Stochastic hydrogeological parameterisation and modelling of the Chalk of England

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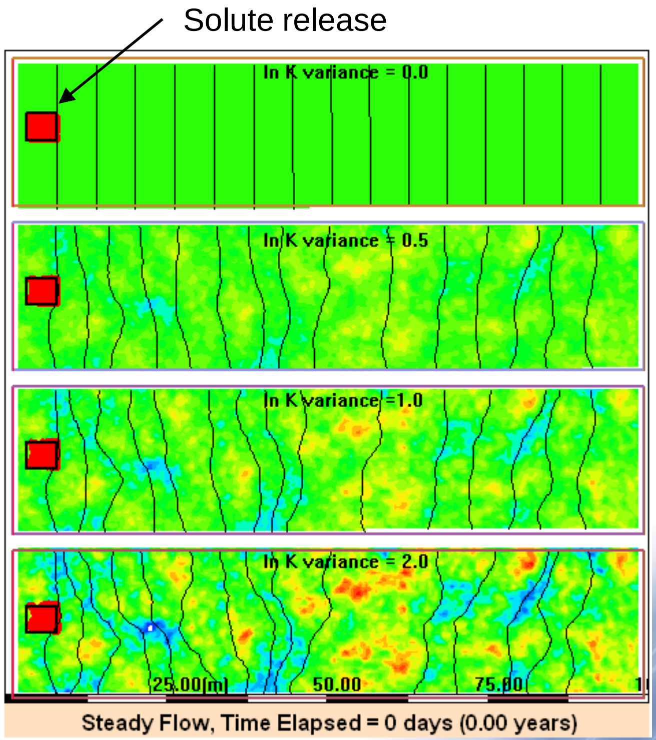
Parameterisation in GW modelling

- Fluid flow and solute transport is controlled by the spatial distribution of few hydrogeological parameters (hydraulic conductivity, transmissivity, porosity, and storativity)
- Parameterisation is the task of generating "representative" distributions of hydrogeological parameters to be transferred to numerical grids for flow and transport simulations



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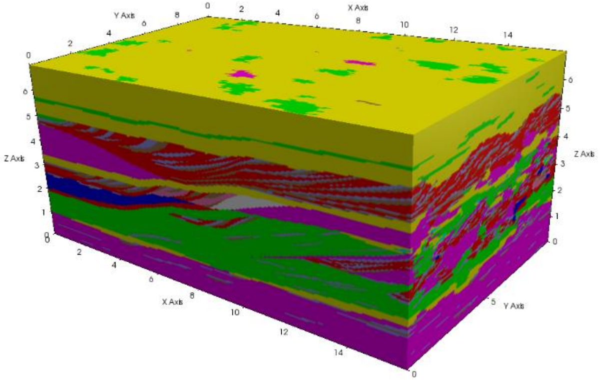
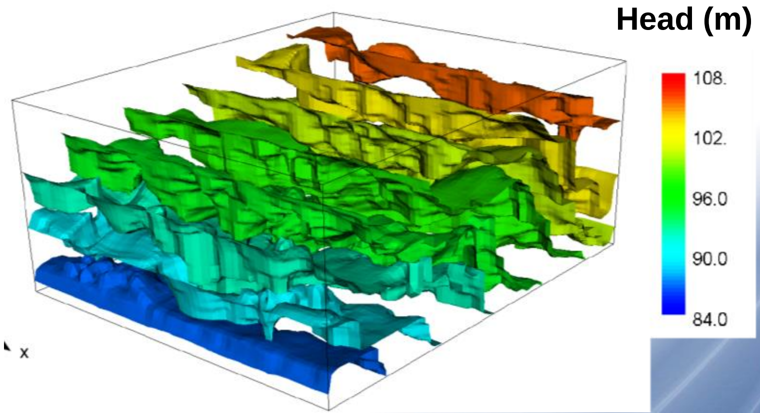
Parameterisation workflow

Geological reality

Parameter field (e.g. K)



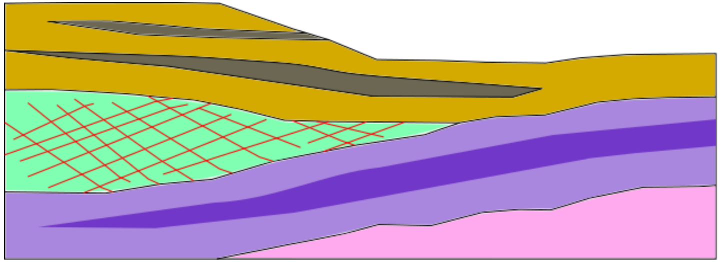
Numerical simulation



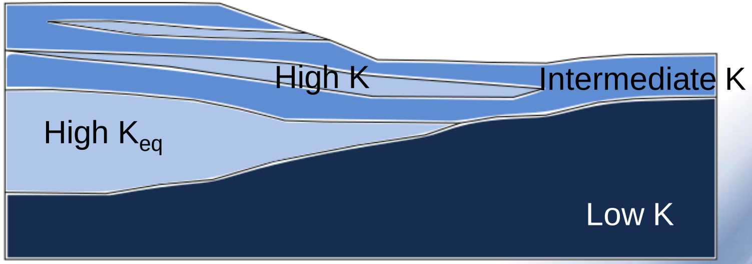
Goal-oriented parameterisation

- Reality is too complex, data are too scarce, computational constraints
- Simplifications of complex heterogeneity needed depending on modelling goal(s).
- Simplifications must maintain features that are relevant for a certain prediction goal whilst reducing less relevant complexity

