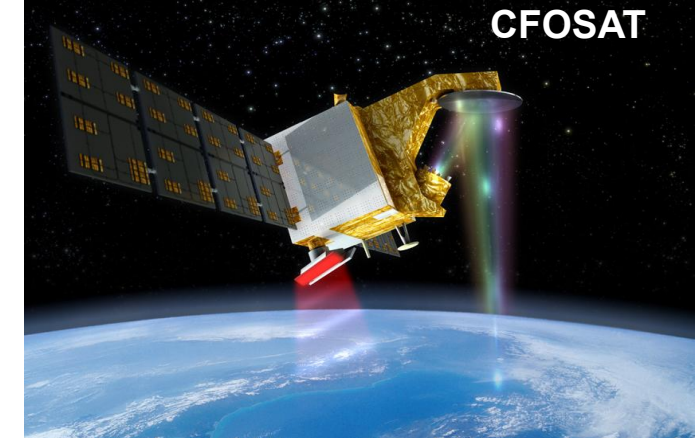


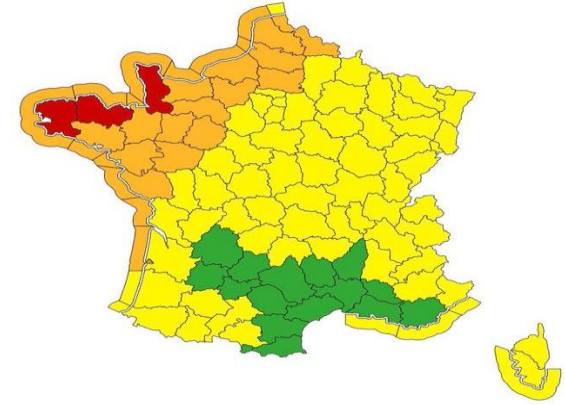


Benefits of satellite wave and wind observations in operational wave forecasting

Lotfi Aouf, Météo-France

Motivation

- Continuous improvement of wave forecasting and reliable wave submersion warnings :Thanks to the assimilation of satellite wave observations (altimeters, CFOSAT, Sentinel-1,...etc) in Near Real Time
- Better understanding of wave coupled processes at the air-sea interface : essential to earth system and ocean prediction
- Preventing extreme wave events from open ocean to coastal regions : safety of people and ship navigation security (dangerous crossing seas (rogue waves))



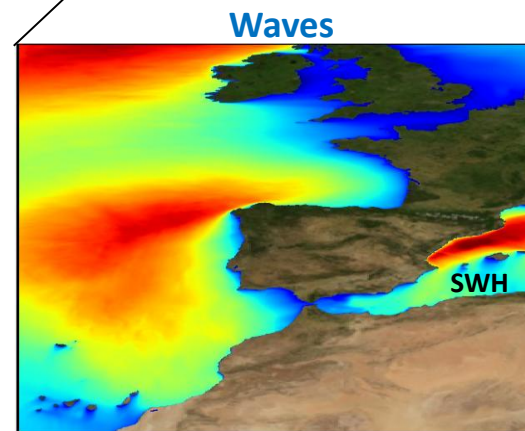
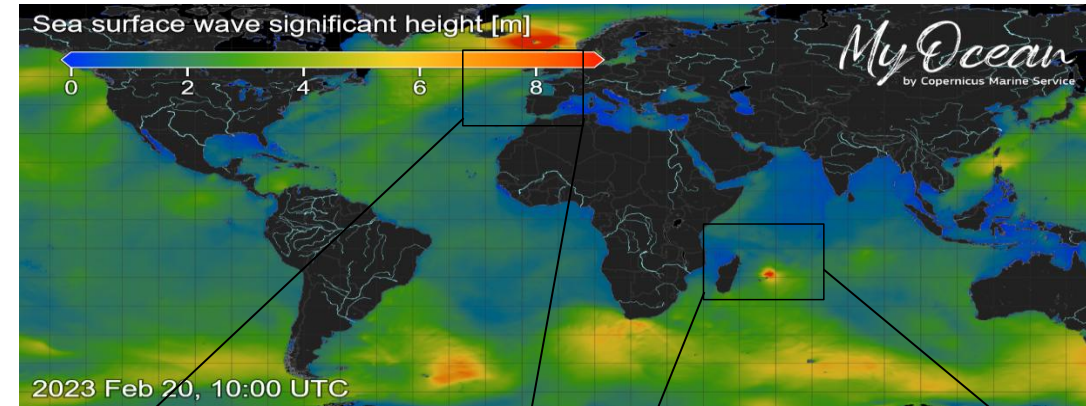
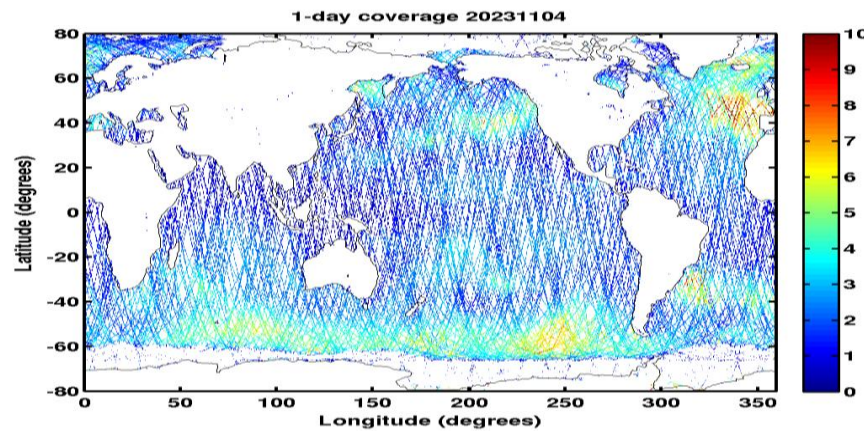
Operational wave systems MFWAM

Snapshot of SWH : global wave products
from marine.copernicus.eu

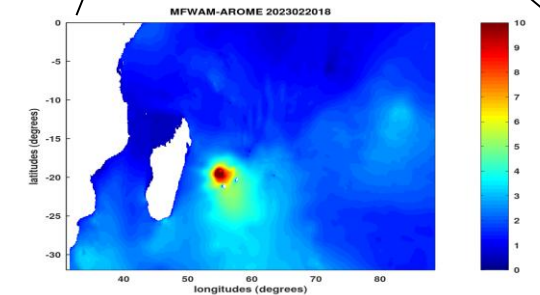
Configuration postcard

Global MFWAM-CMEMS
Grid resolution 10 km
IFS-ECMWF atmospheric forcing
Surface Currents forcing CMEMS-
PHYS
DA altimeters (9 altimeters) and
spectral (CFOSAT and S1)

