

Precise multi-GNSS applications: the future is running

R. Dach,
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L. Prange, S. Schaer, A. Jäggi

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06.–08. June 2012, Paris, France

Outline

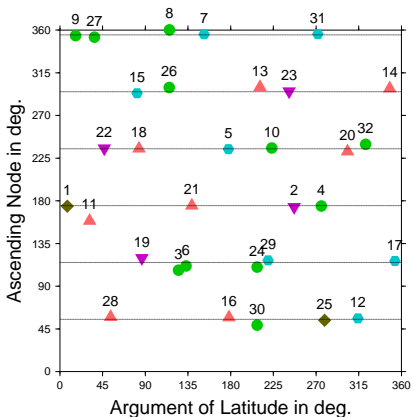
Why multi-GNSS?

First steps in the IGS

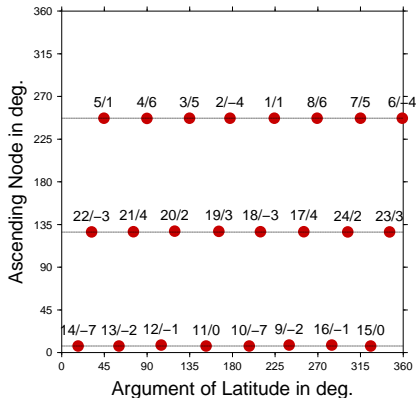
Consequences for Bernese GNSS Software, Version 5.2

Why multi-GNSS?

Current Status of the Operational GNSS



● BLOCK IIA ◆ BLOCK IIF ▲ BLOCK IIR-A ▼ BLOCK IIR-B
● BLOCK IIR-M



● GLONASS-M

Why multi-GNSS?

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More satellites: better geometry

More systems: reducing GNSS-specific effects

More systems: more problems

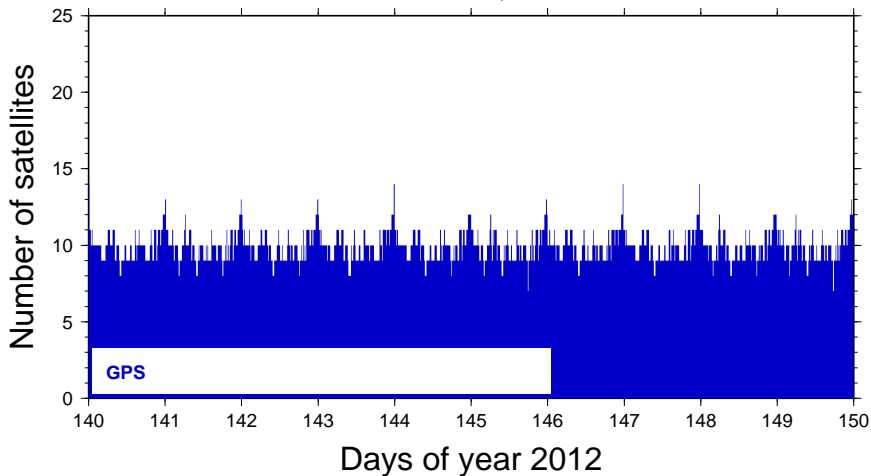
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Number of satellites in view

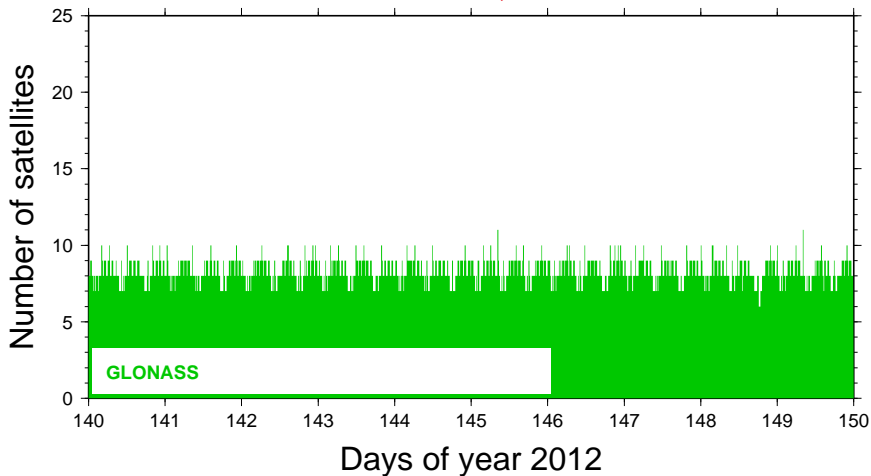
Station: Zimmerwald, Switzerland



Based on 10 days in May 2012

Number of satellites in view

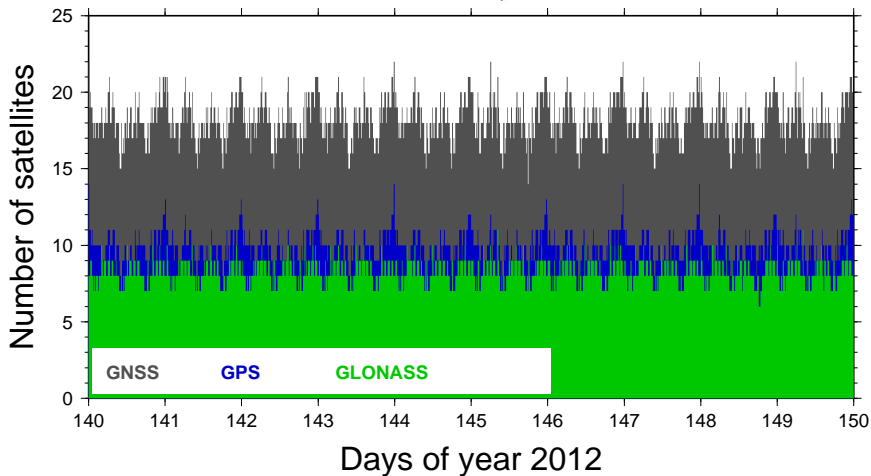
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Number of satellites in view

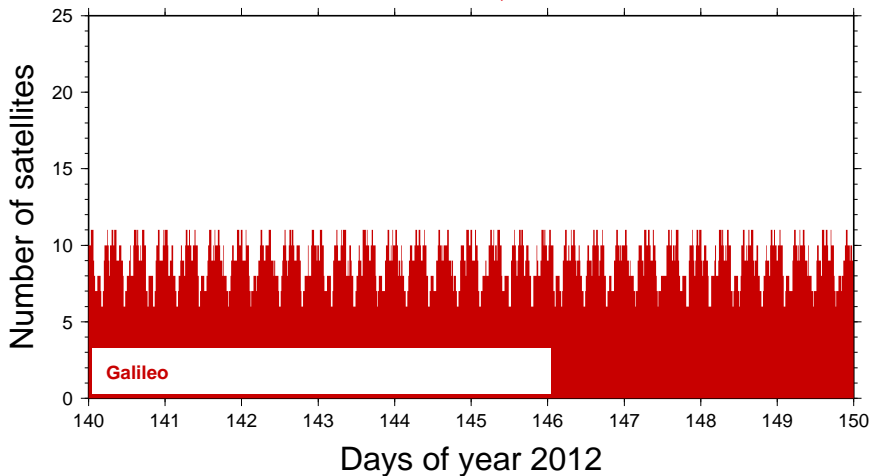
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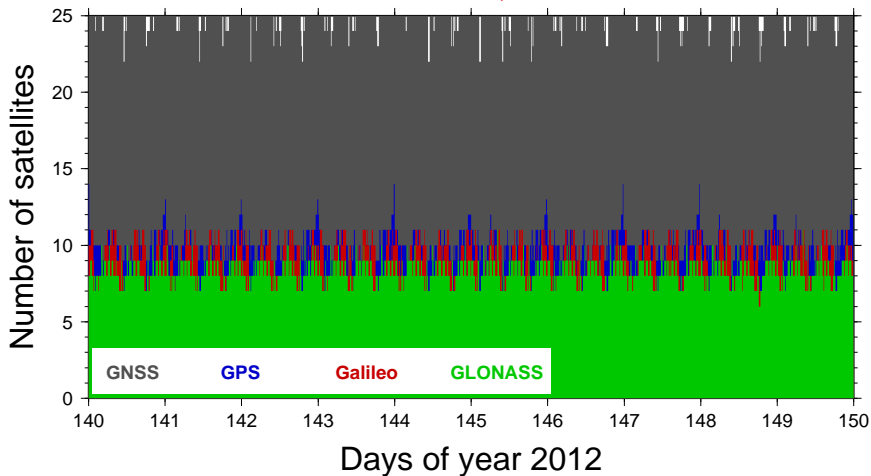
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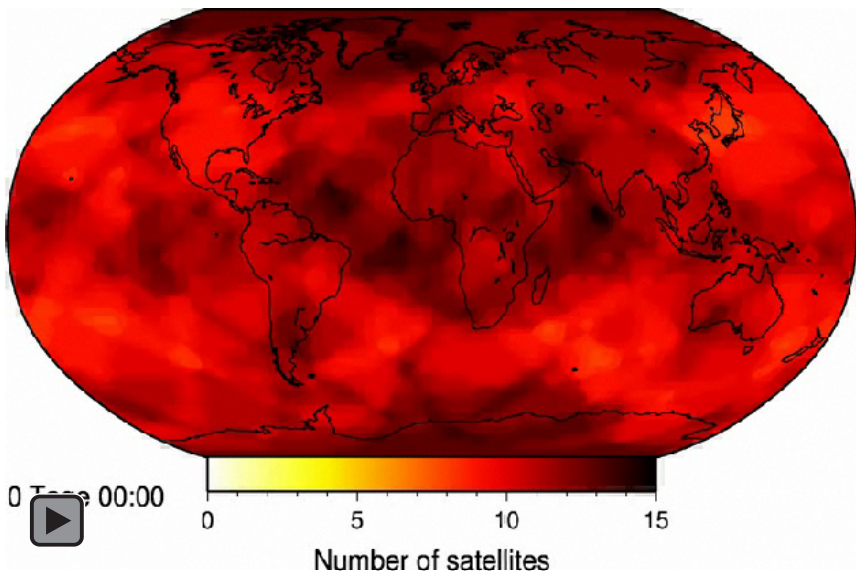
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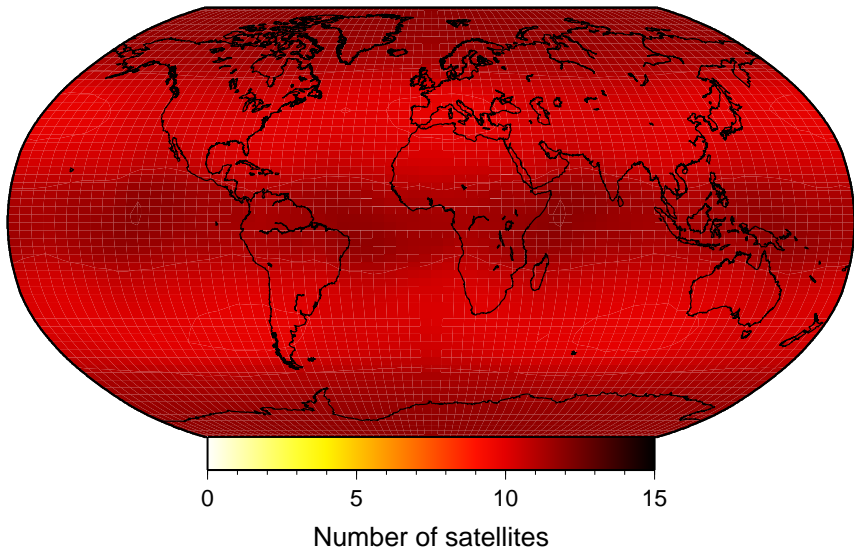
Based on 10 days in May 2012

