climate change initiative

→ SEA STATE

Building a sea state Climate Data Record from satellite observations

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sea state cci

Ifremer

LOPS

Presentation outline

I.

Wave climate variability

why do we need a sea state Climate Data Record ?

II.

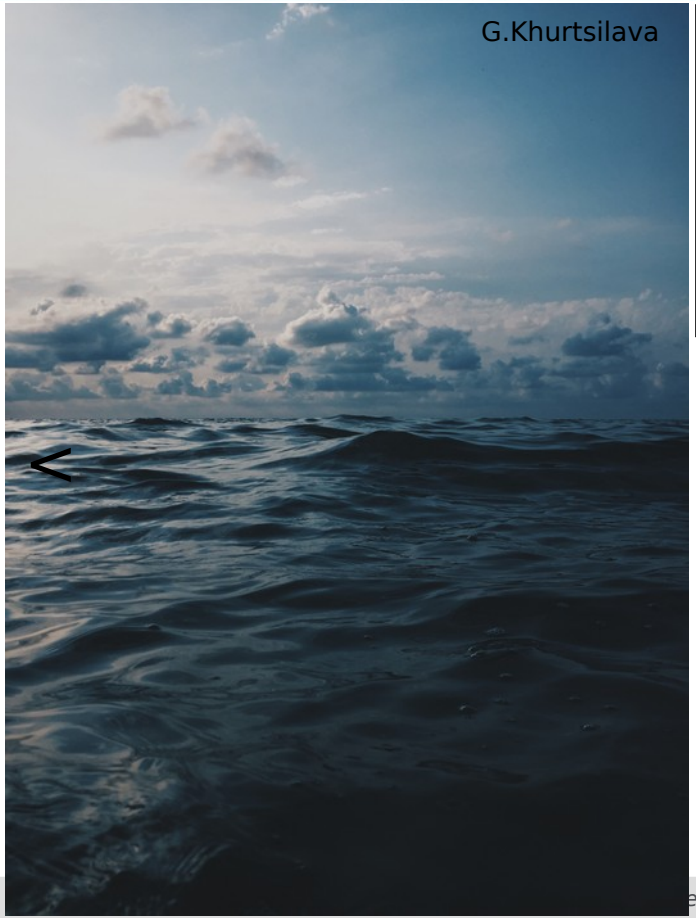
Sea State Climate Change Initiative

how satellite data will contribute to this CDR ?

1

Wave Climate variability
Why do we need a sea state CDR ?

Sea state ?

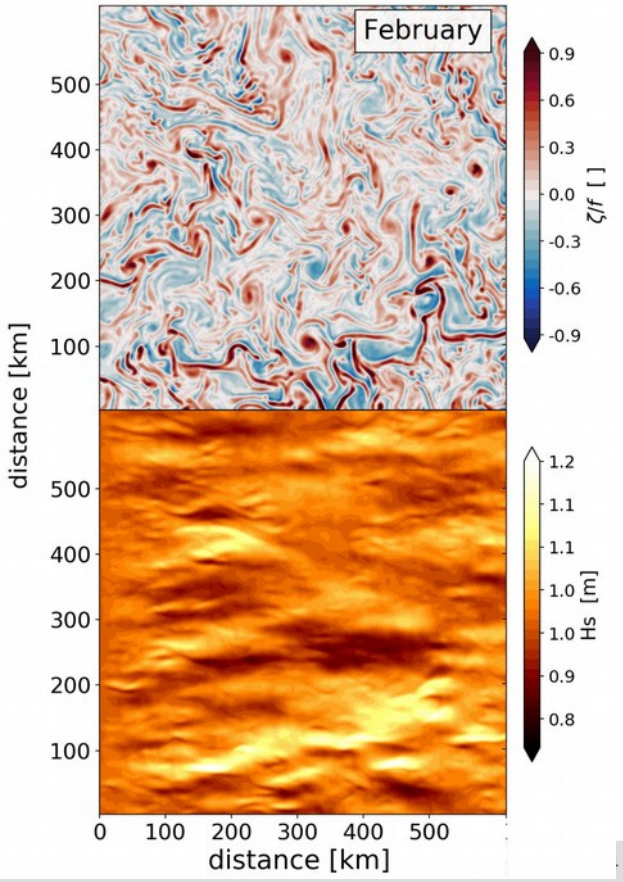


Sea state :

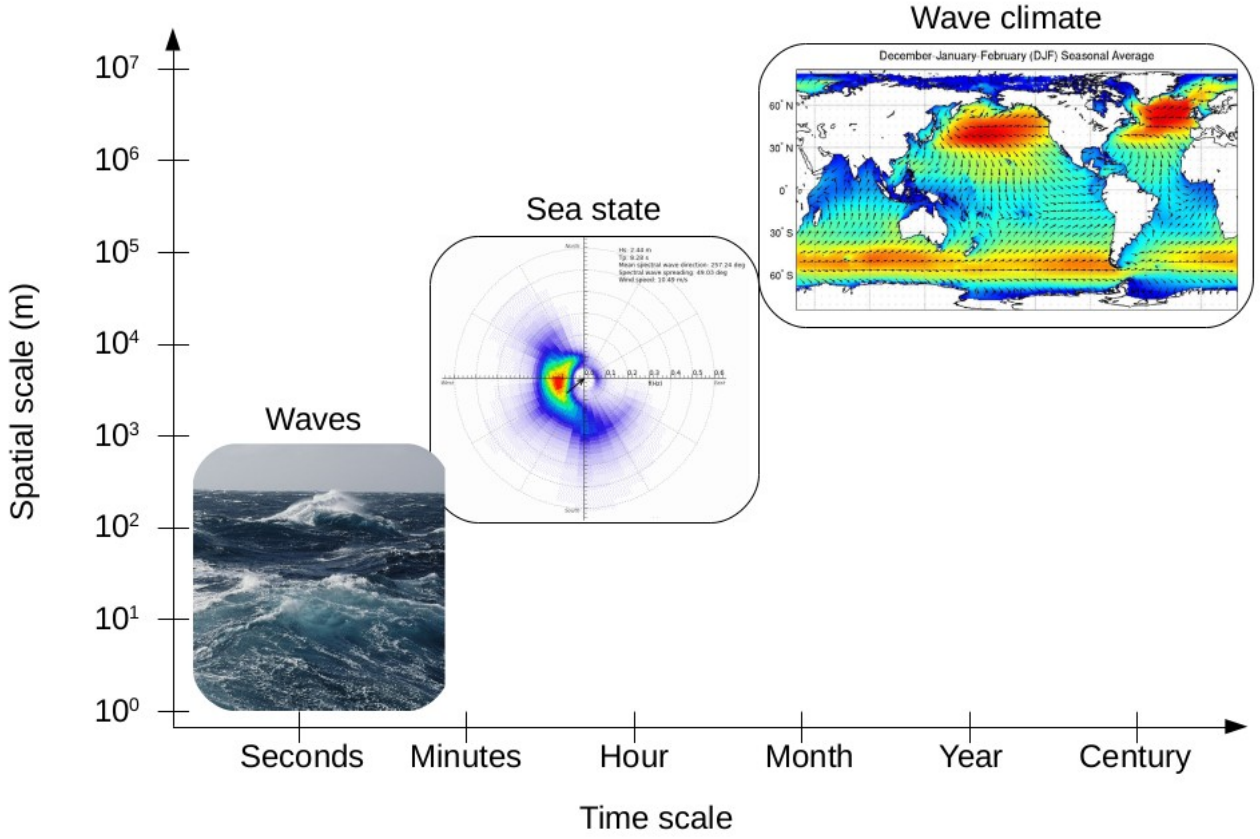
General condition of the free surface on a large body of water (ocean, enclosed seas, lakes) at a specific location and time

