GNSS processing at Université-Grenoble-Alpes for EPOS-GNSS

EUREF Symposium

June 24th 2025

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EPOS GNSS products?

Daily / Weekly Positions

Daily / Weekly Position Time Series

Position Offsets

Secular velocities

Strain rate maps

```
                CLASS_A EPN STATION POSITIONS AND VELOCITIES
                REFERENCE FRAME:    IGb14    AT EPOCH OF 2010.0
                CUMULATIVE SOLUTION OF GPSWEEKS [ 0834 - 2130 ]
                RELEASE NAME:    EPN_A_IGb14_C2130
                RELEASED ON 03/01/2021 BY EPN REFERENCE FRAME COORD
DOMES NB. SITE NAME         TECH. ID.       X/Vx          Y/Vy
          CLASS
-------------------------------------------------------------------
10001M007 SMNE              GPS SMNE  4201791.972   177945.561  47
10001M007                                 -.0130        0.0175
10001M007 SMNE              GPS SMNE  4201791.982   177945.564  47
10001M007                                 -.0130        0.0175
10001M007 SMNE              GPS SMNE  4201791.988   177945.558  47
10001M007                                 -.0130        0.0175
10001M007 SMNE              GPS SMNE  4201791.977   177945.564  47
10001M007                                 -.0130        0.0175
10001M007 SMNE              GPS SMNE  4201791.978   177945.564  47
10001M007                                 -.0130        0.0175
10002M006 GRAS              GPS GRAS  4581690.827   556114.926  43
10002M006                                 -.0137        0.0189
10002M006 GRAS              GPS GRAS  4581690.830   556114.924  43
10002M006                                 -.0137        0.0189
10002M006 GRAS              GPS GRAS  4581690.835   556114.927  43
10002M006                                 -.0137        0.0189
10002M006 GRAS              GPS GRAS  4581690.831   556114.930  43
10002M006                                 -.0137        0.0189
10002M010 GRAC              GPS GRAC  4581708.275   556132.729  43
10002M010                                 -.0137        0.0189
10003M004 TOUL              GPS TOUL  4627845.964   119629.426  43
10003M004                                 -.0120        0.0192
10003M004 TOUL              GPS TOUL  4627845.961   119629.422  43
10003M004                                 -.0120        0.0192
10003M009 TLSE              GPS TLSE  4627851.768   119640.111  43
10003M009                                 -.0120        0.0192
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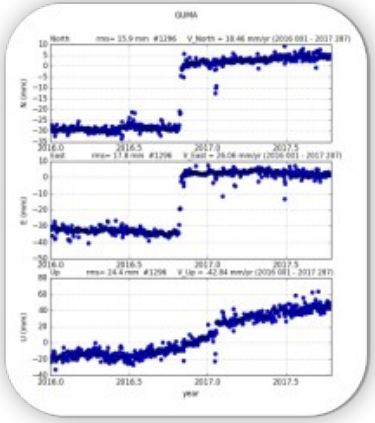
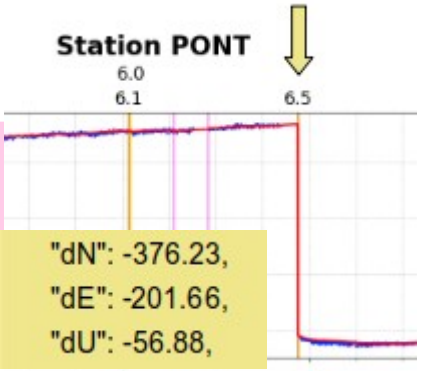
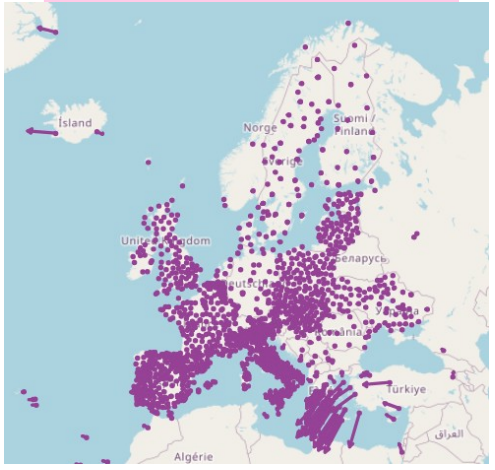
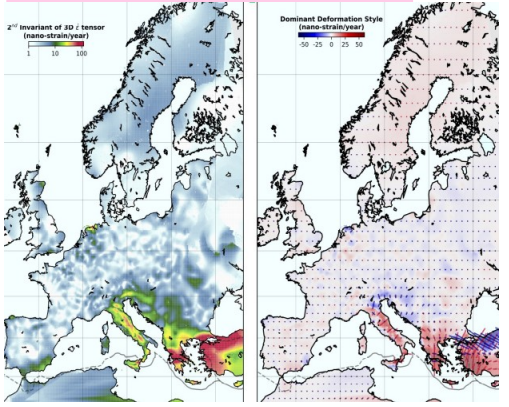




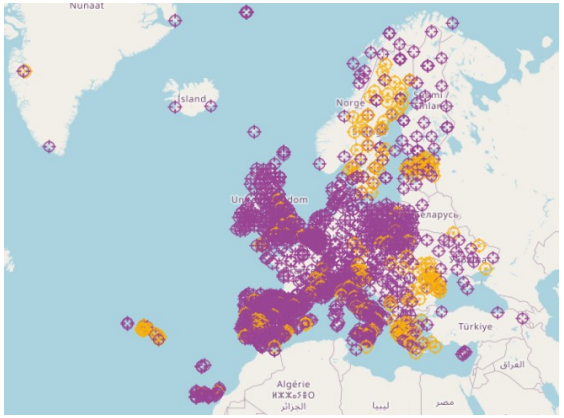




GNSS DATA AND PRODUCTS

What are the different products labels? What are their specificities?

