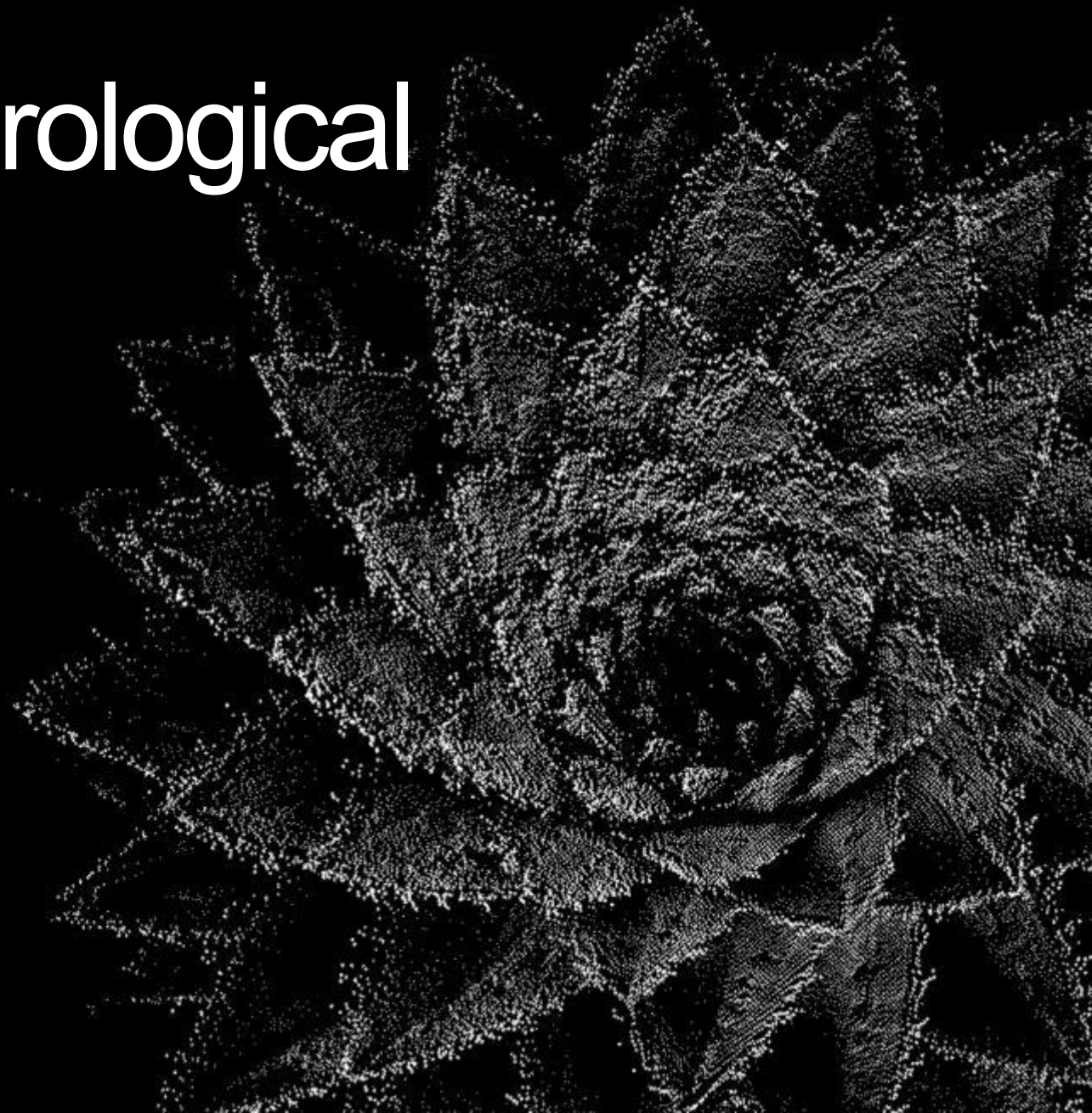
Communicating hydrological data

Dr Steven Cole (plus many others!)
Head of Hydrological Forecasting & Digital Systems

Data-driven approaches to hydrological science
16 July 2025



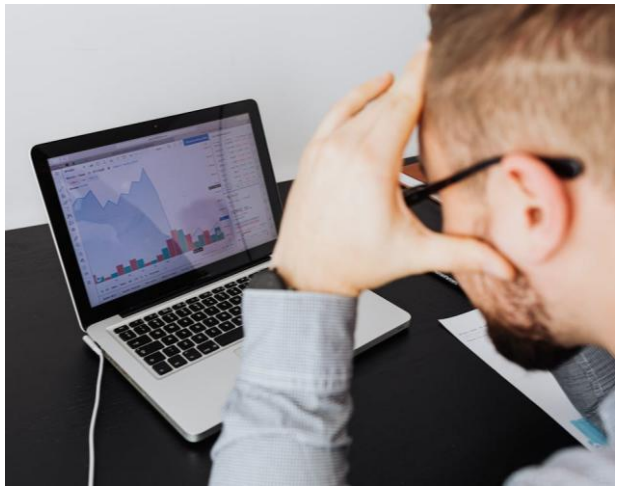
UKCEH

Our planet.
Decoded.

Communicating hydrological data

- Wealth of hydrological data available
  - Point observations (raingauges, river level/flow, snow, …)
  - Gridded area-wide estimates (radar rainfall, satellite, …)
  - Model outputs (deterministic, ensembles, …)

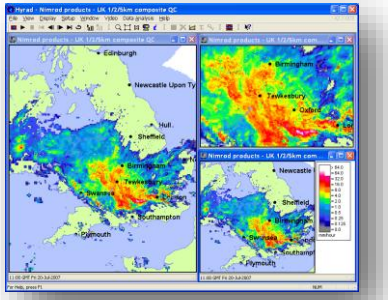
- **Challenge – how to help make data actionable to support decision makers?**

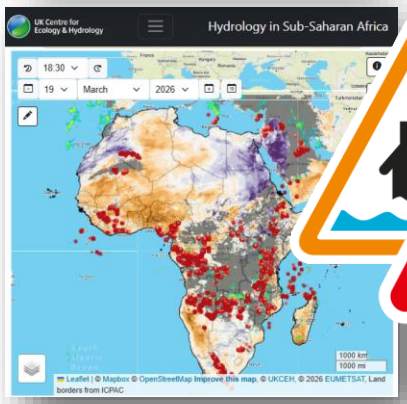


UKCEH

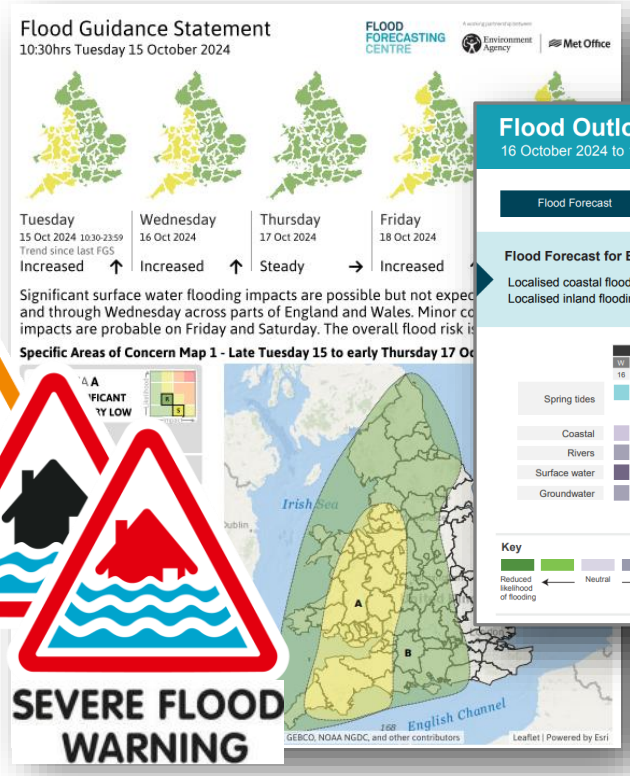
Hydrological Forecasting & Predictions

Observations and nowcasts

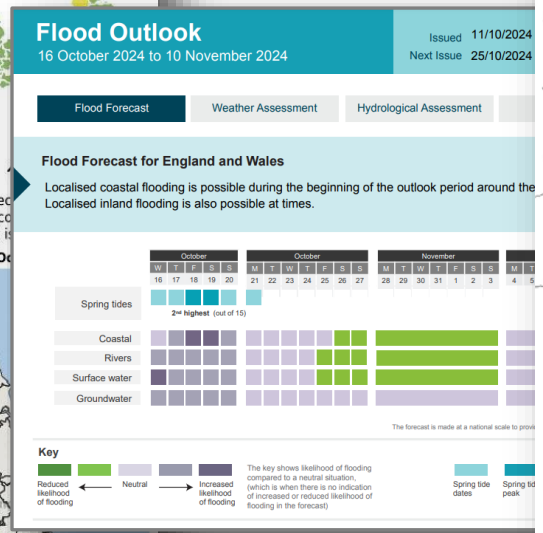




Flood Warning and Flood Guidance Statements

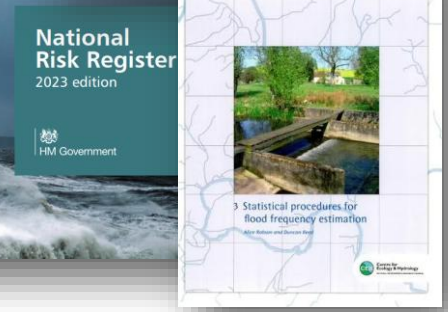


Flood Outlooks



Hydrological Outlooks

Climate Change Risk Assessment and Flood Design



Lead time

Now | Hours | 1-5 days | 4 weeks | 1-3 months+ | 5 years | Decades

Nowcasting | *Weather* | *Sub-seasonal* | *Seasonal*

Global: Sendai Framework

- The expected outcome of the United Nations Sendai Framework for Disaster Risk Reduction (2015-30) is:

  The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries

- Sendai Priority 1 – Understanding Disaster Risk, advocates member state to:

  Develop and apply methodologies and models to assess disaster risks, vulnerabilities and exposure to all hazards

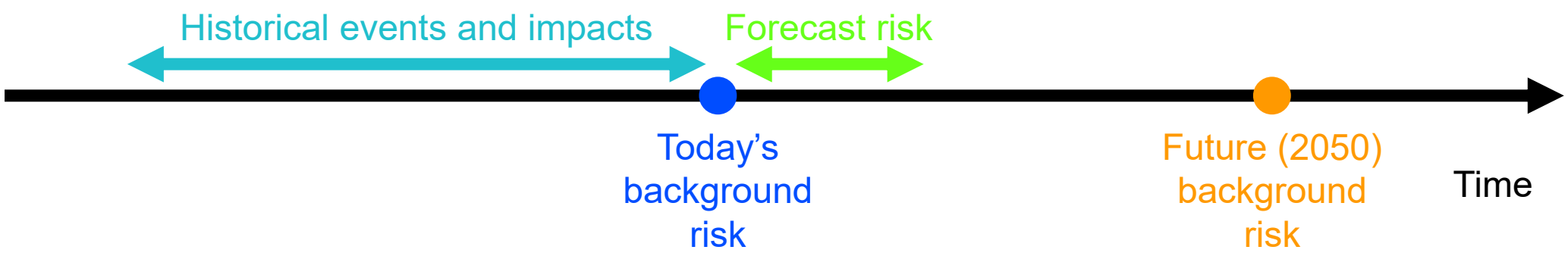
Need for Hazard <u>Impact</u> Modelling

Disaster risk can change with time

Examples of different time frames

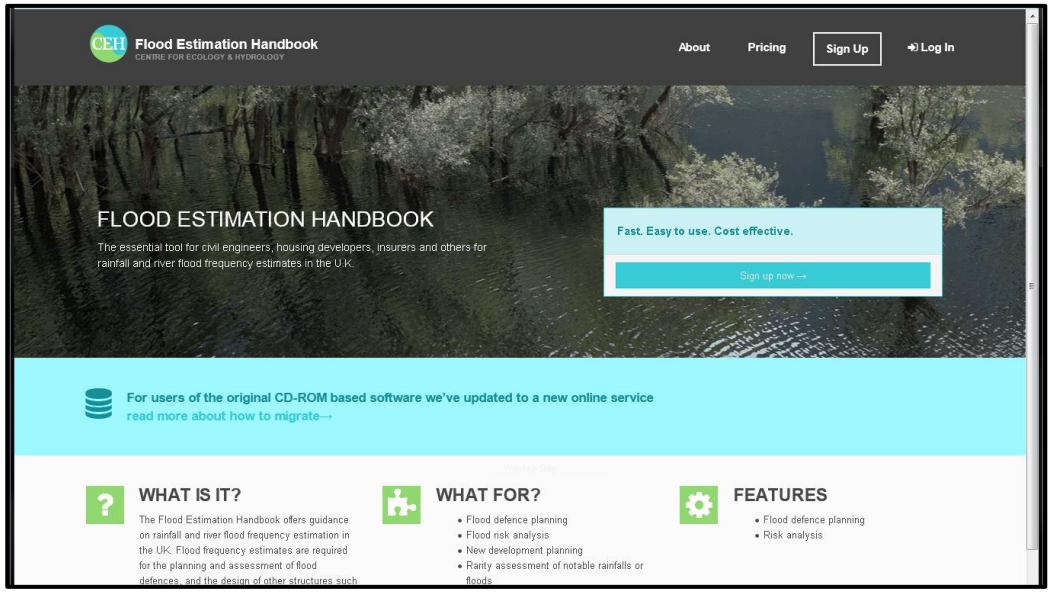
- Current background risk (e.g. average annual flood damage)
- Future background risk (e.g. expected annual flood damage in 2050)
- Forecast risk now and over the next few days/weeks/months/years (e.g. expected impacts)

