Improving Seasonal Prediction of UK Winter Streamflow

Shaun Harrigan

Maliko Tanguy, Laura Baker, Jamie Hannaford, Len Shaffrey, Katie Smith, Simon Parry & Christel Prudhomme

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ECMWF

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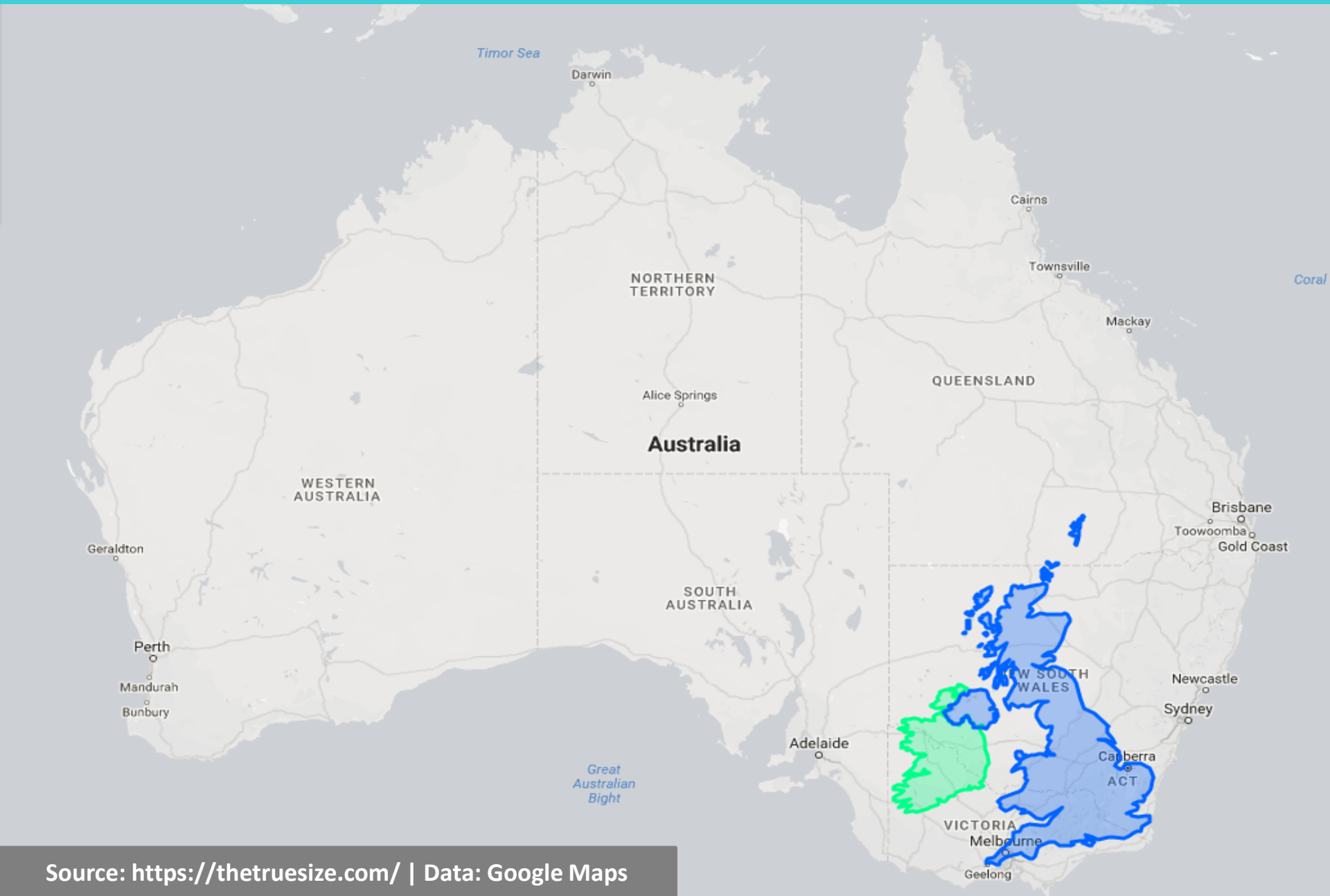
About Drought
Maximising the impact of UK research on drought & water scarcity

IMPETUS
IMPROVING PREDICTIONS OF UK DROUGHT

First, some scale…

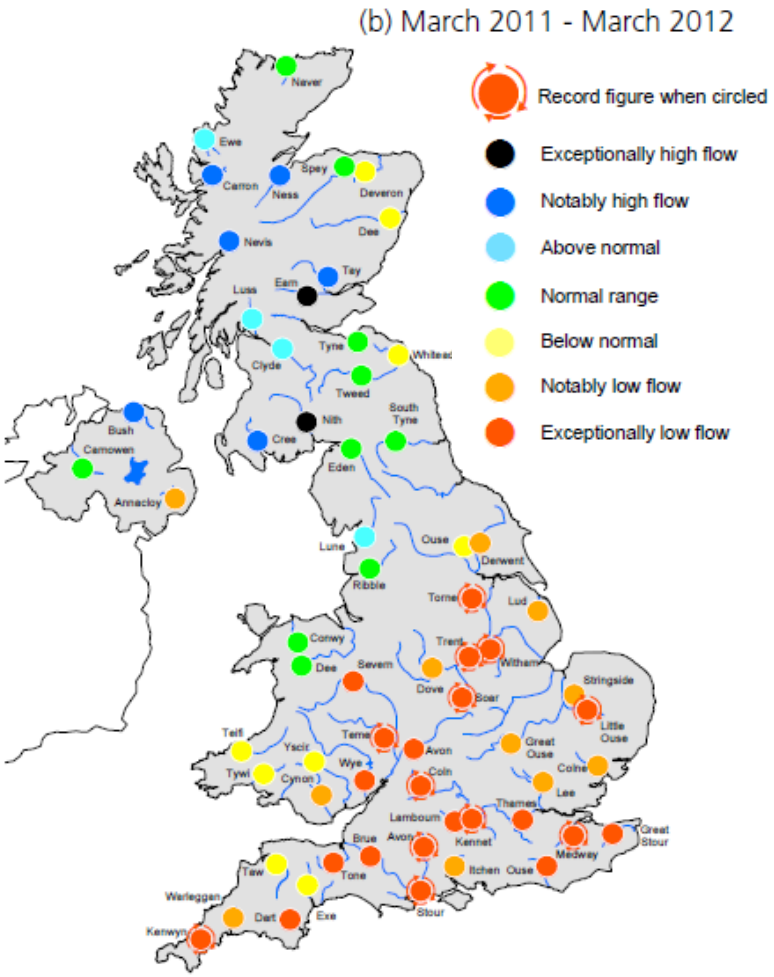


Source: https://thetruesize.com/ | Data: Google Maps

Winter Key for UK Water Resources

- UK winter = Dec-Jan-Feb (DJF)
- Critical period for water resources management:
  - Reservoir replenishing
  - Groundwater recharge
  - ~80% of public water supply in Thames basin (~12M people) from surface water abstraction
- Dry winters ⬆ **Drought risk**

