

Introduction and Objective

In most feasibility studies, the effect of air density variations on wind energy production are usually ignored by adopting a constant value of 1.225 kg/m^3 (ρ_0) close to sea level, and the correspondent constant values at higher altitudes. However, recent studies at specific farms indicate that it may have an important effect on wind energy production. The purpose of this study is to compute the Capacity Factor (CF) estimation error due to air density variations (seasonal and spatial) off the Eastern Scottish coast, focusing on the location of the Hywind Project (world's first commercial floating offshore wind farm).

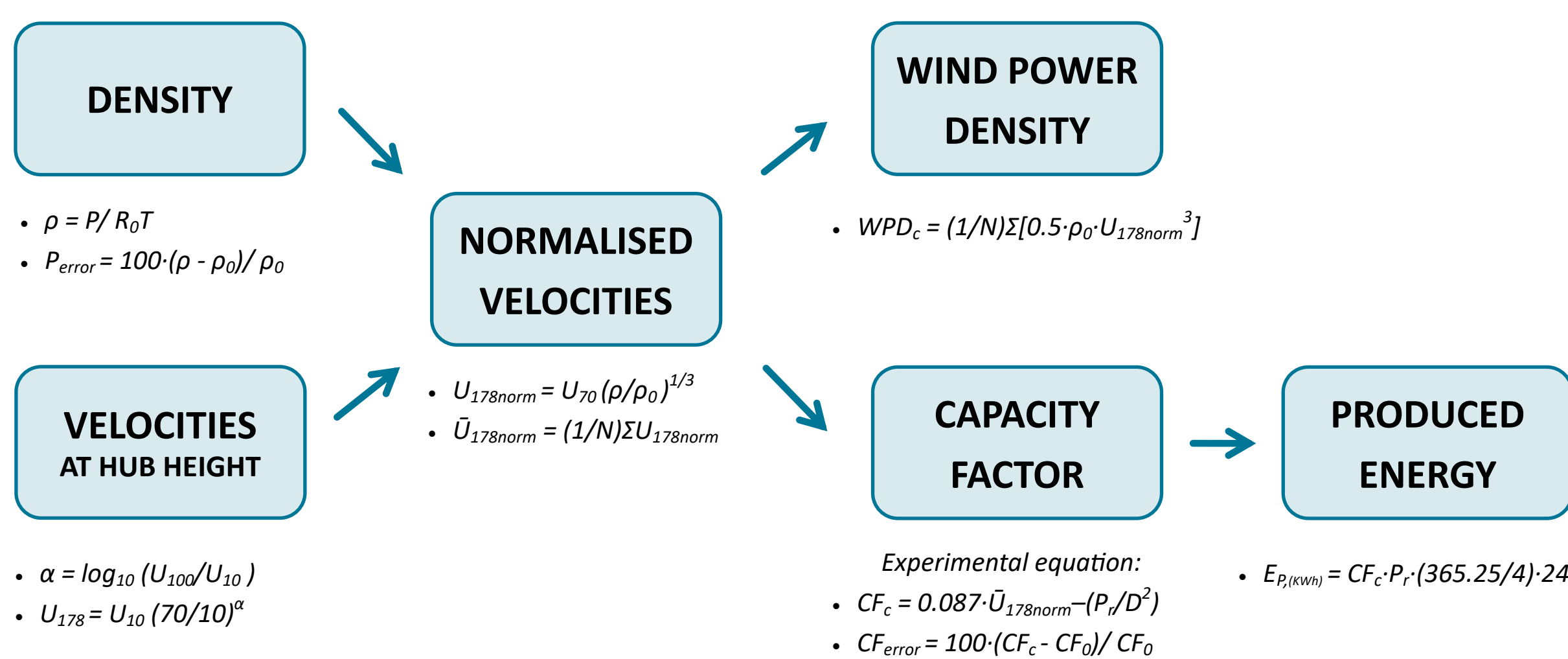
Data and Methodology

ERA 5 Reanalysis (ECMWF)

