Long term assimilation of directional wave data from CFOSAT in the wave prediction model MFWAM

E. Bedossa[(1)(2)(3)], supervised by L. Aouf [(2)], H. Giordani [(3)], S. Law Chune[(4)]

[(1)] CNES, Toulouse [(2)] Météo-France, DirOP , Département Marine et Océanographie, Toulouse, [(3)] Météo-France - CNRM, [(4)] Mercator Ocean International, Toulouse

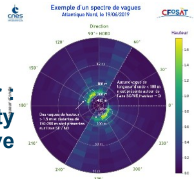
Abstract

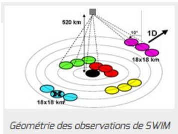
- In recent years, satellite wave observations have stepped forward with the innovative measurements from the wave scatterometer SWIM of the CFOSAT mission which provides both the significant wave height along the nadir-track and the directional wave spectra on each side of the nadir track.
- In climate or ocean circulation models, wave-dependent ocean-atmosphere flows have often been parameterized by surface winds, or have been ignored altogether : too simplistic and far removed from reality.Or in the context of global warming and climate changes, ocean waves forecasting is crucial for predicting and analyzing the exchange of momentum and heat fluxes at the atmosphere/ocean interface and for the protection against natural hazards in coastal regions during severe storms.

The CFOSAT space mission

- Developed jointly by the Chinese (CNSA) and French (CNES) space agencies
- Launched in October 2018 ⇒ data available since January 2019

2 on-board instruments :
- SCAT : wind scatterometer
- **SWIM : wave scatterometer : measures wave energy density and wave numbers and wave heights[(1)]**





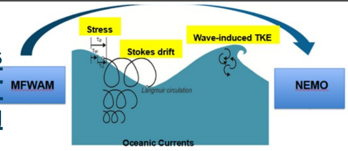
Models and simulations

1st step : assimilation of SWIM data in MFWAM

- Wave forecast model of Météo-France
- Spectral resolution of 24 directions and 30 frequencies
- Assimilation scheme : optimal interpolation

	Grid resolution	Wind forcing	Assimilation of SWH from nadir	Assimilation of wavenumbers components	Period
Run C	0.25°	IFS (CEP)	x	x	2021
Run A	0.25°	IFS (CEP)	✓	✓	2021

2nd step : NEMO simulations with improved or not, wave forcing from MFWAM

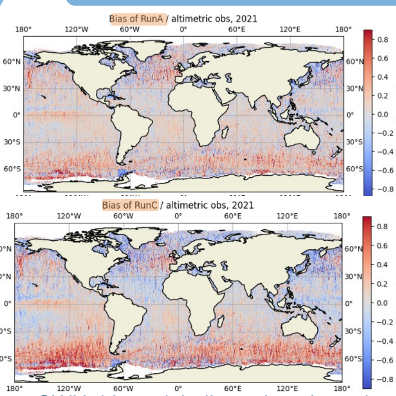


Wave forcing for NEMO computed by MFWAM

Config iORCA025

	Wave forcing from MFWAM	SWIM DA in MFWAM forcing	Wind forcing	Grid resolution
ALL	Stokes drift Stress Wave-induced TKE	SWH (nadir) Wavenumbers components	IFS (CEP)	0.25°
FREE	Stokes drift Stress Wave-induced TKE	No	IFS (CEP)	0.25°

Validation of MFWAM simulations with buoys and altimeters



Area	Exp	Bias (m)	RMSE (%)	SI
Global	RUN C	0.02	12.3	12.3
	RUN A	0.05	10.7	10.5
Tropics	RUN C	-0.03	10.1	10
	RUN A	0.03	8. 9	8.8
Southern Ocean	RUN C	0.22	13.1	11.8
	RUN A	0.15	10.7	10
Arctic	RUN C	-0.1	14.6	14.1
	RUN A	-0.02	13.2	13.2
Middle Latitudes	RUN C	0.02	11.5	11.5
	RUN A	0.05	10.2	10.1

Fig. 1 and Table 1 :Validation of Significant Wave Heights (SWH) in MFWAM simulations in 2021 with Jason3, SARAL, Sentinel-3A and B, CryoSat-2, HII-B

SI reduced for every type of waves, especially for long waves (Tp > 13s) : up to 34 %

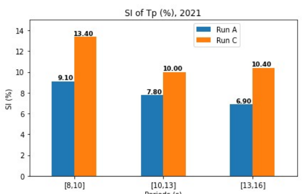


Fig. 2 : Validation of Peak period (Tp) in MFWAM simulations in 2021 with SOFAR (SPOTTER) buoys

- SWH bias globally reduced, and particularly in depressions track in NH, a part of Southern Ocean, North and South Pacific ocean
- Still a large SWH bias in the Southern Ocean relative to uncertainties in the wind forcing

Impacts on integrated wave parameters In the Southern Ocean

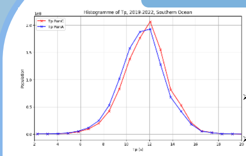


Fig. 3 : Histogramme of T_p for Run A and Run C in the Southern Ocean, 2019-2022.

