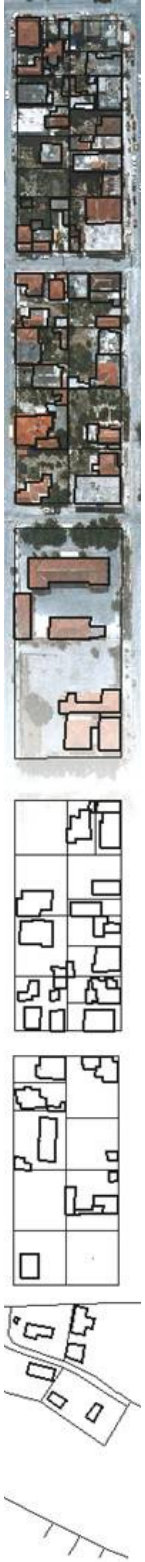

KTIMATOLOGIO S.A.

HEPOS
HEllenic POsitioning System

Detecting permanent displacements caused by earthquakes using data from the HEPOS network

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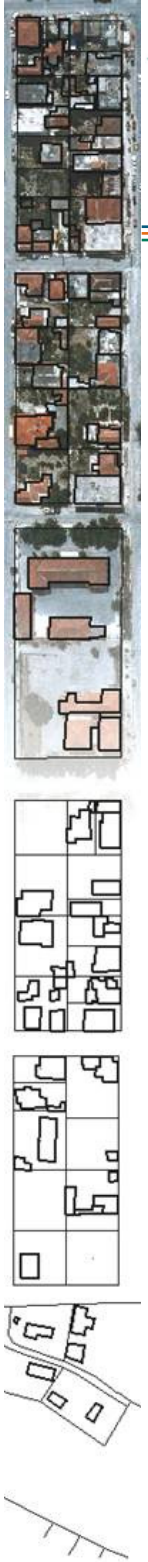
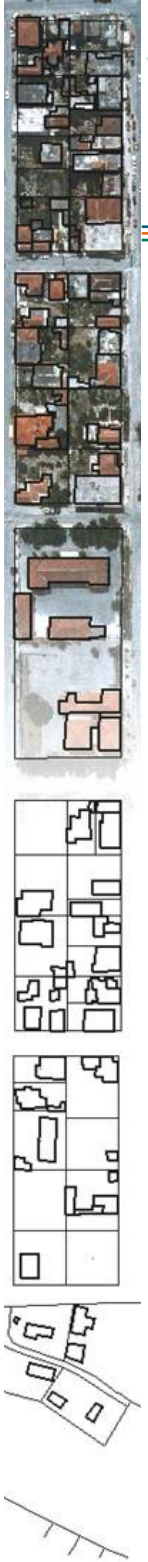


Outline

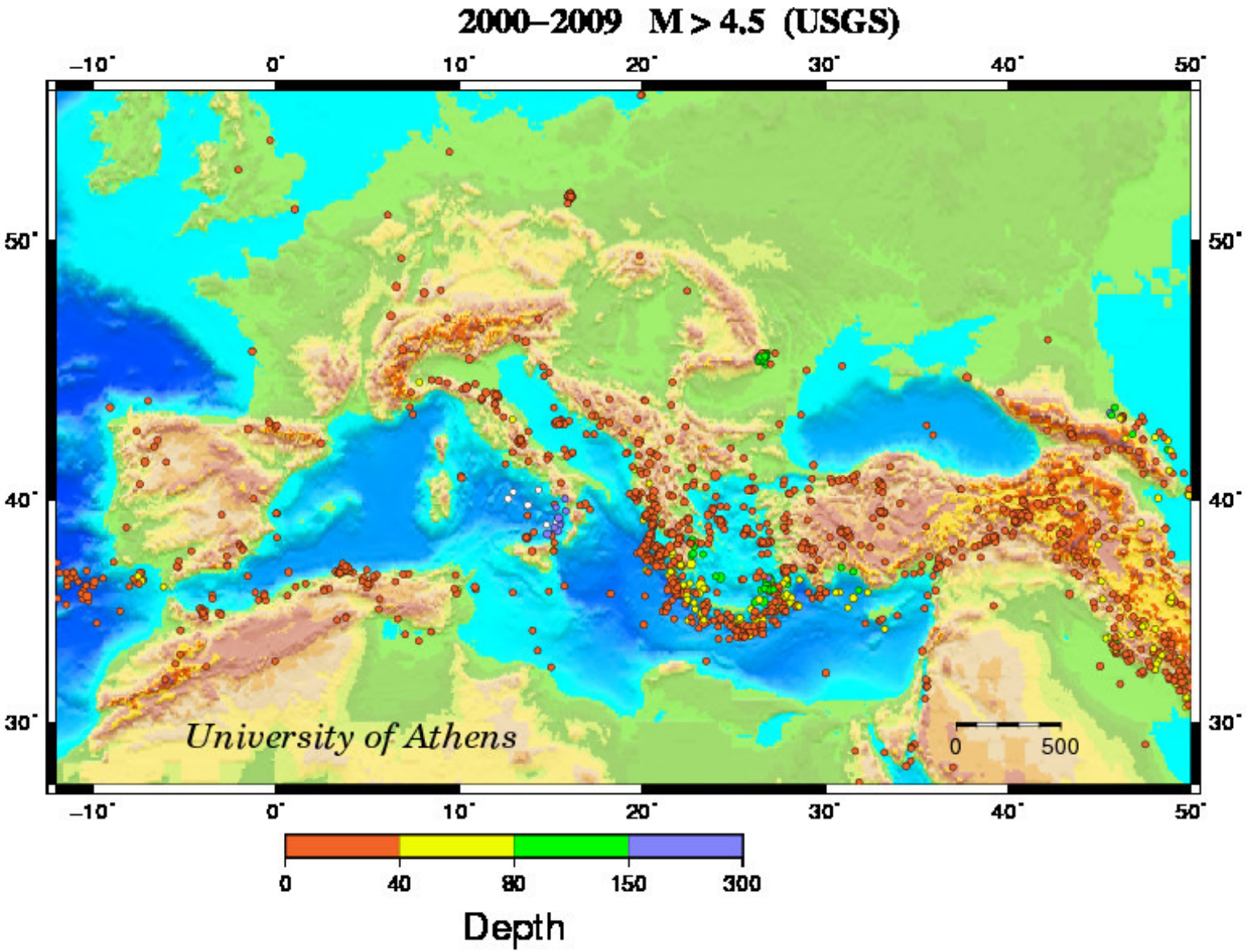
1. RTK-networks and coordinate stability
2. Seismic activity in Greece
3. Earthquakes and permanent displacements
4. Earthquakes investigated
5. Data analysis
6. Discussion
7. Conclusions



