Tsunami Modelling of the 8th September 2017 Mexico Earthquake of M 8.1, Using Two Different Software

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Abstract. On 8th of September 2017, an earthquake of magnitude Mw 8.1 was generated offshore Mexico, Chiapas area, at 04:49 UTC, with a depth of 72 km and the following coordinates: Latitude 15.02 N, Longitude 93.81 W, 98 km away from Pijijiapan (Mexico). The fault plane solution of the event was normal plane. Maximum tsunami waves of 1.1 m were measured at Salina Cruz sea level station, following the earthquake. Tsunami modelling simulations were accomplished using the earthquake’s parameters (location, magnitude, depth) and moment tensor solutions given by 3 different agencies: United States Geological Survey (USGS), German Research Centre for Geosciences (GFZ) and Global Centroid Moment Tensor (GCMT). For every case studied, the affected locations, sea level estimates and maximum wave heights were computed. There are two software used for modelling, the Tsunami Analysis Tool (TAT), provided and developed by the Joint Research Centre, Ispra, Italy and TRIDEC Cloud, provided by the German Research Centre for Geosciences (GFZ), Potsdam, Germany. After analysing the modelling scenarios, a comparison between the results of the two software was accomplished, for the same earthquake parameters. The results show that the parameters of GCMT computed with TAT overestimate those computed with TRIDEC, of maximum 3.9 m wave height at Arista with TAT and 2.46 m with TRIDEC. For the GFZ parameters, the estimates give 3.5 m for Pasito de la Senora with TAT, compared to 1.64 m maximum waves at Puerto Madero with TRIDEC. For the USGS data set, the results are similar, maximum waves of 2.4 m at Pasito de la Senora with TAT, and 2.9 m at Puerto Madero with TRIDEC. The Salina Cruz station, where 1.1 m height waves were measured, gives results only for the simulations ran with TAT, with 1.0 m for the GFZ earthquake parameters, 0.6 m for USGS and 1.4 m for the GCMT parameters.

1. Introduction
The M 8.1 earthquake offshore Chiapas, Mexico, occurred as the result of normal faulting at intermediate depth of 72 km (European Mediterranean Seismological Centre EMSC-CSEM) [1]. Focal mechanism solutions of the earthquake indicate a slip on a fault dipping very shallow towards SW, or on steeply dipping fault striking NW-SE. At the location of this event, the Cocos plate converges with North America, in a NE direction, at a rate of approximately 76 mm/year. The Cocos plate begins its subduction beneath Central America at the Middle America Trench, over 100 km to the SW of the earthquake. The location, depth, and normal-faulting mechanism of this earthquake indicate that it is likely an intraplate event, within the subduction Cocos slab, rather than on the shallower megathrust
plate boundary interface. Earthquakes of high magnitude are described as slip over a larger fault area. Normal-faulting events of the size of this earthquake are usually about 200x50 km (length x width).

A region within 250 km of the hypocenter of this event has experienced 8 other M 7+ earthquakes (Figure 1). Most occurred in the subduction zone to the SE of the September 8 event, near the Mexico-Guatemala border, but none of the events were larger than M 7.5. The largest, a M 7.4 thrust faulting earthquake offshore Guatemala was in November 2012, resulted in 48 fatalities and more than 150 injuries, and also producing significant damages.

![Figure 1. Past earthquakes in the area from 1900 to 2017, from USGS catalogue](image)

The September 2018 earthquake was generated at 04:49:21 UTC time, and located at Latitude 15.02° N, Longitude 93.81° W, 98 km away from Pijijiapan (Mexico), and 357 km from Guatemala City (Guatemala). Following the earthquake, tsunami waves were triggered, of maximum 1.1 m waves, measured at Salina Cruz sea level station.

![Figure 2. Moment Tensor Solutions for the M 8.1 Mexico earthquake](image)
Tsunami modelling simulations were accomplished for this event using 3 different sets of earthquake’s parameters (location, magnitude, depth) and moment tensor solutions given by 3 profile agencies: United States Geological Survey (USGS) [2], German Research Centre for Geosciences (GFZ) [3] and Global Centroid Moment Tensor (GCMT) [4], [5], [6] - see Figure 2 and Table 1. Two different software were used for the modelling, Tsunami Analysis Tool (TAT) and TRIDEC Cloud. The results of the simulations for the same earthquake parameters using the two software were compared to the measured sea level values, for certain locations.

