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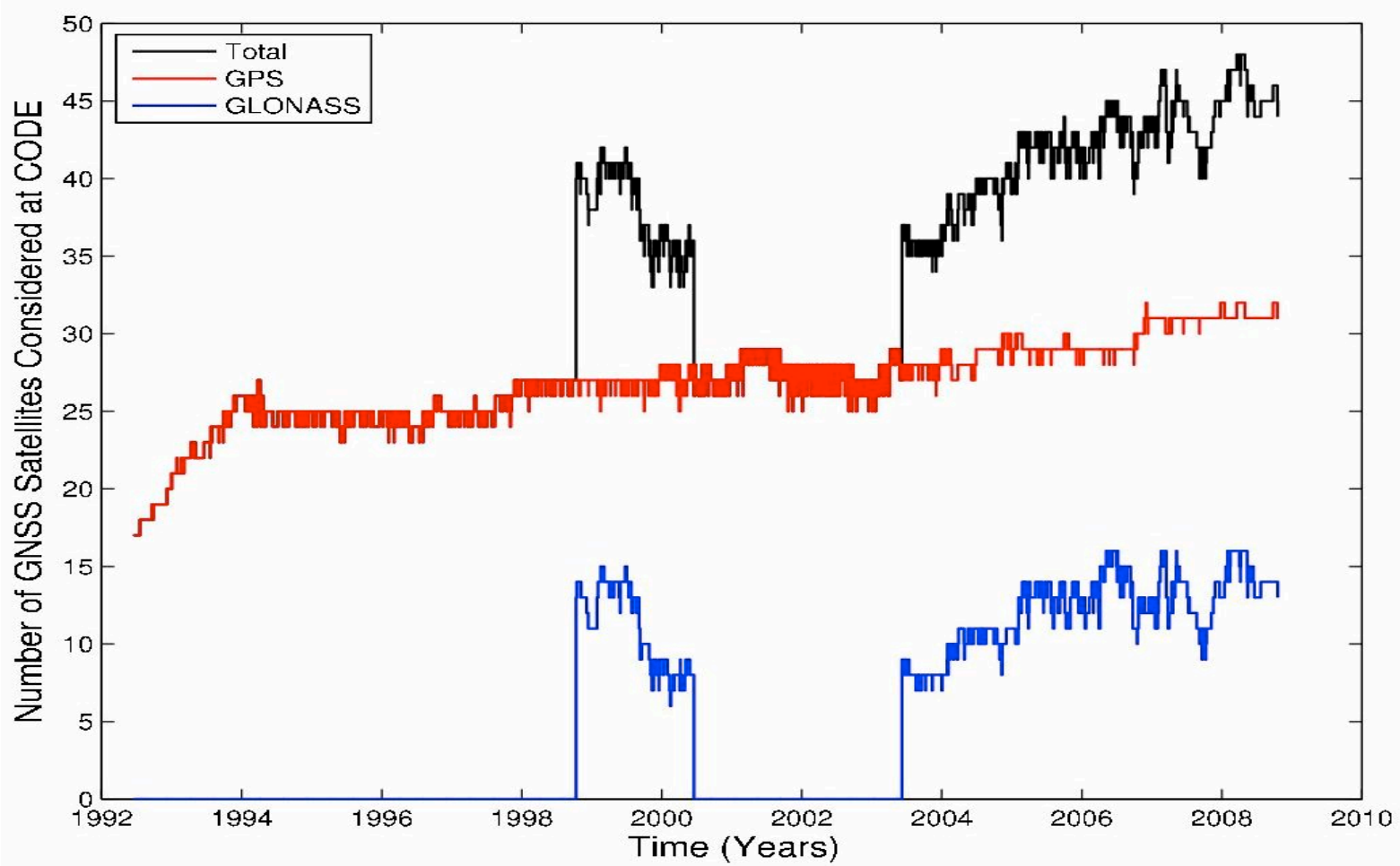
GNSS Tracking Issues

