FP7 Grant Agreement N° 312450

CIPRNet

Critical **I**nfrastructure **P**reparedness and **R**esilience Research **Net**work

Project type: Network of Excellence (NoE)

Thematic Priority: FP7 Cooperation, Theme 10: Security

Start date of project: March 1, 2013 Duration: 48 months

D7.5+7.6 Integration of meteo-climatological simulators, flood forecasts, earthquakes data and analysis tool and Interface to the technical demonstrator for federated CIP MS&A

Due date of deliverable: 31/12/2015
Actual submission date: 24/03/2016

Revision: Version 1

Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)

Project co-funded by the European Commission within the Seventh Framework Programme (2007–2013)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Author(s)	Vittorio Rosato (ENEA), Alberto Tofani (ENEA), Maurizio Pollino (ENEA)
Contributor(s)	Jingquan Xie (FRAUNHOFER), Micheline Hounjet (DELTARES)

Security Assessment	**See deliverables table for security assessment requirements**
Approval Date	9 March 2016 (Hanneke Duijnhoven, TNO)
Remarks	No issues

The project CIPRNet has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 312450.

TABLE OF CONTENTS

1 Introduction – Rationale of this document

The purpose of the deliverable is twofold: 1) to show the simulation facilities that the Decision Support System (DSS) will utilize for predicting the expected geo-physical scenario in a time frame comprised from a fraction of an hour to several days (72 hours) and how these facilities are integrated into the overall DSS workflow [D7.1]; 2) to describe the interface between the DSS and the technical demonstrator for federated CIP MS&A named CIPRTrainer [D6.3].

In particular, the document describes the interfaces between the DSS, the simulation facilities and the CIPRTrainer tool implemented within two DSS instances. The first DSS instance is related to the metropolitan area of Rome city (referred as DSS-IT). The DSS-IT implements the weather and the earthquake workflows described in detail in [D7.1]; these workflows allow the risk forecast on CI networks, primary services and society of heavy rain events, lightening and earthquake events starting from the acquisition of field data. At the moment there is no interface between the DSS-IT and the CIPRTrainer tool.

The second DSS instance (referred as DSS-DE/NL) is related to the cross borders scenario described in [D6.2]. In this case the DSS instance allows the crisis management what-if analysis considering three CI networks on a geographic location across the Dutch-German border where the Rhine River flows. In this case the DSS instance integrates the CIPRTrainer tool that is used to analyse different mitigation strategies for the considered CI networks affected by extreme flooding events.

Regarding the simulation facilities some of them consist of known simulation codes (related to assessed models) run by third parties whose results are available to the CIPRNet consortium (either as being publicly available data or through the action of some collaborative effort with the involved third parties). Others are, in turn, purposely developed for the CIPRNet activity or being related to the institutional work of the different partners. Figure 1 shows an example of internal/external simulation facilities and the relation of the simulation facilities described in this document with the general DSS workflow [D7.1]. In both cases, they will be described in some detail and their integration into the DSS workflow reported.

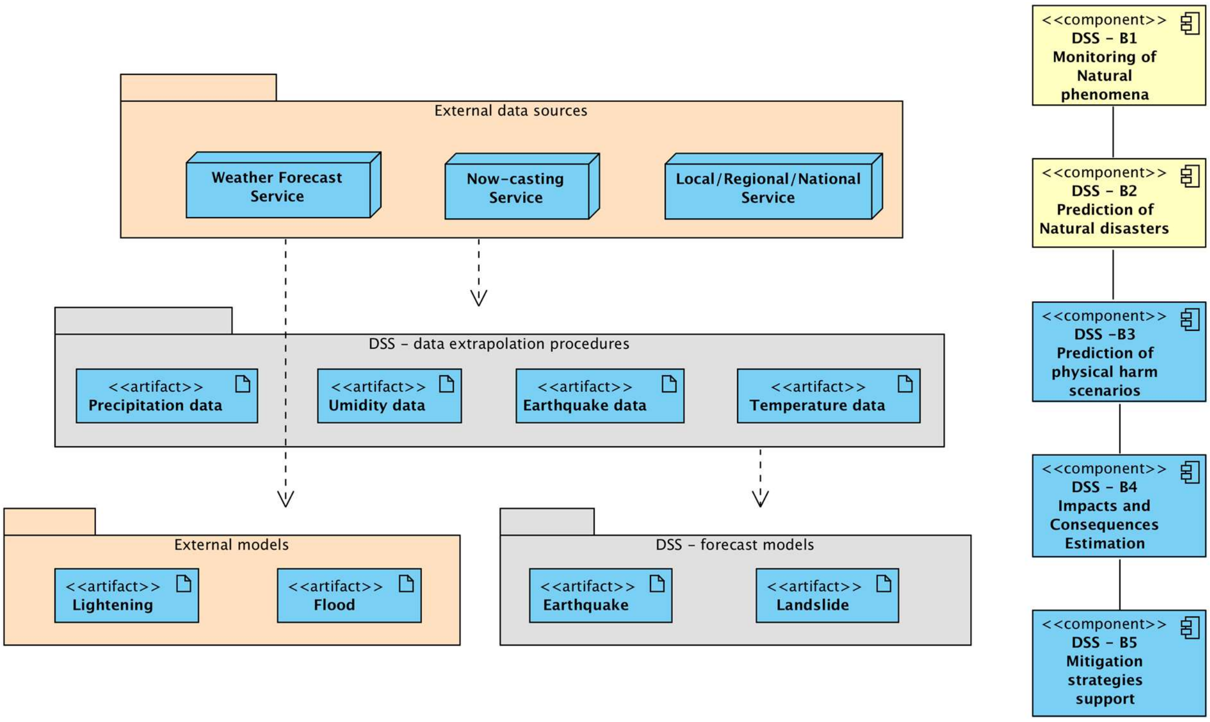

Figure 1 Examples of DSS internal/external simulation facilities; on the right, the involved DSS workflow functional blocks [D7.1]

Figure 2 shows the main component of the technical demonstrator for federated CIP MS&A and the involved DSS functional blocks.

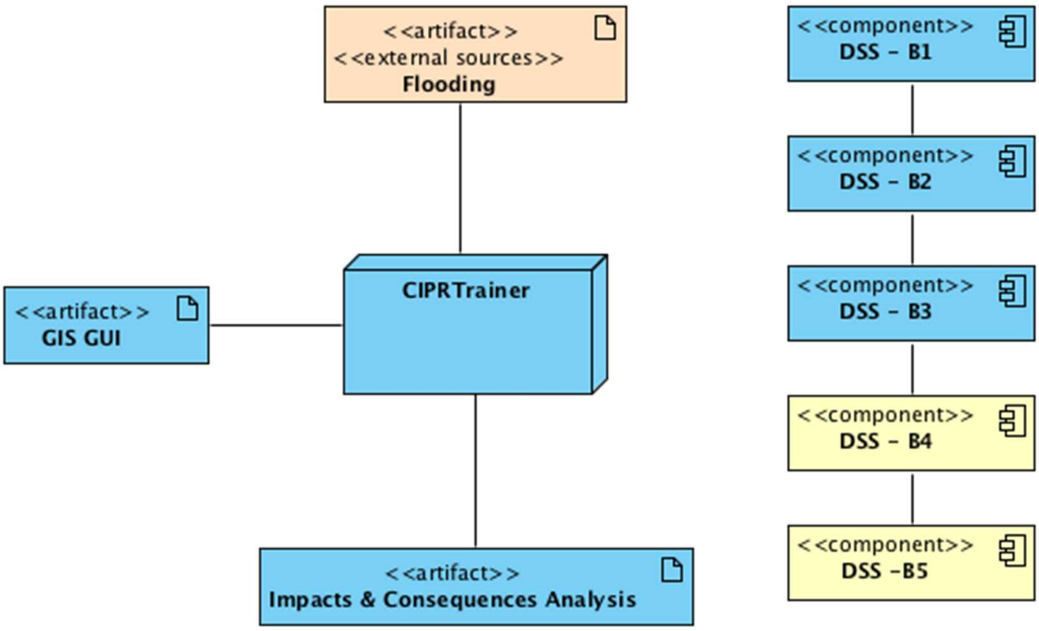

Figure 2 The CIPRTrainer tool and the involved DSS functional blocks

1.1 Document structure

The document is organized as follows:

- Section 2 describes the simulation facilities, in particular the following prediction systems will be described in detail:
    a. the weather forecast
    b. the now-casting
    c. the lightning forecast system
    d. the flooding system (both the 1D and the 2D models)
    e. the earthquake simulator
- Section 3 described how the simulation facilities, their output are integrated within the DSS workflow.
- Section 4 describes the interface of the DSS to the technical demonstrator for federated CIP MS&A.

2 Simulation facilities

The DSS needs to acquire from internal or external *ad hoc* simulation models the expected geo-physical scenario (with a specific forecast time); this information triggers the evaluation of the damage scenario which is performed by correlating the intensity (the severity grade) of the predicted events and the intrinsic vulnerabilities of the different infrastructural assets present in the hit territory [D7.1].

Indeed, the DSS will use other techniques to improve and enforce the predictions made on the bases of the models: the acquisition of field data (where available) by collecting the real time data from field sensors. The DSS has been provided the ability to acquire field data from:

- Seismic sensors.
- Weather stations (reporting data on rain abundance, temperature, humidity, winds, pressure etc.) present in the territory and other devices that could be used to assess the specific weather conditions in a given area.
- Satellite data (i.e. SEVIRI and MODIS satellite data, appropriately post processed by the Italian National Geophysical and Volcanology Institute, INGV, describing the extension of ash clouds surrounding volcanic area during the periods of volcanic activity).

In Section 3, the integration of these data sources into the DSS workflow will be described.

Concerning the major sources of prediction data, in the following sections we will describe the forecasting systems used within two instances of the DSS related to the metropolitan area of Rome (DSS-IT) and the cross borders area between Germany and The Netherlands (DSS-DE/NL). In particular, the following forecast sources will be discussed:

- Weather forecast (DSS-IT). Thanks to a collaboration that ENEA has with the Italian company HIMET SRL in the frame of an Italian National Research project (project RoMA, "Resilience enhancement Of a Metropolitan Area"), the CIPRNet DSS-IT has access to the weather forecast data. In particular, the HIMET[1] [HIMET] company provides LAM (Local Area Model) simulation data related to:
    - *Nowcasting*. The accessed and achieved data are sufficient to estimate damage scenarios and no further data elaboration is made in the DSS

[1] HIMET S.r.l: http://cetemps.aquila.infn.it

- *Lightning*. The accessed and achieved data are sufficient to estimate damage scenarios and no further data elaboration is made in the DSS

These data are related to the metropolitan area of Rome and a large part of the Lazio region. In the future would be of fundamental importance to have access to other sources of data as for instance the weather forecast data of the Italian Civil Protection (data that cover all the Italian territory). The acquisition of new, institutional and more extended data sources is on on-going effort of each partner both for research purposes that for the future deployment of the implemented services within the European Infrastructures Simulation & Analysis Centre (EISAC) that represent the long standing objective of the CIPRNet project.

- Hydrogeological forecast (DSS-DE/NL).
  - *Flooding forecast.* The DSS receives flooding forecast data from different sources. For what-if analysis the DSS makes use of historical flooding maps [LIZARD]. Regarding the acquisition of real time flooding forecasting data DSS will use European and National Flooding Forecasting services (e.g. EFAS[2], RWsOS[3] [EFAS, RWsOS])
- Earthquakes (DSS-IT). In this case, given as initial assumption that no real prediction can be achieved for earthquakes, the DSS receives data from the National websites where official information on the detected earthquakes are released. For example, in Italy, the DSS receives data from the website ISIDE [INGV], the Italian Seismological Instrumental and Parametric Database which promptly releases data on occurred earthquakes (within 1 min from their occurrence). Earthquake information consists of the GPS coordinates of the epicentre, its depth and the measured intensity (Richter scale). In this case, in turn, the accessed and achieved data are not sufficient to estimate damage scenarios. For this reason, the DSS provides further elaboration of these data (for the expected shake maps evaluation) whose final result is input into the damage scenario evaluation section of the DSS workflow.

The acquisition of forecasting sources for the different DSS instance is on on-going work. At the end, all DSS instances should comprise all forecast sources for each natural event relevant for the specific area of interest. For instance, the DSS-IT (and in particular the DSS for the metropolitan area of Rome) will acquire flooding forecast data related to the Tiber river.

