Assessing Statistical models of Temporary River Intermittence for Decision makers

ASTRID project results webinar

Michael Eastman, statistical modelling
Cecilia Svensson, statistical hydrology
Simon Parry, hydrological extremes
Catherine Sefton, hydrological intermittence

with thanks to Eric Sauquet, INRAE, France
and the NERC Landscape Decisions Programme

UK Centre for Ecology & Hydrology

NERC Grant nos.
NE/T004215/1 & NE/T004215/2

LANDSCAPE DECISIONS

Webinar overview

Motivation and context	• The motivation for ASTRID • The global picture on intermittent river research • Hydrological state simulation at catchment scale
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Conclusions and next steps	• Stakeholder consultation • ASTRID conclusions • Data collection

Why the focus on intermittent rivers?

a.k.a temporary or non-perennial

Hydrologically dynamic

Misrepresented

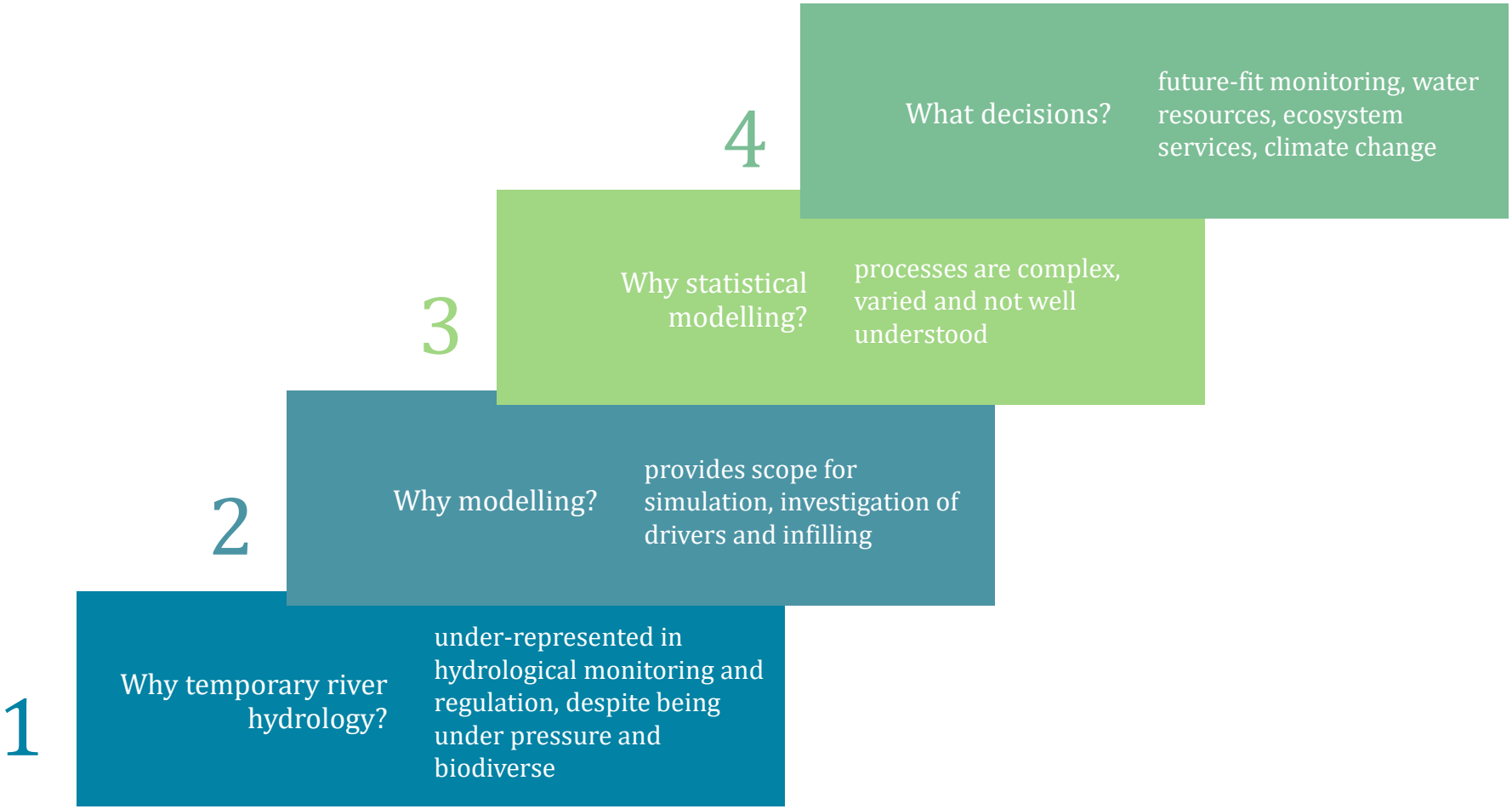
Ecologically diverse

Paraleptophlebia werneri

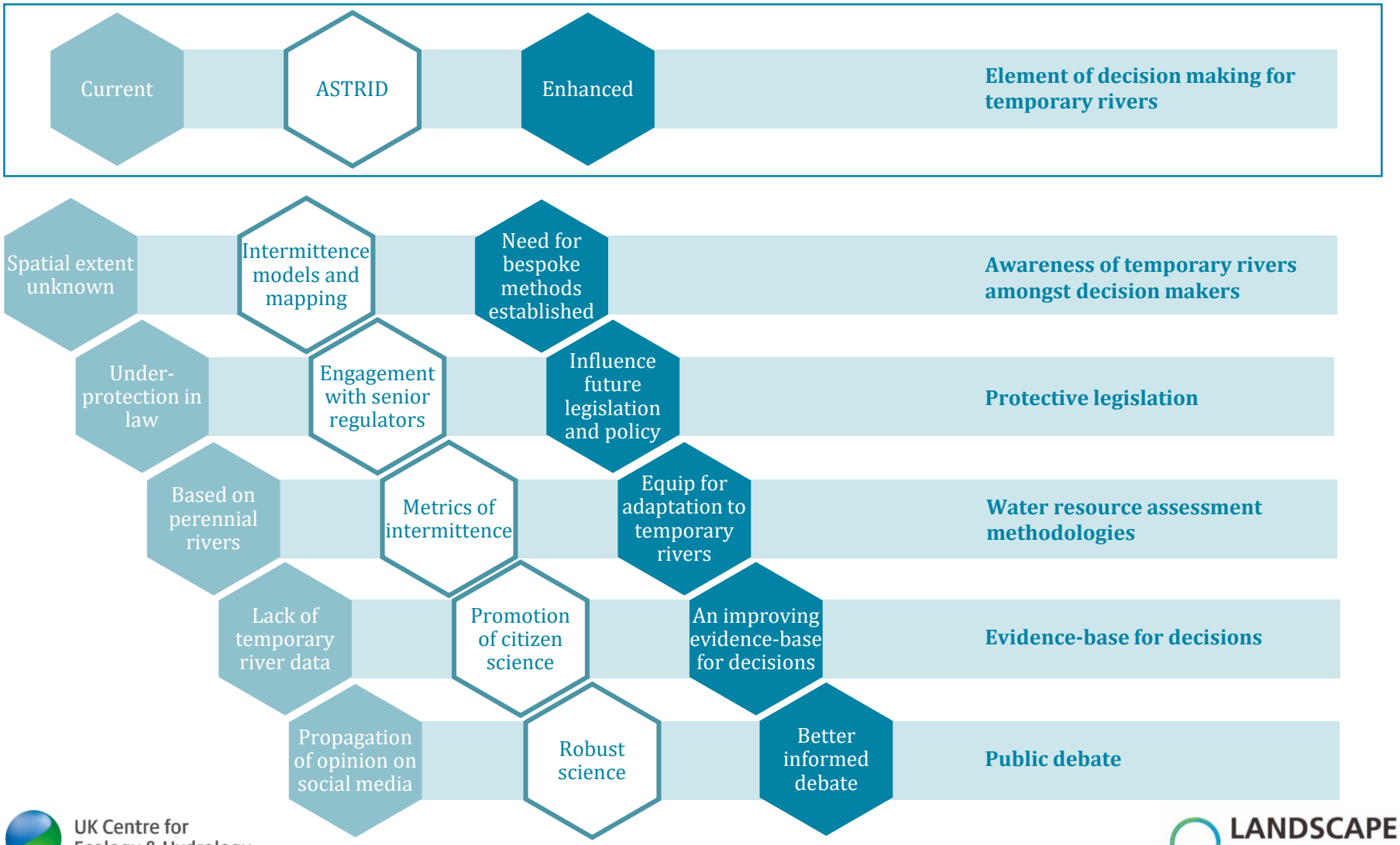
Widespread?

Under pressure

Why Assess Statistical models of Temporary River Intermittence for Decision makers?



What are the needs for enhanced decision making on intermittent rivers in Great Britain?



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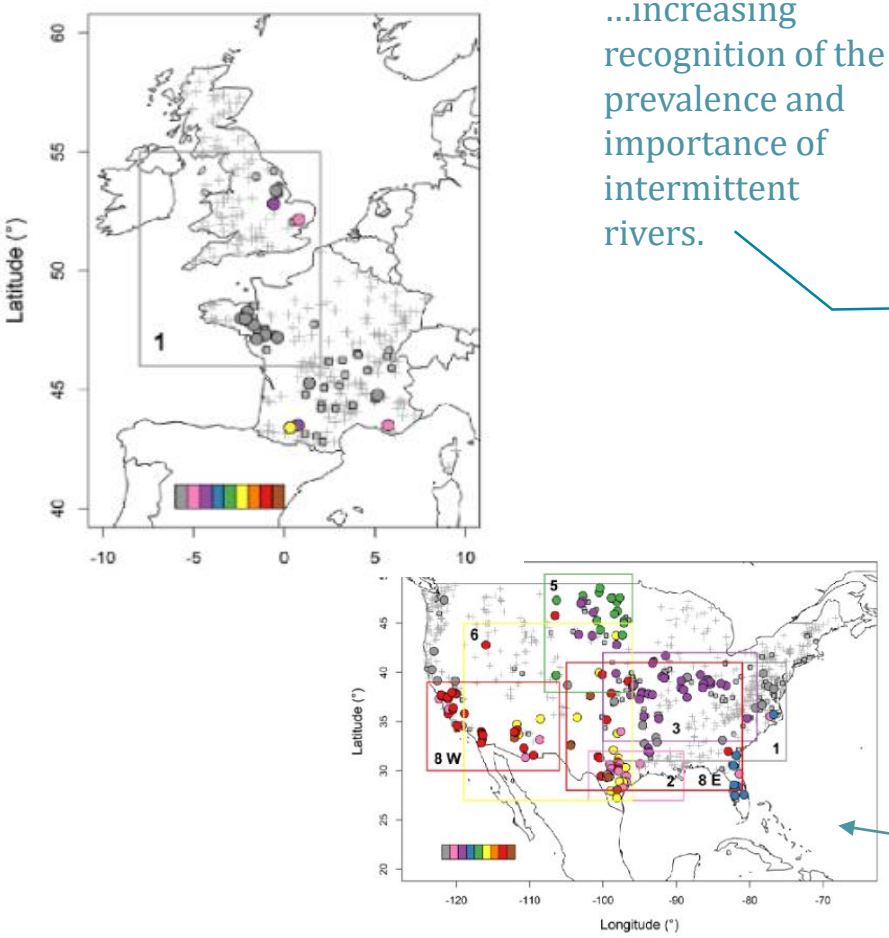
The wider view...



...increasing recognition of the prevalence and importance of intermittent rivers.

