Geoscientific
Model Development
Discussions

Interactive comment on "An orthogonal curvilinear terrain-following coordinate for atmospheric models" *by* Y. Li et al.

Anonymous Referee #1

Received and published: 5 December 2013

Report on: An orthogonal curvilinear terrain-following coordinate for atmospheric models Y. Li1, B. Wang1,2, and D. Wang3 Discussion Paper Geosci. Model Dev. Discuss., 6, 5801–5862, 2013

Scientific significance: In the title and abstract the paper claims to introduce an orthogonal terrain following coordinate which reduces the error of the pressure gradient force (PGF) and also reduces the error of advection for numerical schemes in grids generated by the vertical coordinate of atmospheric models. Given the large errors often associated with the vertical coordinate, it is very interesting to investigate a potential reduction of errors by introducing orthogonal coordinates. In reality the authors address a much smaller problem. The orthogonal coordinate is already introduced in an earlier paper and there also the PGF is investigated. In the present paper the

authors investigate only the accuracy of advection using the very simple test problem of homogeneous (in x-z) horizontal advection in two dimensions. The paper is very difficult to read, as the authors give much information which is of no concern for the simple 2-d test problem they investigate, such as technical details for the computation of the coordinate in 3-d, when their test problem is 2-d. They derive several continuous forms of the Euler equations in 3-d, even though their test is linear advection. Only one equation is about the discretized equations, even though the numerical schemes used are very important for accuracy. All other equations of the rather long paper concern the continuous equations for problems which are actually not solved. The derivation of coordinates and equations is too extensive and goes very much into technical details. This is appropriate for a technical report or a manual, not for a journal paper. The presentation uses terms whose definition is not introduced and gives the impression to be addressed to members of the same institute, not the outside world. For example right in the first sentence when explaining the coordinate, the term "the basis vectors" is used. On this all later explanations hinge. Basis vectors are not unique and the authors should use a name to indicate their special choice, such as natural Basis. This term should then be defined before it is used. After some consideration I now believe that I understand what the authors want. For the following I will use the following understanding of the paper: 1) The natural basis consists of unit vectors in the directions of the coordinate lines. The coordinate is orthogonal when the natural basis is orthogonal. 2) Starting point can be any terrain following coordinate, being called the sigma system. 3) The basis i_x, i_z of the x-z system is for each point in space rotated such that the image of i_z becomes orthogonal to the sigma line. The orthogonal coordinate lines are those which have this rotated field as natural basis. The ordinary differetial equation defining the coordinates is obvious. 4) The rotations of 3 define a rotation angle theta which is used to define different versions of orthogonal coordinates. 5) Using theta and a function b of the coordinates, modified versions of the orthogonal natural bases can be defined, which again lead to new orthogonal coordinates. They also lead to new standard terrain following schemes, which are not used in the paper.

6) By giving 3 definitions for functions b 3 additional versions of are derived. 7) As numerical schemes only centered differences in space and time are used. Arakawa A grid is used and no fancy stuff, such as Asselin filters is considered. 8) The advection tests use homogeneous horizontal velocities above a threshold z-value. Most orthogonal schemes are less curved above the threshold than the sigma scheme used for comparison. The fourth scheme is not curved at all in this area. It is identical to regular x-z grid in this area. In its current version the paper does not substantiate the claim that an improved accuracy is caused by the orthogonal coordinate. From figs 10 and 11 it follows that a strong reduction of the eror is obtained with one of the grids, which has also the property to be identical to the x-z grid where the velocity is different from 0. The tests presented investigate the combined effect of orthogonal coordinates and the regularity of grids. This is not too surprising. It is well known that centered differences have good accuracy only for fairly regular grids. So the increased accuracy of some schemes can well be explained by the fact that the more accurate schemes have grids being more regular and more similar to the x-z grid in the relevant areas. The authors define different versions of terrain following coordinates. Current evidence indicates that it is the terrain following coordinate defined by the vectors and not the orthogonality being responsible for the accuracy. Even though much less results are obtained than expected from title and abstract, some of the results are valuable and make the paper interesting: Investigations of vertical accuracy concentrate often on PGF. Therefore the investigation of advection is useful Until now there are not many investigations investigating orthogonal coordinates for the vertical The construction of terrain following coordinates by defining natural bases may be useful when investigating orthogonal coordinates. These results appear to be important enough to merit publication after a very substantial revision. As the paper presents rather simple tests, the revision should be more concise and much shorter (see below). The revision should also present some more results in order to be consistent with the claim to investigate the Impact of grids generated by orthogonal coordinates: A Fig. 8 suggests that for the coordinates generated by the different choices of b ordinary terrain following schemes can be defined.

