Status of the EPN Tropospheric Products

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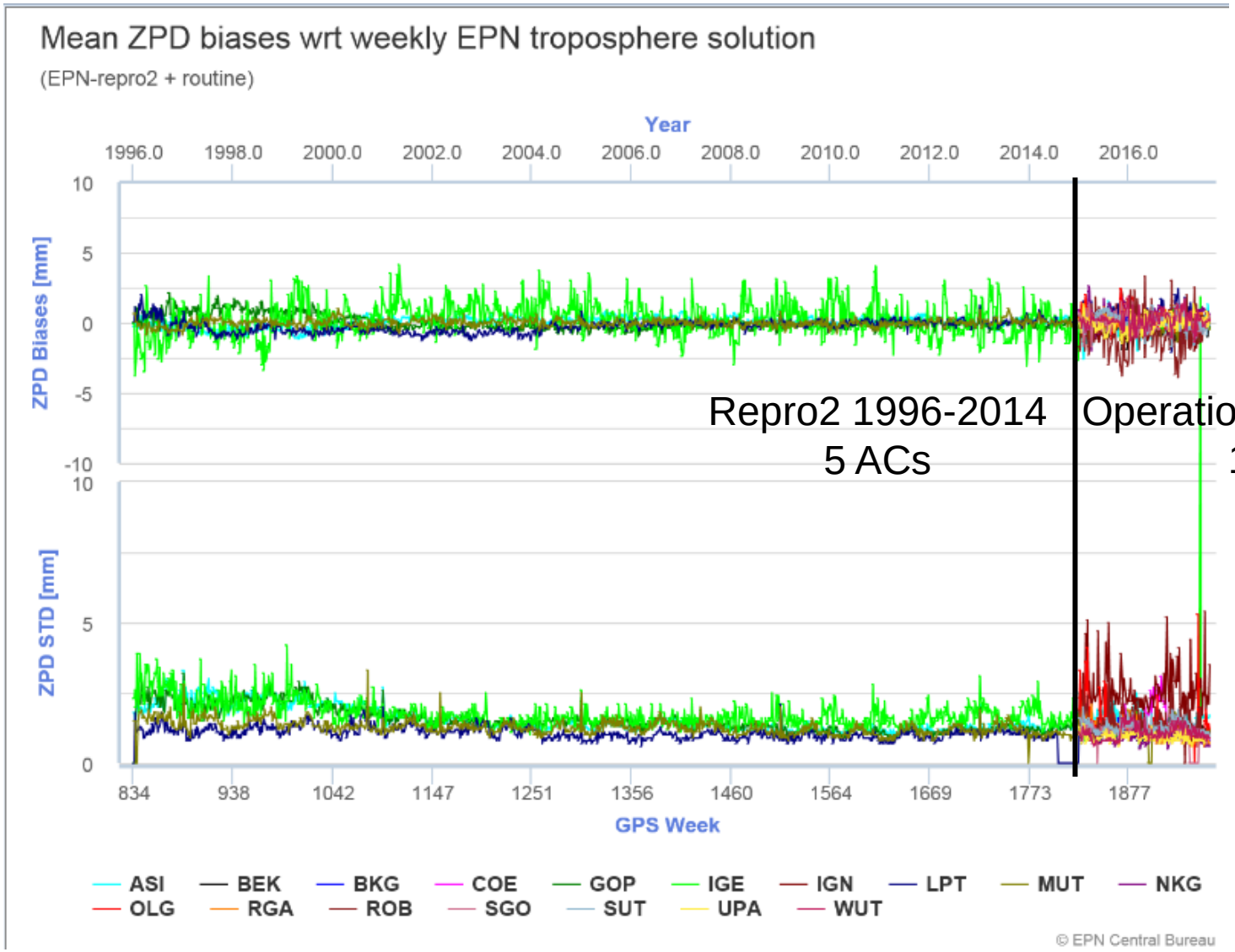
Outline

- EPN Repro2 Combination
- Routine Combination:
  - Processing Options
  - AC redundancy
  - New AC: BEV
  - Cumulative Solution T1963
- Moving forward:
  - Combination of Gradients
  - SINEX_TRO v2.0

Current Status: EPN Repro2 & Operational

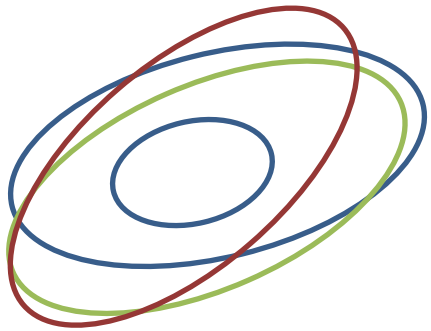
http://www.epncb.oma.be/_productsservices/sitezenithpathdelays/



EPN Repro2 – 1996 to 2014

EPN Repro2 - From GPS wk 0834 to 1824

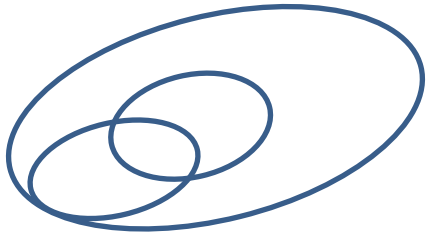
- 5 Input Solutions
- 3 main GNSS SW (Bernese, Gamit, Gipsy)



5 (+3) Solutions

- ASI (GIPSY, Full EPN)
- GOP (Bernese, Full EPN)
- LPT (Bernese, EPN sub-net)
- IGE (Bernese, EPN sub-net)
- MUT (GAMIT, Full EPN)

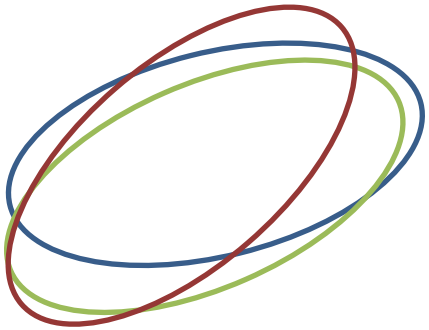
- **Different software**
- **Different networks**



3 Bernese Solutions

- GOP (Full EPN network)
- LPT (EPN Sub-network)
- IGE (EPN Sub-network)

- **Same software**
- **Different networks**



3 Solutions (Full EPN)

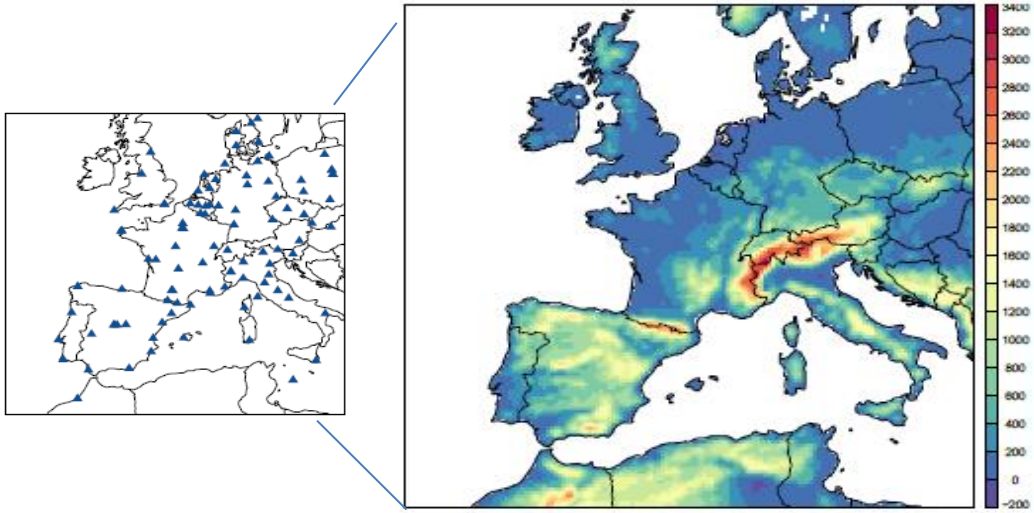
- ASI (GIPSY)
- GOP (Bernese)
- MUT (GAMIT)

