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Lennard Huisman

Netherlands Partnership for Geodetic Infrastructure (NSGI)

EUREF symposium 2021

Reference Frame Validation of GNSS Services Using the National GNSS Infrastructure

Outline

- Background (responsibility, sector requirements)
- Current status (what do we do now)
- New approaches (what we would like to do)
- Results (show that it works)
- Conclusions

Background – the bigger picture

 Netherlands partnership for geodetic infrastructure (NSGI) is responsible for quality assurance (consistent reference frame) of GNSS services



Background – the bigger picture

- Netherlands partnership for geodetic infrastructure (NSGI) is responsible for quality assurance (consistent reference frame) of GNSS services
- How can NSGI assure quality of GNSS services in the future?



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- Station coordinates computed using BSW/EUREF guidelines for densifications
 - 2. User receives reference station observations and computed coordinates



- Coordinate computation
- Provider process
- User process







 Station coordinates computed using BSW/EUREF guidelines for densifications

14211370.CRD: RNX2SNX 211370:

LOCAL GEODETIC DATUM: ETRF2000

X (M)

3787664.31873

3895237.06613

3769403.26805

3924698.11977

39 BRUX 13101M010 4027881.84249 306998.25936 4919498.64367

NUM STATION NAME

32

AMEL 13540M001

APEL 13510M001

69 DLF1 13502M009

BORJ 14268M002

coordinate/troposphere res

382392.26183

440564.01883

406814

EPOCH: 2021-05-17 12:00:00

301124.80440 5001904.99181

Z (M)

5100339.61731

5109098.8771

5017378.05808

- Coordinate computation
- Provider process
- User process



coordinate/troposphere res

EPOCH: 2021-05-17 12:00:00

306998.25936 4919498.6436

301124.80440 5001904.9918

5100339.6173

Augmentation data (Single baseline RTK)





1. Station coordinates computed using **BSW/EUREF** guidelines for densifications

LOCAL GEODETIC DATUM: ETRF2000

13540M001

BORJ 14268M002

BRUX 13101M010

69 DLF1 13502M009

X (M

3787664.31873

3895237.0661

3769403.26805

4027881.84249

3924698.11977

JUM STATION NAM

AMEL APEL 13510M001

- Coordinate computation
- Provider process
- User process _



Augmentation data (Single baseline RTK)



 Station coordinates computed using BSW/EUREF guidelines for densifications

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LOCAL GEODETIC DATUM: ETRF2000

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440564.01883 5109098.8771

306998.25936 4919498.64367

301124.80440 5001904.99181

5100339.6173

5017378.05808

2. User receives reference station observations and computed coordinates



- Coordinate computation
- Provider process
- User process





Current situation



- 1. Station coordinates computed using BSW/EUREF guidelines for densifications
- 2. Reference station observations and computed coordinates are input for provider GNSS software

- Coordinate computation
- Provider process
- User process





Augmentation data (VRS, SSR, MAC, FKP, ...)

- 1. Station coordinates computed using BSW/EUREF guidelines for densifications
- 2. Reference station observations and computed coordinates are input for provider GNSS software
- 3. User receives augmenation data
- 4. Need for validation of end user product (augmentation data)

Current situation

 $\begin{array}{c} + 052.155172899, + 005.387203658, + 0043.255\\ + 051.930469981, + 005.387202169, + 0043.482\\ + 051.705760834, + 005.387201064, + 0043.882\\ + 051.256326592, + 005.387199106, + 0044.478\\ + 051.031609223, + 005.387199106, + 0044.478\\ + 052.379866423, + 005.387195593, + 0045.854\\ + 052.379866423, + 005.387204056, + 0042.852\\ + 052.604549319, + 005.387205310, + 0042.509\\ + 053.053878593, + 005.387206917, + 0041.752\\ + 053.27852194, + 005.387206917, + 0041.358\\ + 053.503146626, + 005.387207186, + 0041.358\\ + 053.503146626, + 005.387207186, + 0041.358\\ + 053.503146626, + 005.387207186, + 0041.358\\ + 053.503146626, + 005.387201394, + 0041.328\\ + 053.5031667527, + 005.021892684, + 0043.263\\ \end{array}$

- Coordinate computation
- Provider process
- User process

Need for validation of end user product

- Two new methods proposed
 - Grid check
 - Systematic quality check

Compared to other methods these two methods are:

- able to validate the end product not the input data
- not labour intensive as they do not require field work

• In addition the systematic quality check can be used to validate several types of GNSS services (PPP, RTK, SPP, DGPS, ...)



