Forecasting offshore wind power in Portugal

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Abstract

Accurately forecasting offshore wind power is important to grid managers (TSO) due to the magnitude of power fluctuations, because offshore wind farms have a high power capacity, and there are no spatial smoothing effects as in inland farms. Thermal effects are recognized as relevant in near and offshore wind profiles. As offshore wind farms are being planned for the Portuguese coast, which is subject to frequent upwelling episodes, it is important to know the ability of models to forecast wind under such events. Forecast differences are analyzed by feeding WRF model with realistic SST data from satellite images by ODYSSEA, instead of using SST given by the global atmospheric model GFS. Conclusions are preliminary but indicate that there is a positive feedback of SST in winds, and that SST influences the atmospheric stability regime up to 200m, and in nearshore regions both in land and sea, by stabilizing and by weakening the characteristic daily cycle.

Contents

1 Introduction

Accurately forecasting offshore wind power is important to grid managers (TSO) not just because offshore wind farms have a high power capacity (usually above 100MW each), but also because there are no spatial smoothing effects due to topographic differences (statistical compensation), and thus the magnitude of power fluctuations can be very significant (Pinson et al., 2008). Also,

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offshore wind farms have higher energy availability than onshore, or capacity factor, due to the lower surface roughness and higher turbine hub heights. This last comes from the fact that offshore turbines can be bigger, with power capacities of 5 MW and hub heights of 120 m, because of ship transportation.

Historically, offshore in situ observations have been undertaken below 100m in height and the stability corrections based on Monin-Obukhov similarity theory on the logarithmic profile have been used to extrapolate wind to the turbine height. However, recent measurements of wind above 50m have shown that this may not be adequate (Sempreviva et al., 2007). While variations in sea surface roughness (e.g. wave field) seem to have a minor impact on offshore vertical wind profiles, the influence of thermal effects (air-sea temperature gradients and thermal winds such as sea breeze) is being recognized as non negligible (Lange (2002), Sempreviva et al. (2007)).

These temperature gradients vary not only with solar radiation and heat capacities, but also with ocean circulation conditions, as for example, coastal upwelling. This is a frequent and intense phenomenon in the Portuguese coast, that occurs between April and September, being stronger and persistent in August. Its influence on the offshore wind profile is not yet quantified. As Portuguese offshore wind farms are being planned, it is important to know the accuracy of forecasts in this area. According to REN (2008), the Portuguese Transmission System Operator (TSO) is prepared to have 550 MW of nearshore wind power (up to 35 meters deep) by 2019, with 60% (330 MW) north of Peniche, 25% (137.5)MW) near Viana do Castelo, and 15% (82.5 MW) south of Lisbon.

Past studies in several locations over the world have shown that feeding realistic sea surface temperature (SST) fields into atmospheric models can significantly improve wind patterns simulation, but that the strength of this coupling is usually underestimated Song et al. (2009). In addition, the influence of upwelling episodes need further study.

In this paper, we analyze the influence of SST variation in offshore wind patterns over Portugal during the upwelling episode of August 2008 by feeding realistic SST fields (ODYSSEA - 2 km) into WRF mesoscale atmospheric model.

2 Methodology

To study the influence of thermal effects in offshore wind patterns on the Portuguese Coast, we applied the mesoscale numerical model WRF in a twin experiment: a control run where SST is given by the global model GFS analysis that is used in initial and boundary conditions, and a test run, where everything is the same as in the control run except for SST, which is here given by ODYSSEA satellite images. The simulation conditions are presented in table 1 and the domain in figure 1. Figure 2 shows the differences in the imposed SST for the day 2008-08-06. ODYSSEA SST images are a multi-sensor merged high-resolution level 4 product on a 0.02 x 0.02 degree grid (approximately 2 x 2 km) for the Mediterranean Sea, every 24 hours. Optimal interpolation techniques are used to combine coincident swath measures of SST from different types of sensor and to fill gaps where no observations are available. (`http://cersat.ifremer.fr/data/discovery/by_parameter/sea_surface_temperature/eur_l4uhfnd_med`). These data are processed at Ifremer/CERSAT, as part of the MEDRESPIRATION project, within the GHRSST-PP project (Global High Resolution SST Pilot Project), and as part of ODYSSEA (Ocean Data Analysis System) for MERSEA (Marine Environment and Security for the European Sea), which is a key component of the Ocean and Marine Applications for GMES (Global Monitoring for Environment and Security).