2.1 Weather forecast

In the case of CIPRNet, ENEA has agreed with the company HIMET Srl (co-partner of ENEA in the Italian funded project RoMA) the free use of their forecast data (weather forecast, now-casting and lightning probability) for research purposes. In particular, HIMET provides to the CIPRNet DSS ECMWF (European Centre for Medium-Range Weather Forecasts4) data related to a large fraction of the centre area of Italy, comprising the Regione Lazio. ECMWF is an independent intergovernmental organisation supported by 34 states. ECMWF is both a research institute and a 24/7 operational service, producing and disseminating numerical weather predictions to its Member States. This data is fully available to the national meteorological services in the Member States [ECMWF]. HIMET, starting from ECMWF data (Figure 3) and using data coming from their radar network and sensors, is able

[2] European Flooding Awareness System: https://www.efas.eu

[3] Operational Forecasting System for the North Sea - https://www.deltares.nl/en/projects/rwsos-north-sea-operational-forecasting-system-north-sea/

[4] http://www.ecmwf.int/

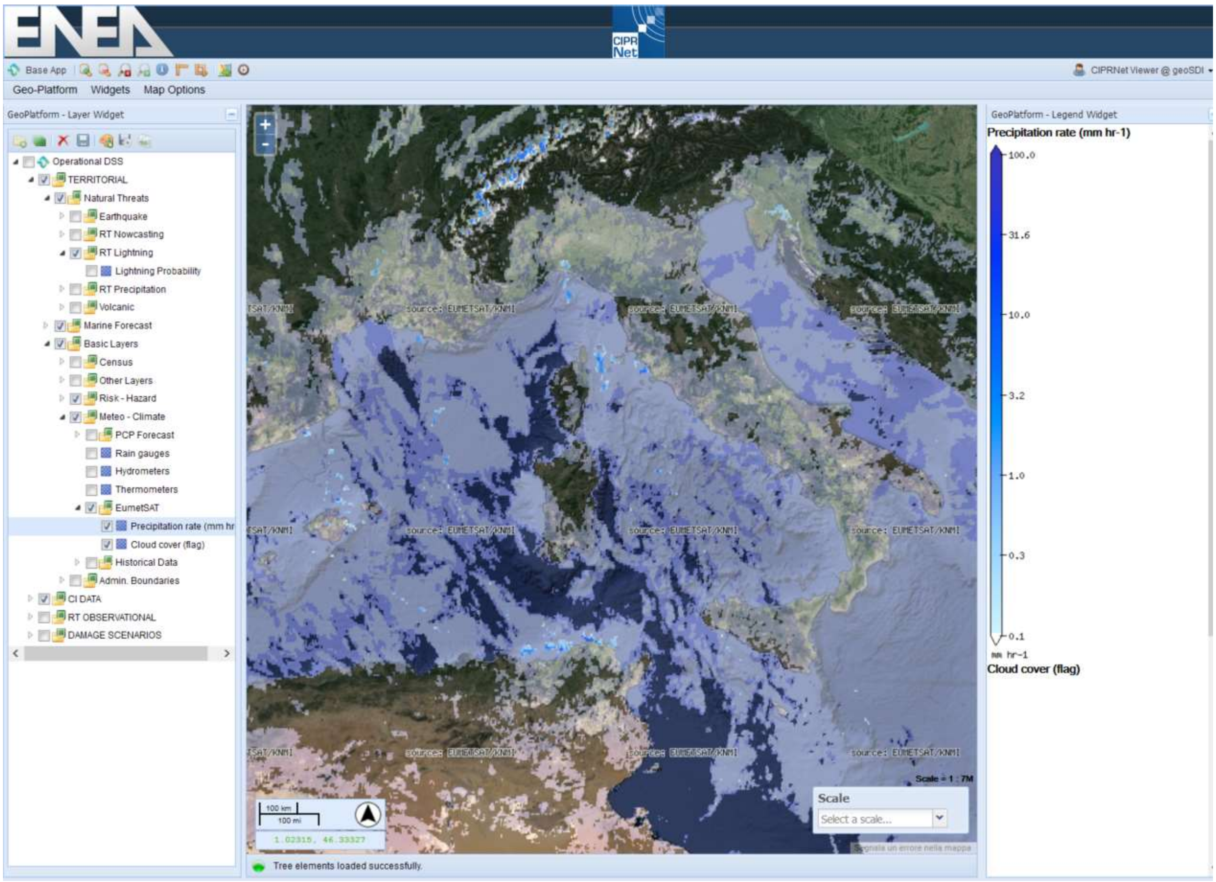

Figure 3 Cloud cover and precipitation rate map views (data source: Eumetsat/ECMWF)

to downscale the weather forecast data to a Local Area Model, in order to create a specific map reporting the spatial distribution (approximately, 5 km x 5 km) of the precipitation rate of rainfall forecasts (mm·hr-1). Forecasts are produced and available for a time span from 0 to 48 hours (6-hours intermediate steps), starting from 0:00 AM – UTC of each day. Such data are continuously and automatically retrieved from a specific HIMET web-service, in NetCDF[5] format, and directly stored into the CIPRNet DB, in order to exploit them within the DSS application (Figure 4).

[5] http://www.unidata.ucar.edu/software/netcdf/

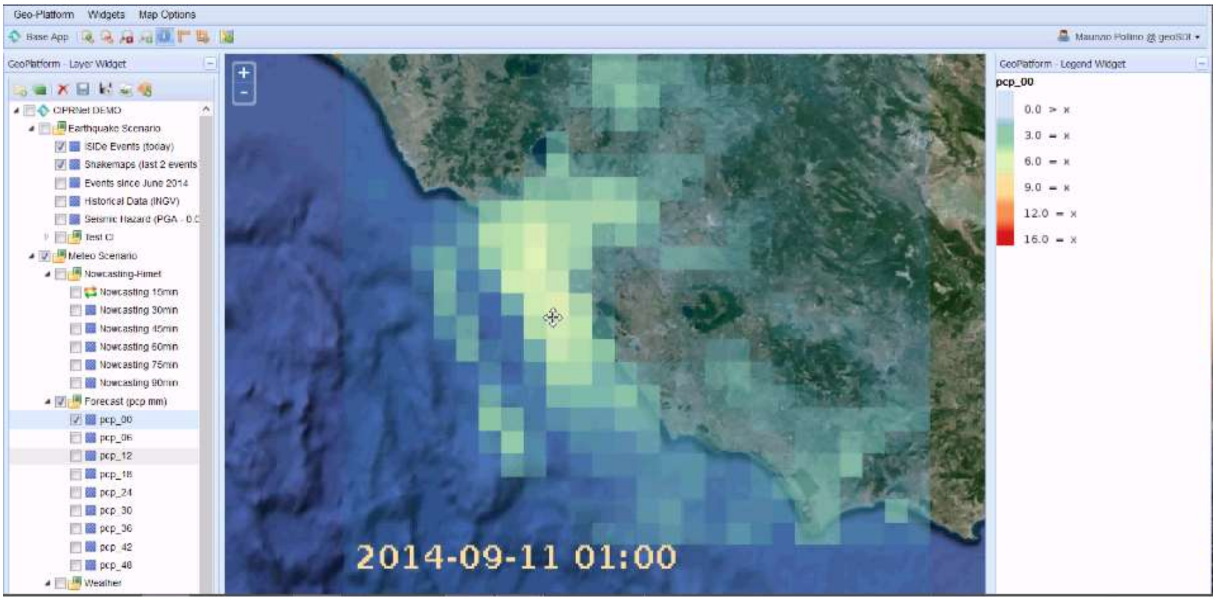

Figure 4 Precipitation rate forecast example map (source: Himet processing of ECMWF data)

2.1.1 Nowcasting

Nowcasting is operated by the use of Meteorological Radars. In the case of CIPRNet, ENEA has agreed with the company HIMET Srl (co-partner of ENEA in the Italian funded project RoMA) the free use of their nowcasting and lightning data for research purposes.

HIMET has a meteorological radar station (X-band) at Mount Midia (in the Apennine region, nearby the city of L'Aquila) whose data covering a large fraction of centre Italy fully comprising the Regione Lazio, are constantly acquired and treated to extract. From the reflectivity signals the rain abundance is estimated. The data are subsequently post processed in order to get the rain abundance prediction, in a grid of 800 Mt of resolution, for the subsequent 90 minutes from the current time. The resulting data (Figure 5) are then inserted into the DSS DB and used to estimate the resulting damage of the CI elements.

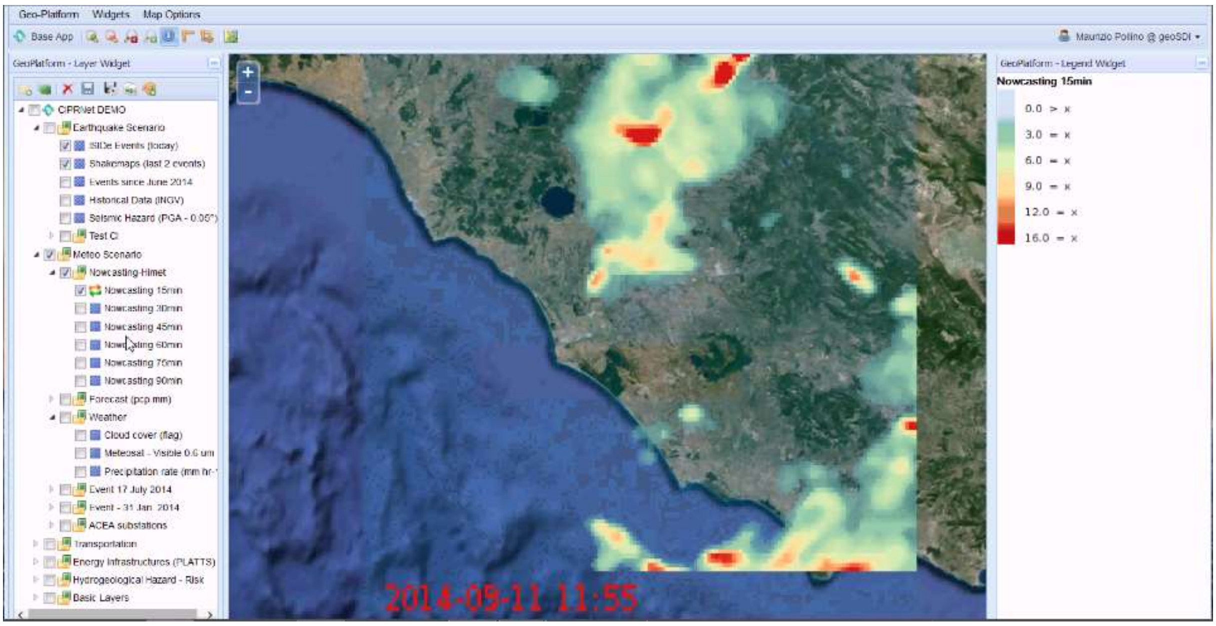

Figure 5 Screen snapshot of the nowcasting prediction

2.1.2 Lightning

As for the nowcasting, the company HIMET Srl provides the lightning prediction. Each 15 minutes, the CIPRNet DSS acquires the lightning probability data related to the next 45 minutes and visualises these data on the geographical interface of the DSS. HIMET computes the lightning probability using various indices of the Weather Research and Forecasting model[6] and the area of monitoring covers a large fraction of centre Italy fully comprising the Regione Lazio (the area of monitoring is centred on the Avezzano city with a radius of about 50 km). Figure 6 shows an example of a lightning probability map. Following the HIMET guidelines for lightning probability greater the 60% the CI operators should monitor their infrastructures and in particular those components that are vulnerable to lightning events.

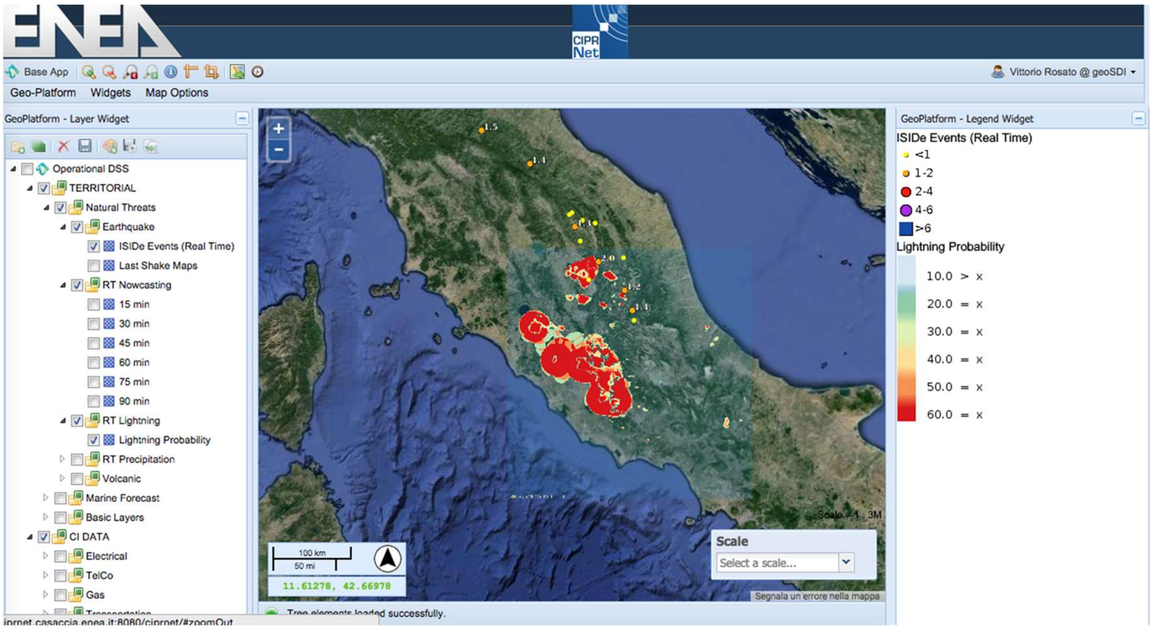

Figure 6 A snapshot of the Lightning Probability map

2.2 Flood simulation and forecasting

The simulation of flooding including flood depths, flow velocities and flood extents is a challenging task and requires high computational effort. Depending on the type of flooding and the required properties of the results, regarding the spatial resolution and accuracy, different modelling approaches are available.

While for smaller areas with a distinctive representation of differences in elevation simplified GIS based approaches can be applied, larger areas require more complex two-dimensional or even three-dimensional flood models, which have to be implemented and calibrated.

In the Netherlands, comprehensive computations have been carried out for the entire country under responsibility of the water boards and in close collaboration with research institutions and private consultants. Possible flooding scenarios have been defined using a harmonized national methodology and various pre-defined boundary conditions for all dike ring areas. The horizontal resolution of these datasets is typically 100 m with a vertical resolution of 1 cm. In the CIPRNet project there are 2 basic way to integrate flooding information, off-line and real time situation that will be described in the following.

