On the stability of regional reference frames in Greece using GNSS permanent stations.

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Presentation Structure

DSO Recent Activity

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 five 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.

Important results, include:

- the recent volcanic activity in *Santorini* (e.g. Papoutsis et al., 2013),
- the 2014 *Kefallonia* earthquakes (e.g. Anastasiou, Chouliaras, et al., 2014)

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,
- improve our academic services (NTUA is a University)

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

The DataSet

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

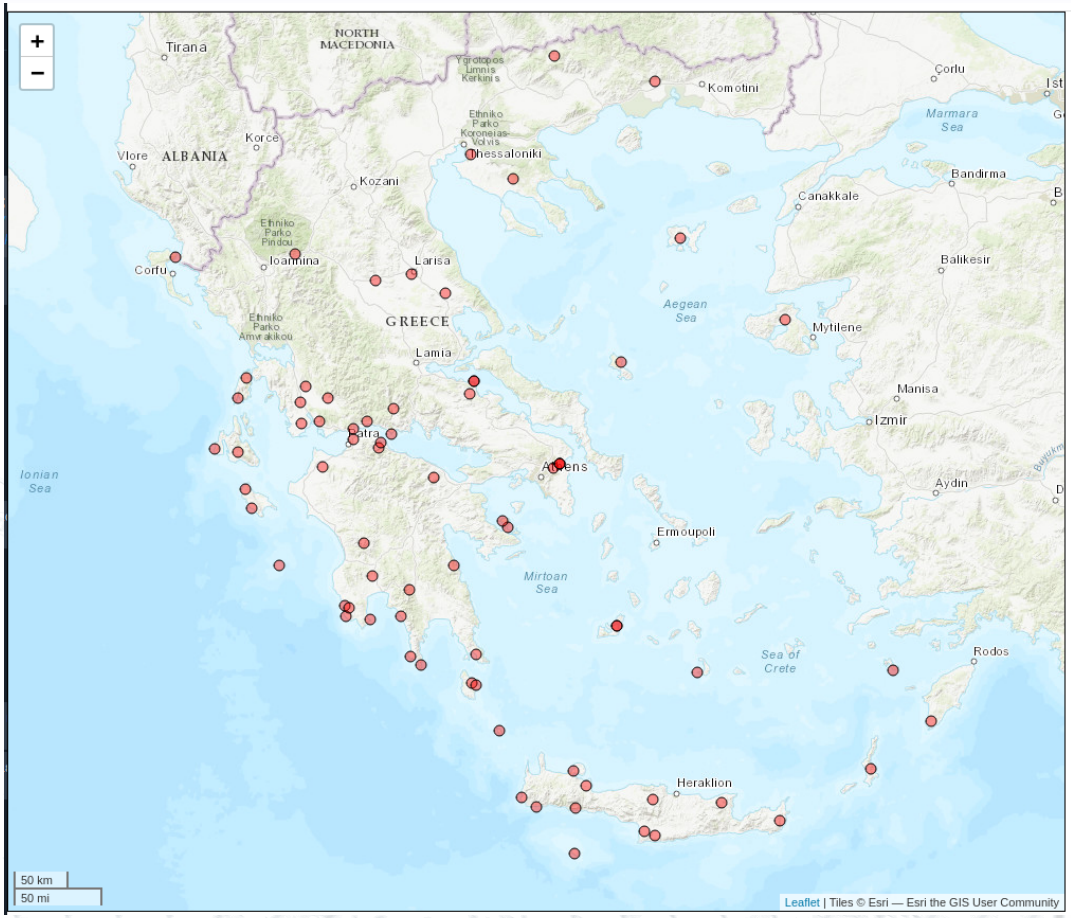
Currently we process whatever we can get our hands on ...
Problems:

- Inhomogenous dataset (`RINEX` of various versions, raw files, etc).
- Various maintainers, different mentalities.
- Different 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 dataset (100) but not all of them are (always/currently) active. Various providers but all with geodetic interest & ecquipment.

