HY-2B now used operationally in multi-mission Sea Level and Wave systems

Feedbacks on performances and contribution to products

CNES & CLS altimetry team

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(1) CLS
(2) CNES

Overview

Context
Operational data processing
Sea level - Integration in CMEMS SL-TAC
Waves and Wind - Integration in CMEMS WAVE-TAC
Conclusion & Perspectives

Context: HY2B satellite overview

HaiYang-2B is an NSOAS satellite, it was launched on 30/10/2018 and belongs to the long series of HY satellites.

Aim:

Monitor the dynamic ocean environment with microwave sensors to detect sea surface wind field, wave heights, sea surface height and sea surface temperature. It includes an altimeter dual-frequency in Ku and C-bands, a scatterometer and a microwave imager.

Orbit:

The orbit is sun-synchronous with a 14-day cycle.

L2 Data:

- **Data type**:
  - IGDR : 2-3 days timeliness
  - SGDR: same as IGDR but includes waveforms
  - GDR: 1 month timeliness

- **Availability:**
  - IGDR: from 15-11-2019
  - SGDR: from 05-07-2020
  - GDR: from 20-12-2019

Context: NSOAS / CNES cooperation agreement

Agreement from HY2A to HY2E

L2 GDR/IGDR/SGDR products

- Orbite mission
- Data feedback

cnes

Data feedback

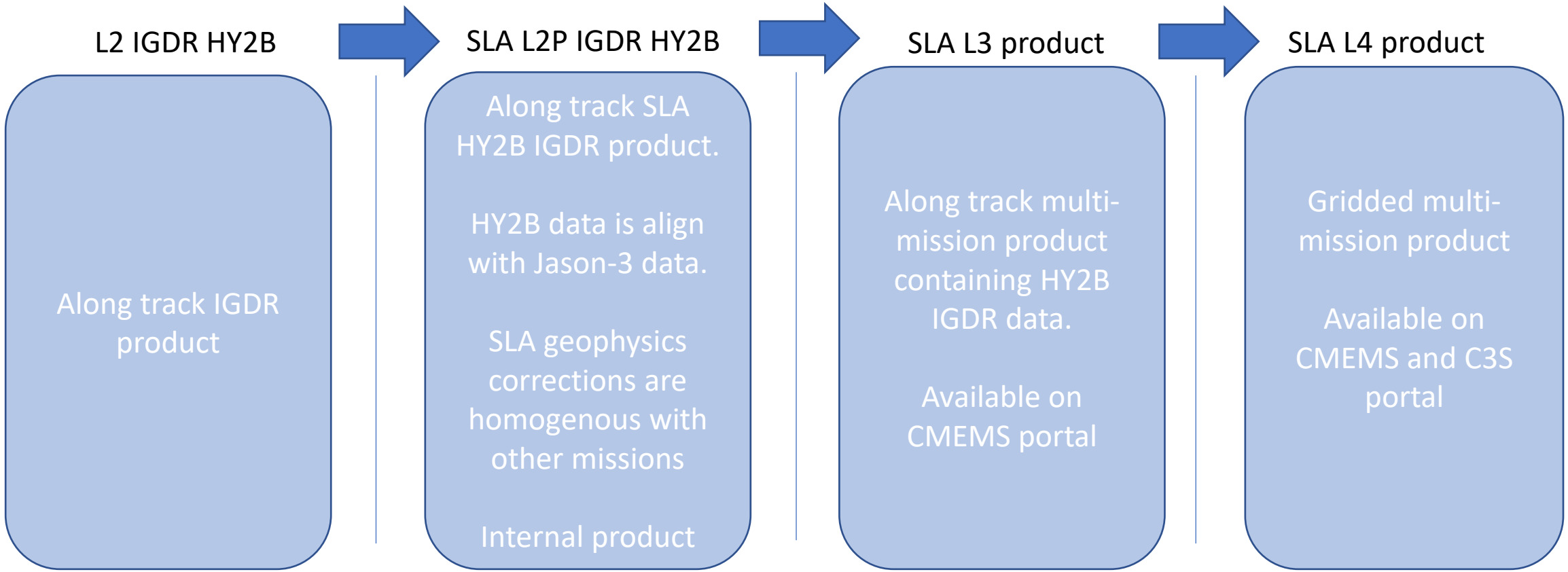
L2 IGDR products

SLA L3/L4 DUACS with HY2B IGDR products
Wind and Waves L3/L4 with HY2B IGDR products

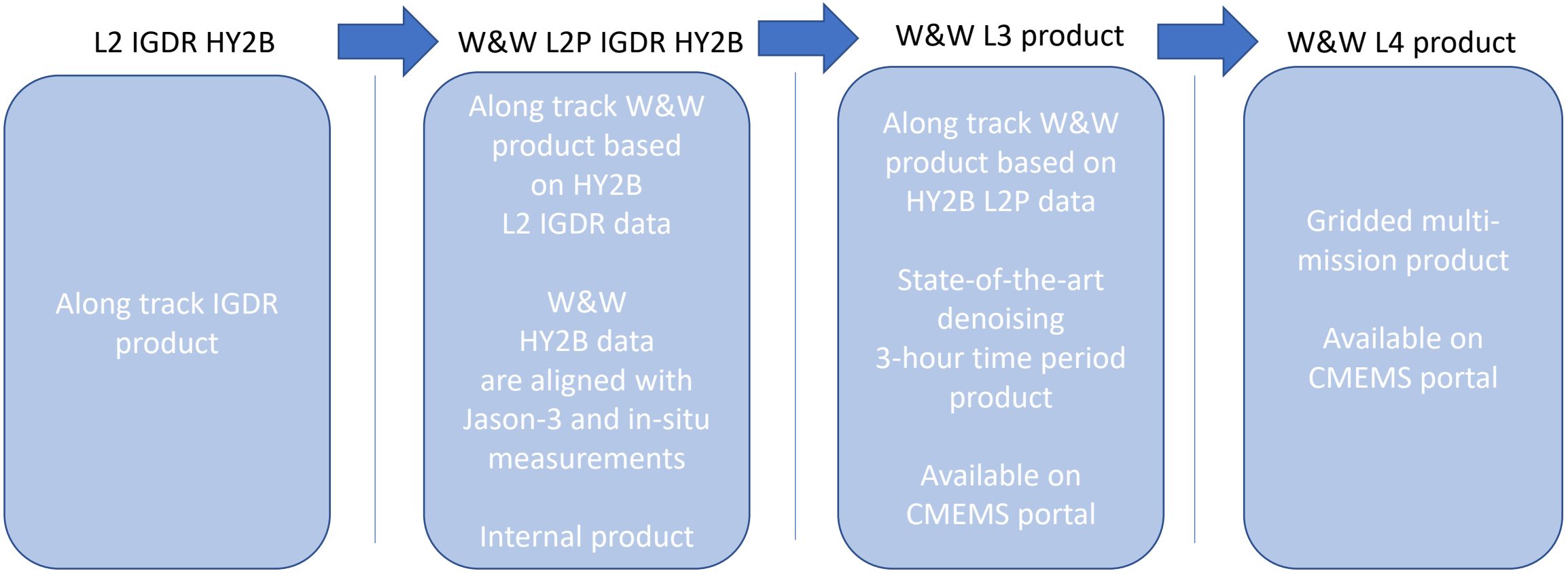
CLS
COLLECTE LOCALISATION SATELLITES

Operational data processing

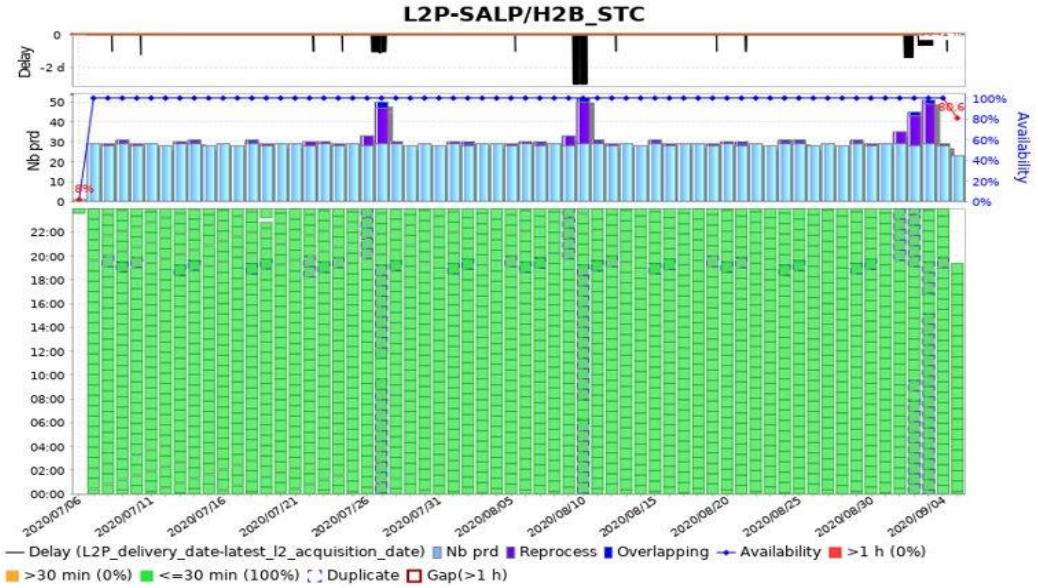
Sea Level Operational processing chains



Wind and Waves: Operational processing chains



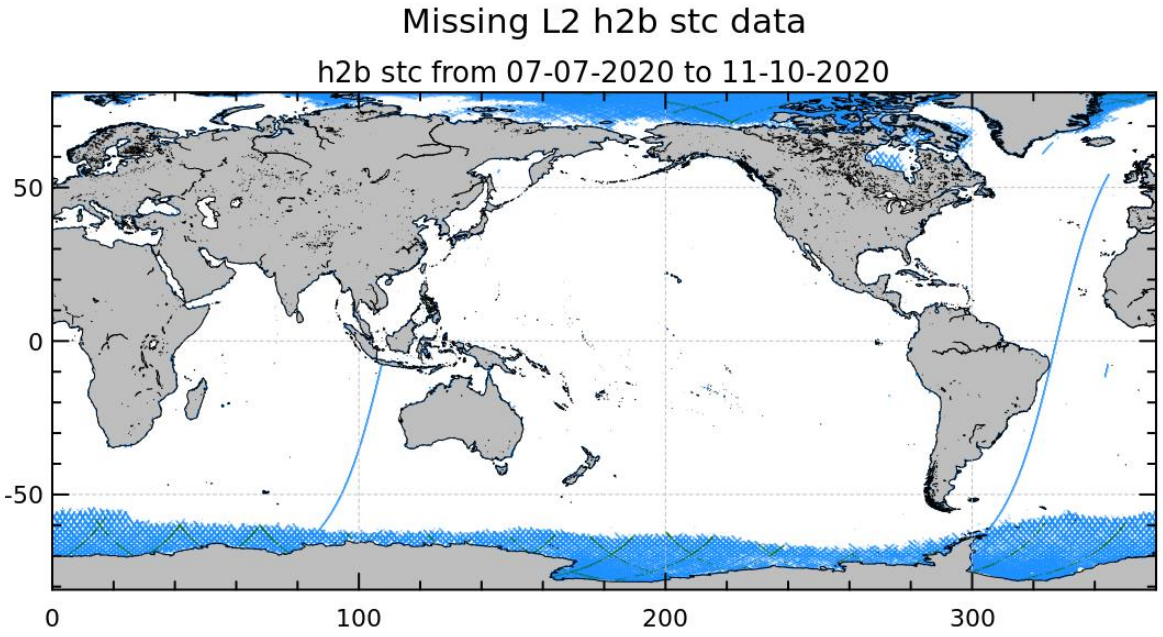
Data availability



The monitoring of Hy-2B L2 products availability and L2-P products production shows an excellent temporal coverage.

This result traduces the robustness and stability of both NSC ground segment operations and L2P production chain.

As mentioned in Raynal et al., OSTST 2019 the spatial data coverage over ocean is excellent with more than 90% of available measurements.