- **Different software**
- **Same network**

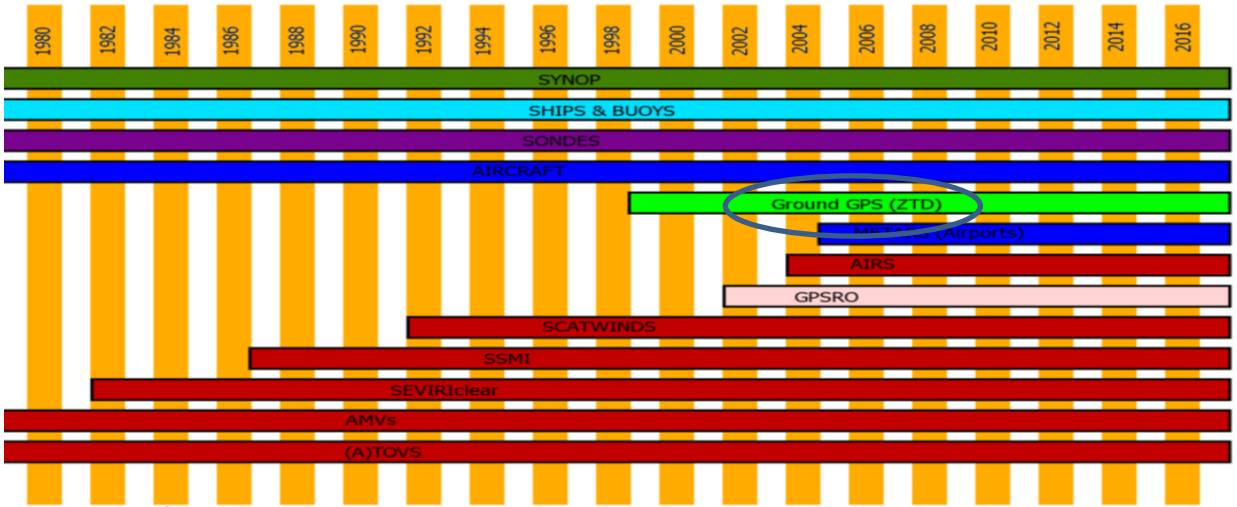
Pacione, R., Araszkiewicz, A., Brockmann, E., and Dousa, J.: EPN Repro2: A reference GNSS tropospheric dataset over Europe, Atmos. Meas. Tech., 10, 1689-1705, https://doi.org/10.5194/amt-10-1689-2017, 2017

Exploitation of EPN Repro2 dataset

Climate Model Simulation
ALARO Climate Model



Berckmans J., Van Malderen R., Pottiaux E., and Pacione R.: Evaluation of the atmospheric water vapor content in the regional climate model ALARO-0 using GNSS observations from EPN Repro2, EMS Annual Meeting, 4–8 September 2017, Dublin, Ireland



UERRA
Uncertainties in Ensembles of Regional ReAnalyses

European ReAnalyses

Ground-Based GNSS

Courtesy G.Halloran, UK MetOffice

Operational – Processing Options

- Period: GPS wk 1825 - 1966
- 8 ACs VMF
- 8 ACs GMF
- 2 ACs do not report (or do not estimate) gradients

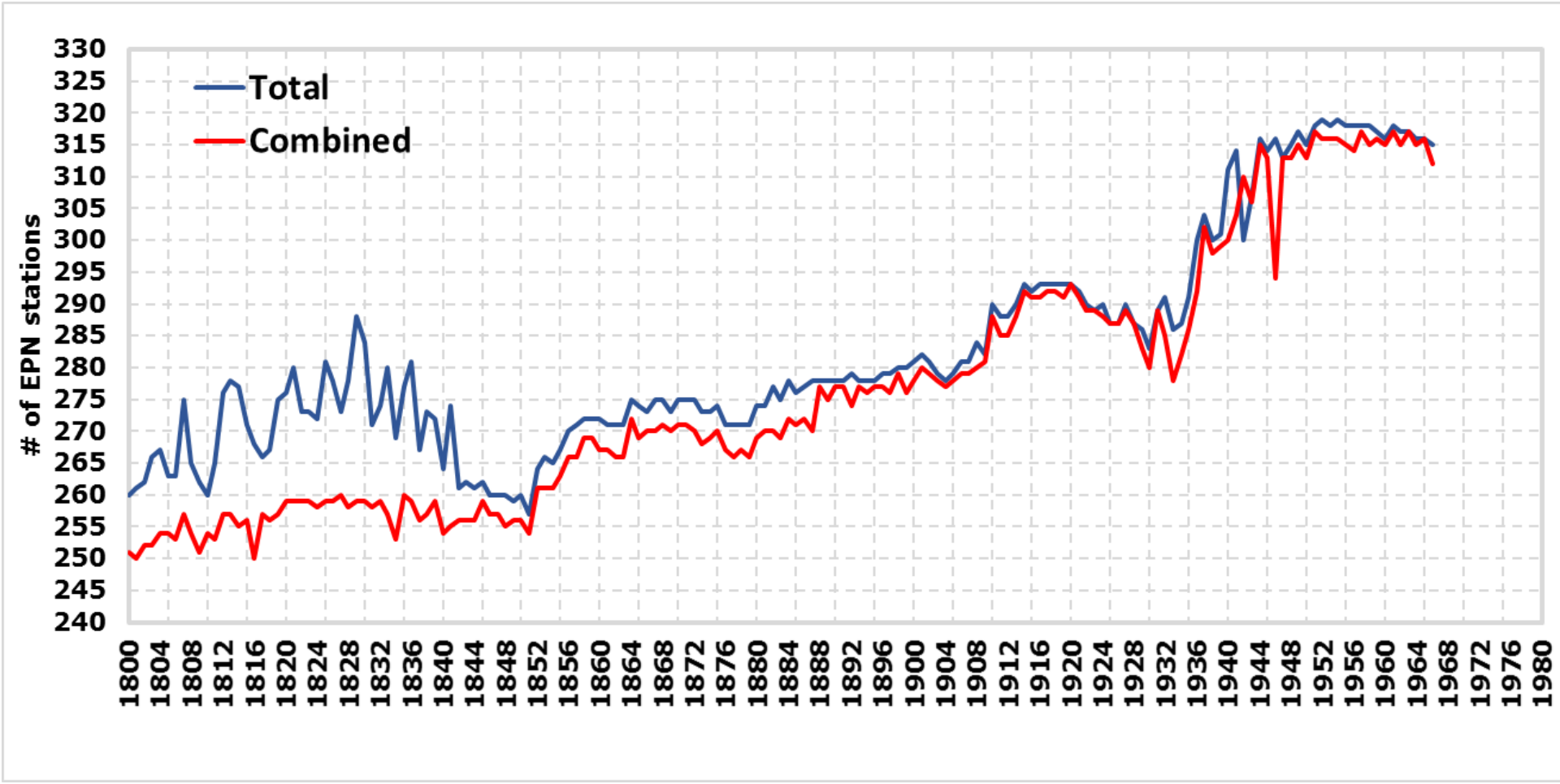
AC	SW	MF	Grad	cut-off	ZTD	Grad	GNSS System
ASI	GIPSY-OASIS	**VMF**	yes	3	5min/1h	5min/1h	G
BEK	BERNESE	WET_GMF	yes	3	1h	?	G+R
BEV	BERNESE	**WET_VMF**	yes	3	1h	1d	G+R
BKG	BERNESE	WET_GMF	yes	3	1h	1d	G+R
COE	BERNESE	**WET_VMF**	yes	3	1h	?	G+R
IGE	BERNESE	WET_GMF	***no***	3	1h	?	G+R
IGN	BERNESE	WET_GMF	yes	3	1h	1d	G+R
LPT	BERNESE	**WET_VMF**	yes	3	1h	1d	G+R+E+C
MUT	BERNESE	WET_GMF	yes	3	1h	?	G+R
NKG	BERNESE	WET_GMF	yes	3	1h	1d	G+R
RGA	BERNESE	**WET_VMF**	yes	3	1h	?	G+R
ROB	BERNESE	WET_GMF	yes	3	1h	1d	G+R
SGO	BERNESE	**WET_VMF**	***no***	3	1h	1d	G+R
SUT	BERNESE	**WET_VMF**	yes	3	1h	?	G+R
UPA	BERNESE	WET_GMF	yes	3	1h	?	G+R
WUT	BERNESE	**WET_VMF**	yes	3	1h	1d	G+R

