K. Katsampalos[1], C. Kotsakis[1], M. Gianniou[2]

[1] **Aristotle Univ. of Thessaloniki, Department of Geodesy and Surveying**
[2] **KTIMATOLOGIO S.A. (Hellenic Cadastre), Geodetic Department**

Hellenic Terrestrial Reference System 2007 (HTRS07) :

A regional realization of ETRS89 over Greece in support of HEPOS

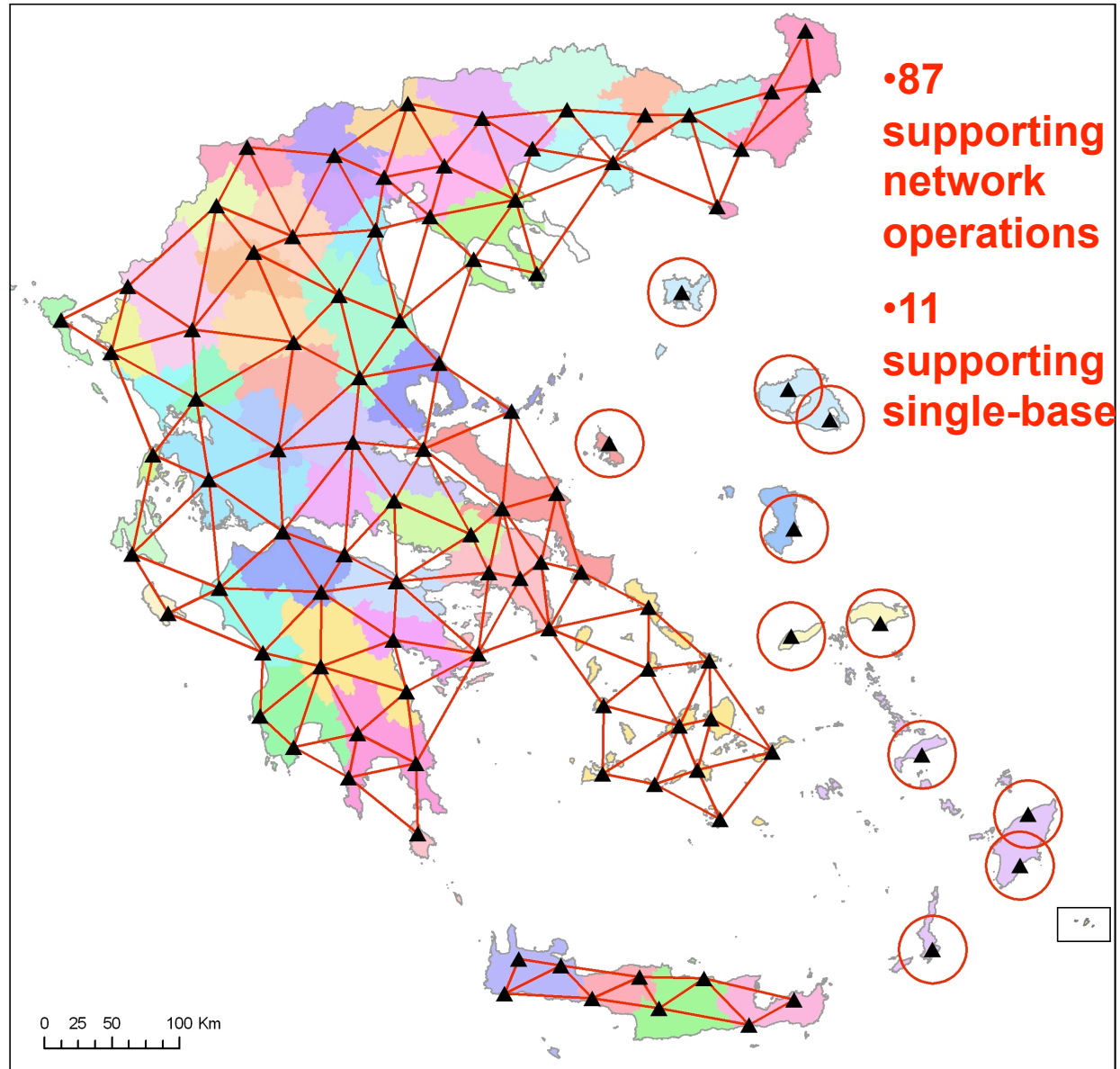**HEPOS**   **Metsovo, 2009**

Contents

1. HEPOS

2. EUREF stations in Greece

3. "Geophysical conditions" – Station velocities

4. HTRS07: System – Frame – Epoch

5. HEPOS network adjustment

6. Development of transformation model
   HTRS07 ↔ HGRS87

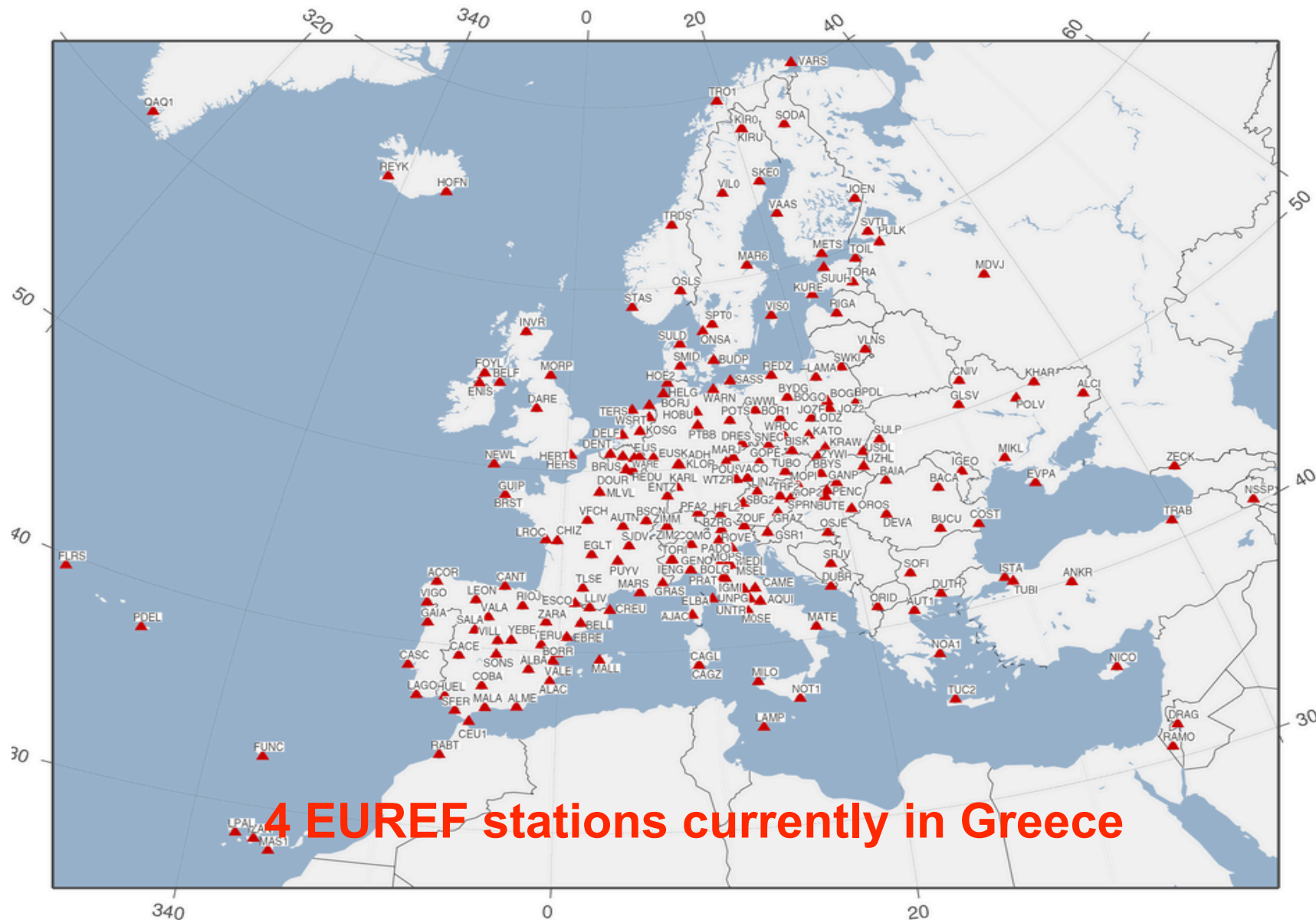7. Software developed

8. Future work

HEPOS

- **HEllenic Positioning System.**
- **Developed by KTIMATOLOGIO S.A.**
- **Consists of 98 GPS CORS distributed all over mainland Greece and (most of) the islands.**
- **55 km average interstation distance in mainland Greece.**
- **Supports Real-Time network-based techniques (VRS, FKP, MAC) & Post Processing.**
- **Has already been used for EU co-funded VLS orthophotomap projects (since 25/2/2008).**
- **25/5/2009 : available to the general public.**
  - **http://www.hepos.gr**

98 Stations of HEPOS

- •87 supporting network operations

- •11 supporting single-base

HEPOS

Metsovo, 2009

EUREF Permanent Tracking Network

4 EUREF stations currently in Greece

GMD 2009 May 15 10:01:39

http://www.epncb.oma.be/

HEPOS   **Metsovo, 2009**

Greek EPN stations
(operational during HEPOS development)

