METEO FRANCE

A study of SWIM directional wave spectra during rogue wave cases

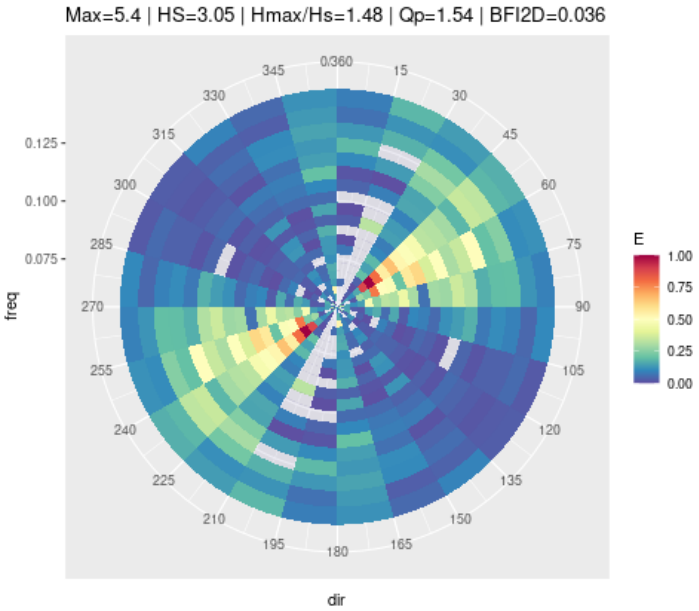
DALPHINET Alice[1], AOUF Lotfi[1], LE MERLE Eva[2], HAUSER Danièle[3]
[1] Météo-France [2] ISMAR [3] LATMOS

13/09/22

3nd CFOSAT International Science team meeting

Context

- SWIM measures 2D wave spectra on 70x90 km boxes, with a good quality from 0,056 Hz to 0,16Hz
- Spectral resolution of 24 directions (ambiguity) and 32 frequencies
- Possibility to compute characteristics of wave spectra and index of extrem waves (peakedness, BFI, r)



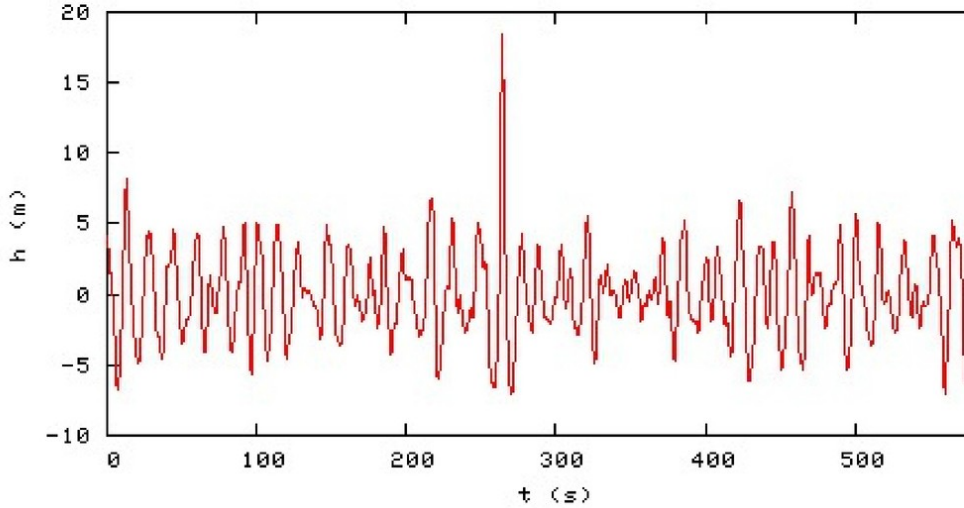
Example of SWIM height spectrum in frequency The 02/01/2020 23:10 in Naturaliste Cape (Australia)

- Is there any correlation between SWIM spectra and rogue waves observations ?

Observation of rogue waves

- Use of the CMEMS in-situ buoys network.
- Selection of buoys measuring maximum wave height.

→ a rogue wave corresponds to Hmax/SWH > 2



The 1995 Draupner wave

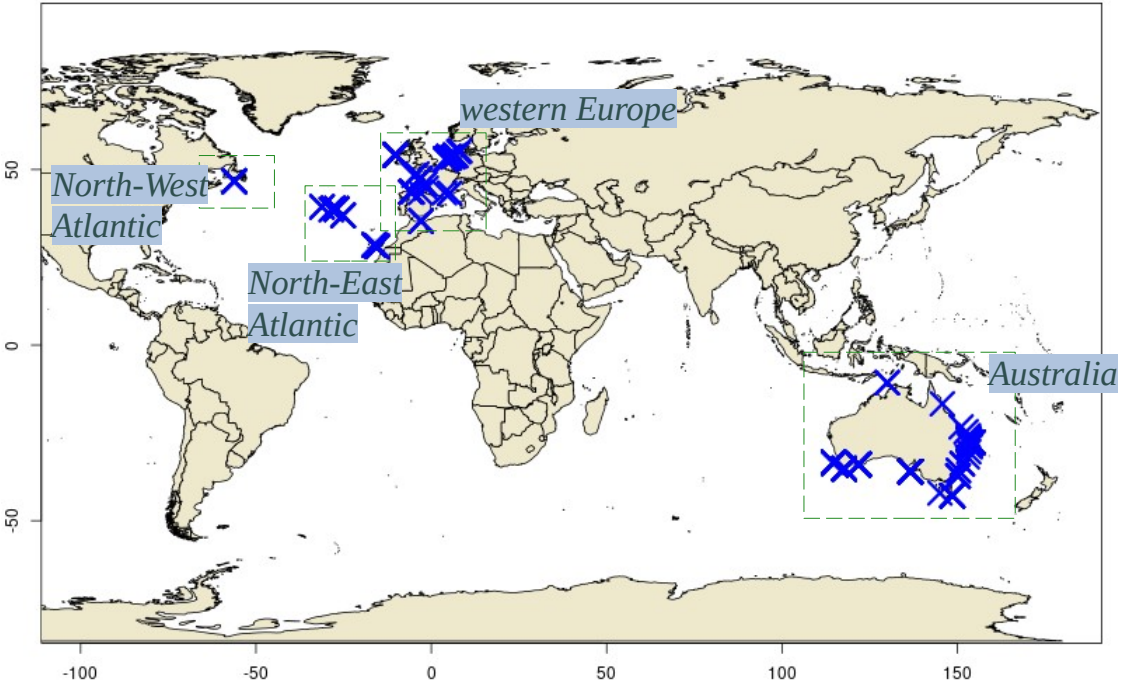
- Colocalisation at 0,5° of distance and 90 min in time.
- Selection of cases with SWH > 50 cm and PP > 8s

→ range of good SWIM data quality

- Filtering of spectra with less than 30% of missing bins

Observation of rogue waves

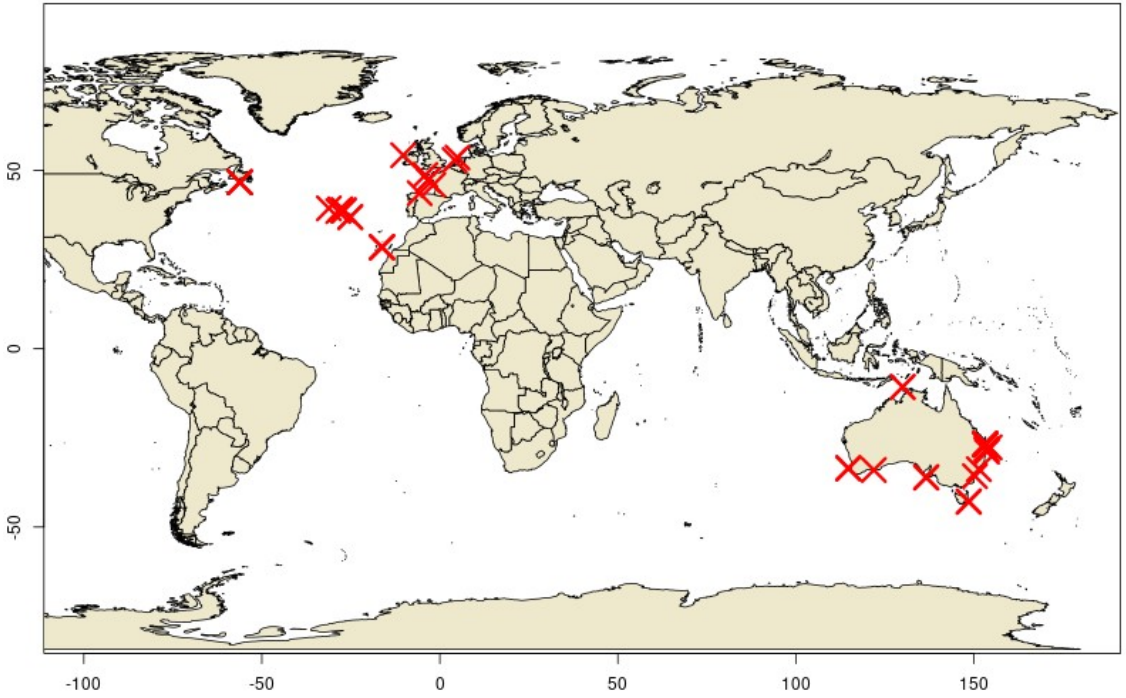
- From January 2020 to July 2022 : 475 colocalisations



Selection from the in-situ TAC of Copernicus Marine Service

Observation of rogue waves

- From January 2020 to July 2022 : 48 cases of rogue waves



Selection from the in-situ TAC of Copernicus Marine Service

Outline

- Computation of spectral indexes on the whole period
- 2022/01/01 Case of swell near french coast
- 2021/08/09 Case of storm near Australia

Container ship after a storm in Pacific in December 2020

Computation of spectral indexes

2021/06/18 at 23h 56006 (Australia)

