Past, Present and Future hydrological variability

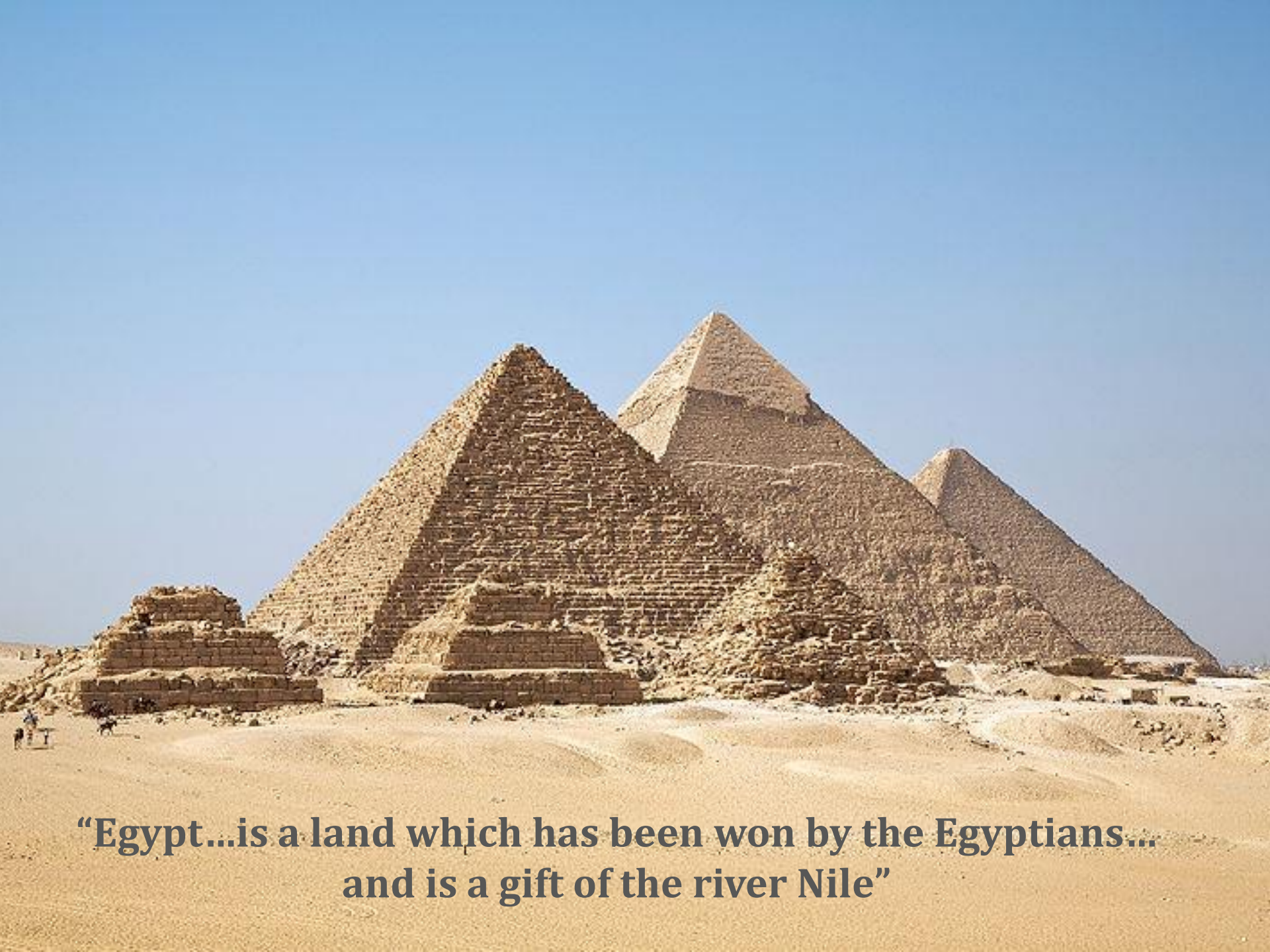
The importance of hydrometric data

Hydro-JULES

Jamie Hannaford

Group Leader,
Hydrological Status
and Outlooks

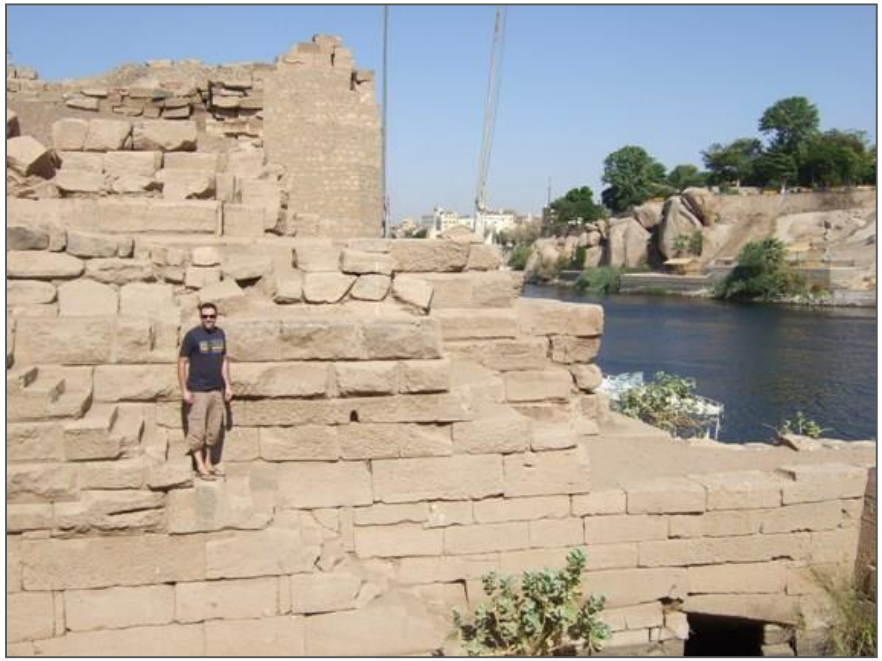
UK Centre for
Ecology & Hydrology



“Egypt…is a land which has been won by the Egyptians… and is a gift of the river Nile”

Hydrological observations: 4000 years ago

'Stage-boards' on Greco-Roman Nilometer



Old Kingdom (< 2000 BCE) Nilometer in 'stilling well'

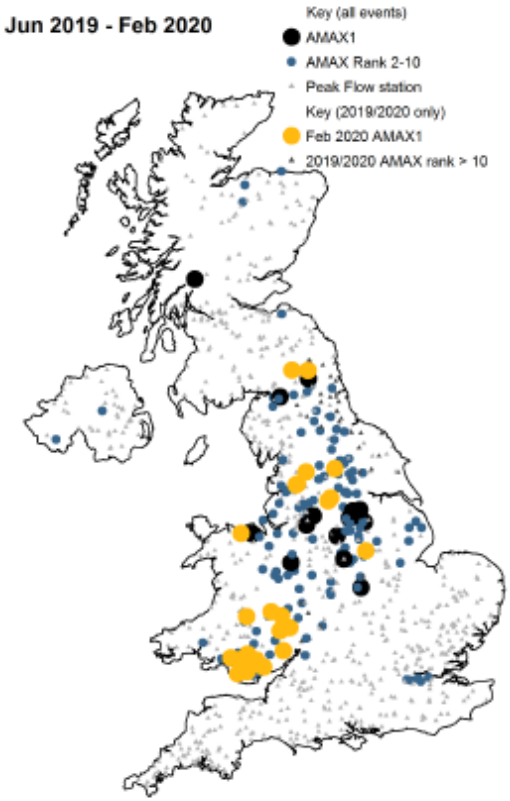
Nilometers on Elephantine Island, Aswan, Upper Egypt

Llwyn-pm reservoir, south Wales, early June 2020. Matthew Horwood. Sunday Times

River Severn at Worcester, 2nd March 2020. (Dave Grubb, via @DaveThroupEA)

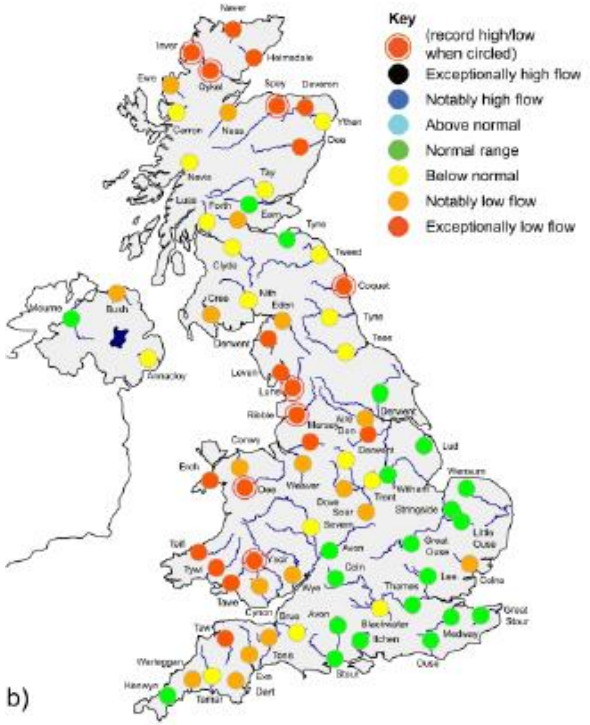
The challenge: water availability and extremes in a warming world

The 2019 – 2020 floods



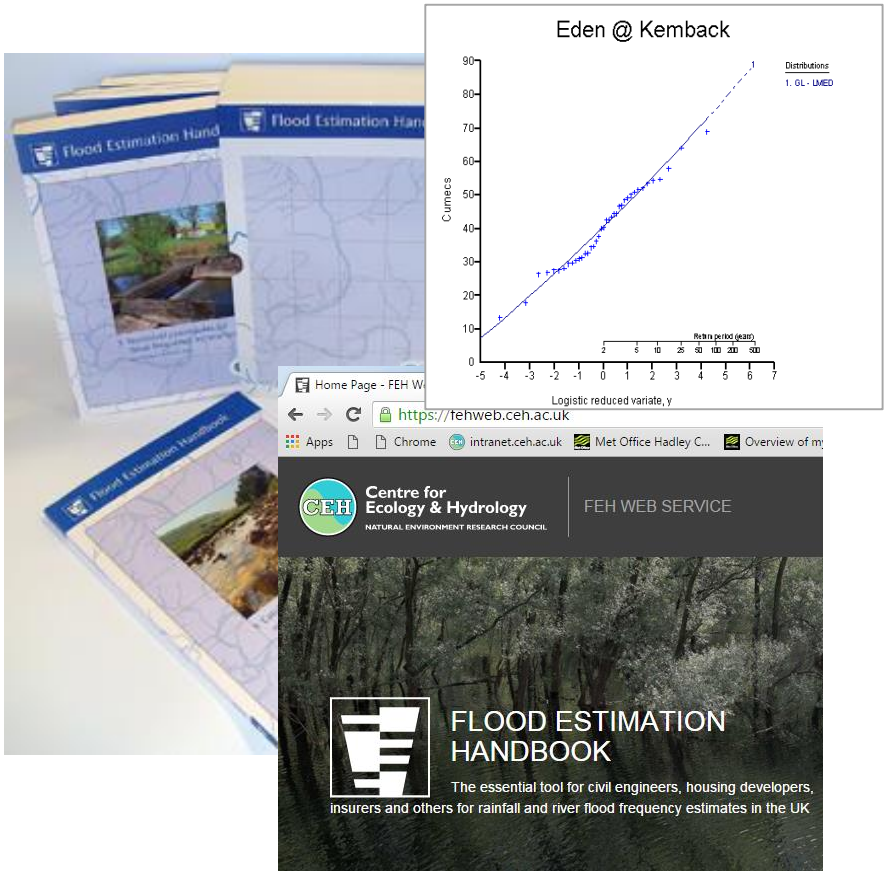
New highest-recorded river flows
(Sefton et al. in press, *Weather*)

The 2018 – 2019 drought



New minimum June-July flows 2018
(Turner et al. in press, *Weather*)

Why is hydrological variability important?



