Hydrological Forecasting in R

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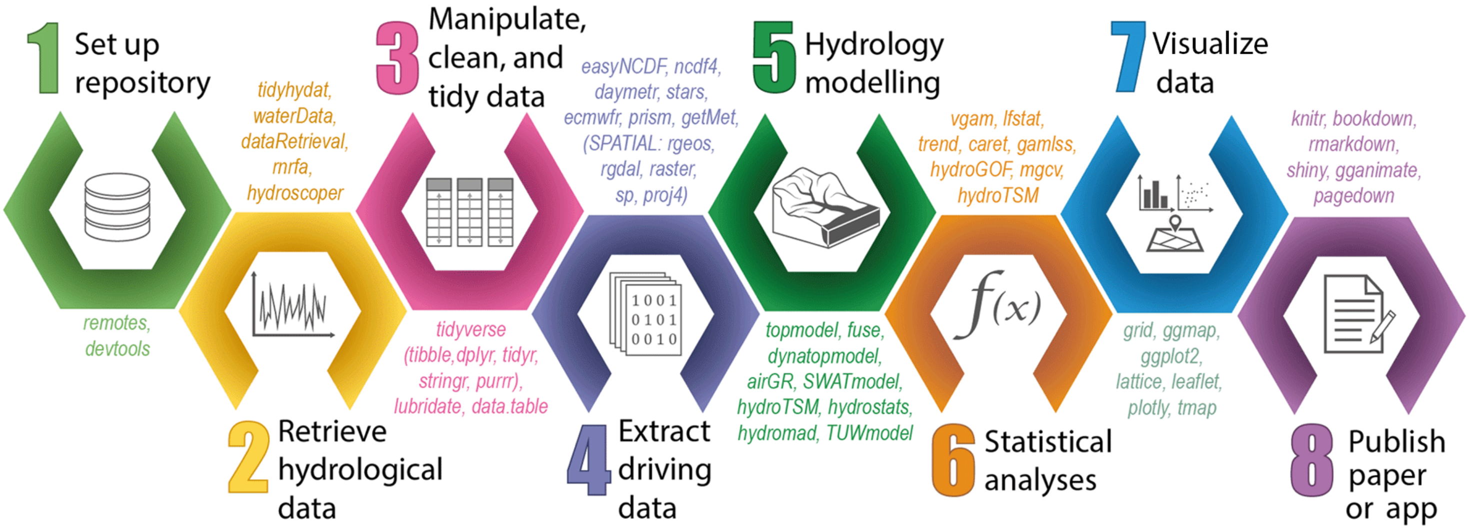
Using R
In
Hydrology

vEGU 2021

Forecasting in R

As with any piece of R work, forecasting has a pretty standard workflow of:

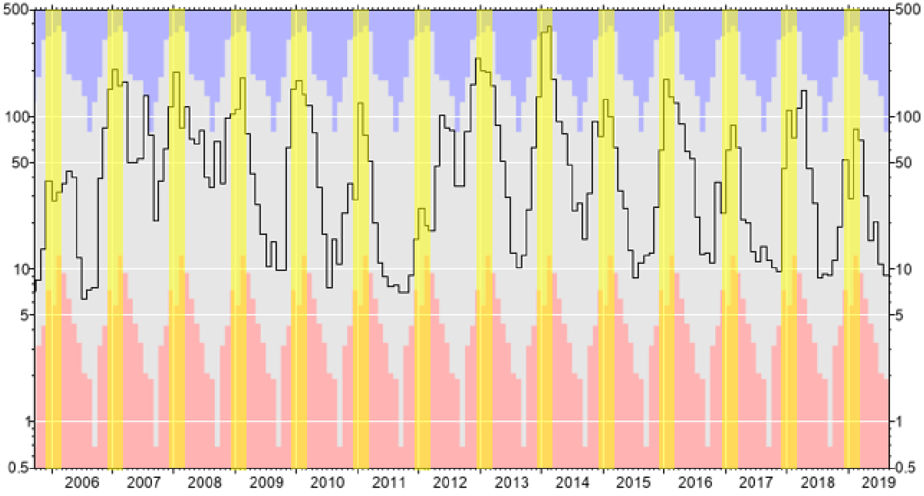
- setting up version control
- retrieving hydrological data for calibration
- tidying data
- extracting driving climate data
- applying a hydrological model
- analysing, visualising, and publishing the results

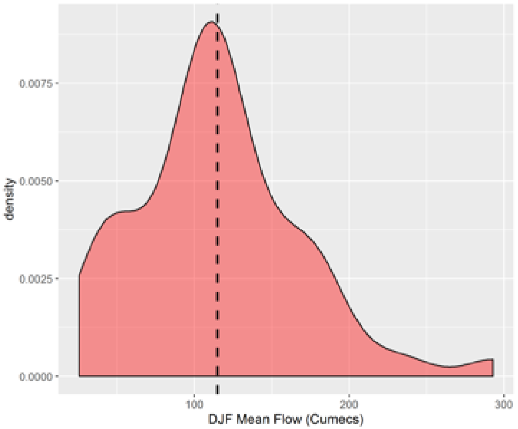


1 Set up repository
remotes, devtools
tidyhydat, waterData, dataRetrieval, mrfa, hydroscoper
2 Retrieve hydrological data
3 Manipulate, clean, and tidy data
tidyverse (tibble,dplyr, tidyr, stringr, purrr), lubridate, data.table
easyNCDF, ncdf4, daymetr, stars, ecmwfr, prism, getMet, (SPATIAL: rgeos, rgdal, raster, sp, proj4)
1001 0101 0010
4 Extract driving data
5 Hydrology modelling
topmodel, fuse, dynatopmodel, airGR, SWATmodel, hydroTSM, hydrostats, hydromad, TUWmodel
vgam, lfstat, trend, caret, gamlss, hydroGOF, mgcv, hydroTSM
f(x)
6 Statistical analyses
7 Visualize data
grid, ggmap, ggplot2, lattice, leaflet, plotly, tmap
knitr, bookdown, rmarkdown, shiny, gganimate, pagedown
8 Publish paper or app

Climatology

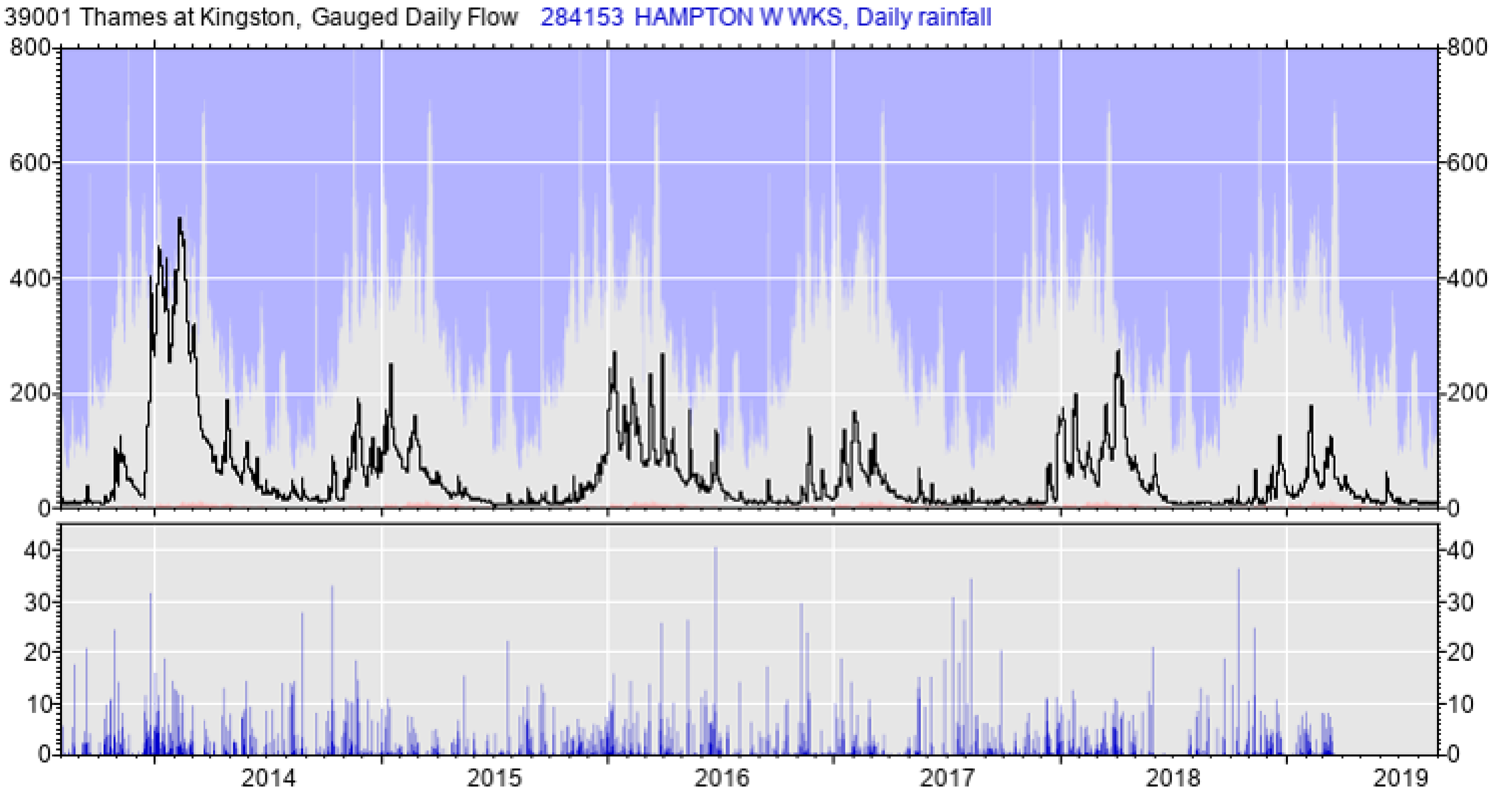
The most basic forecast that we could make is "climatology". This is simply looking at the observed streamflow at this time of year for each year in the past, and using those to form a distribution.





