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Hellenic Terrestrial Reference System 2007 (HTRS07) :

**A regional realization of ETRS89 over
Greece in support of HEPOS**

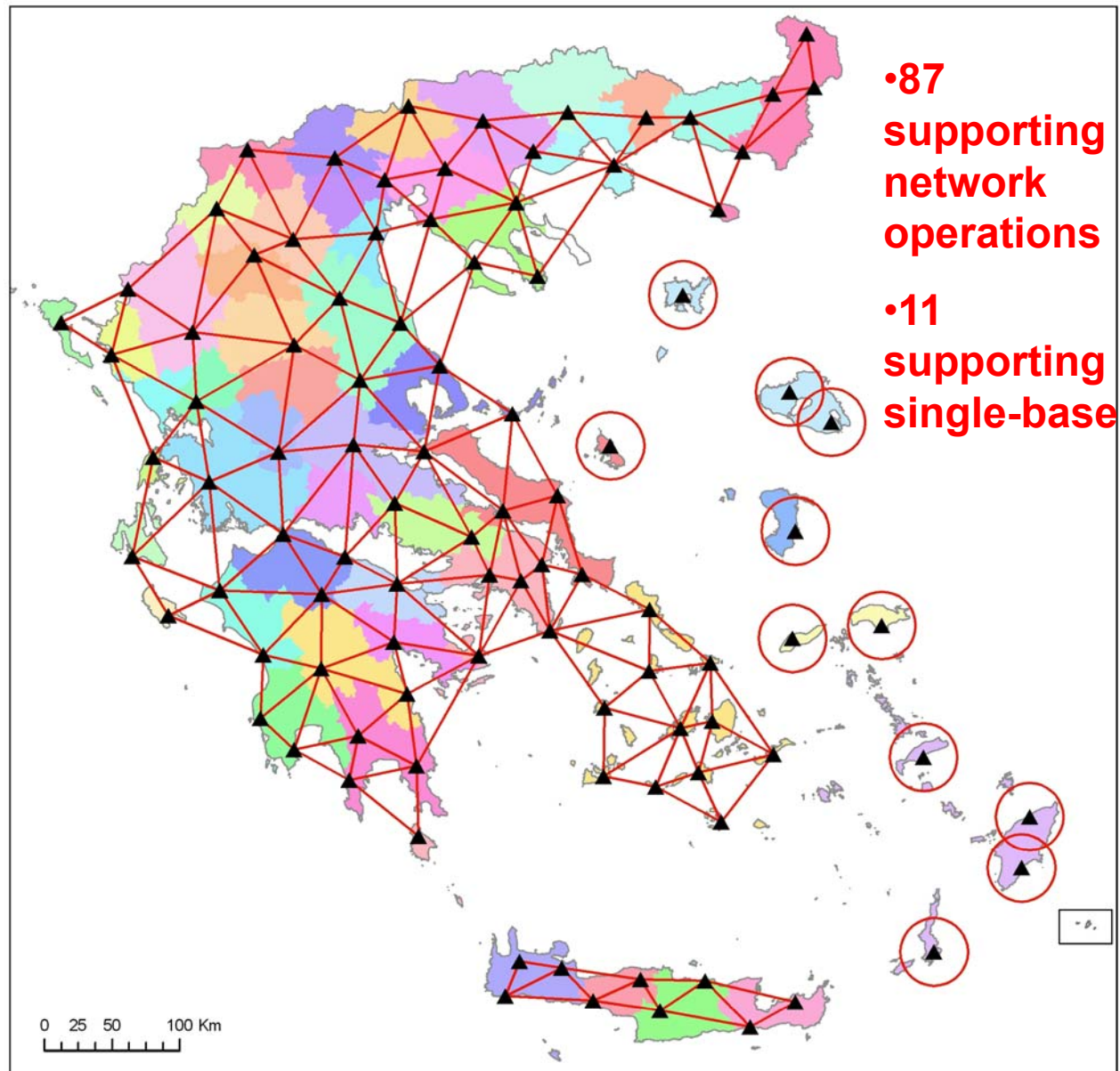
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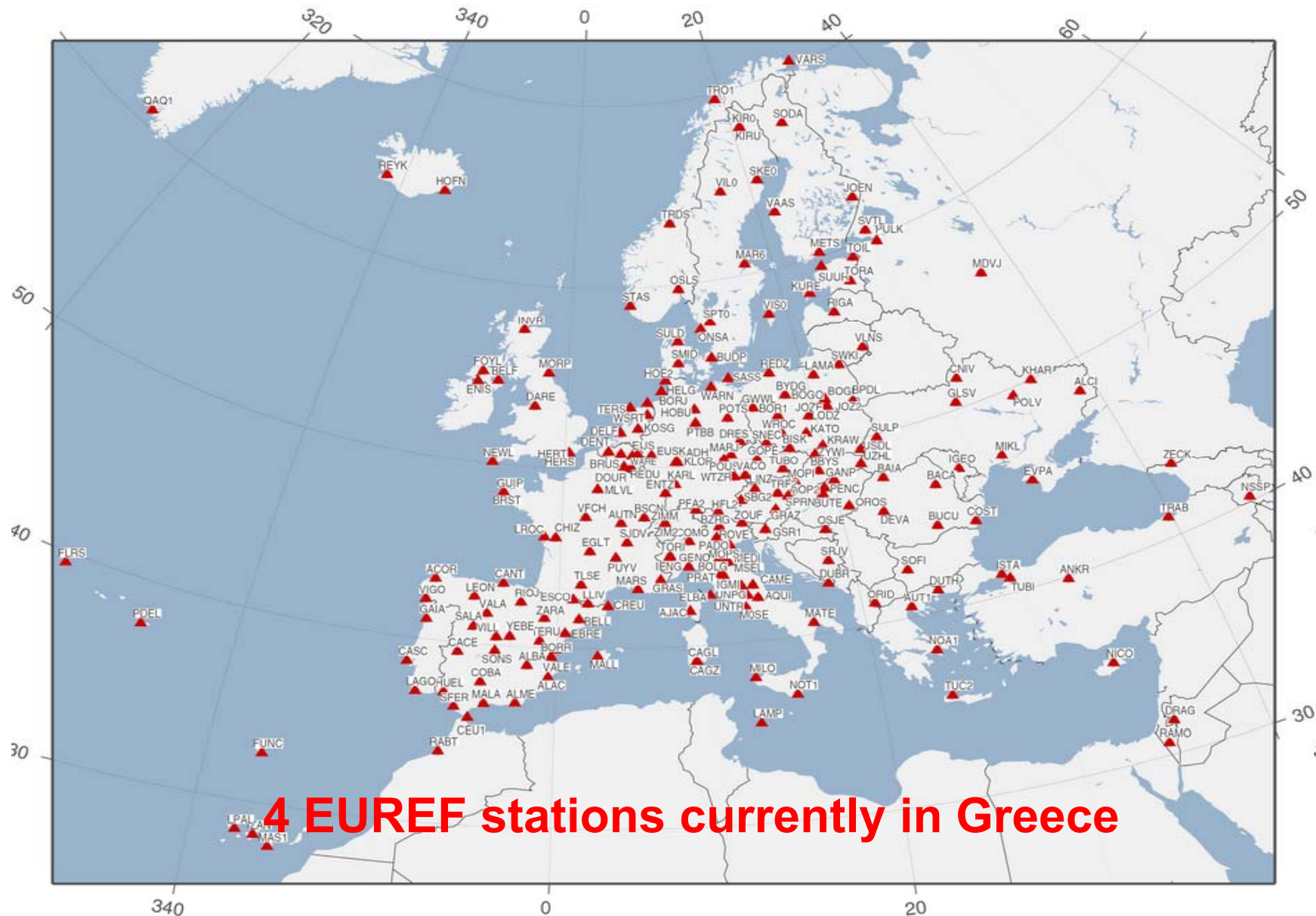
HEPOS

