Modeling the Wake of the Marquesas Archipelago:

A first step to assess this island mass effect

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I. The Archipelago & ROMS-Agrif

The Marquesas archipelago (142°W-138°W/8°S-11°S) is the northern most archipelago of French Polynesia. It is composed by a dozen of small islands (Largest island: 387km^2) and is located on the Northern branch of the Subtropical gyre where the southwestward South Equatorial Current (SEC) encounters these steep oceanic islands.

Waters surrounding these islands present a remarkable biological activity. The aim of this work is to investigate one of the physical processes that might be responsible for the enrichment of the upper layers in the vicinity of the Marquesas islands: Eddy Generation.

We ran a 10 years simulation using the IRD version of the ocean circulation model: ROMS-AGRIF. We employed a configuration with a nested grid and a two way embedding procedure. External forcings are derived from climatologies:

- Heat and fresh water fluxes: COADS
- Boundary condition: WOA 2013
- Wind forcing: QuikSCAT

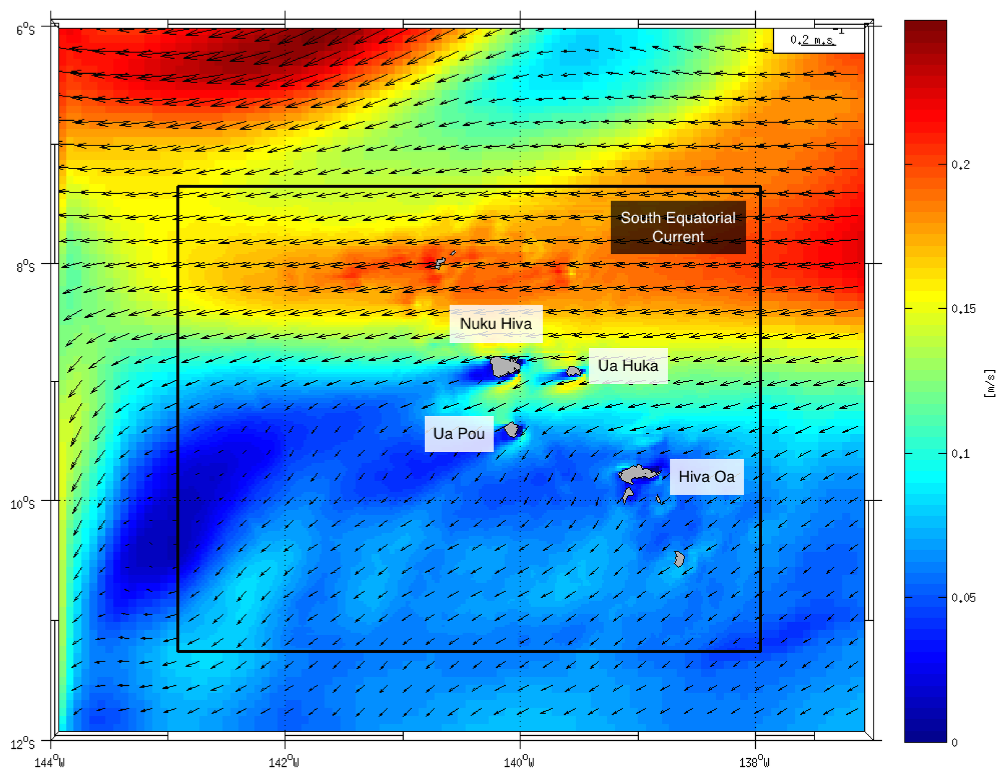

Figure 1: Mean currents [m/s] calculated over Y4 to Y10 at depth -10 m from ROMS-AGRIF simulation. The black frame delimits the child grid (spatial resolution: 1/45°). Parent grid resolution is 1/15°. Island names are given in the white boxes.

