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Interactive comment on "A national topographic dataset for hydrological modeling over contiguous United States" *by* Jun Zhang et al.

Jun Zhang et al.

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Replies to Reviewer1:

Overall, this is a well-explained paper producing a potentially useful dataset. I have some serious concerns about the initial/input DEM used for this entire dataset preparation and analysis. The paper claims to have started from the National Water Model (NWM) digital elevation model (DEM). This is very concerning since the NWM DEM has already been hydrologically-adjusted from the source DEM to meet the needs of WRF-Hydro and the NWM. A more scientifically rigorous approach would be to have started from the source 30m NED to work through your process.

It is unclear to me why the NWM seems such a focus of the paper since it should not

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have been the original DEM used. The NWM DEM has already been D8 processed and the authors then continued to change it into a D4 based hydrologic routing grid. The authors make the argument that they are improving the NWM DEM when really they are simply making it suitable for models that require D4 routing. The NWM grid is suitable already for D8 routing and contains accurate placements for NHDPlus v2 channels on the 250m grid. It is also apparent the authors excluded areas that are included in the NWM, such as the Great Lakes region. I think the authors would have a better justification starting from the source elevation data and creating a new DEM rather than starting from an already hydrologically processed DEM and manipulating it further.

Reply: We would like to thank the reviewer for their comments. We understand the concerns raised here and would like to emphasize 4 points here that were perhaps not clear from the original manuscript. We will emphasize more clearly in revisions:

1) First, the reviewer notes that NWM grid 'already contains accurate placement for NHDPlus v2 channels on the 250m grid'. It is true that the NWM grid has already mapped NHDPlus channels to its grid. However, it is important to note that in the NWM the DEM is used directly for lateral flow across the hillslopes; however the channel network is abstracted for overland flow simulations in their current version. Careful review shows that there are actually many areas of disagreement between the NWM DEM and the channel network that can be seen in the original DEM figures we provide (Figure 3). These disagreements are not as significant limitation for the NWM given the computational approach (i.e. using an abstracted stream network), but are a significant limiting factor for simulation platforms that do not abstract the channel network.

2) The reviewer also notes that we are 'simply making it suitable for models that require D4 routing'. We would like to clarify that the inconsistencies between the DEM and the channel network noted above are an issue for any model that is simulating the stream network directly on the DEM and not abstracting it, regardless of the routing approach that is use. Similarly, because the NWM simulates overland flow within its

channel network layer there is no need for smoothing along the stream channels. Our dataset includes this as an additional, and very necessary, processing step for codes that simulate overland flow directly on the grid. The key advancement that we are making here is ensuring that a consistent drainage network can be generated directly within the DEM that will match with the abstracted stream network from NHDPlus. We setup our processing to provide a D4 connected system because that will be applicable to all hydrologic codes but the differentiation between D4 and D8 is not our key advancement.

We would also like to clarify that many PDE based hydrological models like ParFlow use a finite volume approach to solve the partial differential equations for overland flow and calculates the water balance at every surface cell, for the flows to be mass-conservative there. Fluxes are calculated across cell faces. Having fluxes at the corners are not mathematically possible as there is zero across those interfaces (flux=velocity * area). This is why we develop gradients in four directions. However, it does not mean that we cannot have resulting flow in any direction as a combination of these vectors. The four directions we use here are simply the formulation we use for solving the PDEs, this approach preserves mass and improves the computational efficiency. We understand that our use of the term D4 in the manuscript may have a different connotation for routing routing schemes and will revise this language the whole manuscript.

3) The reviewer expressed concern regarding our focus on the NWM throughout the paper. We would like to clarify that we intentionally use the NWM grid and projection here because we wanted to create a DEM product which is as consistent as possible with the NWM framework to facilitate model comparisons and coupling between any model and WRF-Hydro at national scales. The DEM we provide here is intended for any hydrologic code that uses an entirely gridded approach and is intended to provide results that will be as close to the NWM framework as possible. With this goal in mind, we did start from the 250m NWM DEM. All of the adjustments we make to this initial DEM are to improve the properties of the drainage network. We could have started

from the completely raw DEM as the reviewer suggests but our goal in starting from the NWM DEM was to stay as consistent as possible with this framework. We are only making adjustments where it is necessary to keep the drainage properties consistent. We think that the result is a product which is (1) suitable for gridded codes but (2) still as consistent as possible with two national platforms (NHDPlus and the NWM)

4) Finally, we agree with the reviewer that there are some areas of the Great Lakes that are in the NWM and are not in our domain. Our grid was taken directly from the NWM grid at the time of our analysis as stated in Line 86 that we started from the 250m DEM developed by NWM V1.2. The NWM grid has since expanded, however it was outside the scope of this work to re-create our analysis. Furthermore, as we are not processing Bathymetry data excluded major water bodies from our analysis (e.g. the Great Lakes themselves, they are also excluded from the NWM).

