Evaluation of Ensemble Streamflow Prediction Skill for the UK

Shaun Harrigan, Katie Smith, Simon Parry, and Christel Prudhomme

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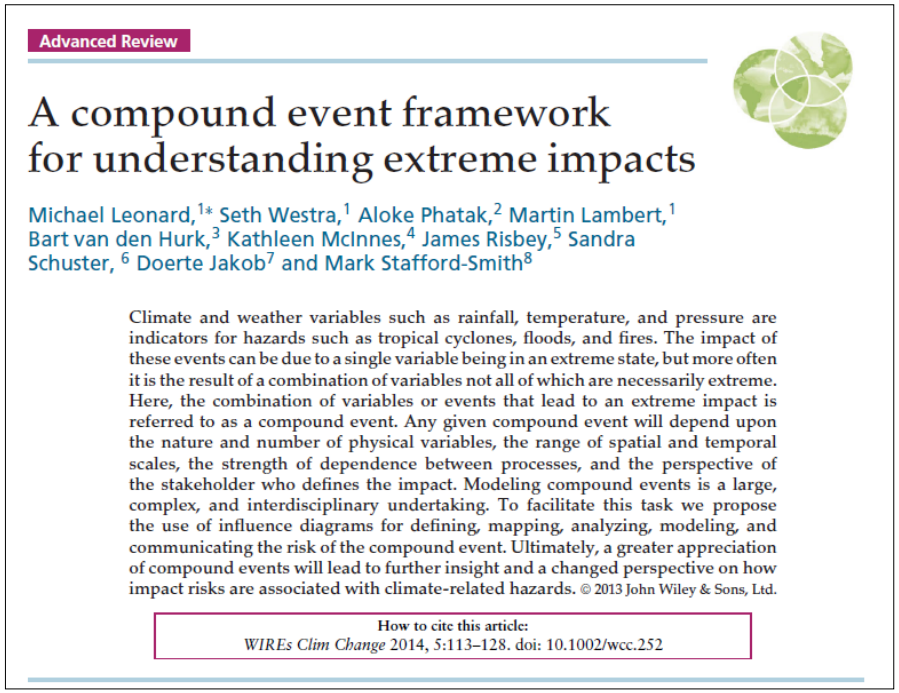
What is ‘high impact’ or ‘extreme’ in hydrology?

- Hydro. Extremes are **‘compound events’**



Advanced Review

A compound event framework for understanding extreme impacts

Michael Leonard,[1]* Seth Westra,[1] Aloke Phatak,[2] Martin Lambert,[1] Bart van den Hurk,[3] Kathleen McInnes,[4] James Risbey,[5] Sandra Schuster, [6] Doerte Jakob[7] and Mark Stafford-Smith[8]

Climate and weather variables such as rainfall, temperature, and pressure are indicators for hazards such as tropical cyclones, floods, and fires. The impact of these events can be due to a single variable being in an extreme state, but more often it is the result of a combination of variables not all of which are necessarily extreme. Here, the combination of variables or events that lead to an extreme impact is referred to as a compound event. Any given compound event will depend upon the nature and number of physical variables, the range of spatial and temporal scales, the strength of dependence between processes, and the perspective of the stakeholder who defines the impact. Modeling compound events is a large, complex, and interdisciplinary undertaking. To facilitate this task we propose the use of influence diagrams for defining, mapping, analyzing, modeling, and communicating the risk of the compound event. Ultimately, a greater appreciation of compound events will lead to further insight and a changed perspective on how impact risks are associated with climate-related hazards.

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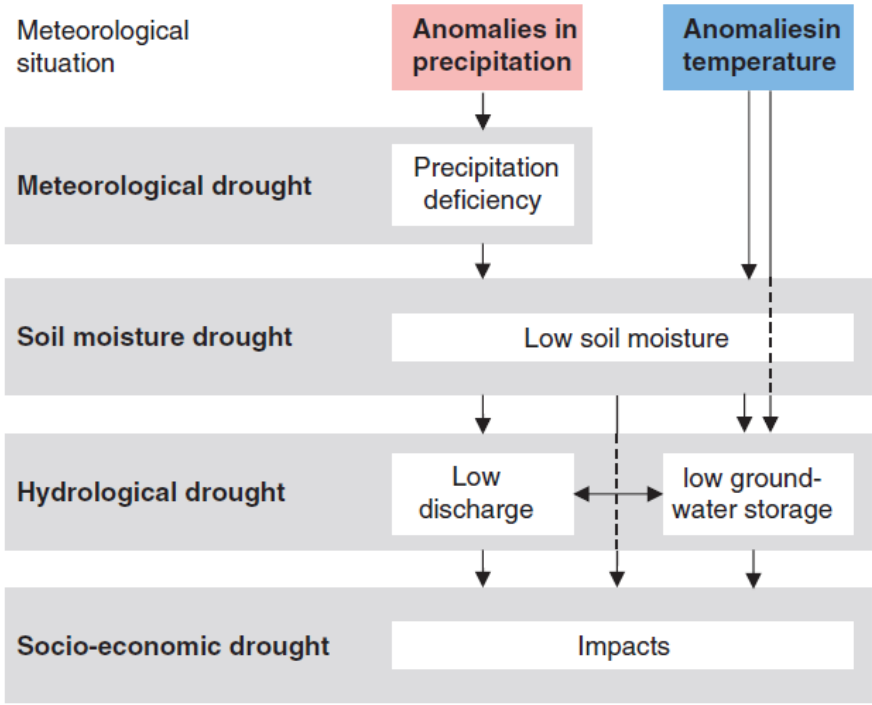
- E.g. Hydro. Droughts



