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

EUREF 2009 Symposium / Florence, May 2009

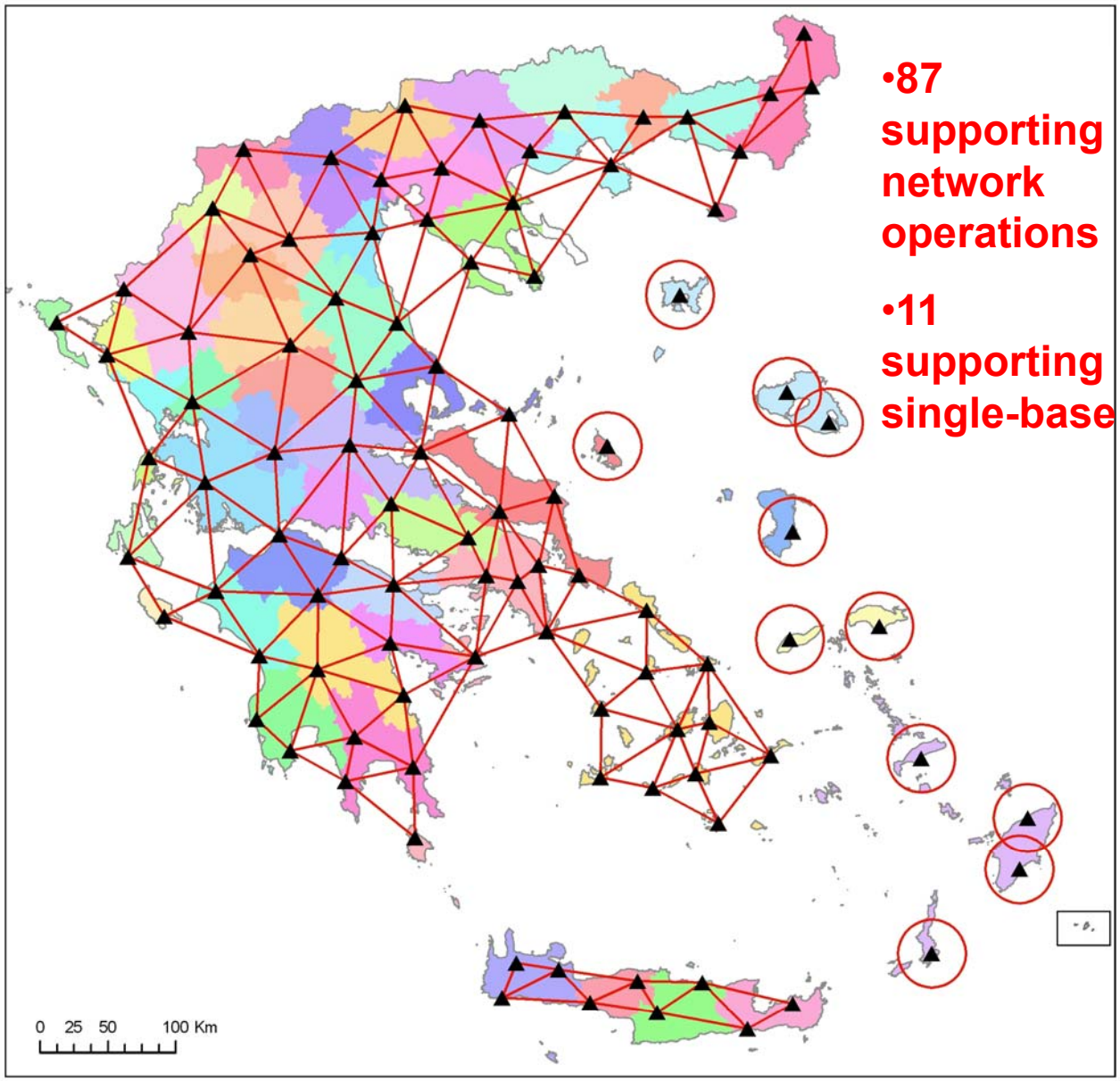
Contents

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

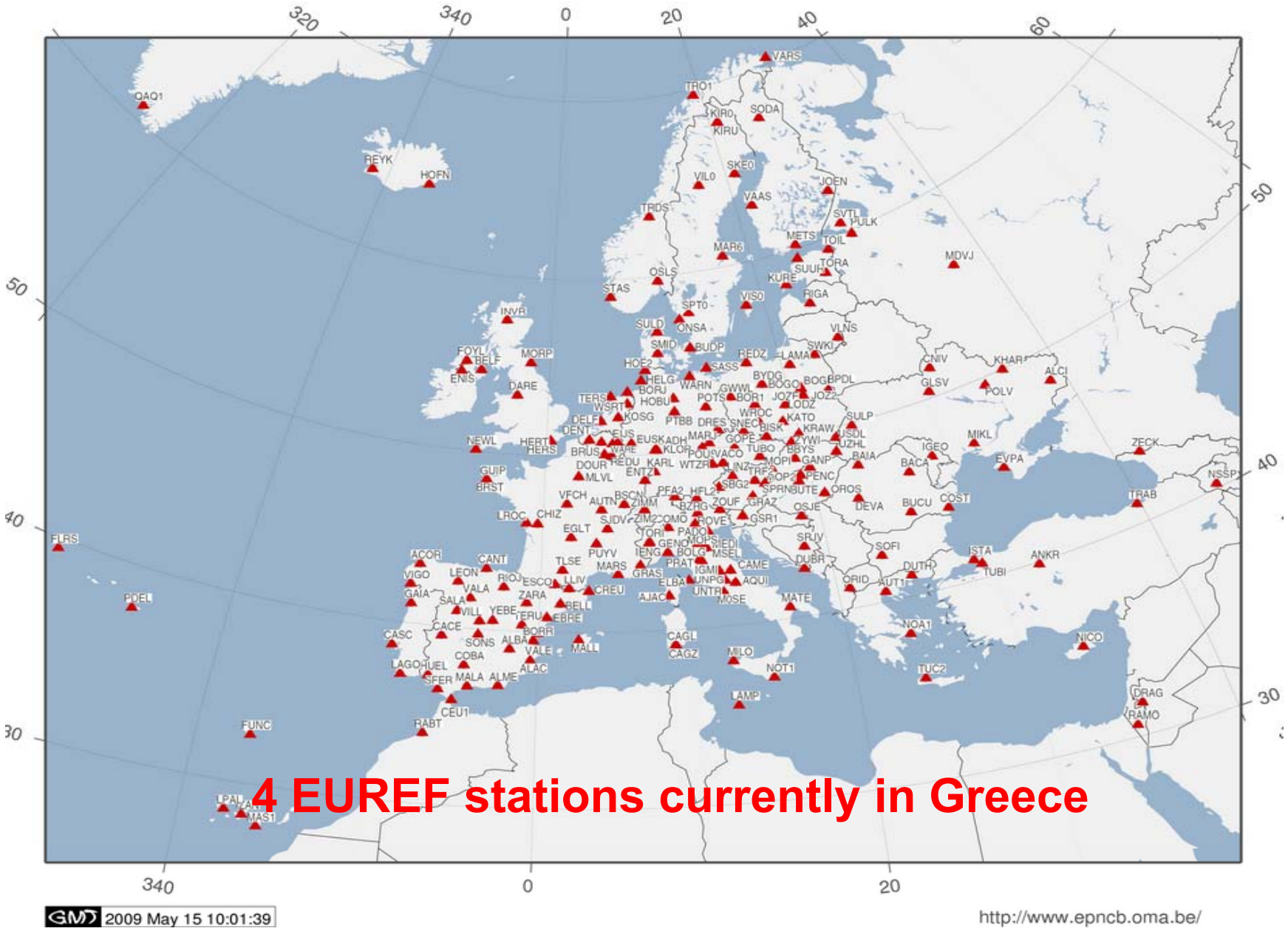
HEPOS

- 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



EUREF Permanent Tracking Network



4 EUREF stations currently in Greece

EUREF 2009 / Florence

HTRS07 in support of HEPOS

Greek EPN stations
(operational during HEPOS development)

TUC2

