A STUDY OF SWIM DIRECTIONAL WAVE SPECTRA DURING ROGUE WAVE CASES

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MOTIVATION:

The transition from wind waves to swell is accompanied by strong non-linear interactions between several wave components and also kinematic effect in presence of strong surface currents. This can lead to dangerous seas and appearance of rogue waves which need to be better forecasted for the marine safety and ship navigation.

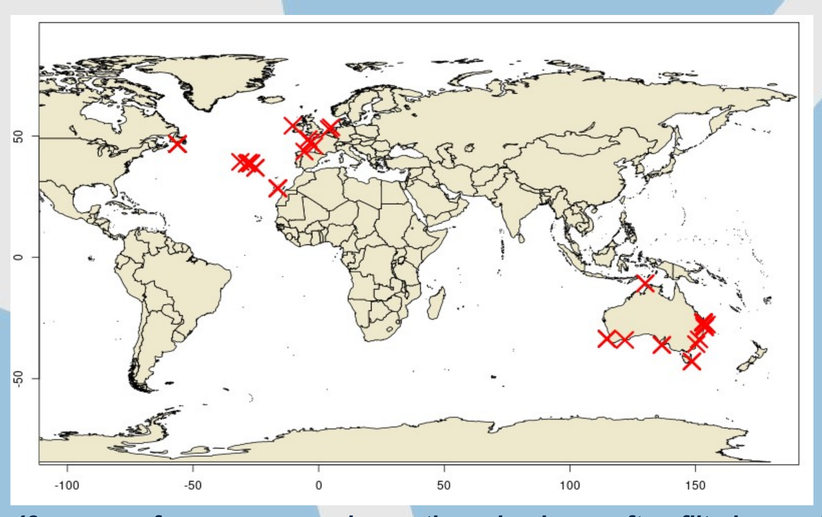
The goal of this work consists in studying cases of rogue waves and investigating whether the probability of occurrence of rogue waves is related to the specific shape of the directional wave spectra obtained with the SWIM instrument.

► Observation of rogue waves by buoy

Use of CMEMS in-situ buoys network

Selection of buoys measuring maximum wave height.
Colocalisation with CFOSAT with 0.5° and 90 min of tolerance.
Selection of cases with SWH > 50 cm and PP > 8 s. Filtering of spectra with less than 30% of missing bins

A rogue wave is defined by SWH/Hmax > 2



48 cases of rogue wave observations by buoy after filtering and colocalisation with CFOSAT, from January 2020 to July 2022

► 2D directional spectra of CFOSAT

Measurement of 2D wave spectra on 70x90 km boxes, with a good quality from 0,056 Hz to 0,16 Hz.

Spectral resolution of 24 directions (ambiguity) and 32 frequencies

→ Spectral peakedness

$$Qp = \frac{2\sum_{f_{min}}^{f_{max}} f\, F^2(f)\, df}{\left[\sum_{f_{min}}^{f_{max}} F(f)\, df\right]^2}$$

Goda, 1976

→ Benjamin Fair index

$$BFI = k_0 \sqrt{m_0} Qp \sqrt{2\pi}$$

Mori et al., 2011

→ directional spread

$$\sigma_\phi(f) = \sqrt{2 \times \left(1 - \sqrt{a_1(f)^2 + b_1(f)^2}\right)}$$

a1/b1 Fourier coef

→ BFI2D

$$BFI_{2D} = \frac{BFI}{\sqrt{1 + \alpha_2 R}} \qquad R = \frac{1}{2}\sigma_\phi^2 \pi Qp^2$$

Mori et al, 2011

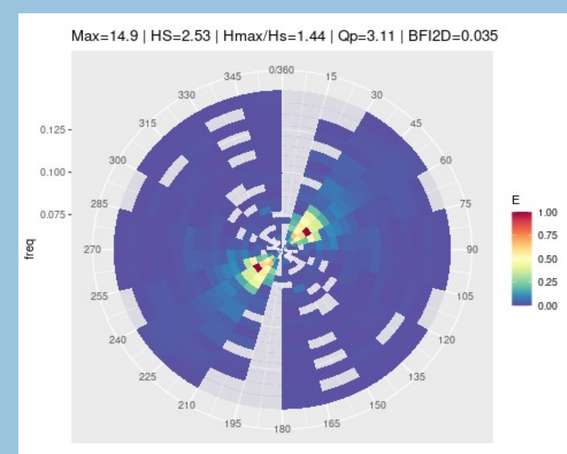
→ Crest-trough correlation r

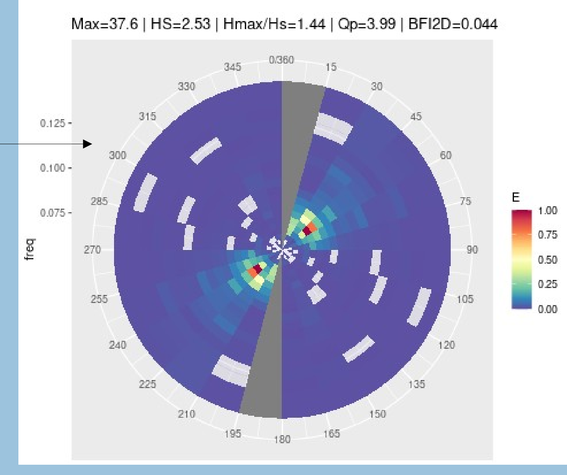
$$r = \frac{1}{m_0}\sqrt{\rho^2 + \lambda^2}, \text{ where } \rho = \int_0^\infty S(f)\cos(2\pi f \tau)df \text{ and } \lambda = \int_0^\infty S(f)\sin(2\pi f \tau)df,$$