Source: Van Loon (2015) WIREs Water

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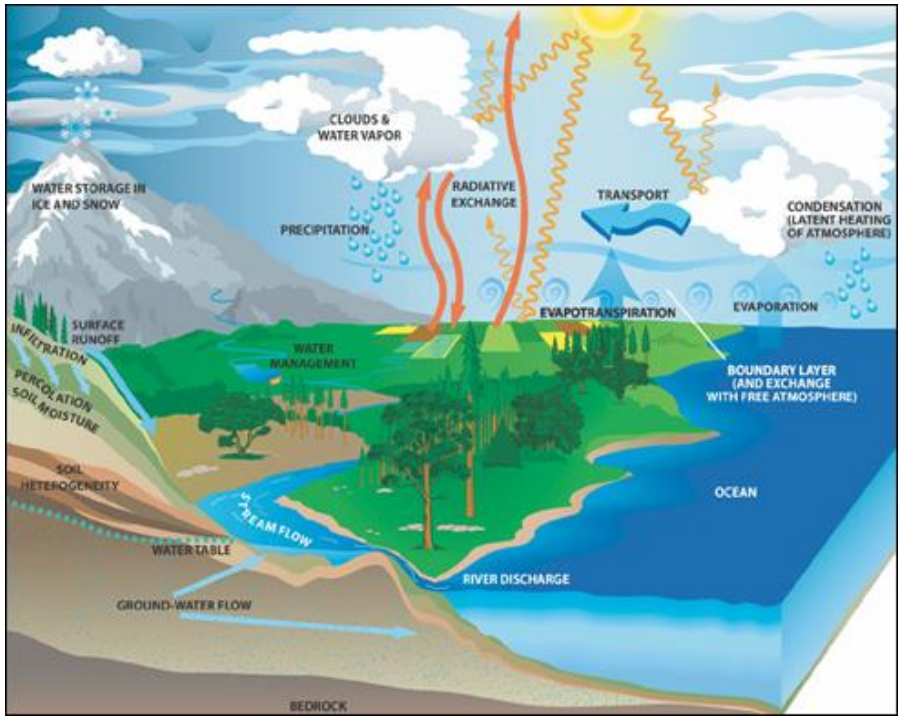
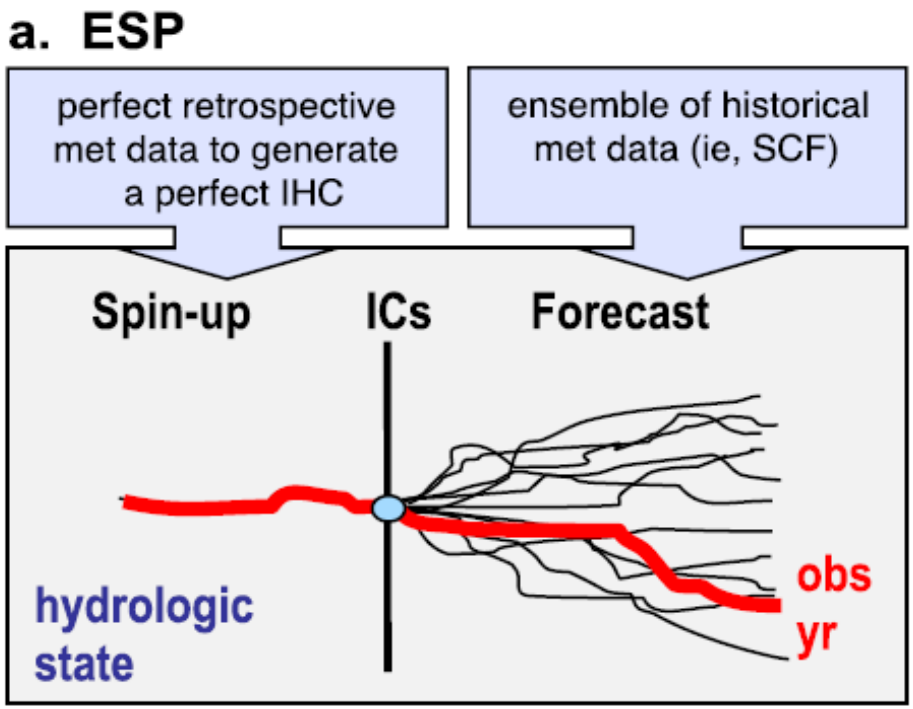
Ensemble Streamflow Prediction (ESP)

