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Swiss Federal Office of Topography (swisstopo)

Inclusion of GLONASS for EPN Analysis at CODE/swisstopo

Stefan Schaer

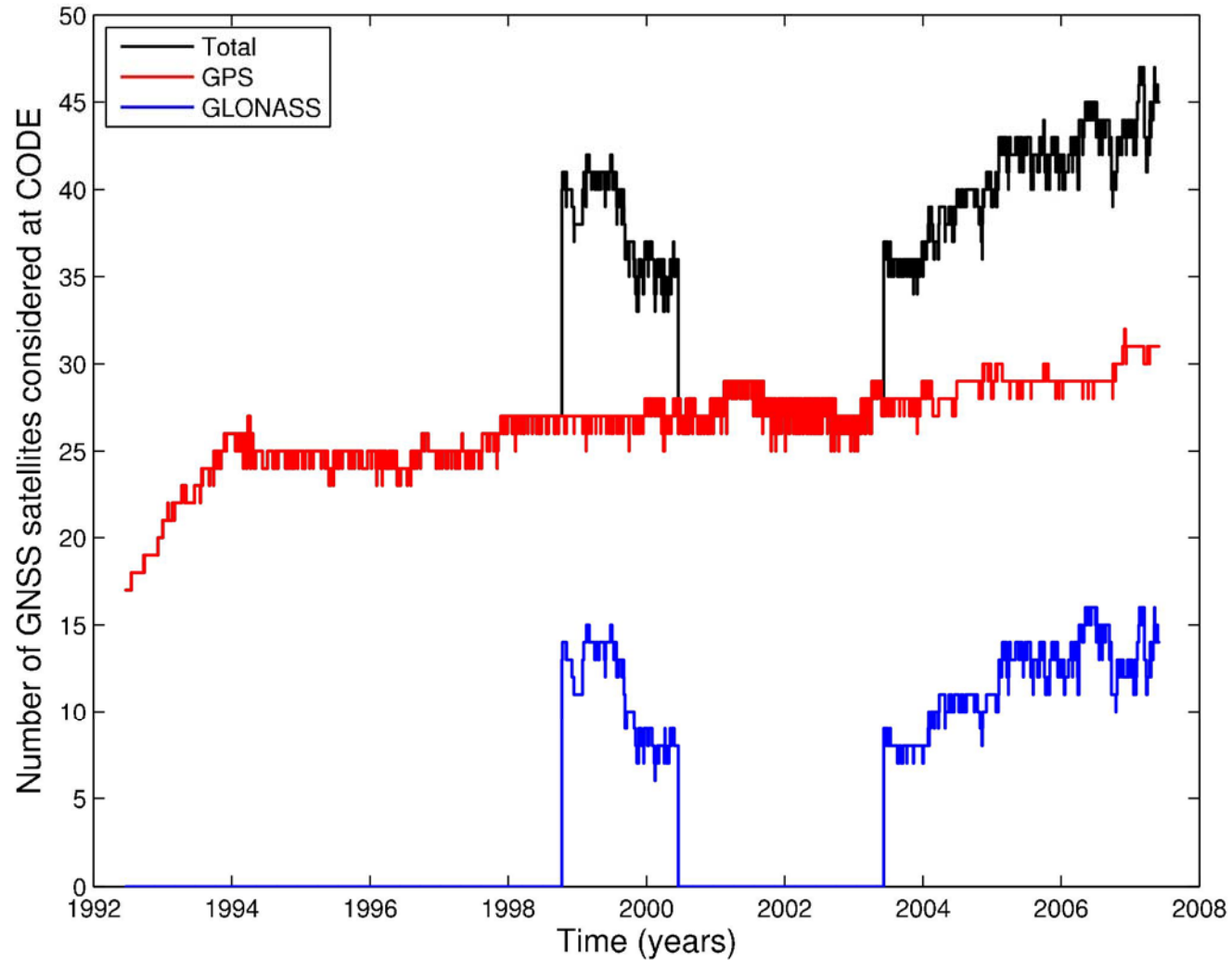


Outline

- GPS/GLONASS-combined EPN analysis at CODE (and at swisstopo), starting with GPS week 1400 (Nov. 5, 2006)
- CODE's completely redesigned EPN BPE processing scheme, a further development of swisstopo's "RNX2SNX" BPE procedures used for EPN and AGNES analysis
- New test solutions set up for regular computation (among them a GLONASS-only solution)
- Issues related to GLONASS ambiguity resolution
- Discussion of additional (shortest-baseline) test solutions computed for the GNSS receiver baseline ZIMJ-ZIMT
- Demonstration of GPS-GLONASS intersystem phase biases
- Summary, conclusions, outlook

