Response to Anonymous Referee#2

We would like to thank the Referee for his/her constructive comments that concerns two major subjects. Through a careful study on the comments, we have made modifications accordingly. The responds to the comments and the main modifications to the paper are as following:
(Review comments are reported in red.)

Referee Comments 1:

My main concern with this manuscript is that it may be difficult for a general audience to follow due to the very technical language used, as well as the assumption of knowledge on behalf of the reader. For instance, section 1.3 is the first instance in which the reader is given an overview of the proposed method. In this section centroidal Voronoi tessellation, field control points, ground checking points, and clipping-based energy estimation are mentioned, assuming the reader knows what they are. Similarly sentences such as 'CVT is driven by a robust discrete curvature as density function, based on the curvature's ability on shape characteristics capturing and shape evolution' are difficult for a non-expert to understand. In order to be accessible to the full geoscience audience, the authors may wish to add a few paragraphs throughout that are written in a less technical manner in which key principles are explained assuming no prior experience in the field.

Response:

The Introduction section is reorganized by removing some technical terms and statements are reconstructed into direct, short sentences accordingly.

The Section 1.3 is reconstructed to state aims and contributions. The involved technical considerations, underlying principles of CVT are rearranged into section 2.3, where three new sub-sections are added, for a clearer statements.

Referee Comments 2:

The manuscript may also be improved by adding some additional validation. As the title highlights the method is a 'high-fidelity multiresolution DEM model' it would be nice to show how the error statistics relative to other methods change over more resolutions and DEM point densities. Also, the authors highlight that there are many approaches one might use when generating a DEM. The validation is conducted against a classic heuristic approach which is defined in the introduction as sub-optimal but computationally efficient. It is interesting that the new method is more accurate, however, it would also be interesting to know how it performs against a wider range of methods. If it is feasible to add this extra analysis it would be a good addition to the manuscript.

Response:

We have carried additional experiments for the validations, based on which some revisions are made on the manuscript. Here the more detailed explanation is outlined below.

For the error statistics comparison over more resolutions, experiments on those two LiDAR derived DEMs with varied resolutions are tested. The added resolutions are ranged from 5% to 0.1% (as ranged from 3.1% to 0.6% setting in [1]). The comparison results of the statistical surface interpolation RMSEs are added to Tab.1, and we copy them here for clarification:

Tab. 1Interpolated elevation RMSEs (m) at varied scale transformation *Ratios*

Dataset	Approx. Method	5%	1%	0.5%	0.1%
St. Helens	cCVT	0.636	1.614	2.455	5.772
	HFPR	1.028	2.371	4.006	11.779
UTM11	cCVT	1.239	3.773	6.593	19.997
	HFPR	3.087	6.712	10.137	28.460

From the results we could see that, under the same resolution (point density), transformed DEM surface from cCVT method is generally more precise than that from HFPR method. While all surface approximation precision (compared to the original) decrease as the resolution coarsened. We have added these modifications to the manuscript (P10, L23-24).

Before comparing cCVT against methods other than the heuristic approach, it might be worthwhile to note that, feature points based heuristic approaches perform DEM transformation really well than those other classical approaches such as very important point filtering (VIPs), resampling, or interpolation on neighbor grids [1, 2]. It is thus might be interesting to compare cCVT with methods come from application domains in Earth and environmental systems where topography is directly involved and topographic effects are greatly concerned.

Here we selected a block refinement grid model (BM) and a transfinite interpolation grid model (TIM) for analysis, they are two widely used computational models in the flood inundation simulation domain where topography dominates the well-known shallow-water process [3, 5]. The BM model is of preferred for its arbitrary enhancement capability [3], while TIM model is of preferred for its quality grid with smooth transition [4]. Besides the ordinary measures as averaging neighbor grid values or high-order interpolations, both models will make utilizes of their grid refinement or adaption to introduce topography variation [5, 6].

And the widely studied Okushiri tsunami experiment is taken for the inundation scenario, the topography of the Okushiri tsunami experiment is illustrated as Fig. 1. The terrain-driven [6] BM grid model (c.f. Fig. 2 a) and TIM grid model (c.f. Fig.2 b) for this experiment come from ANUGA[1] validation case and TELEMAC[2] validation case respectively, both are publicly available from their official websites. Terrain adaptive grid model (TAM) from cCVT is illustrated as Fig. 2 (c). For rough quantitative analysis, we build TAM grids with varied resolution ranged from 24K triangles to 7.8K triangles, and compute different surface approximation metrics for comparison with the fixed-resolution BM grid (with 21K triangles) and TIM grid (with 25K triangles). The results are listed in Tab. 2.

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[1] ANUGA is a general-purposed hydrodynamic modelling tool, developed by Australia National University and Geoscience Australia. https://anuga.anu.edu.au/.