2004 / week 1294

AUT1

2005 / week 1320

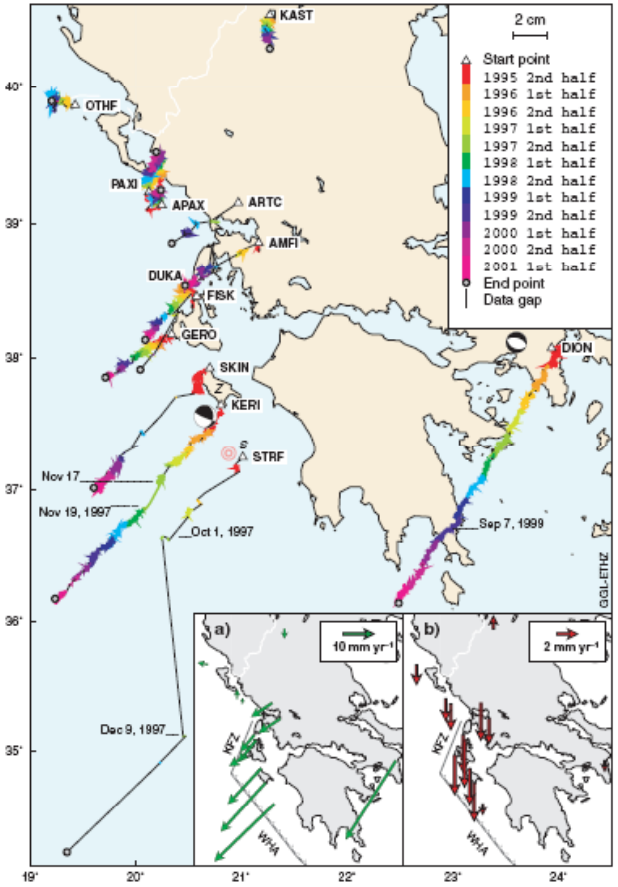
NOA1

2006 / week 1379

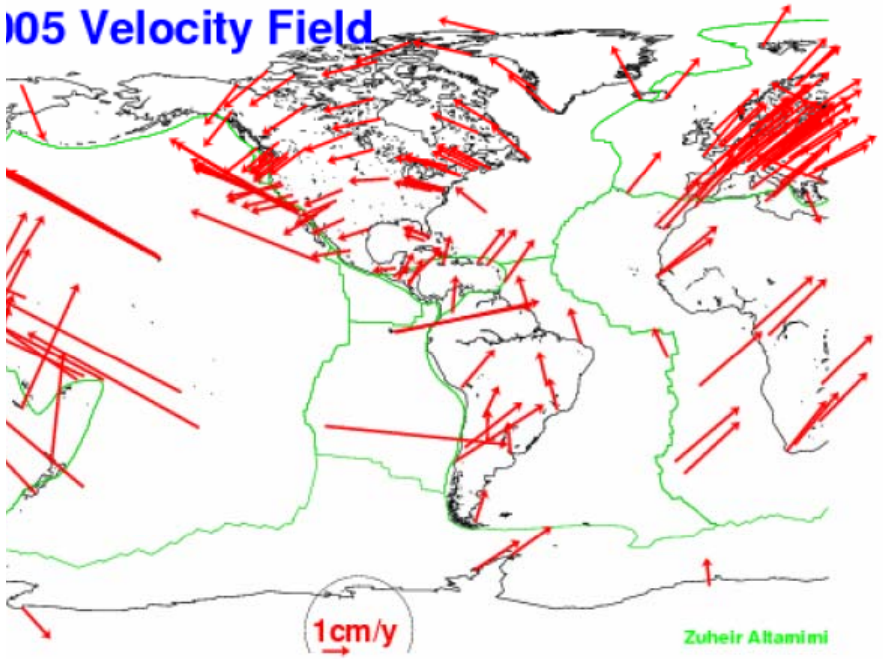
EUREF 2009 / Florence

HTRS07 in support of HEPOS

ITRF2005 and Plate motion:
Horizontal Site velocities with σ < 3mm/y



Hollenstein-Geiger-Khale-Veis (2006)

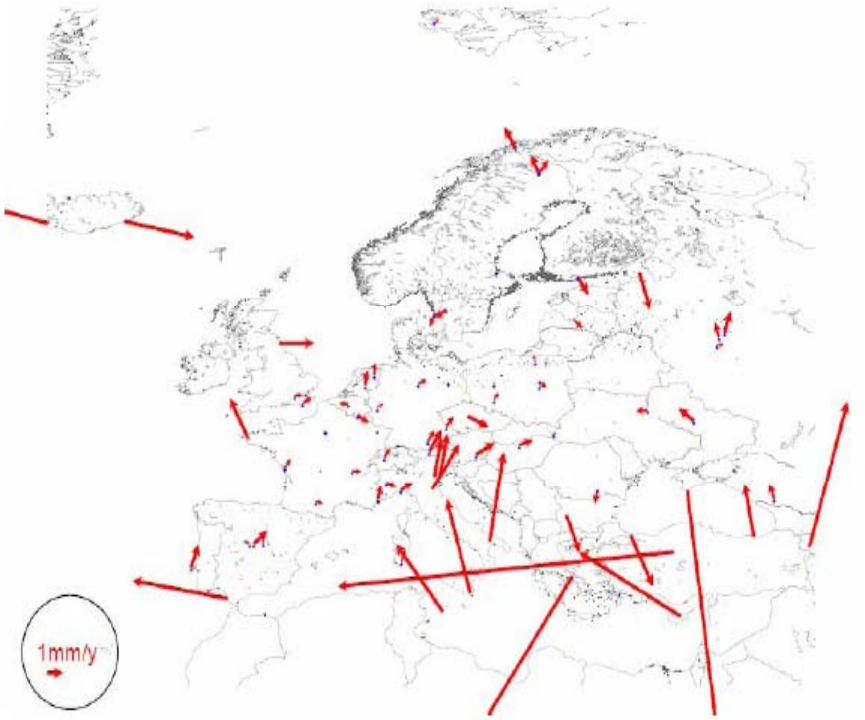


F Symposium, London, June 2007

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

ETRF2005 Horizontal Velocities

(from Altamimi. EUREF 2006)

