

Reference Frame Coordination Status Report

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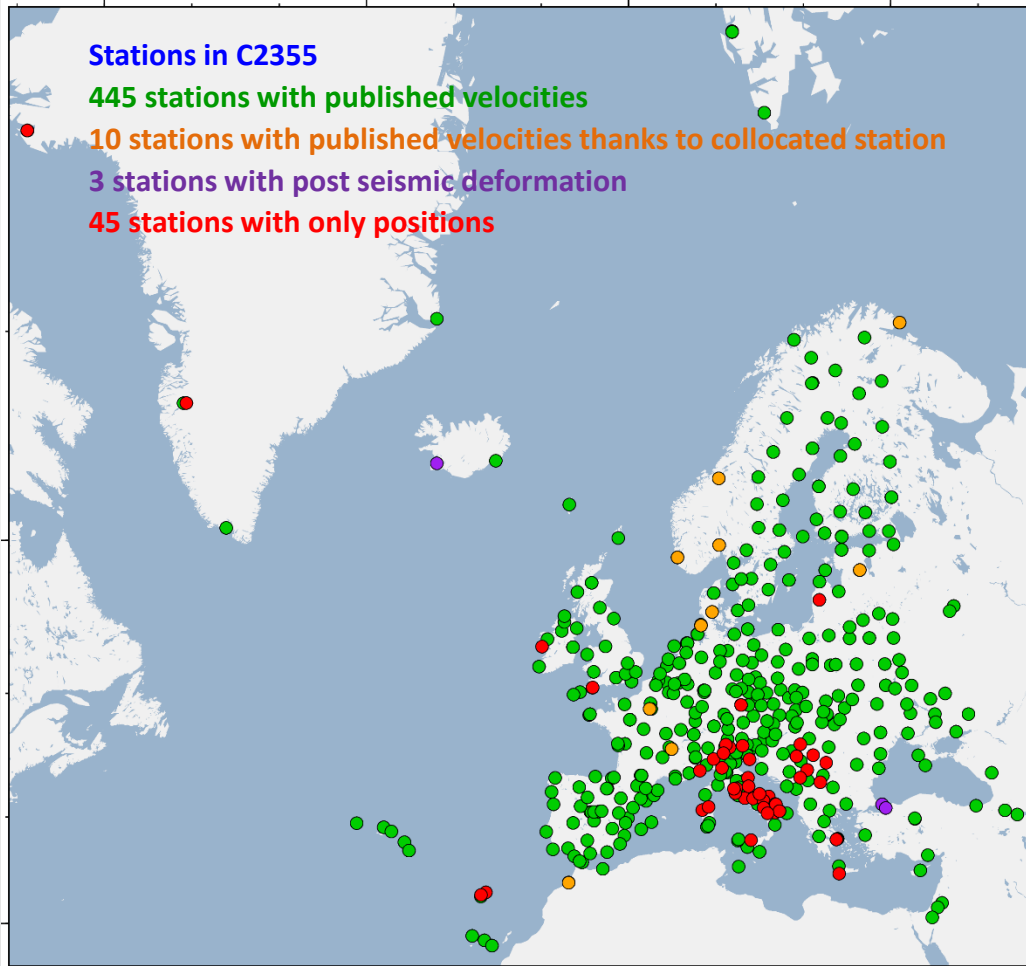
Content

- Current Hybrid Solution C2355
- Publication of Reference Frame Product through EPOS Portal
- New Solution based on Repro 3

Hybrid Solution: C2355 (IGS20)

EPN Stations in C2355

504 Stations



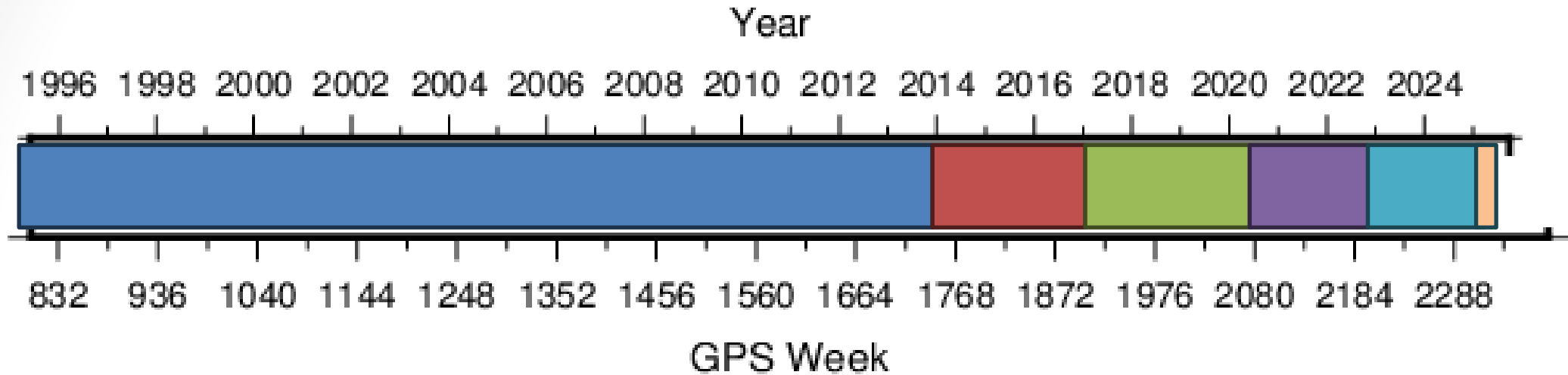
No official EPN Reference Frame Product since November 2022:
switch of EPN daily product to IGS20

Need to create Hybrid cumulative solution

- 504 stations
- Period coverage: 1996-01-01 - 2025-03-02
- Based on various daily combined solutions
- Position and velocity discontinuities to fit IGS (IGb20) discontinuity list
 - EPN stations $\in$ IGS cumulative solution:
 - Position and velocity discontinuities from IGS20 <ftp://igs-rf.ign.fr/pub/discontinuities/soln.snx>
 - Add necessary new discontinuities (EPN specific or recent)
 - EPN stations $\notin$ IGS cumulative solution:
 - Same position and velocity discontinuities as C2235 + recent discontinuities
- Aligned in origin, scale and orientation wrt IGS20 using 54 reference stations

Not suitable as Reference Frame to align official densification
Provide up-to-date station coordinates and velocities for daily monitoring while waiting for the REPRO3 solution

