DTU Library

A Coupled Atmospheric and Wave Modeling System for Storm Simulations

Du, Jianting; Larsén, Xiaoli Guo; Bolanos, R.

Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

PO.ID 181

A coupled atmospheric and wave modeling system for storm simulations

J. Du, X.G. Larsén, R. Bolaños-Sanchez

Wind Energy Department, Technical University of Denmark, Risø Campus, Roskilde, Denmark. jitd@dtu.dk

DTU

Abstracts

This study aims at improving the simulation of wind and waves during storms for wind turbine design and operations in coastal areas. For this particular purpose, we investigated the Coupled-Ocean-Atmosphere-Wave-Sediment Transport (COAWST) Modeling System which couples the Weather Research and Forecasting (WRF) Model with the third-generation ocean wave model (SWAN). A nested function is used in the system. To understand the impact of the interface parameter, the roughness length z_0 , on the modeled storm wind and waves, several approaches for parameterization of z_0 were tested with three chosen storm cases, followed by validation with wind and wave observations. It is found that the system captures in general better strong wind and strong wave characteristics for open ocean condition than for the coastal condition. The wind range during these three storms is not sensitive to the roughness length parameterizations. It was also found, with the current model setup, using high resolution gives better results for strong winds both for the open ocean and coastal sites, but the effect on waves is not conclusive. High resolution bathymetry data will be used in future studies to get a better insight of this.

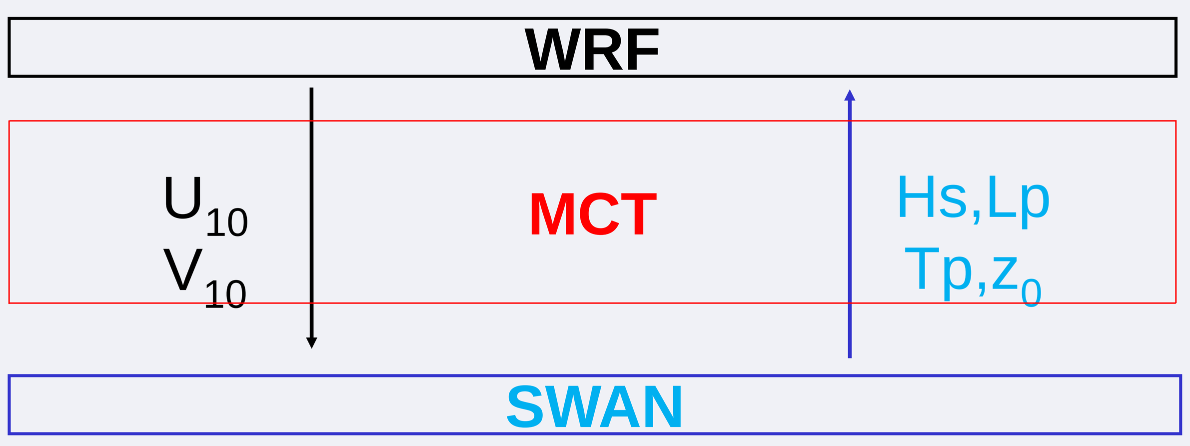
Research Question

What is the optimal setup of a coupled system such as COAWST for the mid-latitude storm modeling? Will the nesting function improve the modeling? What is the best parametrization for z_0 ?

Model Seetings

Name	Resolution	z_0	Coupling
NCPL25	25km	Fairall et al(2003)	Off
NCPL5	5km	Fairall et al(2003)	Off
FCPL25	25km	Fan et al(2012)	On
FCPL5	5km	Fan et al(2012)	On
JCPL25	25km	Janssen(1991)	On
JCPL5	5km	Janssen(1991)	On