Number of GPS-satellites in view



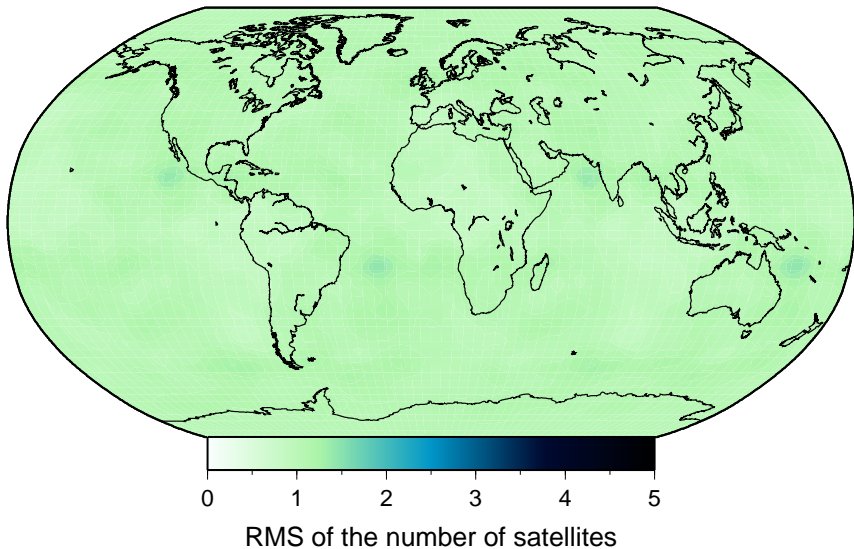
Days since 20-May-2012

Number of GPS-satellites in view



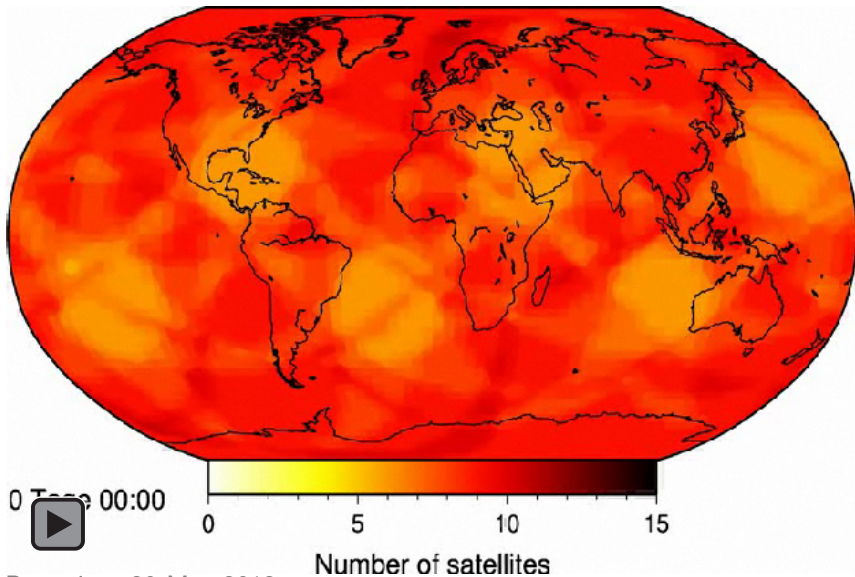
Mean over three days

Number of GPS-satellites in view



RMS over three days

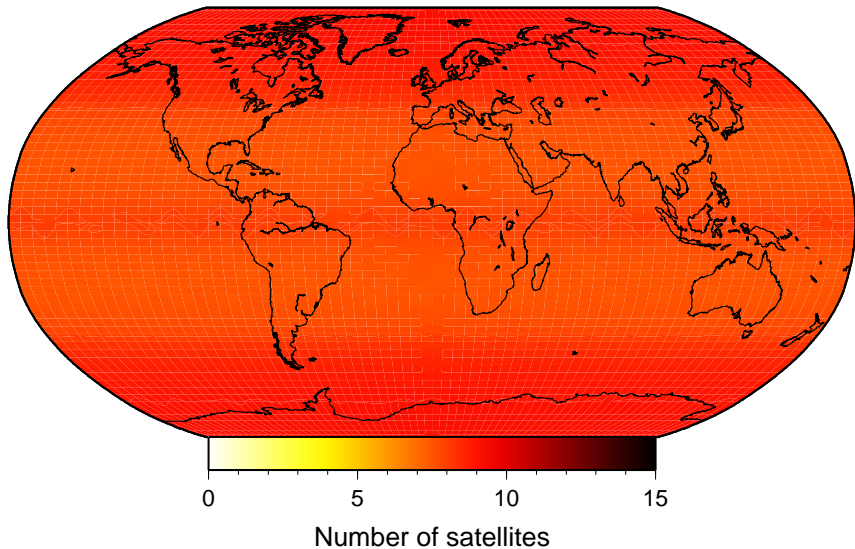
Number of GLONASS-satellites in view



R. Dach et al.: Precise multi-GNSS applications: the future is running
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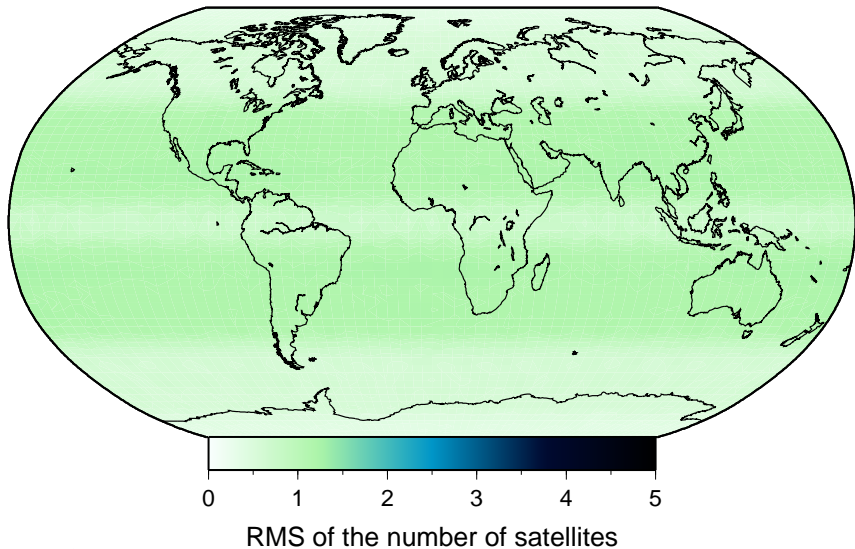
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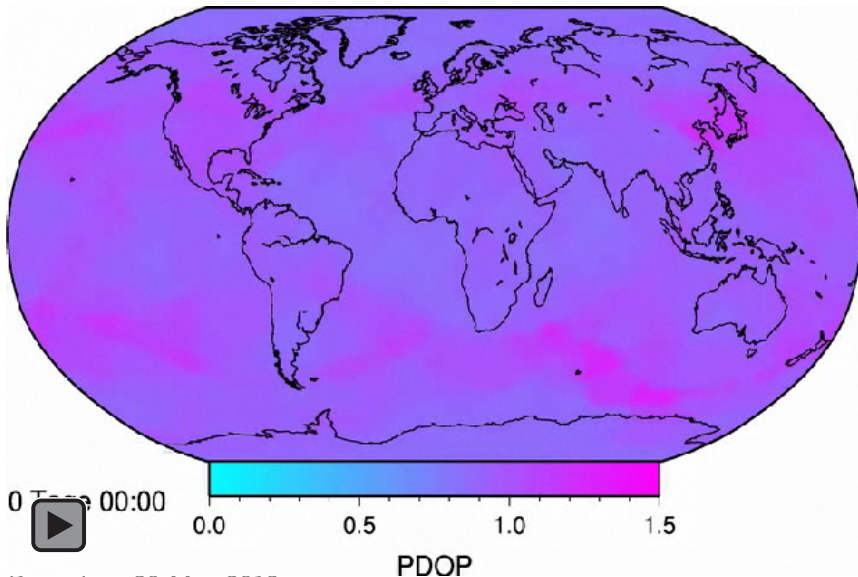
Mean over three days