Hybrid Solution C2355 aligned to IGS20

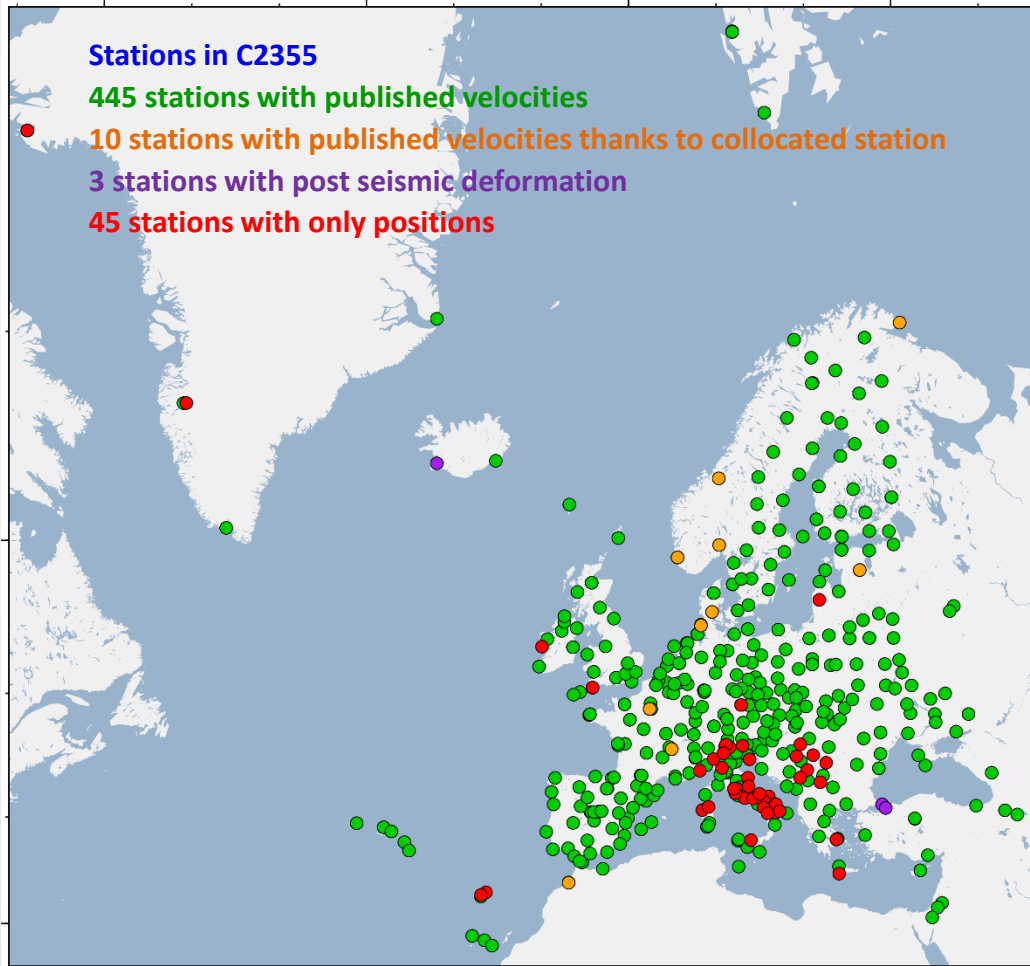


From	To	Type	Antenna Calibration	Offsets	Aligned to
0834 – 1 1996-01-01	1773 – 2 2013-12-31	REPRO2	epn_08.atx (igs08.atx)	Offsets from igs08 to igs14 applied	-
1773 – 3 2014-01-01	1933 – 6 2017-01-29	OPERATIONAL	epn_08.atx (igs08.atx)	Offsets from igs08 to igs14 applied	-
1934 – 0 2017-01-29	2105 – 6 2020-05-16	OPERATIONAL	epn_14.atx (igs14.atx)		IGS14
2106 – 0 2020-05-17	2237 – 6 2022-11-26	OPERATIONAL	epn_14.atx (igs14.atx)		IGb14
2238 – 0 2022-11-27	2351 – 6 2025-02-01	OPERATIONAL	epn_20.atx (igs20.atx)		IGS20
2352 – 0 2025-02-02	2355-6 2025-03-02	OPERATIONAL	epn_20.atx (igs20.atx)		IGb20

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No EPN Reference Frame Product since November 2022: switch of EPN daily product to IGS20

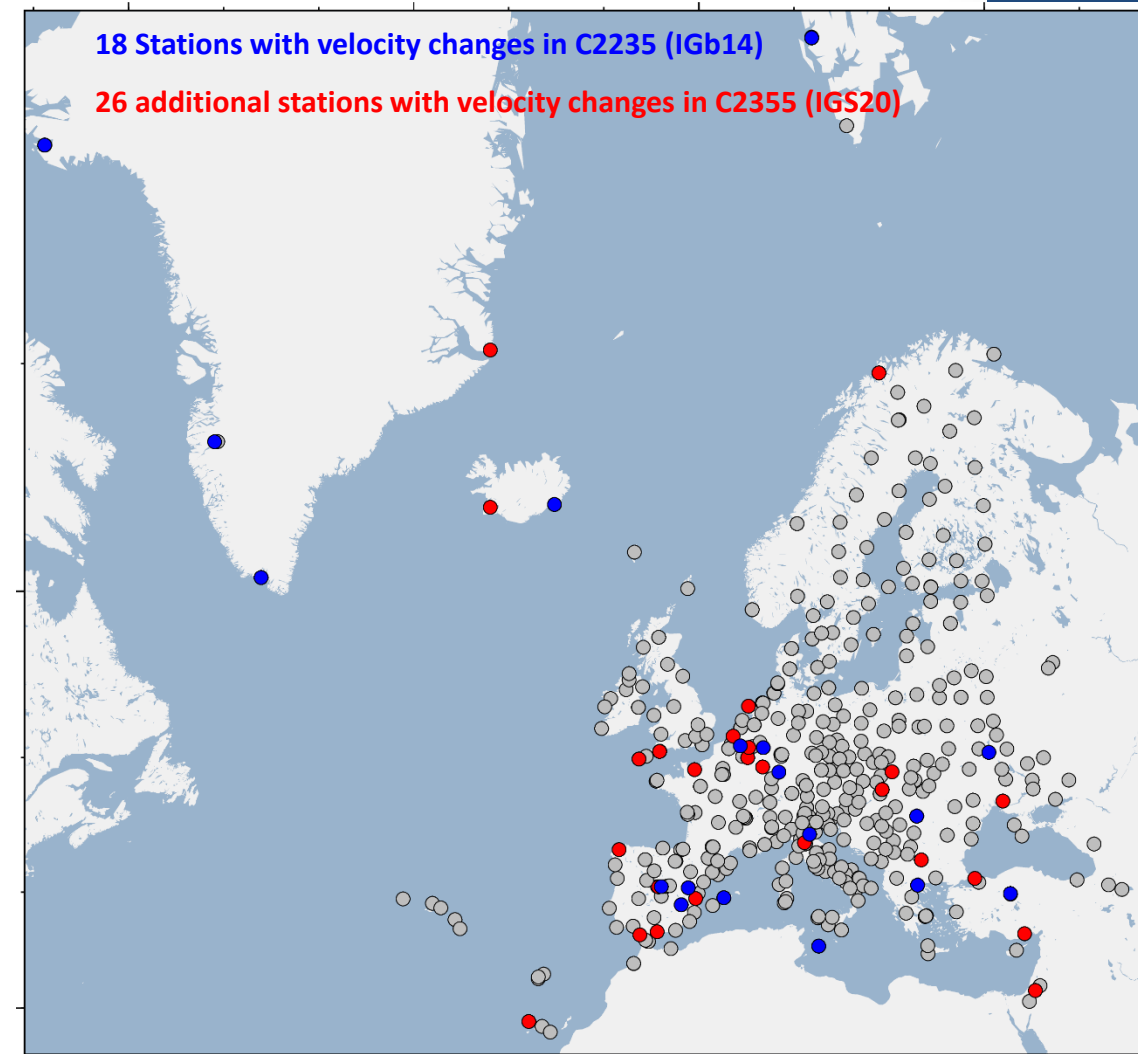
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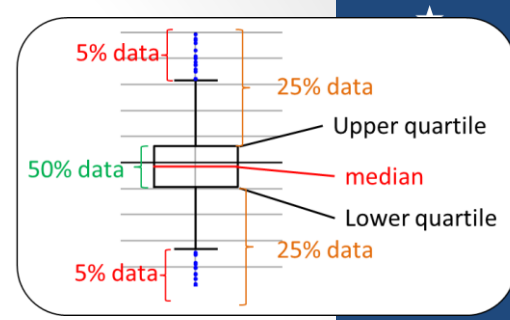
Not suitable as Reference Frame to align official densification
Provide up-to-date station coordinates and velocities for daily monitoring while waiting for the REPRO3 solution