The 2010-2012 UK drought



Marsh et al. (2013) National Hydrological Monitoring Programme - occasional reports

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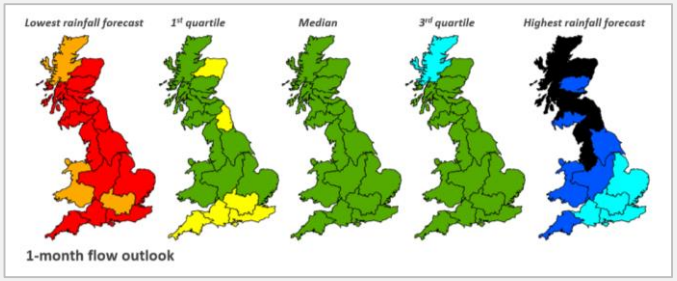
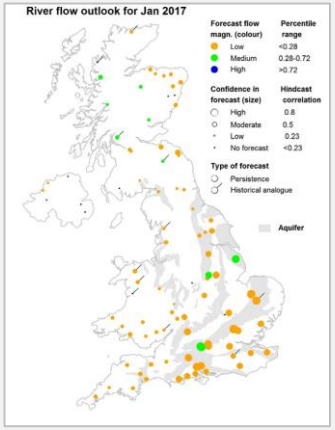
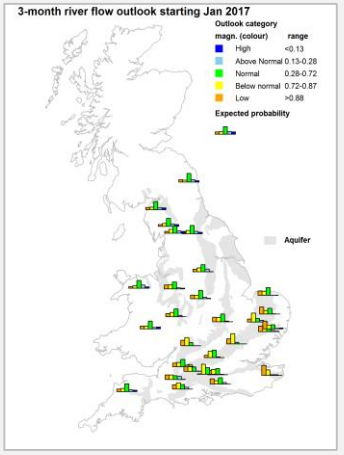
Operational Hydrological Outlook UK

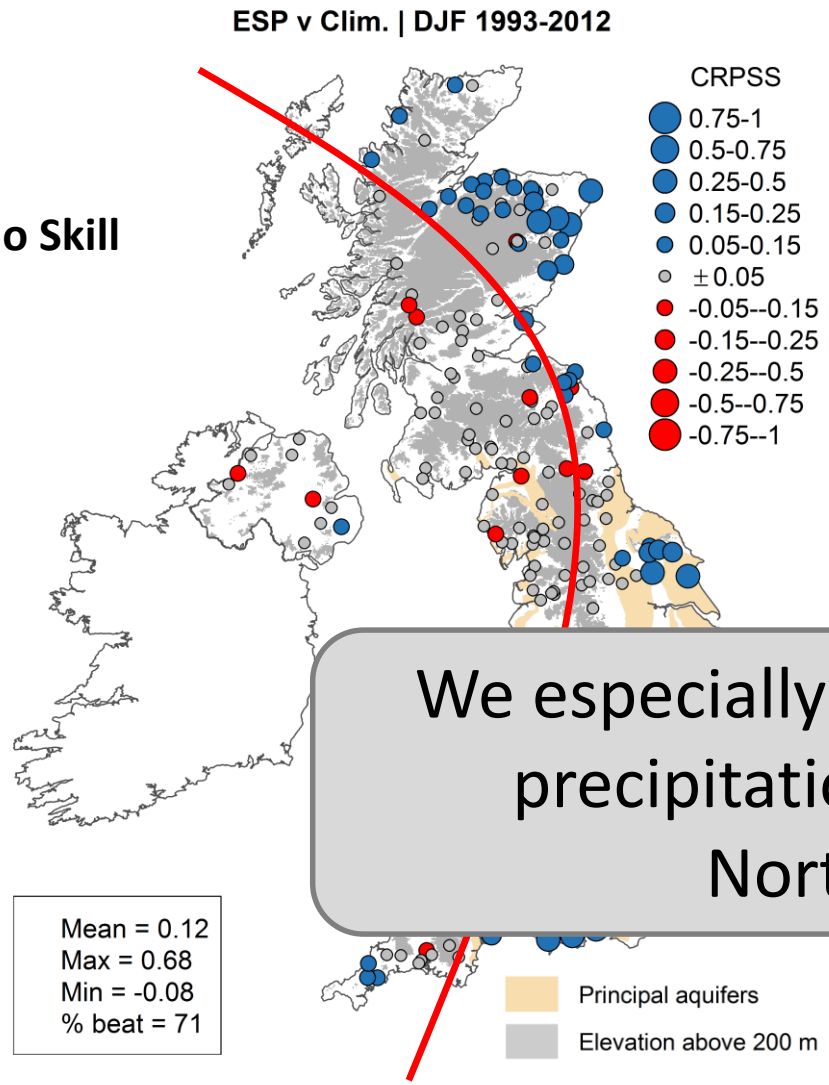
Method	Description	Scale	Forecast horizon	Example forecast
1.) Flows modelled using dynamic rainfall ensemble	*Probabilistic forecasts using GloSea5 rainfall ensemble*	National across Great Britain	1 and 3 months	
2.) Persistence and analogy	*Statistical based on persistence and historical analogues*	Catchments over UK	1 and 3 months	
3.) Ensemble Streamflow Prediction (ESP)	*Probabilistic forecasts using historical rainfall ensemble*	Catchments over England & Wales	Up to 12 months	

Prudhomme, et al. (2017)
Hydrological Sciences Journal

ESP method feeds into the EA 'Water situation reports for England'

British Geological Survey · Centre for Ecology & Hydrology · Environment Agency · Met Office · NERC · Cyfoeth Naturiol Cymru / Natural Resources Wales · Rivers Agency · SEPA

Skill of Ensemble Streamflow Prediction (ESP)



No Skill

Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2017-449
Manuscript under review for journal Hydrol. Earth Syst. Sci.
Discussion started: 28 July 2017

