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# Multi-GNSS Working group

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# Content

- EUREF Multi-GNSS Working group
- Info on RINEX3.02 (and HP-MSM)
- Learning by doing – exercise RINEX3.02 in Zimmerwald (ZIM3)
- Status RINEX3 in the EPN
- Dealing with RINEX3 data
  - bnc2.8
  - AIUB RINEX3 database
  - Pecny RINEX3 analysis

# MULTI-GNSS Working group

- Group established in Gävle (2010)
- No separated EUREF project started (as IGS MGEX project)
- Paper «EUREF TWG Multi-GNSS Working Group: Proposal of action items» released June 14, 2012
  - Infrastructure, data formats, processing know-how
  - Main focus is Galileo
  - GLONASS is also part  (only a part of the ACs are capable to process the data)
  - Setting up of next milestones
  - Communication with various IGS groups – MGEX, RINEX3, etc.

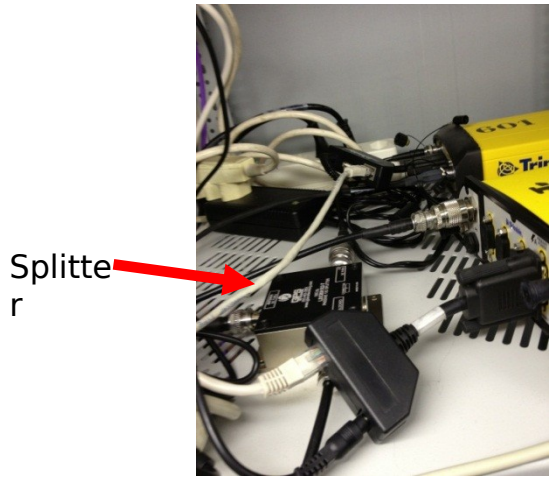
# RTCM – RINEX3 news

- The **RTCM-SC104** meeting (Jan. 31 and Feb. 1,2013 ) in San Diego, Ca, USA:  RTCM-MSM format and related documentation PASSED. -> **Full RINEX 3.02 Compatibility**

- **RINEX3.02 version released** on April, 4 2013 – official format for IGS MGEX project

# swisstopo Test: ZIM3

- ZIM2 GPS+GLO RINEX3 since Aug. 2011
- ZIM3 antenna sharing with ZIM2 (antenna splitter): 25.2.
- RINEX Version tests: 2.10, 2.11, 3.00, 3.02
- RINEX File generation / download tests: daily, hourly / Sampling 30s, 1s, 50Hz / via Receiver or via ConverttoRinex
- RINEX3 download and upload to BGK+CDDIS: 3.3.
- Registration as MGEX site:6.3.

# RINEX3 obs Types: ZIM2 – ZIM3

**Tracking**

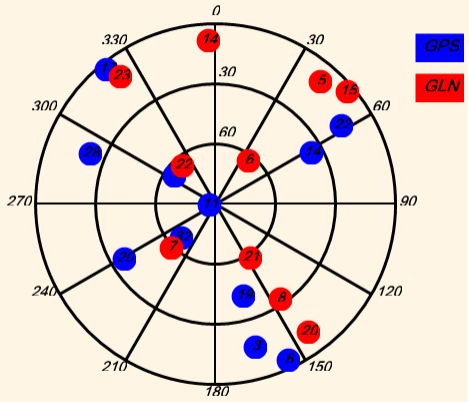
Elevation Mask 0 °

Everest™ Enable

Clock Steering Enable

| Type | Signal | Enable | Options |
|---|---|---|---|
| GPS | L1 - CA | ☑ | |
| GPS | L2 - Legacy | ☑ | |
| GPS | L2 - CS | ☐ | |
| GPS | L5 | ☑ | I + Q |
| SBAS | L1 - C/A | ☐ | |
| SBAS | L5 | ☐ | |
| GLONASS | L1 - C/A | ☑ | |
| GLONASS | L1 - P | ☑ | |
| GLONASS | L2 - C/A(M) | ☐ | |
| GLONASS | L2 - P | ☑ | |

**Satellites - Skyplot**




2013-02-22T07:25:34Z (UTC)

**Tracking**

Elevation Mask 0 °

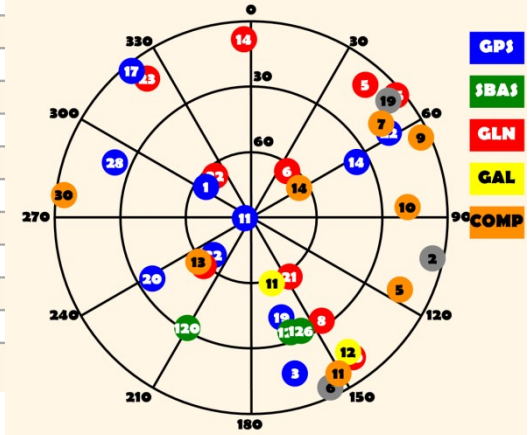
Everest™ Enable

Clock Steering Enable

| Type | Signal | Enable | Options |
|---|---|---|---|
| GPS | L1 - CA | ☑ | |
| GPS | L2 - Legacy | ☑ | L2 - CS and Legacy |
| GPS | L2 - CS | ☑ | CM + CL |
| GPS | L5 | ☑ | I + Q |
| SBAS | L1 - C/A | ☑ | |
| SBAS | L5 | ☑ | |
| GLONASS | L1 - C/A | ☑ | |
| GLONASS | L1 - P | ☑ | |
| GLONASS | L2 - C/A(M) | ☑ | |
| GLONASS | L2 - P | ☑ | L2 - C/A(M) and P |
| GLONASS | L3 | ☑ | Data + Pilot |
| GALILEO | E1 | ☑ | |
| GALILEO | E5 - A | ☑ | |
| GALILEO | E5 - B | ☑ | |
| GALILEO | E5 - AltBOC | ☑ | |
| COMPASS | B1 | ☑ | |
| COMPASS | B2 | ☑ | |
| COMPASS | B3 | ☑ | |
| QZSS | L1 - CA | ☑ | |
| QZSS | L1 - SAIF | ☑ | |
| QZSS | L2 - C | ☑ | |
| QZSS | L5 | ☑ | |
| QZSS | LEX | ☑ | |