- **2 sources of predictability:**
  - **Initial Hydrologic Conditions (IHCs):** (SM & GW)
  - **Atmospheric:** (Skilful) seasonal forecasts (P, T, MSLP…)





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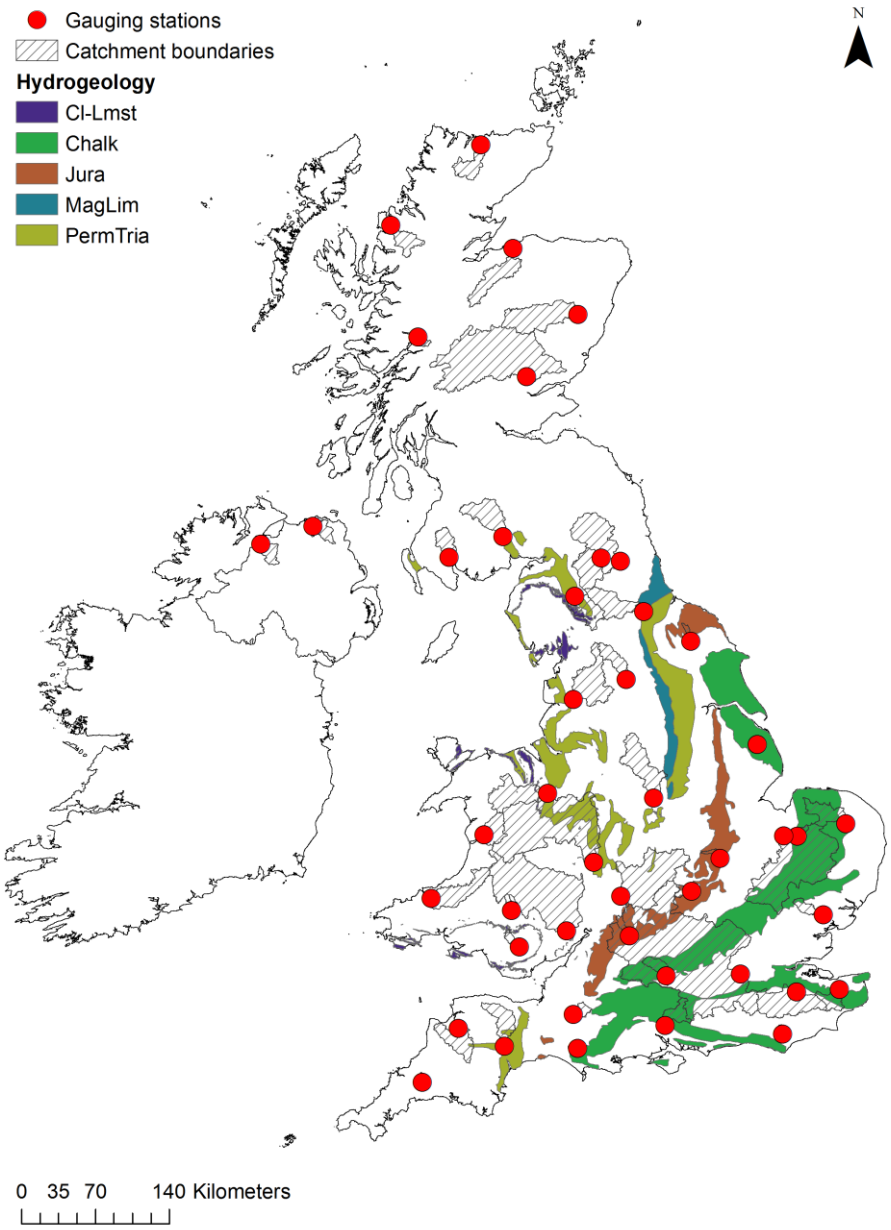
Source: Andy Wood, NCAR

Aim

Benchmark how much **skill** is possible from **IHCs alone**

1) **When**
   (FC Initialisation/Lead time)
2) **Where**
   (spatial/Catchment types)