Velocity Discontinuities

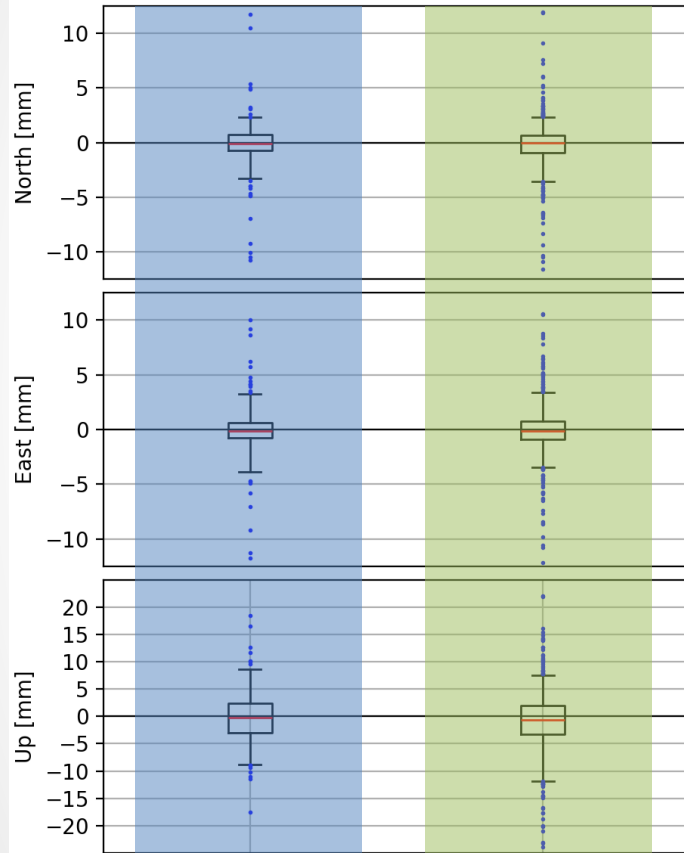
- Positions:
 - 1008 position discontinuities affecting 352 stations
- Velocities:
 - 74 velocity changes affecting 45 stations
 - 18 stations with velocity changes in C2235



Comparison of C2355 wrt IGb20 and IGS cumulative solution (IGS00PSSNX_1994002_2025095_00U_SOL)



