Natural extreme events observed by altimetry

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Abstract

Natural extreme events such as cyclones and tsunamis are high frequency phenomena. Each of them is characterized by specific spatiotemporal scales leading to a low probability of observation by satellite altimeters. Nevertheless, altimetry has the ability to observe such events using dedicated algorithms. Their impact on the ocean has been analysed. Tools have been developed at CLS to systematically observe such events. Deep analyses of these phenomena are possible thanks to the generation of adapted diagnoses of altimetric parameters. In this study, we describe these automatic tools and focus on the observation of recent typhoon/cyclone such as MUIFA and KATIA (Western Pacific in July-August 2011 and Altantic in September 2011). The dramatic Honshu tsunami of March 11th 2011 observed by several altimeters with amplitude up to 60 cm is discussed. Associated secondary waves and ocean state noise following the tsunami front are also clearly shown. These observations highlight the essential role of satellite altimeter measurements to help understanding natural extreme events, to better calibrate the instruments and to improve tsunami wave propagation models.

Automatic tool for the detection of cyclones

In order to facilitate the analysis of the altimeter data when a hurricane is detected, an automatic tool has been developed: it allows the detection of the data related to the cyclone and the computation of dedicated algorithms.

Research and export of observations in dedicated sites such as http://weather.unisys.com/hurricane → Geographical and temporal colocation (4h and 300 km) extracted from the altimeter database → Update of altimeter database with dedicated algorithms described in RELPA study → Automatic report

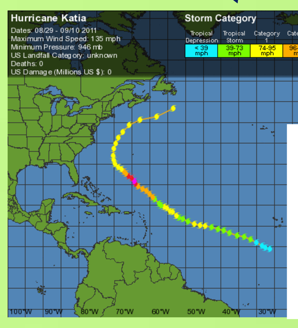


Fig 1: Example of Hurricane KATIA in September 2011

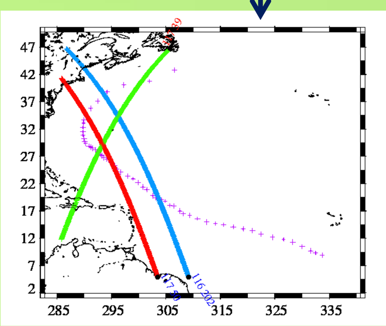


Fig 3: List of J2 passes crossing the Hurricane KATIA

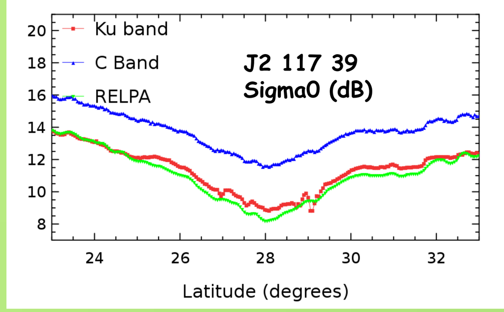


Fig 4: Jason2 cycle 117 pass 39: sigma0 in C and Ku Bands (recomputed with MLE3 algorithm) and the recomputed one (thanks to RELPA study) in green : less noise than Ku and more representative in the case of cyclones

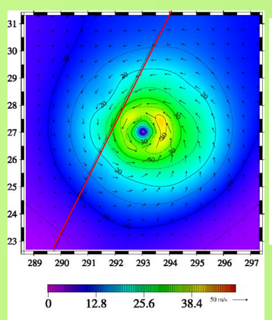


Fig 2: Map of AOML wind speed, with a J2 pass superimposed (the Delta T between J2 and the date of the map if 0.9 hour

