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NEXT GENERATION CAPRA SOFTWARE

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ABSTRACT

The CAPRA risk modeling platform was released in 2008, as an open-source suite of programs specialized in hazard, vulnerability and risk assessment. Here we present a latest version of the platform, totally renewed and delinked from its original funding effort. This version is comprised by 14 different software modules, specialized in hazard, exposure vulnerability and risk assessment due to natural phenomena such as: earthquakes, tsunami, tropical cyclones, heavy rainfall, landslides, floods, droughts and volcanic eruptions. Each program of this suite is oriented to fulfil specific tasks in hazard and risk modelling: SMA (Strong Motion Analyst) focuses on the processing of strong-motion signals and seismological data; SMS (Seismic Microzonation Studio) focuses on the dynamical soil response of 3D geological environments; CRISIS 2015 is the seismic hazard and tsunami module; TCHM (Tropical Cyclones Hazard Modeler) is a state-of-the-art hazard calculator for cyclonic wind and storm surge; FA (Flood Analyst) and SRM (Stochastic Rainfall Modeler) provide the tools for flooding modeling; LHM (Landslide Hazard Mapper) focuses on the calculation of landslide susceptibility and hazard; VHAST (Volcanic Hazard Analysis and Simulation Tool) incorporates probabilistic methodologies to account for volcanic hazard; Drought Pro provides cutting-edge tools for drought simulation; EE (Exposure Editor) focuses on the construction and management of geo-databases for exposed elements; VS (Vulnerability Studio) focuses on the computation and edition of vulnerability functions; CAPRA-GRM is the risk calculation engine of the suite; EvHo performs holistic evaluations of risk; and FileCAT provides data management capabilities to the overall set of programs. The CAPRA suite was developed entirely in Visual Basic .NET and is available at no cost.

Keywords: CAPRA; Multi-hazard risk assessment software; loss estimation; Freeware

1. INTRODUCTION

At present CAPRA stands for *Comprehensive Approach to Probabilistic Risk Assessment*. It was created with the intention to incorporate comprehensive models of natural hazards, exposure and vulnerability, to perform risk assessments and provide risk metrics coherent with the catastrophe risk and classical actuarial risk theories. The first version of CAPRA, released in 2008, was a good approximation to this goal, and certainly improved the quality of disaster risk evaluations, communication and general understanding throughout the world (Cardona et al. 2010, 2012; Marulanda et al. 2013; Reinoso in these proceedings). Nevertheless, during the past 10 years, several improvements have been made to the software, both scientifically and technologically speaking, making it quite different from its original version. The Next Generation CAPRA Software Suite (hereinafter referred to as CAPRA) is possibly the most comprehensive, freely available, software suite for disaster risk modelling, incorporating models for 8 different natural hazards into the same probabilistic risk assessment framework, including: earthquakes, tsunami, landslides, volcanic eruptions, tropical cyclones, convective rainfall, floods and droughts. The main core of CAPRA is composed of 14 software modules as shown in Figure 1. However, other developments are also available as will be explained later. The main characteristics of the modules are presented in the following sections.

2. HAZARD MODULES

CAPRA incorporates modules for 8 different hazards. In all cases, hazard is represented in a fully probabilistic way, following an event-based approach as required for risk assessment.

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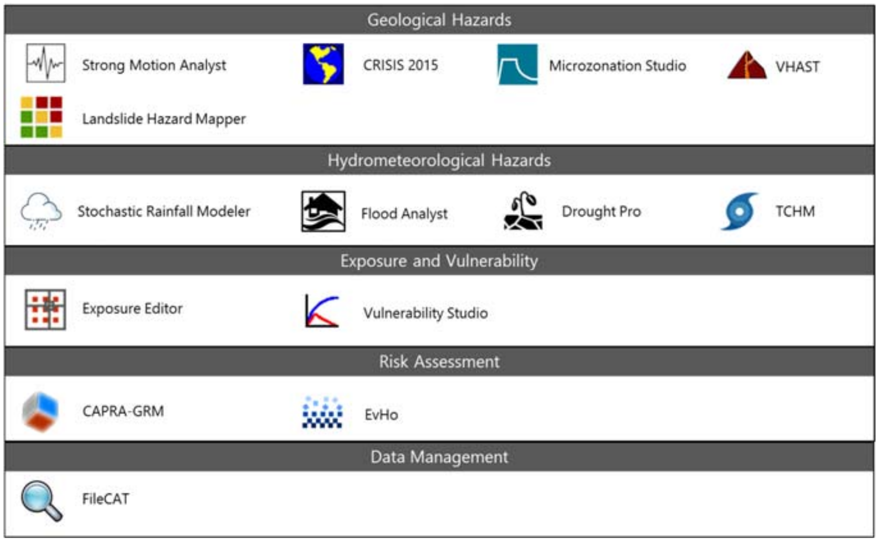

Figure 1. Core modules of CAPRA.

2.1 Hazard representation

The purpose of a probabilistic risk assessment is the characterization and quantification of the losses on a set of exposed elements, given the occurrence of hazardous events. Given that there are uncertainties in the estimation, the loss should be modeled as a random variable. In general terms, one would be interested to know the following about the loss: the universe of all possible losses (i.e. the domain of the random variable describing the loss) and, the probability density function of the loss, which is defined within the domain of the variable.

The objective is to calculate the probability of any loss event that may occur in the future. The definition of said event depends exclusively on what question wants to be answered by the stakeholders. This means that events are defined arbitrarily, depending on the type of decision-making. However, the definition of these events is not of interest; we are interested to know their probability of occurrence. The appropriate mathematical framework that allows the calculation of the probability of occurrence of any loss event, defined in a completely arbitrary way, requires the definition of a set of mutually exclusive and collectively exhaustive loss events to be used as the basis of the calculation of any other loss events. This base of loss events is then obtained and characterized by assessing the loss due to a collection of hazard scenarios, each resulting in a different loss event. Of course, the hazard scenarios must fulfil the basic conditions as well: be mutually exclusive and collectively exhaustive. Fully probabilistic risk assessment requires the definition of hazard scenarios and, therefore, hazard models must return an assessment in terms of a collection of scenarios.