TUC2	AUT1	NOA1

2004 / week 1294

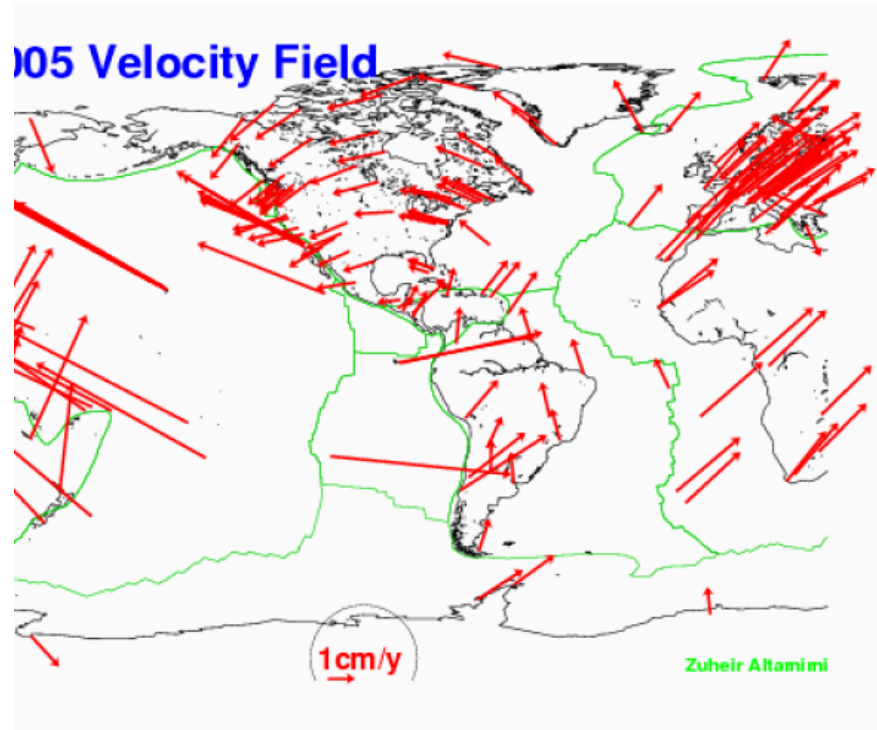2005 / week 1320

2006 / week 1379

HEPOS

Metsovo, 2009

ITRF2005 and Plate motion:
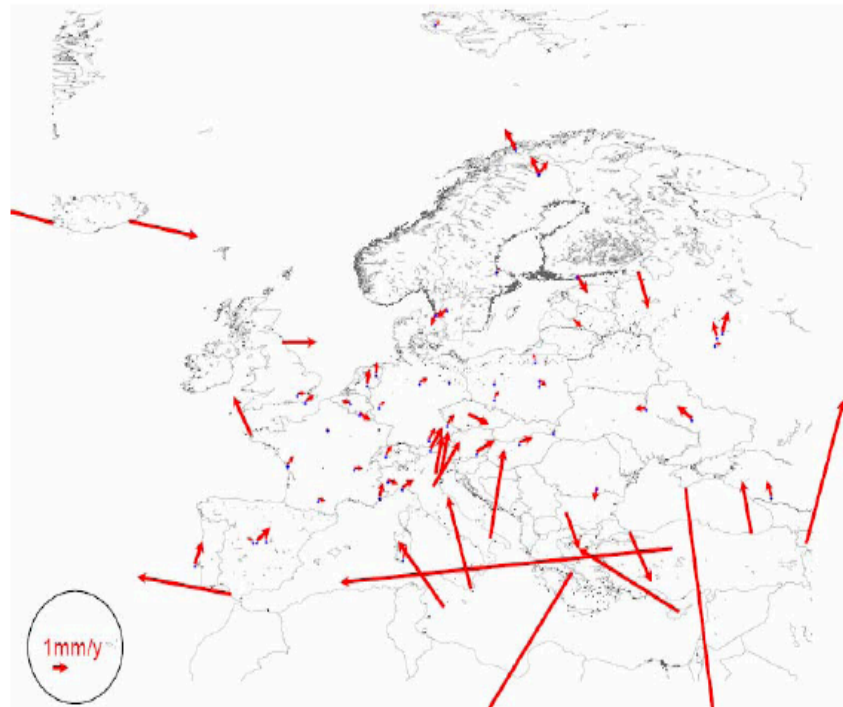## Horizontal Site velocities with σ < 3mm/y
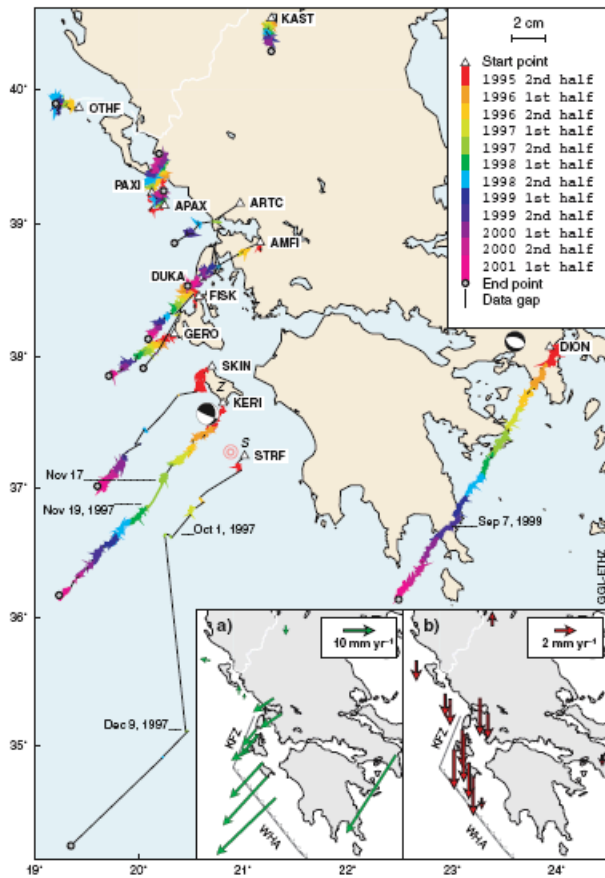
Hollenstein-Geiger-Khale-Veis (2006)

F Symposium, London, June 2007

NOTE: Greece moves SW (up to 3cm/y) relative to the Eurasia plate (!!)

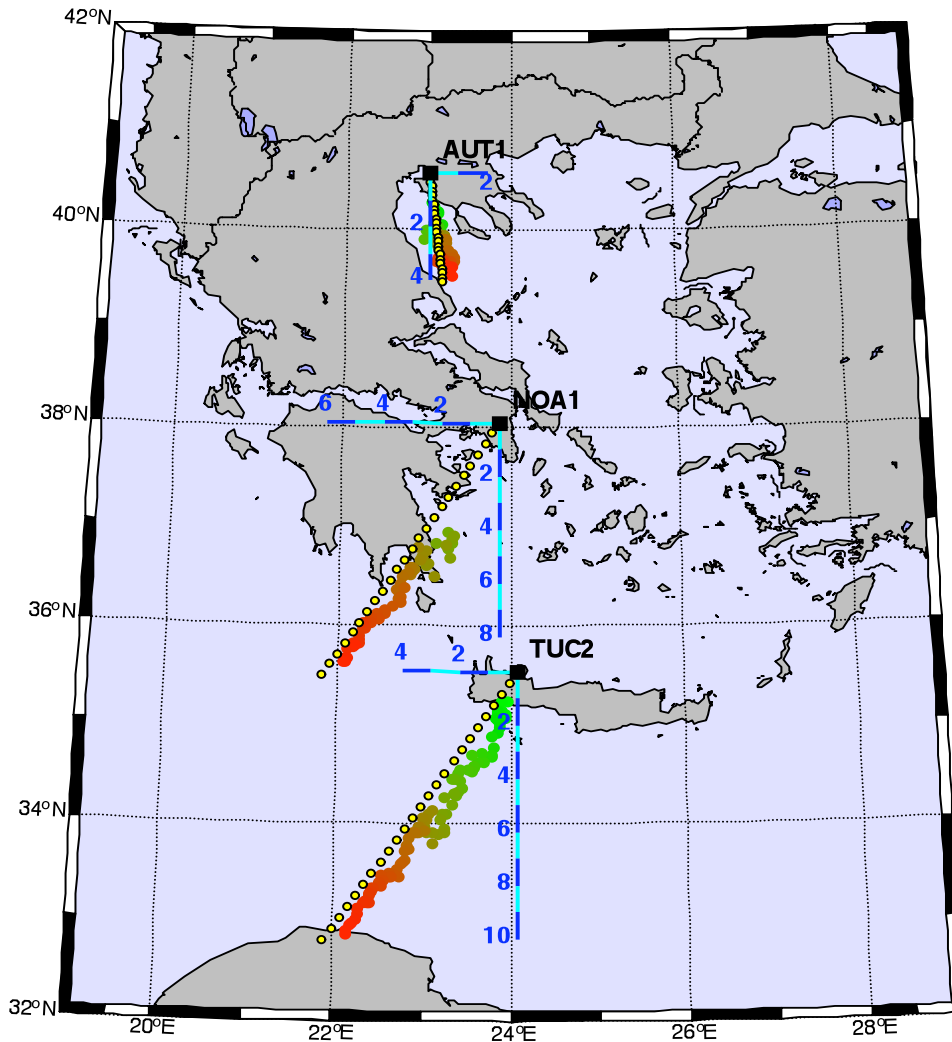ETRF2005 Horizontal Velocities
(from Altamimi. EUREF 2006)

1mm/y

Dionysos 3.1 cm/y 3D

Velocities in SE Europe are TWO ORDERS of magnitude higher than in central Europe !

2005.0-2008.8 : Horizontal trajectories (ETRF2005)
(Based on official EPN coordinate values)

2D velocities

	ETRF2005	ITRF2005
AUT1:	1.03 cm/yr	2.50 cm/yr
NOA1:	2.80 cm/yr	1.33 cm/yr
TUC2:	3.00 cm/yr	1.36 cm/yr

HEPOS

Metsovo, 2009

Fixed EUREF/EPN station
for HEPOS network adjustment: AUT1

When we started (2007):

ITRF05/2000.0   4466283.488 ± 0.003   1896166.775 ± 0.002   4126096.773 ± 0.003

ETRF05/2000.0   4466283.737 ± 0.003   1896166.625 ± 0.002   4126096.618 ± 0.003

AUT1 was decided to be kept fixed to:

ETRF05/2007.5   4466283.7738   1896166.6498   4126096.5588

If we had used ETRF2000, instead of ETRF2005:

ETRF00/2000.0   4466283.731 ± 0.012   1896166.624 ± 0.006   4126096.617 ± 0.011

Using EUREF velocities…

ETRF00/2007.5   4466283.7617   1896166.6345   4126096.5450

Hence, HEPOS/HTRS07 is 1-2 cm off with respect to ETRF00

HTRS07 : Ref System for HEPOS

HEPOS reference system: ETRS89

in the frame : ETRF2005 (epoch :2007.5)

The selected epoch indicates the mid-time of all GPS measurements collected during the HEPOS development project.