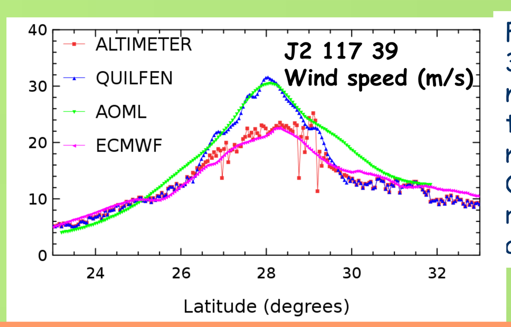
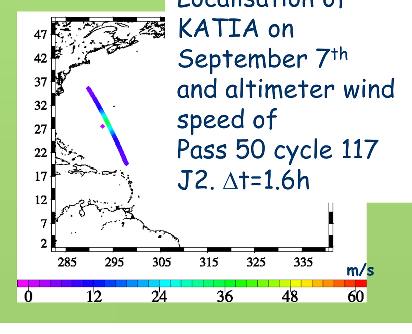


Fig 5: Jason2 cycle 117 pass 39: altimeter wind speed, new Quilfen et al, 2010 and the one from the AOML map:
Quilfen is more representative than altimeter one

Observation of Hurricane KATIA

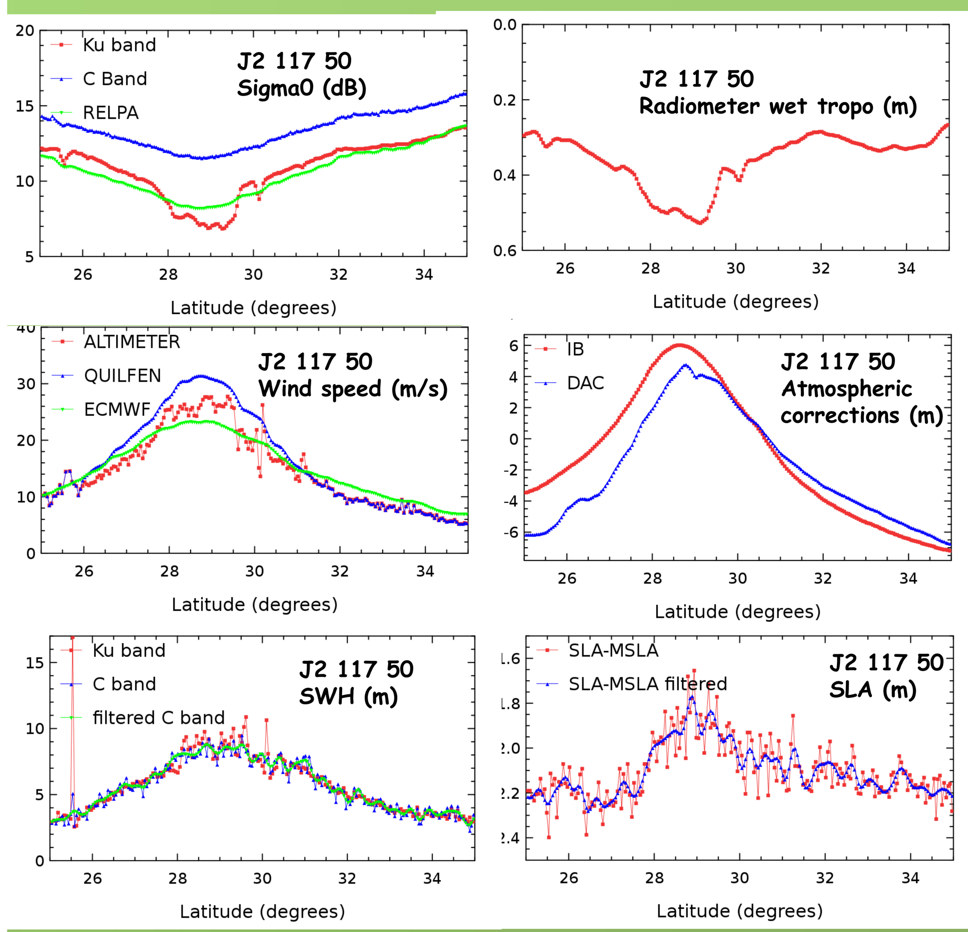
Hurricane KATIA began as a tropical depression on August 29th in the Atlantic Ocean. It was classified as a hurricane in September 1st and reached Hurricane 4 level the 6th. It has been observed by Jason-2 on September the 6th (cycle 117 pass 39) and 7th (cycle 117 pass 50).



