Predictable weather regimes at the S2S time scale

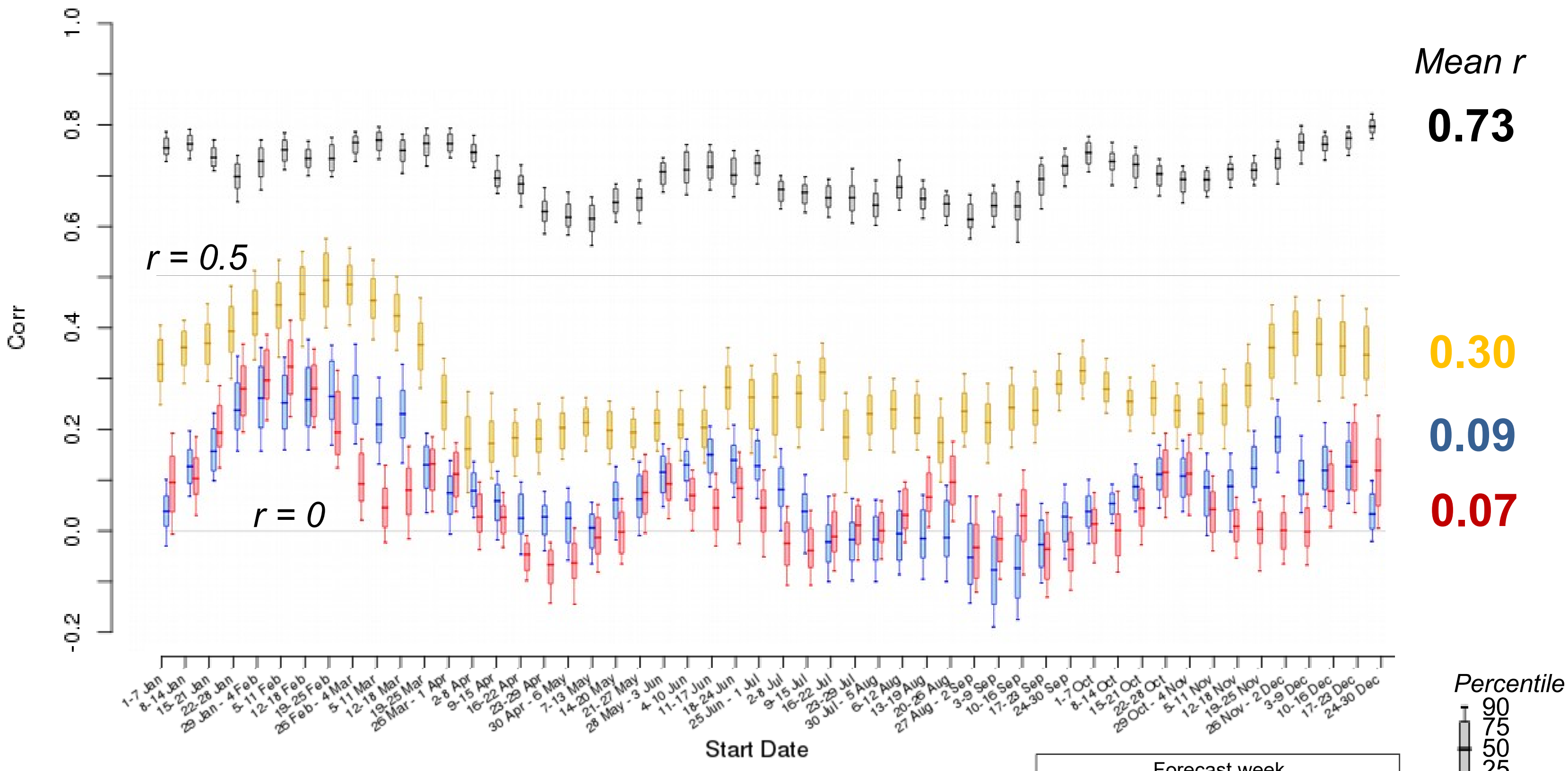
Nicola Cortesi, Veronica Torralba, Llorenç Lledó, Andrea Manrique-Suñen, Nube Gonzaléz-Reviriego, Albert Soret and Francisco J. Doblas-Reyes

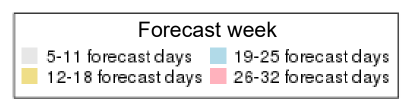
May 2020

Earth System Services (BSC-ES)

This project has received funding from the Horizon 2020 programme under grant agreement n°776787.
The content of this presentation reflects only the author's view. The European Commission is not responsible for any use that may be made of the information it contains.

