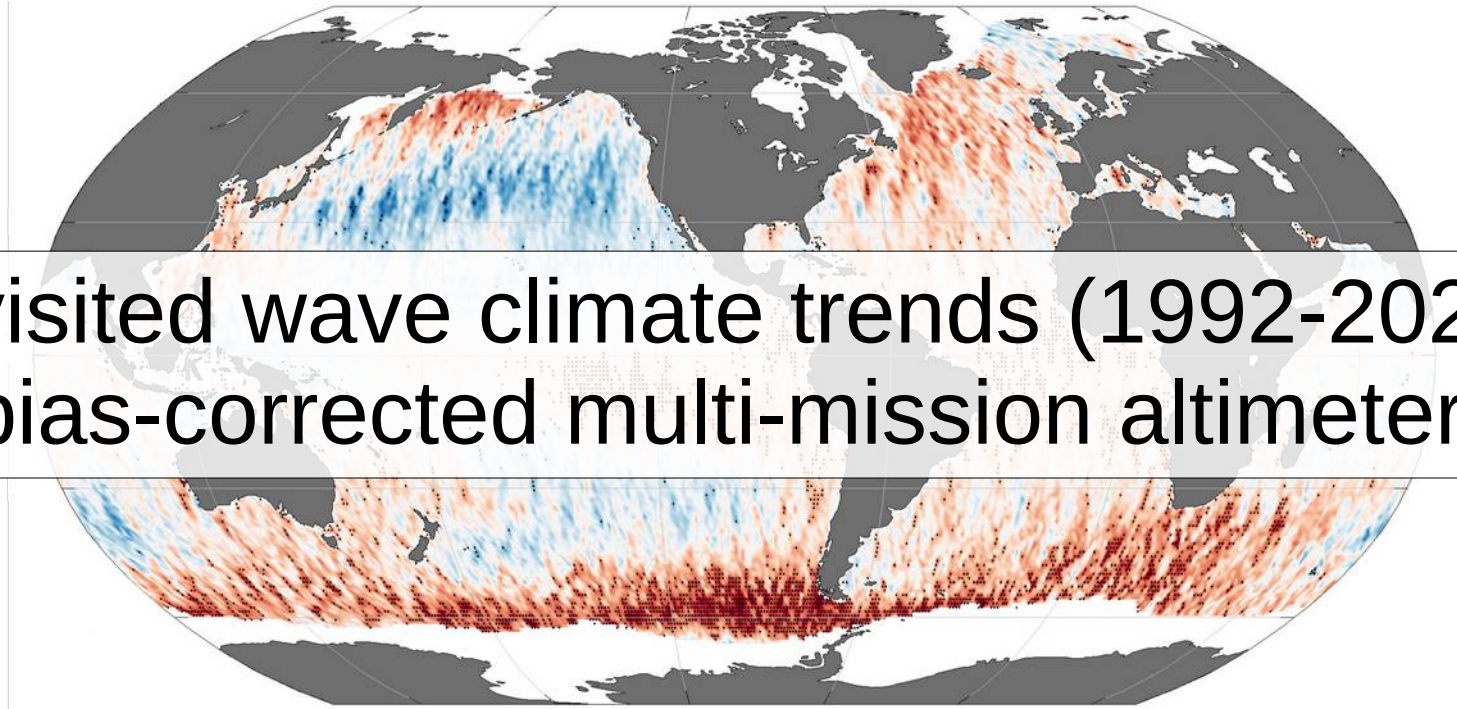


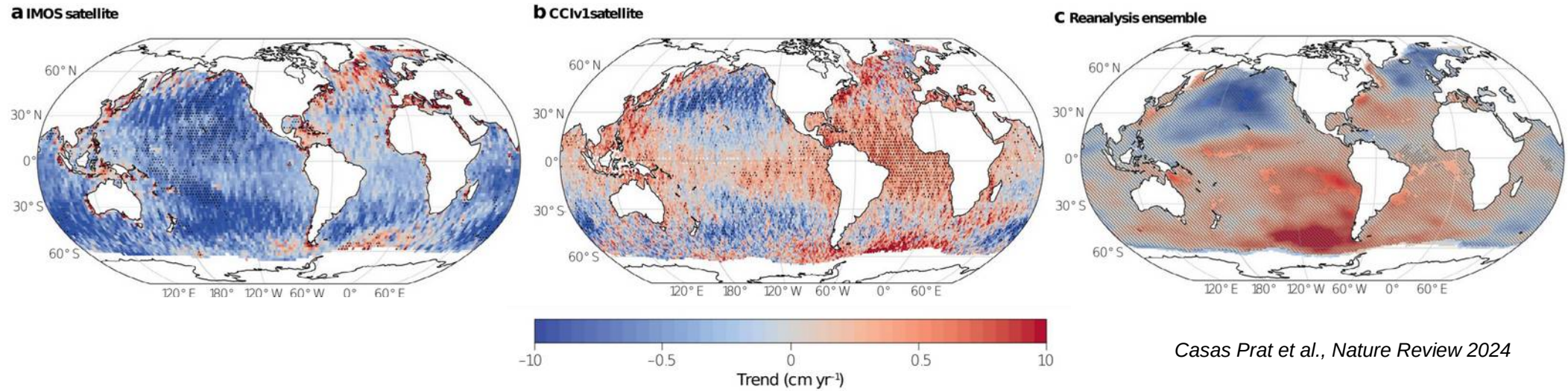
Revisited wave climate trends (1992-2024) from bias-corrected multi-mission altimeter data

G. Dodet, JF. Piollé, E. Sorrieul, A. Nigou, A. Ollivier, F. Ardhuin

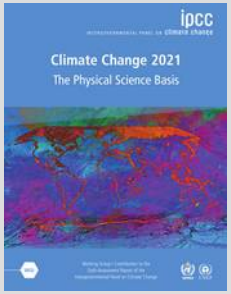
+ contributions from Sea State CCI team

Historical wave climate – state of the art

Satellite observations vs. reanalysis ensemble (1992-2018)



