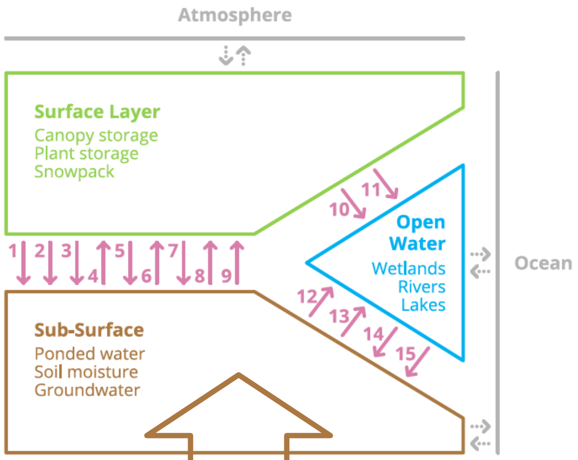
SETAREH NAGHELI, MARCO BIANCHI, JOHANNA SCHEIDEGGER, ANDREW HUGHES AND MANY OTHERS

From Data to Models: Advancing BGWM with a Data-Driven Approach

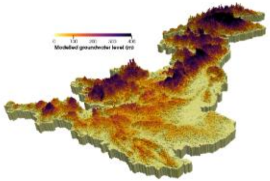
British Geological Survey

Why a national-scale GW model (BGWM)?

- Improve subsurface processes in land surface models (e.g. JULES)
- Develop the first national-scale, groundwater flow model for Great Britain
- Provide modelling platform for groundwater research and decision support at regional and national scales



Bucket model



BGWM

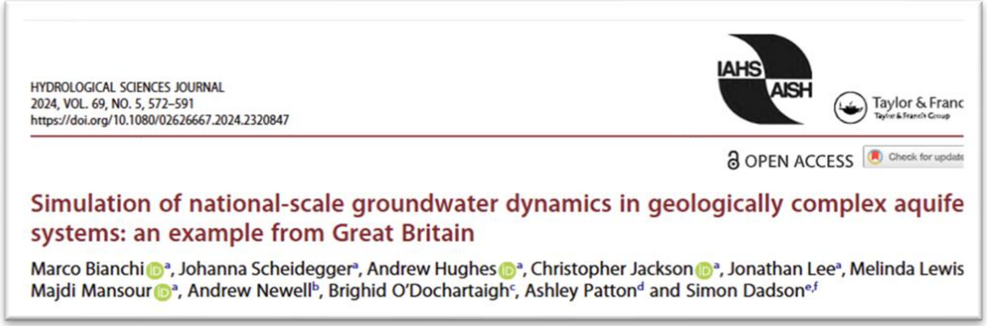
Regional models

Complexity/resolution

BGWM 1.0

Hydrogeological units

- 3-D heterogeneous model
- 15 hydrogeological units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OPEN ACCESS

Simulation of national-scale groundwater dynamics in geologically complex aquife systems: an example from Great Britain

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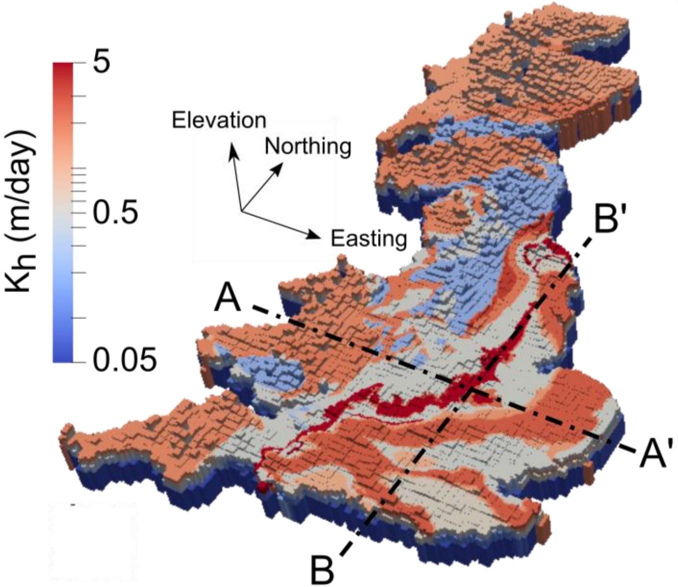
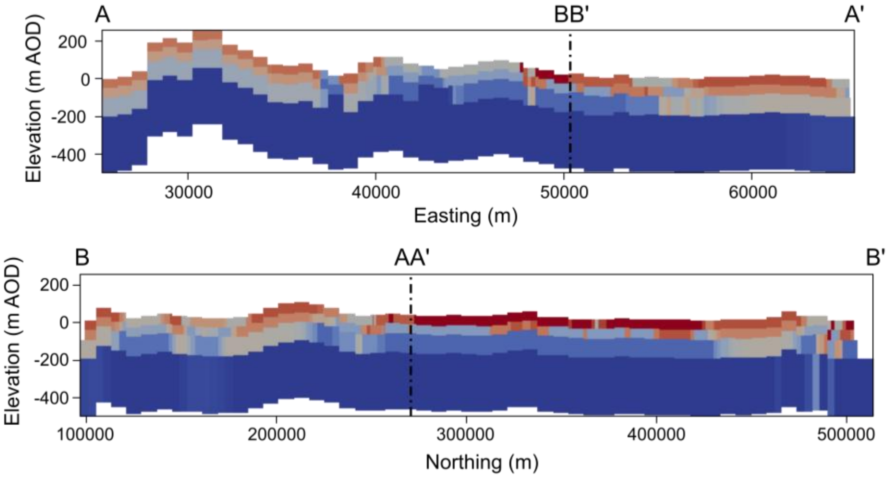
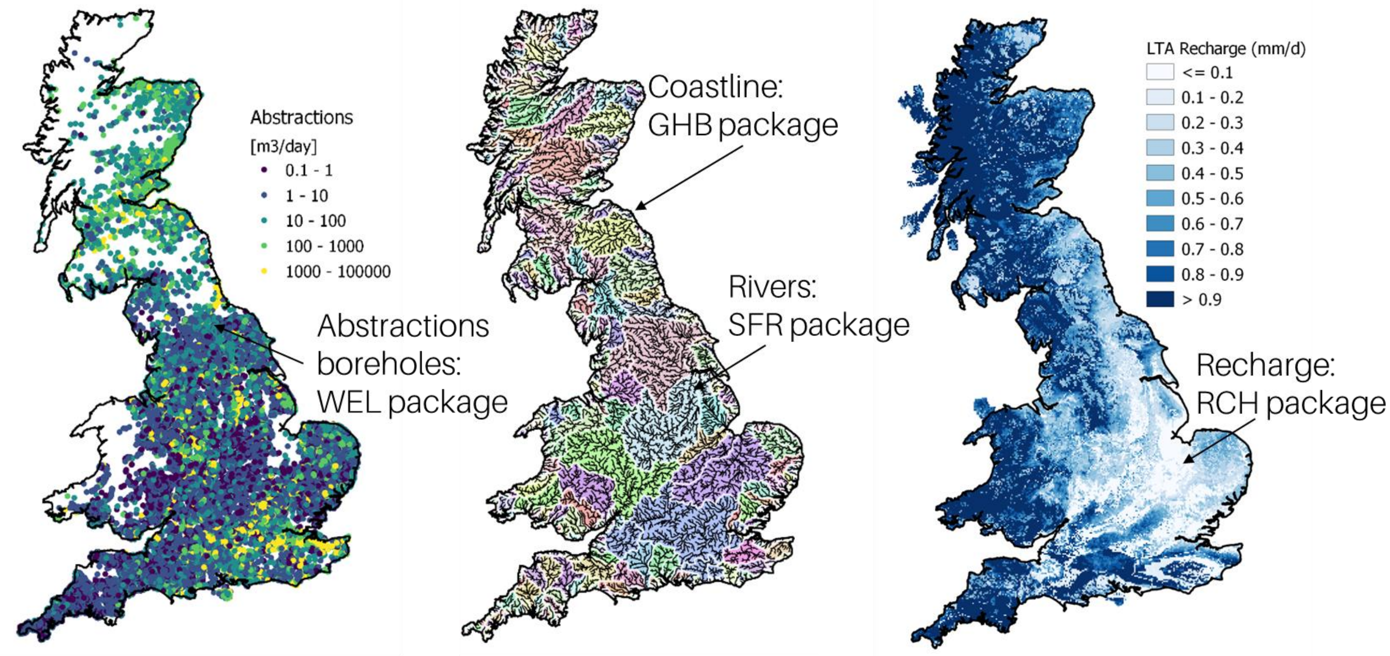




