climate change initiative

SEA STATE

Sea state climates and their evolution: CCI achievements & perspectives

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UCM2, 23 March 2021

sea state cci

LOPS

Outline

1. What is the Sea State CCI project and what we are doing
2. Measuring sea states 101: a quick review of altimetry & SAR imagery
3. Where we are with the CCI v1 and CCI v2 datasets
4. Possible priorities for the coming years (“phase 2” of the CCI+ projects)

1. The CCI program

The objective of the CCI programme is to realise the full potential of the long-term global Earth Observation archives as a significant contribution to the ECV databases required by the UNFCCC

WORKFLOW

- User Consultation and Requirements
- Algorithm Development
- System Development
- Data Collection, Production and Validation
- Climate Data Record Assessment

1. The Sea State CCI project

Phase 1 of project (2018-2021):

2 sources of sea state data: altimeters & SARs wave mode

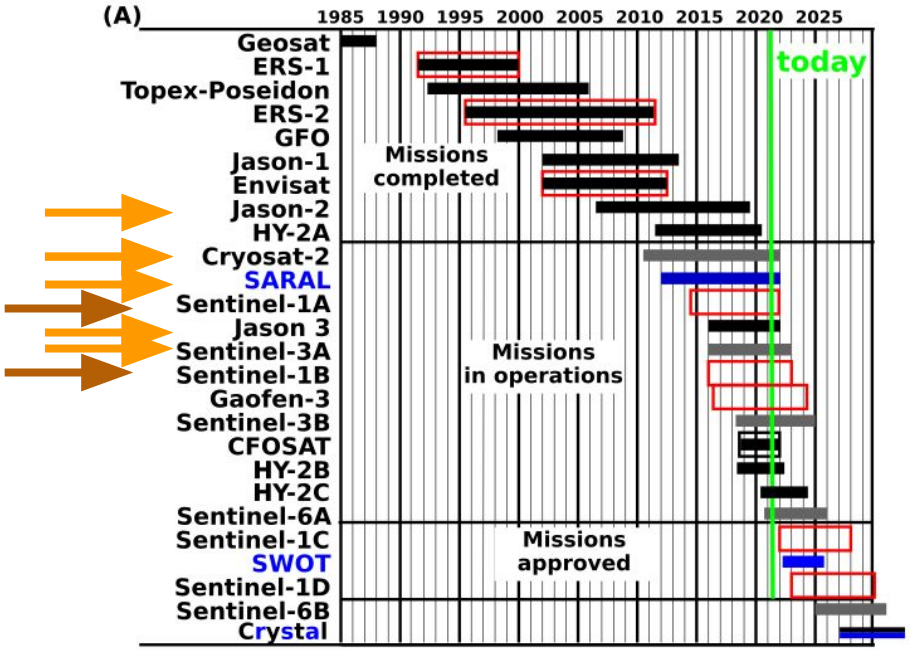
- CCI v1 dataset (published 2019, see Dodet et al. 2020): used "Level 2" data
- CCI v2 dataset (coming out shortly): uses "Level 1" data

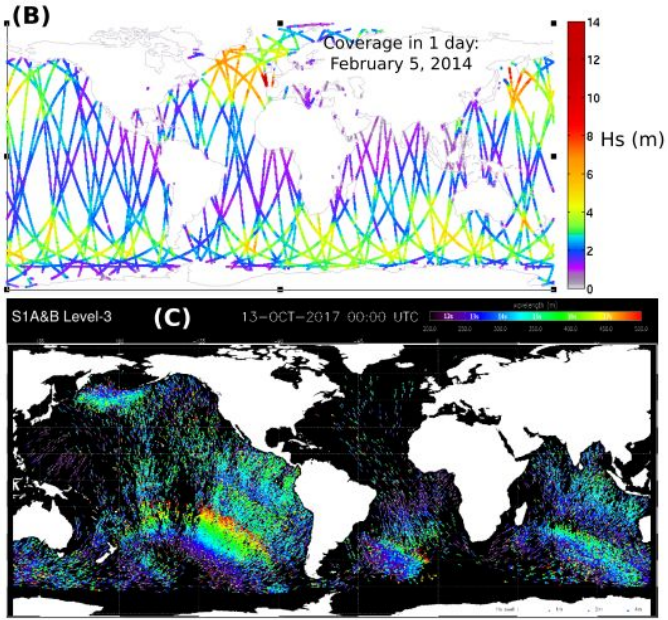
Many steps from collecting the data, validation data, developing & choosing algorithms, producing data, controlling & inter-calibrating, validating…

A big thank you to all who contributed!

