Notes on SCVs statistics

April 10, 2020

1 Deep SCVs in the Atlantic

Figures 1 to 5 are showing horizontal sections of relative vorticity at various depths. A lot of SCVs, mostly anticyclones, are visible. Their spatial distribution seems quite different depending on the depths.

We need a good identification algorithm to be able to isolate coherent vortical structures. Questions are:

- Is the Okubo-Weiss number a good criteria (following Chelton *et al.* (2007)). Or do we need to consider the angular momentum instead (following Le Vu *et al.* (2018))?
- Can we adapt py-eddy-tracker to do the work?

Then once we have a working algorithm for detection, objectives will be to :

- compute the number of vortices (or the probability of presence) as a function of lon, lat, depth, isopycnal.
- compute SCV's parameters: radius, thickness, stratification (N), Rossby number, Richardson number, etc.
- Associate the vertical T/S profiles with the cyclones/anticyclones to check if we will be able to detect them using the argo dataset.
- Add the tracking to be able to understand the life-cycle of the SCVs.

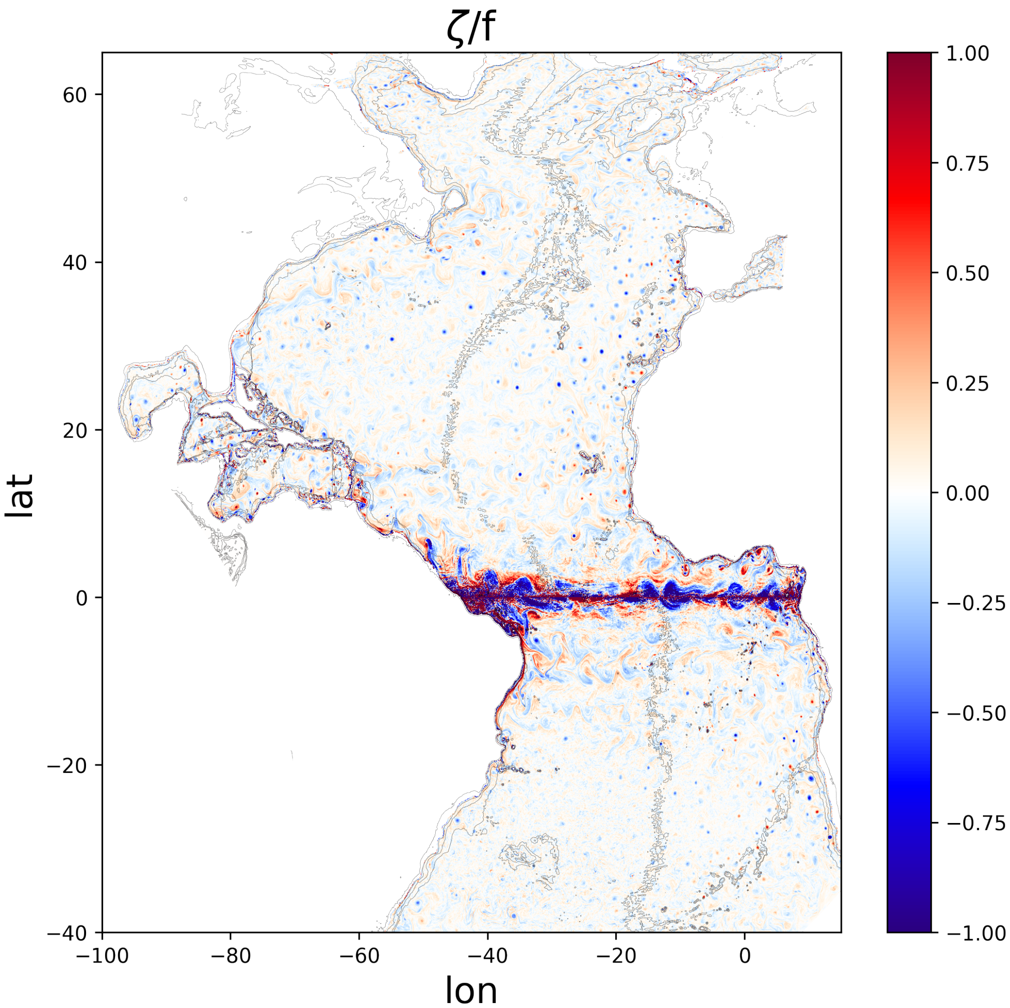

Figure 1: vorticity at 500 m depth

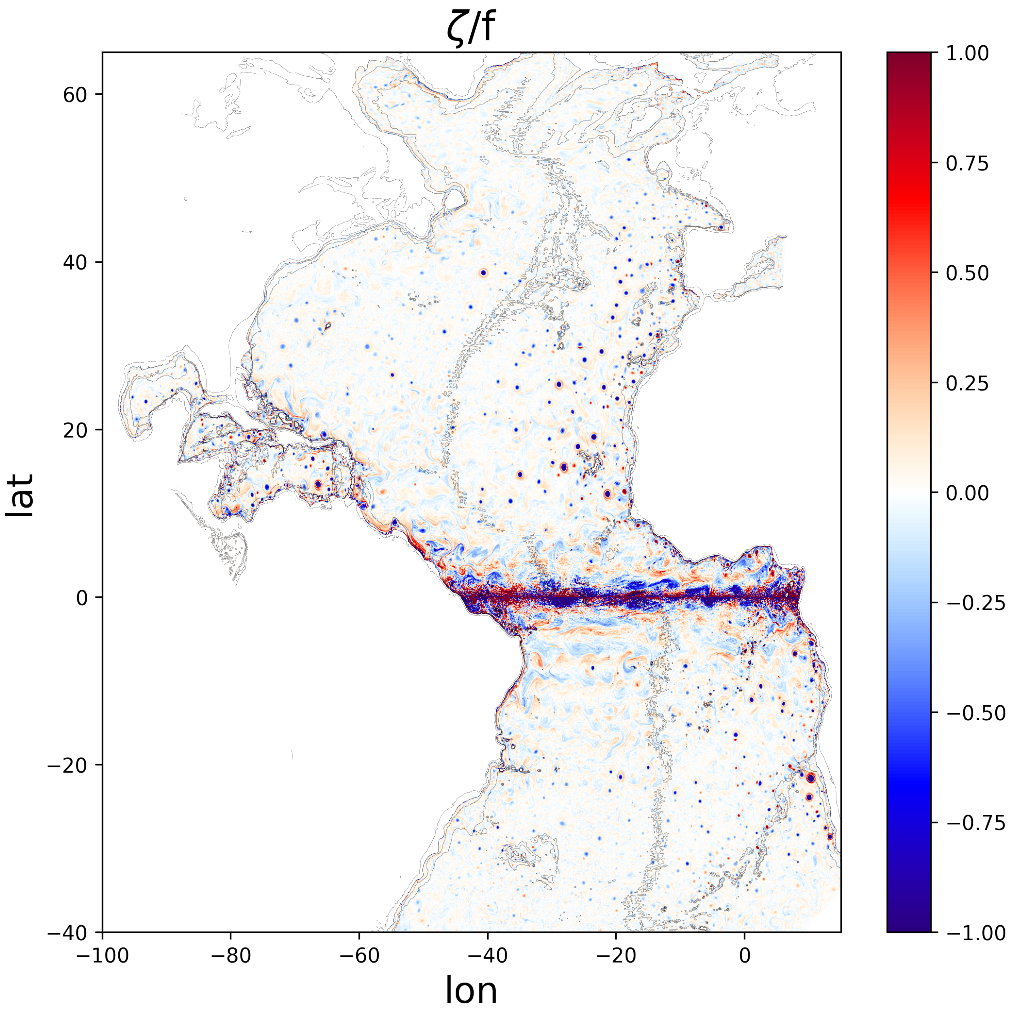

Figure 2: vorticity at 1000 m depth

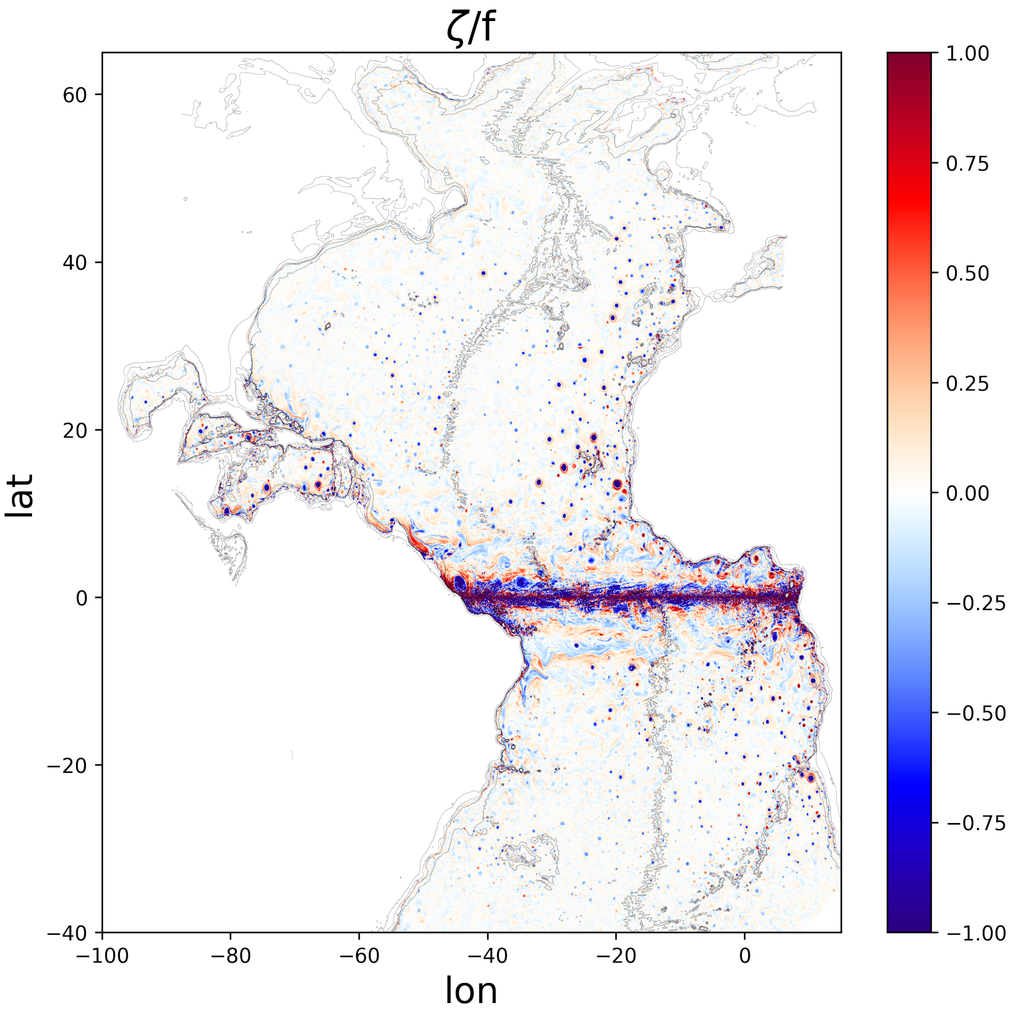

Figure 3: vorticity at 1500 m depth

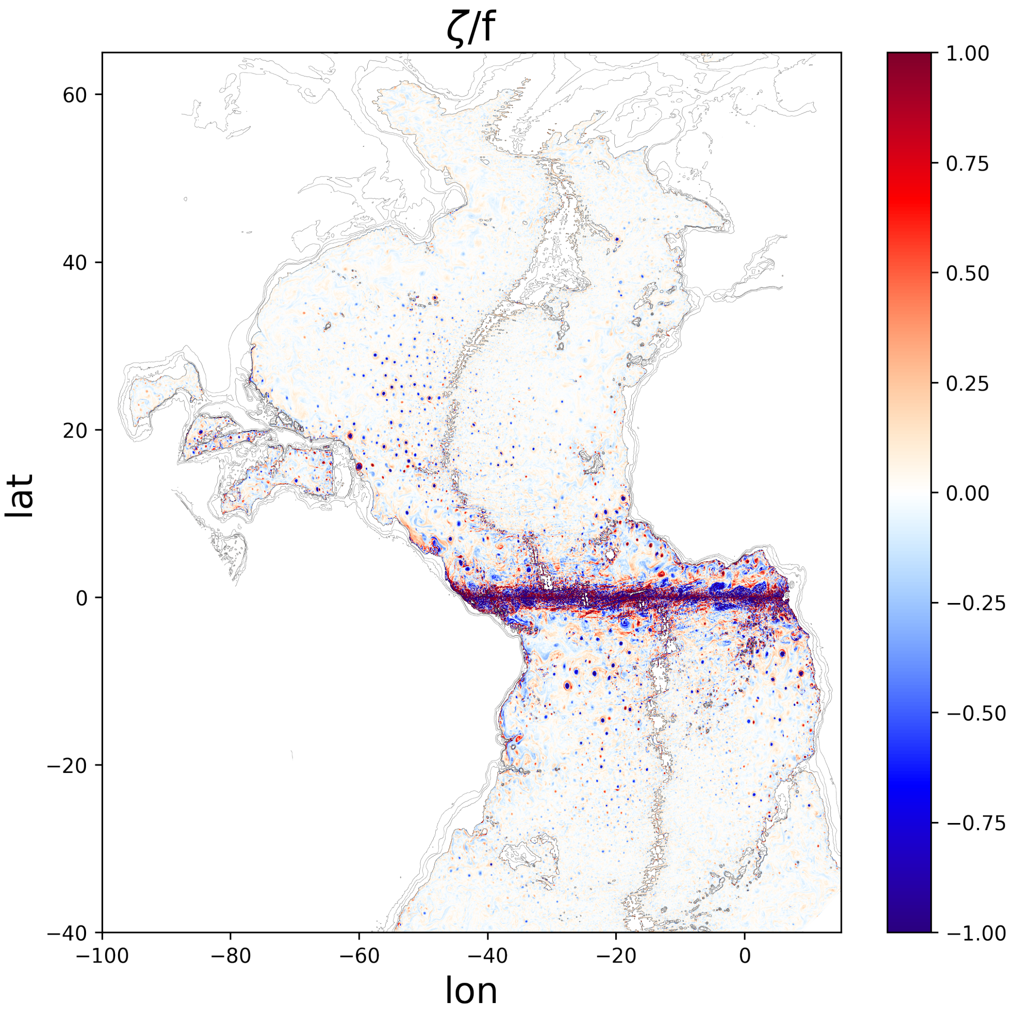

Figure 4: vorticity at 3000 m depth