Table 1: *WRF simulation conditions.*

WRF	Option
Version	3.011
Microphysics	3-class WRF
Radiation	RRTM
LSM	Noah
PBL	Yonsé Univ.
Cumulus	Kain-Fritsch

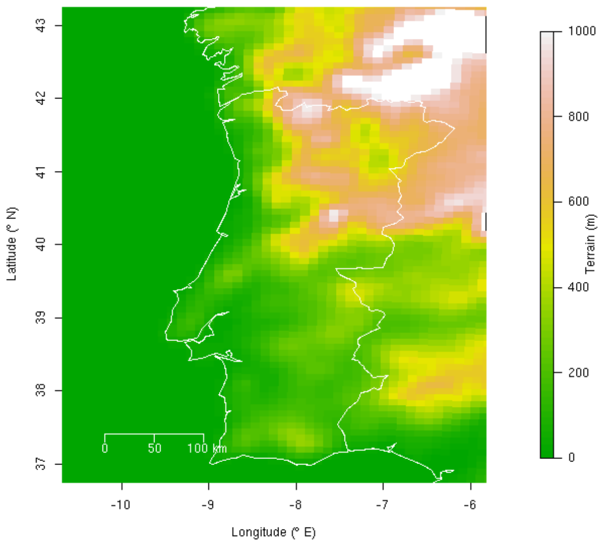

Figure 1: *Terrain of the domain used in WRF simulations. Resolution is 9 km, with* $88 \times 54 \times 27$ *grid points*

August 2008 was characterized by and intense and prolonged upwelling episode on the Portuguese coast, due to the permanent northerly winds caused by the combined action of the Azores High (to the west) and Thermal Lows that form in the Iberian Peninsula (to the right of the Portuguese Coast) (see figure 3). These winds can be strong particularly in the late afternoon due to continental heating.