Geological interpretation

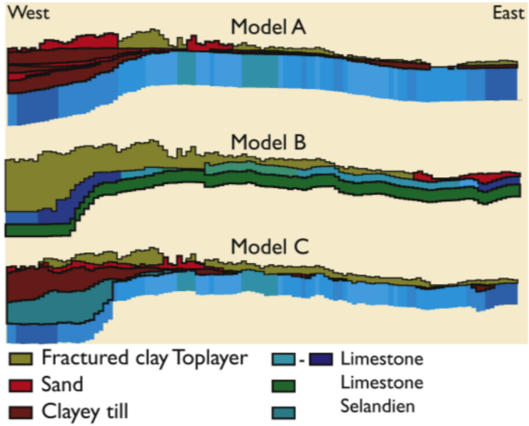


Hydrostratigraphic interpretation based on hydrofacies

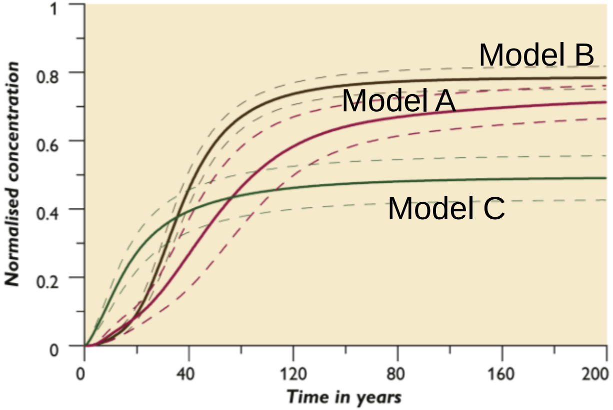


Uncertainty in parameterisation

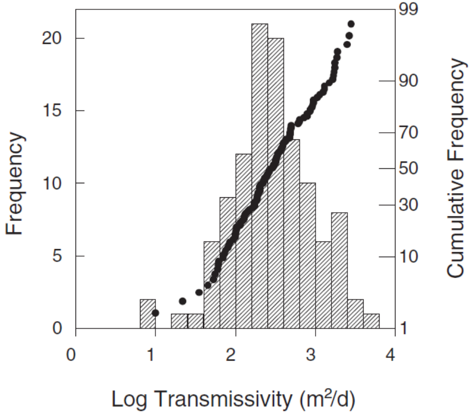
Højberg et al. (2005)



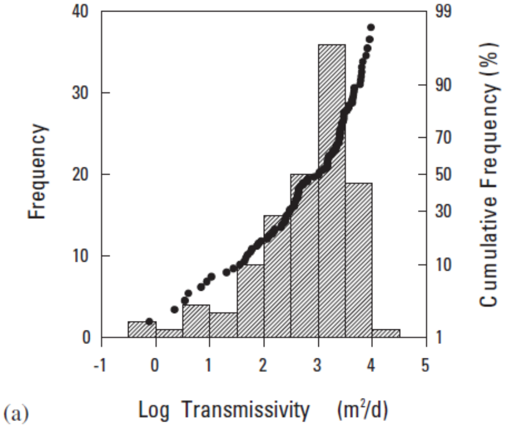
- Conceptual model uncertainty
- Parameter uncertainty



PT sandstones



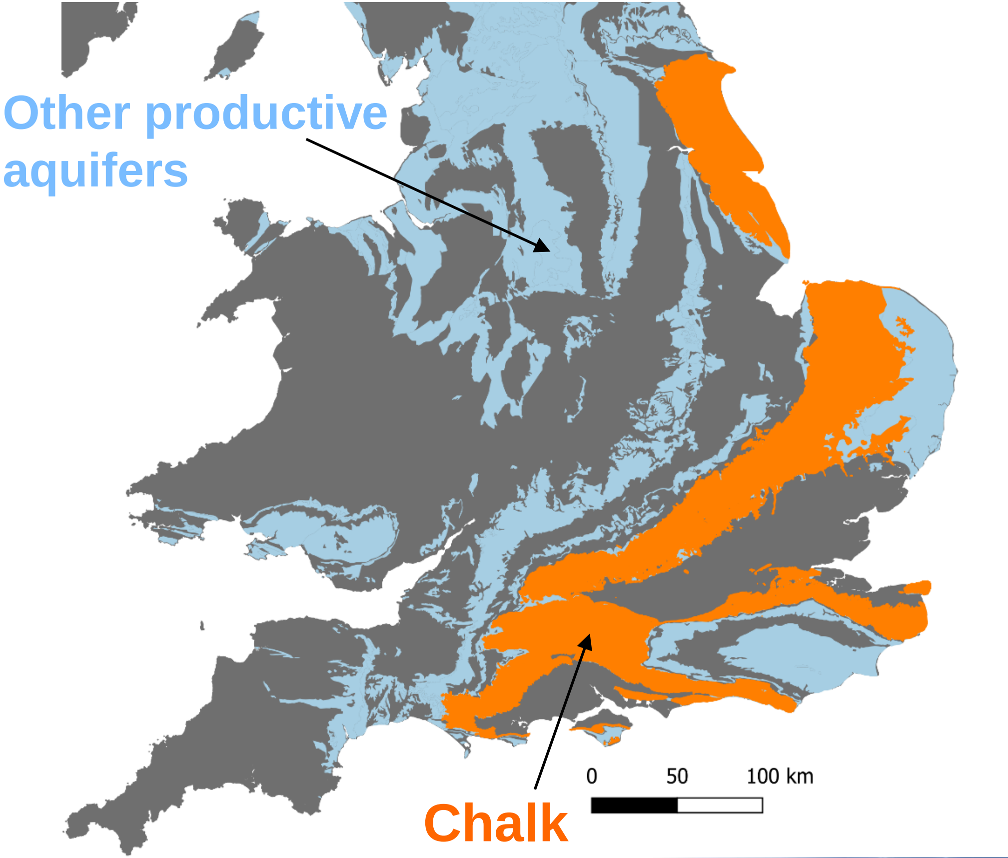
Chalk



Allen et al. (1997)

