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Gateway to the Earth

Characterising major episodes of groundwater drought at national to continental scale

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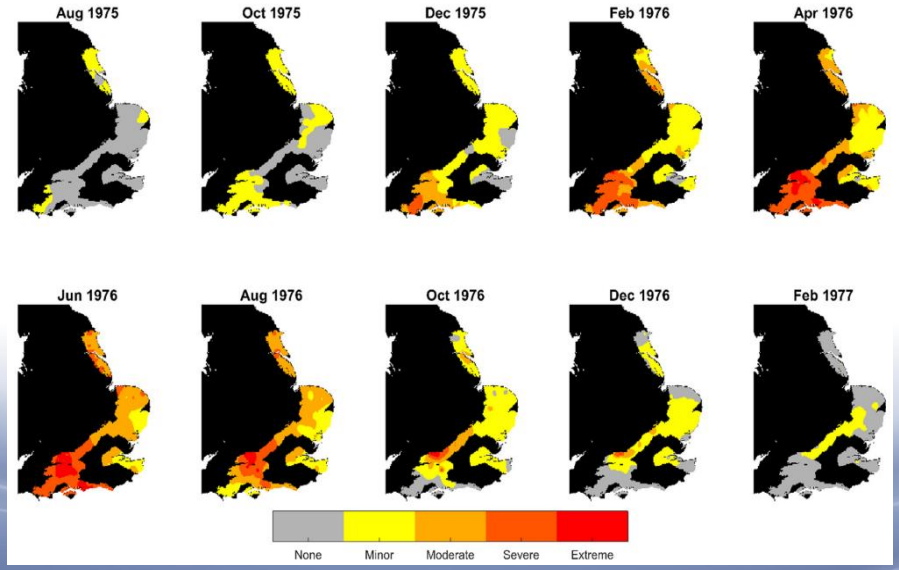
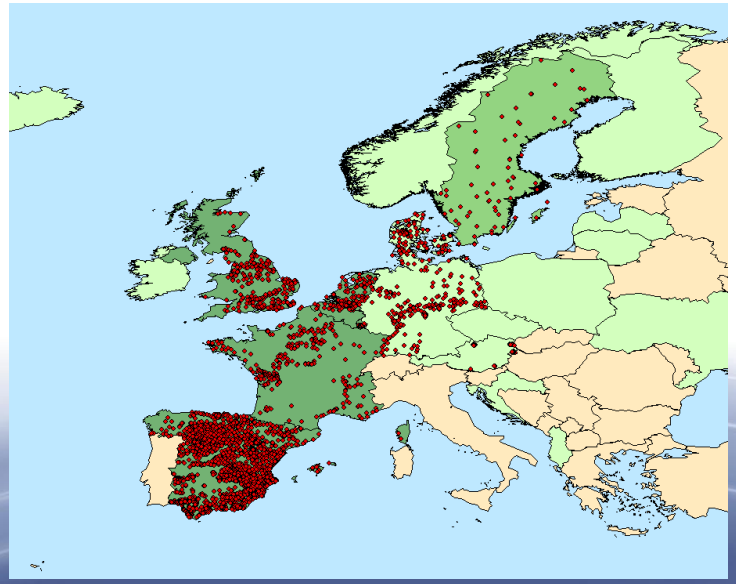
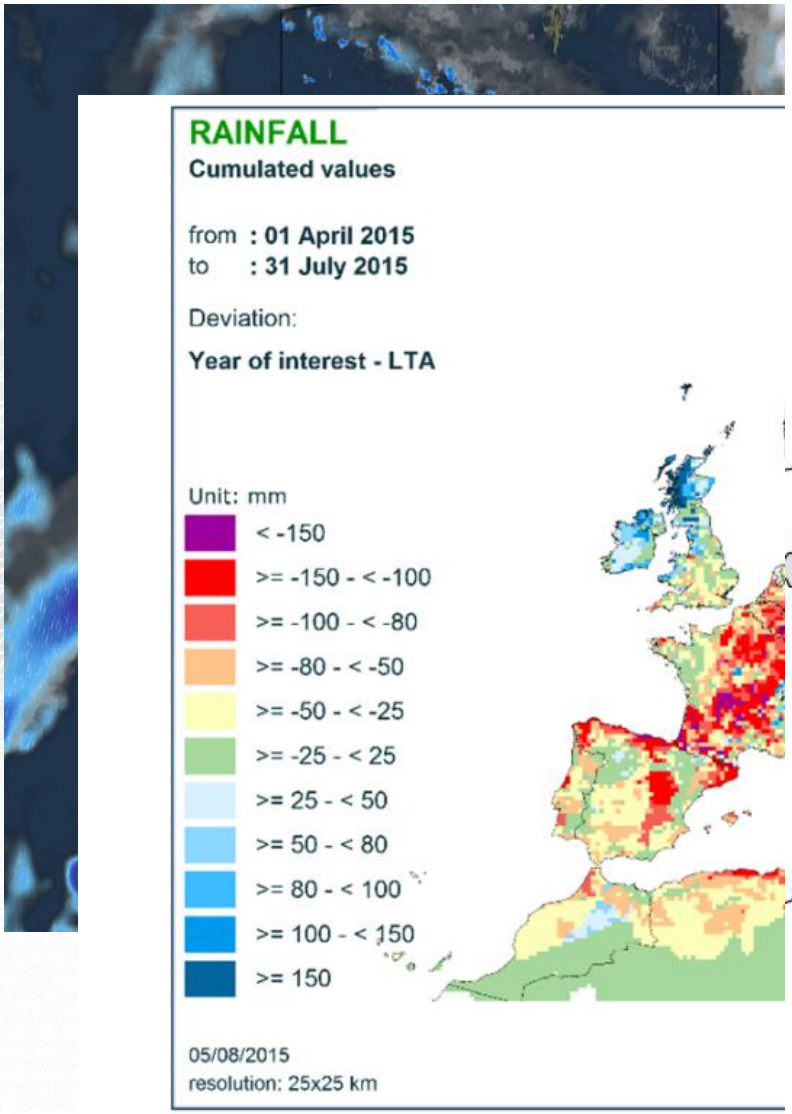
Drought & Water Scarcity: addressing current & future challenges
University of Oxford, 20th & 21st March, 2019

