# Real-time Positioning in ETRS89 using the Hellenic Positioning System

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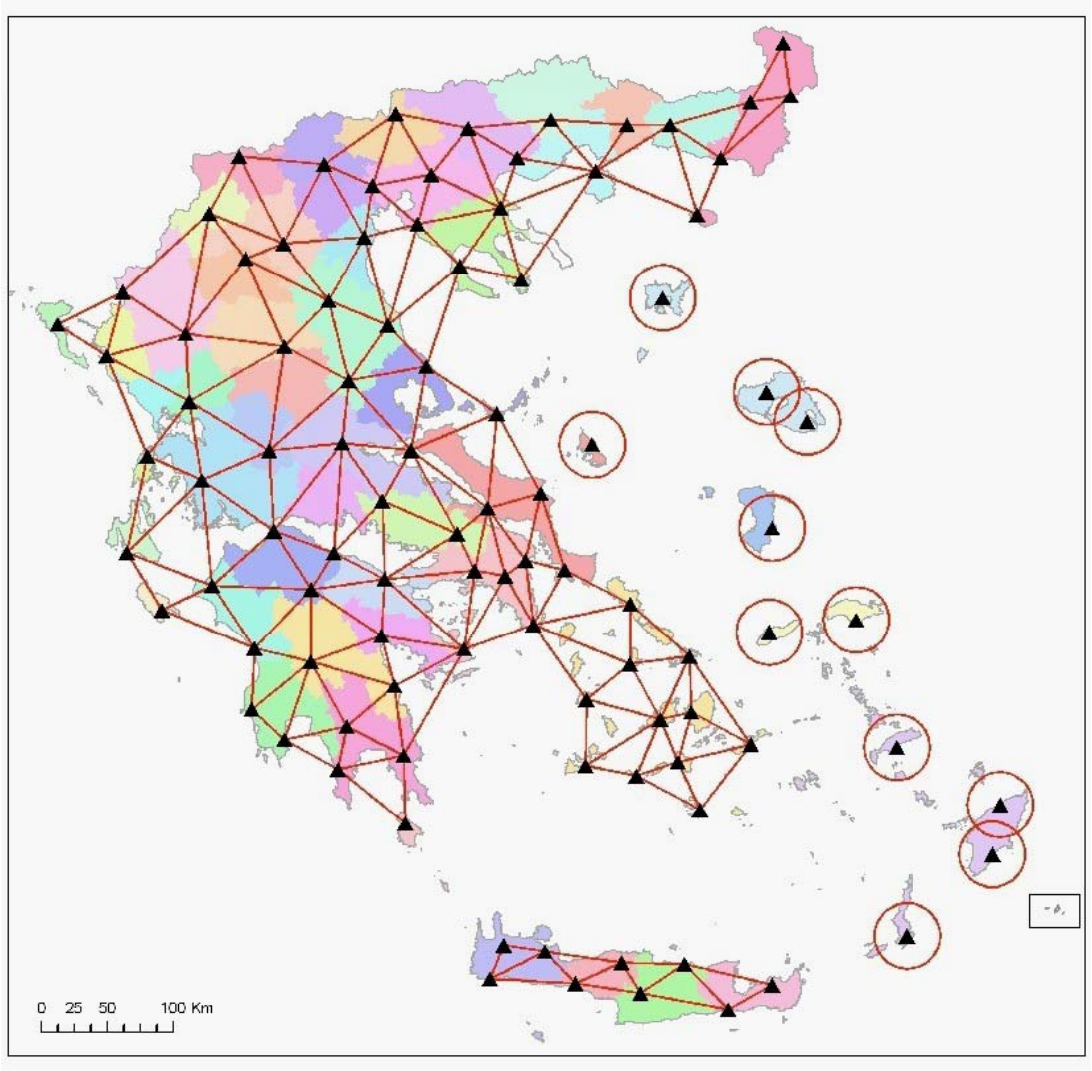
# 1. Description of HEPOS

98 Reference stations:

- 87 supporting network-based techniques
  (VRS - FKP - MAC)
- 11 for Single-base positioning



# 1. Description of HEPOS

## Reference Stations of HEPOS

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# 1. Description of HEPOS

## Services offered by HEPOS

| APPLICATION | SERVICE | DATA FORMAT |
|---|---|---|
| **Post Processing** (www.hepos.gr) | **RS data** | **RINEX, CRINEX** |
| | **VRS data** | **RINEX, CRINEX** |
| **Real Time** (GSM & GPRS supported) | **Network RTK: VRS** | **RTCM 2.3**<br>**RTCM 3.0**<br>**RTCM 3.1**<br>**CMR+** |
| | **Network RTK: FKP** | |
| | **Network RTK: MAC** | |
| | **Single Base RTK** | |
| | **Network DGPS** | **RTCM 2.3** |
| | **Single Base DGPS** | **RTCM 2.3** |

# 2. Network performance

**Latency of incoming data:**

**Highest average values**

Even the highest average values are satisfactory.

