



British
Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

Gateway to the Earth

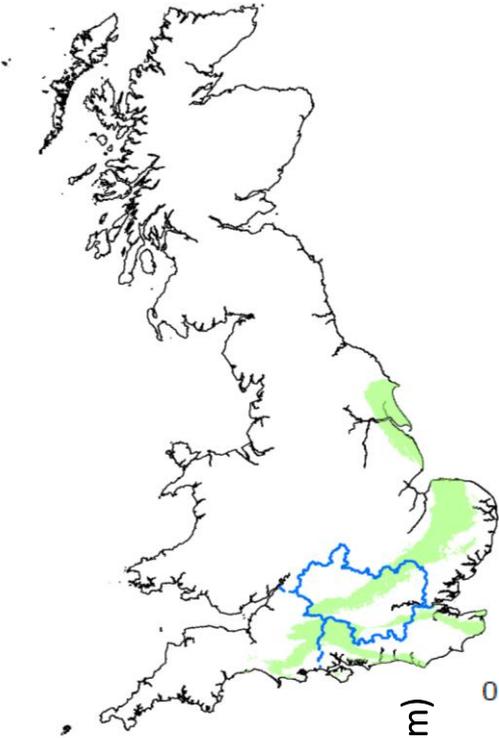
Assessing the sustainable yield of supply boreholes during droughts

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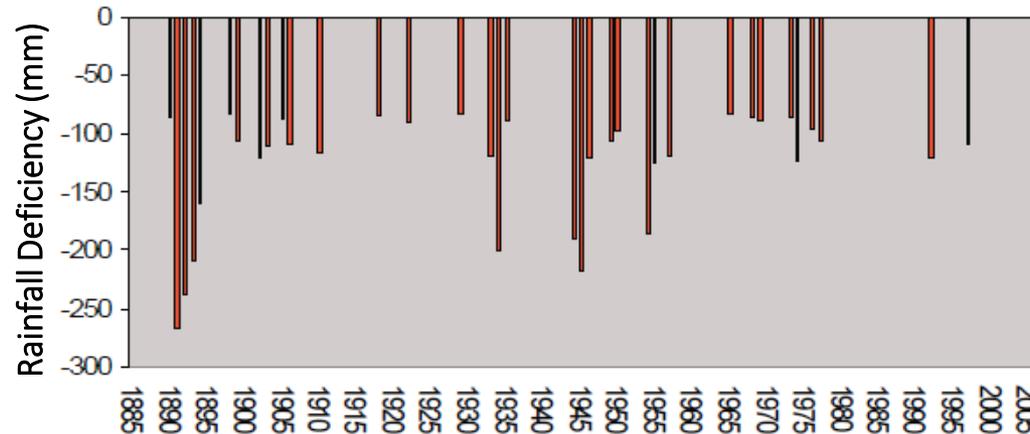
Groundwater Droughts



Dry river bed, Thames Basin, 2005 Drought
Source: CEH Wallingford



Thames Water Publicity Campaign
2010-2012 Drought



Two-year Nov-Apr rainfall deficiencies, Thames Basin
From: Marsh T, Cole G & Wilby R (2007)

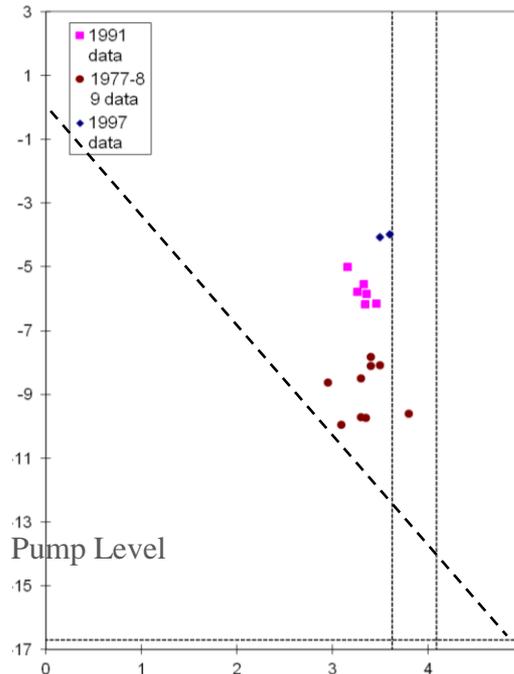
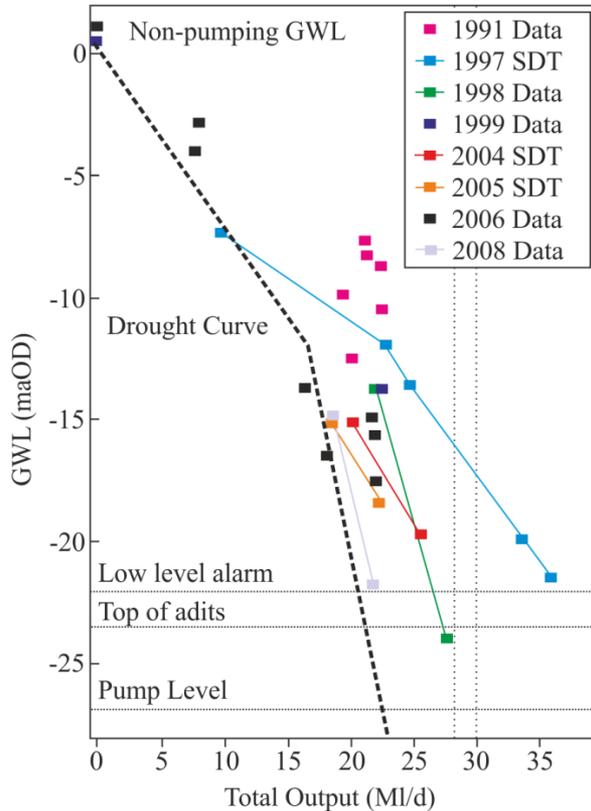
Assessing Sustainable Yield

