GNSS Networks for Solid Earth Science in Europe in the Perspective of EUREF and EPOS

EPOS-N Final Workshop January 27 2021

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Material from the EPOS GNSS group, especially Carine Bruyninx, Rui Fernandes, Anne Socquet
OUTLINE

• What is needed to use GNSS for Solid Earth Science - Back to basics!
• The need for a global infrastructure and the “Global Geodetic Reference Frame
• Presentation of EUREF
• The EPOS GNSS TCS GNSS data & products
• Handling of metadata in EPOS TCS GNSS – common handling also for EUREF
• The EPOS data & product line
• Some brief examples of use cases
Example:
An orbit error of 2 m cause an error in baseline of $10^{-7}$. This cause 10 cm error for a 1000 km baseline.
Precise orbits and clock information are provided from the IGS:

Predicted GPS orbits:
~5 cm
~3 ns (RMS)

Final GPS orbits:
~2.5 cm
~75 ps (RMS)

Final GLONASS orbits:
~3 cm

Also Galileo available

http://www.igs.org/
ITRS and ITRF2014

ITRF2014 map from:
WHAT IS EUREF?

EUREF is the IAG Reference Frame Sub Commission for Europe

Founded in 1987

Members of EUREF are the European countries (following the IUGG membership rules)

Contributors to EUREF are hundreds of agencies and institutions providing data, resources, and manpower on a voluntary basis

EUREF provides all its products on the „best effort“ basis and free of charge to the public

IAG: International Association of Geodesy
IUGG: International Union of Geodesy and Geophysics
WHAT IS EUREF?

Main objectives of EUREF are the maintenance of the

- European Terrestrial Reference System (ETRS89)
- European Vertical Reference System (EVRS)

Basis and infrastructure for them are the

- EUREF (GNSS) Permanent Network (EPN)
- Unified European Levelling Network (UELN)


EUREF Permanent Network (EPN),
Currently some 350 permanent GNSS stations
EUREF AND ETRS89

At the global level we have the International Terrestrial Reference System and Frames (ITRS/ITRF)

For Europe we have the European Terrestrial Reference System, ETRS89, and its realizations:

ETRS89 is by its definition coincident with ITRS at epoch 1989.0, and fixed to the stable part of the Eurasian Plate, i.e. velocities in ETRS89 are related to the “stable part” of the Eurasian Tectonic Plate.

ETRS89 is mandatory for data exchange under the INSPIRE Directive 2007/2/EC, within EU member countries.
EPN Densification [https://epnd.sgo-penc.hu/](https://epnd.sgo-penc.hu/)

Based on EPN, but complemented by computed weekly position solutions from some 20 networks. Today “some 3000” stations.

*Evolves towards common EUREF – EPOS products!!*
Maintain the governance of TCS GNSS Data & Products in EPOS;

Interact with the geodetic community in Europe, at national and Pan-European (EUREF) levels;

Ensure interoperability between EPOS GNSS services (data and products) and EPOS ICS;

Promote multidisciplinary interoperability with other disciplines within EPOS;

Implement distributed dissemination of file-based GNSS data (currently for ~1150 stations), and derived Products: CRD, VEL, STR (currently ~2700 stations).
**EPOS-GNSS**

**EPOS**

**TCS GNSS Data & Products Community**

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**GNSS TCS (EPOS-ERIC) Partners**

**List of Pan-European Service Providers:**

- **BKG** Bundesamt für Kartographie und Geodäsie, DE
- **CNRS-OCA** Observatoire Cote d’Azur, FR
- **CNRS-UGA** Université Grenoble Alpes, FR
- **INGV** Istituto Nazionale di Geofisica e Vulcanologia, IT
- **LM** Lantmäteriet, SW
- **LTK** Lechner Knowledge Center, HU
- **ROB** Royal Observatory of Belgium, BE
- **UBI/C4G** U. Beira Interior/Colaboratory for Geosciences, PT
- **WUT** Warsaw University of Technology, PL

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- **5 Product Centers**
- **3 Portals (M3G, Data, Products)**
- **11 Service Providers**

**Data Providers** (National Research Infrastructures)

- **EUREF** (Data, Data Products & Services)
Not all EPOS-GNSS services are fully operational:
- GNSS network is being build
- GNSS data flow is set up
- GNSS products are being refined

The services that are working are under test

EPOS ambition
Provide access to data from ~3000 GNSS stations
GENERAL GNSS STATION REQUIREMENTS

1. Permanently tracking GNSS stations
   a) Presently active
   or
   b) Decommissioned stations that worked for minimally 3 years

2. Provide free access to daily RINEX data (v2 or v3)

3. Maintain station metadata (site log + other metadata)
Note that the M3G GNSS metadata service is common for EUREF and EPOS and possibly other network stations

https://gnss-metadata.eu
DATA PORTAL

http://gnssdata-epos.oca.eu/

More Details: DATA PORTAL - HOW TO DOWNLOAD DATA & METADATA, M. Vergnolle & J-L Menut
PRODUCTS PORTAL

http://gnssproducts.epos.ubi.pt/

More Details: PRODUCTS - WHAT PRODUCT FOR WHAT USAGE?, Anne Socquet
PRODUCTS PORTAL - HOW TO DOWNLOAD PRODUCTS, M. Bos & J. Manteigueiro
EPOS GNSS work flow
Who contributes to EPOS GNSS Products?