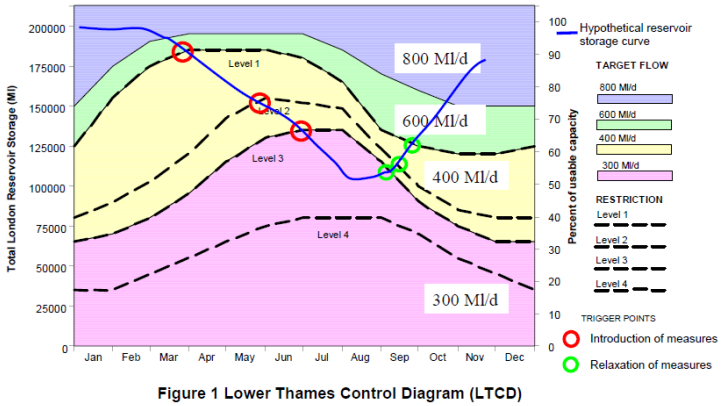


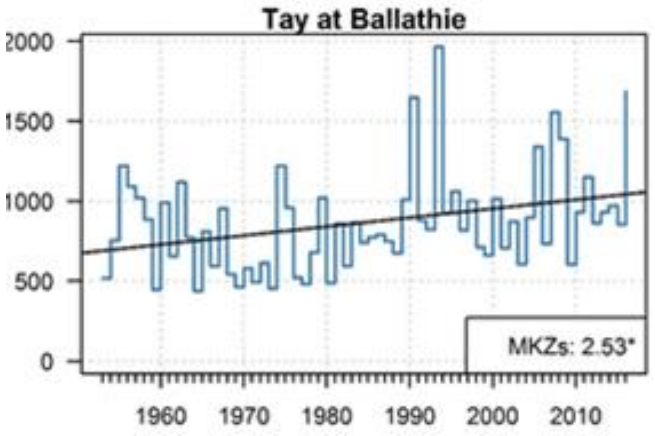
Figure 1 Lower Thames Control Diagram (LTCD)

Risk estimation for engineering design e.g. flood frequency analysis

Design events e.g. 'drought of record' for water resources planning

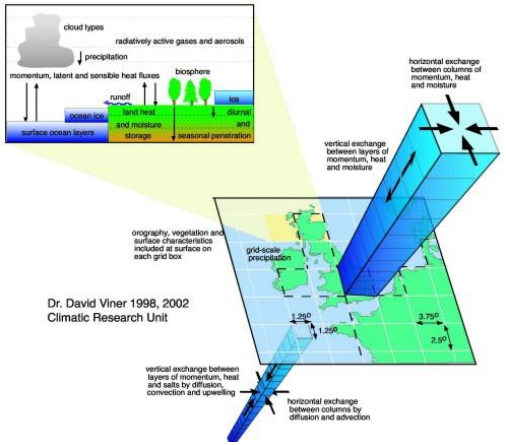
How do we assess changing risk?

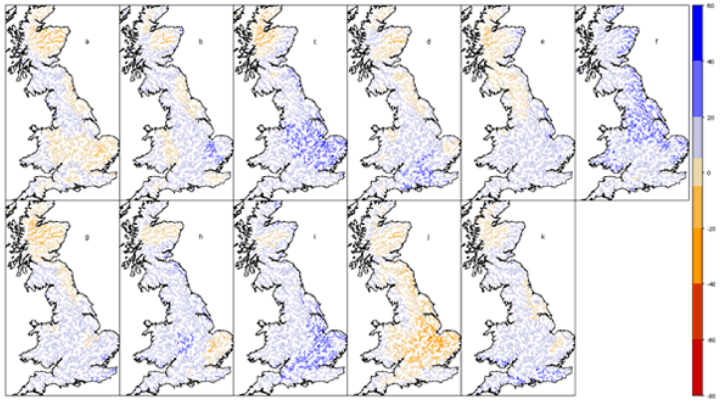
Changes in long-term hydrological datasets



Annual peak flow trends

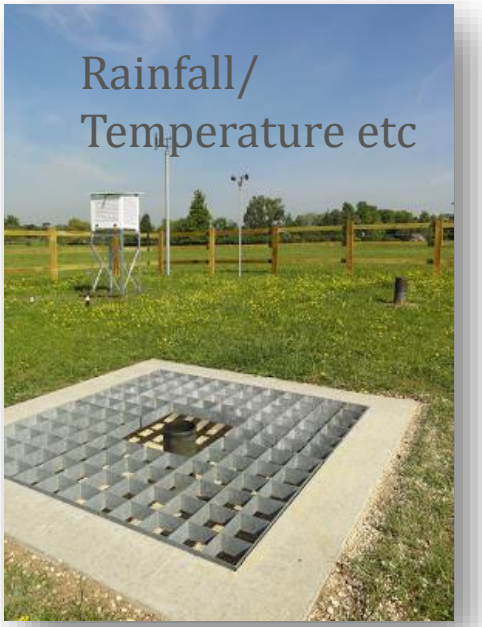
Future climate projections run through hydrological models

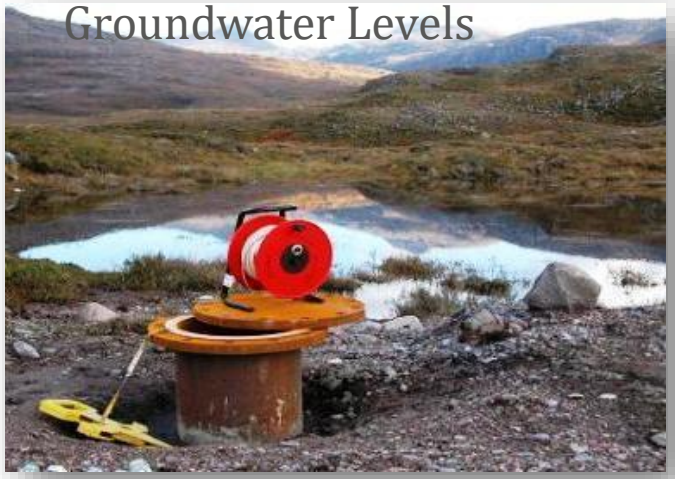




'Future Flows' projections for UK winter river flows

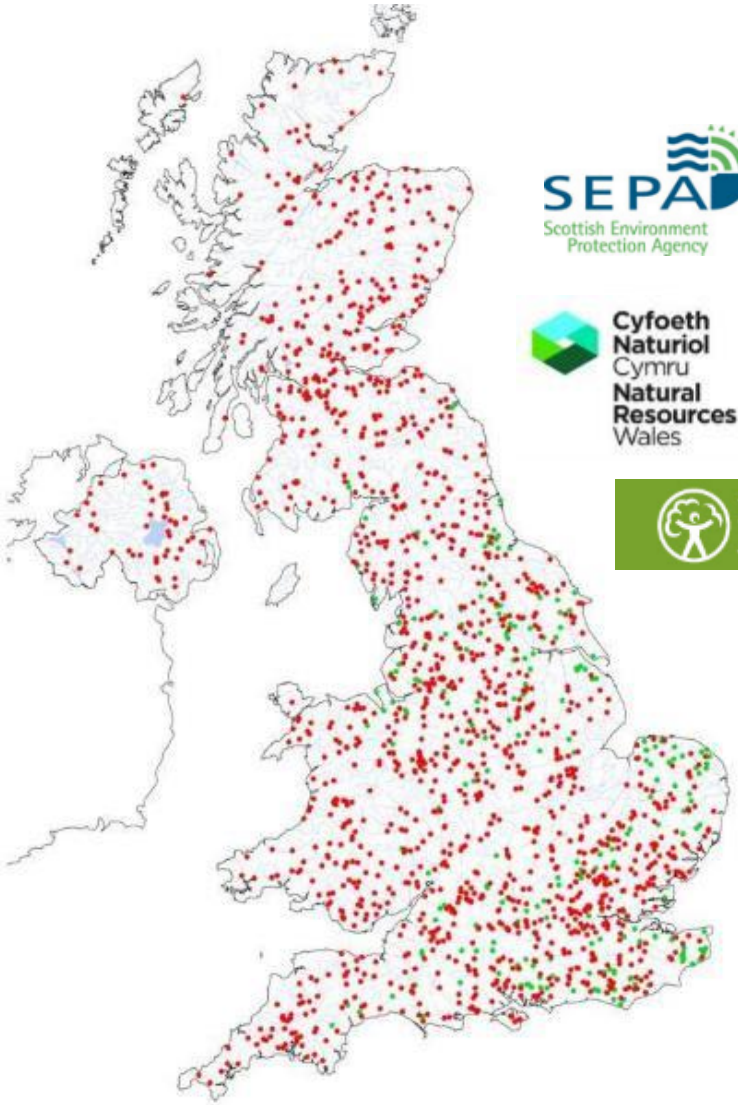
Hydrological data: the foundation for research and decision-making





The UK National River Flow Archive

National River Flow Archive



SEPA Scottish Environment Protection Agency

Cyfoeth Naturiol Cymru Natural Resources Wales

Environment Agency

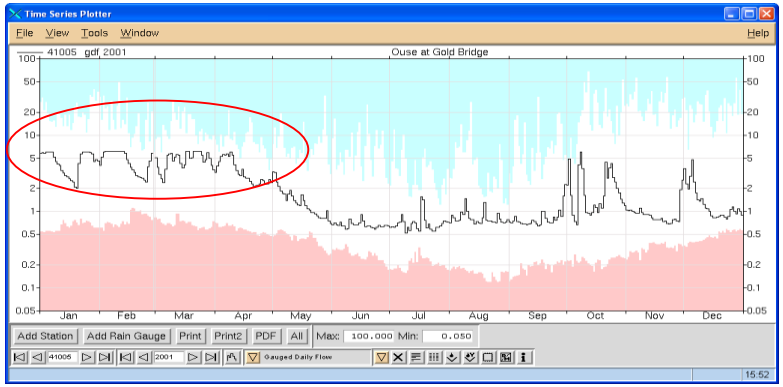
RIVERS Agency

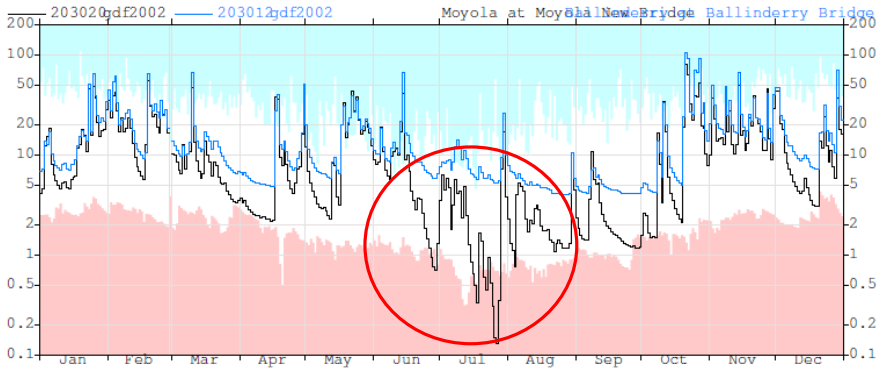
https://nrfa.ceh.ac.uk/

Hydrometric data: caution is required!

Measuring high flows is a challenge!

And low flows aren't necessarily easier!!





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See also the 'Dirty dozen of freshwater science'
Rob Wilby et al. 2017. WIRES Water.