**Table 1. The earthquake parameters used for tsunami simulations**

| Agency | Lat.  | Long. | H (km) | Mag | Dip  | Strike | Slip |
|--------|-------|-------|--------|-----|------|--------|------|
| GFZ 15.00°N | 93.77°W | 64 | 8.1 | 152 | 19 | -76 |
| USGS 15.02°N | 93.89°W | 47.4 | 8.2 | 164 | 20 | -61 |
| GCMT 15.34°N | 94.62°W | 44.8 | 8.2 | 148 | 13 | -83 |

2. Methodology
Using earthquake’s parameters (location, magnitude, depth) and moment tensor solutions from three different sources, tsunami modelling simulations were accomplished with two software: Tsunami Analysis Tool (TAT), provided and developed by the Joint Research Centre (JRC) of the European Commission, Ispra, Italy [7], [8], and TRIDEC Cloud, provided by the German Research Centre for Geosciences (GFZ), Potsdam Germany [9], [10], [11]. TAT software was used in previous studies for the evaluation of this event [12]. Both software are useful tools in tsunami modelling and maximum wave heights estimates, and will be shortly described below.

TAT software was developed in 2007 and upgraded since, for the purpose of assisting the operator from a tsunami warning center in decision making in case of an event which could generate a tsunami. It is used worldwide for tsunami monitoring, real time analysis, modelling, scenario calculations. TAT contains a database with processed simulations, which can be compared with real sea level data, in order to rapidly estimate the effects of an earthquake. The software collects real time earthquake information from USGS and EMS-CSEM.

The TRIDEC Cloud software is a more recent software, which provides important functionality required to act in a real event and integrates historic and real-time sea level data and earthquake information. On-demand tsunami simulations are computed for an event either automatically or manually for immediate processing. Thus, tsunami travel times, estimated times of arrival and estimated wave heights are available immediately for visualization purposes and for further analysis and processing purposes with tsunami forecast points and coastal forecast zones, e.g. important for generating warning messages.

The sea level at Salina Cruz station, with maximum measured waves of 1.1 m, was illustrated in Figure 3 [8]. The results of the simulations will be compared with this value in order to evaluate which earthquake parameters set and which software better estimates the tsunami wave measurement for this event.
3. Results and discussions

Each of the modelling case studies display the following estimates: the maximum wave heights maps, tables with the affected locations and their computed sea level.

After analyzing the modelling scenarios, the results of the two software were presented, for the same earthquake parameters. When comparing the values between the modelled data, the results show that the parameters of GCMT computed with TAT overestimate those computed with TRIDEC, with maximum 3.9 m wave height at Arista location resulted from TAT and 2.46 m at Puerto Madero resulted from TRIDEC. The results are presented bellow as maximum wave heights and affected locations for TAT software in Figure 4, and the corresponding ones for TRIDEC in Figures 5 and 6. This scenario computed 1.4 m wave heights for Salina Cruz station.

| STATION       | MAX WAVE HEIGHT (m) |
|---------------|---------------------|
| ARISTA        | 3.9                 |
| BUENA VISTA   | 3.3                 |
| EL ROBLE      | 2.7                 |
| CACHESBA      | 2.2                 |
| SIUAPAN       | 2.2                 |
| PISQUERA      | 1.8                 |
| MOLEDROS      | 1.7                 |
| SALINA CRUZ   | 1.6                 |
| GABRIELATENAS | 1.5                 |
| COSTA RICA    | 1.4                 |
| SAN FRANCISCO DEL MAR | 1.3 |
| ANTELO | 1.3 |
| MAJADA BELLALOBOS | 1.6 |

Figure 3. Sea level measurement at Salina Cruz station, after the M 8.1 earthquake [13].

Figure 4. Maximum wave heights, affected locations (red, orange and yellow points) and sea level measuring stations (yellow triangles), for the simulation using GCMT parameters and TAT software.
Figure 5. Maximum wave heights and travel times for the simulation using the GCMT parameters and TRIDEC software

Figure 6. Map distribution of the affected locations and corresponding wave heights for the simulation using GCMT parameters TRIDEC software

For the USGS moment tensor and earthquake parameters, the results show maximum waves of 2.4 m at Pasito de la Senora with TAT, and 2.9 m at Puerto Madero with TRIDEC. Figure 7 displays the results of TAT, and Figures 8 and 9 show the simulation results of TRIDEC. At Salina Cruz, this scenario displays 0.6 m.

Figure 7. Maximum wave heights, affected locations (orange and yellow points) and sea level measuring stations (yellow triangles), for the simulation using USGS parameters and TAT software
Figure 8. Maximum wave heights and travel times for the simulation using the USGS parameters and TRIDEC software.

Figure 9. Map distribution of the affected locations and corresponding wave heights for the simulation using USGS parameters TRIDEC software.

The simulation accomplished using the GFZ parameters displays maximum 3.5 m for Pasito de la Senora as resulted from TAT software, and 1.64 m wave heights for Puerto Madero using TRIDEC. Maximum wave heights and affected locations for TAT are displayed in Figure 10, and the corresponding results for TRIDEC in Figures 11 and 12.

Figure 10. Maximum wave heights, affected locations (red, orange and yellow points) and sea level measuring stations (yellow triangles), for the simulation using GFZ parameters and TAT software.
The Salina Cruz station, where 1.1 m height waves were measured, gives nu results with TRIDEC software, only for the simulations ran with TAT, with 1.0 m for the GFZ earthquake parameters, 0.6 m for the USGS and 1.4 m for the GCMT parameters (Table 2). The maximum computed wave values are given for certain locations, which do not correspond to the locations where the measurement was taken.

