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Ocean Science Discussions

Interactive comment on "The multifractal structure of satellite sea surface temperature maps can be used to obtain global maps of streamlines" *by* A. Turiel et al.

A. Turiel et al.

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Reply to comments by Referee 1:

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General answer:

We work to produce a revised version of the paper, in which the novelty of the work here presented will be more evidenced. Notice that, for the first time, we show that singularity exponents obtained from singularity exponents of sea surface scalars are effectively advected by the flow. So far we had only partial evidence of this, mainly due to the lack of well-resolved synoptic maps of streamfunctions: present day altimetry maps have medium spatial resolution and a rough time resolution (of about 10 days), not enough to prove that singularities are advected. With SURCOUF products, derived from four altimeters, we can have a good enough spatial and (mainly) improved time resolution in order to assess this property. We will put this in valor, making clearer which parts are really new. And we will explicit that figure 1 is from previous papers, with permission.

Answer to the precise comments:

1.- Precisely in the spirit that the concepts are not familiar to oceanographers we have given an extensive introduction with some basic concepts; we agree in clearly stating what is new and what is known in the next version of the paper.

Notice that nowhere in the abstract we say that anything is done for the first time. By the end of the Introduction, we claim that we present the first evidence that singularity lines are actual streamlines, something that so far we had just conjectured (Turiel et al, PRL 2005; Isern-Fontanet et al, JGR 2005) or about what we had obtained some indirect evidence compatible with this (e.g. Turiel et al., RSE 2008, our reference Turiel 2008a). Figure 1 in our manuscript is just an overview of what the technique gives on global maps and certainly it is identical to panels in figures 2 and 3 of Turiel 2008a. On the contrary, Figure 2 in our manuscript is conceptually very different from Figure 8 in Turiel 2008a, as we will explain later.

There are two main results in the paper. One is, as pointed by the reviewer, the validation of singularity isolines as actual streamlines; the other is the validation of SURCOUF altimetry products by itself. That is, as we have no perfect synoptic measurement of SSH at a daily basis the only kind of validation we can do is reciprocal validation: if both singularity isolines and SURCOUF SSH isolines correspond, this should be due to the fact that they both trace the streamlines of the flow.

In fact the major question raised by the reviewer concerns the originality of the paper. We think that the reviewer has missed an essential point, that we will try to improve

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in a further version of the paper: there was no way to validate if singularity lines are streamlines, because up to date there is no altimetry map obtained at a daily basis. We have taken profit of a particular altimetry product generated by CLS, SURCOUF SSH maps, which could be generated in a short period extending since 2002 to 2003 in which four satellite altimeters were available. This allowed to generate daily SSH maps with good enough quality to allow comparison with our technique. All past comparisons were very rudimentary due to the inherent lack of accuracy of present altimetry maps, to the point that in Turiel 2008a we used SLA instead of SSH to avoid the problems with the reference ellipsoid. Using SLA implies to study only very energetic areas in which frontogenesis and eddy emission is intense, because the obtaining of SLA removes the stationary part of SSH signal. In addition, SLA maps we have used in the past are sampled at a 10-day basis, which implies to neglect a significant part of the actual dynamics (we have seen with our technique that in three days velocity maps can have a sensible modification). In contrast, in this paper we use SURCOUF data produced at a daily basis and with a better determination of the reference ellipsoid, so we have study the complete streamlines and not only at the most active areas (although we still have that at those most active areas the quality of altimetry record is better).

2.- It is not so evident that material derivatives should be noiser than advective ones as we do not take two finite differences to evaluate material derivatives, just one. As explained in Appendix B, and due to the fact that velocity grid does not coincide with singularity grid, in order to evaluate the derivatives we let each point to evolve, so computing its one-day trajectory. To evaluate both derivatives the difference between the (interpolated) signal at the end point and at the initial point are taken, the only difference is that for advective derivatives the initial and final scalar maps are the same, while for material derivatives the final scalar map is that of a day after the initial scalar map. Notice that in the case of SST difference between material and advective derivatives are too large to be attributed to noise. In the case of singularities, the difference between both types of derivative are small, comparable to the absolute value of the advective derivative and hence, as discussed in the text, they are of the order of the

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uncertainty of velocity signal. Also notice that this result implies that the partial derivative with respect to time must be small, what implies that in ocean streamlines evolve very slowly.