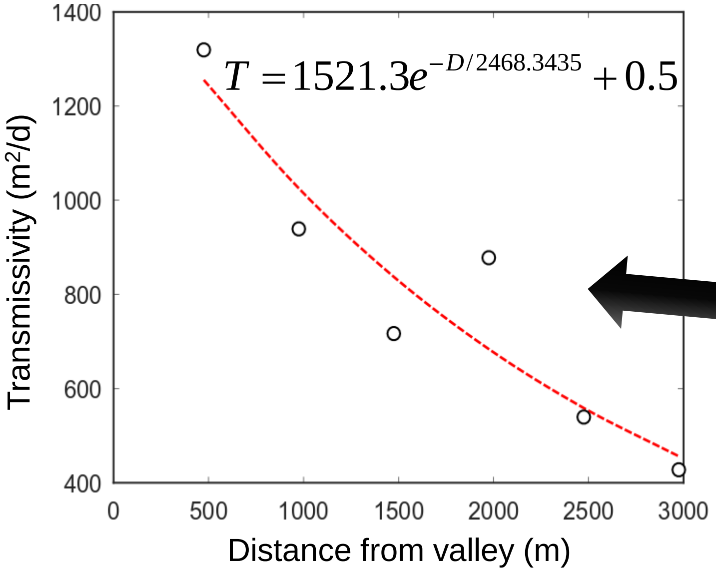
The Chalk

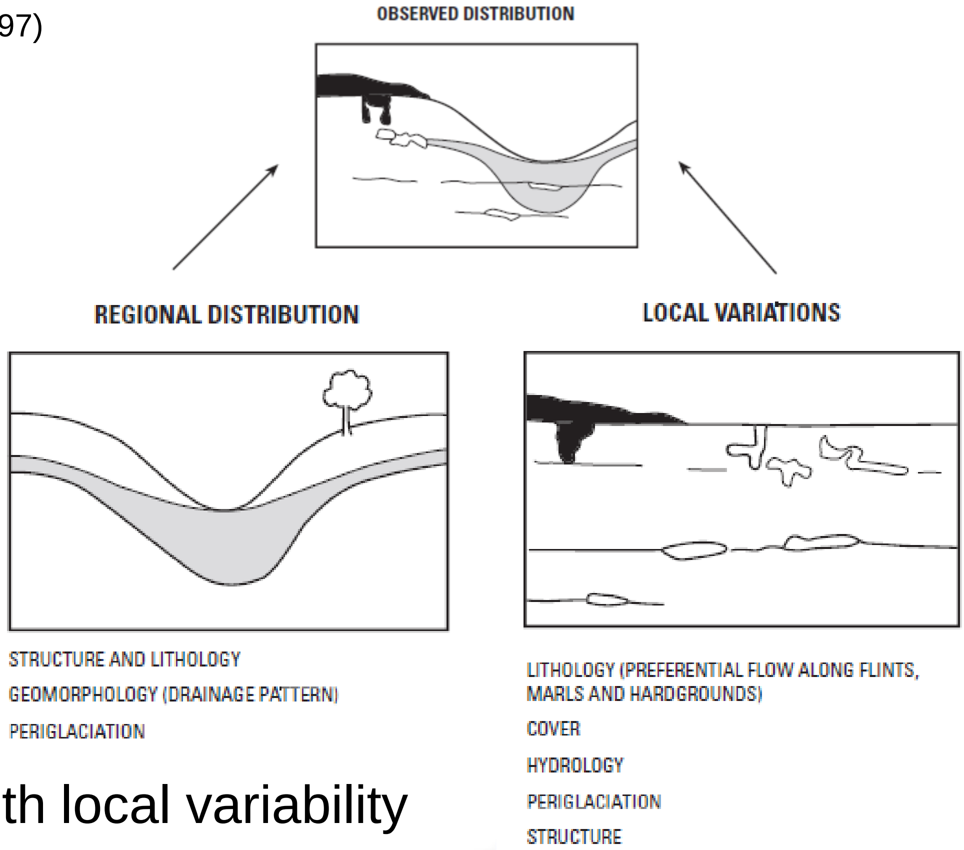
- Fine grained white limestone
- Most important aquifer in Great Britain
- Accounts for more than half of GW used
- Complex flow regime (matrix + fractures + karst)



Variations of transmissivity in the Chalk

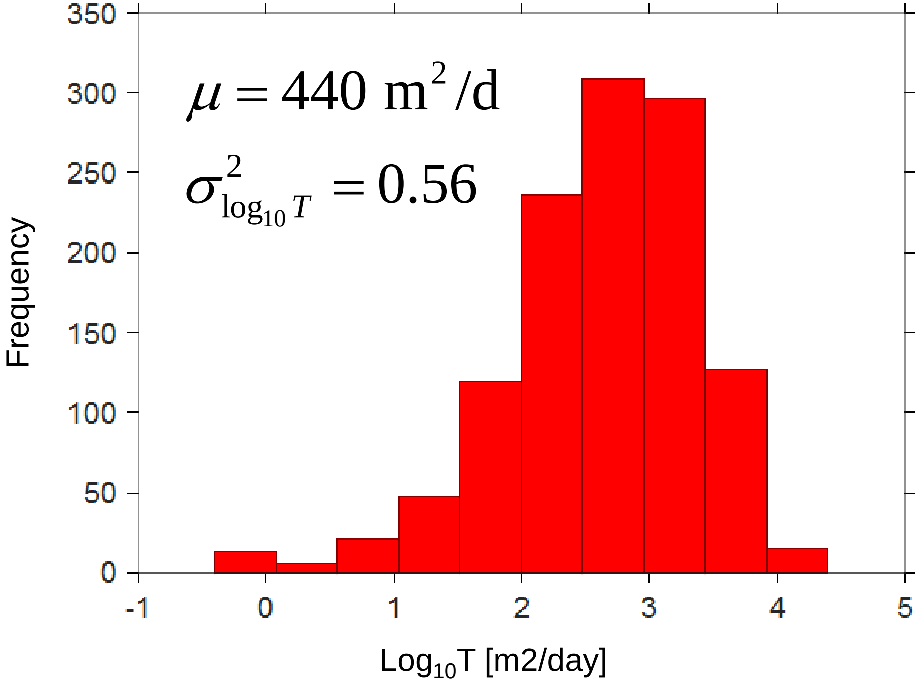
Allen et al. (1997)