[2] TELEMAC is an integrated solver suite for free surface flow. http://www.opentelemac.org/

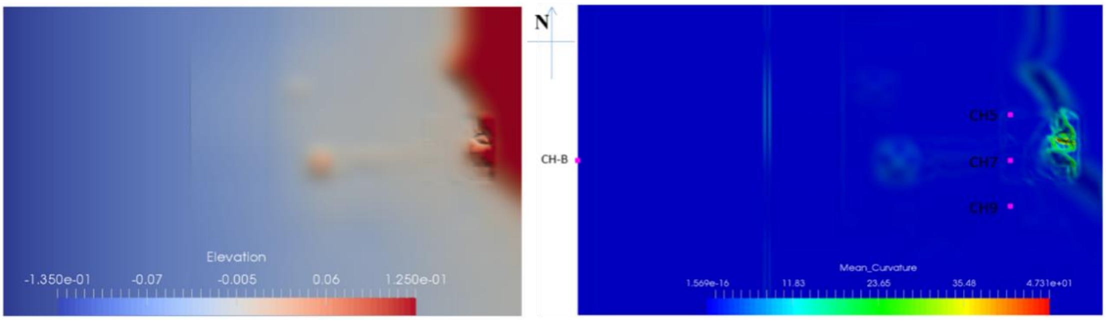

Fig. 1 Topography of Okushiri Tsunami experiment. Left, elevation rendering; Right, mean curvature rendering. (CH-B, CH5-7-9 marks the four gauge locations)

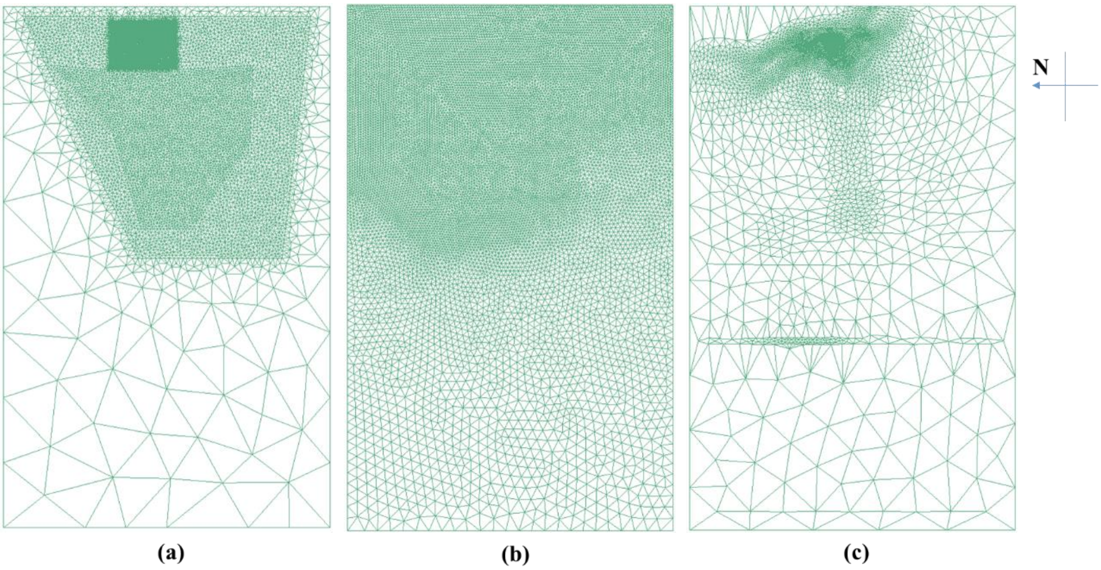

Fig. 2 Different Computational grid. (a) Block-structured grid model, (b) Transfinite interpolation grid model, (c) Terrain adaptive grid model.

From the preliminary results in Tab. 2, we can see that, under the same resolution, for any approximation metric as Hausdorff distance, barycenter elevation interpolation (which is commonly adopted by finite volume methods), or random elevation interpolation, TAM grid (A0) approximates the original terrain surface best. TAM grid with only half samples (TAM A1) to that of BM grid or TIM grid performs fairly well to that of the two comparing grids.

Tab.2 Approximation precision comparison for different grids.

Approx. Metric	BM, 21K	TIM, 25K	TAM A0, 24K	TAM A1, 12K	TAM A2, 7.8K
Hausdorff Dist.(1e-2)	4.147	1.205	0.304	0.354	1.400
Bary RMSE(1e-4)	4.127	2.414	1.653	2.315	3.035
Rand RMSE(1e-4)	3.942	2.823	2.024	2.844	3.947

Deep examination of the feedbacks imposed by the improved topography representation on the hydraulic models is expected in future studies. However, for not digress from the main subject, this part of discussion along with the expected inundation study will not be added to the manuscript.

References:

[1] Zhou, Q. and Chen, Y.: Generalization of DEM for terrain analysis using a compound method, ISPRS Journal of Photogrammetry and Remote Sensing, 66, 38-45, 2011, doi:10.1016/j.isprsjprs.2010.08.005.

[2] Chen, C. and Li, Y.: An orthogonal least-square-based method for DEM generalization, International Journal of Geographical Information Science, 27, 154-167, 2012, doi:10.1080/13658816.2012.674136.

[3] Nikolos, I. K. and Delis, A. I.: An unstructured node-centered finite volume scheme for shallow water flows with wet/dry fronts over complex topography, Computer Methods in Applied Mechanics and Engineering, 198, 3723-3750, 2009, doi:10.1016/j.cma.2009.08.006.

[4] Li, Y., et al.: An orthogonal terrain-following coordinate and its preliminary tests using 2-D idealized advection experiments. Geosci. Model Dev., 7(4), 1767-1778, 2014, doi: 10.5194/gmd-7-1767-2014.

[5] Bates, P.D.: Integrating remote sensing data with flood inundation models: how far have we got? Hydrological Processes, 26(16), 2515-2521, 2012.

[6] Bilskie, M.V., et al.: Terrain-driven unstructured mesh development through semi-automatic vertical feature extraction. Advances in Water Resources, 86, Part A, 102-118, 2015.