| | ID | Station | Received | Delay [s] | Avg. Delay [s] (Ep... |
|---|---|---|---|---|---|
| | 9 | 009A | 7/9/2007 6:33:06 πμ | 0.484 | 0.331 (65848) |
| | 22 | 022A | 7/9/2007 6:33:06 πμ | 0.500 | 0.310 (65848) |
| | 80 | 080A | 7/9/2007 6:33:06 πμ | 0.500 | 0.290 (65843) |
| | 56 | 056A | 7/9/2007 6:33:06 πμ | 0.500 | 0.286 (65848) |
| | 35 | 035A | 7/9/2007 6:33:06 πμ | 0.484 | 0.285 (65848) |
| | 21 | 021A | 7/9/2007 6:33:06 πμ | 0.500 | 0.279 (65848) |
| | 91 | 091A | 7/9/2007 6:33:06 πμ | 0.421 | 0.266 (65845) |
| | 15 | 015A | 7/9/2007 6:33:06 πμ | 0.453 | 0.259 (65848) |
| | 50 | 050A | 7/9/2007 6:33:06 πμ | 0.484 | 0.254 (65848) |
| | 20 | 020A | 7/9/2007 6:33:06 πμ | 0.265 | 0.251 (65836) |
| | 70 | 070A | 7/9/2007 6:33:06 πμ | 0.484 | 0.247 (65837) |
| | 18 | 018A | 7/9/2007 6:33:06 πμ | 0.484 | 0.245 (65848) |
| | 40 | 040A | 7/9/2007 6:33:06 πμ | 0.500 | 0.240 (65848) |
| | 38 | 038A | 7/9/2007 6:33:06 πμ | 0.250 | 0.238 (65843) |
| | 73 | 073A | 7/9/2007 6:33:06 πμ | 0.500 | 0.237 (65848) |
| | 49 | 049A | 7/9/2007 6:33:07 πμ | 0.125 | 0.235 (65837) |
| | 42 | 042A | 7/9/2007 6:33:06 πμ | 0.234 | 0.234 (65787) |
| | 1 | 001A | 7/9/2007 6:33:06 πμ | 0.344 | 0.232 (65848) |
| | 81 | 081A | 7/9/2007 6:33:06 πμ | 0.265 | 0.232 (65848) |
| | 89 | 089A | 7/9/2007 6:33:06 πμ | 0.453 | 0.232 (65848) |
| | 95 | 095A | 7/9/2007 6:33:06 πμ | 0.422 | 0.231 (65848) |
| | 44 | 044A | 7/9/2007 6:33:06 πμ | 0.469 | 0.231 (65847) |
| | 17 | 017A | 7/9/2007 6:33:07 πμ | 0.140 | 0.231 (65834) |
| | 36 | 036A | 7/9/2007 6:33:06 πμ | 0.469 | 0.230 (65848) |
| | 65 | 065A | 7/9/2007 6:33:06 πμ | 0.437 | 0.226 (65848) |
| | 88 | 88A | 7/9/2007 6:33:07 πμ | 0.296 | 0.225 (65849) |
| | 2 | 002A | 7/9/2007 6:33:07 πμ | 0.093 | 0.224 (65849) |
| | 46 | 046A | 7/9/2007 6:33:06 πμ | 0.453 | 0.223 (65841) |
| | 32 | 032A | 7/9/2007 6:33:06 πμ | 0.469 | 0.216 (65848) |
| | 92 | 092A | 7/9/2007 6:33:06 πμ | 0.469 | 0.215 (65847) |
| | 14 | 014A | 7/9/2007 6:33:06 πμ | 0.328 | 0.214 (65848) |
| | 33 | 033A | 7/9/2007 6:33:06 πμ | 0.437 | 0.213 (65848) |
| | 60 | 060A | 7/9/2007 6:33:06 πμ | 0.250 | 0.212 (65848) |
| | 58 | 058A | 7/9/2007 6:33:07 πμ | 0.140 | 0.206 (65849) |
| | 93 | 093A | 7/9/2007 6:33:06 πμ | 0.453 | 0.206 (65848) |
| | 72 | 072A | 7/9/2007 6:33:06 πμ | 0.203 | 0.203 (65848) |

# 2. Network performance

**Latency of incoming data:**

**Lowest average values**

All current values fulfill the specified requirement, that delays must be less than 1 sec.