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

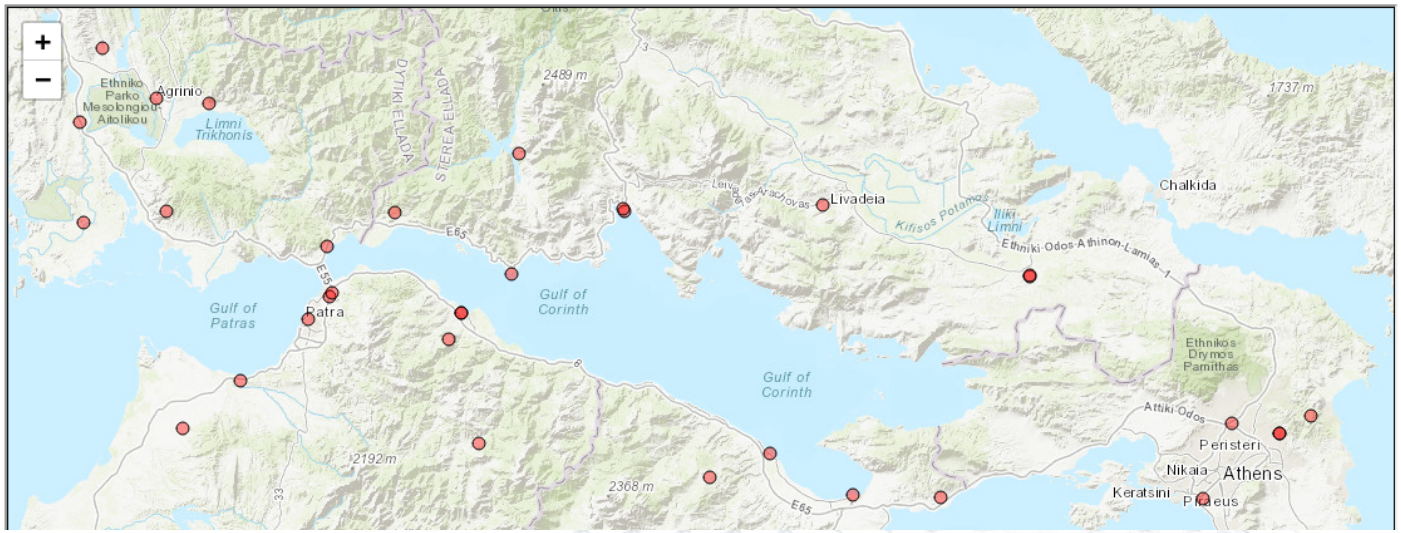


Network GREECE

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

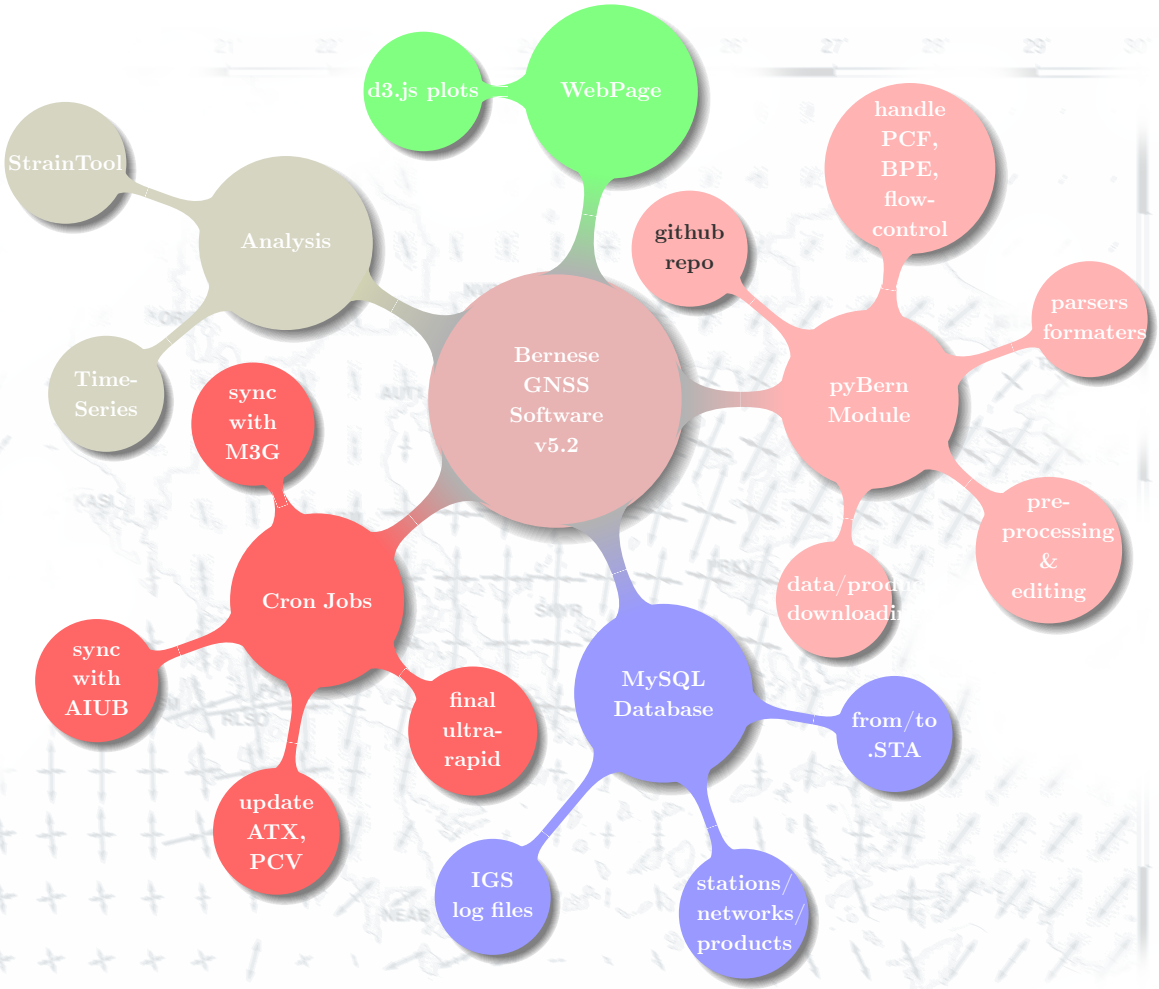


http://dionysos.survey.ntua.gr/dso/enceladus/

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)
- **Time-series** analysis (integrated in routine processing on regular intervals)
- **Strain Rates** via StrainTool (on user demand)



