Vers une amélioration du couplage océan/atmosphère avec les observations directionnelles de la mission CFOSAT

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OUTLINE

1- Motivation

2- impact of SWIM data

3- coupling experiments and impact of waves

4- validation and results

5- conclusions

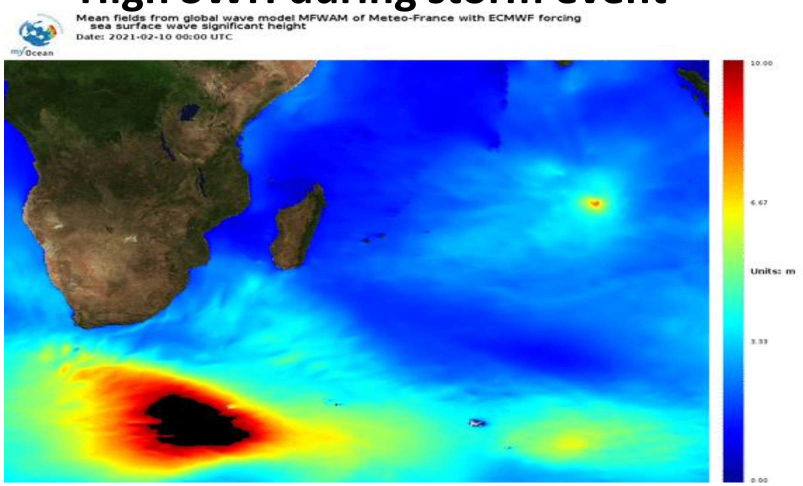
Motivation

◆ **Better sea state forecast with Directional wave observation from CFOSAT opens a better understanding of ocean/atmosphere coupling**

◆ **Investigating the sensitivity to wave forcing to ocean (Stokes drift, Stress and wave induced turbulence**

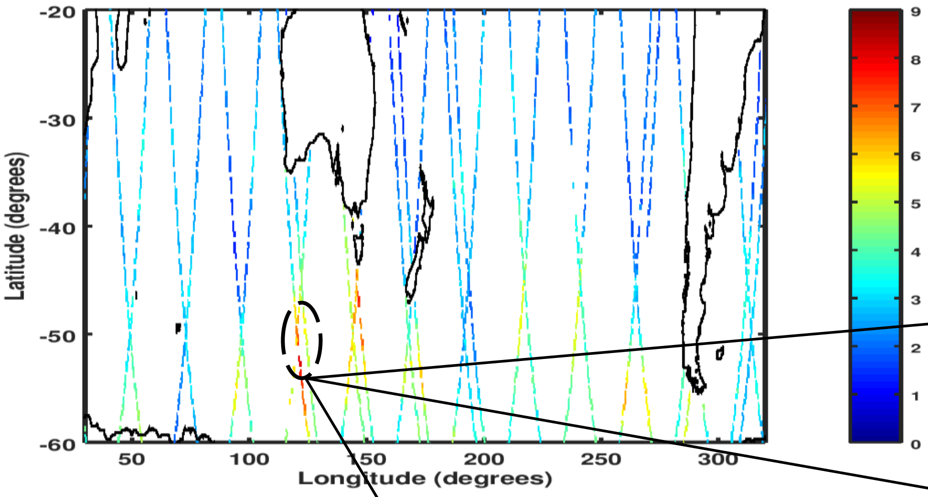
◆ **Impact of waves on ocean circulation key parameters in critical ocean regions, Marginal Ice Zone,….etc**

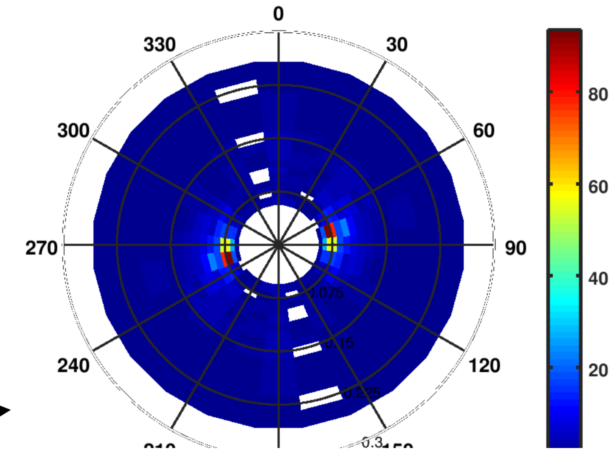
High SWH during storm event

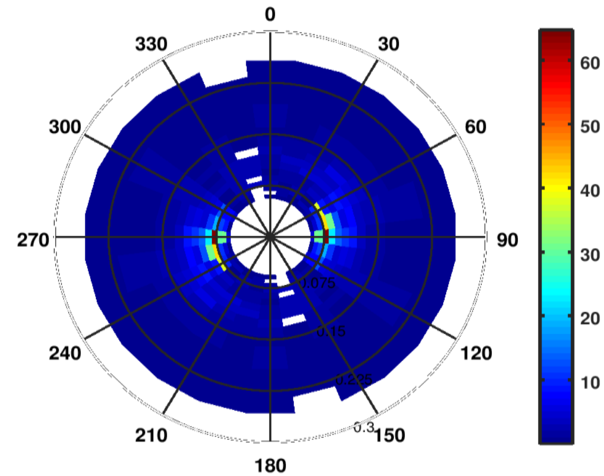


SWIM wave directional spectra and SWH off-nadir

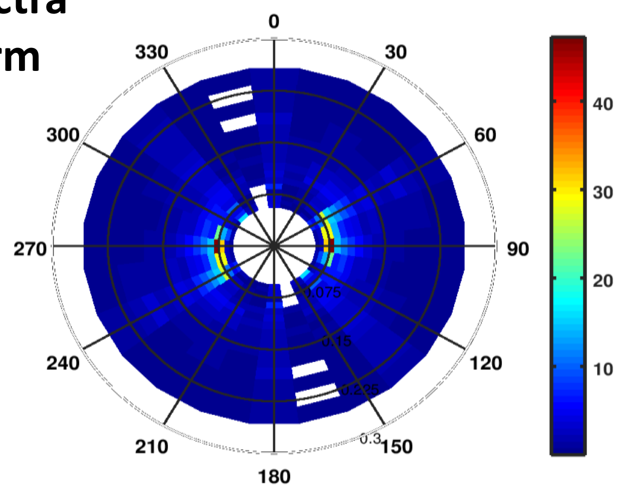
SWH at off-nadir of CFOSAT 26-27 February 2020
During storm event in SO







SWIM wave spectra Observed in storm Event southern Australia

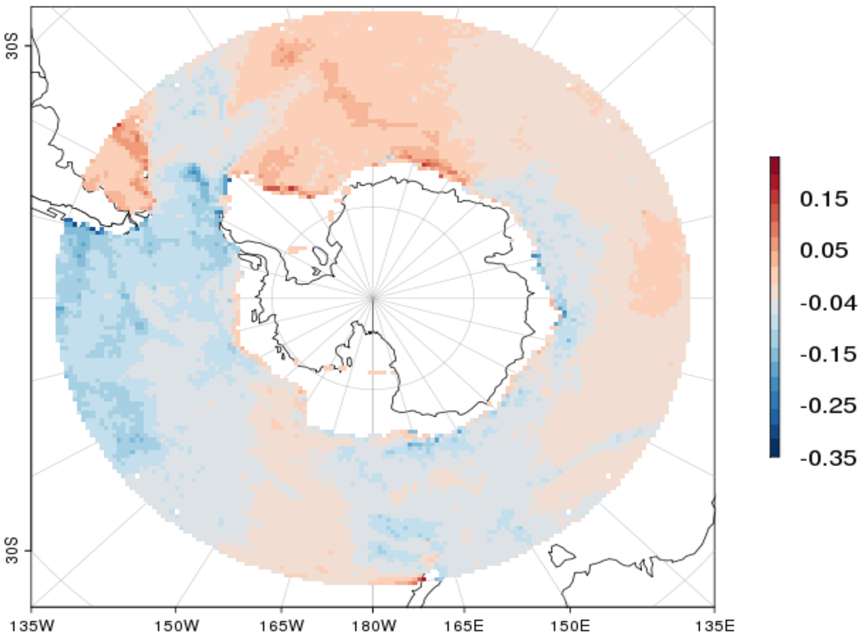


Capturing directional properties of waves during growth phase. We can clearly see the change of energy peak in direction