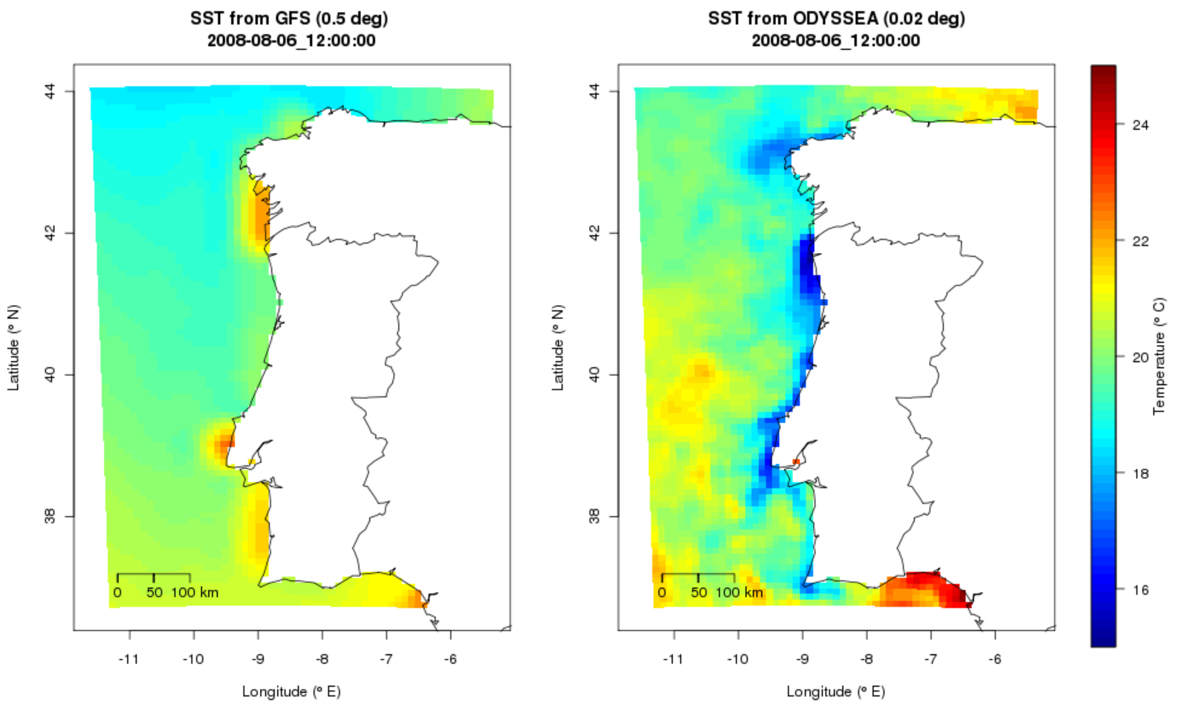

Figure 2: *SST used to force the WRF simulations in the twin experiment. Left: constant SST given by the GFS model. Right: daily SST image for 2008-08-06 given by ODYSSEA. In both images, SST is interpolated to 9 km resolution.*

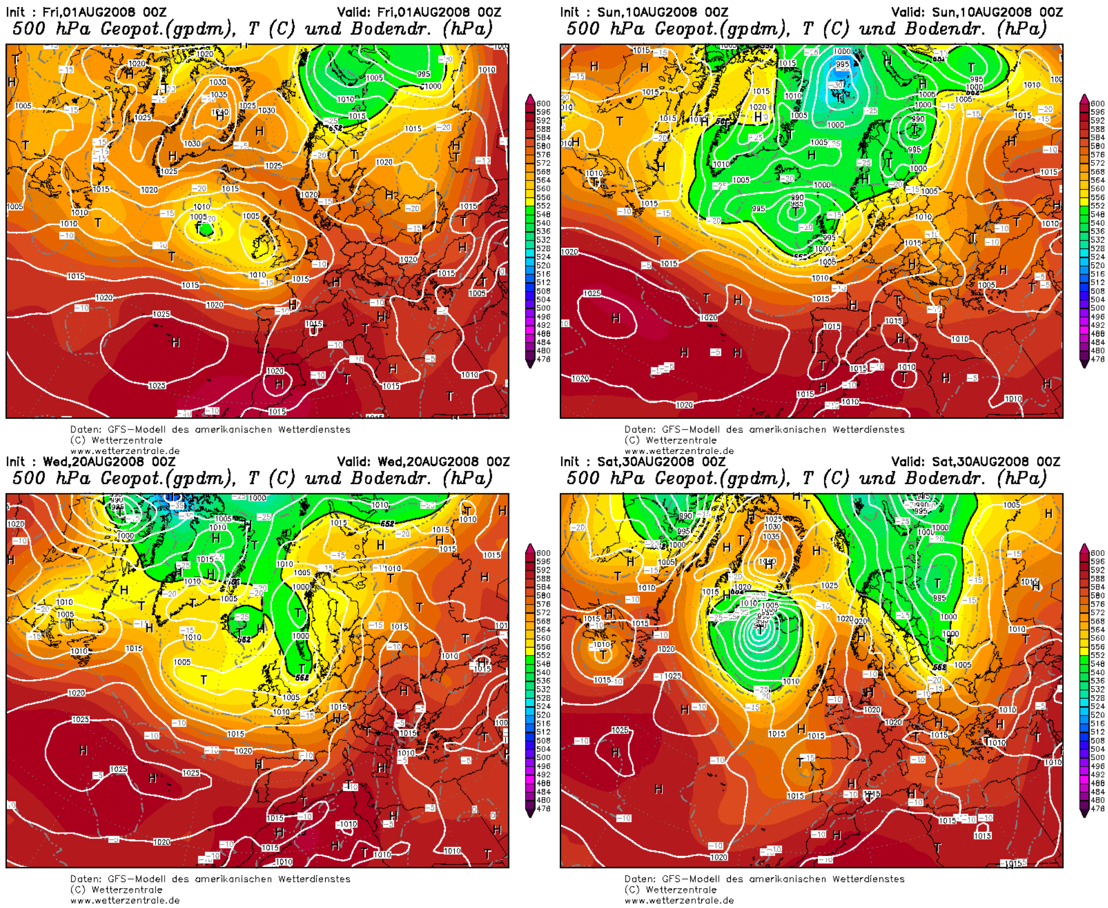

Figure 3: *Synoptic situation in August 2008, days 1,10,20 and 30 at 00:00 UTC given by the global model GFS reanalysis. Colour: 500 hPa geopotential(gpdm), White contours: Pressure at surface (hPa), Dashed gray contours: air temperature (° C); . Source:* `http://www.wetterzentrale.de/topkarten/fsavneur.html`