The accuracy of these schemes should be compared to the OS schemes. I would propose publication also when the impact of OS should turn out to be not very high. B The mountain is rather smooth. The impact of steep mountains up to those supported by one point only should be investigated, also the impact of steepness on stability. C One of the coordinates concentrates the curvature to a small area near the mountain, which in current tests has no velocity different from 0. The impact of this area should be investigated by using velocities different from 0 right to the top of the mountain. Scientific quality: As already indicated, the Paper is much too long and not concise. In the following detailed comments are given with the aim to make it more suitable for publication: The current title suggests that the orthogonal coordinates are presented in this paper. However, they where introduced in Li (2012). A new title should reflect the fact that advection tests are done using a coordinate already introduced earlier. The abstract and conclusion read like they belong to Li (2012). In the current paper no work on PGF is done. So this does not need to be mentioned. It should be mentioned what kind of advection tests and grids are used and that centered difference schemes are used and a sentence on results. Nearly all current content should be deleted as it is not relevant to the investigation. Most of the introduction is nicely written and gives an account of current vertical schemes and current attempts to avoid vertical errors. A paragraph should be added at the end indicating the advection tests to be done. The paper "Performance of the cut-cell method of representing orography in idealized simulations" by Beth Good et al uses rather similar advection tests and you may want to refer to it. It is in print "ATL Atmosperic Science Letters 2013.

Most of the material in sections2,3, including Appendix A,B,C and the tables and Fig 1,2,3 are not relevant to the advection tests and concerning the description of the coordinate it is too technical and detailed for a Journal publication. A very short presentation of the coordinate and scheme should be given involving Eqs 34,35,36, 60,61,62,63 and not much more. The description of the tests in 4 should remain. Fig. 4 gives a nice illustration of the new coordinate. It is redundant with Fig. 5,6,7. Fig 8,9,10 illustrate the experiments done, but Fig 9 is redundant with Fig 10. I suggest to keep the latter. The

red grid may be taken out, as everybody can imagine the regular x-z grid. In the legend of Fig. 10 the names of the grids should be mentioned under a, b, c, d with reference to the text of the paper. It would help understanding, if the graphic presentation of the figs would be as in Fig. 10. When introducing the discretized equations the authors should shortly discuss other possibilities. Centered differences on the Arakawa A- grid are not considered the most suitable approach to numerical modeling. Scientific reproducibility: The advection experiments are sufficiently described, that a reader can reproduce them. Presentation quality: I found no mayor language problems. The logic of the presentation could, however, be improved. Definitions were missing, when introducing a subject. This problem could become better, if the authors follow the suggestion of presenting less of the technical detail. X and z should be scaled to correspond to resolutions currently used in models. Mesh lengths of 8 m and smaller are not often used for atmospheric models. It will not be necessary to create new results, just to rename the axes. Also, the paper should be made more easily readable. For example in the figure captions under each letter a-e the schemes corresponding to the results should be named. Summary: The paper contains much less work than promised in the title and abstract. The work on advection testing is valuable, also the creation of orthogonal schemes and different versions of terrain following coordinates using the b-functions. The grid fig 10e is Cartesian for a large part of the area and for this area the coordinate is z. The curved coordinate lines occur only near the surface. The advection velocities and advection fields are different from 0 for the Cartesian part of the grid in Fig 10e only. In comparison to the other cases this shows only that centered differences perform better on regular Cartesian grids than in irregular grids. This result is well known and by itself does not merit publication. In order to be sufficiently interesting the advection tests should be done for an area reaching down to the top of the mountain. The functions b define different sets of terrain following coordinates. Only one of the 3 choices offered are investigated using orthogonal and standard grids/coordinates for comparison. For the other choices the differences in accuracy can be due to orthogonality or the change to orthogonal coordinates. Only the grid reported in fig. 10e shows

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a good increase of accuracy. This is due to the standard grid, not to the orthogonal coordinates. For the tested part of the grid Fig 10e the standard terrain following grid is already orthogonal. To do justice to the title of the paper it will be necessary for each of the 3 coordinates to create results for standard and orthogonal grids/coordinates and compare these. As described above, the theoretical part of the paper should be made to correspond to the results obtained. In its present form the paper just finds better accuracy for a regular Cartesian grid than for an irregular grid. This is not enough to merit publication. The authors have found an interesting subject, as for the grids generated by terrain following coordinates little work has been done concerning advection testing and the same is true for orthogonal coordinates. Therefore with the suggested further work the paper would merit publication, whether or not a certain of the schemes a-e is very accurate.

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