Operational – New stations

- Period: GPS wk 1908 (16JUL31) - 1951 (17JUN03)
- 34 new stations included

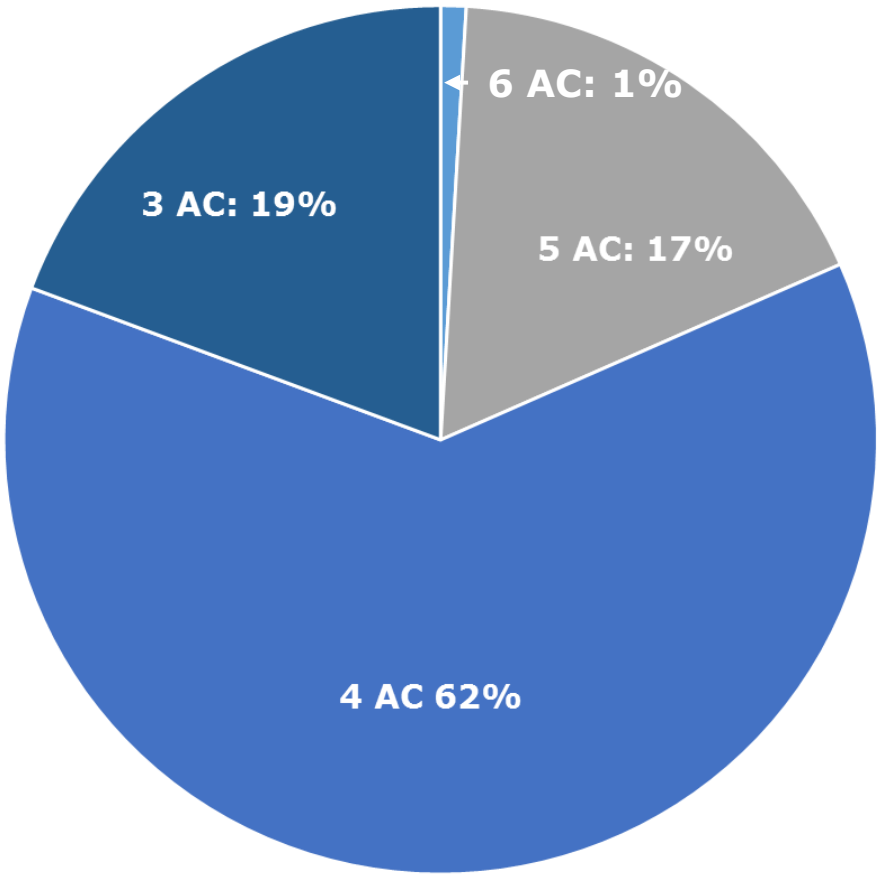
GPS wk	stations							
1908	CASE00ESP							
1910	AUBG00DEU	DIEP00DEU	DILL00DEU	GELL00DEU	GOR200DEU	HEL200DEU	HOFJ00DEU	LEIJ00DEU
1914	SAS200DEU	WRLG00DEU	WRLG00DEU					
1936	ADAR00GBR	SCIL00GBR	SNEO00GBR	ARIS00GBR	CHIO00GBR	PMTH00GBR	SWAS00GBR	
1937	IBIZ00ESP							
1940	LDB200DEU							
1941	SHOE00GBR	FINS00FIN	MET300FIN	VIR200FIN	JOE200FIN	OUL200FIN		
1943	KEV200FIN,	KILP00FIN,	KIV200FIN,	ROM200FIN,	SOD300FIN	VAA200FIN		
1951	RAEG00PRT							

Operational – Total vs Combined



Operational – AC Redundancy

Each of the EPN AC processes a subnetwork of the EPN. The EPN stations are distributed amongst the AC in such a way that each station is analyzed by at least three AC. This guarantees the reliability of the EPN products.



October, 1° 2017: 321 EPN stations

	6 AC	5 AC	4 AC	3 AC
Station #	3	56	200	62
%	1	17	62	19

http://www.epncb.oma.be/_productsservices/analysiscentres/dataprocessingdistribution.php

