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Introduction

The Hydrological Outlook UK (www.hydoutuk.net) is the first operational forecast system for the UK that delivers monthly outlooks of the water situation for both river flow and groundwater levels. It brings together information on current and forecast weather conditions, soil moisture, river flows and groundwater levels, and uses a number of modelling approaches to explore possible future hydrological conditions. It is based on merging three complementary methods:

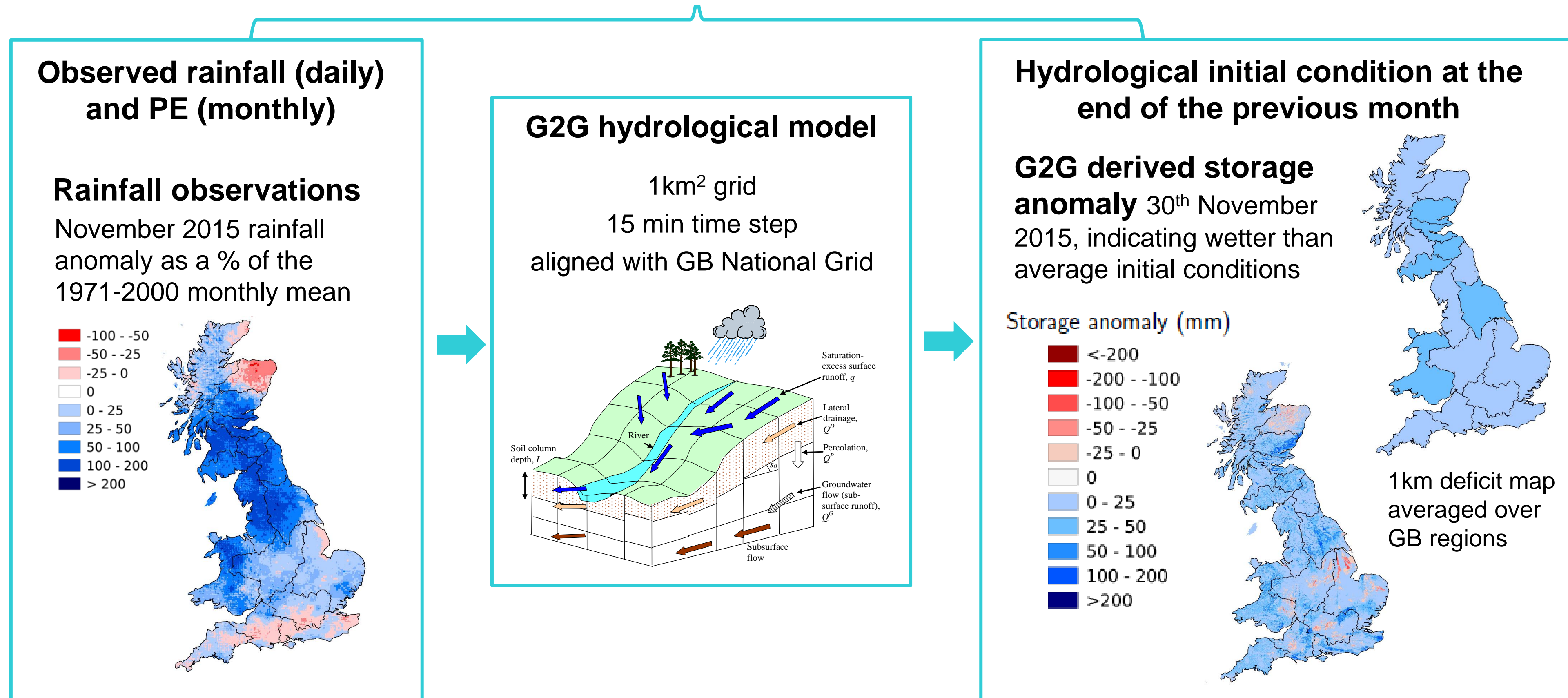
- a statistical method based on river flow analogues and persistence,
- a streamflow ensemble prediction system applied to selected catchments and boreholes; and
- a national hydrological forecast driven by an ensemble of 1 and 3 month-ahead rainfall forecasts from the UK Met Office's GloSea5 model.

