USER-MANUAL

HAZARD-TARGETED TIME-SERIES SIMULATOR (HATSim)

1 Introduction

To assist the structural engineers and designers in obtaining site-specific hazard-targeted ground motion time-series, a Graphic-User-Interface (GUI) program is developed by Jawad Fayaz (https://jfayaz.github.io/layouts/codeandsoft.html/) and research team at University of California- Irvine (UCI) and American University of Beirut (AUB). The program is named as "Hazard-Targeted Time-Series Simulator (HATSim)." The program requires minimum inputs from the user to assure ease of usage. Using these modest inputs, HATSim connects to USGS Unified Hazard Tool (UHT) 2008 website to obtain data on hazard curves, and deaggregation of the seismic hazard and the uses the obtained information to simulate *n* number of ground motions using the DRD site-based simulation model. Among the suggested seismic sources in USGS's deaggregation list for the target site and hazard, *n* sources (equal to the number of ground motions to be simulated) are randomly selected with replacement and are used to randomize their corresponding near-fault parameters using UCERF2 fault information. The randomized near-fault parameters along with the selected deaggregated source information are then used to simulate the site-specific synthetic ground motions that possess the $S_{a,haz}(T)$ (*RotD50* S_a corresponding to the period of structure (T) for the given hazard level) using the algorithm described in Chapter 4 of 'Guidelines for Ground Motion Modeling for Performance-Based Earthquake Engineering of Ordinary Bridges' (Fayaz et. al. 2020).

2 Using *HATSim*

HATSim is a Windows-based program for PCs with a Graphics-User-Interface (GUI). The program requires a working internet connection and MATLAB-Runtime (9.4) (https://www.mathworks.com/products/compiler/matlab-runtime.html) software installed on the PC. This tool only works with Matlab-Runtime 9.4. To run the program, double click on the executable file "HATSim.exe" (shown in Figure 1); this will open a window as shown in Figure 2. As can be seen from Figure 2, the user is required to assign 11 input values, which are explained briefly in the following section.