Pearson correlations between observed and forecasted weekly frequencies of occurrence of the Euro-Atlantic regimes (1998-2017)





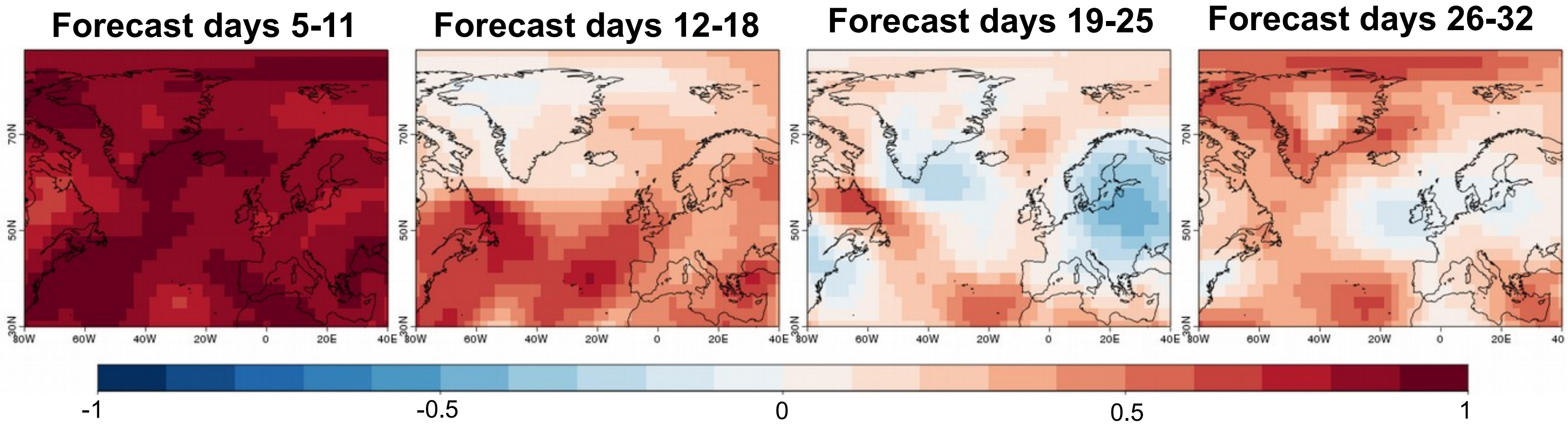
S2S forecast systems are still **unable** to skillfully predict the observed frequencies of occurrence of weather regimes beyond the first forecast week

Source: hindcasts of ECMWF-Ext-ENS (11 members) and ERA-Interim reanalysis
K-means clustering applied to daily SLP 1998-2017 with 4 regimes for Oct-Mar and 4 for Apr-Sep
Correlations in leave-one-out cross-validation and bootstrapped with N=1000

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Anomaly Correlation Coefficient (ACC) of sub-seasonal forecasts of SLP

