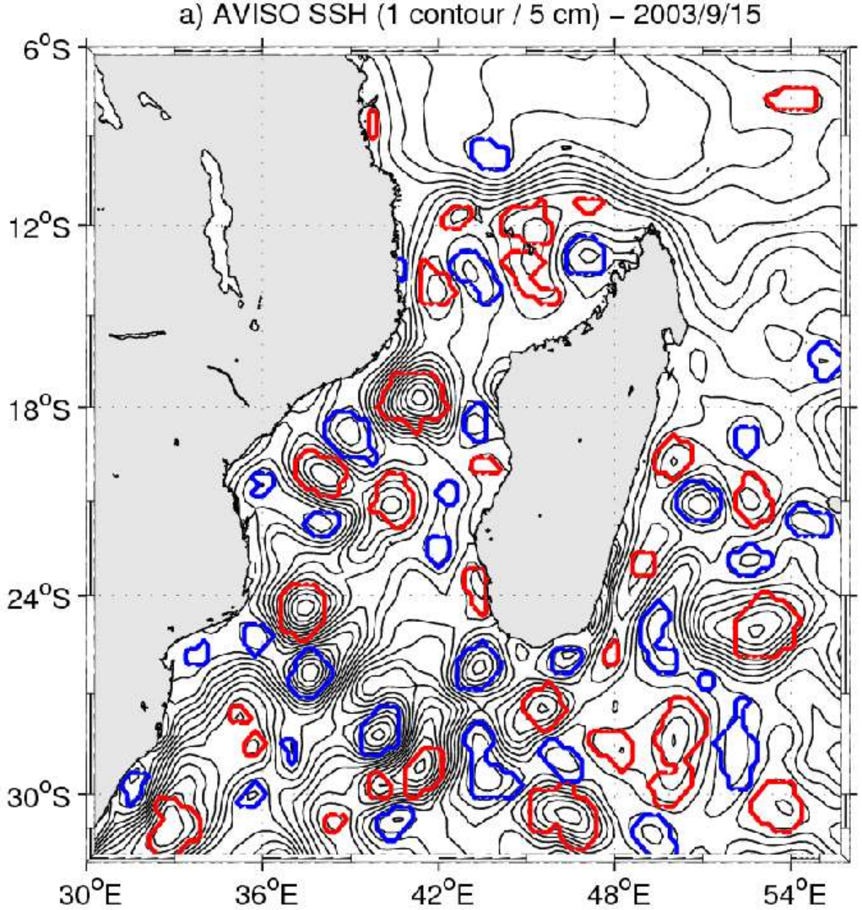
Cyclogeostrophic balance in the Mozambique Channel and application at global scale

Penven, P., I. Halo, S. Pous, and L. Marie

Penven, P., I. Halo, S. Pous, and L. Marie (2014), Cyclogeostrophic balance in the Mozambique Channel, *J. Geophys. Res. Oceans*, **119**, 1054-1067.

Eddies seen by AVISO in the Mozambique Channel



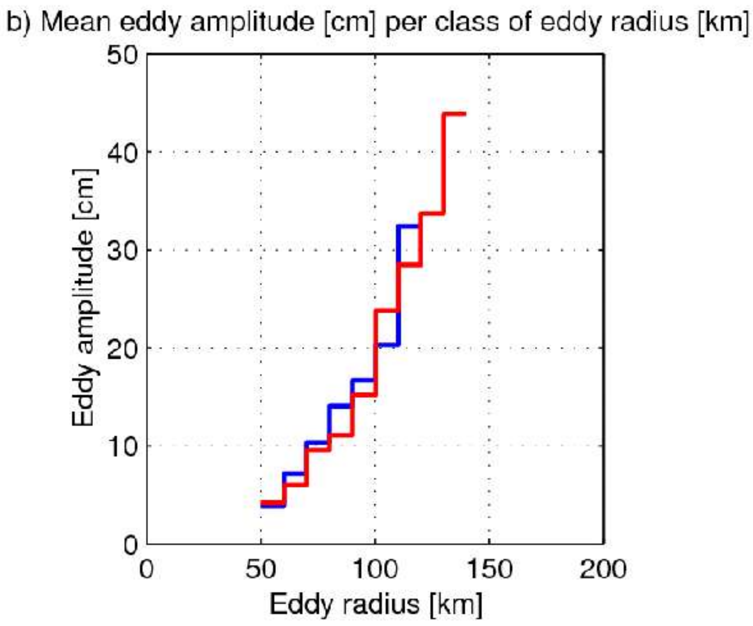


Figure adapted from Halo et al., 2013

For a given size, cyclones have here in general a larger amplitude than the anticyclones

Effect of the centrifugal force on eddies:

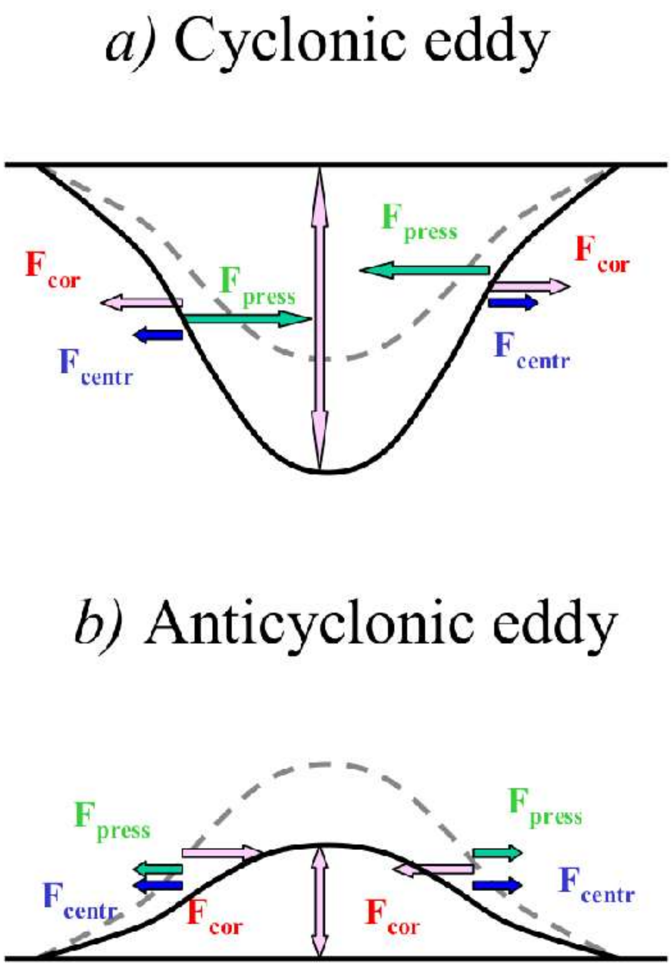


Figure adapted from Maximenko and Niiler (2006)

Including inertia in the derivation of velocities from SSH

$$\mathbf{u}.\nabla\mathbf{u}+f\mathbf{k}\times\mathbf{u}=-g\nabla\eta$$

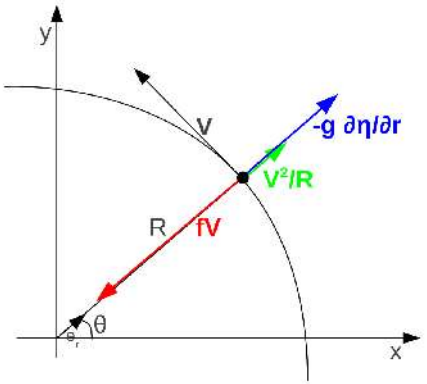
Which can be re-written as a function of geostrophic velocities:

$$\mathbf{u}-\frac{\mathbf{k}}{f}\times(\mathbf{u}.\nabla\mathbf{u})=\mathbf{u_g}$$

Three methods to derive **u**:

- Gradient wind analytical solution (Gold, 1908; Knox and Ohmann, 2006)
- Perturbation method
- Iterative method (Endlich, 1961)

- Wind gradient (assumes mostly circular structures):



$$V + \frac{V^2}{fR} = V_g$$

Solution:

$$V = \frac{2V_g}{1 \pm \sqrt{1 + 4V_g/(fR)}}$$

Needs R (computed from SSH)
Cases without solutions

- Perturbation expansion method (assumes a small Rossby number):

$$\boldsymbol{u_{per}} = \boldsymbol{u_g} + \frac{\boldsymbol{k}}{f} \times (\boldsymbol{u_g} . \nabla \boldsymbol{u_g})$$

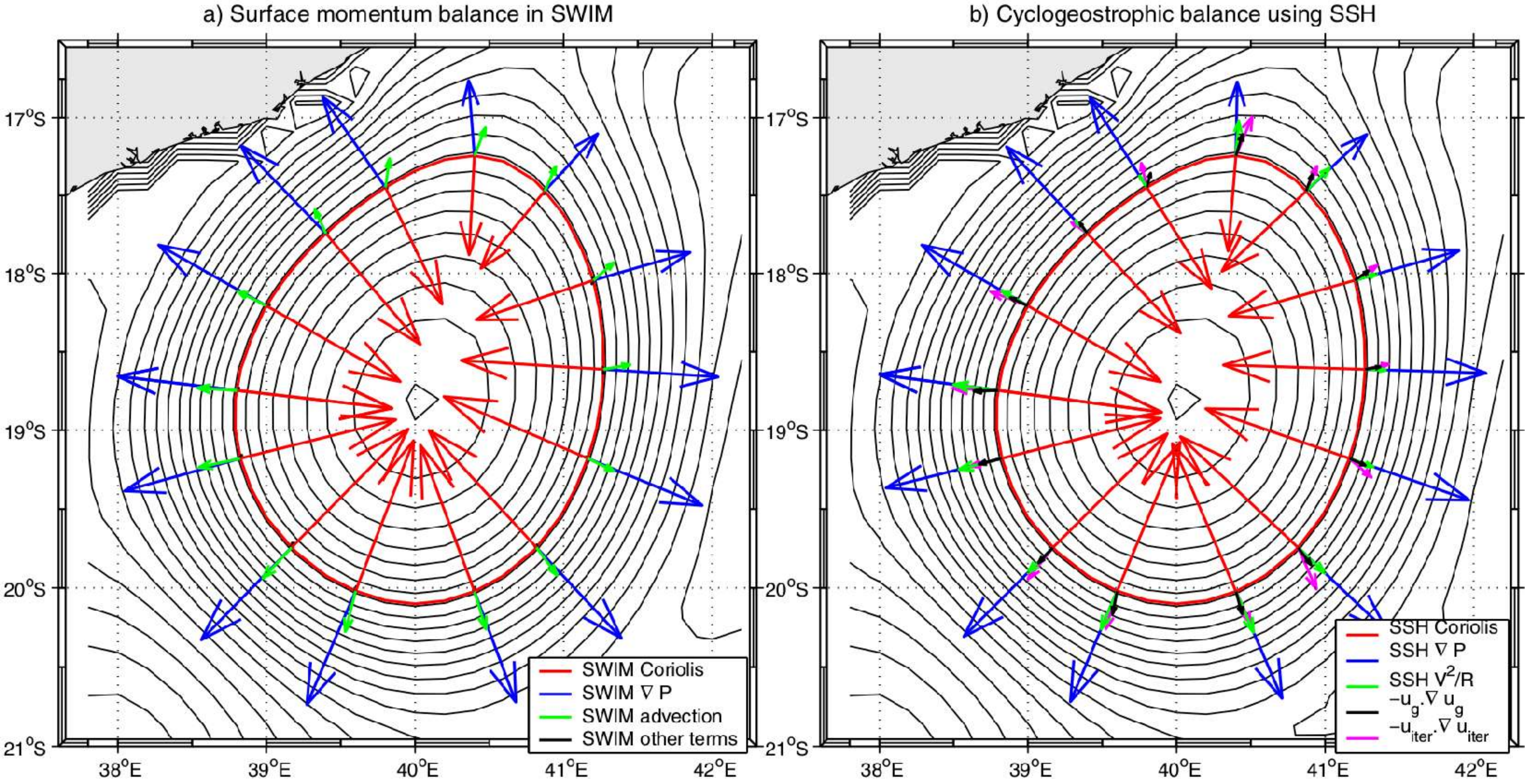
- Iterative method:

$$\boldsymbol{u}^{(n+1)} = \boldsymbol{u_g} + \frac{\boldsymbol{k}}{f} \times (\boldsymbol{u}^{(n)} . \nabla \boldsymbol{u}^{(n)})$$

Can be divergent in some places

Test in a model solution: momentum balance around a Mozambique Channel Ring

ROMS simulation of the Mozambique Channel (Halo et al., 2014)



Pertubation method underestimates the force

Iterative method picks up angles in the balance

Using model SSH to derive velocities In a Mozambique Channel Ring

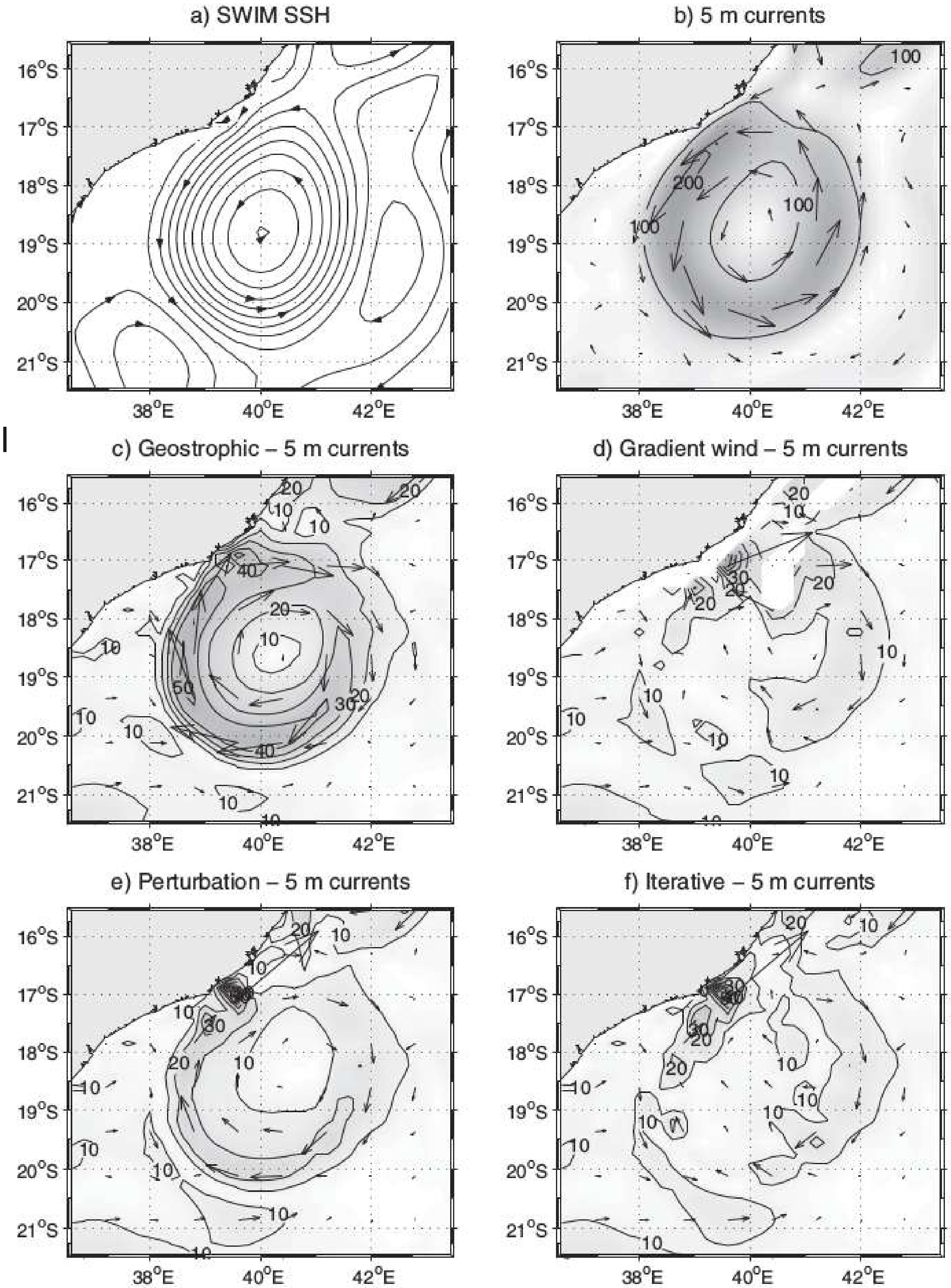
Model velocities can reach 2 m/s in the Ring.

