

Update on DSO's contribution to EUREF Densification and new activities

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ICGC
Institut
Cartogràfic i Geològic
de Catalunya

Presentation Structure

- GNSS Networks in Greece
- Processing
- Results & Outputs
- Discussion / Conclusions

DSO last year

Dionysos Satellite Observatory (DSO) of the National Technical University of Athens (NTUA), has developed and maintains an automated processing scheme to accommodate the routine analysis of all available continuous GNSS stations in Greece.

This daily analysis process is implemented for over ten years now (not always continuous though due to various problems), yielding results which help us further understand the complicated tectonic setting of Greece and nearby regions.

Updates:

- archive old data (from 1995) for reprocessing,
- new network processing (HEPOS)
- develop PPP-AR PRIDE near real time processing for high rate available data
- start updating for Strain Tool

Motivation

Routine GNSS processing and site/network monitoring is crucial, because:

- Greece lies in a region of utmost tectonic and volcanic unrest (e.g. active volcano in Santorini isl.),
- results & products are important to a series of fields spanning the whole range of Geosciences,
- helps us follow and apply state-of-the-art technologies in GNSS analysis & Satellite Geodesy and expand & modernize our research activity,
- contribute to the GNSS/EUREF community and be involved in ongoing/future projects,
- develop new features for high rate processing.
- improve our academic services (NTUA is a University)

Throughout the last years, routine processing & monitoring has helped us gain a more thorough view of the complex tectonic and volcanic setting of Greece.

The Data Set

Routine processing for precise positioning, assumes a well established, credible dataset (metadata). This has proven to be rather challenging! Lately, the introduction of M3G has provided assistance.

Currently we process whatever we can get our hands on ...

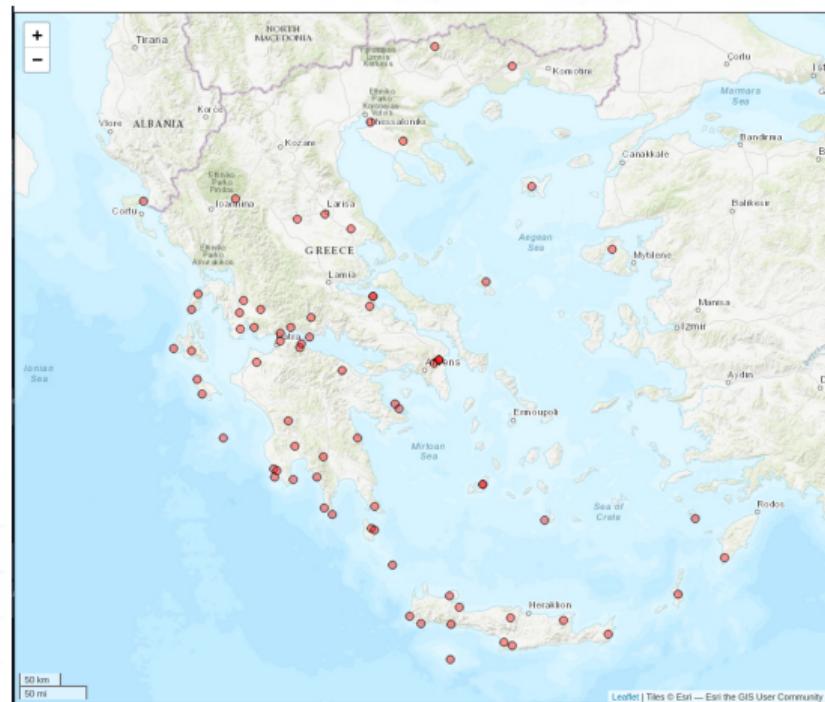
Problems:

- Inhomogenous dataset (**RINEX** of various versions, raw files, etc).
- Various maintainers, different mentalities.
- Different acquisition methods/rates.
- No log files for maintainers with no geodetic interest (e.g. surveying companies).
- Wide variety of equipment (not always included in **atx** files).

Network GREECE

Network **Greece** includes the majority of the available sites (≈ 100) but not all of them are (always/currently) active. Various providers but all with geodetic interest & equipment.

- covers all of Greece
 - different (geodetic type) equipment
 - credible time-span (early 2004 - now)
 - all free available GNSS data
 - large data gaps & inactive stations

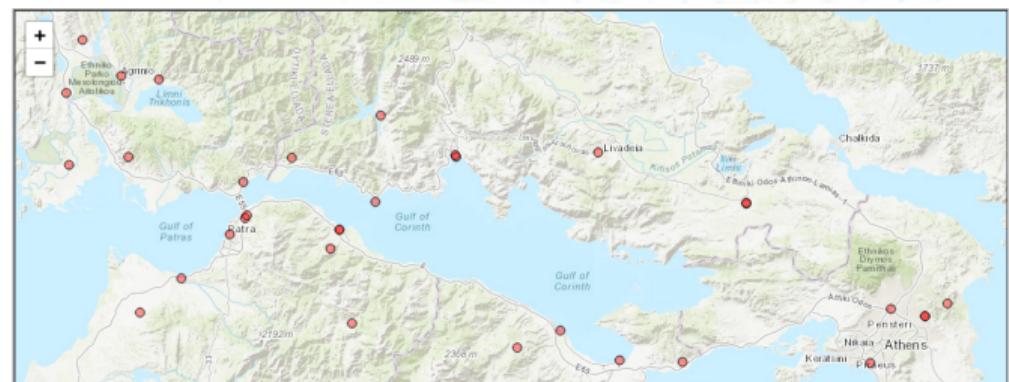


-» Network GREECE

Local Networks

The **Corinth Rift** network is centered around the Corinth Gulf, a region of special tectonic interest. Larger site density compared to the rest of Greece.

