Continued, enhanced ocean altimetry and climate monitoring from space

31 October > 4 November 2022

IDS workshop
OSTST meeting

Venice - Italy

https://ostst-altimetry-2022.com/

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On the improvement of ocean/wave coupling with CFOSAT directional wave observations

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Ocean Surface Topography-Science Team meeting, CFOSAT session, Thursday 3rd November 2022, Venice

Motivation

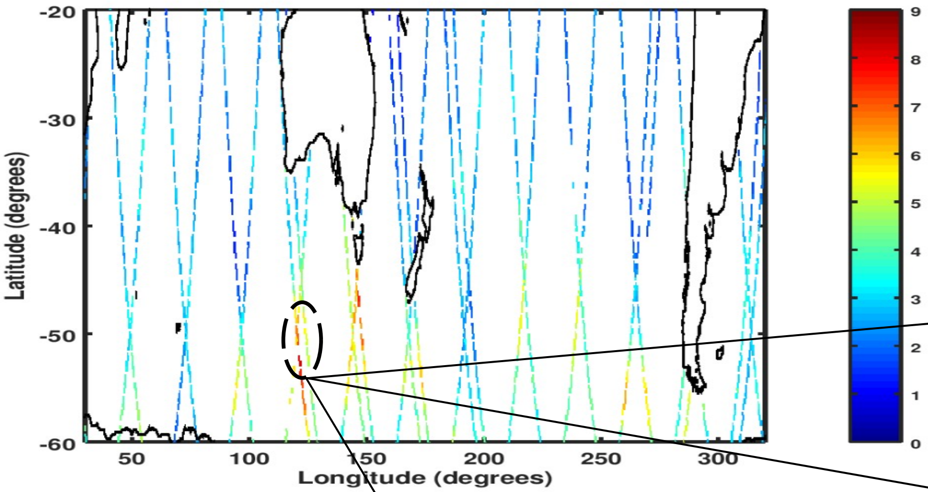
- **Directional wave observations from CFOSAT has shown better scaling of wind-waves in the growth phase and transition to swell regme. consequently improved wave forcing is released to ocean (stress, Stokes,…) and how this affects ocean circulation**

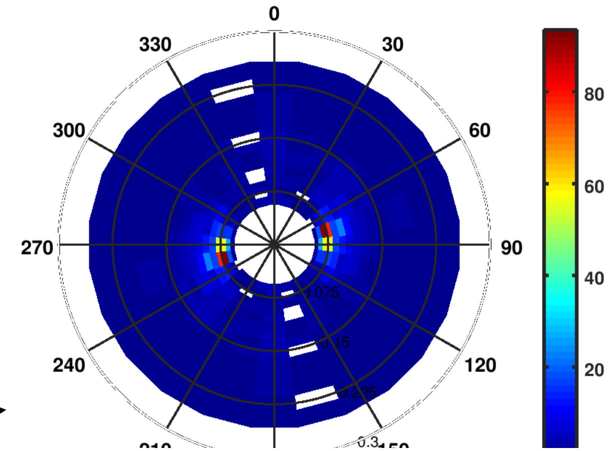
- **Evaluate key parameters (surface currents,SST,..) provided by the ocean/wave coupled experiments with improved sea state from DA of CFOSAT**

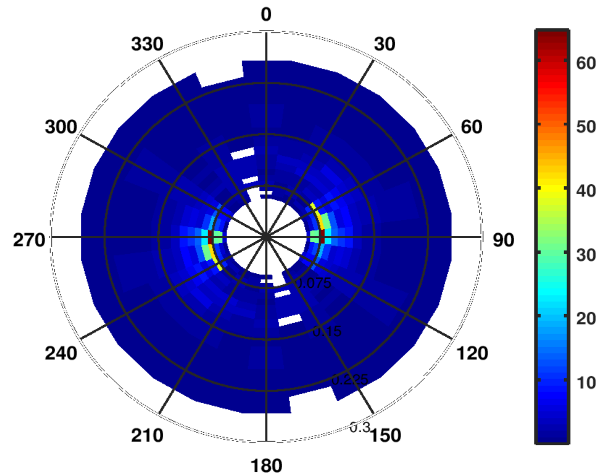
- **Impact of waves on ocean circulation key parameters in critical ocean regions**

SWIM wave directional spectra and SWH off-nadir

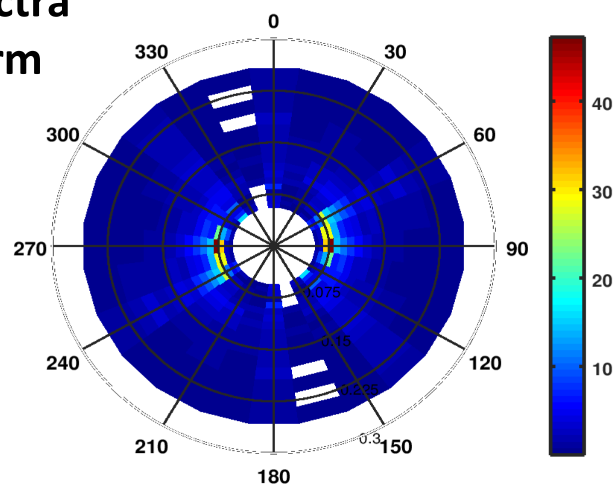
SWH at off-nadir of CFOSAT 26-27 February 2020
During storm event in SO







SWIM wave spectra Observed in storm Event southern Australia



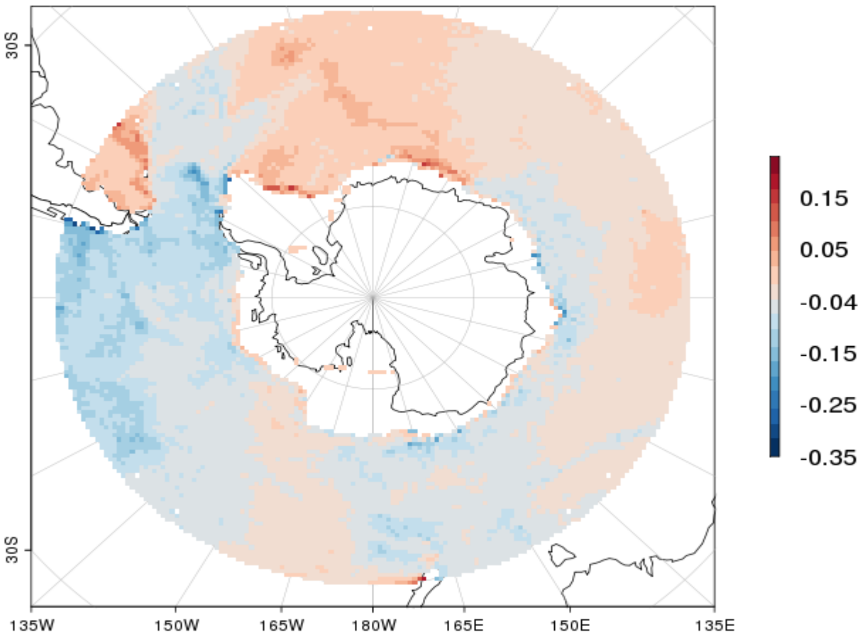
Capturing directional properties of waves during growth phase. We can clearly see the change of energy peak in direction

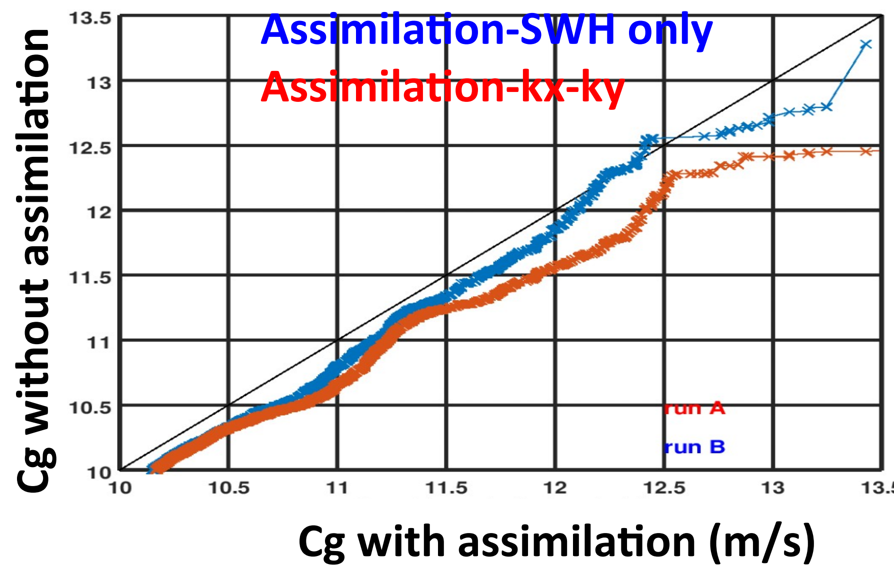
The uniqueness of using directional wave observations from SWIM in Southern Ocean

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

QQplot of wave group velocity

Difference of wave age* at the peak with and Without DA





Only the use of directional wavenumbers can correct group wave velocity under fast Storms with unlimited fetch conditions

Blue indicates overestimation of the model
While red stand for underestimation

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*** Wave age : ration wave phase speed and wind speed**

