Wave attenuation in the Marginal Ice Zone : Thanks to directional wave observations

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OUTLINE

1- Motivation

2- Lessons from SWIM DA

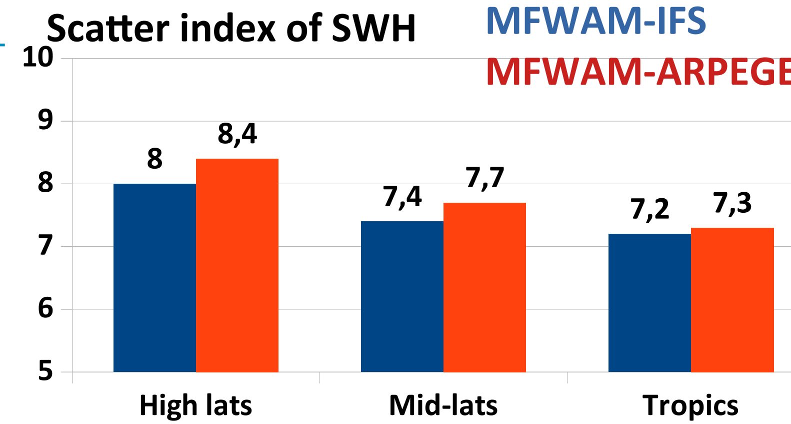
3- Sensitivity to sea ice in SO

4- wave attenuation analysis in Weddell sea

5- conclusions

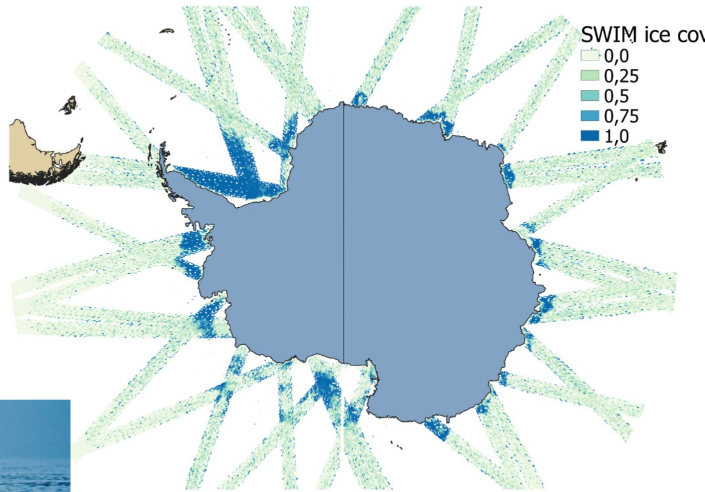
Motivation

→ Since Feb. 2021 SWIM directional observation are Used in the operational global wave model MFWAM. Contributing to improve significantly wave forecasting and to better describe waves from wind-sea to swell regime.



→ Use of DA of directional wave spectra to investigate how wave systems evolve in MIZ : Focus on critical ocean regions in Southern Ocean (Weddell,...)

SWIM Sea ice fraction

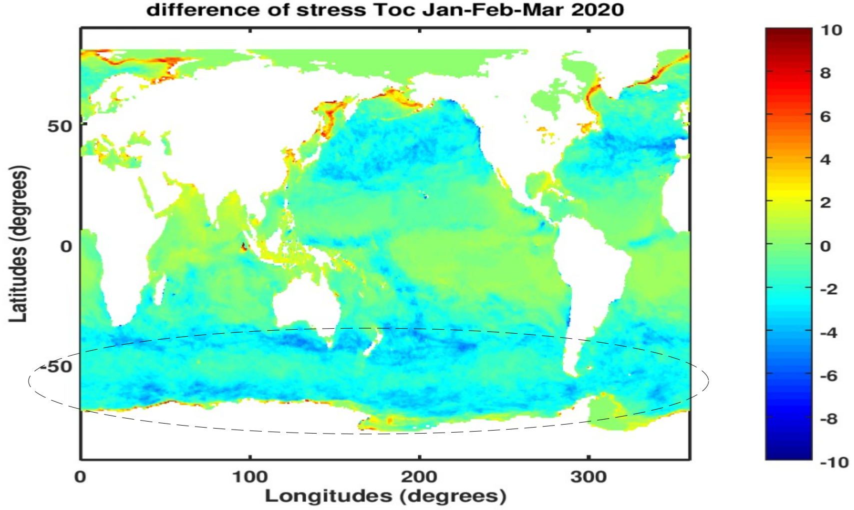


→ Modelling wave attenuation in MIZ and consequences In the ocean mixed layer and ocean circulation. What consequences to possible warming in SO and more giant iceberg dislocations ?

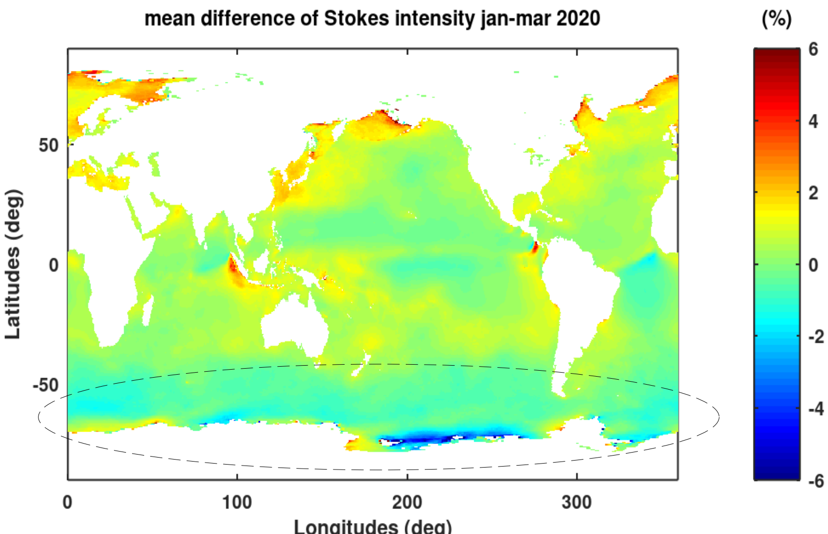
Lessons of using SWIM spectra in operational

DA of SWIM improves significantly the wave forecast in Southern Ocean, which is dominated by storm events with large fetch conditions.

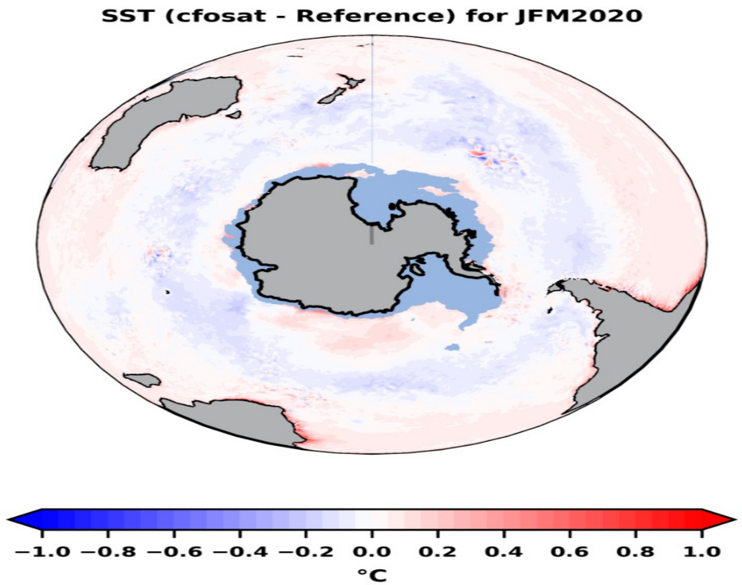
Average of difference (%) of stress τoc w/wo DA Jan-Mar 2020



Average of difference (%) of Stokes intensity



Investigating the link between better wave forcing with CFOSAT and induced SST difference obtained From coupling with ocean model



Mean difference of SST from NEMO with And without wave forcing

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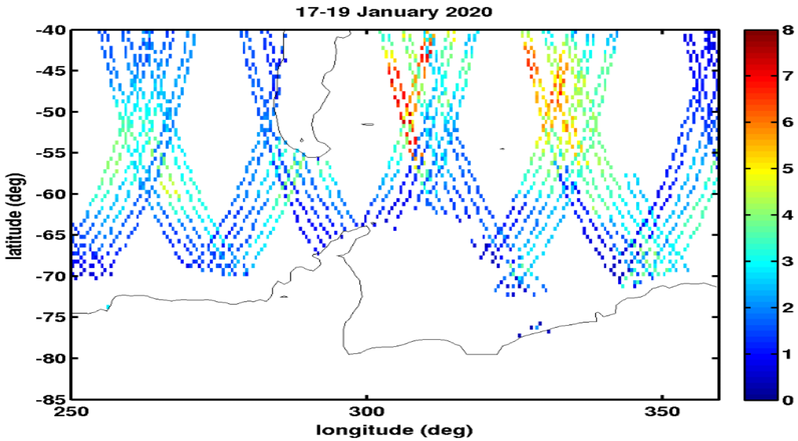
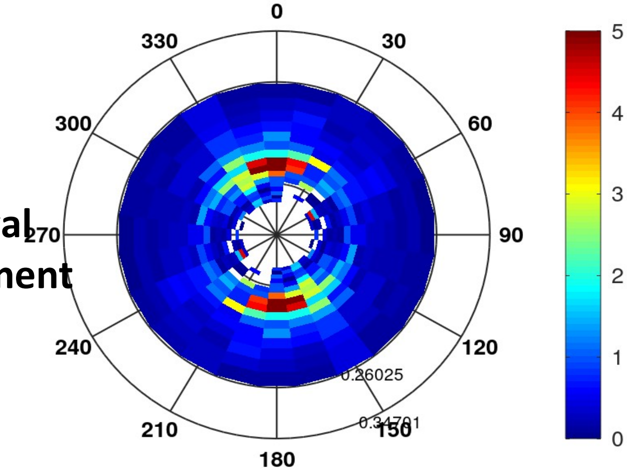
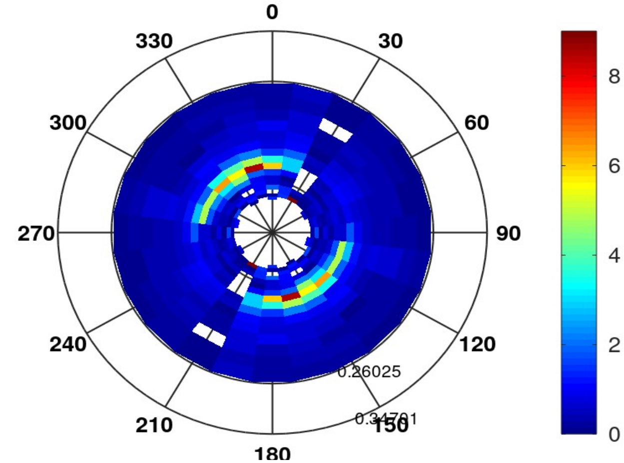
Tracking waves in complex seas (SO-Weddell)

