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Interactive comment on "SiSeRHMap v1.0: a simulator for mapped seismic response using a hybrid model" *by* G. Grelle et al.

G. Grelle et al.

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Dear Referees,

We wish thank you for your encouragement and suggestions about the introduction of this new methodology (a new view and approach) for the spatial simplified assessment of site seismic response. Particularly, perceptibly moving by a depth knowledge of the seismic response field and related issues, you give a precious contribution for the improvement of the paper, thus of the methodology/code.

The following response to the relevant referees comments are reported. We think that such comments might correspond to questions (FAQ) of potential SiSeRHMap users, thus, we will try to provide a more complex and comprehensive argumentations than

ones integrated into the paper, fully exploiting the animus of public discussion review adopted by GMD journal. At the same time, we will try not to excessively load the reader reporting a complete user guide as supplementary files.

+++ -referee #2————————————————————————————————-

"The paper is well written and presents an interesting model. However, the entire model is postulated on a purely deterministic framework. This presents challenges to the stated applicability of the model. For example, the design spectra postulated by the model is based on a single realization of the 3D GCM. Given that there is always uncertainty on subsurface conditions, it is important (in fact, key) that engineers account for this uncertainty in selecting an eventual design spectra.........." This reviewer recommends that these limitations should be discussed up-front. The proposed model does not replace a careful accounting of the uncertainties that are inevitably present in site response modeling. It simply provides a computational platform for conducting analyses that can inform the choice of design spectra or a microzonification study.

1) Comment related to uncertainty: a) Please discuss how uncertainty in lithological properties is accounted for, and, if applicable, whether this uncertainty propagates into the resulting spectra at the surface. b) The use of models on top of models (e.g., the adaptive simulation model on top of a 1D site response model) implies the presence of epistemic uncertainty in the predictions. Since the authors are not accounting for these uncertainties, they should clearly state the limitations of their model.

3) The use of the adaptive simulation model implies the use of a model to reproduce results of another model (equivalent linear 1D site response). How is this justified? The authors do not explain with sufficient clarity the justification for building the adaptive simulation model to reproduce 1D site response. Is it for computational efficiency? Or to obtain values that have a smoother spatial variation?

-referee #1————————————————————————————————

—- "The proposed model brings improved computational efficiency thanks to its metamodels. However, often the preparation of the model (i.e. characterization of wave velocities, thickness of lithological units, etc) requires much more time than the actual computation. This issue is essentially the same for the proposed model. If the characterization of geological units is complete, the reduced computation is obviously a clear advantage, but if it is not readily available, what are the clear advantages of the proposed method over the conventional methods?"

Reply to referees ————————————————————————
The referees suggest to underline user advantages and potential applicability and development of this hybrid model. At the same time, they suggest to highlight the challenges generally encountered in seismic response modelling, and specific of SiSeRHMap application.

The reconstruction of the input model is the base of any numerical code/application. In SiSeRHMap, the Gis-model and the procedures facilitate this necessary process of the subsoil input model. Note that the development of a 3D coherent spatial geometrical model requires the understanding of punctual and/or linear data also supplied by different filed survey. In this context, GCM contained in SiSeRHMap provides a direct support in the geometric input model building, differently, same process is commonly also used in the pre-processing data in the spatial discretized platform (e.g. FEM) necessary in/for complex 3D convention numerical methods. In addition, the GIS is used by many spatial planning operators and the organization and storage of data in geodatasets in increasing especially for urban areas where there is constantly updated historical documentation. For example, the Civil Protection Department of Italy has financed studies and survey for characterization of the seismic microzoning that involve the development of geo-datasets-areas that almost match to the concept of multi-layer zone defined in SiSeRHMap. In addition, the hybrid model at the base of SiSeRHMap allows to divide the underground model (geometric and parametrization) by seismic response analysis (metamodel trainer process) entailing a high computational time dis-

