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Interactive comment on "Rotation of floating particles in submesoscale cyclonic and anticyclonic eddies: a model study for the southeastern Baltic Sea" *by* Victor Zhurbas et al.

Anonymous Referee #1

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Summary

The authors use numerically derived Lagrangian trajectories and rotary statistics to understand the prevalence of distinguishable submesoscale cyclonic over anticyclonic spirals observed in tracer fields. The authors build on previous studies suggesting horizontal shear or mixed layer baroclinic instabilities wind pre-existing linear features of the tracer field that collect particles (e.g. fronts), into predominantly cyclonic spirals. The goal of this paper is to compare the rotary characteristics of cyclonic to anticyclonic spirals to provide an alternative explanation on the prevalence of cyclonic spirals in tracer fields that does not depend on the presence of linear features in the tracer field.

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Discussion paper

The authors find that both uniform and linear tracer initial conditions for Lagrangian particle releases can produce more distinct cyclonic than anticyclonic spirals in the tracer field on the order of a day, and that this is due to cyclonic spirals having larger central angular velocities, enhanced differential rotation, and negative helicity which draws material towards the center of the spiral. This is in contrast to anticyclonic spirals which take longer to develop, have smaller differential rotation, and push material away from their centers which makes them less visible in satellite imagery.

This paper is a valuable addition to existing literature, and I recommend acceptance with minor revisions. While I do not believe any new simulations etc are needed, the manuscript should expand significantly on the results and discussion sections as well as clarify several aspects of the manuscript noted below.

General Comments

- The abstract could use rephrasing. As written it appears that generally it's accepted that the rotary characteristics are between cyclonic and anticyclonic eddies are different, and this paper seeks to confirm that. However, in the introduction the authors do point out that their approach is different than most previous work, and this should be highlighted in the abstract. In addition the last sentence of the abstract should be written more clearly to define the three characteristics measured. The way it is worded it was hard to follow until after reading the manuscript itself. Perhaps a numbered list or commas would clarify.

- The introduction could be made stronger by including the importance of these cyclonic spirals alongside underpinning the mechanisms for their prevalence. A good deal of space is dedicated to describing their existence and previous mechanisms of formation, but not much is provided to describe the relevance. For example, what are the biological impacts given that cyanobacteria trace eddies

out so well or are there implications for eddy tracking with tracer fields? It would also be helpful to include the distinction between helicity and vorticity here, and what they tell you about a flow (e.g. for the helicity, line 170). The differential rotation parameter could also use a descriptive sentence. This will help the reader understand why you have chosen these particular aspects to compare, as well as connect to the mathematical descriptions provided later. Lastly a more thorough literature review is needed with respect to others investigating the impacts on tracer fields in anticyclonic and cyclonic eddies. For example Brannigan 2016 or Brannigan et al 2017.

- The manuscript should more clearly state that the authors are not seeking to explain the skewed tails of the vorticity distribution, only the dominance of the cyclonic spirals seen in tracer fields from satellite images. The previous studies cited provide the mechanisms favoring cyclonic spirals, and also explain why tracers highlight them over anticyclonic spirals. However in this manuscript, although Line 65 does a good job highlighting the objectives, throughout the remaining text the wording leaves it somewhat ambiguous what the authors exact intentions are with respect to both aspects of the problem. For example in the abstract and elsewhere using 'formation of spirals' is slightly misleading since the spirals are already there with respect to the velocity field. Perhaps including references to the tracer field when using this description would help clarify.

- Section 2.2 could be clarified more, specifically the rotary parameters. These should be connected to the introduction as well to give the reader intuition into the authors interpretations of them. Is $\delta r = r_2 - r_1$? This would help clarify the sign dependence of Helicity. How is $\omega(0)$, the vorticity at the center of the spiral, diagnosed here given that particles presumably tend towards stationary at the exact center? A more precise definition is needed. Does this model have the resolution to produce such results?

- The Lagrangian particle simulations and the comparison of gridded to linearly seeded particles to understand the spiral formation should be expanded on. Can you provide justification for using surface constrained particles to understand a 3D tracer field. Do you have an idea of which mechanism for creating cyclonic spirals is most prevalent? That is submesoscale fronts are ubiquitous, what percentage of spirals tends to come from advection of particles into a strong eddy field versus reshaping of linear tracer features?

- Do you think a seasonal pattern could be isolated using these methods? For example, with an intense eddy field in winter perhaps the differences between cyclonic and anticyclonic statistics are more prominent.

- The tables should be moved to an appendix. Figure 8 should be described more thoroughly as it is the most compelling evidence in support of the hypothesis. Are the confidence intervals based on the three days of model output combined into one and are they from bootstrapping or some other method? It would be helpful to explain how these days are included. Additionally why did you choose these snapshots? Do other snapshots show similar statistics?

- The conclusion should include a paragraph at the end with a summary and the thesis of the paper reiterated.

Specific Comments

- What are the minimum and maximum vertical resolutions? Does this adequately resolve the helicity?

- D'Asaro 2019 might be a good reference to include as an in-situ observational compliment.

- Please fully write out dates so there is no ambiguity between Europe and the U.S. etc. For example, the way the date is presented in the caption of Figure 4 is ideal.
- Can you describe the physical intuition for the rotary characteristics of the spirals? For example why does it physically make sense that cyclonic eddies would spin faster?
- **Section 2.1** - Please include the method used to interpolate the topography and initial conditions etc.
- **Line Number 158** - Should this be $|He| << 1$? Why does this assumption mean you can write out the helicity with your given formula? Is this what you actually use to calculate Hel or that given in (3)?
- **Line Number 220** - It is not clear why this would be a validation of the model.

Technical Comments

- **Line Number 59** - "One may expect that the spirals could also be generated." Does this expectation come from observations? Please state your motivation.
- **Line Number 65** - Perhaps: "The objective of this work is to understand the dominance of observed cyclonic spirals by assessing differences between floating particles' rotation in submesoscale cyclonic and anticylonic spirals using high resolution modelling of the Baltic Sea."
- **Line Number 71** - The word 'fabulous' seems out of place here. Perhaps "The most illustrative optical images...' would work instead.
- **Line Number 75** - "eddies, which will be investigated..."

- **Line Number 150** - Please specify that the relation is for the vertical vorticity.
- **Line Number 171** - Change 'It can be seen easily' to just "Large values of Dif...'
- **Line Number 180** - This paragraph could be worded more clearly. Specifically, ' we utilized' instead of 'we addressed'.