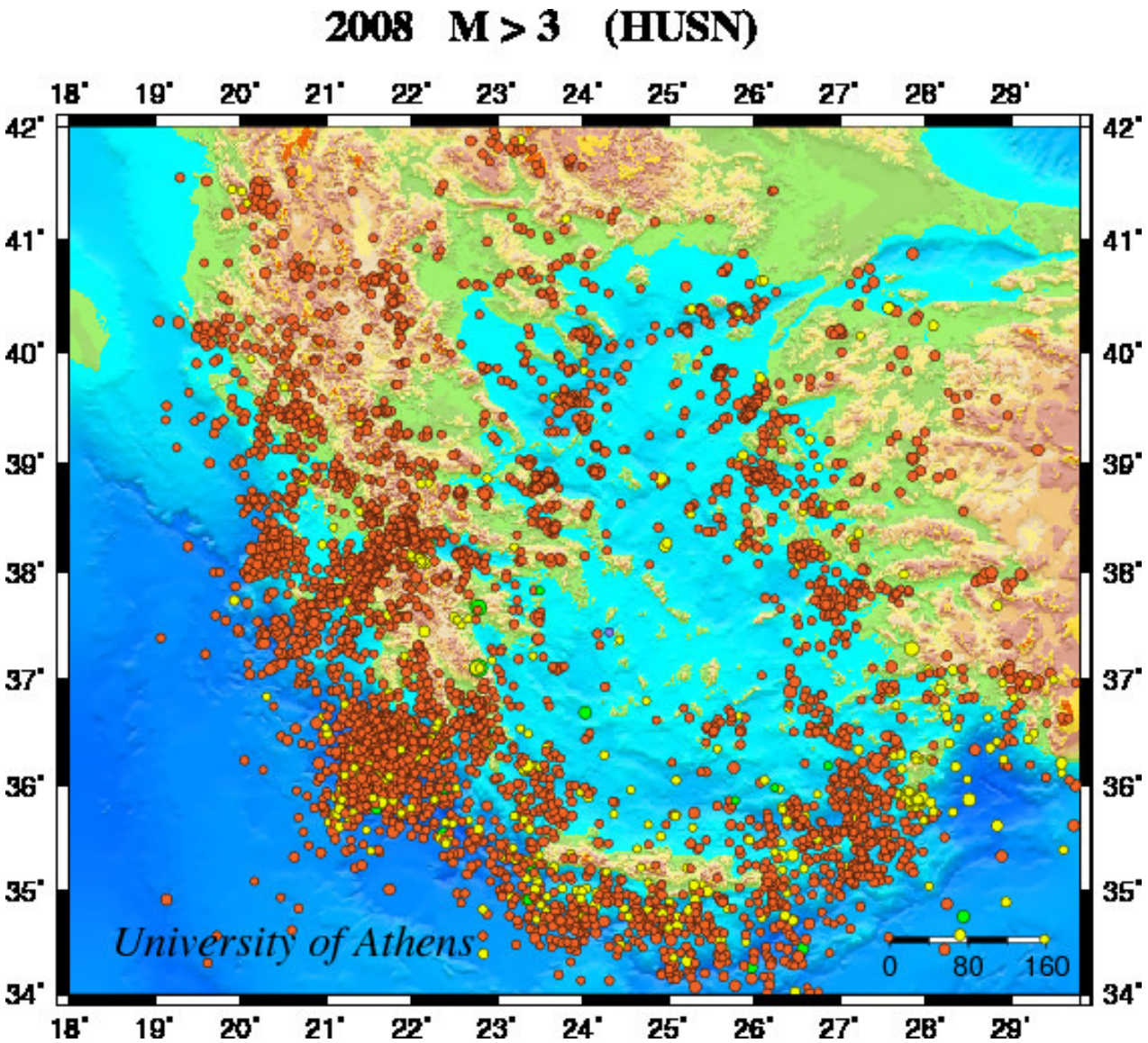
1. RTK networks and coordinate stability

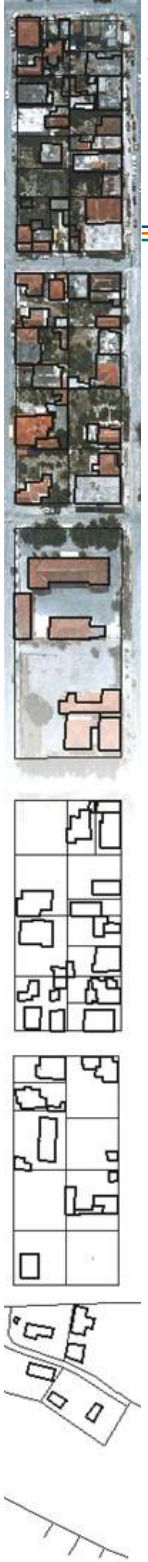
- Single-base GNSS positioning is progressively being replaced by network-based techniques (VRS, FKP, MAC etc).
- These techniques model the error sources in order to eliminate the distance-dependent errors in relative GNSS geodetic positioning.
- The effective modelling of the error sources requires highly accurate coordinates of the reference stations.
- Typically, the coordinates must be consistent to the 1 cm level.
- Displacements caused by earthquakes can seriously affect the consistency of the network.

2. Seismic activity in Greece



2. Seismic activity in Greece





3. Earthquakes and permanent displacements

- The impact of an earthquake depends strongly on its characteristics, like:
  - magnitude
  - focal depth
  - source mechanism
  - characteristics of the subsurface structures.

- For the operators of an RTK-network the major concern regarding earthquakes is the possibility of permanent displacements.

- In this work, eight earthquakes with different characteristics are investigated, in order to detect permanent displacements.