- Spectral peakedness thanks to Goda parameter

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

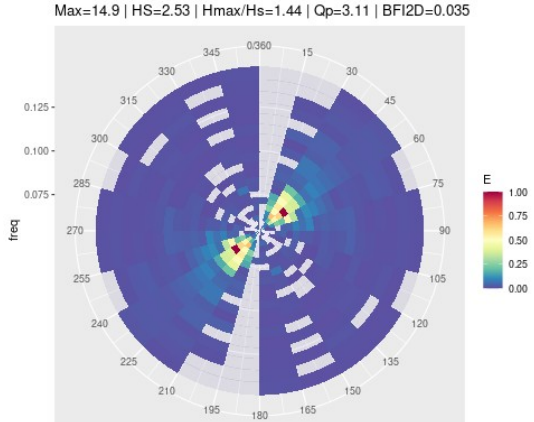
Goda, 1976

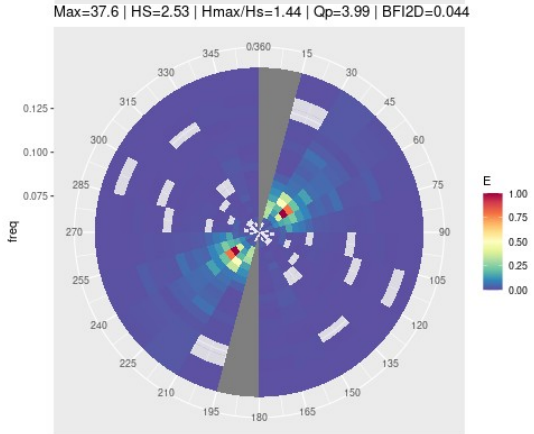
- Benjamin Fair index : indicator of non-linearities of wave interactions and probability of occurrence of extreme waves in the case of unidirectional seas

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

Mori et al, 2011

k_0 : mean wavenumber
m_0 : 0th order moment of the energy of the spectrum





Computation of spectral indexes

2021/06/18 at 23h 56006 (Australia)

- Spectral peakedness thanks to Goda parameter

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Goda, 1976

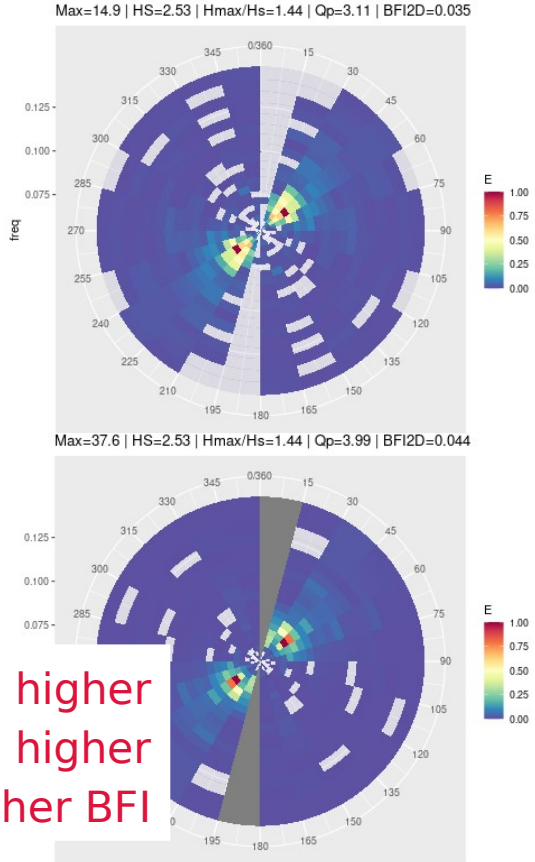
- Benjamin Fair index : indicator of non-linearities of wave interactions and probability of occurrence of extreme waves in the case of unidirectional

Higher the steepness, higher the BFI

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

Mori et al, 2011

k_0 : mean wavenum
m_0 : 0th order mom
the energy of the sp



Qp higher
steepness higher
=> higher BFI

Computation of spectral indexes

2020/04/28 at 23h 56006 (Australia)

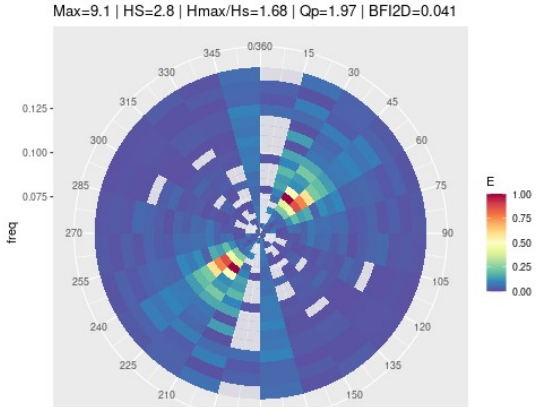
- Directional spread (a_1/b_1 Fourier coefficients)

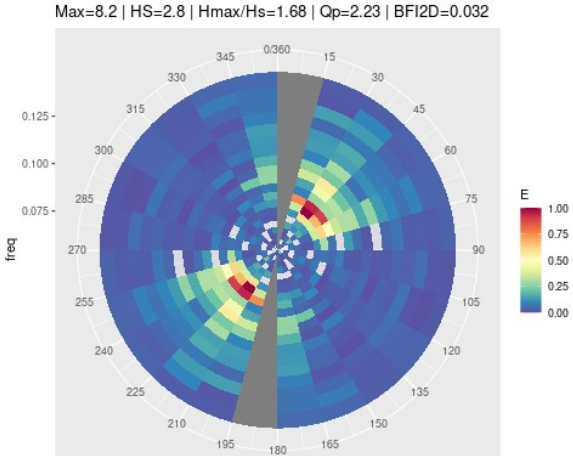
$$\sigma_\phi(f) = \sqrt{2 \times \left(1 - \sqrt{a_1(f)^2 + b_1(f)^2}\right)}$$

- Benjamin Fair index 2D : inclusion of directional effects

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

Mori et al, 2011





Study of spectral indexes on SWIM spectral data :
Le Merle et al, 2021

Computation of spectral indexes

2020/04/28 at 23h 56006 (Australia)

- Directional spread (a_1/b_1 Fourier coefficients)

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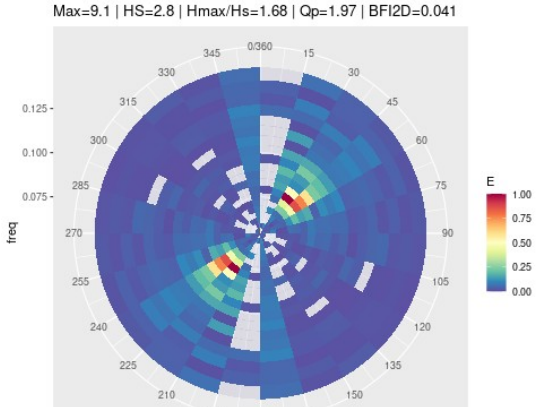
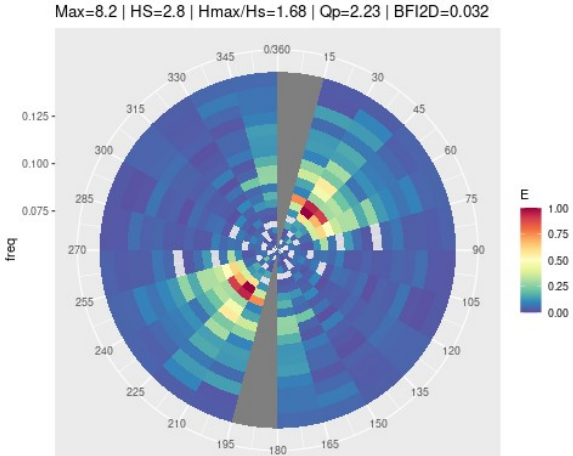
Mori et al, 2011

Smaller the directional spread, higher the BFI





Study of spectral indexes on SWIM spectral data :
Le Merle et al, 2021

Computation of spectral indexes

- Crest-trough correlation r calculated from the spectrum :

Auto-correlation of the sea surface elevation at half the wave period.

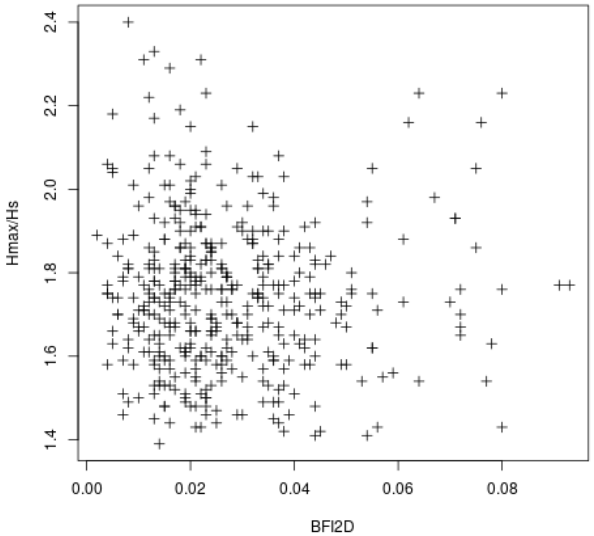
$$r = \frac{1}{m_0}\sqrt{\rho^2 + \lambda^2}, \text{ where } \rho = \int_0^\infty S(f)\cos(2\pi f\tau)df \text{ and } \lambda = \int_0^\infty S(f)\sin(2\pi f\tau)df,$$

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

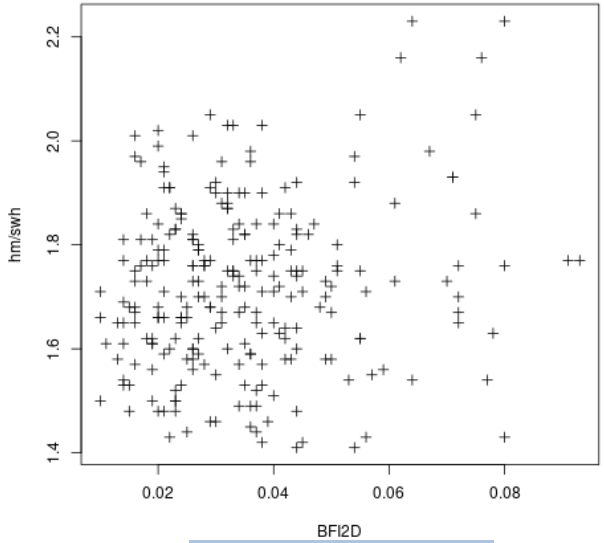
Gemmrich et al, 2022

BFI2D

- No correlation between BFI2D of SWIM data and Hmax/Hs, even for SWH > 2m



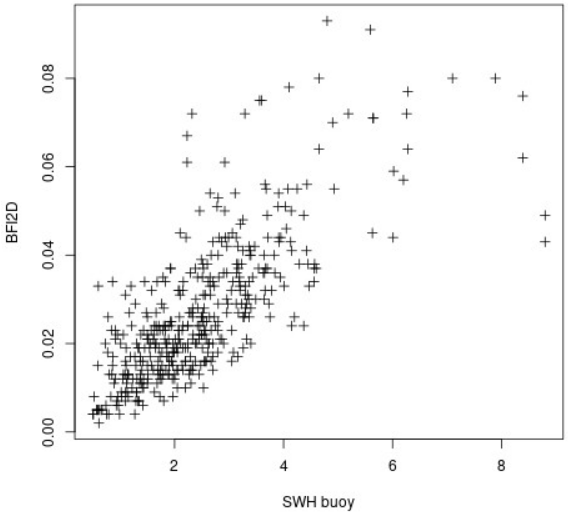
Cases with SWH>1 m



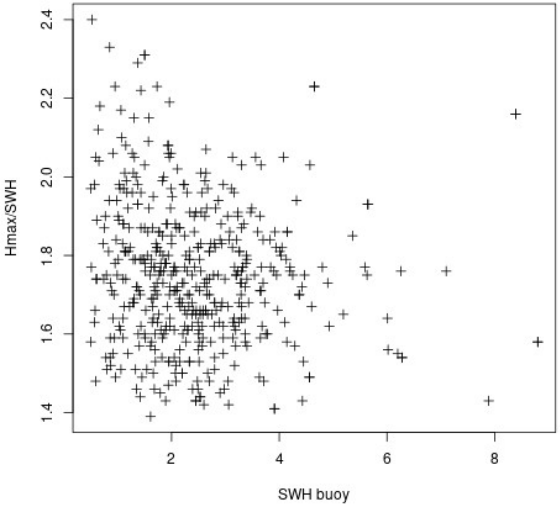
Cases with SWH>2 m

BFI2D

- Graphics of BFI2D function of SWH
  - BFI2D higher with SWH



- Graphics of Hmax/SWH function of SWH
  - A lot of rogue waves with SWH < 2 m

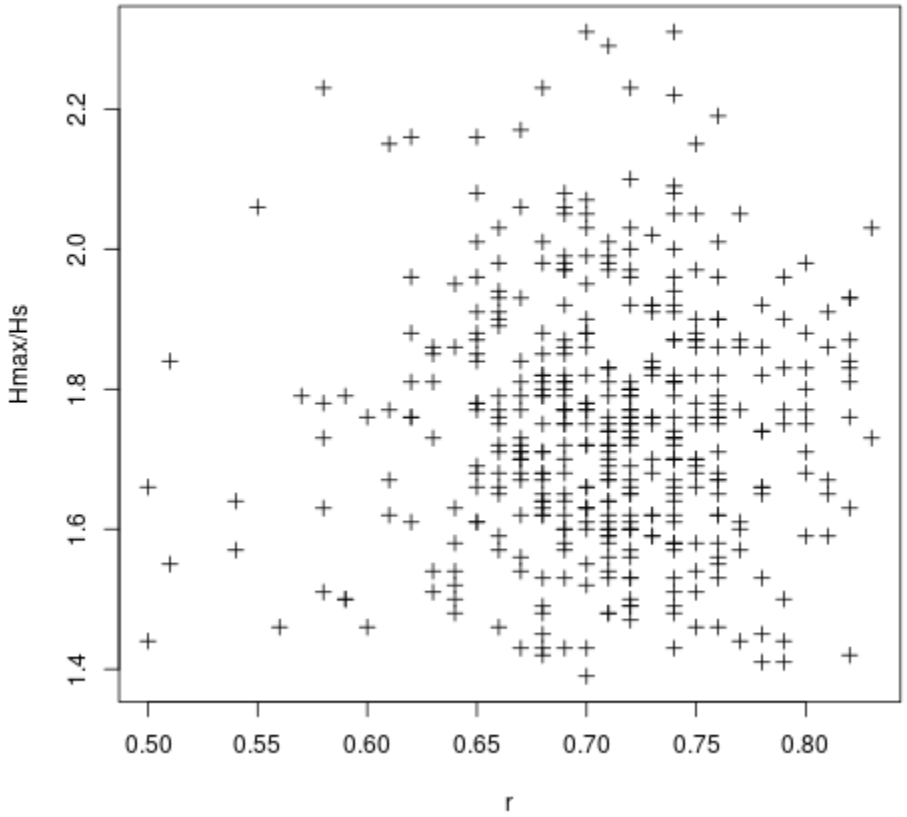


=> We can expect a bad correlation between BFI2D and Hmax/SWH

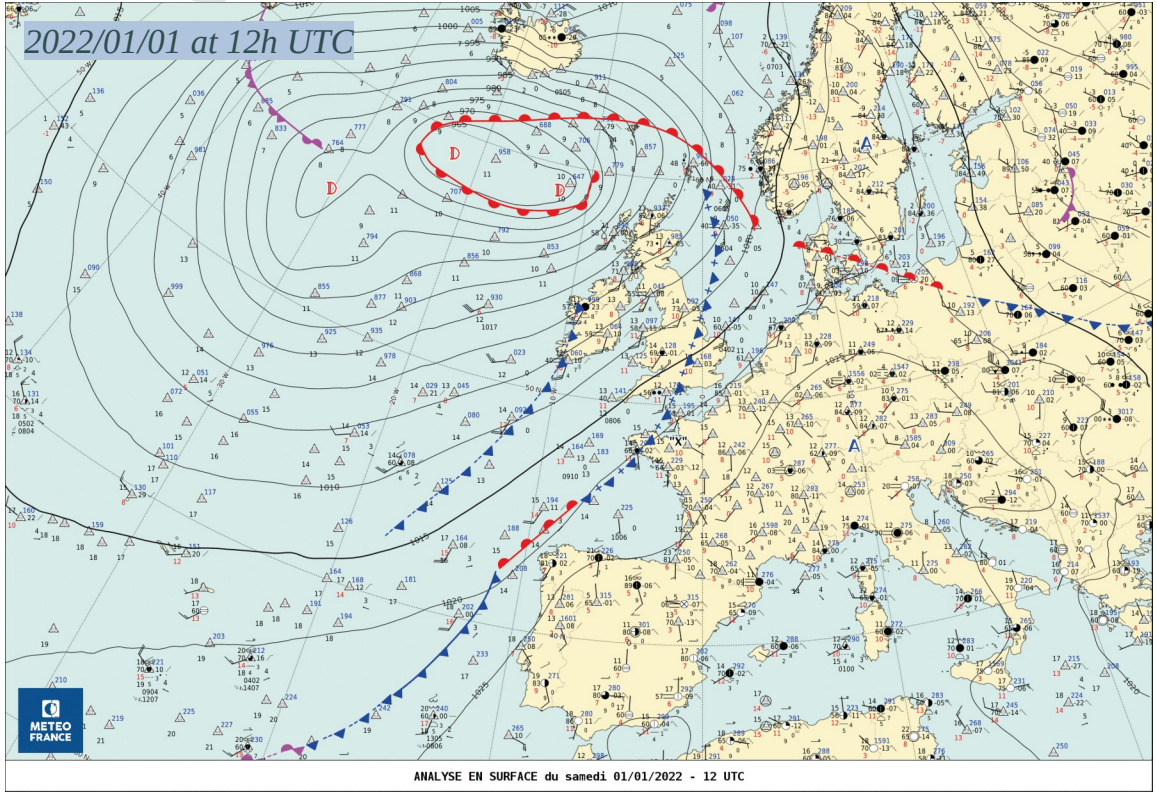
r correlation

- No correlation between r of SWIM data and Hmax/Hs

Cases with SWH>1 m

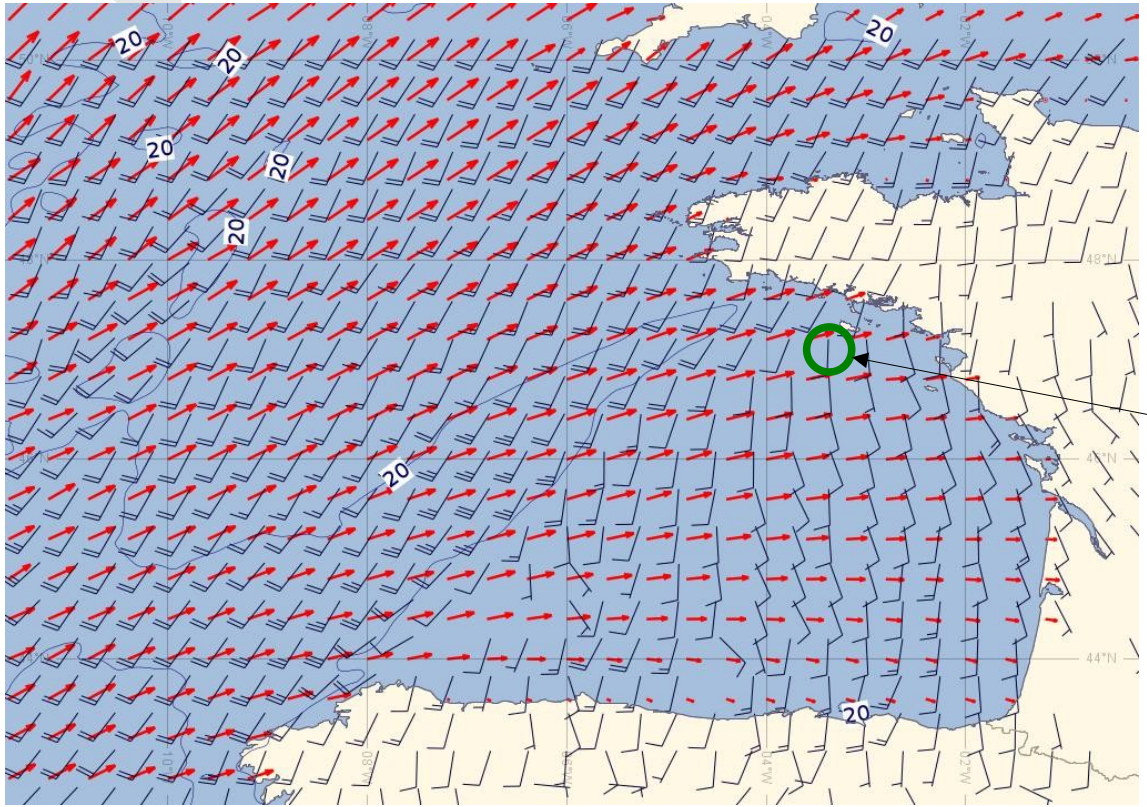


01/01/2022 Case of swell on french coast



- A cold front comes from Atlantic
- It is preceded by a westerly swell of 3,3 m and 12 s

01/01/2022 Case of swell on french coast

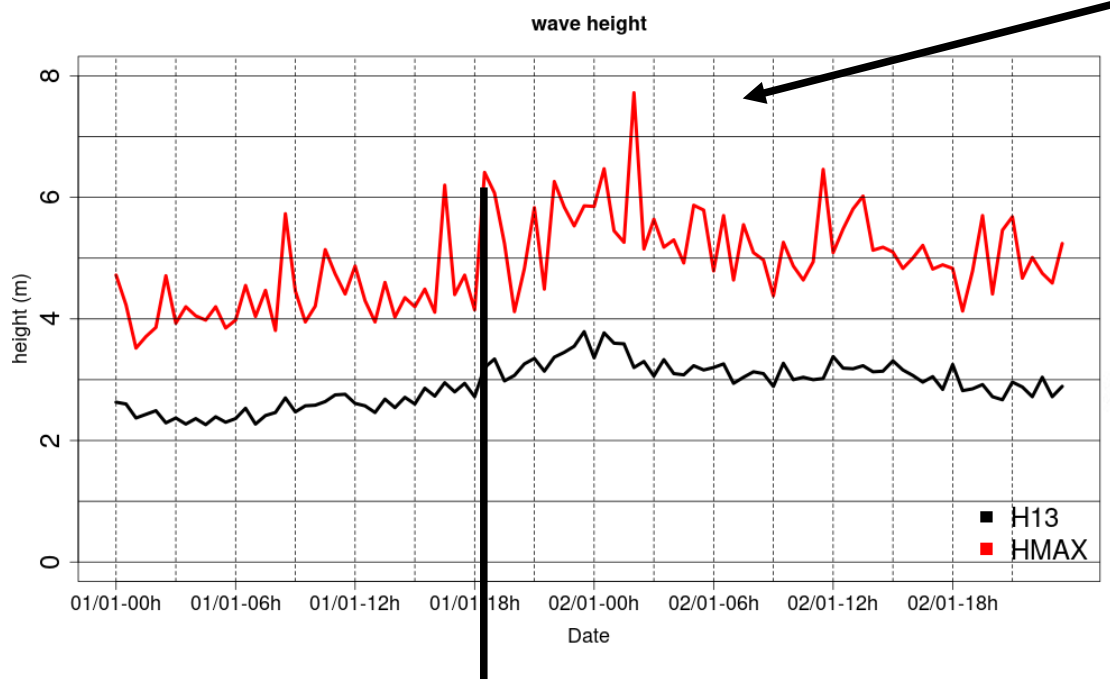


- A cold front is coming from Atlantic
- It is preceded by a westerly swell of 3,3 m and 12 s

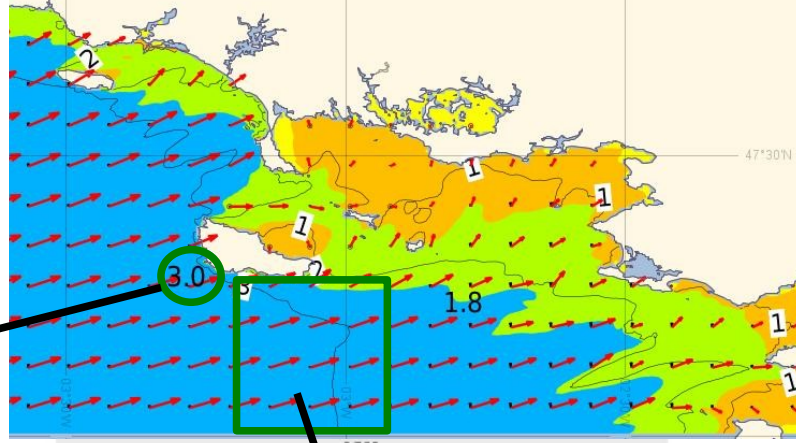
SWIM and buoy observation

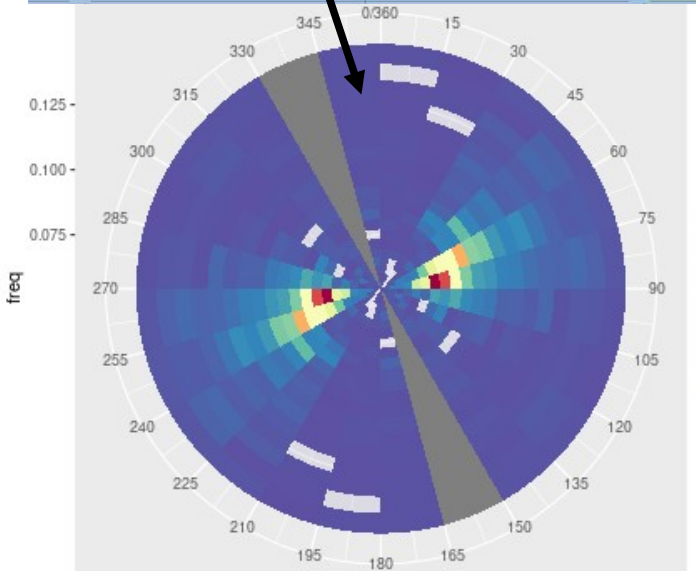
2022/01/01 at 18h UTC
10 m wind in blue from IFS
MFWAM swell in red

Buoy and SWIM observation



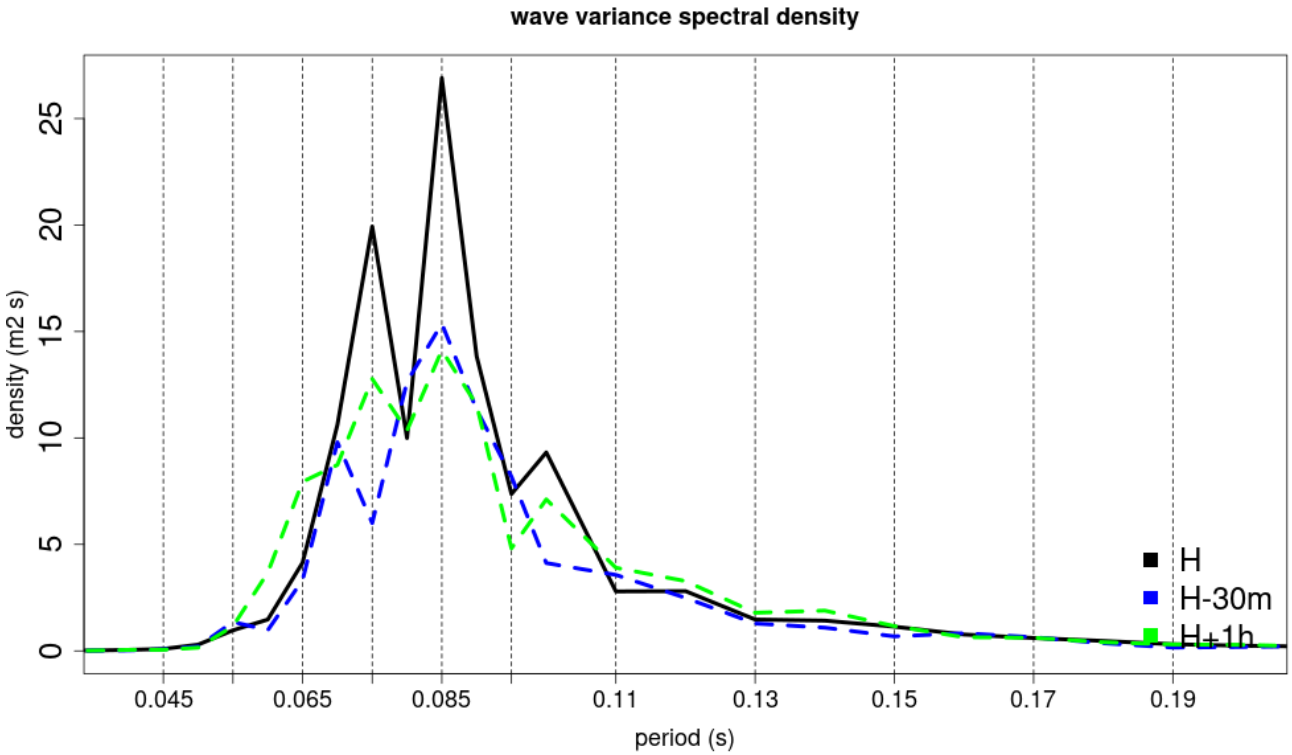
SWH of 3,1 m and Hmax of 6,4 m





2022/01/01 at 18h43 UTC

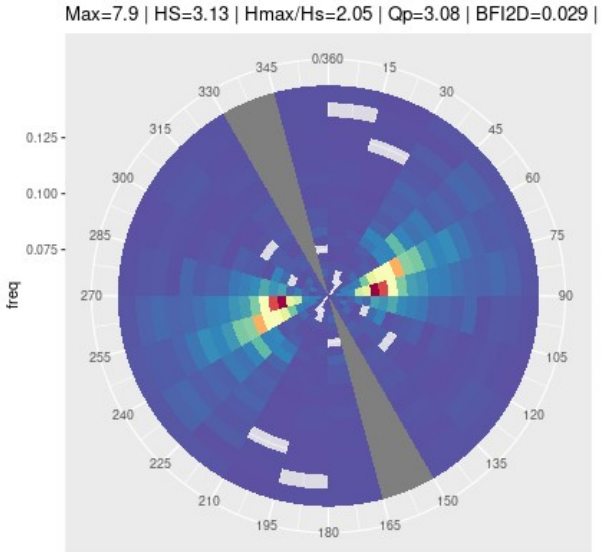
Spectral specificities according to buoy



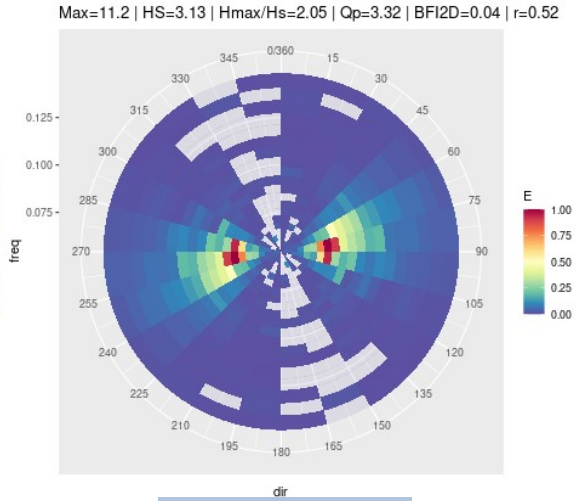
1D spectra at 18h30 2022/01/01 and adjacent time steps at Belle-Ile buoy

- 2 narrow peaks of energy with close frequencies (period : 11,8 s and 13,3s)
- Just before and after the event, the peakedness of each maximum is much smaller

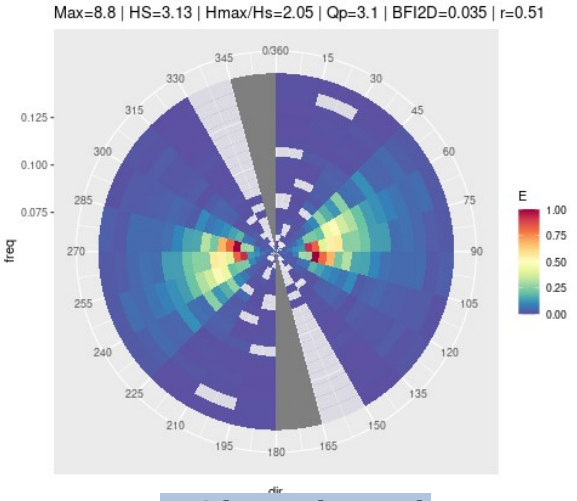
Spectral specificities according to SWIM



Rogue wave place



80 km at the south

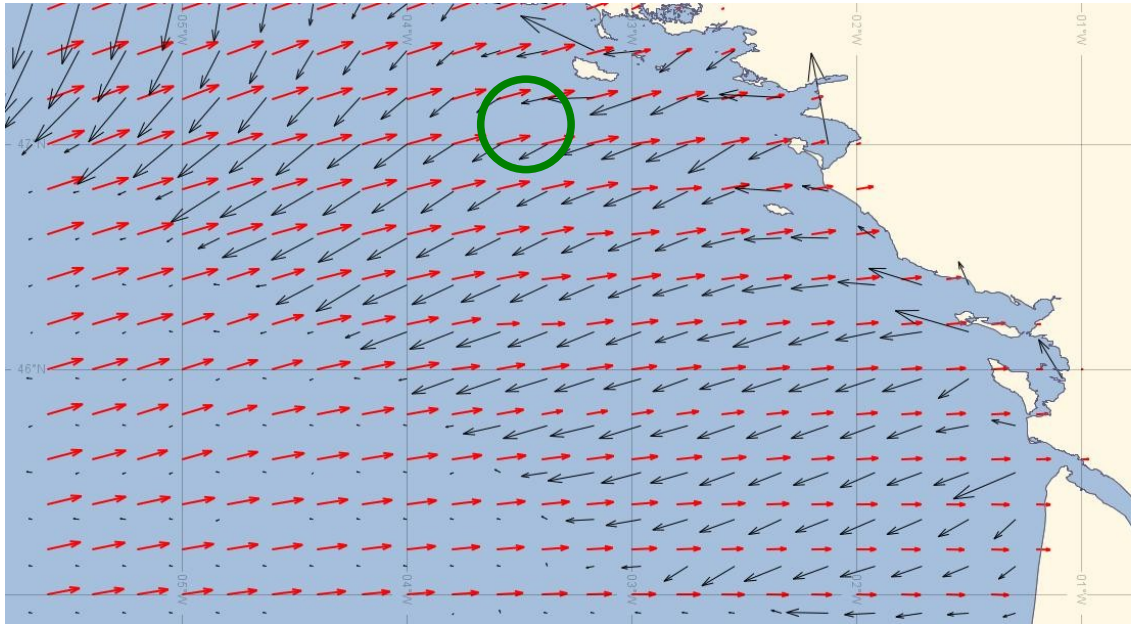


160 km at the south

- 2 peaks at the rogue wave place. 1 peak elsewhere with less variability of energy in frequency and direction space.

Currents impact ?

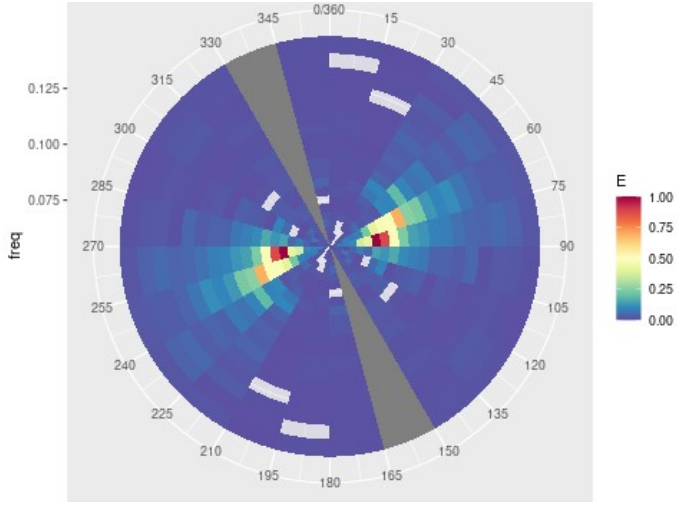
- The rogue wave place occurs exactly at half tide of relatively high tide situation (coef 90)



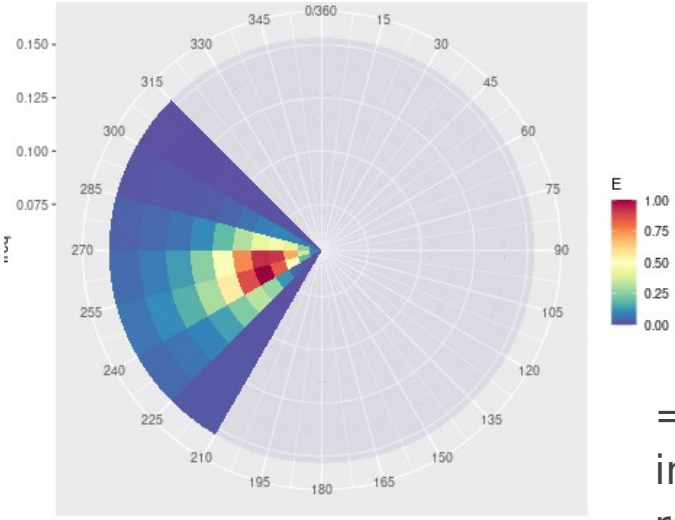
2022/01/01 at 18h UTC barotropic currents in black and swell in red

- According to Hycom2D (barotropic model), the currents reach 0,3 m/s (black arrow)
- Slight angle between currents and swell => partial change of direction
- At the south currents and swell are more lined up

The usefulness of spectral resolution



SWIM



MFWAM

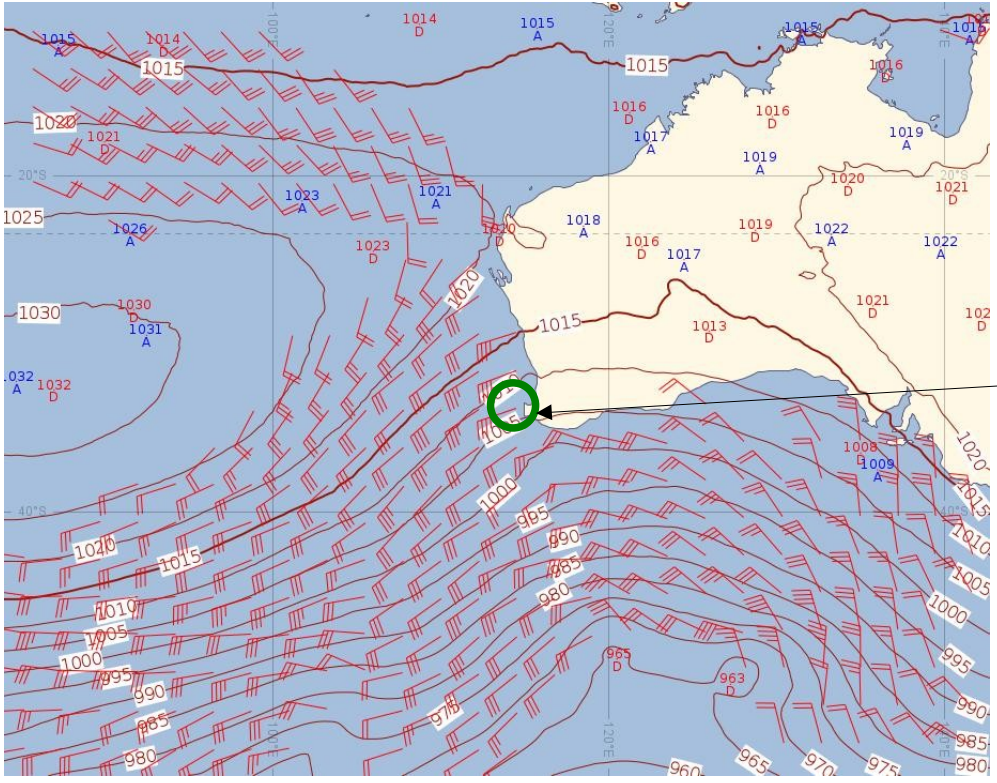
- MFWAM spectrum is smooth with less resolution. It cannot represent 2 peaks of energy.

=> possibility of improvement by a better resolution in direction and frequency

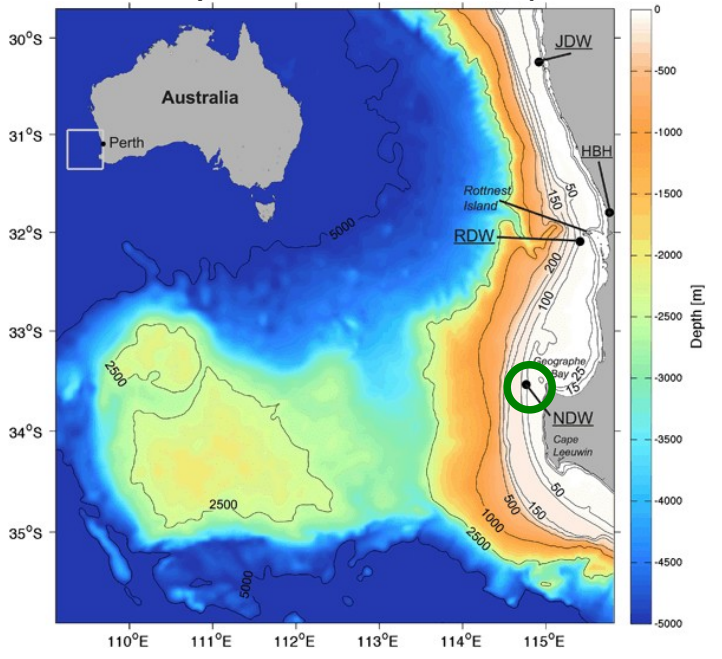
2022/01/01 at 18h UTC

09/08/2021 Case of storm in Australia

2021/08/10 at 0h UTC Pressure and wind from IFS

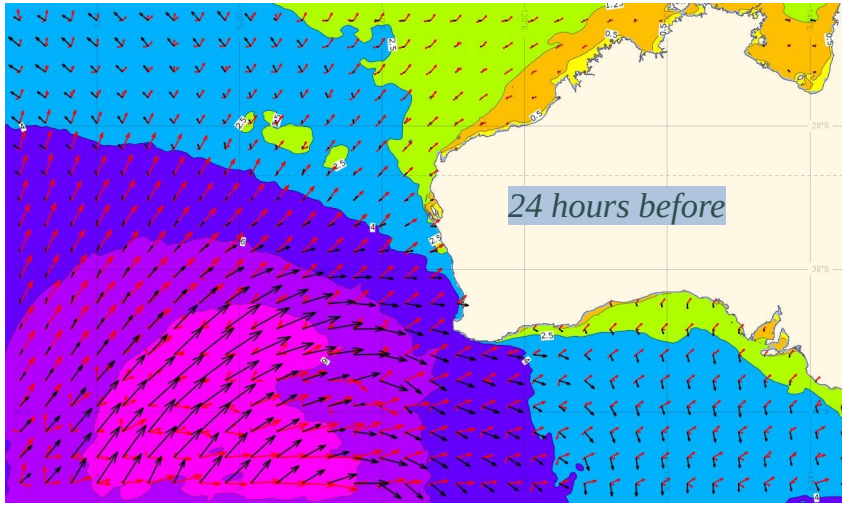


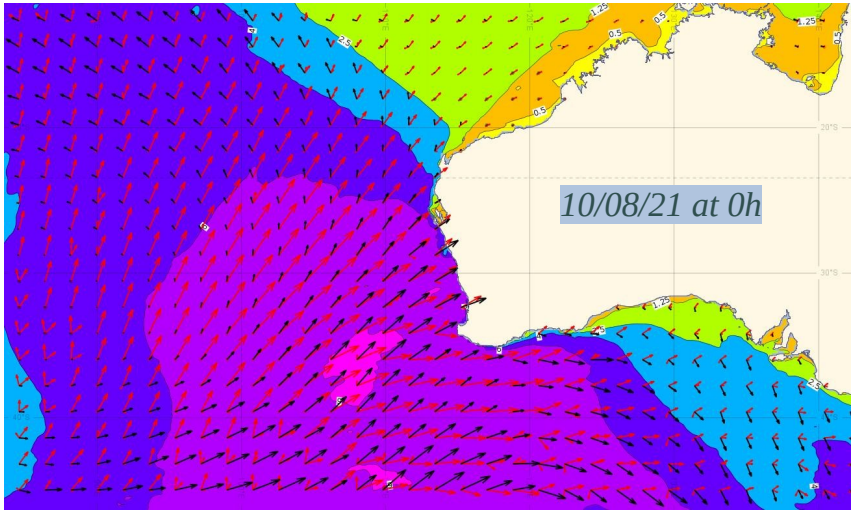
- Strong storm with mean south-westerly winds of 75 km/h



09/08/2021 Case of storm in Australia

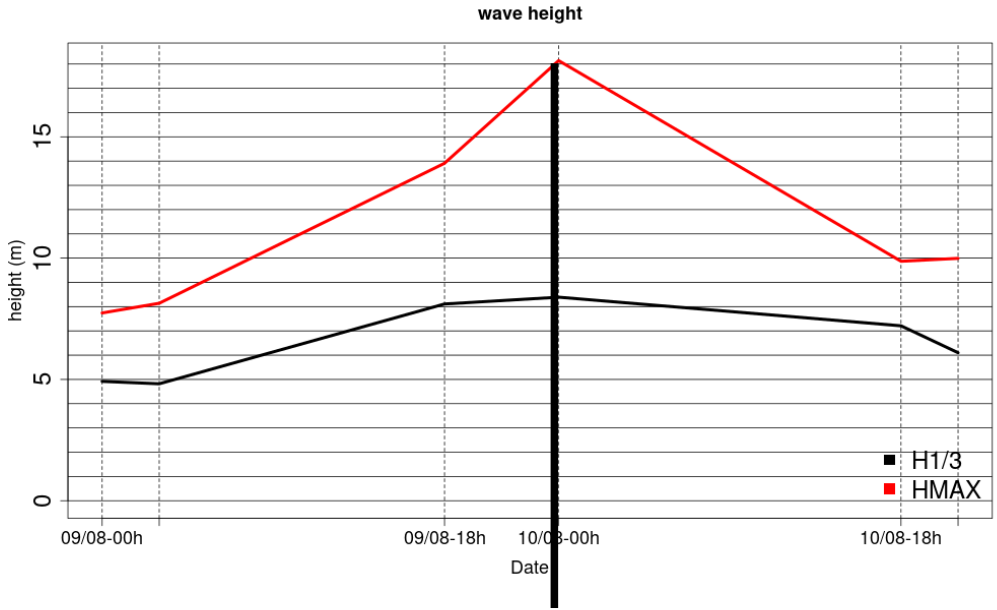
MFWAM . Wind sea in black. Swell in red

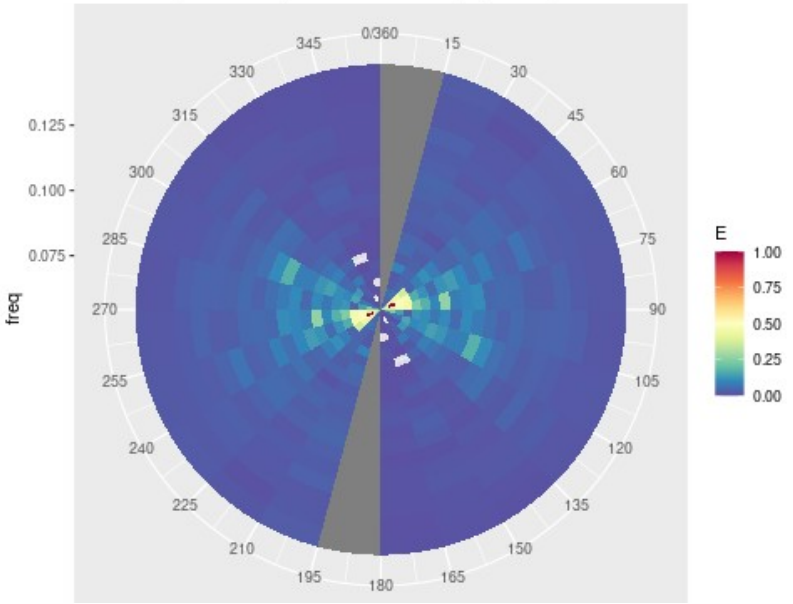




- The model simulates a wind sea of 5,7 m (10,6s), a first swell of 5,1 m and 17,5s.

Buoy and SWIM observation



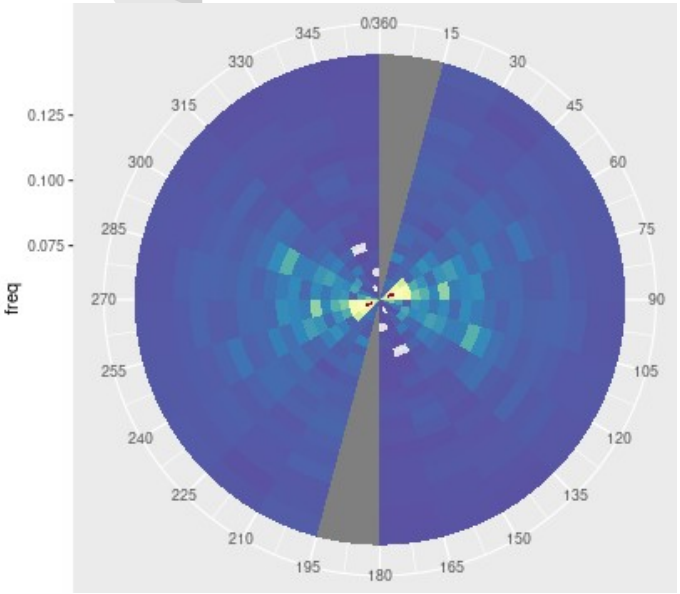


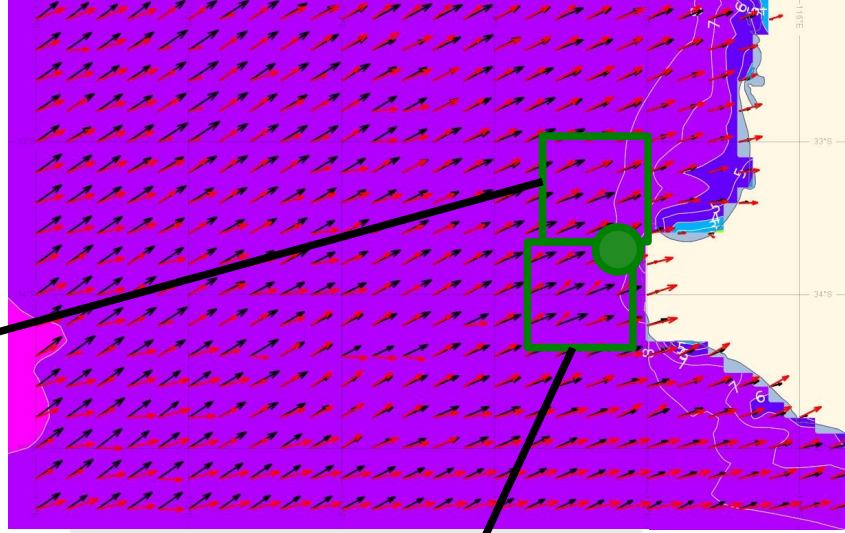
SWH of 8,4 m and Hmax of 18,1 m

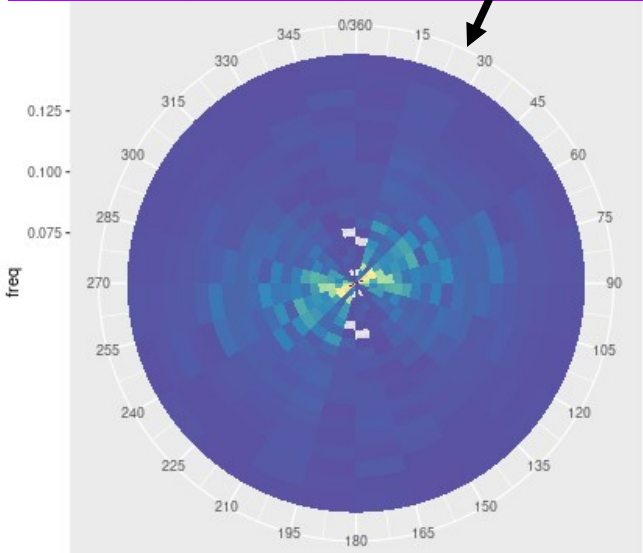
2021/08/09 at 23h08 UTC

2021/08/09 at 23h08 UTC

SWIM observation

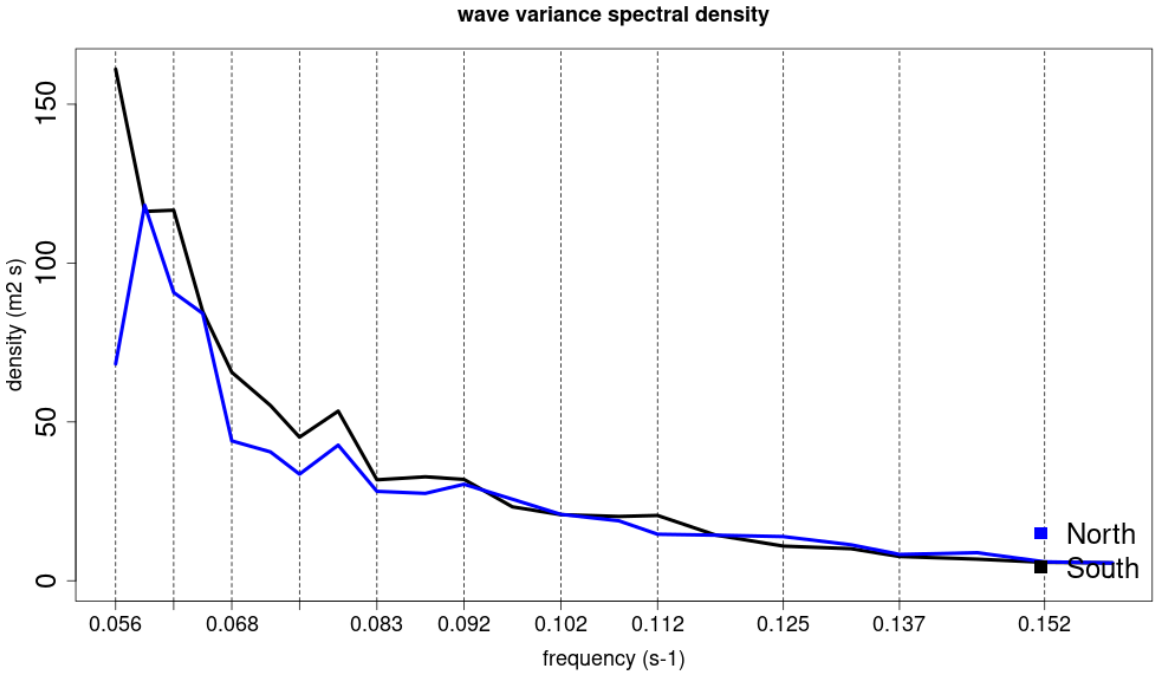






- Narrow peak of energy in low frequency (period 17,5s)
- Unidirectional energy with several frequencies

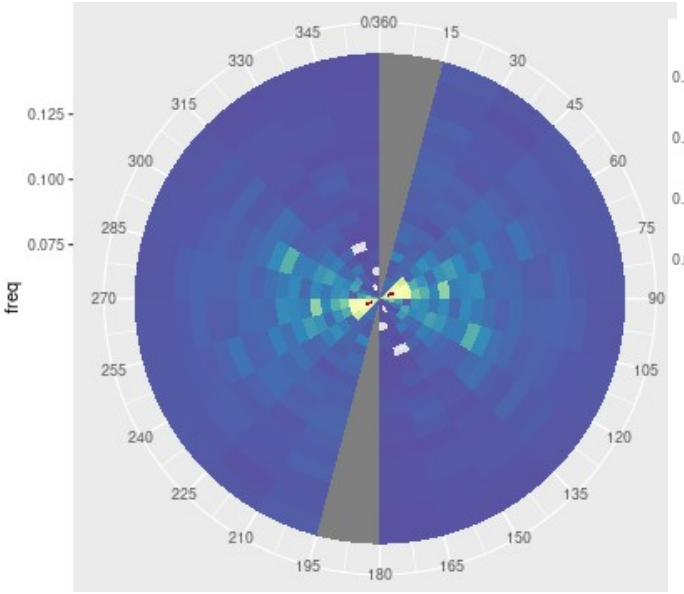
SWIM observation



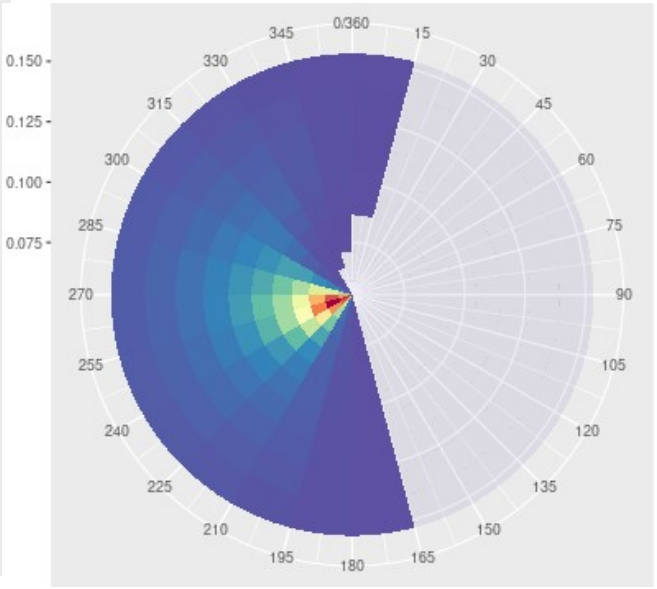
1D spectra of SWIM around cape naturalist, the 09/08/21 at 23h

- High peak of energy in low frequency (period 17,5s)
- Energy near the peak at period 16s and 12,5s (wind sea) => possible interactions between waves of close frequencies

The usefulness of spectral resolution and variability



SWIM



MFWAM

- MFWAM spectrum is smooth with less resolution. Near a Jonswap shape.

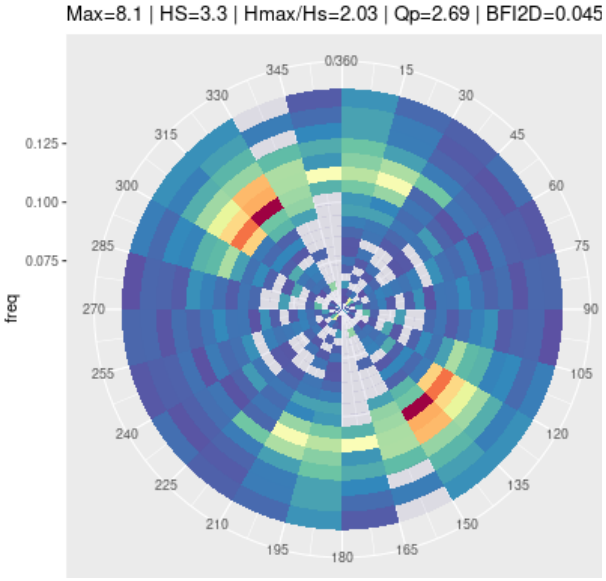
2022/01/01 at 18h UTC

Conclusion

- No obvious relationship between SWIM spectral indexes and rogue waves observations at buoy
- Few rogue waves observations and sometimes too far from buoy in a very variable field
- Spectral indexes from buoy or model may be more correlated with Hmax/SWH (not studied).

Conclusion

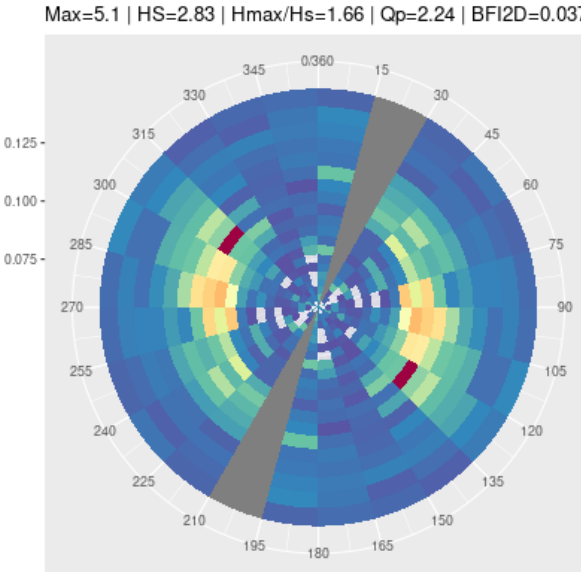
- Some spectra seem to have similar characteristics but correspond to very different Hmax/Hs



2021/12/17 22:23
Newfoundland (Atlantic)

SWH of 3,3 m

Hmax of 6,7 m



2020/01/01 08:33
Ireland (Atlantic)

SWH of 2,8 m

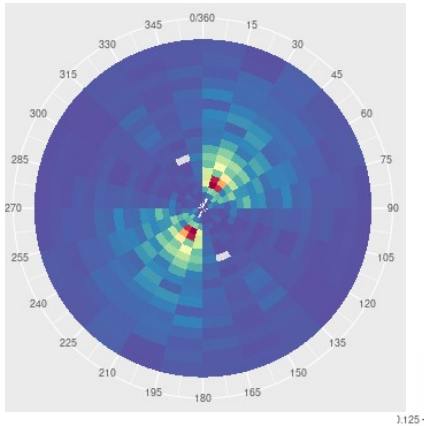
Hmax of 4,7 m

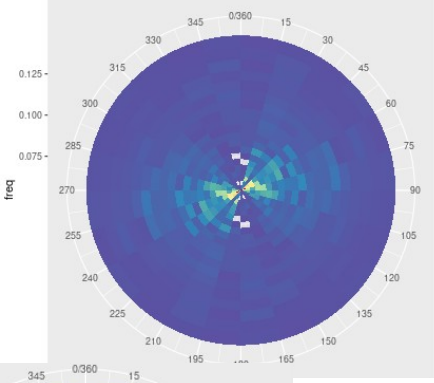
Conclusion

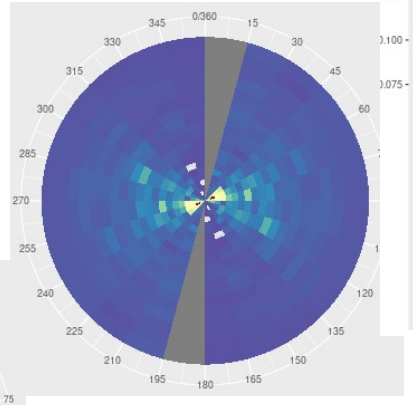
- Some of the rogue wave spectra have a specific narrow and unidirectional shape (case in France and Australia)

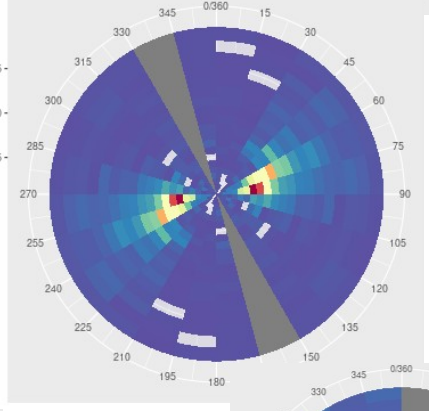
=> possible interactions between frequencies explaining rogue waves

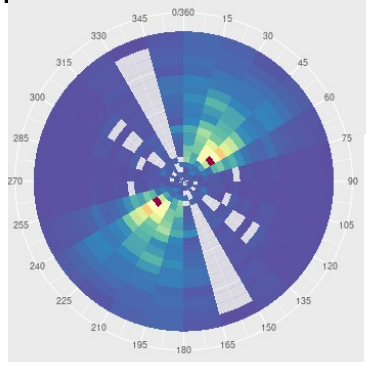
- Capacity of SWIM to represent finely the spectrum

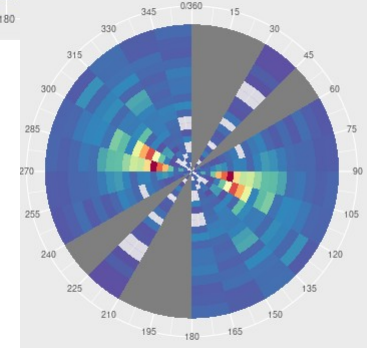




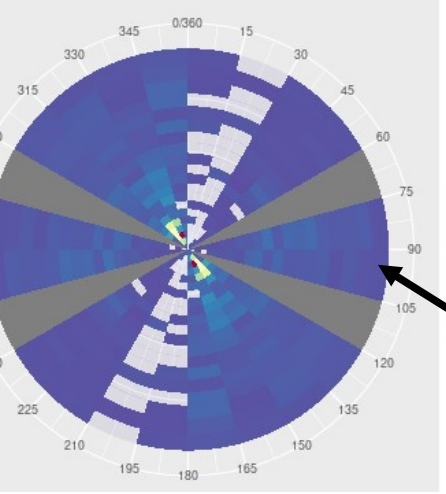




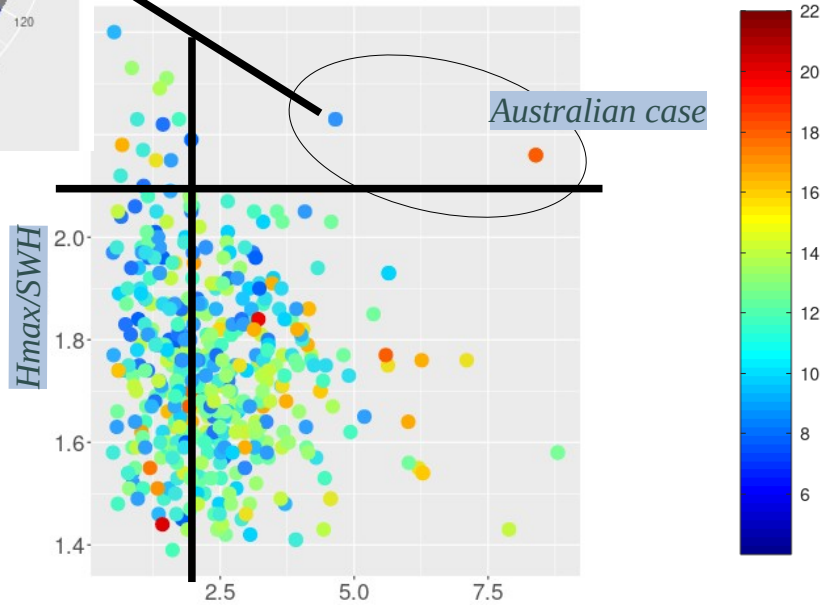




- If we limit to swh > 2 m and Hmax/SWH > 2.1, we get only 2 cases with high BFI2D (0,08)



Azores (North Atlantic) 2022/04/10



Statistics over buoys colocalised with SWIM

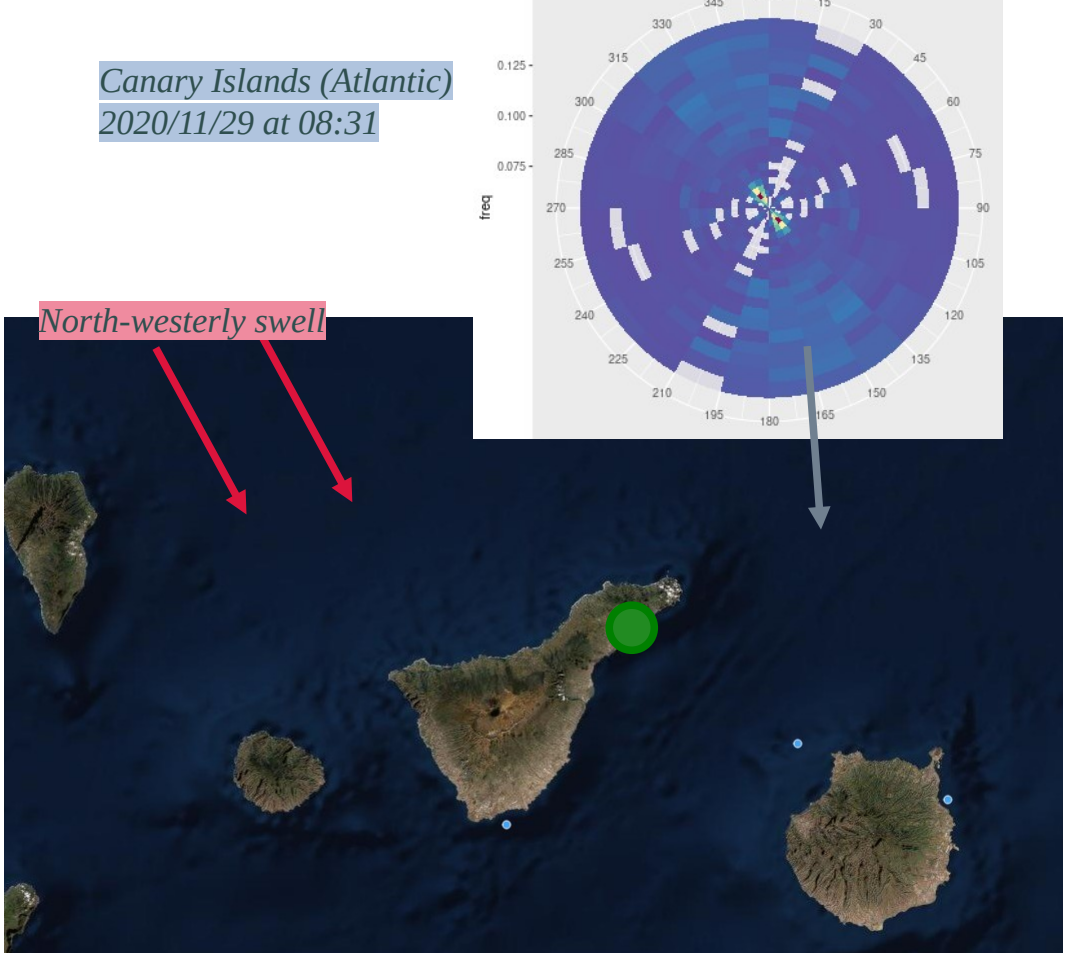
- With more strict constraints on rogue wave definition and on SWIM quality, encouraging results.
- Too few cases to conclude

Thank you for your attention

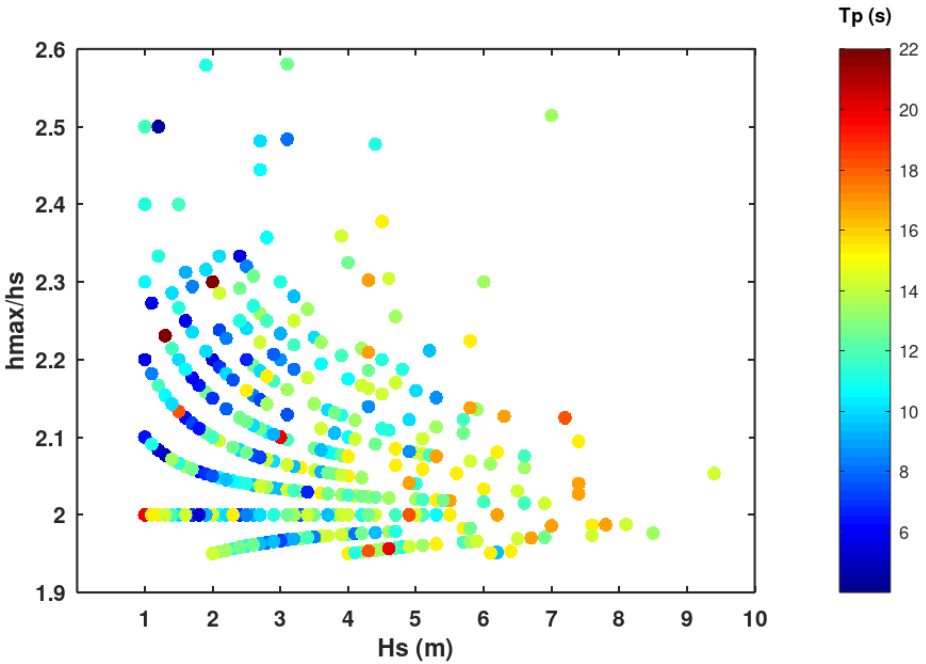
Conclusion

- No obvious relationship between SWIM spectral indexes and rogue waves observations at buoy
- We remind that there are few rogue waves observations and sometimes too far from buoy in a very variable field
- Spectral indexes from buoy or model may be more correlated with buoy (not studied).

Canary Islands (Atlantic)
2020/11/29 at 08:31



Conclusion



Statistics at 2 NE Atlantic buoys during 2 years