Using COAWST version 3.1(Warner, J.C., 2008)
In which, the model coupler is MCT v2.6.0(Model Coupling Toolkit).
Two models are turned on:
WRF v3.6.1(Weather Research and Forecasting Model)
SWAN v40.91A(Simulating WAves Nearshore)
One-way nested, two domains in WRF, with the horizontal resolution from 25km to 5km.
One-way nested, two domains in SWAN with the resolution of 1/8deg. and 1/16 deg.
Initial and boundary condition for WRF is 1x1 deg. Every 6 hours NCEP FNL data.
SWAN initials from zero spectra. Open boundarys are set to Jonswap spectrum with Hs=2m, Tp=8s, Dir=270deg.
Time step for WRF is 100s for the outer domain and 20s for the inner domain.
Time step for SWAN is 300s for the outer domain and 100s for the inner domain.
The data exchange frequency between the two models is every 300 seconds.
During the coupling, WRF transfers U_{10} and V_{10} to SWAN while SWAN transfers H_s, T_p, L_p,and z_0 to WRF.



Remapping

The remapping weights between the two models are calculated by SCRIP—A Spherical Coordinate Remapping and Interpolation Package. The model domains and remapping approach is shown in Fig.1.

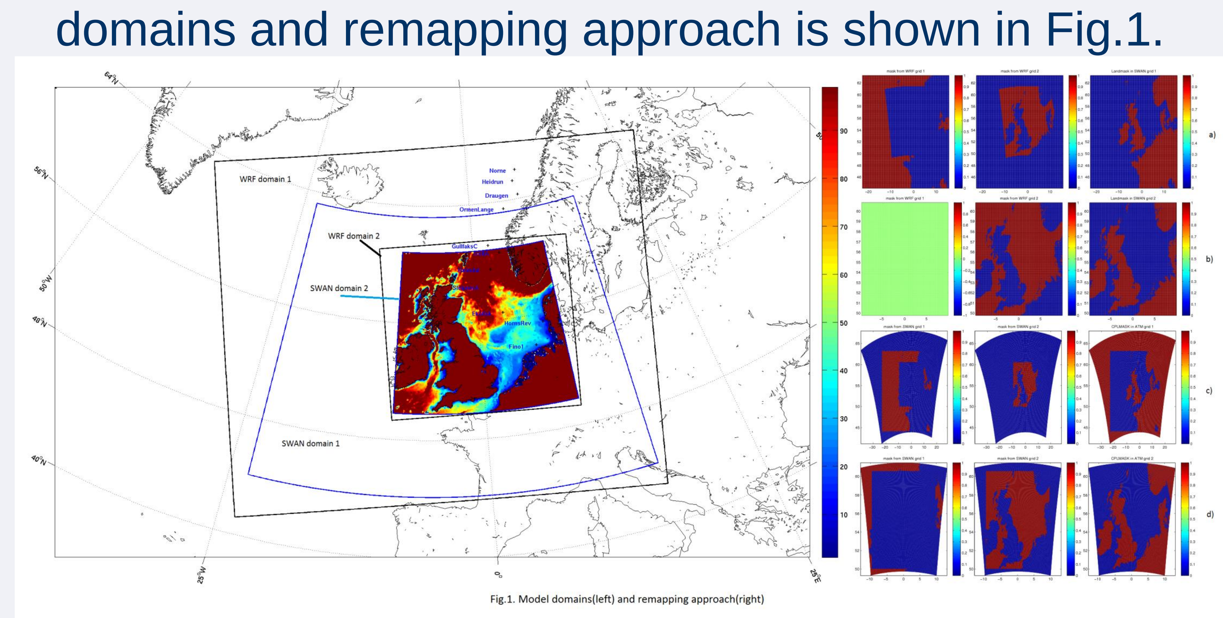


Fig.1. Model domains(left) and remapping approach(right)

Roughness Length Schemes

In this study the z_0 schemes include Fairall et al(2003), Fan et al.(2012), and Janssen(1991) schemes.
Fairall et al(2003) is not coupled. The fixed value of the Charnock parameter (α=0.011) has been replaced by one with a simple wind-speed dependence above 10 m/s.
Fan et al(2003) is coupled. The Charnock parameter is fitted by wave age.
Janssen(1991) is also coupled. SWAN uses Janssen's wind input source function. It gives out a z_0 which will directly used by WRF.

