

KIRSTY UPTON, BEYOND DROUGHT, NOVEMBER 2025

Defining Drought: A Groundwater Perspective

British Geological Survey

Drought Definitions

Drought

World Meteorological Organization (WMO):

“a prolonged dry period in the natural climate cycle that can occur anywhere in the world… typically a slow on-set phenomenon caused by a lack of rainfall.”

“a period of abnormally dry weather characterised by a prolonged deficiency of precipitation below a certain threshold over a large area and a period longer than a month.”

“conditions that are significantly drier than normal or otherwise limiting moisture availability to a potentially damaging extent”

“conditions where there has been a prolonged absence or marked deficiency of precipitation”

Drought

IPCC:

“a period of abnormally dry weather long enough to cause a serious hydrological imbalance.”

1. **Meteorological** – a period with abnormal precipitation deficit
2. **Agricultural and ecological** – combined shortage of precipitation and excess evapotranspiration causes abnormal soil moisture deficit which impinges on crop production and ecosystem function
3. **Hydrological** – a period with large runoff and water deficits in rivers, lakes and reservoirs (groundwater???!)
4. **Socio-economic** – demand for an economic good exceeds the supply due to shortages in water

Drought

UK Government:

“a prolonged period of low rainfall creating a shortage of water... varying in nature, timing, and impacts”

1. **Environmental** – shortage of rainfall has a detrimental impact on the environment… reduced river flows, groundwater levels, and insufficient moisture within soils
2. **Agricultural** – insufficient rainfall and soil moisture to support crop production (including irrigation) and livestock
3. **Water supply** – shortage of rainfall impacts water company supply to customers

Drought is complex and difficult to define quantitatively

Drought has different meanings to different people / systems

Drought as a Hazard

Drought

HAZARD
Location, Magnitude
Duration, Frequency

+

EXPOSURE

+

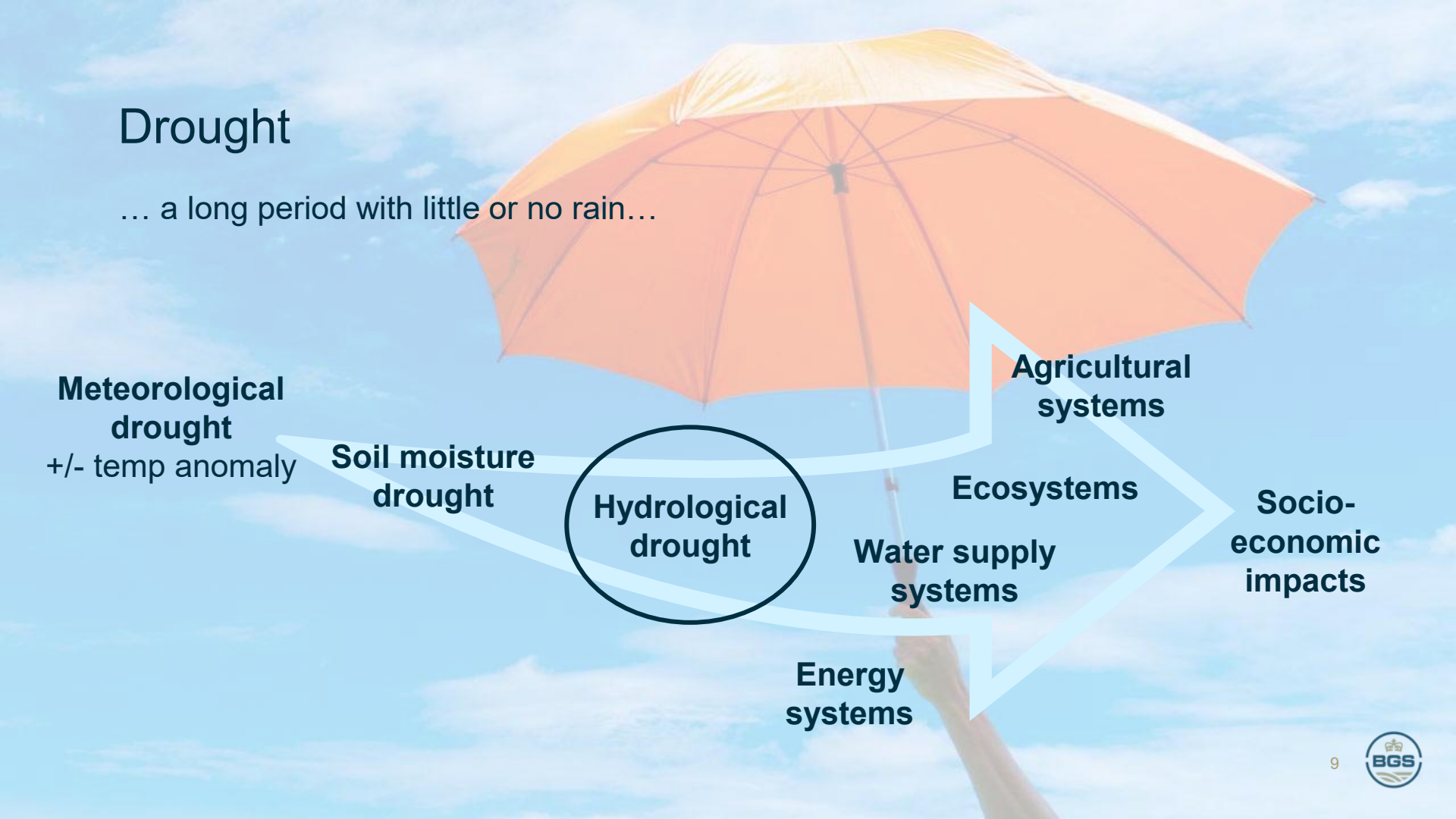
VULNERABILITY

=

RISK: probability of a negative impact on people and systems

Drought

… a long period with little or no rain…



DEFINING DROUGHT: A GROUNDWATER PERSPECTIVE

Hydrological Drought

"Hydrological drought is a broad term related to negative anomalies in surface and subsurface water. Examples are below-normal groundwater levels or water levels in lakes, declining wetland area, and decreased river discharge." Anne van Loon, 2015

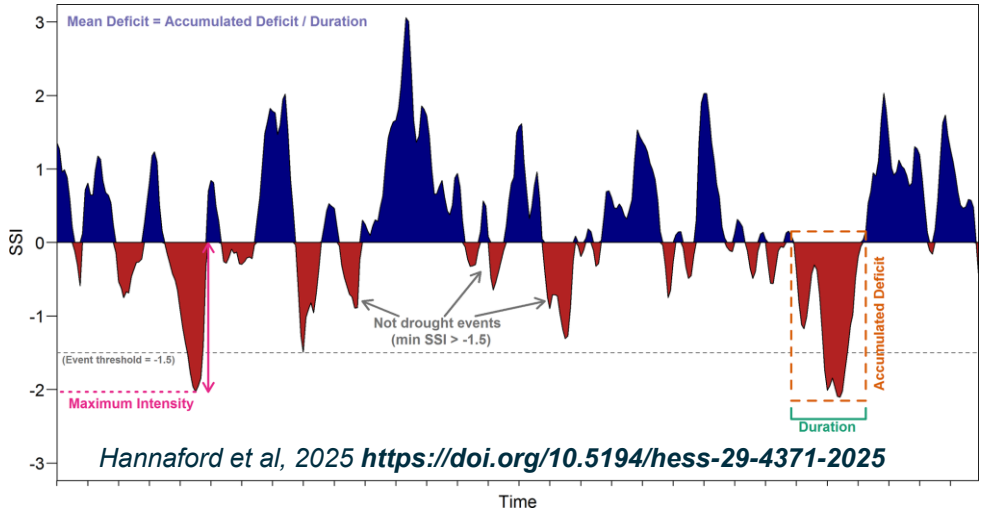
Outline

1. Historical perspective
   - Spatial and temporal propagation across the hydrological system
2. Future perspective
   - Droughts in a changing climate
3. Question of scale
   - From continents to boreholes
4. What next?
   - Data and tools for improved understanding and prediction of drought