Geostrophic velocities could underestimate model velocities by 50 cm/s (consistent with the errors observed by Thernon et al., 2014).

Errors ~ 10 cm/s for wind gradient and iterative methods.

Places with non gradient wind solution.

Ekman is not the main source of errors in Mozambique Channel Rings.



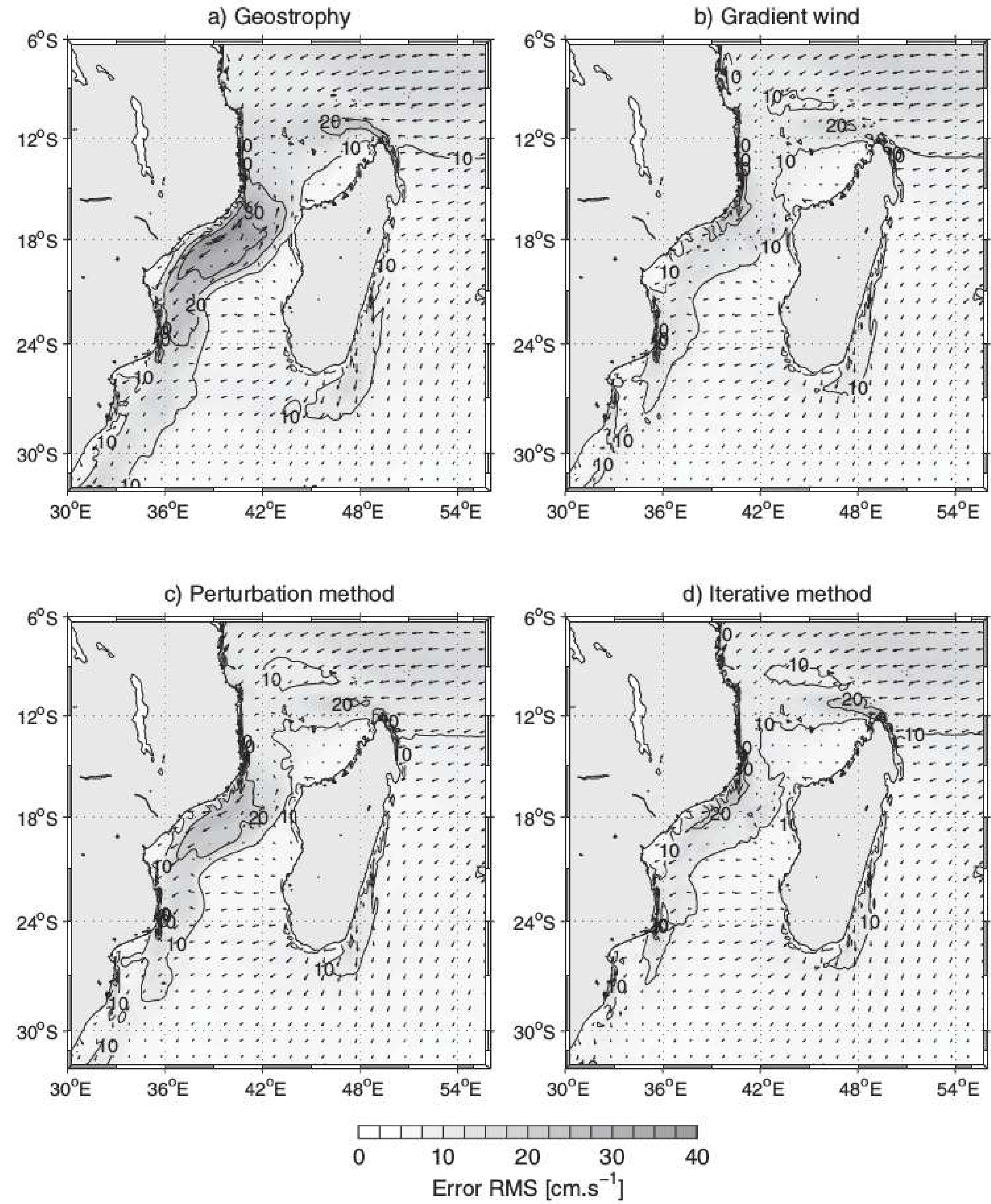
Error RMS between model velocities and velocities derived from model SSH

In the Central Mozambique Channel:

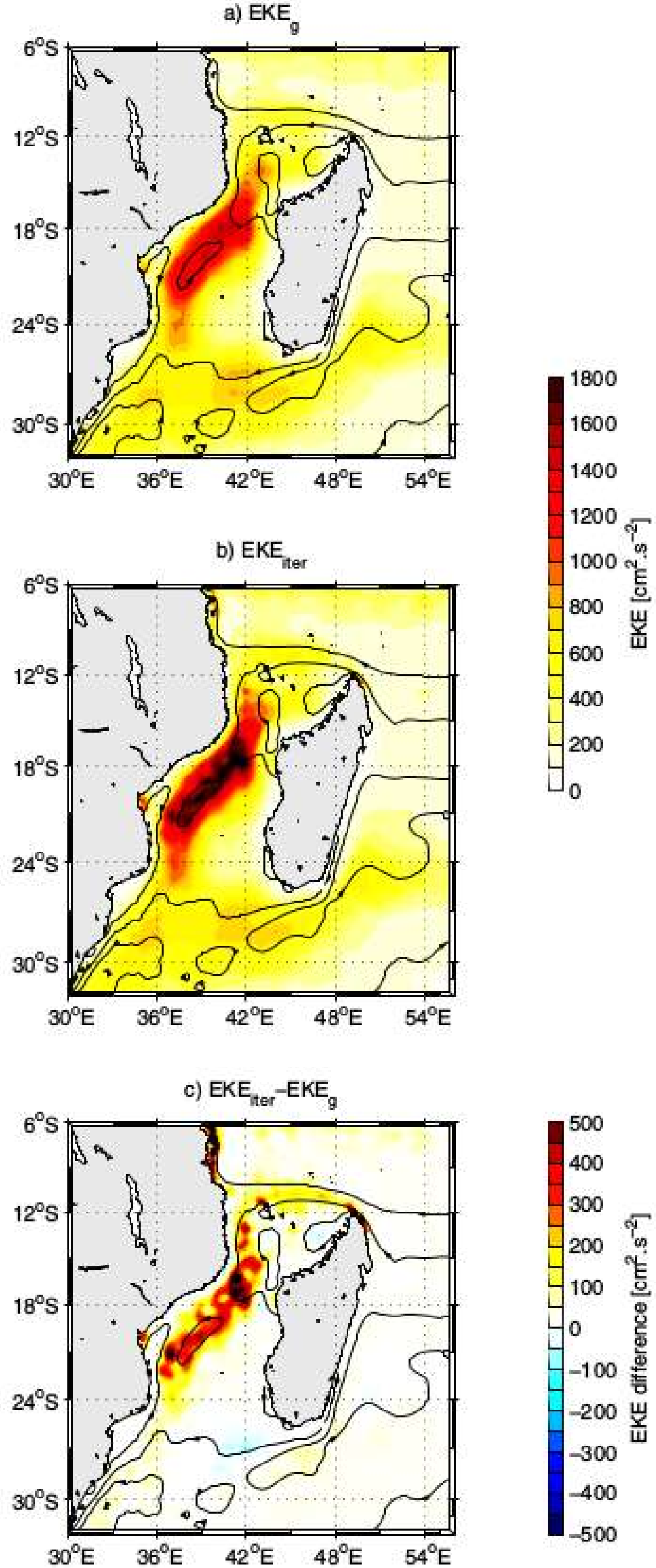
- Large errors with geostrophy

- Errors of ~10 cm/s with gradient wind and iterative methods

Ekman missing in the North



Application to gridded AVISO altimetry SSH: mean eddy kinetic energy



Difference between geostrophy and wind gradient EKE

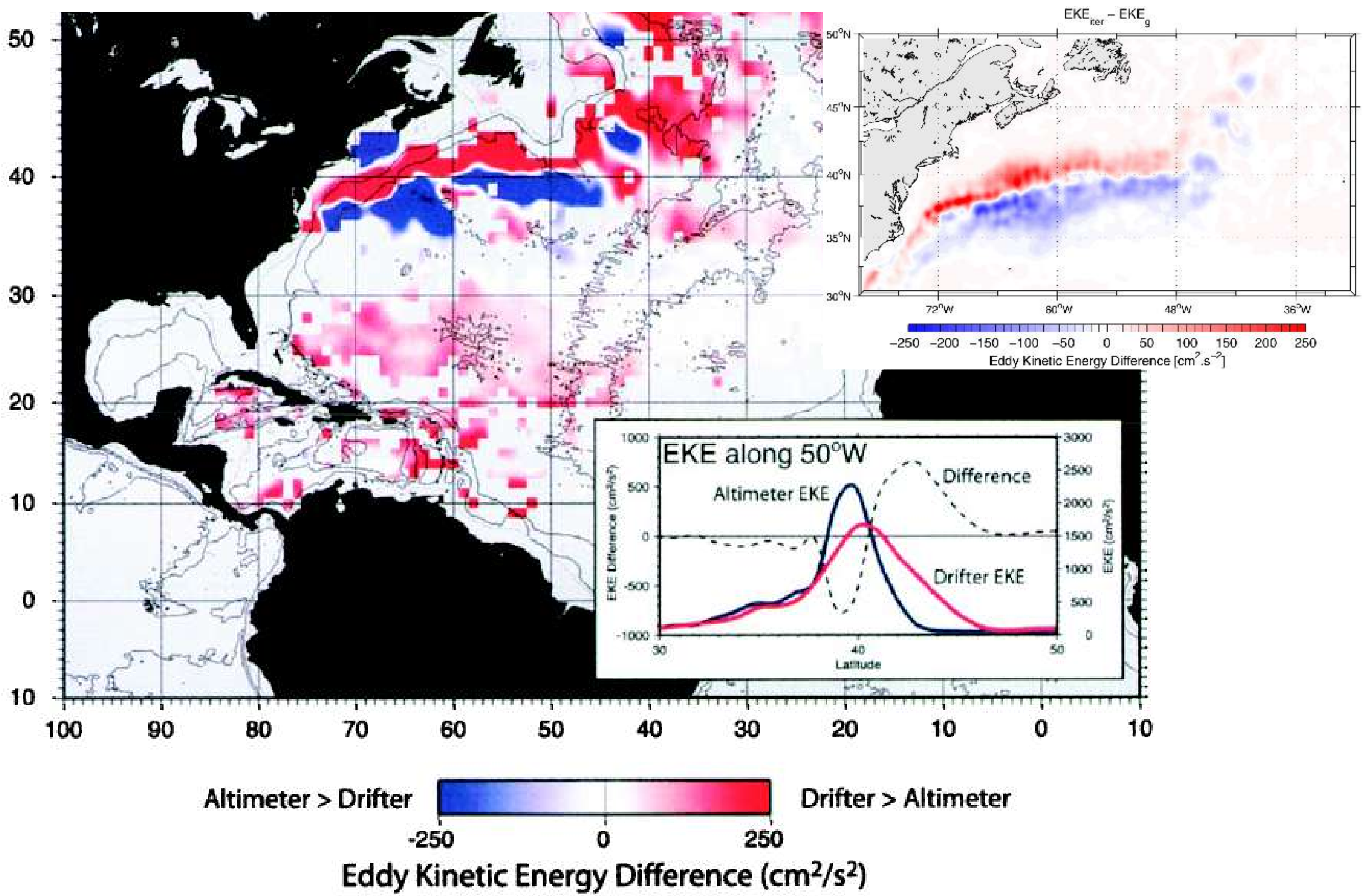