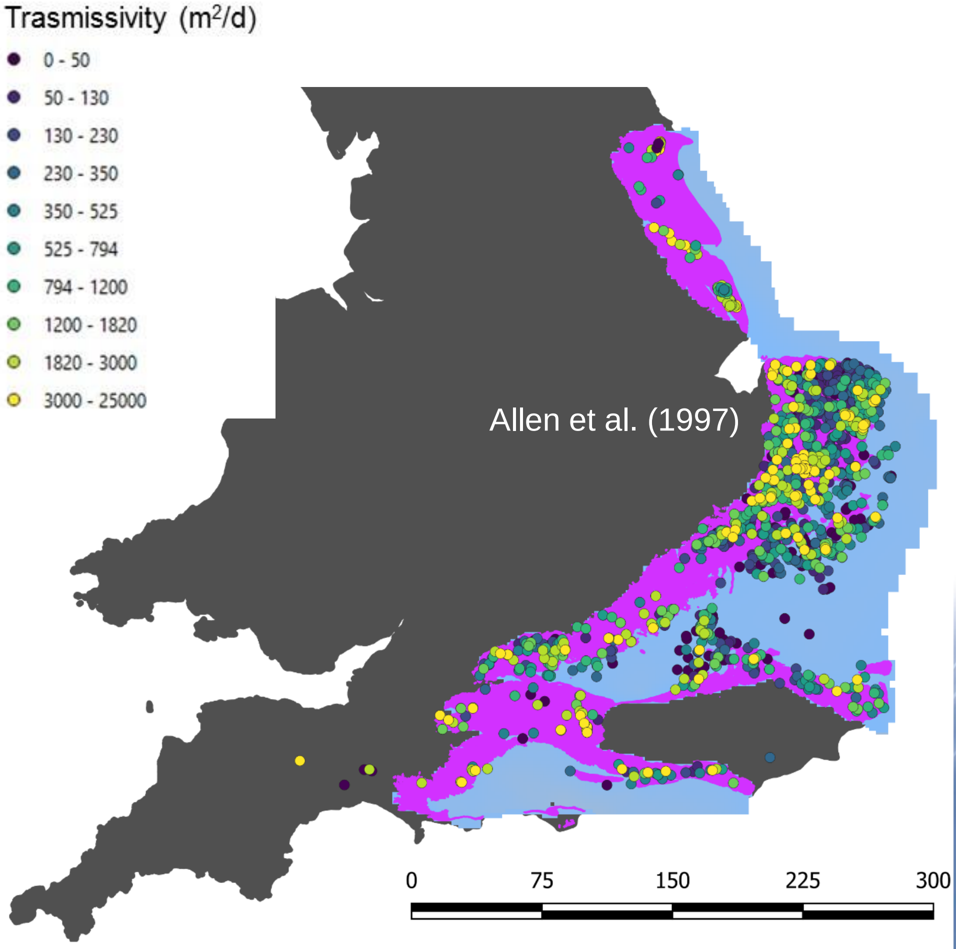


- Combination of regional trends with local variability

T data



$\mu = 440\ \mathrm{m}^2/\mathrm{d}$
$\sigma^2_{\log_{10} T} = 0.56$
Frequency
0
50
100
150
200
250
300
350
-1
0
1
2
3
4
5
Log10T [m2/day]



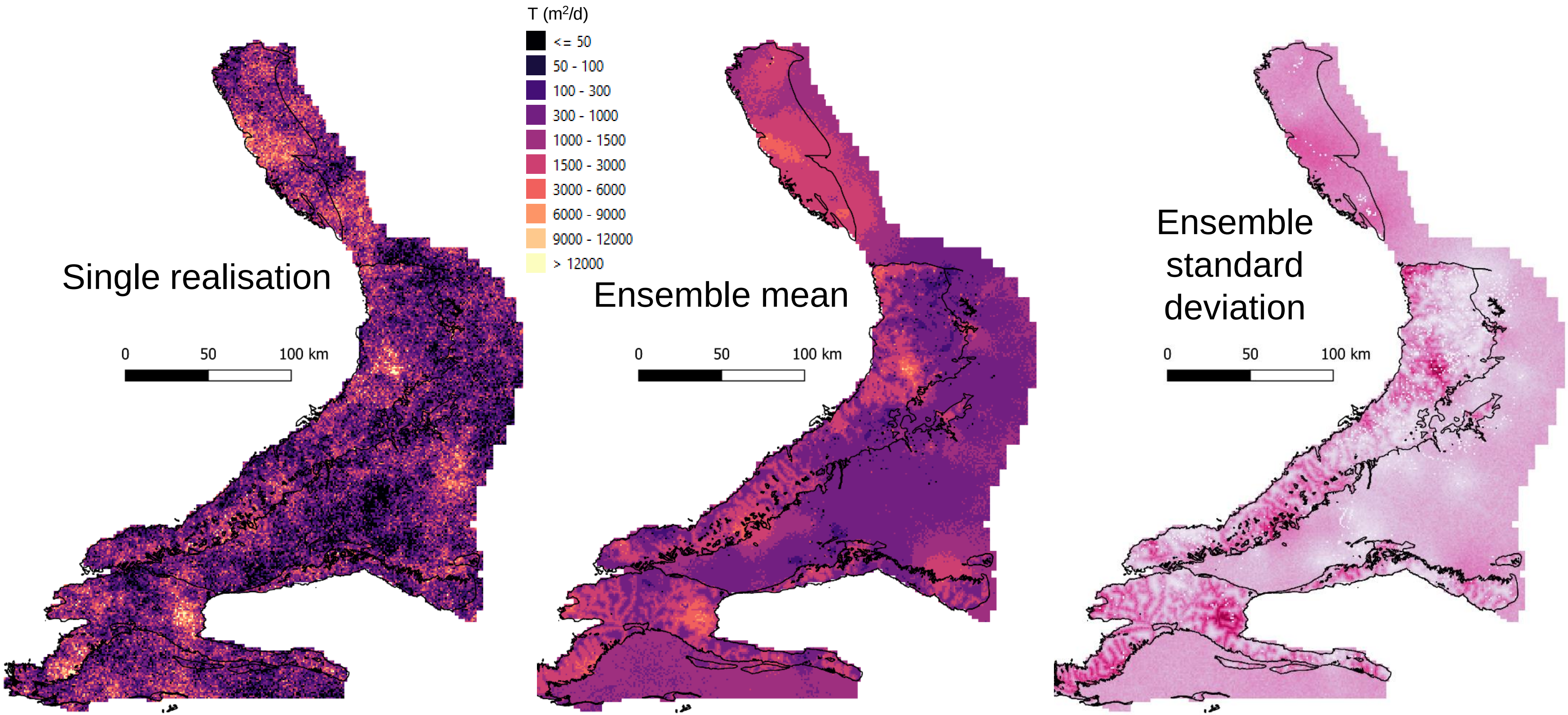
Trasmissivity (m2/d)
0 - 50
50 - 130
130 - 230
230 - 350
350 - 525
525 - 794
794 - 1200
1200 - 1820
1820 - 3000
3000 - 25000
Allen et al. (1997)
0
75
150
225
300

Approach for modelling T distribution in the Chalk

- <u>Confined Chalk</u>
  - Geostatistical structure imitating approach
    - Conditional SGSIM based on T data

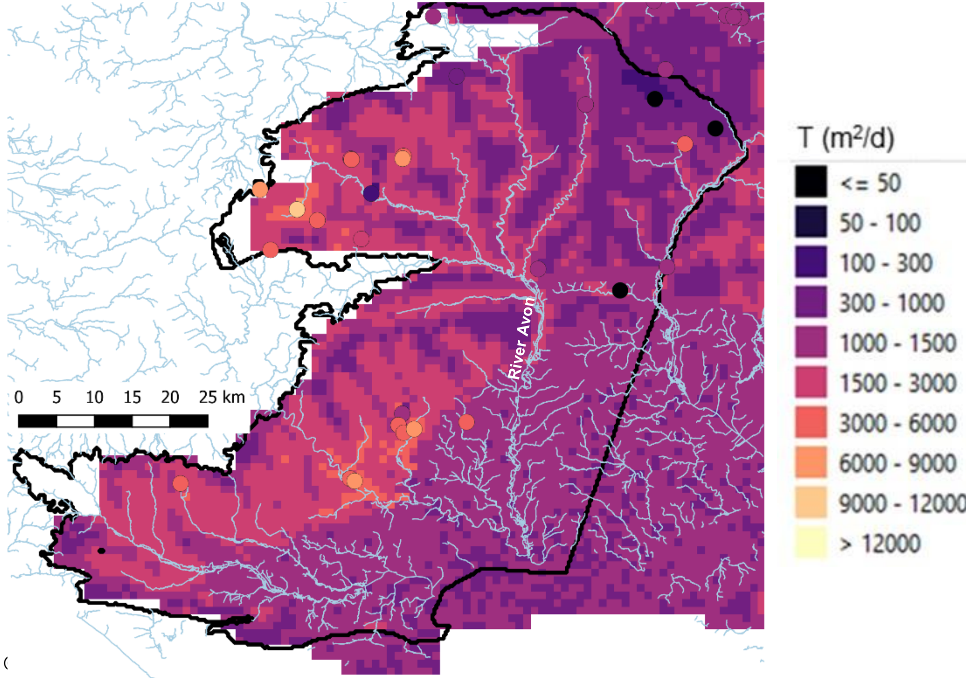
- <u>Unconfined Chalk</u>
  - Combination of descriptive and structure imitating approaches
    - Deterministic component to account for higher T in valleys and lower T at interfluves
    - Stochastic component to adjust the determinist component to actual data at measurement locations

