Offshore Wind: Resource Characterization, Climate Change Impacts, and Multi-Constraint Studies

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Motivation and Introduction

Offshore wind energy (OWE) is a strong contender in the race towards decarbonisation of the energy sector. However, offshore wind development requires significant planning at national and regional levels, in order to implement it successfully. Many issues that promote acceptance and adoption of OWE are also cutting-edge research topics. Here we present three examples of significance:

- OWE resource evaluation, based on numerical models or *in-situ* measurements;
- Potential climate change impacts on OWE resources; and
- OWE resource evaluation under technical, economic, or socio-ecological constraints.

The discussion will focus around OWE research in Mexico and in Mexican Waters, with some regions of interest shown in Fig. 1.

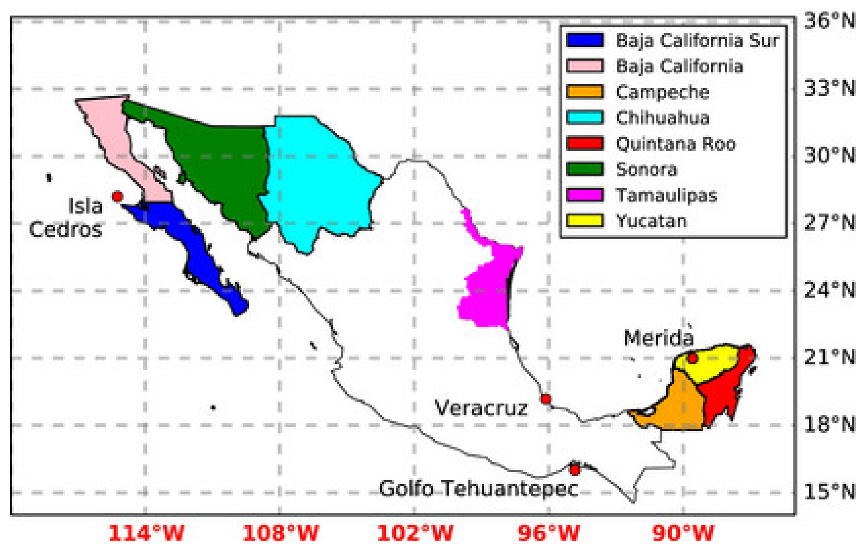


Fig. 1: Study Area with Some Regions of Interest

OWE Resource Assessment

Rarely are meteorological or climatological data available at the height of the wind turbines, and therefore it is common to find the wind speed u at height z from a known wind speed u_r at a reference height z_r, using a power law profile:

$$\frac{u}{u_r} = \left(\frac{z}{z_r}\right)^{\alpha} \tag{1}$$

However, this power law significantly underpredicts the wind speed at the wind turbine heights, because it cannot reproduce some of the characteristics of low-level mesoscale jets (LMJ). This can be improved in two ways:

1. by considering models that can reproduce the LMJ climatologies in the region of interest, and
2. by using a method of interpolation of the wind speeds that is more accurate than eqn. 1.

In [1], the first issue is resolved by using the UPSCALE climatological dataset, documented in [4, 6], configured to reproduce the wind climate for the period February 1985 to December 2011 (control). The second issue was resolved by regressing 30 known vertical profiles against the relationship:

$$\frac{u}{u_r} = \left(\frac{z}{z_r} + az\right)^{b+c/z} \tag{2}$$

Once these problems are resolved, it is worth assessing the OWE resources not only for the control climate, but analyse possible variations under some future climate change scenario. In [2], the RCP8.5 emission scenario is used because it is believed to be closer to reality than lower emission scenarios.

