Wave Ensemble Prediction for Safe Offshore Operations

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Motivations

- **This research has been carried out in the framework of the WEPO project: Wave Ensemble Prediction for Offshore Operations funded by the Norwegian Research Council in collaboration with Conocco-Phillips (PETROMAX initiative).**
- **It makes use of the ECMWF archive of wave ensemble forecasts since 1998 to look at different aspect of the wave ensemble system, in particular looking at weather windows few days ahead in the forecasts.**

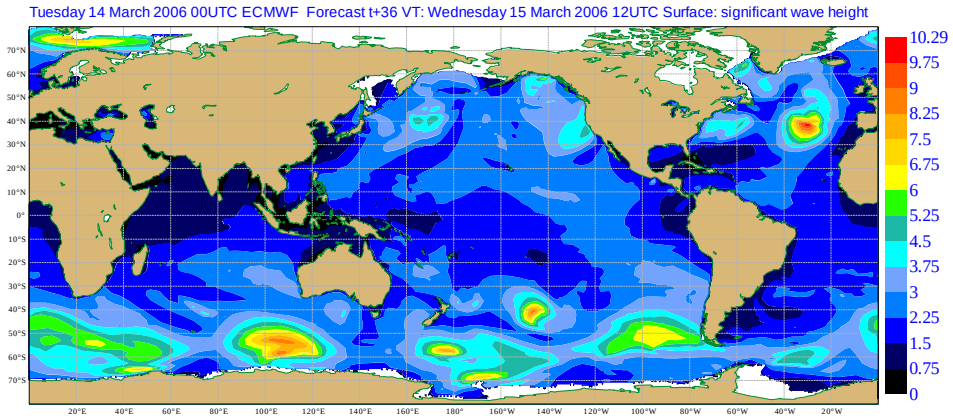
Methodology and results

- **Collocation of 10 years of wave ensemble data with in-situ observations from the North Sea, representative of conditions near and around Ekofisk.**
- **So far a simple Cost/lost model was used.**

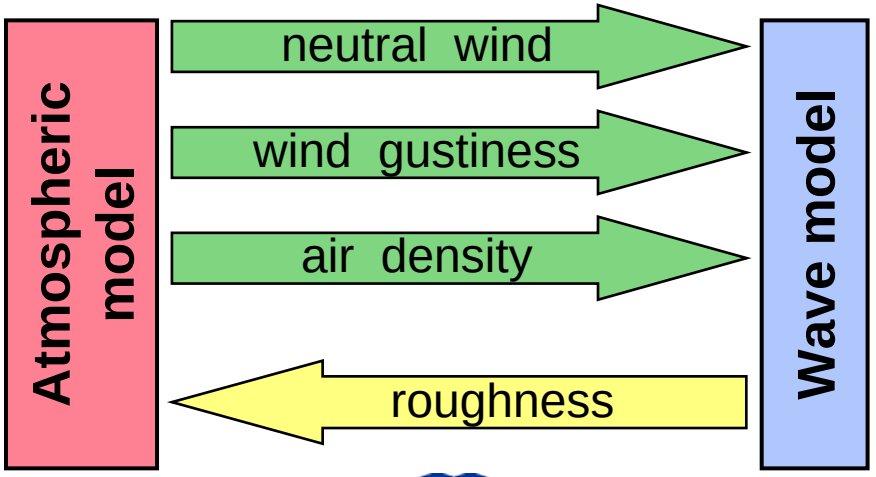
- **Study is ongoing, preliminary results indicates the usefulness of the wave ensemble.**

ECMWF Wave Model Configurations

- **Global from 81°S to 90°N**
- **Coupled to the atmospheric model with feedback of the sea surface roughness change due to waves.**
- **The interface between WAM and the IFS has been generalised to include air density and gustiness effects on wave growth and neutral winds.**



Forecast wave height on 15/03/2006 12UTC.



ECMWF Wave Model Configurations since January 26, 2010:

Deterministic forecasts

(based on one high resolution forecast)

- **28 km grid spacing.**
- **36 frequencies.**
- **36 directions.**
- **Coupled to the atmospheric model with ~16km resolution (TL1279).**
- **Analysis every 6 hrs and 10 day forecasts from 0 and 12 UTC, output every 3 hours up to day 6 then every 6 hours.**