Stefan C. Schaer

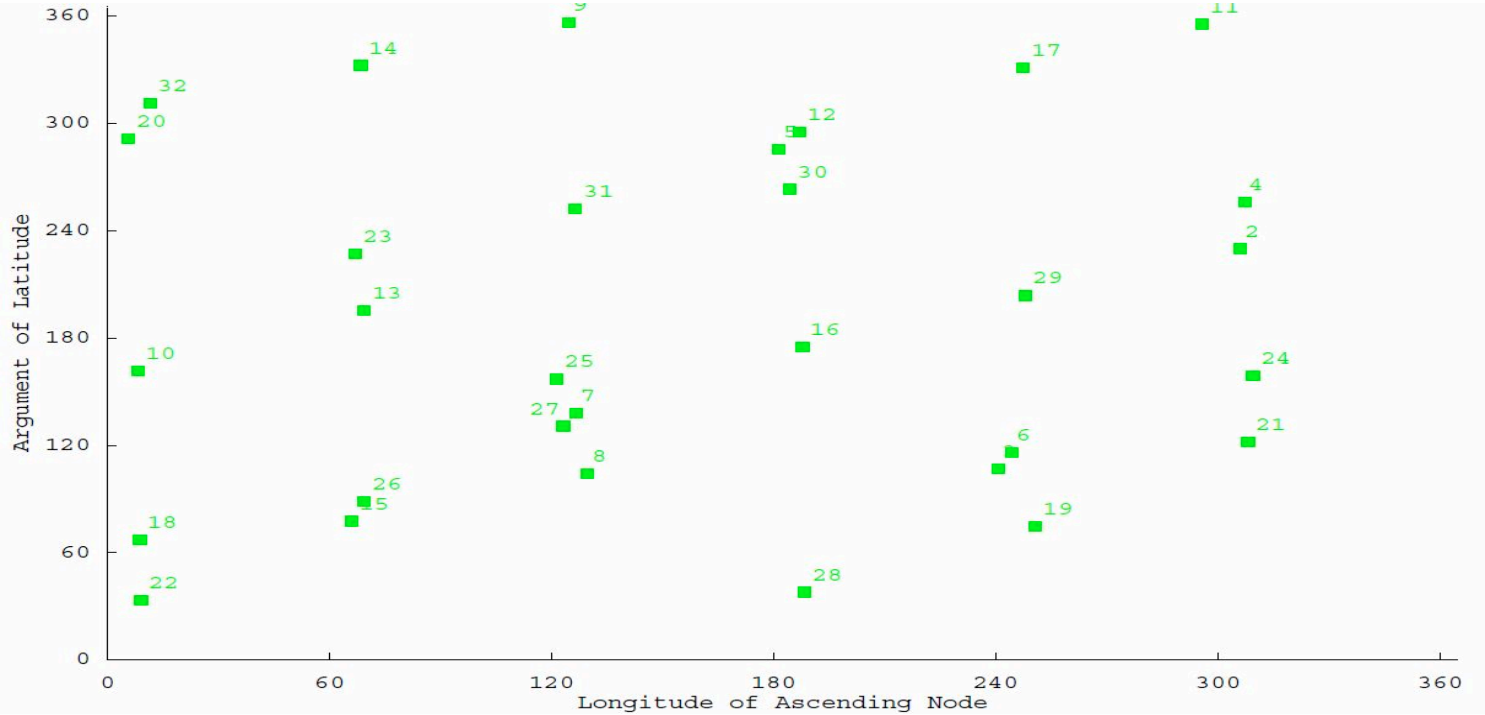
Outline

- Current GNSS satellite constellation
- GLONASS negative frequency channels
- Improved IGS GNSS receiver coverage
- Survey of employed IGS GNSS receiver and antenna/ radome models
- Quarter-cycle issue (RINEX/RTCM)

GNSS Satellite Constellation



GPS Constellation: 31 Satellites



http://gge.unb.ca/Resources/GPSConstellationPlot.pdf

GPS PRN32 Tracking (1/2)

ftp://ftp.unibe.ch/aiub/igsdata/tracking_prn32_sum.txt:

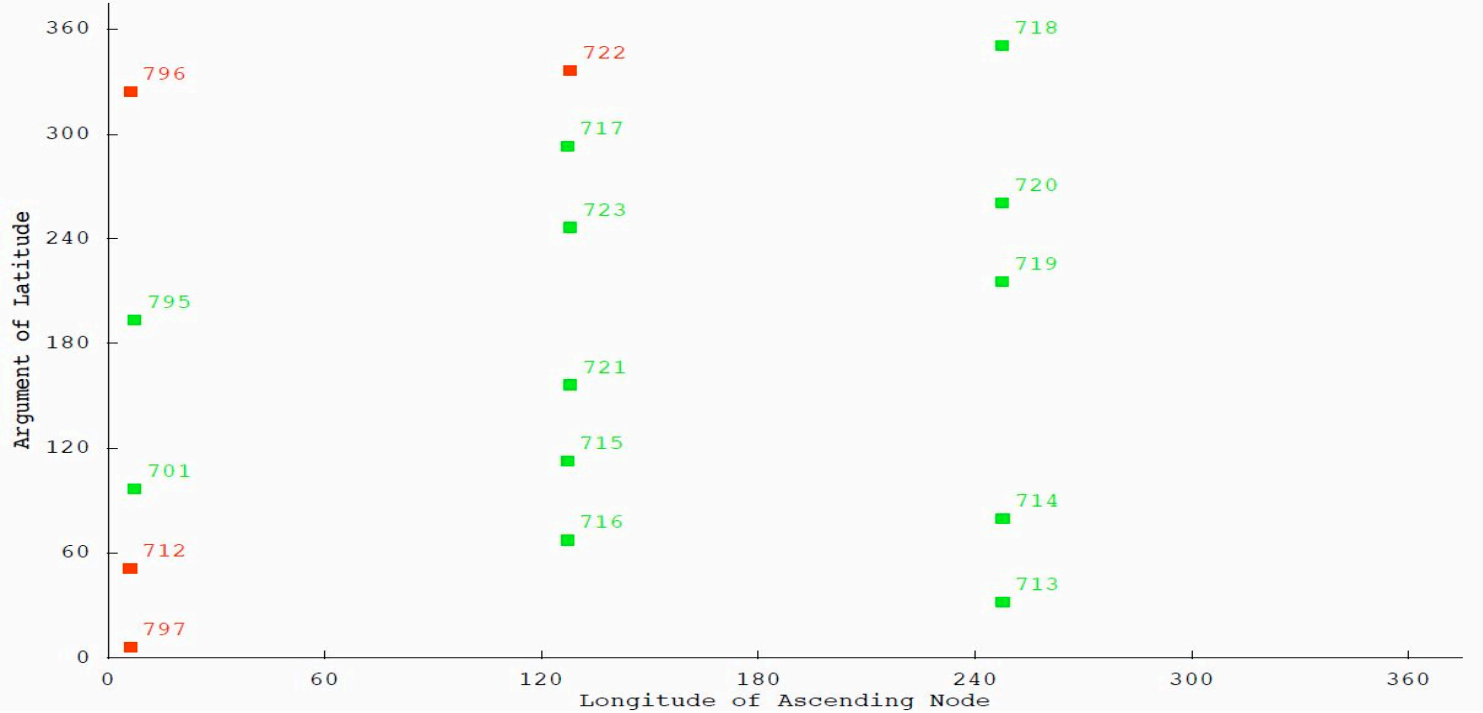
```
AOA BENCHMARK ACT   : 100% ( 19 of  19)
AOA SNR-12 ACT      : 100% (  3 of   3)
AOA SNR-8000 ACT    : 100% (  4 of   4)
AOA SNR-8100 ACT    : 100% (  1 of   1)
ASHTECH UZ-12       : 100% ( 51 of  51)
ASHTECH Z-X         : 100% (  1 of   1)
ASHTECH Z-XII3      : 100% ( 56 of  56)
ASHTECH Z-XII3T     : 100% ( 14 of  14)
ASHTECH Z18         :  50% (  2 of   4)
BLACKJACK           : 100% (  2 of   2)
JPS EGGDT           : 100% (  5 of   5)
JPS EUROCARD        : 100% (  1 of   1)
JPS E_GGD           : 100% (  7 of   7)
JPS LEGACY          : 100% ( 22 of  22)
LEICA CRS1000       : 100% (  2 of   2)
LEICA GRX1200       : 100% (  2 of   2)
LEICA GRX1200GGPRO  : 100% ( 32 of  32)
LEICA GRX1200PRO    : 100% (  3 of   3)
LEICA RS500         : 100% (  1 of   1)
NOV EURO4-1.00-222  : 100% (  1 of   1)
NOV OEMV3           : 100% (  2 of   2)
ROGUE SNR-8000      : 100% (  5 of   5)
SEPT POLARX2        : 100% (  6 of   6)
TPS EGGDT           : 100% (  1 of   1)
TPS EUROCARD        : 100% (  1 of   1)
TPS E_GGD           : 100% ( 12 of  12)
TPS GB-1000         : 100% (  4 of   4)
TPS LEGACY          : 100% (  3 of   3)
TPS NET-G3          : 100% (  1 of   1)
TPS NETG3           : 100% (  4 of   4)
TPS ODYSSEY_E       : 100% (  4 of   4)
TRIMBLE 4000SSE     : 100% (  2 of   2)
TRIMBLE 4000SSI     : 100% (  9 of   9)
TRIMBLE 4700        : 100% (  2 of   2)
TRIMBLE 5700        : 100% (  2 of   2)
TRIMBLE NETR5       : 100% ( 22 of  22)
TRIMBLE NETRS       :  80% ( 17 of  21)
--------------------------------------
TOTAL               :  98% (326 of 332)
```

GPS PRN32 Tracking (2/2)

ftp://ftp.unibe.ch/aiub/igsdata/tracking_prn32_not_ready.txt:

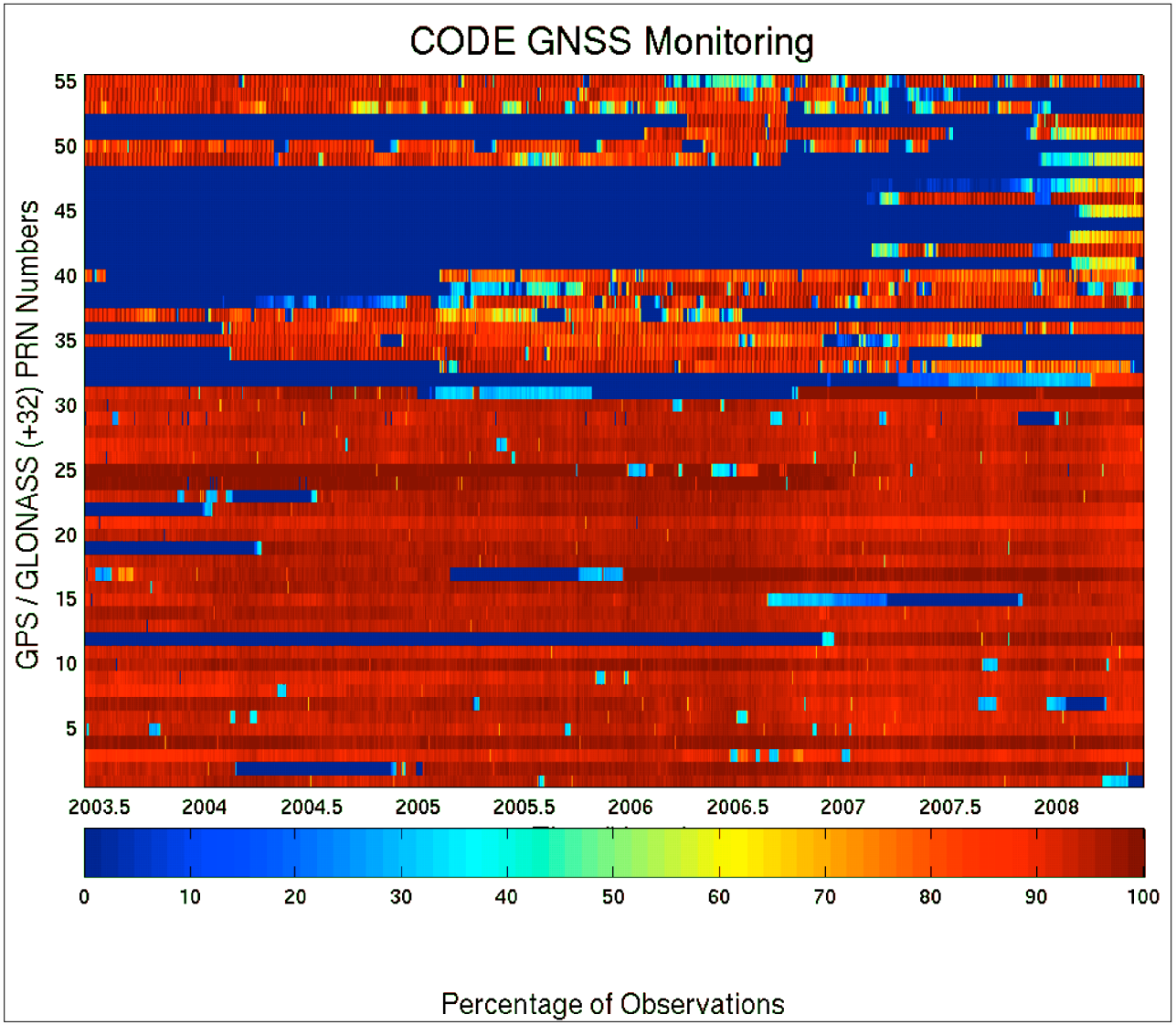
```
ASHTECH Z18          0065                 :          gope
ASHTECH Z18          0065       ZT16      :          mtka
TRIMBLE NETRS        0.4-1 G27 OCT 2005   :          pgc5
TRIMBLE NETRS        1.1-5                :          amu2
TRIMBLE NETRS        NP 1.13 / SP 0.00    :          ssia
TRIMBLE NETRS        NP 1.15 / SP 0.00    :          kgni
```

GLONASS Constellation: 13+3(+1)