3 Results

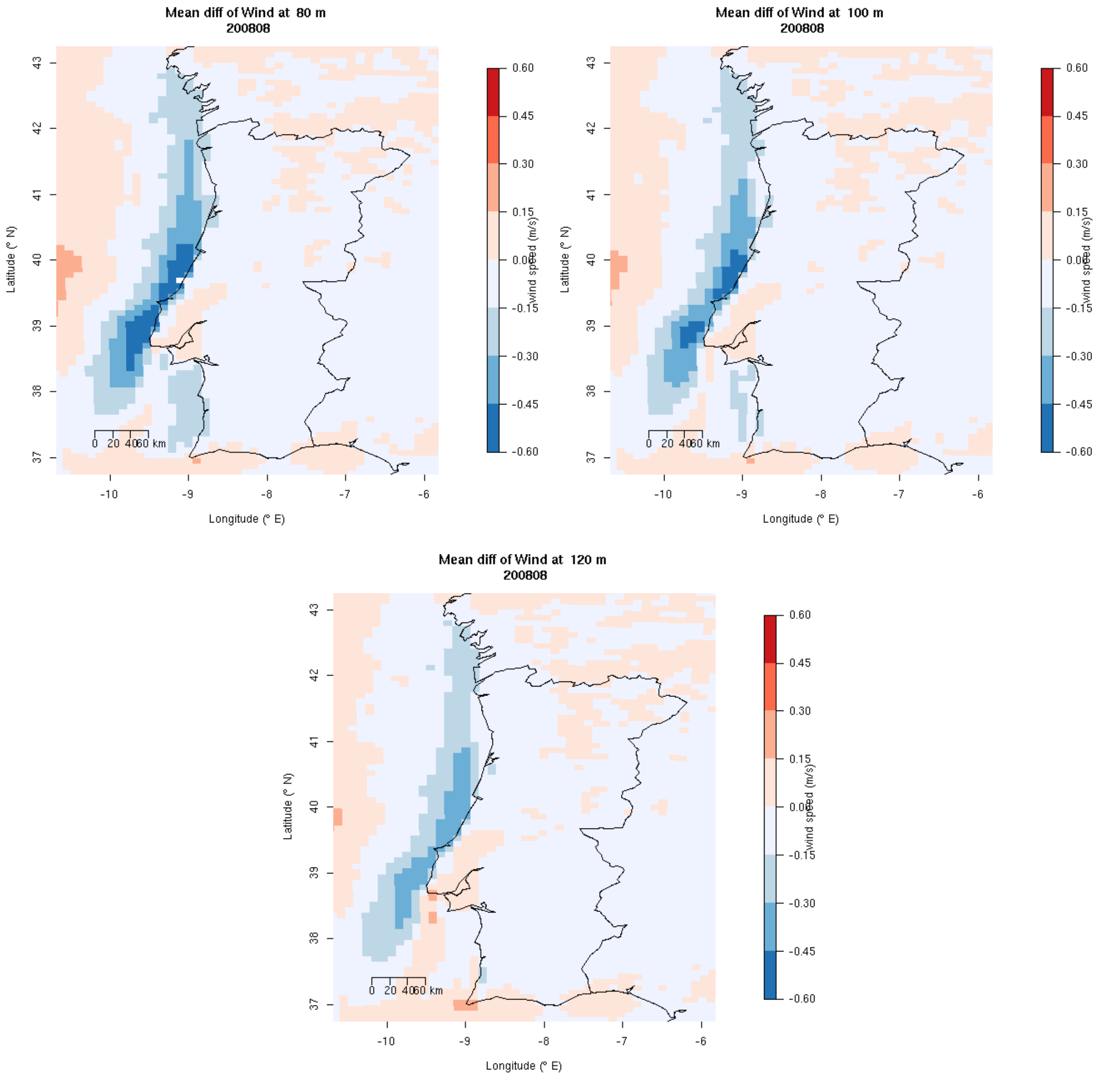

Figure 4: *Mean wind speed difference ($\overline{V_{ODYSSEA} - V_{GFS}}$) for the month of August 2008, and for turbine height 80 (top left), 100 (top right) and 120m (bottom).*