- E (f,θ)
- Hs, Tm, Dir
- Wind sea / swell partitions

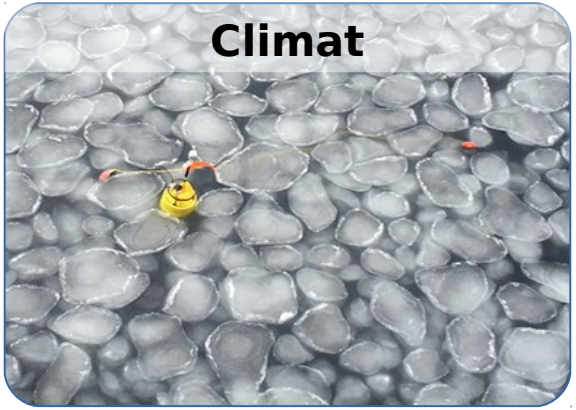
Villas Bôas et al. SWOT meeting 2019



Sea state scales

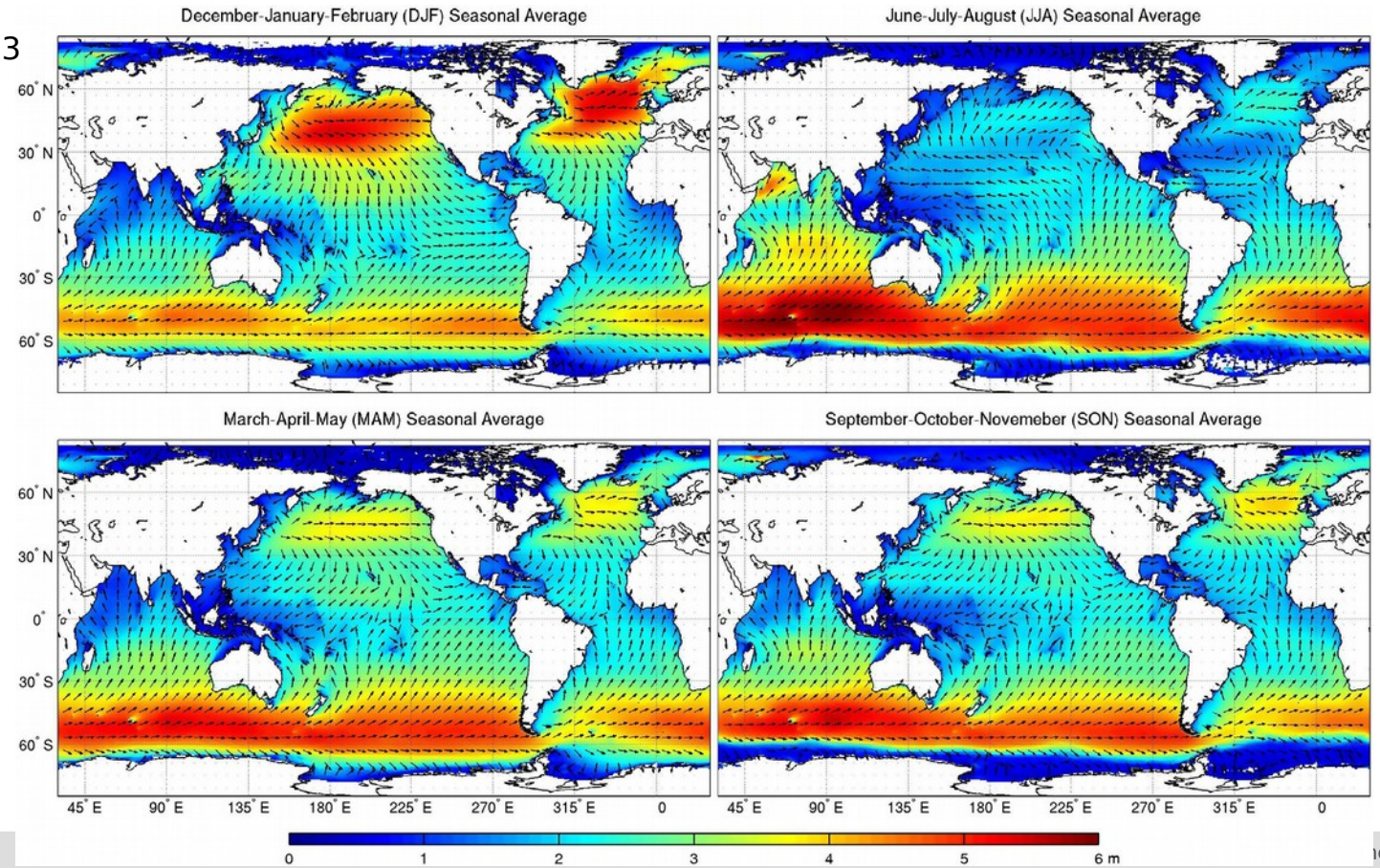


Importance of sea state



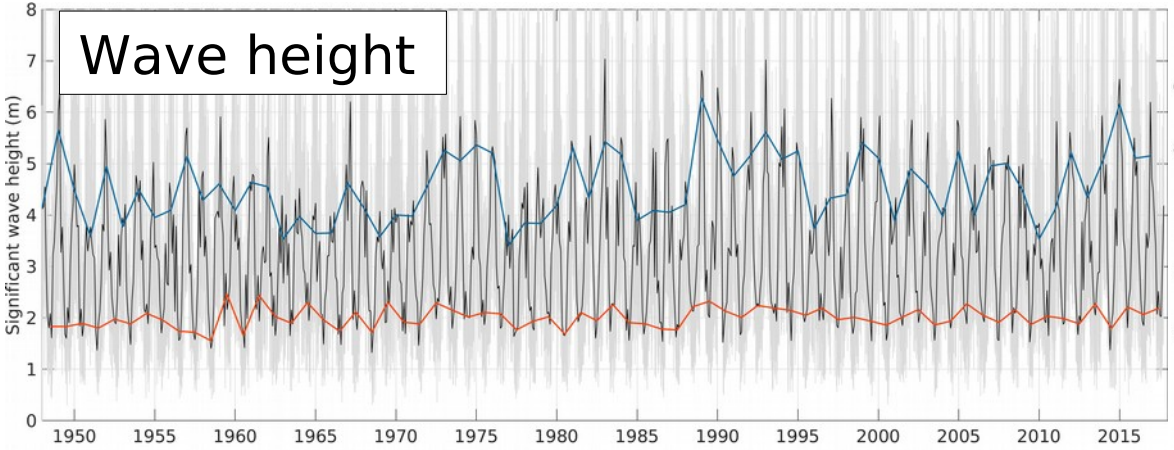
Wave climate variability

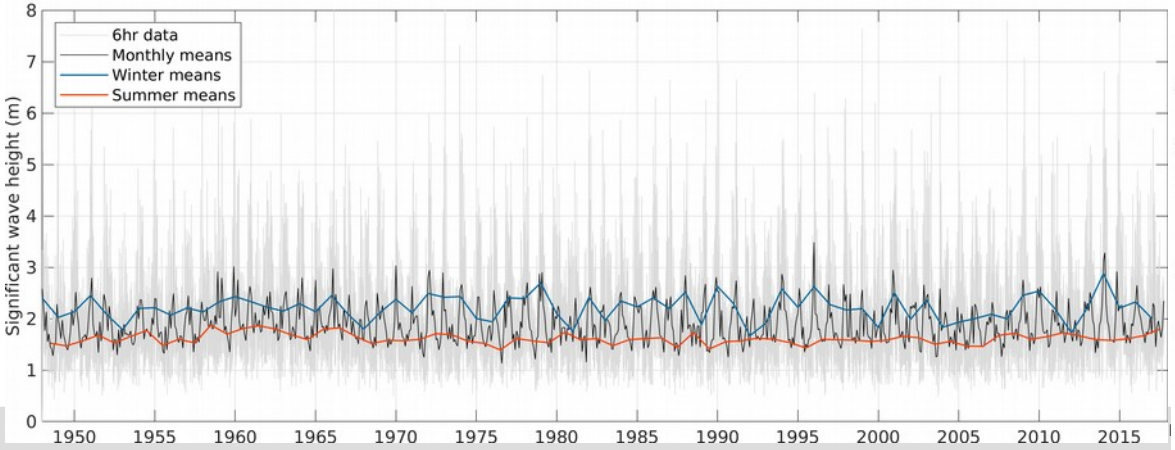
Stopa et al. 2013

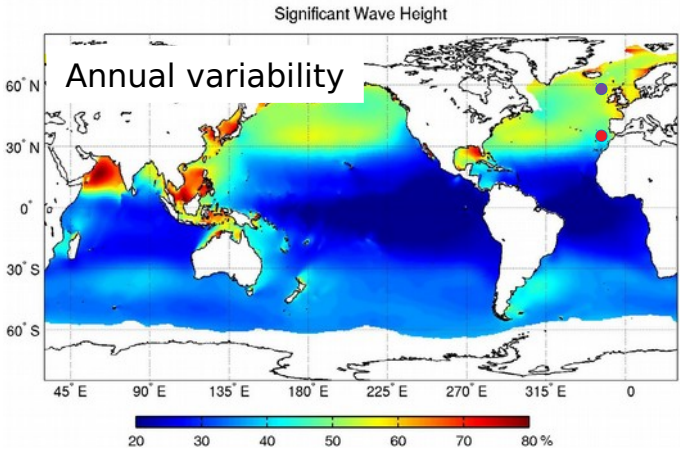


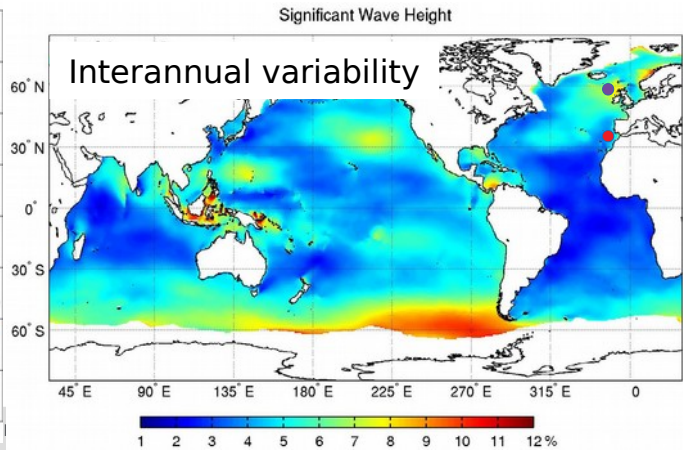
Wave climate variability

Wave height





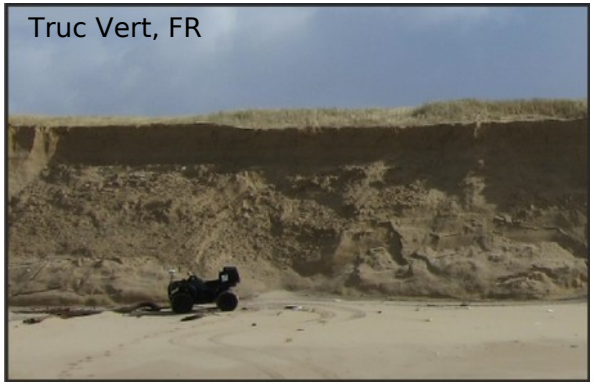


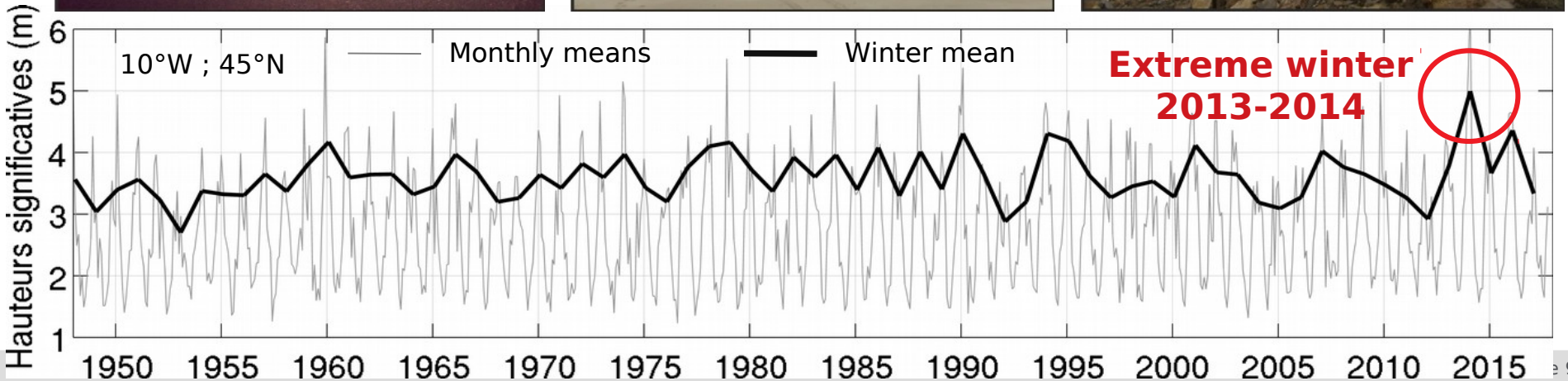


Coastal impact of extreme winter waves

Winter 2013/2014 along the coasts of Europe

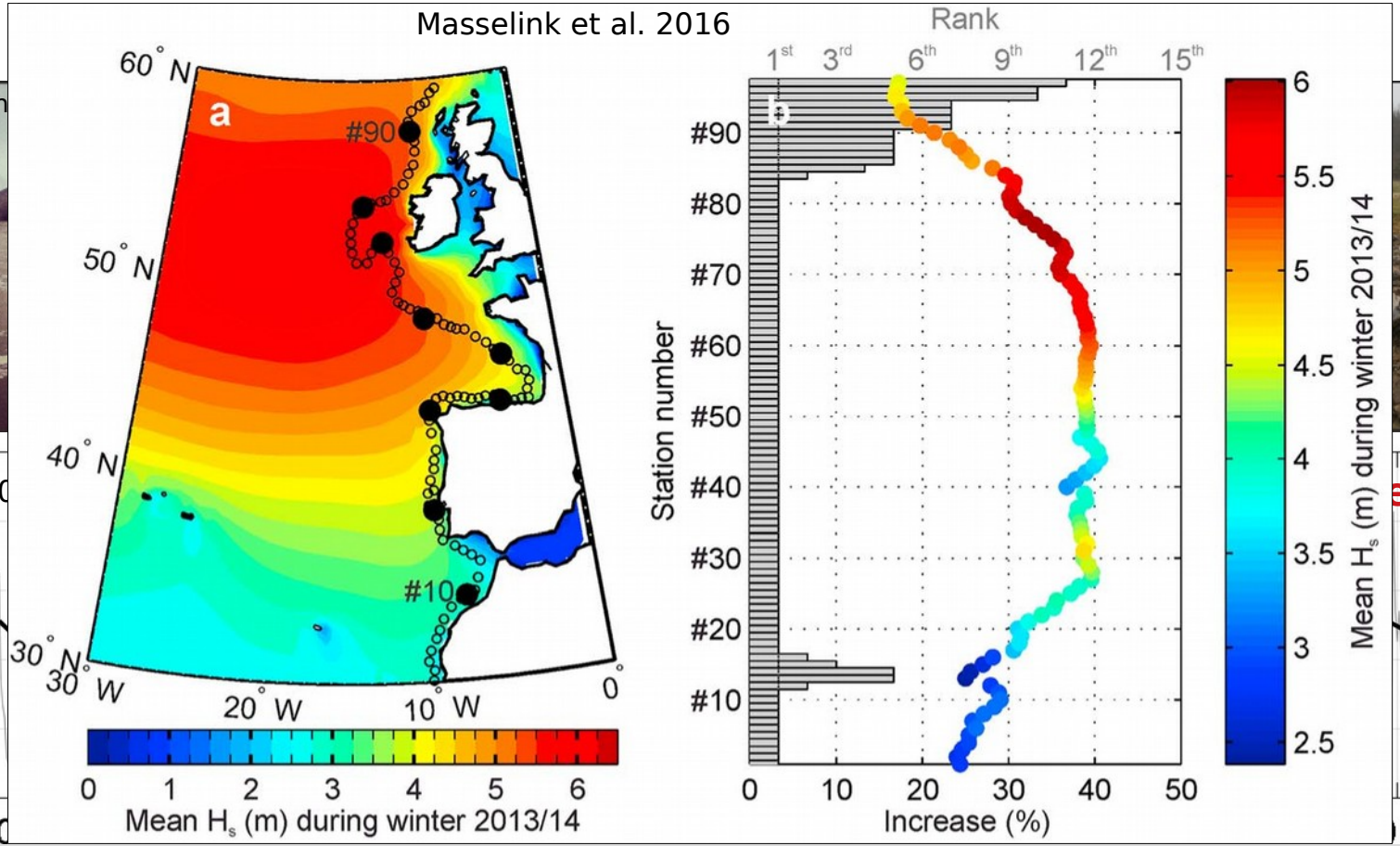
Masselink et al. 2016

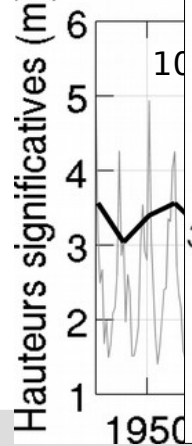


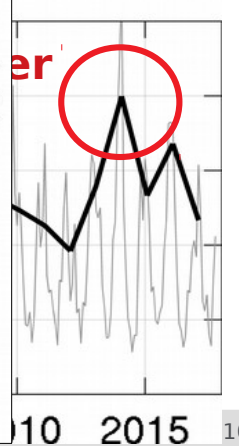


Coastal impact of extreme winter

Masselink et al. 2016

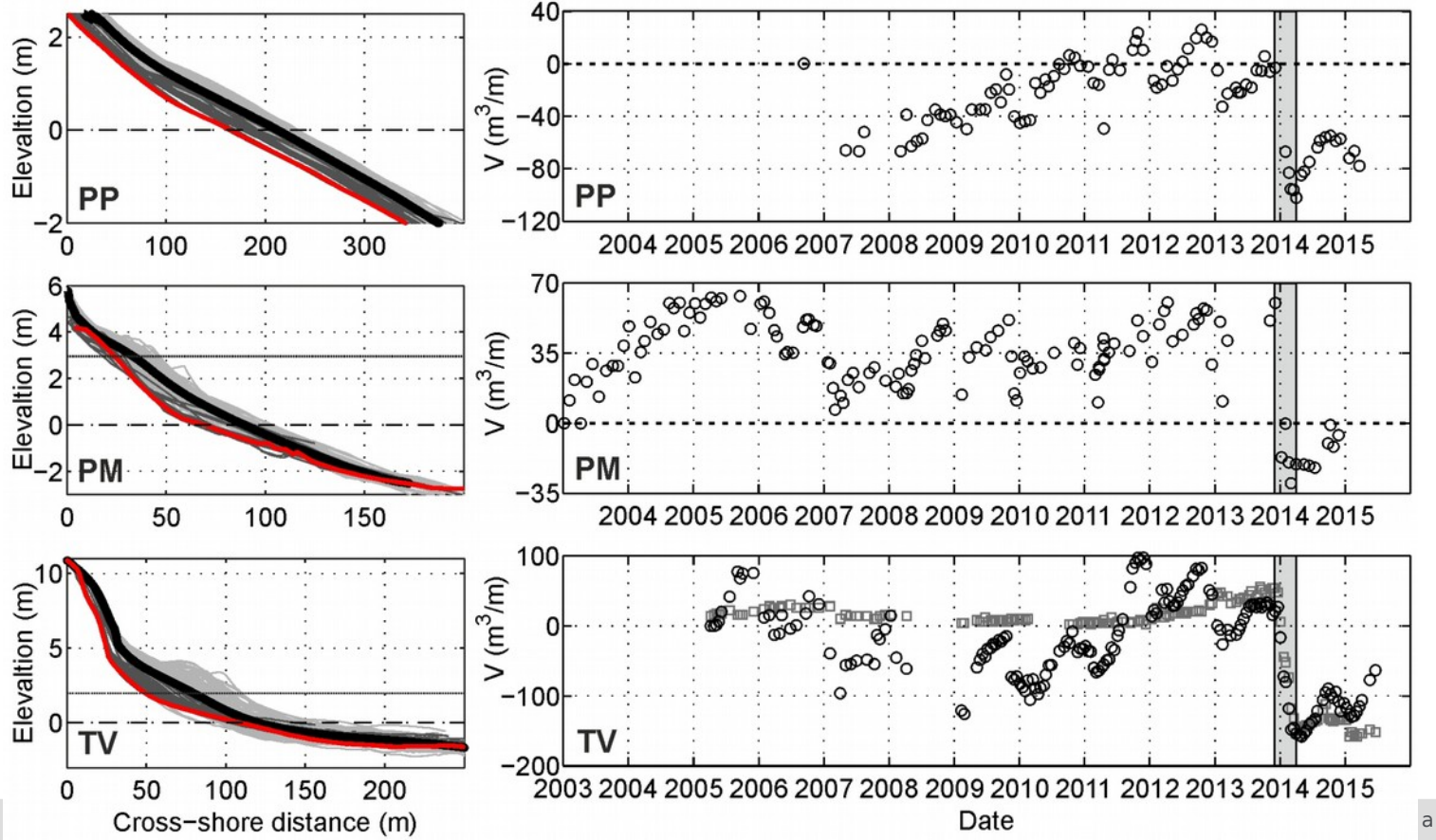


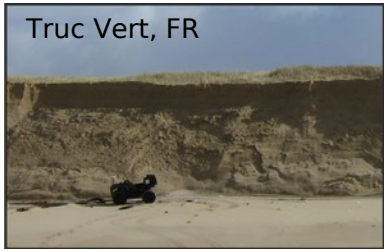




Coastal impact of extreme winter waves

Masselink et al. 2016