Historical events and impacts provides useful context



Flood Estimation Handbook (FEH) – Background Risk

- UK **industry standard statistical methods** for understanding **flood risk**
- E.g. how much **rainfall** or **river flow** does new infrastructure have to cope with?
- Used for **flood risk assessments**, e.g. property, bridge or culvert design

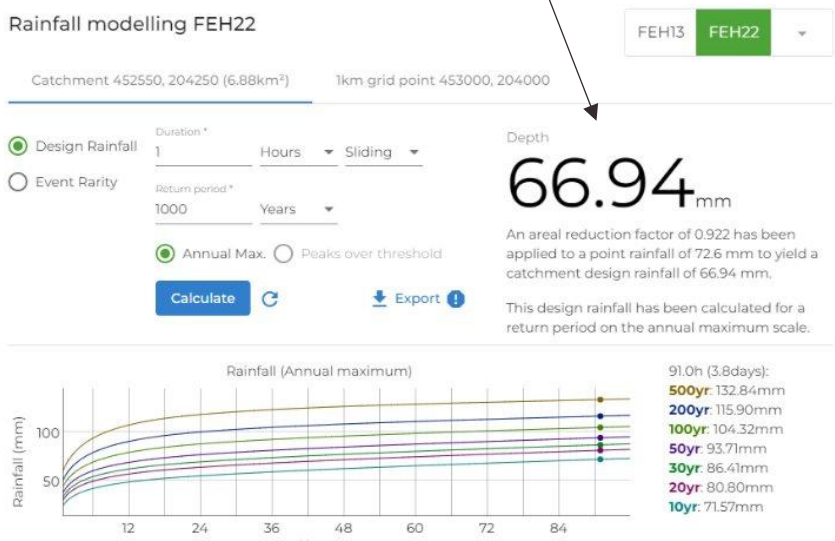


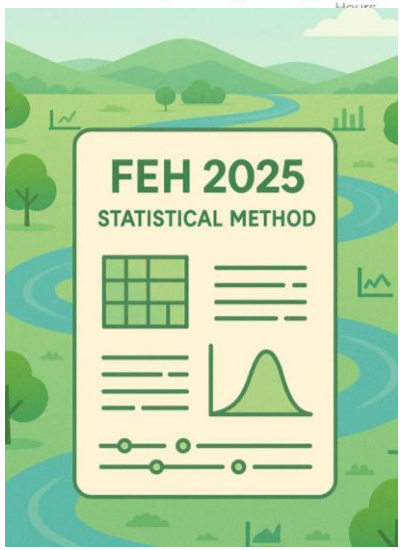
http://ceh.ac.uk/feh

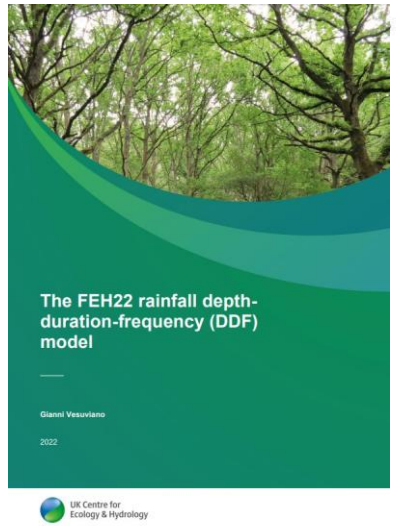
Flood Estimation Handbook (FEH) – Background Risk

- **Depth-duration-frequency (DDF)** rainfall model – uses long records of quality-controlled rainfall daily and hourly rainfall data
- **Flood frequency method** uses regression methods with **catchment descriptors** (e.g. Area, Standard-period Average Annual Rainfall, …) to estimate the Median annual flood (QMED)
- Outputs delivered via **FEH webservice**
- New developments **communicated through reports and British Hydrological Society webinars**

1000 year, 1 hour catchment rainfall







British Hydrological Society

Flood forecasting model chain

Inputs

Flood models

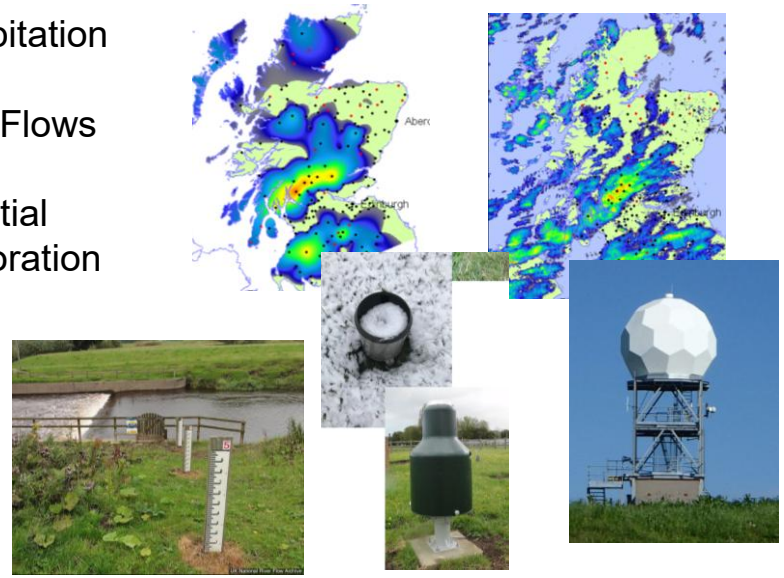
Outputs

Observation-based

Precipitation

River Flows

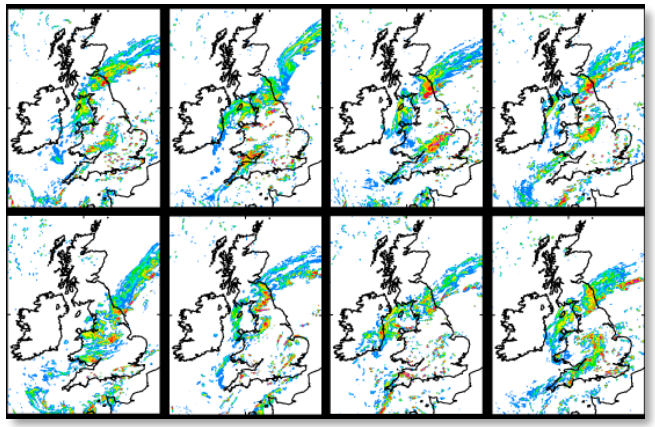
Potential Evaporation

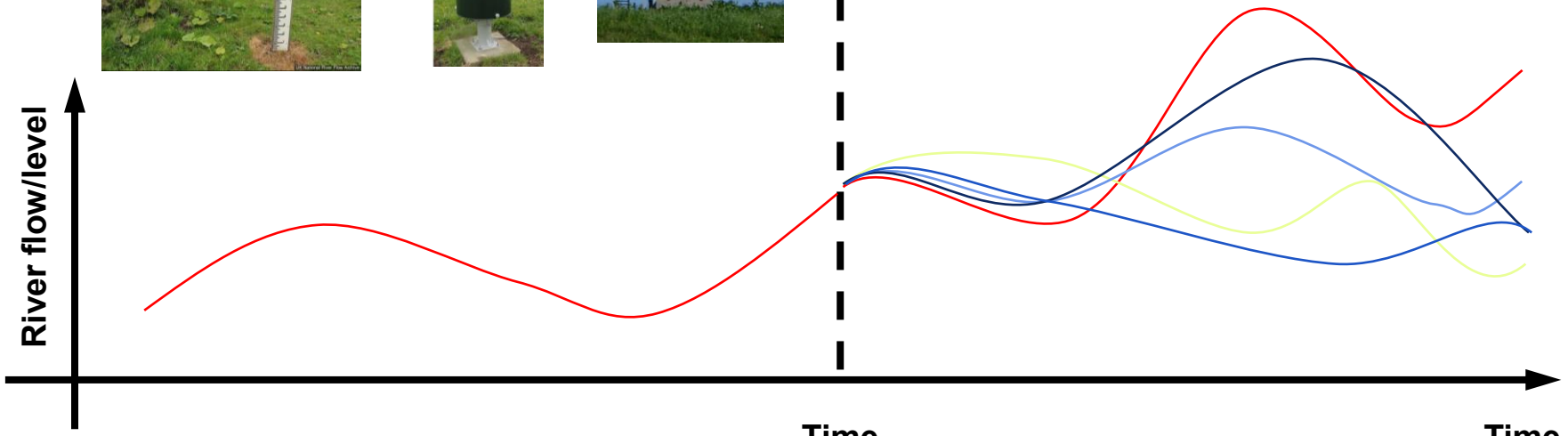


Numerical Weather Prediction (NWP)

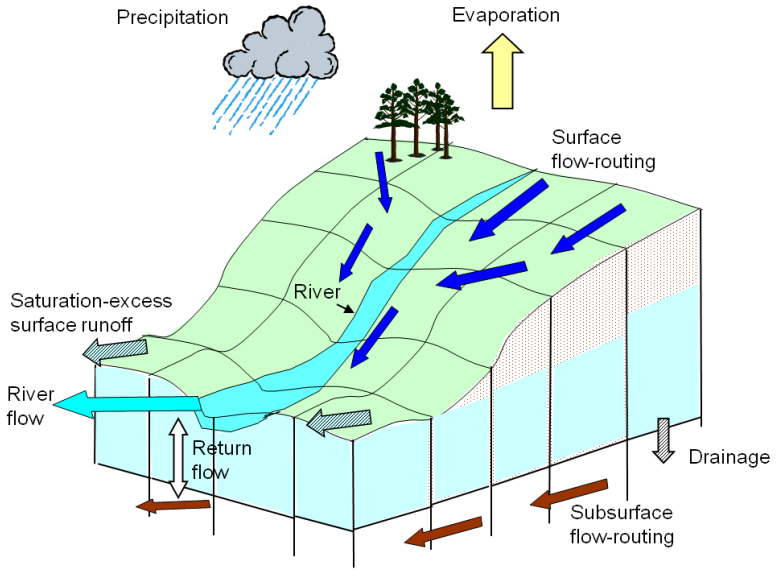
Deterministic

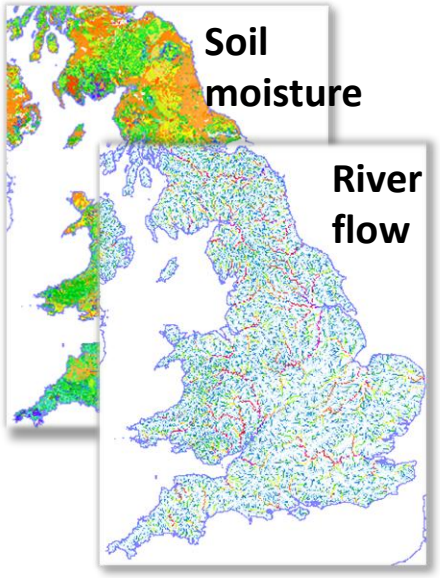
Ensemble

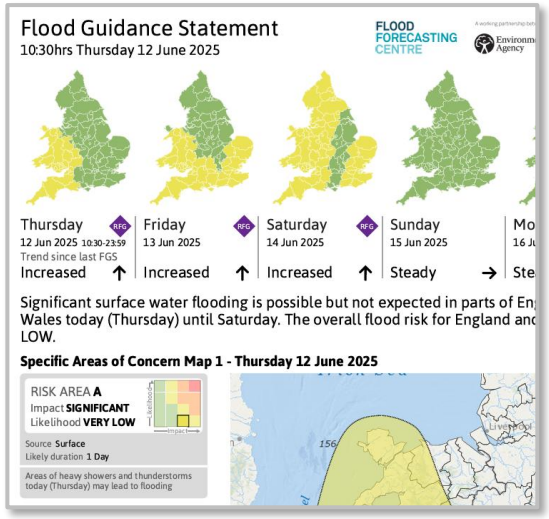




UK National Scale Flood Forecasting







FLOOD FORECASTING CENTRE

A working partnership between

Environment Agency | Met Office

Met Office | SEPA Scottish Environment Protection Agency | Scottish Flood Forecasting Service Working in partnership

