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Deliverable (n°JRA3-D5): Applications and Utilization of ELER Software

Utilization of ELER V2 and Improvements of EMSC Earthquake Impact Estimation Method

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EXECUTIVE SUMMARY

This report presents the performances assessment of ELER (Earthquake Loss Estimation Routine) Software in terms of Level 0 casualty estimation based on Samardjeva and Badal (2002) empirical laws. Due to the lack of required information for Level 1 and 2, performances of Level 1 have been assessed on 25 earthquakes only and performances Level 2 have not been assessed.

The main observations concerning ELER's results are that it is likely to overestimate the number of casualties of low magnitude (M≤5.5) earthquakes or earthquakes located in low vulnerability zones (e.g. Japan). It also tends to underestimate the casualties for large earthquakes (M>7.0) due to the fact that the method only considers the population density and not the total exposed population. This limitation has been identified in the previous version of this deliverable (Merrer et al.; 2009).

In order to handle some the intrinsic limitation of the method, the EMSC developed an extension of ELER Level 0 module named EQIA (Earthquake Qualitative Impact Assessment) based on the same Samardjeva and Badal (2002) empirical laws as ELER Level 0. The main difference with ELER Level 0 is that EQIA does not intend to estimate the number of casualties but rather to determine a qualitative impact of an earthquake. It considers a large number of scenarios in order to take into account uncertainties on epicentre location and magnitude. EQIA also includes 3 different values for the vulnerability: low (e.g. Japan), normal and high (e.g. Iran). Finally EQIA takes into account the size of the rupture for large earthquakes and better takes into account very low density population areas where Samardjeva and Badal (2002) laws may not be adequate anymore.

We assessed the performances of EQIA on the same earthquakes database as for ELER and observed the following:

- EQIA gives correct and well constrained results for catastrophic earthquakes (e.g. Pakistan, 08/10/2005 (73,300 victims), Sichuan 12/05/2008 (69,197 victims), Haiti 12/01/2010 (222,570 victims)).
- It correctly identifies the not damaging earthquakes.
- For light to moderate impacts, the method may sometimes not be accurate due to the intrinsic limitations of the method and the difficulty to assess low impact events.

Finally, contrary to ELER which provides an interactive and multi-parameters tool to assess the number of casualties at Level 0, EQIA is an automatic tool that will allow EMSC to provide to its members a quick email notification service (within 20 minutes after the earthquake), based on the estimated impact.

I INTRODUCTION

Under the JRA-3 component of the NERIES Project, a methodology and software (ELER – Earthquake Loss Estimation Routine) for the rapid estimation of earthquake shaking and losses in the Euro-Mediterranean region have been developed. Deliverable D5, within the last part of JRA3 is dedicated to the utilization and the evaluation of the performances of ELER Level 0 based on Samardjeva and Badal (2002) empirical laws by the EMSC. ELER proposes 2 others Level 0 casualties estimations methods (RGELFE (1992) and Vacereanu (2004)) which have not been studied in this report.

In the previous version of deliverable D5 in May 2009 (Merrer et al.; 2009), the EMSC presented and assessed the performances of its own method to estimate the level 0 impact of an earthquakes based on Samardjeva and Badal (2002) empirical laws. Within this deliverable, a database of recent worldwide earthquakes (from January 2001 to December 2008), with magnitude spanning from 4.8 to 9.3 and with known number of victims has been created to, which 8 recent deadly earthquakes have been added (e.g. L'Aquila on 06/04/2009 or Chile on 27/02/2010).

This report intends to quickly present how ELER works, what are its current limitations and how to extend its use to worldwide context. We then present the performances of ELER Level 0 in terms of earthquake loss estimations by testing it on the database of earthquakes with known number of victims. The last part is dedicated to the improvements of EMSC earthquake impact estimation method called EQIA (Earthquake Qualitative Impact Assessment) and its performances.

II USE OF ELER SOFTWARE

This part is dedicated to the presentation of ELER software, the necessary requirements and a quick description of the steps to follow to use it.

II.1 Requirements and examples

II.1.1 *Methodology*

The ELER software has two modules: the Earthquake Hazard Assessment module (**EHA**) and the Earthquake Loss Assessment module (**ELA**).

The EHA module provides ground shaking intensity maps based on event parameters defined by the user (earthquake epicentre, magnitude and, if available, fault information). Then, the ELA module uses ground motion and intensity information from EHA module as well as population information and building inventory to estimate building damages and casualties. This module includes three levels (0, 1 and 2) of analysis; Level 0 analysis estimates casualties based on magnitude and intensity information. Level 1 analysis estimates casualties and building damages based on intensity information and Level 2 analysis estimates casualties and building damages based on ground motion and spectral parameters.

II.1.2 *Software requirements*

The ELER V2 software has been provided to the EMSC Mid-February 2010 via a DVD but it can be downloaded via ORFEUS ftp site (ftp://www.orfeus-eu.org/pub/software/ELER/). To install ELER software, disk space of **8 GB** is required.

ELER has been developed in MATLAB programming environment. MATLAB is a cross-platform programming language. The current version is only usable on Windows (x64). The MATLAB Component Runtime (MCR) 7.9 is required. This Runtime is free redistributable that allows you to run programs without installing the MATLAB version itself. All the analyses are performed by utilizing the computational and statistical toolboxes of MATLAB and the Mapping Toolbox is used for the display of the results. The software can be used from a GUI (Graphical User Interface).

II.1.3 *Example of use of hazard module*

Here we present the necessary steps to perform and the results obtained for an event in the Euro-Mediterranean region knowing its location and magnitude.

The first step is the computation of the intensity grid using the Hazard Module (EHA). A snapshot of the Hazard GUI is given in Figure 1.

To enter the event source parameters, the user has 2 possibilities:

- Manually enter the source parameters via the Hazard GUI (Figure 1).
- Create an XML formatted file containing earthquake parameters (latitude, longitude, and magnitude). See example below:

```
<shakemap-data>
<earthquake id="0" lat="41.79" lon="14.87" mag="5.9" year="2002" month="01"
day="31" hour="00" minute="00" second="00" timezone="GMT" depth="10.0"
locstring="SOUTHERN ITALY" created="1238988625" />
</shakemap-data>
```

Then, the user must specify the following parameters: Source Type, Site Correction, Ground Motion, and Instrumental Intensity.

For our example we set:
- Source Type: Point Source
- Site Correction: No correction
- Ground Motion: Akkar and Bommer (2007)
- Instrumental Intensity: Atkinson and Kaka (2007)

NB: If one wants to run Levels 0 and 1 modules after Hazard module, it is necessary to select "*Intens*" as an output of "ground motion parameters to plot" (Figure 1).

With all these information, the software computes and draws the map of the intensity distribution (Figure 2).

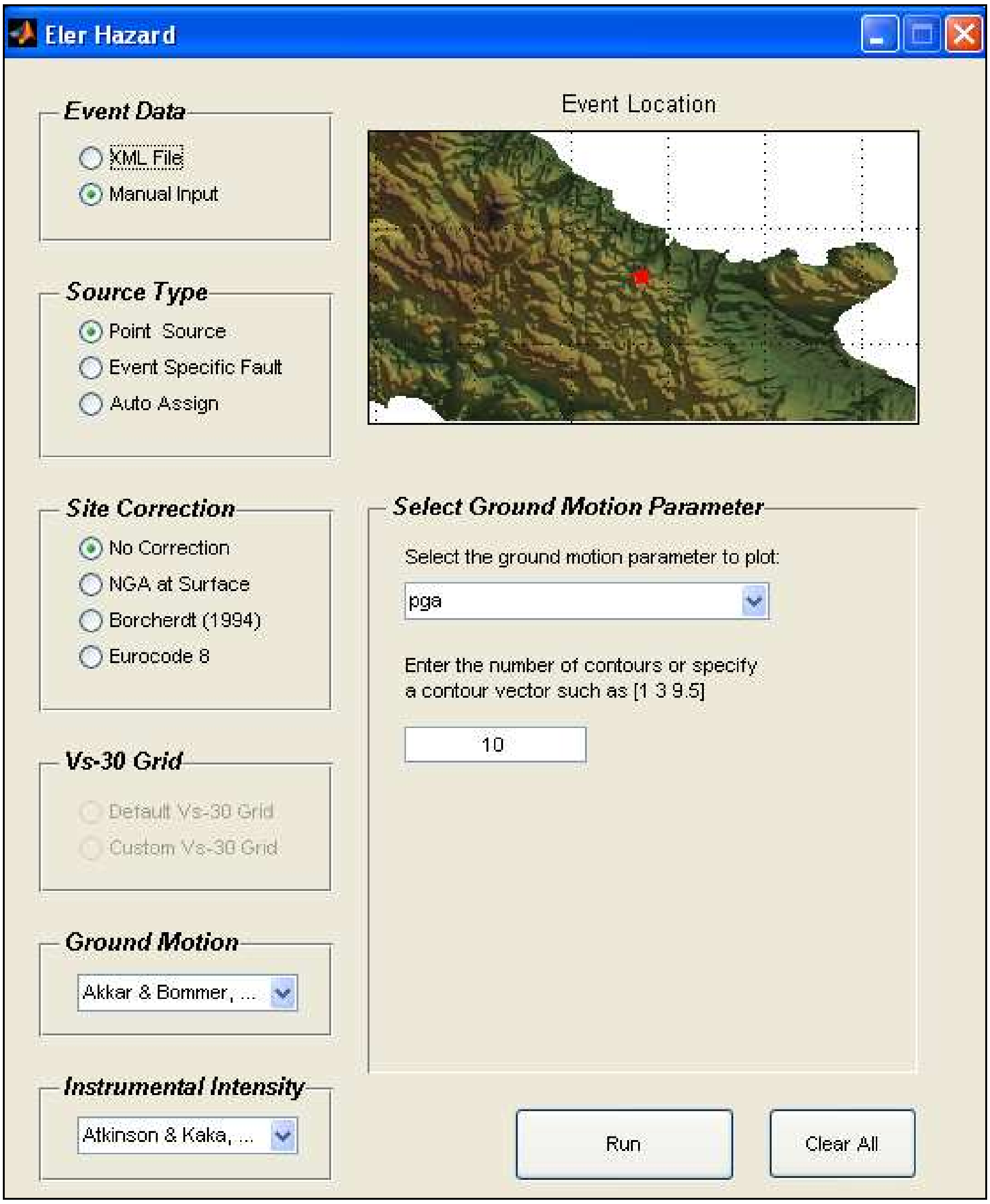


***Figure 1** : Snapshot of Hazard Module GUI for an event located in southern Italy (2002/01/31, lat=41.79°, lon=14.87°, Mag=5.9).*

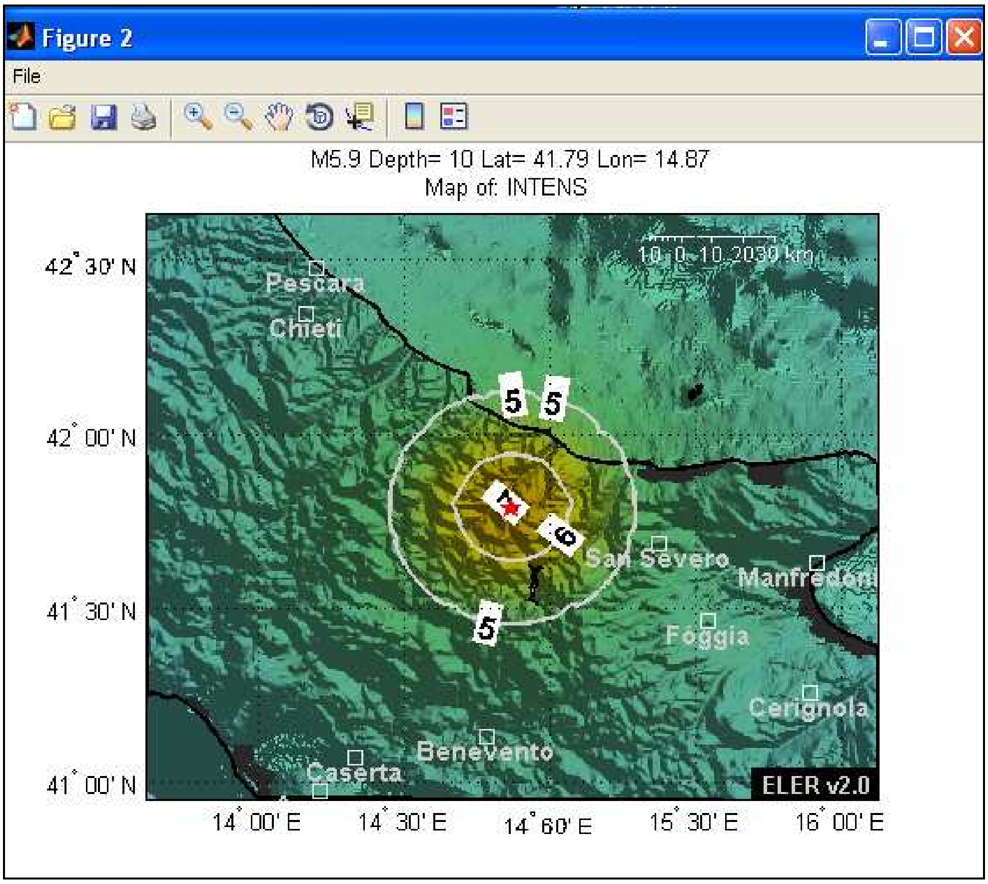


Figure 2 : *Intensity map (Atkinson et Kaka, 2007) obtained with ELER software for an event in southern Italy (2002/01/31, lat=41.79°, lon=14.87°, Mag=5.9).*

II.1.4 *Example of ELA module – Level 0*

After the EHA module is complete, it is possible to proceed to level 0 module to estimate casualties. Outputs are displayed in command window (Figure 3) and in a graphical output (Figure 4).

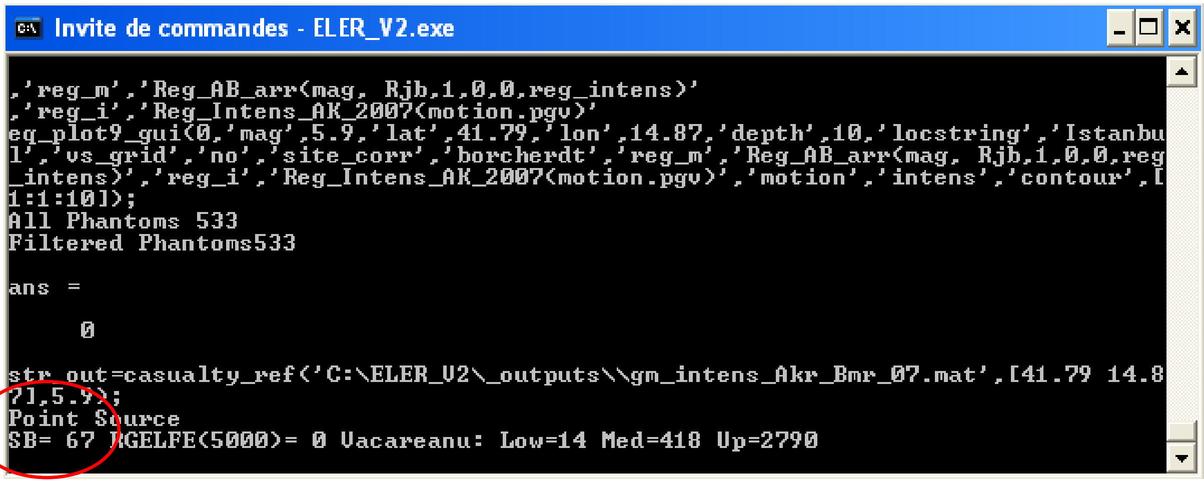
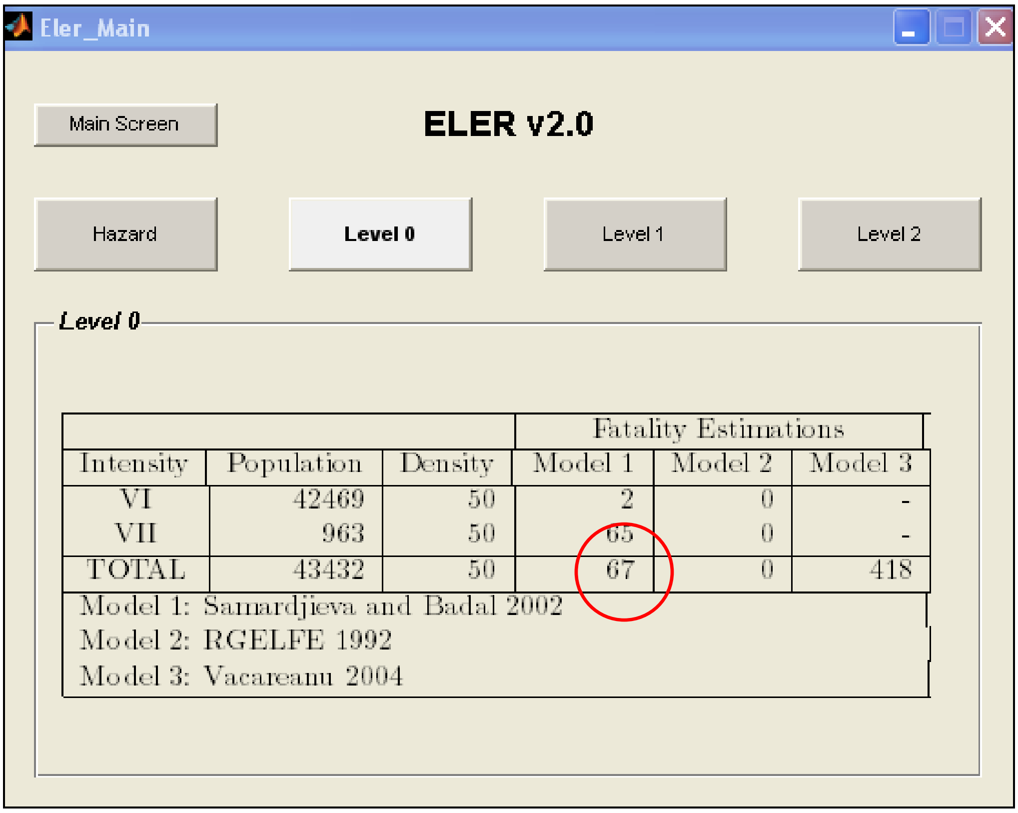


Figure 3 : *Snapshot of the command window obtained after ELA Level 0 execution for an event in southern Italy (2002/01/31, lat=41.79°, lon=14.87°, Mag=5.9).*



			Fatality Estimations		
Intensity	Population	Density	Model 1	Model 2	Model 3
VI	42469	50	2	0	-
VII	963	50	65	0	-
TOTAL	43432	50	67	0	418

Model 1: Samardjieva and Badal 2002
Model 2: RGELFE 1992
Model 3: Vacareanu 2004

Figure 4 : *Graphical output obtained after ELA Level 0 execution for an event in southern Italy (2002/01/31, lat=41.79°, lon=14.87°, Mag=5.9) – casualty estimat ion= 67 victims according to model 1 (Samardjeva and Badal, 2002)*

II.1.5 *Anomaly when insufficient exposed population*

For events located at sea, the exposed population is 0 and the software does not managed to read a variable named "*killed_num*" and returns an error message (Figure 5). The error is caused by insufficient exposed populations. In this case, the estimation of fatality is null. In some other cases, error messages appear in the command window and the graphical table output is empty. However, the fatality estimation is readable is the command window.

