Product User Guide (PUG)

version 4.0, June 2025

Author	**Approved**	**Signature**	**Date**
JF Piollé	Fabrice Ardhuin, Annabelle Ollivier	FArdhuin Aollivier	22 June 2025
ESA Approval	Sarah Connors	Sarah Connors	30/07/2025

QUICK START GUIDE TO ESA SEA STATE CCI PRODUCTS

Where do I get the data?

Simple registration at:

https://forms.ifremer.fr/lops-siam/access-to-esa-cci-sea-state-data/

gives immediate access to ftp account details. The data is first made available in the data/v4interim folder. This is called “interim” because a few months of L2P data is being completed for some of the missions.

Latest data are also linked from the Project web page at:

https://climate.esa.int/en/projects/sea-state/data/.

What are the data products?

For synthetic aperture radar (SAR), only L2P products are provided. Note that L2P and L3 products are most useful for the validation and or assimilation into numerical models: along-track data cannot resolve the fast variability of the sea state and therefore miss many wave events. The L2P and L3 data can also be used for long-term statistics, but the L4 product may be more suitable for these applications.

For Altimetry, three products are delivered:

• L2P : Along-track products separated into satellite directories, including all measurements with flags, corrections and ancillary parameters from other sources. These are expert products with rich content and no data loss. Provided in separate directories for altimeter and SAR-derived products.

• L3 : Edited merged daily products retaining only quality-checked measurements from all altimeters over one day (one daily file), with simplified content (only a few key parameters). This type of content is close to what is delivered in NRT by the CMEMS project.

• L4 : Monthly gridded products averaging quality_checked measurements from all available altimeters over a fixed resolution grid (1°x1°). These products are meant for statistics and visualization through the CCI toolbox.

What is the difference between altimeter and off-nadir SAR data?

Altimeters measure the significant wave height (Hs) all along the satellite track, covering both oceans, inland seas and lakes. The altimeter measurement corresponds to a very narrow footprint (2-10 km, depending on the wave height and satellite altitude). In the Sea State CCI project we provide a homogeneous historical processing that uses Low

Resolution Mode (LRM) in the case of satellites that also operate in Delay-Doppler model (often abusively called "SAR mode") .

Synthetic Aperture Radars (SARs) map the Earth surface at high resolution (pixels are typically less than 20 m. As a result SAR images resolve some of the wavelengths of the sea state and the unresolved waves also contribute to the properties of the image. Combining resolved and unresolved information allows estimates of the following sea state parameters: Hs, mean periods $T_{m0,-1}$ (often called the energy period), first moment $T_{m0,1}$, second moment mean period ($T_{m0,2}$, close to the zero crossing period), dominant swell wave height (SW1), secondary swell wave height (SW2), and windsea wave height (SWW) and windsea mean period (TMW). These 8 parameters are provided for all SAR data. In addition, swell partition parameters(height, period, direction) are provided as an experimental product for Sentinel 1 Wave Mode.

Coverage, resolution and the acquisition modes of SAR instruments

Most SAR instruments toggle between different acquisition modes designed to optimize coverage and resolution, and each mode has a different sampling pattern. For example, Sentinel 1 A/B/C, use these 3 modes:

- Wave mode (WV): each image is 20 km by 20 km, with one image every 100 km on the side of the satellite track. This mode is generally used in the middle of oceans.
- Interferometric Wide Swath Mode (IW): these are 250 km wide, and wave parameters are provided on a 5 km resolution grid. This mode is generally used within 300 km from land, and for coastal seas (North Sea, Mediterranean Sea …)
- Extra Wide swath (EW): these are 400 km wide and typically used in high latitudes where sea ice occurs.

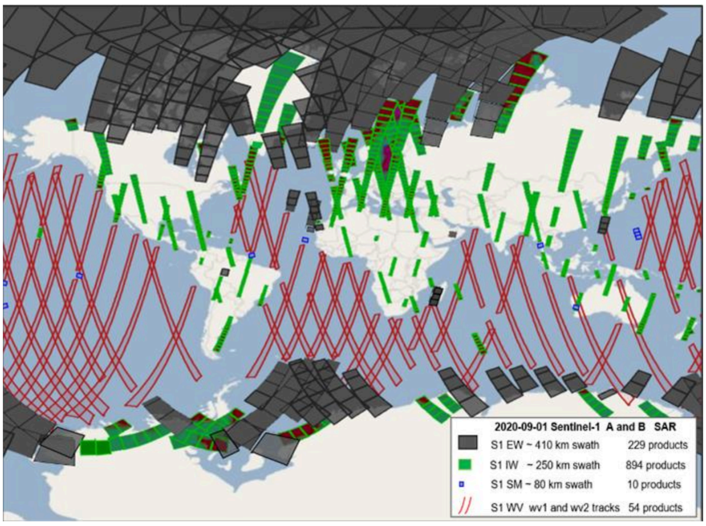


Figure 1: An example of S1-A and S1-B coverage with WV mode (red), IW mode (green) and EW mode (grey). The SM mode data (blue) is not used in Seastate CCI.

