nhess-2021-343:
Tsunami hazard in Lombok & Bali, Indonesia, due to the Flores backarc thrust

The manuscript presented by Felix et al. evaluates the tsunami hazard associated with a potential rupture of the Flores backarc thrust along the Lombok Strait. The manuscript is well written, and properly organized, and figures are legible and of good quality. While modelling in this work uses higher resolution bathymetric and topographic data than previous studies, the following aspects need to be clarified/improved before considering this work for publication:

Thank you for your comments and suggestions. Please see below the list of our responses.

- The fault model is mostly interpreted on the basis of 2D seismic sections, earthquake location, and seafloor morphology (which is not clearly visible from the current figures). Yet, the region used to rupture is > 100 km wide, so one would appreciate few words regarding how potential along-strike structural variations could affect modelling results.

  The fault rupture that we consider is ~116 km wide, stretching across the strait between Bali and Lombok. While there is limited data within the strait to assess the continuity of the fault, there is no reason to believe that there are significant structural variations along strike. The focal mechanisms for the events near Bali have very similar strike and dip to that at Lombok (Fig. 1a). When varying the fault dips to 18° and 34°, representing the minimum and the maximum limits of the fault dip uncertainty, they have minimal impact on the tsunami model. The tsunami of these two models are only 5-8% different from the energy of our model with a 25° fault dip. Minor structural variations would result in minor variations in arrival times and wave heights but would not be likely to have a strong effect on our results.

  Any variations in strike and dip beyond the strait would have no impact on our results, as they would be subaerial. We will include a statement in section 2.1 (Methods – Slip model) to show that an increase in along-strike length would not affect the tsunami in the Lombok Strait, as long as the fault length is wider than the Strait's narrow opening.

- A close up of the bathymetry from Fig.1a would be needed along the Lombok Strait and North Lombok, to properly see that the inferred ramp in Fig. 1a is supported by morphological variations of the seafloor.

  We will improve the presentation of the seafloor morphology in Figure 1b (the closeup view of Lombok Strait and North Lombok) by making the contour lines thicker and darker. We will make the panels in Figure 1 bigger to increase the visibility of the minor details of the maps. A 'bare' version of Fig 1b will be included in the supplementary material where all the overlain layers are removed, except for the contour lines.

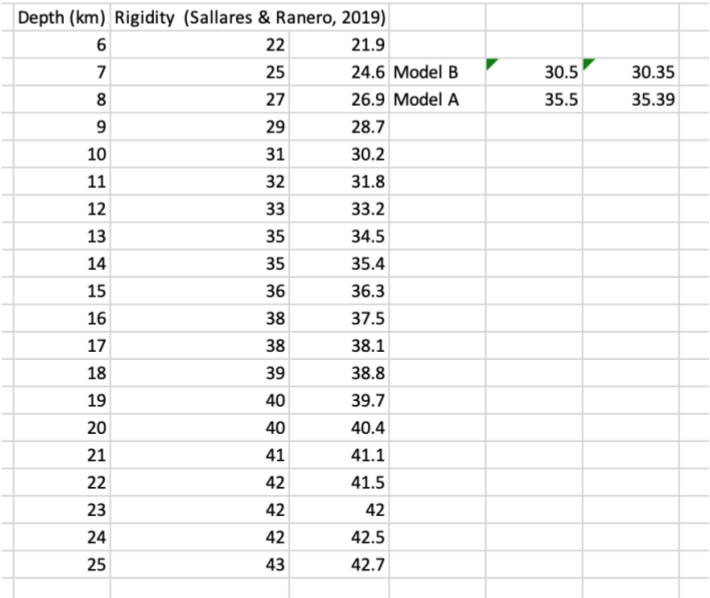
- The potential rupture area spans along the entire Lombok Strait, yet, the 2018 sequence did not rupture through the region of the Strait, its westernmost sequence localized North Lombok (during the 5th of August) according to Lythgoe et al. (2021). So I wonder how realistic is the proposed scenarios in which the entire Lombok Strait ruptures at the same time?

  Indeed, we are not trying to replicate the 2018 earthquakes, but rather consider an earthquake on the neighboring part of the fault that did not rupture in that sequence. The eastern bound of our fault model does overlap slightly with the westernmost limit of the 2018 Lombok earthquake sequence. Such overlapping ruptures have been observed in Kuril Trench (Ammon et al., 2008) and Peru-Chile Trench (Bilek, 2010).