EPOS, EUREF, EUREF-EPOS



Two product solutions developed specifically for EPOS

Principles:

- **Open science, reproducible**
  - **All data available:** RInEx from EPOS-GNSS Data Gateway, metadata available & verified
  - **Fully documented** processing strategies using **scientific software**
- **Specifically designed for geophysical studies** (including for slow movements)
  - Each solution is internally-consistent, generated @ a single Pan-European processing center with one strategy

Daily positions & Multi-year solutions @ 2 Pan-European EPOS Analysis Centers 2 x

Positions
Time Series
Velocities

Quality Check

- Two independent daily solutions :
  - generated @ 2 independent processing centers
  - with 2 independent processing Strategies & Softwares :

Double difference GAMIT/GLOBK/PYACS Automatic updates @ D-2 & D-25	PPP GIPSY-OASIS-II Regular Updates

- Velocities Computed with MIDAS, station classification based on uncertainty

Independent cross-comparison and validation @ Pan-European Analysis Combination Center

- Comparison of Positions Time Series using CATREF
- Identification of outlier and inconsistencies
- Validation or feedback to the EPOS Analysis Centers

LECHNER TUDÁSKÖZPONT

GNSS DATA AND PRODUCTS

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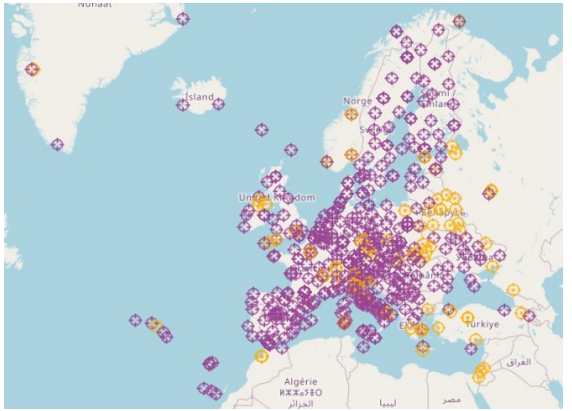


Original EUREF product made available through the EPOS GNSS Product Gateway

Principles:

- **Open data :** RInEx available from EPN data centers, metadata available & verified
- **Specifically designed for geodesy and reference frame studies :**
  - Geodetic-class stations from the EUREF Permanent Network (EPN)
  - Densifies ITRF over Europe and provides access to European Terrestrial Reference Frame (ETRF/ETRS89)

Regional daily position solution @ 16 EPN Analysis Centers

- each station processed by at least 3 ACs to ensure redundancy and increase reliability
- 3 softwares: Bernese, Gamit, Gipsy

Daily and Weekly Combined Positions @ EPN Analysis Combination Center

Positions

- Pan-European combinations with Bernese
- Each AC solution is compared to the combined solution to identify and reject outliers
- Aligned to IGS14 using no-net-translation

Multi-year Solution @ EPN Reference Frame Analysis Center

Time Series

Velocities

- Updated each 15 weeks
- Using CATREF
- Outlier rejection by visual inspection of time series, introduction of position and velocity discontinuities, station classification based on velocity uncertainties from Hector and velocity variability

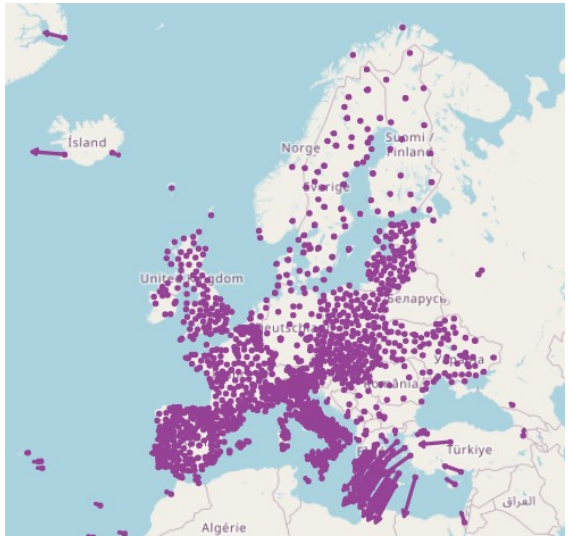
ROYAL OBSERVATORY OF BELGIUM

UGA Université Grenoble Alpes

GNSS DATA AND PRODUCTS

What are the different products labels? What are their specificities?

EPOS, EUREF, EUREF-EPOS



Densification Product from EUREF and EPOS

Principles:

- **Provide a densified velocity field,** including non-EPOS stations that do not release raw data (yet?)

Regional daily position solution @ 30 EPND & EPOS Analysis Centers

- 3 softwares: Bernese, Gamit, Gipsy

Multi-year Combined Solution @ EPOS-EUREF Combination Center

Time Series
Velocities

- Weekly Combined Positions Time Series using CATREF
- Velocities using CATREF, MIDAS, HECTOR
- Station metadata harmonization
- Outlier rejection by automated and visual inspection of time series, introduction of position and velocity discontinuities, velocity filtering, removal of non-representative stations (data quality or monumentation)

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GNSS DATA AND PRODUCTS

Double-difference processing at UGA-CNRS

Complete reprocessing (~yearly)

Reprocessing of all history for all stations, to include newly distributed data.