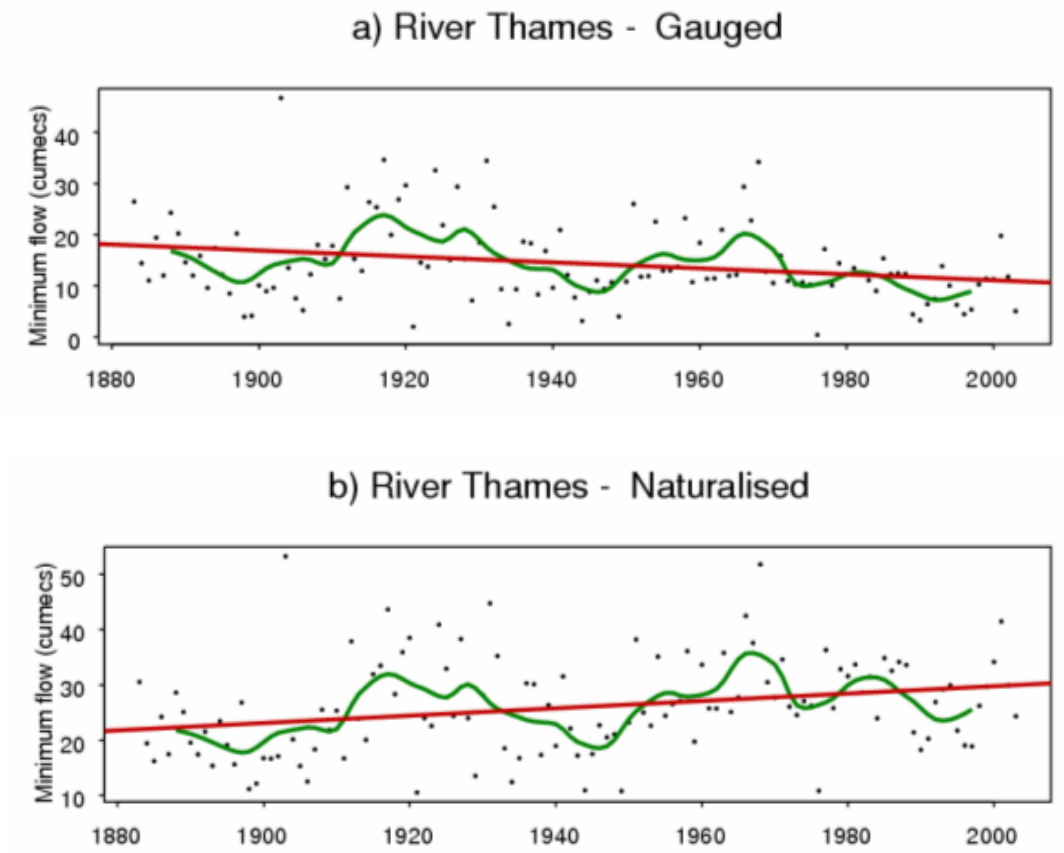
Why is hydrometry like skydiving?

Wikipedia commons

“Getting it right 99% of the time is not enough!” (Terry Marsh)

Hydrometric data: caution is required!

The Thames at Kingston
(Photo: UK Hydrological Yearbook 1983)



River Thames low flows, 1880s – 2000s
Human impacts (in this case water withdrawals for London) can obscure or even reverse natural trends

Hannaford et al. 2006. Int. J. Climatol.

Reference Hydrologic Networks (RHNs)

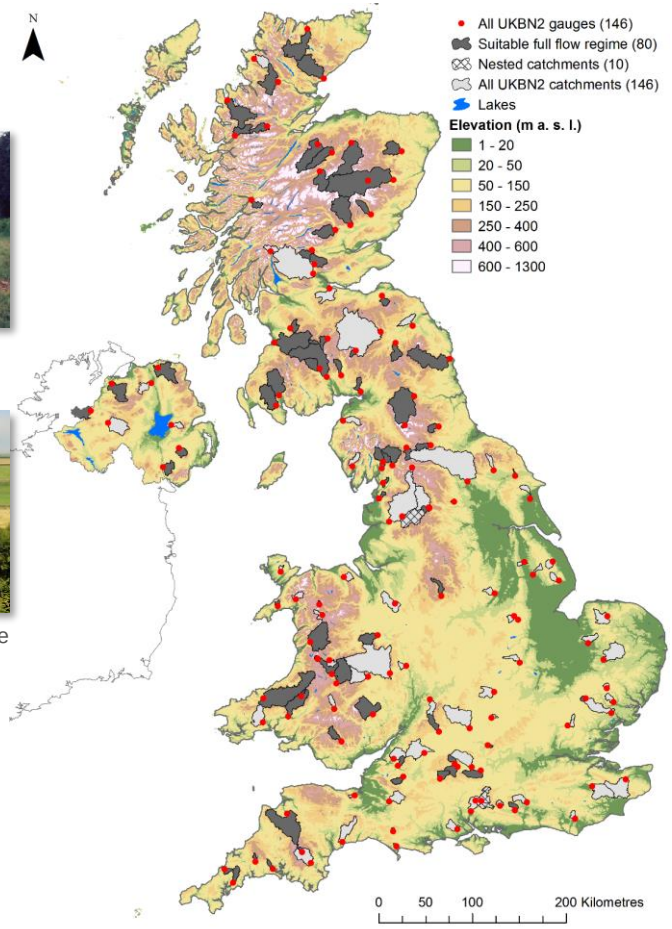
Allow us to discern changes in climate variability from human impacts

The UK Benchmark Network consists of >140 near-natural catchments with good hydrometric performance

Other examples in US, Canada, Australia

Dee at Woodend

South Tyne at Haydon Bridge



Harrigan et al: 2017. Hydrology Research.

Reference hydrologic networks I. The status and potential future directions of national reference hydrologic networks for detecting trends

Paul H. Whitfield[1], Donald H. Burn[2], Jamie Hannaford[3], Hélène Higgins[4], Glenn A. Hodgkins[5], Terry Marsh[3] and Ulrich Looser[6]

[1]*Environment Canada, Vancouver, British Columbia V6C 3S5, Canada*
paul.whitfield@ec.gc.ca
[2]*Department of Civil and Environmental Engineering, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada*
[3]*Centre for Ecology and Hydrology, Wallingford, Oxfordshire OX10 8BB, UK*
[4]*INRS-ETE, Québec, QC, Canada*
[5]*US Geological Survey, Augusta, Maine 04330, USA*
[6]*Global Runoff Data Centre, Koblenz, Germany*

Received 11 May 2011; accepted 17 April 2012; open for discussion until 1 May 2013

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Citation Whitfield, P.H., *et al.*, 2012. Reference hydrologic networks I. The status and potential future directions of national reference hydrologic networks for detecting trends. *Hydrological Sciences Journal*, 57 (8), 1562–1579.

Whitfield et al. 2012. Hydrol. Sci. J
Burn et al. 2012. Hydrol. Sci. J

Long-term trends and variability

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. **26**: 1237–1253 (2006)
Published online 6 March 2006 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/joc.1303

AN ASSESSMENT OF TRENDS IN UK RUNOFF AND LOW FLOWS USIN
A NETWORK OF UNDISTURBED CATCHMENTS

JAMIE HANNAFORD* and TERRY MARSH
Centre for Ecology and Hydrology, Wallingford, OX10 8BB, UK

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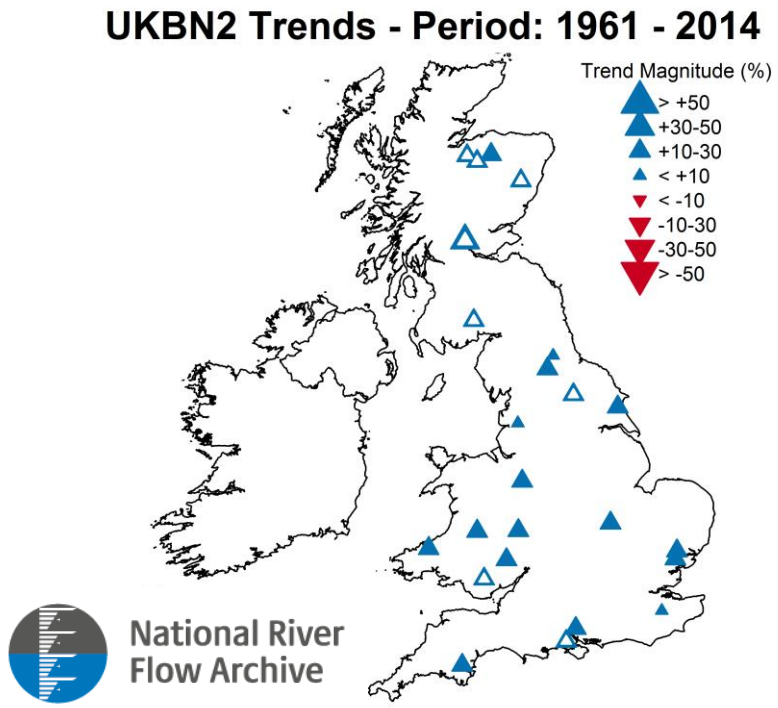
Revised 17 November 2005
Accepted 23 November 2005

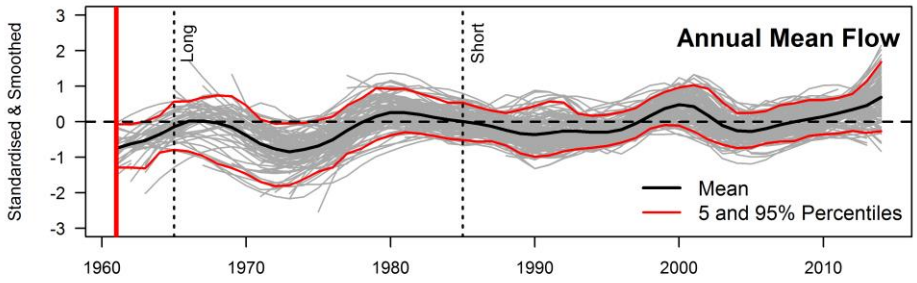
INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. **28**: 1325–1338 (2008)
Published online 22 November 2007 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/joc.1643

RMetS
Royal Meteorological Society

High-flow and flood trends in a network of undisturbed catchments in the UK

Jamie Hannaford* and Terry J. Marsh
Centre for Ecology and Hydrology, Wallingford, OX10 8BB, UK



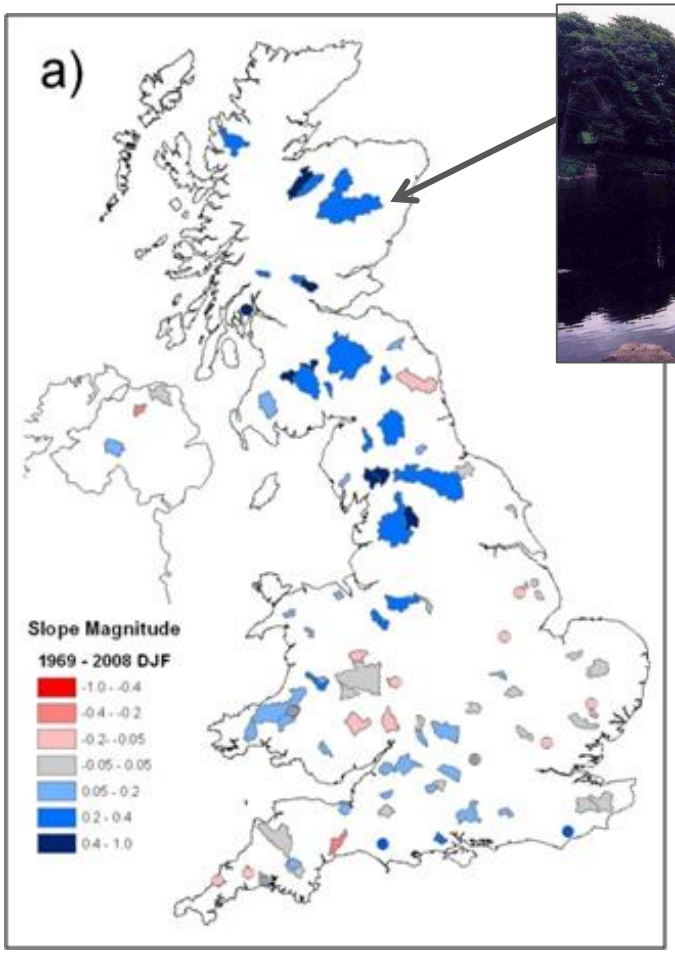


Harrigan et al: 2017

Designation and trend analysis of the updated UK Benchmark Network of river flow stations: The UKBN2 dataset
Hydrology Research