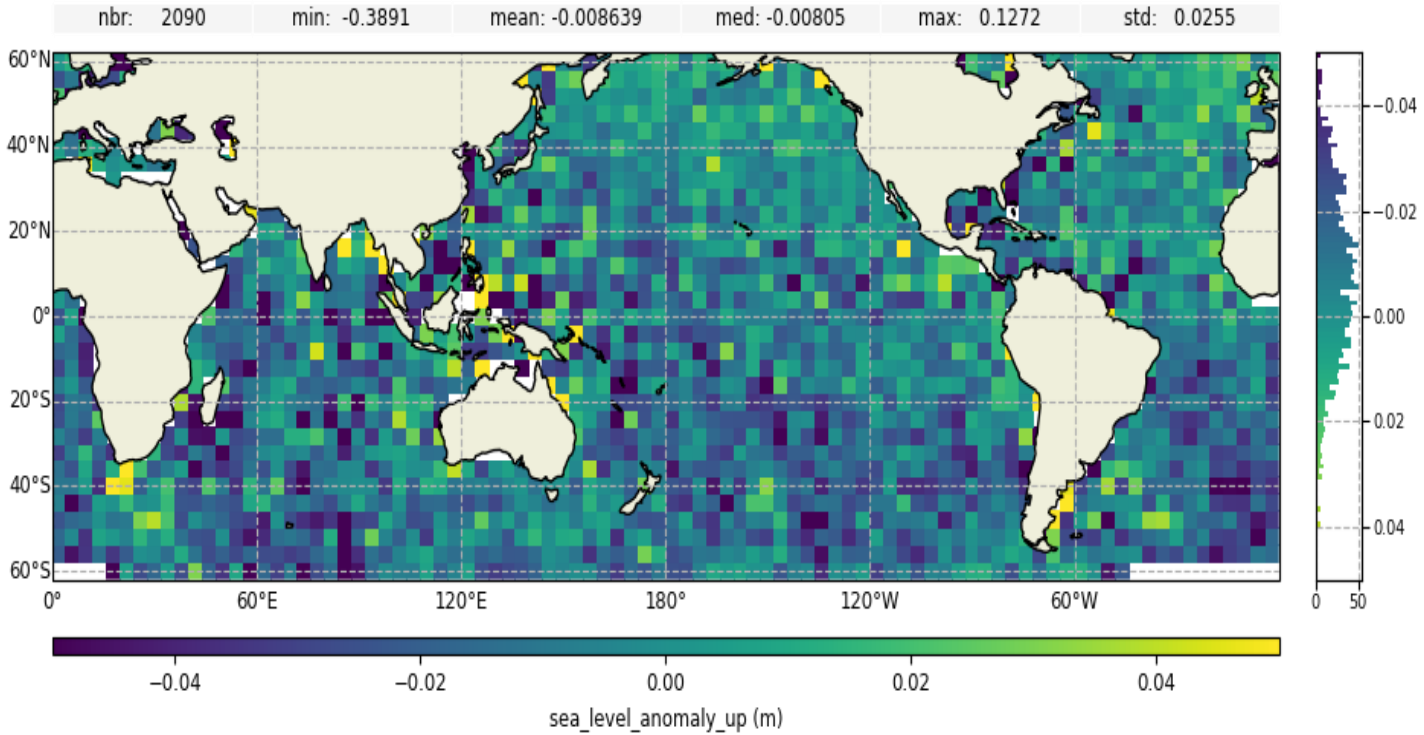
Sea level - Integration in CMEMS SL-TAC

Input SLA data quality

The analysis of Hy-2B mono- mission crossover shows a good agreement between ASC & DSC passes:

- Difference range between -4 and 2 cm only
- No pseudo time tag bias
- A small bias close to -1 cm only observed

SLA Mean difference H2B/H2B at crossover

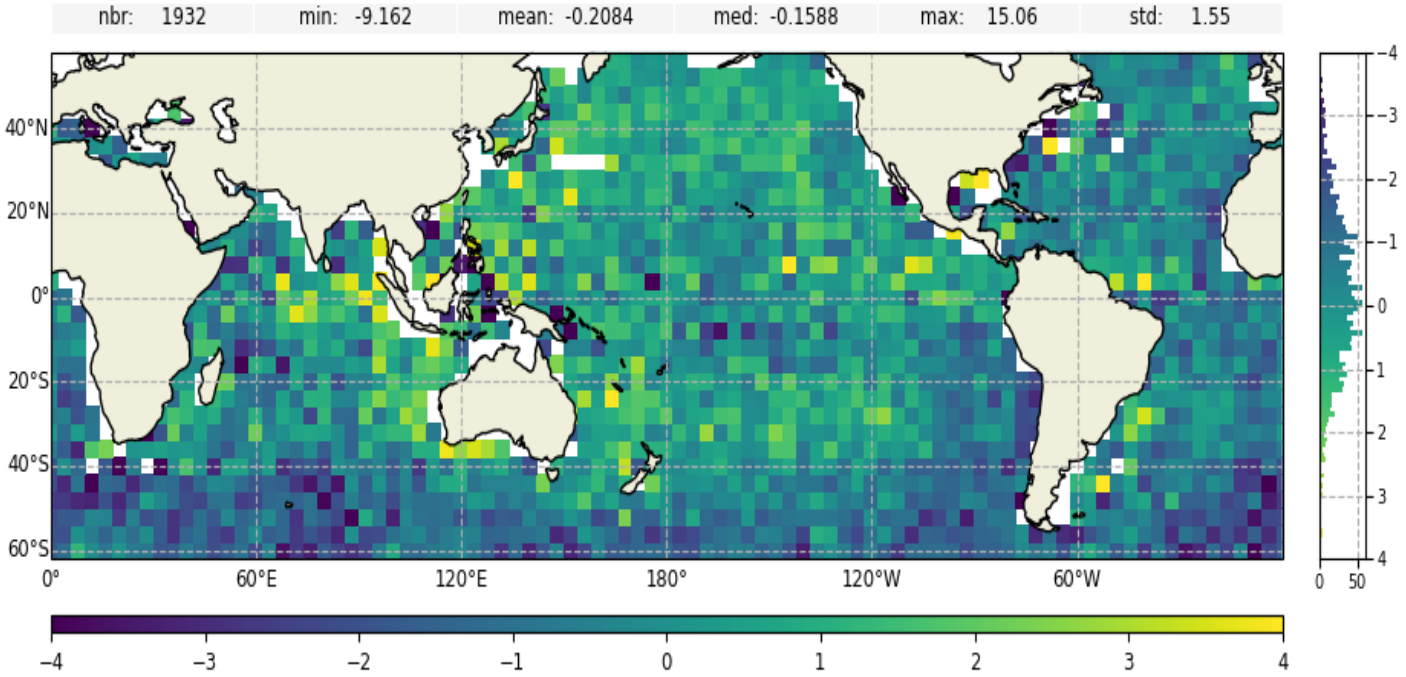


Input SLA data quality

The analysis of Jason-3 / Hy-2B crossover shows an excellent agreement between both satellites:

- Differences are ranged between -2 and 2 cm only
- Almost no absolute bias between the two altimeters (median of residuals is about -1.5 mm)
- Geographical distribution of the SSH residuals is partially correlated with SWH : negative differences in the South hemisphere at high latitudes

SLA Mean difference J3/H2B at crossover (cm)



Input SLA data quality

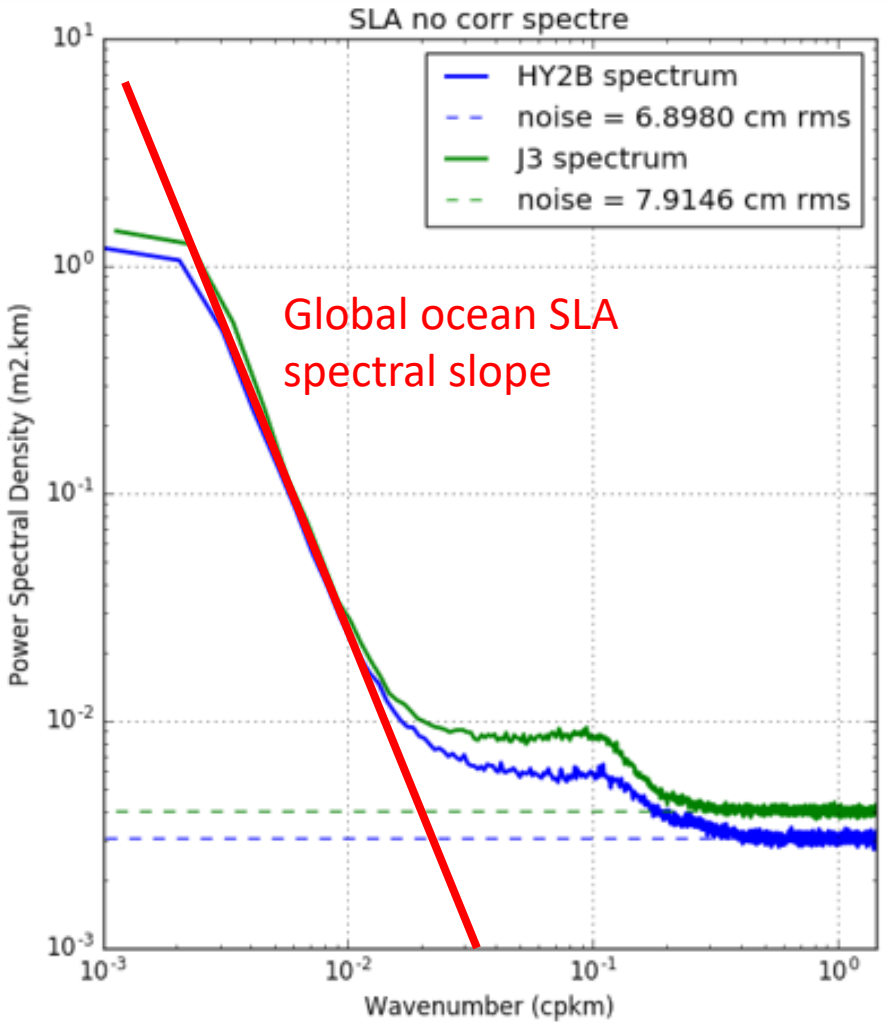
Jason-3 and Hy-2B SLA spectra have been computed over a common period over the open ocean.

- Both satellites observe the same oceanic spectral slope for wavelengths > 80 km ➔ consistent with previous global analyses showing the good agreement

- At short wavelengths (below 3 km), the energy of the noise plateau is slightly lower (by ~20%) for Hy-2B, resulting in a lower 20Hz white noise

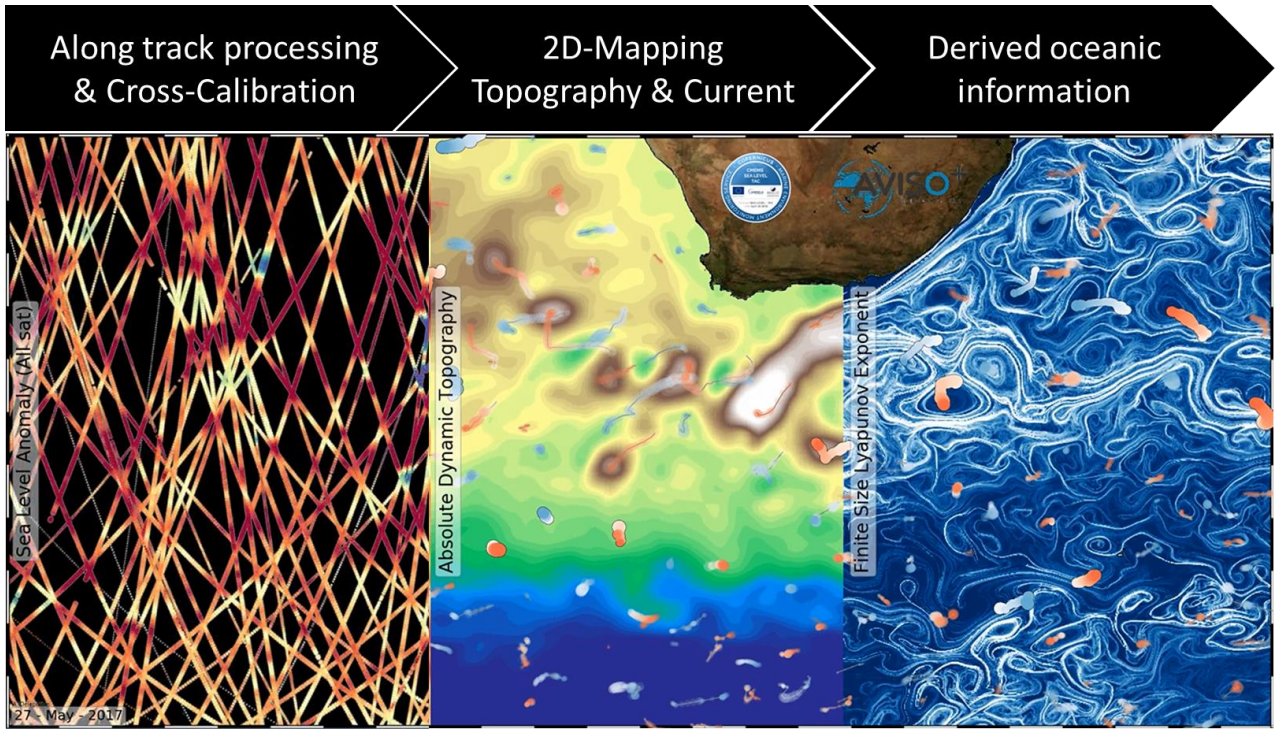
- At sub-mesoscale wavelengths (between 3 and 100 km), the so-called spectral error is observed for both missions. Its amplitude with respect to the white noise plateau appears lower for Hy-2B.

➔ **The Hy-2B altimeter and on ground processing exhibits very good performances**



Sea Level multimission center (DUACS)

DUACS (Data Unification and Altimeter Combination System) is an operational production system operated since 1998 and and the name of a family product from Level2P to Level4 altimetry products. (www.duacs.cls.fr/).