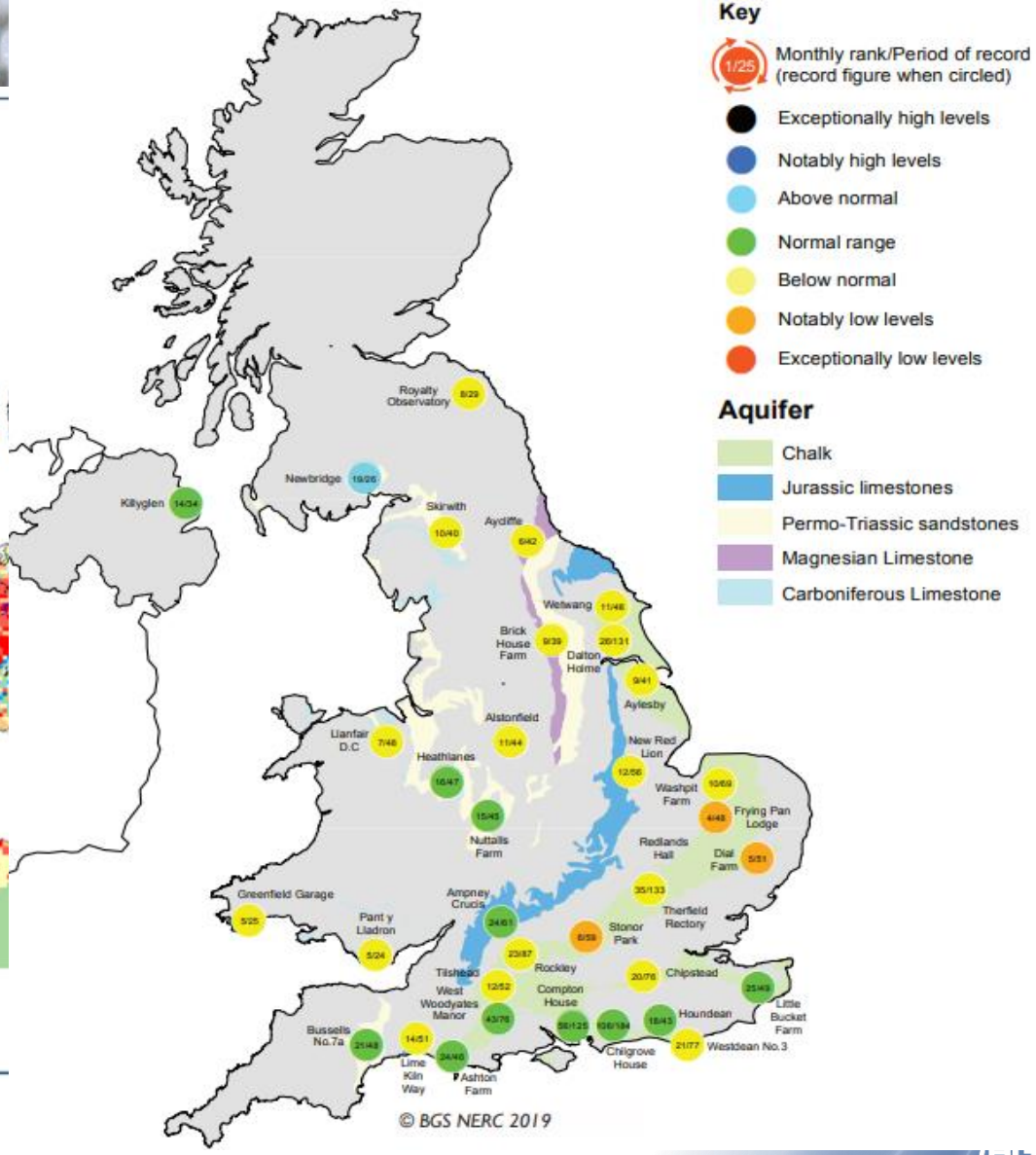




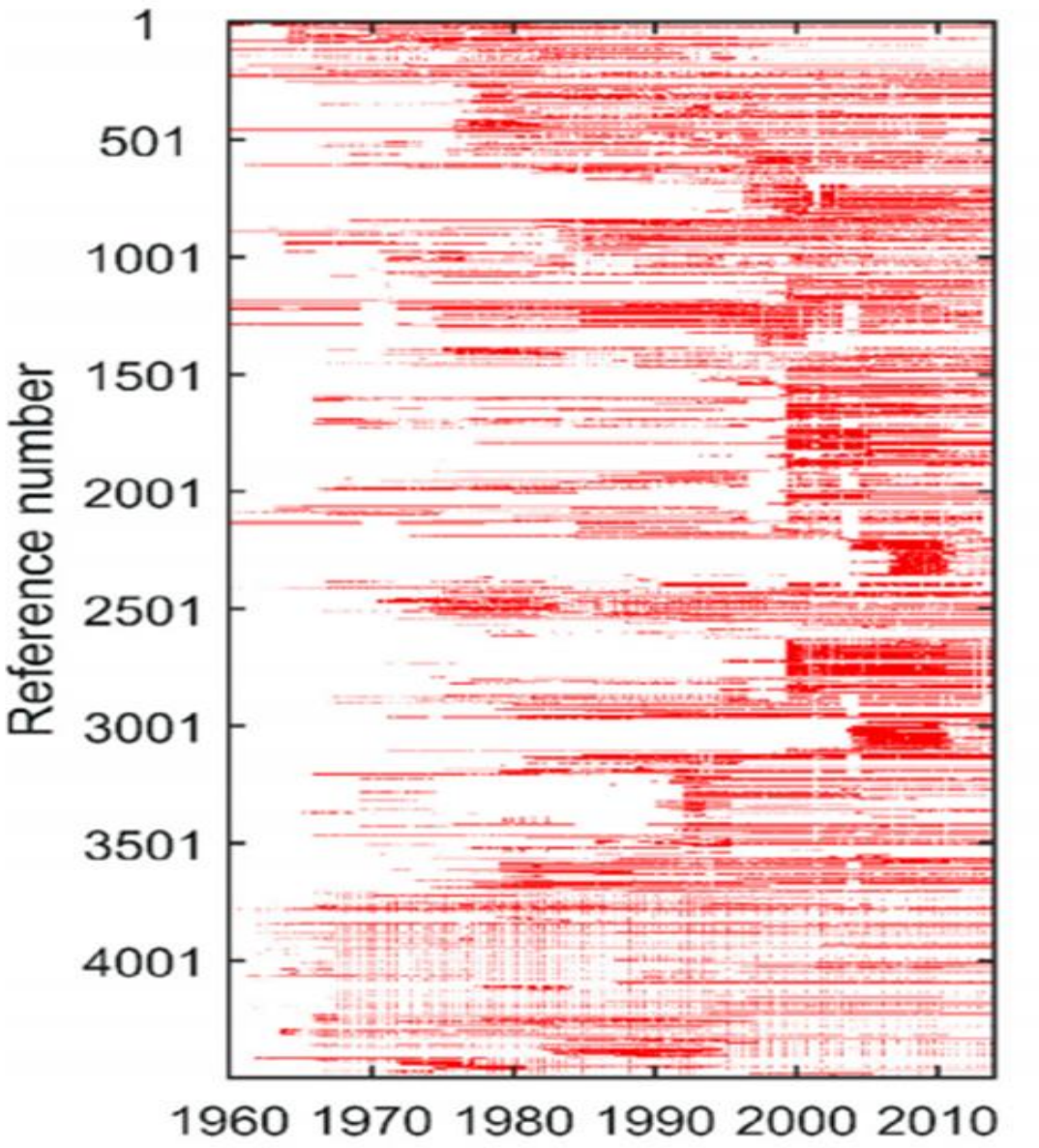
[1]British Geological Survey, [2]University of Birmingham