Start date: Monday 1st of January 1998-2017

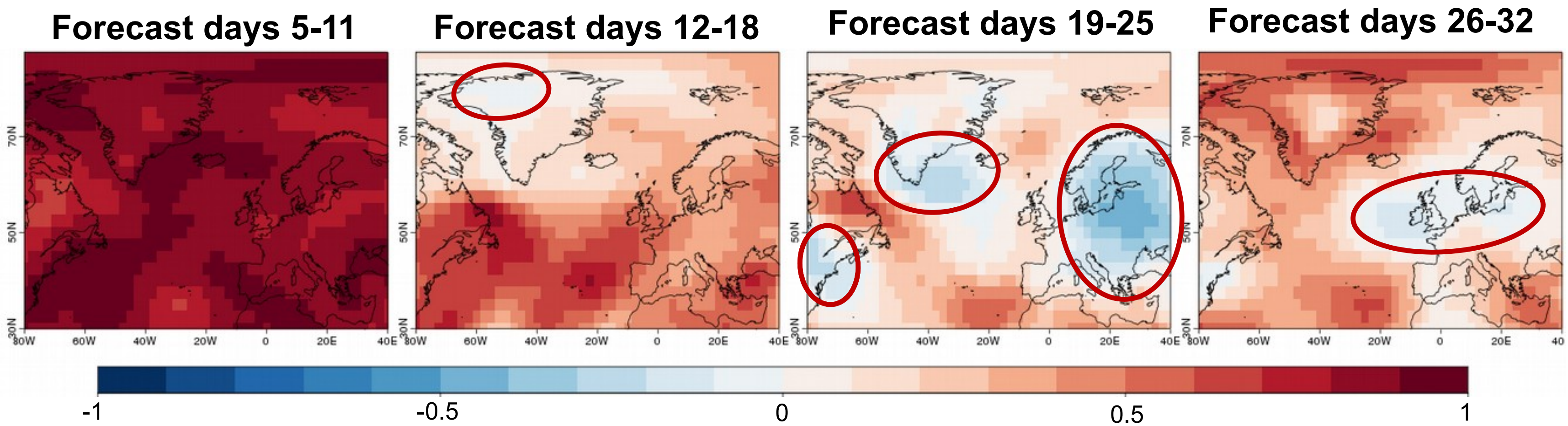


Source: hindcasts of ECMWF-Ext-ENS (11 members) and NCEP reanalysis
K-means clustering applied to daily SLP 1998-2017 with 4 regimes for Oct-Mar and 4 for Apr-Sep

Each S2S forecast system **better simulates certain atmospheric flows** than others. To improve their forecast skill in simulating weather regimes, you can extract the regimes better simulated by the system and employ them for predicting the impact on surface variables. This is the opposite of the common approach of firstly look for the regimes with the highest impact and then measuring their predictability, hoping it is high.

Anomaly Correlation Coefficient (ACC) of sub-seasonal forecasts of SLP

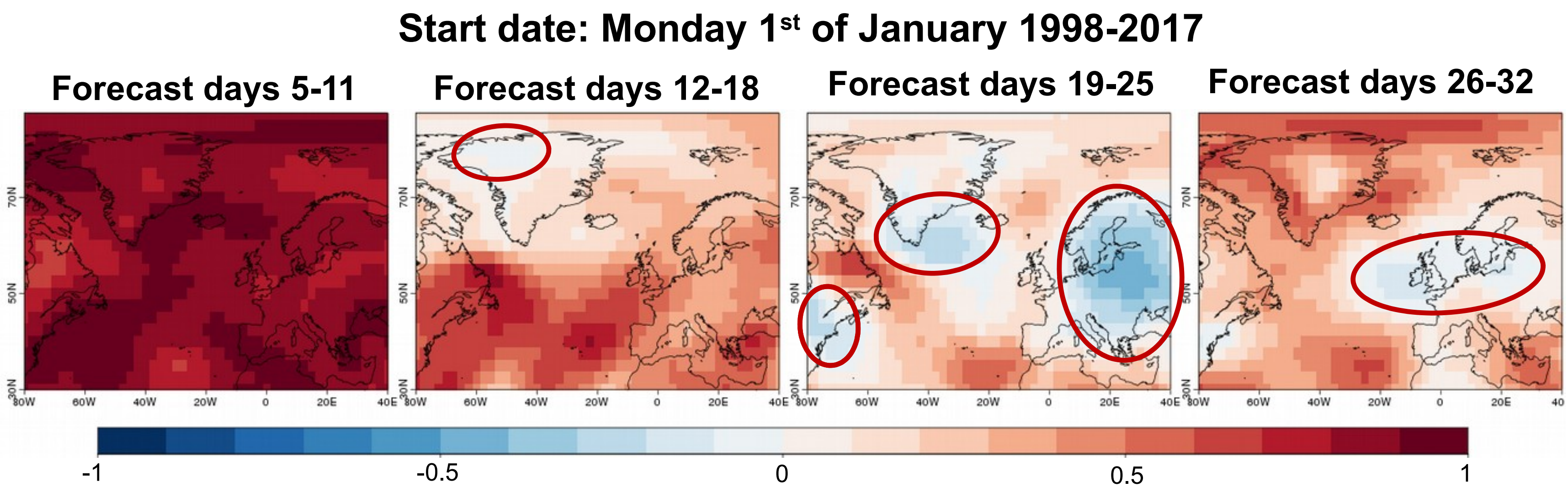
Start date: Monday 1st of January 1998-2017



Source: hindcasts of ECMWF-Ext-ENS (11 members) and NCEP reanalysis
K-means clustering applied to daily SLP 1998-2017 with 4 regimes for Oct-Mar and 4 for Apr-Sep

It is possible to **mathematically prove** that to extract the most predictable weather regimes from any forecast system, you just need to weight (multiply) daily circulation anomalies point-by-point by their **Anomaly Correlation Coefficient** (ACC) before classifying the regimes. Also, for the extraction to work, areas with negative ACC values (red circles) have to be **weighted by zero** instead of the ACC. In this way, cluster centroids are moved away from the areas where the forecast systems are bad in simulating atmospheric circulation (SLP in this case).