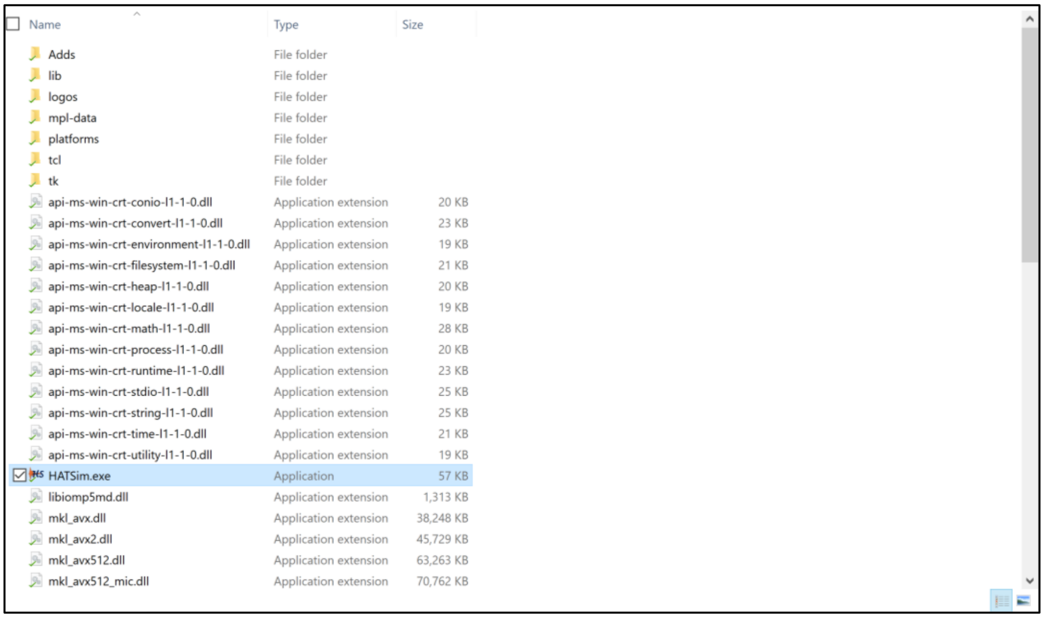

Figure 1: Folder containing HATSim program

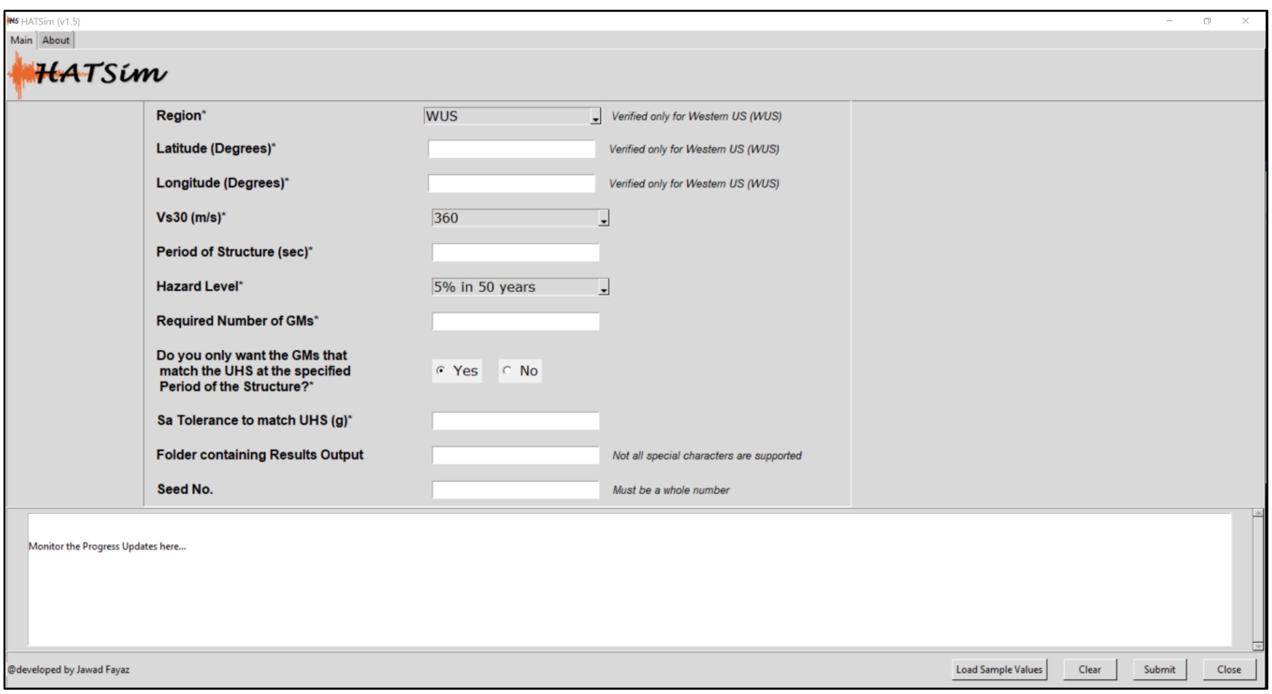

Figure 2: Start screen of HATSim program

2.1 HATSim Inputs

There are ten input values required by the HATSim program. For convenience, the user can click on the `Load Sample Values` button to populate the associated fields with a sample of the input values. Once all the input values are provided, the user needs to click the `Submit` button and monitor the progress in the bar available below the inputs. The program connects to USGS UHT (2008) to collect hazard information and then performs the requested simulations. It is important to note that after the inputs are submitted, the user needs to wait until the results are out or an error is raised. User should press the `Clear` button if they wish to re-use the program. The input values to the program include the following (an example of the inputs is given in Figure 3).

1) *Region*

   This describes the region of the United States for which the deaggregation and hazard curves are to be obtained. This is required to obtain the information from the USGS UHT (2008). There are three available options, which include, WUS (Western U.S.), CEUS (Central Eastern U.S.), and COUS. Currently, the tool has only been verified for WUS (Western U.S.), particularly for Southern California.