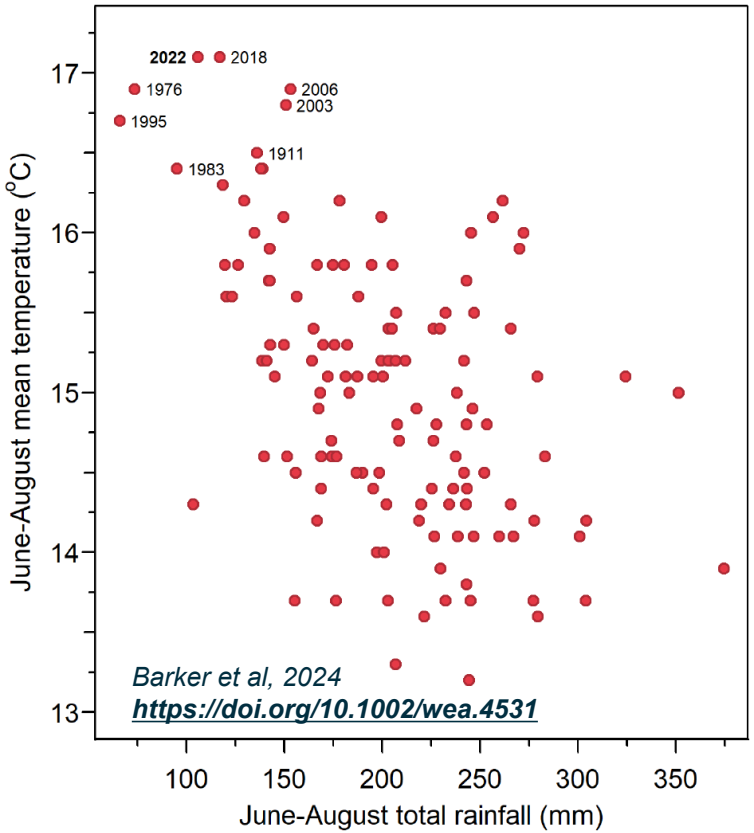
Historical Perspective of Drought

Monitoring and Measuring Drought

- Standardised approaches
  - SPI, SPEI, SSI, SGI
  - Allow regional comparison
  - Relative severity
  - Different accumulation times
- Threshold approaches
  - Percentiles of flow duration curve for thresholds
  - Deficit volume



Major droughts in the UK



Major droughts in England and Wales, 1800–2006

Terry Marsh[1], Gwyneth

The 2010–2012 drought in England and Wales

Mike Kendon[1†]

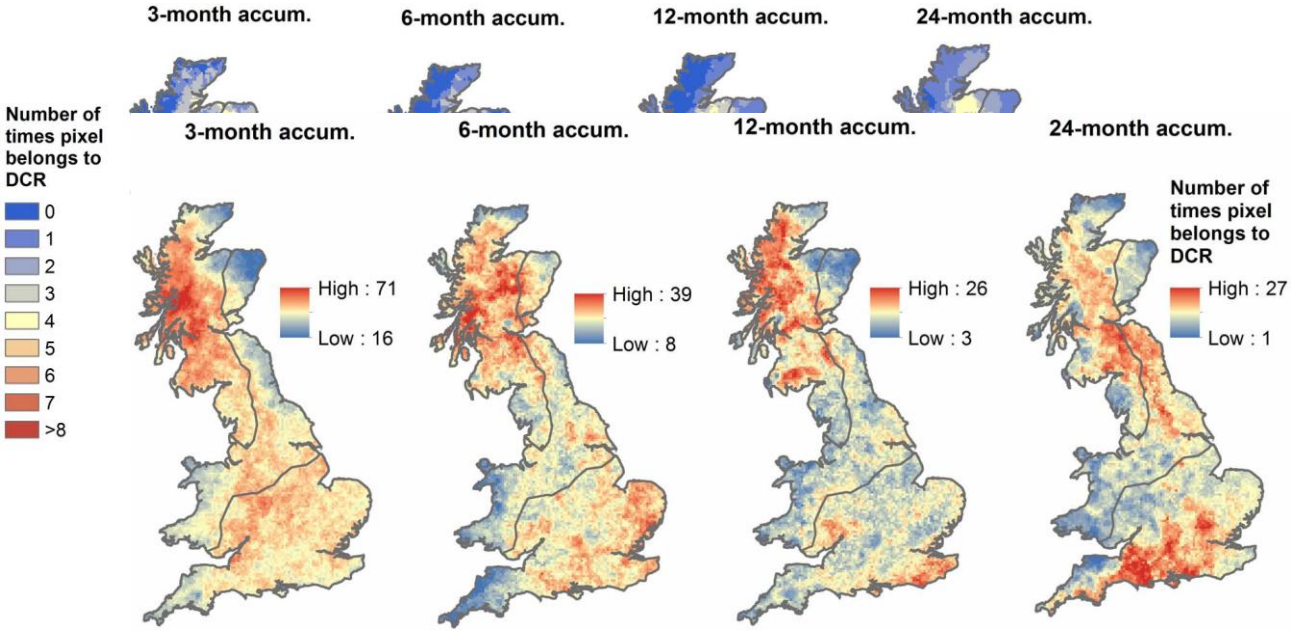
The 2018/2019 drought in the UK: a hydrological appraisal

S. Turner[1], L. J. Barker[1], J. Hannaford[1,2], K. Muchan[1], S. Parry[1] and C. Sefton[1]

[1]UK Centre for Ecology & Hydrology, Wallingford, UK

[2]Irish Climate Analysis and Research UnitS (ICARUS), Maynooth University, Maynooth, Ireland

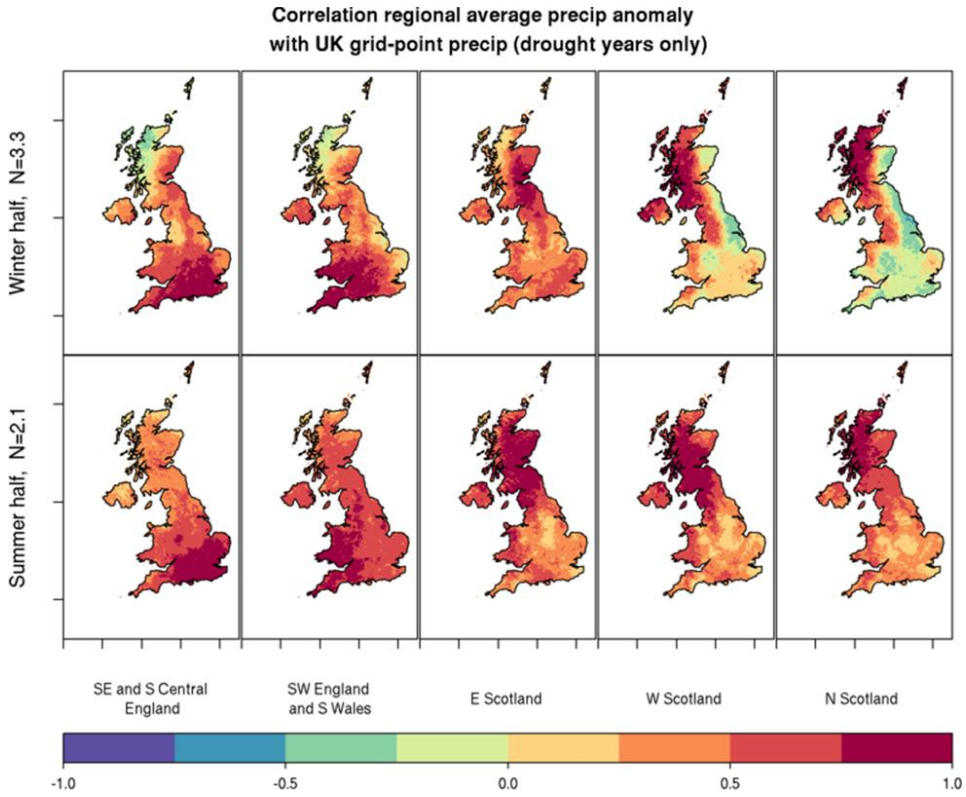
Focus on Meteorological Drought



- 20 most severe droughts mainly in south
- Northern areas experience more frequent, less severe droughts