- The following comment concerns lines 259 to 267. The conversion to Mw from Slip assumes a standard rigidity of 30GPa (Table 1), thus assuming that rigidity is constant along the entire rupture area. In the last few years, it has become clear that rigidity of rocks overlying the fault in the upper-plate decreases trenchwards up to values of < 5 GPa in megathrust regions worldwide. Most importantly, it has been demonstrated that this variation determines shallower larger slip, longer duration and depletion of high-frequencies in the shallow thrust, conditioning tsunami wave height (Sallarès & Ranero, 2019 1038/s41586-019-1784-0; Prada et al., 2021; 10.1029/2021JB022328). Realistic rigidity variations in turn, allowed to explain the rupture of particular megathrust events (Sallarès et al., 2021 10.1126/sciadv.abg8659). Based on this, the authors should assume realistic rigidity variations with depth to provide more accurate values of Mw, assuming a constant rigidity is likely to result in incorrect estimates of Mw and slip along the rupture area (which leads me to my final comment).

  Thank you for the comment and suggested papers. We agree that rigidity, which varies with depth, is a critical issue for many earthquake studies. The low values of rigidity mentioned are indeed especially important in shallow trench regions, where low-angle thrusts cut through weak sediments. In the case of the higher angle Flores thrust, however, we do not expect these low rigidities to be a major factor, especially since the fault does not appear to reach the shallowest sediments.

  Nevertheless, we have explored the impact of rigidity variations in our case study. Using the rigidity the values presented in Sallarès & Ranero, (2019), Prada et al., (2021) and Sallarès et al., (2021), we extracted the rigidity value every one km from 6 km to 25 km depths (the depth range of the fault ramp in our study). We used these values to calculate the average rigidities of our two models. Model A, which includes the whole ramp, has an average rigidity of 35 GPa. Model B, which only includes the upper half of the ramp (from 6km to 15.5km depth), has an average of 30 GPa. Because of the change in the rigidity of Model A, we will update the calculated Mw on Table 1 and include texts after lines 259 to 267 to explain why we use these rigidity values.



Depth (km)	Rigidity (Sallares & Ranero, 2019)				
6	22	21.9			
7	25	24.6	Model B	30.5	30.35
8	27	26.9	Model A	35.5	35.39
9	29	28.7			
10	31	30.2			
11	32	31.8			
12	33	33.2			
13	35	34.5			
14	35	35.4			
15	36	36.3			
16	38	37.5			
17	38	38.1			
18	39	38.8			
19	40	39.7			
20	40	40.4			
21	41	41.1			
22	42	41.5			
23	42	42			
24	42	42.5			
25	43	42.7			

- It is not clear to me what is the rationale behind the choice of slip values (1, 3, and 5 m). If the authors take these values based on previous estimates they should explain it. Alternatively, if the authors estimated the different slip values from Mw of previous events, they should include rigidity values used to perform the conversion. If the authors assumed a constant rigidity (as they did to convert slip into Mw), it is quite likely that they are underestimating the amount of slip that the shallow thrust may generate, and thus, the amount of uplift, and tsunami wave height. Additionally, overestimation of rigidity may also result in overestimation of tsunami arrival times, given that the rupture is likely to propagate much slower in the updip region than in the downdip.

The modelled historical tsunamigenic earthquakes in the Flores Thrust are estimated to have magnitudes ranging from Mw 6.7 to Mw 8.5 (NOAA, Musson et al., 2019; Griffin et al., 2019). Using the scaling by Thingbaijam et al. (2017), these earthquake magnitudes have average slip ranging from 1 to 5 m. In order to represent this range, we use the minimum, the mid-range and the maximum slip values in our modelling. Earthquakes with slip <1 m will result in minimal tsunamis. Earthquakes with slip >5 m are likely too large to be realistic scenarios. We will add this explanation in line 242 of section 2.1 Methodology - Slip model.

As noted previously, the rigidities in this region are unlikely to significantly impact the results, since the fault is steeply dipping and does not reach the surface (where the lowest rigidities can be found).