

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}_{MS} and \mathbf{IM}_{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 \mathbf{IM} and estimated uncertainty bands ($\pm\sigma$). The executable is developed by Jawad Fayaz ([Jawad Fayaz \(jfayaz.github.io\)](https://github.com/jfayaz)) 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.

<https://www.dropbox.com/scl/fo/i3wwzw1tv2i9vj6tuwdjg/ABAaycbVDwTT3yUwAWIDl3E?rlkey=kti chpcsrpwuvfllu0zizuxmb&dl=0>

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
```

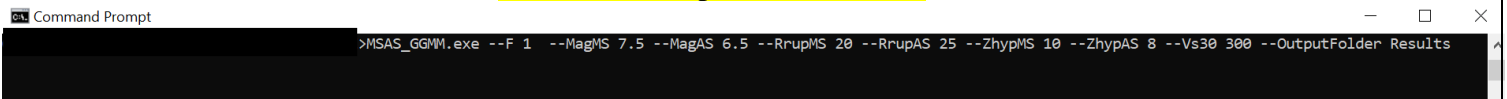


Figure 1: Calling “MSAS_GGMM.exe”

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

```
Please check the inputs
-----

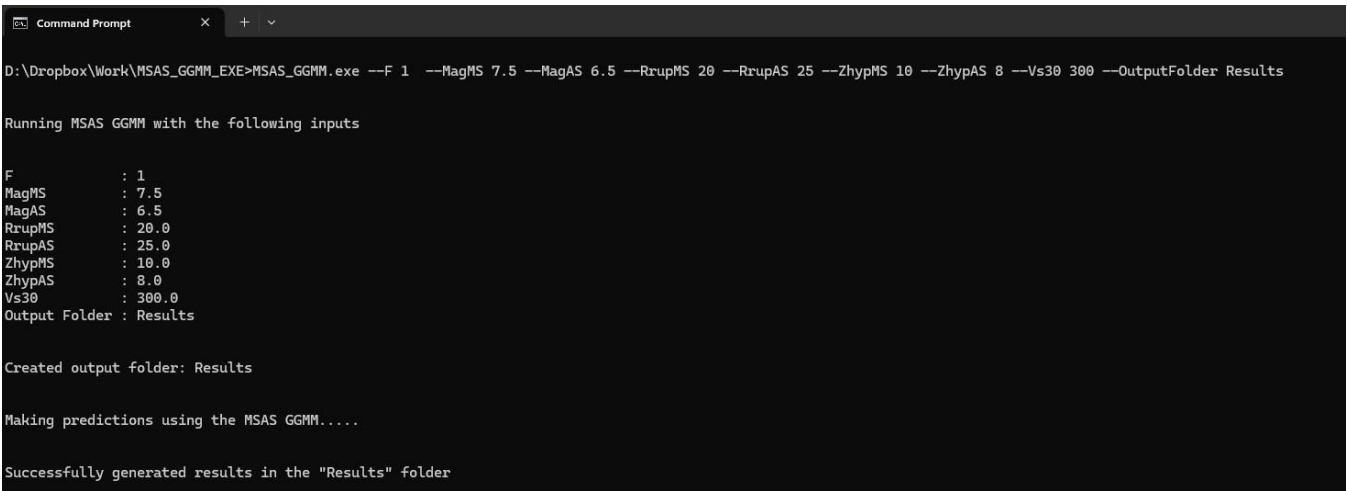
F should be an integer. Use 1 (for Crustal), 2 (for Interface), or 3 (for Inslab)
MagMS and MagAS should be floating numbers between 3 and 9.1
RrupMS and RrupAS should be floating numbers between 0.01 and 250 km
ZhypMS and ZhypAS should be floating numbers between 0.01 and 100 km
Vs30 should be a floating number between 100 m/s and 1800 m/s
-----