Tanguy et al 2021
https://doi.org/10.3389/fenvs.2021.639649

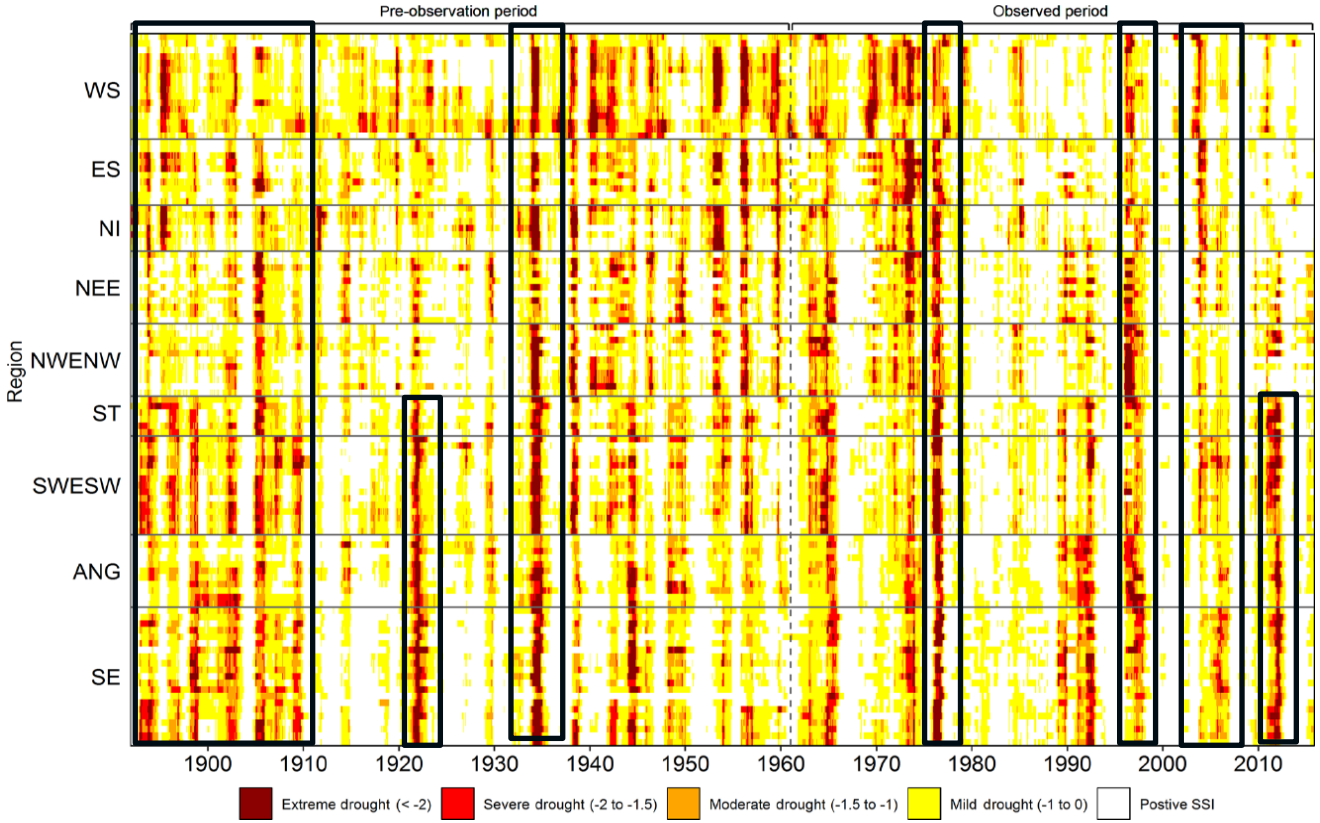
Focus on Meteorological Drought



- Winter droughts preferentially affect southern England
- Summer droughts tend to be spatially coherent across the UK

Folland et al 2015
https://doi.org/10.5194/hess-19-2353-2015

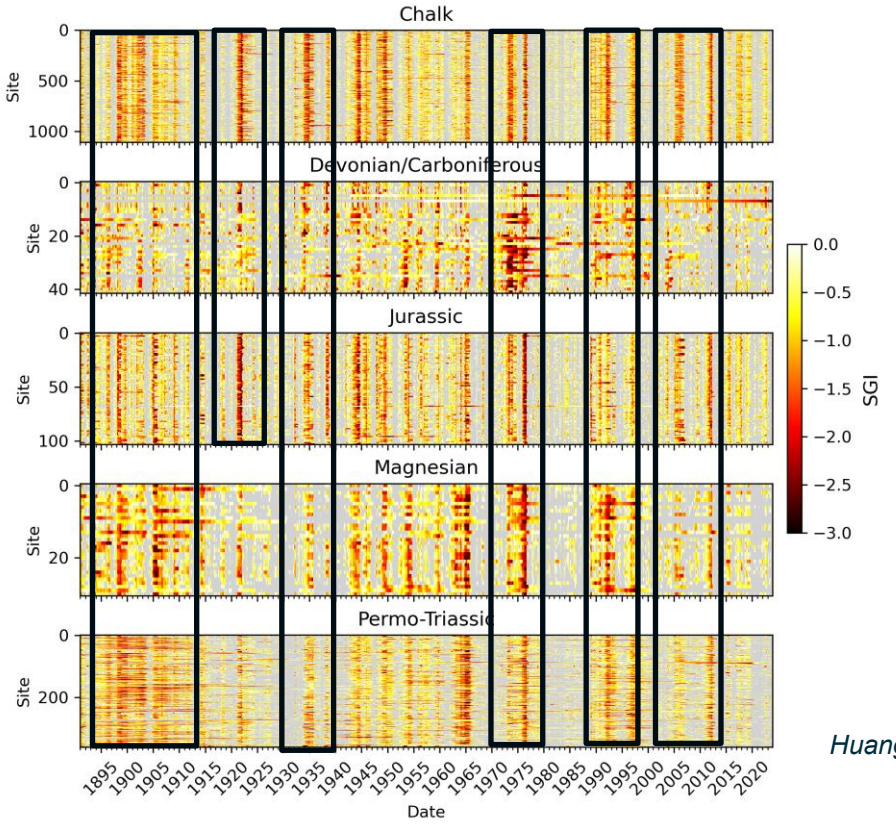
Focus on Surface Water Droughts



- Historically significant and spatially coherent droughts

Barker et al 2019.
https://doi.org/10.5194/hess-23-4583-2019

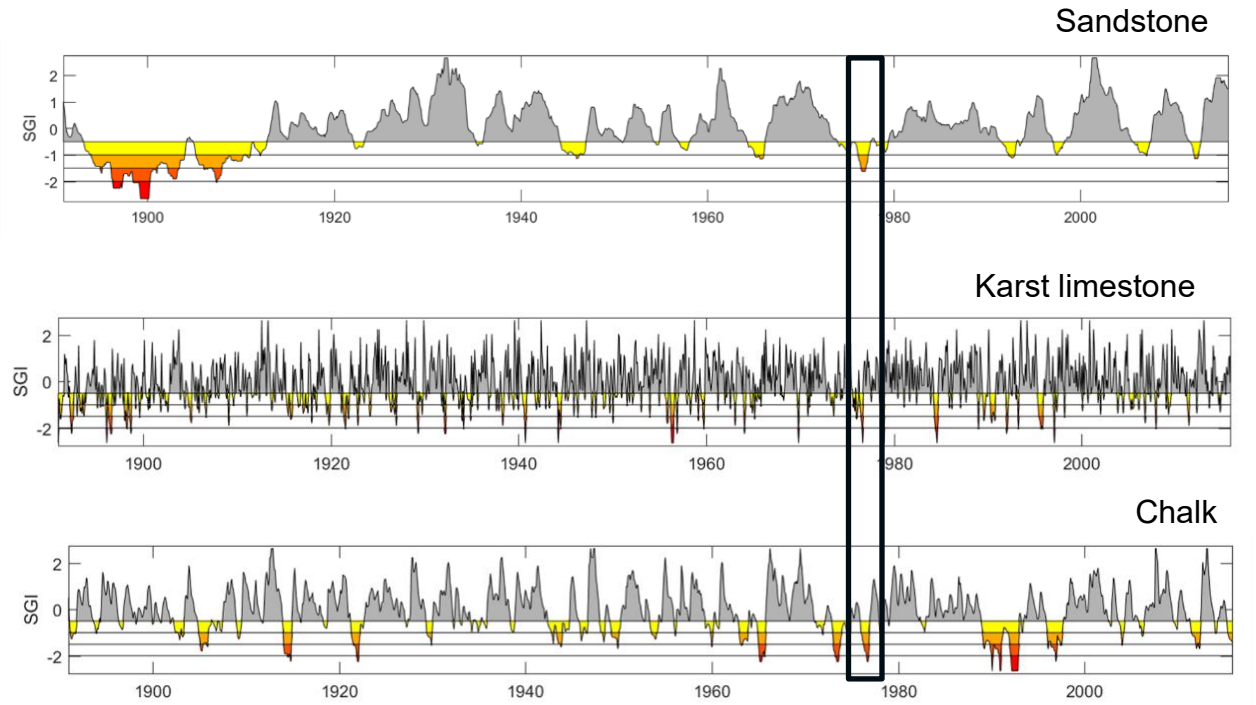
Focus on Groundwater Droughts



- Historically significant and spatially coherent droughts
- Different characteristics both within and between aquifers

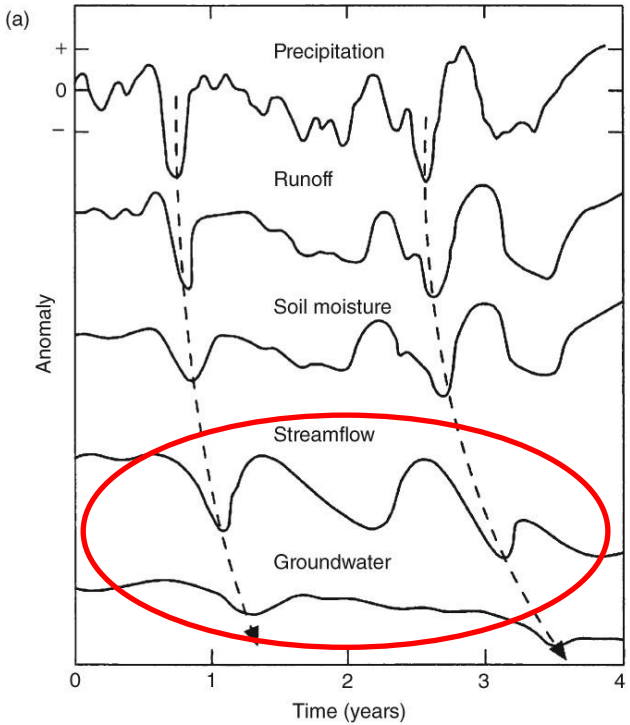
Huang et al, in prep.

