Eulerian and Lagrangian diagnostics from Lamta

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Abstract

This document temporarily details computation of Eulerian and Lagrangian diagnostics using Lamta code (Diagnostics.py).

1 Eulerian diagnostics

Okubo-Weiss parameter (OW):
The Okubo-Weiss parameter (W) identifies oceanic eddies by measuring the importance of deformation (strain, S) *versus* rotation (ω) at given point (i, j) following:

$$W_{i,j} = Sn^2_{i,j} + Ss^2_{i,j} - \omega^2_{i,j} \tag{1}$$

where $Sn_{i,j}$ is the normal strain, $Ss_{i,j}$ is the shear strain and $\omega_{i,j}$ is the relative vorticity. These quantities are evaluated using the daily surface velocity fields (u, v) derived from satellite:

$$\begin{aligned}
Sn_{i,j} &= \frac{\partial u}{\partial x}_{i,j} - \frac{\partial v}{\partial y}_{i,j} \\
Ss_{i,j} &= \frac{\partial u}{\partial y}_{i,j} + \frac{\partial v}{\partial x}_{i,j} \\
\omega_{i,j} &= \frac{\partial v}{\partial x}_{i,j} - \frac{\partial u}{\partial y}_{i,j}
\end{aligned}$$

Maps of Okubo-Weiss parameter (⟨ date ⟩ _OW_⟨velocity field product⟩.png) display $-W \times (60 * 60 * 24)^2$ so that W is expressed in $days^{-2}$ and positive values detects eddies whereas negative values identifies regions dominated by shear.

Kinetic energy:
The kinetic energy (KE) of a flow is the amount of energy due to its motion and is expressed as the sum of the squared velocities (u, v), in $cm^2.s^{-2}$:

$$KE = u^2 + v^2 \tag{2}$$

KE maps (⟨ date ⟩ _KE_⟨velocity field product⟩.png) are computed using daily velocity fields derived from satellite.

2 Lagrangian diagnostics

The Lagrangian diagnostics are derived from the trajectories of thousands of numerical particle traced backward in time for 30-days using the surface velocity fields from satellite. Particles are initially distributed on a regular grid every 0.02 degree and are then advected backward in time using RK4 method and daily velocity fields from the previous 30 days.

Finite-Time Lyapunov Exponent (FTLE):
Finite-time Lyapunov exponents (λ) measure, in day^{-1}, the rate of separation of particles initially closed to one another:

$$\lambda = \frac{1}{2}\frac{log(\frac{d_f}{d_i})}{T} \tag{3}$$

with d_f the final particle separation (distance) at the end of integration, d_i the initial particle separation (distance) and T being the integration time (i.e. number of days of integration). Maps of FTLE (⟨ date ⟩ _FTLE_⟨velocity field product⟩.png) allows for identifying convergent fronts acting as barrier of the flow where particles (water masses) accumulate.

Longitude/Latitude advections (LLADV):
Longitude (latitude) advection maps (⟨ date ⟩ _LLADV_⟨velocity field product⟩_LonAdv(LatAdv).png) display the difference between the initial and final longitude (latitude) of the particle in the initial grid cell. They allow for identifying the water mass origins and can therefore detect fronts between different water masses.

Retention parameter (OWTRAJ):
The retention parameter (W_L) is the Lagrangian version of the OW parameter. It computes the OW (eq. 1) parameter all along particle trajectories and quantifies the amount of time a trajectory has a successive negative W (i.e. the amount of time a particle is trapped in a structure). By mapping these quantities, W_L detects the trapping eddies in the sampling region (⟨ date ⟩ _OWTRAJ_⟨velocity field product⟩.png).

Time elapsed since last contact with bathymetry (TIMEFROMBATHY):
The time from bathy maps (⟨ date ⟩ _TIMEFROMBATHY_⟨velocity field product⟩_*.png) display the time elapsed (in *days*) since a particle has been in contact with a bathymetric level. This diagnostic first detect if particle trajectories reach a specific bathymetric level. If so it computes the time elapsed since the particle was on that bathymetric level, the longitude and latitude of the bathymetric contact at the particle initial position. This diagnostic allows for identifying potential nutrients enrichment due to contact with coasts or topographic features.

Tracer advection (ADV):
Some tracer (SST, SSS or chlorophyll) advection can also be computed by mapping the difference between tracer value, identified from satellite maps of the specific tracer, at the particle initial and final positions (⟨ date ⟩ _ADV_⟨velocity field product⟩.png). Usually 3-day trajectories are considered to compute these diagnostics to take into account the tracer non-conservative characteristic.

How to cite: SPASSO software and the Lagrangian code will be soon made available through Github with an associated reference and doi. Please contact Louise Rousselet or Francesco d'Ovidio at the time of publication to get full reference.