North Atlantic Extratropical cyclones extreme waves from satellite altimetry observations

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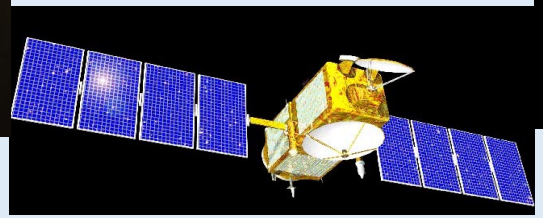
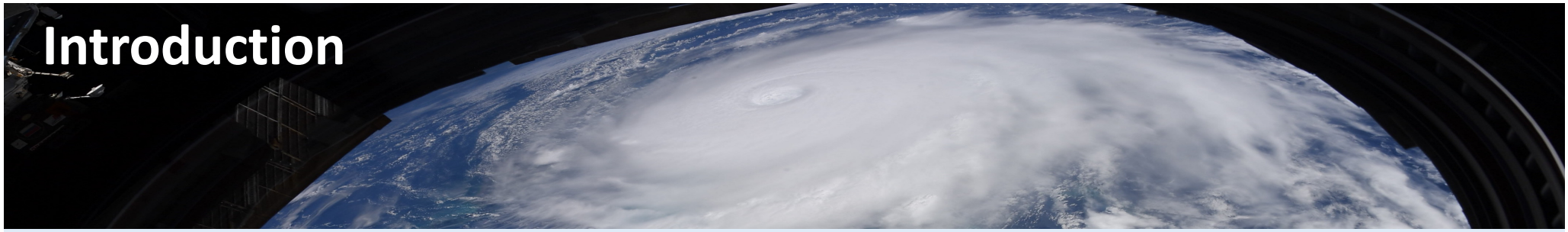


Sea State Climate Change Initiative (CCI), User Consultation Meeting 2019
8-9th October 2019, **LOPS, IFREMER**, Brest, France

Introduction



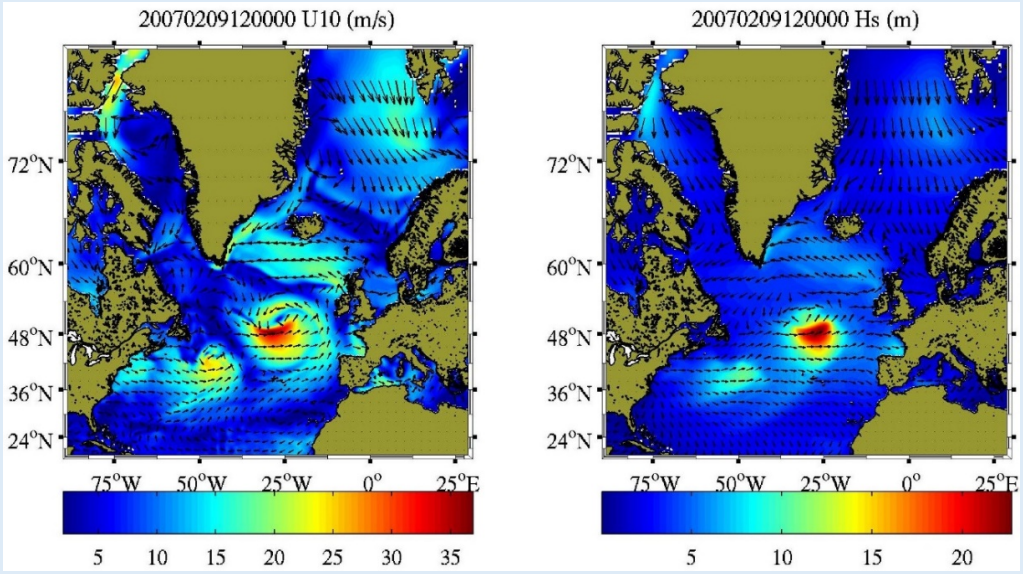
Why is it important the study of Extratropical Cyclones (ETCs)?