Focus on Groundwater Droughts



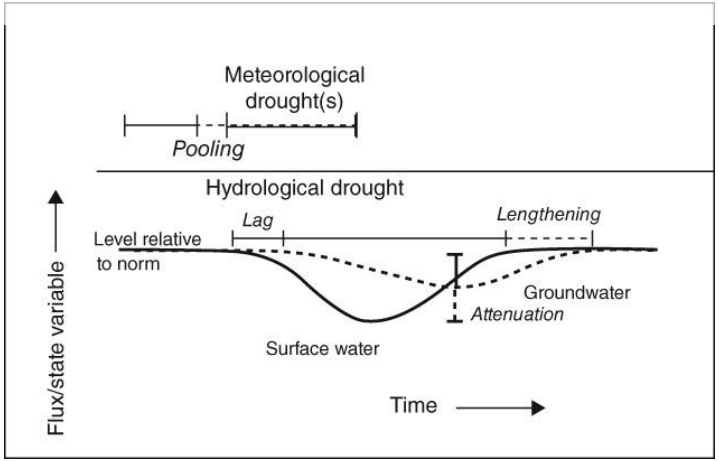
- Clear differences in frequency, duration and magnitude of droughts

Drought Propagation



Van Loon et al, 2015.
https://doi.org/10.1002/wat2.1085

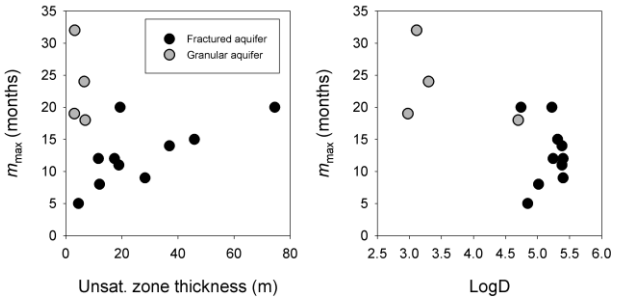
- Pooling: of met droughts into prolonged hydro drought
- Attenuation: smoothing of the signal (lower –ve anomaly)
- Lag: in onset through the hydro system
- Lengthening: of drought period through the hydro system

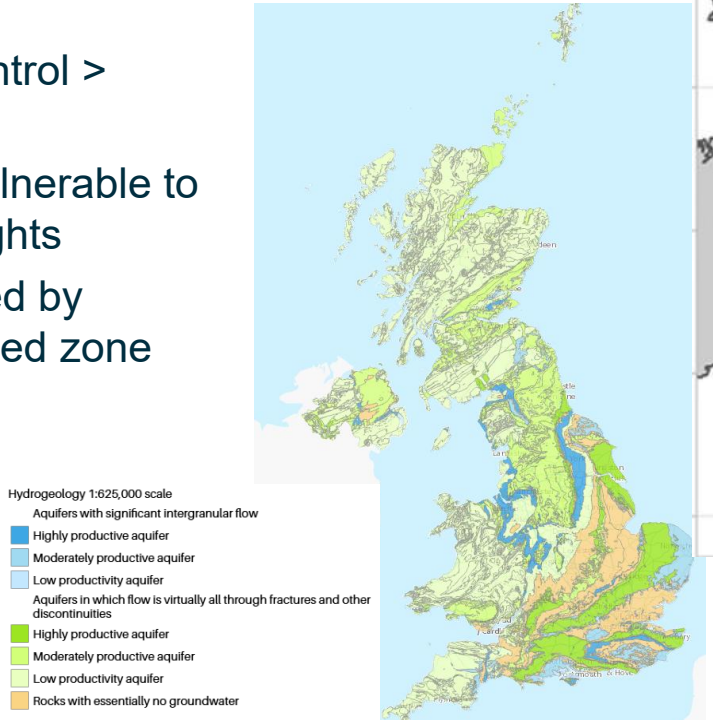


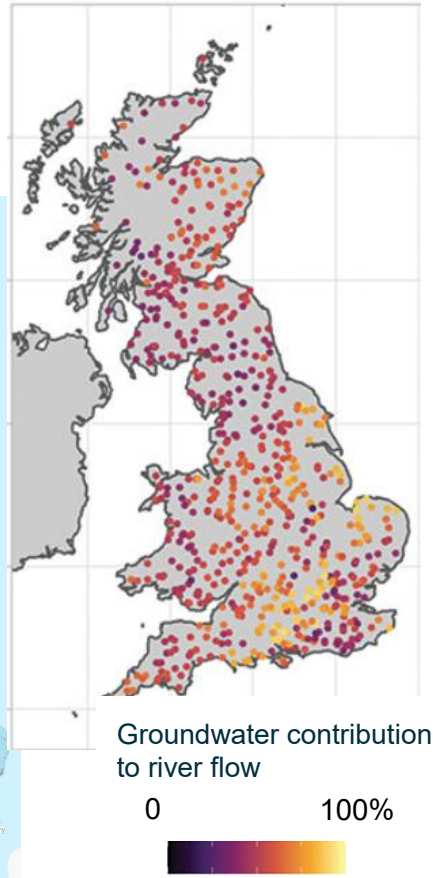
Controls on Drought Propagation

Storage

- Low > strong meteorological control > vulnerable to flash droughts
- Higher > variable response > vulnerable to dry winters and multi-year droughts
- Groundwater response controlled by aquifer properties and unsaturated zone