Hydrology and Earth System Sciences Discussions

Benchmarking Ensemble Streamflow Prediction skill in the UK

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[3]European Centre for Medium-Range Weather Forecasts (ECMWF), Shinfield Park, Reading, RG2 9AX, UK

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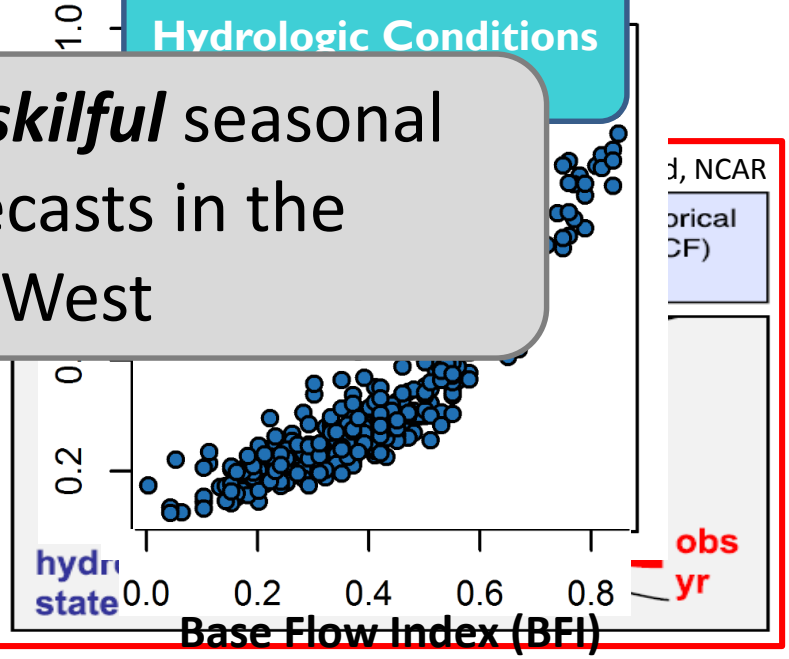
Abstract. Skilful hydrological forecasts at sub-seasonal to seasonal lead times would be extremely beneficial for decision-making in water resources management, hydropower operations, and agriculture, especially during drought conditions. Ensemble Streamflow Prediction (ESP) is a well-established method for generating an ensemble of streamflow forecasts in the absence of skilful future meteorological predictions, instead using Initial Hydrological Conditions (IHCs), such as soil moisture, groundwater, and snow, as the source of skill. We benchmark when and where the ESP method is skilful across a diverse sample of 314 catchments in the UK and explore the relationship between catchment storage and ESP skill. The GR4J hydrological model was forced with historic climate sequences to produce 51-member ensemble of streamflow hindcasts. We

Skill from Initial Hydrologic Conditions

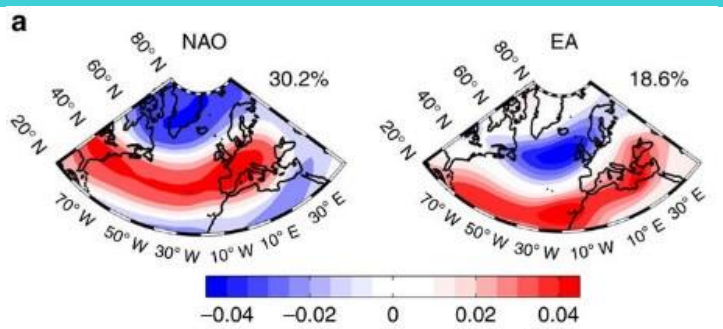


We especially need ***skilful*** seasonal precipitation forecasts in the North and West

Harrigan et al. (2018, accepted ☺)
HESS Special Issue

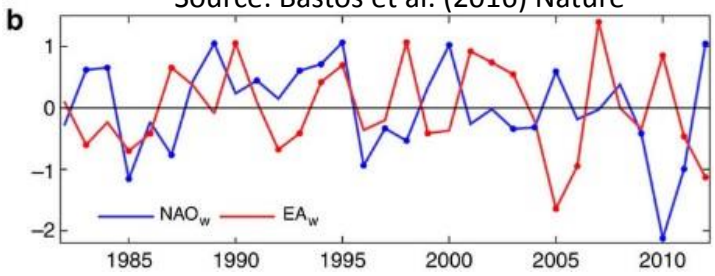
Drivers of UK Winter Precipitation Variability

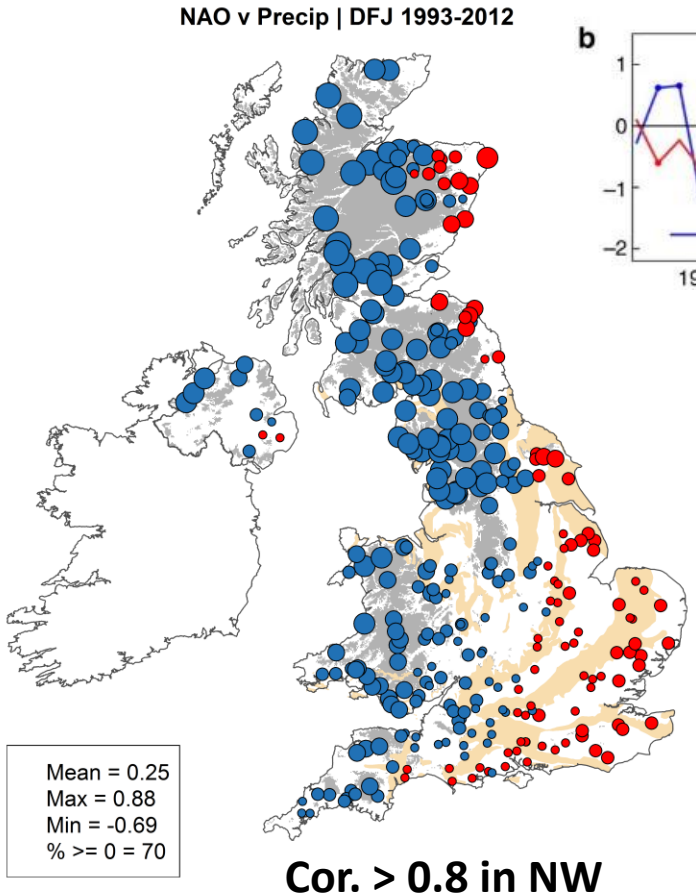
North Atlantic Oscillation (NAO)