Localisation of KATIA on September 7th and altimeter wind speed of Pass 50 cycle 117 J2. Δt=1.6h

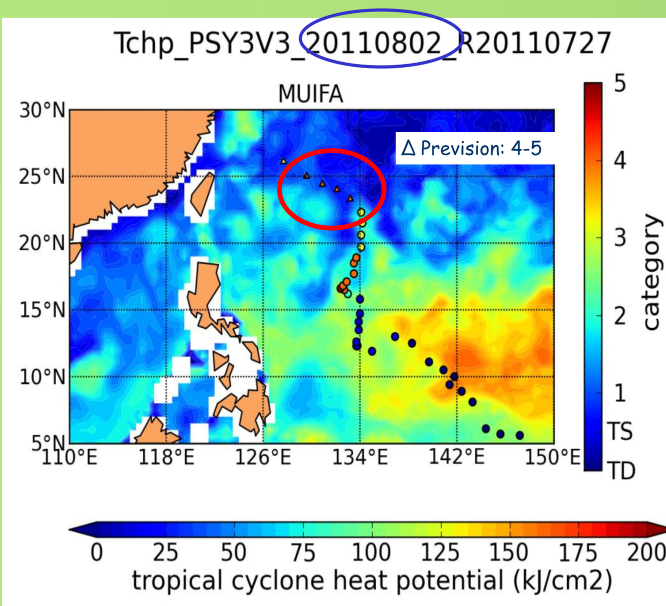
On the right, plots of parameters for J2 cycle 117 pass 50. We note that:

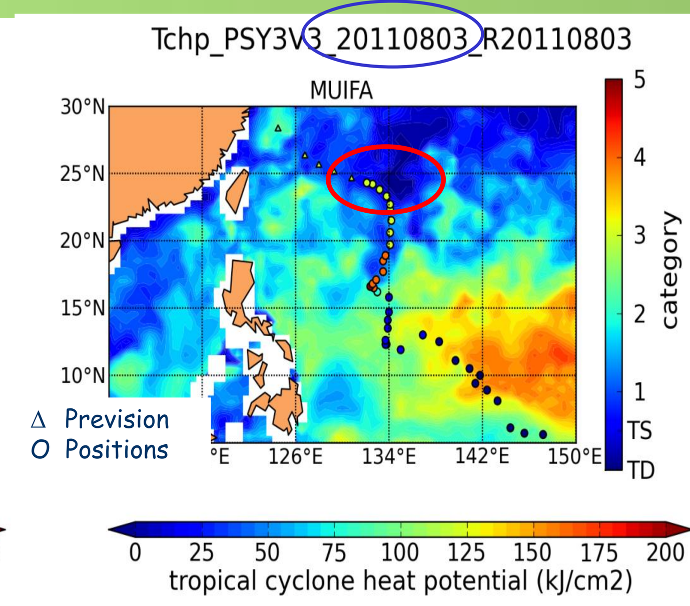
- Sigma0 (calculated with MLE3):
  - Ku band is affected during extreme conditions
  - RELPA Sigma0 (computed from table from Quilfen) is more representative of such event.
- Wind Speed:
  - The usual altimeter wind speed is underestimated and noisier compared to Quilfen et al., 2010.
  - ECMWF wind doesn't see the extreme winds
- SWH (calculated with MLE3):
  - Ku band is more noisier during the event compared to C band
- Wet tropo:
  - The wet tropo correction is very strong (up to 50 cm) with a dissymetry
  - It is strongly impacted by atmospheric attenuation as is the case for the Sigma0 Ku.
- Atmospheric correction:
  - The small effect of the wind is visible on the model forced by pressure and wind (DAC=MOG2D+IB)
  - No variability is seen on pressure (IB)
- SLA
  - We substract (RELPA study) MSLA to filter the oceanic variability not related to the event. The SLA used is in C band (MLE3). The atmospheric corrections are not used.
  - Elevation of **40** cm on the SLA
  - An effect of the wind is mainly visible around 26°.