Hydro-JULES

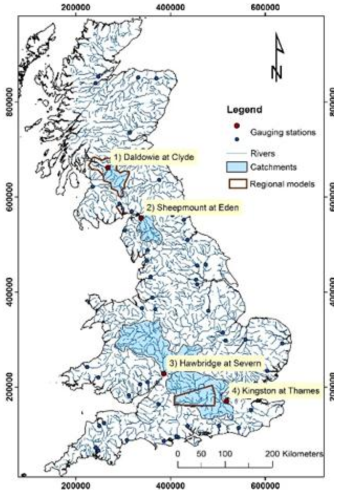
Model inputs

- Abstraction
- Rivers
- Boundaries
- Recharge

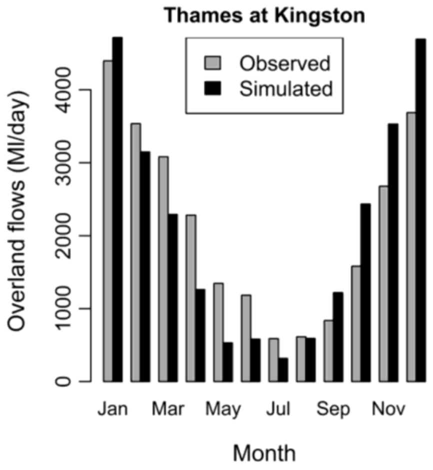


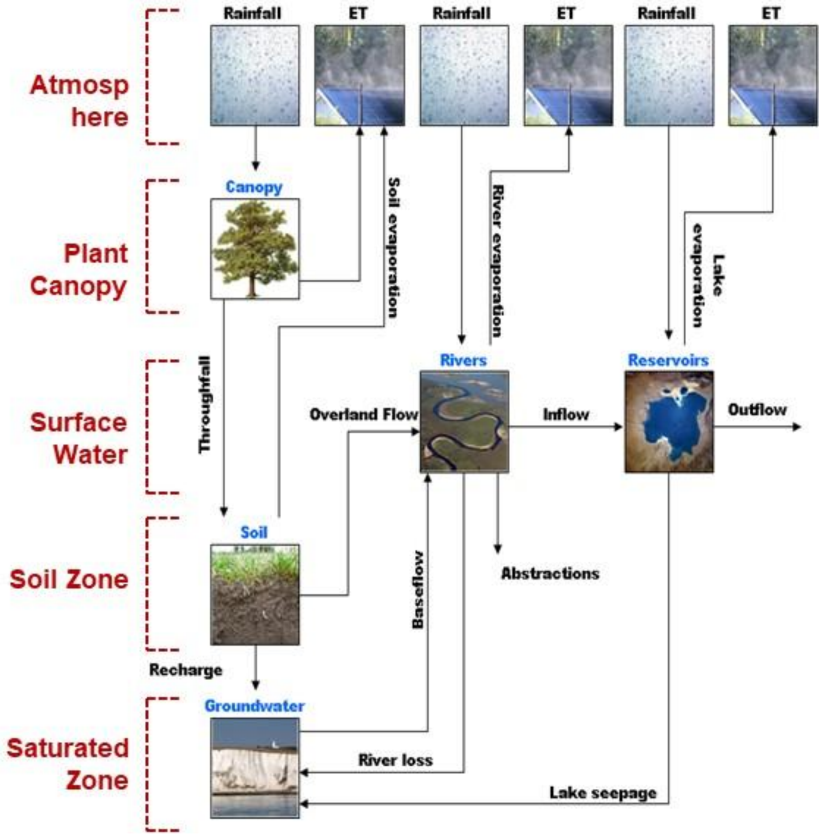
Recharge model

- BGWM is driven by monthly potential recharge rates from a distributed ZOODRM model (2 km resolution) and calibrated against observed runoff flows



Extent and river network



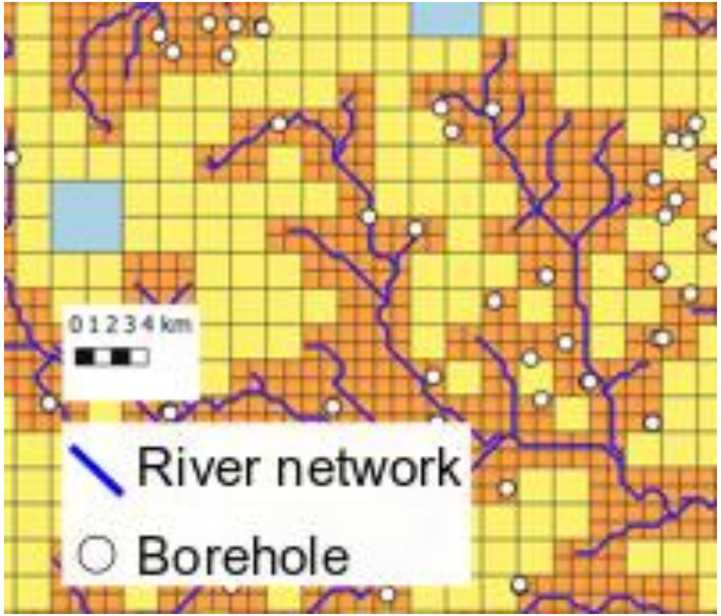


Mansour et al., 2018. QJEGH doi.org/10.1144/qjegh2017-051

Hydro-JULES

- Unstructured 3D quadtree grid (min resolution: 1 km x 1 km)
- transient groundwater flow model implemented in MF6
- 1970 – 2018 simulated period with monthly resolution

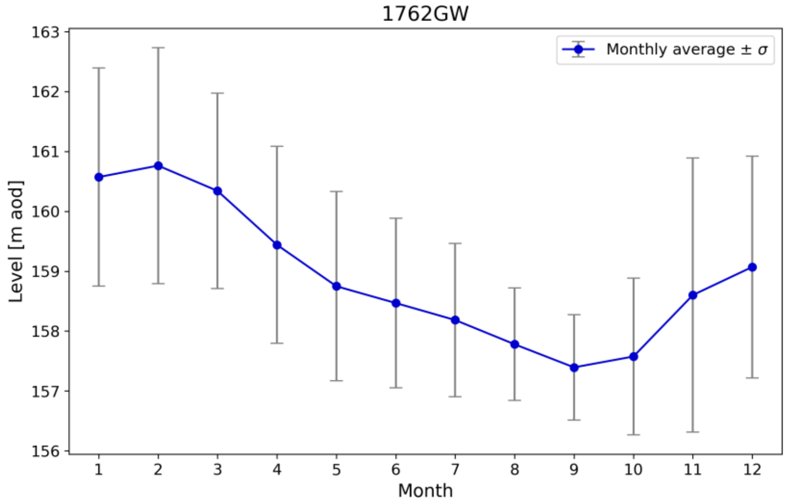
- **Limitations:**
  - Sparse calibration dataset
  - Oversimplified parameterisation
  - Limited abstraction data