Time series post-processing (offsets + velocities)

Daily processing

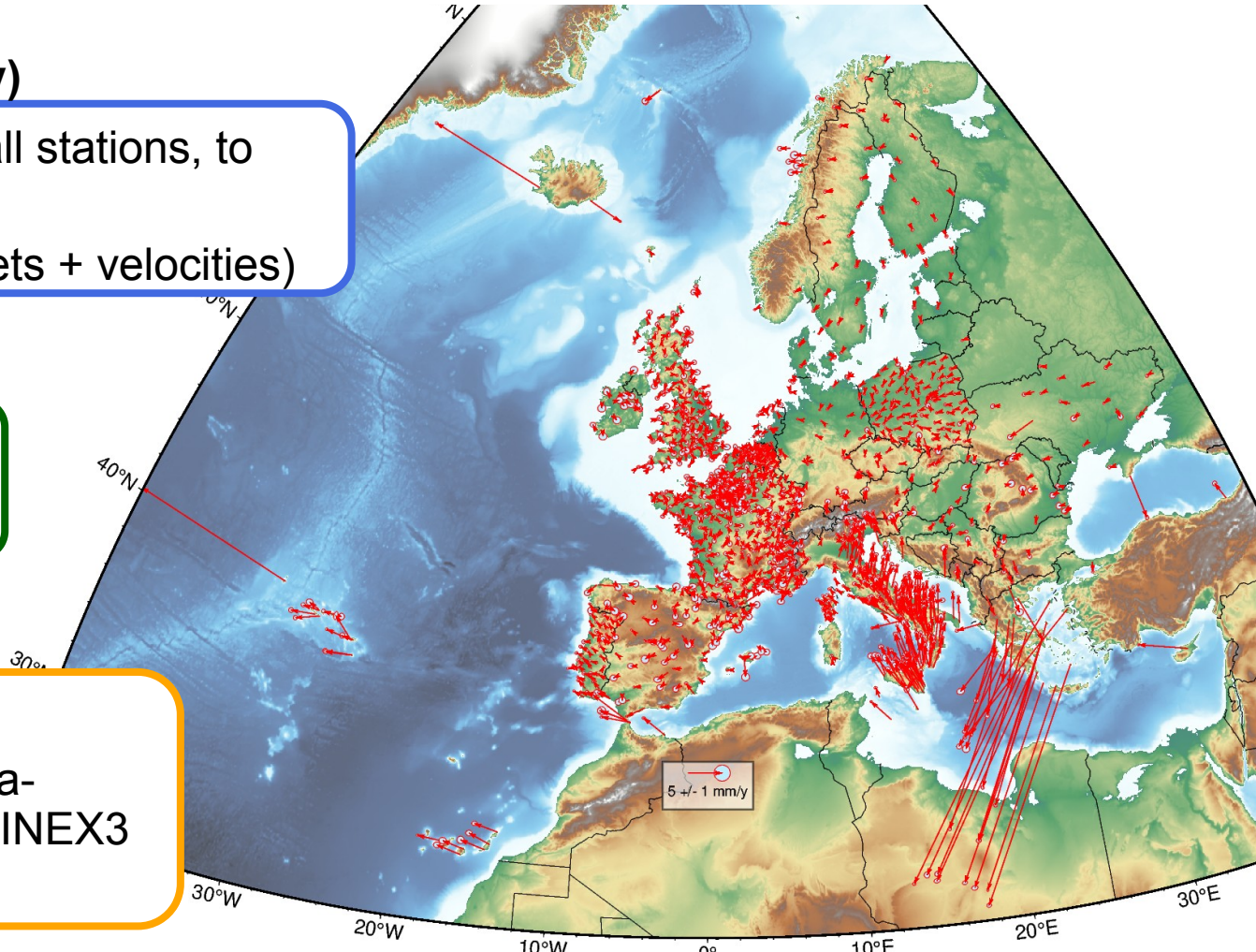
D+2 (rapid) and D+25 (« final »)

Integrated daily on EPOS portal

Tests / feedback

EPOS data / metadata issues :

Data format / content / conflict data-metadata / a priori coordinates / RINEX3 observables

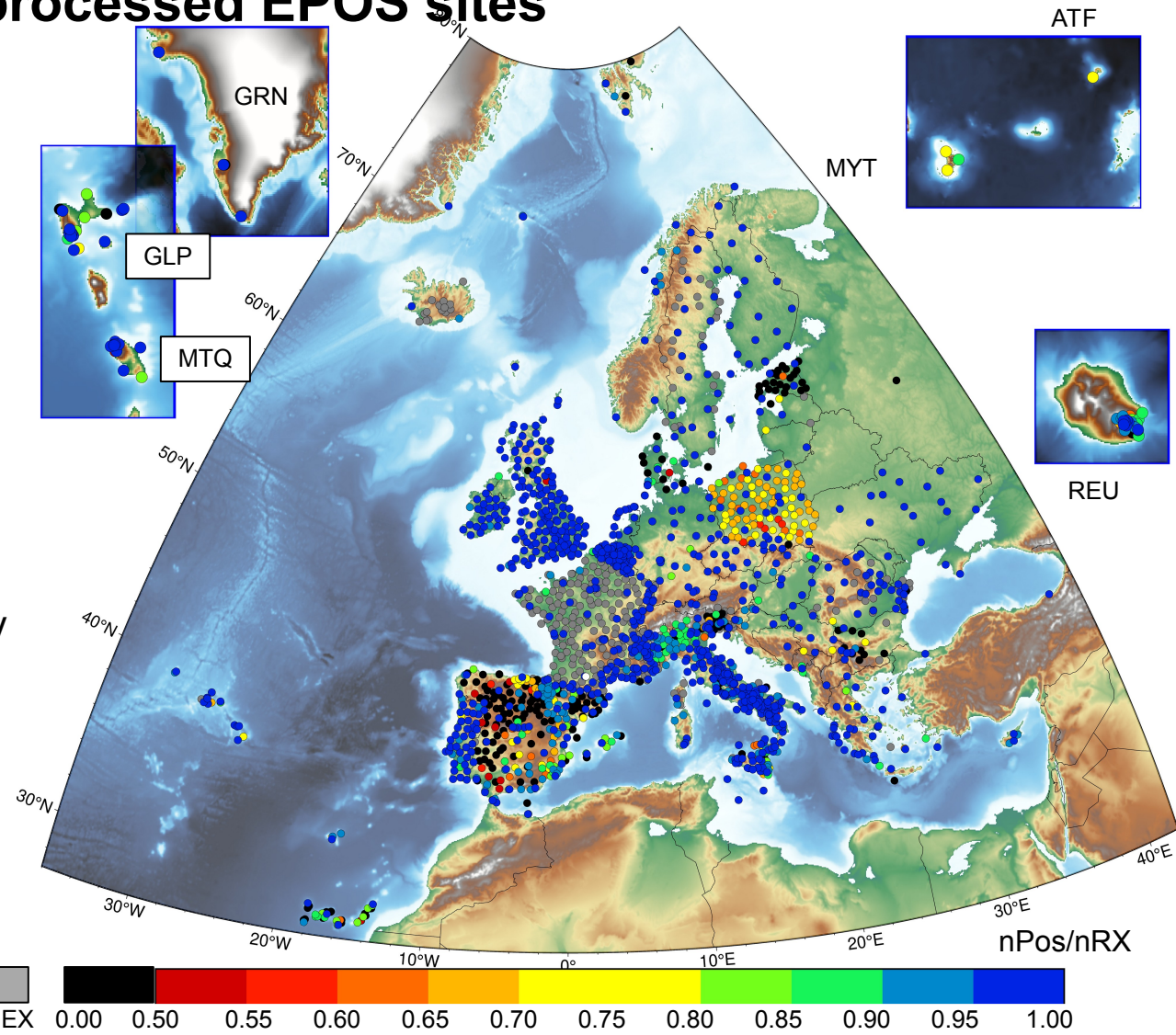


UGA GG/midas velocity solution – IGb14 Eurasia - June 2024

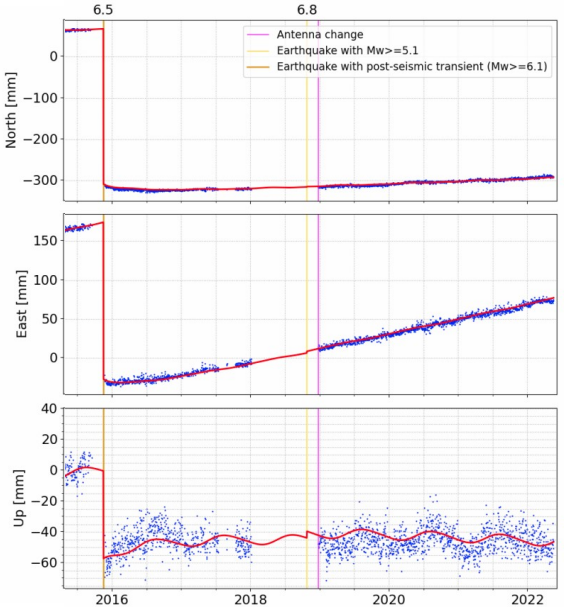
Map of processed EPOS sites

Stats from last repro (June 2024)

- Sites with site log but no RINEX
  Mainly TERIA (FRA)
- Sites with most/many RINEX added during repro (end 2023 - 2024)
  Mainly ESP, POL, EST, DNK
- Older sites with stable data history



GNSS offset product for Geo-INQUIRE – first release mid-2024



For all time series, estimate position offsets :

Equipment offsets for changes listed in site log

Co-seismic offsets

Post-seismic relaxation modelled, not delivered

(EQ / location-dependent)

