Estimating the Submesoscale Inverse Kinetic Energy Cascade from Along-Track Altimetry

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Abbreviated abstract:
On the basis of AVISO and a submesoscale-permitting simulation it is shown that the surface geostrophic inverse scale kinetic energy flux is linearly related to quantities that are computable from along-track altimetry. This linear relationship is used to estimate for the first time the submesoscale inverse kinetic energy cascade, as well as its regional distribution and seasonal cycle for large parts of the global ocean.

Related publications:

- Schubert and Gula (2022): Estimating the Submesoscale Inverse Kinetic Energy Cascade from Along-Track Altimetry, planned to be submitted to *Journal of Physical Oceanography*

Data and methods

From along-track altimetry, there are only two terms of the coarse-graining surface geostrophic scale kinetic energy flux through a particular scale L (Leonard, 1975) computable:

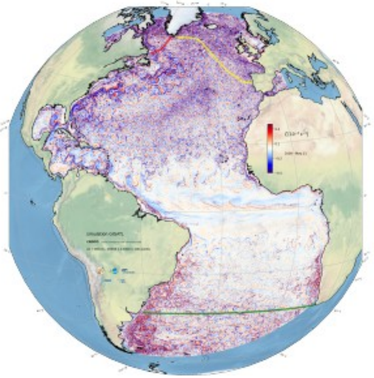
$$\Pi(x,y,t) = -\rho_0\left[(\overline{u^2} - \overline{u}^2)\frac{\partial \overline{u}}{\partial x} + (\overline{uv} - \overline{u}\,\overline{v})\left(\frac{\partial \overline{u}}{\partial y} + \frac{\partial \overline{v}}{\partial x}\right) + (\overline{v^2} - \overline{v}^2)\frac{\partial \overline{v}}{\partial y}\right],$$

Leonard Stress $\tau^u = \overline{u^2} - \overline{u}^2 > 0$ — along-track derivative of the across-track velocity component

where $u = -\frac{g}{f}\frac{\partial \eta}{\partial y},\ v = \frac{g}{f}\frac{\partial \eta}{\partial x}$ are cross- and along-track f-plane geostrophic velocity components, x and y are the cross- and along-track directions (with increasing longitude and latitude), and the over-lines mark along-track convoluted fields using a top-head convolution kernel of size L. Here, we show on the basis of gridded data from AVISO and the submesoscale-permitting simulation GIGATL1 that it is possible to estimate the inverse flux contribution as

$$\Pi^- = \begin{cases} \Pi & \Pi < 0 \\ 0 & else \end{cases} \approx -\rho_0 C_1 C_2 \langle \tau^u \rangle \langle |\frac{\partial \overline{u}}{\partial y}| \rangle, \text{ where } C_1 = \frac{\langle |\frac{\partial \overline{u}}{\partial x}| \rangle}{\langle |\frac{\partial \overline{u}}{\partial y}| \rangle} \approx 0.57 \text{ , and } C_2 = \frac{\Pi^-}{-\rho_0 C_1 \langle \tau^u \rangle \langle |\frac{\partial \overline{u}}{\partial y}| \rangle} \approx 0.31$$

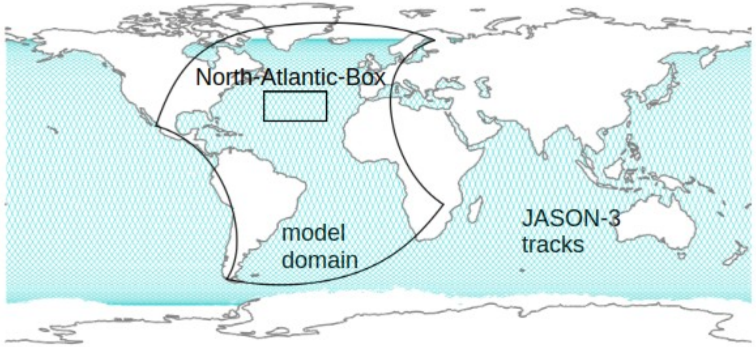
and angled brackets mark 5° x 5° area-means.



GIGATL1 (1 km hor. res.)
- with tidal forcing
- without tidal forcing

AVISO (0.25° hor. res.)