1. The Sea State CCI project

NB: the CCI v2 dataset does not cover all satellite missions but focuses on recent missions, in particular as we are changing from “LRM” to “DDA” altimetry.



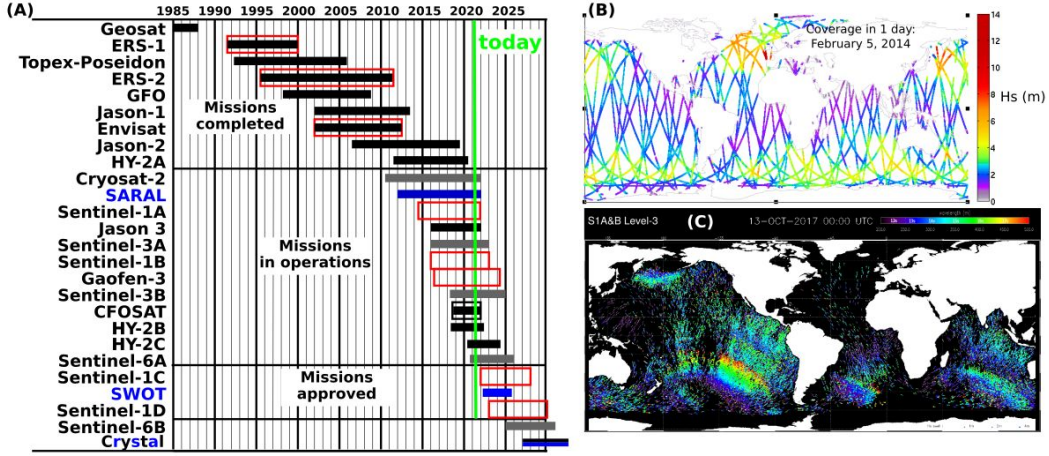


1. The Sea State CCI project

We are just completing CCI v2, but we have to get ready for v3, and the future work in phase 2 (2021-2024) of the project.

With so much work that can be done… we need your input

(PLEASE FILL SURVEY) to prioritise future actions on all these datasets!



2. Measuring sea states

Should users care about which mission the data is coming from?

Well, I wish they did not have to. But …

- Sampling varies with satellite orbits (which can change during the life of some missions)
- Data quality can vary from one to another

So let's give some background to help you out: Sea state remote sensing 101 !

(mostly based on "Measuring Sea States", Frontiers in Marine Science, 2019)

2. Measuring sea states

We'd love to have directional wave spectra everywhere all the time …

But … even buoys do not measure full spectrum (only tyhe "first 5")

And satellite data is often reduced to one number (we'll come back on this):

The Significant Wave Height (SWH or H_s)

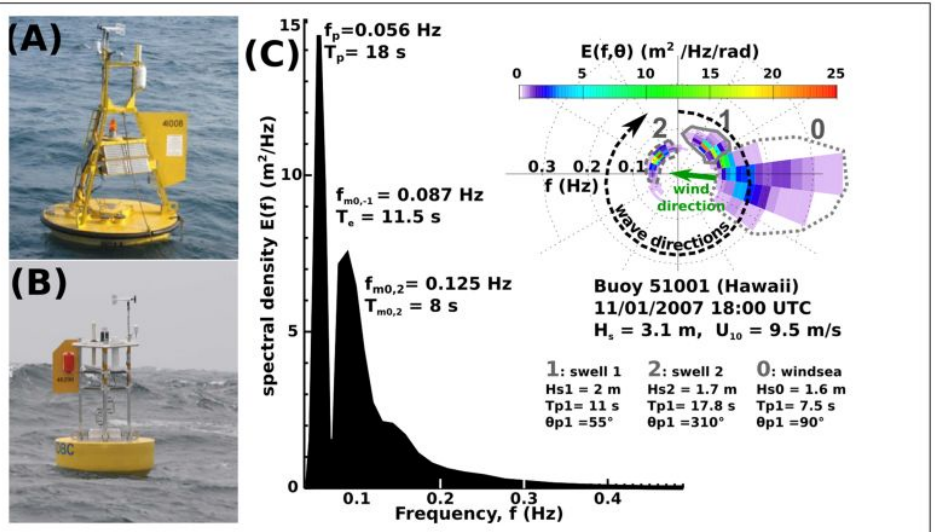


FIGURE 1 | (A,B) show typical layout of NBDC wave buoys with old and new designs. Wave measurements are made by a motion package in the hull and wind measurements use an anemometer at 5-m height. **(C)** Example of wave information derived from a buoy, ranging form the common estimate of H_s to the heave spectrum $E(f)$ in black, or a two-dimensional directional spectrum $E(f,\theta)$ in colors. Note that the buoy does not measure the directional spectrum but, for each frequency, only the "First 5" parameters from which the directional spectrum is estimated here using the Maximum Entropy Method (Lygre and Krogstad, 1986). For many applications it is customary to partition the spectrum into a windsea region (dotted contour labeled 0), and swells (solid and dashed contours labeled 1 and 2) which are usually ordered by decreasing wave energy. For each partition, height, period and direction parameters are estimated in the same manner as they would be estimated from a full (frequency-direction) spectrum.