Example of 9 altimeters daily
coverage in 2024



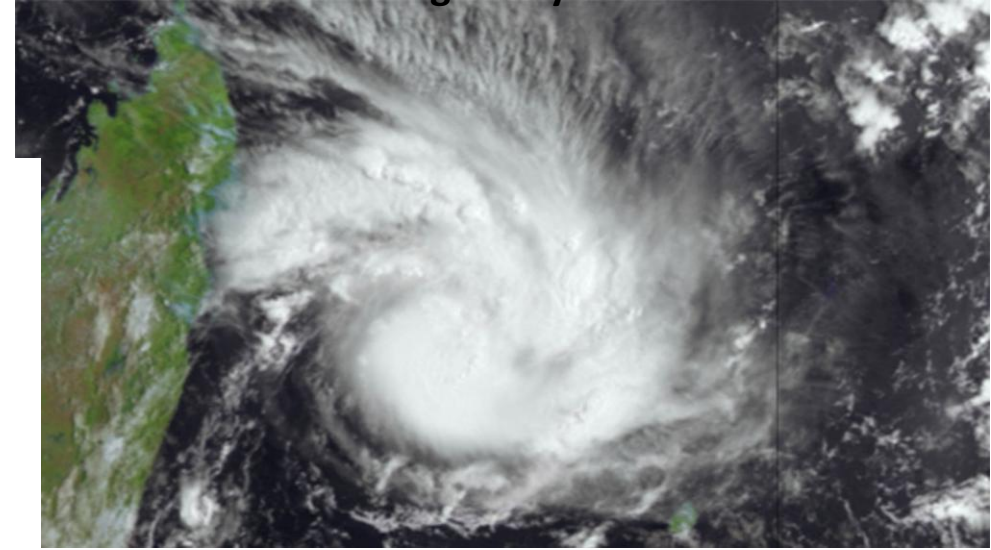
IBI MFWAM model
(NRT: $1/36^\circ \square 2.4$ km)



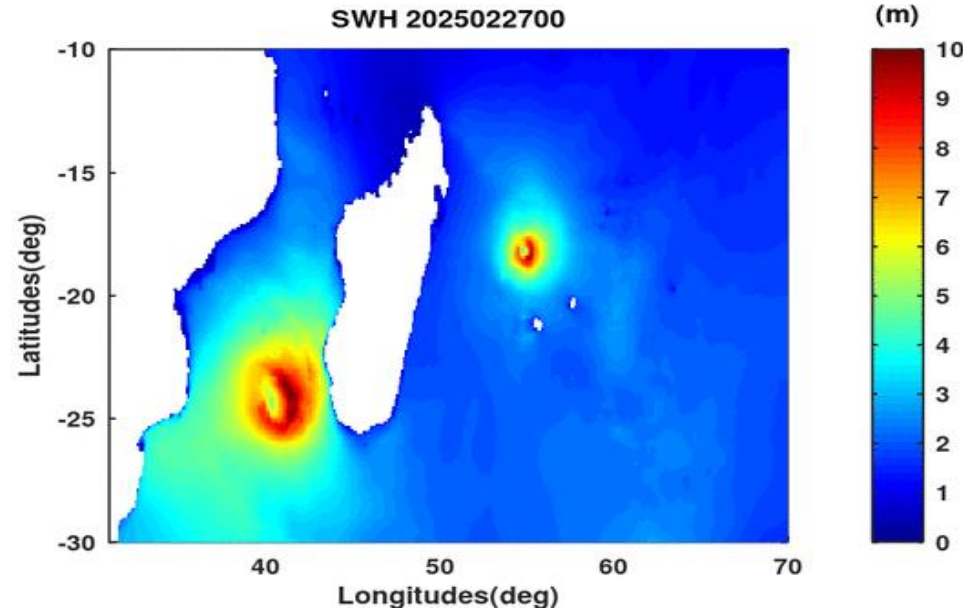
Several high resolution downscaled MFWAM

Wave forecasting in cyclone GARANCE : very damaging extreme event

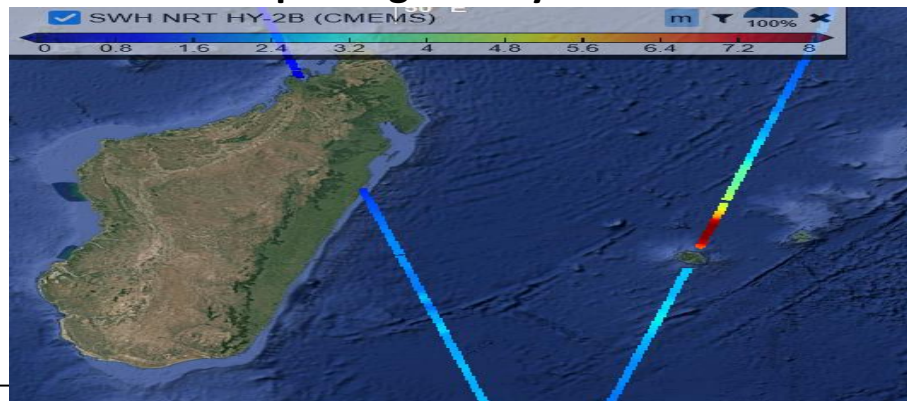
Satellite image of cyclone Garance



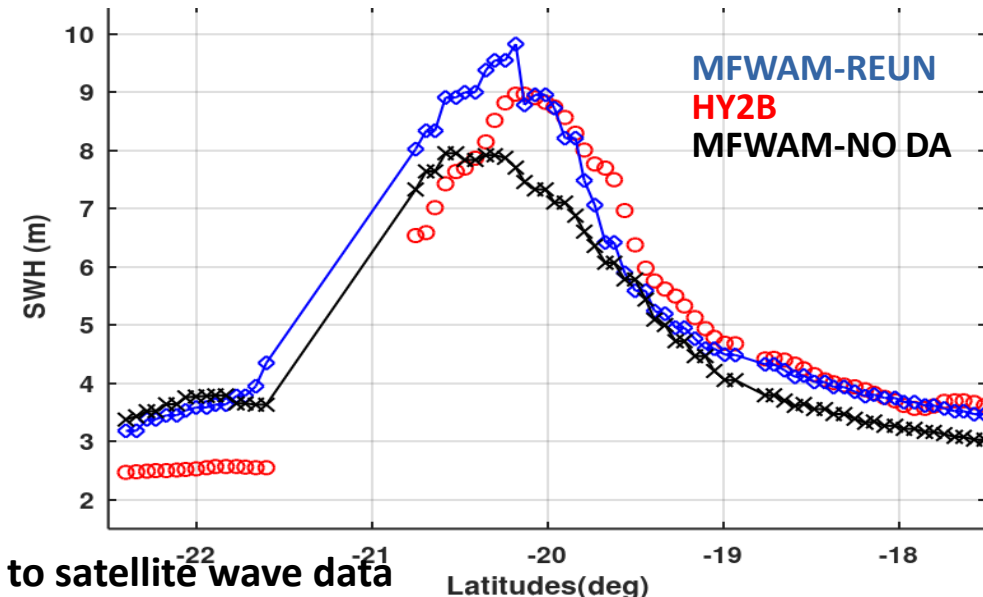
6-hourly snapshots of SWH from MFWAM-Reunion
From 27 Feb. At 0:00UTC until 1 March at 06:00UTC