count and quickly updating. Thus, except for substantial changing in the underground model, new updates seismic response maps can be generate without re-training the metamodel (e.g. running only mod.'s 5.x of code which are the output maps generator); as well as a new parametrization. This advantage increases when iterative entry of different input motions for probabilistic analysis are used (see comments by reviewer #2). It goes without saying that an updated model gradually decreases the epistemic "uncertainties that are inevitably present in site response modeling" (referee #2). In general the same nature of hybrid systems admits the intrinsic uncertainty in the prediction; in contrast these systems show high efficient in term of expected performance in relation to the user convenience (e.g. a hybrid system like a hybrid vehicle does not usually running in the race circuit, in off-road or in high mountain roads, however these vehicles are more and more used with different efficient performance in the common practice winning advantage in high saving and low emission).

This note is reported in the manuscript in P4489 from row 9 and P4490 rows 1-6:

changes/integrations in manuscript————————————————
——— In addition to a need to have a sufficient amount of information suitable for seismic microzonation, computerized data management and spatial distribution in terms of input and output/outcomes, is also a requirement. Therefore, the Geographic Information Systems (GIS) contribute the most to maximizing the available data, in the assessment or estimation of ground-motion amplification (Kolat et al., 2006; Ganapathy, 2011; Hashemi and Alesheikh, 2012; Turk et al., 2012; Hassanzadeh et al., 2013) and seismic-induced effects (Grelle et al., 2011; Grelle and Guadagno, 2013). In this aforementioned context, SiSeRHMap provides synthetic multi-map data regarding a complex phenomenon, such as seismic site response, on the basis of a new hybrid methodology in which a metamodeling process is the core feature. In recent years, the use of the metamodels in many engineering and environmental science fields (Lampasi et al., 2006; Yazdi and Neyshabouri, 2014; Wang et al., 2014; Hong et al., 2014), together with GIS supported analysis (Reed et al., 2012; Fan et al., 2015;

Soares et al., 2014), has produced good performances, providing fast versatility and rapid updating. The same nature of hybrid systems based on metamodel, as such as SiSeRHMap, admits the intrinsic uncertainty in the prediction; this one is due to the use of nonphysical adaptive models trained on simplified physical models. Conversely, these systems permit an efficient analysis in term of expected performance. Essentially, metamodel permits a quick replication of the solutions in a limited context of randomness. In this way the proposed model is very suitable for a continue easy modular update that decrease the epistemic uncertainty over time in assessing of the effects of natural complex phenomena, such as the seismic response, on a real natural system. Therefore, SiSeRHMap is formulated on the concept of "performance", regarding: i) prediction, ii) easy and low computational time, iii) upgrade, iv) output accessibility (GIS-georeferenced data), with respect to the real effect; for these reasons SiSeRHMap aims to give a substantial contribution in the common practice. Contextualized to the "applied" seismic response, limits of usual practice may be currently summarized in: i) partial contribute of the microzonation study in regard to give appropriate quantitative parameters for seismic engineering practice; ii) the inadequate use of few simplified amplified design spectra defined by means few large ranges of Vs refer to 30 m or to the bedrock deep; iii) unsuitable use of the point-data spatial interpolation for the mapped seismic response values. Considering the aforesaid critical issues, in areas with a not very high geological complexity, the proposed methodology can present a high computational efficiency in comparison to expensive rigorous physically based models; this efficiency multiplies when a probability multi-input motion analysis is performed. Therefore, the map-sets of seismic response provided by SiSeRHMap are the result of an advantageous compromise between the intrinsic and epistemic uncertainties and the accuracy and robustness indeed required.