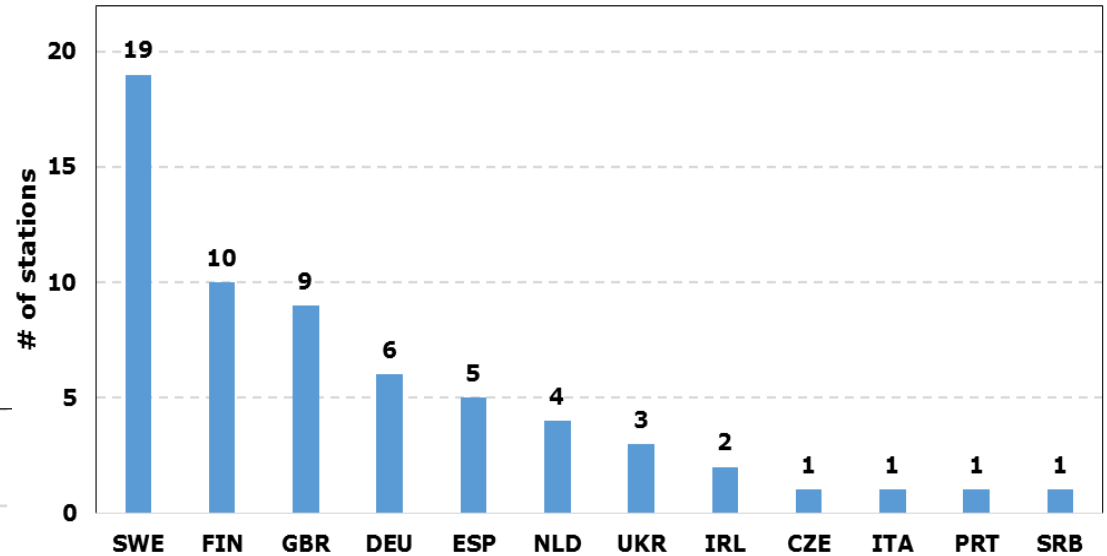
Operational – AC Redundancy

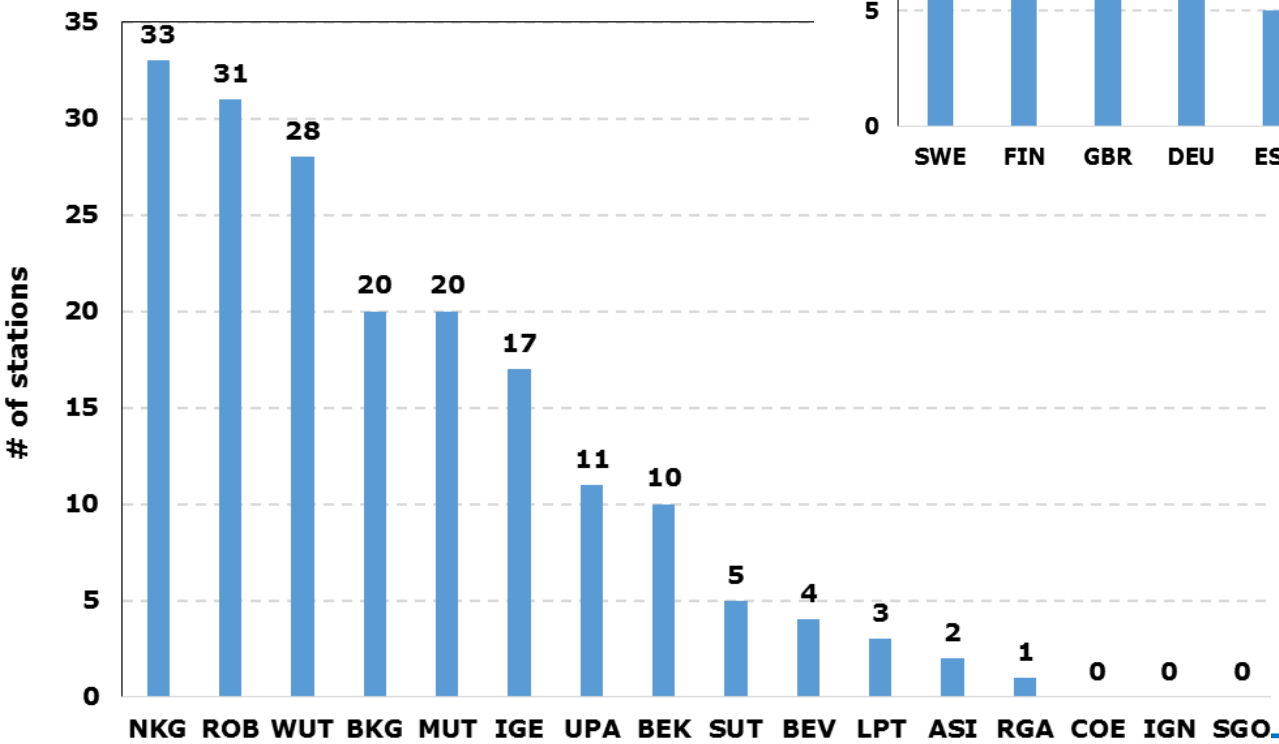
- 62 stations (i.e. 19%) are analyzed by 3 ACs

Station Distribution

vs country

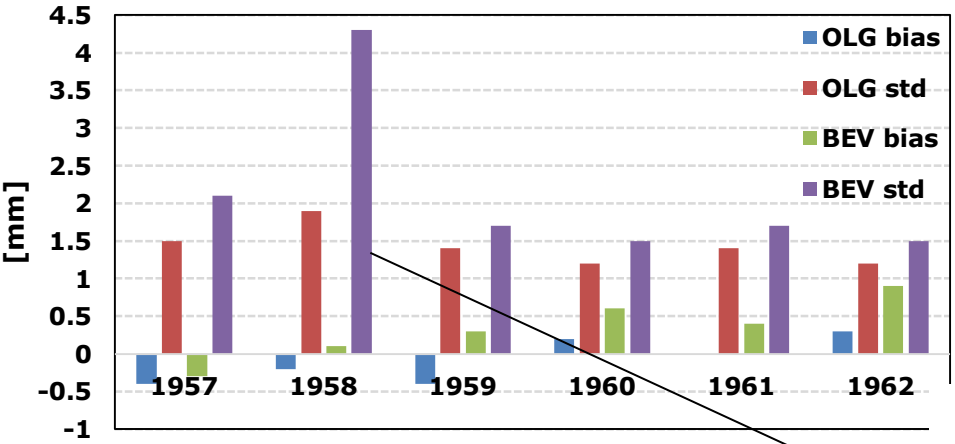
vs AC



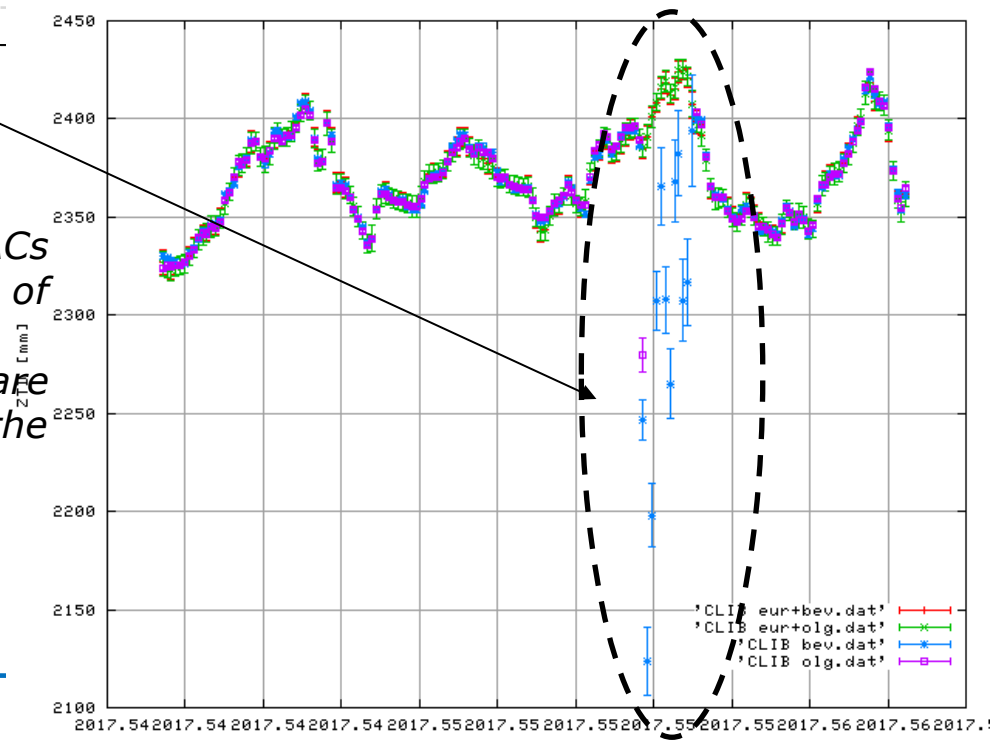


Operational – New AC: BEV

- BEV solutions tested from GPS wk 1957 to 1962
- Officially included from GPS wk 1963



