Weather regimes as a tool to validate seasonal forecasts

Cortesi N. (1), Lee D.Y. (1), Torralba V. (1), González-Reviriego N. (1), Soret A. (1), Lledó L. (1), Bretonnière P.A. (1) and Doblas-Reyes F. J. (1)(2)

(1) Earth Sciences Department, Barcelona Supercomputing Center (BSC), Spain
(2) Institució Catalana de Recerca i Estudis Avançats (ICREA), Spain

1. Background and goals

The skill of a forecast system is affected by the atmospheric flows, since some of them are more stable and predictable than others (Ferranti et al., 2015). Detecting which flows are predictable and which are unpredictable allows to increase the forecast skill without having to modify the forecast system itself (Neal et al., 2016).

Here, we aim to verify the skill of the seasonal forecast system of the **ECMWF System-4** (S4) in simulating the observed North Atlantic-European weather regime anomalies and their interannual frequencies and persistences. SLP data was preferred to geopotential height, even if it is noisier, because it doesn't show any temporal trend (Hafez and Almazroui, 2014).

2. Data and methodology

S4 forecasts of daily mean sea level pressure (SLP) have a spatial resolution of ~80 km and 15 ensemble members during the hindcast period 1981-2015 (Molteni et al., 2011). SLP data was extracted for the North Atlantic-European region (27°N–81°N, 85.5°W–45°E) and daily means were computed as average of 6-hourly data, separately for the **ERA-Interim reanalysis** (Dee et al., 2011) and the hindcasts, referred to the daily climatology filtered by a LOESS polynomial regression to remove the short-term variability (Mahlstein et al. 2015).

To classify the North Atlantic-European regimes, a k-means cluster analysis with *N*=4 clusters (NAO+, NAO-, blocking and Atlantic ridge) was applied to the data of each month separately.

3.1. Results: spatial correlation

Figure 1 illustrates the simulated and observed **regime anomalies** for the four regimes and for different startdates and forecast times. Blocking patterns are the most difficult to reproduce in December, but generally there is a high spatial coherence for all seven previous startdates.