**Table 2.** Maximum waves estimates and their location, using the USGS, GFZ and GCMT earthquake’s parameters, and both TAT and TRIDEC modelling software

| SOURCE | GCMT | USGS | GFZ |
|--------|------|------|-----|
| MAX.WAVE(m) | TAT | TRIDEC | TAT | TRIDEC | TAT | TRIDEC |
| LOCATION | | | | | | |
| ARISTA | 3.9 | 2.46 | 2.4 | 2.9 | 3.5 | 1.64 |
| PUERTO MADERO | | PUERTO MADERO | | PUERTO MADERO | | |
| PASITO DE LA SEÑORA | | | | | | |
| PASITO DE LA SEÑORA | | | | | | |
| PUERTO MADERO | | | | | | |

**Figure 11.** Maximum wave heights and travel times for the simulation using the GFZ parameters and TRIDEC software

**Figure 12.** Map distribution of the affected locations and corresponding wave heights for the simulation using GFZ parameters TRIDEC software
4. Conclusions
An earthquake of Magnitude Mw 8.1 was generated in Mexico, on 8th of September 2017, at Latitude 15.02 N, Longitude 93.81 W, and a depth of 72 km, with a normal fault plan solution. Tsunami waves of maximum 1.1 m were triggered and measured at Salina Cruz sea level station.

Three different sets of earthquake parameters (USGS, GFZ and GCMT) were taken and used for modelling the event, using both TAT and TRIDEC Cloud software. For each parameters set, a tsunami scenario was accomplished, and the results were displayed in different forms (tables and maps). The Salina Cruz station (with measured waves of 1.1 m), is only displayed in the simulations of TAT, with 0.6 m for the USGS earthquake parameters, 1.0 m for the GFZ and 1.4 m for the GCMT parameters. The results show that the best solution is given by GFZ, with the closest value of the computed sea level (1.0 m) to the measured one (1.1 m), at the same location.

Comparing and combining the results of the two software might improve the rapid estimates resulted from modelling and be helpful in first assessments of tsunami waves heights, affected locations and possible casualties. In order to have good tsunami modelling results, it is of high importance to have precise earthquake’s parameters and also a good tool for tsunami waves estimations.

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References
[1] European-Mediterranean Seismological Centre (EMSC-CSEM) - http://www.emsc-csem.org/
[2] United States Geological Survey (USGS) - http://earthquake.usgs.gov/earthquakes/map/
[3] German Research Centre for Geosciences (GFZ) - http://www.gfz-potsdam.de/en/home/
[4] Global Centroid-Moment-Tensor (GCMT) - http://www.globalcmt.org/CMTsearch.html
[5] G. Ekström, M. Nettles, and A. M. Dziewonski, “The global CMT project 2004-2010: Centroid-moment tensors for 13,017 earthquakes”, Phys. Earth Planet. Inter., vol. 200-201, pp. 1-9, 2012.
[6] A. M. Dziewonski, T.-A. Chou and J. H. Woodhouse, “Determination of earthquake source parameters from waveform data for studies of global and regional seismicity”, J. Geophys. Res., vol. 86, pp. 2825-2852, 1981.
[7] A. Annunziato, “The Tsunami Assessment Modelling System by the Joint Research Centre”, Science of Tsunami Hazards, Vol. 26, No. 2, pp. 70 - 92, 2007
[8] Tsunami Analysis Tool website - http://webcritech.jrc.ec.europa.eu/TATNew_web
[9] M. Hammitzsch, J. Spazier, S. Reißland, O. Necmioglu, M. Comoglu, C. Ozer Sozdinler, F. Carrilho, J. Wächter, “TRIDEC Cloud - a Web-based Platform for Tsunami Early Warning tested with NEAMWave14 Scenarios”, Geophysical Research Abstracts, Vol. 17, EGU2015-9084, 2015), General Assembly European Geosciences Union, Vienna, Austria, 2015.
[10] M. Hammitzsch, J. Spazier, S. Reißland, “Advances in the TRIDEC Cloud”, Geophysical Research Abstracts, Vol. 18, EGU2016-12426, General Assembly European Geosciences Union, Vienna, Austria, 2016.
[11] TRIDEC Cloud website - http://trideccloud.gfz-potsdam.de/
[12] R. Partheniu, A.P. Constantin, I.A. Moldovan, D. Ioane, B. Grencu, “Comparison between tsunami modelling and measurements for the Mexico M 8.1 earthquake on 8th of September”, GEOSCIENCE 2017, Bucharest, Romania, Extended Abstract Volume of the Conference, 2017.
[13] (http://webcritech.jrc.ec.europa.eu/TATNew_web)