+++ - referee #2———————————————————————————

—— The paper is well written and presents an interesting model. However, the entire model is postulated on a purely deterministic framework. This presents challenges to

the stated applicability of the model. .... for example those resulting from the use of a single input motion, given that it is known that there is a large degree of motion-to-motion variability in the amplification actors resulting from site response.

reply to referee————————————————————————————-

We are very grateful to the referee for highlighting the importance of the probabilistic feature in the seismic response. This topic/suggestion has promoted a particular integration in the code regarding the possibility to use more input motions in the stratigraphic seismic response models. From these, the code is able to generate the average seismic responses constituting the trainer models in the metamodel process.

This note is reported in some parts of manuscript:

changes/integrations in manuscript————————————————————

—— P4493 row 25: The input motion assumed in the simulation analysis is the same used by Grelle et al. (2014) in the real study area. It is a time-acceleration record that was spectrally-matched with the elastic spectrum design (with damping value of 0.05), which referred to the rigid site. However, many input motions can be inserted and processed in an automatic way.

and new figure (Fig. 8) was added:

The modal function is the core of the Emul-spectra adaptive model. It is a exponential equation capable of reproducing a symmetrical/asymmetrical modal or subordinated bimodal shapes generally shown by acceleration seismic responses in a large spectral range (e.g. in fig. 7) as well as in the multi-input probabilistic way (fig. 8).

P4501 from row 24: The aforesaid process can be iterated using more assigned input motions; in this case the code is able to generate the average seismic responses constituting the training models used in the following metamodeling process. In any cases, the smoothed responses, generated by trained metamodel, suggest a better performance for input motions with response spectra nearest, or matched, to the simplified design spectra.

++ -referee #2——
—- 4) Equation 11 uses an average shear wave velocity that results from a weighted average (where the weighting factor is profile thickness). This is not common practice in earthquake engineering. Average shear wave velocity is defined using the travel-time average [e.g., sum(h,i)/sum(h,i/Vs,i)]. This way o computing average shear wave velocity is coded in US and European building codes and is the basis for the computation of Vs,30. Note that the choice of using travel time to compute average shear wave velocity is not arbitrary, it reflect the fact that average velocity computed in this way will result in more realistic fundamental periods.

reply to referee——
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The use of the weighted shear wave velocity in fundamental period definition (previous mode) is common in Japanese practice. The different mode to define the fundamental period of multilayer sequence does not modify the performance of the metamodel; however, the suggestion of the referee provides more than adequate value in the fundamental periods map as well as in the training models. Therefore, we changed the equation 11 as suggested.

++ -referee #2——
– 5) First paragraph, page 4499. What is meant by dispersion curve? Generally the term dispersion curve is reserved for the change in surface wave velocity with wavelength or frequency. However, the term appears to be used here to the statistical uncertainty in the Vs,z value.

changes/integrations in manuscript————————————————————————
—– P4499 row 9: ....it takes into account the possible increment of rigidity due to

the lithostatic load of the upper cover layers; this case is manifested when the non-rigid bedrock shows relatively low values of the shear wave velocity in the spatial statistical uncertainty of the VS,z values.

++ -referee #2——
—— On the topographic model a) Equations 17 to 19 were developed by the team with the intent of reproducing topographic effects postulated by other authors (Geli et al. 1988, Ashford and Sitar 1987). The only validation presented in the paper for these equations is in Figure 10, where the fit of the proposed model to those of Geli et al. is very poor at some periods. A stronger justification for the choice of the model is needed.

-referee #1——
——- P 4508: How to you justify the model equations (17) and (18)? Can you please discuss why you chose these specific functional forms?

reply to referees:——
——— This subject/integration was reported in the Discussion paragraph (P 4512 from row 6):

changes/integrations in manuscript————————————————————————
——— The simplified frequency depending on the topographic amplification models reported in the equations 17 and 18 is mainly focused on the peak/ridge amplification effect (position 1 in the figure 10) that is the greatest in the regular or pseudo-regular relief. The prediction accuracy on the slops is the result of the progressive spatial smoothing of the topographic amplification and the conservative approach, too. The latter does not admit deamplification and, diversely, it admits a suitable overmatch (overestimation) in almost all of the spectral window permitting so to preserve an adequate prediction trend for irregular reliefs yet. This aspect should be seen at the light of the values of the slope topographic amplifications that are generally lower than ones

occurred to the peak zones.