Grid check



I1421	11370.CRD: RNX2SN)	_211370: Final	coordinate/trop	osphere res 18-
LOCAI	GEODETIC DATUM:	ETRF2000	EPOCH: 2021-0	05-17 12:00:00
NUM	STATION NAME	X (M)	Y (M)	Z (M)
12	AMEL 13540M001	3787664.31873	382392.26183	5100339.61731
14	APEL 13510M001	3895237.06613	406814.31623	5017378.05808
32	BORJ 14268M002	3769403.26805	440564.01883	5109098.87719
39	BRUX 13101M010	4027881.84249	306998.25936	4919498.64367
69	DLF1 13502M009	3924698.11977	301124.80440	5001904.99181







- 2. Compute coordinates for VRSs using BSW/EUREF guidelines for densifications
- 3. Compare computed coordinates with coordinates of requested locations



		eur		
I1423	11370.CRD: RNX:	2SNX_211370: Fina	l coordinate/trop	oosphere res 18-
LOCAI	L GEODETIC DAT	JM: ETRF2000	EPOCH: 2021-	-05-17 12:00:00
NUM	STATION NAME	X (M)	Y (M)	Z (M)
12	AMEL 13540M00	1 3787664.31873	382392.26183	5100339.61731
14	APEL 13510M00	1 3895237.06613	406814.31623	5017378.05808
32	BORJ 14268M003	2 3769403.2680	440564.01883	5109098.87719
39	BRUX 13101M01	0 4027881.8424	306998.25936	4919498.64367
69	DLF1 13502M00	9 3924698.1197	301124.80440	5001904.99181



- Coordinate computation
- Provider process
- Grid check

Grid check

Horizontal differences

Vertical





0.02					
0.015					
0.01					
0.005					
0					
n					
0.04					
0.03					
0.02					
0.01			PMS [mm]		1
		North	Fast	Un	kadaster 🗖
0	Certified provider	1,2	1,9	6,2	
	NETPOS real-time	1,8	2,1	3,4	
					13/18

Grid check (real-time data)





Position errors

 \leftarrow Virtual stations

Reference stations \rightarrow

Introducing errors in

reference station

Position errors

← Virtual stations

Reference stations \rightarrow

positions

m 0.02 0.015 0.015 0.01 0.005 0.005



	RMS [mm]		
	North	East	Up
Grid check (top left)	1,8	2,1	3,4
Station control (top right)	1,6	1,7	3,4
Grid check with erros (bottom left)	2,4	5,4	8,2
Station control with errors (bottom right)	2,2	5,5	7,5

Systematic QC







- 1. Validate benchmark network with grid check
- 2. Request VRS data for grid of locations of benchmark and provider network
- 3. Positioning of benchmark VRS using provider augmentation data
- 4. Compare computed coordinates with coordinates of requested locations



- Coordinate computation
- Provider process
 - Systematic QC

Augmentation data (VRS, SSR, MAC, FKP, ...)

Augmentation data

VRS)

15/18

Systematic quality check (w.r.t. AGRS2010)

Horizontal differences



Vertical differences



NRCAN CSRS-PPP





Trimble Centerpoint RTX

	RMS [mm]			kadaster	
	North	East	Up		
Trimble RTX post-processing	3,3	5,2	18,0		Ā
NRCAN CSRS-PPP	3,6	6,1	17,5		

16/18

Systematic quality check (real-time data)

Horizontal differences

Vertical differences



Infinitive loop

Each ten minutes

- Random point selection
- Get virtual rover station (NETPOS)
- Get virtual reference station (Provider)
- Compute RTK position (kinematic, ~9 minutes)
- Compute RTK session statistics (mean, median, std, rms errors; TTFF; fix epoch)
- Store result in database

	RMS [mm]		
	North	East	Up
Certified provider	5,9	6,1	16,6
Other provider	7,8	6,8	24,0



Conclusions

- Two new methods introduced for reference frame validation of GNSS augmentation services
 - Grid check
 - Systematic quality control
- Errors in the reference frame can be detected, but need to define metrics and criteria
- Grid check is easy to implement for NSGI, but not for GNSS service providers.
- Systematic quality check is future-proof. The method is easy to implement for GNSS service providers, but not for NSGI.



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Reference Frame Validation of GNSS Services Using the National GNSS Infrastructure

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A A A A A A A A A A A A A A A A A A A	12 AMEL 13540M001 3787664.31873 382392.26183 5100339.61731 14 AFEL 13510M001 3895237.06613 406614.31623 5017378.05808 39 BRUX 13101M010 4027881.84249 306998.25936 4919498.64367 69 DLF1 13502M009 3924698.11977 301124.80440 5001904.99181	12 AMEL 13540M001 14 APEL 13510M001 3895237.06613 3895237.06613 39 BRUX 13101M010 4027881.84249 306998.25936 419540.0883 301124.80440 5001904.99181
		$ \begin{array}{c} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$
Join	Augmentation data (VRS, SSR, MAC, FKP,)	 Coordinate computation Provider process Grid check

Systematic QC

3°E 4'E 5'E 6'E 7

53[°] N

52" N

51'N

53° N

52" N

51' N