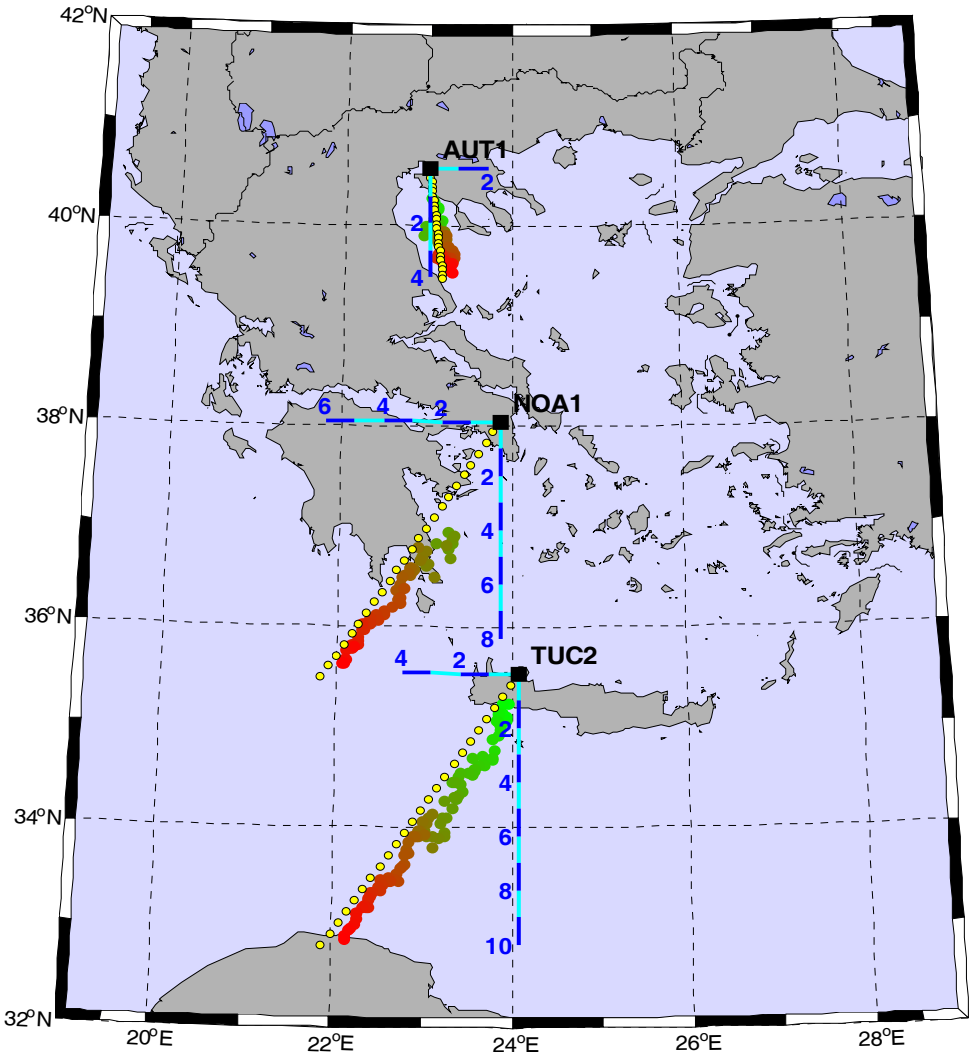


Dionysos 3.1 cm/y 3D

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

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

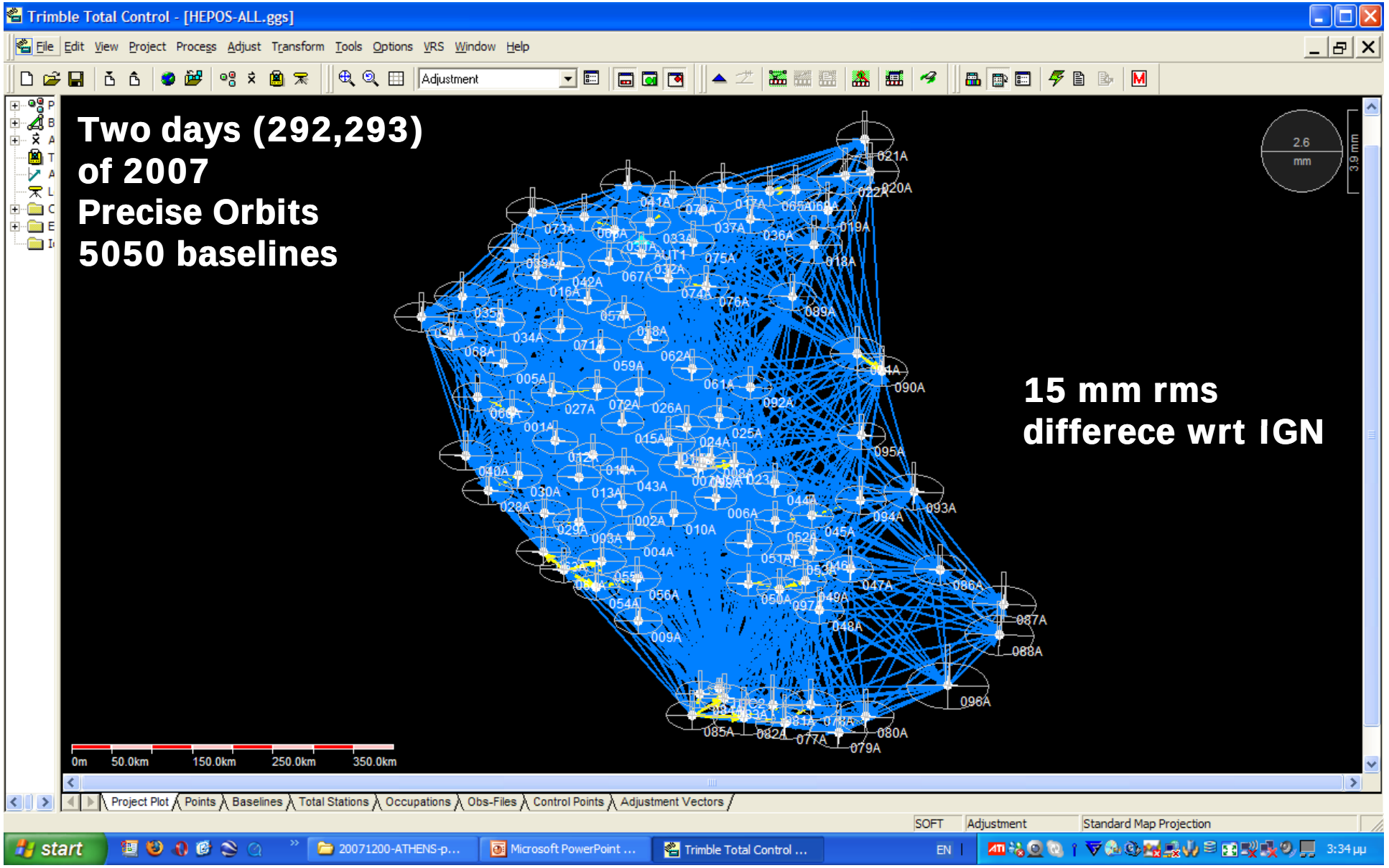
HEPOS 98-stations adjustment