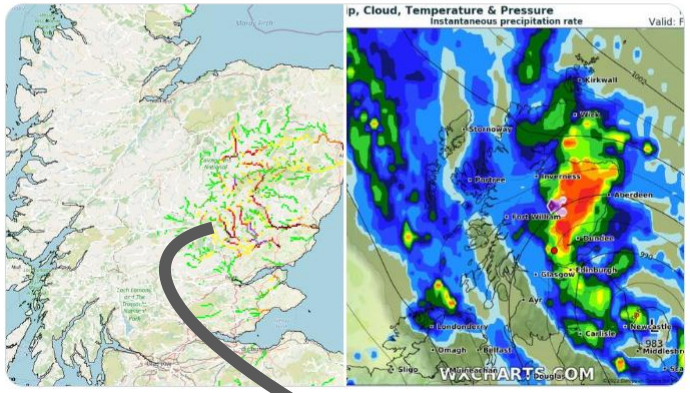
- UKCEH Grid-to-Grid (G2G) hydrological model **used operationally across Britain** at a 1km, 15 min resolution out to ~5 days (for fluvial and surface water forecasts)
- Uses spatial datasets on **terrain, soil/geology, land-cover, rainfall**
- **Probabilistic forecasts** & **Hazard Impact Models** inform **Flood Guidance Statement**

Real-world example, SEPA – Nov 2022

G2G Probabilistic Flood Forecasts

⚠️ Potential for 100mm of rain across parts of eastern Scotland in the next 24 hours. Our hydrological forecasts showing strong response with significant flooding likely across the Grampian and Angus areas.

Check the Scottish flood forecast 👉
scottishfloodforecast.sepa.org.uk/public



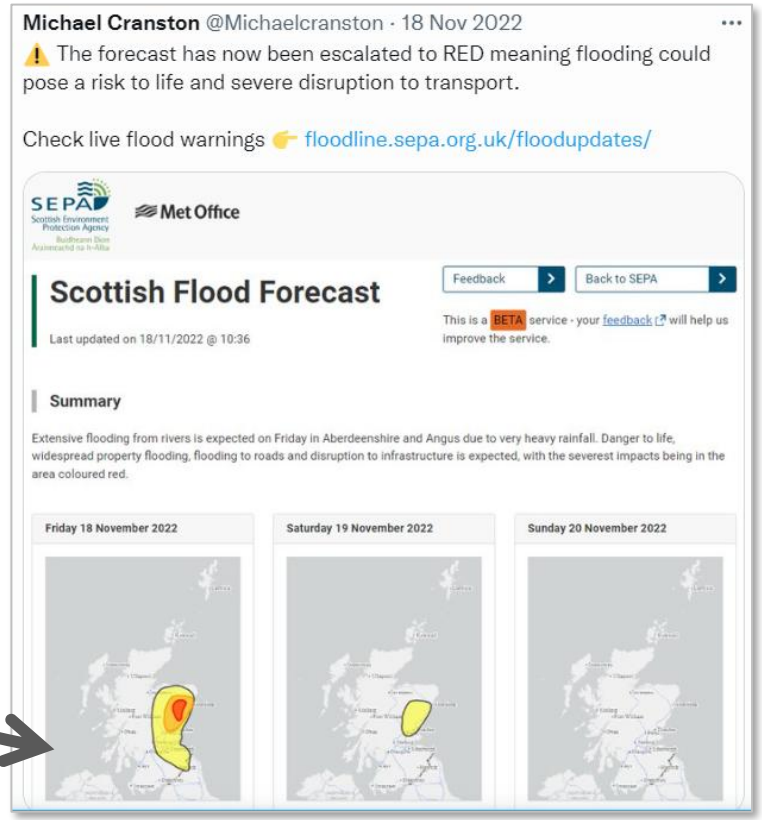
11:15 am · 17 Nov 2022

Public Flood Forecasts/Guidance

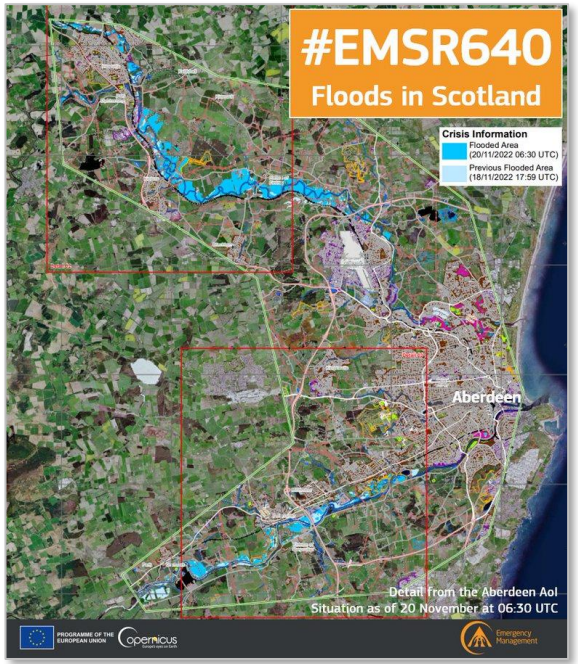
Michael Cranston @Michaelcranston · 18 Nov 2022

⚠️ The forecast has now been escalated to RED meaning flooding could pose a risk to life and severe disruption to transport.

Check live flood warnings 👉 floodline.sepa.org.uk/floodupdates/

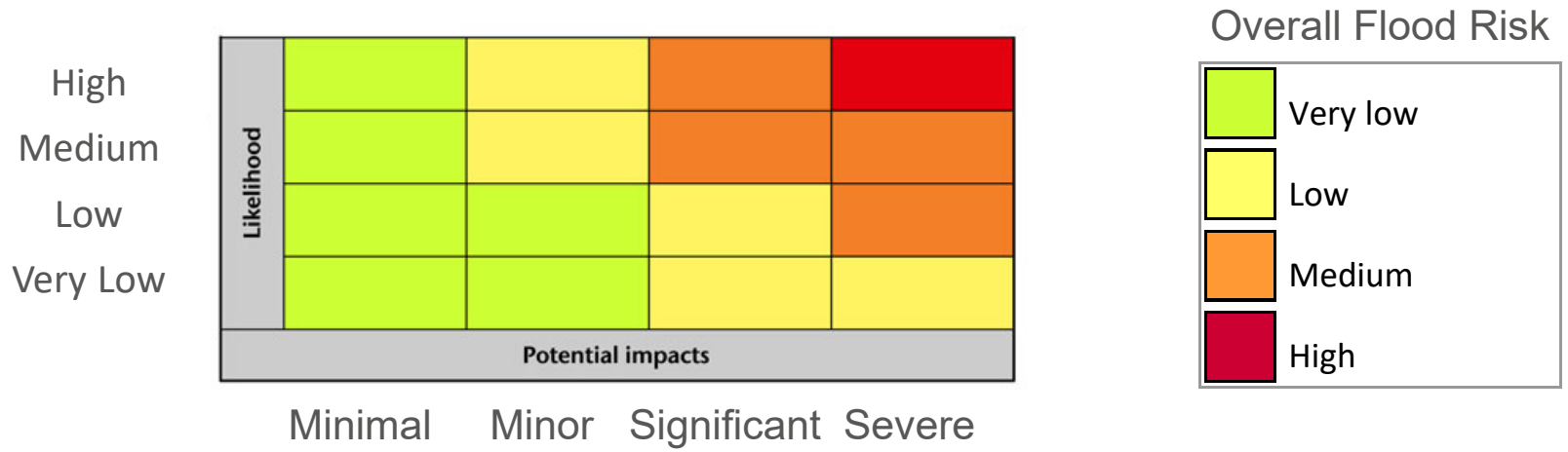


Triggered satellites to capture impact



Impact-based forecasting: risk matrix

- Supporting the move to **Impact-based** Forecasting and Warning – encouraged by WMO (UKCEH now part of writing group for WMO IbF guidelines)
- **Risk Matrix** approach that combines **likelihood** *and* **impacts**
  - ➢ Used for National Severe Weather Warnings and Flood Guidance
- Important to acknowledge and account for **uncertainty**
  - ➢ Make **better**, more informed, decisions



Hazard Impact Models (HIMs)

- **Automatic Hazard Impact Models** are becoming a common tool to help forecasters – use **Risk Triangle** methodology

- The **Natural Hazards Partnership (NHP)** of UK research and government bodies has helped develop HIMs, including for Surface Water Flooding

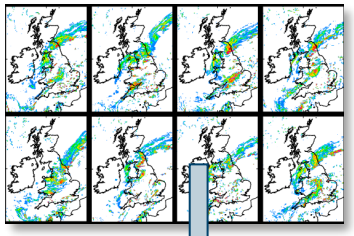
- NHP aims:
  - Focus on **Impacts**
  - Emphasis on **risk reduction and prevention**
  - Develop **new services in partnership**

Surface Water Hazard Impact Model - SWFHIM

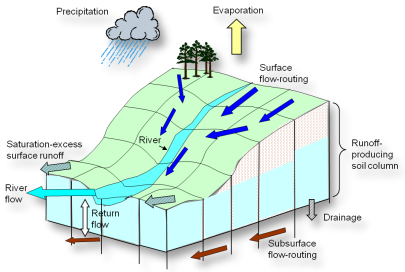
- **Collaborative development** under Natural Hazards Partnership for over 10 years
- **Builds on existing** tools & models, continually developed
- **Operational** 24/7 for the Flood Forecasting Centre since 2020

Natural Hazards Partnership

Rainfall ensembles (MOGREPS-UK)



Grid-to-Grid Hydrology

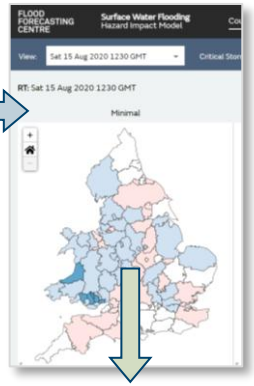


SWF Hazard Footprint

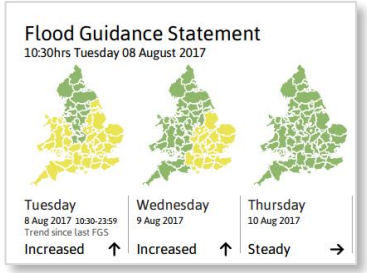
SWF HIM

Real-time SWF risk outputs

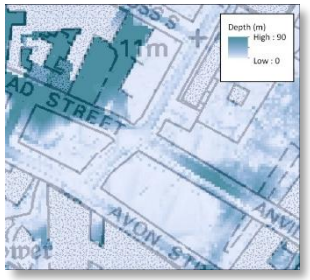
Visualisation



Dissemination



Impact Library

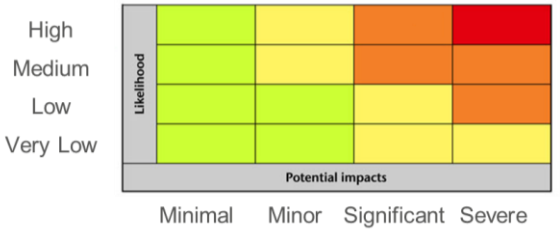


Updated Flood Map for Surface Water

National Receptor Database (NRD)

