Seasonal forecasts of winter and summer precipitation for the Island of Ireland from dynamical-statistical methods

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Introduction

Seasonal hydrological forecasting (SHF) systems aim to leverage understanding of hydro-climatic processes and to accurately predict long-term riverflows/precipitation (up to 1 year in advance). SHFs help enhancing strategic water planning and better preparation for long-lived hazards, e.g. drought and/or persistent flooding. Consequently, recent decades have seen much research focused on developing monthly and seasonal forecasting systems at regional and global scales.

There is consensus that seasonal climate variability can be attributed to atmospheric teleconnections, with many studies showing the relationship between local climate conditions and large-scale climate patterns as a potential predictor for skillful seasonal precipitation and streamflow forecasting, e.g. North Atlantic Oscillation (NAO) has been used as a predictor over regions in the mid-high latitudes in the Northern Hemisphere, especially Western Europe, including the UK and Ireland.

This project seeks to advance our knowledge on seasonal forecasting of precipitation over Ireland by evaluating the extent to which statistical/dynamical methods can provide skilful forecasts of winter and summer precipitation at various lead times.

Datasets and Models

1). Dynamical forecast of mean sea level pressure (MSLP):
Monthly MSLP hindcasts from SEAS5 and GloSea5 were downloaded from the Climate Data Store (CDS) of the Copernicus Climate Change Service (https://cds.climate.copernicus.eu/#!/home) at 1° grid resolution. The spatial coverage is 90°W to 40°E and 20°N to 80°N. This area was used to develop the seasonal forecasting framework for precipitation in winter [DJF] and summer [JJA].

2). Observed Precipitation
Observed daily 0.1° grid-resolution precipitation for the period 1950-2019 was obtained from E-OBS precipitation

3). Statistical Models:
Multiple linear regression (MLR) and Artificial Neural network (ANN) models are used to predict precipitation over different regions and lead-times using predictors derived from MSLP forecasts of SEAS5 and GloSea5.

4). Precipitation forecast from dynamical models
We also extract the precipitation forecast from dynamical models, i.e. SEAS5 and GloSea5 and after applying a bias-correction method, their results are compared to those of statistical-dynamical methods.

Methodology

1). Extract precipitation regions using K-mean clustering method on E-OBS daily precipitation. The time series of precipitation over each region is used as predictand.

2). Deriving MSLP indices as potential predictors using MSLP hindcast from SEAS5 and GloSea5 based on:

- The standardised (i.e., centered about the mean and divided by the standard deviation over the time series) MSLP difference between the maximum and minimum points of correlation.
- The first three rotated empirical orthogonal function (EOFs).

3). Training and validating statistical models, i.e. regression and ANN using k-fold cross-validation method for all lead-times, i.e. 1- to 4-month lead-times and precipitation regions.

