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Wave forecasts for the Faroese Shelf: What are our options?

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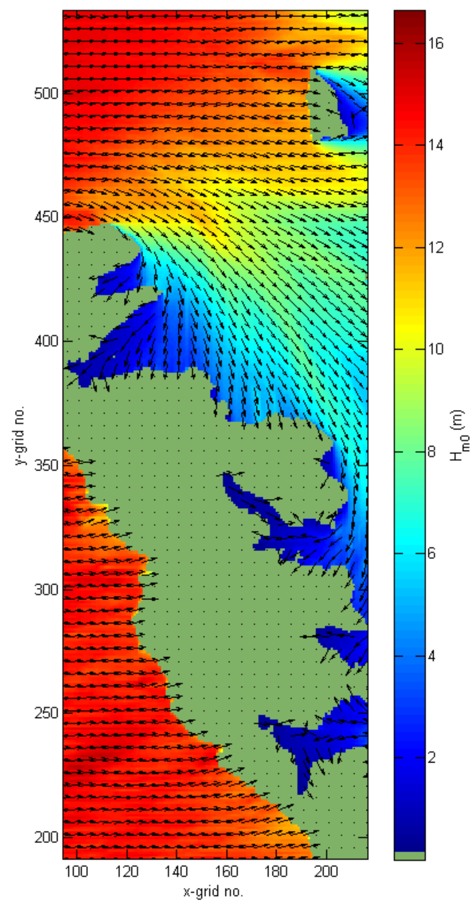

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Abstract

Wave conditions on the Faroese Shelf can become quite rough due to severe wave climate and strong tidal currents. It has therefore for some years been hoped that an operational wave model service could be established for the Faroese Shelf.

Research has been conducted at the University of the Faroe Islands for the last few years that has aimed towards implementing a local operational wave model. In this note we have summarize where we are in this process and discuss where we can go from here.

Introduction

Due to the long fetches and the frequent passings of deep low pressure systems, the offshore wave conditions around the Faroe Islands are among the roughest in the world. Strong tidal currents in the coastal waters can cause smaller vessels to experience potential hazardous wave conditions even in fair weather. Local sailor experience has been handed down trough the generations and some of this information has been documented in graphical charts (Heinesen, 1985).

To improve the safety of local seafarers, a wave- and current-measuring program was started in 1979 (Davidsen & Hansen, 1981), which since then has provided near-real time radio broadcasts of the measured wave height. These measurements are also made available online at the web pages of Landeverk (http://landsverk.fo/ sub page "Aldumátingar") and Data Quality (www.dq.fo sub page "Directional Waverider" under "FOIB-projects"). A historical review of local wave measurements can be found in the report by Heinesen (2001).

Today the area around the Faroe Islands is included in several operational regional wave models. Some of them are publicly available (e.g. www.yr.no, www.sigling.is, http://polar.ncep.noaa.gov/waves/main_int.html and http://ocean.dmi.dk/).

The existing operational models do not, for the time being, include the effects of the fine-scale bathymetry and currents in the coastal regions of the Faroe Islands.

In recent years knowledge of the bathymetry on the Faroe Shelf has improved significantly (Simonsen et al. 2002) and a numerical model capable of predicting the local tidal currents has been constructed (Simonsen, 1999).

The aim of the work done since then has been to utilize this new knowledge and the existing knowledge of wave modelling to work towards a local high resolution wave model.

What have we learned?

Finding proper validation data

Tidal currents are, as mentioned above, known to play an important role in the wave conditions on the Faroese shelf. One difficulty in this respect is that no wave data is available from these locations where the influence of the currents is greatest. This made it difficult to find suited data for validating a wave model that included the effect that the currents have on the waves. Available wave data was investigated, and investigations showed that some suited current induced modulations were recorded by the buoys in the operational wave measuring program (Niclasen & Simonsen, 2005a). These investigations also showed that some of the moorings used in the operational wave measuring program were too rigid and these could induce false recordings of current induced changes in the wave field (Niclasen & Simonsen, 2005b, 2007a).

Finding suited wave model forcing

European Centre for Medium-range Weather Forecasts (ECMWF) is the main supplier of wind and wave model forcing in our region, and a validation study showed that their model gave good results compared to local measurements (Niclasen, 2006; Niclasen & Simonsen, 2007b). Wind and wave forcing from ECMWF were therefore used when setting up and testing local implementations of a wave model.

At the time when this study started the third generation wave model SWAN (Ris, 1997; Booij et al., 1999), was chosen as it could include nonstationary depth averaged currents, and had a large and active user group. Idealised model tests also showed (Niclasen & Simonsen, 2005c) that this model seemed to capture dangerous wave conditions as they are reported in local sailing charts (Heinesen, 1985).