CLIB analyzed by 4 ACs:
bev/olg – mut – rga - wut



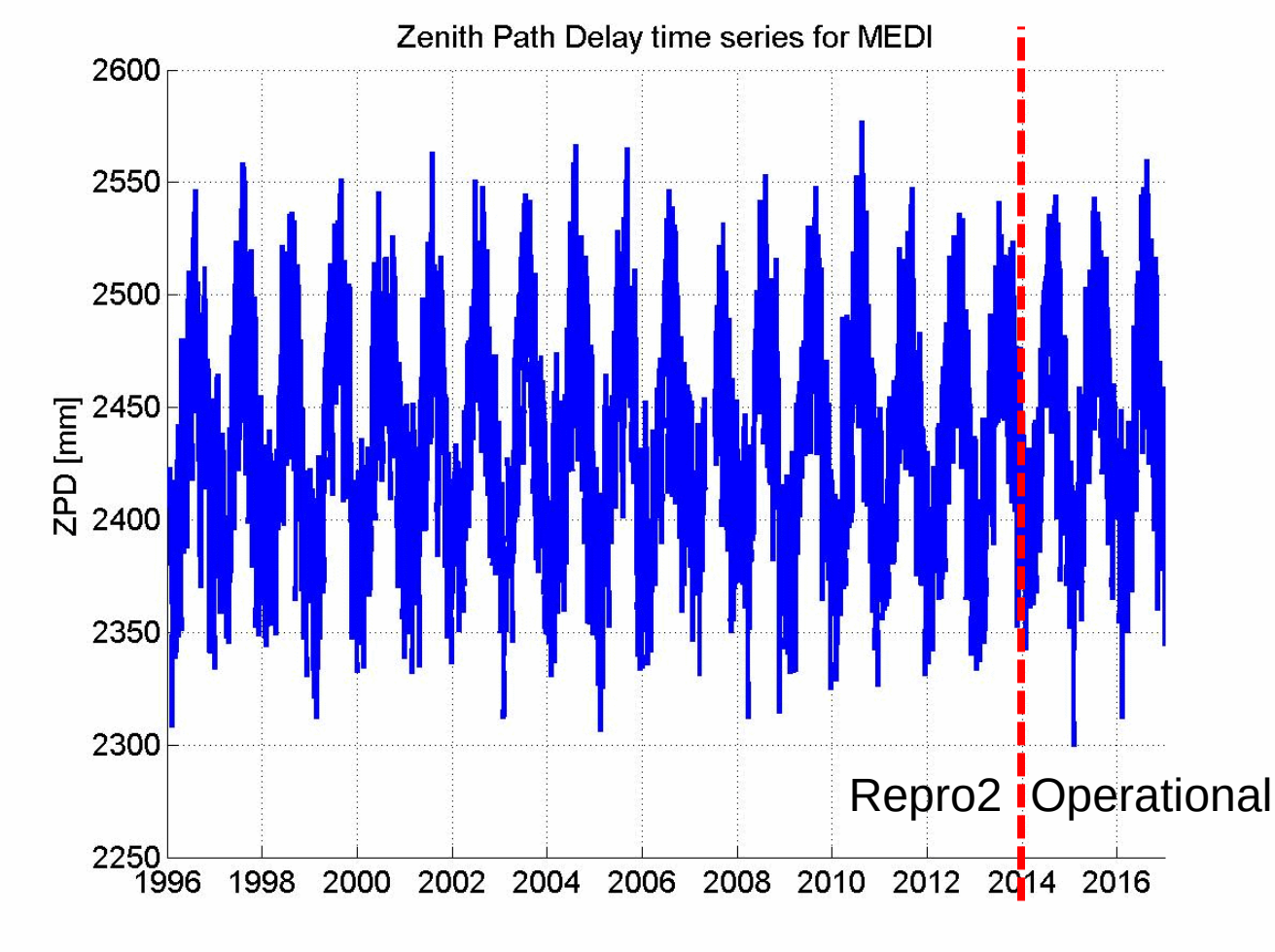
Outlier detection:

- *Weak ZTD estimates of the individual ACs solutions are excluded beforehand because of a standard deviation exceeding* ***15 mm.***
- *Site-specific solutions of a particular AC are eliminated if the standard deviation of the series exceeds* ***20 mm.***

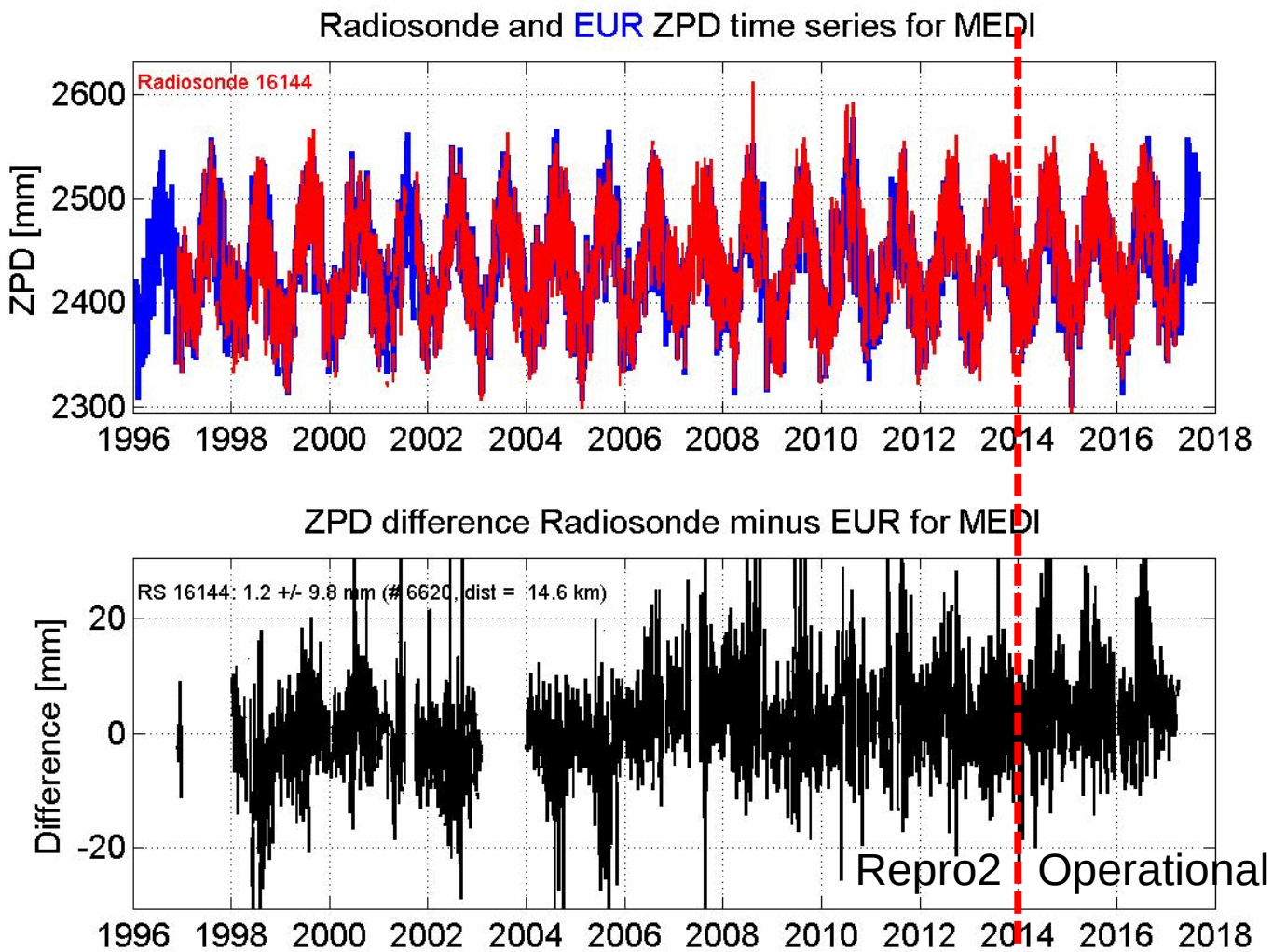
[Pacione et al., JASR 47 (2011) 323–335]