Description of model runs

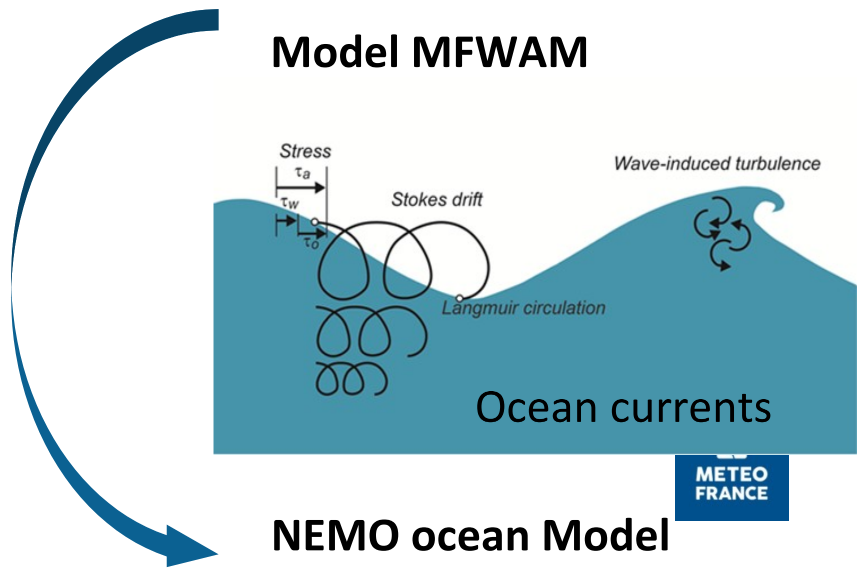
▪ **Wave model MFWAM configuration :**
-global scale with grid size 0.5° and model version CMEMS operational.
- spectral resolution of 24 directions and 30 frequencies
- atmospheric forcing IFS-ECMWF (analysis wind and sea-ice fraction)
- period of run : January-June 2020

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

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

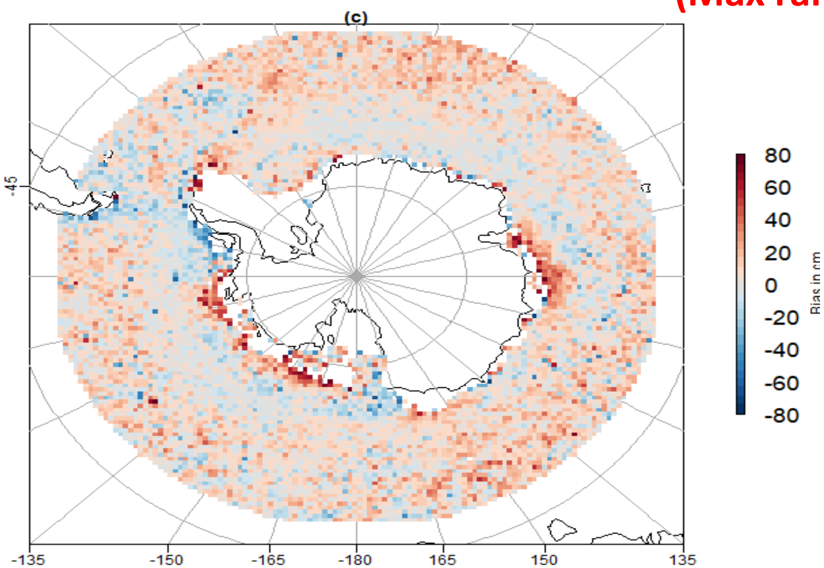
▪ **NEMO model runs : configuration ORCA (0.25°)**

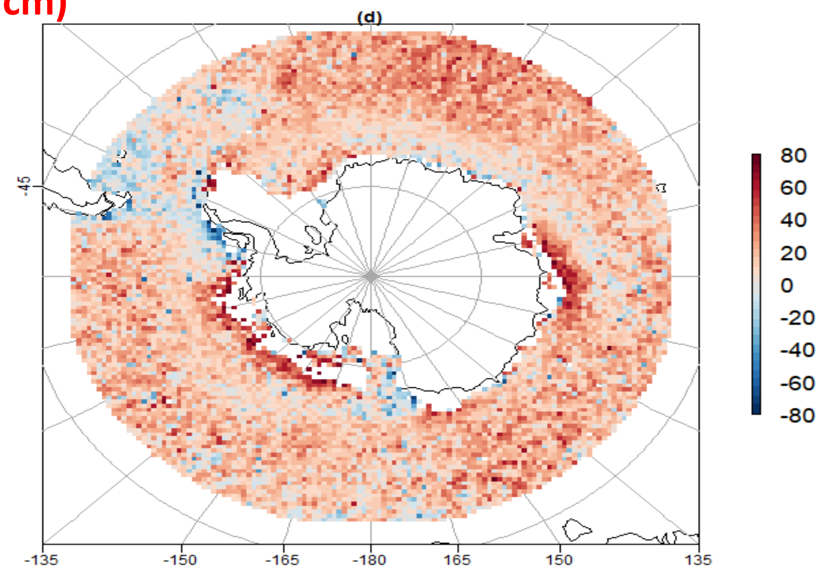
➔wind forcing from IFS-ECMWF
➔two sets of wave forcing with and without DA of CFOSAT. Coupling processes : stress modified by waves, Stokes-Coriolis forcing and wave breaking induced turbulence
➔reference run without wave forcing



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

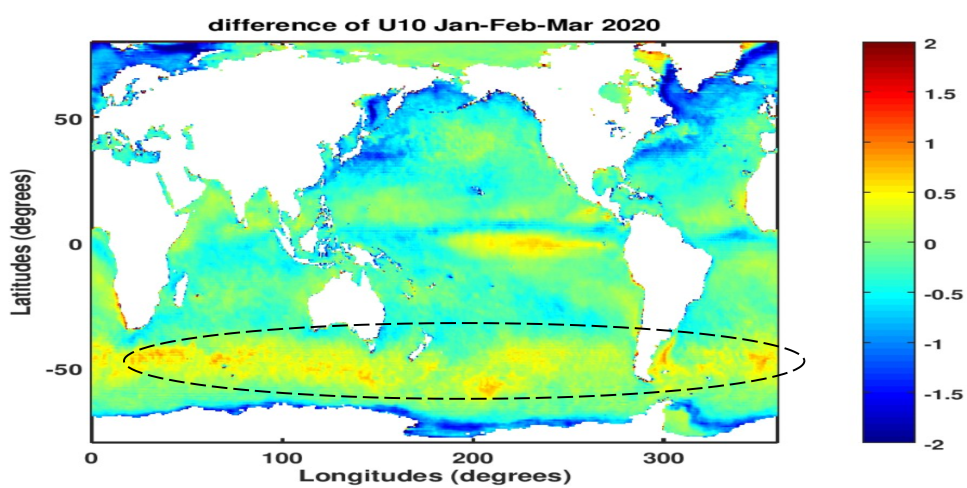
With DA of CFOSAT | **SWH bias map (Max range 80 cm)** | **Without DA**





Significant reduction of SWH bias in SO after using SWIM data

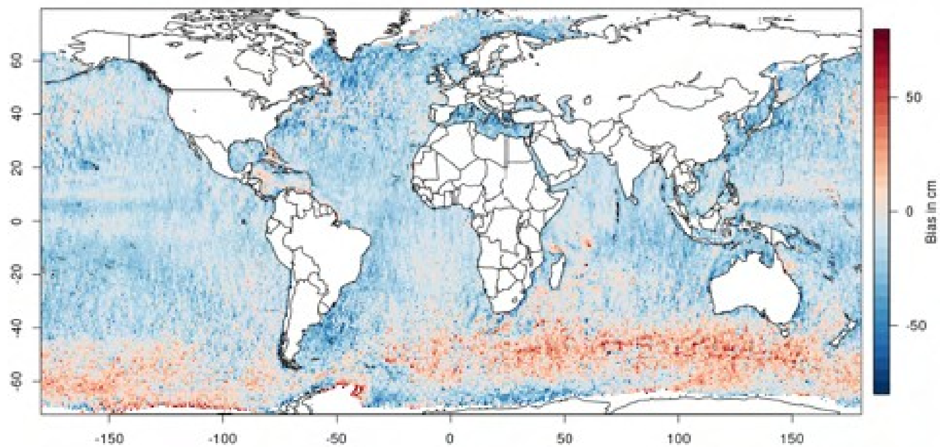
Strong overestimation Of wind from IFS in the SO and strong currents regions

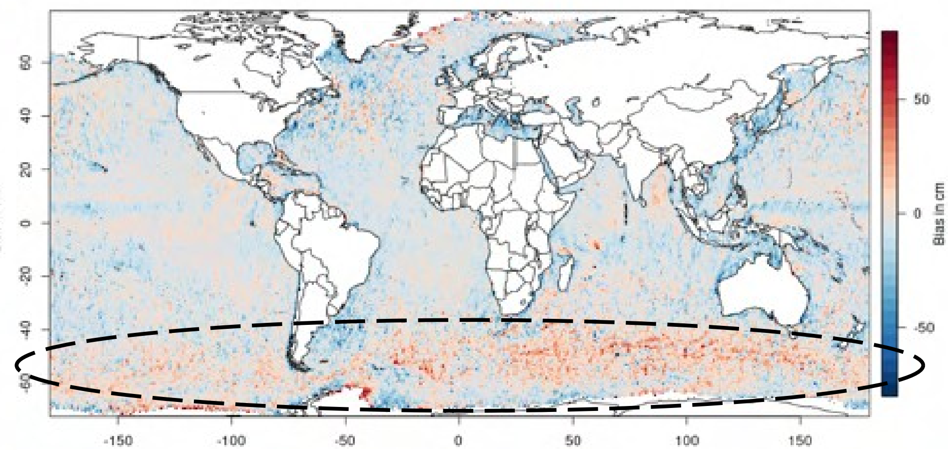


Average difference Between IFS and CMEMS-L4 Scatterometers winds

Validation of SWH from MFWAM model : January-June 2020

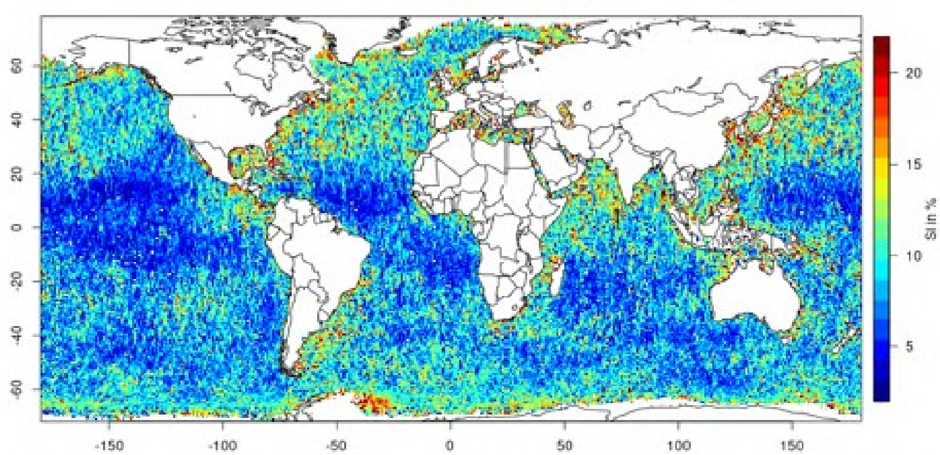
NO DA of CFOSAT | **Bias maps in cm (max. 60)** | **with DA of CFOSAT**