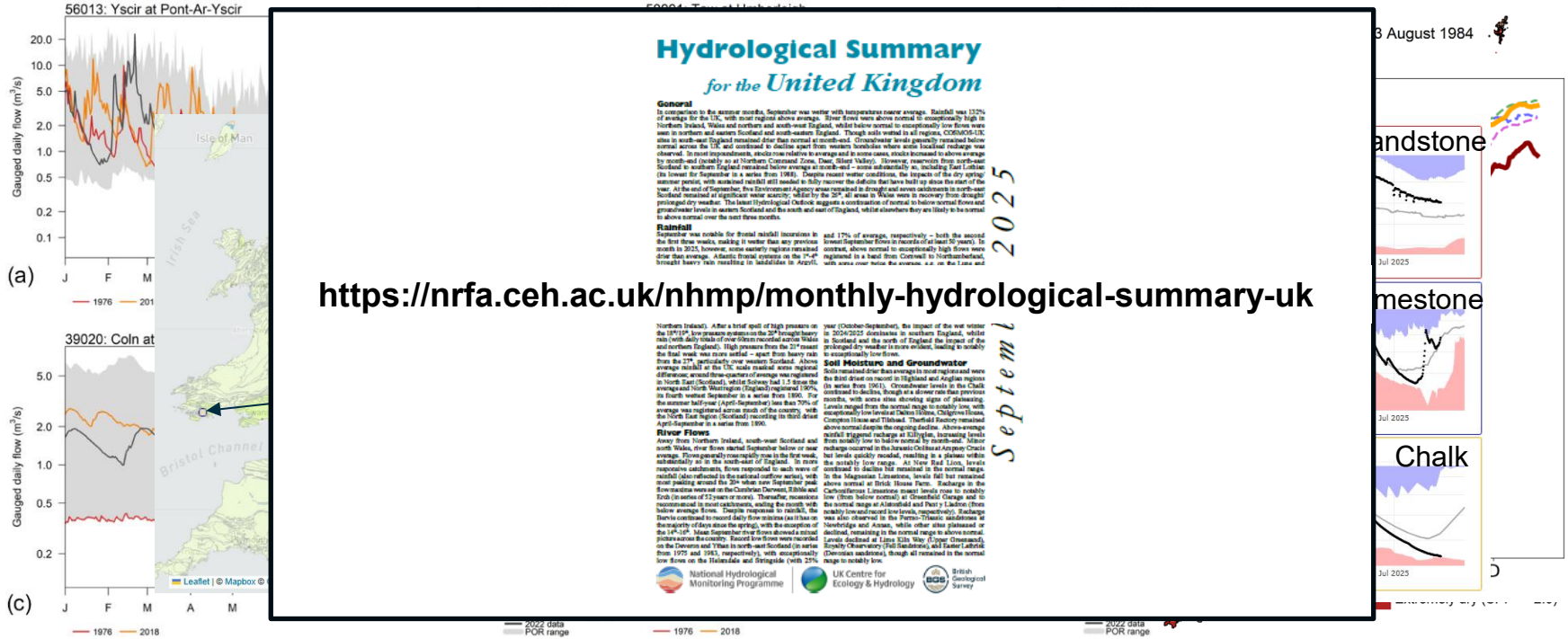






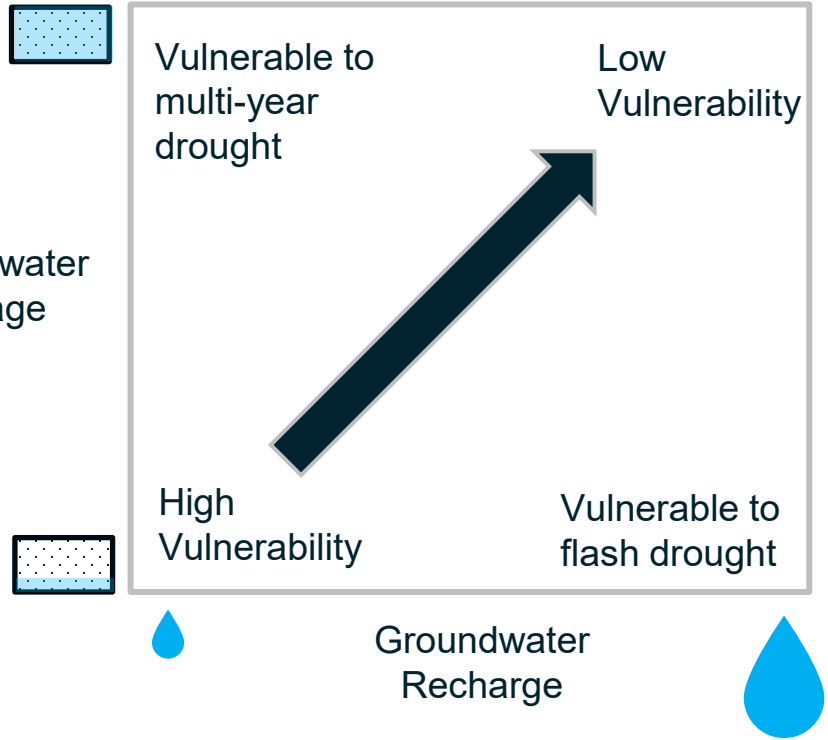
Bloomfield & Marchant, 2013.
https://doi.org/10.5194/hess-17-4769-2013

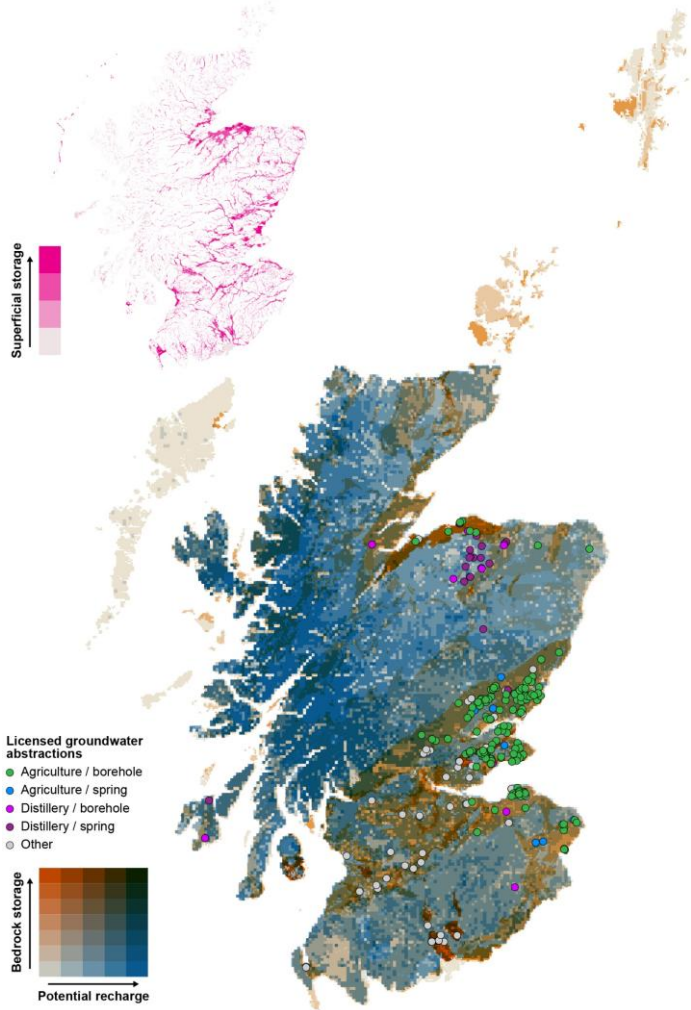
Drought Propagation



Barker et al, 2024 ***https://doi.org/10.1002/wea.4531***

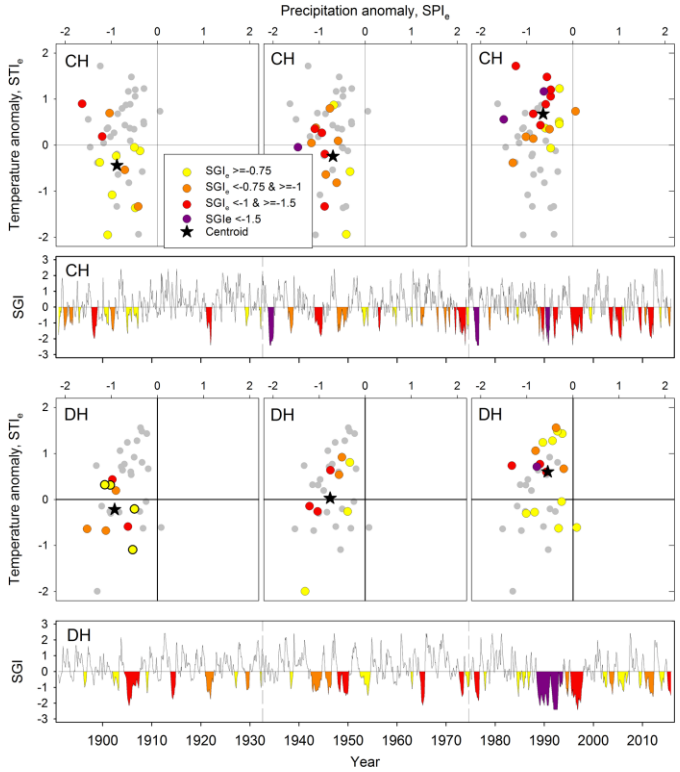
Vulnerability



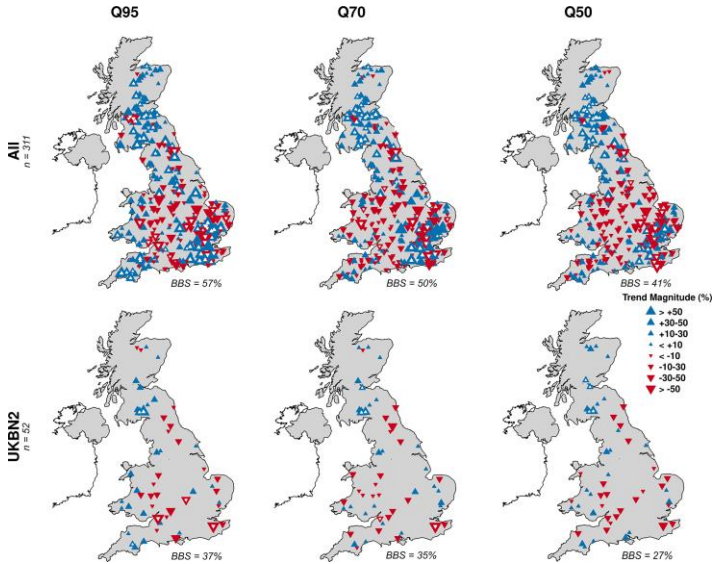


Future Perspective of Drought

Are droughts already changing?