Position differences



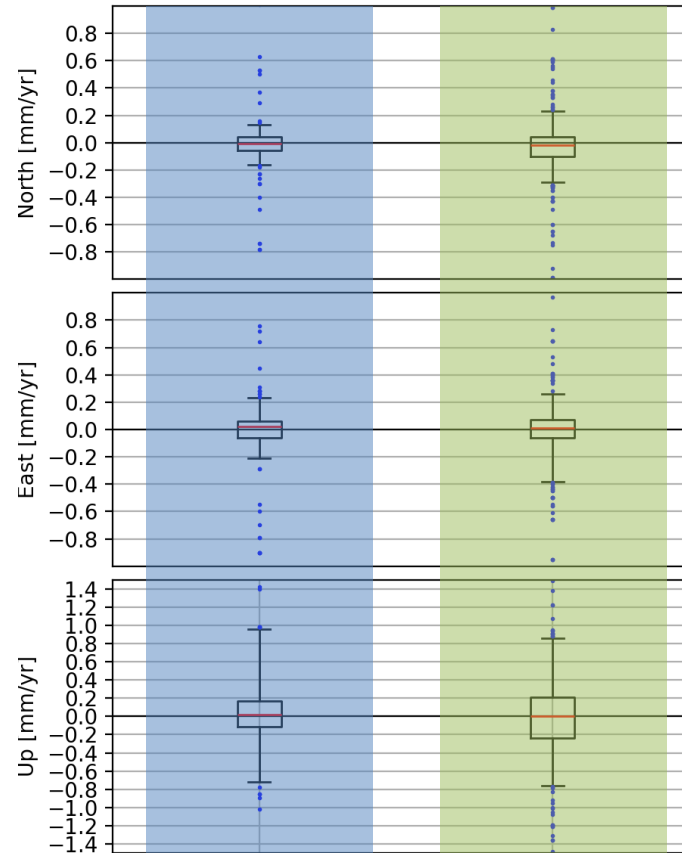
C2355
IGb20

C2355
IGS00PSSNX_
1994002_2025095_
00U_SOL

C2355/IGb20
75 stations
296 position differences

C2355/IGS cumulative
222 stations
768 position differences

Velocity differences



C2355
IGb20

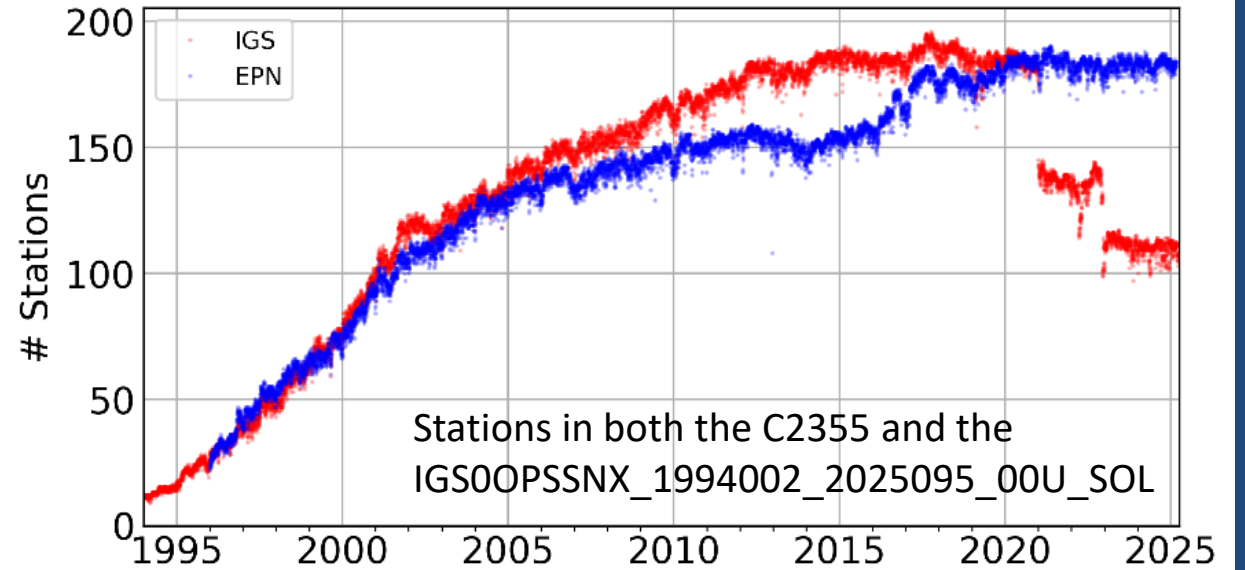
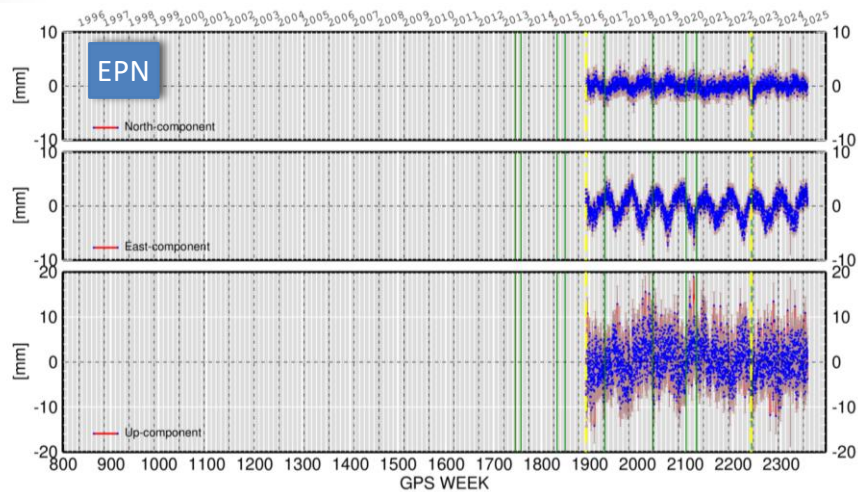
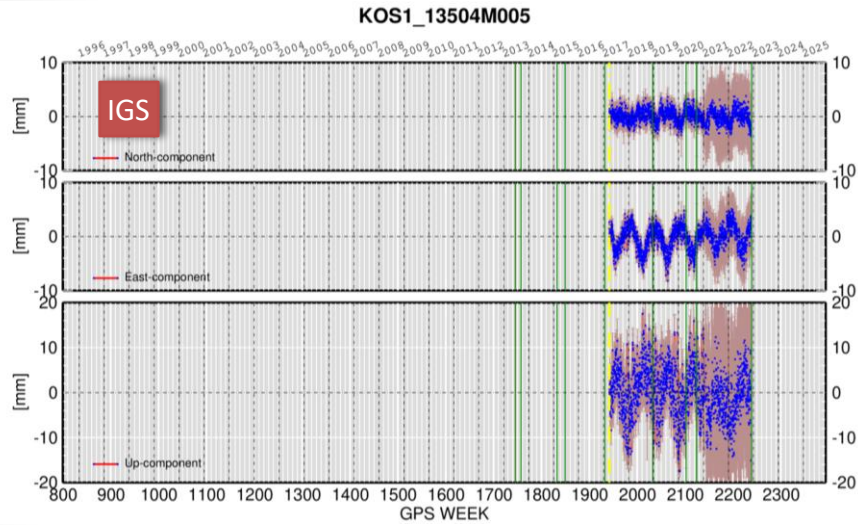
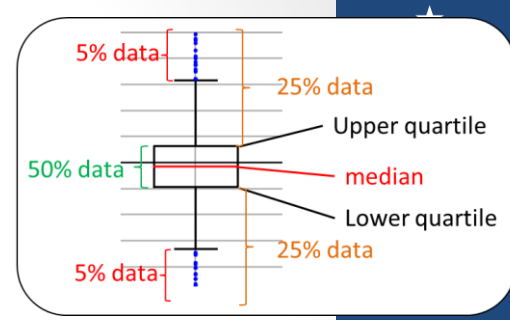
C2355
IGS00PSSNX_
1994002_2025095_
00U_SOL

No systematic effect for
positions or velocities!
Global alignment is reliable.

Agreement better than
4mm on the horizontal and
10mm on the vertical for more
than 90% of the position
estimates

0.2mm/yr on the horizontal
and 1mm/yr on the vertical for
more than 90% of the position
estimates

Comparison of C2355 wrt IGb20 and IGS cumulative solution (IGS00PSSNX_1994002_2025095_00U_SOL)



~40 stations stopped at the end of 2020

~50 stations stopped at the end of 2022

In the IGS cumulative solution

Where can you find the hybrid solution on EPN CB?

<https://epncb.oma.be/productsservices/coordinates/hybrid.php>

Positions & Velocities of EPN stations with more than 3 years

The positions and velocities of the EPN stations with more than 3 years of observations and without modelled post-seismic deformations are provided in the SNX and SSC format and are expressed in 4 different reference frames IGS20, ETRF2000, ETRF2014, ETRF2020.