Number of GLONASS–satellites in view



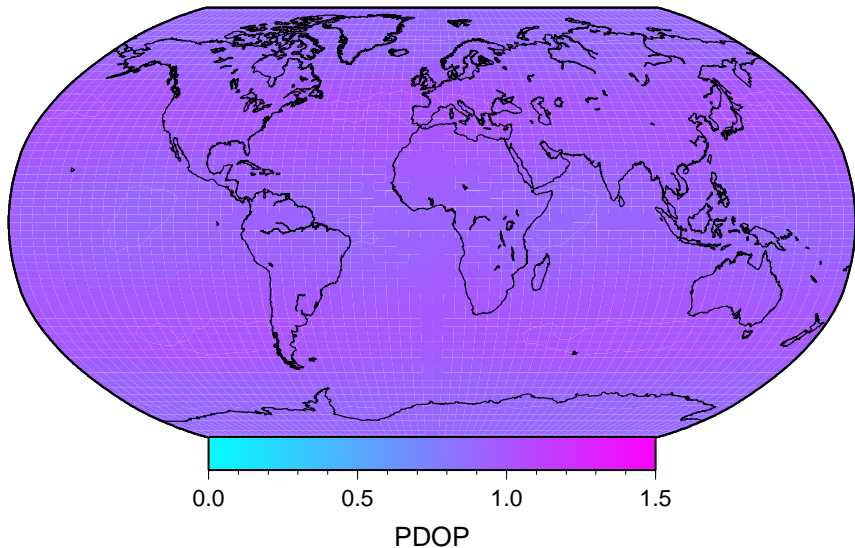
RMS over three days

PDOP from GPS-satellites in view



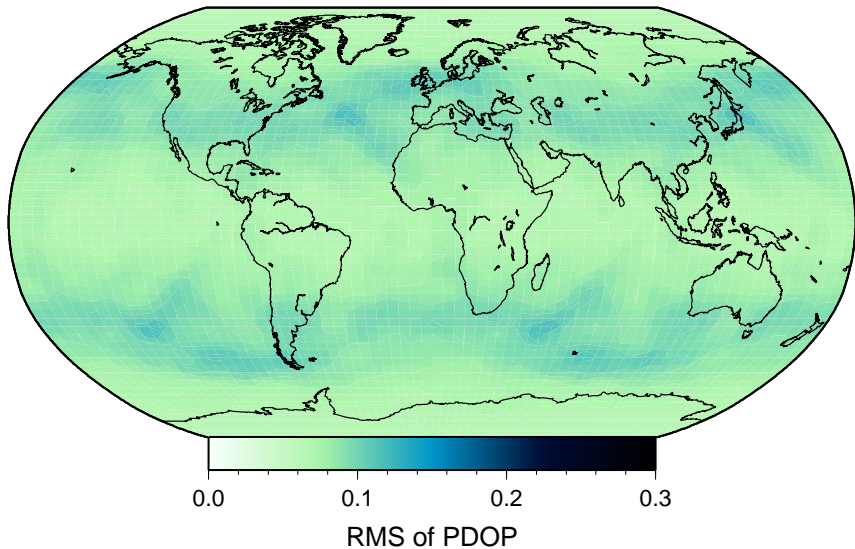
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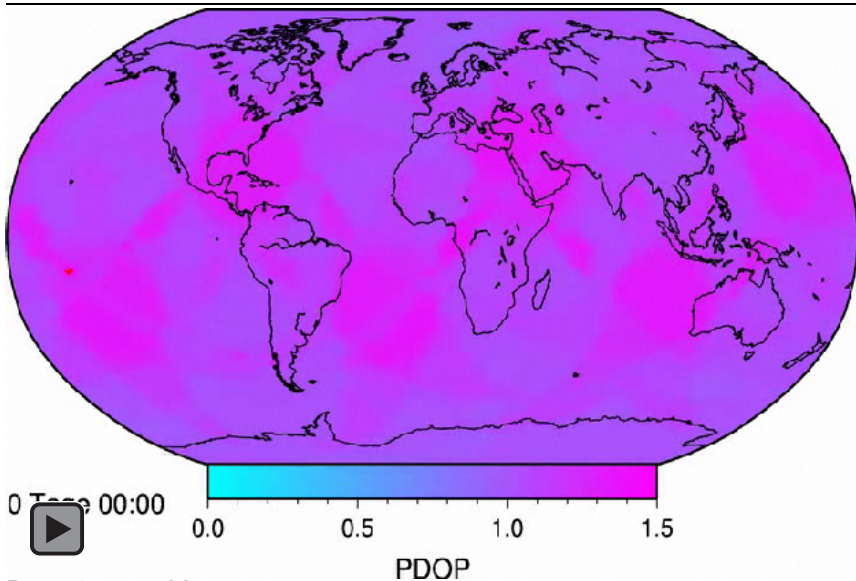
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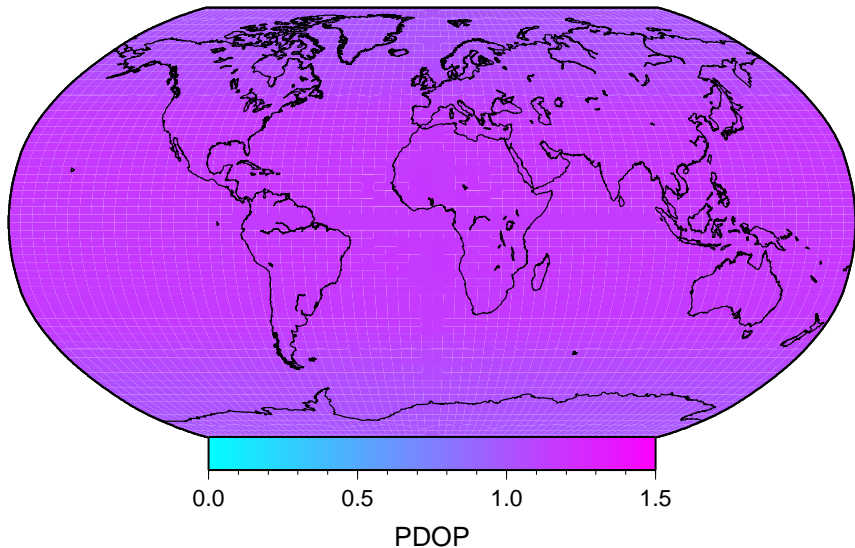
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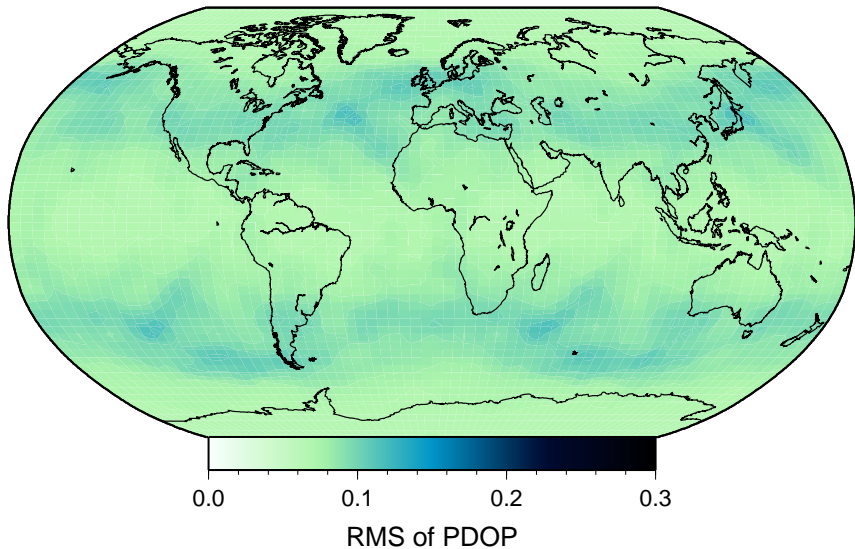
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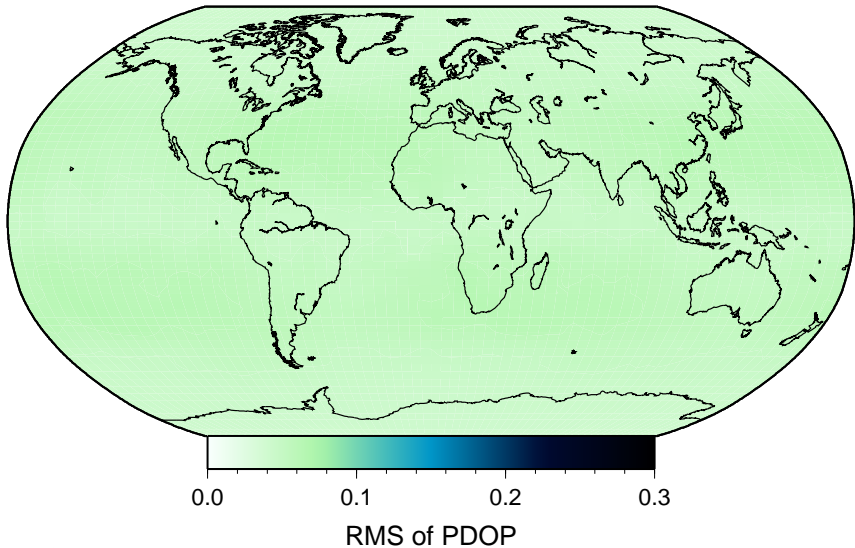
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PDOP from GPS-satellites