Status :

Covers 95% of sites (1543 / 1621 TS)

Remaining sites : local phenomena or short/incomplete time series

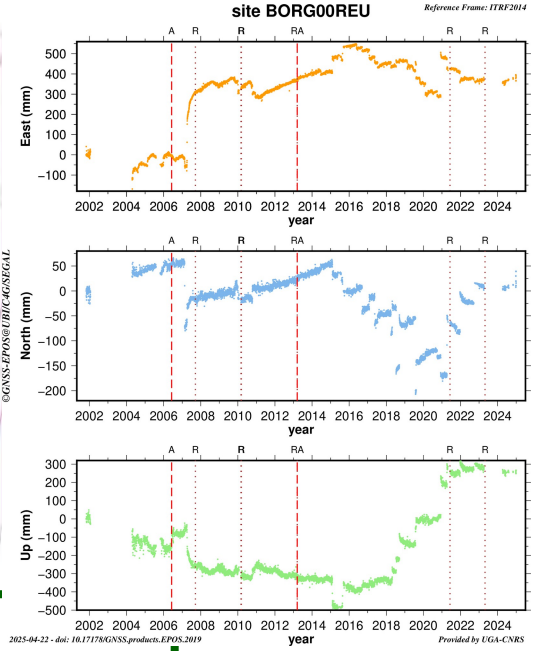
Json format for more flexibility

Format discussed and adjusted with INGV

Next :

Work with portals on improved service (filtering by site / EQ, etc)

GNSS offset product for Geo-INQUIRE – first release mid-2024



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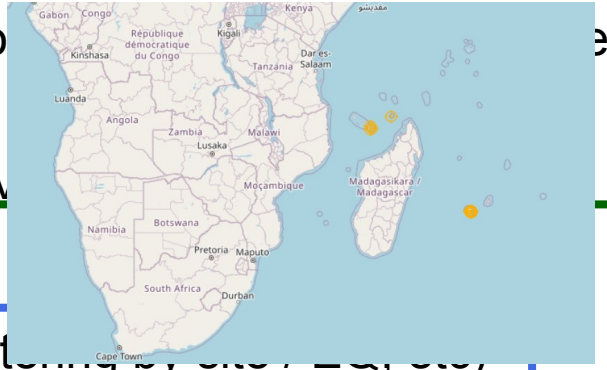

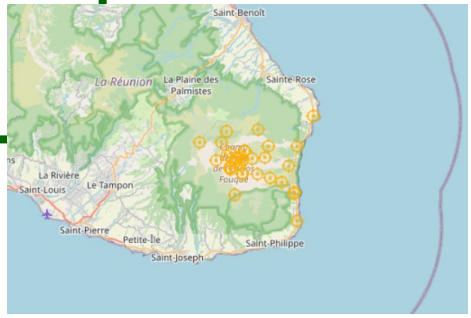

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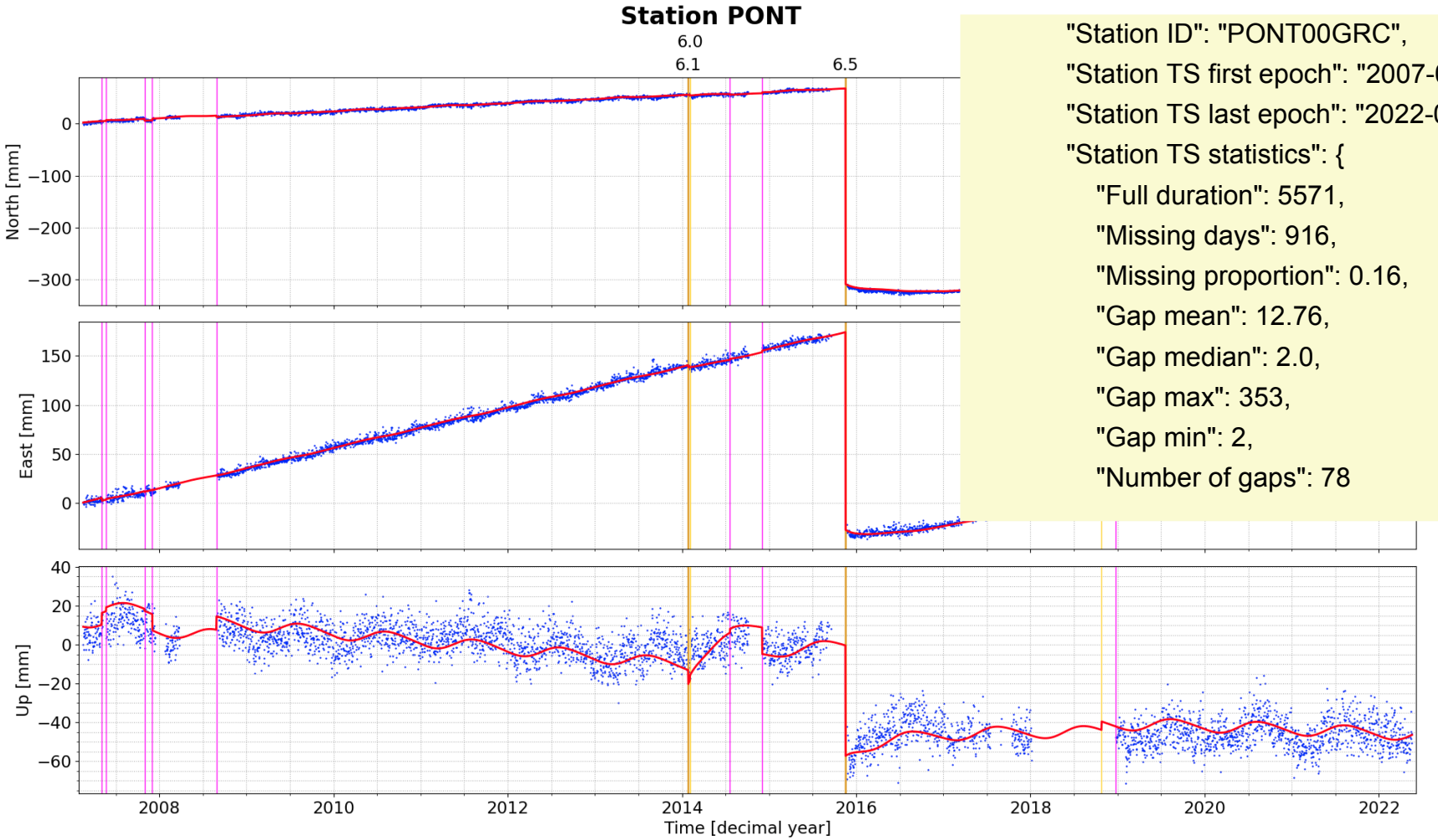
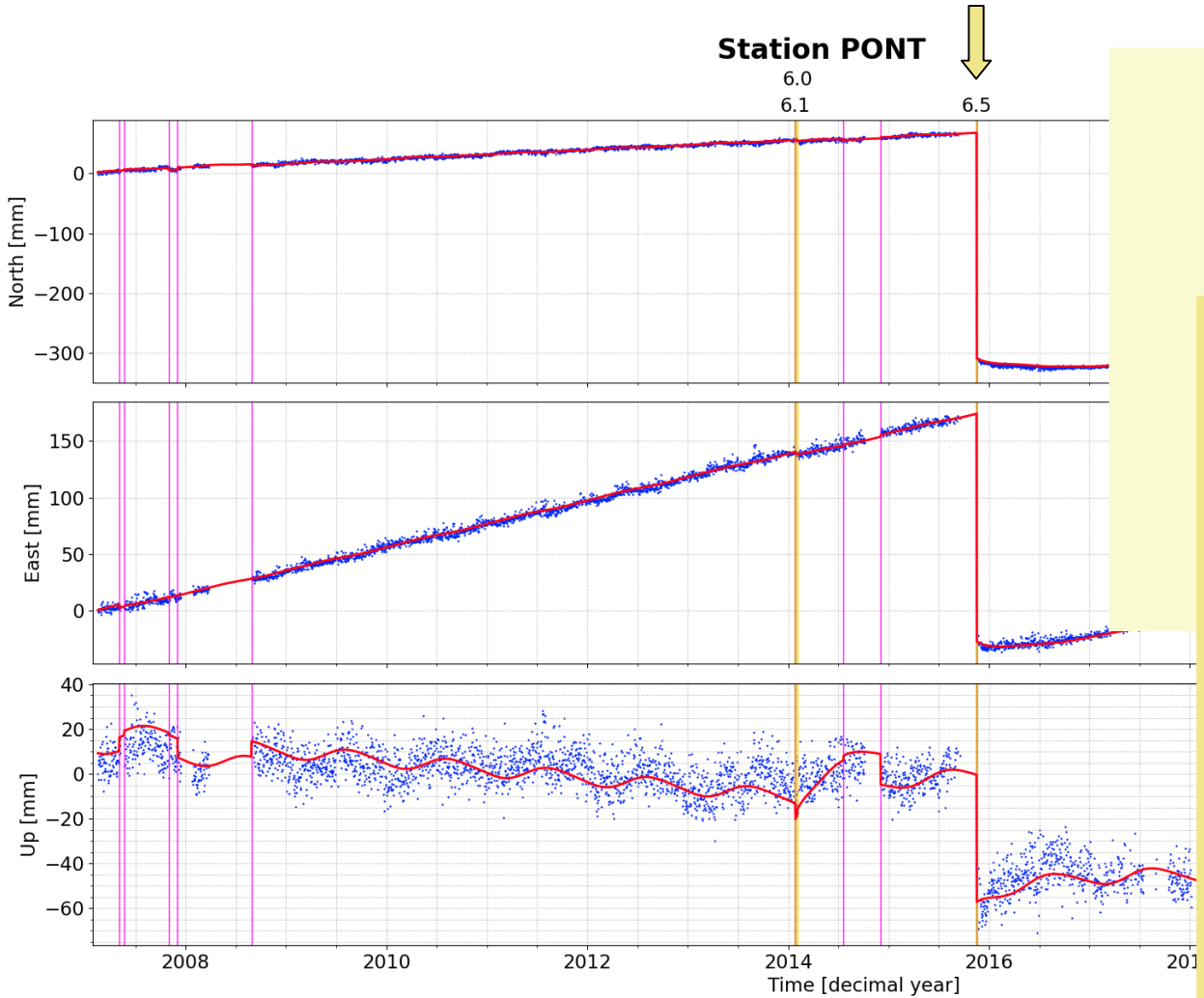
GNSS offset product for Geo-INQUIRE



"Station ID": "PONT00GRC",
"Station TS first epoch": "2007-02-16T12:00:00",
"Station TS last epoch": "2022-05-19T12:00:00",
"Station TS statistics": {
"Full duration": 5571,
"Missing days": 916,
"Missing proportion": 0.16,
"Gap mean": 12.76,
"Gap median": 2.0,
"Gap max": 353,
"Gap min": 2,
