Dear Bob,
Embarassing that we missed to answer Stephen Griffies “specific comments”, which were all good.
We have made all the changes he suggested, which are listed below.
Kristofer

REPLY TO REFEREE GRIFFIES

General comments

1. As detailed here, and in the earlier literature, the TRACMASS approach performs an analytic integration of the trajectory within a grid cell. This point is emphasized in the present manuscript. Importantly, this integration is enabled by an **assumption** that the subgrid scale velocity components are linear functions of their corresponding directions: [u(x), v(y), w(z)]. Surprisingly, this critical assumption is not explicity noted in the present manuscript. It should in fact be emphasized and defended.

How/where will it break down? As written, words such as "the trajectory solutions are exact" (pg 5, line 10) make it look like TRACMASS is performing magic. Instead, it is following an exact treatment based on the assumption of subgrid [u(x), v(y), w(z)].

Answer: We have added a few sentences on this in the first paragraph of section 2 and section 2.2 to better highlight this key assumption. We agree that the use of the word "exact" may mislead readers, and have rewritten a few sentences such as p5, line10 to emphasise that the trajectories are solutions to a differential equation, and that there is nothing magical about it.

2. The differential equations for the position within a grid cell are given by equation (17) for the stationary case, and equation (26) for the time-dependent case. Both equations are offered to the reader as if they should be an obvious consequence of something a priori. However, both equations need more build up to motivate and rationalize. The only statement to suggest where equation (17) comes from is line 19 on pg 5: "The transport and position within the grid box are now related by U = dr/dx...". However, this is a statement that offers no motivation nor a derivation. What is the basis for this relation?

So as written, equations (17) and (26) seemingly appear from no where, and the reader is left scratching his/her head. Sans shared intuition, these equations remain mere black boxes to the reader, which is of no use to the reader.

Answer: We have rewritten the first paragraphs of section 2.2 (stationary scheme) and 2.4 (time-dependent scheme) to better lead up to the differential equations that we use to calculate trajectories. We hope this is clearer to the reader.

3. At the end of Section 2, I found myself wanting to see a clear schematic to summarize the stationary method and the time-dependent method. Likely these schematics appear in

the basic literature. But given that you are rederiving the methods here, it would serve the reader well to have such schematics presented again, perhaps in an updated manner. These schematics could offer far more conceptual understanding than the maths presented in Section 2.

Answer: A very good point and we have both added a paragraph at the end of section 2 and a figure, summarising the resulting differences between the schemes within a time-space cell.

4. The word "this" is used many placed without qualifying. The reader is often left wondering what "this" referes to. Please be more careful with letting the reader know what "this" refers to. It is important to do so in order not to lose the reader, especially the novice.

Answer: We have rewritten a number of sentences in order to remove "this".

SPECIFIC COMMENTS

pg 2, line 25: "This in contrast..." suggest changing to "This method contrasts to the..."

Answer: We have changed as you suggested.

pg 3, line 11: change "an GCM" to "a GCM"

Answer: We have changed as you suggested.

pg 4, equation (4): The grid cell thickness is a function of (i,j,k,n). However, this space-time dependence is not consistently displayed in the manuscript, such as in equation (8) where we only see dependence on (k,n). Where it is relevant, and where (i,j) are exhibited for Delta x and Delta y, please also display such dependence for Delta z.

Answer: We have changed this in Eqs 11, 12, 13, 5, 16 as well as lines 27 and 28.

pg 4, line 17: not all ocean GCMs are incompressible (e.g., MOM and MITgcm have non-Boussinesq compressible options). So please qualify this statement; e.g., "many ocean models are incompressible".

Answer: We have rephrased this to "Note that the mass transport can be replaced by the volume transport in models that assume the fluid to be incompressible, which is the case for most OGCMs."

pg 4, equations (9), (10), (12): As written, these equations are not usable when integrating within the model code online, unless we have the n+1 value of the thickness, density, and/or pressure. So please comment on what operationally you mean by these equations.

