Lotfi Aouf, science lead of CFOSAT
Météo-France, CNRM

Boissonas 1912

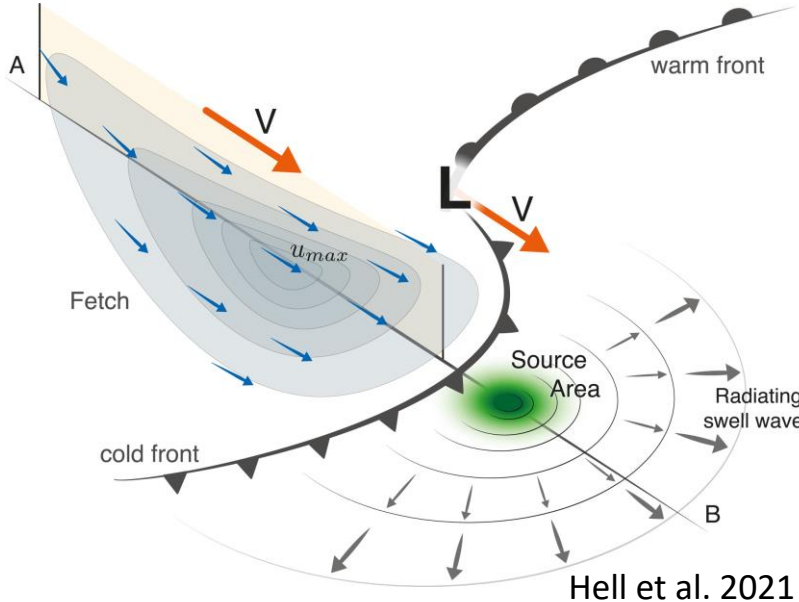
Objectifs de la proposition CFOSAT-NG

- **Observations directionnelles de vagues, de vent et de courants de surface : mieux comprendre les processus physiques complexes et échanges de flux entre l'oéan et l'atmosphère**

- **Améliorer la description de variables essentielles (vent,vagues, courant) pour la sécurité maritime, la prévision opérationnelle de l'état de la mer et de l'océan : Évènement extrêmes, protection des biens et des personnes**

- **Unique synergie entre les observations de courants de surface décrivant petite et grande échelle de circulation océanique (SWIM-NG et SCAT-NG)**

Interactions vent/vagues/courant

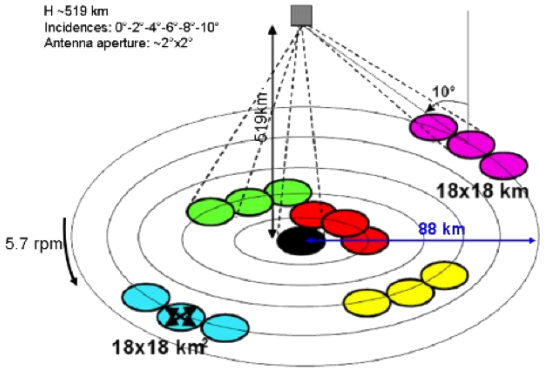


Hell et al. 2021

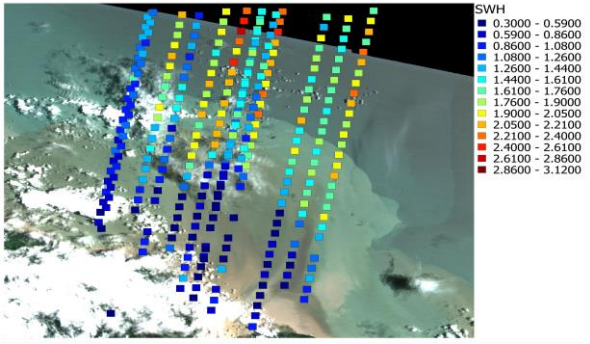
Concept unique de CFOSAT

- Transition from short wind-waves to long wave (growth, extreme,...)
- Wind variability in critical seas
- Better sampling of SWH nadir
- Stokes drift, sea-ice fraction,...etc