2) *Latitude*

   This requires the latitude of the site (in degrees) for which the deaggregation and hazard curves are to be obtained, and ground motions need to be generated. The input (along with the site's longitude, next parameter) is required to introduce the site location to USGS UHT through which a shortlist of sources is suggested for simulating ground motions using the DRD model. Currently, the tool has only been verified for WUS (Western U.S.), particularly for Southern California sites.

3) *Longitude*

This requires the longitude of the site (in degrees) which is used along with the inputted latitude to perform the tasks mentioned above.

4) V_{s30}

This is an input to the shear-wave velocity (V_{s30} in m/s) at top-most 30m of the site. This is required as an input for both obtaining deaggregation and hazard curves at the site, and to simulate the site-based ground motions. Since USGS UHT (2008) contains the data for specific values of V_{s30}, i.e., 180, 259, 360, 537, 760 and 1150 m/s, only these options are provided to the user, to select their V_{s30}.

5) *Period of the Structure*

This is an input to the first mode period of the structure (T) in seconds. This is required as an input for obtaining deaggregation and hazard curves which are then used to obtain the hazard targeted S_a. Since USGS UHT (2008) contains data only for the periods of 0 (*i.e.*, PGA level), 0.2, 1.0 and 2.0 sec, the user suggested period is subtracted from the available values, and then the one with an absolute minimum difference is used to conduct seismic hazard deaggregation. The hazard curves are obtained for all the available periods, which are then used to construct the Uniform Design Spectrum for the given hazard level (next input) using Equations 1 to 6 ($T_L = 8$). From the Design Spectrum, the S_a corresponding to the given period (T), $S_{a,haz}$, is obtained.

$$T_0 = 0.2\left(\frac{S_a(T=1.0)}{S_a(T=0.2)}\right) \tag{1}$$

$$T_s = \frac{S_a(T=1.0)}{S_a(T=0.2)} \tag{2}$$

$$S_a = S_a(T=0.2) \times \left(0.4 + 0.6\left(\frac{T}{T_0}\right)\right) \qquad for\ T < T_0 \tag{3}$$

$$S_a = S_a(T=0.2) \qquad for\ T \geq T_0\ \&\ T \leq T_s \tag{4}$$

$$S_a = \frac{S_a(T=1.0)}{T} \qquad for\ T > T_s\ \&\ T \leq T_L \tag{5}$$

$$S_a = S_a(T = 1.0)\frac{T_L}{T^2} \qquad for\ T > T_L \qquad (6)$$

6) *Hazard Level*

This describes the target hazard level for which the deaggregation is conducted. From the Design Spectrum, the S_a corresponding to the given period (T), $S_{a,haz}(T)$, is obtained which can then be used to simulate ground motions. The user is required to choose one among the 3 options provided for the hazard level: 2% in 50 years (2475 years), 5% in 50 years (975 years), and 10% in 50 years (475 years).

7) *Required Number of GMs*

It requires an integer value suggesting how many ground motions time series are required by the user. The number of ground motions (n) that the user requests, will be generated using the DRD model. If the user's input value is '0' or negative number, then the program will only obtain the data about deaggregation and hazard curves; no ground motion waveforms will be generated.

8) *Do you only want the GMs that match the UHS at the specified Period of the Structure?*

This is a `yes` or `no` input which asks the user whether they want the ground motions to be hazard-targeted (*i.e.* possess the $S_{a,haz}(T)$ at the given period of the structure T) or any random simulation of the deaggregated sources. If the user selects the `yes` option, the ground motions will be generated using the deaggregated event parameters and the randomized near-fault parameters such that the simulated ground motions possess the $S_{a,haz}(T)$ at the given period of the structure, T. This is done using the algorithm described in Fayaz *et al.* (2020a). If the user selects the `no` option, then any random simulation of the ground motions will be generated using the deaggregated event parameters and the randomized near-fault parameters, which may or may not match the $S_{a,haz}(T)$ at the given period of the structure, T.