National Population Database (NPD)

Flood Risk Matrix



- Combines ***likelihood*** and ***impacts***

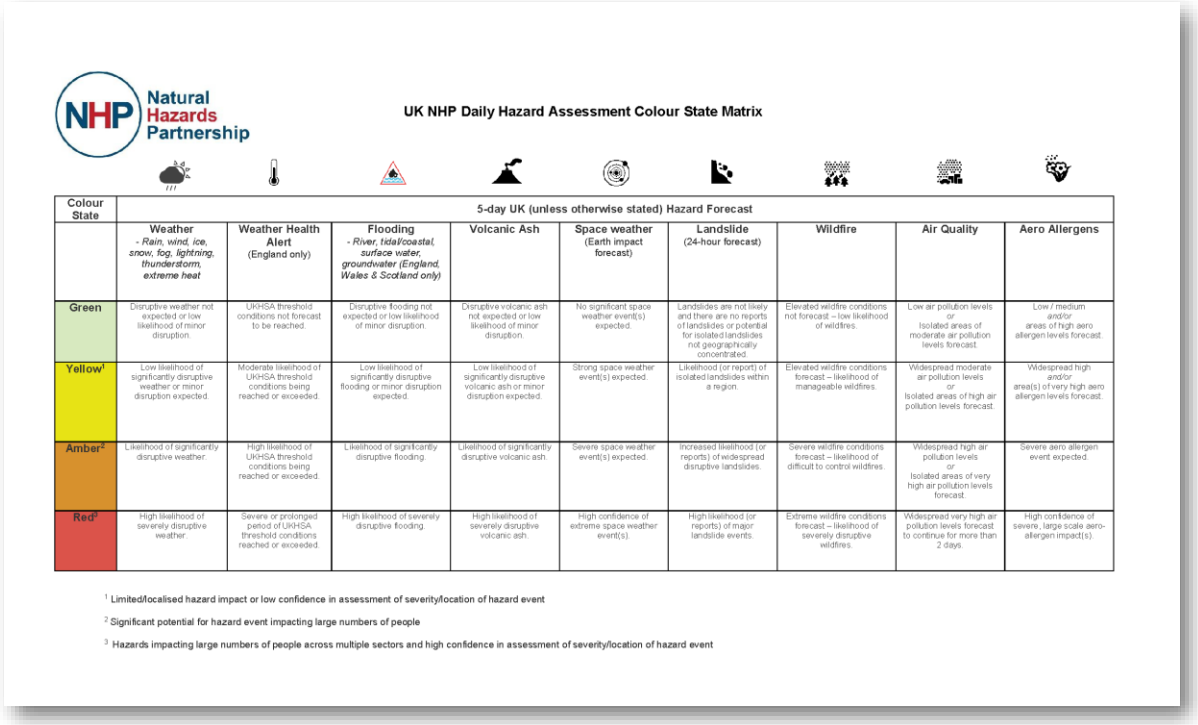
Daily Hazard Assessment

Coherent and coordinated advice

NHP Natural Hazards Partnership

Daily Hazard Assessment

- >1900 recipients
- Single source for 5-day outlook for 9 hazards
- Consistent messages and assessments for 9 hazards
- Links to original official source material – amplifying authoritative voice
- Improved awareness, preparedness and response
- Supports better action & collaboration
- Available via Hazard Manager and Resilience Direct



NHP Natural Hazards Partnership

UK NHP Daily Hazard Assessment Colour State Matrix

Colour State	5-day UK (unless otherwise stated) Hazard Forecast								
	Weather - *Rain, wind, ice, snow, fog, lightning, thunderstorm, extreme heat*	**Weather Health Alert** (England only)	**Flooding** - *River, tidal/coastal, surface water, groundwater (England, Wales & Scotland only)*	**Volcanic Ash**	**Space weather** (Earth impact forecast)	**Landslide** (24-hour forecast)	**Wildfire**	**Air Quality**	**Aero Allergens**
Green	Disruptive weather not expected or low likelihood of minor disruption.	UKHSA threshold conditions not forecast to be reached.	Disruptive flooding not expected or low likelihood of minor disruption.	Disruptive volcanic ash not expected or low likelihood of minor disruption.	No significant space weather event(s) expected.	Landslides are not likely and there are no reports of landslides or potential for isolated landslides not geographically concentrated.	Elevated wildfire conditions not forecast – low likelihood of wildfires.	Low air pollution levels or Isolated areas of moderate air pollution levels forecast.	Low / medium and/or areas of high aero allergen levels forecast.
Yellow[1]	Low likelihood of significantly disruptive weather or minor disruption expected.	Moderate likelihood of UKHSA threshold conditions being reached or exceeded.	Low likelihood of significantly disruptive flooding or minor disruption expected.	Low likelihood of significantly disruptive volcanic ash or minor disruption expected.	Strong space weather event(s) expected.	Likelihood (or report) of isolated landslides within a region.	Elevated wildfire conditions forecast – likelihood of manageable wildfires.	Widespread moderate air pollution levels or Isolated areas of high air pollution levels forecast.	Widespread high and/or area(s) of very high aero allergen levels forecast.
Amber[2]	Likelihood of significantly disruptive weather.	High likelihood of UKHSA threshold conditions being reached or exceeded.	Likelihood of significantly disruptive flooding.	Likelihood of significantly disruptive volcanic ash.	Severe space weather event(s) expected.	Increased likelihood (or reports) of widespread disruptive landslides.	Severe wildfire conditions forecast – likelihood of difficult to control wildfires.	Widespread high air pollution levels or Isolated areas of very high air pollution levels forecast.	Severe aero allergen event expected.
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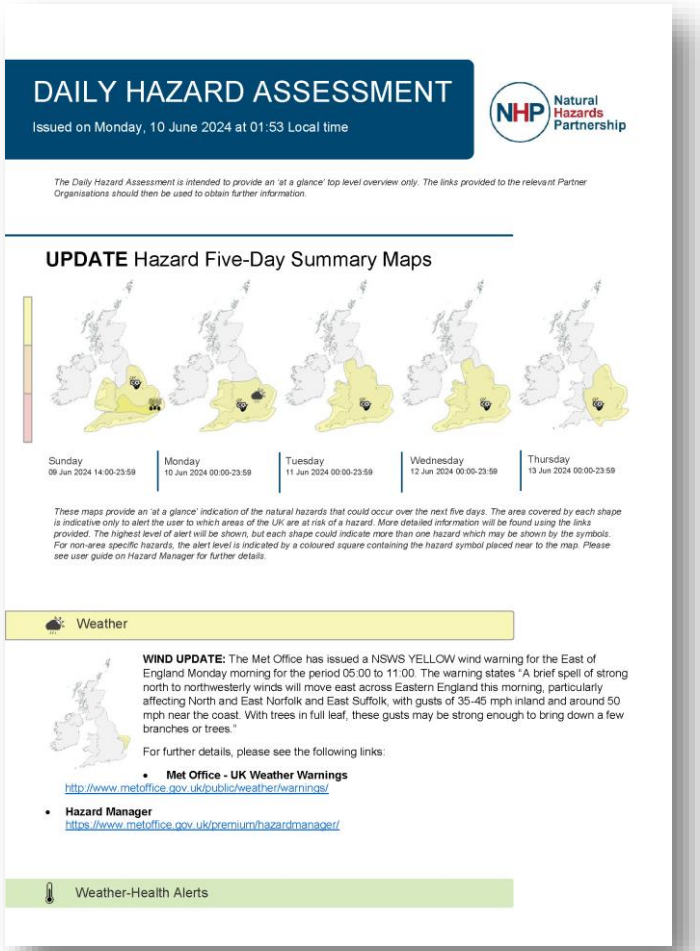
[1] Limited/localised hazard impact or low confidence in assessment of severity/location of hazard event

[2] Significant potential for hazard event impacting large numbers of people

[3] Hazards impacting large numbers of people across multiple sectors and high confidence in assessment of severity/location of hazard event

NHP Natural Hazards Partnership

Daily Hazard Assessment



DAILY HAZARD ASSESSMENT

Issued on Monday, 10 June 2024 at 01:53 Local time

Natural Hazards Partnership

The Daily Hazard Assessment is intended to provide an 'at a glance' top level overview only. The links provided to the relevant Partner Organisations should then be used to obtain further information.

UPDATE Hazard Five-Day Summary Maps

Sunday	Monday	Tuesday	Wednesday	Thursday
09 Jun 2024 14:00-23:59	10 Jun 2024 00:00-23:59	11 Jun 2024 00:00-23:59	12 Jun 2024 00:00-23:59	13 Jun 2024 00:00-23:59

These maps provide an 'at a glance' indication of the natural hazards that could occur over the next five days. The area covered by each shape is indicative only to alert the user to which areas of the UK are at risk of a hazard. More detailed information will be found using the links provided. The highest level of alert will be shown, but each shape could indicate more than one hazard which may be shown by the symbols. For non-area specific hazards, the alert level is indicated by a coloured square containing the hazard symbol placed near to the map. Please see user guide on Hazard Manager for further details.

Weather

WIND UPDATE: The Met Office has issued a NSWS YELLOW wind warning for the East of England Monday morning for the period 05:00 to 11:00. The warning states "A brief spell of strong north to northwesterly winds will move east across Eastern England this morning, particularly affecting North and East Norfolk and East Suffolk, with gusts of 35-45 mph inland and around 50 mph near the coast. With trees in full leaf, these gusts may be strong enough to bring down a few branches or trees."

For further details, please see the following links:

- **Met Office - UK Weather Warnings**
  http://www.metoffice.gov.uk/public/weather/warnings/
- **Hazard Manager**
  https://www.metoffice.gov.uk/premium/hazardmanager/

Weather-Health Alerts

No significant hazards expected.

Flooding

No significant hazards expected.

Volcanic Ash

No significant hazards expected.

Space Weather

No significant hazards expected.

Landslides

No significant hazards expected.

Wildfire

Sunday

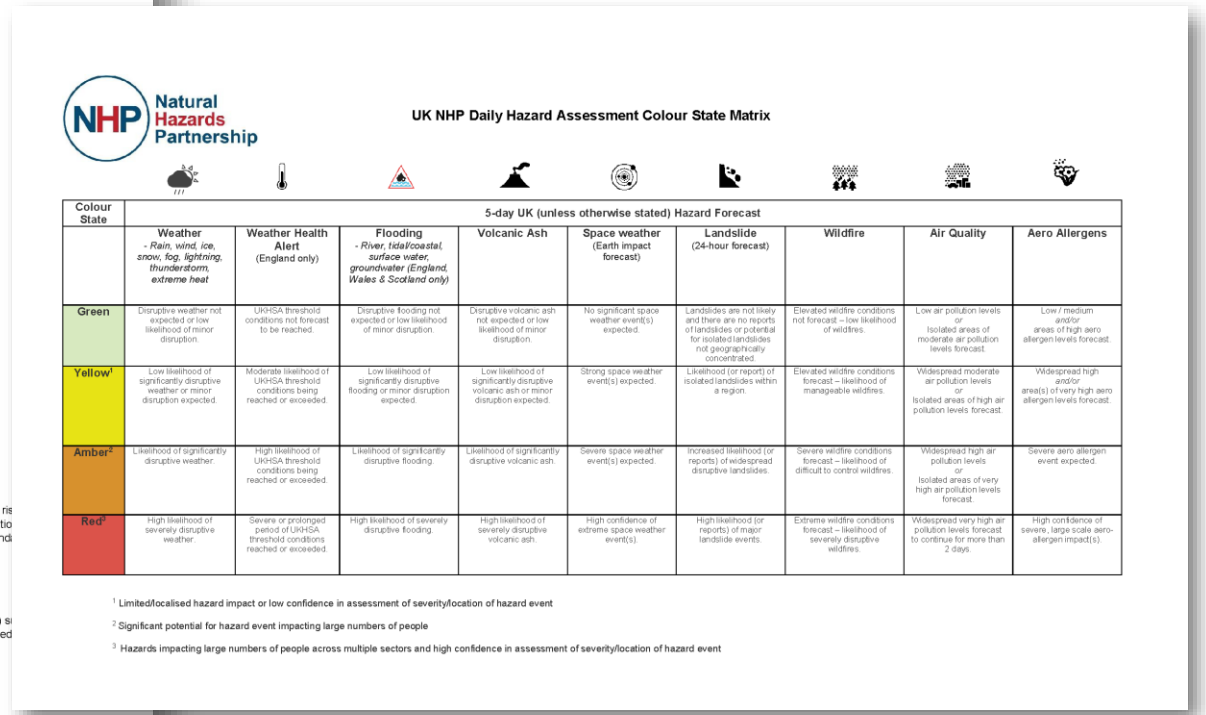
Relatively dry antecedent conditions are likely to lead to an Elevated wildfire ris
Thames Estuary, Thames Valley and parts of the Welsh Marches. This situatio
relived somewhat by rain moving southeast through the area shown into Mondi
in this aspect higher in the east of the area.

