Dear Reviewer,

Thank you for taking the time to read through and comment on our manuscript. Here, we give a point-by-point response to all your comments and detail our proposed changes to the manuscript.

R: Reviewer's comment
A: Author's response
C: Proposed changes to the manuscript; text changes in blue

[All references that we cite herein can be found in the reference list of the modified manuscript.]

R: This paper presents the performance of a new version of ADCIRC on simulating global tides and storm surges, highlighting a mesh design with key parameters identified through experiments, capability of local refinements for extreme events, and improved efficiency brought by updated numerical treatment. The paper is well organized, and the topic is in line with the scope of GMD. The clear improvement over earlier versions of ADCIRC is surely of interest to existing and potential ADCIRC users. The conclusions and recommendations drawn from the experiments on mesh design and local mesh refinement are valuable for unstructured-grid modelers in general. There are a few items to be clarified and issues to be addressed (listed below), and my recommendation is "minor revisions"

A: Thank you for your positive comments. We aim to fully address each of your identified issues as detailed below.

R: Stability constraint:
The paragraph starting from Line 303 mentions that smaller time steps are required for locally refined meshes used in the Katrina and Haiyan simulations. How did you decide on an appropriate dt for each simulation? For ADCIRC users, what is an effective way to find the optimal dt for a mesh with local refinements?
Clearly defining the stability condition is generally difficult for complex models, but the users may need a bit more guidance and reference in choosing the time step. If you have additional benchmark tests or applications (done by ADCIRC v55) besides the three configurations mentioned on Line 305-307, please list their grid resolutions and time steps in a table (maybe in the supplemental materials).
Also, consider mentioning the typical grid resolution for global simulations on Line 101. Mention the typical resolution of the refined meshes on Line 384.

A: We agree that it would be very helpful to know what the "optimal" dt would be for a certain mesh. In the supplementary we conducted the stability analysis to determine what is the stability constraint under the linear 1-D conditions (Sect. S1.5). However, this only provides us knowledge of the maximum value of the product of dt and the numerical parameter, tau0 (for linear stability). Thus, the dt we set for each of the tropical cyclone simulations was actually found by trial-and-error while keeping the ratio of dt and tau0 constant (see Sect. S2.1).

The reason that higher resolution meshes may need a smaller time step could be related to the CFL condition based on the fluid velocity (instead of the gravity wave speed). Considering the maximum fluid velocity *a priori* is not obvious but if we back out the results and consider Cr = 1 to be the stability criteria then for the two tropical cyclone tests we have (note that the values of dx listed are the actual minimum element edgelengths of the mesh while MinEle is the nominal minimum resolution. The stable dt for each mesh is listed in the Sect. S2.1):

Cr = U*dt/dx = > U = Cr*dx/dt:

- MinEle = 1.5 km (both)   : U = 1*300 m / 120 s = 2.5 m/s
- MinEle = 500 m (Haiyan) : U = 1*98.4 m / 80 s   = 1.3 m/s
- MinEle = 500 m (Katrina) : U = 1*135 m / 120 s = 1.1 m/s
- MinEle = 150 m (Haiyan) : U = 1*64.2 m / 30 s   = 2.2 m/s
- MinEle = 150 m (Katrina) : U = 1*91.1 m / 50 s   = 1.8. m/s

The value of U to use in the CFL condition varies by around a factor of 2 between the meshes but this is at least superior to an order of magnitude estimate. Based on the results of these tests, setting U ≈ 2.5 m/s in the CFL condition may be a reasonable guideline to determining a stable dt for ADCIRC simulations using the semi-implicit time integration. However, this is only a guideline and surely does not guarantee stability. It is also unclear how well this will translate into simulations with more wetting-drying.

C:

1) We added this information on velocity-based CFL criteria listed above into the supplementary Sect. S2.1, lines 199-211:

5. dt is set to approximately the largest value that enables reliably stable simulations based on experience and trial-and-error. Although the linear CFL condition is satisfied unconditionally, nonlinear terms introduce instabilities on finer meshes in shallow depths, and could be related to the CFL condition based on the fluid velocity (instead of the gravity wave speed), i.e., Cr = Umax*dt/dx. dt = 120 s was used for all simulations on the global mesh without local refinement, while the stable dt was generally smaller for the storm tide simulations on the meshes with local refinement. Hurricane Katrina: dt = 120 s on the MinEle = 500-m mesh, and dt = 50 s on the MinEle = 150-m mesh. Super Typhoon Haiyan: dt = 80 s on the MinEle = 500-m mesh, and dt = 30 s on the MinEle = 150-m mesh. Based on these results and rearranging the CFL condition for the maximum fluid velocity, Umax with Cr set to 1 as the stability criteria and using the actual minimum element edgelengths of the mesh (rather than the nominal minimum resolution, MinEle) we obtain Umax = 1.1-2.5 m/s. Therefore, setting Umax to 2.5 m/s in the fluid velocity-based CFL condition could be used as a guideline for determining a stable dt for ADCIRC simulations using the semi-implicit time integration. However, this is only a guideline and does not guarantee stability. The corresponding ADCIRC `fort.15' control file parameter for dt is DTDP (https://wiki.adcirc.org/wiki/DTDP).

2) We modified Lines 382-383 (old line 349) to add the reference to Sect. S2.1:

Nevertheless, we found that the numerically stable time step decreases as coastal mesh resolution becomes finer (see Sect. S2.1 for details on setting the time step), which increases computational time.