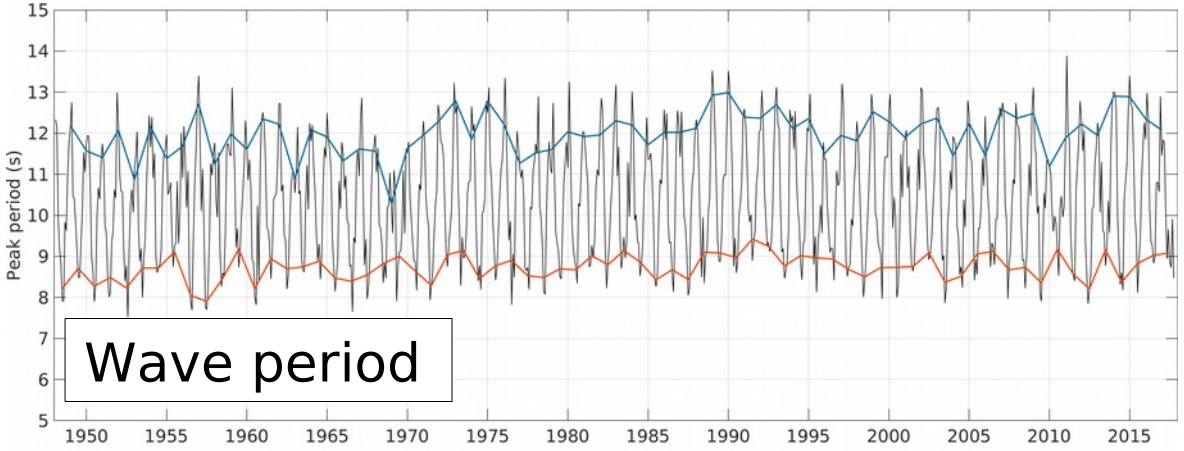


Coastal impact of extreme winter waves

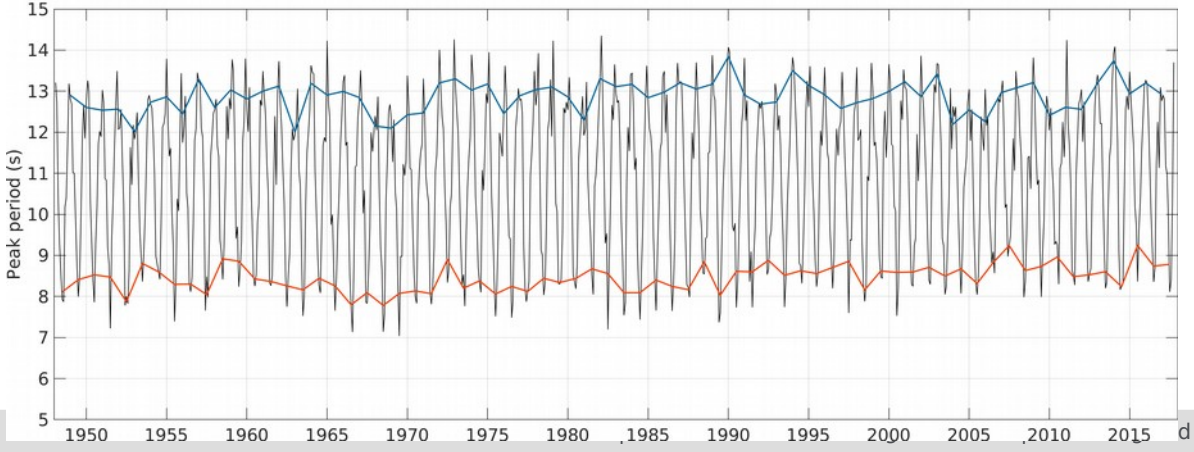
Earlie et al. 2015

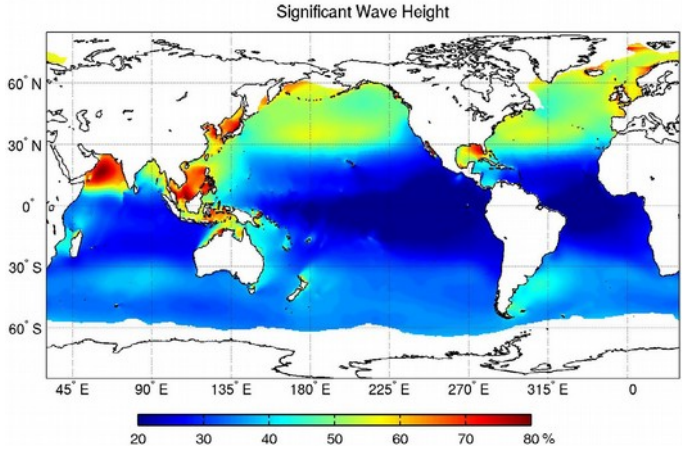
Autret et al. 2016

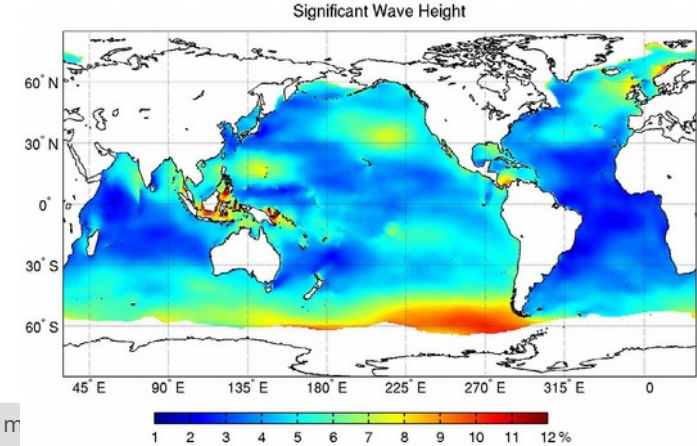
Wave climate variability



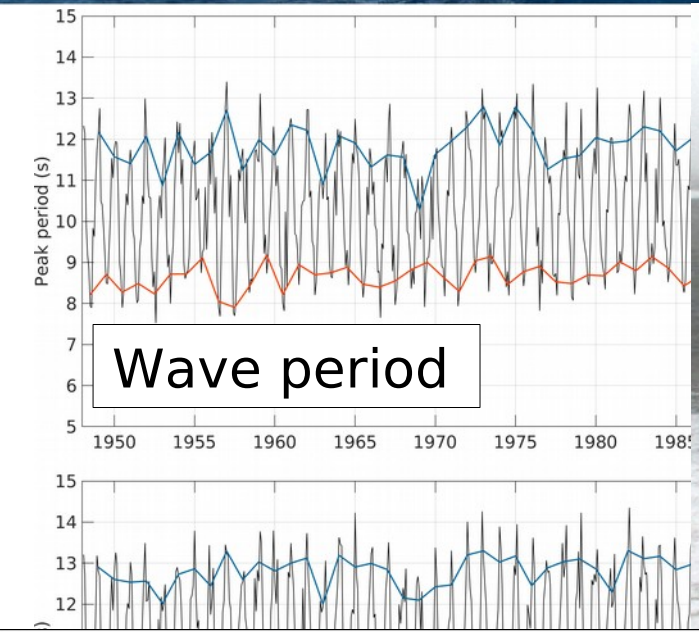
Wave period

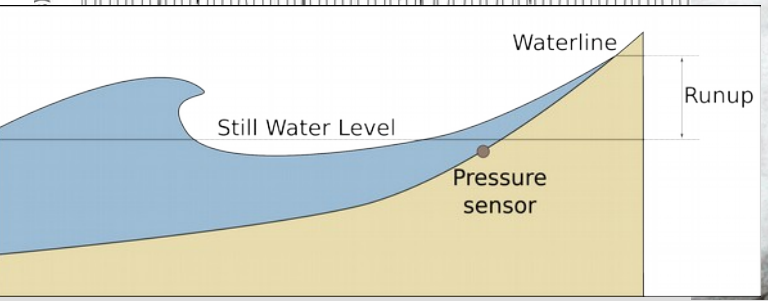






Wave climate variability





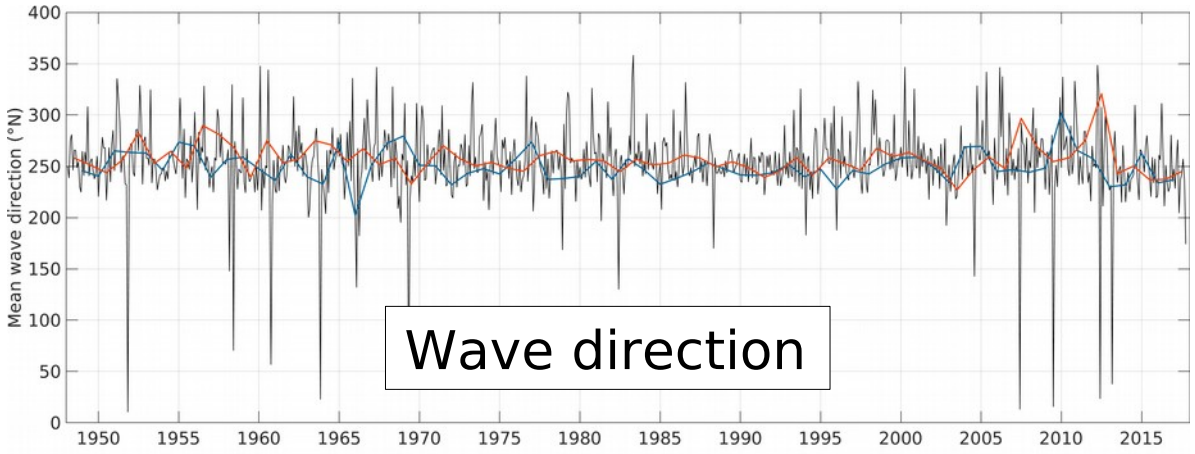
Critical to estimate wave runup !

Hunt, 1956

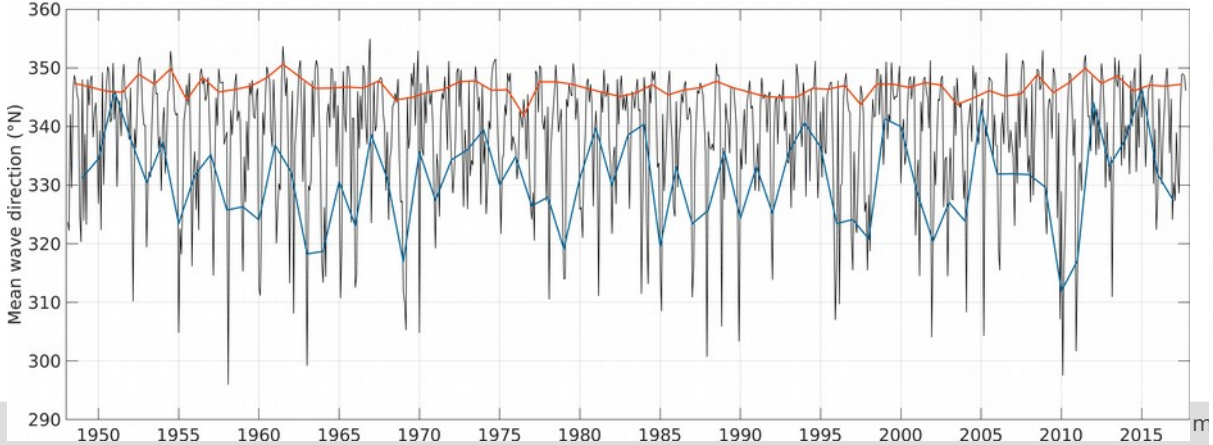
$$\frac{R}{H_0} = K \frac{\tan \beta}{\sqrt{H_0/L_0}}$$

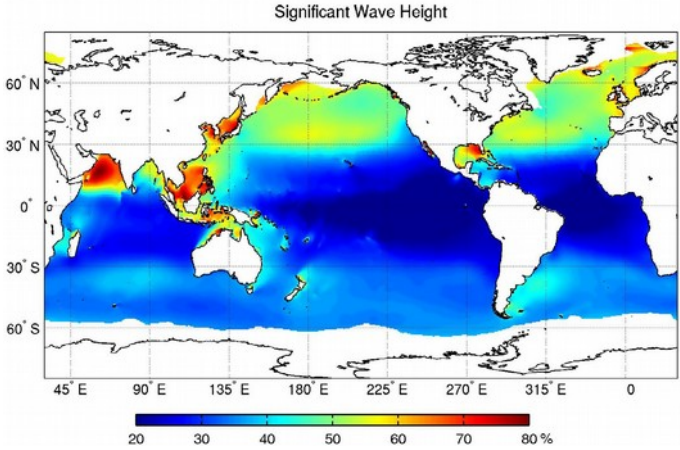
Poate et al., 2016

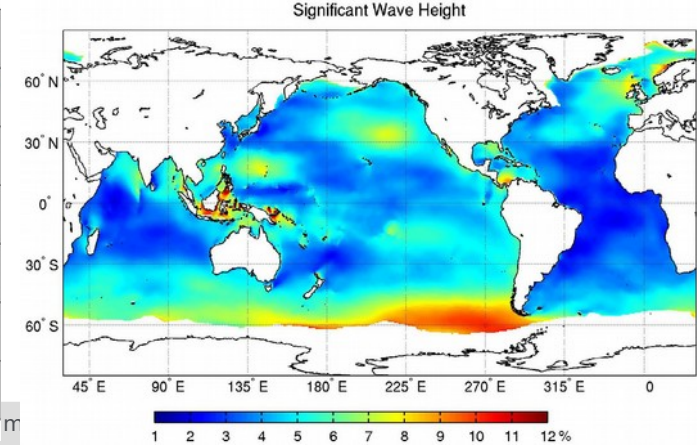
Wave climate variability



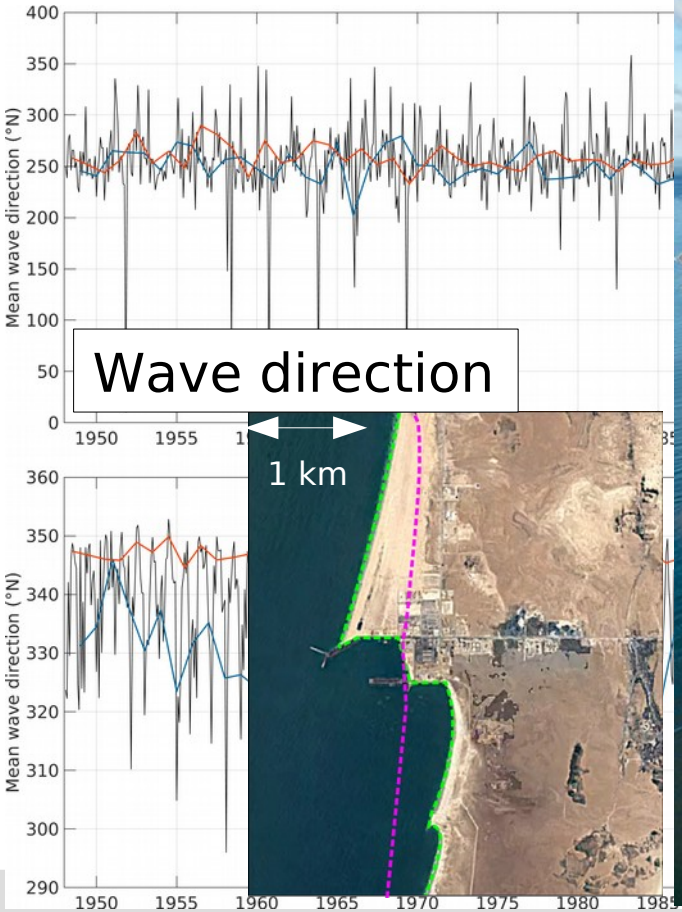
Wave direction







Wave climate variability

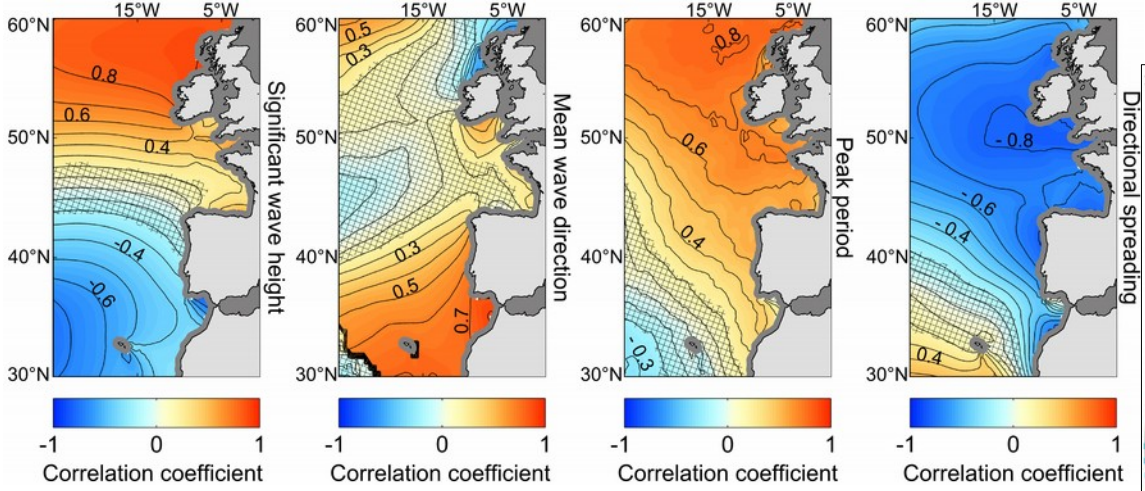


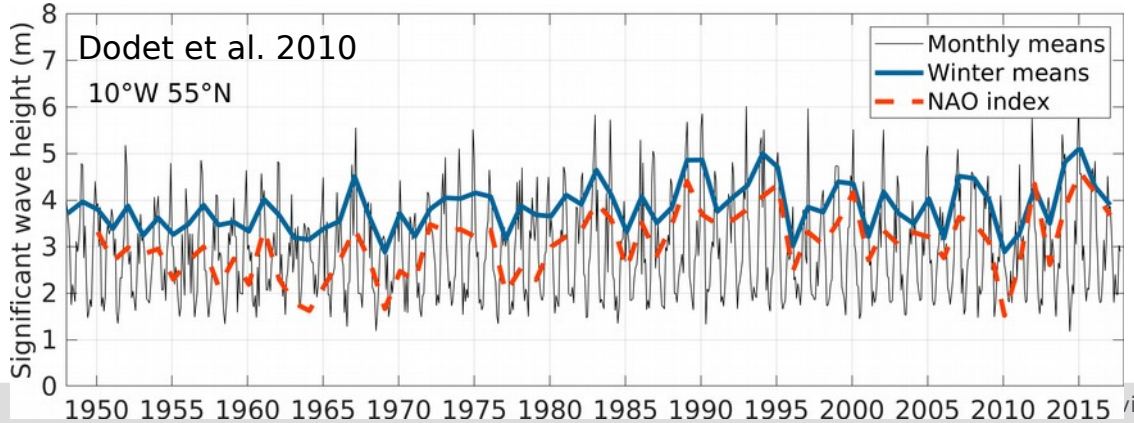
$$Q = \frac{K}{16(\rho_s - \rho_0)(1-\lambda)\sqrt{\gamma_b}} \rho_0 \sqrt{g} H_{sb}^{\frac{5}{2}} \sin 2\theta_b$$