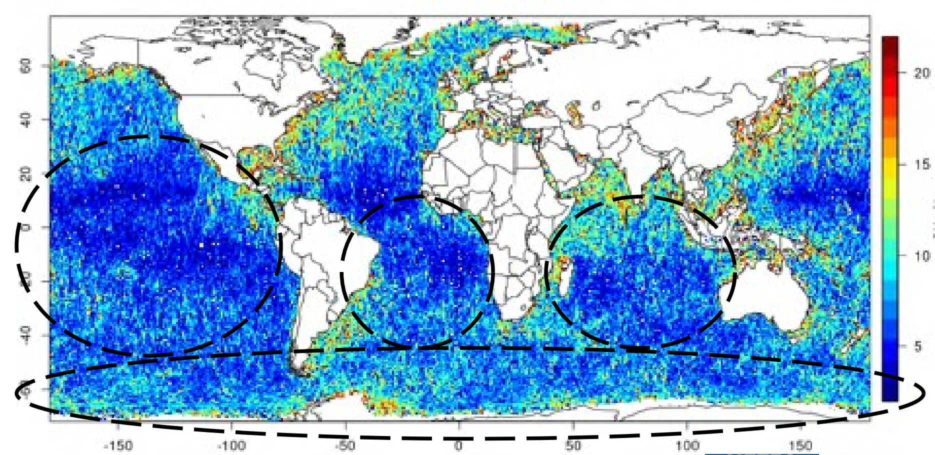




Significant reduction of bias in SO

Scatter index maps (%)





The smaller SI is, the better performance

Strongly reduced SI in swell tracks regions

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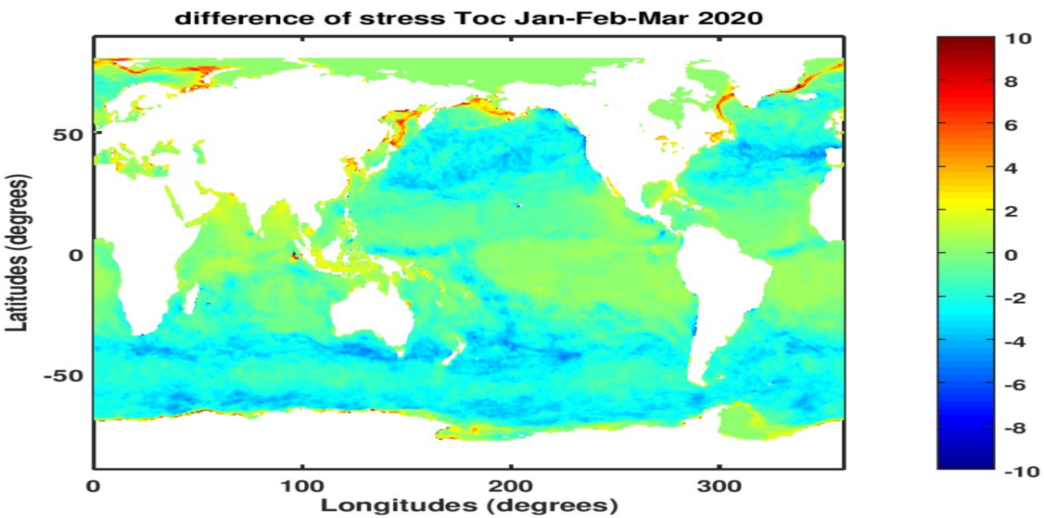
Comparison with independent altimeters

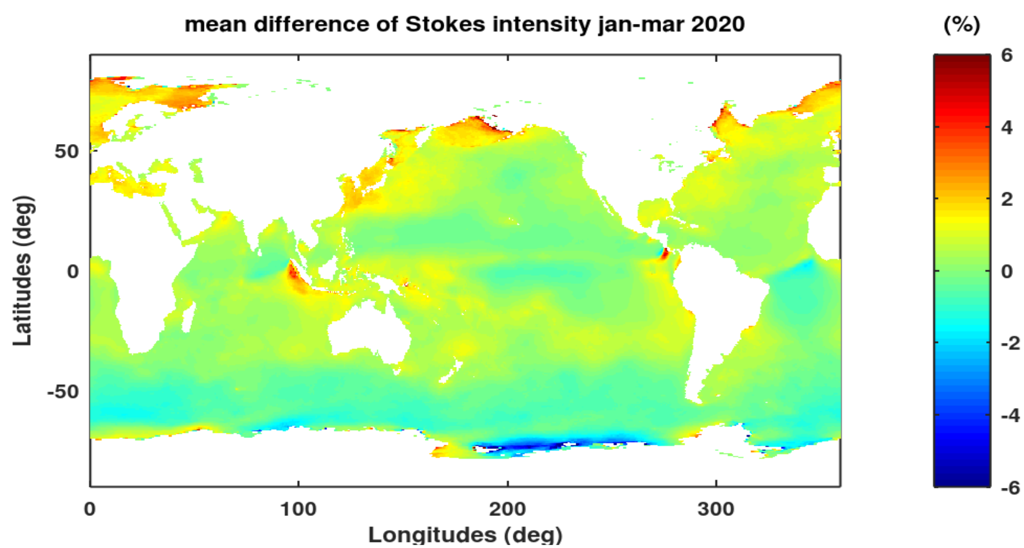
Impact of DA of SWIM on wave forcing to ocean model

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

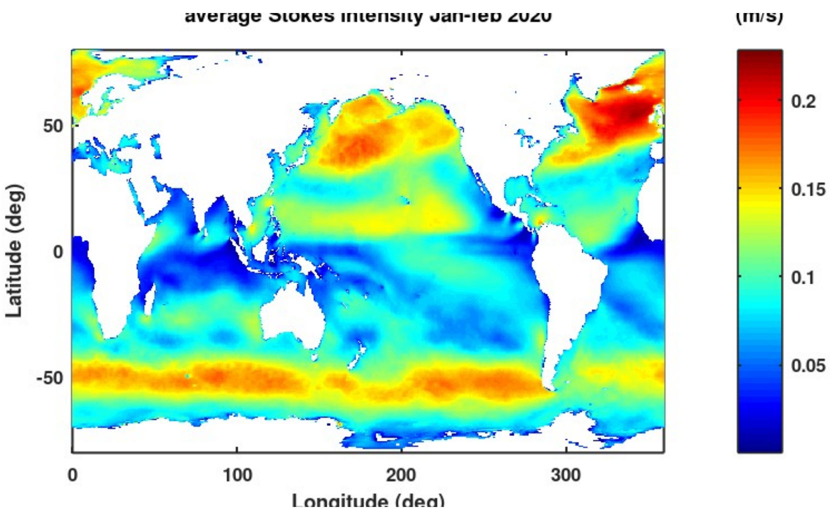


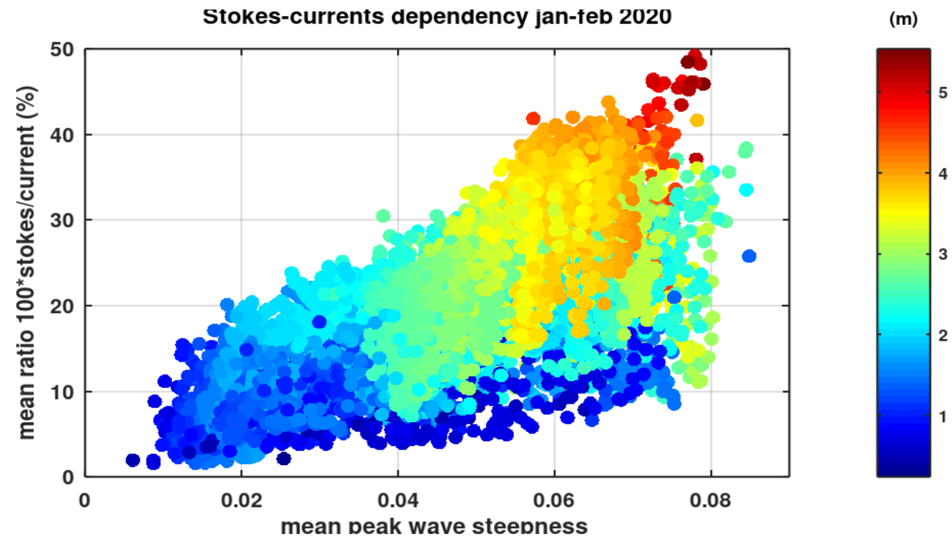
Jan-Feb-Mar 2020

Relevance of Stokes drift in upper ocean layers

Relationship between stokes/current ratio (%), Wave steepness, SWH

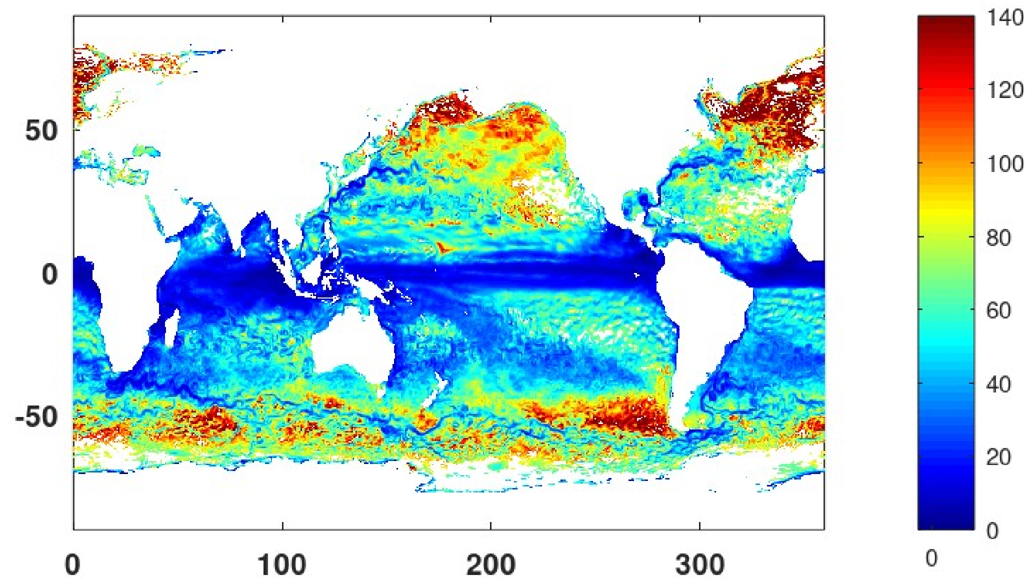
Average of Stokes module (DA)Jan-Feb 2020