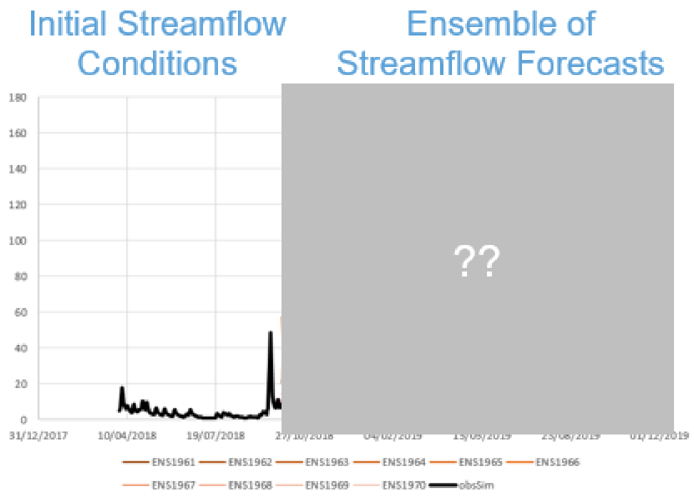
Ensemble Streamflow Prediction

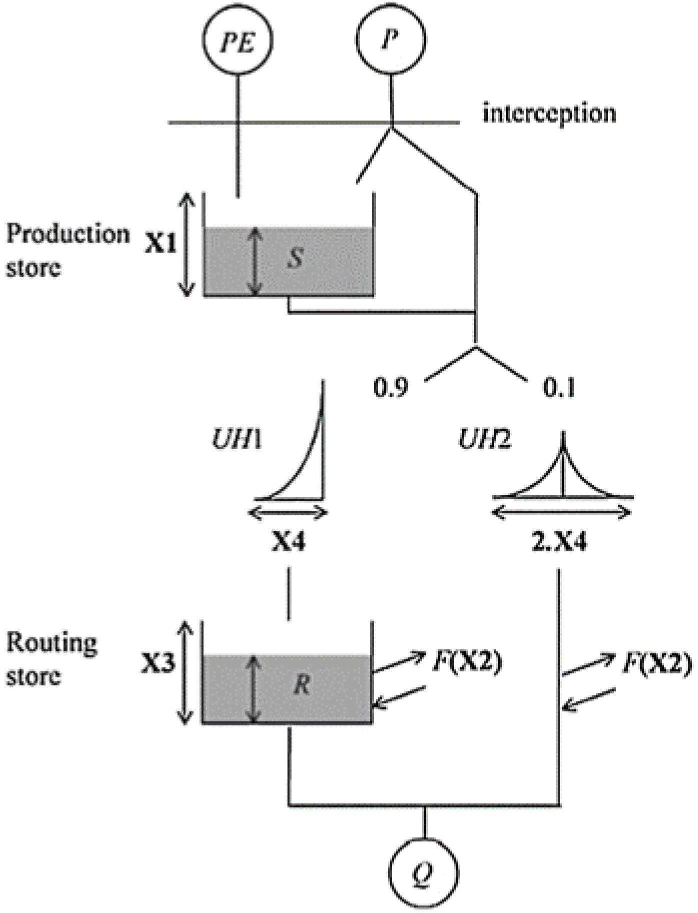
A step up from that is ESP, a very simple method of forecasting that does not require a meteorological forecast. We know our initial conditions, so some of the years in the climatology may not be appropriate.



Ensemble Streamflow Prediction

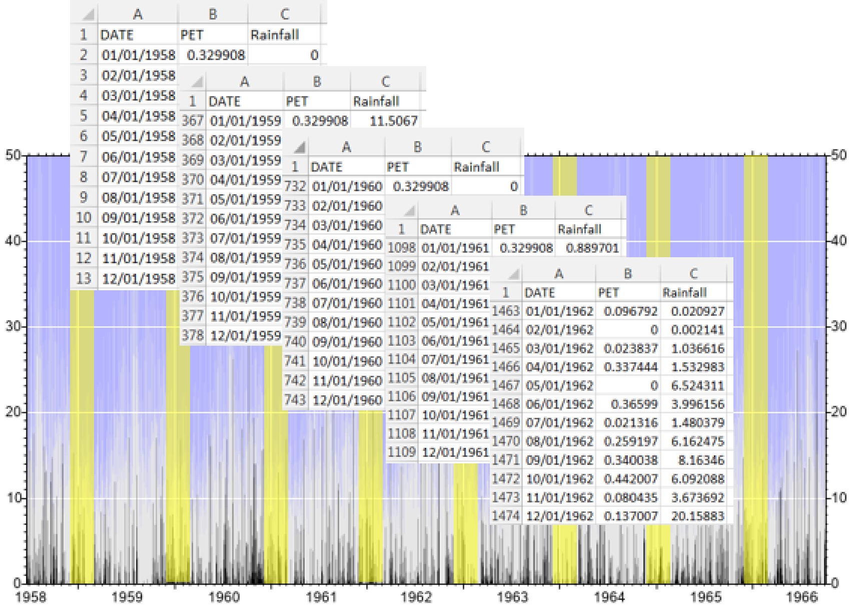
We can model the flow up until the present day, using observed climate data.





Ensemble Streamflow Prediction

Then ESP simply uses past years of observed climate data, and runs a hydrological model as if that climate were to happen from today.



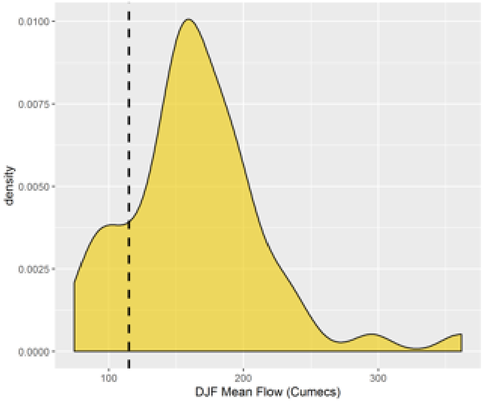
	A	B	C
1	DATE	PET	Rainfall
2	01/01/1958	0.329908	0
3	02/01/1958		
4	03/01/1958		
5	04/01/1958		
6	05/01/1958		
7	06/01/1958		
8	07/01/1958		
9	08/01/1958		
10	09/01/1958		
11	10/01/1958		
12	11/01/1958		
13	12/01/1958		

	A	B	C
1	DATE	PET	Rainfall
367	01/01/1959	0.329908	11.5067
368	02/01/1959		
369	03/01/1959		
370	04/01/1959		
371	05/01/1959		
372	06/01/1959		
373	07/01/1959		
374	08/01/1959		
375	09/01/1959		
376	10/01/1959		
377	11/01/1959		
378	12/01/1959		

	A	B	C
1	DATE	PET	Rainfall
732	01/01/1960	0.329908	0
733	02/01/1960		
734	03/01/1960		
735	04/01/1960		
736	05/01/1960		
737	06/01/1960		
738	07/01/1960		
739	08/01/1960		
740	09/01/1960		
741	10/01/1960		
742	11/01/1960		
743	12/01/1960		

	A	B	C
1	DATE	PET	Rainfall
1098	01/01/1961	0.329908	0.889701
1099	02/01/1961		
1100	03/01/1961		
1101	04/01/1961		
1102	05/01/1961		
1103	06/01/1961		
1104	07/01/1961		
1105	08/01/1961		
1106	09/01/1961		
1107	10/01/1961		
1108	11/01/1961		
1109	12/01/1961		

	A	B	C
1	DATE	PET	Rainfall
1463	01/01/1962	0.096792	0.020927
1464	02/01/1962	0	0.002141
1465	03/01/1962	0.023837	1.036616
1466	04/01/1962	0.337444	1.532983
1467	05/01/1962	0	6.524311
1468	06/01/1962	0.36599	3.996156
1469	07/01/1962	0.021316	1.480379
1470	08/01/1962	0.259197	6.162475
1471	09/01/1962	0.340038	8.16346
1472	10/01/1962	0.442007	6.092088
1473	11/01/1962	0.080435	3.673692
1474	12/01/1962	0.137007	20.15883

