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


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euref IUGG IAG AIG International Association of Geodesy 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 dues 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 hepled 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).

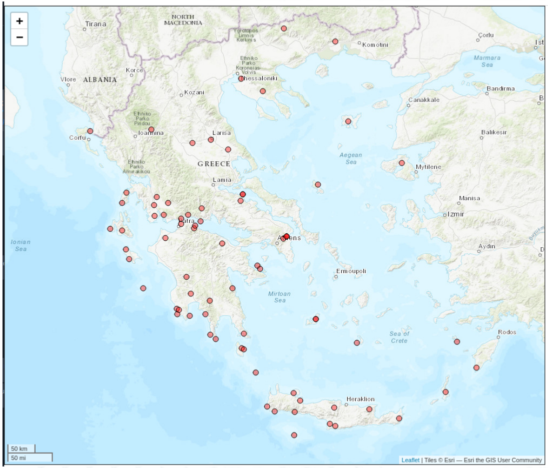
Currently we process whatever we can get our hands on ...
Problems:

- Inhomogenous dataset (`RINEX` of various versions, raw files, etc).
- Various maintainers, different mentalities.
- Different aquisition methods/rates.
- No log files for mainteners 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

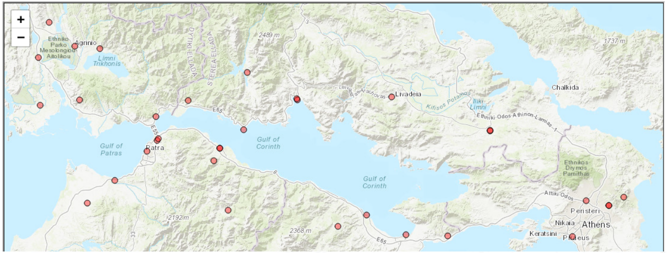



-» Network GREECE

# Local Networks

The **Corinth Rift** network is centered around the Cortinth 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

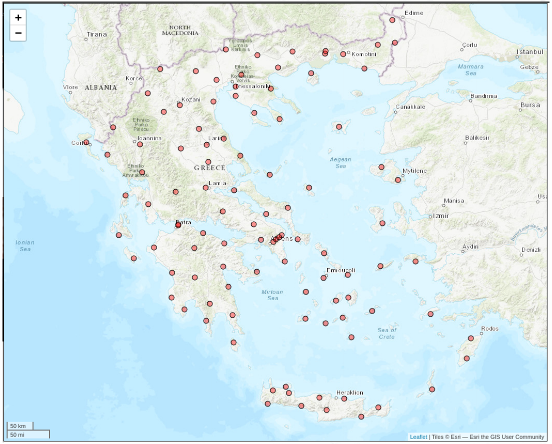
# Network HEPOS (new processing)

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**

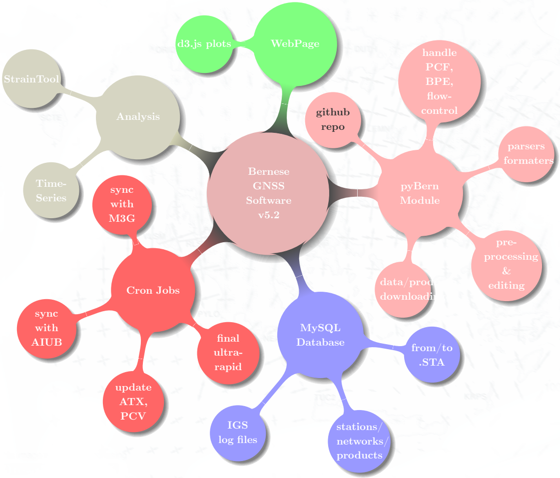



-» Network HEPOS

# 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/DSOlab/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 Indetifiers