The ratio of the mean advective derivative divided by the mean material derivative has no interpretation in terms of the ability of the scalar to delineate streamlines. This ratio can be very small provided that there is a relatively large day-to-day variability (what increases the material derivative), disregarding if the scalar delineates or not streamlines. Notice also that if the spatial scales of variation of the scalar are large you would have a large uncertainty on the streamlines: think about a constant scalar. Its material and advective derivative are zero, but it gives no information about streamlines. It is precisely for that reason that divergence speeds are important.

3.- Qualitative interpretation of divergence speeds: for any scalar θ if you start in a given point, there will be a particular θ-isoline and a particular streamline passing through that point at initial time. As you move along the chosen streamline you will observe that the chosen isoline separates from it. We can try to improve the writing, but this is the idea.

4.- Computing the angles between velocities and gradients would be a good idea if the data were sampled on the same grid, which is not the case. Devising an appropriate interpolation scheme is quite a difficult task, because it should provide good interpolation not only of the signals themselves, but also of their gradients. But notice that gradients of singularities are very large and vary very much on relatively short distances. Actually, this large variation is not a limitation of singularity exponents but the reflection of a very complex structure of ocean streamlines, and thus the problem cannot be easily addressed. In fact, it would be possible to provide an interpolation scheme capable to keep the characteristics of singularity signal, much in the spirit of a recent article by Pottier et al., Rem. Sen. Env (2008), but this would enormously complicate the present discussion.

In addition, when considering real data it is important to realize that due to noise, dis-

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cretization and interpolation effects, etc a too punctual measure will not make justice to the capabilities of one tracer to take punctual measurements. Think for instance that a given point the angle deviates, due to noise and the like, 10 degrees to south, but at the pixel nearby it deviates 10 degrees to north. On the global a spatially incoherent perturbation will not destroy the spatial coherency of the detected patterns, as your eye reveals in figure 2 by simple visual inspection. A way to diminish the influence of noise is to provide integrated measurements, in which the spatially incoherent perturbation would tend to cancel each other. Precisely, our numerical scheme to obtain time derivatives, based on the integration of trajectories, is the most appropriate one.

This is why we have preferred to introduce divergence speeds, which with our numerical implementation are more robust to calculate. Notice that even if the concept is not classical, divergence speeds show unambiguously that singularities trace better than SST. Something interesting to be added in the new version is a figure with the difference of advective and material divergence speeds of SST respect to those of singularity exponents.

5.- We will change colorbars in the next version to enhance details. Notice however that singularity exponents present no definite pattern, which in turn could be considered as an evidence that the observed values are an effect of noise, because of their small amplitude and spatial incoherence. We prefer to keep the global view, although a zoom on a given area (e.g., Gulf Stream or Kuroshio) could be included.

6.- Microwave have better resolution than altimetry (1/4 in front of 1/3), although microwave is uniformly sampled in latitude but altimetry is not-event samples in latitude and close to equator altimetry is better resolved than microwave in the meridional direction. Anyway, the two types of signal have similar resolution and we should not expect the used sampling grids to be better resolving eddies in one case than the other. However, altimetry will have worse resolution at small scales due to the fact that altimetry map is constructed by interpolation of the traces of four different satellites. A zoom on the area you have chosen (around 35 N and far from the boundary) can be included in

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the next version at the cost on including a new figure. Notice that the zoom would not reflect more information than the one already provided by divergence speeds.

7.- The main difference of SURCOUF data is the presence of four altimeters (instead of the two currently operation). We do not understand why you say that SST are of much lower resolution when in fact they are a bit higher resolution (1/4 in front of 1/3). Maybe you mean commonly used SST images, e.g., IR-derived maps, which have resolutions of order 1/24 and so have a much higher (not lower) resolution than altimetry. Notice that IR-derived SST maps have many specific problems (the main one being the large amount of gaps), while microwave has much less gaps, as discussed in Turiel 2008a. In addition we want to compare maps having similar resolution and at that end microwave seems ideal. We do not need to detail that using 4 altimeters instead of 2 has a great impact on altimetry maps because we have cited in the appropriate context an appropriate, conclusive reference Pascual et al. 2006 of our manuscript (Pascual GRL, 2006).

8.- As discussed in the previous answers, altimetry does not allow to study phenomenon on a daily basis and in fact gives a deformed, fuzzy view of the dynamics when maps are generated with only two satellites, as shown in Pascual et al., (2006). Of course altimetry is still useful for some studies, but not for something with requires such a precision as the characterization of signularity advection. No doubt, our statement should be more balanced taking into account what we have just said, and we will do so in the next version.

Interactive comment on Ocean Sci. Discuss., 6, 129, 2009.