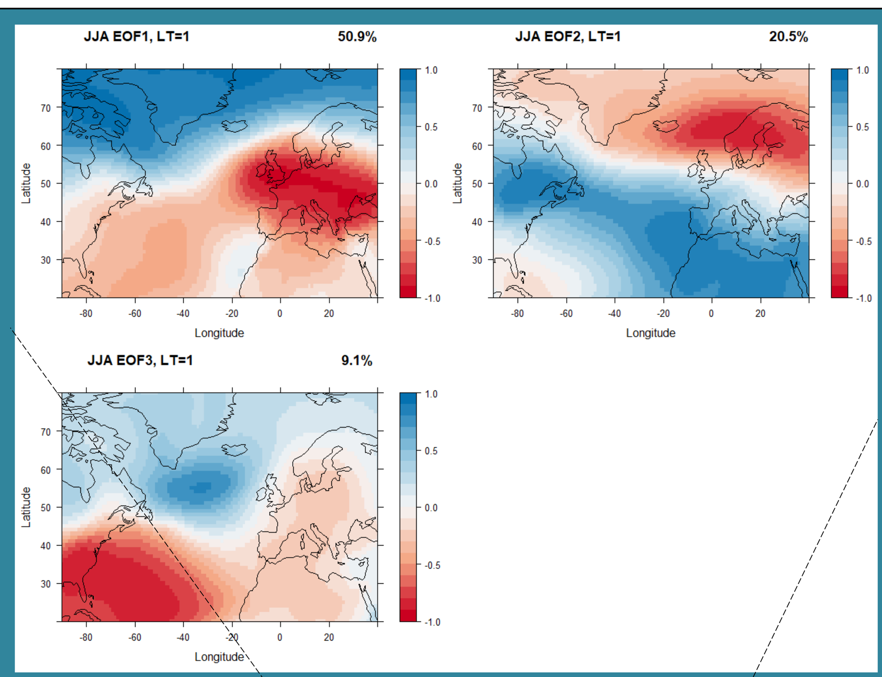


Figure 4. First three EOFs of summer MSLP from GloSea5 with LT=1 month

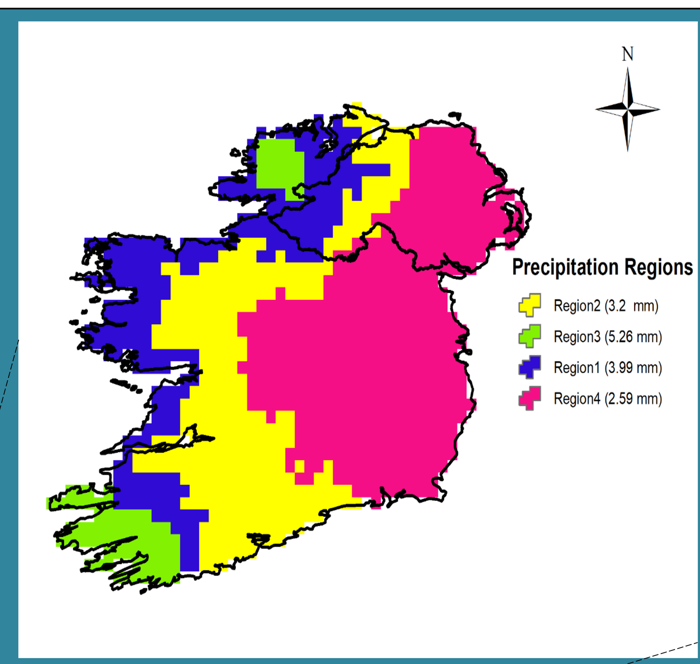


Figure 2. Derived precipitation regions over Island of Ireland

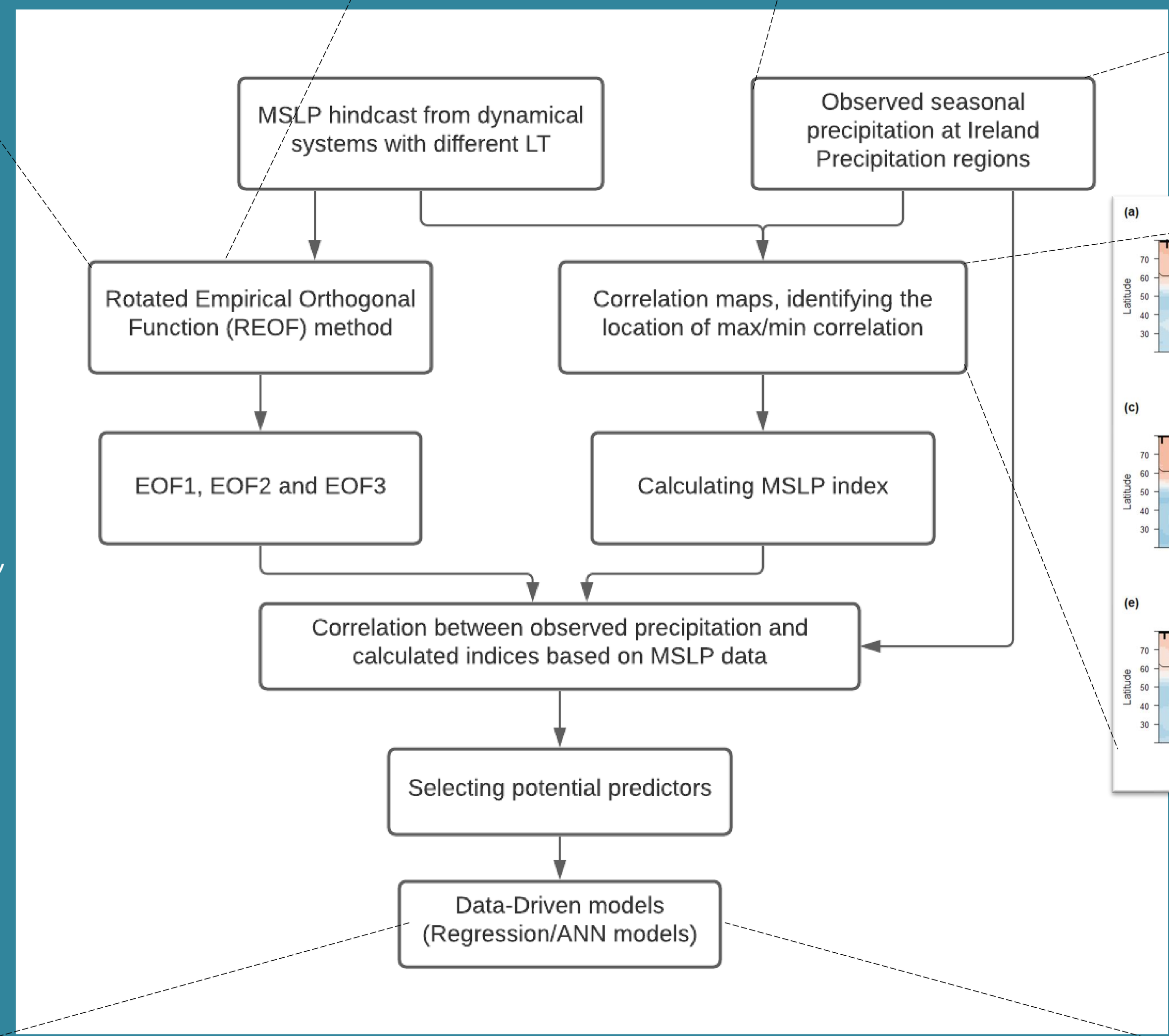


