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Interactive comment on "On the use of Schwarz–Christoffel conformal mappings to the grid generation for global ocean models" *by* S. Xu et al.

Anonymous Referee #2

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Comment on "On the use of Schwarz-Christoffel conformal mappings to the grid generation for global ocean models", by S. Xu, B. Wang, and J. Liu

This manuscript demonstrates the application of conformal mapping techniques to generate orthogonal grids for global ocean models. Many commonly used large-scale ocean models assume the use of an orthogonal coordinate system (specifically, these models use discretizations that do not differentiate between co-variant and contravariant derivatives), so techniques such as that described here could have great value in expanding their versatility. The manuscript presents two new grids, one of which is a variant of the idea of relocating the North Pole into Greenland while minimizing the deviation of the grid from latitude-longitude lines in much of the rest of the domain,

while the other grid aggressively minimizes the amount of land in the grid, but at the cost of dramatically distorting the grid over much of the ocean. While the broad ideas explored in this document could constitute a valuable contribution to the literature on global ocean modeling, in my view substantial improvements, and in particular the demonstration of the successful use of these grids in an actual global ocean simulation, would be required before this manuscript would be acceptable for publication in Geoscientific Model Development.

Major comments:

1. In my mind, the standard for evaluating whether a grid is useful for global ocean models is to actually demonstrate its use in a global ocean model. This manuscript shows pictures of some candidate grids, but does not provide any evidence of their use in global ocean simulations. I believe that such a demonstration, preferably in comparison with a traditional grid of comparable size, is essential before this manuscript could be considered further for publication.

2. One of the strong points of this manuscript is the list (on p. 1340) of considerations that go into designing a global ocean model grid. However I would suggest that there are two other considerations that should be on this list: 10. The grid should facilitate analysis of the model output. The ultimate point of any global ocean model is to learn something about the real ocean. I have seen many examples of lovely exotic grids, very few of which actually translate into useful insights about the real world, largely due to the challenges of analyzing these solutions in a way that is readily understood. This consideration is a strength for the grid depicted in Figures 3-6, but potentially a big weakness for the more exotic grid shown in Figures 8 and 9. 11. The grid should minimize time-step restrictions. Most ocean models use explicit time-stepping schemes that require that are subject to the well-known CFL constraint that the length of stable time-steps are restricted to be less than an order-1 factor times the local grid spacing divided by the local external gravity wave (for the barotropic solver or unsplit models) or the local Doppler-shifted internal wave speed (for the internal mode of split-explicit or

rigid lid models). (The description of the considerations governing the maximum time step on p.1349, lines 3-6, as the global minimum grid spacing divided by the global maximum wave or advective speed is not correct; rather it is the global minimum of the local speed divided by the local grid spacing.) Given that the cost of a simulation scales with the number of timesteps that are taken, this consideration can easily swamp any value from avoiding calculations over land. A map of the number of barotropic or baroclinic time steps that are required per day would illustrate the extent to which the localization of the grid resolution impacts the overall cost of the model.

3. The description and application of the Schwartz-Christoffel mapping are not at all clear to me. Since this is arguably the main point of this manuscript, this is a serious problem. In particular, much of the discussion focusses on mapping irregular polygonal regions onto the unit circle. This makes sense over land, but it is the grid over the ocean that is of interest. Is there some other mapping of arbitrary polygons onto a unit square that is actually being used over the oceans? I have no clue what Figure 2 is supposed to show. I think that it is important that the authors try to have a clearer idea of who is their target audience. If the manuscript is intended to advise and inform people who are building global ocean models (like me), I think that a much more detailed description of the technique would be warranted, preferably including examples without poles in the middle of the domain of interest. If, on the other hand, this manuscript is intended for applied mathematicians who already know all about Schwartz-Christoffel mapping to advise them on new applications of their existing techniques, the current description may be adequate, but in that case it should be submitted to a different journal than Geoscientific Model Development

4. The presentation quality of this manuscript is poor, with many grammatical errors in the text and miniscule figures. There is no excuse not to use an automated grammar checker before submitting a manuscript for peer review.

Specific comments:

1. I do not know what a "Bryan-Cox-Semtner type ocean model" is. The Bryan-Cox-Semtner model was one specific ocean model that was used in the early 1990s, with latitude-longitude coordinates, discretized on an Arakawa B-grid, with a rigid lid and full-cell Z-coordinates in the vertical. I do not believe that this code is still in use anywhere, having been long-since supplanted by more accurate and flexible ocean models. Perhaps "existing structured grid primitive equation ocean models" would be a more apt description of the types of models that the authors intended to describe.

2. P. 1341, lines 5-8, indicates that if a substantial portion of the grid coincides with a latitude-longitude grid, that memory could be saved by only storing 1-d vectors of latitude and longitude, but this will be of negligible value and add complexity if any of the grid does not coincide with latitude-longitude grids. Two 2-D arrays do not contribute substantially to the memory footprint of modern ocean models compared to the 3-D arrays, especially in Earth System models with large numbers of passive tracers.

3. The grid shown in Figure 9 does not appear to include the Black or Red seas. This would be a very serious omission for global ocean modeling, as would immediately be revealed if a global ocean simulation with this grid were to be examined.

4. Much of the argument for the grid described in section 3.3 is that by distorting the grid to exclude the interior of continents, there are fewer ocean model points that are wasted over land. For the example here, about 60% of the continental areas are removed. Since about 70% of the Earth is covered with water, the grid presented here is able to cover all of the oceans with a grid that includes only 70%+0.4x30%=82% of the area of the Earth. This 18% savings is nice but not huge. However, high resolution global ocean models are typically run on grids that are spatially decomposed into subdomains to work on thousands of processing elements, in which case it is easy to achieve savings of the same magnitude by simply not running the ocean model on any subdomains that do not include any ocean cells! If a higher resolution version of the grid shown in Figure 5 were to be decomposed into 10,000 subdomains, I would not be surprised if about 18% of the subdomains did not include any ocean points.

5. A second argument in favor of the conformally mapped grid in section 3.3 is that it broadly aligns the grid with coastlines. However I think that this is a very weak argument for realistic global ocean modeling. There will be reduced truncation errors when the grid is aligned with the coastline and other isobaths at the scale of individual grid-cells. However, actual coastlines are sufficiently irregular at any resolution that such grid-scale alignment cannot be achieved on a regular grid without introducing rapid grid distortions, which would introduce their own truncation errors. Although the grid depicted in figures 8 and 9 is aligned with the coastlines on the largest scales, it clearly is not aligned with the coastlines at the finest scales.

Interactive comment on Geosci. Model Dev. Discuss., 8, 1337, 2015.