Anomaly Correlation Coefficient (ACC) of sub-seasonal forecasts of SLP

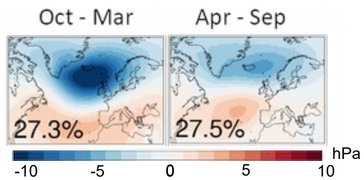


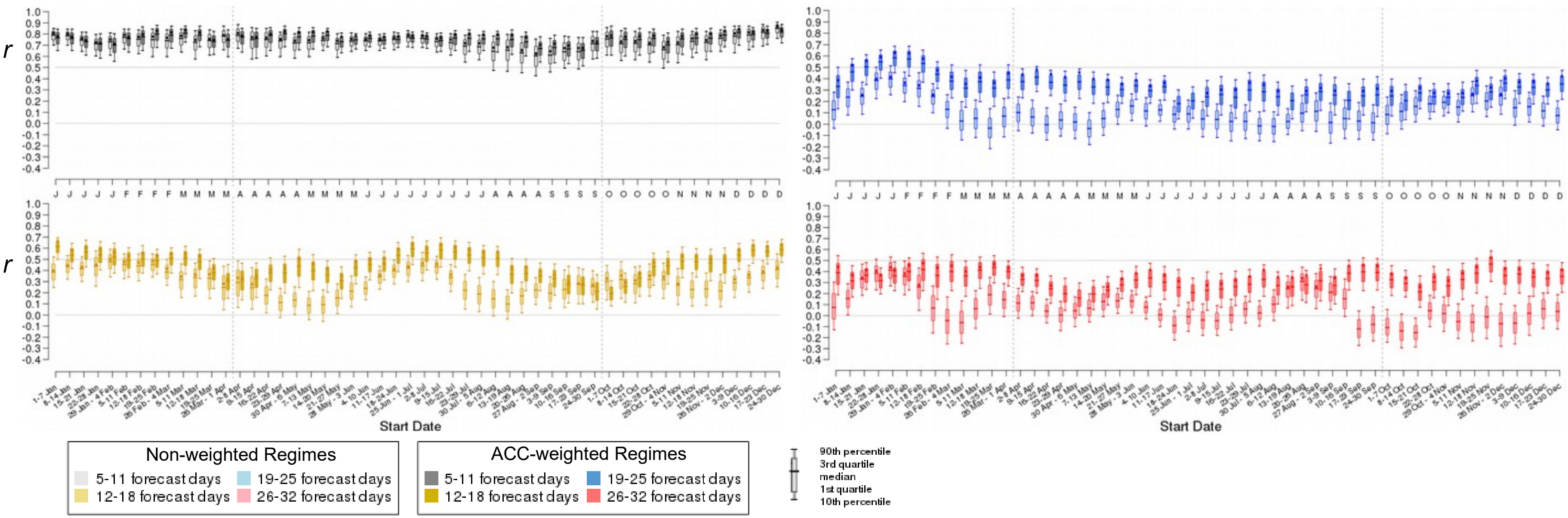
Source: hindcasts of ECMWF-Ext-ENS (11 members) and NCEP reanalysis
K-means clustering applied to daily SLP 1998-2017 with 4 regimes for Oct-Mar and 4 for Apr-Sep

As a consecuence, the difference between the spatial patterns of the observed regimes are the highest possible exactly in the regions where the forecast systems better simulate the observed SLP anomalies. Thus, it is easier for the forecast systems to predict the right regime.

Pearson correlations between observed and forecasted weekly frequencies of occurrence of the Euro-Atlantic regimes (1998-2017)