II. Eddy Kinetic Energy

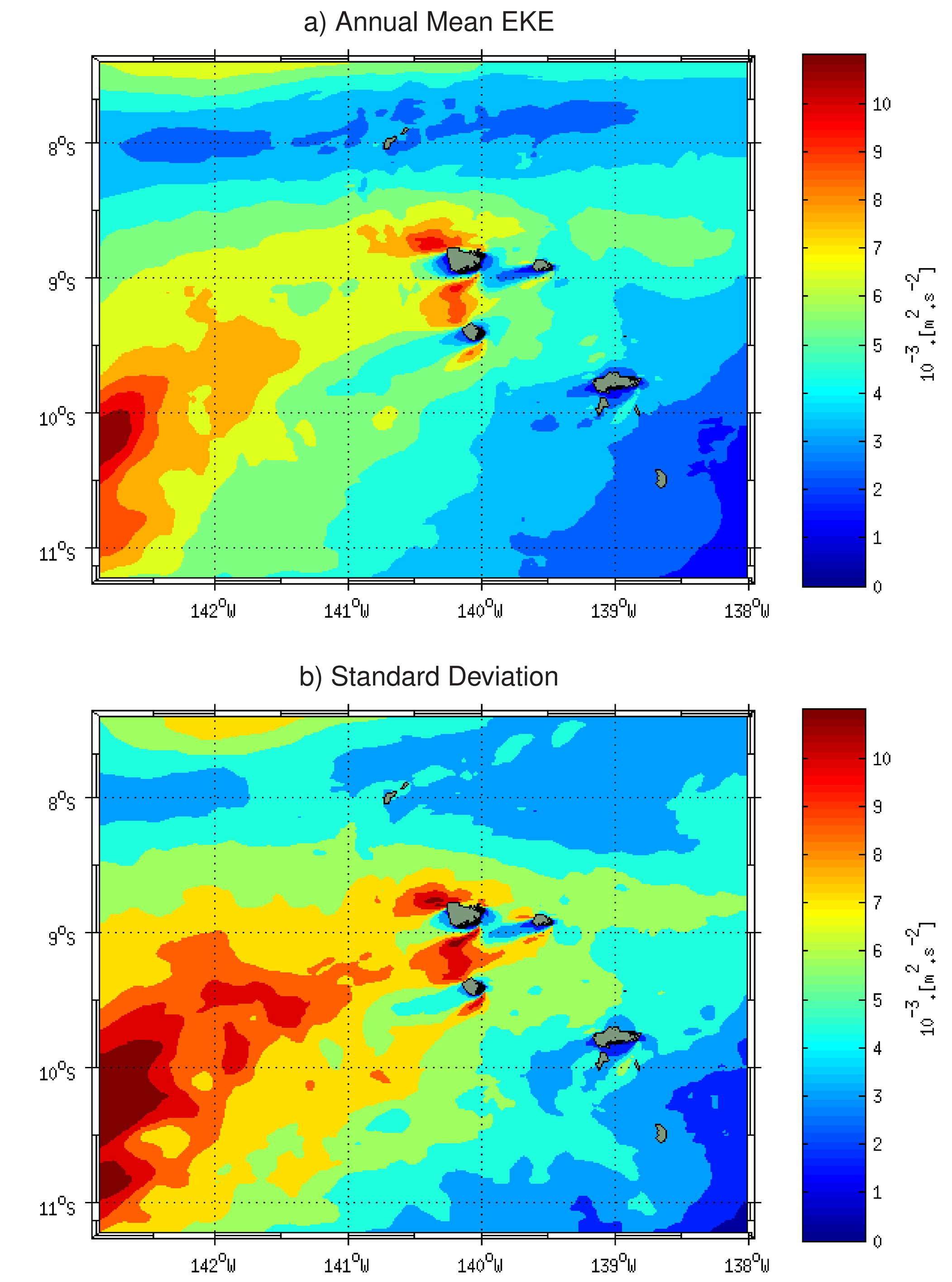

Figure 2: (a) Annual mean Eddy Kinetic Energy calculated over Y4 to Y10 and (b) its standard deviation at depth -10 m

A preliminary survey of the eddy activity can be presented by the Eddy Kinetic Energy maps. High values of EKE are observed on the North and South shores of the main island (Nuku Hiva) but also extend on its lee side.

The energy is relatively weak south the archipelago. This can be explained by the weak values of the currents around the secondary island (Hiva Oa).