- credible time-span
- only covers the Corinth Rift
- different providers (including surveying & cadastral services)
- no log files & equipment changes



-» Network EnCeladus

Network HEPOS (new processing)

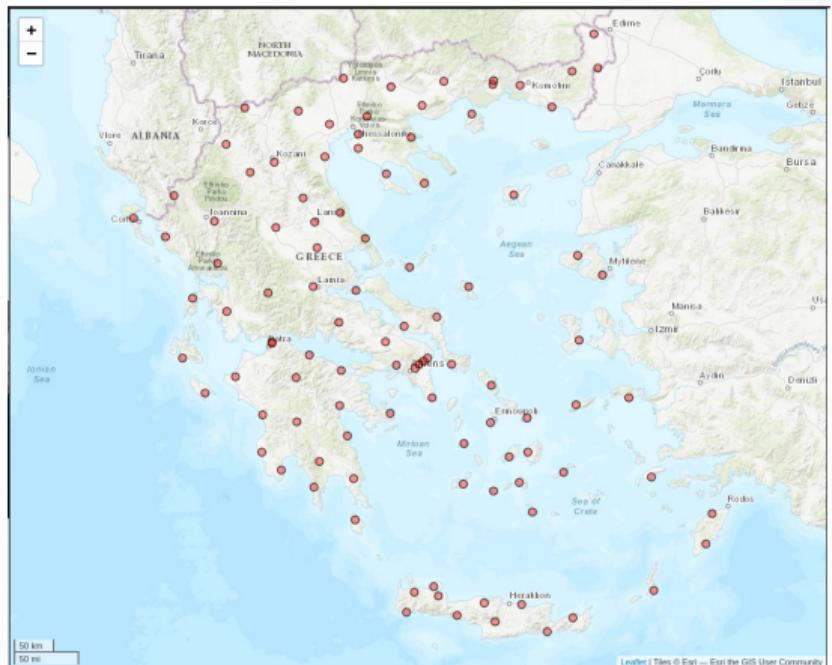
Network HEPOS

- covers all of Greece
- homogeneous equipment
- credible time-span (mid 2007 - now)
-
- only four years available for processing up to now

*Data availability and
funding from
Hellenic Cadastre*



HELLENIC CADASTRE



-» Network HEPOS

The Scheme

The core tool/software is **Bernese GNSS Software v5.2**(Dach et al., 2007).

Integration with

- **MySQL database,**
- **Python module** (product/data downloading, pre-processing, driving cron jobs, etc)
<https://github.com/DS0lab/autobern>
- **Time-series** analysis (integrated in routine processing on regular intervals)
- **Strain Rates** via StrainTool (on user demand)



Upgrade planning - switch to IGS20

⇒ New release Bernese GNSS Software **v5.4**

New values on processing options:

- Reference frame **IGS20**
- Oceans loading corrections (**FES2014**)
- **VMF3** for tropospheric modeling
- ATX file: **igs20.atx**
- Long filename of products according to new IGS convention

⇒ ⇒ Reprocess all available data from late '90s up to now

Results & Output

4. Solution Identifiers

Array of Objects

[expand](#)

5. PCF Variables

Array of Objects

[expand](#)

6. Saved products

Array of Objects

[expand](#)

7. Warnings

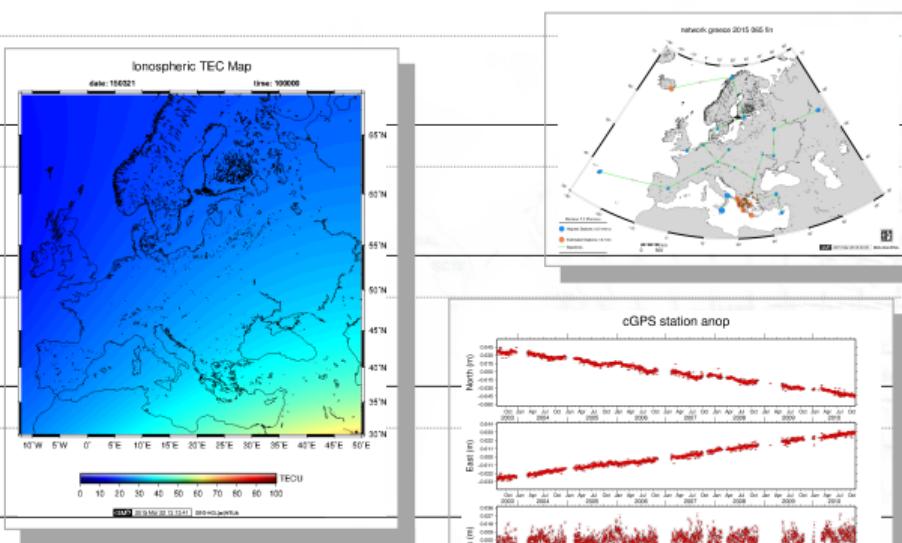
Array of Objects

[expand](#)