HY2B tracks passing over cyclone Garance



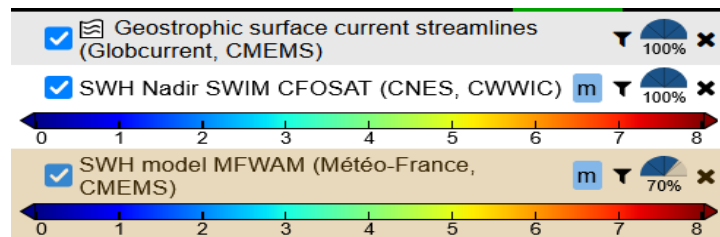
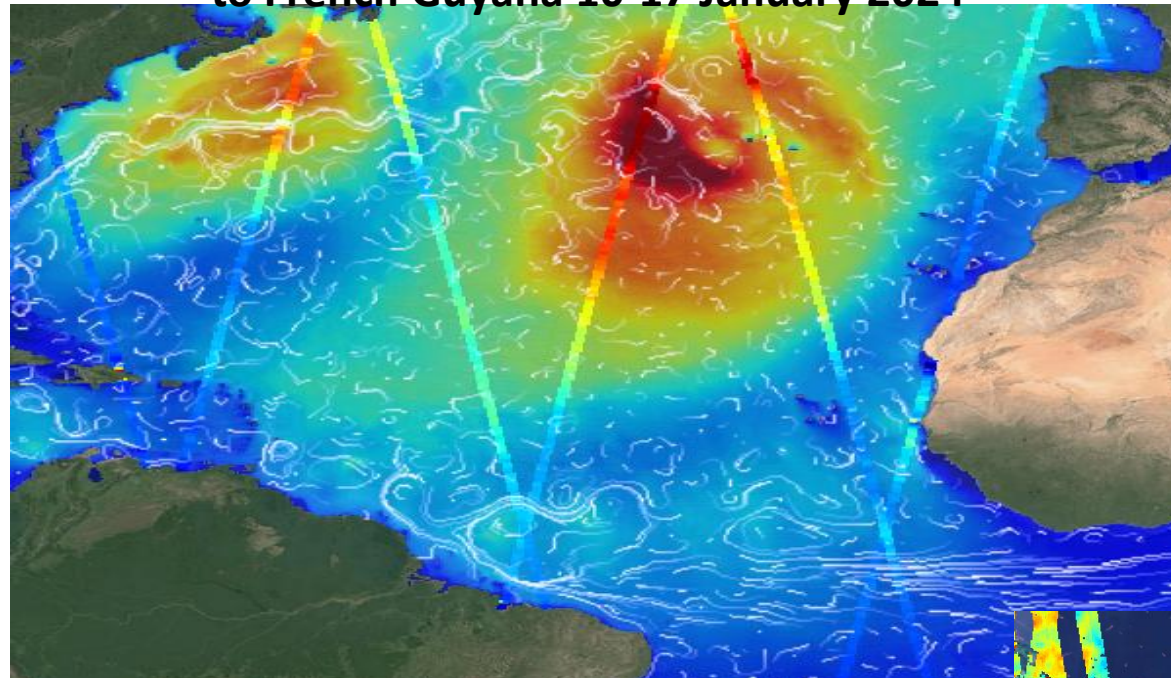
Comparison of SWH with H2B nearby the eye of cyclone
On 28 feb. At 2:00UTC. Good agreement between model
With assimilation and AROME-OM winds



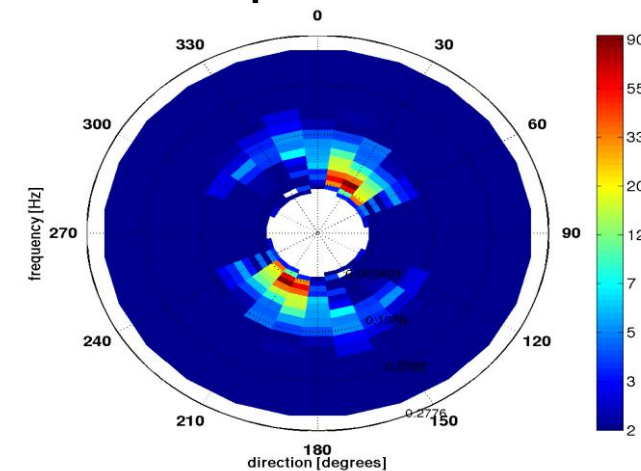
Thanks to satellite wave data

Why we do assimilation of multi-sensors wave observations ?

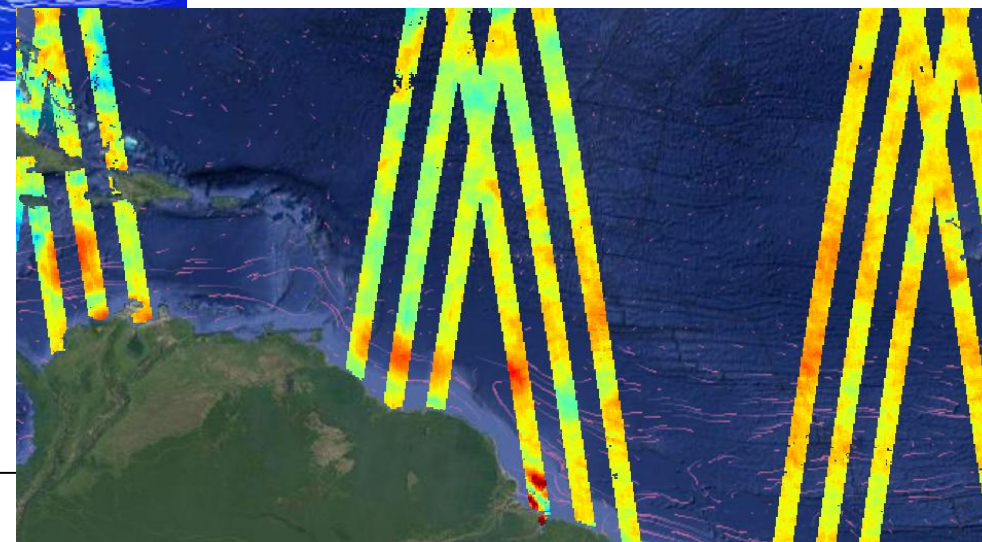
energetic swell propagating from North Atlantic storm to French Guyana 10-17 January 2024