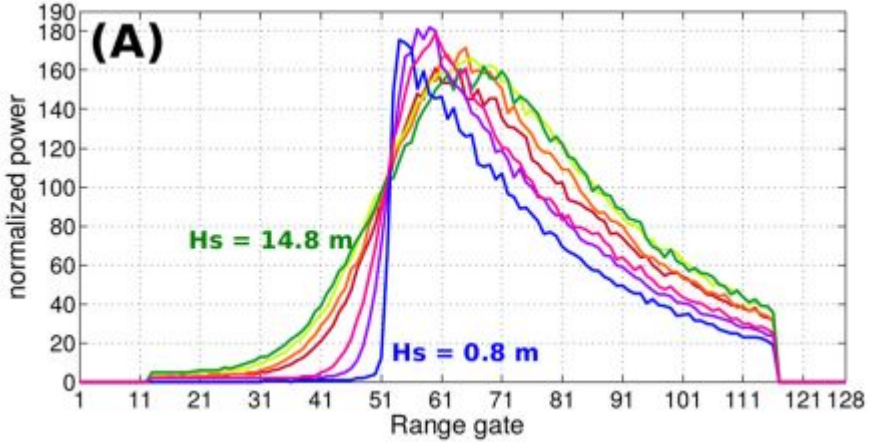
2. Measuring sea states: altimeters

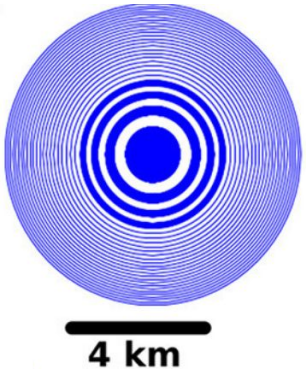
Radar altimeters send radar pulses straight down (“at nadir”) to the ocean and record the echoes.

The spread of echoes over time is the “waveform”

The shape of the waveform contains information on SWH, retrieved by ‘fitting’

For SARAL, one range gate is a 30 cm vertical distance, < 1 km horizontal range.





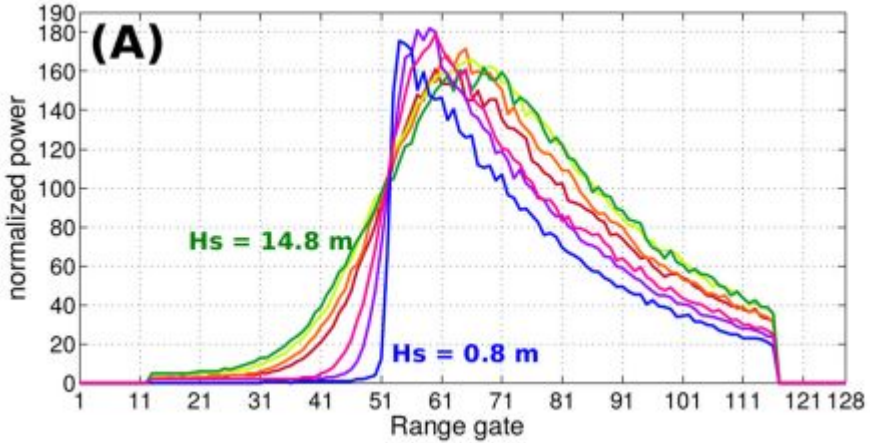
Idealized range gates for flat sea surface

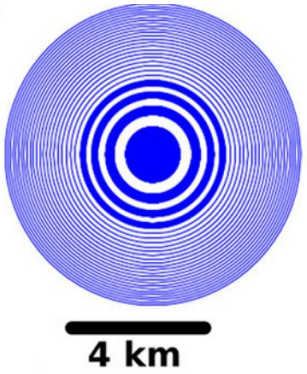
2. Measuring sea states: altimeters (continued)

Objects (land, icebergs …) sticking out of the water will modify the waveform and can make it difficult to recover wave heights.