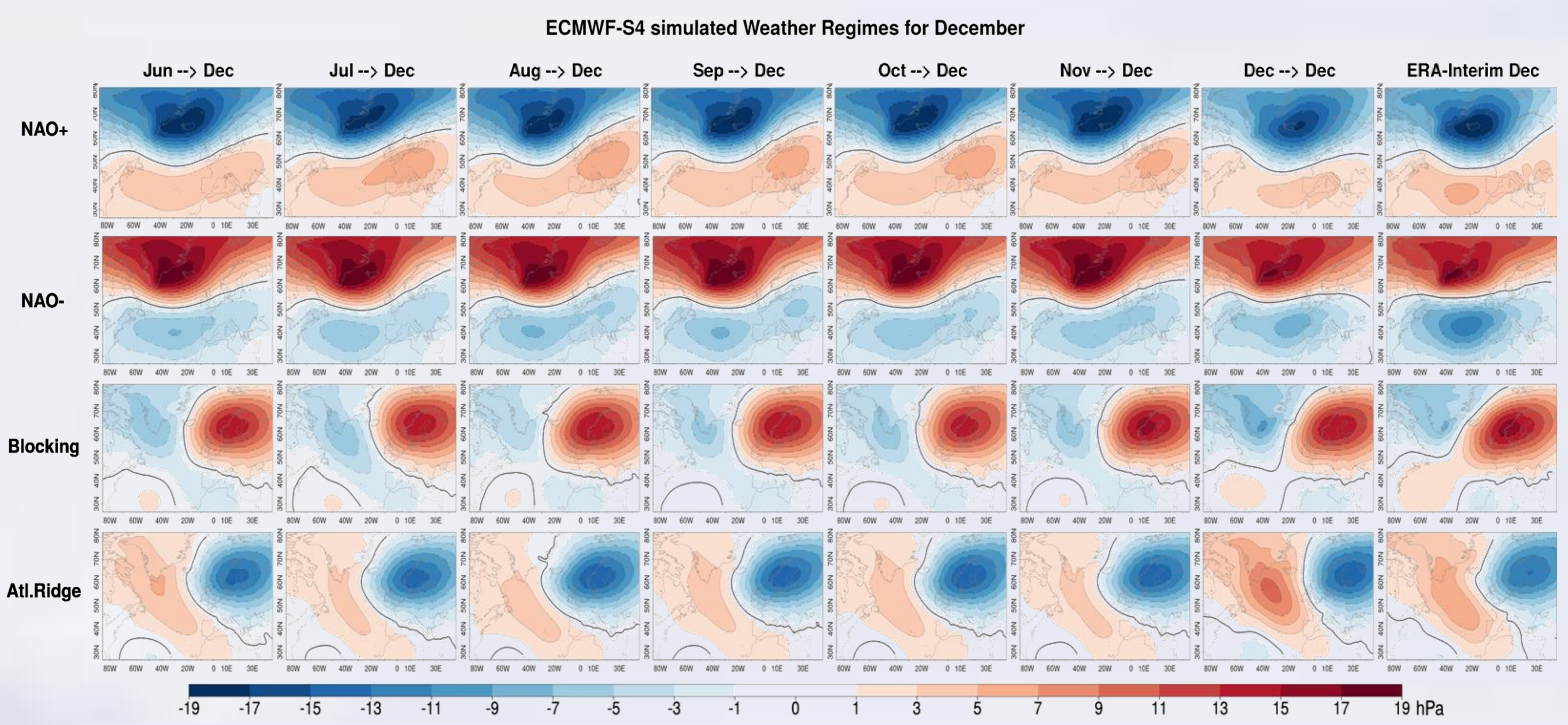

Figure 1. S4 simulated regime anomalies (in hPa) for the target month of December (1986-2015) and different startdates and forecast times (from 6 to 0 months) vs ERA-Interim observed regime anomalies (last column). Black lines show null anomalies.

To summarize all the possible combinations of startdates and forecast times (beyond the December example above), Pearson spatial correlations between simulated and observed regime anomalies are presented in Figure 2. Each triangle represents a spatial correlation, depending on its position and orientation (see square in the legend to the right).

The majority of the correlations are above 0.7; lowest values are measured when the startdate is a month from June to September, particularly forblocking and Atlantic ridge regimes; such low values are caused by clustering structures that are unrepresentative of the blocking/Atlantic ridge regimes (not shown), which were classified not using S4 data, but ERA-Interim data, which has 15 times less data than S4. Hence, sampling daily mean SLP over monthly periods with no reduction of dimensionality isn't always sufficient to adequately represent the clustering space.

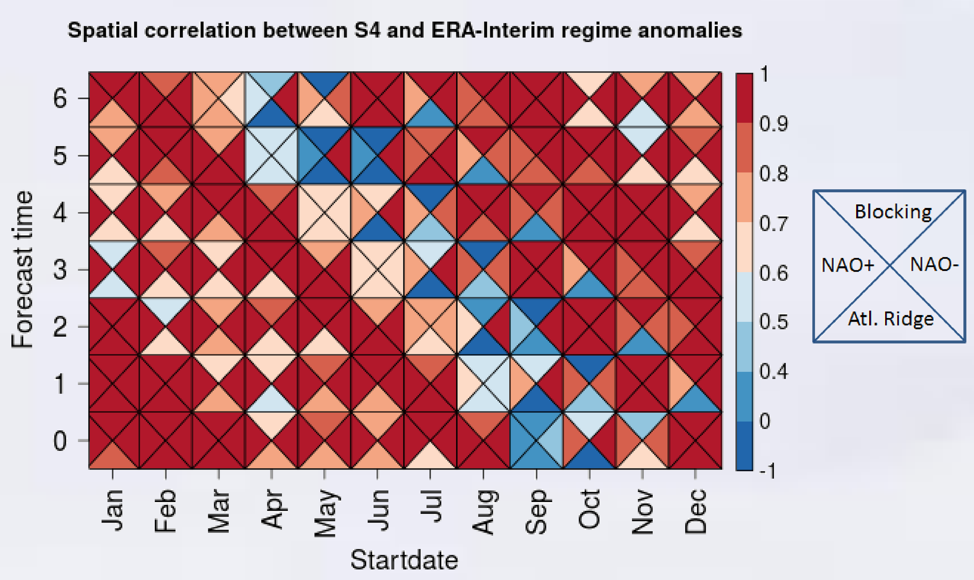

Figure 2. Spatial correlations between simulated and observed regime anomalies.

3.2. Results: temporal correlation

Figure 3 shows the simulated and observed **interannual frequencies of occurrence** of the four regimes for the seven forecast times (similarly to Figure 1). Red and blue bars indicate the monthly frequency (in case of S4, of the 15-members ensemble mean) compared to the average monthly frequency for the whole 1981-2015.