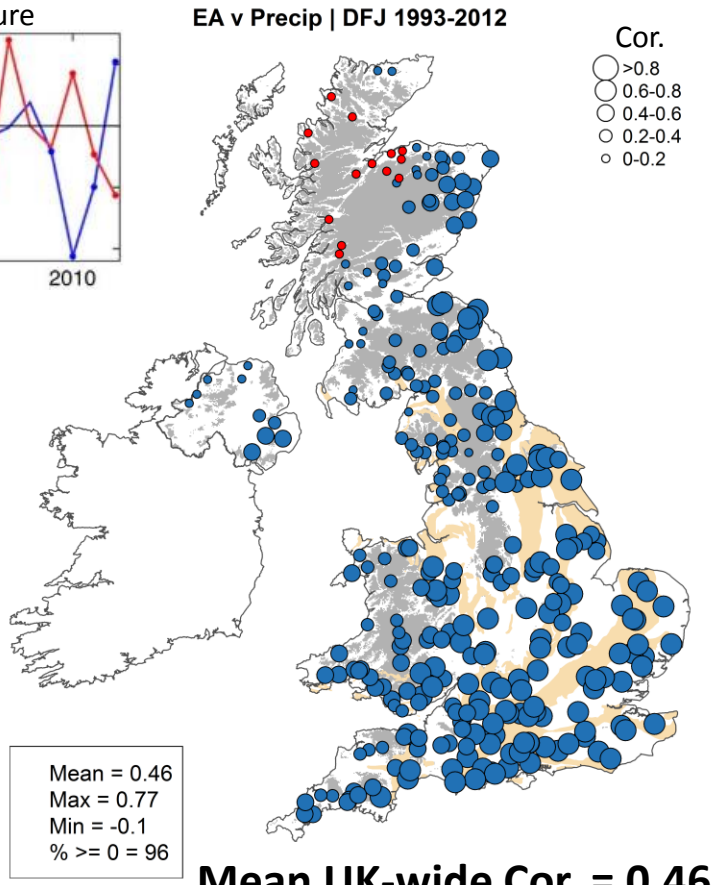
Source: Bastos et al. (2016) Nature

East Atlantic Pattern (EA)





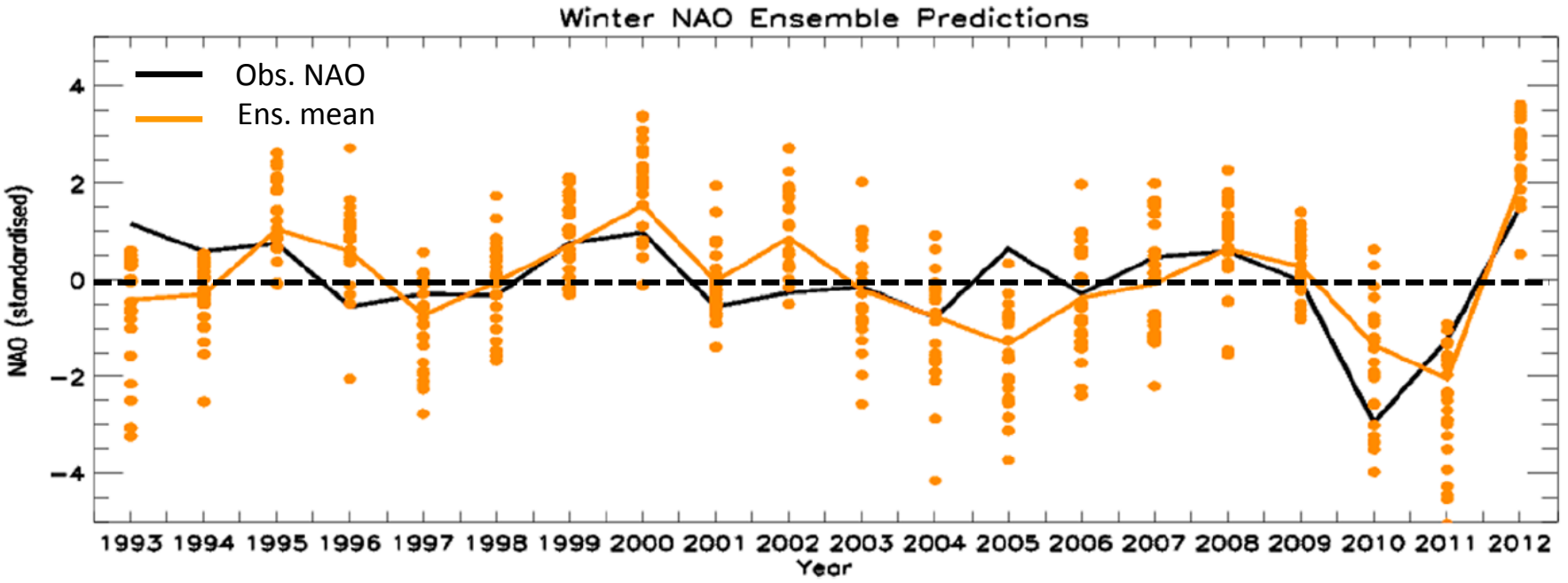
Cor. > 0.8 in NW



Mean UK-wide Cor. = 0.46

Current Winter NAO Predictability

NAO index predictions based on UK Met Office (MO) Global Seasonal forecast System 5 (GloSea5) – Scaife et al. (2014); Cor. = 0.62



NAO sign correct around 65% of the time over DJF 1993-2012 for ensemble mean

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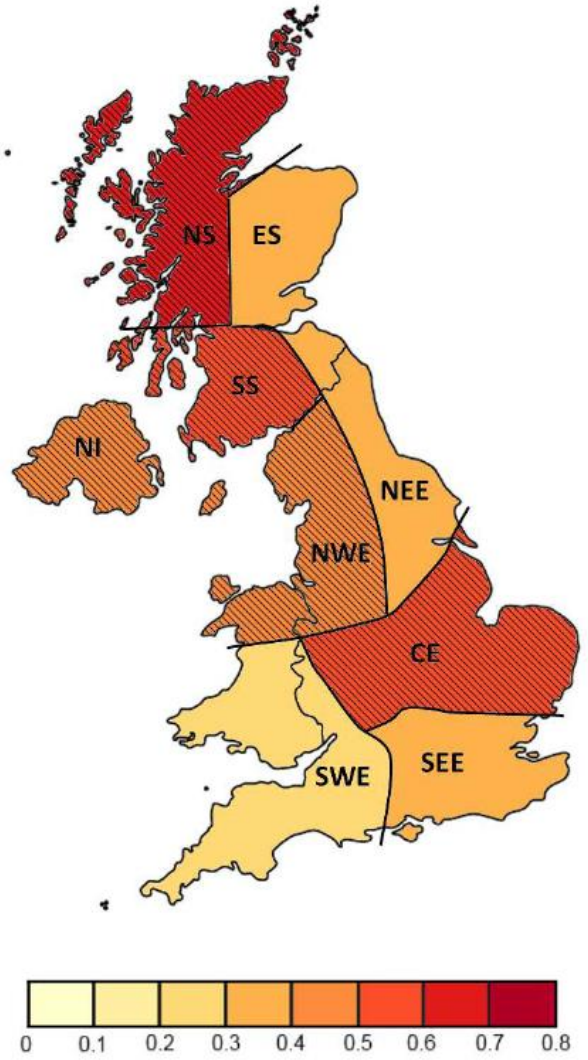
Method 1: Winter precipitation forecasts