Increase of EKE (up to 500 cm^2/s^2) where Mozambique Channel Rings dominate

Slight decrease where cyclones dominates

Application to the Gulf Stream

Drifter EKE– geostrophy altimetry EKE (Fratantoni, 2001)

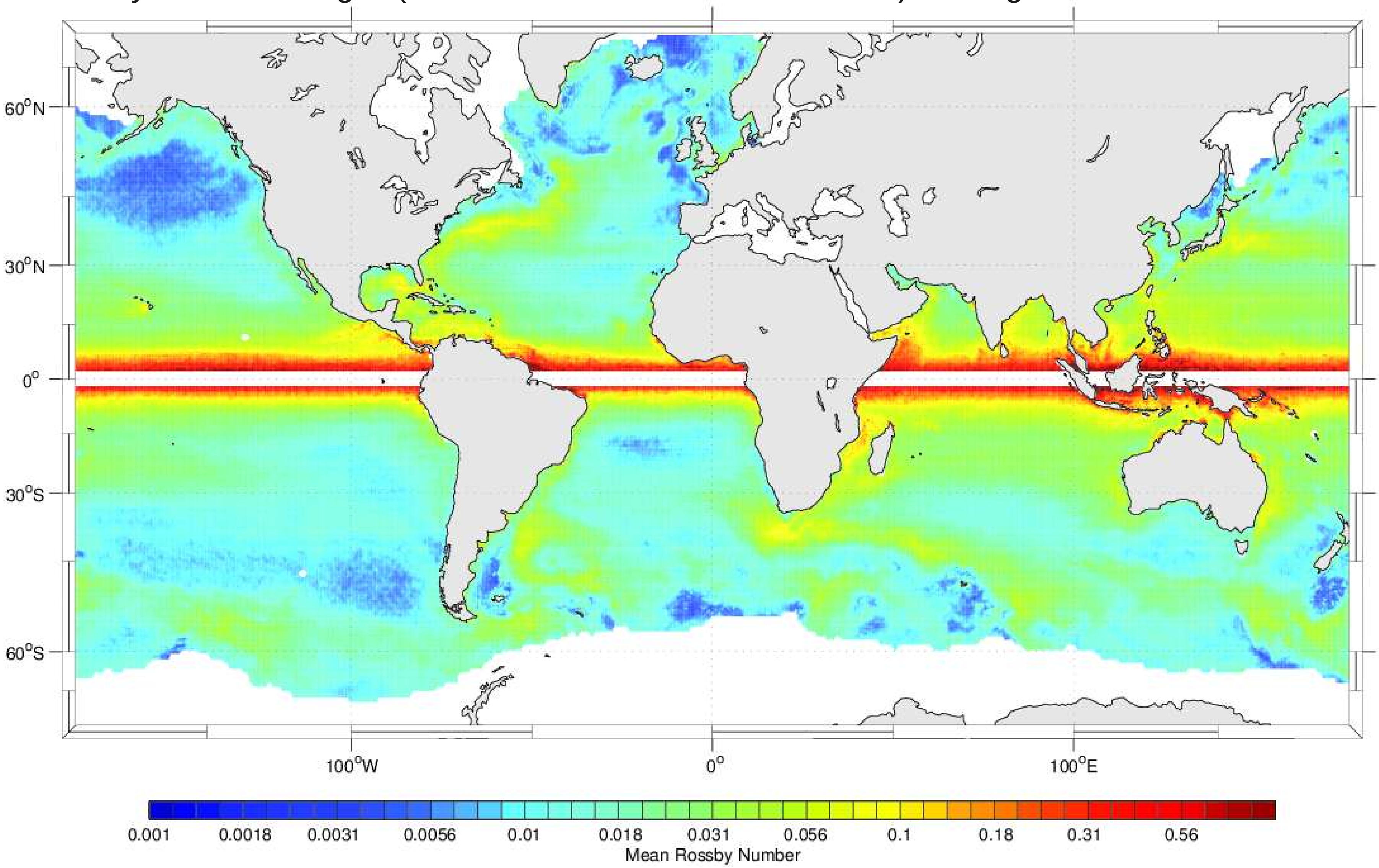
iterative method– geostrophy altimetry EKE



