How well mesoscale eddies are represented in oceanic models?
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The aim of this work is to assess the impact of data assimilation on the dynamics of mesoscale eddies. We do this based on the use of a recent mathematical method from nonlinear dynamics field that is capable of detecting Lagrangian eddies from birth to death. We apply this method on two composites time series of two configurations covering the whole globe with and without assimilation, and carry on various statistical analysis to evaluate the impact of data assimilation on several properties of these Lagrangian mesoscale eddies.

2 Eddy detection method

The method we use here relies on the analysis of the Lagrangian geometrical properties of velocity fields and the use of a grid density-based clustering algorithm [1]. The method can be summarized in the three following steps:

- (i) It starts by segmenting Lagrangian trajectories into rotational \((x_i(t), \omega_i(t))\), with \(\omega(t) = \nabla \times \mathbf{v}(t)\) and \(\mathbf{v}(t) = \text{curl} \omega(t)\), such that \(\mathbf{v}(t) \neq 0\) or \(\omega(t) \neq 0\) and non-rotational segments based on the geometrical properties of their evolving velocities.

\[
\theta(t_{i+1}, x_i) = \cos^{-1}\left(\frac{\Phi_{i+1}^\alpha (x_i(t_{i+1})) \cdot \Phi_{i}^\alpha (x_i(t_i))}{\left|\Phi_{i+1}^\alpha (x_i(t_{i+1}))\right| \left|\Phi_{i}^\alpha (x_i(t_i))\right|}\right)
\]

- (ii) It maps the initial and final position of the extracted rotational segments.

\[
\begin{align*}
\{x_i(t_i), x_i(t_{i+1})\}_{i=1}^{\infty} &= \Phi_i^\alpha (x_i(t_i)), \quad i = 1, 2, \ldots, n \in [\alpha, \beta] \\
\{x_i(t_i), x_i(t_{i+1})\}_{i=1}^{\infty} &= \Phi_i^\alpha (x_i(t_i)), \quad i = 1, 2, \ldots, n \in [\alpha, \beta] \\
\{x_i(t_i), x_i(t_{i+1})\}_{i=1}^{\infty} &= \Phi_i^\alpha (x_i(t_i)), \quad i = 1, 2, \ldots, n \in [\alpha, \beta]
\end{align*}
\]

- (iii) It uses a grid density-based clustering algorithm to group them into different classes characterized by different transport properties, which represent the coherent cores of the eddies.

\[
\begin{align*}
X_{\text{iso}}(k_i, x_{i}(t_{i+1})) &= \{x_{i}(t_{i}), \omega_{i}(t_{i})\}, \quad k_i(t_{i+1}) = \Phi_i^\alpha (x_i(t_i)), i = 1, 2, \ldots, n \in [\alpha, \beta] \\
X_{\text{iso}}(k_i, x_{i}(t_{i+1})) &= \{x_{i}(t_{i}), \omega_{i}(t_{i})\}, \quad k_i(t_{i+1}) = \Phi_i^\alpha (x_i(t_i)), i = 1, 2, \ldots, n \in [\alpha, \beta] \\
X_{\text{iso}}(k_i, x_{i}(t_{i+1})) &= \{x_{i}(t_{i}), \omega_{i}(t_{i})\}, \quad k_i(t_{i+1}) = \Phi_i^\alpha (x_i(t_i)), i = 1, 2, \ldots, n \in [\alpha, \beta]
\end{align*}
\]

where \(X_{\text{iso}}\) is a function that associates to each particle \(p_i\), a given density based on its neighboring. \(d_{ij}, p_{ij}\) denotes the Euclidean distance between particle \(p_i\) and \(p_j\), \(d_{ij} = \min(E_{ij})\) for neighboring. We define a coherent eddy as a time-evolving domain.

\[
E = \bigcup_{i \in [\alpha, \beta]} \bigcup_{j \in [\alpha, \beta]} E(t) \subset R^2 \times [t_i, t_{i+1}] 
\]

in way that \(E\) is a set of adjacent particles \(x_i\) \(E(t)\) characterized by rotational segments that co-exist in the dense regions \(G(x) = \{x_{i}(t_{i}), \omega_{i}(t_{i})\}\) and \(G(x) = \{x_{i}(t_{i}), \omega_{i}(t_{i})\}\) respectively at \(t_i\) and \(t_{i+1}\).

\[
E = G(x) \cap G(x) 
\]

In the light of evaluating the impact of data assimilation procedure on eddies activity, we made use of a recent method from nonlinear dynamics field, together with two historical time series of ocean current derived from ocean model with and without assimilation, and carry on various statistical analysis to evaluate the impact of data assimilation on several properties of these Lagrangian mesoscale eddies.