Mesoscale modelling methodology based on nudging to reduce the uncertainty of wind resource assessment

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Abstract

In the current study, the steps that should be taken to improve the accuracy of the mesoscale models offshore are addressed with focus on the observational nudging technique applied to different stability conditions. It tackles the challenges in the Wind Resource Assessment (WRA) by supporting offshore wind farm projects with a multi-scale approach. Flow modelling uncertainty is an especially important contributor to the total uncertainty in the WRA of the offshore sites, however this uncertainty is rarely quantified rigorously and is often overlooked, leading to unnecessary risk for the project owner, developer, investor, or lender.

Nudging WRF with FINO3 Met Mast observations and validating the model on the neighboring FINO1 showed that this data assimilation technique can improve the accuracy of the model simulation and reduce the uncertainty. The overall root mean square error has been reduced by 12% using observational nudging.

Context

Wind modelling is an important part of wind resource assessment as the cost of offshore wind measurement is very high. However, mesoscale models remain less accurate than on-site measurements. Therefore it is crucial to increase wind modelling accuracy in order to reduce the global uncertainty of offshore wind resource assessment and consequently reduce the cost of offshore wind projects. This study presents a way to reduce this wind modelling uncertainty using observational nudging, as a method.

Objectives

In this study, a way of reducing uncertainty has been defined and assessed with focus on offshore wind farm applications. The present study aims to:

• Accurately simulate the wind flow occurring offshore over the North Sea using observational nudging on Weather Research and Forecasting (WRF) mesoscale model
• Distinguish the influence of observational nudging with respect to atmospheric stability conditions.

Methods

The Objective Analysis (O.A) aims to improve the background field analysis or first guess that will be assimilated to the model. FINO3 6-hours average wind speed observations are incorporated into the model grid by using 135km radius of influence at 30, 60 and 100m heights corresponding to the first three levels of the model. Using Cressman interpolation, O.A. can calculate the weighted average of the observed increments within a radius of influence R surrounding the grid point (C.).

\[
C_{i,j} = W_{i,j}E_{i,j} = \frac{R_i^2 - d_i^2}{R_i^2}
\]

Where \(E_{i,j}\) is the error between the background field value and the observation, \(W_{i,j}\) is the weight calculated by R and d, the radius of influence and the distance between the observation and the grid point respectively. Finally the O.A. Analysis and observations files will be used by WRF to nudge its simulated values towards the observations by using a nudging coefficient in a fixed time-step. This is the observational nudging.

The WRF model setup is based on a study [2] that has compared different PBL schemes, spatial resolution and nesting methods validated with FINO1 measurements. The lowest error is achieved by using MYNN PBL scheme, 3 km spatial grid resolution and 2-way nesting.

To illustrate how sensitive is WRF observational nudging to stability conditions, two cases for both stable/neutral and unstable conditions were tested in the present study. The investigation of the stability conditions were conducted with respect to Richardson number (Ri).

\[
Ri = \frac{\left| g \left( \Delta T \right) + \Delta z \right|}{\left( \Delta T \right)^2 + \left( \Delta z \right)^2}
\]

Where g is the gravitational acceleration, Gd is the dry adiabatic lapse rate, Tv is the potential temperature, \(U\) and \(V\) are the horizontal wind components at two heights and \(z\) is the height.

Results

In order to compare both WRF model with and without observational nudging, statistic metrics have been used. These metrics are:

• the bias or Mean Error (ME),
• the standard deviation of Error (STDE),
• the Pearson correlation factor (R) and
• the root mean square error (RMSE)

The error is defined as the difference between the observation and the model at FINO1. Using the above statistic metrics, the WRF model with and without observational nudging from FINO1 have been compared with observational measurements from FINO1 at two heights: 60m and 100m. This comparison has been done for three different atmospheric stability situations: for stable/neutral condition only, for unstable condition only and for a period with both stable/neutral and unstable atmospheric conditions. Globally we can observe a reduction of around 12% of the root mean square error (RMSE) using the WRF model with observational nudging.

Time series from observation at FINO1 at 100m and WRF model with and without nudging are also presented for June 2012. It confirms visually that results from WRF with observational nudging are closer to FINO1 observations than the WRF model without observational nudging.

Conclusions

Lower bias and lower standard deviation of the error (STDE) can be achieved by an observational data assimilation technique nudging wind speed observations from FINO3 at three different heights. Decreasing bias and STDE decreases the RMSE and subsequently reduces the uncertainty of the wind flow model. In our specific case the RMSE has been reduced by 12% at 100m. The current study shows the principle of the data assimilation using observational nudging. Our future plans in order to apply the technique in an operational way are to:

• Test observational nudging for a longer period in order to display how it affects the seasonal variations;
• Nudge the model using more than one station or Met mast;
• And nudge several variables

References