Geosci. Model Dev. Discuss., 8, C2291–C2301, 2015
www.geosci-model-dev-discuss.net/8/C2291/2015/

Geoscientific
Model Development
Discussions

Interactive comment on "NCAR global model topography generation software for unstructured grids" *by* P. H. Lauritzen et al.

P. H. Lauritzen et al.

pel@ucar.edu

Received and published: 30 September 2015

We thank the reviewer for his/her review of the manuscript. Below the reviewer comments are repeated (or partially repeated) in red font and our reply is in blue font. Changes to the original paper is shown in red font in the revised manuscript (attached).

We would like to inform the reviewers that we have added a newer raw topography data (GMTED2010) to the manuscript even though none of the reviewers have asked for it. Users of the software have requested this newer dataset. In the results section (Section 3) the differences between GTOPO30 and GMTED2010 are highlighted.

The manuscript documents a method to generate topography-related information needed by atmospheric models, either by the dynamical core (smoothed mean topographic height) or by subgrid-scale parameterizations (subgrid-scale variance). Section 3 presents simulations obtained with CAM-SE and different strengths of orography smoothing. Generating topography-related datasets on the model grid is definitely required for any Earth System Model. The novel character of the method is that it deals with unstructured, rather than longitude-latitude target meshes (it also handles lon-lat target meshes). The technically hard pieces are borrowed from previous work related to remapping-based transport schemes. The method is essentially a combination of these technical tools and common sense. The presentation of the method is clear and contains essentially all the information that would be needed to re-implement it, except for the generation of the "supermesh" (see comment 7).

Reply: Thank you! The 'supermesh' comment is addressed under item 7 in detailed comments below

Changes to the manuscript: See item 7 below.

Section 3 is quite independent from the first two. It might be better to study the impact of topography smoothing in a more in-depth, separate paper. Unfortunately without section 3 the present manuscript would boil down to a short, descriptive technical report. My understanding of GMD is that the manuscripts should go beyond this and provide insight into the rationale and consequences of choices made in the method, insight that could be valuable for GMD readers designing similar methods. I would therefore strongly encourage the authors to better document and analyze important characteristics or potential pitfalls of the method, which in fact has probably been done in the design process. I would especially suggest to discuss quantitatively grid imprinting (see comment 6), algorithmic complexity (see comment 7), computational cost/performance. When relevant, it would be important to address as a target mesh not only the cubed-sphere (as in CAM-SE) but also more complicated meshes (e.g. SCVT/MPAS), since a strength of the method is the variety of possible target meshes. This would improve the usefulness of the manuscript for an audience broader than CAM users. Overall I recommend a major revision.

Reply: The reviewers concern about better documenting the characteristics or pitfalls of the method are replied to under the detailed comments below. Regarding Section 3: The author's agree that this section is CAM-SE specific and somewhat detached from the rest of the manuscript. Section 3 has been mostly rewritten. The software has been applied to variables resolution MPAS grids. We do not show topography variables on the MPAS grids as the topography variables look very similar to the CAM-SE and CAM-FV results shown here, although the details of the underlying grids are different.

Changes to the manuscript:

- Climate model simulation results with different levels of smoothing have been removed from the manuscript.
- A discussion on sub-grid-scale variance and smoothing has been added to the manuscript (new addition to the results section).
- Differences in elevation, SGH and SGH30 between the newer GMTED2010 and older GTOPO30 raw elevation datasets is discussed (new addition to the results section).

See Results section in revised manuscript for details.

Detailed comments

1. p. 4624, line 18 : maybe cite Lott (MWR 1999) rather than Lott & Miller (1997) for mountain drag and planetary waves

Reply: Thanks! Done

2. p. 4625 line 1 : I am not sure how orography is represented in global high resolution databases but from a physical point of view, especially with variable gravity, only the surface geopotential is a generally well-defined specification of orography. Φ_s can then be expressed as an elevation 'above' a reference isogeopotential surface. This conversion is simplest (Φ_s = gh) when the variations of gravity are neglected.

Reply: Good point

Changes to the manuscript: The following paragraph has been added to Section 2.2.1:

The raw elevation data is provided on a geoid such as the World Geodetic System 1984 (WGS84) ellipsoid whose center is located at the Earth's center. Latitude and longitude locations use the WGS84 geodetic datum. Similarly elevation above sea-level is defined as the deviation from the WGS84 geoid or WGM96 (Earth Geopotential Model 1996) geoid for newer datasets. Global weather/climate models typically assume that Earth is a sphere so the elevations at a certain latitude-longitude pair on the geoid are taken to be the same on the sphere. The consequences of this approximation in the context of limited area models is discussed in Monaghan et al.