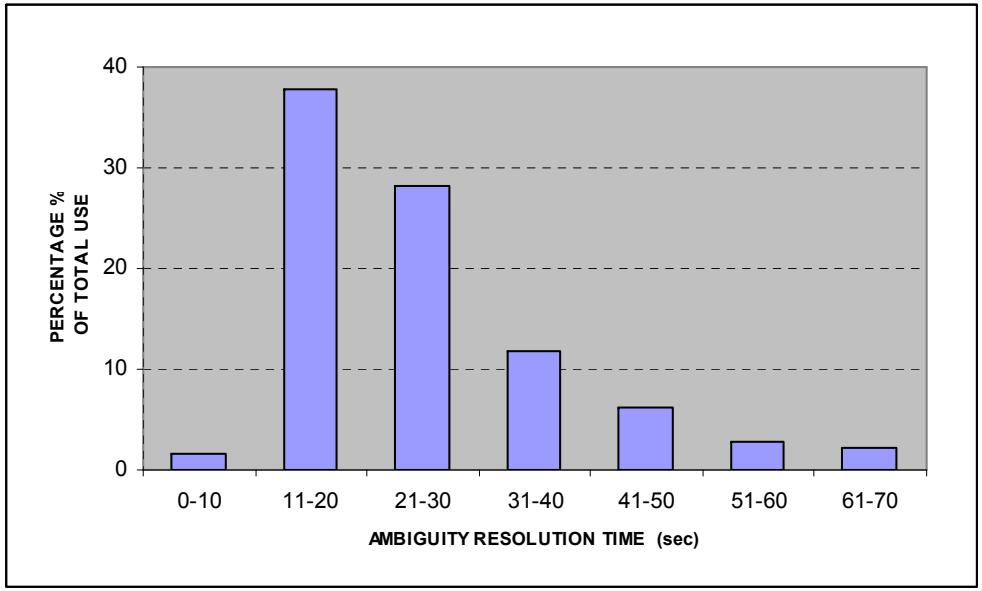
| ID | Station | Received | Delay [s] | Avg. Delay [s] (Ep... |
|---|---|---|---|---|
| 82 | 082A | 7/9/2007 6:35:45 πμ | 0.422 | 0.176 (66006) |
| 12 | 012A | 7/9/2007 6:35:45 πμ | 0.391 | 0.175 (66007) |
| 63 | 063A | 7/9/2007 6:35:45 πμ | 0.406 | 0.175 (66007) |
| 37 | 037A | 7/9/2007 6:35:45 πμ | 0.281 | 0.173 (65996) |
| 67 | 067A | 7/9/2007 6:35:45 πμ | 0.219 | 0.171 (66007) |
| 75 | 075A | 7/9/2007 6:35:45 πμ | 0.203 | 0.168 (66007) |
| 11 | 011A | 7/9/2007 6:35:45 πμ | 0.266 | 0.168 (66007) |
| 10 | 010A | 7/9/2007 6:35:45 πμ | 0.375 | 0.168 (66007) |
| 90 | 090A | 7/9/2007 6:35:45 πμ | 0.406 | 0.168 (66007) |
| 77 | 077A | 7/9/2007 6:35:45 πμ | 0.281 | 0.166 (66007) |
| 29 | 029A | 7/9/2007 6:35:45 πμ | 0.406 | 0.165 (66007) |
| 61 | 061A | 7/9/2007 6:35:45 πμ | 0.141 | 0.165 (66005) |
| 53 | 053A | 7/9/2007 6:35:45 πμ | 0.156 | 0.164 (66005) |
| 84 | 084A | 7/9/2007 6:35:45 πμ | 0.250 | 0.164 (65978) |
| 97 | 097A | 7/9/2007 6:35:45 πμ | 0.375 | 0.163 (66002) |
| 79 | 079A | 7/9/2007 6:35:45 πμ | 0.172 | 0.157 (66007) |
| 26 | 026A | 7/9/2007 6:35:45 πμ | 0.391 | 0.157 (66007) |
| 23 | 023A | 7/9/2007 6:35:45 πμ | 0.156 | 0.154 (66007) |
| 34 | 034A | 7/9/2007 6:35:45 πμ | 0.109 | 0.152 (66007) |
| 28 | 028A | 7/9/2007 6:35:45 πμ | 0.375 | 0.149 (66007) |
| 4 | 004A | 7/9/2007 6:35:45 πμ | 0.141 | 0.148 (66007) |
| 71 | 071A | 7/9/2007 6:35:45 πμ | 0.219 | 0.146 (66006) |
| 39 | 039A | 7/9/2007 6:35:45 πμ | 0.250 | 0.145 (66007) |
| 64 | 064A | 7/9/2007 6:35:45 πμ | 0.375 | 0.144 (66007) |
| 25 | 025A | 7/9/2007 6:35:45 πμ | 0.234 | 0.140 (66007) |
| 6 | 006A | 7/9/2007 6:35:45 πμ | 0.172 | 0.137 (66007) |
| 48 | 048A | 7/9/2007 6:35:45 πμ | 0.172 | 0.137 (66007) |
| 54 | 054A | 7/9/2007 6:35:45 πμ | 0.141 | 0.136 (66007) |
| 3 | 003A | 7/9/2007 6:35:45 πμ | 0.141 | 0.127 (66007) |
| 8 | 008A | 7/9/2007 6:35:45 πμ | 0.359 | 0.125 (66007) |
| 7 | 007A | 7/9/2007 6:35:45 πμ | 0.094 | 0.121 (66007) |
| 98 | 098A | 7/9/2007 6:35:45 πμ | 0.000 | 0.024 (66007) |