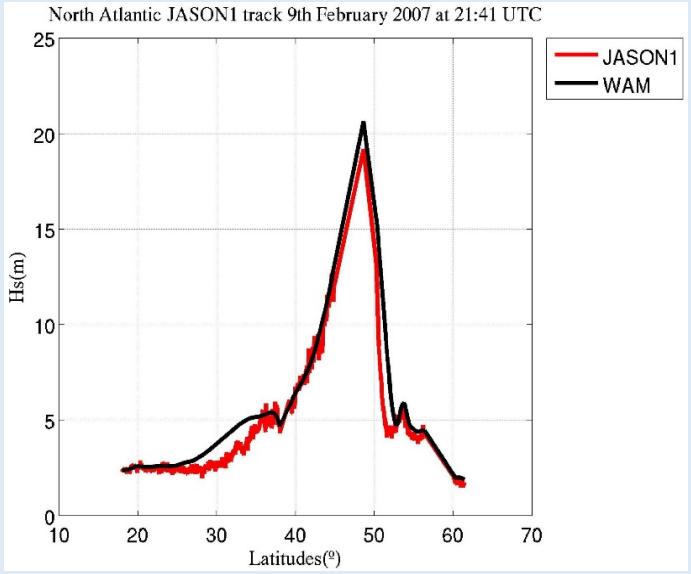
- ETCs play a large role in determining wave conditions in western Europe
- Cyclone activity **controls** the **synoptic variability**
- ETCs are related with natural **coastal hazards**: flooding & storm surges.
- Maritime **safety**, ship routing

- Kita, Waseda & Webb (2018) [*Ocean Dynamics*]
- Mori (2012) [*J. Geoph. Res.*]
- Young & Vinoth (2011) [*Ocean Engineering*]
- Hodges, Lee and Bengtsson (2011)[Journal of Climate]
- Rudeva & Gulev (2010) [*Monthly Weather Review*]
- Carrère, Mertz, Dorandeu, Quilfen, Patoux (2009) [*Sensors*]
- Semple (2006) [Meteorol. Appl.]

Among many other authors

Introduction



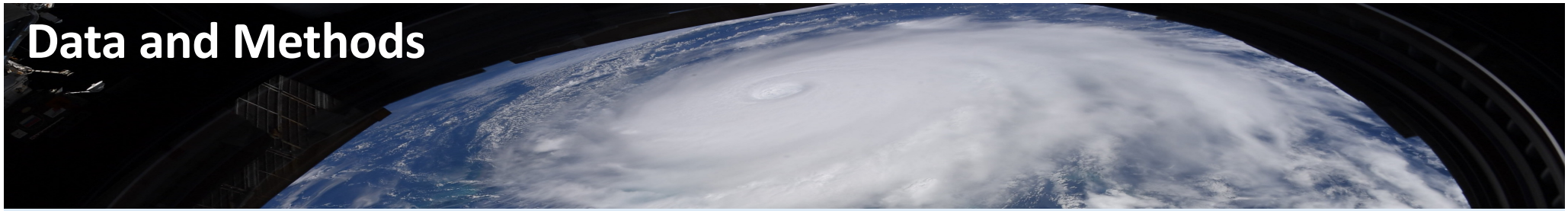


Taken from:

Ponce de León and Guedes Soares, 2014, "*Extreme wave parameters under North Atlantic extratropical cyclones*", **Ocean Modelling 81**, 78-88, http://dx.doi.org/10.1016/j.ocemod.2014.07.005

See also: *Hanafin* et al., 2012. "*Phenomenal Sea states and swell from a North Atlantic storm in February 2011: A Comprehensive analysis*", **Bull. Am. Meteorol. Soc**., 93(12), 1825–1832. https://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-11-00128.1

Data and Methods

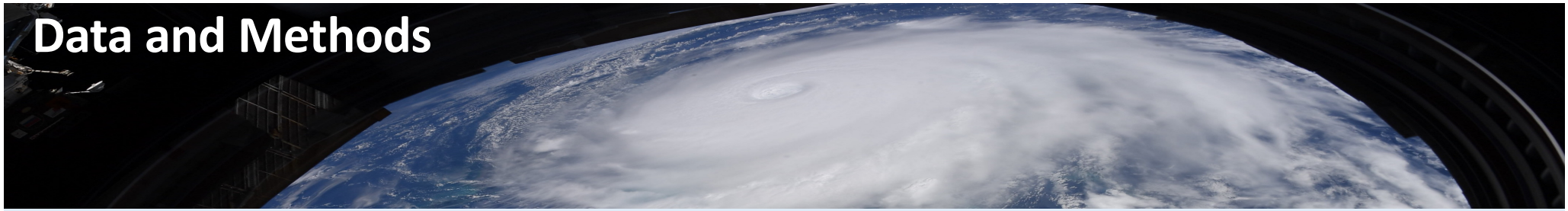


- The **Extratopical Cyclones** (**ETC**) **Database** consists of **58-year** (**1958 to 2016**) record of daily ETC characteristics for the Northern Hemisphere. The **ETC** data is obtained by the **Serreze et al. (1997)** algorithm from the daily **sea-level pressure** (SLP) fields of the **NCEP/NCAR reanalysis** dataset.