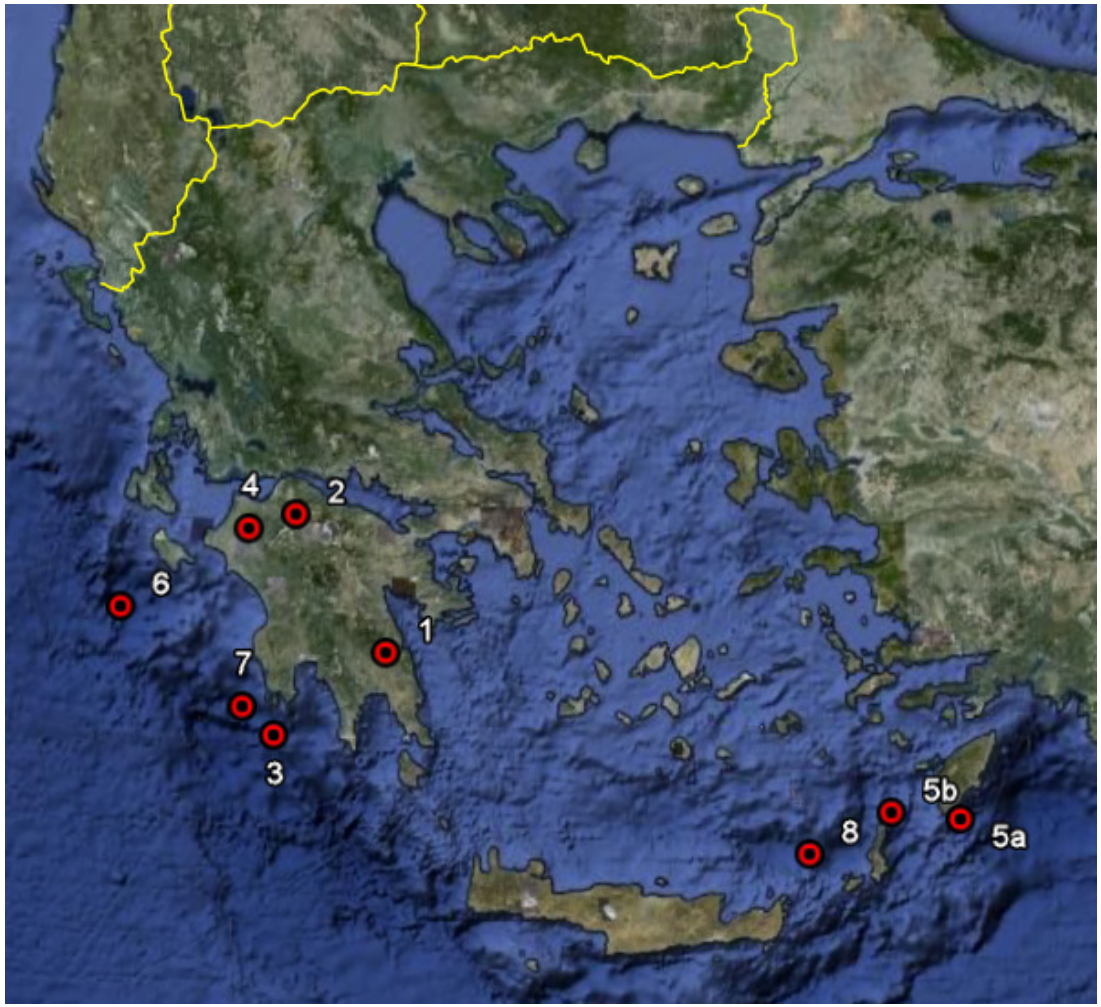
4. Earthquakes investigated

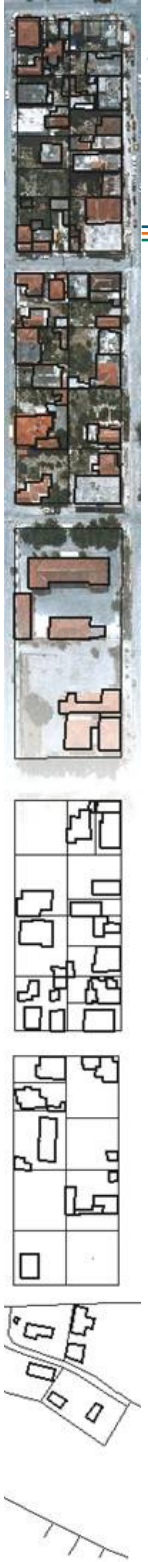
Characteristics of the Earthquakes

EQ	Date	Time (GMT)	φ	λ	Depth (Km)	Magn. (local)
1	06/01/08	05:14	37.11	22.78	86	6.1
2	04/02/08	22:15	38.09	21.94	25	5.0
3	14/02/08	10:09	36.50	21.78	41	6.2
4	08/06/08	12:25	37.98	21.51	25	6.5
5a 5b	15/07/08 >>	03:26 03:45	35.85 35.92	27.92 27.30	56 10	6.2 3.1
6	03/11/09	05:25	37.39	20.35	39	5.6
7	11/02/11	17:16	36.70	21.49	31	4.0
8	01/04/11	13:29	35.64	26.56	63	6.2

4. Earthquakes investigated

Epicenters of the Earthquakes





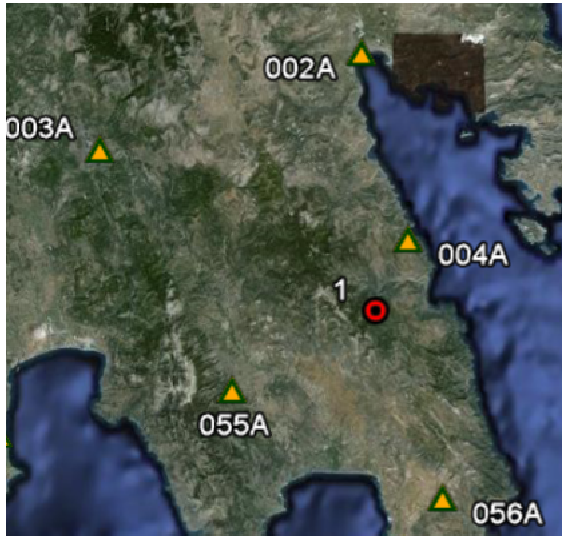
5. Data analysis

For the detection of changes in the coordinates of the stations:

- Data from the closest stations have been processed
- Daily solutions have been computed for several days before and after each event
- Each solution has been computed using 24 hours of data
- Time series of the coordinates have been produced and inspected for changes