"Number of gaps": 78

GNSS offset product for Geo-INQUIRE



"Station ID": "PONT00GRC",
"Station TS first epoch": "2007-02-16T12:00:00",
"Station TS last epoch": "2022-05-19T12:00:00",
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"sE": 0.59,
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"EQEventID": "20151117_0000025",
"QC": {
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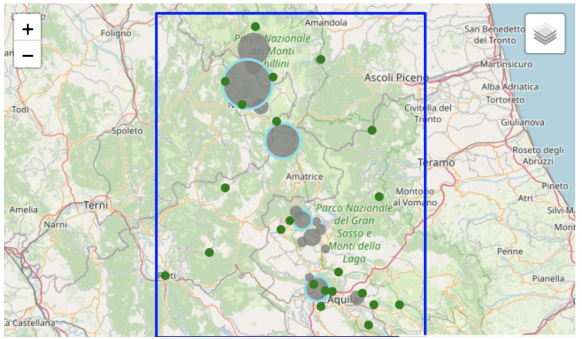
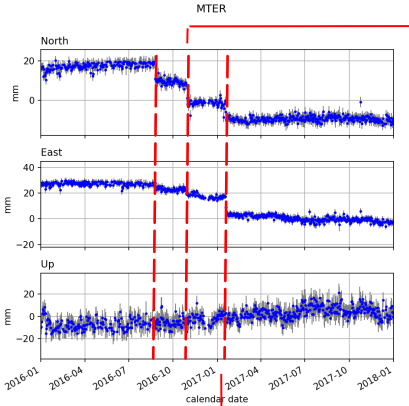
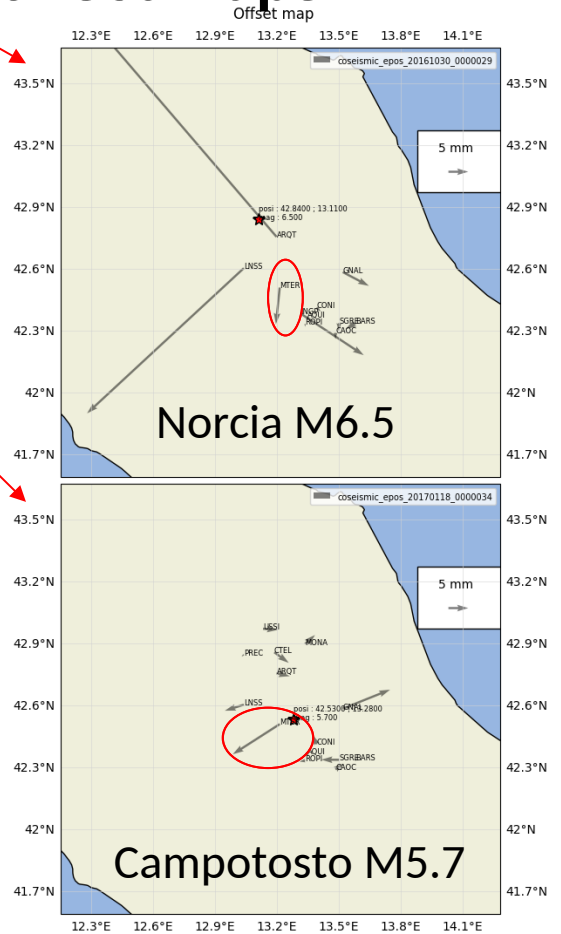
"Last data point before": "2015-09-16",
"First data point after": "2015-11-18"
}

Creation of a Jupyter notebook – GNSS co-seismic offset maps



Amatrice-Norcia sequence 2016





1) Select an earthquake event (magnitude, location)

Use EPOS seismology EMSC catalog service

2) Interrogate the GNSS station metadata service to identify neighbouring GNSS sites

3) Extract and map GNSS co-seismic offsets for this EQ event and neighbouring GNSS stations

