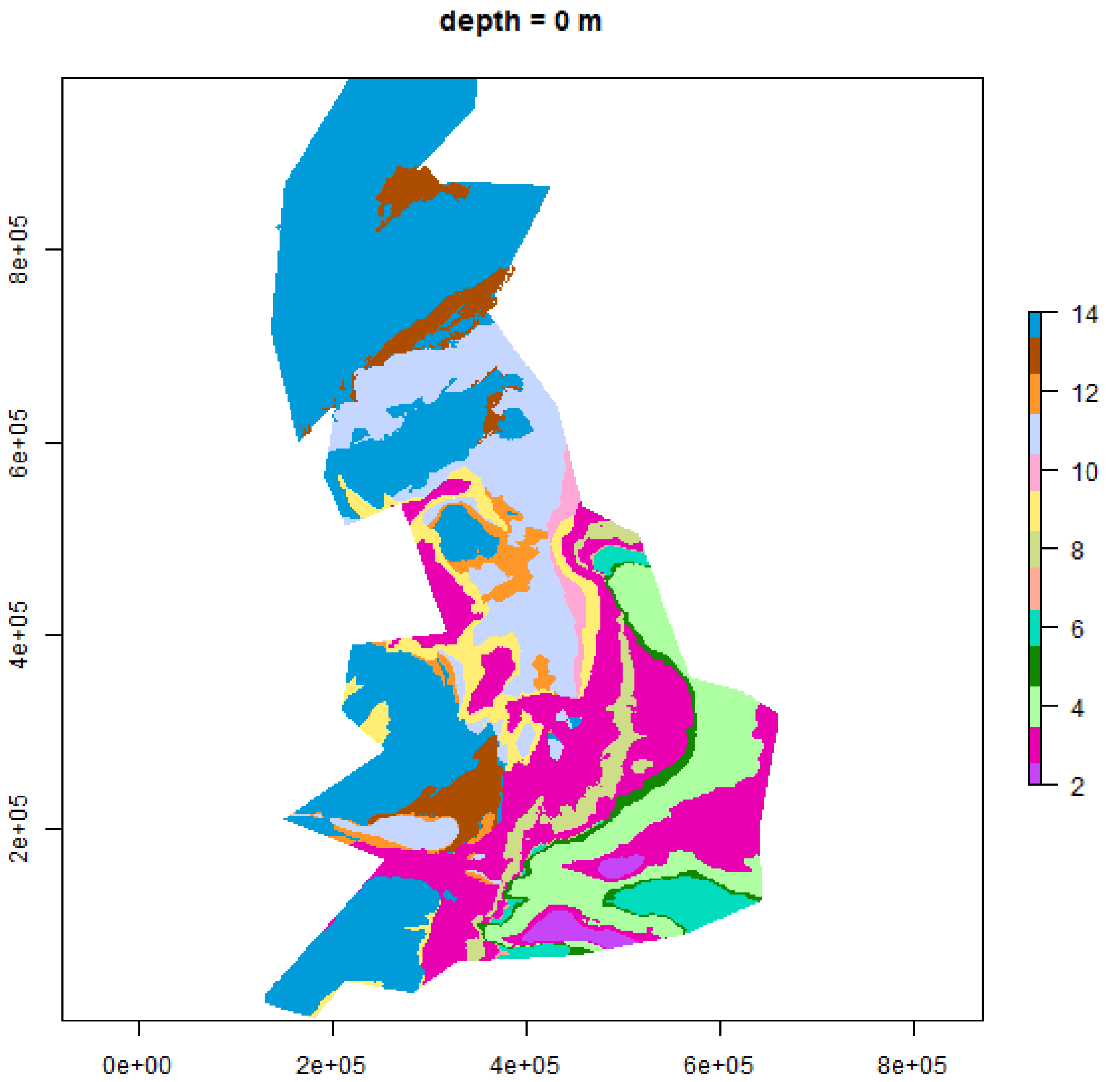
Newell 2019

Geological units with depth

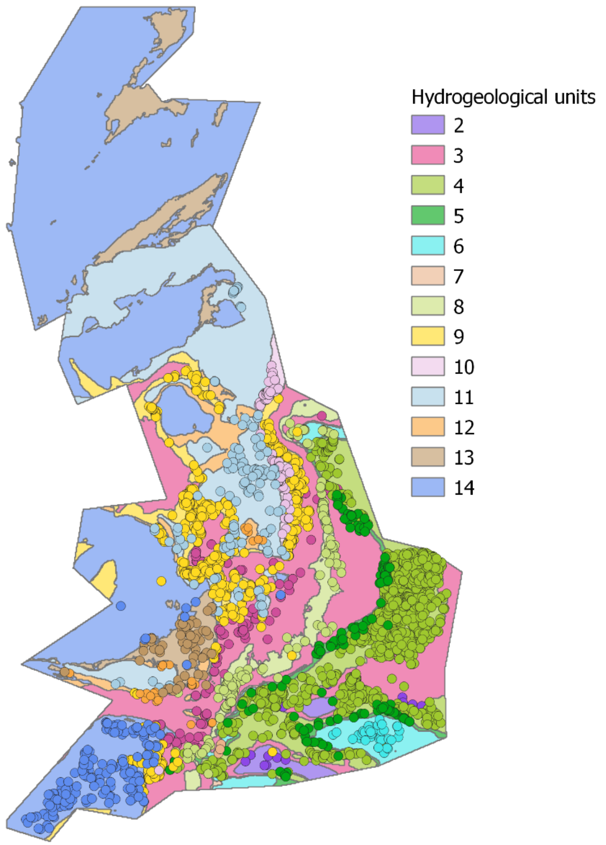


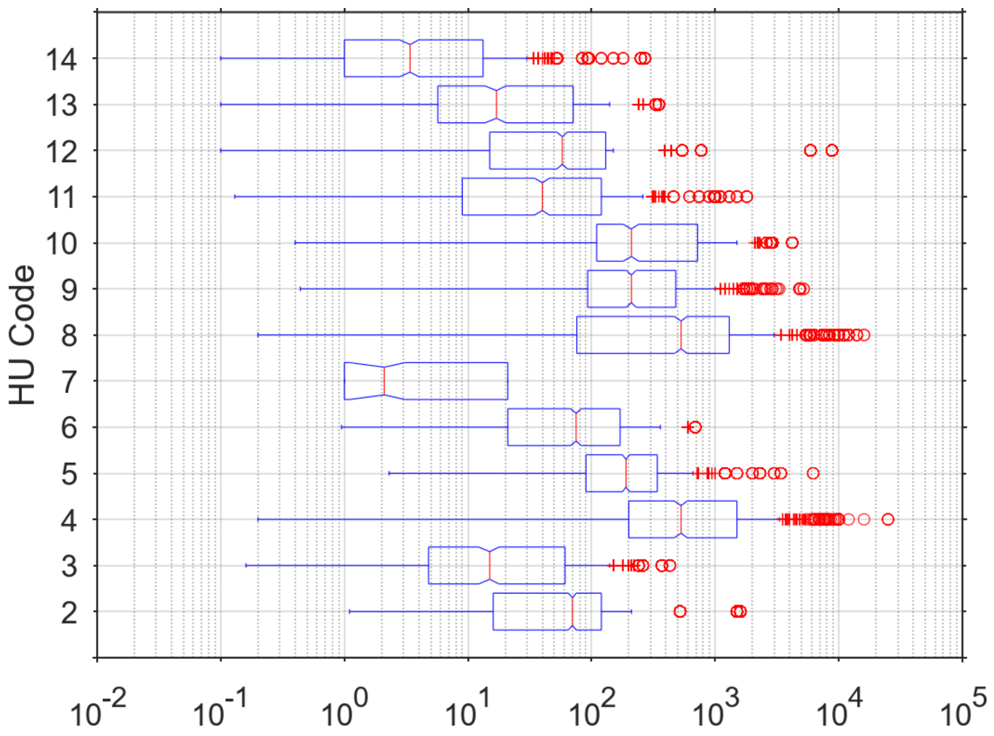
Hydrostratigraphic units with depth





Hydrostratigraphic units and Transmissivity distribution

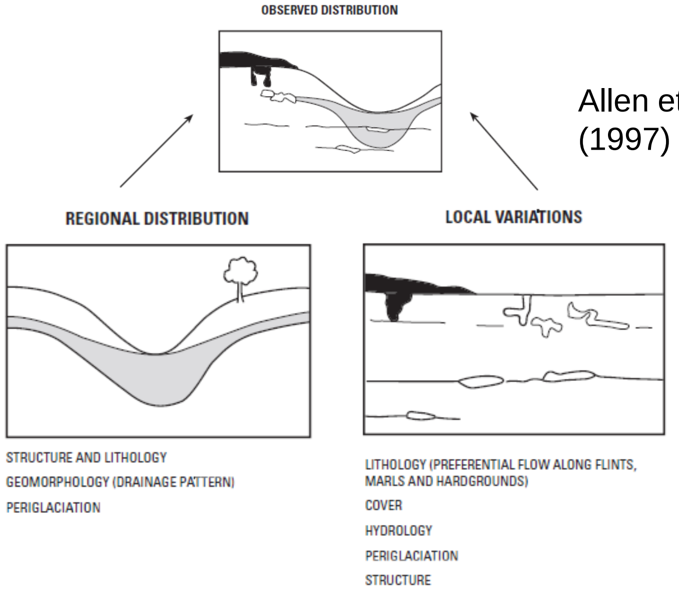




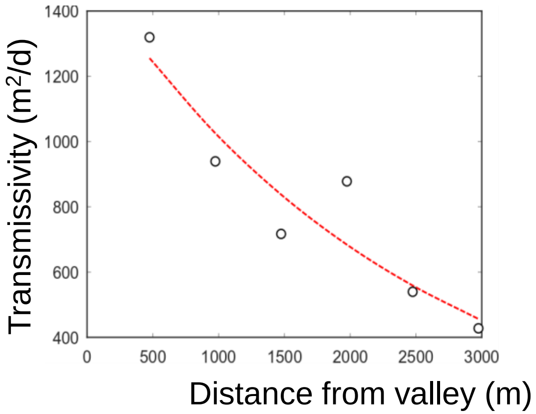
Hydrostratigraphic units and borehole locations

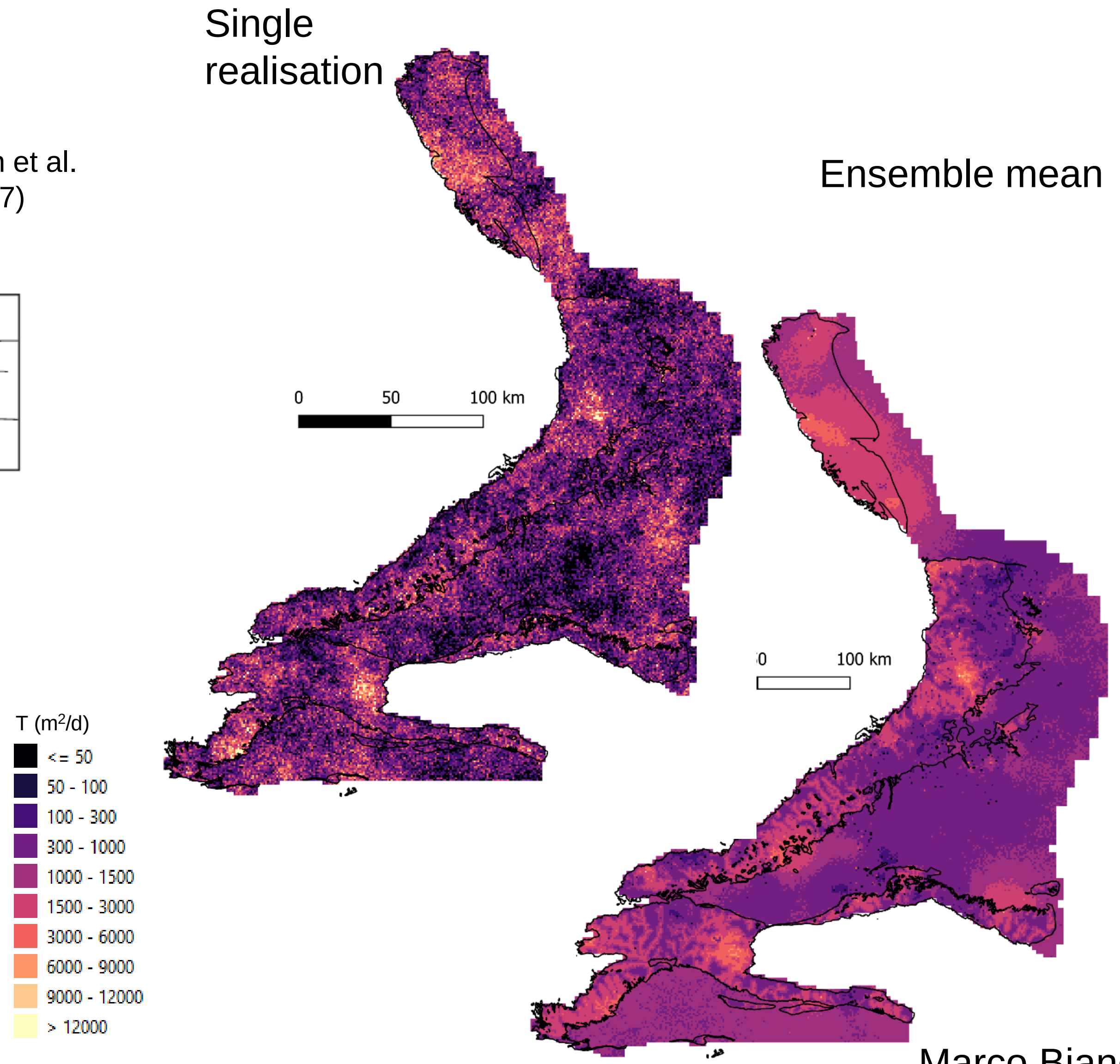
Transmissivity distribution for each hydrostratigraphic unit