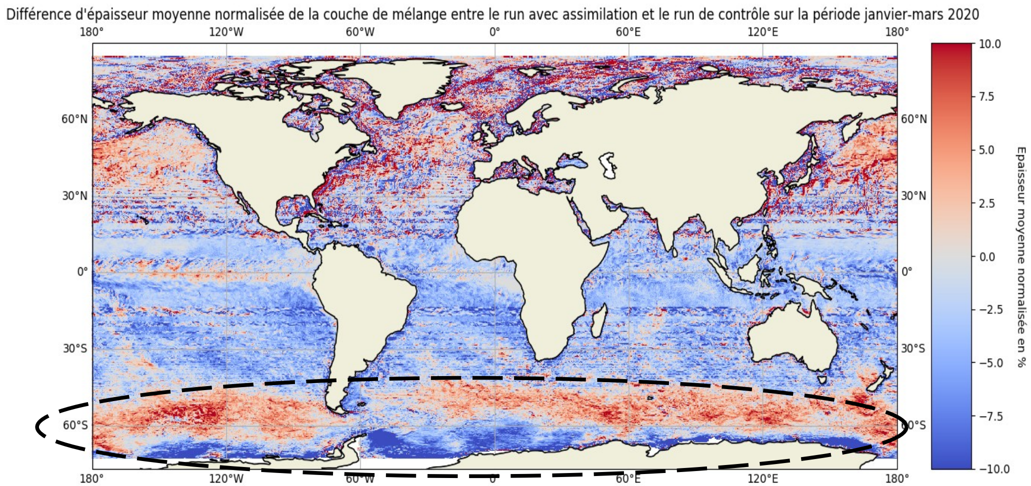
Ratio Stokes/current (%) Jan-Feb 2020

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



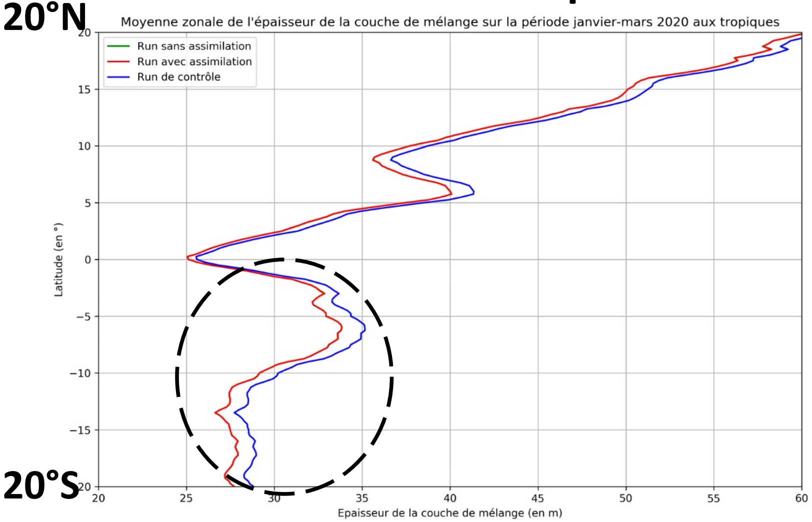
Impact of the wave forcing (with DA of CFOSAT) on ocean mixed layer

Average difference (in%) of Ocean Mixed Layer from model NEMO w/wo wave forcing : Jan-Mar 2020

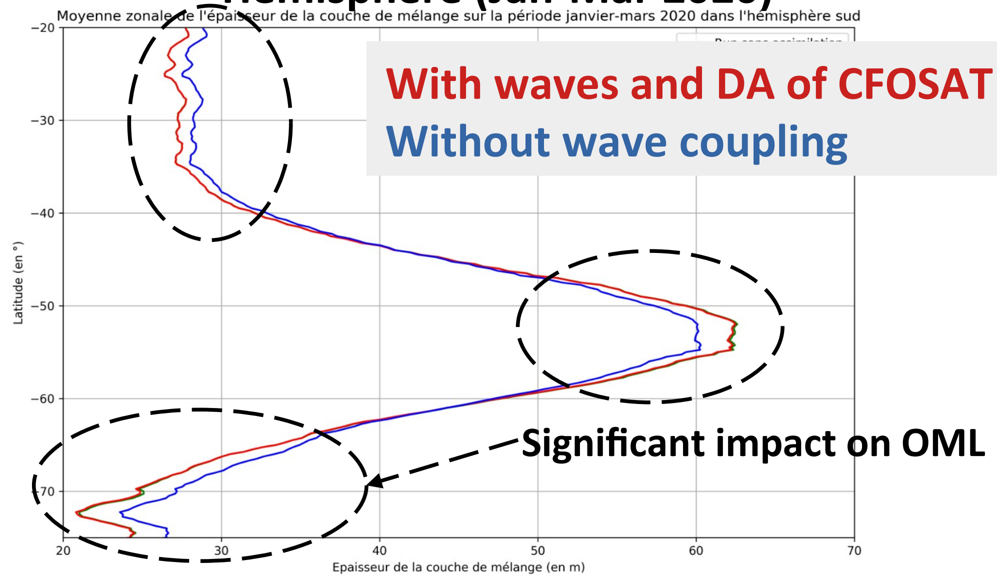


Positive (red) difference means enhanced Ocean mixing by wave coupling, while negative difference indicates reduced Ocean mixing induced by waves

Zonal mean OML in the tropics

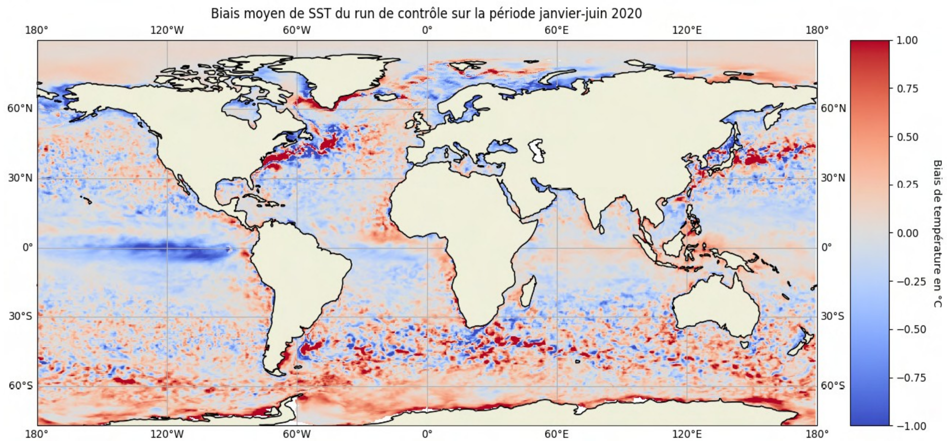


Zonal mean of ocean mixed layer for southern Hemisphere (Jan-Mar 2020)

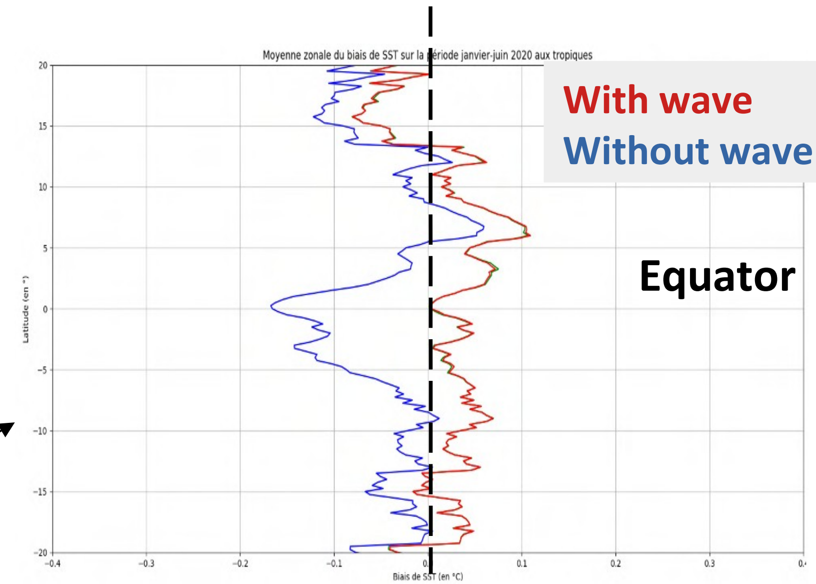


Validation with SST from L4 OSTIA January-June 2020

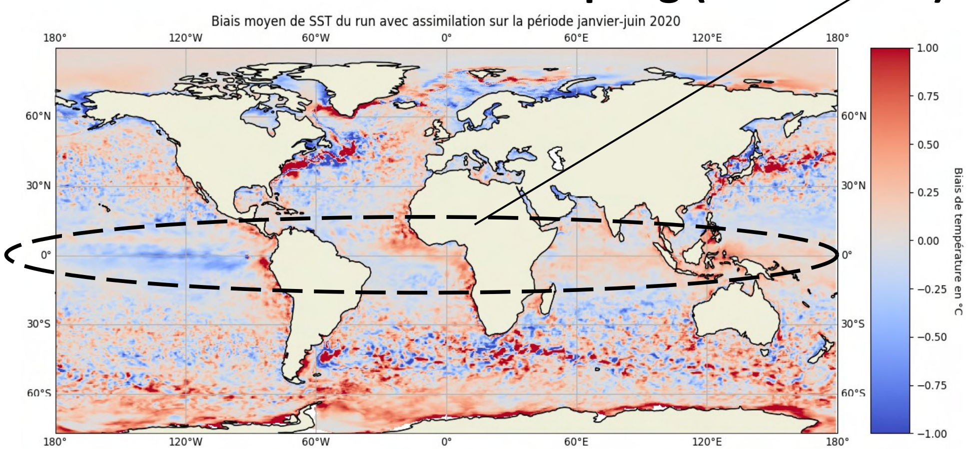
Bias of SST without wave coupling



Zonal mean of SST in the tropics (20°S-20°N)