Within CAPRA, hazard is represented through *ame* files (Torres et al. 2013) that can store the stochastic scenarios as raster grids, regardless of the total number (this is key keeping in mind that usually hazard is represented by a very large number of scenarios), and including all the relevant information in terms of the probability moments of the hazard intensity, the geographical extension and the annual frequency of occurrence.

2.2 CRISIS 2015

CRISIS 2015 (Ordaz et al. 2015) is the seismic and tsunami hazard module of CAPRA. It is a versatile tool to perform Probabilistic Seismic Hazard Analysis (PSHA). Since the development of its first version in 1998, CRISIS has been used worldwide in different projects of seismic hazard assessment. PSHA performed with CRISIS 2015 is in total agreement with the results considered as valid in the recent edition 2014-2015 of the PEER project to validate software to compute seismic. A thoughtful review of CRISIS 2015 can be found in Aguilar-Meléndez et al. (2017).

CRISIS 2015 supports the definition of seismic sources as: Area source, Area planes, Line source, Grid Source, Point (SSG) sources, OQ Rupture and Rectangular Fault. Different models of earthquake occurrence are implemented such as: Characteristic earthquake, Non-poissonian and Gridded (smooth) seismicity. CRISIS 2015 facilitates the use of different Ground Motion Prediction Models (GMPM). At present, it incorporates more than 60 different built-in GMPMs (more are added permanently). In addition, user-defined models can be used as well. With these information, CRISIS 2015 delivers the following outputs: Hazard maps, Uniform hazard spectra, Disaggregation M-R, Disaggregation M-R-Epsilon, Earthquake scenario/Shake Maps and Set of events (CAPRA *ame* file). Finally, CRISIS 2015 includes a tsunami hazard calculation module.

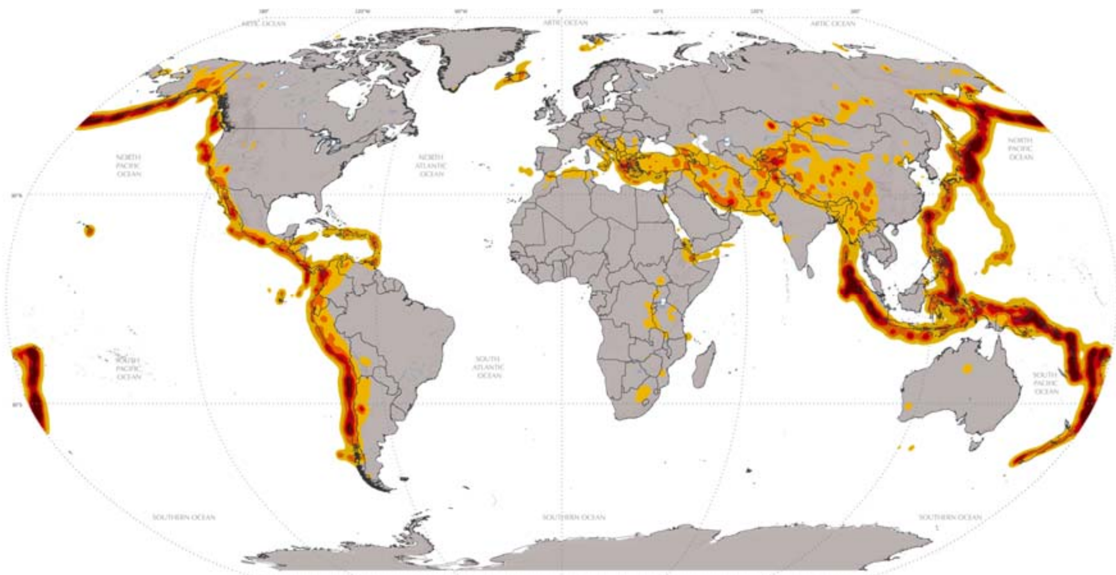

Figure 2. Seismic hazard map for the globe. PGA for 1000 years return period. Calculated with CRISIS 2015 for the Global Assessment Report, GAR, Atlas of Risk (UNISDR 2017; Marulanda et al. in these proceedings).

2.3 Strong Motion Analyst

Strong Motion Analyst (SMA) is a computer program for processing seismological information. SMA implements methodologies for signal processing, site response analysis, strong motion attenuation and processing of seismological catalogs.

SMA implements several signal-processing tasks, including: Baseline correction, Scaling, Time frame cut, Filter, SDF response, Derivative, Integral, Energy and Decompose (into a set of narrow-bandwith components which are the summands of the original signal), among others. In terms of spectral analysis, SMA computes: Fourier Spectrum, Response Spectrum, Spectral Density, Husid Plot and Energy Flux Plot. SMA supports the following operations between signals: Transfer function, Cross correlation, Sum, Substraction, Rotation and Principal components of motion. In addition, SMA includes several tools for comparison of time-histories and spectrums, as well as batch processing features, and can generate synthetic accelerograms using both the stochastic model by Boore (1983) and the hybrid model by Bernal and Cardona (2017).

SMA performs one-dimensional dynamic response of a soft soil stratigraphy, using the nonlinear (linear equivalent) 1D method and the Thompson-Haskel propagating matrix. The results include: surface accelerograms, response spectra, Fourier transfer functions and response spectrum transfer functions. The results can be postprocessed directly in SMA or exported for further analysis. In addition, SMA incorporates the capability to calculate attenuation relationships based on a source spectrum model. The model can be configured so that personalized and specific functions can be obtained for a region in which the seismological parameters that make up the model are known. The attenuation models generated can be exported in a format compatible CRISIS 2015. SMA performs residuals analysis of any GMPE (input in CRISIS ATN format), and calibration of strong motion attenuation functions based on the source spectrum model. SMA carries out basic processing of seismological catalogs, including decluttering, completeness analysis and calculation of gridded (smoothed) seismicity (compatible with CRISIS 2015). Finally, SMA includes a strong motion database which hosts accelerograms taken from two main data sources: The National Accelerograph Network of Colombia (operated by the Colombian Geological Survey), up to December 2016, and the NGA project of PEER. An internet connection is required to query the database. All the accelerograms can be processed and used within SMA.