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 : σE=2mm , sN=2mm, σH=5mm**

AUTh adjustment



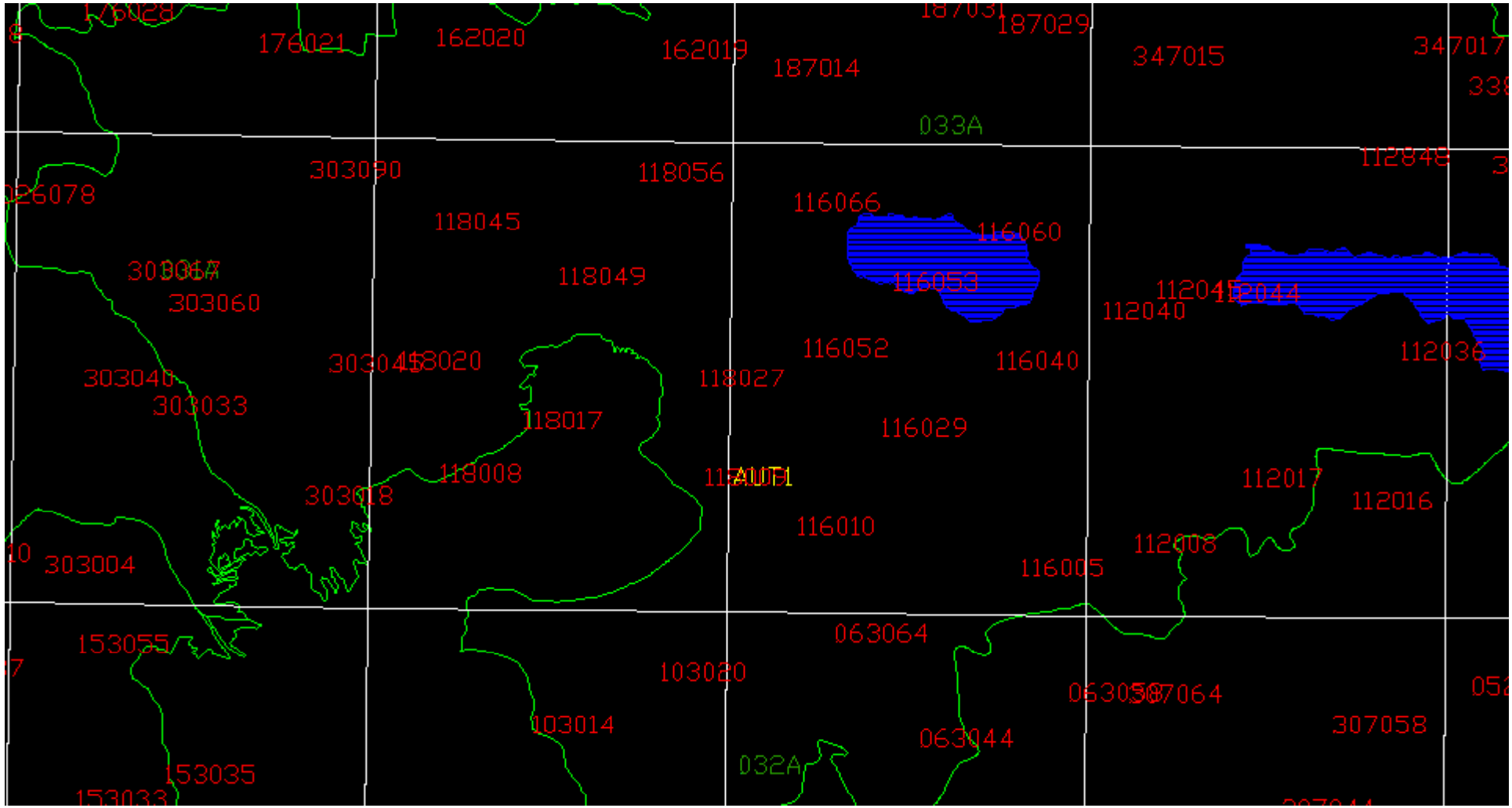
EUREF 2009 / Florence

HTRS07 in support of HEPOS

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.