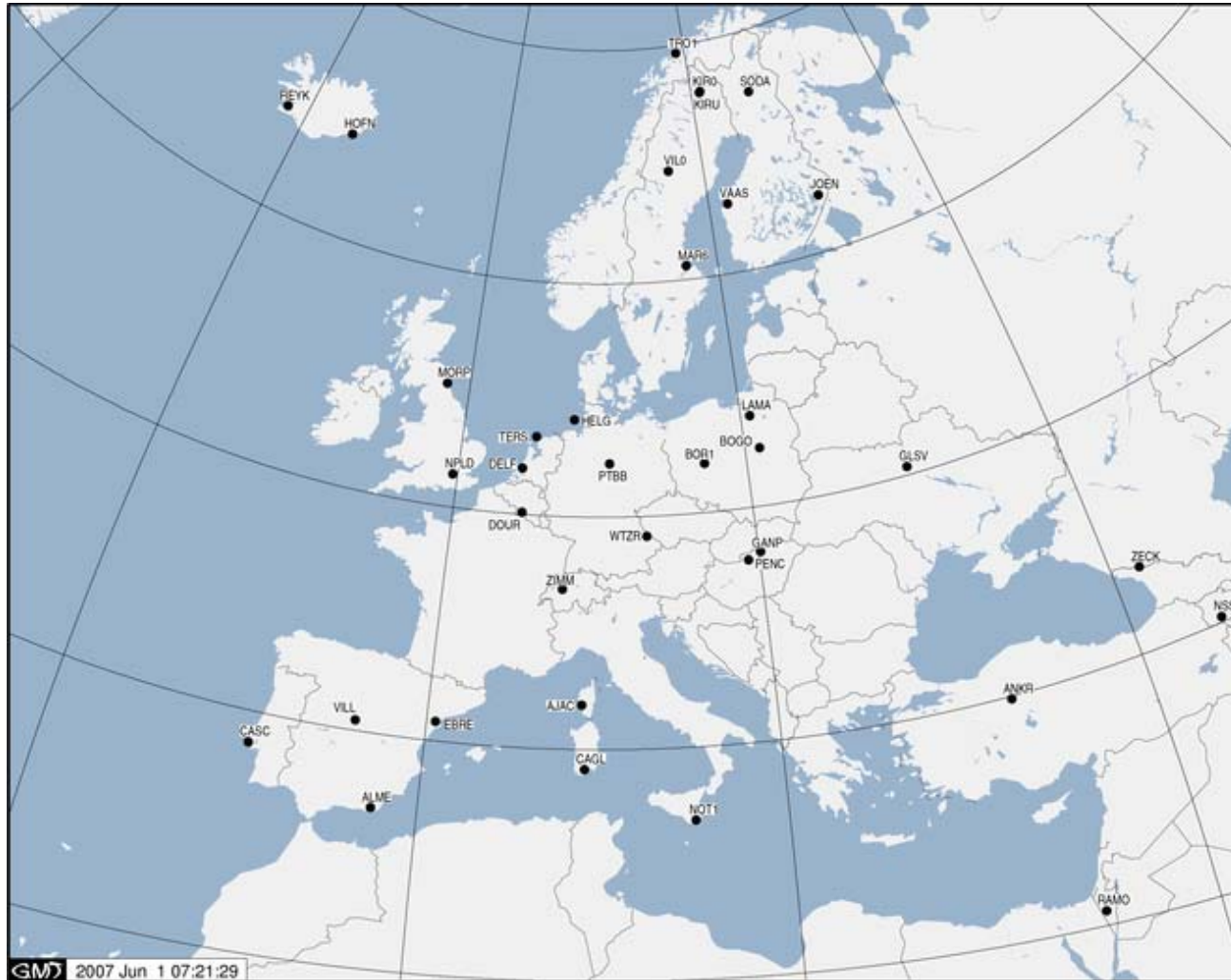


Number of Active GPS/GLONASS Satellites



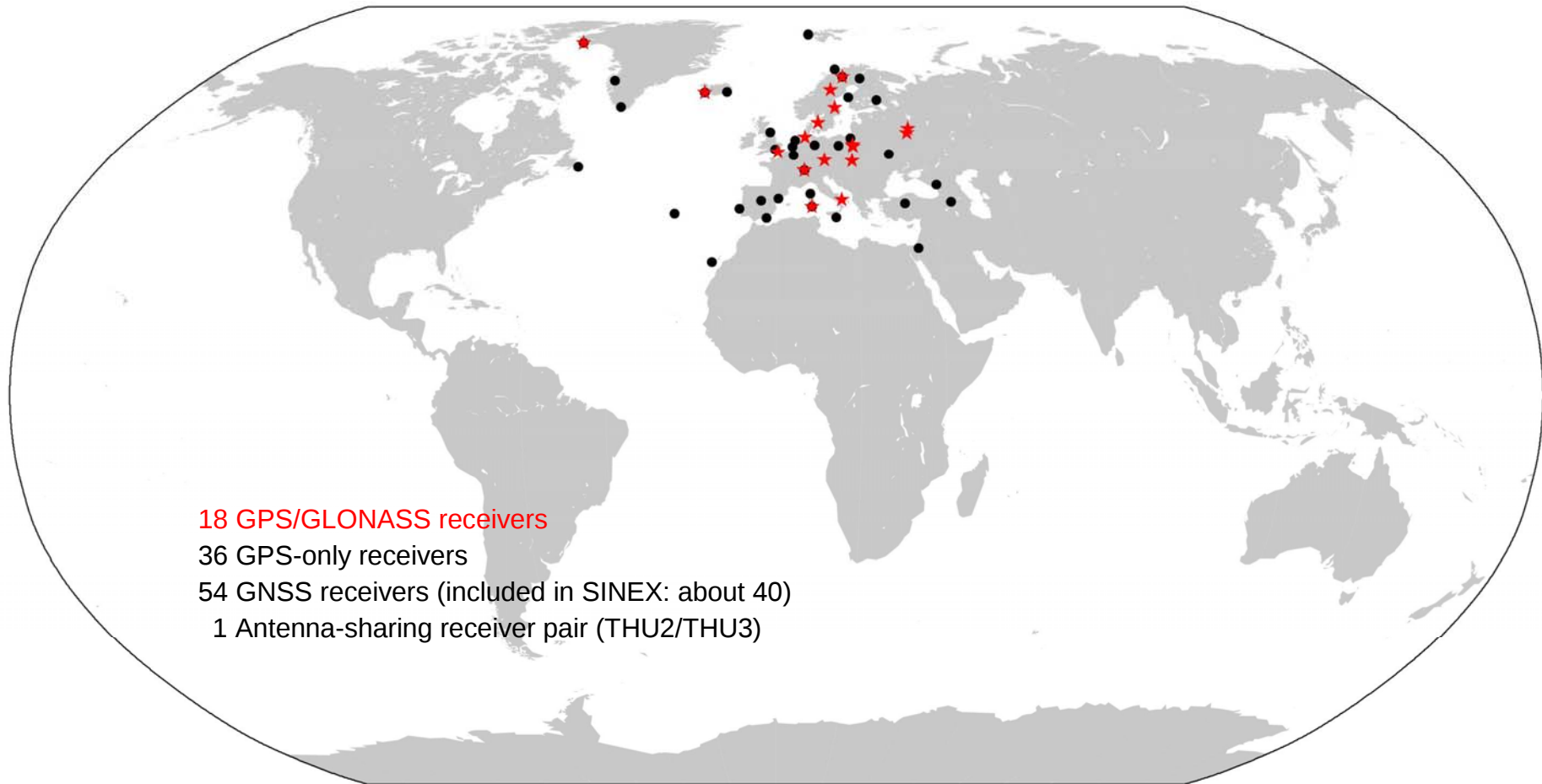


EPN Receiver Subnetwork Processed at CODE



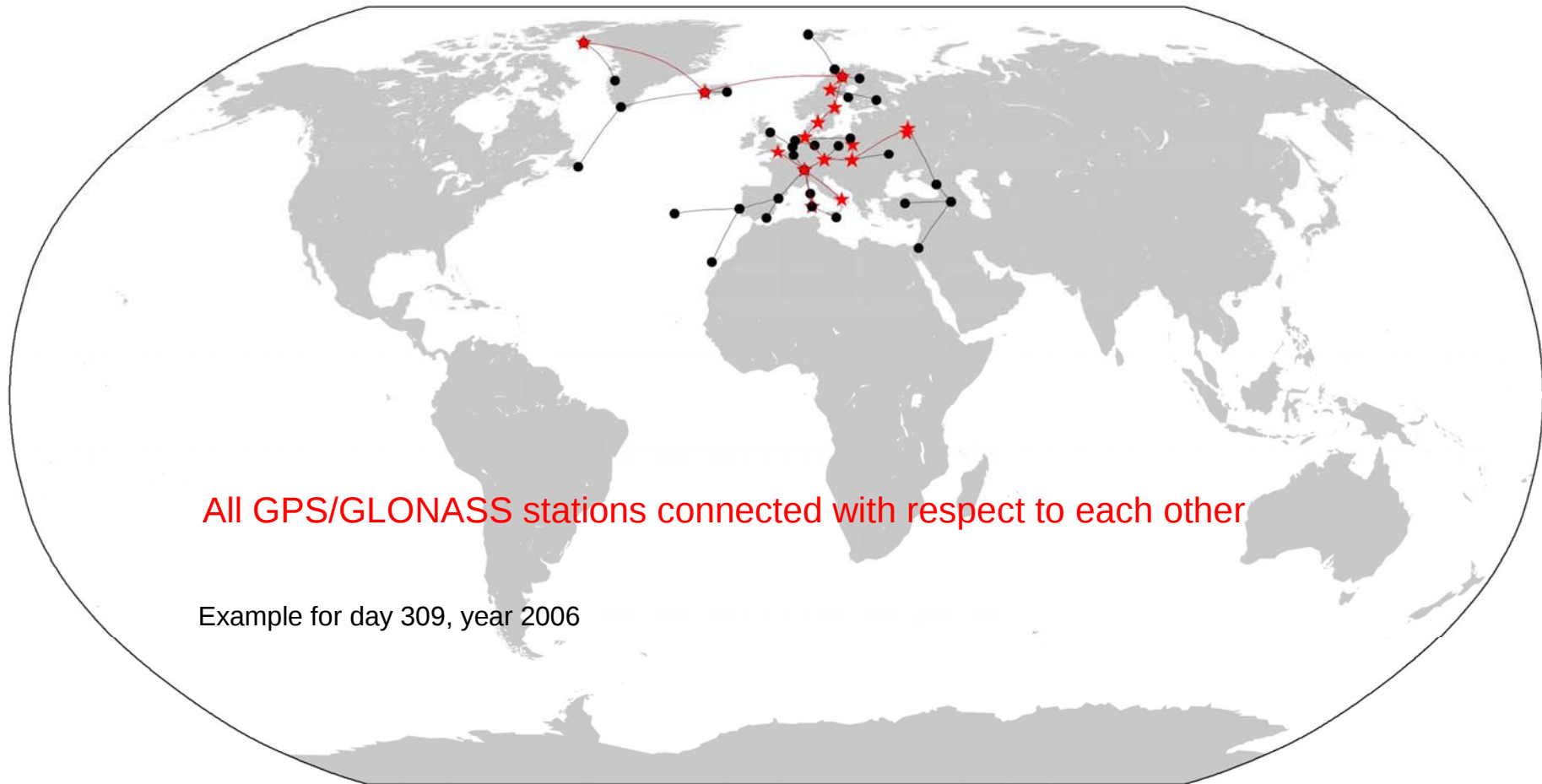


GNSS Tracking EPN/IGS Receiver Network Considered at CODE for Regional Analysis





Forming GNSS Receiver Baselines Using the “Max-Obs” Strategy (of Program SNGDIF)





Program BASLST V5.1: Selecting “GPS+GLONASS” Receiver Baselines for Computation of GLONASS-Only Solutions

Bernese GPS Software Version 5.1

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

BASLST 3: Options

TITLE

BASELINE SELECTION OPTIONS

Baselines with observations from

Maximum baseline length kilometers

Minimum baseline length kilometers

Maximum percentage of resolved ambiguities

Minimum percentage of resolved ambiguities

Receiver name

|| ^Top | ^Prev | ^Next | Cancel | Save^As | ^Save | ^Run | ^Output | Rer^un

> User: igsauto Campaign: \$(Q)/EPNFINAL \$Y+0=2006 \$S+0=3090 File: /u/aiub/igsauto/GPSUSER/OPT/EPN_GLO/BASLST.INP



GPS/GLONASS Analysis Supported by RNX2SNX BPE V5.0: Data Import (Program RXOBV3)

Bernese GPS Software Version 5.1

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

RXOBV3 2: Input Options 1

TITLE

SATELLITE SYSTEM SELECTION
Satellite system to be considered

STATION NAMES
Gather station names from
Action if station not in abbreviation list

SESSION IDENTIFIER
Session ID used for Bernese observation files (blank: AUTO)

DATA SAMPLING
Sampling interval seconds
Sampling offset to full minute seconds

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> User: igsauto Campaign: \$(Q)/EPNFINAL \$Y+0=2006 \$S+0=3090 File: /u/aiub/igsauto/GPSUSER/OPT/EPN_GEN/RXOBV3.INP



