How science supports national preparedness: Geology and Geophysics
The 2016 seismic sequence in central Italy

Istituto Nazionale di Geofisica e Vulcanologia (INGV),
Istituto per il Rilevamento Elettromagnetico dell’Ambiente (IREA-CNR)
Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA)

by Daniela Pantosti, INGV
Science supports national preparedness thanks to a long-lasting cooperation of the Italian Civil Protection Department and Italian Scientific Institutions that are asked to provide support on specific scientific and technical functions.

- **High Risks Commission** - link between the scientific community and the Civil Protection Service; provides technical-scientific opinions on questions posed by the Department Director and provides recommendations to improve the capacity of evaluation, forecast and prevention of the different risks.

- **Operational Committee** - guarantee a **constant flow of information** and a **unitary management** of the emergency activities.

- **Competence Centers** - provide activities, services, studies and specific knowledge of interest for civil protection applications.
INGV is part of the **Operational Committee**, provides data, analysis and models to the **High Risks Commission**, and is a **Competence Center** for earthquakes, tsunami and volcanoes.

To comply with the present legislation, INGV and DPC develop collaborations and agreements. The present agreement will last until year 2020 and is based on 5 main activities:

- Seismic and Volcanic **Monitoring and Surveillance**
- **Tsunami Alert**
- **Data** Management and Distribution
- Emergency **Response**
- Communication, Formation, and Outreach
- **Development and Consolidation** of the Service, Products, and Activities (e.g., Seismic Hazard Map)
CNR-IREA is a Competence Center for surface deformation analysis through EO data, and provides data, analysis and models to the High Risks Commission upon request.

To comply with the present legislation, CNR-IREA and DPC develop collaborations and agreements.

The present agreement will last until the end of 2017 and is based on 4 main activities:

- Main Italian volcanoes (Campi Flegrei and Mt. Etna) surface displacement monitoring with space-borne SAR data
- Co-seismic surface displacement map generation for the main (Mw > 5.5) national and international earthquakes
- 3D representation of building shapes with space-borne SAR derived information, in seismic urban areas
- Development of a pre-operative airborne SAR system
**ISPRA** is part of the **Operational Committee**, provides data, analysis and models to the **High Risks Commission**, and is a **Competence Center** for seismic, geological, hydraulic, water pollution, sea water, coastal, nuclear and environmental risks.

To comply with the present legislation, ISPRA and DPC develop specific collaborations and agreements on request, when emergency occurs.

Some recent examples:

- **2009** Support to geo-hydrological risk evaluation after L’Aquila earthquake.
- **2009–2010** Seismic Microzonation in L’Aquila area and support to SMZ guidelines elaboration.
- **2012** Environmental monitoring around Costa Concordia shipwreck in Giglio Island, Central Italy.
- **2013–14** Support to residual risk evaluation in Montescaglioso (MT) landslide.
INSTRUMENTAL OBSERVATION SYSTEMS monitoring and surveillance

INSTRUMENTAL OBSERVATION SYSTEMS monitoring and surveillance

NATIONAL ACCELEROMETRIC NETWORK (RAN)
NATIONAL SEISMIC NETWORK (RSN) 24/7
SATELLITE DATA
DATABASE
HAZARD ASSESSMENT
NATIONAL GPS NETWORK (RING)
FIELD OBSERVATIONS

TEMPORARY SEISMIC NETWORKS
MACROSEISMIC SURVEY
BUILDING DAMAGE
NATURAL ENVIRONMENT EFFECTS SURVEY
OUTREACH

SEISMOLOGIC DATA ANALYSIS
FAULT GEOMETRY LOCATION
AND KINEMATICS, SHAKEMAPS
SOURCE MODELLING ETC.

UNDERSTANDING OF THE EVENT

RECONSTRUCTION - SEISMIC MICROZONING

DEVELOPMENT OF NEW SCIENTIFIC KNOWLEDGE, MODELS AND HYPOTHESIS. NEW INPUT TO DEVELOP TOOLS FOR SEISMIC RISK MITIGATION.
Activities developed during the 2016 Central Italy earthquake
by INGV, CNR-IREA and ISPRA
Seismic and Tsunami Monitoring and Surveillance

Data from more than 400 seismic and 200 GPS stations are collected in real time.
Seismic and Tsunami Monitoring and Surveillance
Immediately after the earthquake

- INGV provides DPC with the Earthquake Location and Magnitude for M>2.5 (2’-5’-30’; EarthWorm) Report within 60’ (M>4 earthquakes) containing revised earthquake parameters, seismicity of the region for the past 10 yrs, aftershock list and map, shakemaps (I, peak accel, peak vel), focal Mechanisms calculated for the event and for previous earthquakes in the area, historical earthquakes in the area, Seismic Hazard Map.