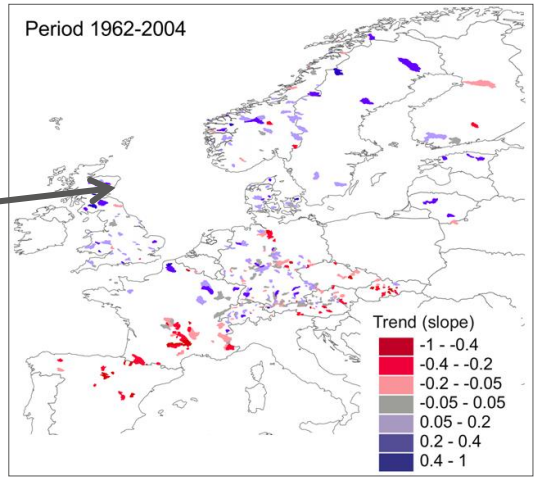
UK Centre for Ecology & Hydrology

From local to global



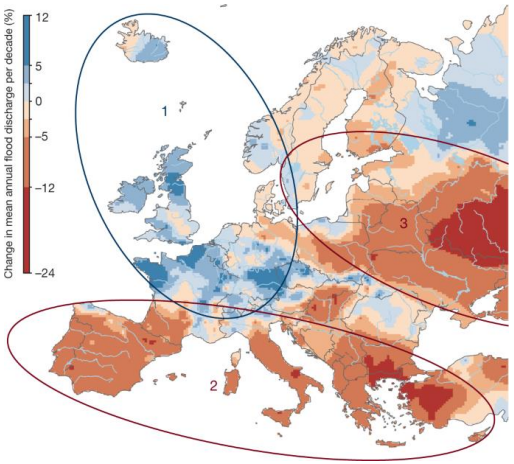
Winter runoff trends 1969 - 2008

Hannaford & Buys, 2012



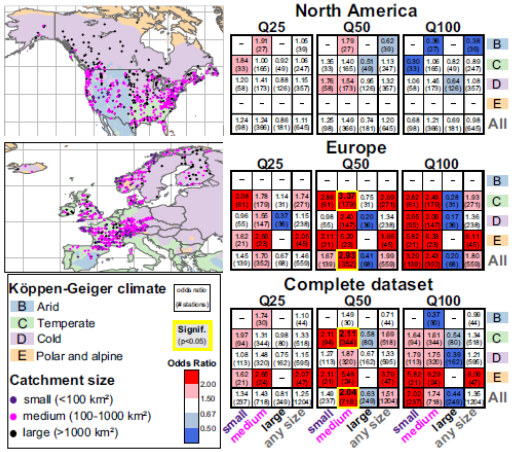
European runoff trends

Stahl et al. 2010



European flood trends

Bloschl et al: 2019



Europe/N. America flood trends

Hodgkins et al: 2017

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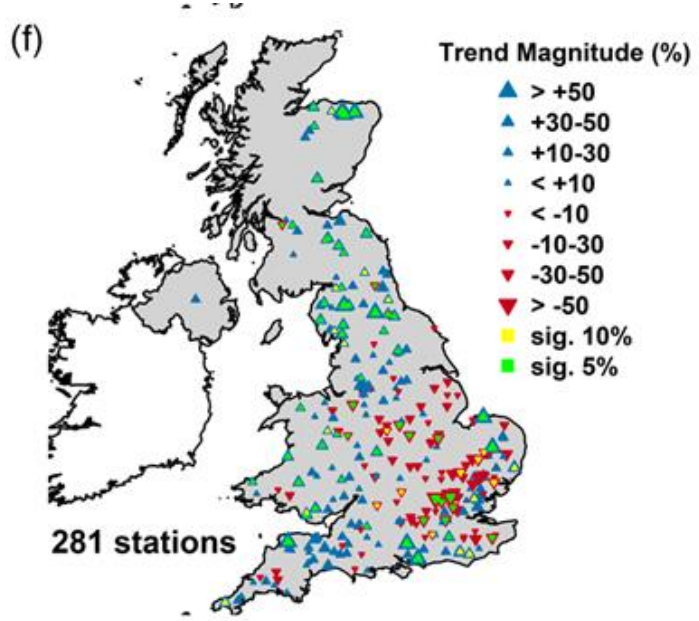
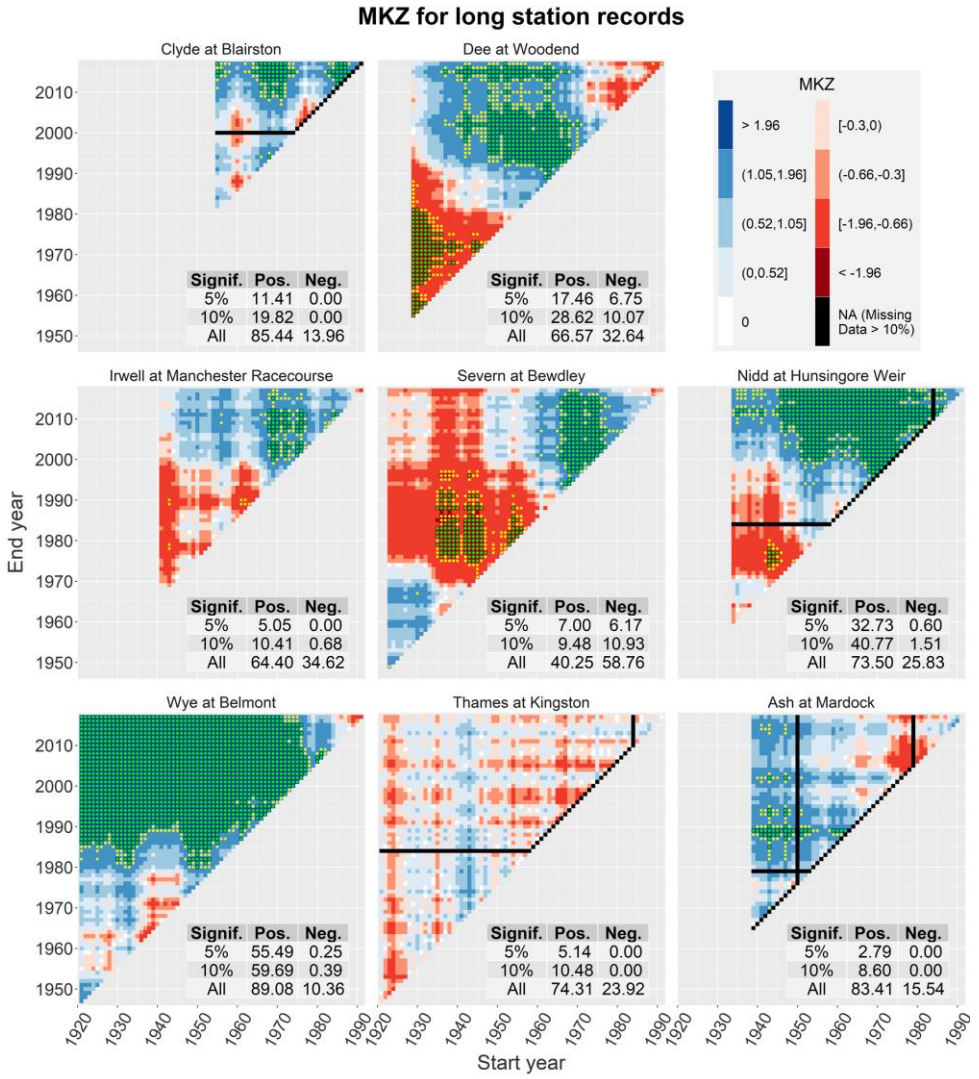
A problem…



Flood trends, 1969 - 2018

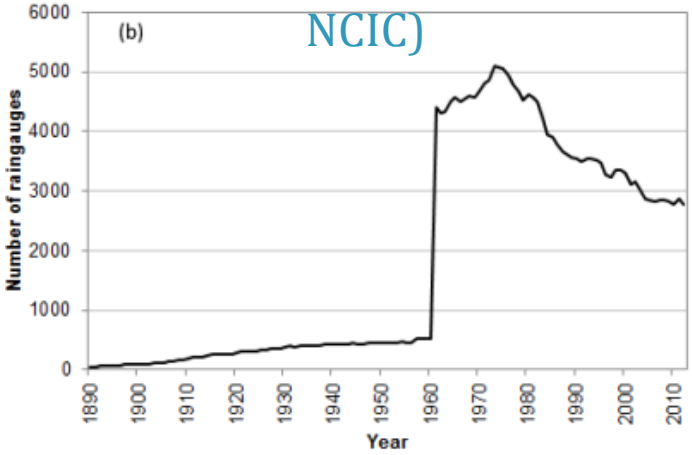


Headline of ‘increased flooding in NW Britain’ is just one pixel in these plots…..

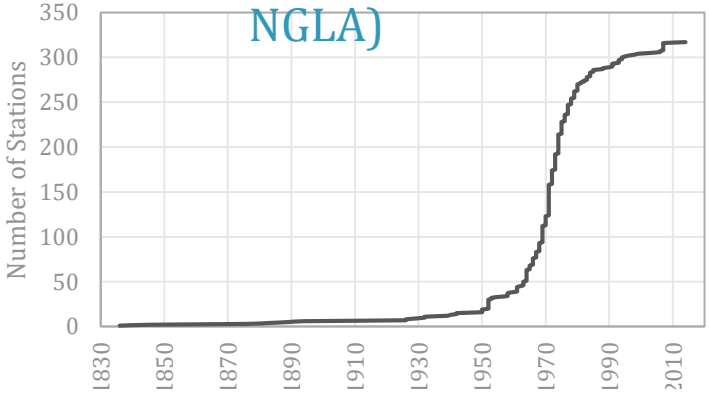
Hannaford et al. 2021. Hydrology Research

Most hydrological records are short…

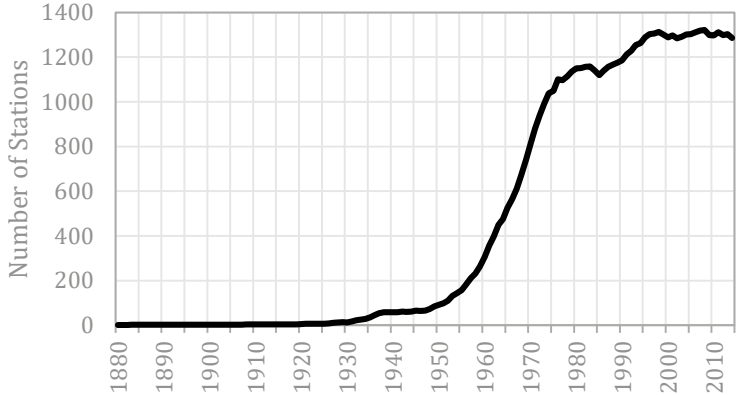
Daily Precipitation (Met Office: NCIC)



Groundwater (BGS: NGLA)



Streamflow (CEH: NRFA)



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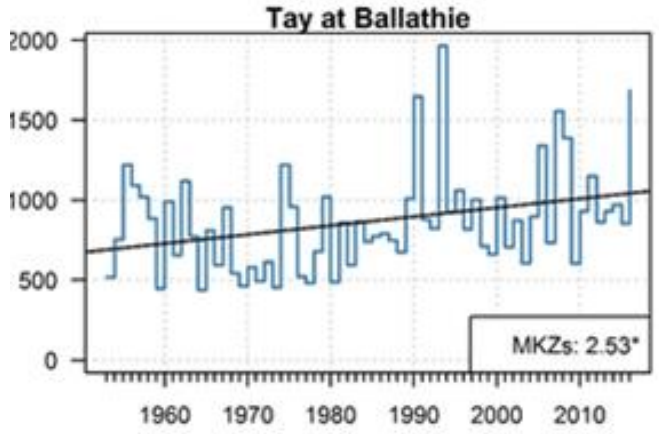
Precipitation graph - Keller, VDJ et al (2015) Earth Syst. Sci. Data 7, 143-155

How do we assess changing risk?