Research challenges – expectations & aspirations





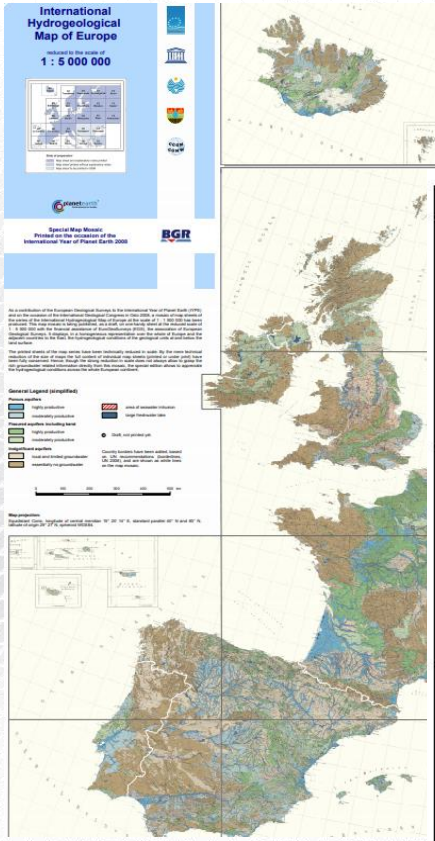
Research challenges - data



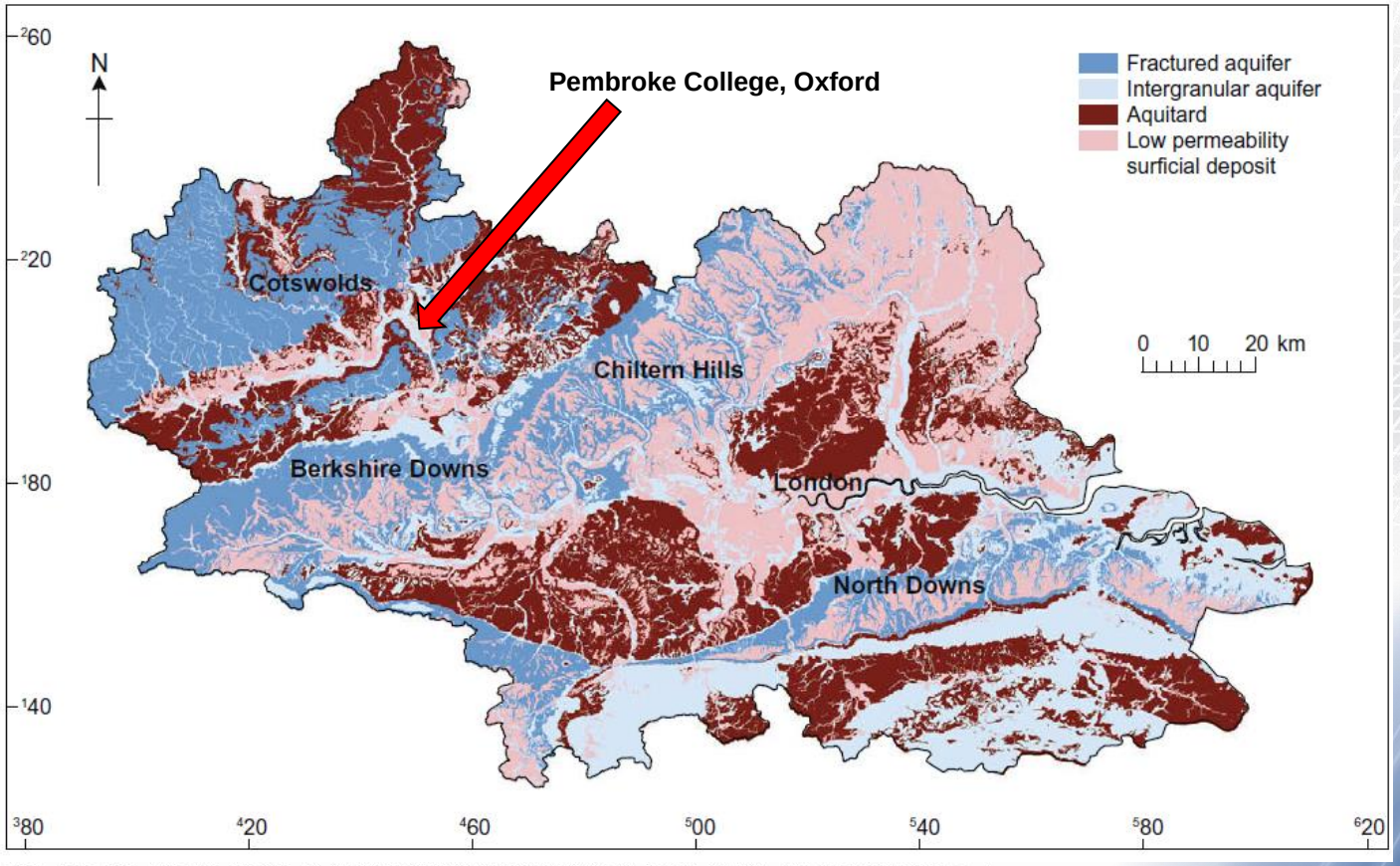
- The Chalk is the major aquifer in the UK
- ~4,000 sites on the Chalk aquifer with groundwater level data
- Very little data pre-1960
- Data is temporally irregular
- Significant gaps in records
  - e.g. 2001 foot & mouth disease
- Currently EA monitor ~3,000 sites
  - telemetry at ~10%

Marchant & Bloomfield, J. Hydrology, 564, 397-413

Research challenges – intrinsic heterogeneity



Hydrogeological Map of Europe



Bloomfield et al., 2009. J. Hydrology, 373, 164-176

Outline

Q. How can we better characterise groundwater droughts at the national to continental scale?

- Context for groundwater drought
- Standardise groundwater levels to compare groundwater drought between sites
- Reconstruct groundwater droughts to provide a longer-view
- Spatio-temporal analysis of groundwater droughts to understand the spatial distribution of droughts through time
  - Chalk in the UK
  - European Groundwater Drought Initiative (GDI)