HTRS07 is a realization of ETRS89 and it is in accordance to the INSPIRE Directive (15/5/2007).

TM07 : Projection for HTRS07

Transverse Mercator (one zone for all Greece)

- **Central Meridian**   : λ0 = 24º East
- **Scale along CM**   : k0 = 0.9996
- **Latitude of origin**   : φ0= 0º
- **False Easting**   : X0= 500 000.00 meters
- **False Northing**   : Y0= -2 000 000.00 meters

For Kastelorizo ONLY :

- **Central Meridian**   : λ0 = 30º East
- **Scale along CM**   : k0 = 1.0000
- **Latitude of origin**   : φ0= 0º
- **False Easting**   : X0= 500 000.00 μέτρα
- **False Northing**   : Y0= -2 000 000.00 μέτρα

Reference Ellipsoid : GRS80

HEPOS 98-stations adjustment

Two weeks (1448 & 1449) of observations
Bernese 4.2
Solution in ITRF2005/2007.79
Memo has NOT been used
Translation to ETRF2005/2007.5
DX=0.3839m, DY=-0.2912m, DZ=-0.2361m

- **Preprocessing : Triple Differences**
- **Cutoff angle : 3 degrees**
- **Data sampling : 30seconds preprocessing / 180 seconds final**
- **Processing : Ionosphere-free double differences**
- **Antenna calibrations : IGS05 model absolute values**
- **Troposphere : Dry-Neill**
- **Ionosphere : Regional model computation**
- **Datum definition : Twelve EUREF stations including AUT1, NOA1, TUC2 and GLSV, JOZE, MATE, NICO, NOT1, TRAB, WTZR, WTZR, RAMO**
- **Orbits : IGS final orbits and ERP parameters**
- **Planetary Ephemeris : DE200**
- **Ocean loading : Onsala FES2005 model**
- **Tidal model : Solid earth IERS 1996 conventions**

- **rms accuracies : $\sigma E=2mm$, $sN=2mm$, $\sigma H=5mm$**

HEPOS   **Metsovo, 2009**

AUTh adjustment

Two days (292,293) of 2007
Precise Orbits
5050 baselines

15 mm rms differece wrt IGN

HEPOS   **Metsovo, 2009**
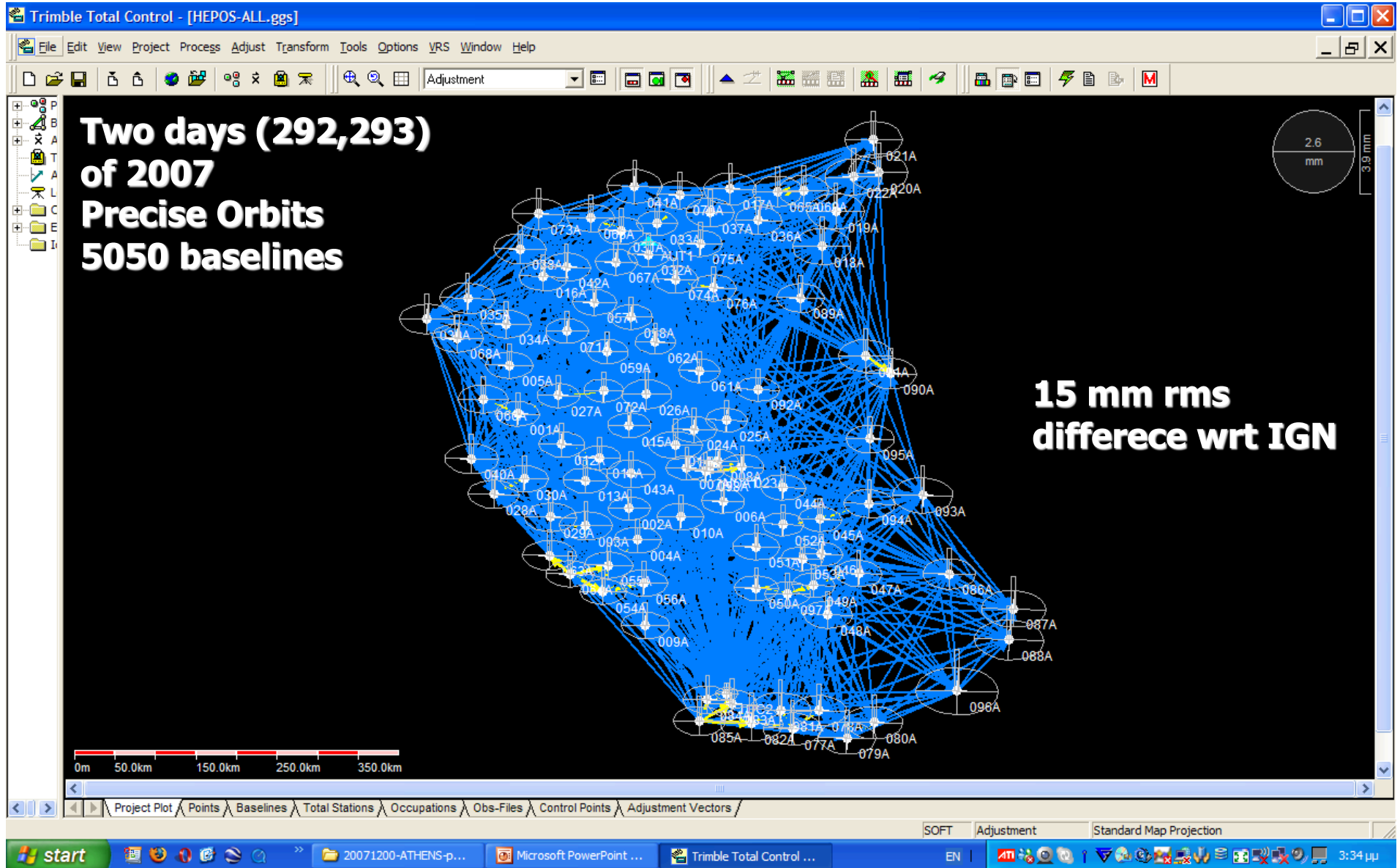
Datum Transformation: HTRS07 ↔ HGRS87

- **HGRS87** is (still) the official (non geocentric) reference system for the Hellenic Cadastre.