# 2. Network performance

## RTK - Initialization times

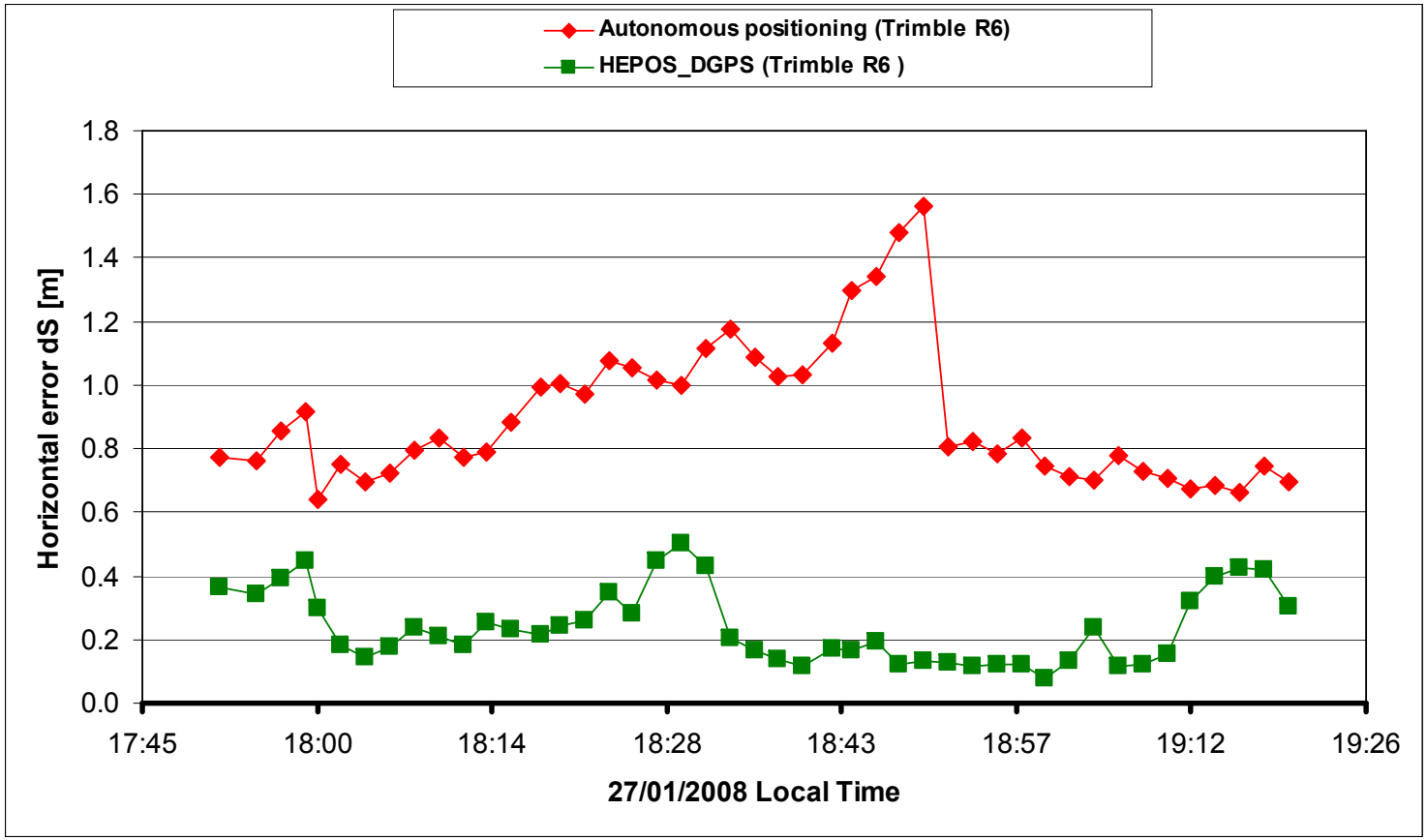
Statistics from the first year of operation:

- Shortest initialization time: 7 sec
- Mean initialization time : 24 sec



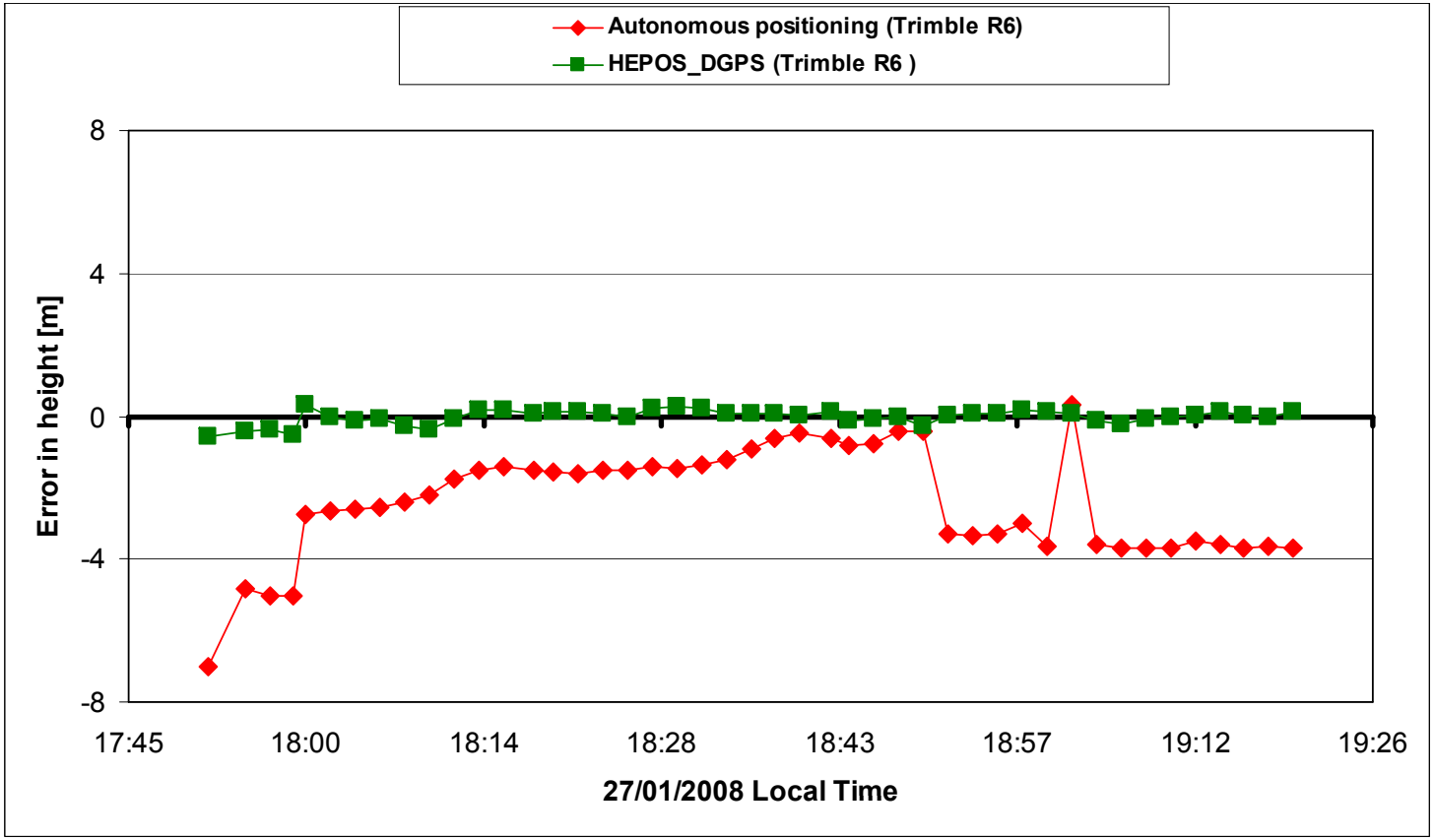
# 2. Network performance

## Accuracy of DGPS (single-base mode)



# 2. Network performance

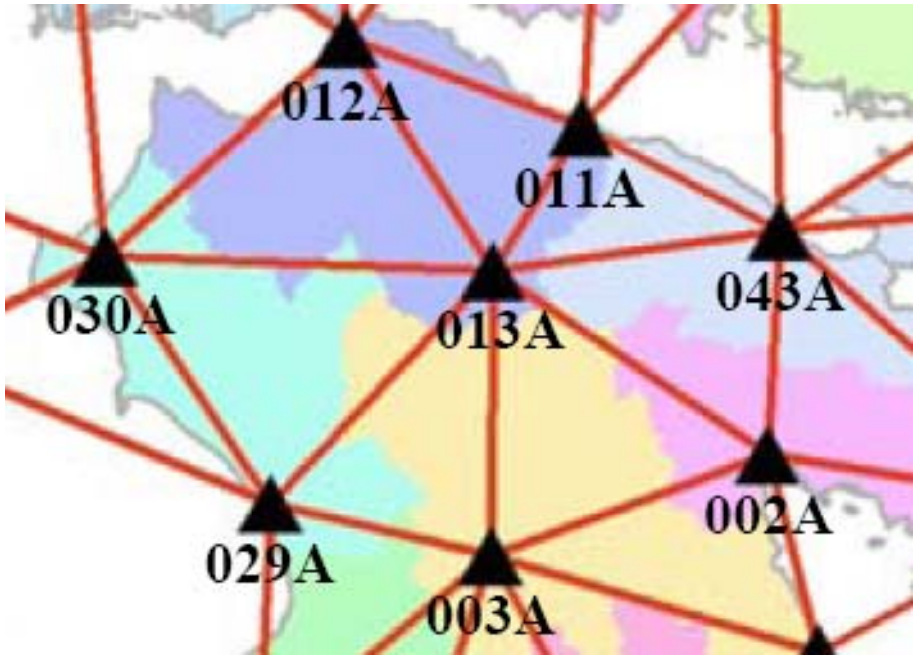
## Accuracy of DGPS (single-base mode)