8. Ambiguity Resolution Summary

Array of Objects

Baseline	sta1	sta2	length (km)	Method	N. of Amb.	Percentage	Satellite system
AUKL	AUT1	KLOK	139.7	pbnl	74	54.1	GPS
AULE	AUT1	LEMN	199.6	pbnl	60	55	GPS
KCTL	KATC	TILO	59	pbnl	50	90	GPS
KLRL	KLOK	RLSO	174.2	pbnl	74	41.9	GPS

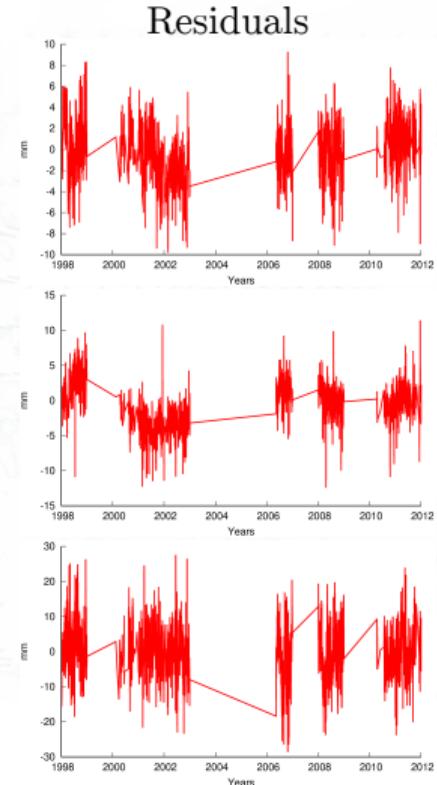
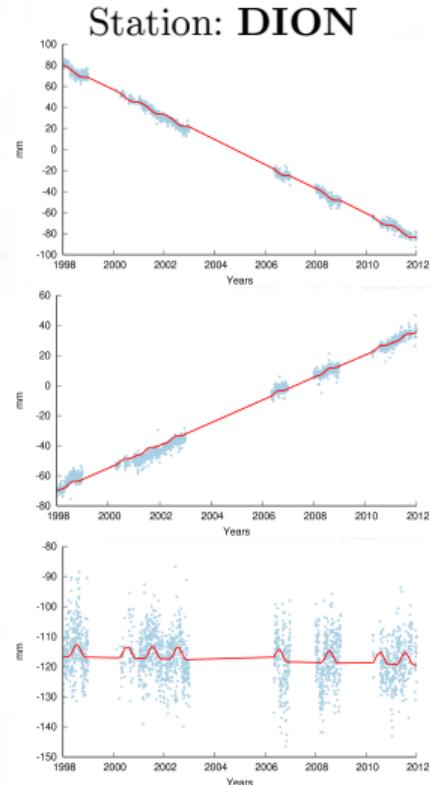


Coordinate estimates - Time series analysis

We analyze time-series using Hector Package

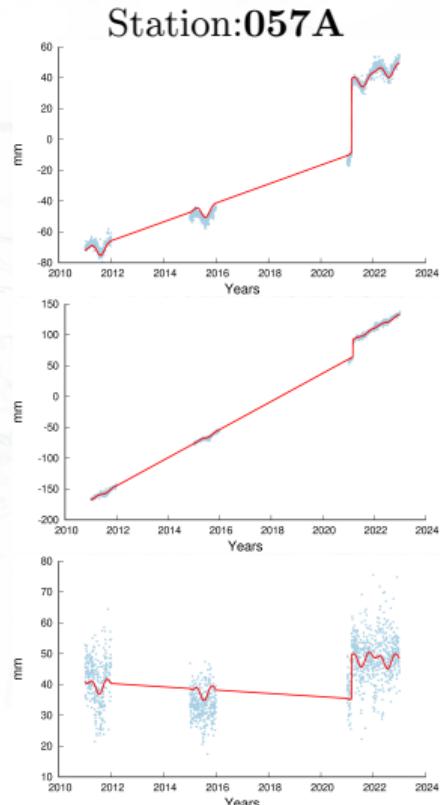
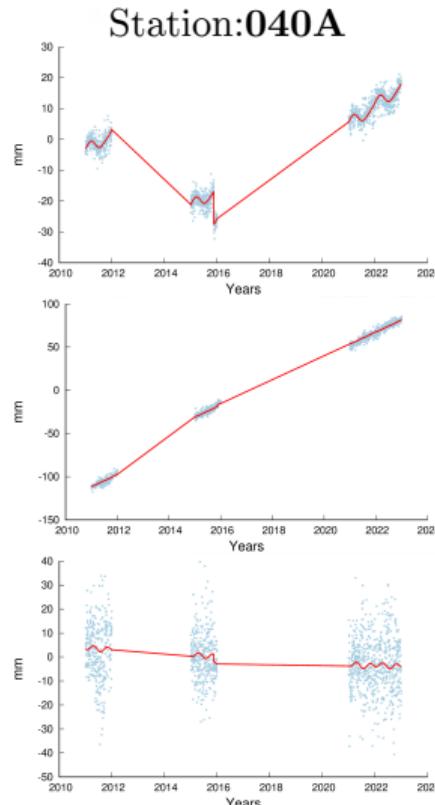
(Bos et al., 2012), to estimate:

- tectonic velocities (linear trends),
- offsets/jumps due to miscellaneous reasons (e.g. instrumentation changes, earthquakes, etc); note that this step requires a-priori knowledge of such events (log-files, NOA earthquake catalogue)
- harmonics signals,
- velocity changes (e.g. inflation of Santorini isl.),
- post-seismic decay (still under development)



Earthquakes, co-seismic offsets

date	Δn	Δe	Δu
	(mm)		
Station: 040A			
26.01.2014	-43.1	25.2	2.2
17.11.2015	-10.8	1.7	3.1
Station: 057A			
03.03.2021	47.9	27.6	14.0



$$\sum_{i=0}^{n_F} s_i \sin(\omega_i t) + c_i \cos(\omega_i t)$$

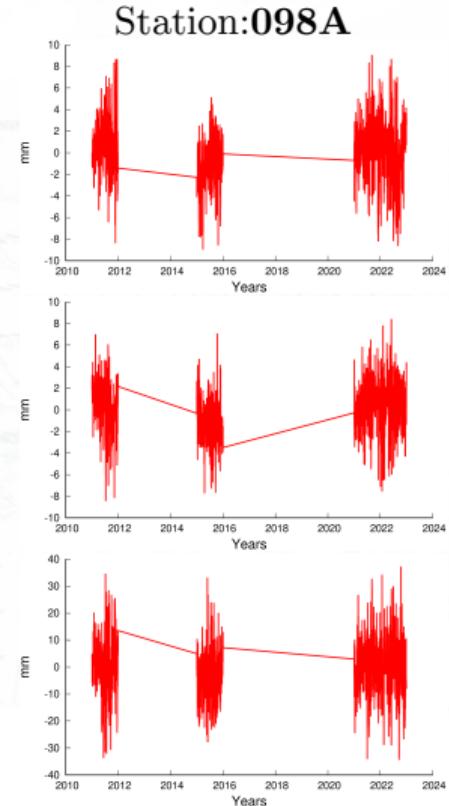
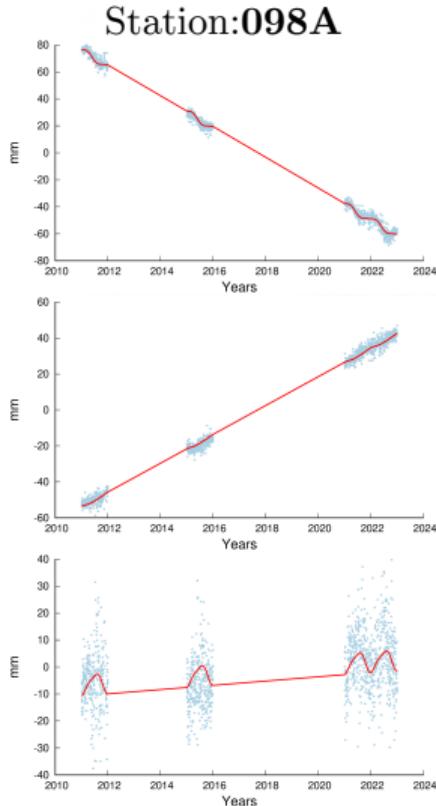
Results:

trend: $-11.398 \pm 0.086 \text{ mm/year}$

cos yearly : $1.428 \pm 0.255 \text{ mm}$
 sin yearly : $1.804 \pm 0.280 \text{ mm}$
 Amp yearly : $2.316 \pm 0.266 \text{ mm}$
 Pha yearly : 51.629 degrees

cos hyearly : $-0.418 \pm 0.206 \text{ mm}$
 sin hyearly : $-0.128 \pm 0.217 \text{ mm}$
 Amp hyearly : $0.493 \pm 0.195 \text{ mm}$
 Pha hyearly : -162.958 degrees