MSAS_GGMM.exe: error: ambiguous option: --Rrup could match --RrupMS, --RrupAS
```

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
1	CAV	6.499492168426514	6.179138597162448	6.819845739690579
2	D595	3.5654349327087402	3.188097606937239	3.9427722584802414
3	PGV	-1.229505181312561	-1.666700156142742	-0.79231020648238
4	Ia	-0.06704803556203842	-0.6856314521600554	0.5515353810359785
5	PGA	-1.8060988187789917	-2.117675895595404	-1.4945217419625796
6	0.1	-1.4033782482147217	-1.7833284240098948	-1.0234280724195486
7	0.15	-1.1915522813796997	-1.5515619276793147	-0.8315426350800847
8	0.2	-1.060215950012207	-1.415868709233169	-0.7045631907912451
9	0.25	-1.0432498455047607	-1.4080181891168029	-0.6784815018927187
10	0.3	-0.9044142365455627	-1.2532915737237929	-0.5555368993673327
11	0.4	-0.9777699708938599	-1.3146973386911749	-0.6408426030965448
12	0.5	-0.9722583293914795	-1.3172529420862324	-0.6272637166967265
13	0.6	-0.9093275666236877	-1.2635727333947608	-0.5550823998526148
14	0.7	-0.9682464003562927	-1.3193824793894948	-0.6171103213230907
15	0.8	-1.0647079944610596	-1.4141730399534076	-0.7152429489687115
16	0.9	-1.1744177341461182	-1.5182330083790971	-0.8306024599131392
17	1.0	-1.2367416620254517	-1.5792894708020617	-0.8941938532488416
18	1.25	-1.4419164657592773	-1.7859718205429433	-1.0978611109756113
19	1.5	-1.537421703338623	-1.8996053671390791	-1.175238039538167
20	1.75	-1.6727979183197021	-2.041974953439789	-1.3036208831996152
21	2.0	-1.8195384740829468	-2.203241914676557	-1.4358350334893368
22	2.25	-1.9233046770095825	-2.2986842038424493	-1.5479251501767155
23	2.5	-2.0605244636535645	-2.4437669070574626	-1.6772820202496663
24	2.75	-2.167952537536621	-2.548184157193146	-1.7877209178800961
25	3.0	-2.2014849185943604	-2.5753140218048856	-1.8276558153838354
26	3.4	-2.268617630004883	-2.6370980816109246	-1.9001371783988408
27	3.8	-2.306067943572998	-2.656526624076455	-1.955609263069541
28	4.2	-2.365187644958496	-2.7065655251823793	-2.023809764734613
29	4.6	-2.5445175170898438	-2.889486162812335	-2.1995488713673526
30	5.0	-2.587768077850342	-2.9302218329368017	-2.245314322763882
31				

Figure 5: Estimated IM output in the “GGMM_MS.out” file

GGMM_AS.out				
	T	Median	Median-sigma	Median+sigma