GPS/GLONASS Analysis Supported by RNX2SNX BPE V5.0: Ambiguity Resolution (Program GPSEST)

Bernese GPS Software Version 5.1

Configure Campaign RINEX Orbits/EOP Processing Service Conversion Help

Lokal: C
Verschlüsselung: C
Verbindungszeit: 1121 sec.

GPSEST 3.1: General Options 1

TITLE EPNFINAL_\$YSS+0_\$(FFFF): QIF ambiguity resolution

OBSERVATION SELECTION

Satellite system	GPS	
Frequency	L1&L2	
Elevation cutoff angle	10 degrees	LEO: 0 degrees
Sampling interval	30 seconds	
Tolerance for simultaneity	100 milliseconds	
Special data selection	NO	
Observation window		

OBSERVATION MODELING AND PARAMETER ESTIMATION

A priori sigma	0.001 meters	LEO: NONE
Elevation-dependent weighting	COSZ	
Type of computed residuals	NORMALIZED	
Correlation strategy	BASELINE	
Polarization effect	geom.	☒ only if later than 2003 09 14
	total	☒ only if later than 2006 11 12

< >

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> User: igsauto Campaign: \$(Q)EPNFINAL \$Y+0=2006 \$S+0=3090 File: /u/aiub/igsauto/GPSUSER/OPT/EPN_QIF/GPSEST.INP



New Test Solutions set up for Regular Computation

Overview of all regional solution types computed at CODE:

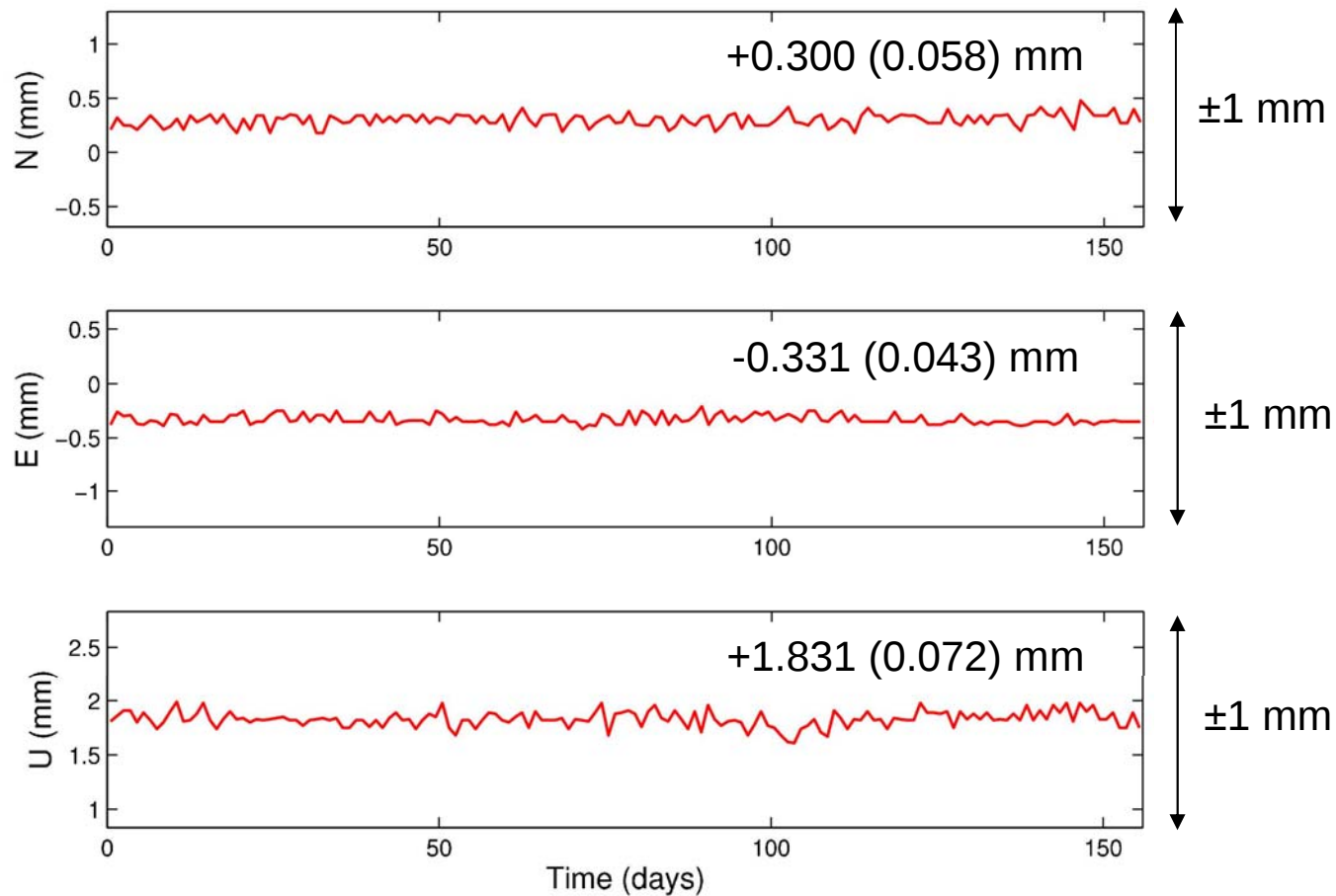
- F1_: GNSS solution (conform to CODE's global analysis)
- F1E: GNSS solution considering the EPN05 GPS PCV model values for individual antenna/radome combinations (if available)
- F1A: GPS-only solution
- F1B: GLONASS-only solution
- F1N: GPS/GLONASS combination on NEQ level (F1A+F1B)
- F1I: GNSS solution considering the IGS/IGLOS orbit products
- X1A: GPS solution considering the IGS orbit product
- X1B: GLONASS-only solution (ambiguity-float)