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-referee #2——————————————————————————————
—— b) It is not clear how the parameters of the model (H and Hr) are computed for different frequencies, since the scale of the topographic feature will depend on the frequency. For example, at high frequencies a small feature may affect simplification, while the same feature will not have an effect at larger frequencies. Hence, H and Hr should be frequency dependent. It is not clear from the formulation that this is the case. c) The models such as those proposed by Geli et al. (1988) and others are based on idealized topographies. IN the experience of the reviewer, it becomes very difficult to select parameters such as H and Hr when the topographic relief becomes very complex. Even parameters as simple as slope and curvature will be a function of the scale of the DEM.

reply to referees:——————————————————————————
——- The scale of the topographic features DEM, Slope, Curvature, is constant and it must be 30m; reaffirmed in the name of input file: DTM_30.txt, Slope_30.txt, Curvature_30.txt. The model, defined by combination of the equations 17 and 18, was calibrated on this aforesaid input map resolution. This assumption is reported in the rows from 28 P 4508 and more specified in the short guide of code (now reported also in the supplementary material). H and Hr are geometrical parameters assumed at specific spatial resolution (DEM scale) and are invariant with frequency; these indicate the altitude (H) from Basal Surface of Relief (BSR) (Appendix C) and the geometrical position (HR) along the homogeneous idealized Geli et al, half-relief's. The dimensionless frequency (eq. 19) is H dependent, "c" and "i" relate the apical and slope angle, while rH increases the slope amplification in approaching the ridge.

changes/integrations in manuscript————————————————————
——— We reported in Appendix C: The BSR is a flat or not flat surface that tries

to isolate local idealized relief conditions, its greater efficacy occurs when one ridge is seen as such in the 2D relief scanning in at least one of the directions. Also, the area assumed in the topographic amplification analysis should be matching the aforesaid requirement.

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Referee #2——————————————————————————————
—- d) The authors mention "topographic fundamental period" in Figure 10 and Page 4509. How is this computed?

reply to referees:——————————————————————————
Topographic fundamental period is computed as reported in row 12 P 4491 (1.2 Background). The equation was reported in caption of figure 10.

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Referee #2——————————————————————————————
— The authors also mention a validation through comparison with Maufroy et al. (2012 and 2015), but this comparison is not given in the paper.

Referee #1——————————————————————————————
— P 4510: Line 6 9: Where is this shown?

reply to referees:——————————————————————————
——- we changed in the manuscript "show" with "suggest" , and this statement (P 4510: Line 6 9) is now integrated in the discussions paragraph.

changes/integrations in manuscript:———————————————————
——— The results of the topographic model (fig. 12) suggest a substantial agreement with other 3-D simplified numerical simulations performed and calibrated in zone with a similar topographic features (Maufroy et al., 2012, 2015). In addition, conversely from totally physical methods, nature of this model permits its general developing and local calibration. In presence of non homogeneous material constituting the relief,

a local frequency calibration, using also seismic noise measures (in single or multi-station recording mode), can be performed assuming a regional shear wave velocity with value different from that used for rigid material (e.g. equivalent VSReg).

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Referee #2————————————————————————————————
——- 1) Line 1, Page 4493: change “liner” to “linear”

reply to referees:——————————————————————————————
——- we have corrected

Referee #2————————————————————————————————
—- 2) The use of the term rigid in the way it is being used (e.g., to define bedrock velocities higher than a certain threshold) can be confusing because the word rigid would imply an infinitely high shear-wave velocity. A truly rigid boundary does not exist in nature, but some numerical models postulate rigid boundaries for simplicity. Moreover, the threshold of 800 m/s does not make a very rigid bedrock in engineering terms (for example, shear wave velocity for bedrock in the Eastern United States can be as high as 3000 m/s).

reply to referees:——————————————————————————————
—— we have better specify in the manuscript from row 3 P4495.

changes/integrations in manuscript:————————————————————
—- ..... the term "rigid bedrock" is not referred to the formal physic dynamic behaviour.