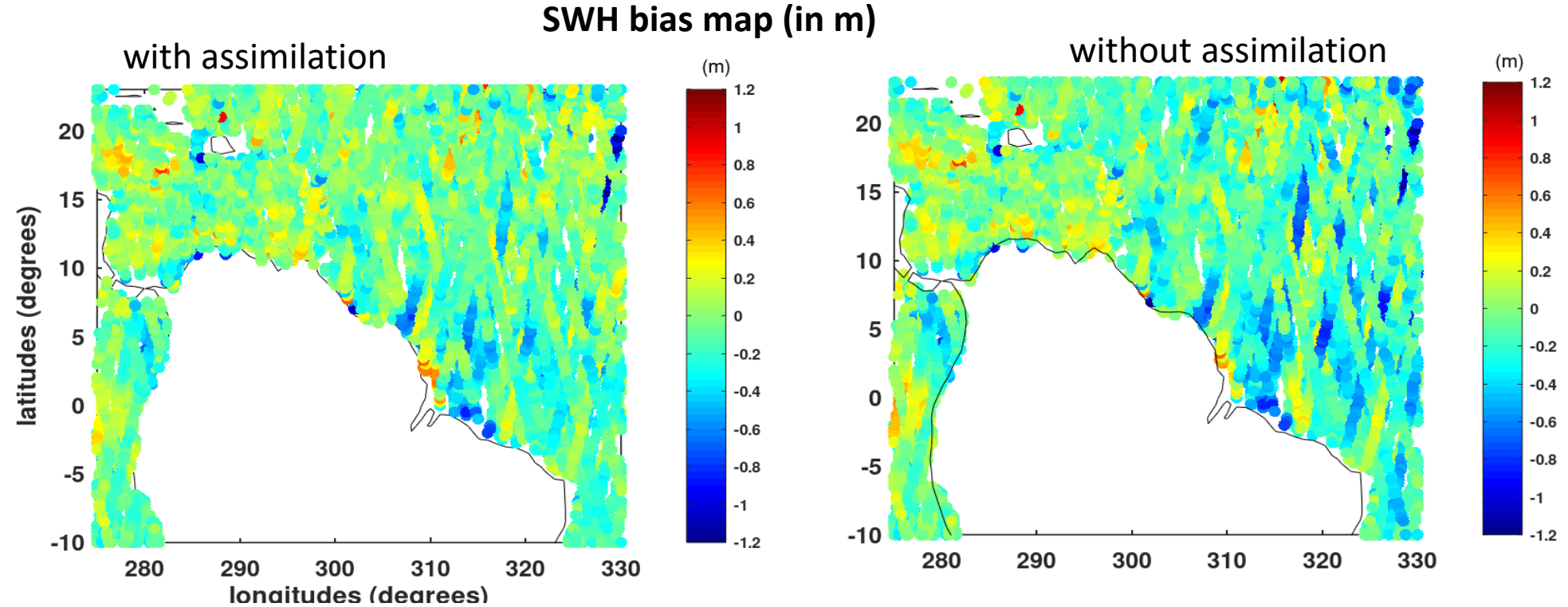
2D wave spectrum from CFOSAT



2D SWH & SSH from SWOT-swath



Combined assimilation of SWOT-swath SWH and wave spectra from CFOSAT in strong wave-current interactions region



energetic swell propagating from North Atlantic storm 10-17 January 2024
Strong reduction of SWH bias during this event. The assimilation of SWOT-swath and SWIM wave spectra improves the standard deviation of SWH in average by 13 %

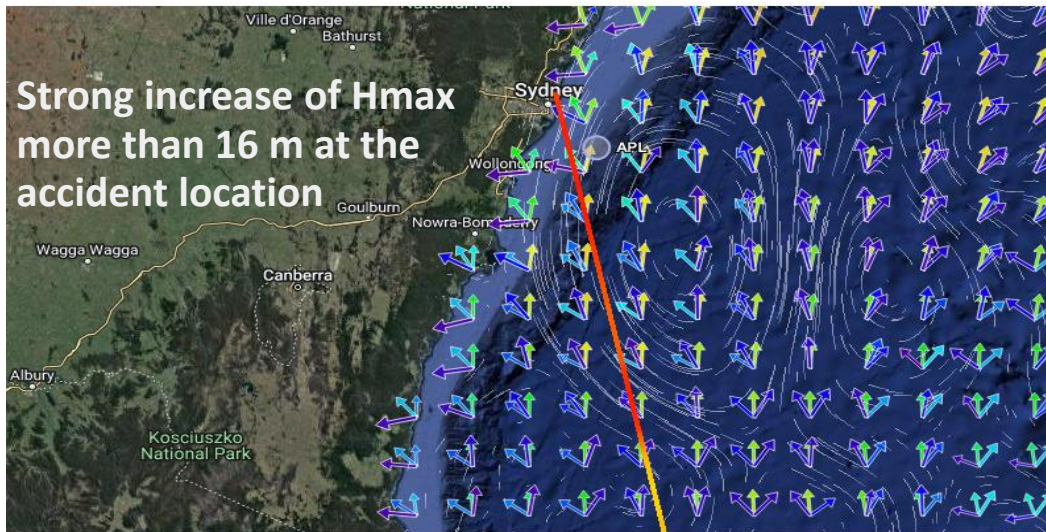
Comparison with independent altimeters

Improvement of dangerous seas and rogue waves detection : thanks to satellite directional wave observations

The case of APL England (24 May 2020 at 6-9h (UTC))



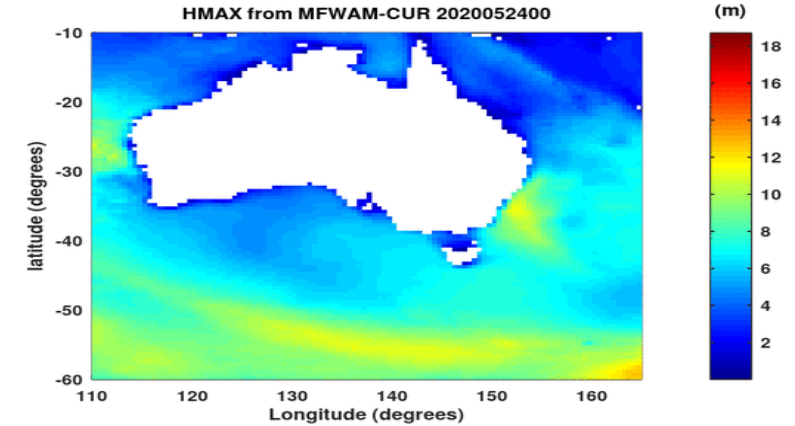
Wind-wave 8.6 sec, 1st swell:9.5sec 2nd swell 12.6 sec