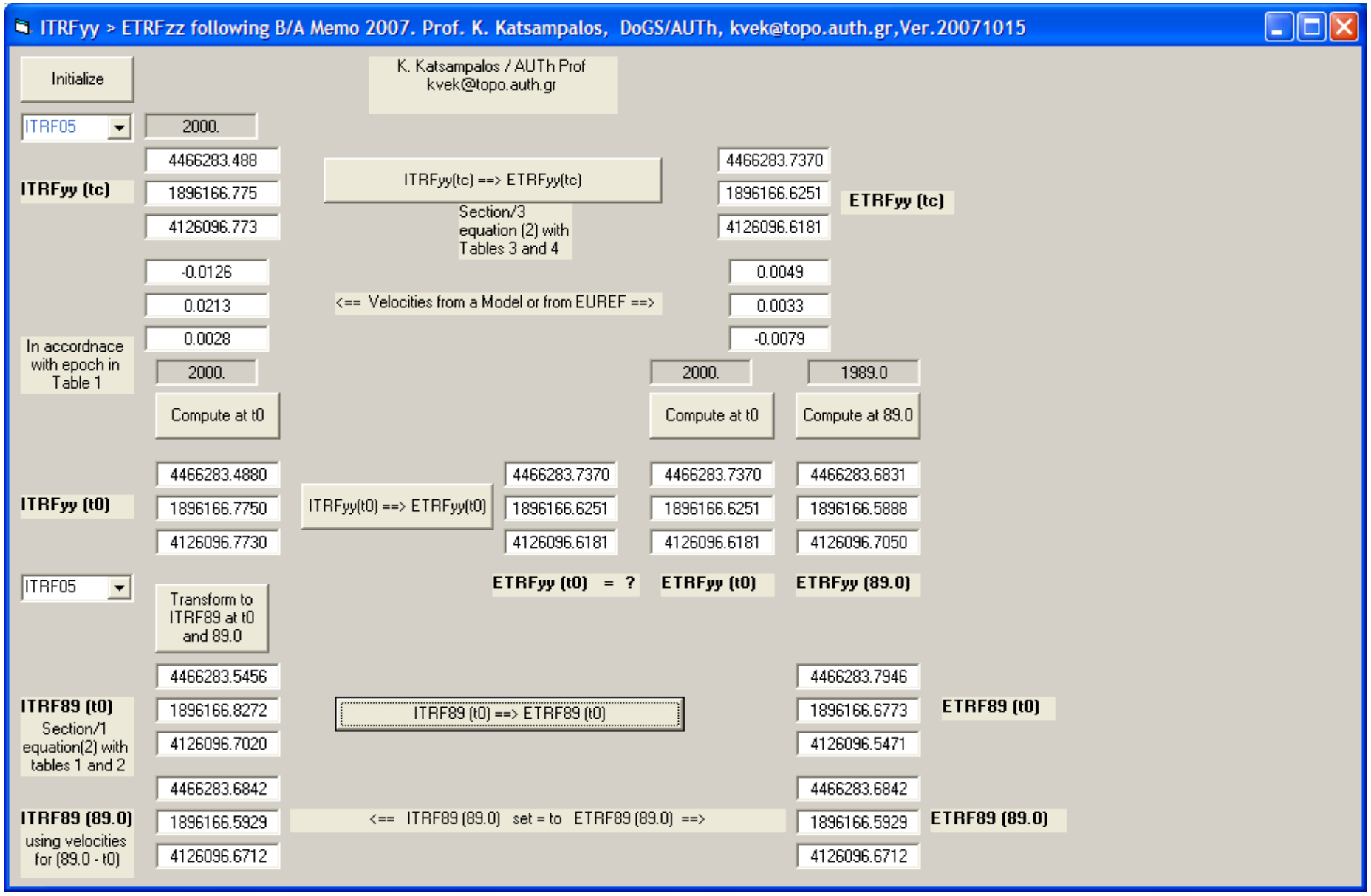
Point distribution around Thessaloniki.
Apprx 8 points / 1:50,000 sheet



EUREF 2009 / Florence

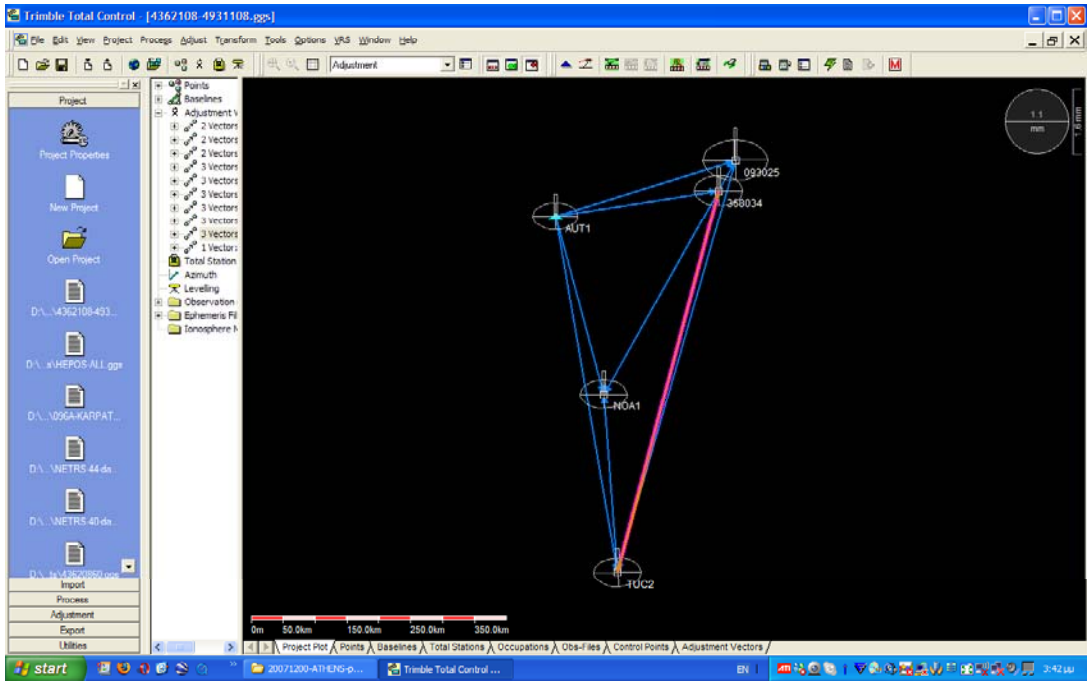
HTRS07 in support of HEPOS

Software : ITRFyy <> ETRFxx (Boucher-Altamimi MEMO)