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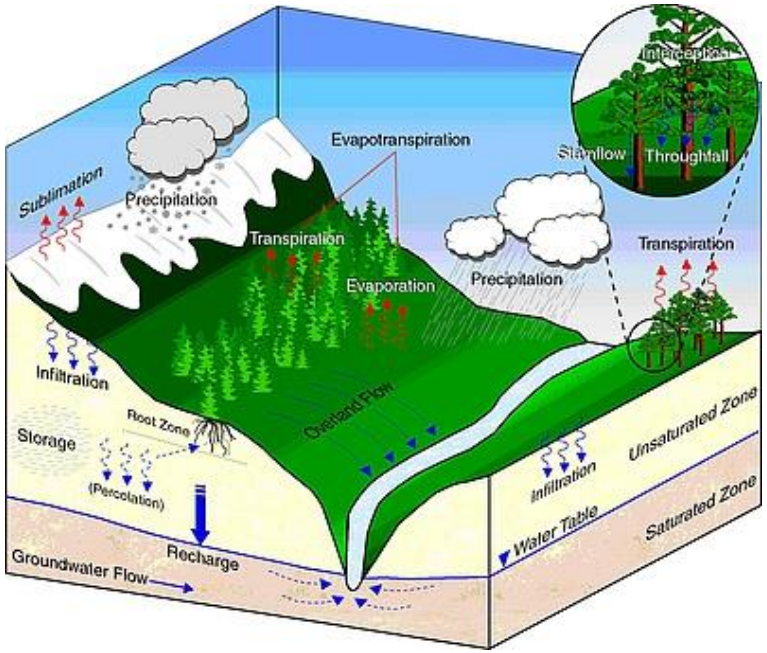
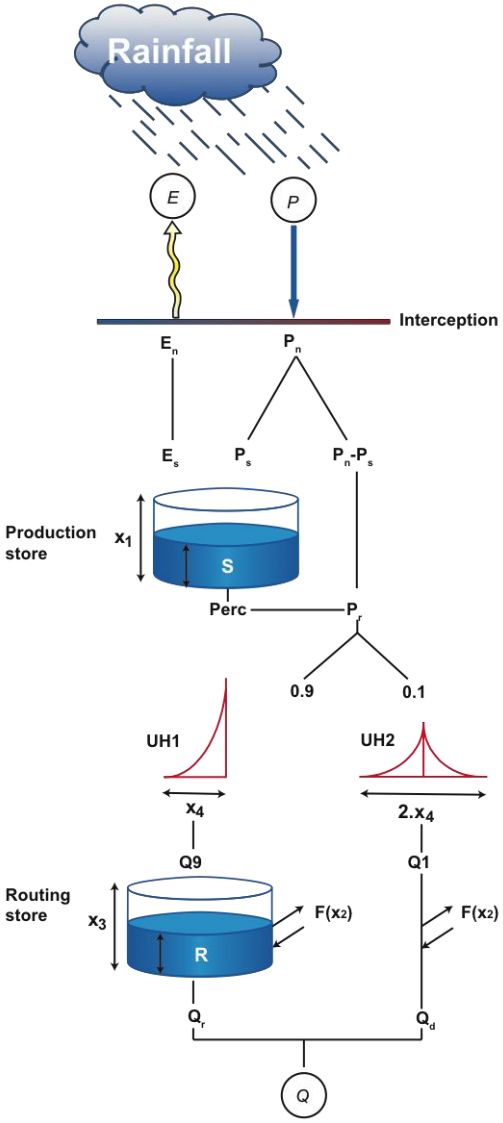
IHCs via Hydrological Modelling



GR4J (Perrin et al., 2003 JH)



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Graphic source: University of Tübingen

Graphic source: eWater Toolkit Wiki

Generation of ensemble streamflow forecasts

1.) IHCs: GR4J run with 4 Yrs Obs P and PET up to day of forecast

2.) Historic Climate Sequences : 50 historic climate sequences extracted from 1961-2012

3.) ESP: Model forced with historic climate sequences to generate a 50-member **ensemble** of 'future' streamflow

Hindcasts for Verification: 1965-2012; Updates 1st Month; 12-Month LT

(564 @ 50 ensmebles -> 30 k per catchment -> 1.3 M series)

ESP skill evaluation

- **Skill sco** … **(MSE_{SS}):**
  - **OBS** … odel
  - **REF** …
  - **FC** … mean)
- **Lead Tim** …

Journal of Hydrology **10** (1970) 282–290; © *North-Holland Publishing Co., Amsterdam*

RIVER FLOW FORECASTING THROUGH CONCEPTUAL MODELS

PART I – A DISCUSSION OF PRINCIPLES*

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Abstract: The principles governing the application of the conceptual model technique to river flow forecasting are discussed. The necessity for a systematic approach to the development and testing of the model is explained and some preliminary ideas suggested.

