Offshore wind energy climate projections for the European region

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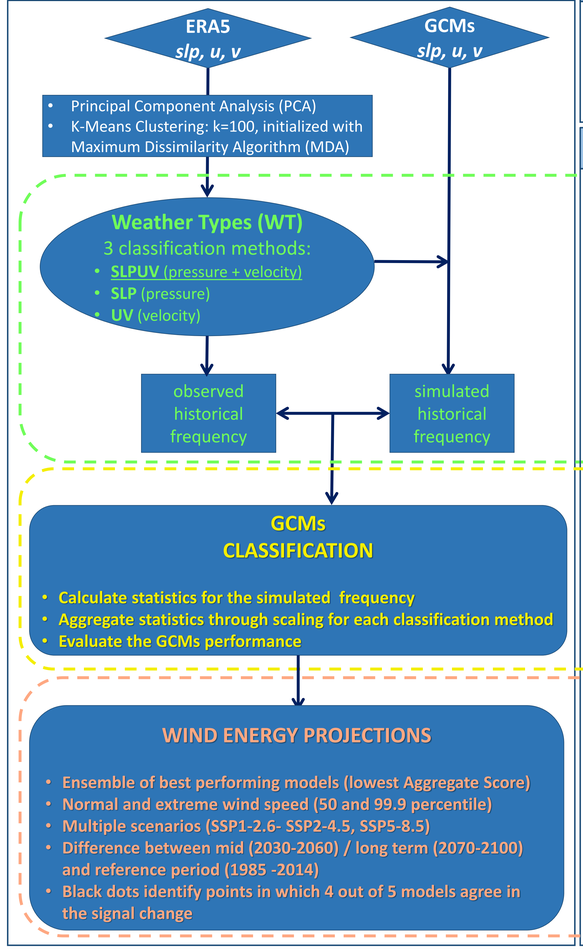
MOTIVATION

- Climate Change can impact significantly on the spatial and temporal distribution of the wind resource
- General Circulation Models are the most advanced tool for climate change projections, but they are characterized by limitations
- Assessing last generation CMIP6 GCM simulations allows to improve projections for offshore wind energy sector

OBJECTIVES

- Obtain several Weather Type classifications from ERA5 pressure, wind speed and direction fields and apply them to the GCM
- Evaluate the performance of the GCMs in reproducing historical synoptic patterns
- Evaluate future changes in the wind resource for the ensemble of the best performing models

METHODOLOGY



DATA

ECMWF ReAnalysis-5 (ERA5)

- Hourly time resolution.
- 1985-2014
- 0.25° horizontal grid

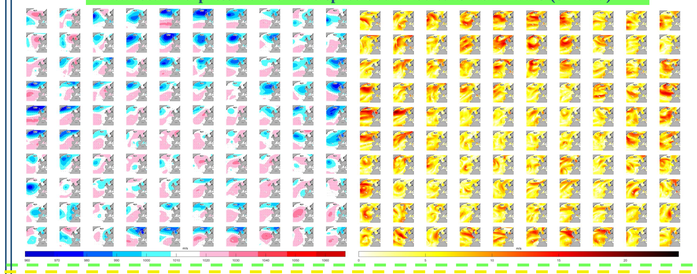
CMIP6 General Circulation Models (GCMs)

- 6-Hourly time resolution.
- 1985-2014, 2030-2060, 2070-2100
- SSP1-2.6, SSP2-4.5, SSP5-8.5

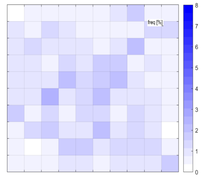
GCM model	BCC-CSM2-MR	CMCC-CM2-SR5	CMCC-ESM2	CNRM-CM6-1-HR	EC-Earth3	MIROC6	MPI-ESM1-2-HR	MRI-ESM2-0
Research Centre	Bejin Climate Center	Centro Euro-Mediterraneo per I Cambiamenti Climatici	Centro Euro-Mediterraneo per I Cambiamenti Climatici	Centre National de Recherches Meteorologiques	EC-EARTH Consortium	Japan Agency for Marine-Earth Science and Technology	Max Planck Institut fur Metereologie	Meteorological Research Institute
Country	China	Italy	Italy	France	EU	Japan	Germany	Japan
Resolution	1.125 x 1.125	1.25 x 0.9375	1.25 x 0.95	0.5 x 0.5	0.7 x 0.7	1.4 x 1.4	0.9375 x 0.9375	1.125 x 1.125

RESULTS

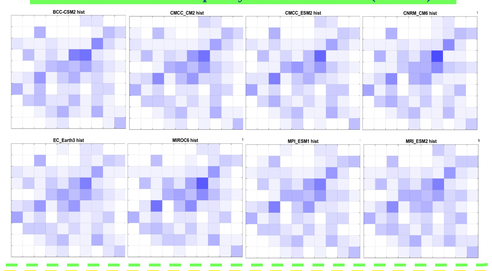
Mean sea level pressure and wind speed of the 100 WTs from ERA5 (SLPUV)