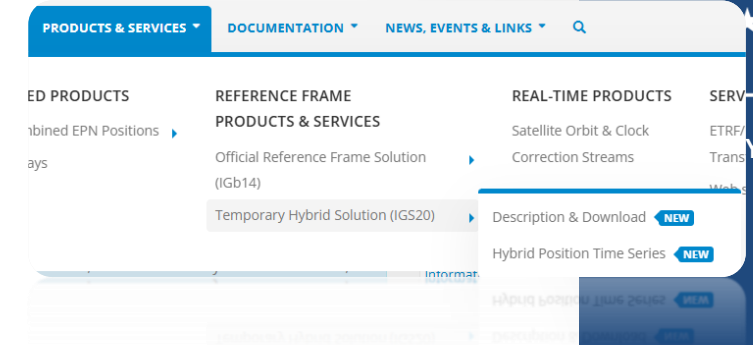
	SINEX Format	SSC Format
ITRS (IGS20 realization)	EUR0EXPSNX_1996001_2025060_00U_SOL.SNX.Z	EUR0EXPSNX_1996001_2025060_00U_SOL_IGS20.SSC
ETRS89 (ETRF2000 realization)	EUR0EXPSNX_1996001_2025060_00U_SOL_ETRF2000.SNX.Z	EUR0EXPSNX_1996001_2025060_00U_SOL_ETRF2000.SSC
ETRS89 (ETRF2014 realization)	EUR0EXPSNX_1996001_2025060_00U_SOL_ETRF2014.SNX.Z	EUR0EXPSNX_1996001_2025060_00U_SOL_ETRF2014.SSC
ETRS89 (ETRF2020 realization)	EUR0EXPSNX_1996001_2025060_00U_SOL_ETRF2020.SNX.Z	EUR0EXPSNX_1996001_2025060_00U_SOL_ETRF2020.SSC

Under test: For Bernese users, a CRD ([EUR0EXPSNX_1996001_2025060_00U_SOL.CRD](#)) and a VEL ([EUR0EXPSNX_1996001_2025060_00U_SOL.VEL](#)) file are available for all the stations observed within the last 270 days. For each station, the position and the velocity of the last available solution number is given.

<https://epncb.oma.be/pub/product/referenceframe/>

- C2220
- C2235
- hybrid
 - C2295
 - C2355
- latest

<https://epncb.oma.be/pub/product/referenceframe/hybrid/C2355/>



[illegible][illegible]

Analysis Center		Processing Strategy Purpose & Usage	Stations & Networks Included Softwares Reference Frames	Updates DOI
EPOS	UGA-CNRS Description	Double difference Internally consistent solution well-suited for geodynamic, tectonic, seismological studies.	All EPOS stations GAMIT / GLOBK, pyacs IGb14	Day-25 Auto Day-2 Rapid 10.17178/GNSS.products.EPOS.2019
	INGV Description	Precise Point Positioning Internally consistent solution well-suited for geodynamic, tectonic, seismological studies.	All EPOS stations GIPSY OASIS 6.4 IGS14 & Europe alignment	Yearly
EUREF	ROB-EUREF Description	Multi-year solution based on EUREF combined daily positions Designed for the maintenance of the European Terrestrial Reference System (ETRS89).	EPN stations CATREF IGb20	15 weeks 10.24414/ROB-EUREF-CWWWWW
	WUT-EUREF Description	Daily and Weekly combination based on double difference (mostly) solutions Provided by 16 EPN ACs. Used by ROB-EUREF for multi-year combination.	EPN stations Bernese, GAMIT/GLOBK, GIPSY IGb20	D-35
EUREF-EPOS	SGO-EPND Description	Multi-year solution based on weekly combination of 30 EPND & EPOS regional solutions	EUREF densified including all EPOS stations CATREF IGb14	Yearly

Analysis Center		Processing Strategy Purpose & Usage	Stations & Networks Included Softwares Reference Frames	Updates DOI
EPOS	UGA-CNRS Description	Statistical Trend Estimation Internally consistent solution well-suited for geodynamic, tectonic, seismological studies.	All EPOS stations MIDAS IGb14	Yearly 10.17178/GNSS.products.EPOS.2019
	INGV Description	Statistical Trend Estimation Internally consistent solution well-suited for geodynamic, tectonic, seismological studies.	All EPOS stations GIPSY OASIS 6.4 IGS14 & Europe alignment	Yearly
EUREF	ROB-EUREF Description	Multi-year solution based on EUREF combined daily positions (provided byWUT-EUREF) Designed for the maintenance of the European Terrestrial Reference System (ETRS89).	EPN stations CATREF / HECTOR IGb14	15 weeks 10.24414/ROB-EUREF-CWWWWW
EUREF-EPOS	SGO-EPND Description	Multi-year combination solution Densified solution well-suited for geodynamic and tectonic studies	EUREF densified including all EPOS stations CATREF / HECTOR IGb14	Yearly

Analysis Center		Processing Strategy Purpose & Usage	Stations & Networks Included Softwares Reference Frames	Updates DOI
EPOS	LM	Strain rates on a regular grid (Shen et al. 2015, Anastasiou et al. 2019)	All EPOS stations + EUREF densified StrainWebTool	When new EUREF-EPOS solution is available 10.23701/sr.0002
	Description	This strain product can be used for geodynamic, tectonic, seismological studies.		

ROB-EUREF products @ EPOS

- EUREF GNSS Daily Position Time Series from ROB-EUREF
 - Cleaned IGS20 Position Time Series of the EPN stations with published velocities
 - Reconstructed based on the reference frame solution C2355
 - Daily positions have been re-aligned to the solution C2355
- EUREF GNSS Velocities from ROB-EUREF
 - Estimated with Hector software (Bos et al., 2013)
 - Estimate a linear trend, an annual and semi-annual signals assuming a temporal correlated noise (power-law + white noise)
 - More realistic velocity error estimates

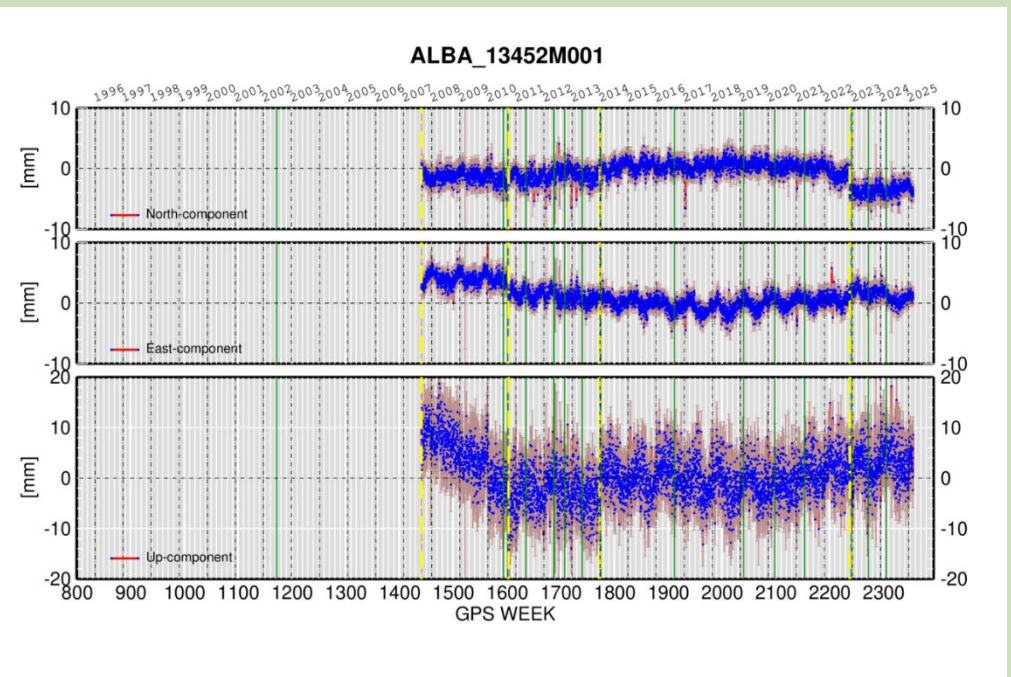
Velocity Product: Example of ALBA00ESP

EPOS GNSS Guidelines:

- Only one velocity per station
- PBO Format for velocities



PBO Velocity file from ROB_2355.0_IGS20.vel Reference Frame : IGS20
Format Version: 1.1.0
Release Date : 20250611
%Begin EPOS metadata
AnalysisCentre: ROB-EUREF
Software : CATREF/Hector
Method-url : https://gnssproducts.epos.ubi.pt/methods/ROB-EUREF_TS.pdf
DOI : 10.24414/ROB-EUREF-CWWW
ReleaseVersion: 2355.0
SamplingPeriod: daily
%End EPOS metadata
Start Field Description
Dot# 4-character identifier for a given station (starting at column 2)
Name 9-character identifier for a given station (starting at column 7)
Ref epoch Date and time at which the station position is as given in ref_XYZ and ref_NEU. Format is YYYYMMDDhhmmss (starting at column 24)
Ref_jday Reference epoch, represented as Modified Julian day (starting at column 39)
Ref_X Reference X coordinate at Ref epoch, meters (starting at column 50)
Ref_Y Reference Y coordinate at Ref epoch, meters (starting at column 66)
Ref_Z Reference Z coordinate at Ref epoch, meters (starting at column 81)
Ref_Nlat Reference North latitude WGS-84 ellipsoid, decimal degrees (starting at column 96)
Ref_Elong Reference East Longitude WGS-84 ellipsoid, decimal degrees (starting at column 112)
Ref_Up Reference Height WGS-84 ellipsoid, meters (starting at column 128)
dX/dt X component of station velocity, meters/yr (starting at column 139)
dY/dt Y component of station velocity, meters/yr (starting at column 150)
dZ/dt Z component of station velocity, meters/yr (starting at column 159)
SXd Standard deviation of X velocity, meters/yr (starting at column 50)
SYd Standard deviation of Y velocity, meters/yr (starting at column 50)
SZd Standard deviation of Z velocity, meters/yr (starting at column 50)
Rxy Correlation of X and Y velocity
Ryz Correlation of X and Z velocity
Rxy Correlation of Y and Z velocity
dN/dt North component of station velocity, meters/yr
dE/dt East component of station velocity, meters/yr
dU/dt Vertical component of station velocity, meters/yr
SNd Standard deviation of North velocity, meters/yr
SEd Standard deviation of East velocity, meters/yr
SUD Standard deviation of vertical velocity, meters/yr
Rne Correlation of North and East velocity
Rnu Correlation of North and vertical velocity
Reu Correlation of East and vertical velocity
first_epoch Epoch of first data used to derive the station velocity, in the same format as ref_epoch.
last_epoch Epoch of last data used to derive the station velocity, in the same format as ref_epoch.
End Field Description
*Dot# Name Ref epoch Ref_jday Ref_X Ref_Y Ref_Z Ref_Nlat Ref_Elong Ref_Up dX/dt dY/dt dZ/dt SXd SYd SZd Rxy Ryz Rxy dN/dt dE/dt dU/dt SNd SEd SUD Rne Rnu Reu first_epoch last_epoch
ALBA ALBA00ESP 20150101000000 57023.0000 4962847.86881 -160853.90242 3990884.53823 38.9779194266 -1.8563987333 751.66954 -0.01450 0.01935 0.00854 0.00009 0.00005 0.00008 -0.041 0.714 -0.042 0.01615 0.01887 -0.00639 0.00004 0.00005 0.00011 0.000 0.000 0.000 20100929000000 20250301000000



- Velocity estimated using Hector (white noise + powerlaw + trend + annual and semi-annual signals)
- More realistic velocity error estimates

Station	Software	Begin	End	VE	SVE	VN	SVN	VU	SVU	
ALBA00ESP	EUREF SINEX	CATREF	2007-08-19	2010-09-11	18.90	0.04	16.13	0.04	-10.03	0.15
ALBA00ESP			2010-09-29	2013-12-28	18.94	0.01	16.20	0.01	-6.54	0.02
ALBA00ESP			2013-12-29	2022-11-26	18.94	0.01	16.20	0.01	-6.54	0.02
ALBA00ESP			2022-11-27	2025-03-01	18.94	0.01	16.20	0.01	-6.54	0.02
ALBA00ESP	EPOS PBO File	Hector	2010-09-29	2025-03-01	18.87	0.05	16.15	0.04	-6.39	0.11

Conclusions

- Hybrid solution C2355 is offering up-to-date station coordinates and velocities for daily monitoring while waiting for the REPRO3 solution
- The solution C2355 is published:
 - at EPN CB at <https://epncb.oma.be/pub/product/referenceframe/hybrid/C2355/>
 - at EPOS GNSS product portal with a slightly different approach:
 - EUREF GNSS Daily Position Time Series from ROB-EUREF
 - EUREF GNSS Velocities from ROB-EUREF
 - One velocity per station
 - Velocity is estimated with Hector software (white noise + power law)
- Hopefully C2355 is the last hybrid solution that will be published