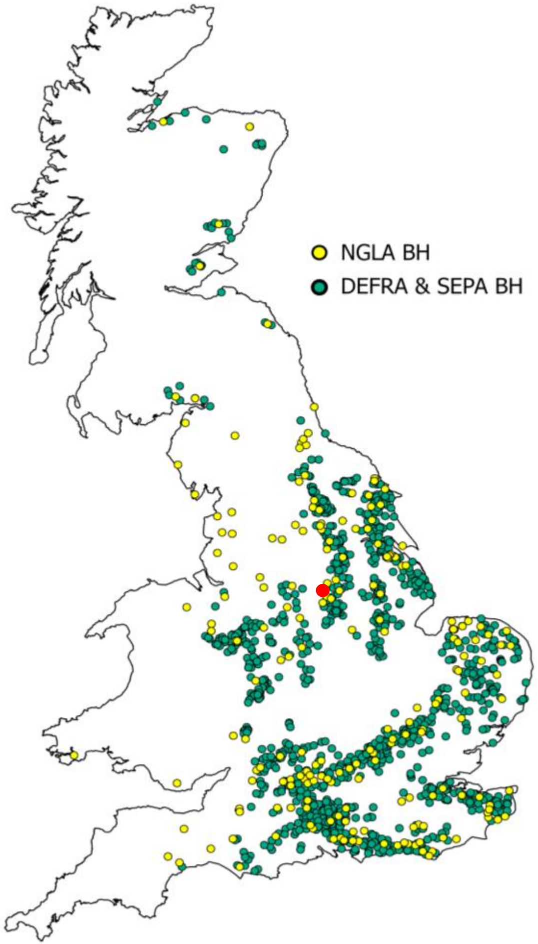


BGWM 2.0

Improving calibration dataset

- ~1000 boreholes with ≥10 years of GW level data - **five** times more than BGWM 1.0 (NGLA, DEFRA portal (EA), SEPA)

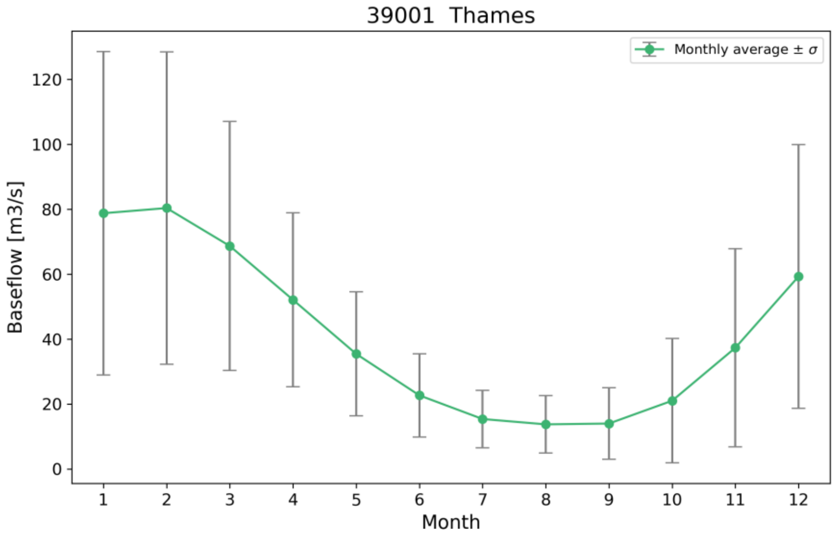


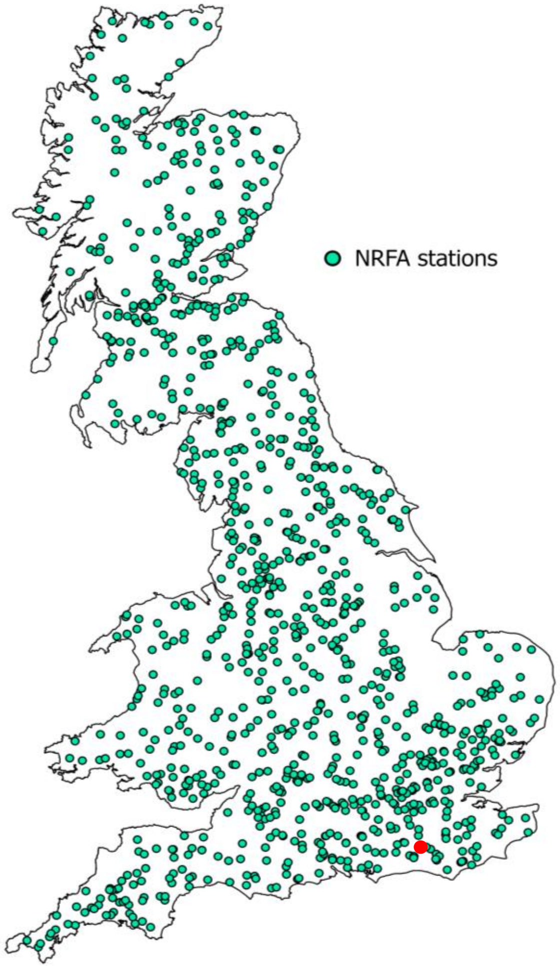


Hydro-JULES

Improving calibration dataset

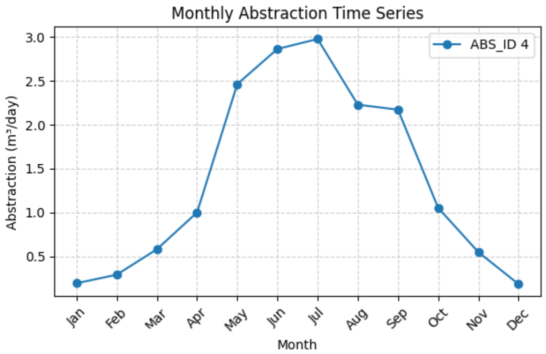
- ~1000 baseflow gauging stations (NRFA)

