A NEW METHOD TO DETECT MESOSCALE EDDIES IN SATELLITE RECORDS

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MOTIVATION

A large portion of the mesoscale ocean variability is associated with vortices, rings, Rossby waves, fronts, and meanders. These different features are generically called eddies, however their dynamics are different and these differences determine their surface geometry."

INTRODUCTION

Ocean eddies are particularly important due to their ability to transport momentum, heat, salt and nutrients away from their area of origin. Satellite images usually show eddies as nearly circular features that propagate similarly to Rossby waves (Oliveira and Polito, 2013) often embedded in their crests or troughs (Polito and Sato, 2015). Usually, eddy detection methods are based on physical or geometric criteria. The first one requires a dynamic knowledge of the ocean flow (e.g. Okubo–Weiss parameter), while the second characterizes the eddies through their nearly circular format of closed streamlines contours(e.g. winding–angle method).

OBJECTIVES

To develop a new geometric method to detect eddies based on Radon transform that can be applied to **any** satellite image or scalar field. For that, two definitions of eddies are useful:

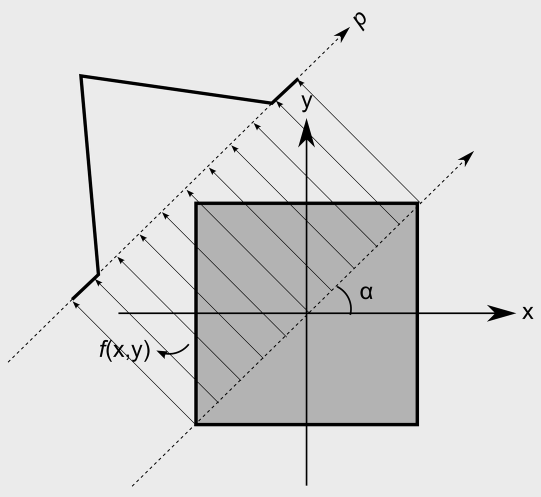
1. Closed stream functions nearly circular and relatively persistent (Cushman-Roisin, 1994).
2. Streamlines nearly circular or in a spiral pattern moving together its core (Robinson, 1991).

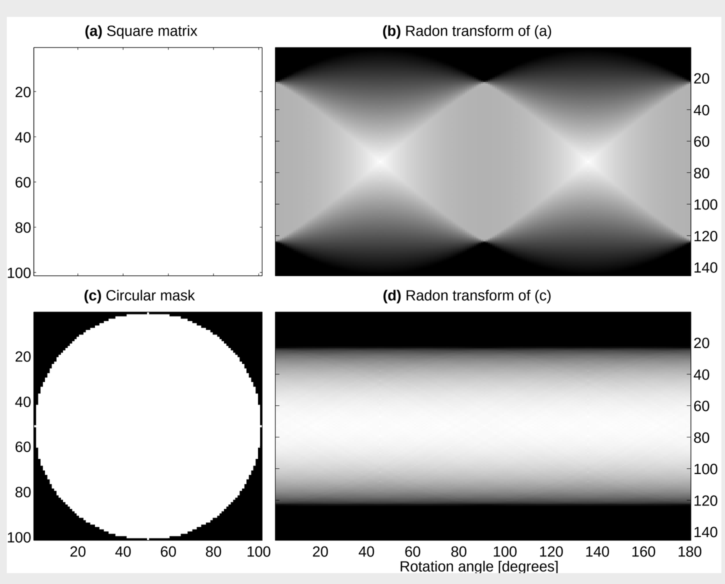
THE RADON TRANSFORM

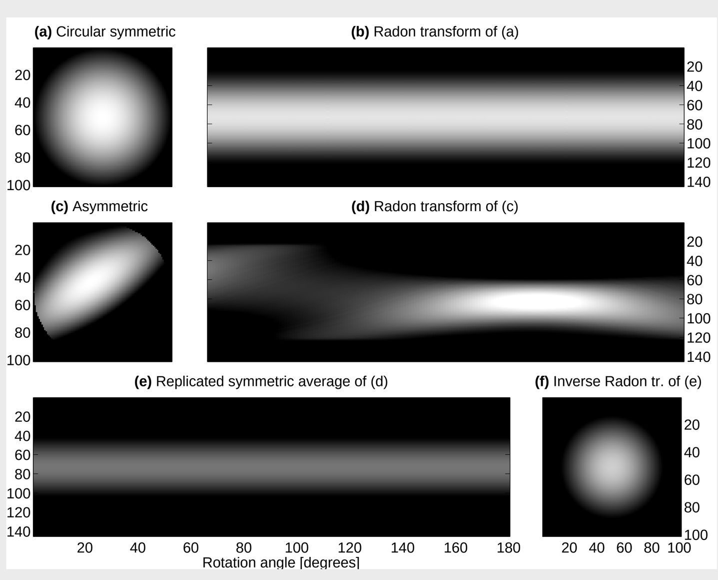
The 2D Radon transform ($\Re$) of a function f(x,y) is defined by:

$$\Re(p,\alpha) = \int_{-\infty}^{+\infty} f(x,y)\,\mathrm{dL}. \qquad (1)$$

where α is the angle between the x-axis and a given line p that cross the origin ($x, y = 0$), and dL is the line domain. $\Re$ will rotate the line p, counterclockwise, and to associate the value of the line integral to a given angle (e.g. $\alpha = 45°$; **upper**). A new image as a function of p and α will be generated (**lower left**, $\Re$ and **lower right**, inverse $\Re$ examples).



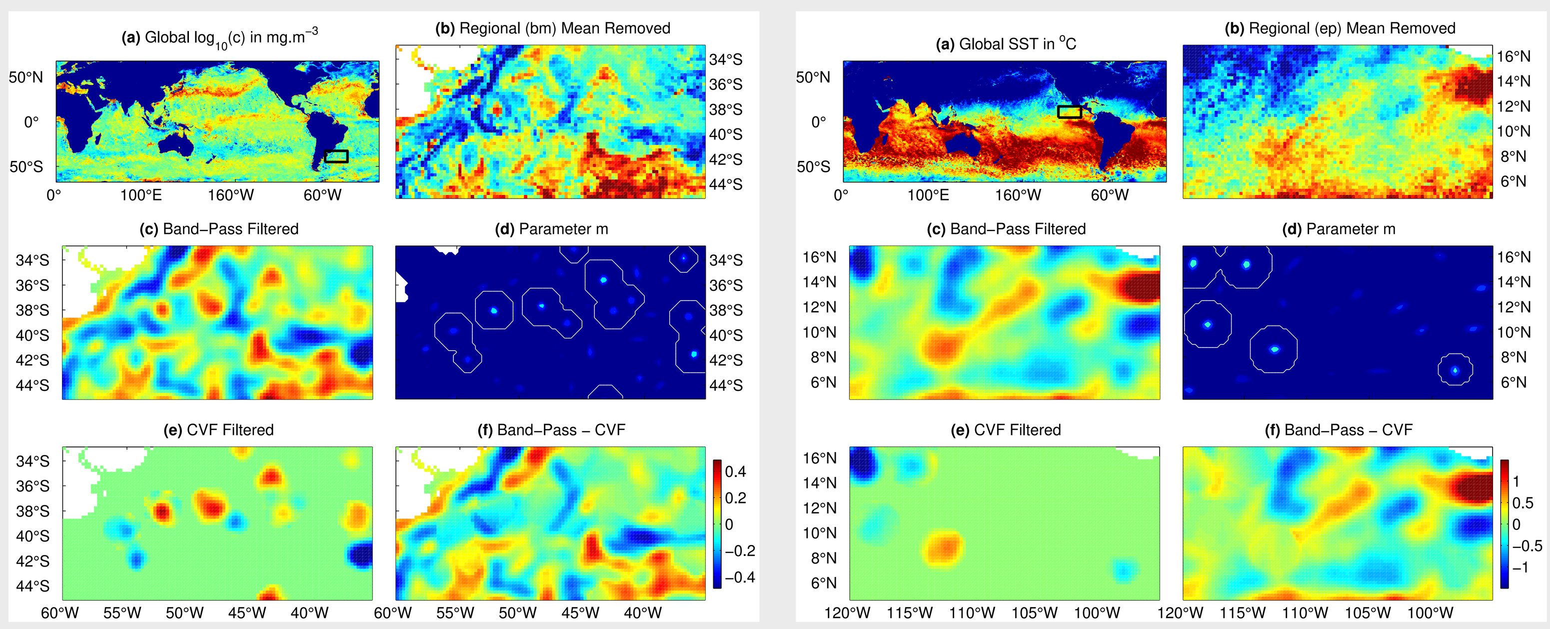


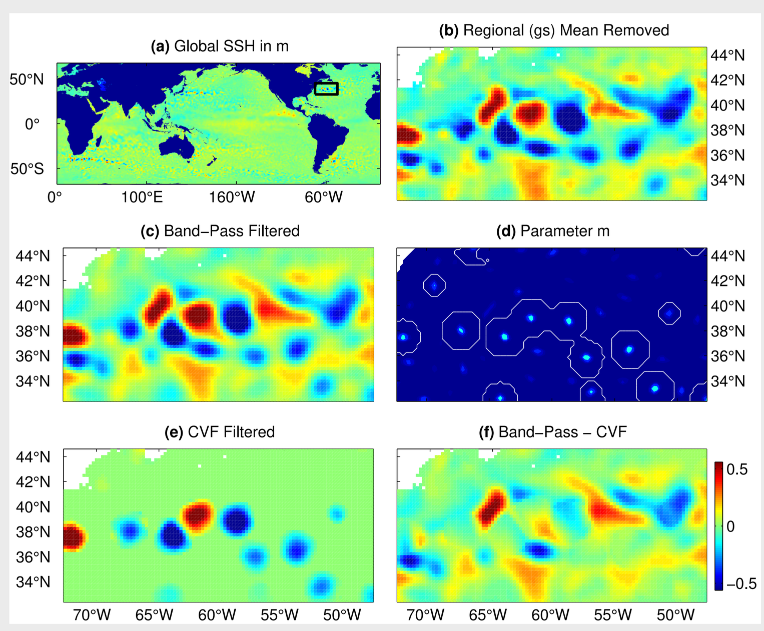


THE CIRCULAR EDDY FILTER (CEF)

The approximate spatial scale of the eddies of interest should be known. The eddies will be identified though their circular symmetry estimated by the Radon transform and must follow the steps below.

1. Remove the signals $\frac{1}{2}$ and $2\times$ the eddies' diameter using two 2D Gaussian FIR filters of $nf \times mf$ points ($nf = mf$, both odd), to obtain $zm(x, y)$.
2. A square matrix $z0(x, y)$ with nv pixels on a side (diameter of a symmetric circular eddy) is selected from each element of zm.
3. $\Re(p, \alpha)$ and its mean $\bar{\Re}$ are computed and $\bar{\Re}$ is replicated along the α-axis to obtain a matrix $\Re m$ (same size as $\Re$). If $\Re = \Re m$, $z0$ is perfectly circular.
4. The circular symmetry is given by the statistic parameter m using a least squares fitting applied to all points of zm until the matrix $m(x, y)$ is fulfilled.