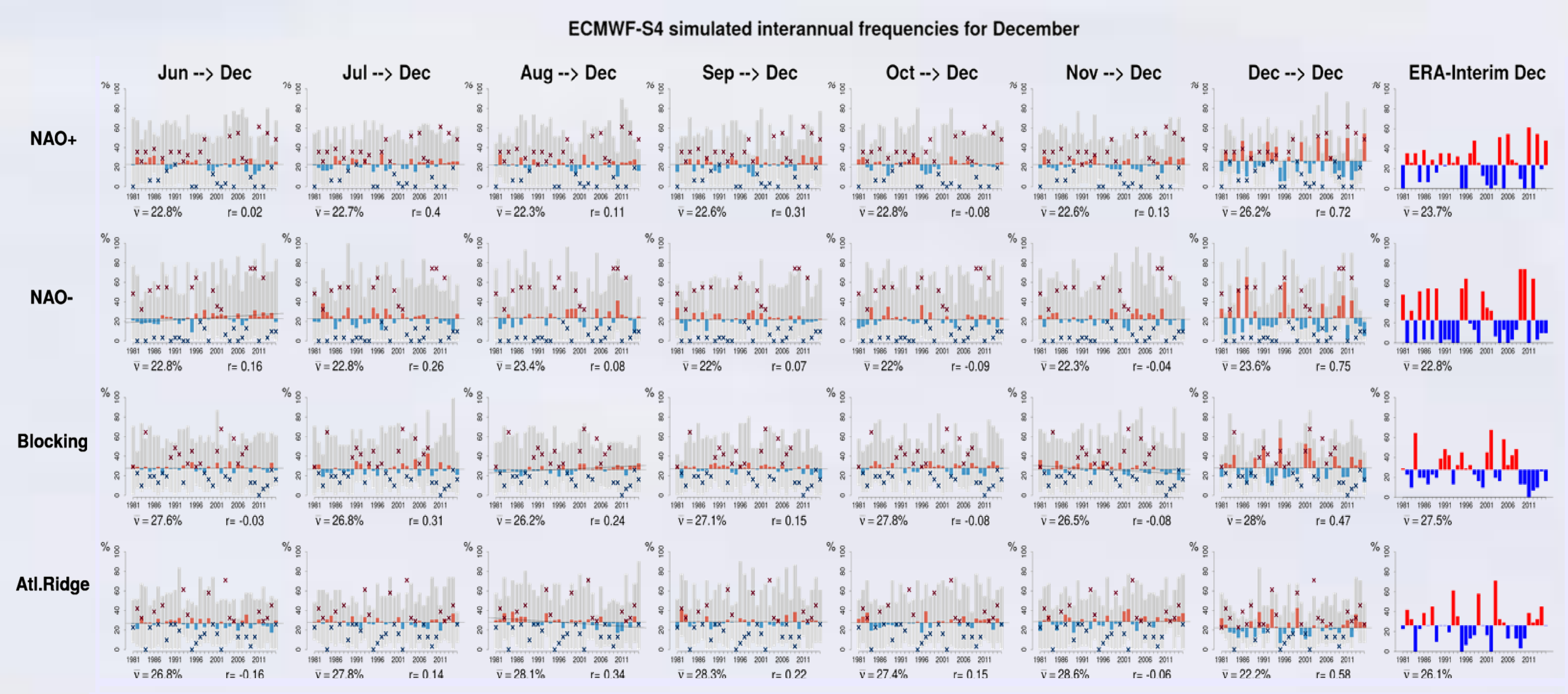

Figure 3. S4 simulated time series (1986-2015) of the interannual regime frequencies (in %) for the target month of December and different forecast times (from 6 to 0 months) vs ERA-Interim observed freq. series (last column). Red and blue bars indicate the monthly frequency (in case of S4, of the 15-members ensemble mean) compared to the average climatological frequency (1981-2015). Gray bars represent the max and min monthly freq. of the 15 members, while red and blue crosses show the obs. freq. (the same shown by the red/blue bars in the last column). Bottom numbers show the climatological freq. (in %) and the correlation with the observed frequency.

The **simulated average monthly frequency is always close to the observed one**; however, the simulated interannual variability of the ensemble mean is much lower than the observed one; furthermore, temporal Pearson **correlations are above 0.5 only at forecast time 0**, and quickly drop below 0.5 at higher forecast times.