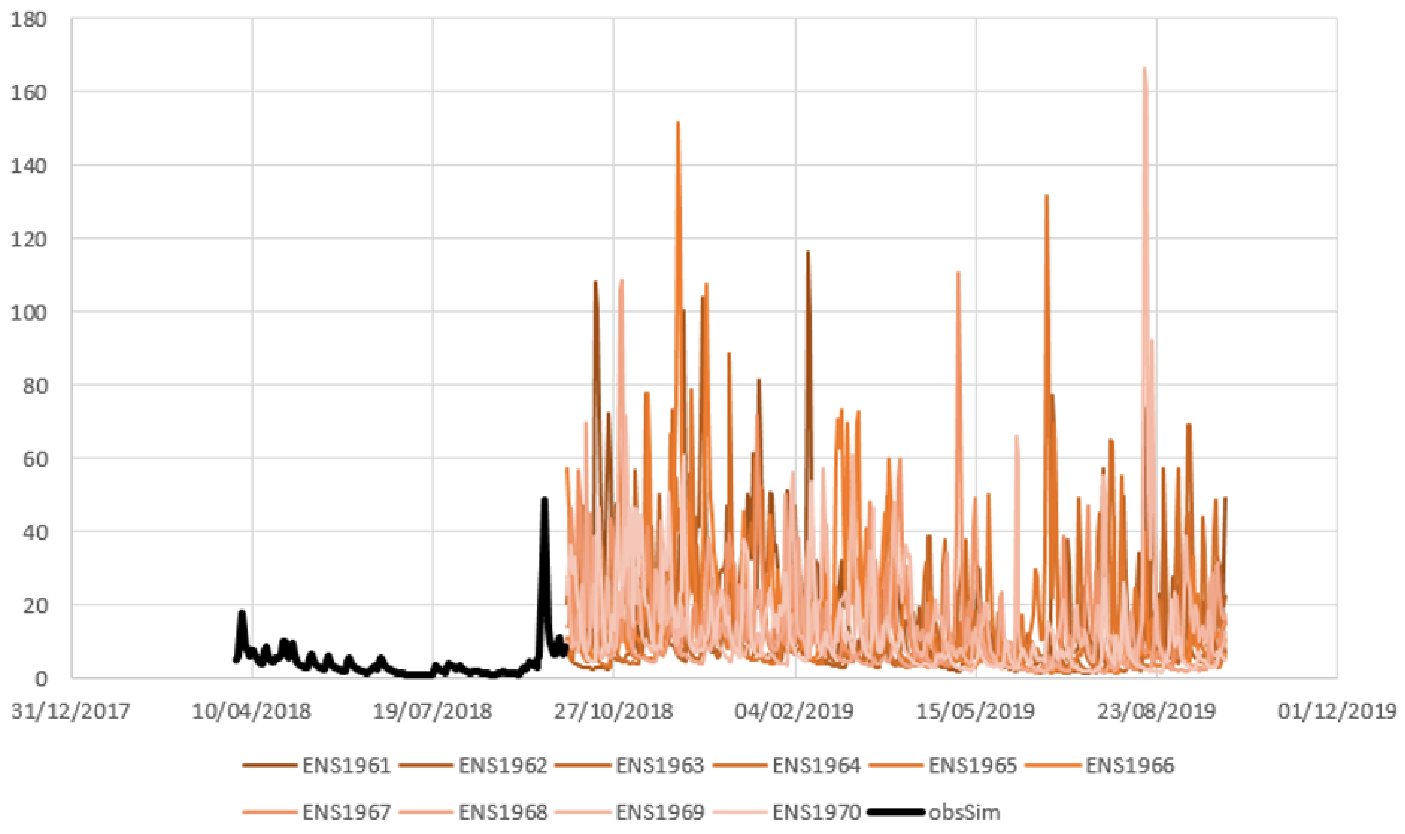


Dashed line = mean of climatology

Ensemble Streamflow Prediction

Initial Streamflow Conditions

Ensemble of Streamflow Forecasts

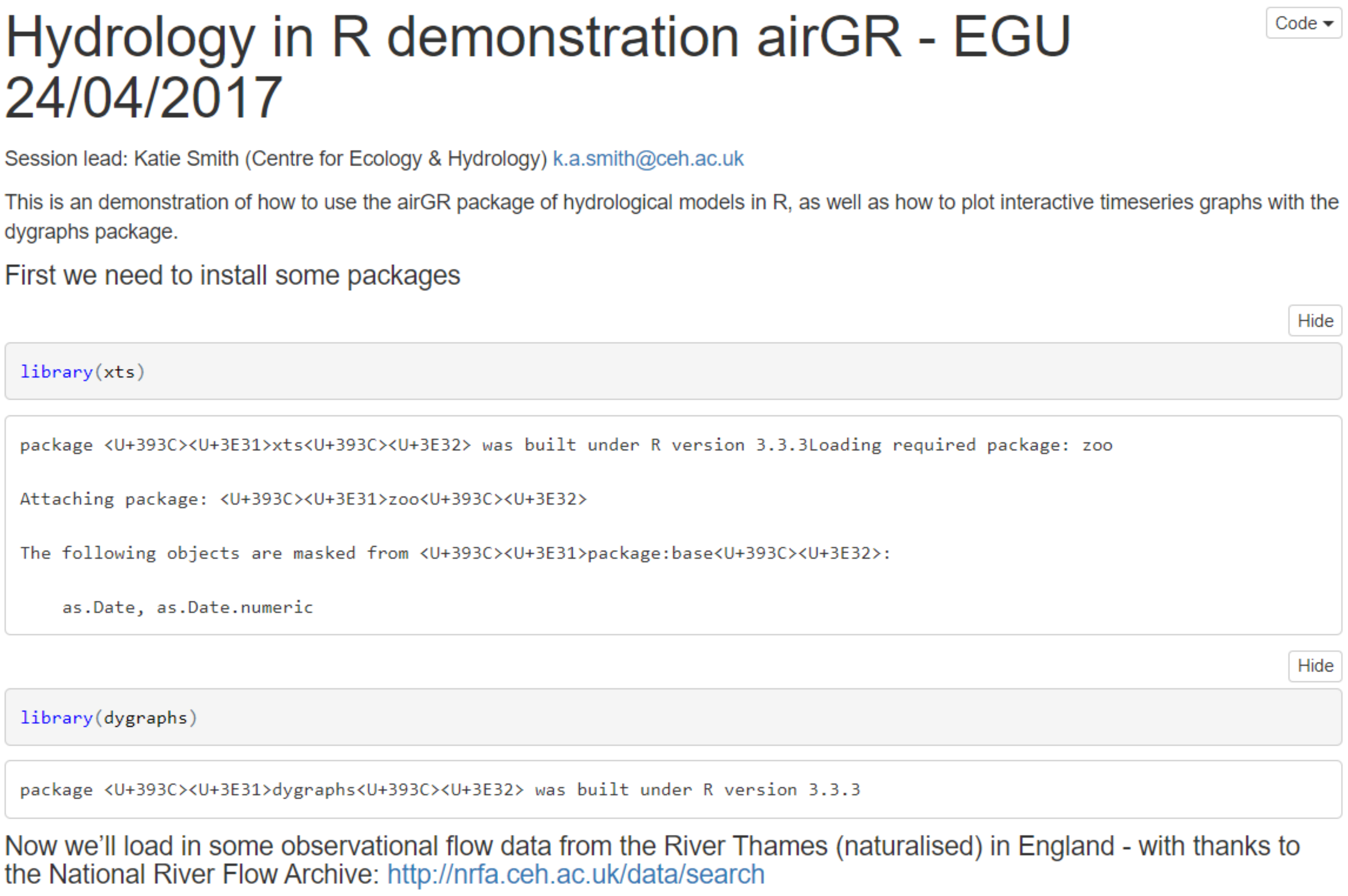


So let's have a go!

Ensemble Streamflow Prediction with GR4J

The first step is to calibrate the GR4J model. A workthrough on how to do that can be found in the R notebook at:

https://github.com/hydrosoc/rhydro_vEGU21/tree/main/presentations/04.hydro_forecas



Hydrology in R demonstration airGR - EGU 24/04/2017

Session lead: Katie Smith (Centre for Ecology & Hydrology) k.a.smith@ceh.ac.uk

This is an demonstration of how to use the airGR package of hydrological models in R, as well as how to plot interactive timeseries graphs with the dygraphs package.

First we need to install some packages

```
library(xts)
```

```
package <U+393C><U+3E31>xts<U+393C><U+3E32> was built under R version 3.3.3Loading required package: zoo

Attaching package: <U+393C><U+3E31>zoo<U+393C><U+3E32>

The following objects are masked from <U+393C><U+3E31>package:base<U+393C><U+3E32>:

    as.Date, as.Date.numeric
```

```
library(dygraphs)
```

```
package <U+393C><U+3E31>dygraphs<U+393C><U+3E32> was built under R version 3.3.3
```

Now we'll load in some observational flow data from the River Thames (naturalised) in England - with thanks to the National River Flow Archive: http://nrfa.ceh.ac.uk/data/search

You'll need some packages:

```
library(airGR)
library(dplyr)
library(ggplot2)
library(reshape2)
```

I also used a couple of personal functions to make life easier that:

- remove leap years from a date series
- make formatted dates from simple arguments (dd,mm,yyyy)

Setting Up

We're working on the Lambourn catchment in the UK, a very groundwater dominated catchment. This is where ESP works the best, as it gets a lot of skill from flow persistence.

```r
# set station and its area
BasinInfoAll<-c(39019,234.1)
getwd()
# Read BasinObs
BasinObs <- read.csv("./Final_New_BasinObs_1961_2017_39019.csv")
BasinObs$DATE <- as.POSIXct(BasinObs$DATE, format = dateFormat)
# Model parameters
Param <- c(455.6977636,-11.6614573,1085.473369,10.2877058)
# set data
DatesR    <- as.POSIXlt(BasinObs$DATE)
Precip    <- BasinObs$PRECIP
PotEvap   <- BasinObs$PET
CatchArea <- BasinInfoAll[2]
```