Control and RCP8.5 scenario

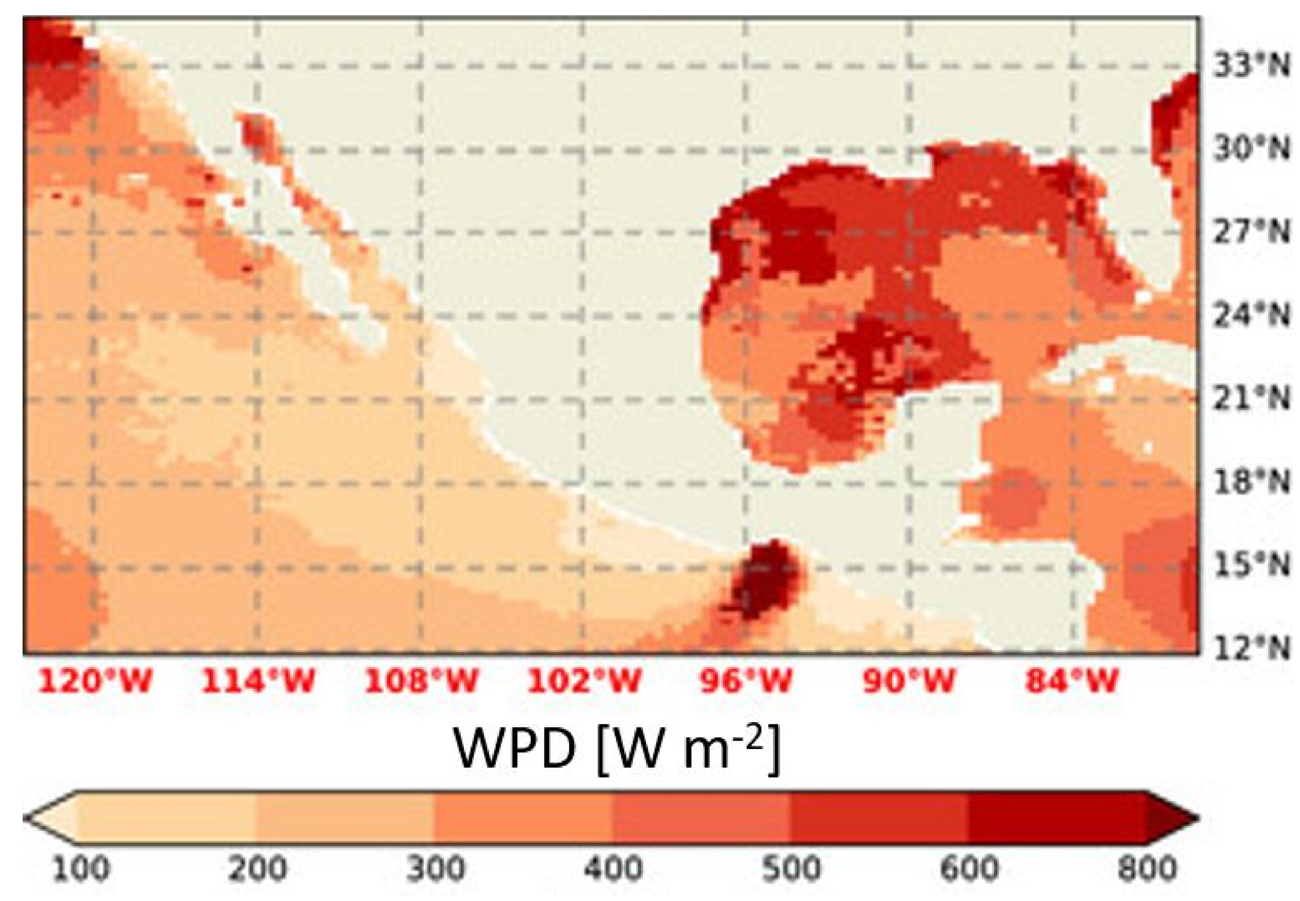
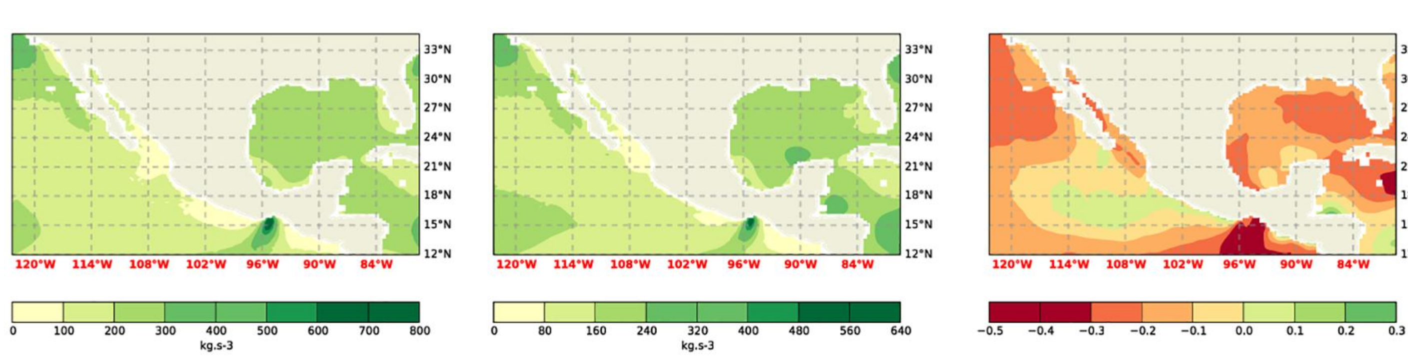