Casas Prat et al., Nature Review 2024

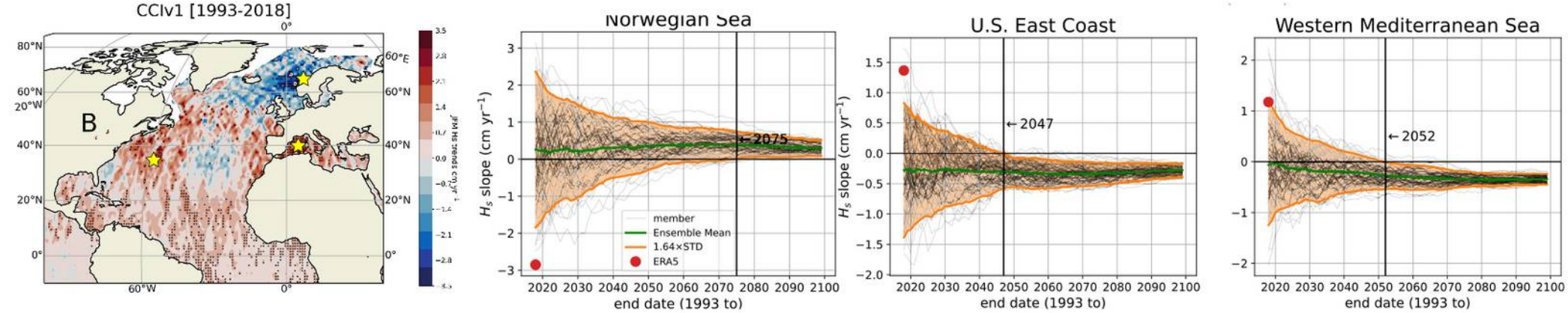


Satellite era trends in wave heights of order 0.5 cm yr $^{-1}$ have been reported [...]. However, ***sensitivity of processing techniques, inadequate spatial distribution of observations, and homogeneity issues*** *in available records limit confidence in reported trends (medium confidence)*.

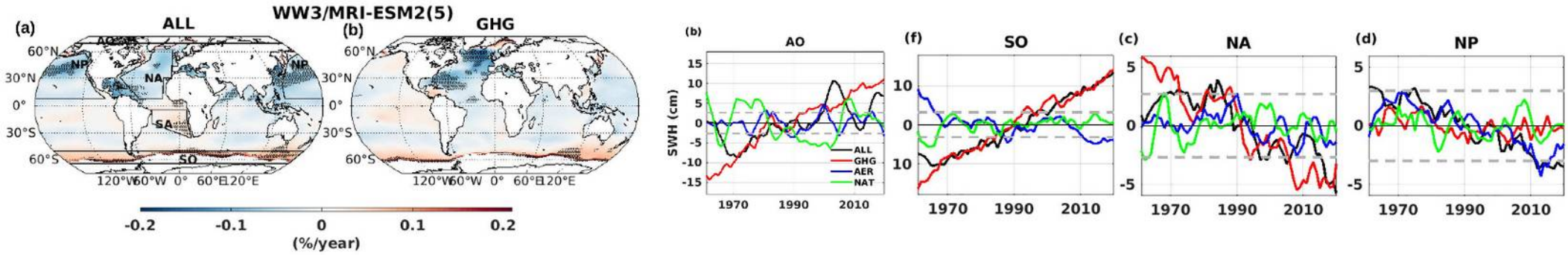
IPCC AR6 Working Group 1, Chapter 9

Wave climate trends – Significance and attribution ?

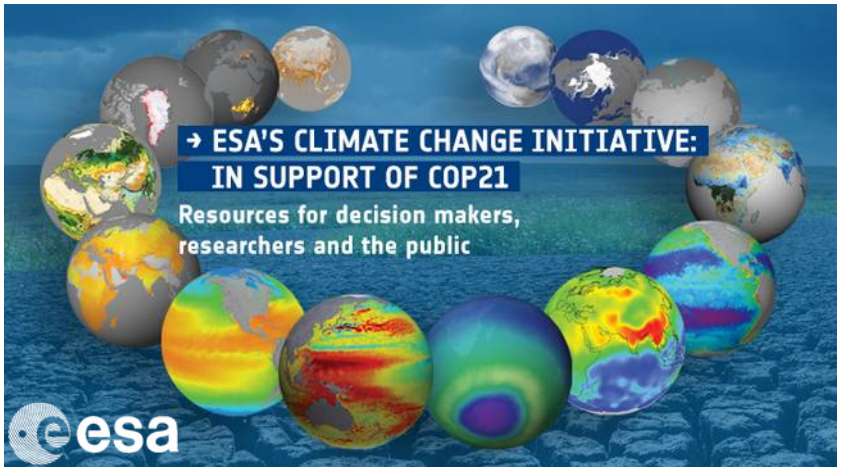
Time of Emergence for Significant Wave Height Changes in the North Atlantic (Hochet et al. GRL 2023)