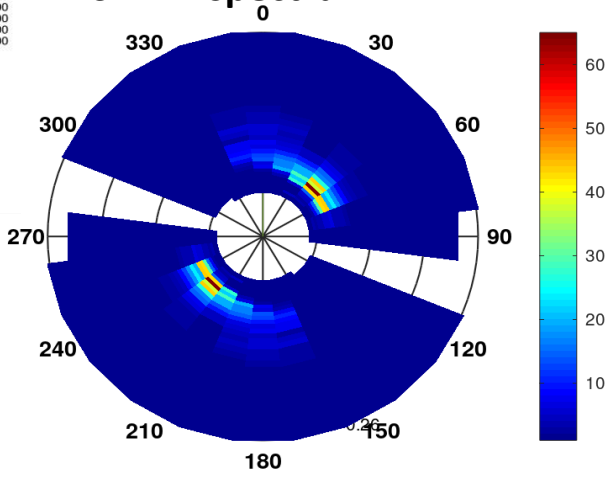
SWIM : diffusiomètre (RAR) à vagues



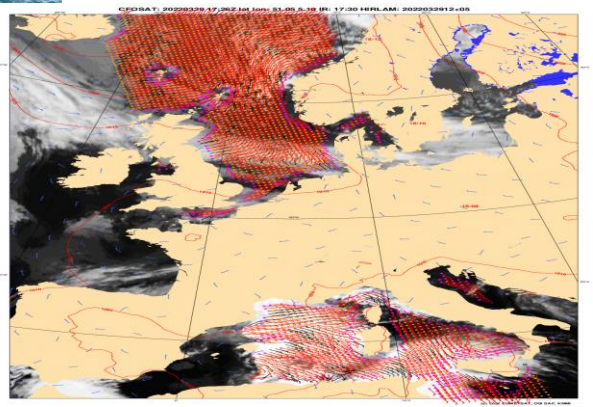
SWH nadir



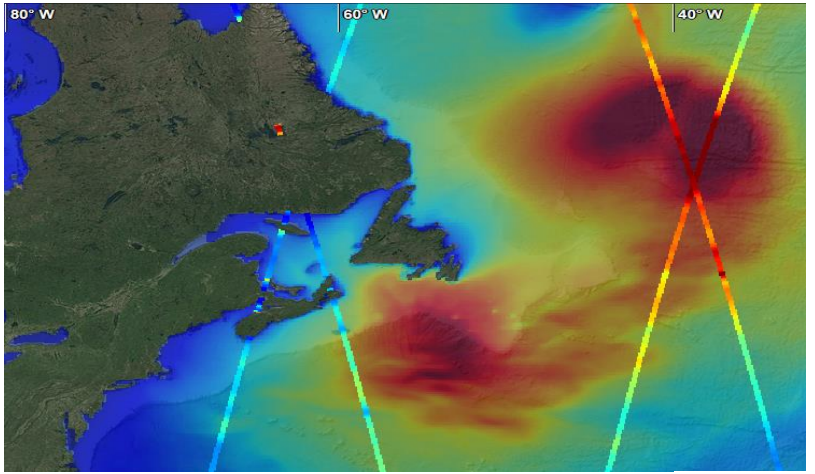
SWIM spectrum

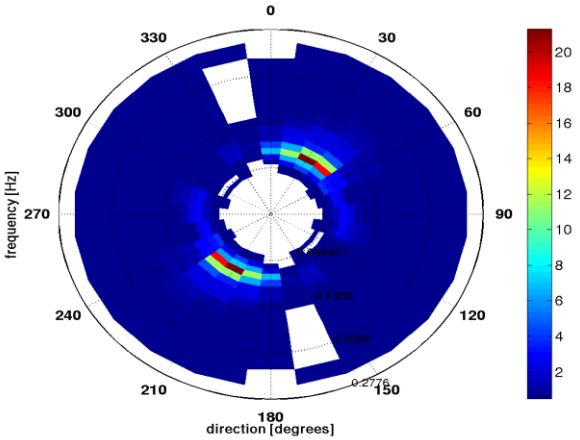


SCAT wind vectors



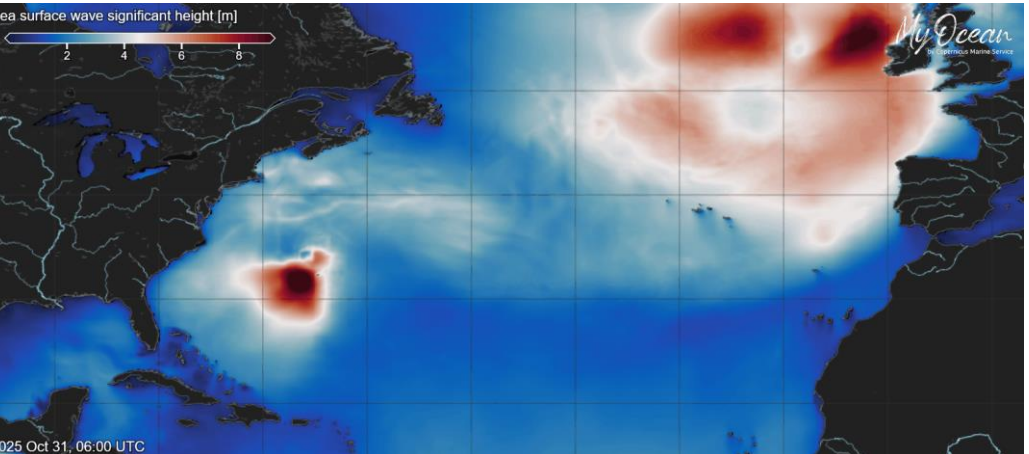
Sur les traces de l'ouragan Melissa 1-2 November 2025 : Spectres directionnels de SWIM durant les évènements extrêmes



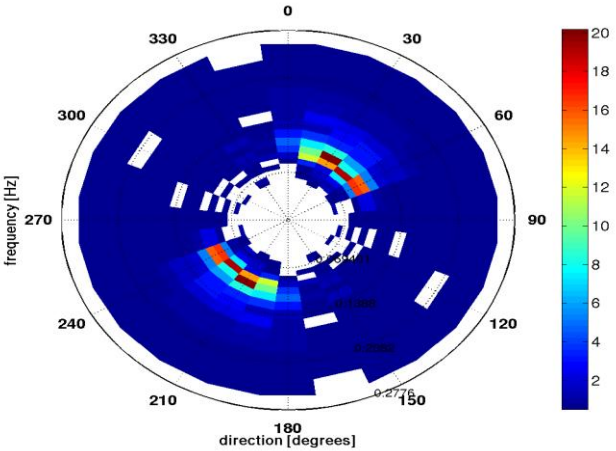


Vigilane vagues submersion Orange à Saint-Pierre et Miquelon

MFWAM-CMEMS SWH



Assimilation de CFOSAT pendant l'ouragan Melissa



Evolution des vagues dominantes spectres directionnels SWIM

CFOSAT : successful achievements beyond expectations

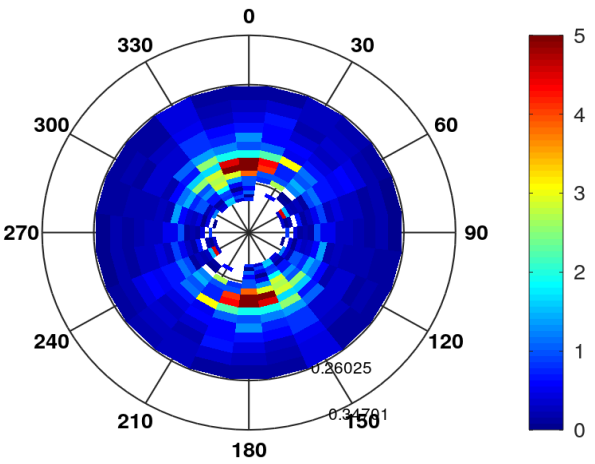
- **SWIM directional wave spectra are game changer for operational wave forecasting :**
  - **efficiency of the assimilation to recover model limiations (non-linear interactions and swell dissipation)**

- **Better understanding of coupling between ocean/waves/atmosphere (Stress, Stokes,...):**
  - **Promising perspectives to earth system and climate studies.**

- **Exploring wave variability in critical ocean regions : Marginal Ice Zone**
  - **Thanks to SWIM sea ice products and directional observations**

- **Better understanding of waves generation in extreme conditions and rogue waves detection (dangerous seas indicators)**

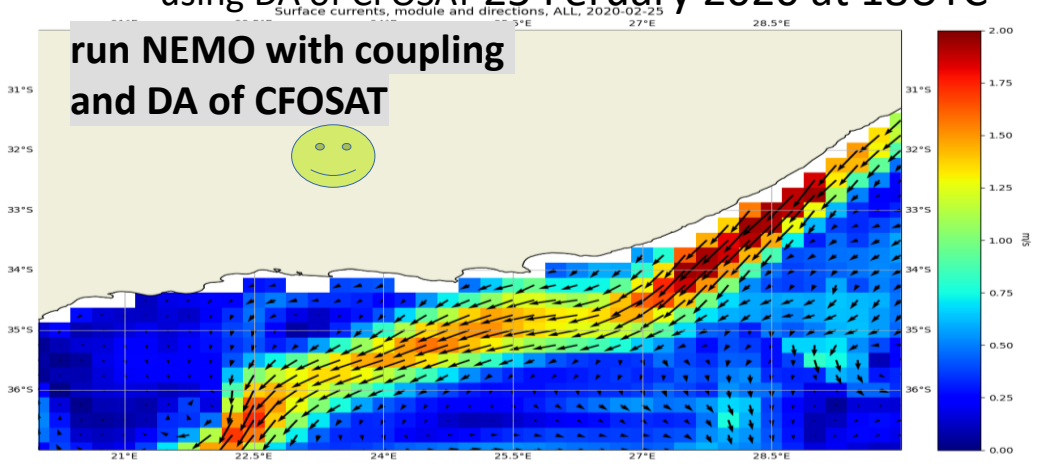
- **Exploring SWIM and SCAT observations synergy : innovative wide swath SWH retrieval**



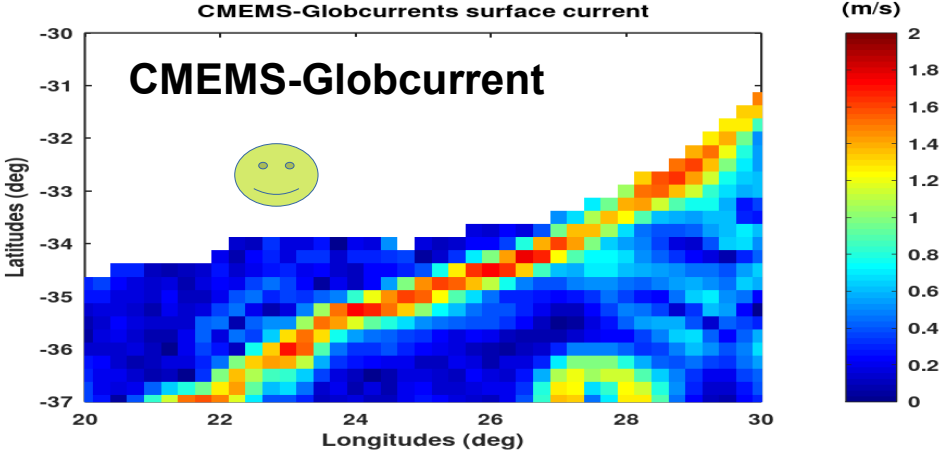
Impact of the assimilation of SWIM spectra in a coupled ocean/wave experiments (Aouf et al. 2024)