- **UoR_P**: Improved seasonal prediction of UK regional precipitation using atmospheric circulation downscaling from GloSea5 MSLP fields (*Baker et al., 2017, IJOC*)
- DJF precip at 5km grid
- 3-month ➔ 1-day using Historic Sequence Correction (HSC; Tanguy et al. (2018), in prep)



Baker et al. (2017)
International Journal of Climatology

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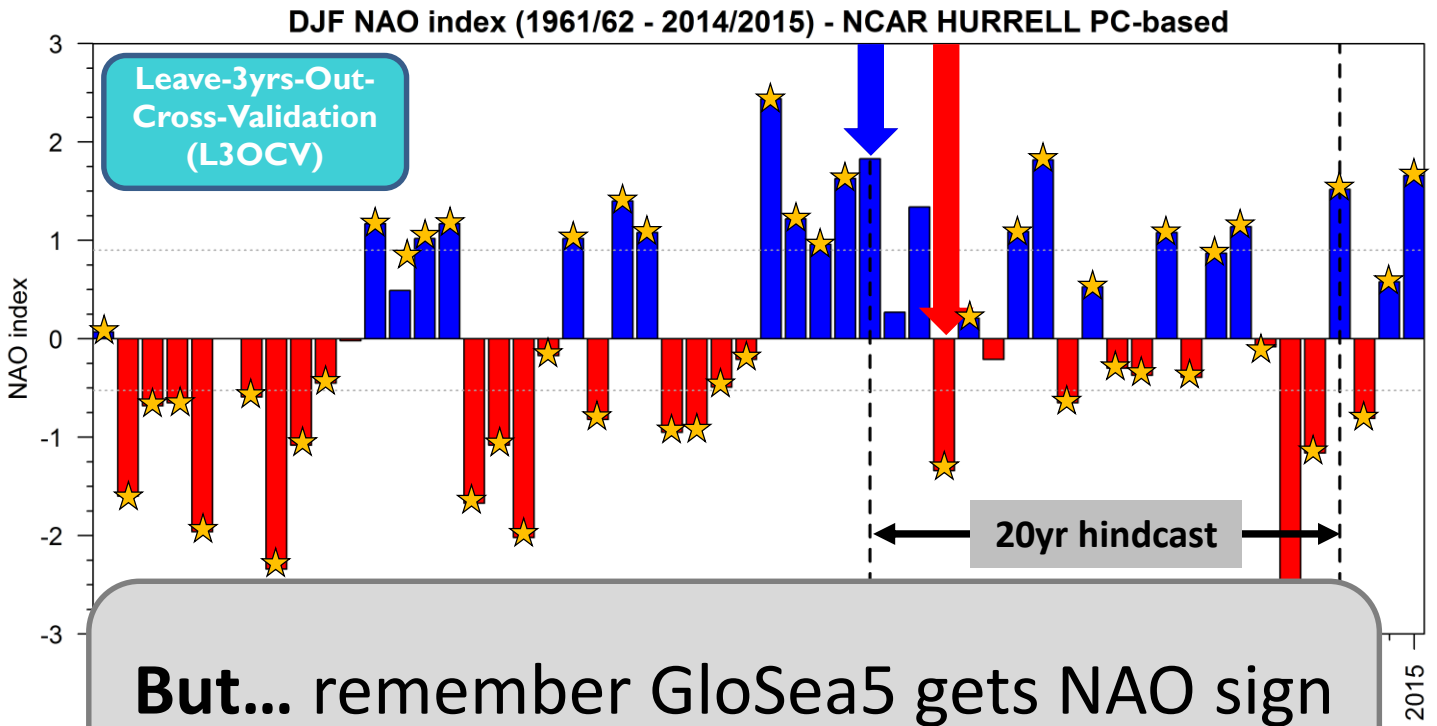
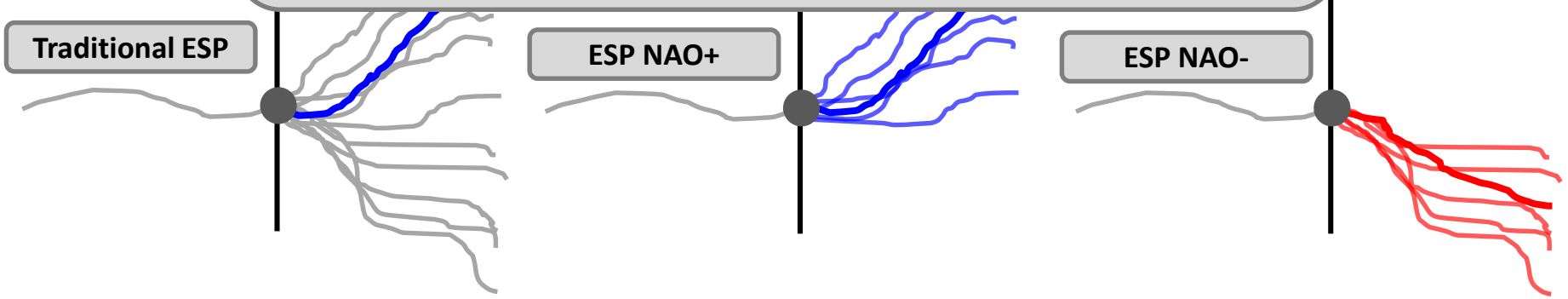
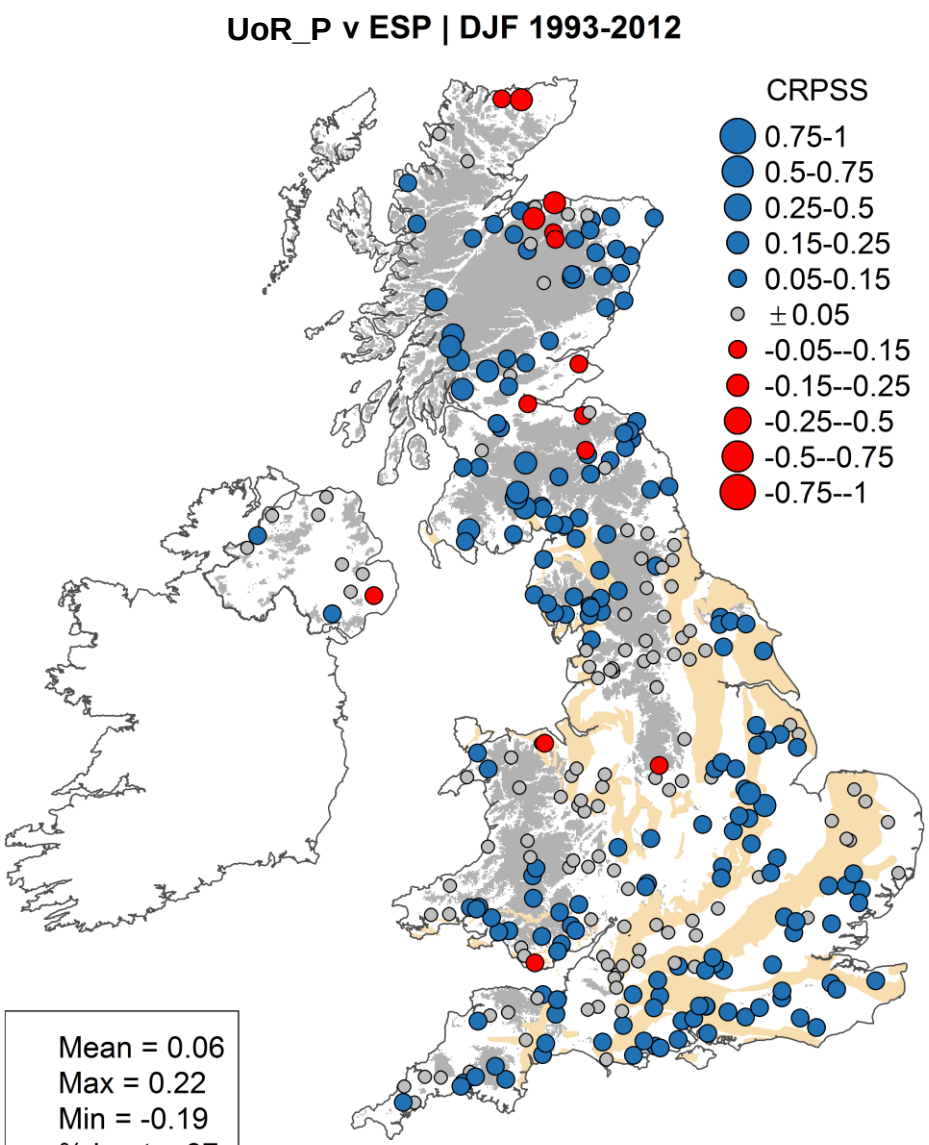
Method 2: ESP sub-sampling on NAO±