Observation of Typhoon MUIFA

The tool can also display maps of Tropical Cyclon Heat Potential (TCHP) computed with temperature fields from MERCATOR (distributed by MyOcean). This is the example of MUIFA typhoon (July-August 2011). On August 2nd, previsions indicated an increase to level 4-5 in the classification of the typhoon (map on the left), but the low TCHP value (less than 50 kJ/cm2), contributed among other factors essentially meteorological to a faster than expected decrease in intensity (down to classification 3).





Perspectives

The tool can be used for NRT data as well as for DT. It has been processed for Delayed Time data for all the available missions. Much work has been done on the Sigma0 and wind speed but the comprehension of parameters can still be improved (comparison with models…).

References:
Carrere L., F. Mertz, J. Dorandeu, Y. Quilfen, J. Patoux, « Observing and studying extreme low pressure events with Altimetry », *Sensors*, 2009, 9, 1306-1329; doi:10.3390/s90301306
Quilfen Y., D. Vandemark, B. Chapron, H. Feng, J. Sienkiewicz, « Estimating Gale to Hurricane Force Winds using the Satellite Altimeter », *Jtech*, 2011, jtechD1005000
Access of Hurricane information: http://weather.unisys.com/hurricane
Access of Wind speed maps http://www.aoml.noaa.gov/hrd/
Site MyOcean for the distribution of MERCATOR products: http:// www.myocean.eu

Tsunamis observation

Overview

Altimeters have been designed to observe the sea level variability.
Question: In which extent is it possible to observe tsunami waves by altimetry?
Objective: Assess if tsunami waves have been observed by altimeters in order to contribute to the validation of model of tsunami wave propagation and dissipation

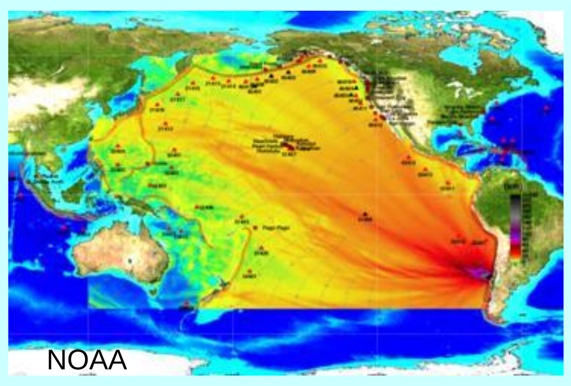
Two conditions are needed for tsunami observation:

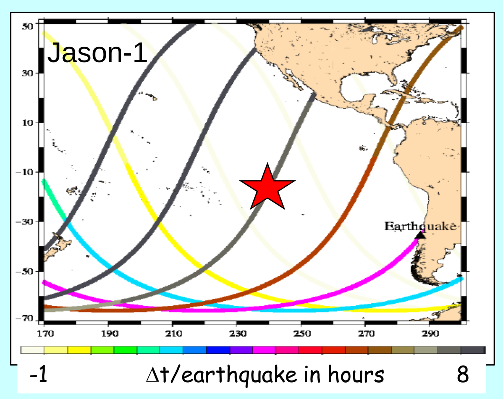
1. A **strong earthquake magnitude** that generates high enough tsunami wave to be distinguished among ocean mesoscale variability
2. Altimeters must **fly over the tsunami wave** within the very few hours following the earthquake so that the wave hasn't vanished or reached the coast.