wave height 17-19 Jan. 2020

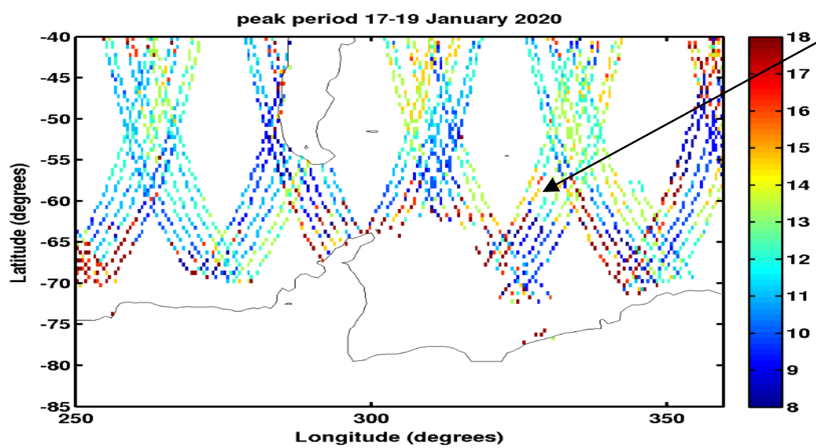


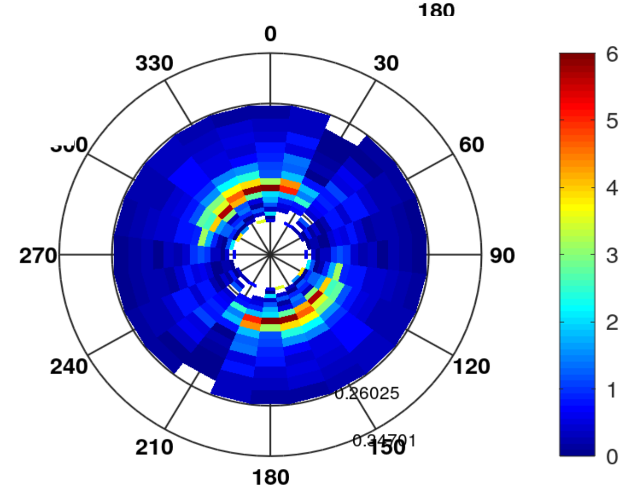


Ambiguity removal by cross-assignement with model

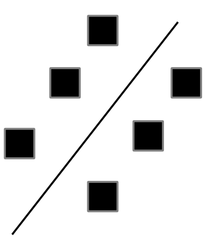


Peak perioc





Spectral variability From SWIM in Storm conditions

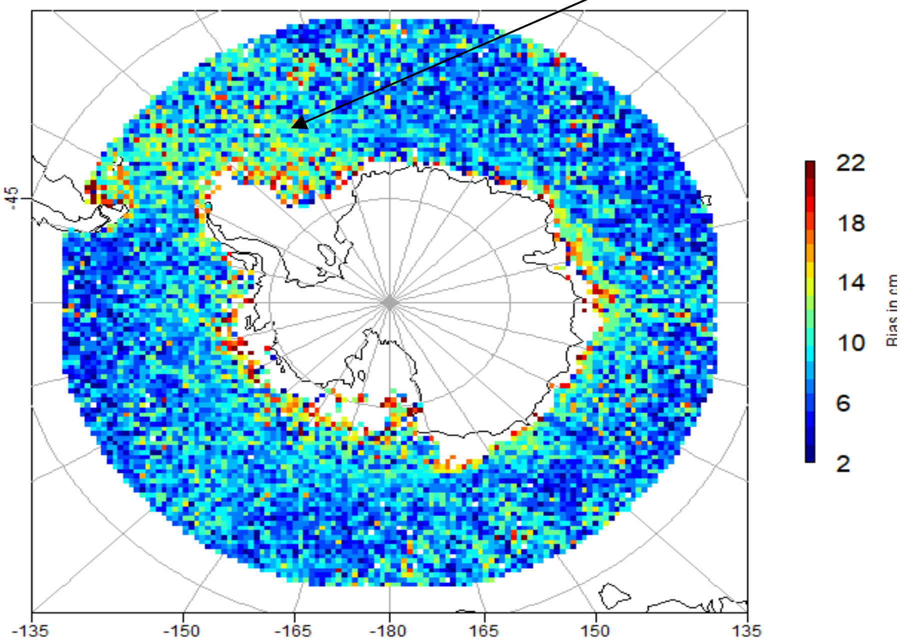


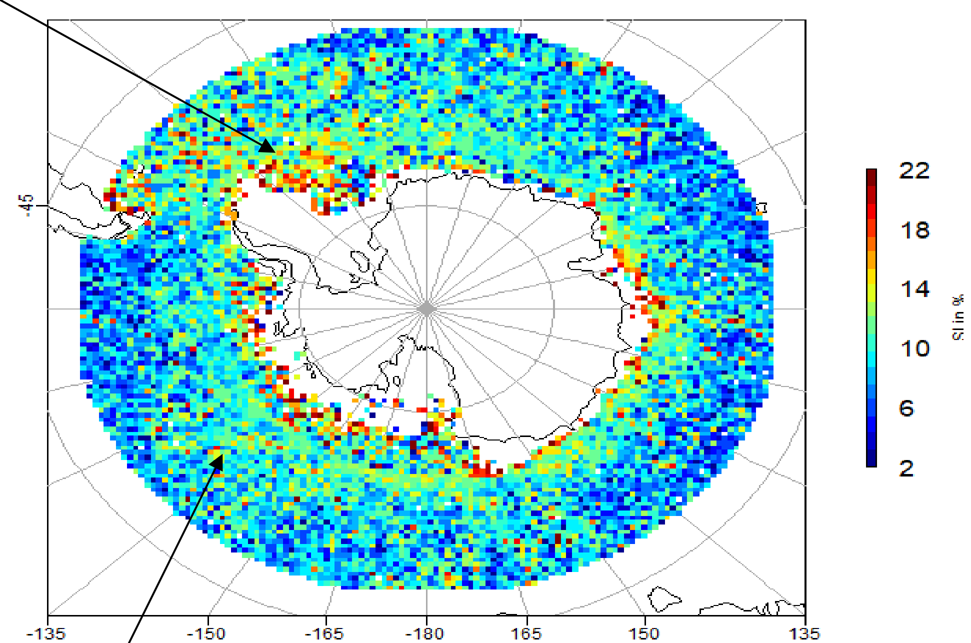
Every passage wave spectra and SWH are provided off-nadir

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





scatter index of SWH is improved and is in average ~8%. significant reduction particularly in Weddell Sea.

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

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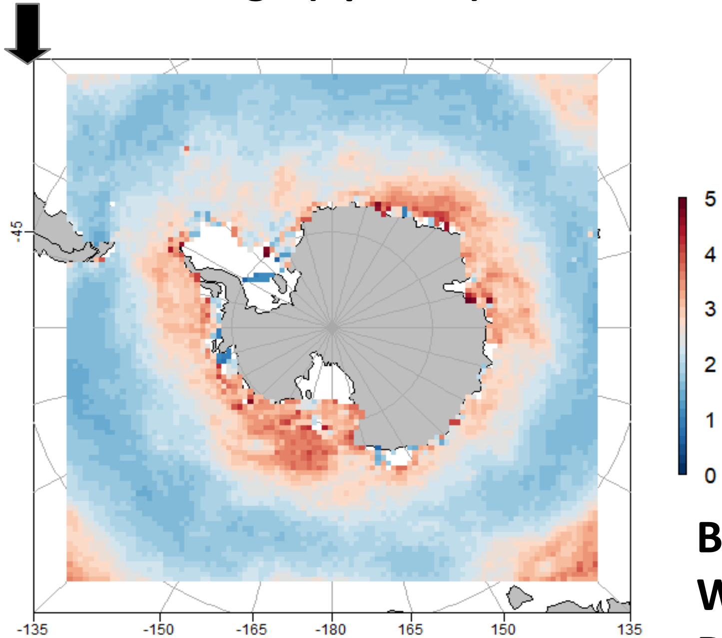
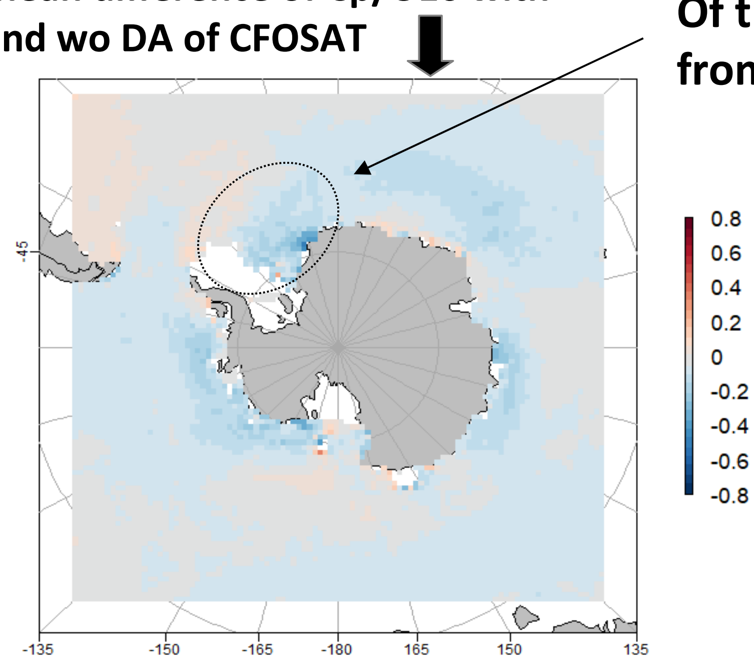
Impact of DA (kx-ky) on wave growth : Jan-Feb 2020

Mean wave age (Cp/U10)



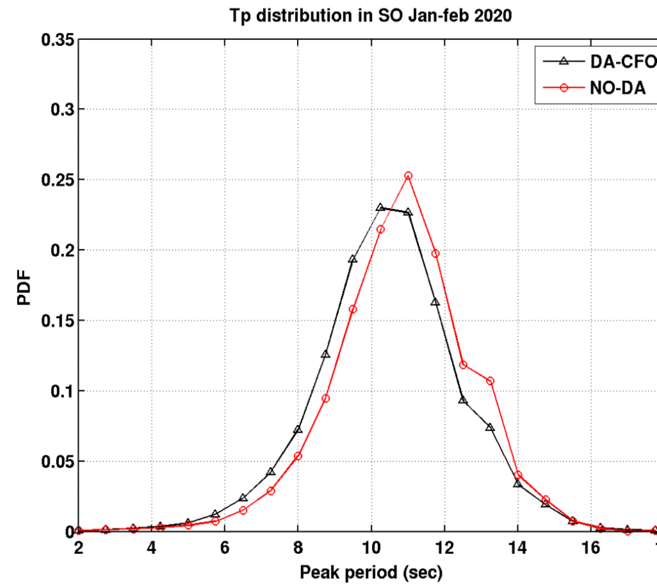
Mean difference of Cp/U10 with and wo DA of CFOSAT