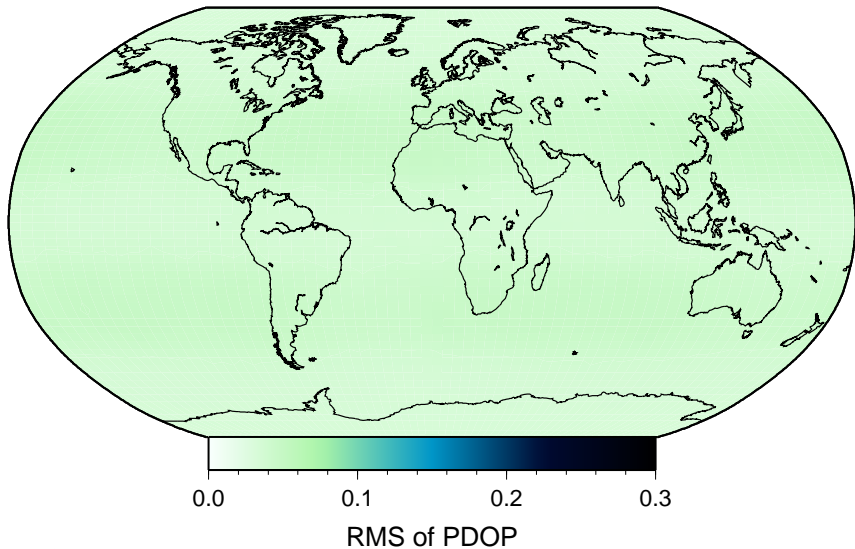
RMS over three days

PDOP from GPS/GLONASS-satellites



RMS over three days

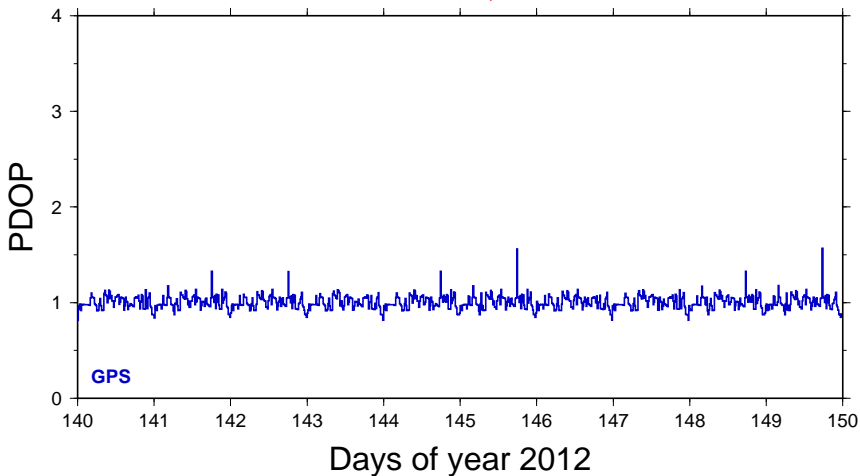
PDOP from GPS/GLONASS/Galileo



RMS over three days

PDOP when combining GNSS

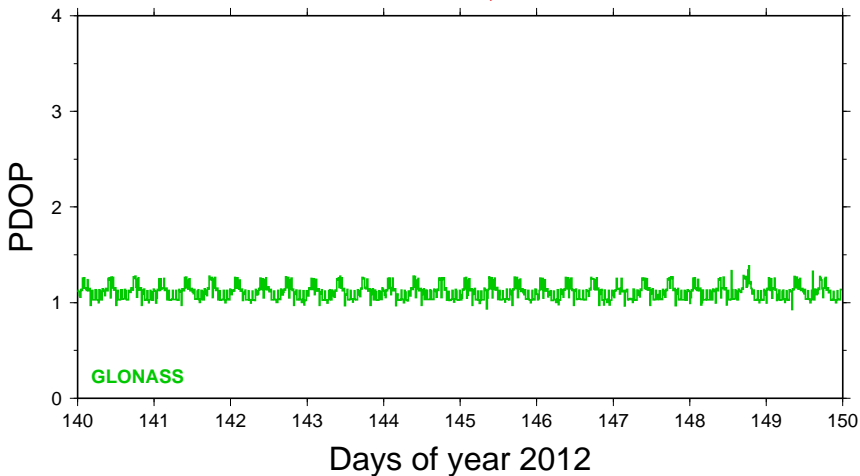
Station: Zimmerwald, Switzerland



Computation based on 10 days in May 2012

PDOP when combining GNSS

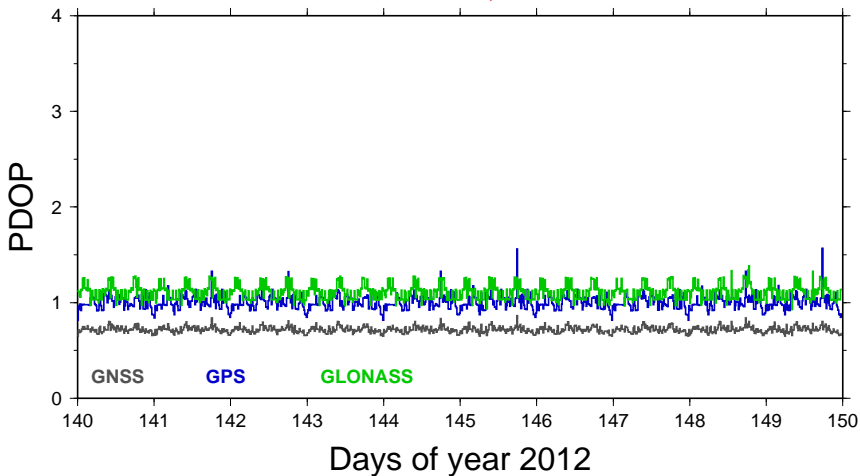
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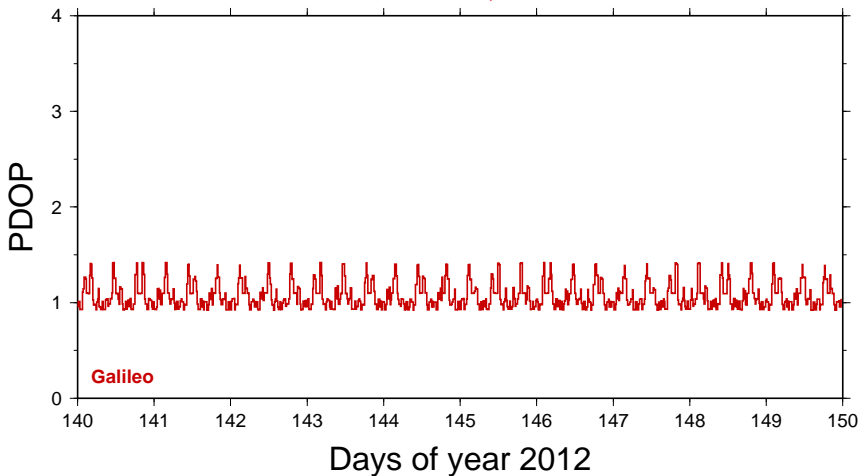
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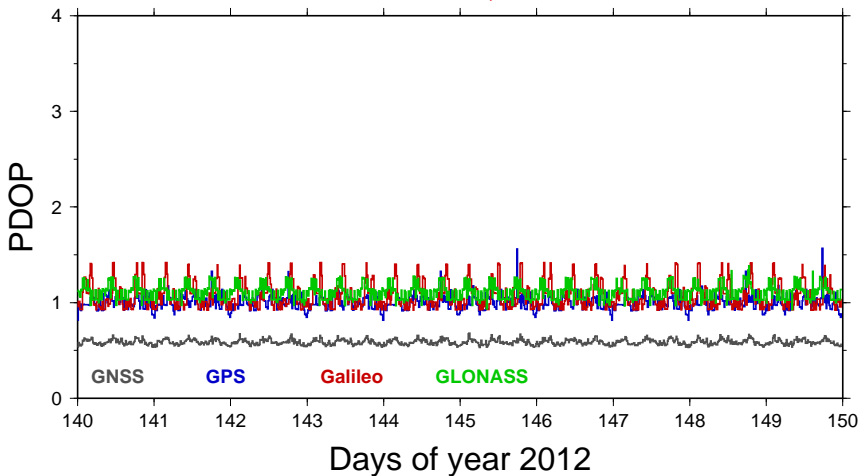
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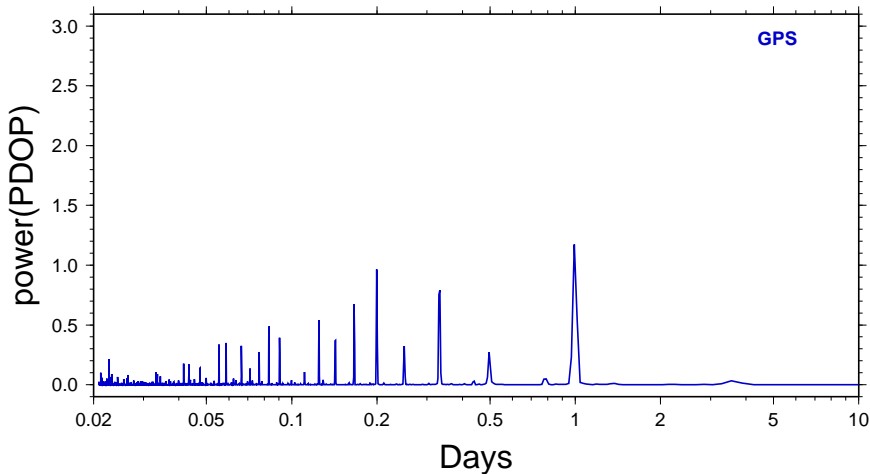
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Spektral analysis of the PDOP