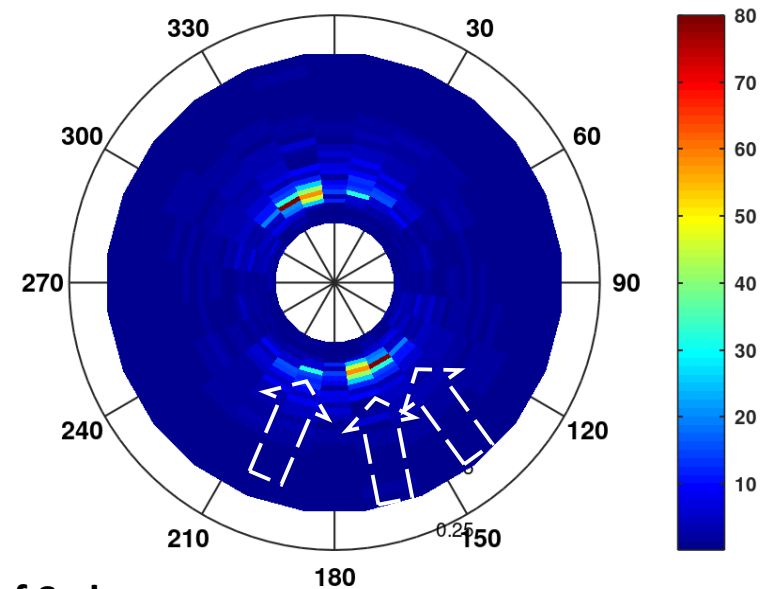
CFOSAT track at 9:25 UTC

Wave-current interactions inducing rogue waves off shore of Sydney

Animation of hmax snapshots during the event (3-hourly from 0:00-21:00)



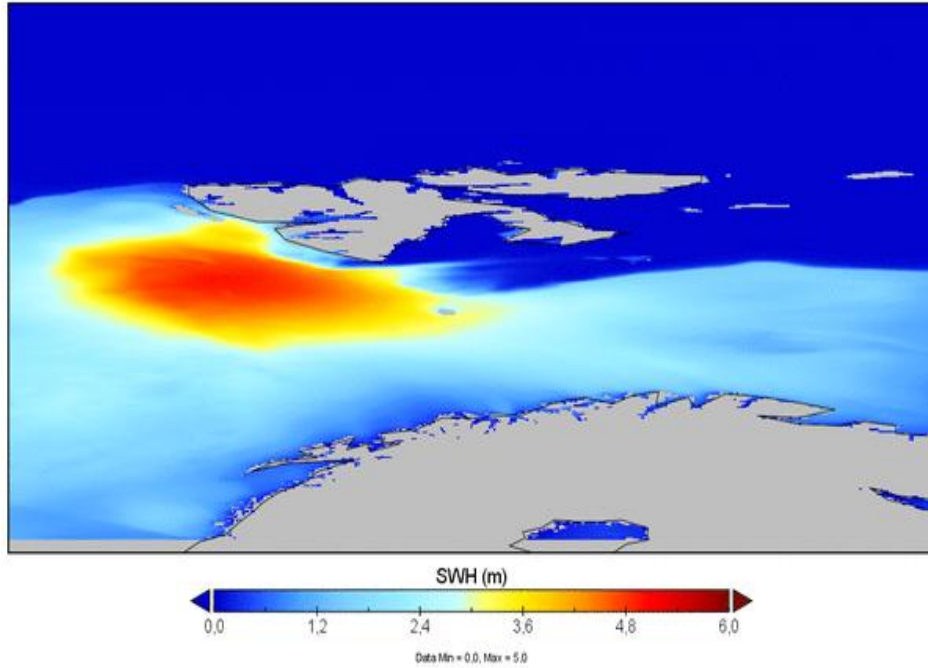
Sea state conditions 40 km from the Location
(increase of skilled parameters BFI2D=0.13)



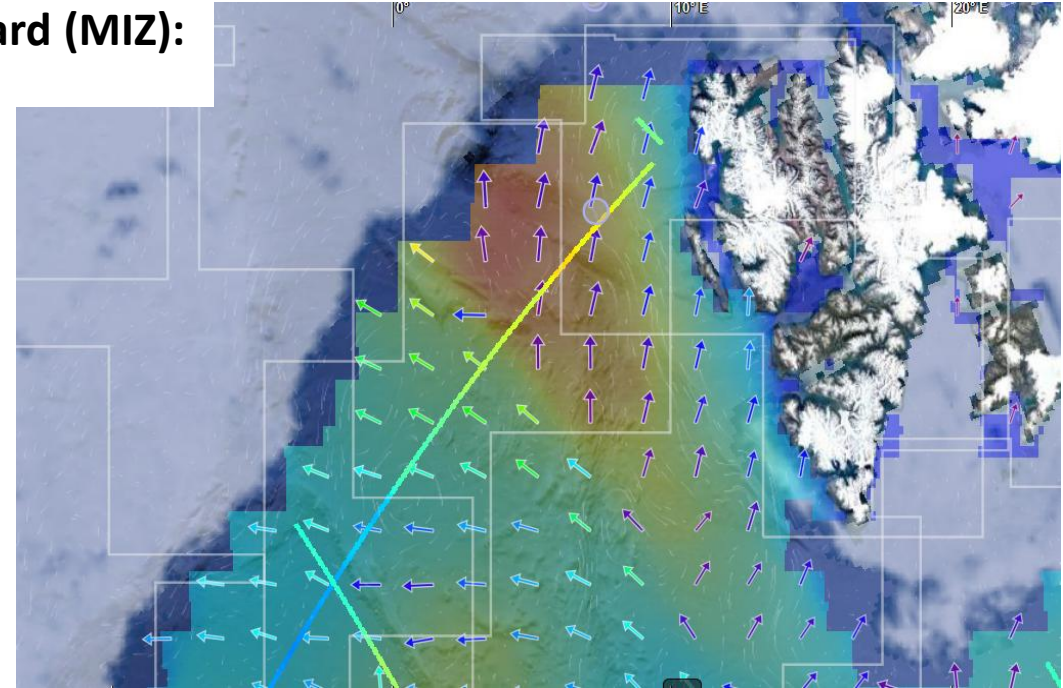
Wave attenuation in sea ice conditions at Svalbard (MIZ): thanks to satellite and drifting wave buoys

