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ON THE USE OF WAVE ENSEMBLE OF THE MODEL MFWAM TO DIAGNOSE EXTREME WAVE EVENTS IN NORTH ATLANTIC OCEAN

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Motivation

■ An ensemble prediction system (EPS) is presented that has been designed to quantify uncertainties in short range (up to 4 days ahead) wave forecasts for the Atlantic Ocean and Mediterranean sea. Ensemble forecasting also provides solutions for rare events probabilistic forecasting. In order to detect large departures from normal conditions, an Extreme Forecast Index (EFI) is based on a great number of hindcasts of the model, its pseudo-climate. The sensitivity of the EFI to the sampling of this climate is assessed in this study in order to optimize its informative value.

■ Implementing a probabilistic approach to prevent extreme events such as rogue waves.

The model

Wave Ensemble model is built on Météo France wave model MFWAM.
It is forced by the weather ensemble global model PEARP 35 members,
With grid resolution of 10 km.

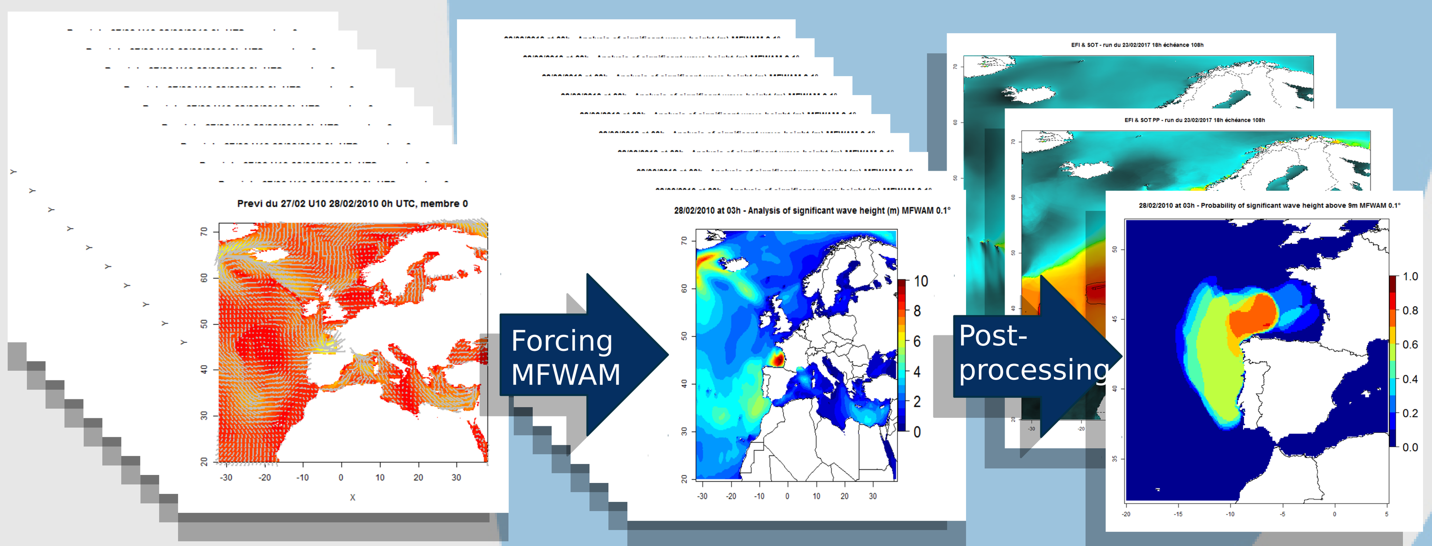


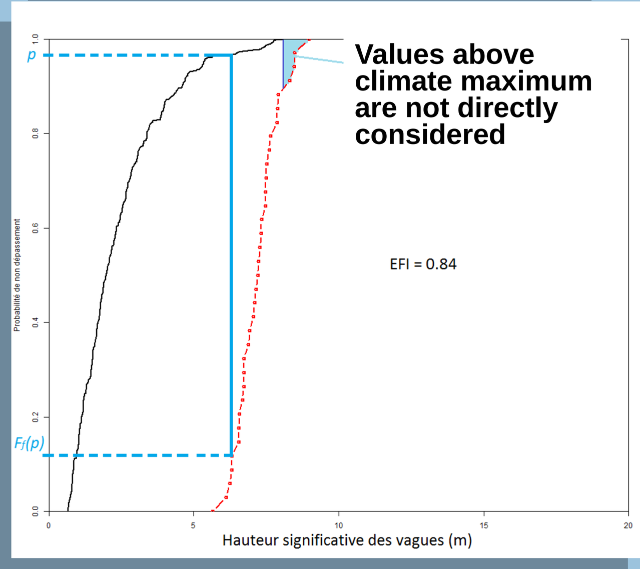
Fig.1: Experimental protocol for EFI production of the MFWAM model

Extreme Forecast index (EFI) for SWH

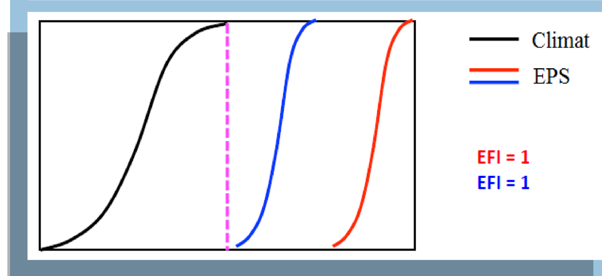
Extreme Forecast Index, (Lalaurette, 2003, Zsoter, 2006), EFI, is used to detect unusual values of an ensemble prediction by comparing it to its pseudo-climate. However, high EFI values may not be enough to detect extreme event above model climate maximum. Shift of Tails (SOT), is used to compare the highest predicted values to the climate tail of distribution.

The CDF of the model p-climate plays a key role in these indices.

$$EFI = \frac{2}{\pi}\int_0^1 \frac{p - F_f(p)}{\sqrt{p(1-p)}}dp$$



Extreme Forecast Index is comparing the whole Cumulative Distribution Function (CDF) of the climate value to the predicted value CDF. Shift Of Tails estimates the departure between the part of both CDF above the quantile 90%.



$$SOT = \frac{Q_f(90) - Q_c(100)}{Q_c(100) - Q_c(90)}$$

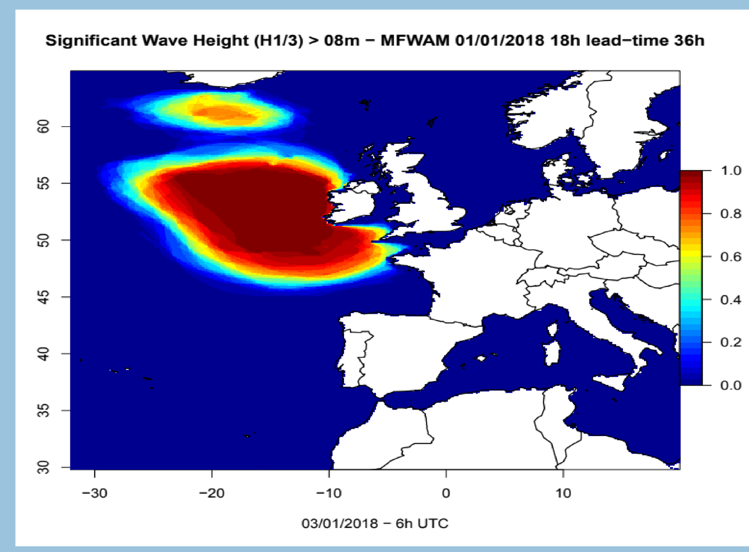
SOT indicates the distance between distributions : the greater the distance, the higher the probability of an extreme event

Application to storm Eleanor 3 January 2018

massive wave trains are pushed towards British Isles and North-western France causing 6 casualties in France and €724 million loss over Europe. Recorded winds reached between 140km/h and 160 km/h.

Figure 1 :Coastal damages at Wimmereux, France

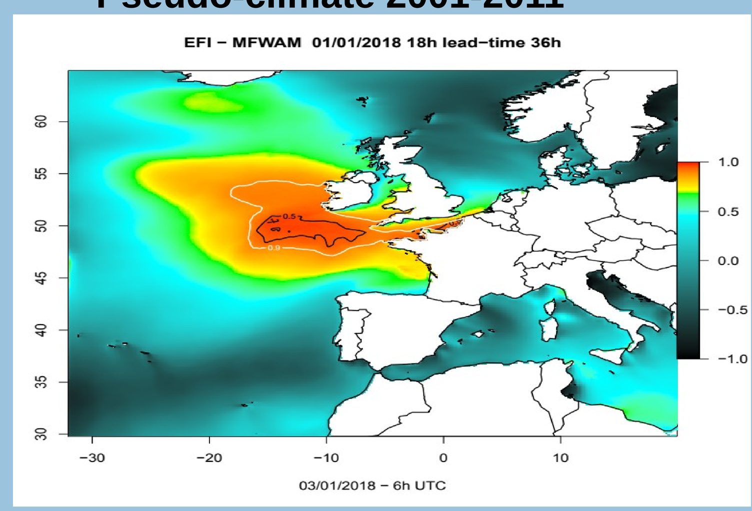
Probability of occurrence SWH > 8 m
Lead time in forecast 36 hours
(1 january 2018 at 18:00 UTC)



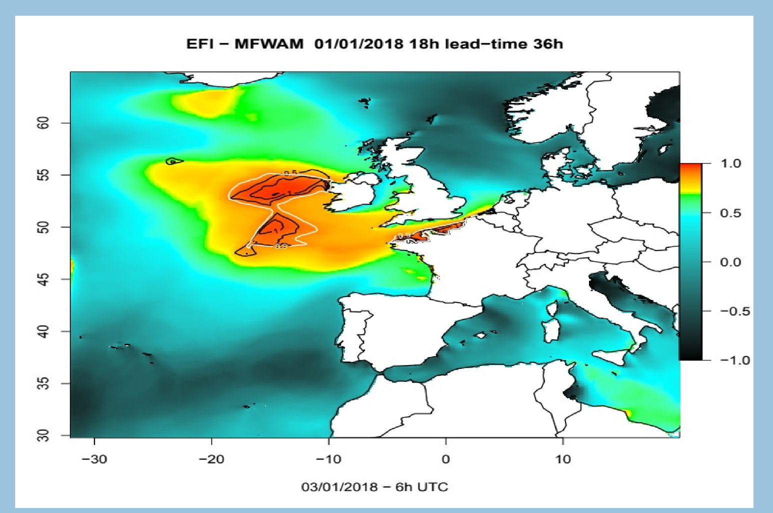
EFI maps : sensitivity to pseudo-climate
Lead time in forecast 36 hours

Pseudo-climate sensitivity

Pseudo-climate 2001-2011



Pseudo-climate 2001-2011+2013+2014



MFWAM reforecast (Pseudo-climate)

PEARP is a multi-physics ensemble model, with a reforecast dataset covering the 1994-2017 period, at a daily frequency. The reforecast dataset is based on 10 members corresponding to the ten different physics schemes of PEARP. The MFWAM model has been forced by the outputs of PEARP-Reforecast during 2001-2011 for winter periods only, to produce the pseudo-climate of MFWAM.

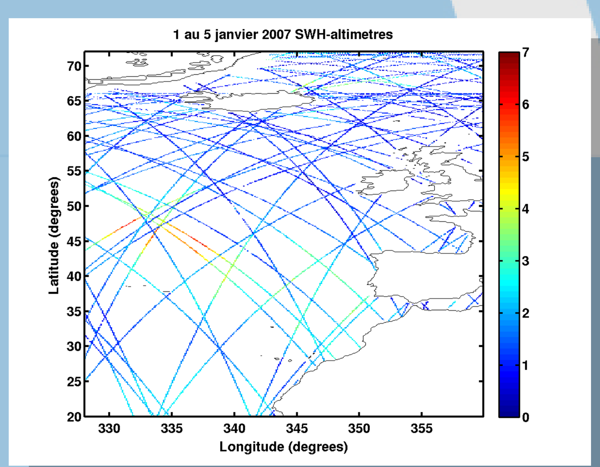


Fig.2: One day altimetric wave height observations used for validation

Pseudo-climate better represented by including intense winter 2013/2014

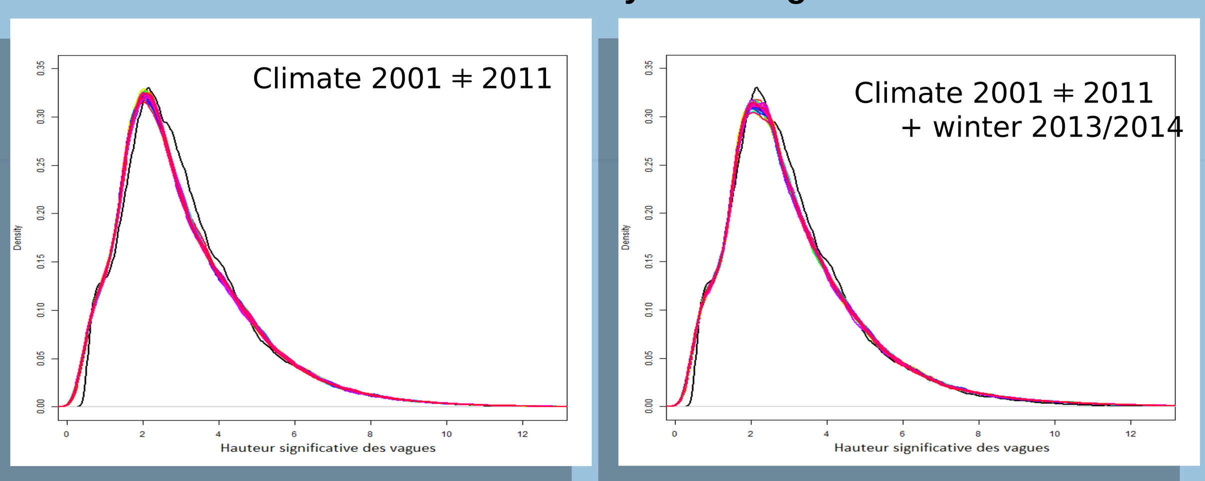
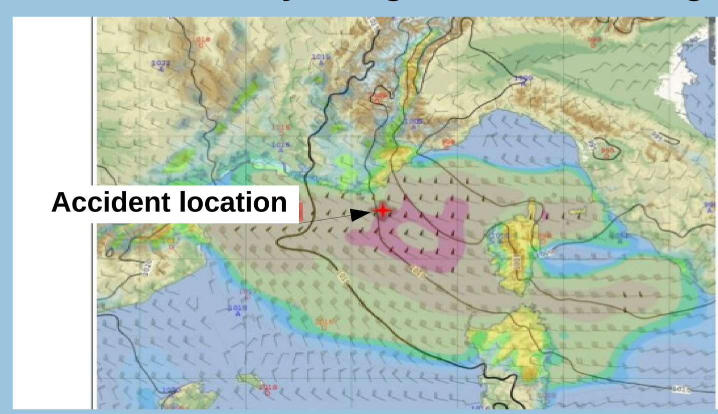


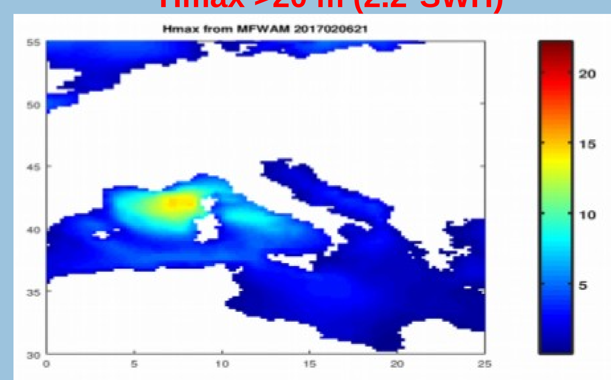
Fig.3: PDF plots of SWH from altimeters and the pseudo-climate (10 members)

Rogue waves case in Mediterranean Sea (line Ajaccio-Marseille) :

On 6 March 2017 at 21:00 UTC, the ferry Jean Nicoli was hit by a rogue waves damaging the bridge of ~22 m



Hmax >20 m (2.2*SWH)



Validation of the MFWAM pseudo-climate

We study the overall quality of the MFWAM pseudo-climate representation before forecast calibration. Fig.3 shows the wave model distribution is fairly comparable to the observations. Waves higher than 4m are over-represented in the model, while 2-3m waves are under-represented. Ensemble scoring is investigated, showing good results for probabilistic wave forecasts (Fig. 4). Only low thresholds have good Brier Skill scores, while Brier scores are fair even for highest thresholds.

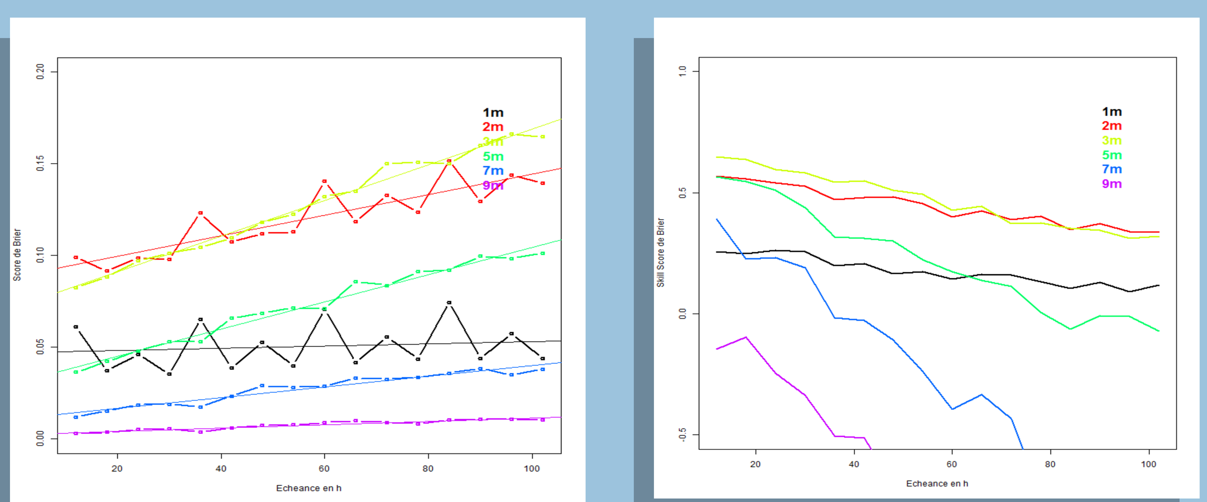
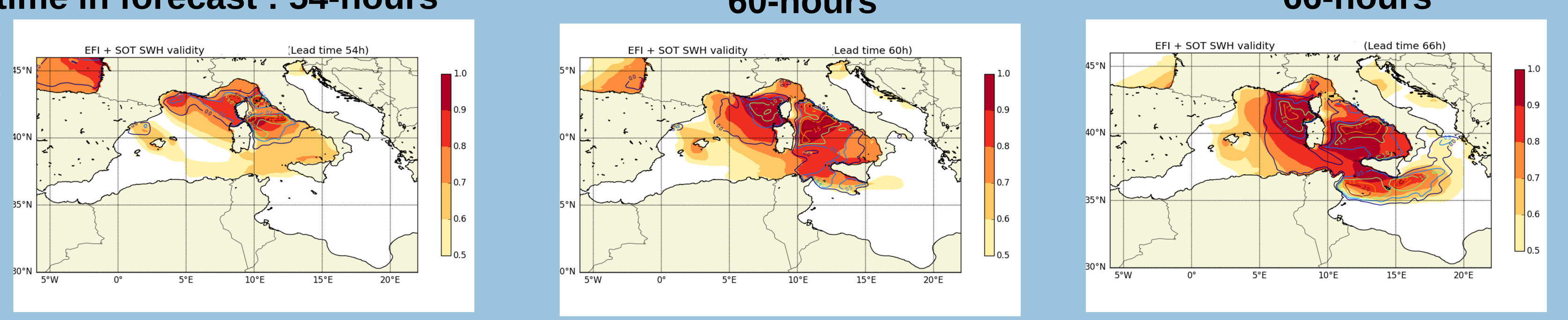


Fig.4: Brier (left) and Brier Skill score Experimental protocol for EFI production of the MFWAM model

Lead time in forecast : 54-hours | 60-hours | 66-hours

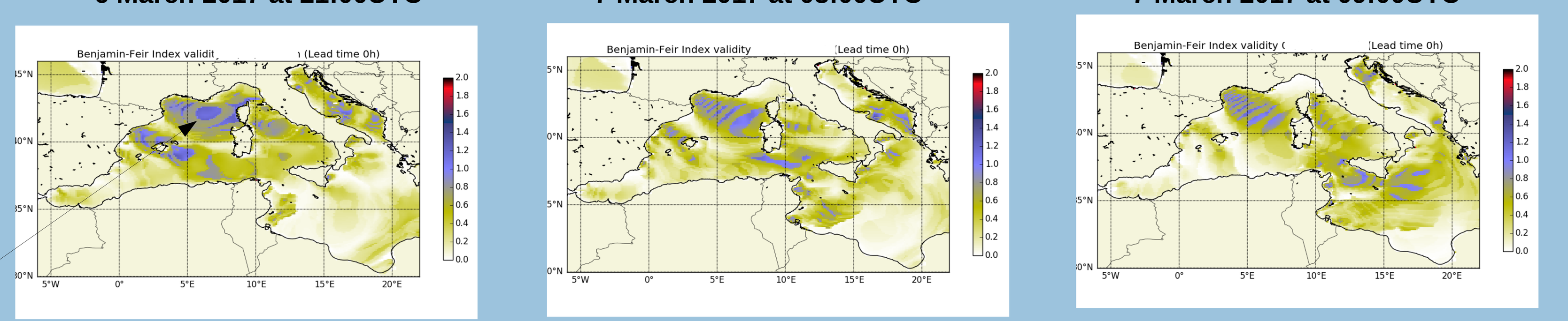
EFI and SOT of SWH



54-hour forecast red patches shows EFI of 1 and SOT greater than 1.5. This corresponds to blue patches of high values of BFI (>1.5), which means a high probability of presence of rogue waves

6 March 2017 at 21:00UTC | 7 March 2017 at 03:00UTC | 7 March 2017 at 09:00UTC

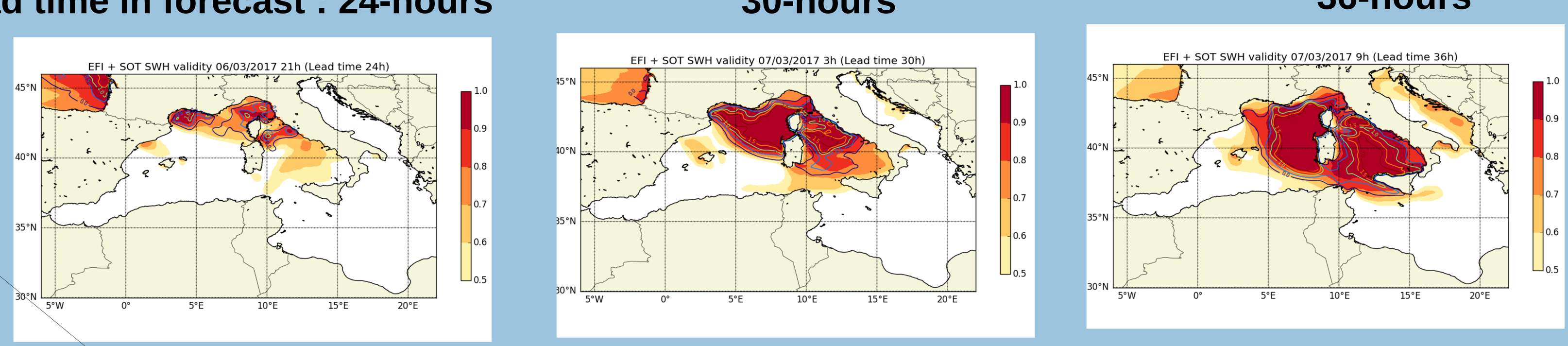
Benjamin-Feir Index (BFI2D)



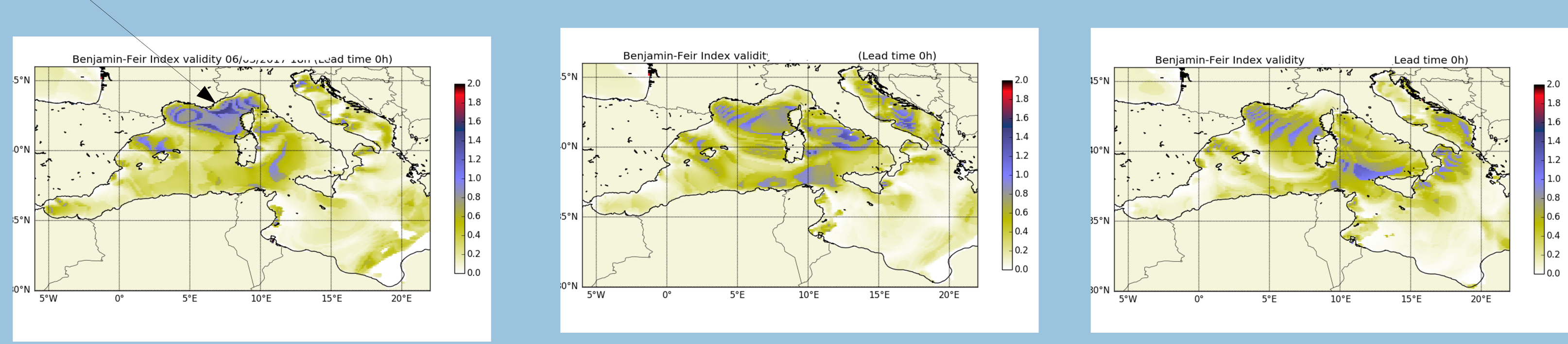
Lead time in forecast : 24-hours | 30-hours | 36-hours

24-hours forecast gives a more accurate patches of EFI and confirms that the location of the accident is greatly indicated as rogue waves

EFI and SOT of SWH



BFI2D



Conclusions

■ Synthesizing extreme forecast helps to provide informative value for decision making. Estimation of the model climate approach is crucial to meet the needs for calibrated probabilities, seeking a compromise between computing costs and the best representation of the model climate.

■ The use of ensemble wave system with EFI and SOT shows a very robust tool in order to improve the prediction of rogue waves. This will ensure greatly a reliable safety of ship routing for instance.

■The ensemble wave system with probabilitic production of indicators will be implemented operationally in 2020

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F. Lalaurette (2003). Early detection of abnormal weather conditions using a probabilistic extreme forecast index. Q.J.R. Meteorol. Soc., 129 : 3037-3057

Descamps, L., Labadie, C., Joly, A., Bazile, E., Arbogast, P., & Cébron, P., 2015

PEARP, the Météo-France short-range ensemble prediction system. Quarterly Journal of the Royal Meteorological Society, 141(690), 1671-1685