Next steps: Update parameterisation of the Chalk



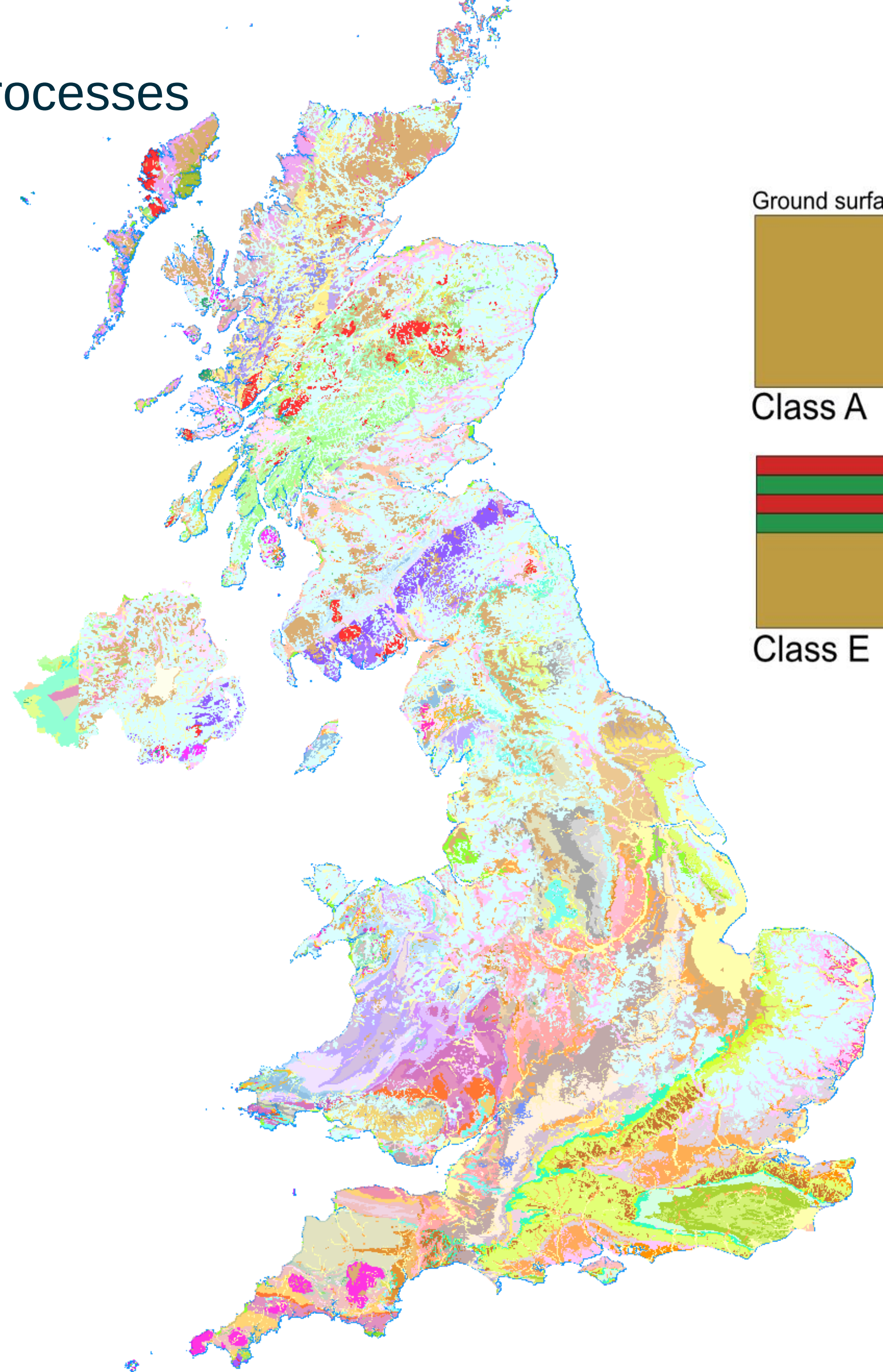
Allen et al. (1997)