Confirms the hypothesis of Maximenko and Niiler (2006)

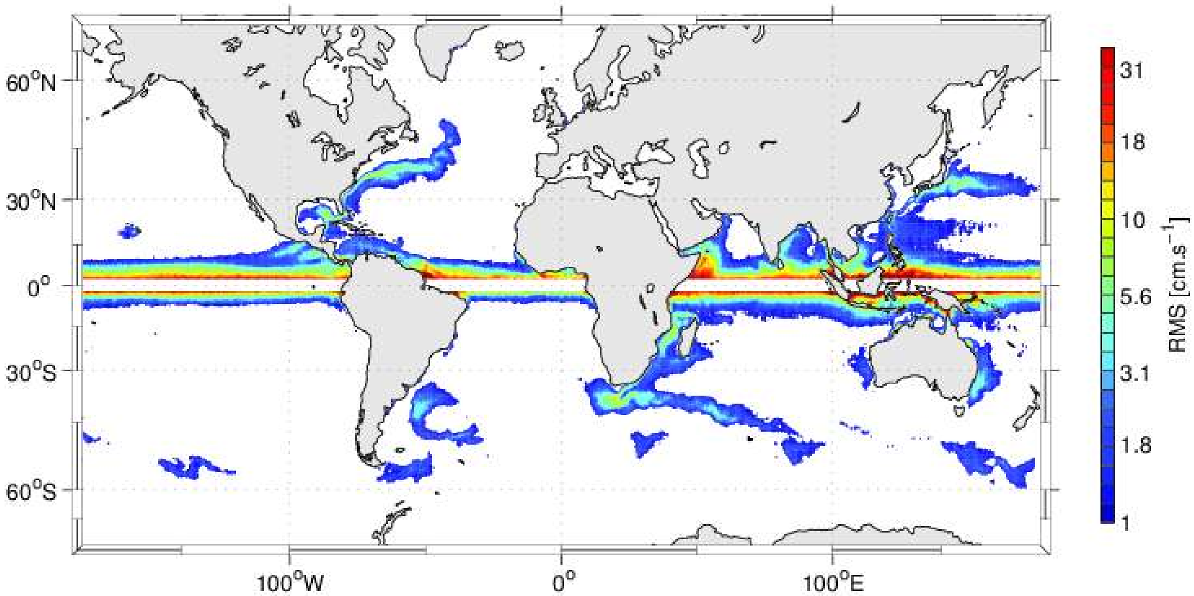
Application at global scale

Mean Rossby number using R (curvature radius seen from AVISO) as length scale:

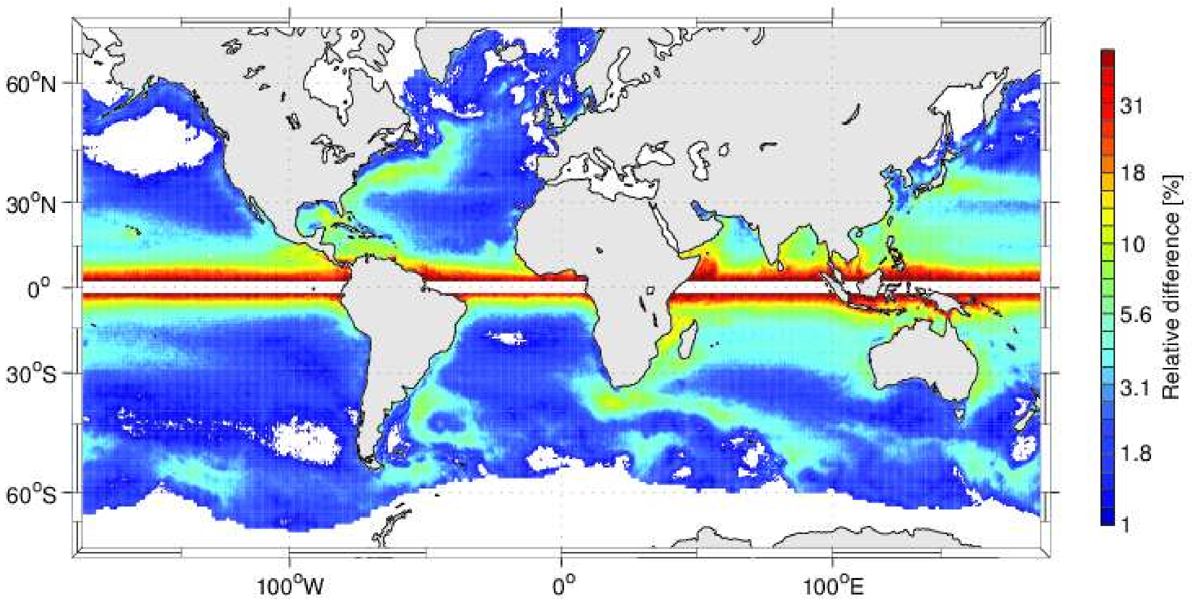


Regions where it is above 0.1: low latitudes and western boundary currents

Difference between cyclogeostrophic and geostrophic speeds



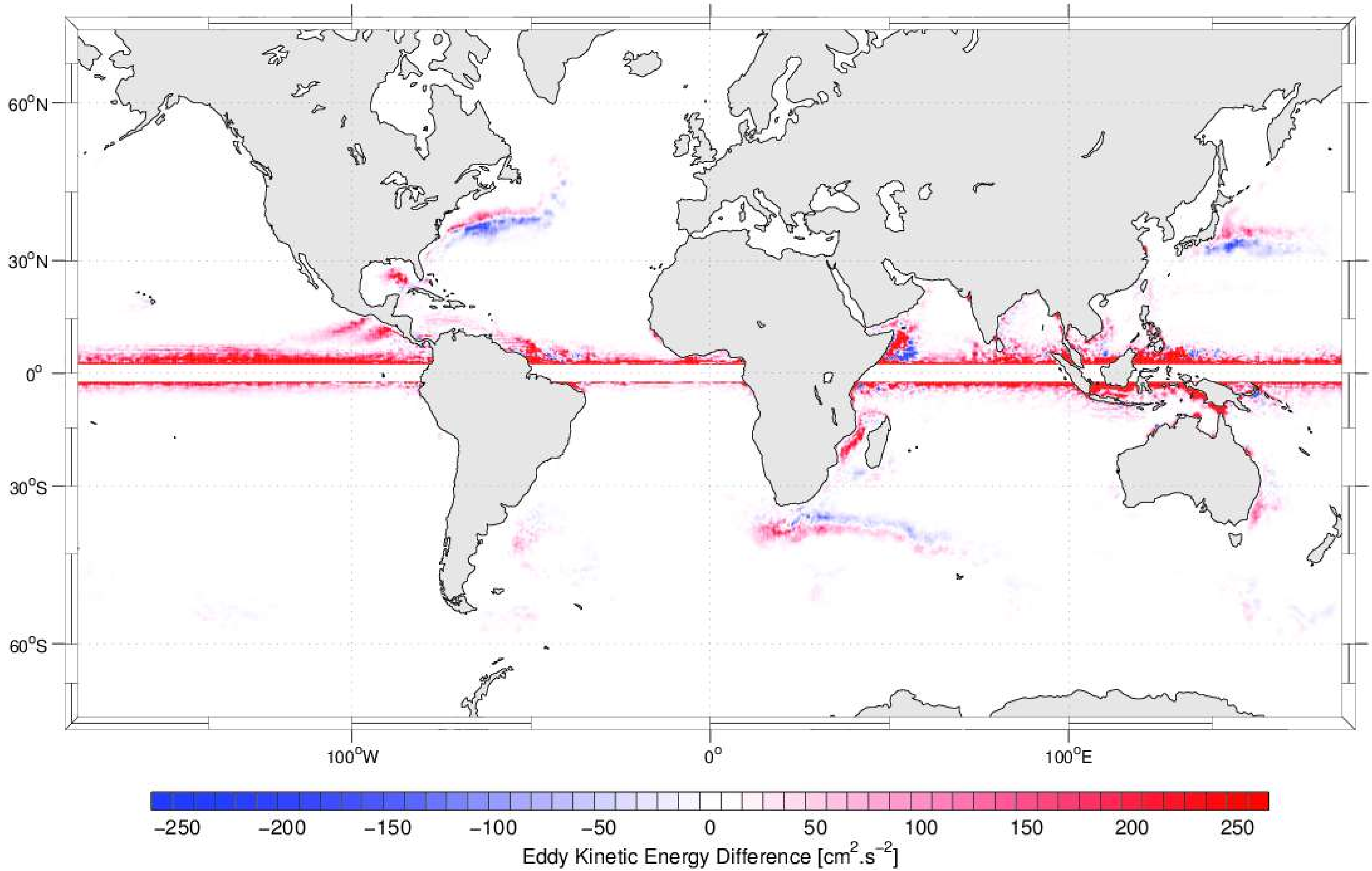
Can reach 20 – 30 cm/s



Attains 10 to 20 % of the currents where the rossby number is not small

(more than 30% in some regions)

Differences between cyclogeostrophic and geostrophic EKE



Typical negative/positive patterns in western boundary extensions currents
Signature of regions dominated by anticyclones.
Large signal in the region of the Great Whirl

Conclusion

Simple methods to add inertial effects in deriving currents from SSH

Significant impact at low latitudes and in western boundary currents

Could improve the extraction of the Ekman component

Problems when the iterative method does not converge or when the wind gradient method does not have a solution

Needs comparisons with in-situ data

Should be more critical at higher resolution