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



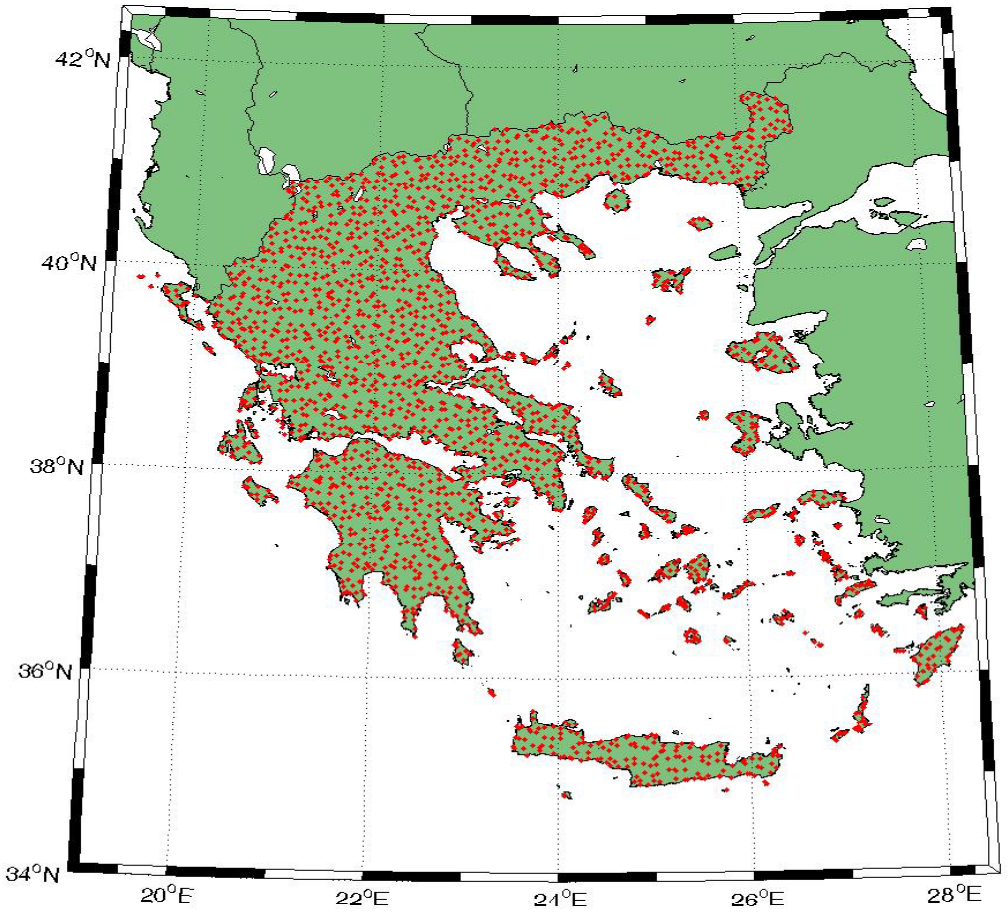
$$X^{E}_{YY}(t_c) = X^{I}_{YY}(t_c) + T_{YY} + \begin{pmatrix} 0 & -\dot{R}3_{YY} & \dot{R}2_{YY} \\ \dot{R}3_{YY} & 0 & -\dot{R}1_{YY} \\ -\dot{R}2_{YY} & \dot{R}1_{YY} & 0 \end{pmatrix} \times X^{I}_{YY}(t_c) \cdot (t_c - 1989.0)$$

- Translation to ETRF2005/2007.5 using offset at AUT1

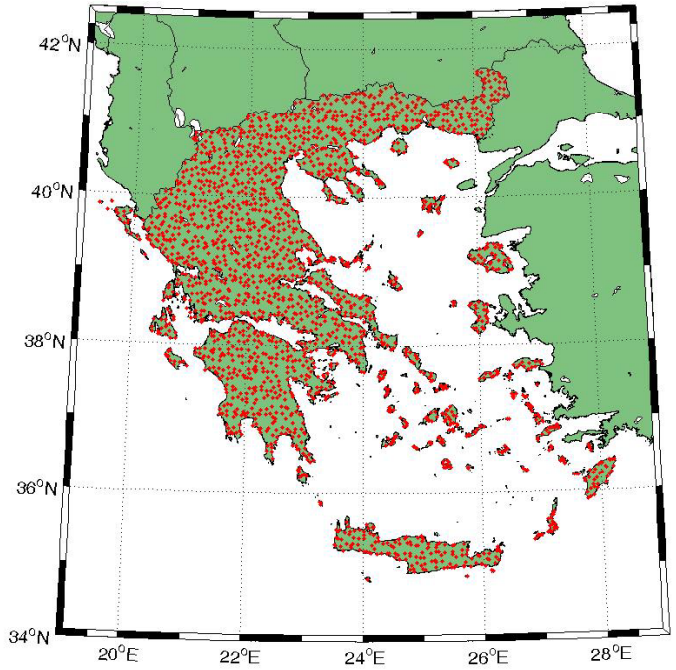
  +0.020, +0.016, +0.004 m

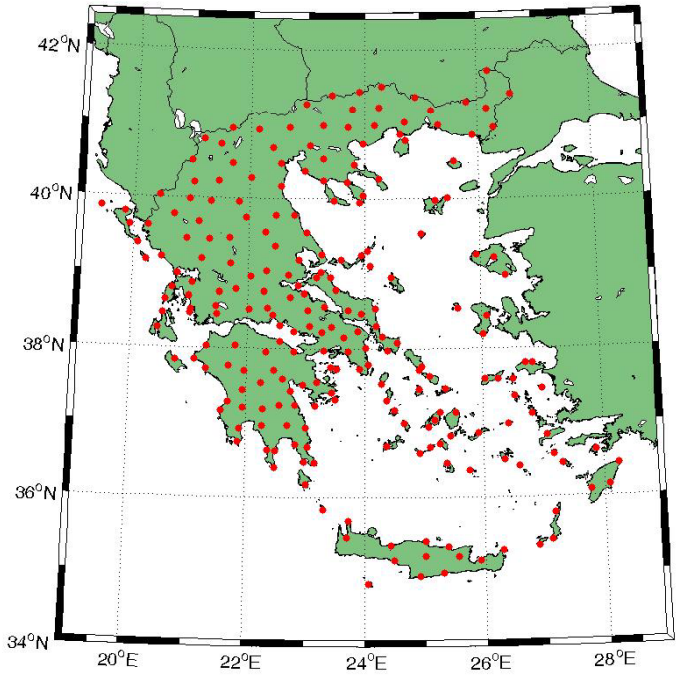
2470 pillars occupied to estimate and validate HTRS07 – HGRS87 parameters

order	#
I	14
II	39
III	328
IV	2085



Transformation & Validation points





For the transformation	2199
For validation	231

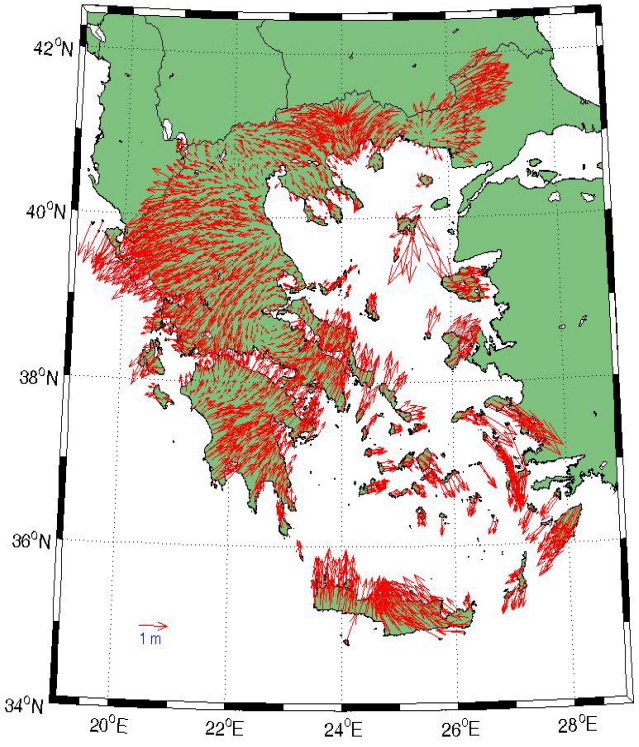
Helmert-type 3D similarity transformation model (7 parameters)