Running a baseline

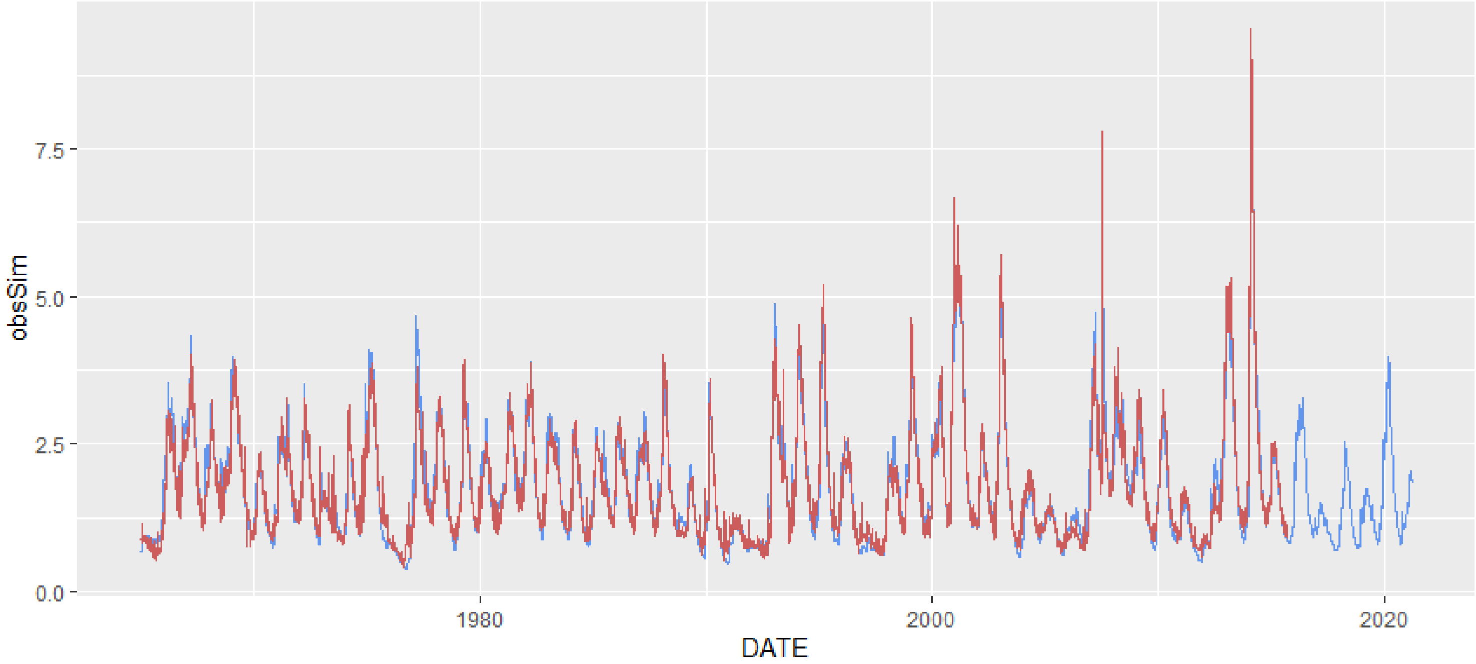
```
# RUN GR4J FOR OBS PERIOD
InputsModel <- CreateInputsModel(FUN_MOD = RunModel_GR4J,
                                 DatesR = DatesR,
                                 Precip = Precip,
                                 PotEvap = PotEvap)
Ind_Run <- seq(1:length(DatesR))
RunOptions <- suppressWarnings(CreateRunOptions(FUN_MOD = RunModel_GR
                                                InputsModel = InputsM
                                                IndPeriod_Run = Ind_R
                                                IniStates = NULL,
                                                IniResLevels = NULL,
                                                IndPeriod_WarmUp = NU
OutputsModel <- RunModel_GR4J(InputsModel = InputsModel,
                              RunOptions   = RunOptions,
                              Param        = Param)
```

Post process the output

```
obsSim<-as.data.frame(matrix(ncol=2,nrow=length(BasinObs$DATE),NA))
obsSim[,1]<-BasinObs$DATE
obsSim[,2]<-OutputsModel$Qsim
# Remove first 4 years as warm-up as change DATE to as.Date
colnames(obsSim) <- c("DATE", "obsSim")
obsSim$DATE<-as.Date(obsSim$DATE)
obsSim <- obsSim[which(obsSim$DATE > MakeDate(31,12,1964)), ]
# convert to cumecs
obsSim$obsSim <- (obsSim$obsSim * CatchArea) / 86.4
# merge with obs
obsSim$obs <- BasinObs$FLOW_cumecs[which(BasinObs$DATE==as.POSIXct(ob
                                     length(BasinObs$DATE)]
```

Plotting the baseline run

```
# MAKE A PLOT
ggplot(obsSim)+
  geom_line(aes(x=DATE,y=obsSim),color="cornflower blue")+
  geom_line(aes(x=DATE,y=obs), color="indianred")
```



Get historic forecast data ready

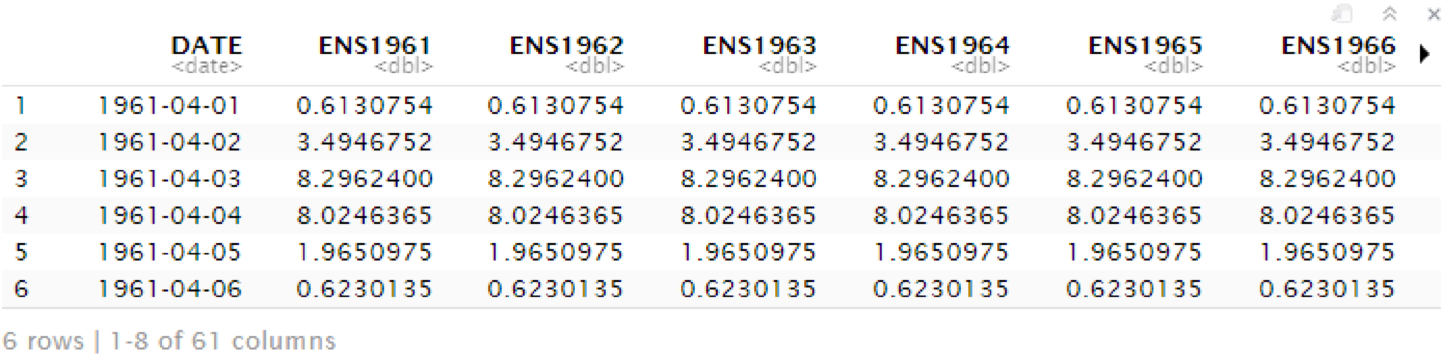
```r
#remove the first few months to mirror start month of forecast
BasinObs <- read.csv("./Final_New_BasinObs_1961_2017_39019.csv")
BasinObs$DATE <- as.Date(BasinObs$DATE)
BasinObs<-BasinObs[which(BasinObs$DATE >= MakeDate(01,04,1961)),]

#remove leap years from BasinObs
NoLeap <- RemoveLeapDay(BasinObs$DATE)
BasinObsNoLeap <- as.data.frame(NoLeap)
colnames(BasinObsNoLeap)<-c("DATE")
BasinObsNoLeap <- left_join(BasinObsNoLeap, BasinObs, by = "DATE")
```

Get historic forecast data ready

Make input matrix for Precip

```
PrecipESPin<-as.data.frame(matrix(NA,nrow=length(BasinObsNoLeap$DATE)
colnames(PrecipESPin)<-c("DATE",paste0("ENS",seq(1961,2020)))
PrecipESPin$DATE<-RemoveLeapDay(seq(MakeDate(01,04,1961),MakeDate(31,
PrecipESPin[1:length(BasinObsNoLeap$DATE),2:ncol(PrecipESPin)]<-Basin
precipmatrix<-as.data.frame(matrix(BasinObsNoLeap$PRECIP,nrow=365,byr
colnames(precipmatrix)<-paste0("ENS",seq(1961,2020))
precipmatrix$DATE<-RemoveLeapDay(seq(MakeDate(01,04,2021),MakeDate(31
PrecipESPin<-rbind(PrecipESPin,precipmatrix)
head(PrecipESPin)
```



	DATE <date>	ENS1961 <dbl>	ENS1962 <dbl>	ENS1963 <dbl>	ENS1964 <dbl>	ENS1965 <dbl>	ENS1966 <dbl>
1	1961-04-01	0.6130754	0.6130754	0.6130754	0.6130754	0.6130754	0.6130754
2	1961-04-02	3.4946752	3.4946752	3.4946752	3.4946752	3.4946752	3.4946752
3	1961-04-03	8.2962400	8.2962400	8.2962400	8.2962400	8.2962400	8.2962400
4	1961-04-04	8.0246365	8.0246365	8.0246365	8.0246365	8.0246365	8.0246365
5	1961-04-05	1.9650975	1.9650975	1.9650975	1.9650975	1.9650975	1.9650975
6	1961-04-06	0.6230135	0.6230135	0.6230135	0.6230135	0.6230135	0.6230135

6 rows | 1-8 of 61 columns

Get historic forecast data ready

Do the same for PET

```
PetESPin<-as.data.frame(matrix(NA,nrow=length(BasinObsNoLeap$DATE),nc
colnames(PetESPin)<-c("DATE",paste0("ENS",seq(1961,2020)))
PetESPin$DATE<-RemoveLeapDay(seq(MakeDate(01,04,1961),MakeDate(31,03,
PetESPin[1:length(BasinObsNoLeap$DATE),2:ncol(PetESPin)]<-BasinObsNoL
petmatrix<-as.data.frame(matrix(BasinObsNoLeap$PET,nrow=365,byrow=F))
colnames(petmatrix)<-paste0("ENS",seq(1961,2020))
petmatrix$DATE<-RemoveLeapDay(seq(MakeDate(01,04,2021),MakeDate(31,03
PetESPin<-rbind(PetESPin,petmatrix)
```