Modeling Forecasting Centers

Climate & Mesoscale studies

New communities, biology, …

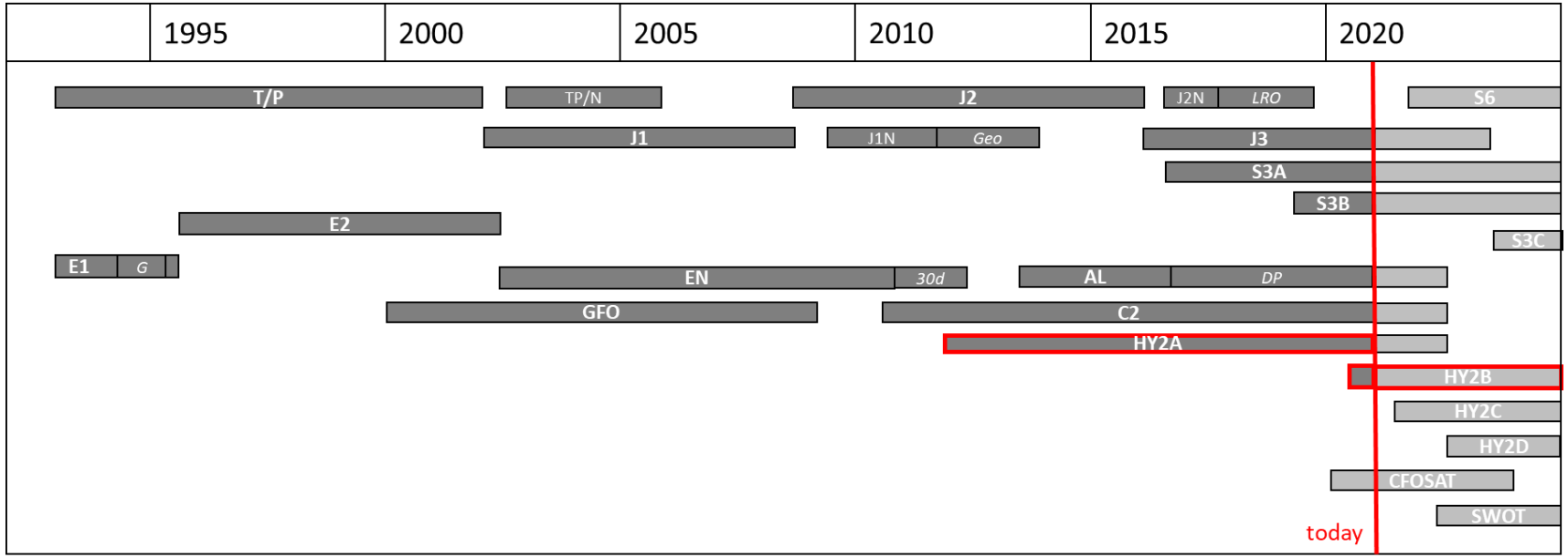
LEVEL 3 products
Along track Sea level & geostrophic current

LEVEL 4 products
Gridded Sea level & geostrophic currents

LEVEL 4p products
Finite Size Lyapounov Exponent
Mesoscale Eddy Atlas Trajectory
Ocean Monitoring Index

Sea Level multimission center (DUACS)

DUACS ingested 14 missions (~100 years of cumulated data), 6 in real time including HY2B



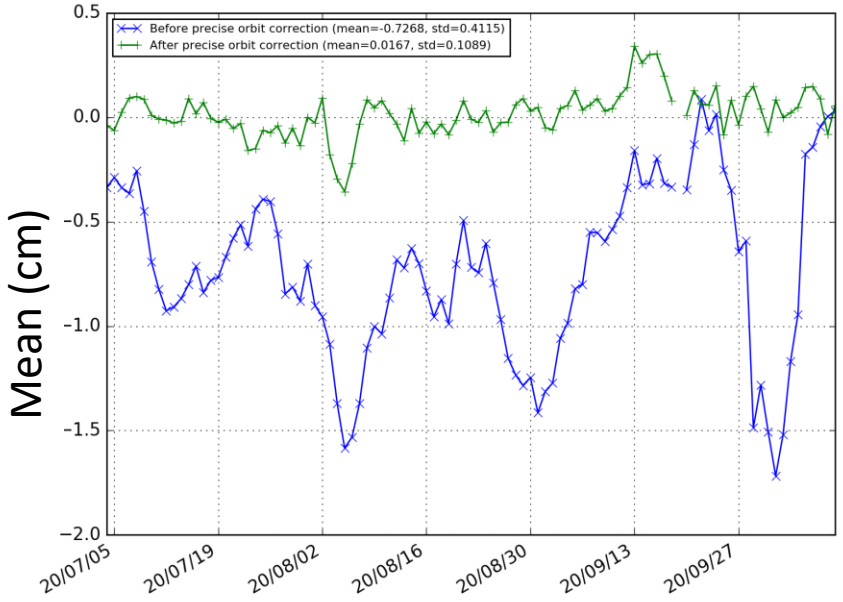
Altimetry data used currently in the DUACS system (dark gray) and to be used in the future (light gray)

- The system relies on reference missions T/P & Jason series which ensure the climate quality of the time series
- Collaborative missions such as GFO, Altika, HY2 series are used to increase the sampling and improve the producst quality at mesoscale
- HY2A has been used in the DUACS system since 2014. **HY2B has been successfully integrated to the system and ingest HY2B data operationally since the 7th of July**

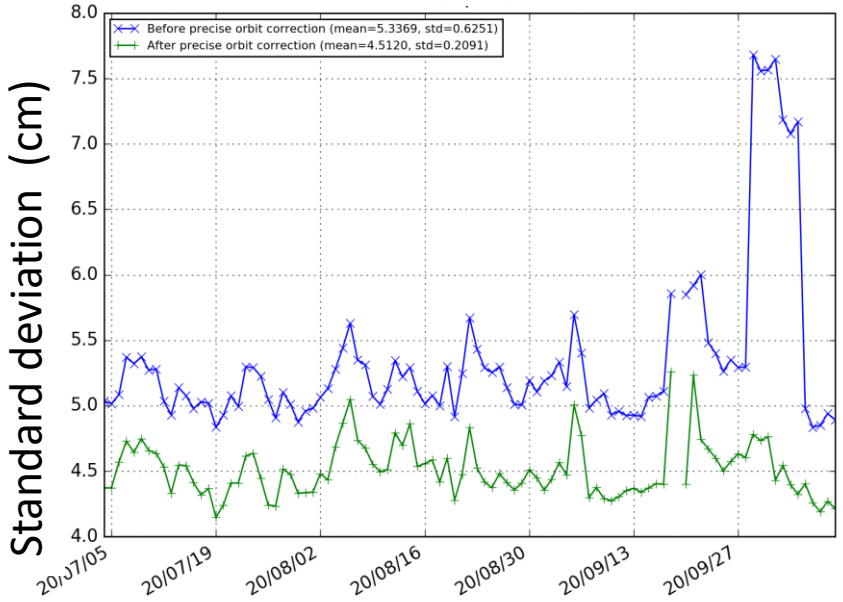
Level 3 - statistics at crossover

- The cross-calibration step allows us to homogenise the large scales of HY2B with the reference mission Jason-3.
- Good performances are observed at HY2B/HY2B crossovers after cross calibration: mean difference at crossovers is about 0.01 cm and mean STD is about 4.5 cm
- High standard deviation is observed on HY2B early October indicating degraded performances of HY2B. These errors have been efficiently removed by the DUACS cross calibration process.

H2B/H2B



H2B/H2B



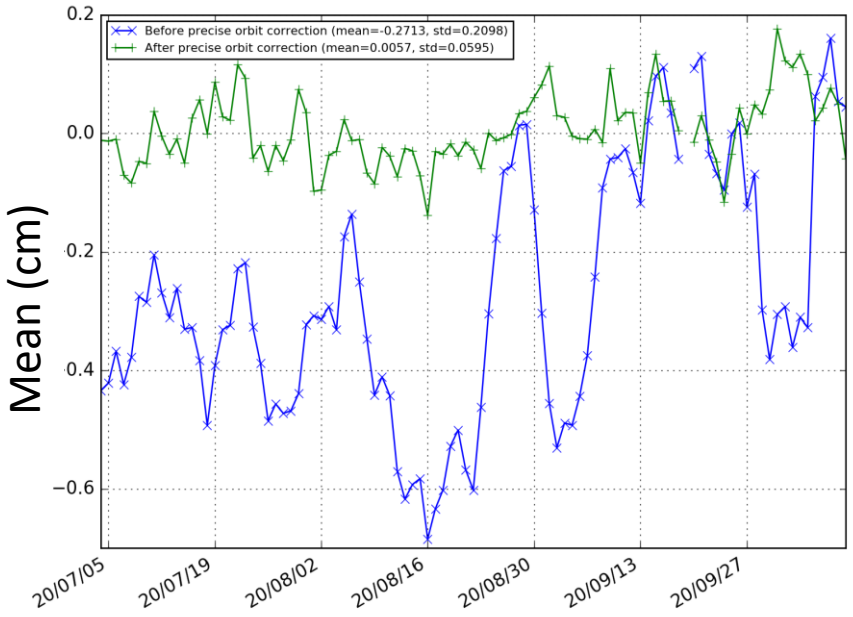
HY2B/HY2B SSH crossover statistics

Blue and green curves represent statistics respectively before and after multi-satellite precise orbit correction.

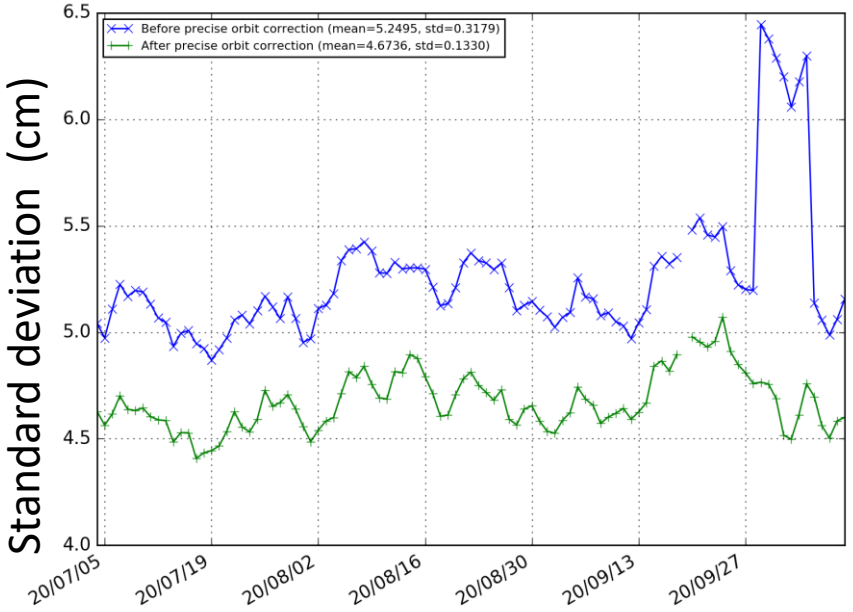
Level 3 - statistics at crossover

- Good performances are also observed on J3/HY2B crossovers after cross calibration.
- Mean difference is about 0.006 cm and Mean STD difference is about 4.6 cm which is of the same order of magnitude as J3/S3A statistic

J3/HY2B



J3/HY2B

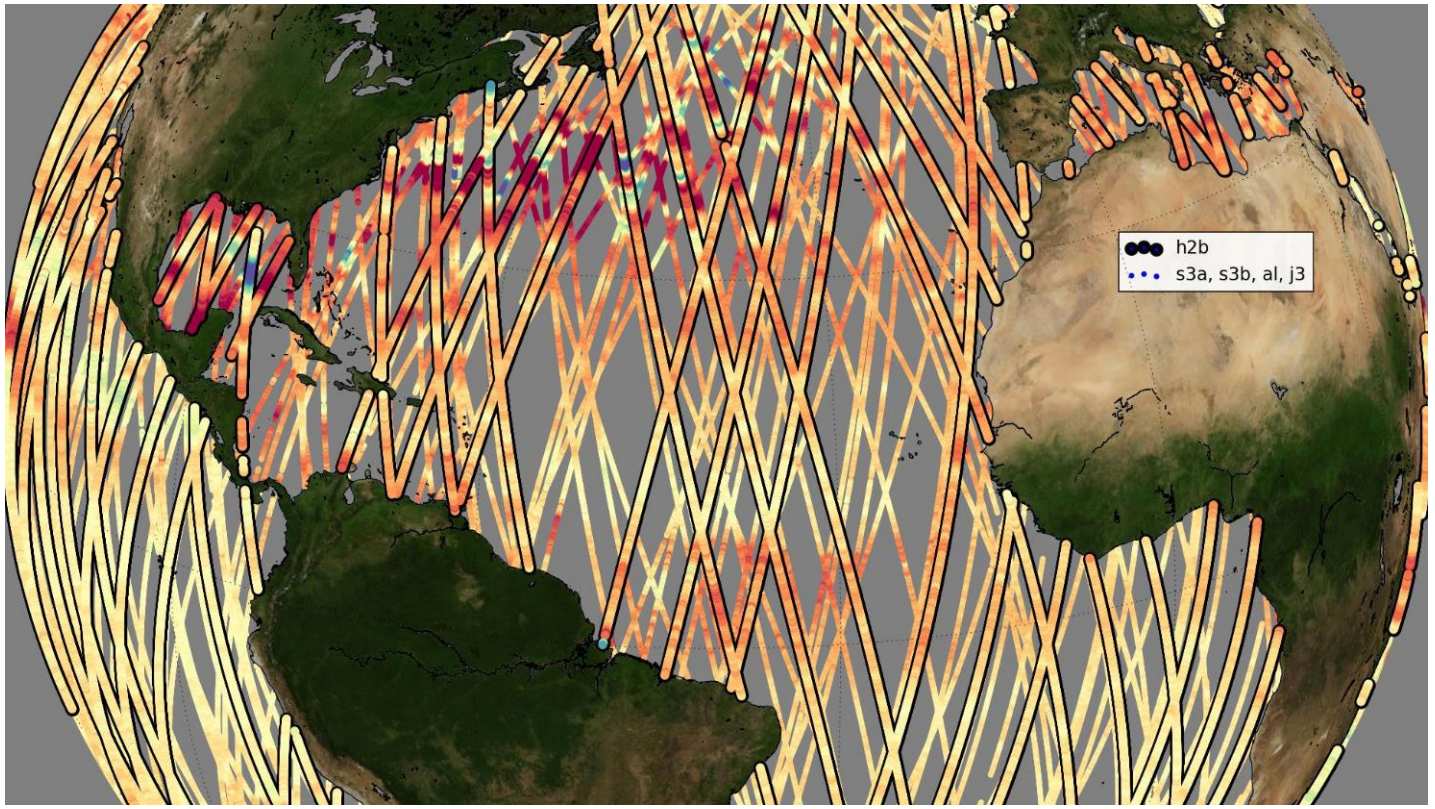


J3/HY2B SSH crossover statistics

Blue and green curves represent statistics respectively before and after multi-satellite precise orbit correction.

