The Sea State CCI dataset V1.1: Towards a sea state Climate Data Record based on satellite observations

SEA STATE CCI TEAM
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Why do we need sea state observations?

Sea States Impact:
- Climate
- Marine safety
- Coastal evolution
- Offshore engineering
- SSH measurements
- Coastal sea level
- Marine energy
A Climate Data Record... what for?

Long-term in-situ data are sparse...

![](image)

Buoys with > 20 years of data

... and not always consistent

![](image)

Gemmrich et al., 2011

... due to changes in buoy hull and payloads

Rapid changes are observed (and projected) in the Arctic due to changes in sea ice extent and wind conditions

![](image)

Stopa et al., 2016

Climate Data Record:
A time series of measurements of sufficient length, consistency and continuity to determine climate variability and change (US NRC)

Large uncertainties remain in past trends and projected changes

![](image)

Hemer et al., 2013
Context

2007
- **IPCC AR4**: Ocean waves are identified as a key driver in the coastal zone, but little information was available on projected changes

2009
- **GlobWave** project initiated by ESA (EOEP-3 DUE) to improve the uptake of satellite wave data by the scientific, operational and commercial community

2010
- ESA launches the **Climate Change Initiative** to exploit EO archives and contribute to GCOS
- The Coordinated Ocean Wave Climate Projections (**COWCLIP**) workshop initiates a collaborative effort to develop a coordinated approach to wave projection studies

2011
- **IPCC AR5**: “Changes in Surface Wave” section (WG1 - Chapter 3)
  
  As the length of (altimeter) data set is short, it is not possible to determine whether their results reflect long-term SWH and wind speed trends, or are part of a multi-decadal oscillation.

2014
- “Sea states” **join the CCI+ program** (2018 - 2021) as a new ECV

2019
- **IPCC SROCC**: “Waves and Extreme Sea Levels” section (Chapter 6.3)
  
  Extreme wave heights across the globe have increased by around 5% over the past three decades (medium confidence).

2021
- **IPCC AR6**: Sea State CCI contribution on sea state observed changes
Altimetry missions from 1984 onwards

Ardhuin et al, 2019
Altimetry missions from 1984 onwards

Ardhuin et al, 2019
Satellite orbits

DAILY GROUND TRACK

ERS-1  ERS-2  ENVISAT  GFO  TOPEX

Difference in spatial sampling, revisit time, instruments, retracking algorithm, formats...

JASON-1  JASON-2  JASON-3  SARAL  CRYOSAT-2
Processing steps

- Data editing
- Inter-calibration
- Denoising
- Validation
Data editing

Before data editing

After data editing
A 1-Hz swh record is rejected in case of:

- Land or ice contamination (ice mask from Sea Ice CCI)
- Undefined or negative sigma0, ssh and swh values
- Unrealistic swh gradient
- Insufficient number of valid 20-Hz waveforms
- Large RMS deviation from the mean swh

\[ \text{swh} = f(\text{something}) \]
Inter-calibration

Global monthly mean over 1992 - 2018

- Drift
- Calibration error
Inter calibration

Global monthly mean over 1992 – 2018 after inter-calibration

Linear or polynomial corrections based on buoy and cross-mission comparisons

See Product User Guide for more information!
- At scale $< 100\text{km}$, swh signal characterized by low SNR
- Signal denoising based on EMD and wavelet thresholding
- **Adaptive** method suited for non-linear and non-stationary processes
- Improved mapping of strong gradients and extreme values
- See presentation from Bertrand Chapron at 4:10pm!
Validation against in-situ data and model outputs

Wave buoy consolidated data set (J. Bidlot)

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Sea State CCI V1 VS. WW3

Before calibration
After calibration
After calibration and denoising
Next step: finding the optimal retracker!

CCI Round-Robin “tournament”

- Retracking algorithm for altimeter waveforms have been initially designed for ssh estimation (range).
- Dedicated retrackers are necessary for swh.
- Sea state CCI is doing a comparative study to select an optimal retracking algorithm for swh.
- More information at 15:50 with Graham Quartly (PML).

![Graph showing 20Hz waveforms measured by Jason-3 on 08-Apr-2016 11:57:36 with annotations: Slope of the leading edge → swh, Epoch → ssh, $\sigma_0 \rightarrow$ Surface roughness / wind.]

- MLE-3
- WHALES
- TALES
- Adaptive
- MLE-4
- STAR
- Brown Peaky

[Question mark indicating uncertainty or open-endedness.]
Climate trends... what can we say?

Trend in mean at NDBC51003 (24 hr mean, <85% rejection)
Linear regression (Hs ~ year)

Buoy data, year (trend) coeff.: -0.0074 m per year.
Significant at 10%, Pr(>|t|) = 0.00051

Timmermans et al. (in prep.)
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Sampling?
Assimilation?
Internal variability?
Step changes?
Calibration?

Timmermans et al. (in prep.)
Summary

Your feedback is critical to:

- Improve the currently available CCI sea state dataset (user feedback to CCI)
- Shape the future of sea state global observations (CCI feedback to GCOS)

Enjoy the Sea State CCI dataset V1

- it’s easy to access (if not please tell us!)
- it will keep improving, and remain stable and available over long-term
- it’s designed for investigating long-term trends, extremes, small-scale variability, interactions with other components of the Earth system (CCI ECV)

Future releases will include:

- full reprocessing with dedicated retrackers
- new missions
- improved editing and calibration
- detailed uncertainty information
- new (spectral) parameters