GNSS processing EPOS@UGA : Getting out of DD, into PPP...

Decided to stop using GAMIT

GAMIT/GLOBK

- High and increasing cost of DD, limitations :
  - Complexity / HR time / compute resources
  - High latency for new stations / networks, agencies that deliver data after D+2
  - Stations identified with 4-char IDs
  - MIT support

Switch to PPP ongoing

Tool	GipsyX	gins
By	JPL, USA	CNES, France
Users	Large user community (user forum)	Smaller user community (SPOTGINS project), reactive support from S. Loyer (CNES)
Status@UGA	Massive GipsyX processing operational at UGA	GINS tests done at UGA

GNSS processing EPOS@UGA : Getting out of DD, into PPP...

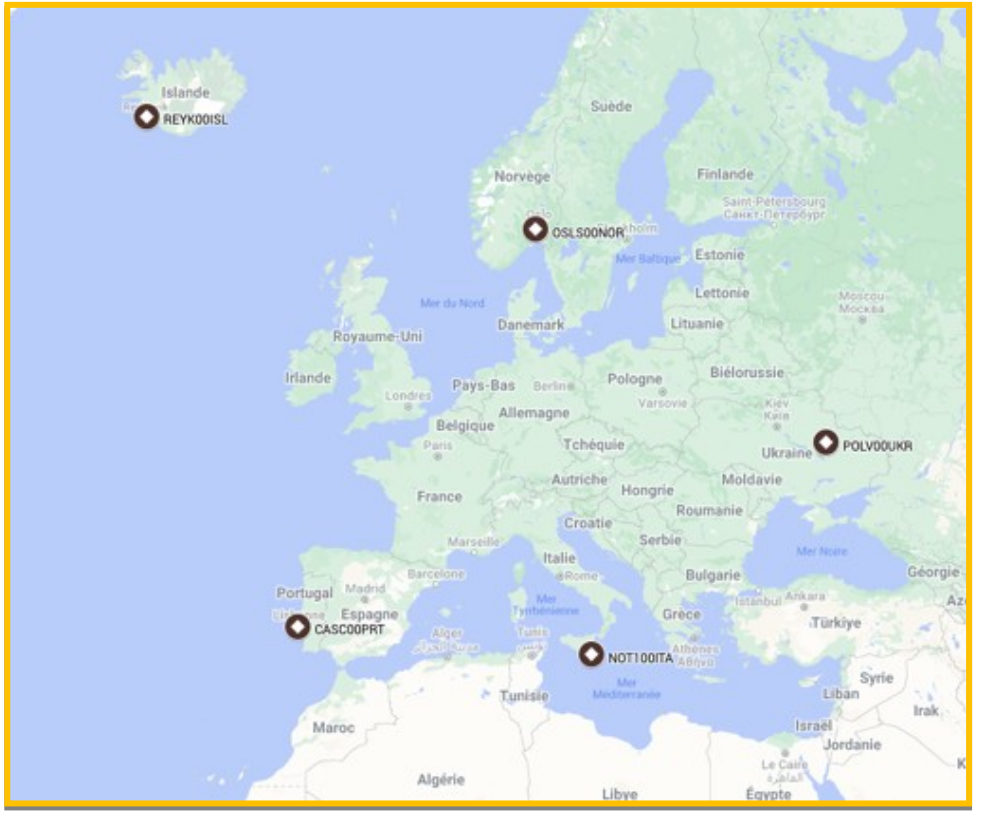
Selection of 5 EPOS test GipsyX time series in IGS20

1) Comparison with NGL IGS20 time series

Parameter tests (Ocean tide, pole ocean tide, random walk) to minimize differences

Some remaining parameter differences (input models, e.g. elevation weighting, ocean tide model, ...)