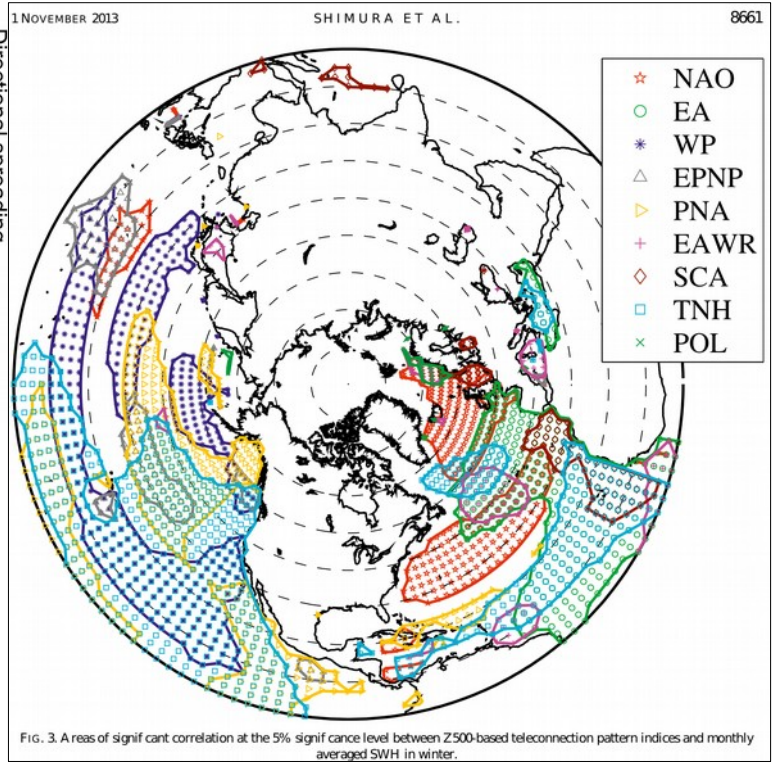
CERC formula, 1984

©Philippe Devanne

Wave climate variability



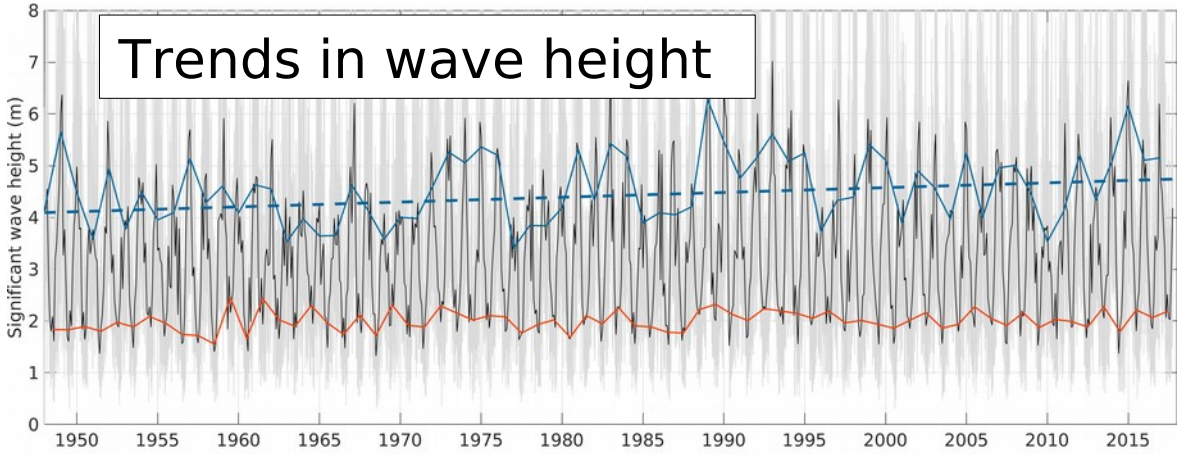


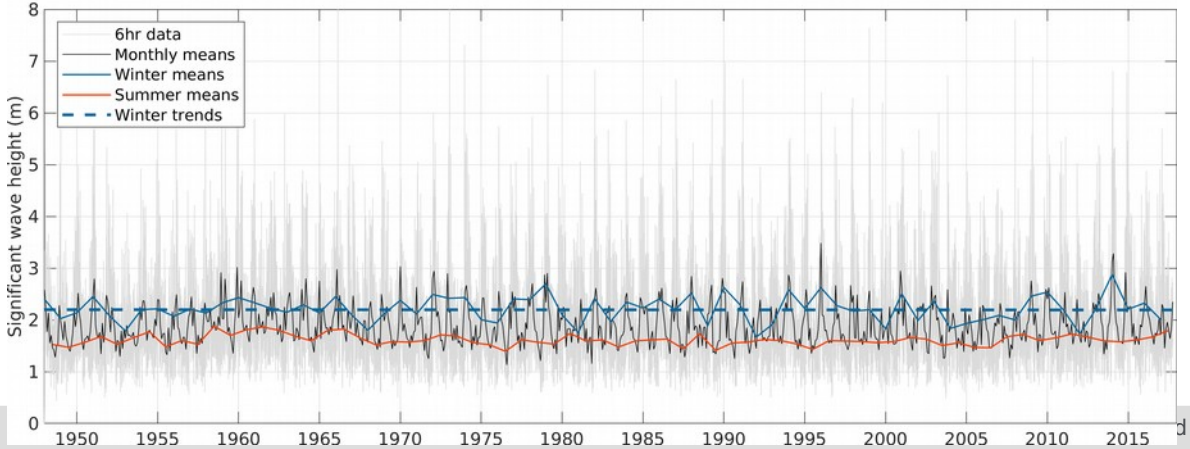


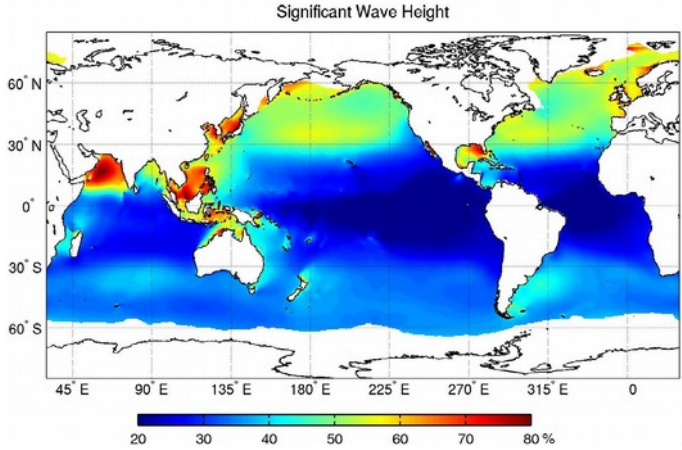
Shimura et al. 2013

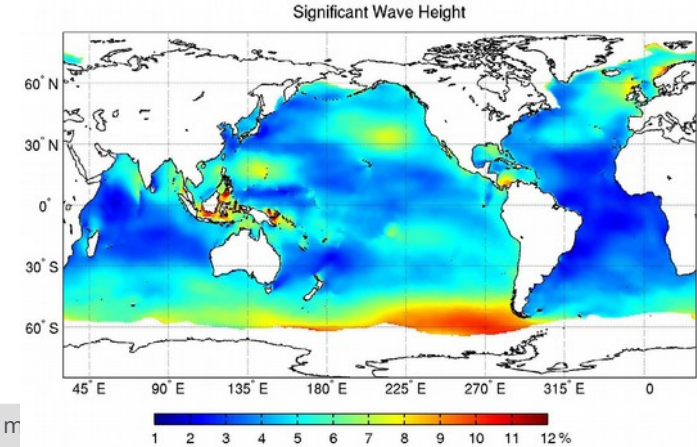
Wave climate trends

Trends in wave height

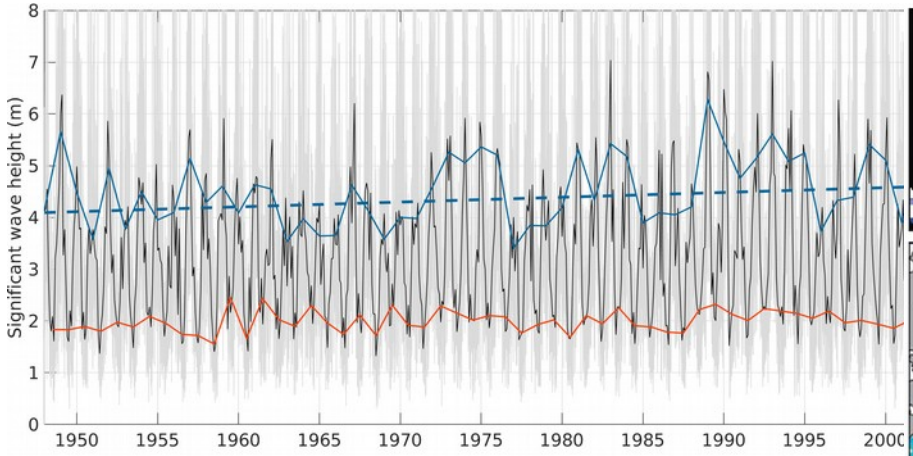


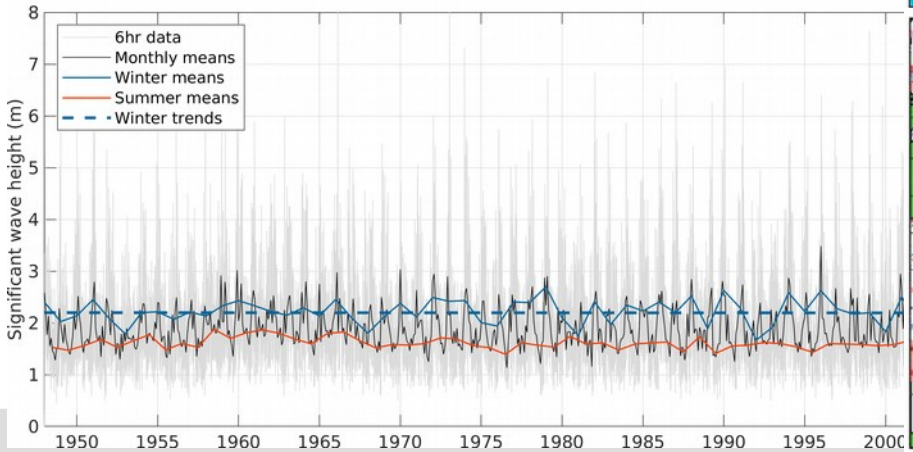


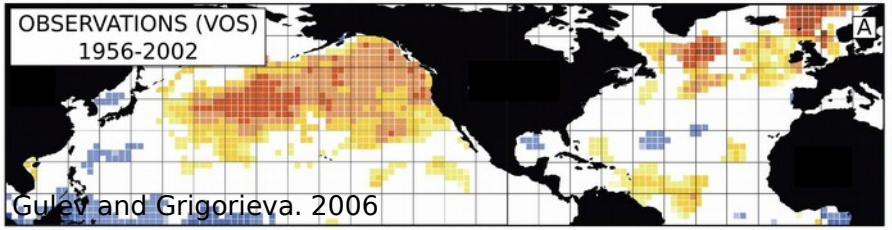


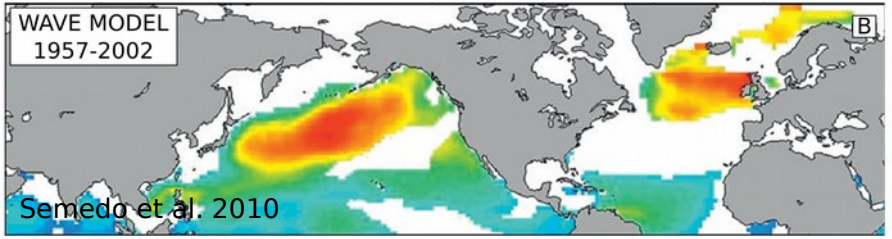


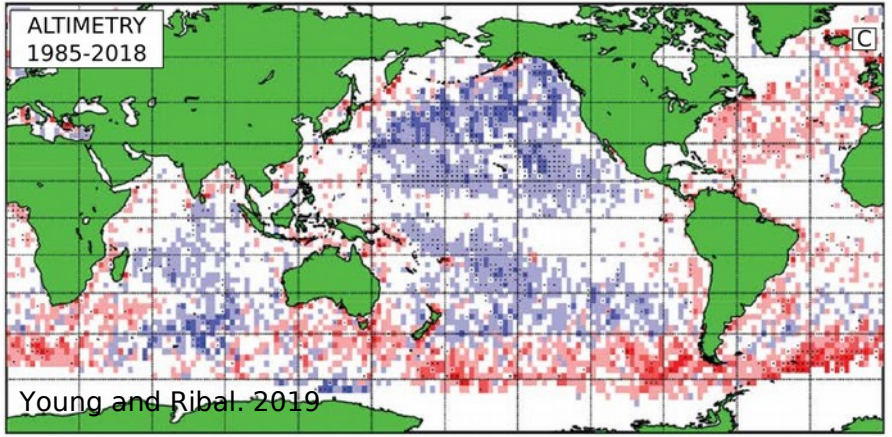
Wave climate trends



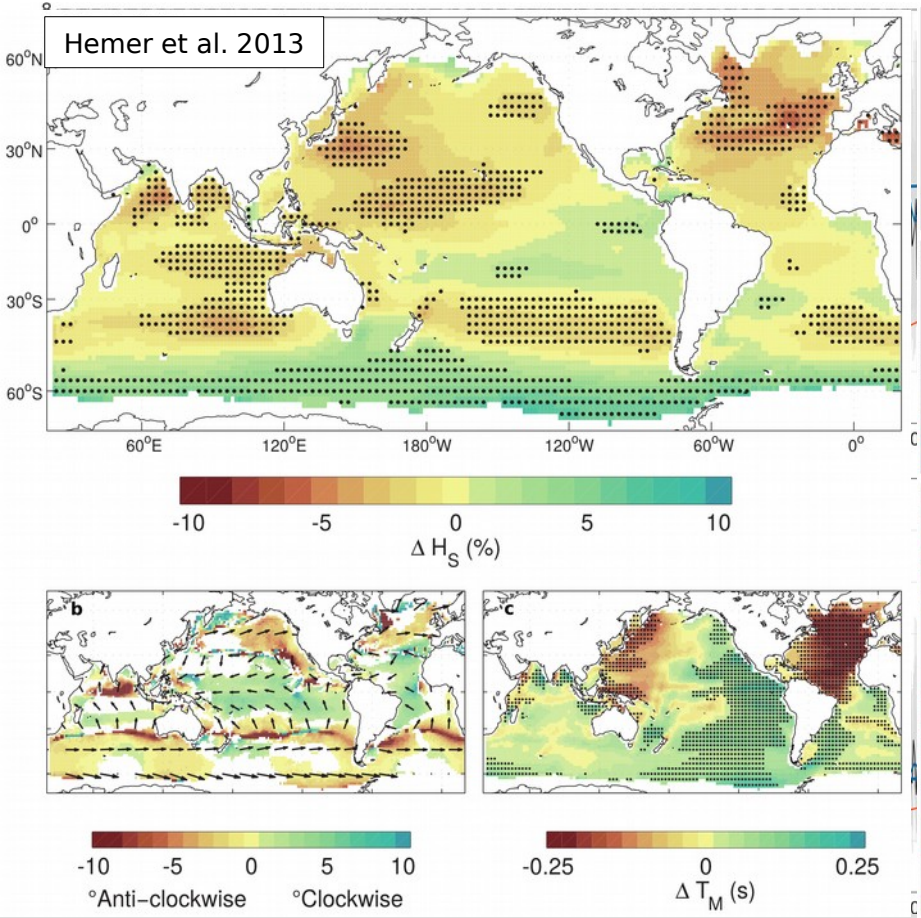


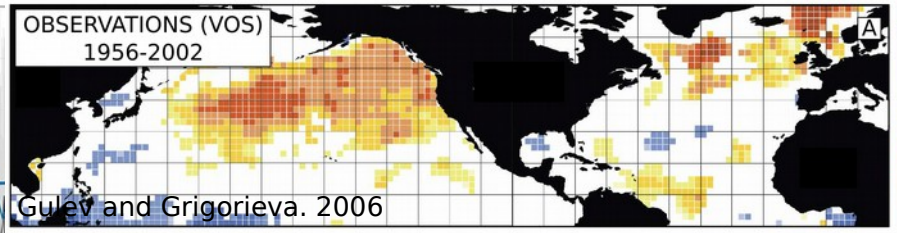


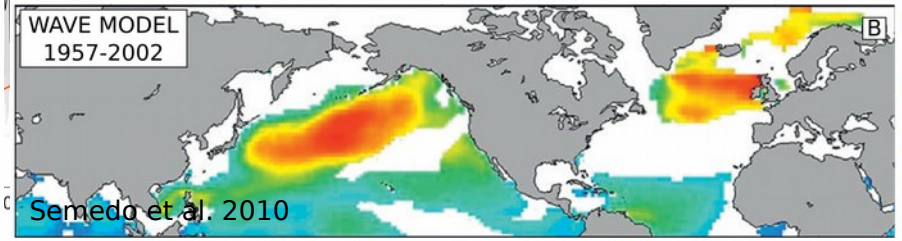


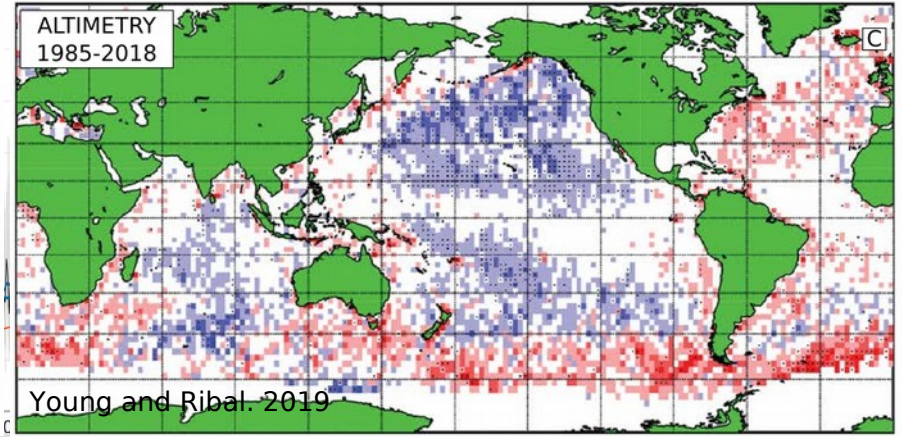


Wave climate projections









Summary

- Importance of sea states for climate science, marine safety, coastal engineering…
- Strong variability of wave climate at various timescales (seasonal, interannual, decadal)
- Wave periods and wave directions play key roles in coastal processes but observations are limited
- Wave climate interannual variability is strongly controlled by atmospheric climate modes
- Significant trends have been detected in the past century, but uncertainty remain
- Wave climate projections show significant trends there is still little confidence in it though

2

The Sea State CCI
How satellite data contribute to sea state CDR ?