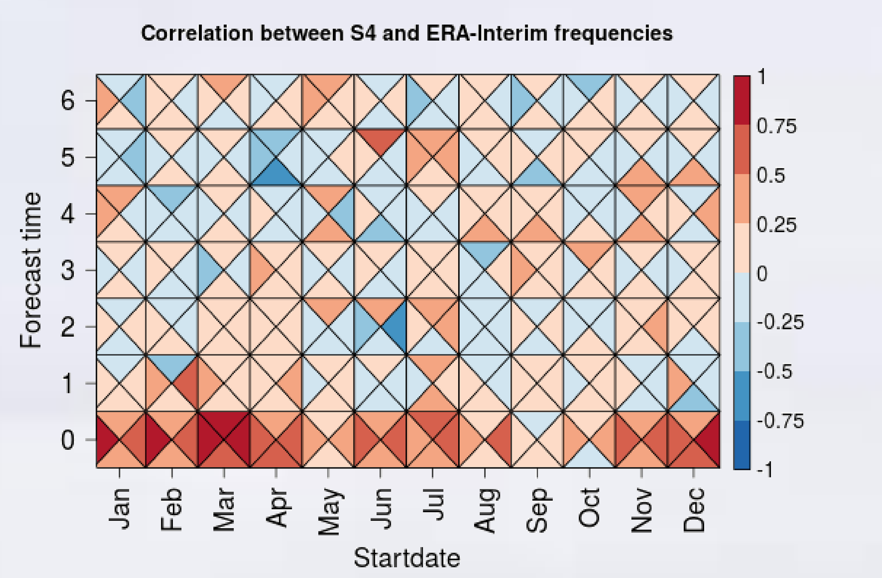

Figure 4. Temporal correlations between simulated and observed interannual frequencies.

The temporal correlation between simulated and observed frequency time series for all regimes, startdates and forecast times is visualized in Figure 4.

Results are similar to those for December: even the other startdates show correlations above 0.5 almost exclusively when the forecast time is zero, and decrease to zero thereafter, making it impossible to predict the monthly frequency of occurrence of any regime beyond the first month.

3.3. Results: frequency bias

The difference between the simulated and observed climatological frequency (in %) of each regime is shown in Figure 5.

Forecasts often **overestimate** observations (red triangles) for blocking and Atlantic ridge regimes, and **underestimate** observations (blue triangles) for NAO+ and NAO- regimes. This is consistent with Ferranti et al. (2015), who also found a similar behavior for the medium-range forecast model of the ECMWF.

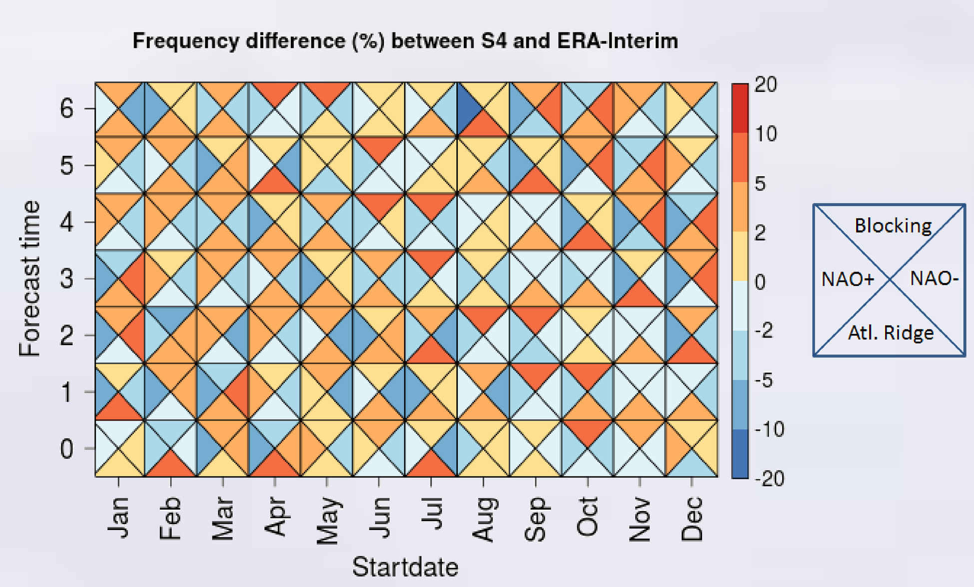

Figure 5. Difference between simulated and observed regime's frequency of occurrence (in %).