Bias of SST with wave coupling (DA CFOSAT)



Significant reduction of SST bias in the Tropics and in strong currents ocean regions

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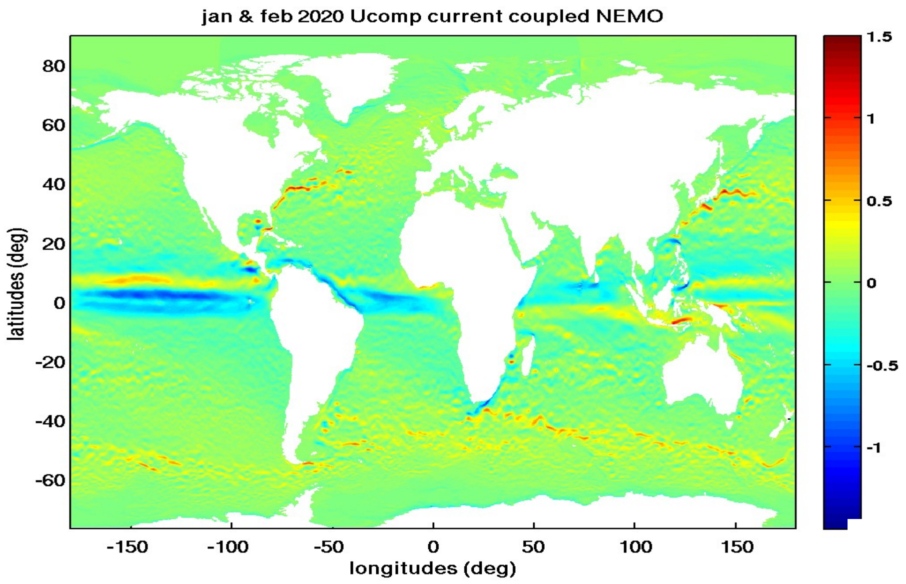
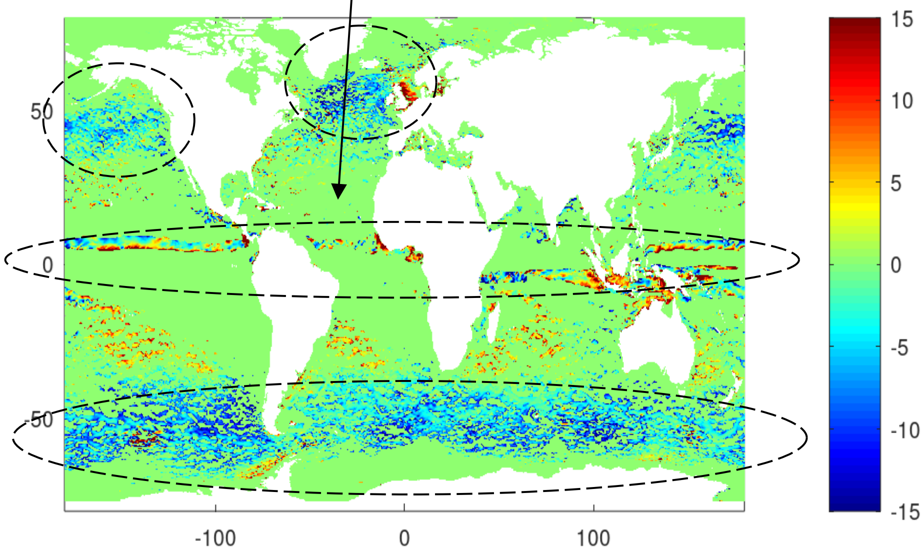
Impact of wave forcing on zonal current component : jan-Feb 2020

Mean U-comp (m/s)



Wave forcing affects significantly equatorial surface current (north and south)

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

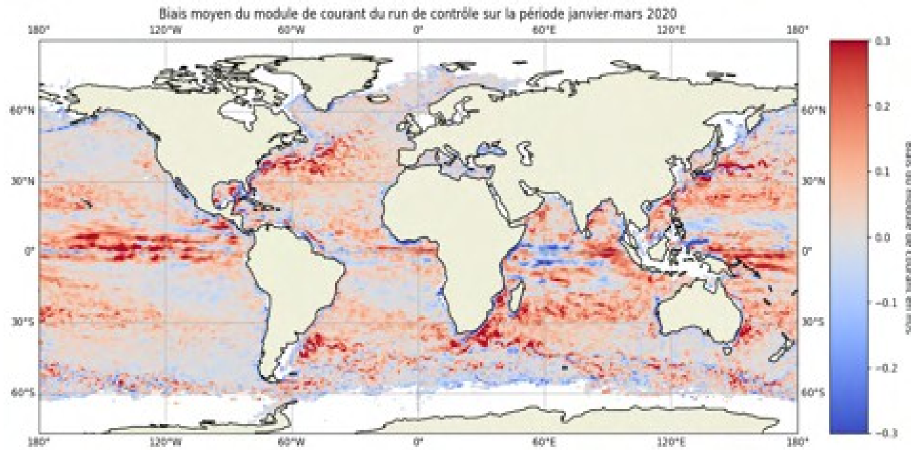


Strong impact on north Atlantic and North Pacific linked to winter storms (overestimation of U-comp because of stress uncertainties)
Also strong impact on ACC current and correction of surface stress on storms tracks in Southern Ocean.

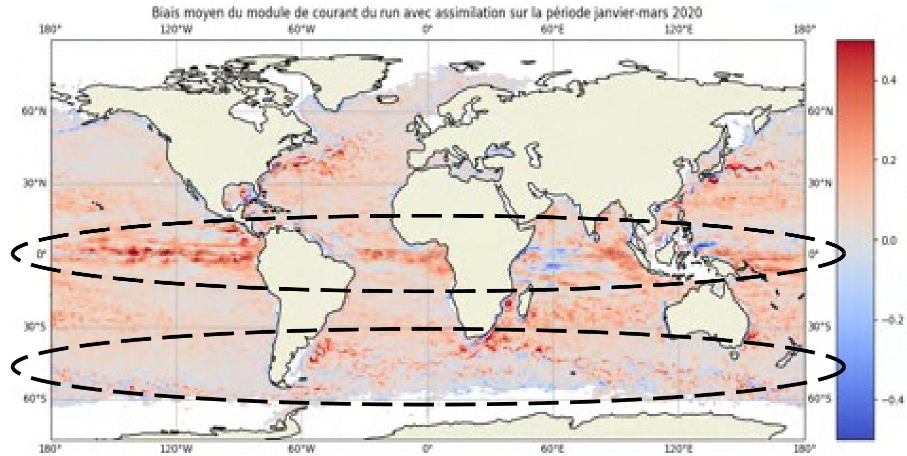
Validation of currents with AOML current from drifters

Period of Jan-Mar 2020

without wave coupling

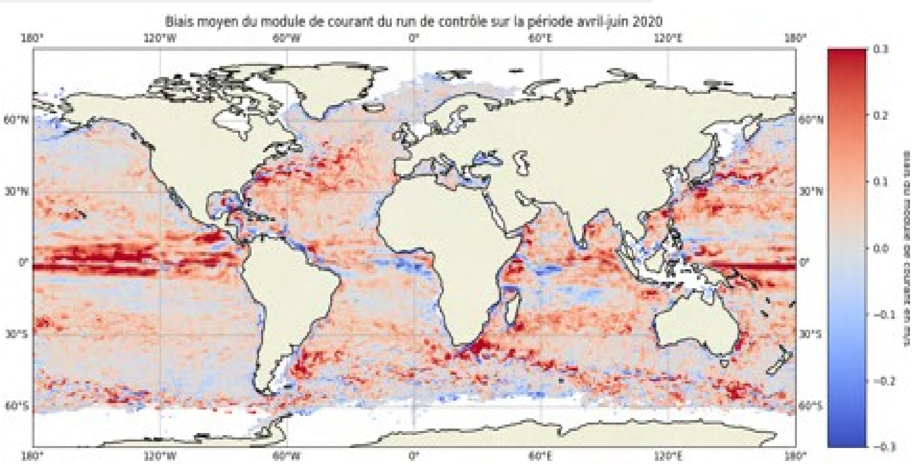


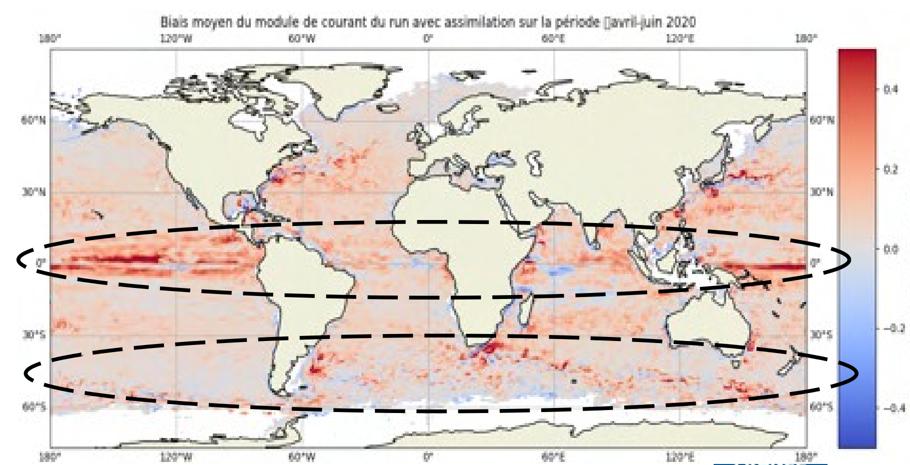
With wave coupling (improved with DA)