- **24000** pillars in Greece, maintained by the Hellenic Geographic Millitary Service (HEGS).

- Available data : E, N or φ, λ and H (mostly from trigonometric leveling)

- **2470 pillars** (10% of Greek triangulation network) re-measured to obtain ITRF/ETRF coordinates.

HEPOS

Metsovo, 2009

Point distribution around Thessaloniki.
Apprx 8 points / 1:50,000 sheet
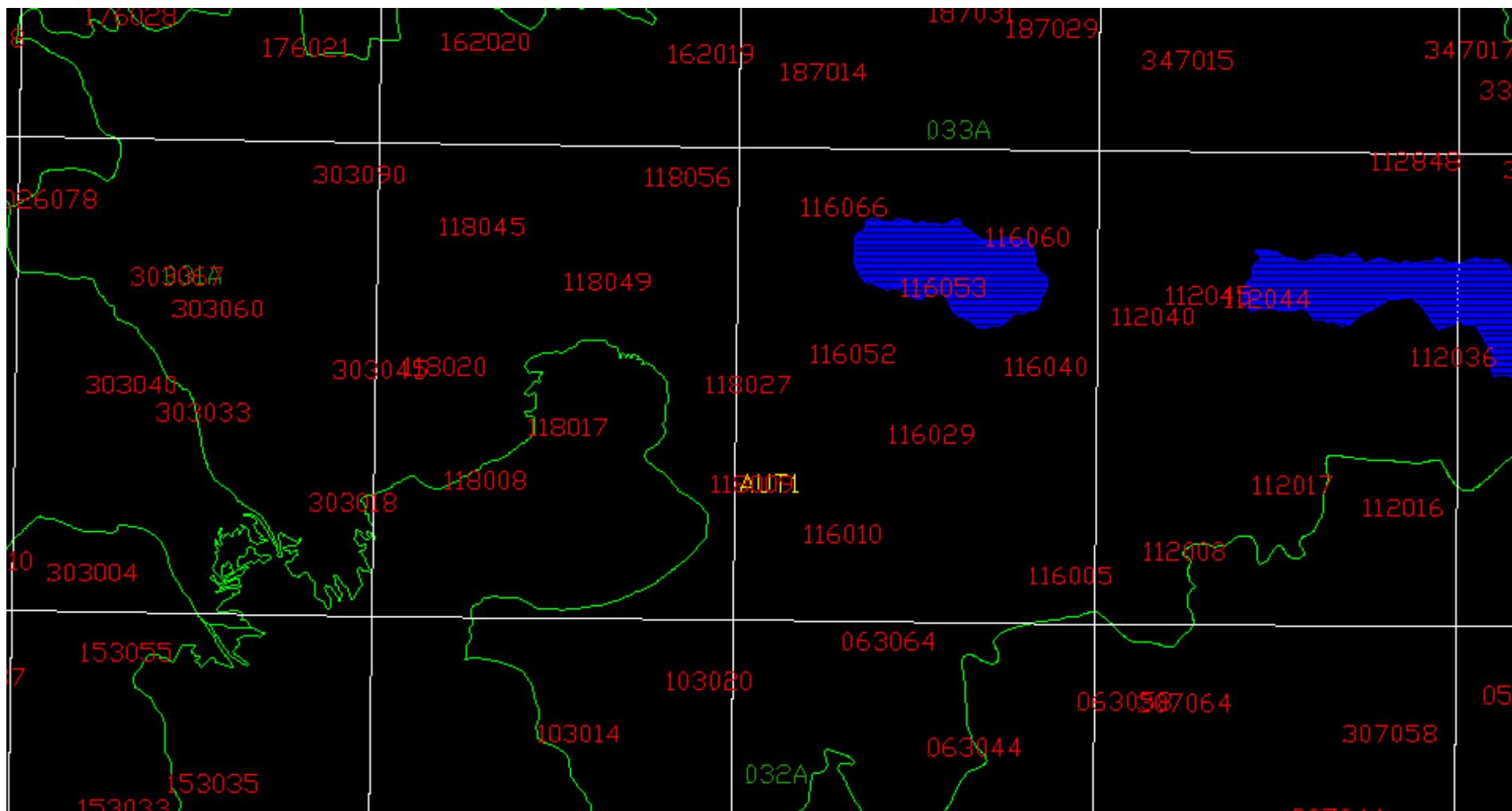
Software : ITRFyy <> ETRFxx (Boucher-Altamimi MEMO)

HEPOS

Metsovo, 2009
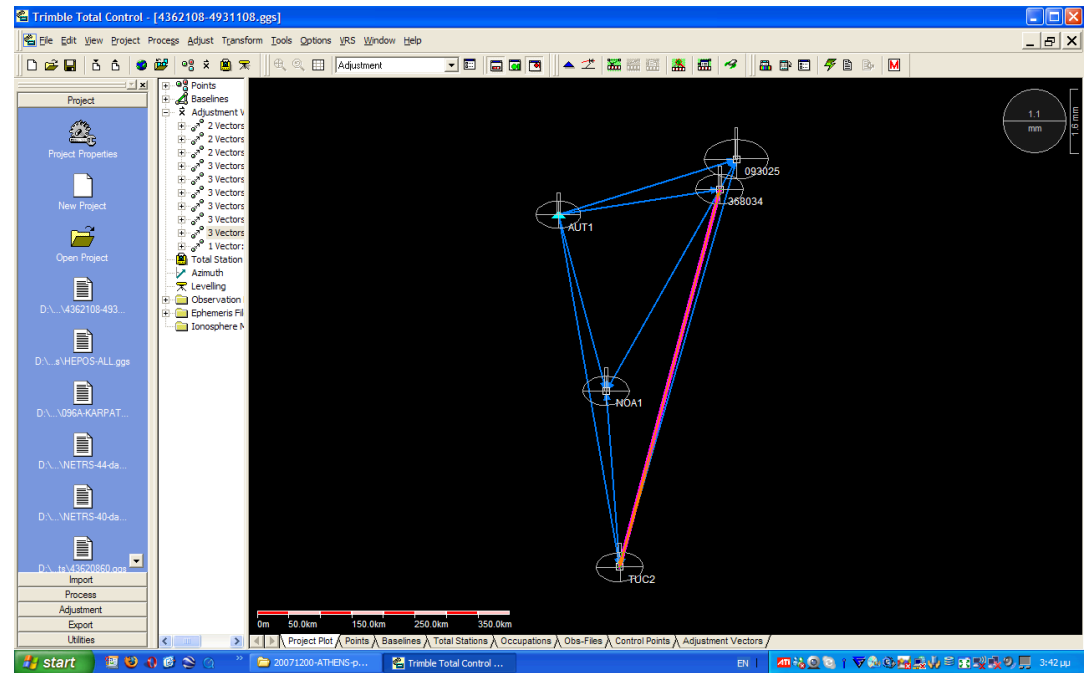
All 2470 pillars positioned in three reference frames

