Evaluation of ensemble prediction forecasts for estimating weather windows

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Introduction

The chaotic nature of the weather system was early pointed out by Edward Lorenz (1917-2008) :

"…two states differing by imperceptible amounts may eventually evolve into two considerably different states. If, then, there is any error whatever in observing the present state — and in any real system such errors seem inevitable — an acceptable prediction of an instantaneous state in the distant future may well be impossible....In view of the inevitable inaccuracy and incompleteness of weather observations, precise very-long-range forecasting would seem to be nonexistent." Lorentz (1963).

Running the same numerical model several times using nearly identical initial conditions and comparing the results, gives an indication of the uncertainty of the weather situation. The 51 ensemble members of wave height shown in Figure 1 indicate that forecasting skills are greatly reduced after day 4.

The European Center for Medium Range Weather Forecast ensemble system (ENS) is global and needs calibration before it can be used to estimate uncertainties of forecasts at specific locations. Some challenges are illustrated in figure1-3.

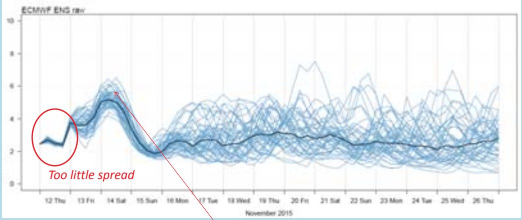

Figure 1: Example of significant wave height forecast from ECMWF ensemble model system with 51 members. Black line is the median. North Sea location.

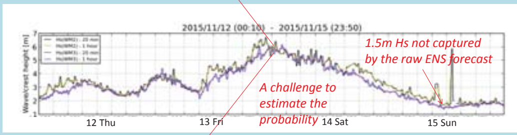

Figure 2: Observed wave height over the three first days of the forecast from two different wave sensors.

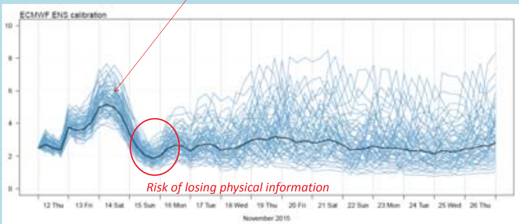

Figure 3: Example of calibrated forecast.

We further look into the possibility of using calibrated ensembles as an alternative to the alpha – factor method when predicting weather windows.

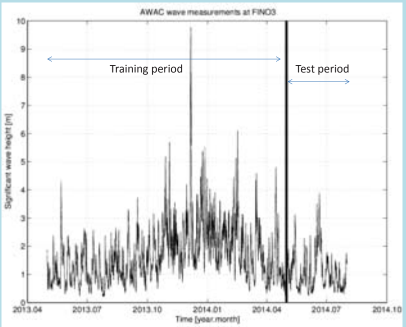

Figure 4: Training and test data set from the FINO-3 Acoustic Wave and Current Profiler.

Using reliable observations over one year from the AWAC (figure 4) at FINO3 (see location in figure 5) the ENS forecasts of significant wave height (Hs) and mean wave period (Tz) are calibrated to give probability forecasts over the 3 months test period. Results on the right part of poster are from the test period.

In locations where there are no observations an alternative is to use the Norwegian Reanalysis of wind and waves (NORA10) (figure 5). NORA10 is a downscaling to 10 km of the ERA-40 dataset and ECMWF forecasts for 1958-2015, which verify well against observations in Norwegian areas (Reistad et al., 2015).

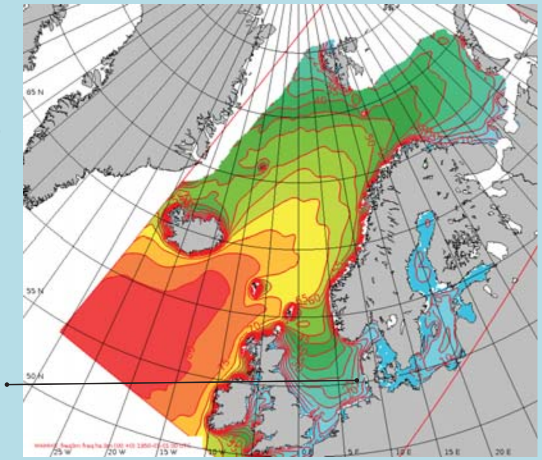

Figure 5: % of the time when significant wave height is above 3m in January. Based on NORA10 data.