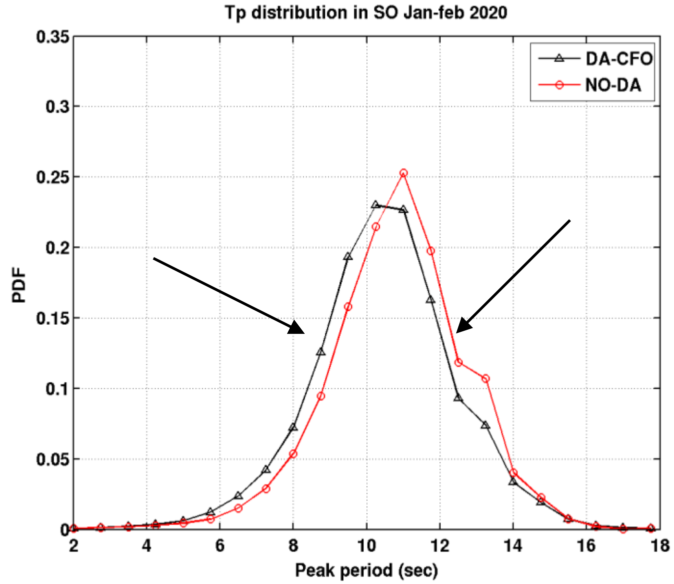
The uniqueness of using directional wave observations from SWIM in Southern Ocean

Wind-wave growth corrected by the Assimilation of directional wavenumbers (Kx-Ky) of partitions from CFOSAT (Aouf et al.2021)

Difference of wave age at the peak with and Without DA



PDF of peak period in Southern Ocean



Better transition of wind-waves to long swell, particularly in Severe storm conditions

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Description of model runs

- **Wave model MFWAM configuration :**
  -global scale with grid size 0.5° and model version CMEMS operational.
  - spectral resolution of 24 directions and 30 frequencies
  - atmospheric forcing IFS-ECMWF (analysis wind and sea-ice fraction)
  - period of run : January-May 2020 & 2021

- **Two runs of MFWAM model have been performed :**
  - with assimilation of SWH (off-nadir) and directional wavenumbers from SWIM spectra of CFOSAT
  - control run without assimilation

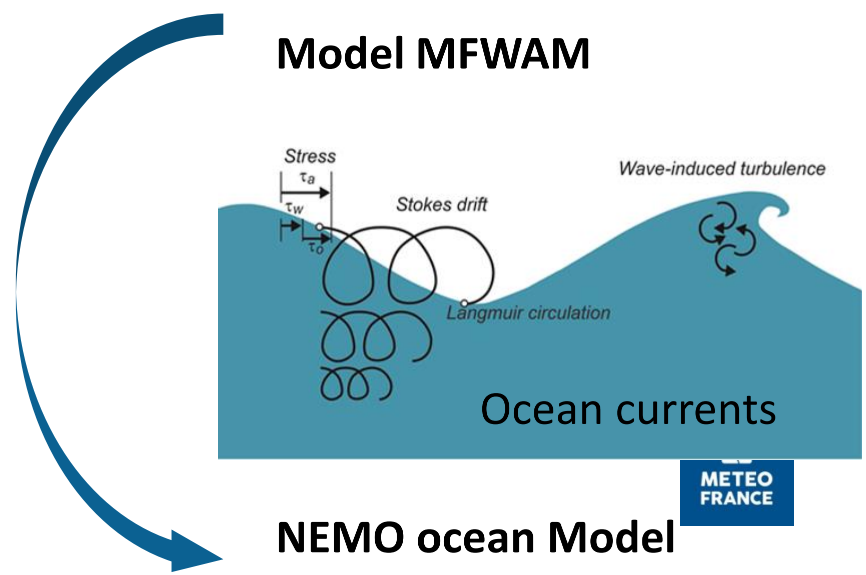
➔ **Validation of SWH with altimeters independent data (Jason-3,Saral,S3)**

- **NEMO model runs : configuration ORCA (0.25°)**

➔ **wind forcing from IFS-ECMWF**

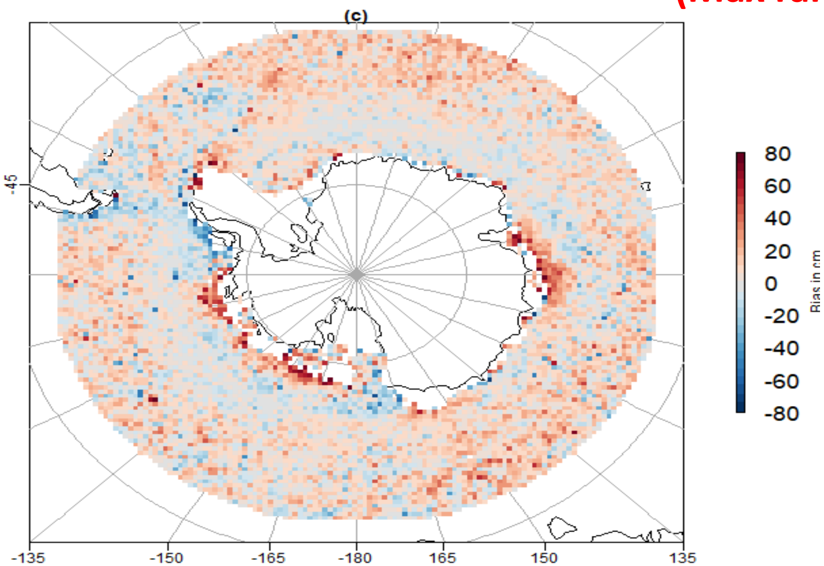
➔ **two sets of wave forcing with and without DA of CFOSAT**

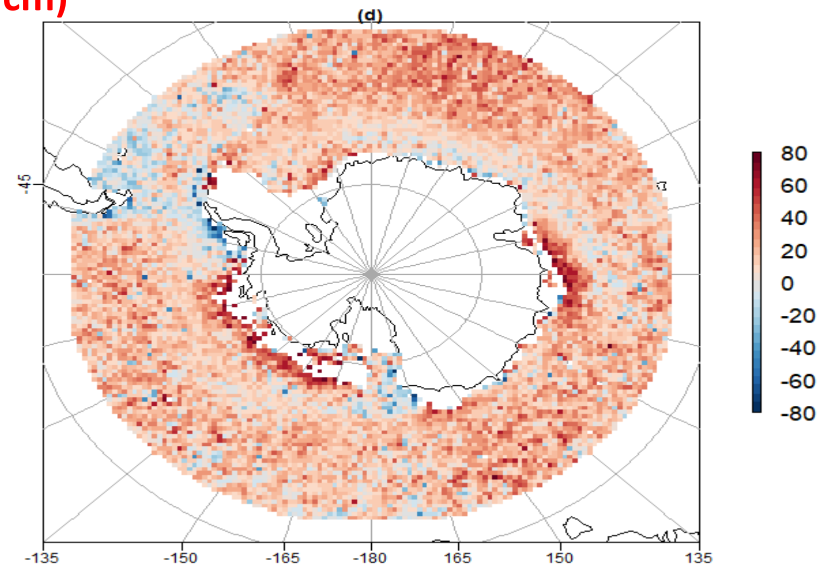
➔ **reference run without wave forcing**



Impact of the assimilation of CFOSAT in SO : Jan-Feb-Mar 2020
Comparison with Jason-3, Saral and S3

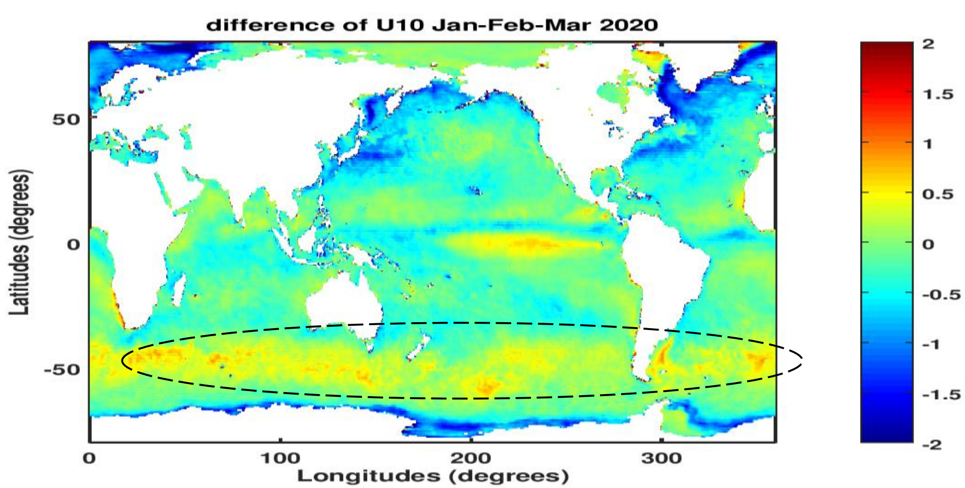
With DA of CFOSAT — **SWH bias map (Max range 80 cm)** — **Without DA**