These anomalies have been reported to ELER's developers who give the following explanations:
"

1. This is important that Intensity 6 contour exists since ELER uses this contour as the boundary of the affected area, calculating the population density inside this region. Events which do not produce intensity values of 6 six are considered too low for the use of SB2002 methodology. Nevertheless the other Level 0 approaches can be used.

2. Contour 6 must enclose a land (populated) area. Since the lowest density range in the SB2002 approach is defined as <25 people per km2 theoretically even densities close to zero will output a number of casualty as function of the event magnitude. It is problematic to implement the Christoskov (1990) distribution model for cases where the estimated casualty is actually larger than the affected population (ie water areas).
"

According to ELER's developers, a better notification will be included in the upcoming version (Figure 6).

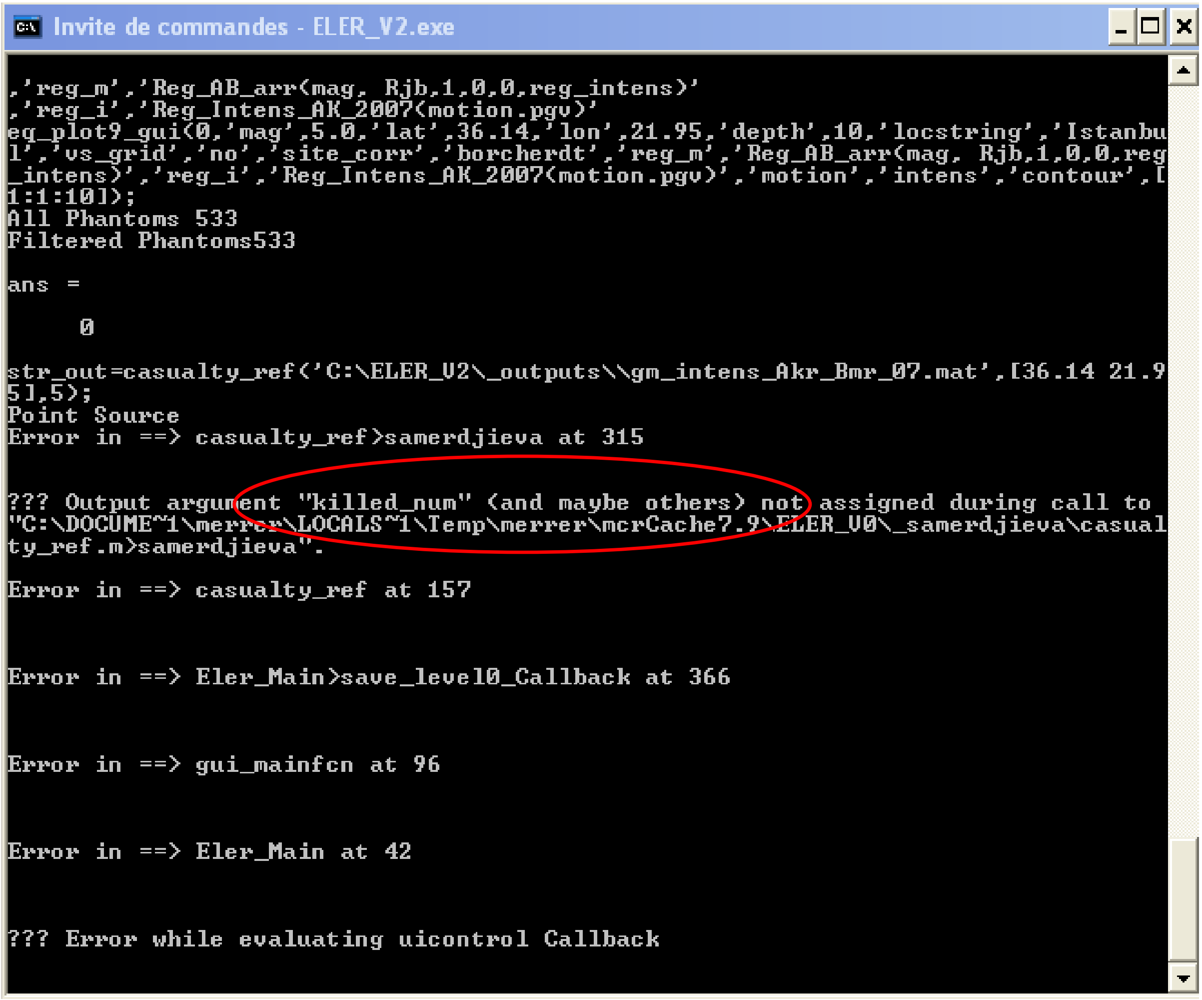


Figure 5 : *Example of command window obtained for an located at sea earthquake in southern Greece (2008/05/08 – lat=36.14°; lon=21.95°; mag=5.0).*

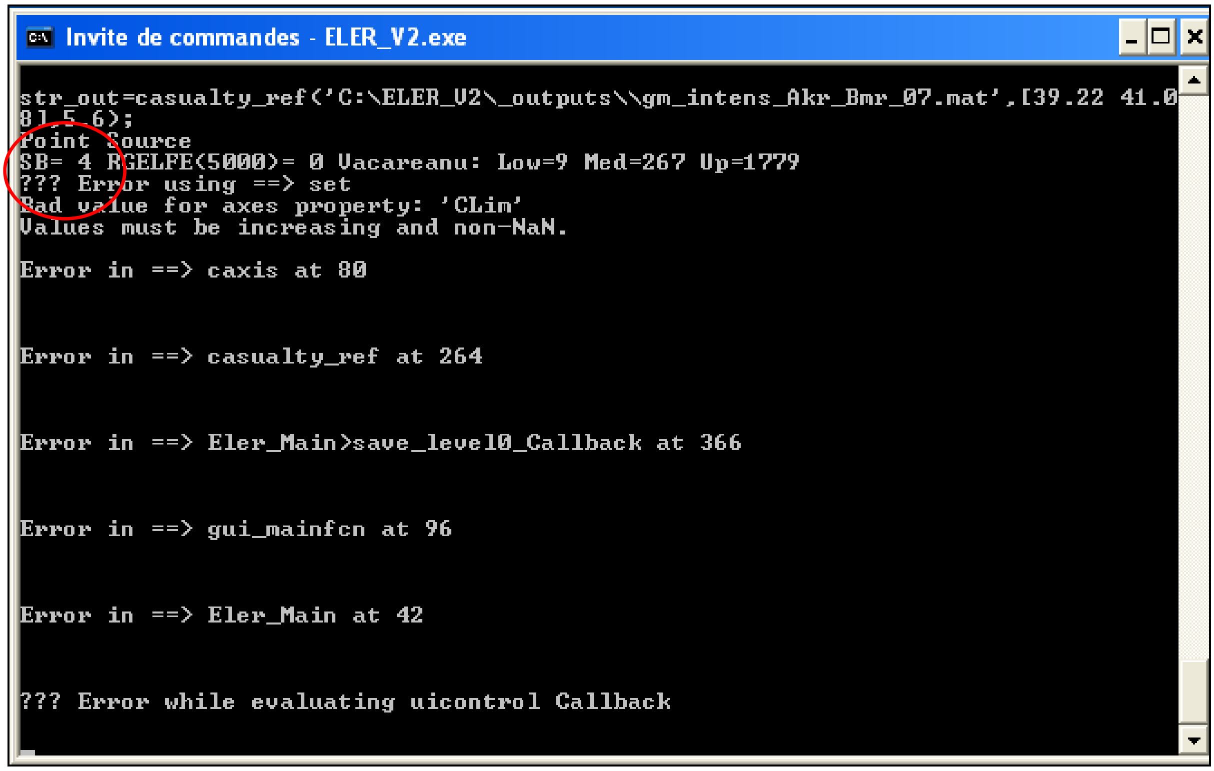


Figure 6 : Example of command window for Eastern Turkish event (2005/06/06 – lat=39.22°, lon=41.08° and magnitude=5.6) + Wald et al, 1999.

II.1.6 *Example of ELA module – Level 1*

Methodology

The Level 1 loss estimation engine of ELER is based on macroseismic damage estimation tools and aims at the assessment of both the building damage and the casualties.

The building damage distribution are calculated by Giovinazzi and Logomarsino (2005) approach and for casualty estimation, there are three possible models (Coburn and Spence, 1992, Risk-UE and KOERI, 2002).

Default inventory

Building inventory and population data for the Level 1 analysis consists of grid (geo-cell) based building classified in terms of Risk UE Building Typology and population distribution. Data for Marmara region (Turkey) are provided to set an example. To study other regions, the building database needs to be developed. Structure of such database is shown in *ELER User Manual – table 12 p 32.*

However, an approximated grid based distribution for the number of buildings and associated structural types are provided as the default inventory of level 1 for 27 countries in Europe (Table 1).

No.	Country Name	No.	Country Name
1	Austria	15	Latvia
2	Belgium	16	Malta
3	Bulgaria	17	Netherlands
4	Cyprus	18	Poland
5	Czech Republic	19	Portugal
6	Germany	20	Romania
7	Denmark	21	Sweden
8	Estonia	22	Slovenia
9	Finland	23	Slovakia
10	Greece	24	United Kingdom
11	Hungary	25	Spain
12	Ireland	26	France
13	Lithuania	27	Italy
14	Luxemburg		

Table 1 : *Countries covered in Corine Land Cover (from ELER Technical Manual – Table 13 p27).*

Moreover, Vulnerability-Ductility tables defining each building type are required. These tables are also provided in ELER DVD for European region. These building vulnerability tables are adjustable for study in specific region with a parameter called "*Regional vulnerability*".

Thus, it is possible to run ELER Level 1 module on some Euro-Mediterranean events of our data base. In our case, 25 earthquakes have been studied (see Appendix III). It concerns principally events located in Italy and Greece and it includes M6.3 L'Aquila earthquake (see Appendix 3). Hereafter, as we do not have the knowledge of each region we study, we set the parameter called "Regional vulnerability" to the default value (zero).

Example

The input specification and results of Level 1 module are presented and illustrated with 2009/04/06 L'Aquila event (Lat=42.38°, Lon=13.32°, Magnitude=6 .3) (Figures 7 and 8). Results for the 24 other events are listed in Appendix III.

7

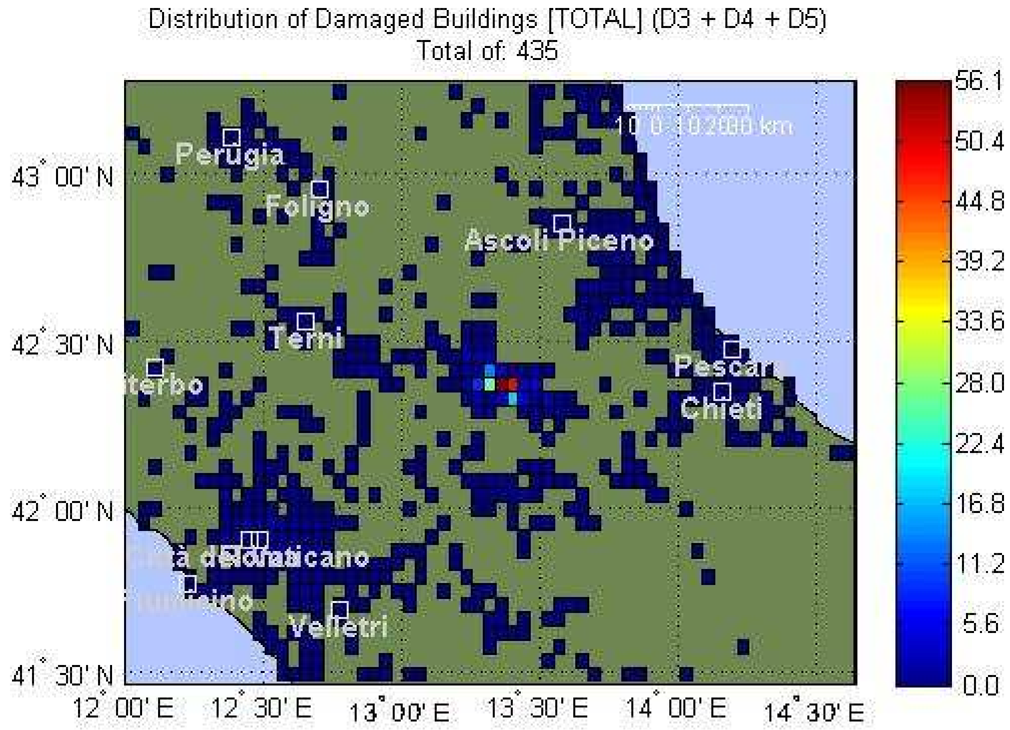


Figure 7 : *Level 1 distribution of damages buildings for the M6.3 L'Aquila earthquake (2009/04/06 Lat=42.38°, Lon=13.32°).*

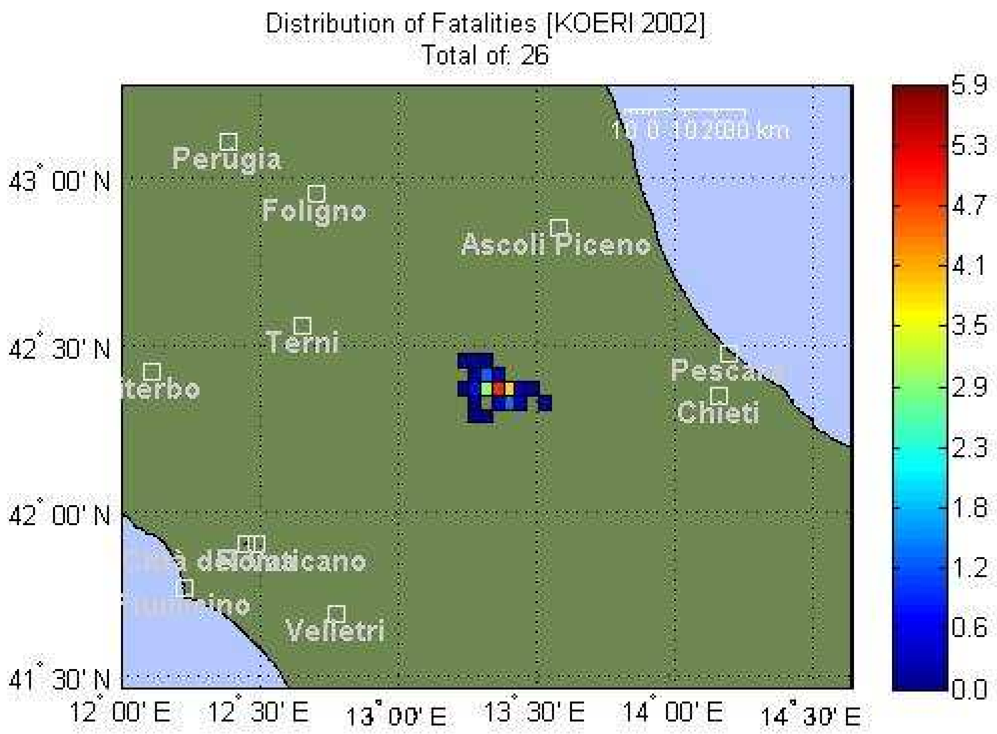


Figure 8 : *Level 1 distribution fatalities for the M6.3 L'Aquila earthquake (2009/04/06 Lat=42.38°, Lon=13.32°).*

II.1.7 *ELA module – Level 2*

Level 2 analysis is essentially intended for earthquake loss assessment (building damage, consequential human casualties and macro economic loss quantifiers) in urban areas.

