Improved Intercalibration of Multimission Altimeter Significant Wave Heights for Climate Data Record

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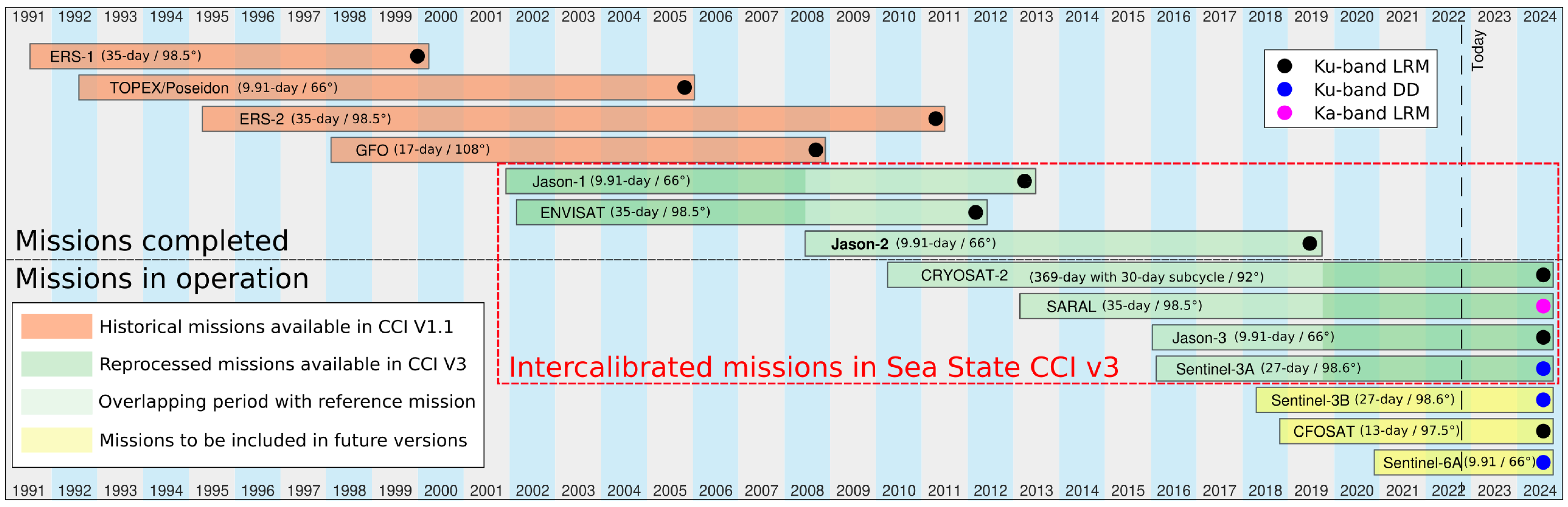
The Sea State Climate Change Initiative

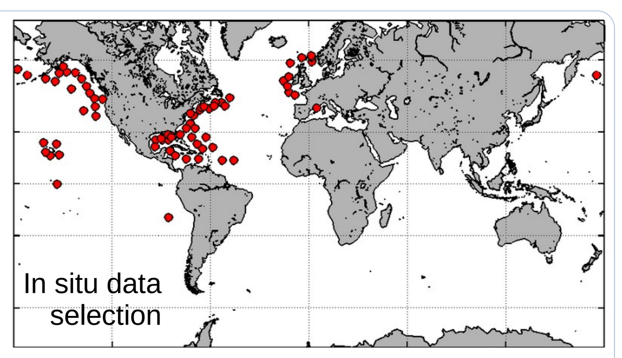
Consistent continuous long-term sea state observations are necessary to assess and measure climate variability and clarify underlying trends. **The ESA Sea State Climate Change Initiative (CCI)** aims at producing **sea state climate data records** by developing **state-of-the-art data analysis methods** and implementing them to historical global satellite data. To date, the most widely used satellite sensors to measure significant wave height (SWH) and spectral wave properties are radar altimeters and SAR imagers, respectively. **A key requirement to produce a robust multi-sensor multi-mission product is the intercalibration process**, which ensures that every mission provides measurements consistent with each other. In this poster, **we present the method developed for calibrating the altimeter missions of the Sea State CCI product**.