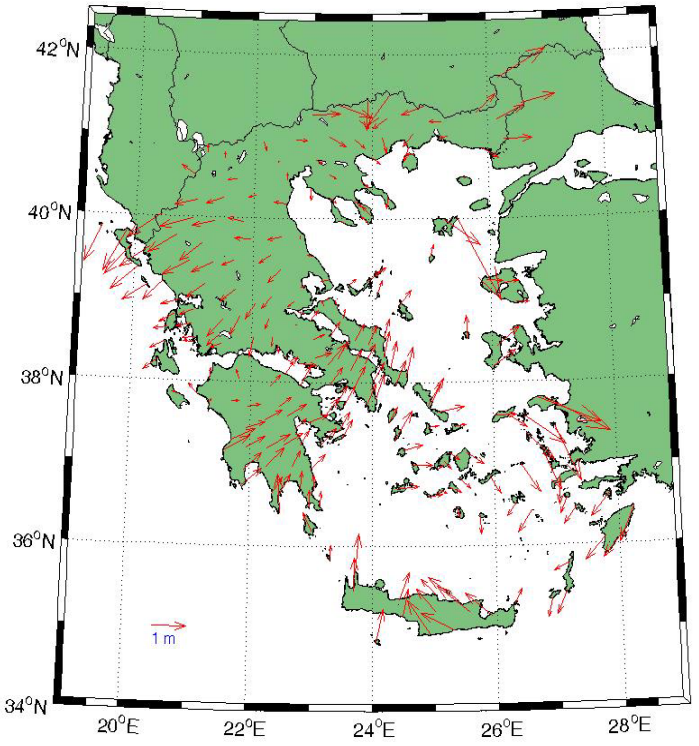
$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} t_x \\ t_y \\ t_z \end{bmatrix} + \begin{bmatrix} (1+\delta s) & \varepsilon_z & -\varepsilon_y \\ -\varepsilon_z & (1+\delta s) & \varepsilon_x \\ \varepsilon_y & -\varepsilon_x & (1+\delta s) \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z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

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

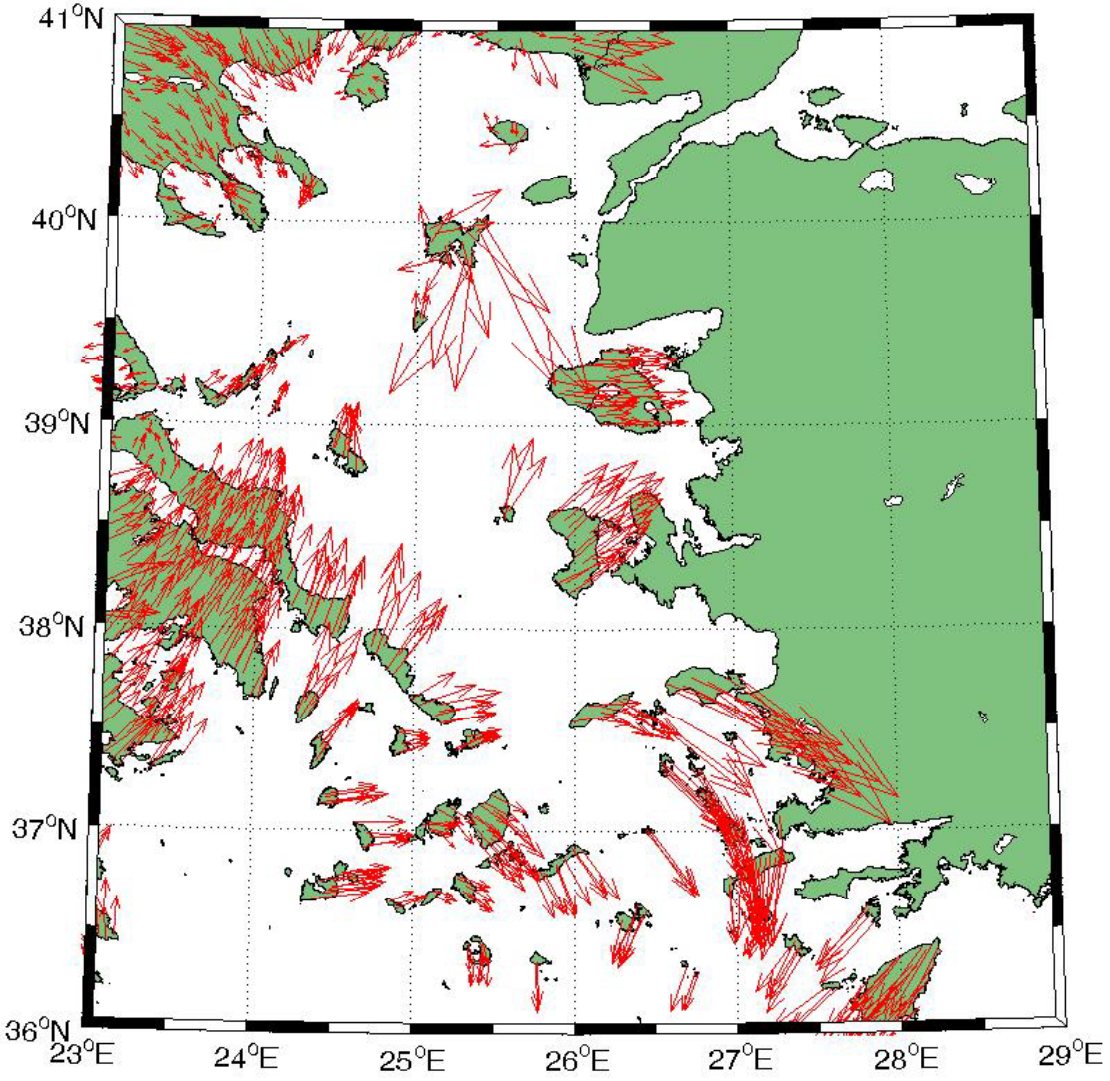
Horizontal residuals at transformation & validation points





