Characterization of European wind speed variability using weather regimes

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1. BACKGROUND AND GOALS

- One of the main objectives of synoptic climatology is the understanding of the impact of the large-scale atmospheric circulation on local climate.
- This study describes, for the first time, where and when weather regimes (WRs), one of the more common atmospheric classifications, can be considered as **source of predictability** of wind speed in Europe.

2. DATA AND METHODOLOGY

- Daily-mean anomalies of SLP from ERA-Interim[1] were filtered with a LOESS regression[2] and weighted by latitude to classify WRs with the ***k-means* algorithm**[3] in the Euro-Atlantic region (27° N - 81° N, 85.5° W - 45° E) for 1981-2016. PCA filtering was not applied to take into account also the more extreme SLP values.
- SLP anomalies were classified for each month of the year, obtaining a set of **four different WRs for each month**[4], corresponding to the more robust WR partition observed during winter months[5].
- To assess the goodness of WRs as sources of predictability of 10-m wind speed, WRs were employed to **reconstruct** (in cross-validation) **the observed average monthly 10-m wind speed** (from ERA-Interim) $W_{m,y}$, as the linear combination of the monthly impact of each WR on wind speed $I_{r,m,y}$ multiplied by its frequencies of occurrence:

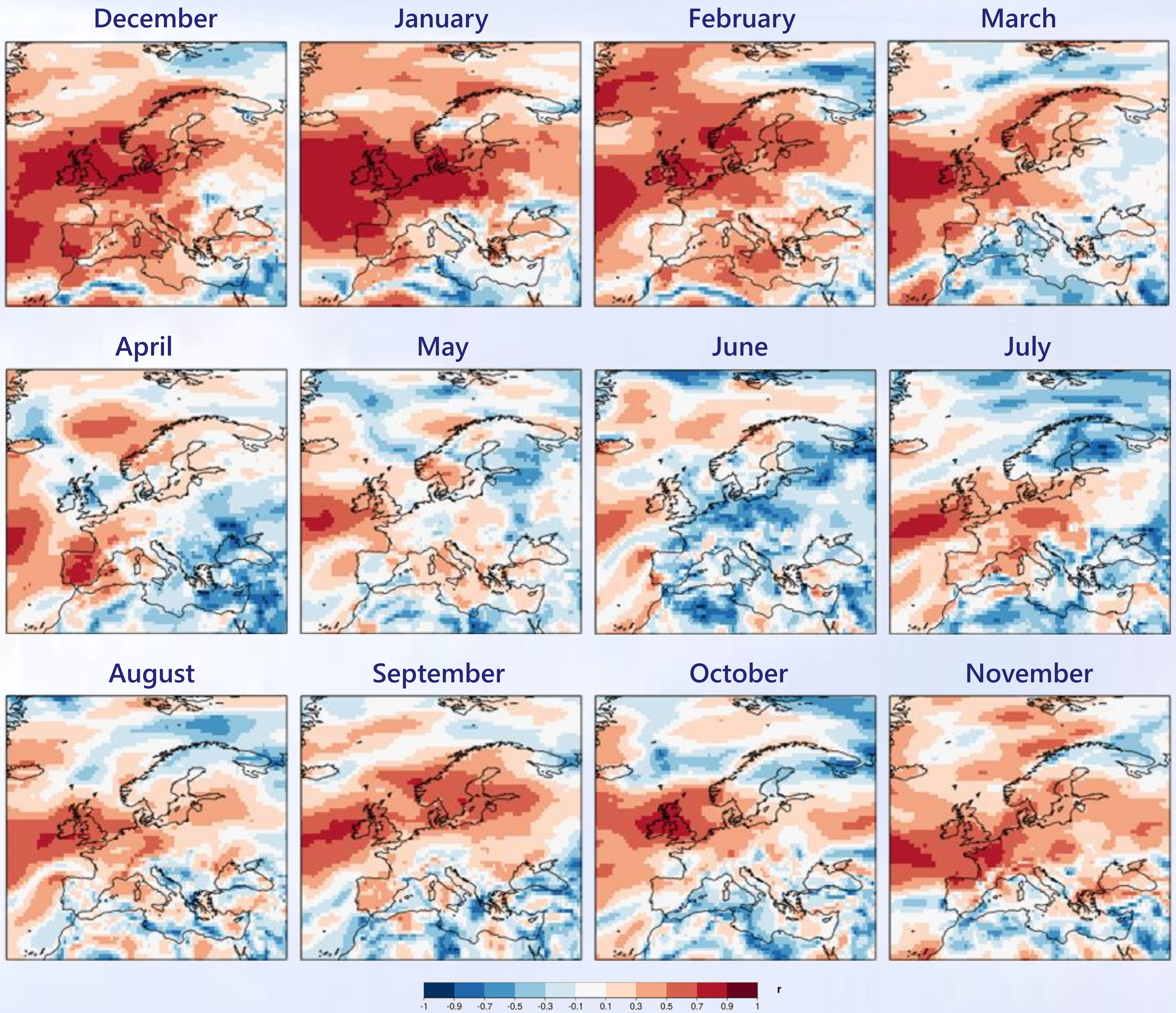
$$W_{m,y}(lat, lon) = \frac{1}{N_{my}} \sum_{r=1}^{4} I_{r,m,y}(lat, lon) \cdot N_{rmy}$$