Probabilistic forecasts

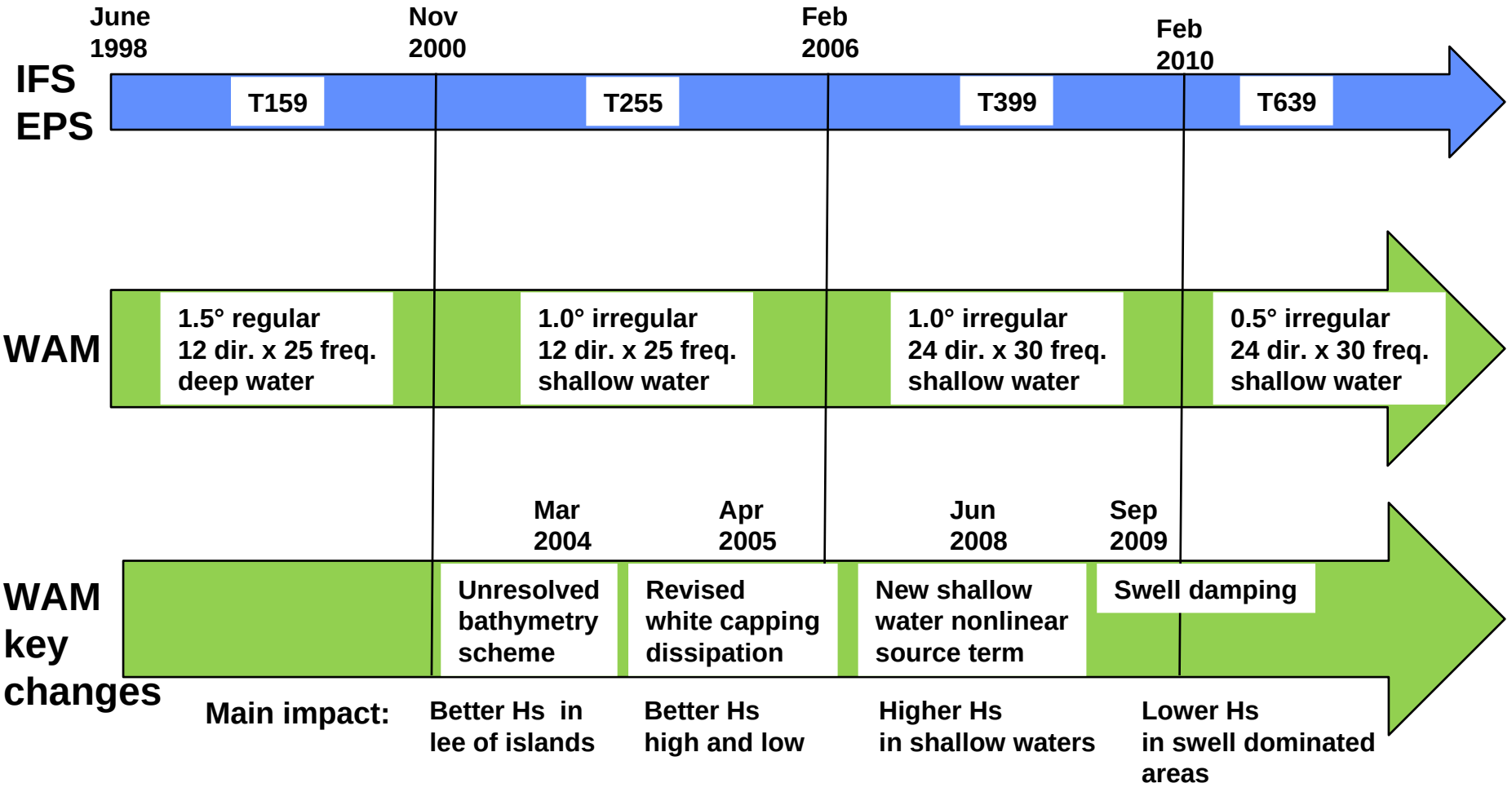
(based on the Ensemble Prediction System (EPS))

- **55 km grid spacing.**
- **30→ 25 frequencies *.**
- **24 → 12 directions *.**
- **Coupled to TL639 (~32km) → TL319 (~64km) model *.**
- **(50+1) (10+5) day forecasts from 0 and 12 UTC (monthly once a week), output every 3 hours up to day 6, then every 6 hours.**

* Change in resolutions after 10 days

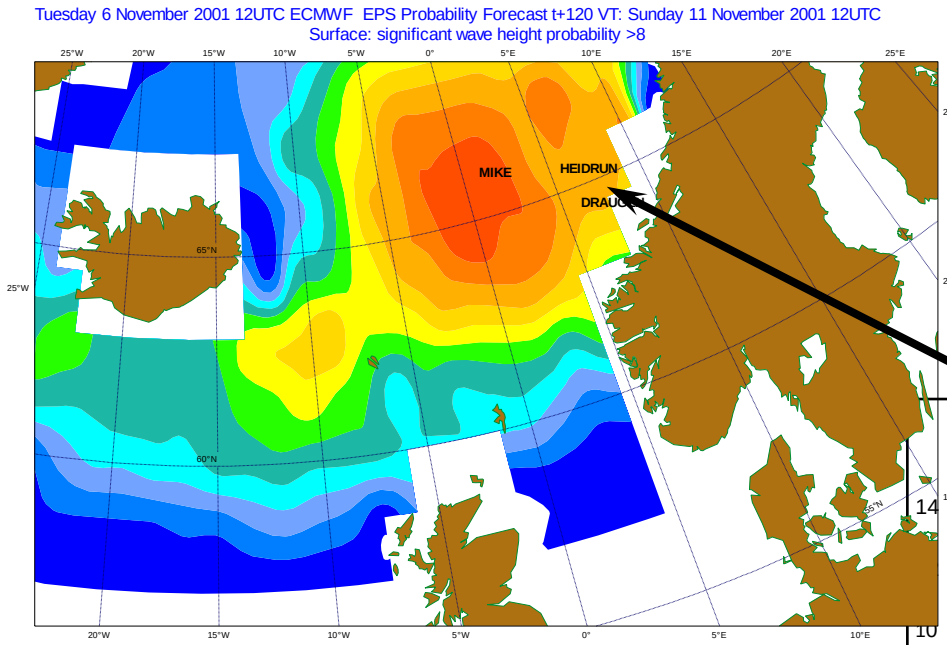
ECMWF

Wave model in ECMWF EPS

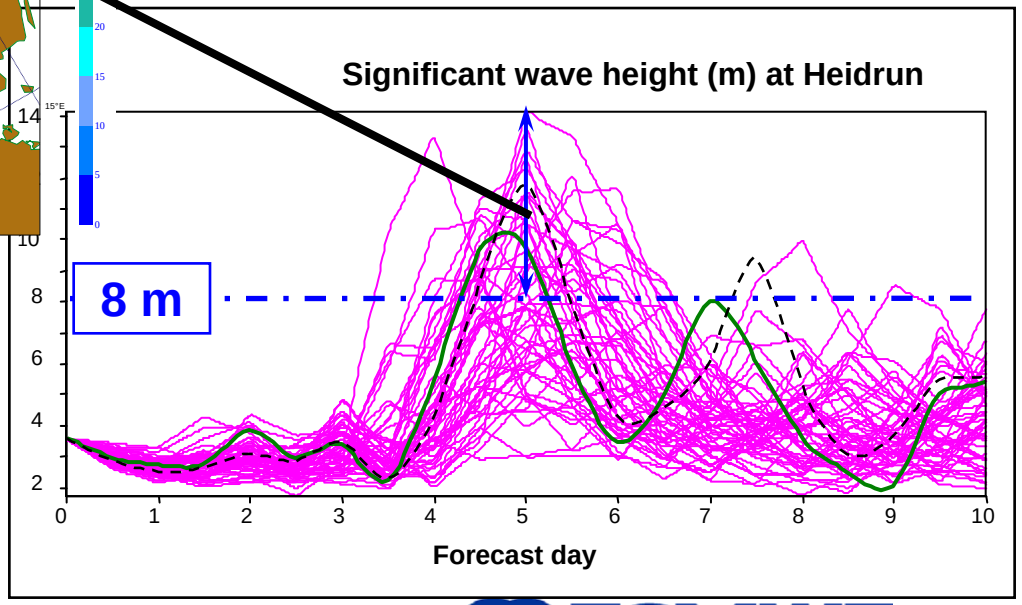


Wave Model Products: EPS

From the EPS wave forecasts it is possible to derive probabilities for certain wave conditions.



