USER-MANUAL

MAINSHOCK-AFTERSHOCK GENERALIZED GROUND MOTION MODEL (MSAS GGMM)

This tool, named as Generalized Ground Motion Model for Mainshocks and Aftershocks (*MSAS_GGMM*), uses a hybrid Recurrent Neural Network (RNN) framework to estimate a 30×1 cross - dependent vectors for mainshocks and aftershocks (denoted as $\mathbf{IM}_{\mathbf{MS}}$ and $\mathbf{IM}_{\mathbf{AS}}$) of RotD50 Spectral Acceleration (RotD50S_a) at 25 periods and geometric means of Arias Intensity ($I_{a_{geom}}$), Significant Duration ($D_{5-95_{geom}}$), Peak Ground Acceleration, (PGA_{geom}) and Peak Ground Velocity (PGV_{geom}) using a set of seismic source and site parameters as inputs. The source and site inputs to the RNN framework include a vector of 8 values including source fault slab mechanism (F), magnitude for mainshock (M_{MS}), magnitude for aftershock (M_{AS}), closest rupture distance of mainshock rupture ($R_{rup,MS}$), closest rupture distance of aftershock rupture ($R_{rup,AS}$), hypocentral depth of mainshock ($Z_{hyp,MS}$), hypocentral depth of aftershock ($Z_{hyp,AS}$), and site's soil shear-wave velocity (V_{s30}). Hence, given the source and site parameters, this tool returns a median prediction of the **IM** and estimated uncertainty bands ($\pm\sigma$). The executable is developed by Jawad Fayaz ([Jawad Fayaz (jfayaz.github.io)](https://jfayaz.github.io)) and collaborator (Carmine Galasso). For further details please read the article mentioned in the "Reference". Though the tool is based on the Fayaz and Carmine (2022) study, the model has been updated with more data from Chile and Japan.

1. *GGMM* Inputs

i. Fault Mechanism (F)

Fault Mechanism (F)	Value
Crustal	1
Interface	2
Intraslab	3

ii. Magnitudes of Mainshock and Aftershock (M): $3 \leq M_w \leq 9$

iii. Closest Rupture Distance (R_{rup}) of Mainshock and Aftershock in kilometers: $0.01 \leq R_{rup} \leq 250$ km

iv. Depth of Hypocenter (Z_{hyp}) of Mainshock and Aftershock in kilometers: $0 \leq Z_{hyp} \leq 100$ km

v. Site's Shear-Wave Velocity (V_{s30}) in meters per second (m/s): $0 \leq V_{s30} \leq 1800$ m/s

vi. Name of Output Folder that the user wants the outputs to be located (*OutputFolderName)*

2 Calling *MSAS_GGMM*

The tool package consists of the executable application “MSAS_GGMM.exe” which can be easily called from any command line or programming language/software. An example to run the GGMM program is given in Figure 1 where the inputs can be in any order with the input tags. The generalized syntax to run the executable is as follows:

MSAS_GGMM.exe --F --MagMS –MagAS --RrupMS --RrupAS --ZhypMS --ZhypAS --Vs30 --OutputFolder

Here is an example to run the program.

MSAS_GGMM.exe --F 1 --MagMS 7.5 --MagAS 6.5 --RrupMS 20 --RrupAS 25 --ZhypMS 10 --ZhypAS 8 --Vs30 300 --OutputFolder Results

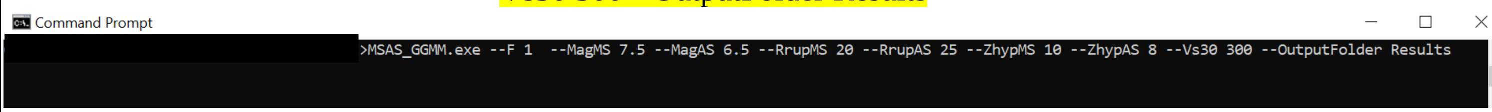

Figure 1: Calling “MSAS_GGMM.exe”

In case all the inputs are not properly provided the tool will throw an error as shown in Figure 2.