- **HE**llenic **P**ositioning **S**ystem.
- 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



GM 2009 May 15 10:01:39

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

EUREF 2009 / Florence

HTRS07 in support of HEPOS

Greek EPN stations (operational during HEPOS development)

TUC2

AUT1

NOA1



2004 / week 1294

EUREF 2009 / Florence



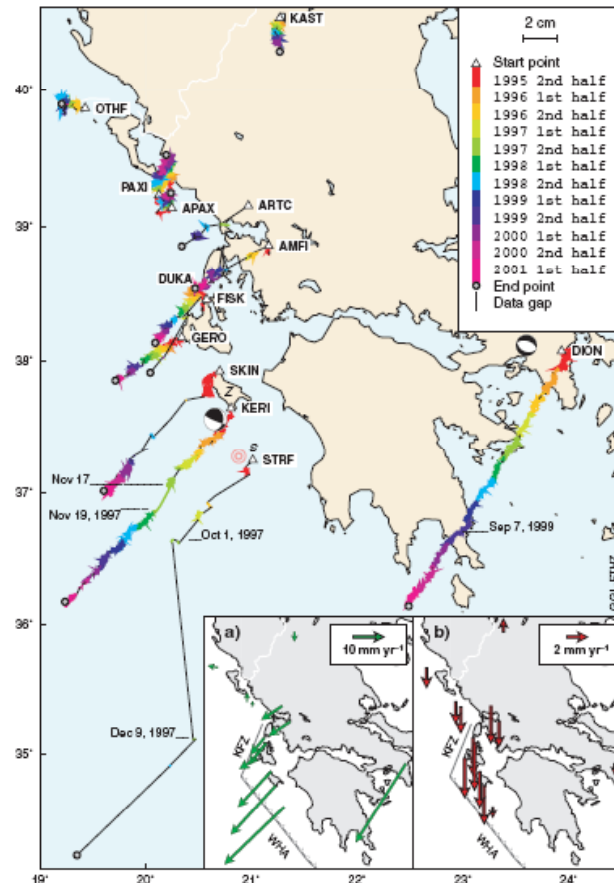
2005 / week 1320



2006 / week 1379

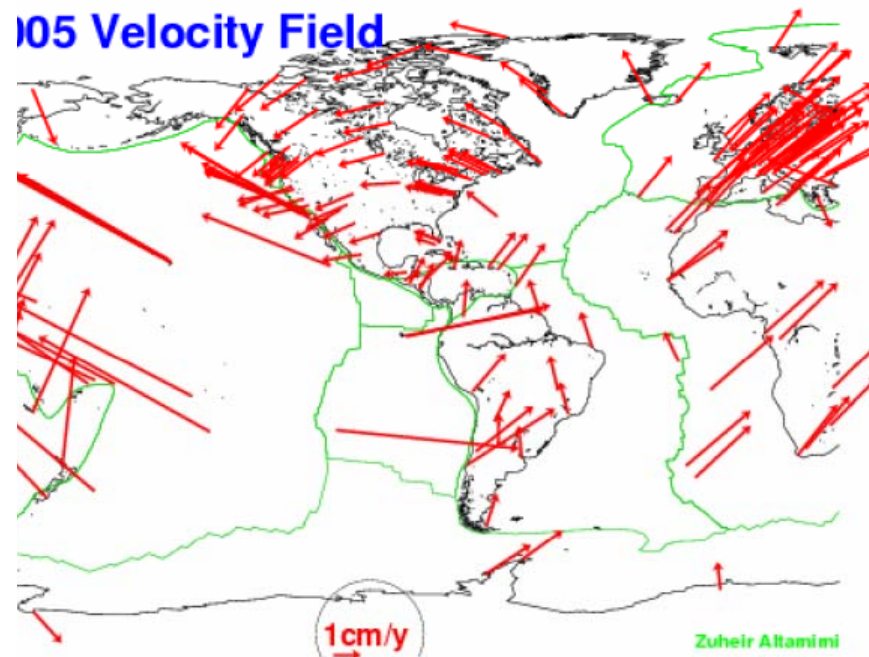
HTRS07 in support of HEPOS

ITRF2005 and Plate motion: Horizontal Site velocities with $\sigma < 3\text{mm/y}$



Hollenstein-Geiger-Khale-Veis (2006)