OK Cancel

**Satellites - Skyplot**




2013-02-22T07:25:12Z (UTC)

# GPS observation codes

| GNSS System | Freq. Band /Frequency | Channel or Code | Observation Codes | | | |
|---|---|---|---|---|---|---|
| | | | Pseudo Range | Carrier Phase | Doppler | Signal Strength |
| GPS | L1/1575.42 | C/A | C1C | L1C | D1C | S1C |
| | | L1C (D) | C1S | L1S | D1S | S1S |
| | | L1C (P) | C1L | L1L | D1L | S1L |
| | | L1C (D+P) | C1X | L1X | D1X | S1X |
| | | P | C1P | L1P | D1P | S1P |
| | | Z-tracking and similar (AS on) | C1W | L1W | D1W | S1W |
| | | Y | C1Y | L1Y | D1Y | S1Y |
| | | M | C1M | L1M | D1M | S1M |
| | | codeless | | L1N | D1N | S1N |
| | L2/1227.60 | C/A | C2C | L2C | D2C | S2C |
| | | L1(C/A)+(P2-P1) (semi-codeless) | C2D | L2D | D2D | S2D |
| | | L2C (M) | C2S | L2S | D2S | S2S |
| | | L2C (L) | C2L | L2L | D2L | S2L |
| | | L2C (M+L) | C2X | L2X | D2X | S2X |
| | | P | C2P | L2P | D2P | S2P |
| | | Z-tracking and similar (AS on) | C2W | L2W | D2W | S2W |
| | | Y | C2Y | L2Y | D2Y | S2Y |
| | | M | C2M | L2M | D2M | S2M |
| | | codeless | | L2N | D2N | S2N |
| | L5/1176.45 | I | C5I | L5I | D5I | S5I |
| | | Q | C5Q | L5Q | D5Q | S5Q |
| | | I+Q | C5X | L5X | D5X | S5X |

Table 2 : RINEX Version 3.02 GPS observation codes

# RINEX3 obs Types: Example ZIM3

- GPS+GLO RINEX 2.11 (1 File, 1 hour, 1 Sek Samp.: 6 Mb)

```
 9    L1    L2    C1    P1    P2    S1    S2    D1    D2# / TYPES OF OBSERV
```

- GNSS RINEX 2.11 (1 File, 1 hour, 1 Sek Sampling: 11 Mb)

```
17    C1    L1    S1    P1    C2    L2    S2    P2    C5# / TYPES OF OBSERV
      L5    S5    C7    L7    S7    C8    L8    S8      # / TYPES OF OBSERV
```

- GNSS RINEX 3.02 (1 File, 1 hour, 1 Sek Sampling: 22 Mb)

```
G   12 C1C L1C S1C C2W L2W S2W C2X L2X S2X C5X L5X S5X      SYS / # / OBS TYPES
S    3 C1C L1C S1C                                         SYS / # / OBS TYPES
R   12 C1C L1C S1C C1P L1P S1P C2C L2C S2C C2P L2P S2P      SYS / # / OBS TYPES
E   12 C1X L1X S1X C5X L5X S5X C7X L7X S7X C8X L8X S8X      SYS / # / OBS TYPES
C    9 C2I L2I S2I C7I L7I S7I C6I L6I S6I                 SYS / # / OBS TYPES

48      Not all listed observation are also recorded…
```

# RINEX3 generation variants (Trimble)

- Directly from receiver (firmware) (e.g. Trimble, Leica)
- Via manufacturer programs accepting realtime data and writing RINEX3 data on the fly (e.g. Trimble GPSBase, VRS3Net, Leica Spider)
- Via converter programs (e.g. Trimble Converttorinex T02->RNX)
- Via realtime data flow NTRIP (e.g. Trimble RT27 -> RINEX3.02 by BKG converter BNC)
- Various programs, various data flow -> identical RINEX3 observations ! TO BE EVALUATED!

```
Data Source – in RINEX3 file name
R – From Receiver  data using vendor or other software
S – From data Stream (RTCM or other)
U – Unknown
```

Could be usefull in the evaluation phase !

# RINEX3.02 Release 1, April 3 2013

- Naming convention ( Example: 1 day, Obs. Mixed, 30 sec)
  - Nov 2012: `ALGO00CANN46282-R-NRC-20121601000-01D-RNXOM-30S.gz`
  - Mar 2013: `ALGO00CAN_R_20121601000_01D_30S_OM.rnx.gz`
  - Apr 2013: `ALGO00CAN_R_20121601000_01D_30S_MO.rnx.gz`

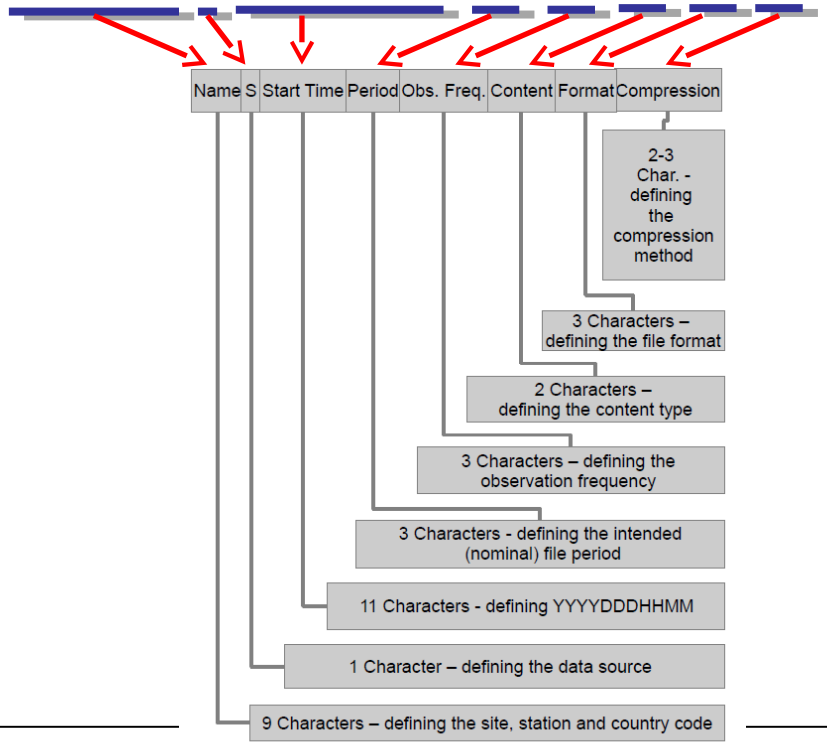
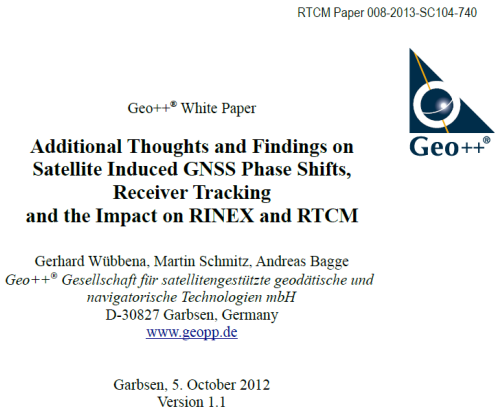