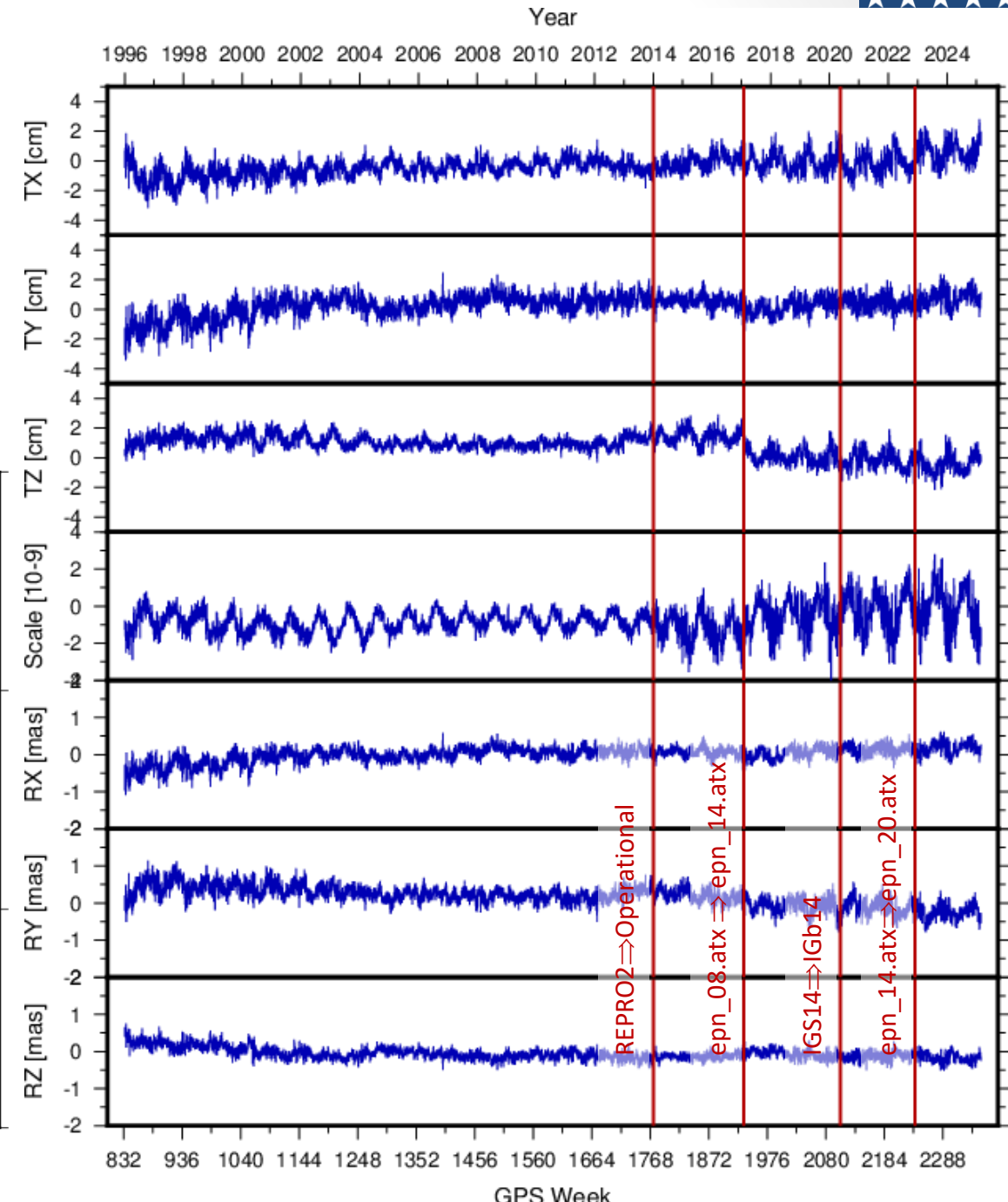
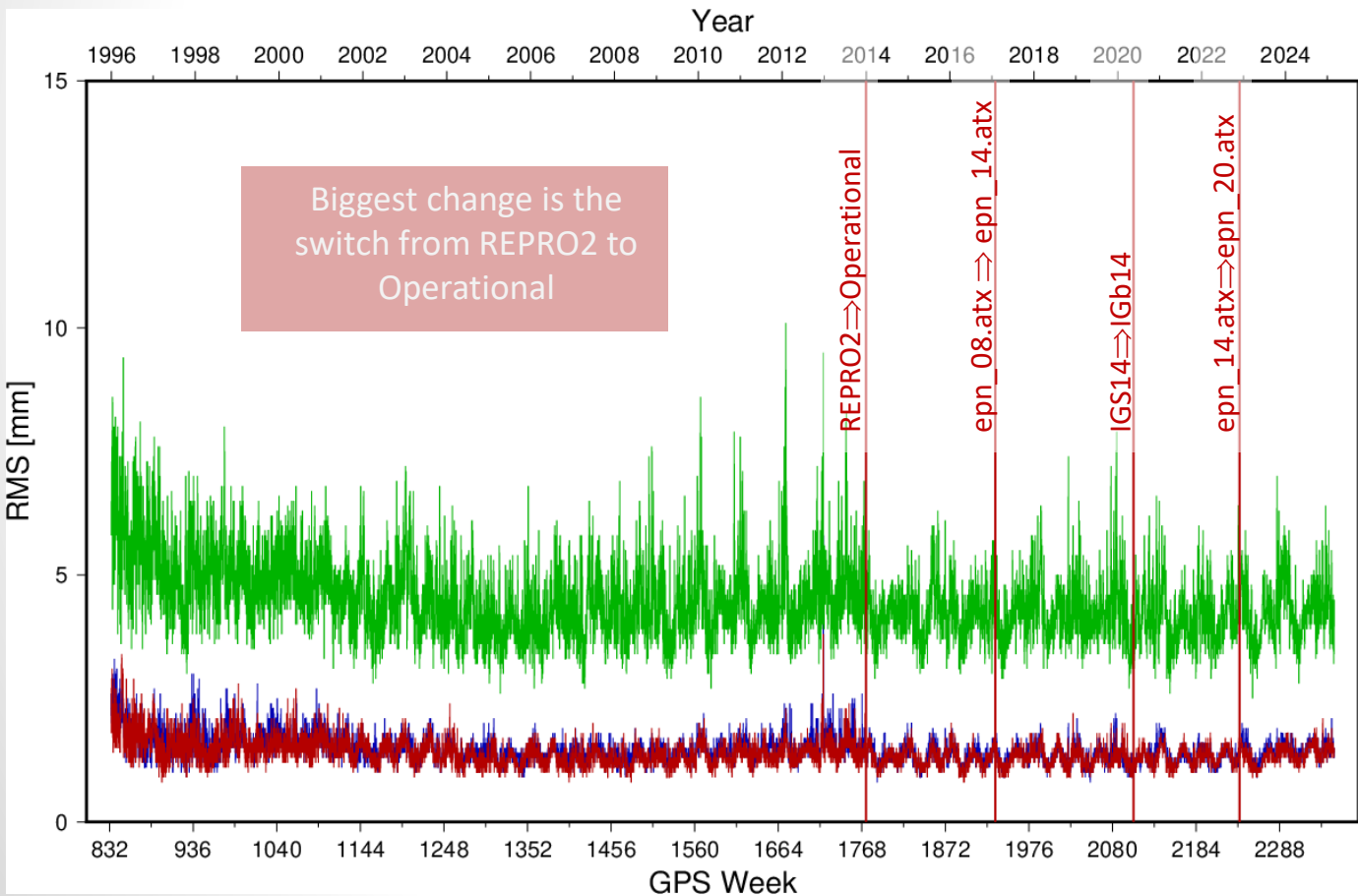
New Reference Frame Product based on Repro 3

- Nothing new on my side: waiting for daily combined Repro 3 solutions
- Plan:
 - Summer: Preparation of the multi-year Reference Frame solution
 - Cleaning and modelization (outlier rejection, position and velocity discontinuities)
 - Harmonization with IGS cumulative solutions
 - Autumn: Publication of a Preliminary Reference Frame solution
 - SINEX, discontinuities and outlier list, no classification
 - Winter:
 - Classification
 - Iteration, Feedback from users, additional tests
 - Official Reference Frame product (SINEX, Classification...)