Results: simulated T field

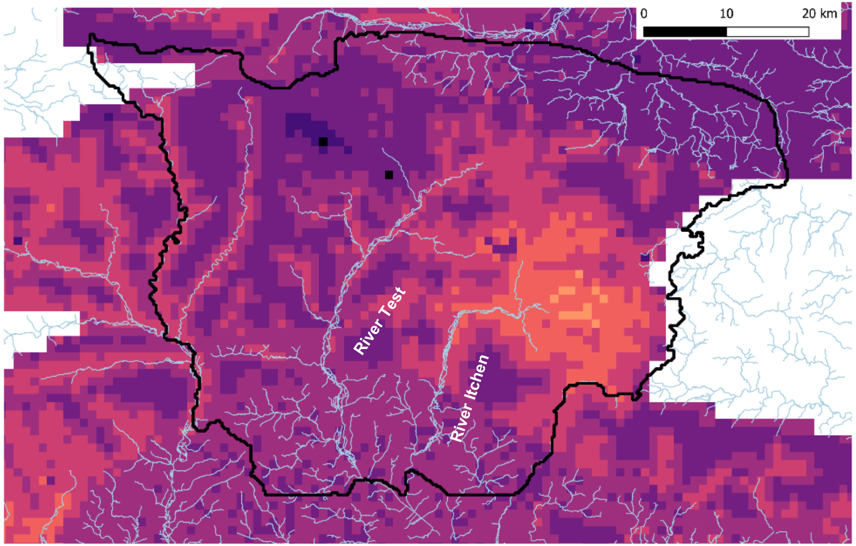


Results: simulated T field

Close up of the mean T distribution in the River Avon basin

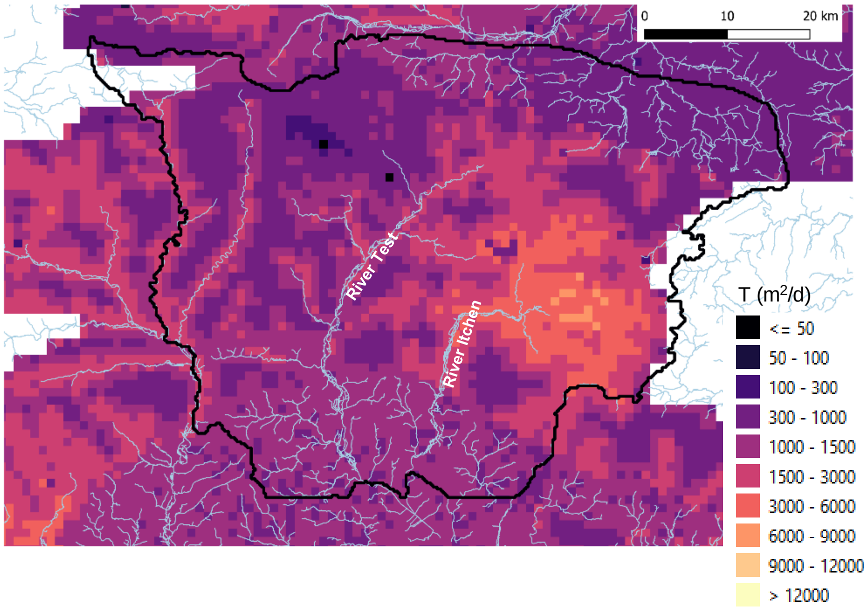


Close up of the mean T distribution in the River Test and River Itchen basins

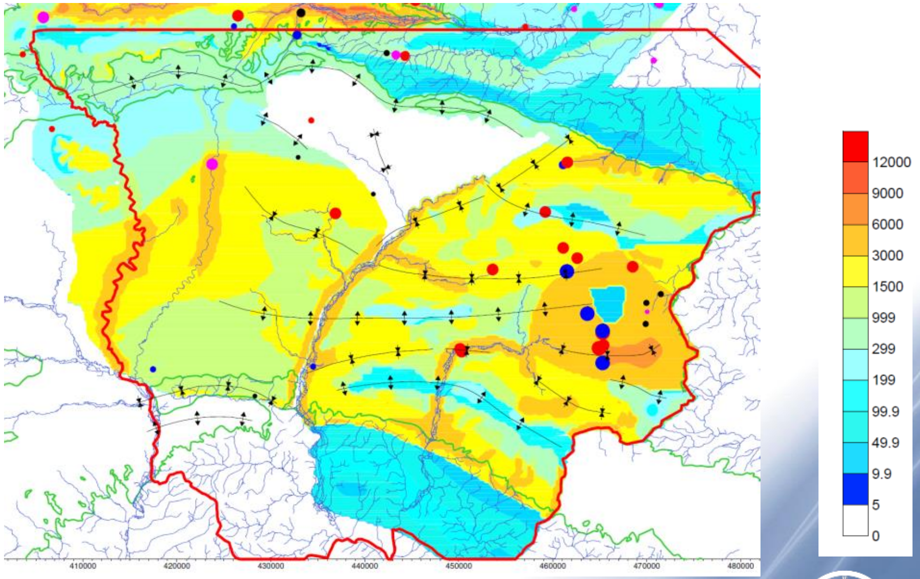


Results: simulated vs calibrated T fields

Simulated mean T distribution in the River Test and River Itchen basins