-> novel “retracking” methods: fitting only the part of the waveform that contains SWH information. (ALES, WHALES, adaptive …).

This require starting from Level1 data (as done for CCI-v2)



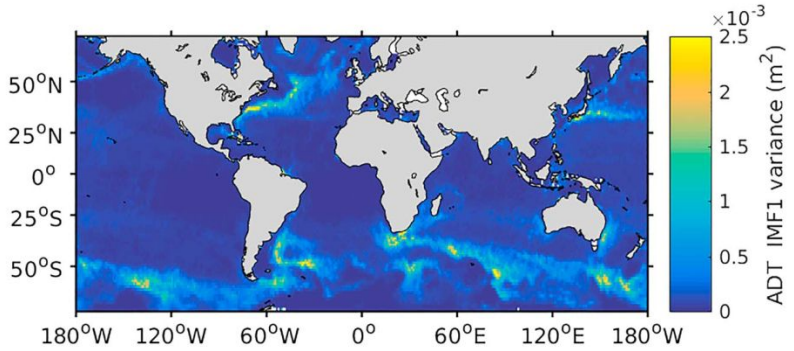


2. Measuring sea states: altimeters & noise

Radar echoes are coming from specular (horizontal) facets, which create random fluctuations (speckle) and thus noise.

Standard fitting methods (all missions operational data except CFOSAT) are particularly noisy: Scales < 100 km are dominated by noise.

However, it is possible to separate noise and signal, hence the “swh_denoised” variable in CCI-v1 data: we can finally see small scale gradients!



Quilfen & Chapron (2019)

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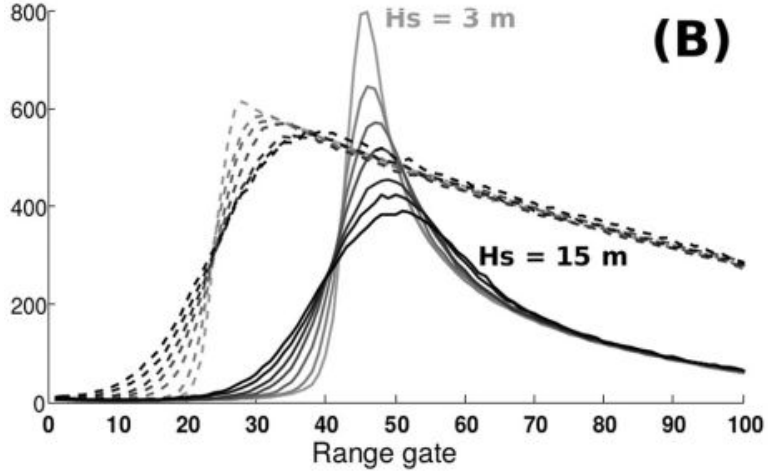
Noise also much reduced with better "fitting"

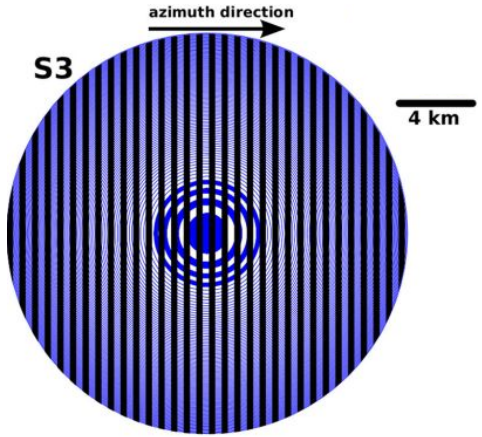
Methods (Schlembach et al. 2020, 2021) as used in CCI-v2

2. Measuring sea states: DDA

Starting with Cryosat-2 and Sentinel 3A, new missions also measure the phase of the radar echo which can be used to form a "Delay Doppler" map: separating the echoes as a function of their Doppler shift, related to their along-track position. This also allows to make "independent looks" of the sea surface and reduce noise.

Instead of a 1D waveform , we now have 2D waveforms! many possible processings



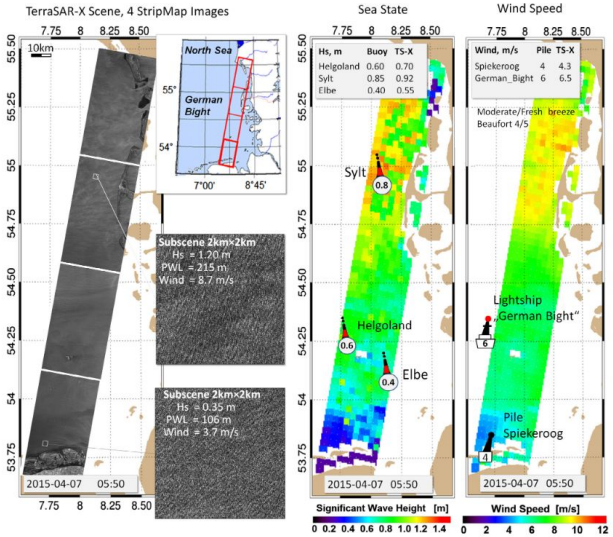


2. Measuring sea states: SAR

This Doppler separation has been used for a long time in imaging radars.