5. Data analysis

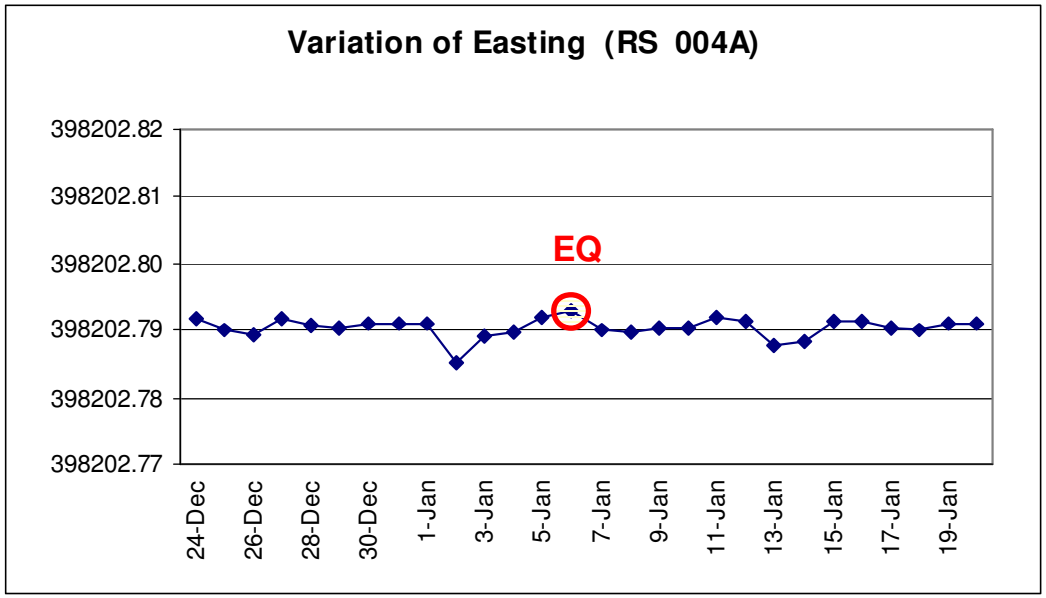
Earthquake 1

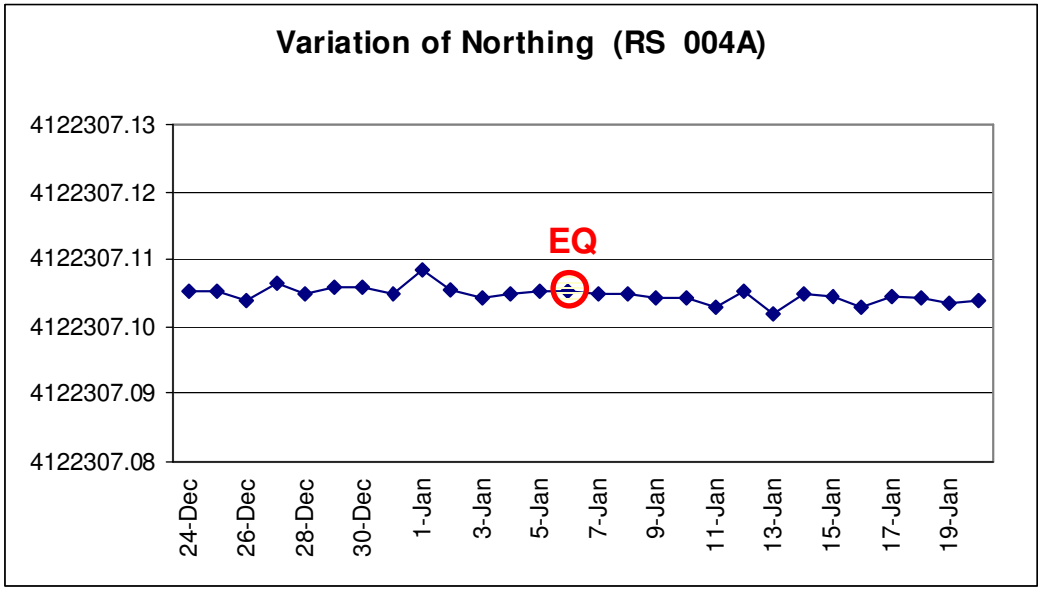


Day: January 6, 2008

Magnitude (L): 6.1

Depth: 86 Km





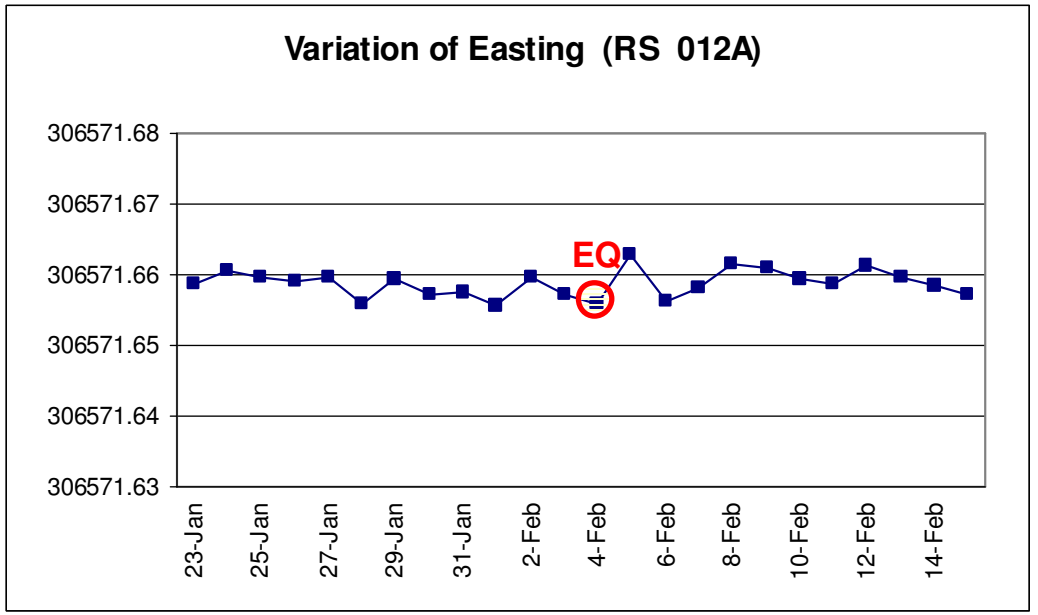
5. Data analysis

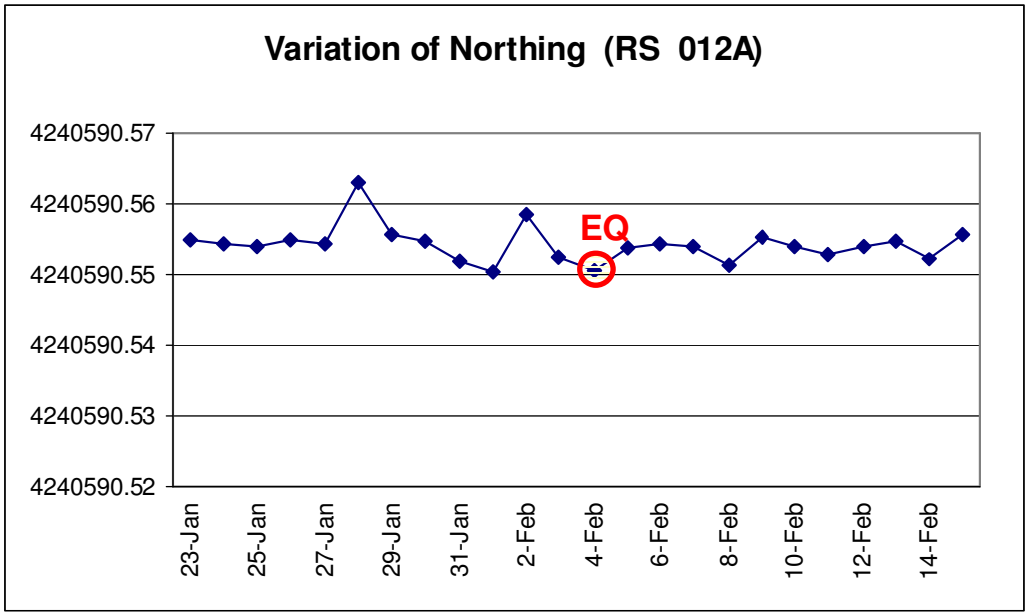
Earthquake 2

Day: February 4, 2008

Magnitude (L): 5.0

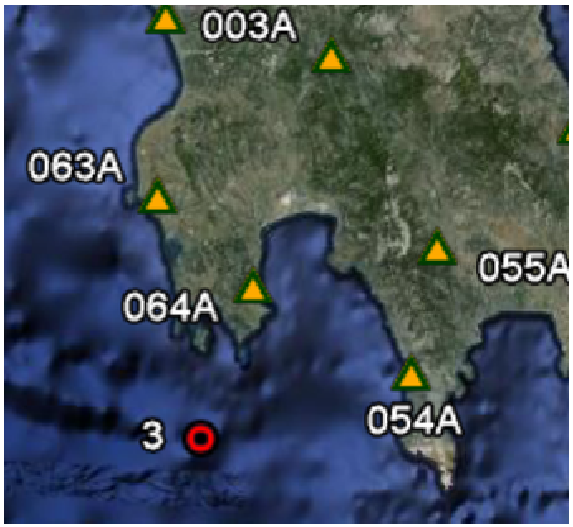
Depth: 25 Km





5. Data analysis

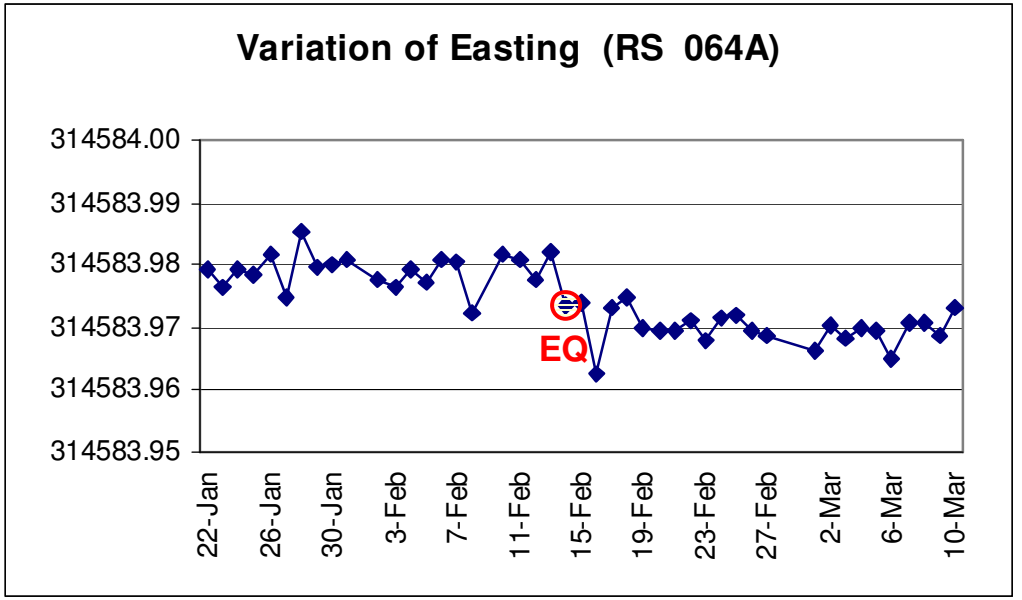
Earthquake 3

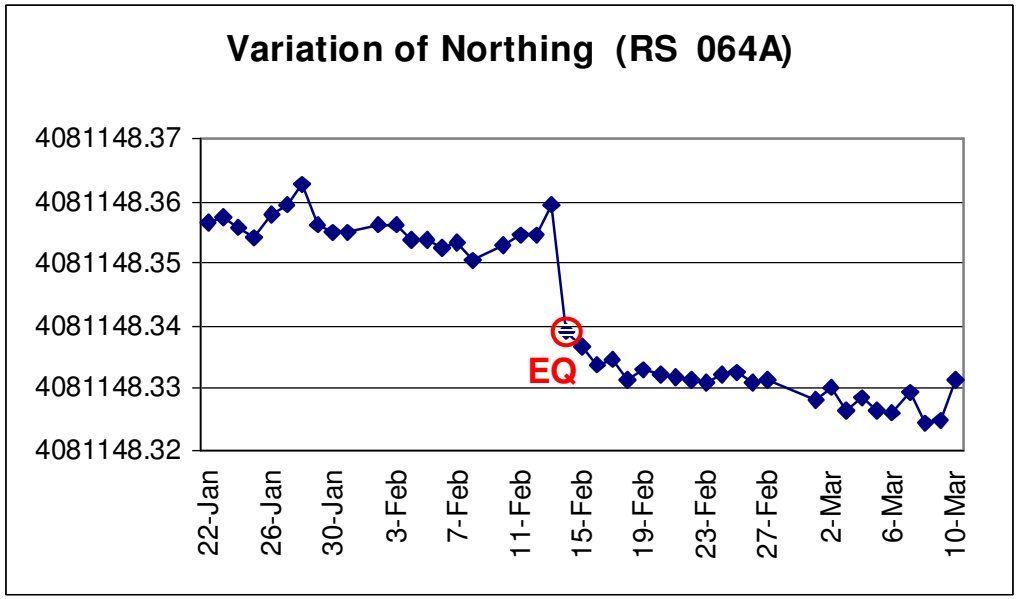


Day: February 14, 2008

Magnitude (L): 6.2

Depth: 41 Km





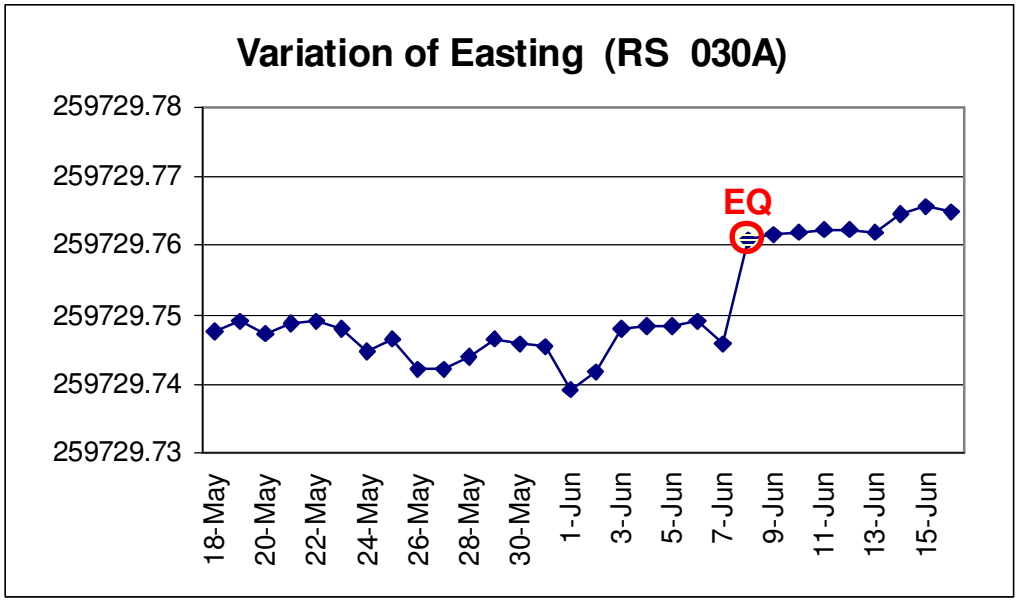
5. Data analysis

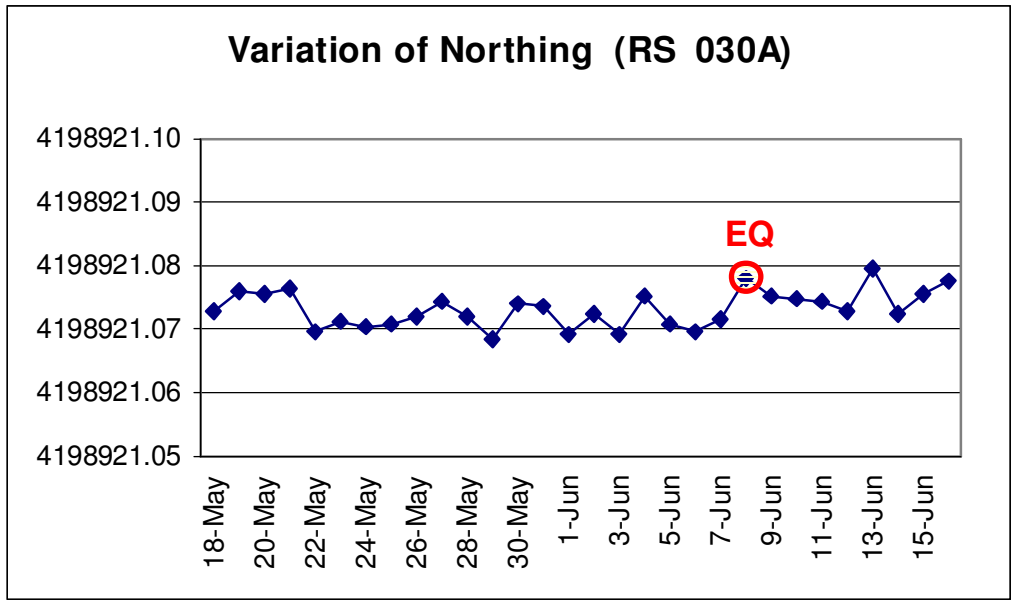