III. Eddy Detection

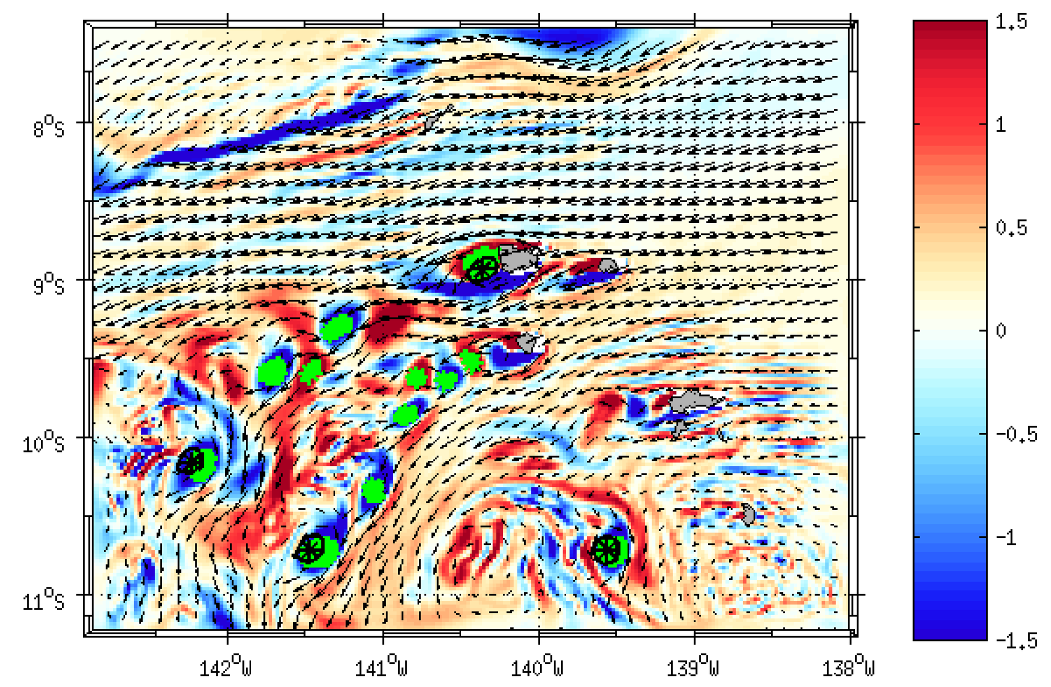

Figure 3: Relative vorticity map for Day10 Month6 Year4 at depth -10m. Detected eddies by Nencioli *et al.* 2010 algorithm are in black and those detected by the Okubo-Weiss method in green.

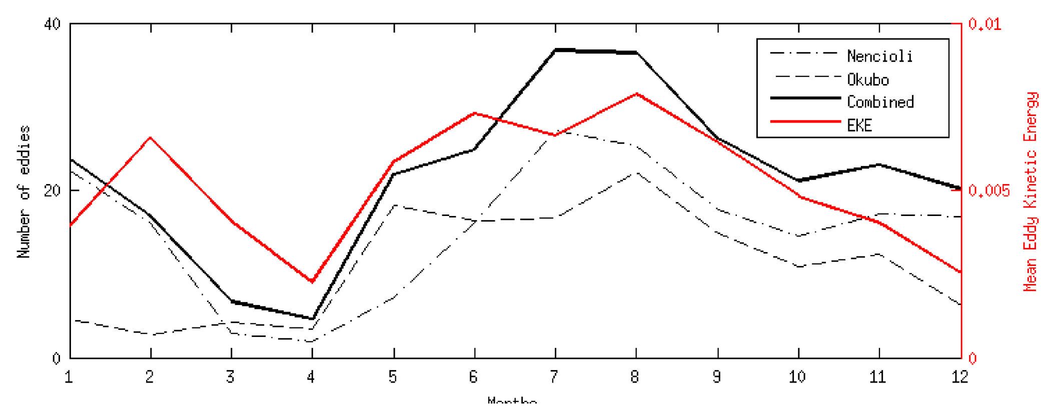

Figure 4: Total number of detected eddies by month from year 4 to 10 using Nencioli algorithm (dash-dotted line), Okubo-Weiss algorithm (dashed line) and the combined method (black bold line). The red bold line is the mean EKE.

We used a combination of 2 detection algorithms. One is based on the geometry of the flow field (Nencioli *et al.* 2010), the other is based on the Okubo-Weiss parameter (Isern-Fontanet *et al.* 2004). The biggest (smallest) eddies are better detected by Nencioli *et al.* (Okubo-Weiss) method. Hence the two methods are complementary.

The number of detected eddies coincides more or less with the EKE curve except at the beginning of the year. The Eddy activity is intense from May to January with a peak in July/August.