General features: consideration of the CODE GNSS orbit product; use of (absolute) IGS05 GNSS PCV model; use of GMF (not NMF); estimation of horizontal troposphere gradient parameters; elevation mask angle of 3 degrees; GPS ambiguity resolution using the pseudorange/narrowlane, QIF, widelane*/narrowlane, direct* method.

*GPS/GLONASS ambiguity resolution



F1E-F1 Daily Solution Differences for GANP Station Coordinates (in North, East, Up):





SITE/GPS_PHASE_CENTER Block in SINEX (1)

```
* -----
+SITE/GPS_PHASE_CENTER
*
*      UP_____ NORTH_ EAST___ UP_____ NORTH_ EAST___
* DESCRIPTION_____ S/N___ L1->ARP(M)_____ L2->ARP(M)_____
A0AD/M_T          DUTD ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
A0AD/M_T          NONE ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
A0AD/M_T          NONE 00404 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 EPN05
A0AD/M_T          OSOD ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
ASH700936A_M      NONE ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
ASH700936A_M      SNOW ----- 0.0893 0.0009 -.0007 0.1177 0.0008 -.0001 IGS05_1421
ASH700936C_M      SNOW ----- 0.0904 -.0001 -.0005 0.1201 -.0005 0.0004 IGS05_1421
ASH700936D_M      SNOW ----- 0.0910 0.0005 -.0001 0.1202 0.0003 0.0000 IGS05_1421
ASH700936E        SNOW ----- 0.0896 0.0002 -.0002 0.1182 -.0001 0.0001 IGS05_1421
ASH700936F_C      SNOW ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
ASH701073.1       SCIS ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
ASH701073.1       SNOW ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
ASH701945B_M      SNOW ----- 0.0905 0.0010 0.0003 0.1183 -.0003 -.0003 IGS05_1421
ASH701945C_M      NONE ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
ASH701945C_M      SNOW ----- 0.0899 0.0002 0.0004 0.1195 -.0008 0.0002 IGS05_1421
ASH701945C_M      UNAV ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
ASH701945E_M      SCIS ----- 0.0890 0.0005 0.0000 0.1190 -.0006 0.0000 IGS05_1421
LEIAT504          NONE ----- 0.0912 0.0001 -.0003 0.1173 -.0001 0.0001 IGS05_1421
TRM29659.00       NONE ----- 0.0920 -.0001 -.0009 0.1205 -.0002 0.0002 IGS05_1421
TRM29659.00       TCWD ----- 0.0956 0.0000 -.0003 0.1241 -.0003 -.0004 IGS05_1421
TRM29659.00       UNAV ----- 0.0889 0.0014 0.0014 0.1194 -.0008 -.0007 IGS05_1421
TRM55971.00       NONE 37385 0.0670 0.0010 -.0001 0.0577 0.0003 0.0002 EPN05
-SITE/GPS_PHASE_CENTER
* -----
```



SITE/GPS_PHASE_CENTER Block in SINEX (2)

```
* -----
+SITE/GPS_PHASE_CENTER
*
*      UP_____ NORTH_ EAST__  UP_____ NORTH_ EAST__
*      DESCRIPTION_____ S/N___ L1->ARP(M)_____ L2->ARP(M)_____
AOAD/M_T      NONE ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
AOAD/M_T      NONE 00404 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 EPN05
ASH700936A_M  NONE ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
ASH700936A_M  SNOW ----- 0.0893 0.0009 -.0007 0.1177 0.0008 -.0001 IGS05_1421
ASH700936C_M  SNOW ----- 0.0904 -.0001 -.0005 0.1201 -.0005 0.0004 IGS05_1421
ASH700936D_M  SNOW ----- 0.0910 0.0005 -.0001 0.1202 0.0003 0.0000 IGS05_1421
ASH700936E    SNOW ----- 0.0896 0.0002 -.0002 0.1182 -.0001 0.0001 IGS05_1421
ASH700936F_C  NONE ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
ASH701073.1   NONE ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
ASH701945B_M  SNOW ----- 0.0905 0.0010 0.0003 0.1183 -.0003 -.0003 IGS05_1421
ASH701945C_M  NONE ----- 0.0912 0.0006 -.0005 0.1201 -.0001 -.0006 IGS05_1421
ASH701945C_M  SNOW ----- 0.0899 0.0002 0.0004 0.1195 -.0008 0.0002 IGS05_1421
ASH701945E_M  SCIS ----- 0.0890 0.0005 0.0000 0.1190 -.0006 0.0000 IGS05_1421
LEIAT504      NONE ----- 0.0912 0.0001 -.0003 0.1173 -.0001 0.0001 IGS05_1421
TRM29659.00   NONE ----- 0.0920 -.0001 -.0009 0.1205 -.0002 0.0002 IGS05_1421
TRM29659.00   TCWD ----- 0.0956 0.0000 -.0003 0.1241 -.0003 -.0004 IGS05_1421
TRM29659.00   UNAV ----- 0.0889 0.0014 0.0014 0.1194 -.0008 -.0007 IGS05_1421
TRM55971.00   NONE 37385 0.0670 0.0010 -.0001 0.0577 0.0003 0.0002 EPN05
-SITE/GPS_PHASE_CENTER
* -----
```

Note: According to IGS standard, antenna/radome combinations with PCV values adopted from the corresponding NONE combination (i.e. uncalibrated combinations) must be suppressed.