- 6H-24H obs & precise orbits / Min constraints
- Solution in ITRF2000/2007.236
- Always check at NOA1 & TUC2
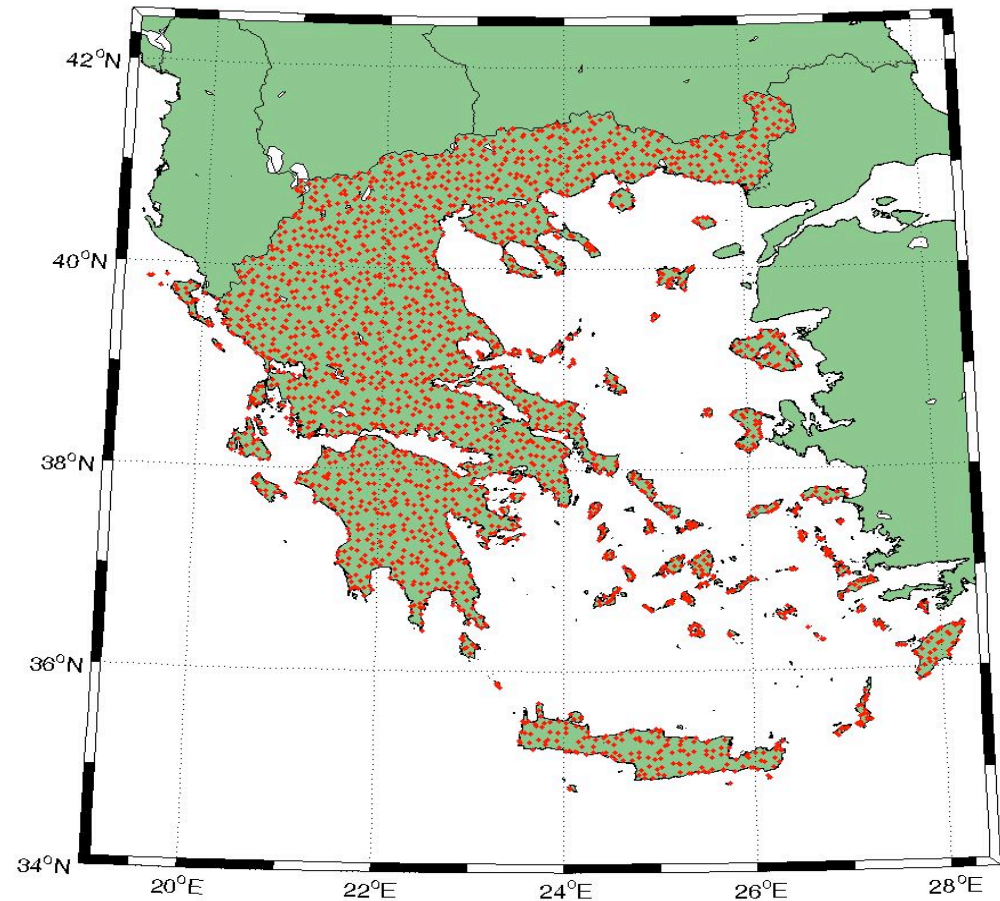- Transformation to ETRF2000/2007.236 using B/A Memo

$$X^E_{YY}(t_c) = X^I_{YY}(t_c) + T_{YY} + \begin{pmatrix} 0 & -\dot{R}3_{YY} & \dot{R}2_{YY} \\ \dot{R}3_{YY} & 0 & -\dot{R}1_{YY} \\ -\dot{R}2_{YY} & \dot{R}1_{YY} & 0 \end{pmatrix} \times X^I_{YY}(t_c) \cdot (t_c - 1989.0)$$

- Translation to ETRF2005/2007.5 using offset at AUT1

  +0.020, +0.016, +0.004 m

HEPOS

Metsovo, 2009

2470 pillars occupied to estimate and validate HTRS07 – HGRS87 parameters

order	#
I	14
II	39
III	328
IV	2085

HEPOS

Metsovo, 2009

Transformation & Validation points
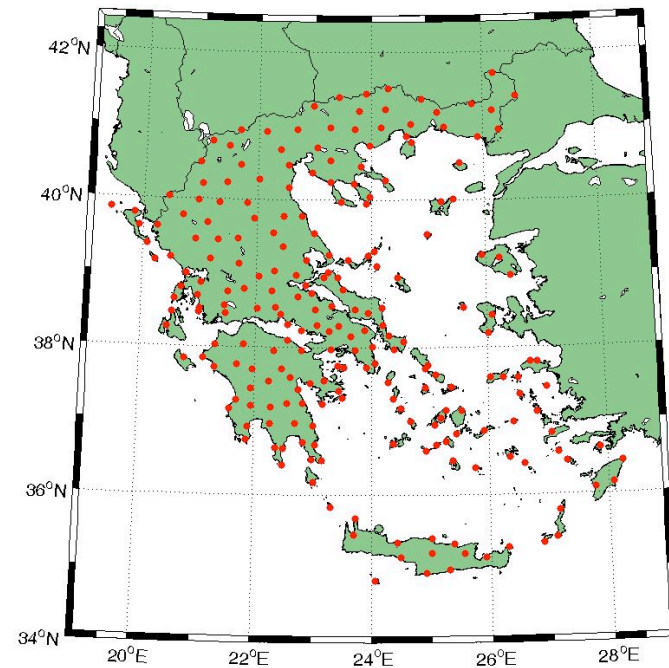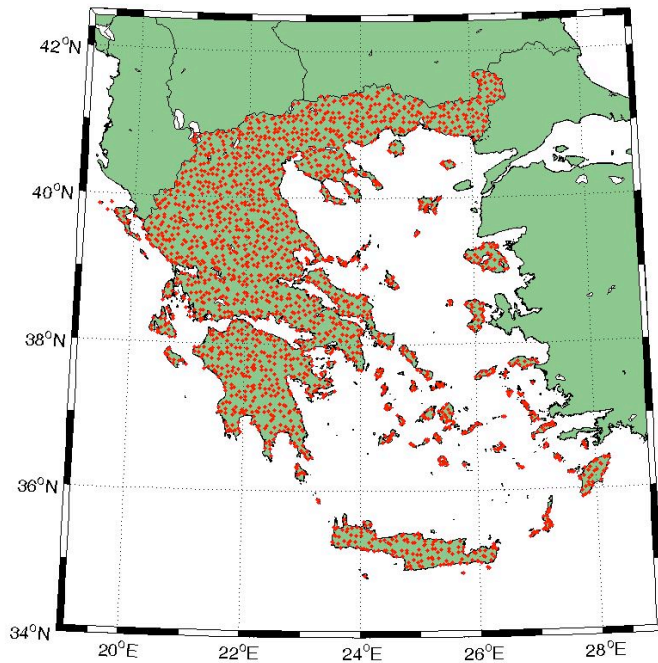
| For the transformation	2199
For validation	231