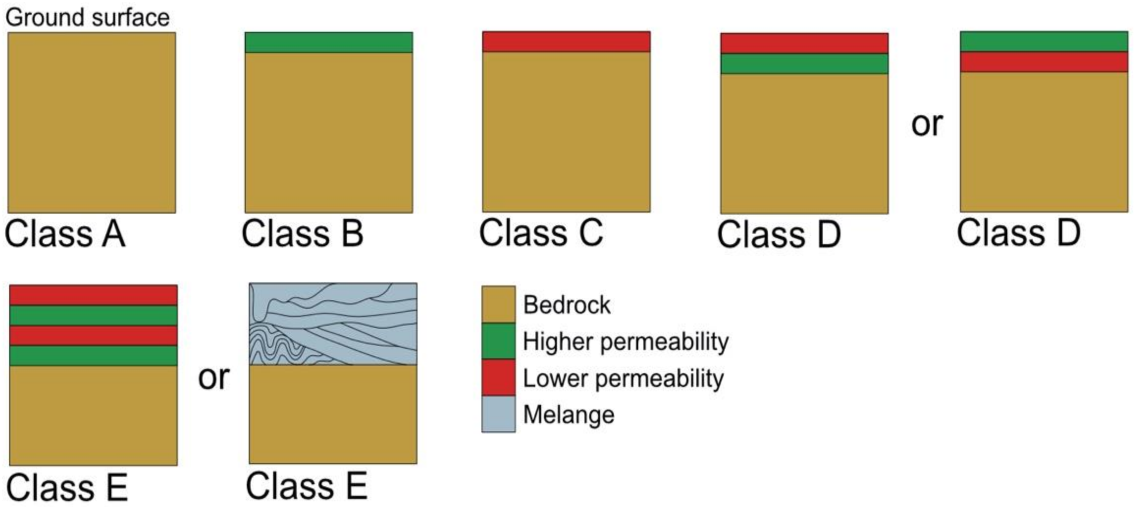




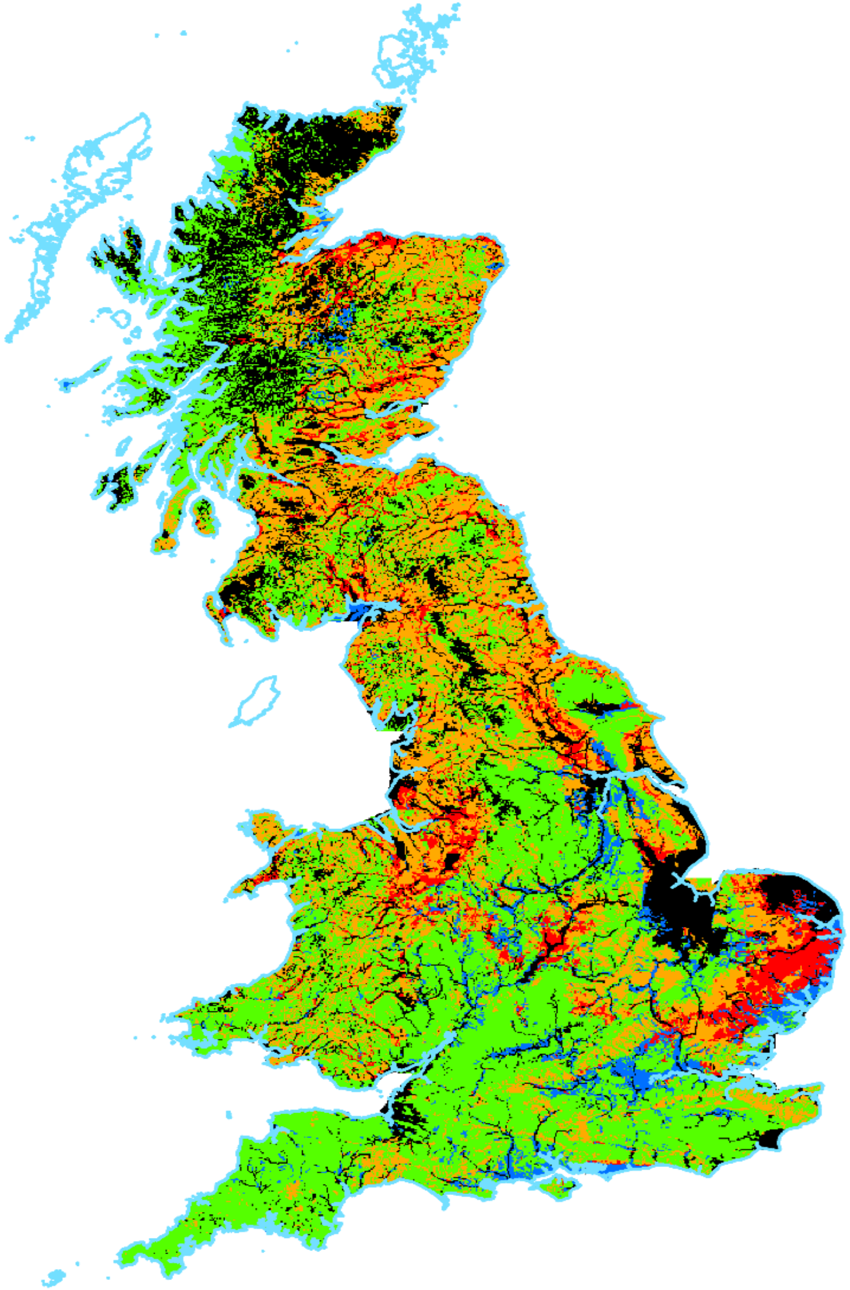
Marco Bianchi

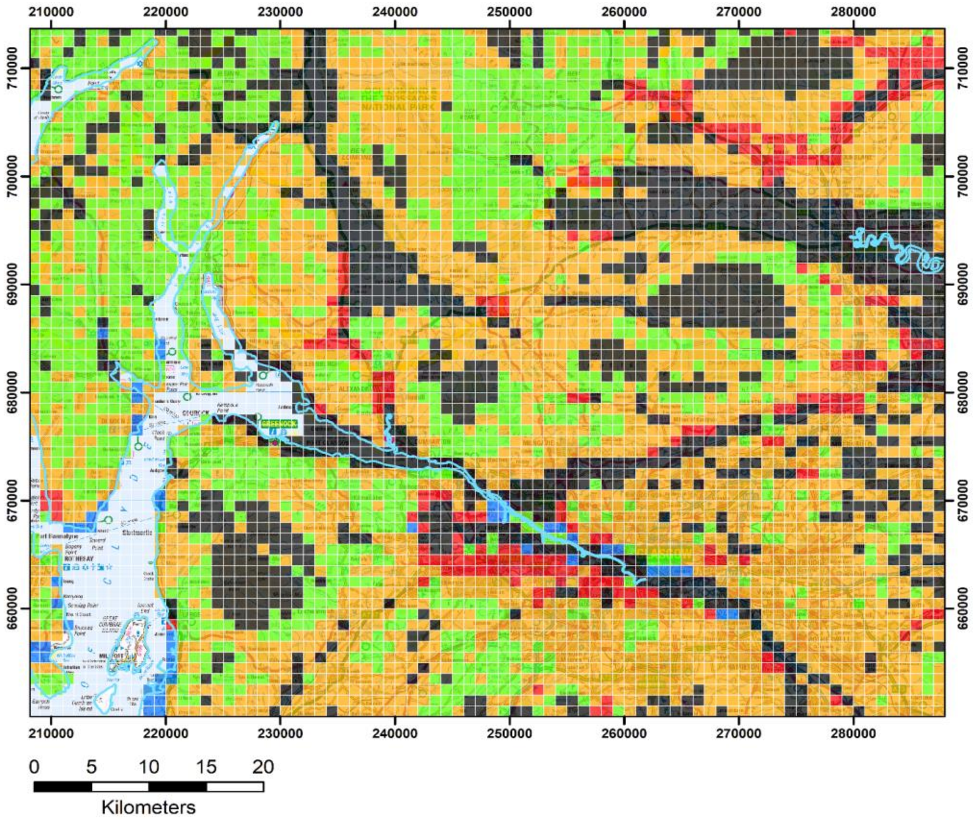
Quaternary processes





Jon Lee

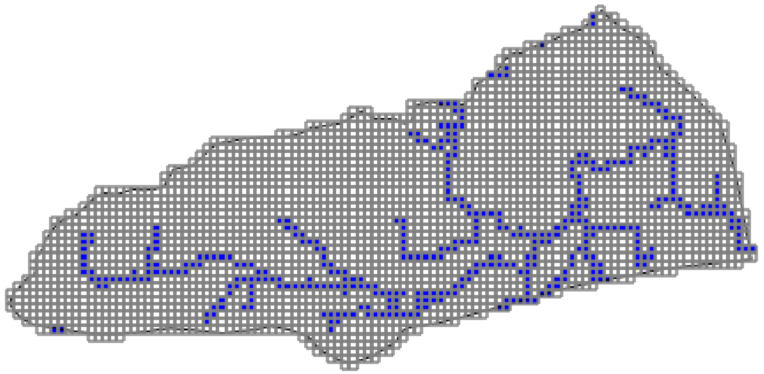




Class	Colour	Description	Hydrogeological complexity
A		Bedrock at surface	Low
B		Bedrock beneath a high-permeability superficial unit	Low
C		Bedrock beneath a low-permeability superficial unit	Low
D		Bedrock covered by single low- and high-permeability units in superposition	Moderate
E		Multiple low- and high-permeability superficial units in superposition above bedrock AND / OR complex and unpredictable geometry.	High

Improving the geological representation: Test 3D geology on a small area

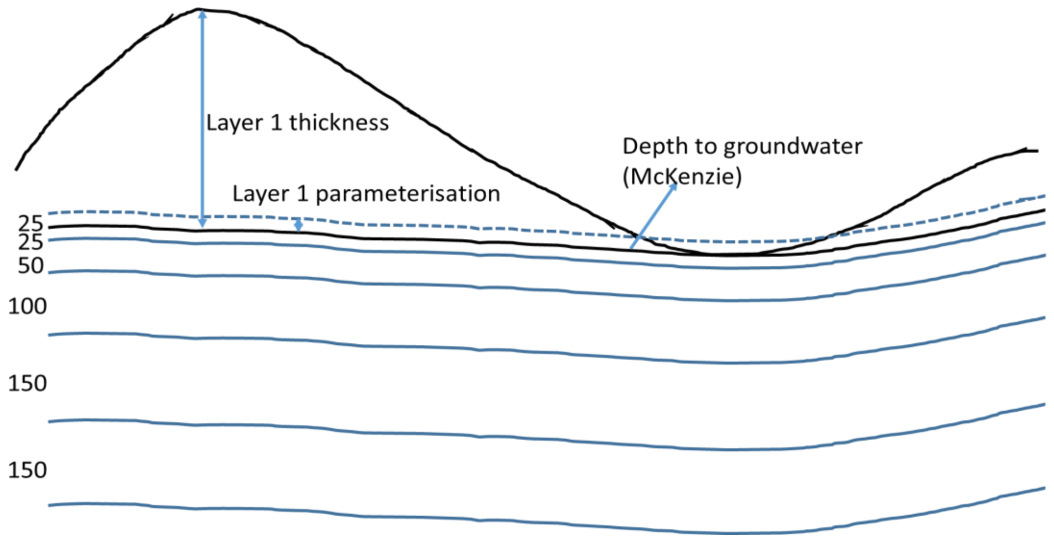
Marlborough and Berkshire Downs, South-west Chilterns



Set-up otherwise unchanged from UK mainland model:

- grid (1 km)
- rivers
- recharge

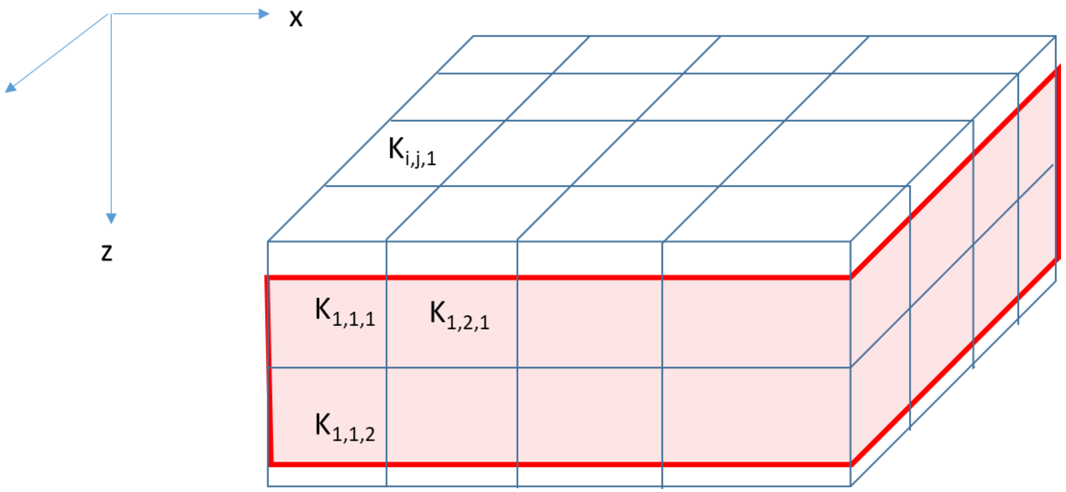
- 1 Layer using the surface geology
- 1 Layer using geological averaging
- 6 Layers: more refined near the surface