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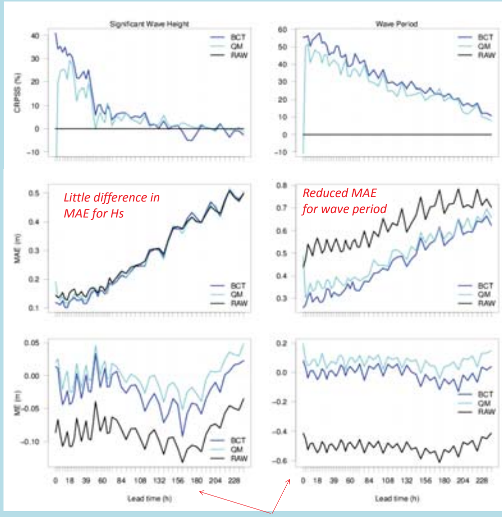
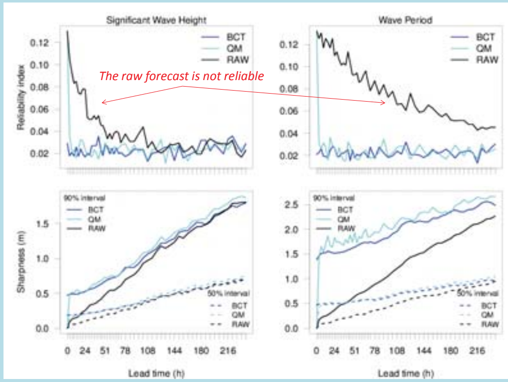
Validation results

The validation of the forecasts of Hs and Tz over the test period is shown in figures below. Continued rank probability skill score (CRPSS) show a 40% improvement in wave height and 60% improvement in mean period from the calibration. Mean absolute error (MAE) is reduced for wave period and the mean error (ME) in both parameters is strongly reduced.



Ranking the observation with the 51 forecasts, the rank of the observation should over time be uniformly distributed if the forecast is reliable, given by the reliability index.



Sharpness is a measure of the width of the 90% and 50% interval in meter for Hs and seconds for Tz. The raw forecast has no spread at analysis time, and therefore 0 sharpness.

Alpha-factor

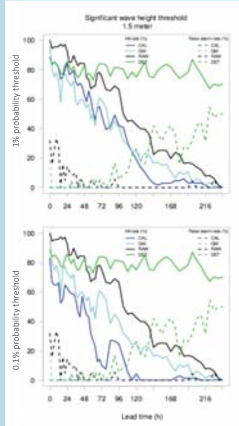


Figure 6: Hit and false alarm rate probabilities of 1 and 0.1 % for Hs<1.5m.

RAW: raw ECMWF ENS forecast
BCT : calibrated forecast
QM : bias corrected forecast
DET : deterministic forecast (α-factor 0.71)

Hit and false alarm rate (Figure 6) at 1% threshold for EPS and 1hr window is not improved compared to α-factor method (green line). The Box-Cox t-distribution (BCT) used for calibration is very flexible (four parameters) and if there is high variability in the observations during the training period this may result in a heavy upper tail in the statistical model. That may be the reason for the conservative result with the BCT in figure 6 and may be improved.

In the tables we've counted the number of 24-hours weather windows for design wave height 1.5m over the test period.

Based on the observations there are 67 forecasts with weather windows and 39 forecasts without. ENS50 of the raw ensemble predicts 4 false weather windows.

	Obs	Forecast	Ctrl	Med.	Mean
BCT	Yes	Yes	44	45	46
	Yes	No	23	22	21
	No	Yes	0	0	0
	No	No	39	39	39
RAW	Yes	Yes	53	53	53
	Yes	No	14	14	14
	No	Yes	0	0	0
	No	No	39	39	39

Table 1: Number of 24 hours weather windows using deterministic forecast and α-factor according to level A – meteorologist on site.

Calibrated ENS – best forecast?

	Obs	Forecast	Ctrl	Med.	Mean	ENS50	ENS49	ENS48	ENS47	ENS46	ENS45
BCT	Yes	Yes	39	40	40	49	51	53	54	54	54
	Yes	No	28	27	27	18	16	14	13	13	13
	No	Yes	0	0	0	0	0	0	0	0	0
	No	No	39	39	39	39	39	39	39	39	39
RAW	Yes	Yes	44	44	44	60	63	64	64	64	64
	Yes	No	23	23	23	7	4	3	3	3	3
	No	Yes	0	0	0	4	4	4	4	6	7
	No	No	39	39	39	35	35	35	35	33	32

Table 2: Number of 24 hours weather windows using deterministic forecast and α-factor according to level C – base case. ENS50 is the uppermost ensemble member at any time, representing approximately 2% probability. ENS49 is the 2nd from the top etc.

Acknowledgements
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