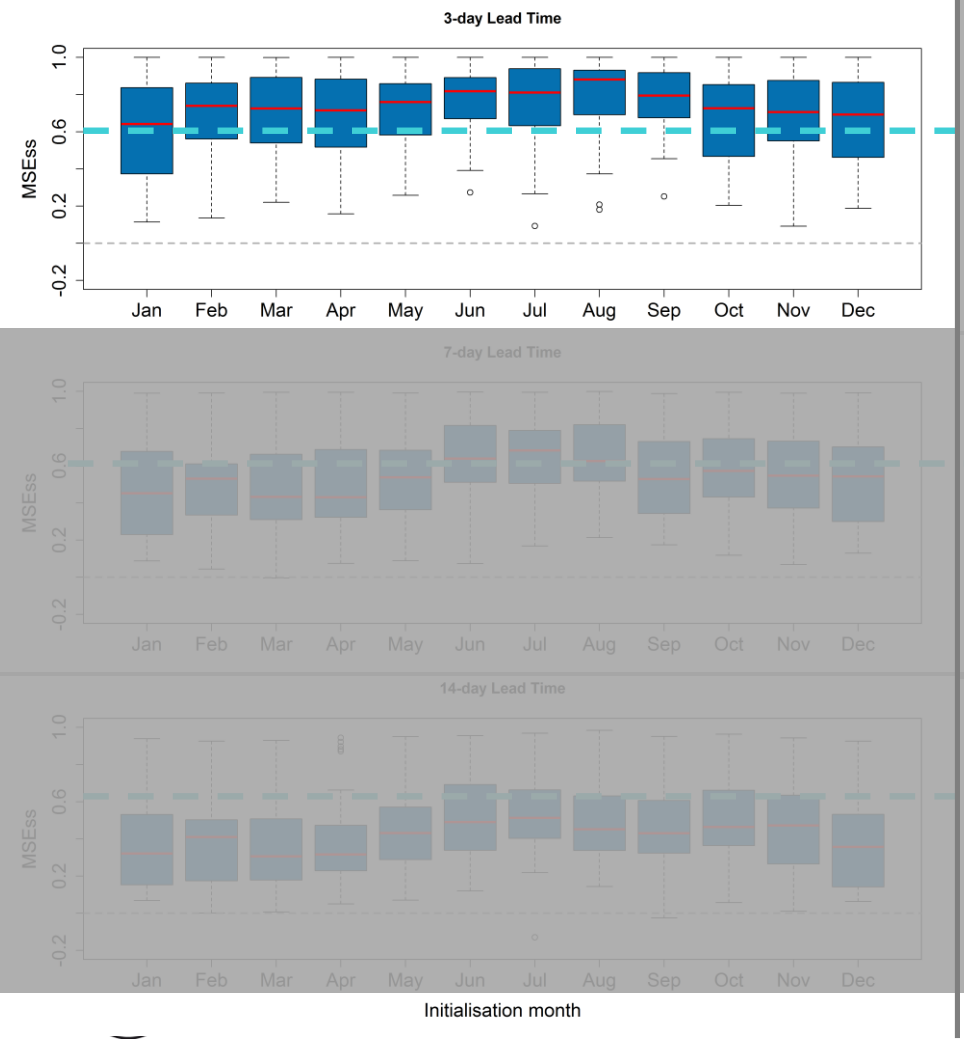
$$MSE_{SS} = 1 - \frac{MSE_{FC}}{MSE_{REF}}$$

- $MSE_{SS} = 1$ (perfect)
- $MSE_{SS} > 0$ (More accurate)
- $MSE_{SS} = 0$ (Accurate as REF)
- $MSE_{SS} < 0$ (Less accurate)

