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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Randomly distributed unit sources to enhance optimization in tsunami waveform inversion" *by* I. E. Mulia and T. Asano

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We are grateful to the reviewer for the comments to enhance the quality of our paper. The following are point by point responses to the reviews. Please note that our line numbering system is different from the reviewed manuscript (see the revised manuscript in the supplementary file).

Comment 1. The abstract should more focus on the proposed methodology and results. Lines 3-11 in the abstract are better to be in the Introduction.

Response

The abstract has been modified and the referred sentences have been moved to the

Introduction as suggested (P1L24) and (P2L18).

Comment 2. Page 3661 lines 23-24: Smoothing constraint can be introduced to tsunami waveform inversion to obtain a more stable solution as shown in previous studies (i.e., Gusman et al., 2010; Gusman et al., 2013).

Response

The suggested papers have been added in the revised manuscript (P2L27). However, we made a brief refutation of the smoothing constraint application in the Results and discussion (P12L4). This is relevant, especially in the cases with coarse spatial resolution of the unit sources, as can be seen in our paper or other studies on small tsunami events.

Comment 3. The target sea surface deformation was generated from a same Gaussian distribution as that used to build the Green's functions. This could be the main reason why all three methods of least squares, GAPSu, and GAPSr can reproduce the target sea surface deformation very well. However, a real tsunami source of initial sea surface deformation does not always follow the Gaussian distribution that is used to generate the synthetics. This should be addressed in the manuscript.

Response

The suggested descriptions have been added in the Results and discussion (P11L2).

Comment 4. The number of unit sources in GAPSr is limited to 28. The number of unit sources to generate the target sea surface deformation is not mentioned in the manuscript, I presume it is also 28. If that so, it is not surprising that the GAPSr can recover the sea surface deformation very well. The GAPSr method can give a very good result because the problem is well conditioned. What happens if the number of unit sources that was use to make the target sea surface deformation was much more than 28, while the GAPSr used 28? The GAPSr method might work better if the number of unknown parameters is not limited to 28. Because of this and my provious comment about the synthetics I argue that the current version of GAPSr could also falls into ill posed problem when used for a real case, which is not in favor to the authors' claim in page 3661 line 29 and page 3662 lines 1-2.

Response

The target source was generated from 10 unit sources with random amplitudes and locations. We decided to use 28 unit sources to reconstruct the target source as it is almost impossible to approximate the profile using only 10 unit sources with the regular Green's function (first design parameter). In the second design parameter (GAPSr), we also used 28 unit sources to make a fair comparison and assessment for both design parameters. The above statement has been added in the manuscript (P10L12). Based on our experiments, more unit sources in GAPSr yielded better fit of waveforms. However, this also led to an overfitting problem. The determination of the optimal number of unit source is case-by-case basis. To put it simply, a more complex or larger tsunami requires more unit source. The GAPSr method aims to provide an optimal Green's function to facilitate the least squares method finds a unique solution, which is a requirement for the well-posed problem. Even so, we agree that at certain level of complexities the method might fail. The application of the method on a real tsunami event is still in progress and the preliminary result is consistent with the result in this paper.

Comment 5. Seems like the initial sea surface deformation is assumed to happen instantaneously (rupture velocity = infinite), please mention this in the manuscript. For great earthquake such as the 2011 Tohoku earthquake the rupture process took about 3 min, in this case a more realistic rupture velocity does matter.

Response

We included the descriptions on the said assumption in the Inversion method section (P4L13).

Comment 6. Lines in Figure 5 are not so clear perhaps thicker lines can be used and comparison for the GAPSu and least squares results can be plotted separately from that for the GAPSr.

Response

We combined all the time series plots into one figure so that the reader can directly examine the differences between all models. The quality of the figure had decreased after conversion to pdf done by the production office of the NHESS. We will send an enquiry on this matter to ensure the figure quality in the final manuscript. In the meantime, please refer to the revised manuscript in the uploaded supplementary file for a better figure.

Comment 7. Pressure gauge moves with ocean bottom deformation during an earthquake. This kind of gauges does not record uplift or subsidence even though the deformation was actually occurred. If Gauge 1 and Gauge 2 are indeed pressure gauges then such uplift shown in Figure 5 will not be recorded.

Response

All the gauges used in this study are artificial, although their locations are similar to the actual gauges available in the study area. It is true that the real Gauge 1 and Gauge 2 are pressure gauges, but here we assume that they are ordinary gauges (tide gauge or wave gauge) that record the waveforms originated from the target source.

Comment 8. Point 5 in page 3670: When the inversion is performed for the final time, is the unit source locations are searched again?

Response

No. During the GA and PS optimization the location of unit sources is changing every iteration. Accordingly, the waveforms are generated by the interpolation (on the fly). Once the optimal unit source locations are obtain, we run the forward modeling for each unit source to avoid errors produced by the interpolation. This final run yields an optimal Green's function for the inversion using least squares. Please see the additional flow chart (Figure 4) in the revised manuscript.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/2/C2446/2014/nhessd-2-C2446-2014-supplement.pdf

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