with N_{my} the total number of days in month m and year y and N_{rmy} the number of days belonging to WR r, month m and year y. The monthly impact of a WR on wind speed $I_{r,m,y}$ is defined as:

$$I_{r,m,y}(lat, lon) = \sum_{d=1}^{N} \frac{1}{N} w_{r,m}(d, lat, lon)$$

with N the number of days belonging to regime r and month m during 1981, ..., y-1, y+1, ..., 2016 and $w_{r,m}(d)$ the 10-m wind speed anomalies for regime r, month m and day d. Notice that $I_{r,m,y}$ was measured in a **leave-one-out cross-validation** framework, in which the year to be reconstructed is excluded from the estimation of $I_{r,m,y}$.

- The monthly series of WRs-reconstructed wind speed anomalies was compared with the monthly series of observed wind speed anomalies employing **Pearson's correlation**, as shown in the figures.



Figures. Pearson's correlation between the observed monthly series of 10-m wind speed anomalies and the ones reconstructed by the four WRs (1981-2016). Areas in dark red colour (r > 0.5) shows where WRs can be considered good sources of predictability of wind speed. All correlations are significant to a *t-test* at the confidence level of 0.95. Notice that WRs were defined on a spatial domain bigger than the one shown, but only correlations for continental Europe are displayed in the figures. *Source:* ERA-Interim.

3. RESULTS

- The overall influence of the WRs on wind speed variability can be divided in three periods:
  1. From December to March, WRs have a **high influence** on wind speed (r > 0.5) over most part of Europe, particularly UK, Ireland, Holland, Denmark, Norway, Sweden, Finland, Poland, the northern part of France, Germany an Spain, the North Sea and the Baltic Sea.
  2. From April to July, WRs have a **low or null influence** on wind speed over continental Europe. A few exceptions can be found, such as the Iberian Peninsule in April or Germany in July.
  3. From August to November, WRs have a high influence on wind speed over UK and Ireland and a moderate one (r > 0.3) over Holland, Denmark, northern Germany and Spain, southern Norway and Sweden, the North Sea and the Baltic Sea.
- In a few European periferical areas, such as northern Scandinavia, Spain and the Aegean Sea (between Greece and Turkey), the influence of WRs is moderate to high for many months.
- Such areas also have high average wind speeds (7-10 m/s), and due to their distance from the North Sea (where most of the European wind power is generated) they could play an **important role** in reducing the high intermittency of total European wind power generation[6].

4. CONCLUSIONS

- This study identifies, for the first time, in which regions and months Euro-Atlantic WRs as a whole can be considered as sources of predictability of wind speed, i.e, where they highly influence wind speed variability, by investigating their ability to reconstruct wind speed.
- This knowledge complements that of the influence of each single WR on wind speed and it is critical for identifying in which areas WRs can be effectively employed to **develop products** tailored to the user's needs.
- The novelty of this work consists in the definition of **a new metric** which summarizes the influence of all the WRs on a target variable, wind speed in this case. Previous studies available in literature, in fact, only focused on the influence of a single WR at time, so they were not able to detect the overall influence of WRs as a whole. A similar approach can be easily extended to other variables such as temperature and precipitation, and it will be the objective of future studies.

5. REFERENCES

[1] Dee et al (2011) The Era-Interim reanalysis: configuration and performance of the data assimilation system. Q J R Meteorol Soc 137(656): 553-597, doi: https://doi.org/10.1002.qj.828
[2] Mahlstein et al (2015) Estimating daily climatologies for climate indices derived from climate model data and observations. J Geophys Res 120(7):2808-2818, doi: https://doi.org/10.1002/2014JD022327
[3] Hartigan and Wong (1975) Algorithm AS 136: a k-means clustering algorithm. J R Stat Soc Series C (Applied Statistics) 28(1):100-108
[4] Cortesi et al (2019) Characterization of European wind speed variability using weather regimes. Clim Dyn (accepted)
[5] Michelangeli et al (1995) Weather regimes: recurrence and quasi-stationarity. J Atm Sci 52(8): 1237-1256, doi: https://doi.org/10.1175/1520- 0469(1995)052h1237:WRRAQSi2.0.CO;2
[6] Grams et al (2017) Balancing European wind power output through spatial deployment informed by weather regimes. Nat Clim Change Lett 7(8): 557, doi https:://doi.org/10.1038/NCLIMATE338

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