Grouping of hydrologically similar intermittent rivers
Sauquet et al., 2021

Received: 9 November 2020 | Accepted: 10 November 2020
DOI: 10.1002/hyp.13979

INVITED COMMENTARY

HP TODAY WILEY

Aqua temporaria incognita

H. J. Ilja van Meerveld[1] | Eric Sauquet[2] | Francesc Gallart[3] | Catherine Sefton[4] | Jan Seibert[1,5] | Kevin Bishop[5]

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[2]INRAE, UR RiverLy, Villeurbanne, France
[3]Surface Hydrology and Erosion group FEHM, IDAEA,
[4]UK Centre for Ecology & Hydrology, Wallingford, Eng
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It has been 12 years since Bishop et al. (2008) w
mentary "Aqua Incognita: the unknown
highlighted that "in most regions, the overv

Hydrological Sciences Journal

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/thsj20

Trends in flow intermittence for European rivers

Yves Tramblay , Agnieszka Rutkowska , Eric Sauquet , Catherine Sefton , Gregor Laaha , Marzena Osuch , Teresa Albuquerque , Maria Helena Alves , Kazimierz Banasik , Aurelien Beaufort , Luca Brocca , Stefania Camici , Zoltán Csabai , Hamouda Dakhlaoui , Anna Maria DeGirolamo , Gerald Dörflinger , Francesc Gallart , Tobias Gauster , Lahoucine Hanich , Silvia Kohnová , Luis Mediero , Ninov Plamen , Simon Parry , Pere Quintana-Seguí , Ourania Tzoraki & Thibault Datry

Article

Global prevalence of non-perennial rivers and streams

https://doi.org/10.1038/s41586-021-03565-5
Received: 12 November 2020
Accepted: 19 April 2021
Published online: 16 June 2021
Check for updates

Mathis Loic Messager[1,2], Bernhard Lehner[1], Charlotte Cockburn[1], Nicolas Lamouroux[3], Hervé Pella[3], Ton Snelder[4], Klement Tockner[5,6], Tim Trautmann[7], Caitlin Watt[1] & Thibault Datry[3]

Flowing waters have a unique role in supporting global biodiversity, biogeochemical cycles and human societies[1–3]. Although the importance of permanent watercourses is well recognized, the prevalence, value and fate of non-perennial rivers and streams that periodically cease to flow tend to be overlooked, if not ignored[4–8]. This oversight contributes to the degradation of the main source of water and livelihood for millions

Journal of Hydrology 597 (2021) 126170

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/jhydrol

Research papers

Classification and trends in intermittent river flow regimes in Australia, northwestern Europe and USA: A global perspective

Eric Sauquet[a,*], Margaret Shanafield[b], John C. Hammond[c,1], Catherine Sefton[d], Catherine Leigh[e], Thibault Datry[a]

[a] INRAE, UR RiverLy, Centre de Lyon-Grenoble Auvergne-Rhône-Alpes, Villeurbanne, France
[b] Flinders University and National Centre for Groundwater Research and Training, Adelaide, Australia
[c] Department of Ecosystem Science and Sustainability, Colorado State University, Fort Collins, CO, USA
[d] UK Centre for Ecology & Hydrology, Wallingford, United Kingdom
[e] Biosciences and Food Technology Discipline, School of Science, RMIT University, Bundoora, Victoria 3083, Australia

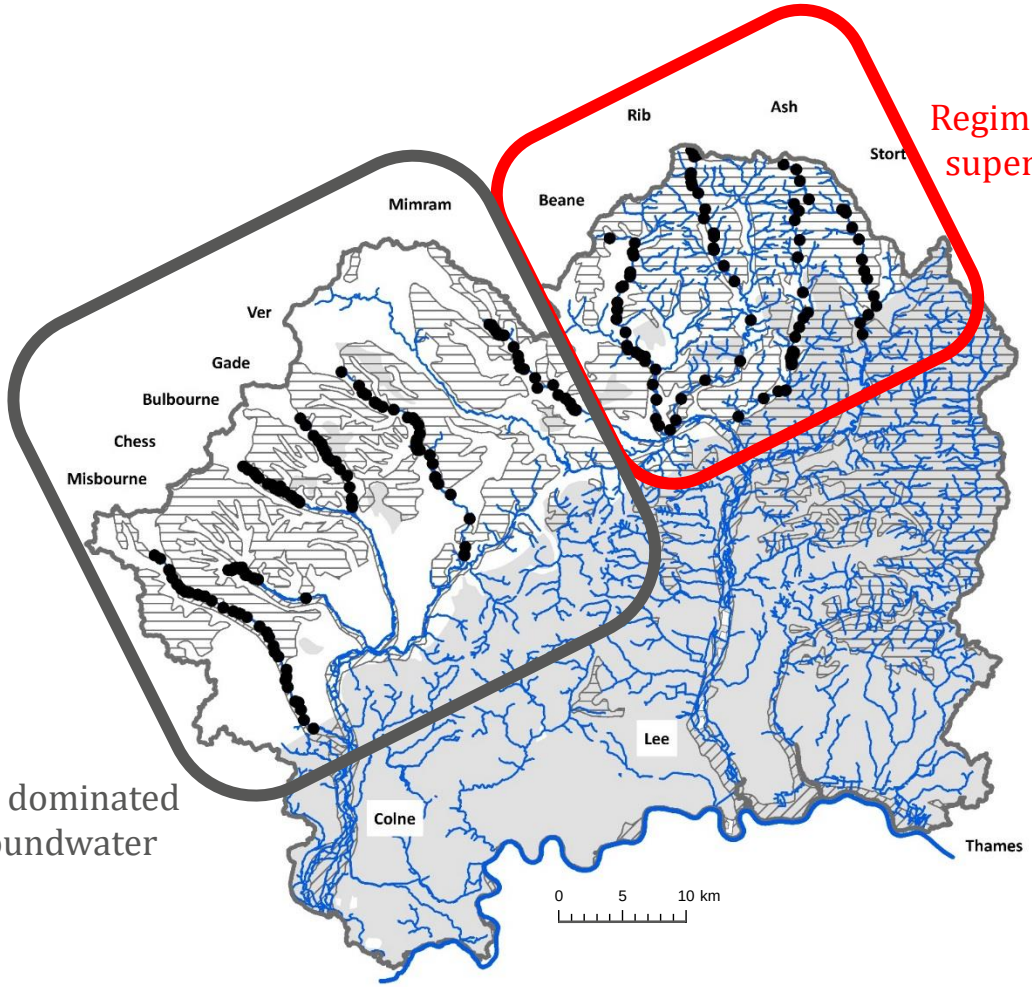
The catchment-scale view...

...what is possible given observations of intermittent behaviour at sufficient spatiotemporal resolution.

Environment Agency

Trained hydrologists
Began in 1997
Approximately monthly

FLOWING
PONDED
DRY



Regime influenced by superficial deposits

Regime dominated by groundwater

● Observation site

Superficial hydrogeology

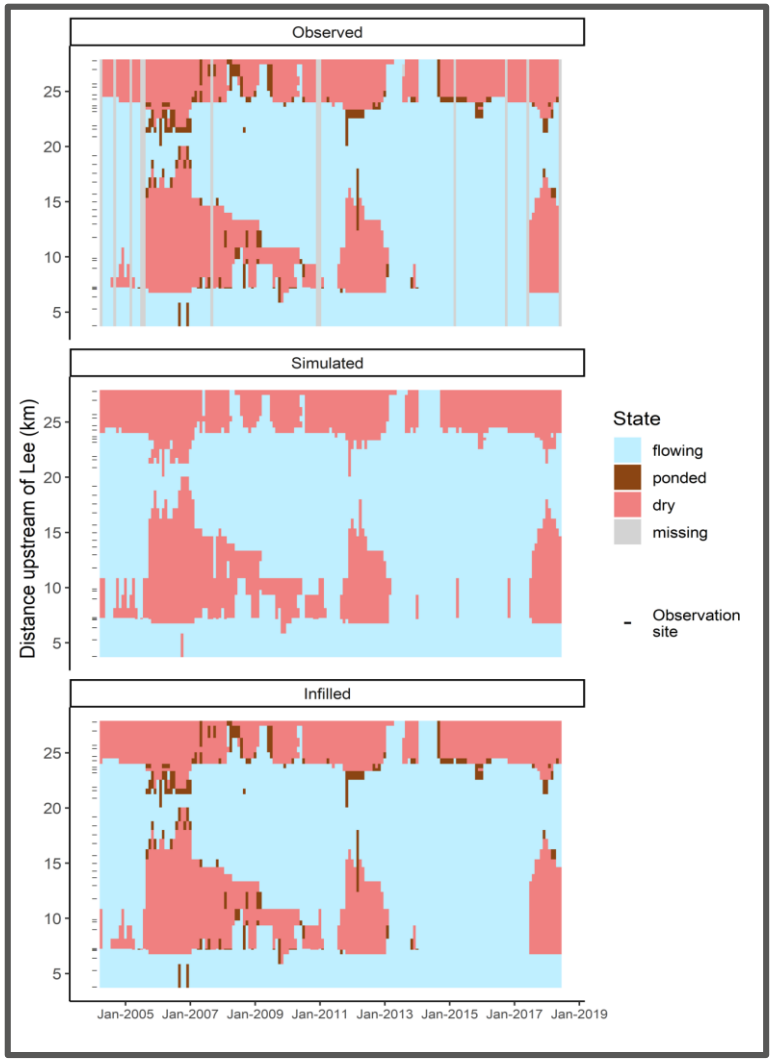
- Generally high permeability
- Generally low permeability
- Mixed permeability

Bedrock hydrogeology

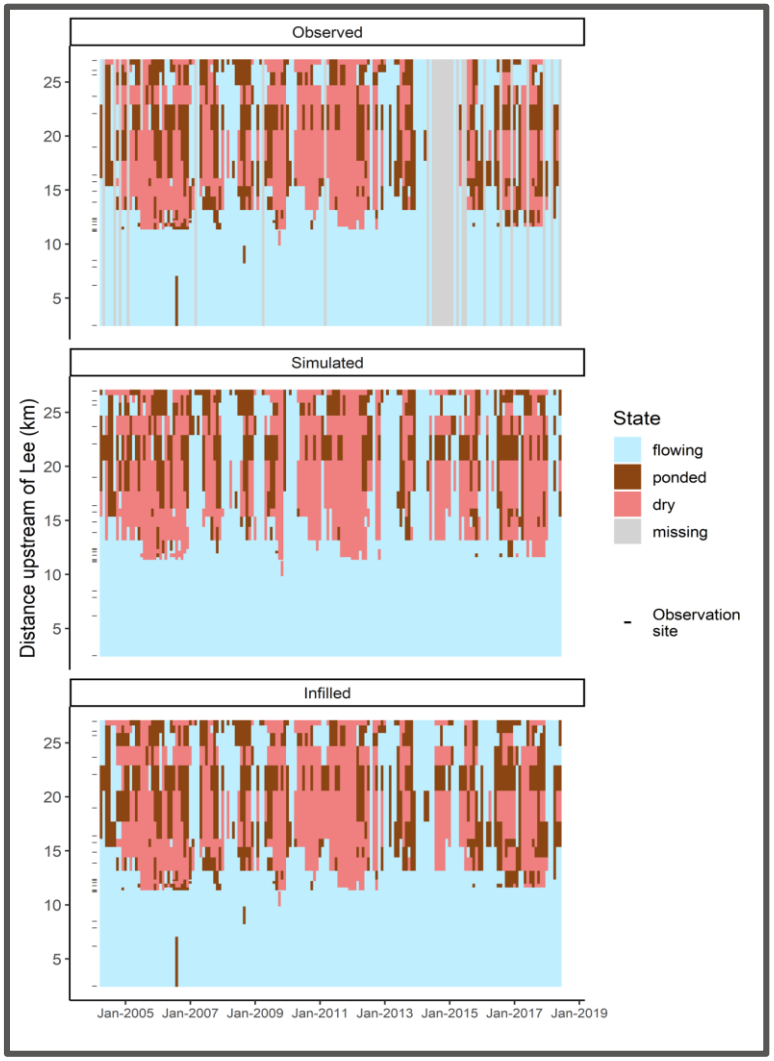
- High Permeability
- Mixed Permeability