2) Comparison with SPOTGINS solution

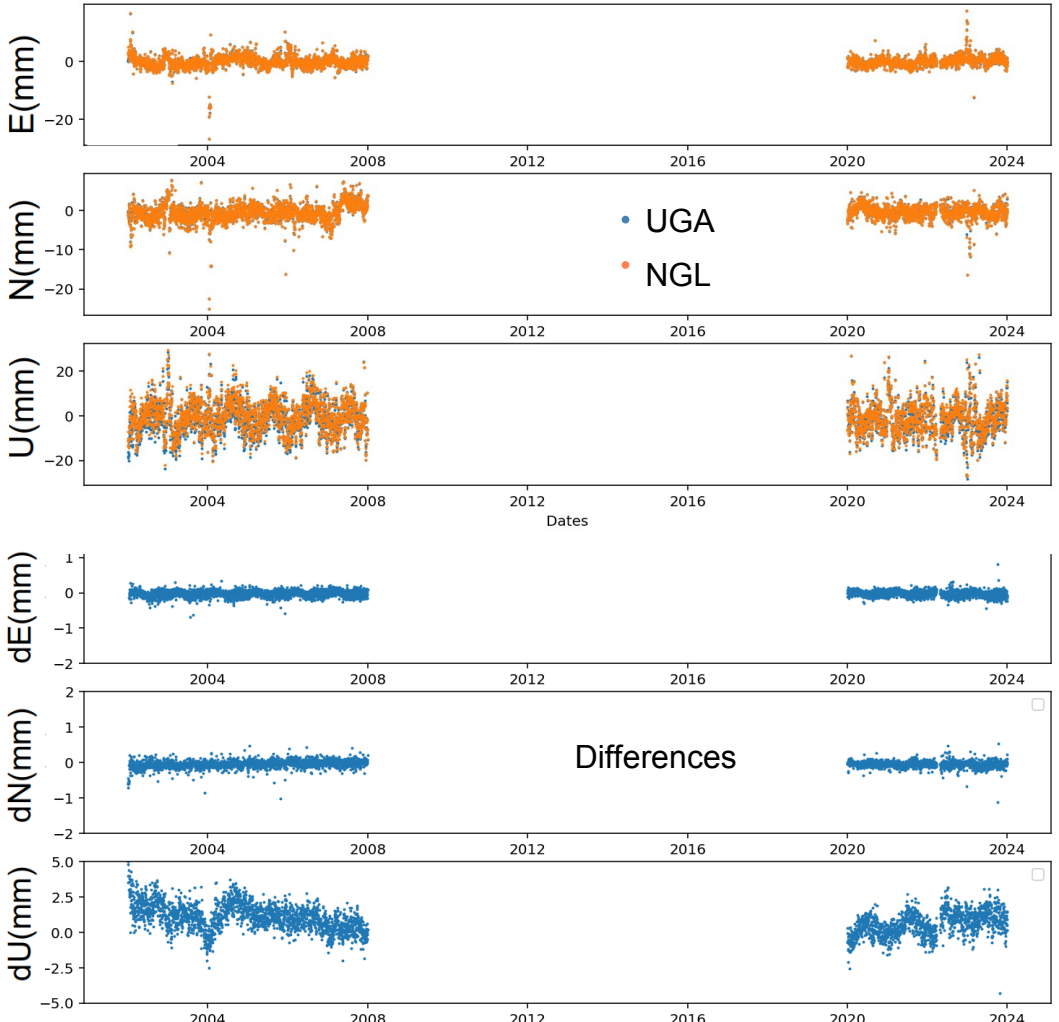


GNSS processing EPOS@UGA : Getting out of DD, into PPP...

UGA vs NGL : GipsyX 2.3

	UGA-CNRS	NGL
Constellation	GPS + Galileo	GPS only
Elevation weighting	DataSigma / sqrt(sin(el))	DataSigma / sin(el)
PCV from	igs20_wwww.atx	igs14_wwww.atx
IGRF model	IGRF13	IGRF12
Ocean Tide Loading Model	FES2022b	FES2004
Earth Orientation Parameter	IERS 2020	IERS 2010
Zenith delay: random walk	0.5x10e-4 km/sqrt(s)	1.0x10e-4 km/sqrt(s)
Horizontal delay gradients: random walk	1.0x10e-5 km/sqrt(s)	1.0x10e-5 km/sqrt(s)

OSLS00NOR detrended time series



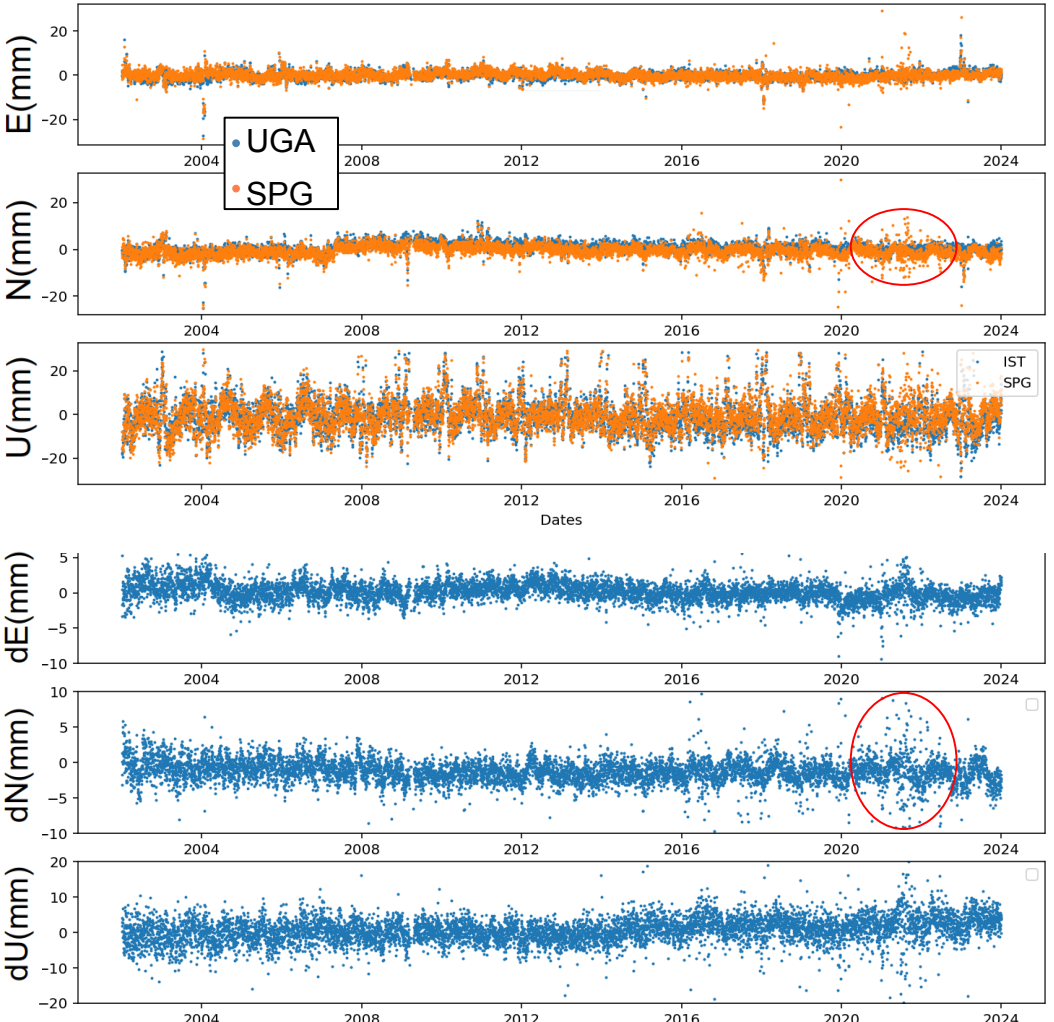
GNSS processing EPOS@UGA : Getting out of DD, into PPP...

UGA vs SPOTGINS

	UGA-CNRS	SPOTGINS
Orbits / clock products	JPL	GRG/G20
Ocean Tide Loading Model	FES2022b	FES2014b
Earth Orientation Parameter	IERS 2020	IERS 2010
Troposphere	Zenith delay and gradients estimate every 5 min	Zenith wet delay solved every hour, gradients horizontal delays solved twice a day