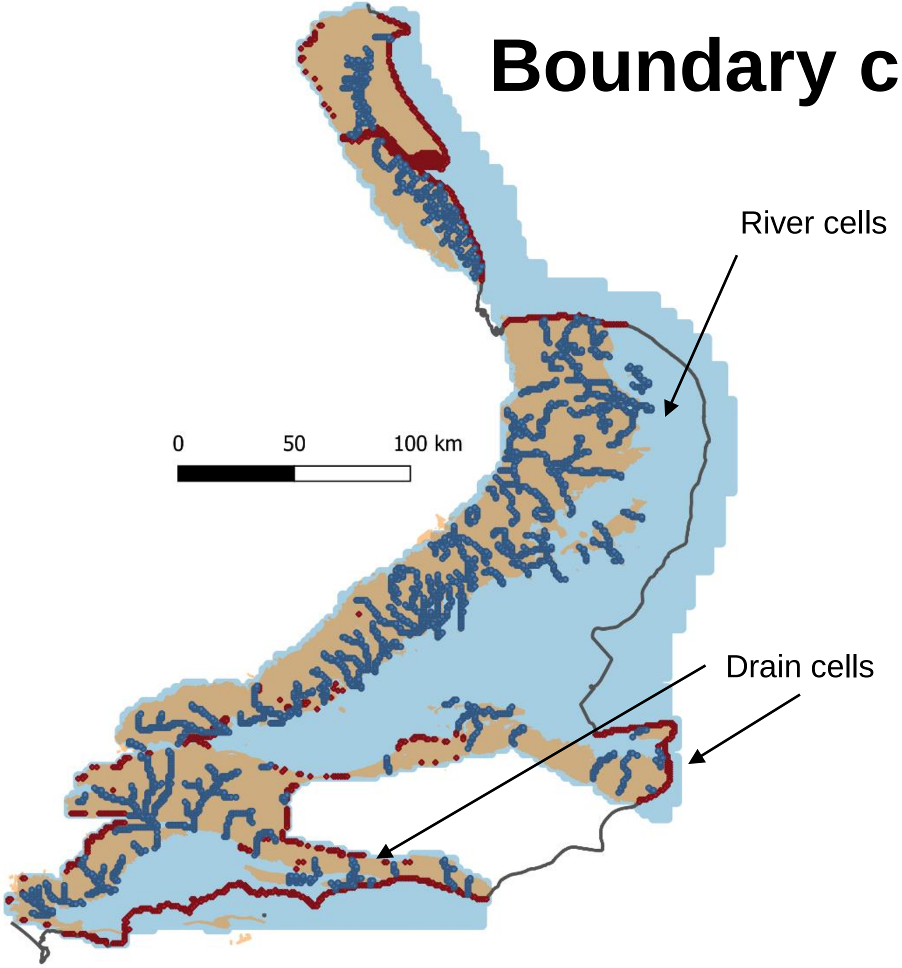
Calibrated T distribution in a GW model (Entec UK Limited, 2005)

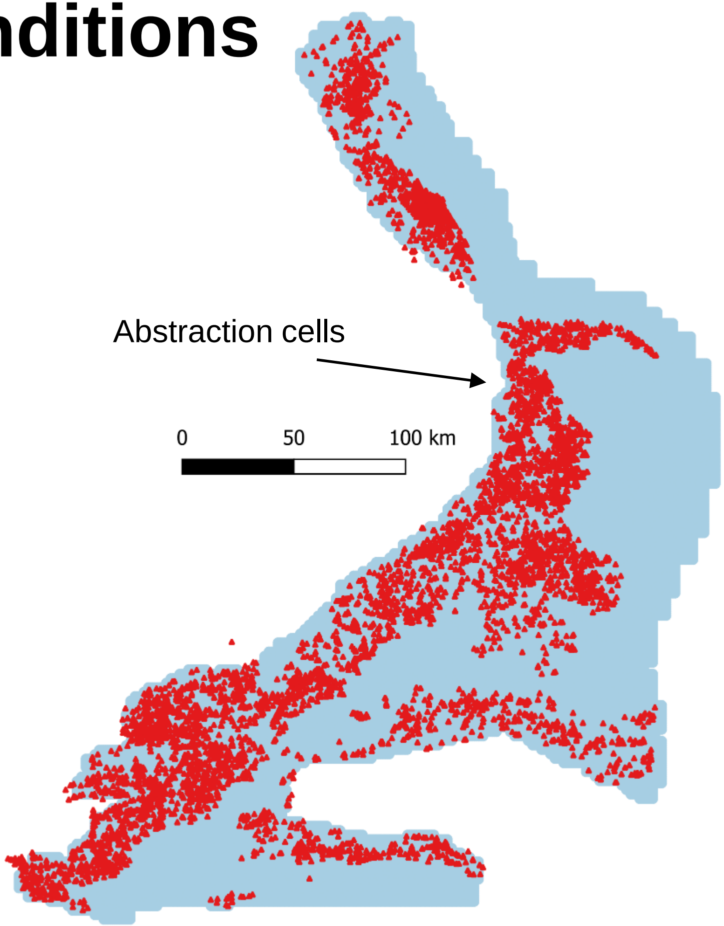


2D groundwater flow model

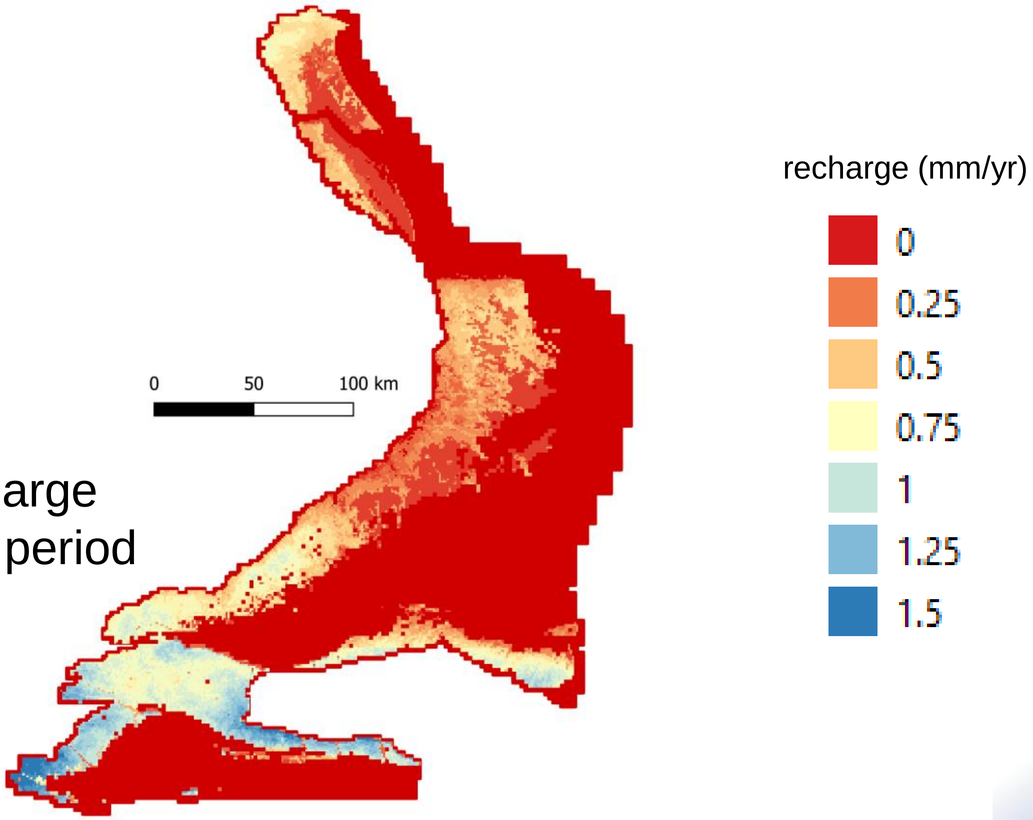
- 1000 m grid resolution (43,852 active cells)
- Simulated period: 1/1/1962 – 31/12/2014 (636 stress periods)
- Boundary conditions:
  - river leakage
  - springs
  - abstractions (licence rates, EA data probably copyrighted),
  - discharge to sea
  - recharge