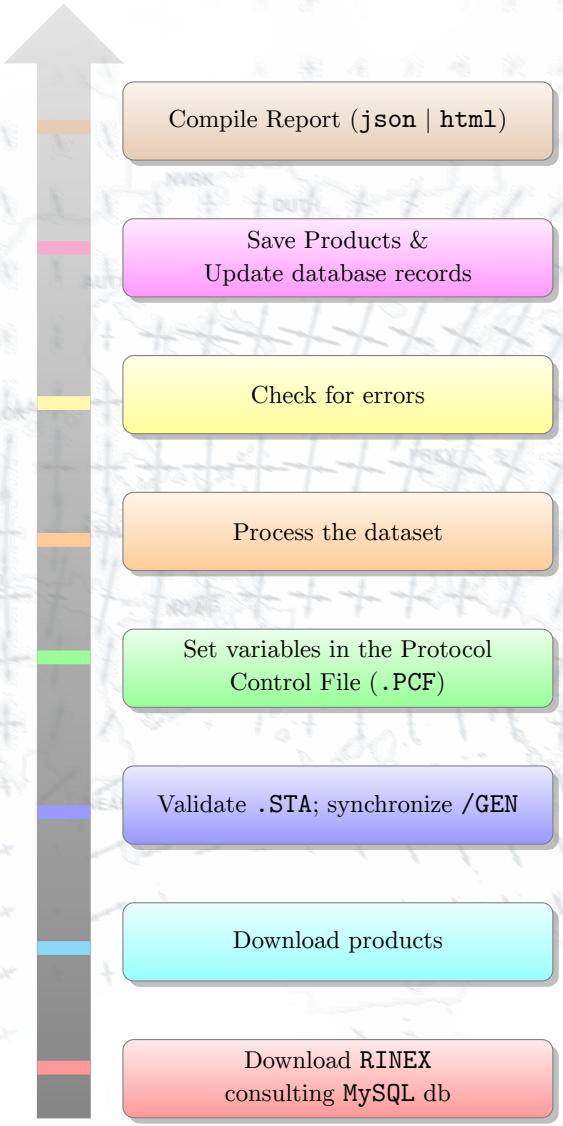
Compliance wrt EUREF standards

Processing is consistent with EUREF standards (Guidelines for Analysis Centres).

- `SINEX` with required info/blocks,
- Reference frame `IGb14`,
- `IERS` Conventions 2010,
- `IGS`/`CODE` products,
- ocean loading corrections (`FES2004`),
- 3° elevation cut-off angle; elevation dependent weighting,
- `GMF` and/or `VMF1`; `Chen-Herring` gradient parameter,
- amiguities fixed (length-dependent algorithm),
- use `GLONASS` obs (when available)
- ———————— ATX/individual calibrations ————————-

Workflow

```
$>ddproces.sh --year= --doy=
--session= --bern-loadgps=
--campaign=
--satellite-system=
--solution-id= --save-dir=
--analysis-center=
--use-ntua-products=
--append-suffix=
--elevation-angle= --update=
--pcv= --apply-exclude-list
```