Analytical fragility relationships and spectral acceleration-displacement-based vulnerability assessment methodologies are utilized for the building damage estimation. Four methods can be used. Casualty estimates are based on the HAZUS methodology relating casualties in different severity levels with number of buildings in different damage states.

To use it, grid based building and demographic inventories are required and database is provided for the Zeytinburnu district of Istanbul only. To run Level 2, user should import its own database. Tools to create custom building database are provided in ELER DVD.

As we do not have enough knowledge of building structure in Europe and as such required fine database are not yet available, we do not present any example in this report. More information on Level 2 are available in ELER Documentation.

II.2 Requirements for worldwide use of Level 0

Since the distributed version of ELER only works for earthquakes located in the Euro-Med region, we present here below the necessary preliminary work to perform, prior to run ELER software on worldwide earthquakes.

II.2.1 *EHA module*

Default inventory

To plot the map of the epicentral region (Figure 1), ELER uses GTOPO30, a global digital elevation model (DEM) with a horizontal grid spacing of 30 arc seconds (Figure 9). GTOPO30 was derived from several raster and vector sources of topographic information. GTOPO30 is provided in the ELER DVD for the "Euro-Med" region only *(W20-E60; S10-N90).*

Moreover, ELER needs DTED Level 1 (Digital Terrain Elevation Data Model with a resolution of 3 arc-seconds) elevation data in order to plot the intensity distribution over the topographic map of the region (Figure 2). The reason for using such a fine elevation data in intensity graphs is the fine colouring and shading.

Requirements for worldwide use

To run ELER on worldwide earthquakes, it is therefore necessary to retrieve the worldwide distribution GTOPO30 in 2 different formats:

- GTOPO30 default distribution. GTOPO30 is manually downloadable from the USGS web site (http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/gtopo30_info), (Figure 9) the distribution is divided in 24 tiles that need to be downloaded one by one. This dataset requires **2.6 GB** of space disk.
- GTOPO30 in DTED Level 1 format. It is possible to derive it from the default distribution using GlobalMapper (publicly available in a trial version from http://www.globalmapper.com/). The final dataset in such a format requires **100 GB** space disk. Moreover, MATLAB expects the DTED files to be organized in a specific directory structure. This structure consists of folders E001...E180…W001…W180, and the dt0 files must reside and have the following names N01.dt0... N90.dt0 … and S01.dt0... S90.dt0.

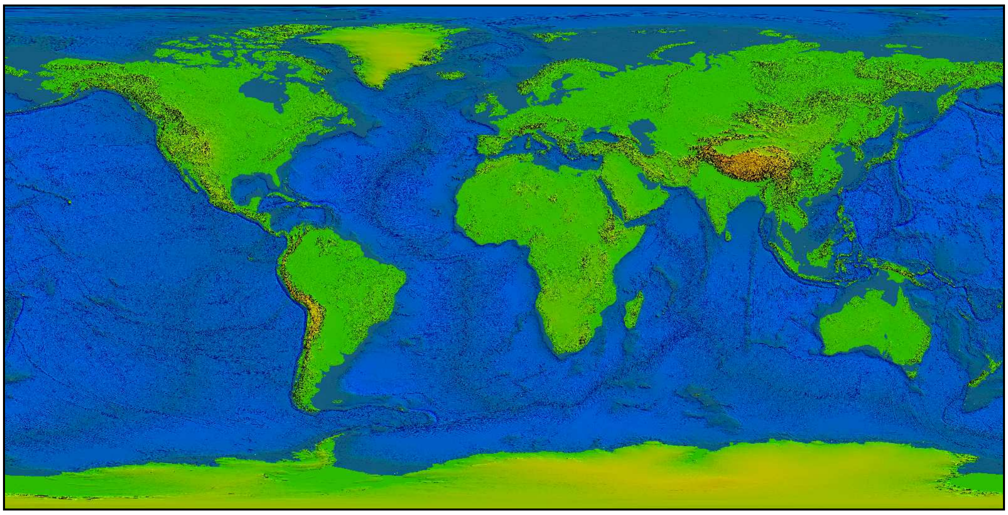


Figure 9 : *GTOPO30, Global 30 Arc Second Elevation Data (with Global Mapper v10 – trial version) – USGS National Mapping Division, EROS Data Center.*

II.2.2 *ELA module – Level 0*

Default inventory

For Level 0 analysis the default inventory consists of population density (*Landscan* Population Distribution Data, 30 Sec-arc), city names, locations and population. This level does not deal with building damage assessment. Casualty estimations are based on the empirical magnitude – casualty relationship.

The default ELER distribution contains:
- Main cities of the Euro-Med Region
- *Landscan* Population distribution data in the following area: W30 - E52; N18 - N 71

Requirements for worldwide use

To run Level 0 on worldwide events, the user must retrieve the worldwide *Landscan* population database (http://www.ornl.gov/sci/landscan/) and then convert it into DTED Level 0 (which has a resolution of 30 arc-seconds). This can be done with GlobalMapper. The worldwide population database requires **1.6 GB** of disk space.

Moreover, as for the GTOPO30 data, MATLAB expects the DTED population files to be organized in a similar specific directory structure.

II.3 Limitations and possible improvements of the ergonomic

As a summary, we identified several limitations of the current distribution of ELER:

- Although the GUI enables the inexperienced users to easily obtain results, it is not possible to run the software as a command line. This would allow the run it over a list of earthquakes or on the same earthquake but with different parameters (via a configuration file for example). According to ELER's developers, it is possible to run each level and phase separately through the source code as functions, but the batch processing of large number of earthquakes would require some of those functions to be reconditioned.

- If one wants to modify only one parameter and check how it affects the results, it is necessary to run the software from the beginning which can be a bit cumbersome while processing

- The current distribution makes EHA and ELA (Level 0) modules to work only for earthquakes located in the Euro-Med region. The use of ELER on worldwide earthquakes requires the installation of the worldwide population database (which is not free) and a very large amount (>100 MB) of additional topographic data. However, most of these additional data are only used to plot nice shaded intensity maps. Therefore, it would be interesting the user could choose to plot this intensity map or not. Another possibility would be to plot the intensity map with the default GTOPO30 database (at 30sec-arc = 2.8 GB) instead of the interpolated one (at 3sec-arc = 100 MB)

However, ELER's developers state that ELER has been designed in a modular structure so as to provide the ability of integration of external ground motion data and inventory in every loss assessment module. The auxiliary data integration tools introduced in ELER v2 have been developed for making this process easier. The user does not have to use the ELER Hazard module to compute the ground motion distribution, he/she can directly input the distribution results obtained from any other tool as an XYZ grid txt file with the *Text2Grid* tool. By doing this the user can bypass using the ELER Hazard module and directly compute the Level 0, 1 or 2 loss assessments.

III ELER LEVEL 0 PERFORMANCES ASSESSMENT

To assess the performance of ELER software, we ran it on our database of 719 earthquakes from 2001 to 2008 that we built in the framework of the previous version of this deliverable (Merrer et al. 2009). We then compared ELER Level 0 casualty estimates with the real numbers of victims.

III.1 Methodology

Among our 719 earthquakes, we considered separately the magnitude lower and greater than 7.0. Indeed, for magnitude lower than 7.0, we considered the source as a point-source and used ELER as such. However, for magnitude greater or equal to 7.0, we considered that the source size exceeded the epicentre location accuracy and that the rupture size had to be taken into account.

III.1.1 *Parameters settings*

ELER provides a lot of possibilities for parameters settings. As an illustration, Level 0 proposes:
- 3 source types
- 4 site corrections
- 6 ground motion laws and their associated parameters
- 2 intensity laws and associated parameters.
- 3 casualties estimations methods

As we explained before, modifying one single parameter requires running again the software from the beginning. It is indeed impossible to run it as a command line or via a configuration file which would be very useful and convenient.

So, we decided to set similar parameters as for the earthquake impact estimation method that EMSC developed (Merrer et al; 2009). Thus we considered the following parameters:
- No site Correction as in Merrer et al; 2009
- Ground Motion Laws: Akkar and Bommer (2007) as in Merrer et al; 2009
- Instrumental Intensity: here we considered separately the 2 possibilities: Atkinson and Kaka (2007) and Wald et al. (1999) because intensity laws are not considered in Merrer et al; 2009
- For Level 0 casualty estimates, we considered Samardjeva and Badal (2002) results as Merrer et al; 2009

This last decision was fostered by the fact that Merrer et al. also used Samardjeva and Badal (2002) empirical relationships and that the 2 others casualties estimations methods (RGELFE (1992) and Vacareanu (2004) propose more crude approaches than Samardjeva and Badal (2002).

III.1.2 *Case of magnitude ≥ 7.0 earthquakes*

For M7+ earthquakes, ELER asks the user to input the coordinates of the rupture as a list of rupture segments. However, ELER DVD only provides this information for Turkey. Therefore, for worldwide earthquakes we considered that a theoretical rupture length as given by Wells and Coppersmith (1994) and the azimuth of the rupture as the one given by the first nodal plane of the double couple solutions taken from the Harvard Global CMT Catalog (http://www.globalcmt.org/CMTsearch.html). With an azimuth and a rupture length, we were able to generate the rupture segment associated to the rupture and to run ELER with these parameters. However, as we do not know the direction of the rupture, 3 rupture scenarios had to be taken into account: 2 for unilateral rupture and 1 for bilateral rupture (Figure 10).

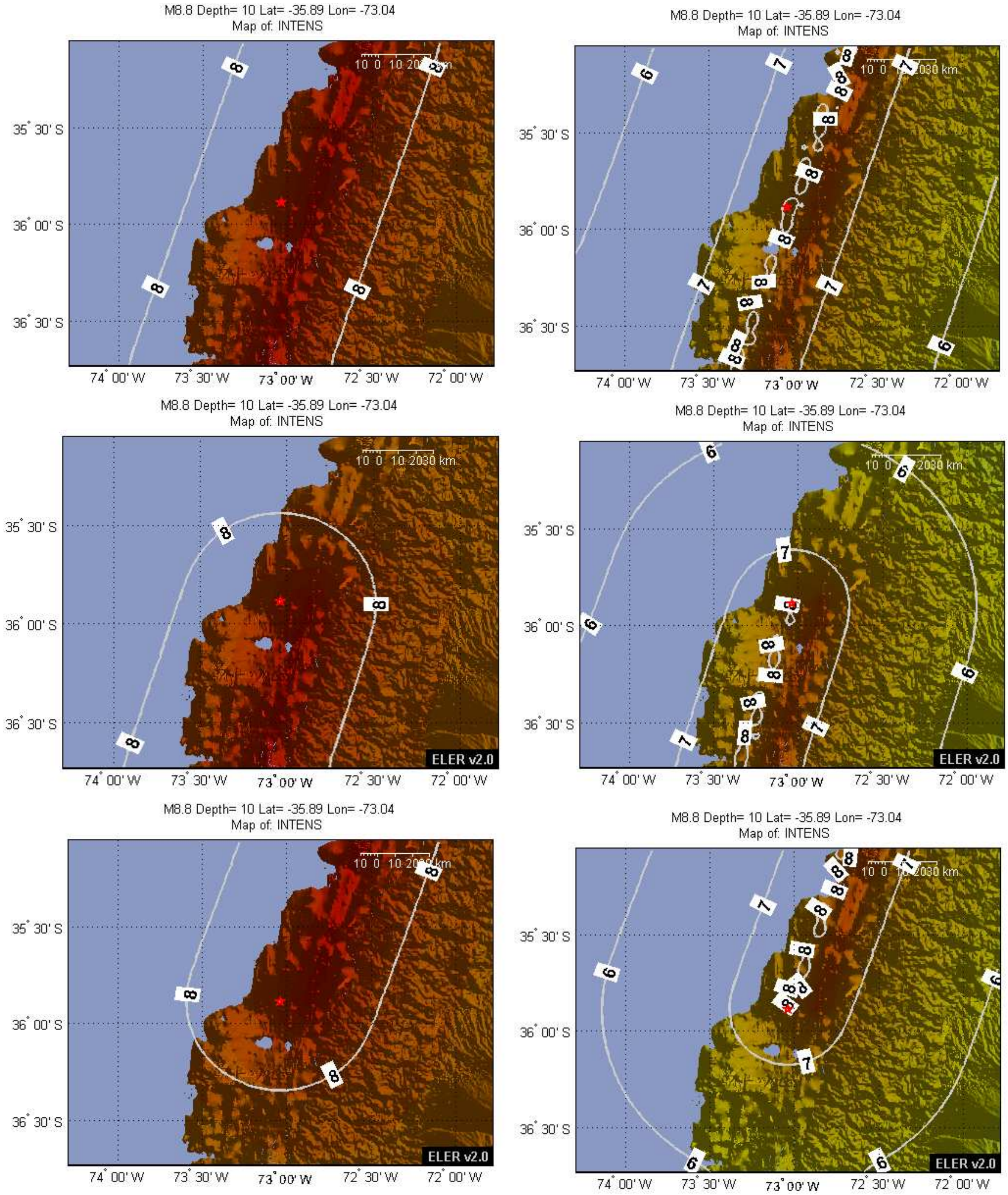


Figure 10 : *Intensity maps obtained for three different rupture scenarios (top: bilateral; middle: left unilateral and bottom: right unilateral) and the two intensity laws (left: Atkinson and Kaka, 2007, right: Wald et al., 1999) for the Mw8.8 Chile earthquake on 27/02/2010*

III.1.3 *Manual processing*

In order to test ELER on the whole database of 719 earthquakes, the EMSC had to run the software 1,630 times. Indeed:

- 1,342 times for 671 earthquakes with M<7.0 (671 earthquakes times 2 intensity laws).
- 288 times for 48 earthquakes with M≥7.0 (48 earthquakes times 2 intensity laws times 3 rupture scenarios).

However, ELER’s developers insist on the fact that ELER was designed in order to provide even an inexperienced user with a GUI which would help him/her customize a scenario event, easily implement different methods, use custom data, see the effects of different parameters on the results. Experienced users are encouraged to use different tools together with ELER, actually this would underline the success of the modular structure that has been one of the main ideas of the software.

ELER’s developers state, when dealing with a large number of scenario, it is more convenient to determine the ground motion distributions with USGS *ShakeMap*, which can only be run from a command terminal in Linux and the obtained ground motion distributions could then be used in the Level 0 casualty assessment via the tools for external data integration.

III.1.4 *Cases for which ELER did not produce any output*

The processing failed for six events including M=9.3 2004 Sumatra earthquakes and five M<7 events in Kazakhstan, Siberia and Laptev Sea. Therefore, ELER produced results for 713 earthquakes.

- **M9.3 Sumatra:**

Concerning M9.3 Sumatra earthquake, according the ELER’s developers, for very large earthquakes, the map extend should be increased so as to allow the intensity to drop till 6 which would make the population density calculation area definable.

Following these recommendations, the EMSC makes further tests on Sumatra event by increasing the size of the map. However, by increasing the size of the map, we never managed to make the Intensity 6 contour visible. Moreover, for larger size of the map, the program fails. Results and observations are presented below:

Default size (1.6x2.5): Error message: *Unable to contour the intensity grid*
Size=3 x 5 degrees: 1,321 victims
Size=5 x 10 degrees: 4,519 victims
Size= 8 x 12 degrees: Error message: *Out of memory*

Solution:
According to ELER's developers, this error is related to the available RAM in the computer and the maximum amount MATLAB can utilize. It is possible to decrease the memory demand of the resulting ground motion distribution by changing the *interp_grid* parameter in *eler_pref.txt* file. When set to 0.016 (arc degree) the program creates a node every 1.77 km and, for large regions, this may result in memory error. By doubling this value, this results in a 4 times lower memory demand. By crude estimation, since it is possible to obtain a 5x10 map, by doubling the value of *interp_grid* it is possible to get a 10 x 20 map.

- **Other cases:**

For the five other cases where ELER did not produce any output, the problem seems to come from bad GTOPO30 DTED Level 1 topographic files that EMSC had to derive from GTOPO30 original distribution. This problem seems to occur for high latitude earthquakes. Further investigations are still required.