The assessment of wildfire conditions provided within the NHP Daily Hazard Assessment (DHA) s
expert analysis of multiple Fire Severity Index model fields to produce a Green-Yellow-Amber-Red
assessment for the UK.

Air Quality

No significant hazards expected.

Aero Allergens



Natural Hazards Partnership

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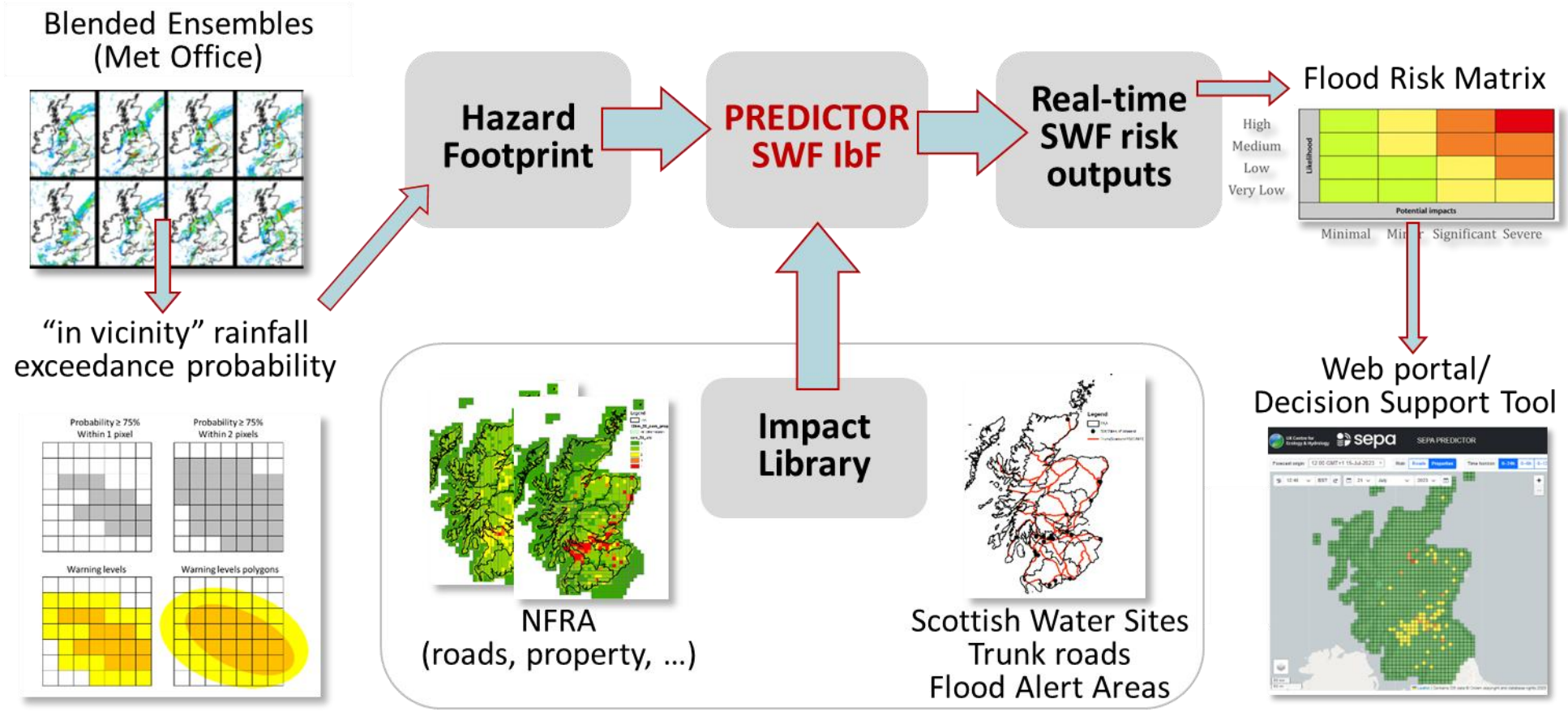
Natural Hazards Partnership

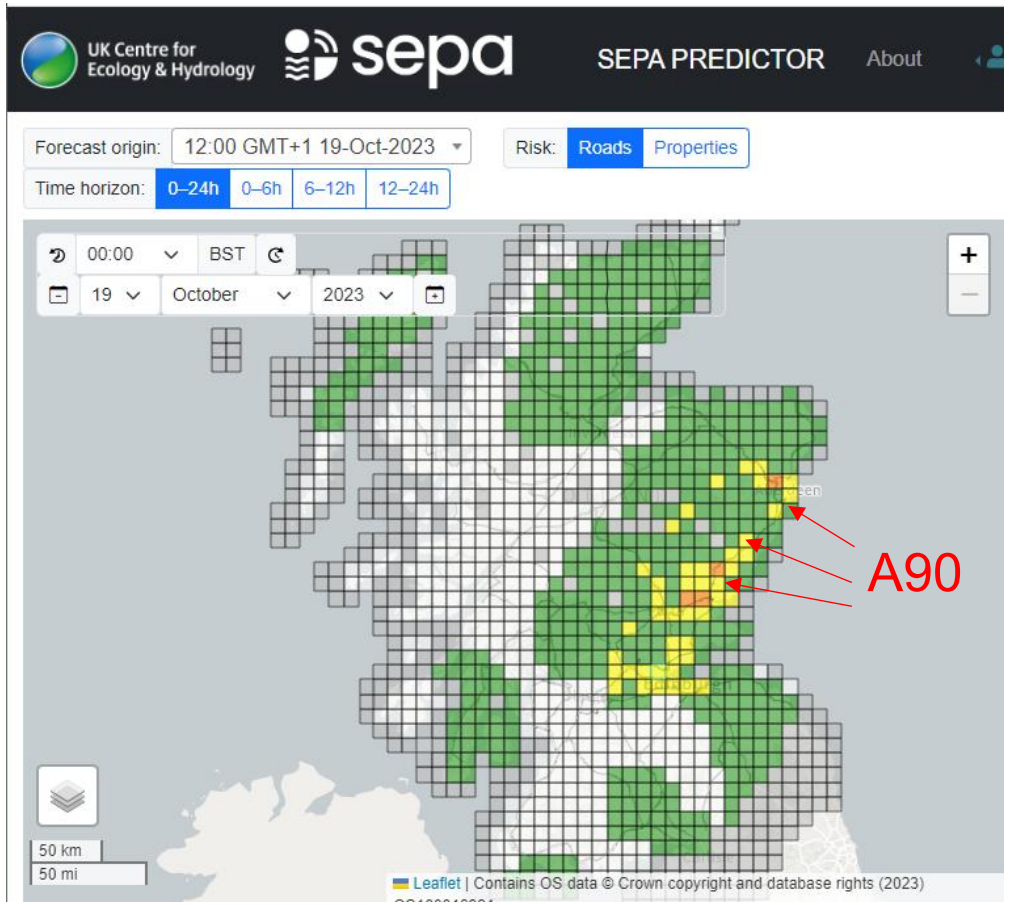
Surface Water Flooding (SWF) tool for Scotland

- PREDICTOR project - real-time SWF Impact-based Forecasting (IbF) tool
- Risk Matrix approach that combines uncertainty *and* impacts (roads & properties)



Case study – Storm Babet

- Step-change in operational forecasting capability – longer lead-times, national coverage
- Earlier flood guidance and warnings allowed for more effective response and mitigation
- Public could prepare earlier
- Councils evacuated homes in advance
- Transport Scotland closed A90 in advance of flooding (first time they've done this)
- Positive feedback from stakeholders and users



UKCEH web-portal
Forecast during Storm Babet

PREDICTOR – Stakeholder feedback following Storm Babet October 2023

> "…this is a very exciting development."
> (Local Authority Flooding Officer, Society of Chief Officers of Transportation in Scotland)

> "…it has given good predictions that tie in well with our system alerts."
> (Technical Manager, Scottish Water)

> "The new PREDICTOR tool combined with direct access to our Met Office Advisor at South Queensferry accurately enabled partners to assess the forecast impacts on the trunk road network."
> (National Operations Manager – Resilience, Transport Scotland)


Dundee

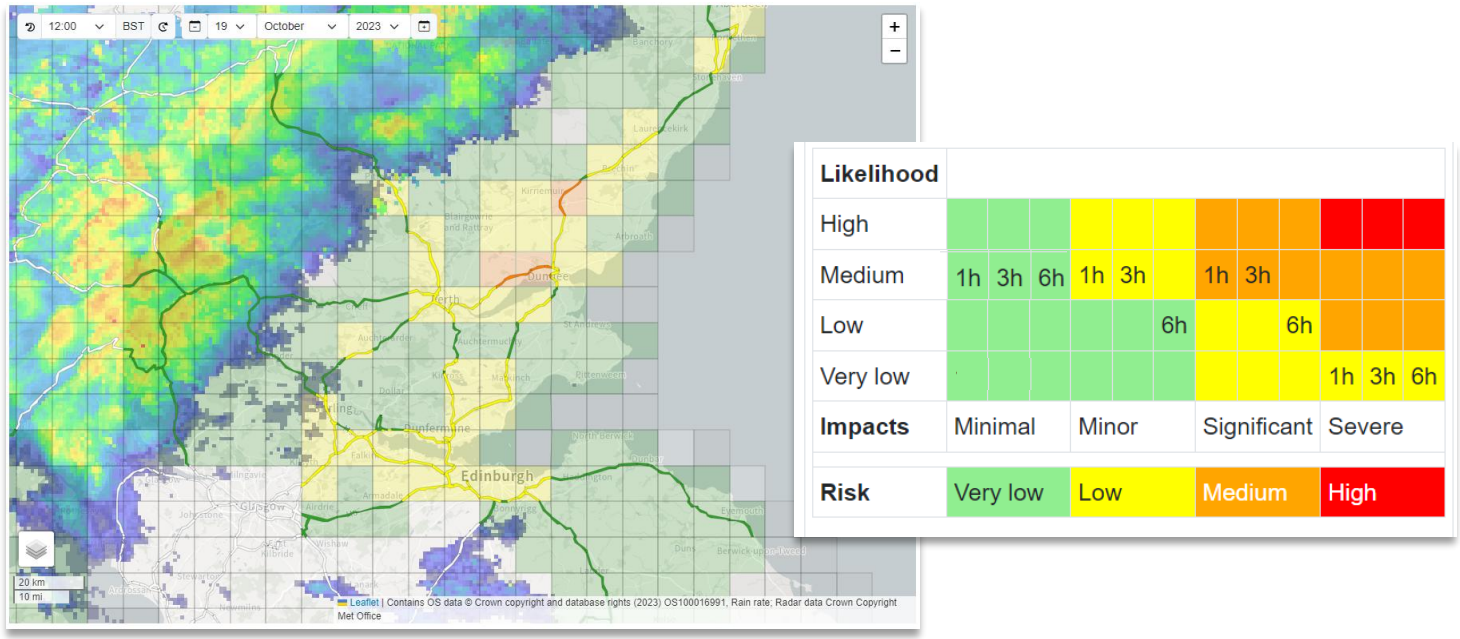
Live Kingsway in Dundee reopens amid Storm Babet travel chaos