Deployable Output

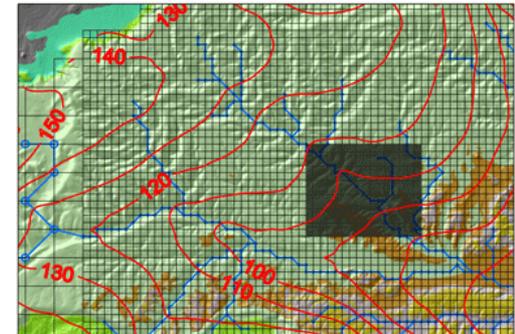
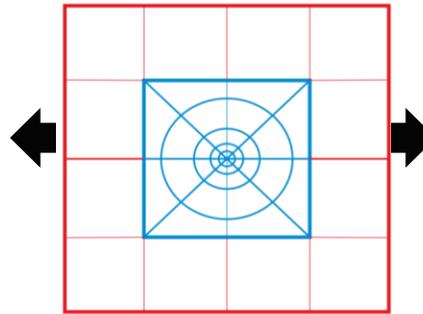
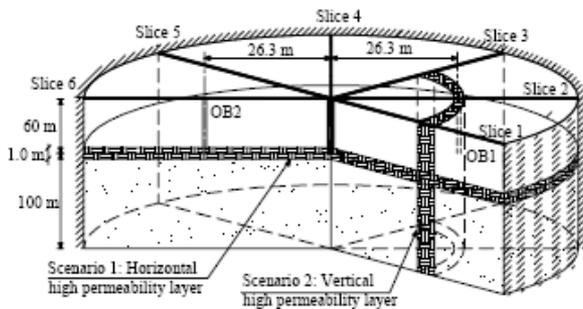
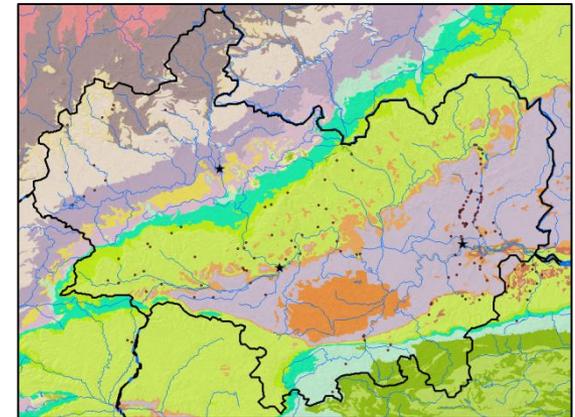
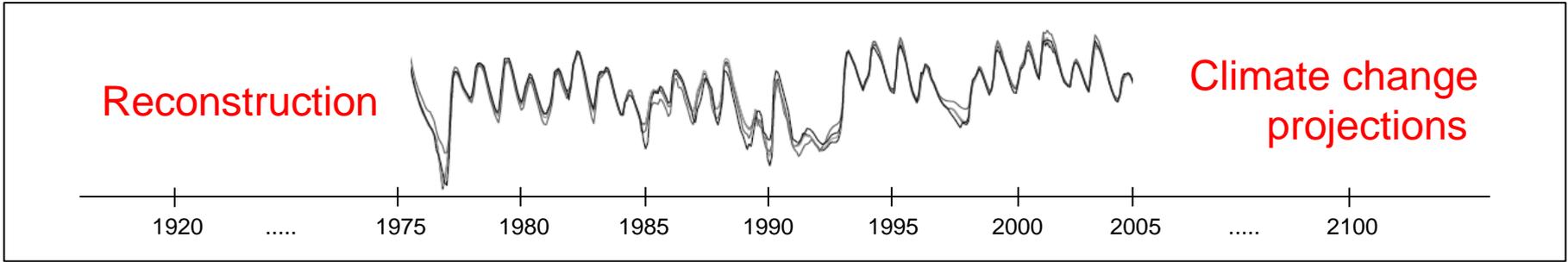
- Reliable yield of a source
- Constrained by properties of aquifer and borehole
- Surrounding environment, licence, water quality, capacity of treatment plant/output mains

Limitations of current methodology:

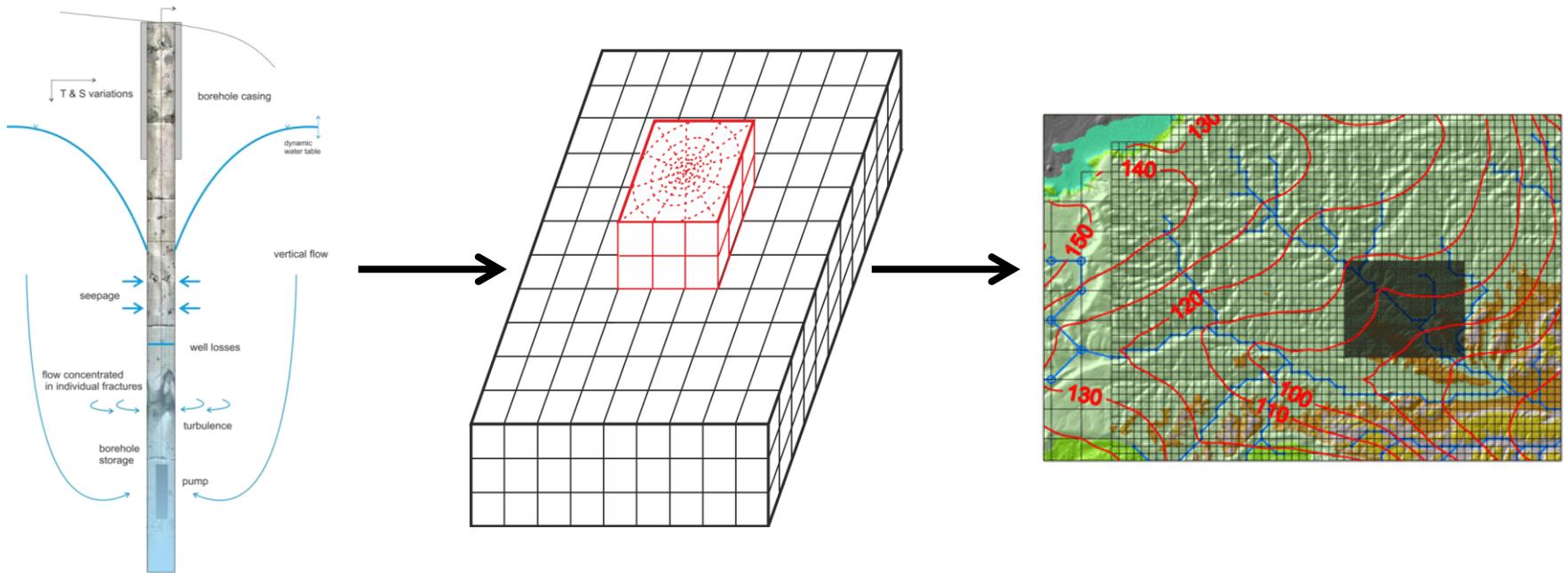
- Availability and quality of operational data
- Extrapolation – vertical heterogeneity?
- Interference?
- Climate change?