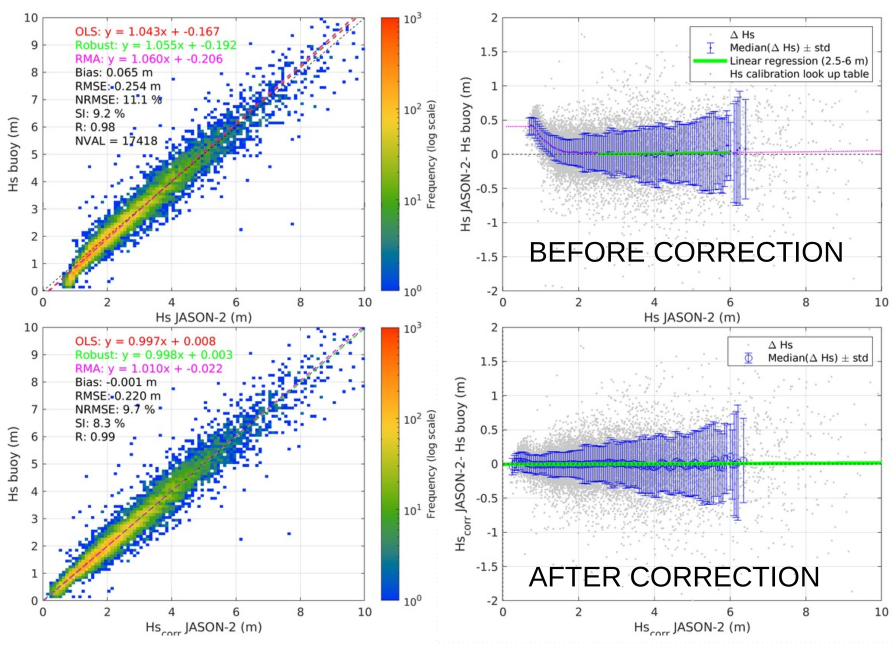


Recent radar altimeter sensors use Delay-Doppler (DD) processing to increase along-track resolution. In the latest release of the Sea State CCI dataset (v3), 6 conventional and 1 DD altimeter mission have been reprocessed (+ Sentinel-1A&B SAR missions).

Absolute calibration of Jason-2 mission

Jason-2 SWH records are **calibrated against in situ data** to provide an absolute reference for calibrating all other missions. Only offshore (>100km from the coast) in situ buoys are used. Matchups between altimeter and in situ records are computed within 100-km distance and 1-h time window.





Calibration Look-Up Tables (LUT)

- Residuals between altimeter and in situ computed versus SWH (grey dots)
- Median and std of the residuals computed for every 20-cm bins, containing at least 100 values (blue error bars)
- Linear regression fitted through the median over the range 2.5-6 m (green line)
- Correction LUT combines binned median values for SWH<2.5 m and linearly interpolated values for SWH>=2.5 m (magenta dots)
- 5-point moving average applied to the 0.05-m spaced LUT to reduce noise in the correction

Validation against buoys

The methodology is validated by comparing uncalibrated and calibrated measurements against in situ data. Systematic and random error metrics show improvements in the calibrated data. In particular **the bias is reduced from 0.09 m to 0.02 m on average**.