The road was flooded between the Myrekirk and Swallow roundabouts.

by Bryan Copland October 20 2023, 5.00pm

Share Comment 0

The Kingsway is flooded at Myrekirk. Image: Mhairi Edwards/DC Thomson



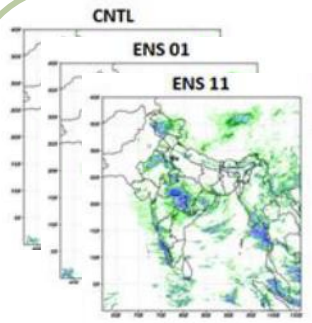
Likelihood												
High												
Medium	1h	3h	6h	1h	3h		1h	3h				
Low						6h			6h			
Very low										1h	3h	6h
Impacts	Minimal			Minor			Significant			Severe		
Risk	Very low			Low			Medium			High		

PREDICTOR Surface Water Flood Risk forecast on the road network during Storm Babet

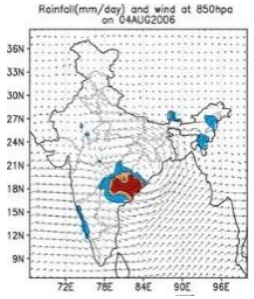
Flood Hazard Impact Model India (FHIM-India)

- **Automated Flood Hazard Impact Model** to support Impact-based Forecasting (IbF)
  - ➢ Risk Matrix approach that combines uncertainty ***and*** impacts ⇨ ENSEMBLES

India

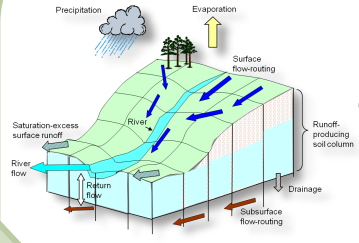


NEPS-R
NCMRWF

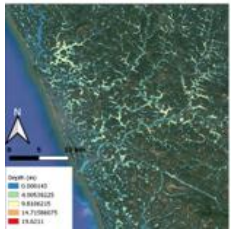


Observations
IMD

UK JASMIN
FHIM-India Workflows

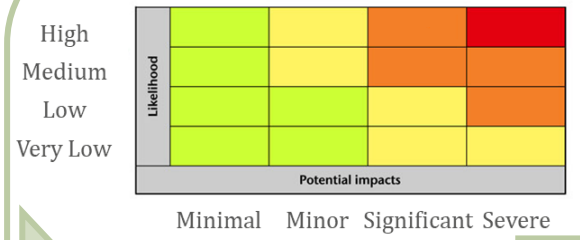


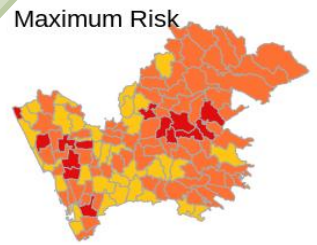
G2G
~1km flood
UKCEH



HiPIMS
~30m flood
Loughborough/ Birmingham

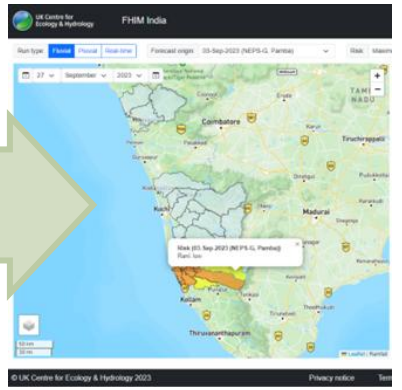
Risk modelling



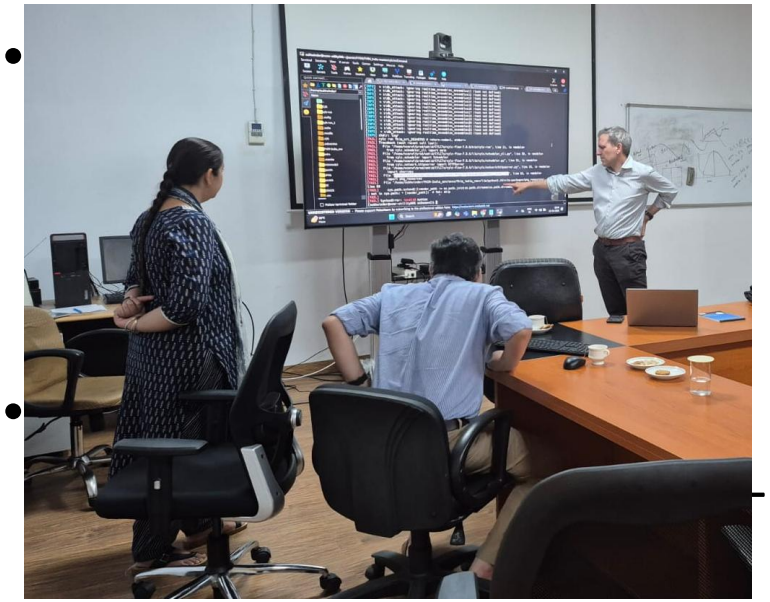


Impact & Risk
HSE

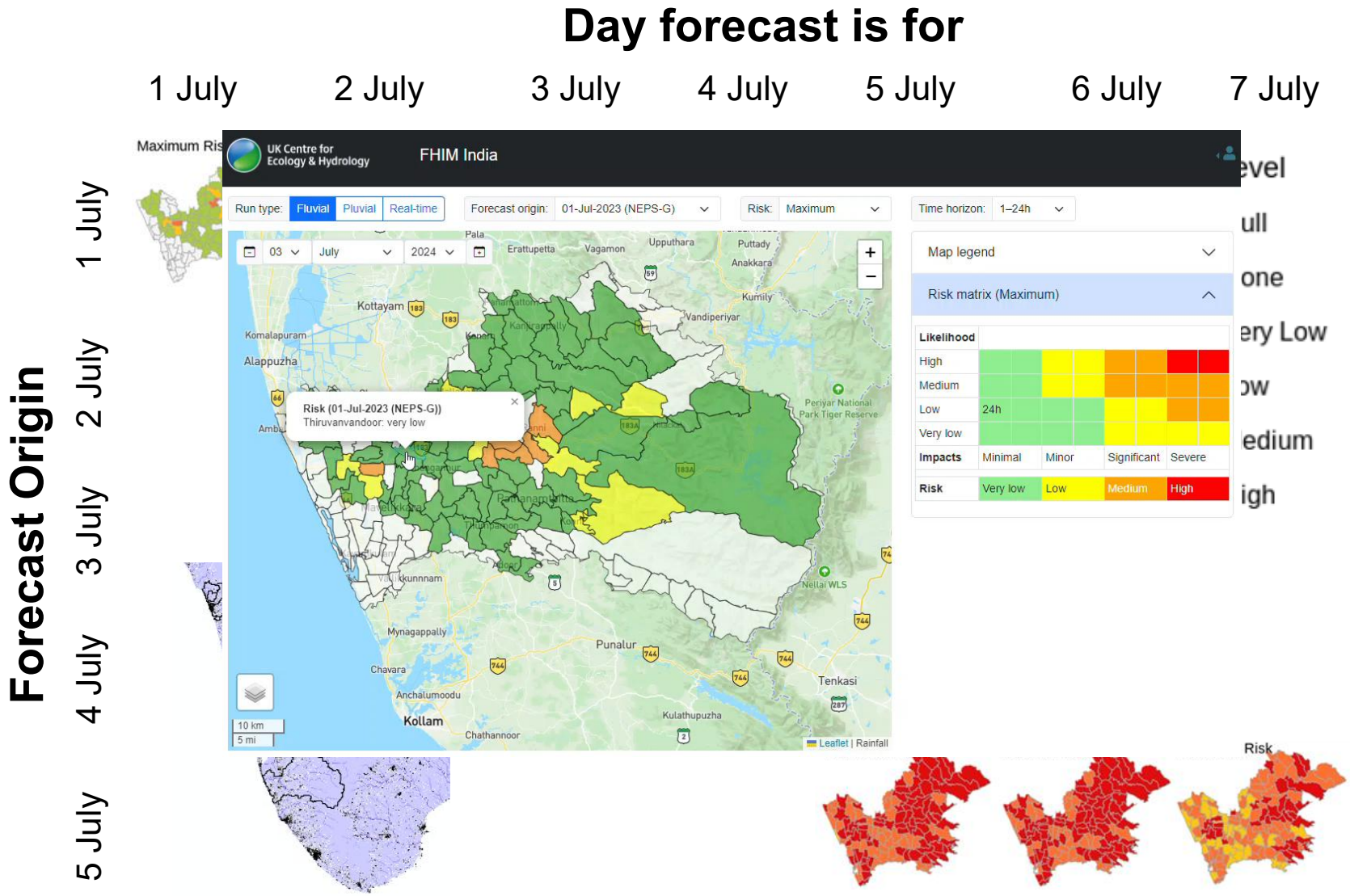
UKCEH hosted Portal



FHIM-India - 1-5 July 2023 Forecasts

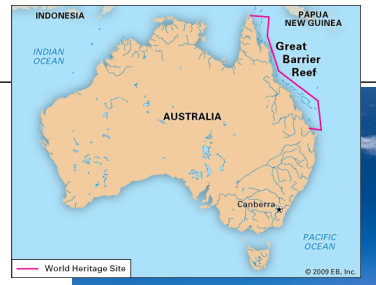


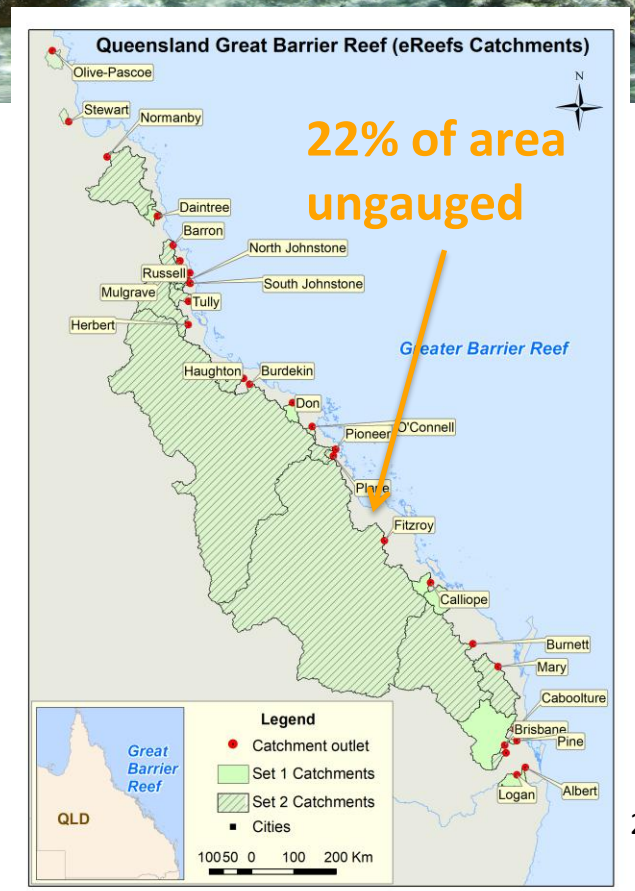
- Code transferred to NCMRWF HPC. Prototype web portal developed.