Significant improvement of surface Current with wave forcing

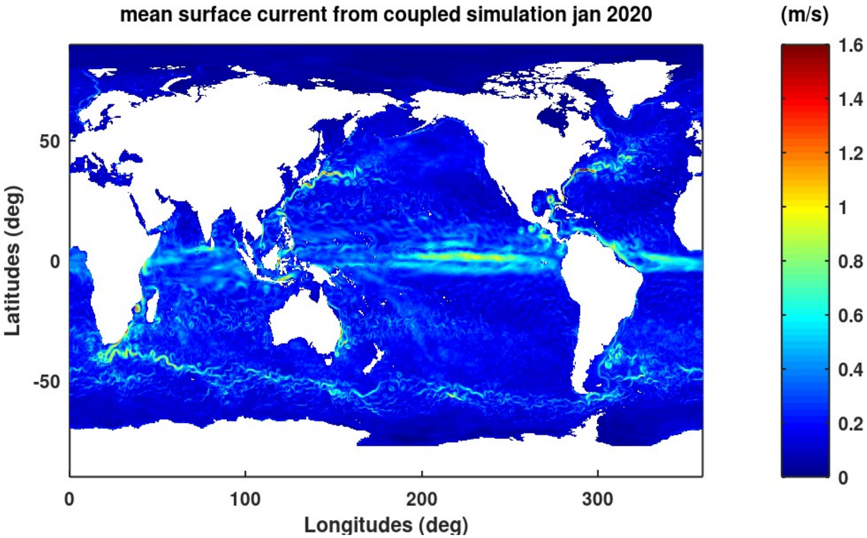
Period of April-June 2020



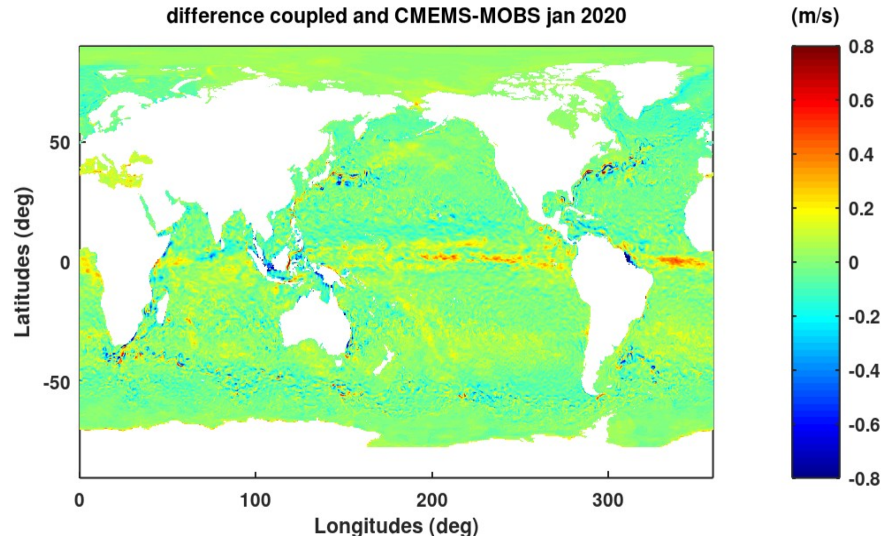


Comparison of current intensity from coupled simulation and L4 CMEMS-currents : January 2020

Mean current intensity from coupled

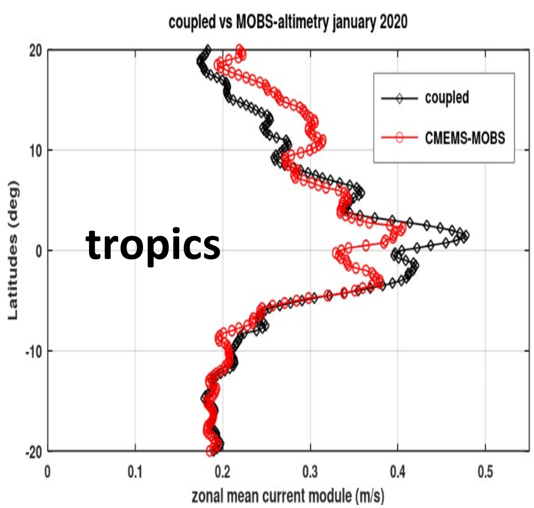


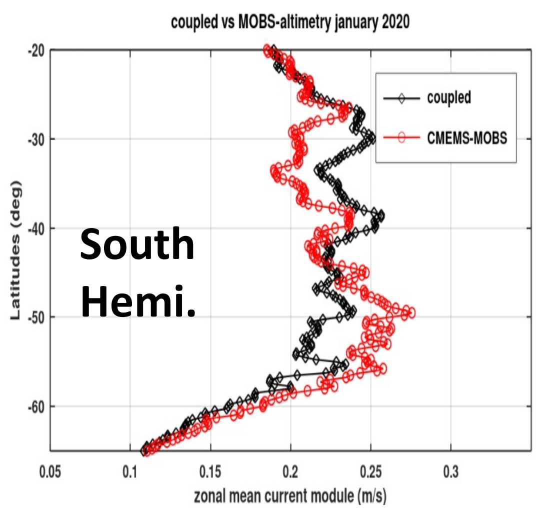
Bias in comparison with l4-MOBS

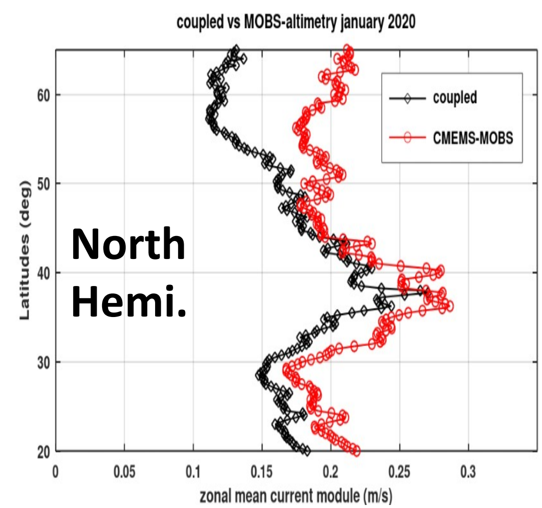


Significant difference in tropics and strong Current regions (ACC, Agulhas,...)

Zonal mean of current in ocean regions



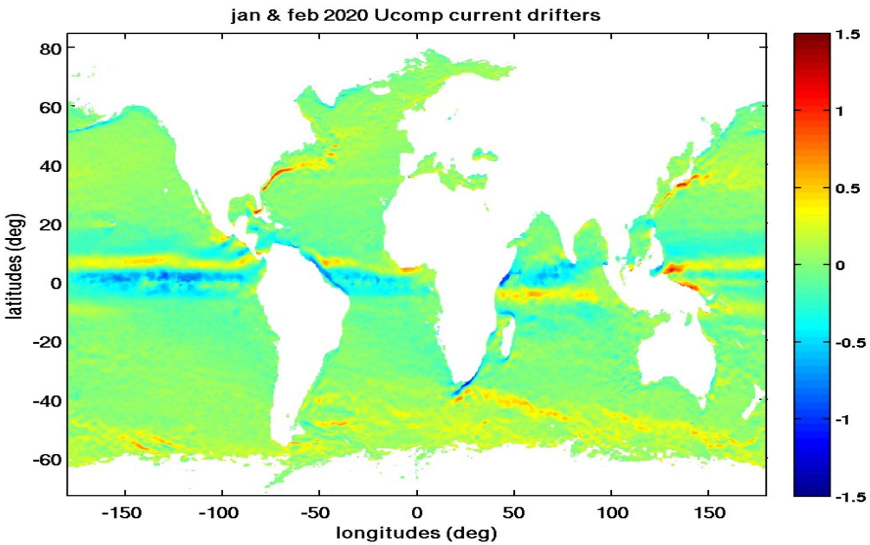




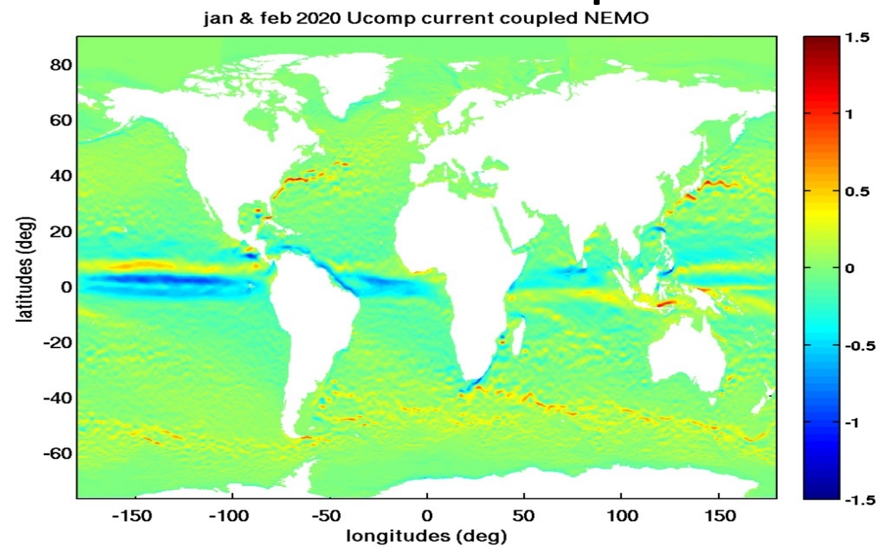
Validation of coupled model currents : Jan. & Feb. 2020

