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Nonlinear Processes in Geophysics
Discussions
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Interactive comment on "Competition between Chaotic Advection and Diffusion: Stirring and Mixing in a 3D Eddy Model" *by* G. J. Brett et al.

Anonymous Referee #1

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In this article, the authors present results of an extensive series of studies about the relative importance of chaotic advection (versus turbulent diffusivity) in the dispersion of passive tracers in a model of an ocean-scale vortex flow. The flow itself is a "rotating can" (or rotating cylinder) flow with an optional perturbation that approximates the effects of a differentially-rotating lid that is slightly off-center – this perturbation is responsible for the chaotic behavior of the advection in this flow (there would be no chaos if the flow were perfectly axisymmetric). The paper includes results from both a kinematic (phenomenological) model of this flow and a flow based on numerical solutions to Navier-Stokes equations. The authors present three different analyses of transport in this flow.

1. The first is based on a very simple (and illuminating) approach in which the "Batch-

elor" length scale (the scale at which thinning of tendrils from chaotic advection is balanced by diffusive smearing) is compared to the size of the chaotic region. This is a very nice approach that can very quickly give good insight into the relevance of chaotic advection in ocean-scale flows, with chaotic advection being important in cases where the chaotic region is wider than the Batchelor scale.

2. A second approach involves the direct simulation of the spreading of an ensemble of tracers in the flow, with added perturbations. The authors distinguish two types of perturbations: either stochastic noise which models the effects of turbulent diffusivity and/or "deterministic" perturbations (the asymmetry) that gives rise to chaotic advection. The simulations demonstrate the relative importance of these two effects.

3. The third approach involves a measure called "Nakumura effective diffusivity" that accounts for both stochastic diffusivity and also the effects of advection which are incorporated into the measure by characterizing the degree of stretching and folding in the flow. This third section also considers the variance $\Chiˆ2$ that grows as advection makes thinner and thinner filamentary structures but which then gets smaller as diffusion smears those structures away. The authors present detailed simulations both of the spatially-averaged Nakumura diffusivity (for different values of added noise and non-symmetric perturbations), along with spatial maps of the local diffusivity and the concentration profiles for evolving tracer distributions.

The results of all of these studies is a very well-considered and demonstrated conclusion that chaotic advection can be very important in understanding ocean dispersion, although it depends critically on the size of the chaotic mixing regions in the flow.

This is an excellent paper, and clearly deserves to be published in NPG. This is a very important issue; i.e., how relevant chaotic advection is to understanding mixing in real oceanic flows,and the arguments made and the analytical techniques discussed are very compelling. The presentation is clear and very comprehensive – the authors have left nothing out. In fact, there is so much detail that other investigators could replicate the results with the information provided here without any need for other references. This will be a good reference for others wishing to look at chaotic mixing in oceanic flows.

I have a couple of small comments that the authors may wish to consider if revising the paper. These are all optional – the article is fine if the authors choose to publish as is.

1. A sketch of the flow would be helpful when first discussed in detail, showing both the rotating flow, the Ekman layers, and the off-center perturbation.

2. The Batchelor scale is a little difficult to follow when first presented at the beginning of section 3, but then there is an outstanding discussion of this in section 3.1 (on p. 11) with ample references. Perhaps move that discussion a little earlier.

3. I will admit that by the time I got halfway through section 5, I was beginning to fade. Although I think that the detail is useful overall, perhaps some trimming of section 5 would be helpful to the readability of the paper. But this isn't critical – it's fine if the authors leave it as is.

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