Global Navigation Satellite System in earthquake studies

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Earthquakes occure daily. Annualy, over 500 000 earthquakes are registered, 100 000 of them can be sensed and fortunately, only 100 cause damages. For example, on 27.10.2010 50 earthquakes (M>2.0) have been registred from Australia to Alaska.(1)

What causes the earthquakes?

Earthquakes are the way the Earth releases stress. They cause seismic waves, which spread in all directions with velocity reaching up to 5 km/s. The tremors cause displacements (up to 10 m) of large blocks of rock along a fault. Figures 1a-1c show the horizontal (blue) and vertical (red) displacements 3, 5 and 7 minutes after the onset of the seismic wave during the Japanese earthquake on March 11, 2011.(2)

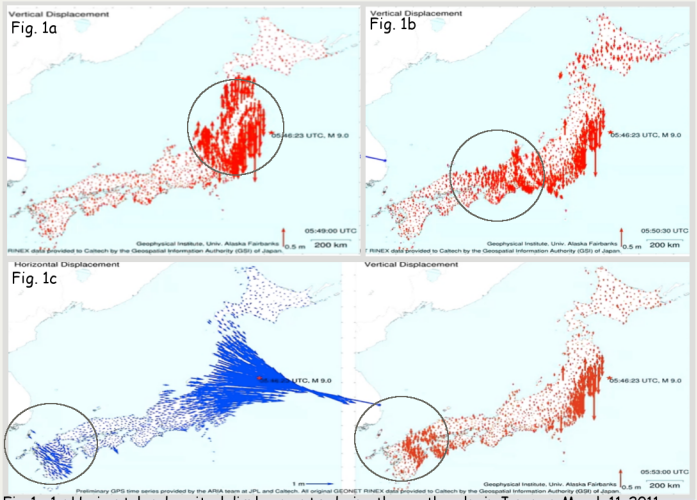

Fig. 1a-1c: Horizontal and veritcal displacements, during the earthquake in Japan on March 11, 2011

How do we register earth displacements?

The GNSS ground observation stations calculate the coordinates of their exact position every second. From the collected data we can generate maps for visual illustrations of earth displacements and the ground distribution of he created seismic waves.

(1) http://www.emsc-csem.org/Earthquake/
(2) http://gps.alaska.edu/ronni/sendai2011.html
(3) http://www.gsi.go.jp/ENGLISH/page_e30068.html

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http://www.phys.uni-sofia.bg/~guerova/gnss_earthquake_11_e.pdf

GEONET (3) is the permanent GNSS network of Japan. It consists of 1200 GNSS premanent stations (fig. 2a). Each station is equiped with antenna (fig. 2b). The construction of GEONET started in 1993 with 110 stations. After the 1994 Hokaido (M 8.1) and the 1995 Kobe (M 7.2) earthquakes the potential of GNSS monitoring was proven and the densest GNSS network was developed.

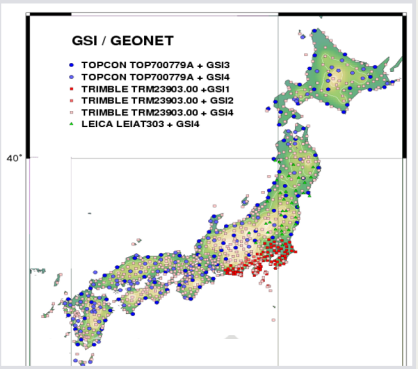


Fig. 2a. Distribution map of GEONET sites (blue dots)

Fig 2b. Reference station antenna

Global Navigation Satellite System (GNSS)

*GPS (USA) – full constellation in 1995 (fig. 3)
*GLONASS (Russia) – full constellation in 2009
*GALILEO (EU/ESA) – full constellation planned for 2015
*COMPASS (China) – full constellation planned for 2020

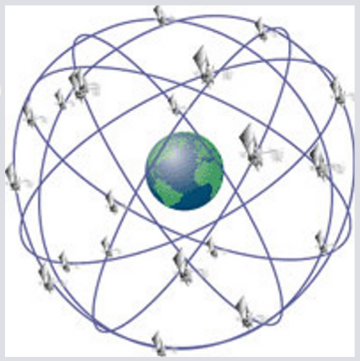


Fig.3:GPS constallation

GPS constellation

-30 active II generation satellites

-6 orbital planes

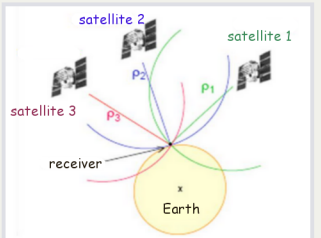
-altitude – 20 200 km

-inclination 55° with respect to the Equator

GNSS has three segments: space segment- the GNSS satellites, control segments and ground segments- networks of reference control stations. For position determination information of four GNSS satellites is necessary.

Position determination

Position determination is identical for all GNSS systems. The satellite sends a signal carrying information about the exact moment in time, when the signal is generated. The receiver detects the exact time the signal reaches. The distance is calculated by multiplying the velocity and the signal travel time.



$\rho_1 = (t_r - t_{01}) . c$,

t_r - signal reception time

t_{01} - signal sending time

c - speed of light

Fig.4a GNSS positon determination Fig.4b

GNSS possibilities in Bulgaria

Earthquake monitoring using GNSS can be applied for Bulgaria. In Bulgaria, there are 3 GNSS networks with over 110 reference stations. Bulgaria is in a region with high seismic activity and has 9 seismic zones. The regions with highest seismic risk are: Struma (Kresna), Plovdiv (Maritsa), Sofia, Gorna Oryahovitsa and Shabla. In Bulgaria, on average 90 earthquakes (M>2.0) are registered each year. The strongest one was in the valley of Struma river in 1904 with a magnitude of 7.8 on the Richter scale. This is one of the strongest earthquakes recorded in Europe.

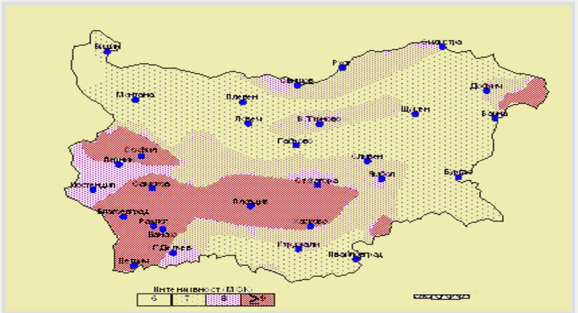


Fig.5: Seismic hazard map, Bulgaria