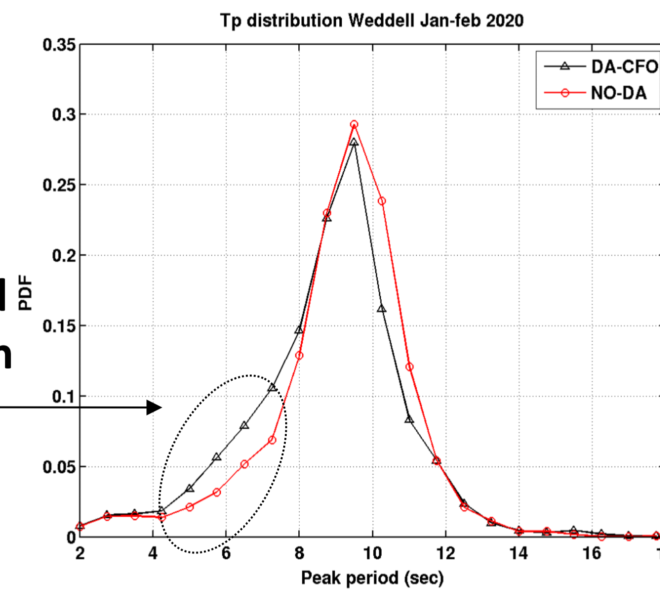
Better scaling of Wave wage with DA and correction Of the overestimate from the model

more younger Seas are affected at Weddell (fetch Conditions)

PDF of peak period in SO

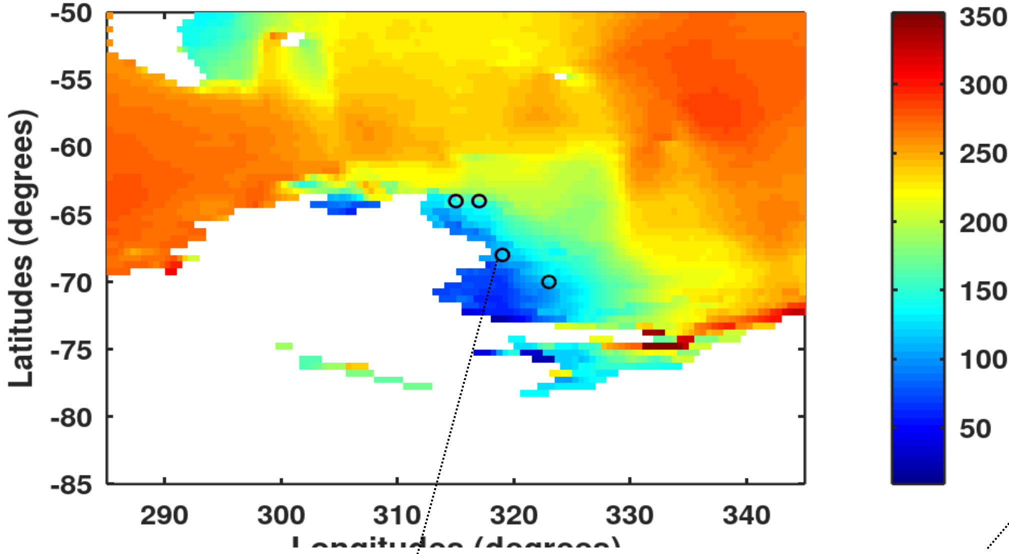


PDF of peak period in Weddell sea

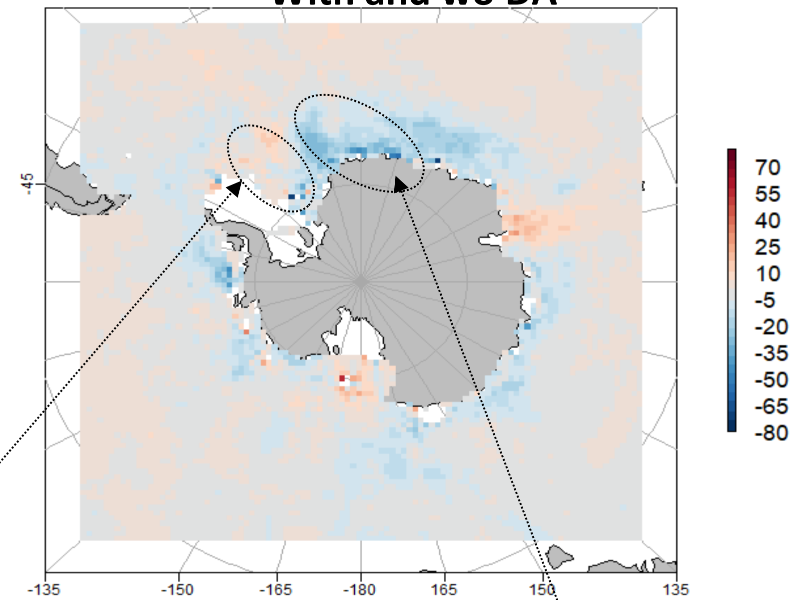


Impact of DA on dominant wave direction (Jan-Feb 2020)

Mean dominant wave direction from at Weddell



Mean difference of dominant direction With and wo DA

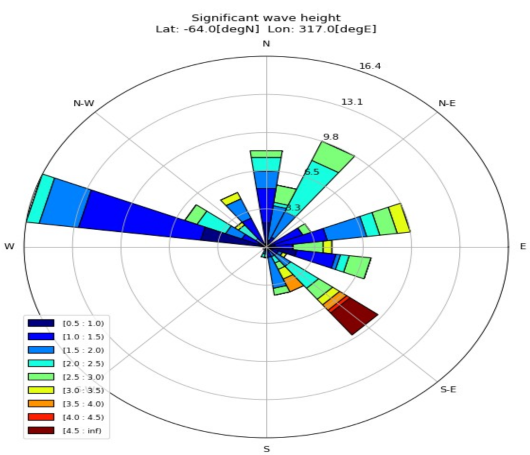


Clockwise increase

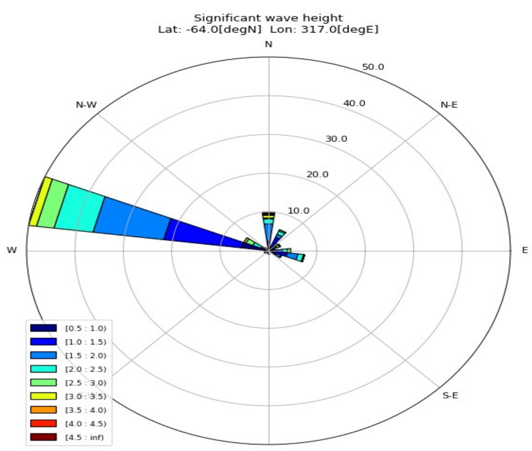
Location 64°S-43°W

Anticlockwise deacrease

Wave rose (dominant dir) DA of CFOSAT (jan-feb 2020)



Wave rose from WAVERYS 2016-2019



Strong variability of dominant wave direction and greater SWH from South-West during austral summer 2020

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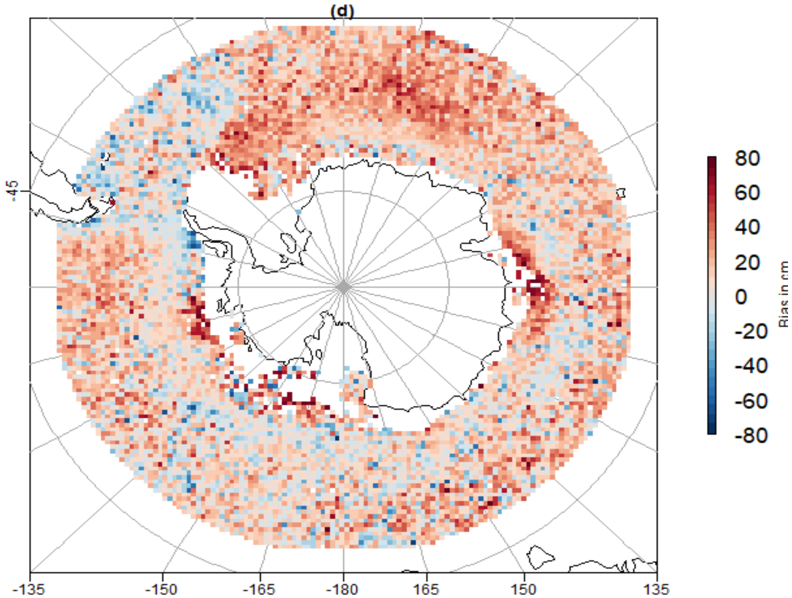
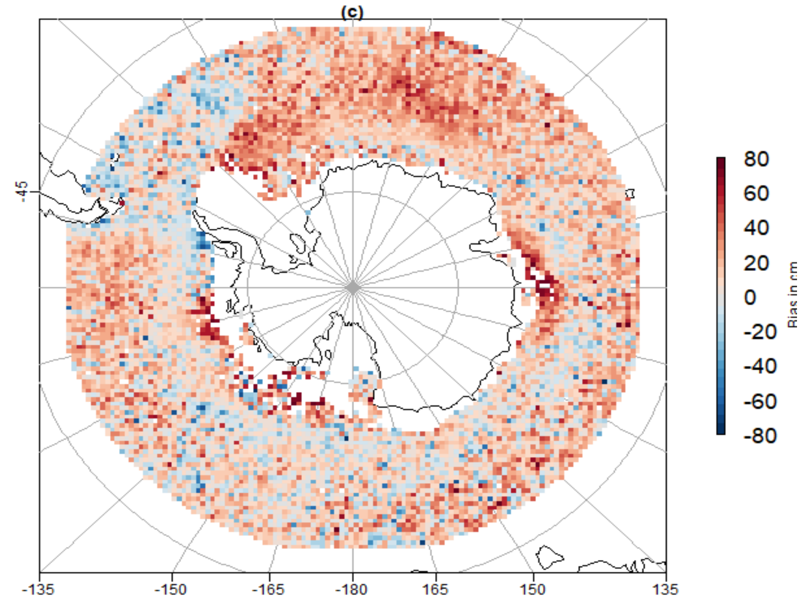
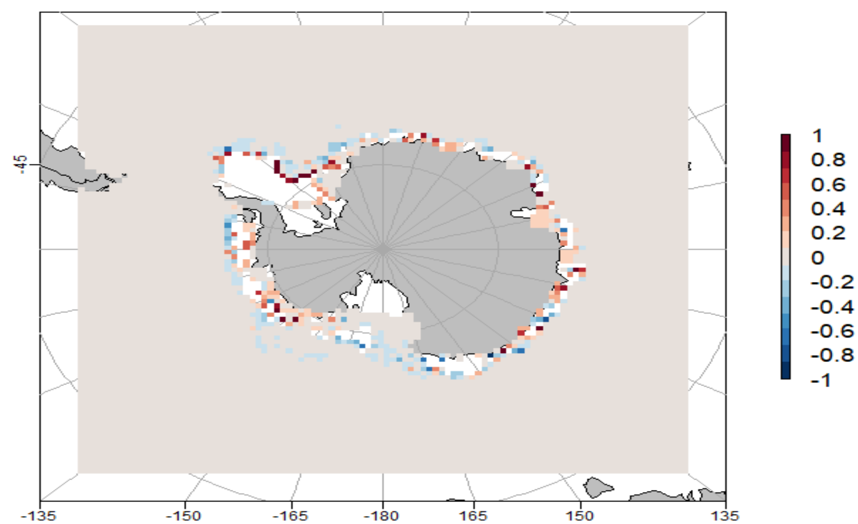
Bias map of SWH from different model runs : Sensitivity to ice fraction
January 2020

IFS Ice fraction (NO-DA) **CMEMS-ICE-TAC Ice fraction (NO-DA)**





Mean difference of SWH (IFS vs CMEMS-TAC)