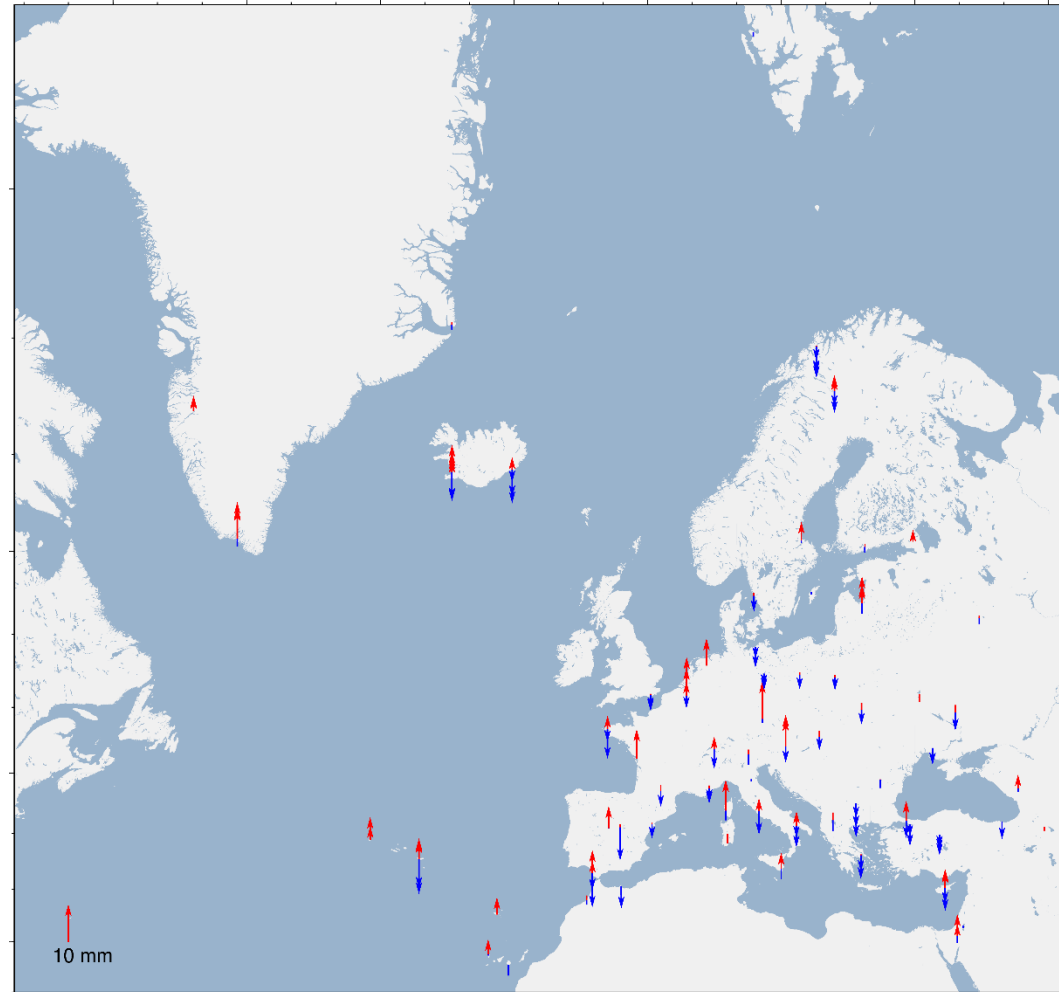
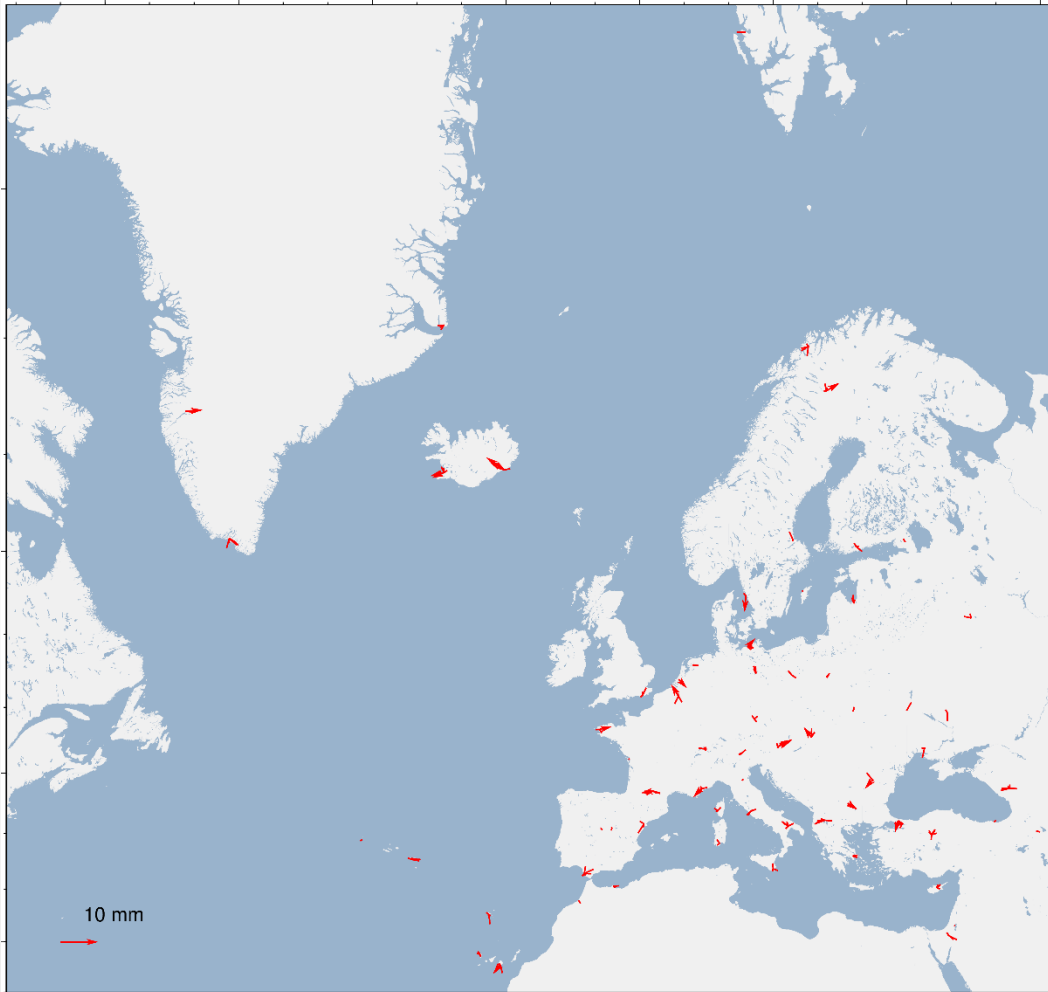
Internal consistency of the hybrid solution:

Transformation Parameters

Transformation parameters between the individual



Comparison with IGb20: Position differences



Comparison with IGb20: Velocity differences