**Array of Objects**

expand

### 5. PCF Variables

**Array of Objects**

expand

### 6. Saved products

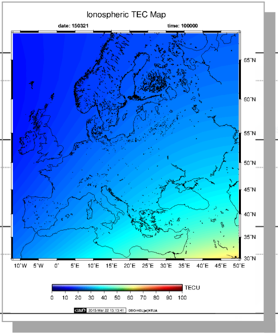
**Array of Objects**

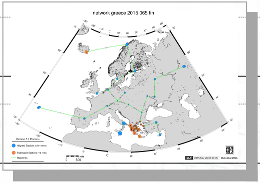
expand

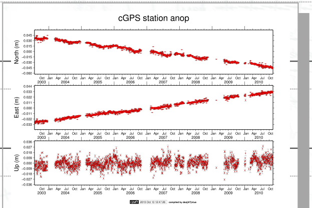
### 7. Warnings

**Array of Objects**

expand




### 8. Ambiguity Resolution SUmmary

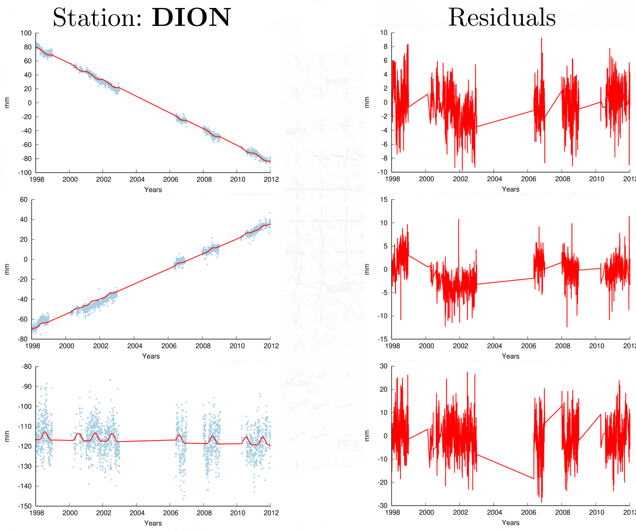
**Array of Objects**

| Baseline | sta1 | sta2 | length (km) | Method | N. of Amb. | Percentance | 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

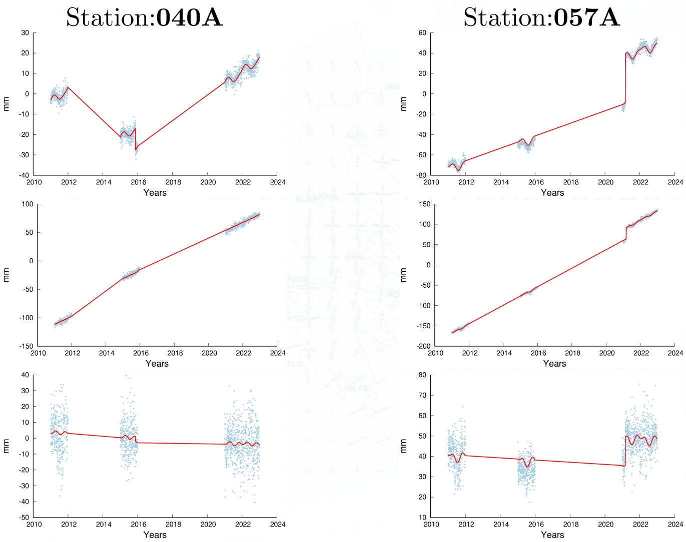
We analyze time-series using Hector Package (Bos et al., 2012), to estimate:

- 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 (mm) | Δu |
|---|---|---|---|
| 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 |

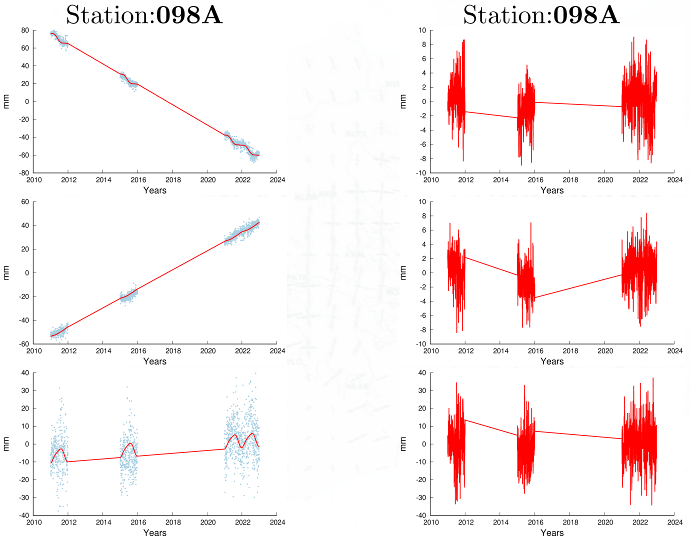


# Harmonic signals

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

Results:

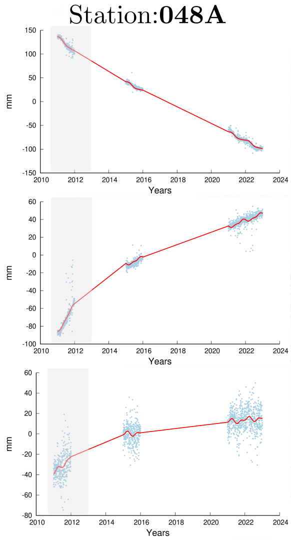
```
--------------------------------
trend: -11.398 +/- 0.086 mm/year
--------------------------------
cos yearly : 1.428 +/- 0.255 mm
sin yearly : 1.804 +/- 0.280 mm
Amp yearly : 2.316 +/- 0.266 mm
Pha yearly : 51.629 degrees
--------------------------------
cos hyearly : -0.418 +/- 0.206 mm
sin hyearly : -0.128 +/- 0.217 mm
Amp hyearly : 0.493 +/- 0.195 mm
Pha hyearly : -162.958 degrees
-----------------------------
```