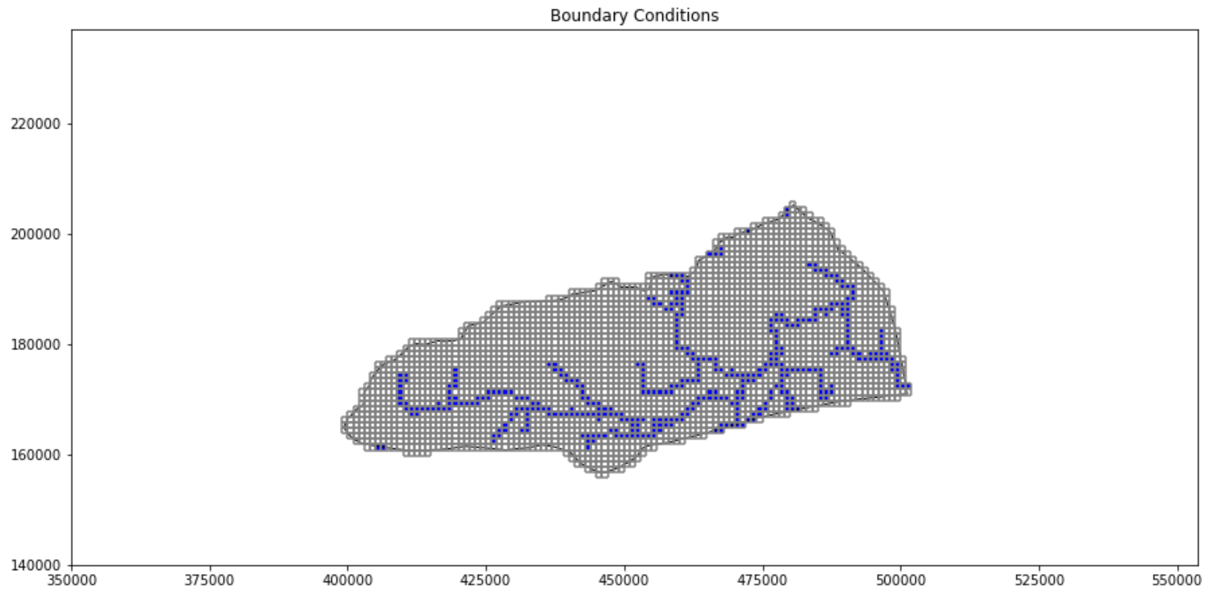
Improving the geological representation: Geological averaging onto the model grid

- Calculate effective hydrogeological properties for each model cell
- Calculate a weighted mean in x, y, z for each model cell

- harmonic mean of groups of cells along the flow direction – preserves properties with lower values
- arithmetic mean of groups of cells perpendicular to the flow direction – preserves properties with higher values



Improving the geological representation: Test 3D geology on a small area: Marlborough and Berkshire Downs, South-west Chilterns