Figure 2: Recommended filename parameters.

# RINEX3.02 (2)

- Phase shifts
  - Background: Carrier phases tracked on different signal channels or modulation bands of the same frequency may differ in phase by 1/4 (e.g., GPS: P/Y-code-derived L2 phase vs. L2C-based phase)
  - Close relation of RTCM decision in Feb. 2013 on the HP-MSM messages (phase shift handling problems starts in real-rime)



RTCM Paper 008-2013-SC104-740

Geo++® White Paper

**Additional Thoughts and Findings on Satellite Induced GNSS Phase Shifts, Receiver Tracking and the Impact on RINEX and RTCM**

Gerhard Wübbena, Martin Schmitz, Andreas Bagge
*Geo++® Gesellschaft für satellitengestützte geodätische und navigatorische Technologien mbH*
D-30827 Garbsen, Germany
www.geopp.de

Garbsen, 5. October 2012
Version 1.1

| Data | GPS | | GPS | | GLONASS | | GLONASS | |
|---|---|---|---|---|---|---|---|---|
| | L1CA | L1P | L2C | L2P | L1CA | L1P | L2CA | L2P |
| (ASH) | none | +0.25 | +0.25 | none | | | +0.25 | none |
| JAV | none | -0.25 | +0.25 | none | none | -0.25 | +0.25 | none |
| LEI | | | -0.25 | none | | | -0.25 | none |
| NAV | | | +0.25 | none | | | | |
| NOV | | | -0.25 | none | | | -0.25 | none |
| TPS | | | -0.25 | none | | | +0.25 | none |
| SEP | | | 0.00 | none | | | 0.00 | none |
| (TRM) | | | +0.25 | none | none | - 0.25 | +0.25 | none |

*Tab. 3: Empirical survey of GNSS manufacturer alignment (value in cycles to be added to tracked raw observables to get aligned observables)*

# RINEX3.02 (3)

- Phase shifts -> phase shift

| | |
|---|---|
| 9-May-2012 | Changed SYS / PHASE SHIFTS to SHIFT |

- Phase shift decision
  - All phase observations **must** be aligned in RINEX 3.01 and later files and the new **SYS / PHASE SHIFT** header is mandatory.
  - If the phase alignment is not known then the observation data **should not** be published in a RINEX 3.0x file.
- Beidou Satellite system added
  - Satellite system (**G/R/E/J/C/S**)
  - Attention: in station log Compass naming “CMP” changed “BDS”: GPS+GLO+GAL+**BDS**+QZSS+SBAS

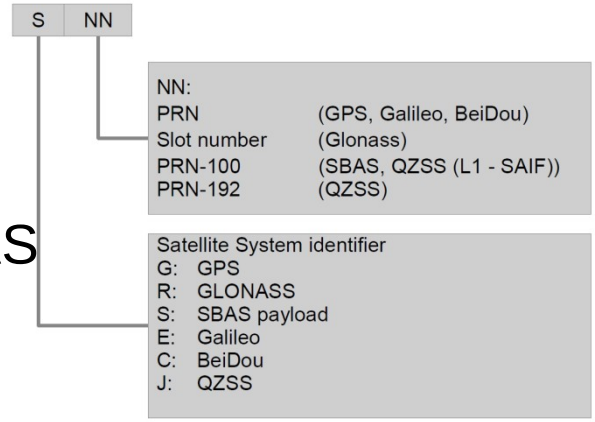


Figure 1: Satellite numbers and Constellation Identifiers

# RINEX3.02 (5)

RINEX 3.02 Format Phase alignment Definition (Attachment A19)

TABLE A19
Reference Code and Phase Alignment by Frequency Band

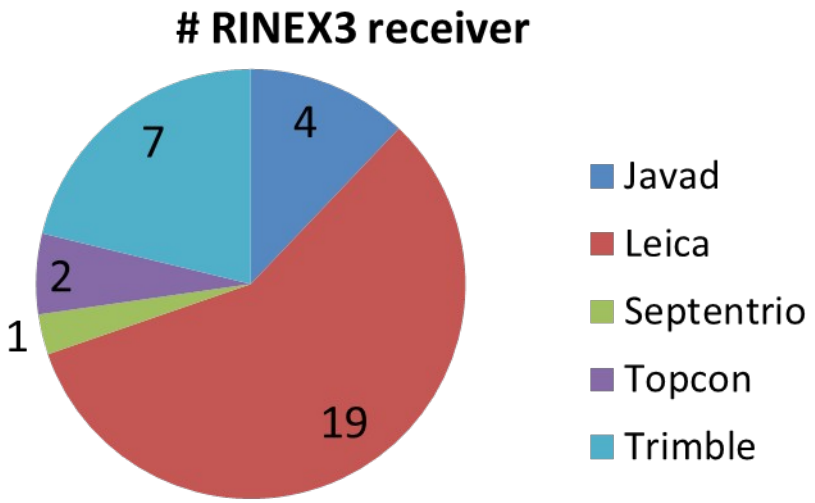
| System | Frequency Band | Frequency [MHz] | Signal | RINEX Observation Code | Phase Correction applied to each observed phase to obtain aligned phase. (φRINEX = φ original + Δφ) |
|---|---|---|---|---|---|
| GPS | L1 | 1575.42 | C/A | L1C | None (Reference Signal) |
| | | | L1C-D | L1D | +¼ cycle |
| | | | L1C-P | L1E | +¼ cycle |
| | | | L1C-(D+P) | L2X | +¼ cycle |
| | | | P | L1P | +¼ cycle |
| | | | Z-tracking | L1W | +¼ cycle |
| | | | Codeless | L1N | +¼ cycle |
| | L2 See Note 1 | 1227.60 | C/A | L2C | For Block II/IIA/IIR – None; For Block IIR-M/IIF/III -¼ cycle See Note 2 |
| | | | Semi-codeless | L2D | None |
| | | | L2C(M) | L2S | -¼ cycle |
| | | | L2C(L) | L2L | -¼ cycle |
| | | | L2C(M+L) | L2X | -¼ cycle |
| | | | P | L2P | None (Reference Signal) |
| | | | Z-tracking | L2W | None |
| | | | Codeless | L2N | None |