Difference can be significant Near coastlines and thick ice conditions

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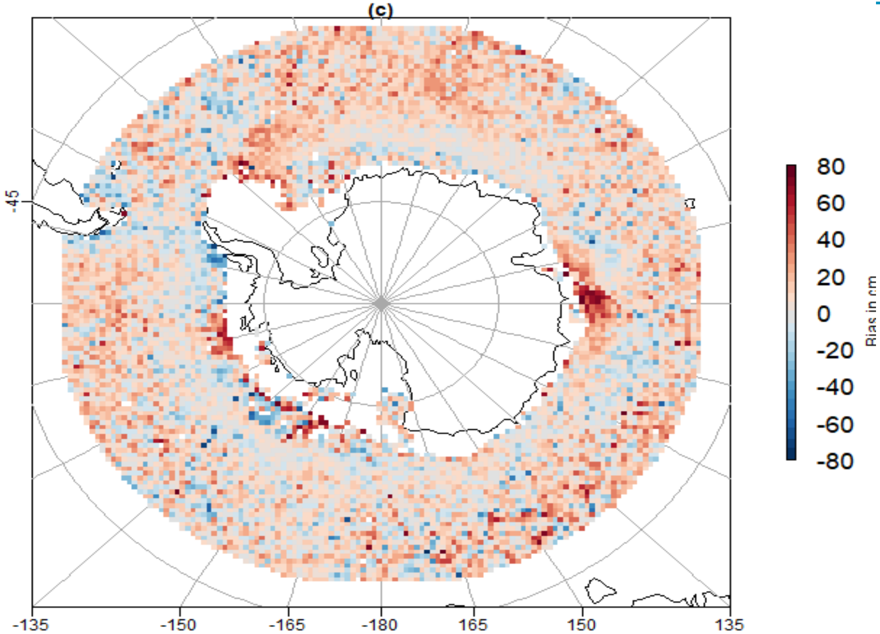
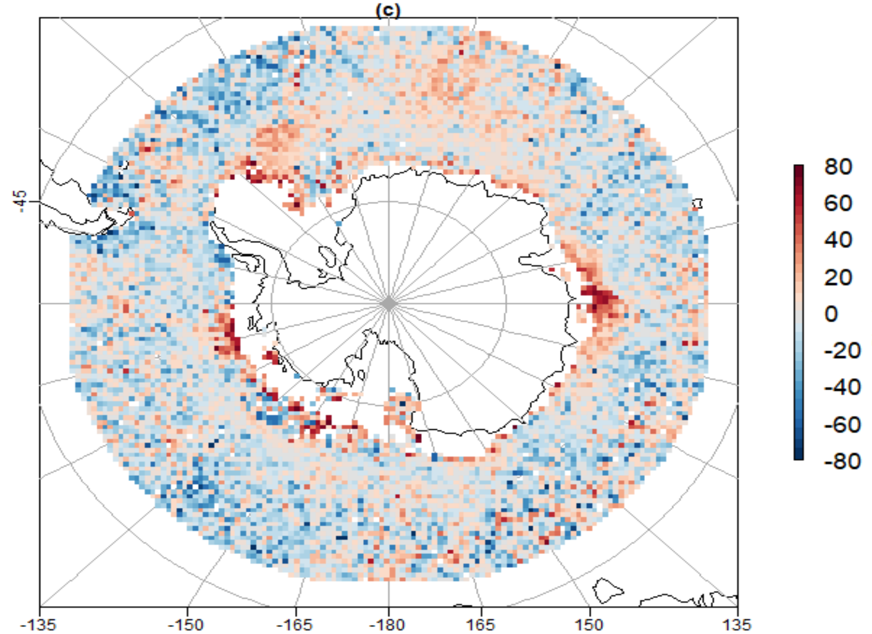
Using DA of SWIM with and without ice flag

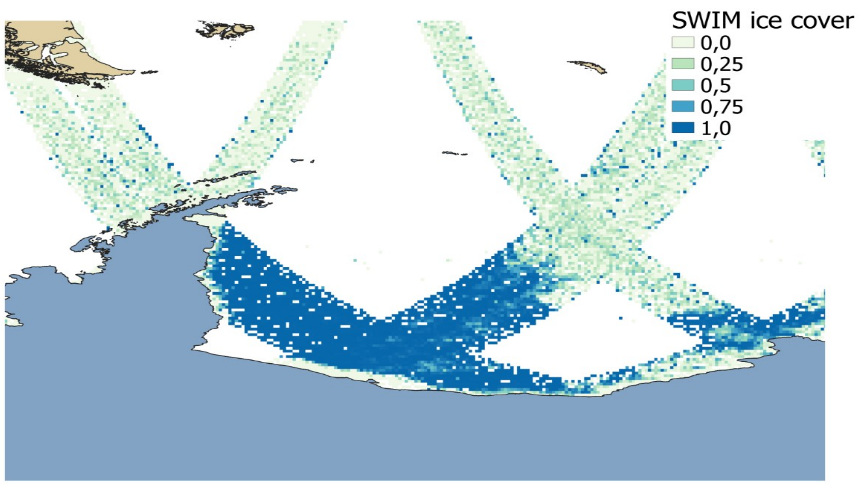
DA-SWIM with IFS-ICE



DA-SWIM No IFS-ICE



SWIM Sea ice fraction 18 january 2020



DA SWIM without ice flag induces a reduction of SWH bias, however there is a more SWH underestimation than using DA of SWIM with Ice-flag.

Using sea ice fraction from SWIM could Remove the underestimation of SWH

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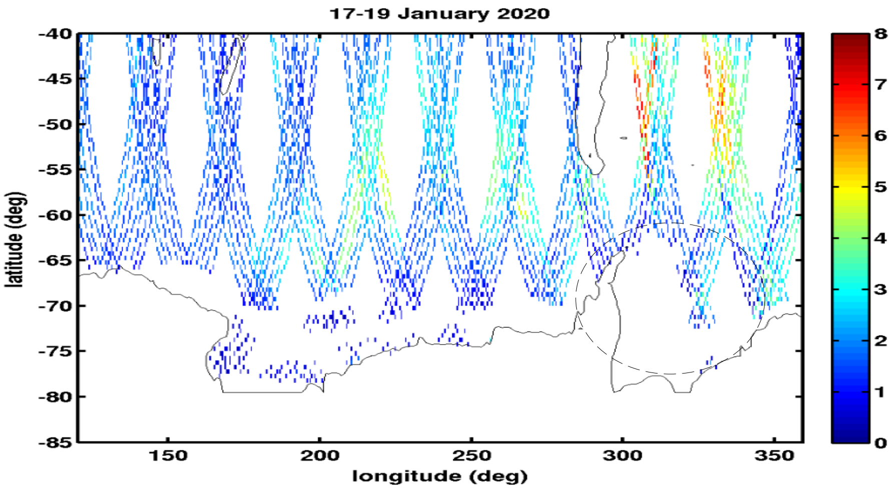
Methodology and model runs

18 january 2020

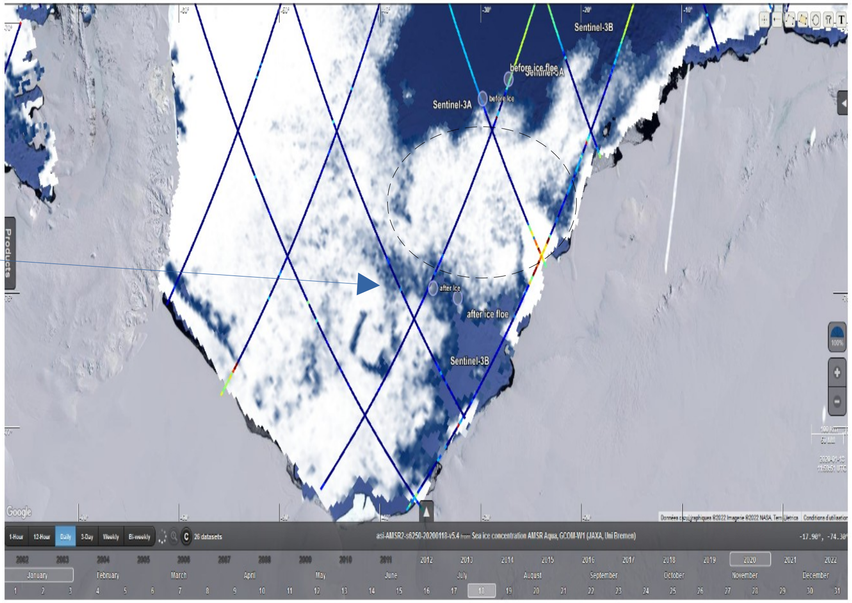
Relaxing sea-ice forcing from IFS and analysing the impact of DA in MIZ (before and adter ice floe)



- **Wave model MFWAM configuration :**

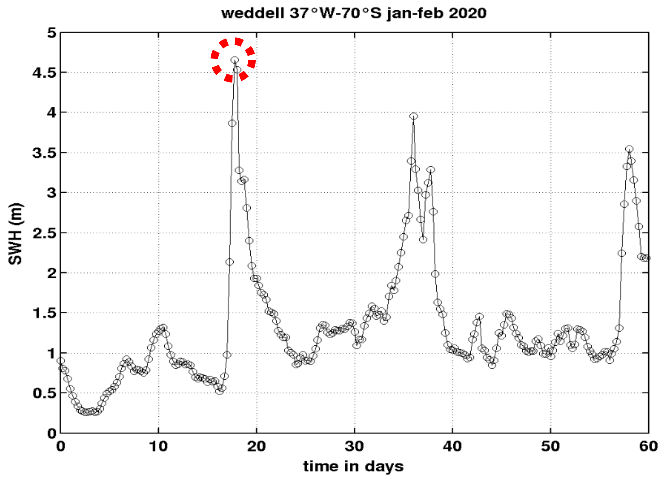
-global scale with grid size 20 km
- spectral resolution of 24 directions and 30 frequencies
- atmospheric forcing IFS-ECMWF (analysis wind
- period of run : Jan 2020

Validation with Sentinel-3 wave data



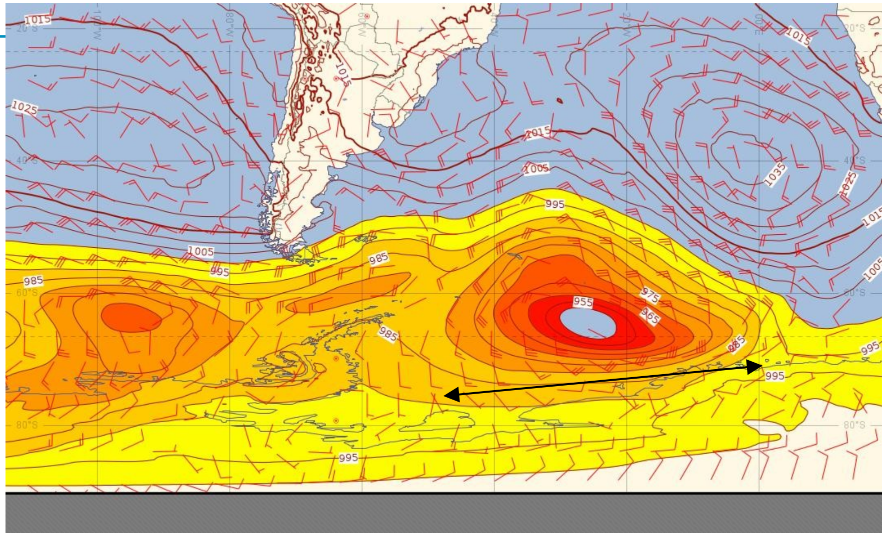
Complex wave systems in Weddell Sea (37°W-70°S)