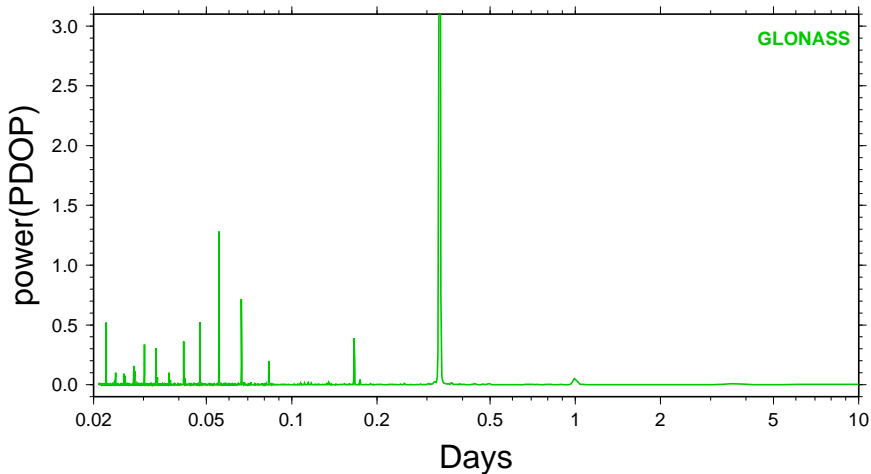
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Computation based on 60 days in April/May 2012

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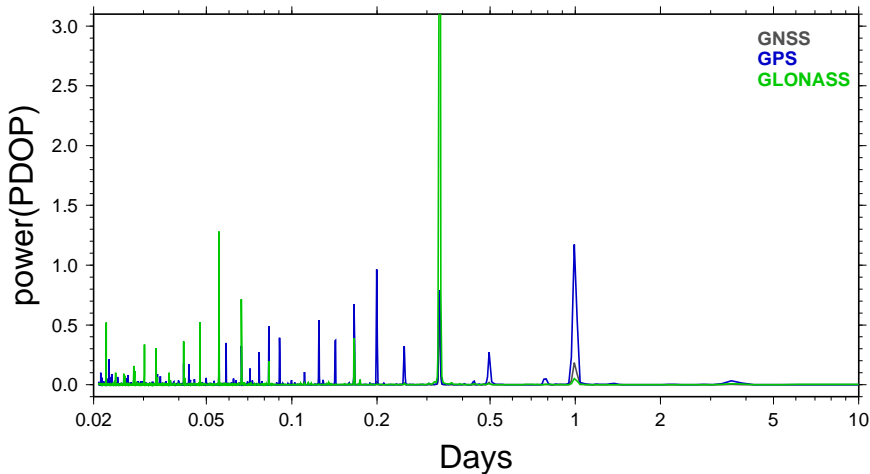
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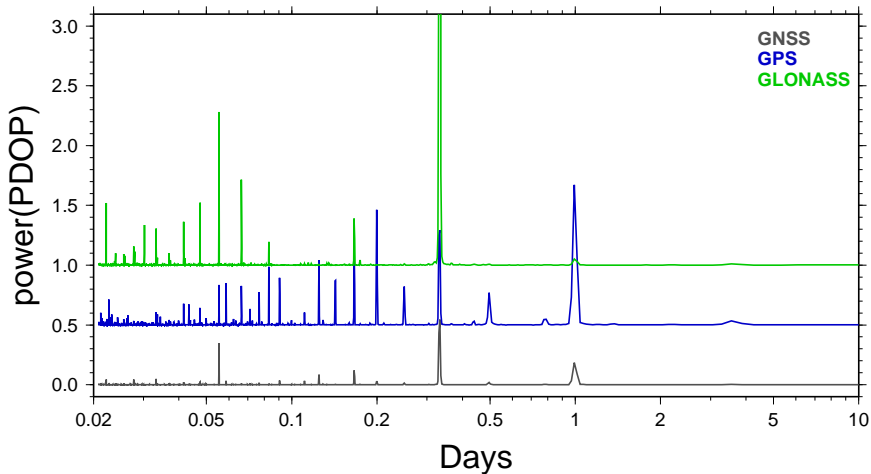
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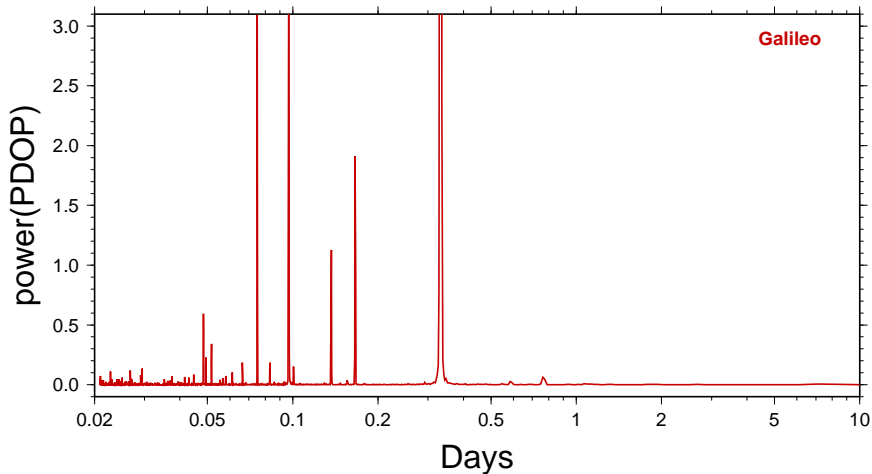
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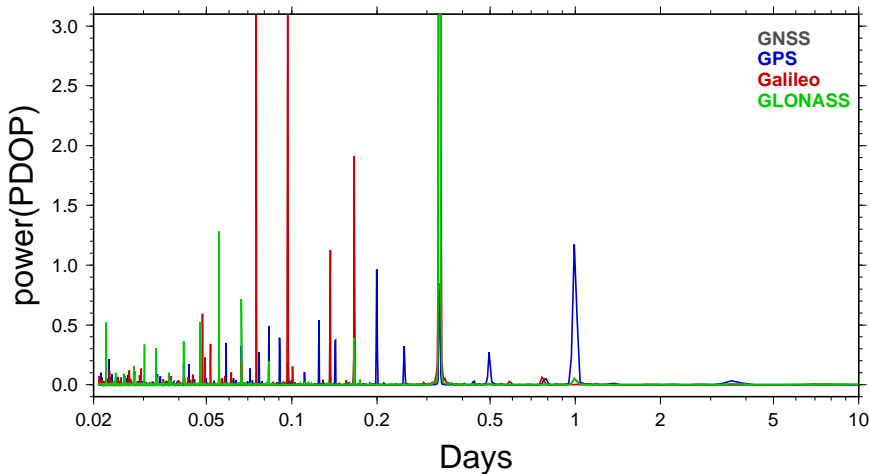
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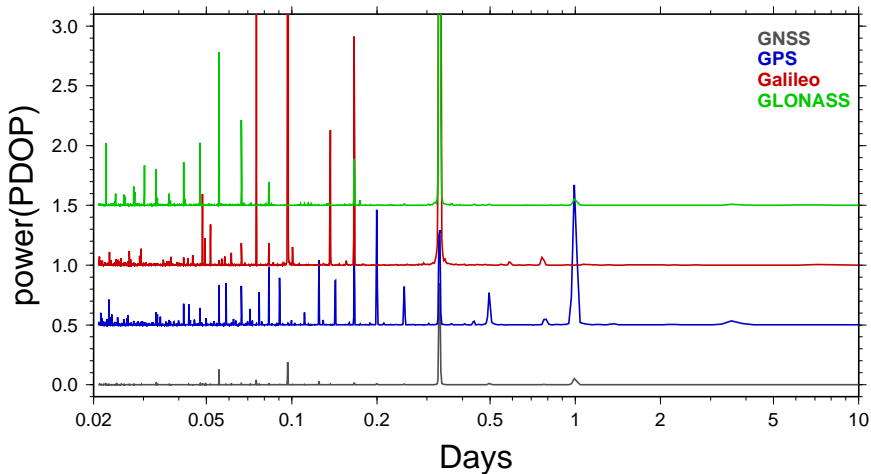
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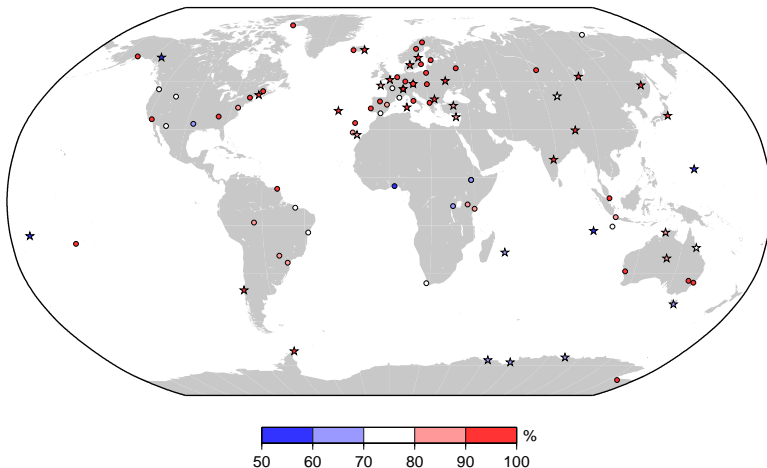
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More systems: reducing GNSS-specific effects

92 globally distributed GPS/GLONASS stations, 2008–2010



PhD thesis from M. Meindl: *Geodätisch-geophysikalische Arbeiten in der Schweiz*, vol. 83.

More systems: reducing GNSS-specific effects

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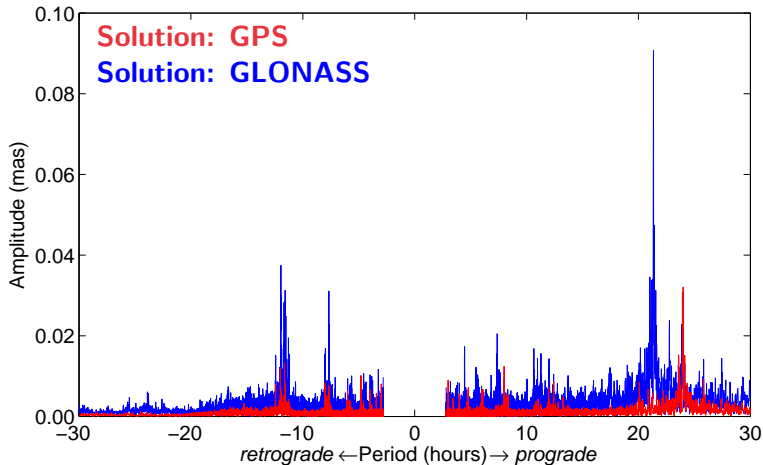
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More systems: reducing GNSS-specific effects

Spectra of the daily ERP series, 2008–2010



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- More satellite types need to be modelled.



GPS Block IIF



GLONASS-M



Galileo IOV

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quarter cycle between L2C and L2P phase measurements

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 - P2-C2 differential code bias
 - Not all satellites provide C2:
quarter cycle between L2C and L2P phase measurements
- The first two satellites with a signal on a third frequency are in space...

First steps in the IGS

Why multi-GNSS?

First steps in the IGS

- IGS–MGEX campaign

- New data flows for RINEX3.xx

- Experience with IGS–MGEX

Consequences for Bernese GNSS Software, Version 5.2

IGS–MGEX campaign

- IGS–MGEX: IGS Multi–GNSS Experiment

IGS–MGEX campaign

- **IGS–MGEX: IGS Multi–GNSS Experiment**

- **August 2011: Call for Participation:**

This Call for Participation for the IGS Multi–GNSS Experiment — IGS M–GEX — recognizes the availability of new additional GNSS signals and new constellations on the horizon. The IGS is preparing for this next phase in the evolution of the IGS to eventually generate products for all GNSS available.

IGS–MGEX campaign

- **IGS–MGEX: IGS Multi–GNSS Experiment**
- **August 2011: Call for Participation:**
 - current modernization programs for **GPS** and **GLONASS**
 - upcoming new systems **Galileo, Compass/BeiDou**
 - regional overlay systems, e.g., **QZSS**

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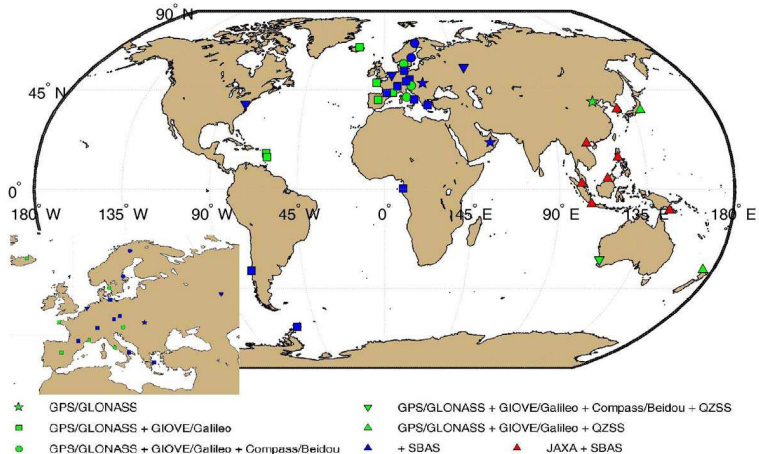
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- **First results are expected at the IGS workshop in Olsztyn, Poland (end of July 2012).**

IGS-MGEX campaign

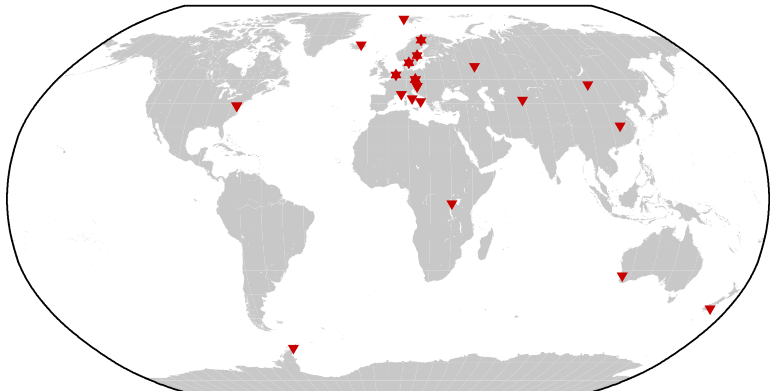
Current Status of the IGS-MGEX network (answer to CfP)



- R. Weber: IGS MGEX – The IGS Multi GNSS Global Experiment Presentation at the IGS workshop on biases, 19./20. January 2012, Bern

IGS-MGEX campaign

Current Status of the IGS-MGEX network (log files available)

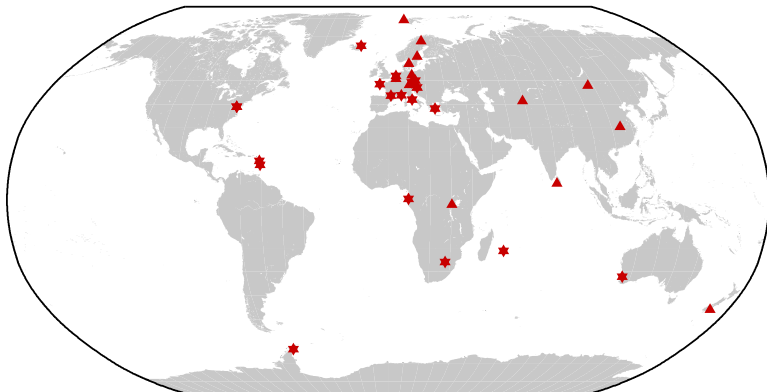


★ GPS+GLONASS+Galileo+SBAS (6)

▲ GPS+GLONASS+Galileo (17)

IGS-MGEX campaign

Current Status of the IGS-MGEX network (RINEX available)

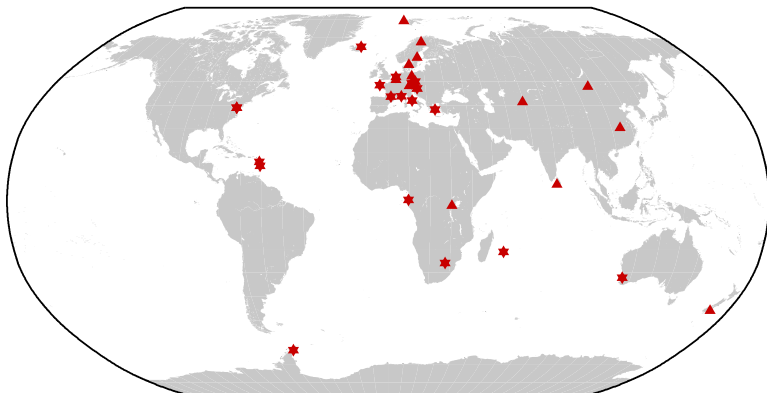


★ GPS+GLONASS+Galileo+SBAS (19)