2005 Velocity Field

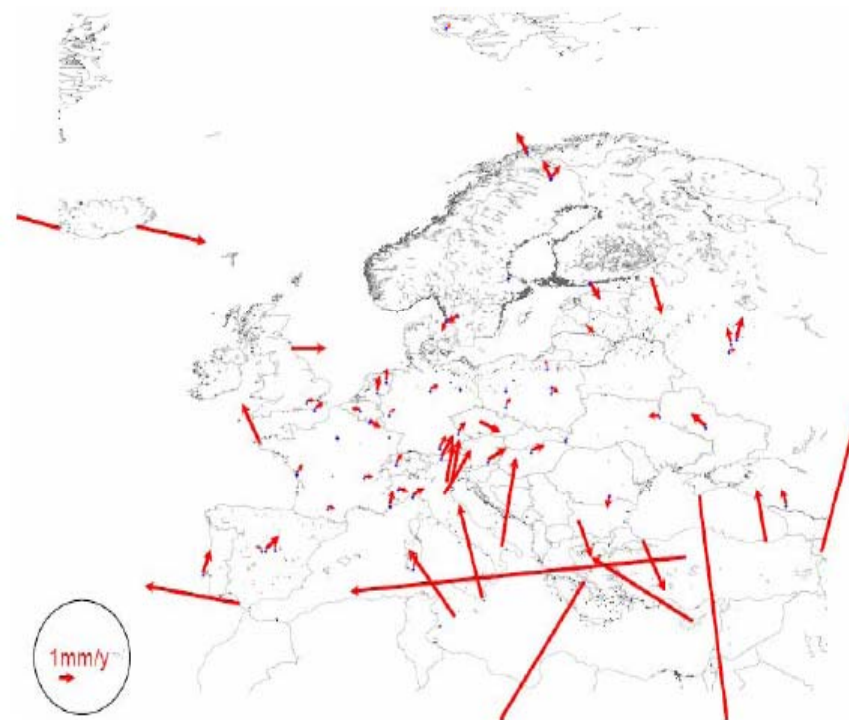


F Symposium, London, June 2007

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

ETRF2005 Horizontal Velocities

(from Altamimi. EUREF 2006)

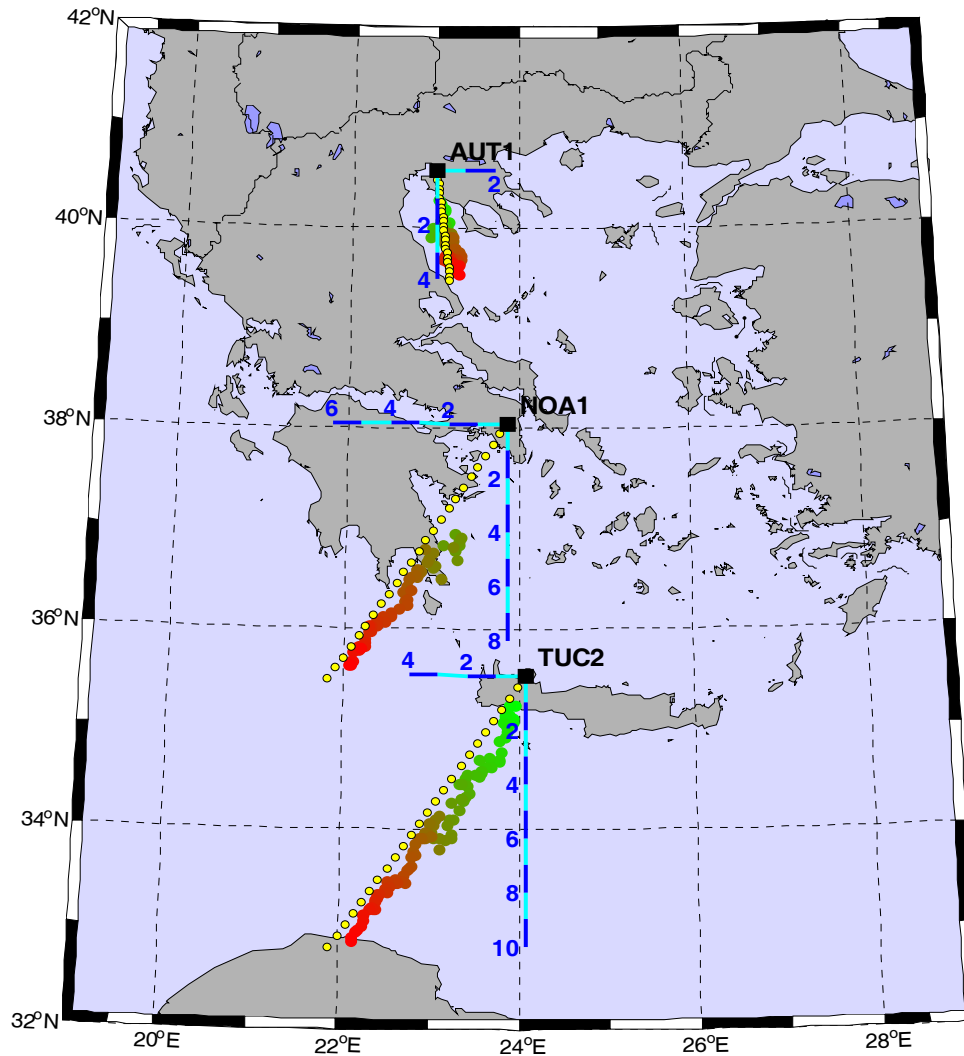


Dionysos 3.1 cm/y 3D

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 $\pm$ 0.003 1896166.775 $\pm$ 0.002 4126096.773 $\pm$ 0.003

ETRF05/2000.0 4466283.737 $\pm$ 0.003 1896166.625 $\pm$ 0.002 4126096.618 $\pm$ 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 $\pm$ 0.012 1896166.624 $\pm$ 0.006 4126096.617 $\pm$ 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 : $\lambda_0 = 24^\circ$ East
- Scale along CM : $k_0 = 0.9996$
- Latitude of origin : $\varphi_0 = 0^\circ$
- False Easting : $X_0 = 500\,000.00$ meters
- False Northing : $Y_0 = -2\,000\,000.00$ meters

For **Kastelorizo** ONLY :

- Central Meridian : $\lambda_0 = 30^\circ$ East
- Scale along CM : $k_0 = 1.0000$
- Latitude of origin : $\varphi_0 = 0^\circ$
- False Easting : $X_0 = 500\,000.00$ μέτρα
- False Northing : $Y_0 = -2\,000\,000.00$ μέτρα