Operational – Cumulative Solution T1963

- EUREF mail 9158
- Next cumulative solution: February/March 2018

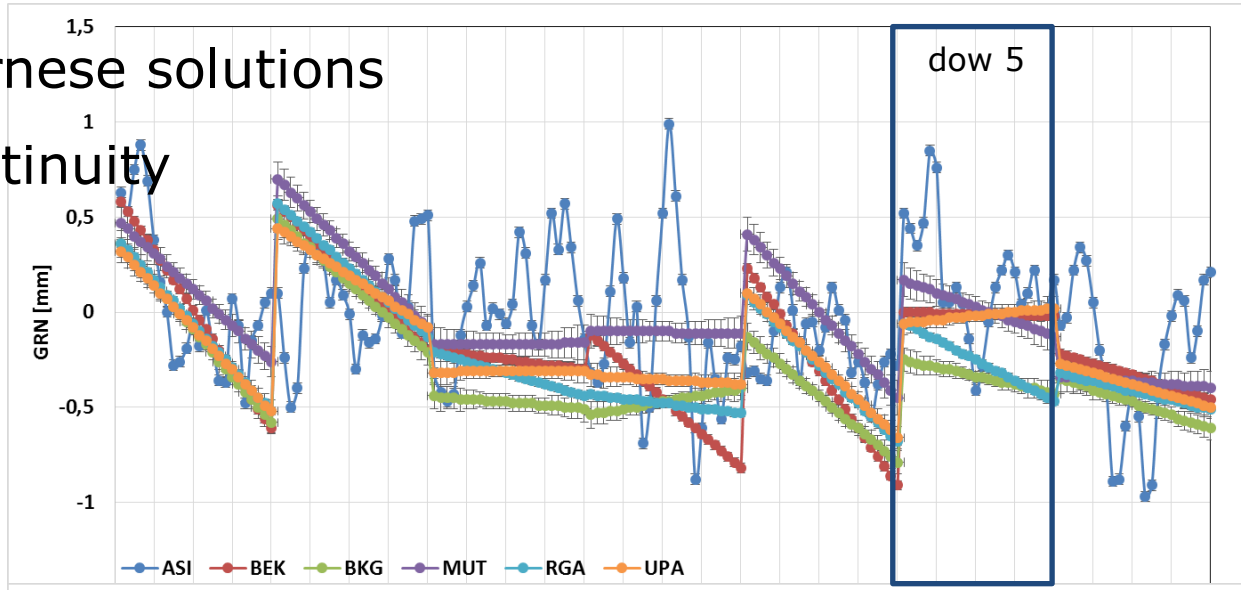


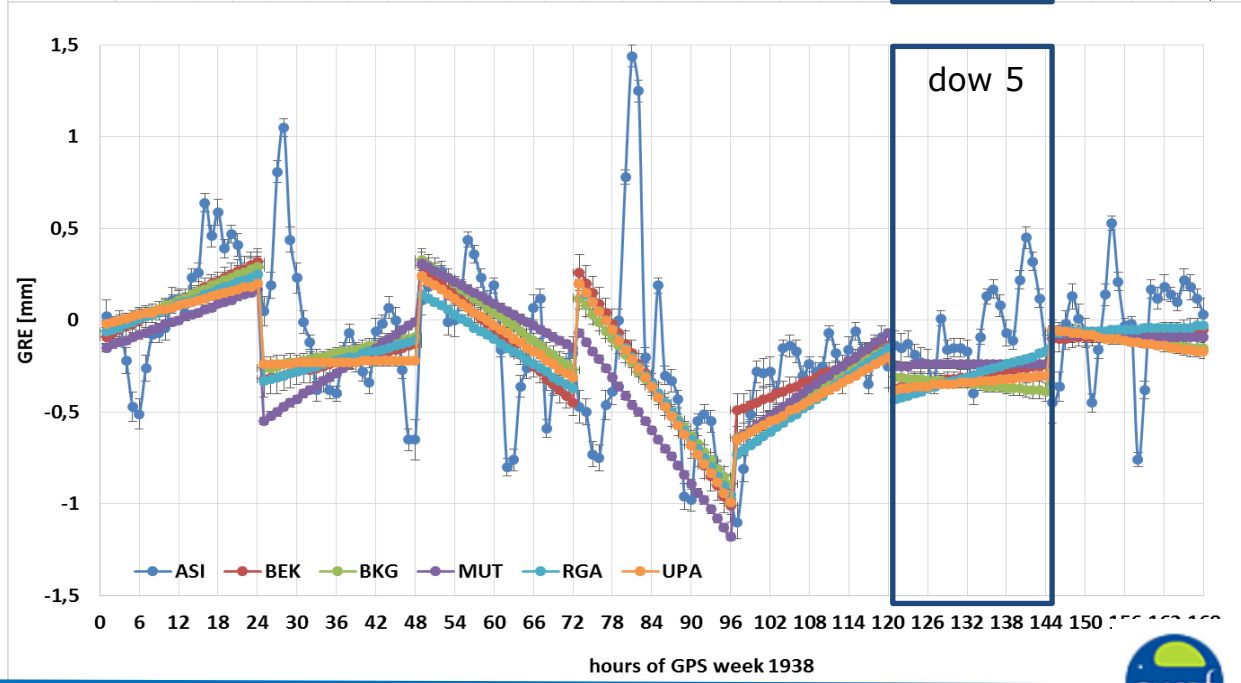
Operational – Cumulative Solution T1963



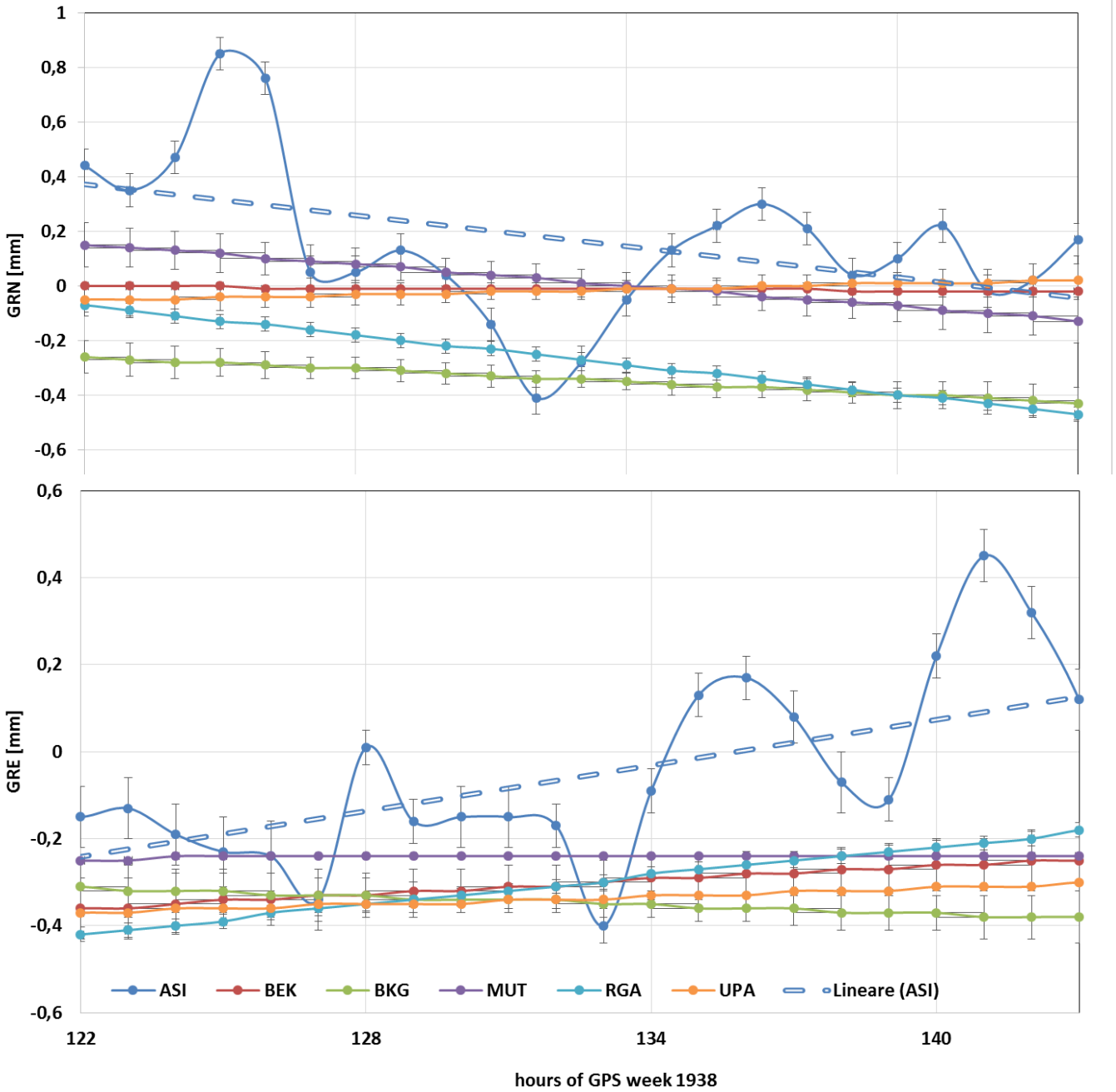
Gradients: MATE GPS week 1938

- Different slopes in Bernese solutions
- Daily boundary discontinuity





Gradients: MATE GPS week 1938 dow 5



SINEX_TRO v2.0: Driver

Unique format to be adopted within all the IAG services and by all the techniques dealing with tropospheric parameters and able to support:

- Parameters from different sources than space geodetic techniques such as numerical weather prediction models and re-analyses, radiosondes and water vapour radiometers;
- Long station names (9 characters) in concordance with RINEX 3 data format;
- Products including slant tropospheric delays;
- Parameters corresponding to long-term time series of individual stations.

SINEX_TRO v2.0: Philosophy

- Simple and flexible design following the philosophy of the SINEX format with regards to metadata description and overall data structure;
- Decoupled from the SINEX, it means that the most of metadata blocks are mandatory in the SINEX_TRO format in order to support a stand-alone and non-ambiguous metadata description;
- Supporting all the necessary information for the conversion to the COST-716 format, so far widely used within GNSS-meteorology applications (http://egvap.dmi.dk/support/formats/egvap_cost_v22.pdf).

SINEX TRO v2.0: File Naming Convention

For file naming, it is recommended to use new format convention according to IGS products:

AAAV_PPP_TTT_YYYYDOYHHMM_LEN_SMP.TRO

Operational

ASI1_OPS_FIN_20170300030_01D_01H.TRO
BEK1_OPS_FIN_20170300030_01D_01H.TRO
BKG1_OPS_FIN_20170300030_01D_01H.TRO
BEV1_OPS_FIN_20170300030_01D_01H.TRO
……
EUR1_OPS_FIN_20170300030_07D_01H.TRO

Repro2

ASI0_REP_FIN_20100300030_01D_01H.TRO
GOP4_REP_FIN_20100300030_01D_01H.TRO
IG0_REP_FIN_20100300030_01D_01H.TRO
LP1_REP_FIN_20100300030_01D_01H.TRO
MU2_REP_FIN_20100300030_01D_01H.TRO
……
EUR0_REP_FIN_20150300030_07D_01H.TRO

SINEX TRO v2.0: File Naming Convention

```
GOPG_OPS_NRT_20150301000_01H_05M.TRO
GOP1_DEM_RTM_20150301000_05M_05M_GOPE.TRO
GOP2_OPS_FIN_20150300000_01D_01H.TRO
ASI2_REP_FIN_20150301030_07D_01H.TRO
EUR2_REP_FIN_20150300030_07D_01H.TRO
GOP2_TST_SUB_20150301000_15M_05M_GOPE00CZE.TRO
```

analysis centre acronym
&
version / solution identifier

file frequency: minutes (xxM), hours (xxH), days (xxD), weeks (xxW), months (xxB), years (xxY), unspecified (00U).

project/campaign identification: operational (OPS), demonstration (DEM), testing (TST), re-processing (REP), undefined (UNK)

data sampling rate:100 Hertz (xxC), Hertz (xxZ), seconds (xxS), minutes (xxM), hours (xxH), days (xxD), weeks (xxW), months (xxB), years (xxY), unspecified (00U).

