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Interactive comment on "A Comprehensive Evaluation of the National Water Model (NWM) – Height Above Nearest Drainage (HAND) Flood Mapping Methodology" *by* J. Michael Johnson et al.

J. Michael Johnson et al.

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Dear Editor and Reviewers,

Thank you all for the opportunity to revise this manuscript.

We want to first note that the suggestions to change error statistics and include an analysis of the bias introduced by the NWM to the NWM-HAND methods (Tarboton) were very useful but caused some changes to the format of the paper. Because of this, not all new additions / changes can be highlighted in these responses. However, we

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have made every effort to specifically address each reviewers' specific concerns.

The largest structural change is that, as the methods section grew, it became more useful to move all methods into their own section and allow the results section to simply communicate what we found. A new (4.2-4.3) section describing the analysis of gaged catchments has been added and the discussion/conclusion have been updated to reflect these results.

Attached to this submission is the revised manuscript, with continuous page numbers and in-text figures.

In the remainder of this response Dr. Tarboton's requests are indicated as **; Our responses are surrounded by » TEXT «; And specific sentences from the text are surrounded by parenthesis (TEXT).

Dear Dr. Tarboton,

First, thank you for the thorough and incisive review. It substantially aided the revisions of this paper and we have added you to the acknowledgements section of the paper.

**Firstly, both reviewers raised concerns with the title of the paper.

»We recognize the challenge with executing a truly comprehensive evaluation as conceptualized by the reviewers. As such the title has been changed (per D. Blodgett's suggestion) to:

An Integrated Evaluation of the National Water Model (NWM) Height Above Nearest Drainage (HAND) Flood Mapping Methodology. «

**Dr. Tarboton suggested changing the error statistic used to better eliminate arbitrary factors.

»Thank you for this comment and pointing out the issues with the arbitrary convex hull and how the inclusion of matching dry regions may bias our results. To address this,

we have adopted a new comparison that calculates accuracy, as well as overprediction and underprediction. These new values guide the remainder of the analysis. These are calculated by classifying the observed and simulated rasters cell-wise as WW, WD, DW, DD where W refers to wet and D refers to dry. The first character in the classification references the cell state in the observed flood map while the second refers to the state of the cell in the simulation.

Accuracy = WW / (WW + WD + DW) (fit index used Zheng 2018, and Sangwan, 2015); Over = DW / (WW + WD + DW); Under = WD / (WW + WD + DW);

These can be found in the revised manuscript as equations 3-5. This new metric did not change the overall conclusions of the tendency of NWM-HAND to under predict floodplain level inundation but did provide a more robust discussion and analysis that have improved the paper. «

**Dr. Tarboton requested that we report the matching and non-matching area between observed and modeled floods as well as total area.

»The agreement of total area (Total Simulated Wet Cells / Total Observed Wet Cells) can be seen in new figures for the flood plain analysis (Fig. 2) and for the catchment level analysis (Fig. 5). The matching and non-matching areas are represented via the Accuracy (matching), Over (non-matching) and Under (non-matching) statistics and visualized in figure 3 as a stacked bar plot and reported in table 2 and 3.

These images were added for clarity and to address this point. «

**Dr. Tarboton suggested generating flood rasters for all NHD catchments that have a USGS gage and compare them to those driven by the NWM ones to better separate out errors.

»A new section (4.2 and 4.3) was added in the revised manuscript addressing this concern for the 54 available catchments that were completely contained in a USFIMR bounding box and had a recorded NWIS and NWM-reanalysis flow values. Overall,

we found that the uncertainties in the NWM forecasts have a limited influence on the accuracy of the simulated flood extent and have documented these findings in the new sections. «

**Dr. Tarboton suggested better articulating the issues with raster resolution. In addition, make figure 5A more compelling and potential problems with roughness (Manning's n), slope, and the synthetic rating curves as sources of error.

Thank you for this comment and pointing out where our prior analysis was unclear. While testing the sensitivity of the SRC Manning Equations to roughness and wetted perimeter, we discovered that our previous inclinations towards wetted perimeter being a driving factor were incorrect. In lines 298-314 we state:

(Keeping slope (NHD attribute) and the cross-sectional area required to generate a stage of 3.8 m constant, we independently varied the roughness coefficient (n) and the hydraulic radius (via the wetted perimeter), solving for a Q of 80 m3/s. In doing so we found that the SRC relationships are generally insensitive to changes in hydraulic radius (needed to be increased by a factor of 10), but were sensitive to changes in Manning's n.)

Similarly, we tested these relationships for all catchments where we had a know Stage (taken from a cross section of the HAND and USFIMR map) and Q (from NWIS)

In doing this, the most sensitive factor is roughness which is discussed at multiple points throughout the revised manuscript and highlighted in both the discussion and conclusion. For example, lines 479-483:

(An analysis of NWM-HANDs sensitivity to changes in Manning's n and cross-sectional geometries indicate that SRCs are insensitive to changes in hydraulic radius (ergo wetted perimeters) but are very sensitive to changes in Manning's n. As a general rule of thumb, the current SRCs underpredict n in lower order reaches and overpredict n in higher order reaches. In all cross-sectional geometries we tested, observed streamflow

(NWIS) stage (USFIMR cross section) relationships were achievable with a variable n, save those with zero relief.) «

**Dr. Tarboton requested a more thorough examination of what went wrong in figure 5B:

»To really understand what was going on in this instance we needed a gaged reach to better dissect whether the previous large stage resulted from poor NWM prediction or a poor SRC curve. As such we changed our analysis to look at gaged reach upstream of our last example. This new reach can be seen in Figure 7A and is discussed in lines 315-322. «

**Dr. Tarboton asked us to explicitly state which NHD versions are used:

»Thank you for this comment. The NHD version used is the medium resolution. This is now stated in line 63-65.

(For the context of this study, all references to the NHD refer to the medium resolution dataset unless otherwise stated.) «

**Dr. Tarboton asked us to remove comment on velocity or expand on its meaning:

»Thank you for identifying the isolated nature of this comment. The idea of integrating the NWM velocity has been expanded on in lines 337-348. In text:

(A second possible alternative to refactoring is to make use of the NWM velocity and flow estimates to define cross sectional areas from the NWM forecast (equation 9). The intention would be to allow the physical model (NWM) and routing-routines (WRF-Hydro) to deal with issues of volume preservation. The resulting cross-sectional areas could be used as an Area-Stage rather than Q-Stage look up within the existing SRCs. This would work around some of the issues with roughness (outsourcing to the NWM) while capitalizing on the observed accuracies in the floodplain cross sections. Moreover, by controlling for the volume of water in the channel instead of the height, low lying areas will be less prone to exaggeration. Such a change would require (A) an

understanding of how the NWM is handling hydraulics and thus velocity and (B) a test of how variations in velocity impact volume estimation. Both are interesting pursuits in their own right but out of scope for this paper.) «

**Dr Tarboton suggested moving the discussion of software from the collusion to the discussion

»Thank you for this suggestion. We have moved this section to the discussion and drastically reduced the detail. Please see lines 462-468. «

**Dr. Tarboton requested a citation of how the methodology has been added to the NWC operational framework:

»Unfortunately, we are unaware of any official citation for this. Instead we have cited the HydroShare resource for Hurricane Harvey (line 45-46). «

(NOAA National Water Center, E. Boghici, D. Arctur (2018). NOAA NWC - Harvey NWM-HAND Flood Extents, HydroShare, https://doi.org/10.4211/hs.fe85a680d0144e79b39e8c483dc1e5aa)

**Dr. Tarboton suggested removing comments of 'first extensive evaluation' comparison

»Thank you for the comment. We have noted the comment and removed all references to first extensive evaluation. Nevertheless, our analysis is novel in that it looks solely at the performance of the integrated NWM-HAND approach for a large sample of locations. «

**Dr. Tarboton requested we state how relief between cells is calculated:

»We made use of the precomputed HAND rasters and have included the TauDEM distance down function reference you provided. This is now explained in line 82-83.

(In the pre-computed HAND rasters, relief was calculated via the TauDEM distance down function (Tesfa et al., 2011)) «

**Dr. Tarboton asked us to clarify what the “appropriate NWM output” means:

»Thank you for identifying this sloppy sentence. The product used was the NWM version 1.2 reanalysis product which is now explicit stated in lines 137-138

(The timestamp of each USFIMR satellite image was used to query the needed NWM v1.2 reanalysis values and generate an inundation map.) «

**Dr. Tarboton asked us to add some info on USFIMR development and how rasters are aligned.

»Thank you for the interest in the USFIMR products. We have pointed to the documentation for the shapefile development (lines 128-130)

(The USFIMR web portal provides more information on each flood, the specific sensor, as well as supplementary data including NED elevation and upstream NWIS hyperlinks (http://sdml.ua.edu/usfimr).)

and have described how rasters were created and aligned in lines 141-147.

(To facilitate comparison, the USFIMR shapefiles were projected from NAD83 / Conus Albers (CRS 5070) to a WGS84 coordinate reference system (CRS 4269). For each shapefile, a clipping extent, derived as a concave hull was created to ensure that all pixels being evaluated were within the USFIMR classification bounds. A waterbody mask was created by combining the perennial NHD water bodies (NHD Fcode 39004, 39009) and NHDAreas (NHD FCode 40300, 40307, 40308, 40309) in each extent. The USFIMR flood, extent, and waterbody mask, were all rasterized to the 10m HAND grid using the fasterize R package (Ross, 2018). All cells that were not within the concave hull or covered by a waterbody mask, were set to NA prior to comparison.) «

** Dr. Tarboton pointed out some technical corrections:

»Thank you for your detailed look at our paper, all suggested technical corrections have been accepted and incorporated in the revised manuscript including grammatical

correction, subjective statements, the description of red/pink. «

Again, thank you for helping make this paper substantially better than its original submission,

Sincerely,

Mike Johnson, Dinuke Munasinghe, Dami Eyelade, Sagy Cohen

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2019-82/nhess-2019-82-AC1-supplement.pdf

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