On the implementation of a global wave ensemble of the model MFWAM at short time range : impact of two wave physics for extreme events

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Alice Dalphinet, Lotfi Aouf, Komlan Kpogo-Nuwoklo, Christophe Bataille
Météo-France *Marine forecasting and oceanography division*

3RD INTERNATIONAL WORKSHOP ON
Waves, Storm Surges, and Coastal Hazards

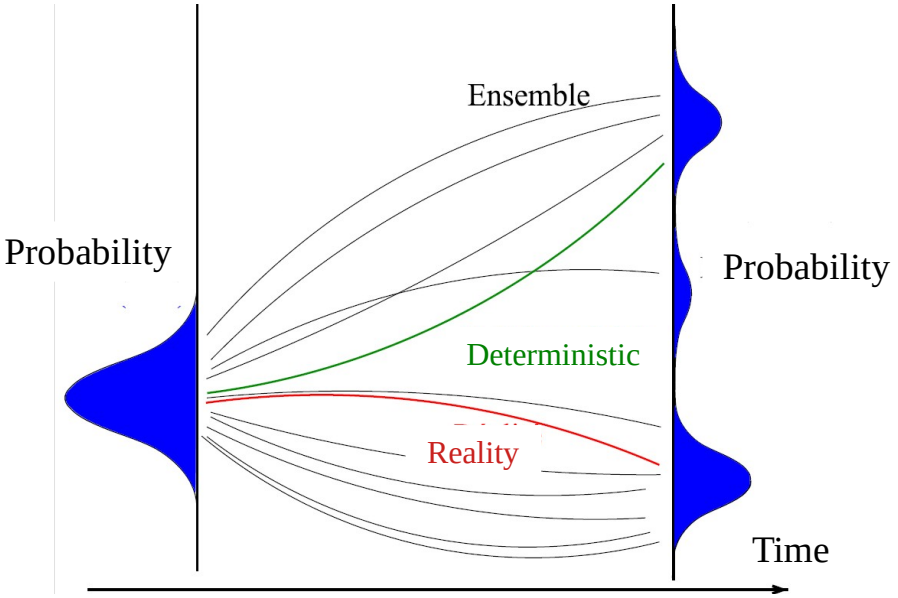
Motivation

- Météo-France operates its own atmospheric ensemble system since 2004, named PEARP

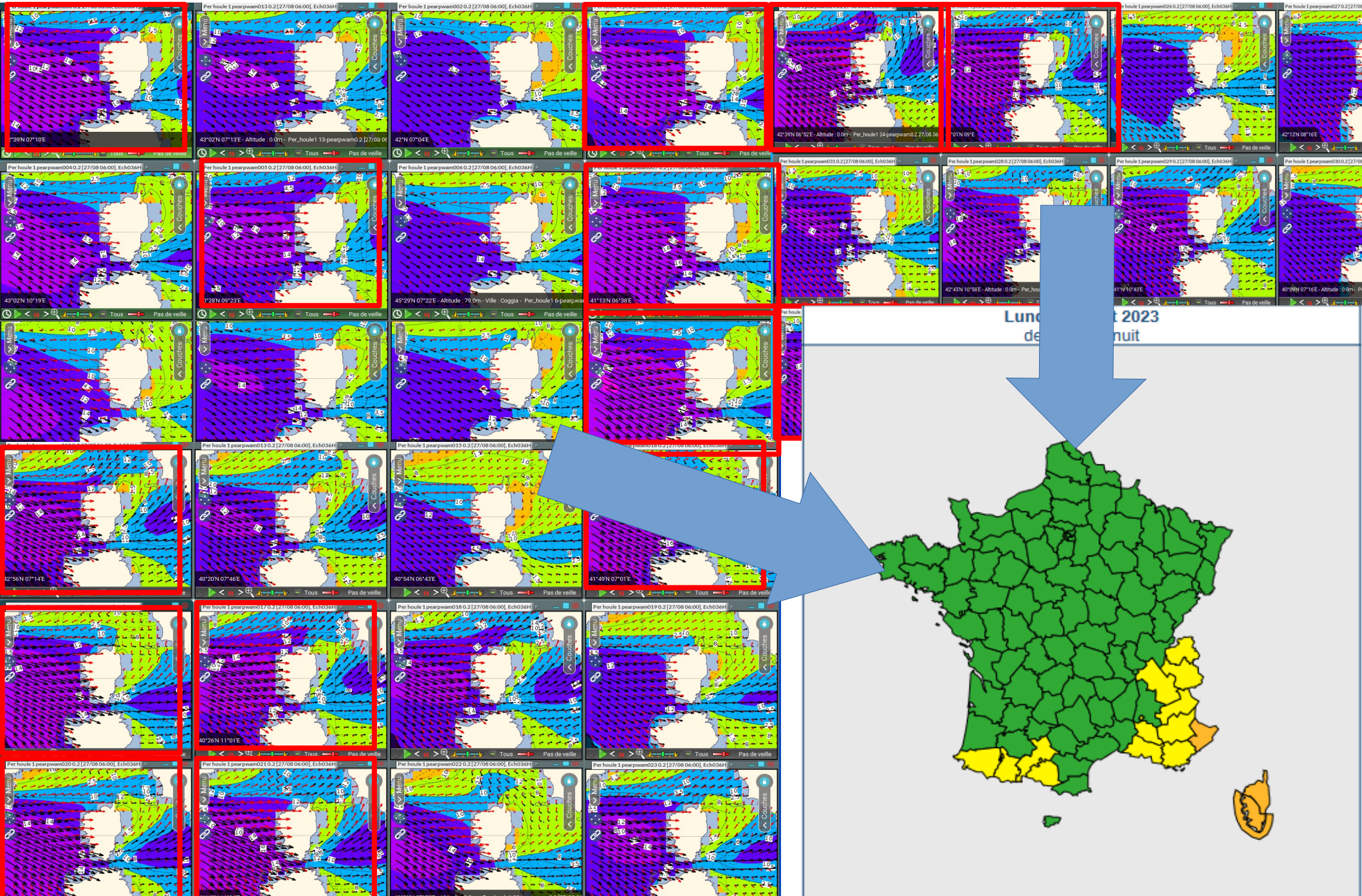
  Descamps, L. & all (2015). PEARP, the Météo-France short-range ensemble prediction system. Quarterly Journal of the Royal Meteorological Society.

- Stretched spatial resolution up to 0,08°, 35 members using 2 convection schemes, 4 runs / day, up to +4 days.

=> implementation of a global wave ensemble system using this atmospheric ensemble forcing
=> produce bounding conditions for a future coastal wave ensemble system



Main objective to improve waves and coastal flooding warning



Global wave ensemble system MFWAM PEARP

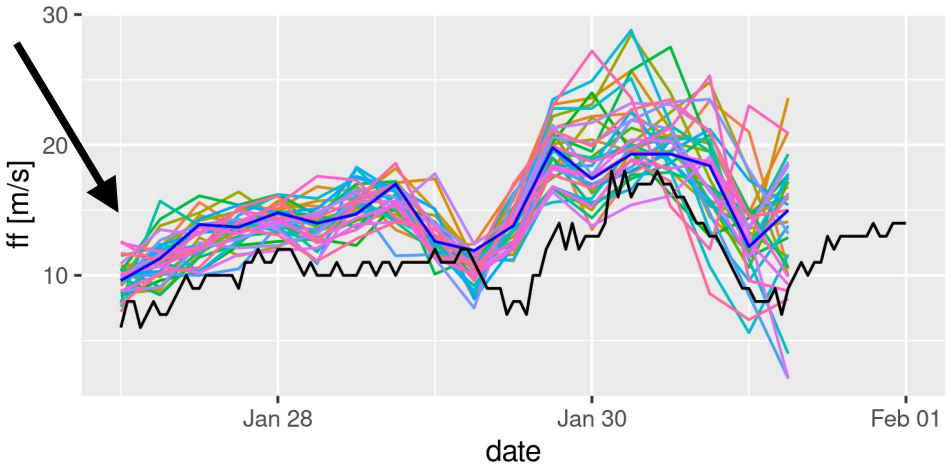
- **Some general characteristics**
- Impact of two wave physics on the ensemble
- Case study on Mediterranean Sea

Global wave ensemble system MFWAM PEARP

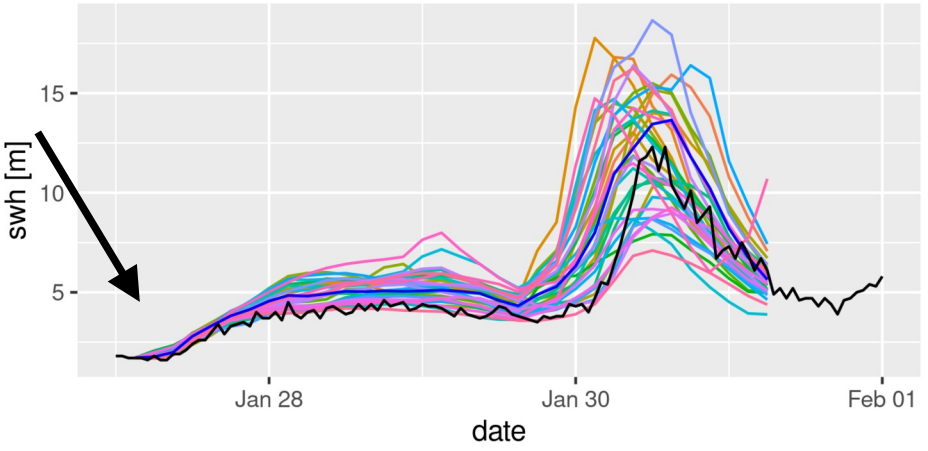
- Run in operations since november 2022
- Resolution of 0,2° like global deterministic MFWAM Arpege.

- Like EPSWAM, we use the same initial conditions.

  => underdispersion in the first 36 hours



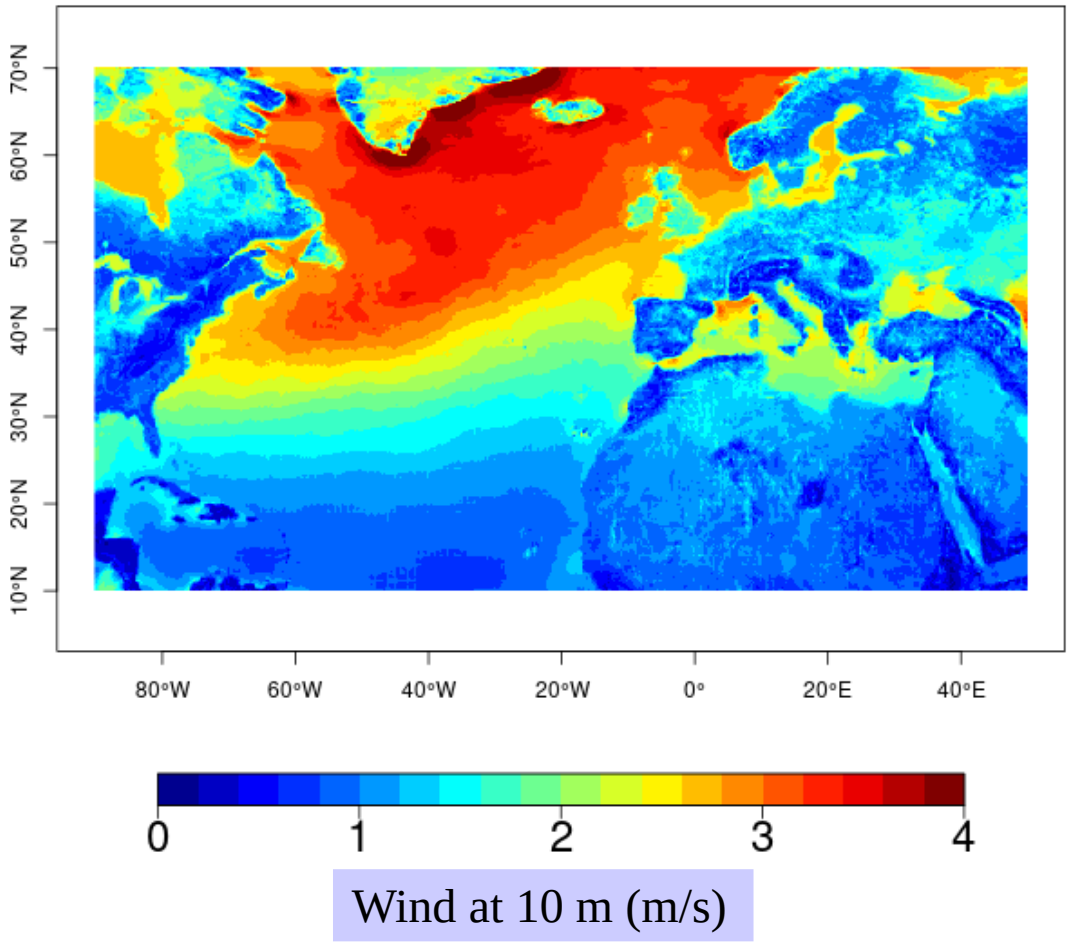
Wind at 10 m(m/s) from PEARP



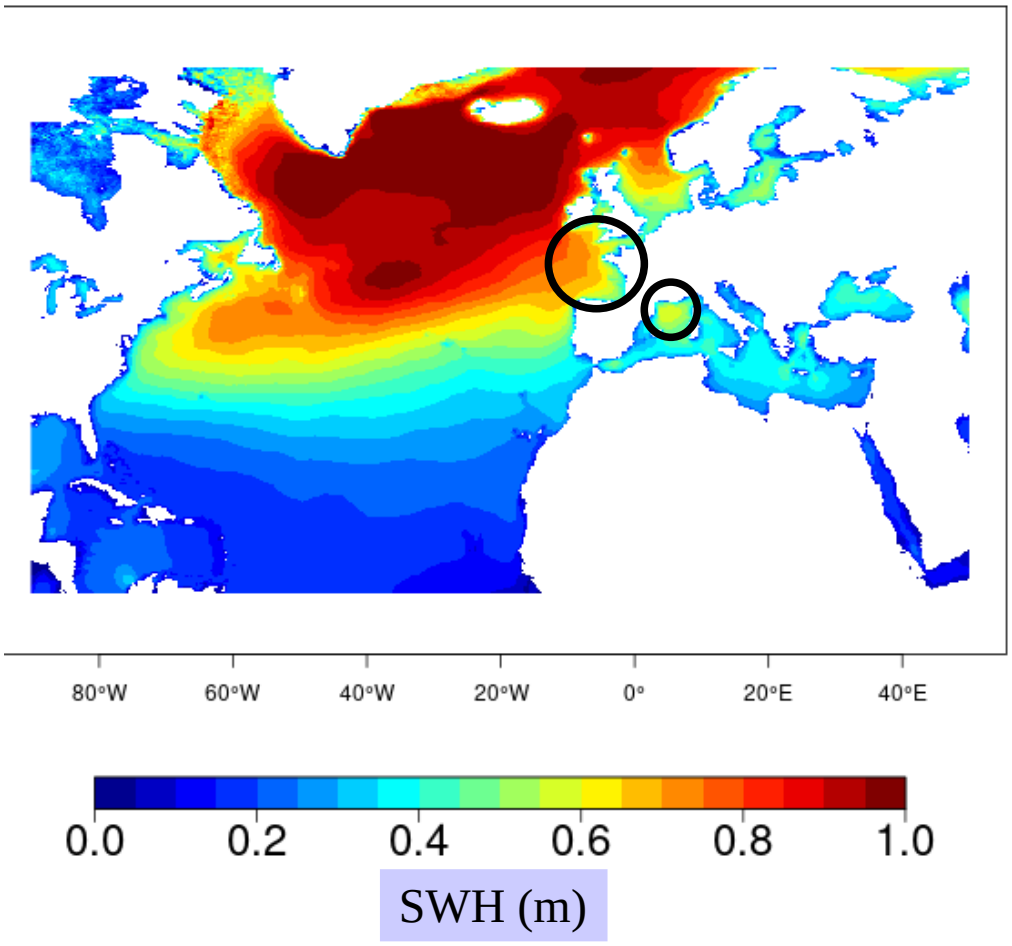
SWH (m) MFWAM PEARP

Run of 27/01/2021 0h UTC at the Brittany buoy (north-east Atlantic)
Observation Déterministic

Dispersion of the significant wave height



Wind at 10 m (m/s)



SWH (m)

- Mean standard deviation at +102h between the 35 members from January to April 2021
- The waves variability depends on the wind variability and the size of the basin
- The relative variability on french Mediterranean coast is higher than on french Atlantic coast

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Global wave ensemble system MFWAM PEARP

- Some general characteristics
- **Impact of two wave physics on the ensemble**
- Case study on Mediterranean Sea

Impact of using 2 physics for the wave model

- A) Current physic in deterministic configurations of MFWAM : waves dissipation depending on energie saturation or contrary wind (ST4 like) => better modeling for swell

  Ardhuin et al. 2010

- B) Previous physic of ECWAM (before 2019) : waves dissipation depending on their mean steepness (ST3 like) => better representation for wind sea

  Bidlot et al, 2007

1PHY	2PHY	EC-ENS
All members with A	- 18 members with A - 17 membres with B	Wave ensemble system from ECMWF

- Comparison of the 3 models on the period January to April 2021

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Validation

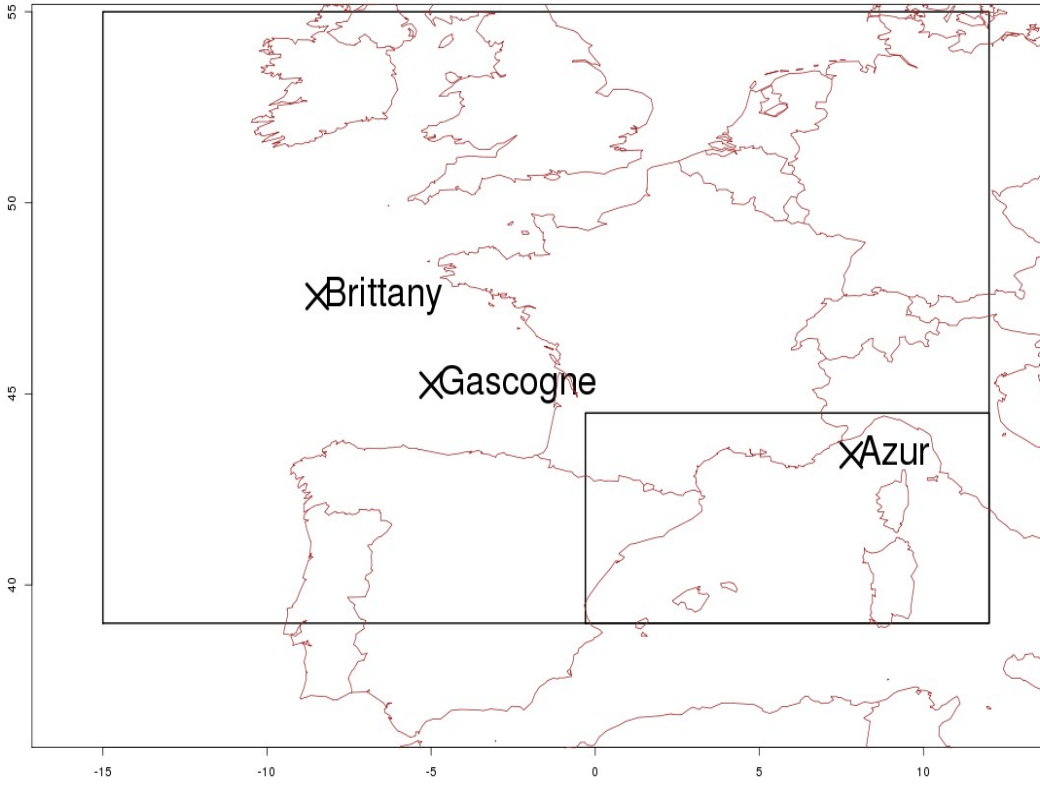
- 3 buoys

  Quite poor population (around 4000 values / buoy for all time steps)

- Altimetric data over 2 areas, Atlantic et Mediterranean.

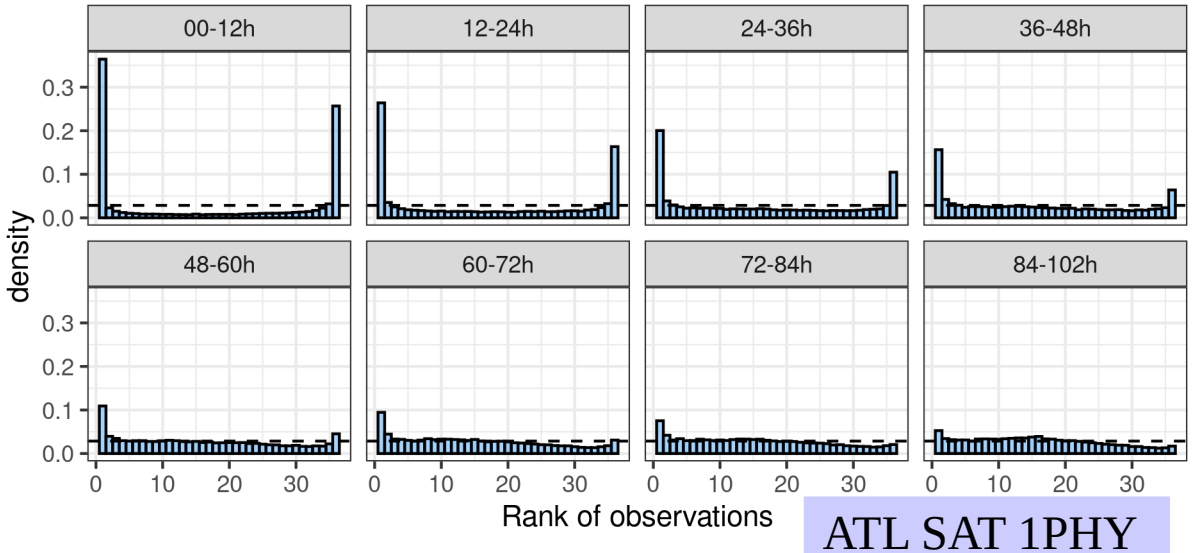
  6 altimeters available on the period

  460 000 values on Atlantic area for all time steps

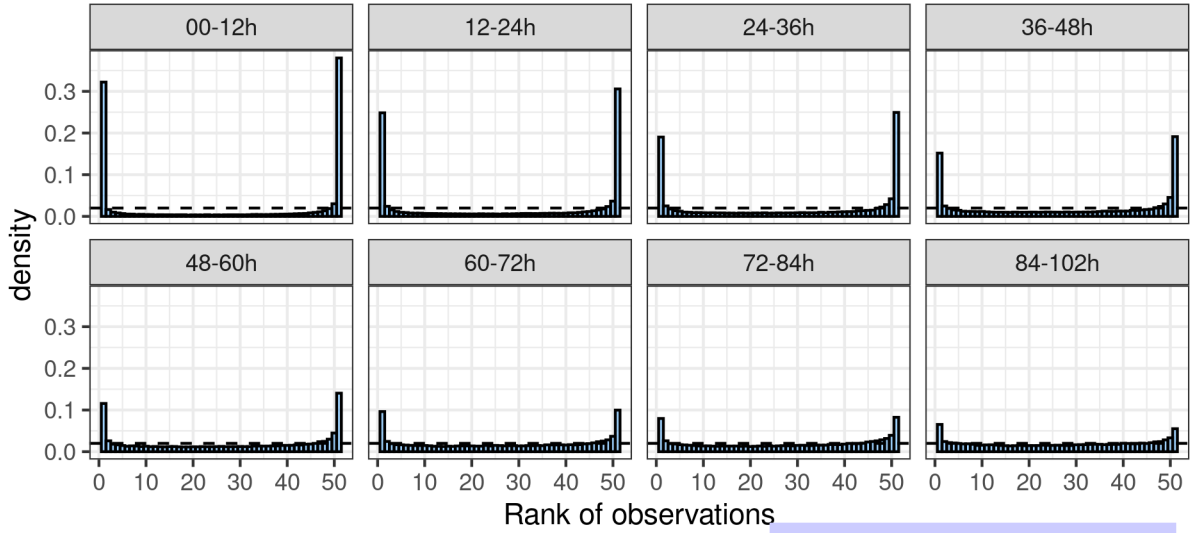


Example of coverage of the 6 altimeters on a week in april 2021

Underdispersion up to 60h in Atlantic



ATL SAT 1PHY



ATL SAT EC-ENS

Rank histogram : position of the observation among the sorted members

- Underdispersion for all models up to 60h
- No difference between 1PHY and 2PHY. Both overestimate the wave height.
- EC-ENS has a weak bias, but lacks more of dispersion than 1PHY/2PHY

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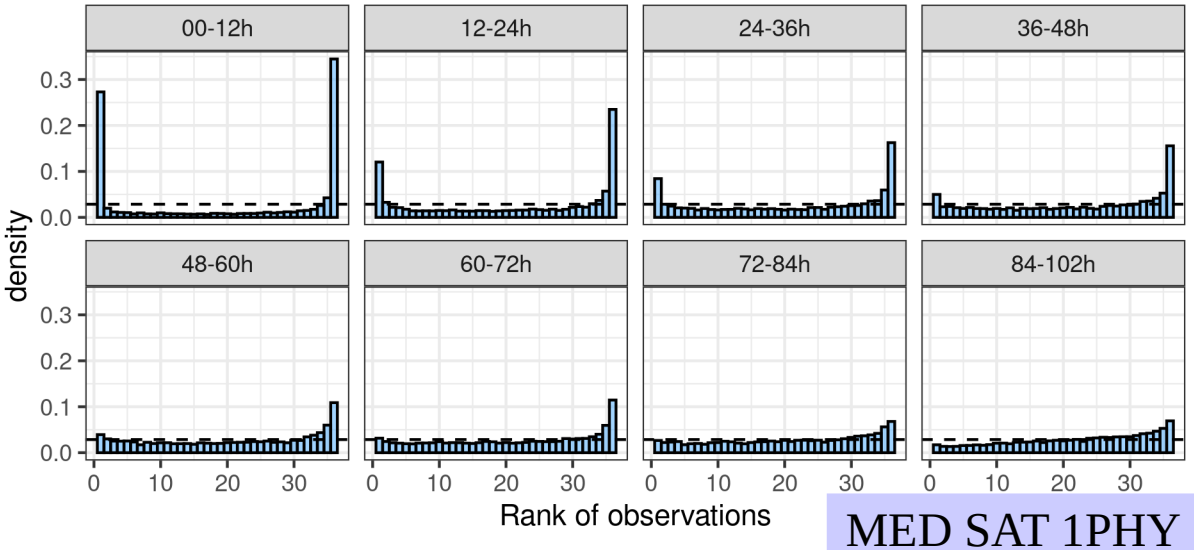
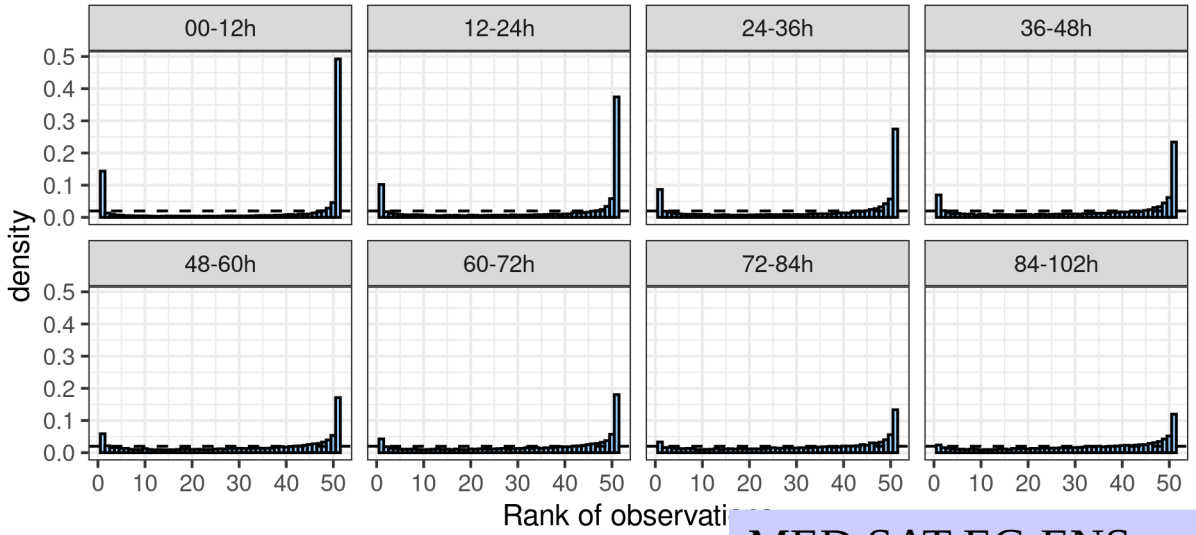
Underdispersion up to 48h in Mediterranean



MED SAT 1PHY



MED SAT EC-ENS

Rank histogram : position of the observation among the sorted members

- Underdispersion for all models up to 48h
- No difference between 1PHY and 2PHY. Both overestimate the wave height.
- EC-ENS is also biased, and lacks a bit more of dispersion than 1PHY/2PHY

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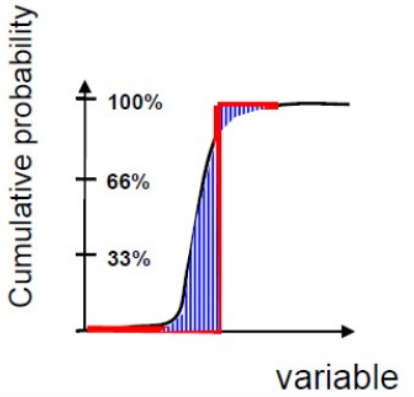
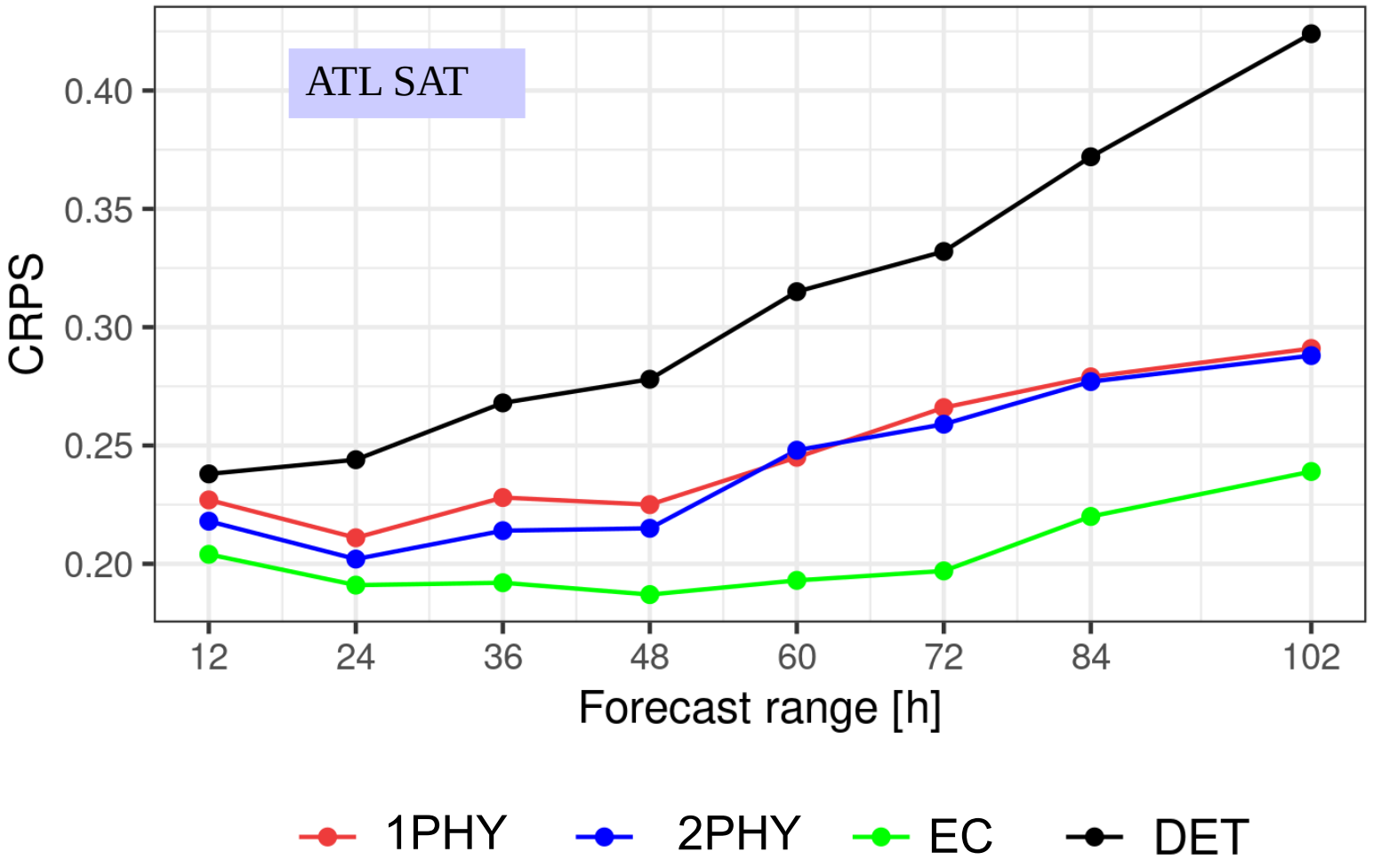
Average error : CRPS - ATL

Continuous Ranked Probability Score





CRPS : distance between the predicted and observed density functions. The weaker, the better.

- Utility of ensemble forecast compared to deterministic
- better score of 2PHY than 1PHY up to 48h
- Very good score of EC-ENS, especially from 60h

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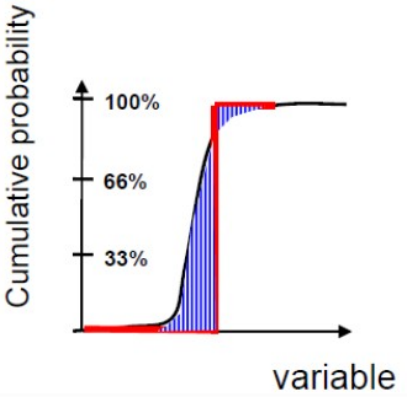
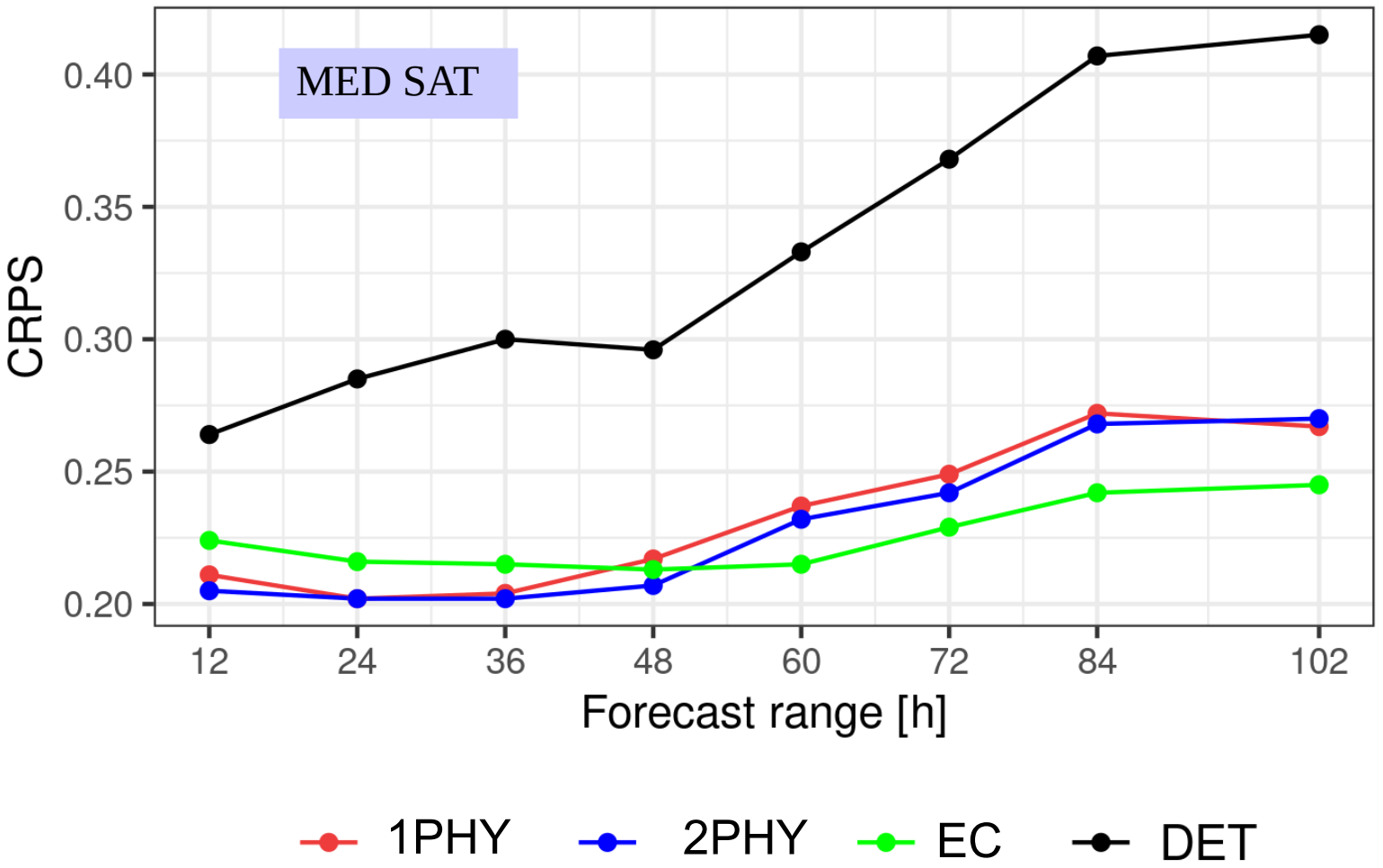
Average error : CRPS - MED

Continuous Ranked Probability Score



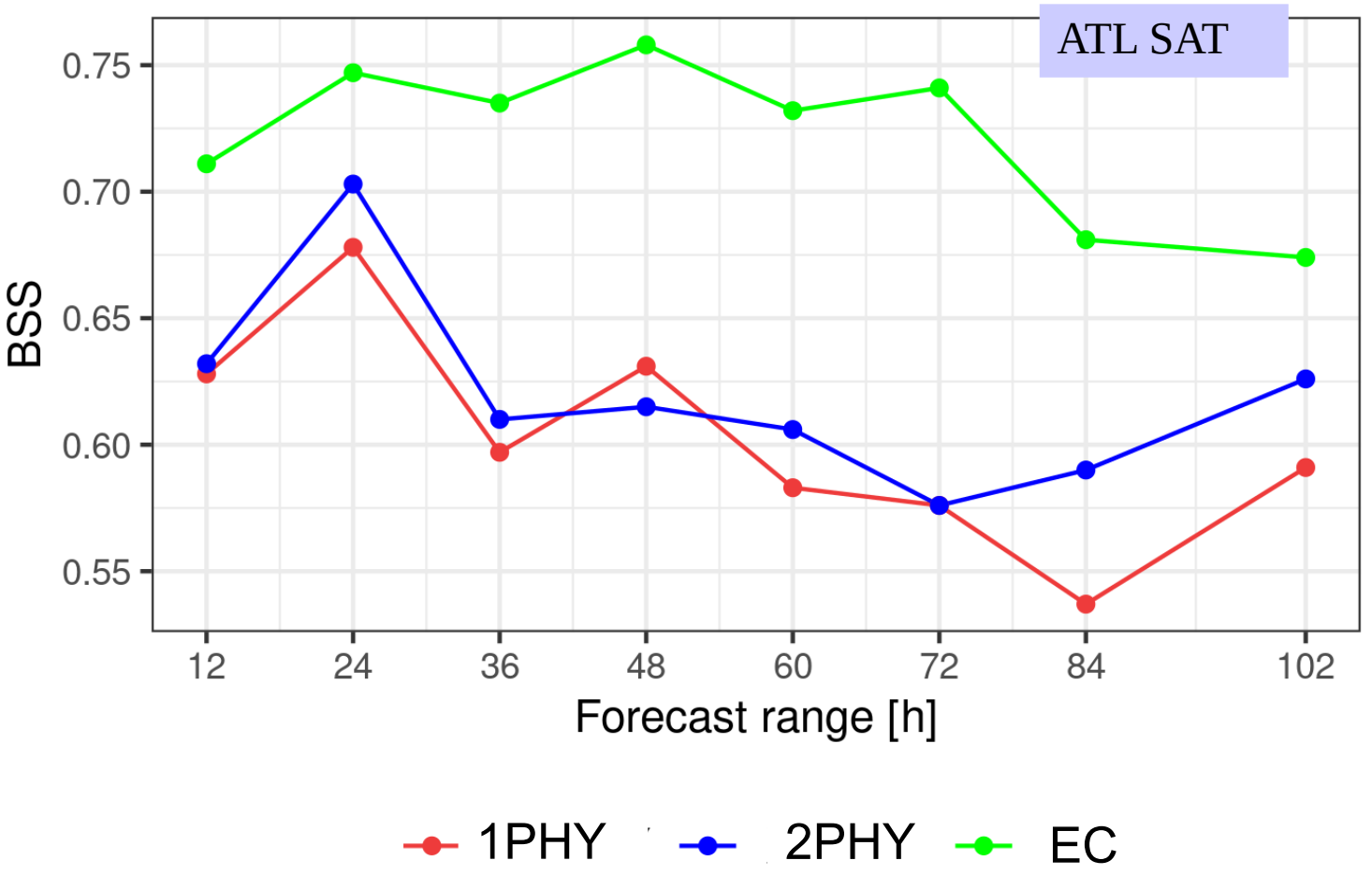


CRPS : distance between the predicted and observed density functions. The weaker, the better.

- Utility of ensemble forecast compared to deterministic
- better score of 2PHY than 1PHY particularly at 48h
- Better score of MFWAM PE before 48h, then EC-ENS has lower error.

BSS in ATL for SWH > 5 m

Brier Skill Score

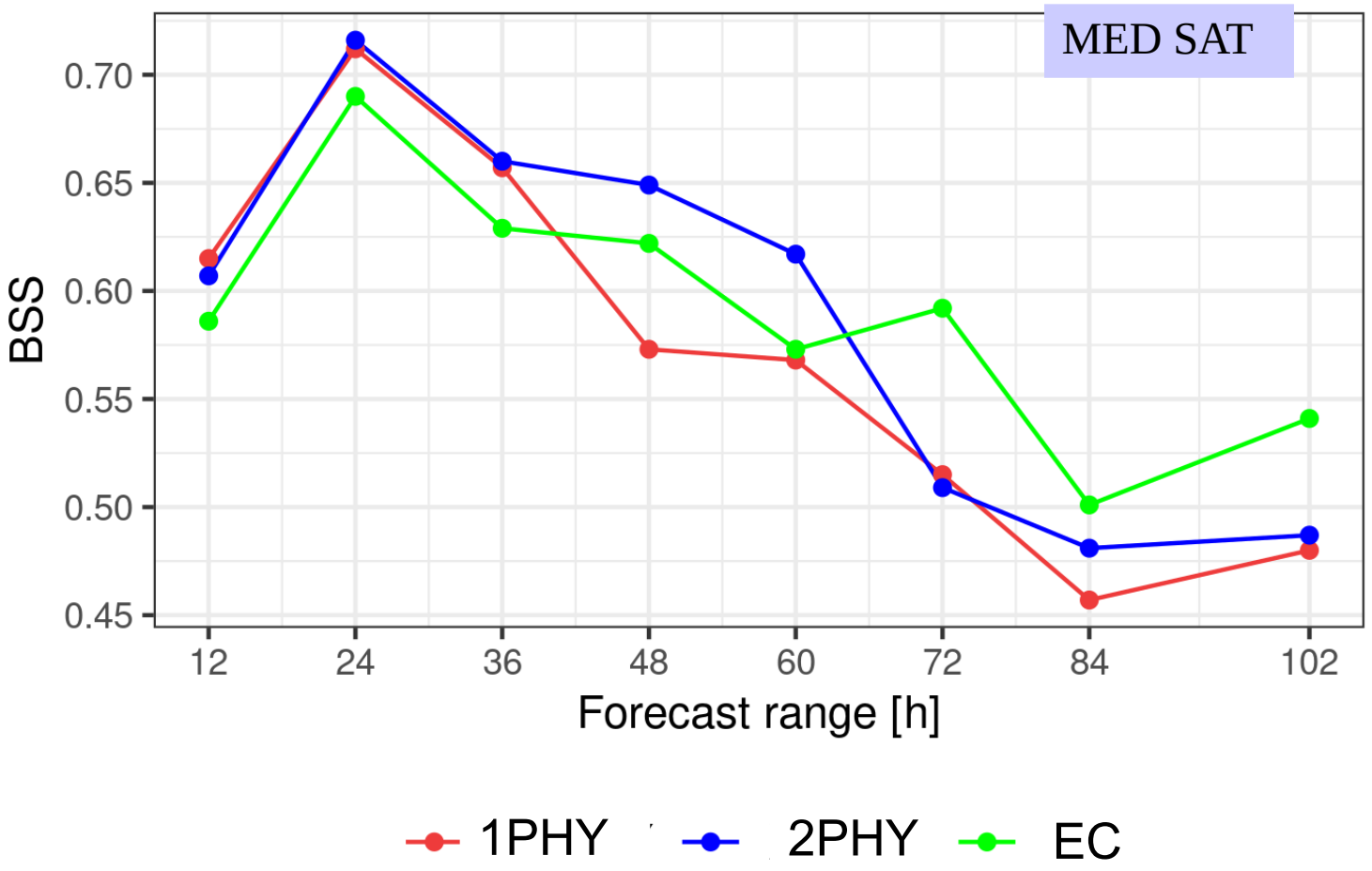


BSS : rate of good prediction relatively to a perfect ensemble forecast. 1 is perfect.

- Good performance of EC-ENS
- Better score of 2PHY than 1PHY for the event SWH > 5 m (Q90) and SWH > 1,27 m (median – not shown).

BSS in MED for SWH > 3 m

Brier Skill Score



BSS : rate of good prediction relatively to a perfect ensemble forecast. 1 is perfect.

- MFWAM PE has better score before 60h, then EC-ENS has better performance
- Better score of 2PHY than 1PHY for the event SWH > 3 m (Q90) near 48h.

Comparison of the configurations

- Better average score of 2PHY than 1PHY at 1 and 2 days of time range on Atlantic
- Better score of high values with 2PHY (ATL, MED)
- Choice of 2PHY for the operational configuration

- EC-ENS shows very good performance, especially on Atlantic. Advantage to have 50 members.

  MFWAM PEARP takes advantage for the Mediterranean Sea at short range (before 48h).

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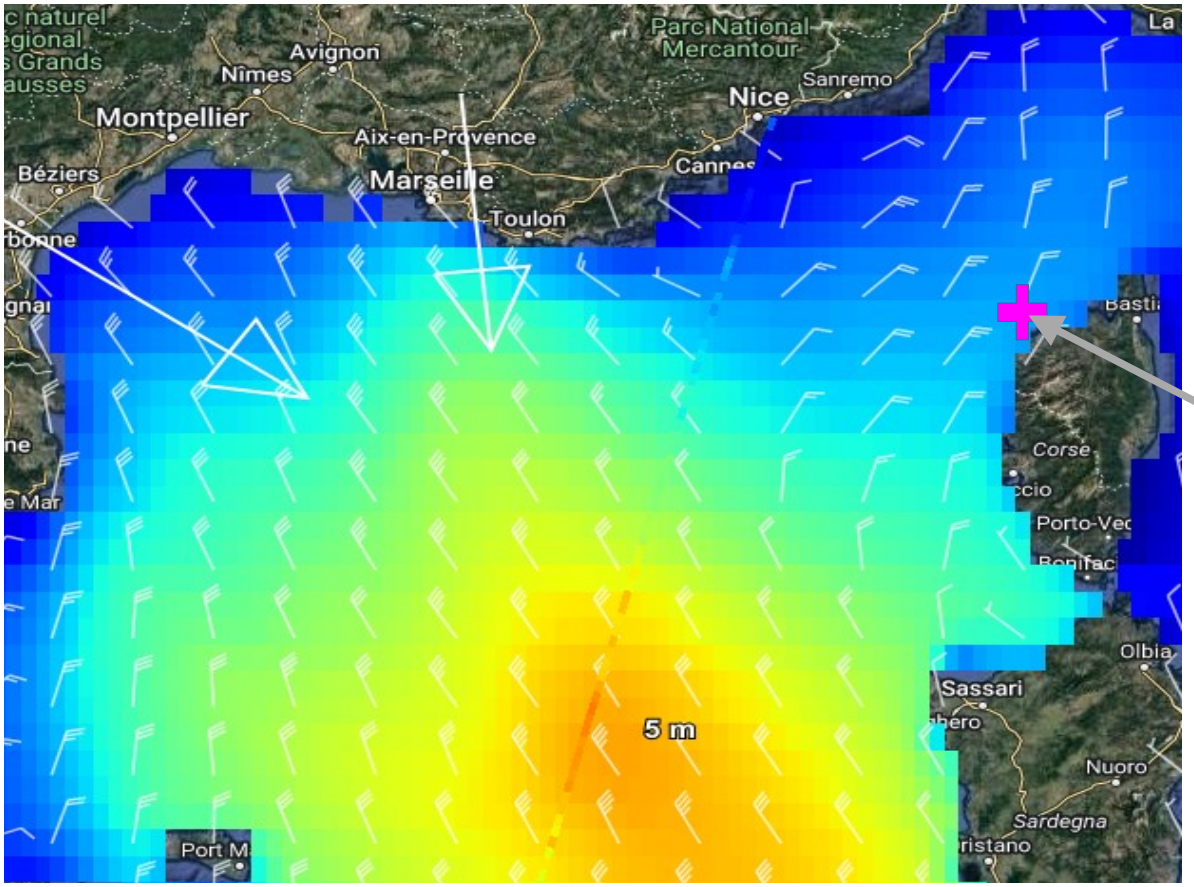
Global wave ensemble system MFWAM PEARP

- Some general characteristics
- Impact of two wave physics on the ensemble
- **Case study on Mediterranean Sea**

Case of strong local wind in the Mediterranean Sea



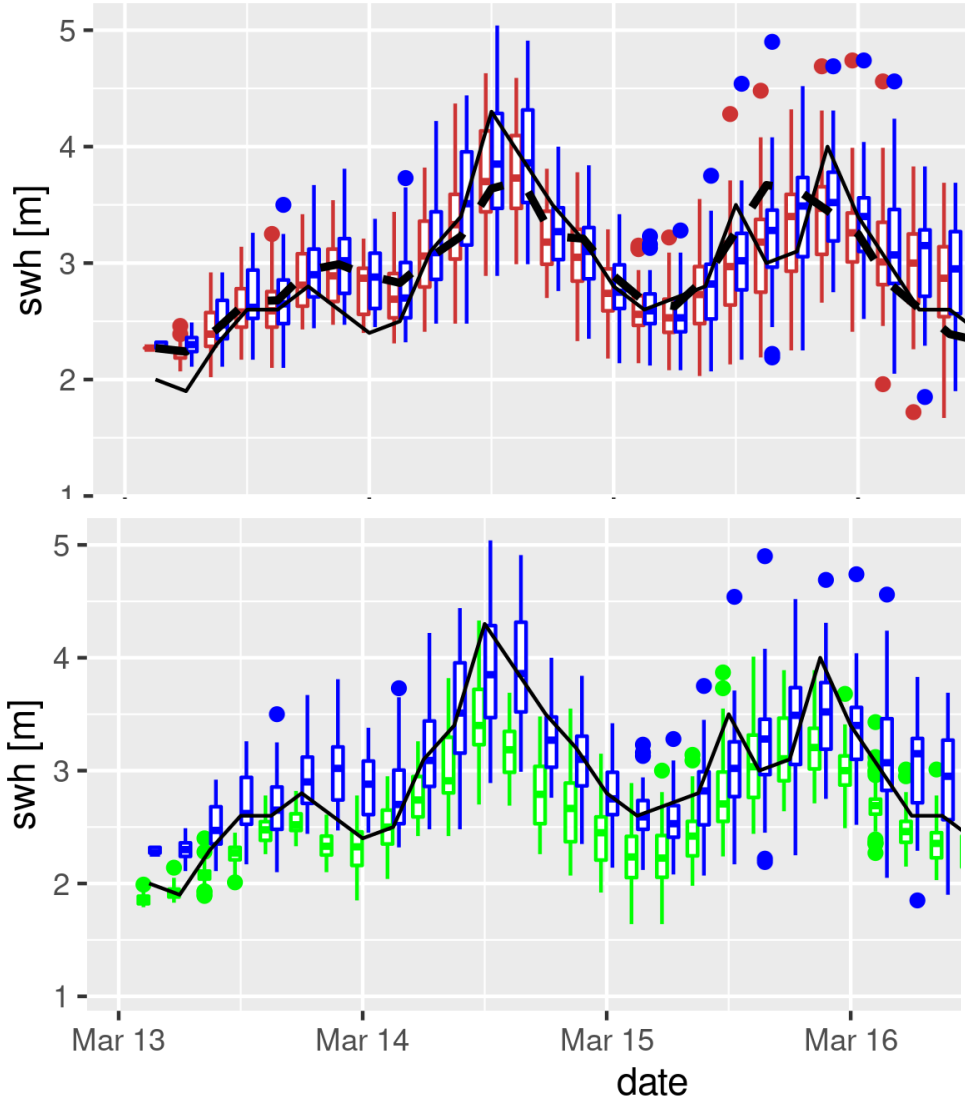
16/03/21 at 9h UTC
SWH of MFWAM in colors
Wind of ECWMF
Track of Sentinel 3

La Revellata buoy

Extraction from https://ovl.oceandatalab.com

- 30 knots wind speed oscillating from north to west during several days. Short and changing fetch with a steady strong wind. The buoy La Revellata is a the edge of the phenomenon.
- What was the predictability of this event ? With the deterministic model and the ensemble systems ?

Forecast of the 13/03 00h at the buoy



- Deterministic model underestimate the wave height 2 days and 4 days before. MFWAM PEARP warns that there is a risk of higher wave.
- 2PHY is slightly better than 1PHY for both days.
- MFWAM PEARP is more accurate for this situation. Its dispersion is more elastic than EC-ENS and gives an information about the incertainty

Boxplot of SWH (m) at La Revellata for the runs of the 13/03/21
Deterministic model (dashed) ***Observation (plain)***
1PHY 2PHY EC-ENS

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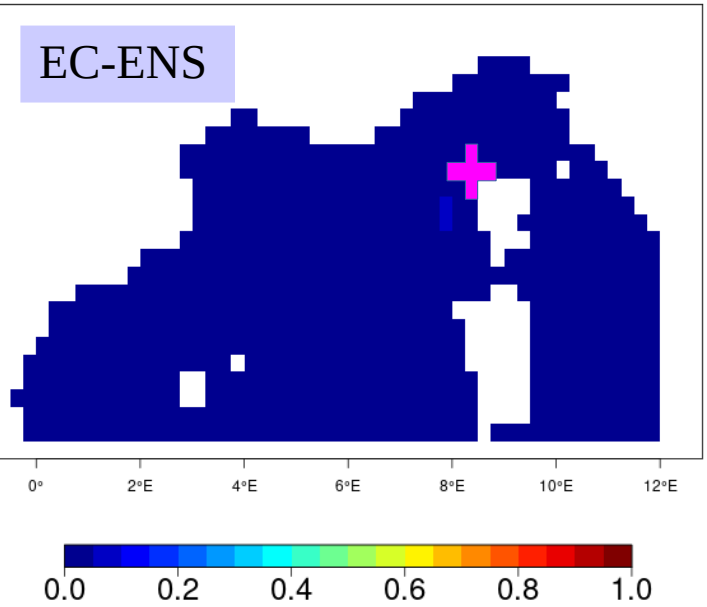
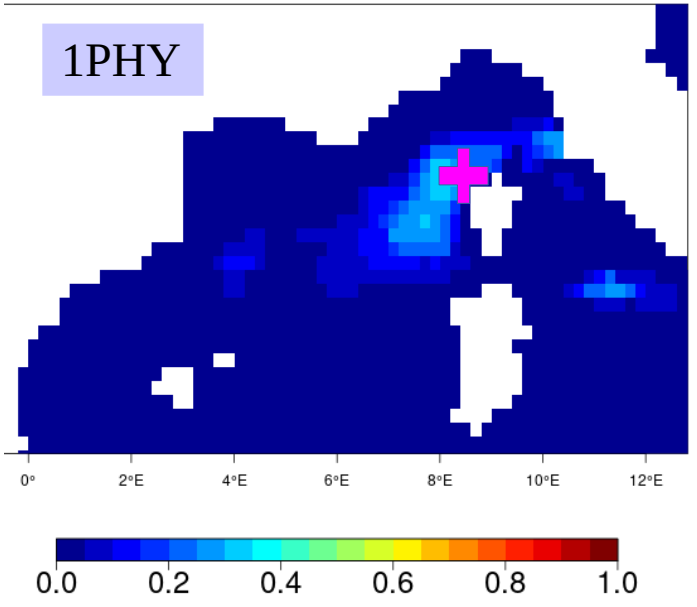
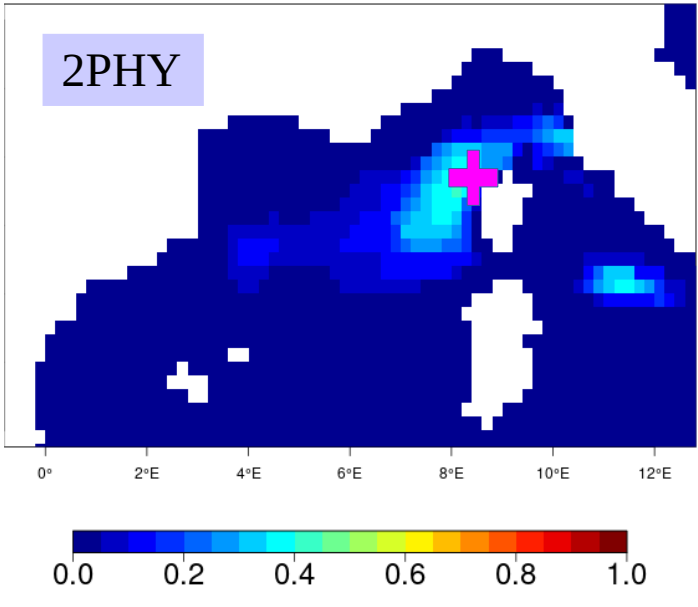
Forecast at 36 hours the 13/03





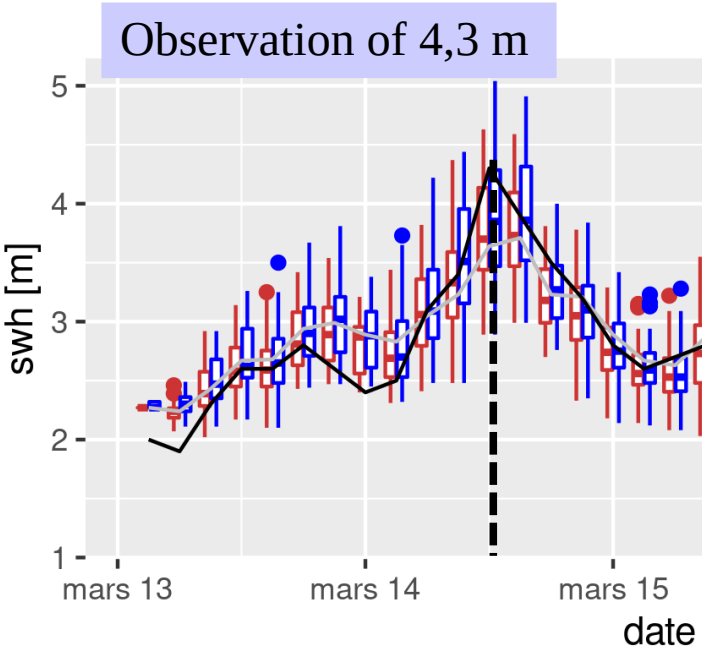


Probability of SWH > 4,3 m for the 36h forecast of the 13/03. Validity date : 14/03 at 12h

La Revellata buoy

- Probability of 30 % of SWH > 4,3 m with 1PHY
- Probability of 40 % of SWH > 4,3 m with 2PHY
- 2PHY is here more accurate.

  It makes a difference for the forecasters, to avoid false alarm or miss

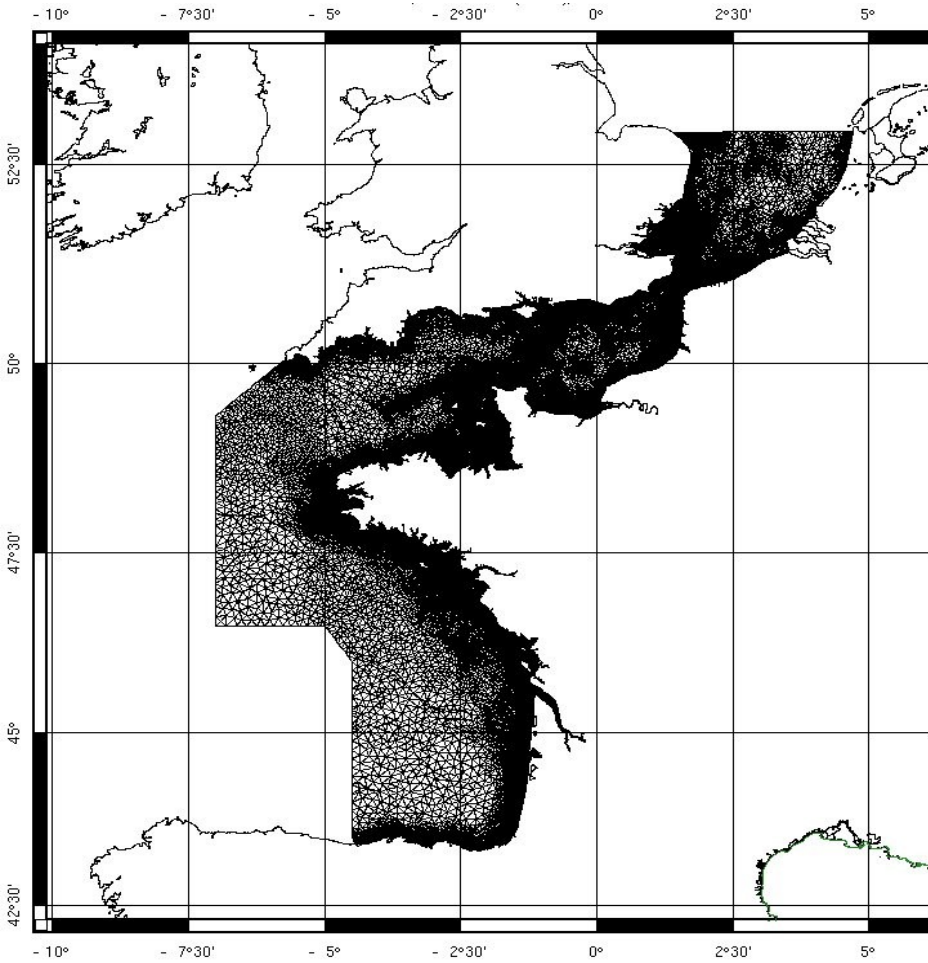


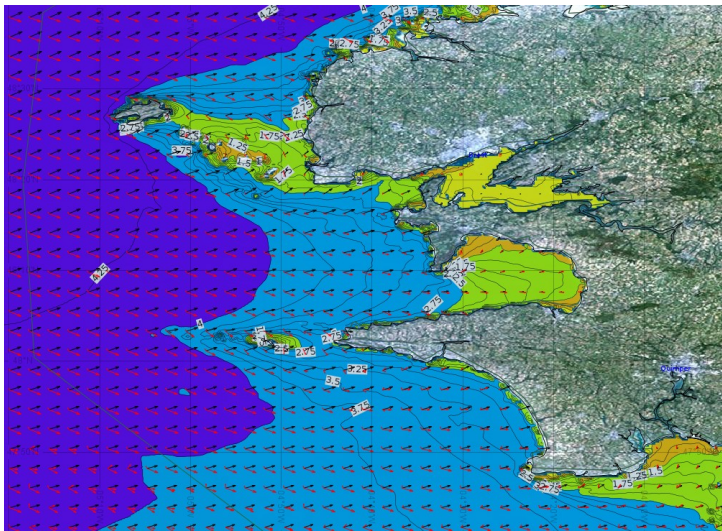
Conclusion

- Use of two wave physics in our global wave ensemble system. We get better result on short range and in general with high wave.
- The configuration is running at operations. There is a great need for the forecasters to get familiar with it.
- Ensemble wave system from ECMWF shows very good skill for Atlantic.
- MFWAM PEARP appears to be particularly interesting in the Mediterranean, which is known for its strong local wind.

=> interest to use both ensemble system

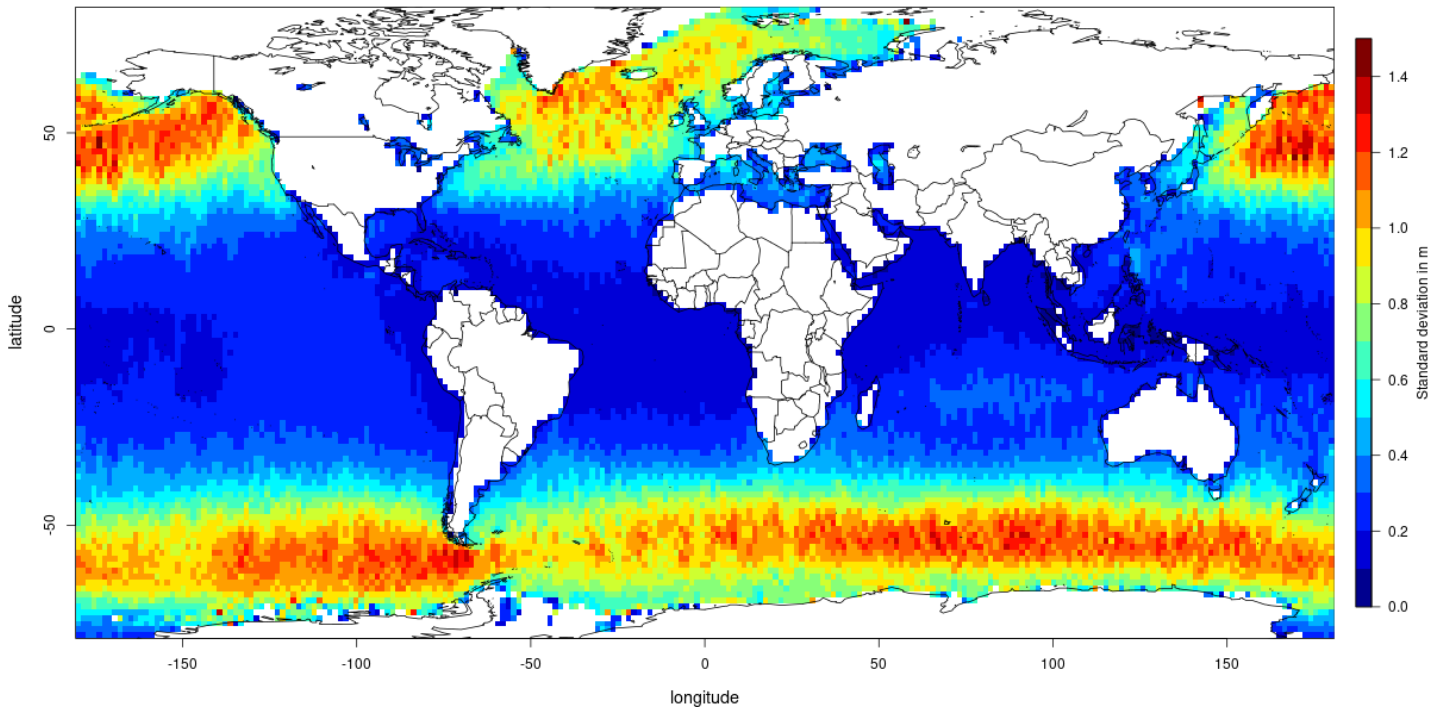
=> motivation to get into smaller scale with a coastal configuration on french coast forced by PEARP or PEAROME (0,025°)





Other perspectives

- Validation on a longer period
- Test of MFWAM forced by ensemble wind of ECMWF
- Production of Extreme Forecast Index (EFI)
- Use of the dispersion between members to improve assimilation
- Ensemble assimilation
- …



Standard deviation of model errors on SWH at 102h of time step

Thank you for your attention