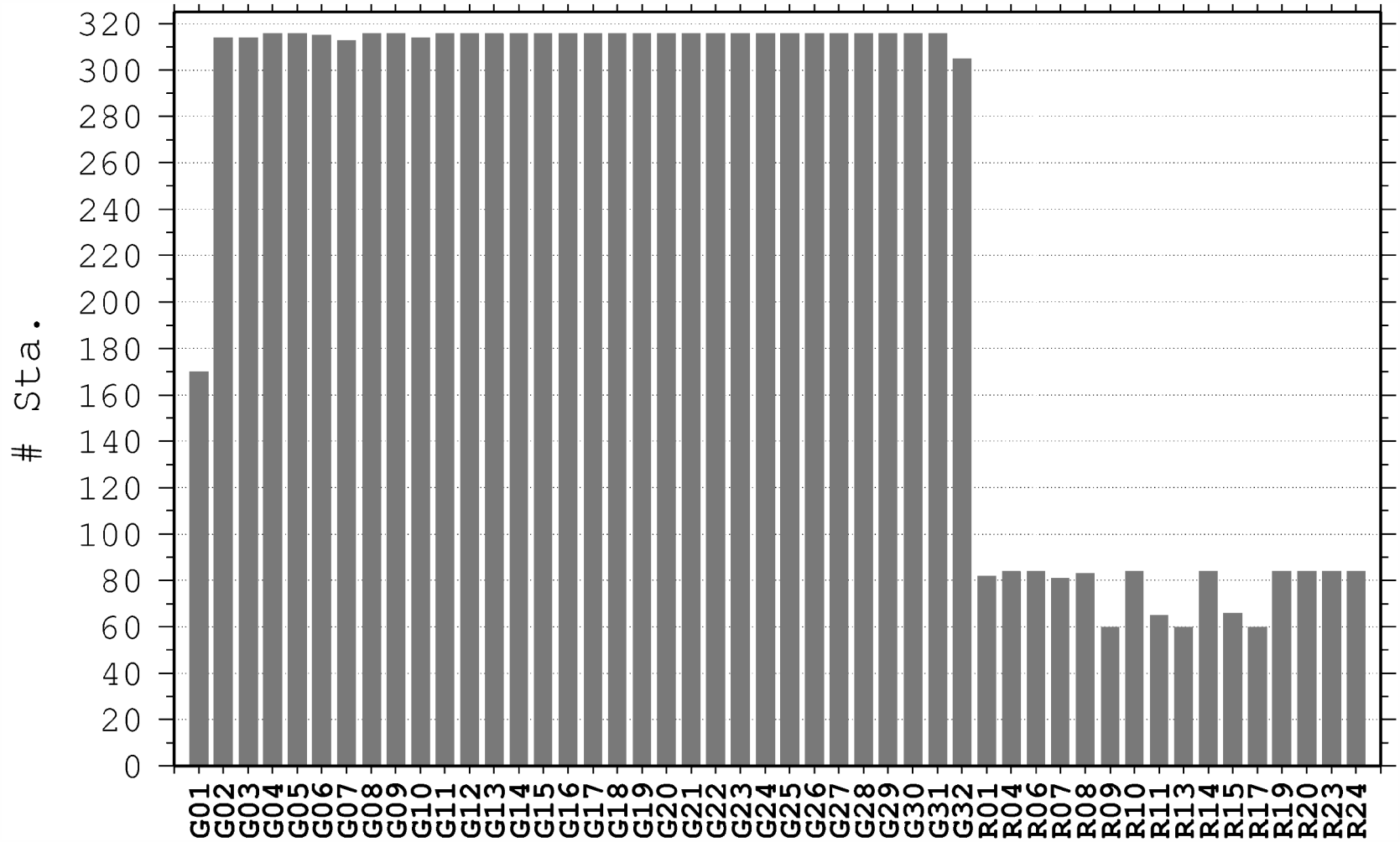


http://gge.unb.ca/Resources/GLONASSConstellationPlot.pdf

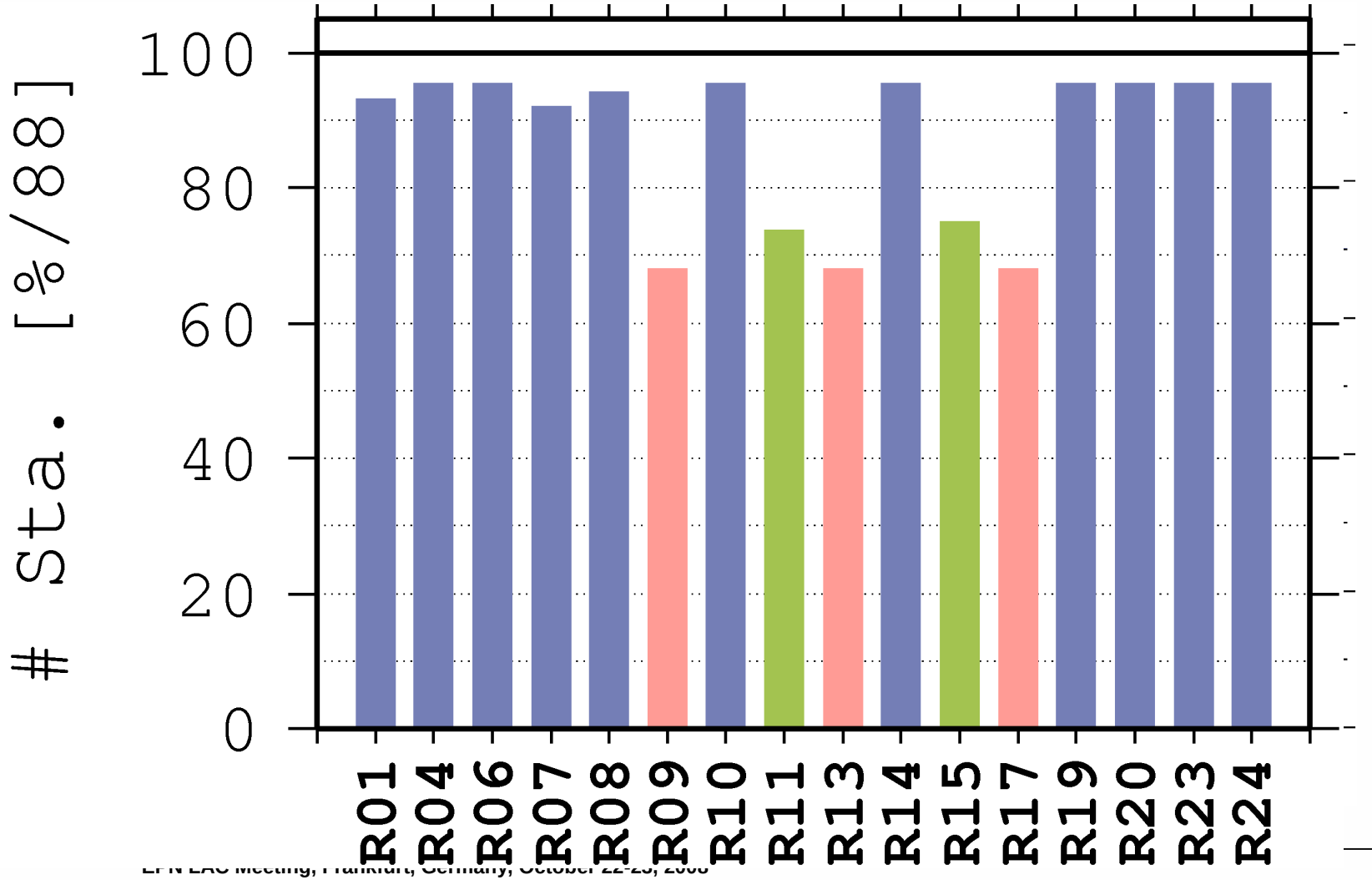
CODE GNSS Monitoring



Number of GNSS Stations Tracking a Specific GPS/GLONASS Satellite (for April 2008)