Reference Ellipsoid : **GRS80**

HEPOS 98-stations adjustment

Two weeks (1448 & 1449) of observations

Bernese 4.2

Solution in ITRF2005/2007.79

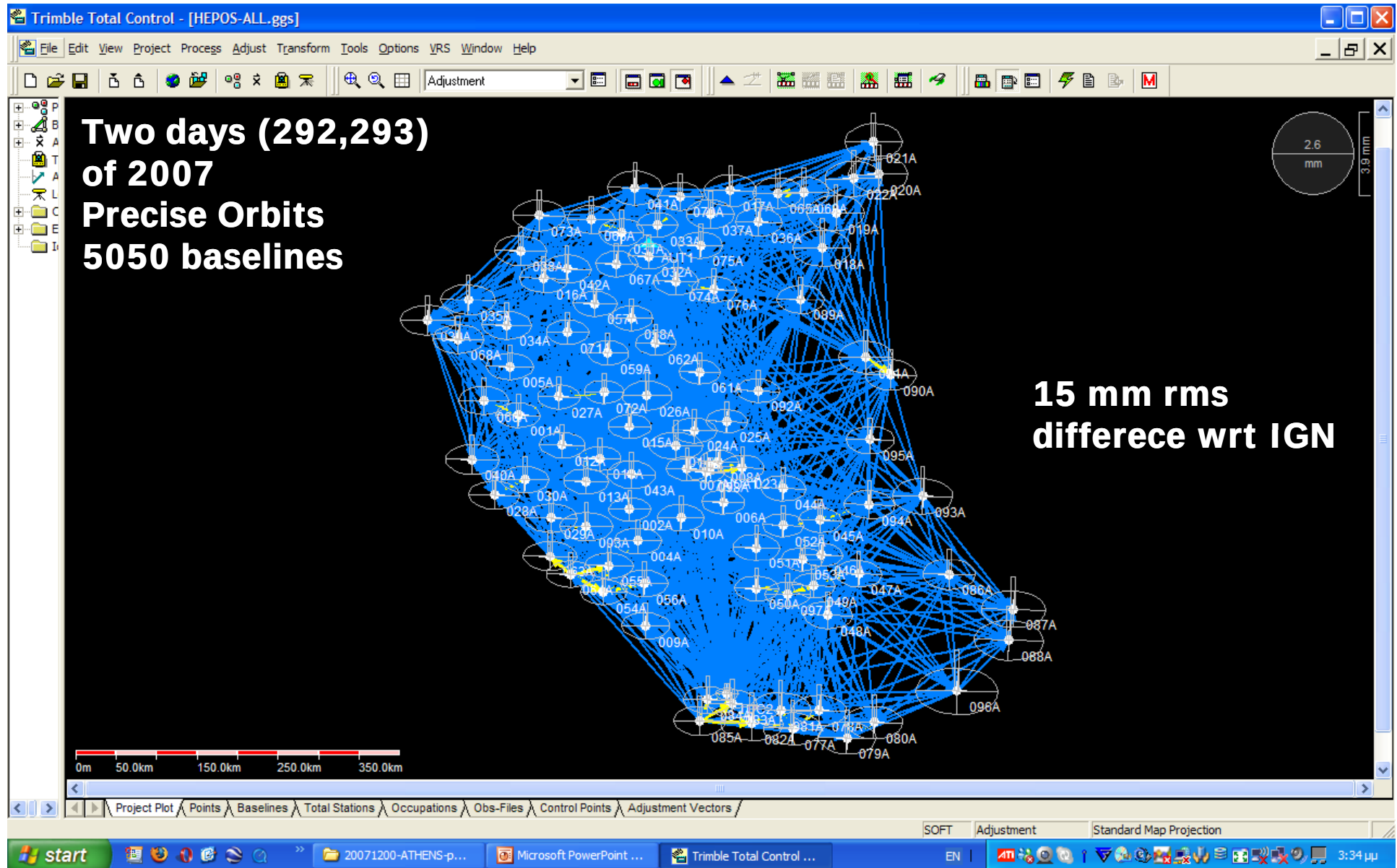
Memo has NOT been used

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** : $\sigma E=2\text{mm}$, $sN=2\text{mm}$, $\sigma H=5\text{mm}$