Prob (Hs>8m)=
Number of fc above 8m/total number



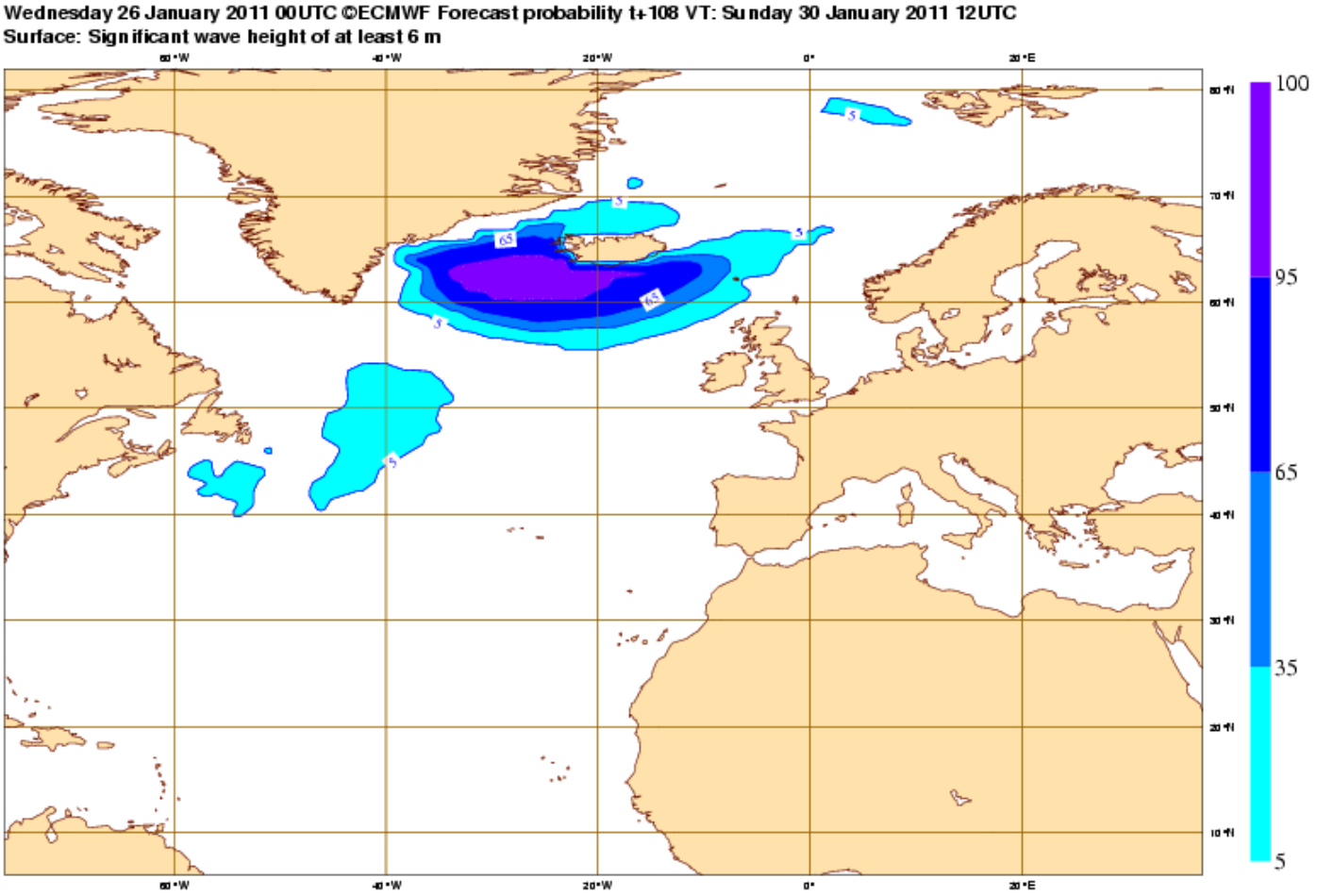
06 Nov. 2001 12 UTC ECMWF EPS probability forecast t+120