[6] http://www.wrf-model.org/index.php

2.2.1 Off-line situation

For the off-line situation, like in a training or exercise situation using the CIPRTrainer, we use pre-calculated flood maps for specific areas. These maps have been calculated according to the EU flood directive and ensure a high quality of the information. These maps cover the most relevant scenarios for a specific region and are therefore very realistic. The results of all flood scenarios are stored and provided within the national flood database “Lizard flooding” [LIZARD], which is a nationwide information system for flood scenarios. It is important to highlight that the regional water boards own the scenarios.

The database facilitates the view of different national and cross-border flood scenarios (Figure 7), related economic damages as well as the number of fatalities to be expected. It is further possible to access and download these scenarios for further analysis, subject to clearance by the owner of the data, i.e. the particular water board.

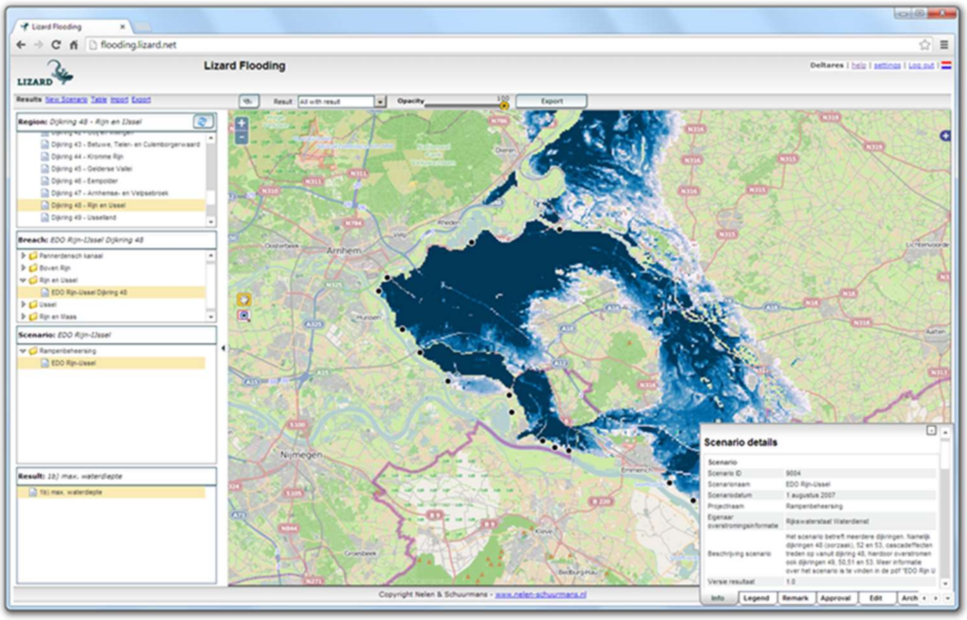

Figure 7 Example of flood scenario in the Lizard database

The regional water board “Waterschap Gelderland”, which is in charge of the area along the river Rhine around the Dutch-German border, gave their approval to use the flood scenarios from the VIKING project in WP6 of the CIPRNet project [D6.2].

The database covers at least 16 breach locations on the left bank and 14 different dike breach locations on the right bank of the river (Figure 8, black spots), for which both datasets ‘max. flood depth’, ‘max. flow velocity’ are available for further analysis. For selected breach location, scenarios for different boundary conditions can be found in the database.

Figure 8 Dike breach locations on the left bank (left figure) and right bank (right figure) in the study area of the CIPRNet WP6

For the what-if analysis in WP6 it is proposed to make use of the results for different dike breach locations at the Dutch-German border.

2.2.2 Real-time situation

For a real-time situation the CIPRNet DSS will link to existing national flood forecast services, as available in most EU countries or provided from the EU via the European Flood Awareness system (EFAS) (see Figure 9). For specific regions dedicated flood forecasting systems can be set-up and used. Every national, regional or local authority involved in flood forecasting within its country can become an EFAS partner. EFAS flood forecasts are provided via password-protected web interface and web services to ensure that the legal obligations of the partners to issue flood warnings to the public are respected. EFAS forecasts are provided for free and are not limited to EU Member States.

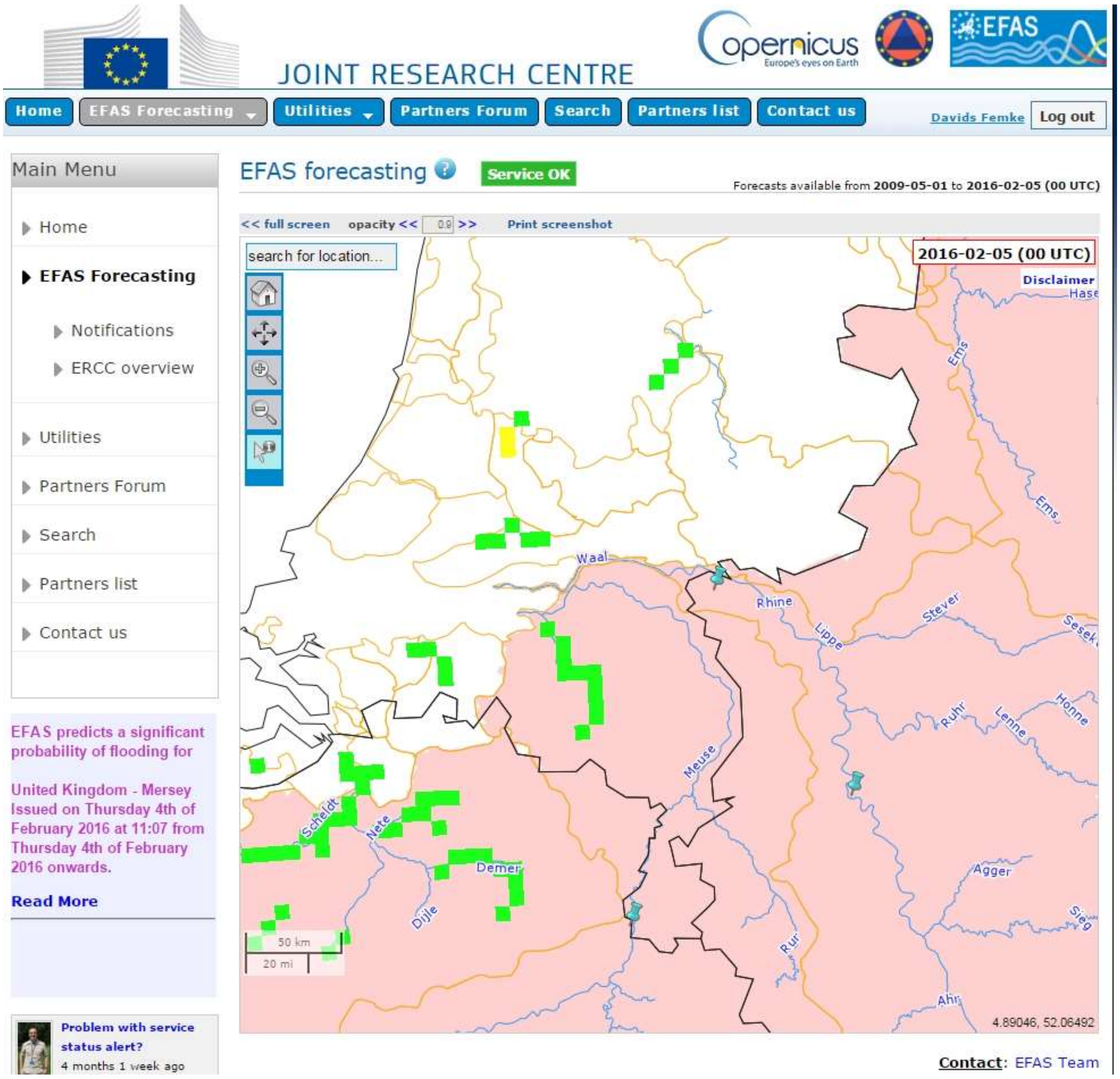

Figure 9 Screenshot of EFAS forecast

For the Netherlands the flood forecasting information will come from the national Forecasting system (RWsOS) (see Figure 10). This system includes forecasting (FEWS Flood Early Warning System) models and interfaces for water level forecasting at the coast, the larger lakes and the main river braches. In case of a high water situation, the water level forecasts can be used to select an appropriate (pre-calculated) flood map. In future the system could be extended with real-time flood extend simulation; newly developed software will enable sufficiently short calculation times. FEWS itself is open source, but the application for RWsOS is developed for Rijkswaterstaat. Several national partners like for instance KNMI (Metoffice of NL) are allowed access to it.

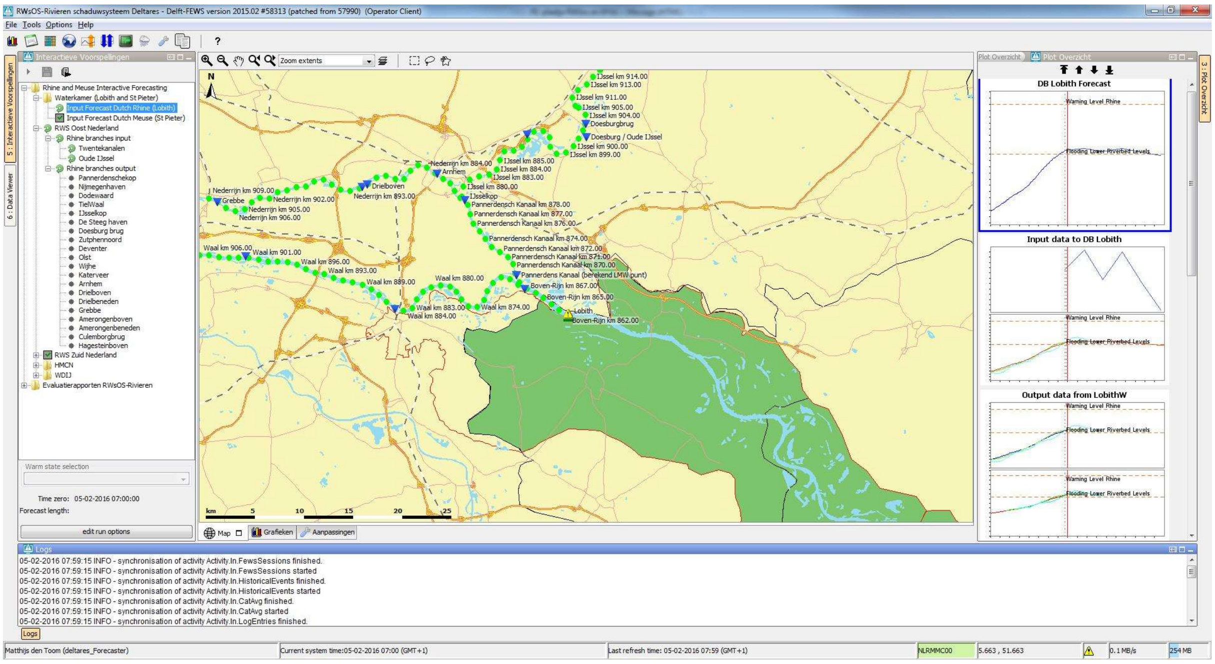

Figure 10 Screenshot of RWsOS system

2.3 Earthquakes

The DSS constantly polls the national public website (in Italy the ISIDe website), which usually provides the recorded information of the last earthquake occurred (in Italy, for ISIDe) with a very short time delay from the shock (usually within less than a minute). Figure 11 reports a typical snapshot of the ISIDe website[7].

ITALIAN SEISMOLOGICAL INSTRUMENTAL and PARAMETRIC DATA-BASE ISIDe

Home Earthquakes Instruments Contacts Language F.A.Q. Enter ISIDe

Italiano English

Last update: August 2012

Lista degli ultimi 20 eventi sismici registrati dalla Rete Sismica Nazionale

Questa lista si aggiorna ogni 10 minuti.

Ultimo aggiornamento (ora locale): 06-12-2015 11:50:02

Tempo Origine (UTC)	Lat	Lon	Prof (km)	Mag	Comuni entro 20km
2015-12-06 10:35:08	43.2	13.1	14.0	ML 1.1	GAGLIOLE(MC) CASTELRAIMONDO(MC) SAN SEVERINO MARCHE(MC) ...
2015-12-06 10:08:46	42.4	15.2	20.0	ML 3.0	-- Nessuno --
2015-12-06 10:02:33	38.5	14.8	10.0	ML 2.5	LENI(ME) MALFA(ME) SANTA MARINA SALINA(ME) ...
2015-12-06 08:54:34	42.4	15.3	17.0	ML 2.7	-- Nessuno --
2015-12-06 07:20:08	38.9	16.0	52.5	ML 2.2	FALERNA(CZ) GIZZERIA(CZ) NOCERA TERINESE(CZ)
2015-12-06 06:49:09	43.1	13.1	10.4	ML 0.8	CAMERINO(MC) SERRAPETRONA(MC) PIEVEBOVIGLIANA(MC) ...
2015-12-06 05:59:04	42.5	15.3	33.8	ML 2.7	-- Nessuno --
2015-12-06 05:35:52	42.4	15.2	28.6	ML 2.8	-- Nessuno --
2015-12-06 05:34:22	42.6	15.4	25.1	ML 2.8	-- Nessuno --
2015-12-06 05:30:41	42.4	15.2	21.6	ML 3.4	-- Nessuno --
2015-12-06 05:28:11	42.6	15.1	26.4	ML 3.9	-- Nessuno --

Figure 11 Snapshot of the Italian ISIDe website

7 http://iside.rm.ingv.it/iside/standard/index.jsp?lang=en

Once earthquake data are issued, the DSS crawler picks them up and reports them into the synoptic chart of the DSS GIS web interface. Figure 12 shows the corresponding result on the GIS interface the same day the ISIDe snapshot has been taken.