Observed historical frequency from ERA5 (SLPUV)



Simulated historical frequency from the 8 GCMs (SLPUV)



Statistical indexes calculation (SLPUV)

$$SI = \sqrt{\frac{\sum_{i=1}^{N}(p_i - p_i')^2}{N}} \Big/ \frac{\sum_{i=1}^{N} p_i}{N}$$

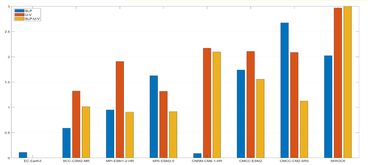
$$Re = \sum_{i=1}^{N} p_i \left| log \frac{p_i}{p_i'} \right|$$

$$std(SI) = \sqrt{\frac{\sum_{i=1}^{N}(std(p_i) - std(p_i'))^2}{N}} \Big/ \frac{\sum_{i=1}^{N} std(p_i)}{N}$$

p_i = ERA5 historical frequency
p'_i = GCM historical frequency
N = 100

GCM	SI	RE	stdSI
EC-Earth3	0.535	0.434	0.562
MRI-ESM2-0	0.554	0.506	0.642
MPI-ESM1-2-HR	0.576	0.509	0.605
CMCC-CM2-SR5	0.603	0.538	0.576
BCC-CSM2-MR	0.608	0.51	0.583
CMCC-ESM2	0.620	0.559	0.620
CNRM-CM6-1-HR	0.678	0.567	0.649
MIROC6	0.696	0.594	0.790

Aggregation (SLP – UV – SLPUV)

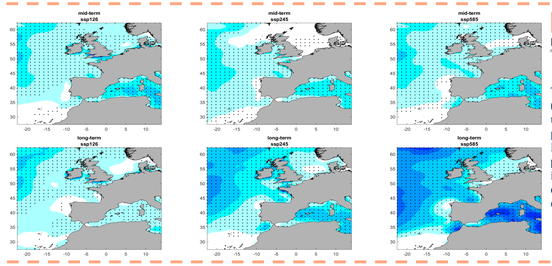


- SI, RE, stdSI are **rescaled to the interval [0,1]**
- Scaled values of SI, RE and stdSI are **summed up** for each of the 8 GCMs and each of the 3 methods

Evaluation (SLP –UV –SLPUV)

GCM	Aggregate Score
EC-Earth3	0.110
BCC-CSM2-MR	2.928
MPI-ESM1-2-HR	3.768
MRI-ESM2-0	3.861
CNRM-CM6-1-HR	4.357
CMCC-ESM2	5.405
CMCC-CM2-SR5	5.888
MIROC6	7.992

- For each GCM, results from the 3 WT methods are aggregated, providing the final classification
- The GCMs with poorest resolution (CMCCs, MIROC6) have the worst performance (highest Aggregate Score)

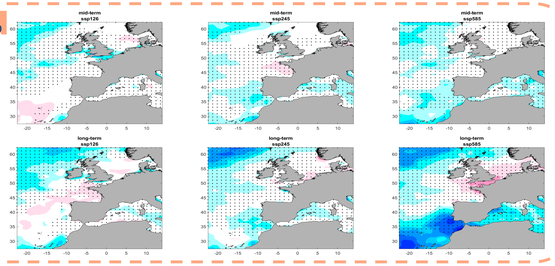


$WSPD_{50}$ %

The **mean wind speed** ($WSPD_{50}$) will **reduce over the whole study area** and particularly in the Mediterranean, **proportionally to the SSP** intensity **and to the distance of the future time slice** considered

$WSPD_{99.9}$

The extreme wind speed ($WSPD_{99.9}$) is expected to **decrease in Gibraltar, Canary Islands, Mediterranean** for the majority scenarios, while **increments** are mostly concentrated **in the northern portion of the study area**



CONCLUSIONS

- Three Weather Type (WT) classifications have been obtained from various combinations of ERA5 pressure, wind speed and direction fields: SLP – UV – SLPUV.
- The performance of the GCMs in reproducing historical synoptic patterns has been assessed through statistical indexes. Only five best performing models were included in the ensemble, improving the robustness of the ensemble results
- Mean wind speed is projected to decrease particularly over the Mediterranean Sea (up to 8%), while extreme wind speed will increment up to 3% along the Atlantic coast of Europe and decrease over Canary islands and Gibraltar

REFERENCES

- Perez, J., Menendez, M., Mendez, F. J., & Losada, I. J. (2014). Evaluating the performance of CMIP3 and CMIP5 global climate models over the north-east Atlantic region. Climate Dynamics, 43(9–10), 2663–2680. https://doi.org/10.1007/s00382-014-2078-8
- Susini, S., Menendez M., Eguia P., and Blanco J.M. (2022). Climate Change Impact on the Offshore Wind Energy Over the North Sea and the Irish Sea. Frontiers in Energy Research 10 (5): 1–17. https://doi.org/10.3389/fenrg.2022.881146.