Significant wave height above 8 m

ECMWF Newsletter 95 – Autumn 2002

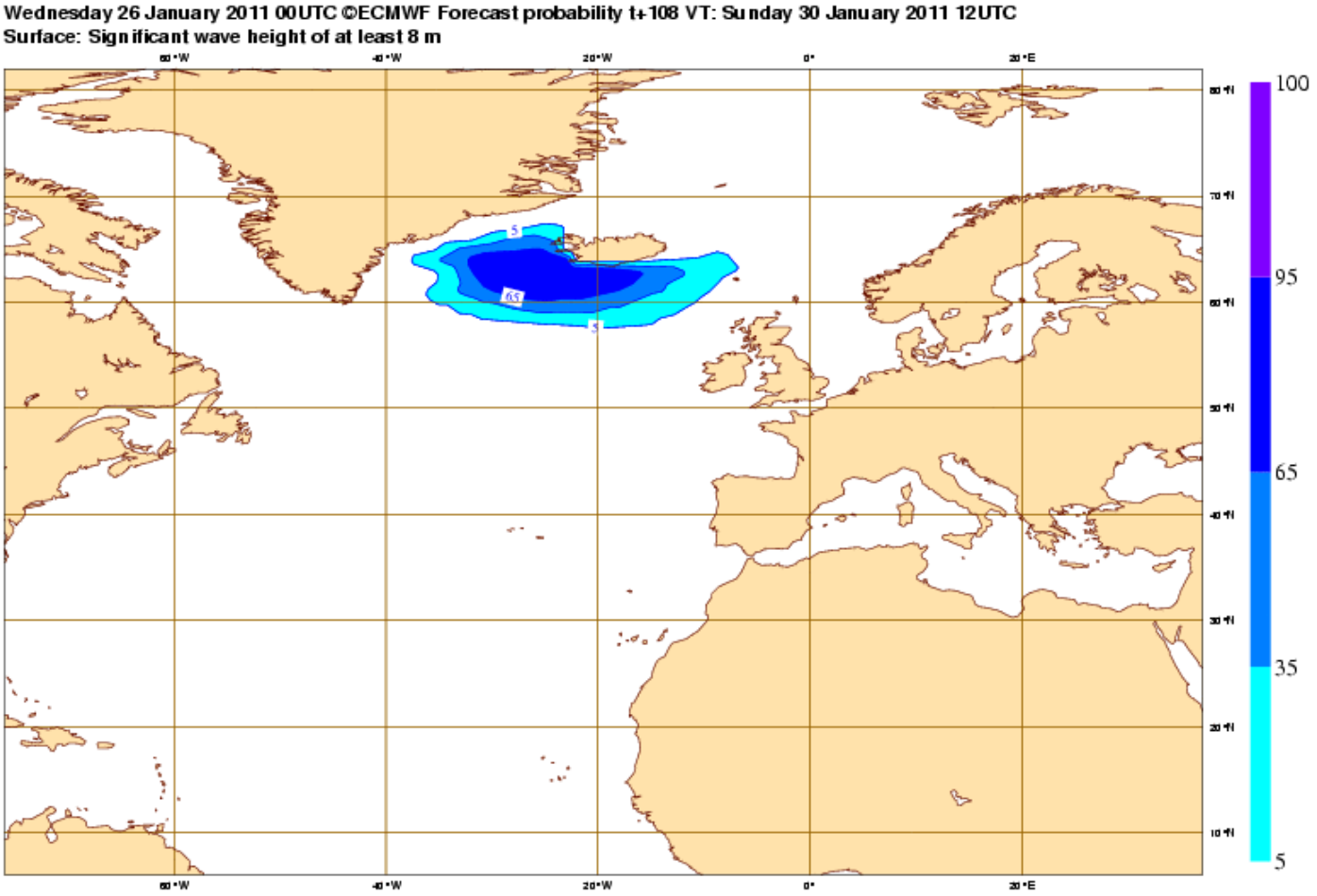
Basic EPS Wave Model Products

probability for set thresholds (6m)

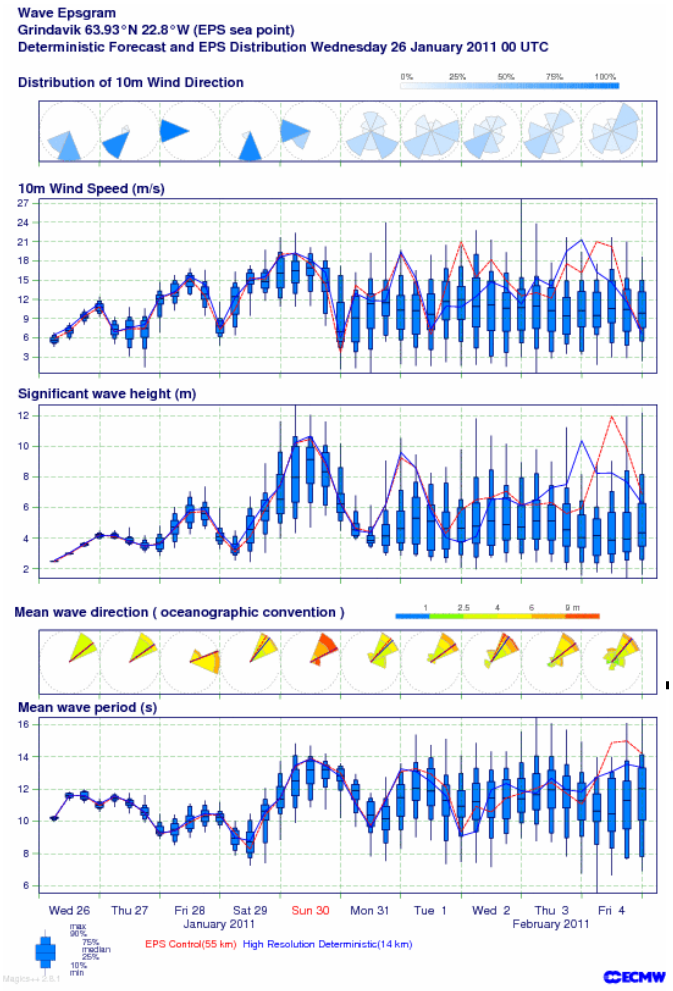


Basic EPS Wave Model Products

probability for set thresholds (8m)