AUTh adjustment



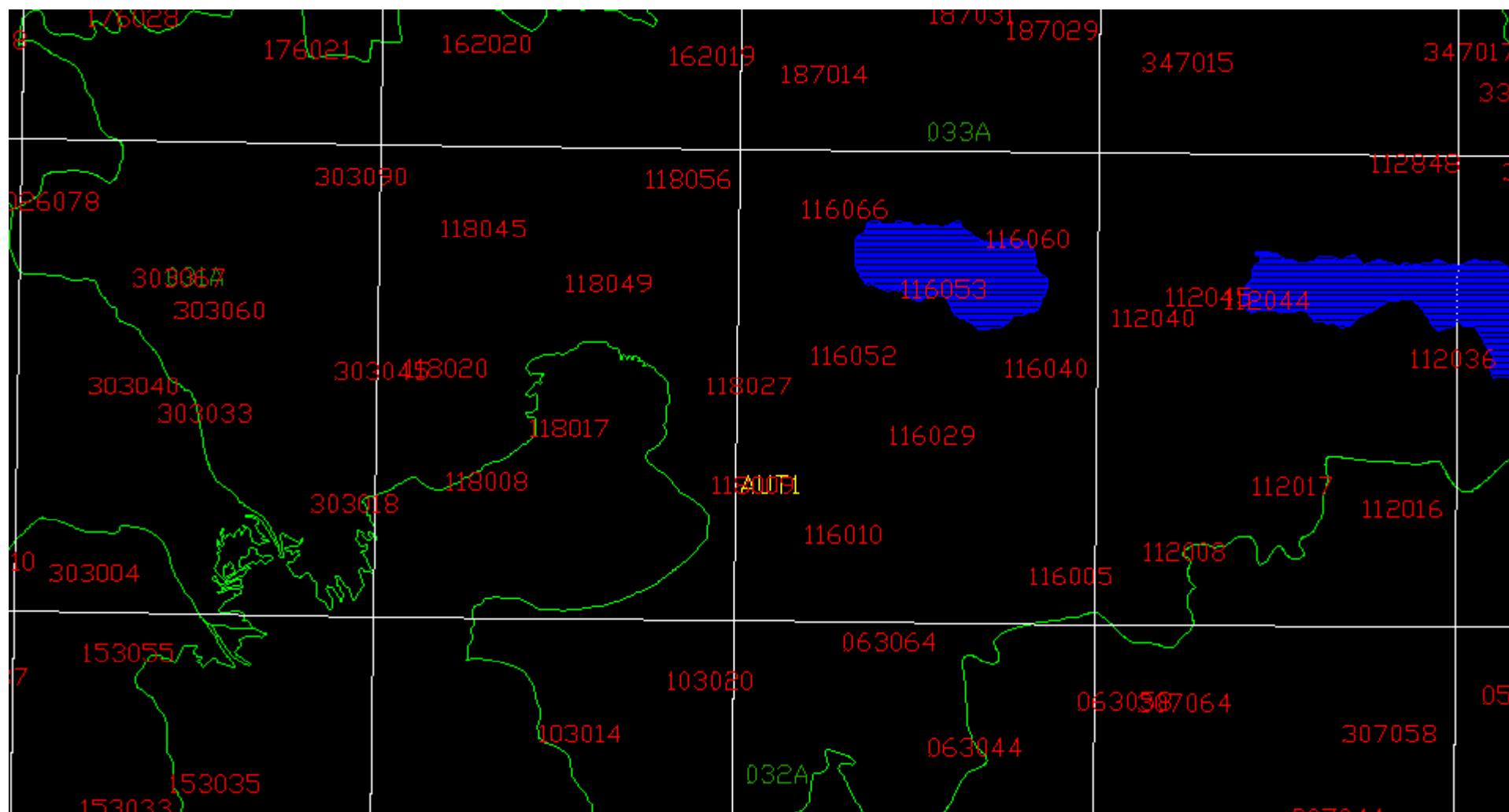
Datum Transformation: HTRS07 ↔ HGRS87

- **HGRS87** is (still) the **official** (non geocentric) reference system for the Hellenic Cadastre.
- **24000** pillars in Greece, maintained by the Hellenic Geographic Military 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



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

ITRFyy > ETRFzz following B/A Memo 2007. Prof. K. Katsampalos, DoGS/AUTH, kvek@topo.auth.gr, Ver.20071015

Initialize

K. Katsampalos / AUTH Prof
kvek@topo.auth.gr

ITRF05 2000.

4466283.488

ITRFyy (tc) 1896166.775

4126096.773

-0.0126

0.0213

0.0028

In accordance with epoch in Table 1

2000.

Compute at t0

4466283.4880

ITRFyy (t0) 1896166.7750

4126096.7730

ITRF05

Transform to ITRF89 at t0 and 89.0

4466283.5456

ITRF89 (t0) 1896166.8272

4126096.7020

4466283.6842

ITRF89 (89.0) 1896166.5929

4126096.6712

using velocities for (89.0 - t0)

ITRFyy(tc) ==> ETRFyy(tc)

Section/3 equation (2) with Tables 3 and 4

<== Velocities from a Model or from EUREF ==>

4466283.7370

ETRFyy (tc) 1896166.6251

4126096.6181

0.0049

0.0033

-0.0079

2000.

1989.0

Compute at t0

Compute at 89.0

4466283.7370

ETRFyy (t0) = ? ETRFyy (t0) ETRFyy (89.0)

4466283.7370

1896166.6251

4126096.6181

4466283.6831

1896166.5888

4126096.7050

ITRF89 (t0) ==> ETRF89 (t0)