Murphy (1988) MWR

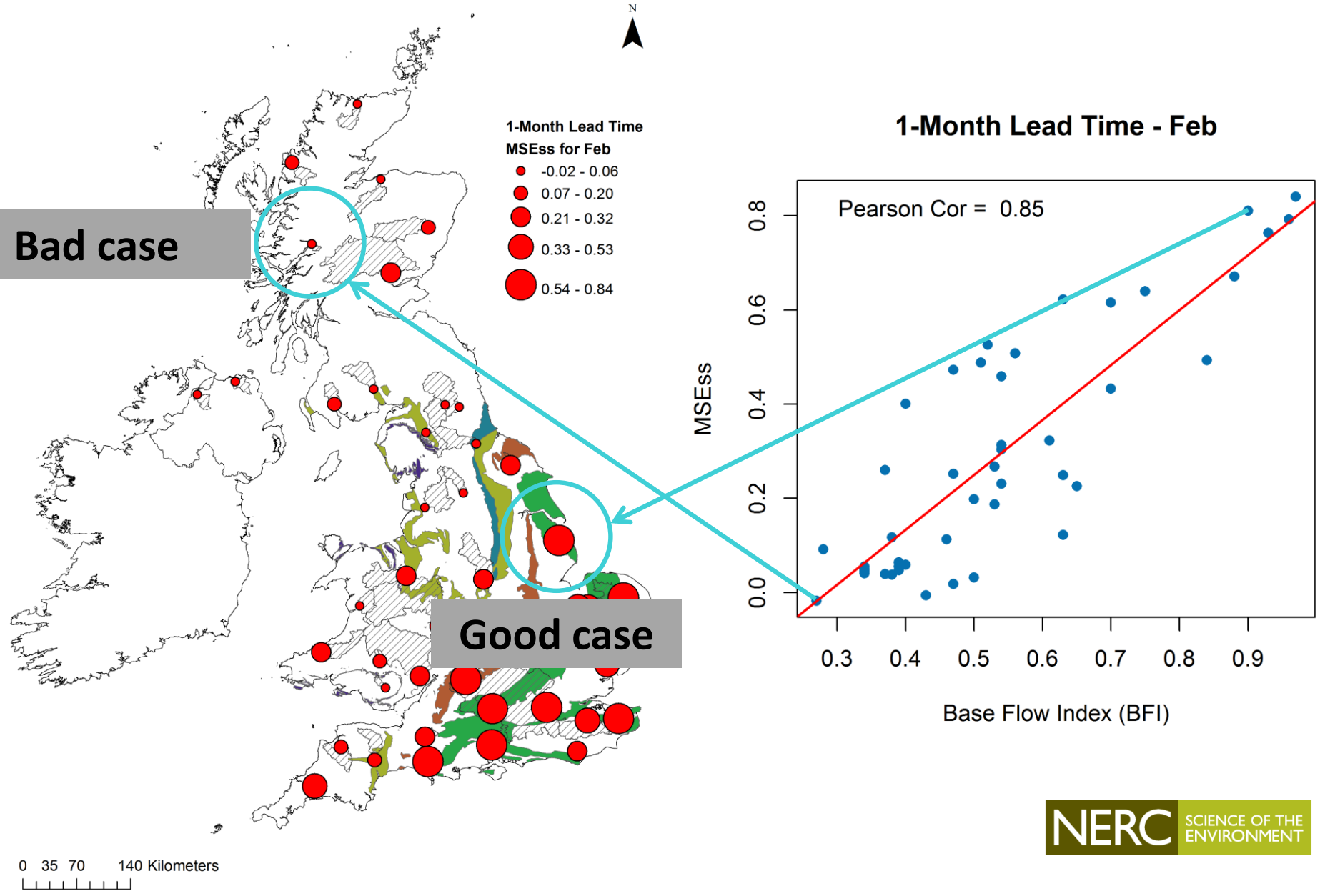
When is ESP skilful?

- Shorter Lead Times
- Longer Lead Times



Boxes Summarise Skill Scores for 45 Catchments

Where is ESP skilful?