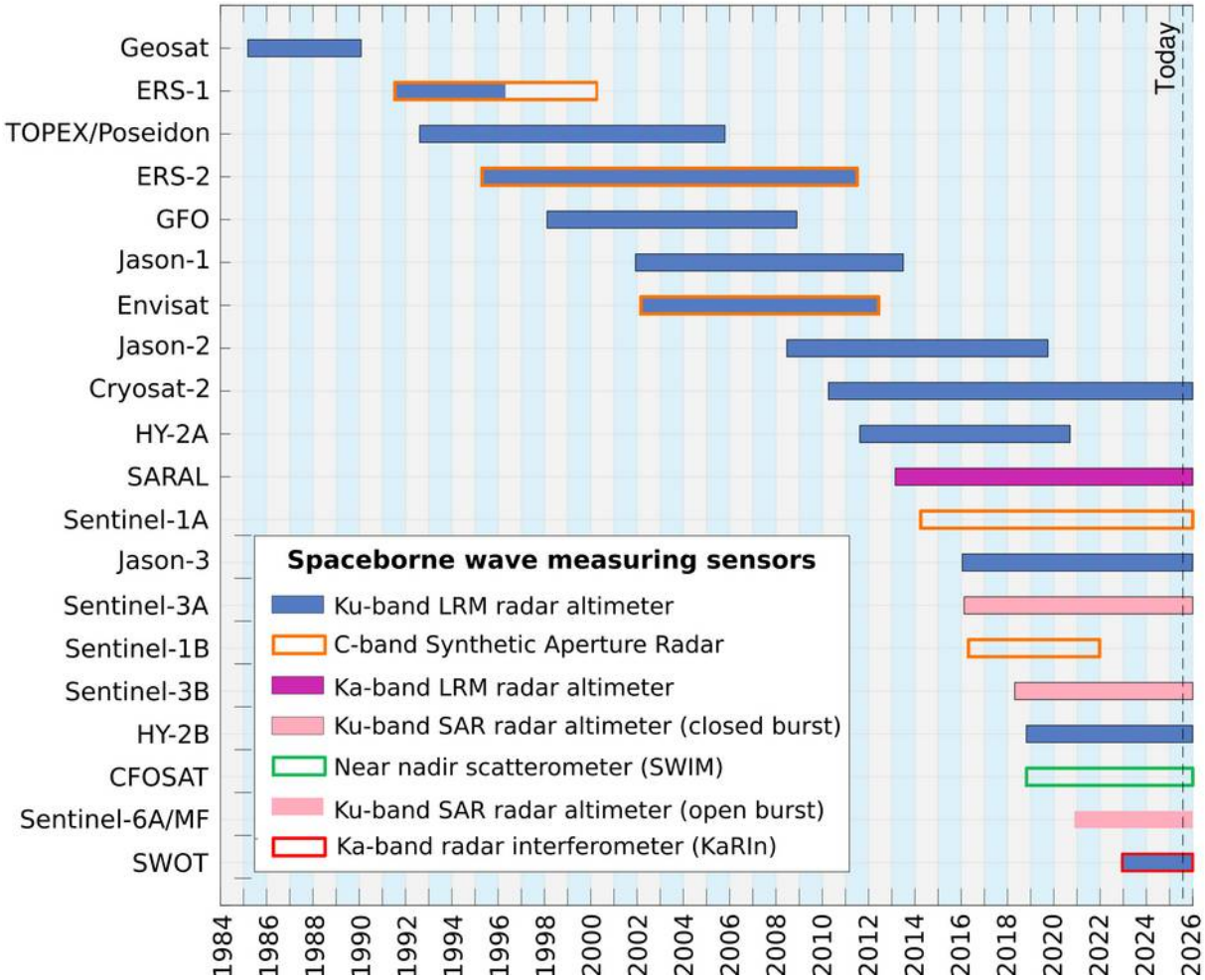
Quantifiying Anthropogenic Influences on Global Wave Height Trend During 1961–2020 (Patra et al. GRL2024)



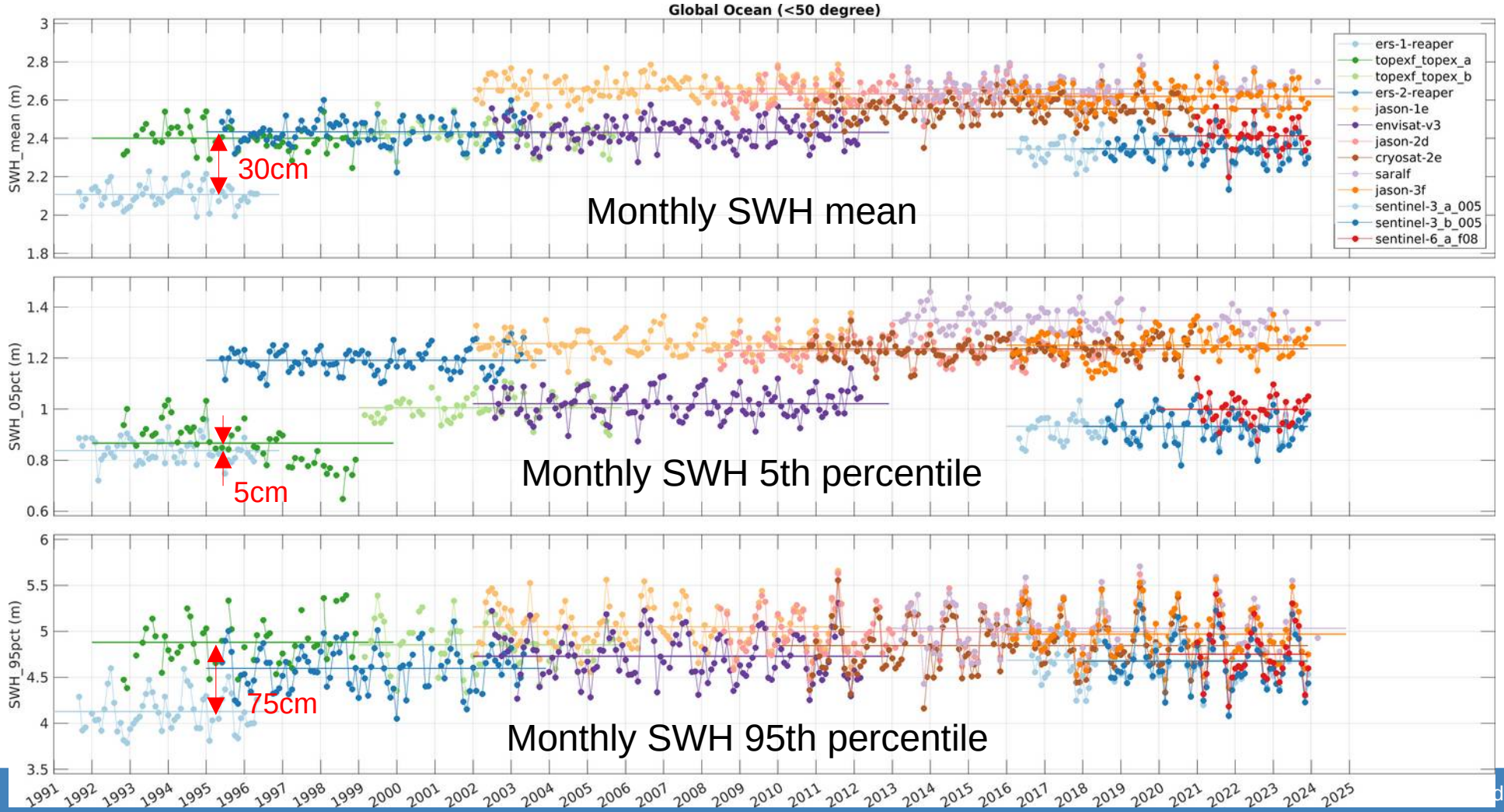
Towards a consistent Sea State Climate Data Record...