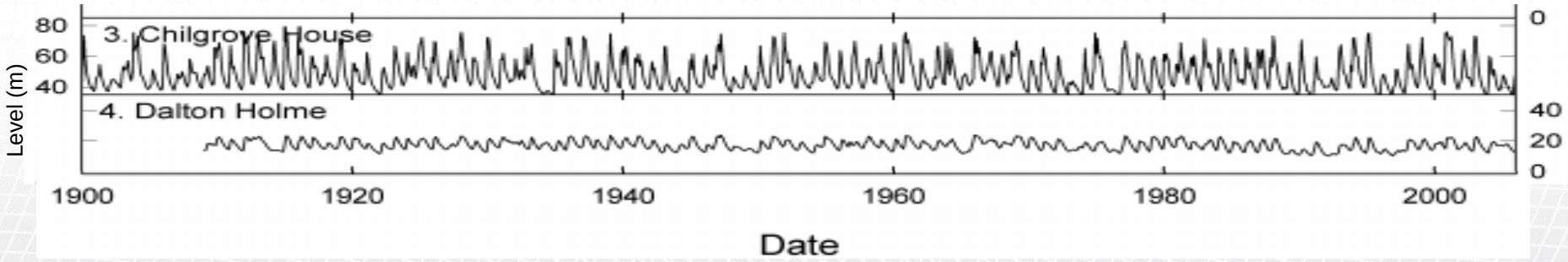
Note:

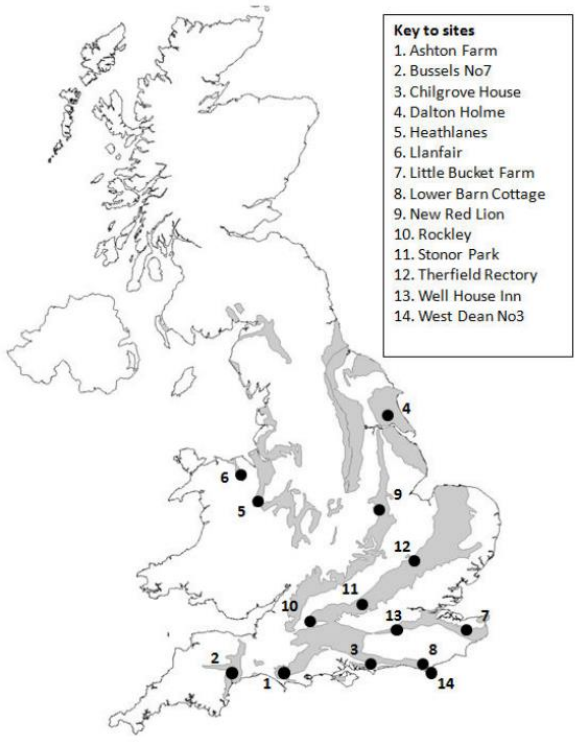
- Focus on UK & Europe (temperate droughts)
- Planning & management, anthropogenic impacts and modelling of future change are out of scope,
  - but will be the focus of a workshop, Birmingham, 1st July 2019

Groundwater drought: Context

- Lowered groundwater levels
- Reduced flows to rivers & GW-dependent ecosystems
- Reduced yields from public & private supply boreholes
- Less water available for agricultural irrigation & industry
- Changes in water quality
- Adverse impact on livelihoods & health in vulnerable communities