where $\tau = \frac{\bar{T}}{2}$ is the lag time at half the spectral mean period $\bar{T} = \frac{m_0}{m_1}$.

Gemmrich et al, 2022

Article on these indexes calculated with CFOSAT : Le Merle et al. 2021





Qp higher

SWH higher in CFOSAT

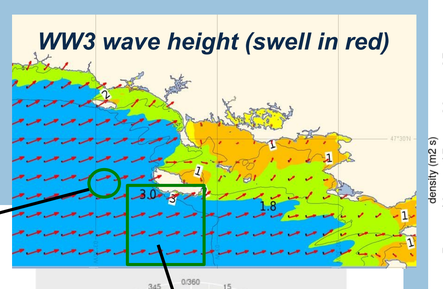
=> higher BFI

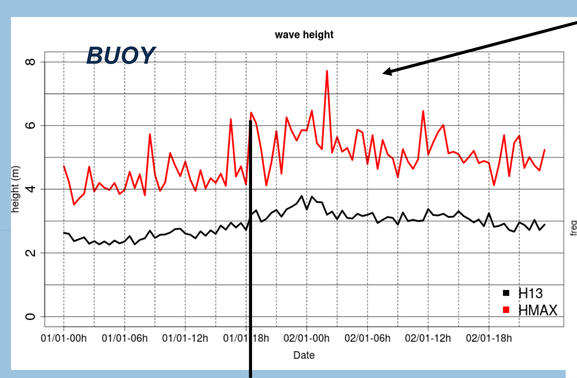
2 consecutive spectra on CFOSAT track, 2021/06/18 at 23h, near Australia

HS and Hmax/HS are buoy data (56006)

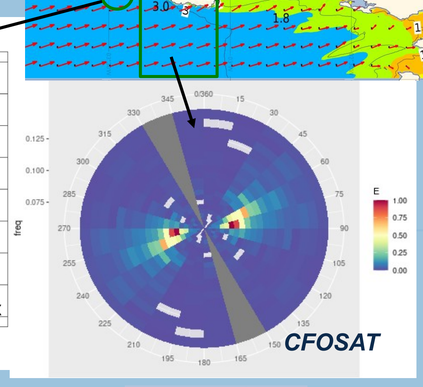
1st of February 2022 case of swell on french coast

At 18h UTC, condition of westerly swell of 3,3 m and 12s, with a weak wind

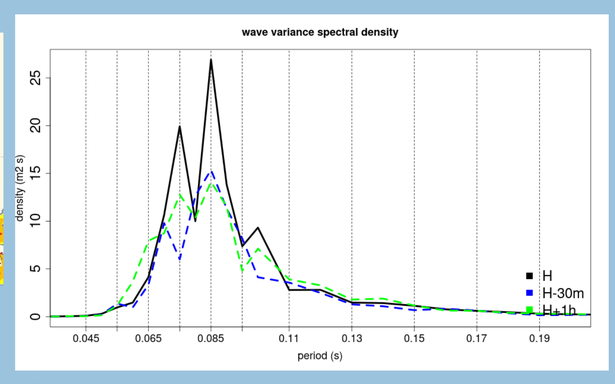




SWH of 3,1 m and Hmax of 6,4 m



2022/01/01 at 18h43 UTC

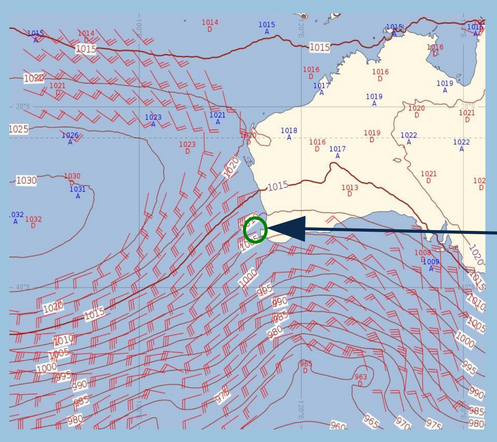


1D spectra observed by buoy at the hour H of rogue waves, just before (blue) and just after (green)

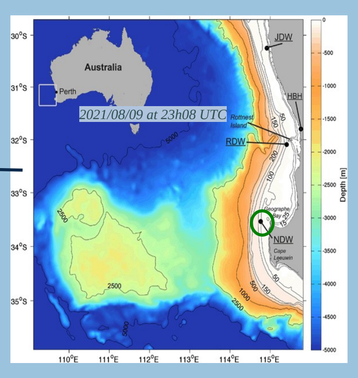
The waves spectrum is seen as bimodal with 2 close peaks in frequency, near the rogue wave location, according to the buoy and CFOSAT

9th of August 2021 a storm in Australia

Strong storm with mean south-westerly winds of 75 km/h

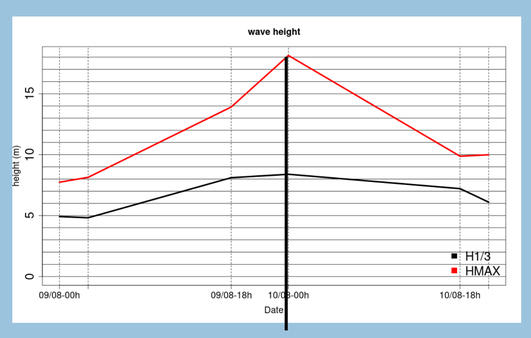


Sea-level pressure and wind from IFS, 2021/08/10 at 0h UTC



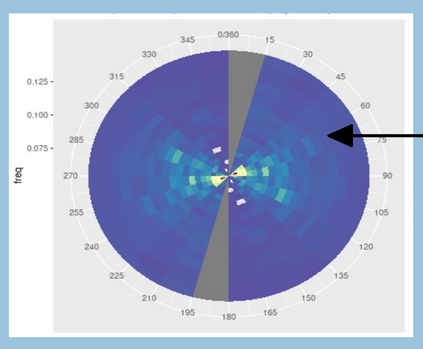
Buoy location

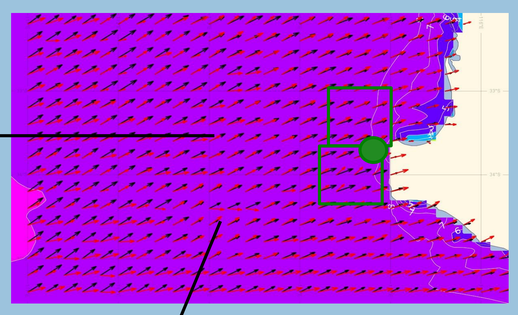
Buoy observation

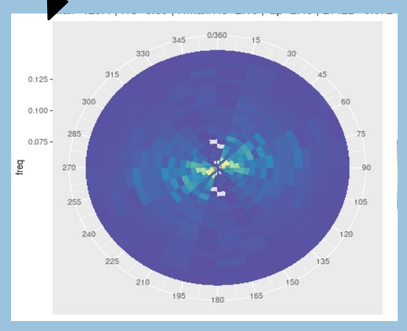


SWH of 8,4 m and Hmax of 18,1 m

CFOSAT observation at 23h08 the 09/08



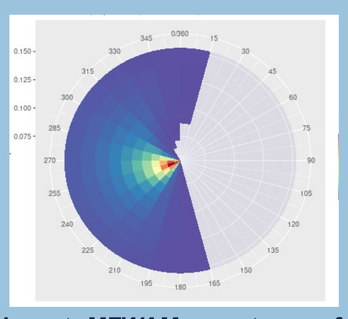




Narrow peak of energy in low frequency (17,5s of period).

Unidirectional energy with several close secondary peaks.

MFWAM spectrum



Closest MFWAM spectrum of the box at the north of the buoy the 10/08/21 at 0h UTC

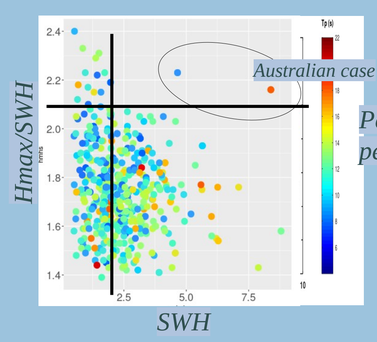
Model spectra are more smooth. They don't represent well secondary peak, particularly if they are close to each other. So they are less appropriate to catch an interaction between close frequencies.

CONCLUSIONS

- CFOSAT has a better spectral resolution than model from 0,056Hz to 0,16 Hz. It can better represent specific spectral characteristics.

- Some spectra seem to be similar but correspond to very different Hmax/SWH. But both cases presented here are frequent in rogue wave cases and not in low Hmax/SWH. It corresponds to narrow peak and unidirectional shape => possible interactions between frequencies explaining rogue waves.

- The study did not indicate a strong correlation between BFI2D, r and Hmax/SWH. However it is clearly observed that BFI2D and r are enhanced during the conditions of rogue waves. Particularly when two wave systems are propagating in closer scale of frequency and direction. More cases are needed to investigate and implement a dangerous seas indicator



Statistics over buoys colocalised with SWIM

Mori, N., Onorato, M., & Janssen, P. A. E. M. (2011). On the estimation of the kurtosis in directional sea states for freak wave forecasting. Journal of Physical Oceanography

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