1	CAV	5.330204486846924	4.98503953218013	5.675369441513718
2	D595	3.2535147666931152	2.910370327012964	3.5966592063732663
3	PGV	-1.8528565168380737	-2.16218873456742	-1.5435242991087277
4	Ia	-1.2371875047683716	-1.7341786659289886	-0.7401963436077545
5	PGA	-2.171846628189087	-2.46893550953595	-1.8747577468422238
6	0.1	-1.4109086990356445	-1.7539051349990387	-1.0679122630722504
7	0.15	-1.3643985986709595	-1.6907828803855185	-1.0380143169564005
8	0.2	-1.1864349842071533	-1.5373048183124034	-0.8355651501019032
9	0.25	-1.0871515274047852	-1.439479318030183	-0.7348237367793872
10	0.3	-1.2738138437271118	-1.6079845167423228	-0.9396431707119008
11	0.4	-1.3305503129959106	-1.6665537248940117	-0.9945469010978096
12	0.5	-1.3603742122650146	-1.7081131816215067	-1.0126352429085226
13	0.6	-1.4618324041366577	-1.8092743913428206	-1.1143904169304948
14	0.7	-1.6800826787948608	-2.0311668028091816	-1.3289985547805399
15	0.8	-1.7322721481323242	-2.094909543677346	-1.3696347525873023
16	0.9	-1.8940523862838745	-2.2509504229245265	-1.5371543496432225
17	1.0	-2.021857500076294	-2.379925941406674	-1.6637890587459139
18	1.25	-1.9353282451629639	-2.300436976222358	-1.5702195141035697
19	1.5	-2.0647690296173096	-2.4375484775752874	-1.6919895816593316
20	1.75	-2.2954442501068115	-2.6683302853735587	-1.9225582148400644
21	2.0	-2.4416089057922363	-2.8172065694645263	-2.0660112421199464
22	2.25	-2.610898494720459	-2.9944285886722017	-2.2273684007687162
23	2.5	-2.8557910919189453	-3.2337899922245934	-2.4777921916132972
24	2.75	-2.9546170234680176	-3.3374719207544157	-2.5717621261816195
25	3.0	-3.166956663131714	-3.554181326673103	-2.7797319995903247
26	3.4	-3.3342363834381104	-3.7304408991931974	-2.9380318676830233
27	3.8	-3.4740753173828125	-3.8771502927497976	-3.0710003420158274
28	4.2	-3.6679294109344482	-4.080811536661014	-3.2550472852078824
29	4.6	-3.848829746246338	-4.272235037356598	-3.4254244551360777
30	5.0	-4.057419776916504	-4.486106404386973	-3.628733149446035
31				

Figure 6: Estimated IM output in the “GGMM_AS.out” file

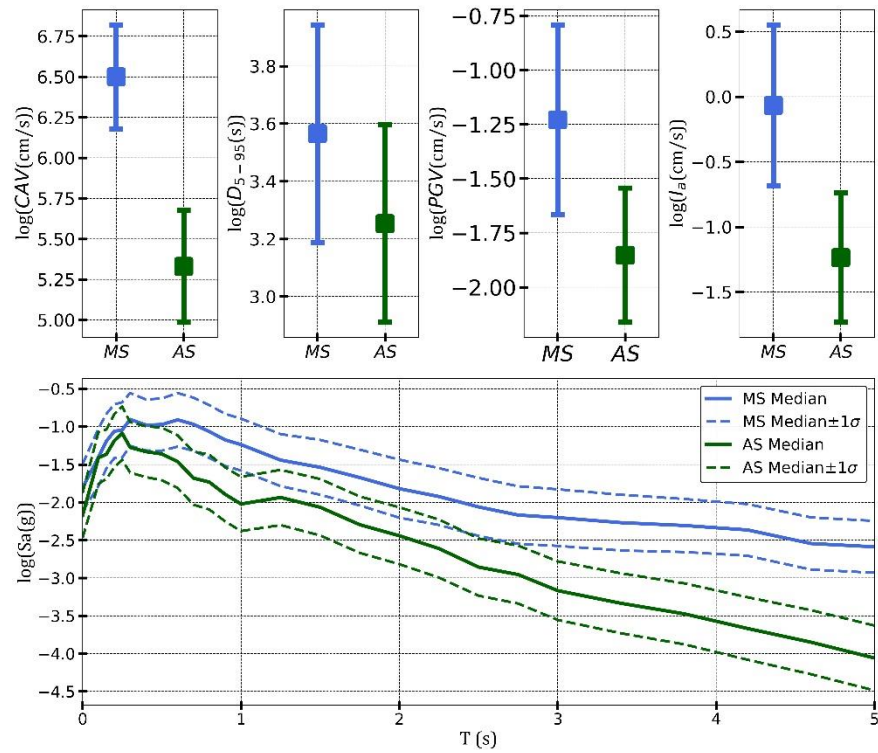


Figure 7: Estimated **IM** output figure (GGMM.jpg)

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, <https://link.springer.com/article/10.1007/s10518-022-01432-w>