5. The only two adjustable parameters are the filter size nf and a sensitivity threshold tr introduced to m, where $m0 = m \geq tr$.
6. nf controls the average output eddy size and tr controls how asymmetric can an eddy be, and still be categorized as a nearly circular eddy.

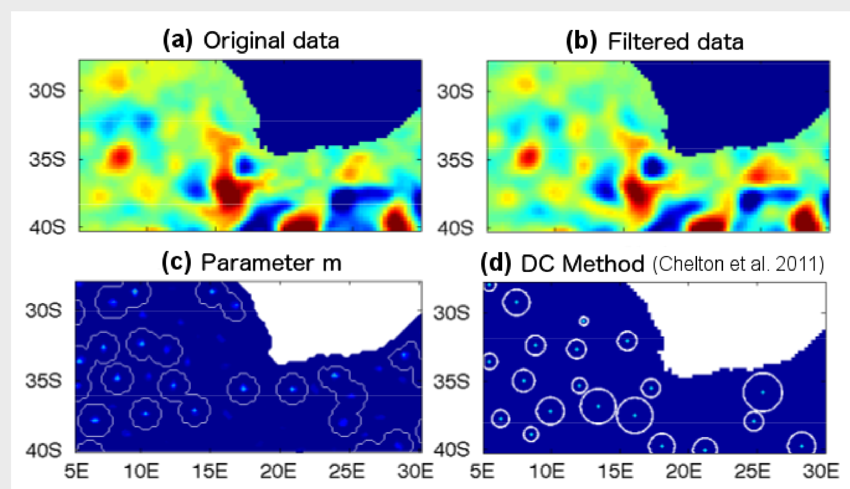




CEF × DC METHOD (CHELTON ET AL. 2011)

A case study for March/2015 detected 624 eddies against 777 from DC method. Coincident eddies totaled 455 eddies (∼60%). Here, we consider those whose centroids were into those detected by the DC method.

- In some cases, false-positives were detected in the DC method.
- Other cases, the CEF missed the eddies' signal because they violated the circular symmetry constraint.



FINAL CONSIDERATIONS

- CEF is independent of the eddy dynamic and the CEF can be applied to different features independent of its momentum balance. We expect that the arrival of SWOT can reinforce the flexibility of the method.
- CEF is not directly sensitive to variations in amplitude and energy dissipation, but rather to the eddies' diameter, making possible to estimate these characteristics by comparing the diameters along time.
- Dynamically, eddies tend to preserve their circular structure. It improves the robustness of the method since roundness is the heart of CEF.
- A tracking mode is expected to be implemented soon.