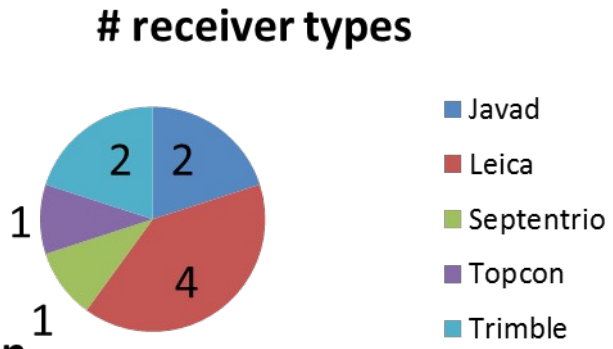
Example ZIM3

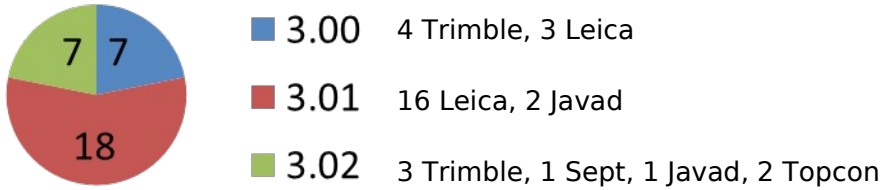
```
G L2X -0.25000                                  SYS / PHASE SHIFT
R L1P  0.25000                                  SYS / PHASE SHIFT
R L2C -0.25000                                  SYS / PHASE SHIFT
```

# RINEX3 data availability: 33 stations

| Marker Name | Country | Receiver Type | Sat. System G | R | E | RINEX 3 data available |
|---|---|---|---|---|---|---|
| ACOR | Spain | LEICA GRX1200PRO | ✔ | _ | _ | _ |
| AJAC | France | LEICA GR25 | ✔ | ✔ | ✔ | ✔ |
| ALAC | Spain | LEICA GR10 | ✔ | ✔ | ✔ | ✔ |
| ALBA | Spain | LEICA GR10 | ✔ | ✔ | ✔ | ✔ |
| ALCI | Ukraine | TRIMBLE 5700 | ✔ | _ | _ | _ |
| ALME | Spain | TRIMBLE NETRS | ✔ | _ | _ | _ |
| ~~AMMN~~ | ~~Jordan~~ | ~~ASHTECH Z XII3~~ | ✔ | _ | _ | _ |
| ANKR | Turkey | TPS E_GGD | ✔ | ✔ | _ | _ |
| AQUI | Italy | TRIMBLE 4700 | ✔ | _ | _ | _ |
| ARGI | Faroe Islands | LEICA GRX1200GGPRO | ✔ | ✔ | _ | _ |
| AUT1 | Greece | LEICA GRX1200PRO | ✔ | _ | _ | _ |
| AUTN | France | TRIMBLE NETR5 | ✔ | ✔ | _ | _ |
| AXPV | France | TRIMBLE NETR9 | ✔ | ✔ | ✔ | ✔ |
| BACA | Romania | LEICA GRX1200PRO | ✔ | _ | _ | _ |
| BADH | Germany | LEICA GRX1200GGPRO | ✔ | ✔ | _ | _ |
| BAIA | Romania | LEICA GRX1200PRO | ✔ | _ | _ | _ |
| BBYS | Slovak Republic | TRIMBLE NETR9 | ✔ | ✔ | ✔ | ✔ |



# RINEX3 data availability

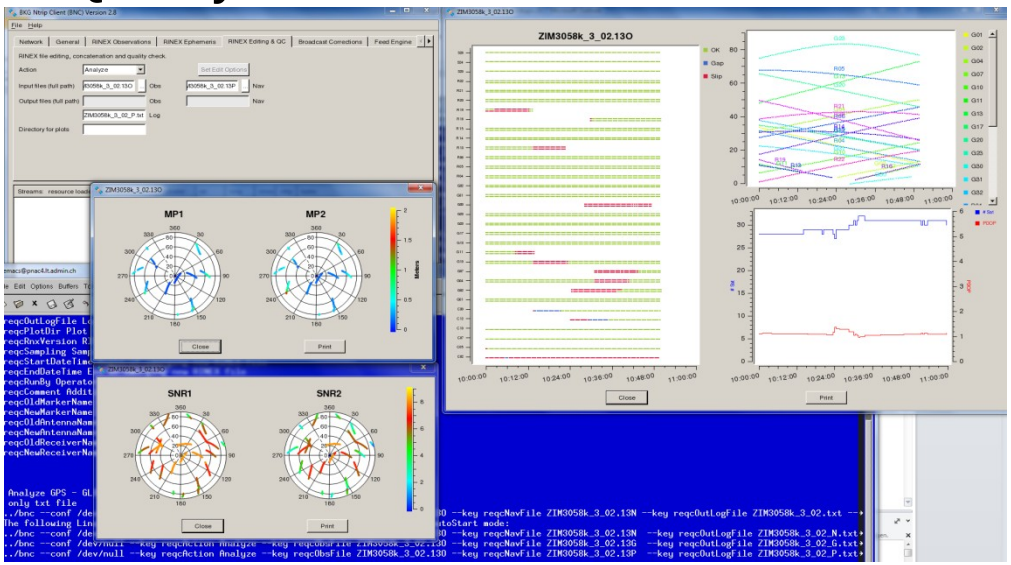
- BKG DC: IGS: ftp://igs.bkg.bund.de/IGS/obs_v3/yyyy/ddd
  EUREF: ftp://igs.bkg.bund.de/EUREF/obs_v3/yyyy/ddd
- Status March 2013: **33 EPN** RINEX3 data (Aug 2011: 8)
- BKG-EUREF: 21 sites (**alac alba axpv bbys bscn cant eglt guip** ildx **m0se** obe4 **pots rio1 scoa smne tlmf usal vale ven1 vfch**); data missing: **bogi** dyng
  delta: +3 last 5 months
- BKG-IGS: 31 sites (**ajac brst brux** conz **ganp** harb **hofn** lhaz lmmf lpgs **mars** mat1 **mate meli** nklg nurk ohi2 ous2 **pots** reun **reyk sass** tash **tlse** ulab **warn** wind **wtzr** wtzz **zim2**)
  delta: +5 last 5 months

