Disproportionate Role of Small-scale Winds on the Mesoscales and Spurious Eddy Killing from Resolution Mismatch.

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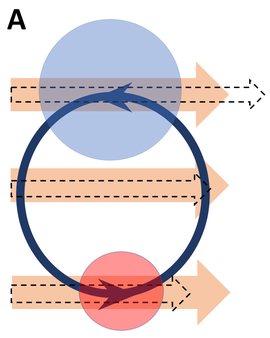
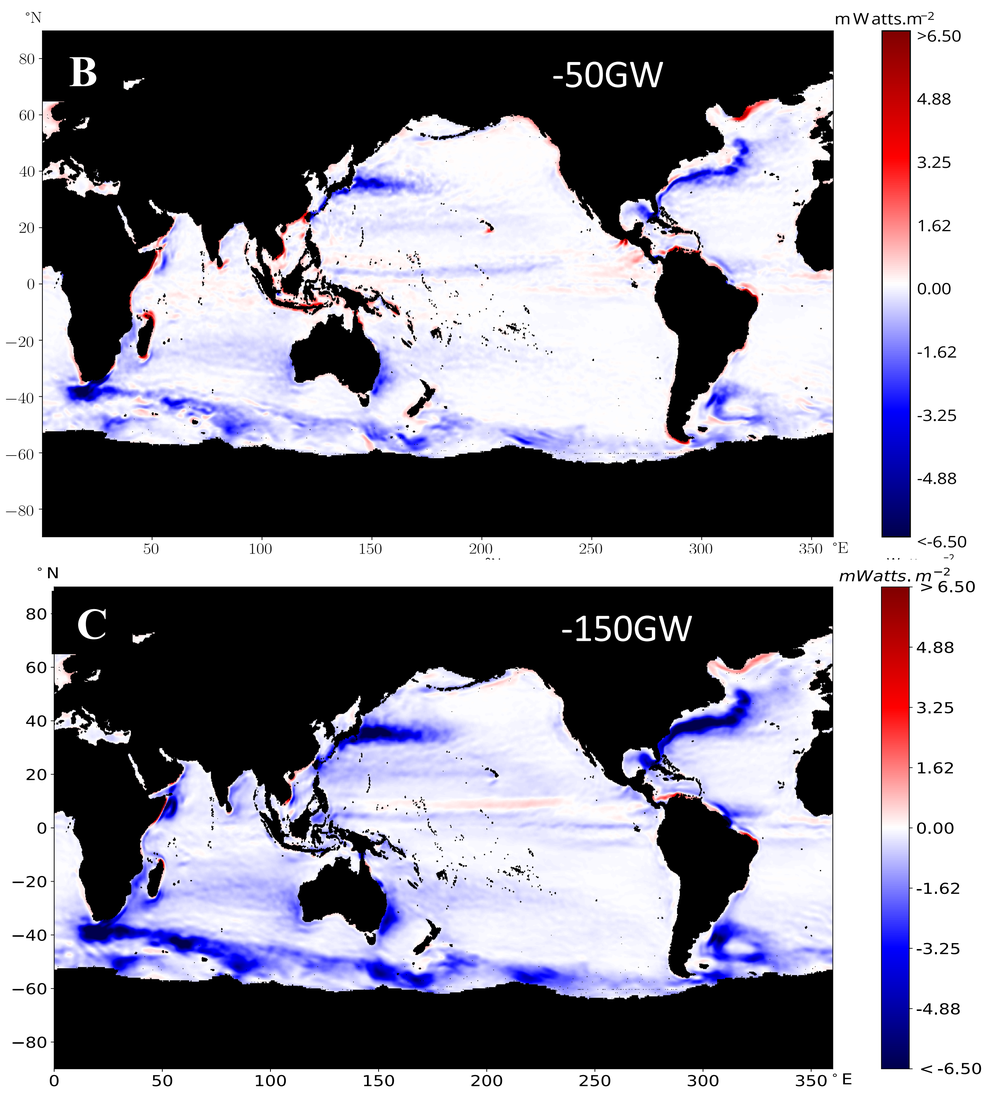
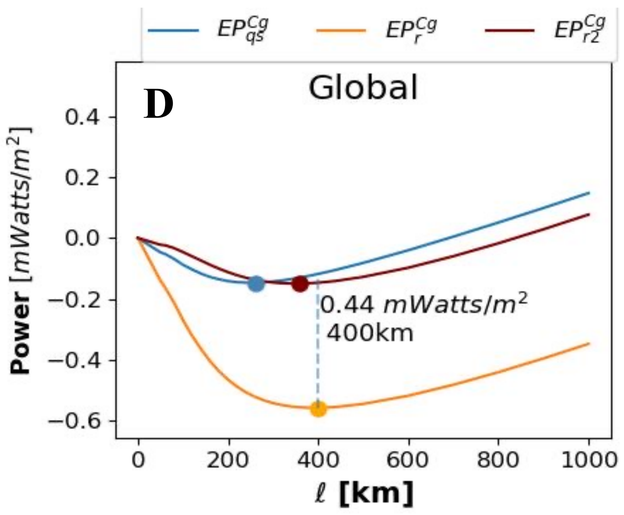
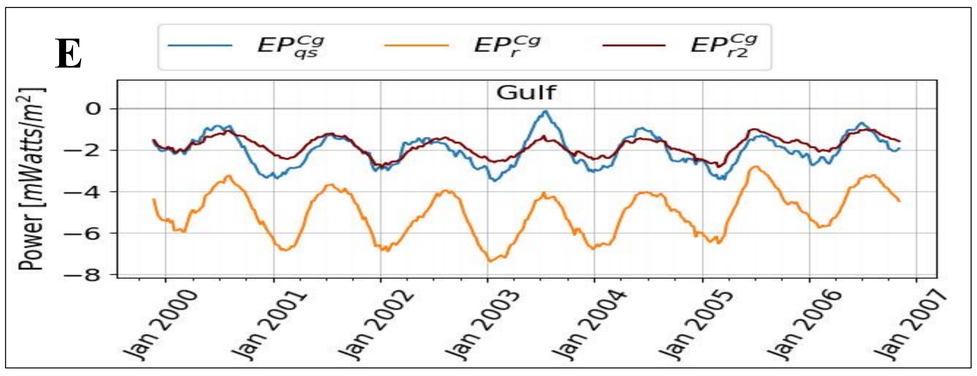
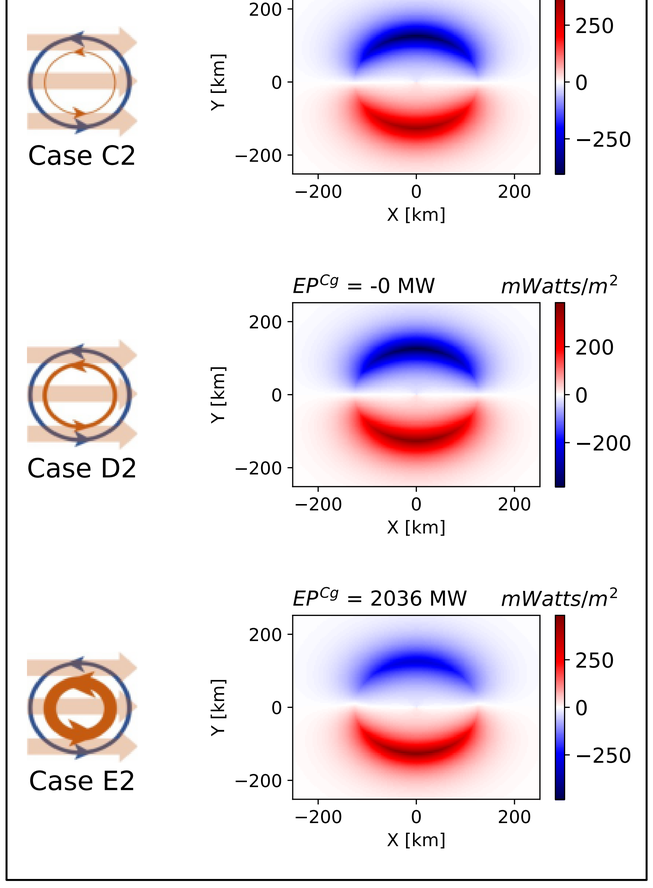
Wind is the primary source of kinetic energy for ocean(Wunsch, 2004), but wind also extract kinetic energy from ocean by process called "eddy killing" (Zhai et. al. 2007, Renault et. al. 2016). Our study shows that it is small scale winds that determine how a mesoscale eddy is forced and the misrepresentation of small-scale winds due resolution mismatch of winds and ocean currents can cause spurious eddy killing that reduces the total wind work. We have proposed a fix to such spurious eddy killing.

