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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.

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The authors would like to thank the referee's thorough and insightful review of the manuscript.

Before specific replies to the comments of the referee, firstly the authors would like to clarify that the major purpose of the manuscript is to demonstrate new grid generation methods, rather than the sample grids. For example, the sample grid in Section 3 (shown in Figure 8 and 9) is the result of the specific choice of the continental regions (listed in Table 1). If another set of regions were used, the quantitative evaluation of the resulting grid would be different. A higher ratio of land removal could be achieved

by using a set of regions with more refined boundaries.

Reply to Major Comment 1: We acknowledge the importance of successful application of the grids in OGCM modeling, as pointed out by the referee. The authors' initial intention was to apply the grid generation methods to global ocean simulation in future work, by: (1) a more refined model grid (rather than the sample grids in this manuscript), and (2) realistic ocean simulation targeted at a certain scientific problem. Under the circumstance that the referee requires the evaluation of the grid by OGCM simulation, the authors carry out simulation with a 3-D OGCM under idealized forcings, using both sample grids. It is shown that the grids can be successfully utilized in real OGCMs. Corresponding materials are added to the manuscript as the evaluation of both sample grids.

Reply to Major Comment 2: We acknowledge the importance of the two new grid design considerations proposed by the referee: (1) to facilitate the analysis of the model output, (2) to minimize time-step restrictions by the grid. One important prerequisite of the easy analysis is that the grid is latitudinal-longitudinal (lat-lon), as is a big advantage of the sample grid in Section 2. The authors would like to point out that most general orthogonal grids (dipolar and tripolar ones) have a significant portion which is not lat-lon, and interpolation is ALWAYS required for the global analysis of the model output on the lat-lon grid. For example: for a dipolar grid with a turning latitude of 20 N, the proportion for non lat-lon part of the globe is about 33%, and for a tripolar grid with a turning latitude of 35 N (as in ORCA grids [1]), the proportion is about 21%. For the proposed grid in Section 3, such an interpolation is also necessary, since most part of the grid is not strictly lat-lon. However, despite the grid's complexity (and the associated interpolation operator), it does not further complicate the analysis routine, since the interpolation is generally required. The authors have merged this rule (easy analysis of model output) to rule number 4, which focuses on the large proportion of lat-lon of the grid. With respect to the time-step restrictions, the authors agree with the more strict definition of the minimum time step as the global minimum of time steps as constrained by the local CFL condition. But the authors would like to argue that: (1) despite the informality, the use of the time step defined by global maximum wave speed and global minimum grid stepping do guarantee stability AND this rule is frequently adopted in practice due to its simplicity, and (2) for the sample grid shown in Figure 8 and 9, the maximum time step is constrained by the oceanic region closest to the Greenland, as is not the result of the conformal mapping. Figures are added to show that the traditional dipolar grid (e.g., GX1 for POP) also feature the same regions for time step constraints. In specific, a map of the barotropic time step sizes per day of the sample grid is shown, assuming an (split) explicit model formulation.

Reply to Major Comment 3: The authors thank the referee for the suggestion to reformulate the description of the Schwarz-Christoffel (SC) mapping and how it is applied to the grid generation, and have revised and simplified this part for clarification in the manuscript. The author would also like to provide some key explanation here for the immediate reviewing. First, in terms of the design principle of the grid generation method in Section 3, we intend to construct an SC mapping of the stereographic projection of the earth (which is a complex plane and contains user-specified, irregular continental boundaries), to a complex plane with these continental regions mapped to slits, which in turn achieves continental area compression, etc. Second, there exists an SC mapping for a multiple-connected region of irregular boundaries to the canonical form of slits, i.e., the existence of the mapping is assured. Third, given a set of polygons with irregular boundaries (as in Figure 2.a), a modeler does not (and can not) quantitatively specify the slits (the radius, angles, etc.), but rather constructs the SC mapping to map the polygons to slits with user-specified types. This is similar to transforming a matrix to the Jordan canonical form: beforehand we only know the properties of the final matrix form, but do not know the specific values in either the transformation matrix or the final Jordan matrix. To summarize, we do not have direct control of the final grid, but rather the choice of continental boundaries and the slit type for each continental boundary.