2) Lines 105-107 (old line 101): With a semi-implicit time integration scheme, the computational time step permitted is larger than the CFL constraint and as a result facilitates computationally efficient global simulations on meshes that have nominal minimum resolutions of 150 m-1.5 km (see Sect 3.3 for details).

3) Line 427 (old line 384): (nominal minimum resolution of 500 m and 150 m)

R: Solution variability with time step:

When model simulations are stable, is there any solution variability with time step? For example, if two simulations are conducted on a same locally refined mesh, one with dt=90 s and another with dt=25 s (values chosen from the suggested range on Line 384), would there be any noticeable difference in the model results (e.g., the timing and elevation of the simulated storm peak)? If not, please add one or two sentences where appropriate to note this.

A: From a limited additional test set we do not see noticeable differences between solutions using different time steps since even the larger 120 s time step is still much smaller than the period of the shallow water waves. We also verified that ADCIRC temporal discretization errors are much smaller than spatial discretization errors in Roberts et al. (2019b) [Section 3.5.2 of that paper]. Variations due to the time step could nevertheless become more apparent when significant wetting-drying occurs since the methodology used in ADCIRC assumes that only one dry element adjacent to a wet element can become wet (and vice-versa for drying) per computational time step.

C: Added this note in paragraph 4 of "Section 4: Discussion" Lines 383-386: Note that additional tests (not shown) were conducted, and these demonstrated that the computational time step used for the same mesh had a negligible effect on storm tide elevation solutions. However, this may not transfer as well for simulations where there is significant wetting-drying due to the one element per time step wetting-drying logic used.

R: Solution variability with mesh resolution:

The effect of mesh resolution on peak elevation and timing is mentioned multiple times in the paper ("Abstract", Section 3.2.2, and "Conclusion"). Do you have any hypothesis on the mechanism behind this? Could it be that the wave speeds are slightly different due to the difference in model bathymetry (because the resolutions of the mesh are different); or the numerical scheme behaves differently under different Courant numbers?

A: We think that this is primarily related to the bathymetry and the geometric representation of shoreline boundary (physical approximation errors) which results in the slightly different wave speeds and wave transformation as the reviewer mentions. Our previous work presented in Roberts et al. (2019b) details these effects. For instance, we showed that the error of the polygonal area of the mesh increases geometrically as the minimum shoreline resolution is coarsened [Figure 4 of Roberts et al. (2019b)]. Similarly, we also showed that the volumetric error of the mesh increases geometrically with mesh coarsening [Figure 7 of Roberts et al. (2019b)]. Section 3.5.2 of Roberts et al. (2019b) discusses the relative make-up of numerical discretization errors versus the aforementioned physical approximation errors for astronomical tide solutions. The findings concluded that ADCIRC numerical discretization errors are non-trivial but generally less significant than the physical approximation errors associated with mesh refinement/coarsening along shorelines and topographic gradients.

C: We added a small note on this to "Section 4: Discussion" on Lines 386-389: The impact of mesh refinement clearly tends to decrease open ocean storm tide elevations in open ocean areas and the timing of the peak occurs later. This could be attributed to larger physical approximation errors of the shoreline geometry and bathymetry with mesh coarsening (c.f. Roberts et al., 2019b) leading to slightly different wave speeds and wave transformation.

R: Improved accuracy compared to the prior version:

The "Discussion" section focuses on mesh configuration but does not explain the clear improvement between the two model versions on a same ref mesh (Fig. 6ab). Among the numerical improvements from v54 to v55, how does each of them contribute to the improved accuracy (mentioned in Section 3.1.1)? Which one is the main factor? Please add a few sentences or a paragraph to discuss this.

A: The reason for the improvement is due to the changes to the governing equations which is discussed in detail in supplementary Sect. S1.2. To summarize, the form of the equations (particularly the continuity equation) solved in the old version of ADCIRC did not correctly consider the curvature on the spherical Earth, so it was technically only valid for "small" domains.

C: We added a paragraph to the beginning of "Section 4: Discussion" to make this clear (Lines 345-351): The new version of ADCIRC (v55) demonstrated improved tidal solutions compared to the previous versions of ADCIRC (denoted as ADCIRC v54). This is because ADCIRC v54 does not solve the correct form of the governing equations in Spherical coordinates and is thus technically valid only for sufficiently small regional domains (see Sect. S1.2 for more details on this comparison). For instance, this old form of the governing equations appears to be sufficient for the western North Atlantic Ocean regional domain, which has been thoroughly validated using ADCIRC since Westerink et al. (1994). The changes made in ADCIRC v55 make it suitable for simulating larger domains, in particular the global domains that we investigated in this study.

R: Local model error:

I agree with Anonymous Referee #1 on that the large local errors (especially those nearshore) need to be discussed and explained, so that the readers/users can have a good understanding of the limitation of this model.

A: Please refer to our first reply to Anonymous Referee #1 for a detailed response to this comment. In essence, we do not think that the presence of some larger local errors is a result of a structural error of the model. Instead, such errors are predominantly related to a combination of imperfect bathymetric data and dissipation approximations that can be "tuned" in a way to further reduce the error. We also added some lines throughout the manuscript to address this as detailed in our second reply to Anonymous Referee #1.

R: Technical corrections:

Line 29: "FMV" should be "FVM".

Line 252: "match".

Line 357: "are able to".

C: Made these corrections.