Three storm cases

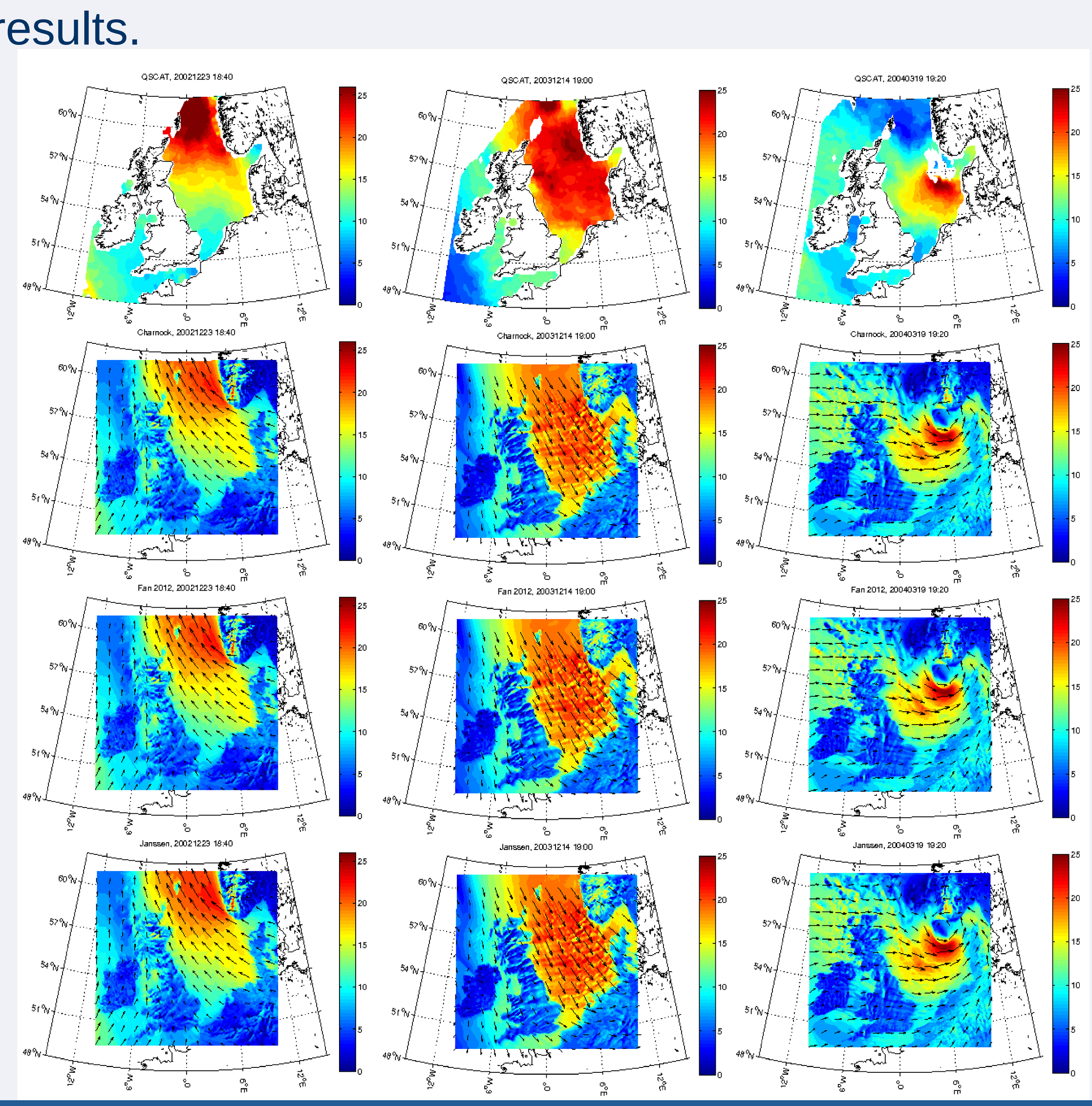
Three storms were tested. They are:

2002/12/22 ~ 2002/12/25, which is an offshore case at Horns Rev. The wind direction mainly from southeast to northwest.