Here we focus on the national scale hydrological forecasts, showing how seasonal river flow forecasts are produced, and how they contribute to the Hydrological Outlooks UK monthly summary.

Seasonal river flow forecasts using rainfall forecasts

CEH's national scale hydrological model, Grid-to-Grid (G2G, Bell et al, 2009), provides an estimate of total subsurface water storage (in both soil and groundwater) across the UK, derived using the most recent observations of rainfall and potential evaporation (PE). This hydrological initial condition then provides a starting point from which estimates of water storage and river flows for 1-3 months ahead can be produced as perturbations from the initial state, using a simple water balance model (Bell et al., 2016, in prep), driven by an ensemble of Met Office rainfall forecasts.

Initial conditions



Forecasts

Met Office GloSea5 seasonal forecast spatially uniform UK rainfall

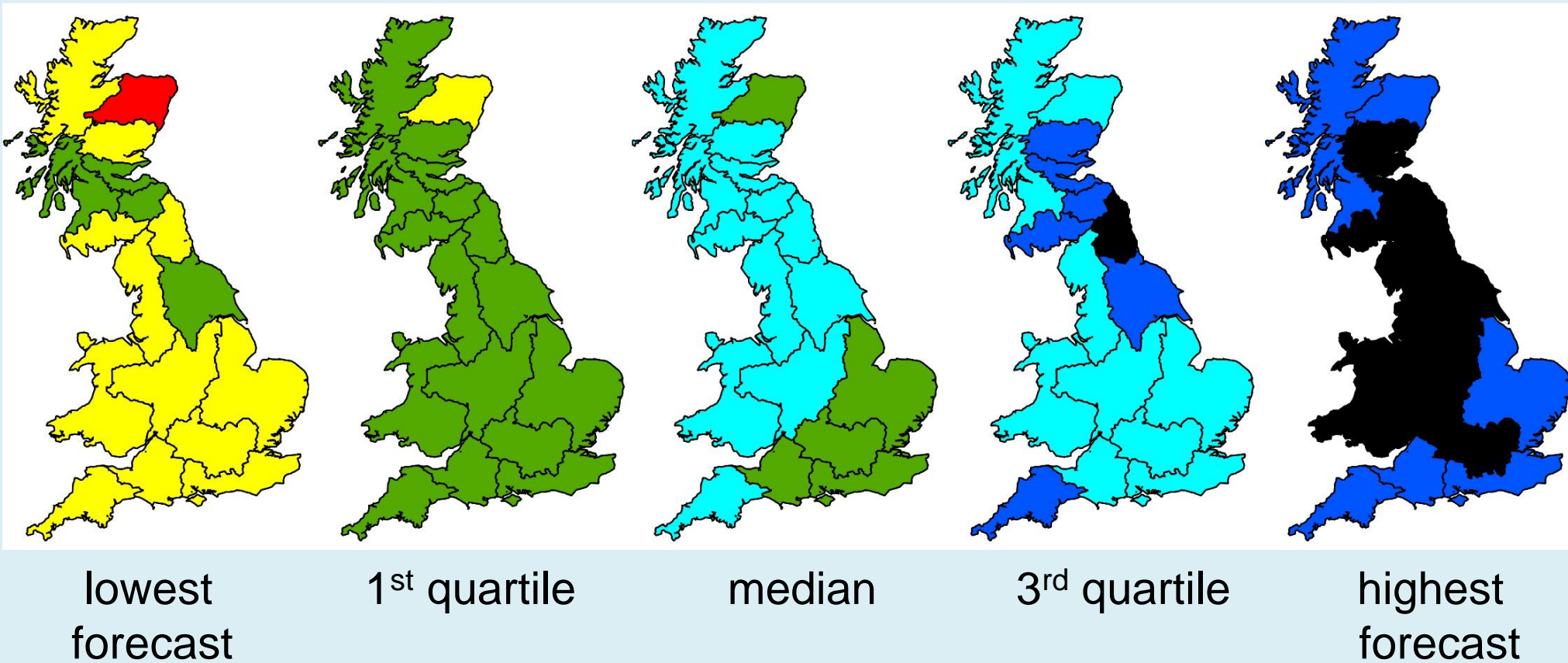
1-month and 3-month UK outlook for precipitation in the context of observed climatology indicates wetter than average