- Evidence of change in the SE but no large-scale significant change in drought characteristics

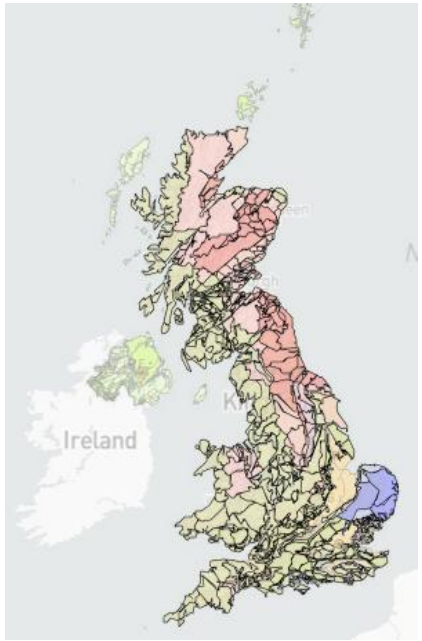


Barker et al, 2024 ***https://doi.org/10.1002/wea.4531***

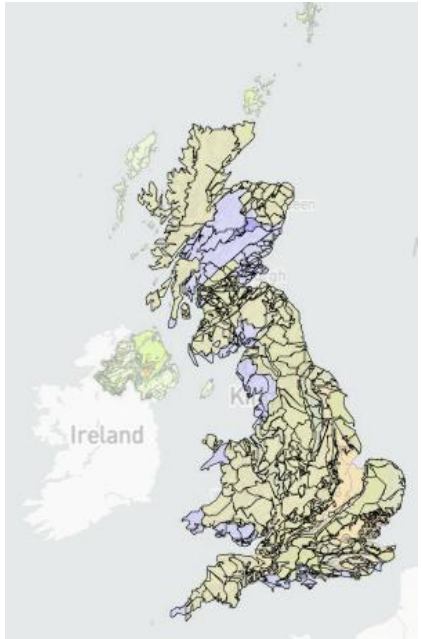
Bloomfield et al, 2019 ***https://doi.org/10.5194/hess-23-1393-2019***

eFLaG: Future Projections

Forecast spring recharge



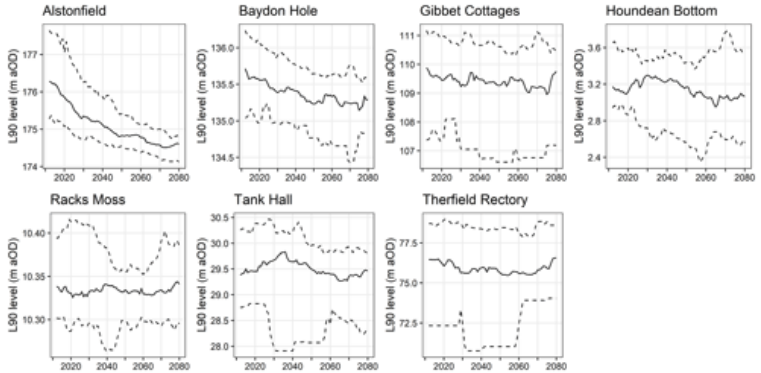
Forecast winter recharge





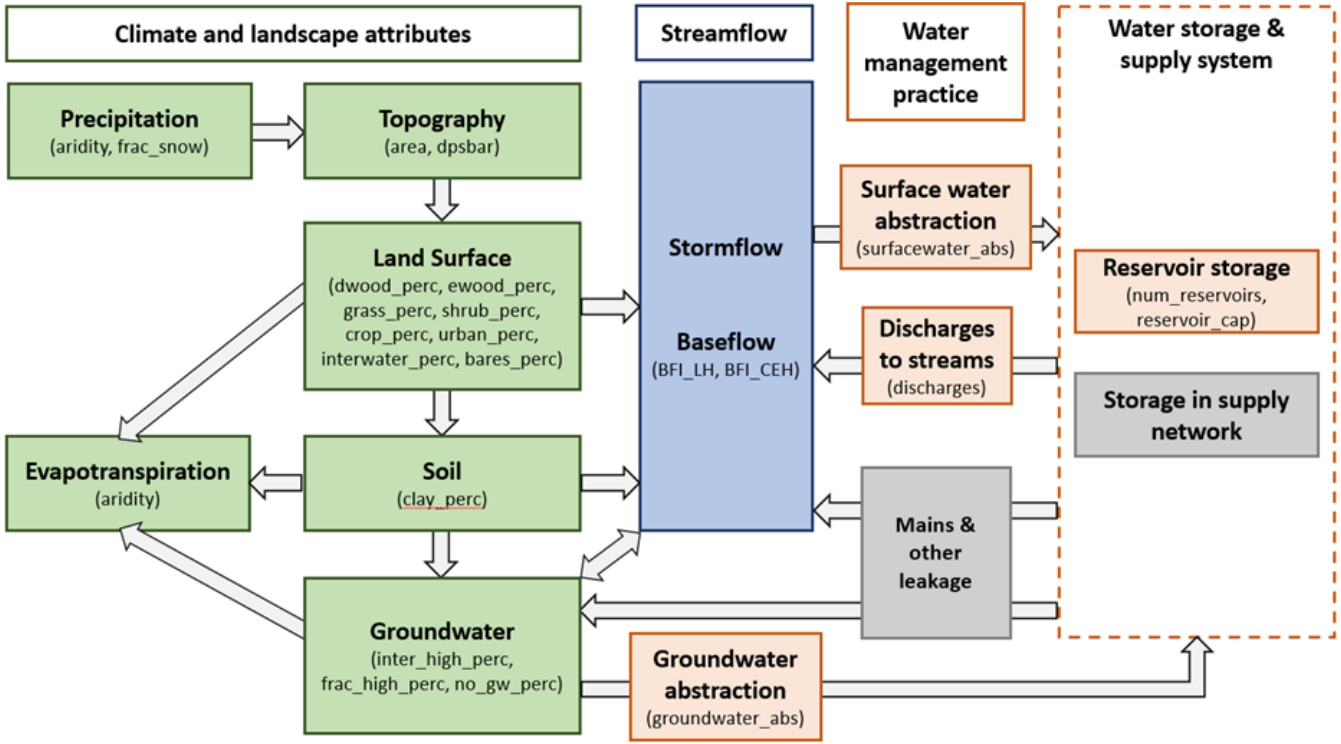
- Consistent projections of declining low flows due to summer rainfall deficits
- Uncertainty for groundwater
- Modest GWL declines at >85% of boreholes, others show increase
- Wetter winters may favour recharge

Forecast future groundwater levels using CMIP 18 for 7 boreholes



Parry et al 2024 ***https://doi.org/10.5194/hess-28-417-2024***

Other factors influencing drought?