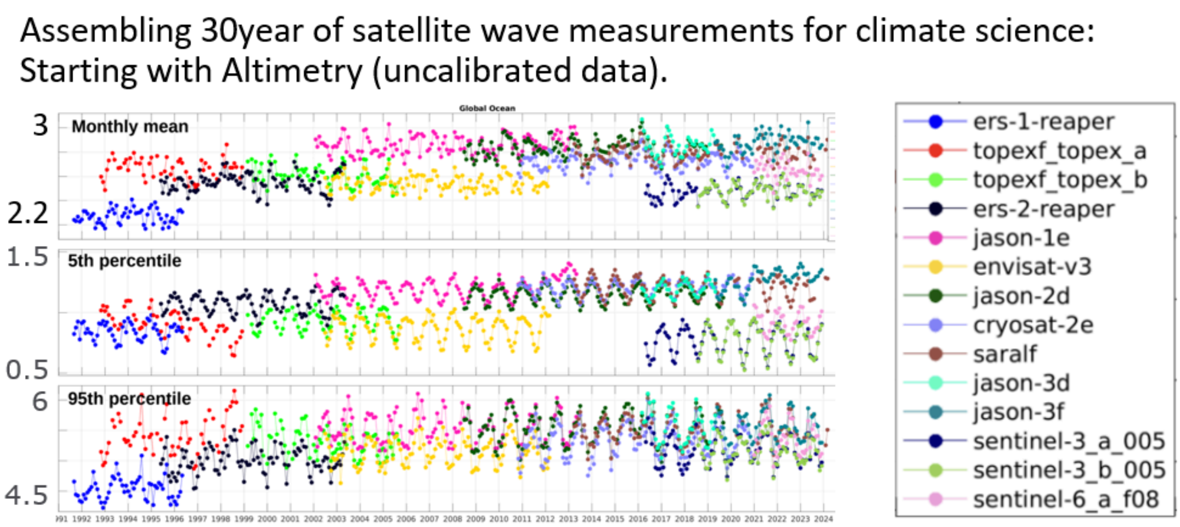
What is the data format?

All Seastate CCI use NetCDF4 Classic format. When appropriate, the data is on a grid: regular grid in latitude and longitude for the L4 data, and grid corresponding to the SAR image geometry for the SAR-derived L2P data for IW and EW modes.

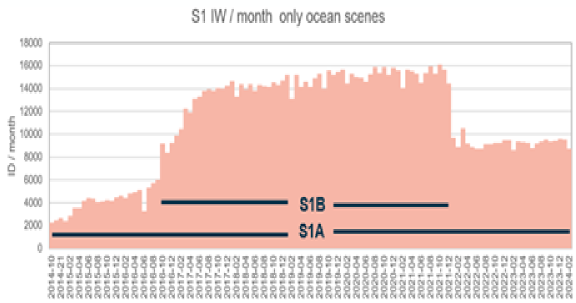
What is the time span?

Altimeter data starts in August 1991 with ERS-1.

SAR-derived data starts in October 2014 for SAR IW mode with Sentinel 1A.



Guillaume Dodet, LOPS 2025



Bjorn Tings, Andrey Pleskachevsky DLR 2025

What is the spatial resolution?

The L2P and L3 altimeter products are along-track with narrow swath and resolution of 7km.

The L4 gridded products have a spatial resolution of 1°.

For SAR data (https://sentiwiki.copernicus.eu/web/s1-products):

- Wave mode imagettes are approximately 20km/20km stamps every 100km.
- Wide swath mode is 5km grids approximately

I am interested in obtaining all the best quality wave height measurements for a particular region and am not concerned about quality control or which satellite the measurements are from.

The L3 product contains all the significant wave height measurements that are considered good quality, merged from all available instruments, and splitted per day.

I am interested in obtaining quick statistics for large areas.

The L4 product contains a statistical summary of the wave height measurements at a spatial resolution of 1° and temporal resolution of 1 month.

Who do I contact for further information?

For general data enquiries contact the Ifremer data team: cersat@ifremer.fr

For application and science issues contact Guillaume Dodet: guillaume.dodet@ifremer.fr

1. INTRODUCTION

1.1 Purpose and Scope

The statistical properties of ocean waves (average heights, periods, directions ...) are known as sea state and their measurements are used in coastal and ocean engineering (e.g. for defining heights and periods with a given return period).