Ionosphere 2nd order	JPL	IGS

Elevation cutoff, weighting, IAU precession/nutation theories...

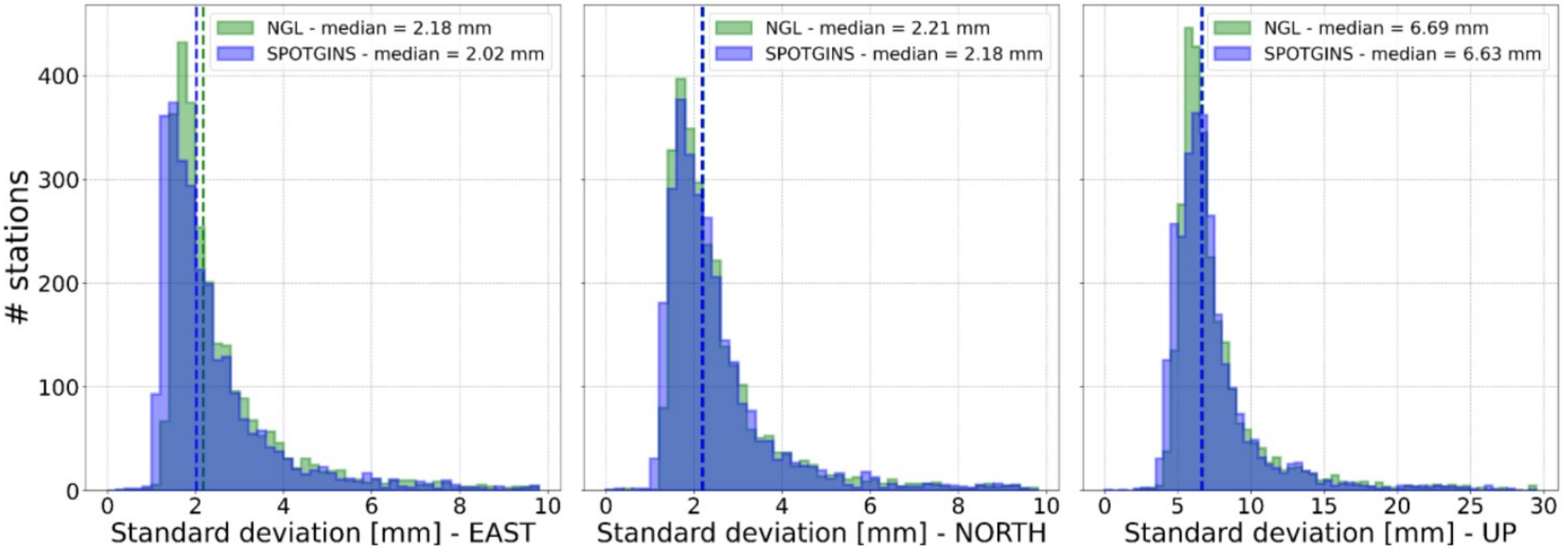
OSLS00NOR detrended time series



GNSS processing EPOS@UGA : Getting out of DD, into PPP...

NGL vs SPOTGINS

From Santamaría-Gómez et al, 2025



Dispersion of the detrended and cleaned series by solution and coordinate component. The same period was considered for each of the 2948 pairs of common stations considered. The typical dispersion of both the SPOTGINS and NGL solutions is at the level of 2 mm and 6 mm, for the horizontal and vertical components, respectively.

Summary

UGA GAMIT-GLOBK solution...

…operational and distributed

Including daily updates

Limitations :

- Limited reactivity for new data
- High ressource requirements

New products

- Instrument and co-seismic offsets
- Jupyter notebook for co-seismic offset mapping

Decision to switch to PPP : GipsyX

Latest version 2.3, IGS20

ASAP (intent : new solution in 2025)