Level 3 -products

- After cross calibration, a set of Level 3 HY2B products is obtained.
- These products are completely homogeneous with Jason-3, Sentinel3A/B, Altika, Cryosat2
- The products have been disseminated since the 7th of July by the Copernicus Marine Service and available here

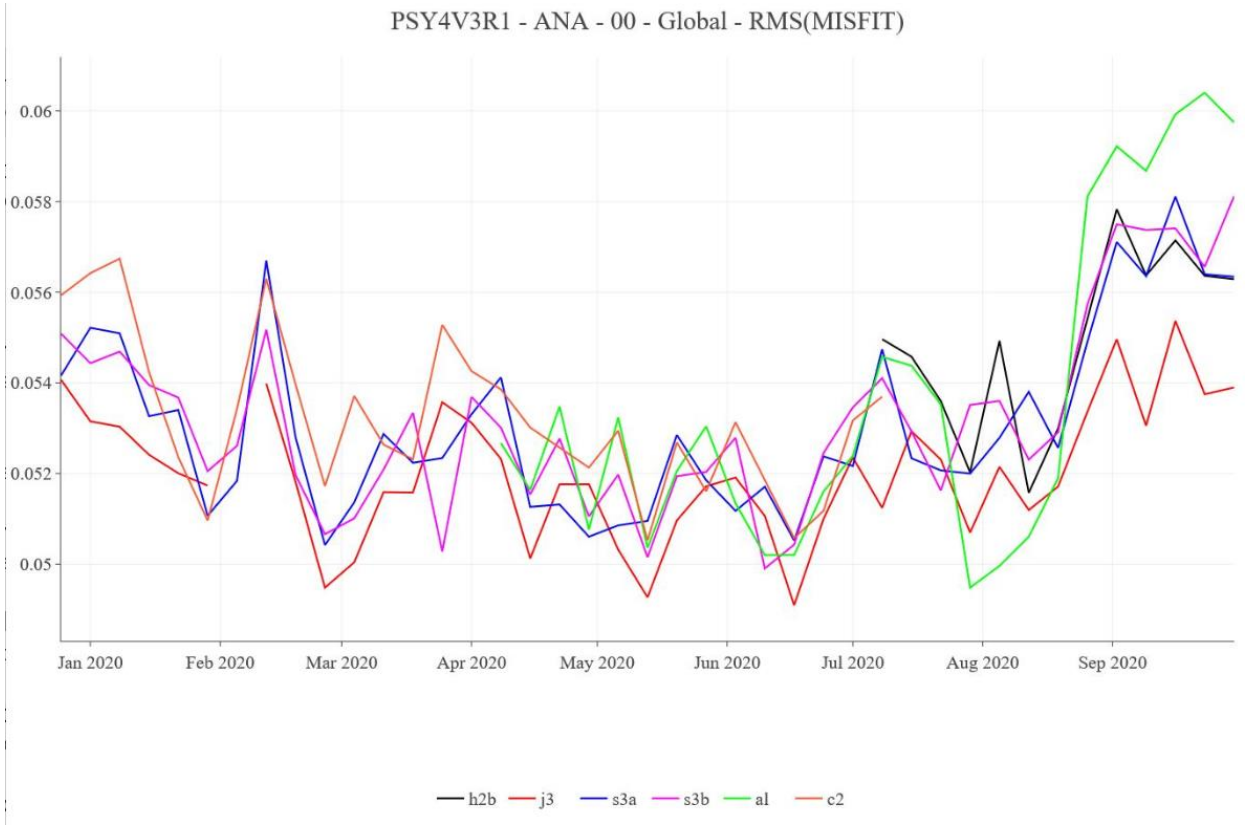


Example of Level3 products for a 3-day period (02/10/2020). Data are plotted for Hy2B (in bold), Jason-3, Sentinel3-A, Sentinel3-B, Altika

Assimilation in Modeling Forecasting Centers

- The HY2B Level3 products have been used operationally in the CMEMS Global MFC since their availability

- The RMS of the difference between forecast Sea Level fields and satellite observations (so-called model misfit) indicates that HY2B (black curve) is seen by the model as consistent relatively to the other missions



Model misfit for CMEMS Global MFC
(Courtesy Marie Drevillon, MOi)

Level 4 – Contribution to mapping

- The HY2B Level 3 dataset are also now operationally ingested in the multimission maps.

- Optimal Interpolation is used to merge HY2B with the other 5 altimeter missions (Jason-3, Sentinel3A/B, Altika, Cryosat2) to reconstruct the SLA over a regular grid

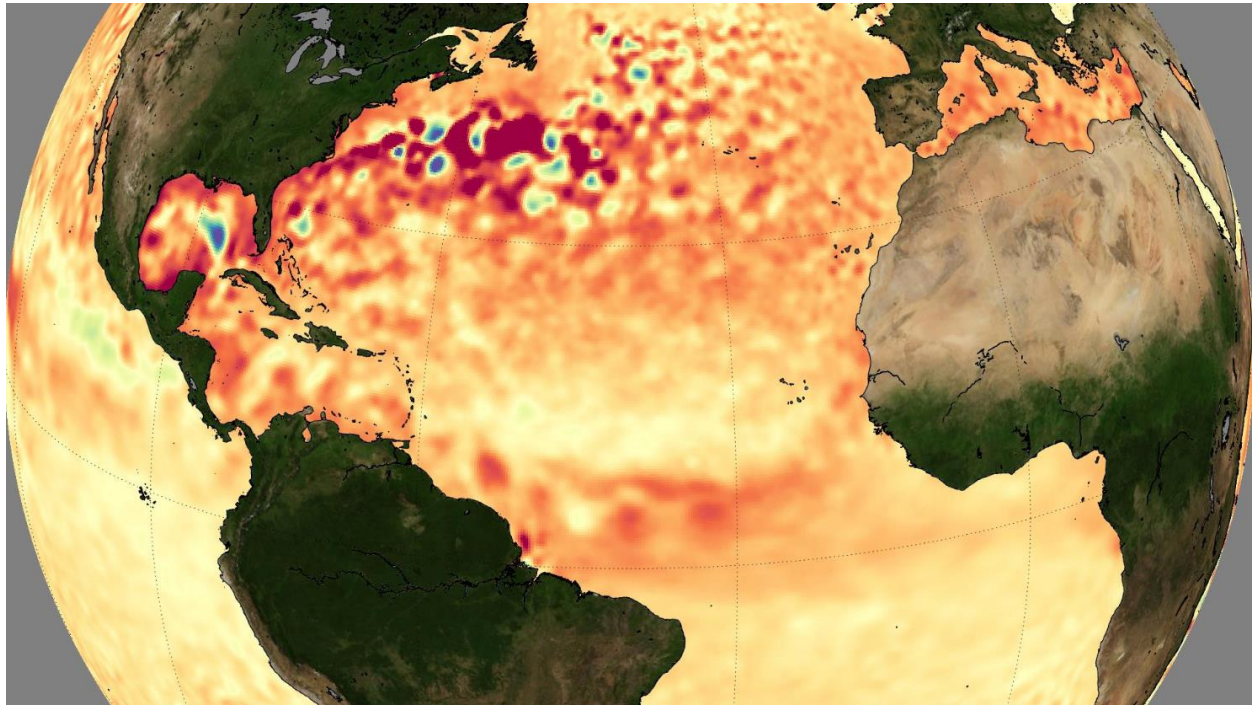
$$SLA_{Estimated}(x) = \sum_i \sum_j w_{xi} SLA_{Observed}(i)$$

Weight estimated to minimize the misfit between estimated/real data

$$W_{xi} = A_{ij}^{-1} C_{xj}$$

Covariance between obs

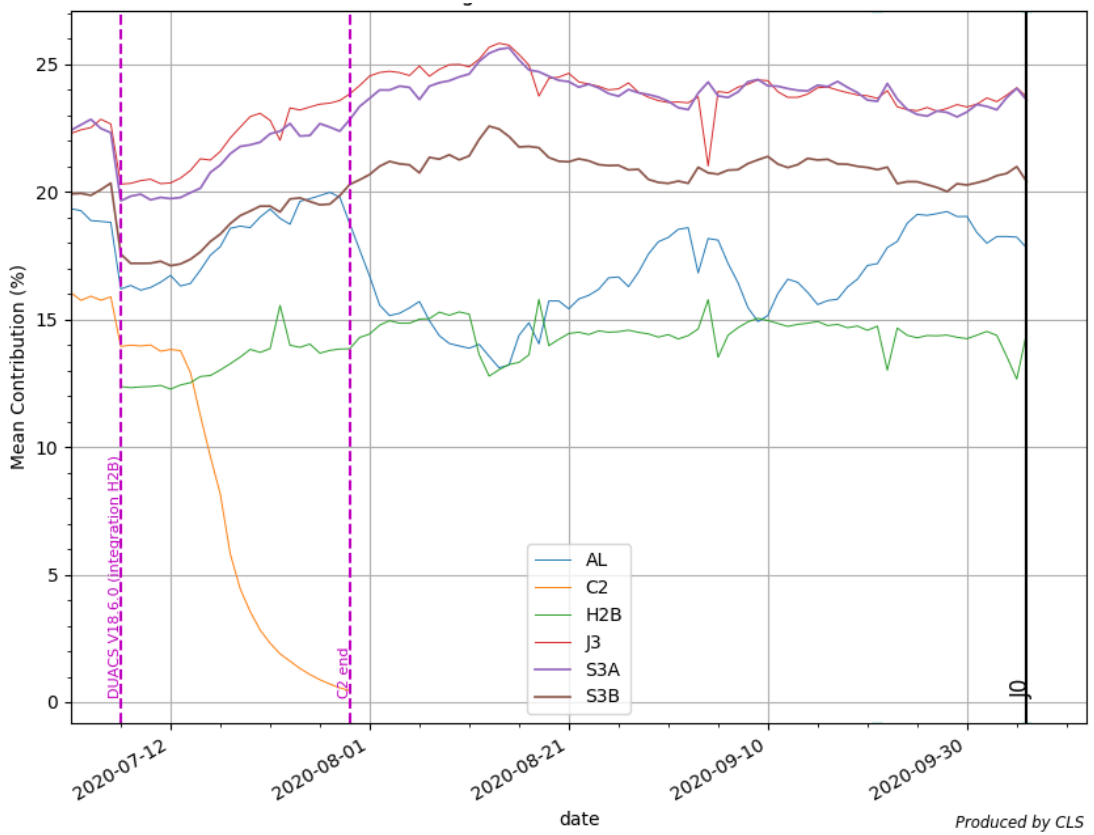
Covariance between obs and field to be estimated