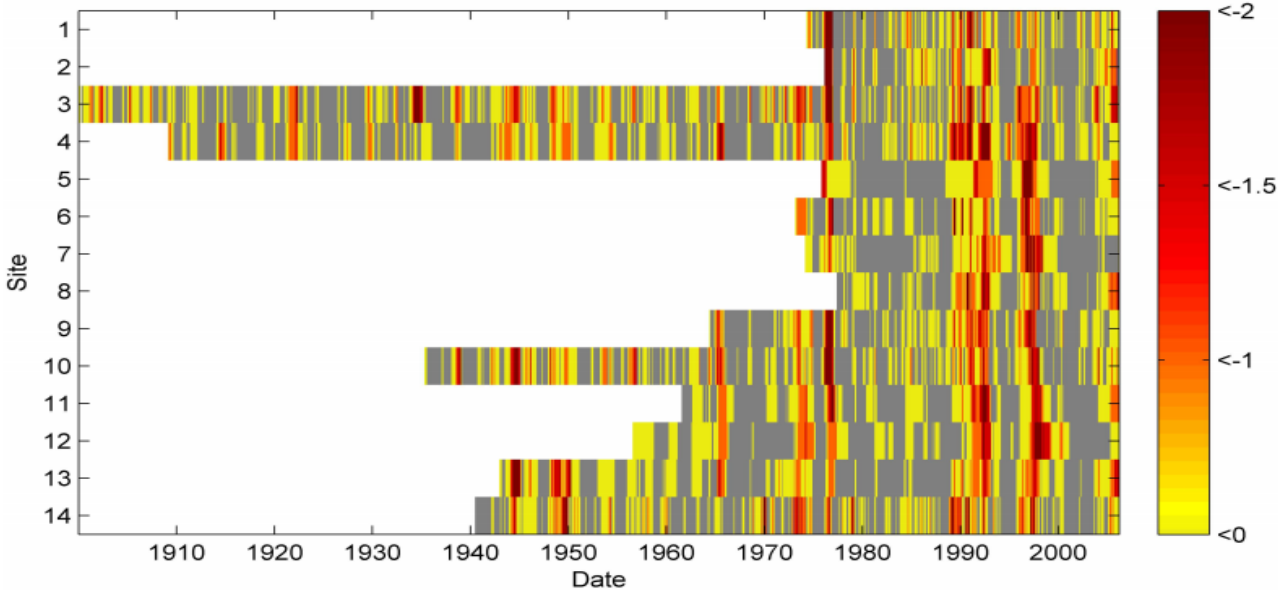
SGI and groundwater droughts



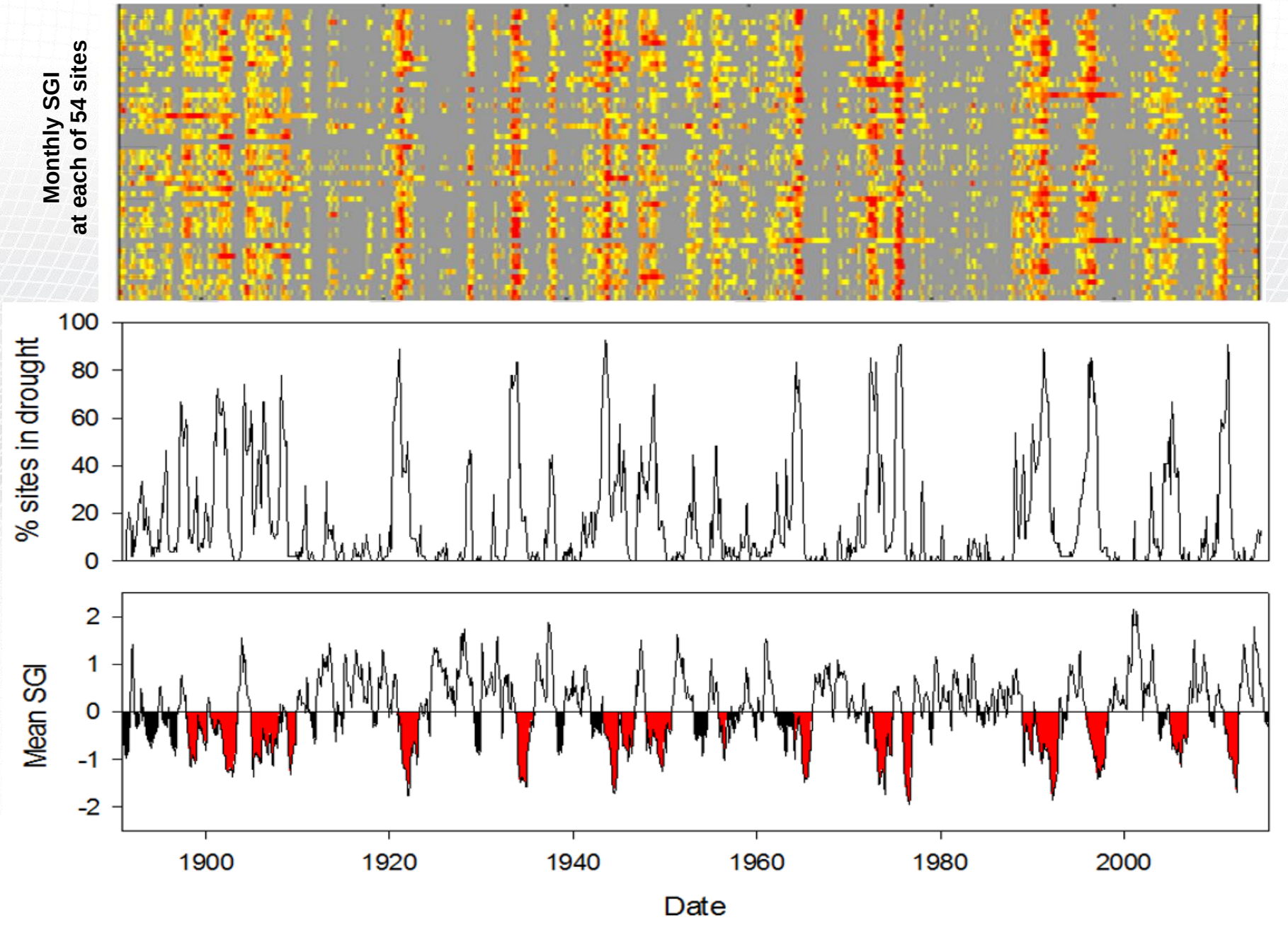


Bloomfield & Marchant, HESS, 2013, 17, 4769-4787

- Standardisation rather than threshold approach enables drought histories between different sites to be compared
- Standardised Groundwater drought Index (SGI) is a non-parametric drought index
- Standardise level hydrographs using (non-parametric) **Normal Scores Transform** to remove seasonality and re-scale to deviations from mean

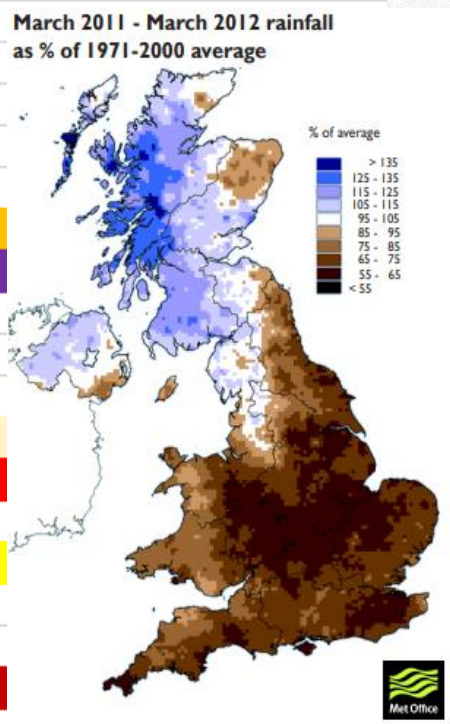


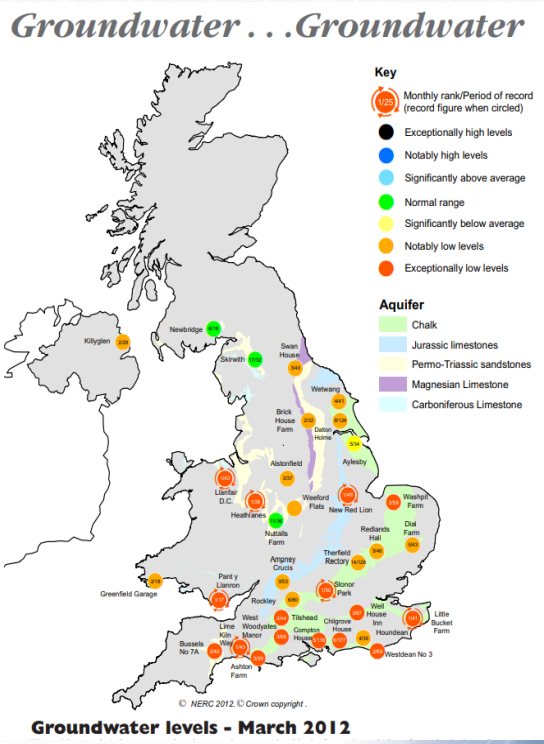
Reconstructing GW droughts



2010-12 groundwater drought in context of groundwater droughts since 1891

Summary of events						
Start	End	Dur.	Tot.Def.	Av.Int.	Max.Int	%age of sites in drought at event maxima
1897.92	1900.08	27	-18.16	-0.67	-1.16	64.81
1900.42	1903.33	36	-25.67	-0.71	-1.36	66.67
1904.83	1907.92	38	-28.89	-0.76	-1.37	74.07
1908.83	1909.83	13	-10.13	-0.78	-1.32	77.78
1920.92	1923.17	28	-25.88	-0.92	-1.77	79.63
1933.75	1935.75	25	-21.73	-0.87	-1.57	88.33
1943.25	1946.67	42	-32.27	-0.77	-1.70	92.59
1947.92	1950.67	34	-22.44	-0.66	-1.26	74.07
1955.92	1956.75	11	-6.29	-0.57	-1.01	48.15
1964	1965.92	24	-20.16	-0.84	-1.48	83.33
1972.67	1974.75	26	-25.23	-0.97	-1.73	83.33
1975.83	1977.08	16	-18.64	-1.16	-1.94	90.74
1988.92	1990.08	15	-9.07	-0.60	-1.13	53.7
1990.33	1992.92	32	-31.24	-0.98	-1.86	87.04
1995.92	1998.25	29	-24.78	-0.85	-1.41	81.48
2005	2007	25	-16.57	-0.69	-1.15	66.67
2010.92	2012.5	20	-17.96	-0.90	-1.69	90.74