We agree that these points, especially the novelty of the DEM may not have been made clearly enough in the original manuscript. We appreciate the reviewer's concerns and improved our discussion in response to the rest of the reviewer's comments.

1. Line 38: "This provides a high-resolution national topography dataset, however it includes no processing for hydrologic utilizations." This is not exactly true. The NHD-Plus product provides snapshots of 30m elevation, hydrologically processed elevation (hydro-dem), and the flow direction and flow accumulation derivatives.

Reply: Yes, NHDPlus provides hydrologic data, but in this sentence we mean that NED dataset has been hydrologic processed to ensure drainage. We have revised the sentence to 'This provides a high-resolution national topography dataset that includes hydrologic information such as flow directions and accumulation, however it is not directly processed for DEM based hydrologic simulations which may require more smoothing.'

2. Line 40: NHDPlus is not only 10m (though it is 10m for High-Resolution NHDPlus), but also medium resolution is derived from 30m.

Reply: Thanks for the comment. We have modified the expression in line 41 to "NHD products are provided in multiple resolutions, i.e. NHDPlus High Resolution in 10m and NHD Medium Resolution in 30m."

3. Line 49-51: NHDPlus does not have much to do with HAND. HAND is an elevation-derived depth product. NHDPlus is a vector hydrography dataset.

Reply: Yes, the previous research demonstrated that NHDPlus streams are not aligned with the DEM used in HAND which may lead to discrepancies in hydraulic properties. We want to illustrate that there exist some concerns in applying the NHDPlus product directly to hydrologic models. To make this more clear the sentence on Line 50 has been changed to 'It was found that NHDPlus stream network is not well aligned with DEM used Height Above Nearest Drainage (HAND) which can lead to discrepancies in hydraulic properties for NHDPlus reaches (Garousi-Nejad et al., 2019). '

4. Line 54: This reference does not say the DEM that supports the NWM is a 30m DEM derived from the NED.

Reply: The reference will be corrected in the revised manuscript.

5. Line 55-60: NWM uses NHDPlus v2 (medium resolution) for it's stream network.

It should be noted that NWM is a customization of the WRF-Hydro community model. The NWM is an operational model ran by NOAA. WRF-Hydro does have the ability to run gridded simulations.

Several things here are not entirely accurate. NWM/WRF-Hydro is inherently a gridded model. Overland and subsurface flow is gridded. The NWM configuration of WRF-Hydro intercepts inputs to the gridded channel network and puts those flows into the 1D Muskingum-Cunge routing scheme. So, the along-channel routing is not performed on the grid, that is true. However, the DEM in NWM is perfectly suitable, and in fact was created to support gridded channel routing. It was decided for computation efficiency in NWM to use Muskingum-Cunge, but the DEM has been hydrologically processed for simulation. You could actually deactivate the User-defined mapping (UDMP) in NWM and it could potentially produce fully gridded streamflow simulations, with the correct parameters to support that configuration.

I also want to point out that WRF-Hydro very much performs physically based calculations of the gridded diffusive wave equations, which are partial differential equations. These are solved on all non-channel cells, representing the surface and subsurface.

Reply: We thank the reviewer for these detailed comments and clarification. We apologize for any confusion, the point here was never to imply any deficiency in the NWM grid configuration (we agree with the reviewer that the NWM grid is very well-suited to WRF-Hydro run in this configuration), merely to point out the that two models have different needs from the gridding and that one grid configuration is not universal. Thanks for the correction, we have corrected the descriptions about NWM in Line 56-61 to

“Although the NWM DEM does include topographic processing and is designed to be used for gridded simulation, the current NWM configuration is using 1-D Muskingum-Cunge routing method for computation efficiency rather than following the actual DEM grid (Gochis et al., 2018; Johnson et al., 2019). As a result, these applications do not need to directly examine the DEM quality along the streams. It is notable that NWM is capable to do fully gridded streamflow simulations by deactivating the user-defined mapping (Gochis et al., 2018).”