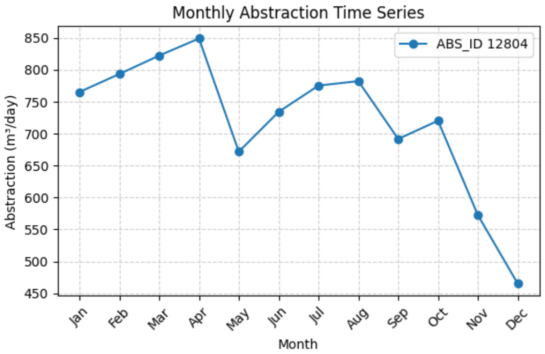


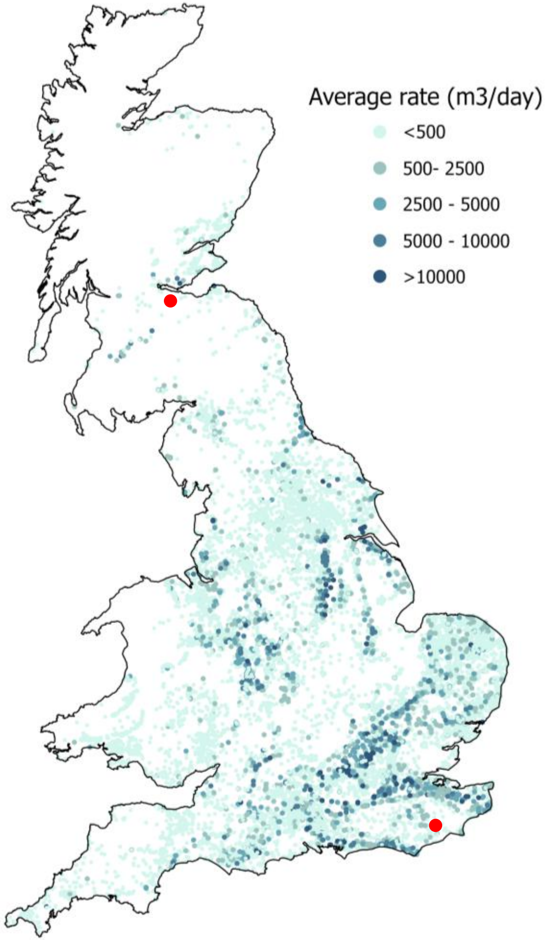


Incorporating Abstraction Data

- Time-variant actual abstraction data: EA(1999–2014) & SEPA(2009–2023),
- ~**16,600** boreholes
- **Sources :**
  - https://data.ceda.ac.uk/badc/desnz-cs-now/data/gridded-actual-flows/AbsDisHoF
  - www2.sepa.org.uk/disclosurelog/ with **F0197446** as reference number

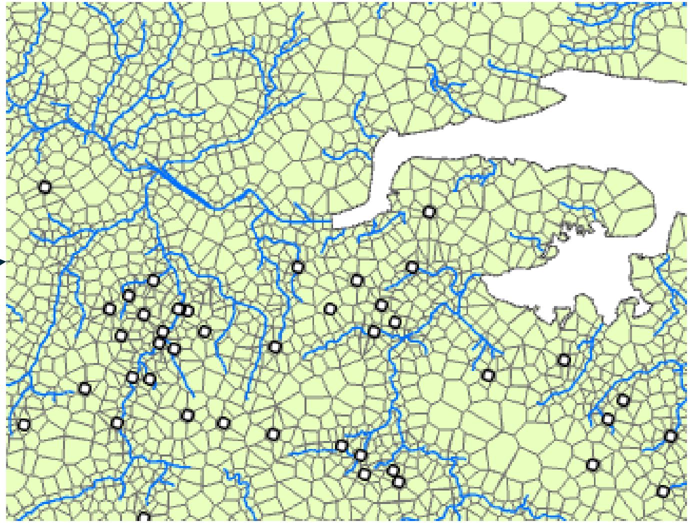






Model Grid Redesign

- Voronoi grid ~ 1km resolution
- 203837 cells per layer
- 20% more cells in upper layer than the first version
- Improved representation of river network, boreholes, and boundaries



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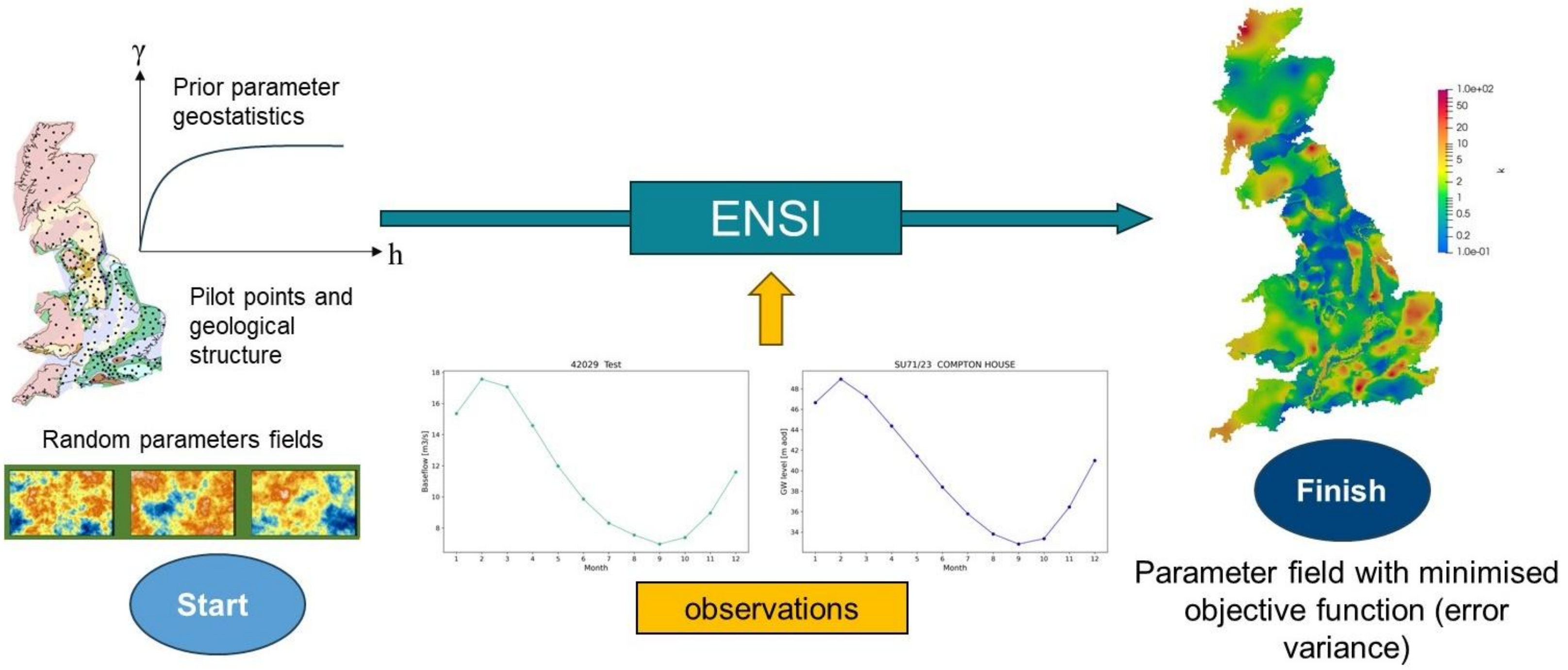
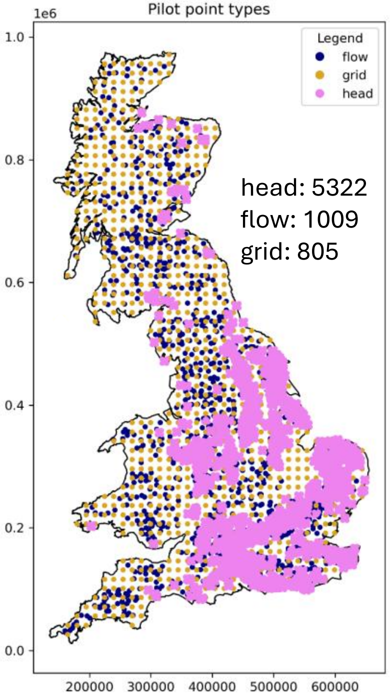
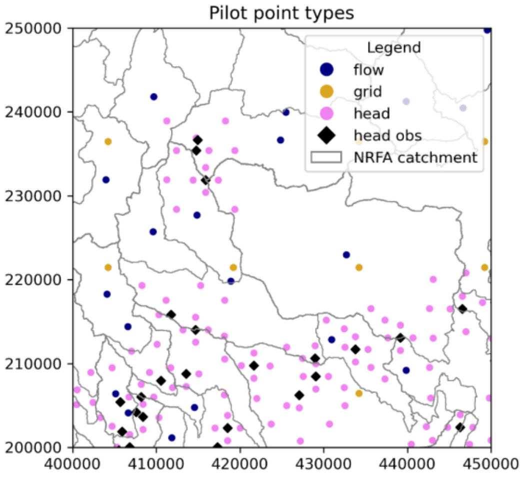
Ensemble Space Inversion (ENSI) calibration approach