Context

1992, *Earth Summit*, Rio de Janeiro

154 Member states

sign the

United Nations Framework Convention on Climate Change

to

stabilise greenhouse gas emission and prevent dangerous anthropogenic interference with Earth's climate system.

WMO

establishes

GCOS GLOBAL CLIMATE OBSERVING SYSTEM

to

- *Meet the needs of UNFCC in terms of climate observing system (COS)*
- *Report on adequacy of current COS*
- *Provide guidance for improvement of COS*

defines

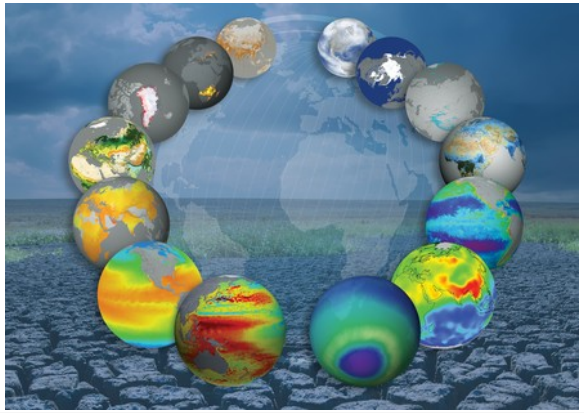
Essential Climate Variables

climate change initiative

esa

Governmental space agencies

contribute to observe



Some climate science concepts

Essential Climate Variable (ECV)

An ECV is a physical, chemical or biological variable or a group of linked variables that critically contributes to the characterization of Earth' s climate.

ECVs are identified based on
- *Relevance*
- *Feasibility*
- *Cost effectiveness*

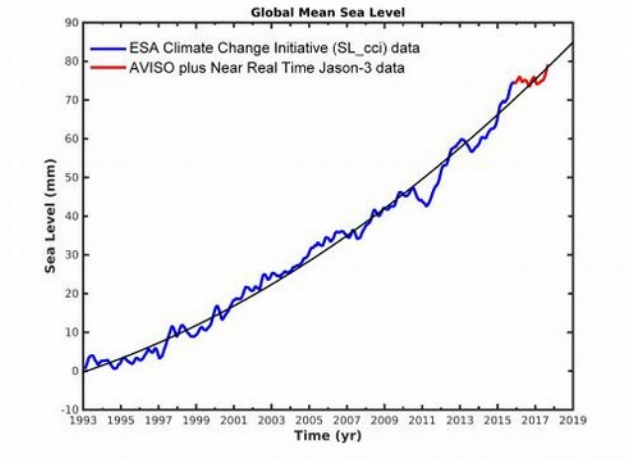
GCOS currently specifies 54 ECVs

Climate Data Record (CDR) or "Product"

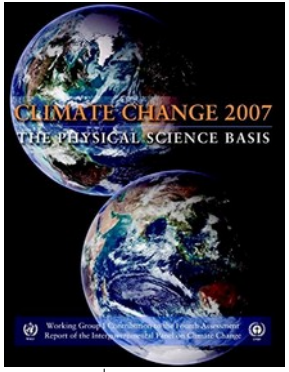
A time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change.

Fundamental Climate Data Record (FCDR)

A well-characterized, long-term data record, usually involving a series of instruments, with potentially changing measurement approaches, but with overlaps and calibrations sufficient to allow the generation of products that are accurate and stable in both space and time to support climate applications

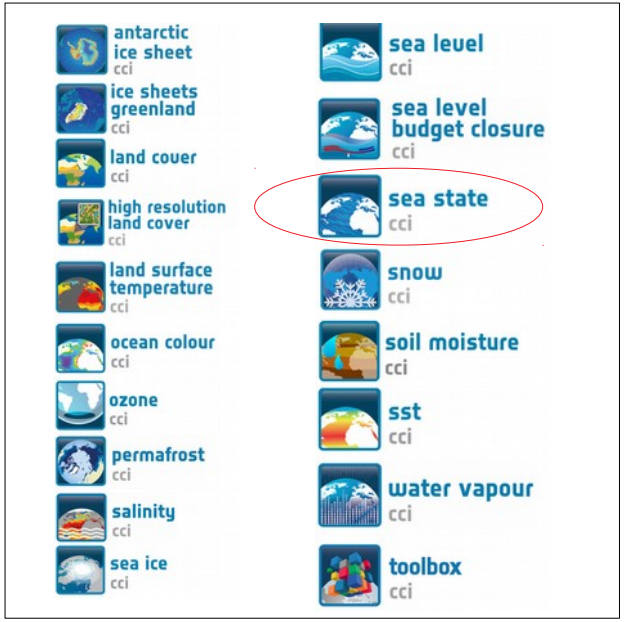


Climate Change Initiative Program



Surface wind waves were identified in the Intergovernmental Panel for Climate Change (IPCC) Fourth Assessment Report (AR4) as one of the key drivers in the coastal zone, but little information was available on projected changes under future climate scenarios.

ESA launches the Climate Change Initiative program



Sea state joins the list of ECVs in CCI+

CCI

CCI+

2007 2009 2018 2024

Sea State CCI project

climate change initiative

sea state cci

Science lead: Fabrice Ardhuin

LOPS + 13 partner institutions

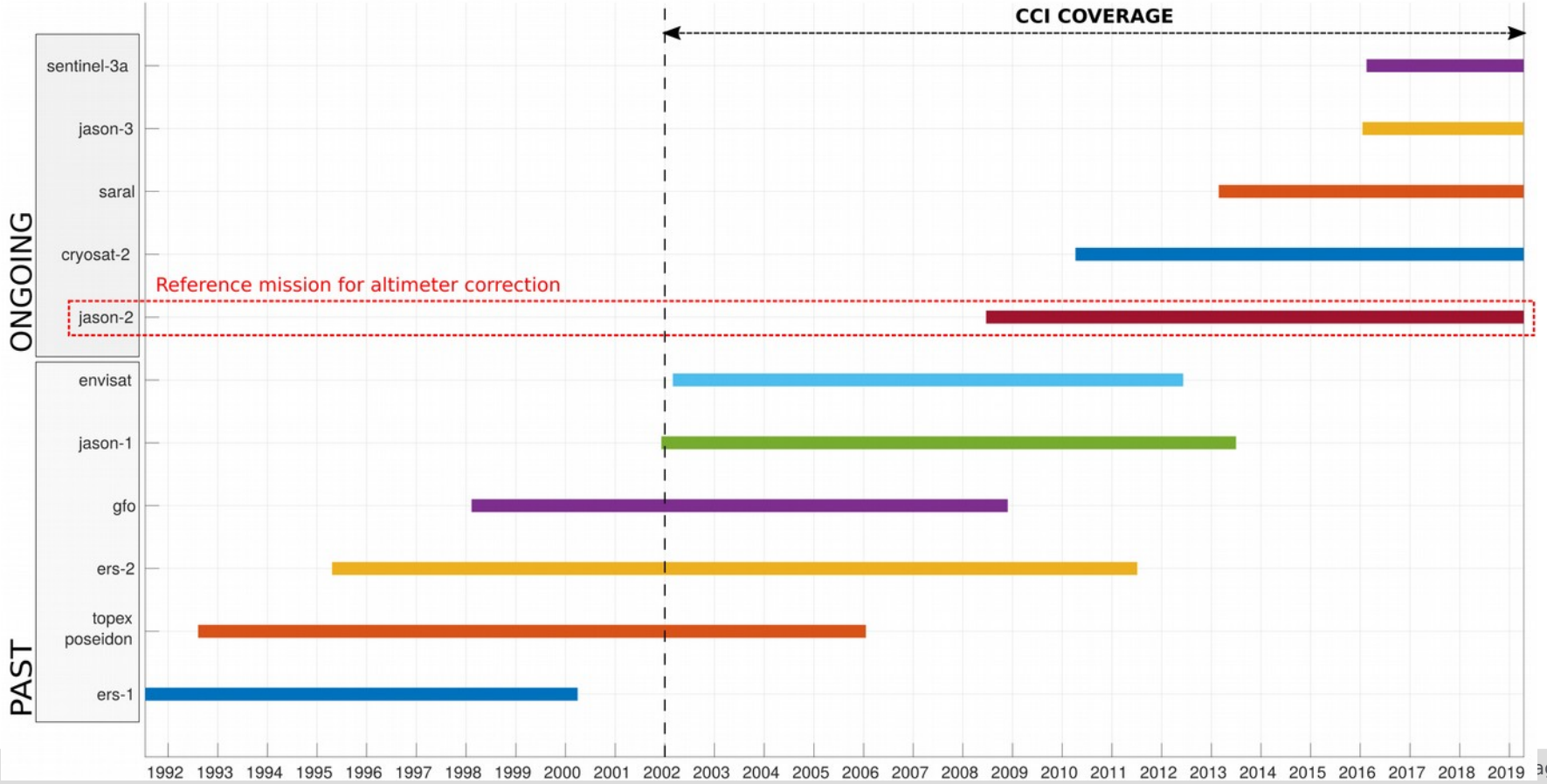
Phase 1: 2018 – 2021

Phase 2: 2021 - 2024

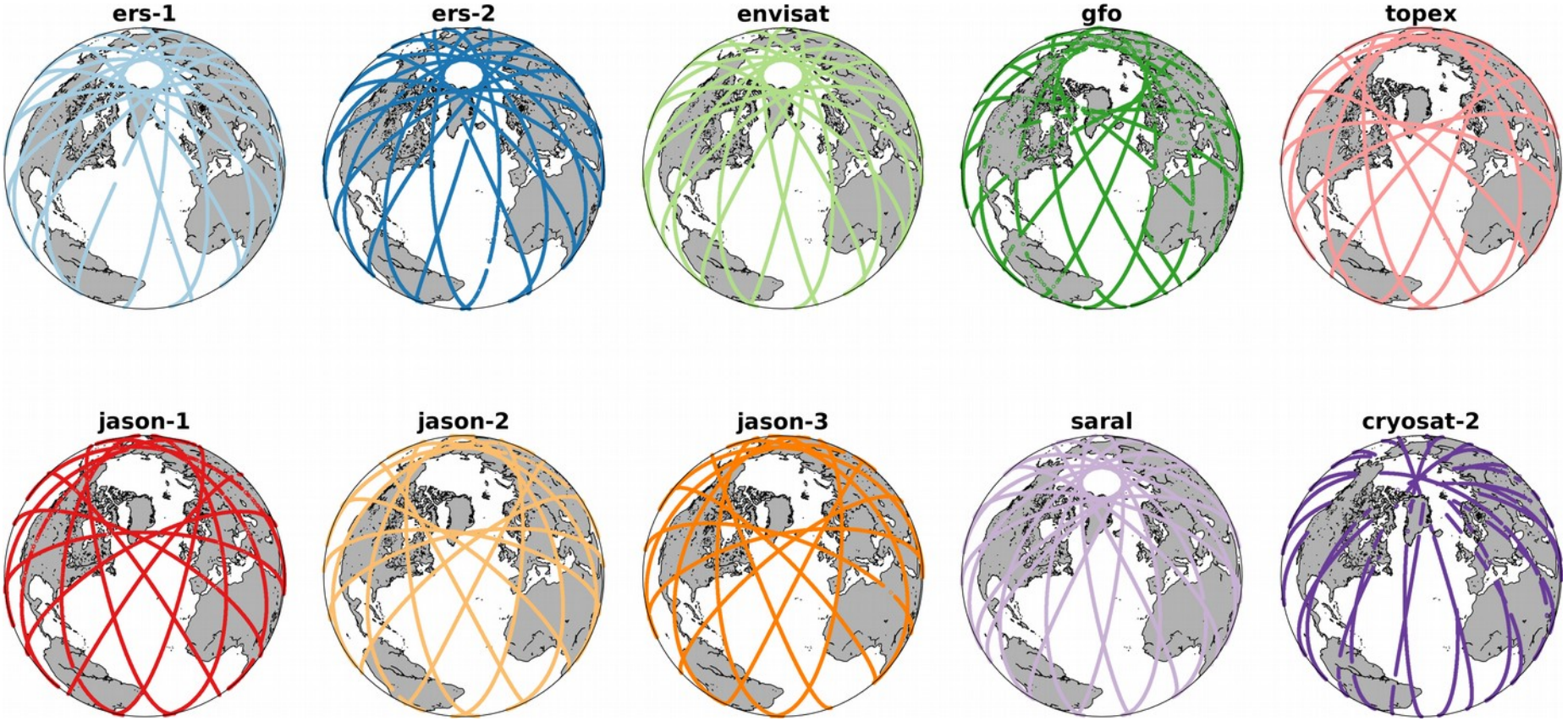
Main objective : provide a wide user community with a sea state Climate Data Record (CDR)

WP 1000 User requirements	WP 2000 Algorithm development	WP 3000 System development
WP 4000 Production & Validation	WP 6000 User federation	WP 6000 Project management

Altimeters


CCI COVERAGE
ONGOING
sentinel-3a
jason-3
saral
cryosat-2
Reference mission for altimeter correction
jason-2
PAST
envisat
jason-1
gfo
ers-2
topex
poseidon
ers-1
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019

Altimeters

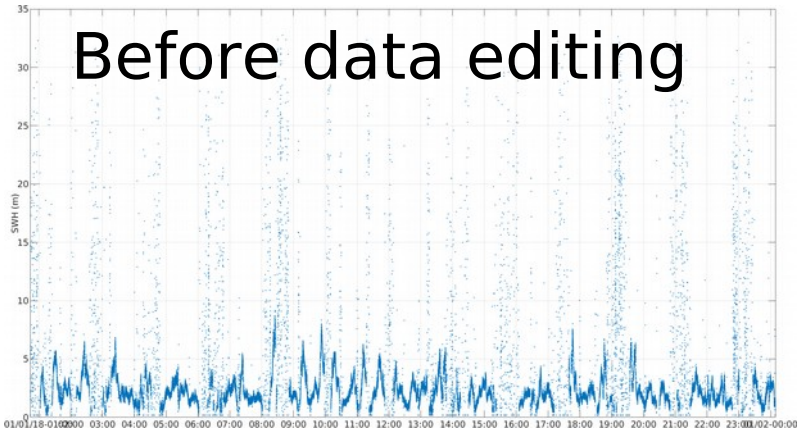

ers-1
ers-2
envisat
gfo
topex
jason-1
jason-2
jason-3
saral
cryosat-2

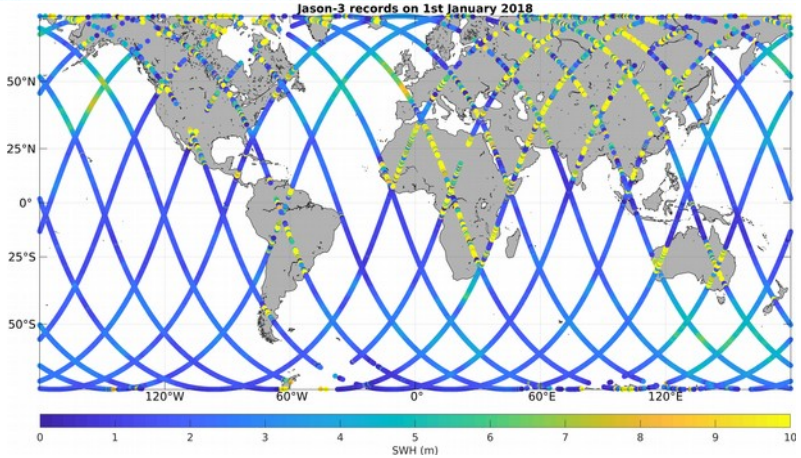
Processing steps

- Step1 : Data editing
- Step 2 : Cross-calibration
- Step 3 : Filtering
- Step 4 : Formatting
- Step 5 : Validation against buoy / model

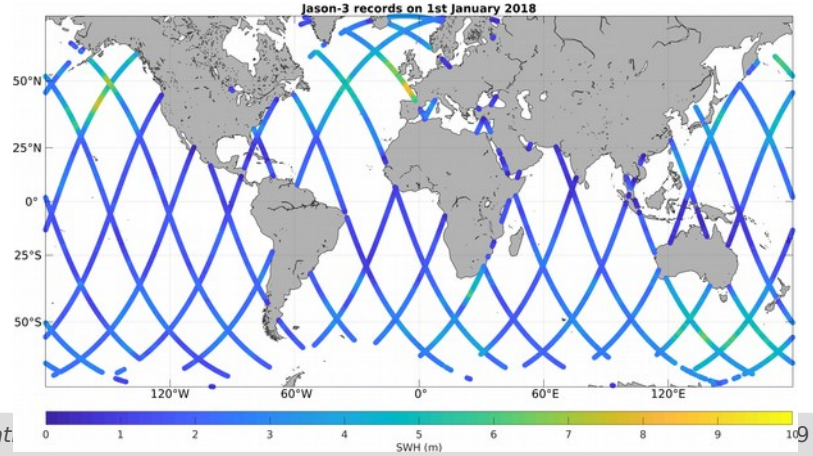
Data editing

Before data editing





After data editing
(*swh_quality_flag* == 3)