2.4 Seismic Microzonation Studio

Seismic Microzonation Studio (SMS) is a computer program for the construction of geotechnical models of seismic response for evaluating site effects within cities. It implements the microzonation approach by Bernal (2014) and Bernal and Cardona (2015).

The development of the seismic response model within SMS is sequential. The steps for the conformation of the model are: 1) *Geometry:* Input of the 3D geometrical models of the geological formations; 2) *Field data*: Exploration data in the field with geotechnical information collected through laboratory tests, 3) *Geotechnical properties*: Definition, in depth, of the geotechnical properties associated with geological formations, 4) *Seismic records*: Strong motion for the analysis of response of soft soil deposit (supports real accelerograms or theoretical Fourier spectra); 5) *Computation sites*: Definition of the calculation (output) sites (SMS generates synthetic stratigraphies at these locations); 6) *Response analysis:* Configuration and calculation of the dynamic response of the soil in the defined locations, based on all previously entered information; 7) *Export*: Several exporting tools are included; 8) *Postprocessing*: Post processing tool for the definition of elastic design spectra based on the outputs of the seismic response and hazard calculation. Uniform hazard spectra can be harmonized to any of the supported design spectra formulations (includes ACI, IBC, Eurocode and ASCE).

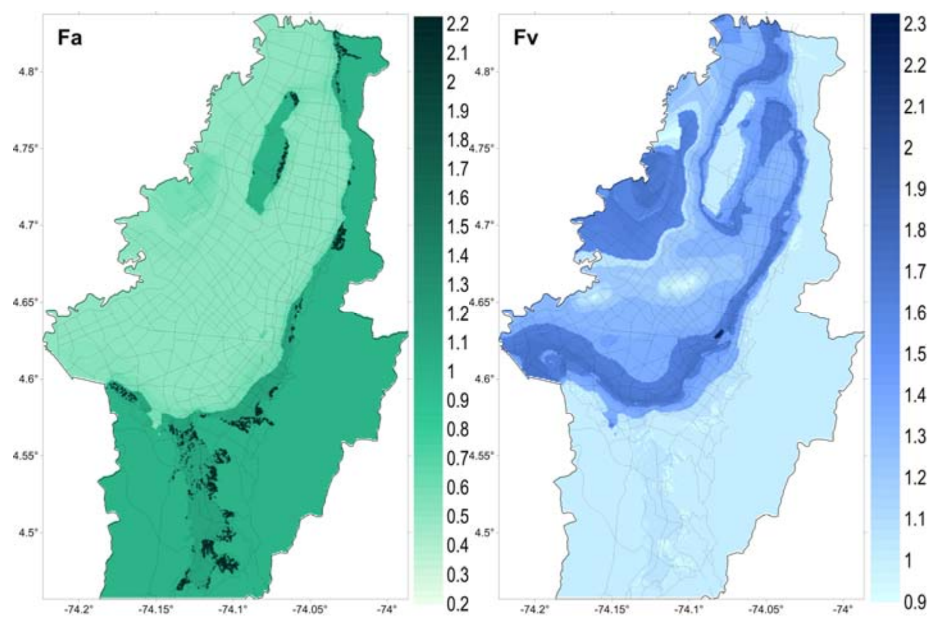

Figure 3. Maps of seismic design soil coefficients Fa and Fv (ACI 318) for Bogotá, Colombia, computed in SMS. From Cardona et al. (2016). After Cardona and Yamin (1997).

2.5 Landslide Hazard Mapper

Landslide Hazard Mapper (LHM) provides tools for the probabilistic assessment of landslide hazard. Within LHM, landslide hazard is divided into two main components: landslide susceptibility and triggering factors. Landslide susceptibility measures the probability of occurrence of a landslide in each location, based on the site intrinsic characteristics such as slope, soil conditions, vegetation coverage, and many others. It is a "static" measure of hazard, given the fact that is computed using the current state of a site that hasn't necessarily slide. This assessment is performed using a black-box model in which an Artificial Neural Network (ANN) is trained to classify each site as susceptible or not (in terms of its probability of being susceptible) as a function of said intrinsic characteristics.

Triggering factors are related to an external action over the static conditions of the site. They are given as a set of seismic or rainfall events, accompanied with threshold definitions for both seismic acceleration and rainfall intensity. LHM computes the probability of exceeding the thresholds given the occurrence of each triggering event, and then aggregates, for each site, the total probability of landslide.

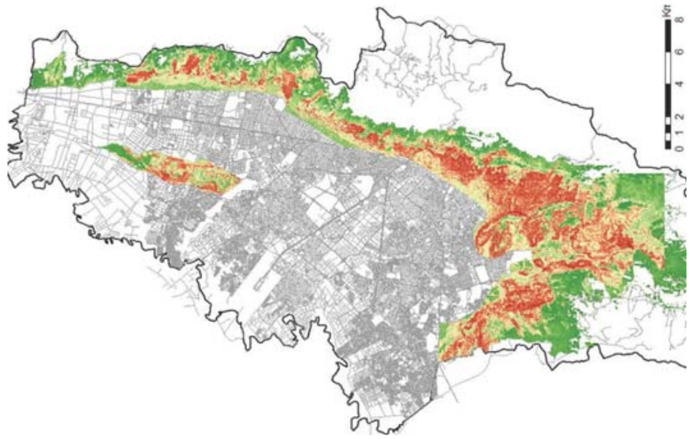

Figure 4. Landslide susceptibility for Bogotá, Colombia, calculated with LHM. From Cardona et al. (2016)

2.6 Volcanic Hazard Analysis and Simulation Tool

VHAST (Volcanic Hazard Analysis and Simulation Tool) implements a probabilistic hazard assessment approach based on eruptions simulations. Based on the history of eruptions of the volcano, and for each volcanic product, eruption magnitude is defined, and magnitude annual excess rates are computed. Excess rates account for the number of times, per year, that a magnitude value is equaled or exceeded in an eruption. For each eruption magnitude, intensity parameters (that define the final extent of volcanic products) are set. Each intensity parameter is modeled as a random variable, allowing for the simulation of several stochastic eruptions for each magnitude value. Each simulation results in a geographical distribution of volcanic products, in terms of gridded random variables. VHAST implements methodologies for the assessment of lahar, lava flows, Pyroclastic Density Currents (PDC), and tephra fall, within the event-based probabilistic approach.