# 2. Network performance

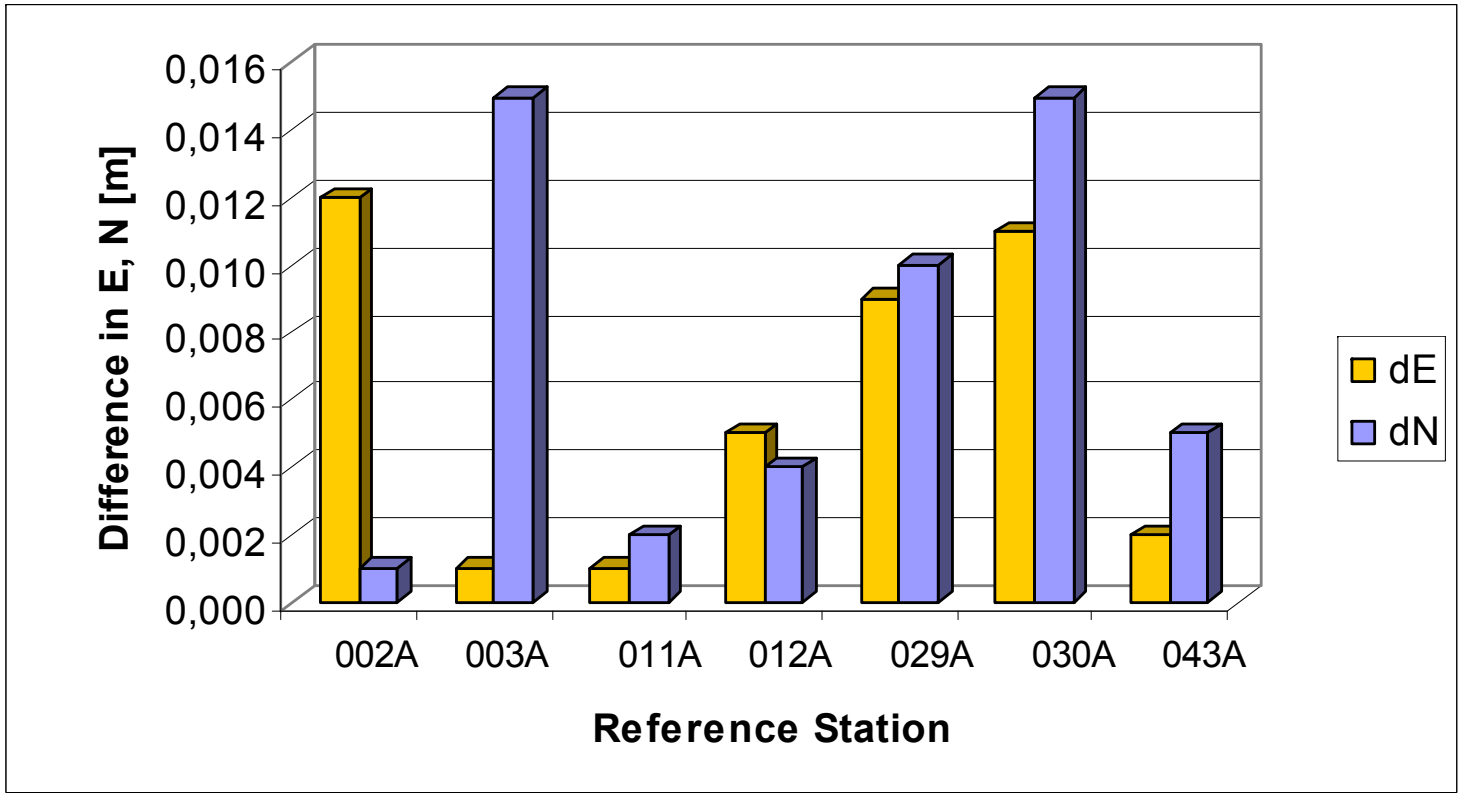
## Quality of VRS data

VRS data were computed at a point next to RS 013A.
The baselines from the next RSs to the VRS were solved. The next slide shows the differences between the nominal coordinates of the VRS and the coordinates resulting by each baseline.
2 hours of observations, processed with commercial SW using broadcast ephemerides; baseline lengths 32-75 Km.



# 2. Network performance

## Quality of VRS data



# 3. Experiences in operating the network

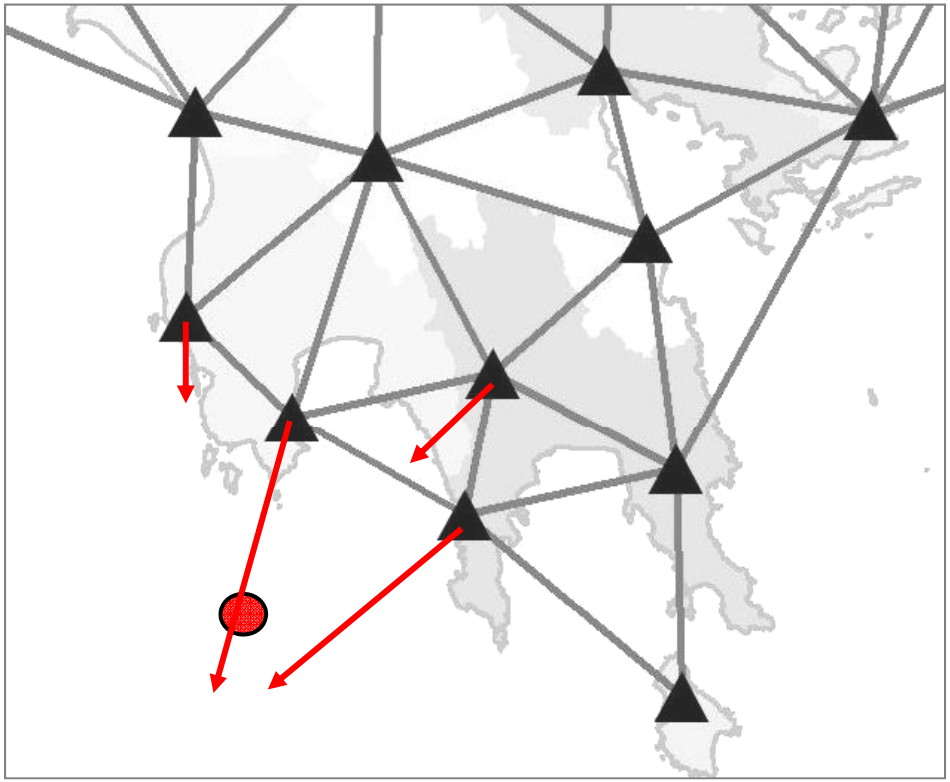
## Earthquakes and coordinate stability

- Several earthquakes took place since the autumn of 2007, when the establishment of HEPOS was completed
- The effects of these earthquakes on the stability of the coordinates of the Reference Stations were investigated
- Mostly, no permanent displacements were detected
- However, in certain cases displacements up to few cm took place
- This situation must be carefully considered