9) *Sa Tolerance to match UHS*

If the user selects the `yes` for input #8, the ground motions will be simulated such that their S_a matches the $S_{a,haz}(T)$ at the given period of the structure, *T*. However, the two values of S_a are not exactly same; they are allowed to differ by a tolerance value in units of g (*i.e.* $S_{a,haz} - S_a \leq$ *Sa Tolerance to match UHS*); this tolerance is only allowed on the positive side. This means that S_a of the ground motion is by no means allowed to be lower than the $S_{a,haz}(T)$ at the given period of the structure, *T*. By default, this value is allotted to be $0.1g$¸ which means only those simulated ground motions are selected that possess S_a between $S_{a,haz}(T)$ and $S_{a,haz}(T)$ +0.1g, at the period of the structure. If the user selects `no` for input 8, this input becomes inactive and a very large value is allotted to this tolerance.

10) *Folder containing the Results Output*

This is the name of the folder in which the final results will be provided. Since the user may need to use the tool multiple times in the same Windows directory, they can provide a different folder name for the results to be generated. By default, this value is set to be 'RESULTS'.

11) *Seed No.*

This requires a whole number as an input and helps the user with reproducibility. Since the simulation process involves various random processes, this input can be used to recreate the ground motions. This input is concatenated with the input to *Folder containing the Results Output*, and the final results are provided in that folder. By default, this value is set to be as '2', hence a folder named 'RESULTS-2' will be created in the current directory containing all the outputs. Please note since the ground motion generation involves many random process, such as selection of *n* deaggregated sources, simulation of white noise, etc., a value of 10 is added to the inputted *Seed No.* for each process. The final *Seed No.* used to simulate ground motions is provided in the first header line of the .AT2 ground motion time-history file.