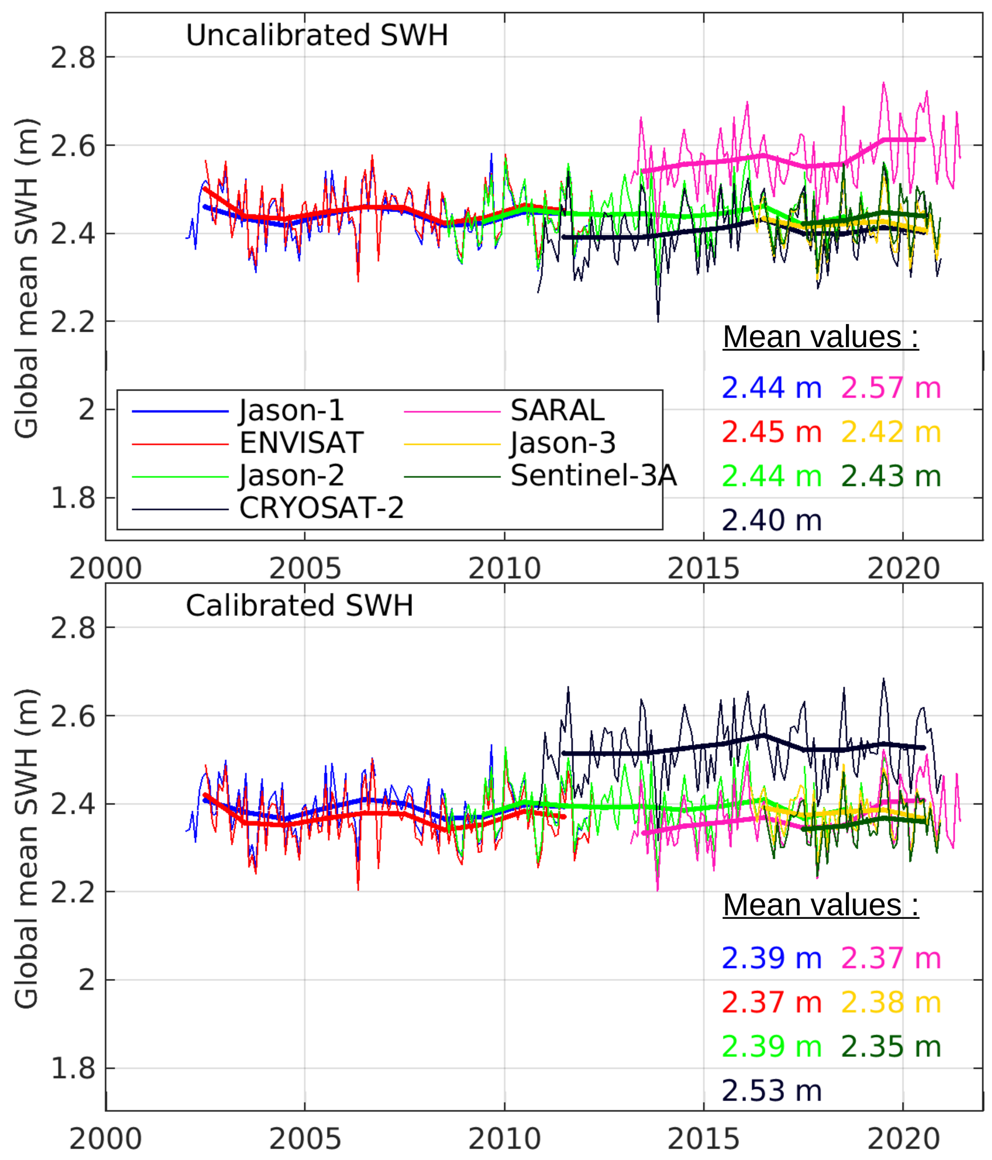
Mission	#values	Bias (m)	$Bias_{cal}$ (m)	NRMSE (%)	$NRMSE_{cal}$ (%)	SI (%)	SI_{cal} (%)	R^2	R^2_{cal}
Jason-1	11433	0.05	-0.01	9.72	8.88	9.55	8.87	0.96	0.97
ENVISAT	14131	0.07	-0.01	9.17	8.48	8.8	8.47	0.97	0.97
Jason-2	17146	0.07	0	9.56	8.34	9.24	8.34	0.97	0.97
CRYOSAT-2	795	-0.09	0.02	8.2	7.23	7.29	7.18	0.97	0.97
SARAL	10909	0.24	0.02	12.37	7.98	8.35	7.94	0.97	0.97
Jason-3	7043	0.07	0.02	9.33	8.13	8.98	8.11	0.97	0.98
Sentinel-3A	12718	0.09	0.01	10.1	9.23	9.38	9.21	0.97	0.97
AVERAGE	10727	0.09	0.02	9.96	8.56	9.1	8.54	0.97	0.97

Time consistency

Global average of the yearly and monthly mean SWH are computed with uncalibrated and calibrated data in order to **verify the improved temporal consistency of the calibrated dataset**. In order to reduce the impact of heterogeneous spatial sampling, global means are computed between 50°S and 50°N.

Uncalibrated data (top panel) show relatively consistent yearly mean time-series, except for SARAL, which overestimates the global mean by ~10cm (~5%).

The calibrated data (bottom panel) shows **improved consistency between SARAL and other missions** (in particular with ENVISAT which shares similar orbit). Overestimation of the global mean by CRYOSAT-2 can be explained by the specific orbit characteristics and LRM acquisition mask of this mission.