- BKG MGEX: ftp://igs.bkg.bund.de/MGEX/obs_v3/yyyy/ddd:

15 sites dlf1, gop6/gop7, grac/gra1/gra2, kir8, mar7, matg, metg, nya2, ons1, wtz2/wtz3, zim3

# RINEX3: manipulation / editing

- BNC2.8 (Win + Linux + Mac)  Released Mar 13, 2013 - Thanks to BKG+TU Prag!
  - Concatenation / Sampling
  - RINEX 3 -> RINEX 2 «translation»/ downgrading
  - RINEX header manipulation (basic fields only)
  - Quality check



# Uni Bern RINEX3 activity


- RINEX3 database (in development)
  - xml metadata generation of RINEX3 Files of ~90 MGEX/IGS/EUREF stations (3.00, 3.01, and 3.02)
    - History + time stamps of data of various DCs
    - Checking header entries
    - Checking observation types (per satellite)
  - Generating reports, inconsistencies, etc.
  - possibility to select stations with certain properties (obs. types, …)

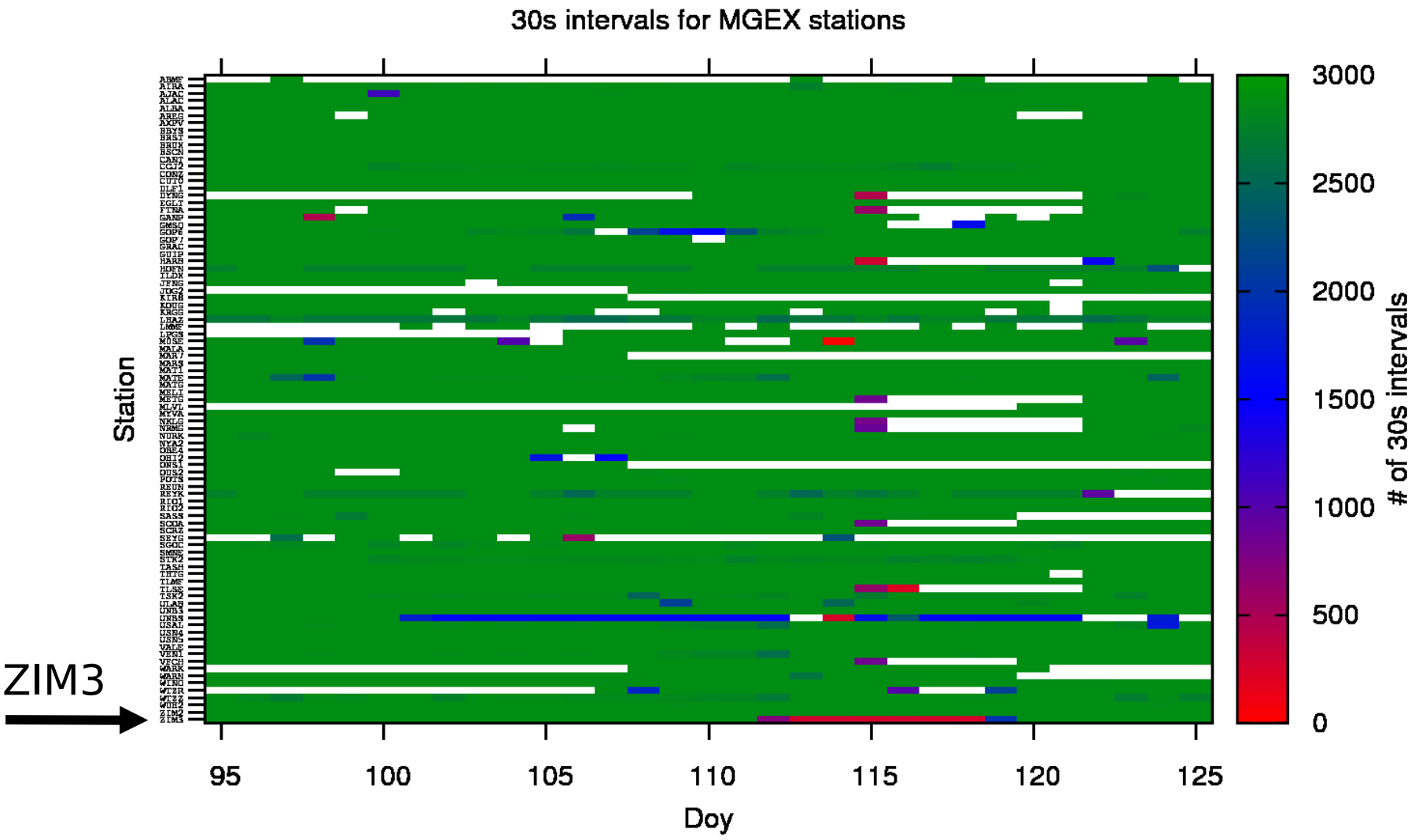
```
<?xml version="1.0" encoding="utf-8"?>
<RINEX>
  <FILE>
    <FORMAT>DOS</FORMAT>
    <MD5>52991b46dedb317ffbd5ed168dc376be</MD5>
    <MOD_TIME_DC>2013-03-15T03:58:01 UT</MOD_TIME_DC>
    <MOVED_TO_DP>2013-03-15T15:47:51 UT</MOVED_TO_DP>
    <NAME>ZIM30730.13O</NAME>
    <PATH_DC>ftp://cddis.gsfc.nasa.gov/pub/gps/data/campaign/mgex/daily/rinex3/2013/073/13d</PATH_DC>
    <PATH_DP>/gpfs/aiub_data/DATAPOOL/MGEX/daily/RINEX3/2013/073/ZIM30730.13D.Z</PATH_DP>
  </FILE>
```

```
<OBS_TYPES>
  <C1C>1219</C1C>
  <C1P>1219</C1P>
  <C2C>1219</C2C>
  <C2P>1219</C2P>
  <L1C>1219</L1C>
  <L1P>1219</L1P>
  <L2C>1219</L2C>
  <L2P>1219</L2P>
  <S1C>1219</S1C>
  <S1P>1219</S1P>
  <S2C>1219</S2C>
  <S2P>1219</S2P>
</OBS_TYPES>
```