Figure 1. Proposed methodology

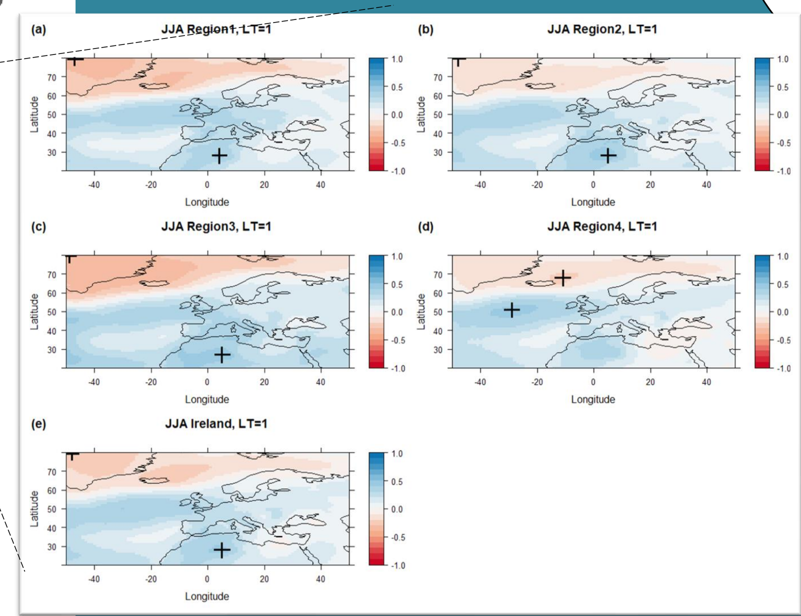


Figure 3. Correlation between summer MSLP with LT=1 month from GloSea5 and summer precipitation. The plus signs show the location of maximum and minimum correlation values