Exemple of Level4 products for the 02/10/2020

Level 4 – Contribution to mapping

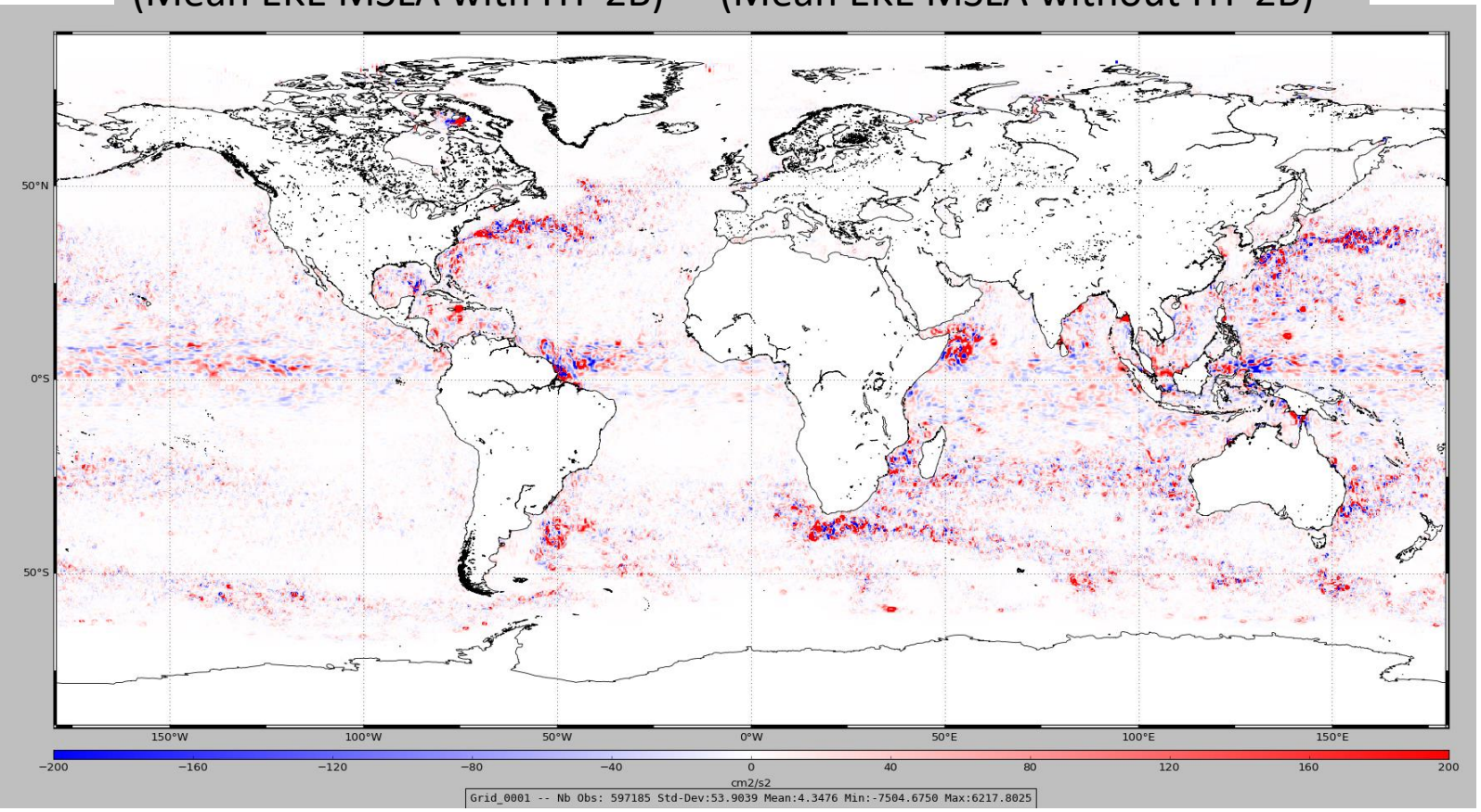
- The contribution of each satellites is estimated using DFS and depends on the sampling capacity of the mission, the latency of the products and the error budget of the altimetry system.
- **HY2B has a 14% contribution to the maps over the July-August period**.
- In particular, HY2B strongly helped to limit the impact of the loss of Cryosat-2 data, temporarily disactivated in the system, and the gaps in Altika measurements due to stronger than usual mispointing events.
- However, the contribution of HY2B could **still be increased by 2-4%** (higher than Cryosat-2) by improving the timeliness of the products, ie using OGDR based products, with a few hours of delay.



Mean Daily Contribution (in %) to the multimission maps (2019-10-09) for each altimetric mission. Hy-2B in green.

Level 4 – Contribution to mapping

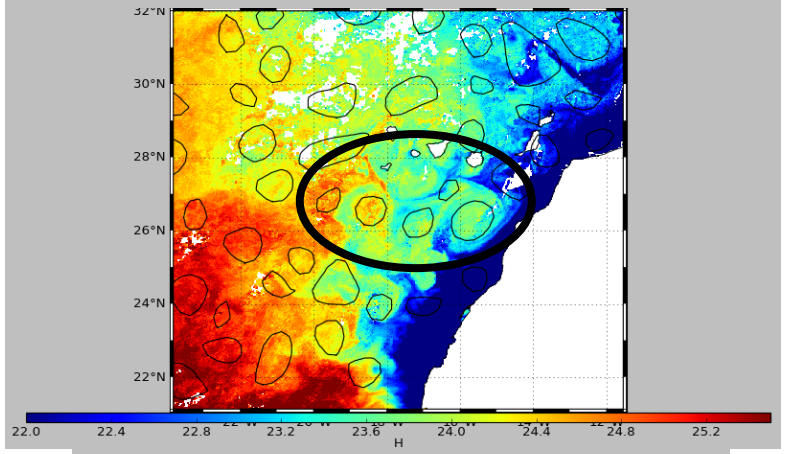
(Mean EKE MSLA with HY-2B) - (Mean EKE MSLA without HY-2B)



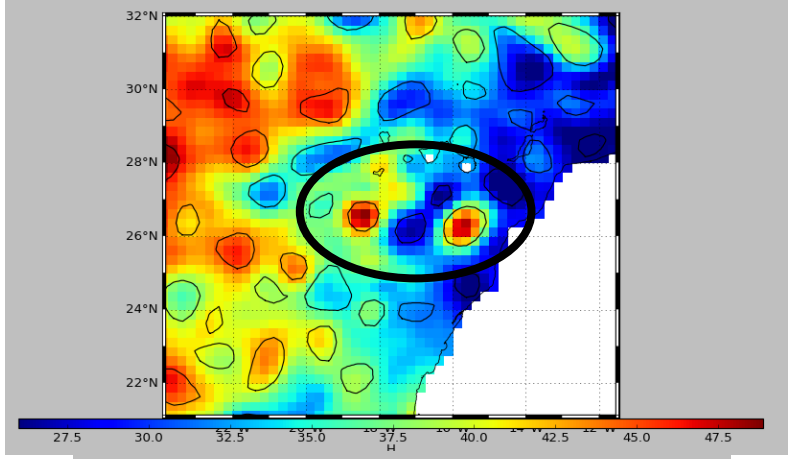
- To assess the contribution of HY2B in DUACS NRT maps, an Observing System Experiment (OSE) has been carried out
- 2 sets of maps have been computed: with and without HY2B over a recent period (14/09/2020 – 06-10/2020)
- Mean Eddy Kinetic Energy have been computed and compared: Adding Hy-2B in the altimetric constellation contributes to an increase of the EKE
- **The increase of energy, visible in regions of high mesoscale variability is expected when using additional missions and indicates a positive impact of HY2B on the maps quality.**

Level 4 – Contribution to mapping

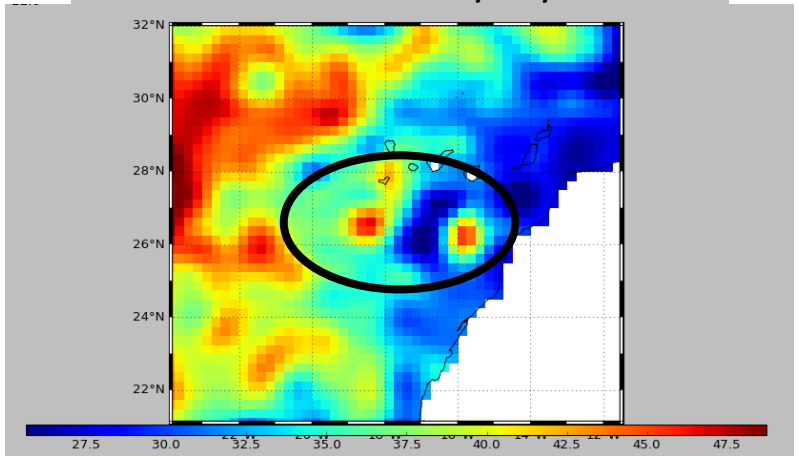
SST - 30/09/2020



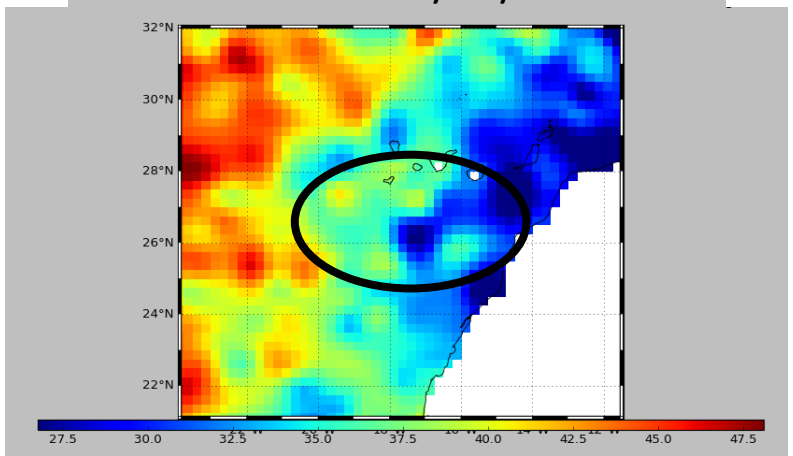
NRT all-sat MADT - 30/09/2020



HY-2B MADT - 30/09/2020



J3 MADT - 30/09/2020



Exemple on 30th September 2020

To evaluate the contribution of HY-2B to retrieve mesoscale; we have performed a quick comparison using independant SST products with mono-mission maps (from HY-2B and the reference mission: J3)

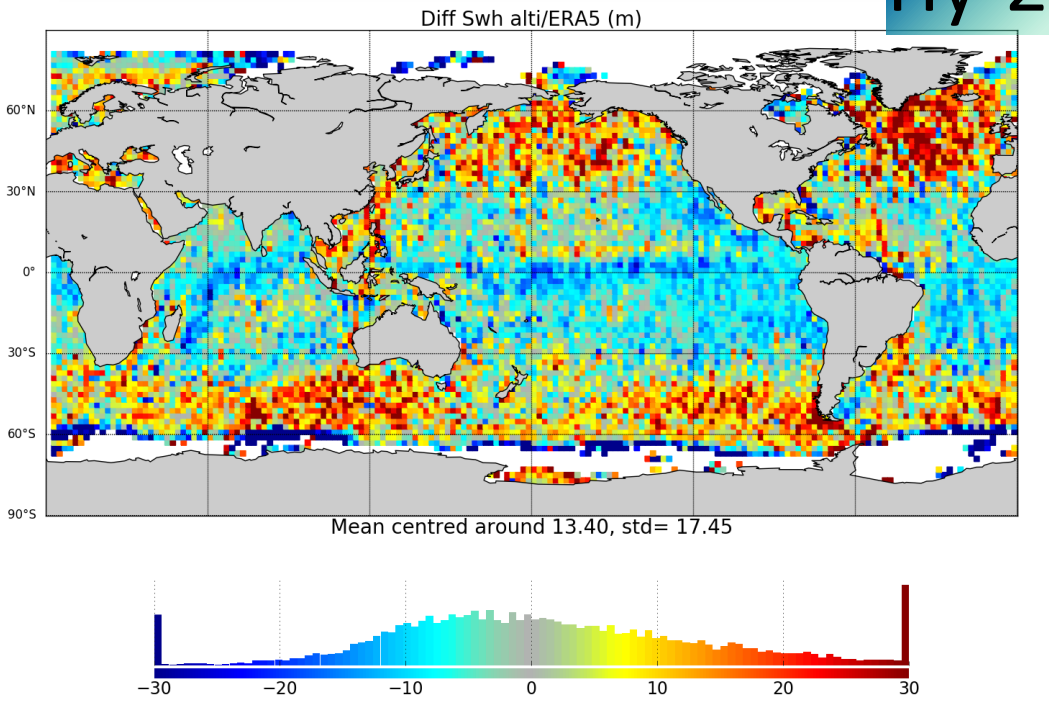
Off the Canary Islands the mono-mission HY2B ADT map can retrieve small eddies that are also spotted in SST maps (black bold circle)

These eddies are missed by the Jason-3 mission.

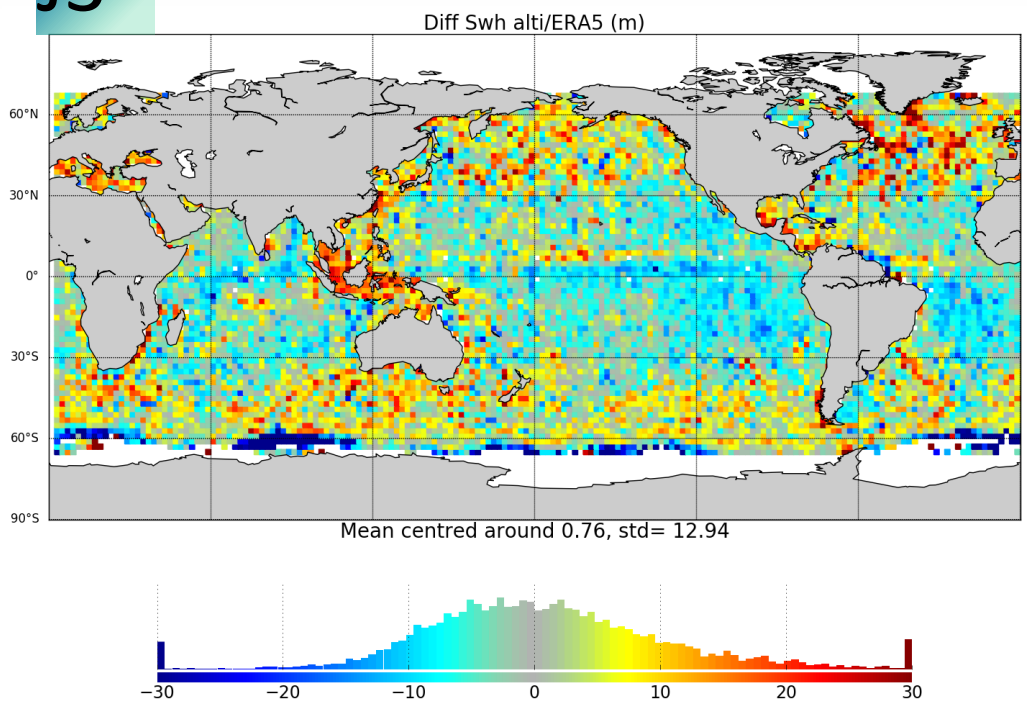
Waves and Wind - Integration in Wave-TAC