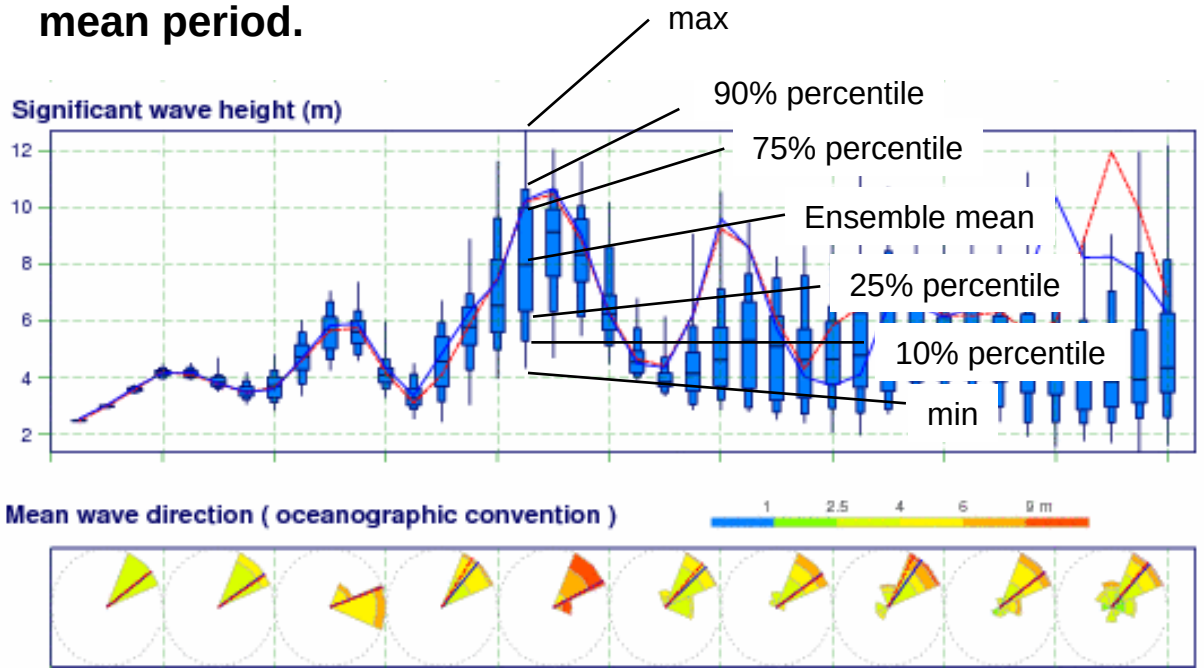


A bit more compact: Wave EPSgram:



West of Grindavik, Iceland

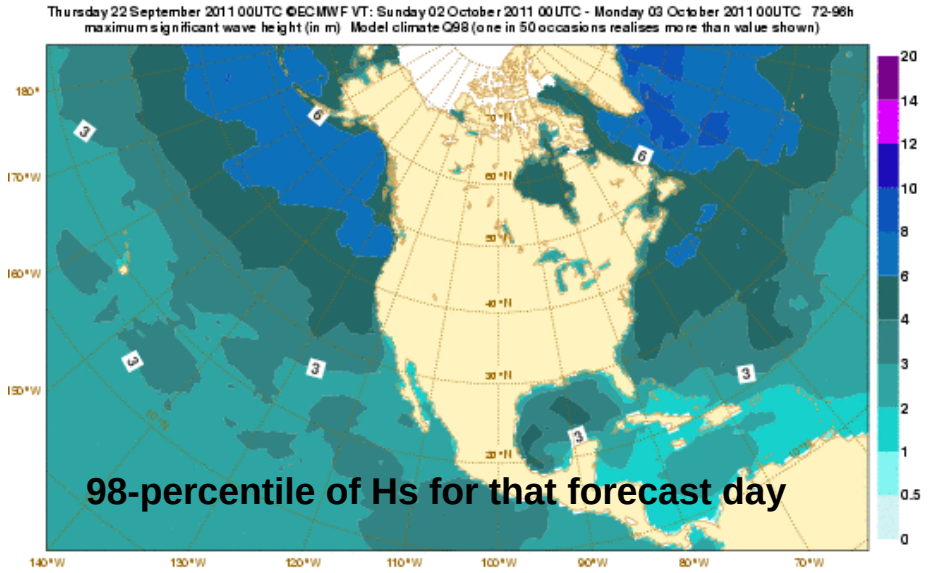
Like normal EPSgram but for wind direction, wind speed, significant wave height, mean wave direction and mean period.

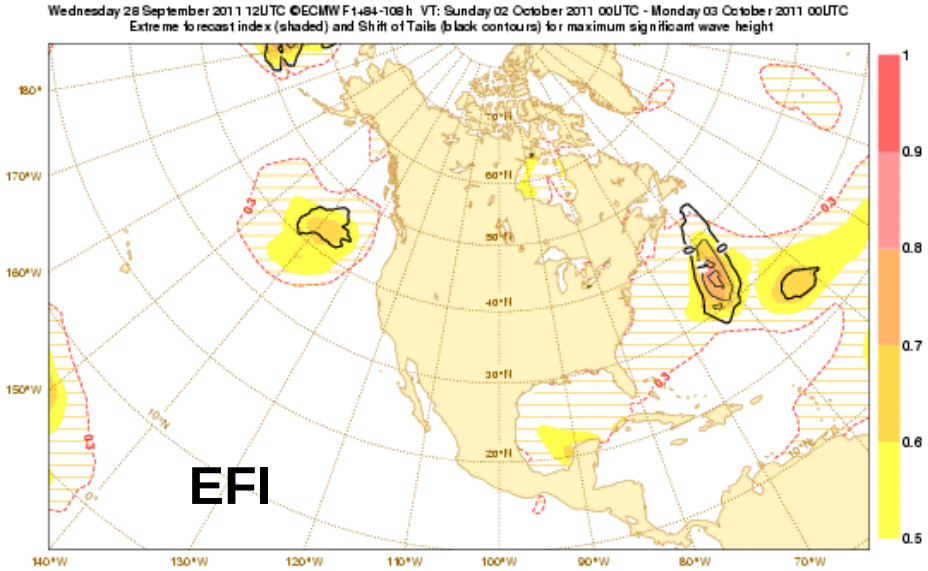


Each octant is coloured based on the distribution of the significant wave height associated with each mean direction. The coloured areas correspond to the fractional number of ensemble members with wave height in the range specified by the coloured ruler.

More advanced EPS Wave Model Products:

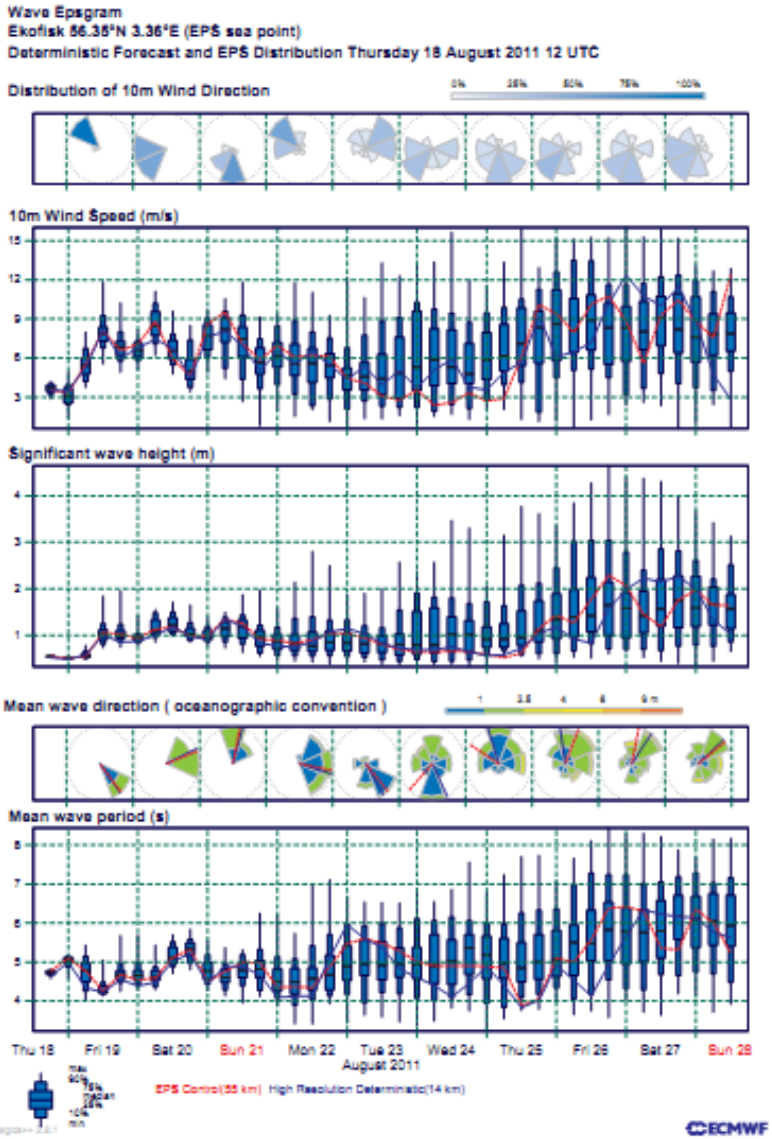
From the model climate distribution, it is possible to derive indices that indicate deviations in probabilistic terms from what is 'expected'.





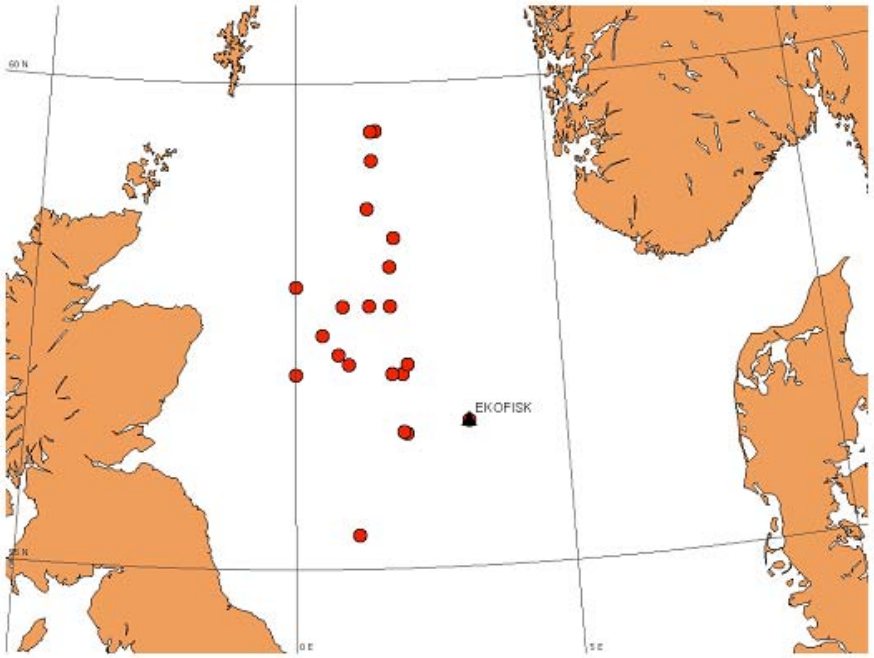
e.g. Extreme Forecast Index (EFI): where 1 means that all EPS are above the climate.

Weather window of calm condition :



Wave Ensemble Prediction for Offshore Operations (WEPO):

- **10 years of wave forecasts EPS data were collocated data with 21 stations near Ekofisk (Jan 1999 to Dec, 2009 = 30,332 collocations).**
- **data were routinely obtained at ECMWF (GTS).**
- **No attempts were made to correct for the inhomogeneity of model data.**



The cost/loss ratio decision model

Decision maker would like to minimize her/his expense over a large number of cases.

Simple Cost/Lost decision model:

forecast	If adverse event is observed: yes	If adverse event is observed: no	
yes	C	C	yes
no	L	0	no

cancel/postpone operation

C : Cost incurred to protect/avoid against adverse event.

L : Lost due to adverse event.

Relative frequency values contingency table :

Hs >= 3m for at least one forecast in [72 -96hrs]

forecast	If adverse event is observed: yes	If adverse event is observed: no
yes	a	b
no	c	d

n = a+b+c+d = 30,332

Economic Value V:

Expenses:

In the absence of forecast information:

$$E_{climate} = \min(C, L(a+c)/n)$$

With forecast information:

$$E_{forecast} = (aC + bC + cL)/n$$

If we always knew the outcome:

$$E_{perfect} = (a+c)C/n$$

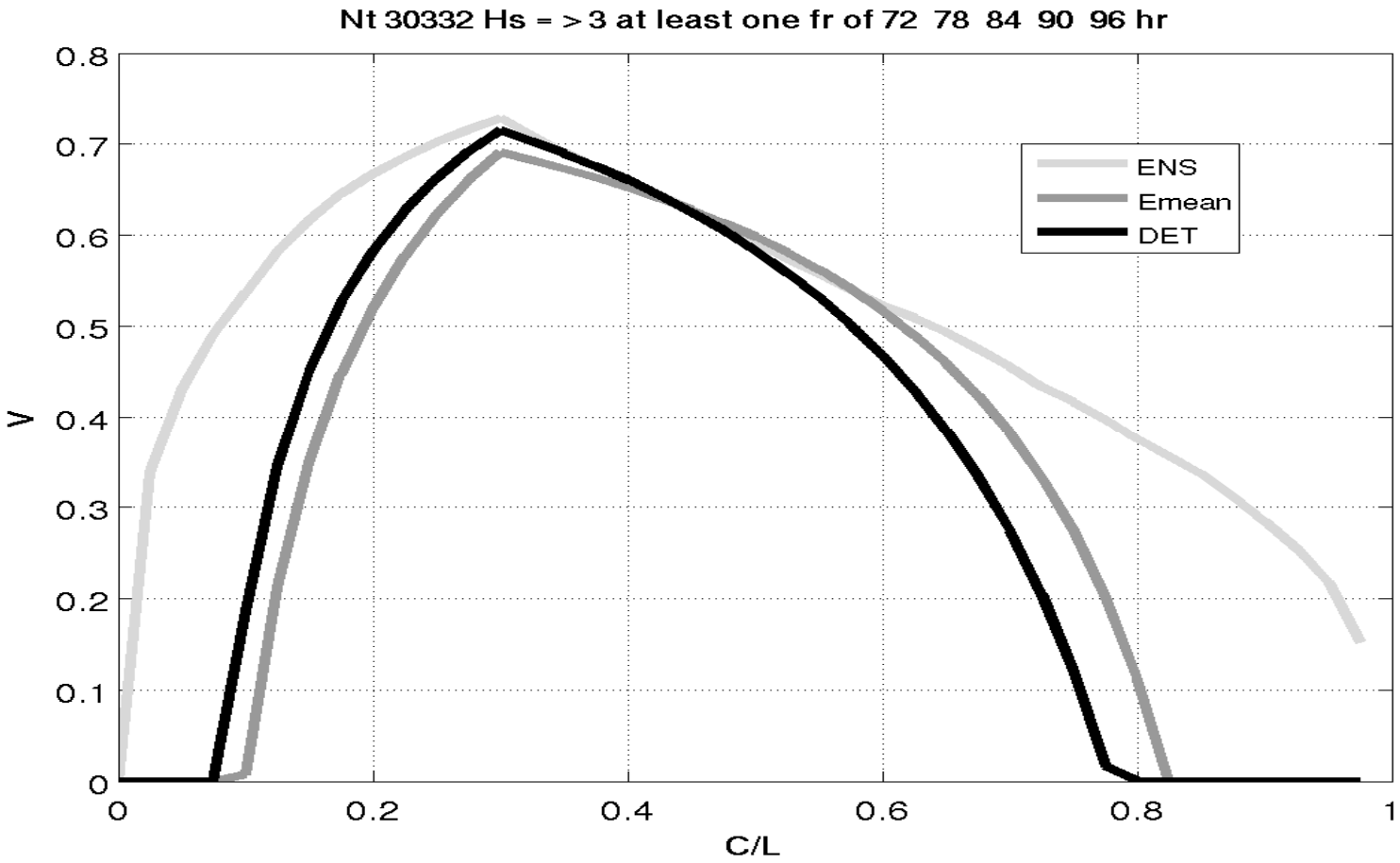
$$V = \frac{E_{climate} - E_{forecast}}{E_{climate} - E_{perfect}}$$

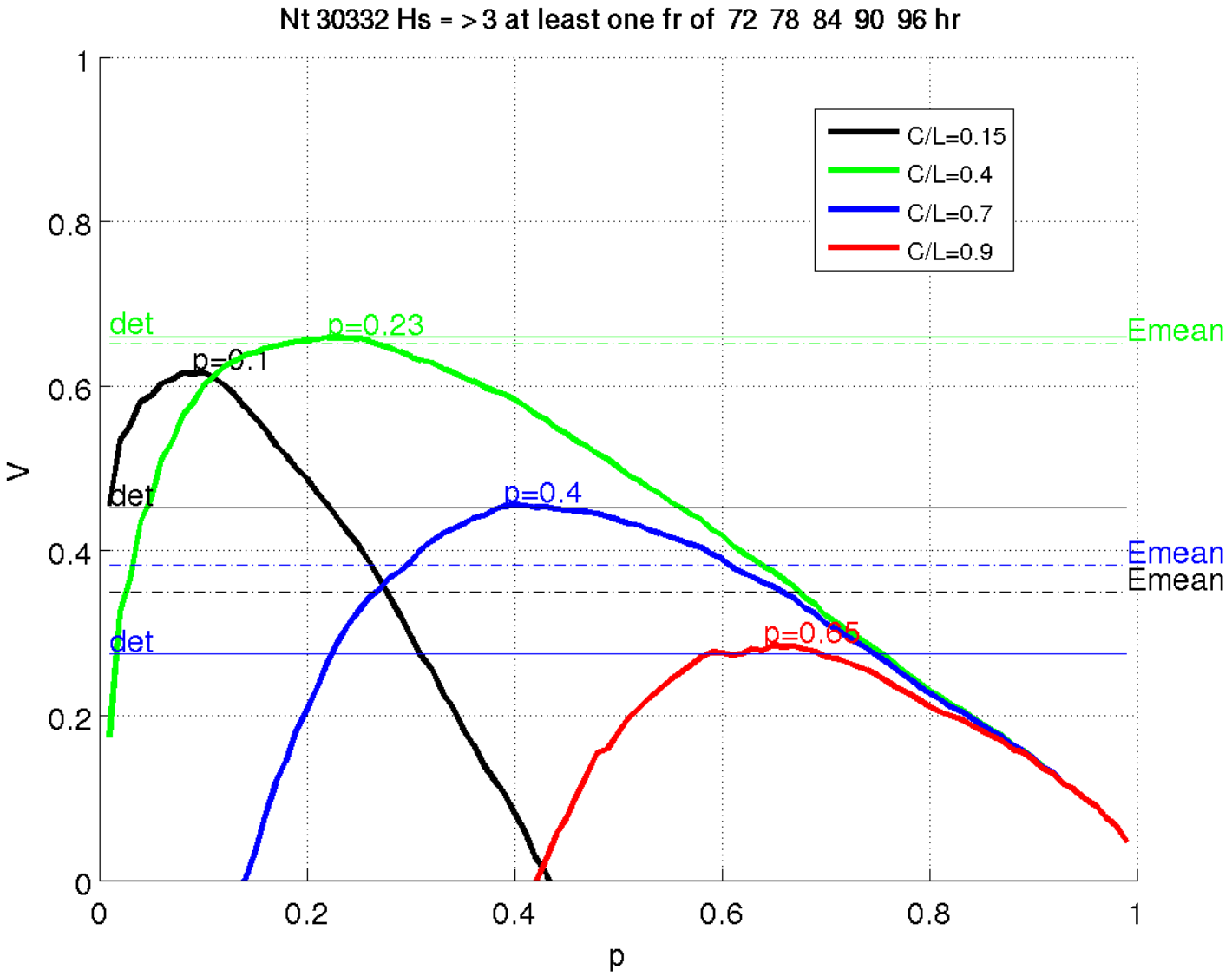
forecast \ observed	yes	no
yes	a	b
no	c	d