Results & Output

4. Solution Indetifiers

Array of Objects

expand

5. PCF Variables

Array of Objects

expand

6. Saved products

Array of Objects

expand

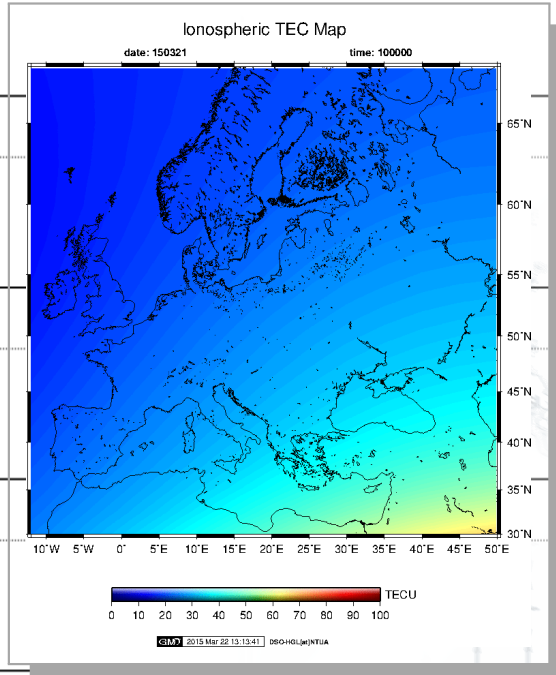
7. Warnings

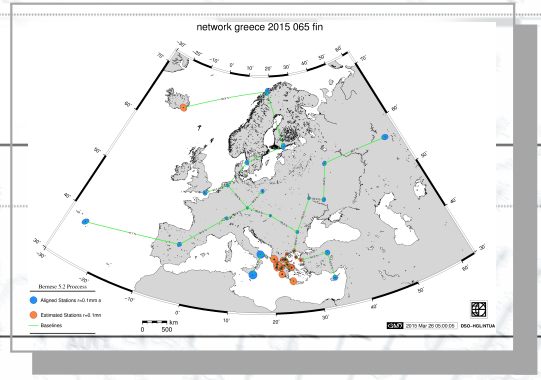
Array of Objects

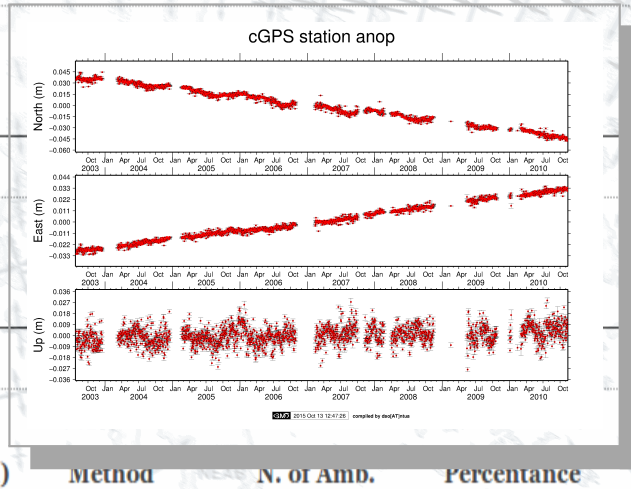
expand

8. Ambiguity Resolution SUmmary

Array of Objects

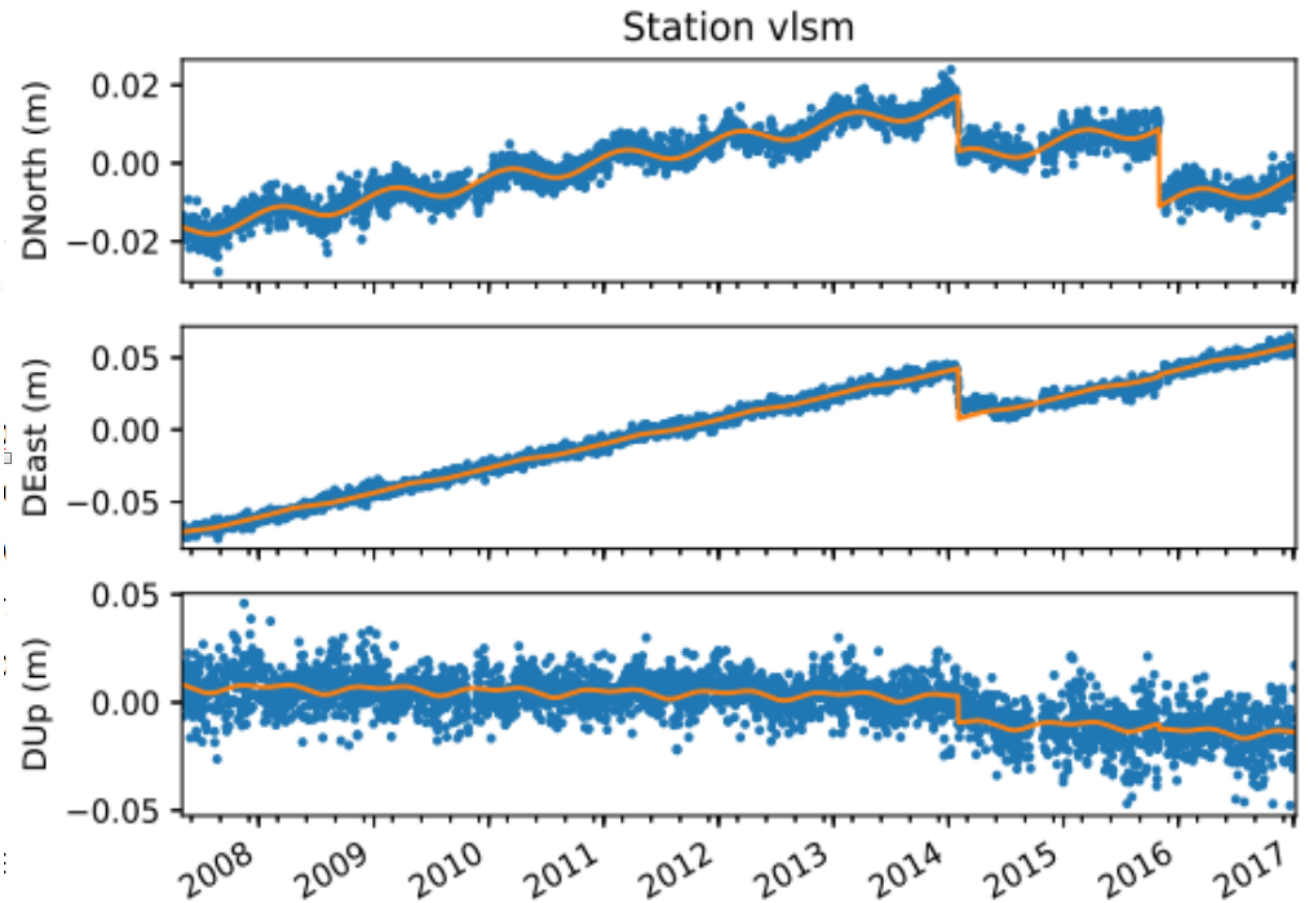