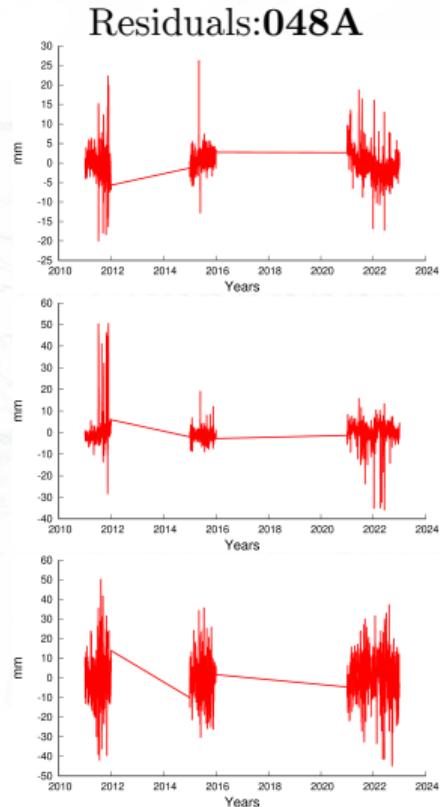
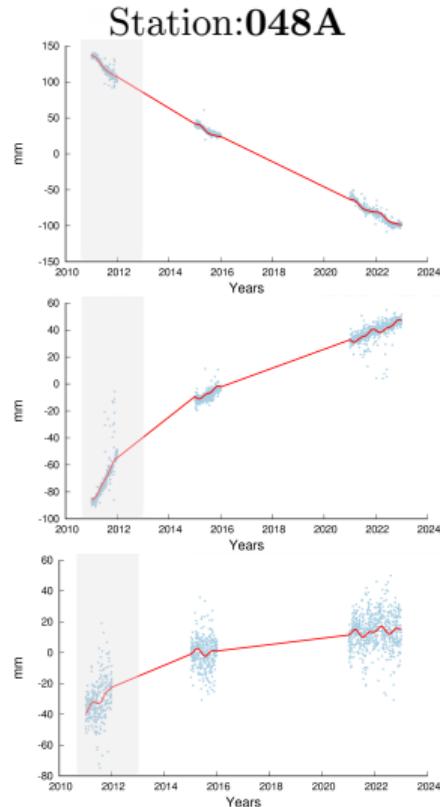
Harmonic signals



Specific case - Santorini

Estimate velocity changes in Santorini station:

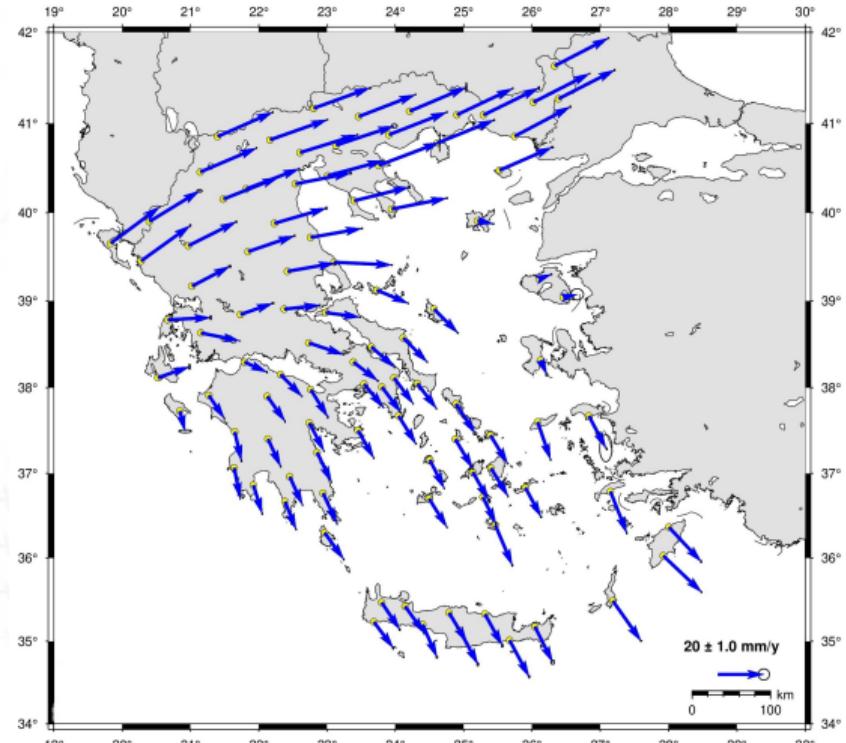
comp	< ~2013	> ~ 2013
	(mm/yr)	
north	-30.1	-17.5
east	31.3	7.0
up	17.2	2.1