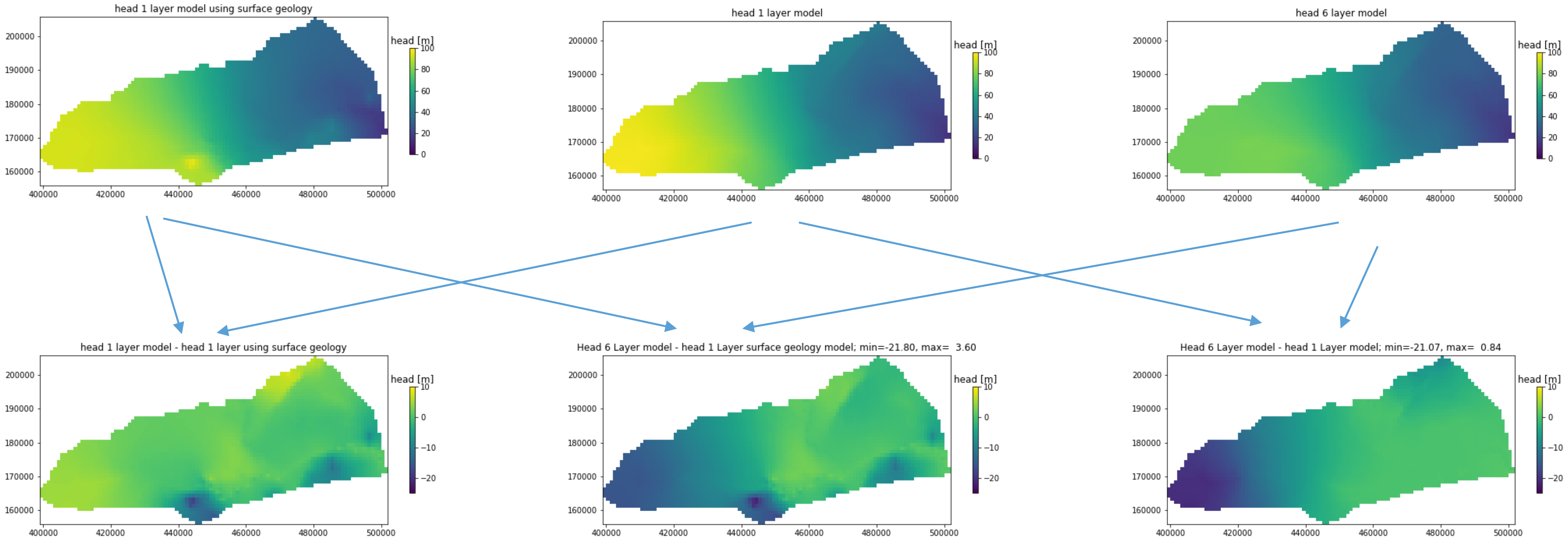


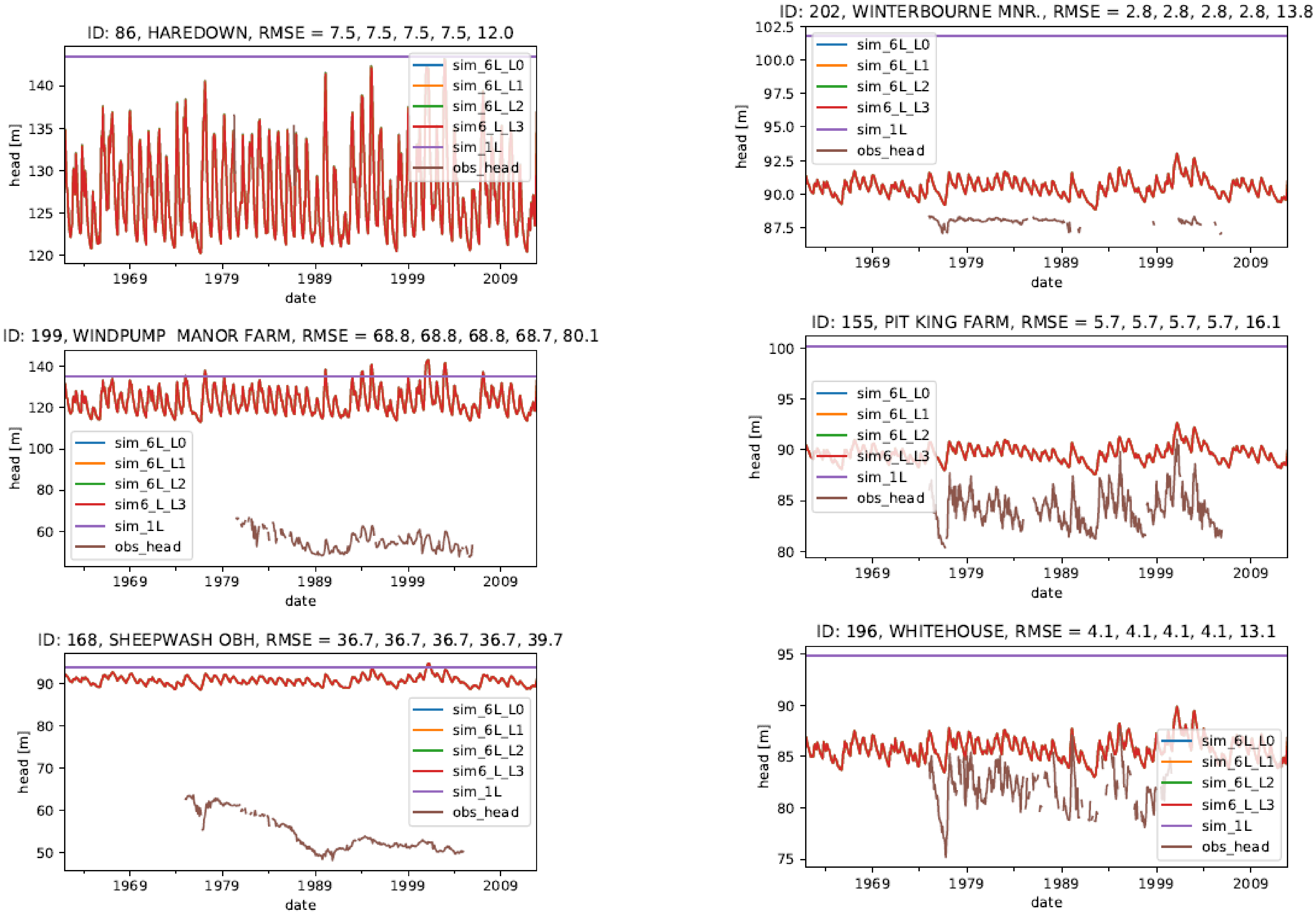
Set-up otherwise unchanged from UK mainland model:
-grid (1 km)
-rivers
-recharge

Effect of geological averaging on steady state hydraulic head

Surface properties

Equivalent hydrogeological properties

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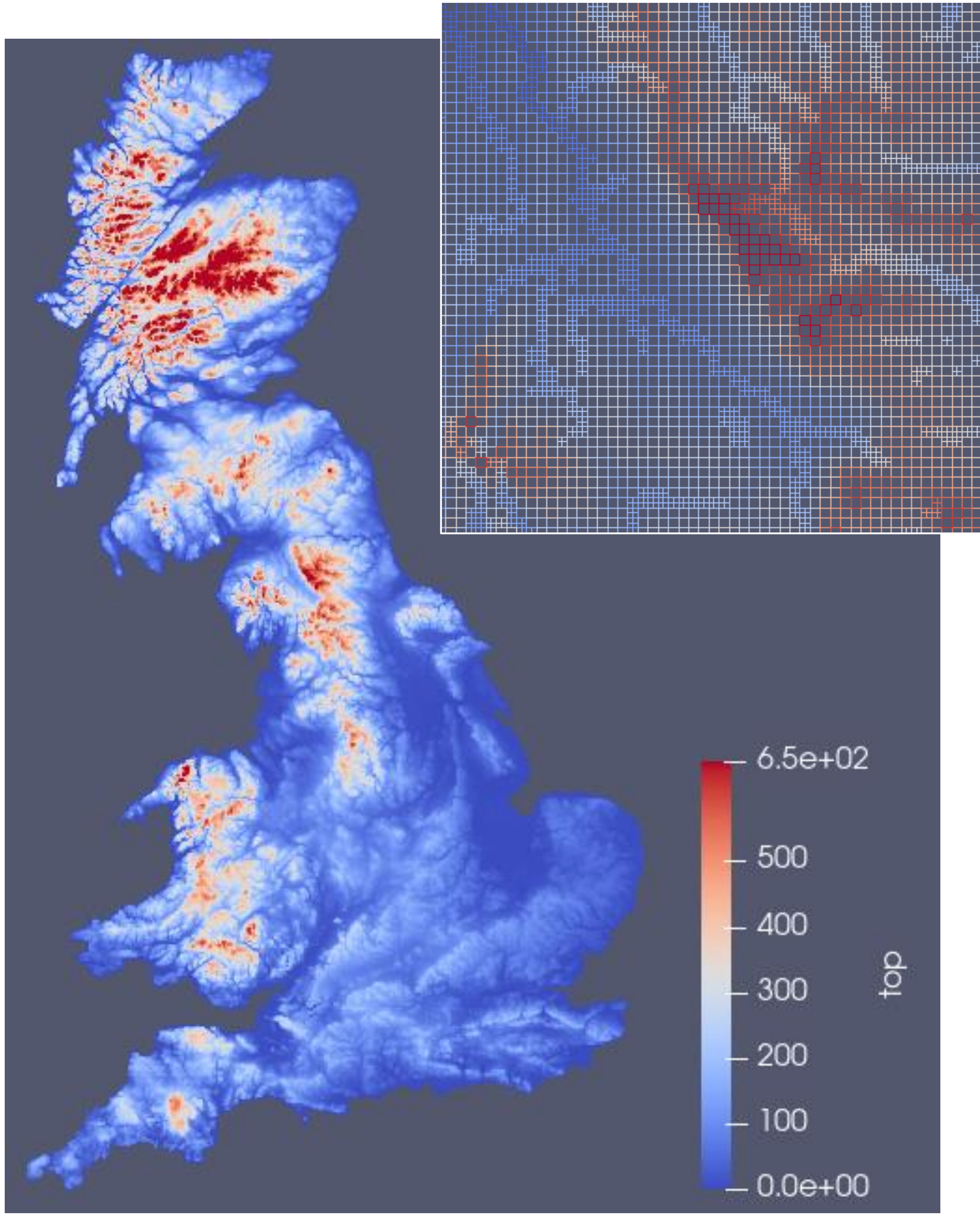
ID: 168, SHEEPWASH OBH, RMSE = 36.7, 36.7, 36.7, 36.7, 39.7
ID: 196, WHITEHOUSE, RMSE = 4.1, 4.1, 4.1, 4.1, 13.1
head [m]
date
1969
1979
1989
1999
2009
sim_6L_L0
sim_6L_L1
sim_6L_L2
sim6_L_L3
sim_1L
obs_head