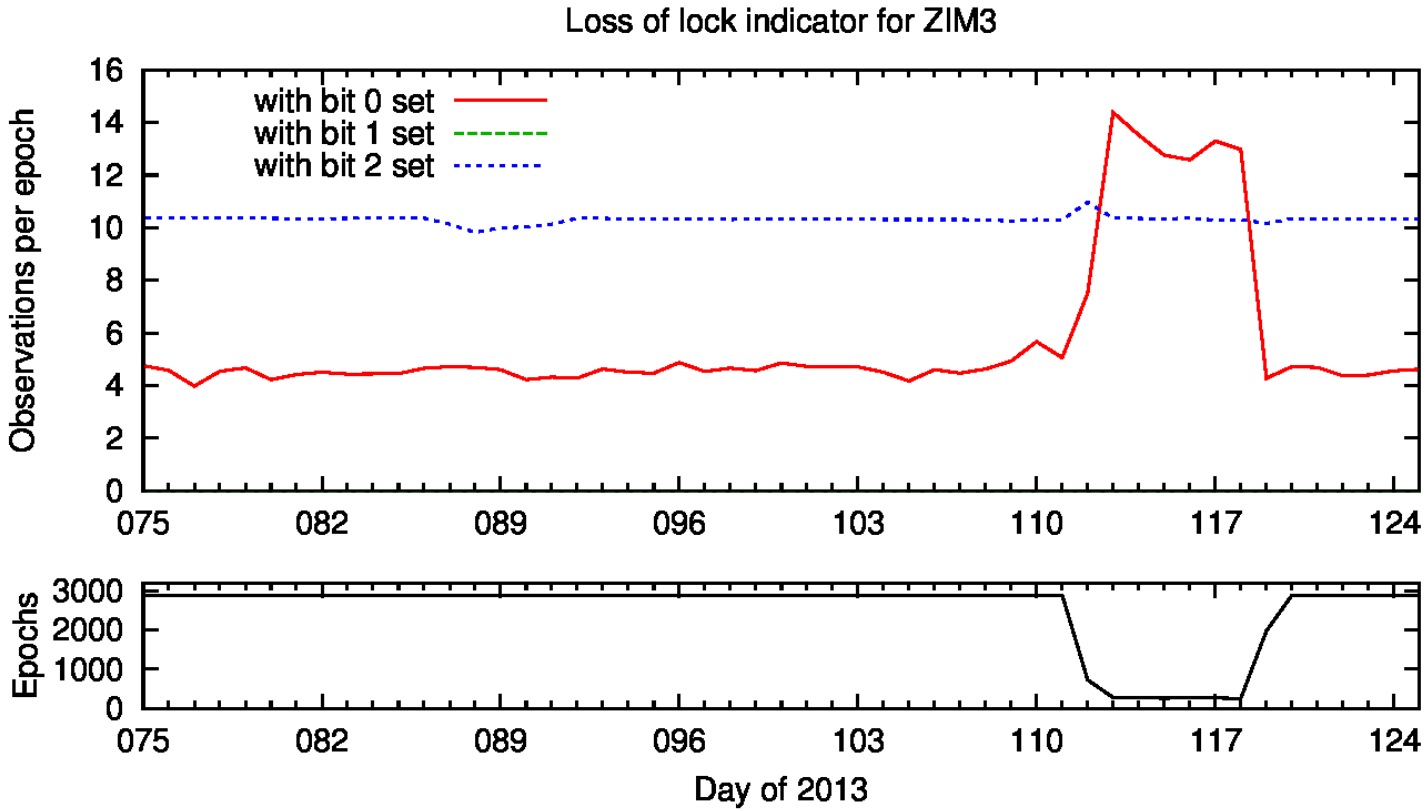
# Variety of observation types (30 days)