ITRF89 (89.0) set = to ETRF89 (89.0) ==>

4466283.7946

ETRF89 (t0) 1896166.6773

4126096.5471

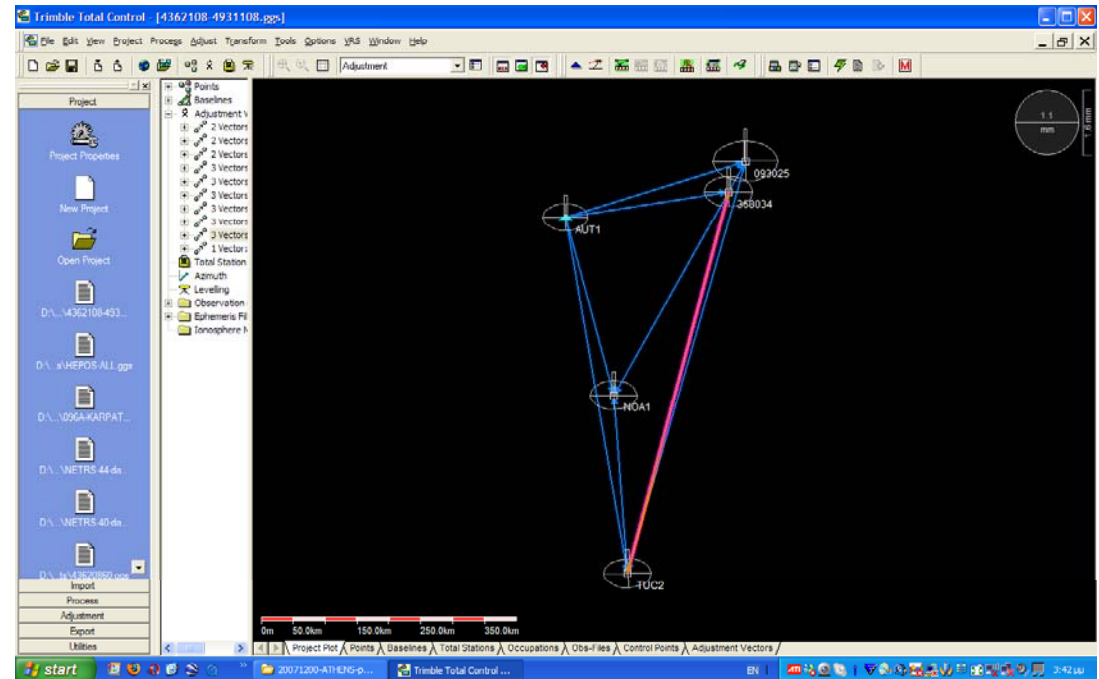
4466283.6842

ETRF89 (89.0) 1896166.5929

4126096.6712

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

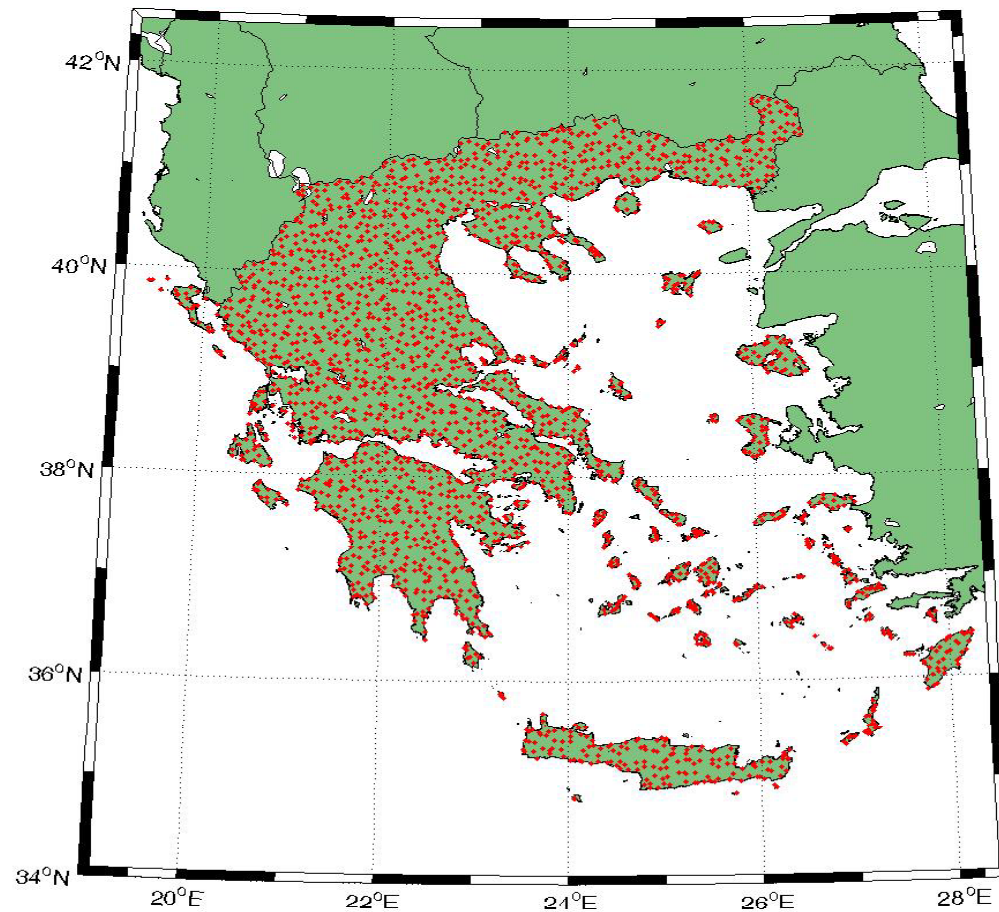


$$X_{YY}^E(t_c) = X_{YY}^I(t_c) + T_{YY} + \begin{pmatrix} 0 & -\dot{R}_{3_{YY}} & \dot{R}_{2_{YY}} \\ \dot{R}_{3_{YY}} & 0 & -\dot{R}_{1_{YY}} \\ -\dot{R}_{2_{YY}} & \dot{R}_{1_{YY}} & 0 \end{pmatrix} \times X_{YY}^I(t_c) \cdot (t_c - 1989.0)$$

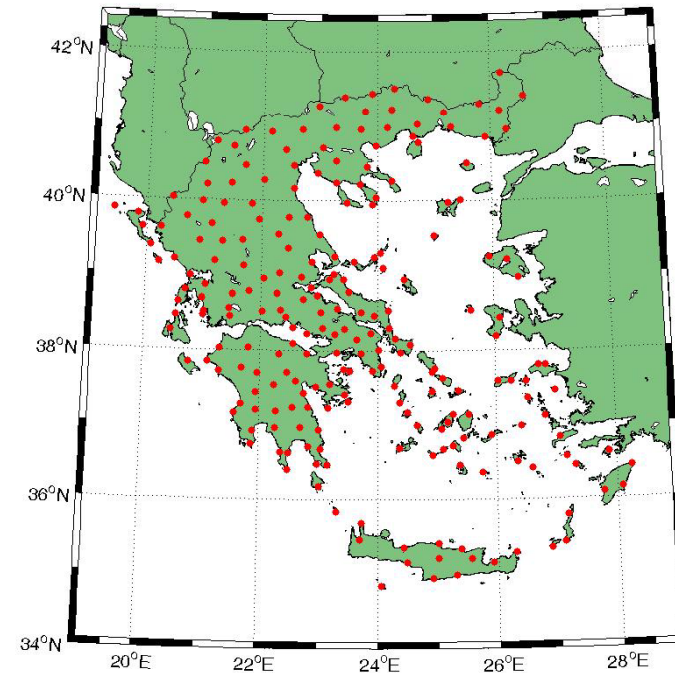
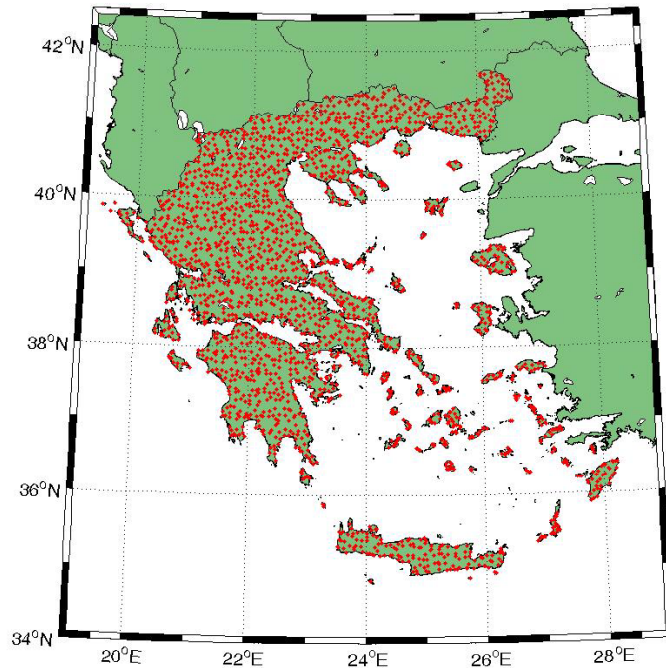
- Translation to
ETRF2005/2007.5 using
offset at AUT1
+0.020, +0.016, +0.004 m