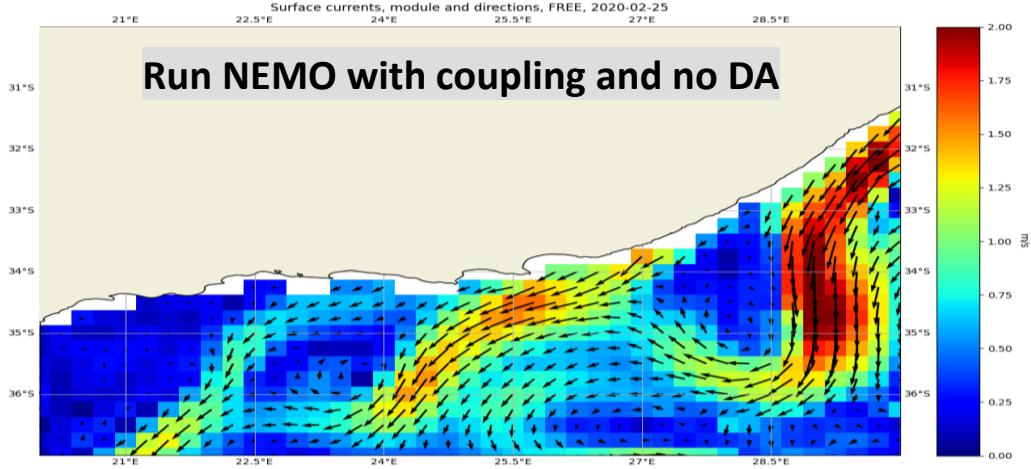
➡ Improved sea state by DA compensates the uncertainties on wind forcing and acts as a nudging to an improved upper ocean circulation in strong current
regions (currents trajectory and SST fronts)

Improved current trajectory when using DA of CFOSAT 25 Feruary 2020 at 18UTC

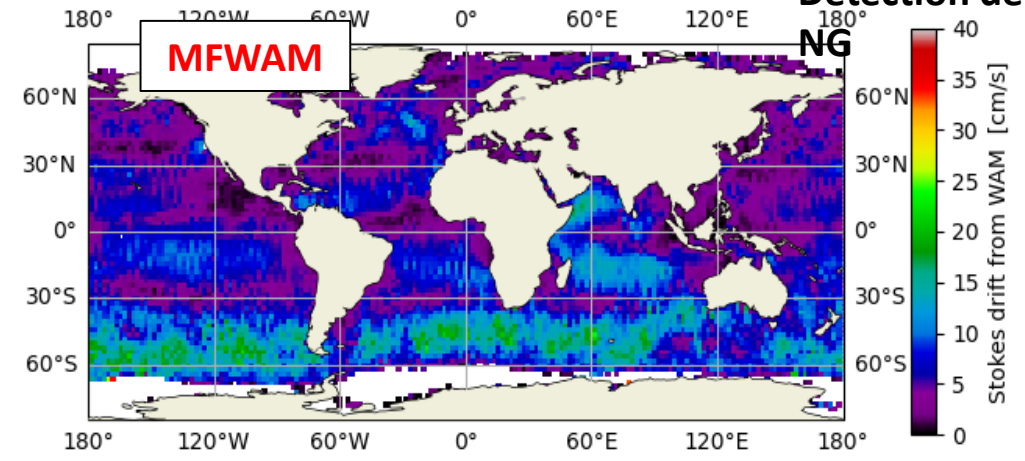


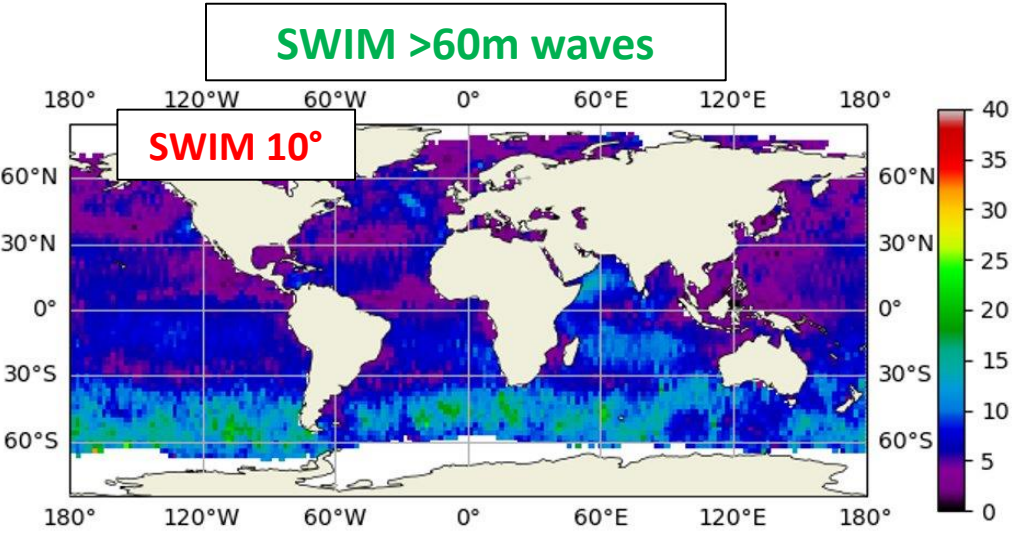
Improved sea state by DA induces a more consistent trajectory of the Agulhas current





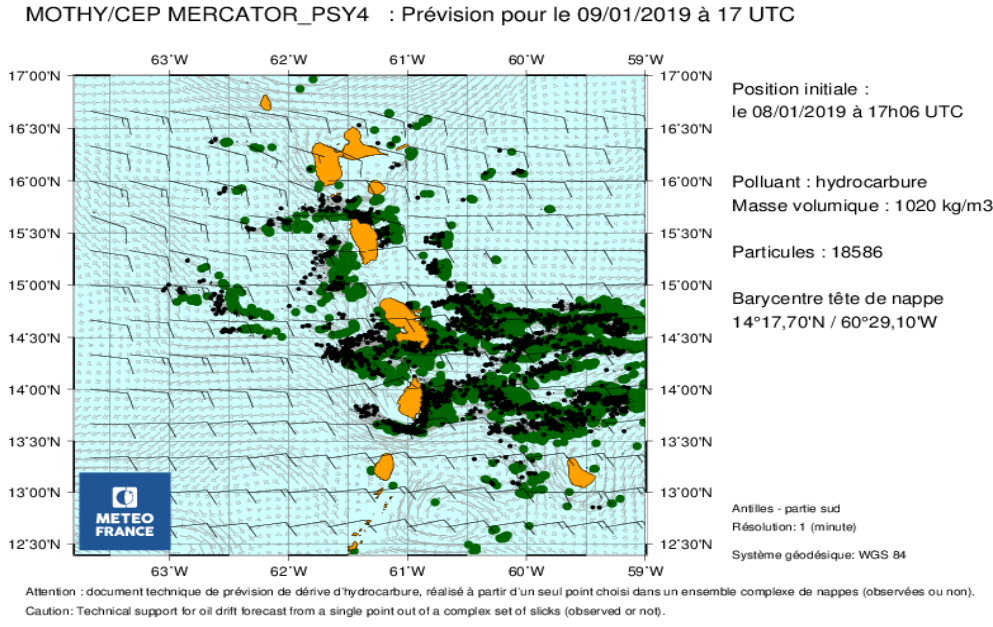
CFOSAT est la seule mission qui fournit la dérive de Stokes : rôle clé dans la dérive des objets flottants, les polluants et le mélange océanique supérieur