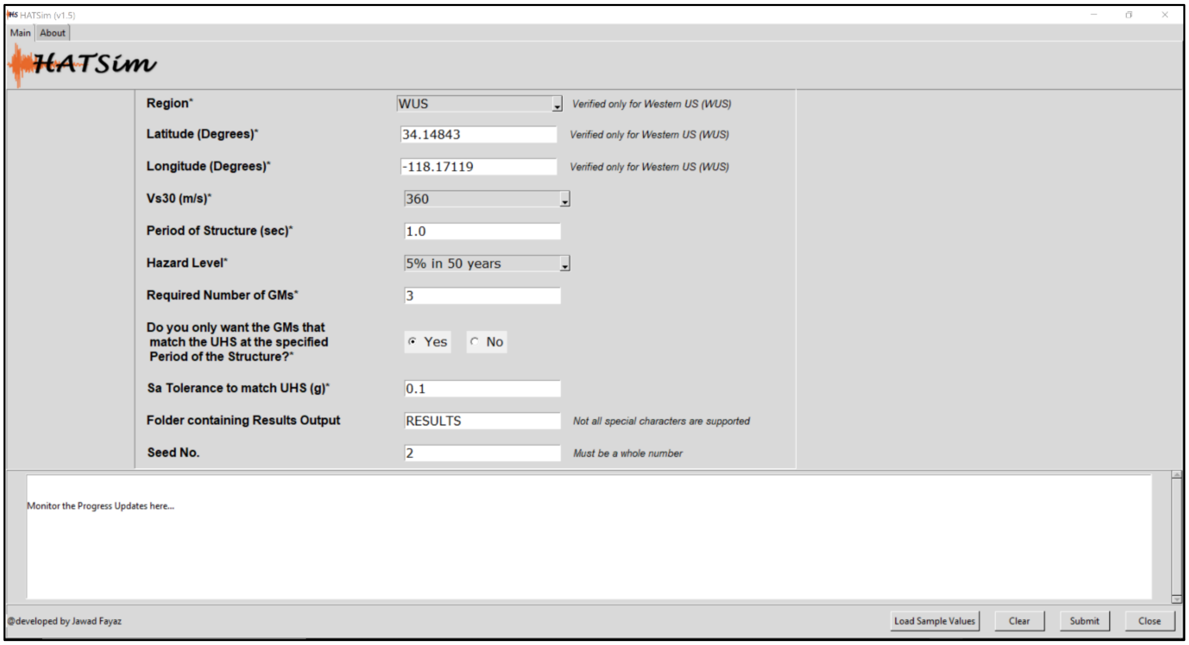

Figure 3: Example inputs for HATSim program

7.2.2 HATSim Outputs

The output screen of the program is shown in Figure 4a and the output is generated in the `Folder containing the Results Output` ('RESULTS' folder in this example) as shown in Figure 4b. From Figure 4 it can be observed that the output information provided by the program include the following: Simulated ground motion `.AT2` files in the `Final GMs` folder (Figure 4c), RotD50 spectra `.txt` files of the simulated ground motions in `Spectra` folder (Figure 4d), figure of hazard curves `Hazard_Curves.jpeg` (Figure 4f), file containing the Design Spectrum, `UHS.txt`, and the figure of Design Spectrum `UHS.jpeg` (Figure 4g), figure of Design Spectrum along with the RotD50 Sa spectra of simulated ground motions, `UHS_with_GMs_Spectra.jpeg` (Figure 4h), and Excel file containing the deaggregation sources and hazard curves of the site, `Hazard Output.xlsx`. Also, the inputs provided by the user to the program are re-written to the `Inputs.txt` file (Figure 4e).

Particularly, the *n* number of ground motion files are saved in the `Final GMs` folder with the naming convention of GM*ij*.AT2, where *i* represents the direction of the bi-directional ground motion and *j* represents the number of the ground motion. The value of *i* can be 1 or 2, representing the two orthogonal directions of ground motions, and *j* ranges from 1 to *n*. The `.AT2` files contain a four-line header comprehending information about the fault and the source from which the ground motion was generated along with the *dt* and number of points (*npts*) of the time-series. The rest of the file contains ground motion acceleration time-history in units of *g*. Examples of the generated files in the two components of ground motions are shown in Figure 5a and 5b. Furthermore, the output of the deaggregation and hazard curves are provided in the excel file `Hazard Output.xlsx`. The file contains two sheets named `Hazard Curves` and `Deaggregation`. The former contains the hazard curves for all 4 available periods on USGS (which include *T* = 0, 0.2, 1, and 2 secs) and the later contains information about the deaggregated sources. It is important to note that until now, the deaggregated information only about *aFault* and *bFault* types of sources are listed and used for ground motion simulation by the HATSim program. Example of the two sheets of the excel file is provided in Figures 5c and 5d.

