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Europe has been, and still is, operating very high standard seismic networks. Jointly, the European networks represent one of the densest and best equipped networks in the world (Figure 1). Many European countries also contribute significantly to the Global Seismic Network through a wide variety of programs (GEOFON, GEOSCOPE, MEDNET, and others). Unfortunately, the diversity in politics, technical implementation and financial support schemas make integration and broad data availability a challenge.

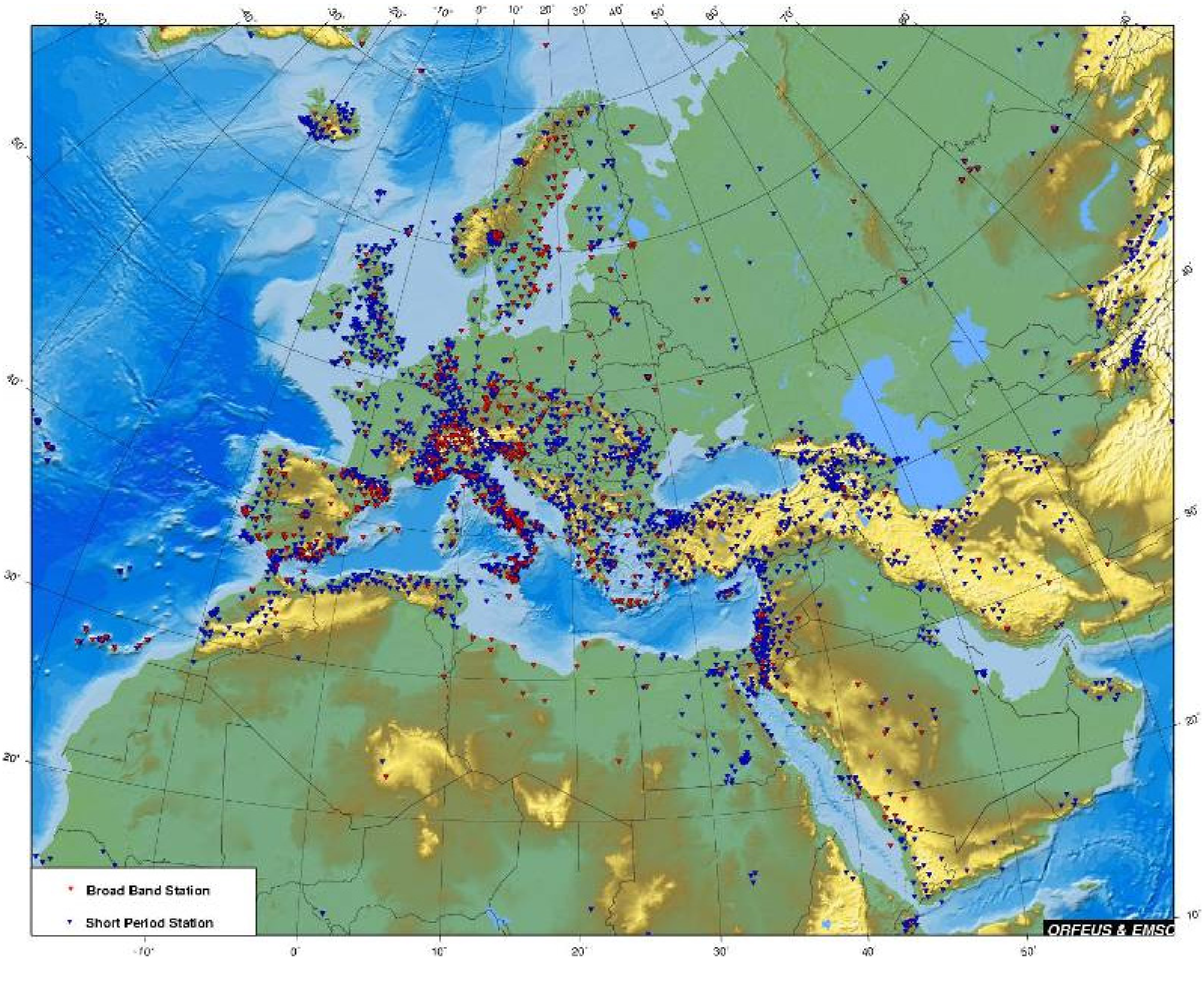


Figure 1. Permanently operating seismic stations in and around Europe. An overview compile in 2008.