SeaState is an Essential Climate Variable that impacts:

- navigation safety
- any operations at sea (energy production) or on the coast

Long term and consistent time series are critical for managing ocean and coastal infrastructure, and planning for the future (adaptation...)

The key questions it raises are :

- what is the wave climate today? (especially for extremes)
- what interannual variability and trends can we expect?
- How do we explain these variations? (winds, currents, sea ice ...)

And the Central and specific work consists of:

- estimating measurement uncertainties,
- inter-calibration methods and uncertainties
- sampling issues: complementarity of models & satellite data

1.2 Document Structure

This document presents the Product User Guide (PUG) for Sea_State_cci.

It is associated with the SSD, associated to a live version, always up to date: CCI Sea State Datasets and System Documentation — CCI Sea State System Documentation

Currently, the version up to date is the fourth, (version 4.0) that have been made available in August 2025, based on retracking altimeter and SAR data with novel algorithms and mode.

This dataset is built upon dedicated algorithms for the retrieval of sea state parameters. It modernizes the version 1 and 3 altimeter time series for the period 2002 to 2024 and adds data from the Synthetic Aperture Radar (SAR) instrument IW/EW.

1.3. The ESA SEA STATE CCI project

The main objective of this Research & Development project is to provide a consistent and long-term time series of sea-state parameters. In practice the ongoing work is the second phase of the Sea state CCI project, and builds upon methods and dataset already produced as part of the first phase. Our work is thus an upgrade of the V3 version (last delivery of phase 1 which covered 2000-2022), and merger with V1 (which covered 1991 to 2008). This project will deliver 2 versions: V4 in 2025 and V5 in 2026, including different time spans, instruments, missions, variables...

We start from observation requirements laid out by GCOS, and the needs of both the climate research community, which are particularly laid out in the COWCLIP publications, and key applications communities that include coastal management and shipping. These requirements will be refined and evolved as part of the project.

Of primary concern is the accuracy and stability of the data set that produce. These include

- Significant wave height from satellite altimeters that include all the ESA missions, and Topex/Jason series.
- Wave spectra from radar imagery: all wave mode from ERS to Sentinel 1 and a sample of larger image mode data.
    - Including Partition Test data set from Sentinel-1 (ODL)
- Wide swath SAR Imager data :
    - Interferometric (IW) + ExtraWide Swath (EW) (DLR)
    - SAR Envisat ASAR (DLR)

Sea state has never been the main focus of satellite altimetry. Except for the results of the Globwave project and new Copernicus Marine Environment Monitoring Service activities, wind and wave parameters from altimeters were a by-product of sea level estimates, leading to inconsistencies between sensors and satellite missions. Our project will thus carry out algorithm development to ensure the best possible quality of wave and wind products with a particular focus on consistency.

A particular challenge is posed by the strong evolution of measurement techniques, in particular going from Range-only to Delay-Doppler processing, and we will work towards harmonizing the processing to arrive at seamless products than span the years 2003 to 2024 as part of this project, and making possible longer time series. The data production system will be fully documented, making future transfer possible, notably to the C3S service for the most mature time series.

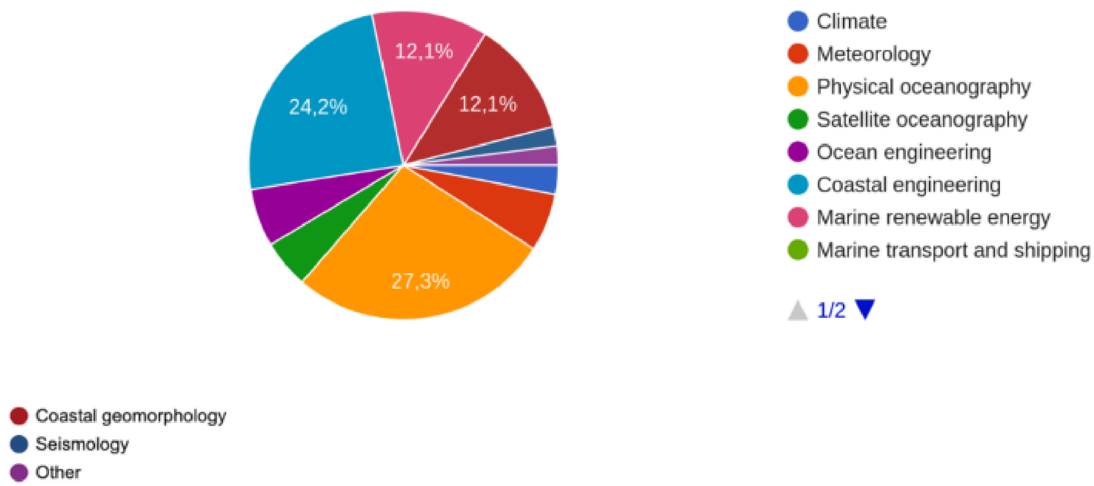
The project will provide time series of wave parameters (by mission - level 2, and consolidated - level 3) and gridded analyses of wave climate parameters (level 4). Based on these products we will work with the Earth observation and climate science community to identify and better analyze key processes that contribute to uncertainties in other ECVs (primarily sea ice and sea level). We also worked in phase 1 with the seismology community to make better use of microseism data for wave event detection and sea state trends analyses. But for the phase2, this is not the main focus.