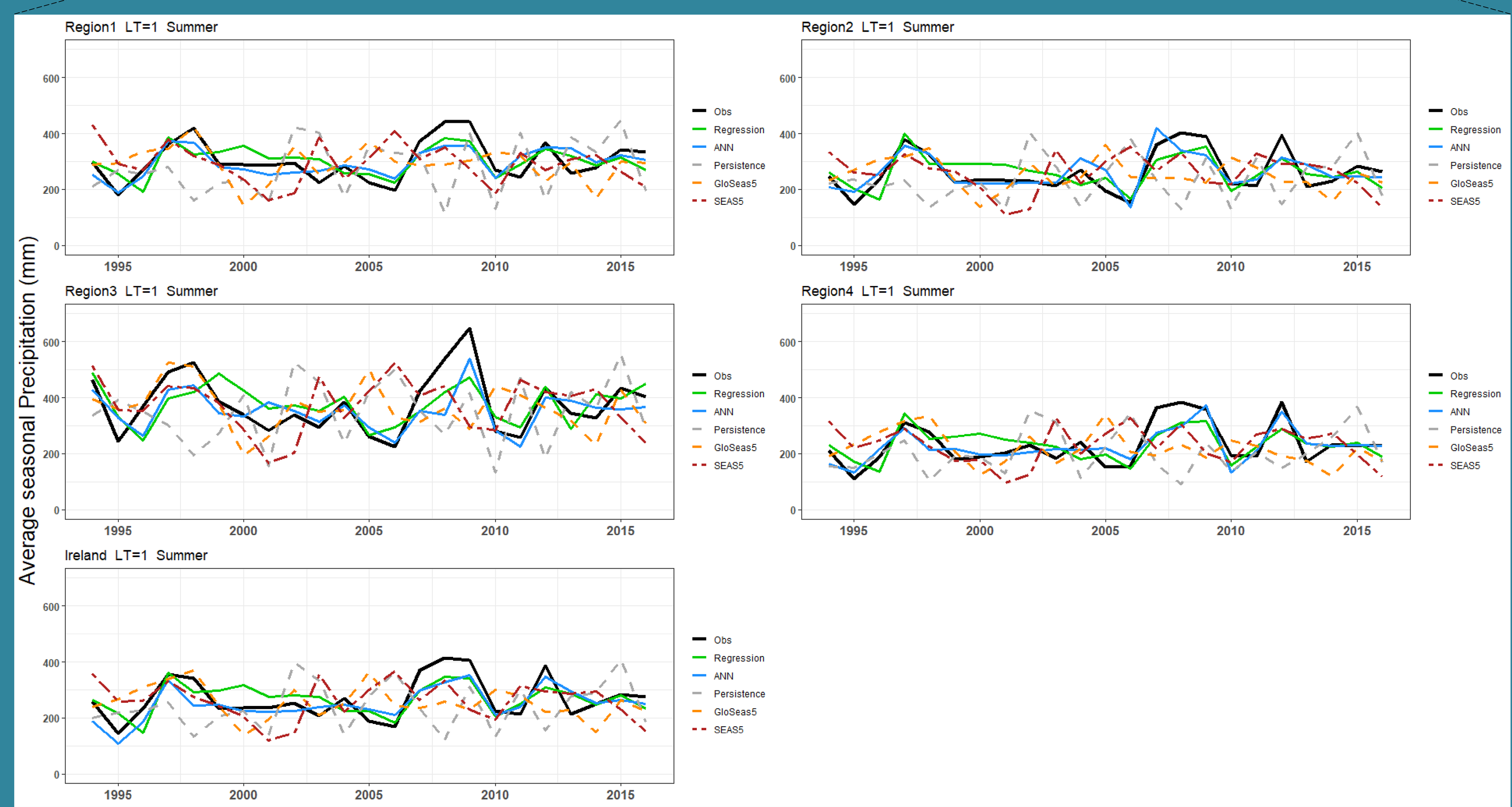


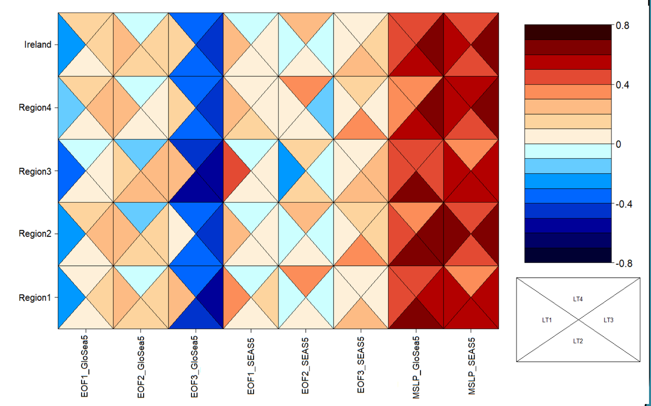
Figure 5- Time series of observed and forecasted precipitation over different regions with 1-month lead-time in summer. Each figure shows the precipitation over a different region, i.e. Region1, Region2, Region3, Region4 and the entire Ireland.

Results1- MSLP based indices

Figure 1 shows the schematic of the proposed methods in this research for seasonal forecasting of precipitation. Figure 2 shows the derived precipitation regions while figure 3 shows the correlation map between observed precipitation and MSLP hindcast with 1-month lead-time. Finally figure 4 shows the first EOF patterns based on MSLP hincast with 1-month lead-time in summer.

Main Observations:

1) Correlation values between derived MSLP indices and precipitation over different regions and lead-times show some strong positive/negative relationship between precipitation and climate indices.
2) Correlations between observed precipitation and EOF derived indices were more variable depending on lead-time and region.



Result2- Forecast Performance

Figure 5 shows the time series of observed and forecasted precipitation over different regions with 1-month lead-time. Based on the correlation coefficient, again ANN and regression have the most skillful results for all lead-times, regions, and seasons with an average correlation value of 0.70 and 0.77 for ANN and 0.57 and 0.71 for regression in winter and summer, respectively.

Main Observations:
1) ANN and regression model outperform other forecasts in both winter and summer.