Simulation of hydrological state - at a monthly time step and along the river

Misbourne



Ash



The story so far…

1. Modelled intermittence at catchment-scale with good spatiotemporal resolution data;

2. Needing to scale up to national, with limited data availability in Great Britain;

3. Spotting a decent resolution dataset with national coverage in France.

Images: www.pixabay.com

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ASTRID project overview

Assessing **S**tatistical Models of **T**emporary **R**iver **I**ntermittence for **D**ecision Makers

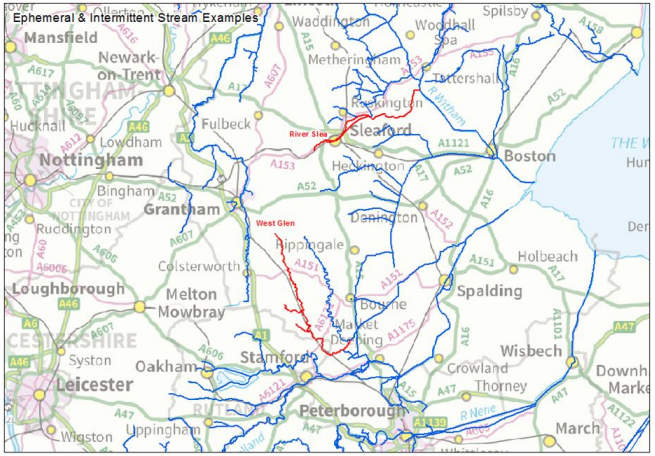
When: 1 Oct 2019 – 30 Sept 2021 (extended by 12 months)

What:

1. Engaging stakeholders in knowledge exchange on hydrological intermittence in Great Britain;
2. Statistical modelling of intermittence in Great Britain's temporary rivers through training and validating models;
3. Mapping hydrological intermittence in temporary rivers across Great Britain.

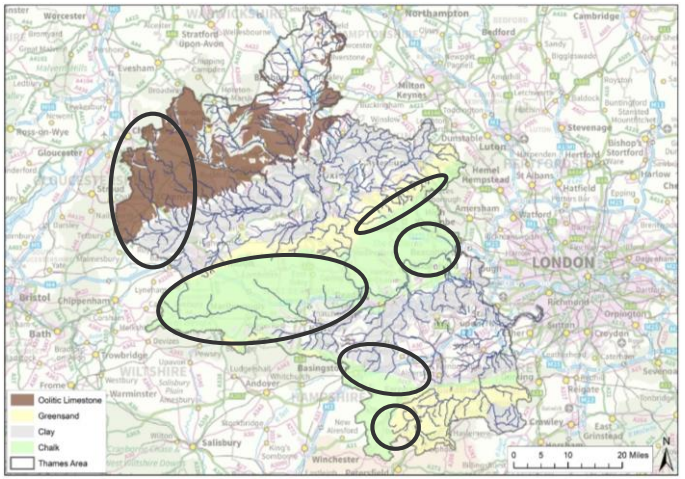
Launch workshop
October 2019

- Knowledge exchange on previous work;
- Discussion on metrics that are useful for decision makers;
- Discussion on useful spatial units, resolution and extent of simulations.



EA Lincs and Northants

EA Thames



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Modelling approach

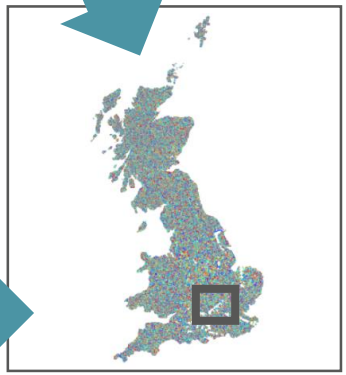
France catchment data

France intermittence data

GB catchment and river network data

GB intermittence data

Statistical model of incidence of intermittence



3222 sites across France

1km resolution points along the network

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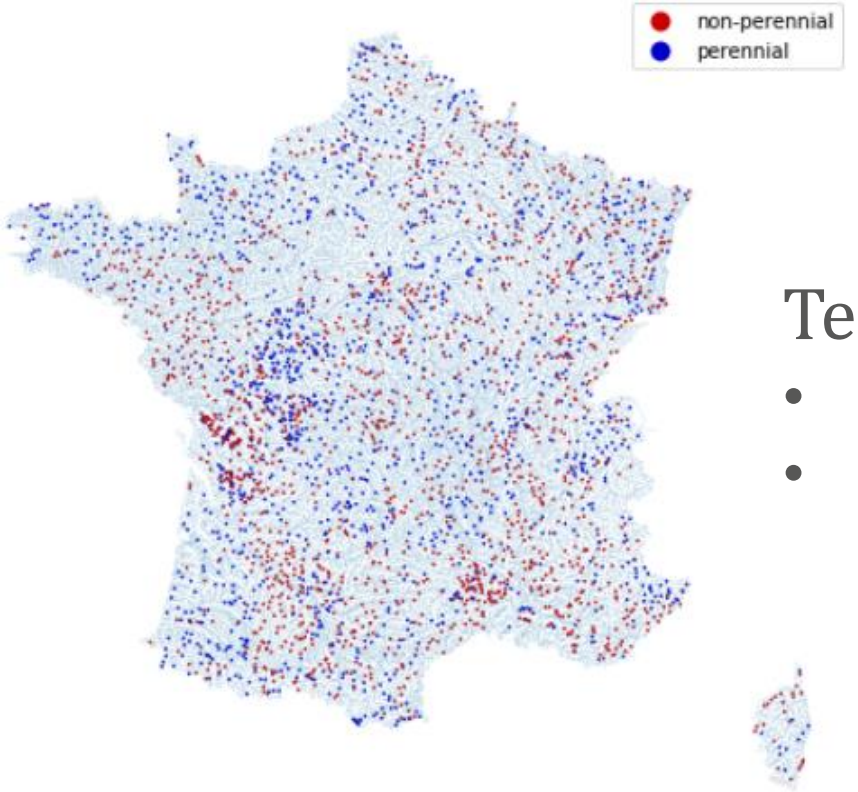
Observatoire National Des Étiages (ONDE)

Observations of hydrological state at >3222 sites in France

- Flow visible
- Flow not visible
- Dry

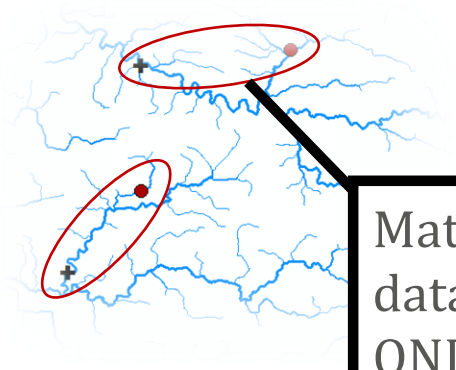


Temporal extent:

- 2012-2019
- May - October

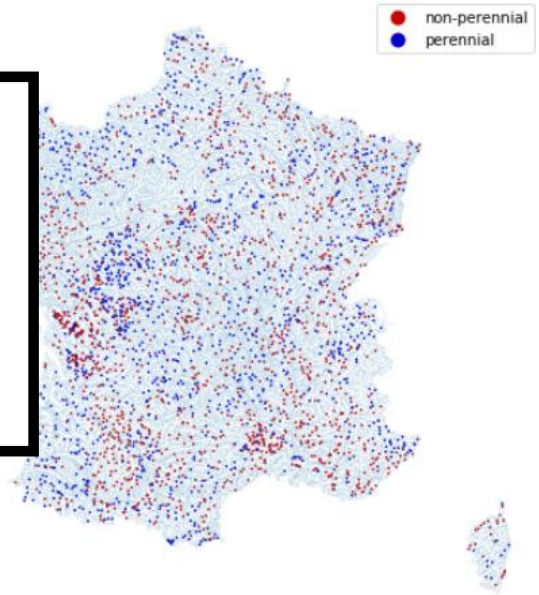
2012	Jan	Feb	Mar	Apr	may	June	Jul	aug	Sep	Oct	Nov	Dec
2013	Jan	Feb	Mar	Apr	may	June	Jul	aug	Sep	Oct	Nov	Dec
2014	Jan	Feb	Mar	Apr	may	June	Jul	aug	Sep	Oct	Nov	Dec

The Data

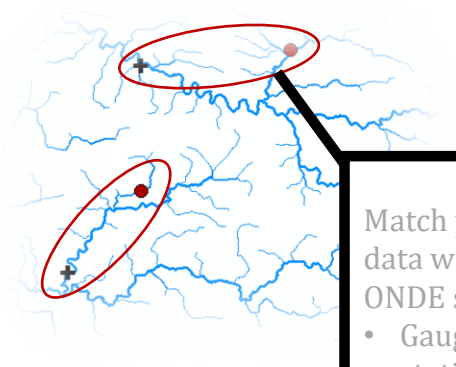


Match point data with ONDE sites:

- Gauging stations
- Boreholes



The Data



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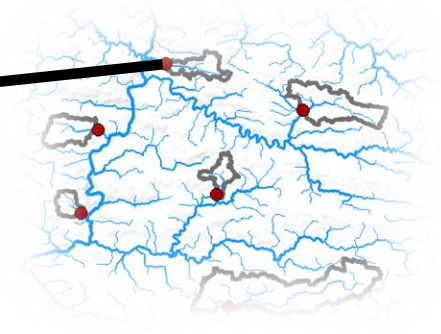
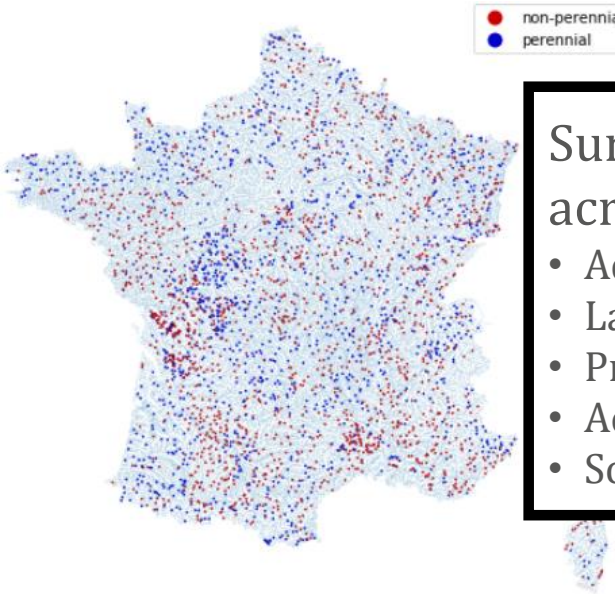
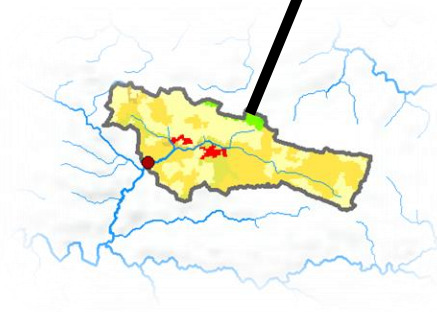
Derive catchment boundaries at ONDE sites