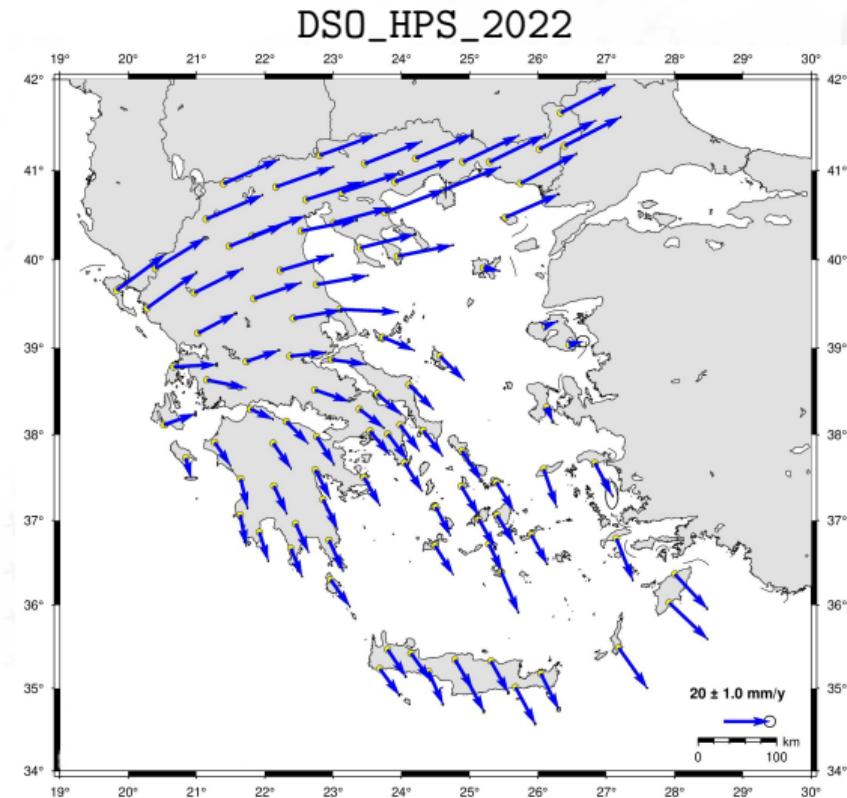
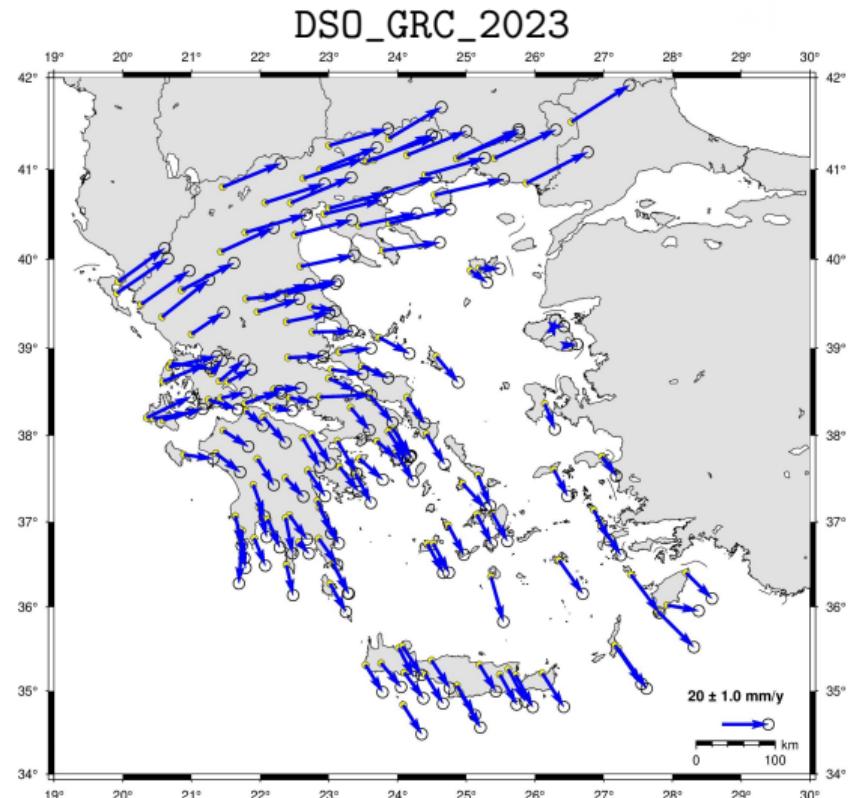
Velocity Field of HEPOS Network

Estimated velocities vary:

comp	min	max
	(mm/yr)	
north	-17.9	15.5
east	2.4	26.0
up	-5.5	4.7

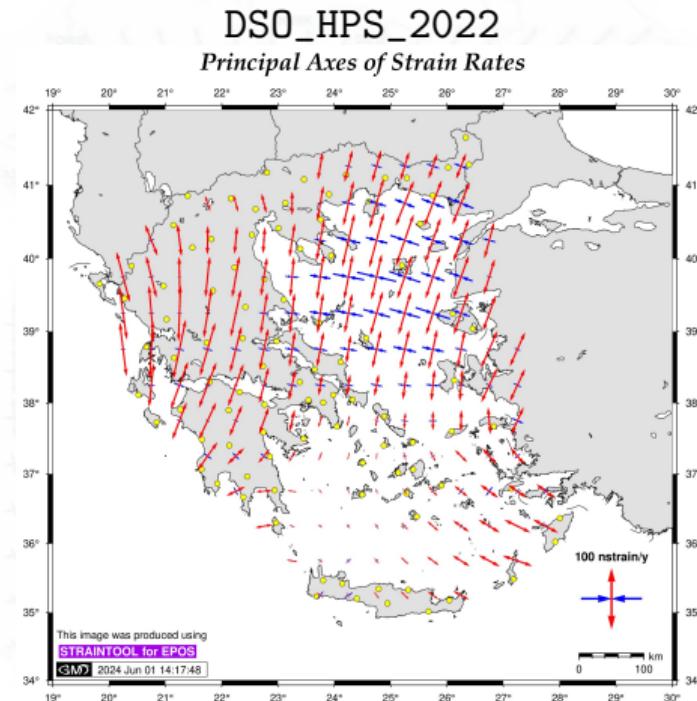
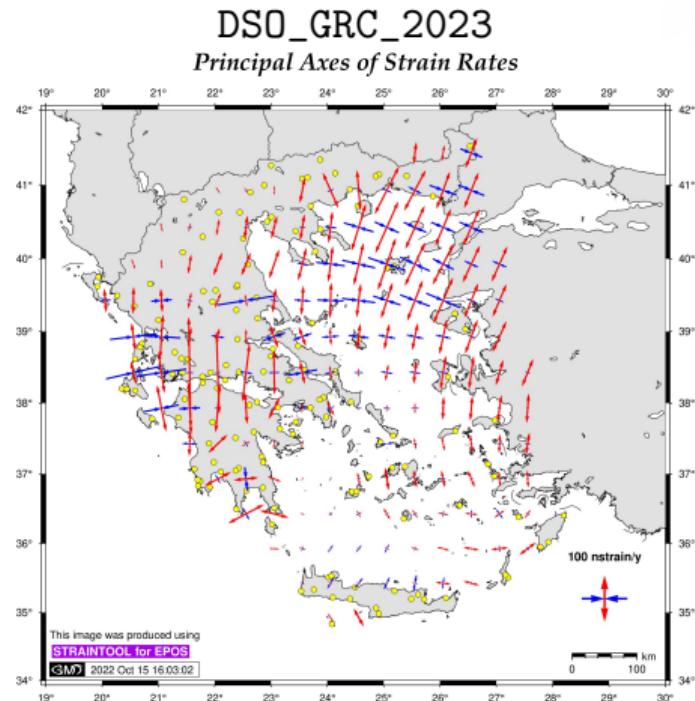


Compare velocity field of different networks



Strain rates

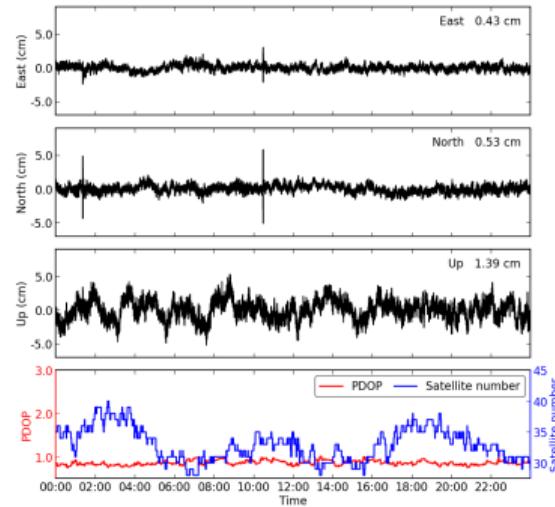
StrainTool software used to estimate strain tensor parameters ([Anastasiou et al., 2021](#))



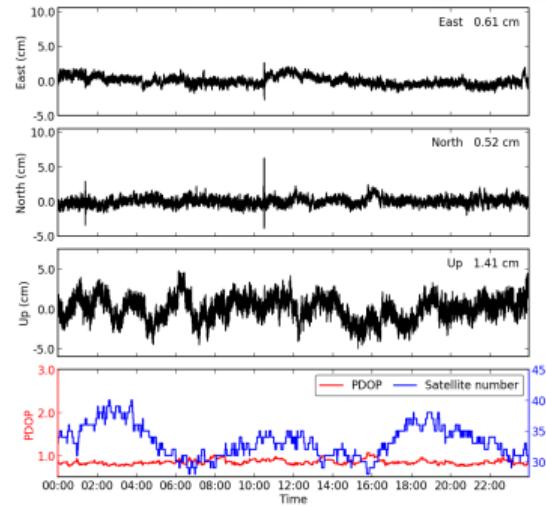
PPP processing for High-rate data

effect from Turkey earthquake (06.02.2023)