solution type: final (FIN), rapid (RAP), near real-time (NRT), real-time (RTM), sub-hourly (SUB), unknown (UNK)

beginning time of nominal data interval

Site name of 4 (old) or 9 (new) char.
RINEX 3 convention is recommended

SINEX_TRO v2.0: Blocks

	FILE/REFERENCE	(Mandatory)
	INPUT/FILES	(Combined product only)
	CENTERS/INFO_MODEL	(Combined product only)
	CENTERS/INFO_SOLUTION	(Combined product only)
	SITE/ID	(Mandatory)
	SITE/RECEIVER	(Mandatory for GNSS)
	SITE/ANTENNA	(Mandatory for GNSS)
	SITE/COORDINATES	(Mandatory for GNSS)
	SITE/ECCENTRICITY	(Mandatory for GNSS)
	TROP/DESCRIPTION	(Mandatory)
	TROP/SOLUTION	(Mandatory for values in zenith directions)
NEW ←	SLANT/SOLUTION	(Mandatory for values in slant directions)

SINEX TRO v2.0: Example for Submission of Trop & Slant Estimates

```
%=TRO 2.00 GOP 2017:157:61799 GOP 2013:168:64500 2013:168:86100 P  MIX
*------------------------------------------------------------------------------
+FILE/REFERENCE
*INFO_TYPE_________ INFO_______________________________________________________
 DESCRIPTION        GOP - Geodetic Observatory Pecny, RIGTC
 OUTPUT             Solution parameters
 CONTACT            gnss@pecny.cz
 SOFTWARE           G-Nut/Geb
 INPUT              GNSS/NWM/RAO/OTH data
 VERSION NUMBER     001
-FILE/REFERENCE
*------------------------------------------------------------------------------
+TROP/DESCRIPTION
*_________KEYWORD______________ __VALUE(S)_____________________________________
 TROPO SAMPLING INTERVAL       300
 SLANT SAMPLING INTERVAL       300
 DATA SAMPLING INTERVAL        300
 GNSS SYSTEMS                  G
 TIME SYSTEM                   G
 TROPO MODELING METHOD         KALMAN FILTER
 GEOID MODEL                   VMF1/EGM96
 OCEAN TIDE LOADING MODEL      FES2004
 ATMOSPH TIDE LOADING MODEL    NOT APPLIED
 ELEVATION CUTOFF ANGLE        7
 OBSERVATION WEIGHTING         SINEL
 A PRIORI TROPOSPHERE          EXTERN
 TROPO MAPPING FUNCTION        GMF
 GRADS MAPPING FUNCTION        CHEN_HERRING
 REFRACTIVITY COEFFICIENTS     77.60 70.40 373900.0
 SOURCE OF MET/DATA            NWP
 TROPO PARAMETER NAMES         TROTOT STDDEV TRODRY TROWET TGNTOT STDDEV TGETOT STDDEV   NSAT   GDOP    IWV  PRESS TEMDRY WMTEMP TEMLPS WMTLPS ZWDDEC
 TROPO PARAMETER UNITS          1e+03  1e+03  1e+03  1e+03  1e+03  1e+03  1e+03  1e+03      1      1      1      1      1      1  1e+03  1e+03      1
 TROPO PARAMETER WIDTH              6      6      6      6      6      6      6      6      4      4      6      7      6      6      6      6      6
 SLANT PARAMETER NAMES         SLTTOT STDDEV SLTDRY SLTWET SLTIWV SLTGRD SATRES SATMPT    SAT SATELE SATAZI FACDRY FACWET FACGRD
 SLANT PARAMETER UNITS          1e+03  1e+03  1e+03  1e+03      1  1e+03  1e+03  1e+03      1      1      1      1      1      1
 SLANT PARAMETER WIDTH              8      6      8      6      6      6      6      6      4      7      7      9      9      9
-TROP/DESCRIPTION
```