- The **GLOBWAVE Database** of **IFREMER,** is a uniform and quality controlled, multi-sensor set of satellite wave data with a consistent characterization of errors and biases.

The data used in this study is the altimeter multimission **Hs** (*Significant Wave Height*) which is a merged global altimeter Hs data set from the six altimeter missions **ERS1&2**, **TOPEX-Poseidon**, **G**EOSAT **F**ollow**O**N (**GFO**), **Jason1** and **ENVISAT** (produced by **CERSAT**/**IFREMER**).

Data and Methods



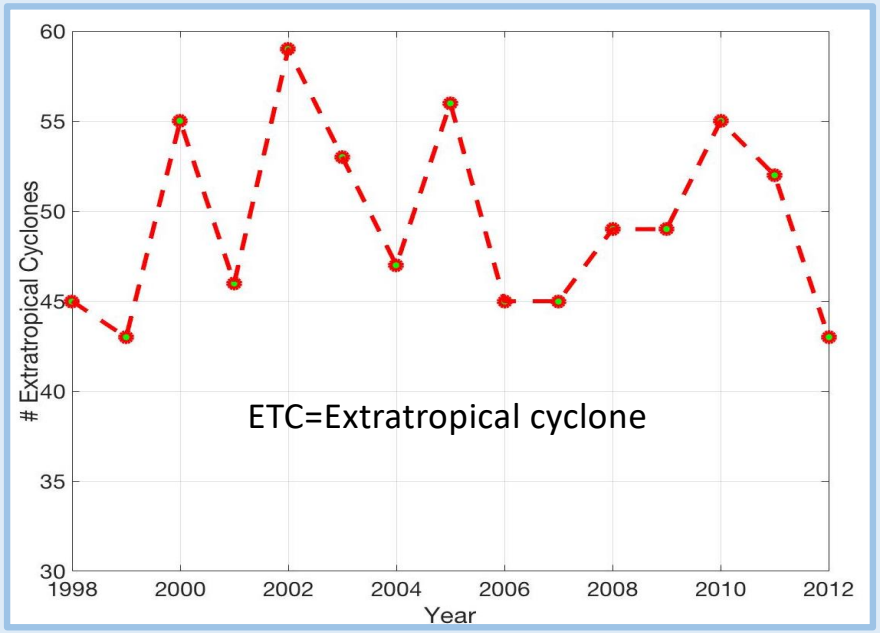
The procedure to map the Hs around the ETCs centers comprises the following steps:

1. **Selection of the ETCs** on a yearly basis
2. **Identification of the satellite tracks** that cross the ETC area
3. **Retrieving of the satellite data** identified in step 2
4. **Mapping of the satellite data** to the coordinate system of the ETC
5. **Smoothing the Hs distribution** around the ETCs centers

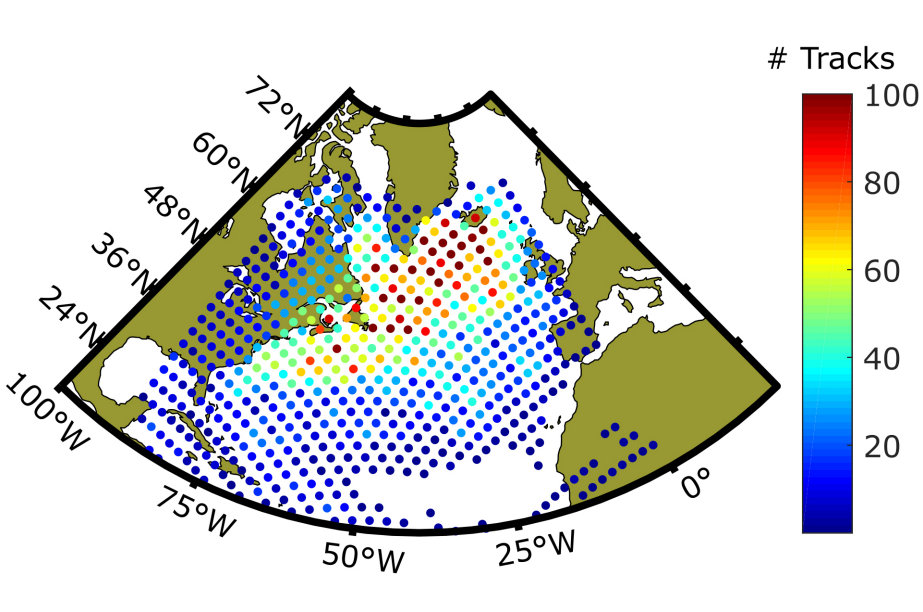
(**ETC**=Extratropical cyclone)

ETC selection

In the period **1998-2012** **742 ETCs** were selected (average **50** ETCs per **year**).