(2013) and in the context of shallow-water experiments in Bènard (2015). Derivation of the equations of motion in more accurate coordinates is starting to emerge in the literature (e.g., White et al., 2008; Gates, 2004; Staniforth and White, 2015)

3. A related question pertains to what “latitude” precisely means, i.e. geodetic vs geocentric latitude. Models typically make the spherical-geoid approximation, in which case both coincide. However the real Earth is slightly flat and high-resolution databases must presumably specify what they mean by latitude and what geodetic system they use, see e.g. Monaghan et al. (2013) http://dx.doi.org/10.1175/MWR-D-12-00351.1

Reply: Responded to in item 2 above.

Changes to the manuscript: See item 2 above.

4. p. 4625 line 25 : while the importance of subgrid anisotropy is stressed in the introduction, the presented method does not compute quantities characterizing this anisotropy, e.g. the coefficients γ and ψ of Lott & Miller 1997, Appendix A. Do CAM physics not require this kind of information ? It might be fair to stress that the presented method addresses only isotropic subgrid-scale physics.

Reply: Good point! The current released version of CAM does not have sub-grid-scale anisotropy. That said, experimental version of the model does have sub-grid anisotropy for drag paremeterizations and will be documented in a separate paper.

Changes to the manuscript: N/A.

5. p. 4631 : maybe this page could be replaced by a reference to Nair et al. (2005) ?

Reply: To follow GMD guidelines of reproducibility (in particular their statement ‘ideally, the description should be sufficiently detailed to allow in principle the reimplementation of the model by others’) we argue that this page should remain in the manuscript.

Changes to the manuscript: N/A.

6. p. 4632 : the cubed-sphere mesh has non-uniform isotropy, as cells near the cube corners have angles close to 60 and 120 degrees while cells near the face centers are close to square. One therefore expects that the position of the cube corners will somewhat affect the results of the method (grid imprinting). This impact might be small but it would be interesting to quantify it. It would be easy to generate V ar(tms) with different positions of the cube corners (e.g. rotating the cube by 45 degrees and/or positioning corners at the poles) and plot the difference.

Reply Figure 1 in this document shows the difference between SGH30 when rotating the cubed-sphere mesh 45°. The data is plotted on a 1° CAM-SE grid. As expected there is a sensitivity to the intermediate cubed-sphere orientation, however, in the context of the uncertainties in scale-separation and the raw elevation data itself (see the comparison between SGH30 with GTOPO30 and GMTED2010 in Figure 9 in the revised manuscript), the differences appear very small.

Changes to the manuscript: N/A.

7. p. 4634, (13) : enumerating the non-empty Ω_{kl} can be a very time-consuming part of the method if done naively. An upper bound of algorithmic complexity is given by a brute-force approach where the intersection of each âĎęk and each A_l is computed. For large meshes this is very inefficient as most intersections are empty. More sophisticated and efficient approaches exist, e.g. doi:10.5194/gmdd-8- 4979-2015 ; how does this part of the method compare, in terms of algorithm and efficiency ? Is it a time-consuming task ?

Reply: Thank you for pointing this out so that this can be addressed in the revised manuscript. See changes to the manuscript:

Changes to the manuscript: The following paragraph has been added to Section 2.2.2:

‘Note that the computation of overlap areas $\Omega_{k\ell}$ is facilitated by the ‘Cartesian’ layout of the equi-angular cubed-sphere grid in computational space. The target grid vertex locations within the cubed-sphere source grid are computed by first locating which panel the vertices are on (using the “coordinate maximality” algorithm) and their locations thereafter trivially result when the vertex coordinates are converted into the particular panels equi-angular coordinates. The overlap areas are computed by finding intersection between the (x, y) gnomonic isolines (‘Cartesian’ layout) and the target grid cell sides. Since topographic variables are computed just once for each horizontal grid resolution computational performance is less critical. On a standard laptop even high resolution (e.g., 25km) grid overlaps are computed on the order of minutes irrespective of the target grid topology (Voronoi, cubed-sphere, etc.). ’

8. More generally, could the authors provide at least indications about the computational time spent in each step of the method for a few representative target meshes/models (e.g. CAM-SE, MPAS) ?

Reply: See reply to item 7

Changes to the manuscript: See item 7.

9. p. 4634-4635, about defining variance with smoothed orography. Definition (16) of variance corresponds to :

[equations not repeated here]

Are there reasons to prefer (18) ? Would switching to one of the above definition make a difference in practice ?

Reply: Very very good point. The smoothing blurs the separation of scales and the sub-grid-scale variance no longer integrates to zero! We have added a paragraph conceptually describing what the reviewer pointed out with equations. See changes to manuscript.

