SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2018 (January 2018-June 2018)
Project Title:	WeatHer rEgimes' REpresentation (WHERE)
Computer Project Account:	SPITMAVI
Principal Investigator(s):	Alessia Balanzino
Affiliation:	Institute of Atmospheric Sciences and Climate, National Research Council (ISAC-CNR), Italy
Name of ECMWF scientist(s) collaborating to the project (if applicable)	/
Start date of the project:	01/01/2018
Expected end date:	31/12/2019

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Current year		Future year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	8,000,000	0	8,000,000	
Data storage capacity	(Gbytes)	32,000	0	64,000	

Summary of project objectives
(10 lines max)

In this special project we plan to carry out a set of atmosphere-only (AMIP) ensemble historical (1950-2014) and future scenario (2015-2050) simulations with the EC-Earth global climate model in order to study the ability of the model to represent the Euro-Atlantic and Pacific North American atmospheric weather regimes (e.g. [Cassou 2010], [Straus et al. 2007]) and the related prevailing teleconnection patterns. Several ensemble members are necessary to assess the relative contribution of the forced and the unforced variability to the frequency of weather regimes. Since all the ensemble members will be run using the same Sea Surface Temperatures (SSTs), the inter- ensemble variability provides an estimate of the internal variability, whereas the forced variability is represented by the variability of the ensemble mean. The activation of a stochastic physics parameterization scheme [Palmer et al. 2009] to represent subgrid-scale processes will be investigated by comparing with the baseline simulations.

Summary of problems encountered (if any)
(20 lines max)

No specific problem encountered in the period January 2018-June 2018.

Summary of results of the current year (from January to June of current year)
This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

The project start date is the 1st of January 2018.

The past 6 months have seen a rapid development effort, in which different model versions had to be tuned in order to set up the AMIP experiments planned for the first year project. In the meantime both weather regimes and blocking diagnostics have been tested on AMIP 30-year long (1979-2008) experiments already performed with a previous version of the EC-Earth model. These were a sub-set of the simulations carried out within the Climate SPHINX project (Davini et al., 2017): specifically to 3 ensemble members for the T255 (80 km standard resolution) and T511 (40 km high resolution) AMIP 30-year long (1979-2008) simulations.

The analysis performed is based on daily fields of wintertime (December–February; DJF) geopotential height on the 500 hPa pressure surface. A seasonal cycle is obtained by averaging the seasonal time series at each grid point over all years. This cycle is then smoothed using a 5-day mean before being subtracted from the daily time series to produce an anomaly time series at each grid point. Empirical orthogonal function (EOF) analysis is then used to reduce the dimensionality of the anomaly data set. The EOF analysis is performed on a European/Atlantic domain defined by the sector 30 –90 N, 80 W–40 E. The principal components (PCs), the time series of the EOF patterns, form the coordinates of a reduced phase space.