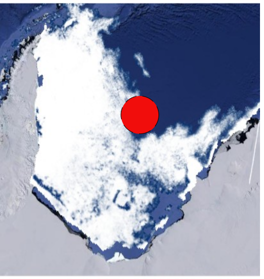
Storm event in 18 January 2020

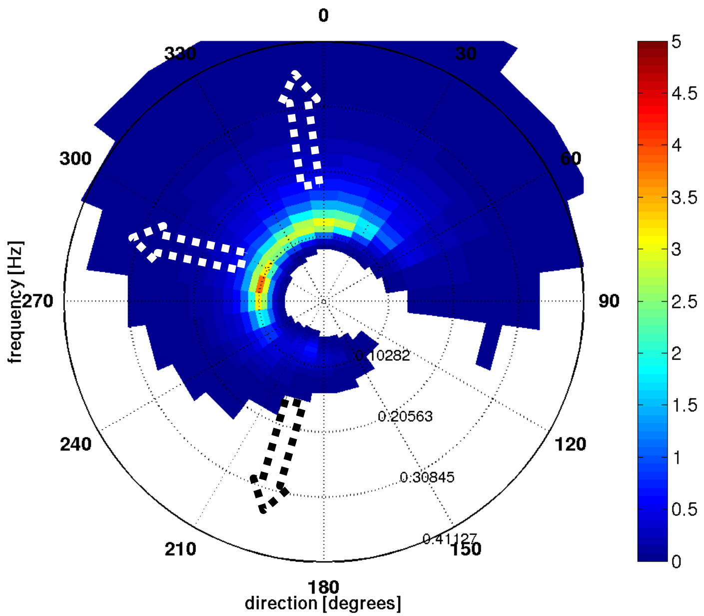


Time series of SWH from MFWAM (DA-CFO) at location 37°W-70°S

weather chart 20200118 at 0:00 UTC







Mean wave spectra from MFWAM
With DA of wavenumbers components
and off-nadir SWH, during the storm
Event from 17-19 January 2020 (3-hourly)

Dominant long swell Westard and
Younger swell in growth northward
and swell toward South-W

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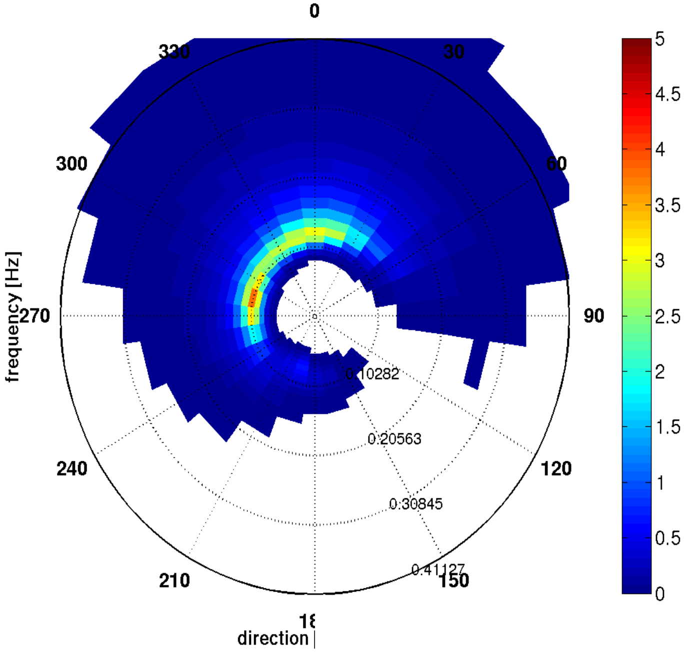
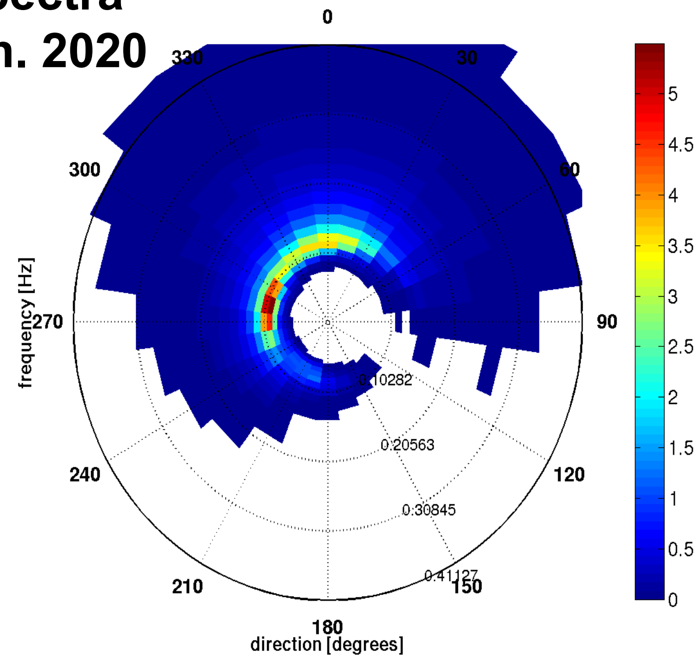
Spectral analysis and impact of DA at 37°W-70°S

With DA of CFOSAT

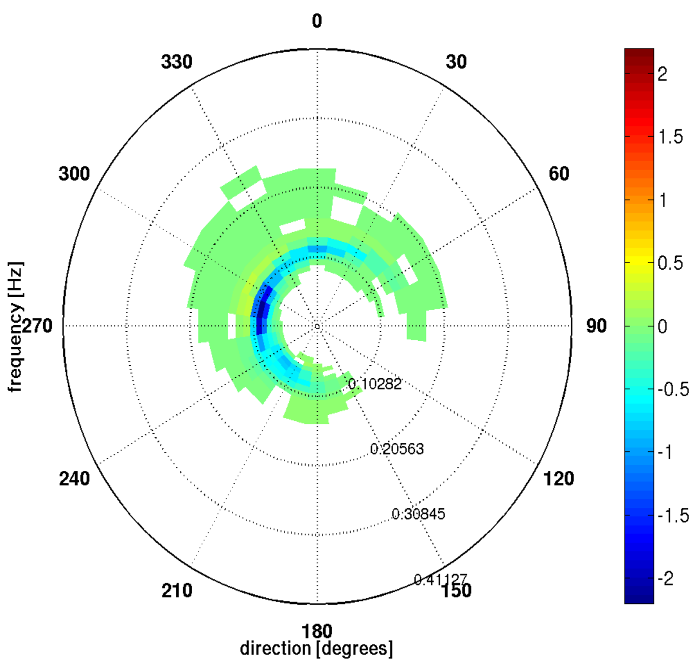
Mean wave spectra From 17-19 Jan. 2020

No DA





Difference of mean With and without DA



Correction of the overestimation of long swell energy (to west) and to North and South-west.
Further good correction of underestimation on younger seas To N-W and N-E,

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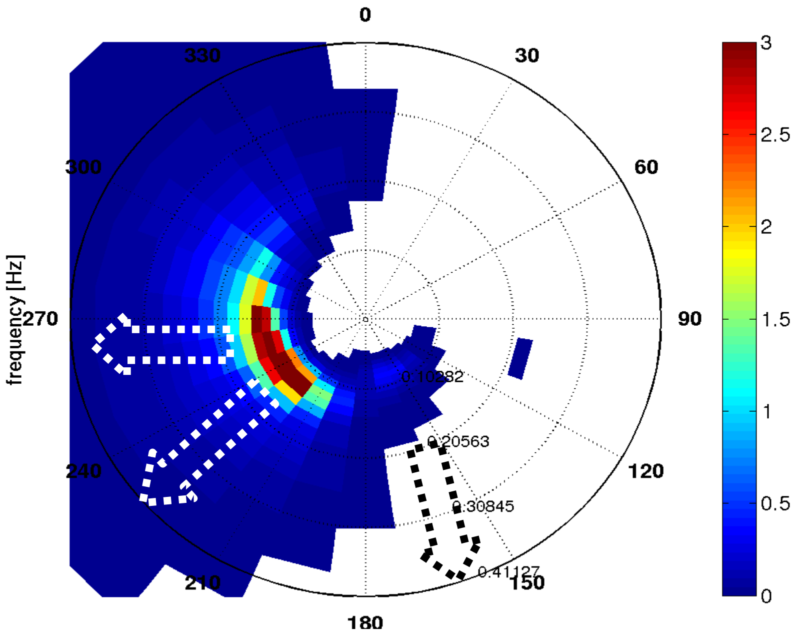
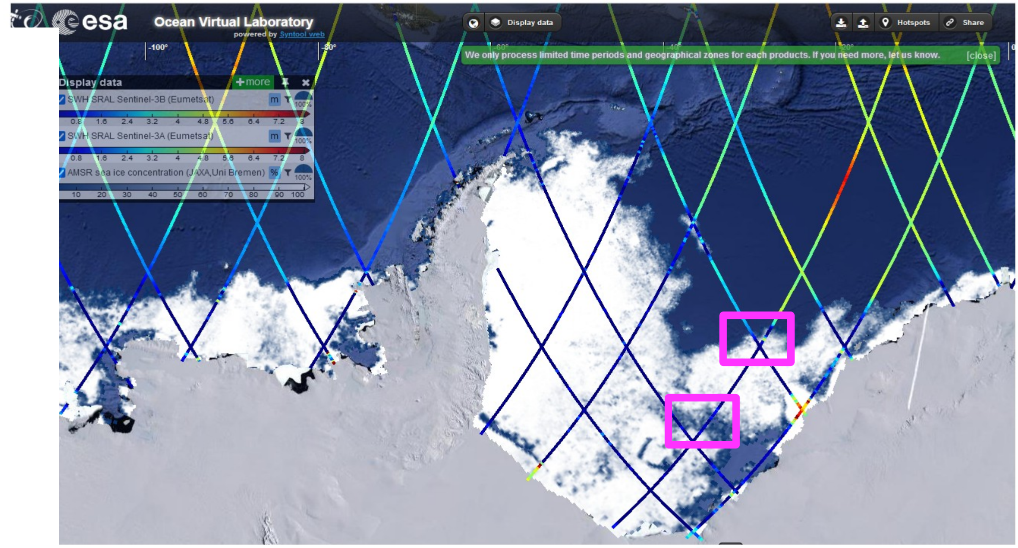
Tracking wave spectra (with DA) in before and after locations (18 January 2020 at 3:00 UTC)

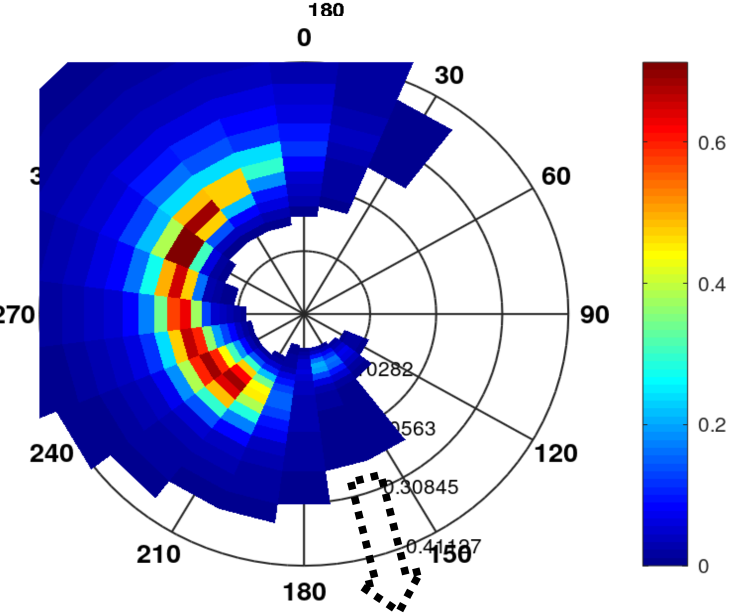
wave spectrum 2020011803 (before)