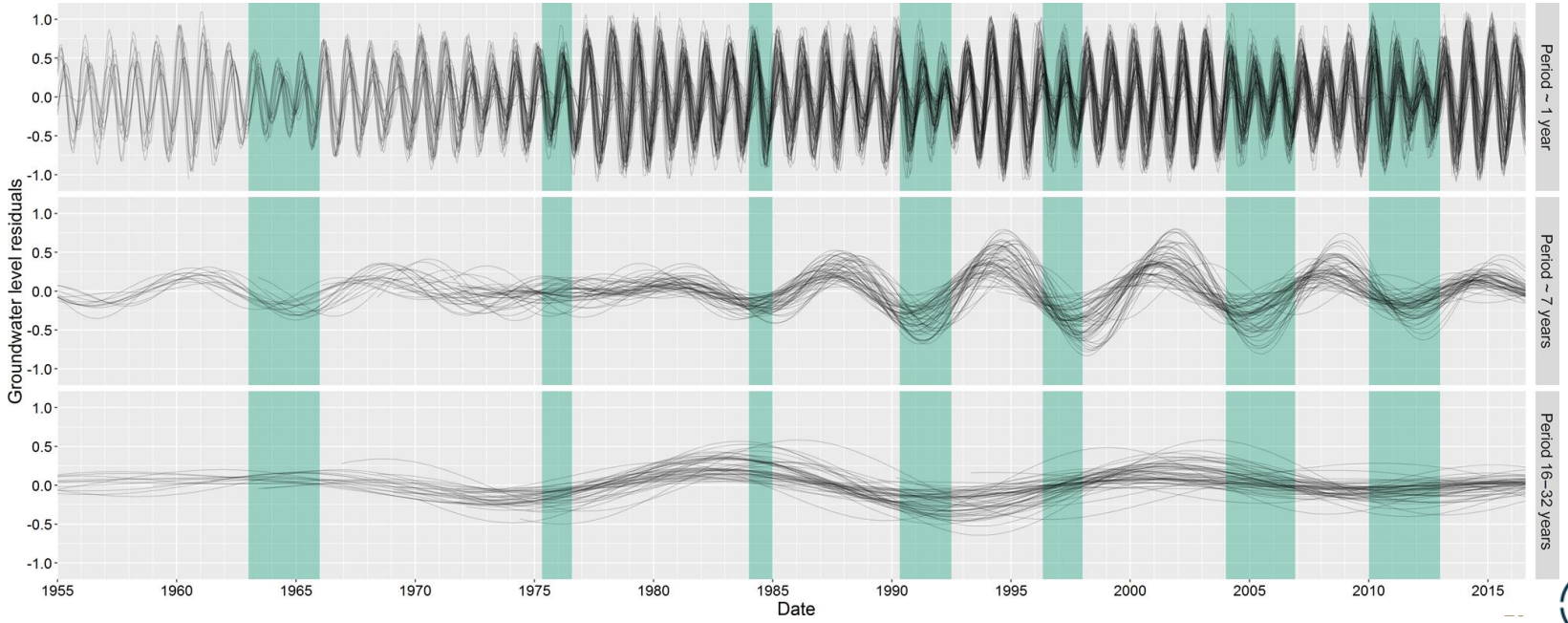


Bloomfield et al 2021 ***https://doi.org/10.5194/hess-25-5355-2021***

Question of Scale

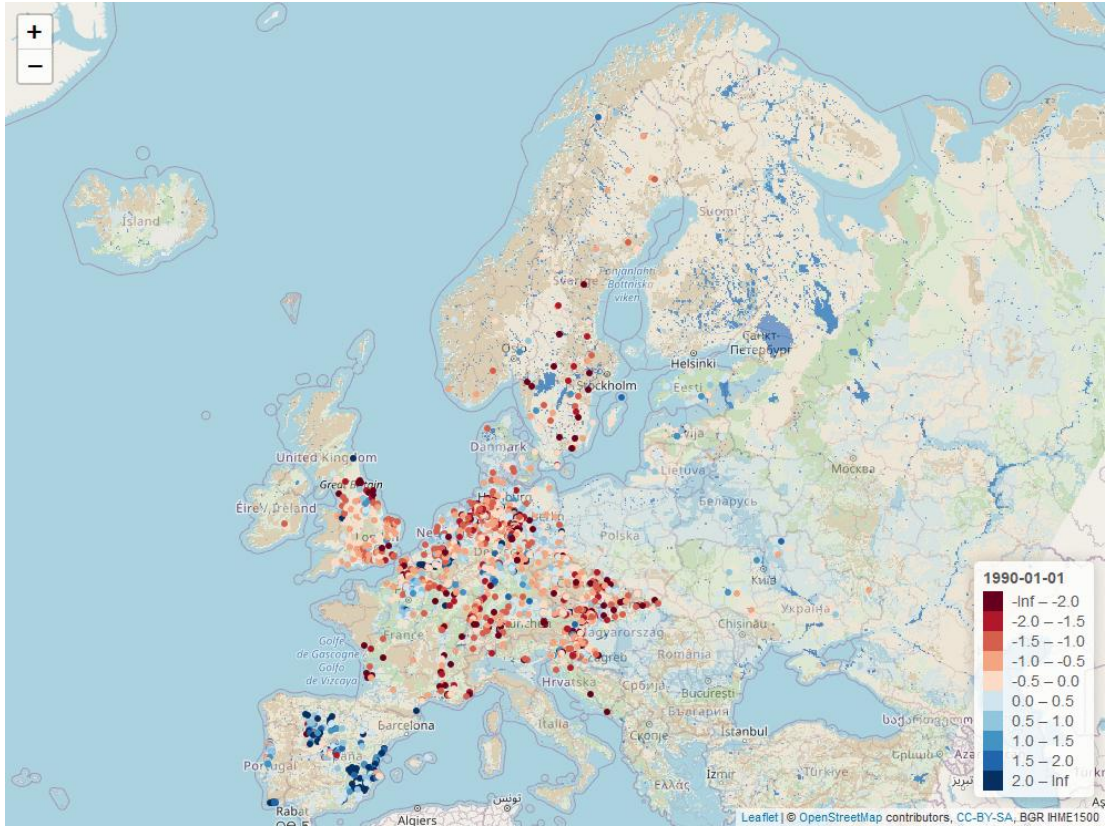
Groundwater Teleconnections

- 7-year NAO-driven cycles in GWL
- Coincident with recent drought occurrence



Rust et al 2019 ***https://doi.org/10.5194/hess-23-3233-2019***

European Groundwater Drought Initiative

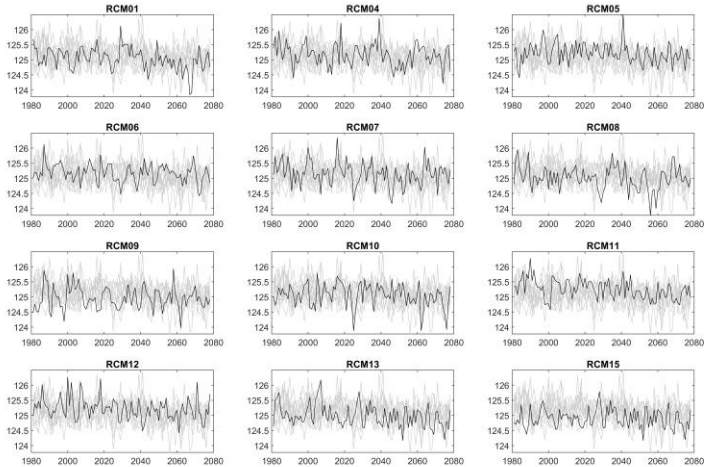


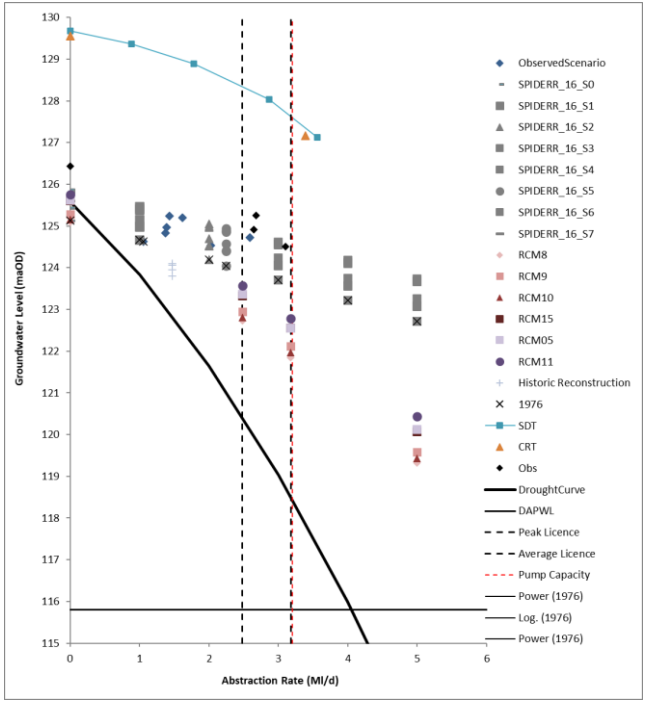
- Large-scale synthesis of European GWL data
- First assessment of spatio-temporal changes in groundwater drought status

Brauns et al 2020
https://doi.org/10.5194/piahs-383-297-2020

Borehole Scale

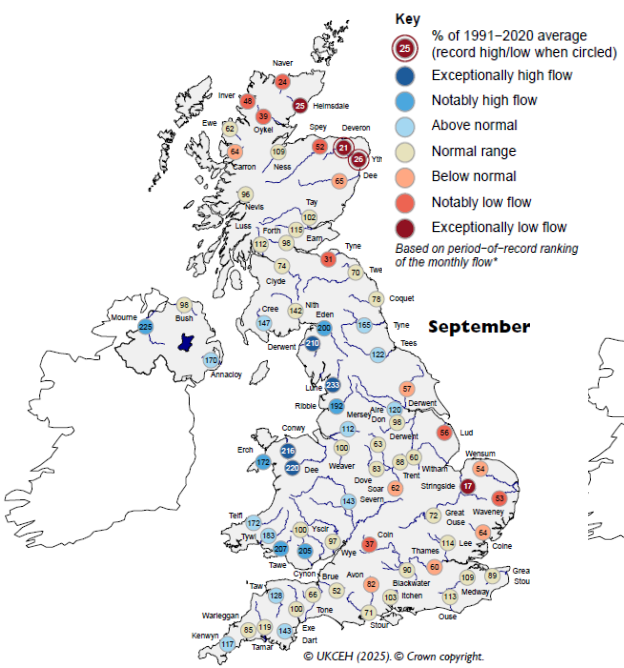
- How do climate change, abstraction and heterogeneity interact to influence the pumped water level in a borehole?



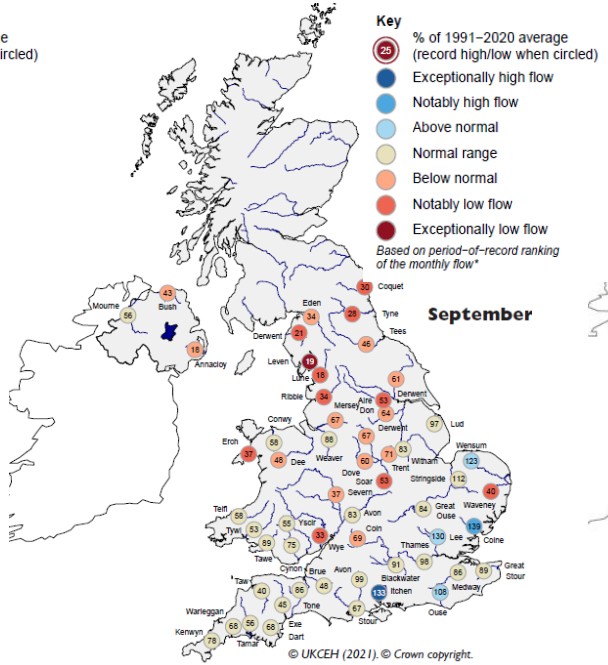


What next?