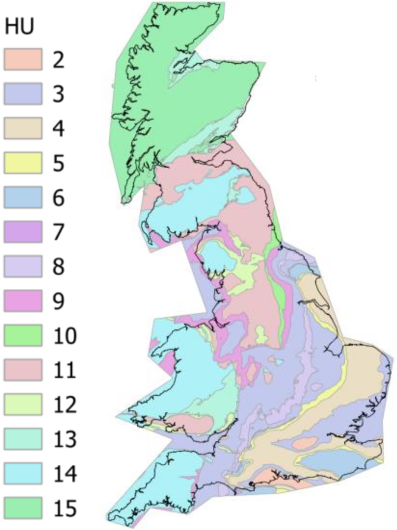


Parameterisation strategy

- 62,210 parameters (reduced to 572)
- Larger scale heterogeneity based on geology (BGWM 1.0) + finer scale heterogeneity (pilot points)







Pilot Points Location Strategy

- Regular 15 km grid across the model domain
- Additional points at river catchment centroids
- Four pilot points placed 1.5 km around each observation borehole
- Duplicate removal: eliminate any points closer than 1.5 km to each other

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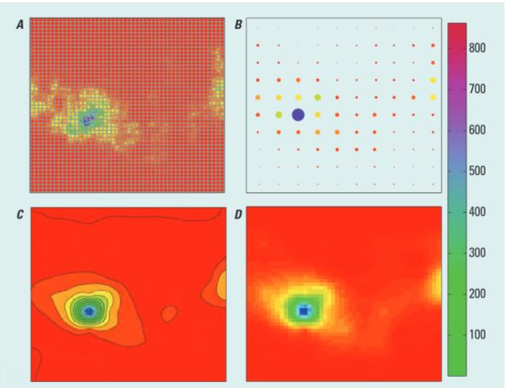
Pilot point multipliers

- 12 parameters groups:
  - Bulk K_h, K_v , Sy, S for 15 HUs (nonrealisation)
  - Kh, Kv, S and Sy multipliers (pilot points)
  - RBC for each SFR reach

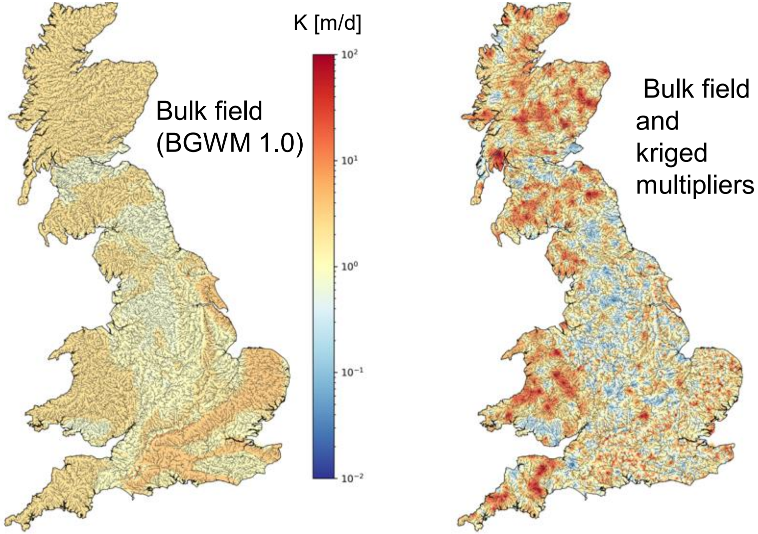
- For BGWM, multipliers are assigned to pilot points to scale the bulk parameter fields based on HUs (e.g., $K = K_{bulk} \times$ multiplier)

- Multipliers interpolated using kriging for smooth spatial fields respecting the geological structure

Pilot point approach

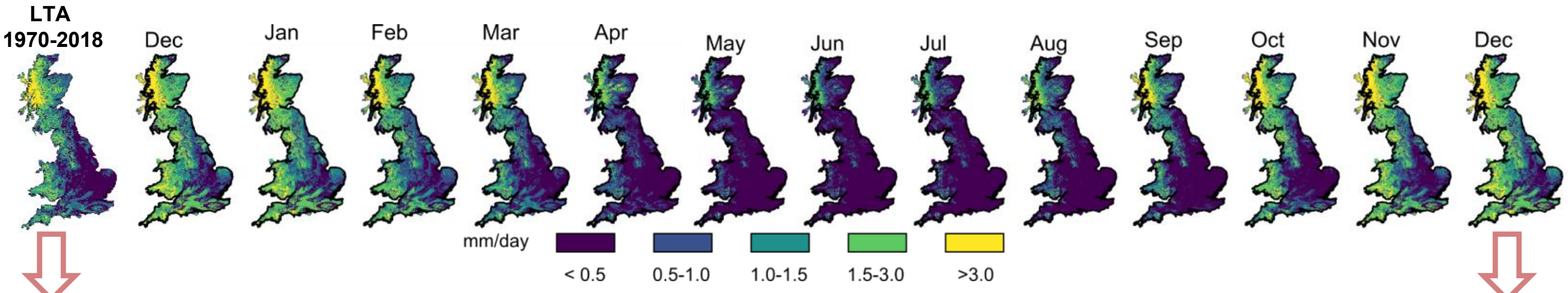


Doherty et al. (2010) U.S. Geological Survey Scientific Investigations Report 2010–5168



Applying ENSI to BGWM

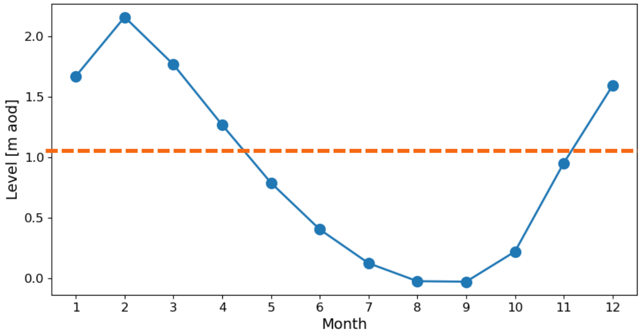
- Full transient model (12h running time) reduced to a simpler model with 14 stress periods (20' running time)