Figure 4 shows the mean wind speed difference ($\overline{V_{ODYSSEA} - V_{GFS}}$) for the month of August 2008, and for turbine height 80, 100 and 120m, the probable heights of offshore turbines. Vertical interpolation of wind was made by fitting a polynomial of degree 2 to the nearest bottom and top two layers (3 points). It can be seen that there's a decrease in wind speed in the upwelling area, and this difference can go up to 0.6 m/s. The difference between the upwelling and the control simulation decreases as we increase vertical distance.

Looking at the mean wind speed for 80 m (figure 5) it can be seen that, for example, near

Figueira da Foz, where the mean wind speed is aproximately 6 m/s, the difference is -0.6 m/s, i.e. a 10% difference. Just to have an idea of the importance of this difference in terms of wind power, and following the conclusions in Lange (2005), that says that and error in wind speed more than duplicates in terms of wind power, it can be said that a 10% difference in wind speed can produce a 20 % difference in wind power, e.g. 100 MW in 500 MW.

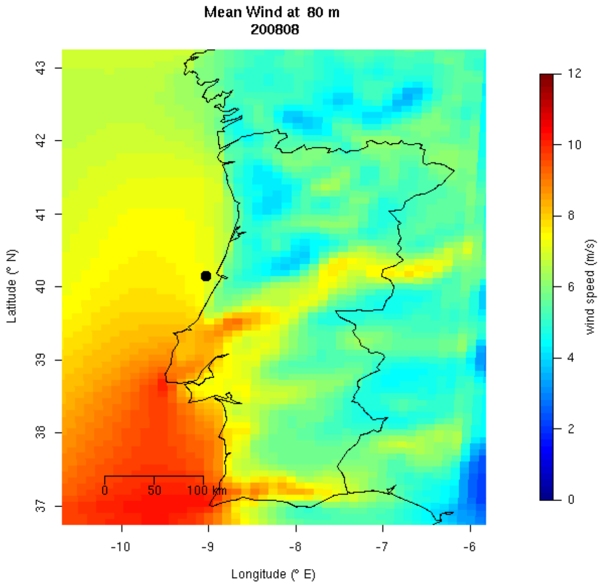

Figure 5: *Mean wind speed for the control run (SST by GFS) for the month of August 2008, and for turbine height 80m. The black dot is the location of Figueira da Foz.*

Further looking at the SST influence on wind speed , it can be seen from figure 6 (top) that the mean vorticity decreases nearshore, meaning that the wind direction has rotated clockwise. This is consistent with the decrease of the mean zonal[1] component of the wind (same figure, bottom left). The overall wind speed decreases because the meridional[2] wind speed also decreases (same figure, bottom right). In this case the component is negative (northerly winds) and the difference being positive means that they are less negative, and thus less stronger.

The decrease in speed and rotation of direction of wind is related to the influence of SST in stability of the atmosphere. As can be seen from fig. 7, in the lower layers of the atmosphere the atmosphere is stable with upwelling, whereas was neutral/unstable without upwelling. This influence goes up to 200m, and thus affects wind power offshore forecasts and resource assessment.

[1]following parallels, positive to east
[2]following meridians, positive to north