▲ GPS+GLONASS+Galileo (14)

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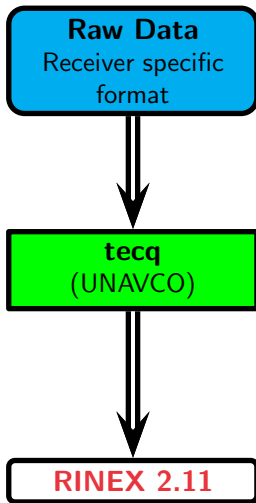


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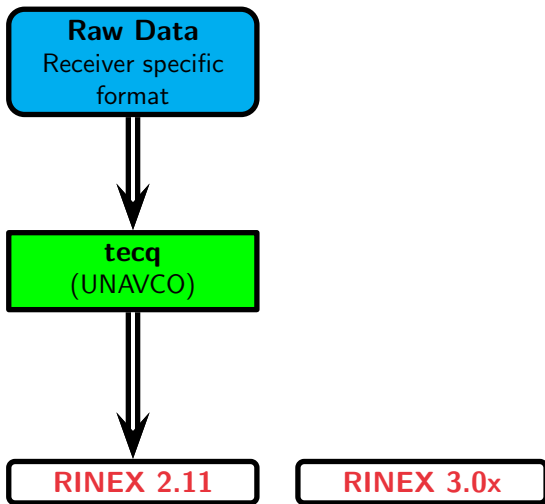
▲ GPS+GLONASS+Galileo (14)

- more stations than expected due to the proposals to the CfP
- data from Compass/BeiDou from three; QZSS from two stations

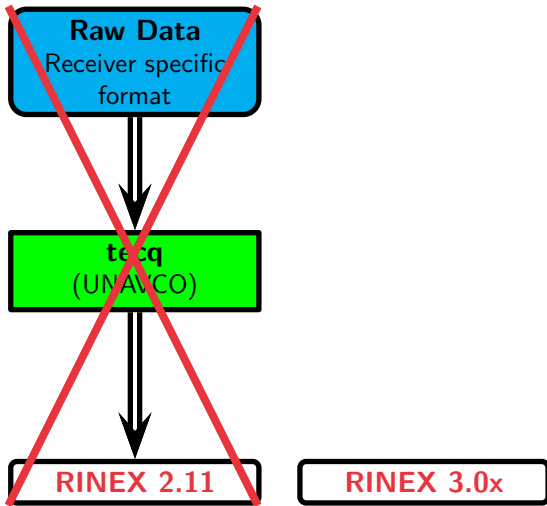
New data flows for RINEX3.xx



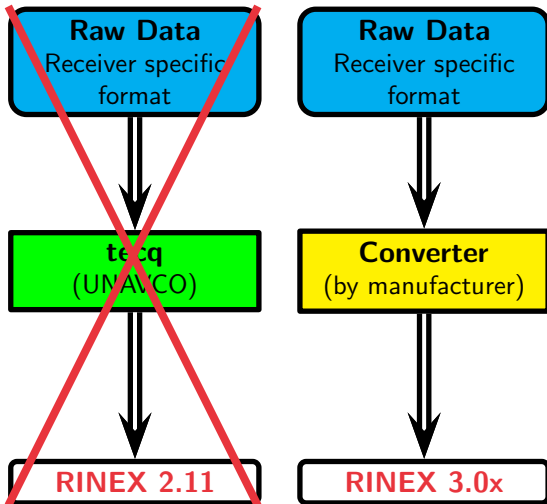
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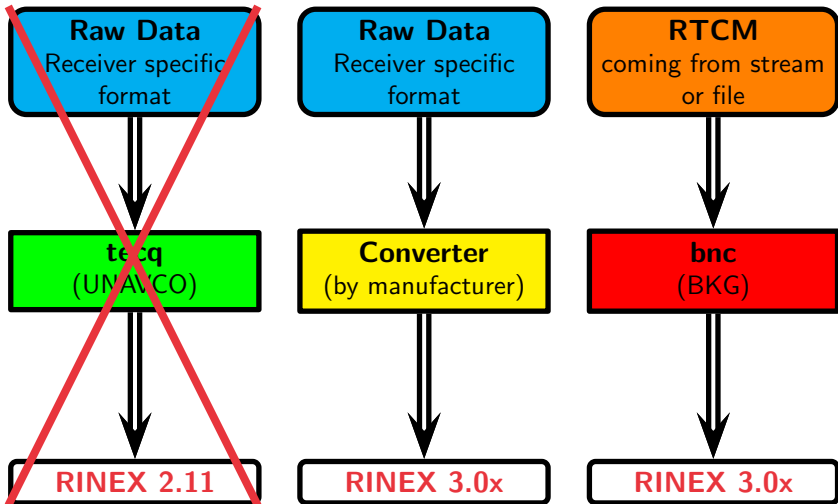
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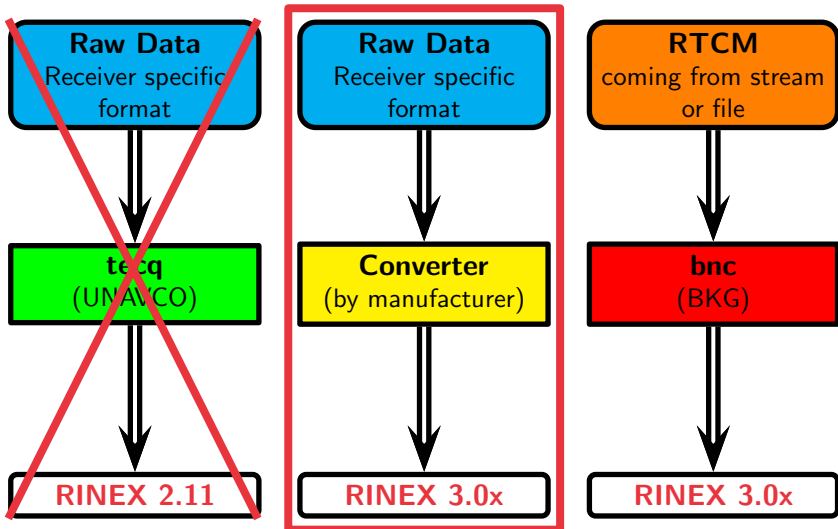
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Comparison between RINEX2- and RINEX3-files:

- List of stations:
 - Converter to RINEX3 from a manufacturer:

sbf2rin	BRUX
SX-NSR	GRAB
GR25	MOSE
NetR9	ABMF, BRST, GRAC, LMMF, REUN
MAKERINEX	NURK, OBE3, OUS2, POTS, TASH, ULAB
ViewLB2	CONZ, WTZR
JPS2RIN	WTZZ
cnvtToRINEX	HARB, MAT1, NKLG, TLSE, ZIM2
 - Writing RINEX3 via BNC:
BOGI, SASS, UNB3, WARN

New data flows for RINEX3.xx

Comparison between RINEX2- and RINEX3-files:

- List of stations:
 - Converter to RINEX2 from a manufacturer:
SX-NSR GRAB
SPIDER M0SE
DAT2RIN MAT1
GPSBase ZIM2
 - Writing RINEX2 from teqc:
ABMF, BOGI, BRST, BRUX, CONZ, GRAC, HARB, LMMF,
NKLG, NURK, OBE3, OUS2, POTS, REUN, SASS, TASH,
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- Inconsistent satellite lists,
e.g., due to treatment of unhealthy satellites

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Comparison between RINEX2- and RINEX3-files:

- List of stations:
ABMF, BOGI, BRST, BRUX, CONZ, GRAB, GRAC, HARB, LMMF, M0SE, MAT1, NKLG, NURK, OBE3, OUS2, POTS, REUN, SASS, TASH, TLSE, ULAB, UNB3, WARN, WTZR, WTZZ, ZIM2
- Inconsistent satellite lists,
e.g., due to treatment of unhealthy satellites
- Differences in the reported firmware version (UNB3, WTZZ)

Experience with IGS–MGEX

Generation of RINEX3 files is the first hurd...

Examples from the IGS–GEX:

ftp://igs.bkg.bund.de/...

MGEX/obs_v3/2012/120/gra21200.12d.Z:

```
3.01 OBSERVATION DATA M: MIXED RINEX VERSION / TYPE
LEICA GEO OFFICE 8.2BEV 20120502 123441 UTC PGM / RUN BY / DATE
GRA2 MARKER NAME
11001 M004 MARKER NUMBER
GEODETTIC MARKER TYPE
Apos BEV OBSERVER / AGENCY
495553 LEICA GRX1200+GNSS 8.51 / 6.110 REC # / TYPE / VERS
725228 LEIAR25.R4 LEIT ANT # / TYPE
4194425.1874 1162700.5789 4647247.1938 APPROX POSITION XYZ
0.0600 0.0000 0.0000 ANTENNA: DELTA H/E/N
G 12 C1C L1C D1C S1C C2P L2P D2P S2P C5X L5X D5X S5X SYS / # / OBS TYPES
R 8 C1C L1C D1C S1C C2P L2P D2P S2P SYS / # / OBS TYPES
E 16 L X D X S X I X C1X L1X D1X S1X C5X L5X D5X S5X C7X SYS / # / OBS TYPES
L7X D7X S7X
...
```

Experience with IGS–MGEX

Generation of RINEX3 files is the first hurd...