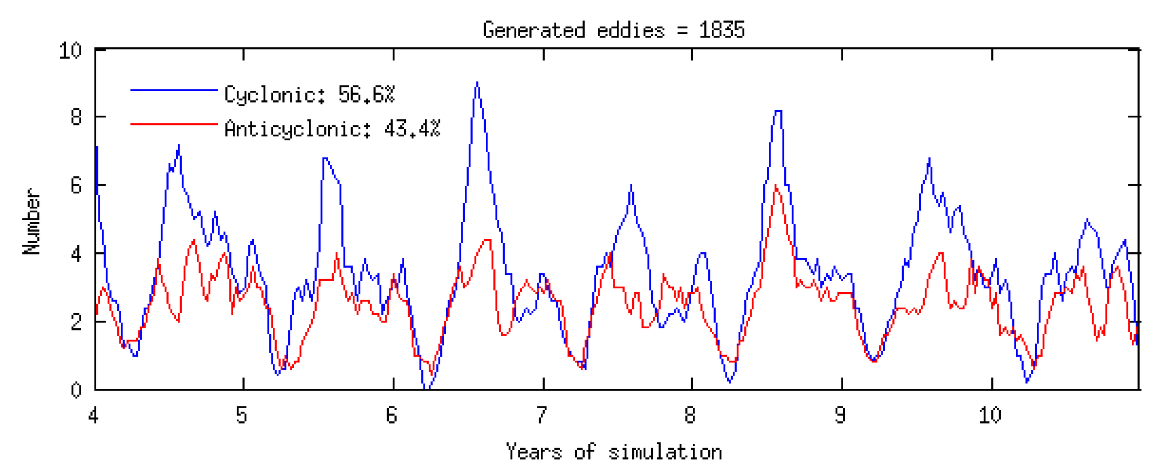

Figure 5: Number of cyclonic and anticyclonic eddies generated in the archipelago (red for anticyclonic and blue for cyclonic eddies).

The time series of eddy generation shows a cyclonic eddy dominance (56.6% vs. 43.4%). In opposition with the total number of detected eddies, we can distinct 2 peaks of activity. The first is intense and extends from May to September. The second occurs from October to January. The rest of the year the activity is weak.

IV. Eddy Properties

Cyclonic eddies are dominant in term of number, size but also lifespan. Anticyclonic eddies are unstable.

Most of the eddies generated from Y4 to Y10 are cyclonic (1039 vs. 796). Moreover, they are slightly bigger than the anticyclonic ones. Eddies smaller than 20km are predominantly anticyclonic; while the ones bigger than 20km, leeward of the islands, are cyclonic.

The average lifetime of cyclonic eddy is twice longer than the anticyclonic eddies. The small value of the anticyclonic eddy lifespan reveals that most of them disappear less than a month after their generation.

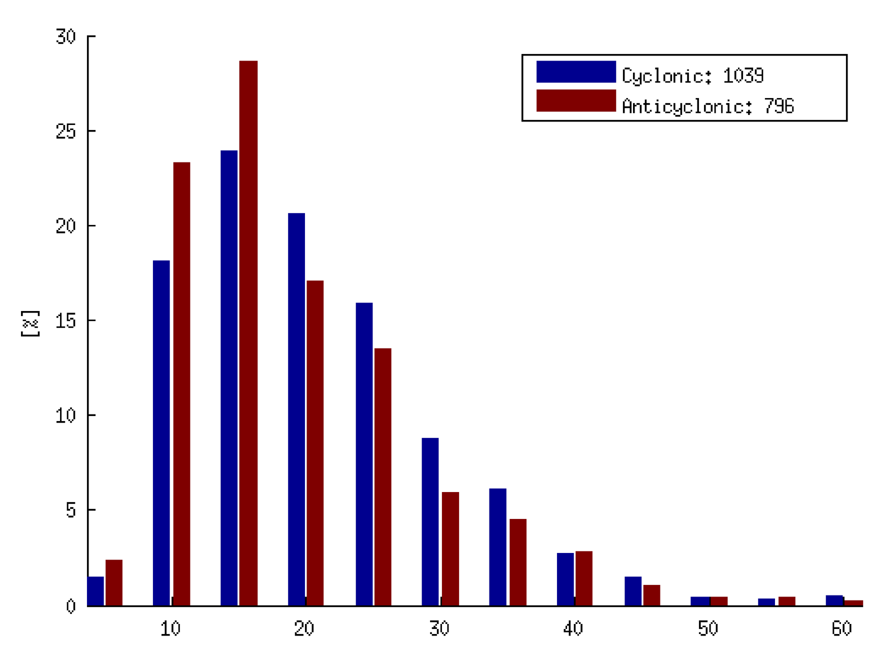

Figure 6: Cyclonic and anticyclonic eddy radii distribution

Eddies	Average	Standard Deviation
Cyclonic	44.9	50.4
Anticyclonic	24.1	15

Table 1: Cyclonic and anticyclonic eddy lifespan [days]