$$n = a+b+c+d$$

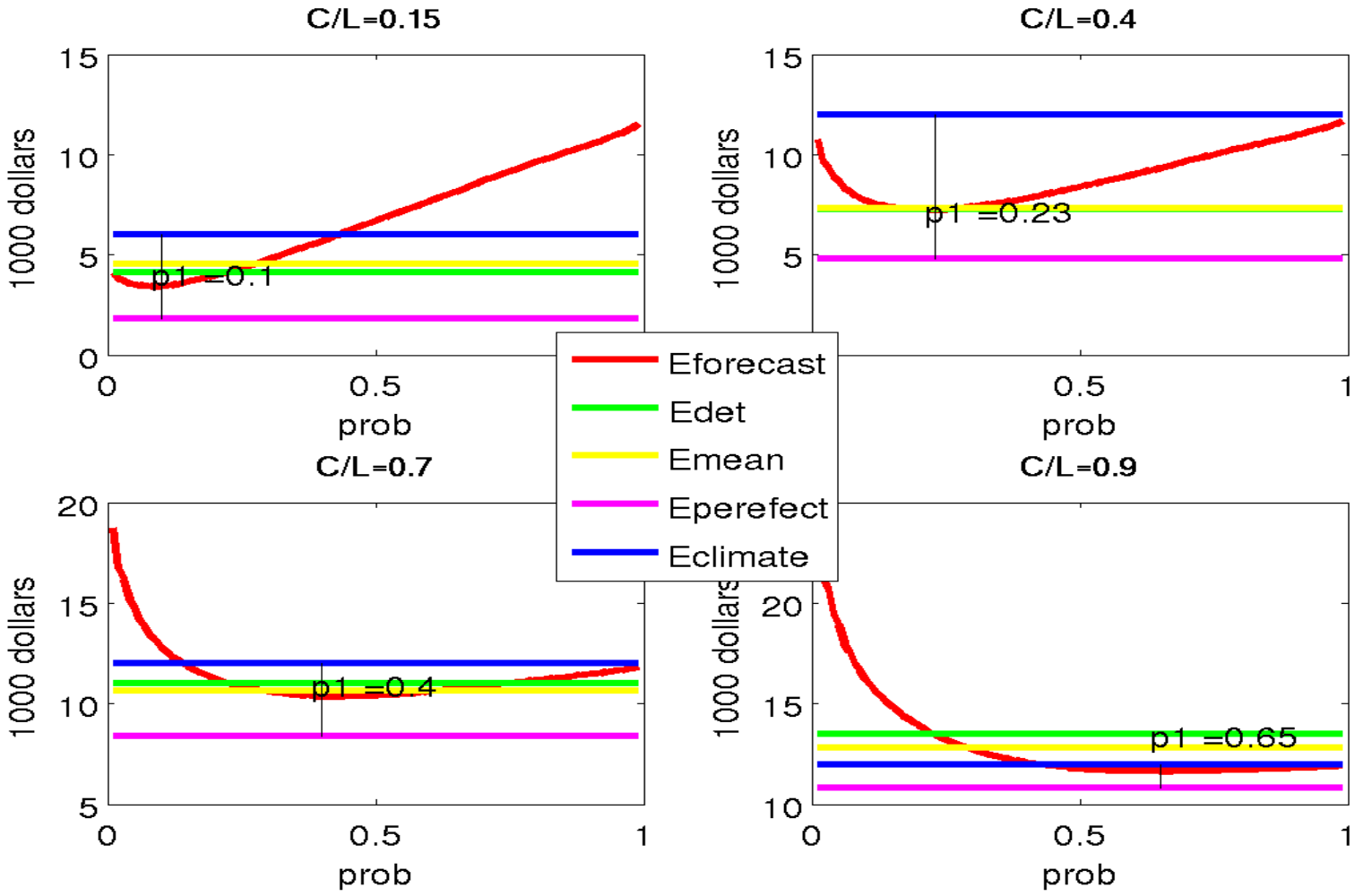
forecast \ observed	yes	no
yes	C	C
no	L	0

$$V = \frac{E_{climate} - E_{forecast}}{E_{climate} - E_{perfect}}$$




Nt 30332 Hs = > 3 at least one fr of 72 78 84 90 96 hr
C/L=0.15
C/L=0.4
C/L=0.7
C/L=0.9
det
p=0.23
Emean
p=0.1
det
p=0.4
Emean
Emean
det
p=0.65
V
p
0
0.2
0.4
0.6
0.8
1

Expenses over a 10-year period for specific user.
Loss=2000000 dollars



Loss = 2000 000 dollars

Expenses in thousand dollars.

X_1								
prob.	$E_f(p)$	E_f^d	E_p	E_f^m	E_c-$E_f(p)$	$b(p)$	$fa(p)$	$h(p)$
$p \approx \frac{C}{L}$						$\frac{a+b}{a+c}$	$\frac{b}{b+d}$	$\frac{a}{a+c}$
0.12	112.5	144.8	51.3	144.2	127.5	1.861	0.245	0.96
0.23	187	194	98	193	241	1.54	0.147	0.894
0.32	233.5	234.5	136.9	232.4	194	1.184	0.095	0.833
0.39	269.7	270.4	171	268	158	1.018	0.066	0.776

Table 1: For a loss L= 2000000 dollars displayed are the expenses in 10^3 dollars and three verification measures at the probability at which the operation should be postponed.

Results

- **10 years of archived wave ensemble data were analysed with respect to weather windows.**
- **Study is ongoing, preliminary results indicates the potential usefulness of the wave ensemble in selecting weather windows for offshore operations.**