Program ADDNEQ2 V5.1: Additional SINEX Option

Bernese GPS Software Version 5.1

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

ADDNEQ2 3.3: Options 3

SINEX OPTIONS

Regularize a priori constraint matrix

Sort stations according to DOMES code ☐

Include ADDNEQ1-style statistics block ☒

Do not write uncalibrated antenna/radome combinations ☐

VAR-COVAR FILE OPTIONS

Representation of coordinates and velocities

ADDITIONAL OPTIONS

Truncate all NEQ station names after position 14

Keep input NEQs in alphabetical order ☐

^Top | ^Prev | ^Next | Cancel | Save^As | ^Save | ^Run | ^Output | Rer^un

> User: igsauto Campaign: \$(Q)/EPNFINAL \$Y+0=2006 \$S+0=3090 File: /u/aiub/igsauto/GPSUSER/OPT/EPN_SNX/ADDNEQ2.INP



Update Concerning Program PHCCNV V5.0: Absolute to Relative PCV Conversion

Bernese GPS Software Version 5.1

Configure Campaign RINEX Orbits/EOP Processing Service Conversion BPE User Help

CONVERT ANTENNA PHASE CENTER CORRECTIONS TO BERNESE FORMAT - PHCCNV 1: Input

GENERAL FILES
Show all general files ☒

INPUT FILENAME
External phase center offsets
Bernese phase center offsets file
Station information file STA

OPTIONS FOR BERNESE INPUT FILE
Conversion from relative to absolute PCV ☐ **abs to rel for ATX ☐**
Consider antennas without radome code ☐

RESULT FILE
Bernese phase center offsets PHG

GENERAL OUTPUT FILES
Program output ☐ use PHCCNV.Lnn or PHCCNV OUT
Error messages ☒ merged to program output or ERROR MSG

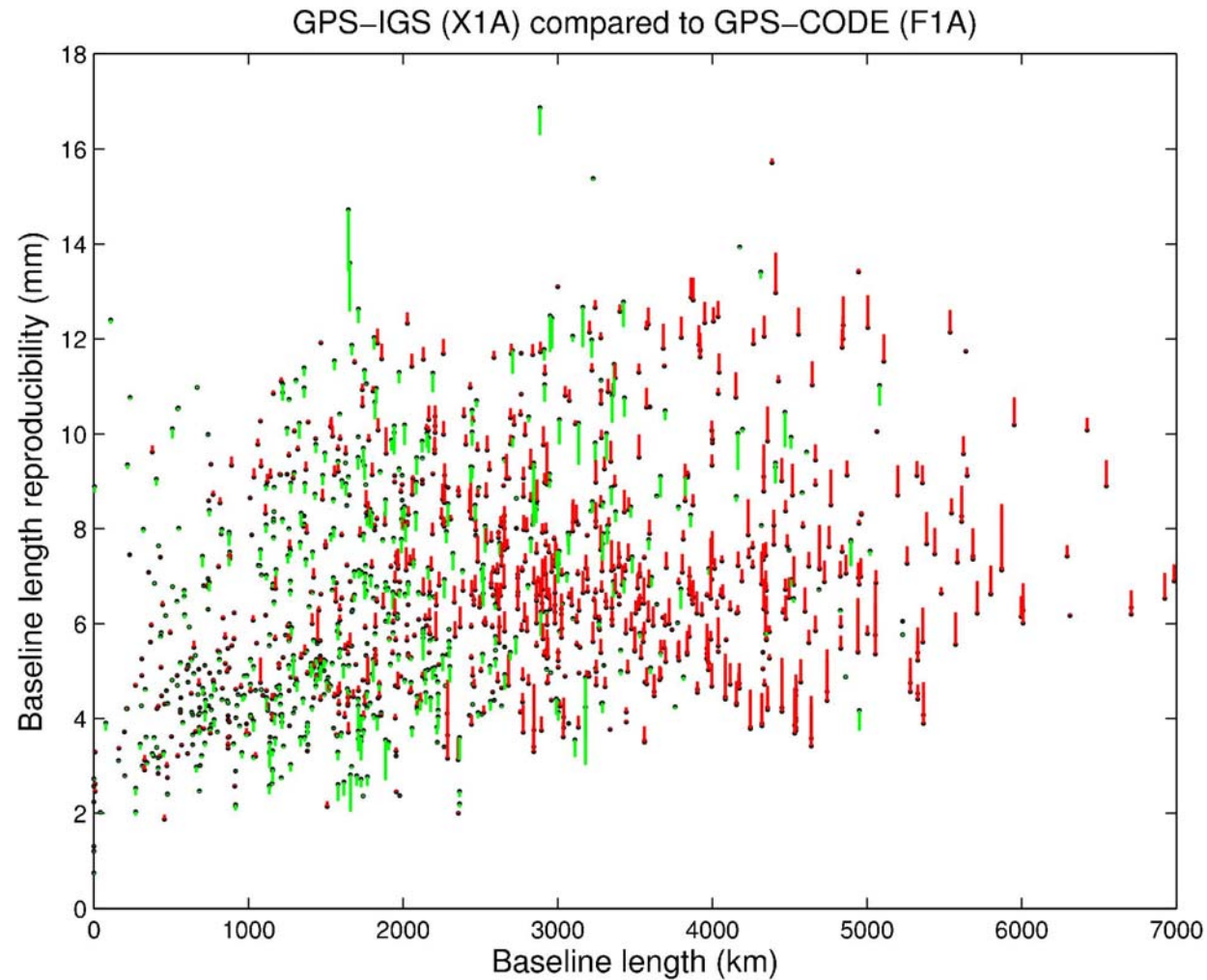
TITLE

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> User: igsauto Campaign: \${Q}EPNFINAL \$Y+0=2006 \$S+0=3090 File: /u/aiub/igsauto/GPSUSER/PAN/PHCCNV.INP