Trends in long-term hydrological datasets



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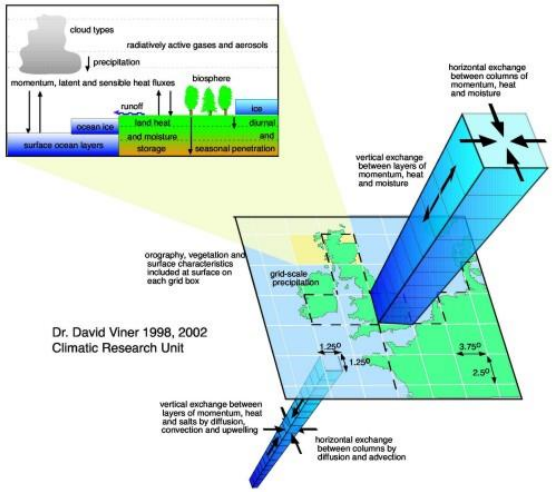
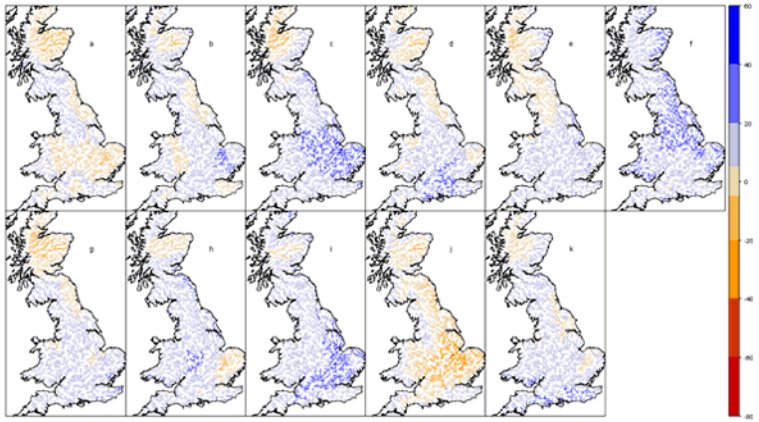
Future climate projections run through hydrological models





Future Flows projections
for winter river flows

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Pushing back in time using models

'Historic Droughts' reconstructions

Catchment/aquifer models:

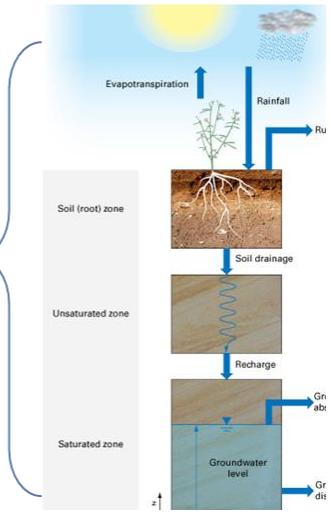
- **GR4J**
- **AquiMod**

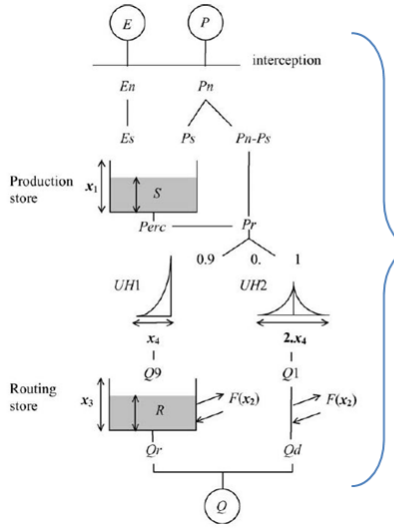
300+ catchments across UK

100+ groundwater boreholes across UK

Ensemble reconstruction with uncertainty

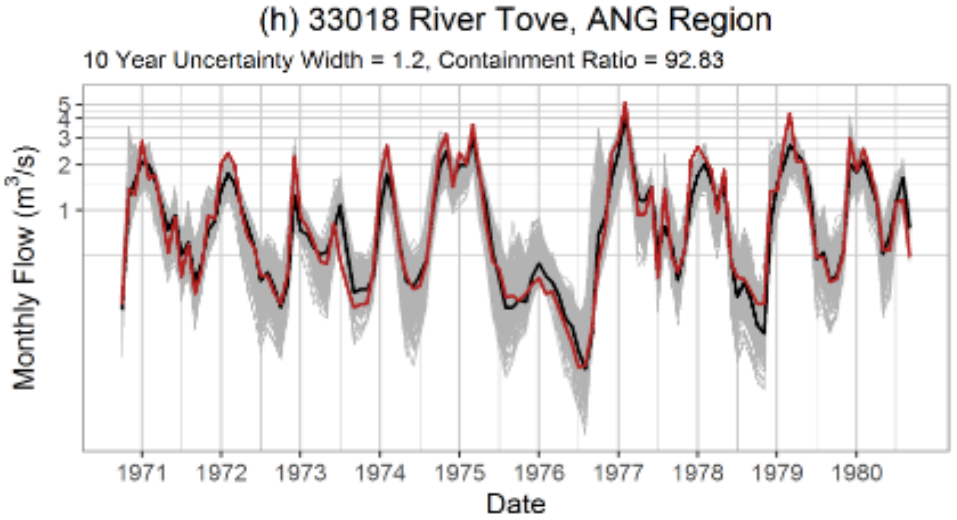
AQUIMOD (groundwater)





GR4J (streamflow)

Katie Smith et al. 2019 (*HESS*).



https://historicdroughts.ceh.ac.uk/content/datasets

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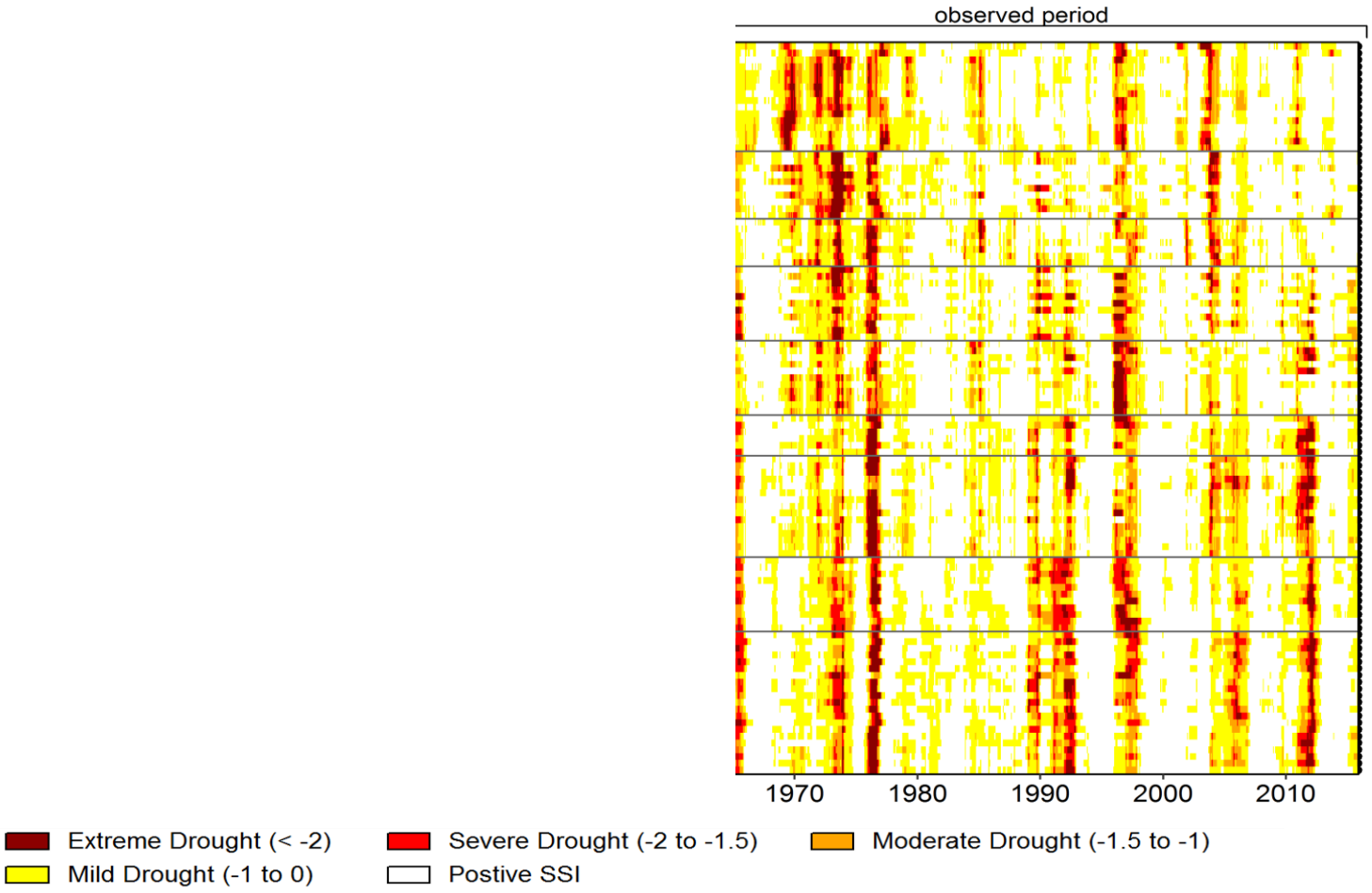
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Met Office

Hydrological droughts: a longer view



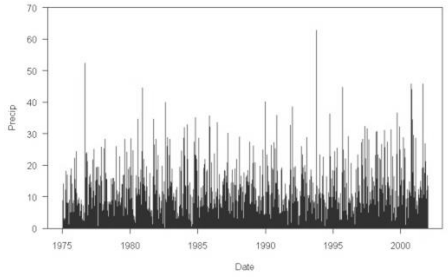
Lucy Barker et al. 2019 (*HESS*).

Historic Droughts

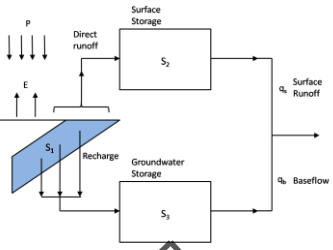
https://historicdroughts.ceh.ac.uk/content/datasets

Future hydrological variability

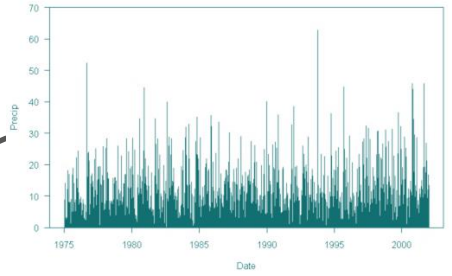
'Current' climate time series (e.g. 1971-2000)



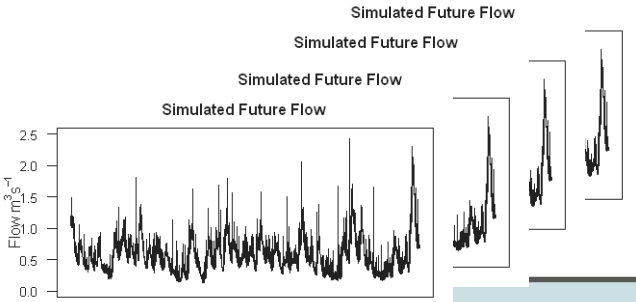
Impact model



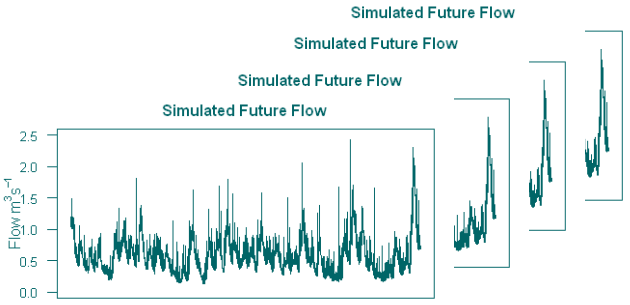
'Future' climate time series (e.g. 2071-2100)