- The Met Office supply a ~42 member ensemble of UK-scale seasonal, 1- and 3-month rainfall forecasts from GloSea5 (MacLachlan et al., 2015).
- The *spatially uniform* rainfall forecasts are converted to *spatially distributed* rainfall amounts according to local (1km pixel) monthly mean rainfall (1971-2000).
- Climatological PE is currently used but temperature forecasts could be exploited in the future to estimate PE.

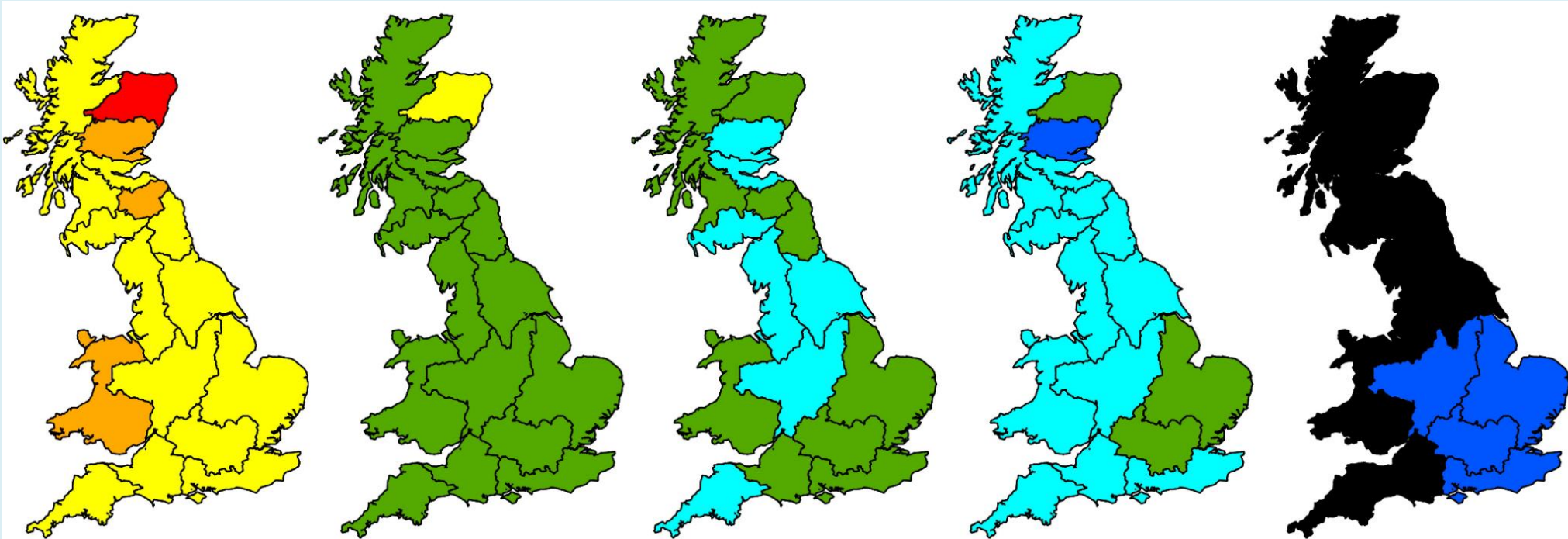
Outputs

Regional forecast monthly mean river flows are derived from the average of 1km river flow estimates within each region and ranked in terms of 49 years of historical flow estimates (1962 – 2010).