Wave age is an indicator of wave dependence on wind : $wave_{age} = \frac{c_p}{U_{10} \cdot \cos\theta}$ With $c_p = \frac{g T_p}{2\pi}$ The peak velocity phase and T_p the peak period

- Waveage = 1.2, the equilibrium between wave and wind fields is reached
- Waveage < 1.2 : the dominant wave regime is the wind sea
- Waveage > 1.2 : the dominant wave regime is swell[(2)]

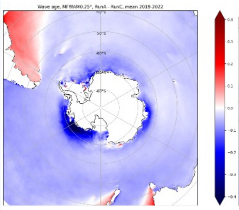


Fig. 4 : Impact of the SWIM DA on the wave age (RunA- RunC) 2019-2022.

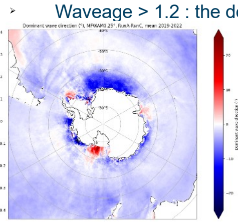


Fig. 5 : Impact of the SWIM DA on the domin direction (RunA- RunC) in the Southern Ocean, 2019-2022.

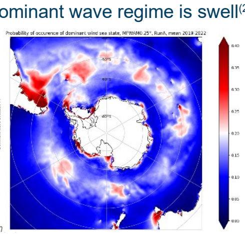


Fig. 6 : Probability of occurrence of swell in RunA in Southern Ocean, 2019-2022

- T_p smaller in RunA compare to RunC ⇒ so is waveage ⇒ wave growth and spread are impacted by SWIM data assimilation
- Southern Ocean is an area with infinite fetch with nonlinearities driving the transition from wind to swell waves : SWIM data assimilation helps reduce these model uncertainties[(3)]

Impacts on ocean key parameters

Integrated wave parameters significantly impacted by SWIM data assimilation ⇒ so are wave-ocean coupling processes

- **Correction of model bias ? → validation of surface currents with AIS data[(4)]**
- **What are the impacts of better represented waves on ocean key parameters? → case of an subtropical storm near Aghulas current**

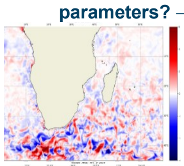


Fig. 7 : Impact of the SWIM data assimilation on the SST (ALL - FREE) in Aghulas current

- Strong SST gradient in the current in ALL simulation
- Waves create an ondulation in this gradient : creation of dipolar structures

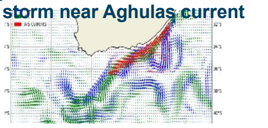
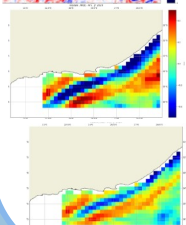


Fig. 8 : ALL, FREE and AIS surface current s

How can we explain that only the ALL simulation is in agreement with the AIS observations?



	Mean bias (m/s) of surface module current
FREE	0.21
ALL	0.15

Fig. 9 : Bias of surface current module of FREE simulation (above) and ALL simulation (below) compare to AIS observations, in Aghulas current (JF 2020)

⇒ Uncertainties related to IFS wind forcing at 10m in this area

⇒ Modification of wind stress received by waves

⇒ Mean wave direction impacted

⇒ A more accurate and faithful description of the directionality of the various wave trains through the assimilation of SWIM data 'compensates' for the wind forcing missfit

Conclusions – Next steps

- Data assimilation reduces model bias on wave height and peak period and reduces the scatter at high latitudes, in the Tropics and in strong currents areas.
- The best corrected wave systems are long waves with peak periods greater than 13s.
- Data assimilation has a impact on the waveage and compensates for uncertainties due to non-linearities in the transition from wind waves to swell in the Souther Ocean.
- Wave forcing for NEMO improved with SWIM DA leads to a significant improvment of the representation of the module and direction of the current of Aghulas
- Ocean key parameters like SST are sensitive to wave forcing improved with SWIM data during a subtropical storm

References

[(1)] *Hauser et al. (2017) SWIM: The First Spaceborne Wave Scatterometer*

[(2)] *Pierson and Moskowitz (1964), Alves et al. (2003)*

[(3)] *Aouf, L., Hauser, D., Chapron, B., Toffoli, A., Tourain, C., & Peureux, C. (2021). New directional wave satellite observations: Towards improved wave forecasts and climate description in Southern Ocean. Geophysical Research Letters, 48, e2020GL091187*

[(4)] Le Goff, C., Boussidi, B., Mironov, A.,Guichoux, Y., Zhen, Y., Tandeo, P., et al. (2021). Monitoring the greater Agulhas Current with AIS data information. Journal of Geophysical Research: Oceans, 126, e2021JC017228. https://doi.org/10.1029/2021JC017228

emma.bedossa@meteo.fr

Météo-France - 42 avenue Gaspard Coriolis, 31100 Toulouse

JC² CNES

16, 17, 18 octobre 2024 - Toulouse