But… remember GloSea5 gets NAO sign wrong 7/20yrs!

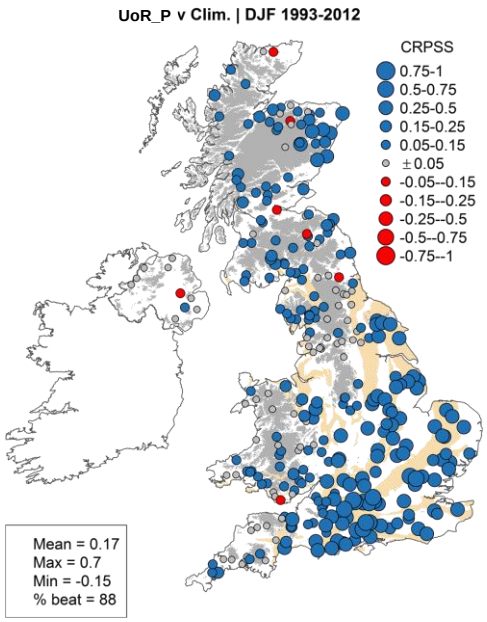


Results 1: UoR_P beat ESP?

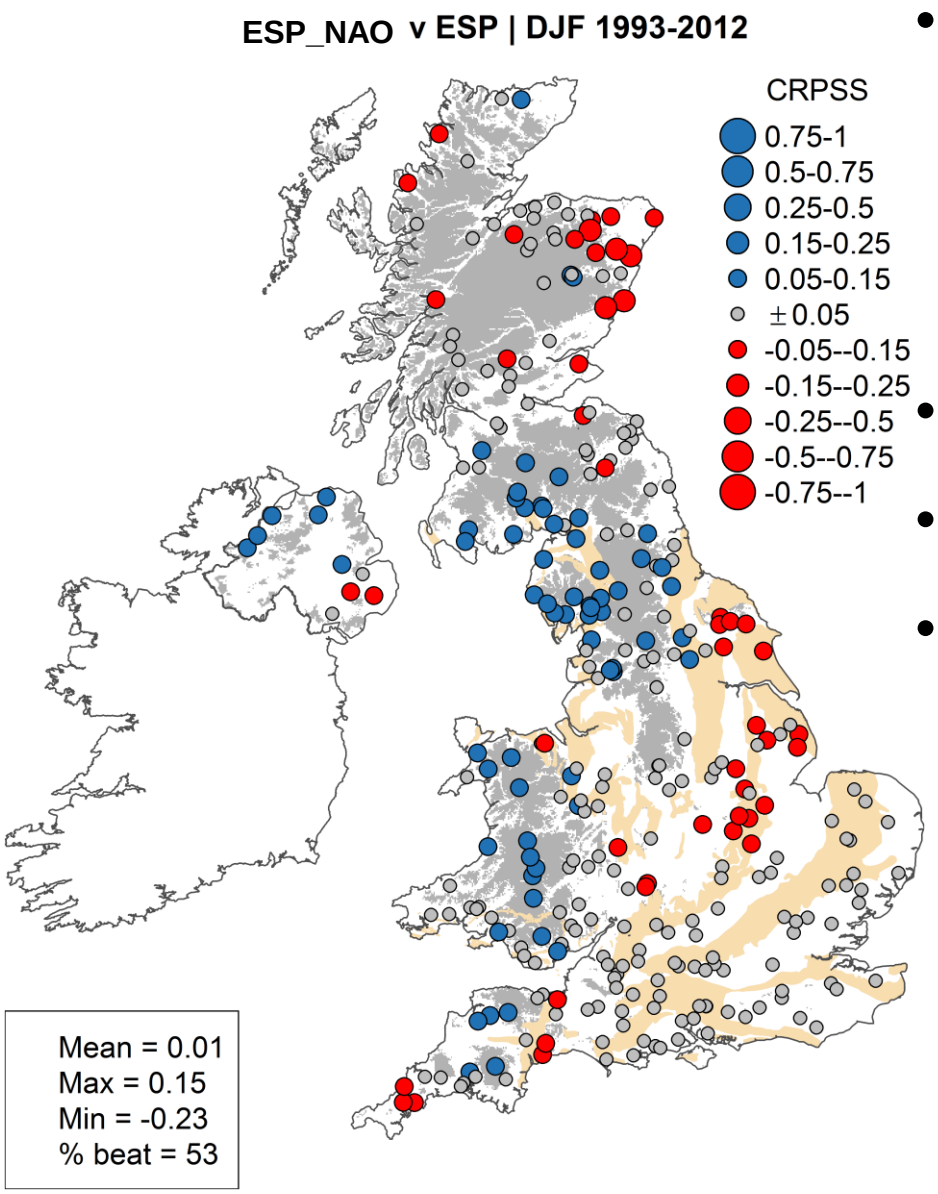


- **FC:** UoR_P (ens=24)
  - Hydro. Model (GR4J) forced with improved DJF rainfall forecasts (GloSea5 MSLP)
- **Obs** = *Proxy obs DJF flow
- **Benchmark:** ESP (ens=24)
- **Skill:** CRPSS

Naïve Skill: Benchmark = Climatology