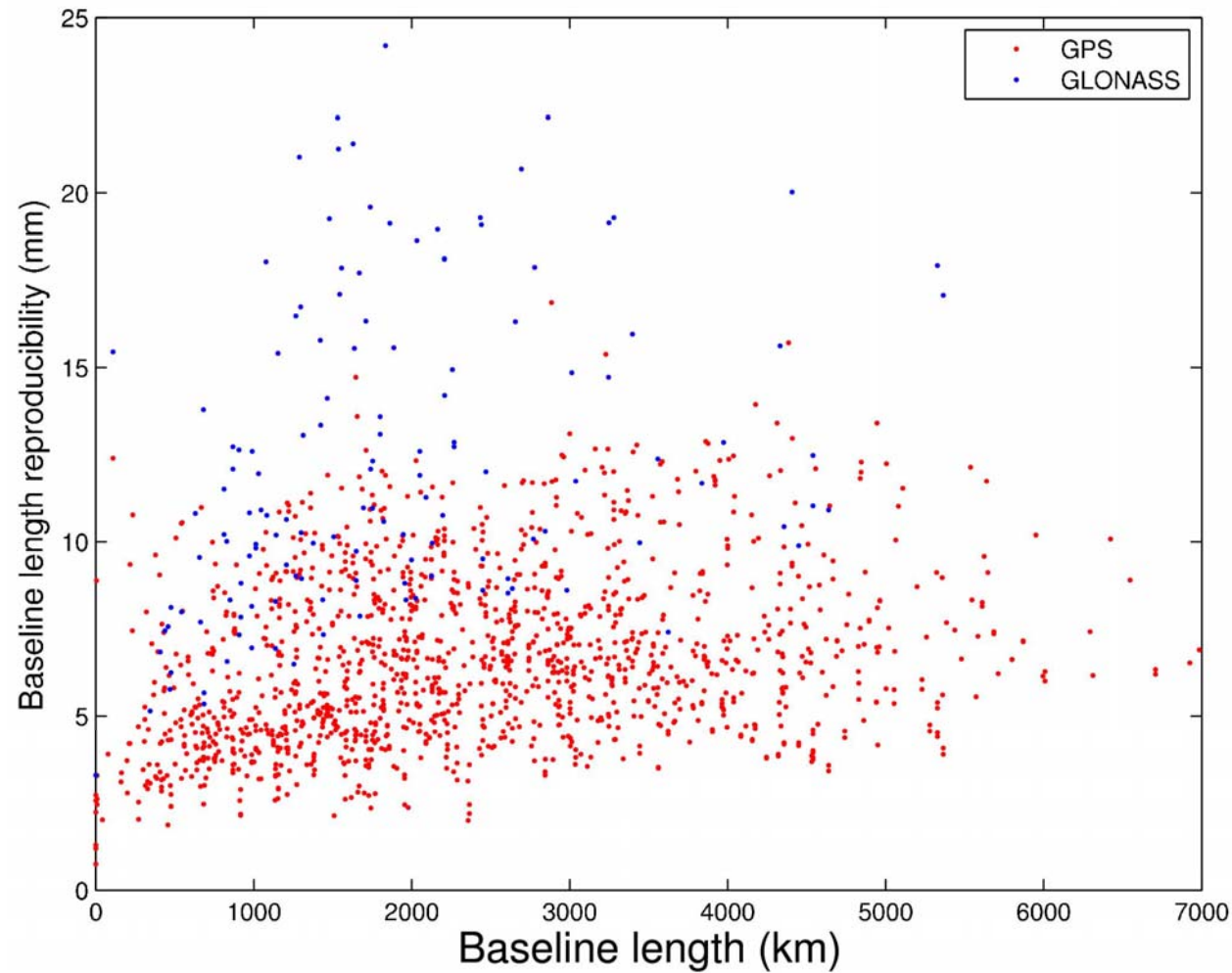


Performance of F1I/X1A (IGS/IGLOS) Compared to F1/F1A (CODE) Solution





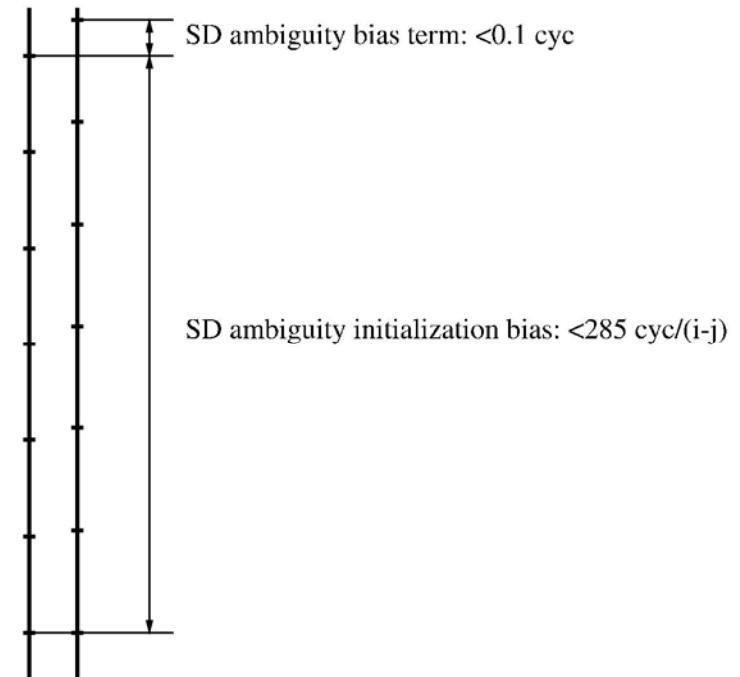
Performance of F1A (GPS) and F1B (GLONASS) Solutions Compared





Issues Related to GLONASS Ambiguity Resolution

- Ambiguity resolution does *not* work in the Bernese SW V5.0: module NORINI: **IF (MIXED.NE.0.AND.1.EQ.2) THEN!**
- Correction made in BSW V5.1 (including V5.0 at swisstopo): Do not fix integers between GPS and GLONASS!
- Shortest-baseline tests confirmed that GLONASS, or GPS/GLONASS-combined ambiguity resolution is possible (100% resolved).
- The single-difference (SD) initialization bias turned out to be crucial, specifically for the narrowlane (as well as QIF).



Example for ZIMJ/ZIMT: approx. 400 L1 cyc, 300 L2 cyc, $400-300=100$ WL cyc, $400+3.53 \cdot 100=753$ NL cyc



Discussion of additional (shortest-baseline) test solutions computed for the GNSS receiver baseline ZIMJ-ZIMT

Solution		Reproducibility		N (m)	E (m)	U (m)	L (m)
N1I:	27	3.43775	0.00023	0.00036	0.00040	0.00036	
G1I:	27	3.43794	0.00027	0.00037	0.00041	0.00038	
R1I:	27	3.43704	0.00038	0.00044	0.00069	0.00041	
N1R:	27	3.43800	0.00021	0.00044	0.00040	0.00045	
G1R:	27	3.43830	0.00027	0.00043	0.00044	0.00046	
O1I:	27	3.43763	0.00031	0.00045	0.00054	0.00048	
O1R:	27	3.43804	0.00031	0.00063	0.00043	0.00062	
R1R:	27	3.43702	0.00027	0.00082	0.00075	0.00080	
N2I:	27	3.43945	0.00024	0.00034	0.00056	0.00033	
G2I:	27	3.43954	0.00025	0.00035	0.00054	0.00035	
G2R:	27	3.43969	0.00026	0.00041	0.00065	0.00042	
N2R:	27	3.43927	0.00021	0.00050	0.00061	0.00049	
O2I:	27	3.43978	0.00031	0.00052	0.00071	0.00050	
R2I:	27	3.43938	0.00045	0.00063	0.00114	0.00060	
O2R:	27	3.43880	0.00024	0.00066	0.00071	0.00065	
R2R:	27	3.43811	0.00040	0.00097	0.00105	0.00090	
N3I:	27	3.43512	0.00036	0.00045	0.00150	0.00047	
G3I:	27	3.43548	0.00035	0.00046	0.00154	0.00050	
N3R:	27	3.43606	0.00041	0.00088	0.00156	0.00091	
R3I:	27	3.43351	0.00094	0.00103	0.00159	0.00096	
G3R:	27	3.43616	0.00044	0.00100	0.00159	0.00105	
O3I:	27	3.43433	0.00083	0.00117	0.00212	0.00122	
R3R:	27	3.43535	0.00082	0.00174	0.00271	0.00163	
O3R:	27	3.43685	0.00089	0.00210	0.00191	0.00207	
F1N:	27	3.44202	0.00041	0.00045	0.00252	0.00051	
R1T:	27	3.44202	0.00039	0.00042	0.00252	0.00051	
X1A:	27	3.44243	0.00036	0.00038	0.00270	0.00053	
F1A:	27	3.44244	0.00038	0.00037	0.00273	0.00054	
F1B:	27	3.43995	0.00118	0.00112	0.00330	0.00107	
F1I:	27	3.44121	0.00099	0.00132	0.00391	0.00140	
F1_:	27	3.44123	0.00102	0.00133	0.00387	0.00142	
X1B:	27	3.44063	0.00102	0.00177	0.00351	0.00157	

Solution code:

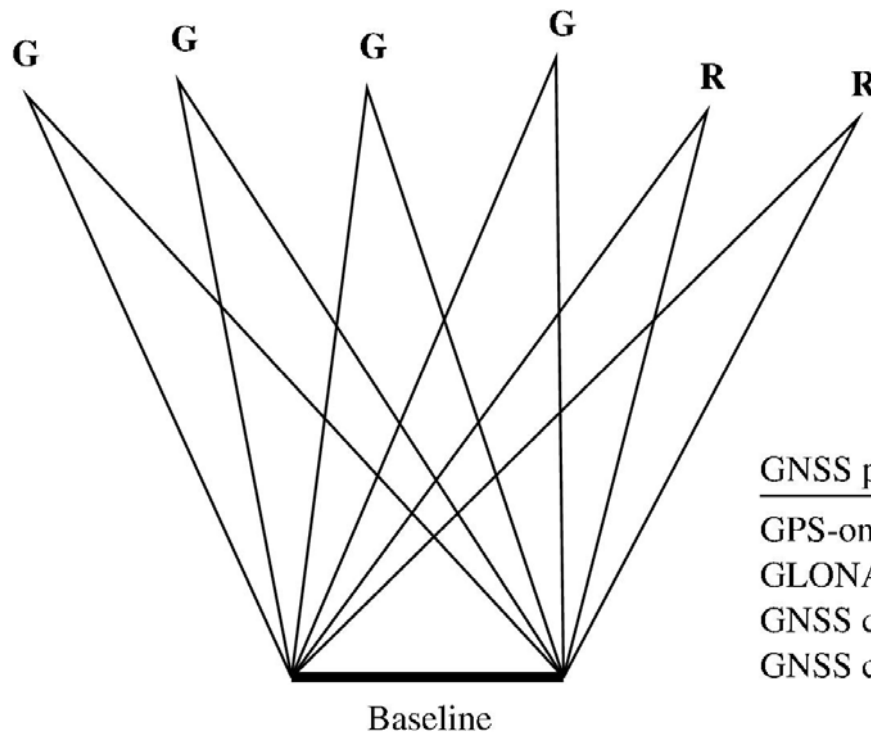
G: GPS / R: GLONASS / O: Obs. / N: NEQ

1: L1 / 2: L2 / 3: LC

R: amb-float (real) / I: amb-fixed (integer)



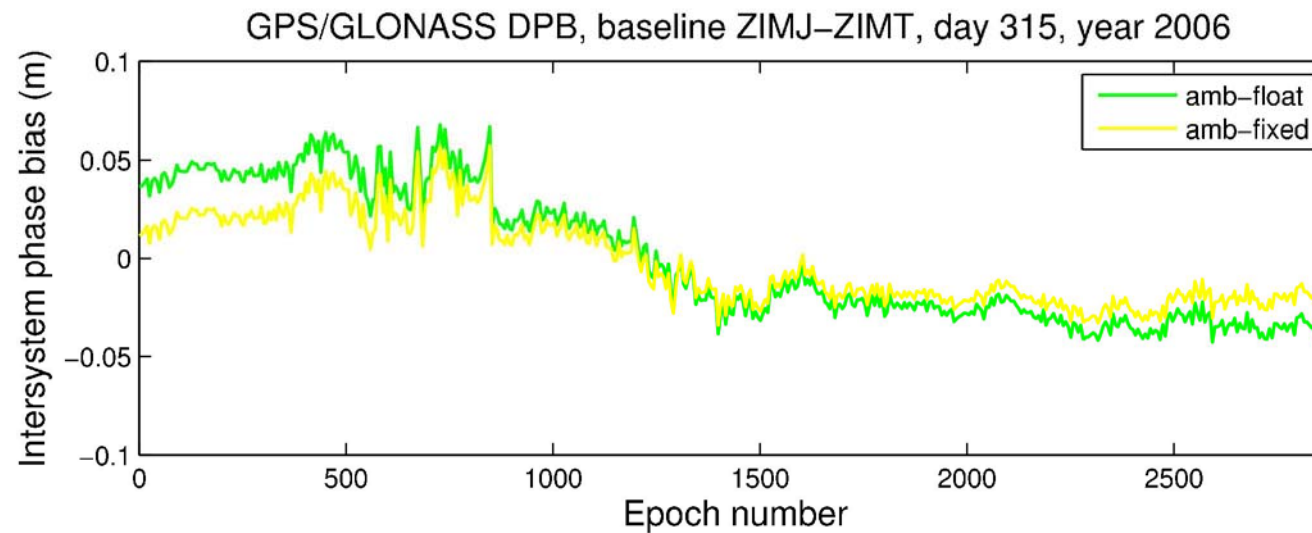
GPS/GLONASS Combination on Observation or on NEQ Level



GNSS processing type	# DD obs. per epoch
GPS-only (G)	$4-1=3$
GLONASS-only (R)	$2-1=1$
GNSS combination on obs. level (O)	$6-1=5$
GNSS combination on NEQ level (N)	$3+1=4$

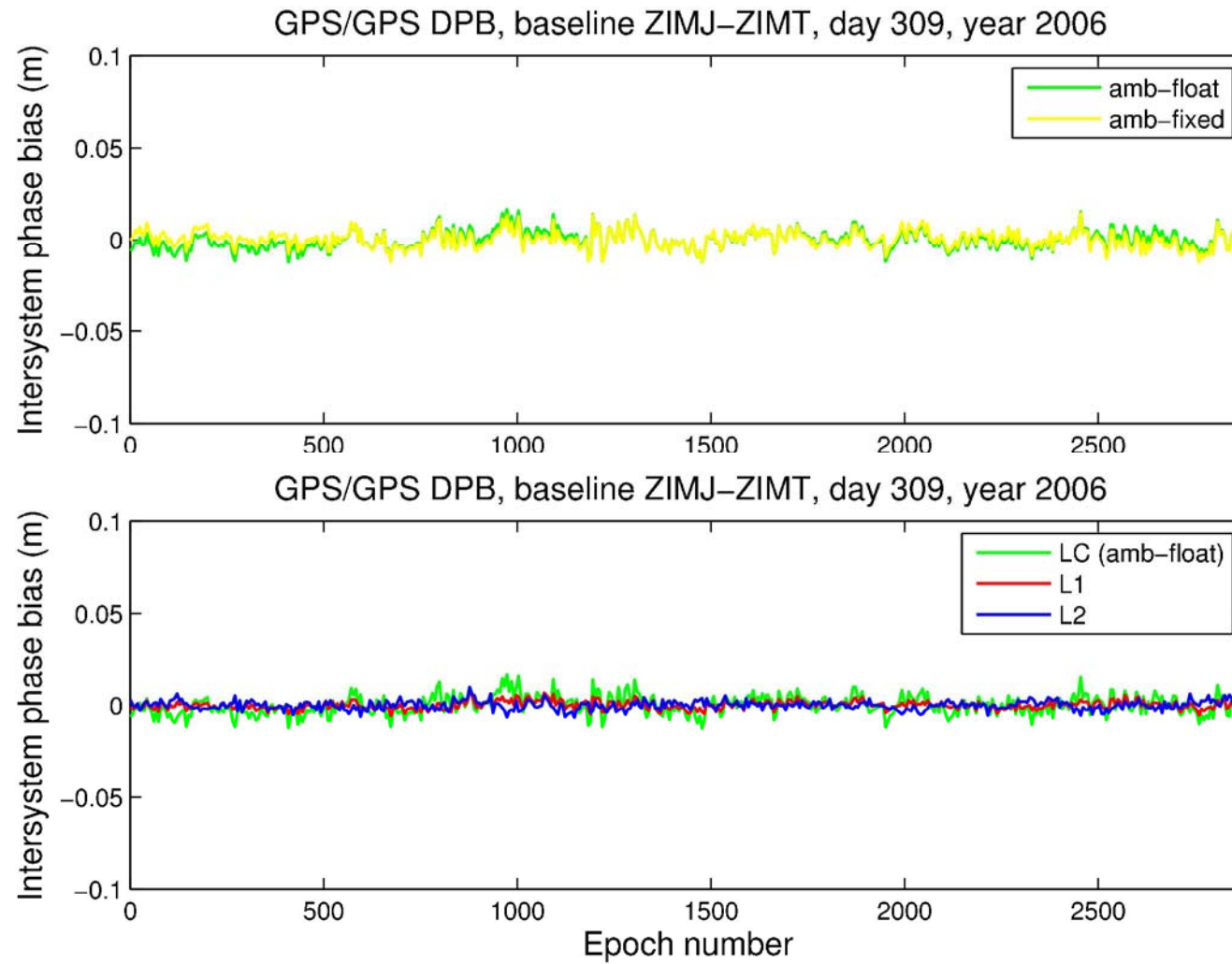


Demonstration of GPS-GLONASS Intersystem Phase Biases (1)