Modelling Sustainable Yield

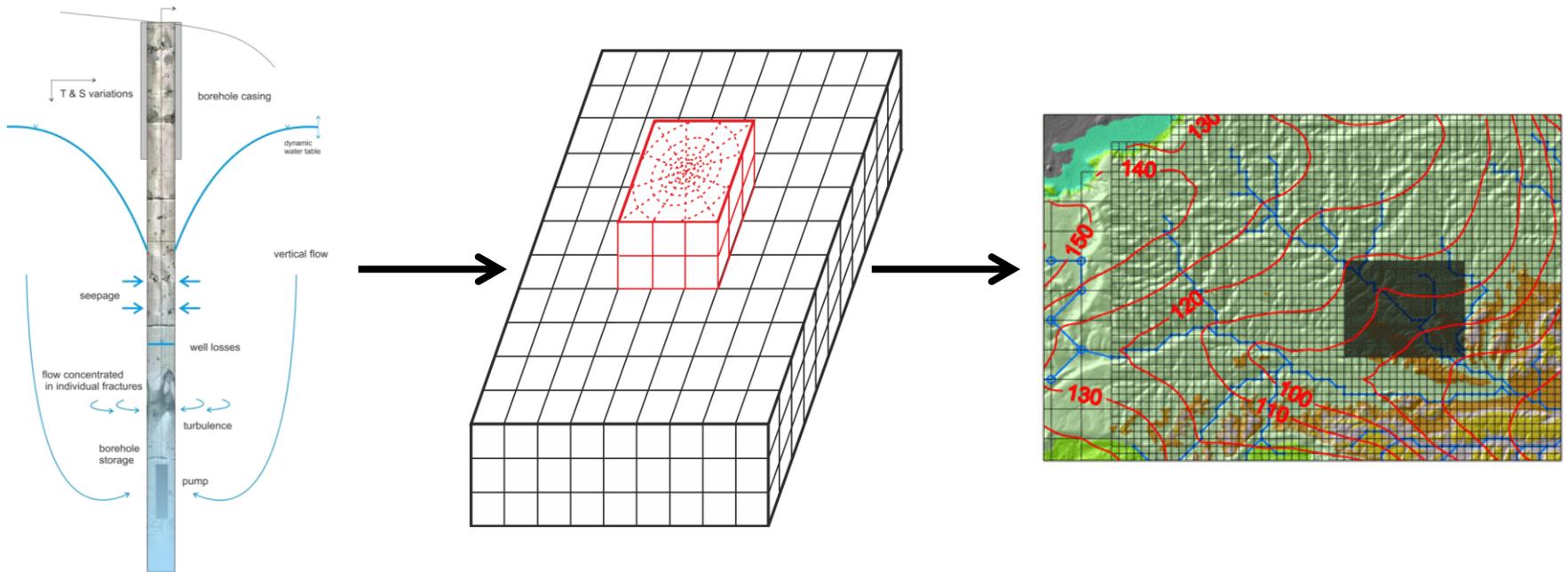


Multi-scale Groundwater Modelling



Radial Flow Model → Radial-Cartesian Coupling → OpenMI → ZOOMQ3D

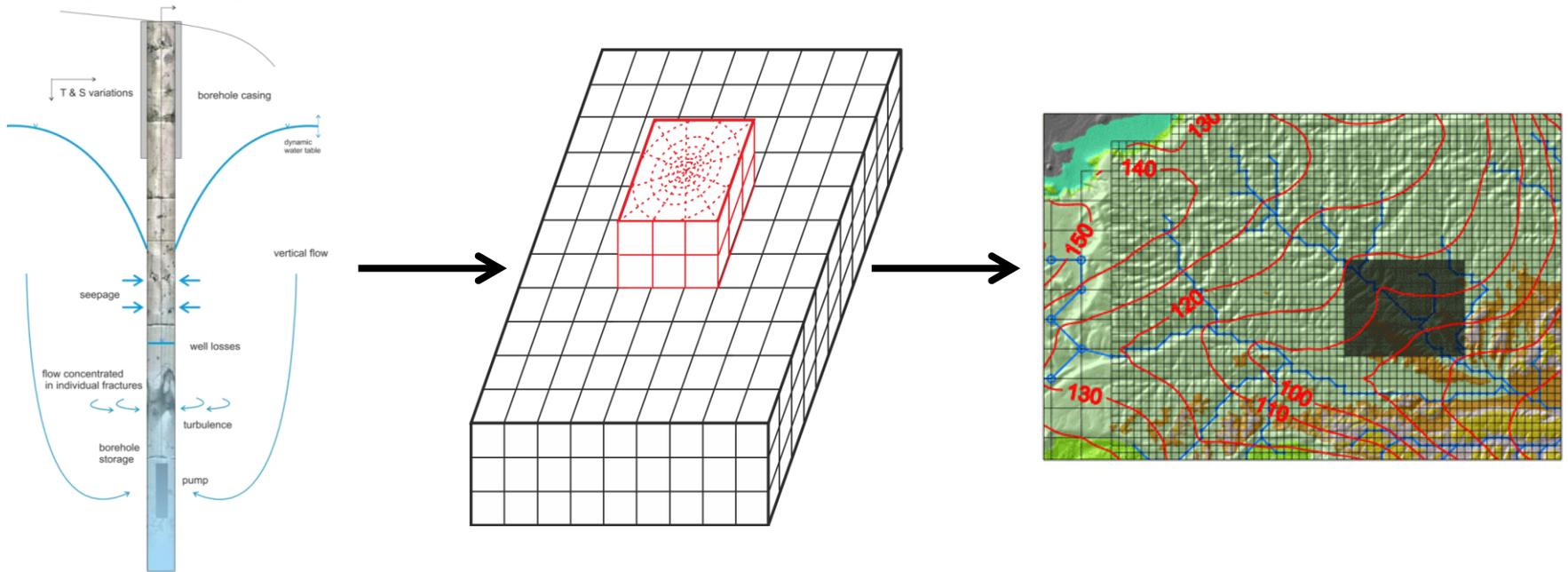
Multi-scale Groundwater Modelling



Radial Flow Model

- Finite difference approximation
- Darcy-Forchheimer (non-linear flow)
- Logarithmic radial node spacing
- Vertical layering
- Vertical & horizontal heterogeneity
- Partially or fully penetrating borehole
- Borehole storage
- Borehole casing & screening
- Seepage face development