Significant reduction of SWH bias in SO after using SWIM data

Strong overestimation Of wind from IFS in the SO and strong currents regions



Average difference Between IFS and CMEMS-L4 Scatterometers winds

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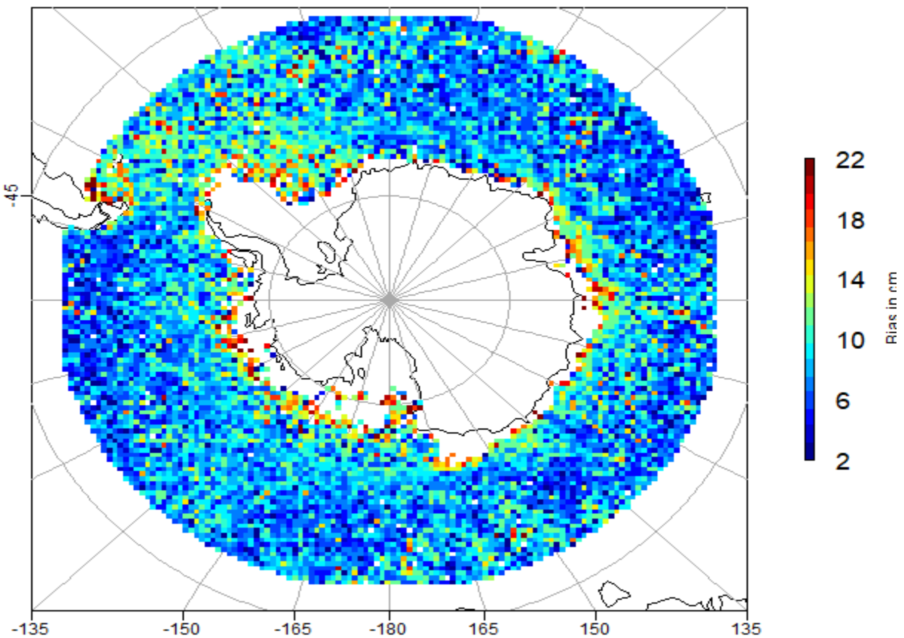
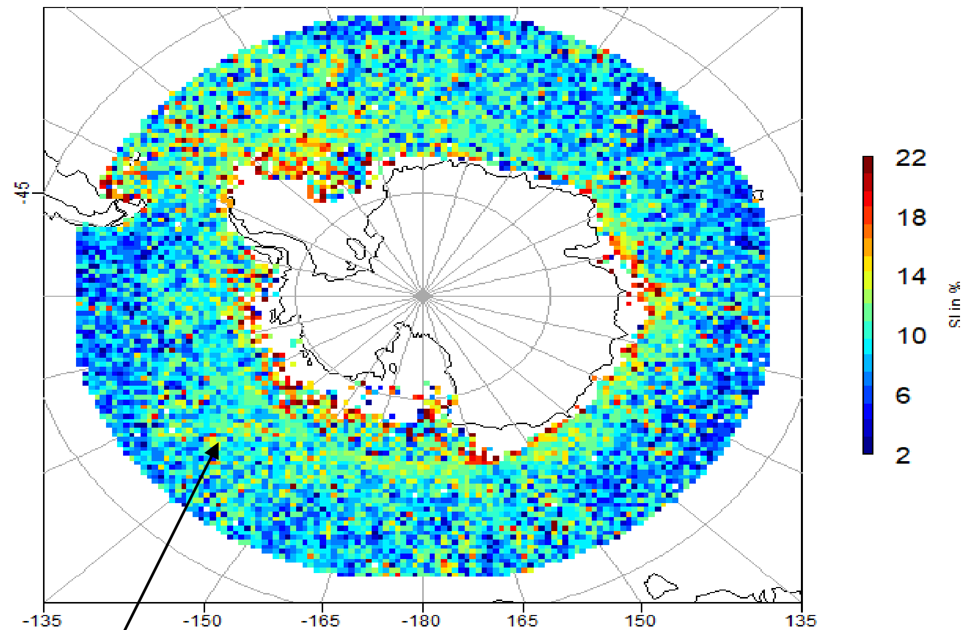
Scatter index of SWH in the Southern Ocean : Jan-Feb-Mar 2020
Validation with Jason-3, Saral and S3

With DA of CFOSAT



Without DA



Improved scatter index of SWH (in average ~8%)

SI is significantly improved in Ocean areas affected by storm events under unlimited Fetch conditions : thanks to directional Wave observations from SWIM

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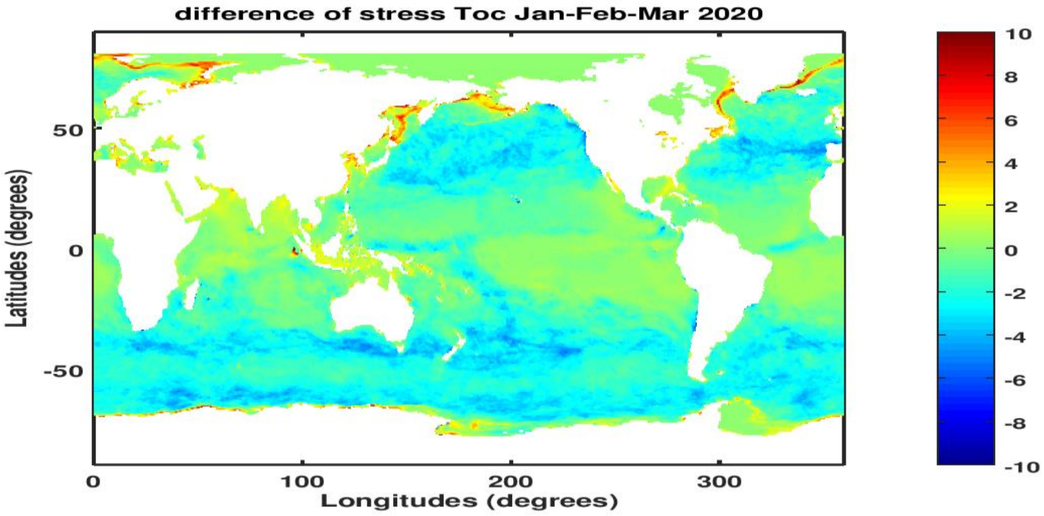
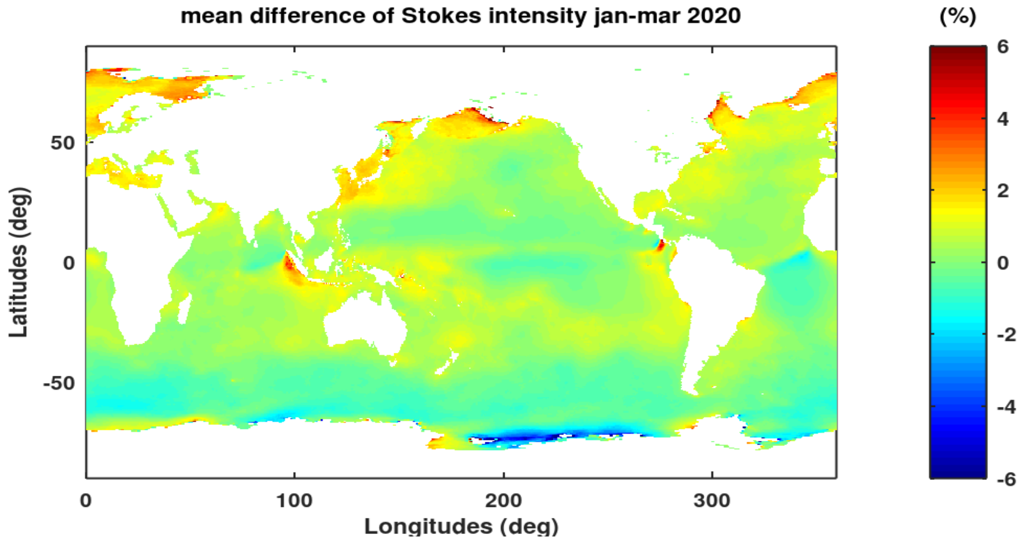
Impact of DA of SWIM on wave forcing to ocean model

Average of difference of stress τoc with and without DA



Significant impact induced by the assimilation mostly in ocean regions affected by uncertainties related to wind forcing