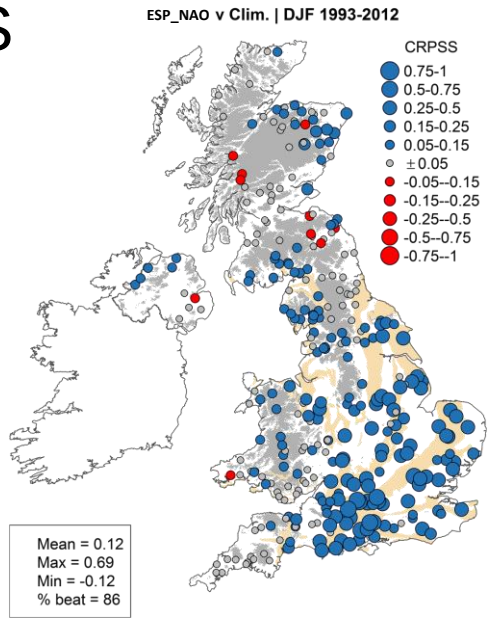


Results 2: ESP_NAO beat ESP?

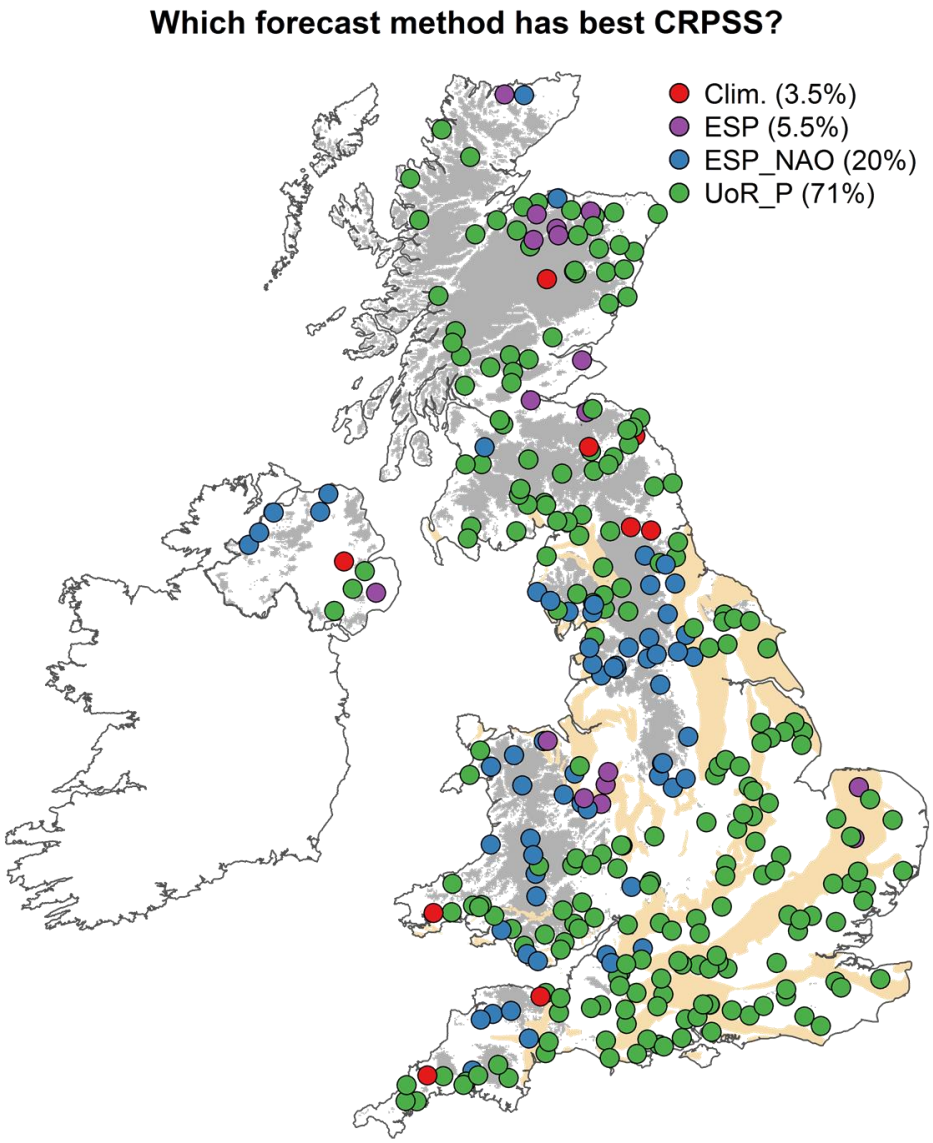


- **FC:** ESP_NAO (ens=24)
  - Hydro. Model (GR4J) forced with P & PET seq. from NAO± years, according to MO GloSea5
- **Obs** = *Proxy obs DJF flow
- **Benchmark:** ESP (ens=24)
- **Skill:** CRPSS

Naïve Skill: Benchmark = Climatology



Which of the tested methods is best?