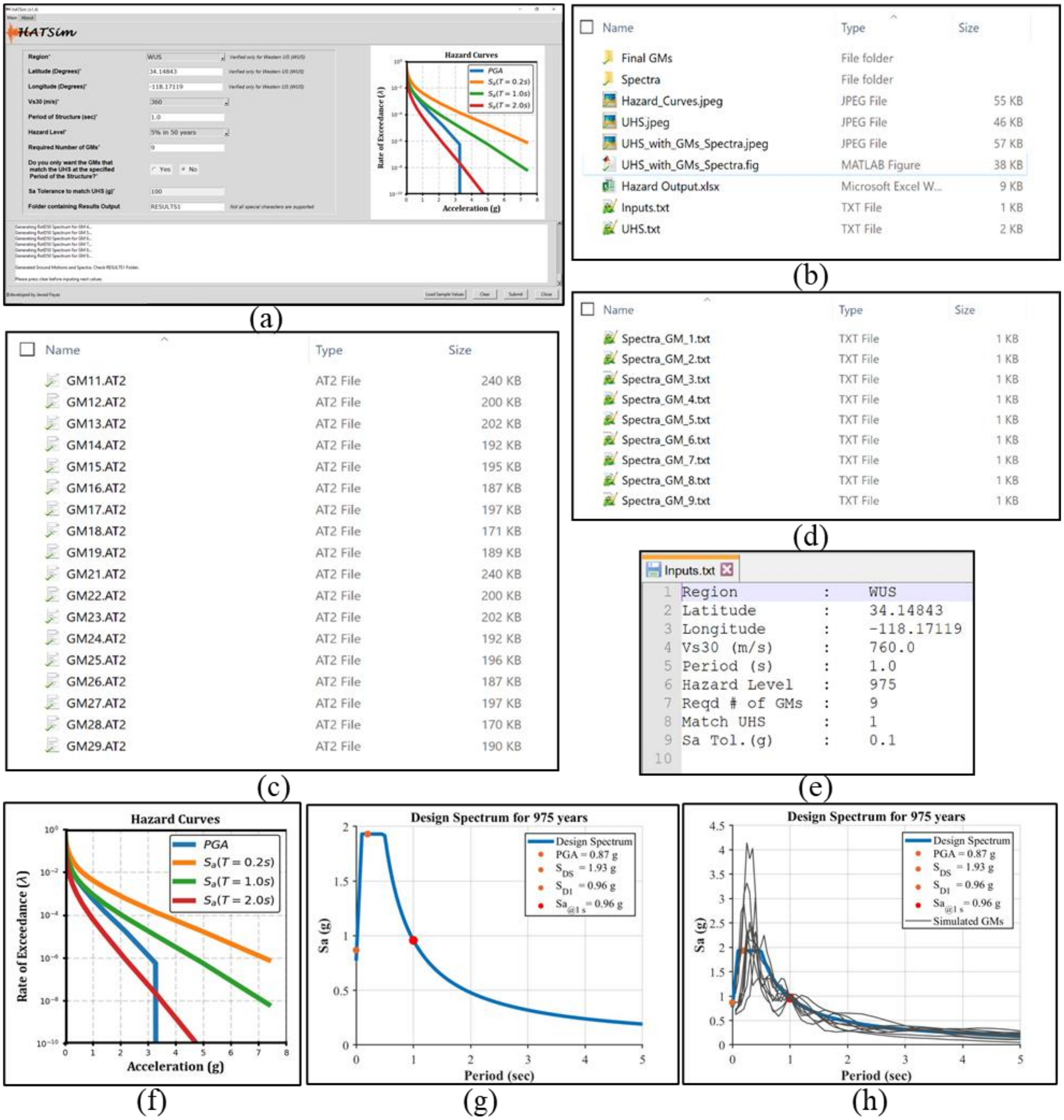

Figure 4: Outputs of the HATSim program

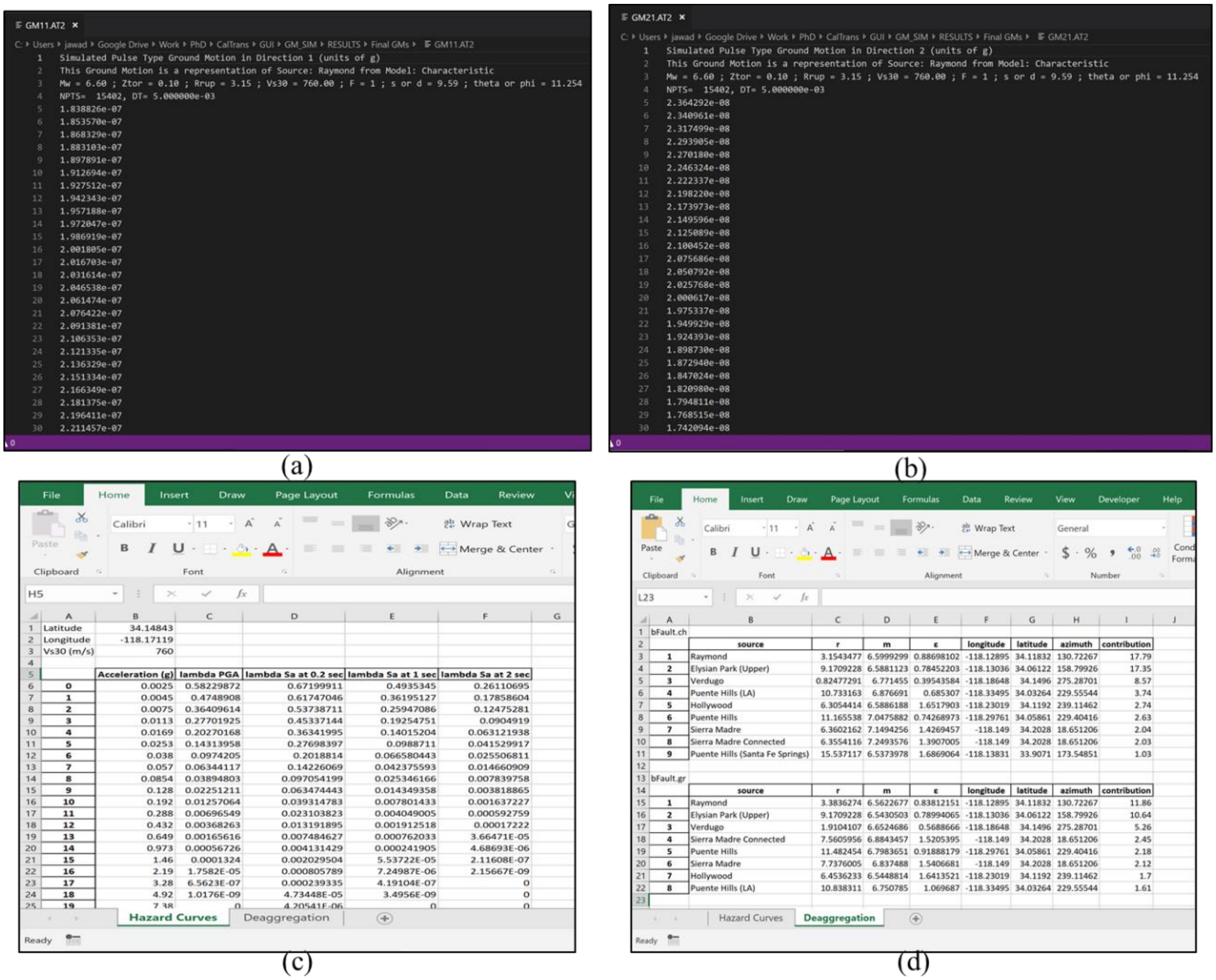

Figure 5: Example for **(a)** GM1 file in direction 1 (GM11.AT2), **(b)** GM1 file in direction 2 (GM21.AT2), **(c)** Hazard Curves sheet of excel file (Hazard Output.xlsx), and **(d)** Deaggregation sheet of excel file (Hazard Output.xlsx)

References

Jawad Fayaz, Sarah Azar, Mayssa Dabaghi, and Farzin Zareian (2020a). " An Efficient Algorithm to Simulate Hazard-Targeted Site-Based Synthetic Ground Motions", *Earthquake Spectra*.

Jawad Fayaz, Sarah Azar, Mayssa Dabaghi, and Farzin Zareian (2020b). "Guidelines for Ground Motion Modelling for Performance-Based Earthquake Engineering of Ordinary Bridges”. *Caltrans Final Report No. 65A0647*

Dabaghi, M., Daoud, Y., Der Kiureghian, A. (2018a). Simulation of near fault ground motions for randomized hypocenter and site locations, *Proceedings of the 11th US National Conference on Earthquake Engineering*, July 25-29, 2018, Los Angeles, CA.

Dabaghi, M., and Der Kiureghian, A., (2018b). Simulation of orthogonal horizontal components of near-fault ground motion for specified earthquake source and site characteristics, *Earthquake Engineering & Structural Dynamics 47*, 1369–1393.

Rezaeian, S., and Der Kiureghian, A., (2012). Simulation of orthogonal horizontal ground motion components for specified earthquake and site characteristics, *Earthquake Engineering & Structural Dynamics 41*(2), 335-353. doi:10.1002/eqe.1132.