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

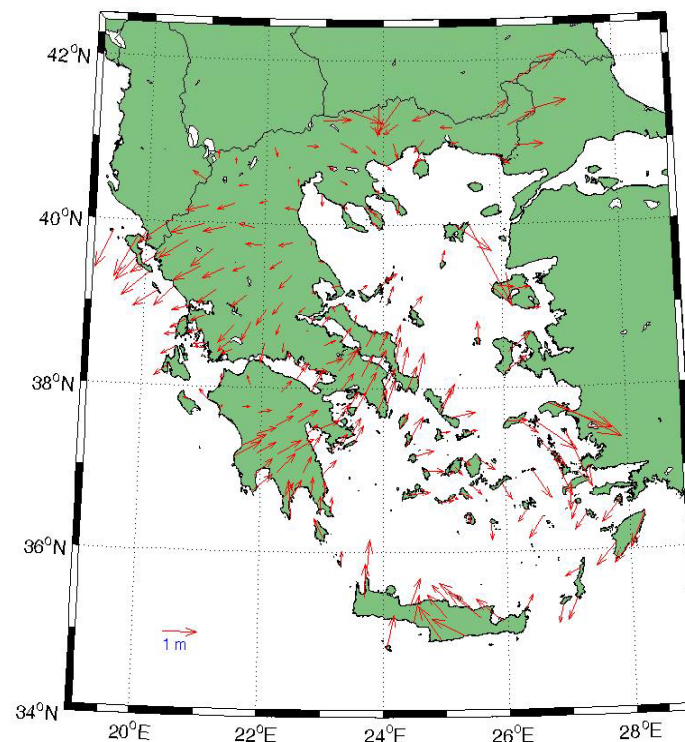
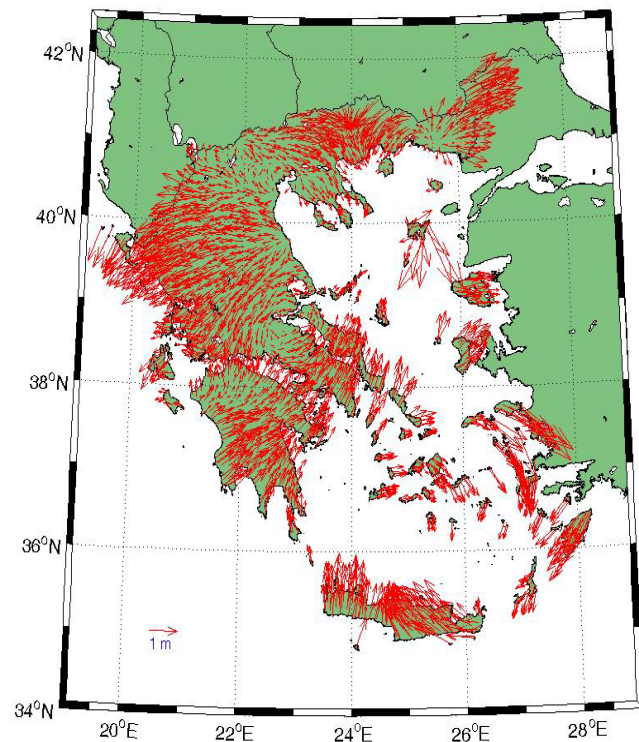
Helmert-type 3D similarity transformation model (7 parameters)

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

Estimated Parameters (HTRS07 to HGRS87)

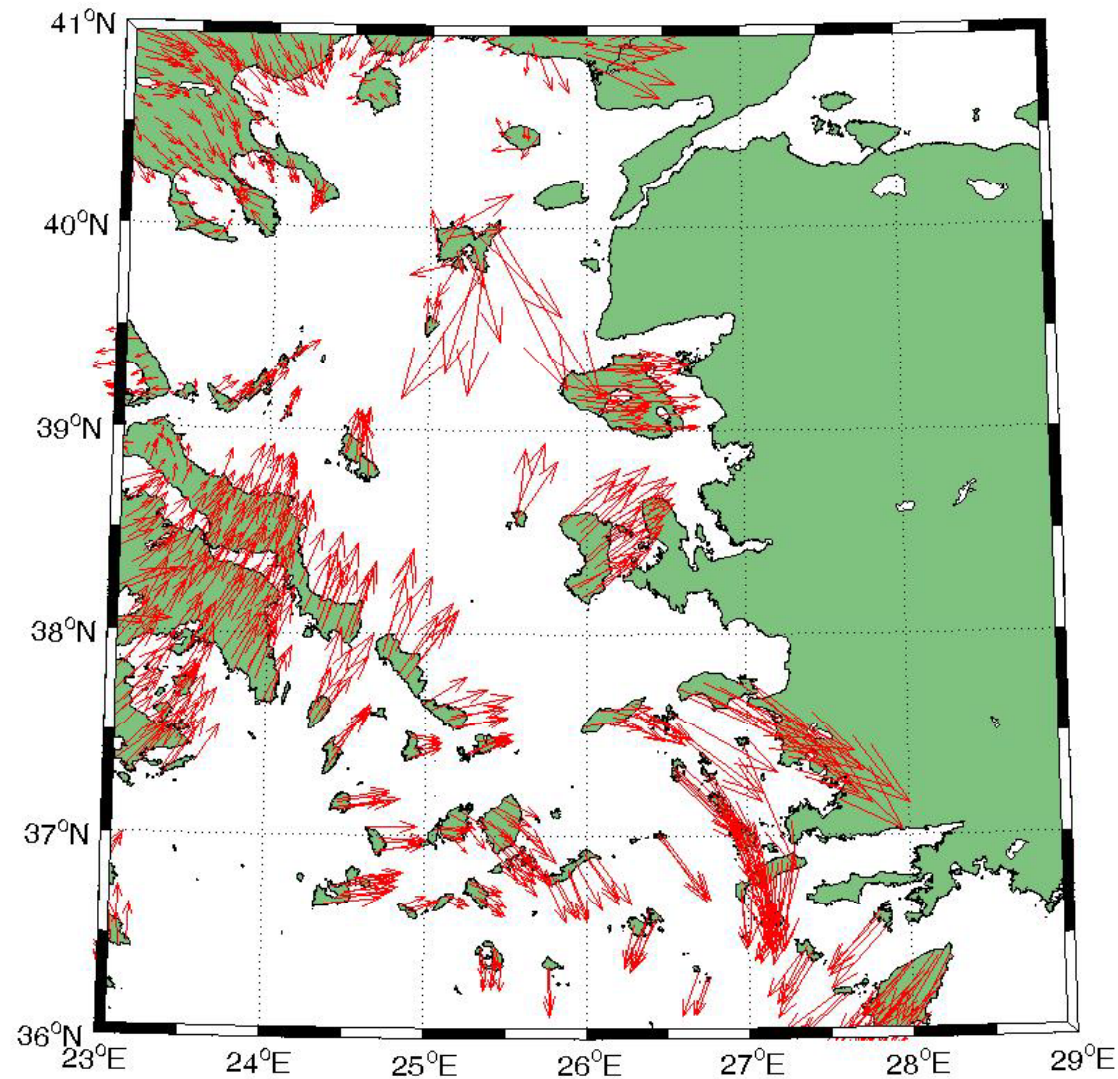
parameter	value	σ
tx	203.437 m	± 0.265 m
ty	-73.461 m	± 0.285 m
tz	-243.594 m	± 0.244 m
ϵ_X	-0".170	$\pm 0".007$
ϵ_Y	-0".060	$\pm 0".009$
ϵ_Z	-0".151	$\pm 0".009$
scale	-0.294 ppm	± 0.031 ppm