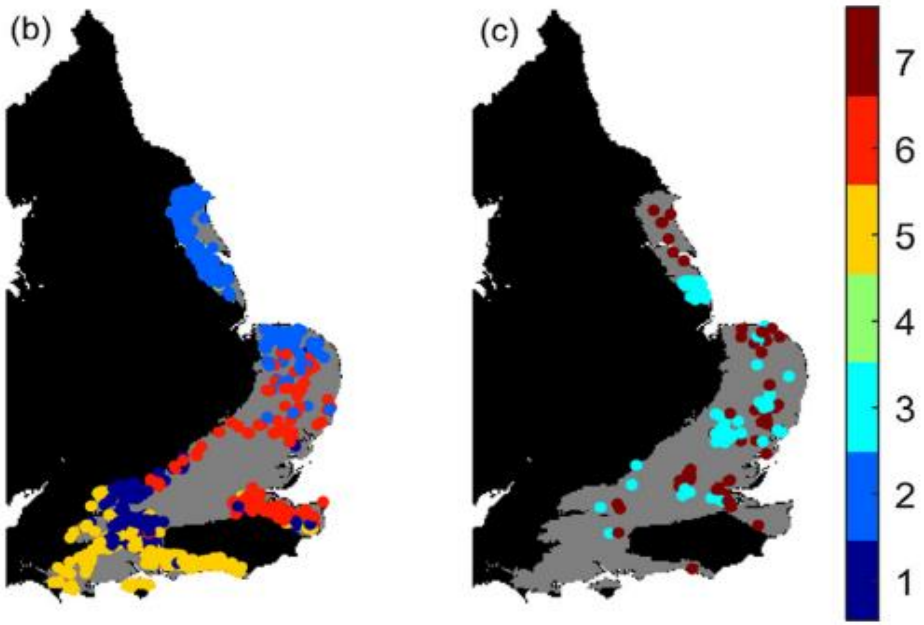




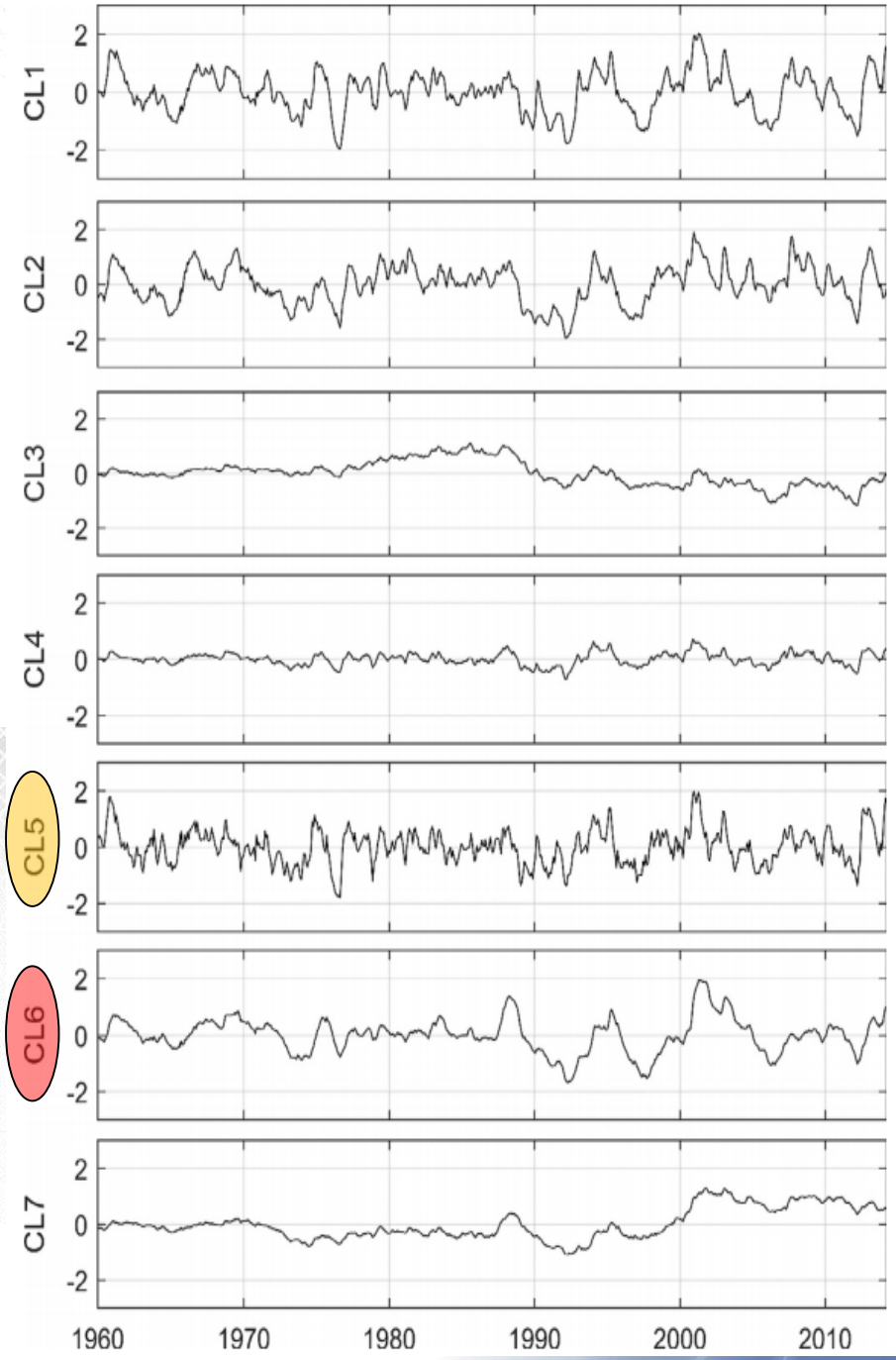
Profile of the 2010-12 drought

- Duration 20 months
- 5th (out of 17) ranked by av. intensity
- 6th (out of 17) ranked by maximum intensity
- Joint 2nd (out of 17) ranked in terms of percentage of sites in drought
  - ~91% sites in drought