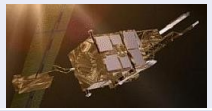
Track density of selected ETCs



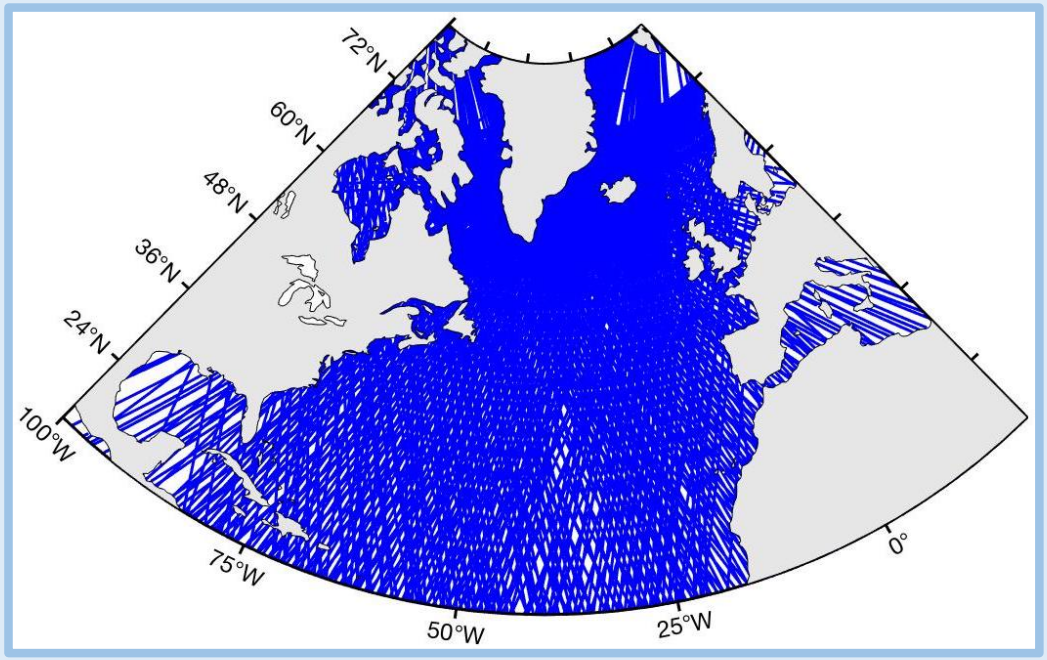
The track density of the selected ETC agrees with track density maps of several reanalysis ETC databases (review by Ulbrich et al., 2009).

Satellite data retrieval

For the period **1998-2012** ~***22k data files*** were retrieved and processed.

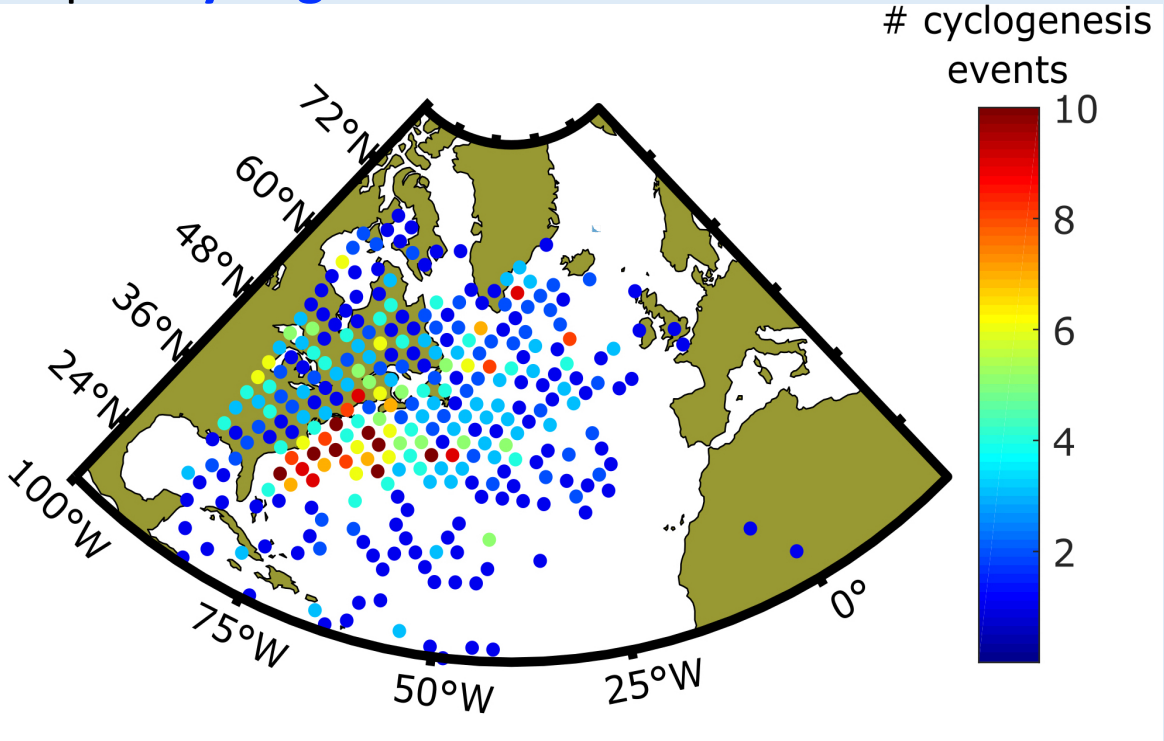
Mission	# Data files
ENVISAT 	4663
ERS-2 	4475
GFO 	3246
JASON-1 	6789
JASON-2 	2835