We agree with the reviewer that the processing NWM has done is perfectly suited for their simulation needs. However, we would like to note that the processing provided in the NWM DEM is not necessarily sufficient for other gridded approaches as it does still result in problematic channel routing and smoothing if used directly. This is demonstrated directly in (1) our comparison of drainage areas with stream gauges and (2) our analysis of stream elevation profiles exemplified in Figure 9. These differences are not caused by D4 vs D8 differences they are a function of the level of processing that was applied to the DEM. This is not meant to be a criticism of the NWM it is simply a difference in the level of processing required for different computational approaches. We worked directly with the NWM team as we were developing our product. Our initial intention was to use the NWM DEM directly for modeling because it has some hydrologic processing already applied. However, the discrepancies noted in our analysis are significant limitations for fully gridded codes (and would also be a limiting factor for the NWM if it runs with the mapping de-activated). The product we provide here is intended to compliment the NWM DEM by providing something that is consistent with that starting point but addresses the limitations we walk through in our manuscript. We see our dataset as complimentary of the NWM platform and not in competition to it.

6. Line 60-65: It is true that NWM can distribute water from any given cell to any of the 8 neighboring cells. It is interesting the authors are advocating for the simpler D4 approach, which will yield a less accurate and 'longer' stream network than D8.

Reply: As noted above we understand that the D4 terminology may have caused some confusion in this case and will modify our discussion and use of this terminology throughout the manuscript. We are not intending to advocate for a D4 routing approach and indeed in our model flow can move in any direction. The point here is that we ensure consistent slopes across cell faces, because models with finite volume approaches such as ParFlow calculate fluxes across cell faces. By directly considering this computational approach in our topographic processing we can ensure consistent slopes that will improve the computational efficiency and preserves the ability for overland flow to move in all directions. We do not mean that ParFlow or any similar model is solving D4 routing, merely that these PDE based models necessarily disaggregate fluxes and slopes into 4 directions perpendicular to cell faces when they do their calculations. We can obtain a better result by taking this into account directly in our processing. We will change the misleading 'D4 routing' in the text for the whole manuscript.

Although NWM is capable of performing gridded simulations in channels, the current applications using Muskingum-Cunge routing method did not require the examination of the DEM smoothness along the streams. Our analysis shows that this can be problematic for generating hydrologically consistent river slopes (Figure 9). Here, too this is not meant as a criticism of the NWM, it was simply a processing step that was not required for their application. In our dataset the slope along the river network has been smoothed to improve the routing performance. The routing performance in this manuscript over CONUS and ongoing simulations present a reliable quality of the dataset for gridded simulation approaches.

7. Line 80: State which version of the NWM, the next version of the NWM this statement will no longer be true. There is more than just CONUS NWM, including Hawaii, Puerto Rico/VI, CONUS + Great Lakes, and soon Alaska.

Reply: It is NWM version 1.2, has been added in the manuscript in Line 79. The NWM grid has since expanded, however it was outside the scope of this work to re-create our analysis.

8. Line 86: How does one obtain the NWM version 1.2 input datasets?

Reply: All input datasets were obtained directly from the NWM development team. We have added this note to the revised manuscript. Also, as noted above we would like to point out that we were in close communication with their team throughout the analysis and development of our DEM to ensure that our additions were not redundant with any processing steps or products that they had already generated.

9. Line 89: I have never heard of upscaling using minimum elevation. There should be more justification for this approach here and preferably references to base this decision on.

Reply: A reference will to be added in Line 89. Several upscaling approaches have been tested and choosing the minimum elevation presented the best performance in preserving the hydrologic features.

10. Line 94: I have worked closely with the NWM development team at NCAR and

this is simply not true. Please remove this statement for the paper or correct it. The channel grid in NWM v1.2 and beyond is 'seeded' using NHDPlus v2 watershed points, in order to match network density. It is definitely not a rasterized version of a vector network.