Fig. 2: Average wind field at 150m predicted by the Control dataset

The wind field obtained at 150 m, as computed in [1], is shown in Fig. 2. One can identify several areas of special interest:

- The Great Island Region and the Upper Gulf of California;
- Bahía Vizcaíno and Bahía Asunción in the Northern Mexican Pacific;
- The Yucatán Shelf off the coast of Campeche and Veracruz;
- Offshore of the state of Tamaulipas; and
- The Gulf of Tehuantepec.

The original and the RCP8.5 scenario wind fields at 10m height, together with their percentage difference (PD), are shown in Fig. 3. The PD results show that the wind speeds are at least 50% lower in the RCP8.5 scenario than in the Control dataset in the Gulf of Tehuantepec. This information is crucial for OWE planners and developers, as the wind speeds define the IEC61400 wind energy class, and determine the choice of the most appropriate technology. Thus, the best technology in 20 years from now will have, necessarily, very different characteristics to those of current best technologies, in locations where the PD is large.



(a) original dataset (b) RCP8.5 (c) difference

Fig. 3: Comparison of WPD computations at 10m using the RCP8.5 Scenario and the Control dataset

WE Resource assessment with multiple constraints

OWF development requires theoretical characterizations of the OWE, as discussed previously, but also a significant effort in marine spatial planning where other natural resources and users of the space are taken into account. In [3], this question is addressed using the Great Island Region (GIR) and the Upper Gulf of California (UGoC) as study area.

The GIR and the UGoC are within the red polygon shown in Fig. 4. Most of the Ecological Conservation Regions have OWF development restrictions. The techno-economical constraints included water depth and access the transmission lines.