And make an output matrix

```
ESPforecasts<-as.data.frame(matrix(NA,nrow=length(BasinObsNoLeap$DATE
colnames(ESPforecasts)<-c("DATE",paste0("ENS",seq(1961,2020)))
ESPforecasts$DATE<-RemoveLeapDay(seq(MakeDate(01,04,1961),MakeDate(31
```

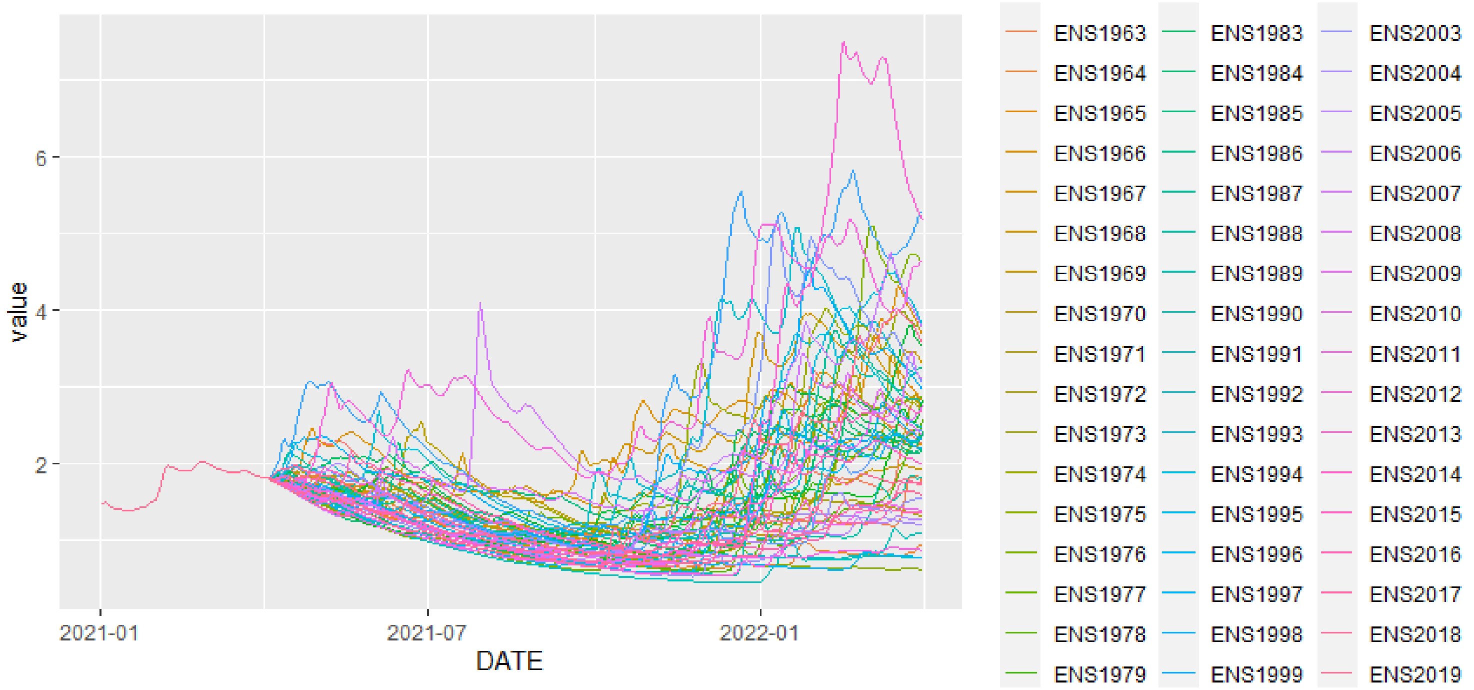
RUN ESP

```
for (i in 2:61){
  DatesR    <- as.POSIXlt(ESPforecasts$DATE)
  Precip    <- PrecipESPin[,i]
  PotEvap   <- PetESPin[,i]
  CatchArea <- BasinInfoAll[2]
  InputsModel <- CreateInputsModel(FUN_MOD = RunModel_GR4J, DatesR =
                                   Precip = Precip, PotEvap = PotEvap
  Ind_Run <- seq(1:length(DatesR))

  RunOptions <- suppressWarnings(CreateRunOptions(FUN_MOD = RunModel_
                                                  InputsModel = Input
                                                  IndPeriod_Run = Ind
                                                  IniStates = NULL, I
                                                  IndPeriod_WarmUp =
    OutputsModel <- RunModel_GR4J(InputsModel = InputsModel,RunOption
                                  Param = Param)
  ESPforecasts[,i]<-OutputsModel$Qsim
}
# convert runoff (mm/day) to flow (M3/s)
ESPforecasts_m3s <- ESPforecasts
ESPforecasts_m3s[,2:61] <- (ESPforecasts[2:61] * CatchArea) / 86.4
```

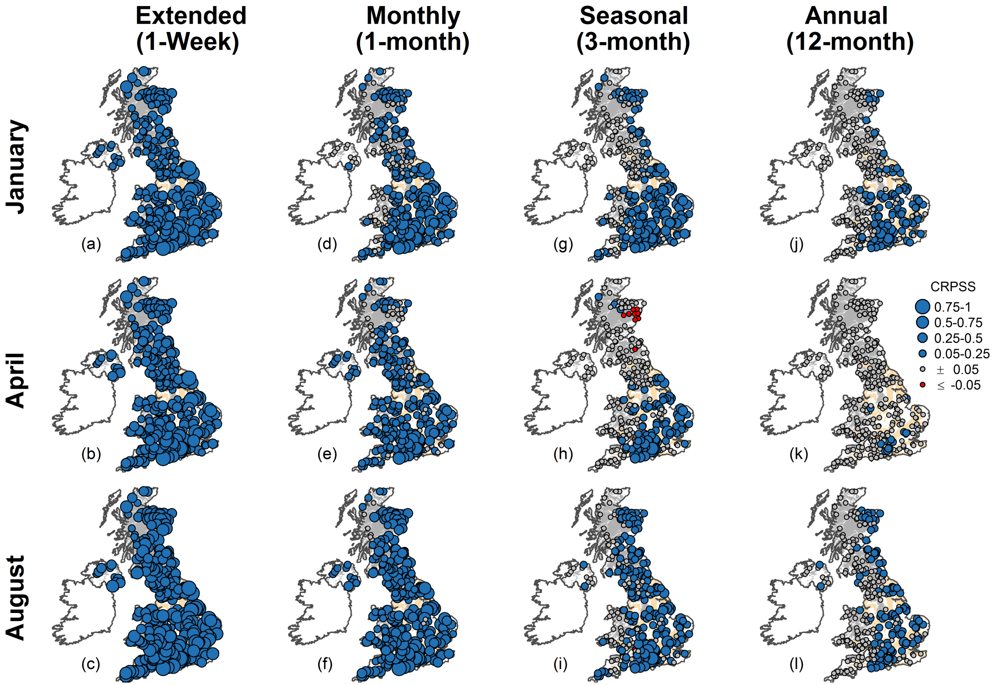
Plot the forecast

```
# MAKE A PLOT
ESPsub<-ESPforecasts_m3s[which(ESPforecasts$DATE>MakeDate(01,01,2021)
ESPmelt <- melt(ESPsub,id.var="DATE")
ggplot(ESPmelt,aes(x=DATE,y=value))+
  geom_line(aes(colour=variable))
```



Assessing the Skill

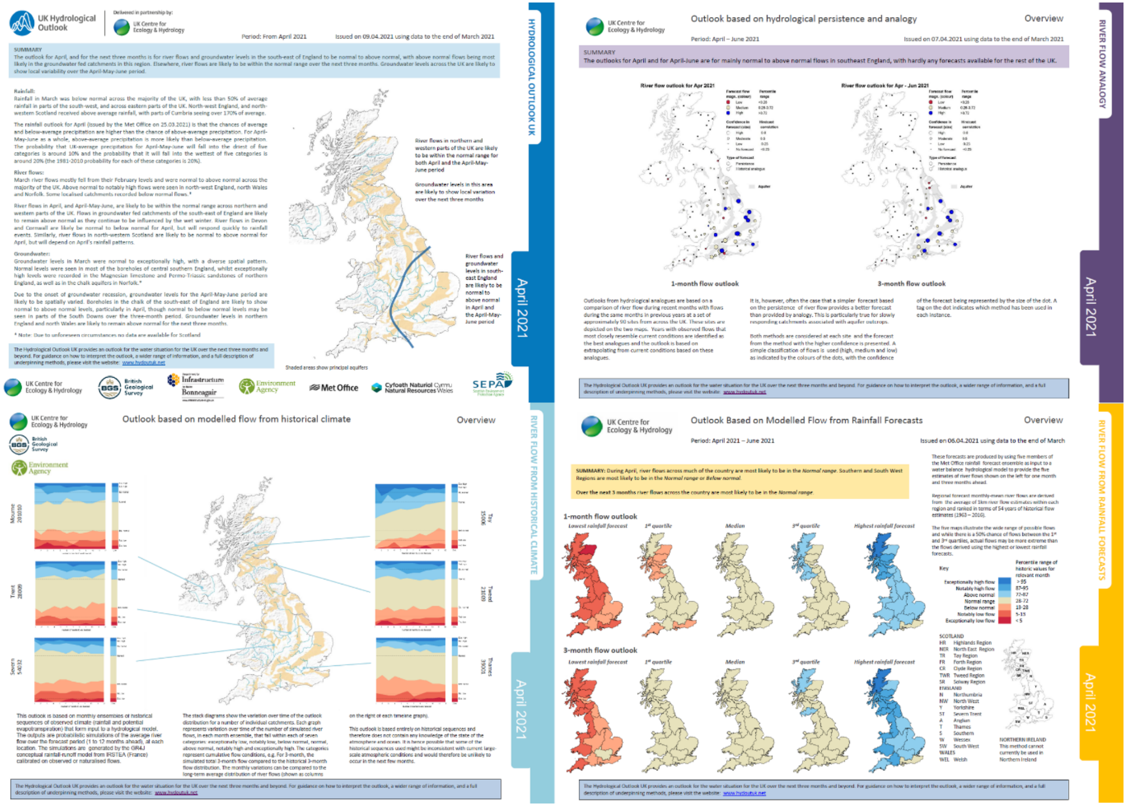
It is important to assess the skill of your forecasting system. You can do this by setting up a "hindcast" experiment (making forecasts of a past date), that you can then compare with observations. For more on this, and how we assessed our system, using the easyVerification R package, see Harrigan et al (2018) https://hess.copernicus.org/articles/22/2023/2018/