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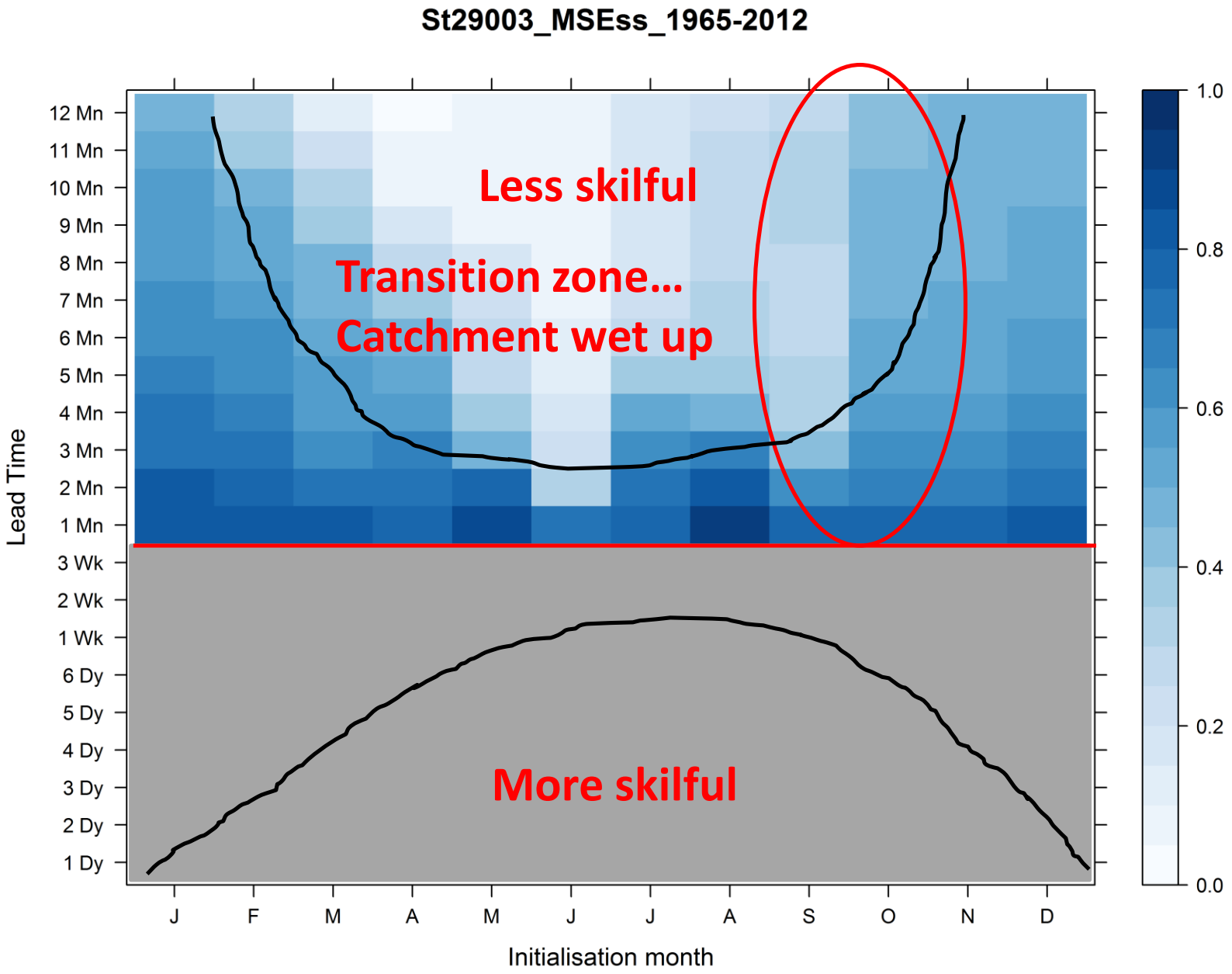
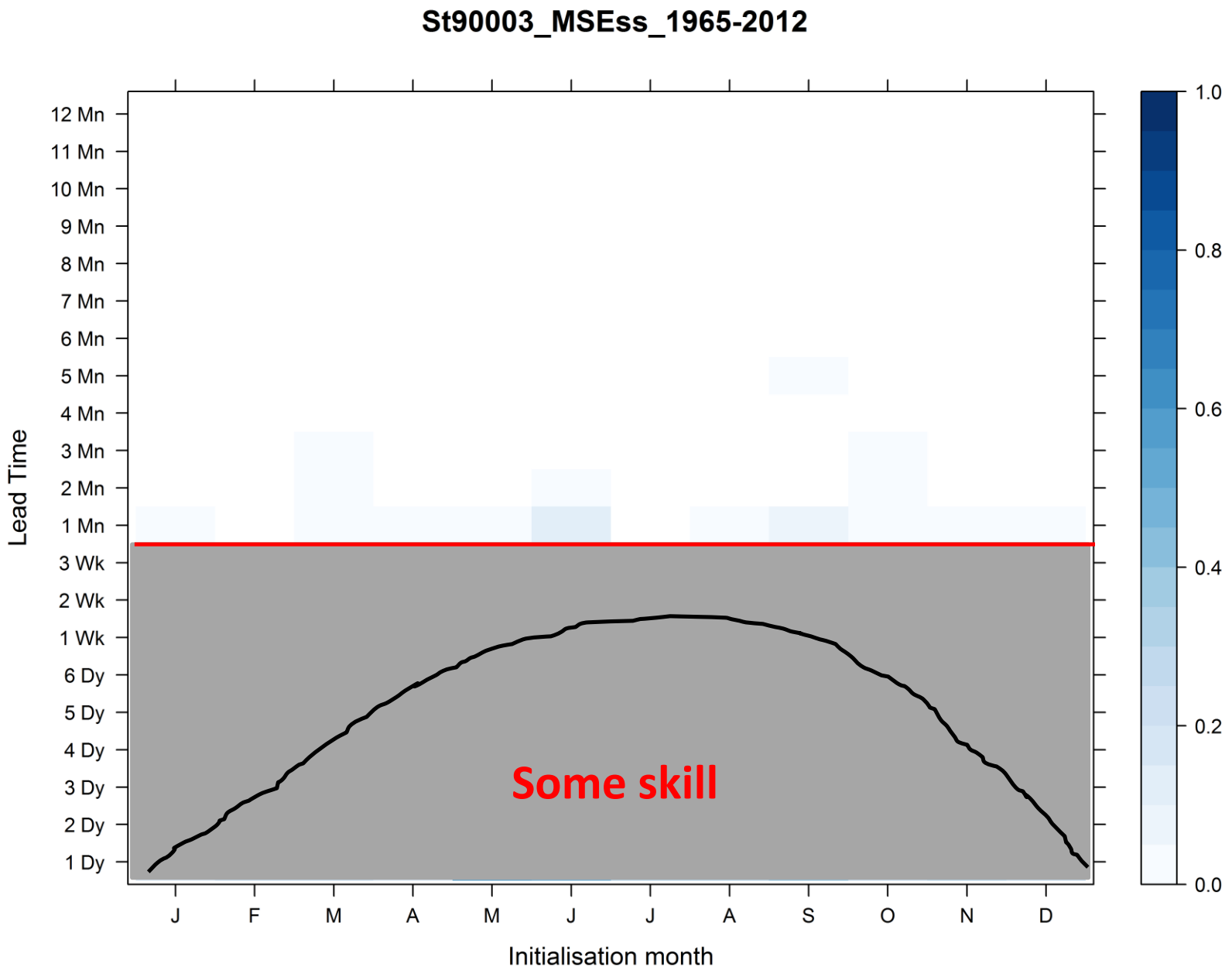
Good case – Lud (BFI = 0.9)



Bad case – Nevis (BFI = 0.27)



Summary: When and where ESP has skill

	Summer (dryer) months	Winter (wetter) months
Short LT	• Surface = **YES** • Groundwater = **YES**	• Surface = **Limited** • Groundwater = **YES**
Long LT	• Surface = **NO** • Groundwater = **Limited**	• Surface = **NO** • Groundwater = **YES**

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Seasonal Atmospheric Predictability?