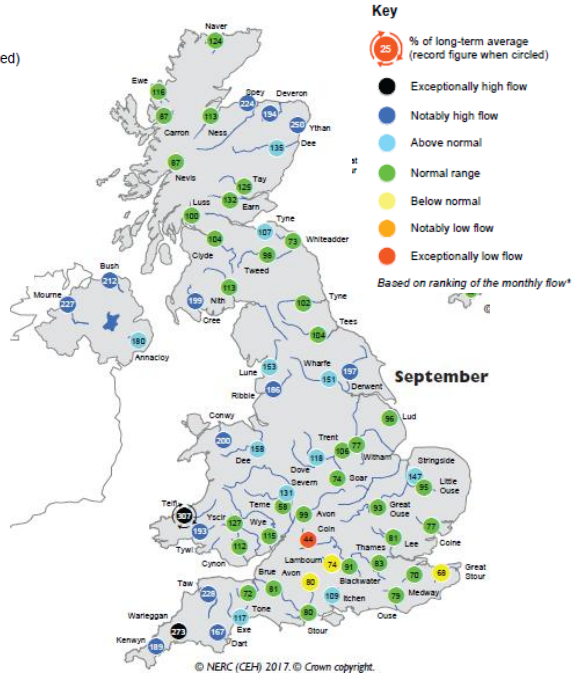
The situation in 2025…



2025

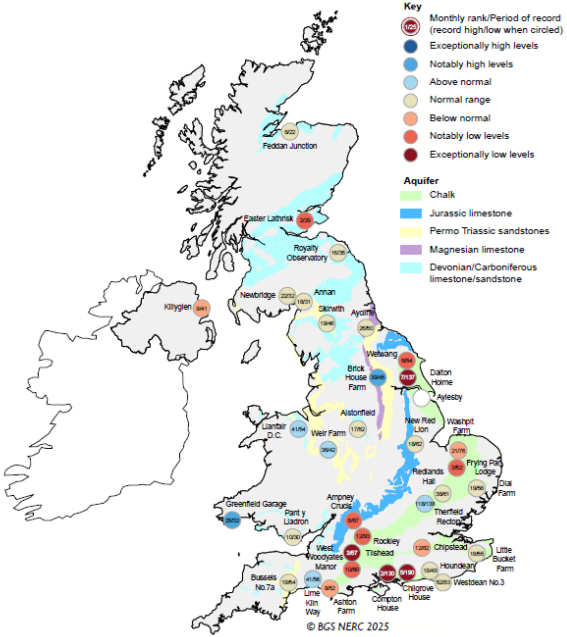


2021

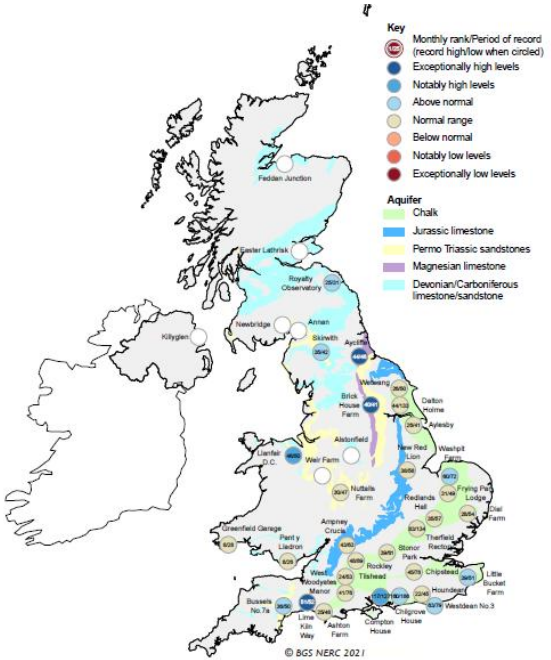


2017

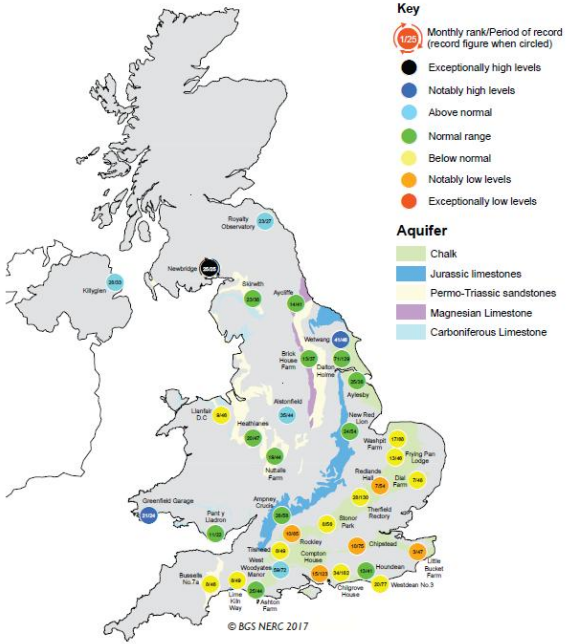
The situation in 2025…



2025



2021



2017

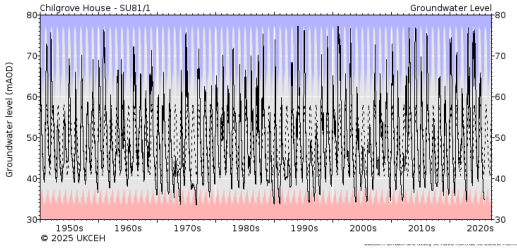
Major knowledge gaps to fill

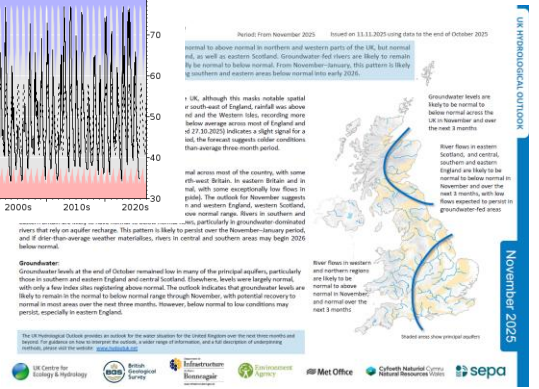
- How does drought propagate through the hydrological system?
- How does abstraction influence drought severity?
- Uncertainty in future projections?
- Downstream impacts?

Data & Analysis

National Groundwater Level Archive

Hydrological Summaries and Outlooks



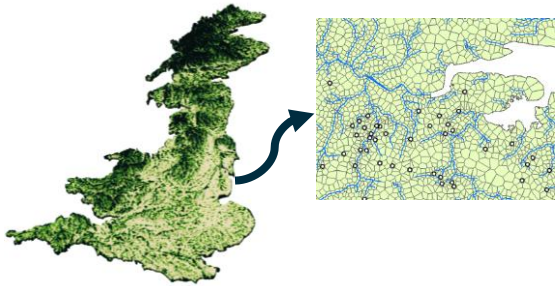


FDRI
FLOODS & DROUGHTS
RESEARCH INFRASTRUCTURE

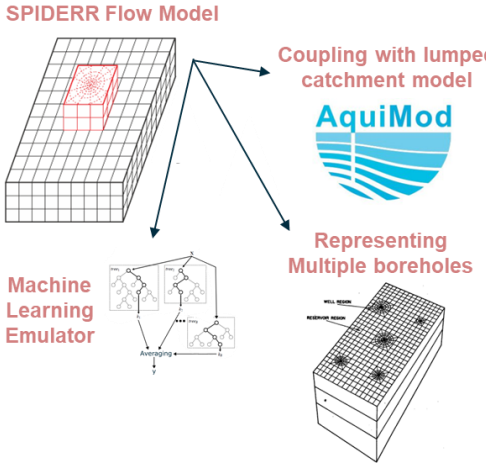
Major knowledge gaps to fill

Models & Tools

British Groundwater Model



GW Deployable Output Tools (GW-DOT)



Climate Change in the Arctic and North Atlantic Region and Impacts on the UK

CANARI

Key Messages

Drought is complex – difficult to define, spatially and temporally variable, with wide-ranging impacts

Drought in the UK is strongly influenced by NW-SE gradients in the climate signal and catchment characteristics, but propagation and human impacts remain key knowledge gaps

Groundwater may be less affected by future climate change than surface water, but uncertainty in future projections is significant

The groundwater narrative

- Have we got it right?
- What more can we do to generate the evidence needed to inform better decisions around groundwater's role in drought resilience and future water security?

The Guardian



British Geological Survey

THANK YOU

Any questions?