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

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The oceanic mesoscale eddies play a major role in ocean climate system. To analyse 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) within a dynamic evolution pattern, which is difficult to accomplish using other tracking methods. To this end, a mononuclear eddy detection method was firstly developed with simple segmentation strategies, e.g. watershed algorithm. The algorithm is very fast by searching the steepest descent path. Second, 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). Third, for tracking when an eddy splits, 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. Additionally, a new look-ahead approach with selection rules effectively simplifies computation and recording. 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). The tracking of each eddy is very smooth because we require that the snapshots of each eddy on adjacent days overlap one another.
Although eddy splitting or merging is ubiquitous in the ocean, they have different geographic distribution in the Northern Pacific Ocean. Both the merging and splitting rates of the eddies are high, especially at the western boundary, in currents and in “eddy deserts”. GEM is useful not only for satellite-based observational data but also for numerical simulation outputs. It is potentially useful for studying dynamic processes in other related fields, e.g., the dynamics of cyclones in meteorology.