The exponential increase of integration of network operations during the last decades in Europe is therefore impressive. Beginning with fax and later email exchange of arrival time, we are currently exchanging real-time data on a large scale. Rapid parameter data exchange is currently well established through the EMSC (~1800 reporting stations). Reliable Internet connections, a simple robust data exchange protocol, SeedLink, and an integrated EU, have been essential ingredients to facilitate waveform data exchange. Currently, more then 450 broadband stations exchange (near) real-time data within the context of the VEBSN. ORFEUS coordinates this waveform data exchange and promotes open access to the waveform data. We expect the VEBSN will increase to about 1000 stations within a few years.

The international waveform data exchange, of which the VEBSN is part, is an initiative of the seismological community; both network operators and researchers, not governmental agreements. Within the US and other large countries this is enforced by a single funding agency; in the US this is the NSF. Between European states and other global countries the motivation is primarily the recognition of mutual benefits. This follows a tradition started by the seismologist in founding the ISS at the beginning of the 20th century. In Europe the waveform data integration developed through a number of initiatives like among others NARS, a mobile network of stations and open data in 1987, followed by GEOSCOPE (IPGP, France) and later GEOFON (GFZ, Germany). Currently two NGO's, the EMSC and ORFEUS, coordinate data exchange in Europe and its surroundings and are successful.

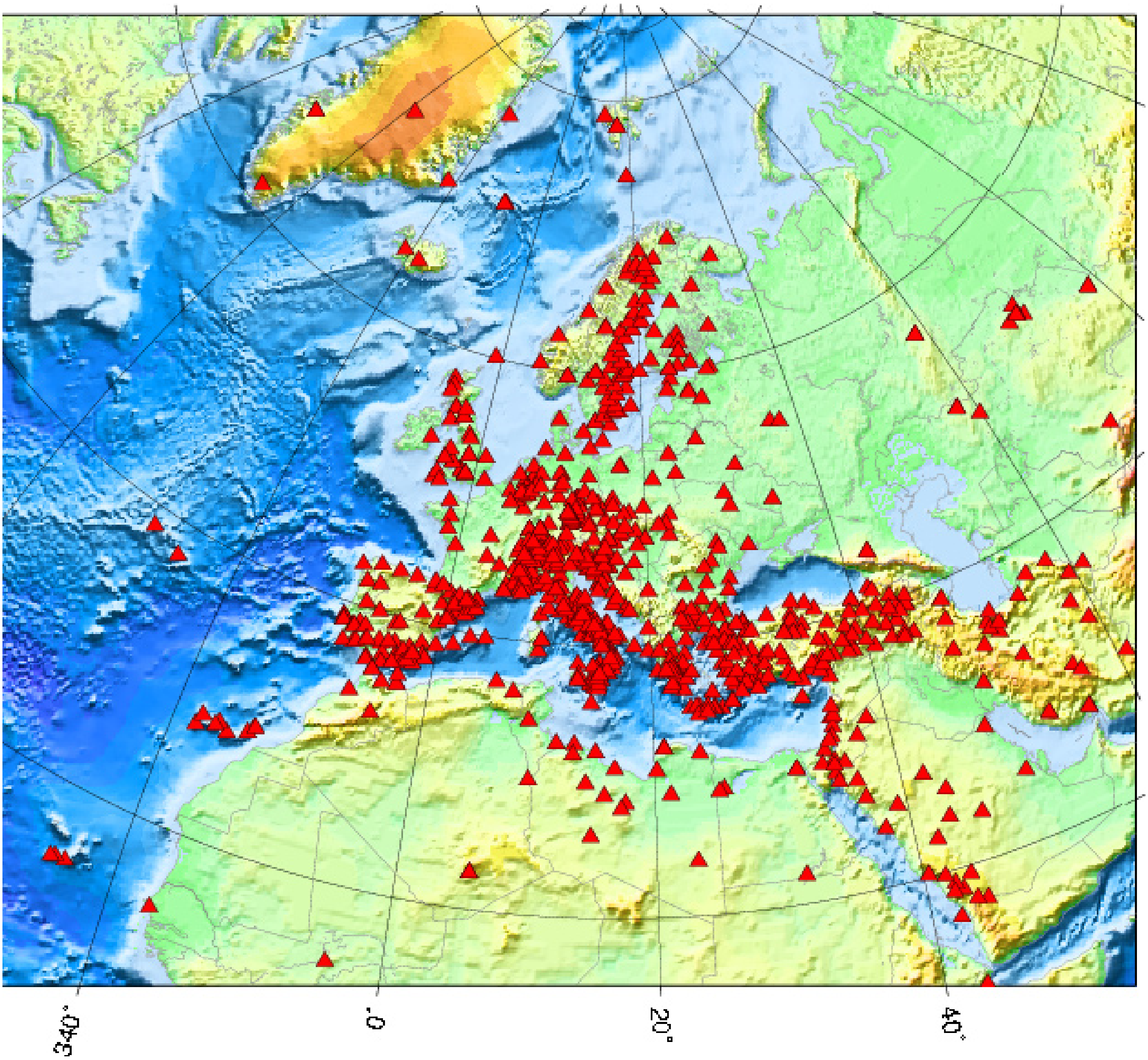


Figure 2. Permanently operating high quality (read: broadband) seismic stations in and around Europe. Compile by ORFEUS in 2009.

Although the current integration is impressive we are still a long way from a well integrated network of in-situ seismological observations (Figure 2). The permanent seismograph stations in and around Europe consist of nearly 2000 stations. Together with the many different mobile deployments, the OBS deployments, (deep) borehole installations, accelerometric networks and other innovative networks, Europe and its surroundings provides an uneven, but still very impressive in-situ earth observation sensor network. A number of recent infrastructure projects, like NERIES, aiming at further improving this integration. We may currently identify three major challenges in the handling of earthquake related seismological data.

The potentially available data offer, when easily accessible, a fascinating prospective for earth science research. The European 'Earthscope' challenge is not installing and deploying networks, as in the US, but integrating existing networks and archiving the mobile deployment data enabling efficient access. Here we give a glimpse of the potentially available data, the challenges ahead to realise our dream of complete data access and the different integration initiatives and projects that start using these datasets. In conclusion; seismologists are well on track in integration all seismological data.

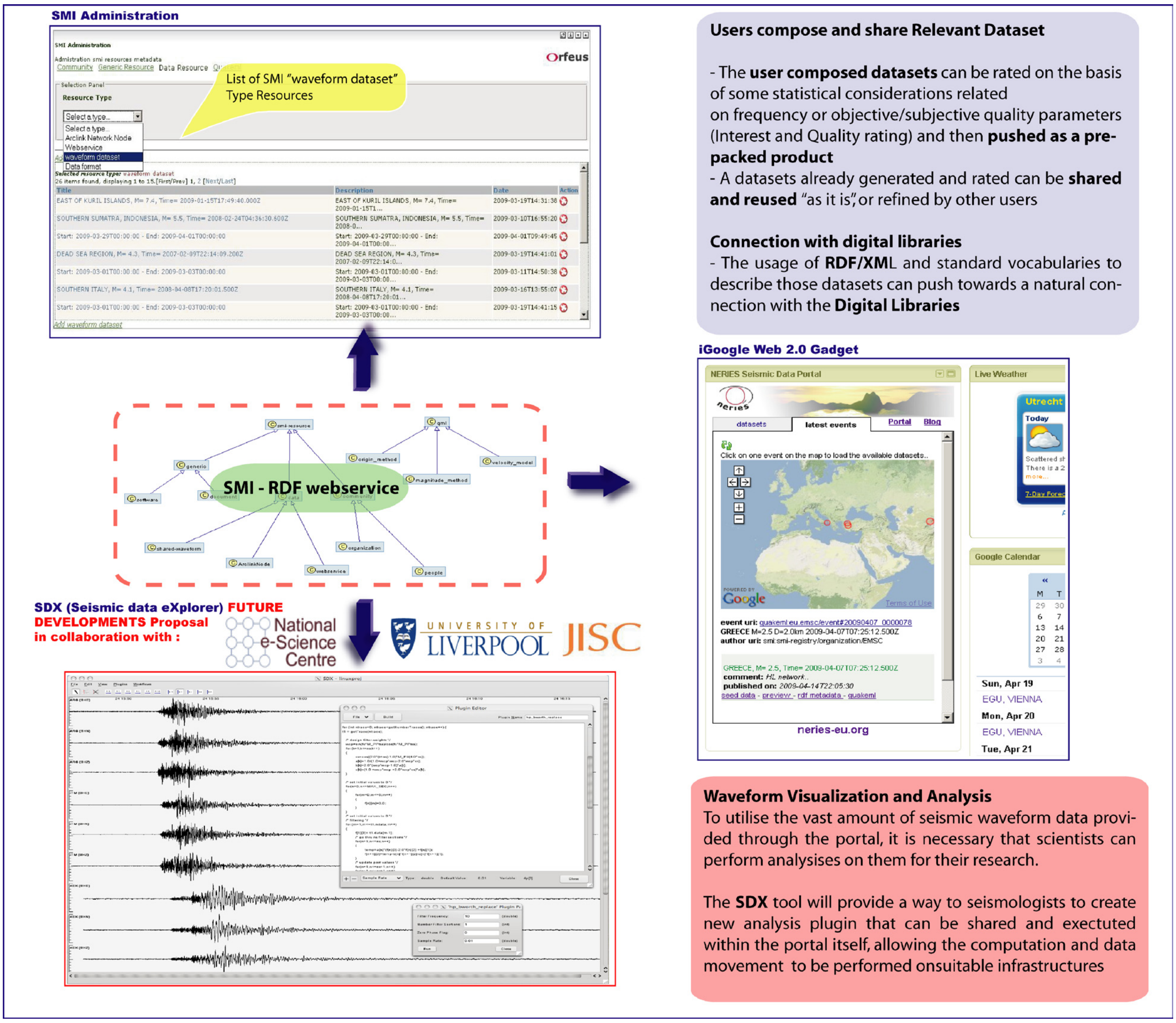


Figure 3. The RapidSeis pilot project aiming at interactive data handling and analysis including workflow documentation, and providing direct access to a distributed data archive and computing facilities (courtesy NESC, Univ Liverpool, ORFEUS, JISC).

As more data is becoming available and more details of the earth's internal structure are sought for, effective data management becomes an important bottleneck providing a new challenge to our community. Efficient data archiving, exchange, quality control, management, information mining, etc. require advanced techniques, not easily available to scientists not residing in one of the few excellently equipped labs. Data access procedures, currently supported by data centres, are mainly relying on robust simple data request routines. The fairly recent involvement of IT experts in seismology has resulted in experimenting with data provenance, integration of web services, new data mining techniques, workflow orchestration, for example. The current challenge in earthquake seismology is to create an efficient E-science environment in earthquake seismology that is robust, easy to handle and maintain, and providing advanced analysis techniques to a broad community of scientists and students. This new challenge, being able to use this vast amount of data cannot be done by seismologists alone and requires active involvement of IT specialists. This approach, in which seismologists cannot do it all by themselves is new, but offers also exciting new opportunities. Currently a few projects, NERIES, SHARE, VERCE, RapidSeis (Figure 3) are experimenting within this environment.

Figure 4. The challenge of combining data from different disciplines (Seismology, GPS, SAR)

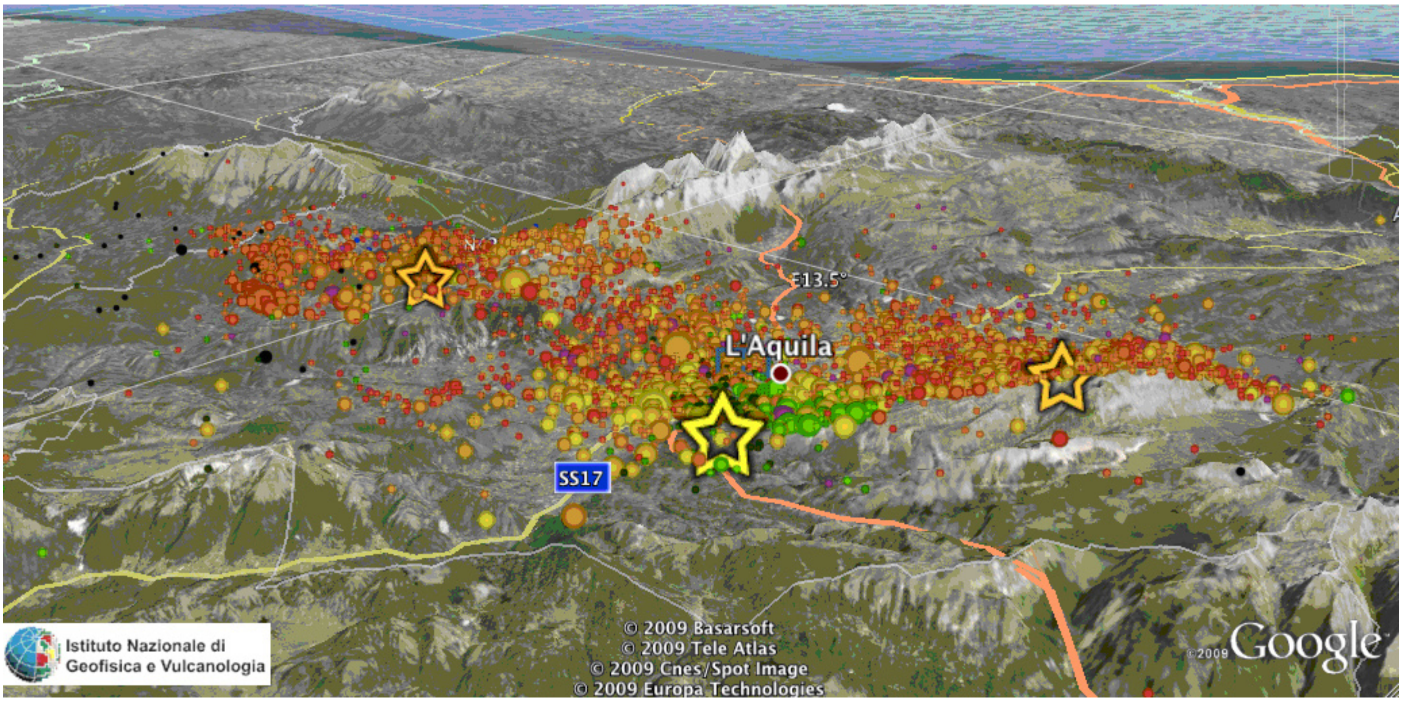
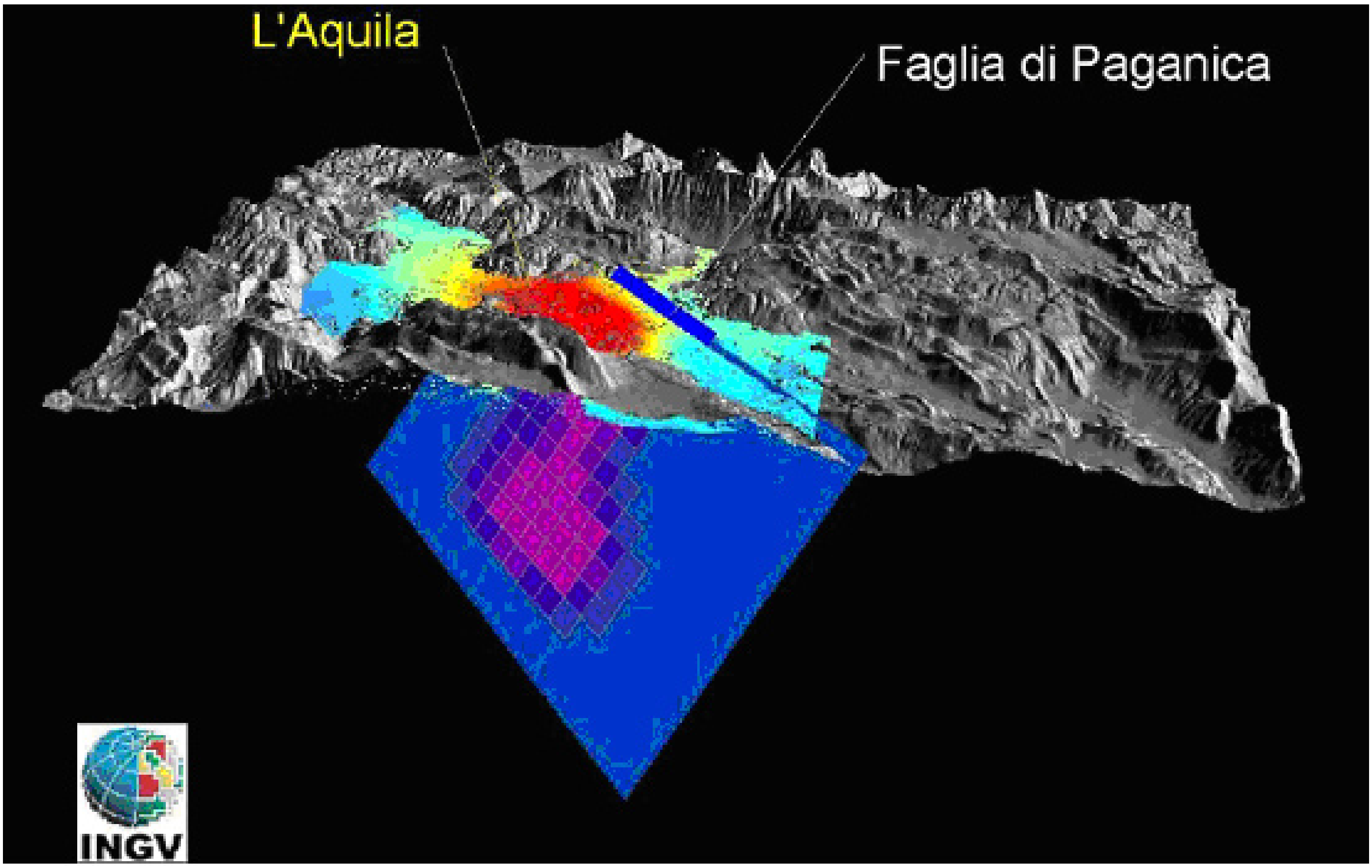


Figure 4a. L'Aquila earthquake and aftershocks. Googlee view of the seismicity from west (Courtesy INGV).

Figure 4b. preliminary analysis of co-seismic satellite surface deformation is the localization (to a good approximation) of the fault responsible for the April 6, 2009, earthquake. The model shows how the deep seismic dislocation corresponds at the surface with the Paganica fault, already reported in geological maps since the 1990 (courtesy ASI-SIGRIS and INGV).



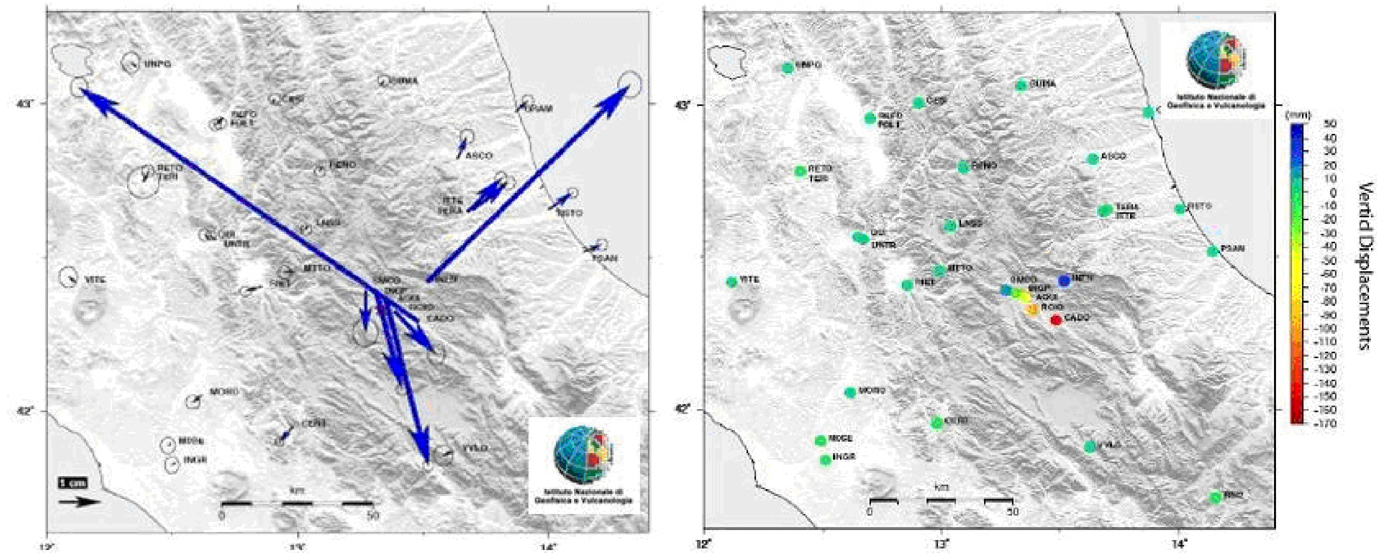


Figure 4c. Comparison between geodetic solution from «Bernese» (red), «Gamit» (blue) e «Gipsy» (gree): Semi permanent sites: CADO (Castello d'Ocre), ROIO (Roio) and SMCO (S. Marco) with data starting on April the 2nd. Permanent sites: RING (Istituto Nazionale di Geofisica e Vulcanologia), Univ Perugia, ASI (Agenzia Spaziale Italiana), INFN -D.P.C. Serv. Sismico Nazionale, sez. Geodetica.

Earthquake seismology data becomes even more intriguing when it can be easily combined with other geophysical data and modelling techniques. The challenge here will be to provide a wide range of possibilities to integrate, visualise and analyse earthquake seismological data together with other geophysical data. Within the space observation technologies much work into this direction is being done. On a global scale GEO(SS), among others, provide an environment in which this is promoted. Projects like INSPIRE aim at facilitating the necessary standardization of data. The earthquake seismology community is involved in a few projects experimenting with this geo-data integration. There are many initiatives pulling in the right direction, therefore this aspect is an important element in the long-term vision of EPOS. However, broad collaboration beyond the geo-sciences will be required to create an infrastructure that can meet the expectations of scientist.

In summary; there are fascinating and promising challenges ahead in realising the next level of data integration and management.