# 3. Experiences in operating the network

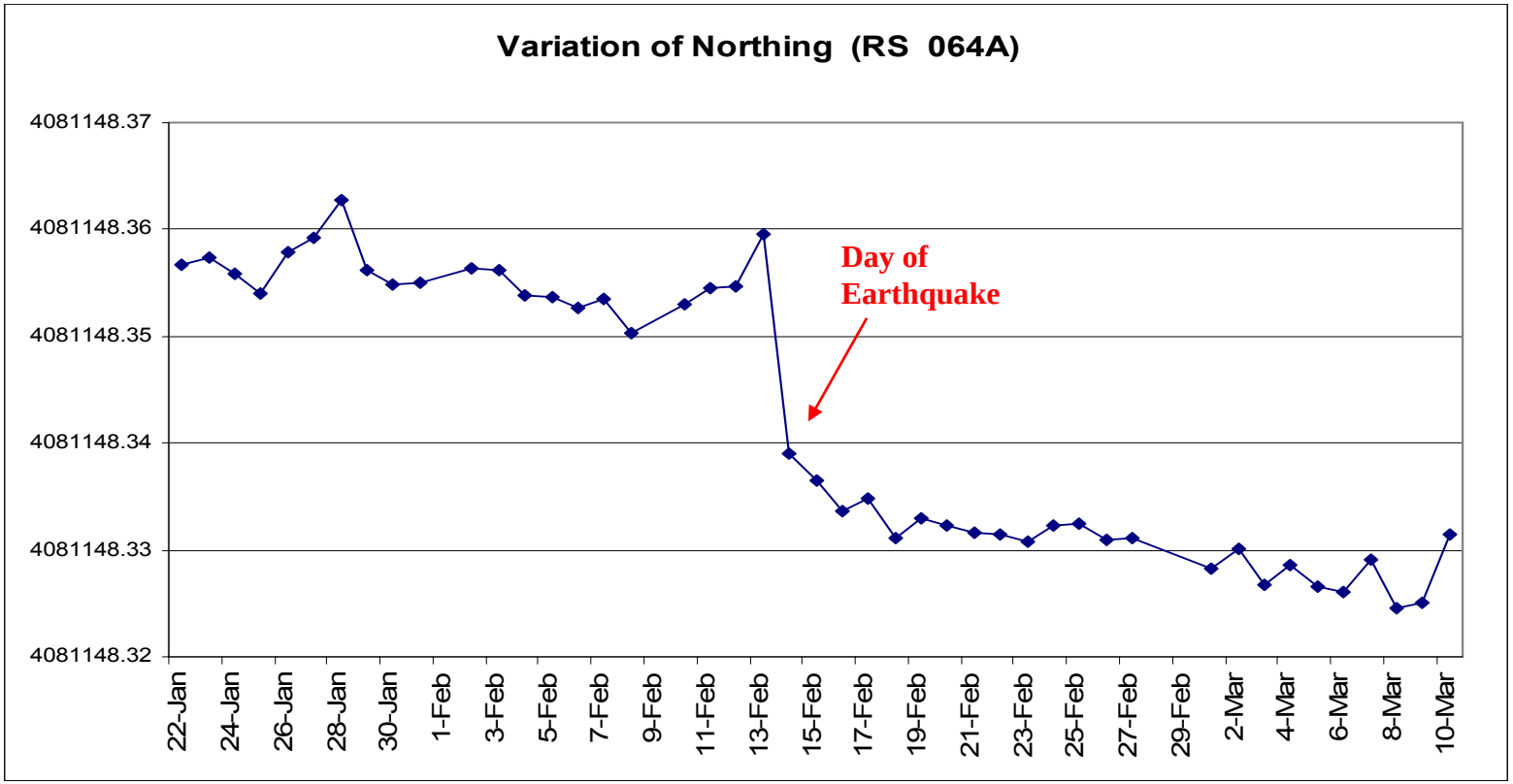
## Earthquakes and coordinate stability

- **The strongest effect was caused by the 14/2/2008 Earthquake SW of Peloponnese.**
  (the red circle denotes the epicenter; the longest arrow corresponds to 2.1 cm)
- Generally speaking, the effect depends on many factors: magnitude, focal length, local Geology etc.