Détection de vagues plus courtes (30 m) avec les spectres de SWIM-NG

Applications pour la dérive de Sargasses

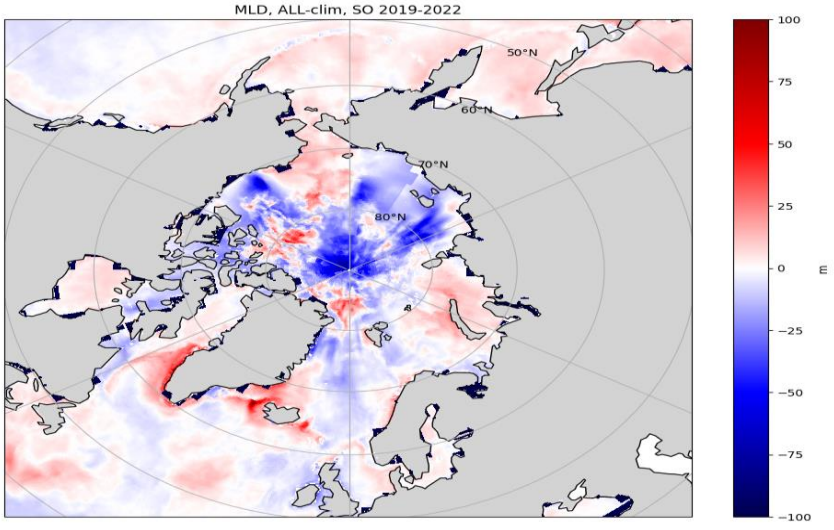


SWIM for the surface Stokes drift : comparison with MFWAM colocated wave model results, after correction accounting for the waves below 30 m length (performed by extrapolating the spectrum with a diagnostic tail)

Résultats remarquables sur le couplage vagues/ocean avec état de la mer amélioré (DA of SWIM), (Bedossa et al. 2025)

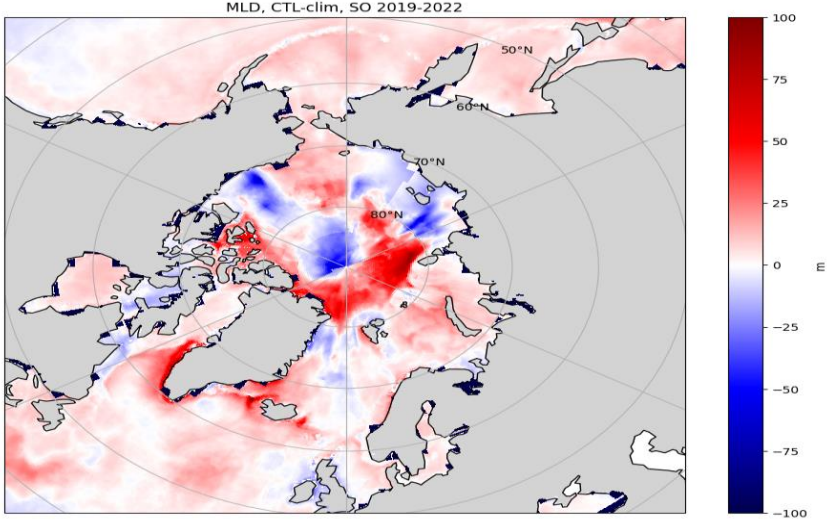
Impact sur la couche de mélange océanque (MLD) pendant Septembre/Octobre 2019-2022

Difference of MLD ALL coupled and climatology



wave/ocean coupled experiments (MFWAM/NEMO) including DA of SWIM wave spectral and SWH. Control without waves

Difference of MLD control and climatology

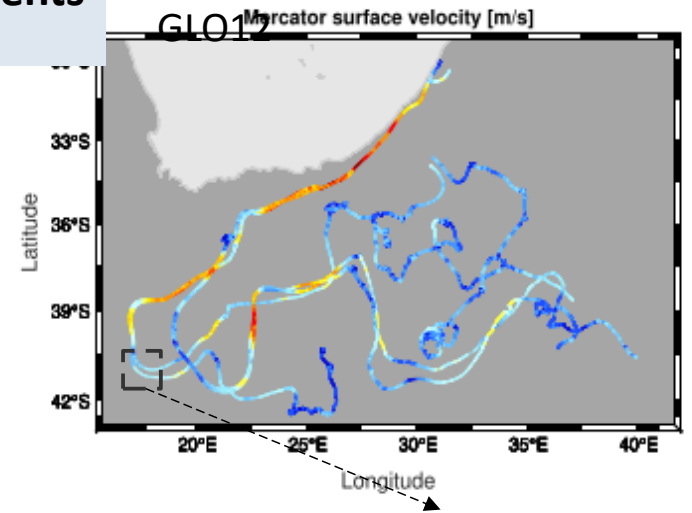


Bonne représentation de la couche de mélange Dans l'arctique avec la simulation couplée et Amélioré par l'assimilation pendant la fin de l'été. Inclure les vagues indique une tendance à raccourcir la MLD la partie est de l'océan arctique

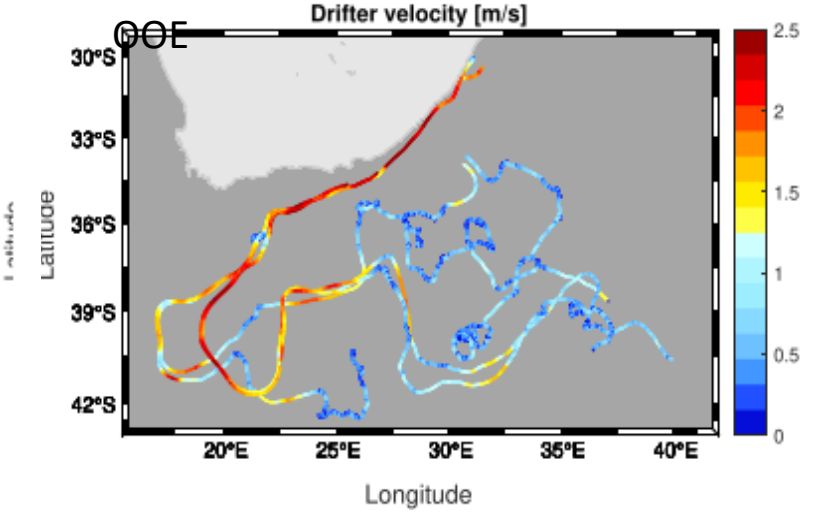
Comparaison avec la climatology de MLD Layer from De Boyer et al. (2023)