Altimeter tracks for **2002** (**59** cyclones)



Cyclone characteristics

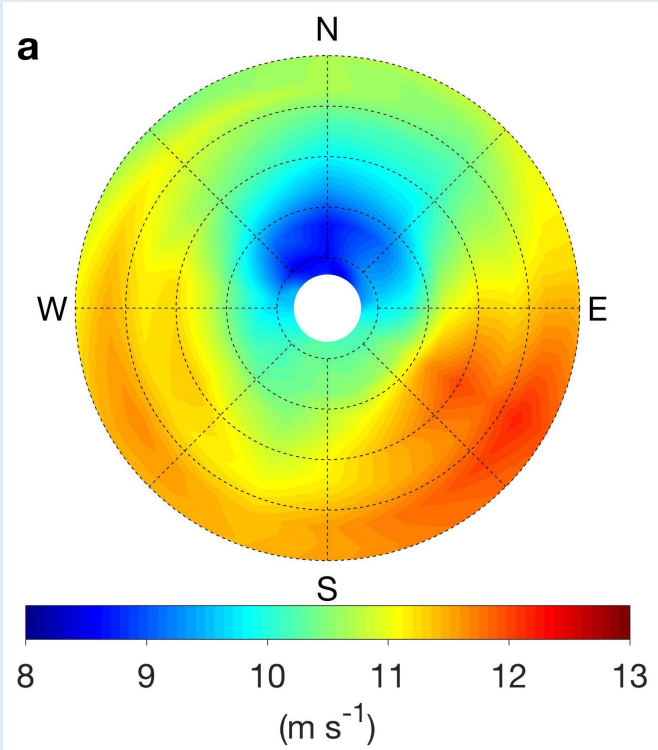
Map of **cyclogenesis** location



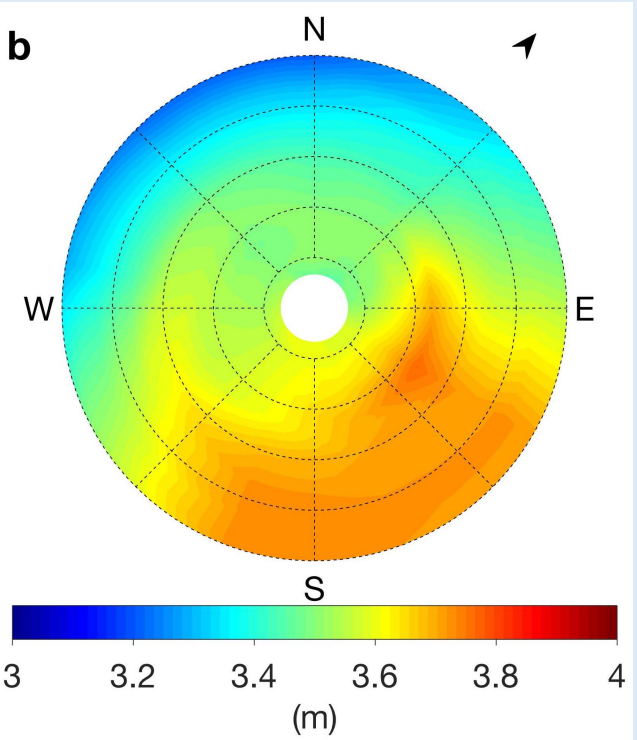
The altimeter *U10* and *Hs* 15-year composite maps

Average distribution

Wind speed (m/s)