Polar storm on 19 April 2024

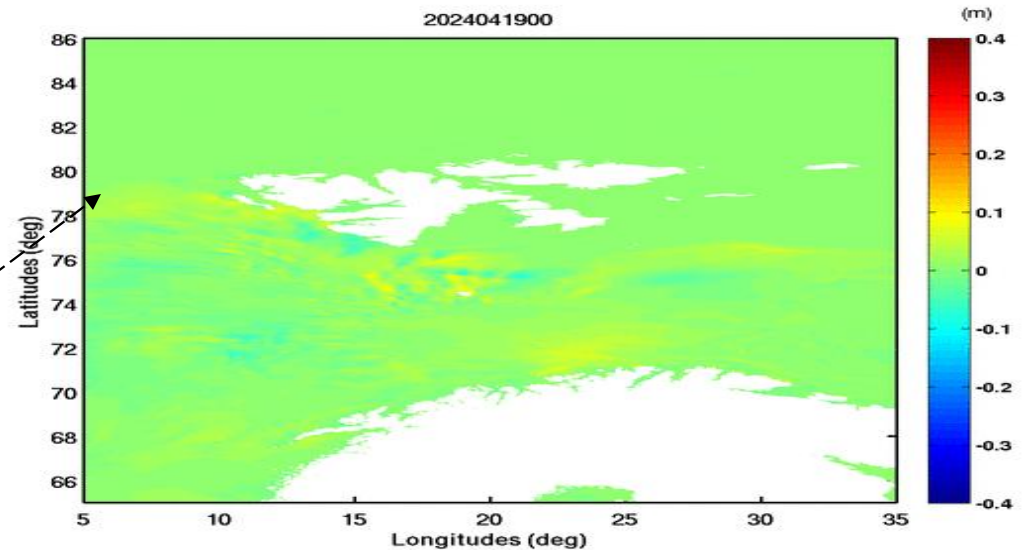
3-hourly snapshots of SWH from
Model with assimilation of CFOSAT



Significant impact near sea ice boudary



3-hourly snapshots of difference with and
without assimilation

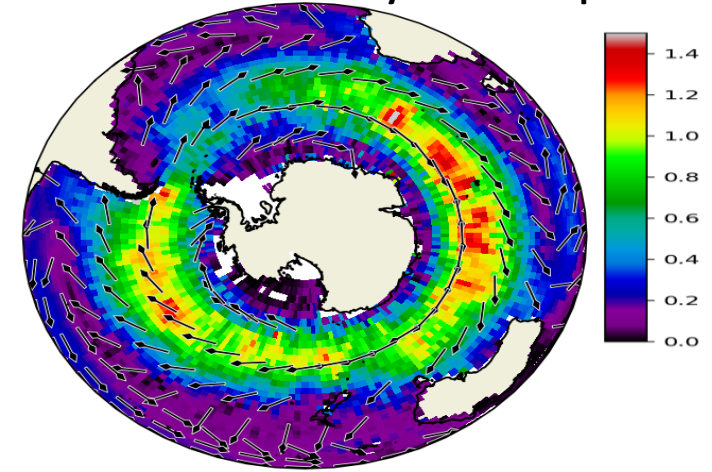


Benefit of wave/ocean coupling in Southern Ocean and Marginal Ice Zone

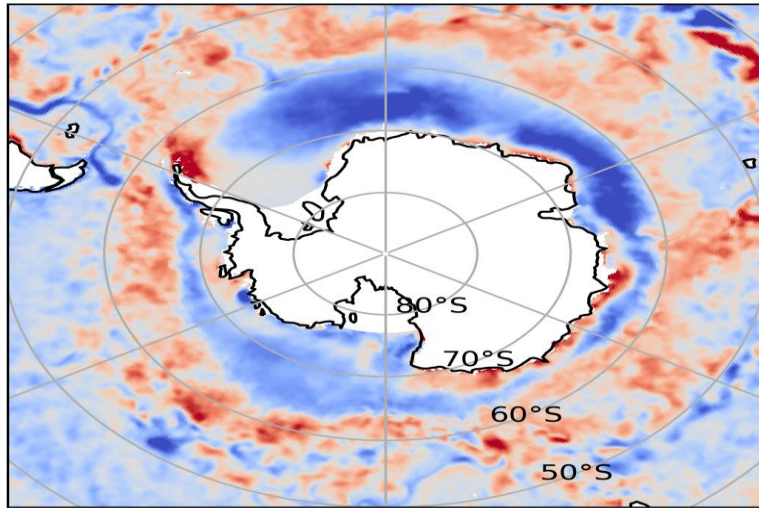
Accounting for wave-coupled processes : surface stress, Stokes drift
And wave breaking inducing turbulence

Sea surface temperature errors compared to
satellite observation OSTIA (DJF 2019-2022)

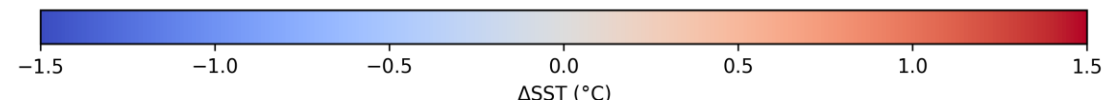
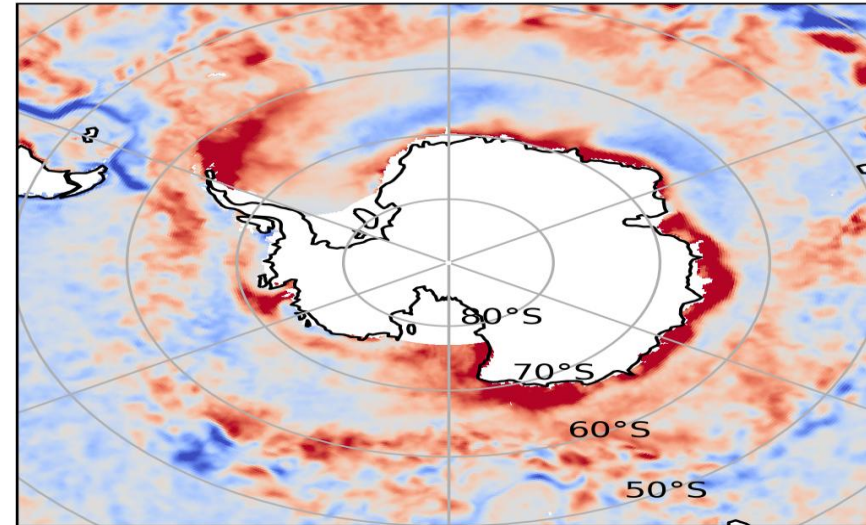
CFOSAT Stokes intensity at 15 m depth