Regime #1



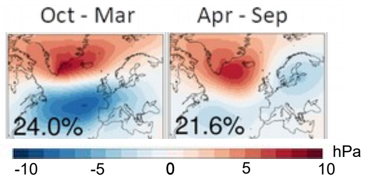


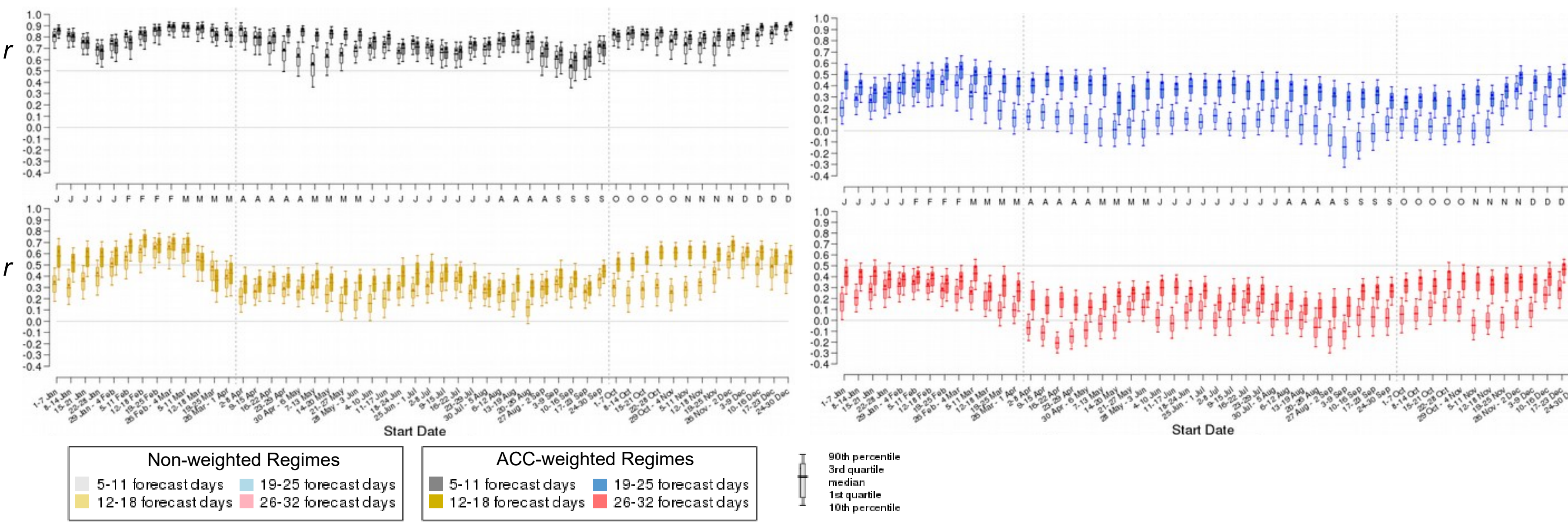
Beyond the first forecast week (5-11 days, gray bars), ACC-weighted regimes have much higher correlations (darker bars) than those of the non-weighted regimes (lighter bars), for the same start date and forecast week.

Source: hindcasts of ECMWF-Ext-ENS (11 members) and ERA-Interim reanalysis
K-means clustering applied to daily SLP 1998-2017 with 4 regimes for Oct-Mar and 4 for Apr-Sep
Correlations cross-validated and bootstrapped with N=1000

Pearson correlations between observed and forecasted weekly frequencies of occurrence of the Euro-Atlantic regimes (1998-2017)

Regime #2



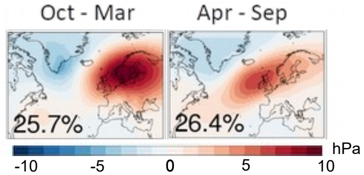


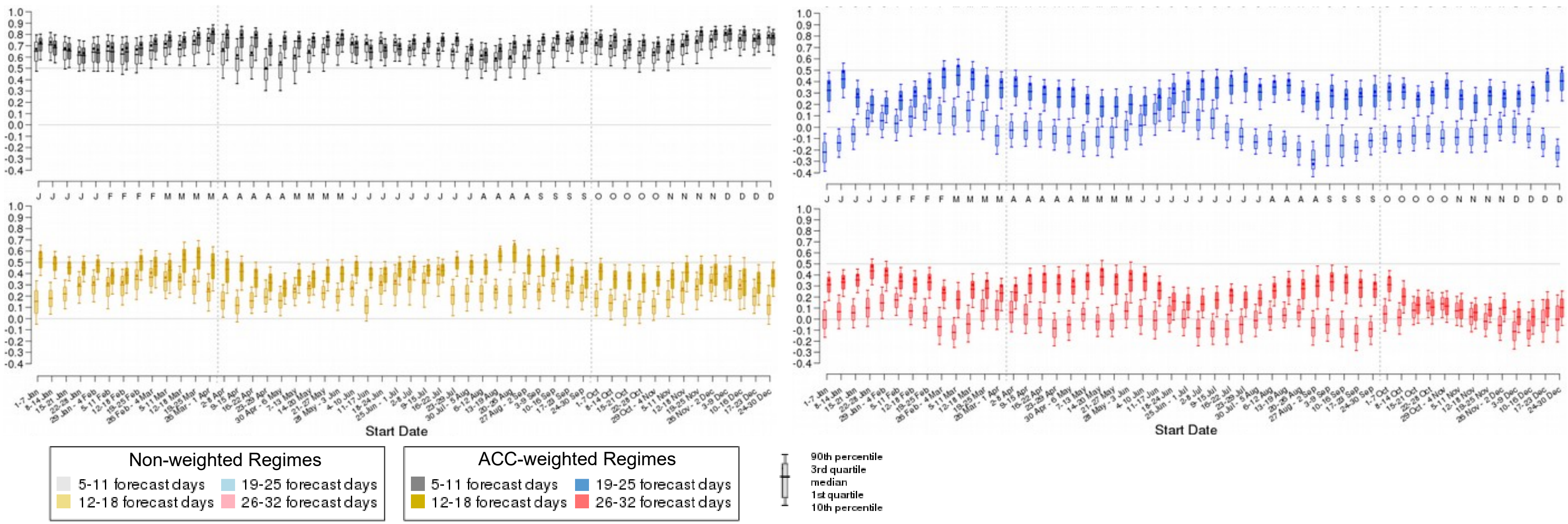
Beyond the first forecast week, forecast skill can still reach values of *r* = 0.5 or higher, particularly in winter start dates of WR 1 and 2, whose spatial patterns resemble those of NAO+ and NAO- winter (DJF) regimes. ACC-weighted regimes can reach correlations values close to *r* = 0.5 also in summer start dates.