How we use our forecasts

UK Hydrological Outlook

The ESP method, along with two other methods of hydrological forecasting (1 - persistence and analogues statistical forecasting, and 2 - forcasting using dynamic climate forecasts), are combined with groundwater forecasts to produce our UK Hydrological Outlook.
www.hydoutuk.net



UK Hydrological Outlook

Delivered in partnership by: UK Centre for Ecology & Hydrology

Period: From April 2021 Issued on 09.04.2021 using data to the end of March 2021

HYDROLOGICAL OUTLOOK UK

April 2021

SUMMARY
The outlook for April, and for the next three months is for river flows and groundwater levels in the south-east of England to be normal to above normal, with above normal flows being most likely in the groundwater fed catchments in this region. Elsewhere, river flows are likely to be within the normal range over the next three months. Groundwater levels across the UK are likely to show local variability over the April-May-June period.

Rainfall:
Rainfall in March was below normal across the majority of the UK, with less than 50% of average rainfall in parts of the south-west, and across eastern parts of the UK. North-west England, and north-western Scotland received above average rainfall, with parts of Cumbria seeing over 170% of average.

The rainfall outlook for April (issued by the Met Office on 25.03.2021) is that the chances of average and below-average precipitation are higher than the chance of above-average precipitation. For April-May-June as a whole, above-average precipitation is more likely than below-average precipitation. The probability that UK-average precipitation for April-May-June will fall into the driest of five categories is around 10% and the probability that it will fall into the wettest of five categories is around 20% (the 1981-2010 probability for each of these categories is 20%).

River flows:
March river flows mostly fell from their February levels and were normal to above normal across the majority of the UK. Above normal to notably high flows were seen in north-west England, north Wales and Norfolk. Some localised catchments recorded below normal flows.*

River flows in April, and April-May-June, are likely to be within the normal range across northern and western parts of the UK. Flows in groundwater fed catchments of the south-east of England are likely to remain above normal as they continue to be influenced by the wet winter. River flows in Devon and Cornwall are likely be normal to below normal for April, but will respond quickly to rainfall events. Similarly, river flows in north-western Scotland are likely to be normal to above normal for April, but will depend on April's rainfall patterns.

Groundwater:
Groundwater levels in March were normal to exceptionally high, with a diverse spatial pattern. Normal levels were seen in most of the boreholes of central southern England, whilst exceptionally high levels were recorded in the Magnesian limestone and Permo-Triassic sandstones of northern England, as well as in the chalk aquifers in Norfolk.*

Due to the onset of groundwater recession, groundwater levels for the April-May-June period are likely to be spatially varied. Boreholes in the chalk of the south-east of England are likely to show normal to above normal levels, particularly in April, though normal to below normal levels may be seen in parts of the South Downs over the three-month period. Groundwater levels in northern England and north Wales are likely to remain above normal for the next three months.

* Note: Due to unforeseen circumstances no data are available for Scotland

River flows in northern and western parts of the UK are likely to be within the normal range for both April and the April-May-June period

Groundwater levels in this area are likely to show local variation over the next three months

River flows and groundwater levels in south-east England are likely to be normal to above normal in April and the April-May-June period

Shaded areas show principal aquifers

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

UK Centre for Ecology & Hydrology · British Geological Survey · Department for Infrastructure An Roinn Bonneagair · Environment Agency · Met Office · Cyfoeth Naturiol Cymru Natural Resources Wales · SEPA

UK Centre for Ecology & Hydrology

Outlook based on hydrological persistence and analogy

Overview

RIVER FLOW ANALOGY

April 2021

Period: April – June 2021 Issued on 07.04.2021 using data to the end of March 2021

SUMMARY
The outlooks for April and for April-June are for mainly normal to above normal flows in southeast England, with hardly any forecasts available for the rest of the UK.

1-month flow outlook

3-month flow outlook

Outlooks from hydrological analogues are based on a comparison of river flow during recent months with flows during the same months in previous years at a set of approximately 90 sites from across the UK. These sites are depicted on the two maps. Years with observed flows that most closely resemble current conditions are identified as the best analogues and the outlook is based on extrapolating from current conditions based on these analogues.

It is, however, often the case that a simpler forecast based on the persistence of river flow provides a better forecast than provided by analogy. This is particularly true for slowly responding catchments associated with aquifer outcrops.

Both methods are considered at each site and the forecast from the method with the higher confidence is presented. A simple classification of flows is used (high, medium and low) as indicated by the colours of the dots, with the confidence of the forecast being represented by the size of the dot. A tag on the dot indicates which method has been used in each instance.

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Outlook based on modelled flow from historical climate

Overview

RIVER FLOW FROM HISTORICAL CLIMATE

April 2021

This outlook is based on monthly ensembles of historical sequences of observed climate (rainfall and potential evapotranspiration) that form input to a hydrological model. The outputs are probabilistic simulations of the average river flow over the forecast period (1 to 12 months ahead), at each location. The simulations are generated by the GR4J conceptual rainfall-runoff model from IRSTEA (France) calibrated on observed or naturalised flows.

The stack diagrams show the variation over time of the outlook distribution for a number of individual catchments. Each graph represents variation over time of the number of simulated river flows, in each month ensemble, that fall within each of seven categories: exceptionally low, notably low, below normal, normal, above normal, notably high and exceptionally high. The categories represent cumulative flow conditions, e.g. For 3-month, the simulated total 3-month flow compared to the historical 3-month flow distribution. The monthly variations can be compared to the long-term average distribution of river flows (shown as columns on the right of each timeline graph).

This outlook is based entirely on historical sequences and therefore does not contain any knowledge of the state of the atmosphere and ocean. It is hence possible that some of the historical sequences used might be inconsistent with current large-scale atmospheric conditions and would therefore be unlikely to occur in the next few months.

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

UK Centre for Ecology & Hydrology

Outlook Based on Modelled Flow from Rainfall Forecasts

Overview

RIVER FLOW FROM RAINFALL FORECASTS

April 2021

Period: April 2021 – June 2021 Issued on 06.04.2021 using data to the end of March

SUMMARY: During April, river flows across much of the country are most likely to be in the *Normal range*. Southern and South West Regions are most likely to be in the *Normal range* or *Below normal*.

Over the next 3 months river flows across the country are most likely to be in the *Normal range*.

1-month flow outlook

3-month flow outlook

These forecasts are produced by using five members of the Met Office rainfall forecast ensemble as input to a water balance hydrological model to provide the five estimates of river flows shown on the left for one month and three months ahead.

Regional forecast monthly-mean river flows are derived from the average of 1km river flow estimates within each region and ranked in terms of 54 years of historical flow estimates (1963 – 2016).

The five maps illustrate the wide range of possible flows and while there is a 50% chance of flows between the 1st and 3rd quartiles, actual flows may be more extreme than the flows derived using the highest or lowest rainfall forecasts.