… with 30 years of changing satellite missions, sensor technology, processing techniques, orbit characteristics etc...

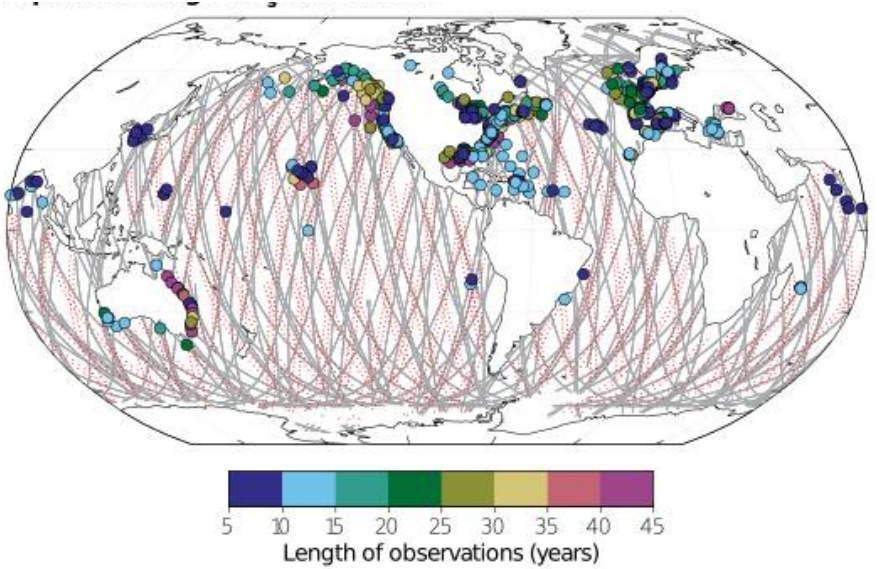


Let’s take a look at the raw altimetry data



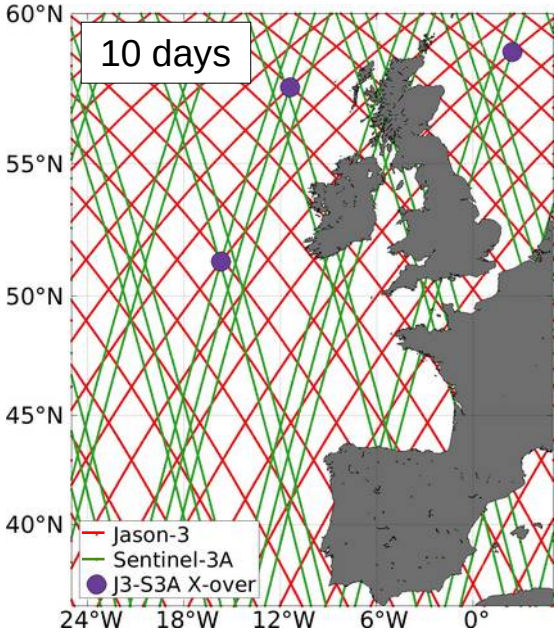
Useful data for altimeter calibration

Altimeter – buoy matchups



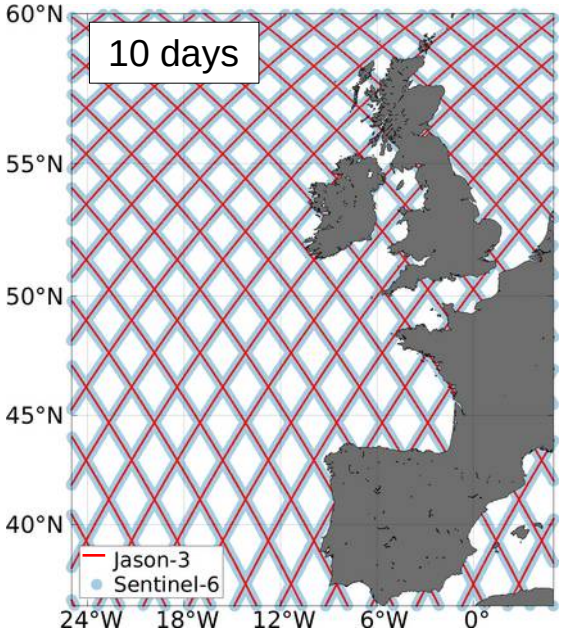
+ ground truth
- sparse : Northern Hemisphere + coastal
- network and platforms change over time
- high representativeness errors

Altimeter – altimeter crossovers



+ low representativeness errors
- limited number of samples
- mostly located in the high latitudes

Altimeter – altimeter tandem records

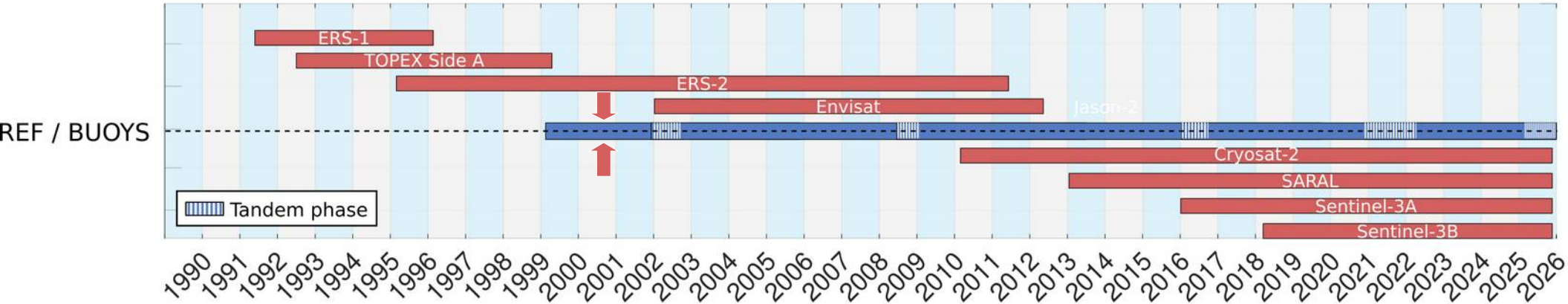


+ lowest representativeness errors
+ very high sampling
+ global coverage
- only for reference missions