HEPOS

Metsovo, 2009

Helmert-type 3D similarity transformation model (7 parameters)

$$
\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} t_x \\ t_y \\ t_z \end{bmatrix} + \begin{bmatrix} (1+\delta s) & \varepsilon_z & -\varepsilon_y \\ -\varepsilon_z & (1+\delta s) & \varepsilon_x \\ \varepsilon_y & -\varepsilon_x & (1+\delta s) \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}
$$

Estimated Parameters (HTRS07 to HGRS87)

parameter	value	σ
tx	**203.437 m**	± 0.265 m
ty	**-73.461 m**	± 0.285 m
tz	**-243.594 m**	± 0.244 m
εx	**-0″.170**	± 0″.007
εy	**-0″.060**	± 0″.009
εz	**-0″.151**	± 0″.009
scale	**-0.294 ppm**	± 0.031 ppm

HEPOS

Metsovo, 2009

Horizontal residuals at transformation & validation points
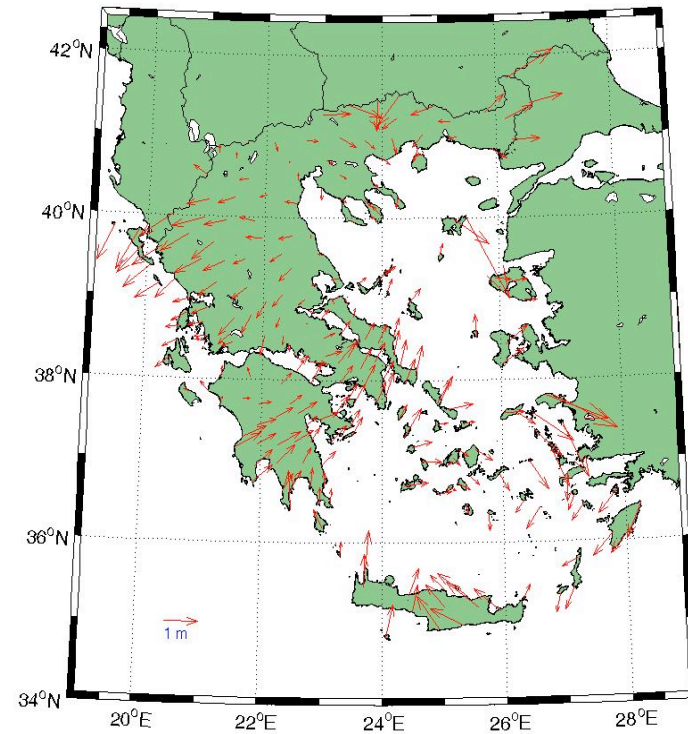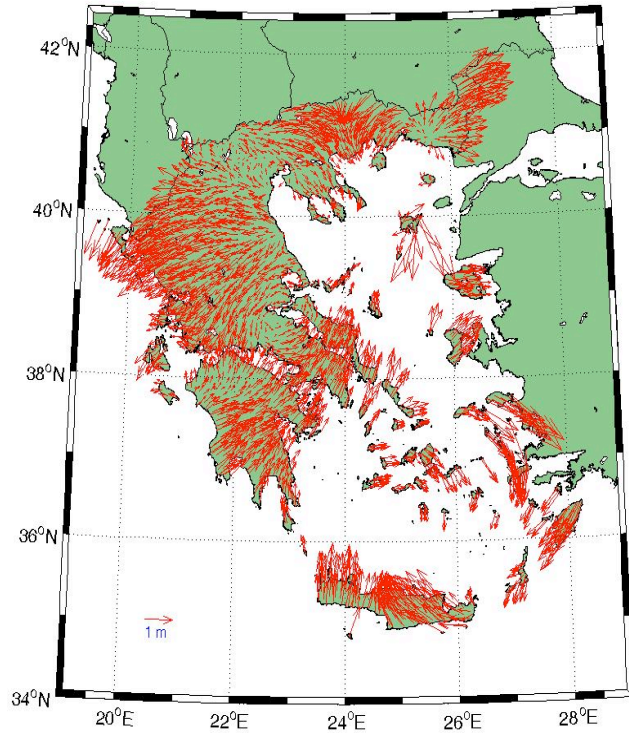
points	max	min	mean	σ	rms
2199	2.342	0.010	0.550	0.301	0.627
231	2.585	0.019	0.584	0.350	0.680