Finding the best physical parameterisation

SWAN was implemented and hindcasts compared to local wave measurements. Also comparability between model and forcing model, at the model boundaries were investigated. The result was that SWAN with WAM3 physics, using a retuned dissipation source term, gave the best results with respect to measurements, forcing model and current induced changes (Niclasen, 2006). This study confirmed, although under much different settings, some of the findings in Rogers et al. (2003).

Computational problems
The University of the Faroe Islands owns a small Linux cluster named 'Teyggjan' (Joensen et al. 2007) which has been used for these wave model runs. Due to severe support difficulties the cluster could not run SWAN in parallel mode before 2007, and the model testing done in Niclasen (2006) were all done in serial mode. Keeping the time limit of the project, this meant that the numerical framework of SWAN had to be stretched beyond common recommendations in the high resolution model runs. Since parallel computations became possible in 2007 all the high resolution runs reported in Niclasen (2006) have been redone with proper numerical settings. The new model runs support all the high resolution model findings in Niclasen (2006), with exception of single source term investigations. This means that the alleged counteraction of S_{nl} source term on the influence that the tidal current has on the wave field, as it is reported in Niclasen (2006), is not accurate. This unfortunately also means that there does not seem to be any clear explanation for why the wave model cannot reproduce the measured tidally induced variations in the T_{m02} mean wave period.

Computational cost vs. accuracy in nonstationary mode
Tests have been conducted to see if it is possible to run a local operational wave model on Teyggjan. Running a local nonstationary model (including nonstationary tidal currents) with a close to 1km spatial resolution, would be possible but some accuracy had to be traded for computational speed.

The difference of running SWAN with recommended propagation termed S&L (high accuracy in nonstationar runs and large domains) and running SWAN with BSBT (implicit and very diffusive) only rendered a marginal difference, as long as the time steps were equal. The strength of the BSBT propagation is that it can run with very high CFL values i.e. coarse time steps and computation time can thus be reduced. There was nevertheless observed a clear trade-off between time step (using BSBT) and model accuracy. The model can run with a time step of 30 minutes, and still give good comparison with measured wave data. In this case the trade-off was a loss of dynamical effects, such as accumulation of wave energy in one area in opposing currents that subsequently was released, as a region with increased wave height, when the currents changed direction.

Due to several narrow fjords, which the wave field can pass trough, the so called garden-sprinkler effect was quite visible. The best option would be to increase directional resolution and add diffusion, but to save computational power only 36 directions could be included and a diffusion corresponding to a waveage of 120 minutes (see definition in SWAN manual) was necessary to insure a realistic smooth wave field after the waves had travelled trough the narrow fjords. The garden-sprinkler issue was present but to a much lesser extent in the BSBT runs.

All in all running SWAN with BSBT propagation and a time step of 5 minutes seemed to be the most appropriate compromise. If explicit propagation was used, a time step in the range of 30 seconds had to be used for the same model setup. Using BSBT and 5 minute time steps, it would take approximately one hour for each forecasted day, if running 9 processes on Teyggjan. The operational range would therefore at most be 48 hours as the forecast aught to be updated each 6-hours.

Stationary model v.s reality

The SWAN model has the option of running in stationary mode. This means that it is assumed that the incoming wave field, wind field and current field are assumed to be constant. This is a viable assumption for small areas, and a rule of thumb is that the model size should be 20 km or less. A local model for our area is almost an order of magnitude larger than this, so it is clear that some accuracy is lost when using this option. There would be no dynamical effects but the most important effect of the currents, i.e. the increase of the wave height in opposing currents and the steepening of the wave field in such cases would still be captured. In order to have a semi continuous forecast, that would resolve e.g. changes in the current directions, outputs aught to be generated once each half hour. As a stationary run typically is properly converged after 5-10 iterations (one iteration takes similar time as one time step in a nonstationary run), it is clear that there is no computational savings in using this option over the nonstationary compromise mentioned in the previous section.

If the influence from the currents was neglected, there would potentially be significant computational savings in using the stationary run type, as one model output for each 3 hours most likely would be sufficient.

There are several comments that need to be mentioned in relation to stationary model runs. The first is of course the assumption that the wind and incoming wave field can be considered constant for the time it takes the waves to travel across the model domain. In deep water the propagation speed of a monochromatic wave is $c=gT/(2\pi)$, where T is the wave period. Using the average value of the T_{m02} wave period, which is as recorded to be in the range of 6.4s (Niclasen & Simonsen, 2007a), and an estimated model size of 150km, this gives a time span of 4.2 hours. Assuming that the wind and the waves are constant for more than four hours is not ideal. On the other hand, this approximation is commonly used in other applications e.g. when deriving wave climate statistics (conditions often assumed stationary in 3-6 hour intervals). The assumption is frequency dependant and is more accurate for lower frequencies and correspondingly less accurate for higher frequencies. The major problem with this type of stationary wave modelling on the

Faroese Shelf, is that the tidal currents are known to be important, and these can only be assumed to be constant in time windows shorter that about one half hour.