Earthquake 4

Day: June 8, 2008

Magnitude (L): 6.5

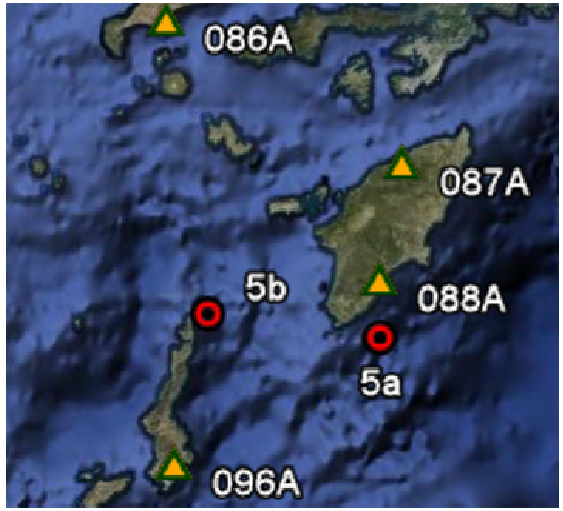
Depth: 25 Km





5. Data analysis

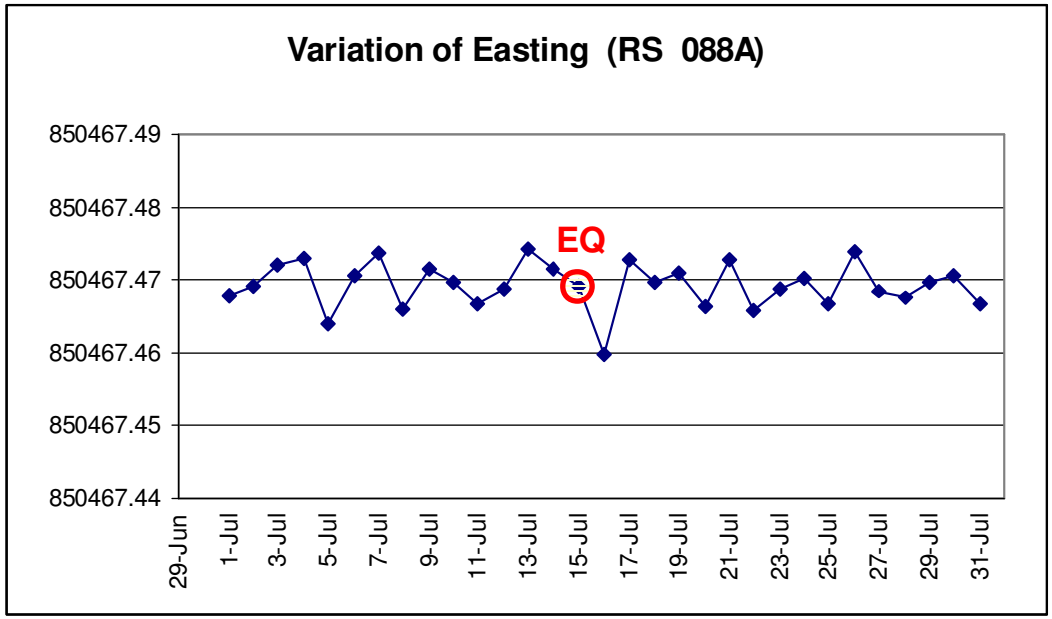
Earthquakes 5a, 5b

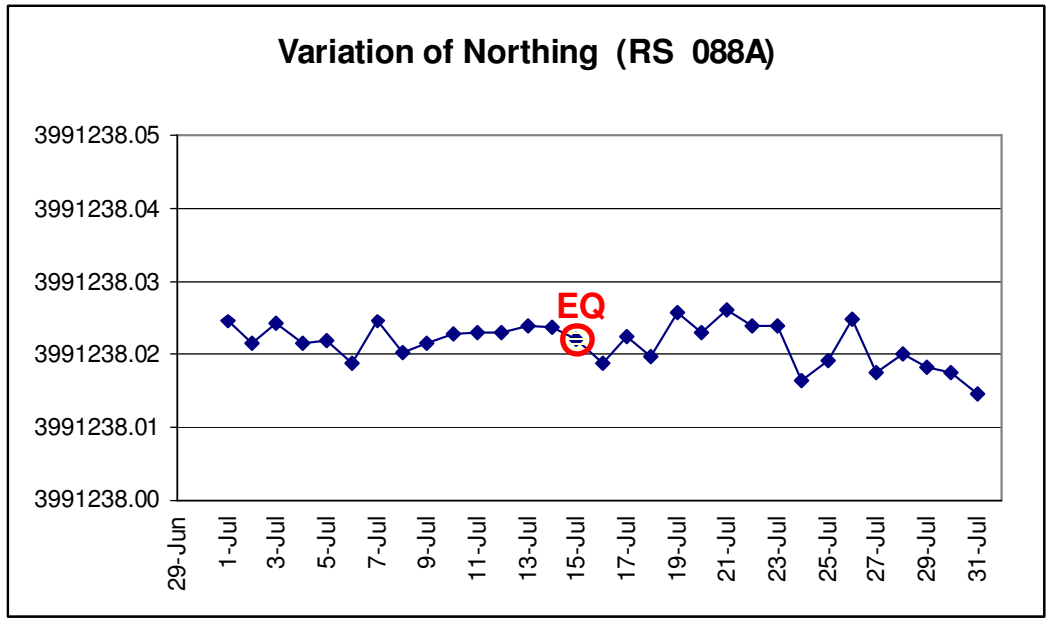


Day: July 15, 2008

Magnitude (L): 6.2 / 3.1

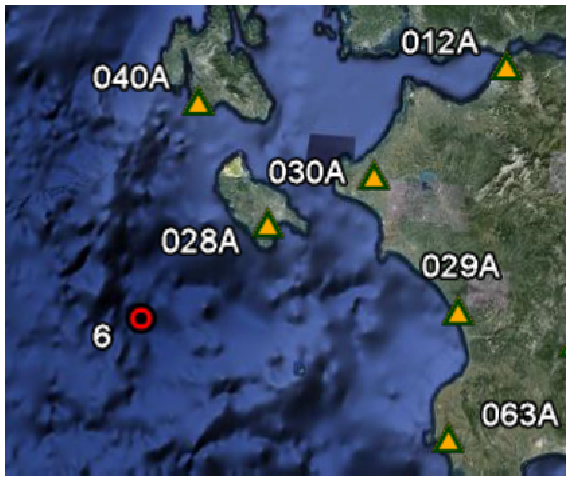
Depth: 56 Km / 10 Km





5. Data analysis

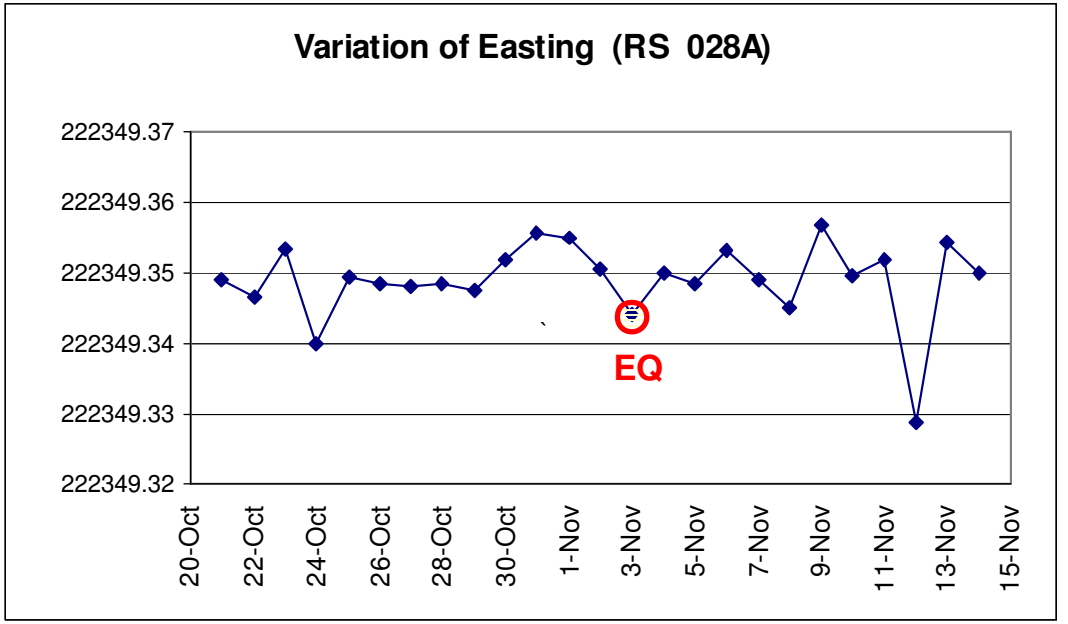
Earthquake 6

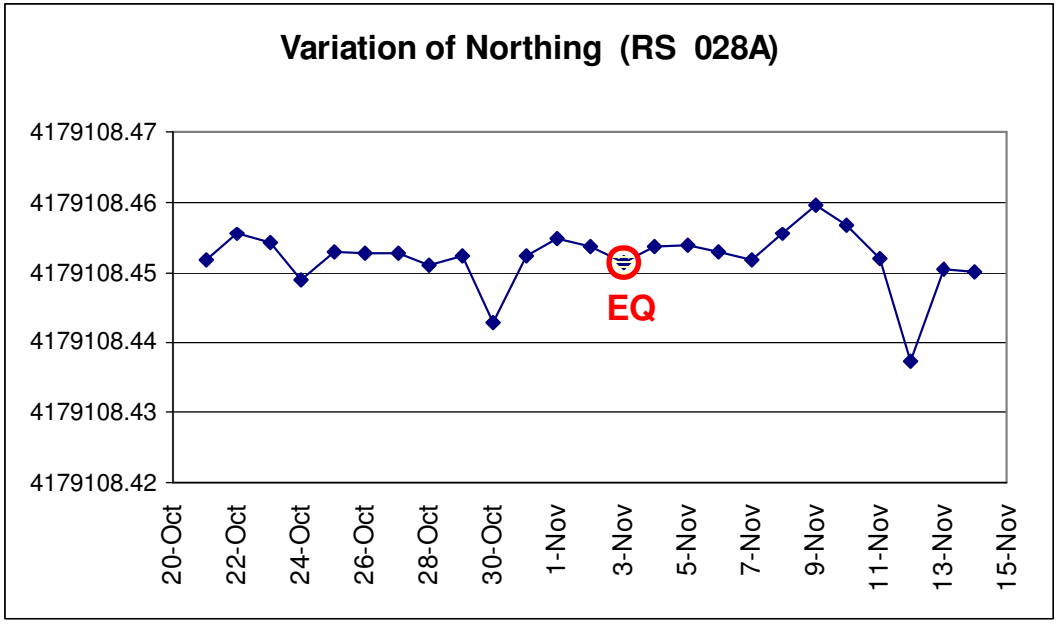


Day: November 3, 2009

Magnitude (L): 5.6

Depth: 39 Km





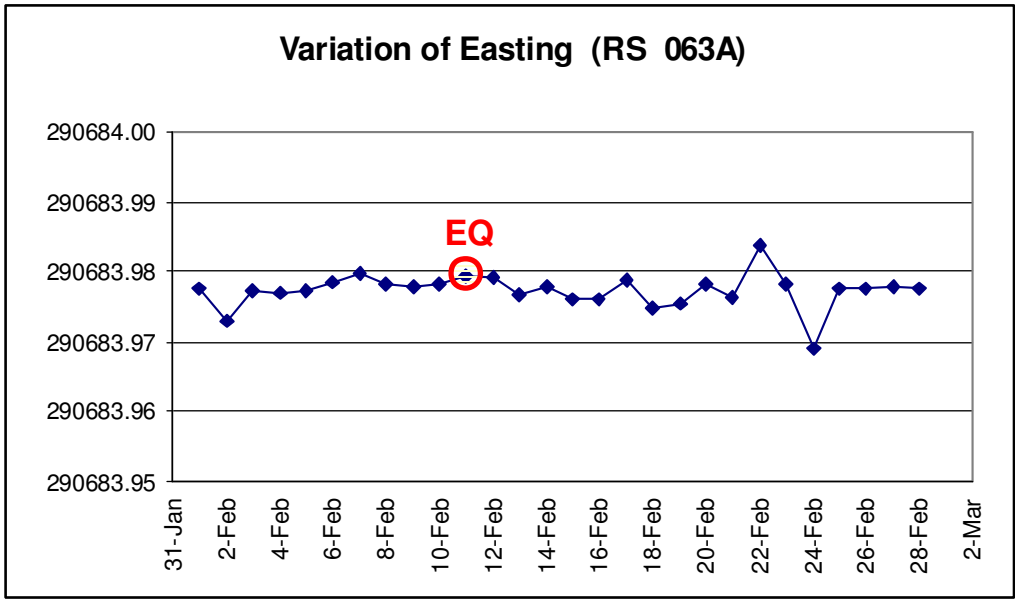
5. Data analysis

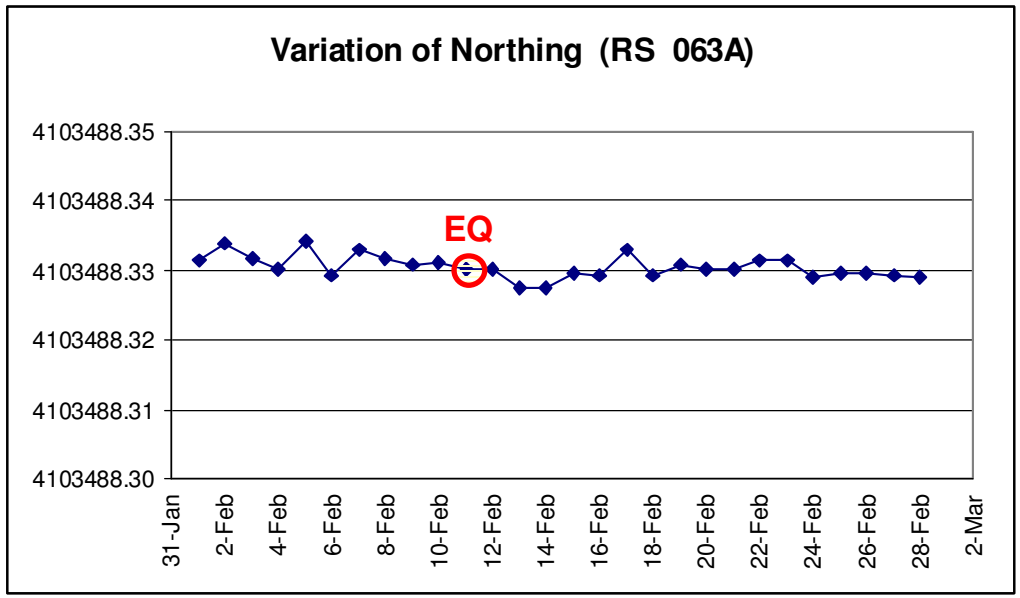
Earthquake 7

Day: February 11, 2011