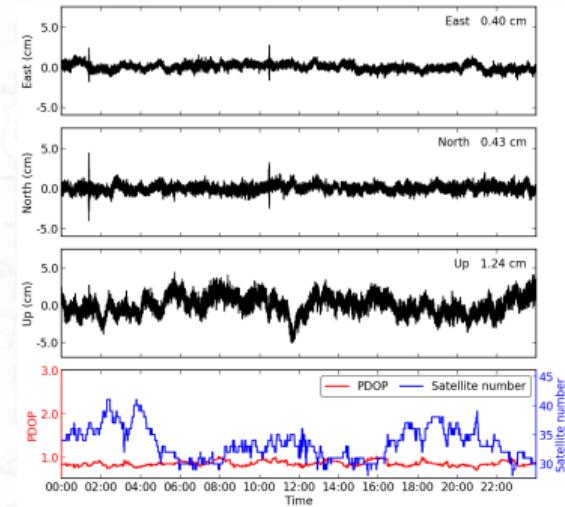
RODO_2023_037



SANT_2023_037

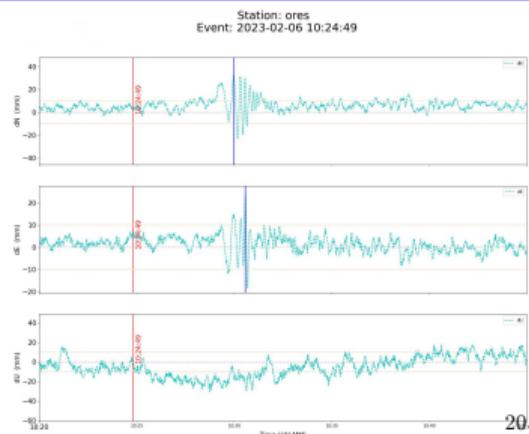
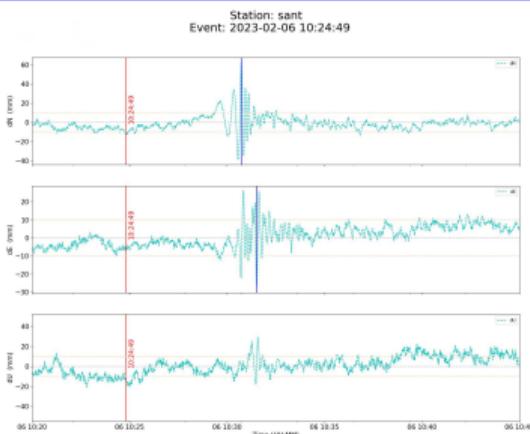
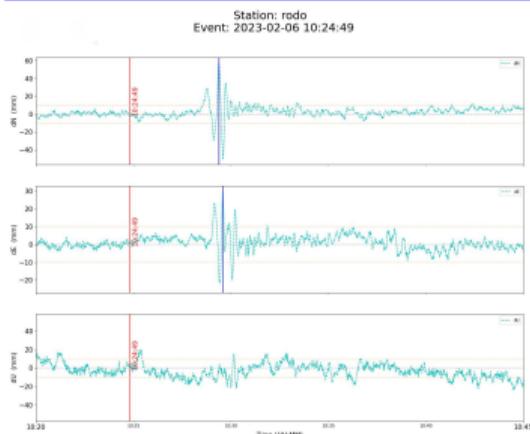
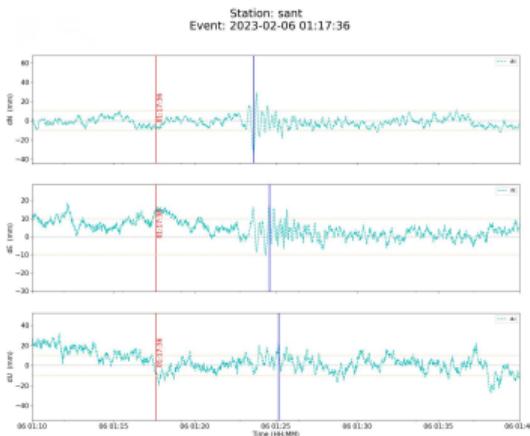


ORES_2023_037



- 1Hz data available, ~50 stations from Metrica SmartNET.
-

Focus on stations



Discussion / Conclusions « είναι το περσινό!

- Greece is located in a complex tectonic background with many changes in the kinematics of the area.
- Routine processing and monitoring are very important and revealing for Greece; products are requested by and disseminated to a wide range of Geoscientists.
- Greece's crustal dynamics are evidently complex and inhomogenous; a difficult task to model by Reference Systems (especially non-dynamic, such as the ones currently in use).
- A dense velocity field for accurate estimation of ground/tectonic motions in the region will help to develop a stable local reference frame and the connection of the region with the global and European reference systems.
- The continuous monitoring of the networks gives useful results for the effect of strong earthquakes or other “abrupt” phenomena; small, dense networks are of great help (even with instrumentation of non-geodetic accuracy).
- Our plan: grow up our team and be more involved to the GNSS/EUREF community.

Thank you for your attention! 

References I



Anastasiou, D., X. Papanikolaou, A. Ganas, and Paradissis .D (2021). "StrainTool: A software package to estimate strain tensor parameters (v1.0-r1)". In: *Zenodo*. DOI: [10.5281/zenodo.1297565](https://doi.org/10.5281/zenodo.1297565). URL: <https://doi.org/10.5281/zenodo.1297565> (cit. on p. 18).



Bos, M. S., R. M. S. Fernandes, S. D. P. Williams, and L. Bastos (Dec. 2012). "Fast error analysis of continuous GNSS observations with missing data". In: *Journal of Geodesy* 87.4, pp. 351–360. DOI: [10.1007/s00190-012-0605-0](https://doi.org/10.1007/s00190-012-0605-0) (cit. on p. 12).



Dach, R., U. Hugentobler, P. Fridez, and M. Meindl (2007). *Bernese GPS Software Version 5.0*. Astronomical Institute, University of Bern (cit. on p. 9).