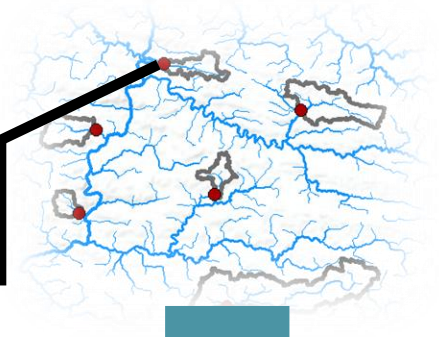


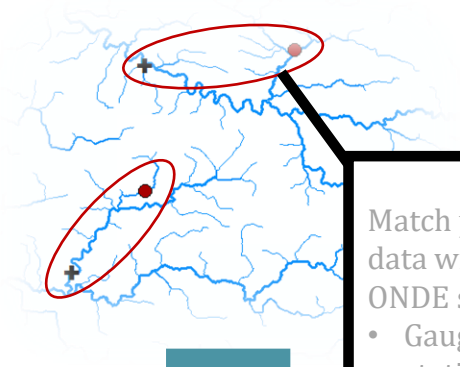
Summarise variables across catchments:
- Aquifer type
- Land cover
- Precipitation
- Actual Evapotranspiration
- Soil moisture



The Data

Derive catchment boundaries at ONDE sites





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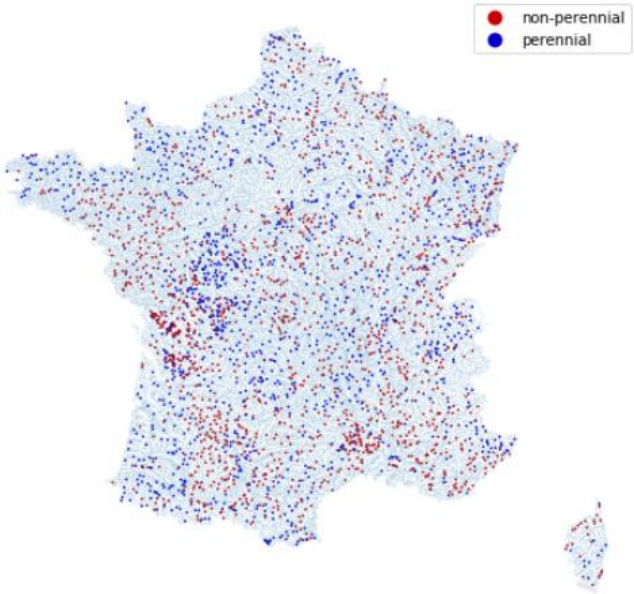

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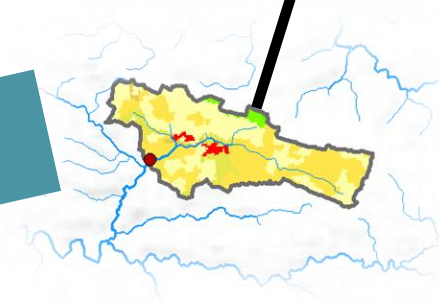
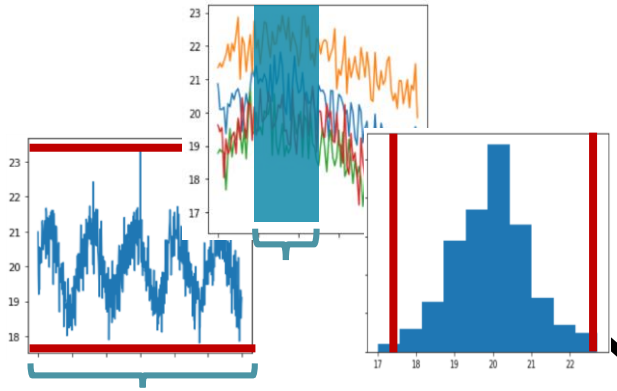


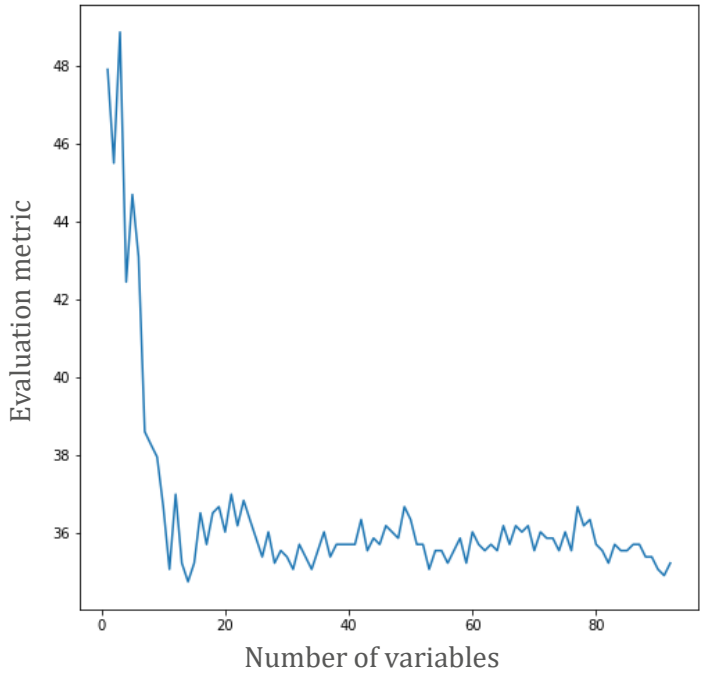


Derive metrics that summarise magnitude and variation of variables

The Data

- Flow responsiveness
  - Magnitude
  - Variation
- Groundwater responsiveness
  - Magnitude
  - Variation
- Actual evapotranspiration
  - Magnitude
  - Variation
- Precipitation
  - Magnitude
  - Variation
- Soil moisture
  - Magnitude
  - Variation
- Aquifer type
- Land cover
- Catchment area

However, not all variables are created equal…



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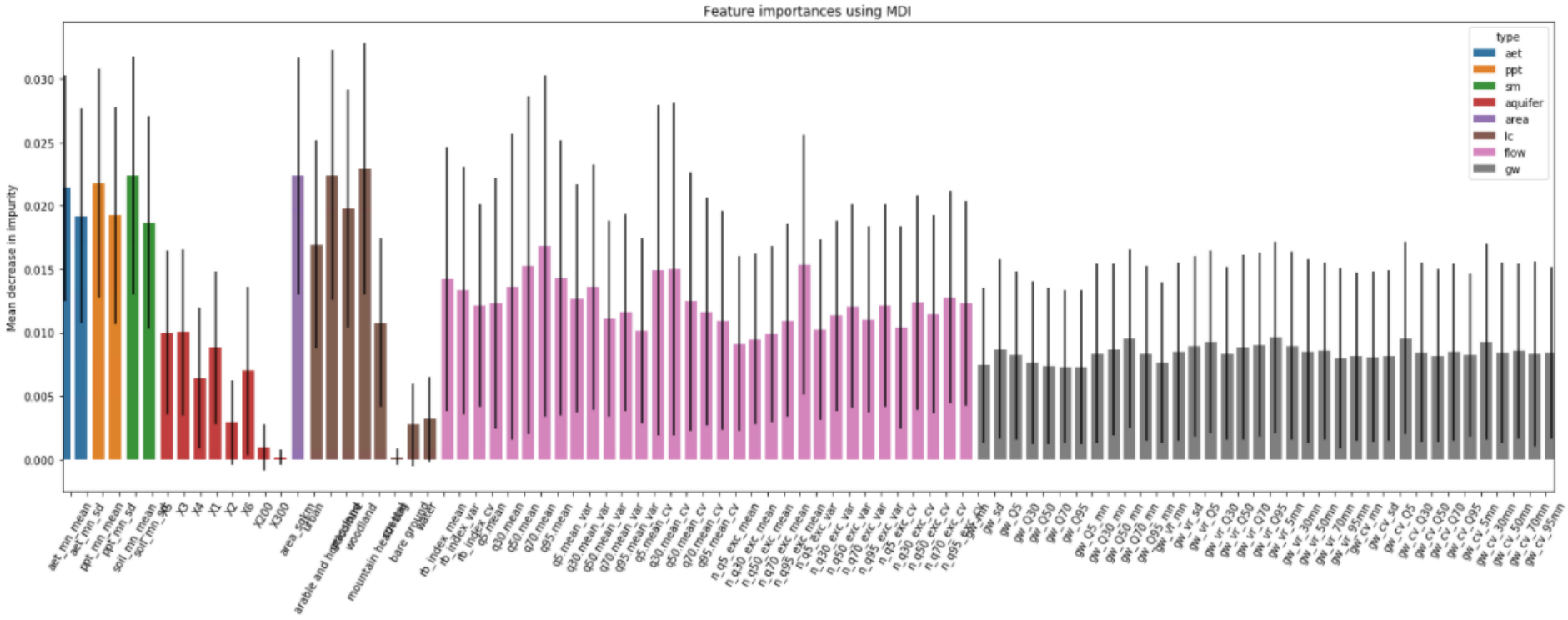
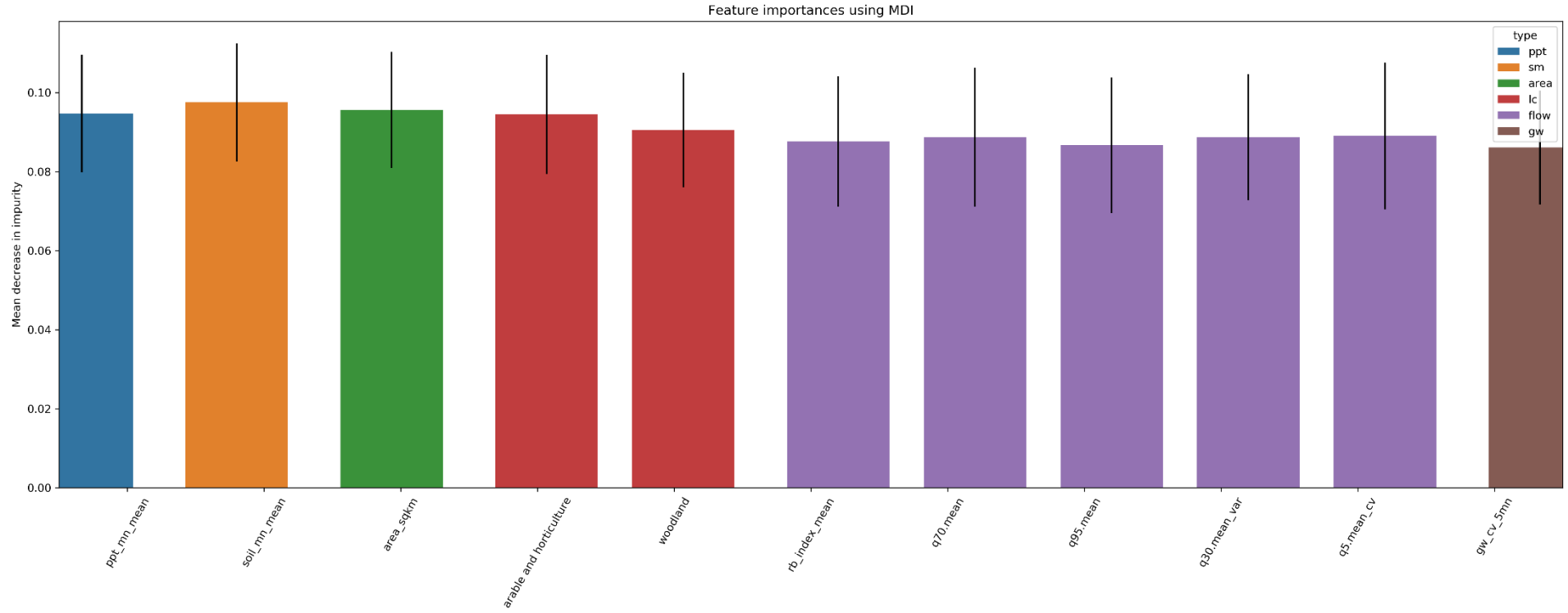