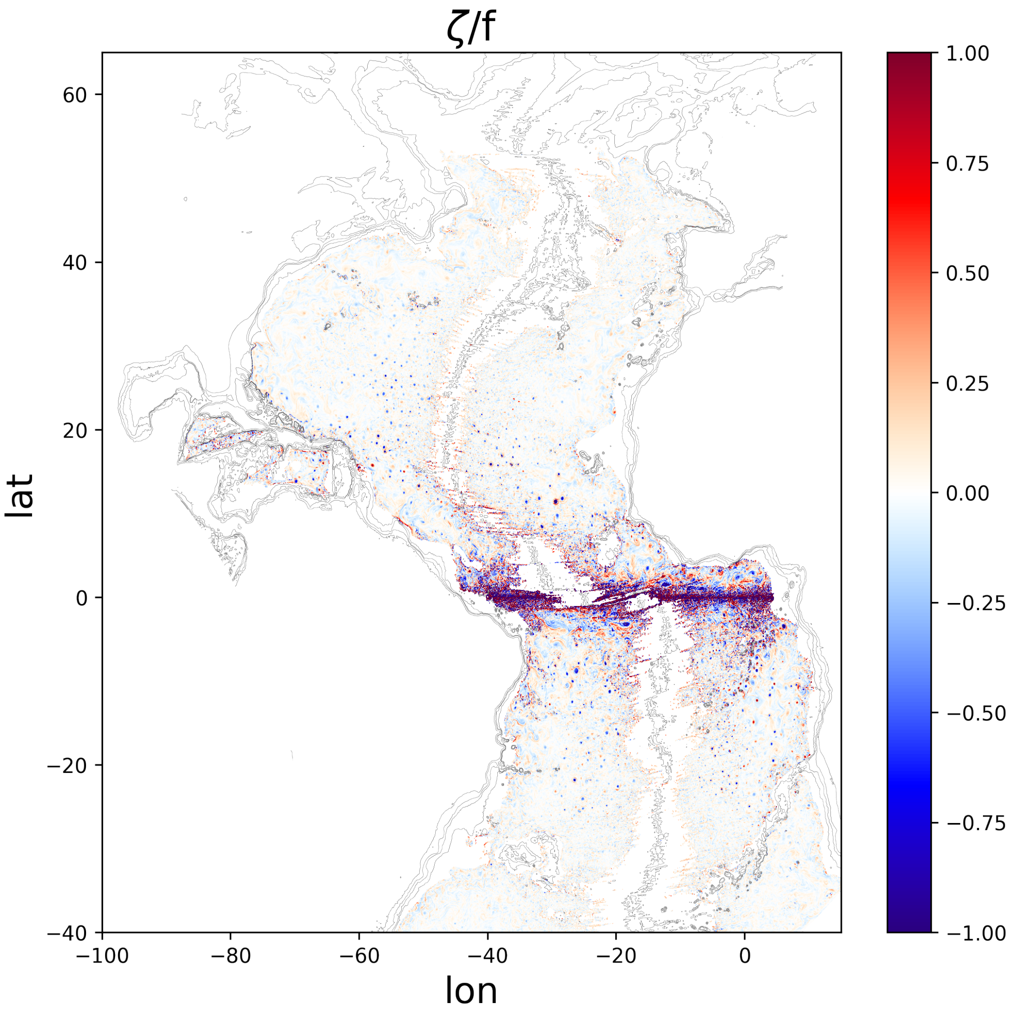

Figure 5: vorticity at 4000 m depth

2 Evaluating a few parameters for deep SCVs in the Atlantic

Important parameters to study the stability of the flow, and in particular vortices are:

- the gradient Rossby number:

$$Ro = \frac{\zeta}{f}$$

- the gradient Richardson number:

$$Ri = \frac{N^2}{|\partial_z u|^2}$$

with ζ the vertical component of relative vorticity, f the Coriolis parameter, $N^2 = \partial_z b$ the vertical stratification, and $\partial_z u$ the vertical velocity shear.

The classical condition for instability for a front in thermal wind balance as derived by Hoskins (1974) can be written:

$$1 + Ro - Ri^{-1} < 0$$

Following Christian's work, in the presence of *curvature*, *i.e.,* when taking into account this criteria may be rewritten as:

$$1 + Ro - (1 + Cu)Ri^{-1} < 0$$

with the Curvature number $Cu = \frac{2v}{fr}$, where v is the azimuthal velocity and r the radius.

For a true axisymmetric vortex the criteria even becomes

$$(1 + Cu)(1 + Ro) - (1 + Cu)^2 Ri^{-1} < 0$$

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2.1 Some examples

Figures 6 and 7 are showing the values of Ro and Ri as well as PV at 1000 m depth from a 3 km simulation over the western subtropical gyre and a zoom over one specific very intense anticyclone. We are not able to compute Cu yet as it requires knowledge of the vortex center (once the detection algorithm is working, that will be easy to do).

