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Natural Hazards and Earth System Sciences
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Interactive comment on "A mathematical formulation for estimating maximum run-up height of 2018 Palu tsunami" *by* Ikha Magdalena et al.

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Dear Referee #2,

Thank you for the time and effort that the reviewers have dedicated to provide your valuable feedback on our manuscript. The suggestions offered by the reviewers have been immensely helpful.

We have been able to incorporate changes to reflect most of the suggestions provided by the reviewers. We have responded to them individually, indicating exactly how we addressed each concern or problem and describing the changes we have made. The revisions have been approved by all authors.

Comment 1: After reading the manuscript, I started to be significantly concerned regarding the applicability of cross-sectionally averages theory to the case of 2018 Sulawesi tsunami. The earthquake rupture happened not across the bay but rather diagonally and near its head. This could be easily seen e.g. at the NOAA tsunami modeling webpage (figure 6 is likely from there) https://nctr.pmel.noaa.gov/sulawesi20180928/ and https://www.youtube.com/watch?v=98scC02hNzo&feature=youtu.be See the attachment, figure 1, for the tsunami wave height right at its initiation. The cross-sectionally averaged shallow water equations assume a uniform wave across the entire bay, which is not the case here. Response: We agree that the earthquake rupture happened not across the bay but rather diagonally and near its head. According to Widiyanto, 2019 [4], there were three main tsunami waves that reached the beach. The first wave is less than 1 meter tall and the second and third waves are the more devastating tsunami waves. From the simulation, we can see that the diagonal Palu-Koro fault earthquake rupture initiated the transverse wave along the bay. This transverse wave struck our point of observation, Besusu Barat, for the first time at the eighth until the twelfth minute of the simulation. This first strike can be treated as the first wave. We can also see from the simulation that there was a wave created behind our fixed point, far from the shoreline near the Pantoloan city, with a high amplitude. Afterward, this wave propagated near-uniformly across the entire bay towards the bay mouth and struck the shore with a high amplitude at the seventeenth until the twenty-fourth minute of the simulation. Please kindly see the Figure 1 below. Because of this reason, we can assume that this wave was the second or third tsunami. Since we are calculating the upper boundary of the run-up, we did not calculate the propagation from the initial earthquake rupture moment, when the first wave is more likely to happen. However, we were calculating the propagation when the near-uniformly wave propagated across the bay towards the onshore and causing a devastating event. This is why we are able to use the cross-sectionally averaged shallow water equations.

Comment 2: In the manuscript it was mentioned that the period of the wave was 3 minutes. Besides the tectonic tsunami caused by the ocean bottom, there were several landslides along the lateral shores, and it is not clear whether the 3 minutes and due to the tectonic and/or landslide components. Overall, the paper would greatly benefit from a short discussion of the tsunami source, wave propagation, observations, etc. This can (or maybe cannot) put a solid footing for the cross-sectionally averaged theory chosen here to model runup. Response: The 3-4 minutes period is the dominant wave period as recorded in de-tided sea level records as stated by Heidarzadeh, 2019 [2]. The dominant wave period is the wave period associated with the highest energetic waves in the area. Using the spectral analysis, it is suggested that the dominant period is the local tectonic source. It is also suggested that a small submarine landslide is occurred using the combination of spectral analysis, numerical analysis and field data [2].

It is a really nice suggestion. We are planning to add a short discussion of wave propagations and observations in Palu bay as in the previous reply.

“Three tsunami waves were recorded across the shore. The first wave is less than 1 meter and the second and third waves are the more devastating tsunami waves (Wahyu Widiyanto et al. (2019)). The dominant period of the wave is 3-4 minutes and it is suggested that this number is the result of a submarine landslide (Heidarzadeh et al. (2019)). From the NOAA simulation, the diagonal Palu-Koro fault earthquake rupture generated a transverse wave along the bay. This transverse wave struck our point of observation, Besusu Barat, for the first time at the eighth until the twelfth minute of the simulation. This first strike can be treated as the first wave. Also from the simulation, there was a sudden wave created behind our fixed point, far from the shoreline near the Pantoloan city, with a high amplitude. This nearly uniform wave propagated across the entire bay towards the bay mouth and struck the shore with a high amplitude at the seventeenth until the twenty-fourth minute of the simulation. It can be assumed that this wave was the second or third tsunami. Since we intended to calculate the upper boundary of the run-up, the initial earthquake rupture moment will not be the initial condition of our calculation. However, we were only calculating the propagation when the wave propagated near-uniformly across the bay towards the onshore and causing a devastating event. Therefore, the cross-sectionally averaged shallow water equations will be used in our analytical analysis derivation."