Passive database forecasting

It is possible to do wave forecasts for an area without running an operational wave model. This is possible if several idealised model runs are computed in advance and the only operational action is to find the idealised model run which forcing resembles reality the most. A series of such model runs, without currents, have been calculated for the southern part of the Faroe Islands (Niclasen & Simonsen, 2009) spanning 16 directions and 18 wave heights (i.e. total 288 idealised model runs). One example showing a section of the model domain is given below in Figure 1. The big advantage in this type of modelling is that they can be conducted with much higher spatial and directional resolution than the unstationary operational model setups mentioned above. Using this type of modelling (and disregarding currents), it is possible to run a model that spans the entire inner shelf with a spatial resolution of 100m.

There are several issues that need to be mentioned in relation to using such idealised model runs as a forecasting database. Firstly they are stationary i.e. they cannot capture dynamical changes in wind, wave or current field. The major difficulty is as mentioned above the current field which cannot be assumed to be stationary in the time interval it takes the waves to travel across the model domain. Secondly the wave conditions are approximated by some idealised wind wave scenario where all boundary conditions are essentially equal i.e. no incoming swells.

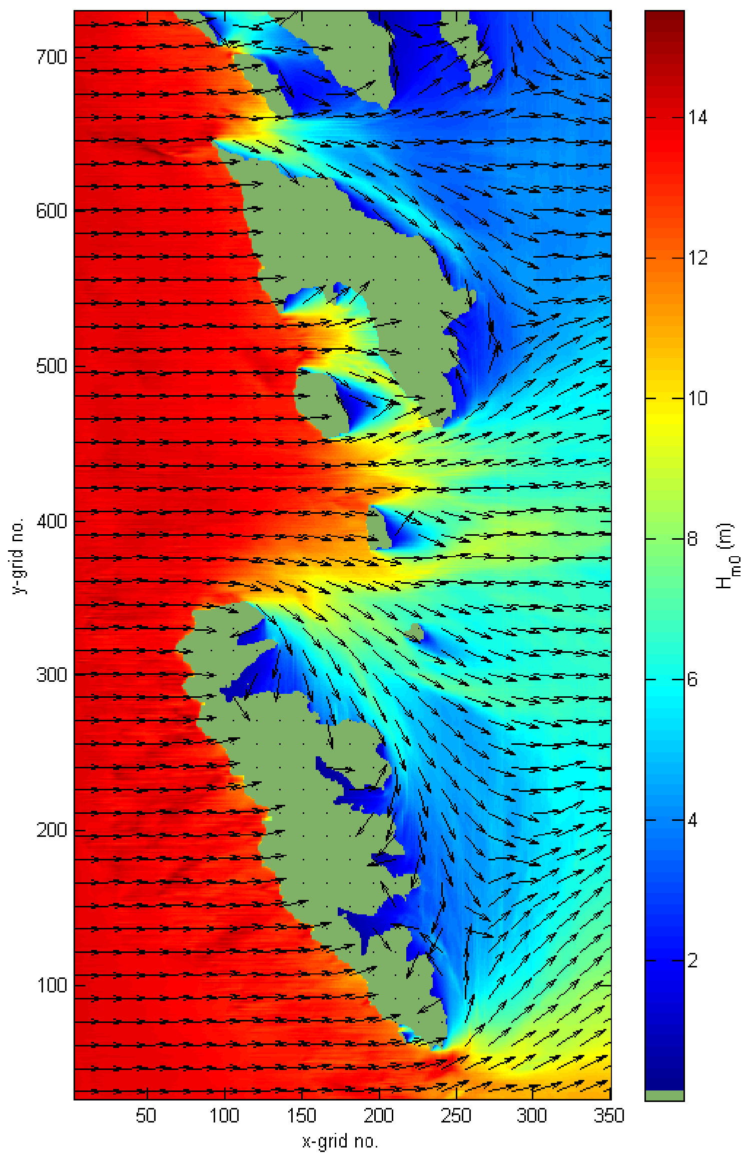

Figure 1 Example (zoom plot) of one idealised model run where that waves and wind come from the west.

Operational output parameters

During the project spanning from 2006-2008, a review was conducted of operational wave parameters that could be linked to vessel safety (Niclasen et al. 2009). In that study a series of interesting parameters were mentioned, but recognizing the total lack of operational wave forecasting in the inner Farese Shelf, only primary parameters such as wave height and direction will be considered in the first attempt.

