Automatic tracking of dynamical evolutions of oceanic mesoscale eddies with satellite observation data

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1. Introduction

- The oceanic mesoscale eddies play a major role in ocean climate system.
- Approximately 10–30 % of eddies may be found in proximity to a neighboring eddy in any given global SLA map, and they frequently interact (e.g., merging and splitting).
- To analyse the spatiotemporal dynamics of oceanic mesoscale eddies, the **Genealogical Evolution Model (GEM)** based on satellite data is developed, which is an efficient logical model used to track dynamic evolution of mesoscale eddies in the ocean. It can distinguish different dynamic processes (e.g., merging and splitting), which is difficult to accomplish using other tracking methods.

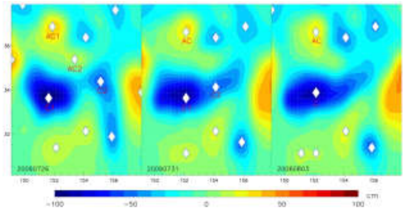

Fig 1. Eddy merging example. The background field shows the SLA, and white dots mark eddy centers.

2. Eddy identification

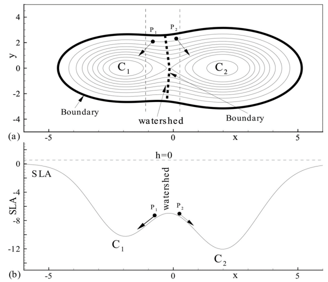

Fig 2. (a) Watershed as the natural division of eddies C1 and C2 from the top view, where contours represent SLA. **(b)** The particles P1 and P2 on the watershed flow downward to the eddy centers C1 and C2 from the cross-section view. The algorithm is very fast by searching the steepest descent path. (Li and Sun, 2015).

- A mononuclear eddy detection method was firstly developed with simple segmentation strategies, e.g. watershed algorithm (Li and Sun, 2015).
- Fig 2a shows two individual but nearby eddies. The cross section (Fig 2b) of the eddy shows that two closely located pixels P1 and P2 on the left and right sides of watershed would slide along the path of steepest descent in the map of SLA data to different eddy centers. The pixels between the two dashed lines are naturally divided by the watershed .

3. Dynamic tracking

The GEM is a logical model used for tracking the dynamic evolution of mesoscale eddies in the ocean. The algorithm consists of two steps:

1. establishing logical relationships of eddies between two time steps;
2. connecting all time steps to the “track tree”.

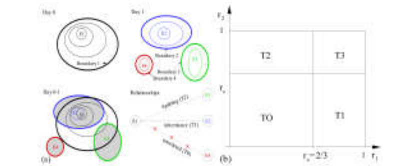

Fig 3. (a) We count the overlap area S_{12} between E1 (area S_1) and E2 (area S_2), and then we calculate the following ratios: $r_1 = S_{12}/S_1$ $r_2 = S_{12}/S_2$. **(b)** Using the similarity vector (r_1,r_2) and critical value r_c, the four different relationships are : T0 (unrelated), T1 (merging), T2 (splitting), T3 (living).

The GEM uses a two-dimensional similarity vector (i.e. a pair of ratios of overlap area between two eddies to the area of each eddy) rather than a scalar to measure the similarity between eddies, which effectively solves the “missing eddy” problem (temporarily lost eddy in tracking).

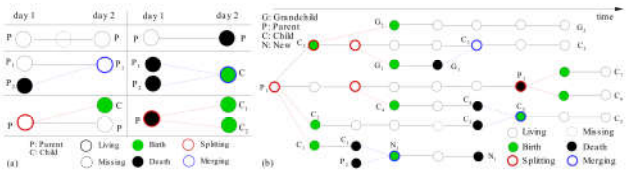

Fig 4. (a) The logical relationships of eddies between two days. (b) The logical genealogy evolution model of an example eddy. All of the computational steps are linear and do not include iteration. Given the pixel number of the target region L, the maximum number of eddies M, the number N of look-ahead time steps, and the total number of time steps T, the total computer time is ***O (LM(N+1)T)***.

- GEM uses both “*parent*” (the original eddy) and “*child*” (eddy split from parent) and the dynamic processes are described as birth and death of different generations.

4. Results

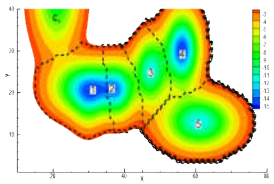

Fig 5. Example of eddy splitting by watershed segmentation strategy in simply connected region.

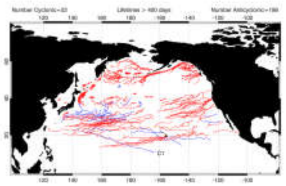

Fig 6. Tracks of long-lived (> 400 days) eddies.

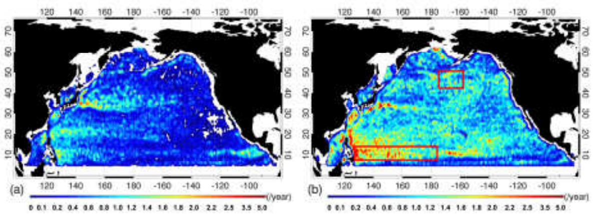

Fig 7. The frequencies of dynamic processes per 1° × 1° grid element. (a) The merging frequency for cyclonic eddies. (b) The merging frequency for anticyclonic eddies. The merging and splitting (not shown) events were homogeneously distributed in the oceans.

- Watershed segmentation strategy can split the multinuclear eddy into mononuclear eddies effectively (Fig 5).
- The tracking of each eddy is very smooth (Fig 6) because we require that the snapshots of each eddy on adjacent days overlap one another.
- The GEM can distinguish different dynamic processes. Merging and splitting events are more frequent for anticyclonic eddies than for cyclonic eddies.
- There is spatial variation in the number of events. Both the merging and splitting rates of the eddies are high, especially at the western boundary, in currents and in “eddy deserts”.

Reference: Qiu-Yang Li, Sun L, Liu S S, et al. A new mononuclear eddy identification method with simple splitting strategies. Remote Sensing Letters, 2014, 5(1): 65-72.
Qiu-Yang Li, Sun L. Technical Note: Watershed strategy for oceanic mesoscale eddy splitting. Ocean Science, 2015, 11(2): 269-273.
Qiu-Yang Li, Sun L, Sheng-Fu L. GEM: a dynamic tracking model for mesoscale eddies in the ocean. Ocean Science, 2016, 12(6): 1249.