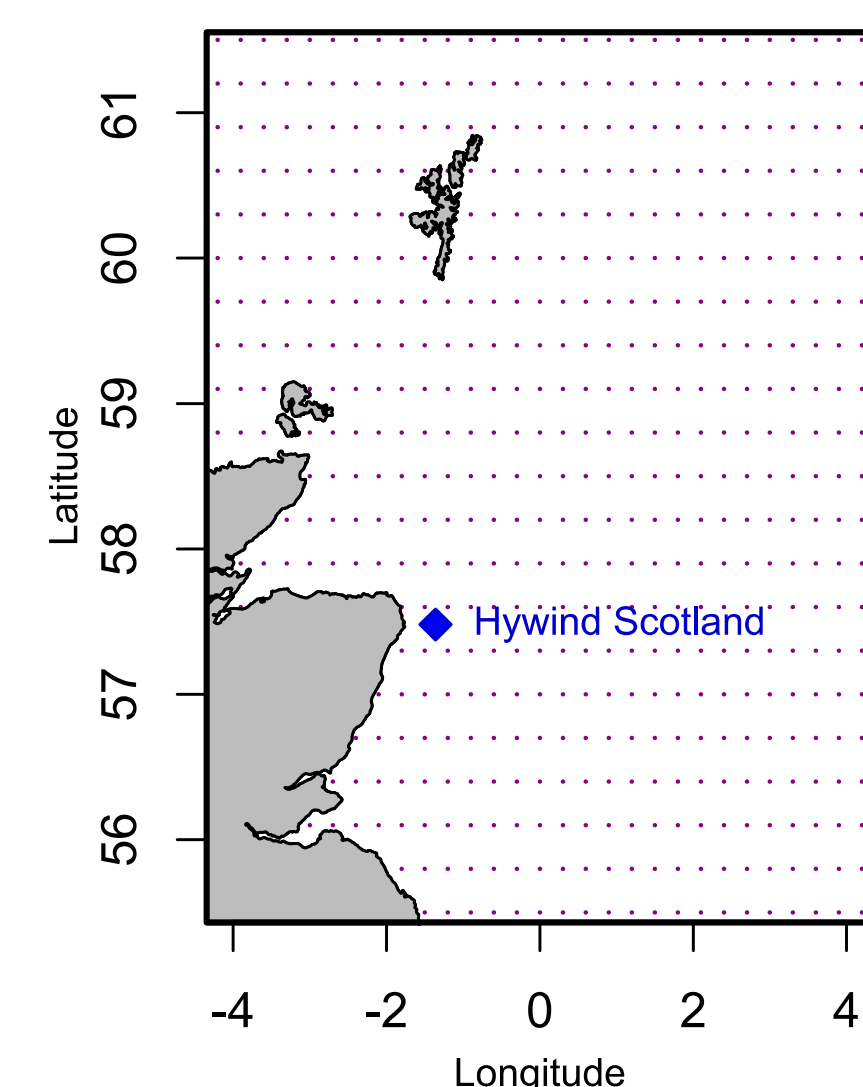
Period	2010-2017	Spatial resolution	0.3x0.3 degrees
Temporal resolution	Hourly resolution, daily means employed	Variables	<ul style="list-style-type: none"> -Sea level pressure (P) -Temperature at 2m (T) -Wind speed at 10m (U_{10}) -Wind speed at 100m (U_{100})