3.4. Results: persistency bias

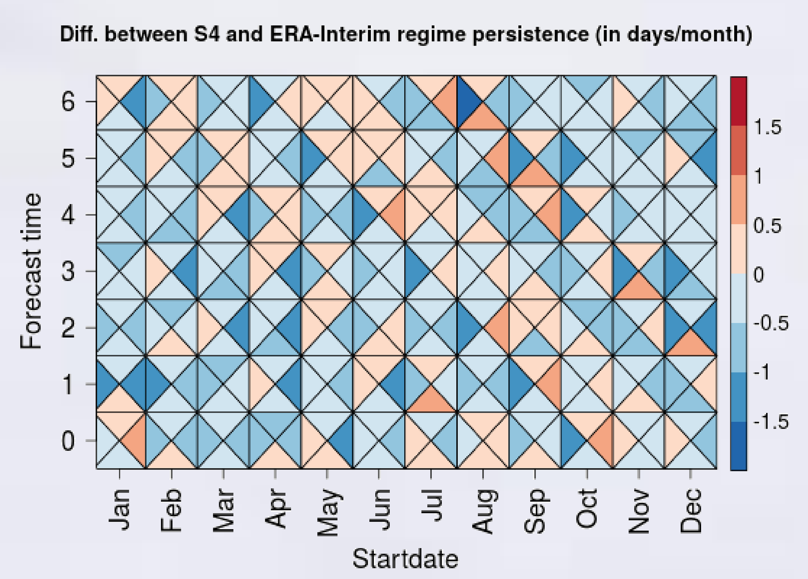

Figure 6. Difference between simulated and observed regime's persistency (in days/month).

Persistence is the measure of the mean number of days before a regime is replaced by a new one; it is typically equal to 3-5 days for North Atlantic-European regimes. The difference between simulated and observed persistence (in days/month) is plotted in Figure 6.

Forecasts tend to **underestimate** persistence (blue triangles) for the two NAO regimes, similarly to the frequency bias (see Figure 5), while blocking and Atlantic ridge regimes don't show any strong bias or any systematic error.

4. Conclusions

- High spatial correlations (>0.7) between simulated and observed regime anomalies are found for almost all startdates, forecast times and regimes, indicating that S4 is able to reproduce the observed regime anomalies quite well.
- S4 skillfully reproduces the average monthly values of the observed interannual frequencies of occurrence of each regime, even for high forecast times (six months in advance); however, it fails at reproducing both the interannual frequency variability and the interannual monthly freq. correlations at forecast times greater than zero. Such low skill might be attributed to the intrinsic unpredictability of the regimes, and not to a model fault.
- S4 forecasts tend to underestimate the monthly frequency of occurrence and persistence of the NAO+ and NAO- regimes, and to overestimate the monthly frequency of blocking and Atlantic ridge regimes.

5. References

Dee, D.P. et al., 2011. The ERA-Interim reanalysis: Configuration and performance of the data assimilation system. *Quarterly Journal of the Royal Meteorological Society*, 137(656), pp.553–597.

Ferranti, L., Corti, S. & Janousek, M., 2015. Flow-dependent verification of the ECMWF ensemble over the Euro-Atlantic sector. *Quarterly Journal of the Royal Meteorological Society*, 141(688), pp.916–924.

Hafez, Y.Y. & Almazroui, M., 2014. Recent Study of Anomaly of Global Annual Geopotential Height and Global Warming. *Atmospheric and Climate Sciences*, 4, 347-357(July), pp.347–357.

Mahlstein, I. et al., 2015. Estimating daily climatologies for climate indices derived from climate model data and observations. *Journal of Geophysical Research Atmospheres*, pp.2808–2818.

Molteni, F. et al., 2011. The new ECMWF seasonal forecast system (System 4), *European Centre for Medium-Range Weather Forecasts.*

Neal, R. et al., 2016. A flexible approach to defining weather regimes and their application in weather forecasting over Europe. *Meteorological Applications*, 1, pp.1–12.

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

SEVENTH FRAMEWORK PROGRAMME

The research leading to these results has received funding by the Seventh Framework Programme (FP7) of the European Commission (GA30837, GA308291), the Ministerio de Economía y Competitividad (MINECO) under the project CGL2013-41055R and the project PCIN-2014-012-C07-07.

This poster can be downloaded at https://earth.bsc.es/wiki/doku.php?id=library:external:posters

Corresponding author: nicola.cortesi@bsc.es

EXCELENCIA SEVERO OCHOA

MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD