ROYAL OBSERVATORY OF BELGIUM

Guidelines for EUREF Densifications

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EUREF Tutorial
May 24, 2016
San Sebastian, Spain

EPN CB: www.epncb.oma.be

ROYAL OBSERVATORY OF BELGIUM

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- Equipment & calibration
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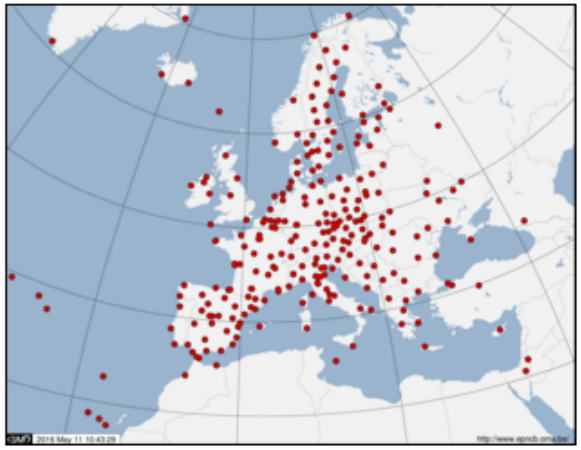
Welcome !

EUREF Permanent GNSS Network

The European Terrestrial Reference System 89 (ETRS89) is used as the standard precise GPS coordinate system throughout Europe. Supported by EuroGeographics and endorsed by the EU, this reference system forms the backbone for all geographic and geodynamic projects on the European territory both on a national as on an international level.



The ETRS89 is maintained by the IAG sub-commission EUREF and it is accessed through the EUREF Permanent GNSS Network (EPN), a science-driven network of continuously operating GPS reference stations with precisely known coordinates in the ETRS89.

All contributions to the EPN are voluntary, with more than 100 European agencies/universities involved, and the reliability of the network is based on redundancy and extensive guidelines guaranteeing the quality of the raw GPS

tation Links

Information | Coordinates

(select a station)

Last Updated/New Pages

2016-04-14 : Official ITRF2014 coordinates/velocities issued by the IERS added to the individual station coordinates web page (e.g. ACOR00ESP).

2016-02-02 : New page showing the actual tracking status.

2016-01-29 : Real-time web page updated.

More ...

Next Meetings

Guidelines

EPN Guidelines

Procedure for Becoming an EPN Station	Last updated: December 18, 2013
Guidelines for EPN Stations and Operational Centres	Last updated: October 26, 2015
Guidelines for EPN Data Centres & EPN Broadcasters	Last updated: March 17, 2015
Guidelines for EPN Analysis Centres	Last updated: Nov. 19, 2013

EUREF Guidelines

Specifications for Reference Frame Fixing in the Analysis of a EUREF GPS Campaign	Last updated: April 27, 2011
Guidelines for EUREF Densifications (previously know as "EUREF Campaign Guidelines")	Last updated: May 28, 2013

IGS Guidelines

IGS New Site Checklist	Last updated: December 21, 2006
IGS Site Guidelines	Last updated: July 06, 2015
Monumentation Design and Implementation Recommendations	Last updated: September 22, 2009

Recommendations

CSTG guidelines for "The International Space Geodetic and Gravimetric Network (ISGN)"	Last updated: January 11, 2001
Real-Time GNSS in Routine EPN Operations (Concept)	Last updated: December 03, 2006

ftp://epncb.oma.be/pub/general/Guidelines_for_EUREF_Densifications.pdf

Guidelines for EUREF Densifications

C. Bruyninx[1], Z. Altamimi, A. Caporali, A. Kenyeres, M. Lidberg, G. Stangl, and J.A. Torres
Questions or remarks can be directed to epncb@oma.be

Version 1: 26-05-2009
Version 2: 04-05-2010: Minor corrections/clarifications based on user feedback
Version 3: 24-05-2012: Encourage the use of GLONASS observations
Version 4: 13-06-2012: Modified links due to the EPN CB web site restructuring
Version 5: 28-05-2013: Replacement of ITRF2005 with IGb08 and additional clarifications

This document outlines the procedure recommended for computing station coordinates in the ETRS89 (European Terrestrial Reference System), in particular in the framework of national densifications of the ETRS89. The document also describes how to proceed to request a EUREF validation of the densification.

CONTENT

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Goal of this document

Guidelines to

- derive positions/velocities expressed in the ETRS89 using data from the EUREF Permanent Network

- report to the TWG about the computation in case a validation of the ETRS89 densification is desired

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Selection of the GNSS Network

GNSS Data – Densification sites

These are the stations for which you wish to submit new ETRS89 coordinates to the EUREF TWG for validation

- They are NOT EPN stations
- Equipment should comply with requirements for EPN stations, see “Guidelines for EPN Stations and Operational Centers”
- Antenna/radome with absolute antenna calibrations *(same requirements as for an EPN station)*
- At least 3 days / 24 hours observations

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GNSS Data – Reference Stations

LAST ITRS densification of the EPN:

EPN class A stations (EPN_A_IGb08.SSC, POS+VEL)

Step 1:

Select

- at least 5 Class A EPN reference stations **around** the densification area (the more the better, and the larger the geographical area, the better)
- + all Class A EPN stations in the densification area

Step 2

Check for each station from step 1 time series at EPN CB

- Data availability during densification
- Antenna change during densification and after date of last Class A realisation
- Avoid stations with noisy time series or large periodic signals

GNSS Data – Reference Stations

LAST ITRS densification of the EPN:

ftp://epncb.oma.be/pub/station/coord/EPN

EPN class A stations

EPN_A_IGb08.SSC → EPN_A_IGb08_C1875.SSC (POS+VEL)

EPN_A_IGb08.SNX.Z → EPN_A_IGb08_C1875.SNX.Z

```
             CLASS_A EPN STATION POSITIONS AND VELOCITIES
             REFERENCE FRAME:    IGb08 AT EPOCH OF 2005.0
             CUMULATIVE SOLUTION OF GPSWEEKS [  834 - 1875 ]
             RELEASE NAME: EPN_A_IGb08_C1875
             RELEASED ON 19/02/2016 BY EPN REFERENCE FRAME COORDINATOR(AMBRUS KENYERES, FOMI, HUNGARY)
DOMES NB. SITE NAME       TECH. ID.       X/Vx         Y/Vy         Z/Vz          Sigmas       SOLN  DATA_START    DATA_END    REF. EPOCH
            CLASS                    ----------------------------m/m/Y-------------------------
-------------------------------------------------------------------------------------------------------------------------------------------
13434M001 ACOR            GPS ACOR  4594489.710  -678367.775  4357066.136  0.001  0.000  0.001  1 99:237:00000 00:001:86370 05:001:00000
13434M001       A                       -0.0098       0.0228       0.0104 0.0001 0.0000 0.0001
13434M001 ACOR            GPS ACOR  4594489.706  -678367.770  4357066.139  0.000  0.000  0.000  2 00:044:00000 07:031:86370 05:001:00000
13434M001       A                       -0.0098       0.0228       0.0104 0.0001 0.0000 0.0000
13434M001 ACOR            GPS ACOR  4594489.704  -678367.773  4357066.134  0.000  0.000  0.000  3 07:091:00000 15:353:86370 05:001:00000
13434M001       A                       -0.0098       0.0228       0.0105 0.0001 0.0000 0.0000
10077M005 AJAC            GPS AJAC  4696989.433   723994.475  4239678.541  0.000  0.000  0.000  1 00:022:00000 08:221:86370 05:001:00000
10077M005       A                       -0.0136       0.0194       0.0120 0.0001 0.0000 0.0001
10077M005 AJAC            GPS AJAC  4696989.438   723994.465  4239678.548  0.000  0.000  0.000  2 08:354:00000 12:343:86370 05:001:00000
10077M005       A                       -0.0136       0.0194       0.0120 0.0001 0.0000 0.0001
10077M005 AJAC            GPS AJAC  4696989.437   723994.475  4239678.546  0.001  0.000  0.001  3 12:344:00000 15:331:86370 05:001:00000
10077M005       A                       -0.0136       0.0194       0.0120 0.0001 0.0000 0.0001
13433M001 ALAC            GPS ALAC  5009051.189   -42072.196  3935057.741  0.000  0.000  0.000  1 99:215:00000 06:050:00000 05:001:00000
13433M001       A                       -0.0100       0.0201       0.0133 0.0001 0.0000 0.0001
13433M001 ALAC            GPS ALAC  5009051.188   -42072.202  3935057.742  0.000  0.000  0.000  2 06:204:00000 10:261:00000 05:001:00000
```

CLASS_A EPN STATION POSITIONS AND VELOCITIES
REFERENCE FRAME: IGb08 AT EPOCH OF 2005.0
CUMULATIVE SOLUTION OF GPSWEEKS [834 - 1875]
RELEASE NAME: EPN_A_IGb08_C1875
RELEASED ON 19/02/2016 BY EPN REFERENCE FRAME COORDINATOR(AMBRUS KENYERES, FOMI, HUNGARY)

DOMES NB.	SITE	NAME CLASS	TECH. ID.	X/Vx	Y/Vy	Z/Vz	Sigmas	SOLN	DATA_START	DATA_END	REF. EPOCH
				----------m/m/Y----------							
13434M001	ACOR		GPS ACOR	4594489.710	-678367.775	4357066.136	0.001 0.000 0.001	1	99:237:00000	00:001:86370	05:001:00000
13434M001		A		-0.0098	0.0228	0.0104	0.0001 0.0000 0.0001				
13434M001	ACOR		GPS ACOR	4594489.706	-678367.770	4357066.139	0.000 0.000 0.000	2	00:044:00000	07:031:86370	05:001:00000
13434M001		A		-0.0098	0.0228	0.0104	0.0001 0.0000 0.0000				
13434M001	ACOR		GPS ACOR	4594489.704	-678367.773	4357066.134	0.000 0.000 0.000	3	07:091:00000	15:353:86370	05:001:00000
13434M001		A		-0.0098	0.0228	0.0105	0.0001 0.0000 0.0000				
10077M005	AJAC		GPS AJAC	4696989.433	723994.475	4239678.541	0.000 0.000 0.000	1	00:022:00000	08:221:86370	05:001:00000
10077M005		A		-0.0136	0.0194	0.0120	0.0001 0.0000 0.0001				

Last data for ACOR included: 353/2015

Campaign period included in period covered by Class A coordinates

OK, ACOR can be used as reference station

Campaign period not included in period covered by Class A coordinates (more recent campaign)

Check ACOR time series (quick update) and verify no coord jump since last Class A computation

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

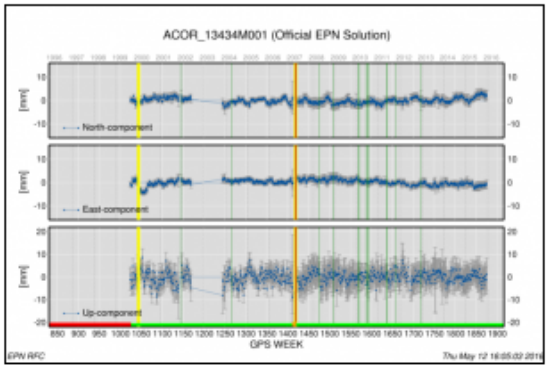
PRODUCTS & SERVICES > POSITION TIME SERIES > **ACOR00ESP (A Coruna, Spain)**

EPN station position time series:
(select a station)

Other residual position time series: ITRF2008

MULTI-YEAR EPN SOLUTION

Official, solutions included up to December 13, 2015 (GPS wk 1875)



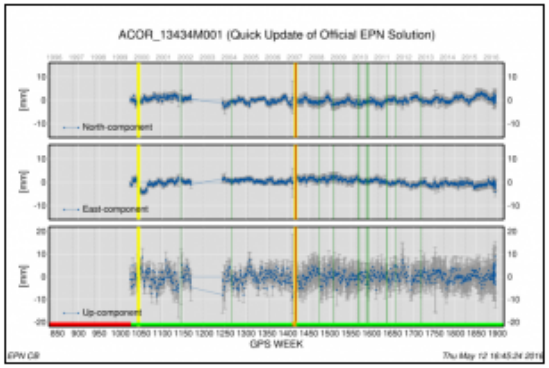
Residual position time series of the cumulative EPN solution (tied to IGS08) with as input:

1. the reprocessed weekly EPN solutions up to GPS week 1408 (corrected to be in accordance with the epn_08.atx antenna calibration model)
2. the weekly (routine) EPN solutions from GPS week 1409 till 1631 (corrected to be in accordance with the epn_08.atx antenna calibration model)
3. the weekly (routine) EPN solutions from GPS week 1632 till 1875

The North, East, Up-components are the position residuals with respect to the estimated station positions and velocities. During the estimation, position outliers have been eliminated and discontinuities have been introduced.

Display outliers eliminated from combination: 1141-1141, 1176-1233
Display estimated position shifts
Download residual time series data

Extended, solutions included up to May 11, 2016 (GPS wk 1896 dow 3)



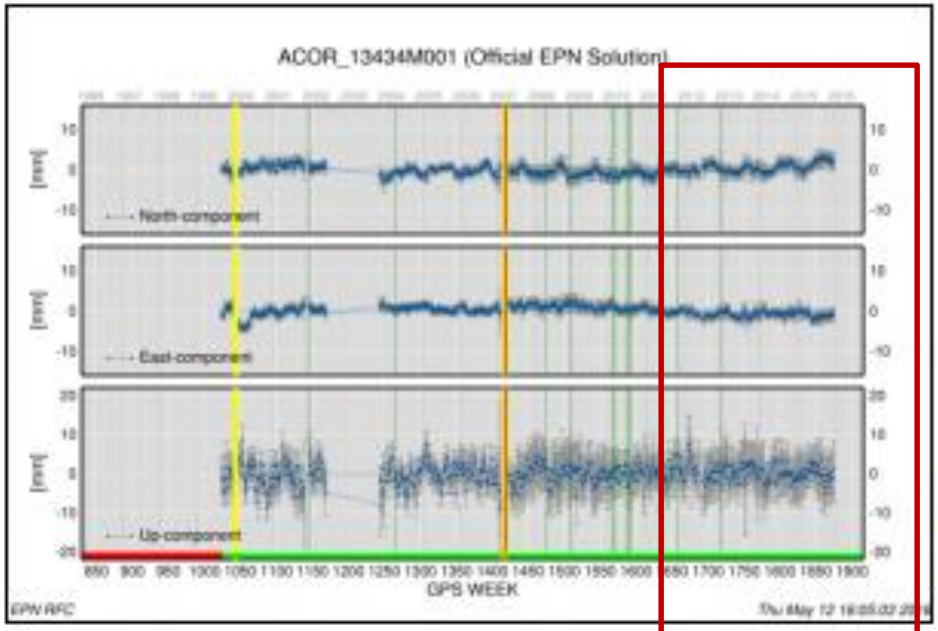
Residual position time series of the cumulative EPN solution with as input:

1. the reprocessed weekly EPN solutions up to GPS week 1408 (corrected to be in accordance with the epn_08.atx antenna calibration model)
2. the weekly (routine) EPN solutions from GPS week 1409 till 1631 (corrected to be in accordance with the epn_08.atx antenna calibration model)
3. the weekly (routine) EPN solutions, from GPS week 1632 till 1680
4. the weekly (routine) EPN solutions, from GPS week 1681 till 1891
5. the daily (routine) EPN solutions, from GPS week 1892 dow 0 till GPS week 1896 dow 3

The North, East, Up-components are the position residuals of each weekly (or daily) solution with respect to the estimated station positions and velocities.
Parts 1), 2) and 3) correspond to the latest official EPN solution and have been corrected for outliers and discontinuities.

MULTI-YEAR EPN SOLUTION

Official, solutions included up to December 13, 2015 (GPS wk 1875)



Residual p

1. the repr
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2. the wee
   antenna
3. the wee

The North,
velocities. D

Display outl
Display esti
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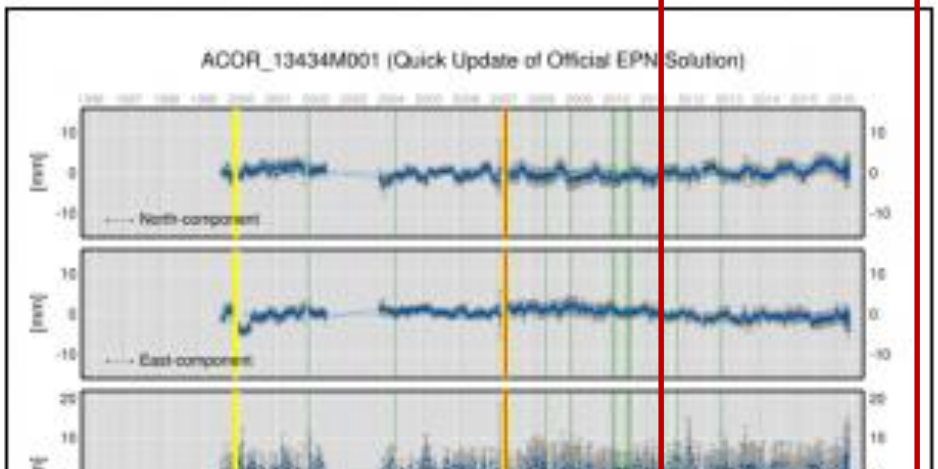
Extended, solutions included up to May 11, 2016 (GPS wk 1896 dow 3)



Residual p

1. the repr
   antenna
2. the wee
   antenna
3. the wee
4. the wee
5. the dail

OK, ACOR can be used as reference station

GNSS Data Analysis

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GNSS Processing Options

Conform with procedure used by EPN Analysis Centers

- Final IGS orbits and ERP (from IGS AC also accepted)
- Absolute antenna calibrations + individual where available
  ftp://epncb.oma.be/pub/station/general/epn_08.atx
- Daily network solutions (minimally constrained)

Guidelines for EPN Analysis Centres:
http://epncb.oma.be/_organisation/guidelines/proc_opt.pdf

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Stacking and Datum Definition

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Velocity Estimation?

- Stacking of daily network solutions

  → positions (& velocities?)

- If 3+ years → velocity estimation

- If 3- years:
  - if station coordinates in ETRS89 change due to intraplate deformations by more than 1 cm over project duration

    → Velocity estimation

Daily Stacking

- Goal to
  - create time series of daily coordinates
  - estimate coordinates (and velocities) for all stations included in the network (densification & reference stations)

- Input in the stacking:
  - daily SNX files
  - Reference station network information:

SSC file (coordinates & velocities)
EPN_A_IGb08.SSC
take into account
Epoch of coordinates
Solution numbers
(discontinuities + LINK)

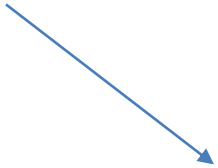
SNX file
EPN_A_IGb08.SNX

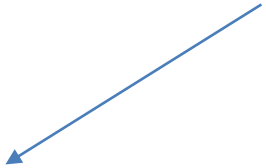
Reference Frame Alignment of Stacked Solution

Use Minimal Constraints :

Only coordinates

Coordinates and velocities





Recommendation on which parameters depends on software

- Translation only
- ….
- 7 parameters

Results

- ITRS (IGb08) coordinates @ epoch of observation
  - densification stations
  - reference stations

- ITRS (IGb08) coordinates and velocities
  - densification stations
  - reference stations

Transformation to ETRS89

- Convert estimated
  - ITRFyy positions at t_{obs}
  - ITRFyy positions and velocities

- to ETRS89 (Memo by Boucher and Altamimi)
  - ETRF2000 (current standard frame) for new projects
  - ETRFyy for comparisons with coordinates from previous national frames can be made

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

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Verification

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Verifications

- Daily coordinate repeatability (in North, East, Up)
  - ~1mm in the horizontal, ~3mm in the vertical

- Quality of chosen reference stations

  Agreement of estimated positions (and velocities) of the EPN reference stations with the reference positions (and velocities) EPN_A_IGb08.SSC

  - < 10 mm in position, < 3 mm/yr in velocity → OK
  - 10+ mm in position or/and 3 mm/yr in velocity → Eliminate affected station from list of reference stations (try to understand why – time series)

Verifications

- No velocity estimation?:
  - Check variation of ETRS89 positions over time. If more than 1 cm, then site velocities should have been estimated.

- Validity of ETRS89 coordinates:
  - Compare estimated ETRFyy coordinates with the ETRFyy coordinates obtained from previous EUREF densification campaigns (make sure to transform in same ETRS89 frame).

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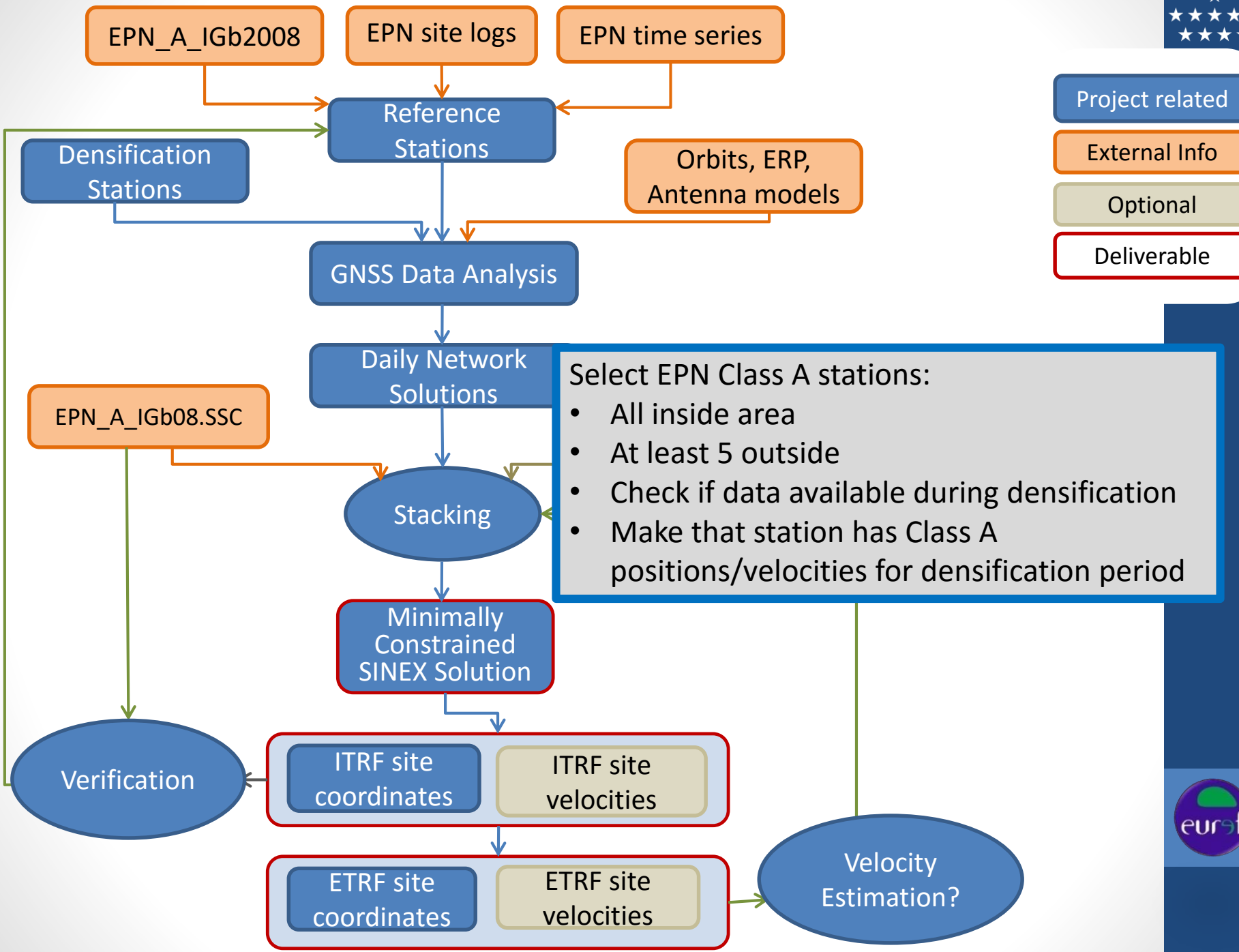
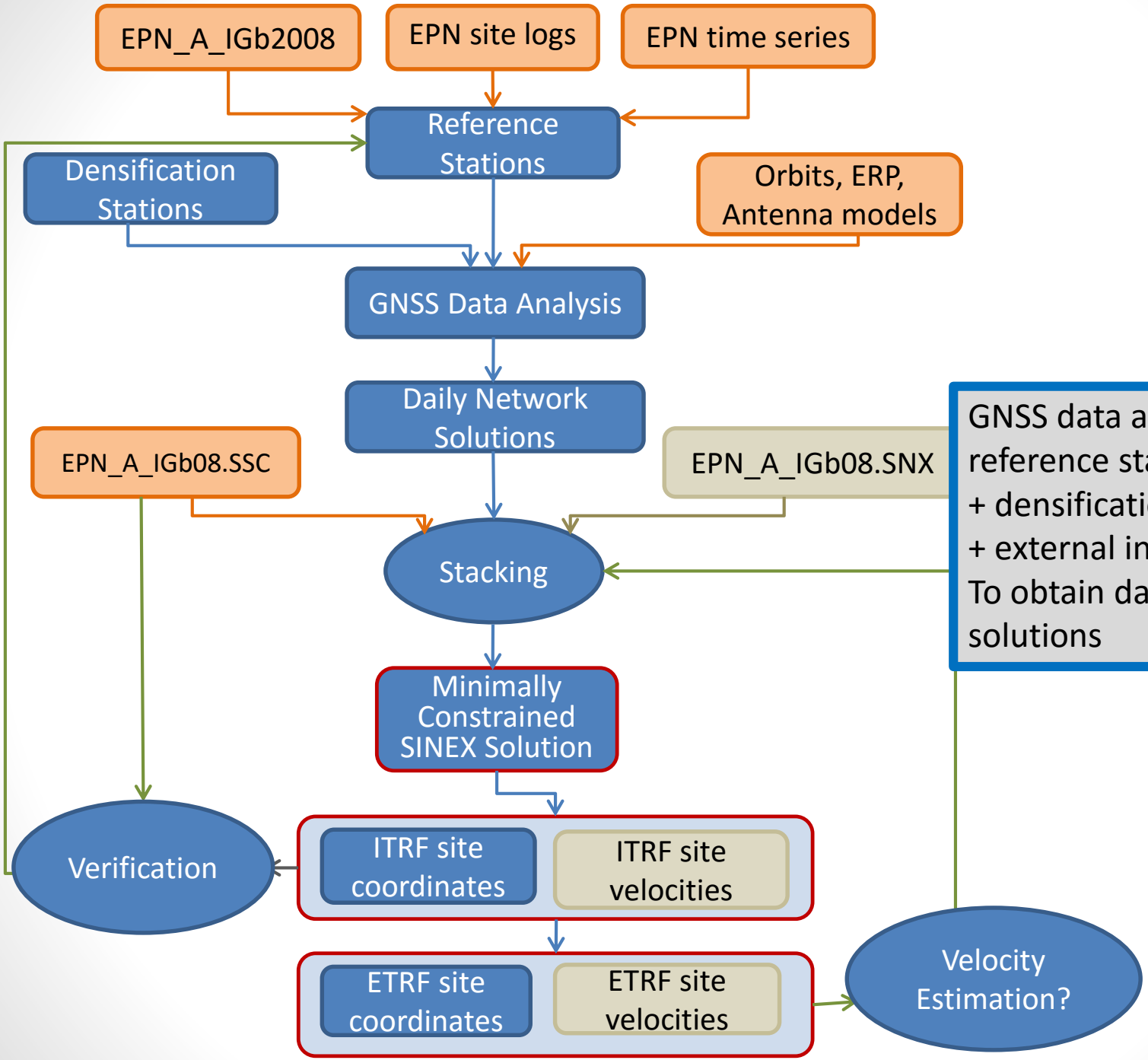
Summary of the Procedure


EPN_A_IGb2008
EPN site logs
EPN time series
Reference Stations
Densification Stations
Orbits, ERP, Antenna models
GNSS Data Analysis
Daily Network Solutions
EPN_A_IGb08.SSC
Stacking
Minimally Constrained SINEX Solution
Verification
ITRF site coordinates
ITRF site velocities
ETRF site coordinates
ETRF site velocities
Velocity Estimation?
Project related
External Info
Optional
Deliverable
Select EPN Class A stations:
• All inside area
• At least 5 outside
• Check if data available during densification
• Make that station has Class A positions/velocities for densification period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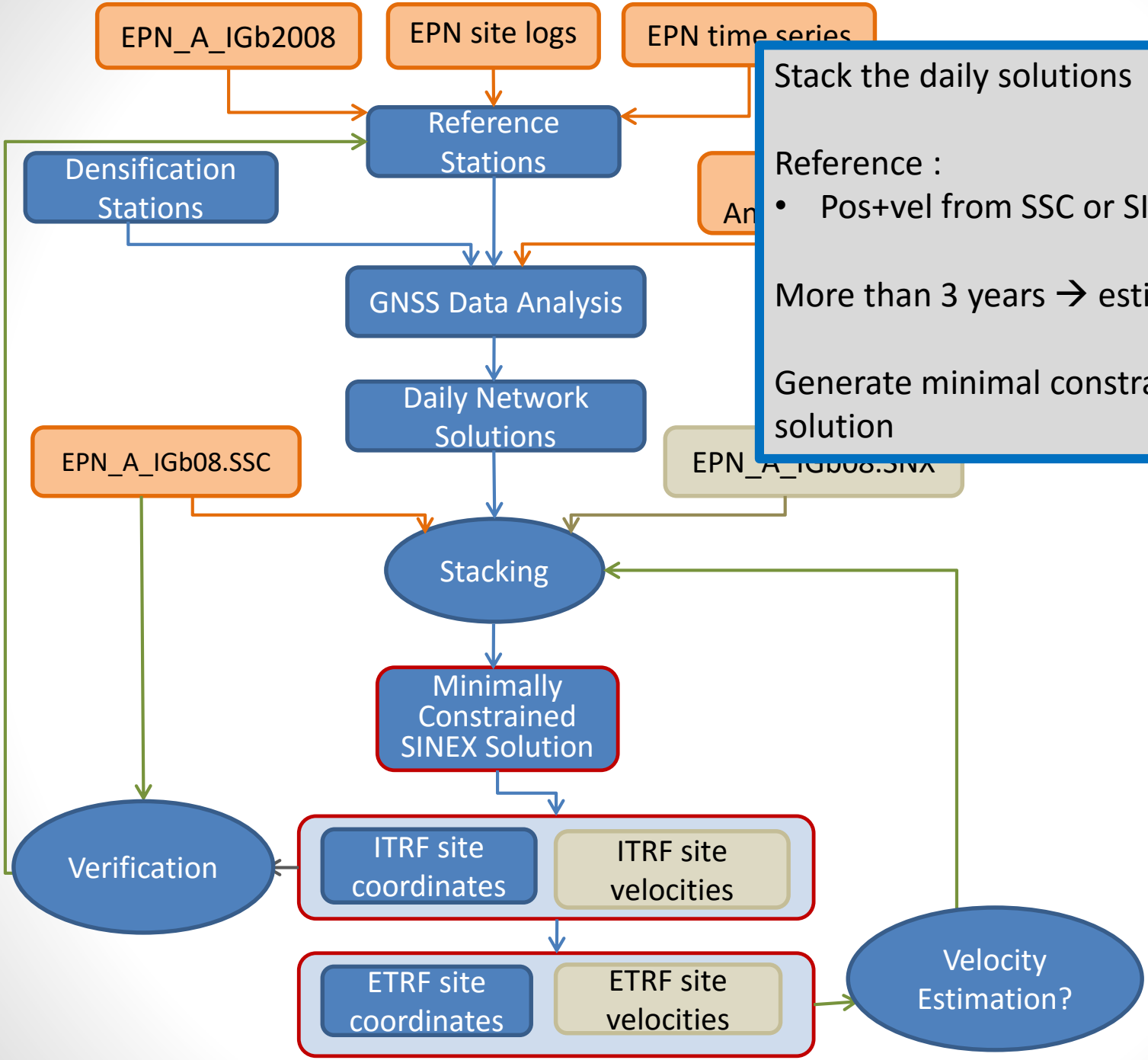
Deliverable
GNSS data analysis using reference stations
+ densification stations
+ external info
To obtain daily network solutions



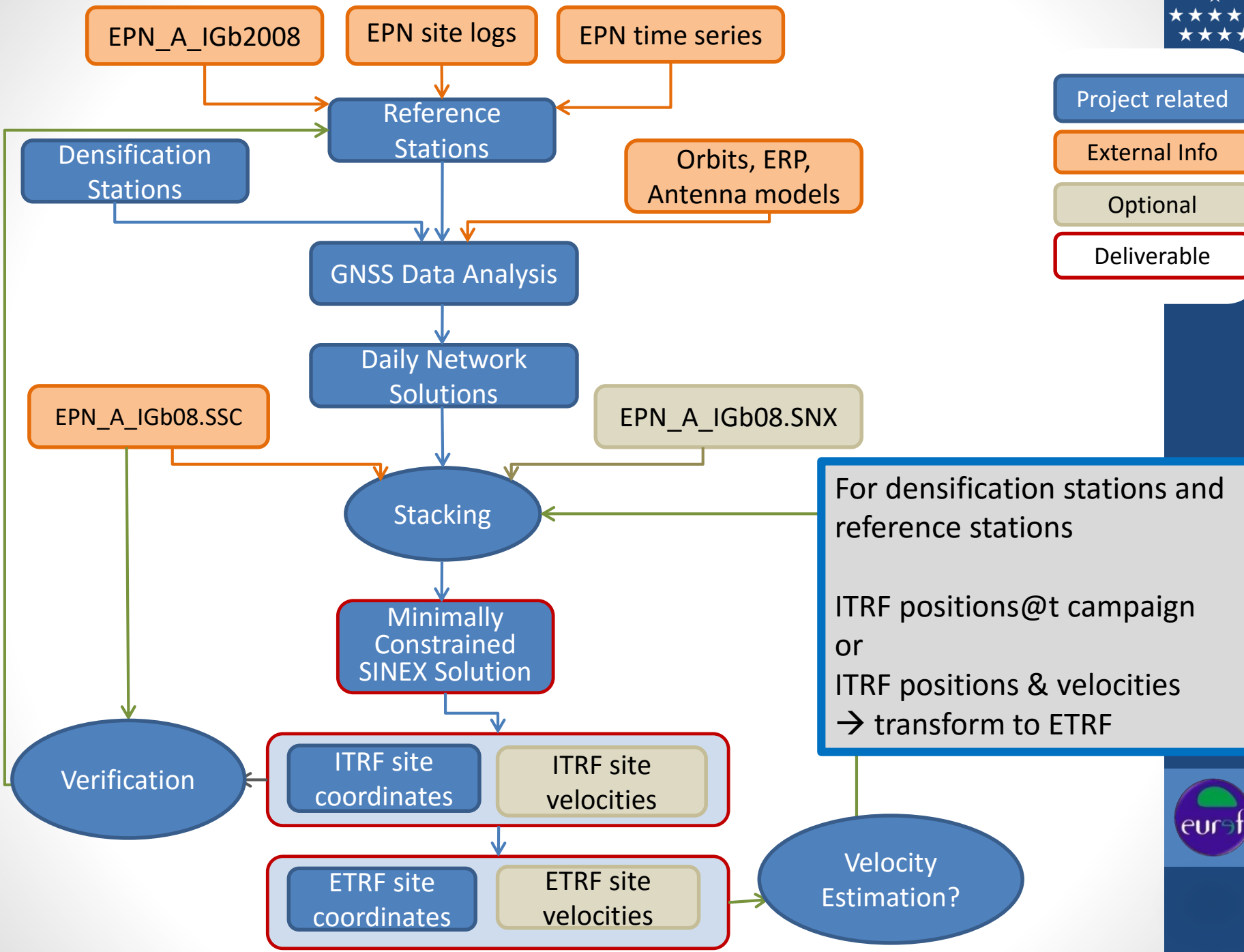
Stack the daily solutions

Reference :

- Pos+vel from SSC or SINEX

More than 3 years → estimate Pos+Vel

Generate minimal constrained stacked solution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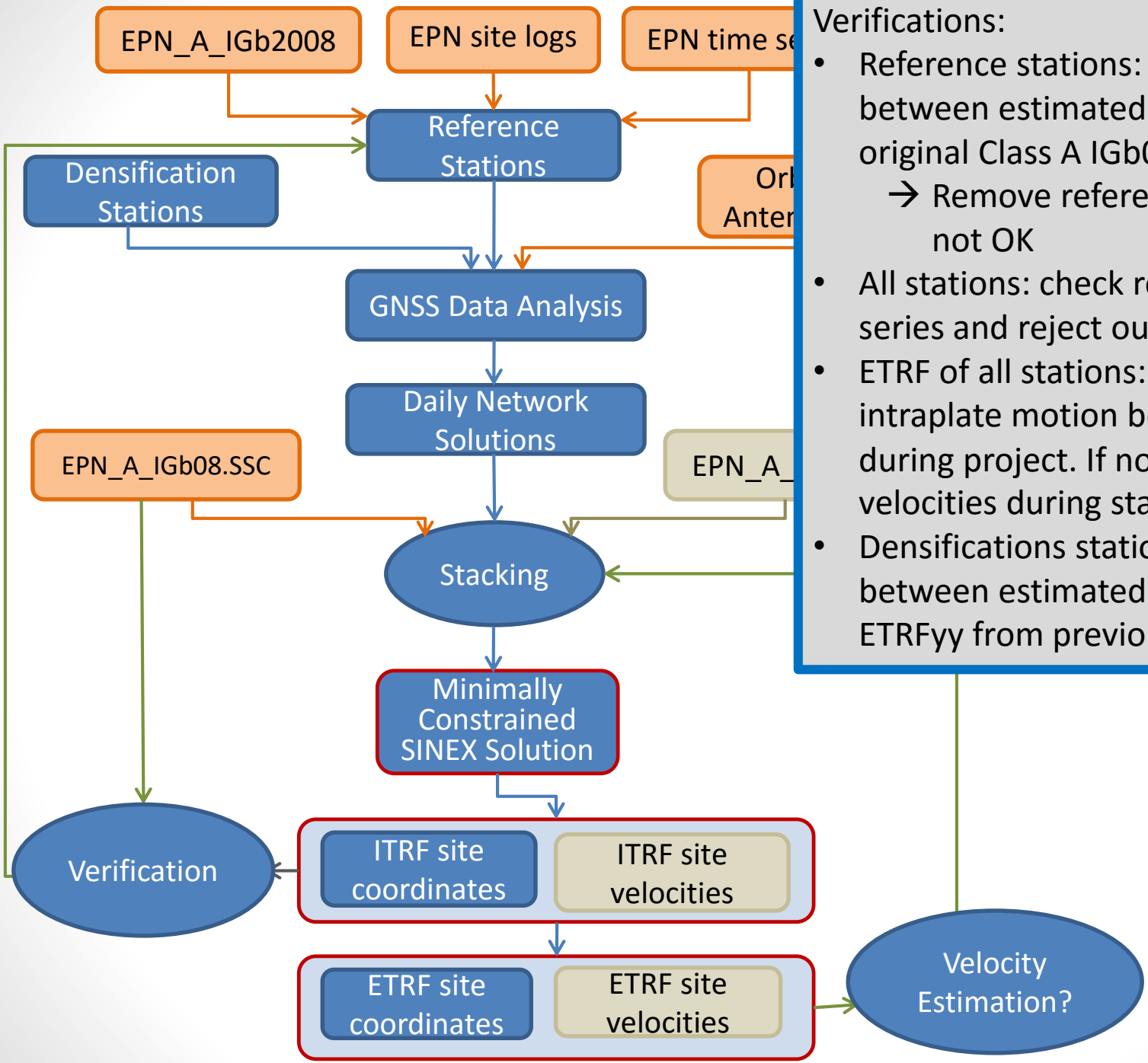
Stacking
For densification stations and reference stations
ITRF positions@t campaign
or
ITRF positions & velocities
→ transform to ETRF
Minimally Constrained SINEX Solution
Verification
ITRF site coordinates
ITRF site velocities
ETRF site coordinates
ETRF site velocities
Velocity Estimation?
Project related
External Info
Optional
Deliverable



Verifications:

- Reference stations: Agreement between estimated pos (+vel) and original Class A IGb08 values
  → Remove reference station if not OK
- All stations: check residual time series and reject outliers
- ETRF of all stations: variation due to intraplate motion below 1 cm during project. If not → estimate velocities during stacking!
- Densifications stations: Agreement between estimated ETRFyy and ETRFyy from previous campaigns

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Validation by TWG: Report & Deliverables

Steps

- Announce to TWG chair one month prior to TWG
- Submit written report at least 2 weeks prior to TWG
- Present results at TWG

Report

- Description of the densification project
  - List of densification stations (full names, 4-char ID, domes numbers, map), Observation period (permanent, campaign type)
  - GNSS equipment (IGS standard names for receiver and antenna/radome), Monument description

- Description of other data used in the processing
  - Identification of Class A solution + List of chosen reference stations (including discontinuities applied)
  - List of verifications performed to check their performance during the densification project
  - If used, list of EPN SINEX solutions
  - List of orbits, ERP, Antenna calibration models

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Report

- Description of processing strategy
  - Software (and version), Schematic processing method, Elevation cut off, Positioning mode (double difference network mode, …), Modeling of loading effects, Ambiguity resolution strategy, Modeling of troposphere (e.g. a priori model, mapping function, constraints, gradients, …), Modeling of ionosphere (e.g. higher order corrections)
  - Optional: alternative strategies for test purposes
  - Method for combining daily network solutions in one densification solution, Parameters used in minimal constraints
- Results from the GNSS processing
  - Daily mean ambiguity resolution percentages
  - Comparison of the daily coordinates solutions (repeatability in North, East and Up). Outliers and discontinuities should be identified, explained and eliminated. Comparison between estimated ITRF coordinates and latest EUREF densification of ITRF (indicate which one was used) for reference stations
  - Transformation to the ETRS89 (frame, including parameters used)
  - Comparison between new ETRS89 coordinates and ETRS89 coordinates from previous ETRS89 densifications

Deliverables

- Site logs
- Minimally constrained solution in the SINEX format
- List of positions for all stations in the network in the ITRFyy at epoch of observation

  or

  List of positions & velocities of all stations in the network in the ITRFyy (for densification projects requiring velocity estimation)
- List of positions for all stations in the network in the ETRS89 (indicate the frame used) at epoch of observation

  or

  List of positions & velocities for all stations in the network in the ETRS89 (indicate the frame used)
- List of reference stations
- ITRFyy coordinates and velocities (+ discontinuities) used for the reference sites

Soon

- IGb08 → IGS14

Questions?