Reply: Thanks for the correction we agree the NWM uses the vector network not the rasterized version. What we were referring to here is a product which we received from the NWM team which was a rasterized version of their vector stream network that they used for processing. We started from this rasterized version as a mask rather than rasterizing the vector network ourselves in order to stay consistent with the NWM analysis. The statement has been updated in Line 93-94 to:

'The stream network mask is derived from a rasterized version of the NWM stream vectors. The original network mask raster was provided from the NWM. The mask we use here is a subset of the NWM stream mask based on Strahler Stream Order thresholds (Horton, 1945; Strahler, 1957). The stream mask is used to guide the drainage patterns in the DEM for the topographic processing in this study.'

11. Figure 1: Please make these different colors. It's difficult to tell what is a lake and what is a sink. The 1km gridded stream network looks really sparse to me. 5th order streams are quite large and so entire headwater regions are missed.

Reply: The color of sinks has been changed to red in Figure 1.

The 5th order streams in the figure are from NWM stream network based on Strahler Stream order. 5th order streams are sparse without headwater regions, while 3rd order streams cover most of the headwater regions. We have compared results from different density of stream networks in 1km and 250m. It is found that 5th order streams provide the best guidance in 1km resolution and 3rd order streams are the optimal for 250m resolution. In Figure 1, we present the map of 1km and 5th order stream network for processing.

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12. Line 125: Move this explanation up to the first usage of D4 on line 145.

Reply: We appreciate the suggestion, and the manuscript has been updated.

13. Line 187: Doesn't this manipulation of elevations between banks and channels enforce a certain stream side-slope? I'm not sure this is actually going to make hydrologic simulations more realistic, since you are burning the stream into the DEM and then enforcing a minimum elevation delta between the stream and the stream bank. Processes like inundation depth will be affected by this processing step.

Reply: Yes, the reviewer is correct that this manipulation will enforce a stream side slope. However, we would like to emphasize that this is only enforcing a minimum stream side slope, locations where the slope is steeper than this threshold do not get adjusted. We enforce a small minimum epsilon (0.1m) between the banks and channels only to make sure the bank cells can still drain into the right channel cells. 0.1m is a slope of 10-4, which is the same as the minimum slope we are applying to the whole CONUS. Furthermore, we would like to note that we are not really burning the stream into the DEM. There is one initial processing step where we apply a very minor 1m stream 'burning' step. This is really just to help provide the location information of the streams in very flat terrain. All significant stream elevation adjustments happen in two subsequent stages: first with the priority flood algorithm which is a mathematically optimal filling operation and secondly with our additional stream smoothing step. The bank slope checking is only necessary because we apply the additional stream smoothing step after the priority flood algorithm is applied. We agree that there is no free lunch here and that any smoothing operation has the potential to eliminate some physically relevant features. However, our analysis of the stream profiles showed that inundation depth would already be significantly impacted by the non-physical inconsistencies existing along the channel that were purely a result of DEM resolution. Therefore, we opted to apply channel smoothing and enforce a minim bank slope.

14. You should note your goal is to improve the usability for a particular model or partic-

ular set of models like ParFlow that use D4. This entire effort is likely to degrade models such as WRF-Hydro, which can operate in D8 space and contain realistic (seeded from digitized headwaters) channel placements already.

Reply: We appreciate the reviewers concern here. We have tried to be very clear about our intended usage throughout the manuscript. However, we disagree that our only contribution here is to provide a D4 DEM. As we have clarified above, our analysis clearly illustrates disagreements in drainage areas and stream profiles that occur in the raw NMW DEM. Again, this is not meant as a criticism of the NWM, we worked very closely with their team when conducting our analysis. It is a function of DEM processing that is completed for different applications. Because the application of the NWM DEM was developed for uses a vectorized stream network, many of the issues that we noted are quite easily compensated for in other parts of the modeling process in NWM. This is not possible for fully gridded models and is what prompted us to expand on the DEM processing that was conducted for the NWM. This issue exists for any finite volume modeling approach. We tried to be as general as possible in our processing choices and we feel that what we have done here will be valuable for other grided simulations (of which there are many other than ParFlow).

The reviewer is of course welcome to disagree. Our intention here is only to share a model input which took significant effort to develop because we expect that other modeling platforms may find it useful. We do acknowledge that other codes may have different needs and that is why we have also put great effort not just to document our dataset and our workflow but to provide all of our tools and instructions for how to use them, so that others can modify this workflow as they see fit. Our hope is that by publishing this as a dataset and providing much more detailed documentation and support than would normally be possible in a typical model publication that others can benefit from this. Topography is a critical input for all hydrologic models, yet topographic processing is often not a very transparent process.