Mean Zonal component U of surface current

AOML Drifters

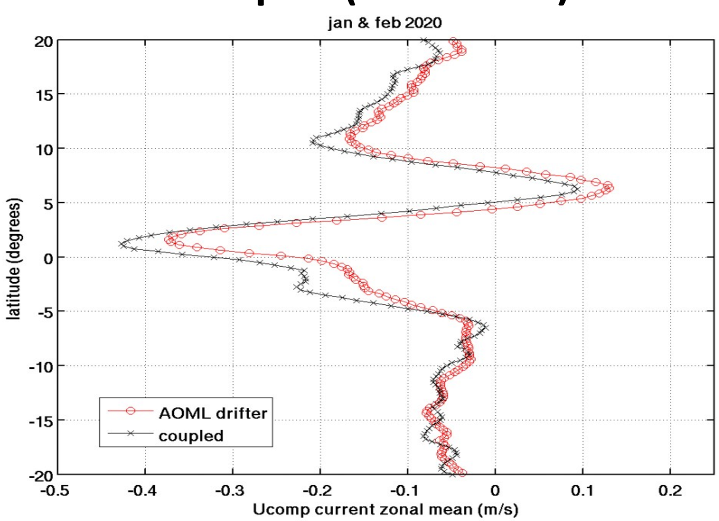


Coupled simulation



➡ **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**

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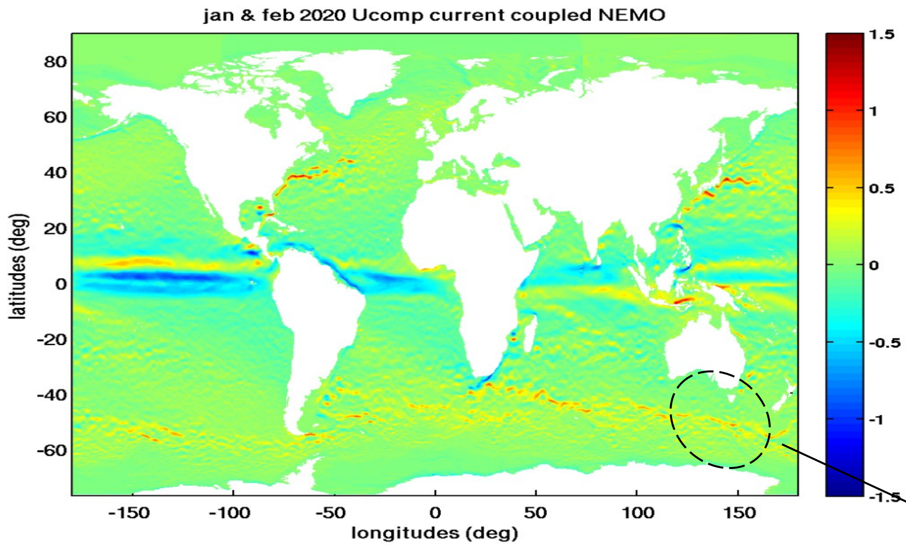
Validation of coupled model currents : Jan. & Feb. 2020

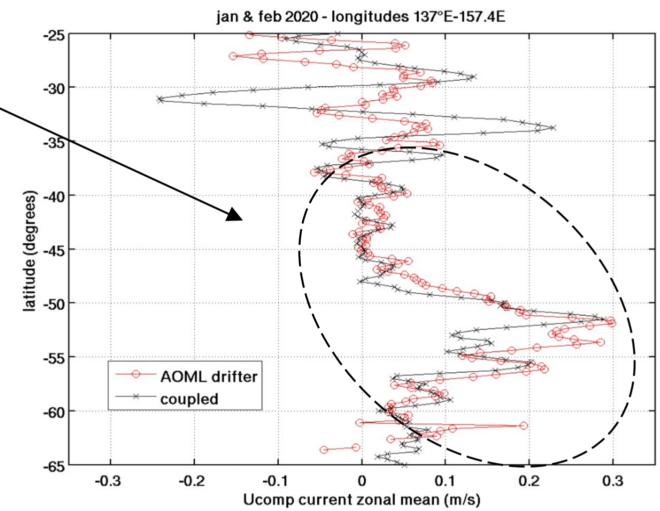
Mean zonal component U of surface current

Coupled simu.

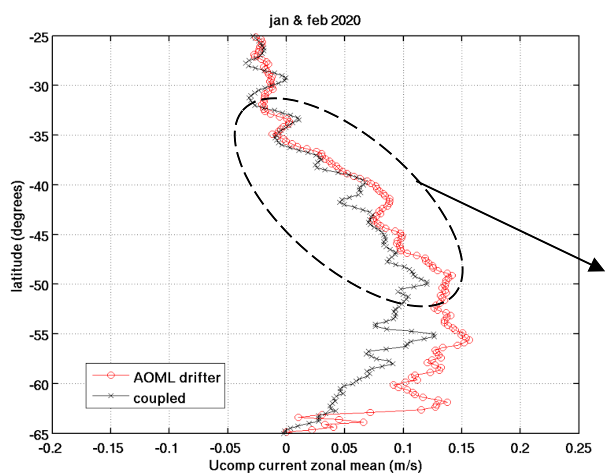


Good agreement between coupled model and drifters in ACC region between Australia and Antarctica.

Zonal mean Ucomp (137°E-157°E)



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

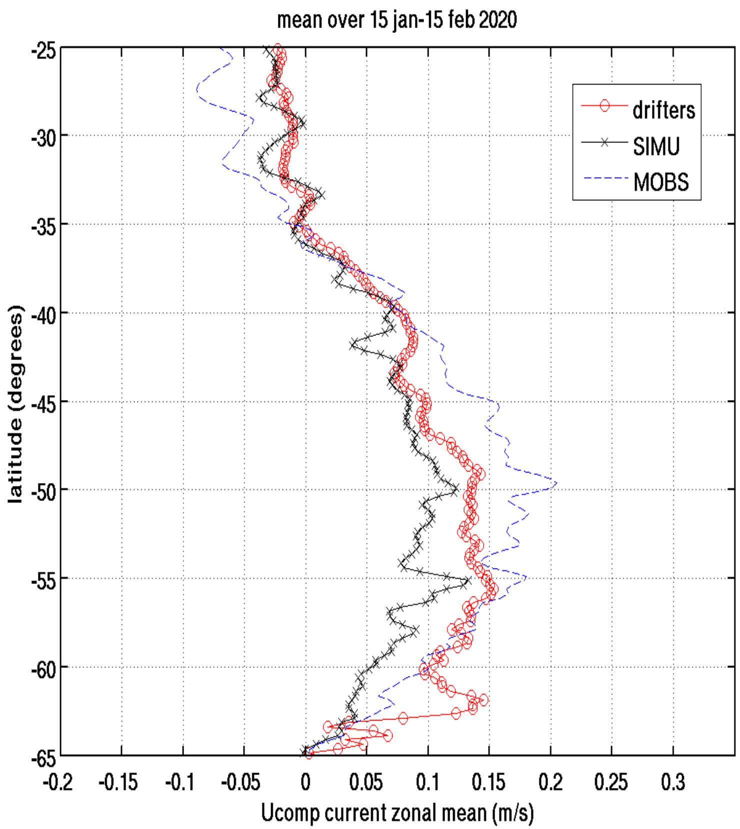


Good agreement in Strong current regions (agulhas, ACC,...)

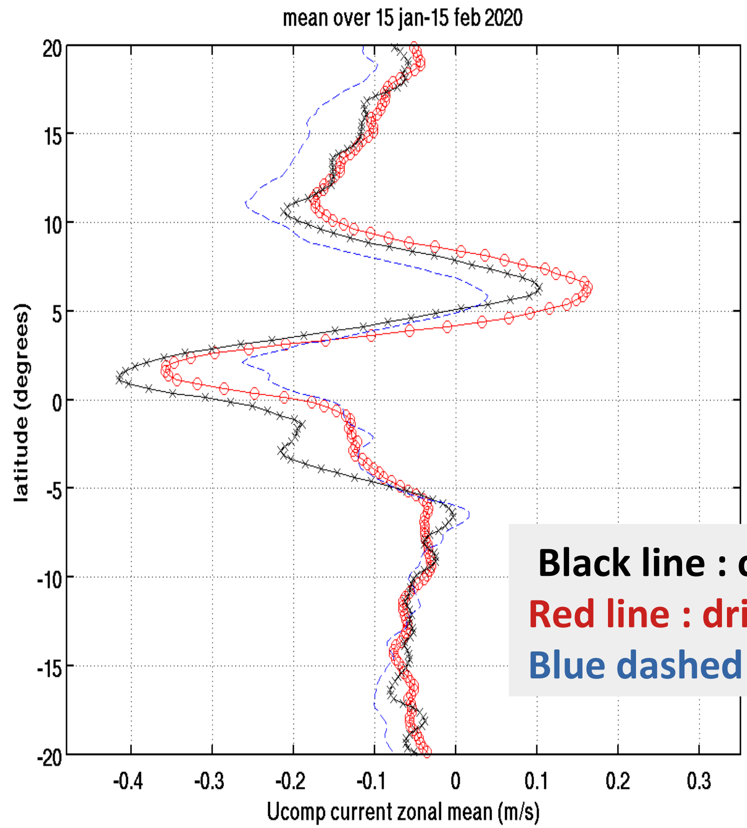
Coupled model vs CMEMS-MOBS : comparison with AOML drifters
Jan-feb 2020

Zonal mean U-comp of current

Southern mid & high lats



Tropics



Black line : coupled
Red line : drifters
Blue dashed : L4-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