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

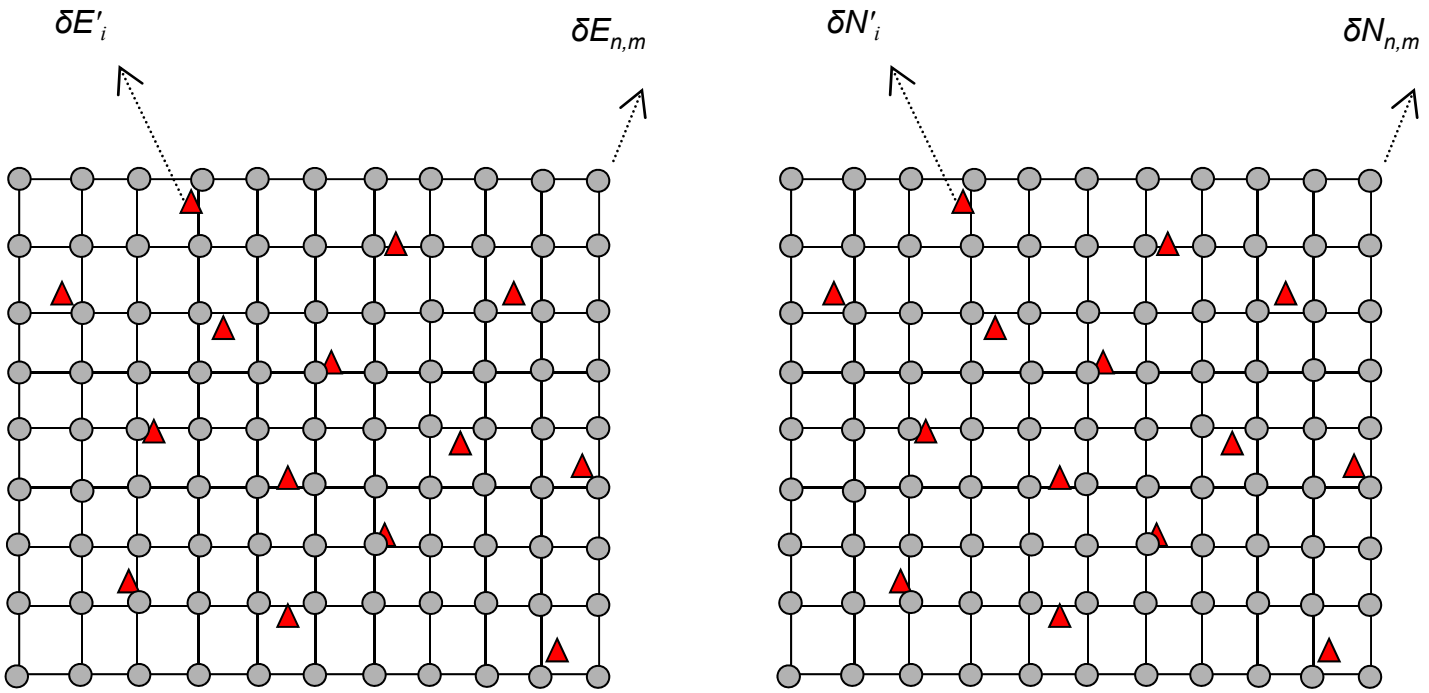
Regional horizontal residuals



EUREF 2009 / Florence

HTRS07 in support of HEPOS

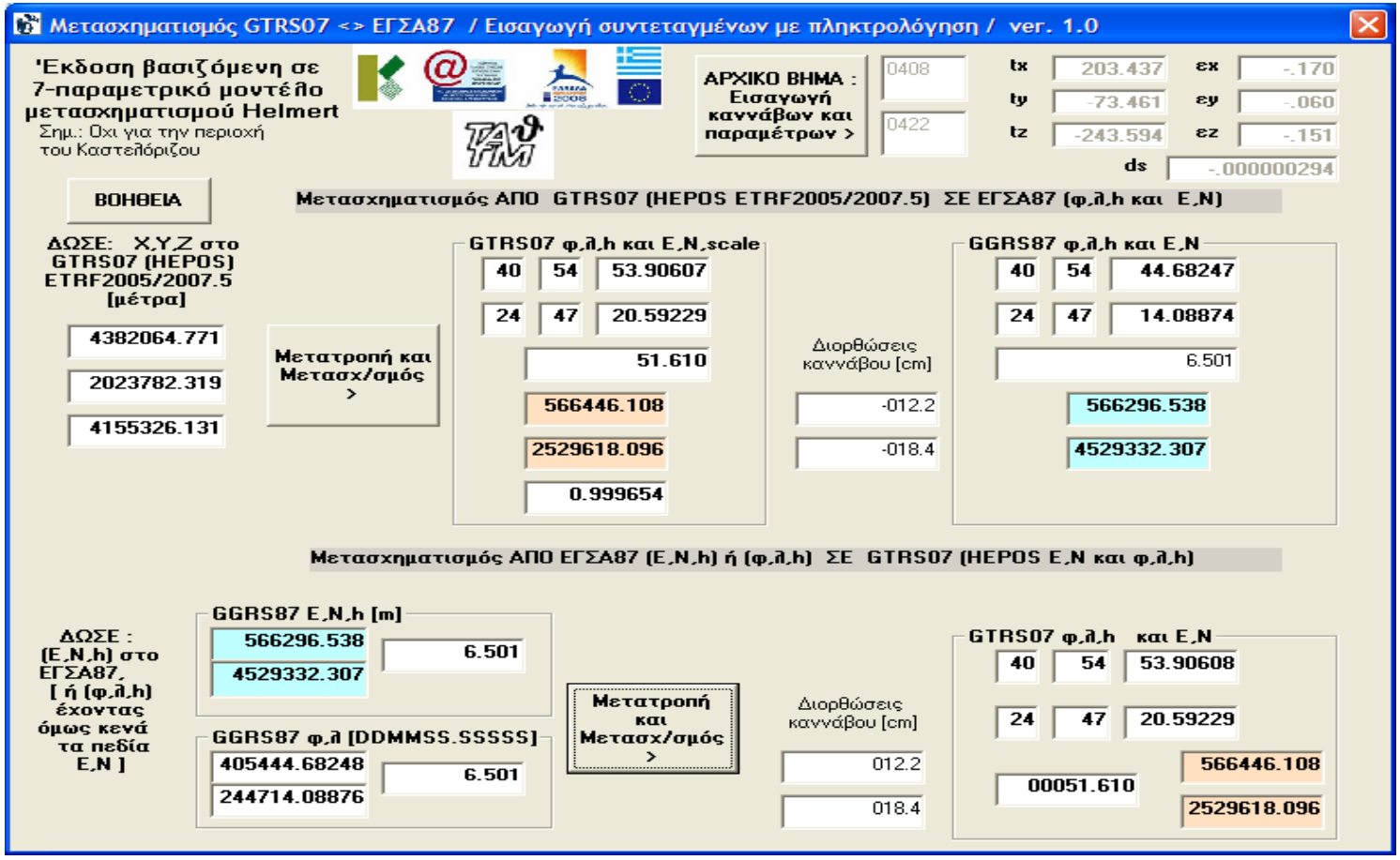
Corrections on a 2x2 km Grid (computed using biharmonic spline interpolation)



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**



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