Number of GNSS Stations Tracking a Specific GPS/GLONASS Satellite (for April 2008)

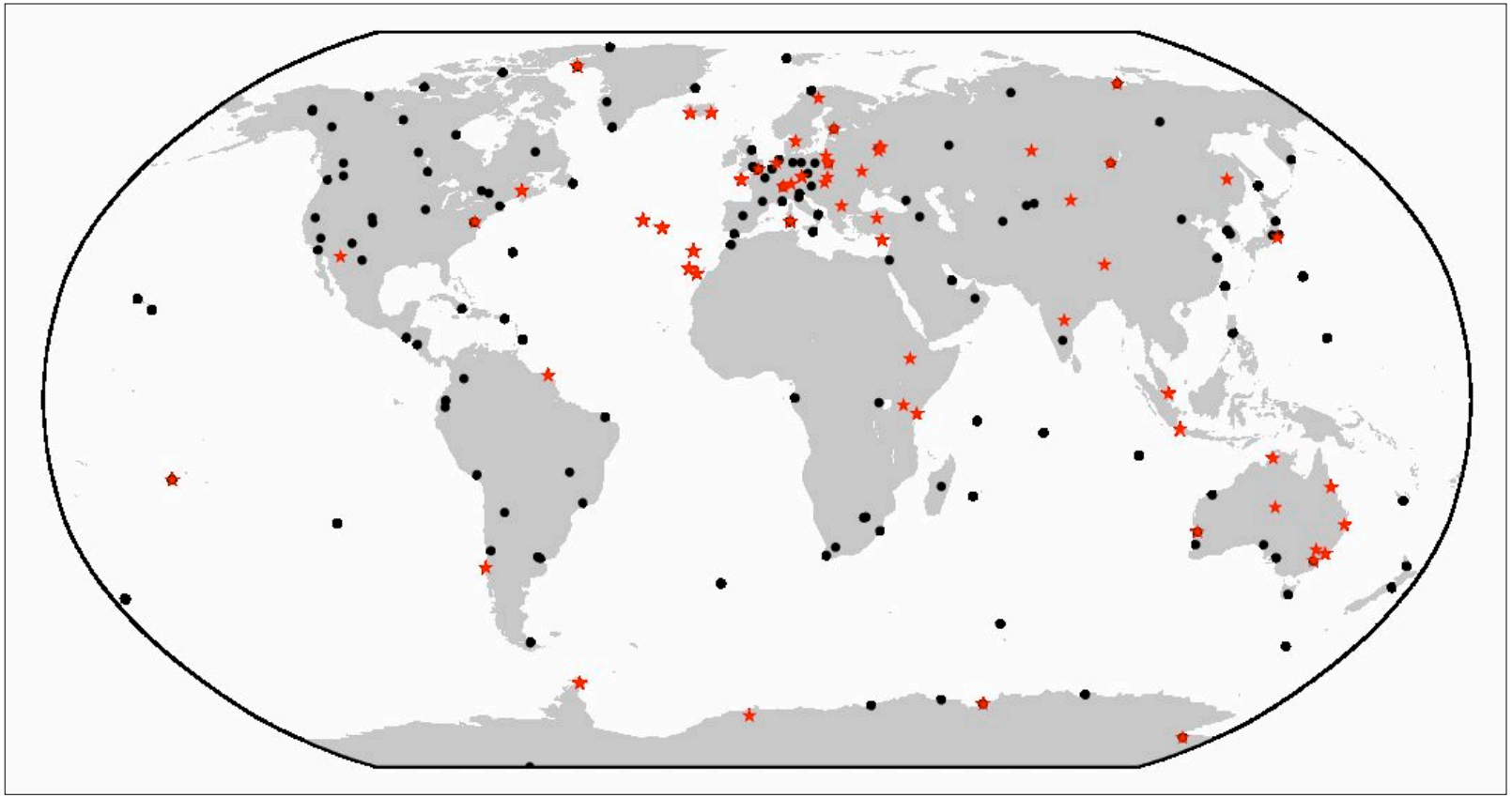


GLONASS Negative Frequency Channels

ftp://ftp.unibe.ch/aiub/igsdata/tracking_glo_neg_freq_not_ready.txt:

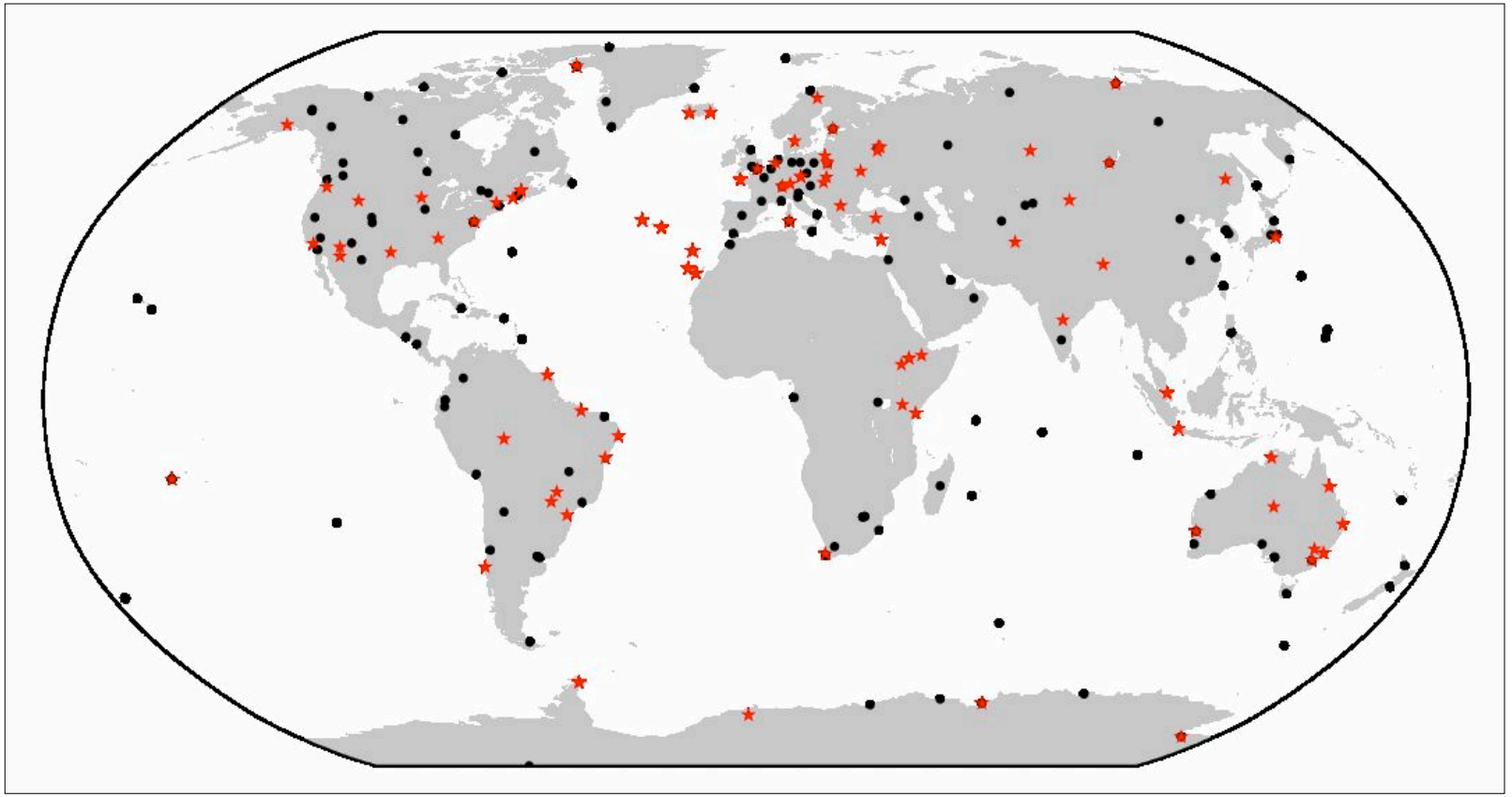
```
bako:     R11     R15      LEICA GRX1200GGPRO  5.00/3.013
cagz:                      TPS E_GGD           3.1 MAR,13,2007 P2
crar:                      TPS ODYSSEY_E       2.5 JUN,22,2005 P1
ctwn:     R11 R13 R15 R17  TRIMBLE NETR5       N/A
ilha:     R11     R15      LEICA GRX1200GGPRO  5.10
mobj:                      TPS LEGACY          2.3 APR,28,2004 P4
mtbg:     R11     R15      TPS GB-1000
mtka:                      ASHTECH Z18         0065      ZT16
park:                      JPS E_GGD           2.5
pous:                      TPS GB-1000         2.5 APR,07,2005 P1B1
snec:                      TPS GB-1000         2.5 JUN,22,2005 P1
sydn:                      JPS E_GGD           2.3P3
tixj:                      TPS ODYSSEY_E       2.5 JUN,22,2005 P1
tsea:     R11     R15      LEICA GRX1200GGPRO  4.10
unpg:                      TPS ODYSSEY_E       3.1 JUN,28,2007 P3
ven1:                      ASHTECH Z18         0065      ZT16
vesl:         R13          TPS GB-1000         3.1 JUN,28,2007 P3
```

