Past, Present and Future hydrological variability

The importance of hydrometric data



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"Egypt...is a land which has been won by the Egyptians... and is a gift of the river Nile"



**Hydrological observations:** 4000 years ago



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

'Stage-boards' on Greco-Roman Nilometer

Nilometers on Elephantine Island, Aswan, Upper Egypt



Ladybower Reservoir, Derbyshire, Nov 2022



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



# The challenge: water availability and extremes in a warming world



New highest-recorded river flows (Sefton et al. in press, <u>Weather</u>) The 2018 - 2019 drought



New minimum June-July flows 2018 (Turner et al. in press, <u>Weather</u>)



# Why is hydrological variability important?



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

200000 Hypothetical reservoi storage curve 800 Ml/d 90 TARGET FLOW 175000 800 MI/d 150000 600 MI/d 600 Ml/d 70 400 MI/d 125000 60 300 MI/d 400 Ml/d 50 10000 750

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

Aug Sep Oct

Figure 1 Lower Thames Control Diagram (LTCD)

300 Ml/d

PROCEP POINTS

0

Introduction of measures

Relaxation of measures

5000

25000



# How do we assess changing risk?

Changes in long-term hydrological datasets 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









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

## Hydrometric data: caution is required!



#### Measuring high flows is a challenge!





#### And low flows aren't necessarily easier!!



UK Centre for Ecology & Hydrology Rob Wilby et al. 2017. <u>WIRES Water</u>.

#### 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)

© Institute of Hydrology

a) River Thames - Gauged



**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

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

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

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6 Global Runoff Data Centre, Koblenz, Germany

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

Editor Z.W. Kundzewicz; Associate editor K. Hamed

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.



#### Harrigan et al: 2017. Hydrology Research.

Whitfield et al. 2012. <u>Hydrol. Sci. J</u> Burn et al. 2012. <u>Hydrol. Sci. J</u>

### 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

> Received 6 June 2005 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



#### 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

#### UKBN2 Trends - Period: 1961 - 2014







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

Standardised & Smoothed



#### Hannaford & Buys, 2012

European flood trends Bloschl et al: 2019 Europe/N. America flood trends Hodgkins et al: 2017



### A problem...



Flood trends, 1969 - 2018



#### MKZ for long station records



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...







Groundwater (BGS:



Streamflow (CEH: NRFA)





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 Future climate projections run through hydrological models



Future Flows projections for winter river flows

UK Centre for Ecology & Hydrology

Annual peak flow trends

# 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

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













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

## Hydrological droughts: a longer view





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

## **Future hydrological variability**



# Future hydrological change in the UK

Change in Summer Flow (JJA, %) for the 2050s



Copyright © NERC (CEH) 2012.Contains Ordnance Survey data © Crown Copyright and Database Right

#### **Future Flows and Groundwater Levels** (<u>Prudhomme et al. 2013</u>) 11x member UKCP09 RCM ensemble run through three hydrological models Here: summer flows for the 2050s





# Managing variability in the here and now...



## **Data accessibility**

Ç	Why GitHub? $\lor$ Team Enterprise Explore $\lor$ Marketplace Pricing $\lor$ S
Director Infa	
<b>&lt;&gt;</b> Co	de 🕕 Issues 0 👔 Pull requests 0 💿 Actions 🔟 Projects 0 🕕 Security 0
Branch: master - nrfa / api / examples / python / basic_example.py / <> Jump to -	
🔘 Si	imon Add python script example
0 cont	tributors
105 lines (87 sloc) 3.77 KB	
1	# -*- coding: utf-8 -*-
2	
3	NFRA API - Python examples of use
4	
5	See https://nrfaapps.ceh.ac.uk/nrfa/nrfa-api.html
6	for a full description of the API and its capabilities.
7	
8	This script is for Python 3
10	For Python 2, use urlind2 instead of urlind.request
10	1.e.
12	<pre>import urilibz nesponse = unllib2 unleren(unl) need()</pre>
13	response - uriiiiz.uriopen(uri).reau()
14	
15	import urllib.request
16	import json
17	
18	# The base URL to access the NFRA API

#### **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





# **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<sup>2</sup> grid across UK)

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







# Data integration across the water cycle



### **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





### 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/ourscience/projects/eflag-enhanced-futureflows-and-groundwater



# **Advances in seasonal forecasting**



# 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?"

UK Hydrological Outlook

#### OR

Hydro-JULES

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

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

### 'Weather whiplash'



UK Centre for Ecology & Hydrology

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# 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 Program been assessing the recent striking hydrological conditions in a historical context. Dr Simon Parry explains...

https://www.ceh.ac.uk/newsand-media/blogs/weatherwhiplash-2021-dry-wetswing-uk



![](_page_32_Figure_11.jpeg)

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