2003/12/14 ~ 2003/12/16, which is an onshore case at Horns Rev. The wind direction mainly from northwest to southeast.

2004/03/19 ~ 2004/03/23, which is another on shore case at Horns Rev. The wind direction mainly from southwest to northeast.

One snapshot for each storm is shown by QSCAT wind speed(25 km horizontal resolution) as well as model results.



Results

From the simulations, the statistics of wind speed and wind direction at measurement heights, roughness length, the drag coefficient, the significant wave height, the wave period, wave age and wave steepness were calculated for a number of sites (see Fig.1). Here, the wind speed and direction at measurement height and the significant wave heights are presented for one open ocean, deep water site Ekofisk and one coastal, relatively shallow water site Horns Rev. The simulation and measurements are shown in Figure 3 and 4 for Ekofisk and Horns Rev, respectively. The spatial distribution of the modeled wind field at 10 m has been compared with all existing QuikScat data at corresponding time stamps. Fig 2 shows one snapshot from each storm.

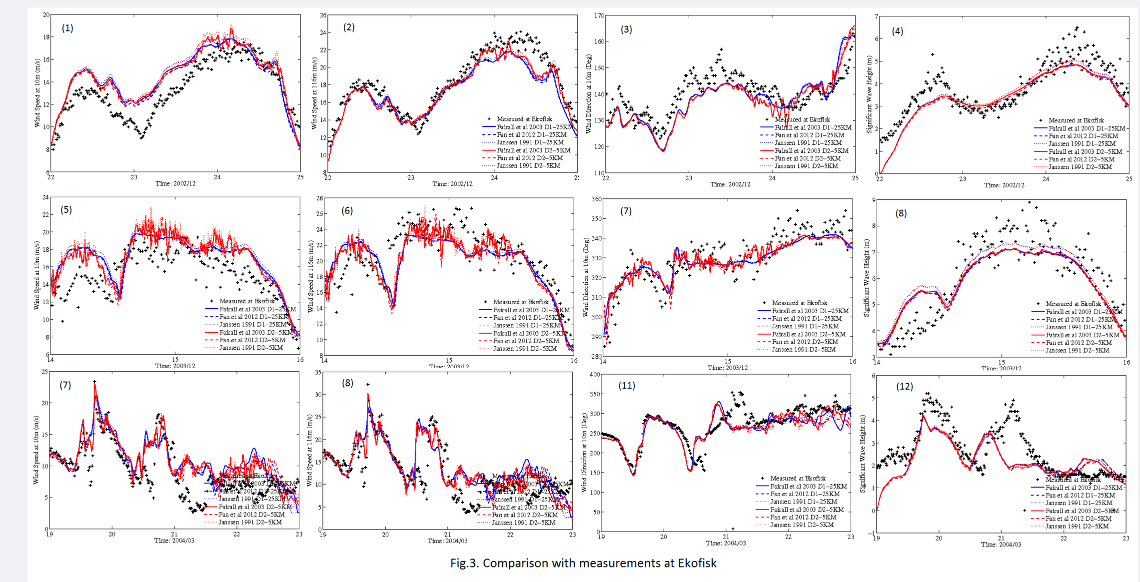


Fig.3. Comparison with measurements at Ekofisk

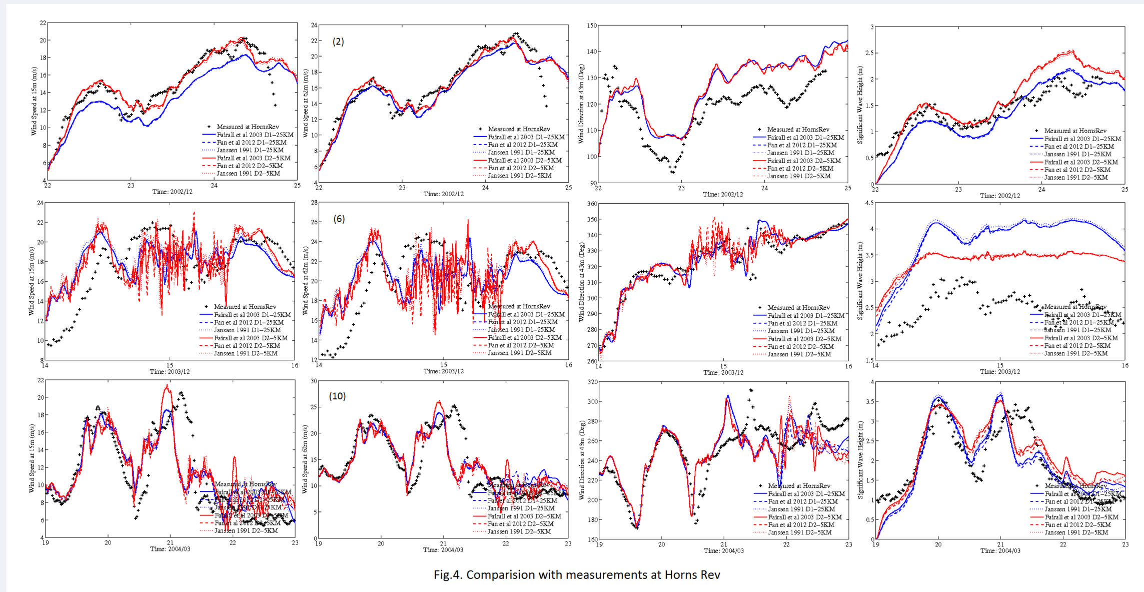


Fig.4. Comparison with measurements at Horns Rev

Conclusions

Validation of modeled wind and wave fields using the nested COAWST system with point measurements as well as QuikScat data suggest the following:

1) The modeling system does better for storms of certain strcture than the other (it performs better for storms from the west than for storms from the north).