Since ERS-1, and thanks in particular to K. Hasselmann, a “wave mode” of acquisition has collected O(10 km) images (now 20 km with Sentinel 1) for spectral analysis: very dense coverage with Sentinel-1A & Sentinel-1B

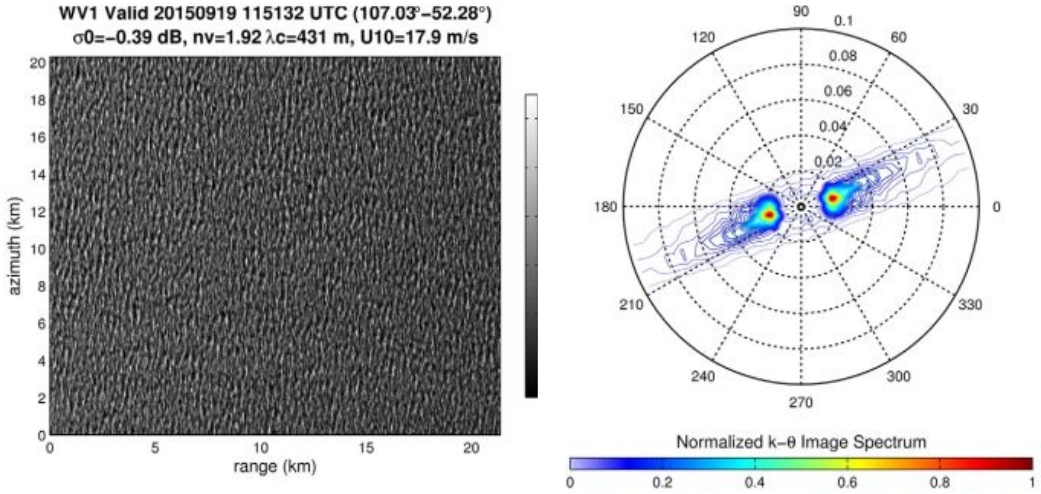
Wide swath (IW mode) images are acquired
By Sentinel 1 and other SAR missions
over all coastal areas making possible
maps of SWH or other parameters at
resolutions < 5 km (e.g. Pleskachevsky et al. 2016)



2. Measuring sea states: SAR

The spectra of these images can be converted to a wave spectrum BUT part of the spectrum is blurred by random small scale orbital velocities that also contribute to the Doppler shift of the signal

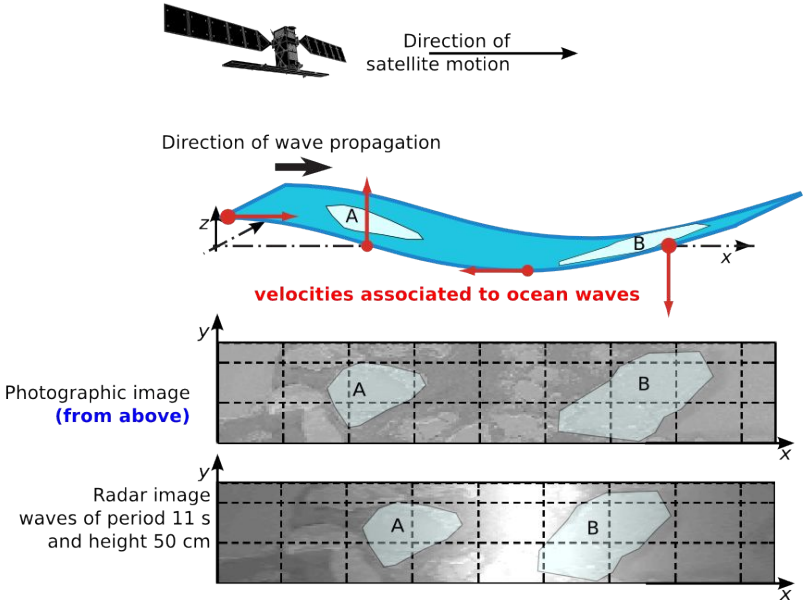
(a "fully focused" SAR image is blind to short waves in the along-track direction)