# 3. Experiences in operating the network

## Earthquakes and coordinate stability



# 4. HTRS07: Realization of ETRS89 in Greece

## HTRS07

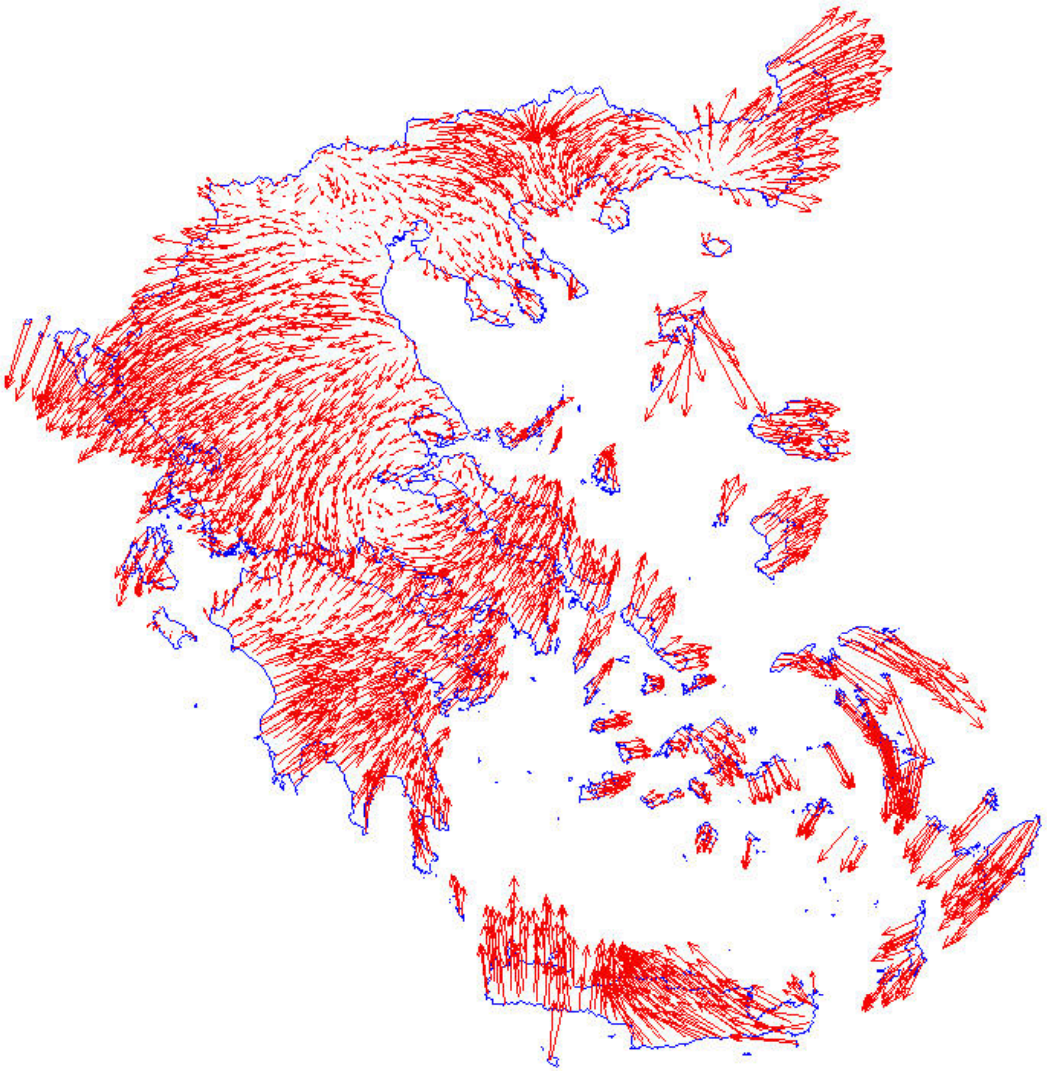
- HTRS07 is the Hellenic Terrestrial Reference System of 2007
- HTRS07 is realized by the 98 Reference Stations of HEPOS
- The coordinates of the 98 Reference Stations are computed in ETRF2005/2007.5

# 4. Transformation between HTRS07 and HGRS87

HEPOS
HEllenic POsitioning System

**A country-wide 7-parameter Helmert transformation between HTRS07 and HGRS87 leaves residuals up to ~2.5m).**

**Thus, a more complex approach is necessary.**



# 4. Transformation between HTRS07 and HGRS87

## Choices regarding the transformation approach

- **Which mathematical model should be used?**
  - Different 7-parameter sets (e.g. FLEPOS)
  - One 7-parameter set plus correction grids (e.g. GBOS)
  - Other (e.g. polynomial model of KMS Denmark, affine model of NLS Finland)
- **How many transformation sets should be used?**
- **In case of >1 transformation sets, how to choose the limits?**
  - physical borders (e.g. FLEPOS)
  - map-sheets

# 4. Transformation between HTRS07 and HGRS87

## Comparison of different transformation models

| | Multiple 7-parameter sets | One 7-parameter set plus Correction Grids |
|---|---|---|
| Implementation | By the user (supported by all office packages and all GNSS receivers) | Needs to be implemented by the manufacturer |
| Application area | Restricted within the limits of each transformation set | Country-wide |
| Risks | Typing errors, omit to switch to the correct set | - |
| Digital size | Negligible | Few MBytes |
| Dimensions | 3D | 2D, (geoid model needed for H) |

# 4. Transformation between HTRS07 and HGRS87

## Comparison of different transformation models

| Models computed and evaluated for the transformation between HTRS07 and HGRS87 | | |
|---|---|---|
| **Model** | **Number of sets** | **Mean RMS *** |
| **7-parameter transformation set per map sheet 1:100.000** | **121** | **~ 10 cm** |
| **7-parameter transformation set per map sheet 1:50.000** | **344** | **~ 5 cm** |
| **One 7-parameter set plus correction grids** | **1** | **~ 1 cm** |

* Based on the residuals of the points used for the computation of the model, not on independent validation points.

# 4. Transformation between HTRS07 and HGRS87

## Chosen transformation model

- One 7- parameter set plus correction grids for ΔE, ΔN
- Grid spacing: 2 Km

# 4. Transformation between HTRS07 and HGRS87

## Implementation of transformation model

- KTIMATOLOGIO S.A. published the transformation model in 11/2008
- Supplied the grids to the interested manufacturers
- Instruction to all manufacturers to implement the grids using the same name “HEPOS_GGRS87”
- The model is already implemented in some GNSS office software and RTK-systems
- Free stand-alone software is available at www.hepos.gr

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