Guidelines for EUREF Densifications

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(1) Royal Observatory of Belgium

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EUREF Symposium, Online from Ljubljana, 26 May 2021

Context

- Guidelines for EUREF densification campaigns
  - *procedure for*
    - *computing station coordinates (and velocities) in the ETRS89*
    - *requesting a validation of the densification campaign by the EUREF GB*
  - *framework: national densification campaigns of the ETRS89*
  - No link with the “EPN Densification Working Group“

- Guidelines have been updated and adopted by the EUREF GB (April 2021)
  - Announced in EUREF Mail 10683 (12/05/2021) https://epncb.oma.be/ftp/mail/EUREF/eurefmail.10683
  - Added clarifications (criteria for reference station selection, velocity estimations,…)
  - Removed classification (A/B) of EPN reference stations
  - Introduced the Tool for reference stations selection
  - Included the IGb14 reference frame

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Content

- **Set Up of the Campaign**
- GNSS Data Analysis
- Stacking and Reference Frame Definition
- Transformation to ETRFYYYY
- Validation by the EUREF Governing Board

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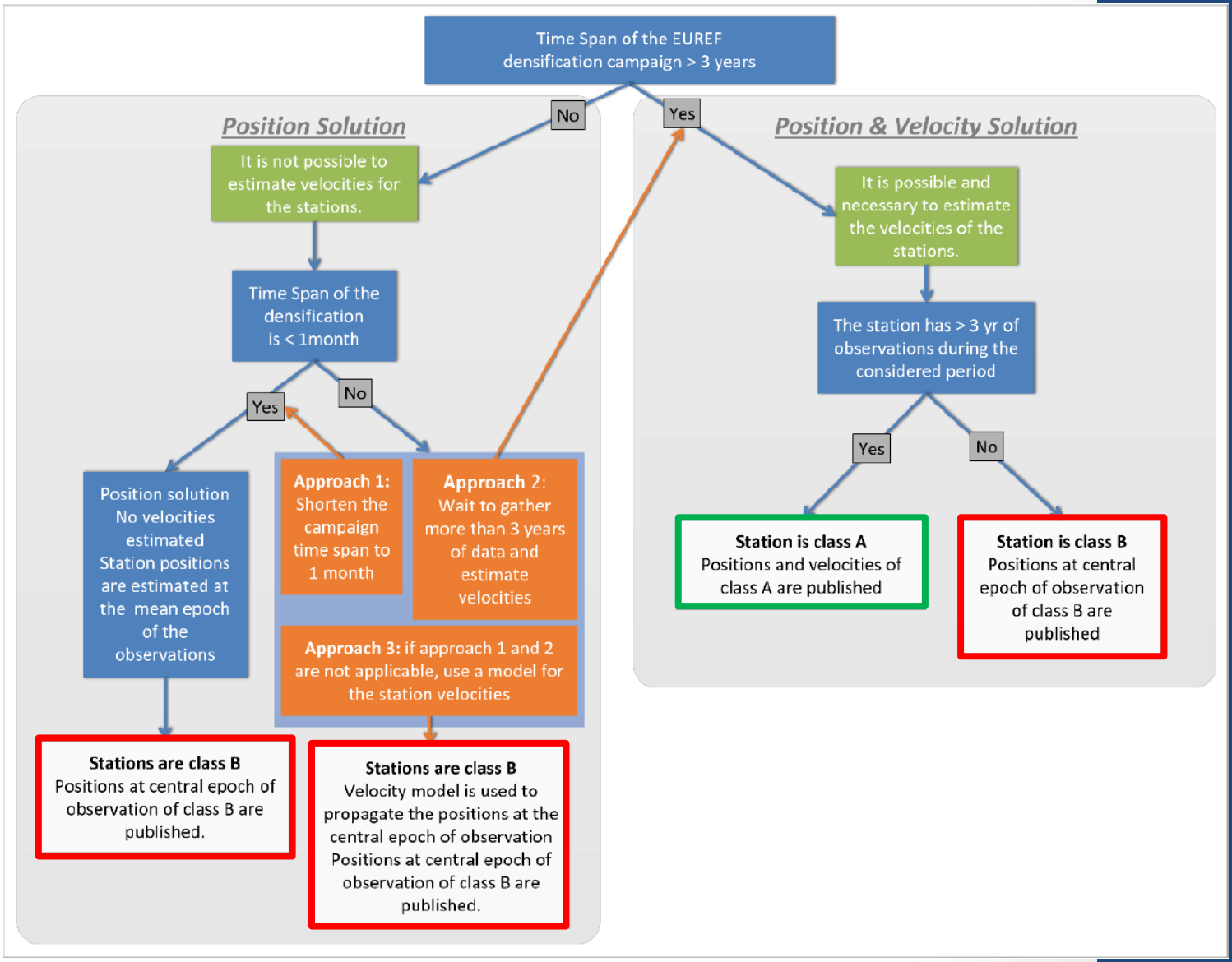
Set up of the campaign

- EUREF densification campaign:
  - GNSS observation campaigns:
    - Few days/weeks (> 3 days)
    - Longer duration of time:
      - Permanent GNSS stations (preferred)
      - Repeated GNSS observations (discouraged)
- Duration of the campaign
  - **Class A** (> 3 years of observation)
    - Positions (precision: 1cm at all epochs)
    - Velocities (precision: 1 mm/yr)
  - **Class B**
    - Positions (precision: 1cm at the epoch of minimal variance)
- Reference Frame Product



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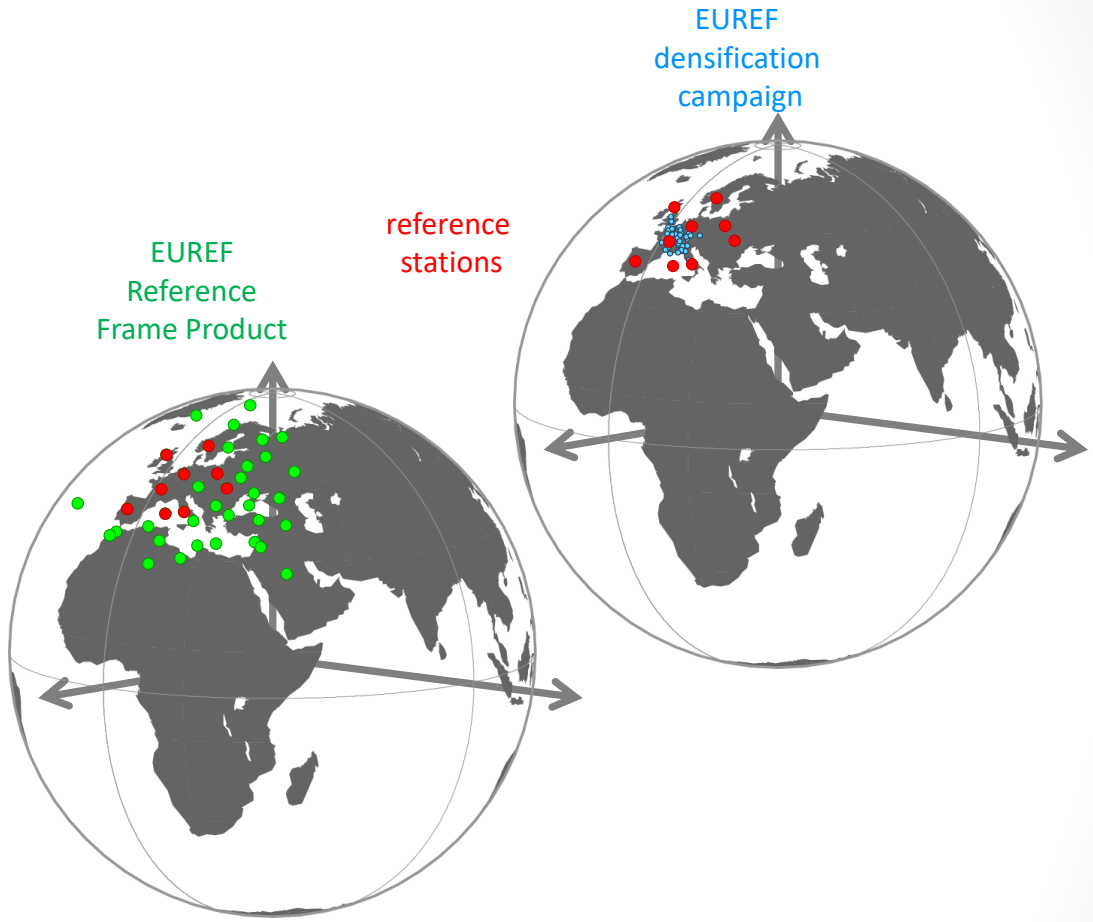
Reference Frame Definition

- Goal: Positions (and velocities) of the EUREF densification campaigns reliably expressed in ETRS89
  - Positions (and velocities) consistent with other countries
- Reference frame definition done by aligning the positions (and velocities) of your EUREF densification campaign wrt to the positions (and velocities) of a reference frame solution using reference stations
- Good consistency between the positions (and velocities) of the EUREF densification campaign and the positions (and velocities) of the reference frame product
- EUREF Reference Frame Product



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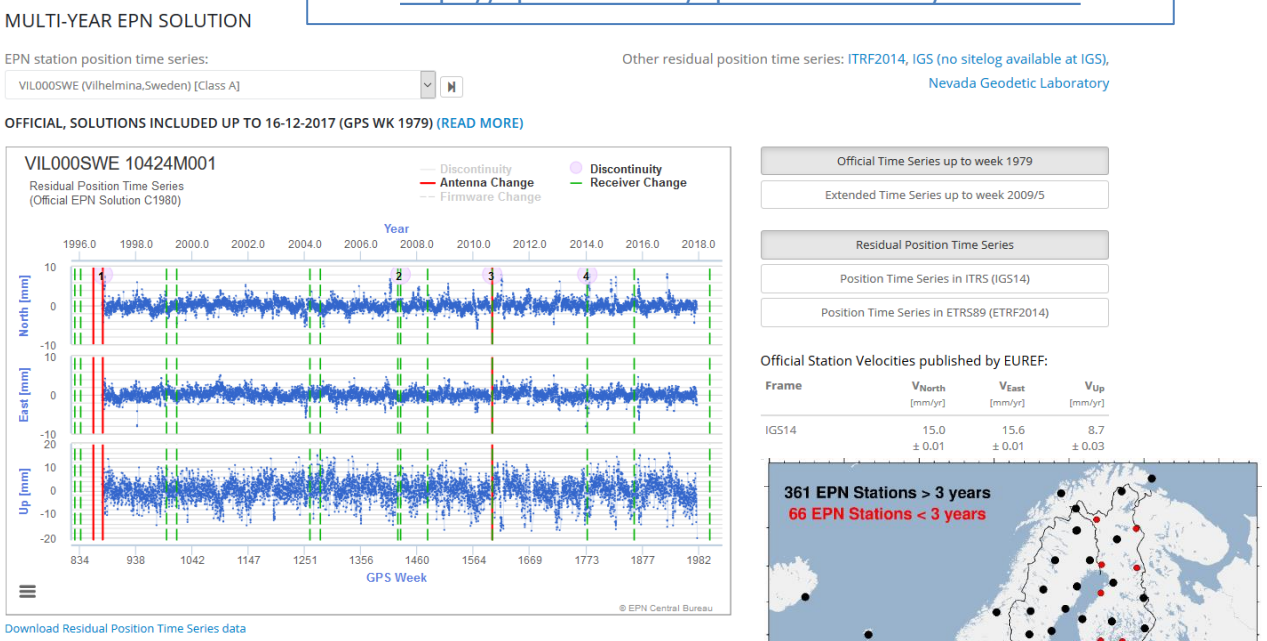
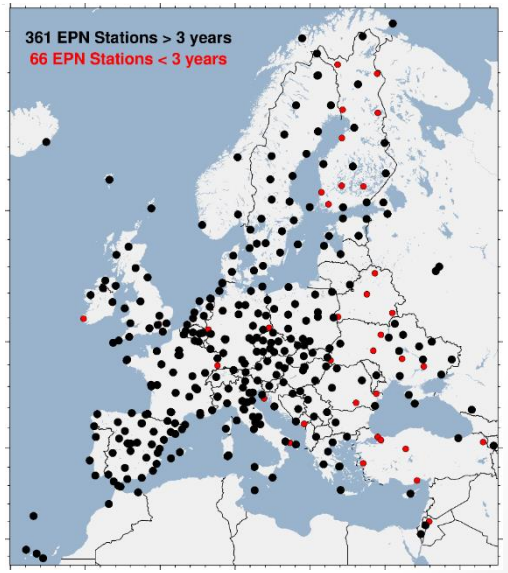
Which product: EUREF Reference Frame Product

- Multi-year position & velocity solution
  - using **CATREF** [Altamimi et al. 2007]
  - expressed in **IGb14**
- EPN **daily** SINEXs: 1996-now
  - **EPN-repro2** solutions (1996-2013)
  - Operational solutions (2014-now)
- Solution is **updated each 15 weeks**:
  - Official Positions & Velocities in IGb14, ETRF2000 and ETRF2014 for stations with more than 3 years (360+ stations)
  - List of position & velocity discontinuities
  - List of daily outliers
  - Cleaned position time series
- Rapid time series (updated on a daily basis)

https://epncb.oma.be/_productsservices/timeseries





https://epncb.oma.be/_productsservices/coordinates

DOI of the last EPN Reference Frame Product
https://doi.org/10.24414/ROB-EUREF-C2145

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EUREF Reference Frame Product: What changed ?

	Before C2145	After C2145
Velocities published for	Class A stations	Stations > 3 years No post-seismic deformation model applied
Files for stations with velocities	282 stations EPN_A_[IGb14/ETRF2000/ETRF2014]	360 stations EPN_[IGb14/ETRF2000/ETRF2014]
Files for stations with positions only	151 stations EPN_B_[IGb14/ETRF2000/ETRF2014]	73 stations EPN_[IGb14/ETRF2000/ETRF2014]_short
How to evaluate the quality of the stations?	A or B	New station categories “On-line Reference Station Selection Tool”

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Which stations: Criteria for the selection of the reference stations

- Same basic principles as in the previous version of guidelines
- But,
  - more detailed
  - more reference stations should be included in the processing
    - 15 a priori stations
    - 10 after checking the position and velocity agreement between the densification campaign and the EUREF reference frame product

- To help the user:
  - station categories
  - “On-line Reference Station Selection Tool”

See next presentation
“On-line Reference Station Selection Tool”

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GNSS data analysis

- How to estimate daily positions?

Goal: Good consistency between the densification solutions and the EUREF reference frame solution!

- Network approach

- GNSS data
  - Equipment: comply with "**Guidelines for EPN Stations and Operational Centres**"
  - Antenna/radome with absolute antenna calibrations

- GNSS processing options:
  - Conform with procedure used by EPN Analysis Centers
    - IGS orbits and ERP
    - Absolute antenna calibrations (epn_14.atx)
    - **Guidelines for EPN Analysis Centres**
    - Minimal Constraints to align daily solutions to the EUREF reference frame solution (IGb14)

- Verifications (ambiguity resolution, daily agreement with reference solution, gross outliers)

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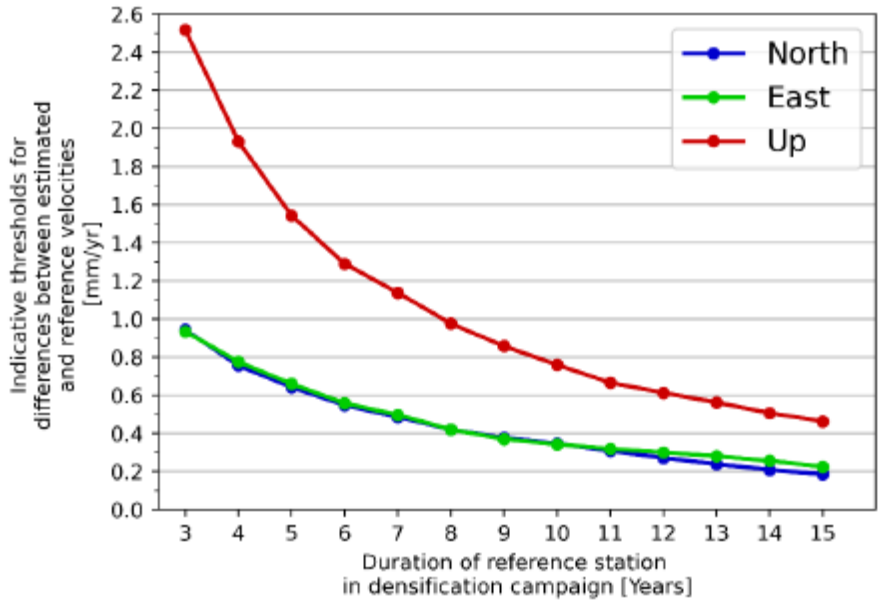
Stacking and computation of ITRFYYYY coordinates

- Stacking of the daily solutions to estimate positions (and velocities) at the central epoch of observations
- Align to EUREF reference frame product (IGb14) using minimal constraints on positions (and velocities) using a selection of reference stations

- Verifications:
  - Outliers rejection
  - Positions changes $\Rightarrow$ discontinuities
  - For EPN stations:
    - Agreement with EUREF reference frame product
      - Discontinuities/outliers
      - Positions and velocities
    - Reference stations: check the agreement of positions and velocities, reject stations, iterate
      - Positions (expected 5 mm, max 1 cm)
      - Velocities (threshold is function of the number of years)



Indicative thresholds for difference between estimated velocities and EUREF reference frame velocities.

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Transformation to ETRS89

- Convert IGb14/ITRF2014 positions at t_0 and velocities to ETRFYYYY
  - using **EUREF TN-1 (Altamimi, 2018)**

    http://etrs89.ensg.ign.fr/pub/EUREF-TN-1.pdf

  - using **ETRS89/ITRS transformation tool** on the EPN web site

    https://epncb.oma.be/_productsservices/coord_trans/

- Verifications:
  - Compare to previous EUREF densification campaigns

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- **Validation by the EUREF Governing Board**

Validation by GB and deliverables

- Announce to GB chair one month prior to GB
- Submit written report and deliverables 2 weeks prior to GB
- Present results at GB

6 Validation and Deliverables

If validation by the EUREF Governing Board (GB) is requested, then a full report of the EUREF densification campaign must be submitted to the EUREF GB at least 2 weeks before the next GB meeting and the analysis centre should present the results at this EUREF GB meeting.

6.1 Report to EUREF Governing Board

The report should contain:

1. Description of the densification project
   a. List of densification stations (full names, 9-char ID, DOMES numbers, map)
   b. Observation period (duration, permanent, campaign type)
   c. GNSS equipment (IGS standard names for receiver and antenna/radome) and elevation cut off setting
   d. Monument description
2. Other data used in the processing
   a. List of reference stations and list of verifications performed to check their performance during the time frame of the densification project
   b. If used, list of daily combined EPN SINEX solutions
   c. Orbits, ERP
   d. Antenna calibration models
3. Processing strategy
   a. Software (and version)
   b. Schematic processing method
   c. Elevation cut off
   d. Positioning mode (using the so-called "network approach")
   e. Modelling of loading effects
   f. Ambiguity resolution strategy
   g. Modelling of troposphere (e.g. a priori model, mapping function, constraints, gradients, ...)
   h. Modelling of ionosphere (e.g. higher order corrections)
   i. As far as they exist, alternative strategies used for test purposes
4. Results from the daily processing
   a. Daily mean ambiguity resolution percentages, separated per system in case of a multi-GNSS solution
   b. Daily agreement in North, East, and Up component between the estimated ITRS coordinates of the reference stations and their coordinates in the EUREF reference frame solution
5. Method of stacking the daily solutions
   a. Method for stacking the daily network solutions in one densification solution
   b. Parameters used to tie the densification solution to the EPN reference stations: name of the EPN SSC file (see section 3.2), parameters of the minimum constraint procedure, including list of EPN reference stations and used reference coordinates/velocities (and validity periods)
   c. List of introduced discontinuities
6. Results from stacking the daily solutions
   a. Residual position time series: comparison of the daily coordinate estimates of each station (repeatabilities in North, East and Up) with respect to the stacked solution. Outliers should be identified, explained and eliminated.
   b. Comparison between estimated coordinates (and velocities, if applicable) and reference coordinates (and velocities, if applicable) in EPN_IGb14_CWWWW.SSC, expressed in North, East and Up. Stations used as reference stations should be listed/mentioned (used in 5.b).
7. Transformation to ETRS89
   a. Transformation to the ETRS89 (including parameters used and selected realization)
   b. Comparison between new ETRS89 coordinates and ETRS89 coordinates from previous ETRS89 campaigns (expressed in North, East and Up).

Remark: the SINEX files must be compliant with the official specifications and contain all the mandatory blocks.

6.2 Deliverables

Once the densification has been validated by the GB, it will be included in the EUREF densification data base. For that purpose, the following deliverables need to be submitted to the EUREF GB:

1. Site description forms (complete the appropriate fields in the Site Information Form available from ftp://epncb.oma.be/pub/station/general/blank.log)
2. Minimally constrained solution that is aligned to the EUREF reference frame product in SINEX format
3. List of position and velocity discontinuities (soln) of the densification solution
4. List of coordinates for all stations in the network in the ITRS at epoch of observation
   or
   List of coordinates and velocities for all stations in the network in the ITRS (for densification campaigns requiring velocity estimation)
5. List of coordinates for all stations in the network in the ETRS89 (indicate the frame used) at the epoch of observation
   or
   List of coordinates and velocities for all stations in the network in the ETRS89 (indicate the frame used)
6. List of EPN reference stations
7. Coordinates and velocities used for the EPN reference stations (including their validity period and name of the EPN_IGb14_CWWWW file, see 3.2.)

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Conclusions

- "**Guidelines for EUREF densifications**"
  - How to compute station coordinates (and velocities) in the ETRS89 using the EUREF Reference Frame Product
  - New version published https://doi.org/10.24414/ROB-EUREF-Guidelines-DENS

- **EUREF Reference Frame Product**
  - Class A/B for EPN reference stations replaced by more detailed station categorization
    - Files EPN_A_[IGb14/ETRF2000/ETRF2014] and EPN_B_ [IGb14/ETRF2000/ETRF2014] are not maintained any more
    - replaced by EPN_[IGb14/ETRF2000/ETRF2014] and EPN_[IGb14/ETRF2000/ETRF2014]_short
  - See EUREF Mail 10683 (12/05/2021) https://epncb.oma.be/ftp/mail/EUREF/eurefmail.10683

- Tool for selection of reference stations

See next presentation
"On-line Reference Station Selection Tool"

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Links

EUREF Permanent Network Central Bureau

https://epncb.oma.be/

EUREF Reference Frame Product

https://epncb.oma.be/_productsservices/coordinates/

https://epncb.oma.be/_productsservices/timeseries/

Guidelines for EUREF densifications

https://doi.org/10.24414/ROB-EUREF-Guidelines-DENS

Tool

https://epncb.oma.be/_productsservices/ReferenceFrame/

Background on the Station Categories

https://epncb.oma.be/_productsservices/ReferenceFrame/Station_Classification.php

Background on the tool

https://epncb.oma.be/_productsservices/ReferenceFrame/Tool.php

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