Bias correction methodology in Sea State CCI version 4

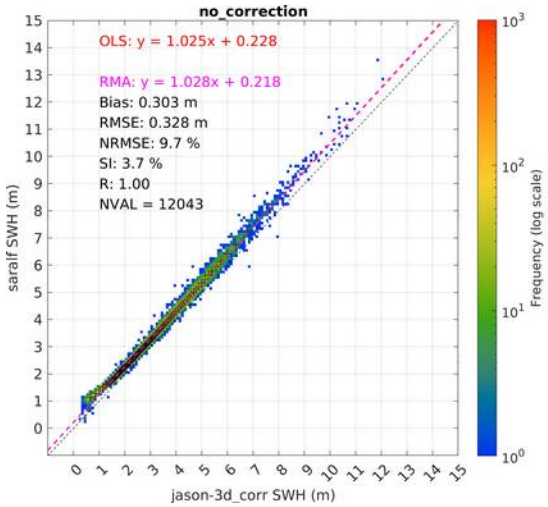
The bias correction method can be decomposed into three main steps :

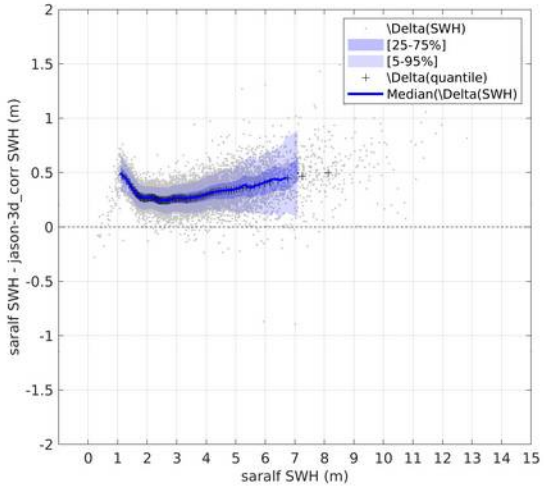
1. **Inter-calibration of the reference missions (based on tandem measurements)**
2. **Absolute calibration of the reference missions (based on altimeter-buoy matchups)**
3. **Inter-calibration of the non-reference missions (based on altimeter-altimeter crossover)**