SS	TS1	TS2	TS3	TS4	TS5	TS6	TS7	TS8	TS9	TS10	TS11	TS12	TS13

Time discretization

Simulated steady-state and monthly averaged heads and baseflow



Output

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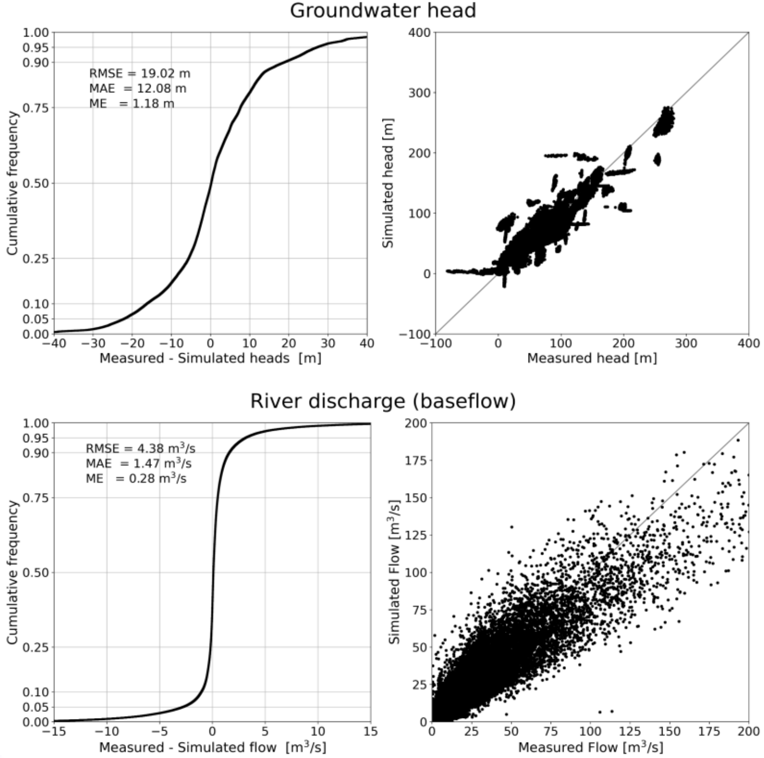
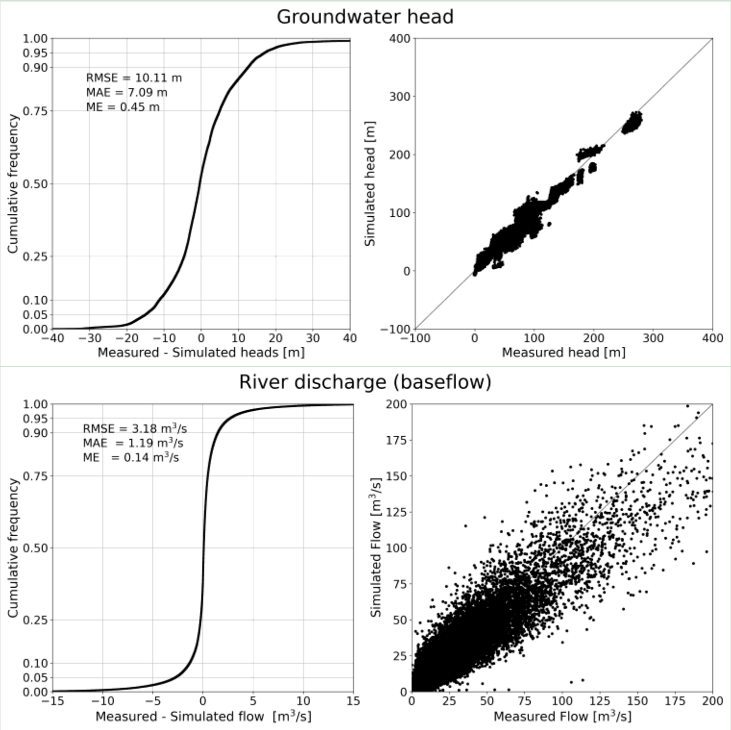
BGWM 1.0 vs BGWM 2.0

BGWM 1.0



BGWM 2.0



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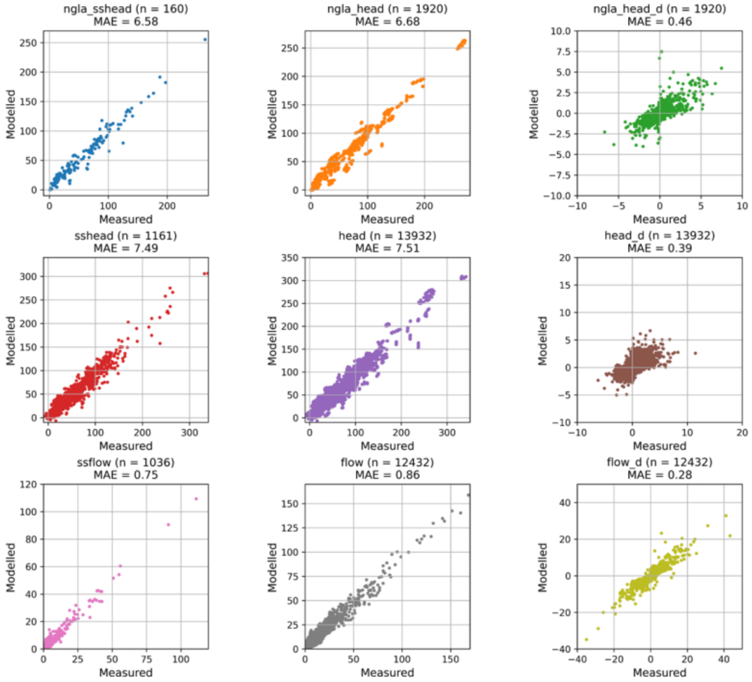
Model Performance & Validation

Calibrated monthly average model



Full Transient Model

	Simulated heads		Simulated baseflow	
	RMSE (m)	MAE (m)	RMSE (m^3s^{-1})	MAE (m^3s^{-1})
Number of observations	1325		1060	
mean	6.24	5.92	1.48	1.12
min	0.22	0.15	0.01	0.01
5% percentile	0.81	0.69	0.08	0.06
Median	4.06	3.75	0.55	0.42
95% percentile	20.36	19.65	6.12	4.57
max	48.47	48.45	36.42	25.94

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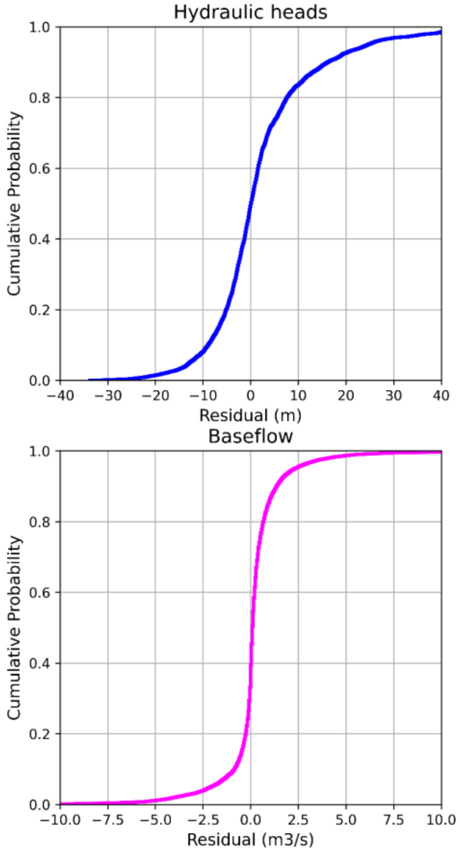
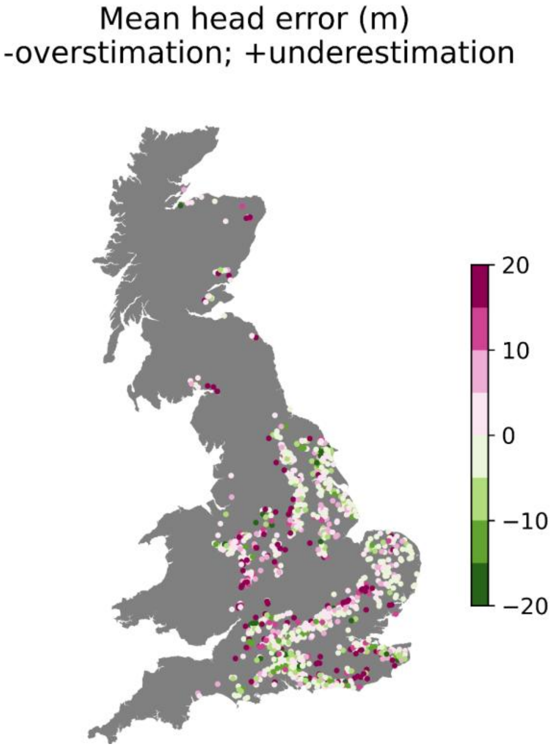
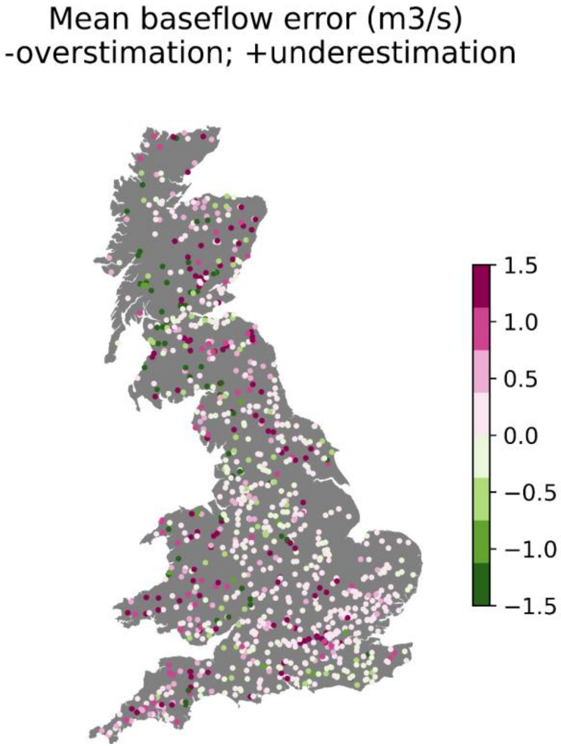
Posterior parameter field accuracy