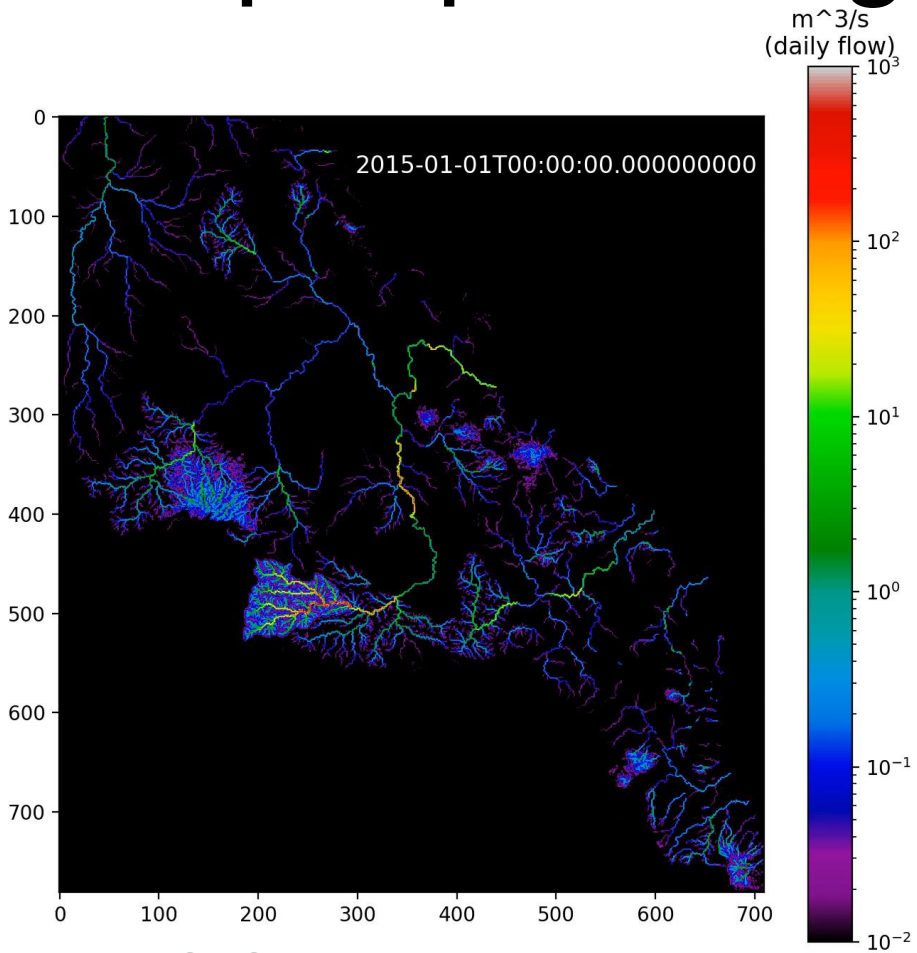
Coupled hydrological and coastal models

- Great Barrier Reef (GBR) 2000km long
- UNESCO World Heritage site
- Catchment management has adversely impacted the coastal water quality & marine ecosystem health
- Major project (www.eReefs.org.au) improving observations, modelling and management practice
- UKCEH and Australian partners applied G2G and coupled with water quality & hydrodynamic models
- Modelling runs real-time in the cloud and supports annual "Report Cards" on the health of the reef





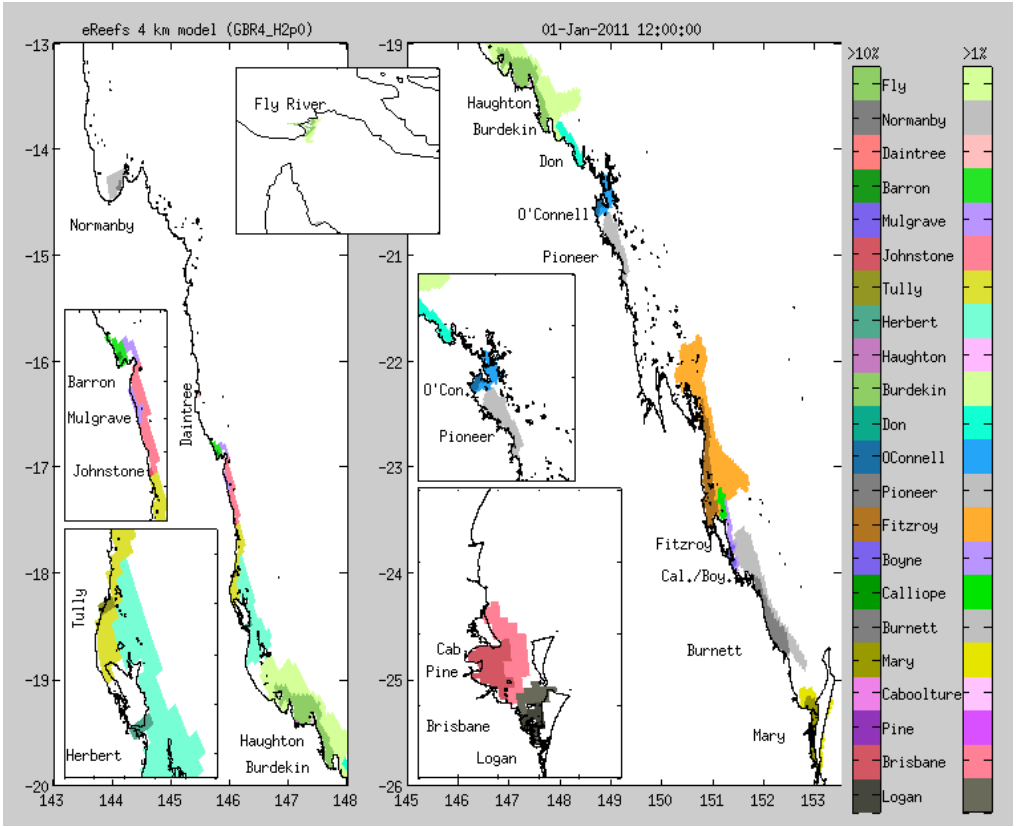
Example: predicting flood plumes



G2G hydrological model
Hourly timestep on 1 km grid

Coupled at 60 coastal nodes

Helps identify which river source is dominant



SHOC hydrodynamic model and biogeochemical model

Climate Change: UK Flood Context

- Third UK Climate Change Risk Assessment (CCRA3) 2022
- Gap between level of risk and level of adaption has increased since CCRA2 report in 2017
- National summaries and Sector Briefings also provided.
- Example from flood study:

*"… unless we take further action, under a **2°C** by 2100 warming scenario annual damages **from flooding** for non-residential properties across the UK is expected to increase by **27% by 2050** and **40% by 2080.** At **4°C** this increases to **44%** and **75%** respectively."*

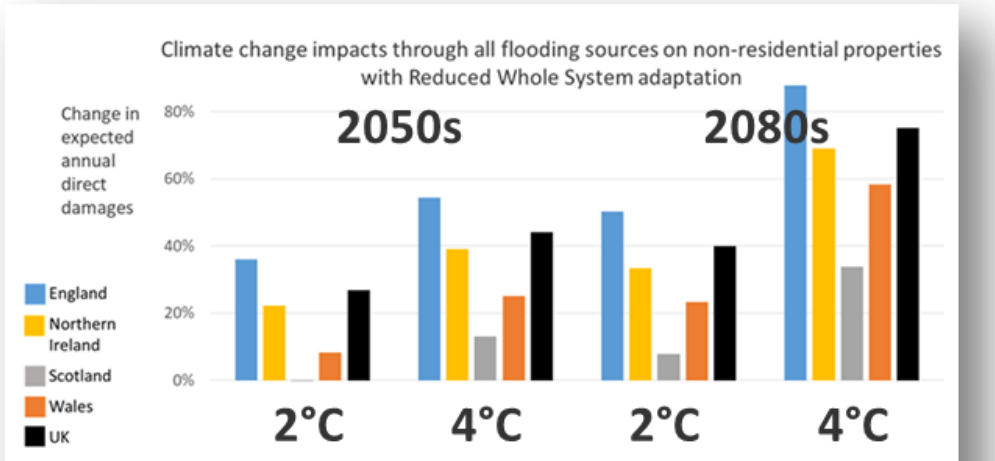
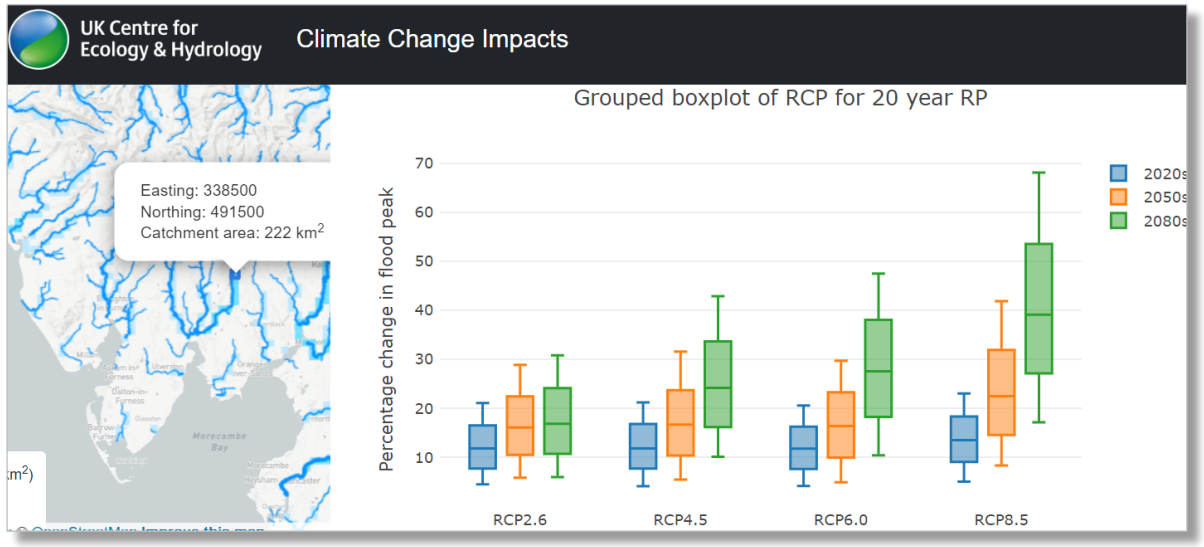


Figure 6.4 Percentage change in expected annual direct damages to non-residential properties from all sources of flooding for scenarios of global warming reaching 2°C and 4°C in 2100. Source: Sayers *et al.* (2020)

Helping plan hydrological input to CCRA4

Climate Change: UK Flood Context

- Web portal showing changes in future floods under different climate scenarios
- Informs climate change uplifts for infrastructure projects
- https://cc-flood-impacts.ceh.ac.uk/



UKCEH Climate Change Impacts web-portal

GOV.UK

Home > Environment > River maintenance, flooding and coastal erosion

Case study

Climate change and peak river flows

Research provided vital information for planners, developers, and flood risk management authorities to prepare for future flooding scenarios.

From: Flood and Coastal Erosion Risk Management Research and Development Programme and Environment Agency