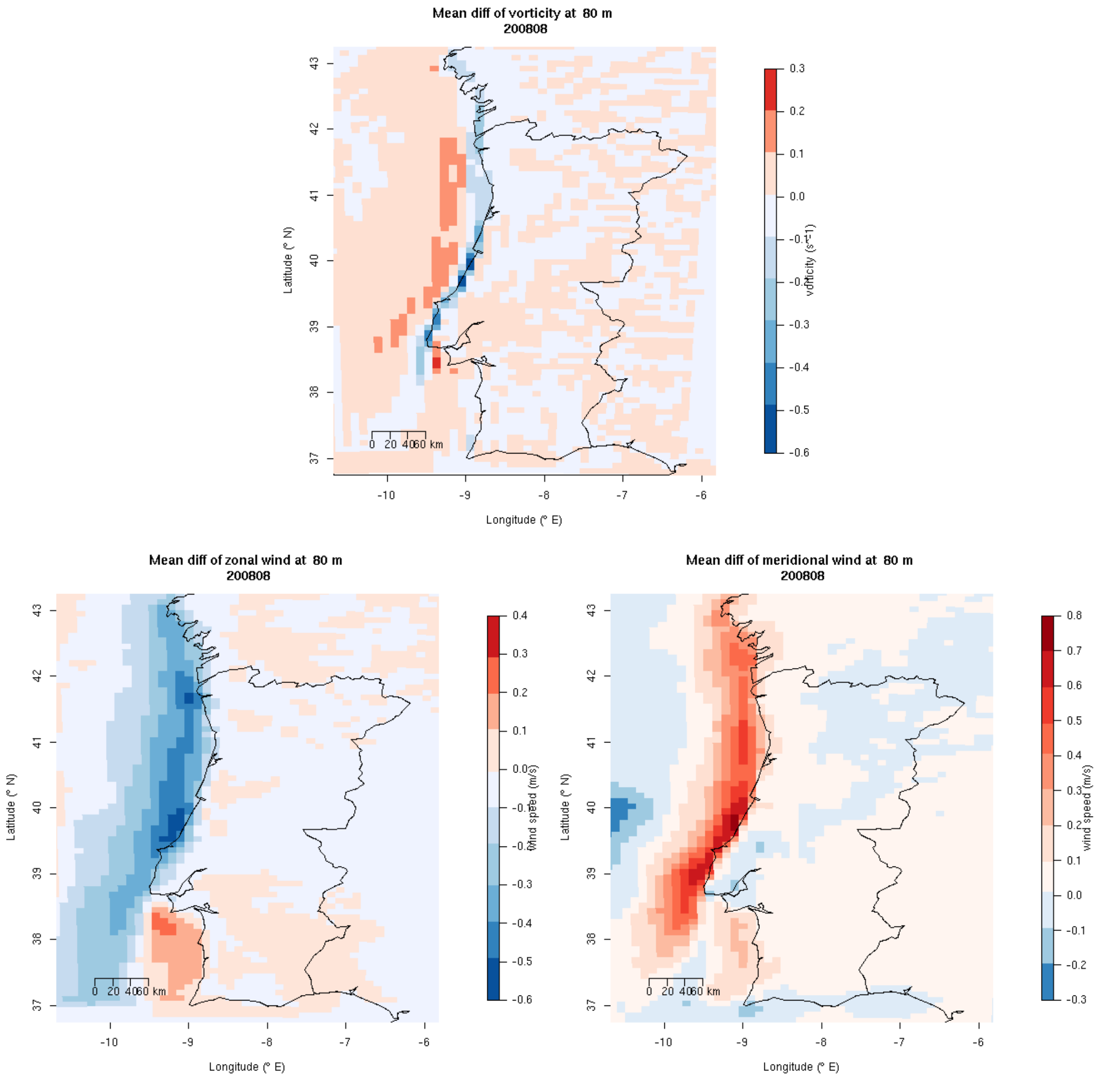

Figure 6: *Mean differences* $(\overline{X_{ODYSSEA} - X_{GFS}})$ *for the month of August 2008 and for turbine height 80m: top is vertical vorticity, bottom left is the zonal wind and bottom right is the meridional wind.*

