Verification of Ensemble Wave Forecast at NCEP

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1.1 The current status

a. Control forecast: the operational NWW3 wave forecast

b. 10 members of the wave ensemble generated using the GFS ensemble wind fields

c. No wave initial field perturbation and the initial wave fields for all members are the same as the operational.

d. These ensemble wave forecasts set running at 0000, 0600, 1200 and 1800 UTC daily out to 126 hours

e. The wave ensemble spreads increase with the forecast hour and the ensemble system effectively catches the uncertainties.

1.2 Main ensemble outputs

Mean: m= $\frac{1}{N}\sum H_i$

Spread: spread= $\sqrt{\frac{\sum (x_i - m)^2}{N}}$

Probability at different threshold

2. Data

2.1 Ensemble forecast data

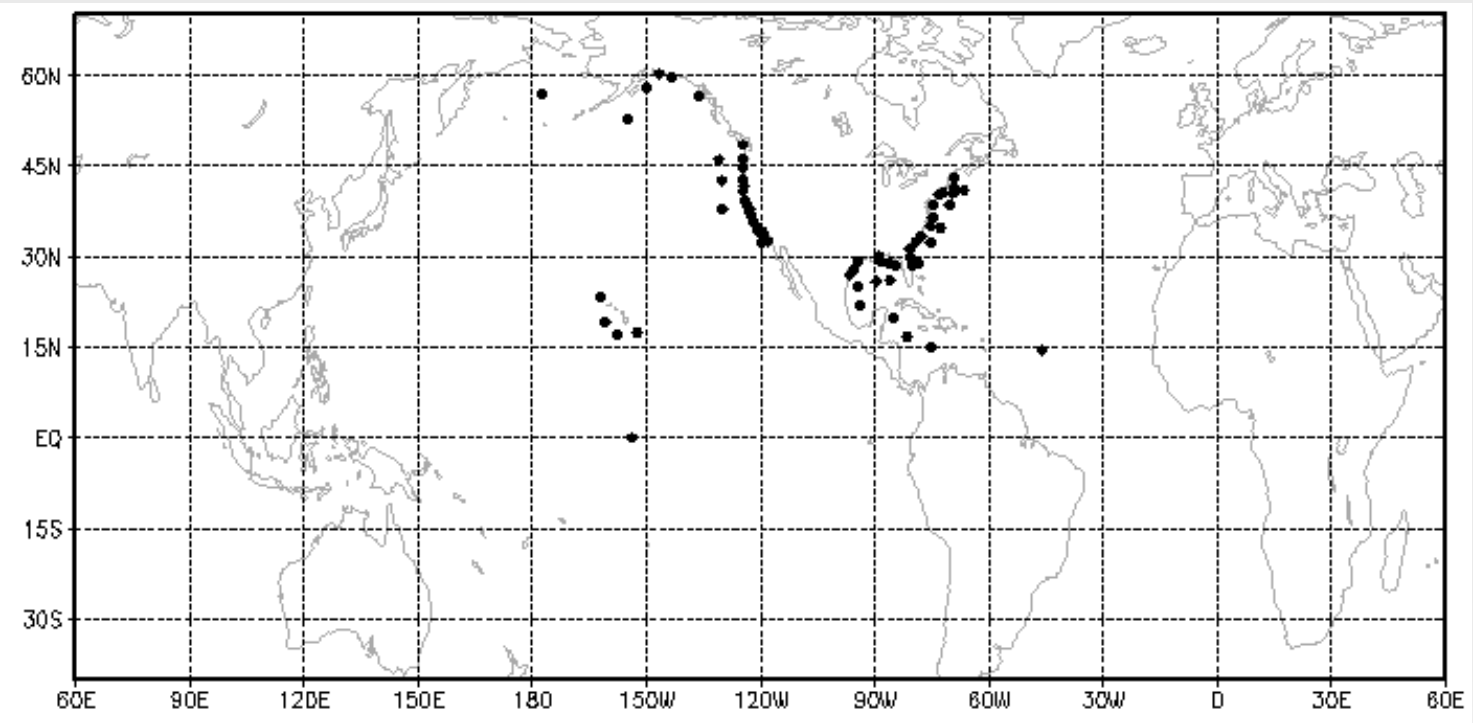
from June 5, 2006 to March 31,2007

2.2 Observation data

NDBC hourly buoy data from June 5, 2005 and March 31, 2007

2.3 Climate data

Hourly wave height and wind climate data generated using 10 years NDBC buoy datasets from Jan. 1997 to Dec. 2006.



Global buoy distribution used in the verification

3. Verification methodology

3.1 Brier score (BS) and Brier skill score (BSS)

3.2 Reliability diagram

3.3 Cost-loss analysis

a. Economical value

b. Relative operating characteristic (ROC)

3.1 BS and BSS

BS measures the mean squared probability error

$$BS = \frac{1}{N}\sum_{i=1}^{N}(p_i - o_i)^2$$

Murphy's (1973) decomposition into 3 terms (for M probability classes and N samples)

$$BS = \frac{1}{N}\sum_{m=1}^{M} n_m(p_m - \overline{o_m})^2 - \frac{1}{N}\sum_{m}^{M} n_m(\overline{o_m} - \bar{o})^2 + \bar{o}(1-\bar{o})$$

Reliability Resolution Uncertainty

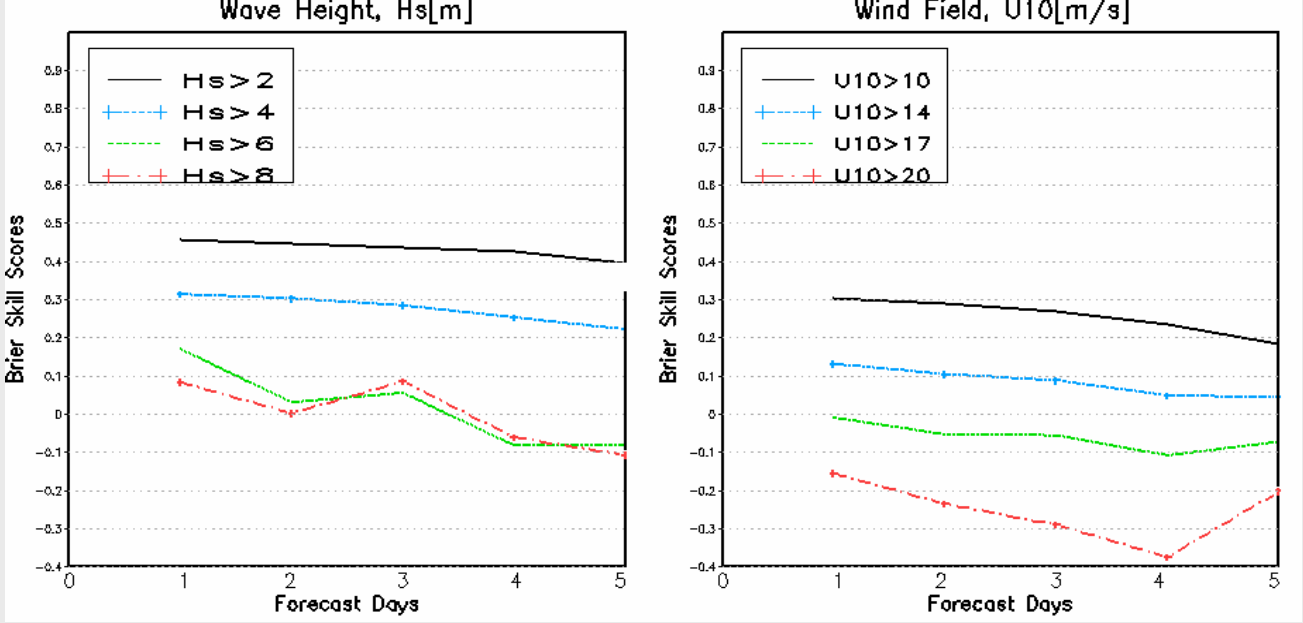
BSS measures the relative skill of the forecast compared to its reference

$$BSS = 1 - \frac{BS}{BS_{ref}}$$

ref.: control, operational run, or climatology

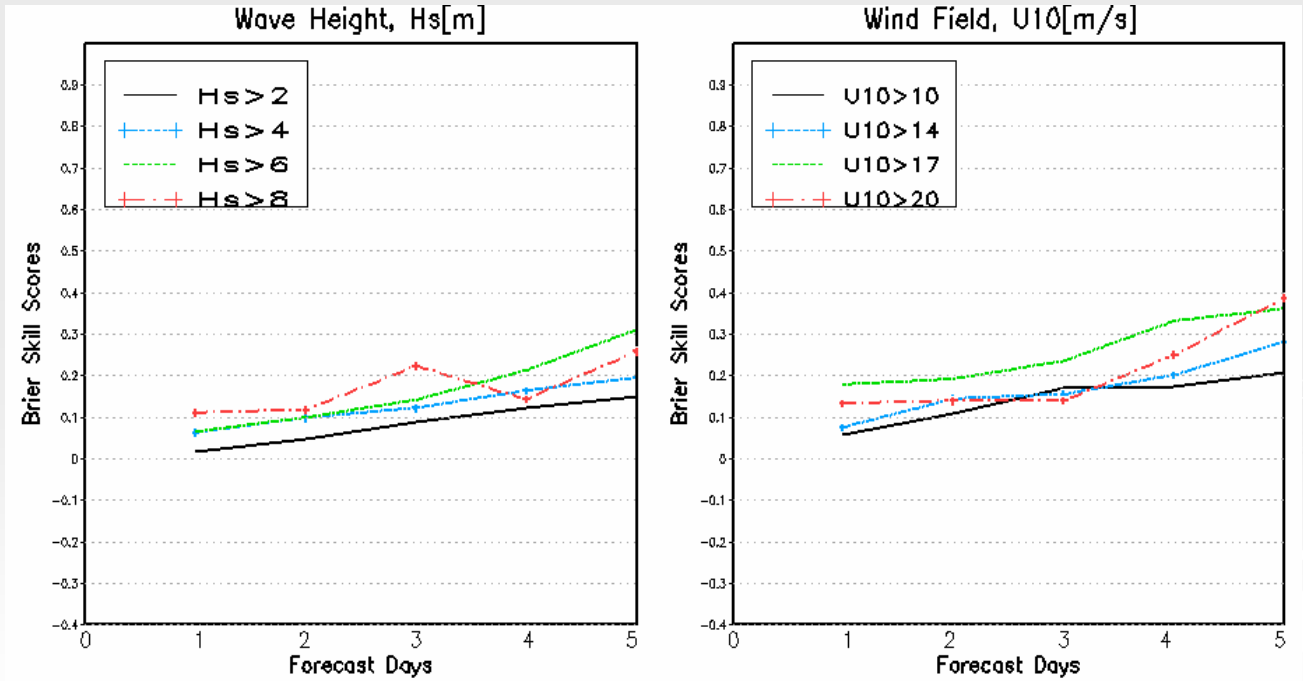
Ref.:

Climatology



Ref.:

Operational Run

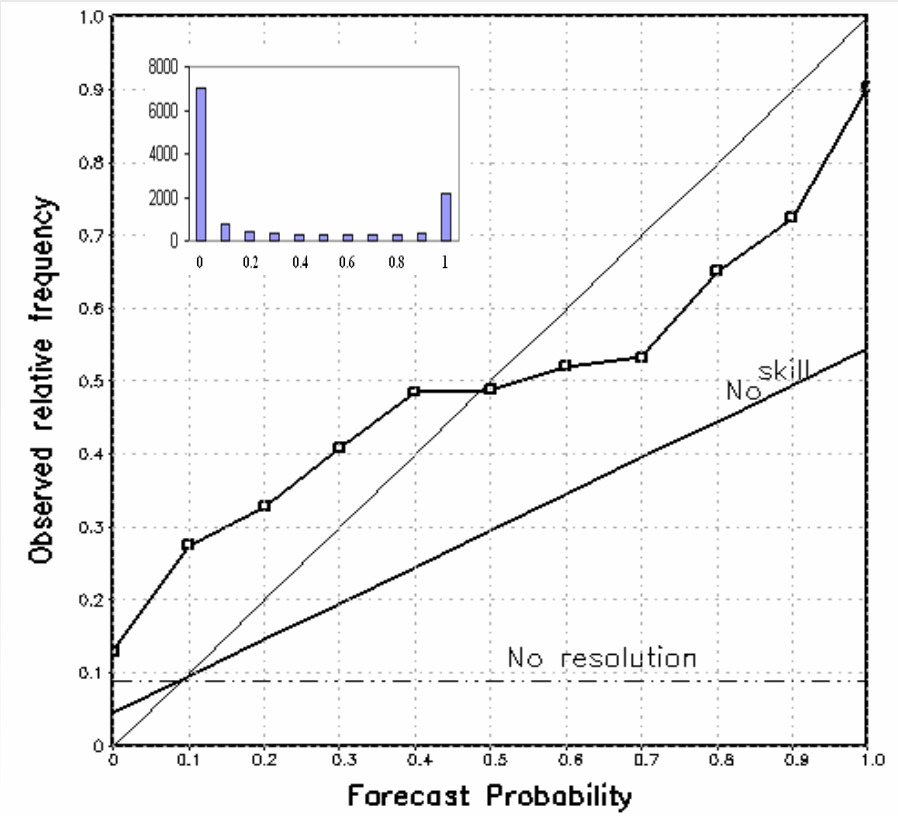


3.2 Reliability diagram

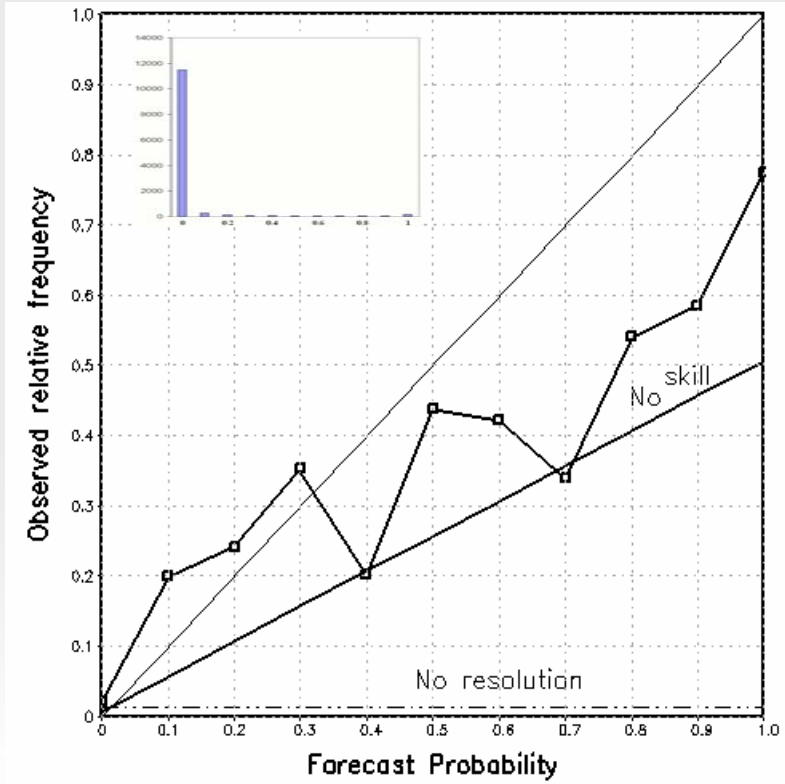
Measures how well the predicted probabilities of an event correspond to the observed frequencies (reliability)

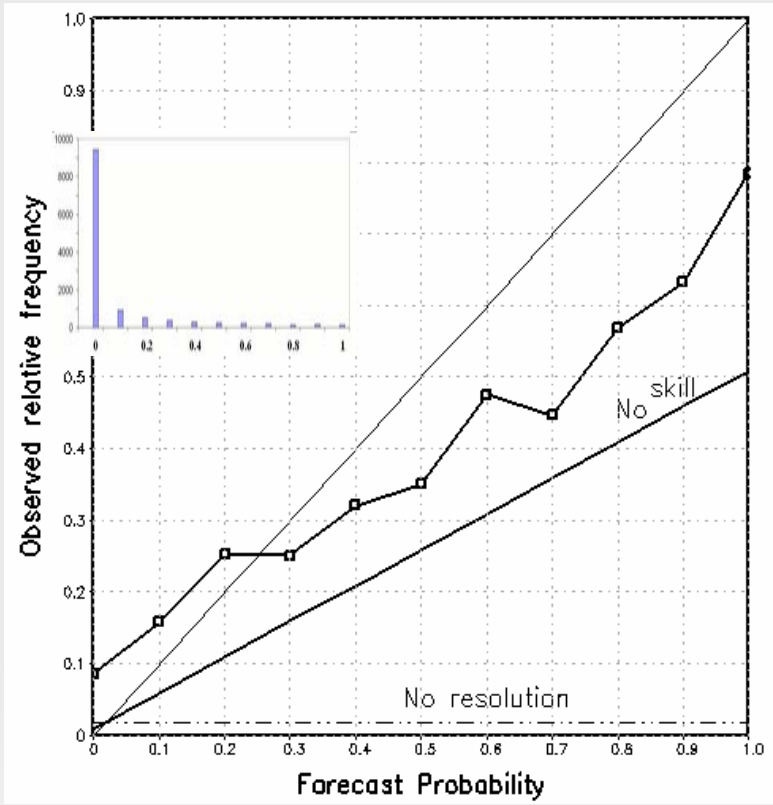
Plot observed frequency against forecast probability for all probability categories.

Hs>2m (Day 5)

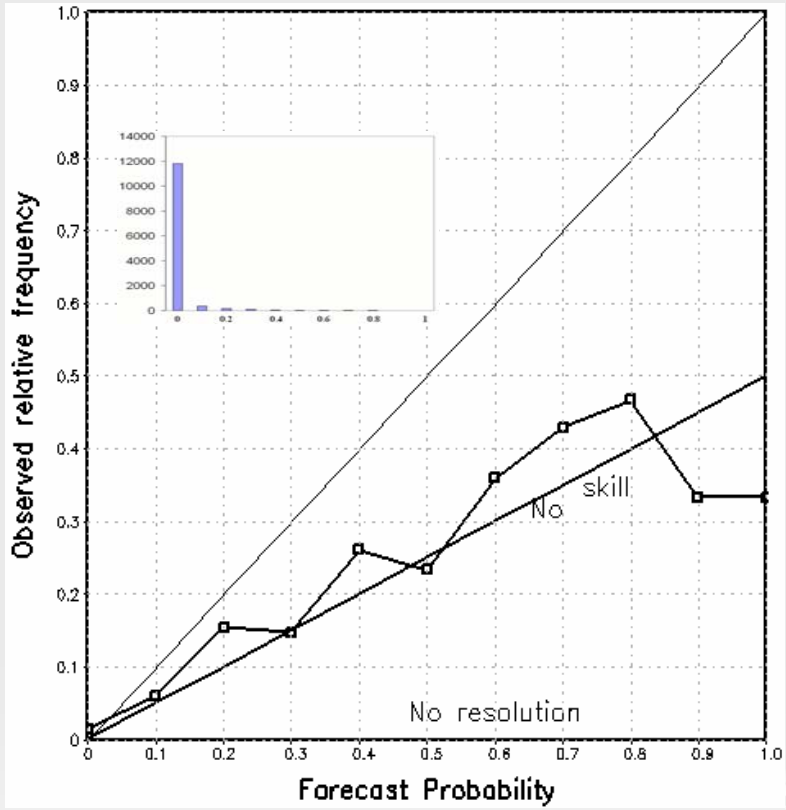


Hs>4m (Day 5)





U10>10m/s (Day 5)



U10>14m/s (Day 5)

3.3 Cost-loss analysis

Table. The costs and losses accrued by the use of the wave prediction, depending on prediction and observed events.

		Forecast / Action	
		Yes	No
Event	Yes	Hit (h) Mitigated loss ($C+L_u$)	Miss (m) Loss ($L = L_p+L_u$)
	No	False Alarm (f) Cost (C)	Correct Rejection (c) No cost (N)

Note:

- Event not occur and user takes no action, there is no cost, N=0.
- Event not occur and user takes action, there is a cost, C.
- Event occurs and user takes action, there is a cost, C, plus unprotectable loss, L_u.
- Event occurs and user takes no action, then there is a loss of L_u plus protectable loss, L_p.

a. Economical value

The definition of the economic value:

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

Where

$E_{climate}$: the expected expenses associated with using climatological data

$E_{climate}=oL_u+\min[oL_p, C]$

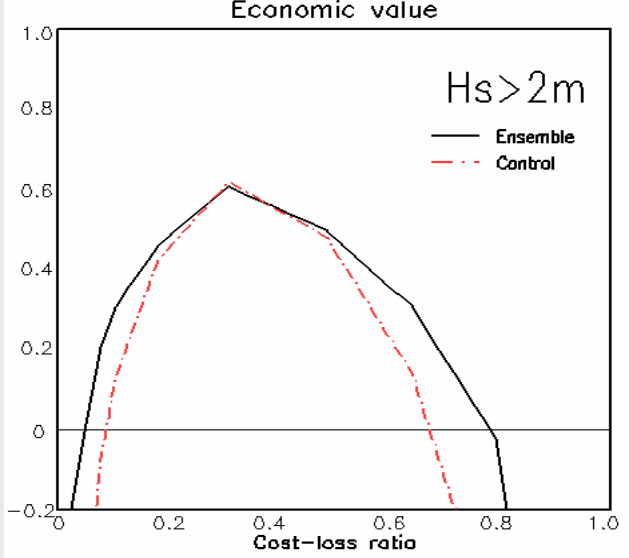
o: the climatological frequency of the event through calculating the altimeter (ENVISAT, GFO and Jason-1)

$E_{forecast}$: the expected user expense of a forecast system

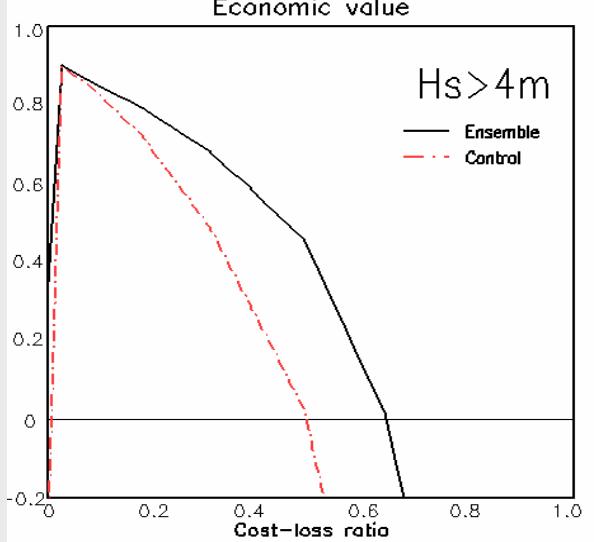
$E_{forecast}=h(C+L_u)+fC+m(L_p+L_u)$

$E_{perfect}$: the minimum expense of a user, given a perfect forecast system that provides accurate predictions for the occurrence and nonoccurrence of a particular event.

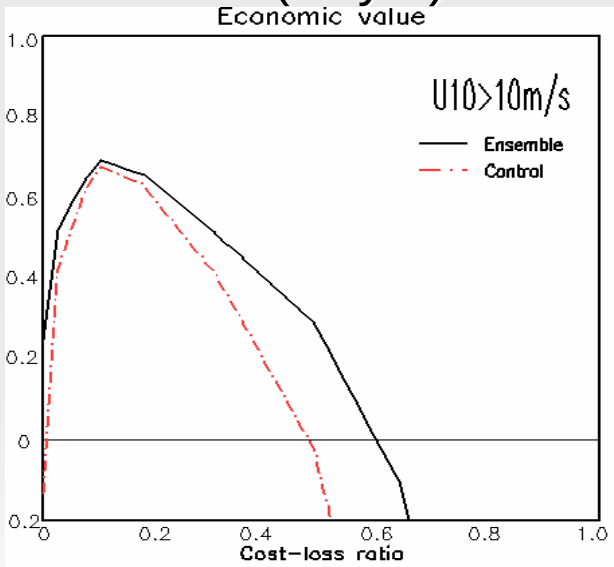
$E_{perfect}=o\ (C+L_u)$



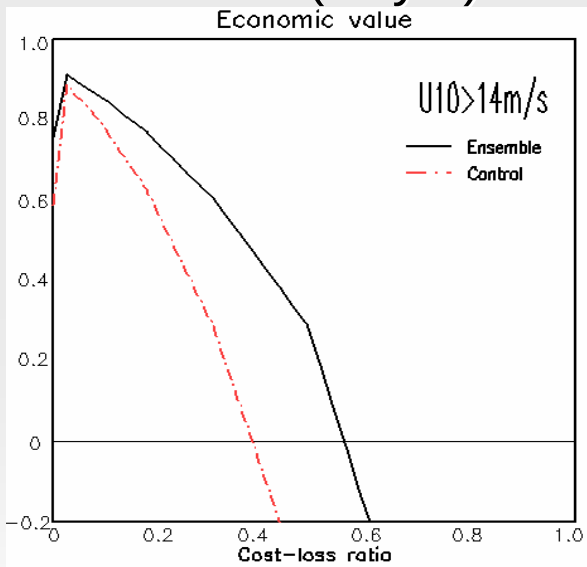
Hs>2m (Day 5)



Hs>4m (Day 5)



U10>10m/s (Day 5)



U10>14m/s (Day 5)

b. Relative operating characteristic (ROC)

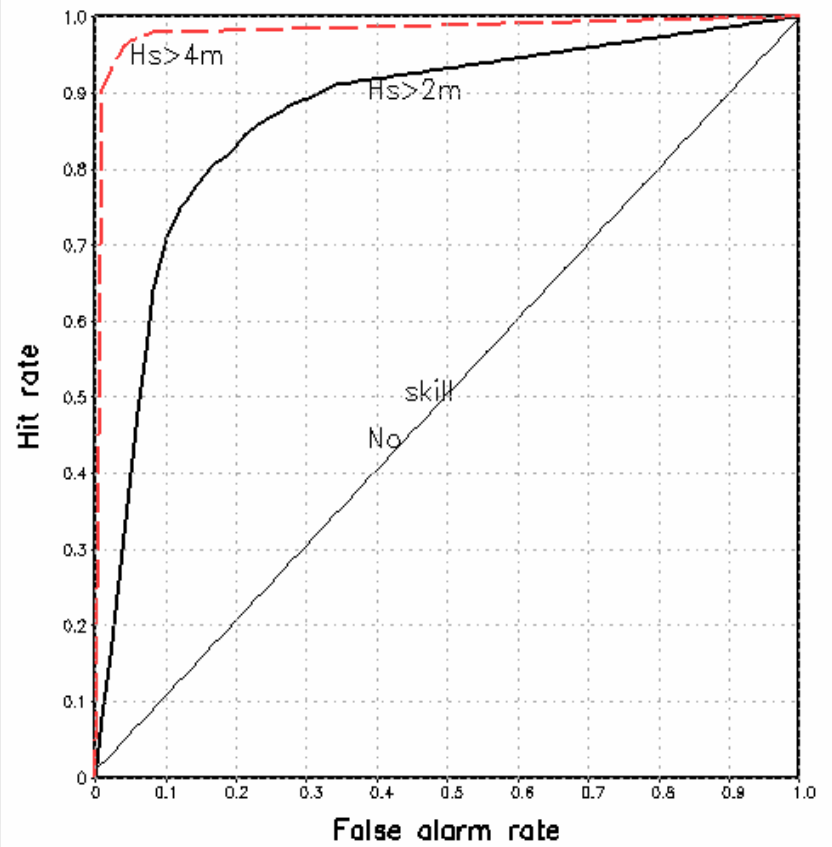
Measures the ability of the forecast to discriminate between events and non-events (resolution)

-- Plot hit rate vs false alarm rate using a set of varying probability thresholds

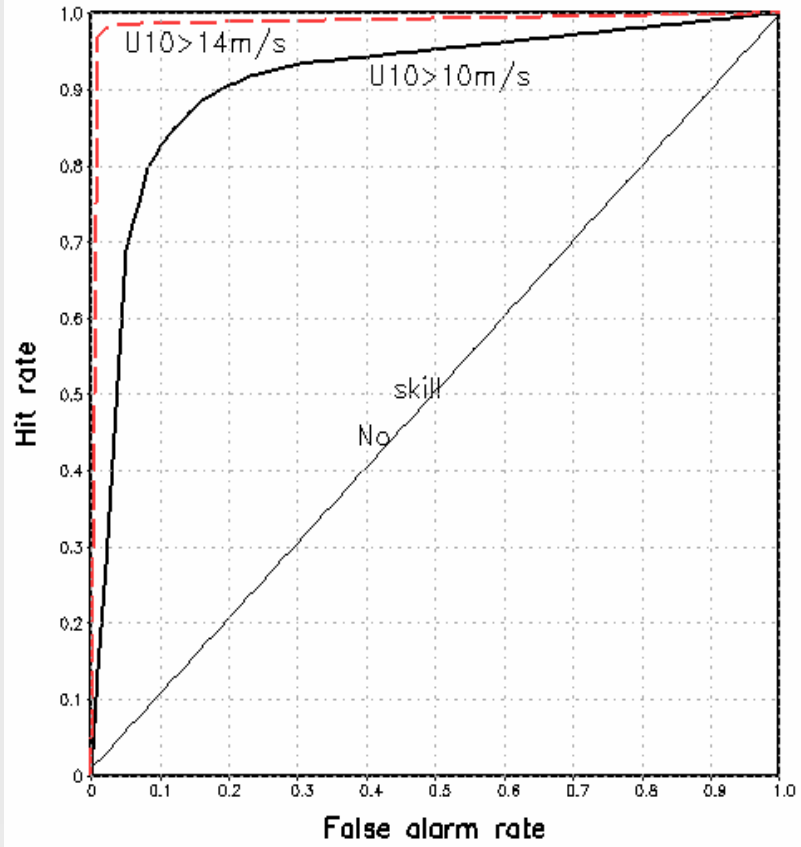
hit rate=hit/(hit+miss)

false alarm rate=false/(false + correct reject)

-- ROC area: area under the curve which is a useful summary measure of forecast skill.



Wave Height (Day 5)



Wind Field (Day 5)

4. Future planes

1). 20 ensemble members.

2). Carry initial conditions from previous cycle.

3). Forecast horizon to 7.5 days.

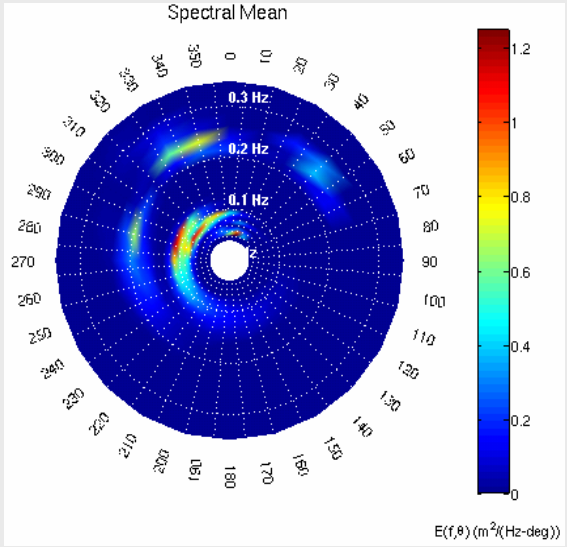
4). Join with FNMOC.

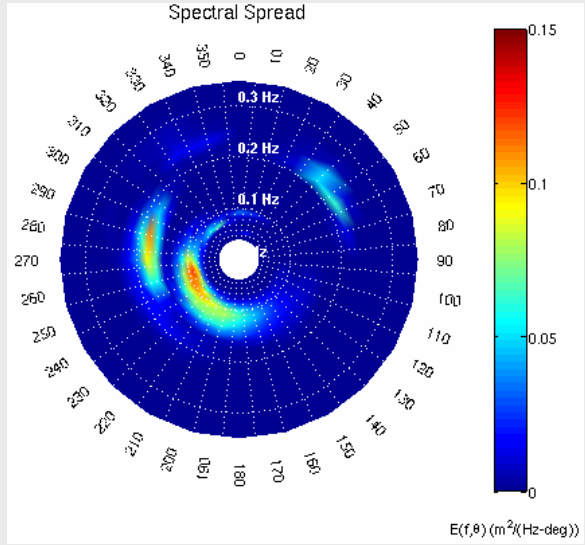
5). Parallel run in April, 2008.

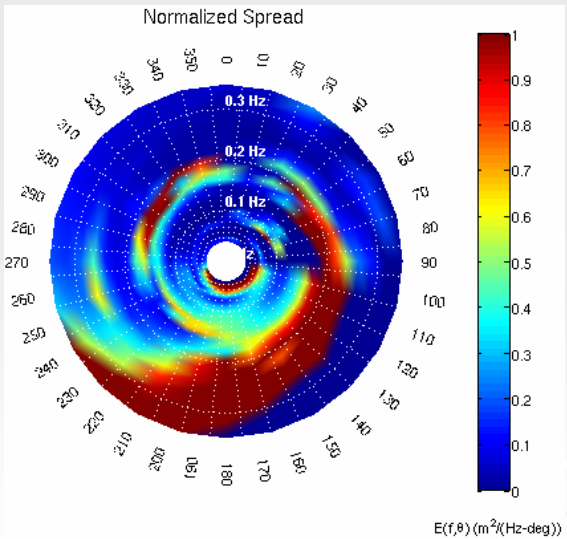
6). Operational run in June, 2008.

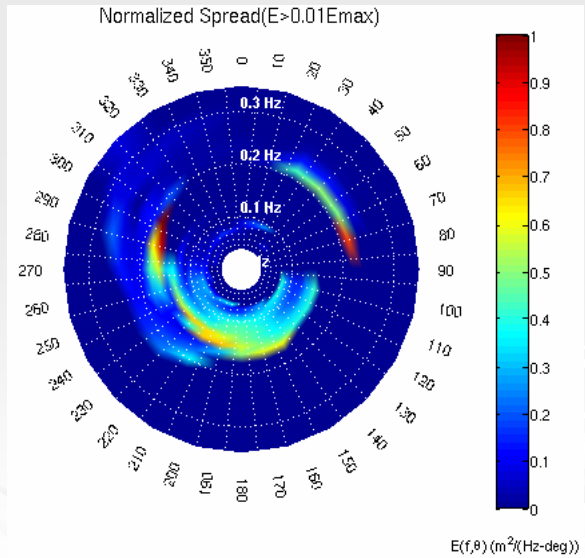
5. Role of wind sea and swell in the wave ensemble

Day 5 wave spectrum for 10/15/2007









6. Summary

1. The ensemble system performs better forecast skill than the deterministic forecast.
2. The ensemble system has good forecast capacity which can catch most forecasted events.
3. The ensemble system is under forecasting in low probability and over forecasting in the high probability.
4. The ensemble spread is mostly contributed by the wind sea, not the swells.