

EARTHQUAKES

THE SOURCE OF AN EARTHQUAKE IS A FAULT RUPTURE OCCURRING IN THE EARTH'S CRUST. USING RADAR AND OPTICAL SATELLITE DATA WE MEASURE THE PERMANENT GROUND SURFACE MOVEMENTS CAUSED BY THE FAULT DISPLACEMENTS AT DEPTH.

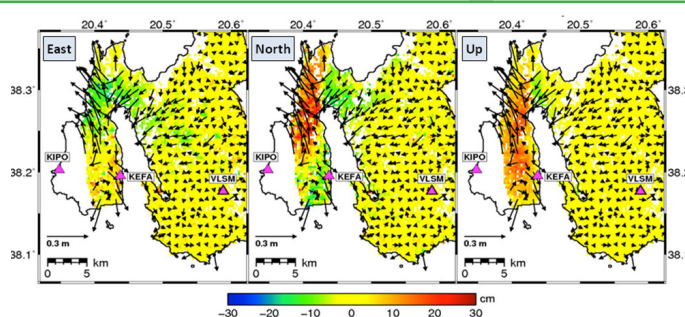
LARGE EARTHQUAKES CAN GENERATE FAULT SCARPS, TOPOGRAPHIC STEPS UP TO TENS OF METERS HIGH AND HUNDREDS OF KILOMETERS LONG, ABLE TO DESTROY OR DAMAGE ALL THE STRUCTURES THEY CROSS. EVEN MODERATE EARTHQUAKES GENERATE DIFFUSE, PERMANENT SURFACE DEFORMATION, WHICH MAY BE INVISIBLE TO THE EYE BUT CAN STRONGLY AFFECT THE HYDROLOGICAL REGIME, AND CAUSE FOR INSTANCE INUNDATION OF SUNKEN AREAS, OR INCREASED EROSION AND LAND SLIDING OF UPLIFTED ONES.

THE RASOR CONSORTIUM PROVIDES TAILORED SERVICES AND INFORMATION PRODUCTS FOR THE MONITORING OF EARTHQUAKE HAZARDS, AND FOR THE GENERATION OF MODELS AND SCENARIOS, WHICH CAN BE ANALYSED WITHIN THE RASOR PLATFORM TO PREDICT THE SPATIAL OCCURRENCE OF AN ADVERSE EFFECT.

CO-SEISMIC GROUND DEFORMATION MAP

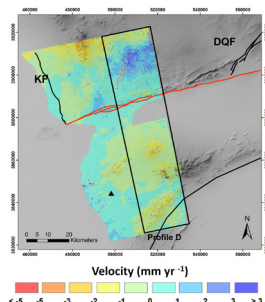
During an emergency, the co-seismic ground deformation map and its derived products are an important product for disaster managers, used for the environmental damage assessment and the situational awareness. RASOR provides this information in near real time (once images are available) using data from a variety of SAR or optical satellites and different analysis methods (range and azimuth interferometry, offset tracking).

The figure shows the intensity of the three cartesian components of the ground displacement caused by the February 3, 2014 Cephalonia earthquake, Greece (Merryman et al., 2015)



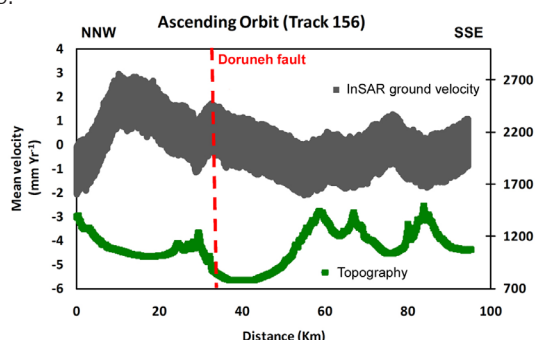
INTER-SEISMIC GROUND DEFORMATION MAP

During the inter-seismic period the faults accumulate tectonic stress which is suddenly released by seismic ruptures. The slow building of crustal deformation can be measured at the surface and used to predict the long-term rate of fault slip through modeling. Risk managers then use slip rates to constrain probabilistic seismic hazard assessment.



RASOR provides inter-seismic ground deformation measurements, as displacement time series and mean velocities, using data from a variety of SAR satellites processed by multitemporal InSAR analysis methods (SBAS, PS-InSAR, mixed methods). Given the rather steady rates of crustal deformation velocities, these measurements are normally updated yearly.

The figure on the left shows the inter-seismic ground velocity map across the Western Doruneh Fault in Central Iran (Pezzo et al., 2012). The red line in the middle is the Doruneh Fault system. The ground North of the fault moves West with respect to the ground on the South side. The black box marks the buffered velocity profile shown below. These data were modeled to provide important information for seismic hazard assessment, as fault kinematics and slip rate.

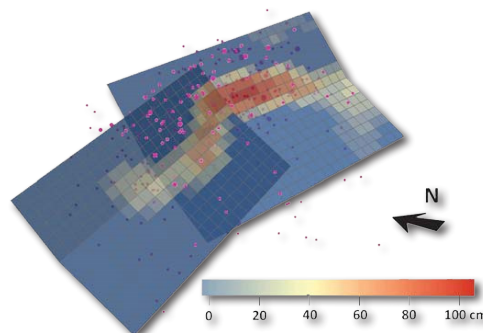


SEISMIC SOURCE MODELS

The characterisation of the seismic source is rapidly needed for the situational awareness following an earthquake, to address the possibility of further adverse effects, as large shocks caused by slippage of locked fault patches, post-seismic increase of surface deformation along damaging fault scarps, or simply to update the hazard models for the region.

The RASOR consortium can provide accurate seismic source models based on the geophysical inversion of the co-seismic deformation field obtained from InSAR and GPS data. We use state of the art modeling procedures to characterise the source location, geometry, extension and fault slip vector. We can also use any additionally available information to validate the model.

The figure shows the modeled sources of the main earthquakes of the 2012 Emilia, Northern Italy, seismic sequence. Purple dots represent the seismicity. (Pezzo et al., 2013)



SLIP RATE ON ACTIVE FAULTS

The slip rate of a fault is defined as the total fault slip occurring during large earthquakes divided by the recurrence interval over geological times. The slip rate provides the long term representation of the fault activity, and is an important quantity for seismic hazard assessment. It can also be estimated from crustal deformation rates obtained from InSAR and GPS geodetic data, and geophysical

modeling procedures.

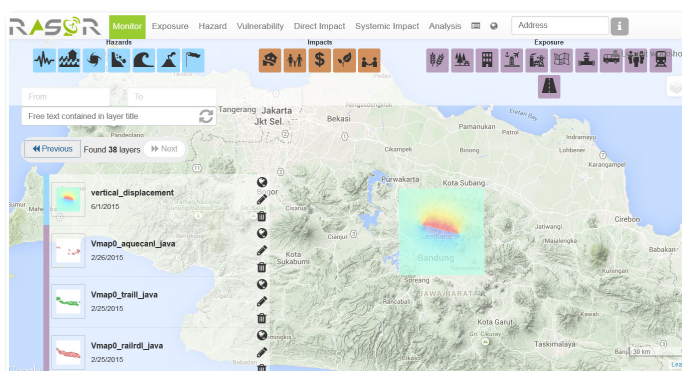
The RASOR consortium can provide estimates of fault slip rates for large active faults for which satellite measurements of surface deformation can be obtained. We also provide validation of the present day slip rate with all the available ancillary information from geological and geomorphological data.

CO-SEISMIC GROUND DEFORMATION SCENARIO

Simulations of the static co-seismic surface deformation induced by earthquakes are used by Risk Managers to assess the effects of earthquakes on man made structures, and take appropriate prevention measures.

In the RASOR platform we provide a tool for the generation of co-seismic ground deformation scenarios. They are obtained through the elastic modeling of the rupture causing the earthquake. The User can select an existing fault, or directly draw one, define the rupture parameters (e.g. based on historical earthquake magnitudes), and simulate the ground displacement in the three cartesian components.

The figure shows the co-seismic ground displacement scenario simulated for a magnitude 6.8 earthquake on the Lembang Fault, West Java Indonesia.

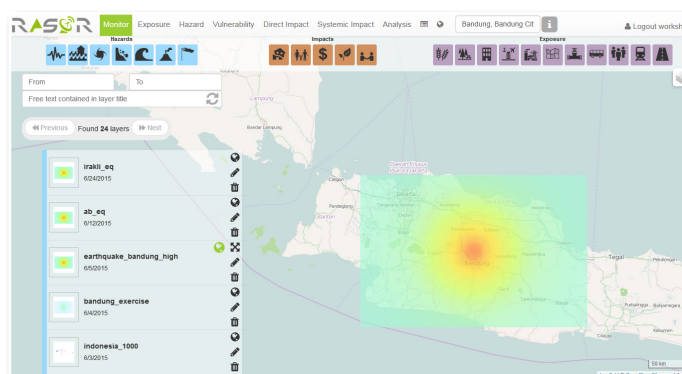


SEISMIC SHAKING SCENARIO

The maximum possible seismic shaking intensity, expressed as Peak Ground Acceleration (PGA) or Peak Ground Velocity (PGV) is the main parameter to be estimated during seismic hazard assessment, associated to a probability of occurrence during a specified time period.

We have implemented in the RASOR platform the ShakeMap code developed by USGS. By defining a point or finite source (earthquake or fault) in a given region, the user can simulate the seismic shaking (PGA, PGV, macroseismic intensities) in any point of the surrounding areas.

The figure represents a seismic shaking scenario for a magnitude 7 earthquake on the Lembang fault in West Java, Indonesia.



STRESS TRANSFER ON FAULTS SURROUNDING A LARGE EARTHQUAKE

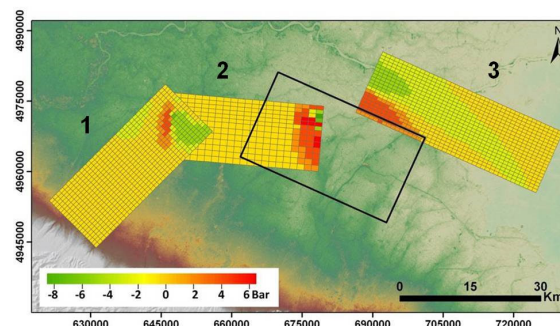
During the sudden crustal rupture process which causes an earthquake, a portion of the pre-existing tectonic stress is redistributed in the crust, and where it adds to a pre-existing stress level, aftershocks are normally triggered. As shown by several examples worldwide, after large earthquakes, further shocks have a higher probability to occur in areas of positive stress variations. Further research is needed to use this scientific result in a quantitative way. However for Disaster Managers the imaging of high post-seismic stress level variations in an area may provide support to important decisions. For instance an increased stress level on a fault located near relief camps can prompt the generation of a shaking scenario to verify the actual safety levels.

In RASOR we provide a geophysical modeling tool to calculate the stress variations caused by a seismic rupture on the nearby active faults.

The stress calculation tool needs as input a seismic source model. The user can select one or more receiving faults on which the diffe-

rential stress is calculated. These receiving faults can be selected from a fault database of defined by the User on the fly.

The figure below shows stress variations caused by the 2012 Emilia, N. Italy, main rupture (black rectangle) on nearby active faults. Rupture of the fault no.2 occurred 9 days after the mainshock and caused increased casualties and damage.



OTHER PRODUCTS

Seismic hazard map, Damage assessment, Affected population, Active fault map, Event monitoring, Off-platform generation of geohazard field data, models, simulations, scenarios for earthquakes and volcanic hazards, Seismological study (network

installation and data analysis for a 3-6 month duration), GNSS monitoring (equipment and data analysis), Geophysical surveys and underground map generation, Fault mapping using field work.