Average of difference of Stokes intensity

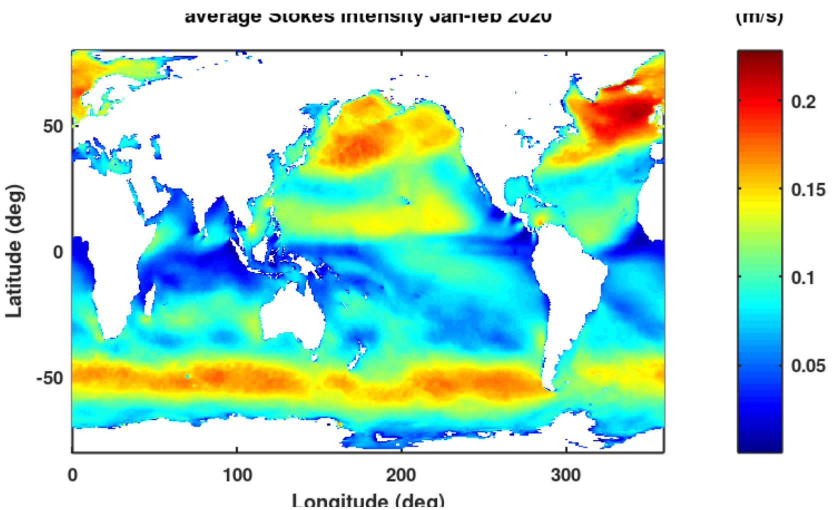


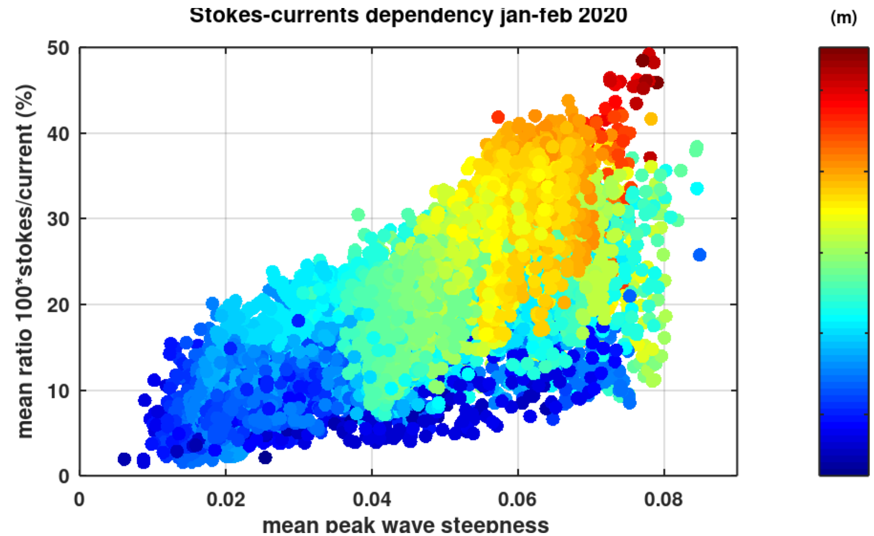
Jan-Feb-Mar 2020

Stokes drift impact on ocean circulation

Relationship between stokes/current ratio, Wave steepness, SWH

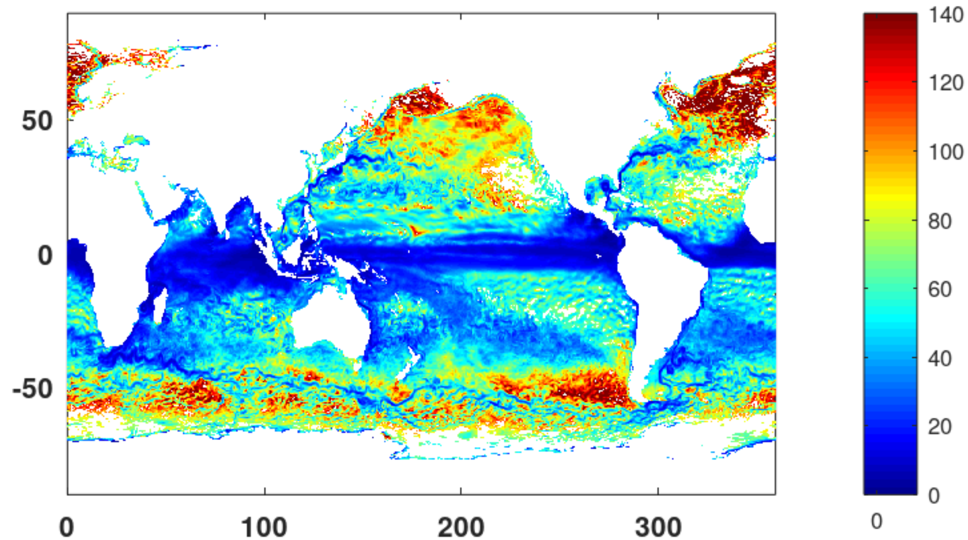
Average of Stokes module Jan-Feb 2020





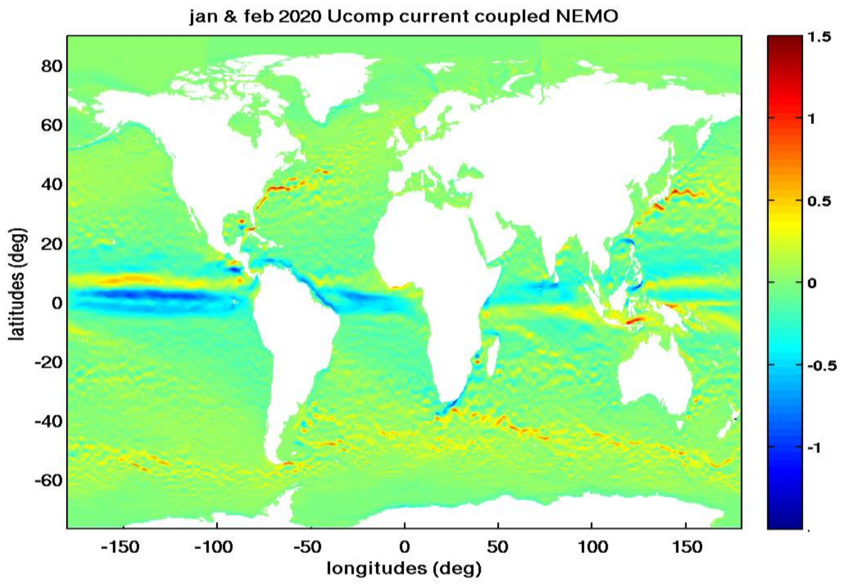
Ratio Stokes/current (%) Jan-Feb 2020

Stokes drift can affect strongly the high Frequency part of surface current particularly in Southern Ocean



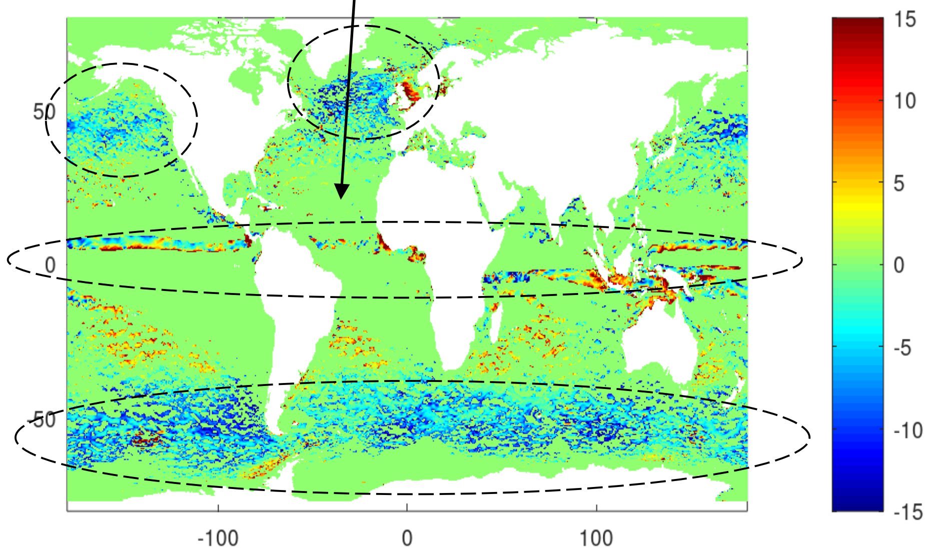
Impact of wave forcing on zonal current component : jan-Feb 2020

Mean U-comp (m/s)



Wave forcing affects equatorial surface current (north and south)

Mean difference of U-comp with and Without wave forcing (%)



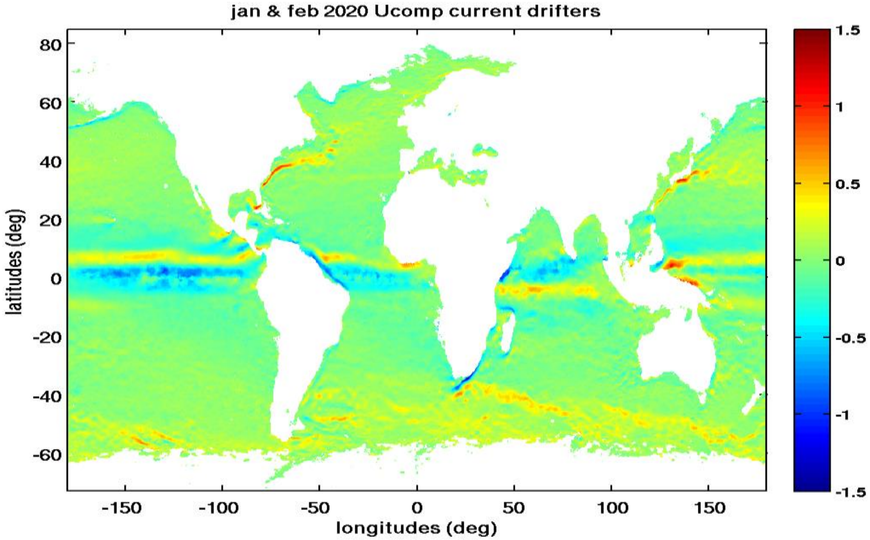
Strong impact on north Atlantic and North Pacific linked to winter storms (overestimation of U-comp because of stress uncertainties)
Also strong impact on ACC current and correction of surface stress on storms tracks in Southern Ocean.