15. Figure 4: You cannot look at any gage below the Great Lakes. The DEM shown

here does not include all drainage areas of the Great Lakes basin, and thus will not be correct.

Reply: We are not sure what portion of the model Great Lakes the reviewer is referring to here. While we exclude the Great Lakes themselves,s we include all of the drainage area that feed each of the gauges going into the Great Lakes in our domain. We are missing drainage areas north of the Great Lakes. However, our domain does extend into Canada to cover the areas that are draining into the US and contributing the stream gauges shown here.

16. Figure 5 - Caption is difficult to understand. Please revise.

Reply: The caption has been revised as follows:

‘Figure 5. (a) and (b) is a selected domain in Great Basin shown as the red box in the upper-right CONUS map. In (a) and (b), the background is the elevation map; blue cells are the drainage networks extracted by DEM; colored dots represent the percentage difference of drainage area between processed and USGS observations (a)without sinks and (b)with pre-defined sinks’

Line 314: Can you ’expand’ or move the stream network visually and maintain topographic connectivity of the network? This has to be done while respecting flow paths. Also, I would not characterize 3rd order streams as ’higher resolution information’. I would call it a different discretization of the same resolution of information as 5th order streams. It isn’t coming from a higher resolution dataset, it is simply a lowering of the stream initiation threshold.

Reply: Thanks for the comments. We will update the figure accordingly to reflect the topographic connectivity more clearly.

The text in Line 314 has been changed to: ‘This was accomplished by visually comparing the 5th order stream network to the higher order streams and NHD streamlines and extending the 5th order stream mask as needed to reflect this additional information in headwater regions.'

17. I recommend including a table with total stream length by region (maybe by NHD HUC2) before and after this "correction" step.

Reply: Thanks for the comments. The stream length after adding additional 3rd stream information does not actually change because we are simply using this to guide the shape of the drainage area network and not to designate cell as streams or not. The additional information is more helpful in guiding the stream position rather than lengthening the streams. As shown in Figure 6(b) and (c), the change in the shape of the stream is much more significant than the stream length.

18. For all figures: Please provide higher quality graphics, correct legends so they do not have lines around the edges.

Reply: The figures will be updated in a higher quality, apologize for it.

19. Section 3.2: The entire point of this section is to illustrate the effect of smoothing on ponding, and it seems like a reduction in ponding (off channel) is preferred, but I'm not sure why. When performing hydrologic modeling, flood inundation is sometimes a desired result. If real variations in topography result in localized ponding, then this is a good simulation. reducing ponding by smoothing the DEM may diminish the inundation simulation ability of the models using that DEM by reducing local variation and localized flooding.

Also, results are being shown for hour 20 of the simulation, when the simulation was run for 200 hours. Why was hour 20 chosen?

Reply: We agree with the reviewer that ponding is not in itself a negative thing and our goal was not to eliminate all ponding. What we were trying to address here is non-physical ponding that is just an artifact of the 1km DEM resolution. Mainly we focus here on the smoothed stream networks to ensure that we have consistent drainage. This is actually very consistent with network-based stream routing approaches which

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generally apply a single slope to each segment at these resolutions. At the hillslope scale we are checking for areas where we have created very spotty drainage patterns due to discontinuities in the slopes. Our goal is not to get rid of all ponding and as can be seen in the graphs we still maintain areas that have much slower drainage. We agree that this is an important and slightly nuanced point though and that it should be made more clearly in the manuscript. We have adjusted our discussion in Line 355 as follows:

'In addition to the drainage network location we evaluate how the topographic processing influences the runoff characteristics of the domain. As described in Section 2.3, this behavior is evaluated using runoff tests and assessing anomalously high ponding depths. Note that in this section we evaluate how our processing reduces ponding locations. This is not meant to imply that we are trying to get rid of all ponding in the domain. Rather we are looking for locations where the DEM resolution is leading to what we expect to be non-physically realistic ponding. Specifically, discontinuities along the drainage network or anomalous locations along the hillslope.'

In response to the second point: We chose hour 20 because we felt it was the best snapshot to show drainage behavior at the headwater location that we selected as our example case. In downstream regions the later portions of the simulation are more illustrative as our single rainfall pulse works its way through the system. We would select a later hour if we presented a downstream region.

20. Figure 8 The grid does not look like the NWM grid which is continuous across the CONUS domain, and uses HydroSheds outside of CONUS. Was the grid you are using here subset from the NWM?