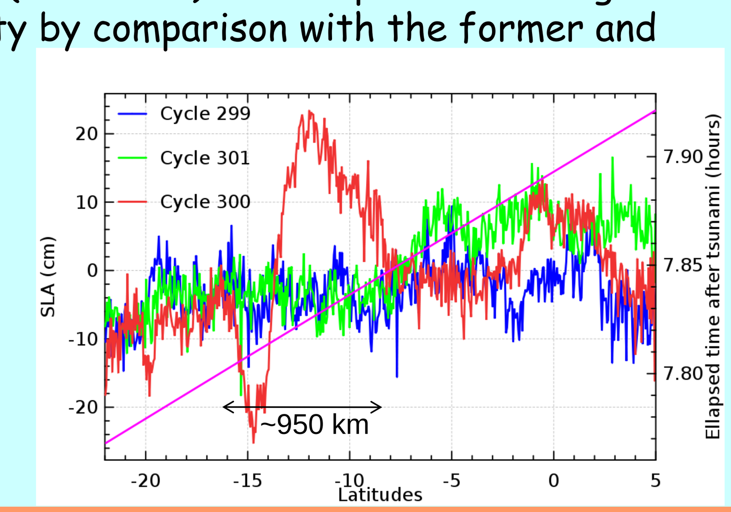
⇒The probability of observation by satellite altimeters is thus rather low

- A **specific tool** has been developed in order to automatically detect passes where the signal may have been observed
  - ⇒ Ambient ocean variability is a major difficulty to extract the tsunami signal in SLA: thus a specific filtering technique is used to extract at best short periods of the tsunami signal.
  - ⇒ Good observation needs strong earthquake magnitude and up to 4 altimeters which overfly the event

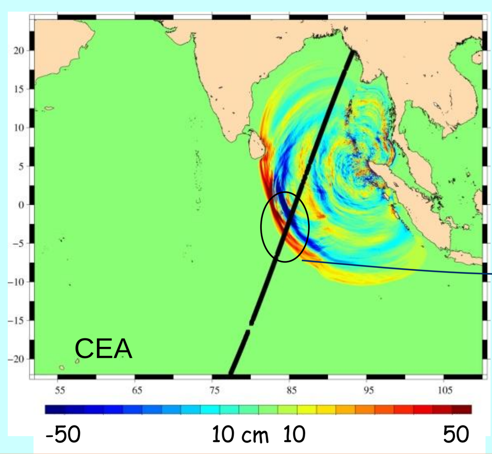
- On February 27th **2010**, an 8.8 Mn earthquake occurred off **Chili** and generated a **tsunami wave** that propagated across the Pacific ocean within 15 hours.
- Altimeters configuration wasn't optimal: among 3 available altimeters measurements, although the tsunami had large amplitude and coverage and ocean variability had been removed, the wavefront has only been detected with Jason-1, 8h after the earthquake with a 20 cm wave amplitude (see below). The amplitude was high enough to be detected with no need of removing the ocean variability by comparison with the former and following cycle.