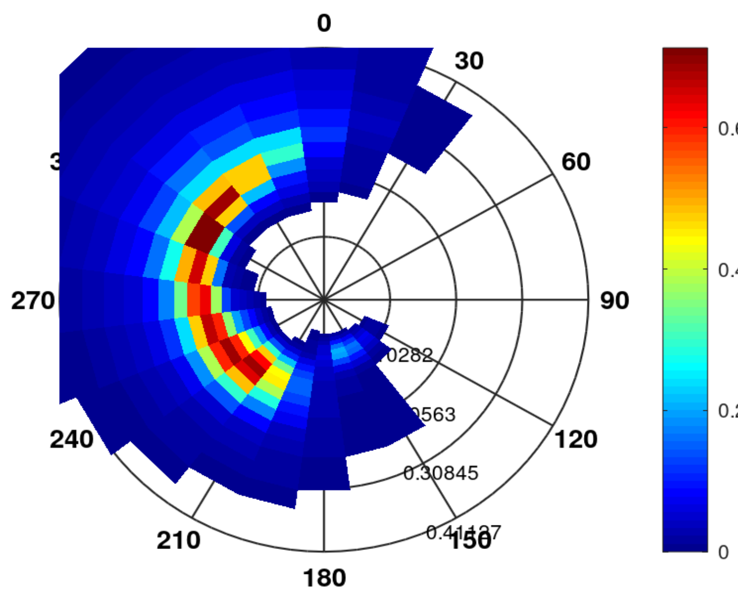


Sea ice fraction from AMSR-2 (Univ. Bremen)

After 03:00 UTC

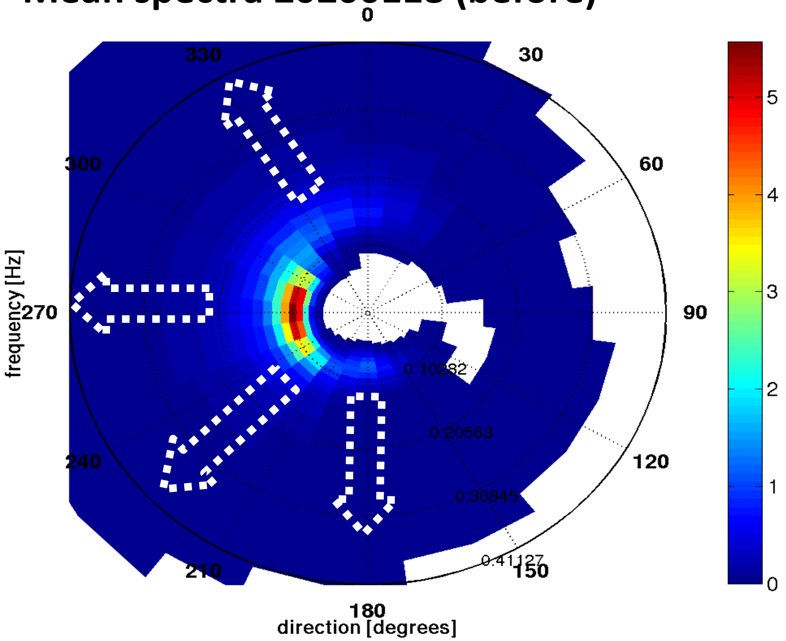


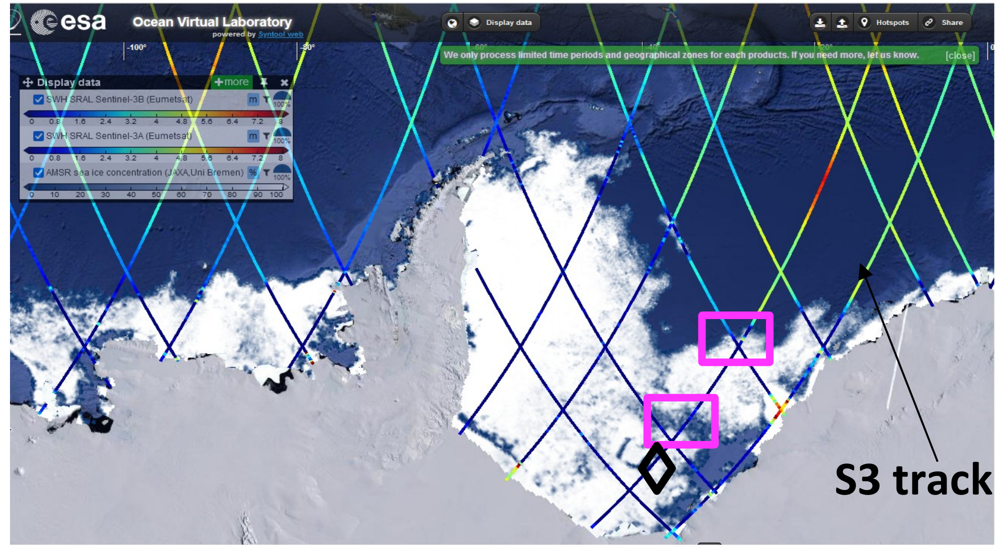
After 06:00 UTC



Spectral analysis in MIZ during storm event at Weddell sea (17-19 January 2020)

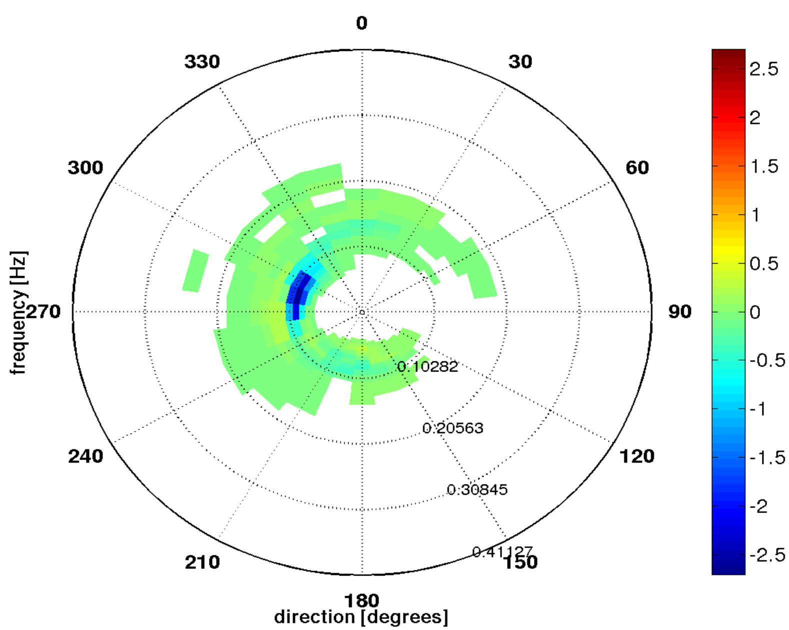
Mean spectra 20200118 (before)





Sea ice fraction from AMSR-2 (Univ. Bremen)
Focus on two zones before and after thick Sea ice (100% in white) zone.

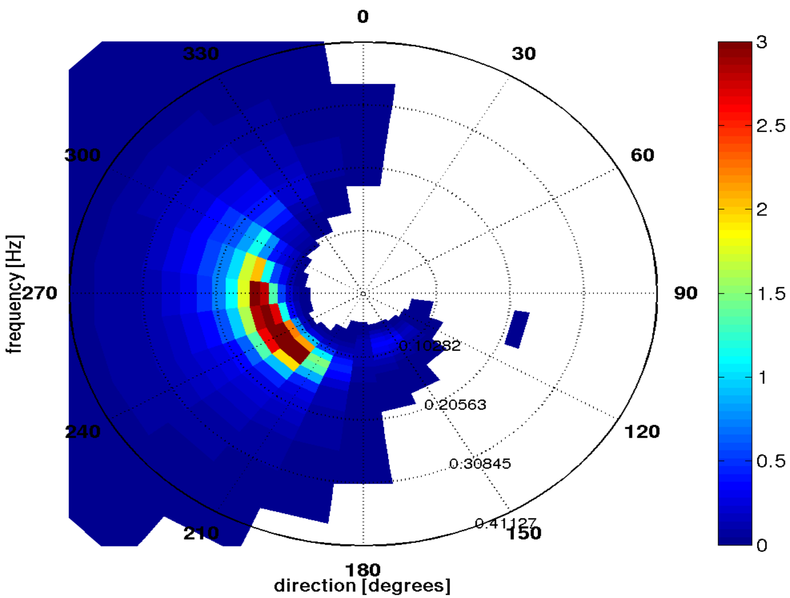
Before : 31.8°W-71°S
After : 31.8°W-73°S
Far : 35°W-75°S



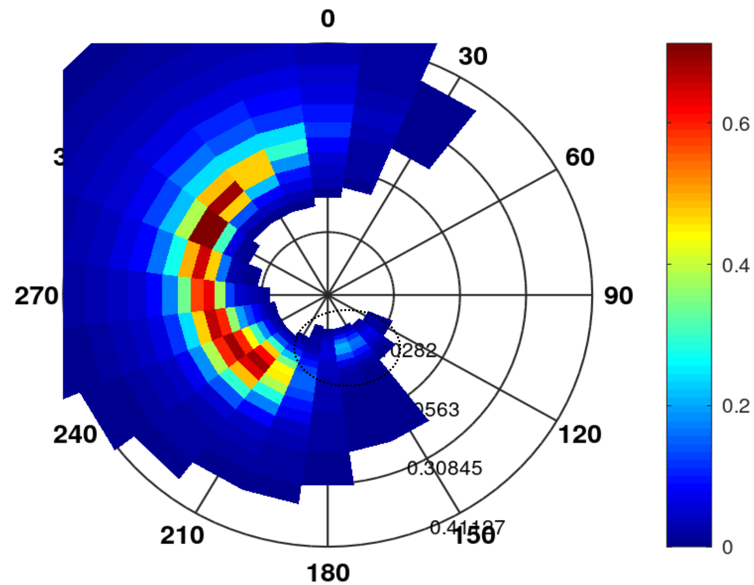
Difference of mean with and without DA of CFOSAT at before during 18 Jan 2020 Correction induced by DA for different frequency ranges (blue indicates model overestimation)