- For M>5.5 earthquakes INGV activates a Crisis Unit to coordinate the INGV operations along with data and information flow to DPC.
Information is published on INGV portal: earthquake source
Information is published on INGV portal: earthquake effects

**August 24, M 6.0**

**October 26, M 5.9**

**October 30, M 6.5**

Did you feel it?
Information is published on INGV portal: aftershocks
Immediately after the earthquake

- **Field Emergency Groups:**
  - **SISMIKO** (start in 2 h) mobile seismic network and integration with national seismic network
  - **QUEST** (start in 1 day) survey of the damage
  - **EMERGEO** (start in 12 h) survey of the coseismic effects on the natural environment
  - **EMERSITO** (start in 1-2 days) monitoring of the site effects
  - **IES** (start after a week) scientific information to the population in the epicentral area

- **New Data Acquisition and Reinforced activities**
  - **Satellite** data modelling
  - **Geodetic** Data
  - **Seismic Data** Analysis and product preparation
  - Additional seismologists in the **Seismic Room** to fasten the location and re-location process and seismic bulletin release
  - Activation of the **Emergency Communication Office**
Mobile Seismic Network

Situation at January 11, 2017

- N. 23 real time stations (18 with 6 components)
- N. 18 installed between August 24 and 30
- N. 3 installed on 27/10/2017 to the north
- N. 1 installed on October 30, 2016 (T1221)

- collaboration with RAN-DPC (10), and BGS (25 BB).
### Mainshocks and Aftershocks

<table>
<thead>
<tr>
<th>Earthquake date</th>
<th>Origin time (UTC)</th>
<th>M&lt;sub&gt;w&lt;/sub&gt;</th>
<th>Epicentral area/Region</th>
<th>Hypocentral Depth (km)</th>
<th>Lat N (°)</th>
<th>Lon E (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 August 2016</td>
<td>01:36:32</td>
<td>6.0</td>
<td>Accumoli (L)</td>
<td>9.2</td>
<td>42.70</td>
<td>13.23</td>
</tr>
<tr>
<td>24 August 2016</td>
<td>02:33:28</td>
<td>5.4</td>
<td>Norcia (U)</td>
<td>7.5</td>
<td>42.79</td>
<td>13.15</td>
</tr>
<tr>
<td>26 October 2016</td>
<td>17:10:36</td>
<td>5.4</td>
<td>Visso (M)</td>
<td>8.7</td>
<td>42.88</td>
<td>13.13</td>
</tr>
<tr>
<td>26 October 2016</td>
<td>19:18:05</td>
<td>5.9</td>
<td>Visso (M)</td>
<td>7.5</td>
<td>42.91</td>
<td>13.13</td>
</tr>
<tr>
<td>30 October 2016</td>
<td>06:40:17</td>
<td>6.5</td>
<td>Norcia (U)</td>
<td>9.2</td>
<td>42.83</td>
<td>13.11</td>
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<td>18 January 2017</td>
<td>10:14:09</td>
<td>5.5</td>
<td>Montereale (A)</td>
<td>9.0</td>
<td>42.53</td>
<td>13.28</td>
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<tr>
<td>18 January 2017</td>
<td>10:25:23</td>
<td>5.4</td>
<td>Montereale (A)</td>
<td>9.0</td>
<td>42.49</td>
<td>13.31</td>
</tr>
</tbody>
</table>
Seismic Moment Release and Event Number

Agg: 02/20/17 09:49:21 (ora locale), Magnitudo di soglia=2
da http://iside.rm.ingv.it/
Time and Space seismicity evolution
The Central Italy earthquake sequence
The Central Italy earthquake sequence

Macroseismic effects survey
Macroseismic effects survey
Macroseismic effects survey

August 24, 2016

October 30, 2016
The Central Italy earthquake sequence

Amatrice, $M_w$ 6.0

Norcia, $M_w$ 6.5

Visso, $M_w$ 5.9

**Accelerometric records**

Legend of PGA [cm/s²]

- unprocessed
- from 0 to 10
- from 10 to 20
- from 20 to 50
- from 50 to 100
- from 100 up

Da: Engineering Strong-Motion database (http://esm.mi.ingv.it)
ISPRA supports the DPC in the field to study activities linked to geo-hydrological issues:

- Quick field surveys to evaluate **residual risk** on roads and villages, mainly for **rockfalls and debris flows** occurred during seismic crisis, suggesting mitigation measures.

- Evaluation of **geo-hydrological compatibility** on sites to be used for temporary housing solutions, schools, tents, containers, wooden houses, production activities, …
Between August 24th and February 28th ISPRA produced more than 300 field survey reports:

- 78 Roads
- 43 Tents/Containers camps
- 162 Temporary housing
- 9 Schools
- 6 Villages
- 51 Other

Survey of the Earthquake effects in the natural environment
Survey of the Earthquake effects in the natural environment: stability evaluation

Some very specific issues, regarding a **Rockfall** in **Pescara del Tronto (AP)** area and a **landslide** near **Campli (TE)** produced specific reports including a back analysis of the movement and a residual stability evaluation.
Earthquake effects in the natural environment: mapping of coseismic ruptures and slope instabilities
Osservazioni relative all’evento del 30 Ottobre 2016 Mw6.5

coseismic rupture

field surveys: collaboration INGV, ISPRA, CNR, ENEA, UCamerino, UInsubria, IRSN, ULeeds, UCollege (about 200 scientists)
The Central Italy earthquake sequence

**GPS record of the earthquake**

- **24 AGOSTO M6.0**
- **26 OTTOBRE M5.9**
- **30 OTTOBRE M6.5**

**PARAMETRIFAGLIA “VETTORE”:**
- LENGTH = 40 km
- WIDTH = 18 km
- DEPTH = 0 km
- STRIKE = 160 gradi
- DIP = 45 gradi
- RAKE = -90 gradi
- SLIP max = 2.5 m
- $M_W = 6.5$
The Central Italy earthquake sequence

Kinematic finite fault inversions

Slip Distribution 2009 - 2017
DInSAR Technique

The Central Italy earthquake sequence

Second Scientific Seminar of the Knowledge Centre for Disaster Risk Management - Science for Policy and Operations - 9-10 March 2017, Rome, Italy
Amatrice EQ: NRT DInSAR Analysis

Amatrice Earthquake
Mw=6.0

Timeline
27-Aug-16 28-Aug-16 31-Aug-16

24-Aug-16

Sentinel-1 ASC
ALOS-2 ASC
CSK DESC
Sentinel-1 DESC

ALOS-2 DESC
Amatrice EQ: NRT DInSAR Analysis

Sentinel-1 ASC

ALOS-2 ASC

CSK DESC

Sentinel-1 DESC

ALOS-2 DESC

Timeline

27-Aug-16  28-Aug-16  31-Aug-16

Amatrice Earthquake
Mw=6.0

24-Aug-16

< -20

LOS Displacement [cm]

> 20

The Central Italy earthquake sequence

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Amatrice EQ: Vertical and East-West deformation components

Vertical

East-West

> 20

< - 20

> 20

< - 20

[cm]
Norcia EQ: Vertical and East-West deformation components

East-West

West: ~40 cm  
East: ~40 cm

Vertical

Uplift  
~15 cm

Subsidence  
~90 cm

Norcia
The earthquake from the satellite

Summary of the main source models of the main earthquakes (2009 to the south and 2016-2017-preliminary)
Seismic Microzonation activity

ISPRA, CNR, INGV, ENEA, some Universities are all part of the CentroMS (Seismic Microzonation Center) which is in charge, according to a recent Law (DL n. 8/2017) to support and coordinate the microzonation activities to ensure the quality and homogeneity of the MZS studies in the Earthquake area.

- Investigated areas: Arquata_Montegallo, Accumoli, Avarice, Norcia_San Pellegrino, Santa Lucia_Capitignano.
- In the Amatrice area: installed 28 temporary seismic stations (episensor+Le5s), array, noise, MASW, geology, seismic input.
Seismic Microzonation activity

Piccolo spessore con Vs<<400

Contrasto di impedenza principale Vs >> 800
Communicating the Earthquake: Data, Products, Dissemination, Information and Outreach

The Central Italy earthquake sequence

- Data and products
- Dissemination
- Information
- Outreach
EARTHQUAKE: emergency activities

INSTRUMENTAL OBSERVATION SYSTEMS
monitoring and surveillance

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NATURAL ENVIRONMENT EFFECTS SURVEY
BUILDING DAMAGE
OUTREACH

UNIVERSITÀ DI SIENA
INGV
OGS
UNICAM
ISPRA
SAPIENZA UNIVERSITÀ DI ROMA
ENEA

OUTREACH
DATABASE
HAZARD ASSESSMENT
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DEVELOPMENT OF NEW SCIENTIFIC KNOWLEDGE, MODELS AND HYPOTHESIS. NEW INPUT TO DEVELOP TOOLS FOR UPDATED SEISMIC HAZARD MAPS, SEISMIC LEGISLATION, AND SEISMIC RISK MITIGATION.