Spatial and temporal patterns in seasonal forecast skill based on river flow persistence in Irish catchments

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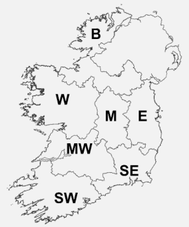
Introduction

The statistical persistence method of seasonal forecasting uses a river's most recently observed flow anomaly (calculated over a predictor period of a given duration) as its forecasted flow anomaly (for a given forecast horizon).



This study assesses the forecast skill of river flow persistence across a sample of 46 catchments representative of Ireland's diverse range of hydrogeological conditions. They are divided across 7 regions: the Border (B), West (W), Mid-West (MW), South-West (SW), Midlands (M), East (E) and South-East (SE).

Data and Methods

Station selection criteria:

- ✓ good, consistent hydrometric data quality;
- ✓ a long record length (25 years minimum);
- ✓ a 'near-natural' flow regime;
- ✓ part of the OPW Flood Studies Update (FSU; Mills et al., 2014) which assigned physical descriptors to each catchment

Evaluation of persistence skill

Assessing the persistence of standardised flow anomalies, rather than absolute flow values, takes the distinct seasonal cycle of river flows into account. Forecast performance is evaluated:

- by assessing the Pearson's correlation coefficient (*r*) between predicted and observed anomalies
- against a streamflow climatology benchmark using the Mean Square Error Skill Score (MSESS). Any positive MSESS value represents the existence of skill relative to the benchmark (1= perfectly skilful).

Multiple linear regression

Regression models were constructed to predict the persistence forecast skill found in each catchment using their physical descriptors as the explanatory variables. Multicollinearity was tested by assessing variance inflation factors and tolerance. The best-performing models were used to predict the likely persistence skill found in 215 catchments across the country.

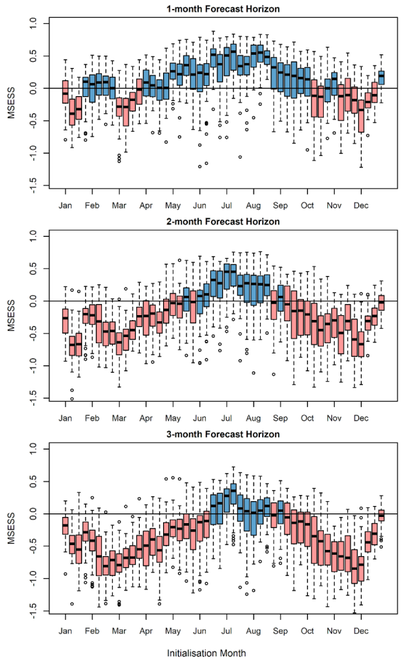


Figure 1. *Network-wide MSESS values at different forecast horizons, holding the predictor period as 1 week.*

Spatial Patterns in Skill

The degree of persistence skill is strongly conditional on the "memory" inherent to each catchment (i.e. their storage capacity), as indicated by significant positive correlations with descriptors like catchment area (Spearman's ρ = 0.40) and the Base Flow Index (BFI_{soil}; ρ = 0.86). The flow regimes of high BFI catchments are dominated by slowly-released groundwater and as such, the initial conditions persist for longer periods of time. A low BFI is indicative of a "flashier" response to precipitation.

Skill has significant negative correlations with standard annual average rainfall (SAAR; ρ = -0.64) and other descriptors linked to the wetness of a catchment, including the proportion of time soils can typically expect to be wet (FLATWET; ρ = -0.36).

Temporal Patterns in Skill

Predictor-forecast period combination

A majority (58%) of persistence forecasts produced across the station network outperform the climatology benchmark using a 1-week predictor period and 1-month horizon. Skill decays as the duration of the predictor period and/ or the forecast horizon increases. Longer forecast horizons give more time to a catchment to "forget" the anomalous river flow conditions of the predictor period, due to an increased chance of weather perturbing the status quo.

Forecast initialisation month

Persistence is most skilful in the drier summer months (JJA) and least skilful in the wetter months when high rainfall events are more likely to disrupt the persistence of flows.