Key		Percentile range of historic values for relevant month
Exceptionally high flow	🟦	> 95
Notably high flow	🟦	87-95
Above normal	🟦	72-87
Normal range	🟨	28-72
Below normal	🟧	13-28
Notably low flow	🟥	5-13
Exceptionally low flow	🟥	< 5

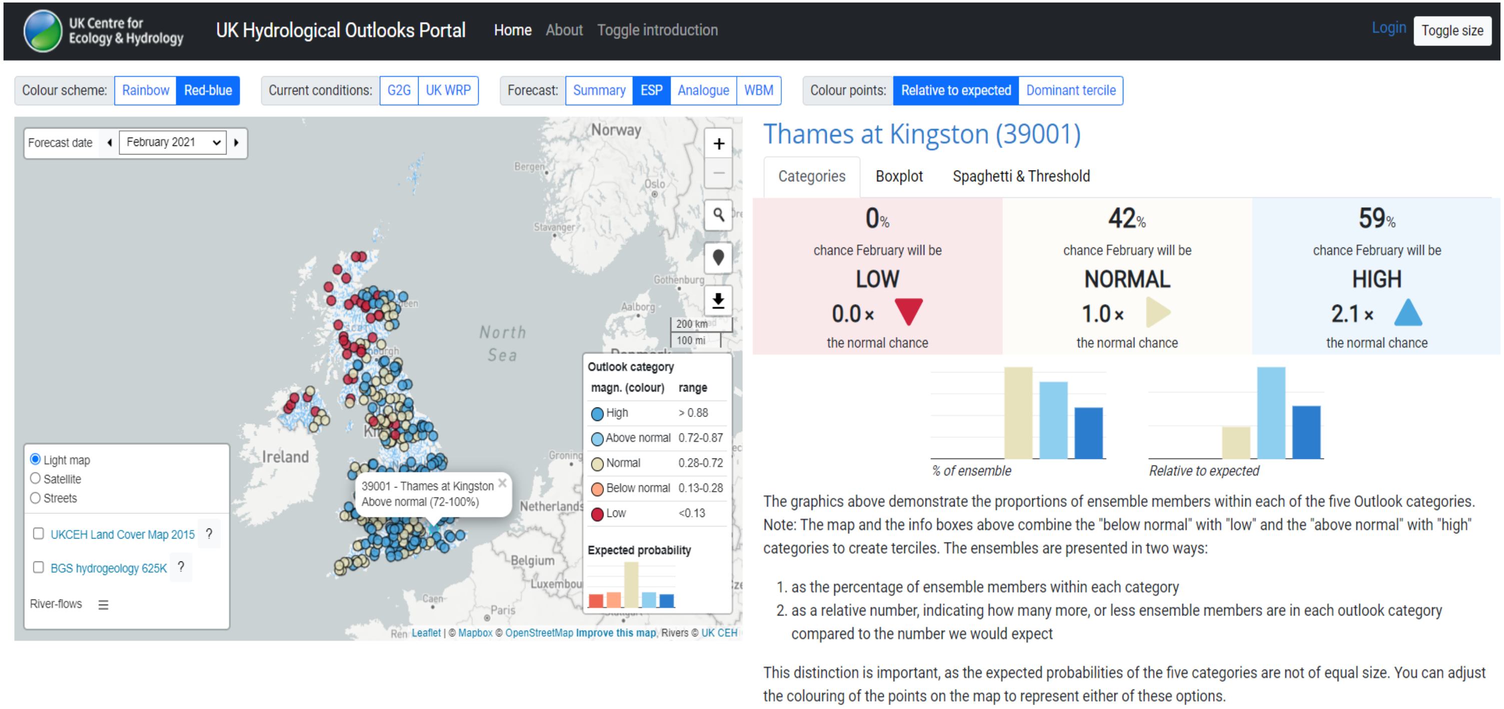
SCOTLAND
HR Highlands Region
NER North East Region
TR Tay Region
FR Forth Region
CR Clyde Region
TWR Tweed Region
SR Solway Region
ENGLAND
N Northumbria
NW North West
Y Yorkshire
ST Severn Trent
A Anglian
T Thames
S Southern
W Wessex
SW South West
WALES
WEL Welsh

NORTHERN IRELAND
This method cannot currently be used in Northern Ireland

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

UK Outlook Portal

We are developing a new interactive web portal, that will allow our users to look at the data in detail. Check back on this link in a couple of months when it will be open to the public. https://eip.ceh.ac.uk/Hydrology/outlooks/



Colour scheme: Red-blue

Current conditions:

Forecast: ESP

Colour points: Relative to expected

Forecast date February 2021

● Light map

39001 - Thames at Kingston
Above normal (72-100%)

Outlook category

magn. (colour)	range
● High	> 0.88
● Above normal	0.72-0.87
● Normal	0.28-0.72
● Below normal	0.13-0.28
● Low	<0.13

Expected probability

Thames at Kingston (39001)

Categories

0%	42%	59%
chance February will be	chance February will be	chance February will be
LOW	NORMAL	HIGH
0.0× ▼	1.0× ▶	2.1× ▲
the normal chance	the normal chance	the normal chance

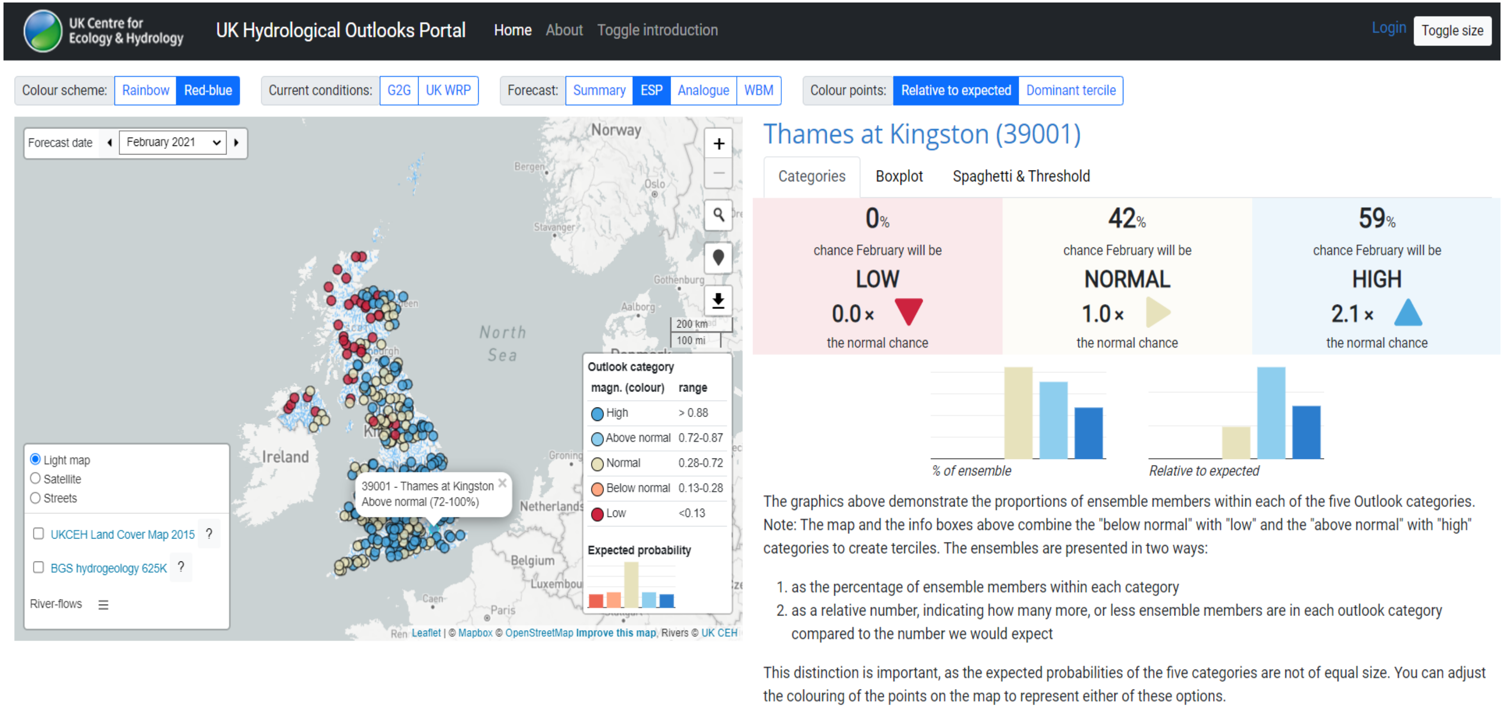
The graphics above demonstrate the proportions of ensemble members within each of the five Outlook categories. Note: The map and the info boxes above combine the "below normal" with "low" and the "above normal" with "high" categories to create terciles. The ensembles are presented in two ways:

1. as the percentage of ensemble members within each category
2. as a relative number, indicating how many more, or less ensemble members are in each outlook category compared to the number we would expect

This distinction is important, as the expected probabilities of the five categories are not of equal size. You can adjust the colouring of the points on the map to represent either of these options.

UK Outlook Portal

This page allows users to look at how many of the ensemble members sit in each category, below normal, normal and above normal. https://eip.ceh.ac.uk/Hydrology/outlooks/


UK Centre for Ecology & Hydrology
UK Hydrological Outlooks Portal
Home
About
Toggle introduction
Login
Toggle size
Colour scheme: Rainbow Red-blue
Current conditions: G2G UK WRP
Forecast: Summary ESP Analogue WBM
Colour points: Relative to expected Dominant tercile
Forecast date
February 2021
Norway
Bergen
Oslo
Stavanger
Gothenburg
Aalborg
North Sea
Ireland
Netherlands
Belgium
Paris
Caen
200 km
100 mi
○ Light map
○ Satellite
○ Streets
□ UKCEH Land Cover Map 2015 ?
□ BGS hydrogeology 625K ?
River-flows ☰
39001 - Thames at Kingston
Above normal (72-100%)
Leaflet | © Mapbox © OpenStreetMap Improve this map, Rivers © UK CEH
Expected probability
% of ensemble
Relative to expected

Outlook category

magn. (colour)	range
● High	> 0.88
● Above normal	0.72-0.87
● Normal	0.28-0.72
● Below normal	0.13-0.28
● Low	<0.13

Thames at Kingston (39001)

Categories | Boxplot | Spaghetti & Threshold

0%	42%	59%
chance February will be	chance February will be	chance February will be
LOW	NORMAL	HIGH
0.0 × ▼	1.0 × ▶	2.1 × ▲
the normal chance	the normal chance	the normal chance