III.2 ELER results analysis

III.2.1 *Positive and negative fakes*

An important issue while assessing the performances of a given method is to evaluate if the method is likely to output positive or negative fakes. A positive fake corresponds to a non-null estimated number of victims while the real number of victims is 0. A negative fake corresponds to a null estimated number of victims while the real number of victims is not null (at least 1 actual victim).

In this part, all events are discussed together whatever their magnitude and the results for the two intensity laws are studied separately in order to find if one method is better than the other.

III.2.1.1 Positive fakes

Among our dataset of 713 events for which ELER produced a usable result, 88% (625 events) did not cause any victim. Among these 625 events, we consider Ne as the estimated number of casualties according to ELER. We then consider the 2 intensity laws.

- **With Atkinson and Kaka, 2007**

With Atkinson and Kaka (2007), the estimated number of casualties according to ELER (Ne) is non null for 233 (37%) events (Figure 11). The results are distributed as follows:

- For 394 (63%) earthquakes, Ne=0
- For 134 (21%) earthquakes, 0 < Ne ≤ 10
- For 88 (14%) earthquakes, 10 < Ne ≤ 100
- For 11 (2%) earthquakes, Ne > 100 victims (Table 2)

Date	Lat (°)	Lon (°)	Mag	Region	AK estimate
2008/02/03	-6.07	149.9	5.4	NEW BRITAIN	112
2008/03/29	-12.07	-77.19	5.4	NEAR COAST OF CENTRAL PERU	122
2008/07/29	33.81	-117.92	5.5	GREATER LOS ANGELES	153
2007/02/19	1.8	30.67	5.6	LAKE ALBERT REGION, CONGO	191
2008/01/07	-0.75	134.03	5.8	NORTH PAPUA, INDONESIA	131
2007/06/15	1.78	30.66	5.9	LAKE ALBERT REGION, CONGO	374
2008/02/04	-20.14	-70.05	6.3	TARAPACA, CHILE	377
2005/10/19	36.4	140.81	6.5	NEAR EAST COAST OF HONSHU, JAPAN	575
2006/12/26	21.8	120.52	7.2	TAIWAN REGION	52-828
2006/04/20	61.1	167.2	7.7	KORYAKIA, RUSSIA	112
2006/05/03	-19.99	-174.21	7.8	TONGA	131

Table 2 :Significant positive fakes. *The 11 earthquakes which made 0 victim but with a casualty estimation according to ELER is greater than 100 using Atkinson and Kaka, 2007 intensity law. Events are sorted by magnitude*

- **With Wald et al., 1999**

With Wald et al. (1999), the estimated number of casualties according to ELER (Ne) is non null for 114 (18%) events (Figure 11). The results are distributed as follows:

- For 511 (82%) earthquakes, Ne=0
- For 56 (9%) earthquakes, 0 < Ne ≤ 10
- For 47 (7%) earthquakes, 10 < Ne ≤ 100
- For 11 (2%) earthquakes, Ne > 100 victims (Table 3)

Date	Lat (°)	Lon (°)	Mag	Region	Wald estimate
2008/02/04	38.2	21.96	4.9	GREECE	914
2008/07/29	33.81	-117.92	5.5	GREATER LOS ANGELES, CALIFORNIA	153
2008/01/13	17.07	120.97	5.6	LUZON, PHILIPPINES	191

2007/02/19	1.8	30.67	5.6	LAKE ALBERT REGION, CONGO	191
2008/05/25	32.62	105.45	5.9	SICHUAN – GANSU, CHINA	161
2007/06/15	1.78	30.66	5.9	LAKE ALBERT REGION, CONGO	374
2008/11/19	8.34	-82.97	6.2	SOUTH PANAMA	120
2006/12/26	21.8	120.52	7.2	TAIWAN REGION	52-2535
2006/04/20	61.1	167.2	7.7	KORYAKIA, RUSSIA	112
2006/05/03	-19.99	-174.21	7.8	TONGA	131

Table 3 : Significant positive fakes. *The 10 earthquakes which made zero victim but with a casualty estimation according to ELER greater than 100 using Wald et al., 1999 intensity law. Events are sorted by magnitude.*

- **Interpretation**

With Wald et al (1999) intensity laws, ELER software finds exactly zero victim in 82% of cases, against 63% for Atkinson and Kaka (2007) laws.

However, we know that light impact earthquakes (less than 10 victims) are very difficult to model because in such cases the number of victims is generally controlled by one deadly event (e.g. the collapse of a fragile building which trapped several persons). Therefore, if we consider that casualty estimations less than 10 victims are acceptable when the real number of victims is 0. We retrieve that Wald et al. (1999) allows to correctly estimate 91% of them, against 84% with Atkinson and Kaka (2007) law.

Concerning the large overestimations of the number of casualties given by ELER (Tables 2 and 3), we get similar results as with our previous method (Merrer at al.; 2009) for several of them. Indeed, in their method to estimate the earthquake impact, we pointed out that Samardjeva and Badal (2002) tended to greatly overestimate the number of casualties in the following cases:

- Earthquakes located in low vulnerability zones (Taiwan, California)
- Earthquake with low magnitude (<=5.5)
- Earthquakes located in Lake Albert, Congo and South Panama regions

For the rest, further studies would be required to understand why ELER overestimates that much the number of casualties.

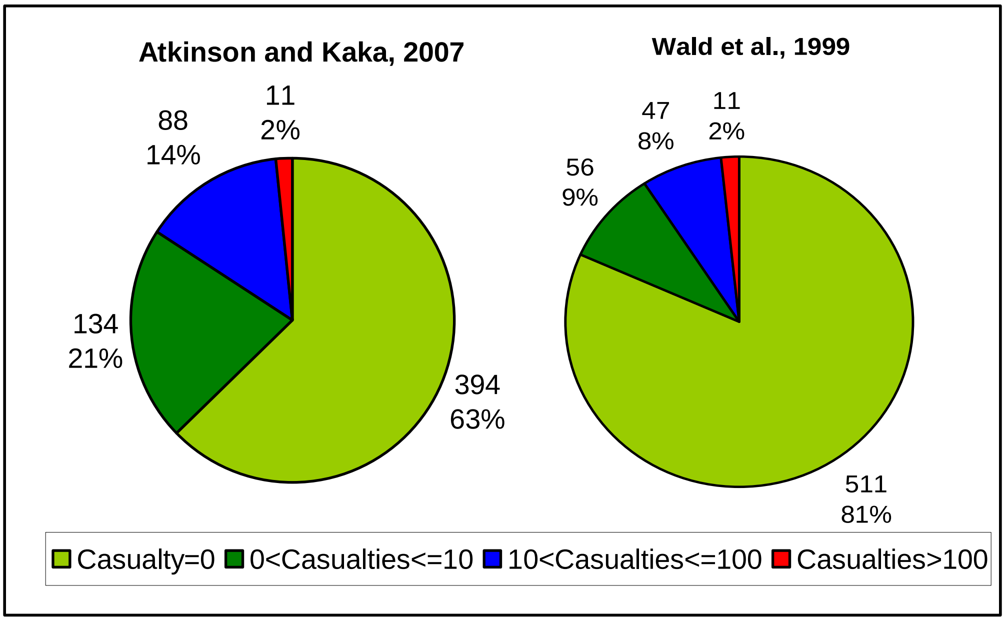


Figure 11 : Repartition of positive fakes*. events that did not cause any victim but for which ELER gives a non-null casualty estimation as function of casualty estimates ranges with Atkinson and Kaka, 2007 (left) and Wald et al., 1999 (right) intensity laws.*

III.2.1.2 Negative fakes

A negative fake corresponds to a null estimated number of victims while the real number of victims is not null (at least 1 actual victim). For Mag>7.0 events, we consider an earthquake as a negative fakes when the three scenarios (i.e. 3 rupture scenarios) give all 0 victim. The lists of negative fakes for the two intensity laws are presented in Table 4 and Table 5.

- **With Atkinson and Kaka, 2007**

Date	Lat (°)	Lon (°)	Mag	Region	Fatalities
2006/12/17	4.82	95.02	5.8	NORTHERN SUMATRA	7
2008/10/25	26.65	55.09	5.2	IRAN	9
2002/03/06	5.87	124.27	6	MINDANAO, PHILIPPINES	15
2009/09/29	-15.42	-172.13	8.1	SAMOA ISLANDS REGION	192

Table 4 : *The four negative fakes obtained with Atkinson and Kaka, 2007*

- **With Wald et al., 1999**

Date	Lat (°)	Lon (°)	Mag	Region	Fatalities
2007-12-09	-14.97	-44.22	4.9	BRAZIL	1
2005-03-09	-26.91	26.79	5	SOUTH AFRICA	2
2006-07-22	28	104.14	5	SICHUAN-YUNNAN-GUIZHOU RG, CHINA	22
2002/03/06	5.87	124.27	6	MINDANAO, PHILIPPINES	15
2006/12/17	4.82	95.02	5.8	NORTHERN SUMATRA, INDONESIA	7
2007/11/25	-8.06	118.62	6.5	INDONESIA	3
2008/06/18	35.36	91.26	5.5	S QINGHAI, CHINA	2
2008/08/21	25.23	97.72	5.7	MYANMAR, CHINA	5
2009/09/29	-15.42	-172.13	8.1	SAMOA ISLANDS REGION	192

Table 5 : *The nine negative fakes obtained with Wald et al., 1999*

- **Interpretation**

With Atkinson and Kaka (2007), 4 negative fakes are produced by ELER against 9 with Wald et al. (1999). However, all negative fakes correspond to casualty estimations less than 22 victims except for 29/09/2009 Samoa Islands earthquake with an estimation of 192 victims for both intensity laws. However, we know that for this event, most of the victims were caused by a tsunami and not by the earthquake itself.

So, whatever the intensity laws, the number of negative fakes produced by ELER is relatively low and only concern low impact earthquakes (less than several tens of victims).

III.2.2 *Remaining cases*

Here, we do not consider the positive and negative fakes. In other words, we only consider earthquakes which caused at least 1 victim and for which ELER also predict at least 1 victim. As a result, we get:

- 83 events for which Atkinson and Kaka (2007) gives non-null casualty estimations.
- 79 events for which Wald et al. (1999) gives non-null casualty estimations.

Because the methodology to study M<7.0 and M>7.0 earthquakes are different, we study them separately.

III.2.2.1 Cases with magnitude < 7.0

The results of ELER are shown in a log-log representing ELER estimates vs real number of victims (Figure 12).

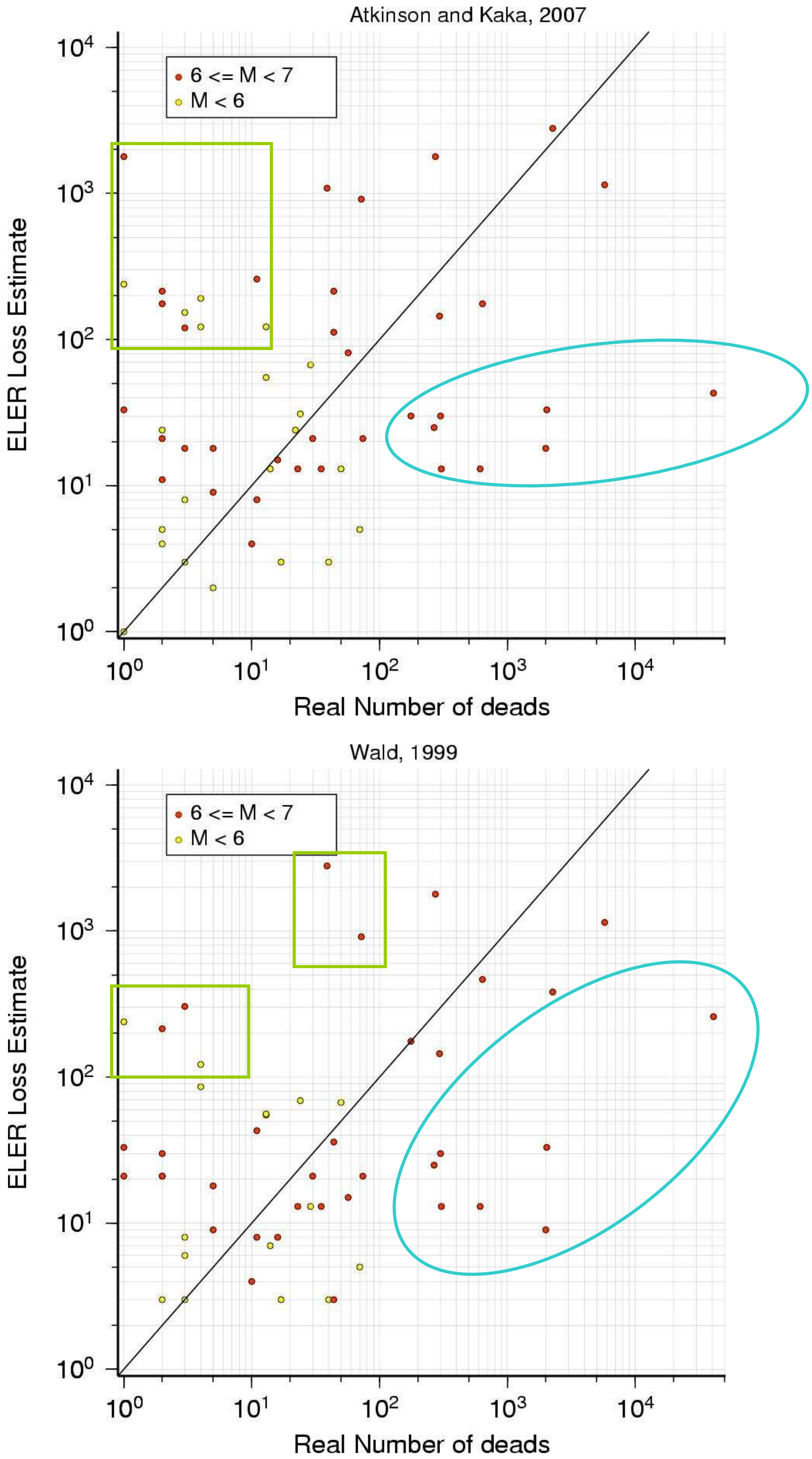


Figure 12 : *Log-Log plot of ELER loss estimates for Atkinson and Kaka, 2007 intensity law (top) and for Wald et al., 1999, intensity law (bottom) as function of real number of victims for M<7 events with non null ELER estimate and non null real number of victims*

On the graphical representation of ELER estimates vs real number of casualties (Figure 12), we identified 2 groups of earthquakes:

- The very underestimated number of victims: Earthquakes with more than 100 victims but for which the estimation is far too low (blue ellipses on Figure 12 top and bottom; Table 6)
- The very overestimated number of victims: Earthquakes with more than 100 victims but for which the estimation is far too high (green boxes on Figure 12 top and bottom; Tables 7 and 8).

- **First observations of the graphical results**

A quick look at Figure 12 reveals that ELER estimations are equally distributed on both side of the Y=X curve. However, we observe a slight trend to overestimate low magnitude (M<6) earthquakes (yellow dots on Figure 12). Indeed, most of the yellow dots are located above the Y=X curve. This observation has been also made in our previous version of this deliverable (Merrer et al.; 2009).

- **Very underestimated number of casualties**

As shown in Table 6, the cases were the number of casualties given by ELER is very underestimated correspond to earthquakes in regions where the vulnerability of the buildings is likely high (Pakistan, Iran, Afghanistan, Qinghai (China), Xinjian (China), Eastern Turkey). It is important to note that we also also made this observation in our previous version of this deliverable (Merrer et al.; 2009). This is due to the fact that Smardjeva and Badal (2002) casualty estimations laws do not take into account the vulnerability of the buildings.

Date	Lat (°)	Lon (°)	Mag	Fatalities	Region	AK, 2007	Wald, 1999
2003/05/01	39.01	40.46	6.4	176	EASTERN TURKEY	30	176
2003/02/24	39.61	77.23	6.3	268	SOUTHERN XINJIAN,CHINA	25	25
2008/10/29	30.53	67.53	6.4	300	PAKISTAN	30	30
2002/06/22	35.67	48.93	6.3	305	WESTERN IRAN	13	13
2005/02/22	30.72	56.91	6.3	612	CENTRAL IRAN	13	13
2002/03/25	36.06	69.31	6.1	2000	HINDU KUSH REGION, AFGHANISTAN	18	9
2003/12/26	29.00	58.31	6.6	41000	SOUTHERN IRAN	43	259
2010/04/13	33.23	96.65	6.9	+ 2000	SOUTHERN QINGHAI, CHINA	33	33

Table 6: Very underestimated number of casualties. *Events with more than 100 real victims but with ELER estimates much lower than the real number of victims (Atkinson and Kaka, 2007 and/or Wald et al.,1999). See blue ellipses in Figures 12 (top and bottom)*

- **Very overestimated number of casualties**

Some large overestimations of the number of casualties given by ELER (Tables 6 and 7) are observed for similar events as for our previous method (Merrer at al.; 2009):

- Events in Serbia and in Panama
- Events near Honshu (Japan) where the low vulnerability of the buildings in Japan may explain this discrepancy.

The two intensity laws tend to greatly overestimate the number of casualty for the same events (Serbia, Sichuan (China), Panama, Honshu) (Table 7 and 8).

Further studies would be required to understand why ELER overestimates that much the number of casualties for these earthquakes.

Date	Lat (°)	Lon (°)	Mag	Region	Deads	Atkinson and Kaka, 2007
2002-04-24	42.44	21.47	5.7	SERBIA	1	239
2003-11-15	27.37	103.97	5.6	SICHUAN-YUNNAN-GUIZHOURG, CHINA	4	191
2003-12-25	8.42	-82.82	6.5	PANAMA-COSTA ICA ORDER EGION	2	214
2004-08-10	27.27	103.87	5.4	SICHUAN-YUNNAN-GUIZHOURG, CHINA	4	122

2005-03-20	33.81	130.13	6.6	KYUSHU, JAPAN	1	1786
2006-07-29	37.38	68.74	5.5	TAJIKISTAN	3	153
2007-06-03	23.09	101.11	6.2	CHINA	3	120
2008-06-08	37.97	21.48	6.4	SOUTHERN GREECE	2	176
2005-11-26	29.7	115.69	5.4	HUBEI-JIANGXI BORDER REG, CHINA	13	122
2007-07-16	37.58	138.44	6.6	NEAR WEST COAST OF HONSHU, JAPAN	11	259

Table 7: Very overestimated number of casualties. *Events for which ELER predicts more than 100 casualties and at least 10 times more casualties than the actual number with Atkinson and Kaka, 2007 intensity law. See green box in Figure 10 (top)*

Date	Lat (°)	Lon (°)	Mag	Region	Deads	Wald, 1999
2002-04-24	42.44	21.47	5.7	SERBIA	1	239
2007-06-03	23.09	101.11	6.2	CHINA	3	305
2004-08-10	27.27	103.87	5.4	SICHUAN-YUNNAN-GUIZHOU RG, CHINA	4	122
2003-12-25	8.42	-82.82	6.5	PANAMA-COSTA RICA BORDER EGION	2	214
2004-10-23	37.38	138.85	6.8	NEAR WEST COAST OF HONSHU, JAPAN	39	2793
2007-03-06	-.39	100.43	6.3	INDONESIA/MALAYSIA/SINGAPORE/W SUMATRA	72	914

Table 8: Very overestimated number of casualties. *Events for which ELER predicts more than 100 casualties and at least 10 times more casualties than the actual number with Wald et al., 1999 intensity law. See green box in Figure 10 (bottom)*

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III.2.2.2 Cases with magnitude ≥ 7.0

Here, we only consider earthquakes with magnitude larger or equal to 7.0 which caused at least 1 victim and for which ELER also predicted at least 1 victim. This represents 24 earthquakes.

Because we consider 3 rupture scenarios, we ran ELER three times for each earthquake. As a result we plot the minimum and maximum casualty estimations given by ELER for the three scenarios (Table 9; Figure 13). We observe the following:

- A trend to overestimates the number of victims is noticeable when the real number of victim is lower than 100 for both intensity laws
- The very damaging earthquakes (number of victims > 1000) are a little bit underestimated but the estimated numbers of victims are still significant.

Although based on our small number data, we can say that ELER seems to correctly estimate the impact of very deadly earthquakes.

DATE	Lat (°)	Lon(°)	Mag	Fatalities (USGS)	Region	AK 2007			Wald 1999		
						S1	S2	S3	S1	S2	S3
2010/02/27 06:34:14.1	-35.89	-73.04	8.8	507	OFFSHORE MAULE, CHILE	611	611	1905	611	611	611
2010/02/27 06:34:14.1	-35.89	-73.04	8.8	507	OFFSHORE MAULE, CHILE	611-1905			611		

Table 9 : *Example of application of ELER on 3 rupture scenarios for the 2010/02/27, M 8.8 Chile earthquake.*

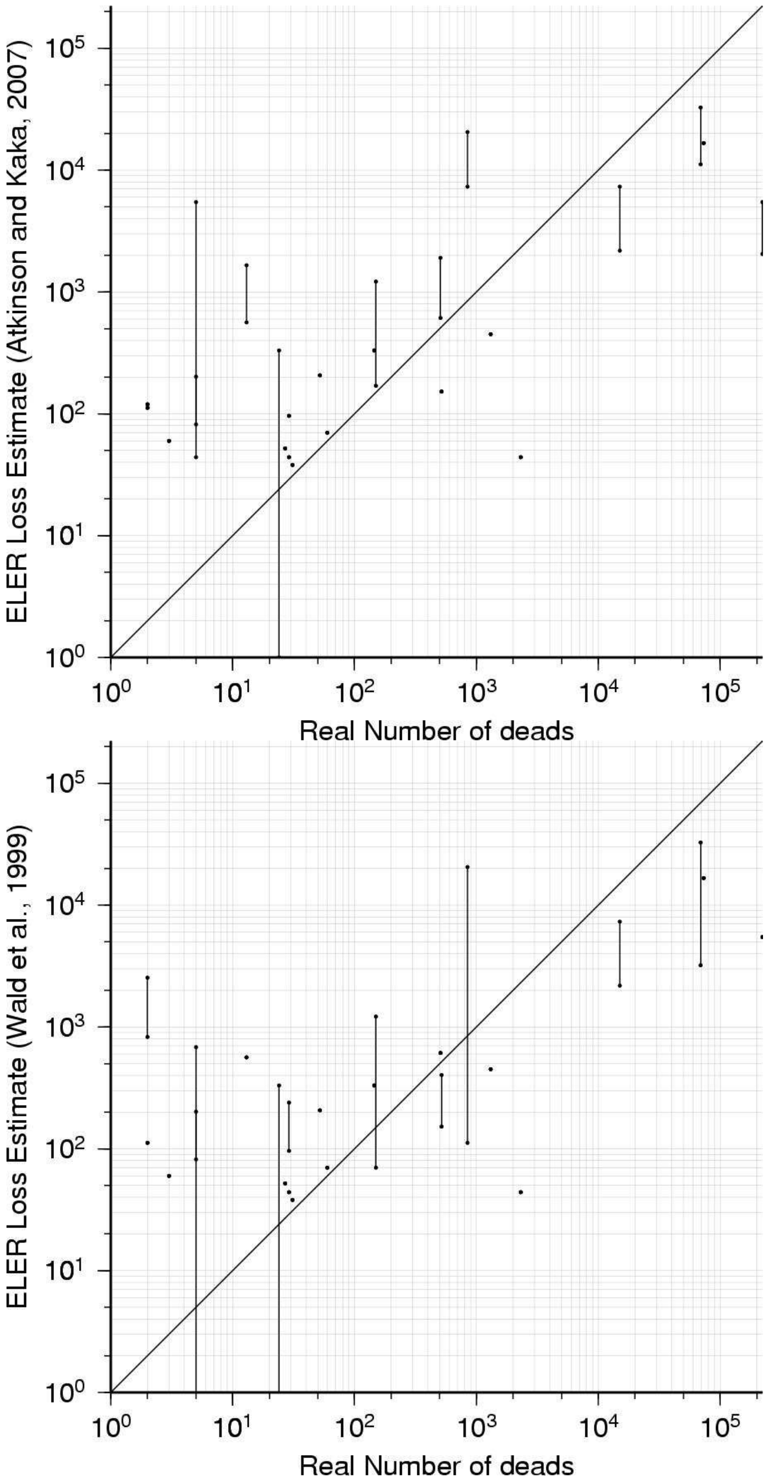

Figure 13 : *Log-Log plot of ELER loss estimates for Atkinson and Kaka, 2007 intensity law (top) and for Wald et al., 1999, intensity law (bottom) as function of real number of victims for M≥7 events with non null ELER estimate and non null real number of victims. The three rupture scenarios are represented as min/max estimations*

III.2.3 *Comparison of Level 0 and Level 1 performances*

We applied ELER Level 1 on 25 earthquakes only, due to the lack of required information to apply outside the Europe. It concerns 20 events in Greece, 4 in Italy and 1 in United Kingdom (Appendix III) with real number of victims ranging from 0 to 295. Only 3 earthquakes have non null real numbers of victims: M5.9 Southern Italy on 31/10/2002 (29 victims), M6.4 Southern Greece on 08/06/2008 (2 victims) and M6.3 Central Italy, L'Aquila on 06/04/2009 (295 victims).

A quick observation at Appendix III shows that Level 1 seems to better estimates non deadly earthquakes as it strongly attenuates the tendency the Level 0 has to overestimate the number of casualties for low magnitude earthquakes:

- For 23 out the 25 earthquakes, the Level 1 is better of equal to Level 0.
- For M5.9 Southern Italy on 31/10/2002 (29 victims), Level 0 predicts 13 or 67 victims (depending on intensity laws) whereas Level 1 predict only 6 victims. However, we know that all the victims of this earthquake were due to the collapse of 1 single building (a school in Molise). This again shows how it is difficult to estimate the impact of low impact earthquakes.
- For L'Aquila earthquakes (295 victims), Level 0 predicts 145 victims (for both intensity laws) whereas Level 1 only predicts 26 victims. At this stage, we have no indication on the reason why Level 1 does not give a correct estimate.

IV IMPROVEMENT OF EMSC EARTHQUAKE IMPACT ASSESSMENT: EQIA

In the previous version of this deliverable (Merrer et al.; 2009), we presented the method that the EMSC developed to estimate earthquake impact based on Samardjeva and Badal (2002) empirical relationships and called EQIA (Earthquake Impact Assessment Method). In our conclusions we proposed several ways to improve our method. These improvements are presented below as well as the EQIA performances.

IV.1 Reminders

IV.1.1 *Definition of the affected area*

We remind that Samardjeva and Badal (2002) empirical laws return the number of casualties given the magnitude of the earthquake and the density of population in the affected area. In our method the affected area is determined considering an attenuation law on rock site. Moreover we considered that the first damages can occur from a theoretical peak ground acceleration (PGA) of 0.15g for high vulnerability zones (as Iran, Afghanistan, Pakistan), 0.30g for low vulnerability zones (as Japan, Taiwan and California) and 0.20g for the other cases (Merrer et al., 2009). Then we consider the average density of population within the isoPGA circle centred on the epicentre.

IV.1.2 *Definition of the impact*

Rigorously a quantitative casualty estimate can not be estimated considering the limitations and uncertainties of the method and thus could not be relevant (Merrer et al.; 2009). Therefore we proposed a qualitative approach. For this we defined the *earthquake impact* as a range of casualties derived from Samardjeva and Badal (2002) (Merrer et al.; 2009). For example the impact is *Heavy* if the number of casualties is of several hundred but less than 1000.

IV.1.3 *Integration of uncertainties*

In our previous study, 15 scenarios were played out, in order to take into account uncertainties on epicentre location and magnitude as follows:

- 3 different values of magnitude : actual magnitude and magnitude ± uncertainty (namely 0.2)
- 15 different locations : actual epicentre, and a 15 km uncertainty northward, southward, eastward and westward

The impact estimation was thereafter estimated as an impact range (minimum and maximum impact) derived from these scenarios.

IV.2 Increasing the number of scenarios

In our previous method, our way to integrate uncertainties on the epicentre location and on the magnitude was not satisfactory, as it gave too much weight to the less probable scenarios.

As we proposed in the previous report, we increased tremendously the number of scenarios to derive a mean value and a standard deviation. We proceeded as follows:

- 7 different values of magnitude : M, M ± 0.05, M ± 0.1 , M ± 0.2
- Several epicentral coordinates:
  - o Within a 7.5 km circle, all positions on a 30” grid (which is the resolution of the Landscan database) were played out
  - o In the annular 7.5-15 km, half of the positions on a 30” grid were played out (only half not to give to much weight to these scenarios which are hopefully less likely than the positions closest to the epicentre location)

Samardjeva and Badal (2002) laws are applied on each of these scenarios to retrieve a number of victims for each scenario. Finally, we exclude all the results that fall outside 2 standard deviations (σ) interval around the mean value.

In order to check if this new definition of scenarios helps to reduce the uncertainties of our method, we ran our previous and our new methods on the same dataset of earthquakes with a real impact larger of equal to "Moderate" (i.e. more than several tens of victims) because those are the earthquakes for which we want our method to be as accurate as possible. Indeed, we know that our method can have strong limitations to estimate the impact of Light impact earthquakes (i.e. until several tens of victims).

In our method, the uncertainty is characterized by the difference between the maximum and the minimum estimated impacts. As we defined 6 levels of impacts (null, light, moderate, heavy, very heavy, extreme), we define 6 levels of uncertainties: 0 (very small uncertainties) if the minimum and maximum estimated impacts are the same; 5 (very large uncertainties) if the difference between minimum and maximum estimated impacts is of 5 units. We call this value "Uncertainty index"

We compare the size of the impact range derived from the previous method with the one derived from our new method (Figure 14) and show 2 examples where uncertainty reductions appear clearly (Figures 15 and 16).

Though the improvement in terms of reduction of the uncertainties is not dramatic, we still observe that our new method reduces the number of cases with very large uncertainties (i.e. uncertainty index=4) and we increase the number of cases with small/moderate uncertainties (i.e. uncertainty index = 1 or 2) (Figure 14).

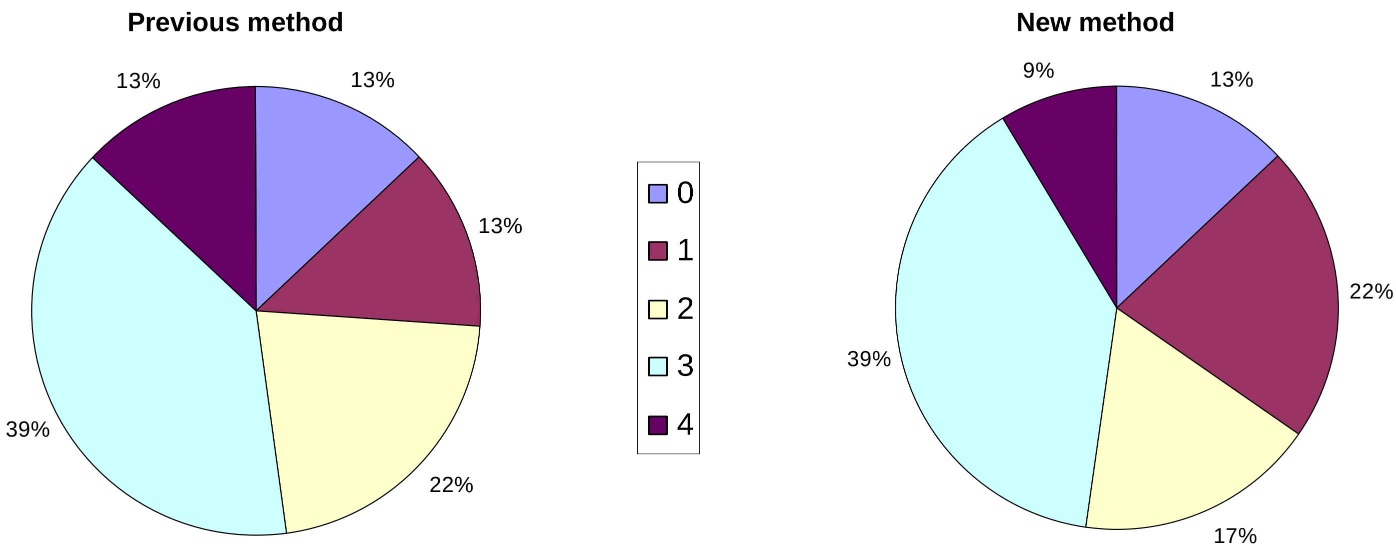

Figure 14 : Distribution of uncertainty index of impact estimation for the previous and new methods. 0=very little uncertainty; 4=very large uncertainties

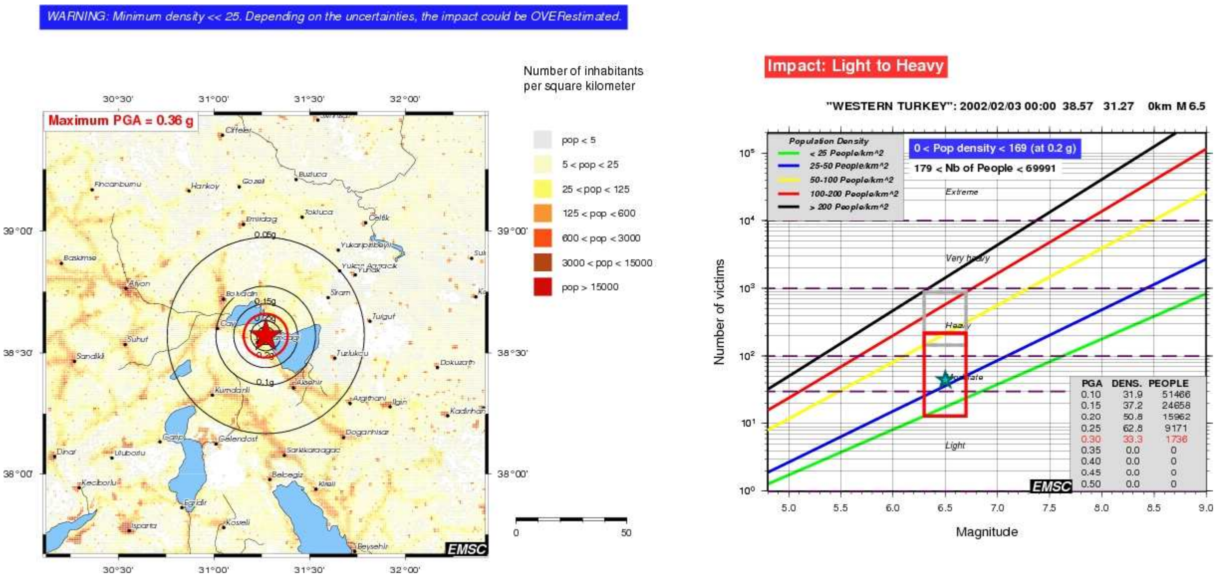

Figure 15 : Comparison of previous and new impact estimation methods for an M6.5 in Western Turkey. Red boxes show the results given by the new method. Grey boxes show the results given by the previous method.

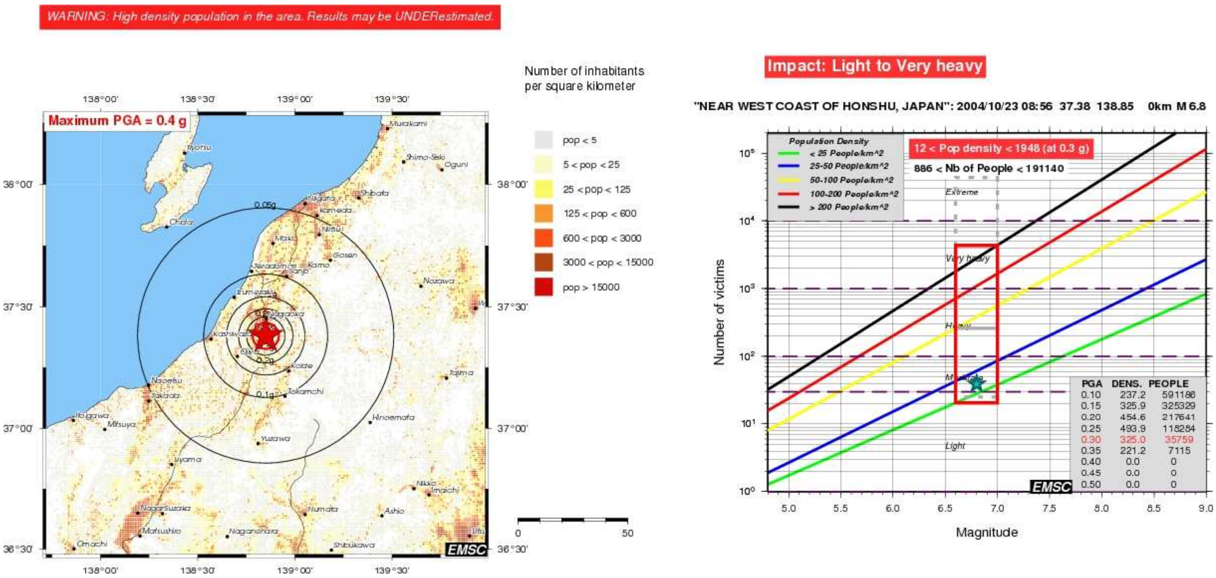

Figure 16 : Comparison of previous and new impact estimation methods for an M6.8 in Honshu. Red boxes show the results given by the new method. Grey boxes show the results given by the previous method

IV.3 Redefinition of *Light* impact

In the previous version of the deliverable, we highlighted the difficulty to estimate the impact of low impact events (until several tens of victims). We suggested that redefining the limits between Light and Moderate impact might take this effect into account and therefore improve our estimations for low impacts.

For this comparison, we considered the 62 deadly earthquakes with magnitude lower than 7.0. Indeed, for M7+ earthquake, the method to estimate casualty is different as it requires taking into account the size of the rupture (see §IV.5). Among these 62 impact estimations, we only consider those which would be affected by a modification of the limit *Light/Moderate (Table 10)*.

By modifying the limit between Light and Moderate impact, we affect the results of 9 events (Table 10) and 40 seems to be the most appropriate limit to better take into account Light impact earthquakes.

However, by setting the new limit at 40, we see that 2 impacts (Western Iran 31/03/2006 and Kyrgystan 05/10/2008) are not correctly estimated anymore. Nevertheless, these events occurred in regions where the vulnerability is high (Iran) or likely to be high (K=Xizang, China) where we know the method is likely to underestimate the actual impact.. High vulnerability cases are discussed later in this report.

DATE	REGION	LAT/LON	MAG	Real number of Deads	Min/Max casualty estimations	Light/Moderate border		
						10	30	40
08/06/2008	SOUTHERN GREECE	37.97,21.48	6.4	2	11 - 304		x	x
25/12/2003	PANAMA-COSTA RICA BORDER REGION	8.42,-82.82	6.5	2	13 - 815		x	x
10/08/2004	SICHUAN-YUNNAN-GUIZHOU RG, CHINA	27.27,103.87	5.4	4	23 - 191		x	x
16/07/2007	NEAR WEST COAST OF HONSHU, JAPAN	37.58,138.44	6.6	11	0 - 4		x	x
01/11/2002	NORTHWESTERN KASHMIR	35.52,74.65	5.4	17	2 - 5		x	x
06/10/2008	EASTERN XIZANG	29.79,90.33	6.6	30	15 - 28	x		x
28/05/2004	NORTHERN IRAN	36.29,51.61	6.3	35	9 - 18	x		x
31/03/2006	WESTERN IRAN	33.63,48.76	5.7	70	4 - 10	x		
05/10/2008	KYRGYZSTAN	39.515,73.768	6.6	74	15 - 28	x		

Table 10 : Impact estimations affected by the modification of the limit between Light and Moderate impact for M<7.0 deadly earthquakes. The crosses "x" show the cases where the impact is correctly estimated.

IV.4 Considering very low population densities

One of the limitations of Samardjeva and Badal (2002) method is that it is unable to predict "No victim". This limitation has been point out in the previous version of this deliverable (Merrer et al.; 2009) and is due to the fact that these laws are logarithmic can therefore not return 0. So, there are only two ways in our method to obtain an impact equal to *None*:

- When the size of the isoPGA circle in which we expect damage to occur is null. This necessarily concerns low magnitude events
- If the isoPGA circle do not contain any populated area (e.g. earthquake located at sea)

IV.4.1 *Reminder about the previous method*

In the previous method, we proposed to define as "very low population density" when the population density was very lower (i.e. less or equal to 5 inhab./km²) than the lower curve of Samardjeva and

Badal (i.e. density < 25 inhab./km²). Indeed, one can assume that the death toll is fairly different for a population density of 1 compared to 24 whereas Samardjeva and Badal (2002) laws would give the same results in both cases.

As a results, in the previous method, when at least one of the 15 scenarios concerned a very low population density area, we decreased by one order the minimum impact derived from our method. This correction corresponded to dividing by 10 the minimum number of casualties returned by Samardjeva and Badal laws.

IV.4.2 *Adaptation to a large number of scenarios*

Now considering a large number of scenarios, this correction is not adapted anymore. The idea is therefore to modify the Samardjeva and Badal law for very low density areas.

In such a case, we now multiply the value returned by Samardjeva and Badal (2002) low curve (i.e. density < 25 inhab./km) by the ratio of the actual density divided by 25. For instance, for an earthquake of magnitude 6.5, Samardjeva and Badal estimates 17.6 casualties for an area with density lower than 25. In the case of an actual density of 5, our correction would provide an estimation of 17.6 x 5 / 25 = 3.5 (i.e. 3 victims).

To assess the relevance of this correction, we applied on the 343 M<7.0 earthquakes located in populated areas (Table 11). Indeed, in unpopulated areas, our method already returns an impact equal to *None*. It appears that this correction is particularly relevant and allows to better estimate a large number of non-destructive earthquakes.

	Previous method	New method Raw estimation	New method Low density correction
Correct impact estimation	130 (263)	233	315
Over estimation	198 (68)	101	14
Under estimation	15 (12)	9	14

Table 11 : Effects of the correction of "very low" population density on the quality of the impact estimation for the 343 earthquakes of magnitude lower than 7.0 located in populated areas. The figures in parenthesis stand for the results after applying the correction for very low density population

IV.5 Considering the size of the source for M7+ events

In the previous report, we showed a limitation of the method for large events. Indeed, we did not consider the fact that the earthquake was not a point-source anymore (Wells and Coppersmith, 1994) and that we had somehow to take into account the population exposure instead of the population density alone.

For this, we calculate the density over a isoPGA oblong shape surrounding the rupture path instead of simply considering a circle around the epicentre. By doing so, we better integrate the fact that such large earthquake not only affect the epicentral region but also all the region along the rupture.

Then, we determine the average population density in this oblong shape and apply Samardjeva and Badal laws. We retrieve a number of casualties which we multiply by the ratio of the surface of the isoPGA oblong shpae by the surface of the isoPGA circle. We call this correction ***the 2D correction*** as it consist of taking into account the 2D effects of the rupture. The effects of this correction for M≥7.0 earthquakes are presented in Appendix V.

Finally, knowing the focal mechanism (i.e. strike of the first nodal plane) is not enough. As we do not know the a priori direction of the rupture, we have to consider 3 different rupture scenarios: 2 unilateral and 1 bilateral ruptures.

V EQIA PERFORMANCES ASSESSMENT

We ran EQIA on our database of 719 earthquakes with known number of casualties and analyzed the results.

V.1 Results for M<7.0 earthquakes

V.1.1 *Quality of impact estimation*

As shown on Figure 17, 95.5% of the impact for M>7.0 earthquakes are correctly estimated which is a clear improvement compared to the previous method with 88% of correct estimations (Merrer et al.; 2009).

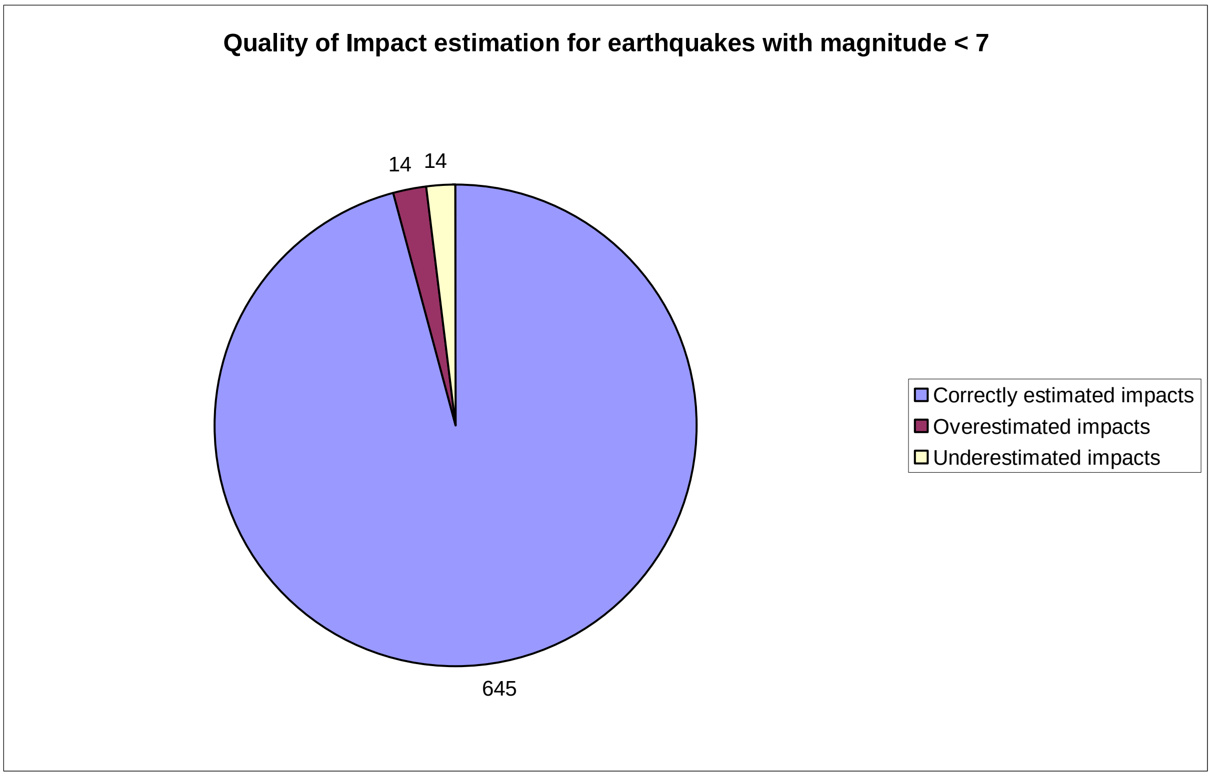

Figure 17 : Distribution of quality of impact estimation for M<7.0 earthquakes

V.1.2 *Overestimated impacts*

As shown on Figure 16, our method overestimates the impact for 14 earthquakes. We notice that for 13 out of those 14 cases were already overestimated by the previous method (Merrer et al.; 2009).

It is important to notice that all the overestimated impact for M<7.0 earthquakes are actually positive fakes. No other case of overestimation did show up.

Another observation is that all the overestimated impacts show a minimum impact equal to *Light* and we know that Light impact earthquakes (less than tens of victims) are very difficult to model because, in such cases, the number of victims is generally controlled by one of few deadly events (e.g. the collapse of one single building). This limitation has been identified since the first version of this deliverable (Merrer et al.; 2009).

Another observation is that 10 out of 14 of these overestimated impacts concern low-moderate magnitude events (M<6.0) located in China in, or near very densely populated areas (Table 12; Figure 18).

In the previous method, we identified a tendency to overestimate the impact of small to moderate earthquakes (M<6.0). Our new method seems to still overestimate low-moderate magnitude earthquakes but mostly in this part of China. To better understand these discrepancies, we compare our results with those of ELER. It appears that ELER's overestimate the earthquakes of Table 12 that same way as our method does.

As a conclusion, the Samardjeva and Badal (2002) laws seem not to be adequate in this region. This observation corresponds to the limitation of Samardjeva and Badal approach which consider global laws instead of regional ones.

DATE	REGION	LAT/LON	MAG	DEADS	Impact estimation
15/02/2008	LEBANON - SYRIA REGION	33.35,35.36	5.1	0	Light to Moderate
12/05/2008	EASTERN SICHUAN, CHINA	31.81,104.5	5.3	0	Light to Heavy
19/05/2008	SICHUAN-GANSU BORDER REG, CHINA	32.29,105.02	5.3	0	Light to Moderate
05/06/2008	SICHUAN-GANSU BORDER REG, CHINA	32.28,105.08	5.3	0	Light to Moderate
23/12/2008	NORTHERN ITALY	44.62,10.43	5.4	0	Light to Heavy
06/06/2005	EASTERN TURKEY	39.22,41.08	5.6	0	Light
01/08/2008	SICHUAN-GANSU BORDER REG, CHINA	32.04,104.74	5.7	0	Light to Heavy
30/08/2008	SICHUAN-YUNNAN BORDER REG, CHINA	26.32,101.93	5.7	0	Light to Heavy
12/05/2008	EASTERN SICHUAN, CHINA	31.32,103.77	5.8	0	Light to Moderate
13/05/2008	EASTERN SICHUAN, CHINA	30.99,103.28	5.9	0	Light to Heavy
17/05/2008	SICHUAN-GANSU BORDER REG, CHINA	32.29,105.05	5.9	0	Light to Heavy
25/05/2008	SICHUAN-GANSU BORDER REG, CHINA	32.62,105.45	5.9	0	Light to Heavy
05/08/2008	SICHUAN-GANSU BORDER REG, CHINA	32.79,105.63	6.0	0	Light to Heavy
08/10/2004	SOLOMON ISLANDS	-10.59,162.16	6.9	0	Light

Table 12 : The 14 M<7.0 earthquakes for which the impact is overestimated

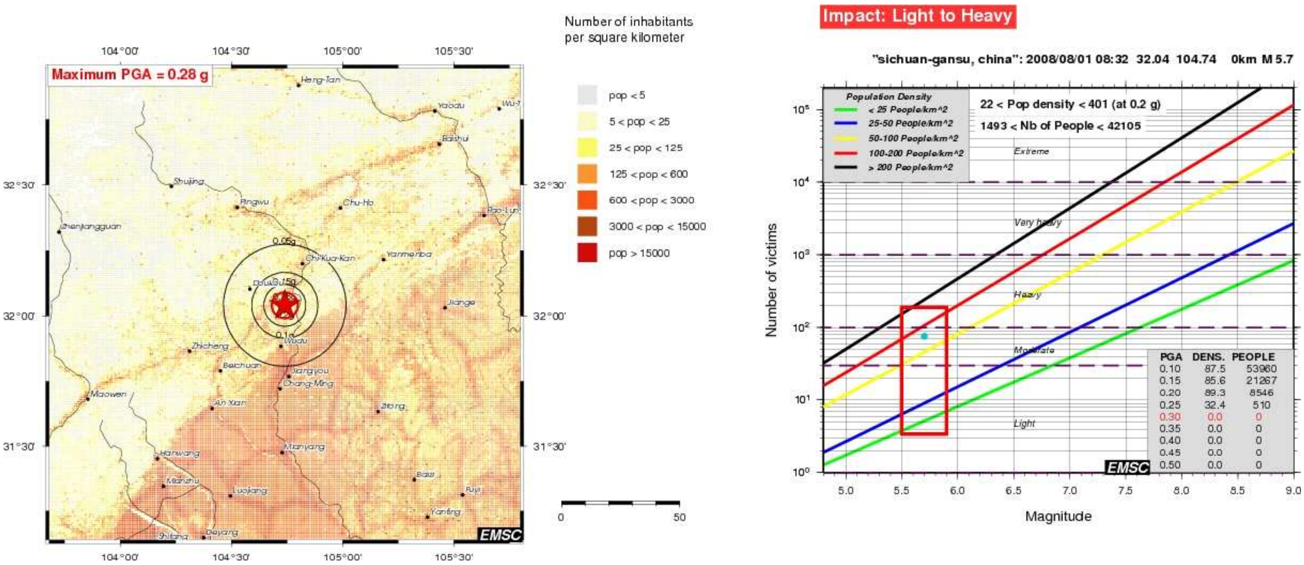

Figure 18 : Example of an overestimated impact for an earthquake of moderate magnitude (M=5.7) located in Eastern China. This earthquake is located at the edge of a quite populated area which makes the maximum estimation rising up to a Heavy impact

V.1.3 *Underestimated impacts*

Our method shows underestimation of the impact for 14 earthquakes out of the 671 M<7.0 earthquakes of the database (Table 13).

Seven out those 14 are negative fakes but have all a real impact equal to *Light*, which means an number of casualties lower than 40. This again corresponds to the difficulty to model light impact earthquakes, as we already pointed out in the previous report and again in this report.

Moreover, the remaining cases all correspond to high vulnerability areas (Iran, Afghanistan) or earthquake in Xizang (China), Qinghai (China) and in Kyrgystan where the vulnerability is likely to be high.

This observation concerning high vulnerability areas has been already made in the previous method (Merrer et al.; 2009). To tackle this problem, the previous method proposed to extend the impact range upwards of one unit (i.e. multiplying the maximum estimated number of casualties by 10) for earthquake located in high vulnerability areas. This correction is not always relevant as earthquakes in high vulnerability areas are not systematically underestimated, as shown in Table 14. Further studies are required to better estimate the impact in high vulnerability zones.

DATE	REGION	LAT/LON	MAG	REAL NB of VICTIMS	REAL IMPACT	Estimated Impact
25/03/2007	NEAR WEST COAST OF HONSHU, JAPAN	37.45,136.52	6.9	1	Light	None
18/06/2008	SOUTHERN QINGHAI, CHINA	35.36,91.26	5.5	2	Light	None
25/11/2007	SUMBAWA REGION, INDONESIA	-8.06,118.62	6.5	3	Light	None
10/11/2008	NORTHERN QINGHAI, CHINA	37.68,95.88	6.5	5	Light	None
17/12/2006	NORTHERN SUMATRA, INDONESIA	4.82,95.02	5.8	7	Light	None
16/07/2007	NEAR WEST COAST OF HONSHU, JAPAN	37.58,138.44	6.6	11	Light	None
06/03/2002	MINDANAO, PHILIPPINES	5.87,124.27	6.0	15	Light	None
31/03/2006	WESTERN IRAN	33.63,48.76	5.7	70	Moderate	None to Light
05/10/2008	KYRGYZSTAN	39.515,73.768	6.6	74	Moderate	None to Light
22/06/2002	WESTERN IRAN	35.67,48.93	6.3	305	Heavy	Light
22/02/2005	CENTRAL IRAN	30.72,56.91	6.3	612	Heavy	None to Light
25/03/2002	HINDU KUSH REGION, AFGHANISTAN	36.06,69.31	6.1	2000	Very heavy	Light to Moderate
13/04/2010	SOUTHERN QINGHAI, CHINA	33.23,96.65	6.9	2039	Very heavy	Light
26/12/2003	SOUTHEASTERN IRAN	29,58.31	6.6	41000	Extreme	None to Heavy

Table 13 : The 14 M<7.0 earthquakes for which the impact is underestimated

DATE	REGION	LAT/LON	MAG	REAL NB of VICTIMS	REAL IMPACT	Estimated Impact
14/05/2005	CENTRAL IRAN	30.62,56.84	5.5	0	None	None to Light
27/11/2005	SOUTHERN IRAN	26.9,55.81	5.5	0	None	None to Light
25/03/2006	SOUTHERN IRAN	27.6,55.87	5.5	0	None	None
18/06/2007	CENTRAL IRAN	34.51,50.83	5.5	0	None	None to Heavy
28/06/2006	SOUTHERN IRAN	26.98,55.82	5.7	0	None	None to Light
13/03/2005	SOUTHEASTERN IRAN	27.15,61.92	5.8	0	None	None to Light
25/03/2006	SOUTHERN IRAN	27.62,55.74	5.8	0	None	None
28/02/2006	SOUTHERN IRAN	28.13,56.89	6.0	0	None	None to Light
27/11/2005	SOUTHERN IRAN	26.73,55.82	6.1	10	Light	None to Light
14/02/2004	PAKISTAN	34.77,73.22	5.5	24	Light	Light to Heavy
12/04/2002	HINDU KUSH REGION, AFGHANISTAN	35.96,69.42	5.9	50	Moderate	None to Heavy

Table 14 : List of all M<7.0 earthquakes in high vulnerability areas for which the impact estimation was correct

Concerning the large discrepancies for the 3 last earthquakes of Table 13 (Hindu Kush 25/03/2002 (2,000 victims), Southern Qinghai 13/04/2010 (2,039 victims) and Bam, Southern Iran 26/12/2003 (41,000 victims) respectively), we compared our results with ELER's ones. It appears that ELER also greatly underestimates the impact of these 3 earthquakes by predicting 18, 33 and 43 victims with Atkinson and Kaka (2007); 9, 33 and 259 victims with Wald et al. (1999) respectively. It seems that these 3 earthquakes caused huge number of victims, probably due to very high local vulnerable buildings, which were therefore impossible to predict.

V.2 Results for M≥7.0 earthquakes

In our earthquake database, we have 48 earthquakes with a magnitude greater than or equal to 7.0, for which we apply our new impact estimation method.

We first assess the effects of our new approach (large number of scenarios, Limit Light/Moderate impact, very low population density) without taking into account the *2D correction* exposed in section §IV.5. We then apply the *2D correction* and evaluate how it improves the results.

V.2.1 *Without 2D correction*

In order to assess the effects of our new approach to determine impact estimation, we compare our results with ones of the previous method.

It appears that our new method tends to dramatically decrease the number of overestimated impacts (Figure 19) but to increase a bit the number of underestimated impacts. However, the number of underestimated impacts will dramatically decrease while applying the *2D correction* (see here after).

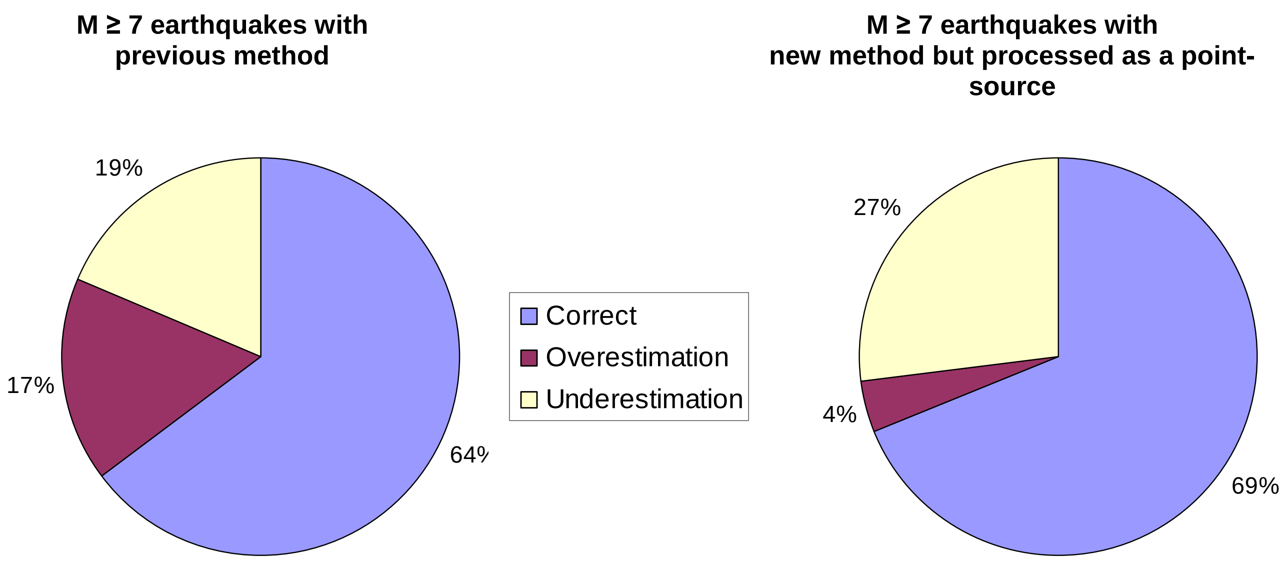

Figure 19 : Effects of the new approach to estimate earthquake impact without taking into account the 2D correction

V.2.2 *With 2D correction*

We remind that for M>7.0 earthquakes, we have to consider 3 rupture scenarios which can sometimes give very different results, depending if the rupture crosses populated areas or not.

Considering this aspect, it is not possible to conclude directly on the quality of the results. Therefore, we propose 2 interpretations:

- The *Most favourable* case: when at least 1 scenario gives a **correct** impact estimation, we consider that the estimation is **correct**
- The *Least favourable* case: when at least 1 scenario gives a **wrong** impact estimation, we consider that the estimation is **wrong**

The 2D correction clearly improves the quality of the results of our method. Even in the least favourable case, we clearly decrease the number of underestimated impacts (Figure 20) although we increase a bit the number of overestimated impacts (Figure 19 and Figure 20). Finally, in the most favourable case, we get 88% of correctly estimated impacts (Figure 20) after applying the 2D correction on top of the other corrections presented before (i.e. large number of scenarios, Limit Light/Moderate and correction for very low density).

Earthquake with M ≥ 7 in 2D new method least favourable case

Earthquake with M ≥ 7 in 2D new method most favourable case

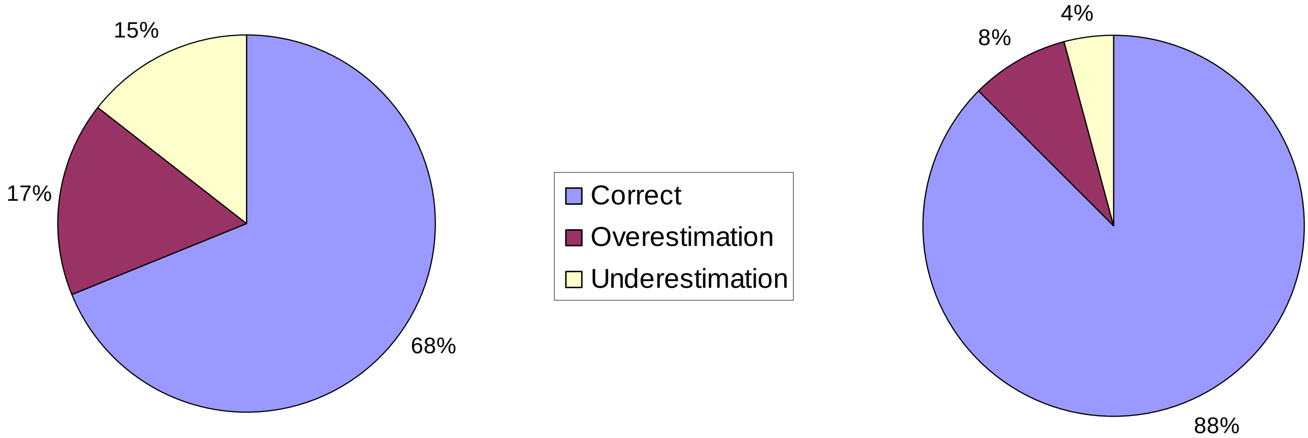

Figure 20 : Effects of the new approach to estimate earthquake impact without taking into account the 2D correction

V.2.3 *Overestimated and underestimated impacts*

Even after applying our 2D correction, we still get 6 earthquakes for which the impact is not correctly estimated (Table 15). However:

- For 3 of them, we predicted a minimum impact equal to *Light* whereas the actual number of victims was 0. Again, this corresponds to the difficulty to estimate light impact earthquakes that we mentioned several times in this report.
- For 2 of them (M8.1 Samoa 29/09/2009 (192 victims) and M9.3 Sumatra 26/12/2004 (300,000 victims)), the very large proportion of the casualties were caused by the tsunami consecutive to the earthquake instead of the earthquake itself.
- The last one is the Mw7.2 that occurred in Baja California, Mexico on 04/04/2010 (Figure 21) and made 2 victims but for which our method, whatever the rupture scenario, predicts at least a minimum impact equal to Heavy (i.e. > several hundreds of victims). As a comparison, ELER estimate also shows the same discrepancy with the actual number of victims by overestimating the casualties the same way as our method. Indeed, ELER returns between 120 and 2535

victims, depending on the rupture scenario and the intensity law, which correspond to a heavy to very heavy impact.

DATE	REGION	LAT/LON	MAG	Real Victims	Real Impact	2D Unilateral (left)	2D Bilateral	2D Unilateral (Right)
22/02/2006	MOZAMBIQUE	-21.29,33.44	7.1	0	None	Light to Moderate	Light to Moderate	Light to Heavy
20/03/2008	XINJIANG-XIZANG BORDER REGION	35.49,81.48	7.2	0	None	Light	Light	Light
20/04/2006	KORYAKIA, RUSSIA	61.1,167.2	7.7	0	None	Light	Light	Light
04/04/2010	BAJA CALIFORNIA, MEXICO	32.3,-115.08	7.2	2	Light	Very heavy to Extreme	Heavy to Extreme	Heavy to Very heavy
29/09/2009	SAMOA ISLANDS REGION	-15.42,-172.13	8.1	192	Heavy	None	None	None
26/12/2004	OFF W COAST OF NORTHERN SUMATRA	3.5,95.72	9.3	300000	Extreme	Very heavy	Very heavy	Light to Heavy

Table 15: Earthquakes for which the impact estimation is wrong after applying 2D correction. Red stands for overestimated impacts. Green stands for underestimated impacts.

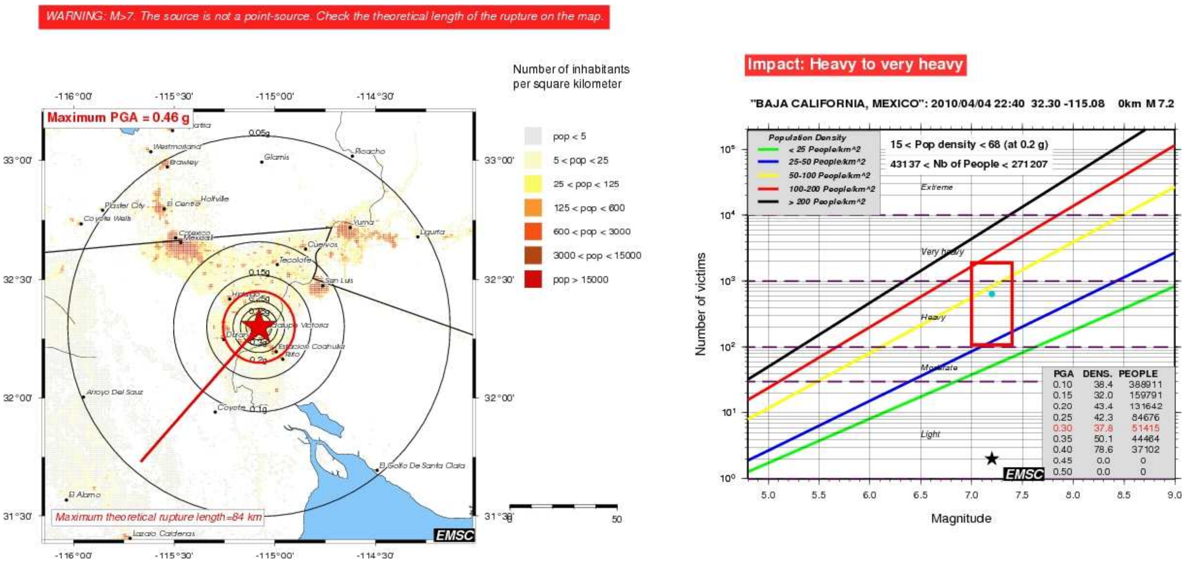

Figure 21 : The most overestimated impact produced by our method: Baja California on 04/04/2010. Impact heavy to very heavy is predicted by our method whereas there were only 2 victims

VI COMMENTS FROM ELER'S DEVELOPERS

This report has been conducted with several discussions with ELER's developers. Here below are presented their explanations and

VI.1 ELER: A loss estimation tool for the Euro-Med Region

It should be noted that the goal of the JRA3 project was stated as "…*to develop the capability to rapidly compute maps of earthquake shaking (Shake-maps) and loss estimation for the Euro-Med region*." In our effort to achieve this goal we have tried to adopt several of the implemented methodologies to this region. While much of this work was done in creating an European building database for Level 1, Samardjeva and Badal (2002) approach has also been implemented keeping in mind this region. Namely while in their article Samardjeva and Badal suggest the use of contour line V as the boundary of the area where casualty is expected, in ELER this limit has been implemented as contour VI because we assume low vulnerability in this region. Of course this is a crude assumption and from our own experiences in Turkey we know that even inside national borders vulnerability tends to vary vastly from south to north and east to west. Nevertheless this assumption seems reasonable, keeping in mind that other European countries have a much more uniform development pattern. For global casualty estimations the contributing factors would be numerous, Figure 22 shows the global development in three categories (low, medium and high) with the obvious colour codes.

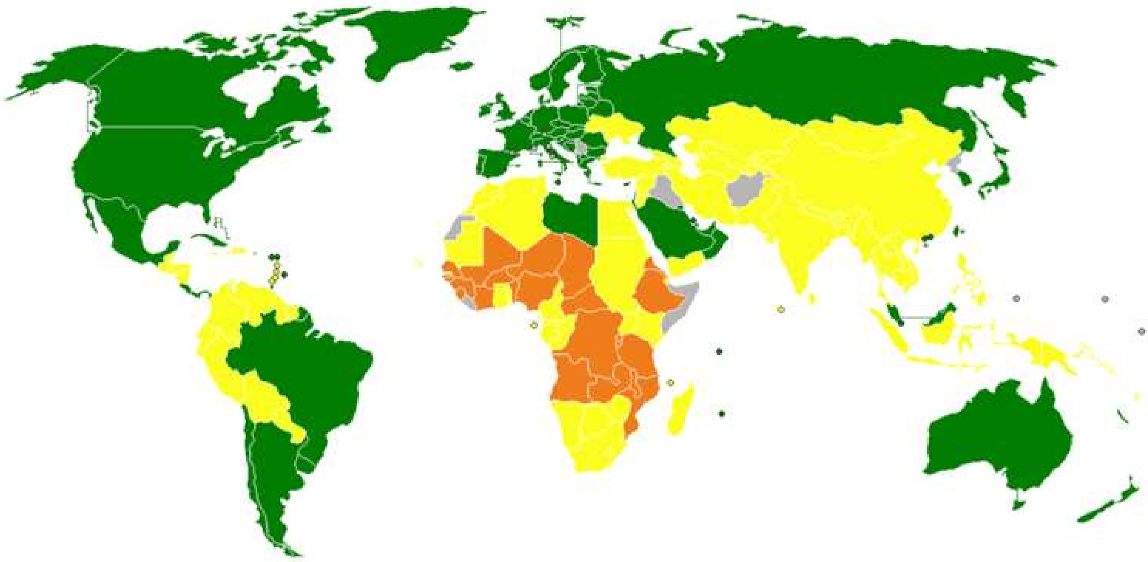

Figure 22: UN Human Development Report 2007

VI.2 Using the same parameters for different events

Although, due to the underlying methodology of Samardjeva and Badal (2002), the results of this study are mainly dominated by the chaotic nature of population distribution coupled with intensity/PGA variation we would like to underline some shortcomings of simulating different events with same parameters as it may affect analytical results such as Level 1 and Level 2.

VI.3 Effect of map area on results

In events with large magnitudes, the use of default map extent area (1.6 x 2.5 degrees centring the epicentre) will limit the intensity distribution area, preventing the program from taking into account the full event effect.

VI.4 Effect of fault projection on results

It is common that faults have both dip and strike slip components. In higher magnitudes this would require taking into account the fault projection, an area, rather than a line. This is widely applied in ground motion estimation software and will of course affect the distribution of PGA and intensity. A USGS ShakeMap output for the M8.8 Chile event is given in Figure 23. Notice that the map extent has been increased to capture the full impact of the projected fault.

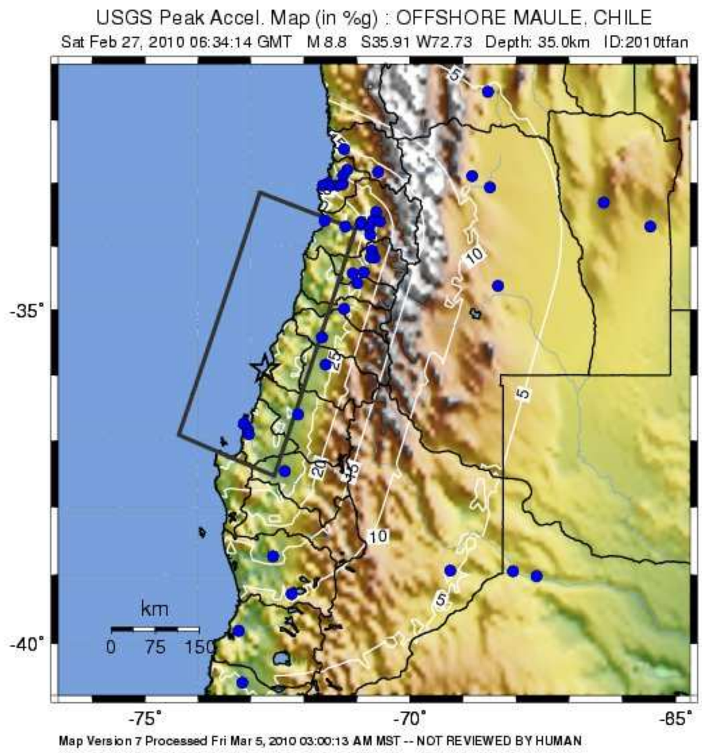

Figure 23: USGS ShakeMap output for the Mw8.8 Chile earthquake

VI.5 Samardjieva and Badal (2002): Expectations and reality

Throughout the conducted study the Samardjieva and Badal (2002) casualty estimation method is taken as basis. Several modifications, classifications and conditions are introduced in order to reach better casualty estimation. Before evaluating the performance of these implementations (be it ELER or EQIA), we should first look at our basis in order to know what we begin with.

VI.5.1 *Database used*

One should be aware of the precision and selectiveness of the database used in the Samardjieva and Badal (2002) study. Besides the fact that for many events the casualty numbers used may include some side effects (tsunamis, landslides etc) the authors specifically state that they have omitted several "extreme cases" from their study:

"*Some earthquakes in eastern China were excluded because of the extremely high population density, those in Turkey and Iran because of the old type of buildings, and other events because of the epicenter's location under a big city or offshore, and so forth*"

Actually if we look at the Appendix section of the article where the authors present the *List of Earthquakes that Caused Human Losses during the Last Century* we see that several of these deadly earthquakes have been omitted with different reasons. Table 16 presents the number and percentage of these "extreme case" earthquakes.

Reason for exclusion	**Number (total of 478)**	**%**
Epicenter offshore	47	9.8
Epicenter under big city	3	0.6
Extremely high population	14	2.9
Extremely low population	4	0.8
Depth > 60 km	14	2.9
No magnitude estimation	3	0.6
Old type construction	2	0.4
Uncertain data	1	0.2
Total	*88*	*18.4*

Table 16: Data excluded from Samardjieva and Badal (2002) study

Rather then attributing the casualty estimation differences between ELER and EQIA to variations in the implementations of this approach we should acknowledge the fact that the Samardjieva and Badal (2002) method was developed from carefully selected data. If we still insist on conducting such a comparison, then a similar filtering could be applied beforehand.

VI.5.2 *Uncertainty intervals*

The regression coefficients obtained in Samardjieva and Badal (2002) for different population density zones are given together with their standard deviations respectively in Table 17.

Population Density (people/km^2)	1900–1950				1951–1999			
	a	b	r	σ	a	b	r	σ
$D < 25$	−3.41	0.66	0.88	0.341	−3.11	0.67	0.84	0.343
D = 25–50	−3.00	0.71	0.90	0.295	−3.32	0.75	0.85	0.342
D = 50–100	−2.60	0.75	0.92	0.295	−3.13	0.84	0.82	0.345
D = 100–200	−2.17	0.77	0.92	0.292	−3.22	0.92	0.70	0.397
$D > 200$	−2.09	0.86	0.83	0.344	−3.15	0.97	0.75	0.348

Table 17: Regression coefficients table from Samardjieva and Badal (2002)

If we are interested in assigning an uncertainty level to our results, the reasonable thing to do would be to use these standard deviation values. As an example lets consider a M7 event dated after 1951. Table 18 gives the estimations and the confidence bounds calculated using the standard deviations for two density ranges.

Density Range	Lower Bound	Median	Upper Bound
D=50-100	254	562	1,244
D=100-200	665	1,659	4,140

Table 18: Casualty estimations for a M7 event

VI.5.3 *Propagation of uncertainties*

If we want to take into account the uncertainty regarding the calculation of the event magnitude we can use the following equations for the propagation of the uncertainty.

The casualty estimation model is given in the form of:

$$\log\left(N_k\right) = a + b \cdot M \tag{0.1}$$

We derive the expression for the variance of the model with regard to the uncertainty of M as:

$$\begin{aligned}
&Var_M(N_k) = Var(a+bM)\\
&Var(a+bM) = E\left((a+bM)^2\right) - E\left(a+bM\right)^2\\
&= E\left(a^2 + 2abM + b^2M^2\right) - \left(a + bE\left(M\right)\right)^2\\
&= b^2E\left(M^2\right) - b^2E\left(M\right)^2\\
&= b^2\left(E\left(M^2\right) - E\left(M\right)^2\right)\\
&= b^2Var\left(M\right)
\end{aligned} \tag{0.2}$$

Also we have the model uncertainty defined with the standard deviation given in Table 17. Assuming normal distribution we can define the initial variance of the model as

$$Var_I\left(N_k\right) = \sigma^2 \tag{0.3}$$

The resulting total variance and standard deviation of the model can be estimated as:

$$\begin{aligned} Var(N_k) &= Var_I(N_k) + Var_M(N_k) \\ Var(N_k) &= \sigma^2 + b^2\sigma_M{}^2 \\ \sigma_{new} &= \sqrt{\sigma^2 + b^2\sigma_M{}^2} \end{aligned} \tag{0.4}$$

With these results let us consider three possible magnitudes for this event, namely M6.8, M7 and M7.2. The models new standard deviation for D=50-100 will be:

$$\begin{aligned} \sigma_{new} &= \sqrt{\sigma^2 + b^2\sigma_M{}^2} \\ \sigma_{new} &= \sqrt{0.345^2 + 0.84^2 \times 0.2^2} \\ \sigma_{new} &= 0.3837 \end{aligned} \tag{0.5}$$

The new confidence bounds for a magnitude uncertainty of $\sigma_M = 0.2$ are given in Table 19.

Density Range	Lower Bound	Median	Upper Bound
D=50-100	232	562	1,360
D=100-200	605	1,659	4,545

Table 19: Confidence bounds with magnitude uncertainty

Also one can go with the conservative approach, calculating the estimates for each magnitude and taking the minimum of the lower bounds and the maximum of the upper bounds. The results of this approach are given in Table 20.

Density Range	Lower Bound	Median	Upper Bound
D=50-100	172	562	1,832
D=100-200	435	1,659	6,324

Table 20: Conservative confidence bounds with magnitude uncertainty

Since the inherent uncertainties of a model can not be reduced by pre processing the inputs or post processing the results, we believe that it is sufficient to give the confidence bounds calculated from the standard deviation values.

VI.5.4 *Limitation of the model*

Apart from the limitations already stated by the EMSC team in their previous report, a good model should yield better results when the input data is improved. Unfortunately this is hardly the case with Samardjieva and Badal (2002). We have come across cases where a ground motion prediction equation, although estimating the ground motion more accurately, yields to less accurate casualty estimations. When we look closely at the model we see that the population density, which is the sole parameters that has to be defined, tends to dominate the results. Weather we define the affected area boundary as the isoPGA 0.15g circle or the intensity contour VI we can not expect more accurate results when our ground motion prediction improves. Let's consider the example illustrated in Figure 24, at first we consider a basic attenuation of the ground motion resulting in a circular boundary. We can see that this boundary encloses a populated place (represented by a grey box). If we want to improve our ground motion estimation and take into account the site amplification effect, this boundary would be deformed and extended outward so as to compensate for the amplification due to the soft sediment around the river bed. As a result of this our affected area will increase. If this increase is not matched by a proportional increase in the population the population density will change, on the boundaries of the density ranges if it increases we might get what we expected: Higher intensities higher casualty. But if we don't have so many people living near the river bed we may drop to lower density range leading to low casualty estimations.

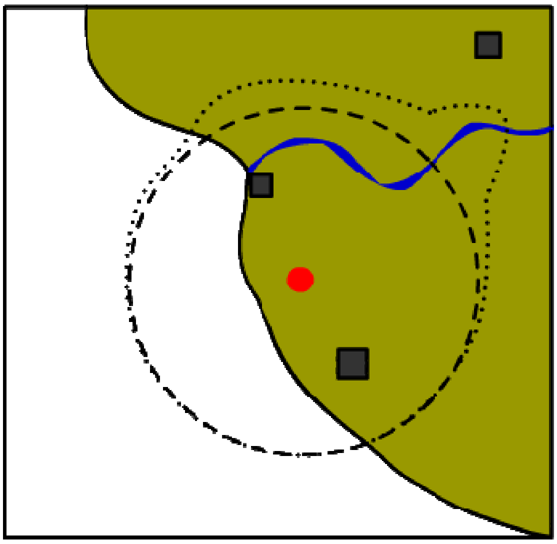

Figure 24: Improvement of GMPE

RGELFE (1992) method however will be able to incorporate this improvement in the ground motion prediction since it assigns a casualty rate to the population in each intensity zone.

VI.6 Other casualties estimations methods proposed by ELER

Apart from Samaradjeva and Badal (2002) methodology, ELER proposes 2 other casualty estimations methodologies:

RGELFE (1992):
This method is based on intensity and population distribution (not density) and does not take into account event magnitude
Based on empirical data RGELFE (1992) provides for major cities, the following fatality rates for various levels of intensities: 0.0014%, 0.031%, 0.48% and 6.8% for intensity zones VI, VII, VIII and IX respectively. This kind of crude casualty prediction models exhibit a high level of regional dependency.

Vacereanu (2004):
This method uses only magnitude and does not take into account neither population nor intensity. Considering major earthquakes in the 20th century, Vacareanu et al. derived a relationship between the number of deaths and the magnitude of the earthquake as follows: $D=ce^{1.5M}$ where D is the number of deaths, M the magnitude and c a coefficient which can take 3 different values.

VII CONCLUSIONS

We assessed the performances assessment of ELER (Earthquake Loss Estimation Routine) Software in terms of Level 0 casualty estimation (i.e. only based on population and theoretical intensities).

De to the lack of required information for Level 1 and 2, performances of Level 1 have been assessed on 25 earthquakes only and performances Level 2 have not been assessed.

The main observations concerning ELER's results are that it is likely to overestimate the number of casualties of low magnitude (M≤5.5) earthquakes or earthquakes located in low vulnerability zones (e.g. Japan). It also tends to underestimate the casualties for large earthquakes (M>7.0) due to the fact that the method only considers the population density and not the total exposed population.

The EMSC developed an extension of ELER Level 0 module named EQIA (Earthquake Qualitative Impact Assessment) based on same Samardjeva and Badal (2002) empirical. The main difference with ELER Level 0 is that EQIA does not intend to estimate the number of casualties but rather to determine a qualitative impact of an earthquake.

EQIA considers a large number of scenarios in order to take into account uncertainties on epicentre location and magnitude. EQIA also includes 3 different values for the vulnerability: low (e.g. Japan), normal and high (e.g. Iran). Finally EQIA takes into account the size of the rupture for large earthquakes.

We assessed the performances of EQIA on the same earthquakes database as for ELER and observed the following:

- EQIA gives correct and well constrained results for catastrophic earthquakes (e.g. Pakistan, 08/10/2005 (73,300 victims), Sichuan 12/05/2008 (69,197 victims), Haiti 12/01/2010 (222,570 victims)).
- It correctly identifies the not damaging earthquakes.
- For light to moderate impacts, the method may sometimes not be accurate due to the intrinsic limitations of the method and the difficulty to assess low impact events.

Finally, contrary to ELER which provides an interactive and multi-parameters tool to assess the number of casualties at Level 0, EQIA is an automatic tool that will allow EMSC to provide to its members a quick email notification service (within 20 minutes after the earthquake), based on the estimated impact.

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X TABLES INDEX