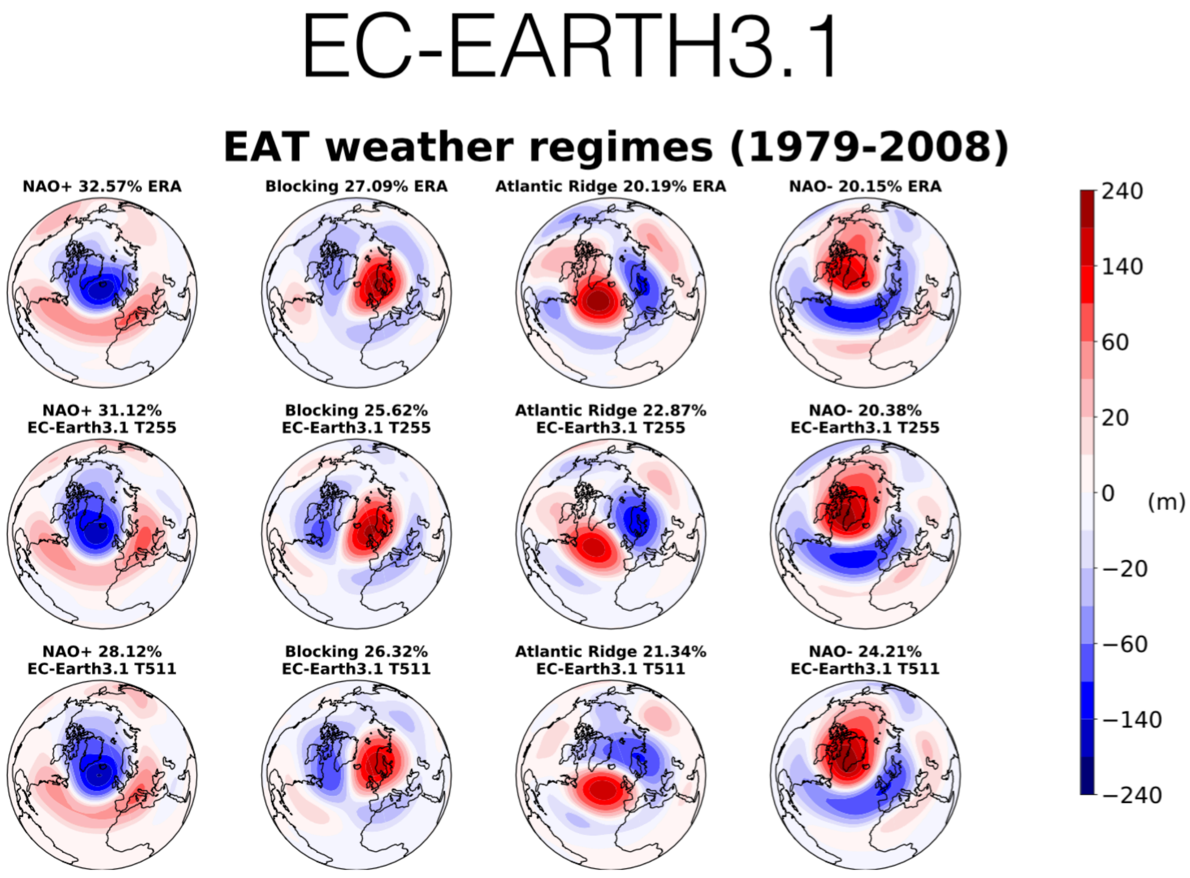
The k-means cluster analysis method Straus et al. (2007) is used to identify clusters in the reduced phase space. The clustering procedure aims to identify preferred regions of the phase space, which can be interpreted in the framework of regimes.

The null hypothesis when applying the cluster analysis is that there are no regimes, and hence that the probability density function (pdf) of the underlying phase space follows a multi-normal distribution. In order to assess if this null hypothesis can be rejected, Monte Carlo simulations using a large number of synthetic data sets are applied, as in Straus et al. (2007). The cluster analysis is applied to 500 synthetic data sets, each one composed of independent Markov processes having the same lag-1 autocorrelation as the corresponding PC of the data set being tested. Significance is reported as the percentage of times the optimal variance ratio computed for a synthetic data set does not exceed the variance ratio obtained from clustering in the data set being tested. Large values of significance for a cluster partition therefore indicate that the given variance ratio is unlikely to have been found by chance in a data set with a multi-normal pdf.

Prior to EOF analysis, data from both the renalysis and the model data sets are interpolated onto a 2.5 2.5 latitude longitude grid. This procedure ensures that variability is considered on the same range of horizontal scales in all cases. We show results from clustering in the phase space spanned by the leading 4 EOFs. The leading 4 EOFs account for around 50% of the variance in geopotential height in ERA and both model configurations (cluster patterns do not change if a much higher number of EOFs is retained, however since the data-record is limited significance might be sensitive to the number of EOFs –i.e. dimensions in phase space- retained).

Figure 1 top row shows composite height maps for the k = 4 cluster partition from ERA. The clusters are presented in order of their climatological frequency. The significance of this cluster partition is 96%, as determined by the test described above. Therefore these clusters are interpreted as circulation regimes in the European/Atlantic domain. The high level of significance in the k = 4 partition is also found when the clustering is applied in a larger 11-dimensional phase space, which retains around 80% of the total variance in geopotential height in the European/Atlantic domain. This is indicative of the robustness of the clusters in the ERA data set.