Feature importances using MDI
Mean decrease in impurity
0.030
0.025
0.020
0.015
0.010
0.005
0.000
type
aet
ppt
sm
aquifer
area
lc
flow
gw

The Data

Rainfall
Soil moisture
Catchment area
Land cover
Flow
Groundwater

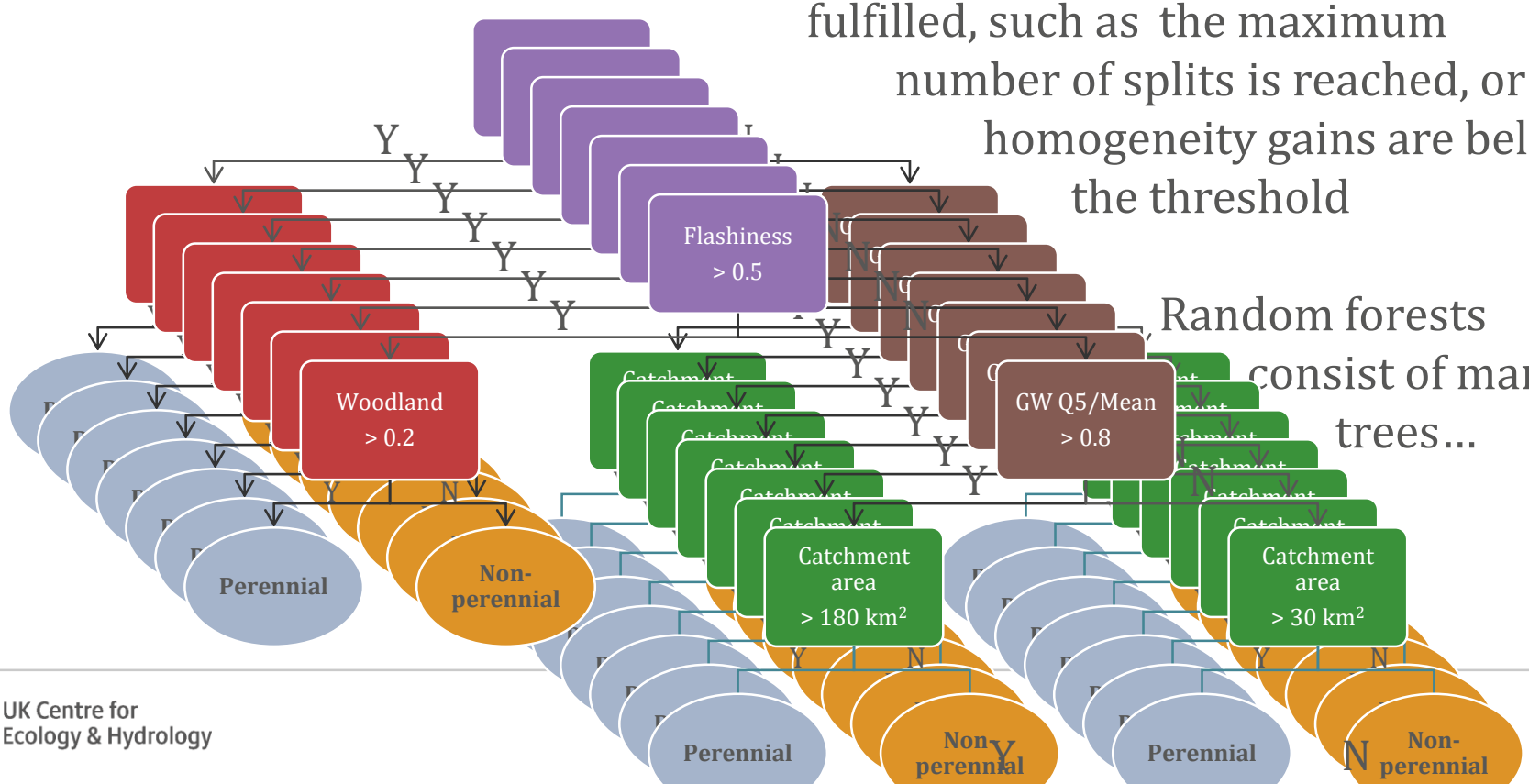


Random Forests

Data is split into partitions that maximise their homogeneity

This continues until stopping criteria are fulfilled, such as the maximum number of splits is reached, or homogeneity gains are below the threshold

Random forests consist of many trees…



Model tuning

1. What can we model?

Simulating whether a reach is intermittent exhibits the largest skill improvement

Hypothesis	Baseline error	Modelled error
1. Perennial or non-perennial	0.495	0.352
2. Permanence category	0.238	0.256
3. Permanence	0.142	0.139

Error using simplest model
e.g. all reaches = perennial

Error using an automatically tuned random forest

Model tuning

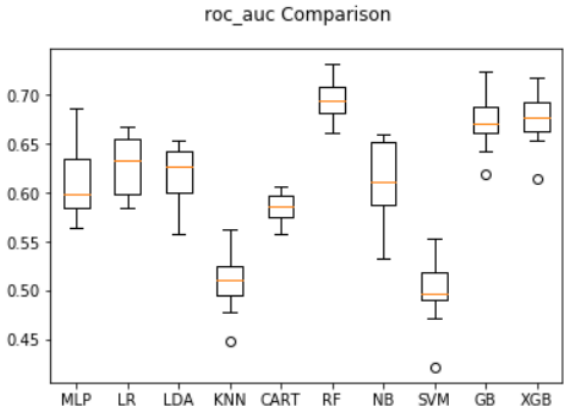
After evaluating a number of options it was concluded that 400 trees, with a maximum split of 140 was the most appropriate fit in France, accounting for efficiency and Skill.

3. How can we improve the model?

Number of trees	200, 400, …, 2000, 2500, 5000, 10000, 25000, 100000
Maximum splits	100, 140, …, 500

2. What model should we use?

10 different models were trained, but the three standouts all belong to the decision tree family of models



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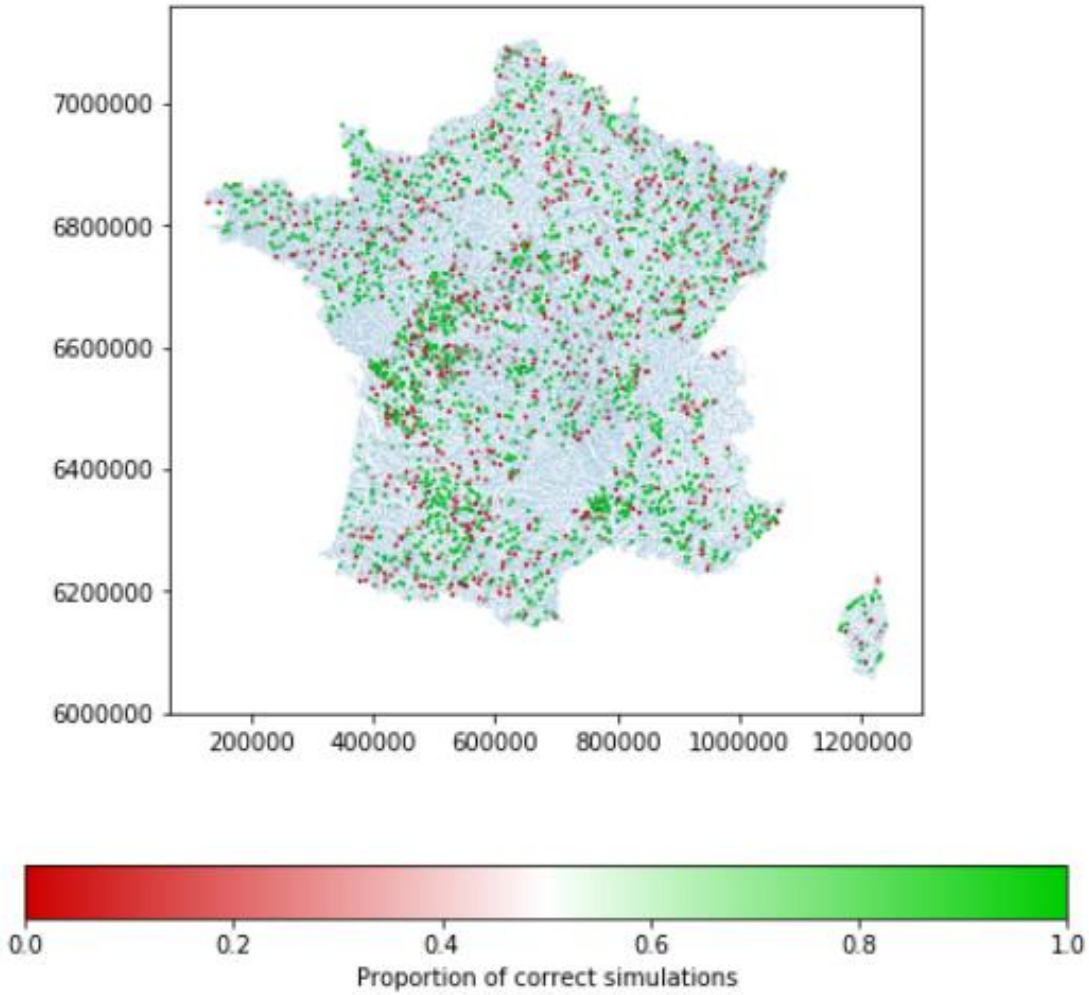
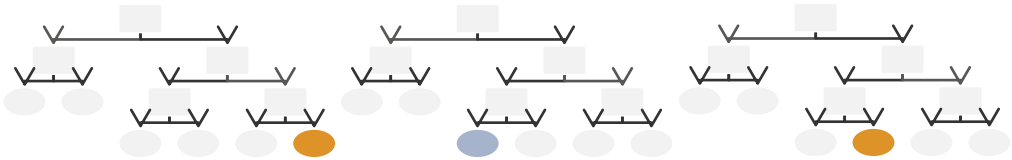
Model performance



- Model accurately simulates whether ONDE sites are intermittent across France
- No immediately obvious spatial pattern in performance
- However, accuracy is higher on catchments dominated by:
  - Arable & horticulture
  - Grassland
  - Aquifer classes 4 & 6 (relatively unproductive)