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1248 | 54.55% | G:L1C | G:C1C | | | | | | | G:L2X | G:C2X | | | G:L2W | G:C2W | | G:L5X G:C5X |
| 414 | 18.09% | G:L1C | G:C1C | G:L1W | G:C1W | | | | | G:L2X | G:C2X | | | G:L2W | G:C2W | | G:L5X G:C5X |
| 117 | 5.11% | G:L1C | G:C1C | | | | | | | G:L2X | G:C2X | | | G:L2W | G:C2W | | |
| 109 | 4.76% | G:L1C | G:C1C | G:L1W | G:C1W | | | | | | | | | G:L2W | G:C2W | | |
| 97 | 4.24% | G:L1C | G:C1C | | | | | | | | | | | G:L2W | G:C2W | | |
| 87 | 3.80% | G:L1C | G:C1C | | | | | | | | | G:L2P | G:C2P | | | | |
| 83 | 3.63% | G:L1C | G:C1C | | G:C1W | | | G:L2L | G:C2L | | | | | G:L2W | G:C2W | G:L5Q | G:C5Q |
| 36 | 1.57% | G:L1C | G:C1C | | | | | | | | | | | G:L2W | G:C2W | | G:L5X G:C5X |
| 29 | 1.27% | G:L1C | G:C1C | | | G:L2D | G:C2D | | | | | | | | | G:L5Q | G:C5Q |
| 29 | 1.27% | G:L1C | G:C1C | | | G:L2D | G:C2D | | | | | | | | | | |
| 28 | 1.22% | G:L1C | G:C1C | | | | | | | | G:C2X | | | G:L2W | G:C2W | | G:L5X G:C5X |
| 7 | 0.31% | G:L1C | G:C1C | | | | | | | | | | | | | | |
| 2 | 0.09% | G:L1C | G:C1C | | | | | | | G:L2X | G:C2X | | G:C2P | G:L2W | G:C2W | | G:L5X G:C5X |
| 2 | 0.09% | G:L1C | G:C1C | | | | | | | G:L2X | G:C2X | | G:C2P | G:L2W | G:C2W | | |
| 1091 | 48.32% | R:L1C | R:C1C | R:L1P | R:C1P | R:L2C | R:C2C | R:L2P | R:C2P | | | | | | | | |
| 633 | 28.03% | R:L1C | R:C1C | | | | | R:L2P | R:C2P | | | | | | | | |
| 282 | 12.49% | R:L1C | R:C1C | | | R:L2C | R:C2C | R:L2P | R:C2P | | | | | | | | |
| 216 | 9.57% | R:L1C | R:C1C | R:L1P | R:C1P | | | R:L2P | R:C2P | | | | | | | | |
| 29 | 1.28% | R:L1C | R:C1C | | | R:L2C | R:C2C | | | | | | | | | | |
| 7 | 0.31% | R:L1C | R:C1C | R:L1P | R:C1P | | | | | | | | | | | | |
| 582 | 33.82% | | | E:L1X | E:C1X | | | E:L5X | E:C5X | | | | | | | | |
| 559 | 32.48% | | | E:L1X | E:C1X | | | E:L5X | E:C5X | | | E:L7X | E:C7X | | | E:L8X | E:C8X |
| 388 | 22.55% | | | E:L1X | E:C1X | | | E:L5X | E:C5X | | | E:L7X | E:C7X | E:L8Q | E:C8Q | | |
| 83 | 4.82% | E:L1C | E:C1C | | | E:L5Q | E:C5Q | | | E:L7Q | E:C7Q | | | E:L8Q | E:C8Q | | |
| 51 | 2.96% | | | | | | | E:L5X | E:C5X | | | E:L7X | E:C7X | | | E:L8X | E:C8X |
| 29 | 1.69% | E:L1C | E:C1C | | | E:L5Q | E:C5Q | | | | | | | | | | |
| 28 | 1.63% | | | E:L1X | E:C1X | | | E:L5X | E:C5X | | | E:L7X | E:C7X | | | | |
| 1 | 0.06% | | | E:L1X | E:C1X | | | E:L5X | E:C5X | | | E:L7X | E:C7X | | | E:L8X | |
| 963 | 79.00% | S:L1C | S:C1C | | | | | | | | | | | | | | |
| 256 | 21.00% | S:L1C | S:C1C | S:L5I | S:C5I | | | | | | | | | | | | |
| 412 | 79.54% | C:L2I | C:C2I | C:L6I | C:C6I | C:L7I | C:C7I | | | | | | | | | | |
| 83 | 16.02% | C:L2I | C:C2I | | | C:L7I | C:C7I | | | | | | | | | | |
| 23 | 4.44% | C:L2I | C:C2I | | | | | | | | | | | | | | |
| 116 | 32.86% | J:L1C | J:C1C | J:L1X | J:C1X | J:L2X | J:C2X | J:L5X | J:C5X | | | | | | | | |
| 100 | 28.33% | J:L1C | J:C1C | | | J:L2X | J:C2X | J:L5X | J:C5X | | | | | | | | |
| 85 | 24.08% | J:L1C | J:C1C | J:L1X | J:C1X | J:L2X | J:C2X | J:L5X | J:C5X | J:L6X | J:C6X | | | | | | |
| 29 | 8.22% | J:L1C | J:C1C | | | J:L2X | J:C2X | J:L5X | J:C5X | J:L6X | J:C6X | | | | | | |
| 23 | 6.52% | J:L1C | J:C1C | J:L1X | J:C1X | J:L2X | J:C2X | | | | | | | | | | |