GB model

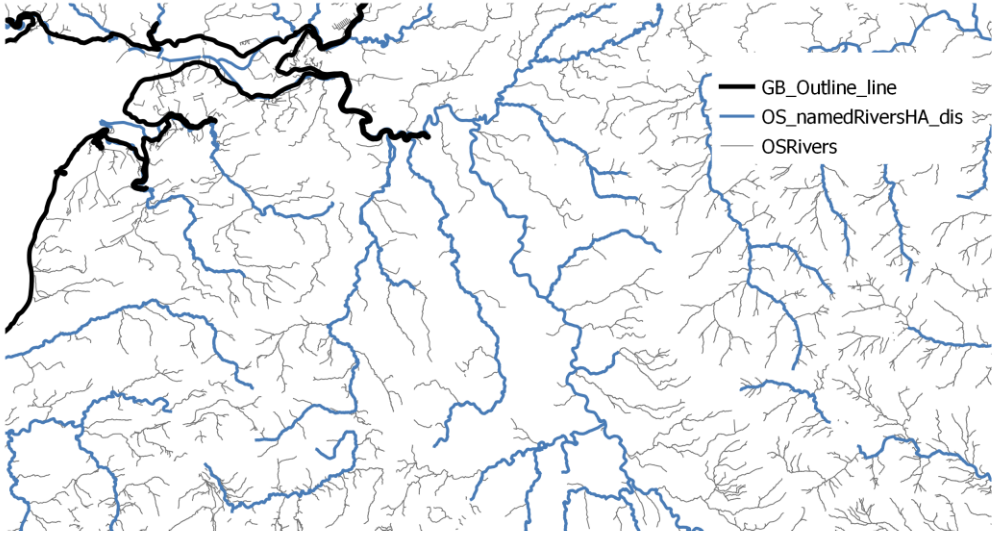
- Unstructured DISU grid
- Horizontal resolution: 1000 m, 500 m
- Vertical resolution: 25 m, 25 m, 50 m, 100 m, 150 m, 150 m
- 14 Hydrostratigraphic units
- Top based on the 50m DTM
- 1,467,148 active nodes