Magnitude (L): 4.0

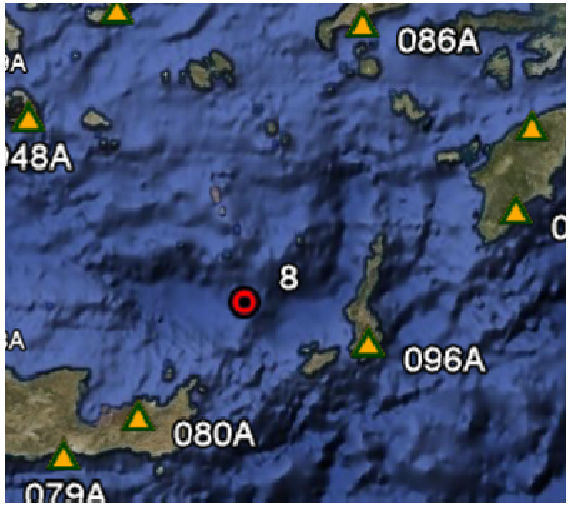
Depth: 31 Km





5. Data analysis

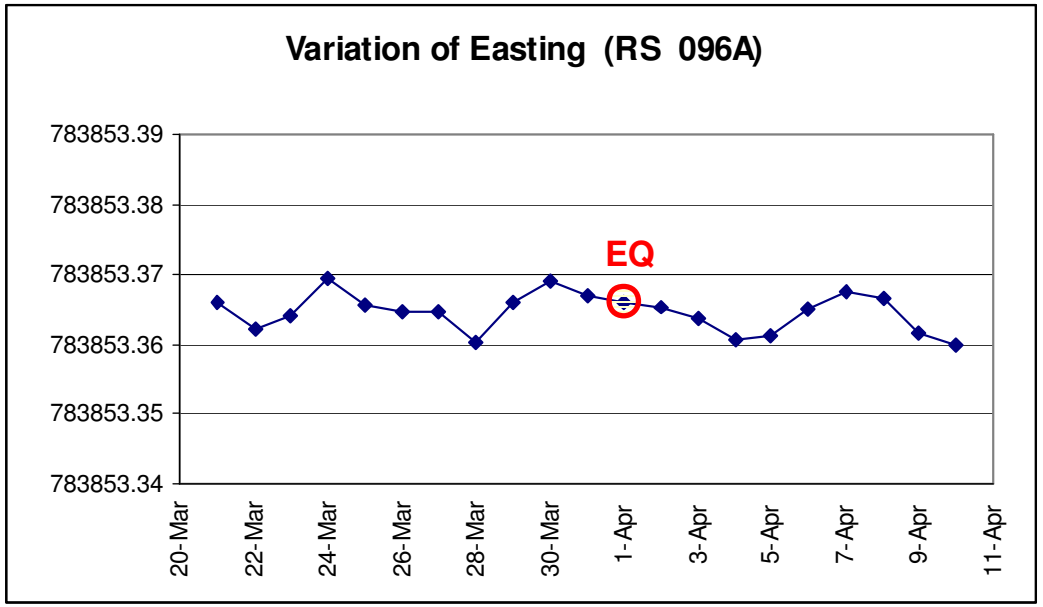
Earthquake 8

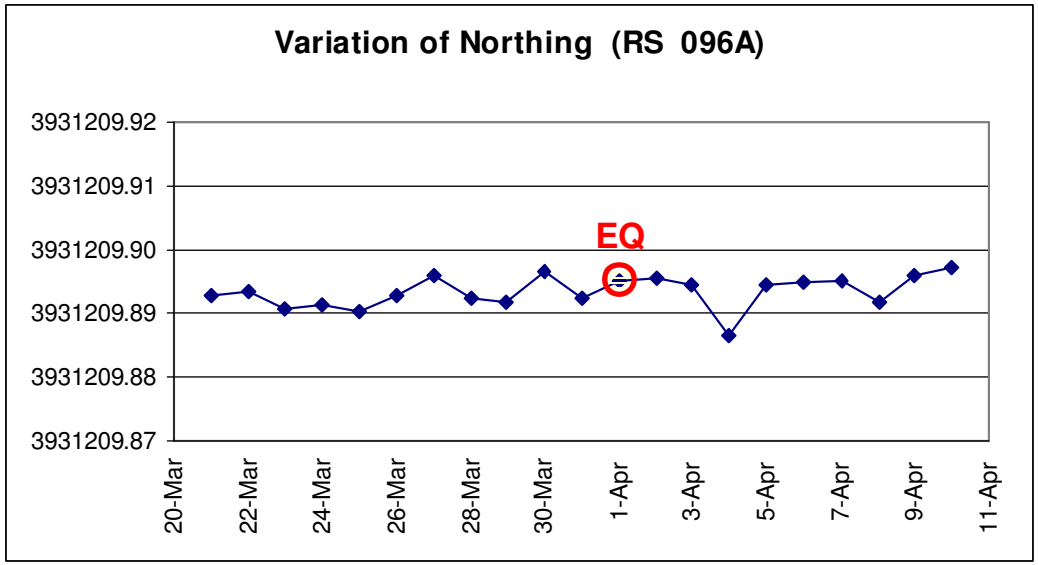


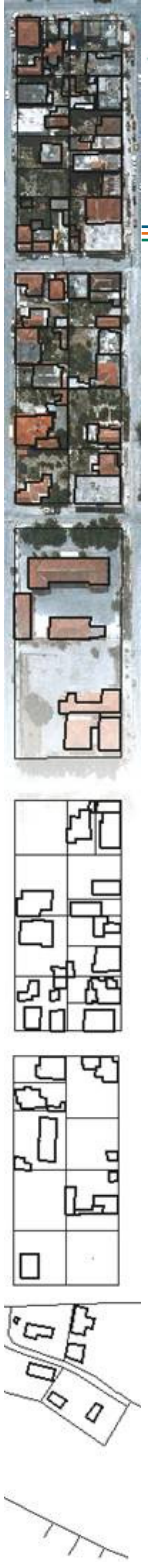
Day: April 1, 2011

Magnitude (L): 6.2

Depth: 63 Km





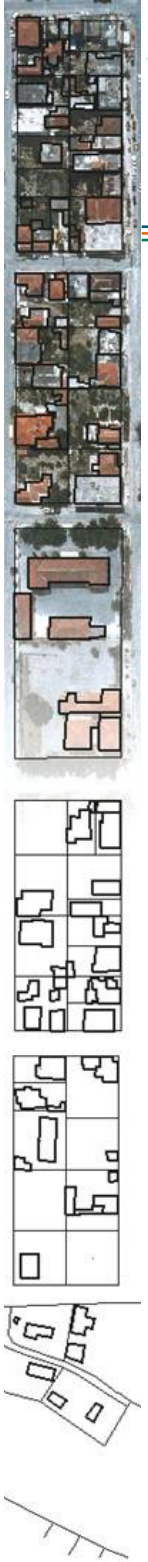


6. Discussion

- In some exceptional cases, earthquakes taking place in Greece can cause permanent displacements.
- If the displacements are significant, the coordinates of the affected stations should be updated.
- To keep parcels' coordinates as stable as possible, a velocity model could be used to refer all coordinates to a common reference epoch.

6. Discussion

- **For practical reasons, the use of a velocity model is inconvenient because:**
  - A complex velocity model is needed to describe both constant tectonic trends (e.g. the eigenvelocities of the Aegean plate) and abrupt changes.
  - This model should be implemented in geodetic receivers and office software, which in turn requires the intervention of GNNS vendors and the distribution of the model to ALL users.
  - In the case of displacements due to earthquakes, it is practically very difficult to know how the displacements are “propagating” between the stations.
  - No experience exists in Europe. Little international experience exists (e.g. New-Zeeland), imposing very carefully planned strategies.
- **Possible scenarios are being examined in collaboration with the EUREF-TWG.**



7. Conclusions

- HEPOS can be used for the detection of permanent displacements resulting from earthquakes.
- Based on the three years of operation of HEPOS it can be concluded that the majority of the earthquakes do not cause permanent displacements.
- A strategy for handling the exceptional cases of significant displacements, must be carefully developed.

Acknowledgments

The HEPOS project is part of the Operational Program “Information Society” and is co-funded by the European Regional Development Fund.