Examples from the IGS–GEX:

ftp://igs.bkg.bund.de/...

MGEX/obs_v3/2012/148/gra21480.12d.Z:

```
3.01 OBSERVATION DATA M: MIXED RINEX VERSION / TYPE
LEICA GEO OFFICE 8.2BEV 20120529 123441 UTC PGM / RUN BY / DATE
GRA2 MARKER NAME
11001 M004 MARKER NUMBER
GEODETIK MARKER TYPE
Apos BEV OBSERVER / AGENCY
495553 LEICA GRX1200+GNSS 8.51 / 6.110 REC # / TYPE / VERS
725228 LEIAR25.R4 LEIT ANT # / TYPE
4194425.1874 1162700.5789 4647247.1938 APPROX POSITION XYZ
0.0600 0.0000 0.0000 ANTENNA: DELTA H/E/N
G 12 C1C L1C D1C S1C C2P L2P D2P S2P C5X L5X D5X S5X SYS / # / OBS TYPES
R 8 C1C L1C D1C S1C C2P L2P D2P S2P SYS / # / OBS TYPES
E 16 C8Q L8Q D8Q S8Q C1X L1X D1X S1X C5X L5X D5X S5X C7X SYS / # / OBS TYPES
L7X D7X S7X
...
```

Experience with IGS-MGEX

Generation of RINEX3 files is the first hurd...

Examples from the IGS-GEX:

ftp://cddis.gsfc.nasa.gov/...

pub/gps/data/campaign/mgex/daily/rinex3/2012/120/12d/conz1200.12d.Z:

```
3.01 OBSERVATION DATA M: Mixed RINEX VERSION / TYPE
ViewLB2 v1.3.7.0 LEICA GEOSYSTEMS 20120430 061501 LCL PGM / RUN BY / DATE
CONZ MARKER NAME
41719M002 MARKER NUMBER
Automatic BKG/GOWetzzell OBSERVER / AGENCY
495886 LEICA GRX1200+GNSS 8.20/4.007 REC # / TYPE / VERS
10020007 LEIAR25.R3 LEIT ANT # / TYPE
1492007.7900 -4887911.1400 -3803640.1200 APPROX POSITION XYZ
0.0574 0.0000 0.0000 ANTENNA: DELTA H/E/N
0.0000 0.0000 0.0000 ANTENNA: DELTA H/E/N
G 16 L1C L2X L2W L5X C1C C2X C5X C2W D1C D2X D2W D5X S1C SYS / # / OBS TYPES
S2X S2W S5X SYS / # / OBS TYPES
R 8 L1C L2P C1C C2P D1C D2P S1C S2P SYS / # / OBS TYPES
E 0 SYS / # / OBS TYPES
S 4 L1C C1C D1C S1C SYS / # / OBS TYPES
S 0 SYS / # / OBS TYPES
...
R19 111630760.34318 86823935.09217 20868188.960 20868188.940 1458...
R17 126254984.09117 98198305.61916 23593770.500 23593775.860 -4538...
S38S35S33> 2012 04 29 00 01 0.0000000 0 21
G20 108930525.95108 84881007.83707 20728747...
```

Experience with IGS-MGEX

Generation of RINEX3 files is the first hurd...

Examples from the IGS-GEX:

ftp://cddis.gsfc.nasa.gov/...

pub/gps/data/campaign/mgex/daily/rinex3/2012/149/12d/conz1490.12d.Z:

```
3.01 OBSERVATION DATA M: Mixed RINEX VERSION / TYPE
ViewLB2 v1.3.7.0 LEICA GEOSYSTEMS 20120529 061501 LCL PGM / RUN BY / DATE
CONZ MARKER NAME
41719M002 MARKER NUMBER
Automatic BKG/GOWettzell OBSERVER / AGENCY
495886 LEICA GRX1200+GNSS 8.20/4.007 REC # / TYPE / VERS
10020007 LEIAR25.R3 LEIT ANT # / TYPE
1492007.7900 -4887911.1400 -3803640.1200 APPROX POSITION XYZ
0.0574 0.0000 0.0000 ANTENNA: DELTA H/E/N
0.0000 0.0000 0.0000 ANTENNA: DELTA H/E/N
G 16 L1C L2X L2W L5X C1C C2X C5X C2W D1C D2X D2W D5X S1C SYS / # / OBS TYPES
S2X S2W S5X SYS / # / OBS TYPES
R 8 L1C L2P C1C C2P D1C D2P S1C S2P SYS / # / OBS TYPES
E 0 SYS / # / OBS TYPES
S 4 L1C C1C D1C S1C SYS / # / OBS TYPES
...
R17 118373557.91217 92068326.02116 22120929.540 22120929.560 -935...
S33 198729865.52017 37817029.260 78.902 46.850
S38 200909366.45318 38231789.820 -1.151 48.600
S35 210349463.05017 40028165.120 -.559 44.800
> 2012 05 28 00 01 30.0000000 0 21
G04 115507257.43408 90005643.53907 21980297...
```

Experience with IGS–MGEX

Generation of RINEX3 files is the first hurd...

Examples from the IGS–GEX:

ftp://igs.ensg.ign.fr/...

pub/igs/data/campaign/mgex/daily/rinex3/2012/120/tlse1200.12d.Z:

```
      3.00      OBSERVATION DATA      Mixed(MIXED)      RINEX VERSION / TYPE
cnvtToRINEX  2.12.0  REGINA      30-Apr-12 00:10 UTC  PGM / RUN BY / DATE
-----
TLSE      COMMENT
10003M009  MARKER NAME
GEODETIC  MARKER NUMBER
GNSS Observer      CNES      OBSERVER / AGENCY
70405      TRIMBLE NETR9      4.42      REC # / TYPE / VERS
47086      TRM59800.00      NONE      ANT # / TYPE
      4627853.2692      119640.4157      4372996.1787      APPROX POSITION XYZ
      1.0530      0.0000      0.0000      ANTENNA: DELTA H/E/N
R   16   C1C C1P C2C C2P D1C D1P D2C D2P L1C L1P L2C L2P S1C  SYS / # / OBS TYPES
      S1P S2C S2P      SYS / # / OBS TYPES
G   16   C1C C2W C2X C5X D1C D2W D2X D5X L1C L2W L2X L5X S1C  SYS / # / OBS TYPES
      S2W S2X S5X      SYS / # / OBS TYPES
S   4    C1C D1C L1C S1C      SYS / # / OBS TYPES
E   16   C1  C5X C7X C8  D1  D5X D7X D8  L1  L5X L7X L8  S1   SYS / # / OBS TYPES
      S5X S7X S8      SYS / # / OBS TYPES
...

```

Experience with IGS-MGEX

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Examples from the IGS-GEX:

ftp://igs.ensg.ign.fr/...

pub/igs/data/campaign/mgex/daily/rinex3/2012/149/tlse1490.12d.Z:

```
      3.00      OBSERVATION DATA      Mixed(MIXED)      RINEX VERSION / TYPE
cnvtToRINEX  2.12.0  REGINA      29-May-12 00:23 UTC  PGM / RUN BY / DATE
-----
TLSE      COMMENT
10003M009  MARKER NAME
GEODETIC  MARKER NUMBER
GNSS Observer      CNES      OBSERVER / AGENCY
70405      TRIMBLE NETR9      4.42      REC # / TYPE / VERS
47086      TRM59800.00      NONE      ANT # / TYPE
      4627852.4544      119640.4611      4372994.4027      APPROX POSITION XYZ
      1.0530      0.0000      0.0000      ANTENNA: DELTA H/E/N
R   16  C1C C1P C2C C2P D1C D1P D2C D2P L1C L1P L2C L2P S1C  SYS / # / OBS TYPES
      S1P S2C S2P      SYS / # / OBS TYPES
G   16  C1C C2W C2X C5X D1C D2W D2X D5X L1C L2W L2X L5X S1C  SYS / # / OBS TYPES
      S2W S2X S5X      SYS / # / OBS TYPES
S    4  C1C D1C L1C S1C      SYS / # / OBS TYPES
E   16  C1X C5X C7X C8X D1X D5X D7X D8X L1X L5X L7X L8X S1X  SYS / # / OBS TYPES
      S5X S7X S8X      SYS / # / OBS TYPES
...

```

Experience with IGS–MGEX

Generation of RINEX3 files is the first hurdle:

- Many problems in generating RINEX3 files using manufacturer tools have been meanwhile solved by reconfigurations or software updates.
- Numbers used for the GIOVE satellites are quite inconsistent

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(e.g., the mass of the Galileo IOV satellites is smaller than the mass of the GPS and GLONASS satellites)

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- ...

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Bernese GNSS Software, Version 5.2

- The version contains the necessary basic features to process Galileo data in a dual frequency mode.

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 - the new data types can only be processed in an **experimental** mode.
- For product generation, we can recommend to use this version for the dual–frequency processing of GPS and GLONASS, only.
- On the other hand, **observations from the new data types are very welcome** to help answering the open questions and to provide you with a reliable processing capability also for these data types in a future version of the software.

THANK YOU

for your attention



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