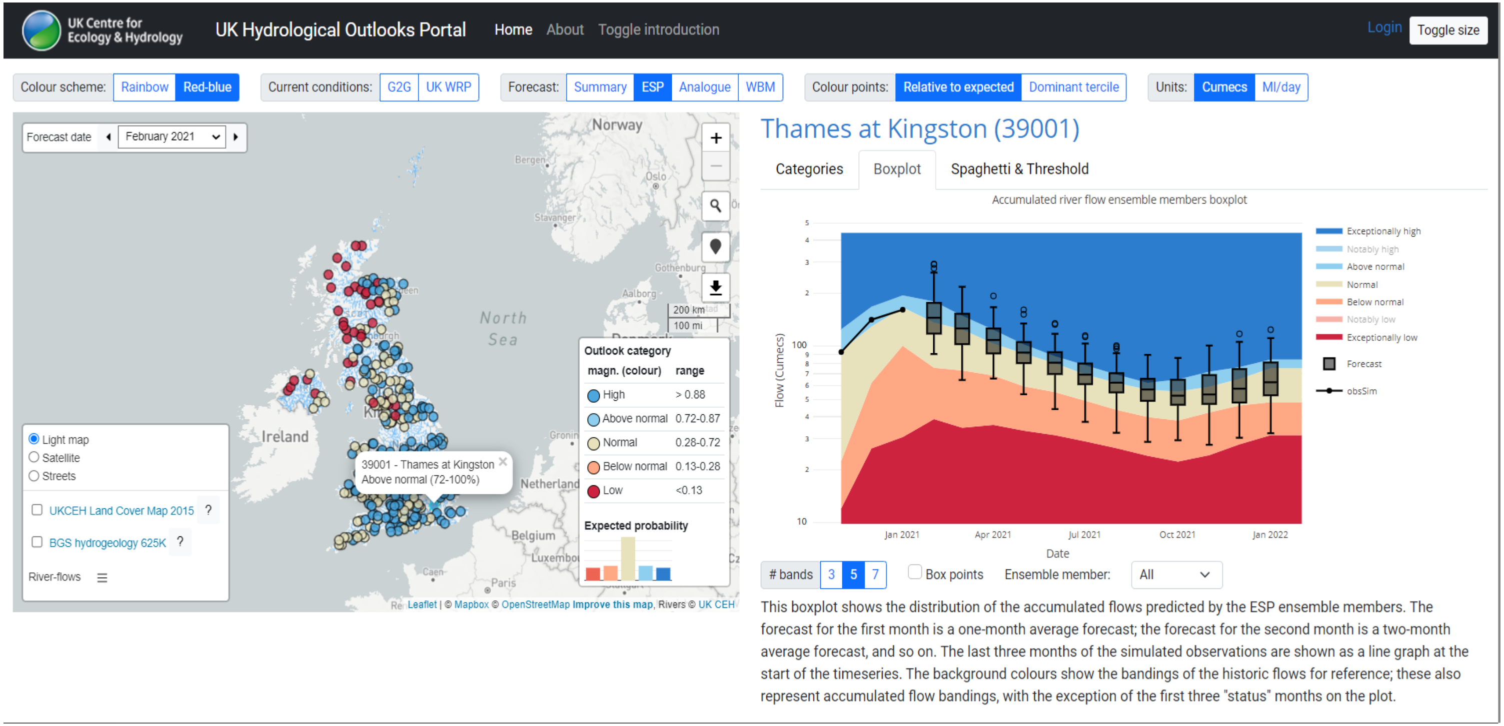
The graphics above demonstrate the proportions of ensemble members within each of the five Outlook categories. Note: The map and the info boxes above combine the "below normal" with "low" and the "above normal" with "high" categories to create terciles. The ensembles are presented in two ways:

1. as the percentage of ensemble members within each category
2. as a relative number, indicating how many more, or less ensemble members are in each outlook category compared to the number we would expect

This distinction is important, as the expected probabilities of the five categories are not of equal size. You can adjust the colouring of the points on the map to represent either of these options.

UK Outlook Portal

This page show users the full ensemble distributions for the forecasts moving forward, against the historic bands of normal flows. https://eip.ceh.ac.uk/Hydrology/outlooks/



Colour scheme: Rainbow **Red-blue**

Current conditions: G2G UK WRP

Forecast: Summary **ESP** Analogue WBM

Colour points: **Relative to expected** Dominant tercile

Units: **Cumecs** Ml/day

Forecast date ◂ February 2021 ▸

● Light map
○ Satellite
○ Streets

□ UKCEH Land Cover Map 2015 ?

□ BGS hydrogeology 625K ?

River-flows ☰

39001 - Thames at Kingston ×
Above normal (72-100%)

Outlook category

magn. (colour)	range
● High	> 0.88
● Above normal	0.72-0.87
● Normal	0.28-0.72
● Below normal	0.13-0.28
● Low	<0.13

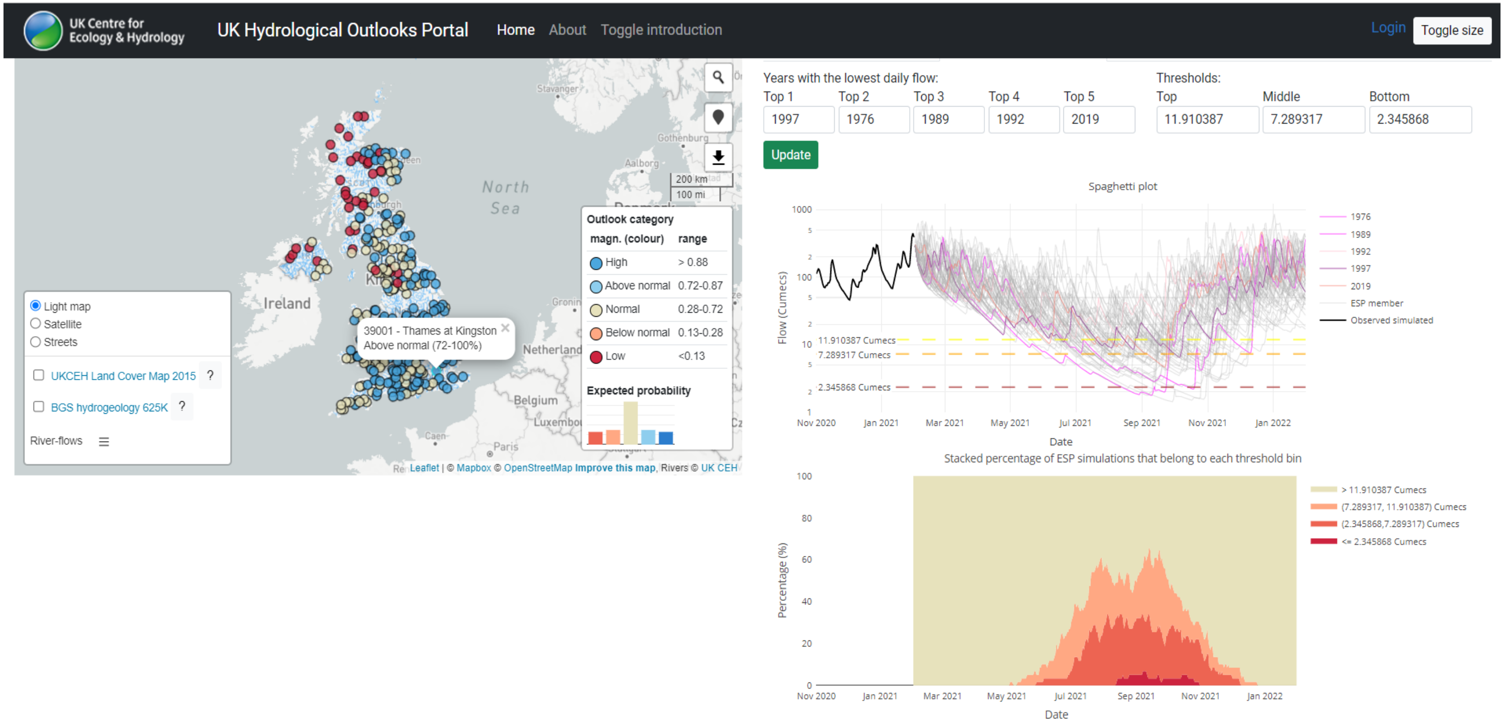
Expected probability

bands 3 **5** 7 □ Box points Ensemble member: All

This boxplot shows the distribution of the accumulated flows predicted by the ESP ensemble members. The forecast for the first month is a one-month average forecast; the forecast for the second month is a two-month average forecast, and so on. The last three months of the simulated observations are shown as a line graph at the start of the timeseries. The background colours show the bandings of the historic flows for reference; these also represent accumulated flow bandings, with the exception of the first three "status" months on the plot.

UK Outlook Portal

Finally, this page allows users to select past years of interest to see how the forecast would run if that weather were to happen again now. It also lets users define flow thresholds, and the bottom plot shows the likelihood of flows falling below those thresholds. This is particularly useful for reservoir management. https://eip.ceh.ac.uk/Hydrology/outlooks/



Years with the lowest daily flow:

Top 1	Top 2	Top 3	Top 4	Top 5
1997	1976	1989	1992	2019

Thresholds:

Top	Middle	Bottom
11.910387	7.289317	2.345868

Outlook category

magn. (colour)	range
● High	> 0.88
● Above normal	0.72-0.87
● Normal	0.28-0.72
● Below normal	0.13-0.28
● Low	<0.13

39001 - Thames at Kingston
Above normal (72-100%)

● Light map
○ Satellite
○ Streets

☐ UKCEH Land Cover Map 2015
☐ BGS hydrogeology 625K

Thank you for listening!

The slides and materials are available on Github:
https://github.com/hydrosoc/rhydro_vEGU21/