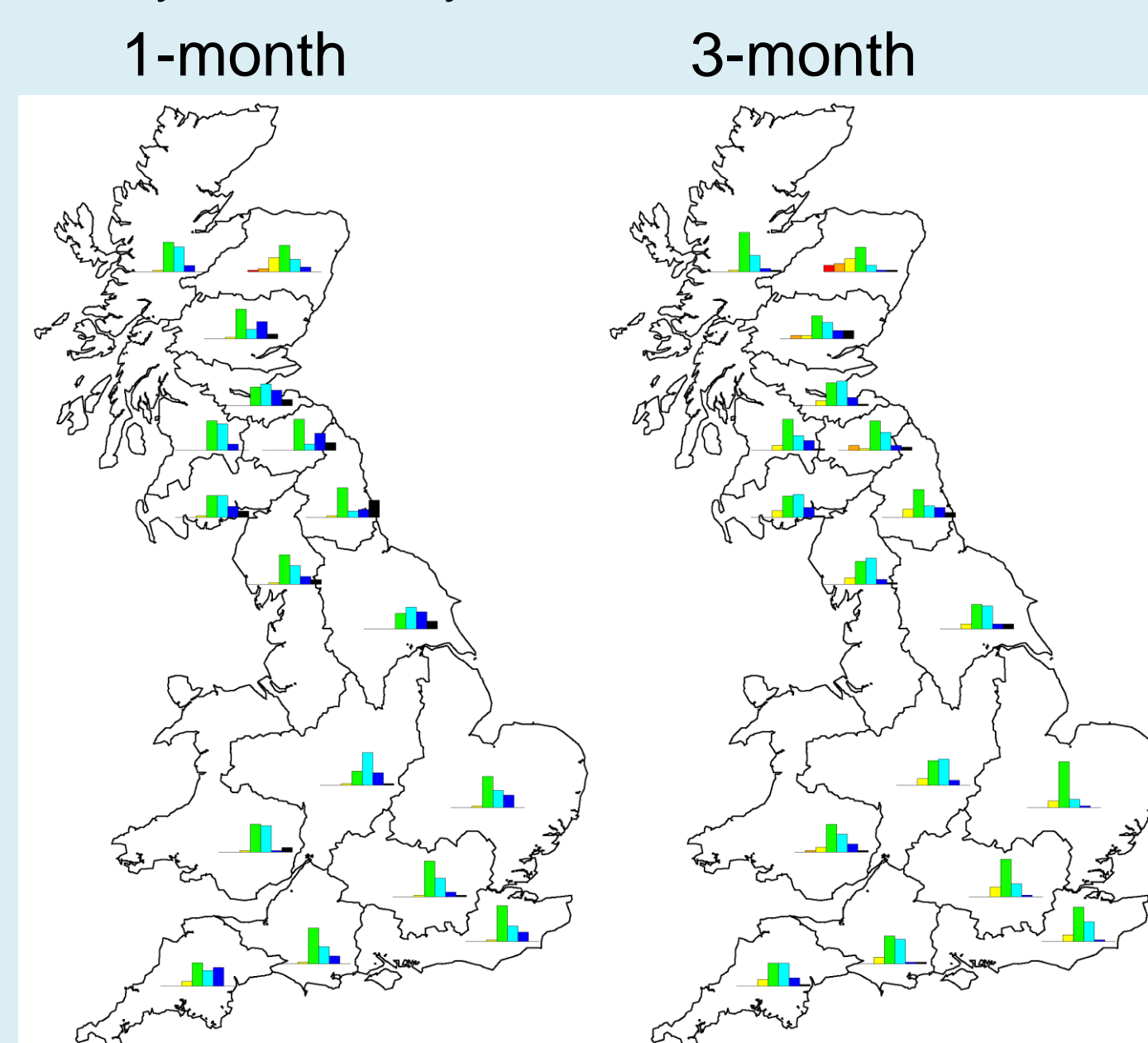
1 month ahead river flow forecasts – December 2015