Boundary conditions



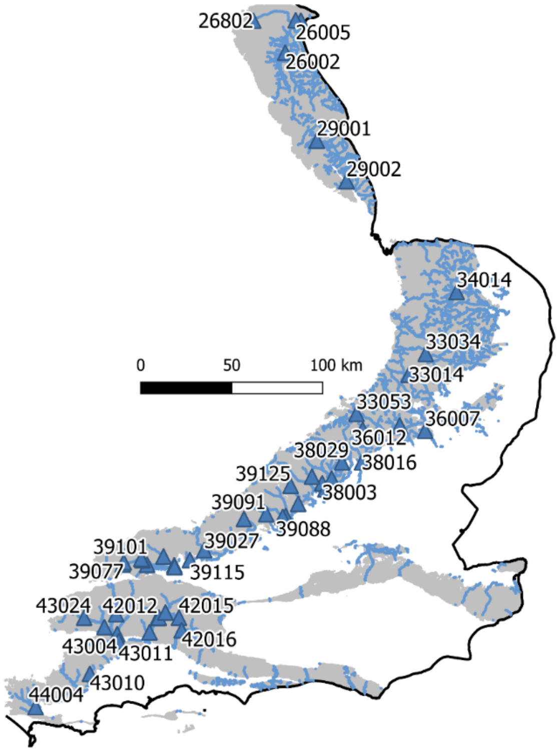


Time variant monthly ZOODRM recharge model (Mansour and Hughes, 2004)



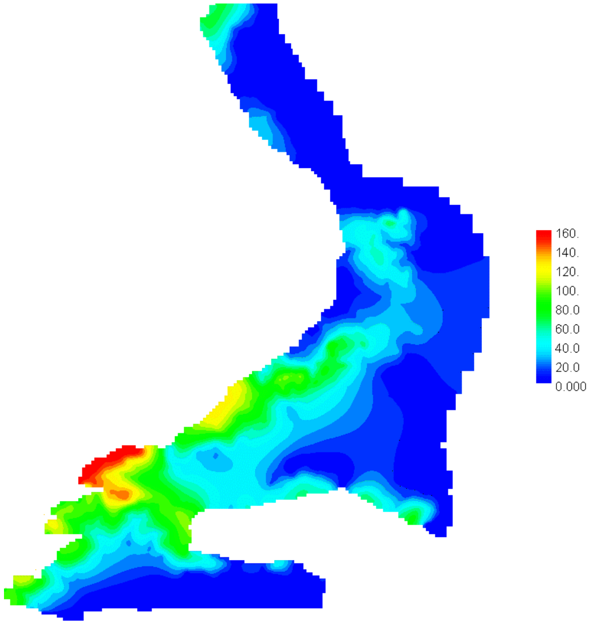
Average recharge
over simulated period

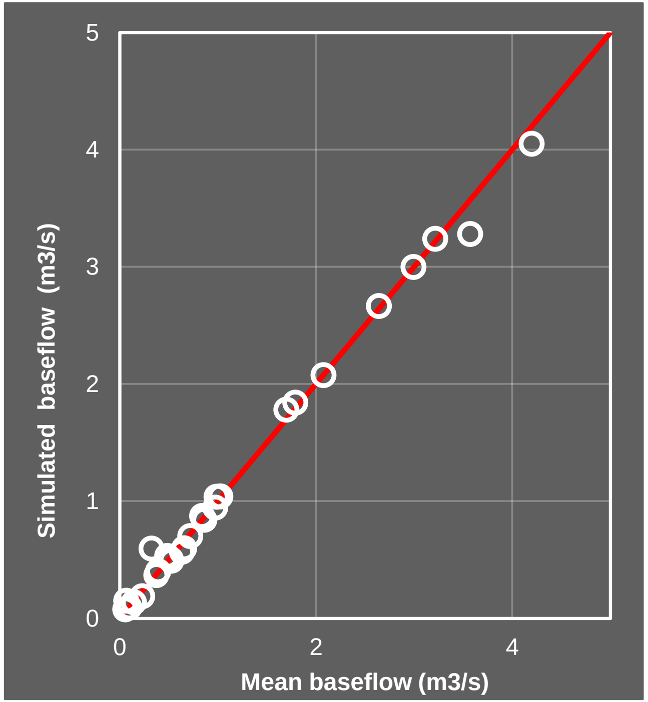
Hydraulic heads and river flow observations