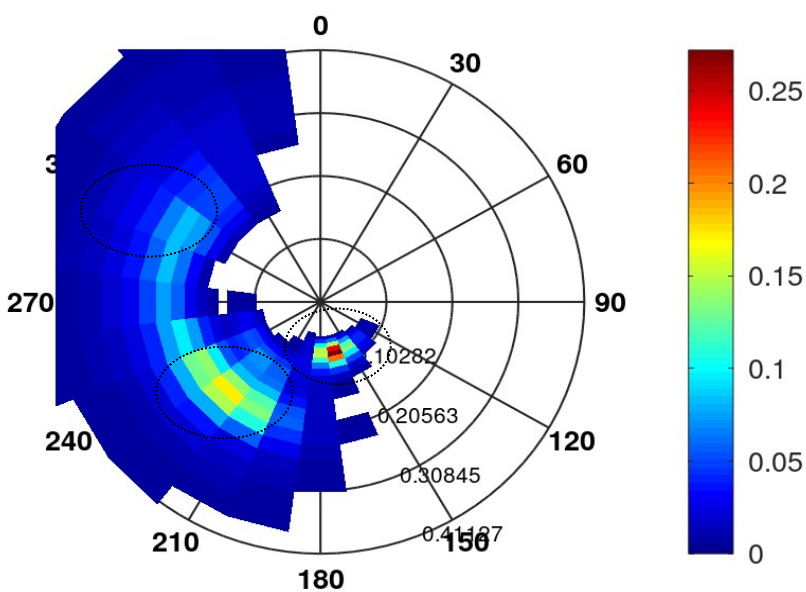
Variation of wave spectra in MIZ at Weddell Sea (storm 18 January 2020)

Before 03:00 UTC



After 06:00 UTC





→ **Energy damping of swell toward South**

→ **Increase of freqency spreading for waves propagating toward west and South-west directions and energy damping .**

FAR (35°W-75°S) 09:00 UTC

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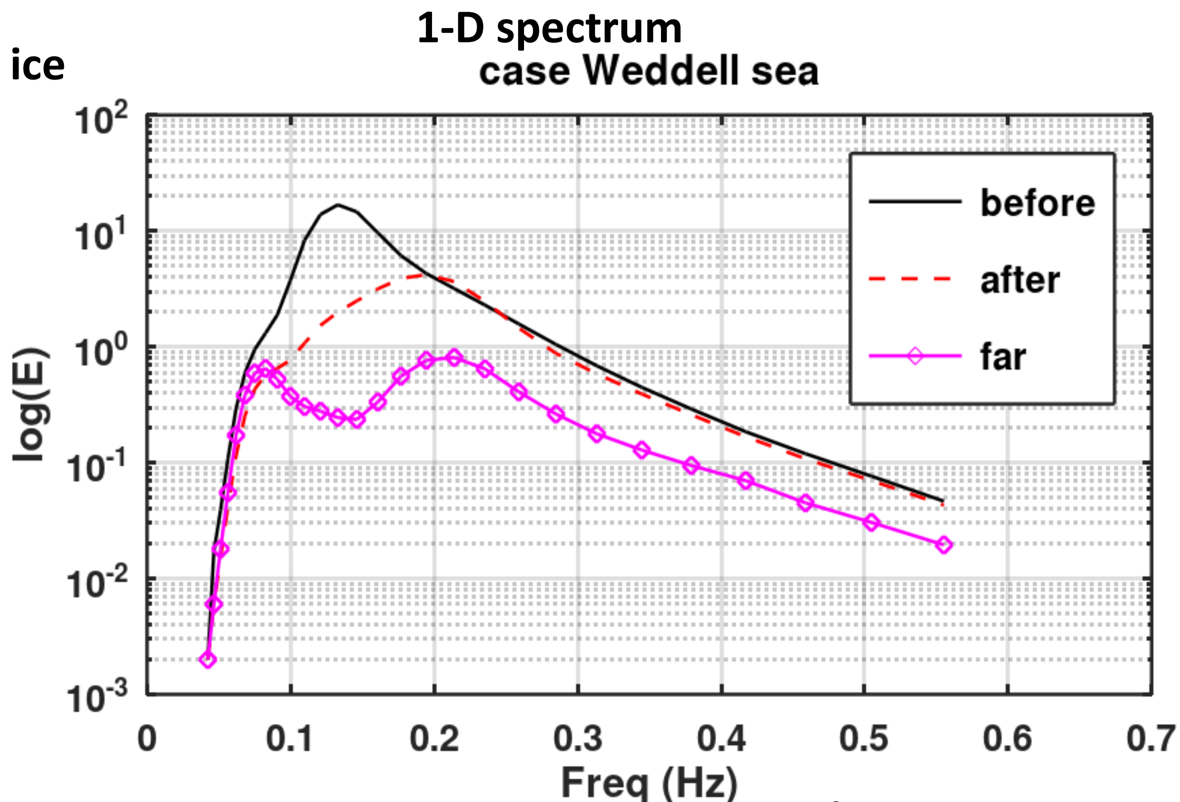
Spectral analysis following the 3 locations on 18 January 2020

Wave spectrum variation
In the MIZ : Impact of sea ice
at After and far locations

Density of energy



Wave frequency

- **Modelling the attenuation and usein wave model**

  $E(f,\theta) = E0(f,\theta)*\exp(B)$

Where B is a function depending on sea-ice fraction, wave frequency and Distance from initial location before ice floe and the considered point

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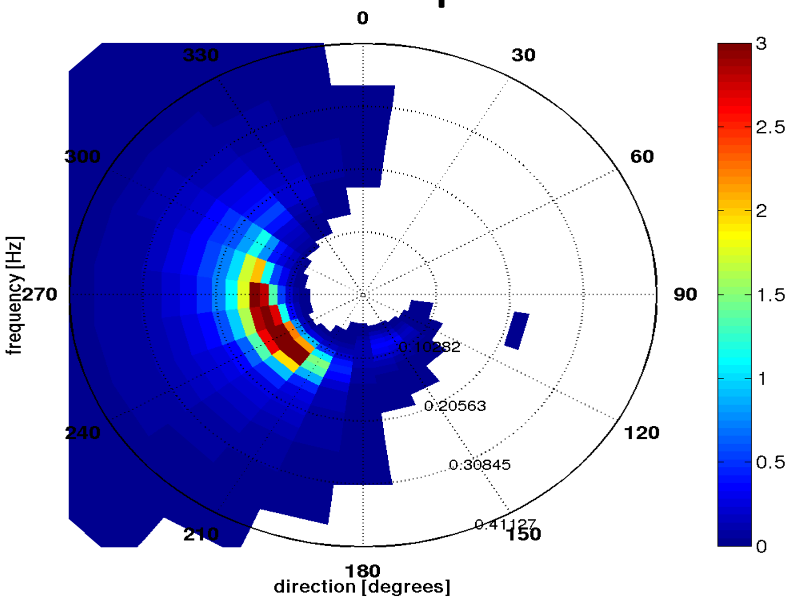
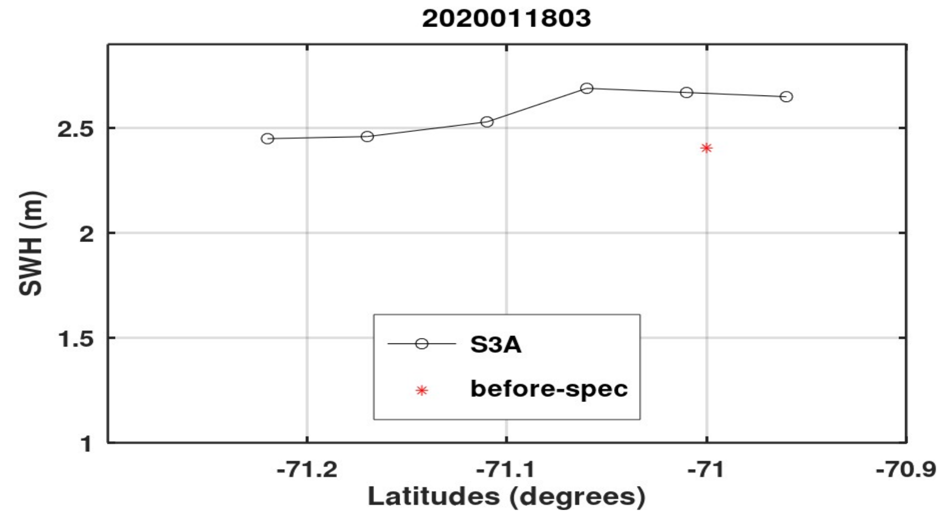
Consistency of DA results at weddell sea (modification induced by sea-ice)

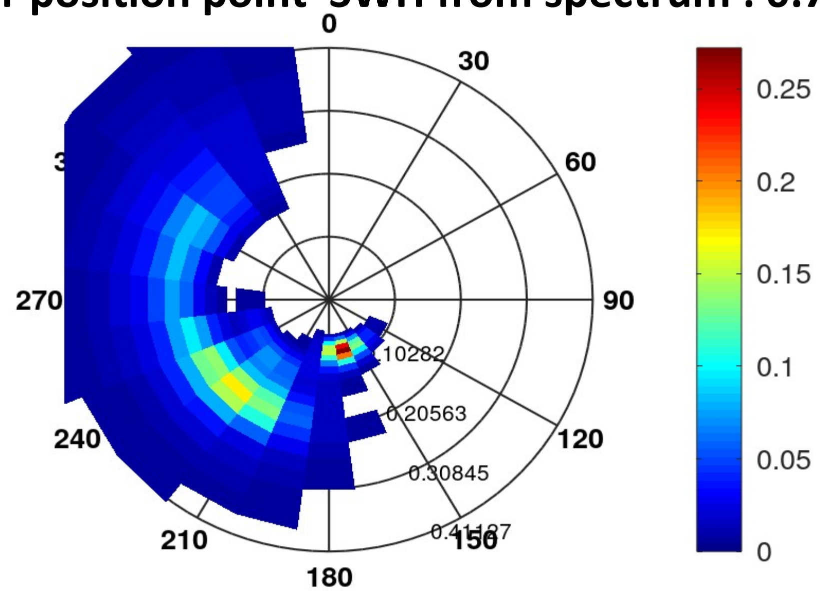
Before SWH from spectrum : 2.41 m



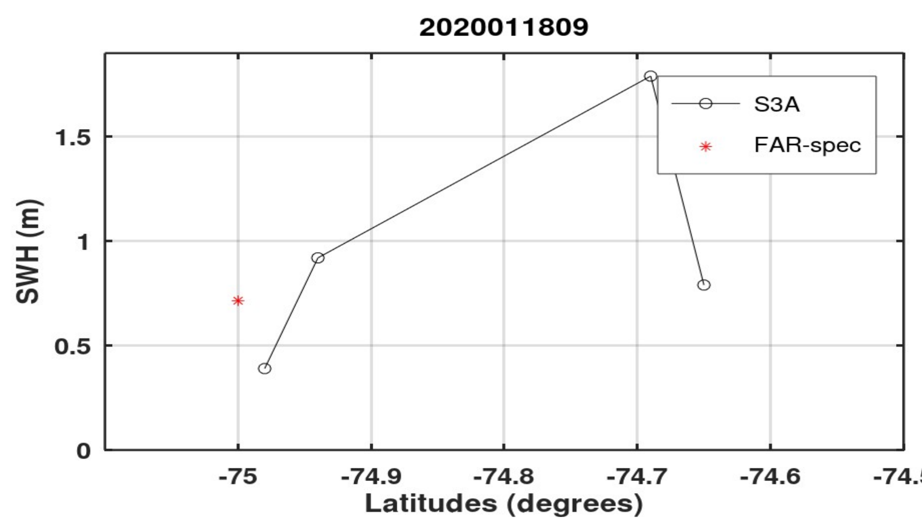
Comparison with S3A (2020011803)



Far position point SWH from spectrum : 0.71 m



Comparison with S3A (2020011809)



Ocean/waves coupling experiments (MFWAM/NEMO models)