Turbine: SIEMENS 160/6

Rated power (P_r)	6000 KW
Diameter (D)	160 m
Hub Height	178 m

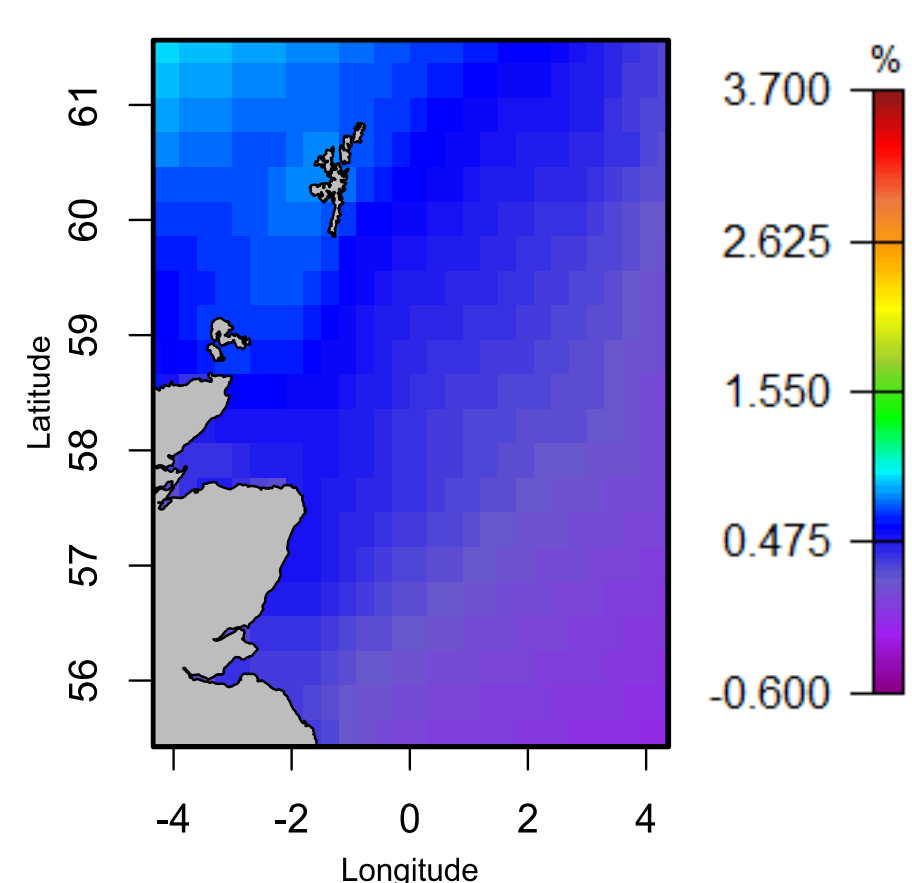


Area of study (gridpoints)

