FINAL REPORT PROGRAM LEFE

Program LEFE/ action(s)	Project Title	Years
IMAGO	The interplay between Tropical Cyclones and ocean mesoscale eddies	2017-2018

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Participating Laboratories:
LATMOS/LMD-ENS/DMA-ENS

Contribution to
Nom des programmes internationaux

Other funding sources:
N/A

Context :

This project focused on the interactions between Tropical Cyclones (TCs) and mesoscale ocean eddies. It was innovative in that it was based on recent advances to characterize ocean eddies using *in situ* measurements from the profilers of the international Argo program (http://www.coriolis.eu.org).

Objectives / scientific questions :

Our project was mainly motivated by two questions:
Q1: What is the link between ocean mesoscale eddies and the rapid intensification of TCs?
Q2: How do TCs modify the characteristics of these ocean eddies (intensity, vertical profile, characteristic size)?

Main results *:*

Description
This project was directly linked to the LEFE action IMAGO. When it started, I was then AGPR at the ENS. It was built in collaboration with two researchers and a PhD student from the Laboratoire de Météorologie Dynamique (LMD: S. Speich, C. Muller and R. Laxenaire), and a researcher from the Département de Mathématiques et Applications (DMA: E. Dormy). It was part of a growing scientific landscape, asking the question of the interaction of Tropical Cyclones (TCs) with the anticyclonic ocean mesoscale eddies. This is a particularly important issue, because related to the rapid intensification of TCs.

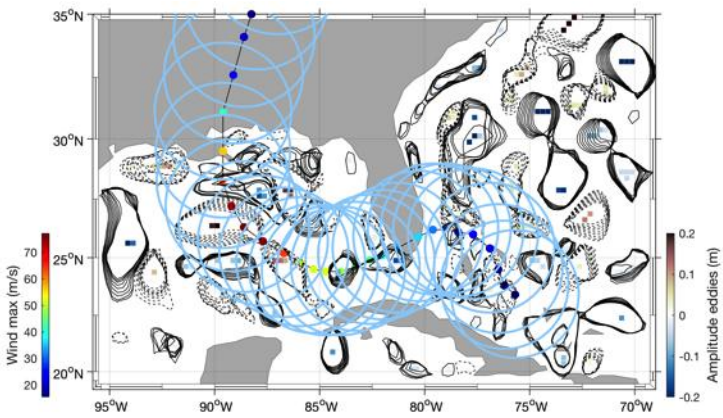
Methods
The ocean mesoscale eddies component of my project was based on the grilled altimeter product AVISO (http://www.aviso.oceanobs.com), which corresponds to the best spatio-temporal resolution available for the observation of mesoscale structures (daily maps with a spatial resolution of 0.25°x0.25°), and the vortex tracking algorithm developed by A. Chaigneau and optimized by Rémi Laxenaire (Laxenaire *et al*, 2018). Regarding observational data for the TC component, the WMO International Best Track Archive for Climate Stewardship (IBTrACS) (Knapp *et al*, 2010) has provided us with a database of TC characteristics since 1979 (trajectories and intensities every 6h).

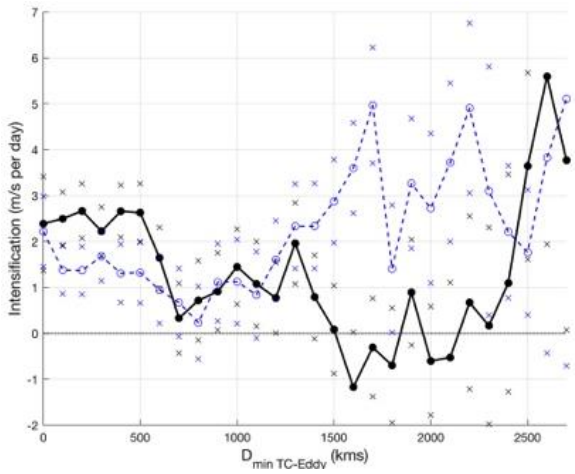
Main results
As a first step, we carried out a special case study in which a warm-core ocean eddy (anticyclonic) induced a rapid intensification of a TC encountering it, by significantly altering the vertical structure of the ocean (e.g. Shay et al, 2000; Jaimes & Shay, 2009; Wu et al, 2007; Lin et al, 2008). The associated thermal content, and therefore the energy reservoir available for the cyclone, were amplified. Figure 1 illustrates this mechanism in the case of Hurricane Katrina, which devastated New Orleans in 2005 after its passage on an anticyclonic ocean eddy.

These preliminary studies allowed us to identify relevant diagnostics in the study of the effect of mesoscale

ocean eddies on TC intensification. Quantification of TCs intensification, ocean eddy intensity, the question of minimum eddy size that may affect the cyclone, their position relative to the TC (in connection with the particular structure of the TC, in terms of eyewall and eye) or the distances involved in the TC-ocean eddy interaction are all subtle and important questions that needed to be investigated. This is in order to prepare more systematic approaches, that is to say, for a large number of TCs, ensuring as much as possible their relevance. There are indeed many biases in existing "statistical" studies. For example, Figure 7b in Lloyd & Vecchi (2011) shows an inverse correlation between surface temperature cooling and cyclone intensification, interpreted as the negative feedback of SST cooling caused by TC passage, on their own intensity. We were able to show that this result is actually biased by the choice of definition for the intensification of TCs, chosen as the change in maximum wind speed over a time period of 36 hours and which is actually inversely proportional to the intensity of TCs.

Until now, no statistical studies have been conducted directly linking TC intensity to ocean eddies. We conducted this type of statistical study using the IBTrACS database and the Laxenaire et al (2018) database. We first focused on the North Atlantic and Northeast Pacific regions over the time period 1993-2016. Figure 2 shows an average intensification that is greater when the minimum distance to the nearest anticyclonic ocean eddy is small (black curve), which is consistent with a positive effect of warm ocean eddies on TC intensification. The same trend was identified for cold eddies (blue curve), suggesting a geographic bias. The life cycle of TCs combined with the SST distribution indeed explains the general tendency for TCs to intensify to the west of the basin, a region also rich in ocean eddies. The other basins thus remain to be investigated.





<u>Figure 1</u>: Track of Hurricane Katrina (2005) and cyclonic (full black) and anticyclonic (dashed black) ocean eddies between 24 and 30 August 2005. Light blue circles: diameter of Katrina (600 km). Made with the IBTrACS and Laxenaire et al databases.

<u>Figure 2</u>: Average intensification of the TC as a function of its distance from the nearest anticyclonic (black) and cyclonic (blue) eddy, defined as the distance between the TC center (location of the minimum surface pressure) and the eddy center (local extremum of the absolute dynamic topography). Cross: 95% confidence interval.

Future of the project:

Among the scientific results obtained, we have highlighted the importance of spatial and temporal wind variations within the TC in their interaction with ocean structures. At this stage, it is therefore important to explore the question of the spatial-temporal structure of winds within TCs.

Nombre de publications, de communications et de thèses

Colloque de Bilan et de Prospective du programme LEFE

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