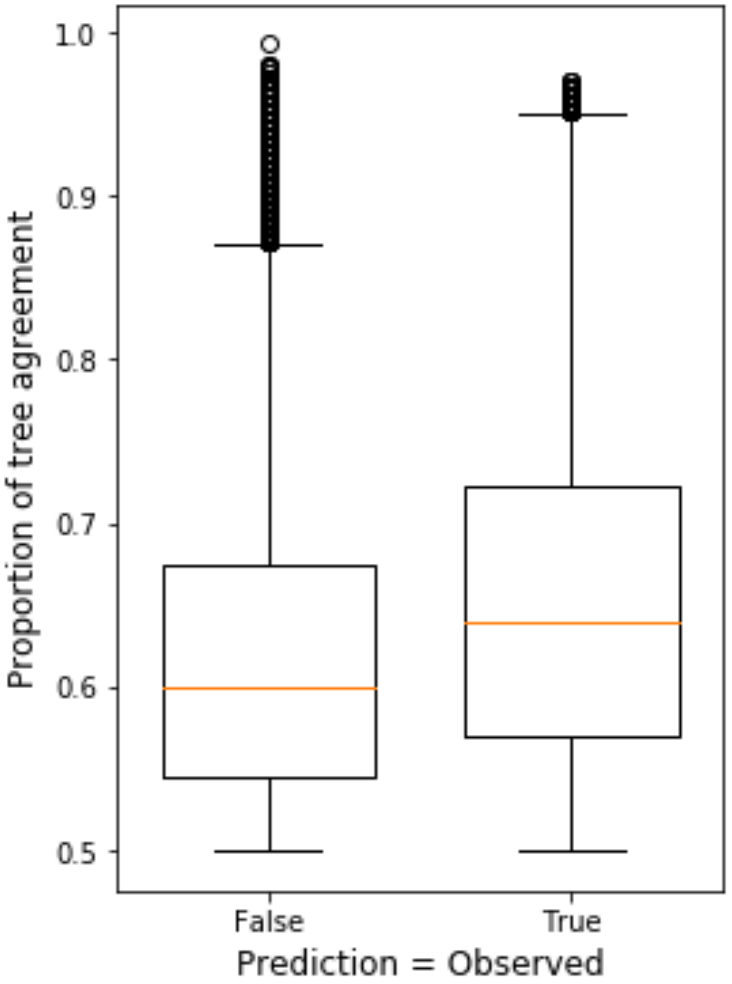
Tree Agreement



2/3 tree agreement

Welch's independent t-test:
t statistic = -96.68
p-value <0.01

More confident in estimates that have higher tree agreement



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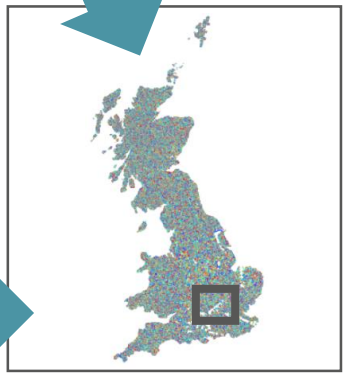
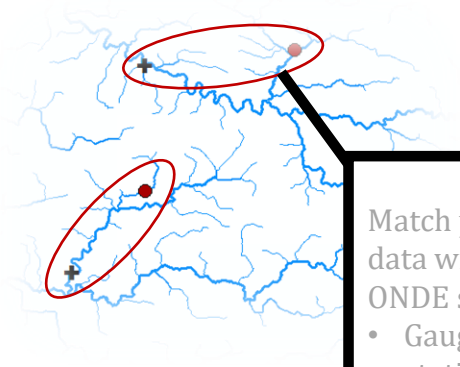


3222 sites across France

1km resolution points along the network

GB Data



Match point data with ONDE sites:
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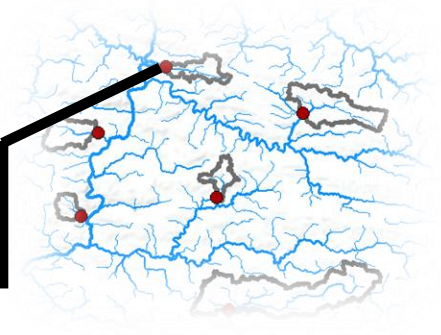
Derive catchment boundaries at ONDE sites



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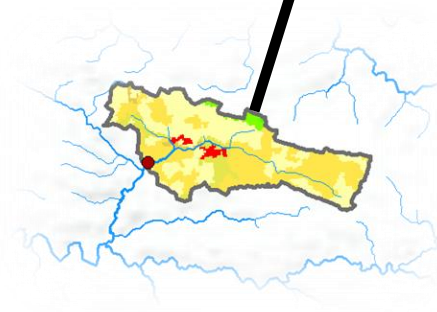
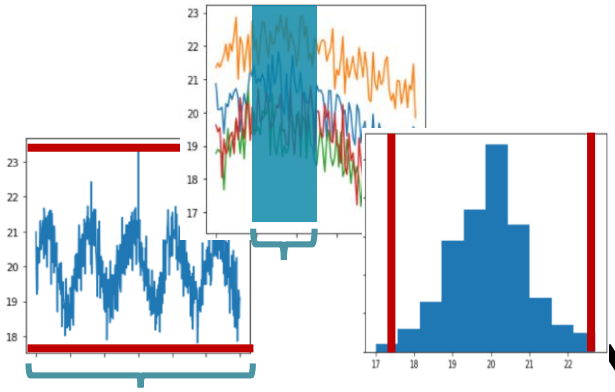


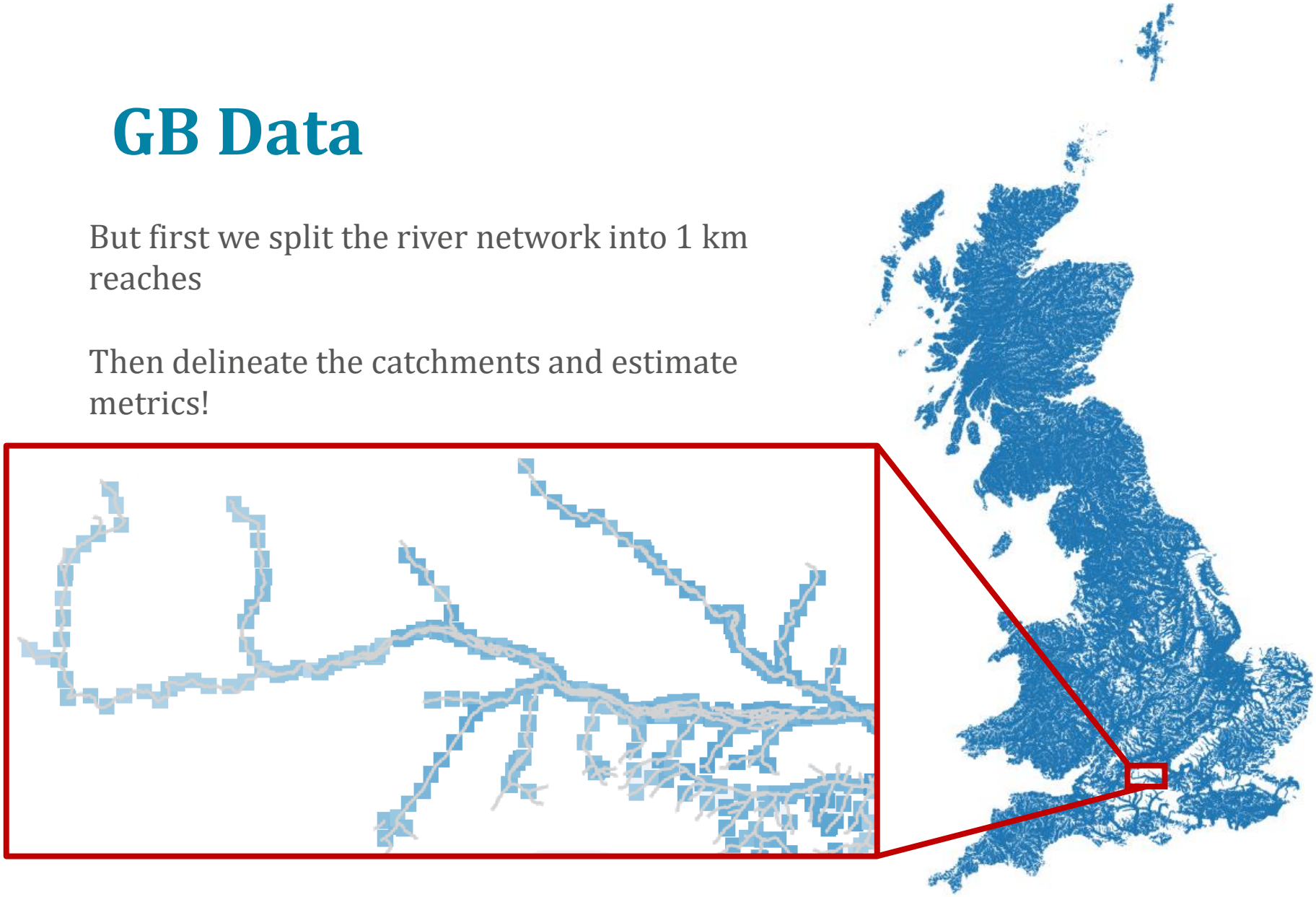


Derive metrics that summarise magnitude and variation of variables

GB Data

But first we split the river network into 1 km reaches

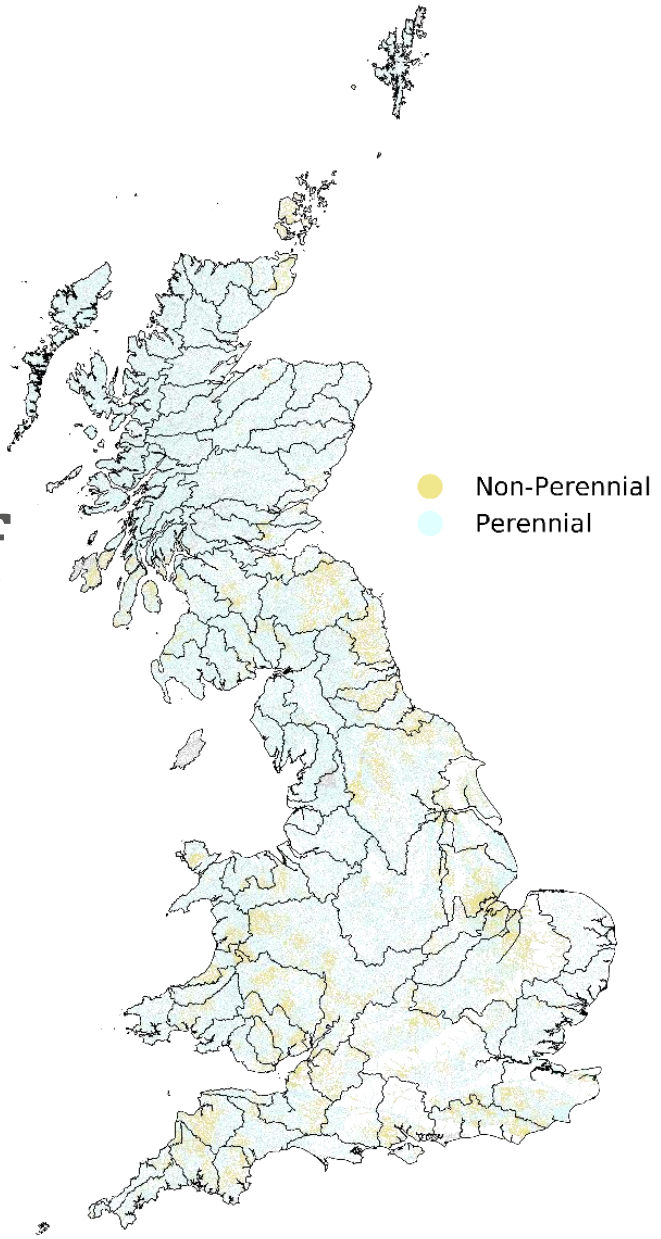
Then delineate the catchments and estimate metrics!