Source: hindcasts of ECMWF-Ext-ENS (11 members) and ERA-Interim reanalysis
K-means clustering applied to daily SLP 1998-2017 with 4 regimes for Oct-Mar and 4 for Apr-Sep
Correlations cross-validated and bootstrapped with N=1000

Pearson correlations between observed and forecasted weekly frequencies of occurrence of the Euro-Atlantic regimes (1998-2017)

Regime #3



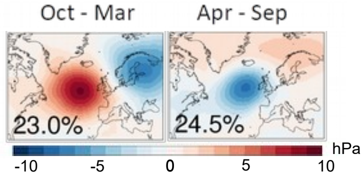


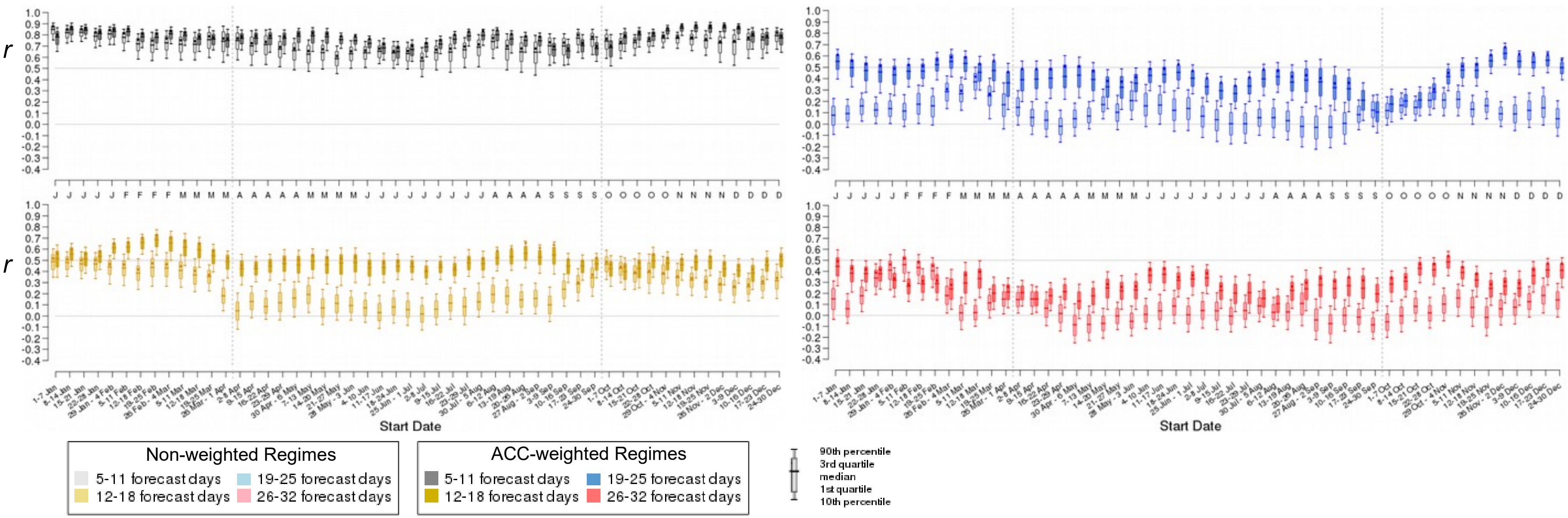
Spatial patterns of WR 3 resemble that of blocking regime in winter. It is the regime with the lowest skill of all, probably because it lacks a strong negative centroid. Beyond the first forecast week (5-11 days), only the ACC-weighted regimes are able to reach $r = 0.5$.