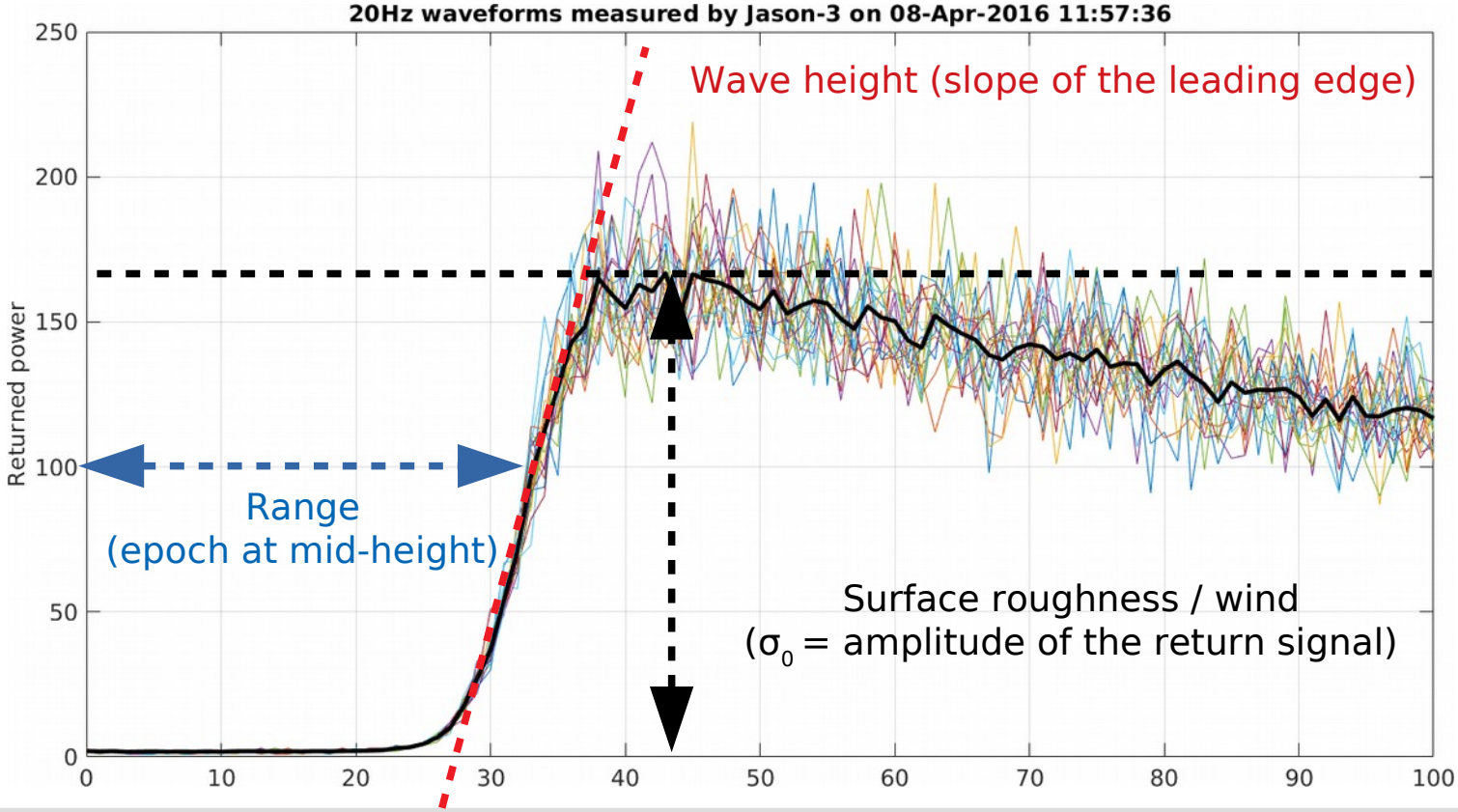


Data editing

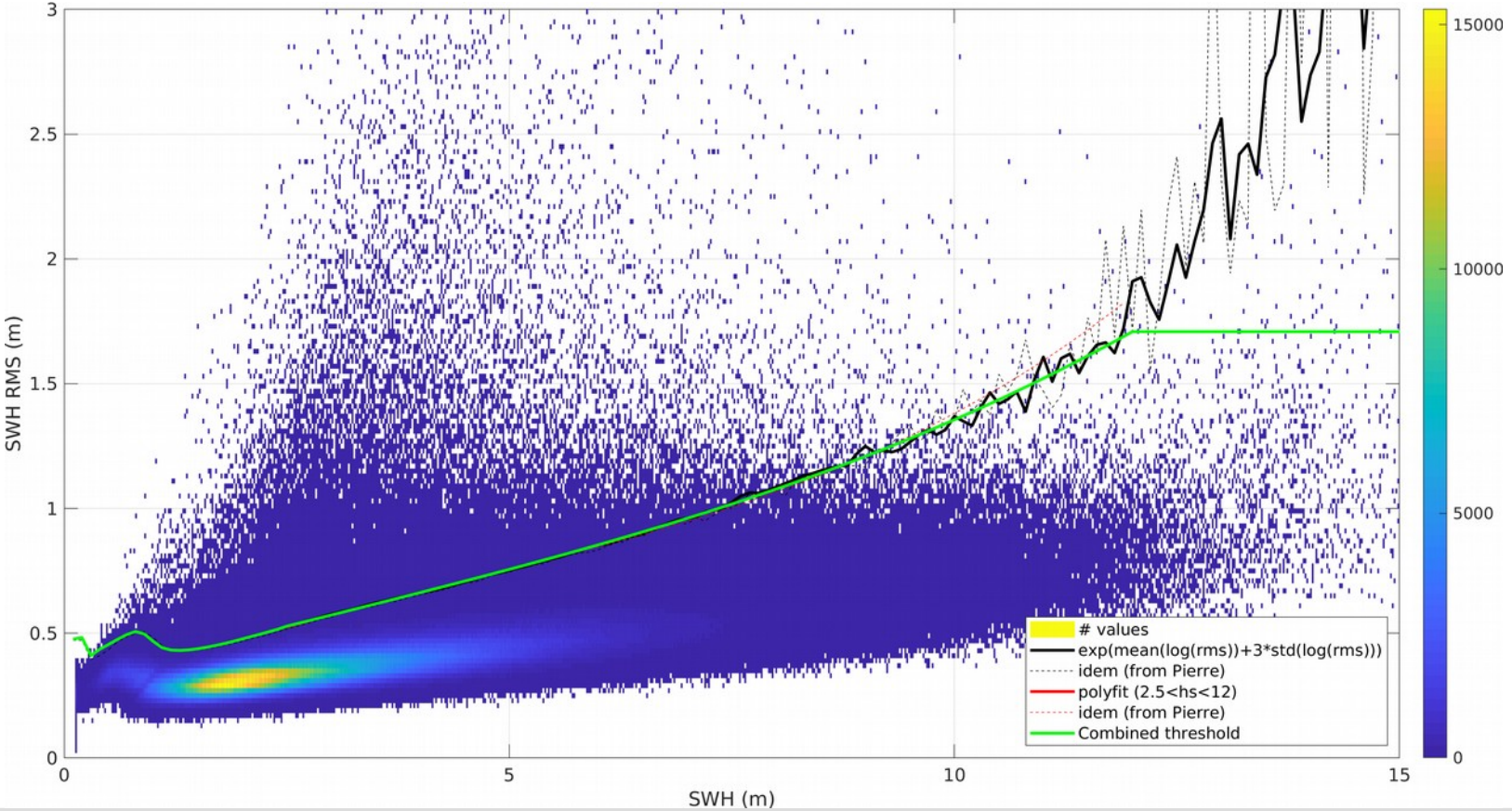
8 rejection flags

- not_water: the surface type is not water. It may be land, continental ice,.... We try to keep lake and inner seas measurements
- sea_ice: the measurement has possible ice contamination. The sea ice fraction is taken from an external source (such as the CCI Sea Ice microwave based daily maps). Sea ice contamination is defined as areas where the sea ice fraction is greater than a minimal threshold
- swh_validity: the SWH measurements were considered as invalid (for instance because out of the possible range)
- sigma0_validity: the sigma0 measurements were considered as invalid for water surface type
- waveform_validity: the measurements were considered as invalid as there are indications of unsuitable waveforms for a proper SWH calculation
- ssh_validity: the SWH measurements were considered as invalid as they were issues on SSH which was considered as an indication of problematic quality for SWH too
- swh_rms_outlier: the measurements were considered as invalid when the RMS of the SWH measurements used to estimate each 1 Hz SWH measurement was beyond the acceptable threshold for a given range of SWH
- swh_outlier: the measurements were considered as invalid when performing the SWH outlier test, based on the neighbouring measurements within a 100 km window.

Swh rms threshold?