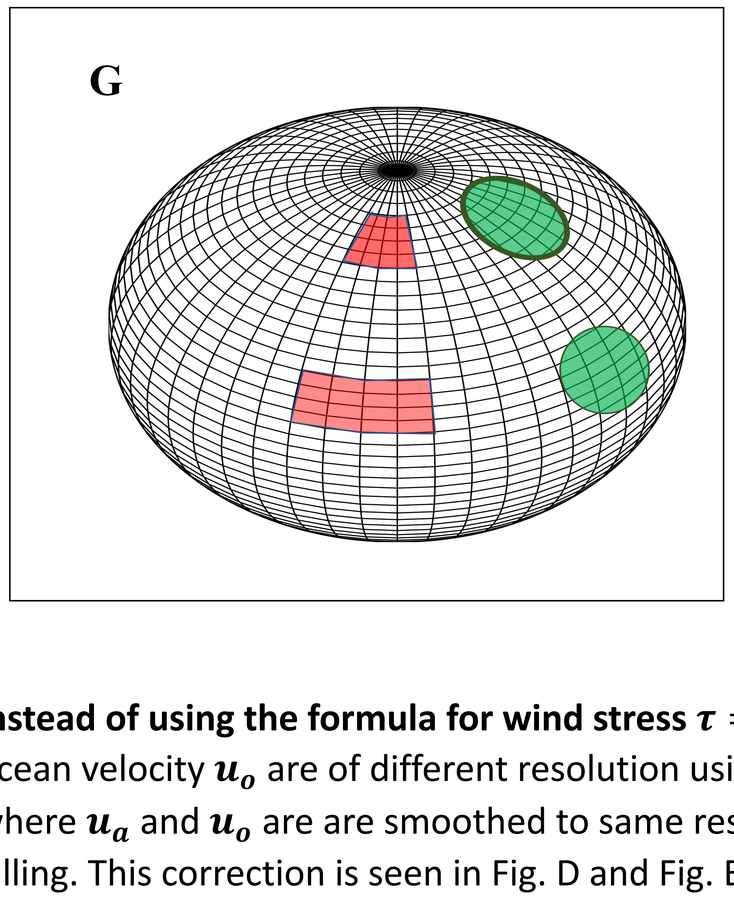












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Power to small scales from coarse graining:

$$EP^{Cg} = \overline{\boldsymbol{\tau}.\boldsymbol{u}} - \overline{\boldsymbol{\tau}}.\overline{\boldsymbol{u}}$$

We derive an analytical criterion for eddy killing:

$$EP^{Cg}_{\ell} = C_d|\overline{\boldsymbol{u_a}}|\left([\boldsymbol{u_a}]'_\ell \cdot [\boldsymbol{u_o}]'_\ell - [\boldsymbol{u_o}]'_\ell \cdot [\boldsymbol{u_o}]'_\ell\right)$$