Comment 3: Please explain applicability of the monochromatic wave assumption to compute the runup of Sulawesi tsunami in the Palu bay. This methodology is applicable in some theoretical computations to show importance of the bay geometry, wave period, etc. But we rarely have seen monochromatic tsunami waves. I would almost say 'never have' seen. Response: The aim of this paper is to find the upper boundary of the tsunami run-up height in the observed location. The monochromatic wave leads to the worst scenario of the tsunami run-up. It is easy to see that the monochromatic wave can lead to a more devastating run-up compared to the solitary wave, the usual approximation of a tsunami wave. The greater result of monochromatic wave run-up compared to solitary wave run-up in the parabolic bay can be also seen in [1].

Comment 4: Derivations of the analytical solutions could be shortened since the bay profiles depend on the exponential. For example, a reader could be referred to Garayshin et al., (2016) and Anderson et al., (2017) who considered runup of long wave runup in the general case of U-shaped and V-shaped bays. These authors also showed that the triangular shaped bay can produce a larger runup, given all other parameters constant. Response: It is a really nice suggestion. However, the reason we elaborate on the formulae derivation is we want to emphasize each characteristic of the bay profile.

References [1] Golinko, V., Osipenko, N., Pelinovsky, E.N. and Zahibo, N., 2006. Tsunami wave runup on coasts of narrow bays. International Journal of Fluid Mechanics Research, 33(1). [2] Heidarzadeh, M., Muhari, A. and Wijanarto, A.B., 2019. Insights on the source of the 28 September 2018 Sulawesi tsunami, Indonesia based on spectral analyses and numerical simulations. Pure and Applied Geophysics, 176(1), pp.25-43. [3] NOAA: Modeled Amplitudes for Sulawesi Tsunami 2018 September 28, MOST Forecast Model, 2018 [4] Widiyanto, W., Santoso, P.B., Hsiao, S.C. and Imananta, R.T., 2019. Post-event field survey of 28 September 2018 Sulawesi earthquake and tsunami. Nat. Hazards Earth Syst. Sci, 1, pp.1-23.

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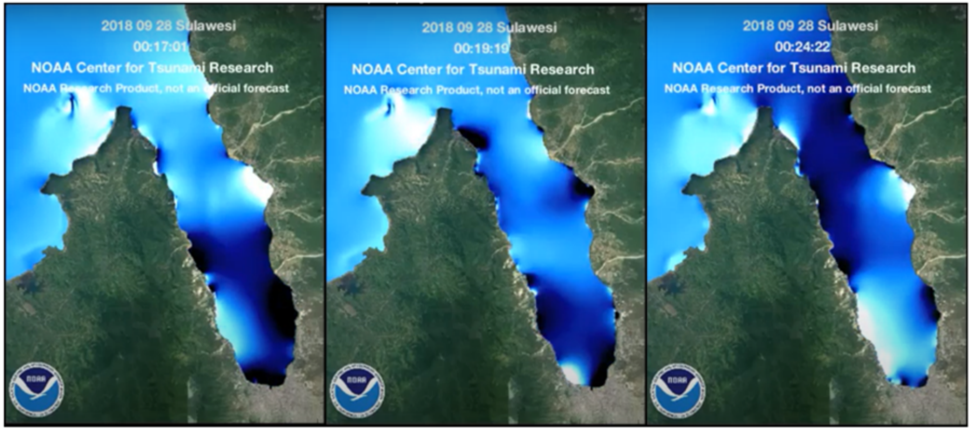

Simulation time: 17 m 01 s Simulation time: 19 m 19 s Simulation time: 24 m 22 s

Figure 1. Nearly uniform tsunami wave propagation towards the bay mouth (NOAA, 2019) [3]

Fig. 1.

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Discussion paper