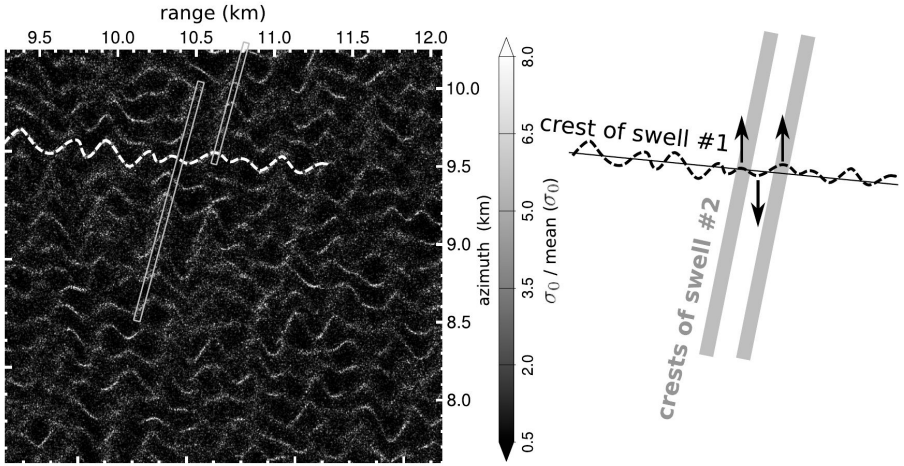


This spectral analysis can be by-passed to produce parameters such as SWH (Shulz-Stellenfleth et al. 2007). This will be included in CCI next version

2. Measuring sea states: SAR in sea ice

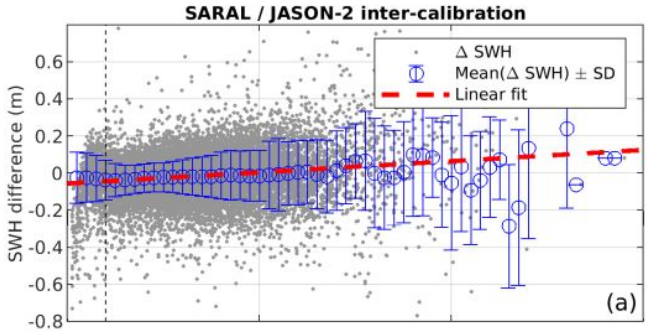
Fun fact: in the presence of sea ice the short waves are gone, and the SAR imaging process becomes nearly linear. It can be easier to measure waves in the presence of sea ice!

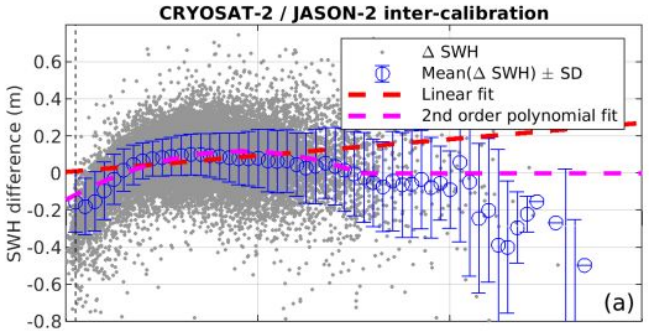




3. CCI datasets

- Before CCI: Globwave (there are also other databases): “bad data” was out
- CCI-v1: 1994 to 2018, all data included (need to use quality flag)





CCI-type datasets will never be real time!

We are working with CMEMS to make it as uniform as possible with real time and near-realtime CMEMS data.