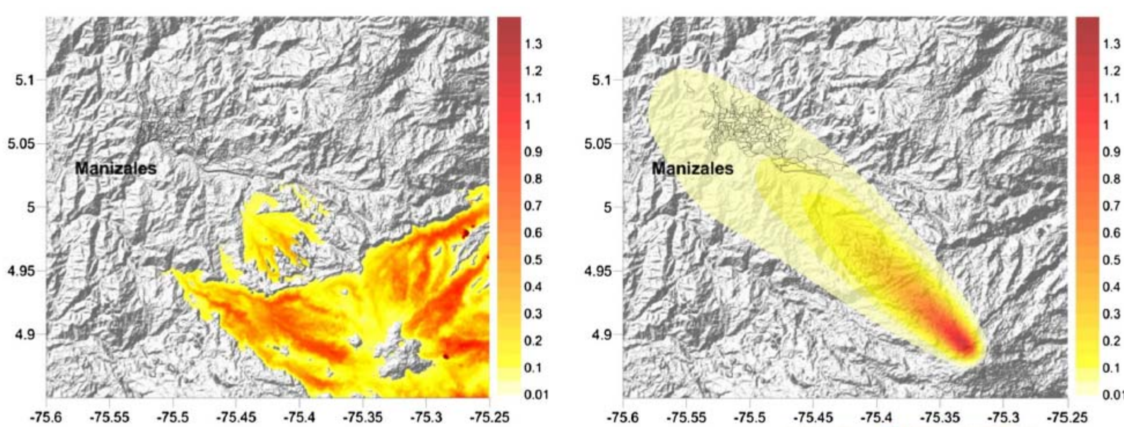

Figure 5. PDC (left) and tephra fall (right) hazard scenarios for Nevado del Ruiz volcano (central Colombia) computed with VHAST. From Bernal et al. (2017a)

2.7 Tropical Cyclones Hazard Modeler

TCHM (Tropical Cyclones Hazard Modeler) is CAPRA's module for tropical cyclones hazard. It implements calculation methodologies for strong winds, storm surge and accumulated rainfall. Within TCHM, many cyclones are stochastically generated form a model which is based on the historical records, to forecast, for an entire country or region, the future hazard conditions due to the passing of several feasible tropical cyclones. TCHM follows a hybrid simulation approach, in which a large amount of tropical cyclone tracks is created by perturbating the historical tracks, using random-walk technics (e.g. a bi-dimensional Wiener process). The randomly generated tracks and then altered by incorporating a balance model to take into consideration parameters from the atmospheric-oceanic system that influence the life cycle of a tropical cyclone. This approach allows to adequately simulate the strengthening and weakening of tropical cyclones as they progress along the random tracks.

Once the full set of cyclone tracks has been defined for the hazard model (usually including both historical and simulated tracks), the effects of those cyclones must be evaluated at the local scale. These effects are: strong winds, storm surge and heavy rainfall. To assess the site-specific effects of a tropical cyclone, TCHM uses physics- driven models, which means that it can model the physics involved in the life cycle of tropical cyclones.

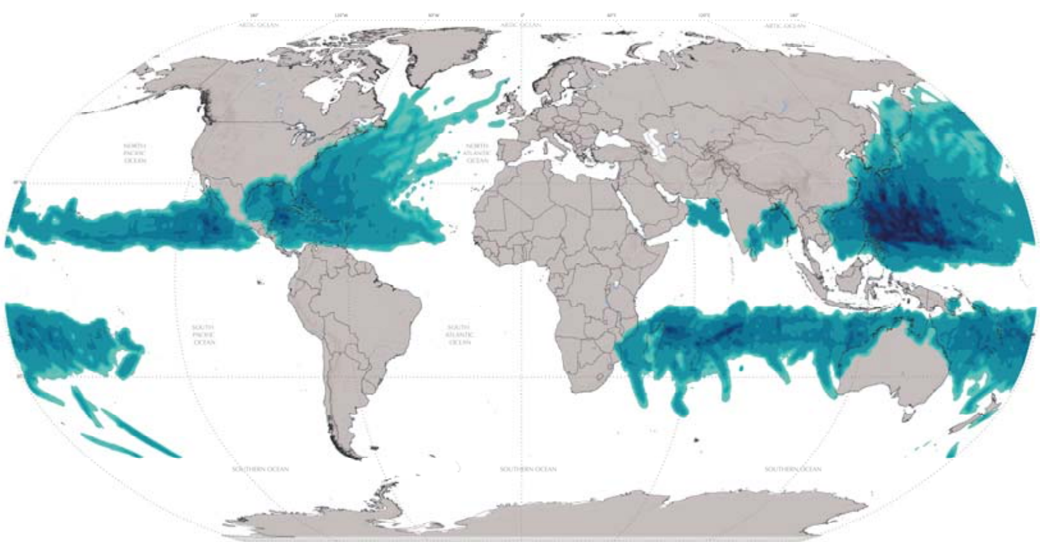

Figure 6. Strong wind hazard for the Globe. 100 years return period. Calculated with TCHM for the Global Assessment Report, GAR, Atlas of Risk (UNISDR 2017; Marulanda et al. in these proceedings).

2.8 Stochastic Rainfall Modeler

Stochastic Rainfall Modeler (SRM) is the CAPRA module of convective rainfall. It is based on the spatial analysis of rainfall patterns in a region, in terms of PADF curve (see, for example, WMO 1969). The objective is to establish the relationship between the maximum average precipitation depth (P), the area (A) over which this rain falls, the duration (D) during which this precipitation occurs and the frequency (F) with which an event with those characteristics of depth, spatial coverage and duration is presented. In addition, historical isohyets are analyzed to define typical patterns of spatial distribution of precipitation events, and preferential locations of these patterns can be determined within the area. With these components (i.e., PADF curves, typical patterns and preferential location) SRM can generate synthetic precipitation events. The results generated by SRM are compatible with both the landslide hazard assessment and the hydrological modeling for riverine flood hazard.

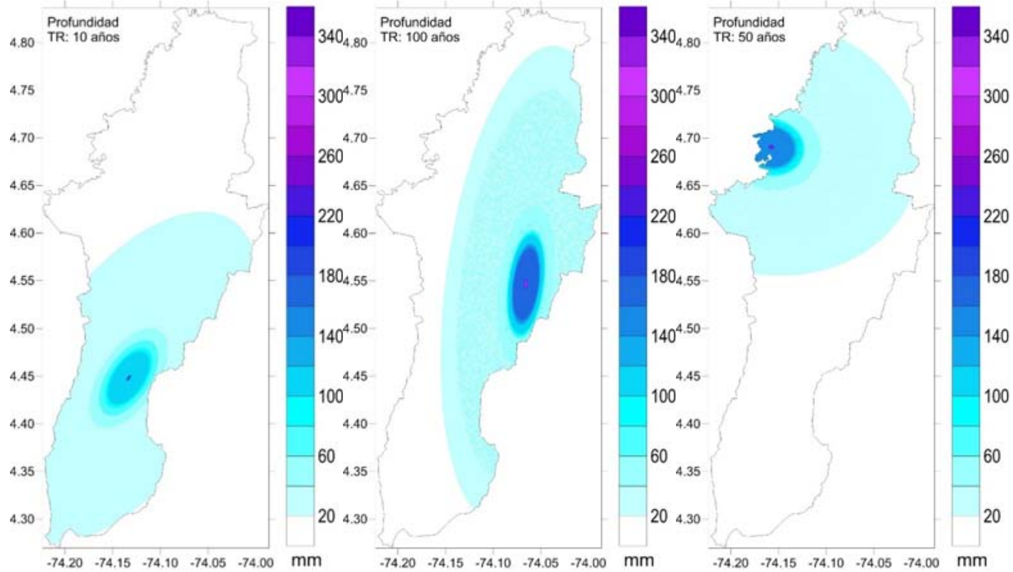

Figure 7. Convective rainfall scenarios generated for Bogotá, Colombia, using SRM, from Cardona et al. (2016a)

2.9 Flood Analyst

Flood Analyst (FA) is the riverine flood hazard module of CAPRA. Within FA, the hydrological response of the catchment of the river is modeled by means of the modified Clark model (modClark) which accounts for the runoff transformation processes of translation and attenuation. In the modClark approach, the catchment is rasterized, and each pixel is modeled using the original Clark model and a specific arrival time to the exit of the catchment. The hydrographs contributed by each pixel are coherently added to obtain the input for the hydraulic model.

The hydraulic engine of FA is HEC-RAS 5 (US Army Corps of Engineers, 2015). HEC-RAS is a widely used software for the hydraulic analysis of rivers. Version 5 of HEC-RAS allows the coupling of 1D and 2D hydraulic models, as well as flood defenses such as dikes. FA simply automatizes the execution of HEC-RAS, so that the hydrographs obtained from the catchment response to each stochastic storm (calculated in SRM) are used as input to the hydraulic model. After HEC-RAS has competed the hydraulic analysis, FA gathers the results and constructs a flood scenario for each input storm. Example of detailed flood risk assessments and optimal risk management action plan is available at Cardona et al. (2016b).

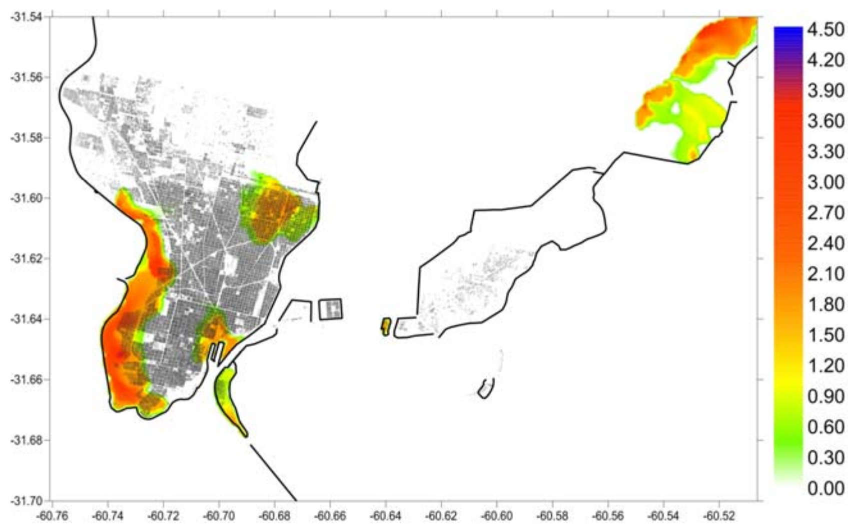

Figure 8. Flood hazard map of Santa Fe, Argentina. 100 years return period. Calculated with FA. The thick surrounding the city are dikes used for flood defense. (INGENIAR-CIMNE, 2015).

2.10 Drought Pro

Drought Pro implements a state-of-the-art methodology to account for drought risk in agriculture. Within Drought Pro, a stochastic climate generator creates many simulations of weather variables (such as precipitation and temperature), based on the historical daily series available in the territory. These stochastic series are used to identify feasible droughts using standardized drought indices. Ones the simulated droughts are selected, Drought Pro performs water response analysis to the crops on the analysis region, to calculate the reduction in yield as consequence of the water stress caused by the drought. The results are added probabilistically to come up with actuarial metrics of risk. Details of the drought risk model and applications are available in Bernal et al. (2017b).

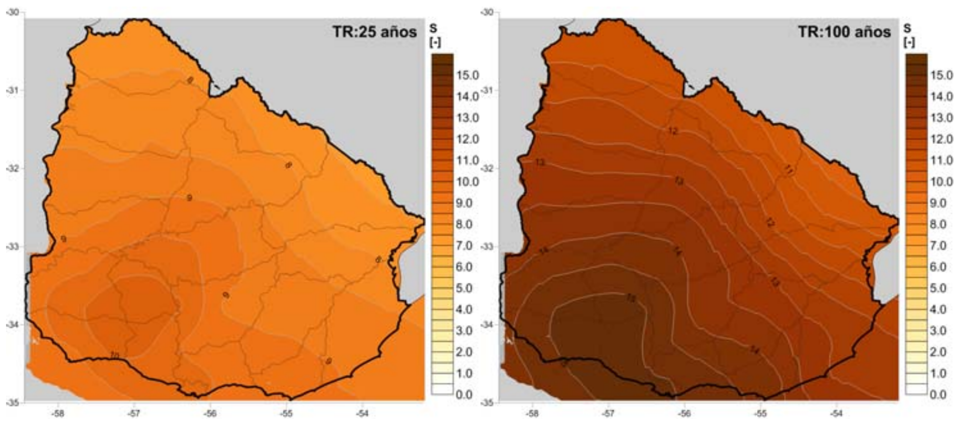

Figure 9. Drought hazard maps of Uruguay. 25 years (left) and 100 years (right) return period. The maps are given in terms of drought severity. Calculated with Drought Pro. (Cardona et al. 2017).

3. EXPOSURE AND VULNERABILITY MODULES

3.1 Exposure Editor

The description, characterization and appraisal of the physical inventory of the exposed elements for a probabilistic disaster risk assessment has been, in every case and at any scale, a process that has presented serious challenges for modeling. Appealing to the law of large numbers, characterizations and evaluations are carried out assuming that the errors are compensated in the final results by involving large estimations of exposed assets.

Exposure Editor provides tools for the creation of geographical exposure databases. The data is stored in a relational database, including both the elements attributes and their geometry. Exposure Editor supports connections to Oracle 10G and PostgreSQL. The exposure data can be inserted and modified directly from Exposure Editor, asset by asset or as groups of many asset. The data is interpreted by the main program and presented as layers in a map. Exposure Editor has basic capabilities of a Geographical Information System (GIS), that allow the user to navigate the map and query information of the visible layers. The exposure databases can be exported to ESRI Shapefile for further processing in a GIS.

3.2 Vulnerability Studio

For probabilistic risk assessment, the vulnerability of exposed elements is modelled using mathematical functions that relate the intensity of the hazard to the direct physical impact. Such functions are called *vulnerability functions* and they must be estimated (or assigned from existing databases) for each one of the construction classes identified in the exposure database. Vulnerability functions are characterized by the variation of the statistical moments of the relative loss to the hazard intensity. This enables the estimation of the loss probability function at each level of intensity.

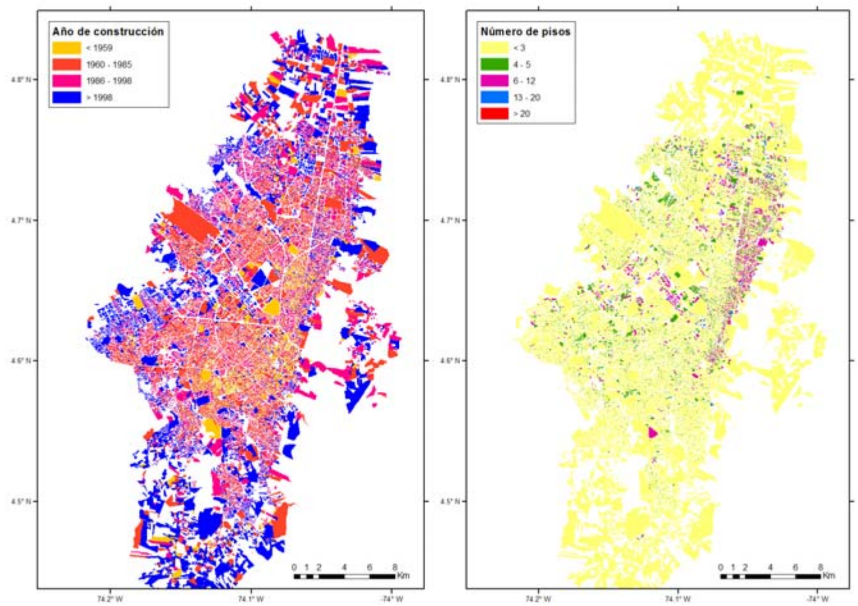

Figure 10. Maps of year of construction (left) and number of stories (right) of buildings in Bogotá, Colombia, from a database of 897,583 buildings created with Exposure Editor. From Cardona et al. (2016)

Vulnerability Studio is a software specialized in the creation and editing of vulnerability functions. It implements methods for creating vulnerability functions for different hazard intensities such as: earthquake strong motion, cyclone strong winds, coastal run-up (of storm surge or tsunami), PDC dynamic pressure, ash fall thickness and flood depth.

For earthquake, Vulnerability Studio supports different methodologies to create vulnerability functions: The methods proposed in ATC–13 (Earthquake Damage Evaluation Data for California; ATC, 1985), Capacity spectrum, Fragility Curves and Lognormal Function. It can create vulnerability functions for both physical loss and human casualties. In addition, Vulnerability Studio comes with a functions database which hosts all the vulnerability functions used in the Global Risk Model of the UNISDR GAR reports of 2013, 2015 and the GAR Atlas of 2017. An internet connection is required to query the database. All the vulnerability functions stored in the database can be edited within Vulnerability Studio.

4. RISK ASSESSMENT AND DATA MANAGEMENT MODULES

4.1 Probabilistic Framework in CAPRA

It is widely recognized that disaster risk assessment is a problem with several sources of uncertainty. Considering, for example, the seismic hazard, many aspects of the future earthquakes are unknow, such as when the next earthquake will occur, where, at which depth, with which magnitude, how the seismic waves will propagate through the earth's crust, how acceleration will amplify (or not) due to the response of soft soil or other site effects, how buildings and infrastructure will respond to strong motion (i.e. their level of vulnerability), and finally, how the damages caused by the earthquake are associated to economic or human losses.

As there are many sources of uncertainty, the problem seems impossible to solve. Fortunately, it is far from being so. Probability theory (and in a more general sense, random sets theory) brings the scientific tools to address problems with uncertainty. Additionally, actuarial theory for risk (commonly known as Lundberg-Cramér theory) provides the conceptual framework to approach the problem in terms of probability. Certainly, risk theory considers (as it is natural) that the occurrence of disasters is not determined in time. Fillip Lundberg proved in 1903 that the occurrence of losses in time can be modeled as a Poisson process. A Poisson process is a stochastic process, widely used in multiple applications in science and engineering, that sets the occurrence of events in time in a totally random way. The events, within this context, do not refer to hazardous events but to the occurrence of losses, independent from their origin. This is the reason why risk theory is suitable for any phenomenon, natural or not.

The Poisson process is defined in terms of a unique parameter, its intensity or rate. In catastrophic risk, this parameter is the loss exceedance rate. It is the inverse value of the average time between the occurrence of events that exceed a loss amount ***p***. Therefore, when calculating risk on a portfolio of exposed elements (i.e. the probability that a certain loss ***p*** is exceeded within a time window), its exceedance rate ***v(p)*** must be calculated as a function of the probability of occurrence of any of the possible hazardous events that exceed ***p***. This configurates a Poisson process which enables the estimation of the probability of exceedance of loss ***p*** within any time frame.

The assessment of the exceedance rates ***v(p)*** cannot be limited to a unique value of ***p***. Therefore, the Loss Exceedance Curve (LEC) is calculated (i.e. ***v(p)*** is calculated for any ***p***). The LEC provides an exhaustive quantification of the risk problem, in terms of probability. It will never be possible to know the exact magnitude of a future disaster (in terms of the loss and consequences that will cause), but it is possible with the LEC to know the probability than any loss amount will be exceeded within any time frame, and use this information to support the decision-making process for risk reduction.

4.2 CAPRA-GRM

CAPRA-GRM (Global Risk Model) is the risk calculation engine of CAPRA. CAPRA-GRM calculates the LEC for any exposed database, due to any of the supported hazards, using the above-mentioned probabilistic framework. This means that CAPRA-GRM does not rely on simulations approaches (such as Monte Carlo, for example), but on the analytical solution of the loss exceedance rates.

CAPRA-GRM is capable of aggregating losses from different hazards, into multihazard risk outcomes (see Figure 11). Besides the LEC, CAPRA-GRM also provides the Average Annual Loss (AAL) and the Probable Maximum Loss (PML) for the analysis portfolio. AAL is also computed asset by asset.

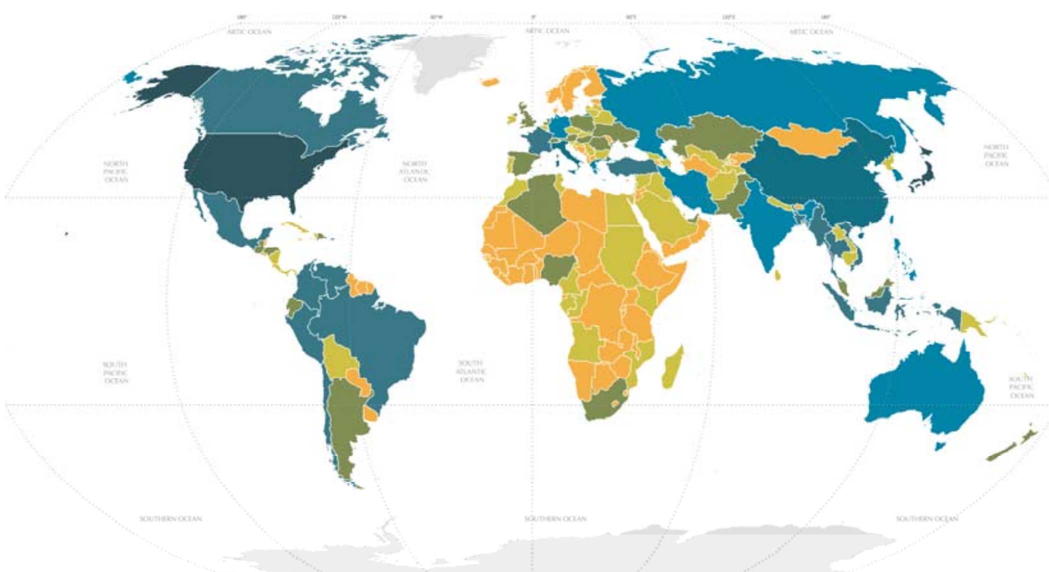

Figure 11. Map of multihazard AAL for 216 countries. Calculated with CAPRA-GRM for the Global Assessment Report, GAR, Atlas of Risk (UNISDR 2017; Marulanda et al. in these proceedings).

4.3 EvHo

EvHo stands for Holistic Evaluation (in Spanish: **Ev**aluación **Ho**lística). The holistic approach for risk assessment was developed by Cardona (2001) and Carreño (2006), and has been widely used in the past to incorporate socioeconomic aspects to the overall assessment of risk (Carreño et al., 2007; Marulanda et al., 2009; see Cardona et al. and Marulanda et al. in these proceedings). Within the Holistic approach (and within EvHo), the physical risk (the one calculated with CAPRA-GRM) is only one part of the risk evaluation process from a comprehensive perspective. The other components are defined in terms of social, political, environmental, and human development aspects (among others) that exacerbate the vulnerability conditions of settlements or economic sectors (as risk drivers or amplifiers), making the consequences of a disaster far more serious than what is revealed from the physical risk. EvHo implements the Holistic approach methodologies and applies Moncho's equation to quantify Total Risk, operating as a post-processor of CAPRA-GRM, to provide an integral, holistic, view of risk from many other perspectives.

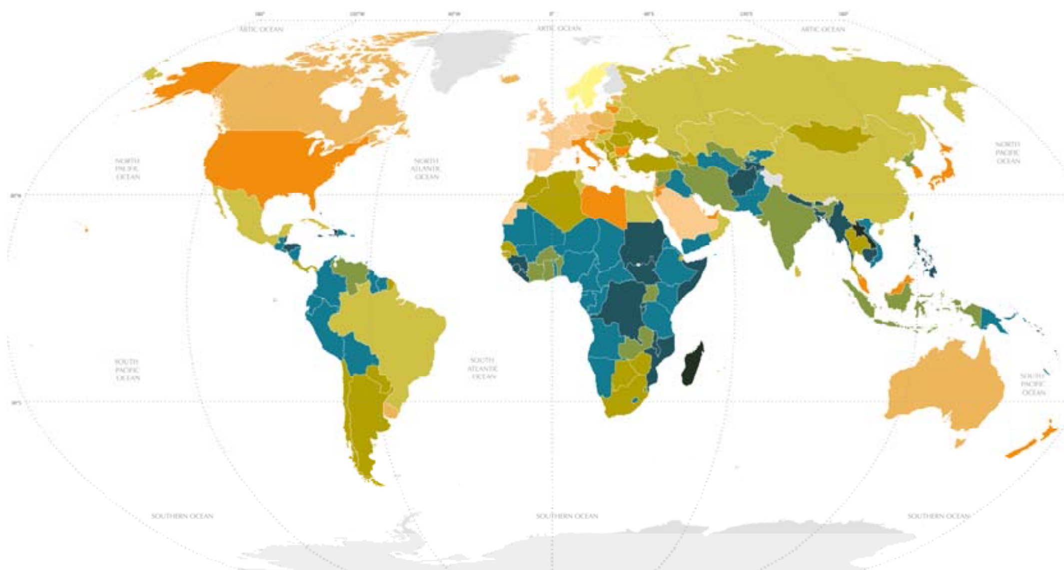

Figure 12. Map of Total Risk (Country Disaster Risk Index, CDRi) for 216 countries. Calculated with EvHo for the Global Assessment Report, GAR, Atlas of Risk (UNISDR 2017; Marulanda et al. in these proceedings).

4.4 FileCAT

FileCAT provides data management tools to the overall set of programs of CAPRA. It allows the user to list, organize and preview files of any kind, easily and quickly. Given that many of the file formats used within CAPRA are specific for the platform, FileCAT includes file preview functions of these file formats. Besides the CAPRA formats, FileCAT supports different type of files, such as: Documents (PDF, MS Office files, HTML), image (PNG, BMP, JPG, EMF), CAD (DWG, DXF) multimedia (AVI, WMV, MP4, MP3), among others. In addition, FileCAT comes with a Toolbox that comprises a set of small windows applications that are useful for executing small processes and formats conversion.

5. OTHER DEVELOPMENTS

5.1 LISA

LISA (Laboratory of Automated Seismic Information, in Spanish) is a tool designed to aid risk management in cities, as it provides important inputs for the correct assignment of physical and human resources during a seismic crisis. LISA constantly monitors the accelerograph network of the city from which receives the acceleration time-history recorded after the occurrence of an earthquake, and automatically calculates the intensities of strong motion at the ground surface, and the expected damage to buildings throughout the city. These results are published to an FTP site and sent via email and SMS to users registered in the system, a few minutes after the earthquake. Currently there are 4 LISA systems developed for the cities of Manizales (SISMAN-LISA) and Bogotá (SISMARB-LISA) in Colombia, and Port-of-Spain and San Fernando (Quake Response) in Trinidad and Tobago. Further details are presented in Bernal et al. (2016) and Cardona and Bernal in these proceedings.

5.2 CAPRA-based Modeling Systems

The CAPRA-based Modelling Systems are software suites, based in the CAPRA platform, that are personalized for a city or region. For example, a CAPRA-based modeling system was developed for Bogotá's Risk and Climate Change Management Institute (IDIGER). This platform, called SISMARB, is used to centralize and integrate all the efforts carried out from the different working areas within the Institute, in a way that it provides a better understanding of disaster risk in the city. SISMARB implements hazard and risk models for earthquakes and landslides (triggered by seismic activity and convective rainfall). SISMARB has been conceived as a software platform that will allow the Institute to manage all hazard and risk information, as well as to manage the calculation models that generate said information and results. It is a dynamic and updateable tool, capable of providing the Institute with the latest available information and with updated results, adapted to the changing reality of the city. Further details in Cardona et al. (2016).

6. CONCLUSIONS

The Next Generation CAPRA Software is presented in this paper, in terms of the general overview of the implemented risk calculation framework and summarized descriptions of its software modules. As was mentioned in the introduction, CAPRA is possibly the most advanced and comprehensive, free-of-charge, catastrophe modelling platform available nowadays. We have included along the text, several examples of results taken from ongoing and past projects in which CAPRA has been applied. This to illustrate the reader on the capabilities of the software, which has and still serves as a fundamental piece in disaster risk applications. One limitation of CAPRA is related to the use of rather simple hazard models in some modules (for example, some methodologies implemented in VHAST for volcanic hazard, are simplified approximations). Despite some of these approaches are simple, they are still robust for a good-enough risk assessment. This is not a generalized characteristic though, as some modules implement very advanced, state-of-the-art, hazard calculation models (for example, CRISIS, SMA, SMS, TCHM and Drought Pro). More than a limitation, this is a window of opportunity for further development in the future, to add robustness to hazard assessments in CAPRA.

Other hazards will be included in CAPRA in the next future. Currently the authors are working on modules of hail storms and forest fires. Regarding earthquakes, improvements are made constantly to these modules to keep up with the continuous advance of knowledge. In addition, Drought Pro is being expanded to incorporate models of impact in the hydropower generation infrastructure and on the water availability for human consumption. Furthermore, new improvements to the general catastrophe risk theory are being developed by the authors, to coherently incorporate Climate Change estimations into the risk assessments from hydrometeorological hazards, by expanding the framework to non-homogeneous Poisson processes. We hope that, 10 years from now, CAPRA looks very different from what is presented here, as our desire is that it keeps evolving, gaining robustness and complexity, and becomes the center of an even larger community of researchers and users worldwide.

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