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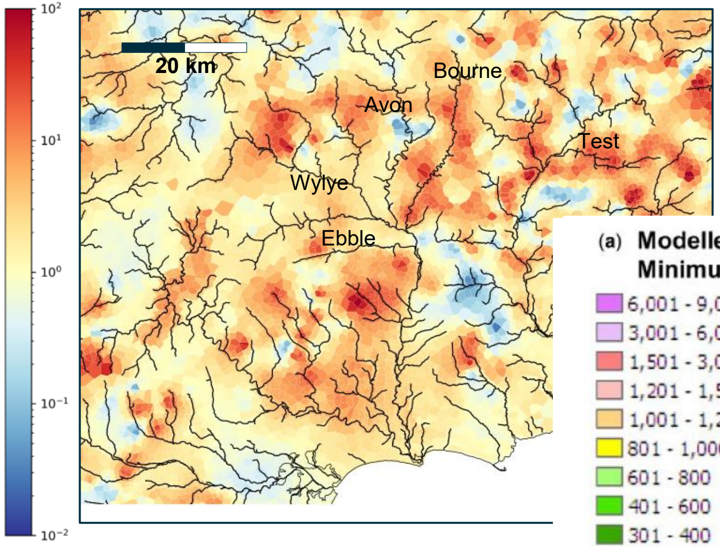
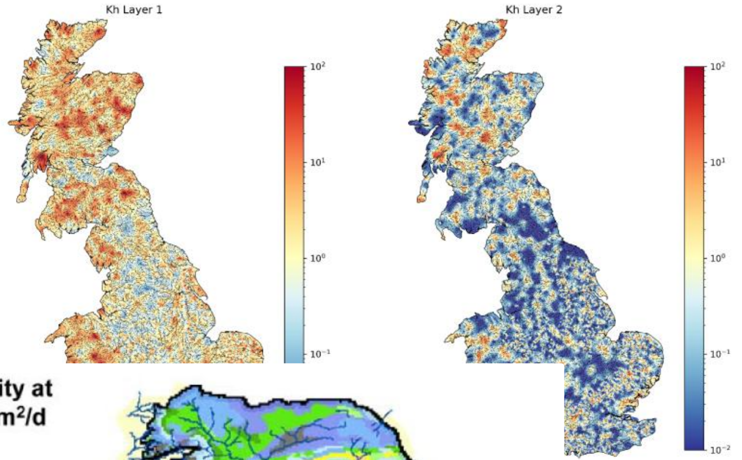
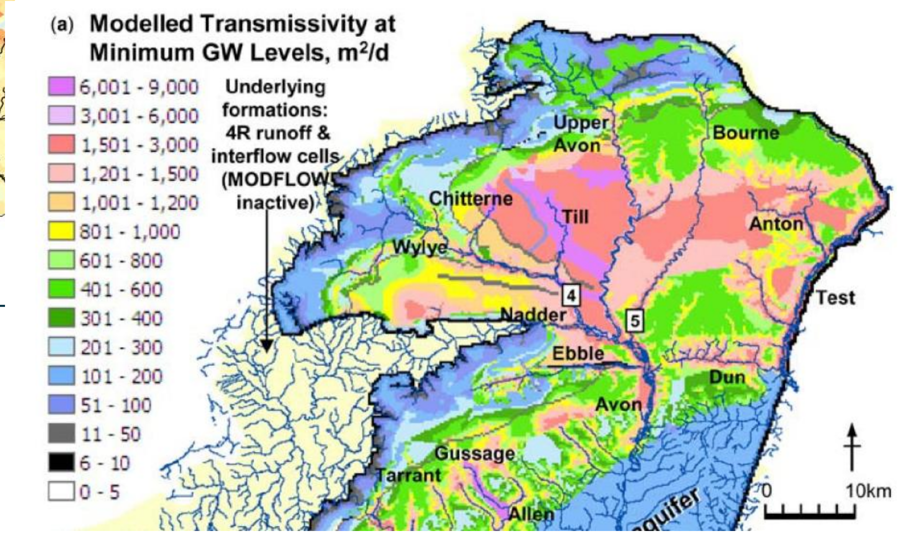
Calibrated parameter fields







Wessex basin regional model (Soley et al., 2012)