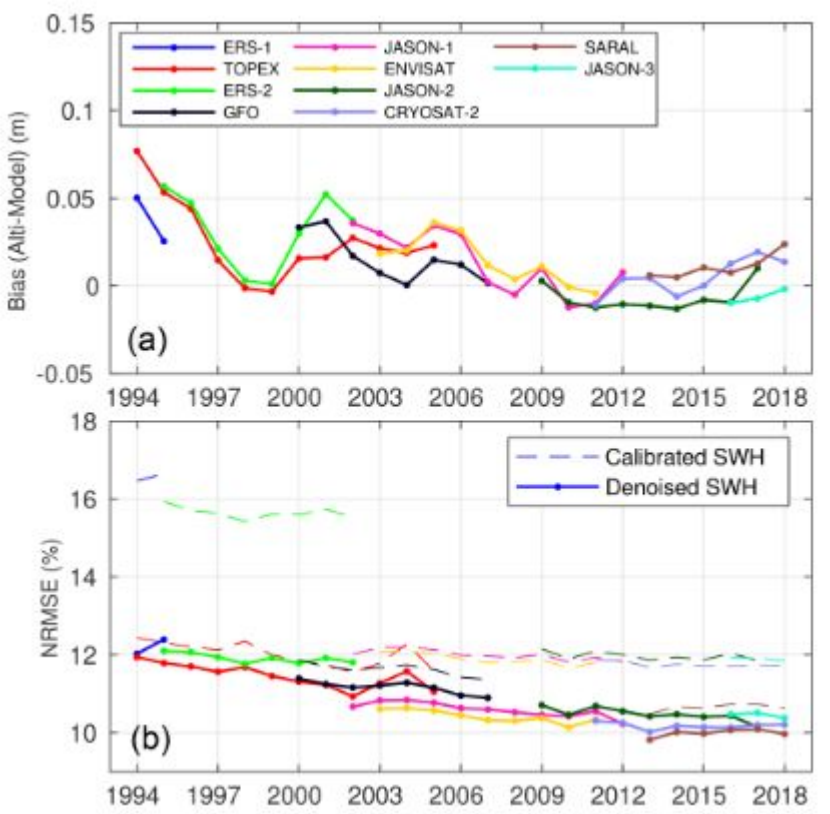
3. CCI datasets: v1

Mission inter-calibration:

Used Jason-2 as reference and verified with independent model run (see Dodet et al. 2020)

Recent & ongoing work:

- checking on trends with other datasets (Timmermans et al. 2019) other models + microseism data (see Stopa et al. 2019)
- Coastal applications
- Wave energy resources (Rusu et al. 2020)



3. CCI datasets: v2

After selection of 2 algorithms for LRM and DD (S3) missions

Jason 1, Jason 2, Jason 3, Envisat, Cryosat-2, Saral (2002 to 2019) have been retracked at Ifremer with “WHALES”

Sentinel 3A has been retracked at CLS with “LR-RMC” (delivered few days ago)

Editing and production of a 1 Hz data (i.e. 7 km along-track) done at Ifremer

Denoising with EMD method done

Intercalibration done for the LRM missions

None of these steps were easy, but CCI-v2 finally coming out. (see G. Dodet poster tomorrow)

4. Where do we go from here?

Possible priorities for future”phase 2” of the Sea State CCI project

- Extend back in time (ERS-1, Poseidon)
- Increasing sampling with other missions (e.g. HY-2B, GFO)
- Extending towards present (CFOSAT, S6FM), in coordination with CMEMS
- Expand to other variables:
    - LRM altimeters with mean square slopes / wind / mean periods
    - DD altimeters with orbital velocities / Tm02 …
    - SAR wave mode with Tm02, swell partitions, spectra
    - CFOSAT/SWIM with partitions & spectra

- specific processing for waves in / near sea ice?

How much do we push for more integration with models?

- Bias corrections for reanalyses / hindcasts
- Helping future assimilation in models?

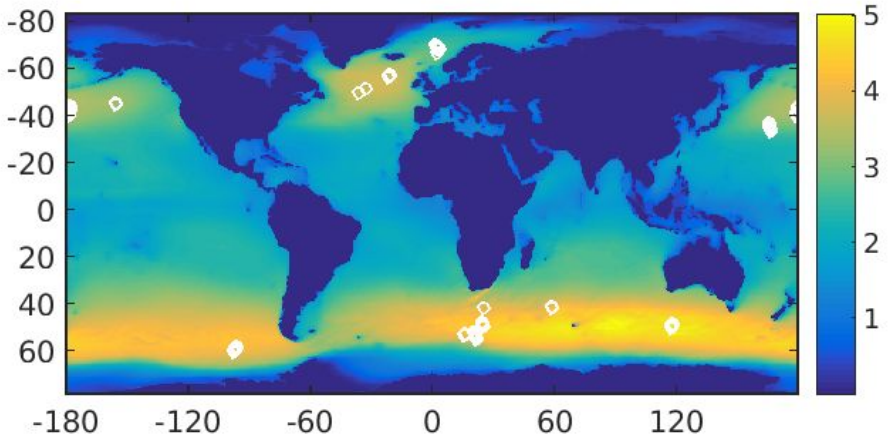
https://esa-survey.limequery.org/977385?lang=en