Source: hindcasts of ECMWF-Ext-ENS (11 members) and ERA-Interim reanalysis
K-means clustering applied to daily SLP 1998-2017 with 4 regimes for Oct-Mar and 4 for Apr-Sep
Correlations cross-validated and bootstrapped with N=1000

Pearson correlations between observed and forecasted weekly frequencies of occurrence of the Euro-Atlantic regimes (1998-2017)

Regime #4

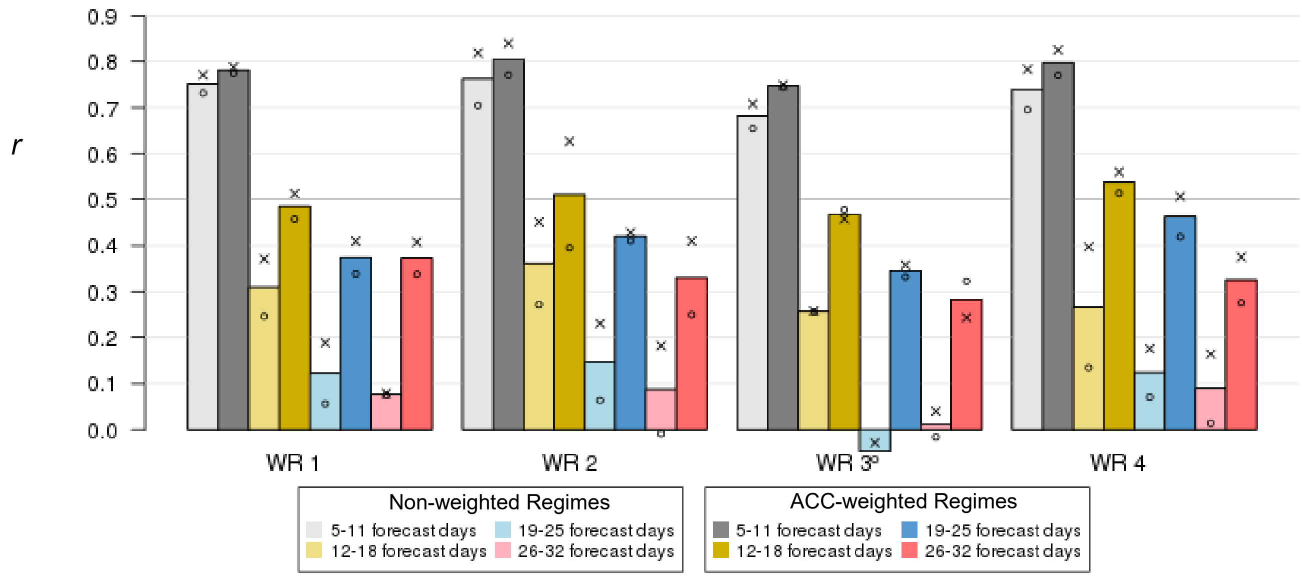




WR 4 resemble in Oct-Mar the Atlantic ridge regime and in Apr-Sep its opposite phase. ACC-weighted regimes largely improve its correlations, especially in summer start dates of the second forecast week (12-18 days, yellow bars), when they can also achieve values above $r = 0.5$ in case of some February, March and August start weeks.

Source: hindcasts of ECMWF-Ext-ENS (11 members) and ERA-Interim reanalysis
K-means clustering applied to daily SLP 1998-2017 with 4 regimes for Oct-Mar and 4 for Apr-Sep
Correlations cross-validated and bootstrapped with N=1000

Average Pearson correlations between observed and forecasted weekly frequencies of occurrence of the Euro-Atlantic regimes



Forecast skill was averaged over all 52 start dates and shown in this bar plot, separately for each regime and forecast week (crosses and circles show the average over Oct-Mar and Apr-Sep start dates, respectively). The ACC-weighted regimes have more than three times the average correlation values of the non-weighted regimes, in case of the third and fourth forecast weeks (blue and red bars). Average values of the second forecast week (yellow bars) are also close to r = 0.5 for all regimes.