'Current' river flow time series



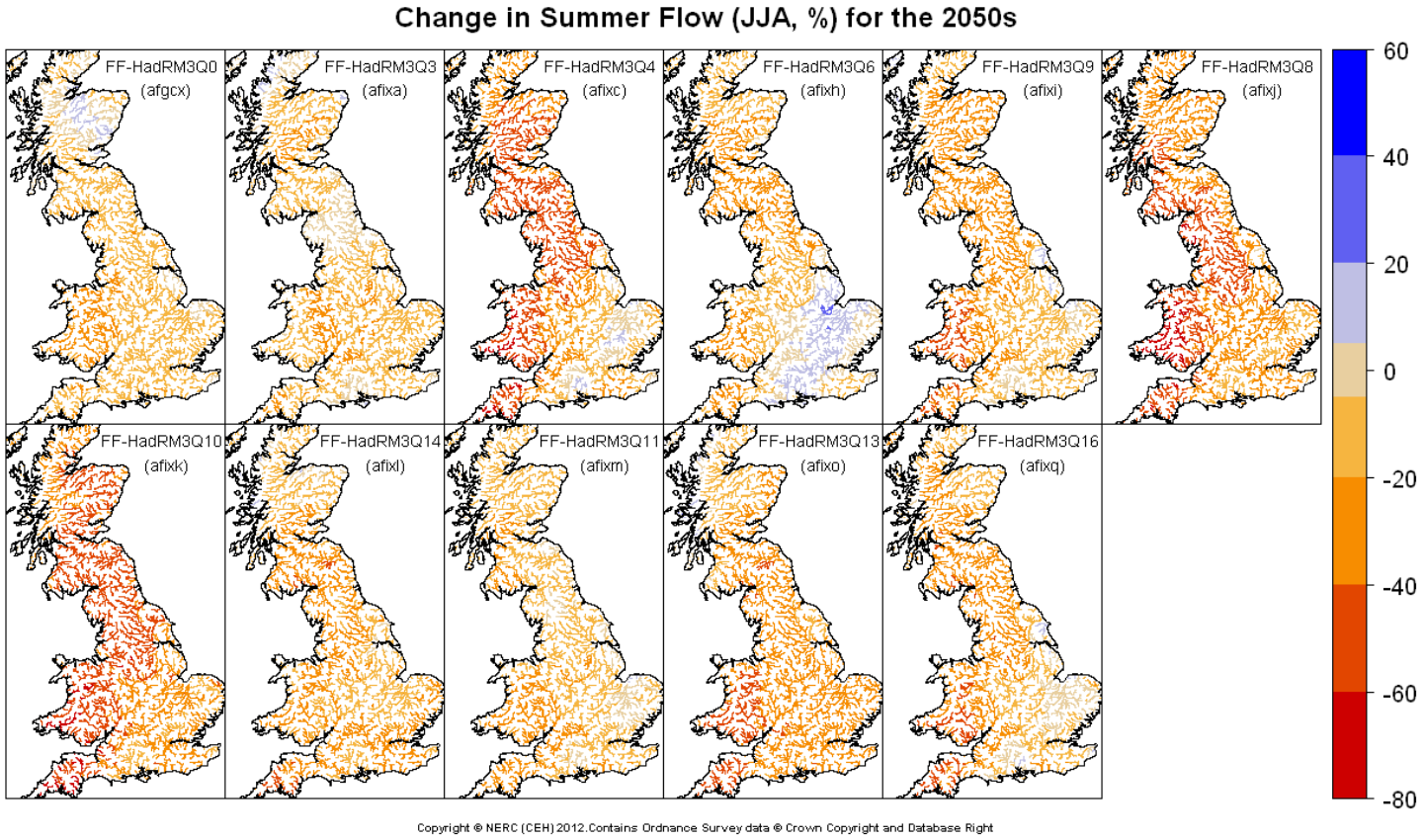
'Future' river flow time series



Compare and quantify changes

One change per future run/ scenario

Future hydrological change in the UK



Future Flows and Groundwater Levels (Prudhomme et al. 2013)

11x member UKCP09 RCM ensemble run through three hydrological models

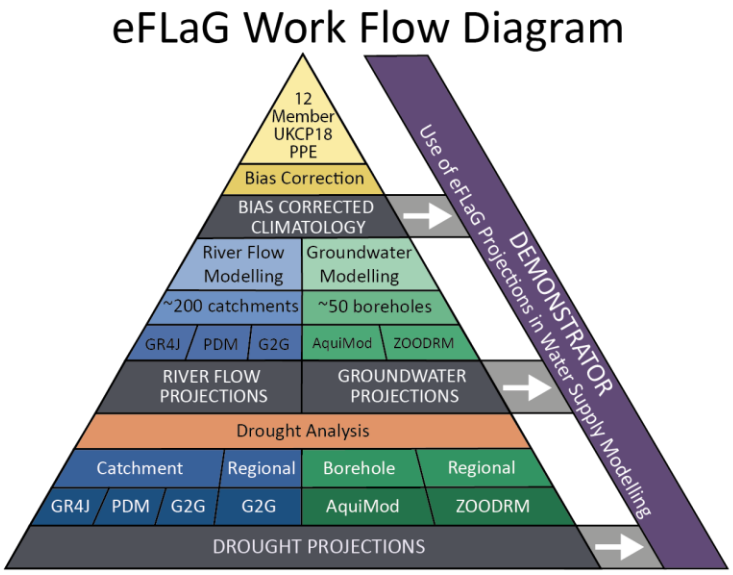
Here: summer flows for the 2050s

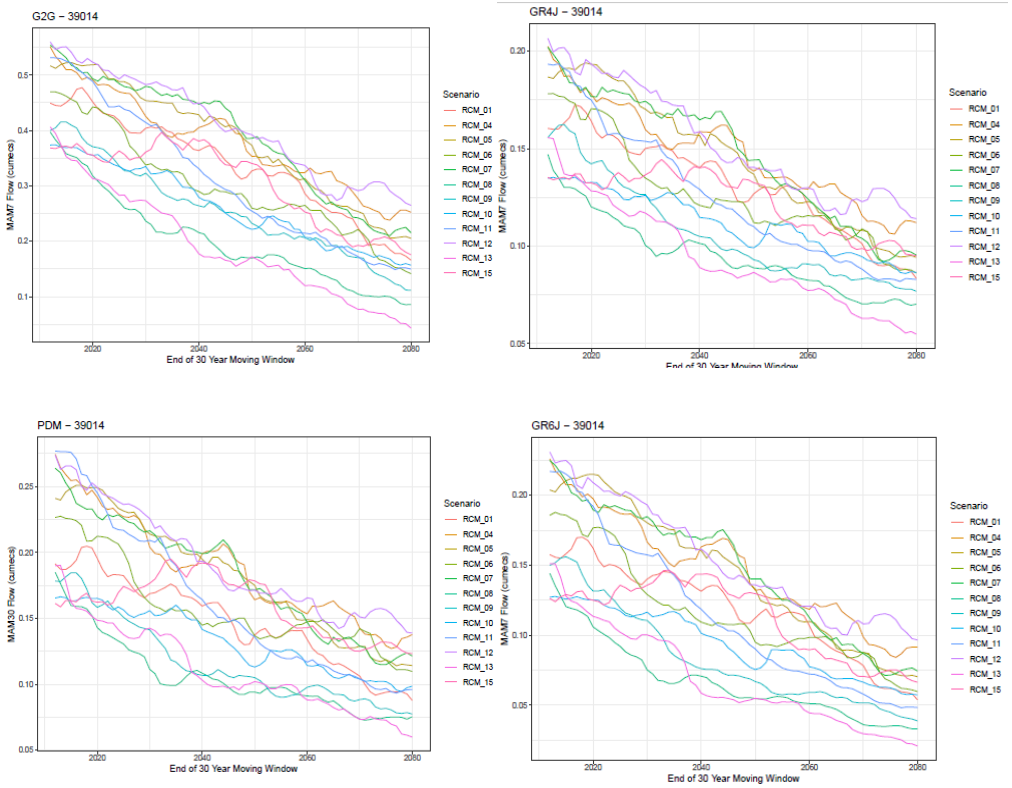
Enhanced Future Flows & Groundwater (eFLaG)

https://www.ceh.ac.uk/our-science/projects/eflag-enhanced-future-flows-and-groundwater

Nationally consistent hydrological projections based on UKCP18

200 catchments (50 groundwater boreholes)





Projections for the 21st C:
minimum flows in 30-year moving windows to 2080. 12x RCM runs, 4x hydrological models

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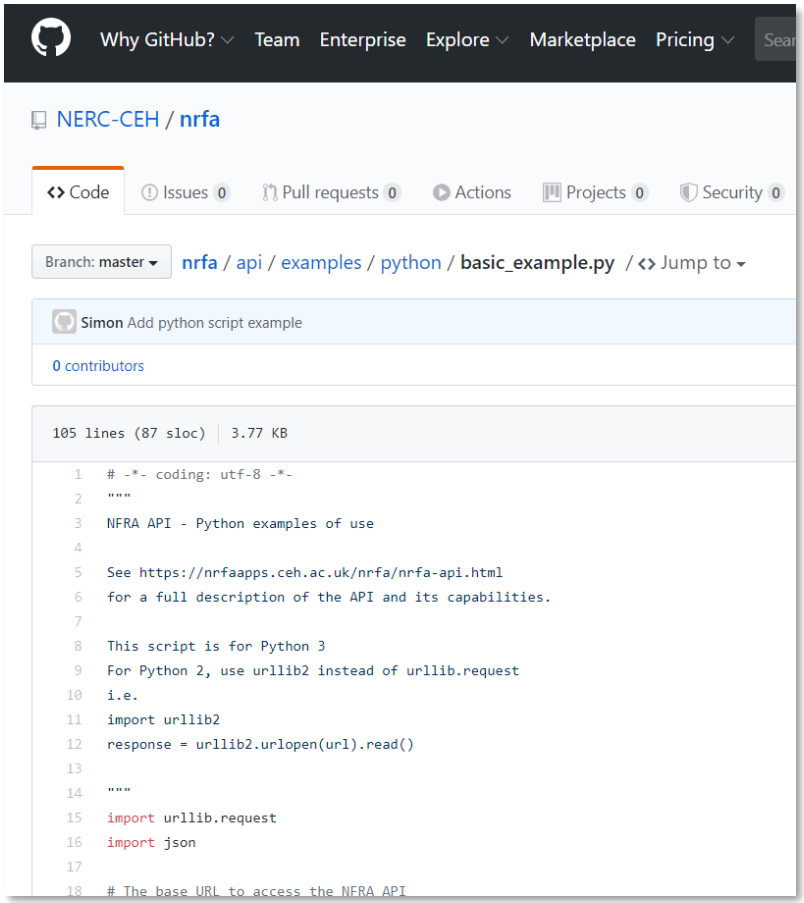
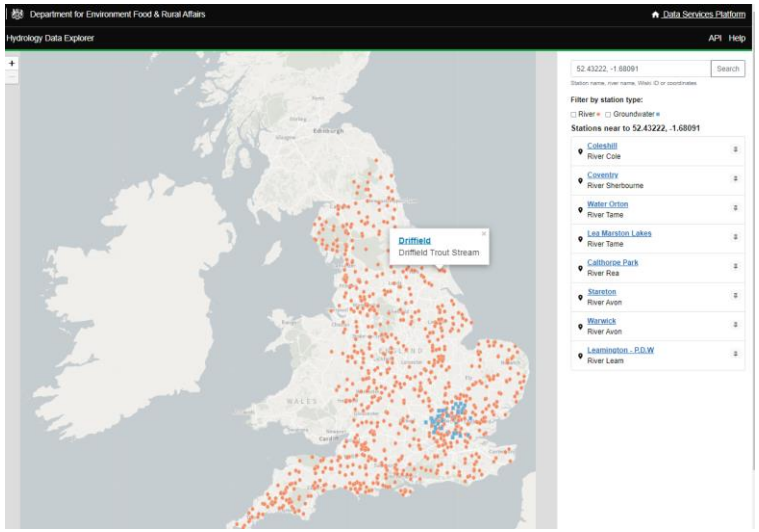
Managing variability in the here and now…