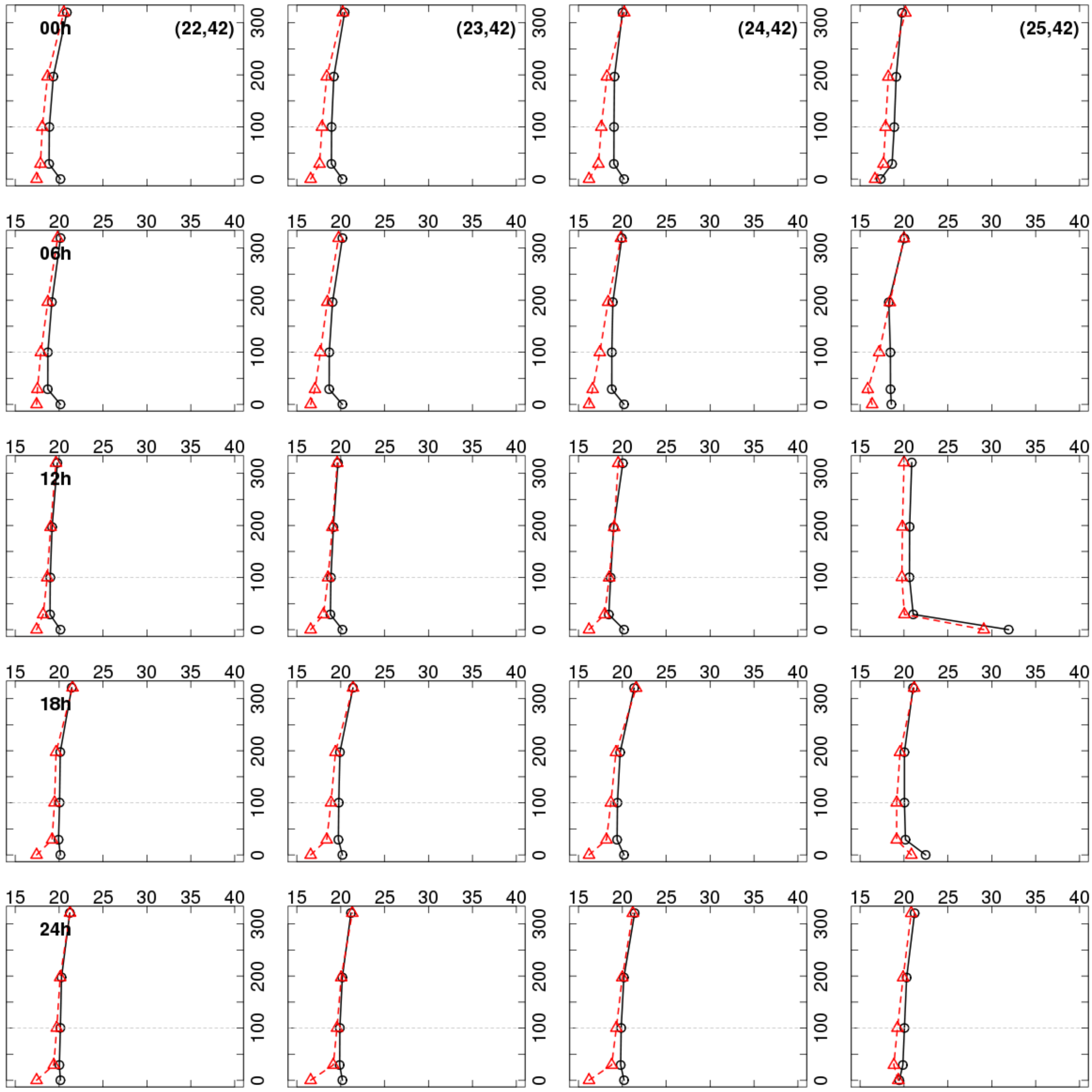

Figure 7: *Vertical profiles of potential temperature with height. From left to right, each graph is for three grid points near Figueira da Foz (see location in figure 5), being the leftmost graph an inland point, and the other three into the sea. From top to bottom, each graph is the profile for 00h, 06h, 12h and 18h (UTC).*

4 Conclusions

From the results discussed above, it can be seen that offshore wind forecasting presents different challenges than onshore, both in terms of the underlying physical processes but also in computational costs if it is to couple to an ocean model that can provide realistic SST to the atmospheric model. The twin experimen indicates that there is a positive feeback of SST in winds, e.g., a decrease in SST causes a decrease in the nearshore wind speed, and that the influence of SST in stability is stabilizing effect that can go up to 200m, well within the range of wind power turbines. Also, there seems to be a clockwise rotation of the northerly winds, which could weaken the transversal sea breeze, but this results are preliminary and further study is needed. However, it can be concluded that, in upwelling areas, offshore wind resource assessment and forecasts should take into account sea interaction, otherwise they can be too optimistic.

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