What are our options?

There is at present no governmental agency, or private company for that matter, that have the necessary computational power to run a dynamic (nonstationary) wave model forecast for the Faroese Shelf. There is a small cluster at the University, that could satisfy the minimum requirements, but the setup, stability and support of the system does not make it suited for operational purposes. There is also a substantial financial aspect of running an operational service, and at present there is no such funding neither governmental nor private.

If there was funding for this type of service, it could be established locally, but it could also be outsourced. We have been in contact with a private company in Iceland that could take on such a service. They have also shown interest in starting a common research project with external financing (e.g. NORA) aimed at installing a wave forecast into their operational system.

If we want a local solution, with only sequential time-limited project based funding, it seems that a web service based on a passive database of idealised model runs is our only feasible option. A series of projects building up such a service could be as follows:

1. Generating database of idealised model runs for the entire Faroese Shelf. It is recommended to perform runs with wave heights from 0.5m to 18.0m in 0.5-1.0m intervals, and in at least 16 directions. The PM spectrum could serve as an estimate of the spectral shape. The model results should be made available on the internet.
2. Create a user-friendly web page based on the results from the previous step, which also imports online free regional forecasts (e.g. NOAA[1]), and local wave measurements (Landsverk and DQ).
3. Expand database by adding different spectral shapes and or swell situations. Update web page so that the added options are included in an intuitive manner.

Acknowledgements

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[1] Other regional forecasts could quite possibly be made available in exchange for giving direct access local wave measurements.

Reference List

Booij, N., Ris, R. C. & Holthuijsen, L. H. 1999. A third-generation wave model for coastal regions - 1. Model description and validation. Journal of Geophysical Research-Oceans 104: 7649-7666.

Davidsen, E. & Hansen, B. 1981. The Faroese Wave-Measuring and Current-Measuring Project. Coastal Engineering 5: 111-123.

Heinesen, F. 1985. Tidal current around the Faroe Islands. Klaksvik, Faroe Islands: Fischer Heinesen.

Heinesen, S. P. GEM Faroewave Q/A, Quality Assurance of Faroese Wave Data 1979-2000. 1-77. 2001. Sp/f Data Quality.

Joensen, H. P., Jacobsen, B. K., Nguyen, K. D., Niclasen, B. A., Simonsen, K. & Sørensen, D. High-Power Computer Facilities at the Faculty of Natural Sciences. 2007:09. 2007. University of the Faroe Islands. NVDRit.

Niclasen, B. A. An operational wave model for the Faroe Shelf. 1-127. 2006. University of the Faroe Islands.

Niclasen, B. A. & Simonsen, K. Current induced variations in measured wave parameters in data from the Faroe Islands. 2005:03. 2005a. University of the Faroe Islands. NVD-rit.

Niclasen, B. A. & Simonsen, K. Inspection of possible mooring related problems in wave data from the shelf of Faroe Islands. 2005:04. 2005b. Torshavn, University of the Faroe Islands. NVDrit.

Niclasen, B. A. & Simonsen, K. Modelled influence of bathymetry and tidal currents on wave conditions in the Faroese area. 2005c. Höfn, Iceland. 2. International Coastal Symposium in Iceland. Viggoson, G.

Niclasen, B. A. & Simonsen, K. 2007a. Note on wave parameters from moored wave buoys. Applied Ocean Research 29: 231-238.

Niclasen, B. A. & Simonsen, K. 2007b. Validation of ECMWF analysis wave data for the area around the Faroe Islands. Societas Scientiarum Færoensis.

Niclasen, B. A. & Simonsen, K. Wave induced resuspension in fish farming areas of Suðuroy: and introductory model based investigation. 2009:03. 2009. University of the Faroe Islands. NVDRit.

Niclasen, B. A., Simonsen, K. & Magnusson, A. K. 2009. Wave forecasts and vessel safety: A review of possible operational warning parameters. Subm.
Ris, R. C. Spectral modelling of wind waves in coastal areas. 1-160. 1997. Delft University of Technology.

Rogers, W. E., Hwang, P. A. & Wang, D. W. 2003. Investigation of wave growth and decay in the SWAN model: Three regional-scale applications. Journal of Physical Oceanography 33: 366-389.

Simonsen, K. Tides and tidal simulation in the area around the Faroe Islands. 166. 1999. Bergen, Nansen Environmental and Remote Sensing Center.

Simonsen, K., Larsen, K. M. H., Mortensen, L. & Norbye, A. M. New Bathymetry for the Faroe Shelf. 2002:7, 1-9. 2002. Faroe Islands, Faculty of Science and Technology. NVD Rit.