Need for improved wave/curents interactions

Mercator ocean GLO12



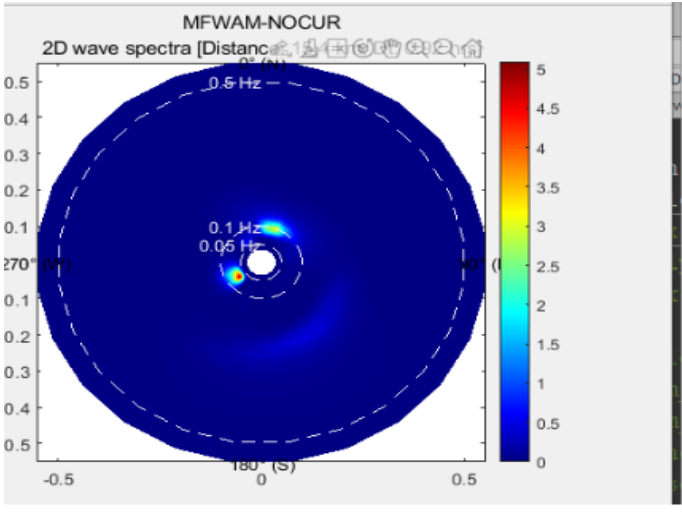
Surface current from drifters OOE



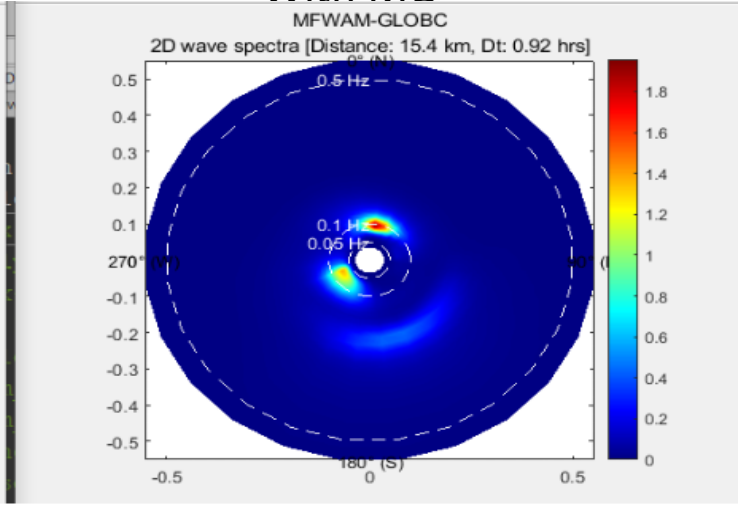
misfit of model surface currents wrt One Ocean Expedition (OOE) Drifters and consequences on wave spectra (Altipamaki et al. 2024)

2D-spectra from MFWAM

No

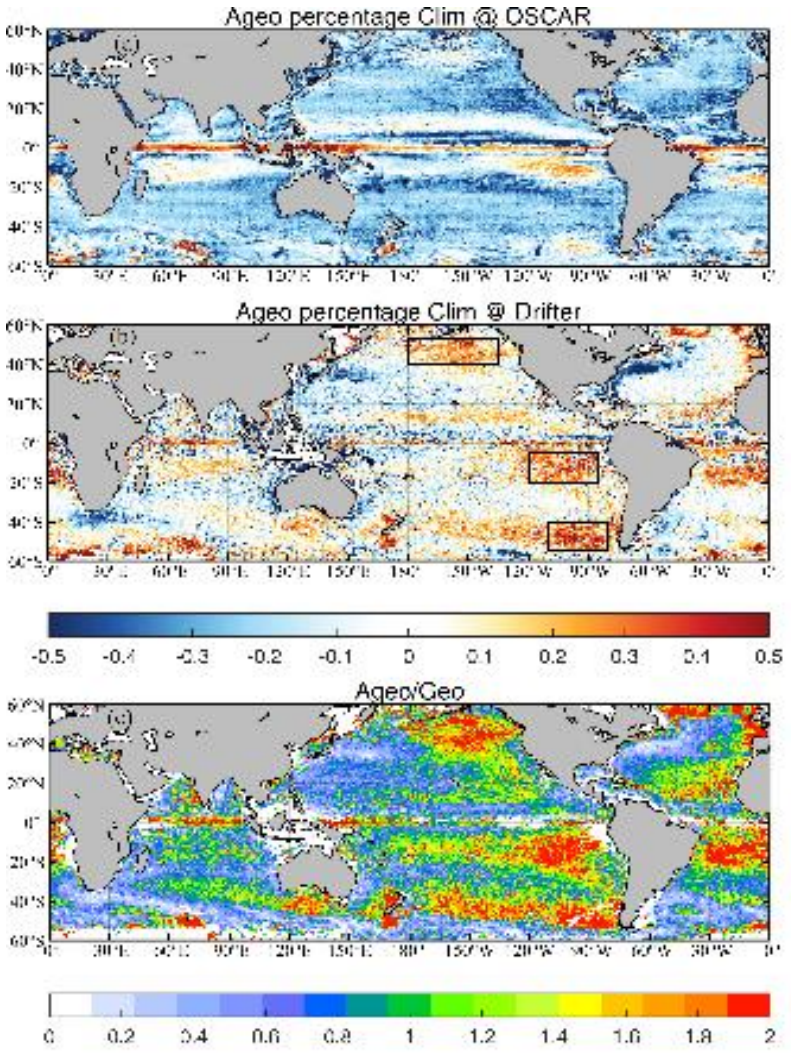


With MO



Wrong position of submeso Circulation cells from ocean model can enhance SWH bias

Relevance of non-geostrophic currents



The non-geostrophic currents determine the directions of the total currents in the near-equatorial trade winds and mid-latitude westerly winds prevailing regions, where the maximum non-geostrophic speed can reach twice the geostrophic speed and exceed 60% of the total current.

The OSCAR data cannot reveal the non-geostrophic processes in these regions and underestimate the weakening effect of the non-geostrophic process in the strong western boundary currents and the Antarctic Circumpolar Current.

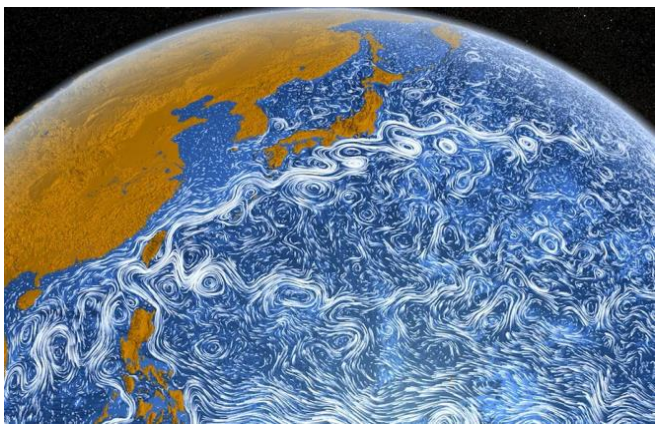
Mission objectives and challenges

➔ **The first satellite observation of global Total Ocean Surface Currents (TOSC), both in near nadir and wide-swath observation (1000 km)**