Reply: We are not sure exactly what the reviewer is referring to here. We are using exactly the same grid and projection as the NWM V1.2 and all of our initial datasets provided by the NWM team as stated in Line 86 of the manuscript that 'We start from a 250m DEM that was developed for the NWM V1.2 . . .'. We made no adjustments to the grid except to exclude the large water bodies from our analysis (note that they are still technically in our grid and the NWM DEM values are available here they were just not processed for this analysis because it would require a separate bathymetry analysis.

21. Figure 8: What do the boxes and circles mean? If you are using these they need to be explained in the caption.

Reply: The circles and boxes are examples used in the text. The explanation has been added to the caption as 'Figure 8: The spatial distribution of ponding depth from runoff tests from four slope cases (a) No Smooth (b) Add Stream Smooth (c) Add Flat Fix (d)Remove secondary. (e) stream network from Priority Flood approach with drainage area over 100km2. The circles and boxes are examples to be explained in detail in the text.'

22. Please correct the grammar and the use of capitalizations in captions.

Reply: The grammar and capitalizations have been corrected.

23. Figure 9: These colors are difficult to differentiate in both panels a and b.

Reply: The colors in Figure 9 have been updated as attached.

24. Figure 10: Please explain this is summarized by what appears to be NHDPlus HUC2s.

Reply: The barplots are the percentage decrease of cells with ponding depth over 0.1m (those we assume are anomalies ponding points) relative to the baseline case (No Smooth) summarized by HUC2s. This shows the improvement of drainage performance after the slope smoothing.

25. Gochis, D. J., Dugger, A., Barlage, M., Fitzgerald, K., Karsten, L., McAllister, M., McCreight, J., Mills, J., Rafieeinasab, A. and Read, L.: The NCAR WRF-Hydro Modeling System Technical Description, 2018.

This is not the correct citation, authors are missing from the list and the WRF-Hydro version is not included in the title.

Reply: The reference has been corrected to 'Gochis, D. J., Barlage, M., Dugger, A., FitzGerald, K., Karsten, L., McAllister, M., McCreight, J., Mills, J., RafieeiNasab, A. and Read, L.: The WRF-Hydro modeling system technical description,(Version 5.0), NCAR Tech. Note, 107, 2018'

Replies to Reviewer2:

I don't have major comments on the technical aspect of the manuscript; the presentation is also ok. But I am not very sure whether the work of this manuscript can be considered as a new dataset. My feeling is that it is an improved version of the National Water Model (NWM) v1.2 hydrographic data. All three inputs of the algorithm come from the NWM hydrographic data which are processed data, not raw data product. Besides, I am not sure whether the improvements are necessary. As a hydrologic modeler, my focuses are more on the simulation performance. True that the drainage area of the basins are more consistent with those provided by the USGS gauges, but how about the streamflow simulation performance? Does it have obvious improvements for real case simulations? Perhaps the authors can show the improvements using a real storm event for some basins in complement with the synthetic experiment they already had. Rather than those, I am also not sure how is this improved NWM dataset compared to other hydrographic data products for the CONUS and for the globe (HydroSHEDS) in terms of a visual inspection and, more importantly, hydrologic simulations.

Reply: We would like to thank the reviewer for the comments. While it is true that all three inputs (domain mask, DEM and channel networks) are from NWM v1.2, we disagree that this starting point limits the novelty or value of the dataset we are providing here. We intentionally used the NWM grid and projection here because we wanted to create a DEM product which is as consistent as possible with existing national frameworks to facilitate model comparisons. We think that this is actually a positive feature to the dataset we provide because we show that our DEM is a significant hydrologic improvement over existing DEMs (as demonstrated by our results) but it is still as compatible as possible with other datasets.

The reviewer notes that as a hydrologic modeler they are concerned more with streamflow performance than drainage area. However, drainage area can be one of the largest sources of biases in streamflow simulation if the DEM is not processed properly. No hydrologic simulation is needed to see that if you have a 40% bias in drainage area you will have a similar bias in the total precipitation inflow to a watershed. Without correcting for this bias any simulation will be wrong or will be right for the wrong reasons. We could show this bias using a hydrologic simulation but we feel it is not helpful here because the results would be specific to the model and storm event chosen – the point we make here is that without correct drainage areas the inputs to your hydrologic simulation will be off in many cases quite significantly.

We feel the need for this product is clearly demonstrated by Figure 3. As shown here, starting form just the NWM DEM for a hydrologic simulation, even if we had a completely perfect model, we would have streamflows that would be off by 50-100% just due to incorrect drainage areas. This is a significant limitation for any hydrologic simulation and is what our data product addresses. Our processing has significantly improved the agreement of drainage area between DEM derived and USGS observation (shown in Figure 7), which eliminate the simulation error caused by the bias of drainage area.

We would also like to note that we have done an overland flow performance evaluation using an integrated hydrological model as described in Section 2.3 and 3.2. We compared the overland flow performance after applying different smoothing approaches to the channel network. This behavior is evaluated using runoff tests and assessing anomalously high ponding depth. Examples of real storm events are not presented here because the simulated streamflow is affected by multiple factors (surface and subsurface configurations etc.), not only the topographic datasets. We tried to present our analysis in a way that would highlight the properties of the dataset and not the properties of the model that we are using to look at the datasets. Therefore, we focused on unit responses and changes in streamflow dynamics as a result of our processing. We think that this will provide information to other hydrologic modelers interested in using the product regardless of the model they choose to use.

We do agree that these points, especially the novelty of the DEM may not have been made clearly enough in the original manuscript. We appreciate the reviewer's concerns and improved our discussion in the manuscript to better highlight the novelty and benefit of our work. .

Here are some minor suggestions:

1. I suggest to merge Figure 3 and 4 and add four more panels. Two panels represent the area differences between figure 3 and 4; the other two for the selected regions illustrate the improvement from the manual processes.

Reply: Thanks for the suggestions. The reviewer is suggestion to merge Figure 3-6 to one, we will consider it carefully for the updated manuscript.

2. A better way is needed to present the y-axis labels of Figure 10.

Reply: The figure will be improved in the updated manuscript.

3. I suggest to use a log-transform drainage area map for Figure 11c.

Reply: It is log-transform in the map, the legend will be corrected to avoid the confusion.

4. Please align the panel number in Figure 12.

Reply: It will be corrected in the updated manuscript.

Interactive comment on Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2020-291, 2020.

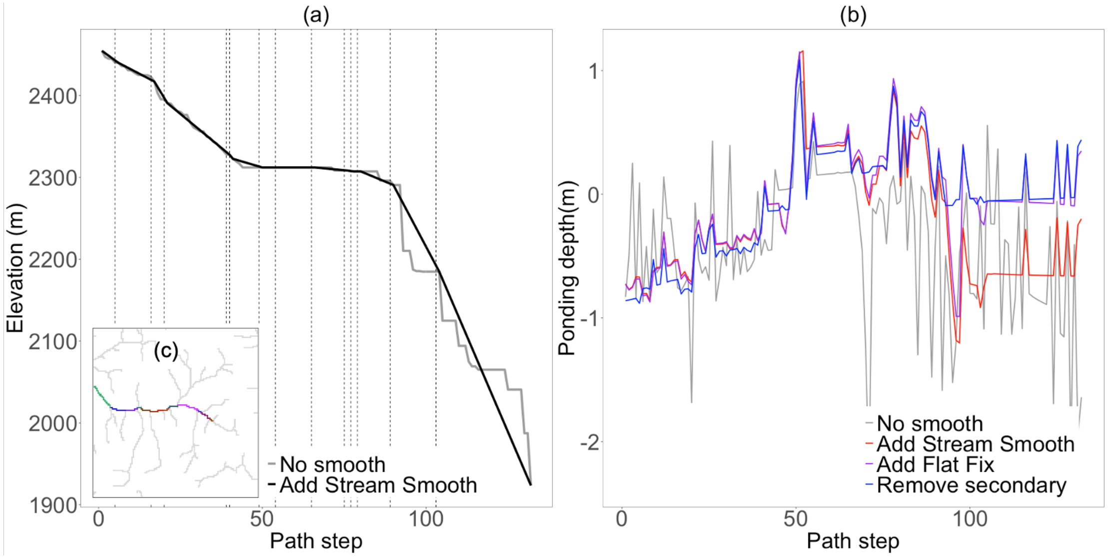

Fig. 1. Figure 9: (a) the elevation along an example stream segment (shown in c) before and after smoothing applied along the stream divided into segments by dashed lines; (b) the ponding depth along the ma

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