Answer: We have changed the finite differences in Eqs 12, 13 and 15 to backward-difference schemes and added the sentence: "Note that in the case of "off-line" calculations, one may instead use centred or forward finite time differences in Eqs. 12, 13 and 15."

pg 5, line 16: It is useful to here state that r = x/Delta x is defined separately for each direction and for each grid cell. Namely, there is no assumption that Delta x is uniform across the model.

Answer: We have now instead included the index i,j to Delta x and added the sentence at line 12 p.6: " The above procedure is repeated for meridional and vertical displacements, where now ..."

pg 5, line 16: change "velocity" to "transport"

Answer: We have rewritten the beginning of section 2.2. Starting with velocities and then replacing it with volume or mass flux.

pg 6, lines 9-10: this sentence appears to be an orphan from another paragraph. Perhaps it should go into the previous paragraph, though with some editing to reduce redundancy.

Answer: It was in the wrong position and has been removed now.

pg 6, line 30: remove "with" at start of line.

Answer: We removed "with".

pg 6, line 30: Global GCMs are often run with time steps of **hours** to minutes. For example, the GFDL-CM2.1 ocean component, which is one degree, uses a 2hours time step. GFDL-CM2.5, which is 1/4 degree, uses 30minutes.

Answer: We have now written: "If this is undertaken "on-line", i.e., in the same time as the GCM is integrated, this time interval will simply be the same as the time step the GCM is integrated, which is typically between minutes to a few hours in a global GCM."

pg 7, line 11: I believe that "spatial resolution" should be changed to "spatial grid spacing". Namely, resolution is a pure number whereas grid spacing has units of length. You are stating (Delta x,Delta y,Delta z), which is grid spacing, not resolution.

Answer: We have changed it as you suggested.

pg 7, equation (25): which time level do you use for Delta z in the case where the grid cell thickness is a function of time? n? n-1? average?

Answer: We have included at page 8, line 7, the sentence: "The vertical grid box spacing is for models with time dependent grid cell thicknesses replaced with an average between the two time steps ...".

pg 9, line 15: suggest "...is that in the time-dependent scheme, the transit times..."

Answer: Changed as suggested.

pg 11, line 8 and title to Section 3.1: No one has proven that 1/12th degree **resolves** mesoscale eddies globally. Instead, such models **admit** mesoscale eddies, but they are surely not fully resolved globally. So to state the ORCA12 is "eddy resolving" is an overstatement that is not justified.

Answer: Yes, you are right and we have replaced "eddy resolving" with "high resolution".

pg 12, line 32: what is "this" referring to in the middle of the line? pg 13, line 17: "the the"

Answer: This section has now been rewritten.

pg 13, line 32: "...quantify this **difference** we compared..."

Answer: Changed as you suggested.

pg 14, line 26: It is stated here that the time-dependent scheme is more accurate than the alternatives. I suspect that it is indeed more accurate. But I see no where in the paper where a "truth" is used to base this conclusion. Or did I miss something??

Answer: We havre rephrased and softened this by writing: "The study has shown that the TRACMASS "time-dependent" scheme is likely to be more accurate as well as faster than the "stepwise-stationary" scheme with intermediate steps."

pg 15, lines 14, 16, 25: please specify what "this" refers to on each of these lines. The reader should not be asked to assume he/she knows what you are referring to.

Answer: We have now rewritten the three sentences: 1) "The mass transport was tested in the Agulhas experiment, where the "fixed GCM time step" scheme favoured relatively the Agulhas retroflection with more trajectories returning into the Indian compared to the

"time-dependent" and "stepwise-stationary" schemes., 2) "This difference in mass transport can be explained by the delicate path of the Agulhas leakage, which requires an accurate temporal evolution so that particles can be retained in Agulhas rings.", 3) "This requirement of mass conservation will always be somewhat more demanding than for other trajectory codes, since it requires a total understanding of the various GCM coordinate systems as well as incorporating them in the TRACMASS framework."

Figure 1 caption. Remove first "blue" in the second sentence. C4

Answer: Removed.

Figure 2 caption "the the"

Answer: Corrected.