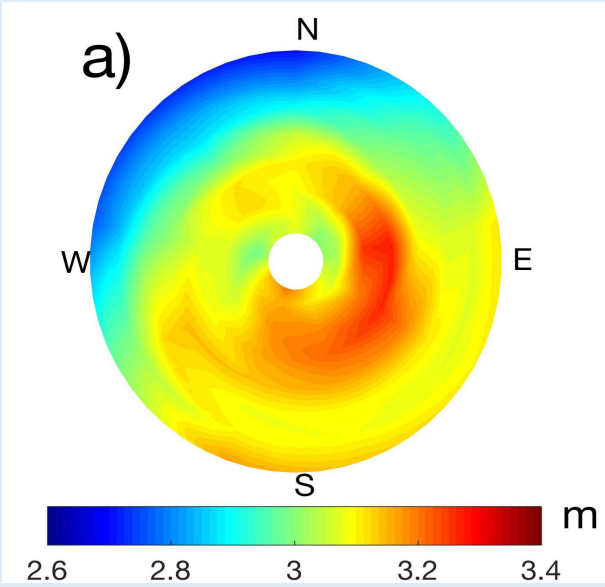


Hs (m)



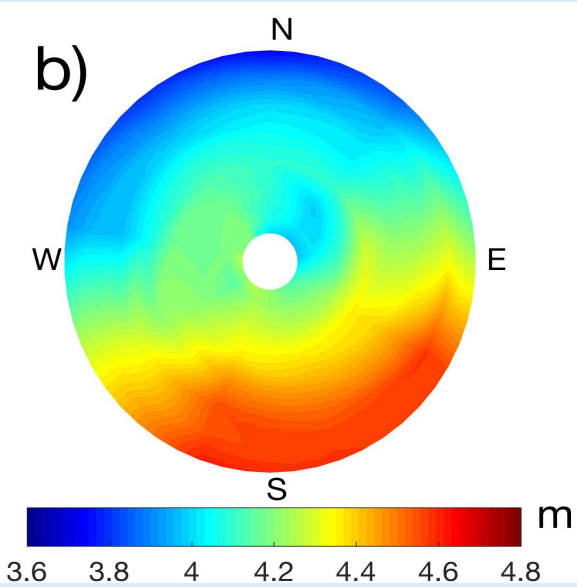
Hs composite vs cyclone life stages

Development



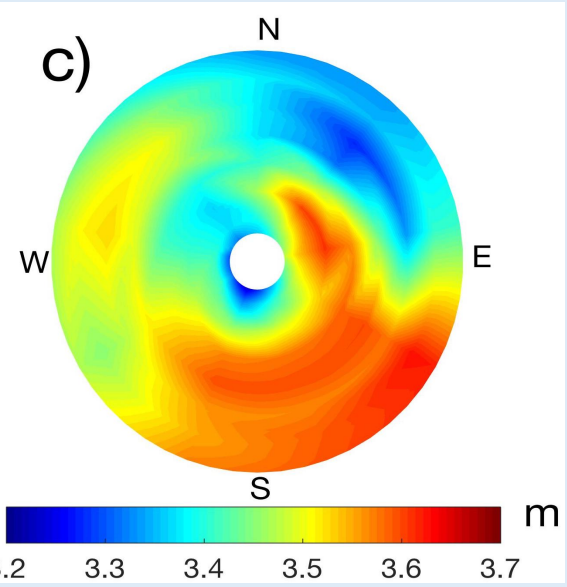
This comprises a period between the Cyclogenesis and up to a day before the Sea Level Pressure minimun (SLP)