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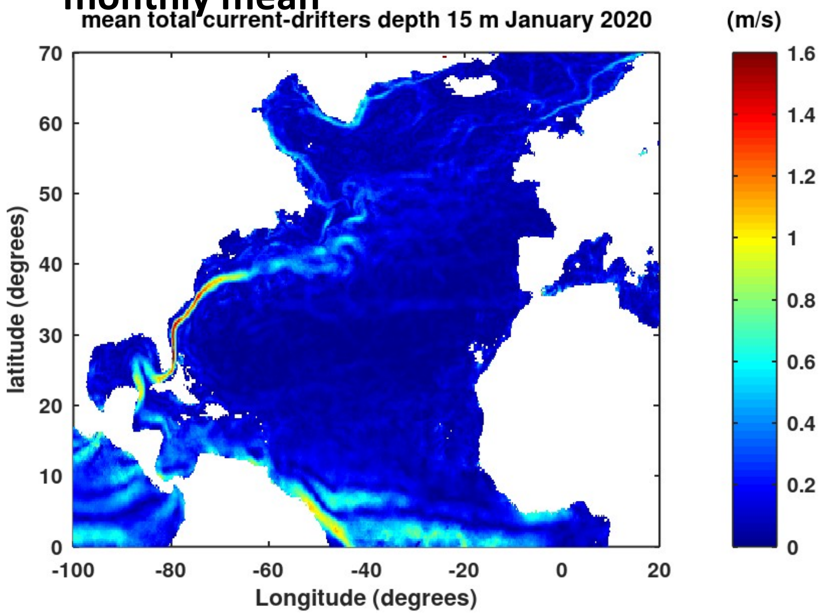
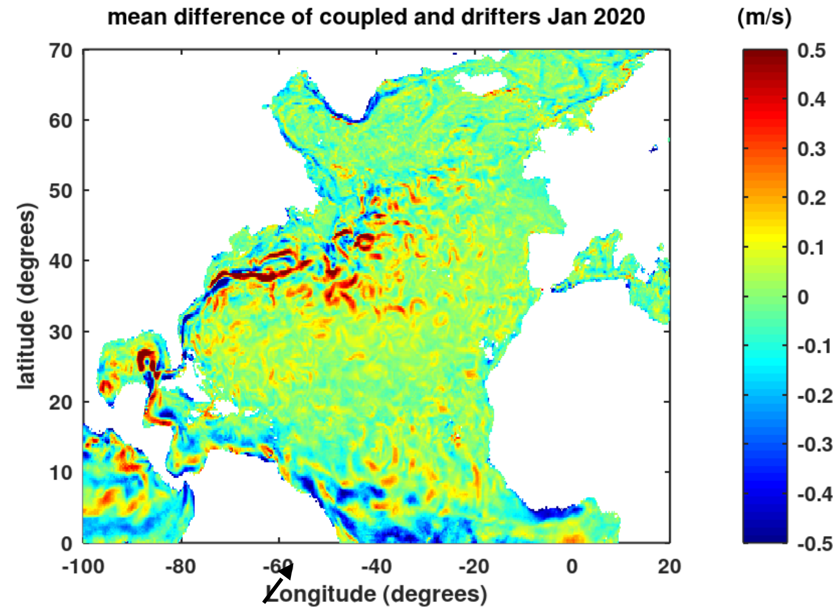
Comparison with WOC (NA-EUL depth 15m) : January 2020

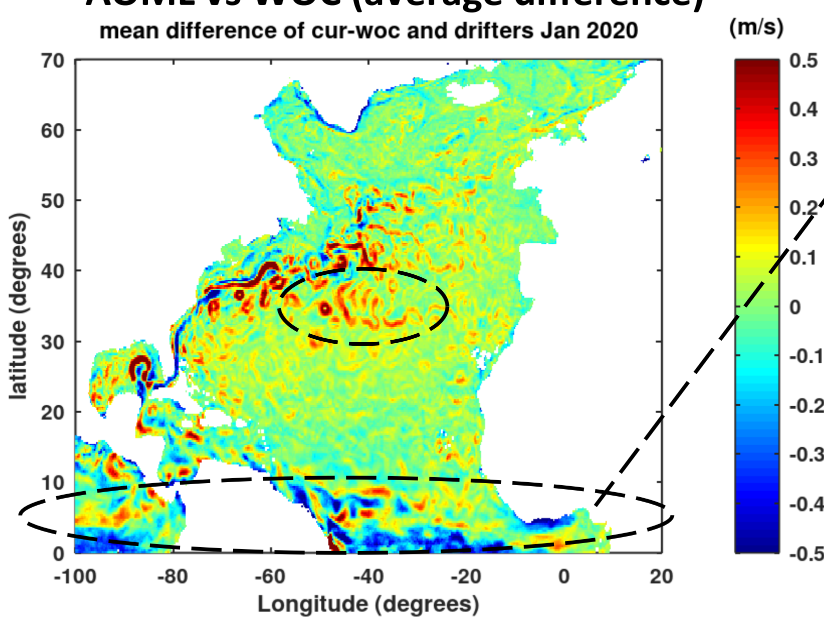
AOML/drifters current monthly mean



AOML vs coupled (average difference)



AOML vs WOC (average difference)



Good consistency with drifters : NA-EUL enhances the current in mid and high lats

NA-EUL : North Atlantic Eulerian

WOC project products (C. Ubelmann)

Key messages

→ The assimilation of SWIM directional wave spectra induces a substantial improvement of sea state description, particularly in the Southern ocean.

→ The wave coupling affects significantly the ocean mixed layer and induces better estimate of ocean key parameters (currents, SST, …). This is mostly Induced to improvement of surface stress and Stokes forcing.

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

→ coupled simulation indicates better surface currents than altimetry currents (L4-CMEMS). The improvement can be remarkable in ocean region as tropics and southern Australia.

→ Longer coupled experiment will be conducted in future works with more validation on ocean parameters in critical regions

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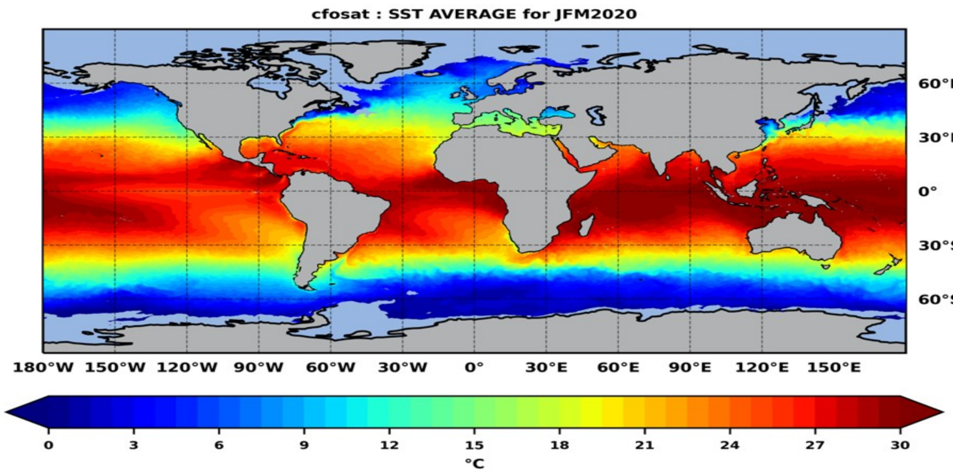
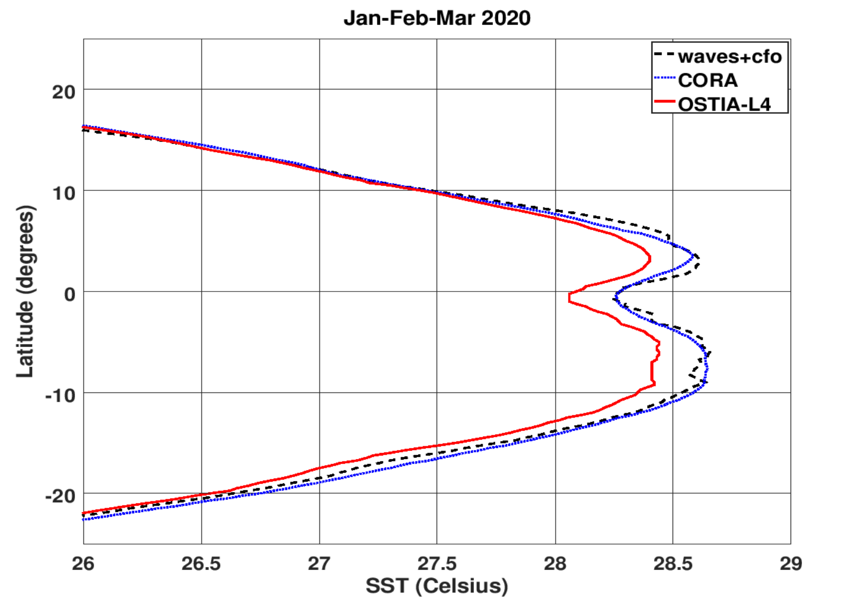
Coupling Ocean/wave models with DA of CFOSAT

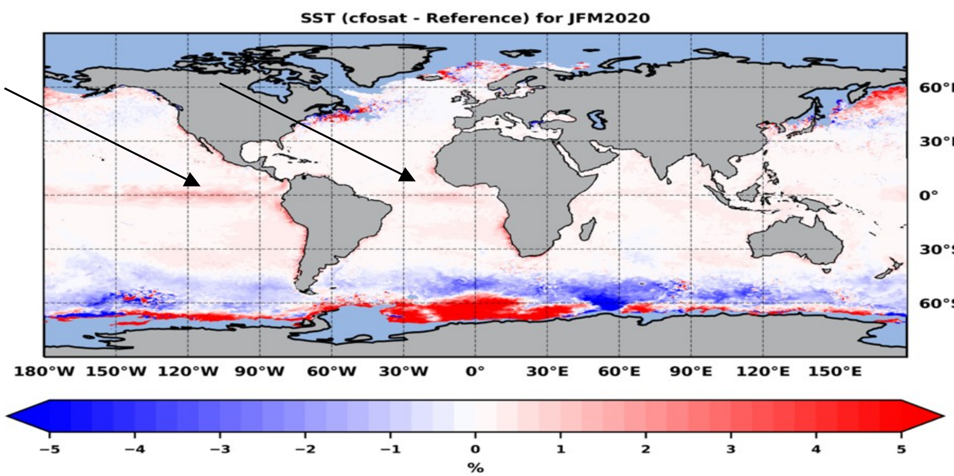
Average SST from NEMO with CFOSAT (jan, fev-mar 2020)



Zonal mean of SST (jan-feb-mar 2020) (coupled vs CORA and OSTIA L4)



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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