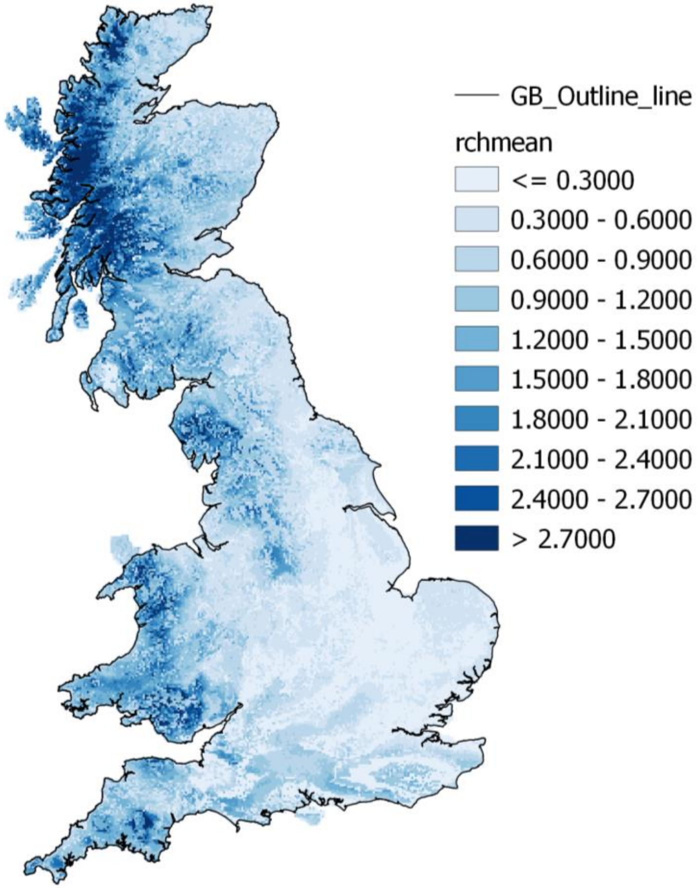


Marco Bianchi

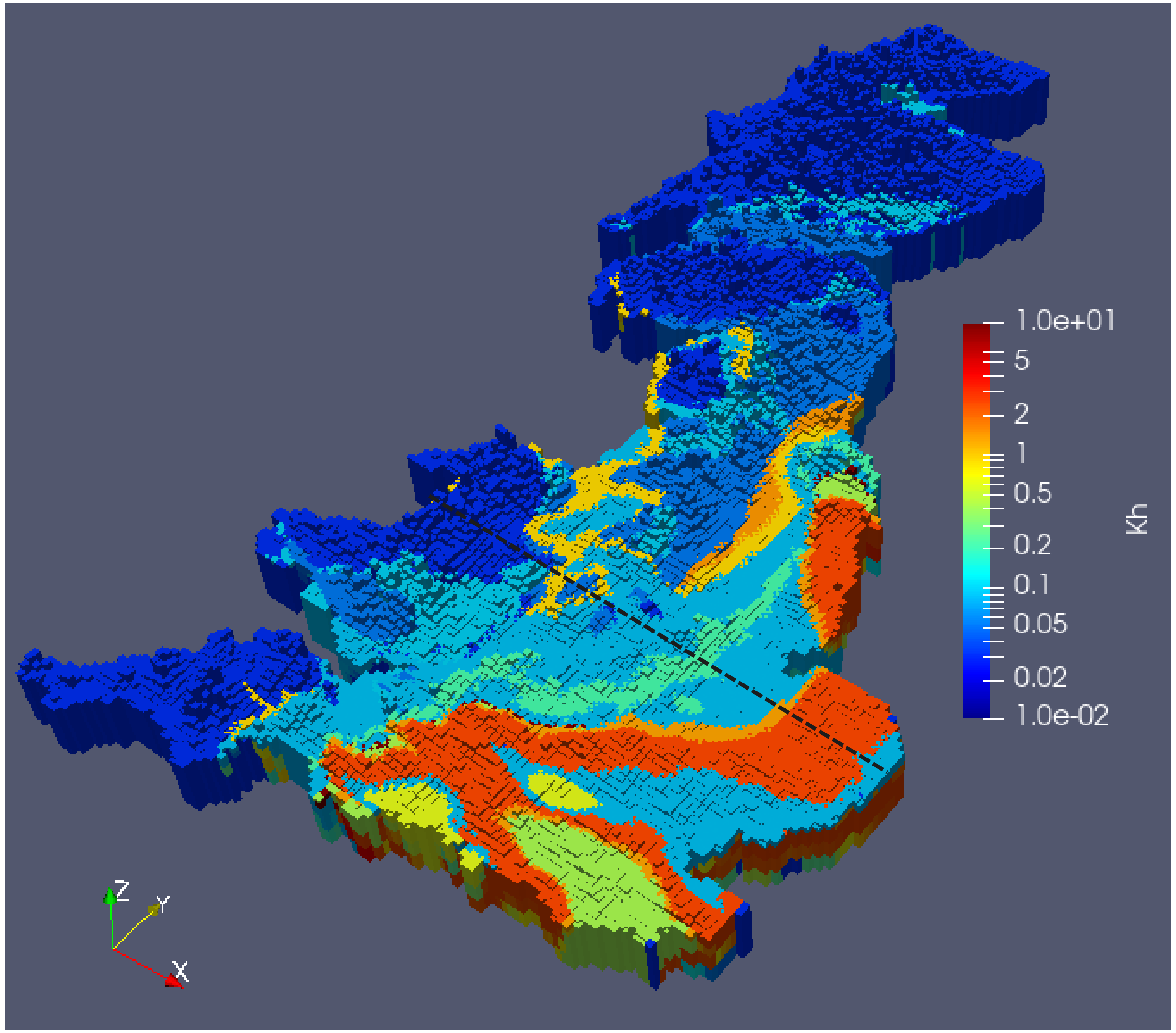
Boundary conditions

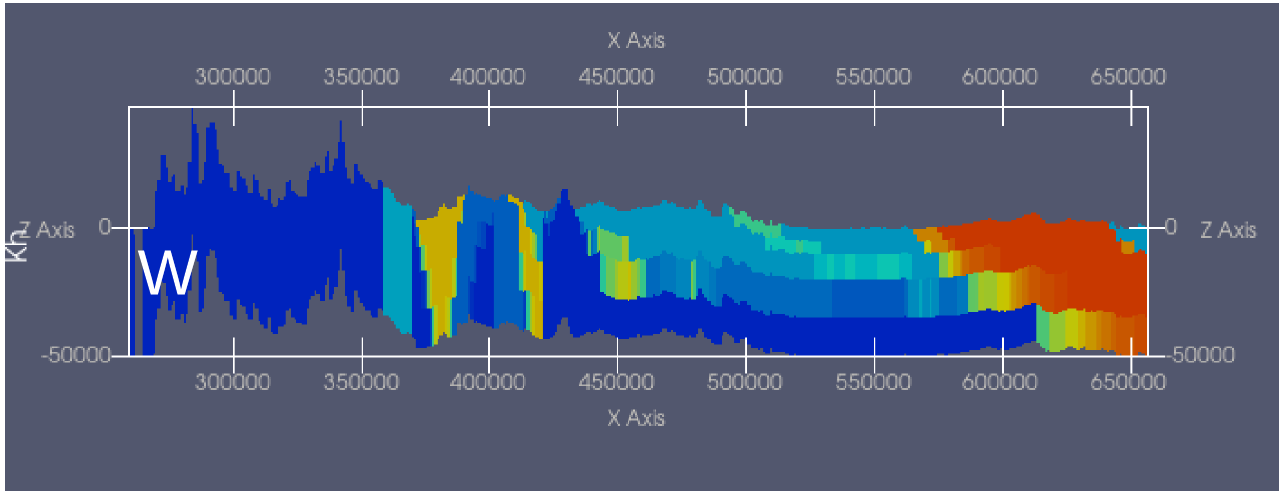
- Coastline: CHD package
- Rivers: RIV/SFR package
- Recharge: RCH package
- Abstractions: WEL package



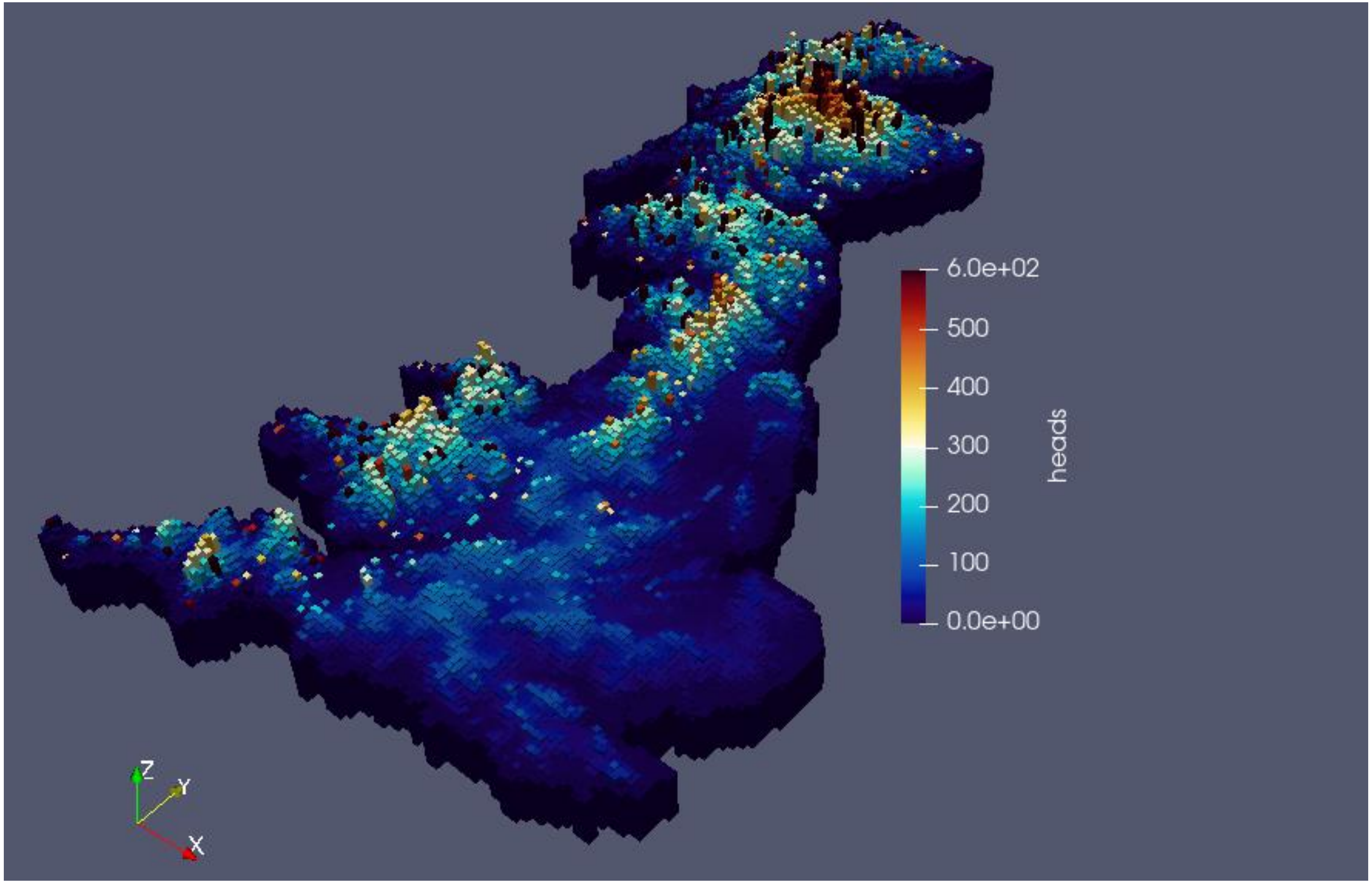


Hydraulic conductivity



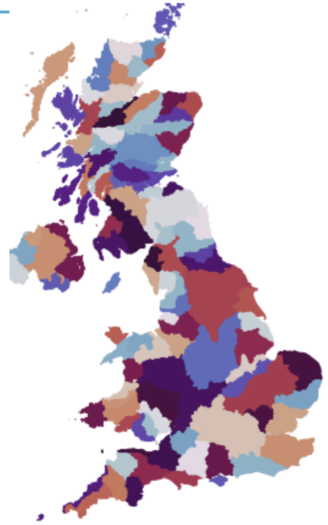


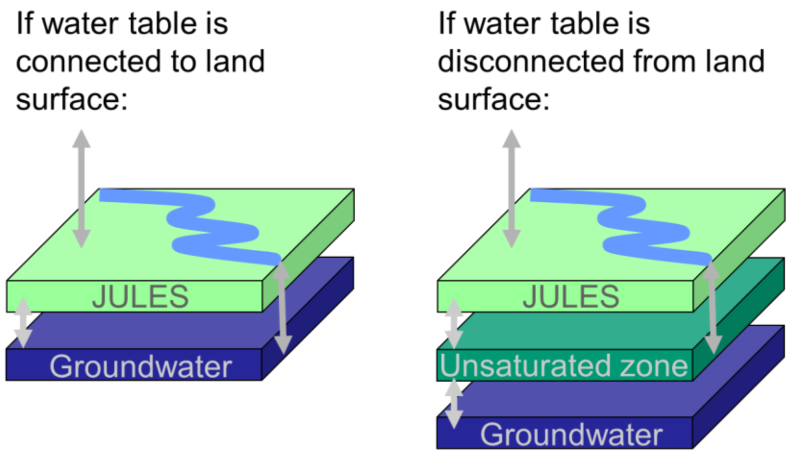
Steady state simulation



Next steps

- **Model calibration**
  - Observed groundwater heads
  - Compare the simulated and observed heads and river flows for different river catchments and geological units
  - Seasonality and extremes
- **Integration into the Hydro-JULES framework**
  - MODFLOW 6 integration into the Hydro-JULES modelling framework
  - British Mainland model will be an example for an integrated model
  - Integrated groundwater – surface water assessment for flooding and drought





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Hydro-JULES

UK Centre for Ecology & Hydrology

BGS British Geological Survey

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL