Synergy between SWOT swath data and CFOSAT directional wave spectra : Application to regional IBI wave system of the Copernicus Marine Service

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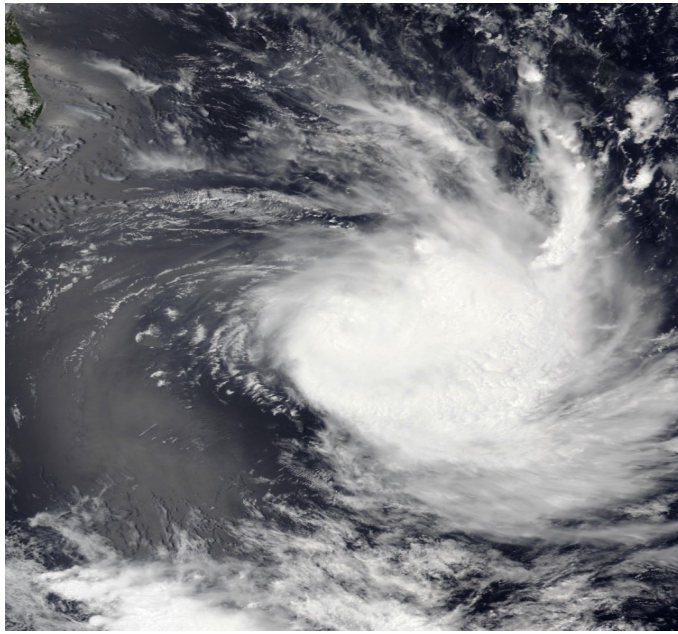
4th International workshop of Waves, Storm surge and Natural Hazards
22-26 September 2025, Santander, Spain

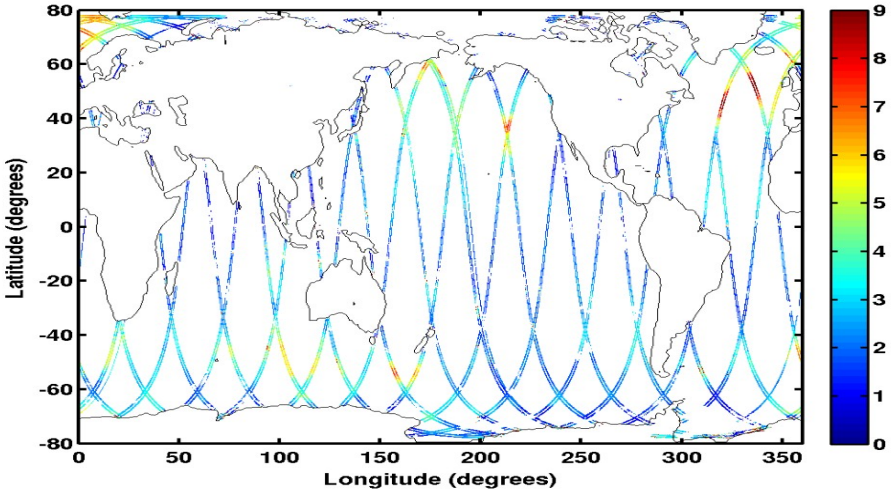
Motivation

- Improvement of global and regional sea state froecast : enhanced reliabitlity of wave submersion warnings
- Relevance of the assimilation of new data such as swath SWH from SWOT and directional observations for extreme wave conditions
- Evaluation improved processing PIC2 for swath SWH and wave spectra

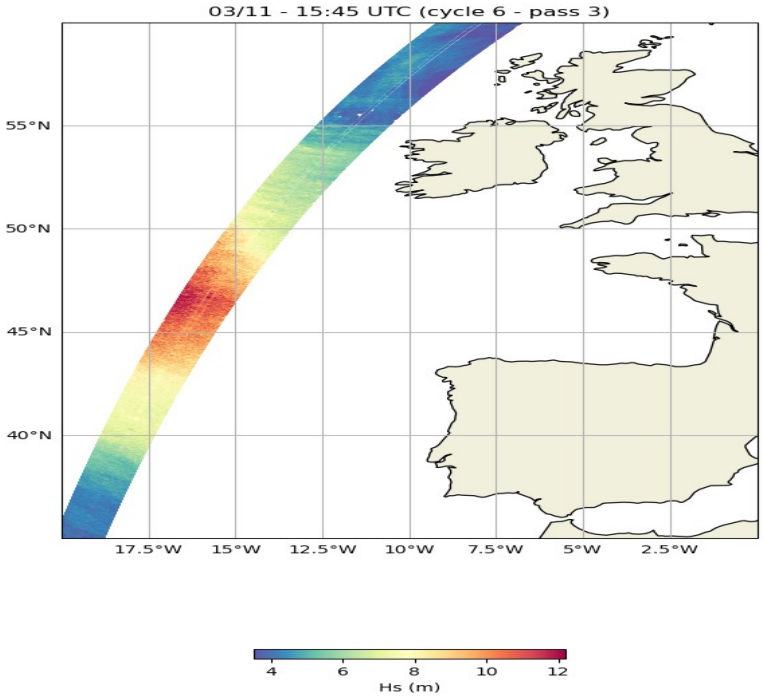


SWOT (Ka radar interometer swath altimeter)

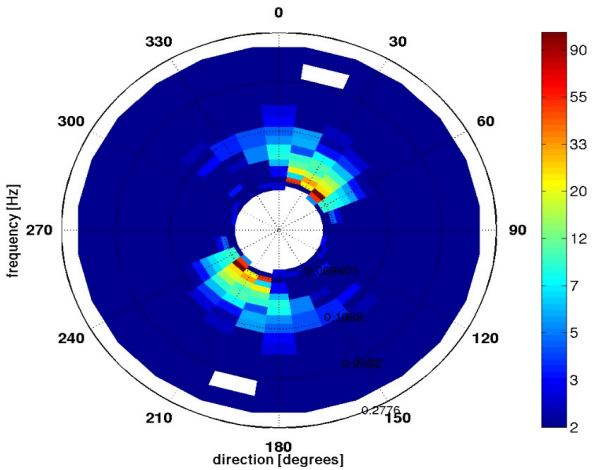
Exemple de restitution de SWH de SWOT-swath :
30 jan 2025



Example of retrieval of SWH from SWOT (nadir et Karin)



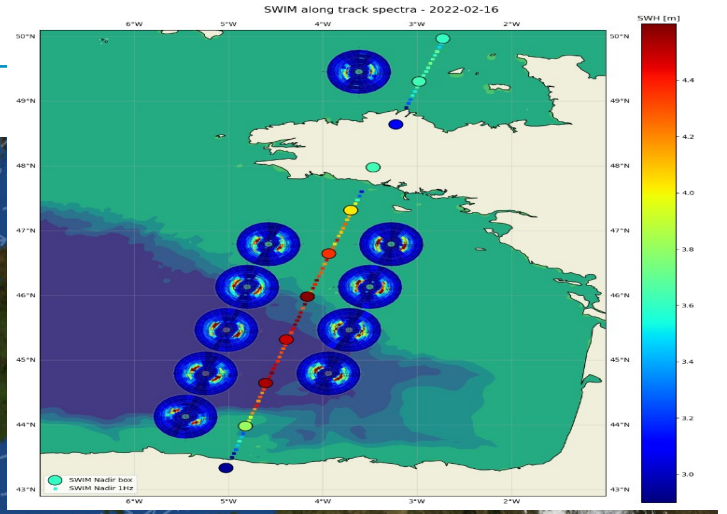
SWIM Wave spectrum (CFOSAT)



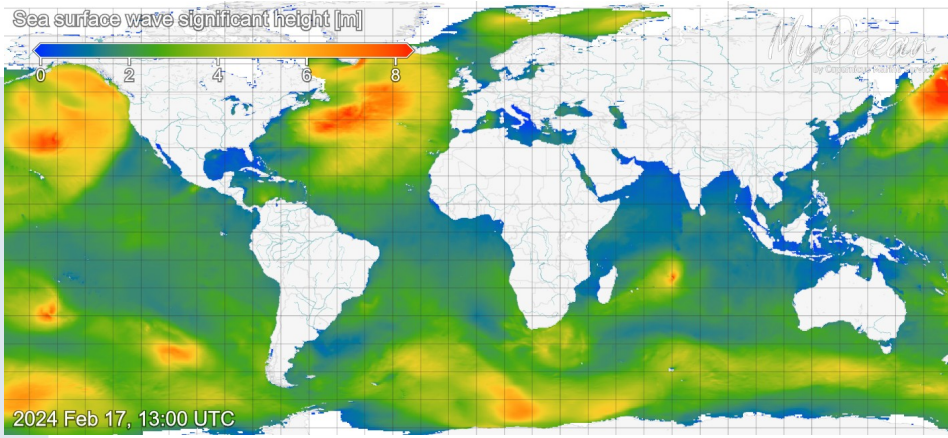
SWH on the swath of SWOT (60 km on each Side of nadir) : grid resolution of 2 km
Level 2 processing updated in October 2024

Complementary use of SWOT and CFOSAT : swath SWH and directonal Wave spectra

Storm in North Atlantic : 17 February 2024

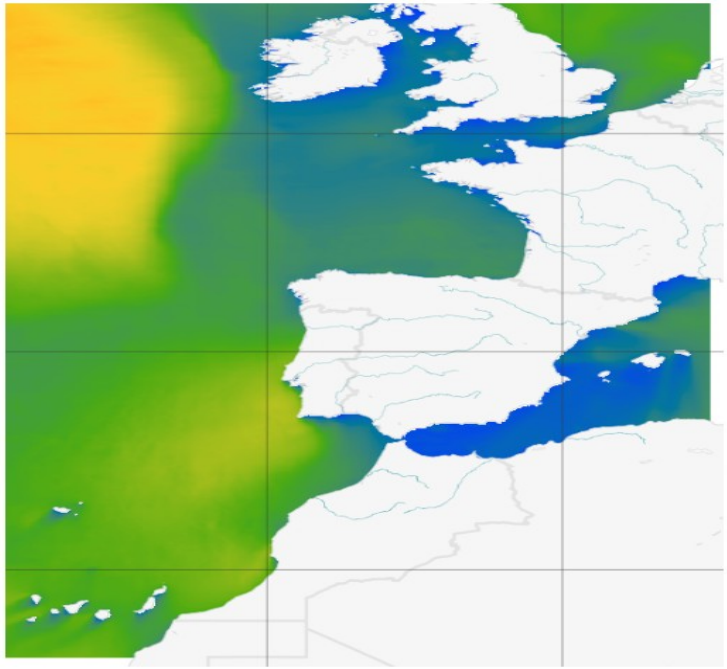


Framework of model runs



➔ **Global MFWAM model :**
20 km grid size, spectral resolution 30 freq and 24 dir
IFS-ECMWF wind and ice forcing

➔ **time period with updated L2 processing of SWOT-swath data : Jan-February 2025**



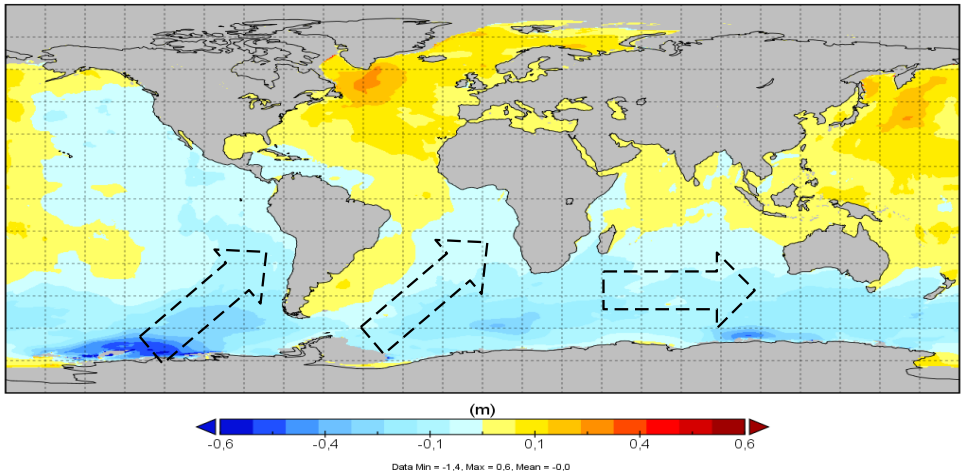
Regional MFWAM model : IBI (Iberian-Biscay-Ireland)
5 km grid size, spectral resolution (30x24)
ARPEGE-MF wind forcing
Boundary conditions from global

■**Validation with atlimeters**
SWH (Jason-3,Saral,CFO, S3, H2B) and available drifting buoys

METEO FRANCE

Upgraded PIC2 processing for swath SWH of SWOT

Average difference of SWH w/wo DA swth SWOT : Feb 2025



SWH bias variability with peak period

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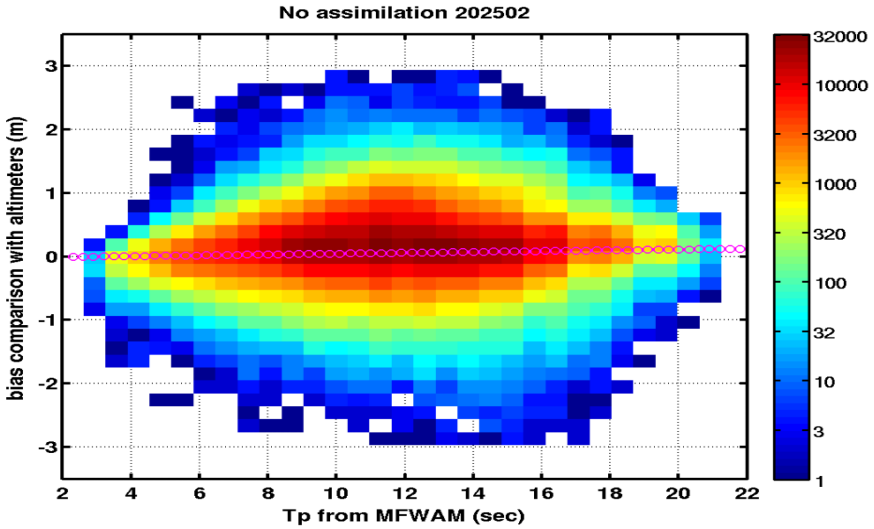
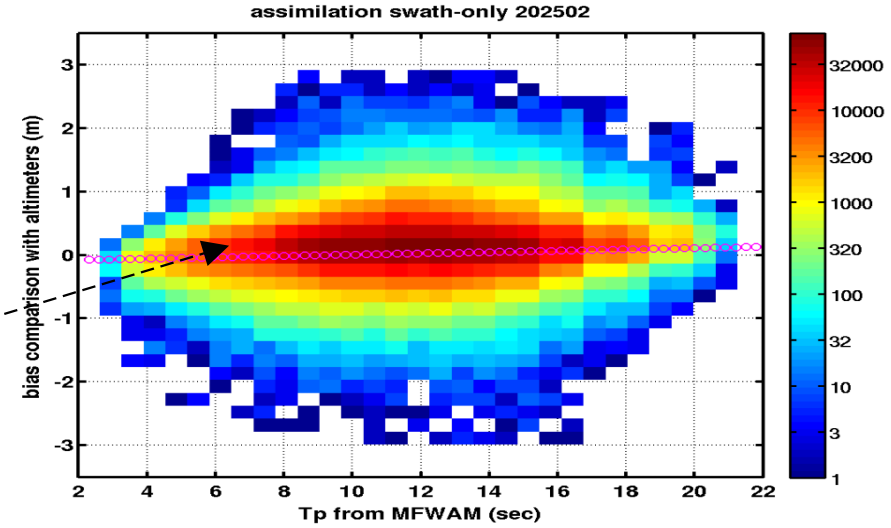


With DA of swath SWH



Reduced SWH bias for swell particula for Tp greater than 10 sec

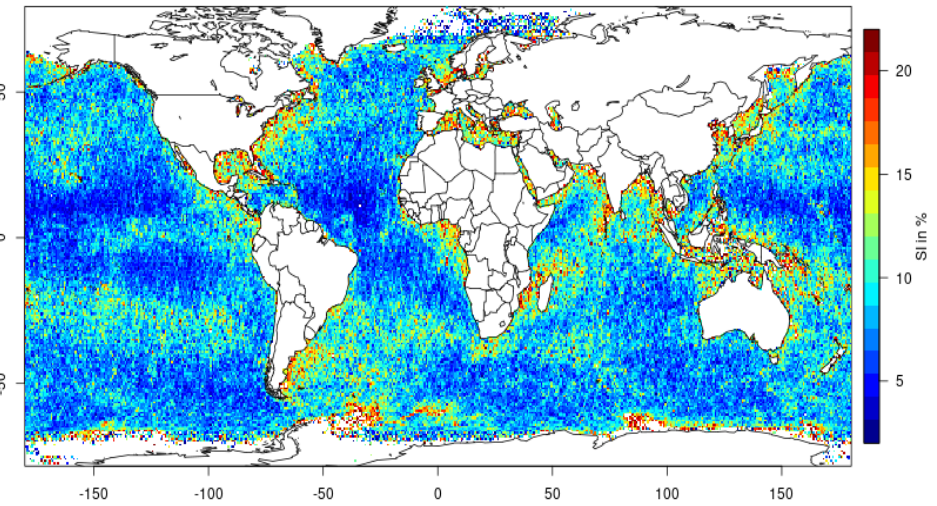
Slope=0.012

Intercep=-0.082

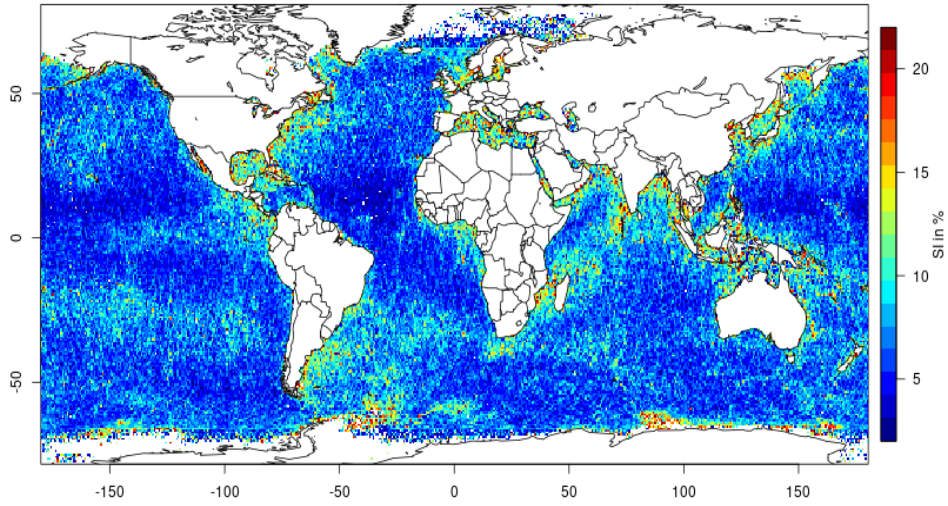
Performance of the combined assimilation : Jan & Feb 2025

Scatter index of SWH maps (in %)

SWOT-nad-swath

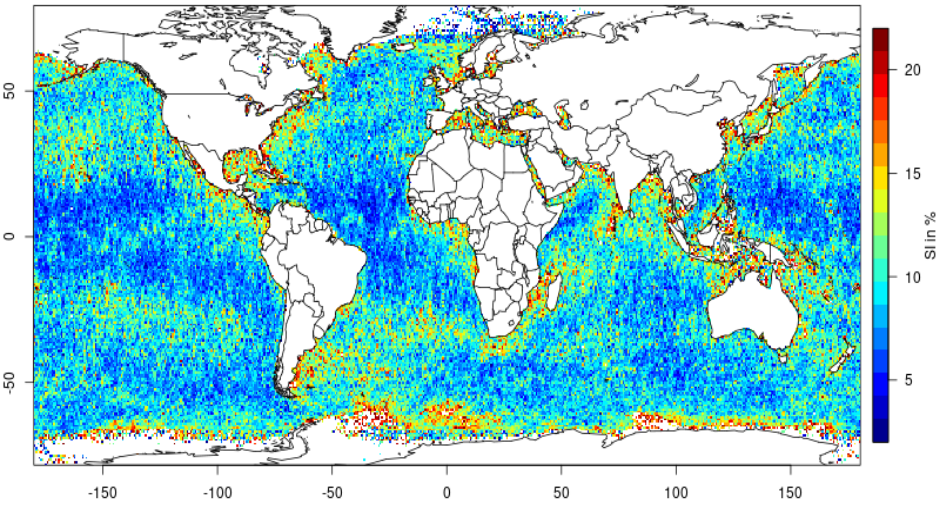


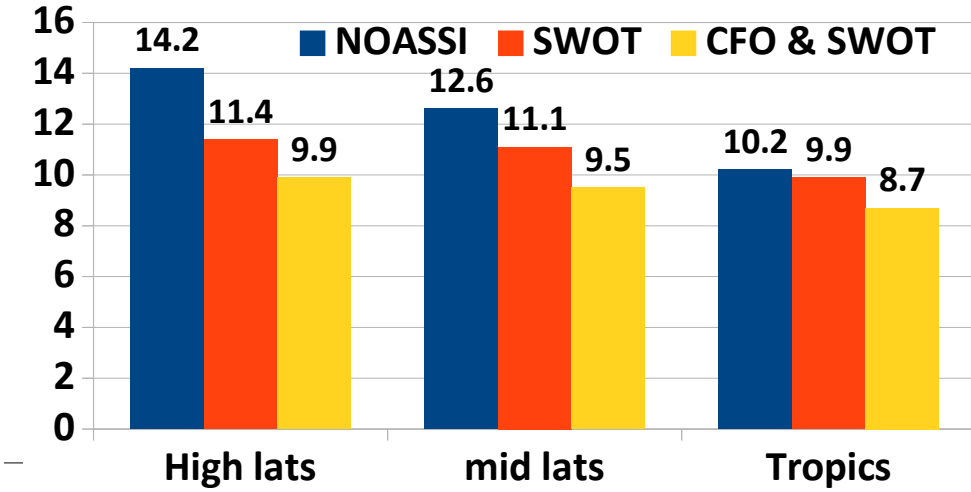
SWOT & CFO



Enhanced impact when using combined (particularly in mid lats)

Noassi

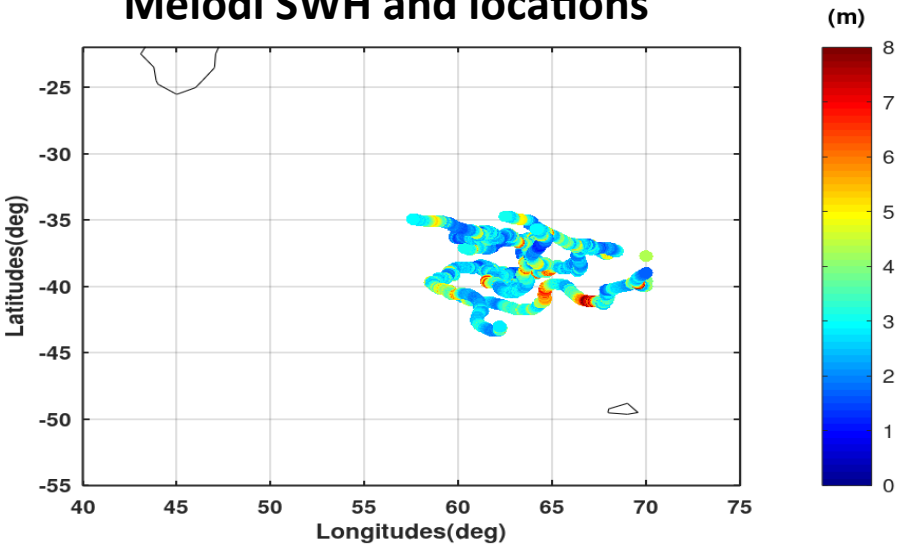




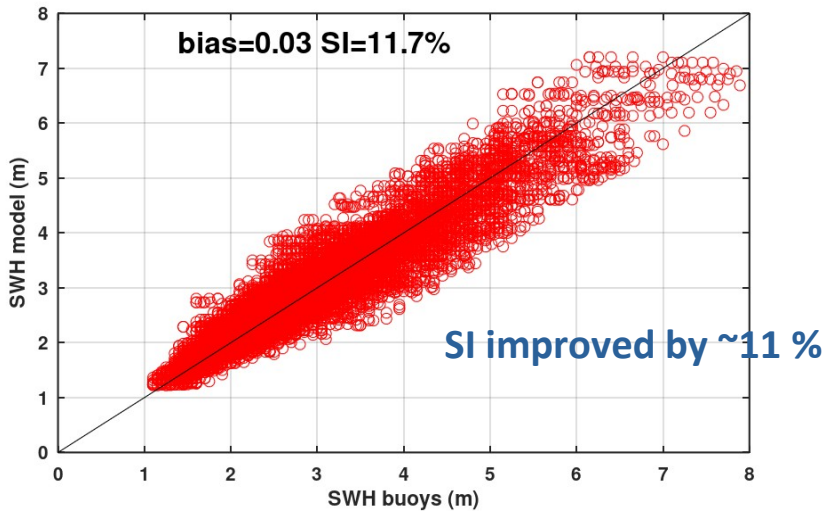
Validation with altimeters

Comparison with SWH from MELODI drifting buoys (thanks to C. Maes & EODYN)

Melodi SWH and locations



DA CFOSAT+SWOT



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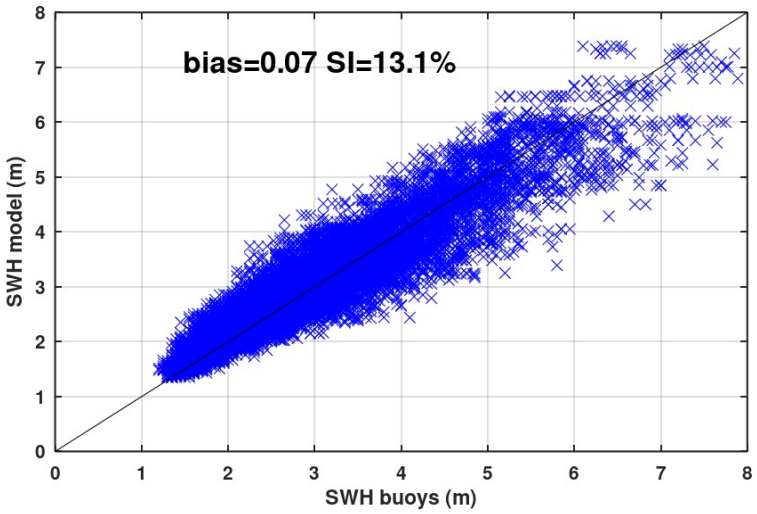
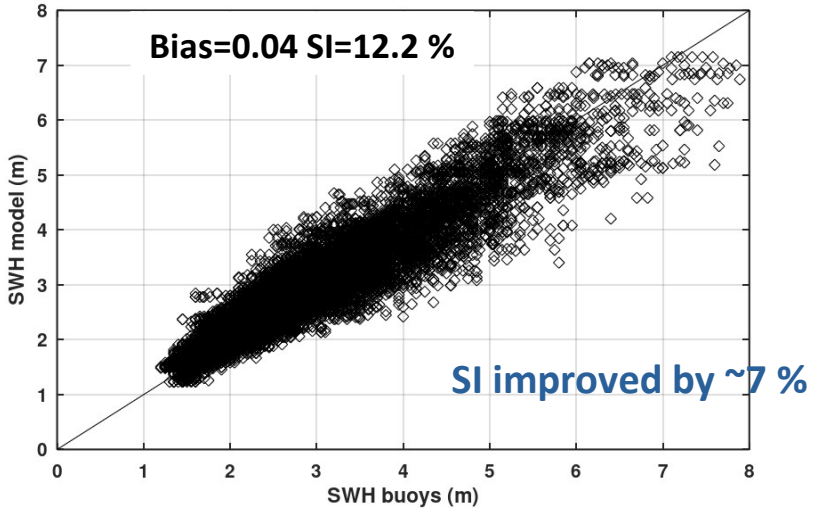
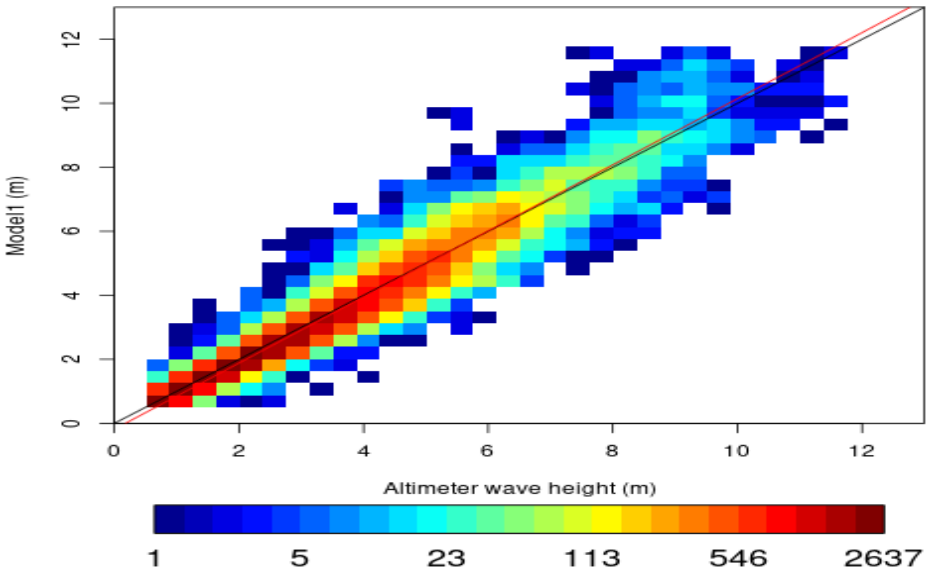


DA SWOT

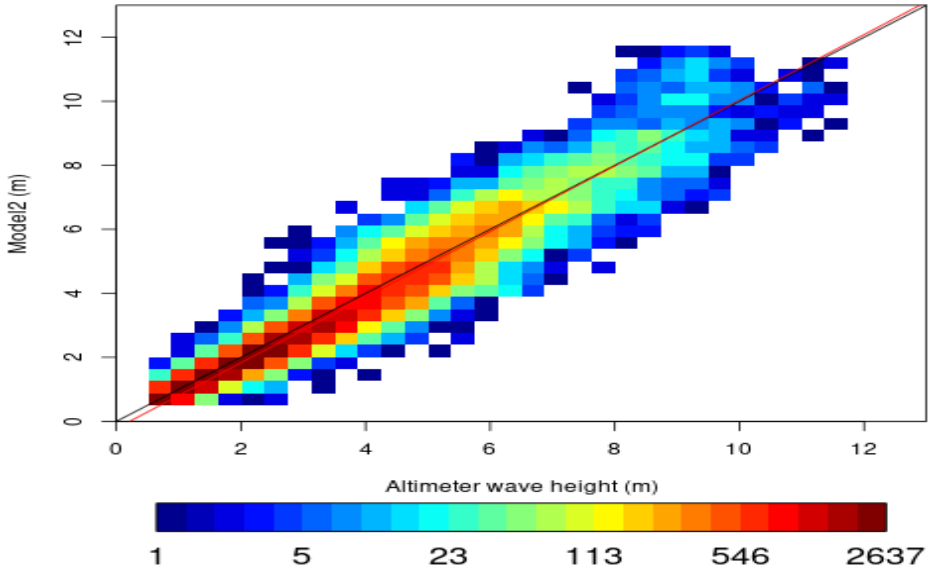


Validation of the combined assimilation for high resolution of IBI : February 2025

With combined DA



Without DA



Bias=-0.08 m
SI=13.8 %
Slope=1.03
Intercept=-0.18

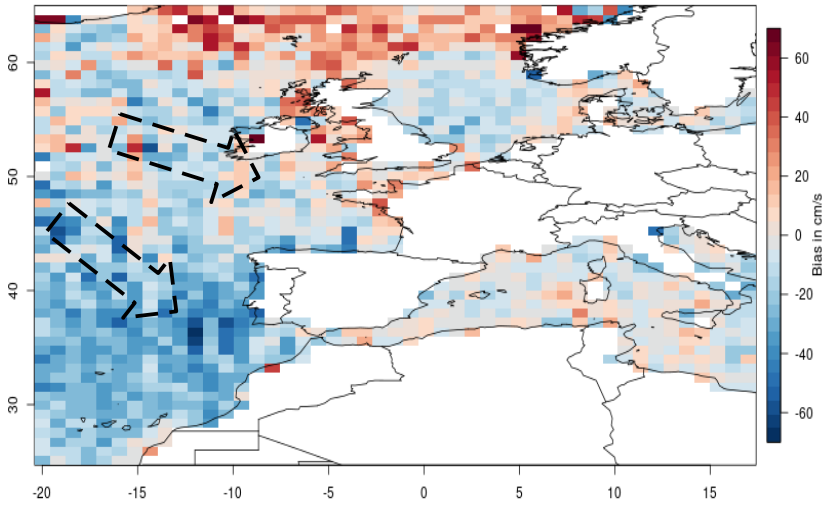
Reduced bias and scatter of SWH
Particularly in the range of 2-6 m

Bias=-0.14 m
SI=14.6 %
Slope=1.03
Intercept=-0.22

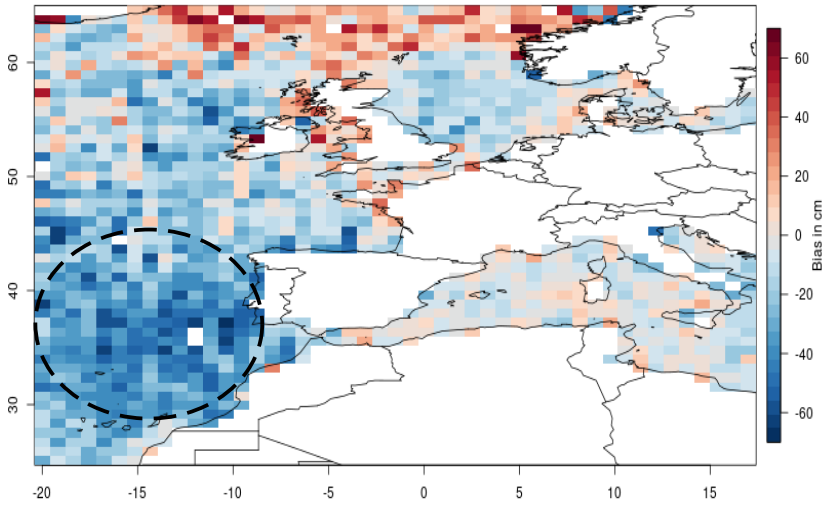
Validation of the combined assimilation with altimeters SWH : February 2025

Bias of SWH (in cm)

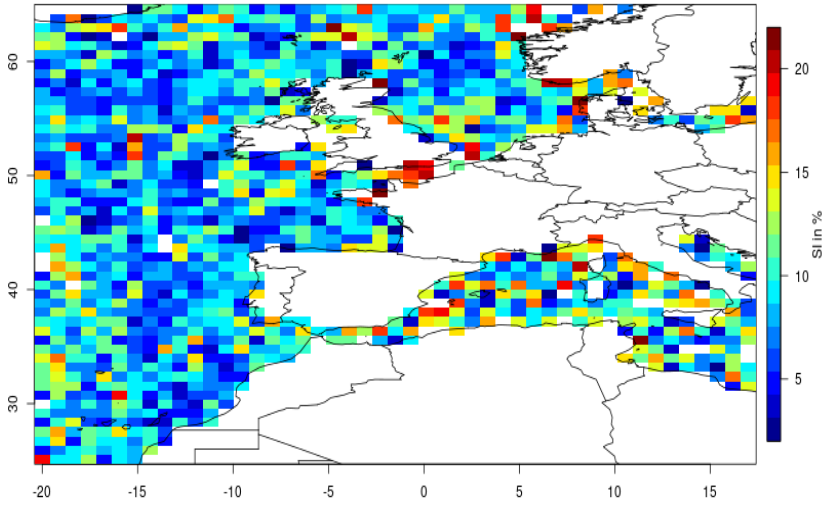
With combined DA

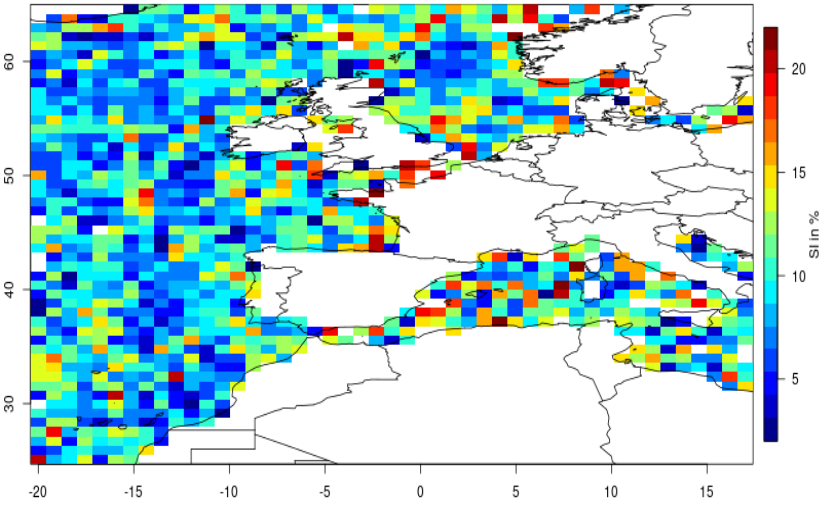


Without DA



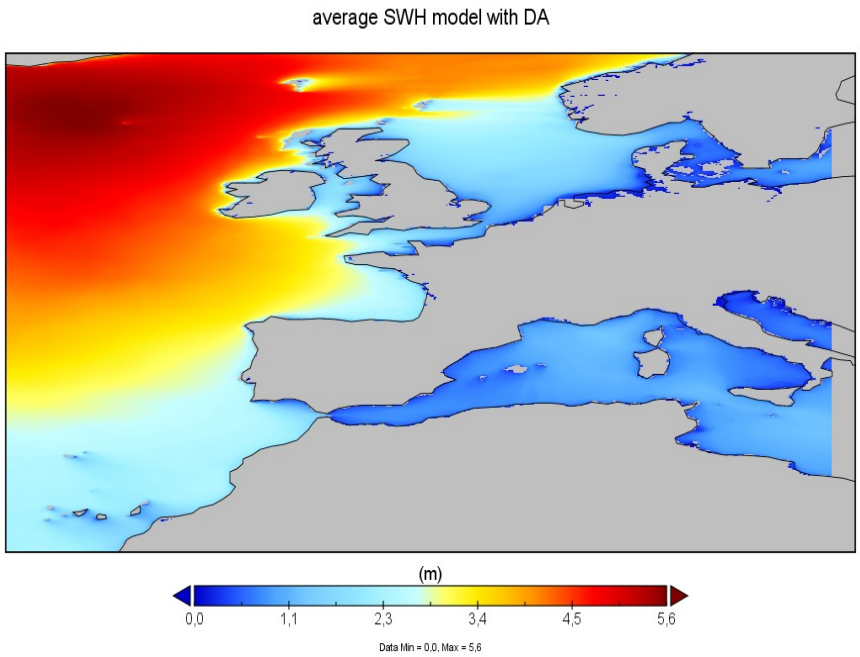
Significant reduction of SWH bias and SI on swell propagation tracks





Assimilation of SWOT & CFOSAT in High resolution model : Feb. 202502

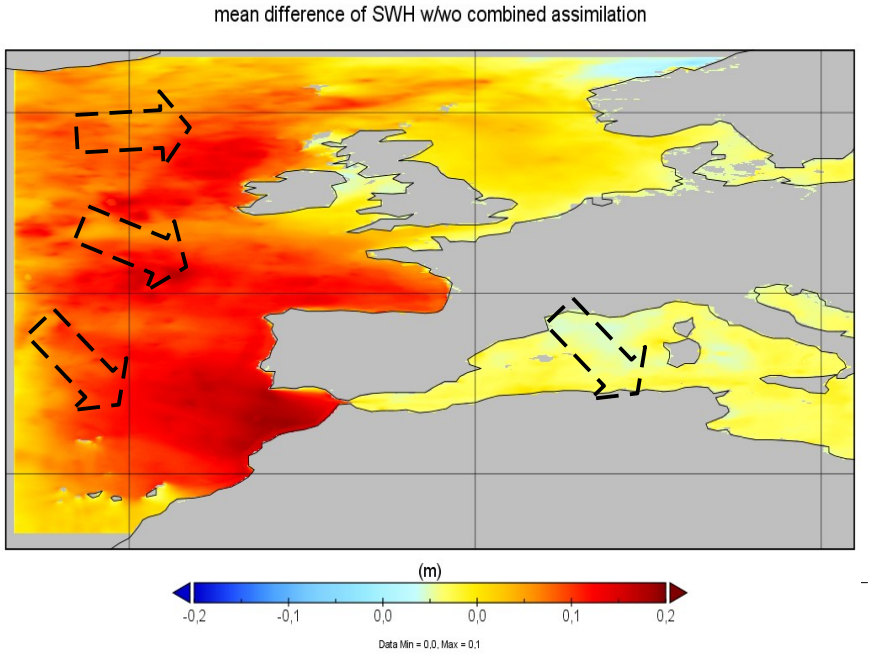
Average of SWH



Simulation with MFWAM-IBI : 5 km grid size
ARPEGE atmospheric forcing

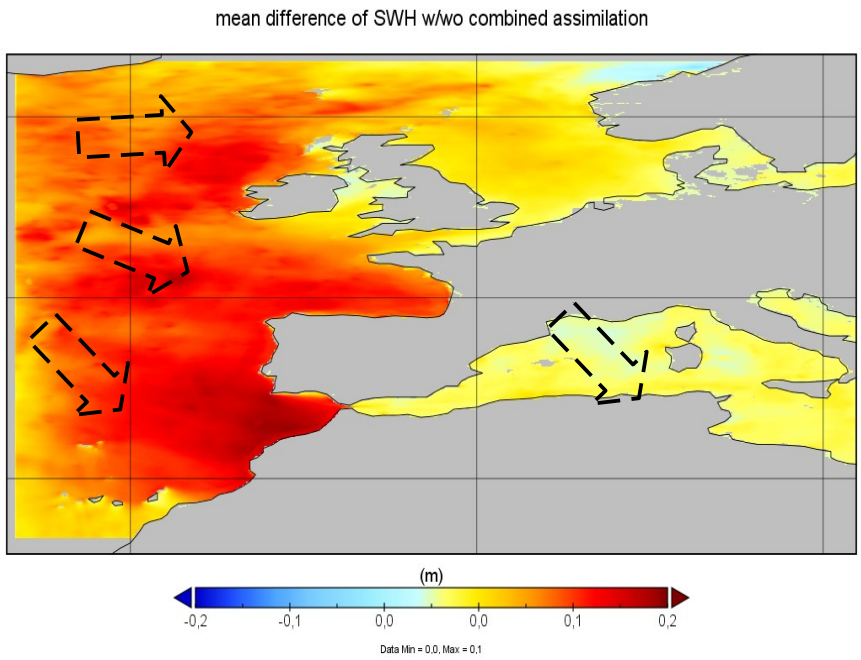
Enhanced impact on swell propagation tracks

Average difference of SWH w/wo DA of



Assimilation of SWOT-swath in High resolution model : Feb. 202502

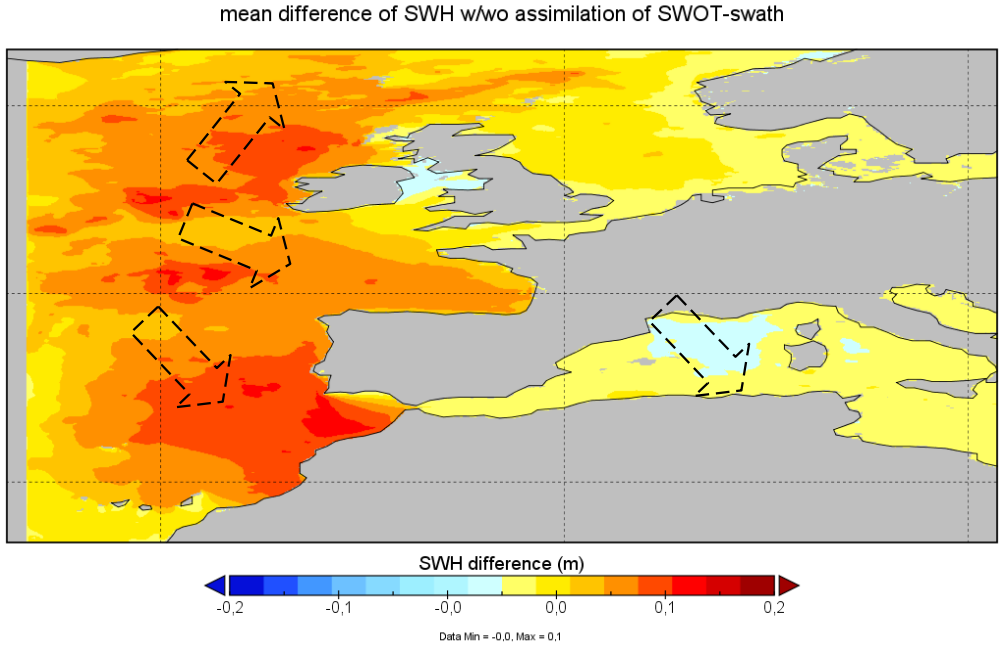
Average difference of SWH w/wo DA of SWOT & CFOSAT



Enhanced impact on swell propagation
Areas with combined DA

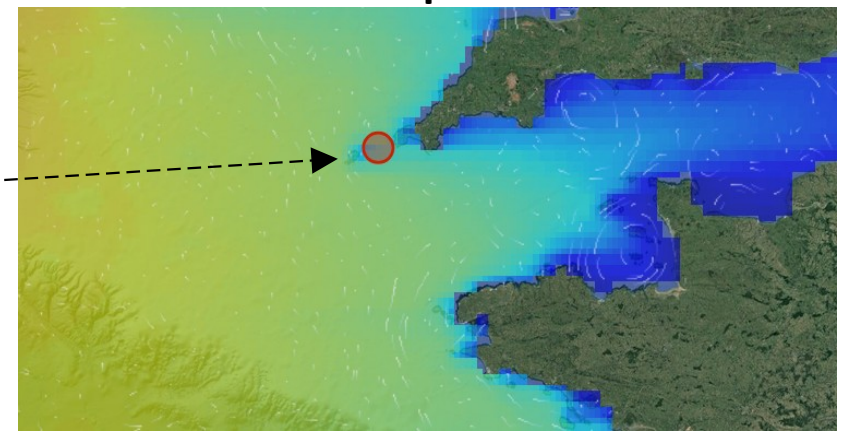
Simulation with MFWAM-IBI : 5 km grid size
ARPEGE atmospheric forcing

Average difference of SWH w/wo DA of SWOT-swath

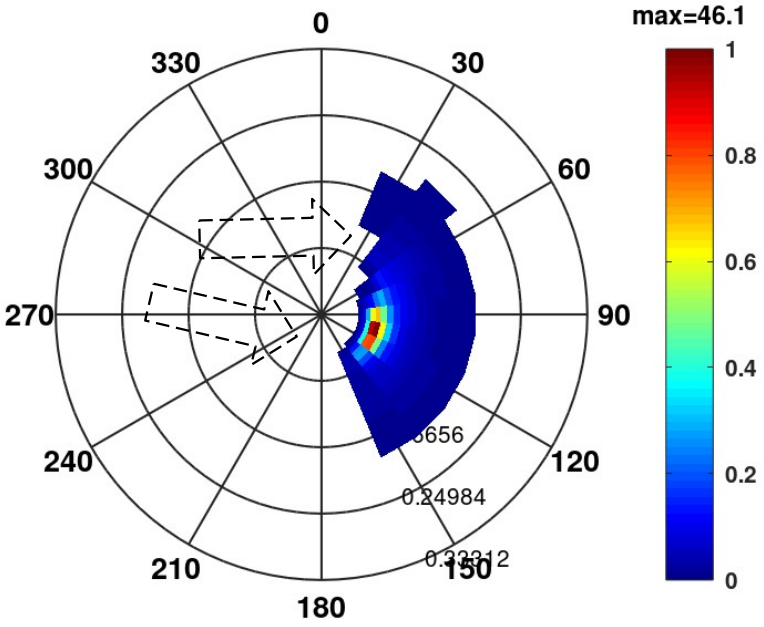


Impact of spectral assimilation on 28 february 2025 at 18:00UTC

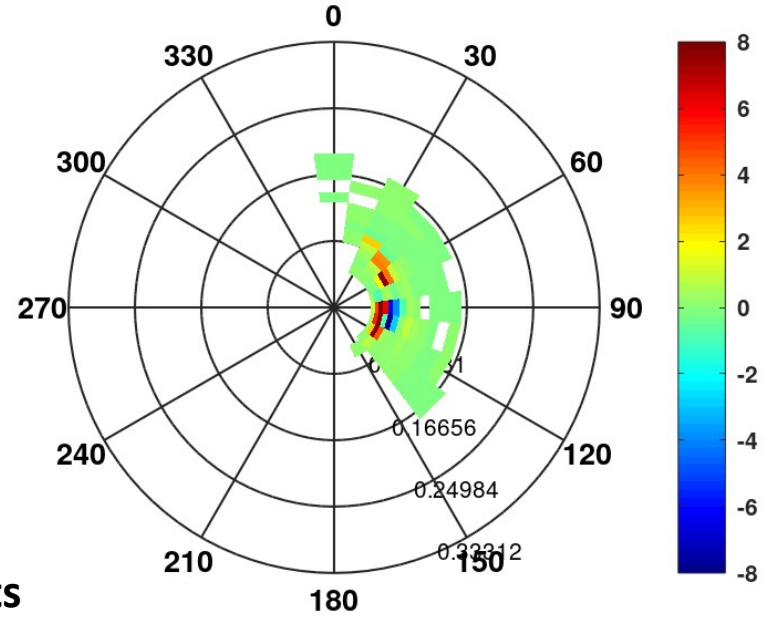
Location of wave spectrum : channel



Wave spectrum with DA of SWOT &SWIM



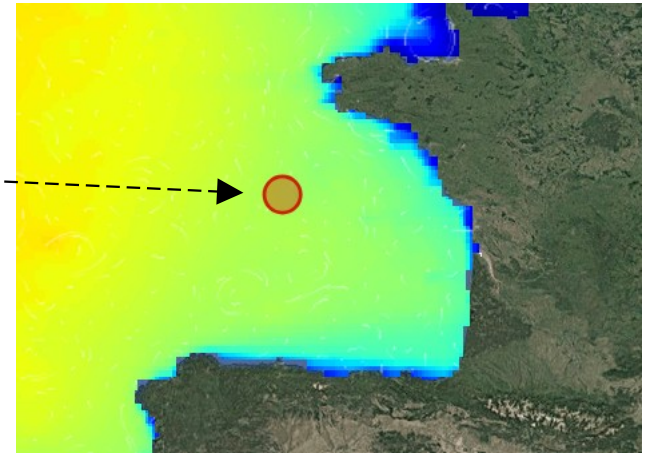
Difference w/wo DA



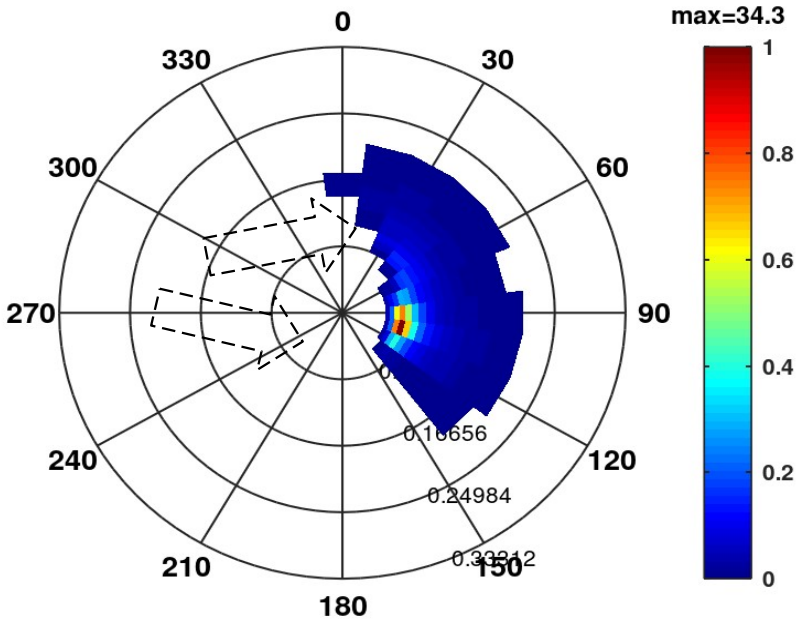
Combined DA induces a positive Increment for longer swell, which suggests Faster arrival of the swell at the coast

Impact of spectral assimilation on 28 february 2025 at 18:00UTC

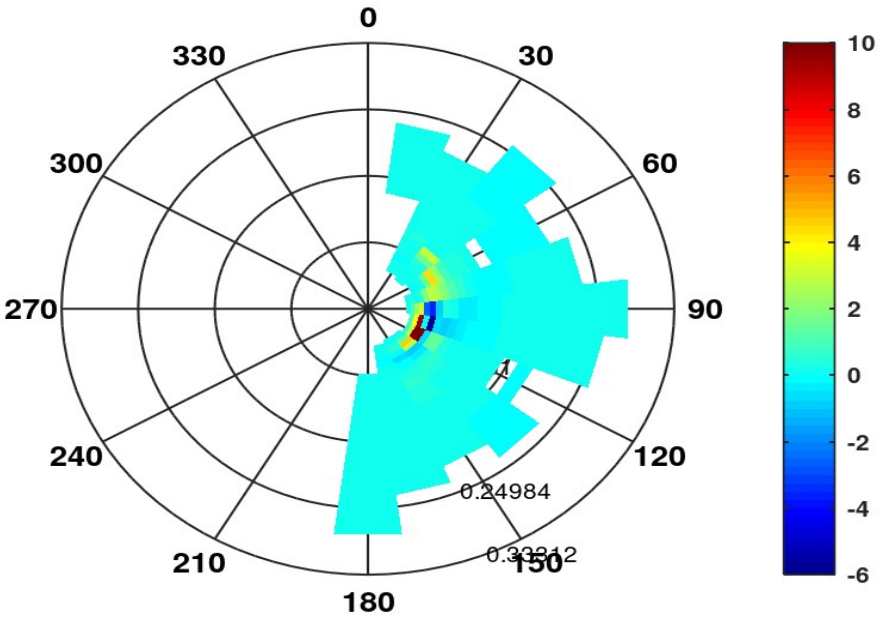
Location of wave spectrum : biscay



Wave spectrum with DA of SWOT &SWIM



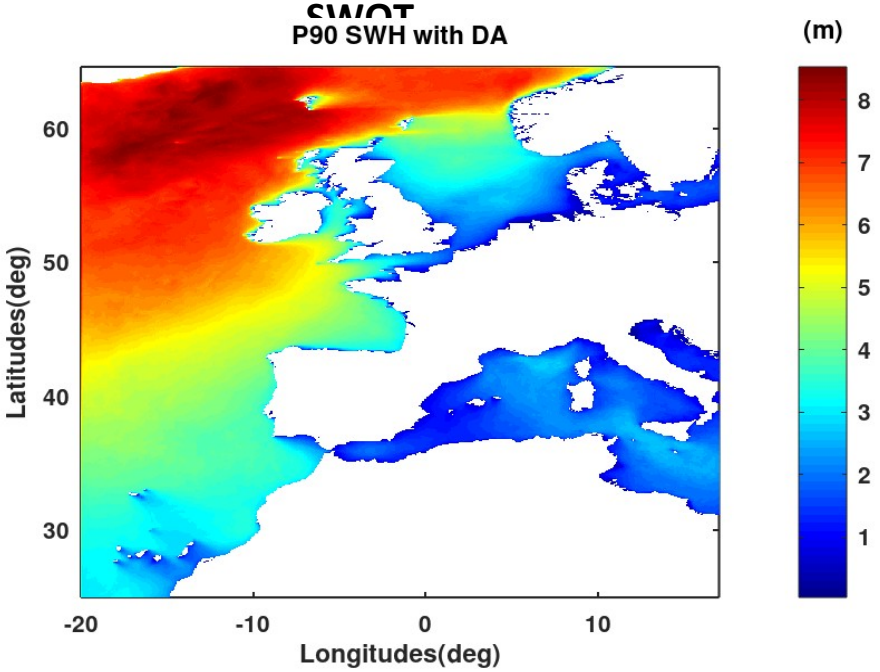
Difference w/wo DA



More complex increment induced
By Combined DA for gulf of biscay

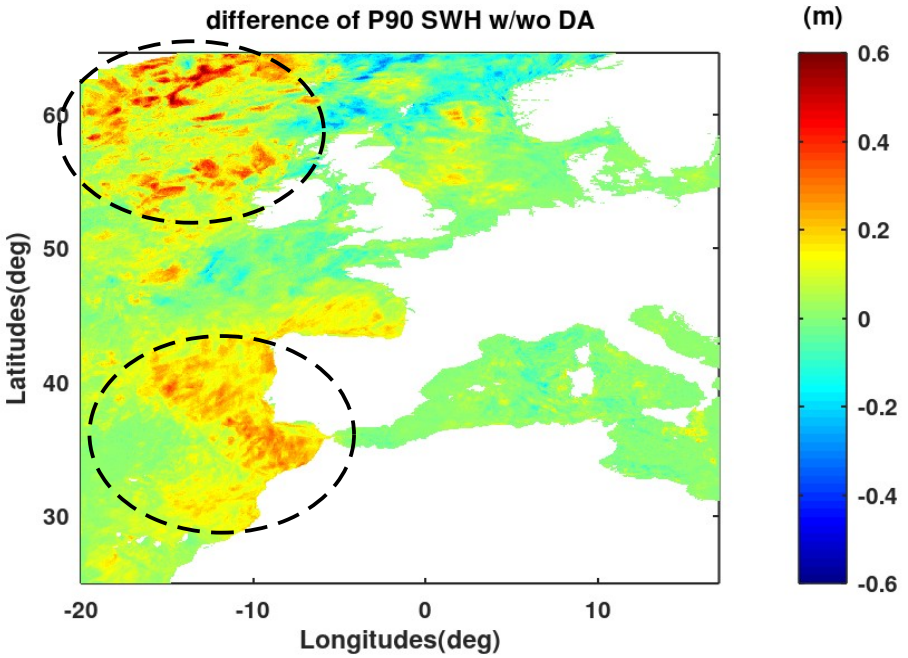
Impact of combined SWOT and CFOSAT on extreme wave height (P90) Feb. 202502

P90 SWH with assimilation of CFOSAT and SWOT



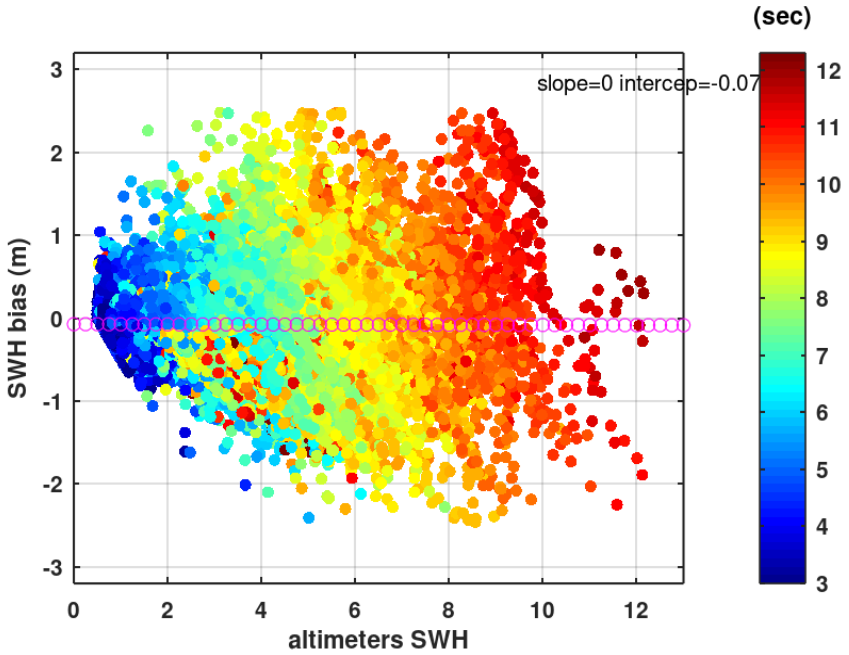
Significant impact on P90 in gulf of biscay, Coastal iberian peninsula and morrocan Coast.

fference of P90 SWH w/wo assimilation



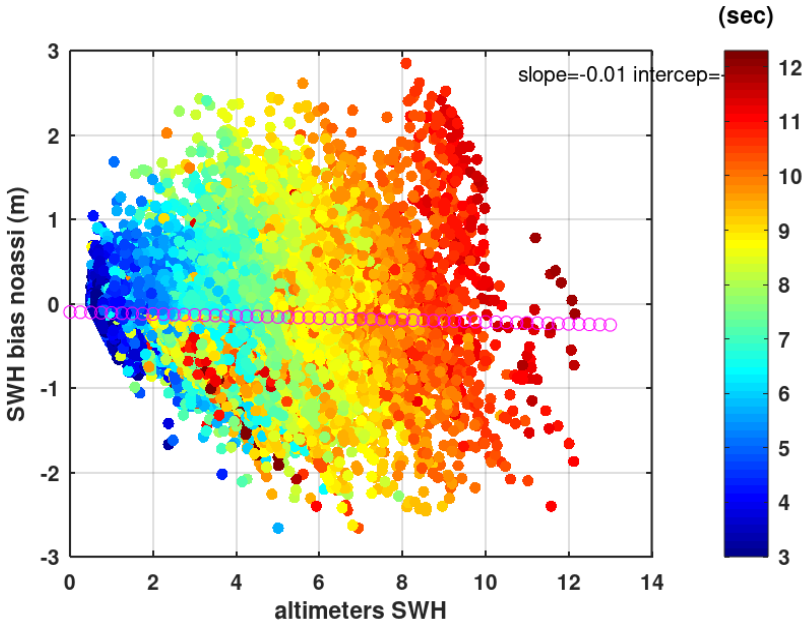
Validation of the combined assimilation : February 2025

With combined DA



Slope=0 intercept=-0.07

Without DA



Slope=0.01 intercept=-0.10

Reduced SWH bias for long swell and correcting the model underestimation Of wave period of swell

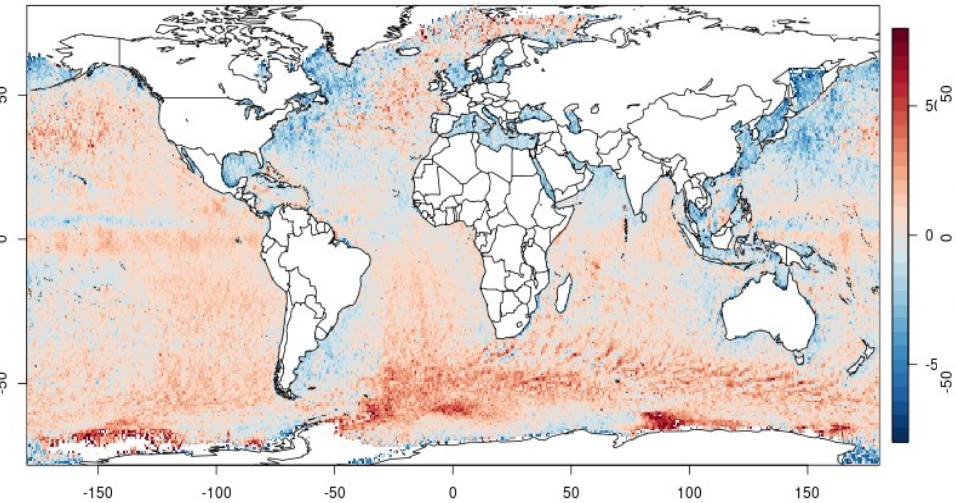
Key messages

- **Significant positive impact of combined assimilation of SWOT-swath and SWIM wave spectra**
- **Validation with altimeters SWH shows significant improvement of long swell in north-east Atlantic affecting coastal areas such gulf of biscay, iberian peninsula, canarias islands and morrocan coast.**
- **Very interesting benefits of combined assimilation on extreme wave height**
- **Further validation with drifting buoys from Ocean summer schhool 2025 (April and May 2025). Also investigating improved sea state by combined assimilation for coastal applications (forcing SWASH).**

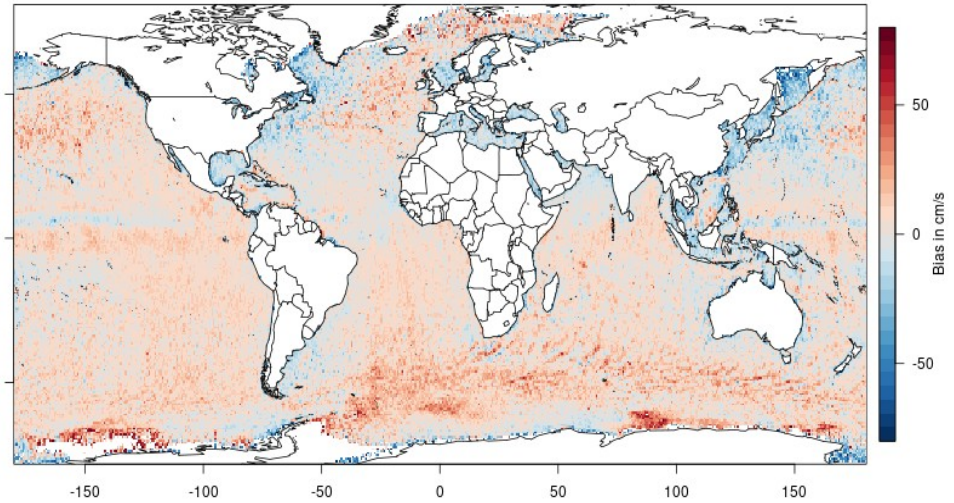
Performance of the combined assimilation : Jan & Feb 2025

SWH bias maps (in cm)

SWOT-nad-swath



SWOT & CFO



Enhanced reduction of bias when using Combined DA

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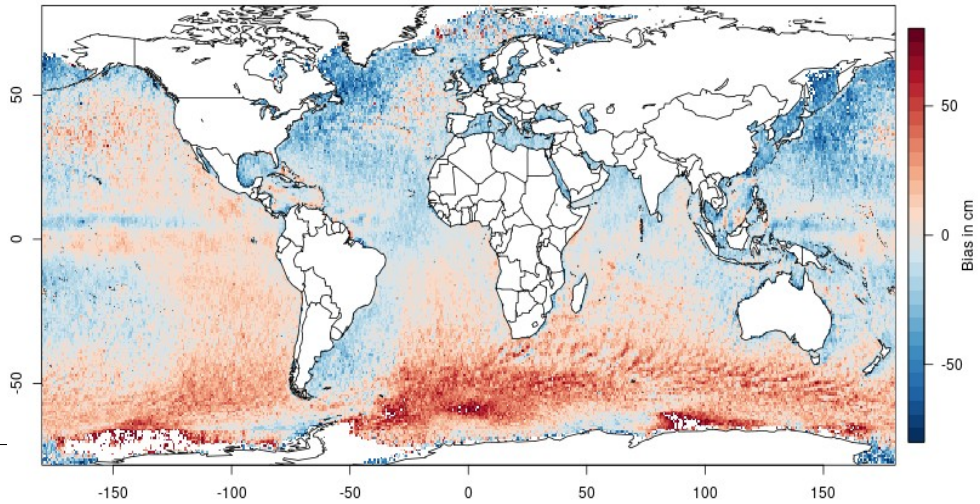
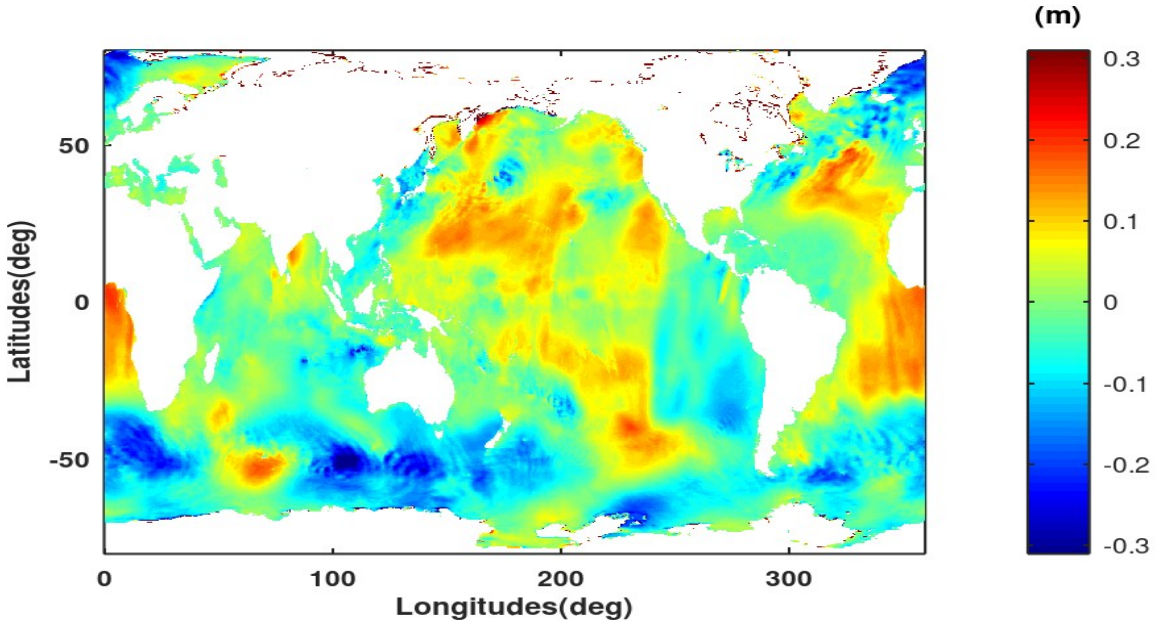


Model overestimation In SO and east pacific

Validation with altimeters

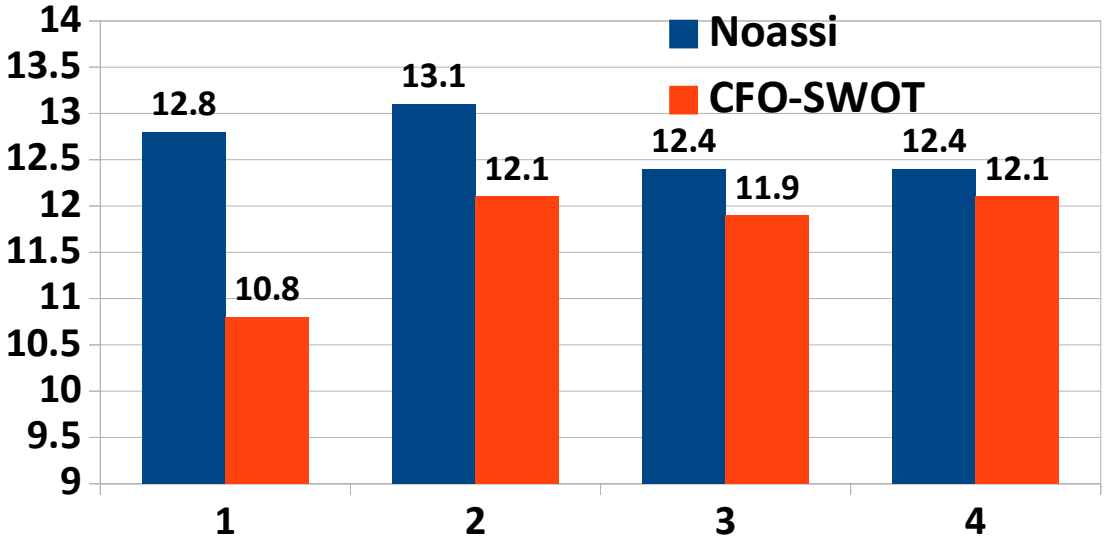
Performance of the assimilation in the forecast mode

Average difference of SWH in the forecast



Significant impact in average when stopping the assimilation

Scatter index of SWH (%)



Impact on SWH still efficient after 3 days of forecast