2) The storm wind field favors from the nested, high resolution modeling.

3) The system is not sensitive to various roughness length parametrization schemes for the wind speed range from these three storms.

4) The modeling is better for the open ocean site than for the coastal site.

Further investigation will:

1) use higher resolution tests for the coastal zone

2) include more severe storms

3) use different large scale atmospheric forcing, such CFSR data

4) use very high resolution bathymetry data for the coastal area

5) examine heat exchange

6) include ocean model

Acknowledgement

This study is funded mainly by the Danish Forskel project X-WiWa (PSO-12020). The second author acknowledges the EU INNWIND project for the support.

References

1. Warner, J.C., Sherwood, C.R., Signell, R.P., Harris, C., Arango, H.G., 2008b. Development of a three-dimensional, regional, coupled wave, current, and sediment-transport model. Computers and Geosciences, 34, 1284-1306.
2. Warner, J.C., Armstrong, B., He, R., and Zambon, J.B., 2010, Development of a Coupled Ocean-Atmosphere-Wave-Sediment Transport (COAWST) modeling system: Ocean Modeling, v. 35, no. 3, p. 230-244.
3. Fairall, C. W., E. F. Bradley, J. E. Hare, A. A. Grachev, and J. B. Edson, 2003: Bulk parameterization of air–sea fluxes: Updates and verification for the COARE algorithm. J. Climate, 16, 571– 591. Journal Article, Name of Journal
4. Fan, Yalin, et al. "Global ocean surface wave simulation using a coupled atmosphere-wave model." Journal of Climate 25.18 (2012): 6233-6252.
5. Janssen, P.A.E.M., 1991: Quasi-linear theory of wind wave gen- eration applied to wave forecasting. J. Phys. Oceanogr., 21, 1631–1642.