We refer to clusters 1 and 4 (Figure 1a and d) as NAO+ and NAO- regimes respectively, as they are consistent with the spatial patterns of the positive and negative phases of the North Atlantic Oscillation. The second most frequent cluster (Figure 1b) has a positive geopotential height anomaly centered over Scandinavia with negative anomalies to the east and the west. This pattern is referred to as a blocking regime. The third most frequent cluster (Figure 1c) consists of a positive geopotential height anomaly over the North Atlantic and a negative anomaly over Scandinavia and Eastern Europe. This cluster is referred to as the Atlantic Ridge regime. These four regimes are qualitatively similar to those found in other studies (e.g. Michelangeli et al., 1995; Dawson et al.2012).



a. **b.** **c.** **d.**

Figure.1 Clusters

Equivalent clusters diagnosed in the standard resolution T255 of the EC-Earth model (ECT255) configuration are shown in the middle row of Figure 1, again shown in order of their climatological frequency of occurrence. The climatological frequencies of occurrence and the spatial patterns of the ECT255 clusters are consistent with ERA (and actually the average spatial pattern correlation exceeds the 80%), however blocking and NAO+ frequencies are underestimated, while the Atlantic Ridge frequency is overestimated. The ECT255 cluster partition has an average significance of 70%, ranging from the 80% of ensemble member No.1 to the 49% of ensemble member No.2. This indicates that the ECT255 has a more gaussian phase space pdf, and hence does not simulate the same type of regime behavior as seen in ERA. When the model resolution is increased to T511 (low row in Figure 1) the average spatial pattern correlation slightly decreases (76%), however the average significance of the partition increases significantly (88%), with ensemble member No.3 reaching the 95%. The enhanced resolution affects the cluster frequency as well: the occurrence of the "blocked clusters", i.e. NAO- and blocking, is more frequent, while there is an evident underestimation of the "zonal" regime (NAO+). These results seem consistent with the findings of Davini et al. 2017 on the same dataset, but using a different diagnostics.

Summary of plans for the continuation of the project

(10 lines max)

In the second half of year 2018 we will perform ensemble AMIP simulations with the EC-Earth model in which we are going to compare the representation of Weather Regimes in EC-Earth in integrations including (or not) Stochastic Physics (Palmer et al. 2009).

References

Cassou C. (2010). *Euro-Atlantic regimes and their teleconnections*. Proceedings: ECMWF Seminar on Predictability in the European and Atlantic regions, 6–9 September 2010, 1–14.

Davini, P., Hardenberg, J. V., Corti, S., Christensen, H. M., Juricke, S., Subramanian, A., Palmer, T. N. (2017). Climate SPHINX: Evaluating the impact of resolution and stochastic physics parameterisations in the EC-Earth Global Climate Model. Geoscientific Model Development, 10(3), 1383–1402.

Dawson, A., Palmer, T., and Corti, S. (2012): Simulating regime structures in weather and climate prediction models, Geophys. Res. Lett., 39, L21805, doi:10.1029/2012GL053284, 2012.

Michelangeli, P.-A., R. Vautard, and B. Legras (1995), Weather regimes: Recurrence and quasi stationarity, J. Atmos. Sci., 52(8), 1237–1256, doi:10.1175/1520-0469(1995)052<1237:WRRAQS>2.0.CO;2.

Palmer T.N., Buizza R., Doblas-Reyes F., Jung T., Leutbecher M., Shutts G.J., Steinheimer M. and A. Weisheimer (2009) *Stochastic parametrization and model uncertainty*. ECMWF Technical Memorandum 598.

Straus, D. M., S. Corti, and F. Molteni (2007), Circulation regimes: Chaotic variability versus SST-forced predictability, J. Clim., 20(10), 2251–2272, doi:10.1175/JCLI4070.1.