Maximum strength



This stage encompasses 48 h interval around the SLP minimum

Decay stage

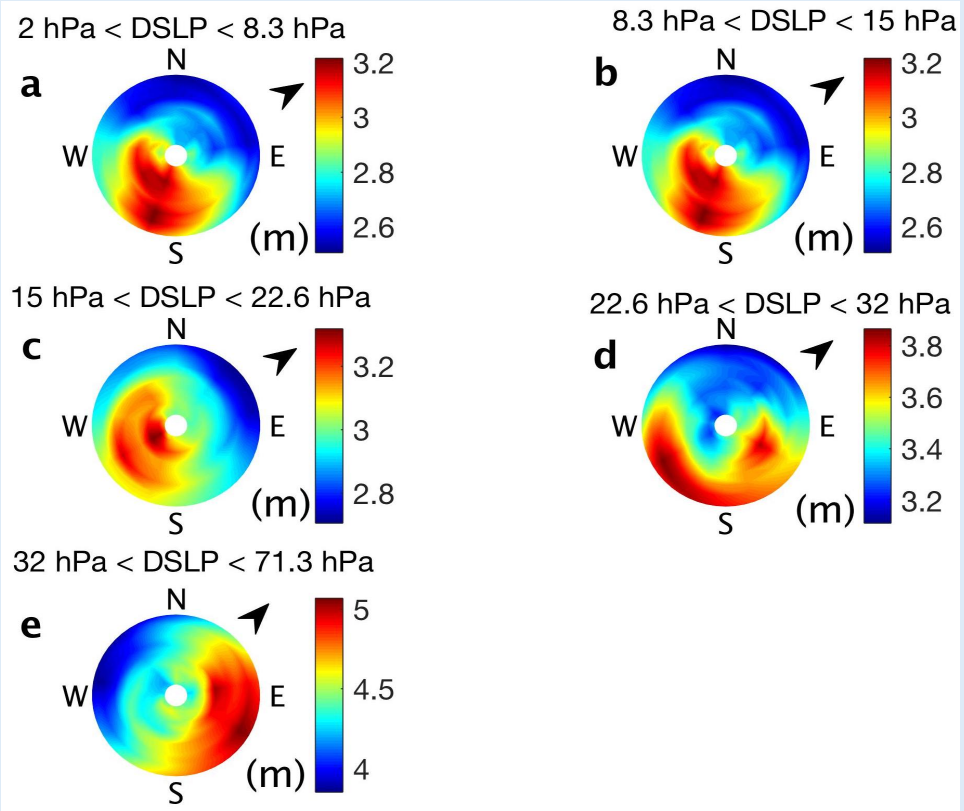


This stage goes from 24 h after the SLP min to Cyclone lysis

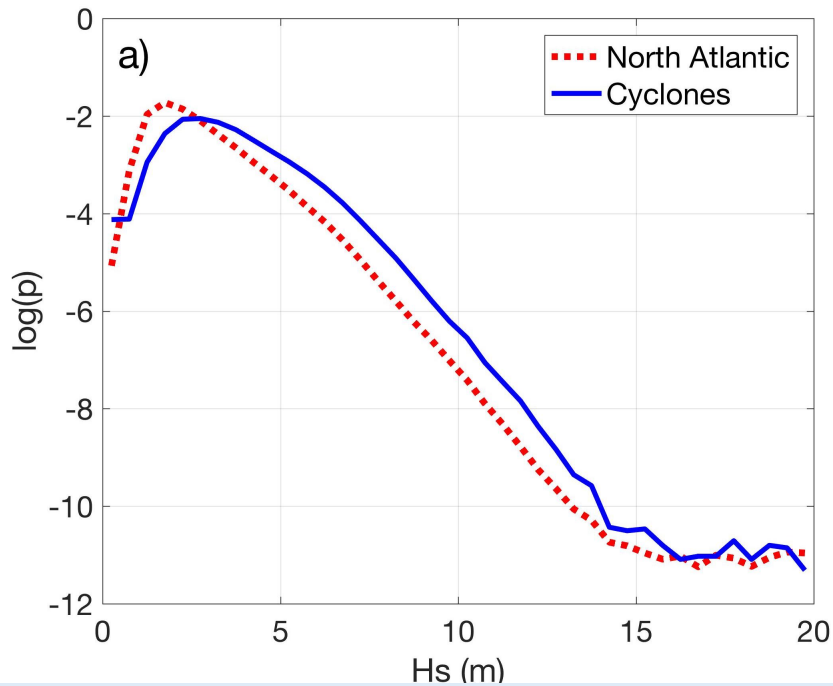
Hs composites vs intensity of the ETC

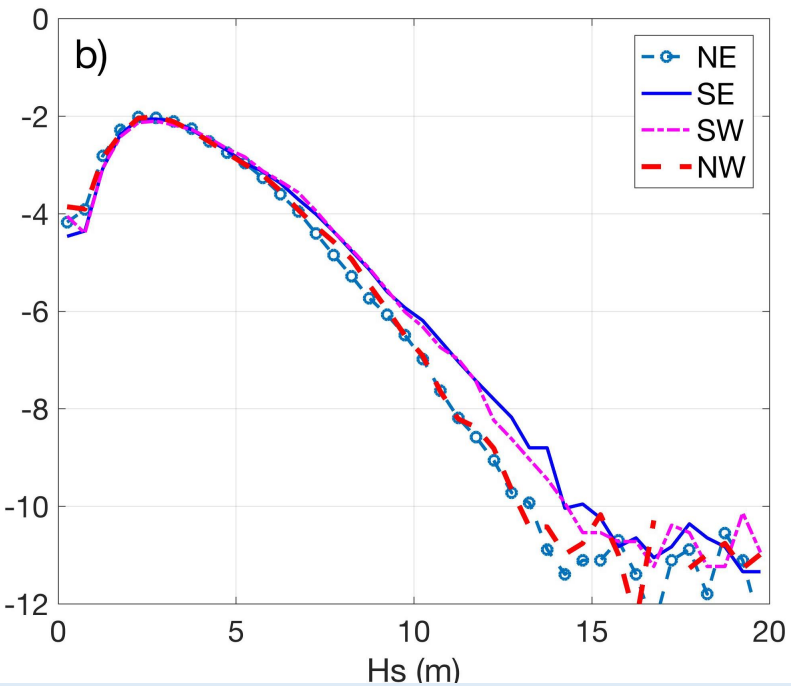
The DSLP is the difference between the SLP at the cyclogenesis and the SLP minimum during the cyclone life.