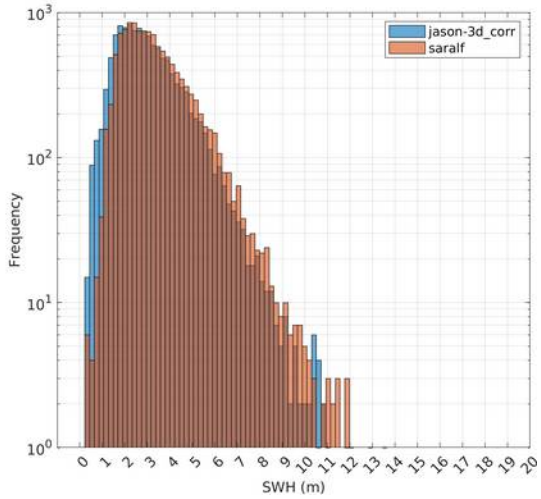


Non-linear bias correction

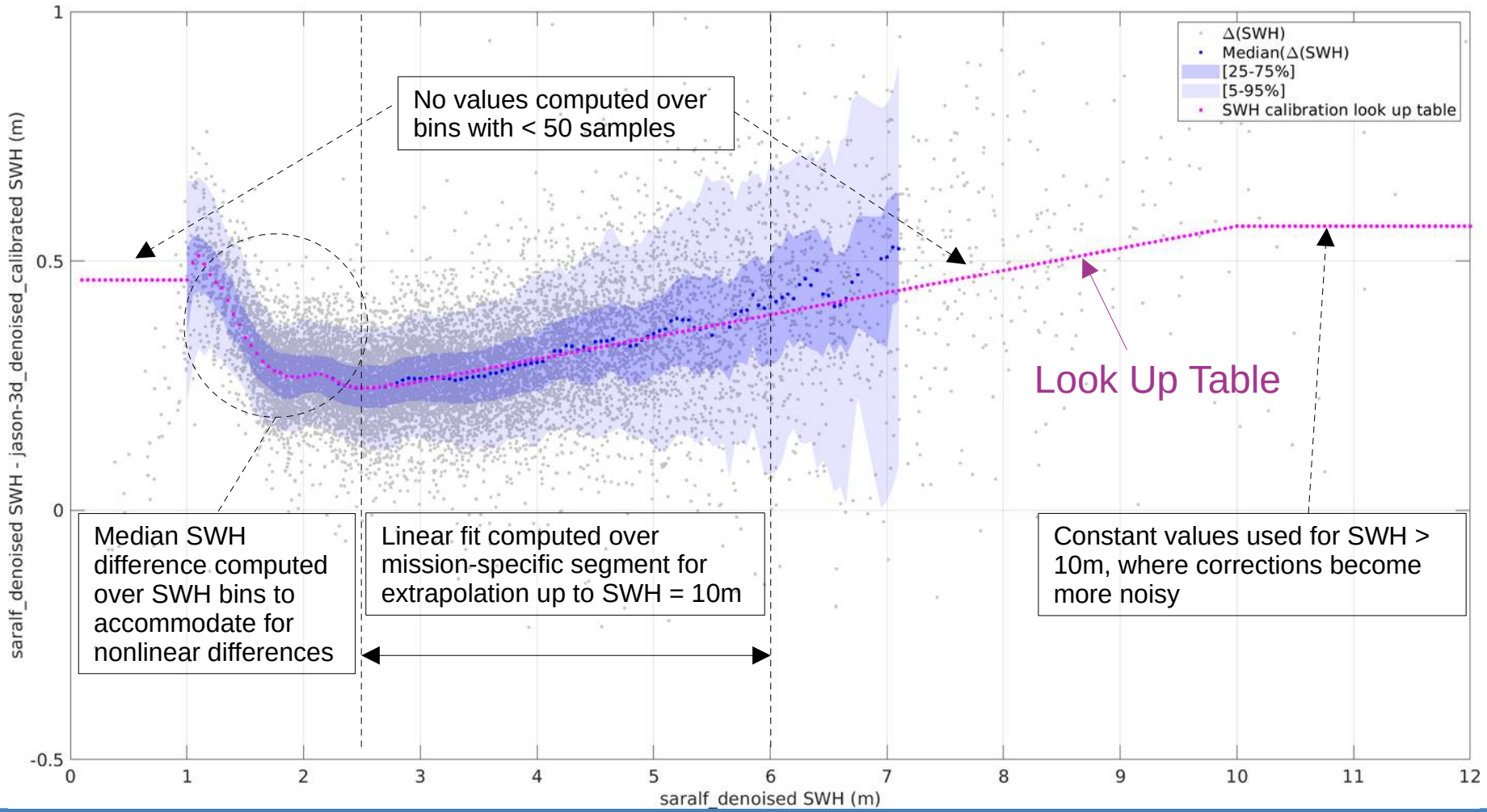
BEFORE CORRECTION





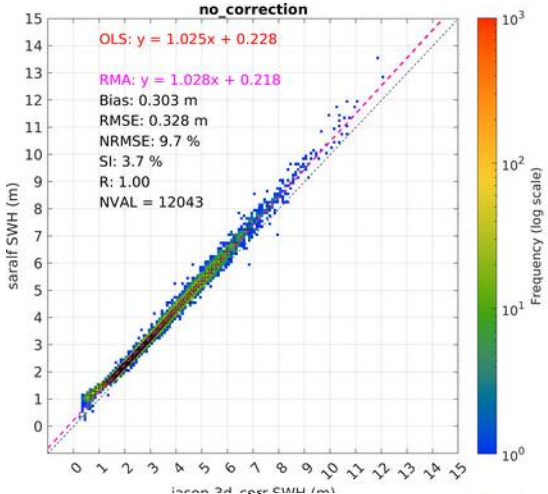


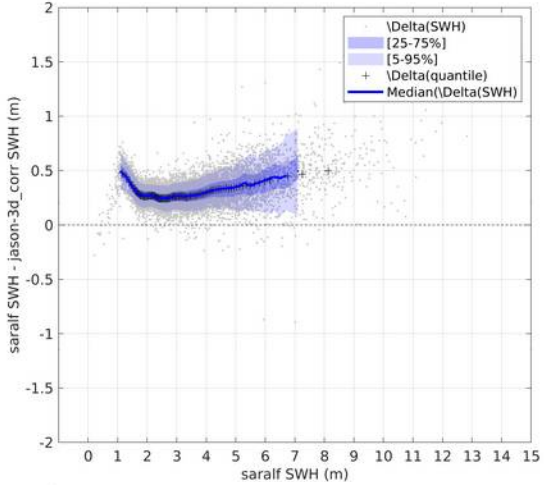
Non-linear bias correction

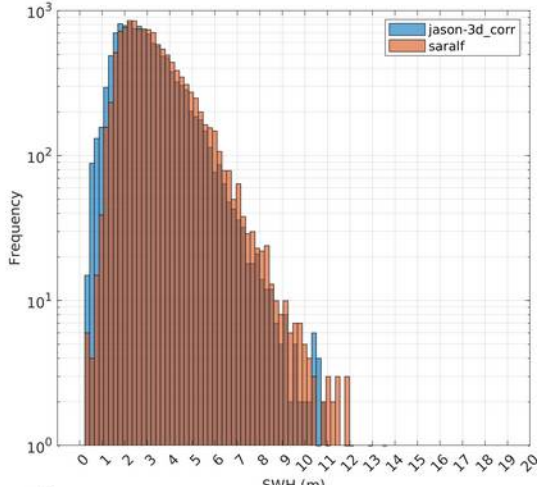


Non-linear bias correction

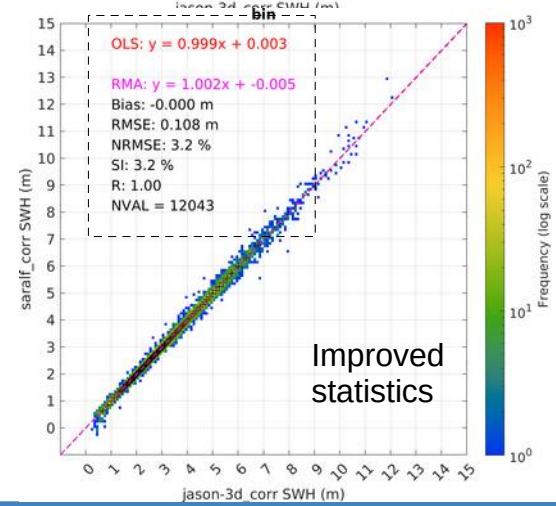
BEFORE CORRECTION

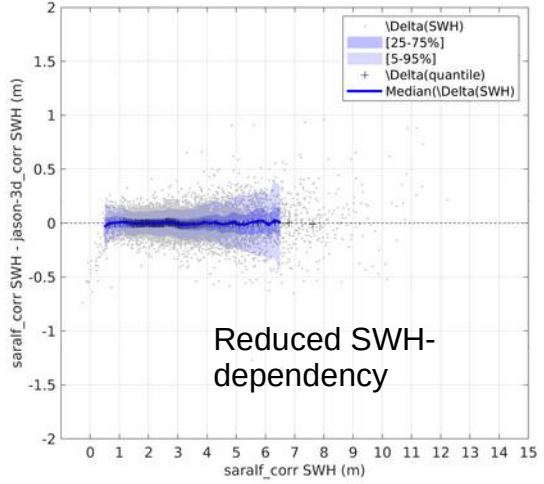


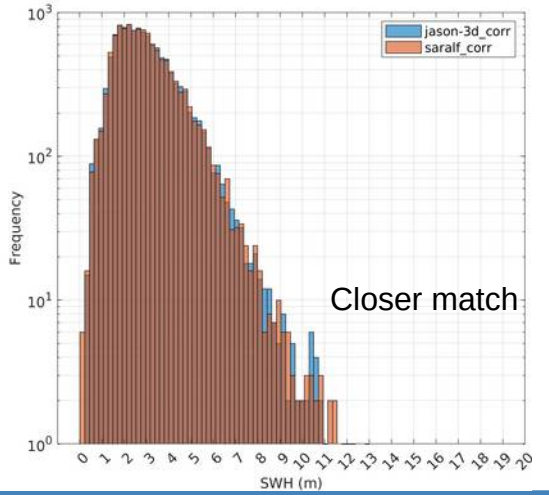




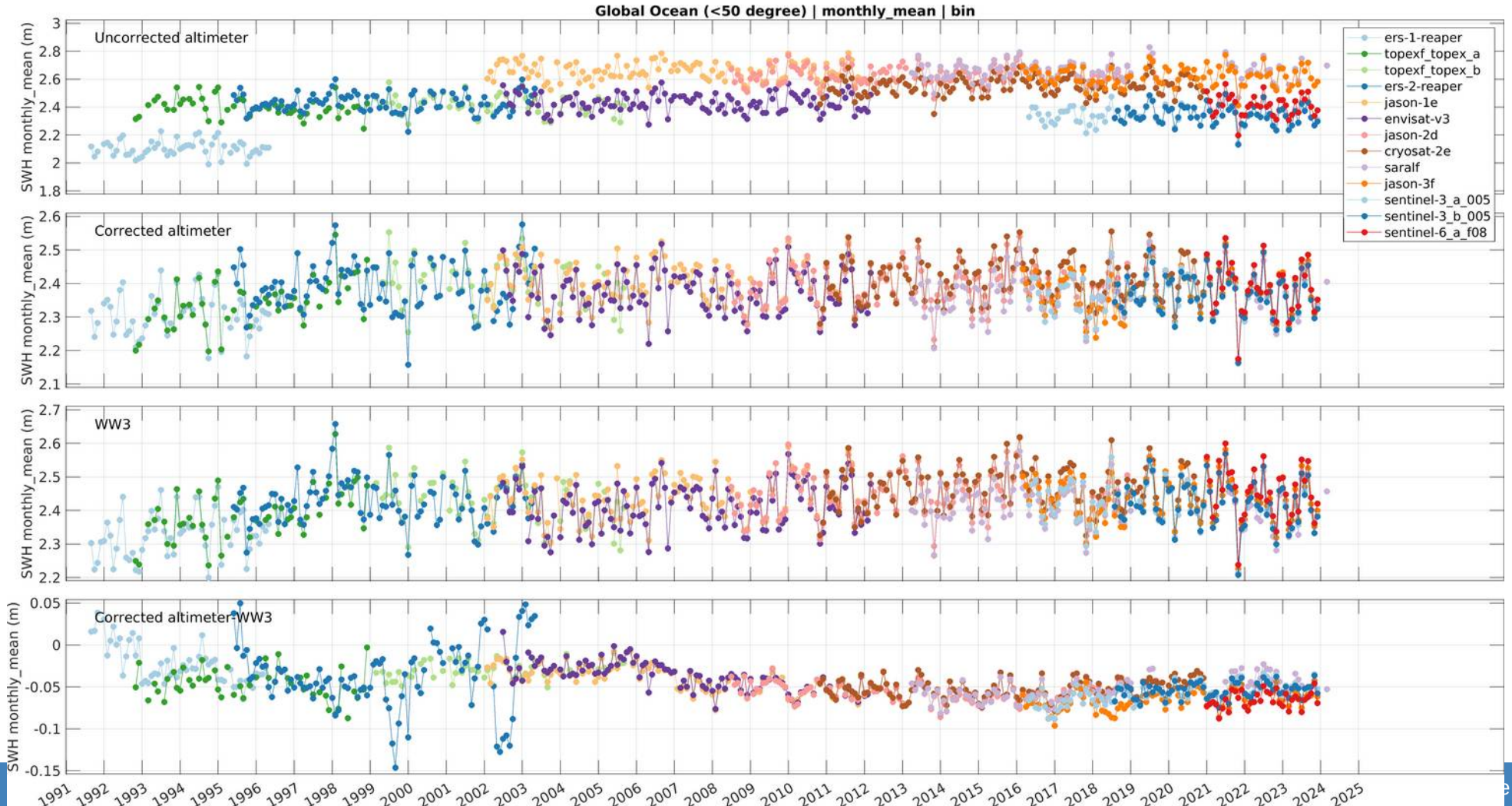
AFTER CORRECTION





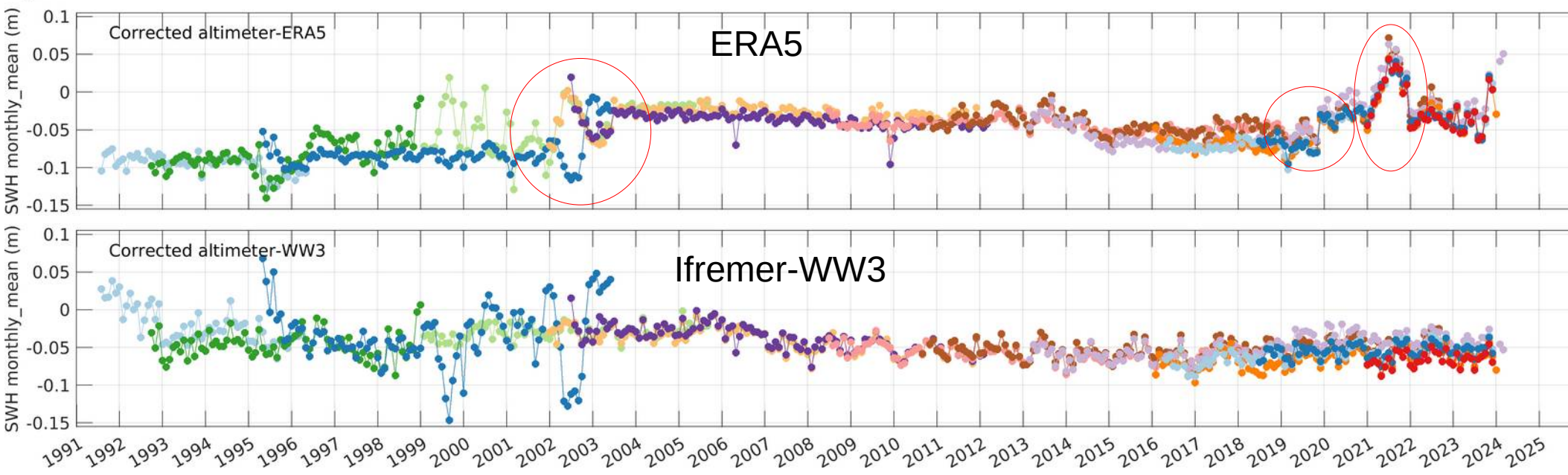


Validation of the calibration approach

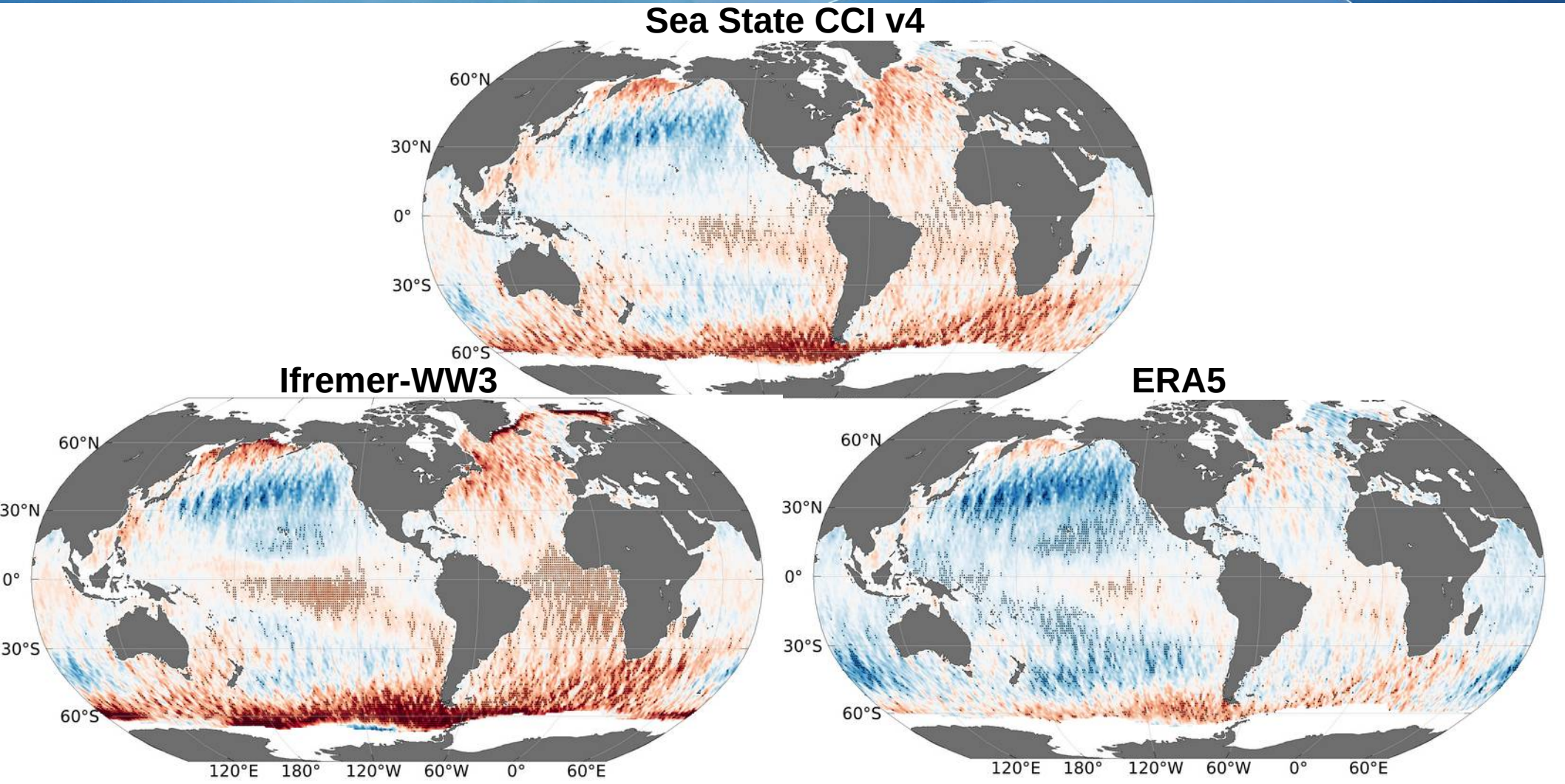


Validation of the calibration approach

Bias-corrected altimeter data can be used to assess model consistency over time