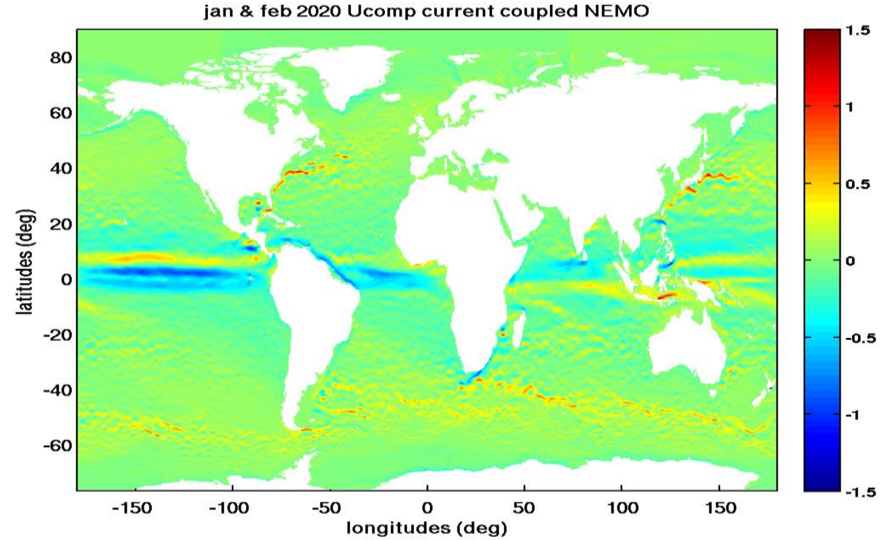
Validation of coupled model currents : Jan. & Feb. 2020

Mean Zonal component U of surface current

AOML Drifters

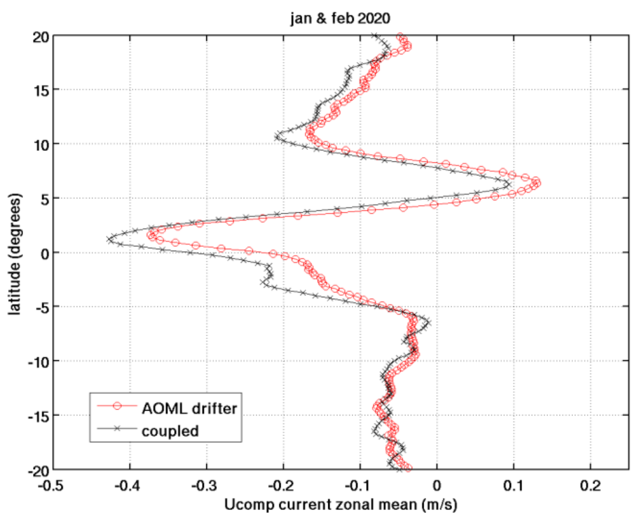
Coupled simu.





➡ **Good consistency between coupled model and drifters climatology**

Zonal mean Tropics (20° S-20° N)

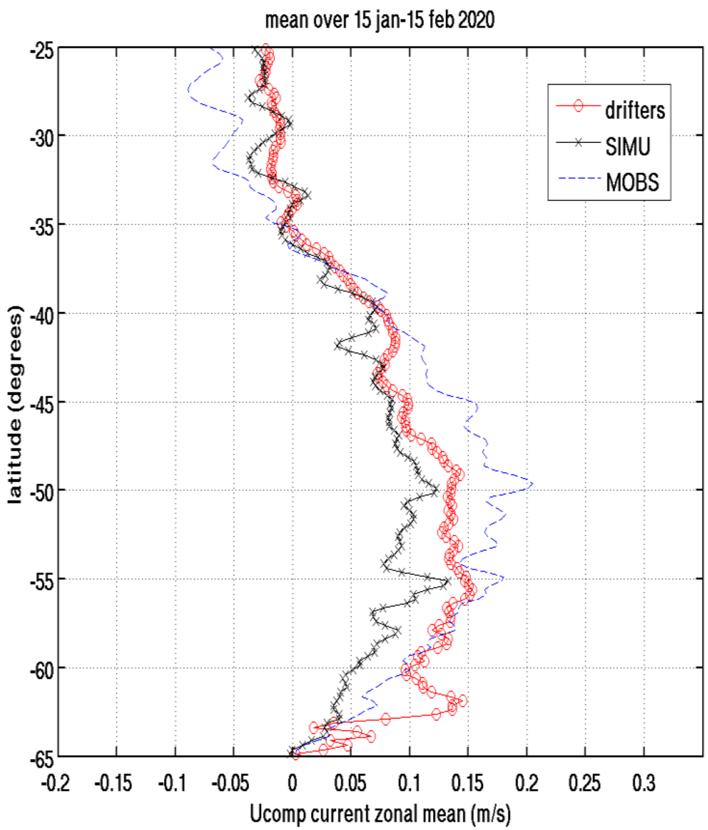


➡ **Good agreement between coupled model and drifters climatology. We can see slight overestimation in southern equatorial U-comp current**

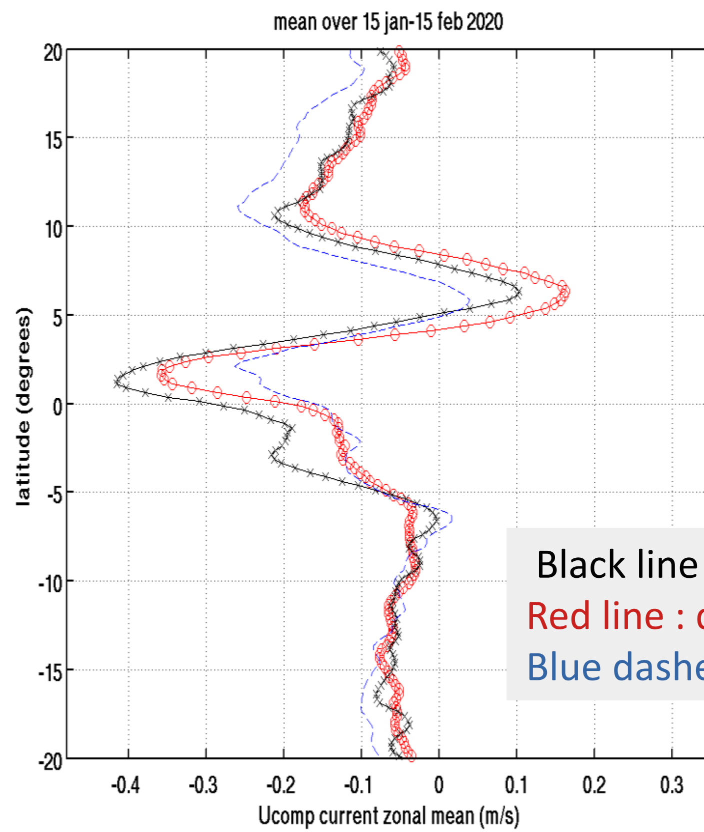
Coupled model vs CMEMS-MOBS : comparison with AOML drifters
Jan-feb 2020