V. Next Step

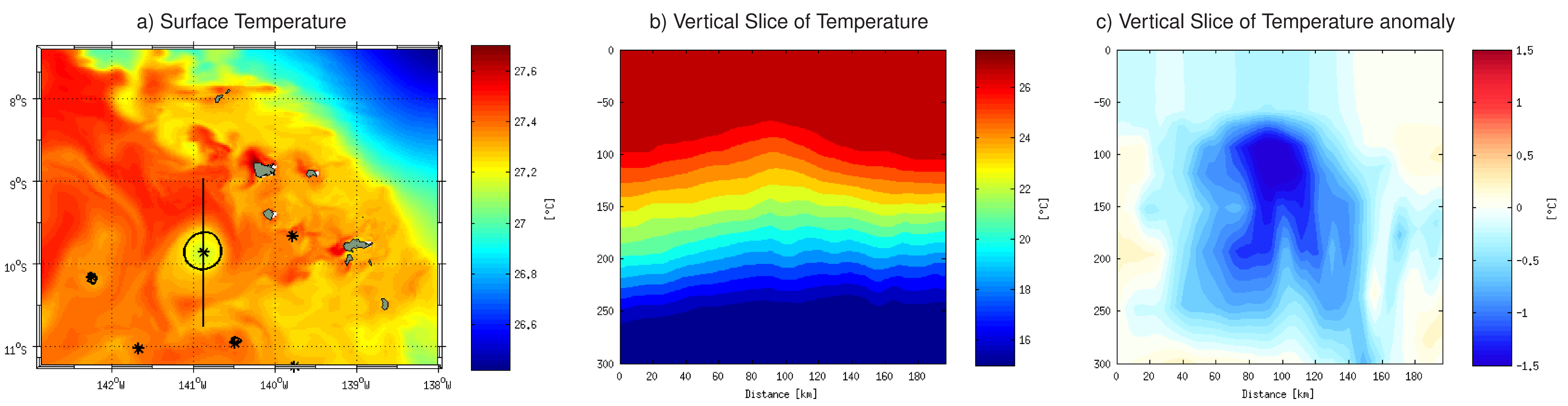

Figure 7: (a) Surface temperature and the detected eddies at Day2 Month10 Year5 with the transect (black straight line) crossing the center of a cyclonic eddy. (b) is the corresponding vertical section of temperature and (c) the temperature anomaly.

A large cyclonic eddy is present in the lee of the archipelago at Day2 Month10 Year5. Its core is colder than the surrounding waters. The vertical slice shows an uplift of the thermocline (about 30m). The temperature anomaly reveals that the eddy has an impact at more than -250m. Being the cyclones dominant in the lee of the archipelago, they can play a key role in the enrichment of the surface layer.

This study permitted us to assess the eddy activity and some of their characteristics. In particular, cyclonic eddies generated leeward the islands are suspected to play a key role in the uplift of nutrients. The next step of this study is to assess the influence of the dynamic on the biogeochemical processes by coupling ROMS-AGRIF with the environmental model PISCES.

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References

[1] L. Debreu, P. Marchesiello, P. Penven, and G. Cambon. Two-way nesting in split-explicit ocean models: algorithms, implementation and validation. *Ocean Modelling*, 49:1–21, 2012.

[2] J. Isern-Fontanet, J. Font, E. García-Ladona, M. Emelianov, C. Millot, and I. Taupier-Letage. Spatial structure of anticyclonic eddies in the algerian basin (mediterranean sea) analyzed using the okubo–weiss parameter. *Deep Sea Research Part II: Topical Studies in Oceanography*, 51(25):3009–3028, 2004.

[3] F. Nencioli, C. Dong, T. Dickey, L. Washburn, and J. C. McWilliams. A vector geometry-based eddy detection algorithm and its application to a high-resolution numerical model product and high-frequency radar surface velocities in the southern california bight. *Journal of Atmospheric and Oceanic Technology*, 27(3):564–579, 2010.