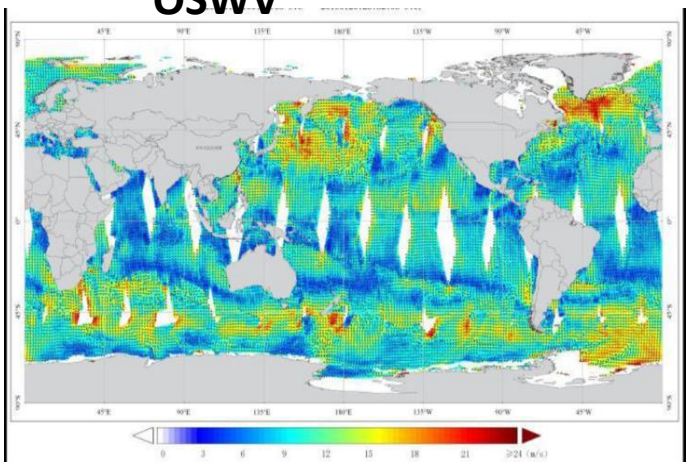
➔ **Continous satellite observation of global Ocean Surface Winds Vectors (OSWV) and Ocean Surface Wave Spectrum (OSWS) by CFOSAT**

➔ **For the first time, large-scale and synchronous observations of OCS, OSWV, OSWS Will be acchieved**

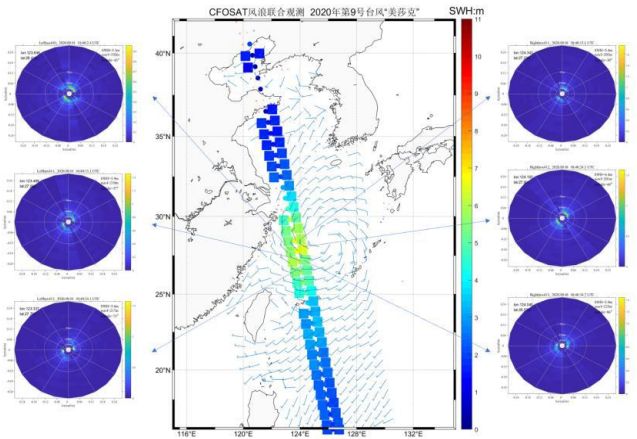
OSC



OSWV



OSWS

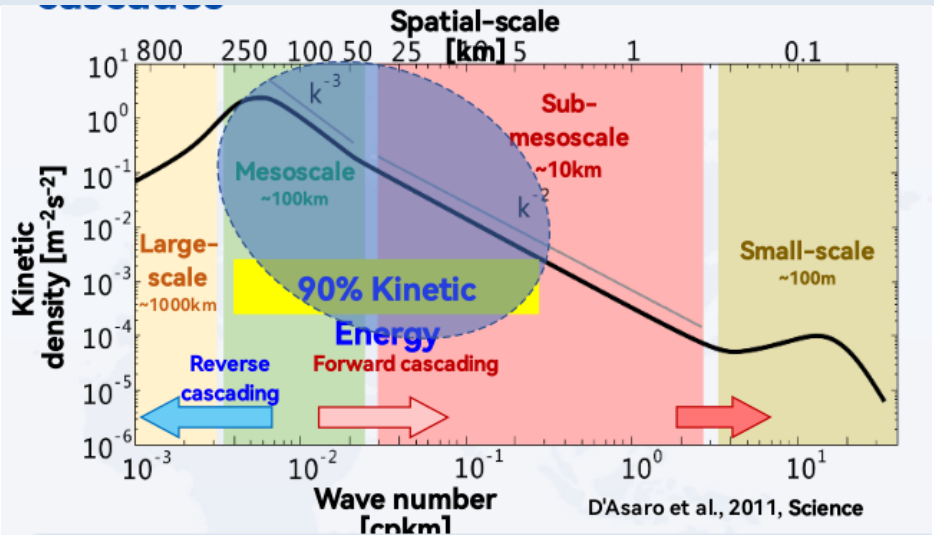


Besoins pour des réalisations scientifiques accrues avec CFOSAT-NG

- **Continuité de l'assimilation des spectres directionnels de type SWIM dans les modèles opérationnels et futurs systèmes terre (MF, CMEMS, ECMWF,...etc)**

- **Amélioration des processus couplés genérés par les vagues et meilleure prise en compte des vagues dans les échanges de flux entre l'ocean et l'atmosphère (Austral, polaire, MIZ, tropiques)**

- **Unique observations de la dérive de Stokes et le courant total de surface dans l'océan global (synergie entre petite et grande échelle).**



Understand multi-scale processes

Besoins pour des réalisations scientifiques accrues avec CFOSAT-NG

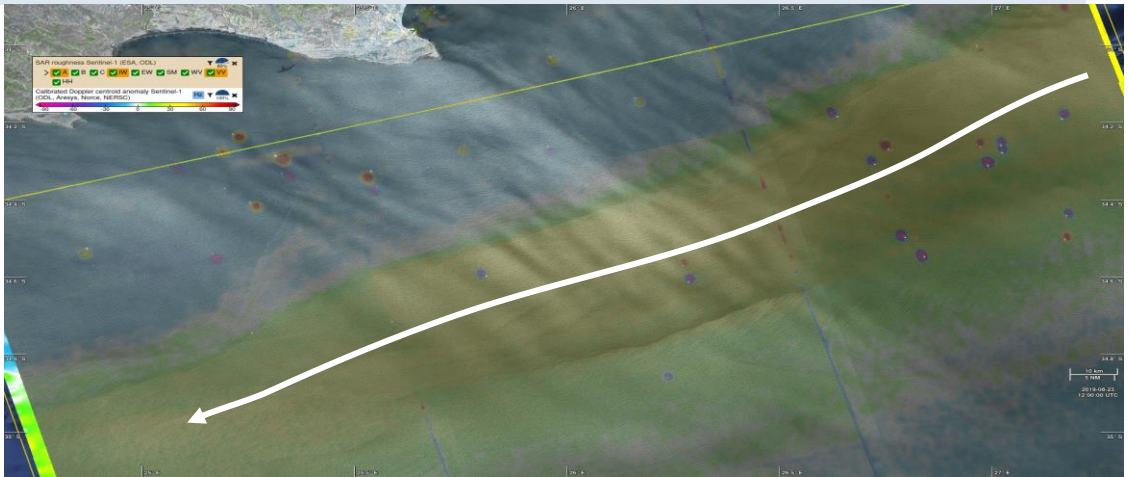
➔ **Défis pour SWIM-NG :**

- **Spectre directionnel de vagues : longueur d'onde 30-1100 m (petite et grande échelle), résolution directionnelle de 10°**

- **Observations nadir SWH améliorée (SAR mode) and capacité de restitution de l'élévation de surface et courant géostrophique)**

- **Capacité Doppler pour SWIM-NG et mesures du courant total de surface (précision de ~10%)**

Courant et doppler Vagues observés par Sentinel-1 (zone agulhas)



Exigences sur les observations et défis : (étude Phase O au CNES)

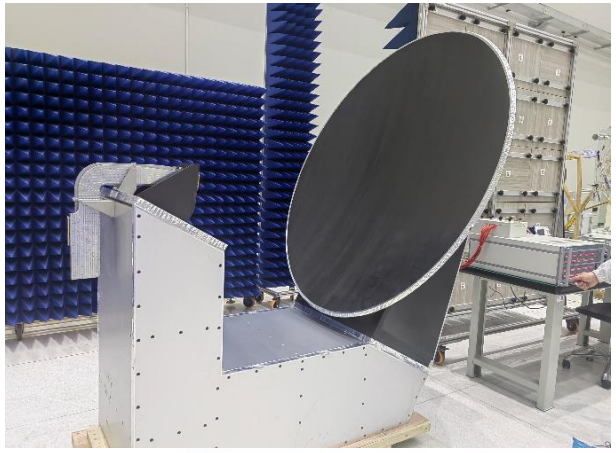
- improvement of wave spectrum retrieval (On going/future studies on simulator)