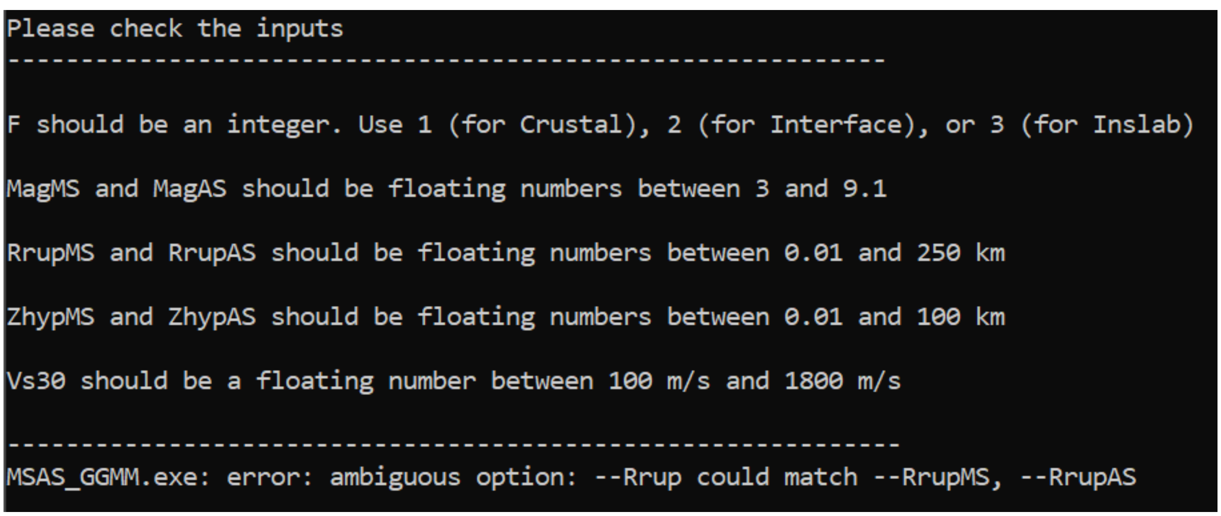

Figure 2: Error screen of “MSAS_GGMM.exe”

3 *MSAS_GGMM* Outputs

The tool creates a folder named as inputted by the user in the *OutputFolderName* (as described) within the current directory of the tool. The output screen of the framework is shown in Figure 3.

```
Command Prompt

D:\Dropbox\Work\MSAS_GGMM_EXE>MSAS_GGMM.exe --F 1  --MagMS 7.5 --MagAS 6.5 --RrupMS 20 --RrupAS 25 --ZhypMS 10 --ZhypAS 8 --Vs30 300 --OutputFolder Results

Running MSAS GGMM with the following inputs

F             : 1
MagMS         : 7.5
MagAS         : 6.5
RrupMS        : 20.0
RrupAS        : 25.0
ZhypMS        : 10.0
ZhypAS        : 8.0
Vs30          : 300.0
Output Folder : Results

Created output folder: Results

Making predictions using the MSAS GGMM.....

Successfully generated results in the "Results" folder
```

Figure 3: Output screen of “MSAS_GGMM.exe”

The outputs consist of four files as shown in Figure 4: 1) “GGMM_MS.out” file containing the estimated median **IM** predictions and its uncertainty bands for mainshock, 2) “GGMM_AS.out” file containing the estimated median **IM** predictions and its uncertainty bands for aftershock, 3) “User_Inputs.txt” containing the record of the inputs as entered by the user, and 4) “GGMM.jpg” file showing the median and sigma bands of the estimated intensity measures in **IM** vectors for both mainshock (blue) and aftershock (green). The outputs are shown in figures 5, 6 and 7.