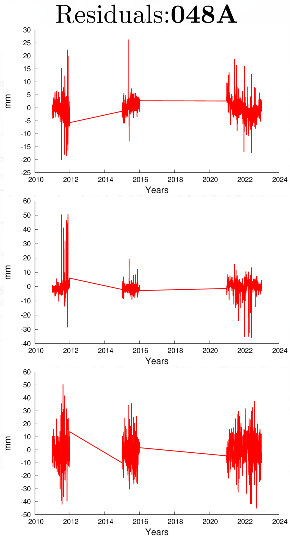


# Specific case - Santorini

Estimate velocity changes in Santorini station:

| comp | $< \sim$2013 | $> \sim$ 2013 |
|---|---|---|
| | (mm/yr) | |
| north | -30.1 | -17.5 |
| east | 31.3 | 7.0 |
| up | 17.2 | 2.1 |

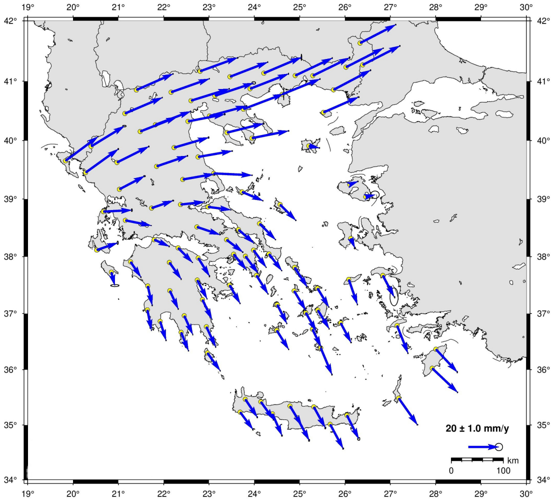


# Velocity Field of HEPOS Network

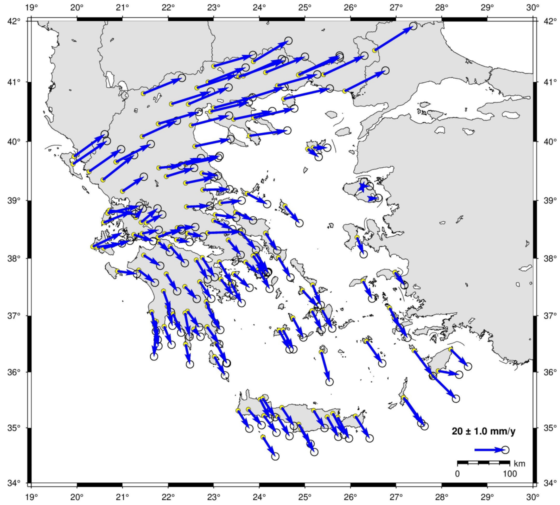
Estimated velocities (IGb14) vary:

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

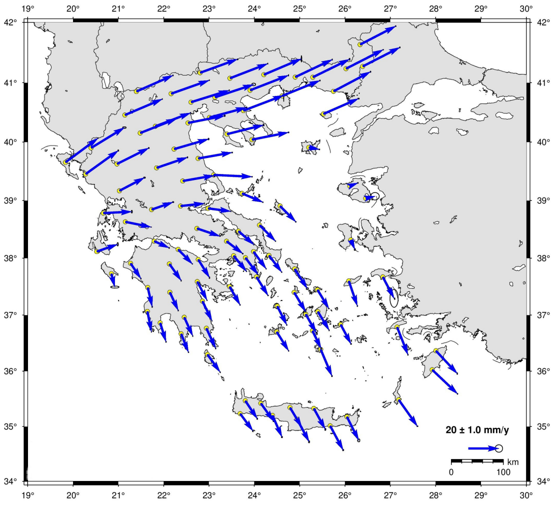


# Compare velocity field of different networks

DSO_GRC_2023




DSO_HPS_2022

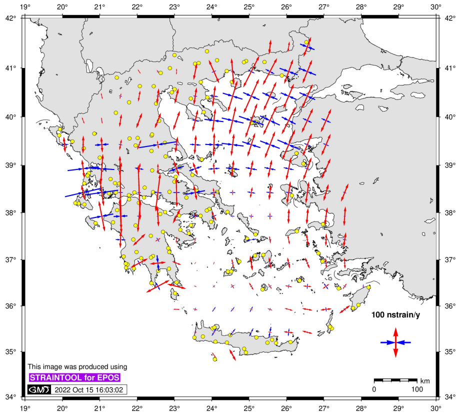


# Strain rates

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

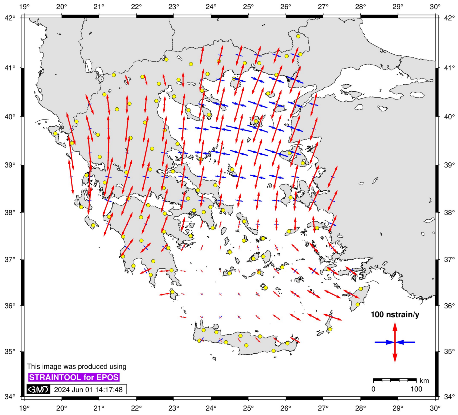
## DSO_GRC_2023

*Principal Axes of Strain Rates*



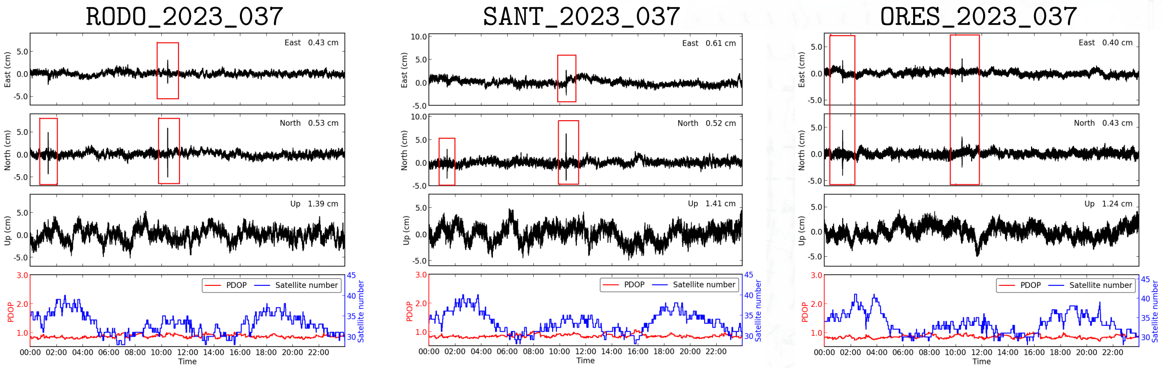

## DSO_HPS_2022

*Principal Axes of Strain Rates*



# PPP processing for High-rate data

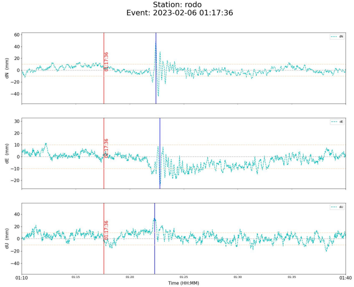
## effect from Turkey earthquake (06.02.2023)

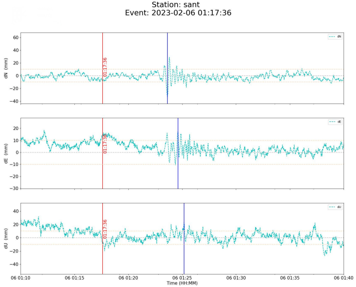



PRIDE Lab
Positioning Racers to Image & Decipher the Earth

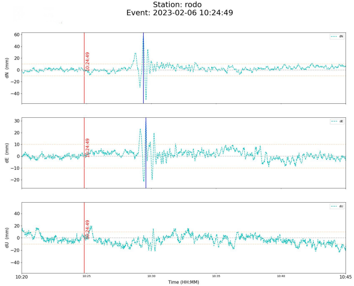
- 1Hz data available, ∼50 stations from Metrica SmartNET.
- PPP-AR analysis for 3 days (DOY: 036, 037, 038)

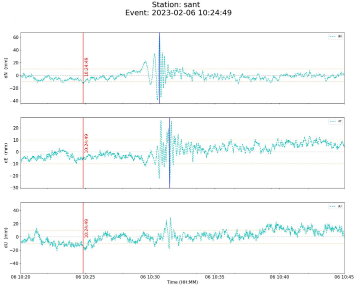
# Focus on stations

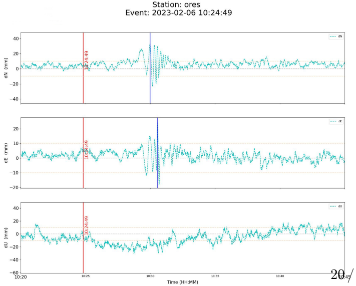






# Discussion / Conclusions

- 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.
- 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).
- DSO is upgrading its scientific output and processing activity via new datasets and real time processing.
- Our plan: grow up our team and be more involved to the GNSS/EUREF community.

**Thank you for your attention!**

*compiled via XeLaTeX*

# 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. 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 (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).