- Spatial distributions of K_h, K_v, Sy, and S

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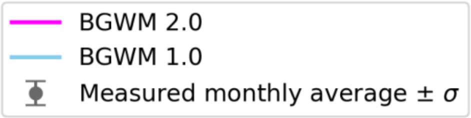
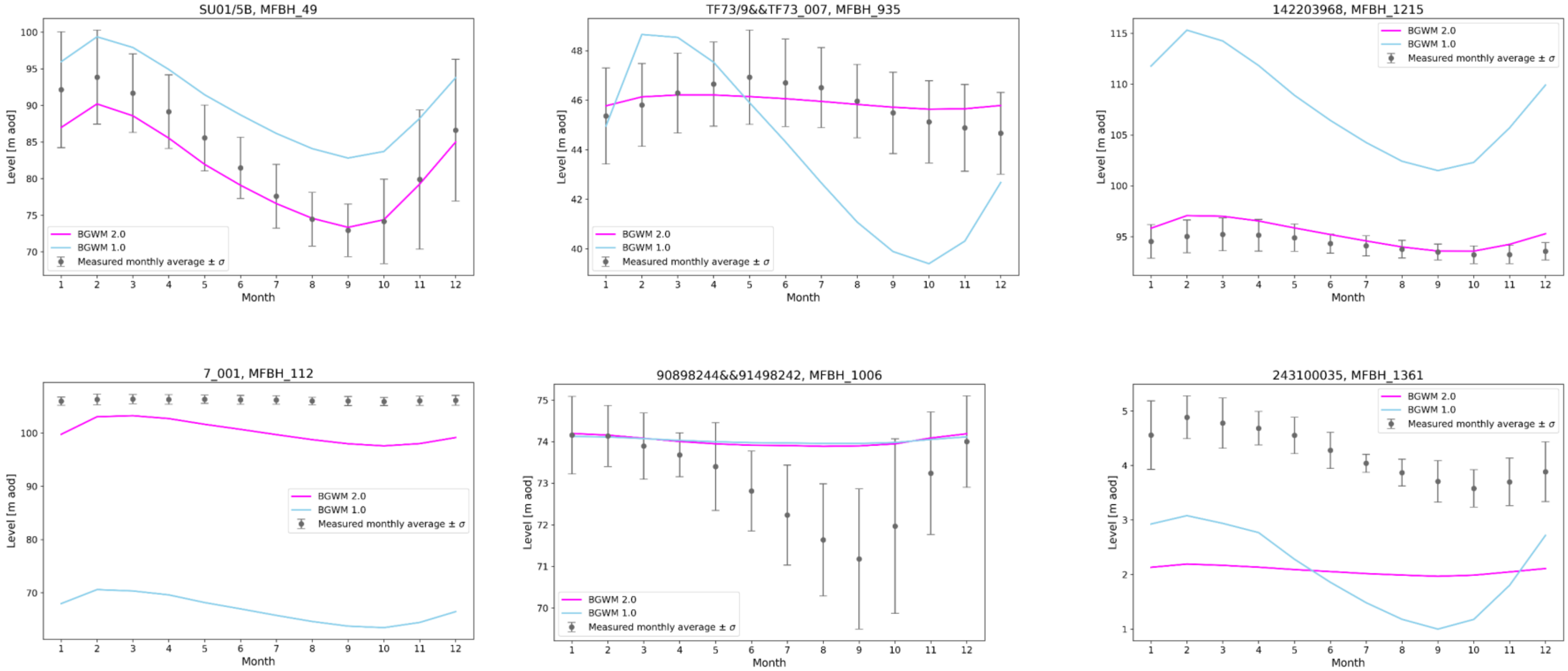
Simulated monthly head hydrographs





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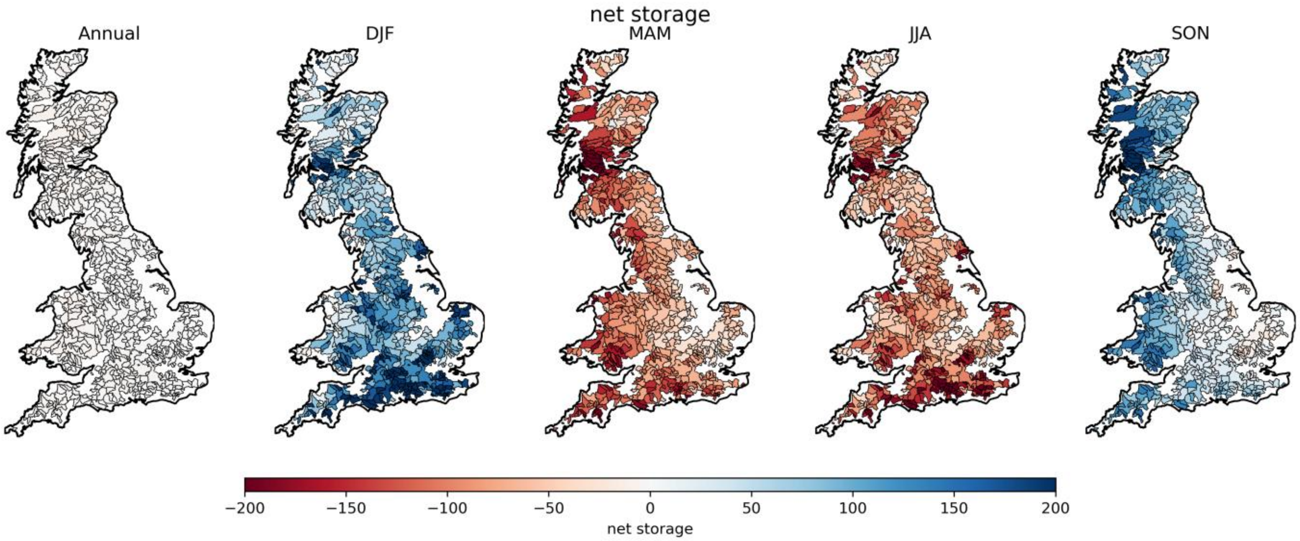
Summary

BGWM 2.0 represents a significant advancement in national-scale groundwater modelling, driven by:

- Higher-quality input data
- Enhanced observational datasets
- A more robust calibration approach



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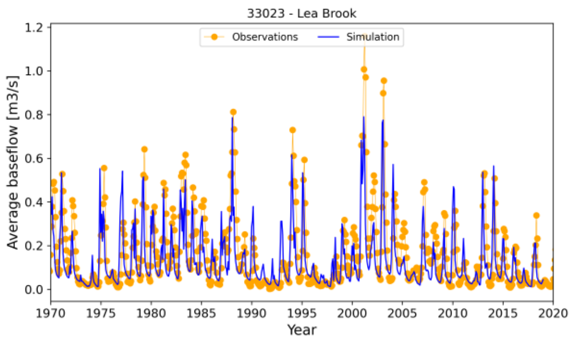
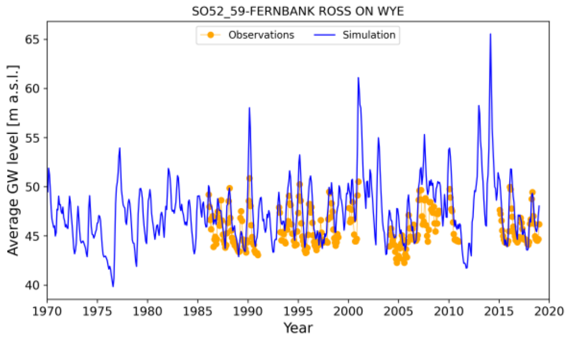
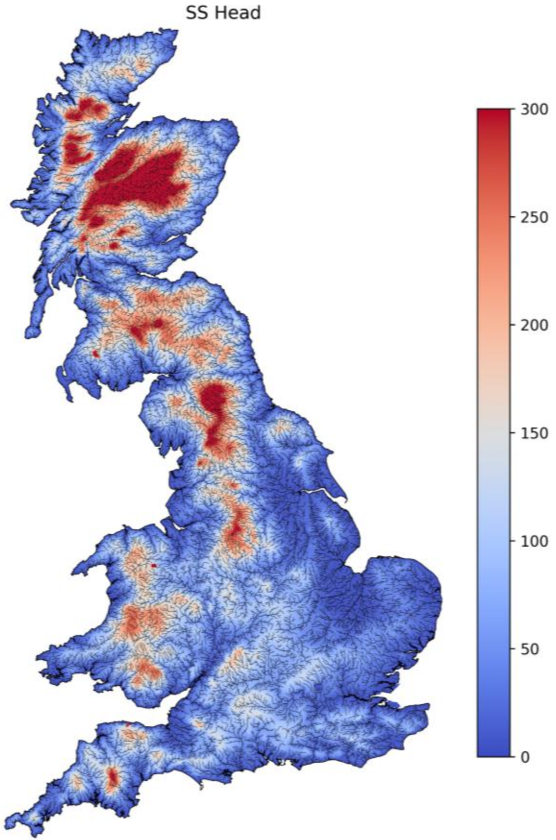
Implications & Applications

- Reliable digital representation of groundwater resources
- Supports water resource management, policy, and climate resilience
- Foundation for future enhancements (e.g., climate scenarios)







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THANK YOU

Any questions?