Global trends of mean significant wave height



Conclusions / Take home message

- Altimeter SWH bias-correction is key for deriving meaningful long-term wave statistics
- Nonlinear SWH-dependent error structure of altimeter measurements prevents from using linear corrections
- Negative trends in Topex (Side A version F) SWH records impacts long-term statistics (not shown). First-guess corrections is applied in the CCI version4 dataset
- Comparisons between ERA5 and CCI version 4 presents several step changes along time, which may result from the assimilation of heterogenous altimeter wave data
- Trends computed over 1992-2024 indicate statistically significant opposite trends in the mid-latitudes of the Atlantic and Pacific oceans, and positive trends in the tropical Atlantic and Pacific basins as well as over the Southern Ocean

Thank you !

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Sea State CCI dataset

The Sea State CCI version 4 dataset is available on :

- https://data-cersat.ifremer.fr/data/ocean-waves/cci-seastate/v4/
- ftp://ftp.ifremer.fr/ifremer/cersat/data/ocean-waves/cci-seastate/v4/

With the full documentation here:

- https://cciseastate.gitlab-pages.ifremer.fr/ccidoc/intro.html

Future improvements in Sea State CCI dataset / aka Version 5 (to be released in 2026)

- Adding more altimeter missions : Poseidon, GFO, CFOSAT (nadir), SWOT (nadir)
- Cross-calibrating altimeter and SAR-derived total SWH
- Homogenizing sigma0 records for wind speed studies
- Adding sensor and sea sate dependent uncertainty estimates

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