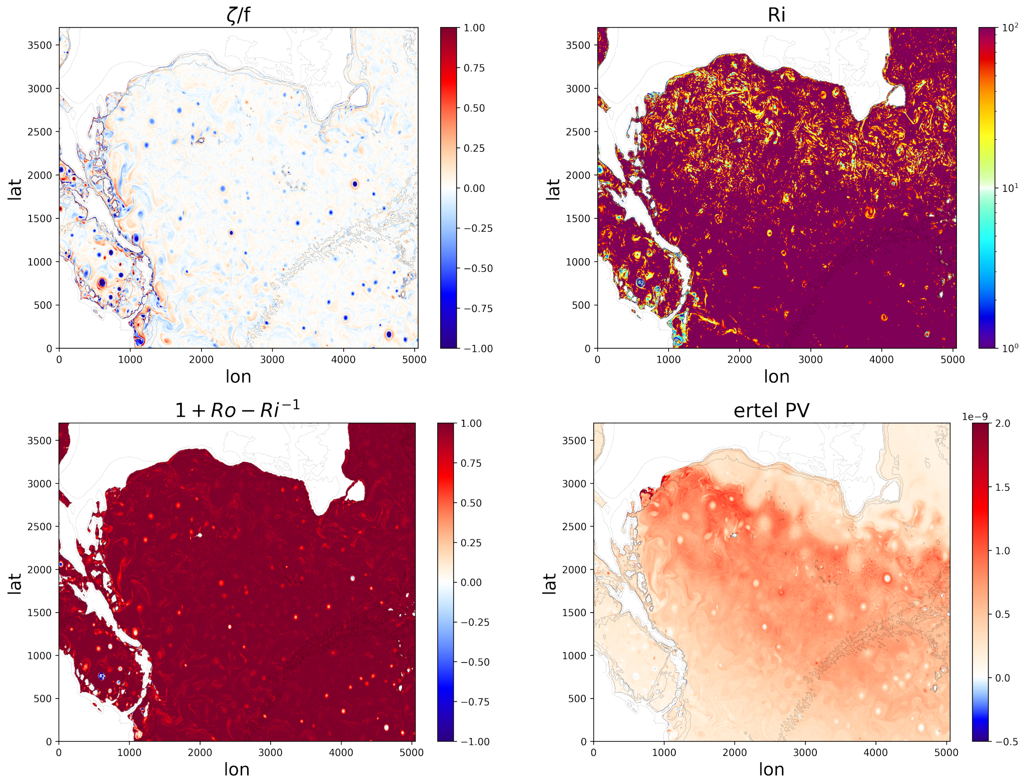

Figure 6: (a) Rossby Number, (b) Richardson Number, (c) Rayleigh's PV $1 + Ro - Ri^{-1}$, and full ertel PV at 1000 m depth from GIGATL3 zoomed over the western part of the subtropical gyre.

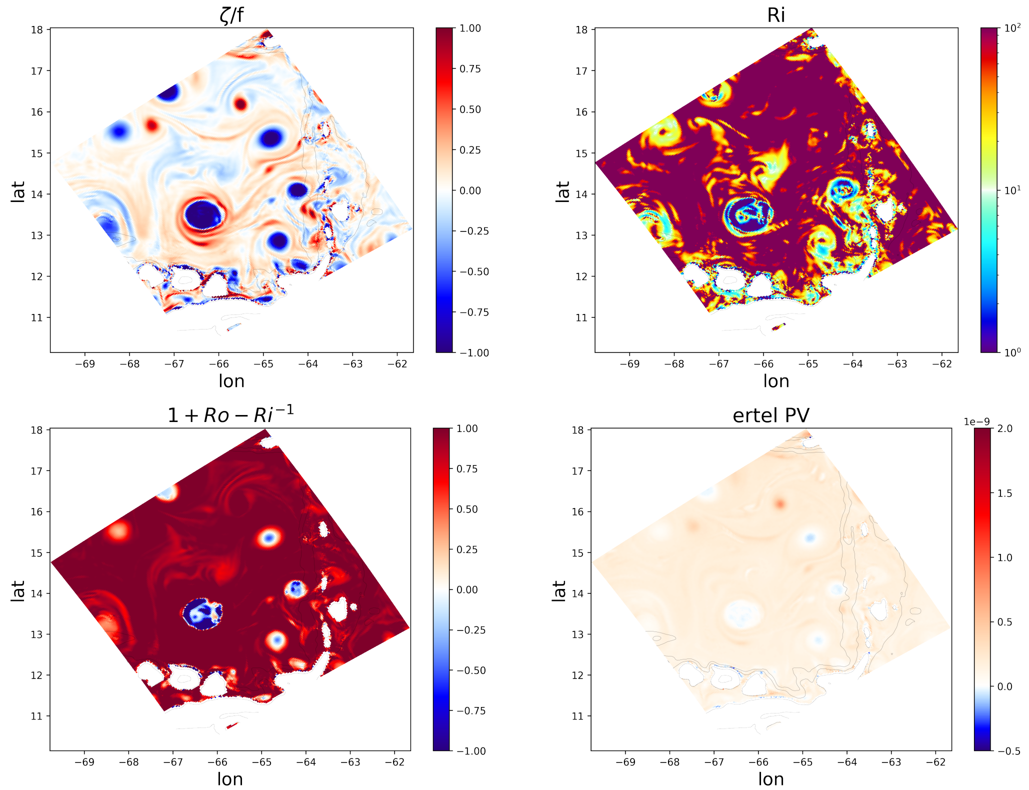

Figure 7: Zoom of Fig. 6.

2.2 Some statistics

We look globally at the statistics of some parameters (Ri,N for now) for cyclones and anticyclones.

Below are example of statistics at various depths for a snapshot of GIGATL3. They include horizontal sections of vorticity as well as distributions of Ri, N/f and $1 + Ro - Ri^{-1}$ for the full domain (minus the equatorial region), and only for "anticyclones" and "cyclones" here crudely defined as points with $Ro < -0.5$ and $Ro > 0.5$, respectively.

References

Chelton, Dudley B., Schlax, Michael G., Samelson, Roger M. & de Szoeke, Roland A. 2007 Global observations of large oceanic eddies. *Geophys. Res. Lett.* **34** (15).

Hoskins, B. J. 1974 The role of potential vorticity in symmetric stability and instability. *Q.J.R. Meteorol. Soc.* **100**, 480–482.