DSLP measures how much has the cyclone deepened during its lifetime.



Hs normalized *probability density functions* inside ETC's

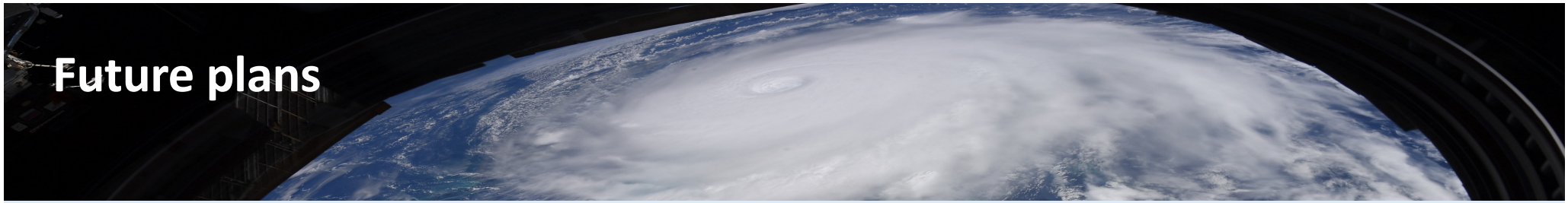




Conclusions

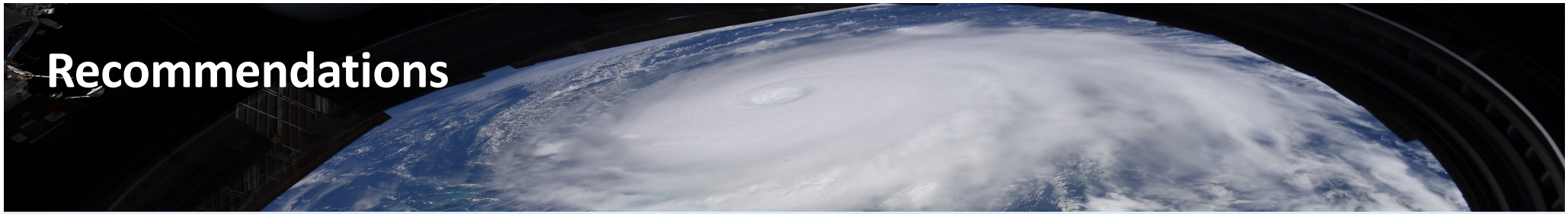
- The Hs of North Atlantic extratropical cyclones considering a **15 year period of satellite altimetry** data was studied.
- The composite of all ETCs shows **higher Hs** in the **SE quadrant**, but there is a **high Hs variability** due to individual cyclone diferences.
- **Stronger ETCs** (Q5) have **higher Hs** in the **NE and SE sectors**; weaker ETCs (Q1,Q2) show higher Hs in the SW sector.
- During the **maximum strength stage** of ETCs, **Hs** averages can reach **5.5 m** in the **SE** and **SW** sectors.
- ETC have higher probability of large wave occurrence and the **most dangerous sector is the South East** where the **largest waves can be found**.

This work was recently published in Advances of Space Research Journal:
https://www.sciencedirect.com/science/article/pii/S0273117719305277
Composite analysis of North Atlantic extra-tropical cyclone waves from satellite altimetry observations
https://doi.org/10.1016/j.asr.2019.07.021



Future plans

- Estimate n-year Hs return values based on spatial extreme value theory
- Use EOF to extract modes of variability of the composite Hs
- Extend the study to other regions: South Atlantic and Pacific oceans and Mediterranean Sea



Recommendations

The Integration of sea surface and lower atmospheric data in the sea state CCI is very positive!

Really nice when wave spectra are made available !!!