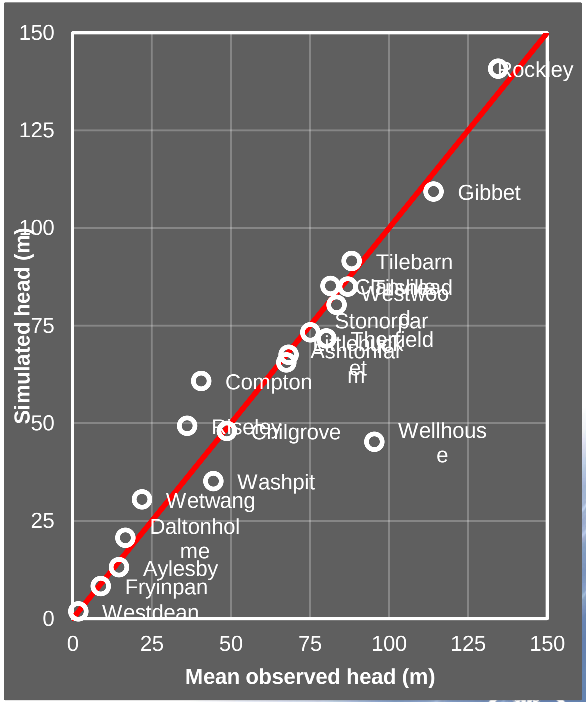


Simulated hydraulic heads

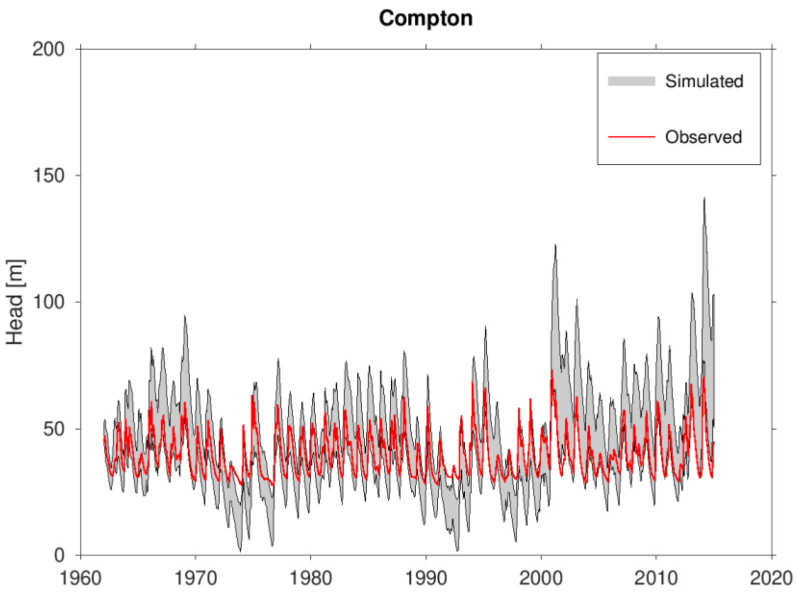
Initial conditions (steady state simulation based on average recharge and average T)

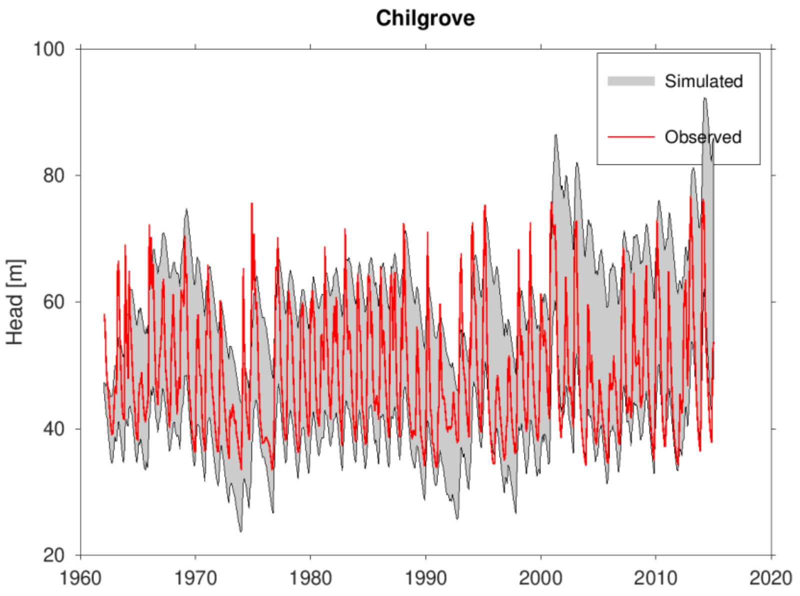




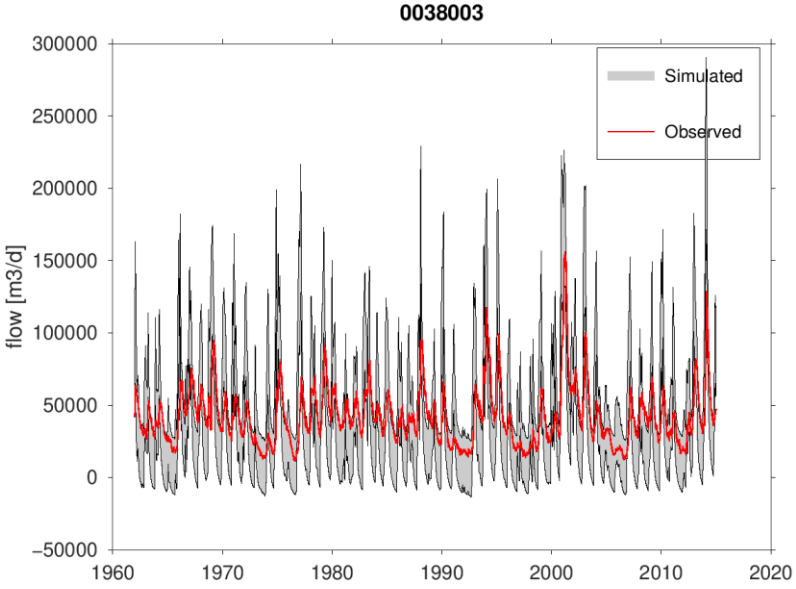


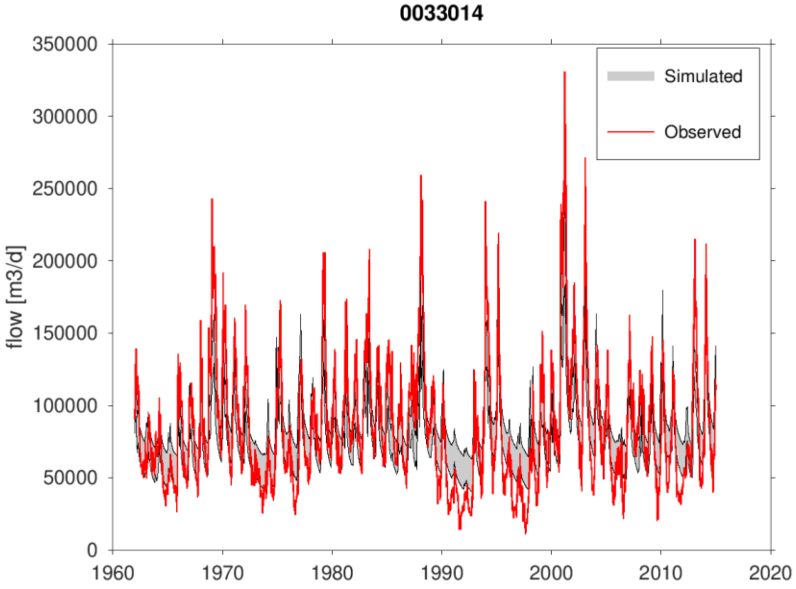
Simulated transient heads





Simulated transient river baseflow





Conclusions

- First “basin scale” stochastic model of the Chalk
- Hybrid parameterization combining regional trends and local variability
- Ongoing work for applying the model to understand aquifer dynamics in relation to changes in anthropogenic and climatic stresses