Zonal mean U-comp of current

Southern mid & high lats



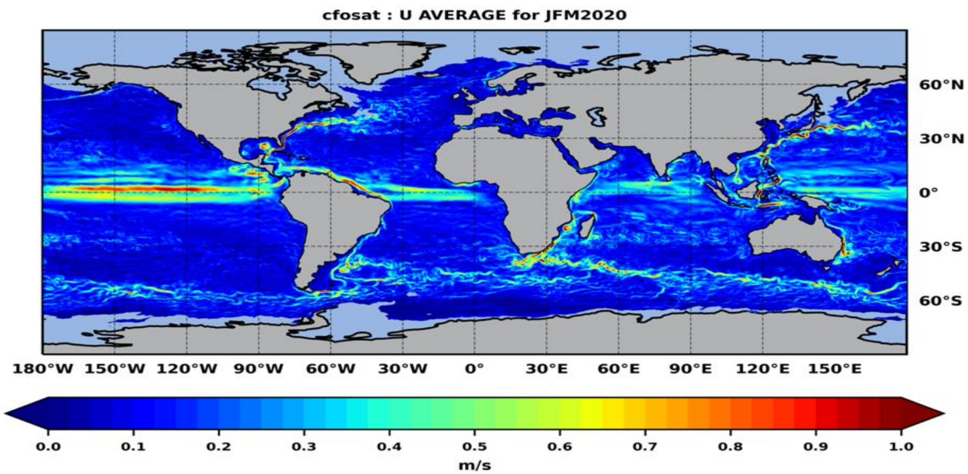
Tropics



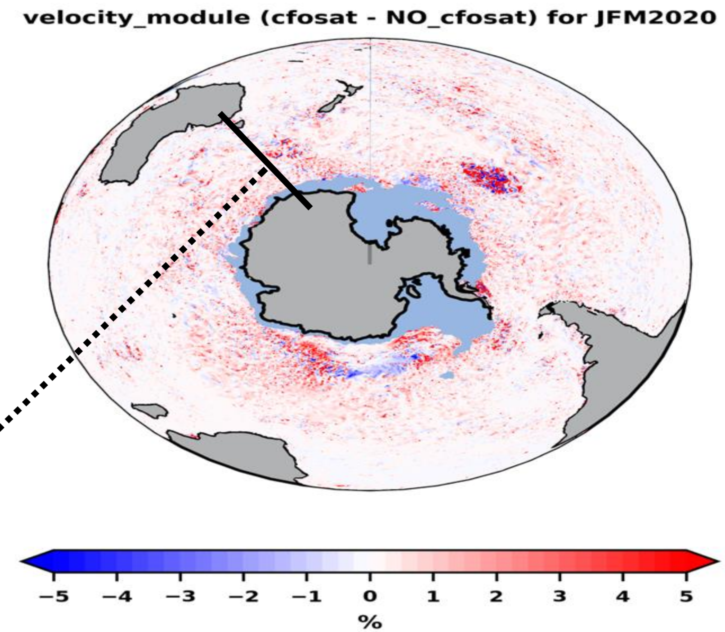
Black line : coupled
Red line : drifters
Blue dashed : MOBS

Improved U-comp current from coupled compared to L4-CMEMS-MOBS.
For high latitudes we mention the coarse grid size of drifters, which leads to more uncertainties. This can explain the overestimation from drifters For latitudes greater than 60° S

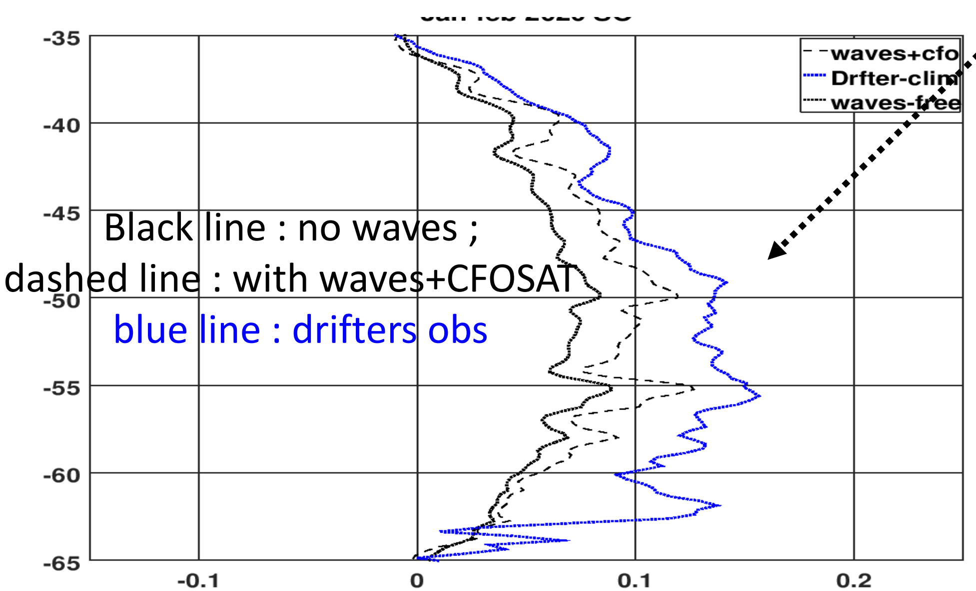
Average currents from NEMO with CFOSAT (Jan, Feb, Mar 2020)



Difference of current intensity with (Data Assimilation of CFOSAT) and without wave forcing (%)



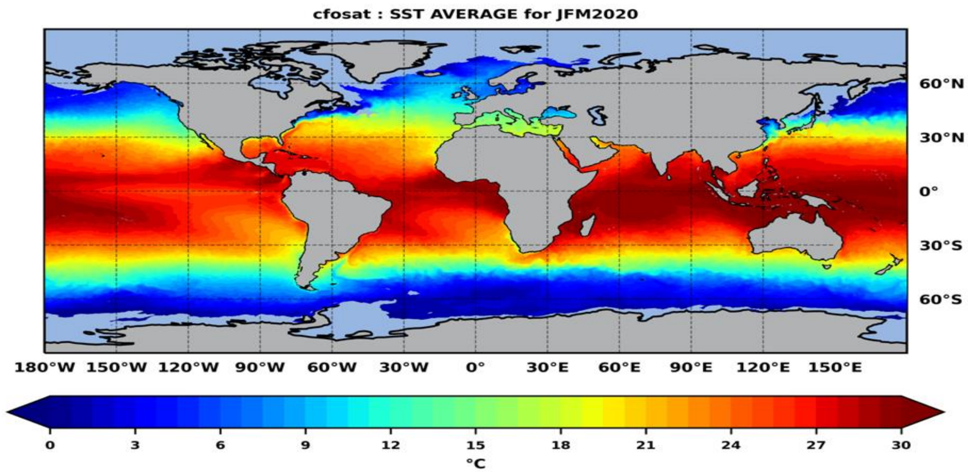
Improvement of currents U-zonal mean (145°E-149°E) : Better ACC in SO when using waves (DA of CFOSAT)



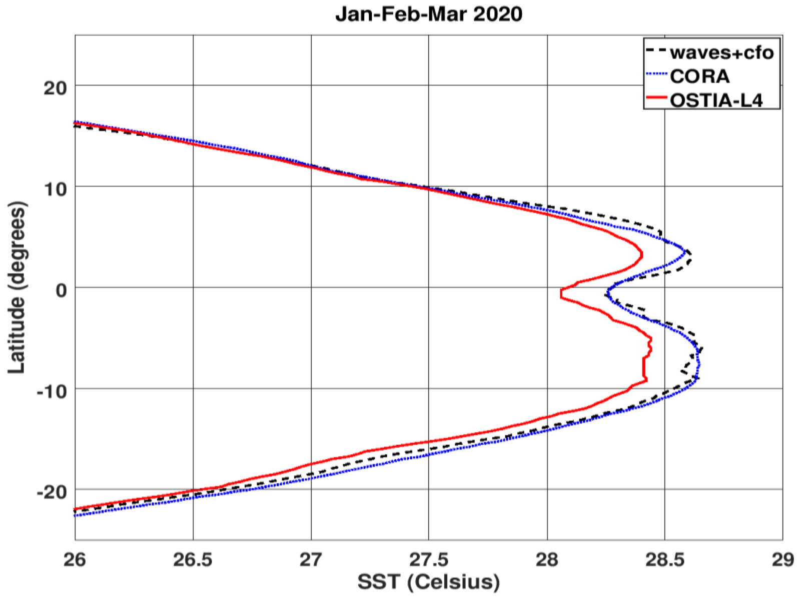
The assimilation of SWIM data enhances the currents intensity as indicated by dominant redish color. Hot spots can be observed in the Atlantic, Eastern Indian sectors of Southern Ocean. Also increase is observed South of Australia.

Coupling Ocean/wave models with DA of CFOSAT

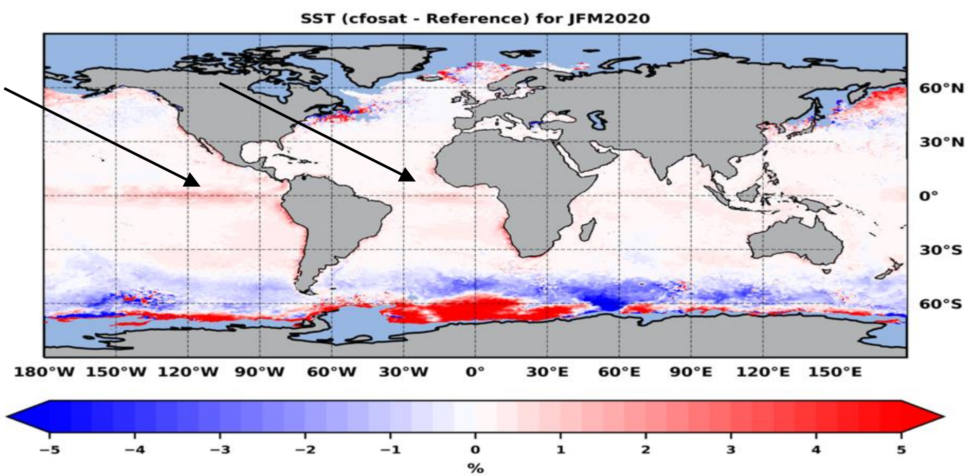
Average SST from NEMO with CFOSAT (jan, fev-mar 2020)



Zonal mean of SST (jan-feb-mar 2020) (coupled vs CORA and OSTIA)



Global difference of SST from NEMO With and without waves (with DA of CFOSAT)



Using better waves forcing (assimilation of CFOSAT spectra) shows excellent fit with CORA in-situ obs. in the tropics, while OSTIA analysis (CMEMS) underestimates SST between 10°N-10°S