Input SWH data quality

Hy-2b

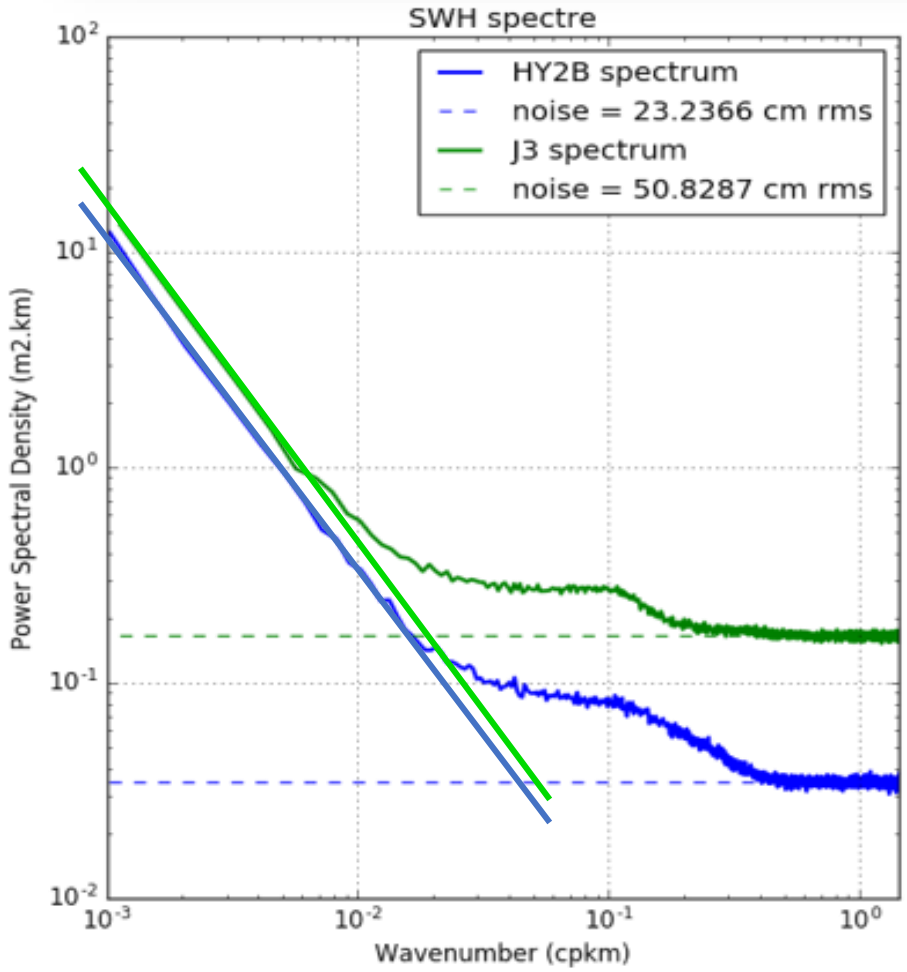


J3



- SWH are slightly overestimated (~10 cm). Geographical patterns (significantly stronger than for J3) are correlated with SWH

Input SWH data quality



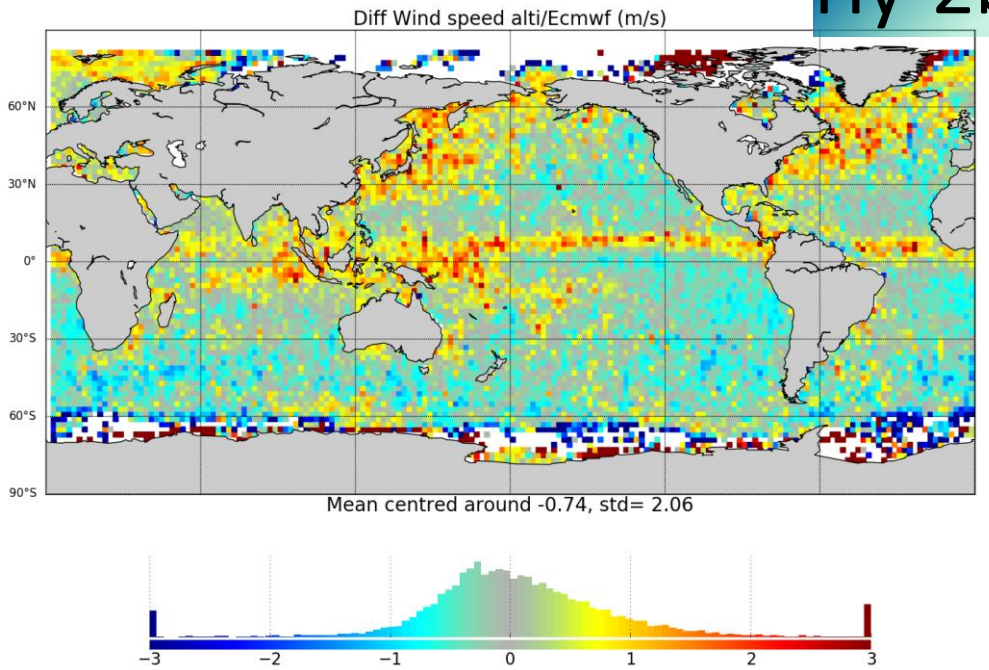
Jason-3 and Hy-2B SWH spectra have been computed over a common period over the open ocean.

- SWH spectral slope slightly steepest for Hy-2B at long wavelengths. Related to the geographical biases described previously.

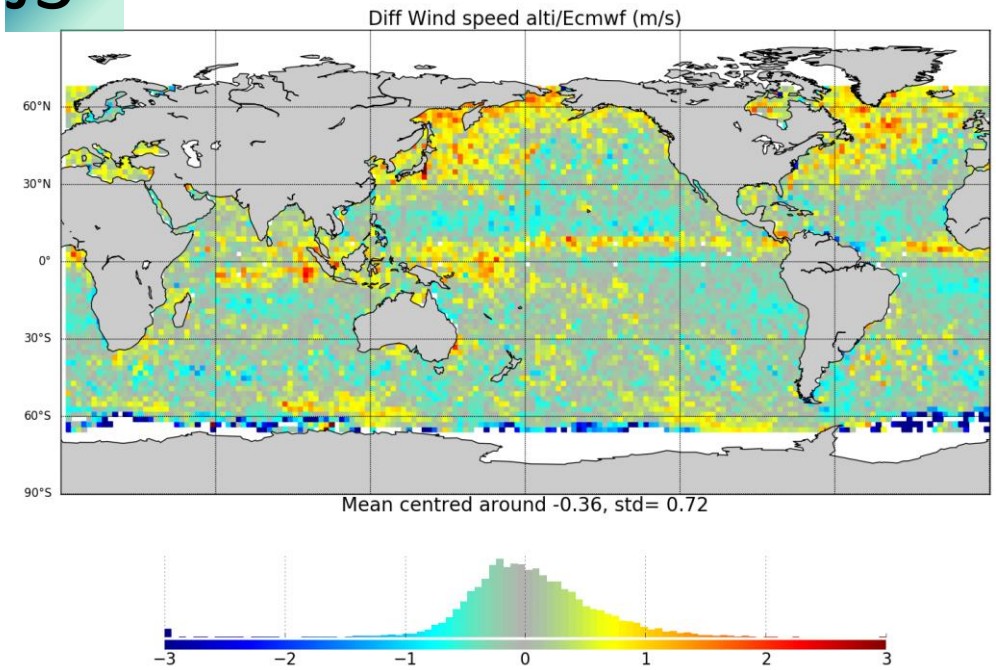
- Huge reduction (~80%) of the plateau energy for Hy-2B. SWH white noise significantly reduced.

Input Wind Speed data quality

Hy-2b

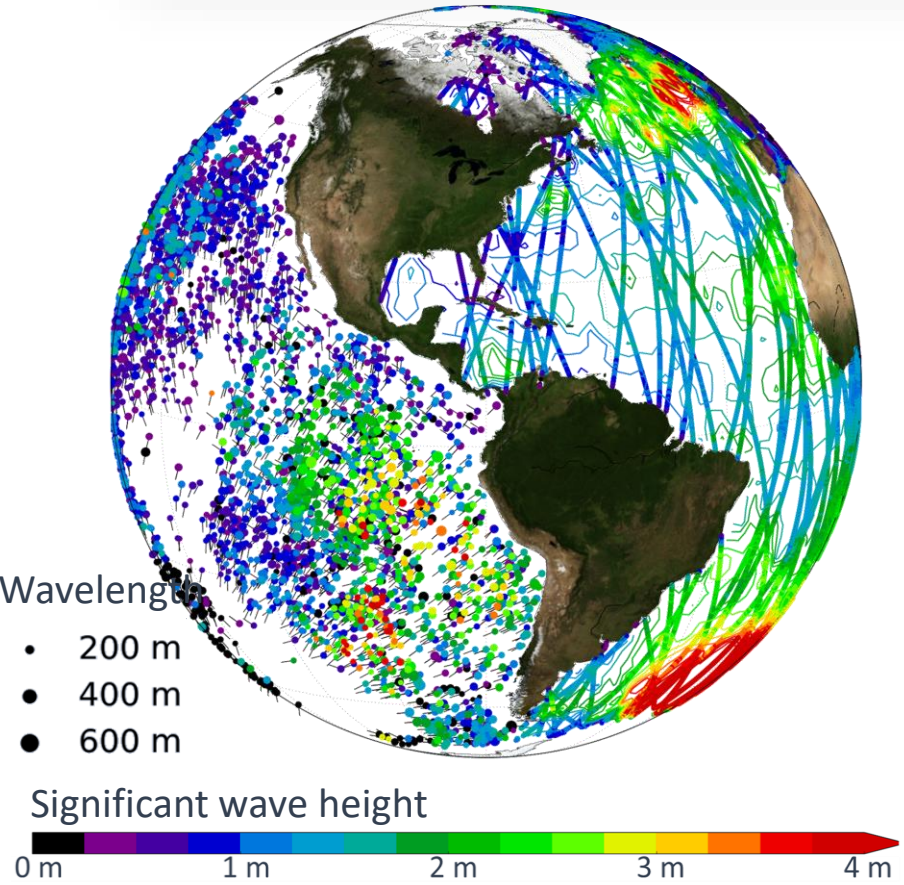


J3



- The wind speed estimation is slightly underestimated (-0.7 m/s) compared to ECMWF model
- Geographical patterns (slightly stronger than for Jason-3) are correlated with atmospheric attenuation

CMEMS WAVE-TAC: Available products and missions



Pacific: SAR-derived swell conditions ; Atlantic: Altimetry-derived along-track and gridded (contours) significant wave height

WAVE_GLO_WAV_**L3_SWH_NRT**_ OBSERVATIONS_014_001:

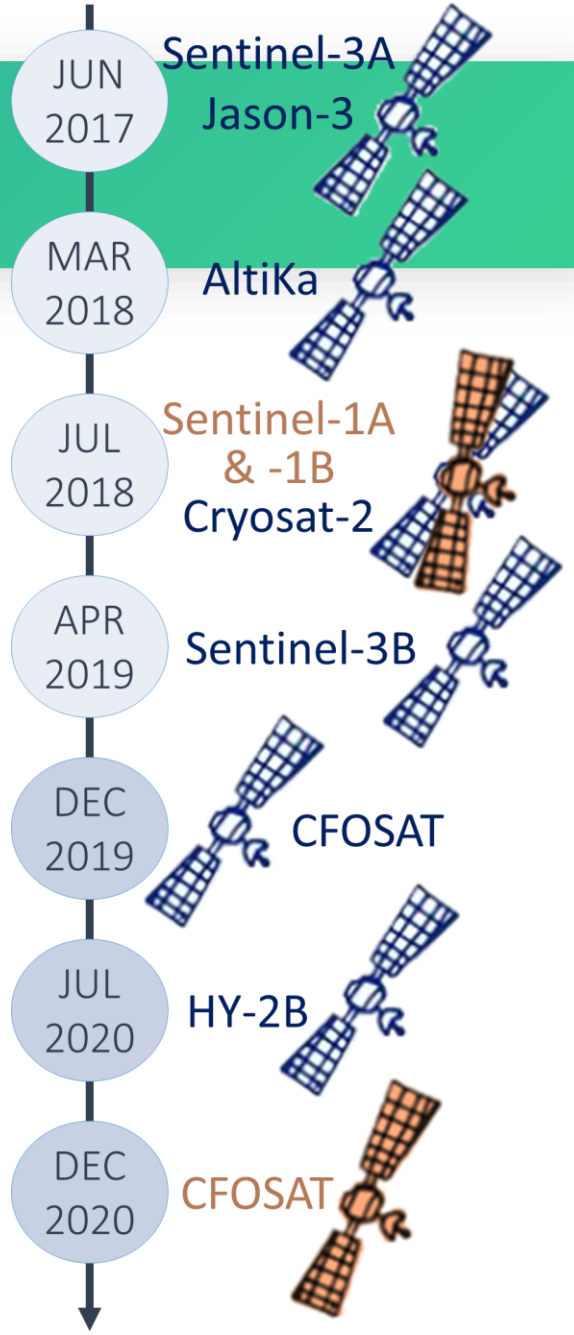
- Real-Time Level-3 waves from altimetry
- Edited, inter-calibrated, noise-filtered significant wave height (SWH)