  - radial stokes velocity in different directions (uncertainties ~10%)

- surface radial velocity (uncertianties ~10%)

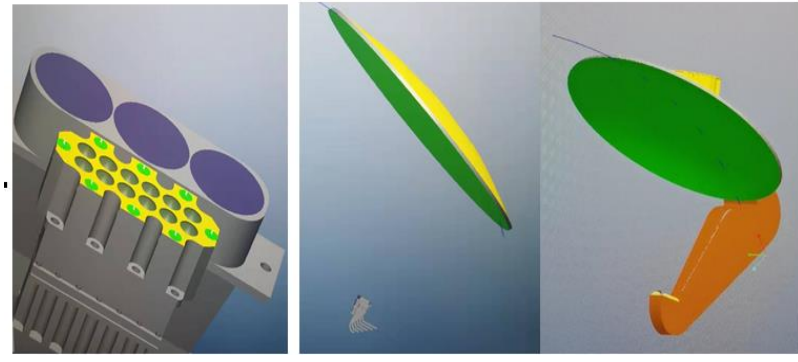
SWIM-NG	parameters	uncertainties
Wave spectrum	Wavelength scale 30-1100 m 36 directions Ambiguity removal (doppler) Stokes drift peakdness	Dominant wave parameters : 10 % Ustokes : 10 %
Nadir (SAR mode)	SWH, wind speed (1Hz-5hz) Sea level Gestrophic current Ug	5-10%
wave doppler	Radial stokes velocity (direction) Radial surface velocity	10 %
Nadir & beam	Total surface current velocity (TSCV)	10 %

SCAT-NG : Dual Frequency Doppler Scatterometter (from NSSC China)

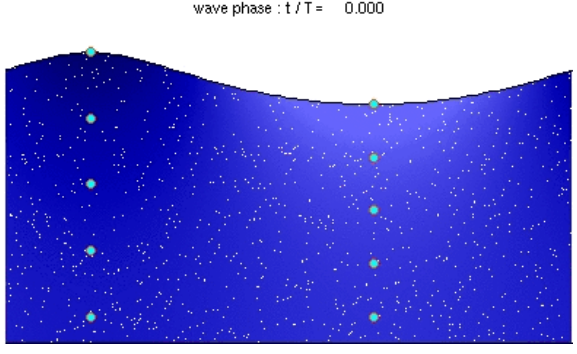


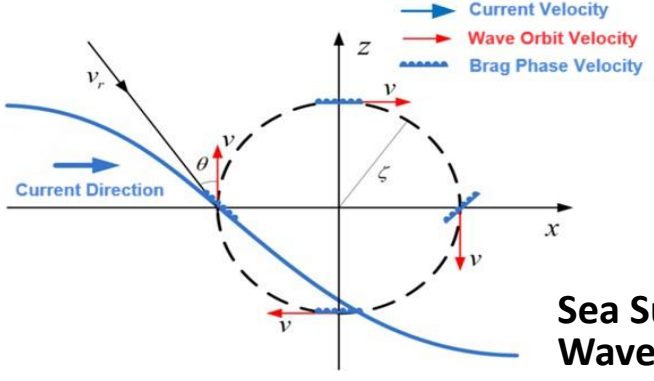
Payload

- Ka+Ku Multi-beam Conical Scan
- Incident Angle from 46° to 49°(TBD, adjust with orbit height)
- Multiple looks at Azimuth Angle



- Sea surface current & wind
- Ka+Ku sigma0 and Doppler spectrum





Sea Su.ace Velocity = Current Velocity + Wave Orbit Velocity + Bragg Phase Velocity

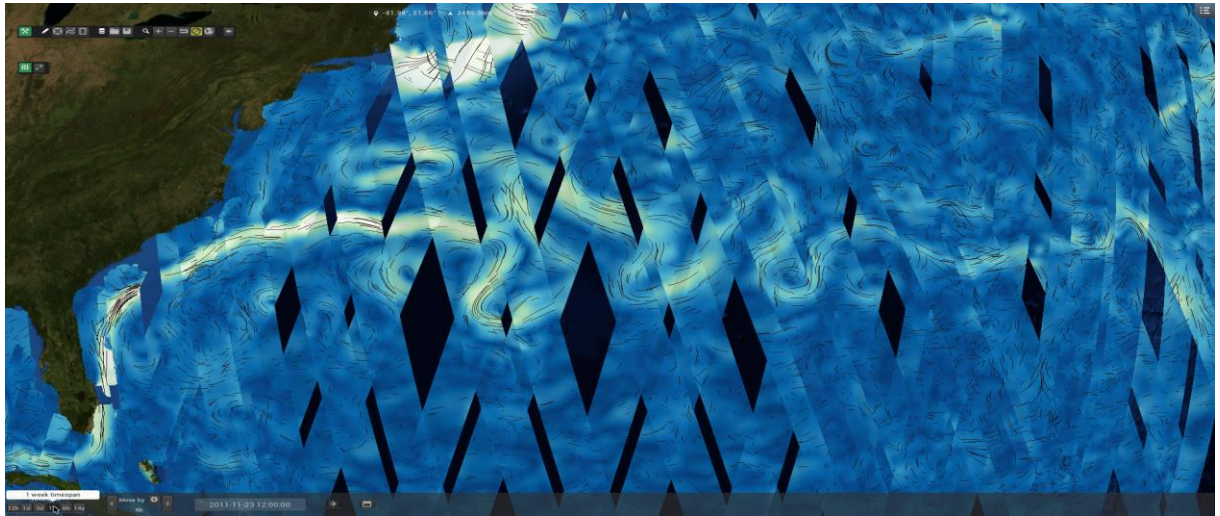
Payload synergies : SCAT-NG (China) with SWIM-NG (France)

➔ SWIM-NG provides wave information for retrieval of surface current from SCAT-NG

➔ SCAT-NG provides simultaneous observation of wind vectors to SWIM-NG to complete Total current retriaval (essential to reach uncertianties of 10-15%)

➔ SCAT-NG provides additional flag setting and ambiguity removal for SWIM-NG

➔ Collocated and simulataneous observations of wind, wave and currents will refine our understanding of air-sea energy fluxes, high sea state, individual wave, ...etc