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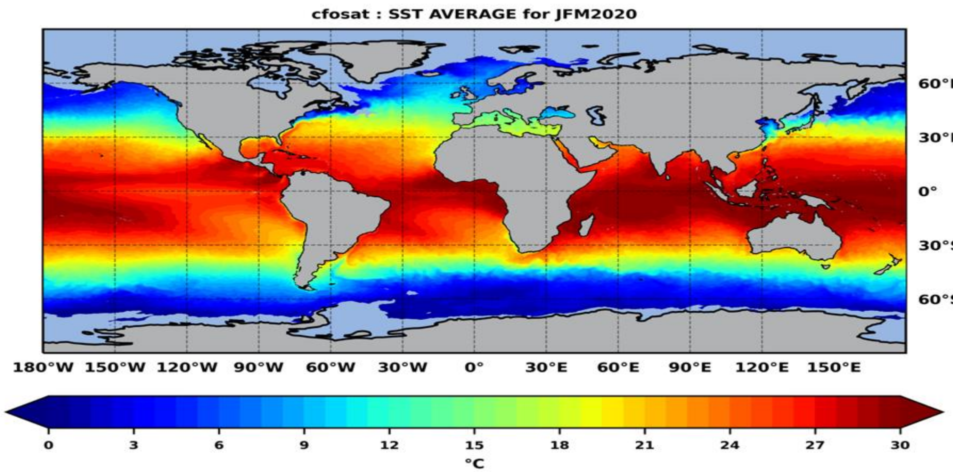
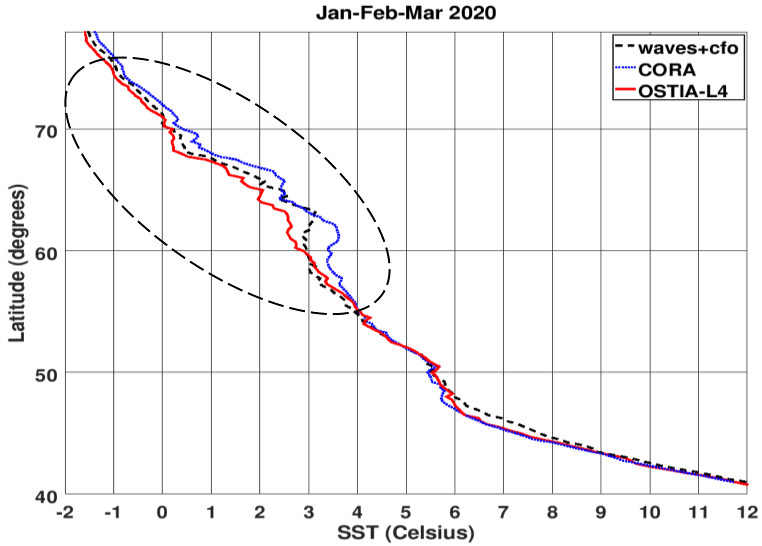
Coupling Ocean/wave models with DA of CFOSAT

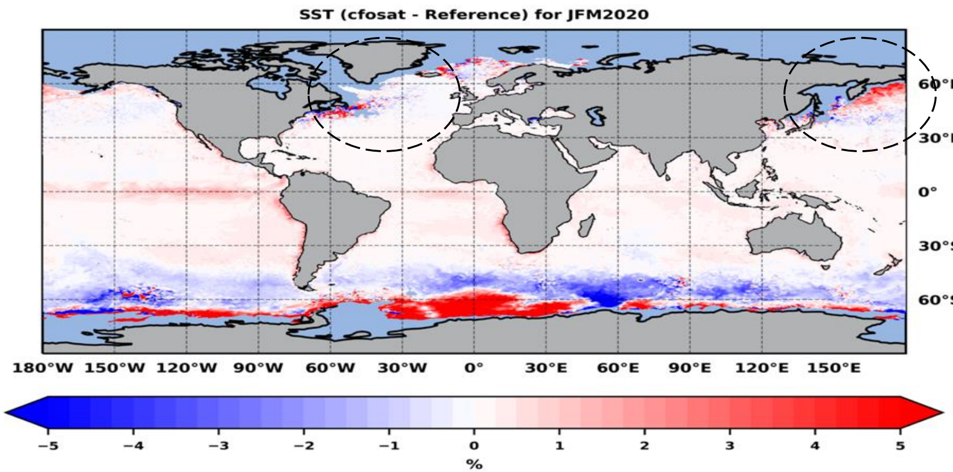
Average SST from NEMO with CFOSAT (jan, fev-mar 2020)



Zonal mean of SST (jan-feb-mar 2020) (coupled vs CORA and OSTIA)



Global difference of SST from NEMO With and without waves (with DA of CFOSAT)



Good agreement of SST from coupled simulation compared to CORA and OSTIA-L4 In northern hemisphere

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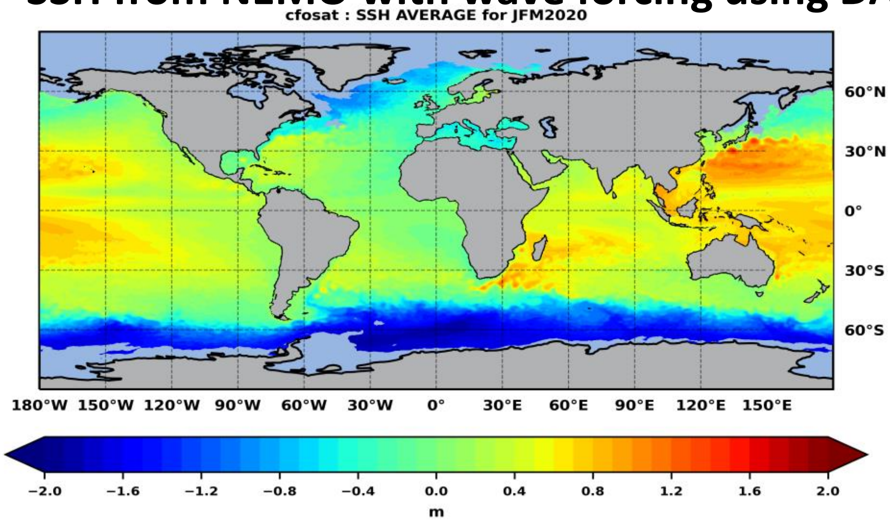
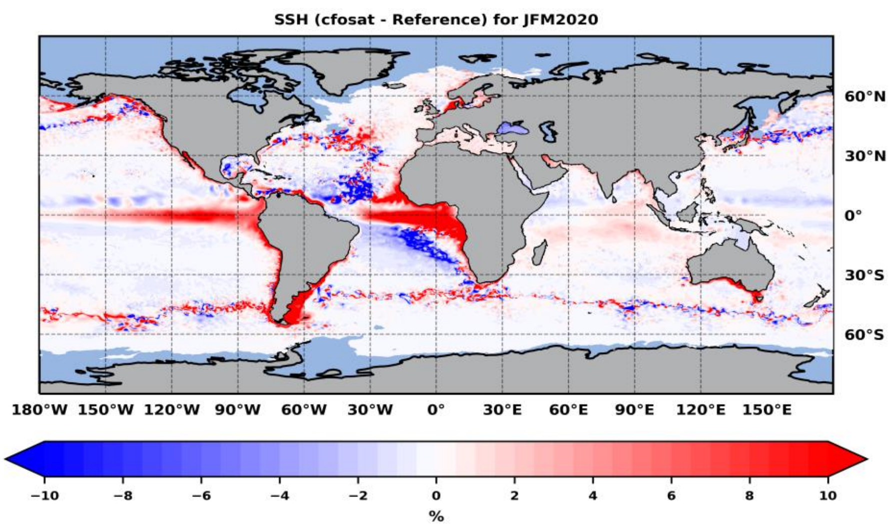
Impact of the assimilation of CFOSAT on SSH : Jan-Feb-Mar 2020

SSH from NEMO with wave forcing using DA

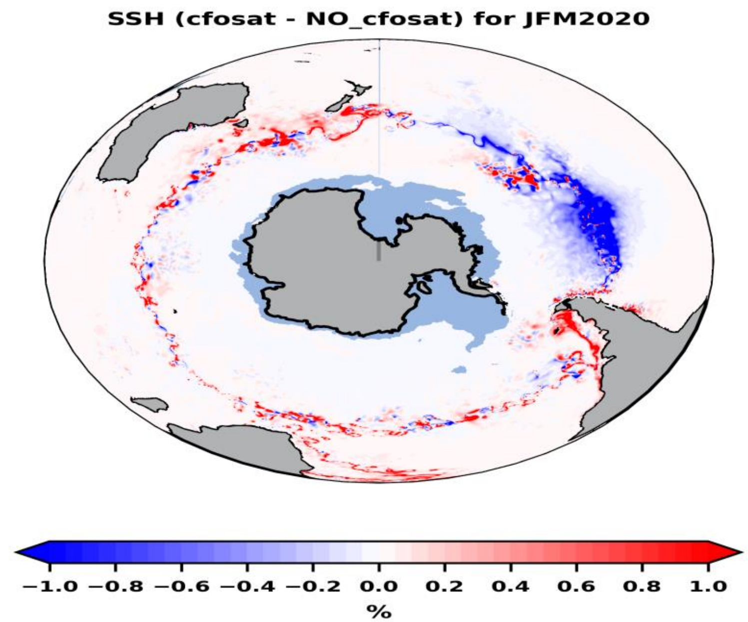


Global difference of SSH from NEMO
With and without waves (CFOSAT)



Significant impact in the tropics, strong currents
Areas and upwelling zones

Differnce of SSH with and without CFOSAT (%)



The assimilation of SWIM data induces an increase of SSH in the ACC region, and also a decrease in the east pacific sector of SO.