$\overline{\boldsymbol{\tau}}$	large scale wind stress
$\overline{\boldsymbol{u}}$	large scale ocean current
$\overline{\boldsymbol{u_a}}$	large scale wind
$[\boldsymbol{u_a}]'_\ell$	small scale winds
$[\boldsymbol{u_o}]'_\ell$	small scale ocean current
C_d	coefficient of Drag

If the term $[\mathbf{u_a}]'_\ell \cdot [\mathbf{u_o}]'_\ell - [\mathbf{u_o}]'_\ell \cdot [\mathbf{u_o}]'_\ell$ is negative, there is eddy killing. If it is positive the eddy is energized. The magnitude and orientation of the small-scale winds determine if an eddy is forced positively or negatively. The large-scale wind is only a factor to increase the magnitude of the forcing to the eddy.

Fig.	Description
A	Mechanism of Eddy Killing. A large-scale wind forces half of eddy positively and half negatively. The negative forcing dominates and wind extracts energy from the eddy.(Zhai e.t. al. GRL, 2007, Renault et. al. JPO, 2016)
B	Eddy killing revealed with Coarse Graining Technique. We find wind extracts energy at rate of -50 GW by eddy killing and is concentrated in dynamic regions. (Rai et. al, SciAdv. 2021)
C	Eddy killing is overestimated with relative NCEP winds because of resolution mismatch. Eddy killing is exaggerated by 3 times. (Rai et. al. JAMES, 2023(under review))
D	Coarse Graining reveals the lengthscales of eddy killing and shows the overestimation of eddy killing by relative NCEP winds. Blue line is correct eddy killing, orange line is the overestimated eddy killing and brown line is after fixing the overestimation of eddy killing.(Rai et. al. JAMES, 2023(under review))
E	Coarse Graining reveals the seasonality of eddy killing and shows the overestimation of eddy killing by relative NCEP winds is persistent thought all times. Blue line is correct eddy killing, orange line is the overestimated eddy killing and brown line is after fixing the overestimation of eddy killing.(Rai et. al. JAMES, 2023(under review))
F	Schematics explaining how small scale winds (small thin brown arrow) have the disproportionate role in eddy killing. The magnitude and direction of small scale winds are important. .(Rai et. al. JAMES, 2023(under review))
G	Green color circle shows our coarse graining kernel size and shape does not change with latitude. The convolution we are using commutes with derivative. (Aluie, GEM-Int.J.Geomaths, 2019. Aluie et. al. , JPO, 2018)
H	QR code for our SciAdv. Paper and Manuscript for JAMES.

Instead of using the formula for wind stress $\boldsymbol{\tau} = C_D|\boldsymbol{u_a} - \boldsymbol{u_o}|\,(\boldsymbol{u_a} - \boldsymbol{u_o})$ where wind velocity $\boldsymbol{u_a}$ and ocean velocity $\boldsymbol{u_o}$ are of different resolution using the formula $\boldsymbol{\tau} = C_D\left|\overline{\boldsymbol{u_a}}_{\boldsymbol{\Delta}} - \overline{\boldsymbol{u_o}}_{\boldsymbol{\Delta}}\right|\,(\overline{\boldsymbol{u_a}}_{\boldsymbol{\Delta}} - \overline{\boldsymbol{u_o}}_{\boldsymbol{\Delta}})$ where $\boldsymbol{u_a}$ and $\boldsymbol{u_o}$ are are smoothed to same resolution $\overline{\boldsymbol{u_a}}_{\boldsymbol{\Delta}}$ and $\overline{\boldsymbol{u_o}}_{\boldsymbol{\Delta}}$ will not cause spurious eddy killing. This correction is seen in Fig. D and Fig. E from the brown lines.

Data Used: Winds Data: QuikSCAT and NCEP **Ocean Current Data:** AVISO Altimetry

Acknowledgements

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