2) It can be seen that both ANN and regression models show poorer performance in winter relative to summer, while the ANN models perform much better in winter compared to regression, especially for 3 and 4-month lead-times.

Conclusions

Of the potential predictors used in this study, those based on standardized MSLP showed strong correlations ranging from 0.35 to 0.63 with winter and summer precipitation across all lead times and regions. This highlights that indices based on MSLP provide a reliable basis for forecasting precipitation over the Island of Ireland.

Consistent with Baker et al. (2018b), we find that a statistical-dynamical approach improves forecast skill over bias-corrected dynamical forecast system output. Both our ANN and regression approaches provide greatest skill for all lead times and regions in both summer and winter and outperform precipitation output from dynamical models and the persistence-based method.

The encouraging performance of these models, particularly the ANN in summer, is noteworthy.

References

Baker, L.H., Shaffrey, L.C. and Scaife, A.A., 2018. Improved seasonal prediction of UK regional precipitation using atmospheric circulation. International Journal of Climatology, 38, pp.e437-e453.

Emerton, R., Zsoter, E., Arnal, L., Cloke, H.L., Muraro, D., Prudhomme, C., Stephens, E.M., Salamon, P. and Pappenberger, F., 2018. Developing a global operational seasonal hydro-meteorological forecasting system: GloFAS-Seasonal v1. 0. Geoscientific Model Development, 11(8), pp.3327-3346

Mariotti, A., Ruti, P.M. and Rixen, M., 2018. Progress in subseasonal to seasonal prediction through a joint weather and climate community effort. npj Climate and Atmospheric Science, 1(1), pp.1-4.