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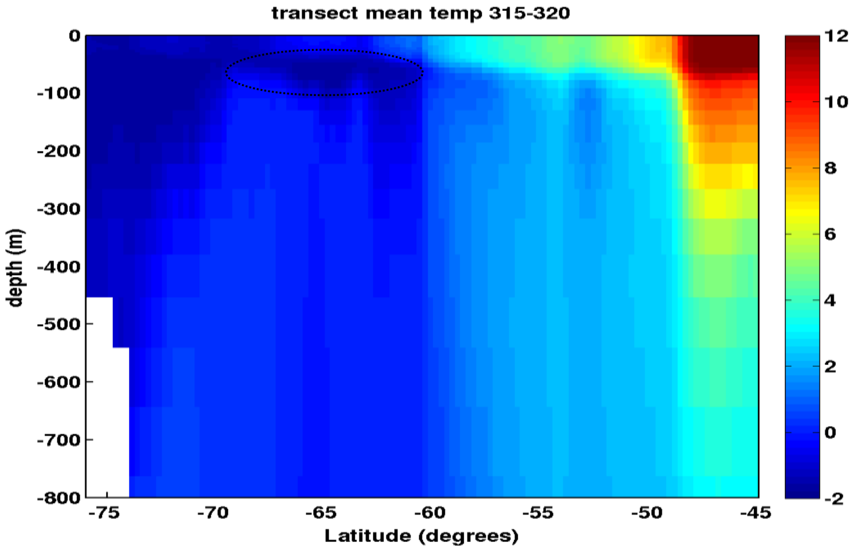
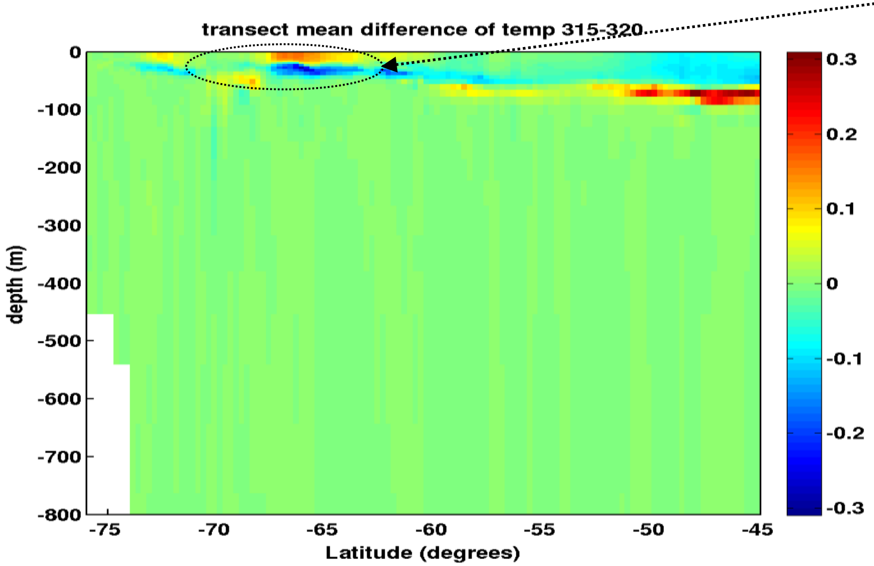
Impact on SST at Marginal Ice Zone Weddell sea : jan-Mar 2020

Transect of mean SST (40° W-45° W) from NEMO with wave forcing (DA)



Mean difference of SST from NEMO with and Without waves



Strong stratification in ocean upper layers at Weddell sea shown by the transect and warming of SST induced by wave forcing (with DA of CFOSAT).

Conclusions

→ ocean/wave coupling with improved sea state from CFOSAT improves significantly key ocean parameters (SST, Surface currents, SSH), particularly in the Southern ocean and tropics.

→ surface currents from coupled simulation shows remarkable agreement with Drifters climatology means, particularly in the tropics and ACC circulation trajectory, and western boundary currents.

→ Longer coupled simulation will be analysed to assess the impact of wave forcing. Also comparison between global and regional ocean coupling will be investigated.

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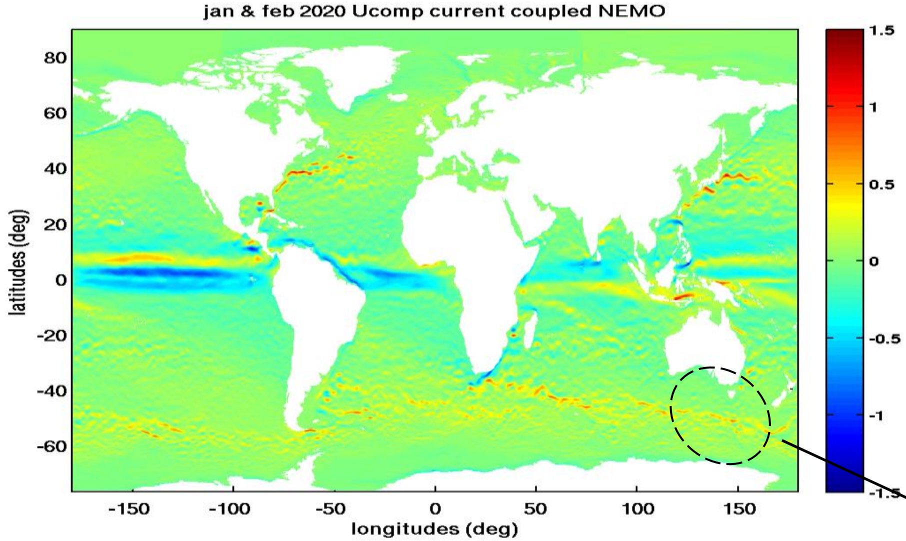
Validation of coupled model currents : Jan. & Feb. 2020

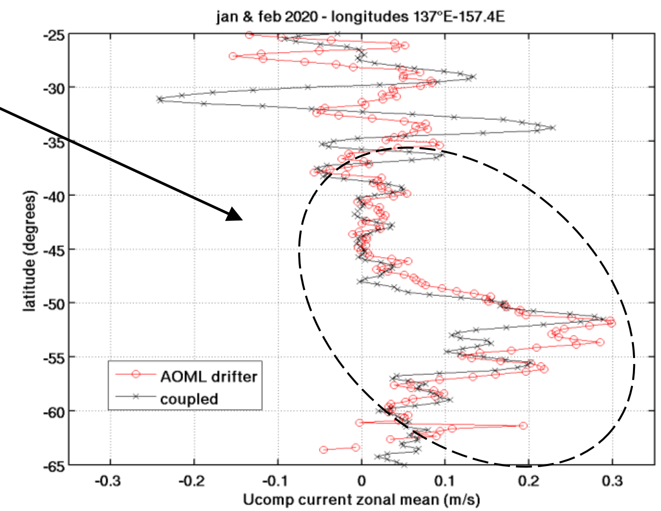
Mean zonal component U of surface current

Coupled simu.

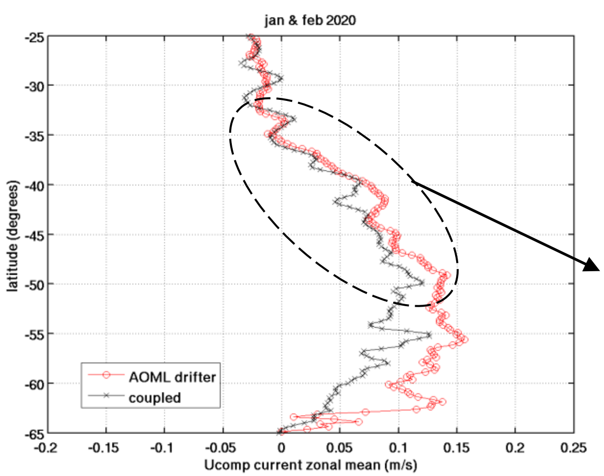


Good agreement between coupled model and drifters in ACC region between Australia and Antarctica.

Zonal mean Ucomp (137° E-157°



Zonal mean Southern mid & high lats (25° S-65° S)



Good agreement in Strong current regions (agulhas, ACC,...)