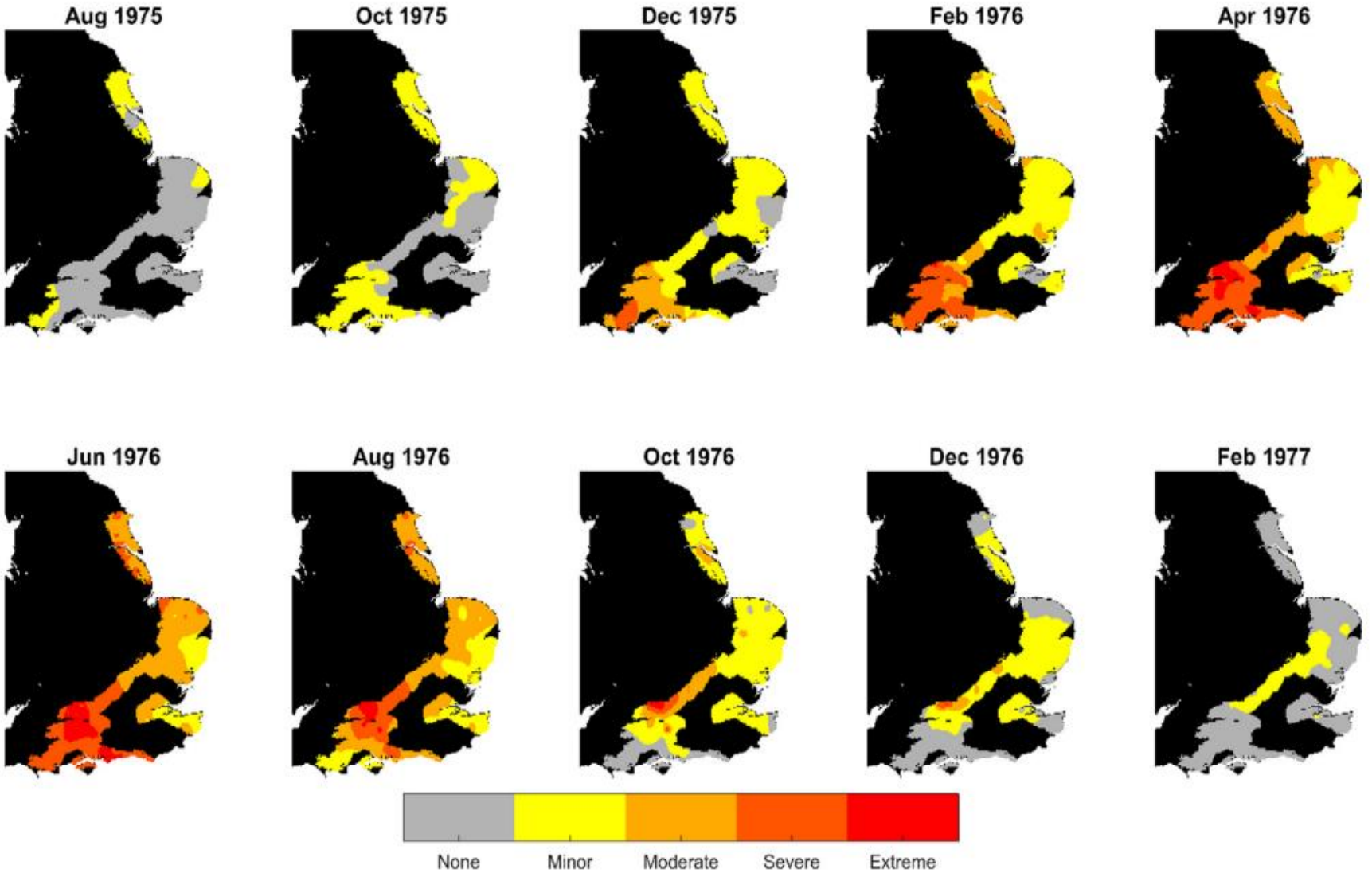
Spatio-temporal analysis - Chalk



- Four spatially coherent clusters of SGI hydrographs consistent with hydrogeological variations in the Chalk
- Two anthropogenically impacted clusters
  - Declining levels
  - Groundwater rebound



Marchant & Bloomfield et al., J. Hydrology, 2018, 564, 397-413

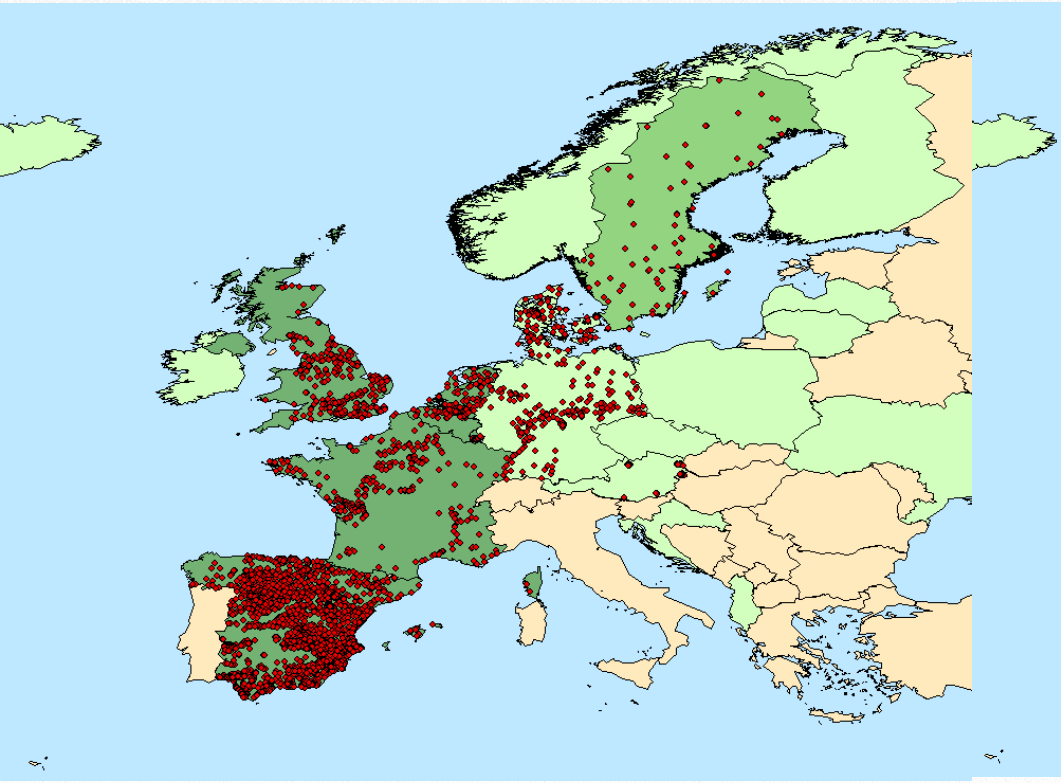


- Kriging of monthly data shows spatio-temporal development of groundwater drought in the Chalk
- Example from 1975-76 drought