Changes to the manuscript: The following paragraph has been added to section 3:

‘The implications of topography smoothing on SGH is problematic as illustrated on Figure 7. A strict decomposition of the topography into its grid box average and deviations from that average is conceptually simple. In this ideal situation, the model dynamical core represents circulations forced by grid-box mean topography (thick black line, Fig.

7a) and a parameterization scheme represents the drag and other effects induced by waves forced by "unresolved" topographic deviations (thin black line, Fig. 7b). The grid-mean of these deviations is zero.

However, when additional smoothing is applied to the grid-box mean topography (thick blue line, Fig 7a) the situation becomes less well defined. It is difficult to argue that the "unresolved" topographic forcing is fully captured by the deviations from the grid-box mean. On the other hand, the deviations from the smooothed topography (thin blue line, Fig. 7b) have properties that make it unclear how to incorporate them in a traditional gravity wave parameterization framework. The grid box mean of these deviations is not zero. Non-zero deviations can exist far from actual topographic forcing. In the case of real-world topography, Figure 8 shows the difference between $\sqrt{\mathsf{Var}^{(\mathsf{gwd,smooth})}}$ and $\sqrt{\mathsf{Var}^{(\mathsf{gwd,raw})}}$. There are significant differences between SGH based on smoothed or unsmoothed topography. We do not advocate any particular strategy for parameterization of subgrid orographic effects, our software is simply intended to make the generation of the forcing data sets for global models traceable and transparent.'

10. p. 4638, section 3 : the experiments are presented as 'topography smoothing experiments'. However if I understand correctly, each (differently smoothed) hËIJ will also be associated to a different subgrid variance V ar(gwd,smooth) . Hence the differences between the experiments are due not only to different h but also to different V ar(gwd,smooth) . What is the predominant effect here ?

Reply: Good questions. Due to both reviewers concern about the simulation results they have been removed from the manuscript

Changes to the manuscript: Simulation results removed from the manuscript.

11. More generally, the impact of topography smoothing is a problem quite independent from the method used to generate the topography-related quantities. Furthermore this problem exists independently from the structured/unstructured character of the mesh. Different models might have different sensitivities to topography smoothing, but the reason may lie more in the numerical formulation or physics than in the mesh per se. Section 3 only scratches the surface of the problem. It might be more relevant to address it more in-depth in a separate paper

Reply Agreed. Topography smoothing experiments have been removed from the manuscript.

Changes to the manuscript: Topography smoothing experiments have been removed from the manuscript.

Please also note the supplement to this comment:
http://www.geosci-model-dev-discuss.net/8/C2291/2015/gmdd-8-C2291-2015-supplement.pdf

---

Interactive comment on Geosci. Model Dev. Discuss., 8, 4623, 2015.

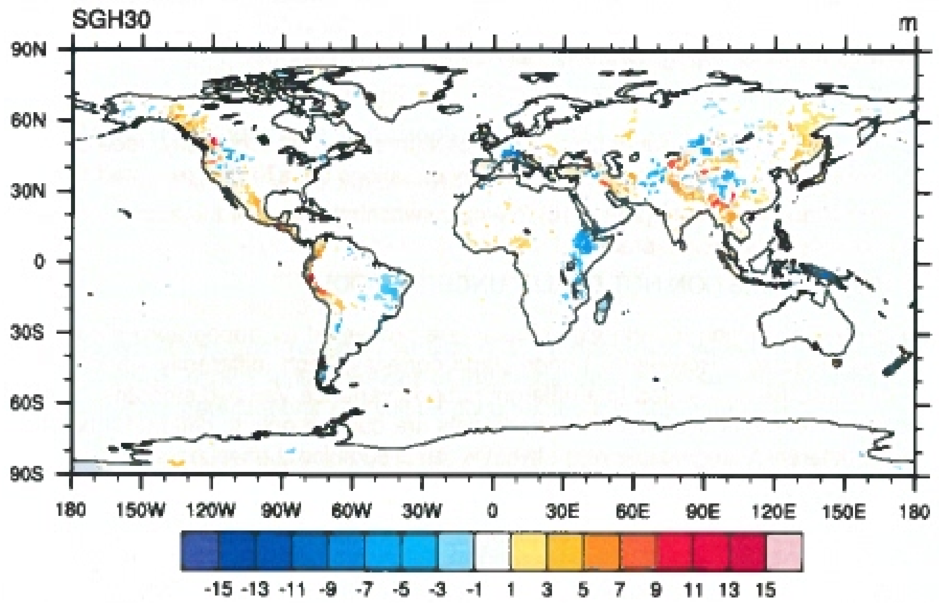
SGH30
m
90N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
-15 -13 -11 -9 -7 -5 -3 -1 1 3 5 7 9 11 13 15

Fig. 1.