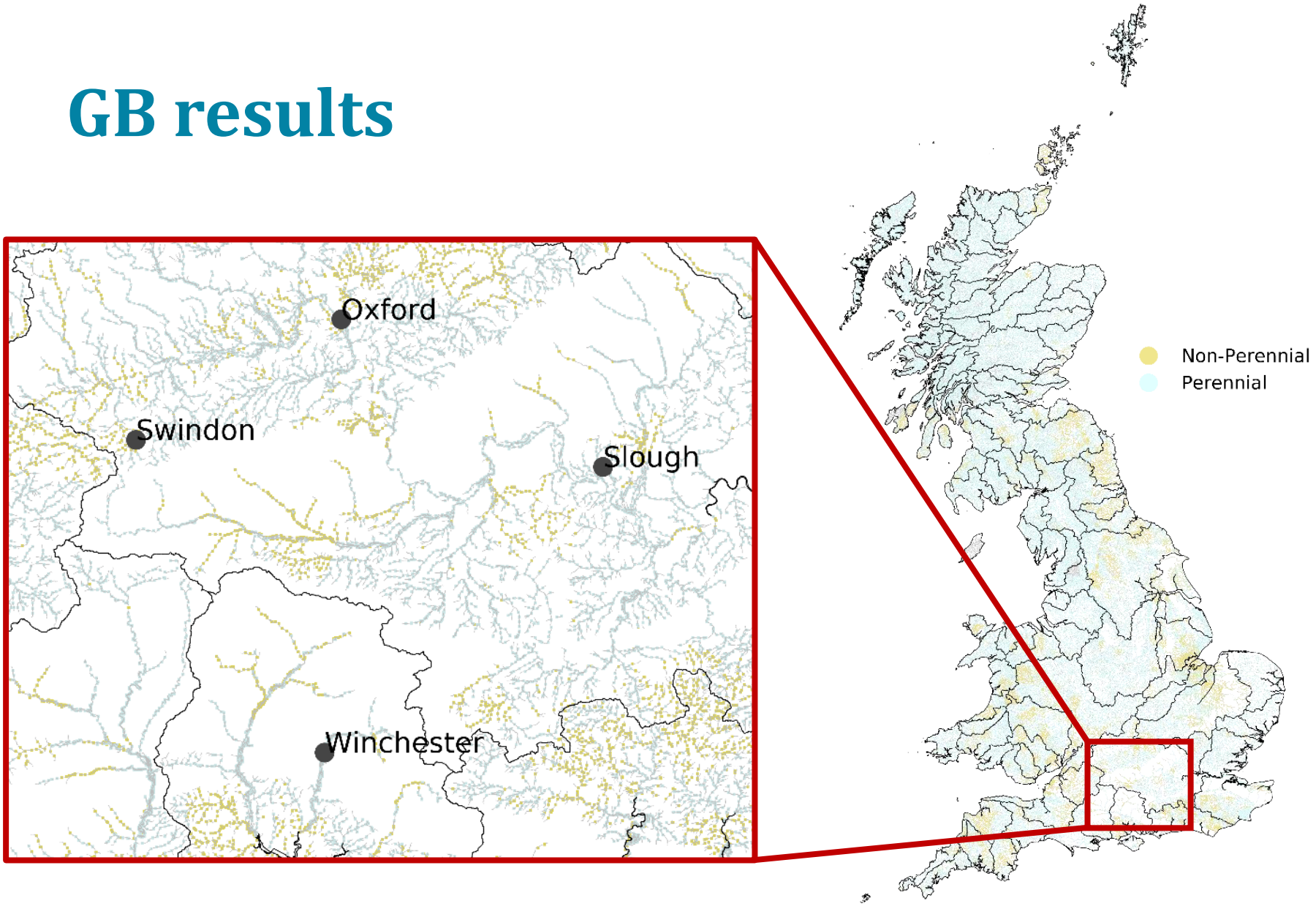
GB results

Model simulated 17% of points as non-perennial

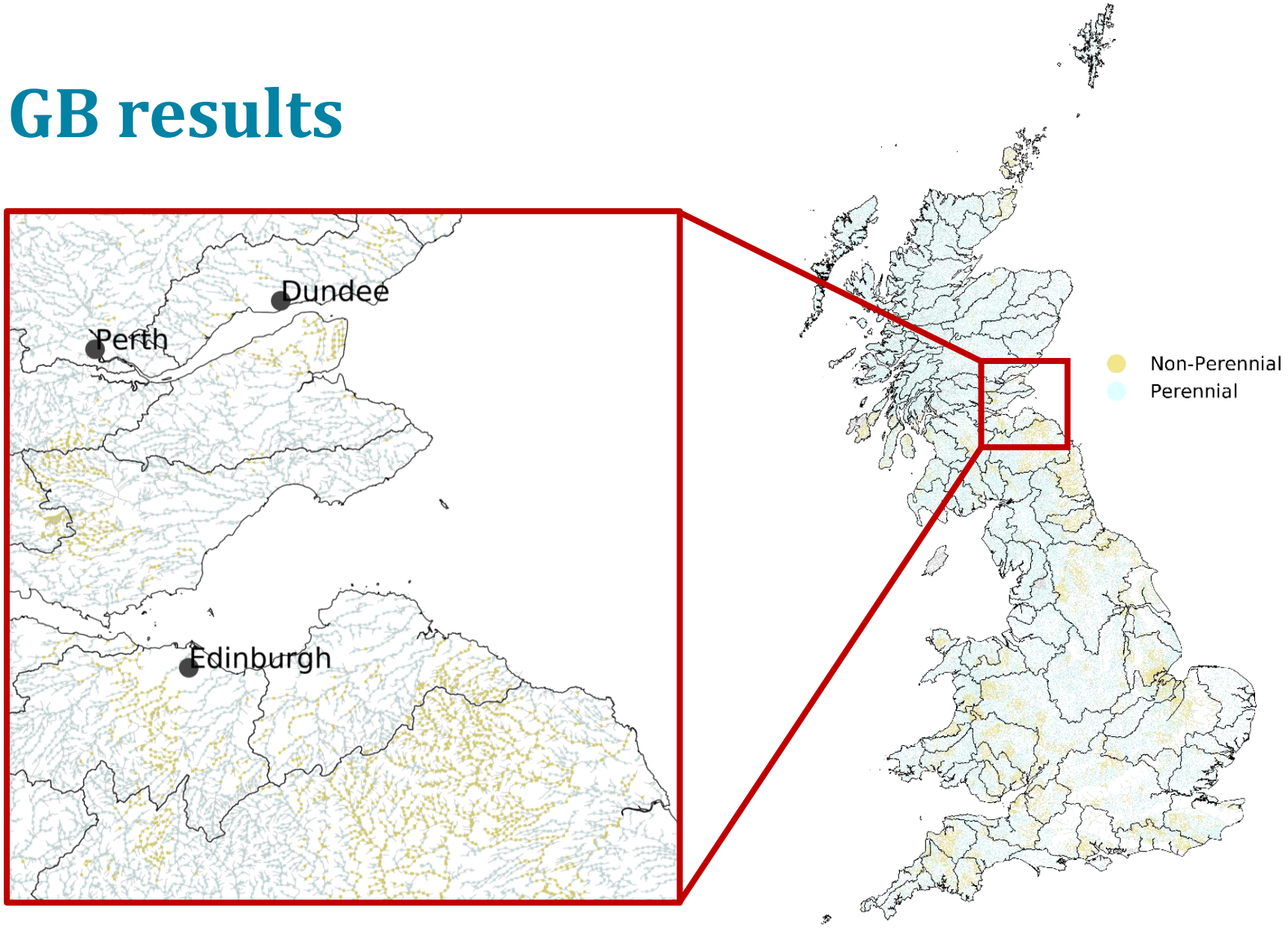
Model used 60:40 tree agreement threshold for perennial:non-perennial estimates