Ocean model without wave coupling



Model with wave coupling

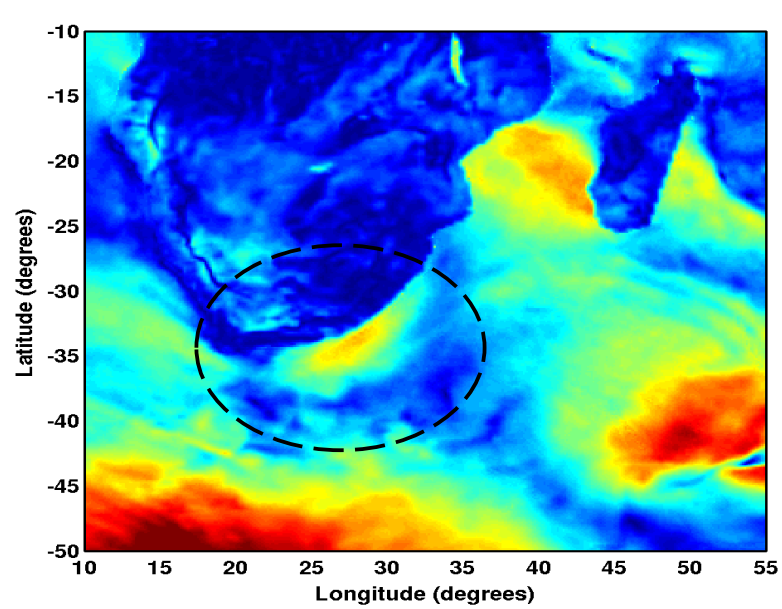


Significant bias reduction in indian ocean and pacific ocean
sectors for latitudes greater the 60°S, where model without
coupling underestimates SST.

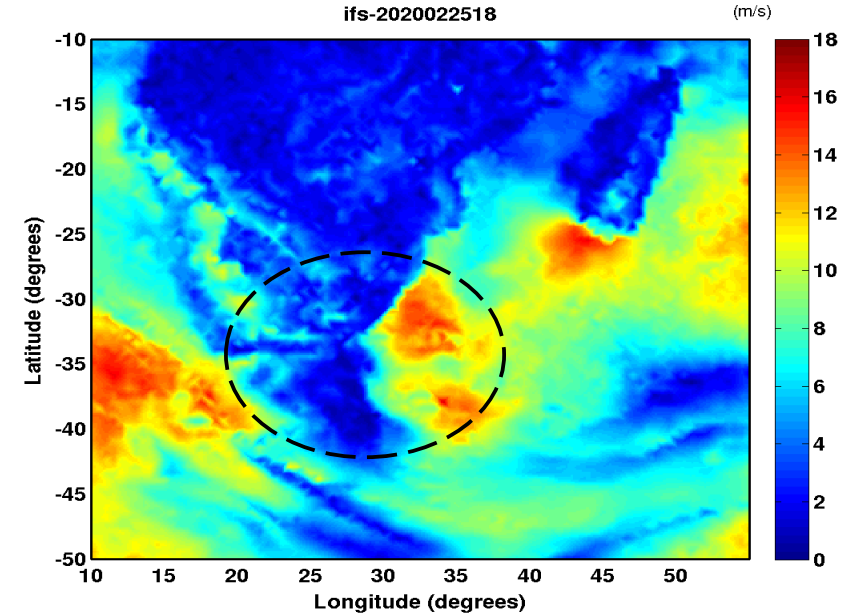
Wind uncertainties in the Agulhas ocean region : Thanks to scatterometers and high resolution SAR of Sentinel-1

Wind speed

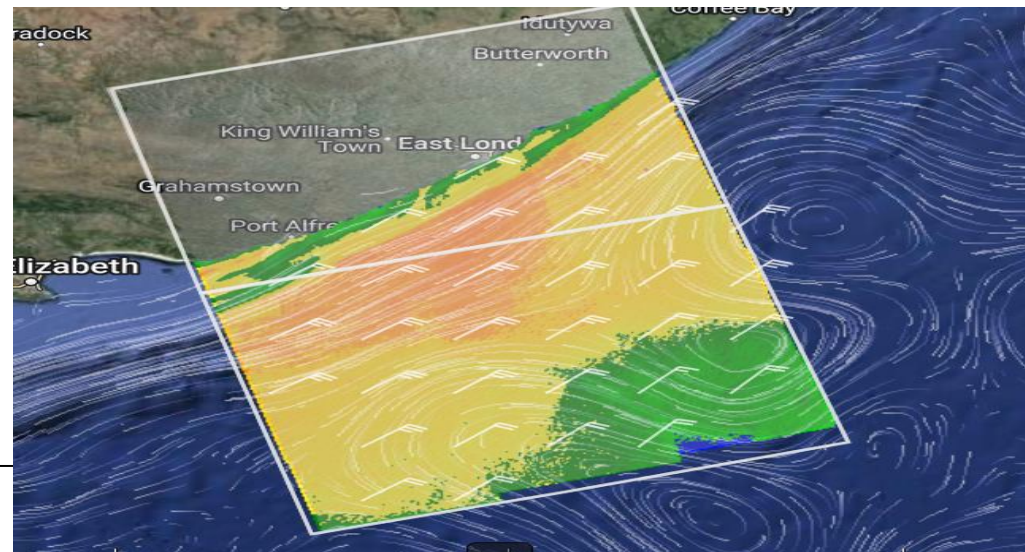
L4 scatterometers winds (CMEMS)



IFS-ECMWF

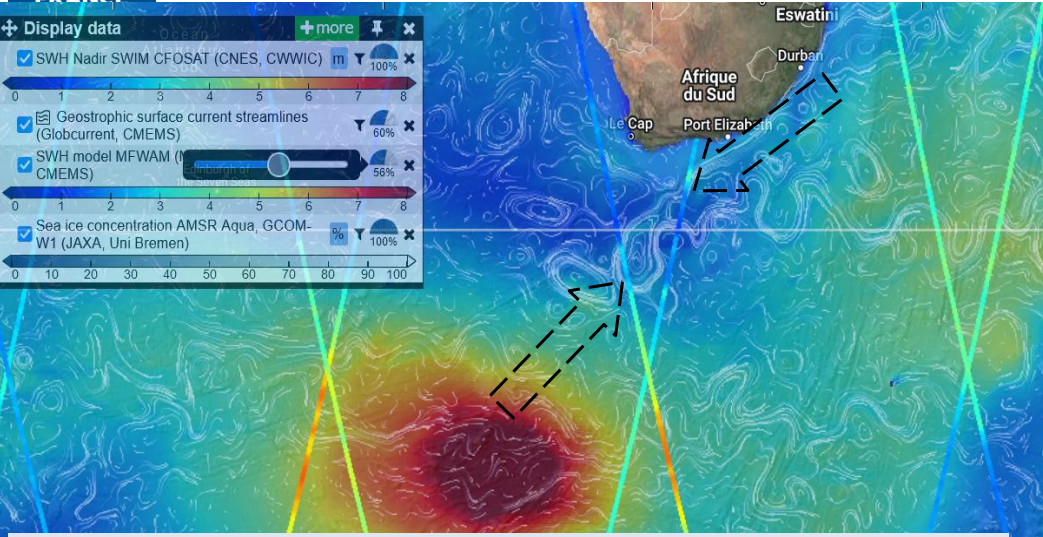


High resolution winds
From SAR of Sentinel-1A :
Rapid increase of the wind
Barbs show wind direction