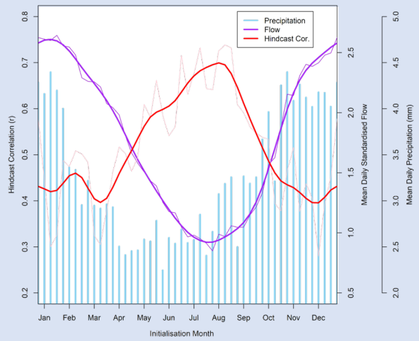


Figure 2. *Network-wide weekly mean daily precipitation (mm) and weekly mean standardised flow compared with mean persistence forecast performance (r).*

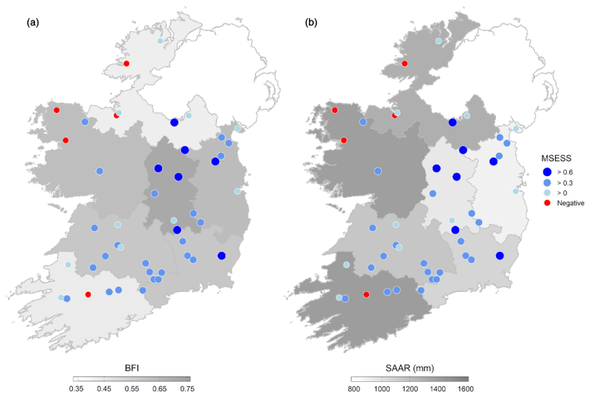


Figure 3. *Median (a) BFI values and (b) SAAR values for stations in each region, compared with the median summer persistence skill score (MSESS) of each individual station at the 1-month forecast horizon.*

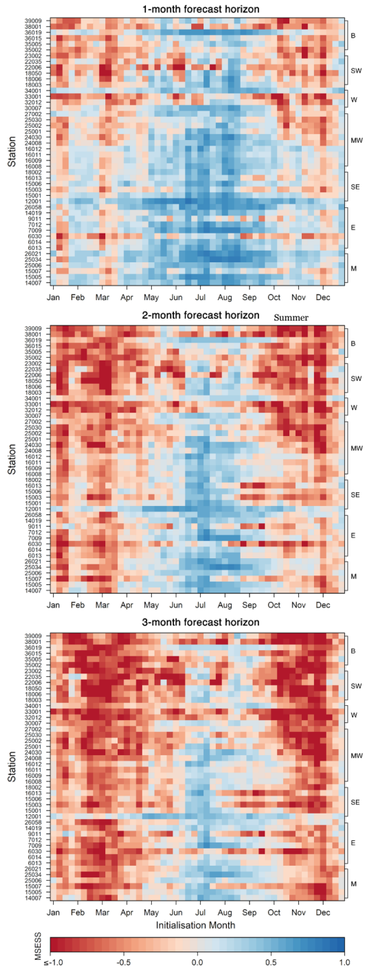


Figure 4. *Variation in forecast skill using the 1- to 3-month forecast horizons for each station, grouped into their respective regions.*

Skill Outside Catchment Sample

The best-performing multiple regression model (adjusted R^2 = 0.89) used BFI, SAAR and FLATWET as predictors of median persistence forecast skill at the 1-month forecast horizon

Median MSESS = 1.239*BFIsoil – 0.000184*SAAR -0.728*FLATWET

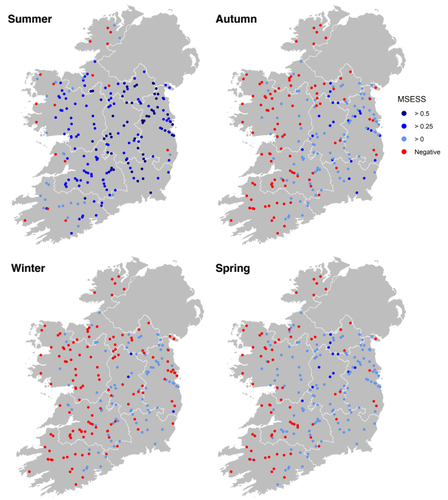


Figure 5. *Median predicted seasonal persistence skill scores for the 215 FSU catchments at the 1-month forecast horizon.*

Conclusion

Persistence forecast skill is greatest during the summer months and in lowland regions characterised by lower annual average rainfall totals, permeable lithologies and/ or well drained soils (such as the Midlands and South-East). Meanwhile, skill tends to be poor during the winter months and in the wetter, impermeable catchments of the South-West and Border regions.

By using such physical catchment characteristics and/or similar hydrological metrics (such as the flashiness index), it may be possible to anticipate the level of streamflow persistence skill for catchments beyond Ireland.

Reference:
Mills, P., Nicholson, O., and Reed, D., 2014. Physical catchment descriptors. Volume IV, Flood studies update technical research report. Dublin: Office of Public Works.