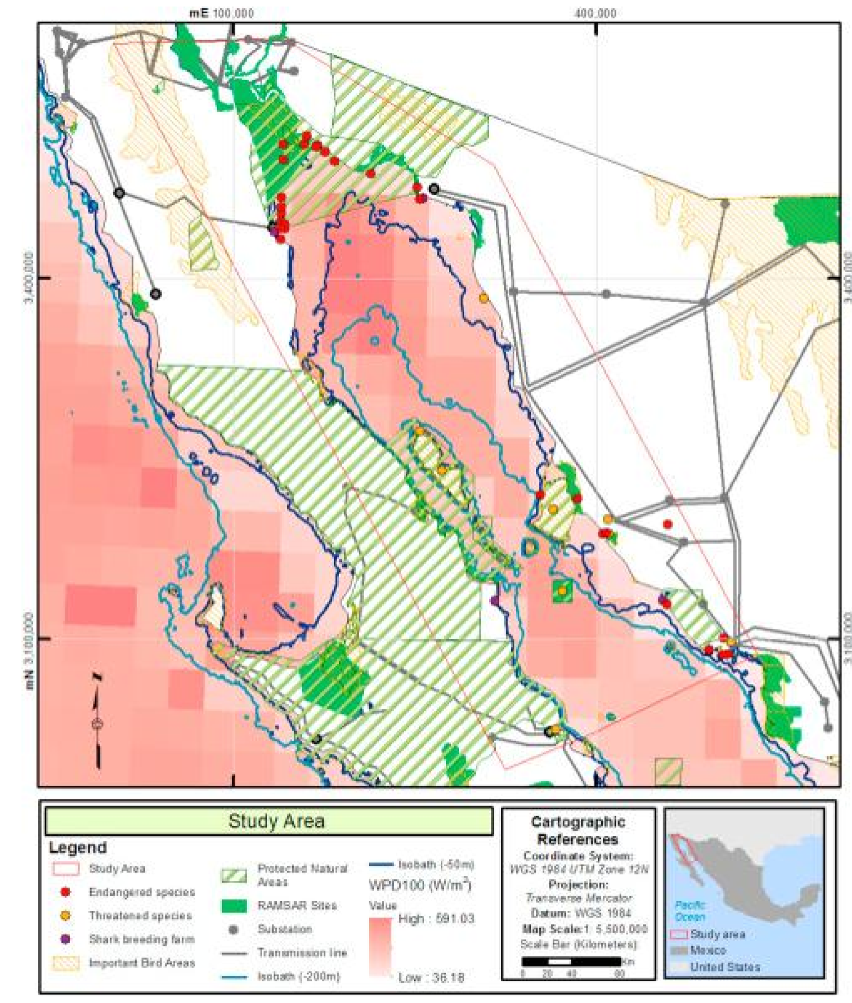


Fig. 4: WPD100 and Ecological Conservation Regions in the GIR and UGoC.

The number of fishing communities using the space is considered an important social and economic constraint for OWF developments, and this information is well known [5]. A schematic with all the marine techno-economical and socio-ecological constraints is shown in Fig. 5a, together with WPD at 100m (WPD100) in Fig. 5b.

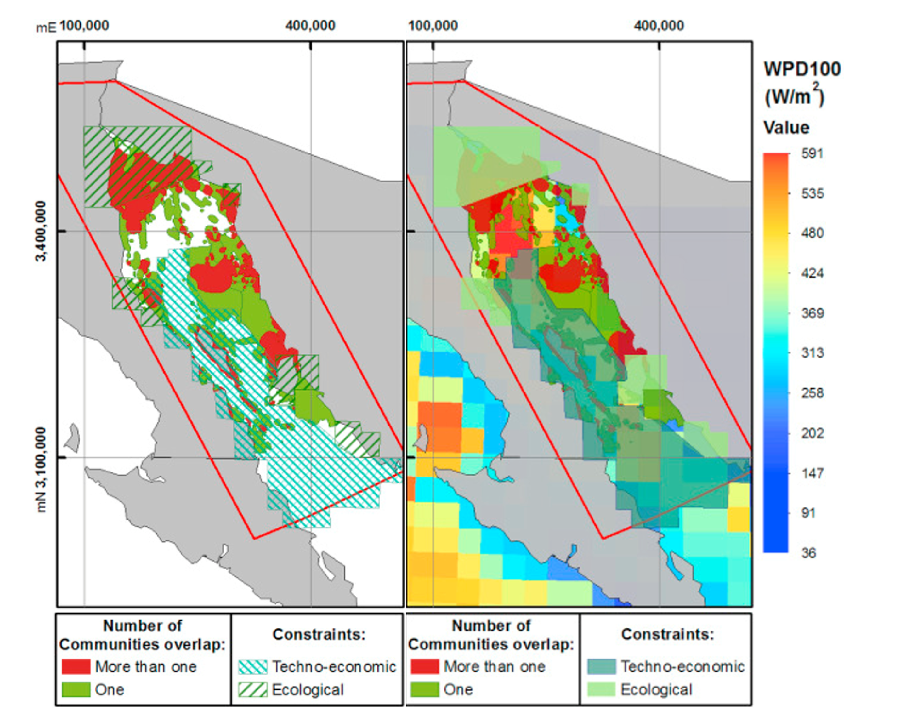


Fig. 5: WPD100 and Ecological Conservation Regions in the GIR and UGoC.

Such constraints affect where OWF may be deployed. However, If all constraints are taken into account, and turbines of 6MW of installed capacity are deployed at appropriate distances, a total of up to 52GW in Offshore Wind Farm installed capacity could be envisaged in this region.

References

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