B) Supplementary text01 (**Supplementary methods**):

Simple methods to estimate volume transport and net surface flow in the ocean from satellite observations

Data and methods

Data

Wind-driven volume transport was calculated using QuikScat wind fields available at http://www.remss.com . Quarter-degree gridded QuikScat data are produced by Remote Sensing Systems and sponsored by the NASA Ocean Vector Winds Science Team. The altimeter products (geostrophic currents) were produced by Ssalto/Duacs and distributed by Aviso, with support from CNES. The Aviso data can be found here: http://www.aviso.altimetry.fr/duacs||www.aviso.altimetry.fr/duacs .

Methods

Wind-driven volume transport

From Ekman's theory (Pond and Pickard, 1983), the zonal (x) and meridional (y) components of mass transport, due to momentum transfer from the wind, can be defined as the integral of Ekman velocity (U_{E},V_{E}) from the sea surface to a depth (d) below the Ekman layer:

$$M_{Ex} = \int_{-d}^{0} \rho U_E dz, \quad M_{Ey} = \int_{-d}^{0} \rho V_E dz \qquad (1)$$

Balance between the frictional force and the Coriolis force in the Ekman layer can be simplified as:

$$\frac{1}{\rho}\frac{\partial \tau_x}{\partial z} = -fV_E, \quad \frac{1}{\rho}\frac{\partial \tau_y}{\partial z} = fU_E \qquad (2)$$

Combining (1) and (2), we get the net mass transport per unit length associated with the Ekman flow as:

$$M_{Ex} = \frac{\tau_y}{f}, \quad M_{Ey} = -\frac{\tau_x}{f} \qquad (3)$$

where τ_{x} (τ_{y}) is the zonal (meridional) component of the wind stress; ρ ($1024\unit{\, kgm^{-3}}$) is the density of seawater; and f is the Coriolis parameter. Calculation of mass transport by this method is more robust (i.e., based on fewer assumptions) than calculation of velocities (Stewart, 2009). However, a primary source of uncertainly, besides the steady-state assumptions, may come from the estimation of wind stress (τ) from wind speed (u_{10}), which is parametrized using a constant (that is not true in practice) drag coefficient ($C_{D}=1.34\times10^{-3}$) and average air density ($\rho_{a}\sim1.3\unit{\, kgm^{-3}}$) as $\tau=\rho_{a}C_{D}|u_{10}|u_{10}$.

Finally, the two components of volume transport were computed as:

$$Q_x = \frac{\delta Y M_{Ex}}{\rho}, \quad Q_y = \frac{\delta X M_{Ey}}{\rho} \tag{4}$$

where δX (δY) is the east-west (north-south) distance ($\sim0.25^{\circ}$) across which the meridional (zonal) transport is calculated.

Net surface current

Velocity at the sea surface could retain two parts - one associated with the horizontal pressure gradient and the other with vertical friction. Sum of the geostrophic and non-geostrophic components constitute - exclusive of a residual - the net flow at the surface.

The geostrophic velocities (u_{g},v_{g}) are computed from gridded sea surface heights with respect to a twenty-year mean, based on multi-mission satellite altimeter observations, and are distributed by Aviso. The $1/3^{\circ}$ products are interpolated to the 0.25° QuikScat grid using a minimum curvature surface fitting method (Franke, 1982).
The magnitude of the total Ekman surface current (V_{0}), and the components (u_{E},v_{E}) were estimated as (Pond and Pickard, 1983):

$$V_0 = \frac{\tau}{\rho\sqrt{A_z f}} \tag{5}$$

$$u_E = V_0 \cos\left(\frac{\pi}{4} - \theta\right), \quad v_E = V_0 \sin\left(\frac{\pi}{4} - \theta\right) \tag{6}$$

where the vertical eddy viscosity coefficient (A_{z}) is assumed to be $10^{-2}m^{2}s^{-1}$ (see e.g., Yu and O'Brien (1991)), and θ is the satellite-derived wind direction (in radians).

Assuming a linear system the sum of the two solutions is also a solution, hence the components of the net surface flow were estimated as:

$$u_{NET} = u_g + u_E, \quad v_{NET} = v_g + v_E \tag{7}$$

References

Franke, R. (1982), Smooth interpolation of scattered data by local thin plate splines. *Computers & Mathematics with Applications*, 8(4):273 – 281.

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Stewart, R. H. (2009), Introduction to Physical Oceanography. University Press of Florida, ISBN 9781616100452. URL http://books.google.co.uk/books?id=3dXTRAAACAAJ .

Yu L., and J. J. O'Brien (1991), Variational estimation of the wind stress drag coefficient and the oceanic eddy viscosity profile. *J. Phys. Oceanogr.*, 21(5):709–719.