Referee #2————————————————————————————————
— 3) Line 2, Page 4501. Separate “therefore” and “it”

reply to referees:——————————————————————————————
—- we have corrected

Referee #2————————————————————————————————

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4) Line 14, page 4501. The use of the word “experimental” brings to mind laboratory tests. In this case, the authors are referring to a “trial” strain level. Please modify the wording.

reply to referees:——————————————————————————————
——- we have changed

Referee #2————————————————————————————————
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5) Line 14, Page 4512. The reference should be to Figure 13.

reply to referees:——————————————————————————————
—- we have corrected

Please also note the supplement to this comment:
http://www.geosci-model-dev-discuss.net/8/C2014/2015/gmdd-8-C2014-2015-supplement.pdf

Interactive comment on Geosci. Model Dev. Discuss., 8, 4487, 2015.

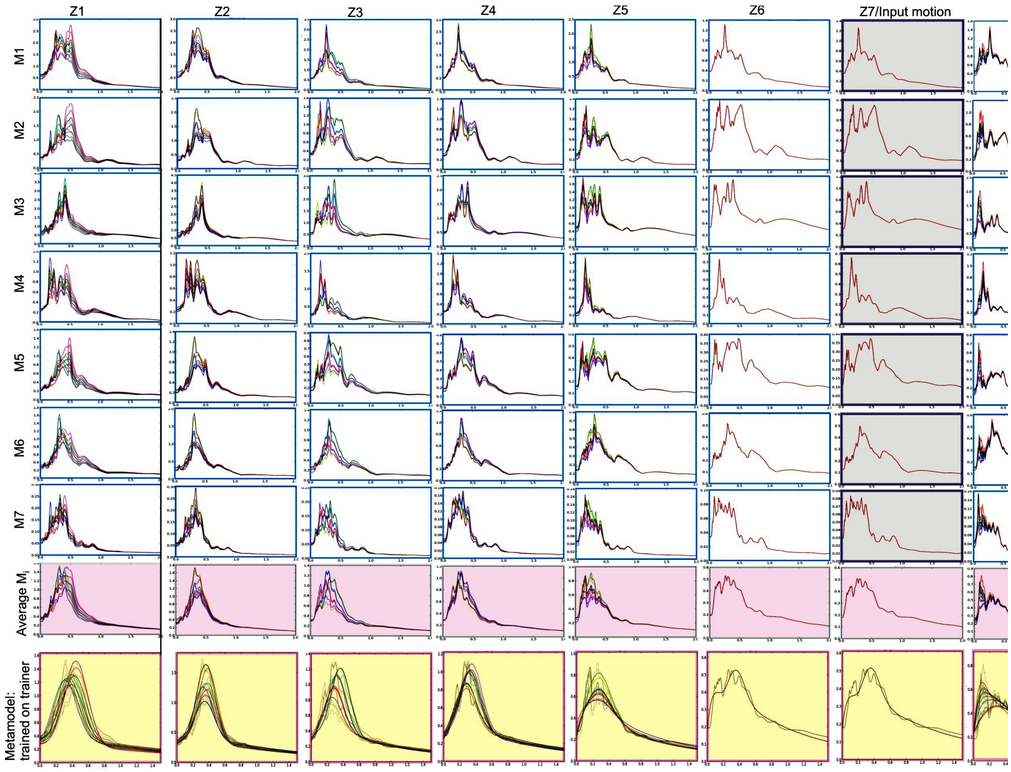

Fig. 1. new figure 8:Example of metamodel processing for the SRS using seven input motions having average spectrum matched on an unamplified design spectrum. This last corresponding to the average spectrum of