IOP Publishing Environ. Res. Lett. 10 (2015) 064006 doi:10.1088/1748-9326/10/6/064006

Environmental Research Letters

LETTER

Long-range forecasts of UK winter hydrology

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OPEN ACCESS

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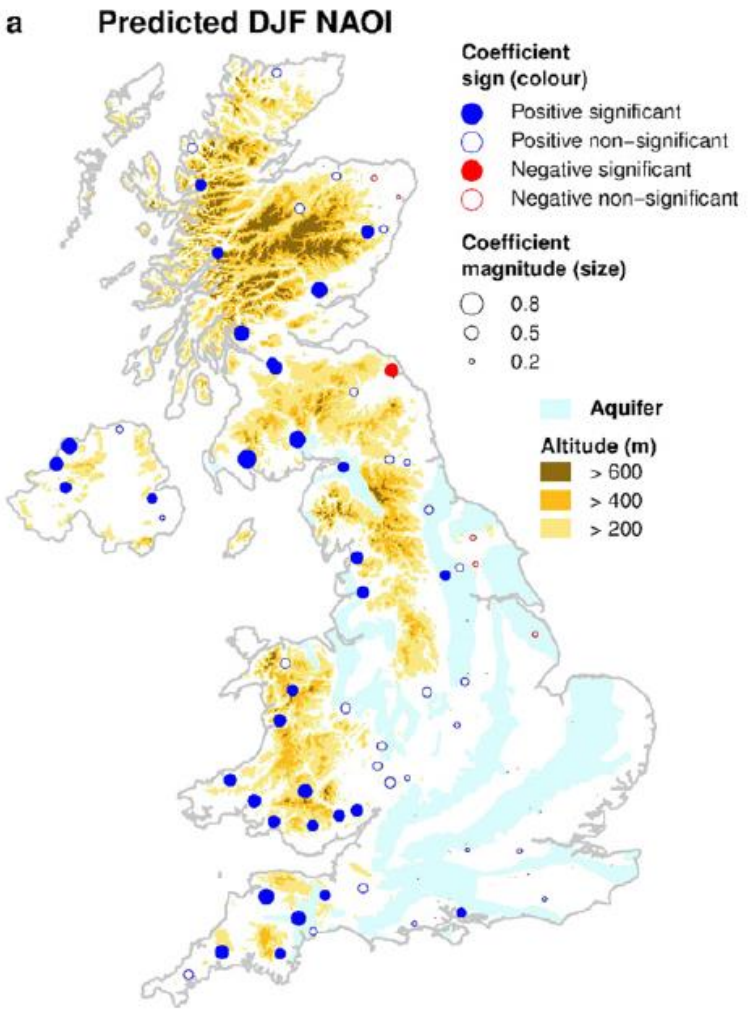
Abstract

Seasonal river flow forecasts are beneficial for planning agricultural activities, river navigation, and for management of reservoirs for public water supply and hydropower generation. In the United Kingdom (UK), skilful seasonal river flow predictions have previously been limited to catchments in lowland (southern and eastern) regions. Here we show that skilful long-range forecasts of winter flows can now be achieved across the whole of the UK. This is due to a remarkable geographical complementarity between the regional geological and meteorological sources of predictability for river flows. Forecast skill derives from the hydrogeological memory of antecedent conditions in southern and eastern parts of the UK and from meteorological predictability in northern and western areas. Specifically, it is the predictions of the atmospheric circulation over the North Atlantic that provides the skill at the seasonal timescale. In addition, significant levels of skill in predicting the frequency of winter high flow events is demonstrated, which has the potential to allow flood adaptation measures to be put in place.



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Next steps and Challenges…

- Integrate **ECMWF Seasonal Forecast System 4** hindcasts
- **UKMO GloSea5** – MSLP/NAO (Uni. of Reading)
- **Scientific Dev.:**
  - Improvement of long-range **Summer** atmos. predictions
    - What processes need to be (better) simulated?
    - Persistent events (e.g. blocking)?
  - 'Drought termination' (Parry et al., 2015 HESSD)
  - How (best) to downscale these to daily/sub-daily?

Thank You!

Photo : iStockPhoto

Questions / Feedback?

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