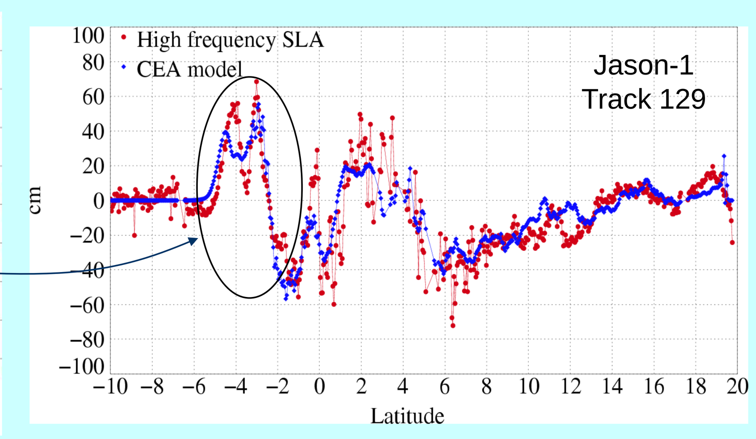




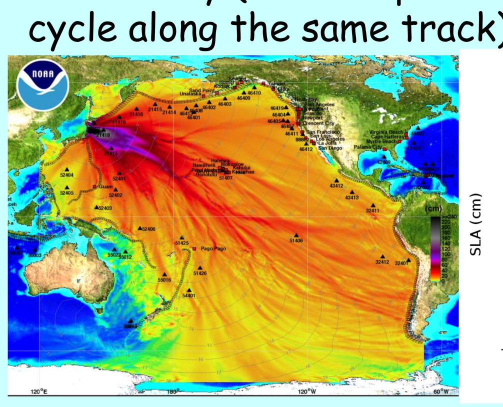


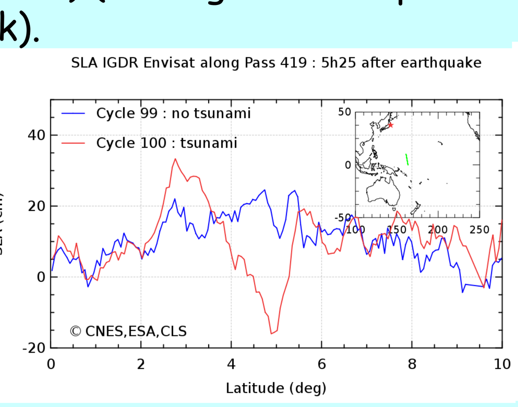
- **The Indian Ocean earthquake of December 26th 2004** (magnitude of 9) generated a tsunami which has been well observed by satellite altimeters in the open ocean (Ablain et al., 2006, Geophys. Res. Lett., 33).
- **Observation of tsunami waves in altimeter measurements:** Jason-1, TOPEX, Envisat and Geosat Follow-On overflew the wavefront from 2h00 until 9h00 after the earthquake.
- We show here the along-track Sea Level Anomaly of Jason-1 (Pass 129) which overflew the wavefront 2 hours after the earthquake. A 60 cm amplitude is observed and a good accuracy has been demonstrated by consistent comparisons with CEA model (A. Sladen and H. Hebert, 2006).

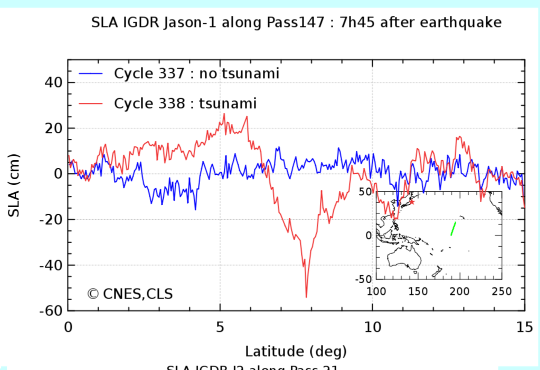




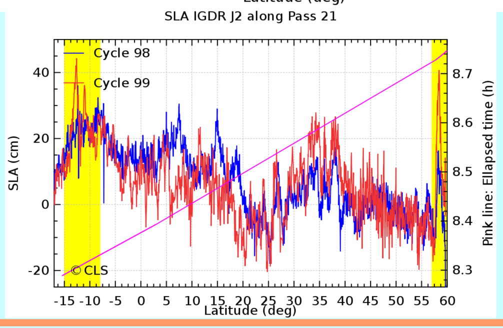
The **2011 Honshu tsunami** has been generated by a Mw 8.9 earthquake 130 km east of Japan (USGS). The wave front has not been observed soon after its generation but it has been overflown later by Jason-1 & 2 and Envisat altimeters which reveal 25 cm amplitude signal with a 5h25 delay (Envisat pass 419) and 35 cm amplitude with a 7h45 delay (Jason-1 pass 147) (see figures: comparison with the signal of previous cycle along the same track).







Tsunami related secondary waves have been also observed with Jason-2 pass 21 (through the Pacific ocean from Indonesia to Alaska) (see next figure, the comparison with the signal along the same track 10 days before). To our knowledge, this is the first time that such signal is observed.



Conclusions

- Tsunami waves are physical signals which can be observed with altimetric SLA. The only tsunamis waves clearly measured in the open ocean by altimetry are the **2004** event in the **Indian ocean**, the **2010 Chilean** tsunami and the 2011 **Honshu** tsunami in **Japan**
- This study shows that tsunami alert is NOT possible with altimetry, due to the delay of data acquisition and processing and the low probability of observation
- Altimetry could provide an **independent measurement** of the tsunami wave propagation with high accuracy which could help to **improve** the parameterization of propagation **models**. These are **the only one which provide quick enough warning to inhabitants**

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