3 month ahead river flow forecasts – Dec, Jan, Feb



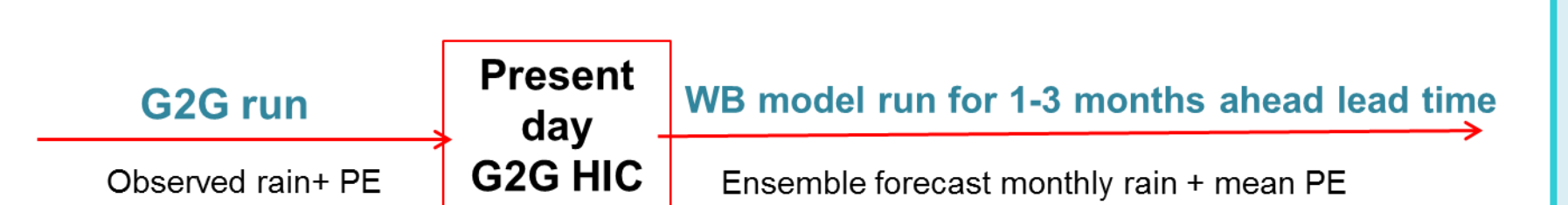
The regional bar charts show the percentage of ensemble forecasts falling in each of the flow categories as generated by the monthly-resolution water-balance model.



Exceptionally high flow
Notably high flow
Above normal
Normal range
Below normal
Notably low flow
Exceptionally low flow

Water balance hydrological model

This uses a simple water-balance model (Bell et al., 2013) to provide forecasts of storage, runoff and river flows for 1- and 3-months ahead (Bell et al., 2016, in prep).



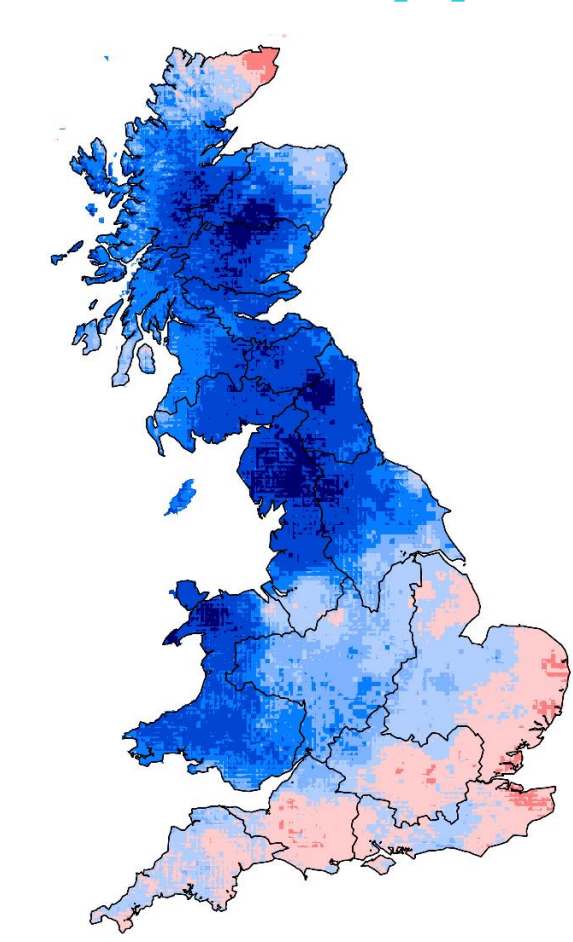
SUMMARY:

This month, following above average November rainfall for much of Britain it is likely that river flows will be in or above the *Normal range* for December, and to the North and West there is a high chance of *Above normal* flows, possibly reaching *Exceptionally high flows* in many places. North East Region is the exception, where, following low rainfall in November, it is more likely that river flows will be in or below the *Normal range*.

Over the next 3 months

There is a high chance of river flows being *Normal* or above for all regions, except for North East Region where there is a high chance of river flows being *Normal* or below.

What happened in reality?



Rainfall anomaly as a % of the 1971-2000 monthly mean

Prolonged heavy rainfall to northern and western areas (named storms 'Desmond', 'Eva' and 'Frank') caused widespread and repeated flooding, bringing significant disruption to transport, utilities and agriculture and flooding over 16,000 homes in England alone (CEH, 2016).

Mean flows for December 2015 for rivers in northern England (e.g. the Eden, Tyne, Tees, Wharfe and Yorkshire Ouse) recorded three times their average flow for December (CEH, 2016).