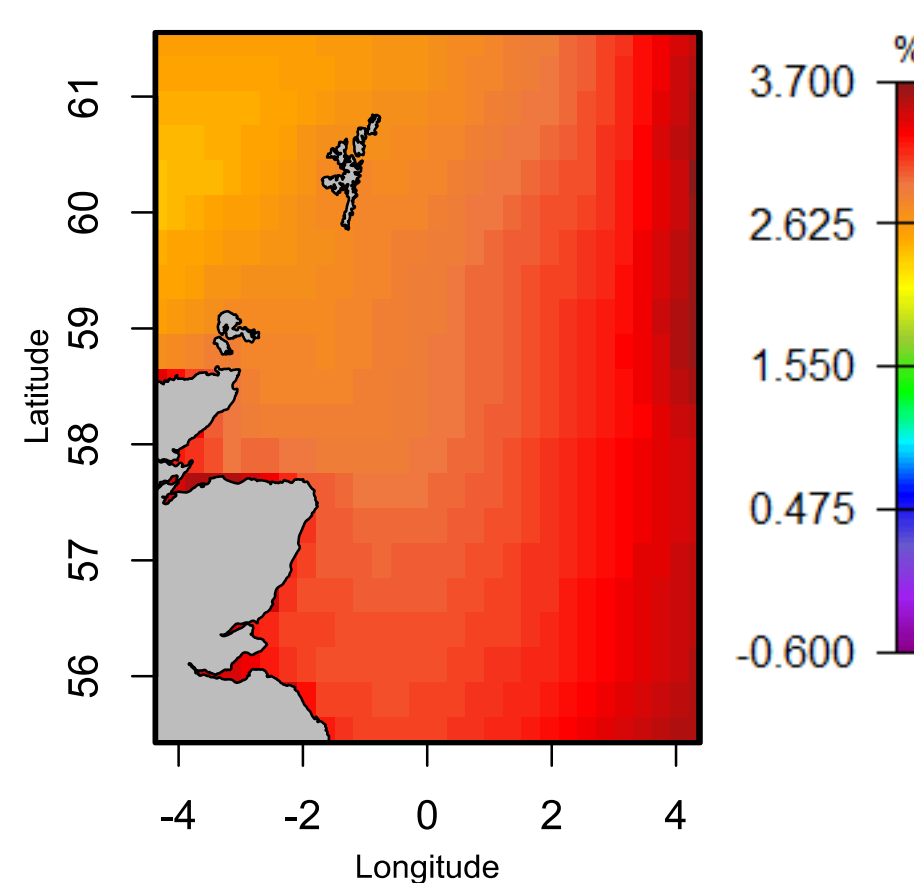


Results and Discussion

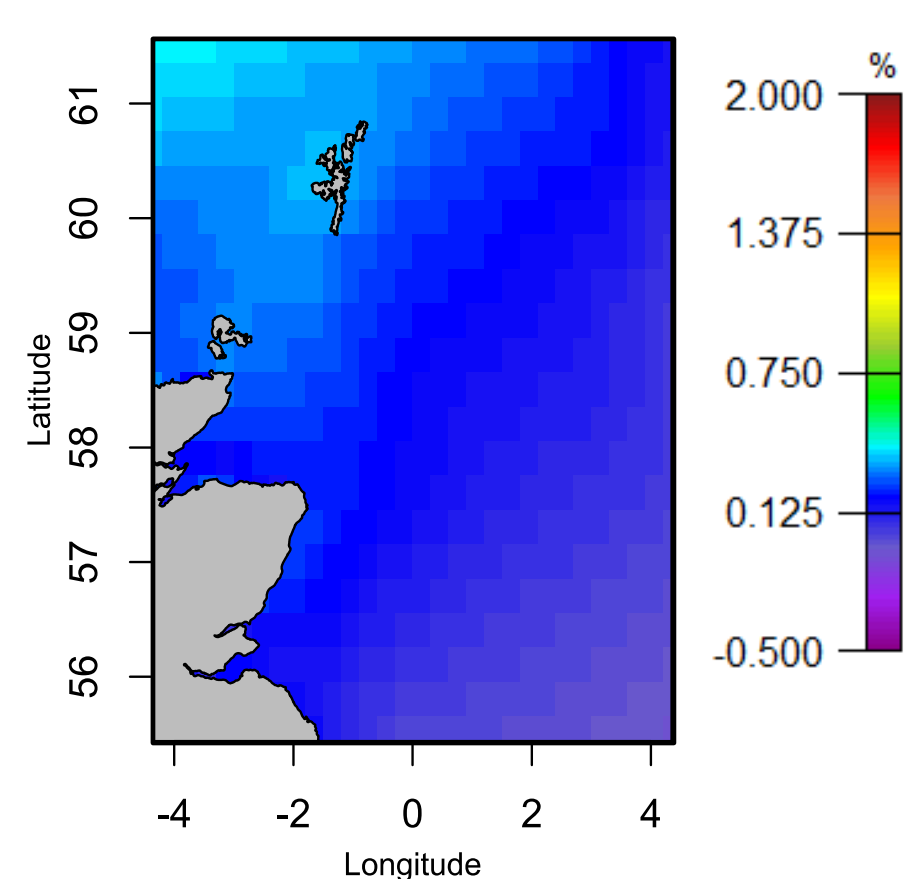
Seasonal air density error (SUMMER JAS)