Horizontal residuals at transformation & validation points

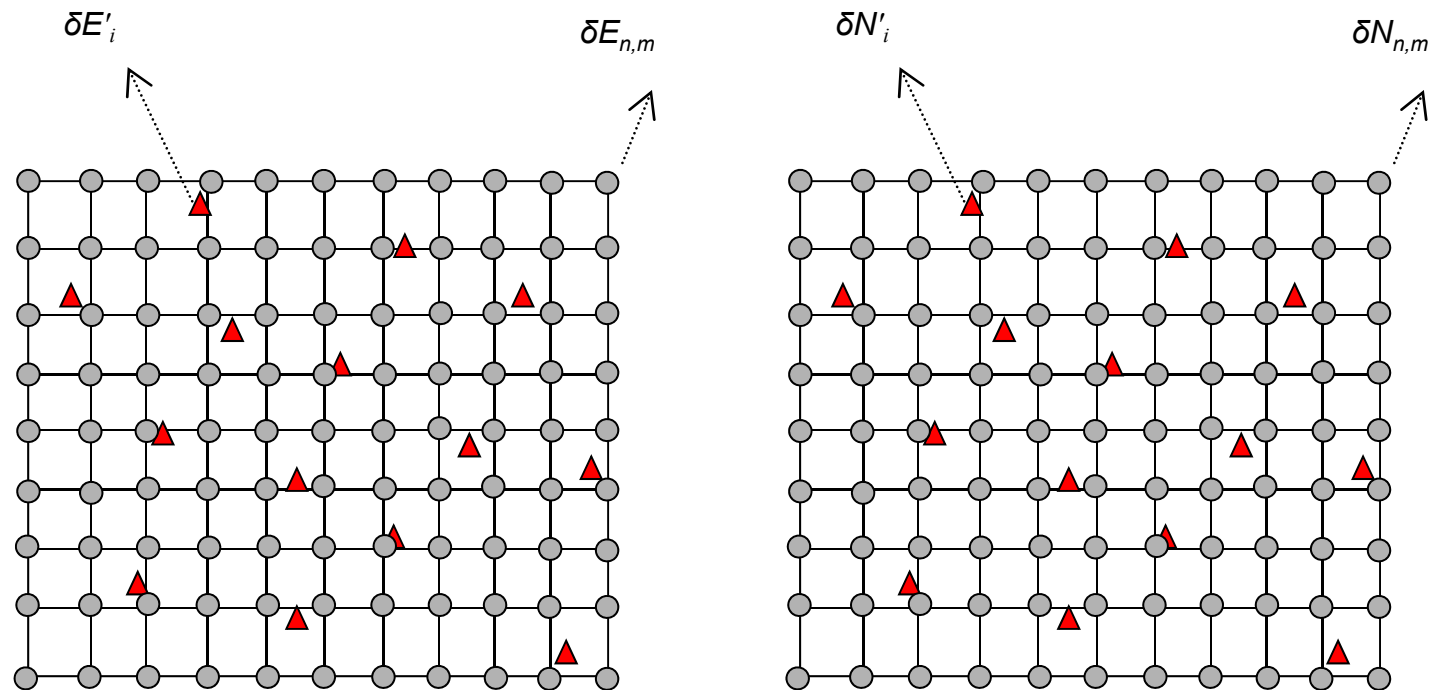


points	max	min	mean	σ	rms
2199	2.342	0.010	0.550	0.301	0.627
231	2.585	0.019	0.584	0.350	0.680

Regional horizontal residuals



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

Μετασχηματισμός GTRS07 <> ΕΓΣΑ87 / Εισαγωγή συντεταγμένων με πληκτρολόγηση / ver. 1.0

Έκδοση βασισμένη σε 7-παραμετρικό μοντέλο μετασχηματισμού Helmert
Σημ.: Όχι για την περιοχή του Καστελλόριζου

ΒΟΗΘΕΙΑ

ΑΡΧΙΚΟ ΒΗΜΑ : Εισαγωγή καννάβων και παραμέτρων >

tx 203.437 ex -170
ty -73.461 ey -060
tz -243.594 ez -151
ds -0.00000294

Μετασχηματισμός ΑΠΟ GTRS07 (HEPOS ETRF2005/2007.5) ΣΕ ΕΓΣΑ87 (φ,λ,η και Ε,Ν)

ΔΩΣΕ: X,Y,Z στο GTRS07 (HEPOS) ETRF2005/2007.5 [μέτρα]

4382064.771
2023782.319
4155326.131

Μετατροπή και Μετασχ/σμός >

GTRS07 φ,λ,η και Ε,Ν, scale

40 54 53.90607
24 47 20.59229
51.610
566446.108
2529618.096
0.999654

Διορθώσεις καννάβου [cm]

-012.2
-018.4

GGRS87 φ,λ,η και Ε,Ν

40 54 44.68247
24 47 14.08874
6.501
566296.538
4529332.307

Μετασχηματισμός ΑΠΟ ΕΓΣΑ87 (Ε,Ν,η) ή (φ,λ,η) ΣΕ GTRS07 (HEPOS Ε,Ν και φ,λ,η)

ΔΩΣΕ : (Ε,Ν,η) στο ΕΓΣΑ87, [ή (φ,λ,η) έχοντας όμως κενά τα πεδία Ε,Ν]

GGRS87 Ε,Ν,η [m]

566296.538 6.501
4529332.307

GGRS87 φ,λ [DDMMSS.SSSSS]

405444.68248 6.501
244714.08876

Μετατροπή και Μετασχ/σμός >

Διορθώσεις καννάβου [cm]

012.2
018.4

GTRS07 φ,λ,η και Ε,Ν

40 54 53.90608
24 47 20.59229
00051.610 566446.108
2529618.096

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

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