The Project results, from the new algorithms, to the data set and their application in key areas will published in world class peer-reviewed scientific journals, in particular in time to contribute to IPCC Assessment Reports.

1.3.1. User requirements gathering

Answering end users' needs is one of our main concerns. Regularly, User Requirement Documents compile the synthesis of who are the users, what they require and how they use the datasets. User Consultations Meeting was also organised in phase 1 and will be renewed for phase 2 in order to link the upstream developments and the downstream uses.

The latest document is available here: ESA-signed and sums up the results of a survey sent to a large community of Wave interested people around the world (100 answers around 18 countries).



Distribution among the field of applications

1.3.2. The future

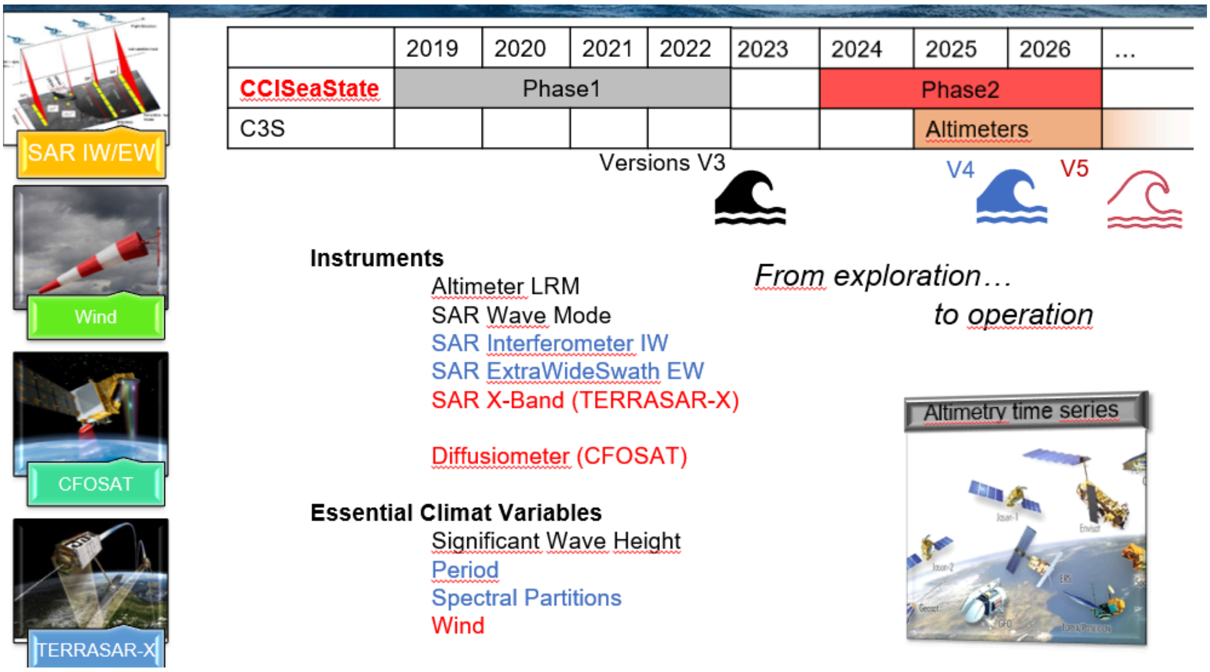
Our main concern for the moment is to identify relevant metrics related to climatic evolution of the wave characteristics (monthly average evolution, number of extreme events...)

Starting with their energy (Significant Wave Height) we plan to expand the analysis to other parameters (spectral width, wavelength, direction...) derived from different types of sensors...

The idea is then (in Version V5) to explore other complementary types of observations (diffusiometer, XBand SAR...) and variables (Wind...).

A strong effort is also made to define relevant uncertainties associated with each datasets.

The most mature algorithms, data series and missions are then expected to be pushed towards (Copernicus Climate Change Service) that will prolongate operationally the time series on the flow.



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