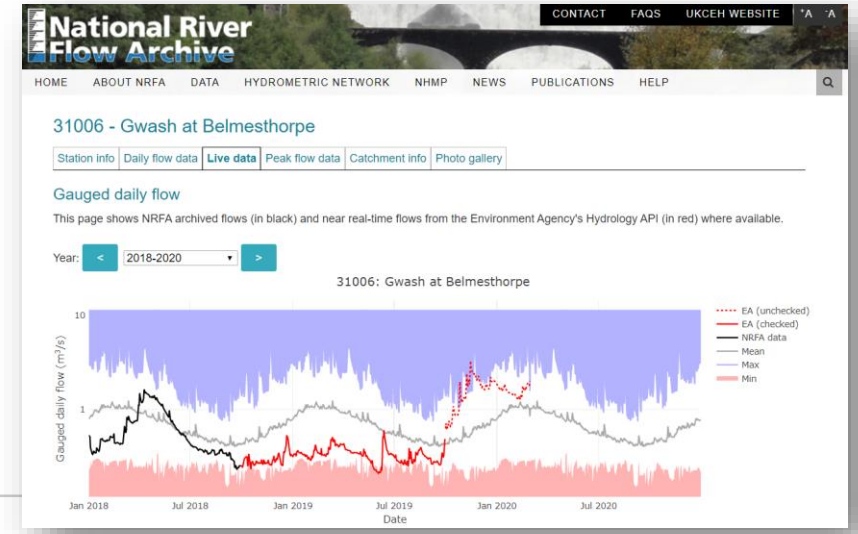
Data accessibility



National River Flow Archive API
http://nrfaapps.ceh.ac.uk/nrfa/nrfa-api.html



EA Hydrology Data Explorer (&API)
https://environment.data.gov.uk/hydrology/index.html#/landing



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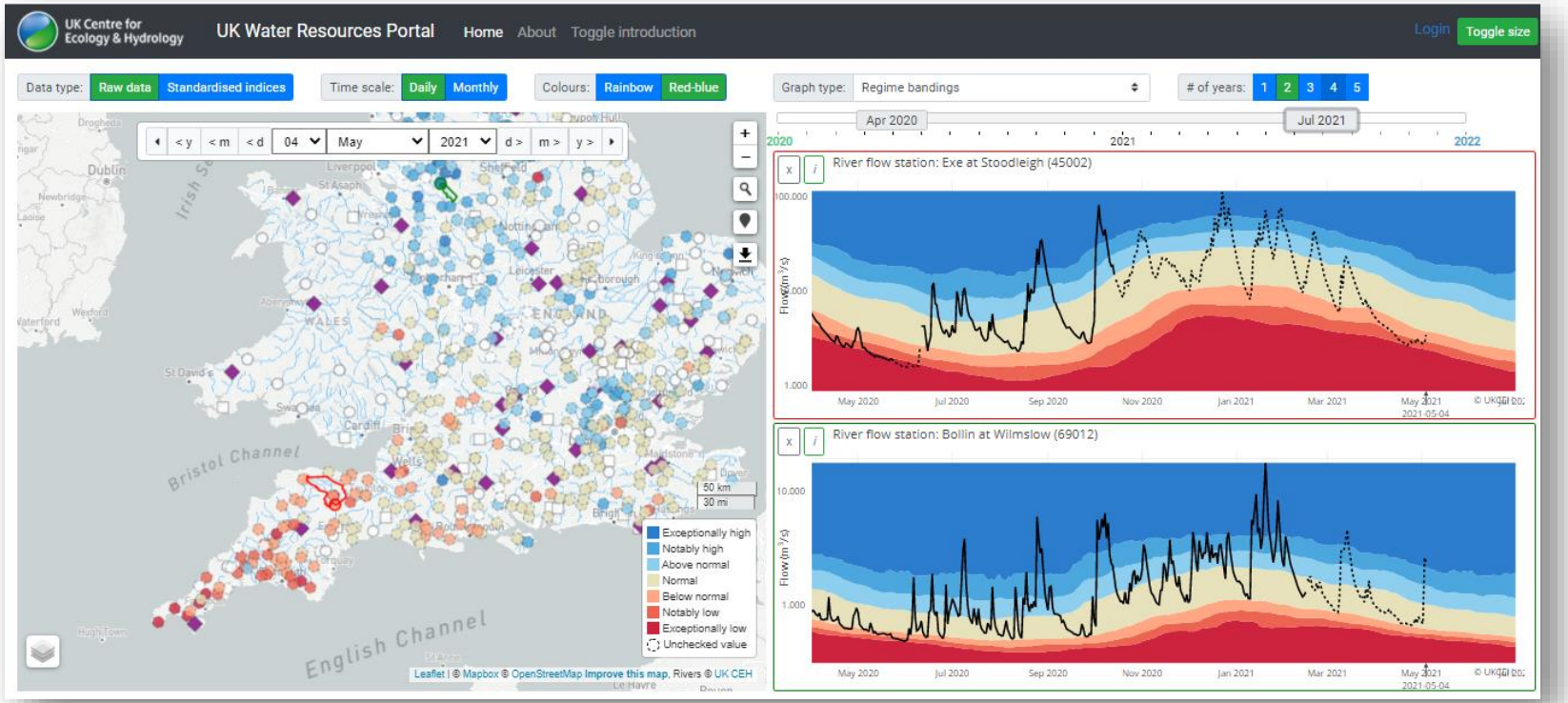
Interactive, real-time status monitoring: the UK Water Resources Portal (launched 2020)



- Daily **real-time** river flows (>670 sites)
- **Real-time** COSMOS-UK soil moisture (50 sites)
- Groundwater (>50 boreholes)
- Rainfall (catchment and 1km^2 grid across UK)

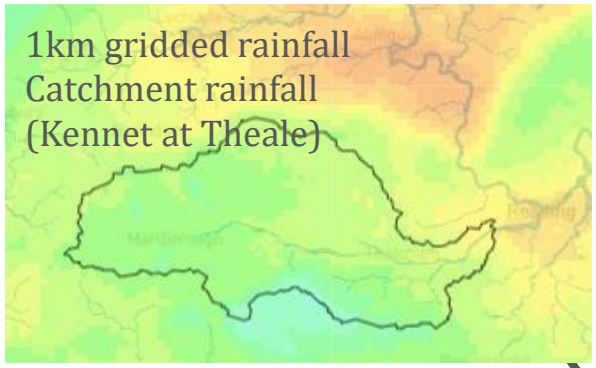
https://eip.ceh.ac.uk/hydrology/water-resources/

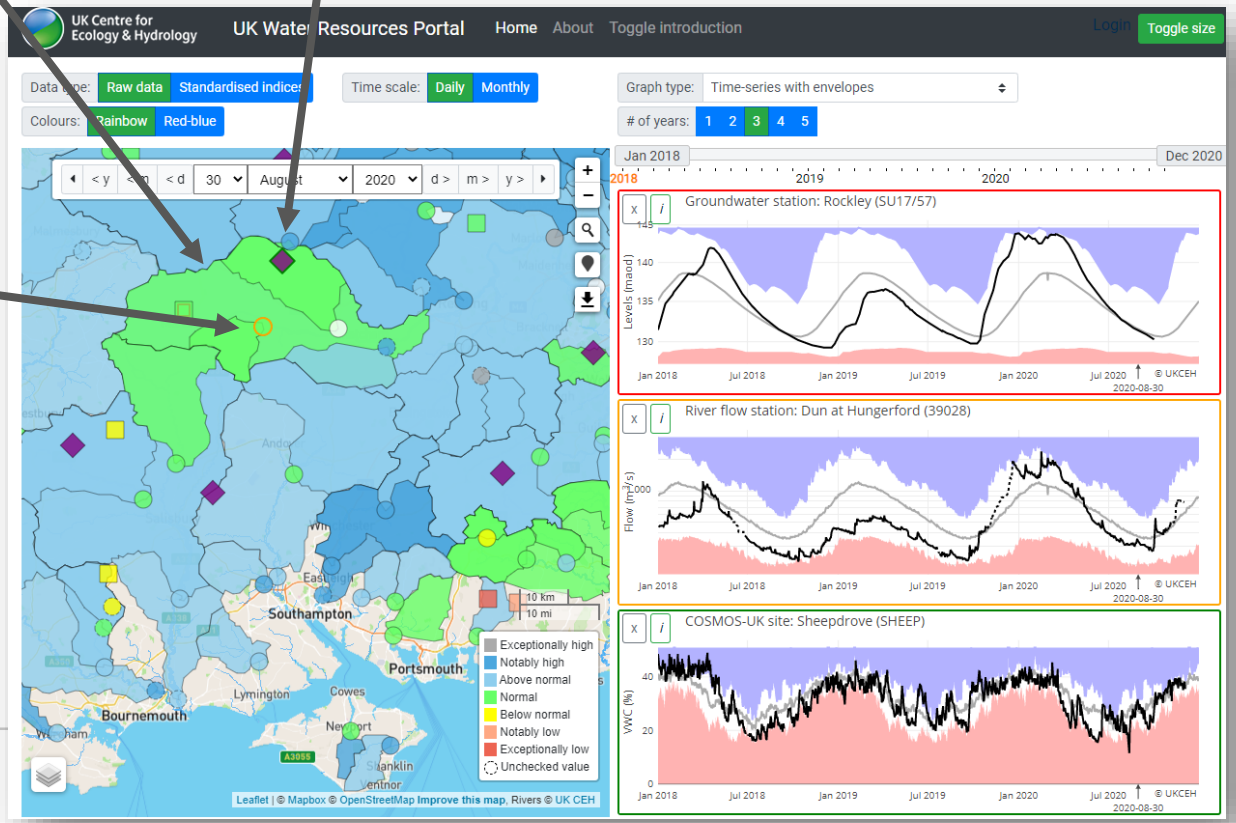
UK Centre for Ecology & Hydrology

UK-SCAPE
UK Status, Change and Projections of the Environment

About Drought
Maximising the impact of UK research on drought & water scarcity

Data integration across the water cycle





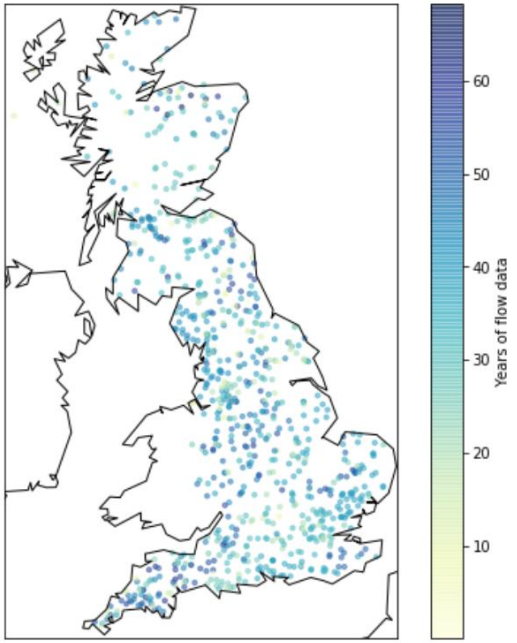
Layering catchment rainfall, soil moisture, river flows and groundwater

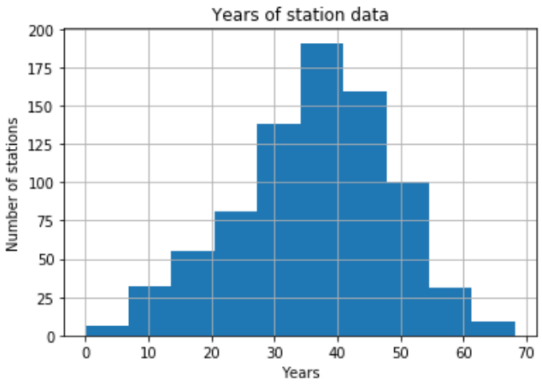
UK Centre for Ecology & Hydrology

Improving data access in Hydro-JULES

Hydro-JULES is:

- Collating datasets from UK agencies
  - Rainfall : tipping bucket, 15 minute, hourly
  - Streamflow : 15 minute data, 800 stations
  - COSMOS-UK, etc.
- Providing access via JASMIN
- Resolving data licensing
- Producing data products (e.g. CEH-GEAR-1hr)





Thanks to Matt Fry

Thank you

Thank you

Any questions?

jaha@ceh.ac.uk

National River Flow Archive

https://nrfa.ceh.ac.uk/

National Hydrological Monitoring Programme

https://nrfa.ceh.ac.uk/nhmp

Hydrological Outlooks

https://www.hydoutuk.net/

UK Water Resources Portal

https://eip.ceh.ac.uk/hydrology

eFLaG

https://www.ceh.ac.uk/our-science/projects/eflag-enhanced-future-flows-and-groundwater

CAMELS-GB

UKCEH partners (with BGS) in U. Bristol led collaboration

Developed first ‘large sample hydrology’ dataset for the UK

Access to over 600 NRFA stations, and accompanying metadata and statistics

Largely based on NRFA and other UKCEH datasets (CEH-GEAR, CHESS)

Earth System Science Data
The data publishing journal

https://doi.org/10.5194/essd-2020-49

Preprints

Abstract | Assets | Discussion | Metrics

Submitted as: data description paper

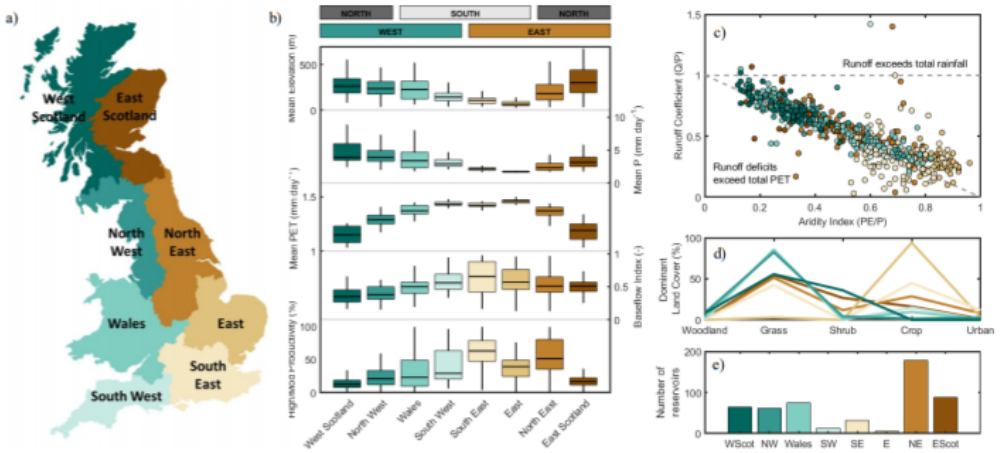
14 Apr 2020

Review status
This preprint is currently under review for the journal ESSD.

CAMELS-GB: Hydrometeorological time series and landscape attributes for 671 catchments in Great Britain

Gemma Coxon[1,2], Nans Addor[3,a], John P. Bloomfield[4], Jim Freer[1,2], Matt Fry[5], Jamie Hannaford[5,6], Nicholas J. K. Howden[2,7], Rosanna Lane[1], Melinda Lewis[4], Emma L. Robinson[5], Thorsten Wagener[2,7], and Ross Woods[2,7]

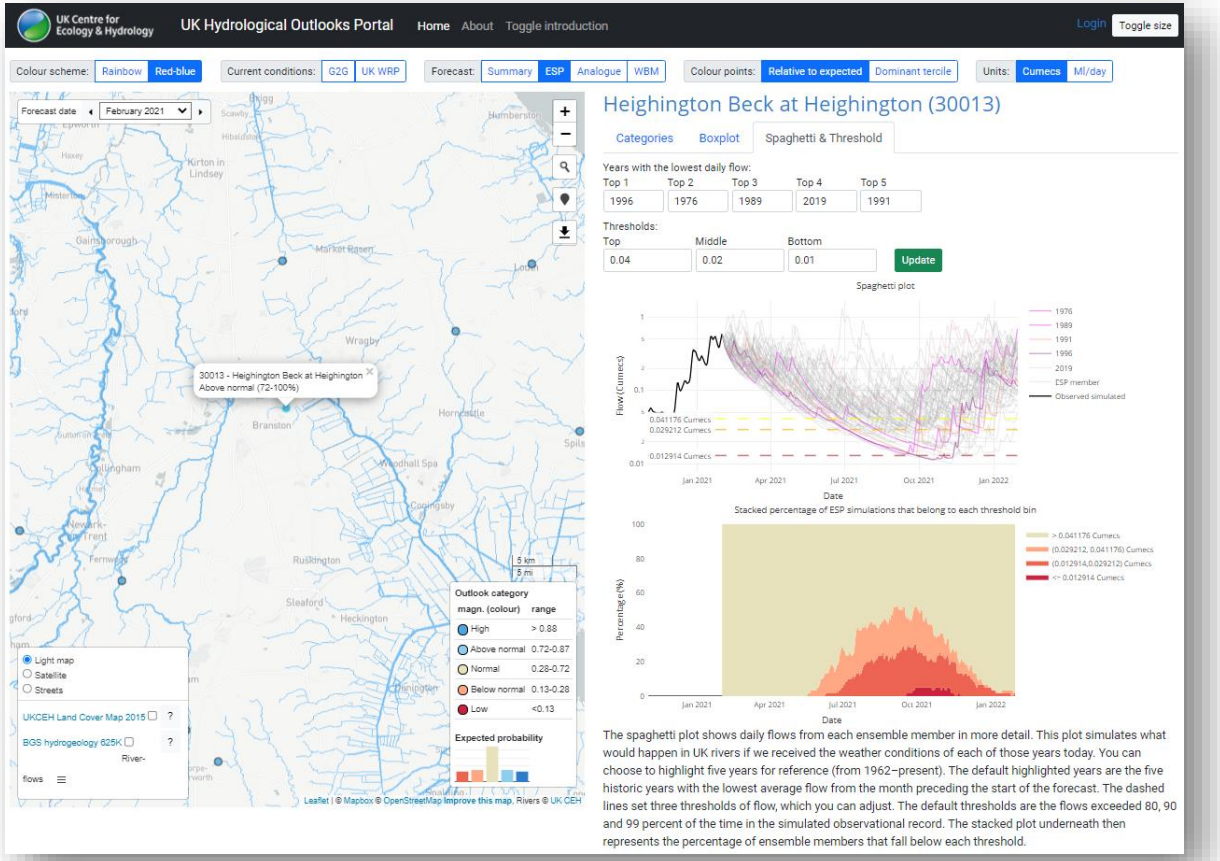
[1]Geographical Sciences, University of Bristol, Bristol, UK
[2]Cabot Institute, University of Bristol, Bristol, UK
[3]Climatic Research Unit, Schoolof Environmental Sciences, University of East Anglia, Norwich, UK
[4]British Geological Survey, Wallingford,Oxfordshire, UK
[5]UK Centre for Ecology & Hydrology, Maclean Building, Crowmarsh Gifford, Wallingford, UK
[6]Irish Climate and Research Unit, Maynooth University, Ireland
[7]Department of Civil Engineering, University of Bristol, Bristol, UK
[a]now at: Department of Geography, College of Environmental and Life Sciences, University of Exeter, UK



DOI dataset: https://doi.org/10.5285/8344e4f3-d2ea-44f5-8afa-86d2987543a9

Advances in seasonal forecasting

UK Hydrological Outlook



Outlooks Portal planned release: early 2022. Beta for testing available soon

These plots can help answer the question: "What's the likelihood of reaching a given river flow threshold (e.g. **Hands-Off Flow**) over the next 1 – 12 months?"

OR

What's the likelihood of sustained high river flows leading to protracted floodplain inundation?

BUT: are forecasts ready for 'prime time'? Thursday keynotes

UK Centre for Ecology & Hydrology

UK-SCAPE
UK Status, Change and Projections of the Environment

Hydro-JULES

‘Weather whiplash’

UK Centre for Ecology & Hydrology

About us Science Data Services Staff News & media Cymraeg

A weather whiplash? Assessing the abrupt swing from dry to wet in Spring 2021

Home > News and media > Blogs > A weather whiplash? from dry to wet in Spring 2021

Scientists from the National Hydrological Monitoring Prograr been assessing the recent striking hydrological conditions in a historical context. Dr Simon Parry explains...

https://www.ceh.ac.uk/news-and-media/blogs/weather-whiplash-2021-dry-wet-swing-uk

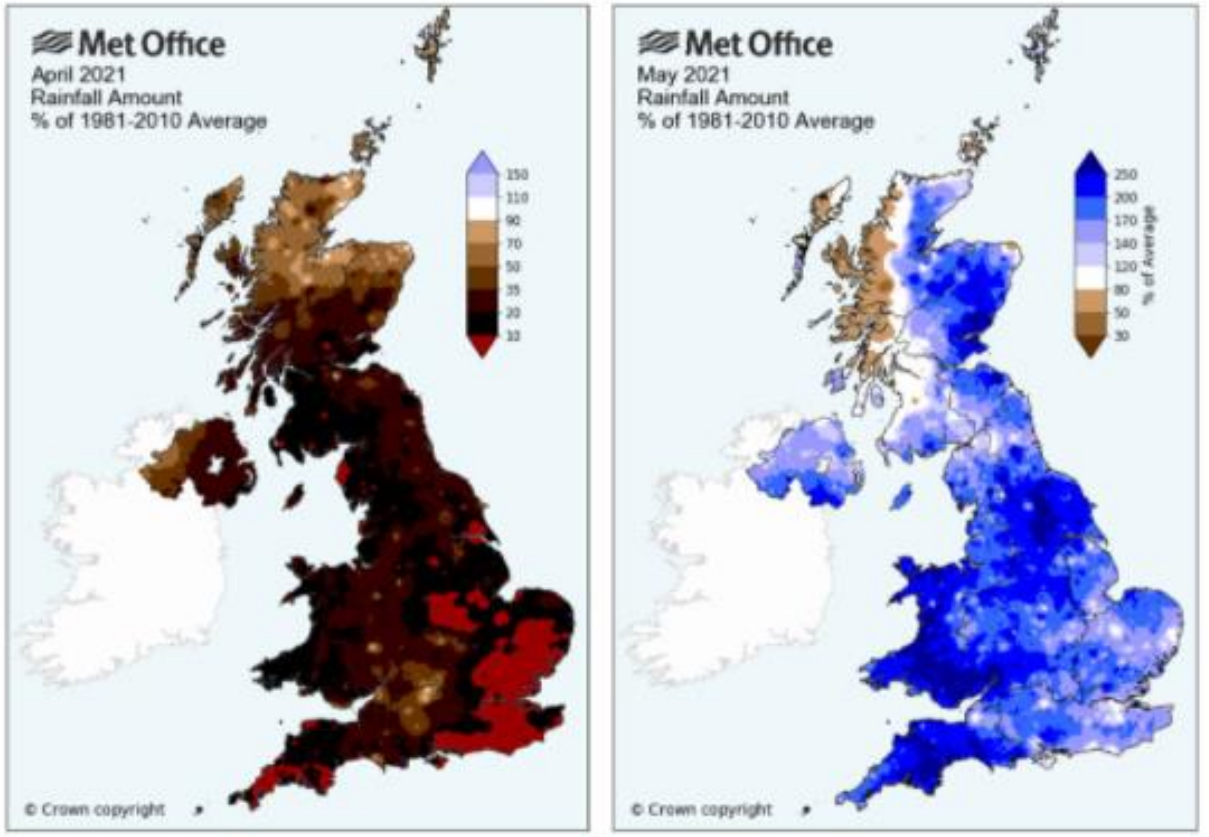


Figure 1: Rainfall anomalies for the UK in: (a) April 2021; (b) May 2021