Advanced GNSS techniques for earthquake assessment and monitoring

Athanassios Ganas, aganas@noa.gr

Research Director, NOA

NOA GPS Project http://www.gein.noa.gr/gps.html

Hemus NET Project http://www.hemus-net.org/

NOA Faults http://194.177.194.200/services/GPS/GPS_DATA/1_NOAFaults/

GPS was originally set up by the Department of Defense (DoD) of the United States for military purposes. Things changed on 1st May 2000, when U.S. president Bill Clinton brought the position accuracy to less than 10 metres, giving birth to the commercial development of GPS technology.

Today, the GNSS/GPS industry is worth billions of Euros; almost any new smart phone or car has an embedded GPS receiver for navigation purposes, and there are many on-line Information Systems (Google Earth, Microsoft Virtual Earth, etc.) that provide GPS tools in their description of reality.

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Station KLOK
NOA-INGV

Station ATAL
NOA-NTUA

Station NOA1
EUREF since 2006

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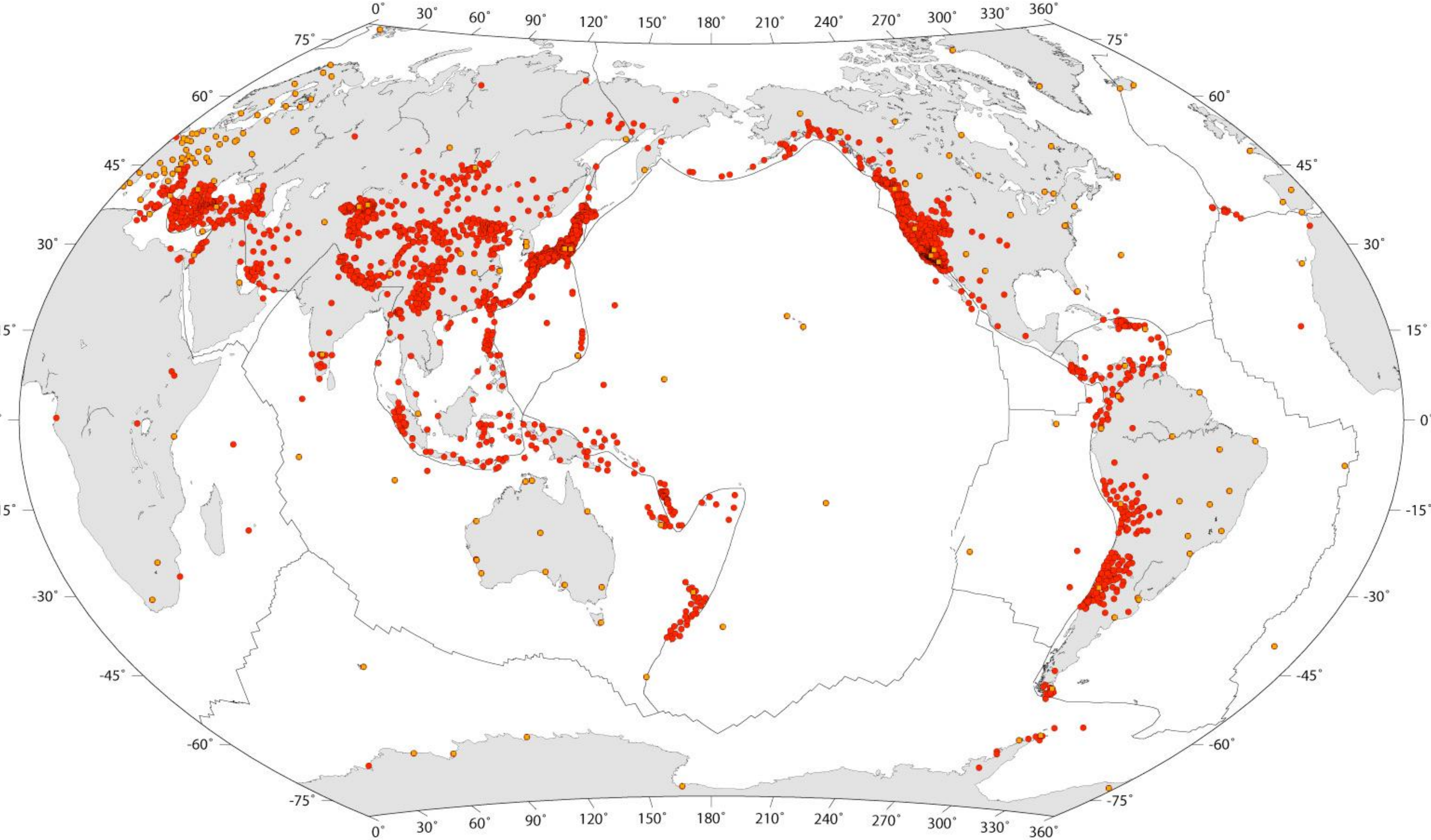

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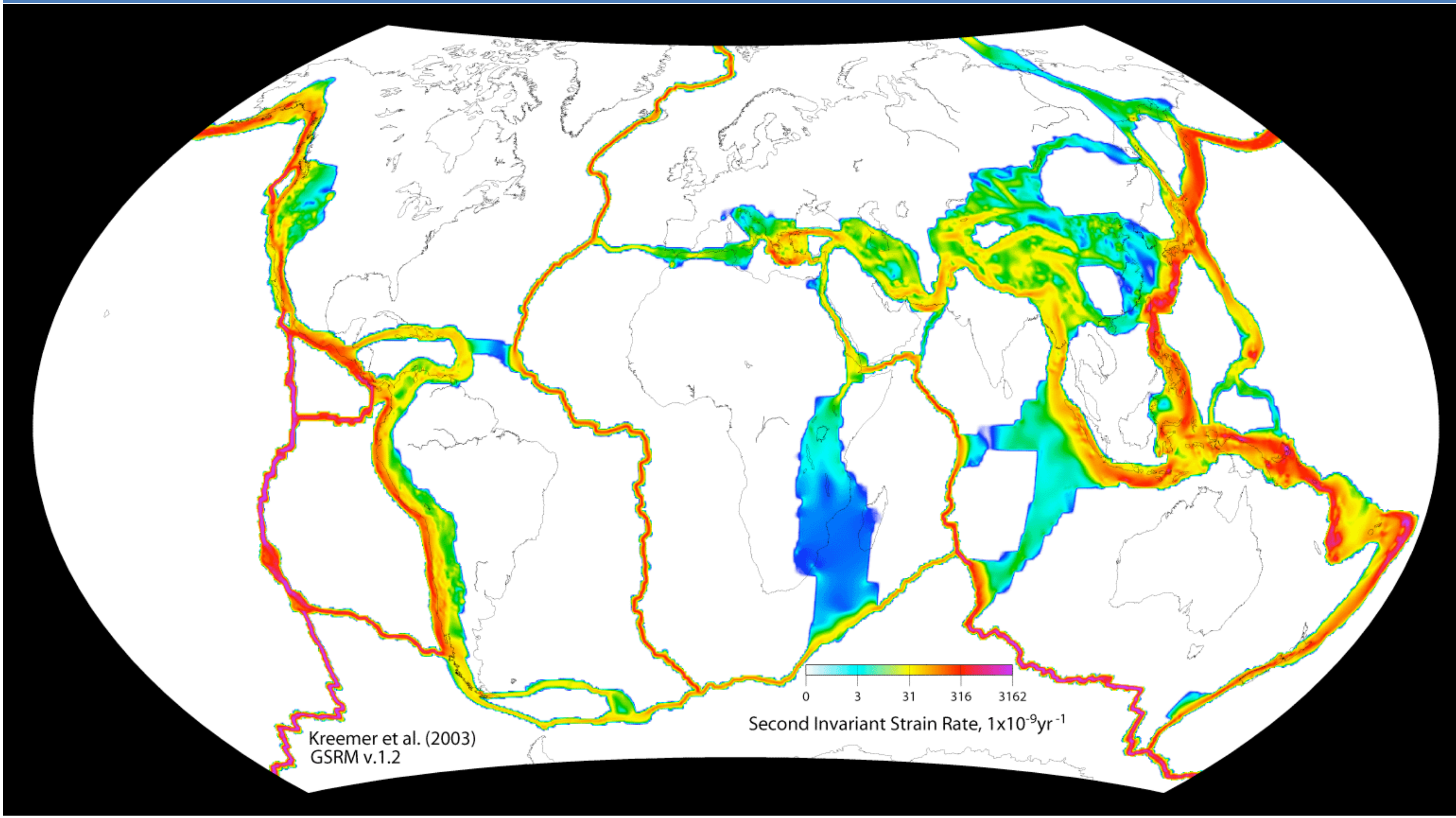
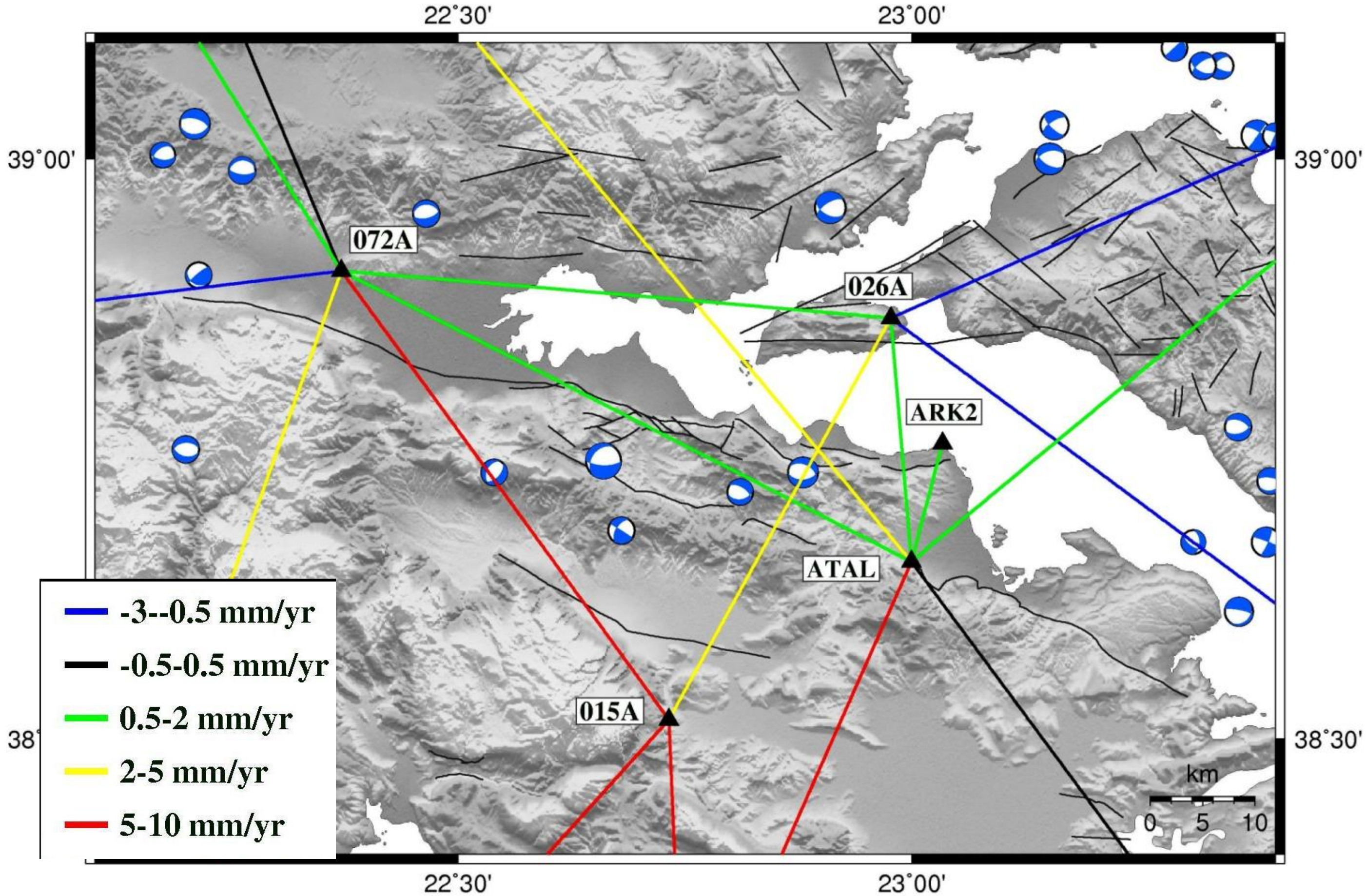


$$I2 = \varepsilon_{11} \cdot \varepsilon_{22} + \varepsilon_{22} \cdot \varepsilon_{33} + \varepsilon_{11} \cdot \varepsilon_{33} - \varepsilon_{12}^2 - \varepsilon_{23}^2 - \varepsilon_{13}^2$$

Chousianitis, K., Ganas, A., Gianniou, M., 2013. Kinematic interpretation of present-day crustal deformation in central Greece from continuous GPS measurements. J. Geodynamics, 71, 1-13.



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Since early 2000s, GPS has been effectively used to contribute in earthquake studies. The main product is the mm-size detection of the static displacements of a GPS receiver.

GPS has since been appointed as a powerful tool to assess earthquake parameters (fault characteristics) and to contribute to early tsunami warnings.

GPS seismology was effectively used to assess many recent global earthquakes (e.g., Alaska 2002 Mw 7.9, Chile 2010 Mw 8.8, California 2010 Mw 7.2).

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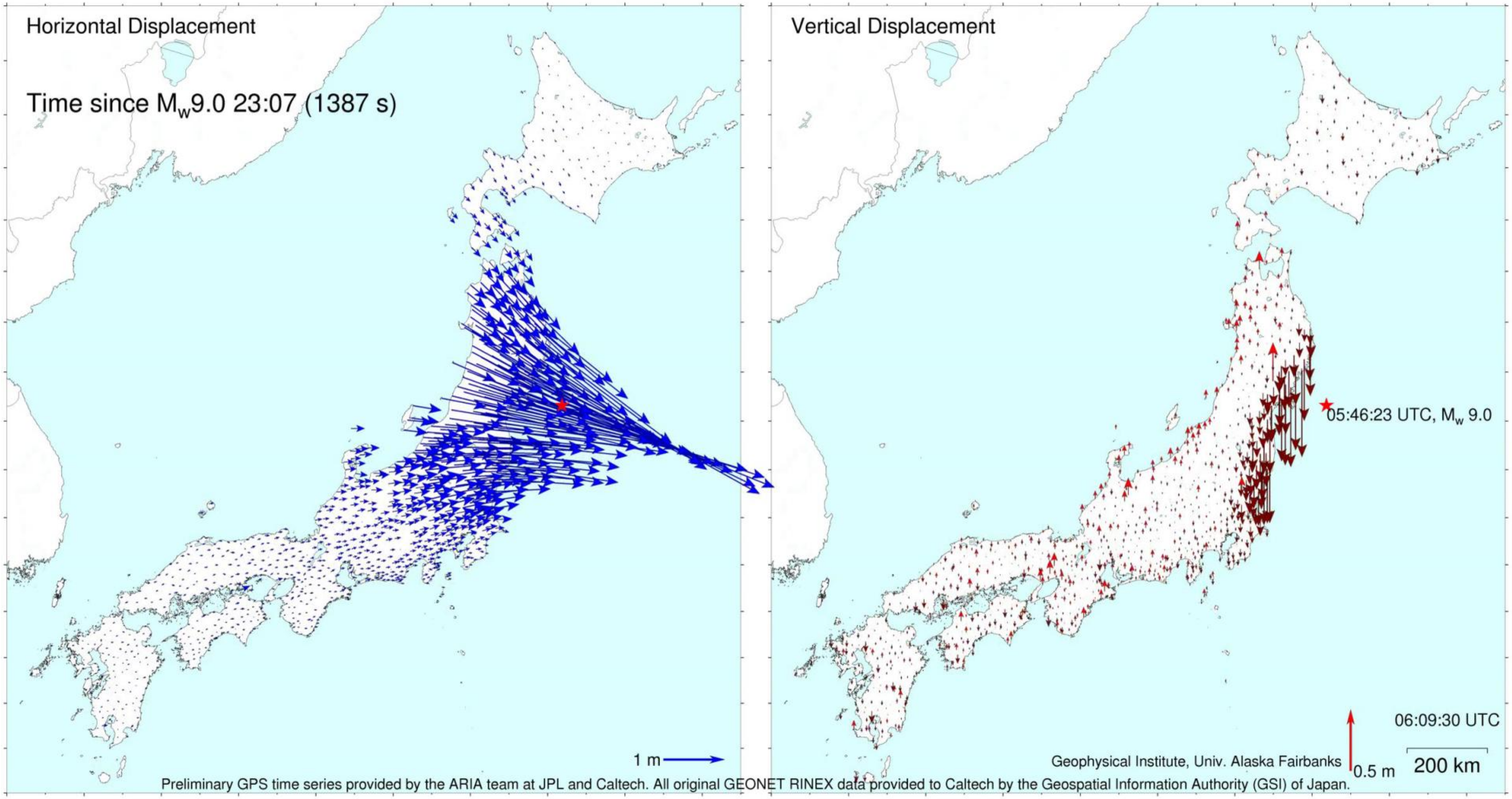

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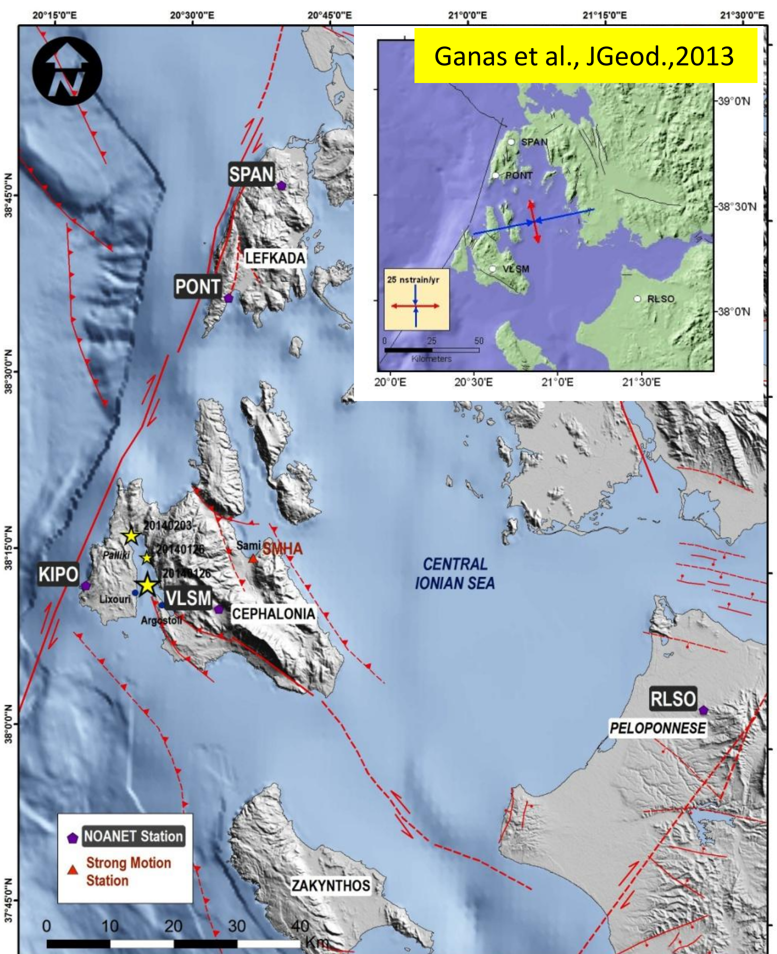

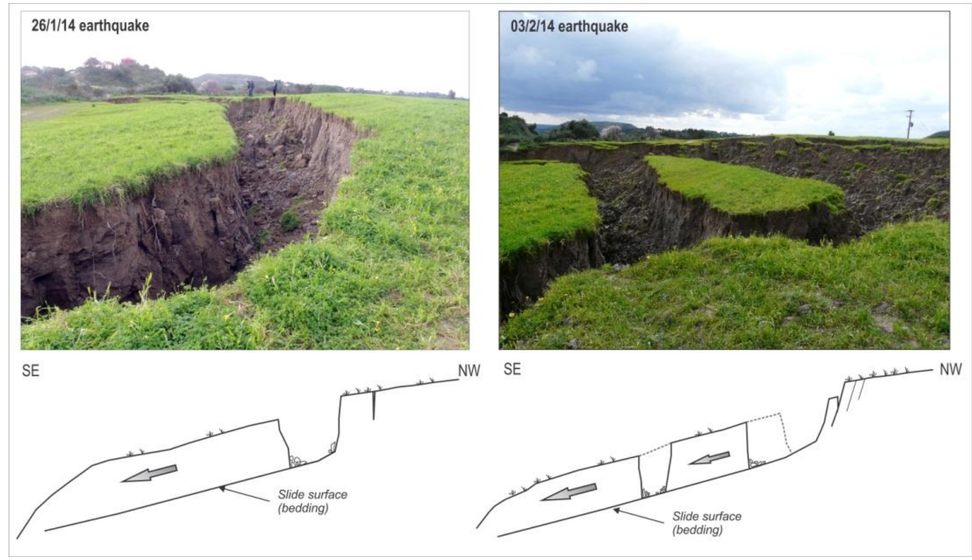

Valkaniotis S., Ganas A., Papathanassiou, G., and Papanikolaou M., 2014. Field observations of geological effects triggered by the January-February 2014 Cephalonia (Ionian Sea, Greece) earthquakes, *Tectonophysics*, DOI:10.1016/j.tecto.2014.05.012

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High-rate GPS is used to estimate in real-time the co-seismic displacement waveforms induced by an earthquake. It is the so-called GNSS seismology, which aims to exploit GPS to contribute in the estimation of important seismic parameters (e.g., seismic moment and moment magnitude).

In particular, some key features distinguish GPS with respect to other well-known seismological instruments (e.g., seismometers and accelerometers). Seismometers measure either velocities or accelerations and one needs to operate mathematical integration(s) to achieve the instrument positions. Instead, GPS now returns directly positions, which are essential to seismic assessment.

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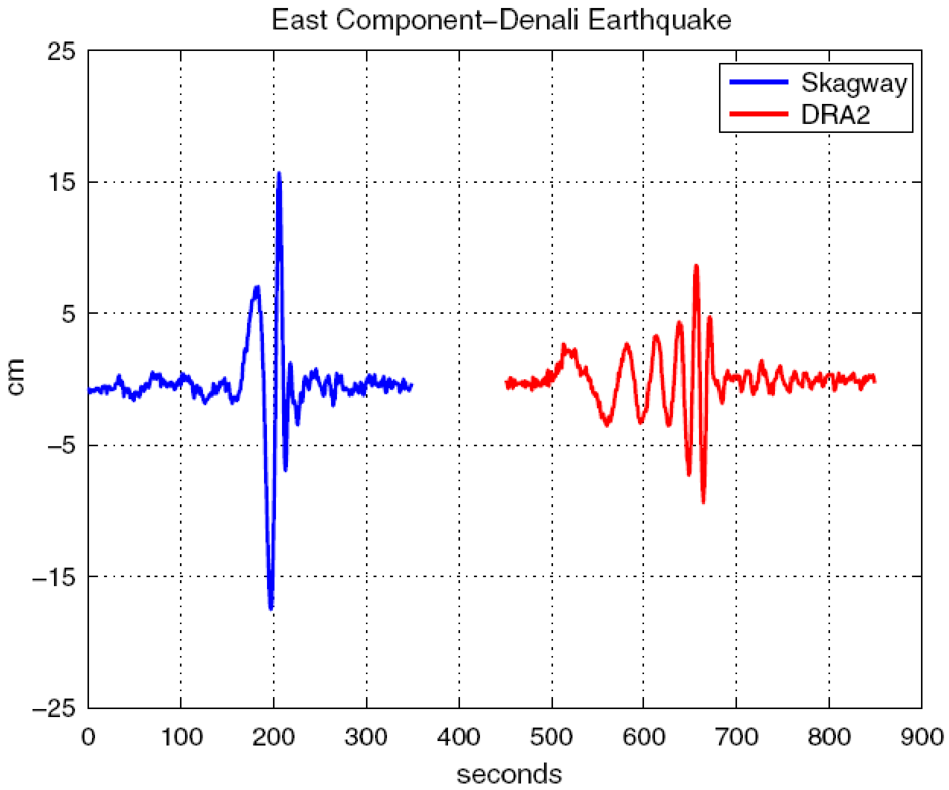

Fig. 2 East component GPS displacement records for a Skagway site and DRA2. These GPS receivers were located over 700 and 2,200 km, respectively, from the Denali epicenter. The difference in arrival times for the seismic displacements reflects the additional time it took the surface waves to travel the 1,500 km between Skagway and DRA2

Denali (ALASKA): 3 November 2002, Mw=7.9 Displacement Time Series (1 Hz)

K. Larson, GPS Seismology, J. Geod (2009), 83: 227-233

Secondly, the high energy released by strong earthquake can "blind" the acquisition capabilities of seismometers located in the vicinity (up to a 100-300 km) of the epicentre in what is known as the saturation problem.

Instead, even though GPS is less sensitive than seismometers, it does not saturate, not even for very strong earthquakes (e.g. Tohoku 2011)

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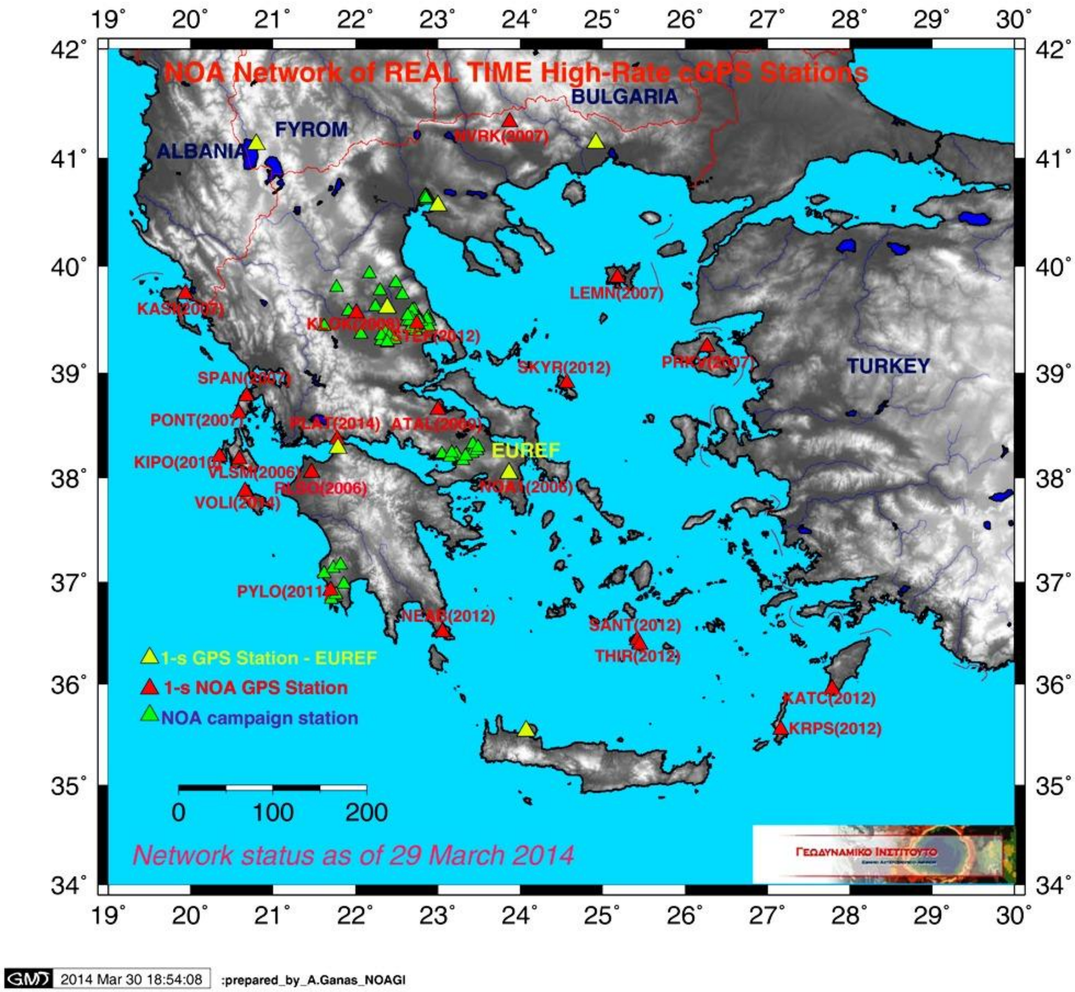

following the EUREF (*Regional Reference Frame Sub-Commission for Europe*) Permanent Network standards

22 stations at 1-s 24/7

12 stations co-located at 1-10m with seismometers and strong-motion sensors

55 benchmarks

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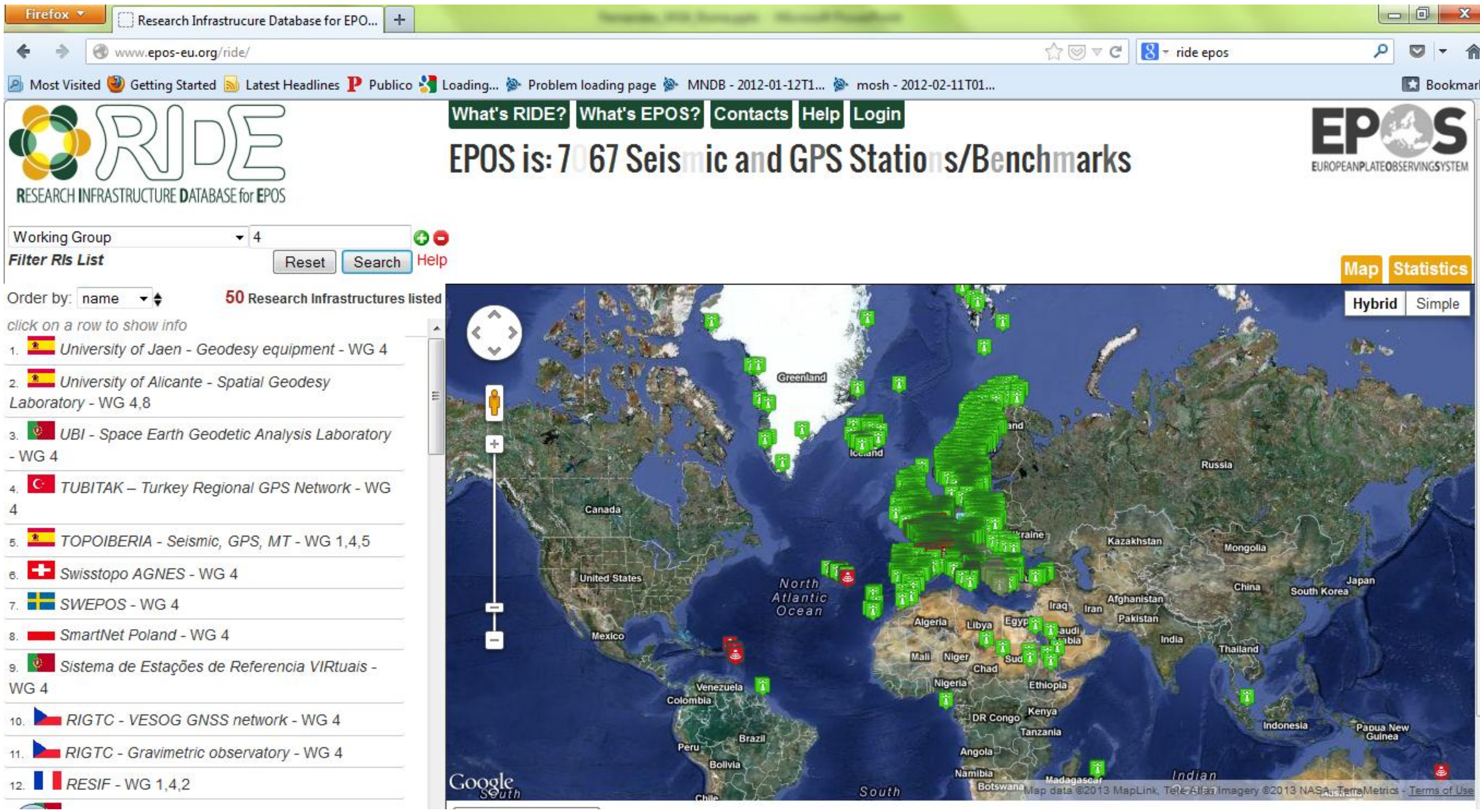

EPOS Database http://www.epos-eu.org/ride/

About 2200 cGNSS stations, managed by 52 research infrastructures (RI), potentially available for EPOS

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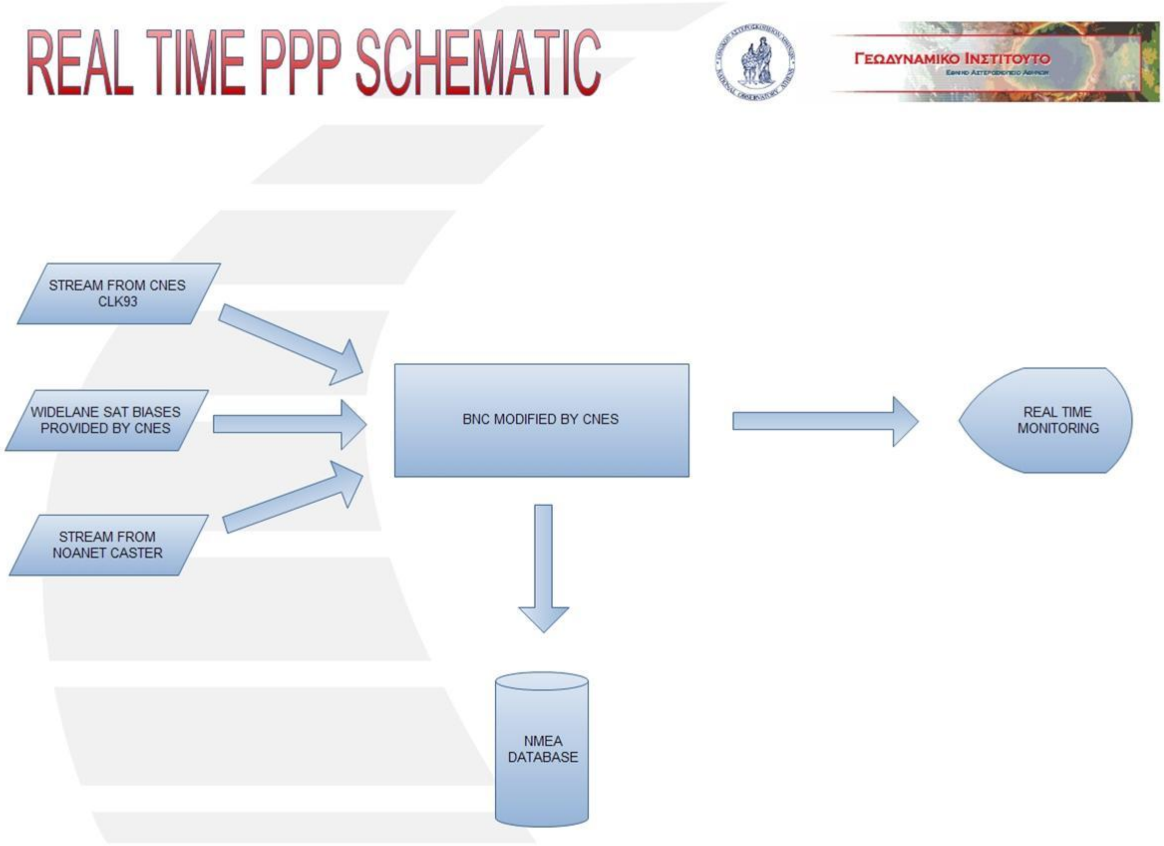

The PPP (Precise Point Positioning) processing technique is used to detect offsets in XYZ positions of GNSS stations in the Ionian Sea and Santorini Island, where tsunami hazard is high. PPP works on a single station, double-frequency, basis, continuously using the real-time RTCM v3.0 stream. PPP is a method to determine the exact coordinates of a single point using code or phase measurements with precise clocks and orbits.

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Today, the PPP approach can contribute to GPS seismology with the aim of accurately estimating the displacements caused by an earthquake in real-time and using a single receiver with a few centimetres accuracy level.

Simple transmission equipment can be added to allow communication if a defined displacement threshold is exceeded. With such a configuration, in case a large earthquake occurs, the displacements can be retrieved in real-time and immediately transmitted to a remote control centre, which can decide whether or not to raise a tsunami alert.

We really hope that GNSS will provide an effective contribution to tsunami warning systems and that the possibility to work with low-cost receivers will lift up the application of GPS (and possibly of other GNSS like GLONASS (Russian), GALILEO (European) and Compass/Beidou (Chinese), in an interoperability framework) as an earthquake monitoring device.

Thanks for your attention!