Name	Date modified	Type
GGMM	29/03/2024 17:27	JPG File
GGMM_AS	29/03/2024 17:27	OUT File
GGMM_MS	29/03/2024 17:27	OUT File
User_Inputs	29/03/2024 17:27	TXT File

Figure 4: Outputs of the MSAS_GGMM.exe

GGMM_MS.out

```
T    Median  Median-sigma     Median+sigma
CAV 6.49949216842651 4    6.17913859716244 8    6.81984573969057 9
D595     3.5654349327087402  3.188097606937239   3.942772258480241 4
PGV -1.22950518131256 1  -1.66670015614274 2  -0.79231020648238
Ia  -0.0670480355620384 2     -0.685631452160055 4 0.551535381035978 5
PGA -1.806098818778991 7 -2.11767589559540 4  -1.494521741962579 6
0.1 -1.403378248214721 7 -1.783328424009894 8 -1.023428072419548 6
0.15     -1.1915522813796997 -1.5515619276793147 -0.8315426350800847
0.2 -1.06021595001220 7  -1.41586870923316 9  -0.70456319079124 51
0.25     -1.0432498455047607 -1.4080181891168029 -0.6784815018927187
0.3 -0.904414236545562 7 -1.253291573723792 9 -0.555536899367332 7
0.4 -0.977769970893859 9 -1.314697338691174 9 -0.640842603096544 8
0.5 -0.972258329391479 5 -1.317252942086232 4 -0.627263716696726 5
0.6 -0.909327566623687 7 -1.263572733394760 8 -0.555082399852614 8
0.7 -0.968246400356292 7 -1.319382479389494 8 -0.617110321323090 7
0.8 -1.064707994461059 6 -1.414173039953407 6 -0.715242948968711 5
0.9 -1.174417734146118 2 -1.518233008379097 1 -0.830602459913139 2
1.0 -1.236741662025451 7 -1.579289470802061 7 -0.894193853248841 6
1.25     -1.4419164657592773 -1.7859718205429433 -1.0978611109756113
1.5 -1.53742170333862 3  -1.899605367139079 1 -1.17523803953816 7
1.75     -1.6727979183197021 -2.041974953439789  -1.3036208831996152
2.0 -1.819538474082946 8 -2.20324191467655 7  -1.435835033489336 8
2.25     -1.9233046770095825 -2.2986842038424493 -1.5479251501767155
2.5 -2.060524463653564 5 -2.443766907057462 6 -1.677282020249666 3
2.75     -2.167952537536621  -2.548184157193146  -1.7877209178800961
3.0 -2.201484918594360 4 -2.575314021804885 6 -1.827655815383835 4
3.4 -2.26861763000488 3  -2.637098081610924 6 -1.900137178398840 8
3.8 -2.30606794357299 8  -2.65652662407645 5  -1.95560926306954 1
4.2 -2.36518764495849 6  -2.706565525182379 3 -2.02380976473461 3
4.6 -2.544517517089843 8 -2.88948616281233 5  -2.199548871367352 6
5.0 -2.58776807785034 2  -2.930221832936801 7 -2.24531432276388 2
```