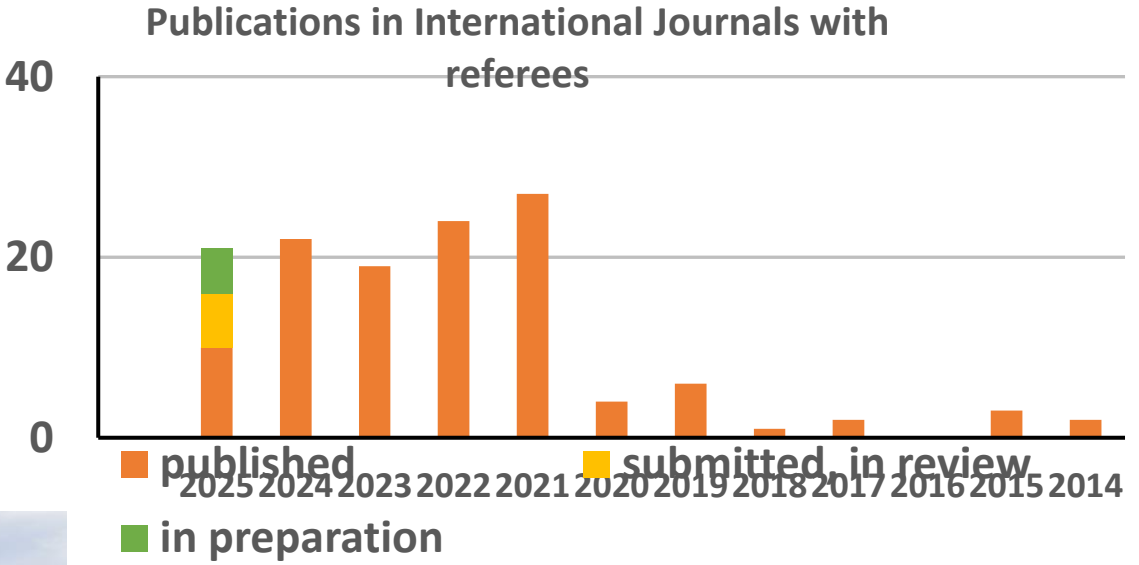


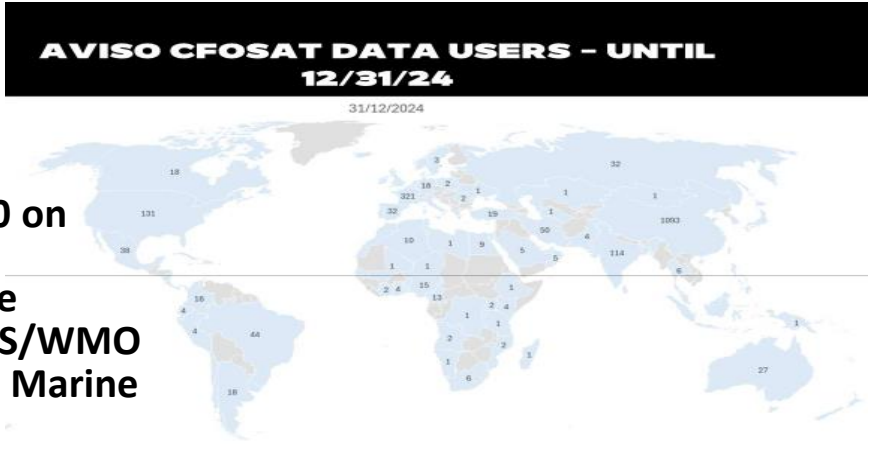
Example of 7 day Retrieval of current from SKIM (gulf stream

Active science publications and communications

CFOSAT Science team : ongoing
International cooperation :

CNSA and CNES has renewed the CFOSAT Science Team for 2023-2027
International (except China) call released by CNES on April 2022
23 projects received from 13 countries (7 France, 7 Europe, 9 international)
70 PI et co-I selected





More than 2100 on AVISO portal CFOSAT data are available on GTS/WMO and Copernicus Marine Service

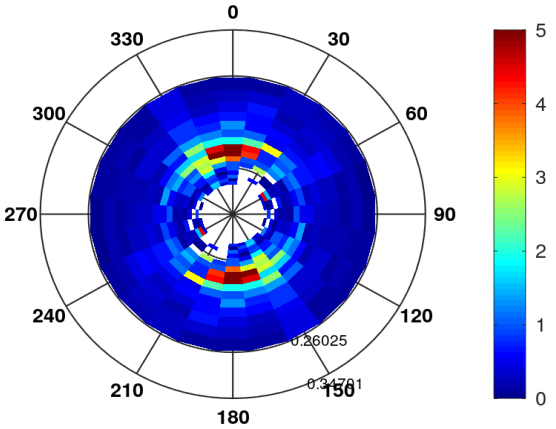
Conclusions

➔ **Observer le triptyque vent, vagues et courant à l'interface air-mer est un moteur de la prévision du climat et l'analyse des évènements extêmes.**

➔ **CFOSAT-NG va permettre de mieux comprendre les différentes échelles de vagues et de courants de surface sur l'océan.**

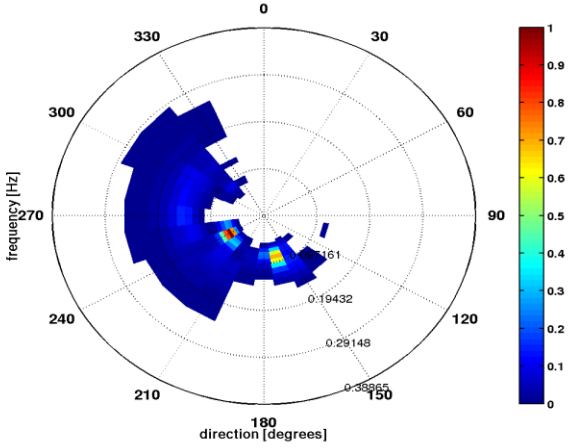
➔ **Coopération Franco-Chinoise dynamique et fructueuse dans le cadre de la science team de CFOSAT**

➔ **CFOSAT-NG pourra créer une synergie avec d'autres missions satellitaires Harmony, Sentinel-1-NG et S3NG-Topo**



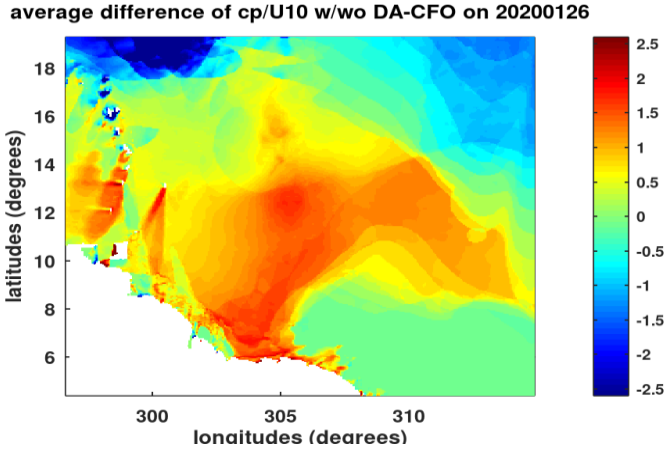
Wave feedback in the atmospheric boundary layer (EUREC-4A): Thanks to SWIM wave spectra (Giordani et al. 2025)

MFWAM 2D-wave spetrum after DA 310°E-12.2°N (26 jan 15:00)



MESO-NH coupled with MFWAM Jan & feb 2020

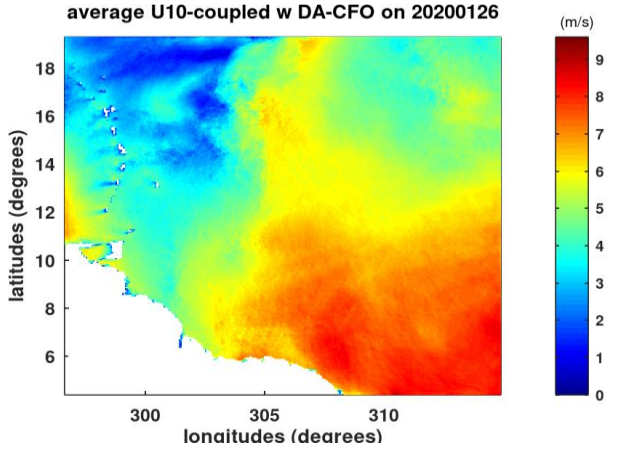
Average difference on Cp/U10 (wave age)



Correction des partitions affecte directement la vitesse de phase des vagues. Ceci agit sur le stress et les flux

Impact of coupling w/wo DA on key Parameters : 26 January 2020

Average U10 with spectral DA



Average difference on wind speed