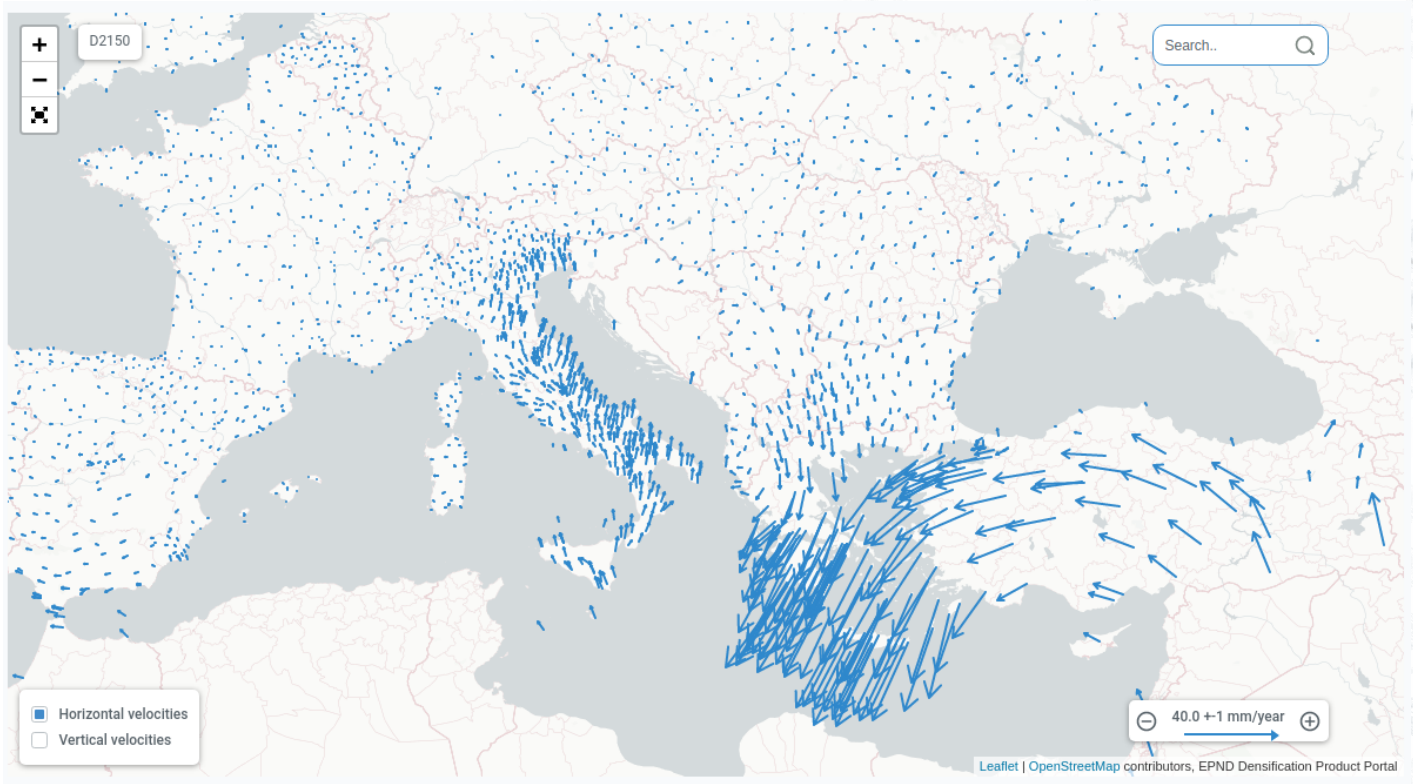


Baseline	sta1	sta2	length (km)	Method	N. of Amb.	Percentance	Satellite system
AUKL	AUT1	KLOK	139.7	pbnl	74	54.1	GPS
AULE	AUT1	LEMN	199.6	pbnl	60	55	GPS
KCTL	KATC	TILO	59	pbnl	50	90	GPS
KLRL	KLOK	RLSO	174.2	pbnl	74	41.9	GPS

Coordinate estimates - Time series analysis



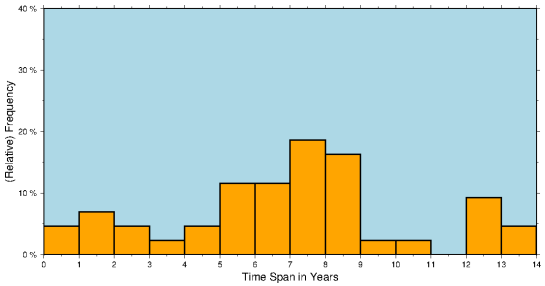
Velocity field in Europe - Densfication project