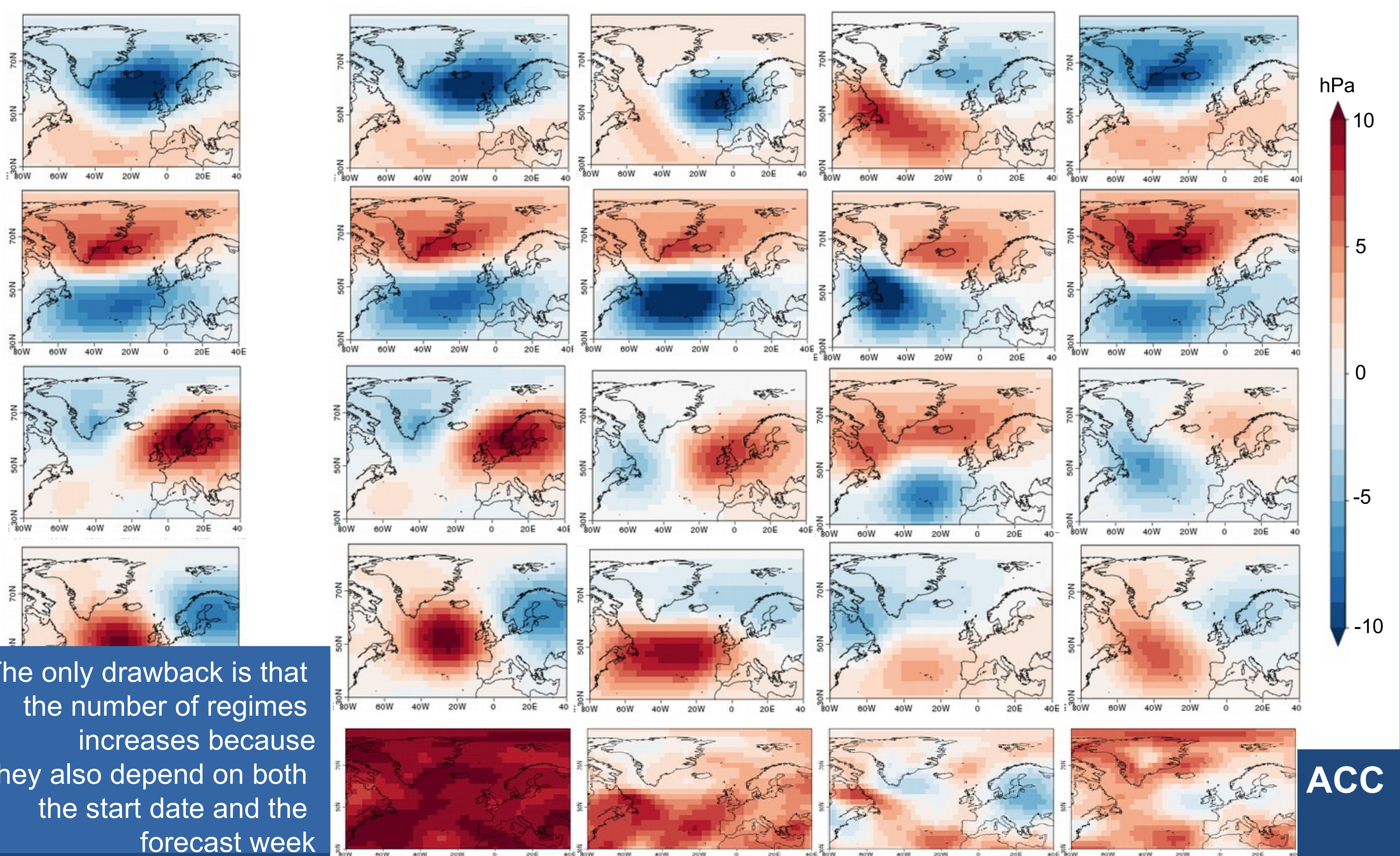
Source: hindcasts of ECMWF-Ext-ENS (11 members) and ERA-Interim reanalysis
K-means clustering applied to daily SLP 1998-2017 with 4 regimes for Oct-Mar and 4 for Apr-Sep
Correlations cross-validated and bootstrapped with N=1000

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Example: WR patterns for start date of January the 1st

ACC-weighted regimes October-March

October-March WRs | **Forec. 5-11 days** | **Forec. 12-18 days** | **Forec. 19-25 days** | **Forec. 26-32 days**



The only drawback is that the number of regimes increases because they also depend on both the start date and the forecast week

Advantages and caveats of the ACC-weighted regimes

+ *large skill gain beyond first forecast week (r = +0.3)*
  Skill gain is high if ACC shows a large spatial variability inside the study domain
+ *can be applied to any WR methodology based on clustering*
+ *can be transferred to any region where regimes can be defined*
+ *might improve skill of seasonal forecasts too*
+ *might improve teleconnection skill too*

- *ACC-weighted regimes are usually different from traditional ones identified in the literature (NAO+/-, etc). Thus, they also have a different impact on surface variables of users' interest.*
- *ACC-weighted regimes are much more numerous, as they also depends on the start date and the forecast week*