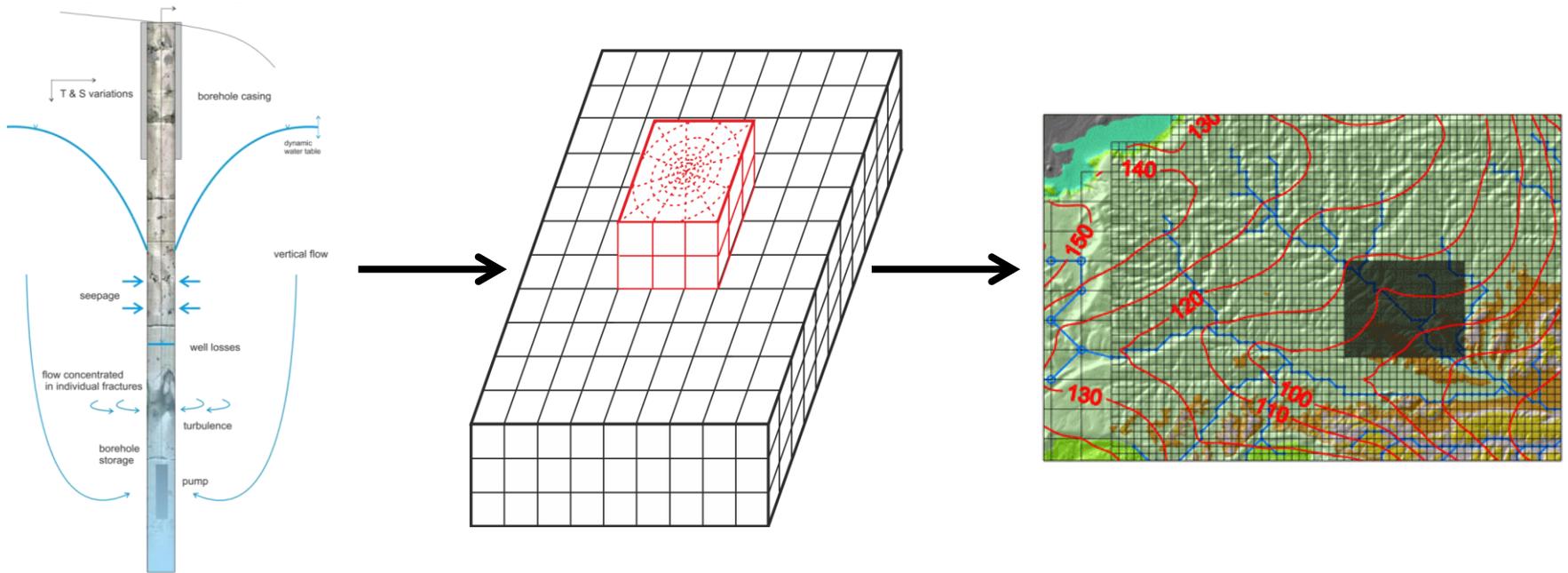
Multi-scale Groundwater Modelling



Radial Flow Model → Radial-Cartesian Coupling

- Hybrid radial-Cartesian method applied in petroleum reservoir models
 - Limitations of grid construction
- BUT
- Quick, simple & user friendly

Multi-scale Groundwater Modelling

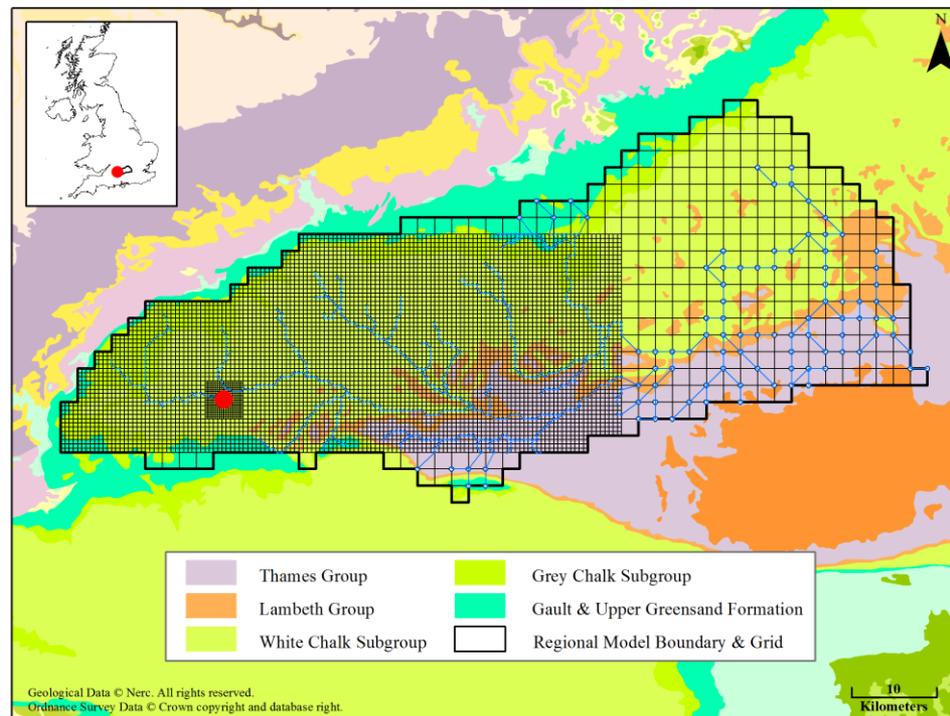


Radial Flow Model → Radial-Cartesian Coupling → OpenMI → ZOOMQ3D

- OpenMI standard for linking models
- Data exchange maintains consistency between two models
- Quick and easy to link several borehole models
- Make use of existing regional models

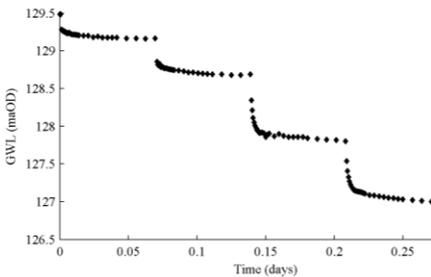
Model Application

1. Calibration of radial flow model to pumping test data
2. Coupling of radial model with ZOOMQ3D regional model
3. Historic simulation and comparison with operational data
4. Abstraction scenarios to inform sustainable yield assessment

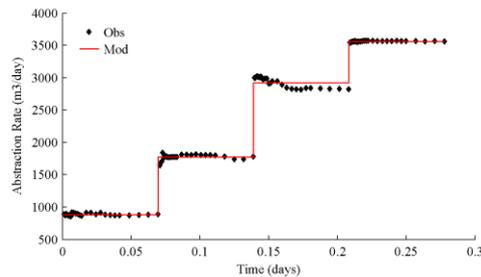


Model Application

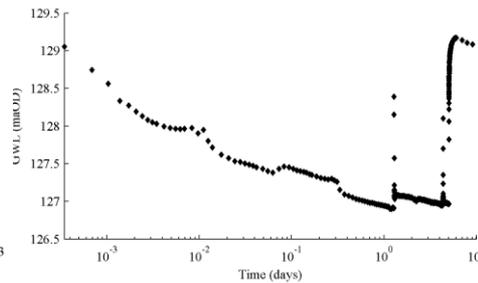
1. Calibration of radial flow model to pumping test data



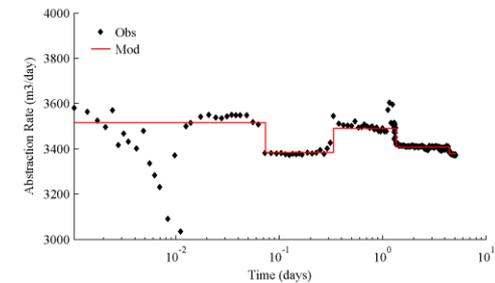
SDT: drawdown



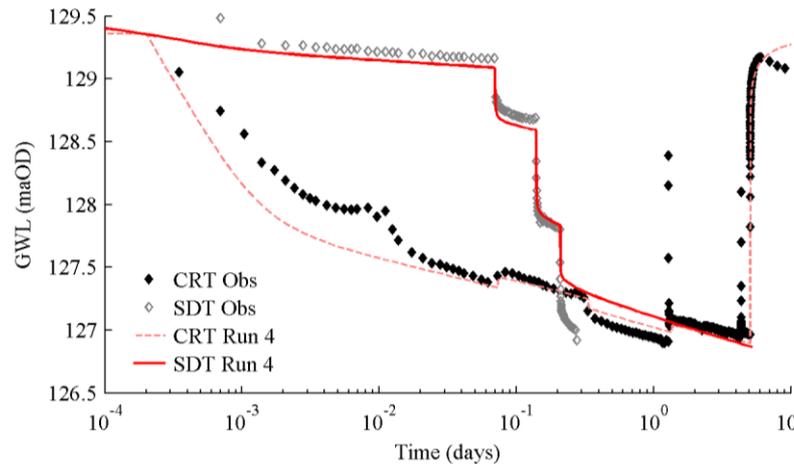
SDT: abstraction rates



CRT: drawdown



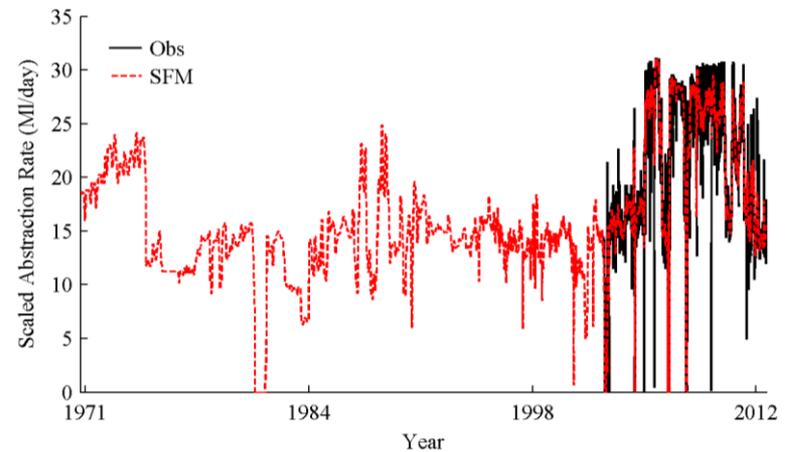
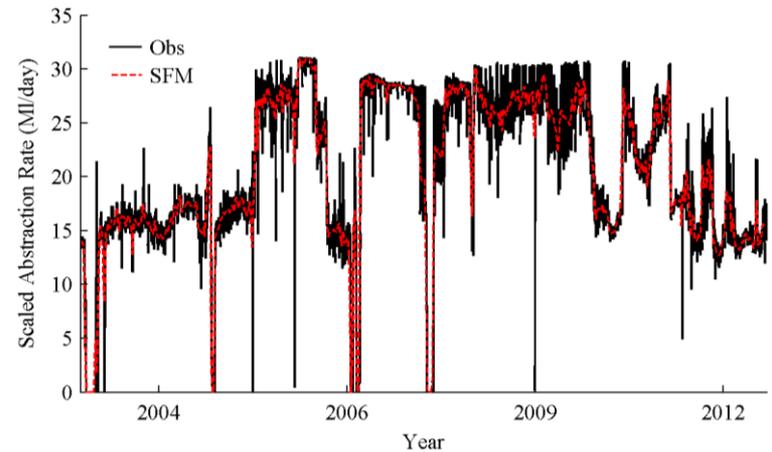
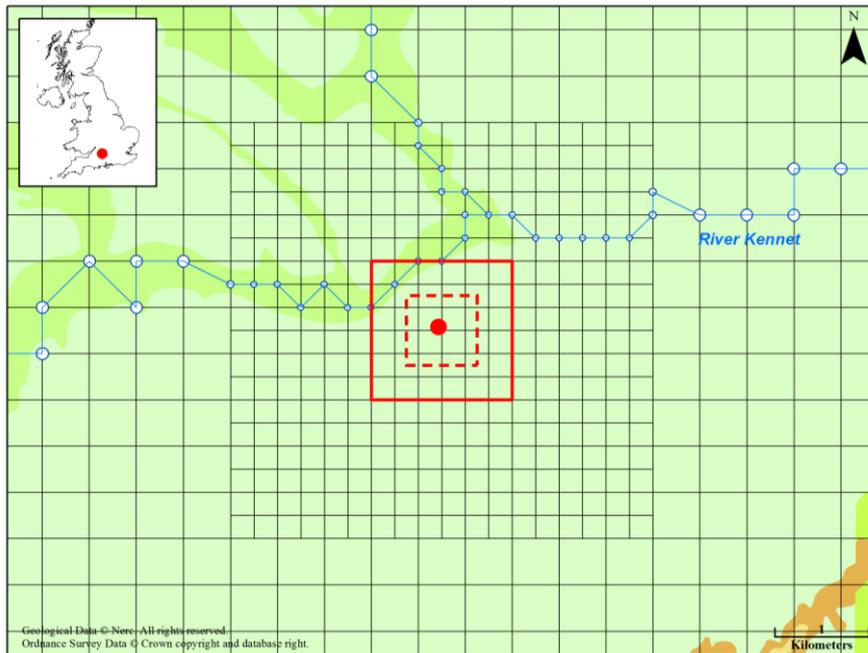
CRT: abstraction rates



Modelled and observed drawdown for the SDT and CRT

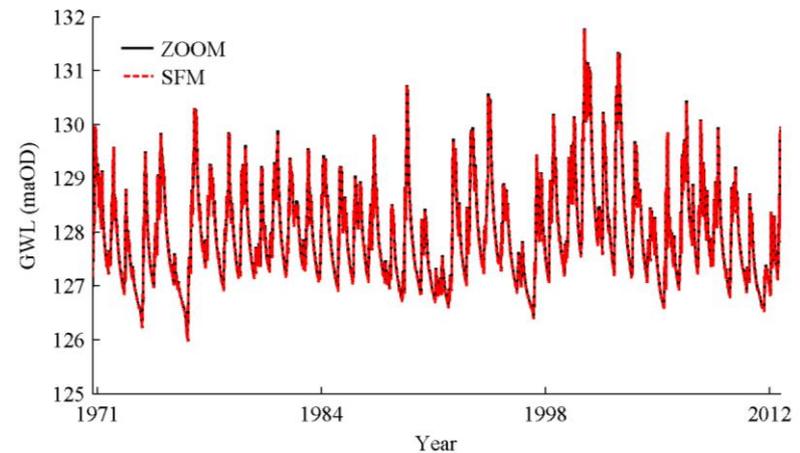
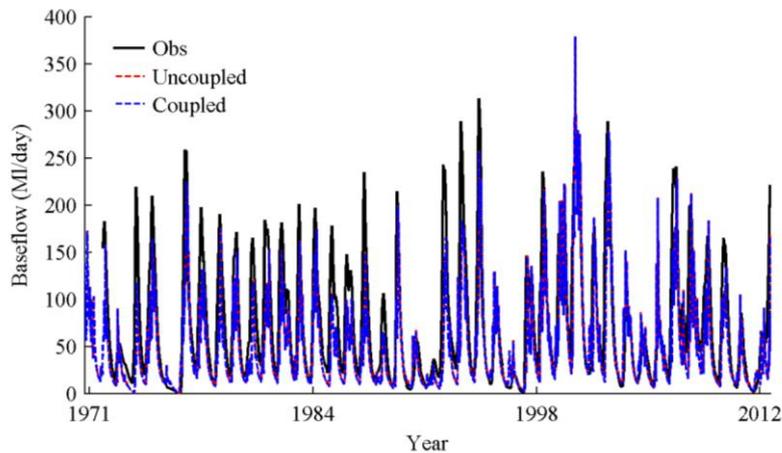
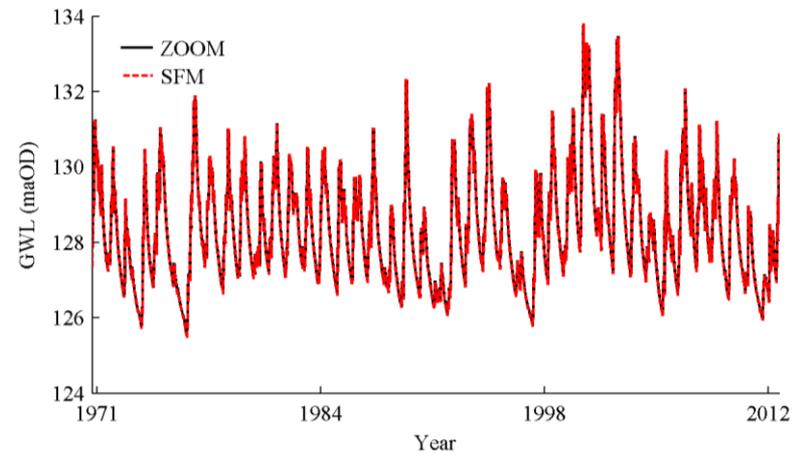
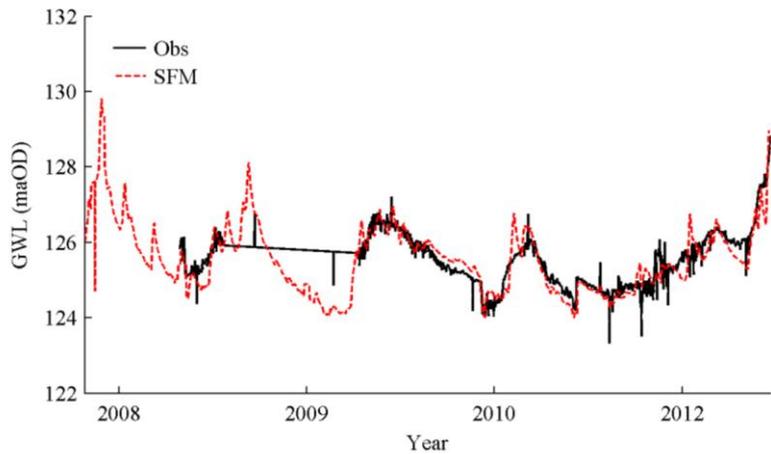
Model Application