GB results


Oxford
Swindon
Slough
Winchester
Non-Perennial
Perennial

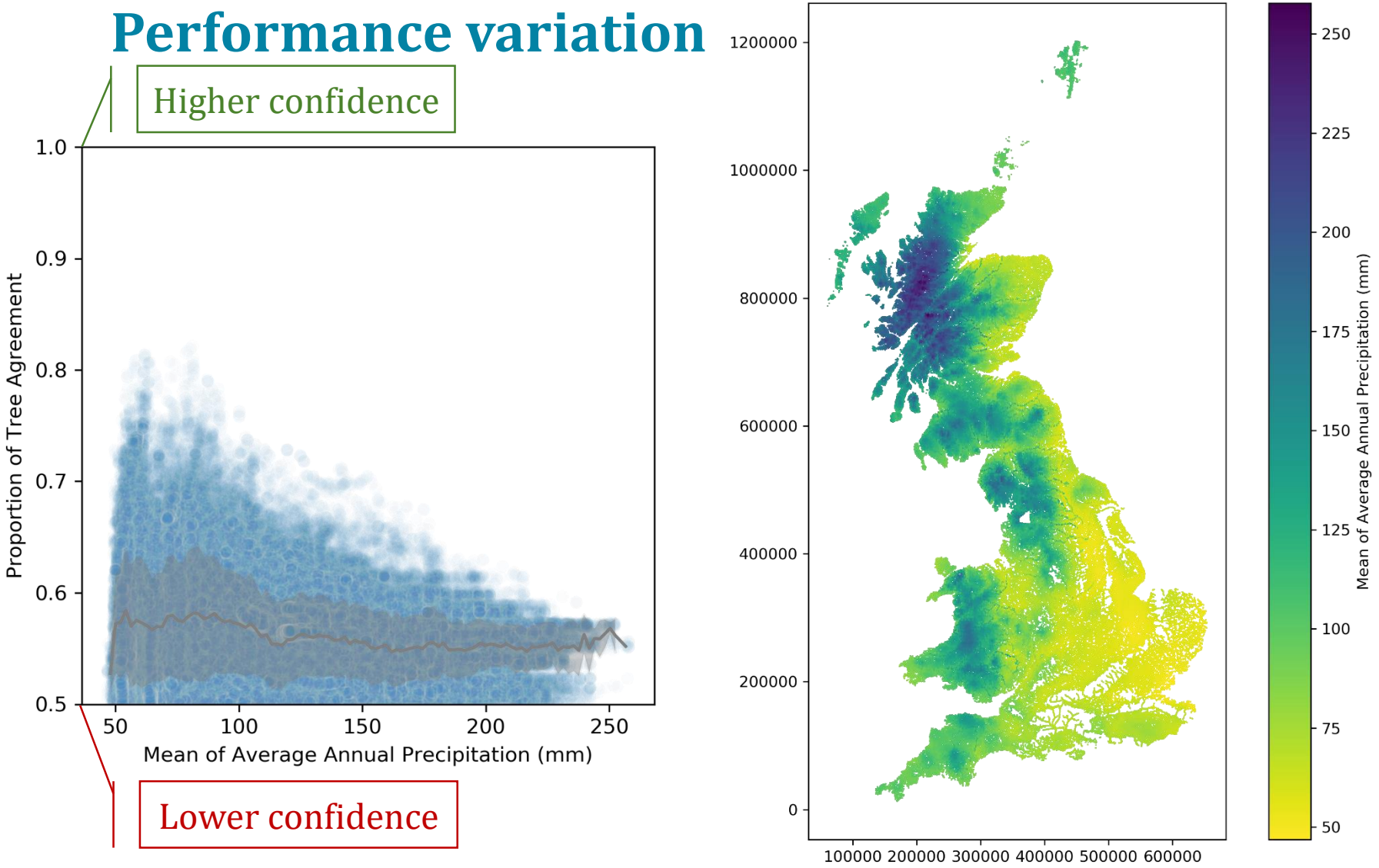
GB results



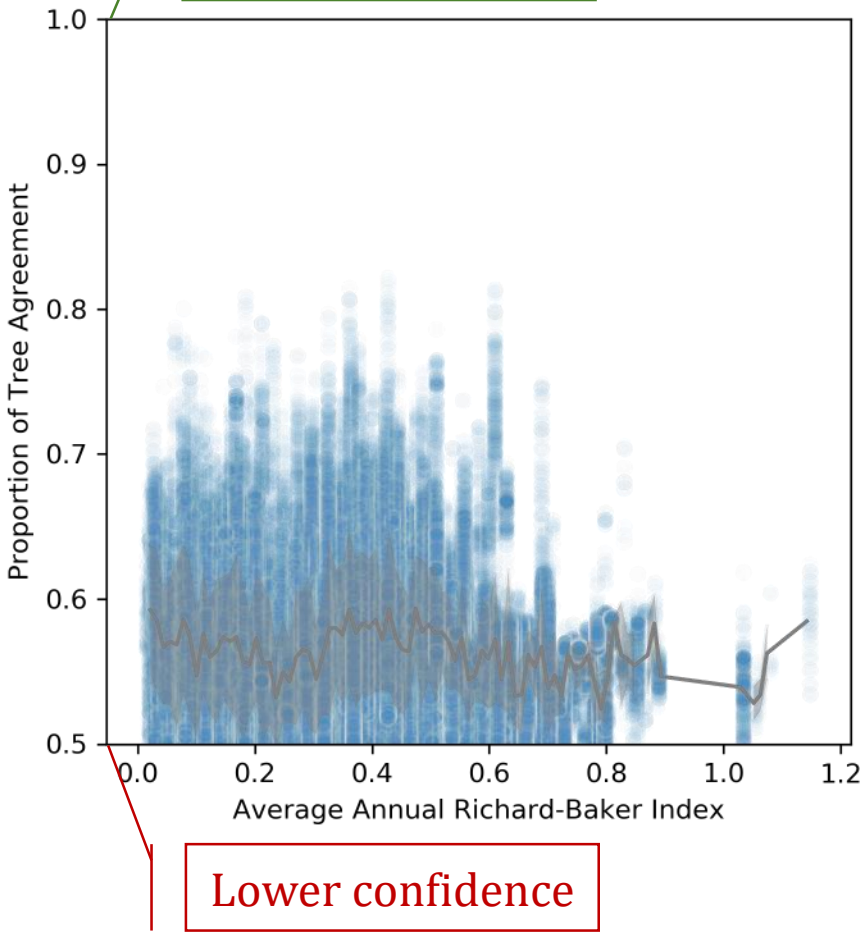
Webinar overview

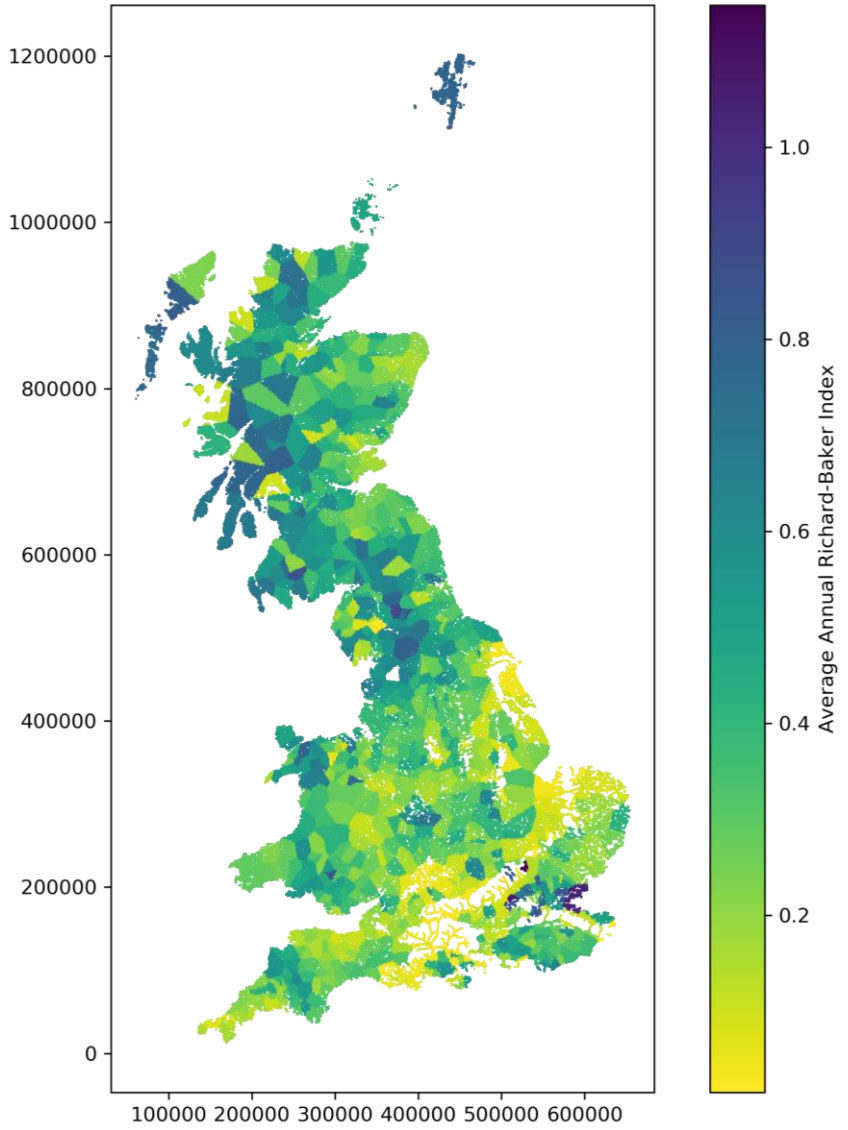
Motivation and context	• The motivation for ASTRID • The global picture on intermittent river research • Hydrological state simulation at catchment scale
ASTRID introduction	• Project overview • Launch workshop • Modelling approach
Model training	• Data • Model • French results
Model application	• Data • GB results • Performance variation
Conclusions and next steps	• Stakeholder consultation • ASTRID conclusions • Data collection

Performance variation

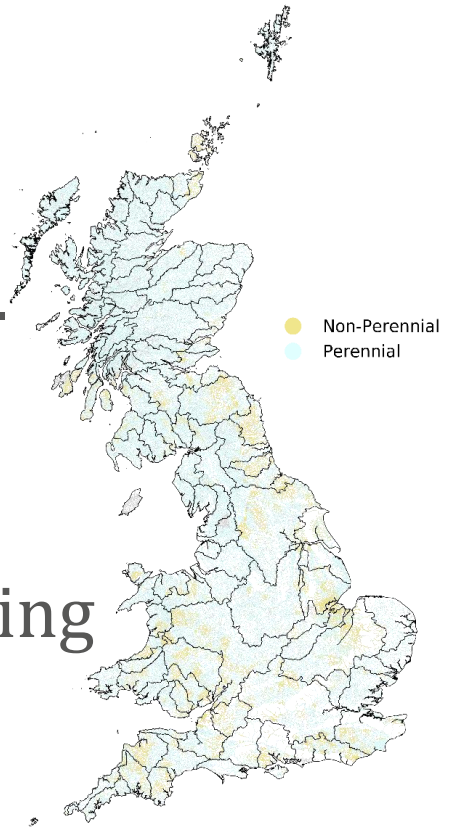


Performance variation



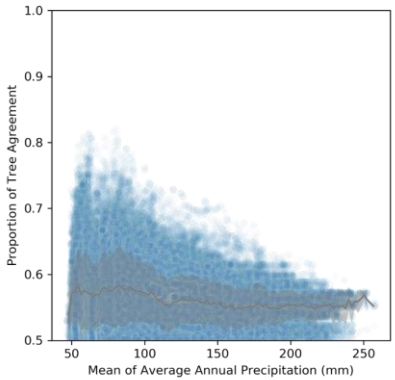


Summary of ASTRID results



17% of points were simulated as non-perennial

Intermittence is distributed throughout Britain, with many simulations overlapping current understanding of occurrence of intermittence



Model performance varies with environmental variables

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Consultation on ASTRID results

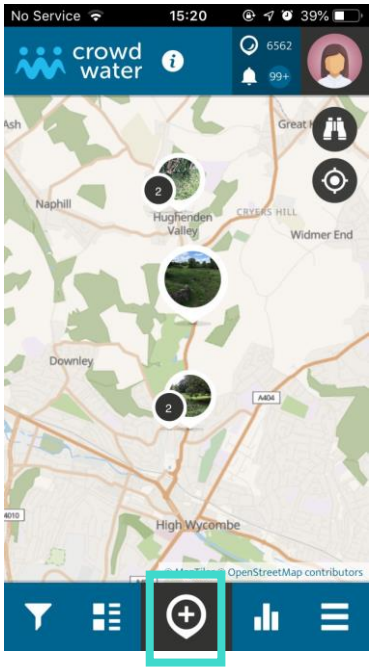
- Two weeks, from Monday 6th to Friday 17th September 2021;
- Maps and this webinar downloadable from a dedicated webpage https://www.ceh.ac.uk/astrid-project-stakeholder-consultation
- Plus a short questionnaire to collate views on:
  - Your interest in intermittent and ephemeral river hydrology;
  - Your knowledge on where and how the model is right/wrong;
  - Questions about intermittent and ephemeral rivers you would like to see addressed;
  - Interest in a Hydrological Intermittence Forum;
- The responses will be anonymously summarised, circulated to stakeholders and made available via the ASTRID and Landscape Decisions Programme websites.

Conclusions

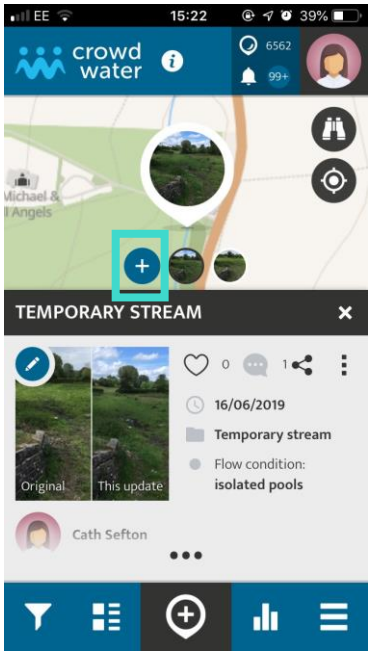
- Statistical modelling of national hydrological intermittence for Great Britain using available data has proven possible but challenging;
- Maps of hydrological intermittence for Great Britain are useful for raising awareness at national level, but highlight the need for data at regional scale;
- Year-round monitoring of intermittent rivers and streams is needed to support their effective management and prevent deterioration;
- Local knowledge will improve understanding of how model performance varies across Great Britain;
- Progress towards consistent and robust decision making in the management of intermittent rivers is enhanced by collaboration.

Citizen science - CrowdWater app

Create a new spot or…



…update an existing spot, then…



…upload a photo and select a flow state:

DRY STREAMBED: no visible water and the streambed is dry
WET STREAMBED: no visible water, but the streambed is wet (for at least 2 cm depth below the surface)
ISOLATED POOLS: separated pools of water that are not visibly flowing are present on the streambed
STANDING WATER: water but no visible flow
TRICKLING WATER: very small flow, but clearly visible flowing water
FLOWING WATER: a continuous pathway of water that is flowing

"We call on hydrologists and citizens to observe, sense and report the hydrological state of the aqua temporaria incognita… **without these data, it is as if we are trying to complete a puzzle** on how headwater catchments function and how water affects ecological processes, **while the majority of the puzzle pieces are hidden under the carpet**."

van Meerveld et al., Aqua Temporaria Incognita, 2021

Thank you

Any questions?

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Michael Eastman miceas@ceh.ac.uk

Simon Parry spar@ceh.ac.uk

Cecilia Svensson csve@ceh.ac.uk

Photo: River Og at Ogbourne St Andrew
Cath Sefton, June 2019

UKRI Grant no.: NE/T004215/1 & NE/T004215/2

LANDSCAPE DECISIONS