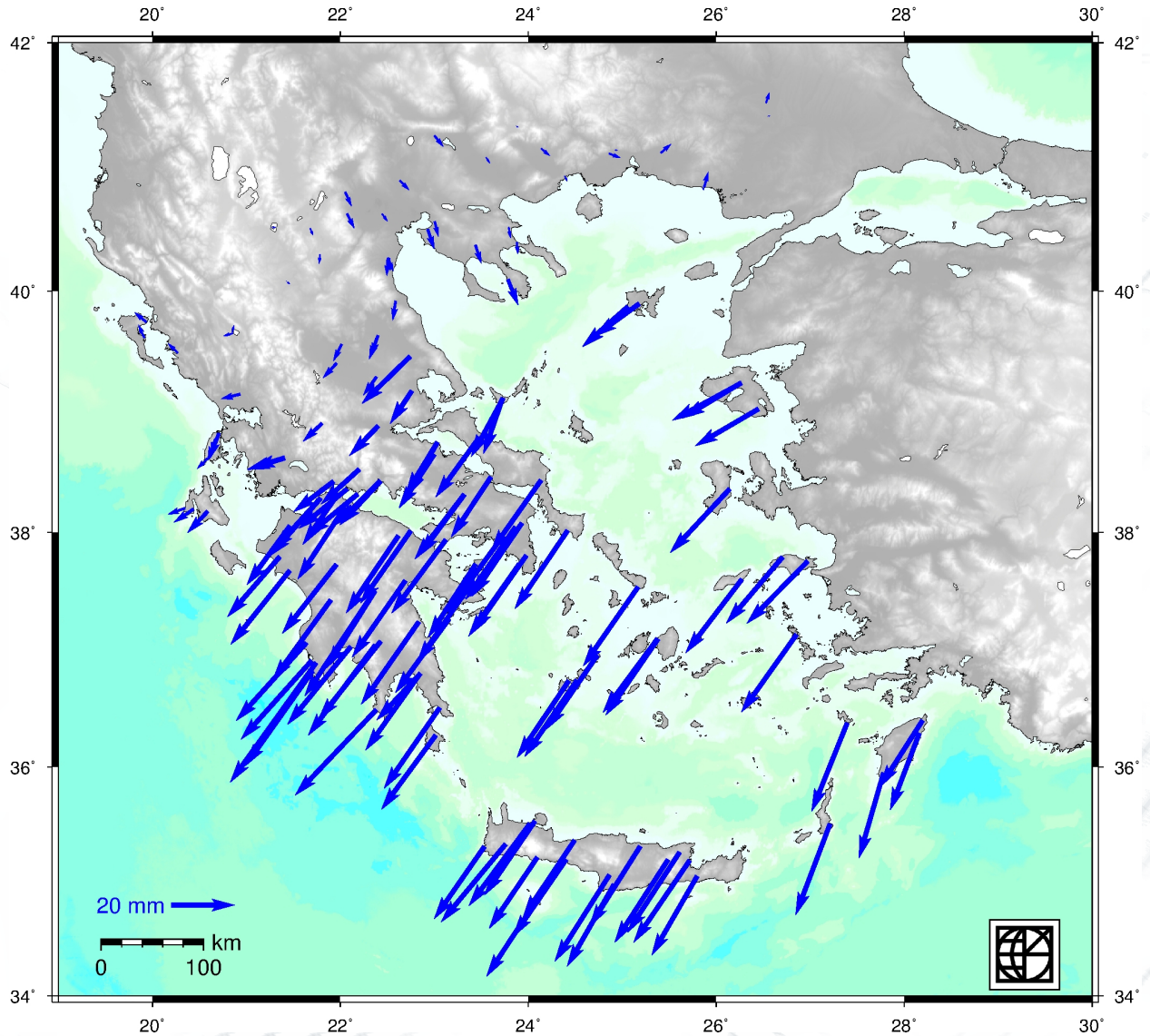


https://epnd.sgo-penc.hu/velocities/

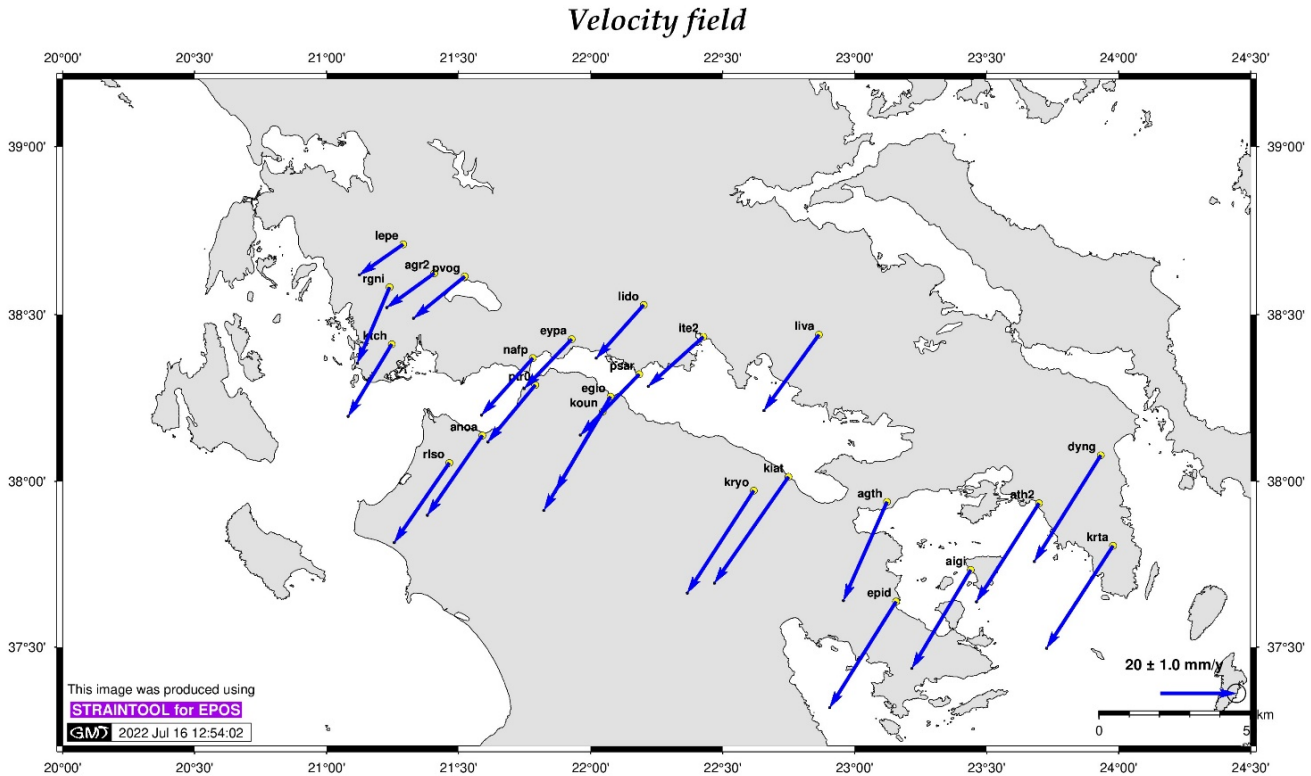
Velocity field in Greece wrt a stable Europe

- 100 station
- data availability > 3 years
- Velocity field w.r.t. a stable Europe (Kreemer et al., 2014)