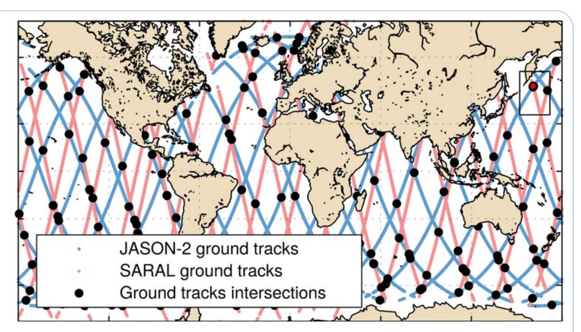
Key features of the Sea State CCI v3 dataset :

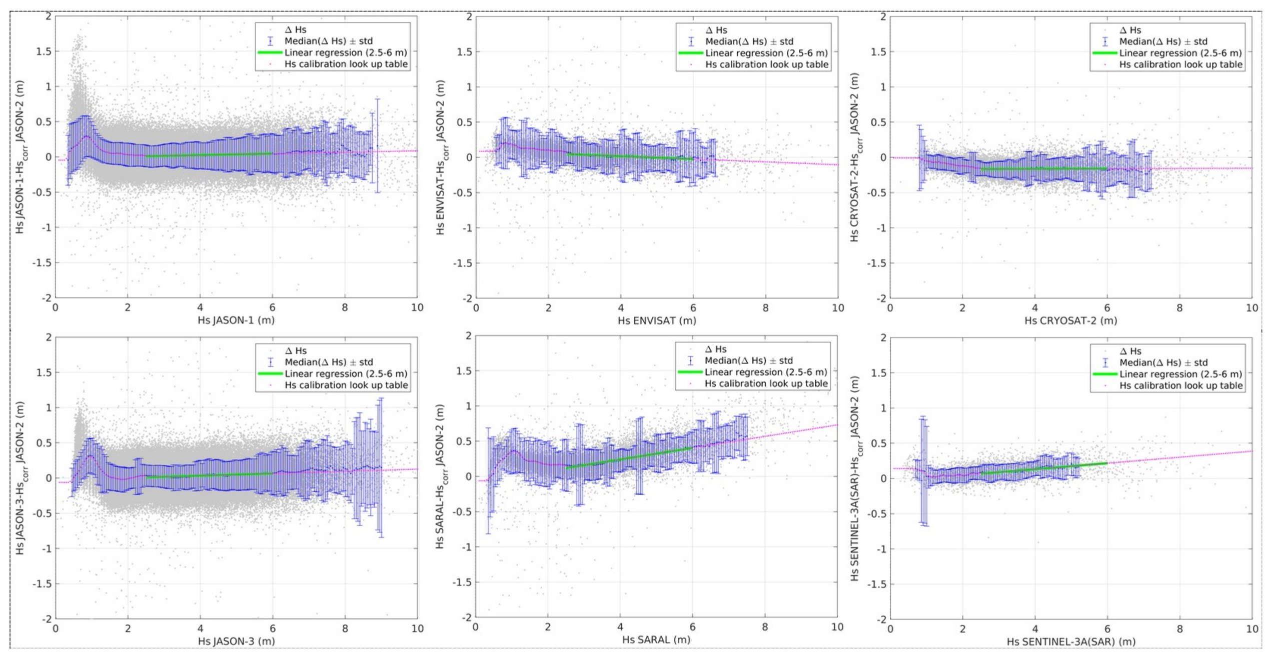
Check it on :

- **novel waveform retracking algorithms** for conventional (WHALES) and SAR altimetry missions (LR-RMC)
- **total SWH** from S1A&B SAR missions using neural net. approach
- **wave directions and wavelengths** from ENVISAT, S1A&B (SAR)
- **consistent data editing and intercalibration** across all missions
- **EMD-based denoising** of 1Hz along-track SWH

Inter-mission calibration at crossover

All missions are inter-calibrated against the corrected Jason-2 mission, using crossover measurements during overlapping time periods (ΔX< 100 km, ΔT < 1-hr). Altimeter SWH are filtered using 50-km along-track average.

