Air-sea exchanges under tropical cyclones

Lisa Maillard (lisa.maillard@ifremer.fr) [1], Swen Jullien [1]

[1] Ifremer, Univ. Brest, CNES, CNRS, IRD, Laboratoire d'océanographie physique et spatiale

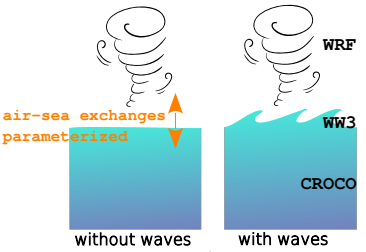
1 Motivation

If the forecast of **tropical cyclone's (TC)** tracks have greatly improved in the last decades, the prediction of their intensity still fails to capture rapid intensity changes (Emanuel 2018). Among the factors likely to help improve forecasts is the in-depth understanding of air-sea interactions.

Air-sea exchanges indeed regulate exchanges of mass, heat, momentum and gas between the ocean and the atmosphere, which drives the development of TCs. **Surface waves** (the ones that surfers love) have been shown to modulate such exchanges. However, observing and modeling waves and air-sea exchanges under intense rotating and translating cyclonic winds is a real challenge. Air-sea exchanges are therefore **parameterized** in state-of-the-art forecasts and climate models, but the existing parameterizations are imperfect. Thanks to newly available **satellite observations** and **high-resolution coupled models**, we aim at evaluating and improving wave-induced effects on air-sea interactions under TCs.

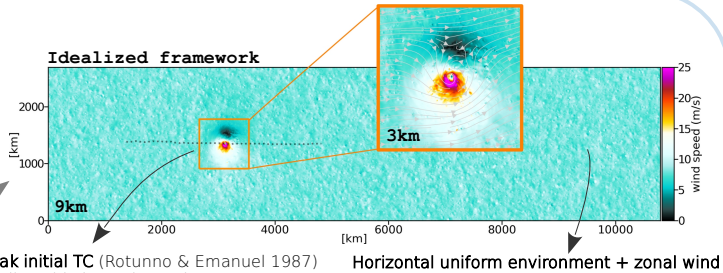
2 Modeling tropical cyclones

Tropical cyclones interact with the background environment (land, basin dynamics, synoptic flow, etc.) and each tropical basin has its own specificity. To overcome these specificities and **focus on the impact of air-sea exchanges only**, a **simplified modeling framework** is constructed in which a TC is translated by a uniform zonal flow.



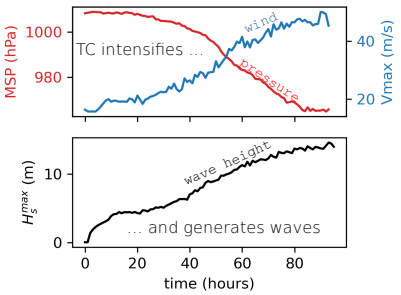
Three high resolution models:
- **atmosphere** 9km + 3km around TC (+ 1km soon)
- **waves** 9km
- **ocean** (soon) 9km

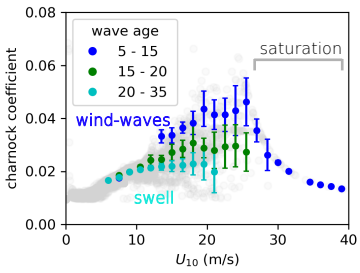
Only forced simulations for now
Coupling coming soon ...



Weak initial TC (Rotunno & Emanuel 1987)
→ adjustable intensity & size

Horizontal uniform environment + zonal wind
→ adjustable coriolis, sea surface temp., wind
⚠ Not trivial! Follows Nolan et al. 2011





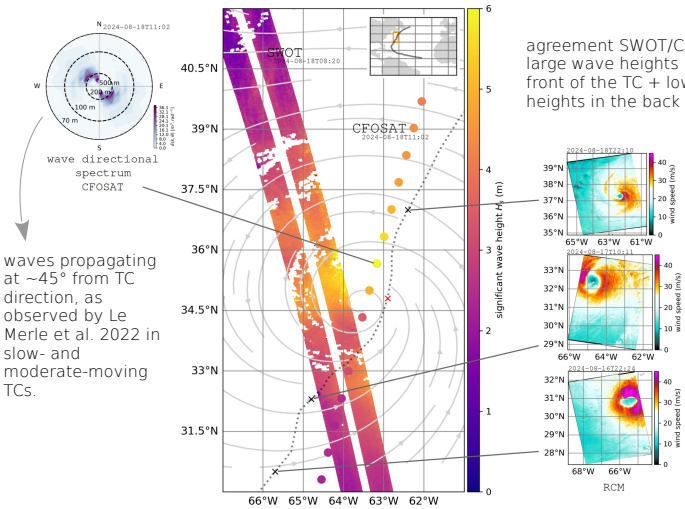
Evolution of proxy of air-sea exchanges (charnock) with wind speed

3 Observing sea state under cyclones

Our understanding of air-sea interactions in tropical cyclones is slowed down by the difficulty of observing the sea state and its spatial variability under such extremely violent conditions. Two CNES satellites have recently added new elements to the characterisation of this complex sea state:

- **CFOSAT**
  SWIM instrument
  full wave spectrum
  ✓ under TCs (Le Merle et al. 2022)
- **SWOT**
  KaRIn instrument
  wave height
  very wide swaths
- **Other data**
  altimeters
  wind (radars & radiometers)

Case study: **TC Ernesto** (Cat 2, August 2024)



agreement SWOT/CFOSAT: large wave heights (6 m) in front of the TC + lower heights in the back

waves propagating at ~45° from TC direction, as observed by Le Merle et al. 2022 in slow- and moderate-moving TCs.

4 Toward a synergy obs. & model

Future efforts oriented toward a comparison between collected observations & simulated TCs:

- characterize the sea state in simulated & observed TCs (categories of translation speed, intensity, and size)
- evaluate the sensitivity of simulated TCs on various air-sea exchange parameterizations (based on wave age, peak period of wind waves, wave directional spreading, new source terms and coupled exchanges in WW3 ...)
- use obs. to evaluate the most realistic parameterization(s)
- compare simulations with/without waves: what physics is missing when waves are not taken into account ?

→ Results will be tested on several real-case simulations of TCs impacting French overseas territories, on which CFOSAT and/or SWOT observations are available.

5 Summary

What are most climate models missing in TC dynamics by not simulating waves ? Which parameterization should they use to be the most accurate ? How does the spatial asymetry of waves under a TC impact its dynamics and structure ? Using our idealized framework in synergy with newly acquired satellite observations of the sea state, we will try to answer these questions.

ANR AWARE
CFOSAT-LAGOON