2. Coupling of radial model with ZOOMQ3D regional model



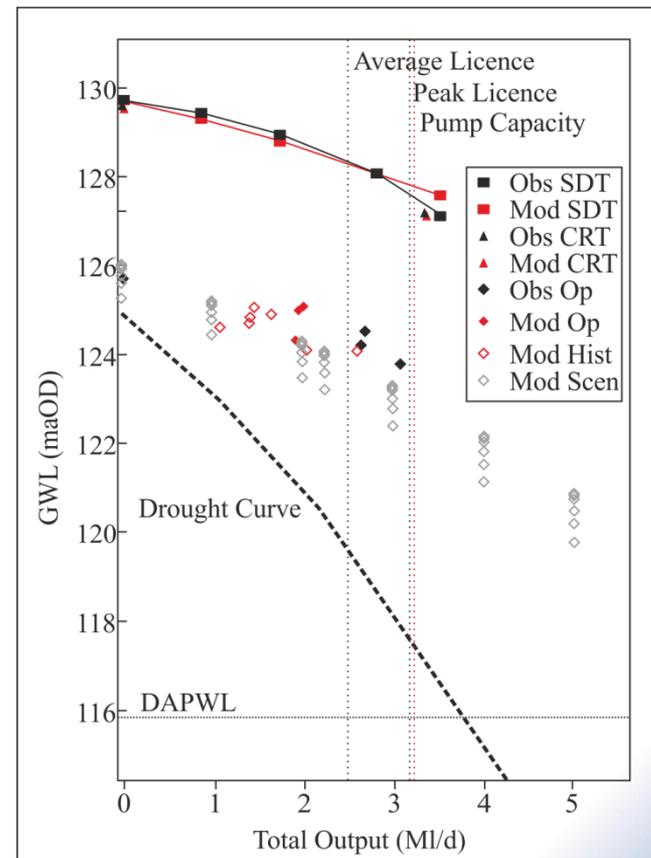
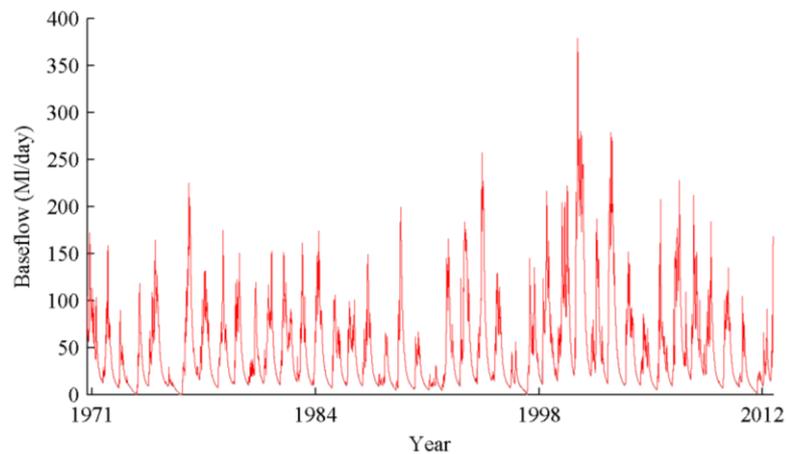
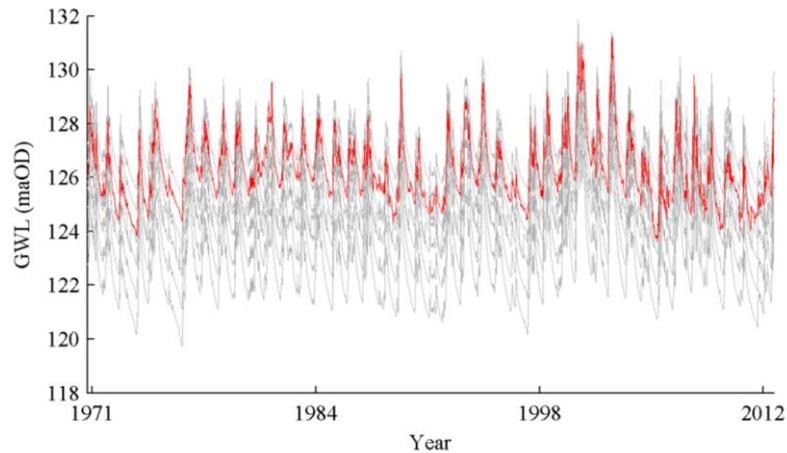
Model Application

3. Historic simulation and comparison with operational data



Model Application

4. Abstraction scenarios to inform sustainable yield assessment



Conclusions

- Multi-scale methodology provides useful tool for assessing the sustainable yield of supply boreholes during drought
- Suggests whether further work would be useful to determine whether larger yield could be sustained OR if deployable output should be reduced
- Coupling allows impacts on neighbouring abstractions/rivers to be assessed
- Development to allow two radial models to be simulated in a single Cartesian grid
- Tool for assessing climate change impacts