4. Sampling and extremes (just a teaser)

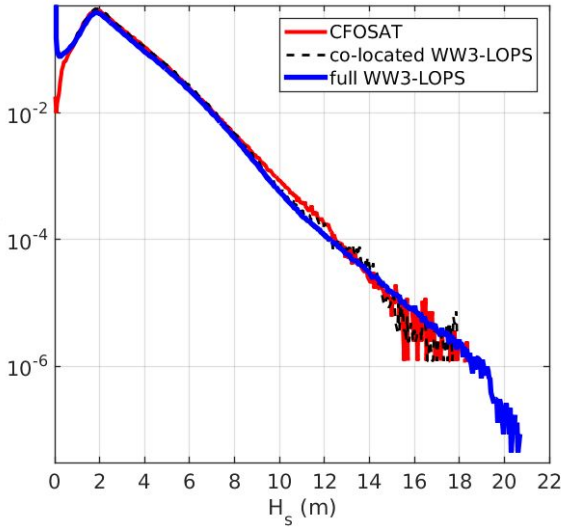
CFOSAT extreme events are a subset of all extremes: 11 events with N>3 consecutive (1 Hz) values > 14 m. Compared to 55 model events with Hs > 14 m.

Generally consistent: CFOSAT measures Hs up to 18 m without outliers.

Even if CFOSAT does not catch the peaks of model events, what do we learn about model accuracy ? What about other satellites?

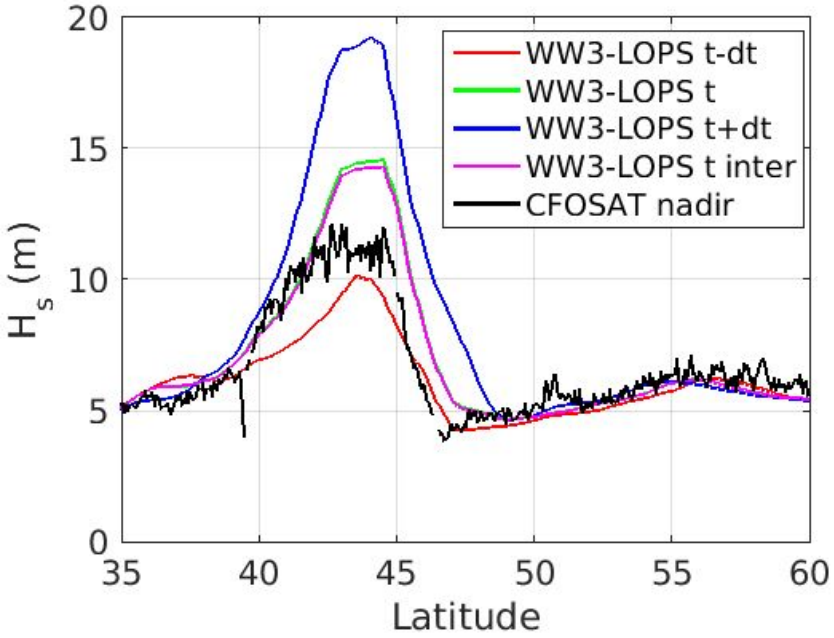


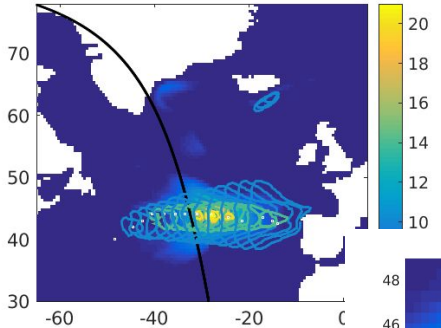
model mean Hs and CFOSAT > 14 m.

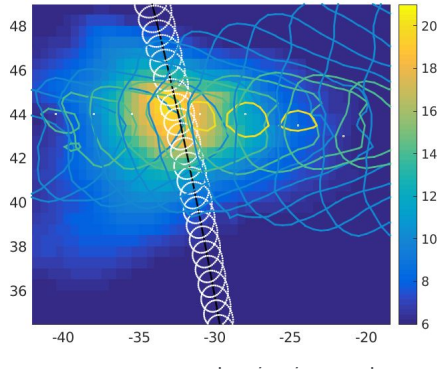


4. Sampling and extremes (just a teaser)

CFOSAT nadir beam did not catch the peak of the storm (according to model), it still had Hs > 11 m, 6 hours before the model peaked at 20 m What is wrong? Is the model wind early ? more info in Off-nadir beam spectra across a 160 km swath







Thank you … and please fill in the survey

Thanks for joining in this week

Please fill the survey https://esa-survey.limequery.org/977385?lang=en

Your feedback will help us improve the datasets (v1 and v2) and prioritize work on our future efforts.