Le Vu, Briac, Stegner, Alexandre & Arsouze, Thomas 2018 Angular momentum eddy detection and tracking algorithm (ameda) and its application to coastal eddy formation. *Journal of Atmospheric and Oceanic Technology* **35** (4), 739–762.

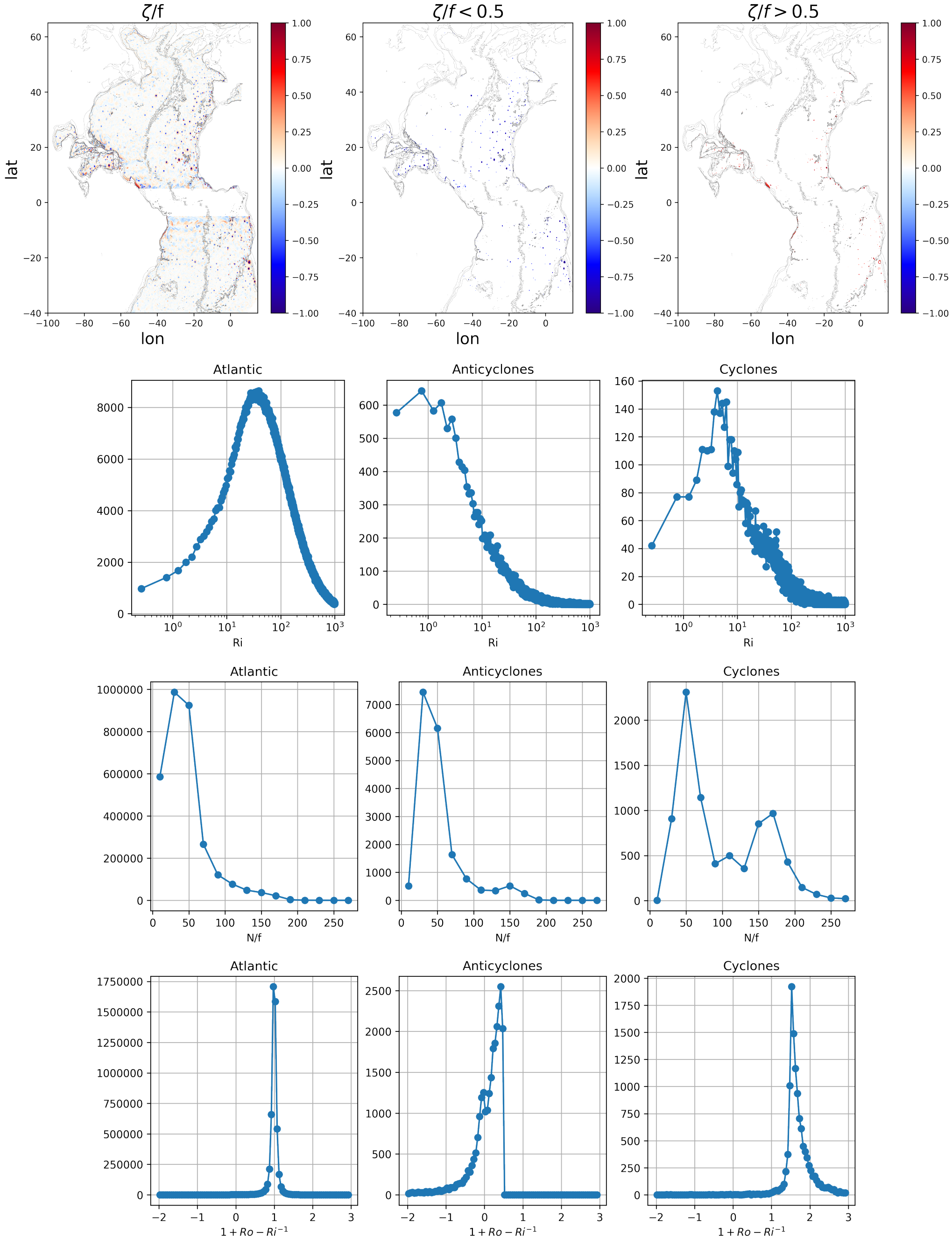

Figure 8: Statistics at 1000 m depth

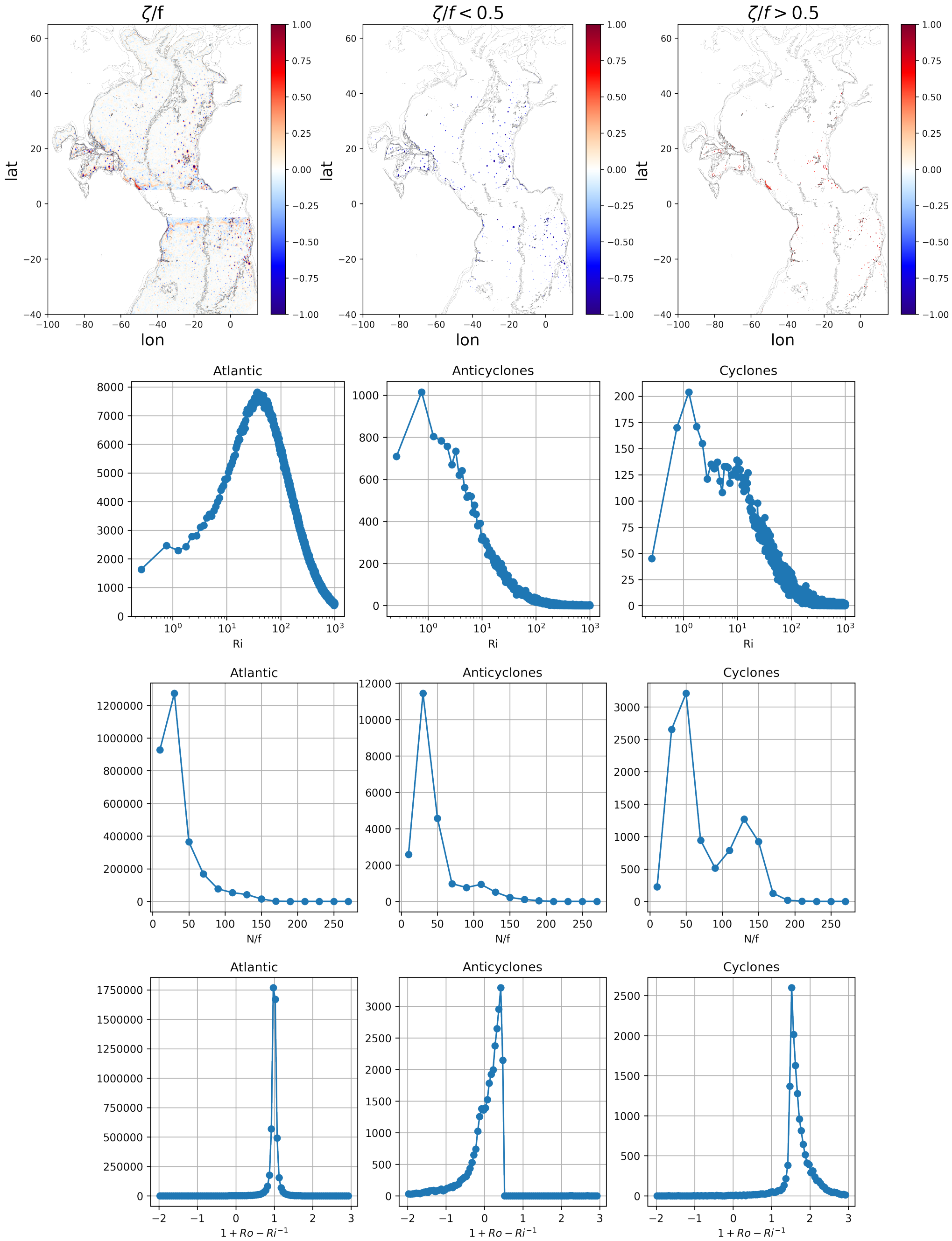

Figure 9: Statistics at 1500 m depth

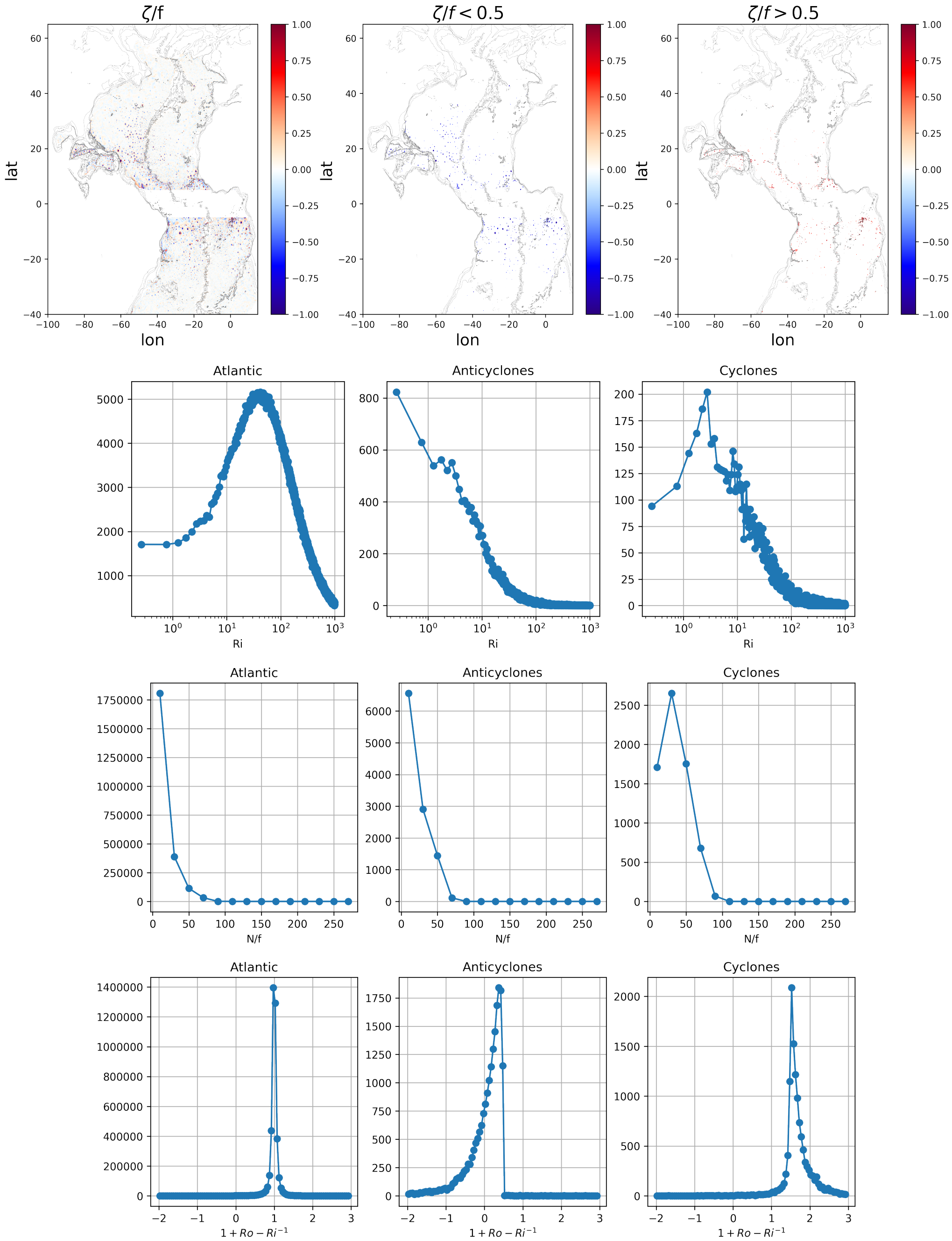

Figure 10: Statistics at 3000 m depth

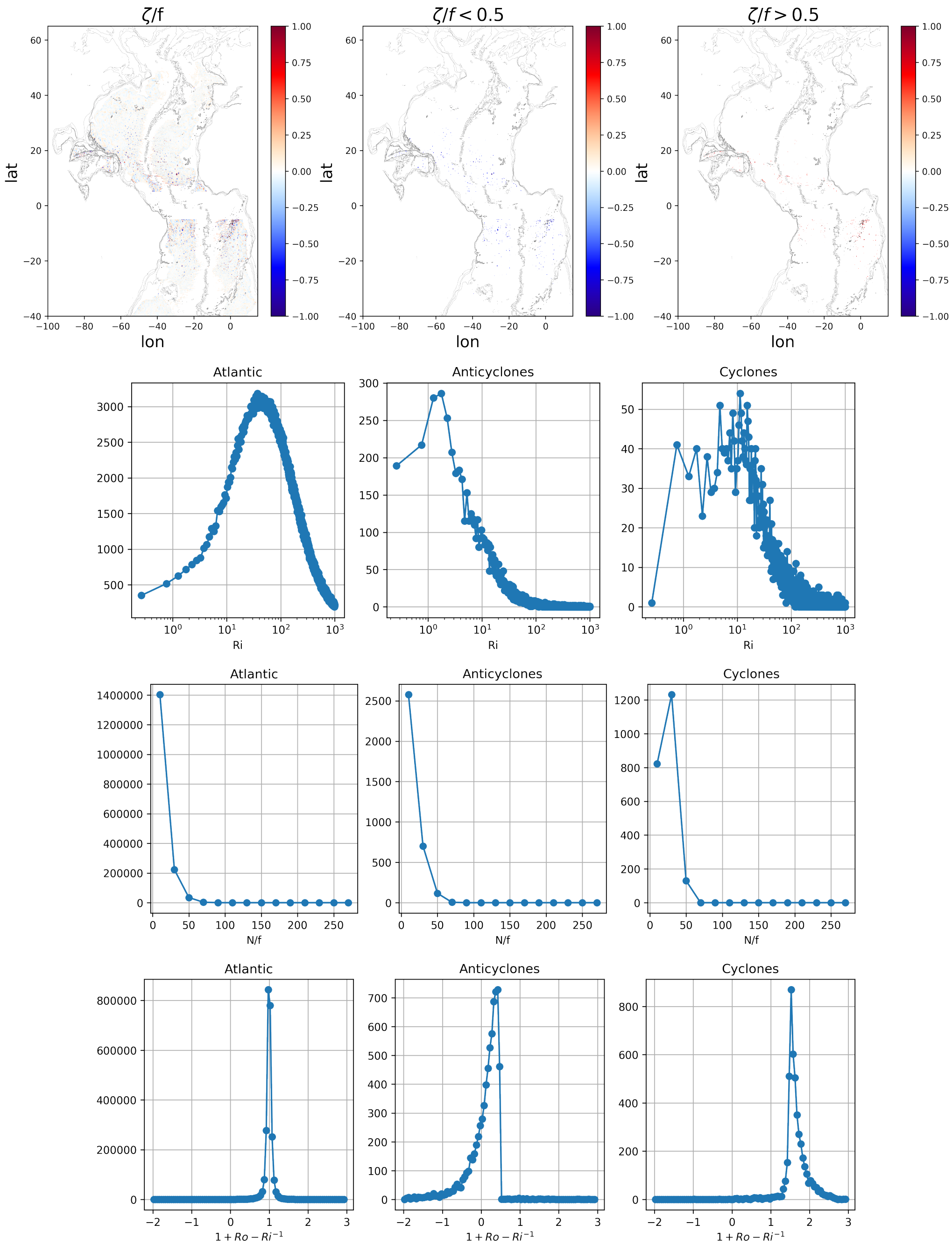

Figure 11: Statistics at 4000 m depth