# Completness of daily observation files



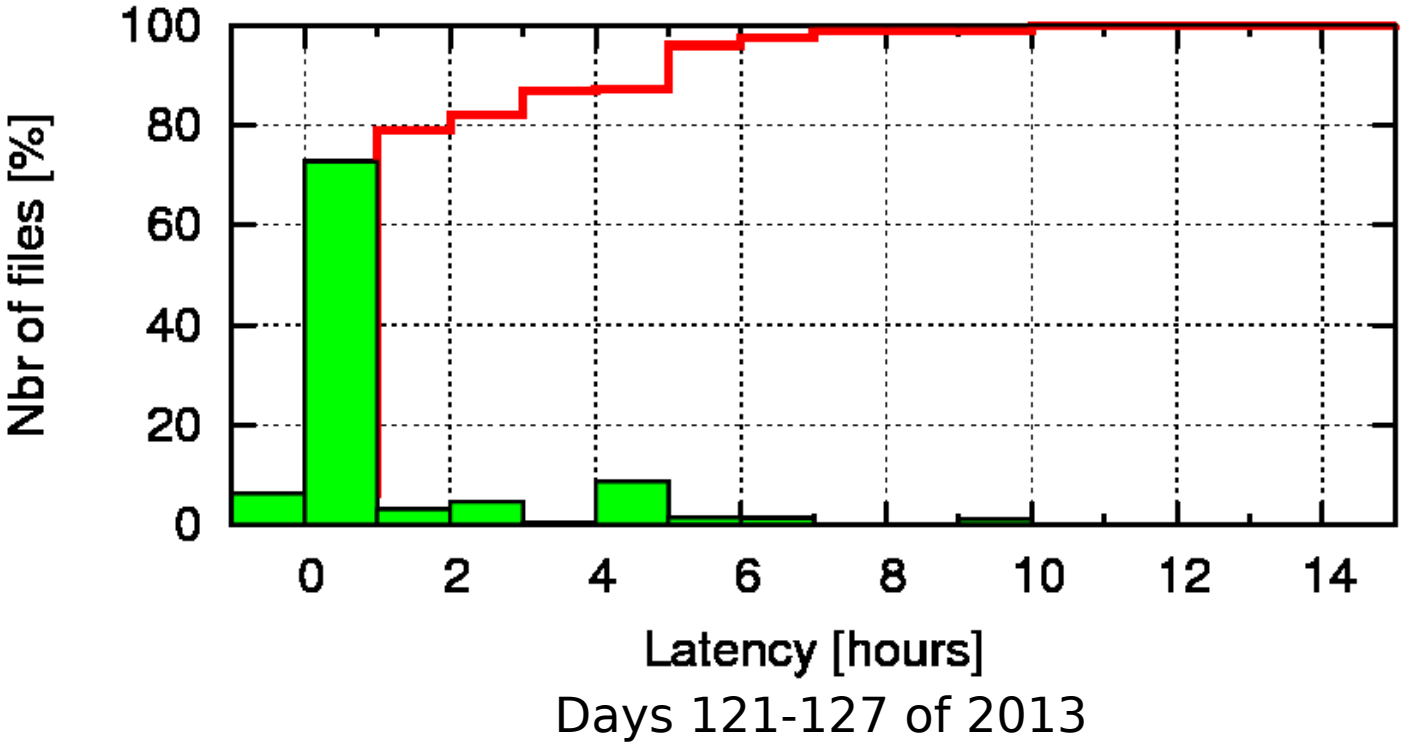
# Quality assessment of the raw data




Bit 0 set: Loss of lock, cycle slip possible
Bit 1 set: Half-cycle ambiguity/slip possible
Bit 2 set: Galileo BOC tracking of MBOC signal

# Latency of daily observation files

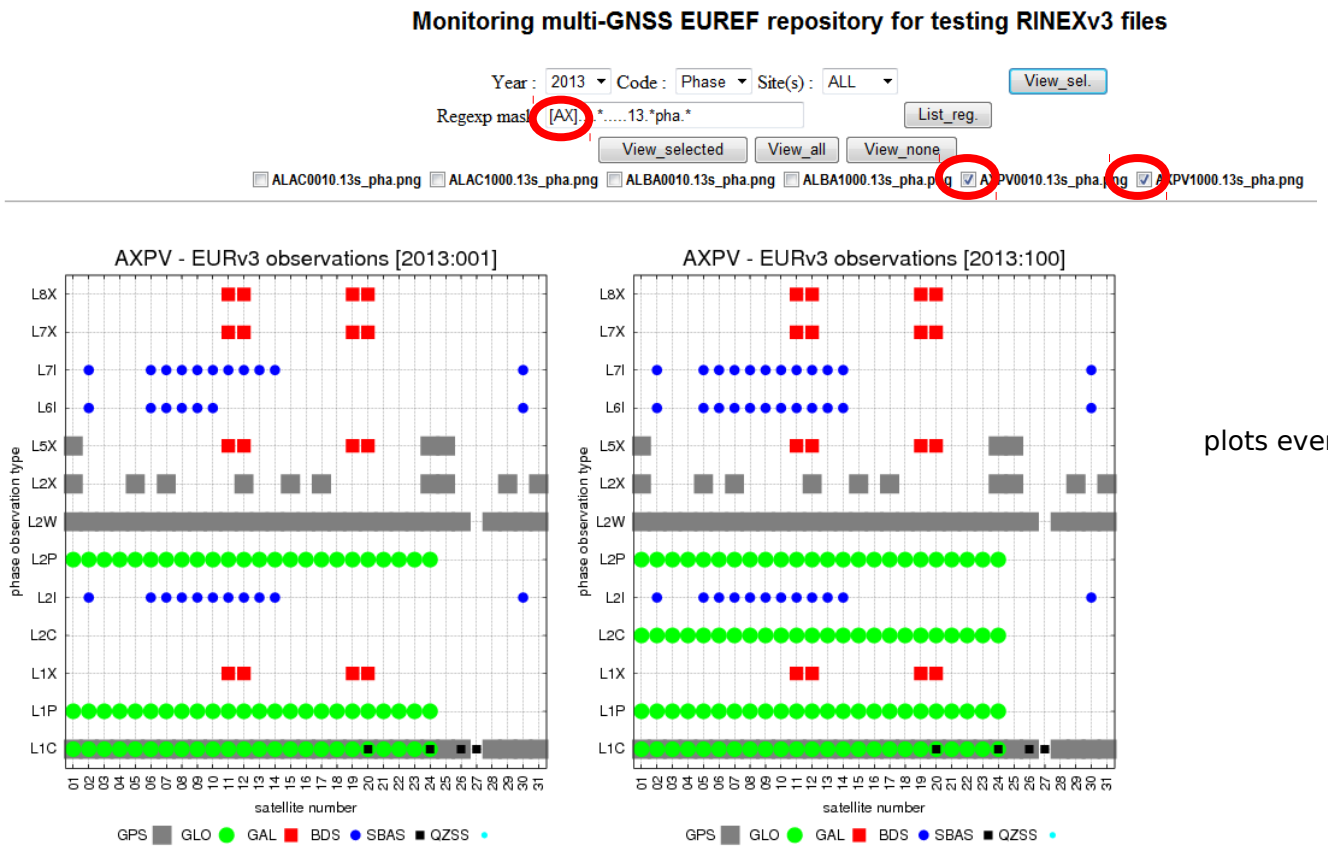
- Availability of files on data centers is checked every hour
- Identical files in data pool are not replaced
- Usually, at 05:00 UT more than 90% of the RINEX 3 files are downloaded




Days 121-127 of 2013

# Pecny RINEX3 activity (Pavel Vaclavovic, Jan Dousa)

- http://www.pecny.cz/WWW_IMG/MULTI-GNSS/EURv3/




plots every 100 days