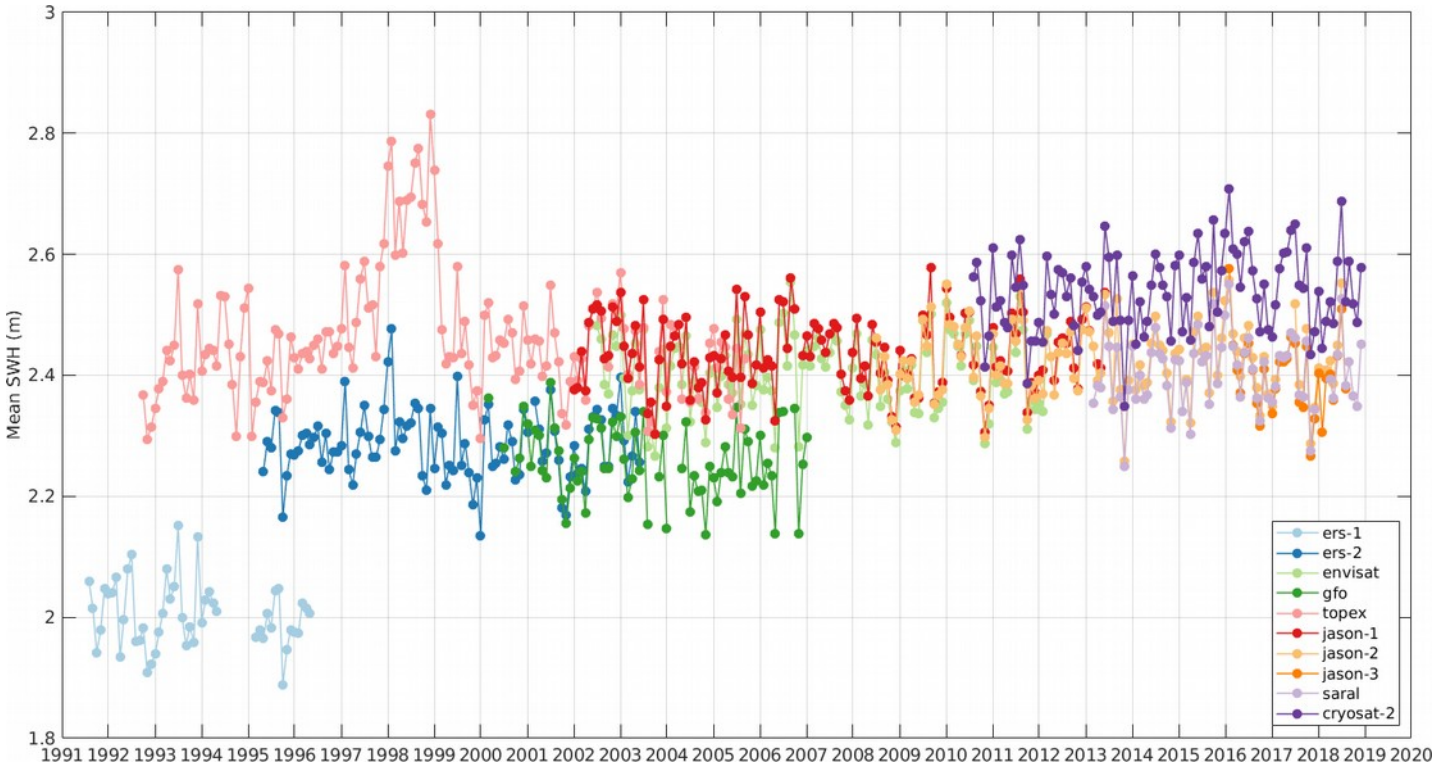


Data editing

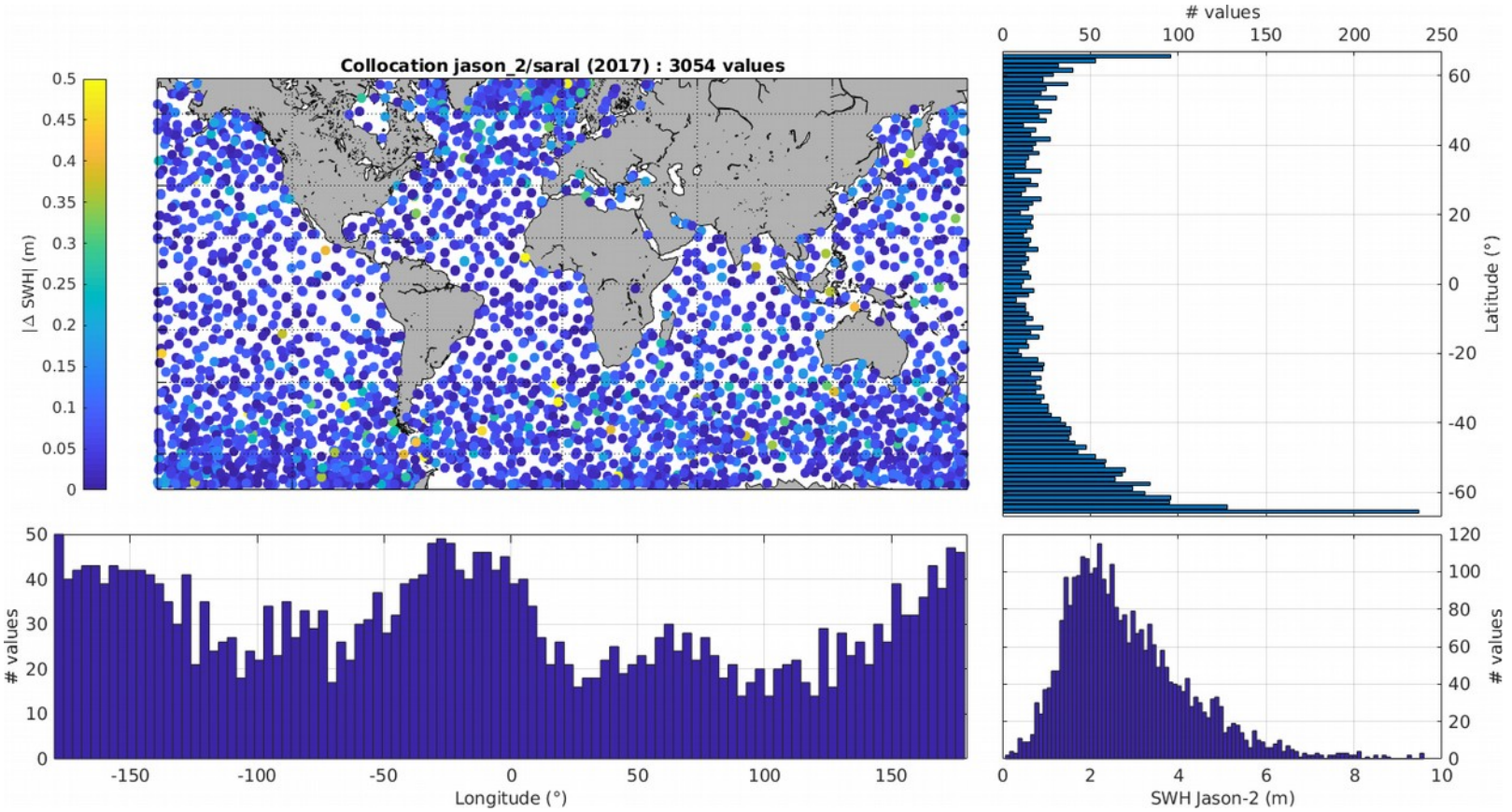


Altimeter cross-calibration

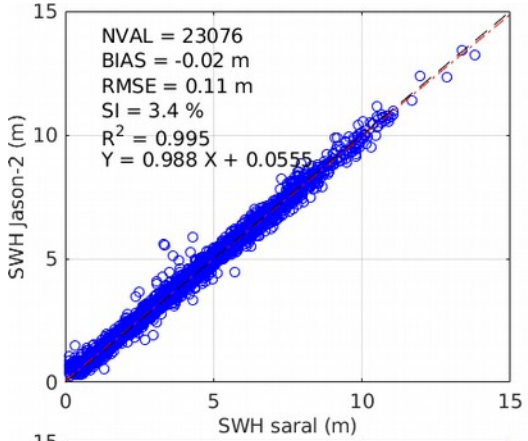
Global monthly swh mean

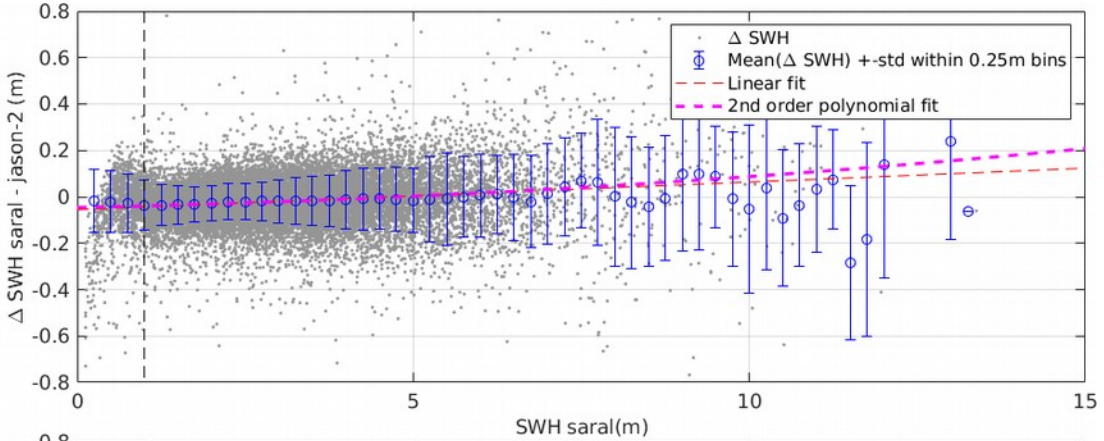


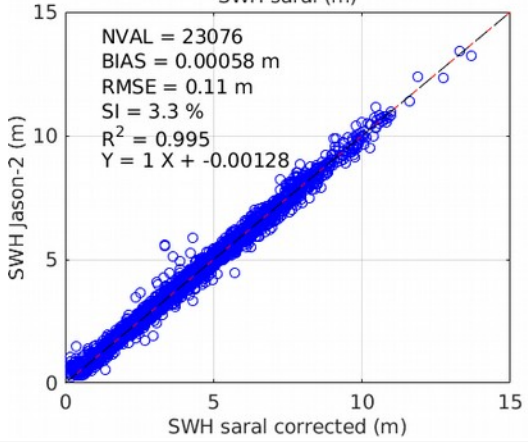
Altimeter cross-calibration

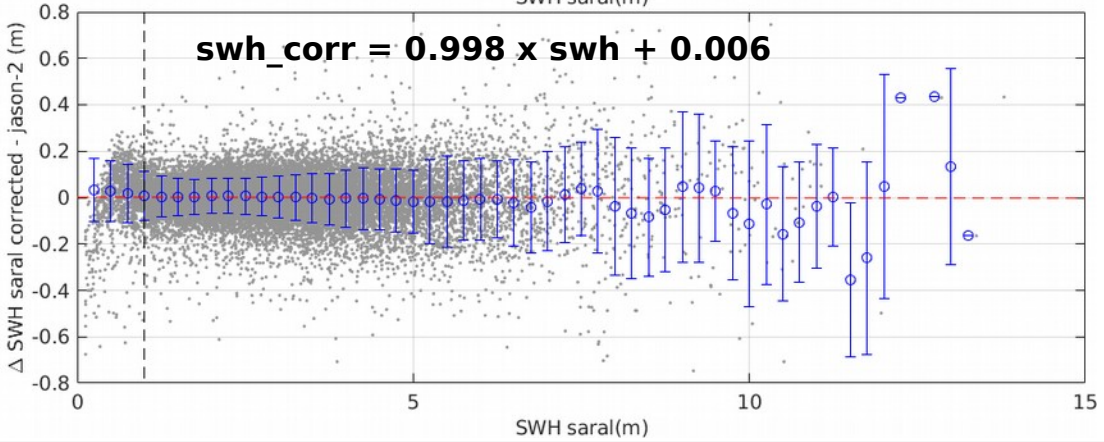


Altimeter cross-calibration

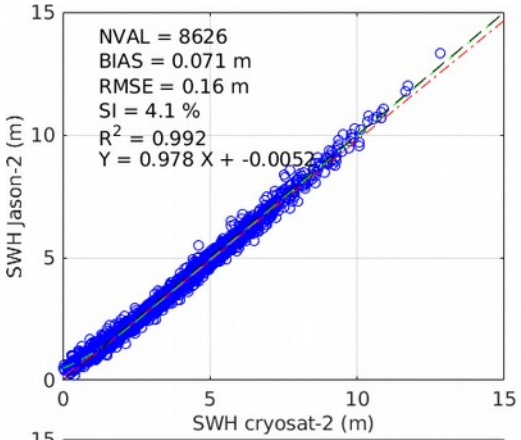


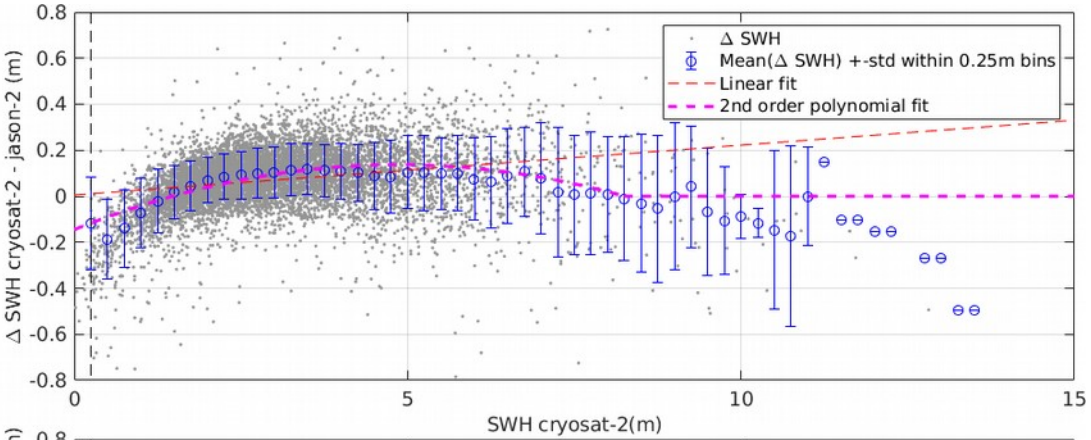


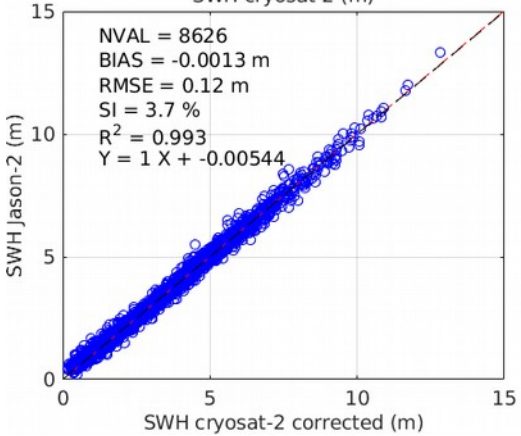


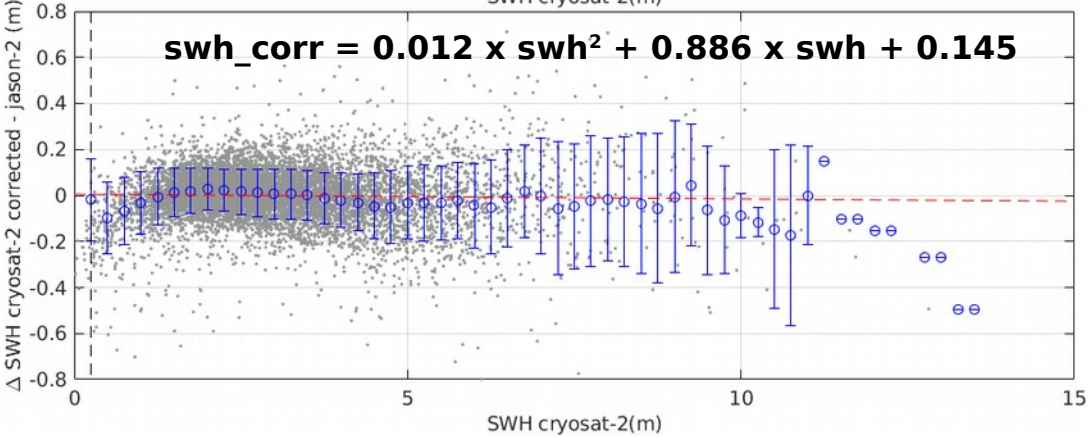


Altimeter cross-calibration



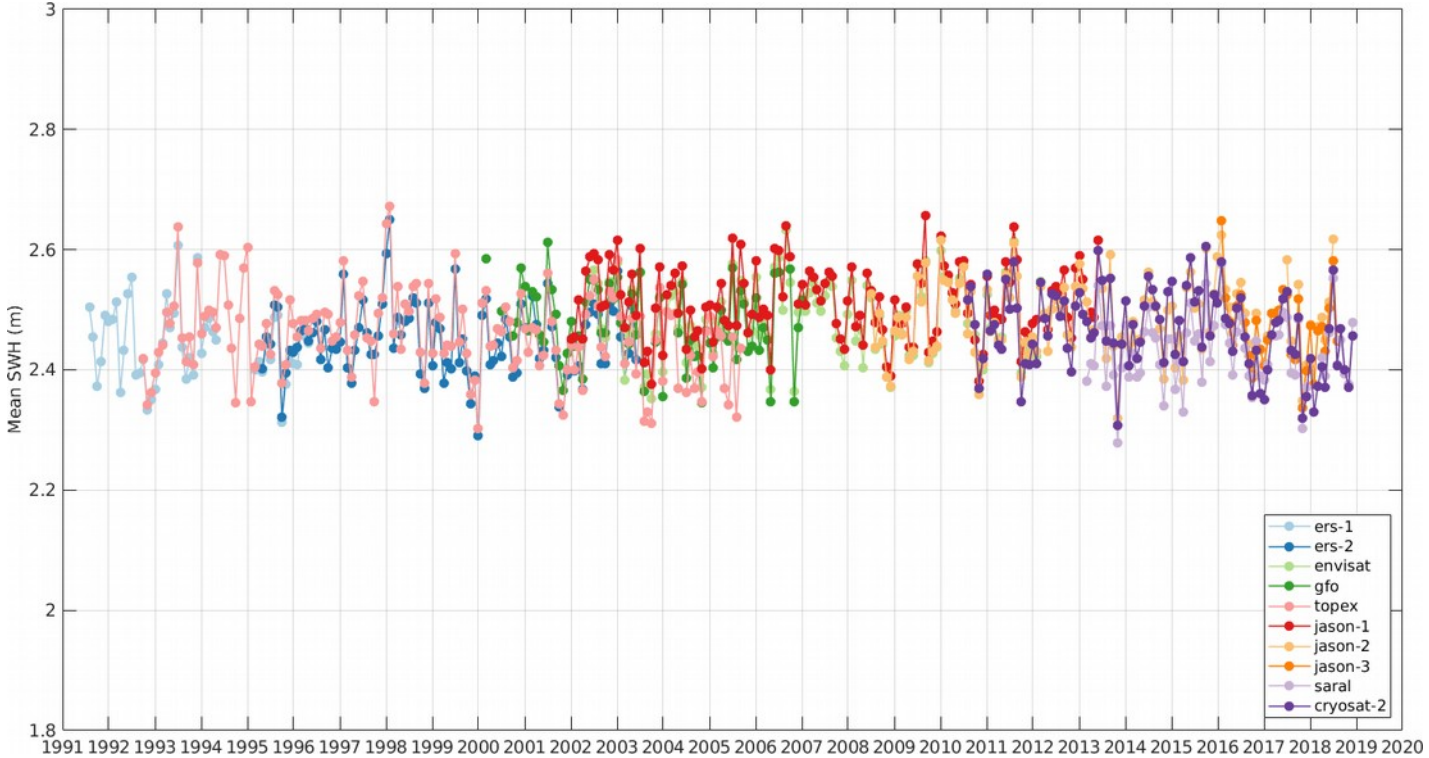




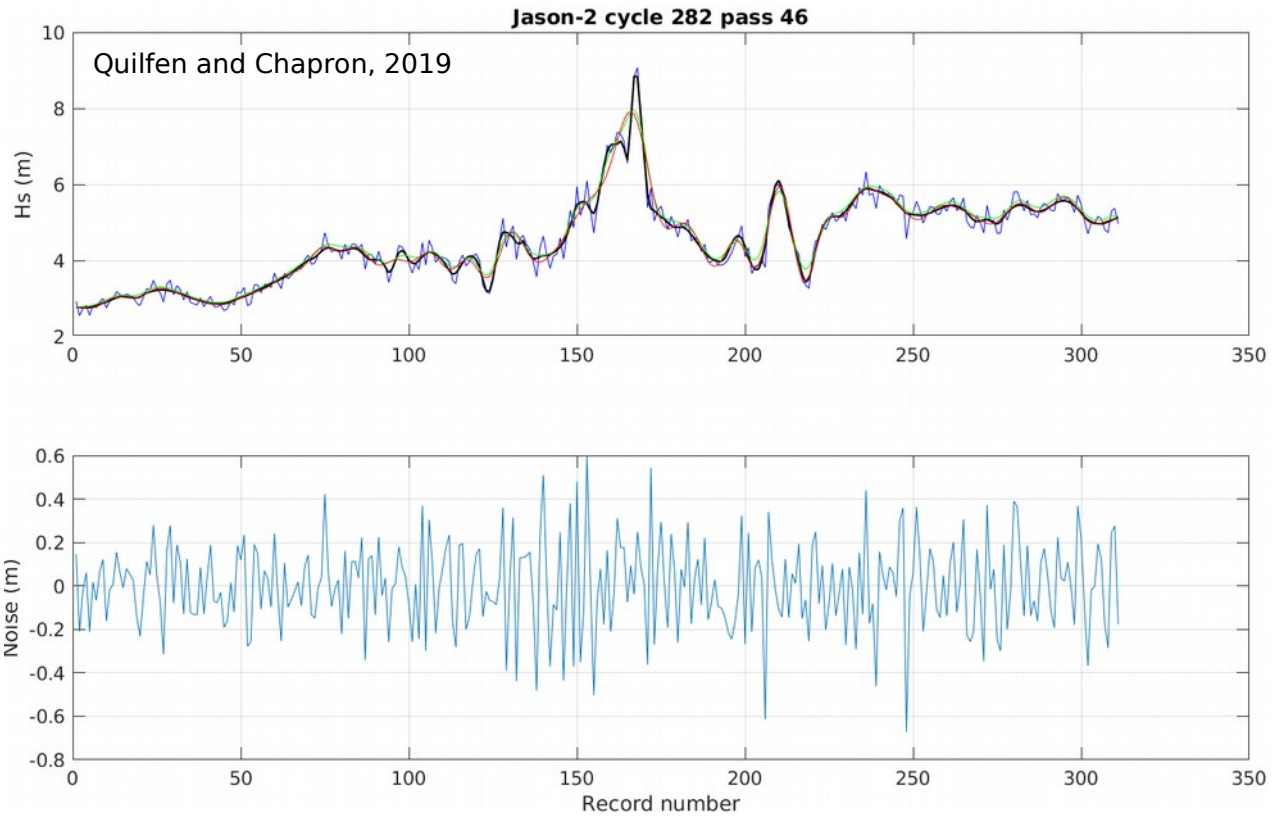


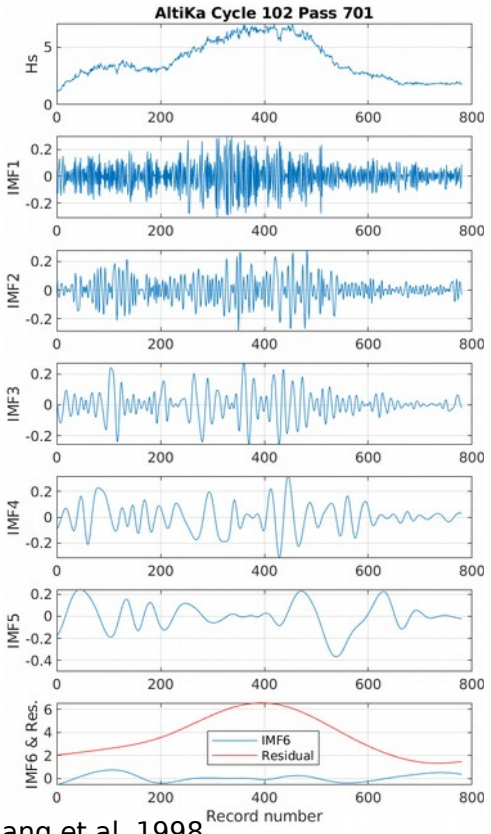
Altimeter cross-calibration

Global monthly swh mean after calibration



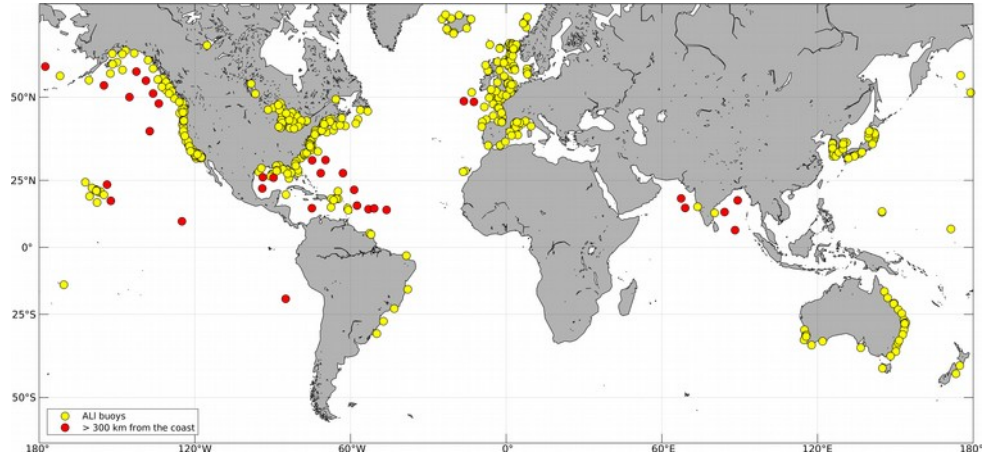
Denoising (based on EMD)