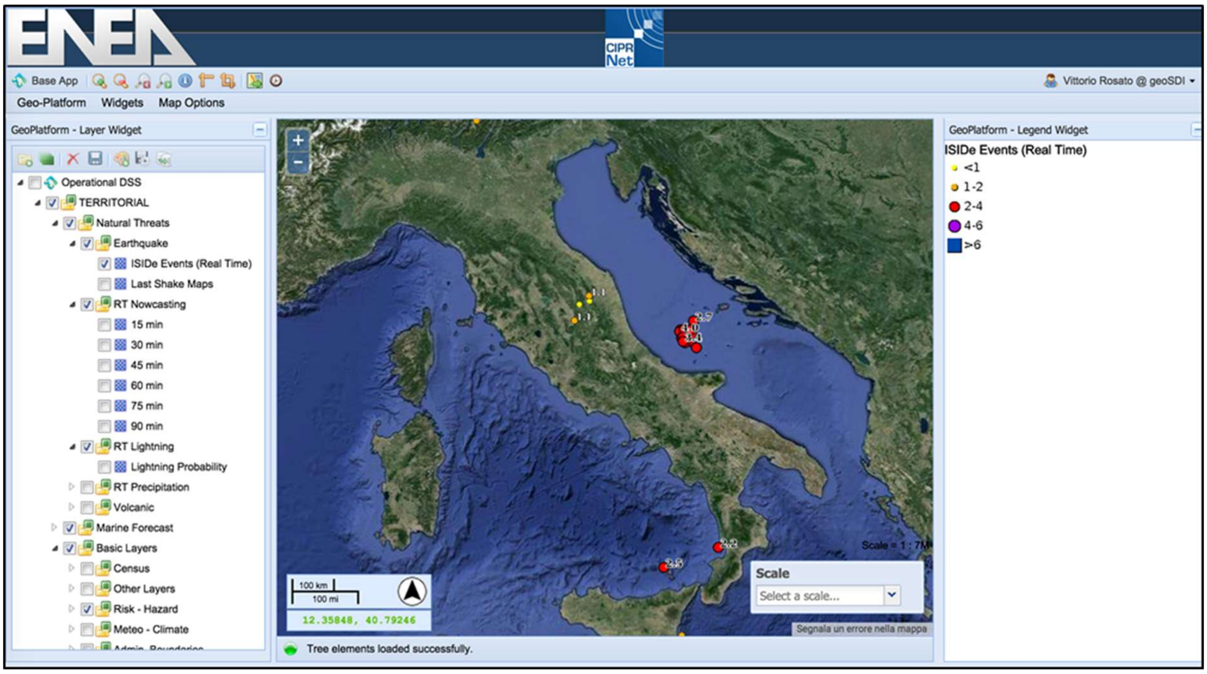

Figure 12 ISIDe data are immediately reported into the DSS DB and visualized on the GIS web interface.

However, the simple knowledge of the coordinates, the depth and the magnitude of the earthquake (basic earthquake's features) are not sufficient to estimate the "physical manifestations" associated to the natural event. Indeed, the earthquakes create distinct types of waves with different velocities; when reaching seismic observatories, their different travel times allow locating the source of the hypocentre:

- Primary waves (P-waves) are compressional waves that are longitudinal in nature and travel faster than other waves through the earth to arrive at seismograph stations first (hence the name "Primary");
- Secondary waves (S-waves) are shear waves that are transverse in nature: following an earthquake event, S-waves arrive at seismograph stations after the faster-moving P-waves and displace the ground perpendicular to the direction of propagation.

In the case of local or nearby earthquakes, the difference in the arrival times of the P and S waves can be used to determine the distance to the event. Once ISIDe operators perform their validation procedures, data of last earthquakes are immediately available: based on the basic earthquake's features, the DSS is able to convert them into a Shake Map dataset which contains, for each spatial point of a given area (as large as that involved by the physical manifestations associated to the event), the Peak Ground Acceleration (PGA) distribution induced by the seismic event. Figure 13 shows an example of a shake map.

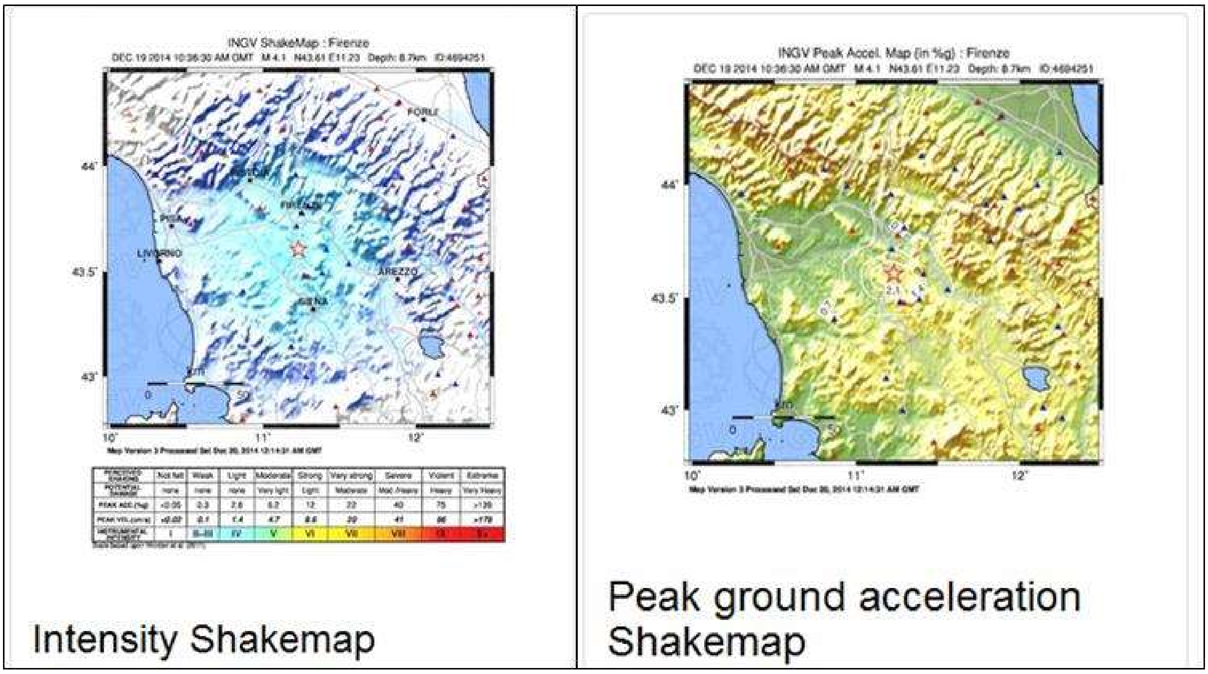

Figure 13 A typical shake map of an earthquake, with the indication of the peak ground acceleration and the intensity.

Shake maps are usually measured by seismometers spread over the territory (data are first collected and then post processed by INGV, the Italian national seismic Authority) and then released by the INGV through the specific information websites. This process normally takes a time of the order of a fraction of hour (20-30 min). In order to have available an earthquake shake map in a shorter time (in order to use them for rapidly estimating expected damages), the DSS, starting from the basic earthquake's features, tries to estimates the "predicted shake map" (Figure 14) on the bases of empirical propagation models of shock waves in the ground and of the specific ground seismic properties (lithography and waves conductivity properties). Two different approaches have been implemented:

1) Empirical prediction of Macroseisminc Intensity/PGA propagation without local site seismic effects;
2) Empirical prediction of Macroseisminc Intensity/PGA propagation with local site seismic effects.

Concerning the first approach (without local site effects), the methodology proposed by Akkar and Bommer[8] (2007) has been adopted. In this case, for seismic events with low magnitude (< 4), PGA is estimated as follows:

$$log_{10}(PGA) = A + B \cdot (M - 6) + C \cdot log_{10}[sqrt(R\_epi^2 + H^2)]$$

where:

M is the magnitude of the earthquake;

R_epi is the distance from the epicentre (in km);

and A, B, C and H are statistical parameters (these parameters can be applied for the Italian geolithological conditions):

[8] Akkar, S. and Bommer, J.J., 2007. "Empirical prediction equations for peak ground velocity derived from strong-motion records from Europe and the Middle East," Bulletin of the Seismological Society of America, Vol. 97(2), 511-530

A = 4.037; B = 0.572; C = -1.757; H = 6.0

In case of events with magnitude greater than 4, Akkar and Bommer have proposed the following formula:

$$log_{10}(PGA) = b_1 + b_2 \cdot M + b3 \cdot M^2 + (b_4 + b_5 \cdot M) \cdot log_{10}[sqrt(R\_epi^2 + b_6^2)]$$

where:
M is the magnitude of the earthquake;
R_epi is the distance from the epicentre (in km)
and:

b1	b2	b3	b4	b5	b6	s1	s1m	s2	s2m
1.647	0.767	-0.074	-3.162	0.321	7.682	0.557	-0.049	0.189	-0.017

Then, PGA conversion to I_{MCS} (Macroseismic Intensity) is performed, by means the Decanini et al.[9] formula (1995):

$$log\ PGA = 0.594 + 0.197 \cdot I_{MCS}$$

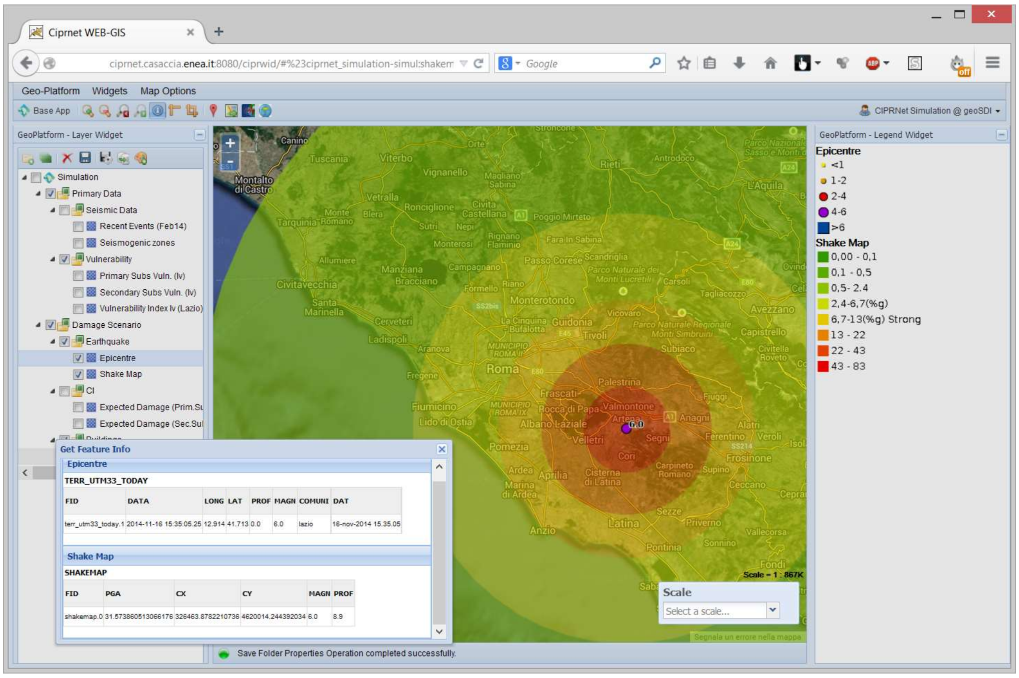

Figure 14 Simulated empirical shake map, produced by means of the Akkar and Bommer approach (without taking into account local site effects

9 Decanini, L., Gavarini, C. & Mollaioli, F., 1995. «Proposta di definizione delle relazioni tra intensità macrosismica e parametri del moto del suolo», Atti 7.mo Convegno L'ingegneria sismica in Italia, 1, 63-72

The second approach is applied when local site information about surface geology and lithology are available, in order to properly take into account of local amplification factors of seismic waves. In this case, it is possible to estimate directly the macro-seismic intensity I_{MCS0}, by means of the Crespellani et al. formula (1992):

$$I_{MCS0} = 8.6 + 1.4M - 6.4 \ln(R\_epi + 14)$$

where:

M is the magnitude of the earthquake;

R_epi is the distance from the epicentre (in km).

By taking into account the amplification factor *fa* for the area of interest, local site effects can be considered in terms of increments ΔI of the macro-seismic intensity as follows:

$$\Delta I = \frac{\ln fa}{\ln 1.6}$$

and, consequently:

$$I_{MCS} = I_{MCS0} + \Delta I$$

Thus, both for approach 1) and approach 2), the mean damage[10] μ_D is assessed by calculating it as function of macro-seismic intensity I_{MCS}, Vulnerability (V) and Ductility (Q = 2.3):

$$\mu_D = 2.5\left[1 + \tanh\left(\frac{I + 6.25V - 13.1}{Q}\right)\right]$$

ENEA is improving the DSS GUI to allow end user to choose the more suitable seismic attenuation formula for the specific area and local site condition. Currently, this new capability is under testing considering the Tuscany region as the focus area (Figure 15). The final objective is to define different seismic attenuation formula in order to cover all the National territory.

[10] S.Giovinazzi, S. Lagomarsino: A macroseismic method for the vulnerability assessment of buildings. 13th World Conference on Earthquake Engineering, Vancouver, BC, Canada (2004)

S. Lagomarsino, S.Giovinazzi: Macroseismic and mechanical models for the vulnerability and damage assessment of current buildings. Bull Earthquake Eng., 4:415-443 (2006)

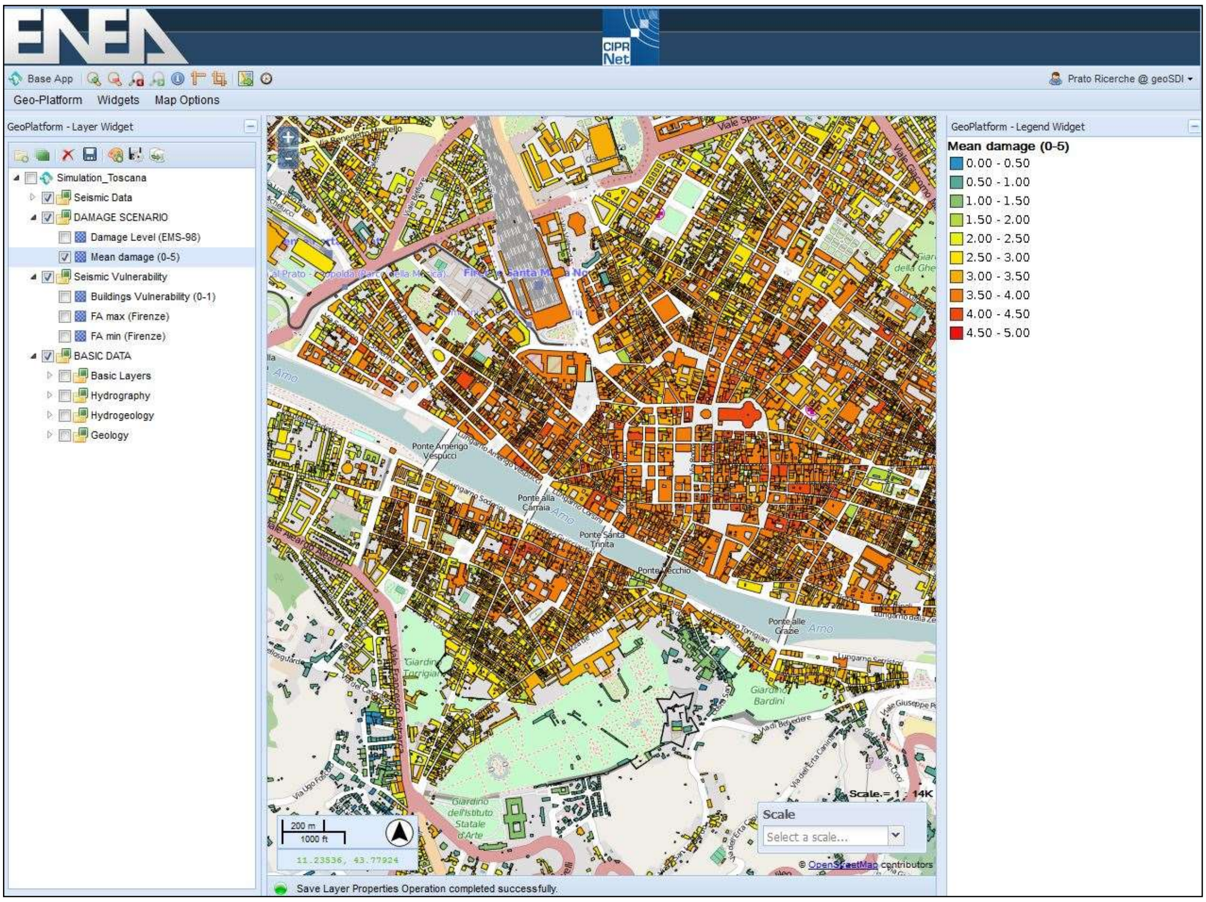

Figure 15 Map reporting the distribution of buildings mean damage, produced for a simulated earthquake in the area of Florence (Italy)

3 Meteo-climatological simulators, flood forecasts, earthquakes data and DSS integration

This section describes the details related to the integration of meteo-climatological simulators, flood forecasts, earthquakes data within the DSS workflow. Data Flow Diagrams are used to specify integration of data and DSS workflow. Figure 16 shows the main building blocks of a Data Flow Diagram (DFD in the following).

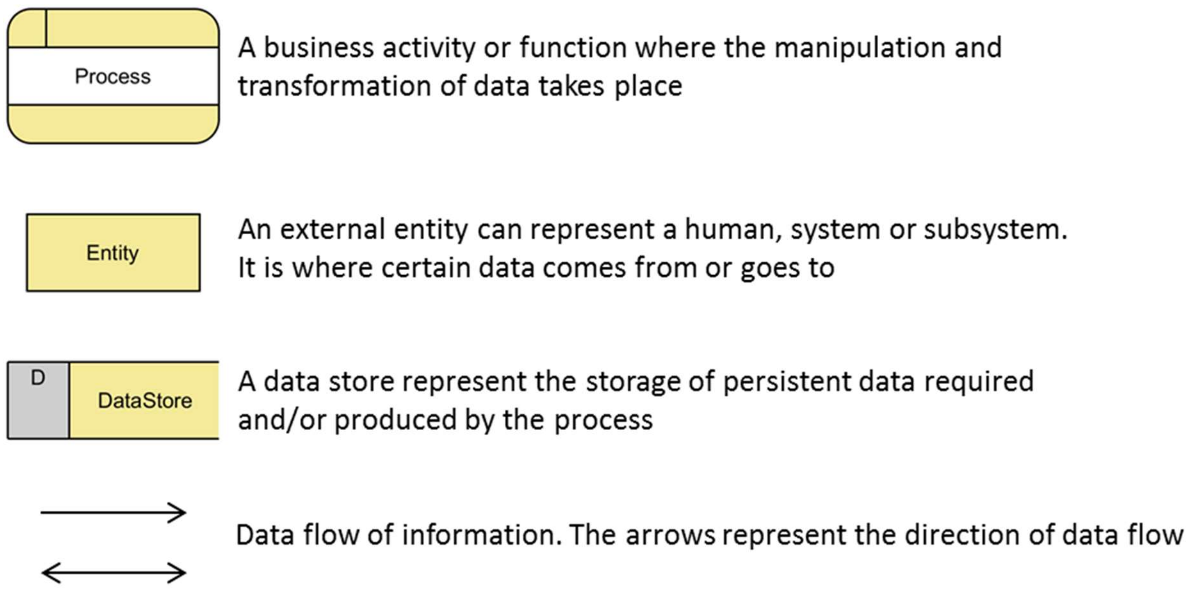

Figure 16 Data Flow Diagram main components

3.1 Weather forecast Data Flow Diagram

Figure 17 shows the DFD for the integration of nowcasting and lightning probability data within the CIPRNet DSS. HIMET S.r.l provides these data as NetCDF (Network Common Data Format, that is, self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data) files. The CIPRNet DSS has a service getting these files from the HIMET server (both files are updated each 5 minutes). Within the DSS these files are processed for being:

1) Transformed in a raster format that can be visualised with the GEOSDI platform (the GeoServer produces WMS files that can be visualised in the WEB GUI from the geotiff format) and

2) Stored within the CIPRNet Database.

The Damage Estimate processing block use these data to computes the CI components that can be damaged by the rainfall and lightning events. To this end the Damage Estimate block uses the CI vulnerability data stored within the CIPRNet Database. At the moment only vulnerability data related to the distribution electrical grid of Rome with respect to heavy rainfall are stored within the DB.

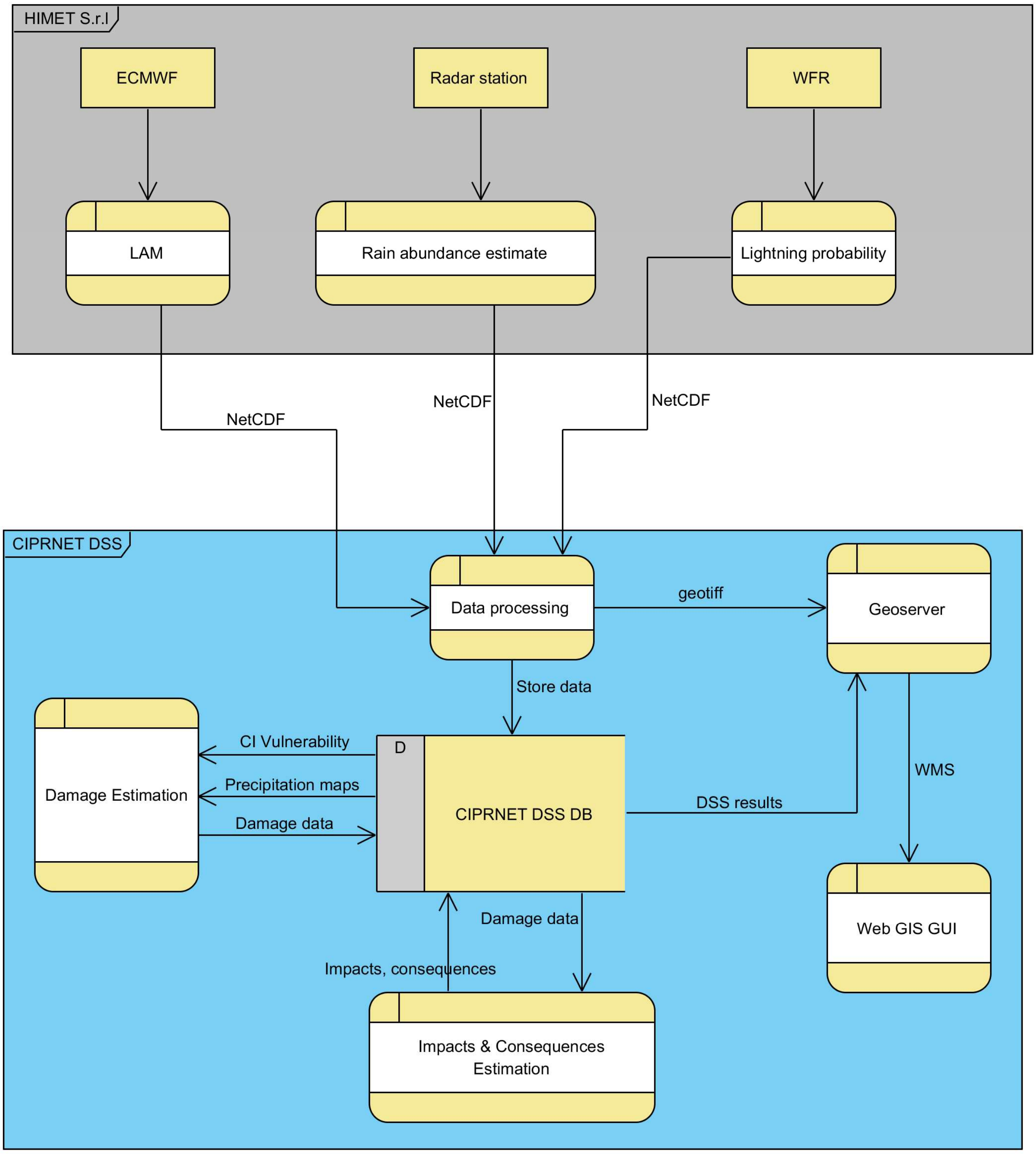

Figure 17 Integration of now-casting and lightning probability within the CIPRNet DSS

3.2 Flooding Forecast Data Flow Diagram

For the what-if analysis in WP6 it is proposed to make use of the results for different dike breach locations at the Dutch-German border. The information from the Lizard website [LIZARD] has to be stored in a database[11], from which the geo-tiff files for maximum water depth, maximum flow velocity and flood extent can be quickly accessed.

The spatial flood datasets are available via a GeoServer application installed in a Deltares server, from where it can be requested using WMS or WCS services (Figure 18). From Ge-

[11] Note that the data can't be directly accessed from Lizard. The files have to be stored in a CIPRNet own database.

oServer a dataset, i.e. a time step, can be requested by specification of the current extent (bounding box) of the analysis. The response of the Web Service will make use of the WCS protocol. GeoServer is an open source server for sharing spatial data. For more information, see www.geoserver.org.

Currently, the numerical flood simulations are available in 15 minutes time steps.

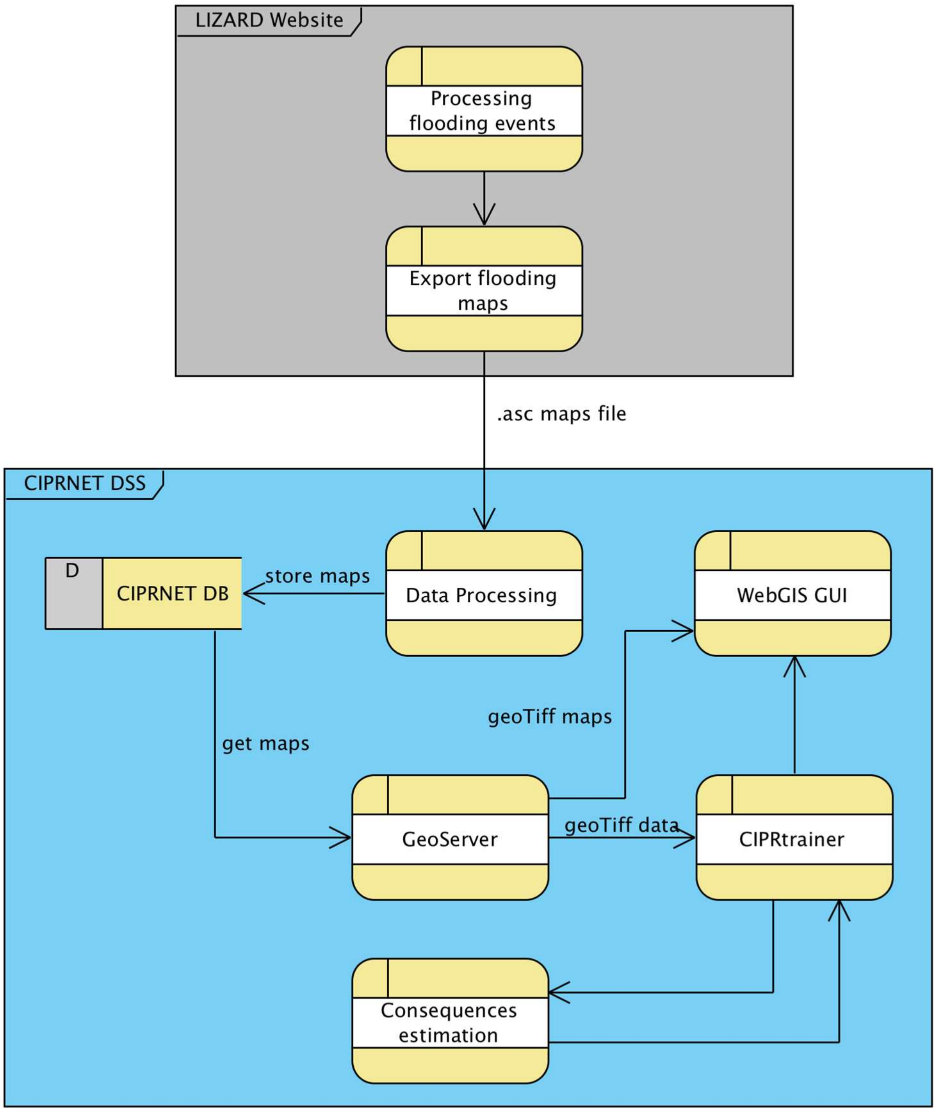

Figure 18 Flooding Data Flow diagram for what-if analysis

The CIPRtrainer process uses the consequences estimation process data for the what-if analysis and to analysis the performance of the chosen mitigation strategies.

3.3 Earthquake Data Flow Diagram

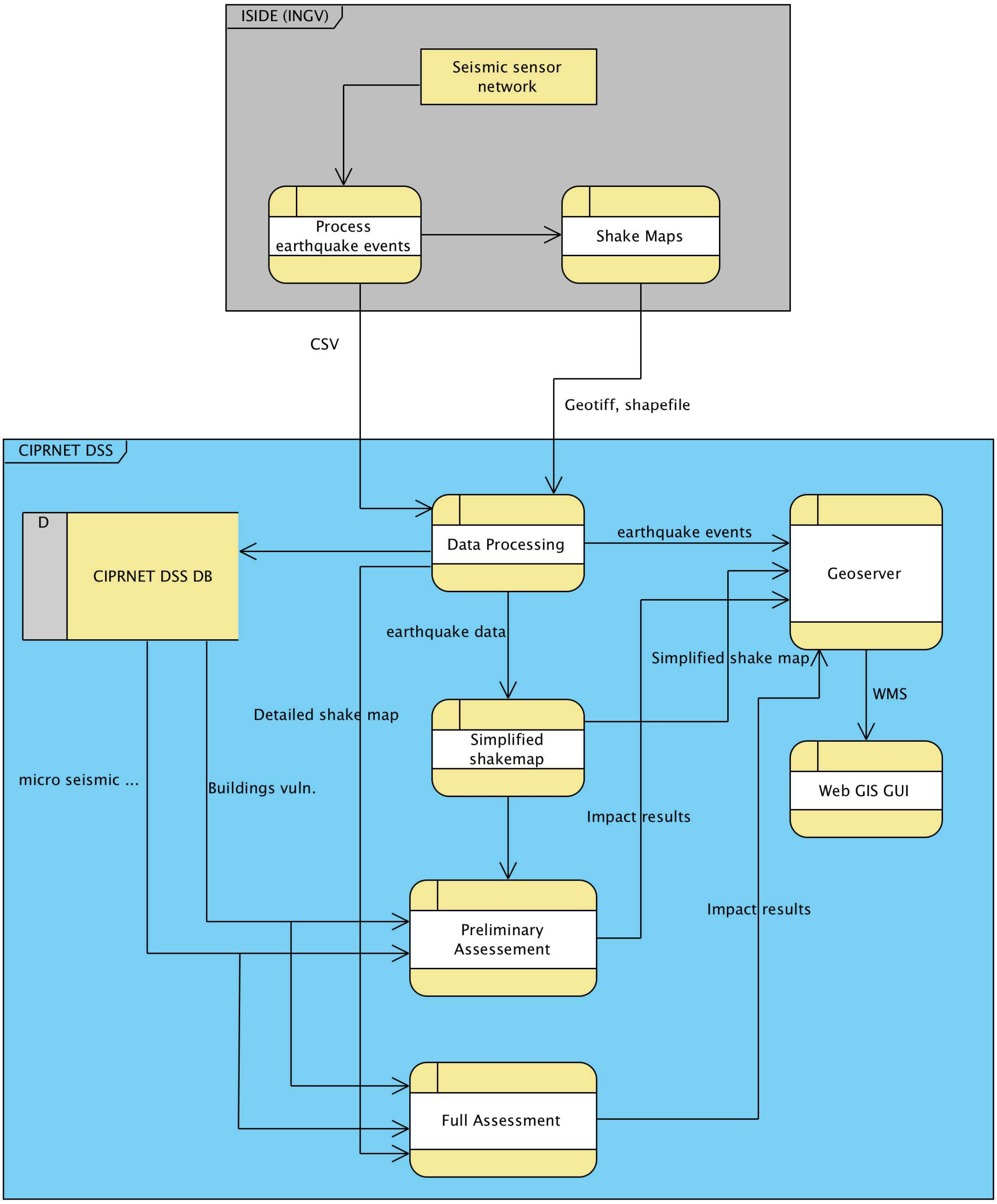

Figure 19 shows the data flow diagram related to the integration within the CIPRNet DSS of the earthquake data (magnitude and epicentre). The DSS gets (each 5 minutes) INGV data representing earthquake data (i.e. epicentre coordinates and magnitude) coming from the INGV ISIDE sensor network. These data are provided as CSV files. As already explained in [D7.1] the DSS is able, using the data stored within the database (building vulnerability data and, when available, micro seismic zoning data) to perform a preliminary impact assessment.

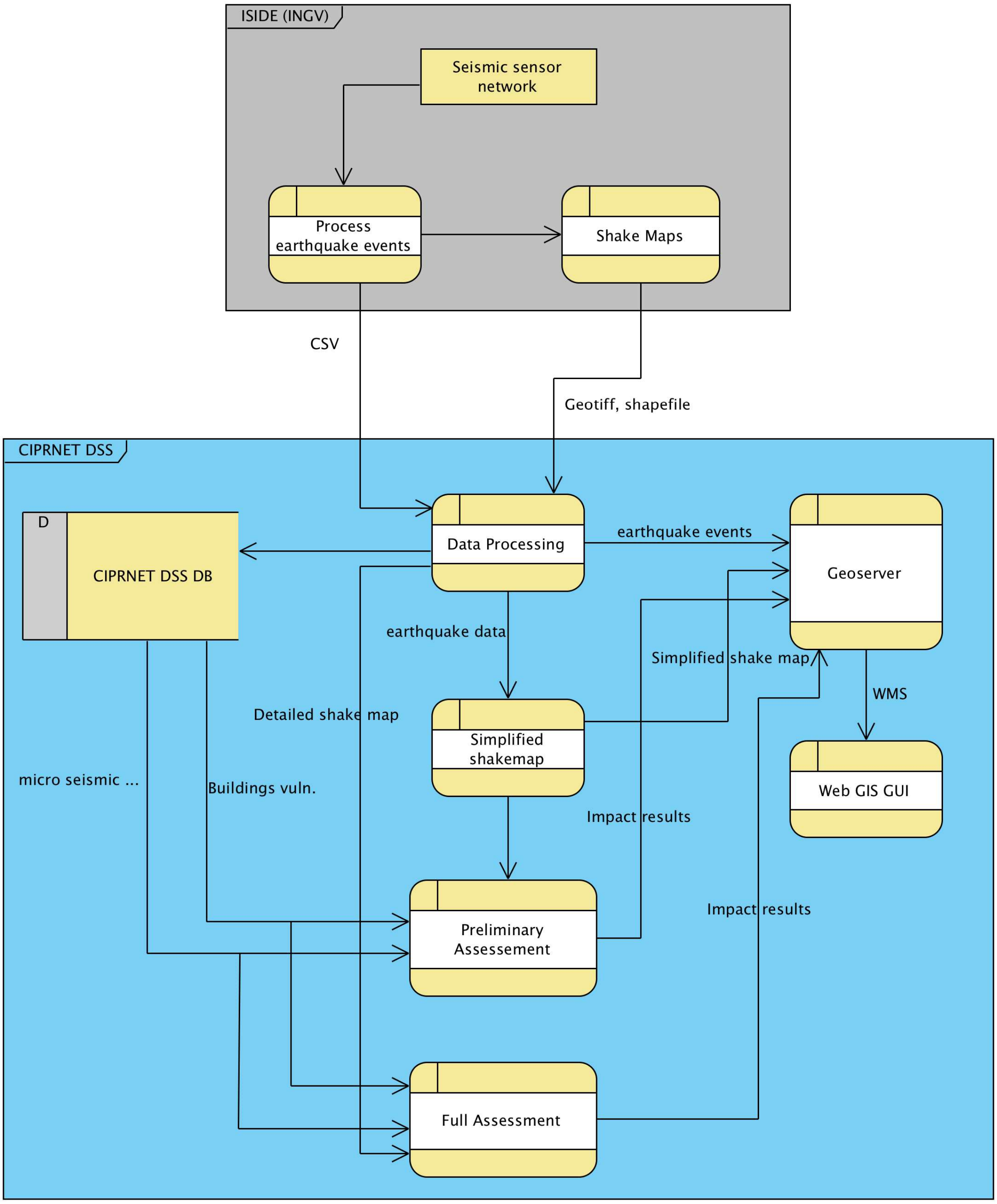

Figure 19 Earthquake data flow diagram

In this way, in a timeframe of a few minutes, the DSS is able to assess, with a certain degree of approximation, the damage that an earthquake event has on the building and, more in general, on the CI compo-

nents (the Preliminary Assessment process in

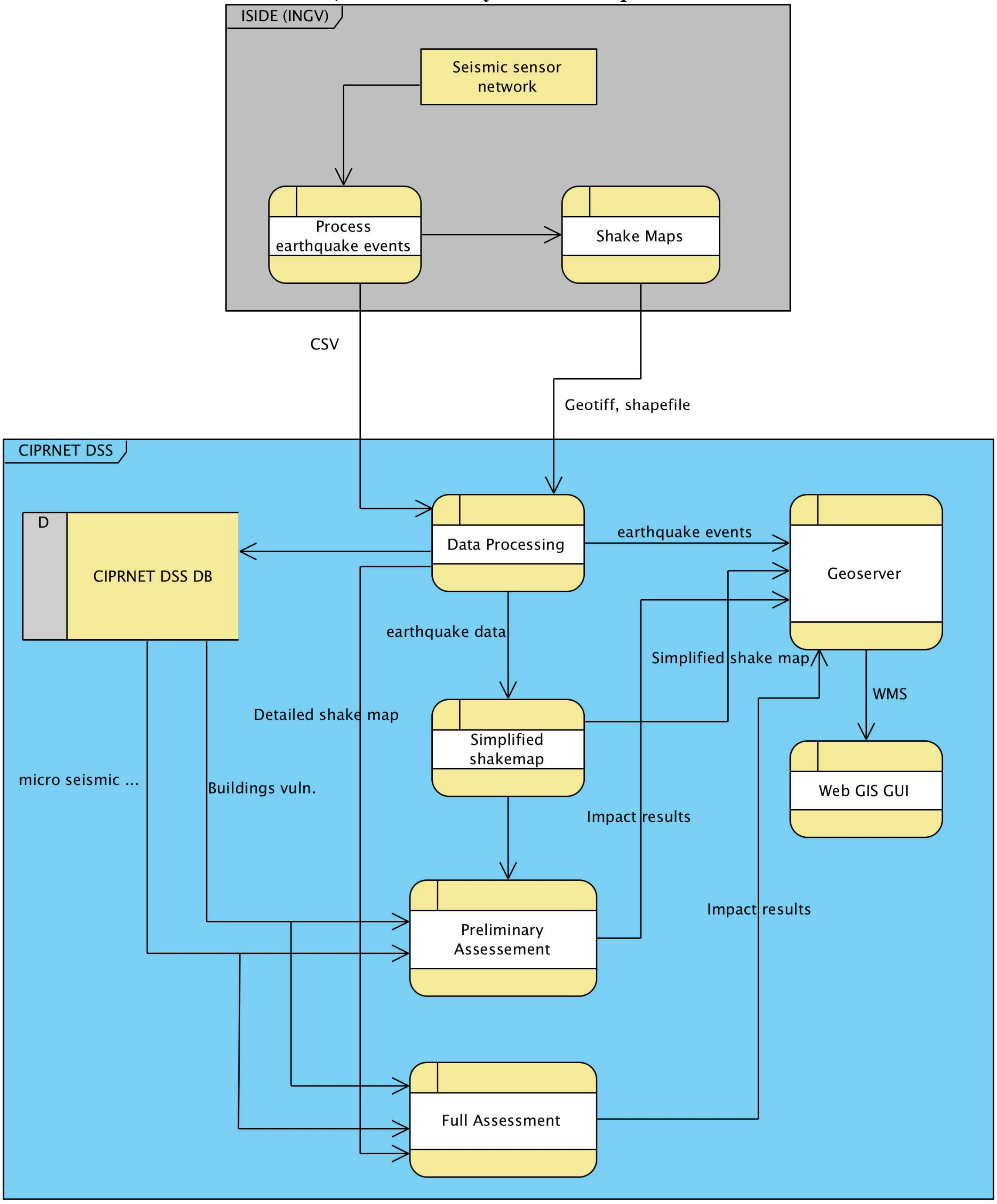

Figure 19 realizes the DSS impacts and consequences assessment). The web GIS GUI can visualise both the simplified shake maps computed in the preliminary assessment and impact assessment results. After some hours after large earthquake events (magnitude greater than 4.0) the INGV makes available the related shake map (in this case the shake map is measured not computed using a mathematical model). In future, the CIPRNet DSS will be able to consider the measured shake map to better assess the impact of large earthquake events (but this will be possible only after some hours after the event).

4 Interface of the DSS to the technical demonstrator for federated CIP MS&A

4.1 Introduction of the federated simulation system in CIPRTrainer

As described in D6.3, the demonstrator of the what-if analysis with federated simulation is called CIPRTrainer. It focuses on the training application of the crisis managers (e.g. Civil Protection) not the CI operators.

Federated simulation plays a central role in the training application. It provides realistic system dynamics based on sophisticated simulations done by domain-specific simulators. Currently three domains are considered: electrical network, telecommunication network and railway systems (see Figure 20). For each domain a simulator is used to provide system dynamics based on the provided model. In this current configuration,

- SINCAL [SINCAL] is used for calculating the load flow in electrical networks. It is a commercial product from SIEMENS. It is a MS Windows desktop application with an advanced graphical user interface to model and manage the simulation. A Microsoft COM-based interface is available to enable the integration of other applications with SINCAL.
- For the telecommunication network, the open source ns-3 simulator [ns-3] is adopted. Comparing to SINCAL, ns-3 does not provide any interface per se for integration with other application. Our solution is to build an additional layer similar to the COM interface for SINCAL. With this layer, other applications can talk with ns-3 at runtime to manage the models and simulations.
- The commercial railway simulator OpenTrack [OpenTrack] is used to provide detailed information about the railway networks like the location and speed of trains at a given time; the signal status and the time tables. In recent versions of OpenTrack, SOAP based communication is supported by OpenTrack to integrate itself with other application.

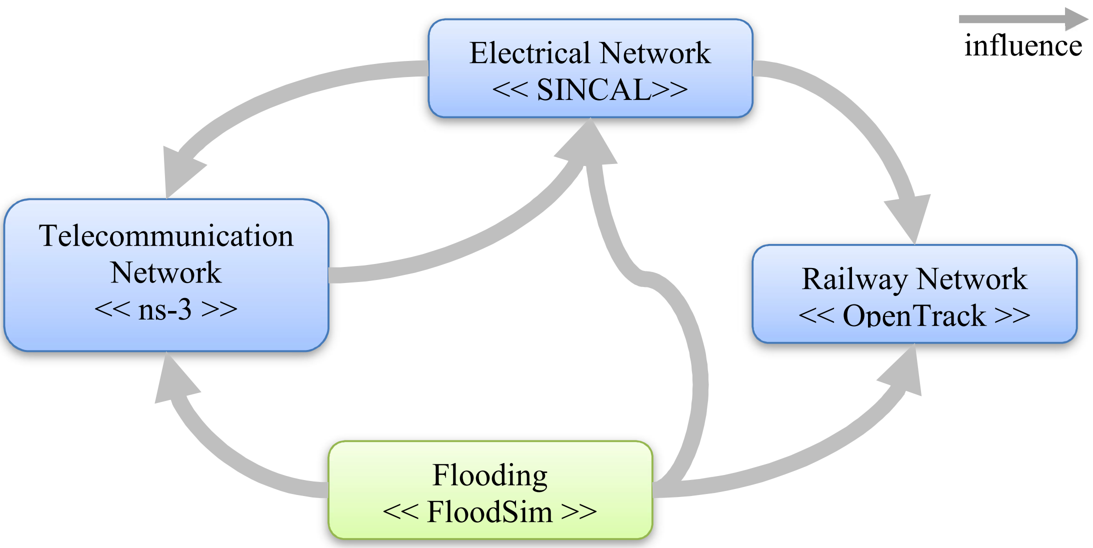

Figure 20 The dependency graph of simulation domains

In addition, different threat simulators can also be integrated to enable threat evolution support. Realistic threat developments can provide more reliable information about the threats that affect the complete CI networks. For the purpose of CIPRTrainer, we developed a database-centric flood simulation with pre-calculated flooding information for fast threat generation.

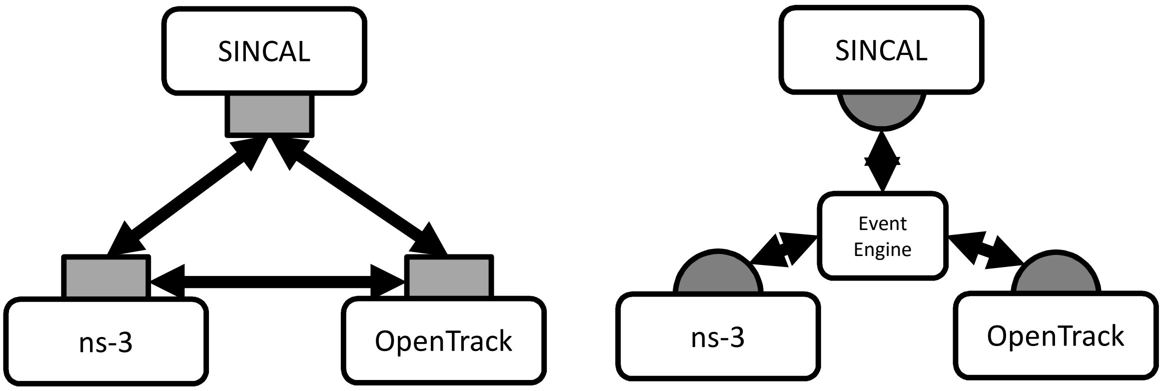

Figure 21 The original DIESIS federation middleware on the left and the improved version with event processing and declarative rule base on the right.

The proposed federated simulation system is a further development of the DIESIS approach. The major improvement is depicted in Figure 21,where the diagram on the left side denotes the original DIESIS federated simulation middleware, where each simulator communicates with others directly through dedicated adapters. The diagram on the right hand illustrates the improved version with event processing in mind. A rule base, embedded in the rule engine, is constructed to handle most of the federation logics in a declarative fashion. Since the federation logics are relocated from the dedicated adapters to the event engine, the original adapters with hardcoded imperative code for federation logics are becoming lightweight declarative rules.

4.2 Design of simulator adapters

The simulator adapters, as illustrated in Figure 22, work as a bridge between the training system and the domain-specific simulators. On one side it needs to communicate with the simulators in a simulator-specific way, e.g. COM for SINCAL, Apache Thrift for ns-3 and SOAP for OpenTrack. On the other side it needs to communicate with the event processing system – this is where we as system design have sufficient control on.

We use the idea of RESTful web services to provide a unified interface to all simulators. With “unified”, it is meant for the event engine that only needs to use one “vocabulary” to be able to talk with all configured simulators.

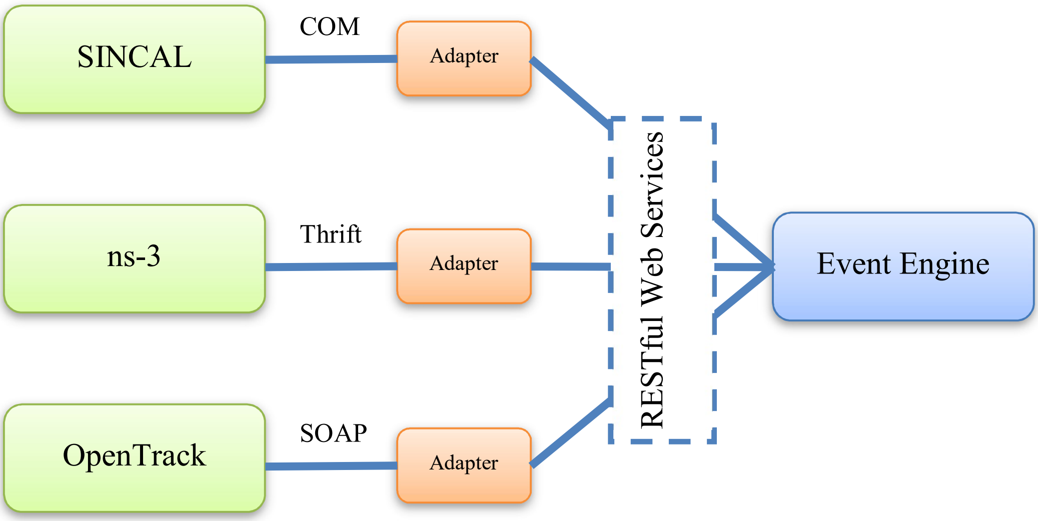

Figure 22 Input and output of simulator adapters

For each simulator adapter, at least two RESTful endpoints need to be defined:

- Manage the models by changing the physical parameters at simulation runtime
- Control the simulation with start, stop, step, pause and continue.

The technical details of these two RESTful endpoints are given in Table 1 and Table 2.

Table 1 RESTful endpoints for model management

POST /fedsim/{sim}/command	
Parameters	
sim	the simulator name: sincal, ns3, opentrack
Request	add a new command to the simulation adapter command queue.
Headers	
Body	
{ "command": "start" }	
Response	200
Headers	
Content-Type: application/json	
Body	
{ "status": "success" }	

Table 2 RESTful endpoints for simulation control

PUT /fedsim/{sim}/{type}/{name}/state/{state}	
Parameters	
sim	the simulator name: sincal, ns3, opentrack
type	the type of the CI element. Depending on the domain, it can be e.g. transformer for sincal, router for ns3, and track for opentrack
name	the unique name of a given elemnt type
state	the pre-defined states: norman, stressed, crisis, recovery
Request	Change element state of a given model.
Headers	
Body	
{}	
Response	200
Headers	
Content-Type: application/json	
Body	
{ "status": "success" }	

More RESTful endpoints will be needed depending on the requirement of the systems to be integrated.

4.3 GIS support of the federated simulation system

Most of the elements in the CI networks are geo-referenced. For instance, a transformer in the SINCAL model has always a coordinate. Similarly routers in the ns-3 models also possess spatial information. Domain-specific simulators normally have little support for modelling these kinds of geographical information. We have extensively investigated the three simulators that are used in CIPRTrainer and all of them miss sufficient GIS support for our use case.

A QGIS-based tool (see Figure 23) is currently being developed and used to create the spatial models for the federated simulation system. It provides high-level concepts that are essential part of CI networks. For instance, in traditional GIS tools, points, lines and polygons are the basic objects. All operations like add, delete, move are based on these elements. The proposed QGIS-based tool allows CI related operations. For example the proposed tool allow the management of power lines and router and their specific physical attributes. In the future, automatic generation of the CI model based on the GIS system will be implemented to provide a more consistent modelling workflow.

Figure 23 One screenshot of the CI models in the GIS tool

4.4 Interfaces between DSS and CIPRTrainer

After an overview and several core technologies of CIPRTrainer are introduced in the previous section, in this section, the interfaces between CIPRTrainer and DSS will be described. The integration of the two systems can be used in different phases of the crisis management cycle:

- Crisis Response: the DSS forecast an extreme natural event (e.g. heavy rainfall) on a specific area. CIPRTrainer starting from the damage scenario produced by the DSS it is used to analyse the different possible mitigation strategies;
- Crisis Preparation: the DSS is used to assess the impacts and consequences of synthetic natural events (e.g. earthquakes) and/or synthetic damage scenario (e.g.: anthropic hazards). CIPRTrainer can be used to analyse the various possible scenarios.

4.4.1 Overview

In general, interface is one problem of system integration and in this case the integration of two systems – CIPRTrainer and DSS. Widely used methods for system integration (see Figure 24) include:

- Shared databases – different sub-systems write and read the information need to be exchanged through a central and shared database in a transactional way. Transactions are however very time and resource intensive, i.e. using shared databases to integrate systems is rather inefficient.
- Remote procedural (RPC) calls with heavy and lightweight web services (like SOAP and RESTful) – remote procedurals are traditional ways to access different process on the same machine and further developed to access processes on other machines running in the same local network. Originally it is not designed for machines intercon-

nected through Internet. Therefore to overcome these drawbacks, SOAP standard is proposed to enable an efficient and flexible way of communication through Internet.

- Shared file systems – this fashion of system integration is very similar to the shared databases. Instead of using transactional databases, the rather ad-hoc and flexible file systems are used – either local or remote. The communication complexity is then pushed down to the file system drivers, which should be able handle concurrency and asynchronous access from different sub systems.
- Message Bus– message buses are quite new and come from enterprise information integration. Most of the sub-systems in an enterprise environment need to communicate with each other in a way that the content to be exchanged can be modelled as simple messages. Therefore dedicated message buses are then developed to fit this kind of needs. It provides a reliable and efficient way to integrate local-area enterprise systems. However, for web-based system integration, it is not always a good candidate.

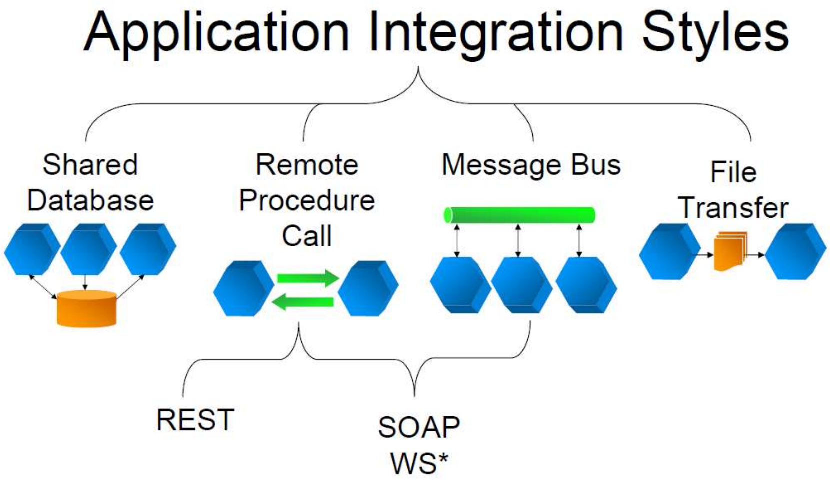

Figure 24 Four typical application integration styles [REST08]

Due to the heterogeneity of the two systems – in terms of system design, technical implementations, software frameworks, runtime environments, it is preferable to adopt the RESTful web services as the design basis for interfacing these two systems.

4.4.2 Interface design

DSS is mainly for interacting with the users. It focuses on the visualisation of the information stored in the database or accessed / provided at runtime by the federated simulation system within the CIPRTrainer. Any state change of the elements like CI elements (routers, base stations, power lines, etc.) will be reflected in the DSS front-end.

On the other hand, the federated simulation system expects input from DSS like the damage scenarios (at which time what happens), the user actions that change the element states e.g. send action forces to a certain location, etc. Based on the inputs from DSS, the federated simulation system can perform a simulation to predicate what the simulated world could look like during e.g. the next few minutes or even hours. Together with common consequence analysis module, the impacts and consequences can be calculated and eventually sent back to the DSS for further visualisation.

In addition, the threats simulator like the flood simulator illustrated in Figure 9, can also provide information to the federated simulation system indicating that certain area is flooded and the eventually certain CI elements like a substation with high-voltage transformers are flooded and disrupted. This kind of information can be further visualised in DSS and used as inputs to the federated simulation system to analyse the cascaded effects of the threats due to the dependencies between CI. For instance if a substation is flooded, several minutes later the routers that gets power supply from this substation will fail (assuming that no backup power supply is modelled), this can further influence the SCADA system used to monitor those tele-controlled power systems and water supplies. Functional interfaces are summarised in Figure 25.

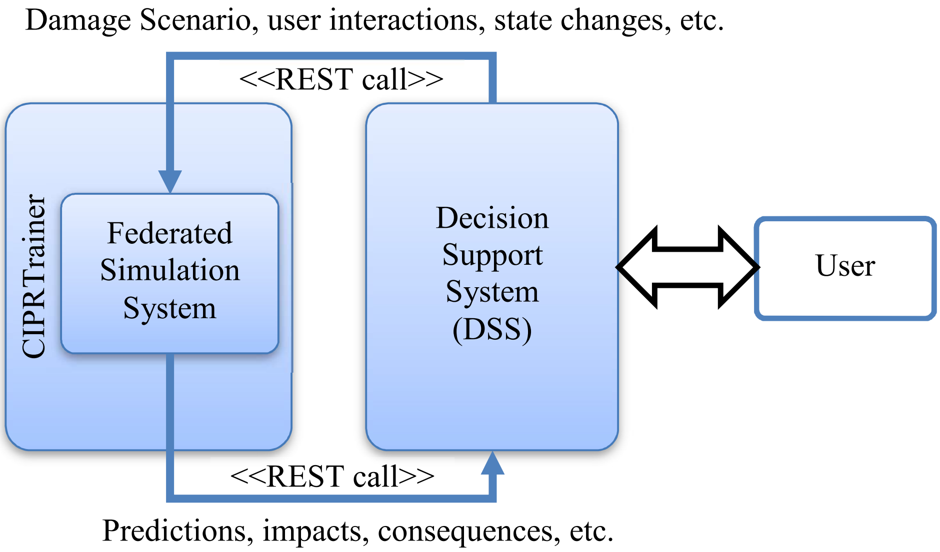

Figure 25 Functional interfaces between DSS and CIPRTrainer

4.4.3 Interface specification

In order to facilitate the communication between DSS and the federated simulation system of CIPRTrainer, a list of RESTful endpoints / services are defined. Each end point is equipped with an HTTP operation: GET, POST, PUT or DELETE. Each end point corresponds to an entity that is commonly defined for both sides – in this case, the DSS and CIPRTrainer.

In the current design, DSS is mainly active, that means, at runtime, DSS access the services defined on the CIPRTrainer side to actively push and retrieve information. All the serialised information should be coded as JSON strings. The following tables describe the interface of the different services.

Table 3 Insert scenario

POST **/damage_scenario**	
Parameters	
No parameters defined in the URL	
Request	Add a new damage scenario to the federated simulation
Headers	
`Content-Type: application/json`	
Body	
`The scenario description in json format conforming the defined JSON schema`	
Response	200
Headers	
`Content-Type: application/json`	
Body	

```
{
  "scenario": {
    "id": 4F3C, # the scenario ID that is generated for future reference
  }, …
}
```

Table 4 Change CI element state

PUT **/element/{type}/{name}/state/{state}**	
Parameters	
type	element type like transformer, router
name	the unique name of the given type
state	damaged or not (can be extended later with more fine-grained states)
Request	Add a new damage scenario to the federated simulation
Headers	
`Content-Type: application/json`	
Body	
`{}`	
Response	200
Headers	
`Content-Type: application/json`	
Body	

```
{
  "result": "ok"
}
```

Table 5 Retrieve damage scenario impacts

GET /impact/{ds_id}	
Parameters	
ds_id	the damage scenario id that is returned by the POST request
Request	Add a new damage scenario to the federated simulation
Headers	
`Content-Type: application/json`	
Body	
`{}`	
Response	200
Headers	
`Content-Type: application/json`	
Body	
`The damange in JSON`	

Table 6 Retrieve damage scenario consequences

GET /consequence/{ds_id}	
Parameters	
ds_id	the damage scenario id that is returned by the POST request
Request	Add a new damage scenario to the federated simulation
Headers	
`Content-Type: application/json`	
Body	
`{}`	
Response	200
Headers	
`Content-Type: application/json`	
Body	
`The consequence in JSON`	

The interfaces defined are by no means closed. It is still possible to add additional endpoints for other interactions. A general workflow of consuming these services is depicted as UML sequence diagram in Figure 26.

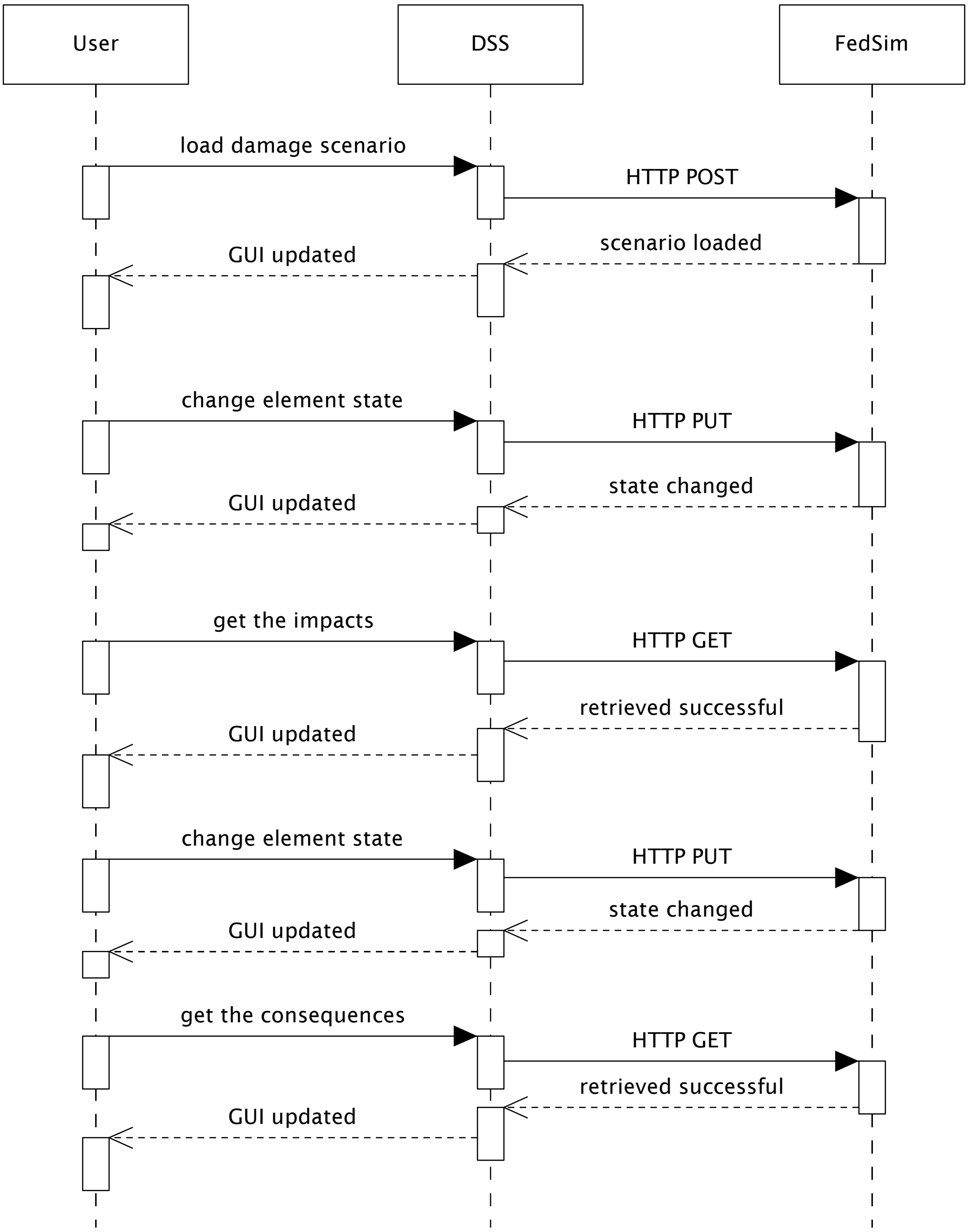

Figure 26 Interaction workflow as UML sequence diagram

5 Conclusion

This document describes the integration of meteo-climatological simulators, flood forecasts, earthquakes data and analysis tool and the interface to the technical demonstrator for federated CIP MS&A. This integration allows completing the part of the DSS workflow that joins the "external scenario awareness" to the prediction of the expected Damage Scenario.

In particular, the document describes the results that have been obtained when implementing the simulators and the analysis tools. Two DSS instances are described:

(1) The DSS-IT (related to the metropolitan area of Rome city) which implements the weather and the earthquake workflows described in previous WP7 deliverables; these workflows allow the risk forecast on CI networks, primary services and society induced by heavy rain events, lightening and earthquake events (triggered by field data and simulation application codes);

(2) The DSS-DE/NL (related to the cross borders scenario described in [D6.2]). In this case, the DSS instance connects to the CIPRTrainer tool, a new application that provides a new capability for training crisis management by exploring different courses of action and comparing their consequences ('what if' analysis), based on federated modelling, simulation and analysis.

Although being applied just to two test cases, the DSS now allows, in principle, in presence of specific context data, to provide an external scenario awareness report and the related Damage scenario in a whatsoever EU area.

In conclusion, the present document describes how various data sources and core simulation facilities have been integrated into the CIPRNet DSS and the resulting functionalities that have been activated. The use of:

- Standardised lightweight interfaces (e.g. the RESTful web services for interfacing the DSS and the CIPRTrainer),
- Standardised data exchange formats (e.g. NetCDF, Geotiff) used for the integration of meteo-climatological data sources,
- GIS web mapping standards (e.g. WMS) for data visualization

makes the DSS platform easily customizable for the specific need of specific areas/regions.

The completion of the DSS workflow was needed to reach the final objective, i.e. the realization of specific application to deal with each part of the DSS workflow. In particular, this part (from external awareness to Damage Scenario) has allowed exploiting some functionality of the DSS for the benefit of CI operators. An instance of the DSS-IT system that implements all functional blocks of the risk forecast workflow described in D7.1 is under validation and test at the Operating Centre of the multi-utility ACEA SpA in Roma.

Further activities will be related to the set up of the DSS-DE/NL that will integrate, with the same strategies adopted for the DSS-IT case, meteo-climatological and natural events forecast data related to the cross border scenarios described in D6.2.

6 References

[D6.2] EU FP7 CIPRNet, CEA, Deliverable D6.2 – Application Scenario (2014)

[D6.3] EU FP7 CIPRNet, Fraunhofer, Deliverable D6.3 – Federate CI Models (2015)

[D7.1] EU FP7 CIPRNet, ENEA, Deliverable D7.1 – Design of the DSS with consequence analysis (2014)

[DOW] Annex I – Description of Work (Annex to the Grant Agreement FP7-312450-CIPRNet)

[INGV] European Commission, represented by REA: Grant Agreement FP7-312450-CIPRNet

[ECMWF] http://www.ecmwf.int/

[EFAS] European Flooding Awareness System: www.efas.eu

[RWoS] Operational Forecasting System for the North Sea: https://www.deltares.nl/en/projects/rwsos-north-sea-operational-forecasting-system-north-sea/

[REST08] Pautasso, Cesare, Olaf Zimmermann, and Frank Leymann. “Restful web services vs. big'web services: making the right architectural decision.” Proceedings of the 17th international conference on World Wide Web. ACM, 2008.

[LIZARD] http://flooding.lizard.net

[HIMET] http://cetemps.aquila.infn.it