Environment Agency flood warnings and alerts map December 2015 (EA, 2015).

References

- Bell et al. (2009). Use of soil data in a grid-based hydrological model to estimate spatial variation in changing flood risk across the UK. *J. Hydrol.* 377, 335-350.
Bell et al. (2013). Developing a large-scale water-balance approach to seasonal forecasting: application to the 2012 drought in Britain. *Hydrol. Pro.* 27.
MacLachlan et al. (2015). Global Seasonal forecast system version 5 (GloSea5): a high-resolution seasonal forecast system. *QJRM*, 141, 1072-1084.
Environment Agency (2015) <http://www.independent.co.uk/news/uk/home-news/storm-eva-lancashire-families-evacuated-as-floods-threaten-again-a6786416.html>
Bell et al. (2016) *in prep*. A national-scale seasonal hydrological forecast model: development and evaluation over Britain.
CEH (2016). Briefing Note: Severity of the December 2015 floods – preliminary analysis. http://www.ceh.ac.uk/sites/default/files/Northern_UK_Floods_Dec2015_Briefing_Note.pdf

Acknowledgements

Thank you to the Met Office for the observed PE, rainfall data and seasonal rainfall forecasts.

Hydrological Outlook UK

Period: From December 2015

Issued on 11.12.2015 using data to the end of November 2015

SUMMARY

The one-month outlook is for December flows to be above normal across most of northern and western Britain, with an increased likelihood of exceptional flows in some regions. These projections reflect the exceptionally wet November in much of northern Britain. In actuality, early December has already witnessed exceptional rainfall and flooding in northern England and parts of Scotland, so it is highly likely that total flows for December will be exceptional. With meteorological projections favouring wetter-than-average conditions over the next three months, there is an increased likelihood of above normal winter flows in many northern and western areas, and high groundwater levels are also likely to persist in some eastern areas. In the south and east of England, winter river flows and groundwater levels are largely expected to be normal or above, although below normal levels are likely to persist in some eastern areas.

Note: Up-to-date flood warnings are available from the websites of the Environment Agency, Natural Resources Wales and Scottish Environment Protection Agency.

Rainfall:

For December and December-January-February as a whole above-average precipitation is more probable than below-average. The probability that UK-average precipitation for December-January-February will fall into the driest of five equal categories is between 10% and 13% and the probability that it will fall into the wettest of five categories is 25% (the 1981-2010 probability for each of these categories is 20%).

River flows:

November river flows were mostly in the normal range in southern and eastern England and in the far north of Scotland, with below normal flows in a few catchments in the latter. Elsewhere in northern and western Britain, river flows were above normal, with exceptionally high flows in northern England and north Wales. The one month outlook is for a similar picture: river flows are likely to be above normal across most of northern and western Britain and there is an increased likelihood of exceptional flows in many places. In south-east England, normal to above normal flows are expected while in north-east Scotland flows are likely to be normal. The three month outlook is for a continuation of above normal flows in some northern and western regions, but in others (including Wales and much of Scotland) flows are more likely to return to the normal range. In south-east England flows are likely to be normal to above normal.

Groundwater:

In the Chalk, November levels were mostly in the normal range or below, with below normal levels mainly in eastern England. In other aquifers levels were mostly normal to above normal. The one month outlook is for a continuation of this situation, with mostly normal levels in the southern Chalk and normal to below levels further east, and above normal levels in parts of the Permo-Triassic sandstone. The three month outlook suggests a mixed pattern for the Chalk, with below normal levels in some eastern areas contrasting with above normal levels for the South Downs. Elsewhere normal to above normal levels are likely and parts of the Permo-Triassic sandstone in the north west may see exceptionally high levels. These increases reflect the wetter-than-average rainfall projections and the latter looks increasingly likely given early December rainfall in north-west England. However it should be noted that high levels in the Permo-Triassic sandstone do not play a significant role in flooding.

The Hydrological Outlook UK provides an outlook for the water situation for the UK over the next three months and beyond. For guidance on how to interpret the outlook, a wider range of information, and a full description of underpinning methods, please visit the website: www.hydoutuk.net