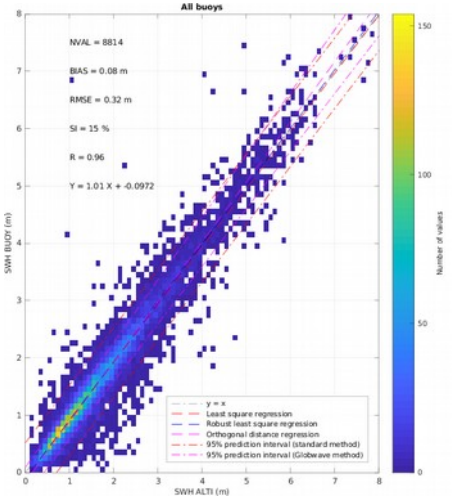


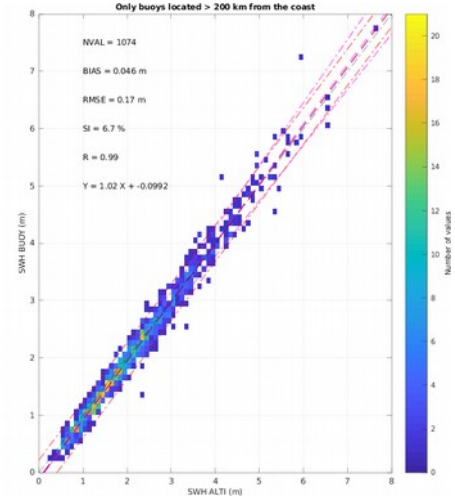
Huang et al, 1998

Validation against buoys

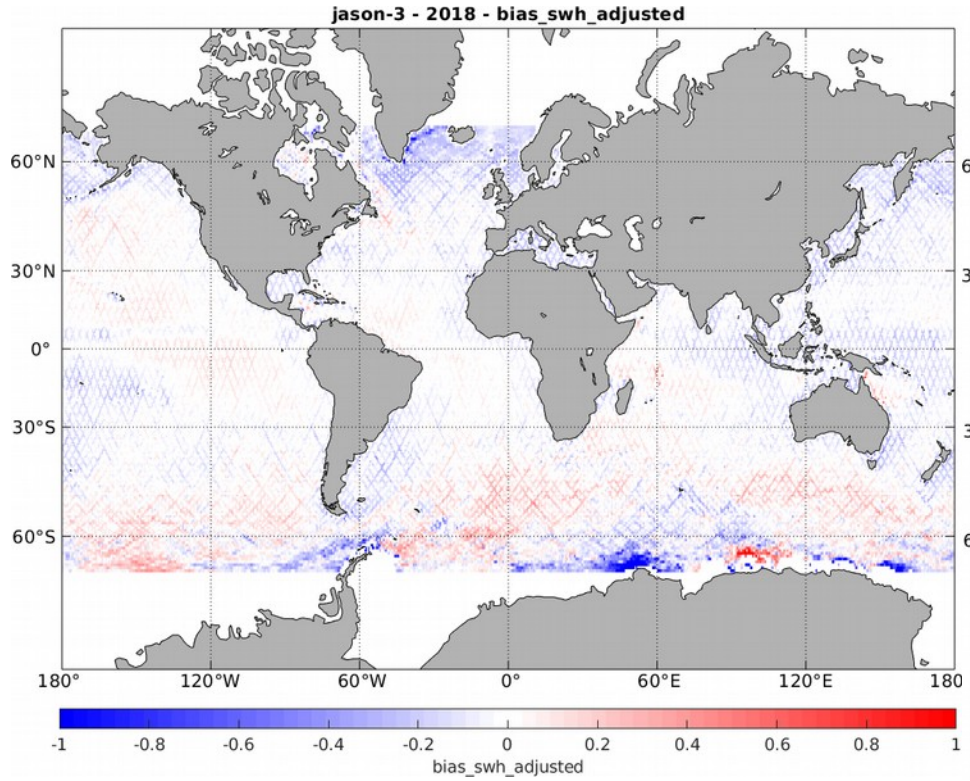


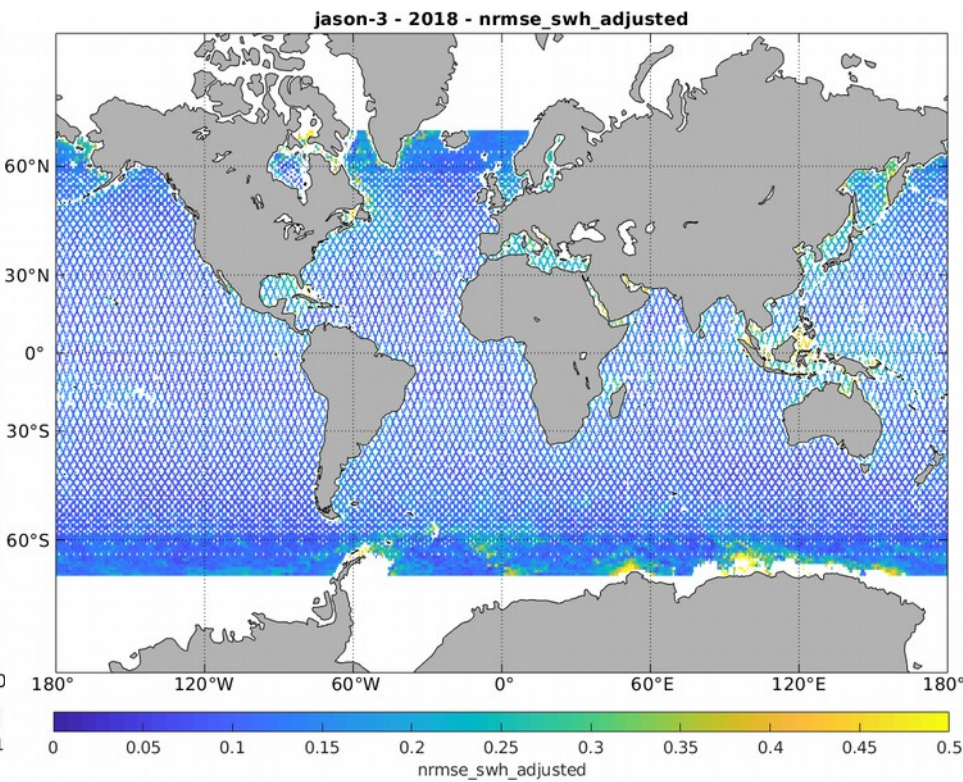
MISSION	NYEAR	NCOLOC	BIAS (M)	RMSE (%)	NRMSE (%)	SI (%)
ers-1	3	1018	-0.072	0.26	9.95	8.41
ers-2	17	9207	0.014	0.24	10.41	8.96
envisat	11	8286	0.044	0.23	10.05	8.58
gfo	9	5221	0.026	0.26	10.91	9.46
topex	12	7797	0.014	0.24	9.74	8.39
jason-1	12	11094	0.010	0.22	9.58	8.31
jason-2	11	14395	0.069	0.21	9.67	7.86
jason-3	3	4181	0.097	0.21	9.95	7.48
saral	6	7876	0.088	0.21	10.14	7.96
cryosat	9	7913	0.048	0.19	9.00	7.57
AVERAGE	**9.3**	**7698.8**	**0.034**	**0.23**	**9.94**	**8.30**



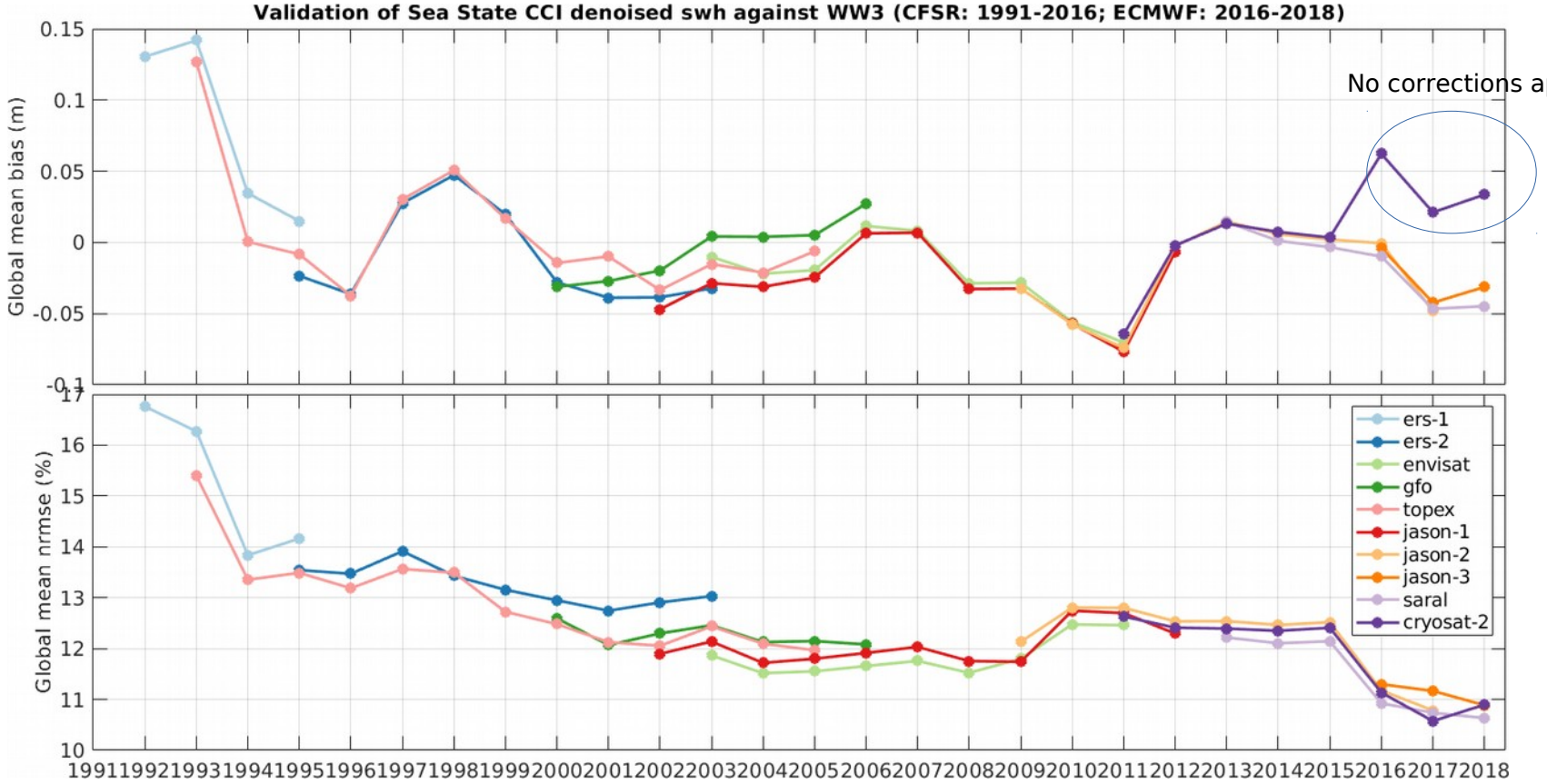


Validation against WW3





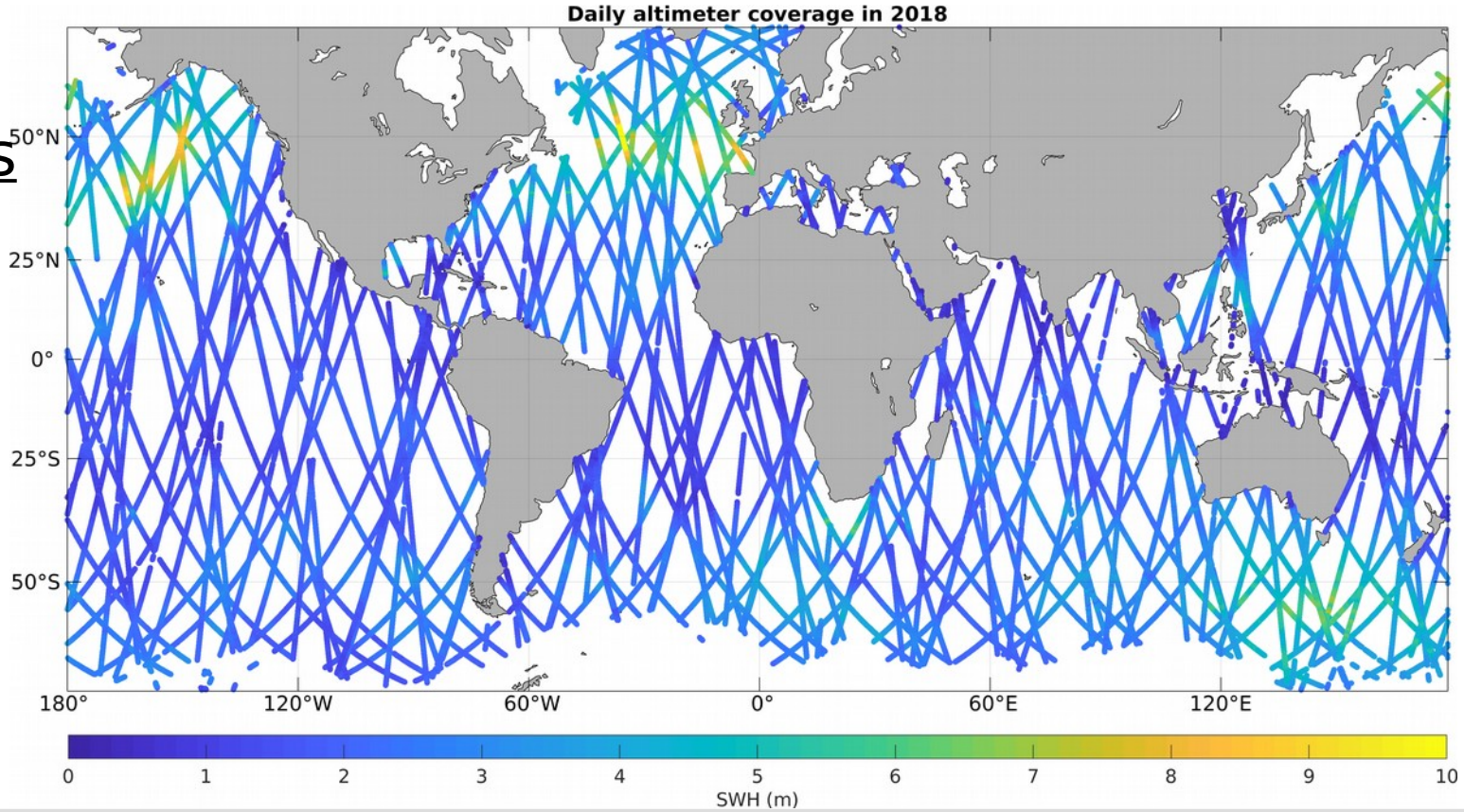
Validation against WW3



Dataset V1

3 products

- L2P
- L3
- L4



More to come !

- New retracking algorithm dedicated to waves
- New data editing methods
- More altimeters to be included (Geosat, CFOSat, HY-2)
- SAR data (Sentinel 1A/1B, ENVISAT) included with additional parameters (wavelength, wave direction)
- Inter-calibrated sigma0 → wind information

Thanks for your attention !

https://seastatecci-ucm.sciencesconf.org/

More information on
http://cci.esa.int/seastate

Sea State *CCI dataset V1* available on :

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

Other database available on ftp.ifremer.fr :
- in-situ wave data (Globwave)
- WW3 outputs (HOMERE)

Ardhuin *et al.*
« Observing sea states »
Frontiers 2018