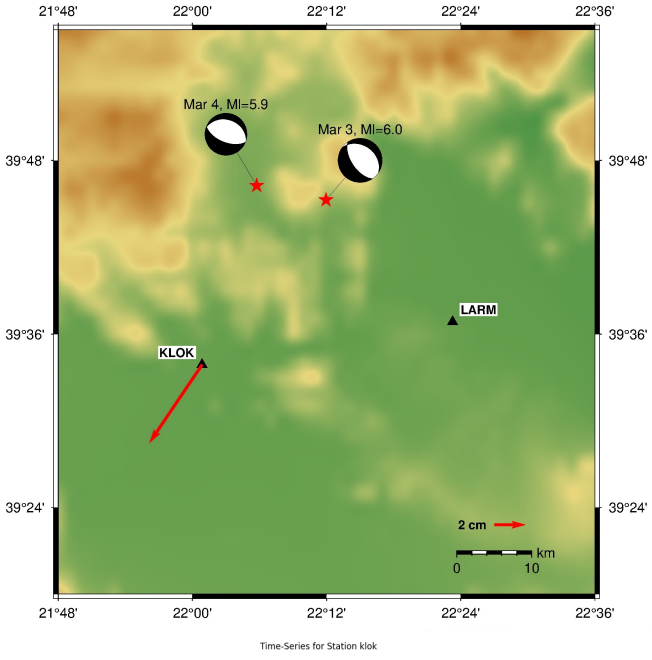


Focus on specific regions - Corinth Gulf

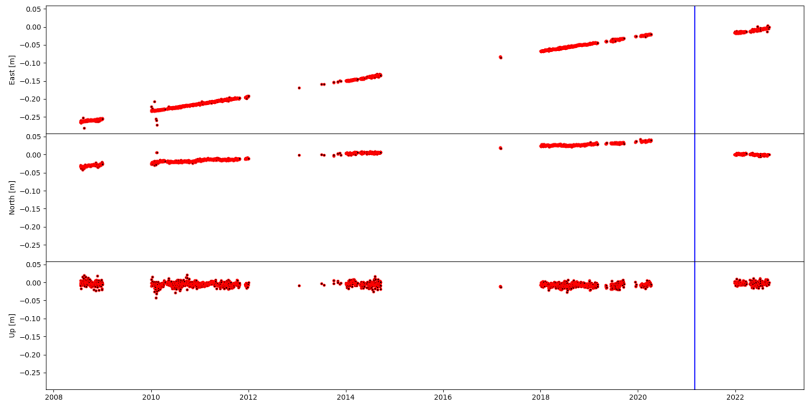


Recent Earthquakes

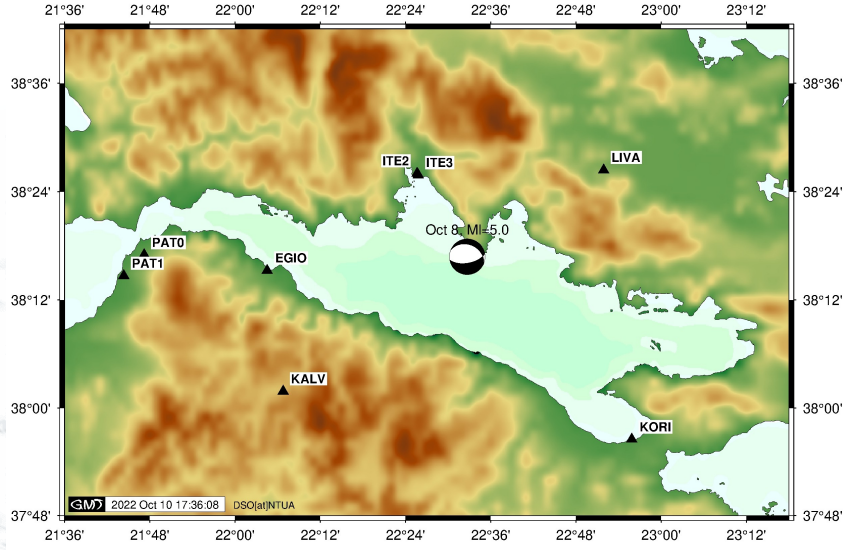
Thessaly 2021



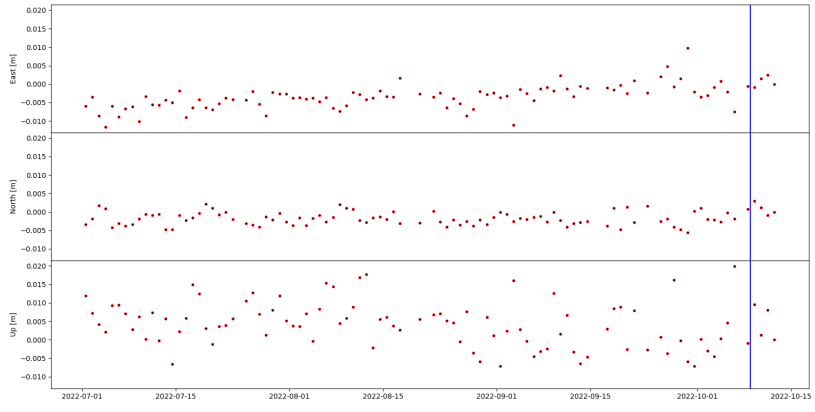
Time-Series for Station klok



Itea 2022

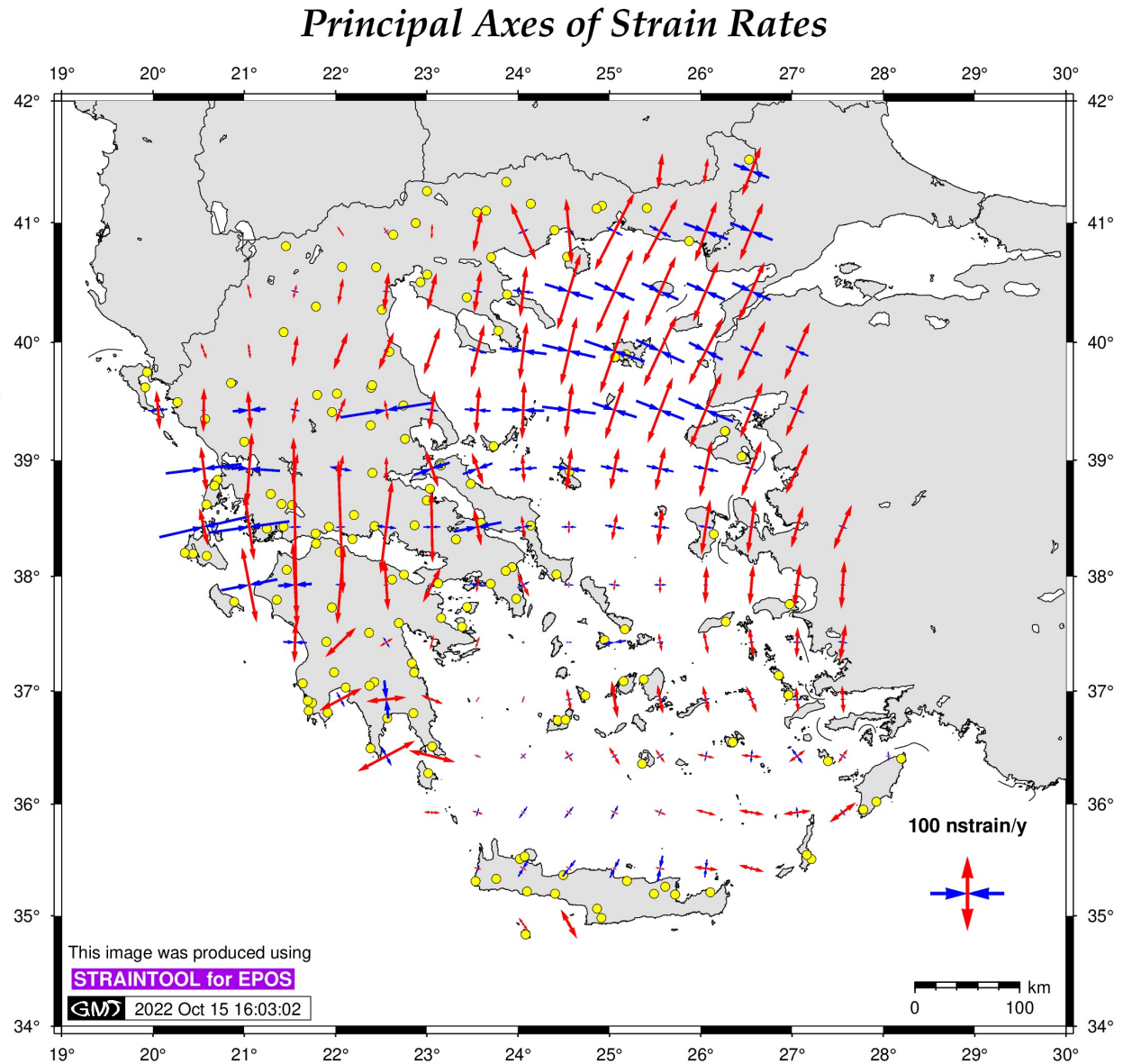


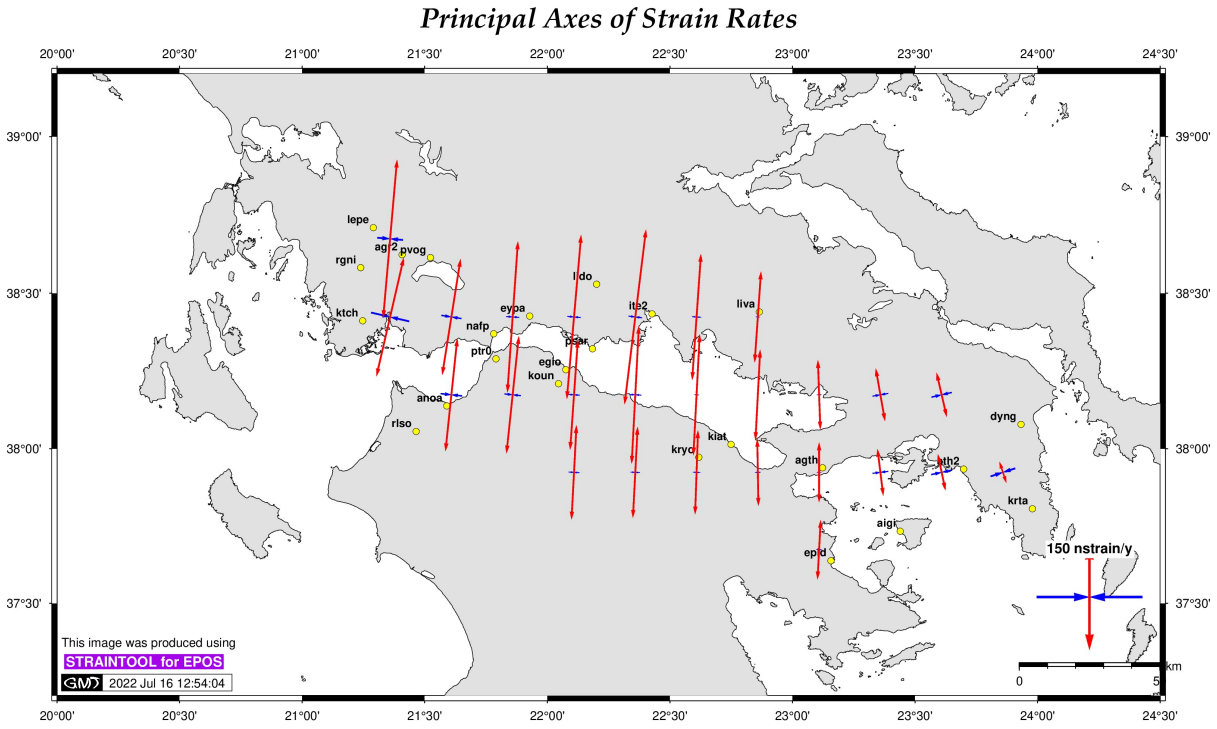
Time-Series for Station ite3



Strain rates

- **StrainTool** software used to estimate strain tensor parameters (Anastasiou, Papanikolaou, et al., 2021)
- grid step 0.5°




Principal Axes of Strain Rates
20°00'
20°30'
21°00'
21°30'
22°00'
22°30'
23°00'
23°30'
24°00'
24°30'
39°00'
38°30'
38°00'
37°30'
lepe
ag12
pvog
rgni
ktch
nafp
eypa
ptro
egio
koun
anoa
rlso
lido
ita2
pdar
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agth
ath2
dyng
krta
aigi
epid
150 nstrain/y
This image was produced using
STRAINTOOL for EPOS
GMT 2022 Jul 16 12:54:04
0
km

Discussion / Conclusions

- Greece is located in a complex tectonic background with many changes in the kinematics of the area
- A dense velocity field for accurate estimation of 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 phenomena on smaller areas of interest

Thank you for your attention!

compiled via XeLaTeX

References I

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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. 17).

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