Reply to Major Comment 4: The authors would like to thank the referee for pointing out

the grammatical and spelling errors in the manuscript, and provide a revised version to get rid of such problems.

With respect to the specific comments of the referee:

Reply to Comment 1: According to the suggestions of the referee, the authors would correct the misuse of "Bryan-Cox-Semtner type ocean models" to "structured grid primitive equation ocean models". The authors also add an extra subsection in Section 1 in the revised manuscript, for a more thorough background introduction of the usage of orthogonal curvilinear grids in OGCMs.

Reply to Comment 2: The authors agree that from the perspective of memory footprint, the 2-D array of lat-lon locations of grid points is small, especially when compared with 3-D tracers of potentially large numbers. However, it is worthwhile to point out that not only grid point locations, but also other grid variables could also be compressed in terms of memory footprint. In a common ocean model, almost all 2-D grid variables fall into this category: grid point spacing, U/T-cell edge sizes and areas, Coriolis parameters, etc. Despite that even when combined, these variables are small in terms of memory footprint, they usually have a different memory usage behavior than passive tracers, i.e., they are accessed more frequently. Hence the potential improvement over memory usage could be large. The actual saving in terms of active memory access is subjected to further analysis.

Reply to Comment 3: The authors would like to point out that the Black Sea is indeed excluded when constructing the sample grid in Section 3, as indicated on line 12, p. 1354. But the sample grid DOES include Red Sea, as in Figure 8. Although Black Sea is included in some global ocean circulation simulation as a semi-enclosed sea (as in ORCA012 of NEMO [1]), there are cases when it is treated as an enclosed sea and in effect inactive in global ocean circulation (as in 0.1 deg. TX01 POP [2] or the 1/12 deg. HYCOM [3]), or just ignored (as in MPAS-O [4]). But the authors would like to re-emphasis that the sample grid is only provided as an example of the grid generation methodology. If the inclusion of Black Sea is mandatory, a modified Eurasia continental boundary could be used to achieve this.

Reply to Comment 4 (about reduction of continental areas): The authors would like to emphasize that: the 60% percent reduction in continental areas is the result of the sample grid to demonstrate the grid generation methodology. If we use a set of more refined continental boundaries for the SC mapping construction, a larger portion of the land could be removed.

Reply to Comment 4 (about computational performance) The authors would like to point out that although traditional computational load balancing strategies could be used to exploit the inactive processors, the grid proposed in Section 3 still brings much improvement in that it exempts model users of these load-balancing efforts. The authors are fully aware that the popular load balancing algorithms (such as re-mapping MPI-process with Space-Filling curves [5,6]) could be utilized when inactive processors are present. But with the proposed method in this manuscript in Section 3, such algorithms are no longer necessary. I.e., model users are exempt of the effort in analyzing the load imbalance and tuning of corresponding algorithms.

Reply to Comment 5: The authors agree with the referee that it is virtually impossible to align grid lines to coastlines, mostly due to the multi-fractal properties of earth's isobaths. The authors would like to further clarify that: (1) for the grid generation method in Section 3, the grid lines are in total alignment with the boundaries used for SC mapping construction, and their alignment with coastlines is a collateral effect if the aforementioned boundaries coincide with coastlines; (2) the grid lines are never intended to align with coastlines at every spatial scale (which is not possible), but rather at larger scale; and (3) the alignment of grid lines to coastlines at finer spatial scales could be achieved when higher grid resolution is needed, by using a set of finer continental boundaries for the SC mapping construction. Revisions to the manuscript are made to clarify that the alignment to coastlines are at the largest scale.

The authors would like the referee again for the invaluable advices in helping us to improve the manuscript.

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