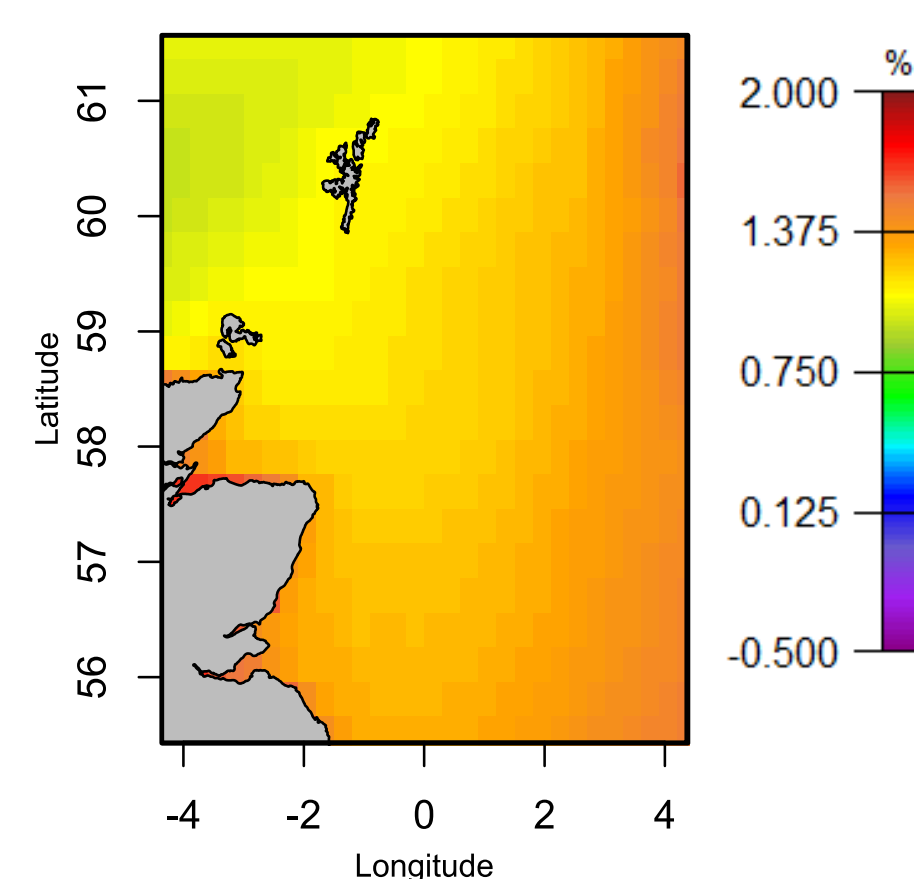
Seasonal air density diff (WINTER JFM)



Seasonal CF error (SUMMER JAS)



Seasonal CF error (WINTER JFM)



Results for Hywind Scotland

Stat. Ind.	Summary of Air Density (kg/m^3)	WPD diff with respect to Mean
Min	1.17	-7.1%
1 st Qu.	1.23	-1.2%
Mean	1.25	0.0%
3 rd Qu.	1.27	1.8%
Max	1.35	8.9%

- The density estimation error is close to 0 in summer, while it increases to 3.5 % in winter, due to cool temperatures.
- Eastern area suffers higher density variations.
- Capacity factor estimation error is close to 0 in summer, but it reaches 2 % in winter: 0.27 GWh more production each winter, 27,000 £ according to the LCE of offshore wind energy in UK (2015).
- Standard air density is nearer to 1st quartile than to the mean value at Hywind's location.
- The difference between maximum and minimum density case reaches 0.18 kg/m^3 at Hywind's location.
- WPD extreme cases under -7% and above 8% with respect to the mean at Hywind's location.

Conclusion

This method to characterize the WPD, CF and electricity production corrected by air density, and to measure the errors involved in the supposition of constant standard air density; proves that the effects of air density variation (spatial and temporal) are not negligible and have a considerable economic impact.

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