SINEX TRO v2.0: Example for Submission of Trop & Slant Estimates

```
*------------------------------------------------------------------------------
+SITE/ID
*STATION__ PT __DOMES__ T _STATION DESCRIPTION__ _LONGITUDE _LATITUDE_ _HGT_ELI_ _HGT_MSL_
 GOPE00CZE  A 11502M002 P                        14.785625  49.913706   592.716   630.502
 WTZR00DEU  A 14201M010 P                        12.878912  49.144199   666.119   705.725
 ZIMM00CHE  A 14001M004 P                         7.465279  46.877099   956.324  1000.057
-SITE/ID
*------------------------------------------------------------------------------
+SITE/COORDINATES
*STATION__ PT SOLN T __DATA_START__ __DATA_END____ __STA_X_____ __STA_Y_____ __STA_Z_____ SYSTEM REMRK
 GOPE00CZE  A    1 P 2013:168:00000 2013:168:86100  3979315.993  1050312.623  4857067.191  IGS08   GOP
 WTZR00DEU  A    1 P 2013:168:00000 2013:168:03300  4075580.457   931853.932  4801568.218  IGS08   GOP
 ZIMM00CHE  A    1 P 2013:168:00300 2013:168:86100  4331296.936   567556.035  4633134.023  IGS08   GOP
-SITE/COORDINATES
*------------------------------------------------------------------------------
+SITE/ECCENTRICITY
*                                                     UP______ NORTH___ EAST____
*STATION__ PT SOLN T __DATA_START__ __DATA_END____ AXE ARP->BENCHMARK(M)_________
 GOPE00CZE  A    1 P 2013:168:64500 2013:168:86100 UNE   0.1114   0.0000   0.0000
 WTZR00DEU  A    1 P 2013:168:64500 2013:168:86100 UNE   0.0710   0.0000   0.0000
 ZIMM00CHE  A    1 P 2013:168:64500 2013:168:86100 UNE   0.0000   0.0000   0.0000
-SITE/ECCENTRICITY
*------------------------------------------------------------------------------
+SITE/ANTENNA
*STATION__ PT SOLN T __DATA_START__ __DATA_END____ DESCRIPTION_________ S/N_________________ PCV_MODEL_
 GOPE00CZE  A    1 P 2013:168:64500 2013:168:86100 TPSCR.G3        TPSH -------------------- IGS08_1664
 WTZR00DEU  A    1 P 2013:168:64500 2013:168:86100 LEIAR25.R3      LEIT -------------------- IGS08_1664
 ZIMM00CHE  A    1 P 2013:168:64500 2013:168:86100 TRM29659.00     NONE -------------------- IGS08_1664
-SITE/ANTENNA
*------------------------------------------------------------------------------
+SITE/RECEIVER
*STATION__ PT SOLN T __DATA_START__ __DATA_END____ DESCRIPTION_________ S/N_________________ FIRMW______
 GOPE00CZE  A    1 P 2013:168:64500 2013:168:86100 TPS NETG3            -------------------- -----------
 WTZR00DEU  A    1 P 2013:168:64500 2013:168:86100 LEICA GRX1200+GNSS   -------------------- -----------
 ZIMM00CHE  A    1 P 2013:168:64500 2013:168:86100 TRIMBLE NETRS        -------------------- -----------
-SITE/RECEIVER
*------------------------------------------------------------------------------
```

SINEX TRO v2.0: Example for Submission of Trop & Slant Estimates

```
+TROP/SOLUTION
*STATION__ ____EPOCH_____ TROTOT STDDEV TRODRY TROWET TGNTOT STDDEV TGETOT STDDEV NSAT GDOP    IWV   PRESS TEMDRY WMTEMP TEMLPS WMTLPS ZWDDEC
 GOPE00CZE 2013:168:64500 2334.3    5.3 2166.8  167.4   0.99   0.85   0.14   0.93    7  2.2  27.26  951.92  299.6  285.7   7.20   7.21   3.32
 GOPE00CZE 2013:168:64800 2334.2    5.2 2166.8  167.4   1.00   0.84   0.17   0.92    6  1.9  27.25  951.90  299.6  285.7   7.20   7.21   3.32
 GOPE00CZE 2013:168:65100 2333.0    5.1 2166.8  166.2   1.00   0.83   0.29   0.91    7  2.2  27.06  951.90  299.6  285.7   7.20   7.21   3.33
...
 ZIMM00CHE 2013:168:85800 2275.0    4.6 2081.5  193.5  -0.18   0.65   0.79   0.86    9  1.1  31.16  913.97  296.3  282.6   7.21   6.74   2.94
 ZIMM00CHE 2013:168:86100 2274.7    4.7 2081.5  193.2  -0.20   0.66   0.84   0.85    8  1.4  31.11  914.01  296.2  282.5   7.20   6.74   2.94
-TROP/SOLUTION
*------------------------------------------------------------------------------
+SLANT/SOLUTION
*STATION__ ____EPOCH_____   SLTTOT STDDEV   SLTDRY SLTWET SLTIWV SLTGRD SATRES SATMPT  SAT  SATELE  SATAZI    FACDRY    FACWET    FACGRD
 GOPE00CZE 2013:168:64500   8363.0    9.9   7748.2  603.3   98.2   10.4    1.1    0.0  G05  16.000  39.323  3.575822  3.603292 12.159794
 GOPE00CZE 2013:168:64500   5635.5    8.2   5226.3  405.1   66.0   -0.2    4.2    0.0  G06  24.340 276.596  2.411963  2.419605  5.273237
 GOPE00CZE 2013:168:64500   3527.2    6.5   3266.0  252.6   41.1    0.8    7.8    0.0  G16  41.483 305.307  1.507287  1.508554  1.698072
 ...
 ZIMM00CHE 2013:168:86100   6721.5    8.0   6146.0  573.3   92.3   -7.0    9.3    0.0  G28  19.603 279.934  2.952592  2.967259  8.150843
 ZIMM00CHE 2013:168:86100   2366.6    4.7   2156.7  200.2   32.2   -0.2    9.8    0.0  G32  74.810 235.655  1.036111  1.036160  0.281091
-SLANT/SOLUTION
%=ENDTRO
```

Summary

- **EPN Repro2** combined products delivered end of 2016;
- **Routine** tropo combination and monitoring activities on going

  -Review of the Guidelines for the EPN Analysis;
- **Horizontal Gradients:** define a standard processing among the Bernese ACs;
- **SINEX_TRO v2.0:** format officially presented at the IGS Workshop and at the Unified Analysis Workshop in Paris

Acknowledgment: e-GEOS work is carried out under ASI contract 2015-050-R.0