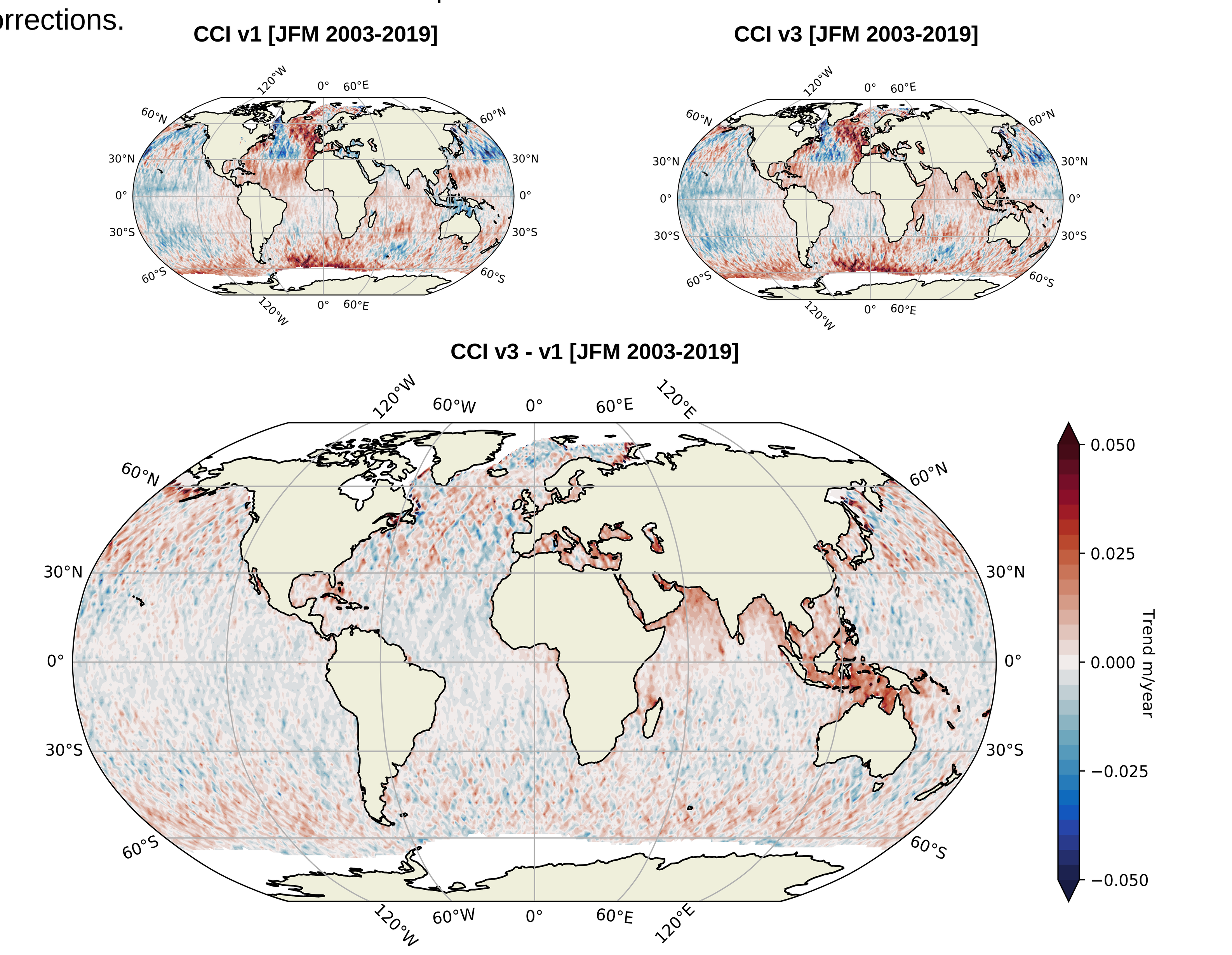




This figure shows the corrections (magenta dots) obtained for each mission and highlights the **different behaviors of each sensor at low and high sea states.** The non linear relationship between sensors, in particular at low sea states, **clearly prevents from applying linear calibration.**

Impact on trends

Linear trends of the winter (JFM) mean SWH are computed with the version 1 and version 3 of the Sea State CCI products, which use different processing techniques (waveform retracking, intercalibration). **Differences between these products are mostly found in enclosed seas**, where low sea states are more frequent and where LUT corrections differ the most from linear corrections.



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Information on the Sea State CCI project (publication, data, user consultation meetings...) can be found at : **https://climate.esa.int/en/projects/sea-state/**