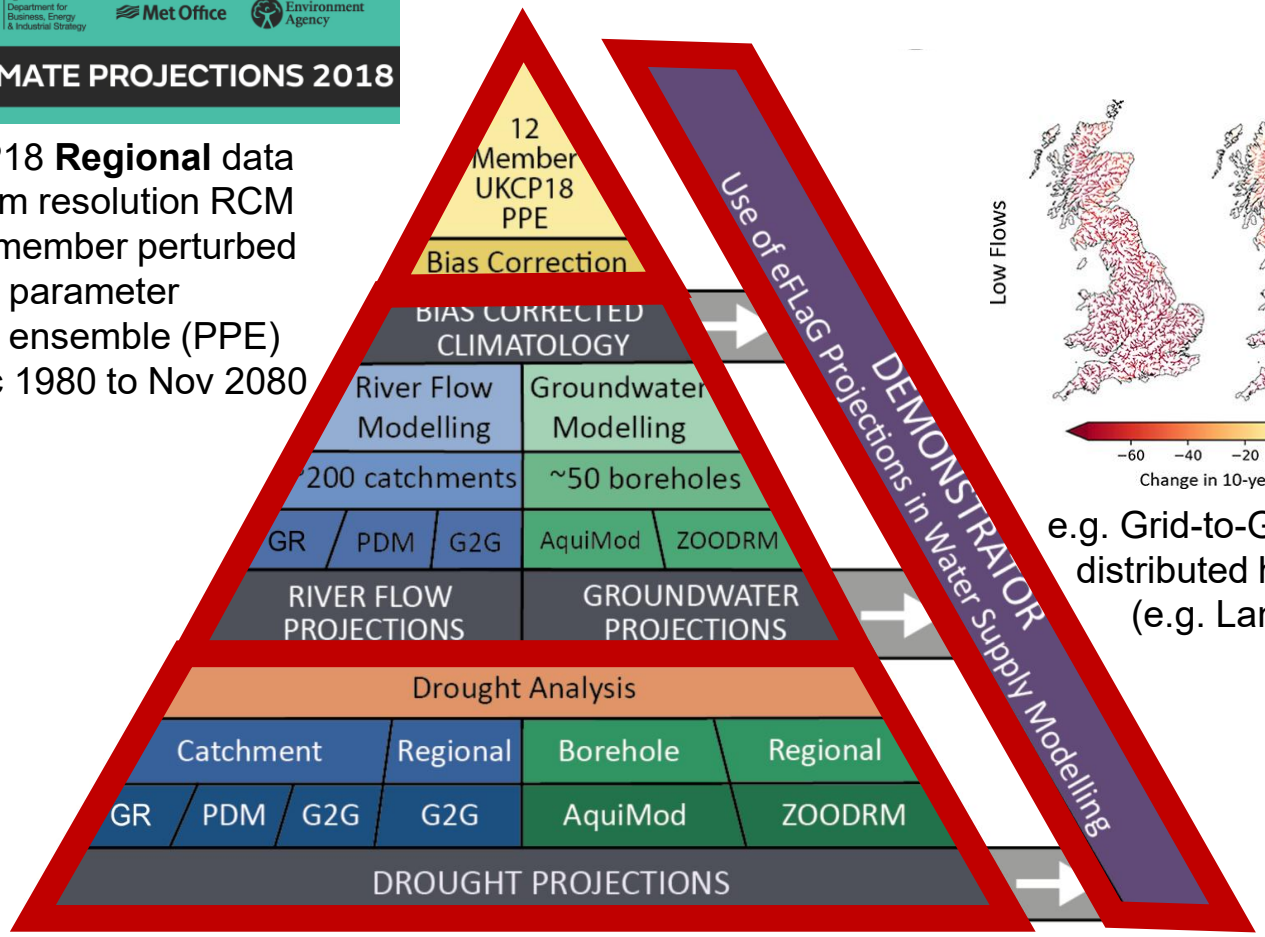
Published 4 April 2025

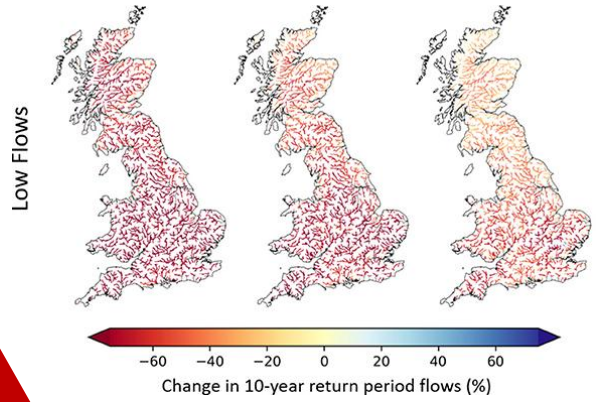
Benefit case study by the Environment Agency

Water Resources future projections: The eFLaG dataset

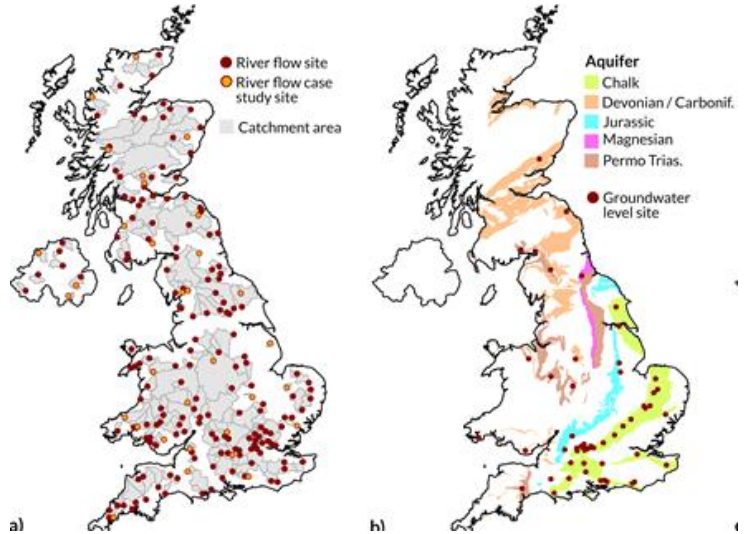
UK CLIMATE PROJECTIONS 2018

UKCP18 **Regional** data
12km resolution RCM
12-member perturbed parameter ensemble (PPE)
Dec 1980 to Nov 2080





e.g. Grid-to-Grid: a national-scale distributed hydrological model (e.g. Lane & Kay 2021)



Maps of the 200 eFLaG Catchments and 54 Boreholes


eFLaG: enhanced future FLows and Groundwater. A national dataset of hydrological projections based on UKCP18

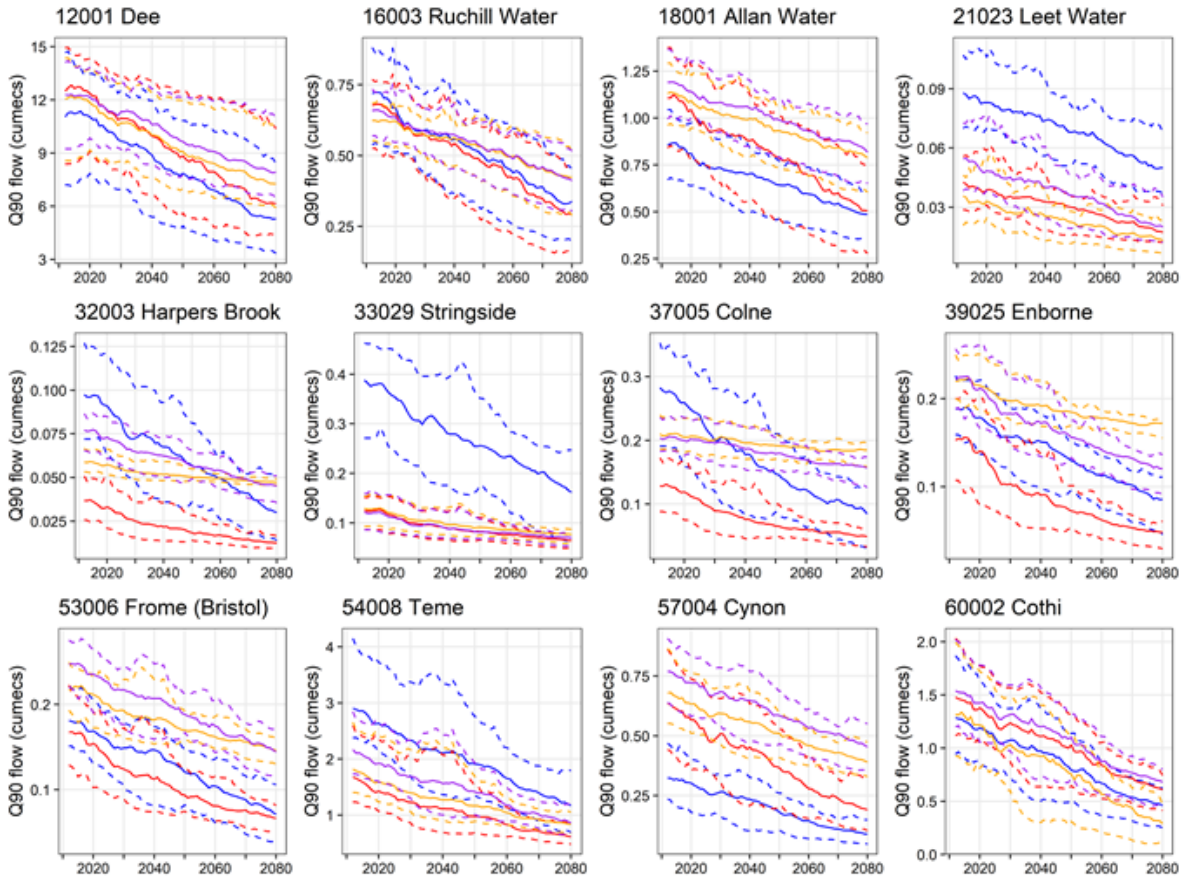
The full story:
Data Paper,

UK Centre for Ecology & Hydrology
British Geological Survey
hrwallingford

Example results: diminishing future flows

Headline: low flows getting lower, but how low will they go? Uncertainty in magnitude of future changes

Low flows (Q90) in 30 year moving windows, 1980 - 2080



Ensemble projections: Range of 12x RCM ensemble members (climate model uncertainty)

Multi-model: four hydrological models (hydrological model uncertainty)

Transient: look at interannual and interdecadal variability rather than time-slices

UK Centre for Ecology & Hydrology

British Geological Survey

hrwallingford

Simon Parry et al. 2024 (HESS)

Demonstrator applications to test water supply resilience

London

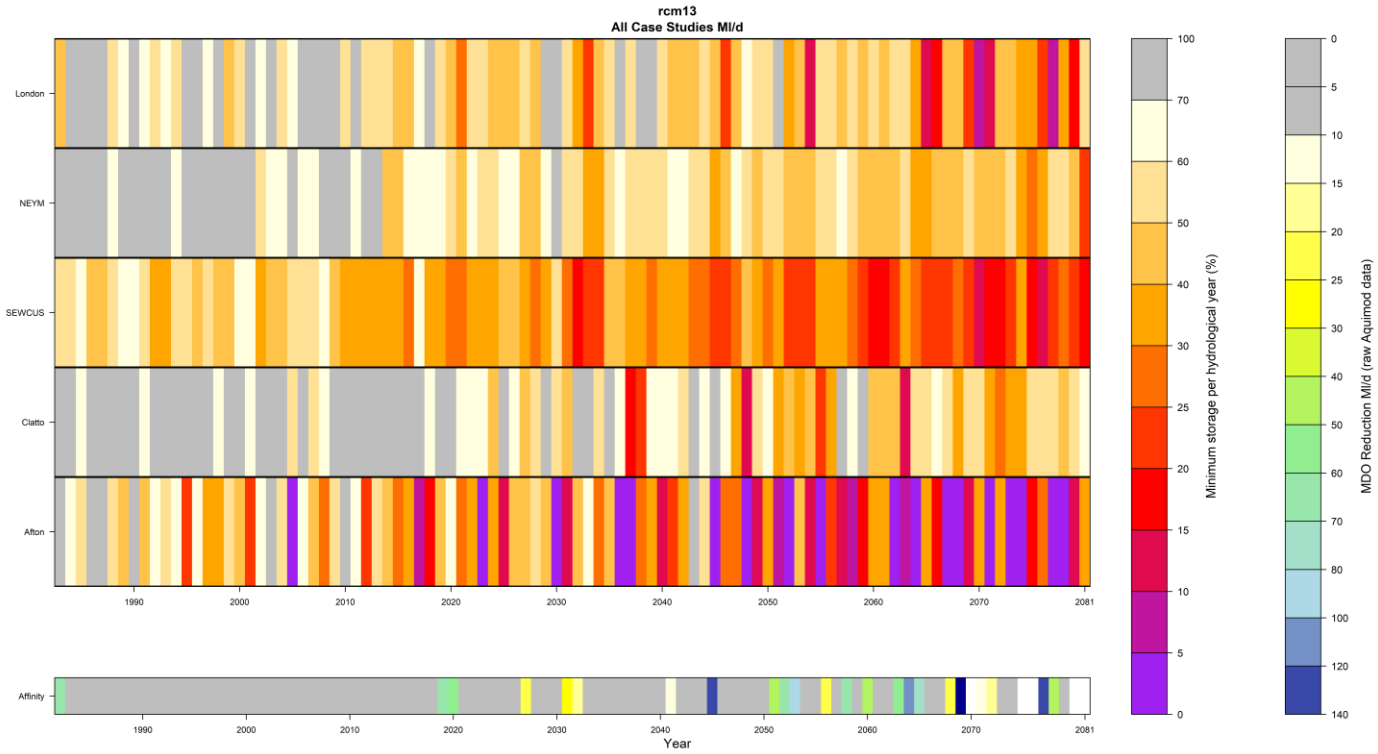
NEYM (N Wales)

SEWCUS (SE Wales)

Clatto (Dundee)

Afton (Ayrshire)

Affinity (SE England)




Usk Reservoir. Nigel Davies, Geograph

Headline: multi-model, spatially coherent, transient projections like eFLaG can add significant value to water resources planning

UK Centre for Ecology & Hydrology

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Scottish Water
Always serving Scotland

Dŵr Cymru Welsh Water

Thames Water

AffinityWater