Pan-European Service providers for EPOS-GNSS Products:
- 5 Analysis Centers
- 1 Product Gateway
- 4 Other Product-Related Services

National contributions to EPOS-GNSS Products:
- 16 EUREF Analysis Centers
- 30 Analysis Centers for EPOS-EUREF-Densified

Who contributes to EPOS GNSS Products?
What are the GNSS products?

- Daily / Weekly
- Position Time Series
- Secular velocities
- Strain rate maps
- GNSS DATA AND PRODUCTS
What are the different products labels? What are their specificities?

**EPOS, EUREF, EPOS-EUREF**

**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 **open-source softwares**
- **Specifically designed for geophysical studies** (including for slow movements)
  - Each solution is internally-consistent, generated @ a single Pan-European processing center with one strategy

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

- 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

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**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

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**Positions Time Series Velocities Quality Check**

- Automated outlier rejection, introduction of discontinuities in time series
- Velocities Computed with MIDAS, station classification based on uncertainty
What are the different products labels? What are their specificities?

**EPOS, EUREF, EPOS-EUREF**

**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)

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**Regional daily position solution**

- @ 16 EPN Analysis Centers
  - each station processed by at least 3 ACs to insure redundancy and increase reliability
  - 3 softwares: Bernese, Gamit, Gipsy

**Daily and Weekly Combined Positions**

- @ EPN Analysis Combination Center
  - 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
  - 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
What are the different products labels? What are their specificities?

EPOS, EUREF, EPOS-EUREF

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

➢ 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)
WHAT PRODUCTS FOR WHAT USAGE? USE CASES

UC1: Structural geologist wants to get the secular displacement rates and the strain rate maps in Spain

Recommended products:
- EPOS–EUREF densified Velocity field from LTK rotated wrt Stable Europe
- Strain Rate products from LM

Additional products:
- EPOS velocity fields from INGV and UGA-CNRS rotated wrt stable Europe
- EUREF velocity field from ROB-WUT rotated wrt stable Europe

Secular GNSS Velocities (EPOS-EUREF solution)

Style of Deformation

Strain Rate

Piña Valdes et al., in prep
WHAT PRODUCTS FOR WHAT USAGE? USE CASES

UC2 : Seismologist wants to get the time series associated with the 2016 earthquake sequence in Italy

Recommended products :
- EPOS daily time series from INGV and UGA-CNRS

Additional products :
- EUREF daily time series from ROB-EUREF
- EPOS-EUREF densified weekly time-series from LTK

EPOS position times series showing displacements associated with Amatrice (Mw 6.2) & Norcia (Mw 6.1) earthquakes
WHAT PRODUCTS FOR WHAT USAGE? USE CASES

UC3: Volcanologist wants to get updates on time series in the area affected by recent volcanic unrest

Recommended products:
- EPOS daily time series from UGA-CNRS (rapid solution)

Additional products:
- EPOS daily time series from INGV
- EUREF daily time series from ROB-WUT

Inflation/deflation processes before/after an eruption onset at Mt Etna (modified from Bruno et al., 2012)
UC4: Geodynamicist wants 3D velocities to constrain models of isostatic rebound

**Recommended products:**
- EPOS–EUREF densified Velocity field from LTK rotated wrt Stable Europe

**Additional products:**
- EPOS velocity fields from INGV and UGA-CNRS rotated wrt stable Europe
- EUREF velocity field from ROB-EUREF rotated wrt stable Europe

Horizontal & Vertical velocities of EPOS-EUREF solution compared to model of Glacial Isostatic Adjustment NGK2016LU (Vestol et al. 2019)
WHAT PRODUCTS FOR WHAT USAGE? USE CASES

UC5 : Geodesist wants to get reference positions and velocities for his processing

Recommended products:
- EUREF Positions and Velocities (SINEX format) from ROB-EUREF wrt ITRF2014 or ETRF2000/2014

Additional products:
- EPOS–EUREF Positions and Velocities (SINEX format) from LTK wrt ITRF2014

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**ITRF2014 (IGb14)**

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Thanks a lot for your attention!

Martin.lidberg@lm.se