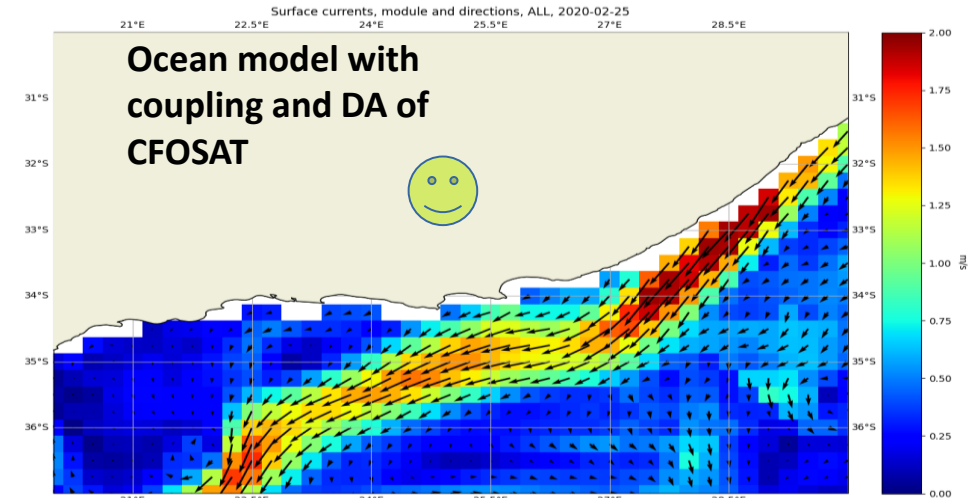
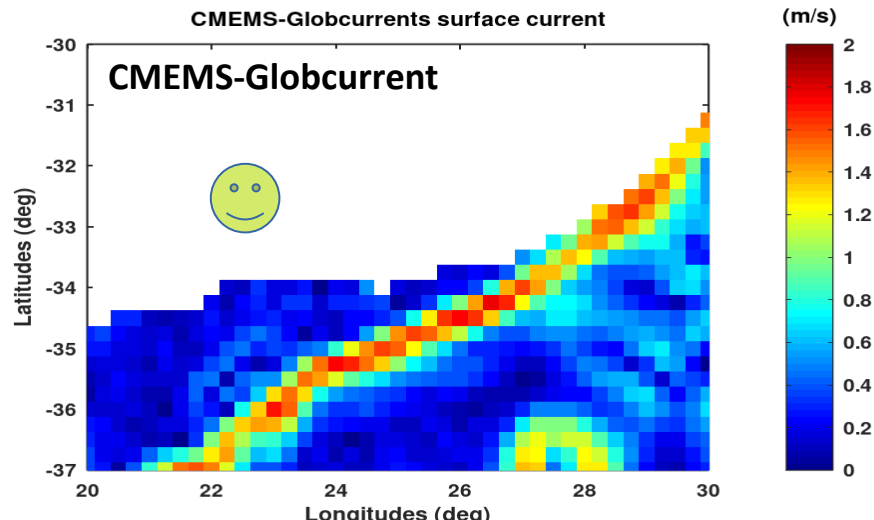
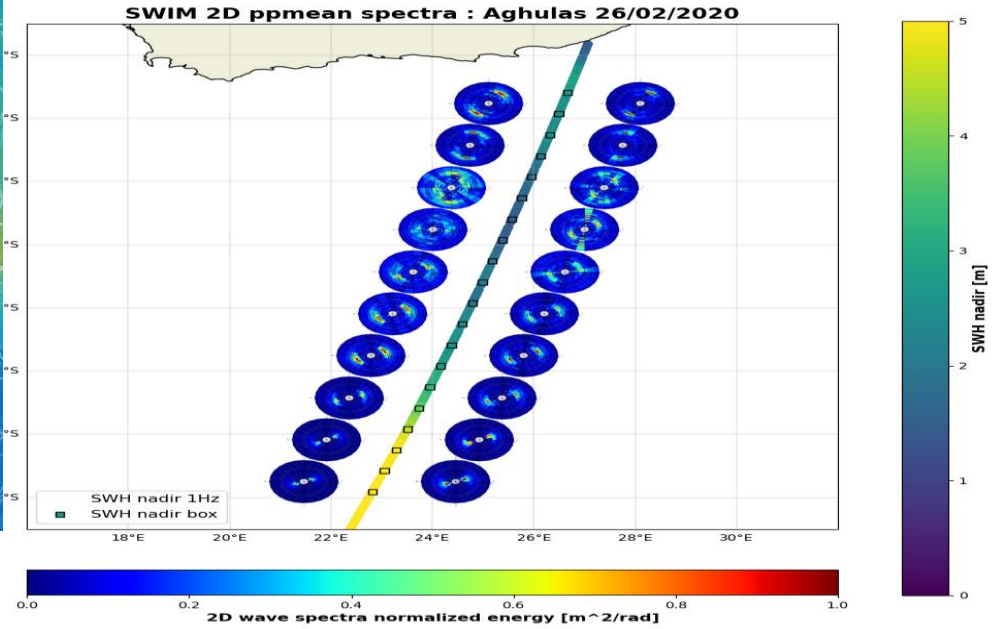
25 February 2020 at 18:00 UTC

Benefit of wave-coupled processes on ocean circulation



Dashed arrows indicate opposing direction between surface current and dominant wave direction

sWIM wave data (SWH and wave spectra)



Improved sea state by DA induces a more consistent trajectory of the Agulhas current (Jan-Mar 2020)

Key messages

- **Essential use of satellite wave observations for operational wave forecasting : Ensuring safety and security in open ocean and coastal areas**
- **Enhanced improvement by using innovative remotely sensed wave observations (CFOSAT, SWOT, Sentinel-1, S3NG,...)**
- **Improved wave-coupled processes plays a key rôle in earth system (impact on atmospheric Boundary layer, upper ocean circulation,...)**
- **Better understanding of wave climate in critical seas : Polar oceans, Marginal Ice Zones,...**