TECHNICAL NOTE

RISe: Illustrating geo-referenced data of seismic risk and loss assessment studies using Google Earth

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Predicting the consequences of large earthquakes to the built environment is of high importance for disaster control, civil protection and emergency planning. A number of software tools are now available to estimate physical building damage and associated losses in terms of casualties and economic losses. In recent years, SELENA, a seismic risk and loss assessment software which makes use of the capacity spectrum method (CSM) has been developed into a widely applicable tool. Since SELENA functions independently from a Geographic Information System, we developed *RISe* (*R*isk *I*llustrator for *Se*lena), a stand-alone tool that illustrates SELENA files in Google Earth. *RISe* is customized to the Selena file structure and allows easy conversion of all geographically referenced files such as building inventory data, soil conditions, ground motion values, as well as final risk and loss results. *RISe* is distributed as public domain open-source software that allows the user to take full advantage of Google Earth's features including high-resolution satellite images from nearly every built environment worldwide.

INTRODUCTION

Since the late nineties, a number of software tools have been developed to compute the expected risk levels and associated losses caused by earthquakes. An overview of some of the most popular software is given by Molina et al. (2009). Irrespective of the way earthquake ground motion or building vulnerability is provided, the main purpose of these programs is to derive useful estimates of building damage, economic losses and human casualties for a

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certain study area such as a district, a city, or a metropolitan region. While risk and loss assessment methodologies certainly are of great interest from a scientific point of view, their practical application within emergency planning and immediate disaster response is of highest importance. As stated by Wald et al. (2008), local governments and emergency planners have an urgent need for information about the likely impact of an event affecting a city so that effective measures of emergency response can be taken in order to minimize secondary losses after an earthquake. This is especially of interest for central governments if remote areas were affected by an earthquake and communication lines have been interrupted. However, the prediction of reliable losses is important not only for the organization of immediate response actions in the wake of a disaster but also in a community's preparation for a future event.

A tool that can assist a community in understanding an earthquake's consequence is an earthquake scenario. With scenarios, the generation of maps illustrating not only the direct shaking effects (e.g. ShakeMaps; Wald et al. 1999) but also predicted building damage and losses by using Geographical Information Systems (GIS) has proven to be very suitable. Nowadays, a wide range of GIS tools are available both as commercial or proprietary software (e.g., ArcView, ArcGIS, MapInfo) as well as public domain open source software (e.g., GRASS, SAGA, ILWIS, Quantum, GMT). As a consequence of this direct visualization need, some loss estimation software tools were interlinked to certain GIS, such as e.g. HAZUS-MH (NIBS 2003) which is fully embedded into the ArcGIS software package (ESRI). To date, HAZUS-MH is probably the most widely used loss estimation software developed and distributed by FEMA (http://www.fema.gov/plan/prevent/hazus/). Even though the software itself is offered as freeware, users must acquire an expensive ArcGIS license in order to take full advantage of the mapping capabilities. Experience from developing countries has shown us that the purchase of these software tools often cannot be afforded.

In contrast, since 2004, the International Centre of Geohazards (ICG; http://www.geohazards.no) through NORSAR (http://www.norsar.no) has been developing an open-source software tool for seismic risk and loss assessment called SELENA (Molina and Lindholm 2005; Lang et al. 2008a; Molina et al. 2009). SELENA which stands for Seismic Loss Estimation using a Logic Tree Approach, is a software tool for computing seismic risk (i.e., physical damage to the building stock of a certain study area) and the associated losses (i.e., economic and human losses). It is a stand-alone application which is not tied to any particular GIS adding versatility to the software so that it can be used across operating systems and platforms. In order to make the users more comfortable and to make the whole computation process as transparent as possible, all input files required by SELENA and the generated output files are in plain ASCII text format. This also allows users to use their favorite GIS for displaying the results.

From experience as well as user feedback we know that generating suitable maps in various Geographic Information Systems can be difficult and will always be constrained by a system's abilities. Moreover, due to the vast amount of different input and output data, the process can be very time-consuming. Therefore we decided to develop *RISe*, a software tool able to convert SELENA input and output files into KML files that can then be used with Google Earth freeware illustrate risk and loss results.

RISe (Risk Illustrator for SELENA) is a user-friendly, open-source software that is intended to be applied in parallel to SELENA in order to assist the user during the different stages of the risk computation process. *RISe* is distributed as freeware together with SELENA through the NORSAR/ICG webpage (http://www.norsar.no) and linked to the Google Earth visualization. Thus the user automatically takes full advantage of the partly high-resolution satellite images provided by Google Earth that can be used, for instance, to demarcate study areas or to overlay risk and loss results. The availability of *RISe* with Google Earth is particularly important in situations where other commercial packages do not provide a high resolution database or for developing countries where many cities and municipalities cannot be displayed on high resolution base maps other than Google Earth satellite images.

TECHNICAL FEATURES AND APPLICATION

The current version of *RISe* is customized to the needs of SELENA users and to the structure and format of SELENA input and output files. As illustrated in Figure 1, *RISe* serves as an intermediary between SELENA and Google Earth to assist in the preparation of input files, the KML file generation of input, inventory and output files. *RISe* is intended for use before, during and after the core damage and loss computation process which is done using SELENA.

INSTALLATION AND SYSTEM REQUIREMENTS

As stated above, *RISe* is provided as open-source software which can be downloaded free of charge from the NORSAR/ICG webpage. Suitable operating systems are Windows Server 2003, Windows Server 2008, Windows Vista, and Widows XP with standard hardware requirements. Further, *RISe* requires the Microsoft .NET Framework (at least version 2.0) or a similar C# interpreter if a computer architecture different from Windows is used.

The *RISe* software itself is provided as an executable (.exe), a separate folder containing the map legends in conventional graphic format (.jpg), and a regularly updated user manual (version 1.0, Lang et al. 2008b).

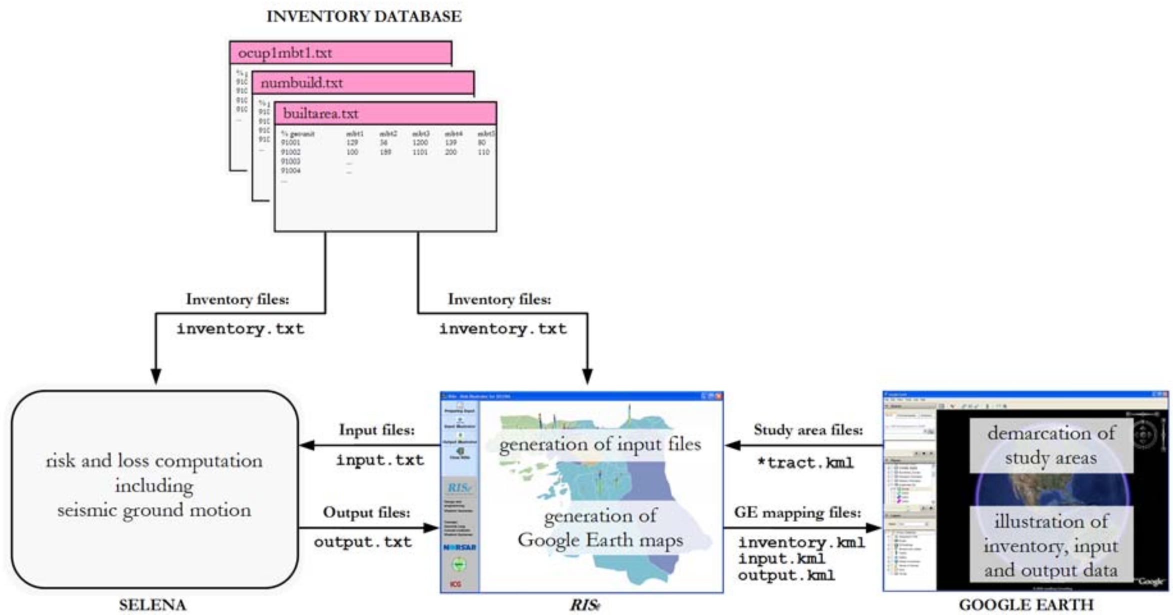


Figure 1. Flow chart illustrating the principle integration of *RISe* in a seismic risk and loss assessment study. *RISe* can assist the user in generating some of the input files (i.e., soilcenter.txt) as well as to generate the Google Earth maps (i.e. KML files) for the inventory, input and output files.

STEPS OF APPLICATION

Figure 1 demonstrates how SELENA (Molina et al. 2008) is used as a pure computational tool and *RISe* in principle represents a separate layer between SELENA and Google Earth in order to illustrate geo-referenced information in input and output files.

Demarcation of geographical districts for aggregation (Google Earth)

SELENA, like many risk estimation software tools, considers the minimum geographical unit (i.e. geounits, census tract) as the smallest area unit. In most cases, this unit will be related to building blocks or to smaller city districts and computations are conducted for aggregated data within each unit. The decision on the size of each unit and how to demarcate it has to be made considering different variables such as soil conditions, constant surface topography or level of building quality within the demarcated area (socioeconomic aspects). The resolution of the satellite images in Google Earth to at least the level of individual buildings and building blocks allows an easy demarcation of the single geounits. Both, the margins and the center points (centroids) of each geounit can be drawn by using the polygon and placemark tools already available in Google Earth. After assigning the polygons and centroids for each geounit they need to be saved as separate KML files (PolyTract.kml and CentroidTract.kml, respectively). These two files will serve as the main geographical reference for all maps to be generated afterwards.

Generation of input files (*RISe*)

The file CentroidTract.kml can be imported by *RISe* and used to prepare the input files for SELENA carrying the soil information in each geographical unit. Near-surface soil conditions can be categorized according to different classification schemes provided in seismic building codes (e.g., NEHRP soil classes as applied by IBC-2006; Table 1). By assigning each geounit to an index of the respective soil class (Figure 2), the risk computation software SELENA later automatically considers the corresponding soil amplification factors.

Table 1. Soil classification according to the NEHRP provisions (FEMA 1997) used by the International Building Code IBC-2006 (ICC 2006).

Index	NEHRP site class	Site class description	Shear-wave velocity $v_{s,30}$ [*m/s*]
1	A	hard rock	> 1500
2	B	rock	760 – 1500
3	C	very dense soil and soft rock	360 – 760
4	D	stiff soil	180 – 360
5	E	soft soil	< 180

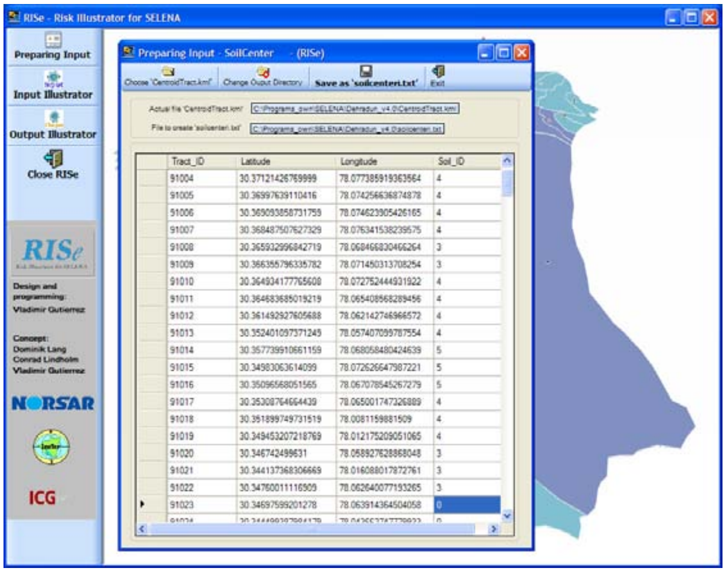


Figure 2. Sub-menu of *RISe* which is used to prepare the soil information input file based on the file CentroidTract.kml prepared in Google Earth. The user can interactively enter the soil indices for each geographical unit according to different soil classification schemes (such as the NEHRP classification as given in Table 1).

Computation of risk and loss (SELENA)

The intrinsic computation of damage and loss is done using SELENA and will not be described in more detail herein. Calculated results for each geographical unit including ground-motion values, damage probabilities, absolute building damage, economic losses and casualties are provided as separate ASCII text files with predefined file names.

Generation of Google Earth mapping files (*RISe*)

By using fixed file names for inventory, input and output files, *RISe* automatically recognizes files containing geo-referenced data and determines how these data can be best illustrated. Using the previously generated *Tract.kml files (CentroidTract.kml and PolyTract.kml) *RISe* will take only a few seconds to convert the text files into the Google Earth mapping files (KML). Figure 3 shows the sub-menus to convert input and output files into the corresponding kml-files.

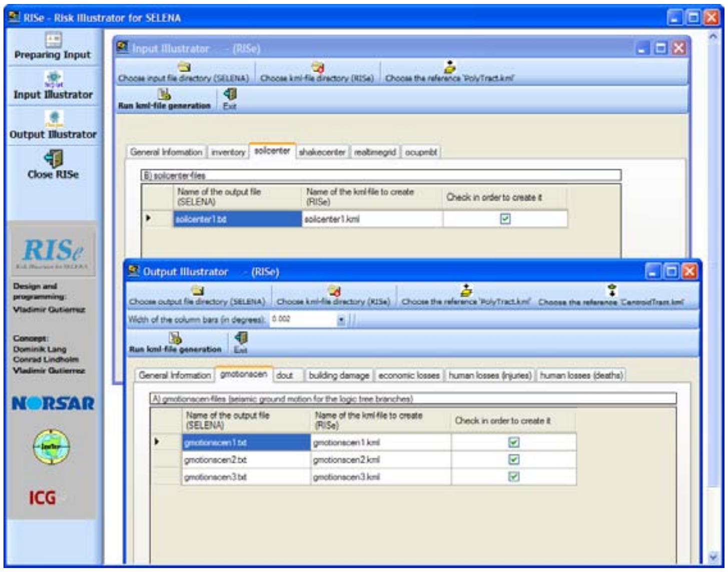
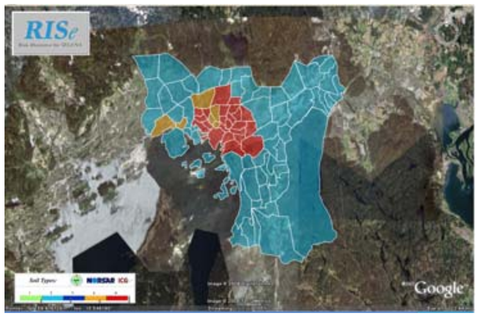
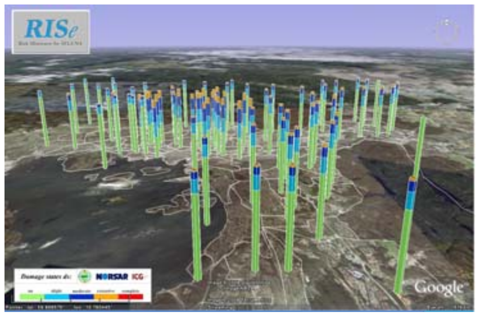
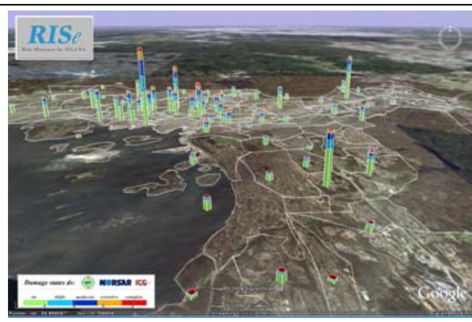


Figure 3. Sub-menus of ***RISe*** to convert input and output files into the corresponding Google Earth (KML) files. The final decision as to which of the files shall be converted is made by the user.

Depending on the data to be converted, different mapping types are required to illustrate input and output results in the best possible way. The current version of ***RISe*** includes three different mapping types which are shown in Table 2. The total number of input and output files which are suitable for conversion varies from case to case since each risk and loss computation is based on a different database (e.g., with varying numbers of building types and occupancy classes) and conducted in a different way. In addition, SELENA allows the definition of a logic tree computation scheme that directly influences the number of input and output files (Molina et al. 2009) and thus the number of KML maps to be generated. A detailed overview of the different maps generated and how they are illustrated is given in the user manual which is provided with the ***RISe*** software (Lang et al. 2008b).

Table 2. Mapping types of *RISe* in order to illustrate the different data

Mapping type	Example	Comment
I: color-shaded plot		For each geographical unit, a single data type can be plotted, e.g., soil class information, ground motion values
II: normalized bar-chart plot		Mapping type to illustrate the shares of damage probabilities (SELENA input files dout*i*.txt) in the five different damage states for one particular model building type. The heights of the column are identical and represent 100 % of cumulative damage probability.
III: absolute bar-chart plot		Mapping type to illustrate absolute values of risk and loss results in the five different damage states. The heights of the columns are different and represent the amount of damage, economic loss or casualties in the respective geographical unit.

APPLICATION OF RISE IN RISK AND LOSS ASSESSMENT STUDIES

Graphical representation of seismic risk and loss computations are generally of great importance not only from a scientific point of view or in terms of its practical application but also to detect possible errors in the input database or computation process. The latter is especially facilitated by the clarity of results depicted in colored maps as compared to ASCII tabulated files or spreadsheets. This becomes even more important for large inventory databases with a multitude of geographical units, building types and occupancy classes.

RISe is customized to the SELENA file structure and thus applications other than in the framework of risk and loss computations conducted with SELENA are not foreseen. It is intended that the use of *RISe* will grow among the SELENA user community and that the outcomes of many future risk and loss assessment studies will be illustrated by using *RISe* and Google Earth. To demonstrate the capability of *RISe* and its applicability to illustrate complex results, several examples of successful applications based on different risk and loss computations are given in the following.

COLOR-SHADED MAPS

The two-dimensional color-shaded maps (which can have different projection angles) are especially used for the mapping of inventory and input files but also for the output files containing ground-motion parameters. Most of these files carry more data than can be illustrated by one single plot. Once opened in Google Earth, the corresponding KML files allow the illustration of different maps by checking and de-checking the respective buttons on the left scroll-down menu (Figure 4). In addition, the subfolders in the scroll-down menu provide the respective geounit ID with specific data values (e.g., percentages, accelerations) that facilitates reliability checks of the mapped results. This is especially interesting since most of the data are illustrated by a five-color plot where each color represents a certain range of data, thus hiding the specific values.

The KML files gmotion.kml, shakecenter.kml and realtimegrid.kml which contain the acceleration values of seismic ground-motion for SELENA's deterministic, probabilistic and real-time analysis options, respectively, can be used as conventional 'shake-maps' showing the spatial distribution of shaking intensity in terms of peak ground or spectral acceleration (Figure 5).

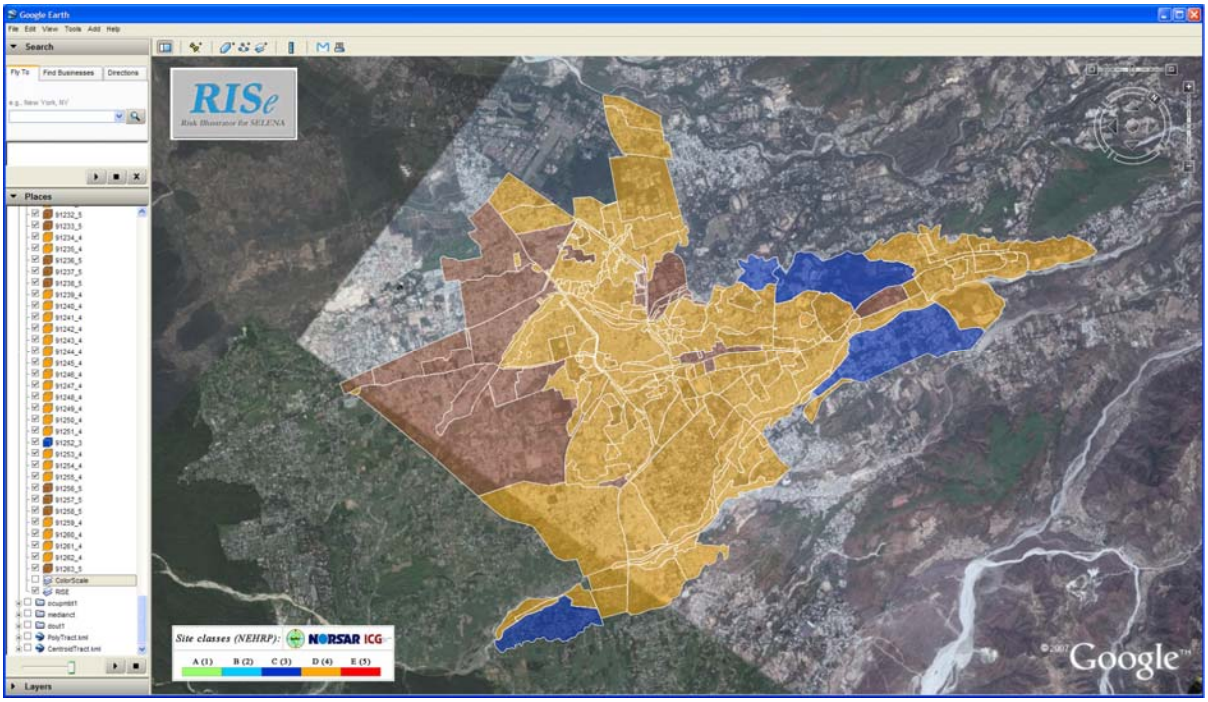


Figure 4. Illustration of input file soilcenter.txt by color-shaded plots. The five-color scale represents NEHRP soil classes A – E in the geographical units. The scroll-down menu on the left lists the indexes of all geounits and their respective soil class index.

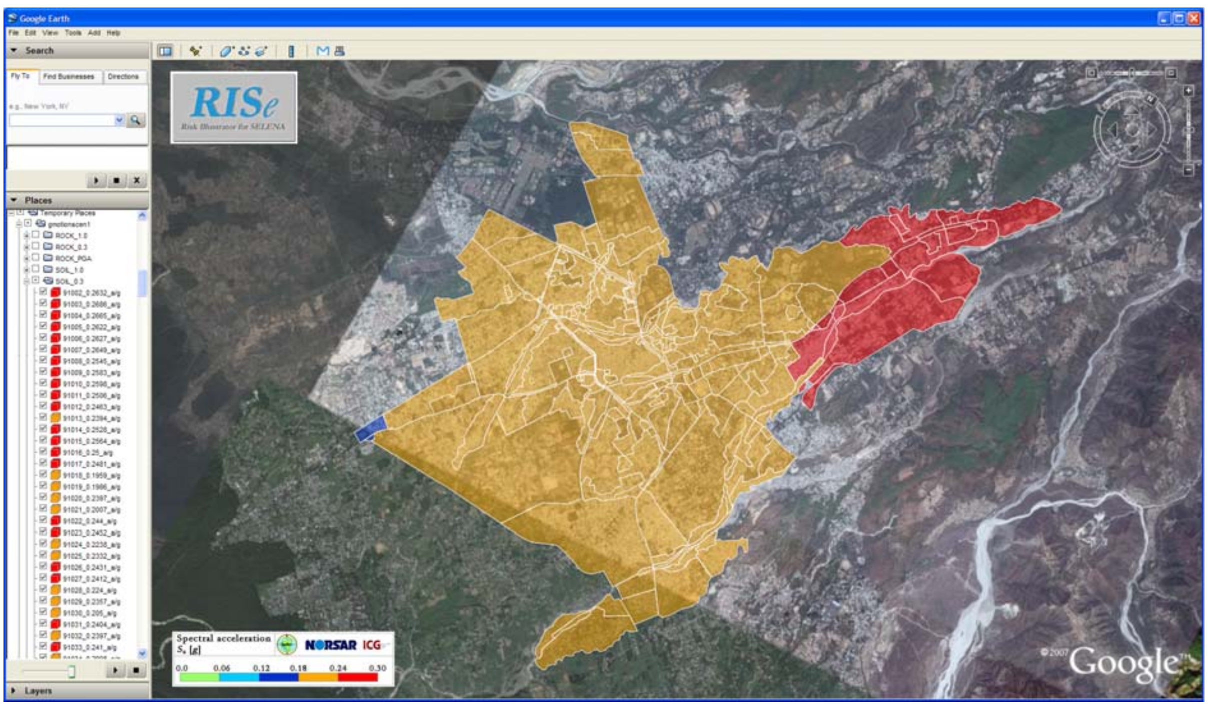


Figure 5. Illustration of output file gmotion.txt by color-shaded plots. The corresponding file gmotionscen1.KML (see scroll-down menu on the left) includes six ground motion maps for Peak Ground Acceleration (T = 0.01 *s*), spectral acceleration at 0.3 *s*, and spectral acceleration at 1.0 *s* with and without soil amplification. The distinct numbers of ground motion accelerations for each geounit are listed on the left scroll-down menu.

BAR-CHART MAPS

The bar-chart maps are especially customized to illustrate the SELENA output files, in particular the damage and loss results. As mentioned earlier, the seismic risk and loss assessment software SELENA computes physical building damage estimates for different states of damage. Structural damage is classified into the five damage states *no*, *slight*, *moderate*, *extensive* and *complete*, as defined by HAZUS (NIBS 2003). These generalized ranges of damage are used by SELENA primarily to describe structural damage as a measure of building deformation under lateral earthquake loading. Since the distribution of structural damage for one particular building type into the five different damage states is impossible to illustrate by two-dimensional plots, we suggest the use of three-dimensional bar-chart maps. For output files dout.txt which carry damage probabilities of each building type under a certain ground motion level, normalized bar-chart plots are generated (Figure 6). The total height of the columns is identical for each geographical unit, as it represents cumulative damage probabilities for the five different damage states. The coloring of the columns allows the user to quickly identify regions (geographical units) where one particular building typology may undergo higher damage. For the illustration of absolute damage that basically is the product of damage probability and the inventory of the respective building typology in one geounit, absolute bar-chart plots are provided as illustrated in Figure 7.

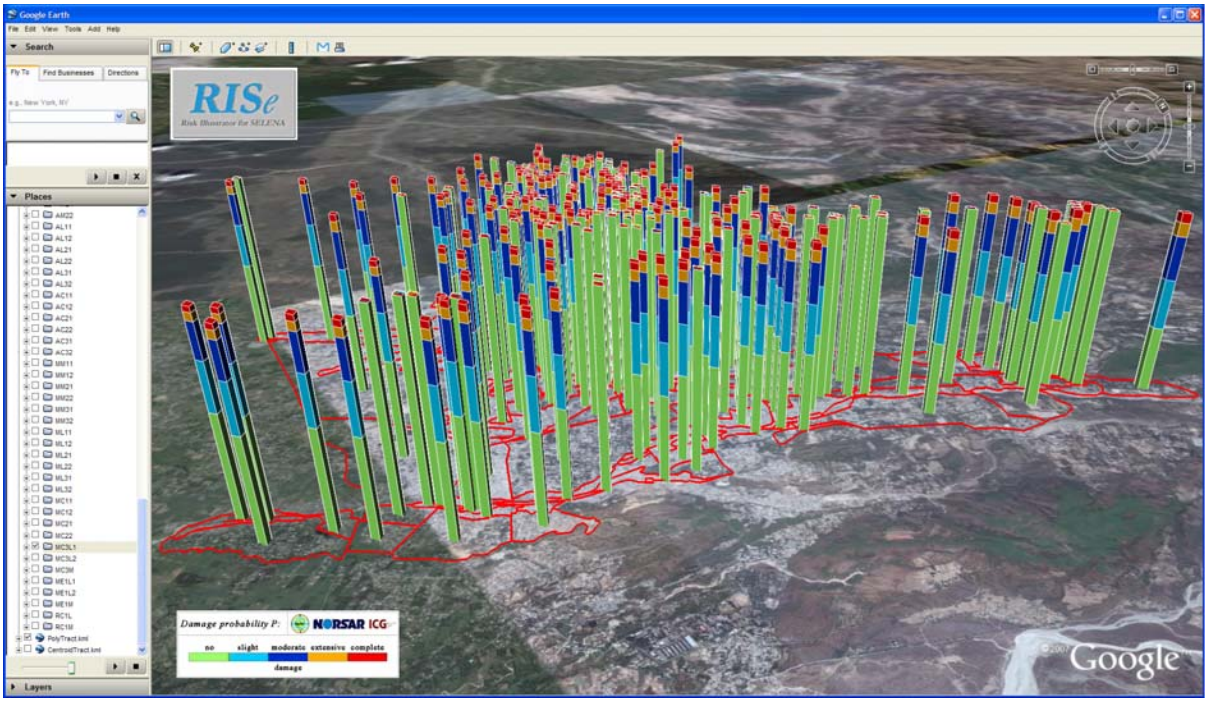


Figure 6. Illustration of output file dout.txt by normalized bar-chart maps. The total heights of all columns are similar as each column represents cumulative damage probabilities of the five damage states *no*, *slight*, *moderate*, *extensive* and *complete*. (Additionally, the reference file PolyTract.kml is underlain illustrating the margins of the single geographical units.) Separate maps for each available model building type can be illustrated by checking the respective box in the scroll-down menu on the left. (Additionally, the reference file PolyTract.kml is underlain illustrating the margins of the single geographical units.)

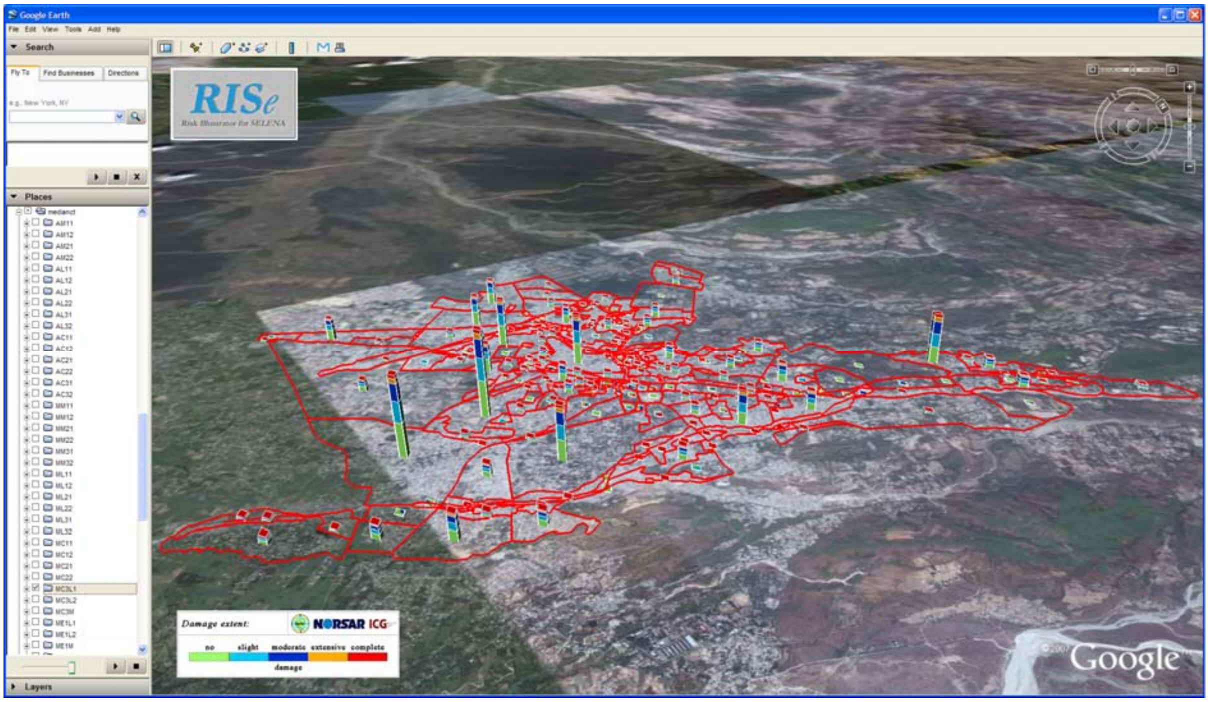


Figure 7. Illustration of output file medianct.txt by absolute bar-chart maps. The total height of each column represents the absolute damage extent in terms of damaged buildings or damaged building floor area of the five damage states *no*, *slight*, *moderate*, *extensive* and *complete*. Separate maps for each available model building type can be illustrated by checking the respective box in the scroll-down menu on the left. (Additionally, the reference file PolyTract.kml is underlain illustrating the margins of the single geographical units.)

CONCLUSIONS

While the described software tool *RISe* can be seen as a translator for SELENA ASCII files into KML files able to be read into Google Earth, its features are customizable to the requirements of SELENA users, thereby facilitating further the use of SELENA for seismic risk and loss computations. The fact that *RISe* is distributed as public domain open-source code and that it is available free of charge will hopefully help to disseminate the tool and initiate other applications. In competition with commercial or other non-proprietary Geographic Information Systems (GIS), *RISe* provides several advantages which can be summarized as follows:

1. The KML files are plotted on top of satellite images which are available in sufficient resolution for nearly every built environment worldwide.
2. Most users have already installed Google Earth due to its wide dissemination and numerous applications.
3. There is no need for sophisticated installation procedures or licensing of a commercial GIS program.
4. The *RISe* maps allow visual checks on the completeness and correctness of data during all stages of the risk computation process. Thus, erroneous results can be quickly identified; this feature is very important when the size of a study area (i.e. number of buildings or geounits) increases.
5. The illustration types are chosen so that output results (3-dimensional bar-chart plots) can be plotted on top of inventory or input data (2-dimensional color-shaded plots).

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