Marchant & Bloomfield et al., J. Hydrology, 2018, 564, 397-413

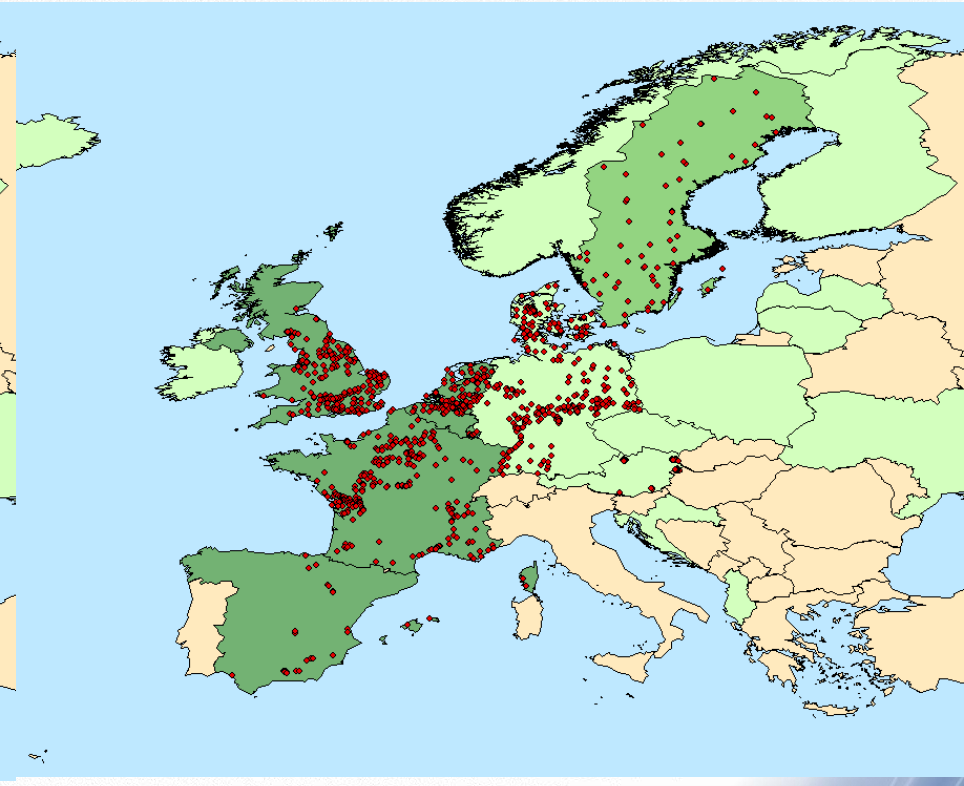
European GW Drought Initiative (GDI)

All data received



n = 4014

Sites with >240 monthly observations

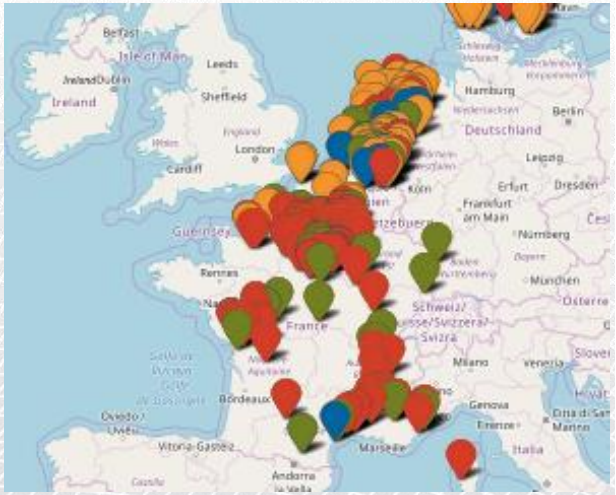


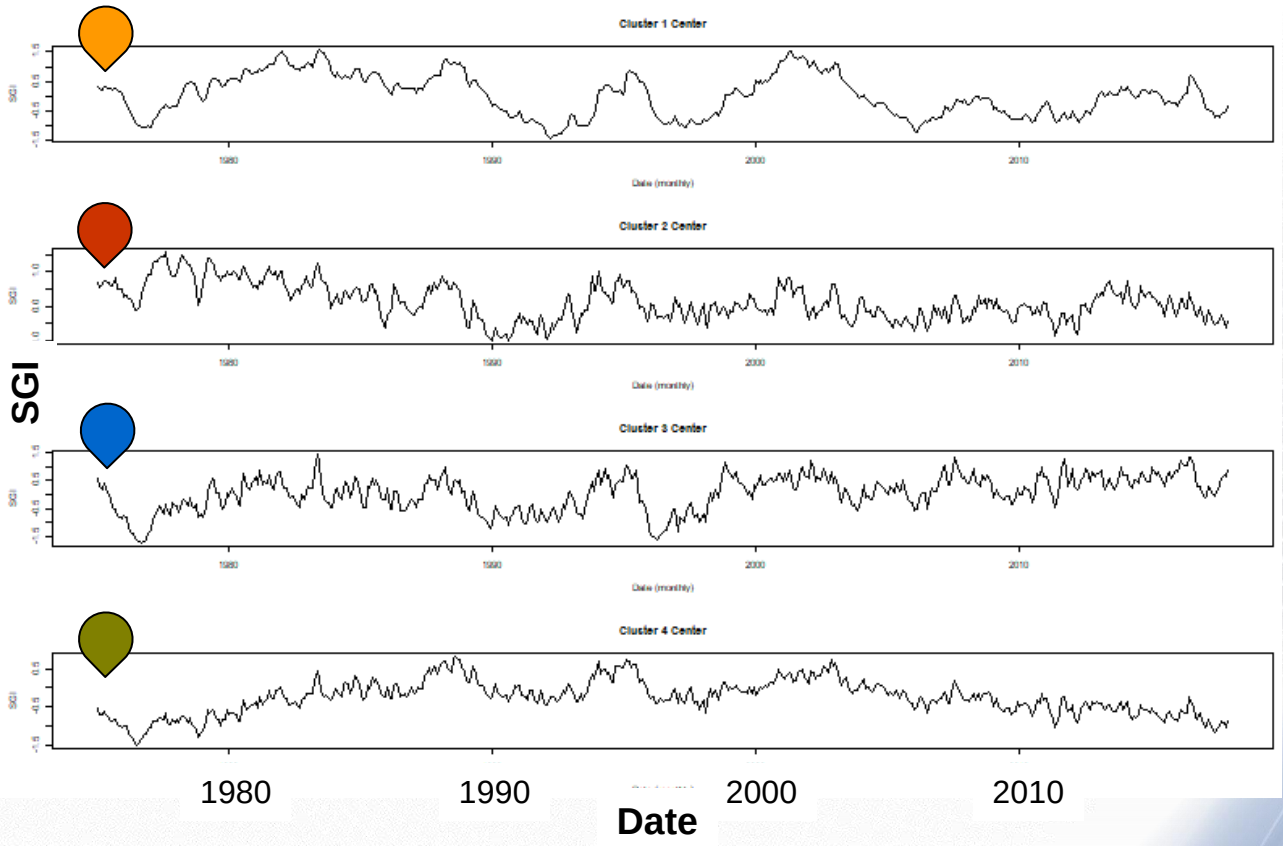
n = 1017

Data obtained

Waiting for data,
Agreement in principle

European GW Drought Initiative (GDI)





- Example of cluster analysis of SGI time series from France and the Low Countries
- Four SGI cluster centroids identified
- Cluster 1 (yellow) long autocorrelation compared with other clusters
- Cluster 2 (brown) consistent with previously published European climatology (Lloyd-Hughes & Saunders, 2002)

Conclusions

- Aspiration for & expectations of hydrological services still lag behind meteorological services
  - significant opportunities to improve understanding of groundwater drought if we bring all current available data together
- Groundwater level reconstructions yield insights into pre-observational groundwater droughts
    - How can reconstructions be used effectively in water resource/drought management planning? (Thursday pm)
- For drought characterisation at national to continental scale
  - clustering & kriging standardised level hydrographs can identify spatially-coherent responses of groundwater to drought
    - How do observed groundwater droughts translate into societal impacts? (Wednesday pm)
    - How can information be effectively used in risk perception & communication? (Thursday pm)