Figure 5: Estimated **IM** output in the "GGMM_MS.out" file

GGMM_AS.out

```
T    Median  Median-sigma     Median+sigma
CAV 5.330204486846924    4.98503953218013     5.675369441513718
D595     3.2535147666931152  2.910370327012964    3.5966592063732663
PGV -1.8528565168380737 -2.16218873456742    -1.5435242991087277
Ia  -1.2371875047683716 -1.7341786659289886 -0.7401963436077545
PGA -2.171846628189087  -2.46893550953595    -1.8747577468422238
0.1 -1.4109086990356445 -1.7539051349990387 -1.0679122630722504
0.15     -1.3643985986709595 -1.6907828803855185 -1.0380143169564005
0.2 -1.1864349842071533 -1.5373048183124034 -0.8355651501019032
0.25     -1.0871515274047852 -1.439479318030183  -0.7348237367793872
0.3 -1.2738138437271118 -1.6079845167423228 -0.9396431707119008
0.4 -1.3305503129959106 -1.6665537248940117 -0.9945469010978096
0.5 -1.3603742122650146 -1.7081131816215067 -1.0126352429085226
0.6 -1.4618324041366577 -1.8092743913428206 -1.1143904169304948
0.7 -1.6800826787948608 -2.0311668028091816 -1.3289985547805399
0.8 -1.7322721481323242 -2.094909543677346  -1.3696347525873023
0.9 -1.8940523862838745 -2.2509504229245265 -1.5371543496432225
1.0 -2.021857500076294  -2.379925941406674  -1.6637890587459139
1.25     -1.9353282451629639 -2.300436976222358  -1.5702195141035697
1.5 -2.0647690296173096 -2.4375484775752874 -1.6919895816593316
1.75     -2.2954442501068115 -2.6683302853735587 -1.9225582148400644
2.0 -2.4416089057922363 -2.8172065694645263 -2.0660112421199464
2.25     -2.610898494720459  -2.9944285886722017 -2.2273684007687162
2.5 -2.8557910919189453 -3.2337899922245934 -2.4777921916132972
2.75     -2.9546170234680176 -3.3374719207544157 -2.5717621261816195
3.0 -3.166956663131714  -3.554181326673103  -2.7797319995903247
3.4 -3.3342363834381104 -3.7304408991931974 -2.9380318676830233
3.8 -3.4740753173828125 -3.8771502927497976 -3.0710003420158274
4.2 -3.6679294109344482 -4.080811536661014  -3.2550472852078824
4.6 -3.848829746246338  -4.272235037356598  -3.4254244551360777
5.0 -4.057419776916504  -4.486106404386973  -3.628733149446035
```

Figure 6: Estimated **IM** output in the "GGMM_AS.out" file

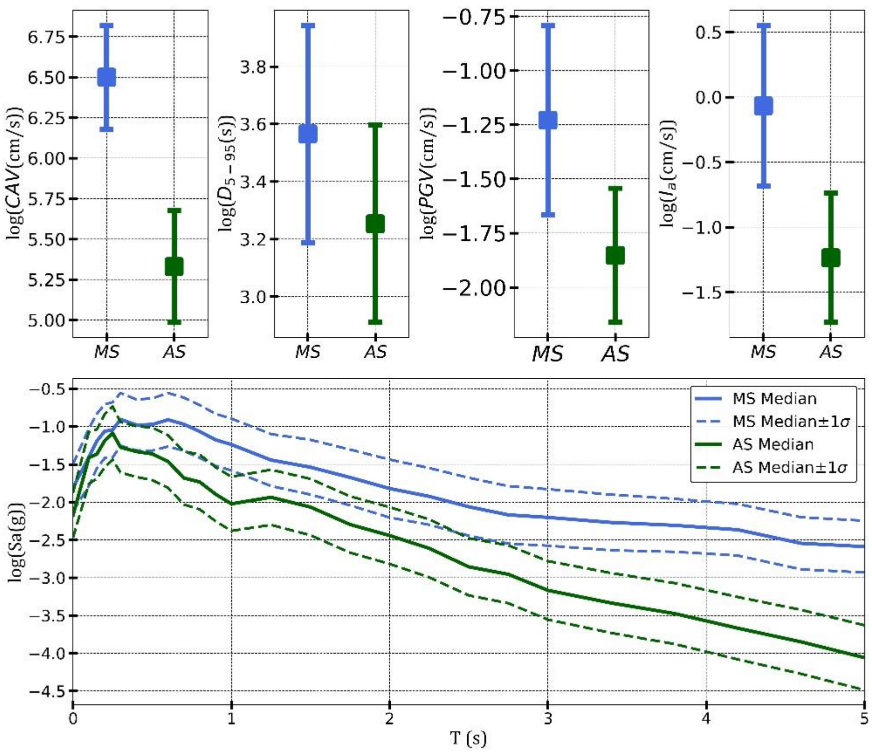

Figure 7: Estimated **IM** output figure (GGMM.jpg)

Reference

Jawad Fayaz and Carmine Galasso (2022). "A Generalized Ground Motion Model for Consistent Mainshock-Aftershock Intensity Measures using Successive Recurrent Neural Networks". *Bulletin of Earthquake Engineering*, Vol. 20, Pages 6467-6486.