WAVE_GLO_WAV_**L3_SPC_NRT**_ OBSERVATIONS_014_002:

- Real-Time Level-3 waves from SAR
- Spectral integral parameters (SWH, period, direction, wavelength) + backward and forward propagation from the swell observation

WAVE_GLO_WAV_**L4_SWH_NRT**_ OBSERVATIONS_014_003:

- Real-Time Level-4 waves from altimetry merging all available measurements onto a 2°x2° grid in daily files



CMEMS L3 SWH along-track product

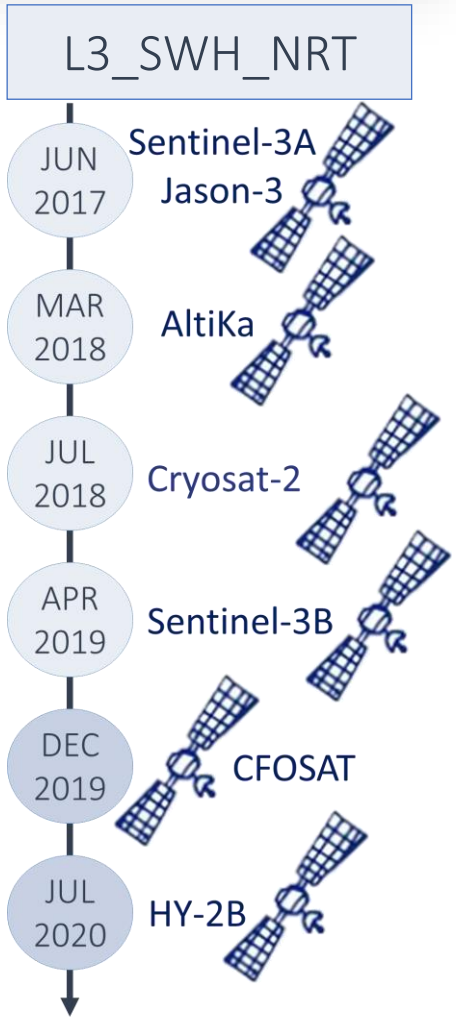
- **HY-2B was integrated successfully in L3 SWH product on the 7th of July 2020**

- Content: Along-track Significant Wave Height [meters] @1-Hz (~7km):
  - Unfiltered SWH
  - Filtered SWH
  - Wind speed

- Data processing
  - Acquisition of L2 NRT files
  - **Editing (thresholds, flags, RMS dispersion)**
  - **Inter- and absolute calibration (wrt Jason3 and in-situ)**
  - **Noise-filtering (following EMD denoising method, Quilfen and Chapron 2019)**
  - Quality monitoring: Daily automated controls + Quality controls reports

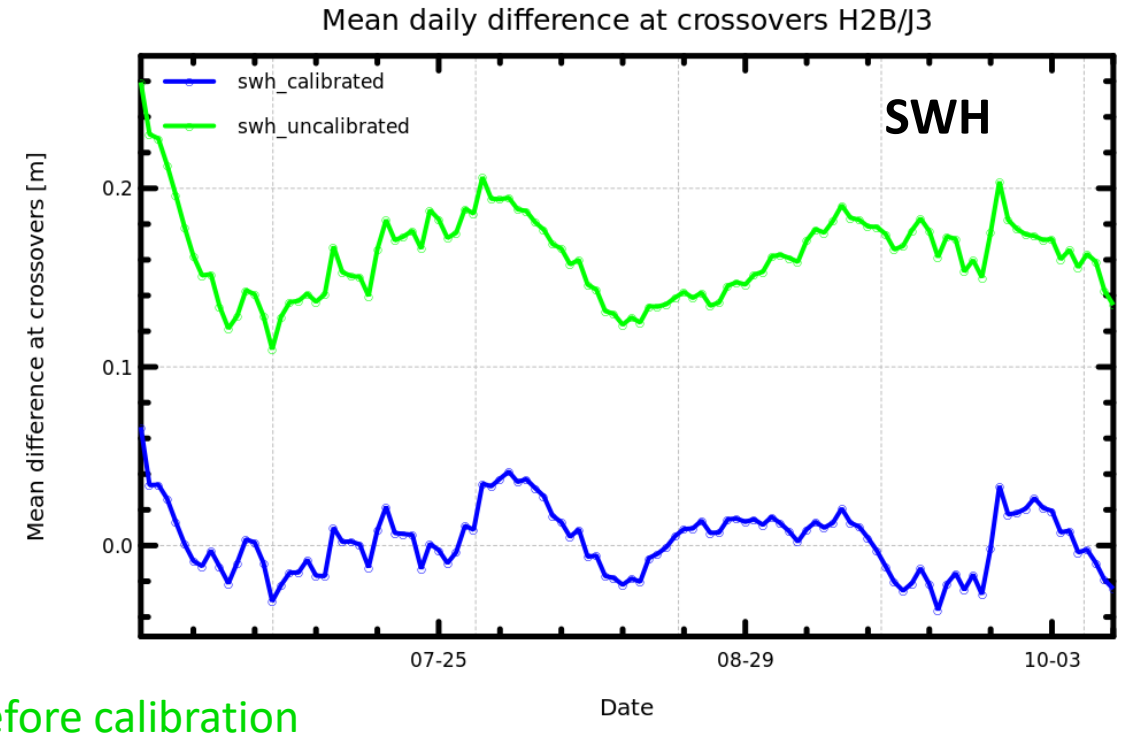
- Documentation QUID (format, processing, validation): http://marine.copernicus.eu

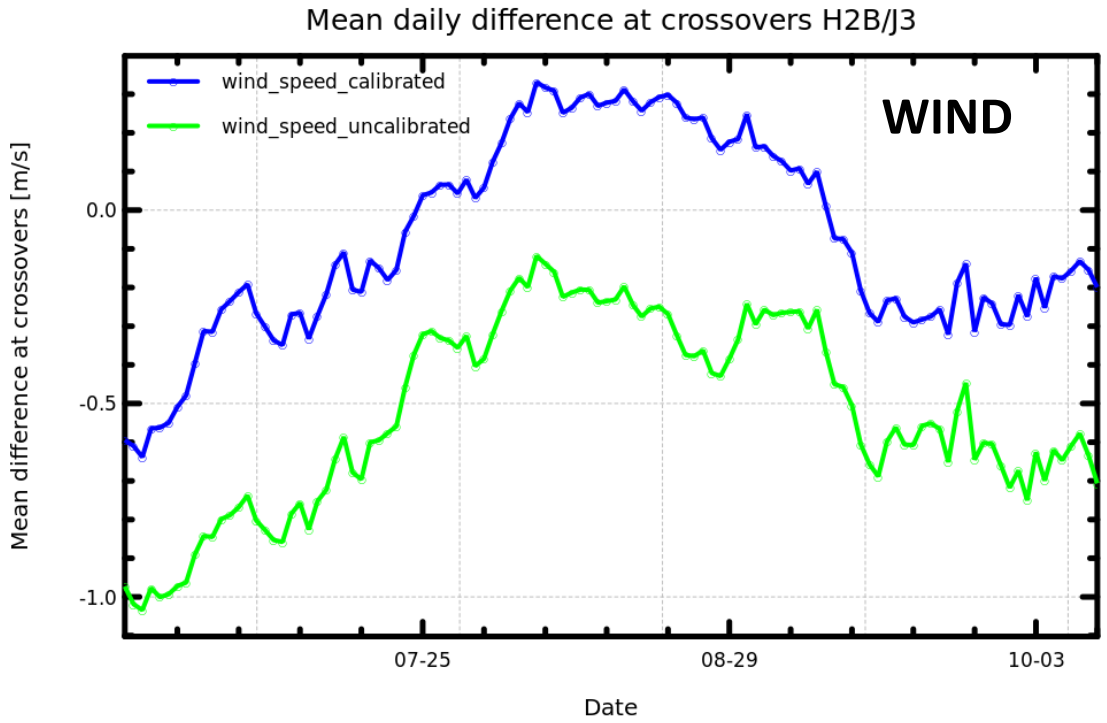
- Delivered in 3-hourly netcdf files
- 1st file production starts 3h after file starting time, then updated every 30min if new L2 data available.
- Distribution via ftp: ftp://nrt.cmems-du.eu/WAVE_GLO_WAV_L3_SWH_NRT_OBSERVATIONS_014_001



CMEMS L3 SWH product: Intercalibration

L3_SWH_NRT





Before calibration

After calibration

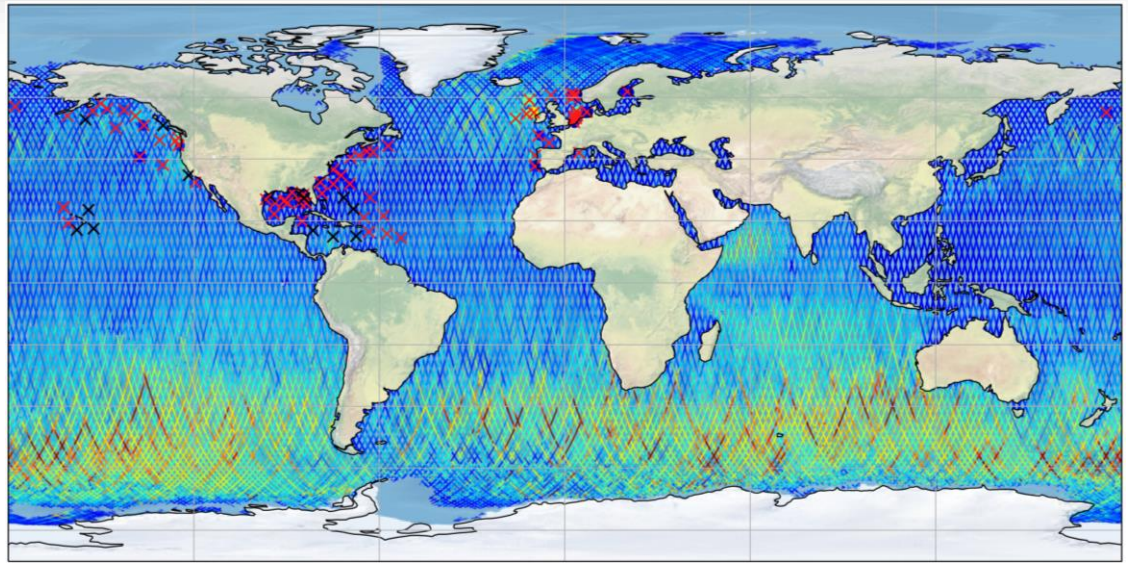
As demonstrated in the previous CalVal slides there is a need to inter-calibrate the Hy-2B SWH and Wind Speed estimations to generate multi-mission products

After calibration the global and regional biases observed with respect to Jason-3 are significantly reduced.

CMEMS L3 SWH product: Comparison with in-situ

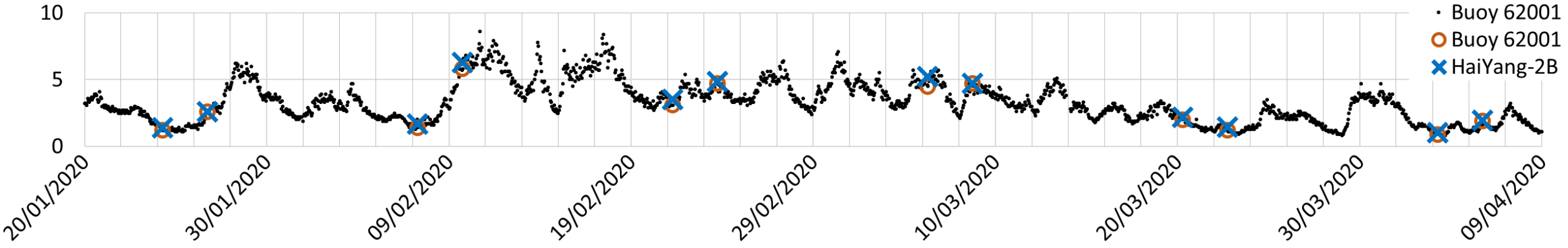
L3_SWH_NRT

- Level-3 SWH product is compared to a set of ~100 offshore wave buoys (CMEMS in-situ TAC) during the 6-month period January–June 2020
- Buoy SWH measurements are compared to the average of Level-3 SWH data selected within 30 min and 50 km of the buoy record



Match-ups between HaiYang-2B along-track SWH measurements and in-situ moorings are marked with red crosses

Example at the Gascogne buoy:



CMEMS L3 SWH product: Comparison with in-situ

L3_SWH_NRT

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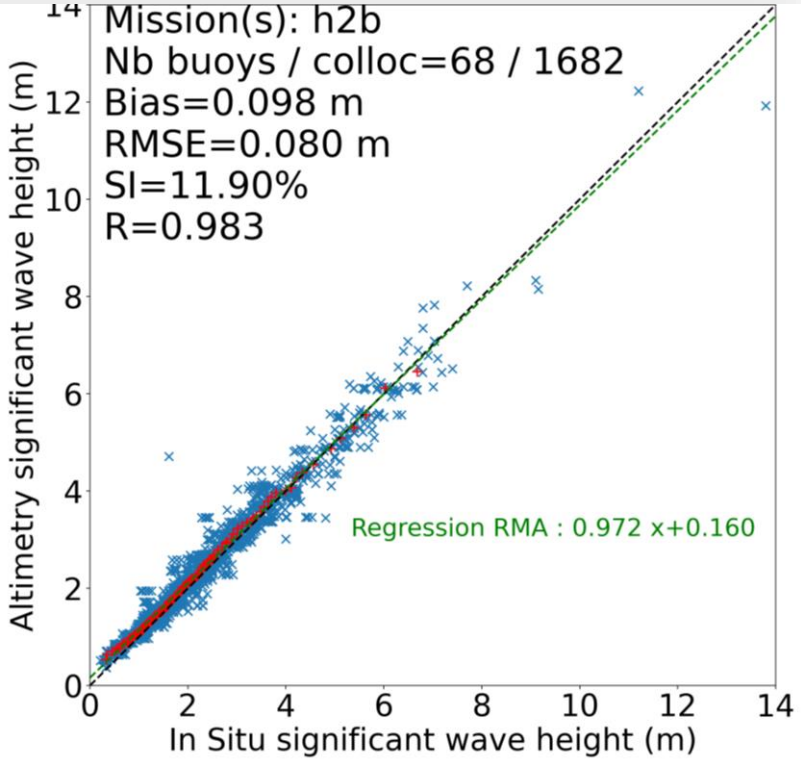
- Buoy SWH measurements are compared to the average of Level-3 SWH data selected within 30 min and 50 km of the buoy record

	Nb of match-up	Bias	RMSD	SI	R
L3 HaiYang-2B	1682	9.8 cm	8 cm	12%	0.98
L3 Jason-3	2276	8.6 cm	7.8 cm	13%	0.98
L3 Sentinel-3A	2303	10 cm	7.4 cm	12%	0.98
L3 Sentinel-3B	2079	8.4 cm	9.4 cm	14%	0.98
L3 AltiKa	1247	7.8 cm	4.2 cm	12%	0.98
L3 CryoSat-2	1935	8 cm	6.2 cm	11%	0.98

- **Compared to in-situ measurements, HY-2B presents performances similar to Jason and other primary missions.**

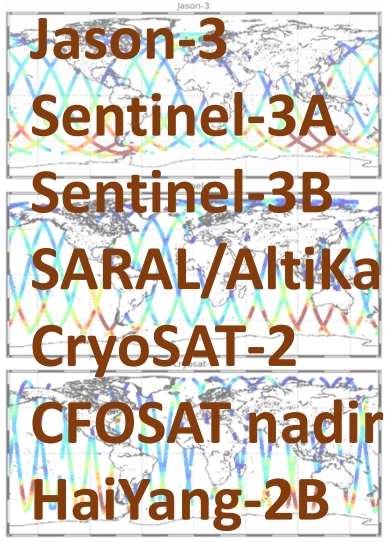


Scatter (blue crosses) and quantile-quantile (red crosses) plot of HaiYang-2B comparison with in-situ measurements [January-June 2020]

Integration of HY-2B in CMEMS L4 SWH product

L4_SWH_NRT

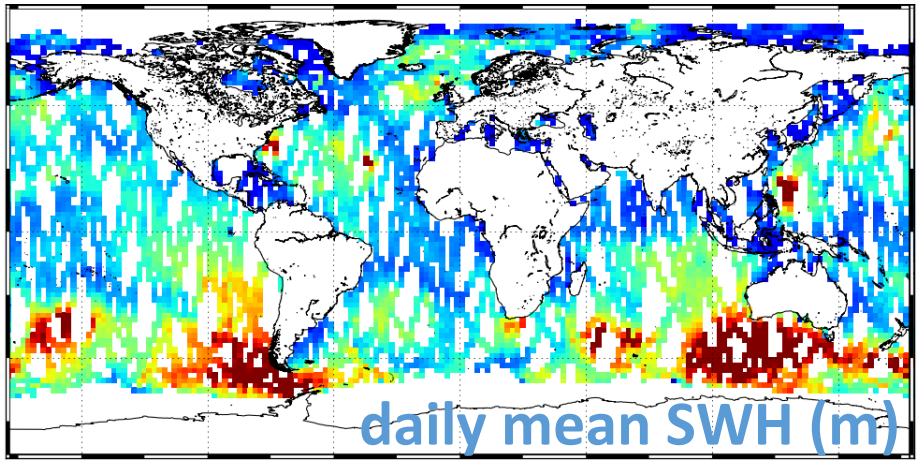
Along-track Level-3



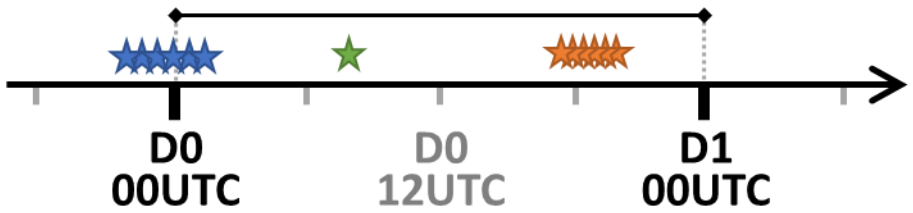
- Jason-3
- Sentinel-3A
- Sentinel-3B
- SARAL/AltiKa
- CryoSAT-2
- CFOSAT nadir
- HaiYang-2B

Example of L3 measurements over one grid cell (2°x2°)

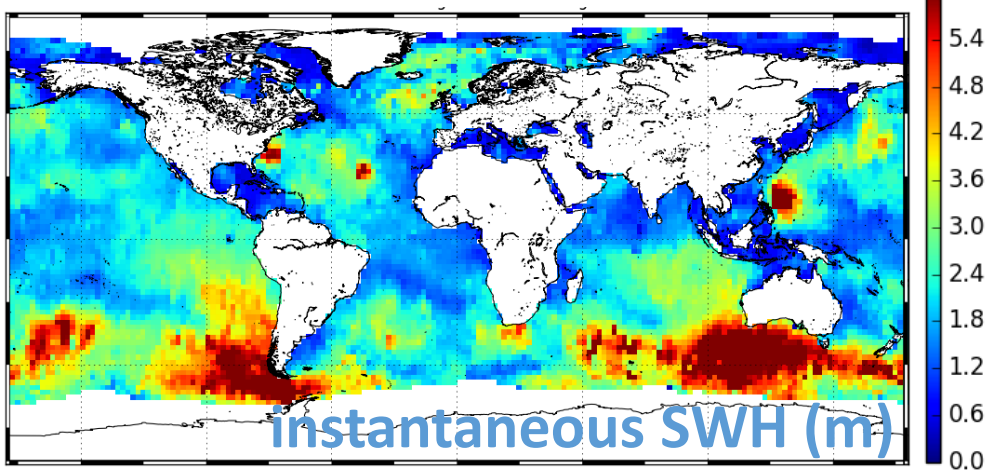
Daily fields



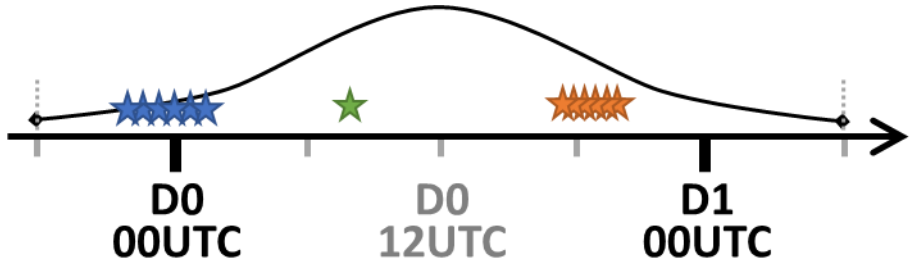
VAVH_DAILY_MEAN: average of available Level-3 along-track measurements from 00 UTC until 23:59 UTC



Instantaneous fields

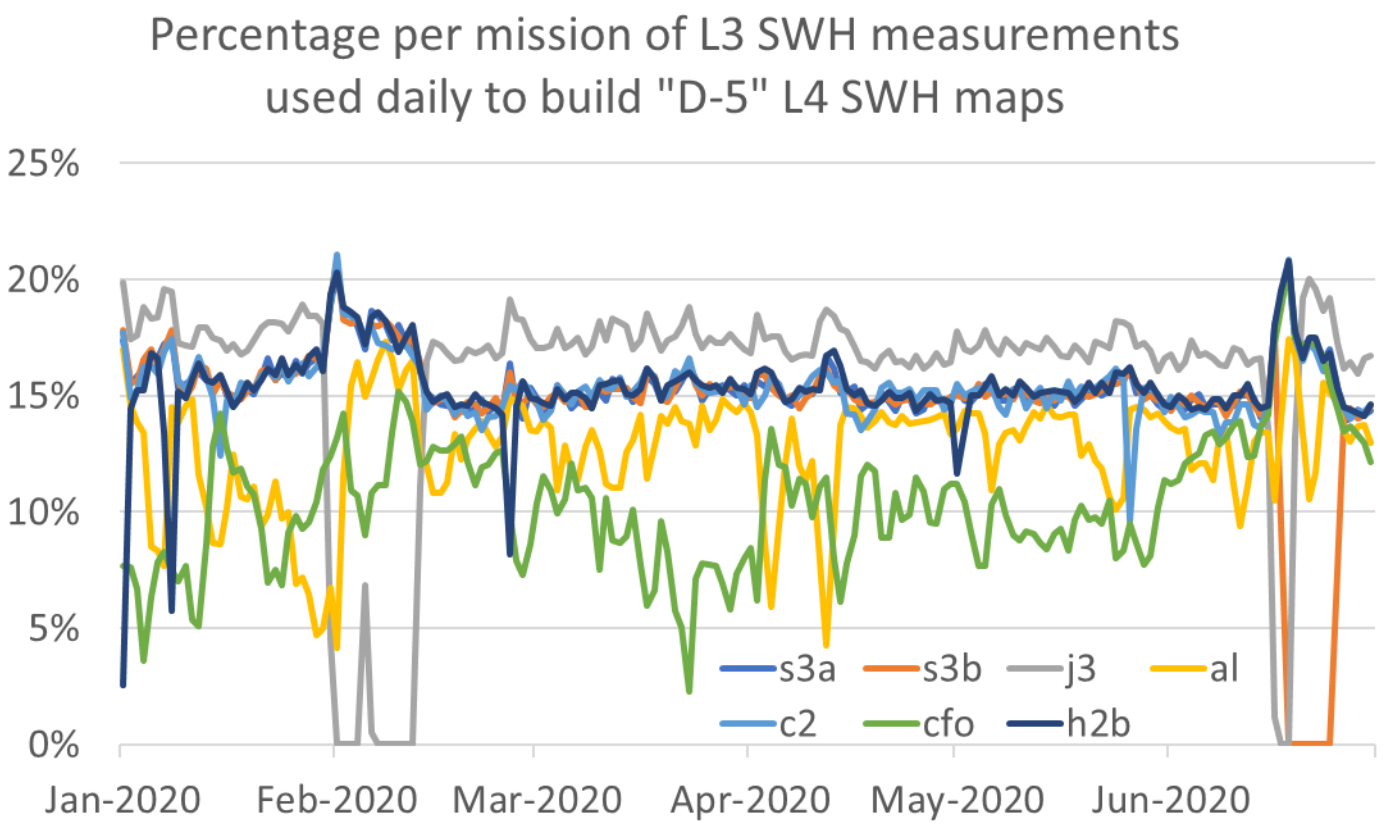


VAVH_INST: weighted average of level-3 available along-track measurements to account for their temporal proximity and spatial interpolation when no measurements



Integration of HY-2B in CMEMS L4 SWH product

L4_SWH_NRT



- L4 SWH maps are computed with a delay of 1 day (D-1), 2 days (D-2) and 5 days (D-5) after the time of the map
- **HY-2B only contributes to the final "D-5" map, as IGDR data are not available on time for the "D-1" and "D-2" maps**
- The contribution of HY-2B (dark blue line) was very steady during the 1st semester of 2020. The amount of measurements used daily to build the L4 SWH map is similar to missions such as Sentinel-3A, -3B and CryoSAT-2

Conclusion & perspectives

Conclusion

HY2B has been used operationally in the Sea-Level and Wave multi-mission systems since the 7th of July. From these 3 months of operation the main feedbacks are:

Operational data processing: Very good temporal L2 product availability and spatial coverage

Sea Level

- Good general data quality of input data. High crossovers standard deviation have been noticed early October. These errors have efficiently been removed by the DUACS cross calibration process.
- HY2B has a 14% contribution to the maps over the July-August period. By improving the timeliness of the products, ie using OGDR based products, with a few hours of delay, the contribution of HY2B could still be increased

Wind & Waves

- Good general data quality of input data, with a significantly reduced white noise for SWH. Wind speed and SWH are respectively under- and over-estimated compared to ERA5. Those biases were successfully removed through the intercalibration process.
- HY2B has a 15% contribution to the D-5 maps over the January-June period. The availability of OGDR products would allow using HY2B data in input of near-real-time L4 maps (D-1 and D-2) and forecasting wave systems

Perspectives

- Computation of an HY2B 3D Sea State Bias
- New algorithm of wet tropospheric correction, updated by the NSOAS during july 2020 → Assess the possibility of use the radiometer in SLA products
- Assessment of GDR HY2B for ingestion in the Delayed Time production line
- Full reprocessing of the altimetry products including HY2A & B: Dissemination of L2P in march 2021 and L3/L4 in Septembre 2021
- Development of high resolution products
- Implementation of next Hy-2C into SL and W&W products