HEPOS

Metsovo, 2009

Regional horizontal residuals

HEPOS

Metsovo, 2009
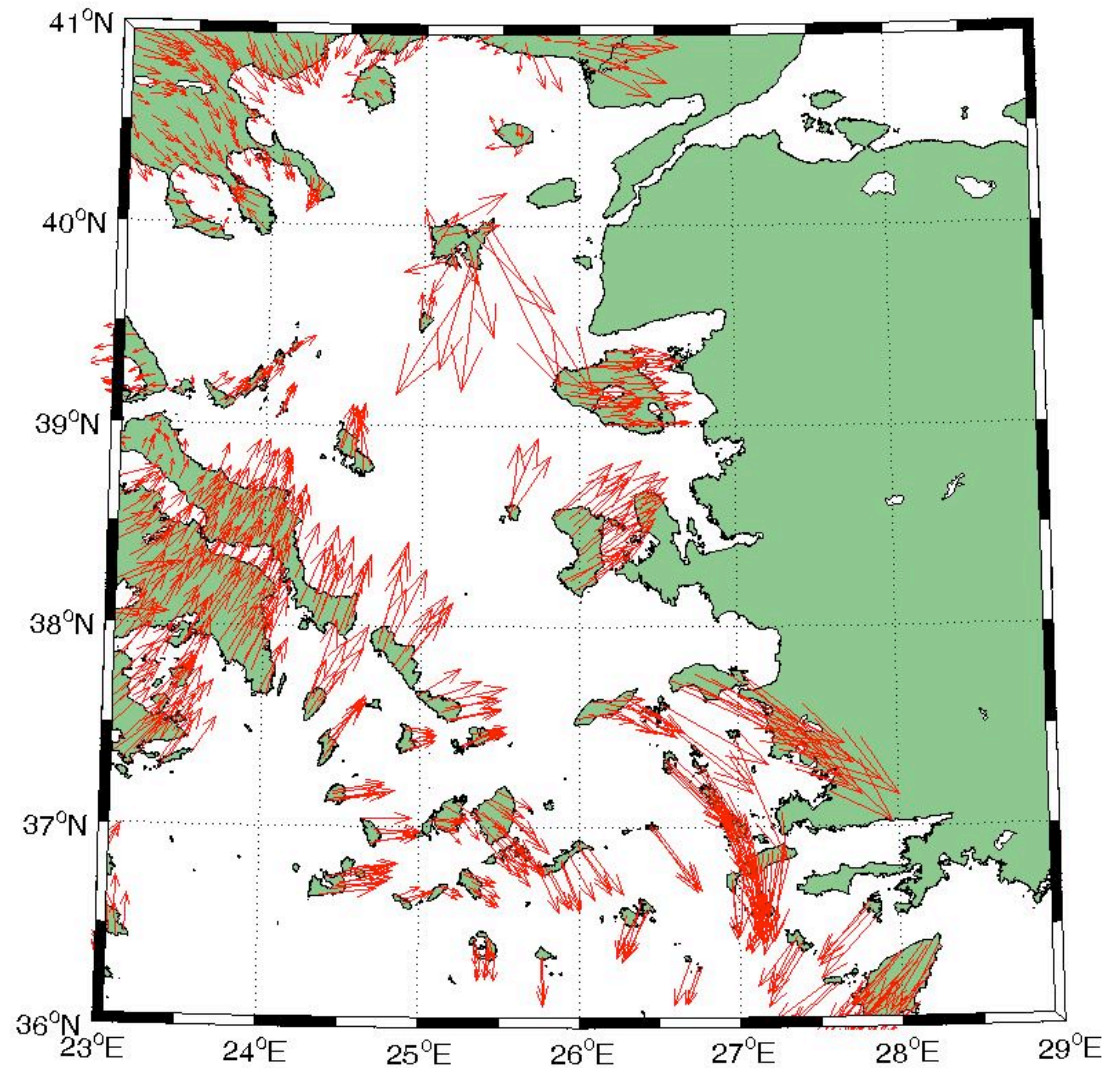
Corrections on a 2x2 km Grid
(computed using biharmonic spline interpolation)
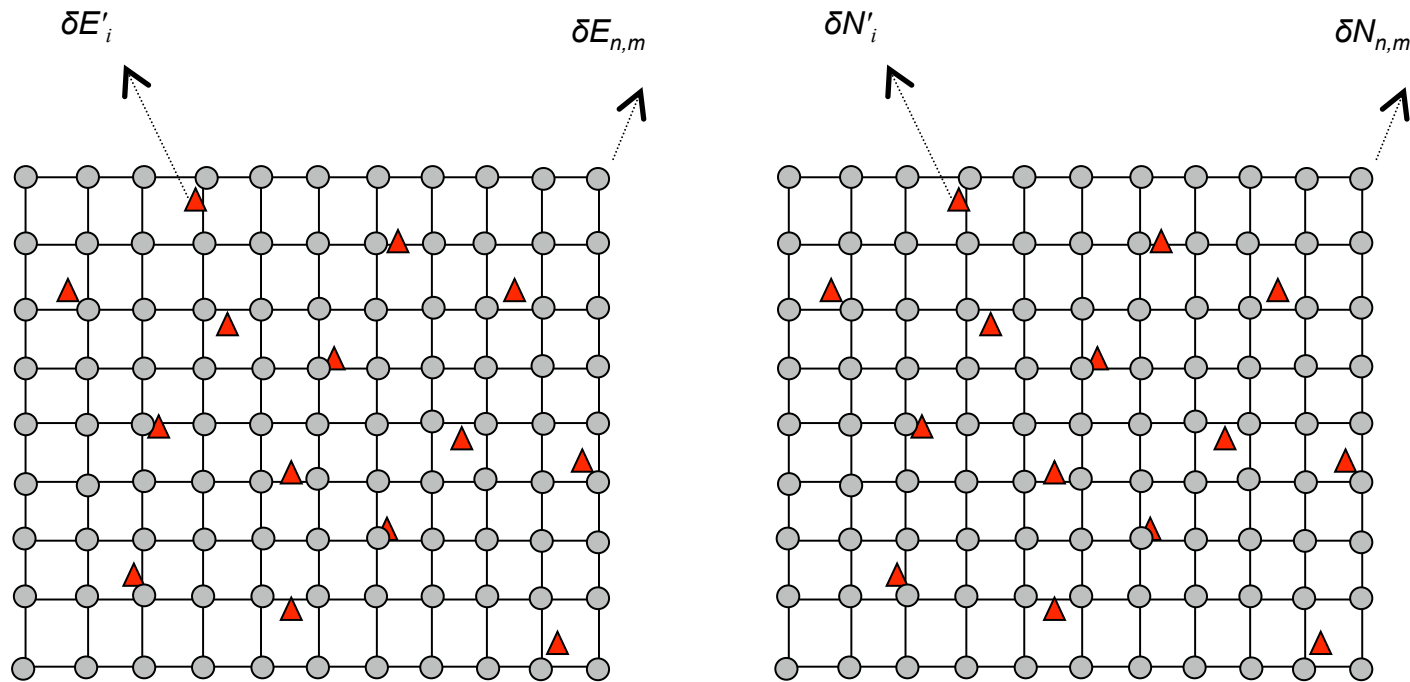
points	max	min	mean	σ	rms
2199	0.049	0.000	0.007	0.004	0.008
231	0.244	0.006	0.068	0.047	0.082

Software for the transformation : HTRS07 <> HGRS87

- 7-parameter model + gridded corrections on a 2kmx2km grid
- Four versions, available from **www.hepos.gr**
- 8 cm rms transformation accuracy everywhere in Greece

HEPOS   **Metsovo, 2009**

Future Work

- Apply TWG recommendation for ETRF2000   (?)

- Official change from HGRS87 to HTRS07

- A reliable geodetically computed velocity field model for the tectonic motions in Greece (estimated up to 3 cm/year). The contribution of the 98 HEPOS stations. Repeated (yearly?) adjustment of the network.

- Define a new national **vertical** reference system, in support of HEPOS.

- Compilation of a new geoidal model ?

- Use the new EGM08 model for the conversion h=H+N.

Thank you

Prof. K. Katsampalos, AUTh
kvek@topo.auth.gr

Assc Prof. Ch. Kotsakis, AUTh
kotsaki@topo.auth.gr

Asst Prof. M. Gianniou, KTIMATOLOGIO SA
mgianniu@ktimatologio.gr