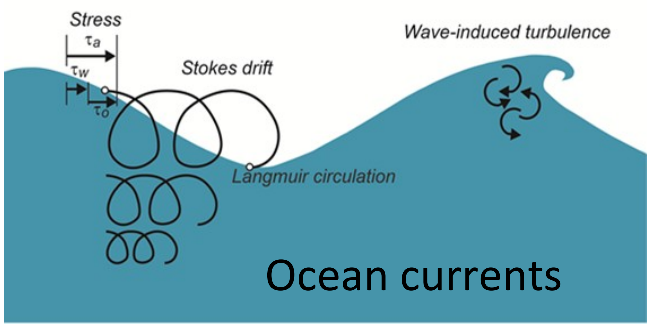
Three coupling processes included (3-hourly Wave forcing) :

→ Stress momentum flux modified by waves

→ Stokes-Coriolis forcing

→ Wave breaking inducing turbulence in the Ocean mixed layer (computed from dissipation term of wave model)

Model MFWAM



NEMO ocean Model

Three runs of coupled NEMO have been Performed (Jan-Feb-Mar 2020) :

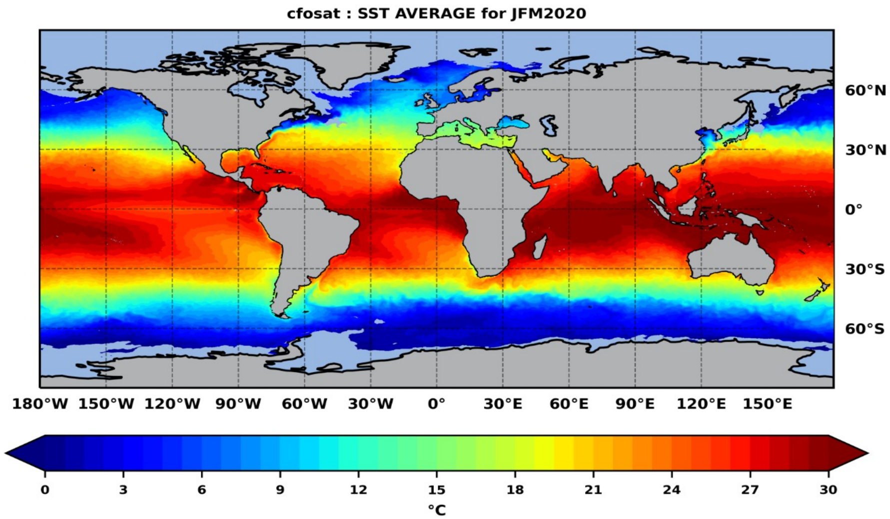
→ NEMO run with wave forcing not Including DA of CFOSAT

→ NEMO run with wave forcing with DA of CFOSAT

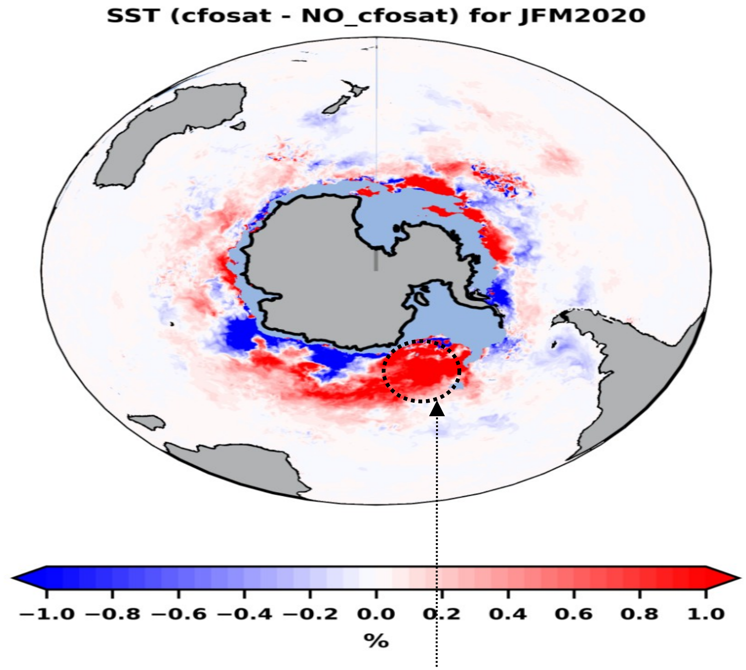
→ NEMO control run without wave forcing

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

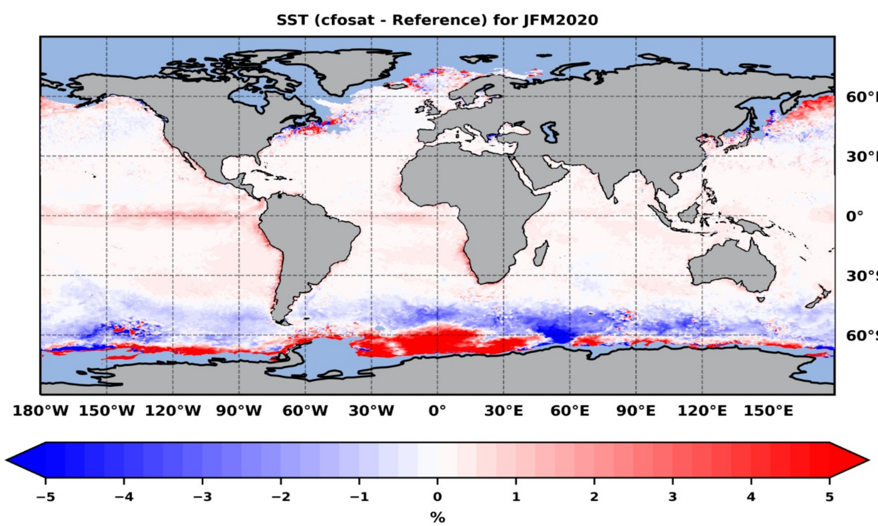
Average SST from NEMO with CFOSAT



Differnce of SST with and without CFOSAT (%)



Global differenceof SST from NEMO With and without waves (CFOSAT)



The assimilation of SWIM data reduces The overestimation of SST indicated by Blueish, but also shows an increase of SST near the MIZ particularly in Atlantic Sector of SO.

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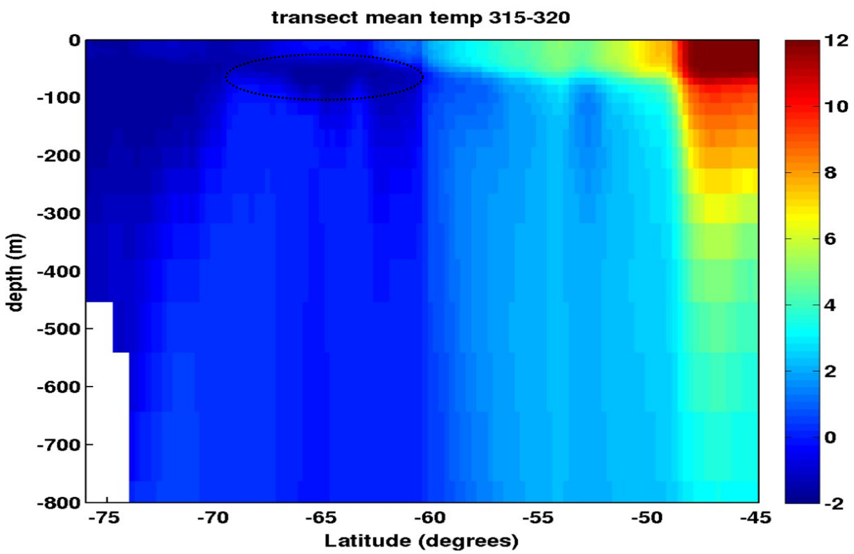
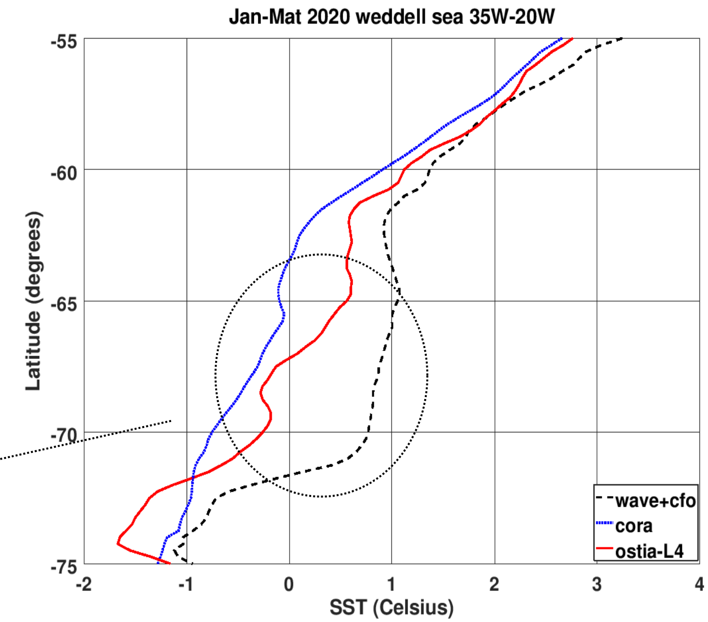
Validation of SST with observations : jan-Mar 2020

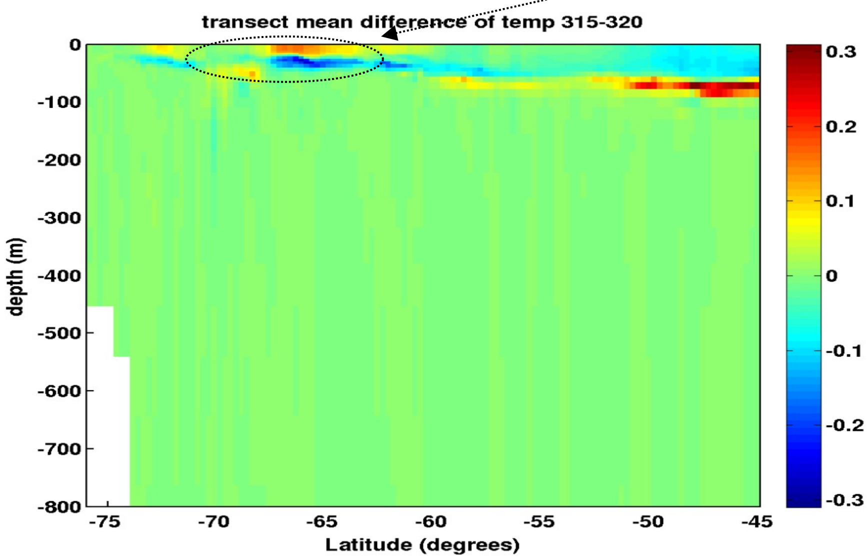
Transect of mean SST (40°W-45°W) from NEMO with wave forcing (DA)



Zonal mean of SST (35°W-20°W)



Mean difference of SST from NEMO with and Without waves



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

The difference of SST between model and Observations 63°S-68°S is in the error Margin.

Conclusions

→ DA of CFOSAT shows the capacity to well describe wave attenuation Induced by the presence of ice floe in the MIZ, typically in Austral summer : successful example in Weddell sea.

→ Sea ice fraction from SWIM could be used as forcing in wave model In order to better spread the impact of DA

→ Improved wave forcing with DA of SWIM directional observations in the coupling with ocean model indicates SST warming at Weddell Sea between 63°S-68°S.

→ Further investigations will be performed to set a source term for wave damping induced by sea-ice.