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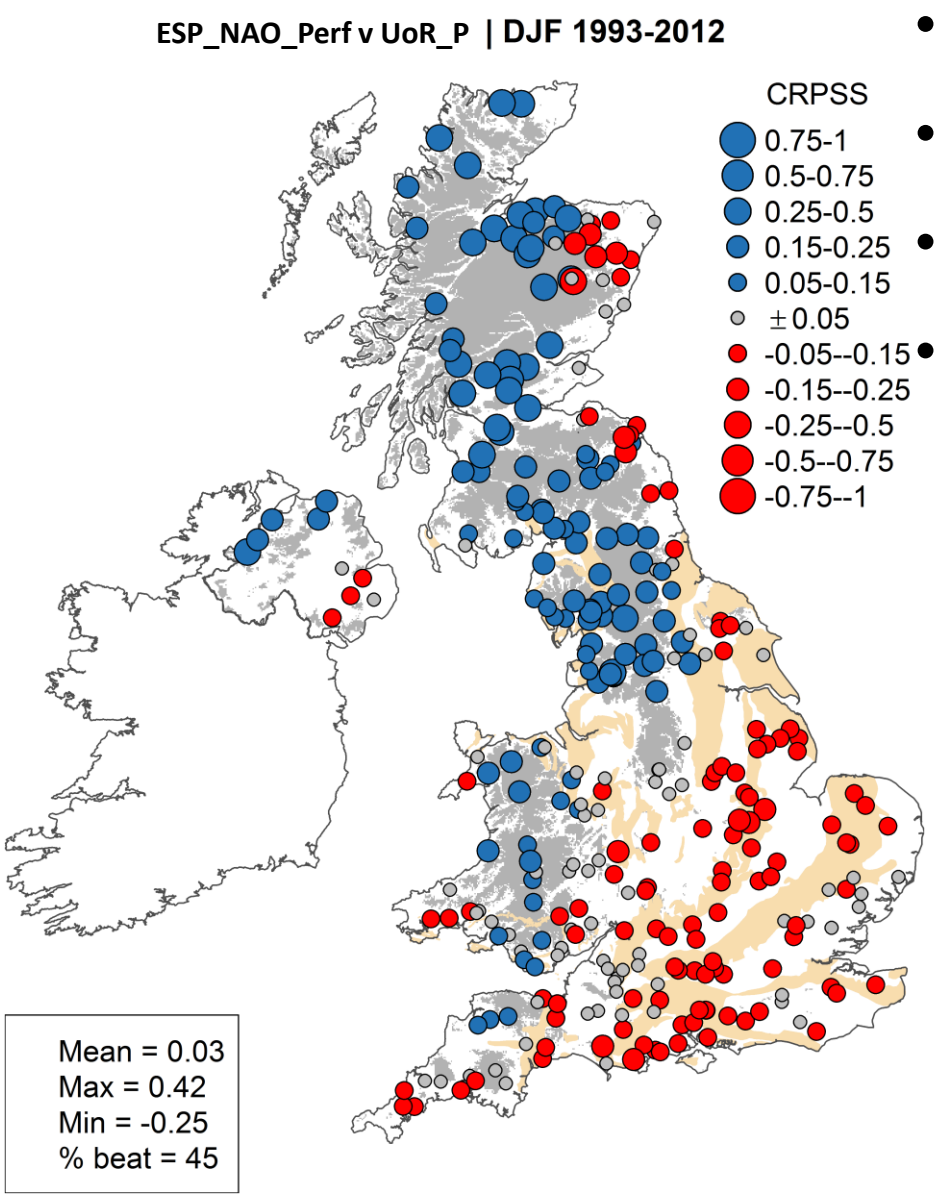
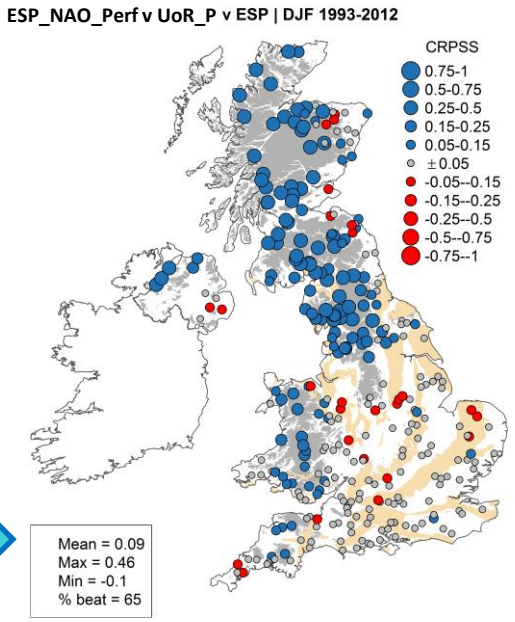
What if we could predict perfectly NAO±!?



- **FC:** ESP_NAO_Perf (ens=24)
- **Obs** = *Proxy obs DJF flow
- **Benchmark:** UoR_P (ens=24)
- **Skill:** CRPSS

With Benchmark = ESP



Summary

- **Traditional ESP** is skilful, but mainly in S and E (IHCs)
- **UoR_P** beats ESP for DJF in **87% of catchments**
- **ESP_NAO** according to GloSea5 beats ESP & UoR_P in **20% of catchments** across NW England, Wales, & Northern Ireland
- **Hydro. forecasting can benefit greatly from incremental improvements in seasonal climate prediction systems…**
  - e.g. downscaling from more predictable MSLP than raw P
  - e.g. better prediction of even NAO sign
  - e.g. skilful prediction of less studied modes… EA pattern
- **Next:** ENDOWS (About Drought Maximising the impact of UK research on drought & water scarcity) - Work closely with end-users/partners co-designing case studies

Thank You!

Questions / Feedback?

shaun.harrigan@ecmwf.int

Photo : iStockPhoto

Summary:

- **Traditional ESP is skilful, but mainly in S and E**
- **UoR_P bests ESP in 87% of catchments**
- **ESP_NAO according to GloSea5 beats ESP & UoR_P in some parts (20%) of N and W**
- **Hydro. forecasting can benefit greatly from incremental improvements in seasonal climate prediction systems**