# Eddy Killing from Global Satellite Observations

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While wind is the primary driver of the oceanic general circulation, we find that it kills the ocean's most-energetic motions—its mesoscale eddies—at an average rate of 50 GW. We used satellite observations and a recent method to disentangle multiscale processes in spherical systems, including in an inertial confinement fusion implosion.[1] To our knowledge, a length-scale analysis of air–sea energy transfer on the entire globe had not been previously undertaken. In fact, we show that the temporal mean-eddy decomposition (i.e., Reynolds averaging) commonly used in oceanography fails to unravel eddy killing. Our results present the first evidence that eddy killing is a major seasonal sink for the oceanic eddies, peaking in winter. We find that eddy killing removes a substantial fraction (up to 90%) of the wind power input in western boundary currents such as the Gulf Stream and Kuroshio. This process, often overlooked in analyses and models, is a major dissipation pathway for mesoscales—the ocean's most-energetic scales.

At the surface of the ocean, wind deposits kinetic energy at the rate of $\tau \cdot u_\text{o}$, where $\tau$ is the wind stress at the surface of the ocean and $u_\text{o}$ is the surface ocean velocity.[2] The power deposited in eddies, smaller than the size of $l$, is captured by Eq. (1). The overline represents the coarse-graining operation at length-scale $l$.

$$EP_l^{\text{Cg}} = \overline{\tau \cdot u_\text{o}} - \overline{\tau} \cdot \overline{u_\text{o}}. \tag{1}$$

Equation (1) is analogous to the frequently used wind power input from Reynolds decomposition[3] as given in Eq. (2). The angled brackets represent temporal averaging and the primes represent deviation from temporal averaging.

$$EP^{\text{Rey}} = \langle \tau \cdot u \rangle - \langle \tau \rangle \cdot \langle u_\text{o} \rangle = \langle \tau' \cdot u'_0 \rangle. \tag{2}$$

Studies using Reynolds decomposition, for example in Ref. 4, find that global power inputs to the eddies as measured from Eq. (2) are positive. Our work shows that eddy killing is an inherently spatial process and requires a spatial scale analysis to unravel it [Eq. (1)]. We find that wind power input is negative for length scales smaller than 260 km, implying eddy killing at those scales [see Fig. 1(b)]. Eddy killing is especially pronounced in Western Boundary Currents (WBC's) (e.g., the Gulf Stream and Kuroshio) and the Antarctic Circumpolar Current (ACC), while the remainder of the ocean has negligible eddy killing [see Fig. 1(a)]. Figure 1(c) reproduces the temporal analysis of previous studies and highlights the stark contrast with a spatial analysis, where we see a dominance of positive wind power input into the ocean, falsely suggesting a lack of eddy killing. This is contrasted by a dominance of negative values in Fig. 1(a).

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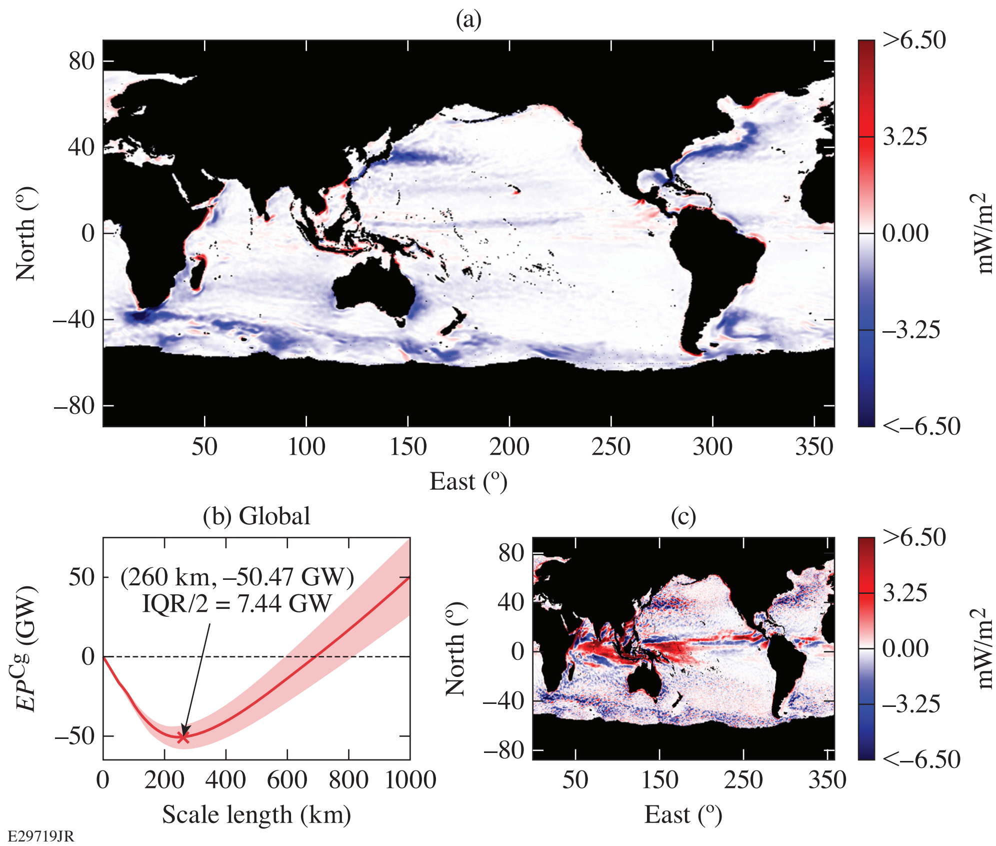


Figure 1
Direct measurement of eddy killing by coarse-graining satellite observations. (a) Wind power input (in mW/m$^2$) to the flow at scales <260 km using our measure $EP^{\text{Cg}}$ in Eq. (1). We are able to clearly detect eddy killing (negative values) throughout the global ocean, especially in WBC's and the ACC. Areas in black include land and ocean regions with seasonal or permanent ice coverage. (b) Performing a scan over an entire range of length scales to unravel scales at which eddy killing operates globally, in addition to its magnitude. This is a key advantage of coarse graining. At any scale $l$, the plot shows wind power input to all scales smaller than $l$. By attaining a minimum at $l$ = 260 km, it implies that eddies only at scales smaller than 260 km (but not larger) are losing energy to the wind, on average. The envelope shows interquartile range (IQR) (25th to 75th percentiles, Q1 to Q3) of temporal variation about the weekly climatology (as calculated from the seven years of data) of $EP_l^{\text{Cg}}$, and IQR/2 = (Q3 to Q1)/2. For reference, IQR/2 = 95.63 GW for the global $\tau \cdot u_{\text{o}}$ without any decomposition. (c) Reproducing eddy killing using the traditional Reynolds (or temporal) decomposition, $EP^{\text{Rey}}$, as in prior studies. It shows a stark contrast to our measure $EP^{\text{Cg}}$, with sporadic values of mixed sign without a clear indication of eddy killing. The two decompositions differ starkly in the tropics but agree near some land boundaries, where we expect winds to drive small-scale currents.

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