JASON-3 (7 km hor. res.)
- noise floor below 50-70 km



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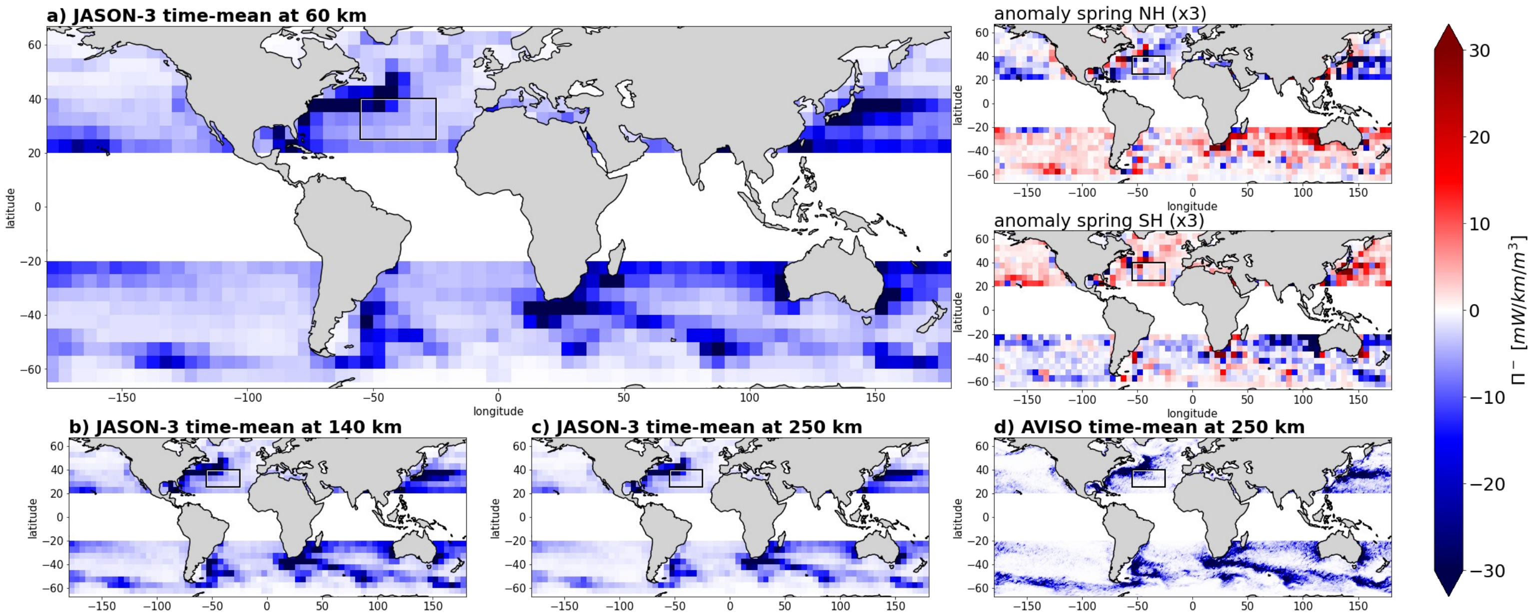
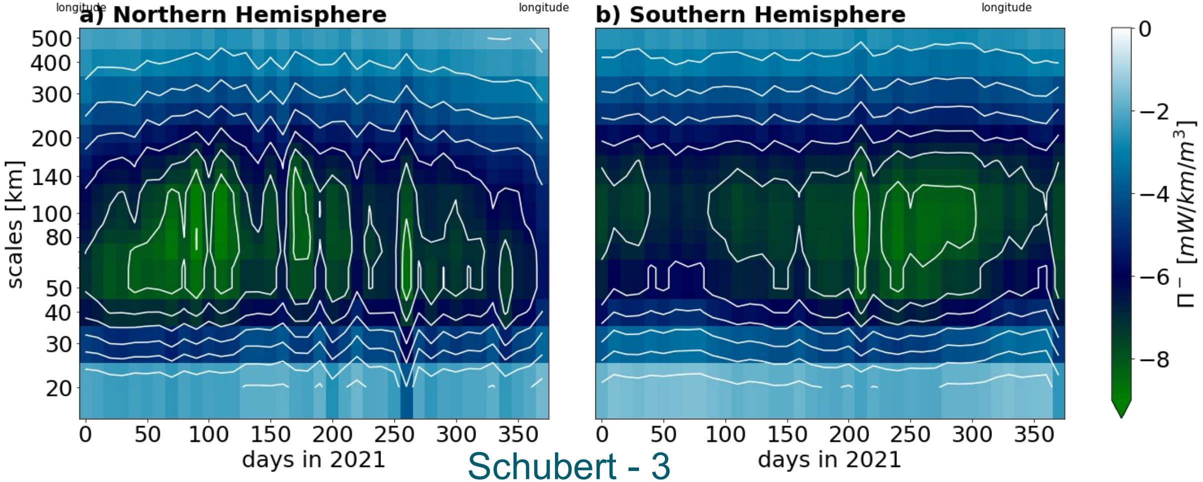
Results





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Discussion and conclusions

The along-track-altimetry-based estimation of the inverse scale-kinetic-energy flux through horizontal scales of 60 km indicates that the inverse cascade at this scale occurs in large parts of the global ocean. It is found to be strongest in regions of large-scale currents, as well as in spring (in Feb-Apr in the Northern Hemisphere and in Aug-Oct in the Southern Hemisphere). The latter is consistent with the dominant formation of strong mixed-layer eddies in the deep winter-time mixed-layers and their subsequent absorption of submesoscale mixed-layer eddies by mesoscale eddies which has been suggested by numerical studies, very regional observational studies, and indirect comparisons of spectral properties of satellite data.