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

Anonymous Referee #3

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I read the manuscript before inspecting the reviewer comments that have already been posted, but then noticed that most of my comments would coincide with what has already been said in the two previous reviews. Thus, I will restrict myself to a few essential points. Moreover, as I agree with the other reviewers in that the manuscript is not sufficiently mature to be acceptable for publication in a peer-reviewed journal, I will not address any linguistic and grammar errors in the manuscript.

General evaluation: The authors present the mathematical description for an orthogonal curvilinear terrain-following coordinate, claiming that this type of coordinate will improve the numerical accuracy of advection and the pressure-gradient term compared to models with a conventional non-orthogonal terrain-following coordinate. Unfortunately, only passive advection tests are presented in the main part of the paper, leaving the

question behind if a model code that actually solves the 3D prognostic atmospheric equations in the orthogonal coordinate system (OS) already exists. Given the results that are available up to now, the mathematical description of the OS (sections 2 and 3) is much too detailed. Moroever, parts of these sections are quite difficult to understand because there is no clear separation in nomenclature between a coordinate system and a coordinate. Section 4, presenting the results of the passive advection tests, suffers from comparing apples with oranges (see comment #4 below), and the conclusions again mention improvements in the computation of the pressure-gradient term that have nowhere in the paper been demonstrated. Some specific remarks follow.

1. (Fig. 4) The strong convergence of the vertical coordinate lines at mountain peaks not only imposes a severe limitation on numerical stability when really solving the atmospheric equations (CFL criterion) but also leads me to the question what will happen in real mountainous orography with steep mountain ridges and deep narrow valleys. Will the valleys be reasonably resolved with the OS approach, or will nearly all vertical coordinate lines cluster around the mountain crests? If the latter is the case, the OS approach will be useless for practical purposes, because the main goal of high-resolution NWP (or modelling in general) in mountainous regions is usually to forecast the atmospheric conditions in the valleys as accurately as possible.

2. (End of section 3.1) As already mentioned by another reviewer, the projections of the gravitational acceleration on the horizontal directions constitute in fact a second component of the horizontal pressure-gradient terms. Thus, it is by no means clear a priori that the OS reduces the related discretization errors. By the way, the authors should also distinguish clearly between scalars and vector components. Their transformation behaviour is essentially different.

3. (section 4.1) A Leapfrog-centred difference scheme, which nowadays no one would ever use for advecting positive definite tracers, tends to exaggerate the numerical artifacts induced by small-scale orographic structures in the coordinate surfaces.

4. (section 4.1; Figs. 8–16) For a meaningful comparison between the CS and OS coordinates, the authors need to consider pairs of experiments with equal shapes of the coordinate surfaces. So far, only Cs and OsBr1 are comparable, showing just a tiny improvement by a few per cent when changing from CS to OS, which is not very convincing. The fact that smoother coordinate surfaces improve the numerical accuracy of advection is not a specific property of the OS coordinate – this is valid for the CS coordinate as well, as has been demonstrated extensively for the SLEVE coordinate and similar approaches. I also have to note that the extremely strong squeezing of the coordinate surfaces appearing in OsBr3 would very likely lead to numerical instabilities in a full model solving the prognostic atmospheric equations. Thus, the good behaviour of this coordinate type in the advection tests is at best of academic interest.

Interactive comment on Geosci. Model Dev. Discuss., 6, 5801, 2013.