Demonstration of GPS-GLONASS Intersystem Phase Biases (2)





Extended COE Weekly Analysis Summary

		Weekday		Repeatability (mm)			Residuals wrt IGS05		
Station	#Days	0123456	N	E	U	N	E	U	F
AJAC 10077M005	7	XXXXXXX	1.22	0.72	4.39				
ALME 13437M001	7	XXXXXXX	1.99	0.90	3.43				
ANKR 20805M002	4	XXXX	1.53	1.12	5.43				
BOGO 12207M002	7	XXXXXXX	1.34	0.98	4.15				
BOR1 12205M002	7	XXXXXXX	0.96	0.82	3.51	0.27	0.64	2.11	
CAGL 12725M003	1	X	0.41	0.46	0.47	4.89	2.44	-6.39	
CASC 13909S001	4	XXXX	1.09	0.52	3.31				
DEL1 13502M004	7	XXXXXXX	1.21	0.73	4.03				
DOUR 13113M001	7	XXXXXXX	0.85	0.58	2.29				
EBRE 13410M001	7	XXXXXXX	1.68	0.66	3.08				
GANP 11515M001	7	XXXXXXX	1.91	1.52	4.30				
GLSV 12356M001	7	XXXXXXX	1.36	0.63	4.39	-0.38	0.03	-0.36	
HEL6 14264M001	7	XXXXXXX	0.94	0.87	6.64				
HOFN 10204M002	6	XXXX XX	1.03	1.48	1.48	3.56	-4.00	-9.26	
JOEN 10512M001	7	XXXXXXX	1.28	1.39	4.25				
KELY 43005M002	6	XXXXX X	2.92	2.53	10.38	-8.39	4.08	-14.84	
KIR0 10422M001	7	XXXXXXX	0.77	1.22	2.89				
KIRU 10403M002	6	XXXXX X	1.17	0.85	8.14				
LAMA 12209M001	6	X XXXXX	1.77	1.14	4.87				
MAR6 10405M002	7	XXXXXXX	1.20	1.22	2.41				
MAS1 31303M002	7	XXXXXXX	1.96	1.49	6.16	2.93	-0.28	6.83	
MORP 13299S001	7	XXXXXXX	0.50	1.64	7.54				
NOT1 12717M004	6	XXXX XX	1.49	1.22	5.79	-2.42	0.94	9.80	
NPLD 13234M003	5	XXXXX	1.36	0.79	3.85				
NSSP 12312M001	7	XXXXXXX	1.66	1.49	6.03				
NYA1 10317M003	7	XXXXXXX	0.73	0.48	3.59	1.70	-1.67	6.68	
PDEL 31906M004	7	XXXXXXX	1.92	0.48	5.13	0.64	0.42	4.36	
PTBB 14234M001	7	XXXXXXX	1.16	0.79	3.46				
QAQ1 43007M001	7	XXXXXXX	1.01	1.48	2.29	-0.86	3.05	-6.35	
RAM0 20703S001	5	XXX XX	2.38	1.90	4.46	-1.89	0.06	5.90	
REYK 10202M001	7	XXXXXXX	0.64	0.28	3.37	0.38	1.86	-6.49	
SODA 10513M001	7	XXXXXXX	1.37	0.92	3.16				
TERS 13534M001	7	XXXXXXX	0.76	0.81	8.20				
THU3 43001M002	7	XXXXXXX	0.65	0.95	2.92	-4.18	-1.49	-4.43	
TRO1 10302M006	7	XXXXXXX	0.77	0.80	2.99	-0.64	-0.75	-5.65	
VAAS 10511M001	7	XXXXXXX	1.70	1.13	6.24				
VIL0 10424M001	7	XXXXXXX	1.62	1.00	1.96				
VILL 13406M001	5	XXXXX	1.57	1.49	3.45	-1.53	-2.72	11.69	
WTZR 14201M010	7	XXXXXXX	1.23	1.07	3.43	2.41	1.41	0.88	
ZECK 12351M001	5	XXX XX	1.43	1.02	5.04				
ZIMM 14001M004	7	XXXXXXX	0.81	0.49	2.07	1.43	0.63	-4.06	
Total			1.36	1.07	4.67	2.95	2.10	6.98	
Total number of stations included in SINEX: 41									
3-PARAMETER HELMERT TRANSFORMATION WRT IGS05:									
Translation in X/Y/Z (mm):						0.00	0.01	0.00	
Number of accepted/rejected(R)/all fiducial stations:						21	0	21	

Example for GPS week 1400



... Would Look for the GLONASS-Only Solution Like:

Station	#Days	Weekday 0123456	Repeatability (mm)			Residuals wrt IGS05			
			N	E	U	N	E	U	F
CAGZ 12725M004	1	X	0.20	1.86	2.30				
GANP 11515M001	7	XXXXXXX	2.72	7.01	5.03				
HELG 14264M001	7	XXXXXXX	3.40	7.10	12.46				
HERT 13212M010	6	XXXXXX	2.29	6.18	11.84				
JOZ2 12204M002	6	XXXXXX	2.39	3.78	7.43				
KIR0 10422M001	7	XXXXXXX	3.62	5.56	5.36				
MAR6 10405M002	7	XXXXXXX	3.28	7.26	9.00				
MAT1 12734M009	7	XXXXXXX	10.75	14.55	17.35				
MDVJ 12309M005	7	XXXXXXX	6.21	5.65	16.56	-0.11	-1.70	-11.42	
MOBJ 12365M002	7	XXXXXXX	6.16	3.89	19.63				
ONSA 10402M004	7	XXXXXXX	2.17	7.79	8.39	-1.53	2.43	7.40	
REYZ 10202M003	7	XXXXXXX	3.64	6.91	7.65				
THU2 43001M002	7	XXXXXXX	5.57	4.01	9.38	1.29	-1.26	3.72	
VIL0 10424M001	7	XXXXXXX	2.98	6.72	8.00				
WTZR 14201M010	7	XXXXXXX	1.66	7.17	5.26	0.34	0.53	0.30	
ZIMJ 14001M006	7	XXXXXXX	1.58	7.63	10.47				
ZIMT 14001M005	7	XXXXXXX	2.07	7.40	6.98				
Total			4.46	7.24	10.96	1.18	1.88	8.15	
Total number of stations included in SINEX: 17									
3-PARAMETER HELMERT TRANSFORMATION WRT IGS05:									
Translation in X/Y/Z (mm):						0.02	0.00	0.00	
Number of accepted/rejected(R)/all fiducial stations:						4	0	4	