GNSS Receiver Network as Used in CODE's Final Analysis (for GPS Weeks 1497-1498)



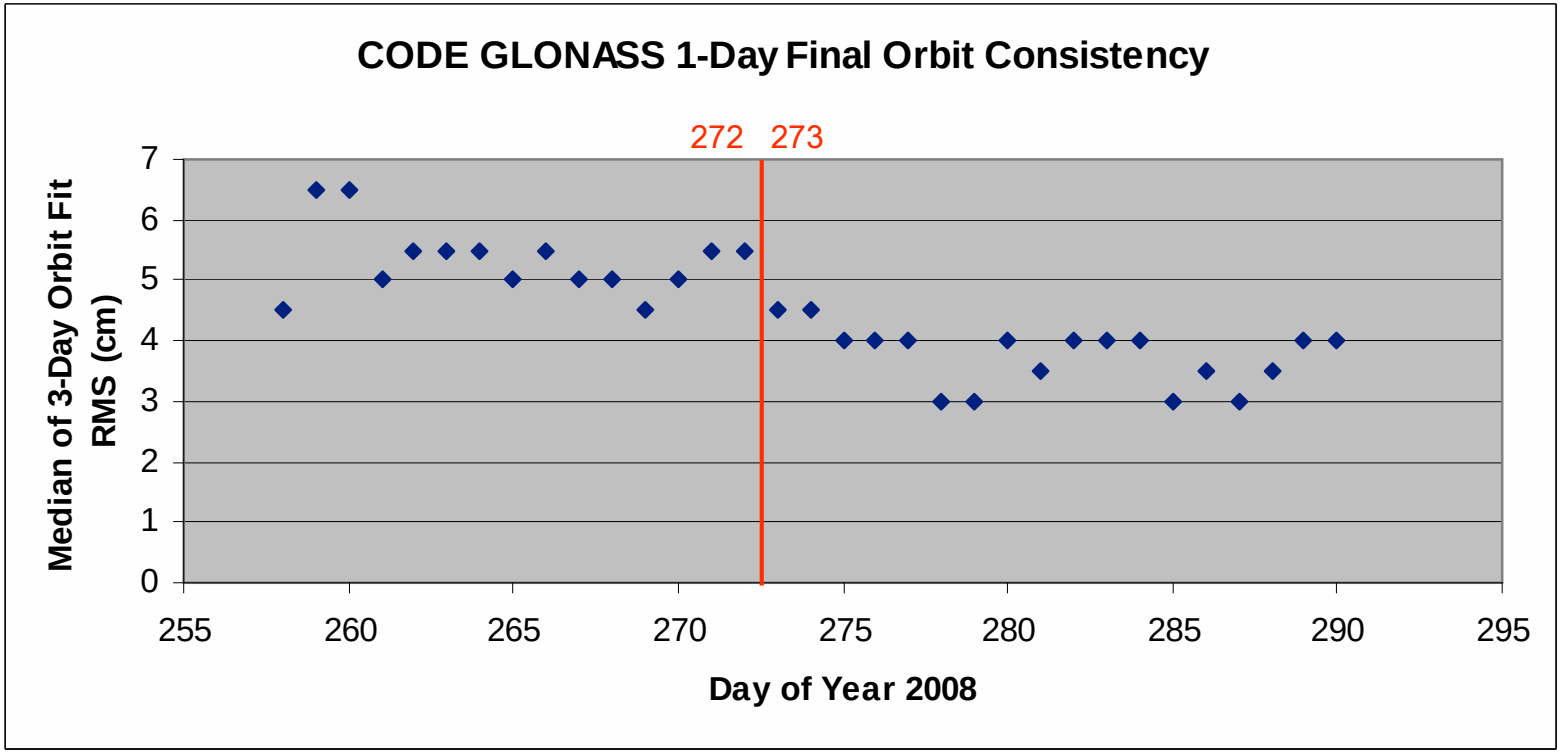
227 GNSS stations:158 GPS-only (70%) + 69 GPS/GLONASS (30%)

GNSS Receiver Network as Used in CODE's Final Analysis (for GPS Weeks 1499-1500)

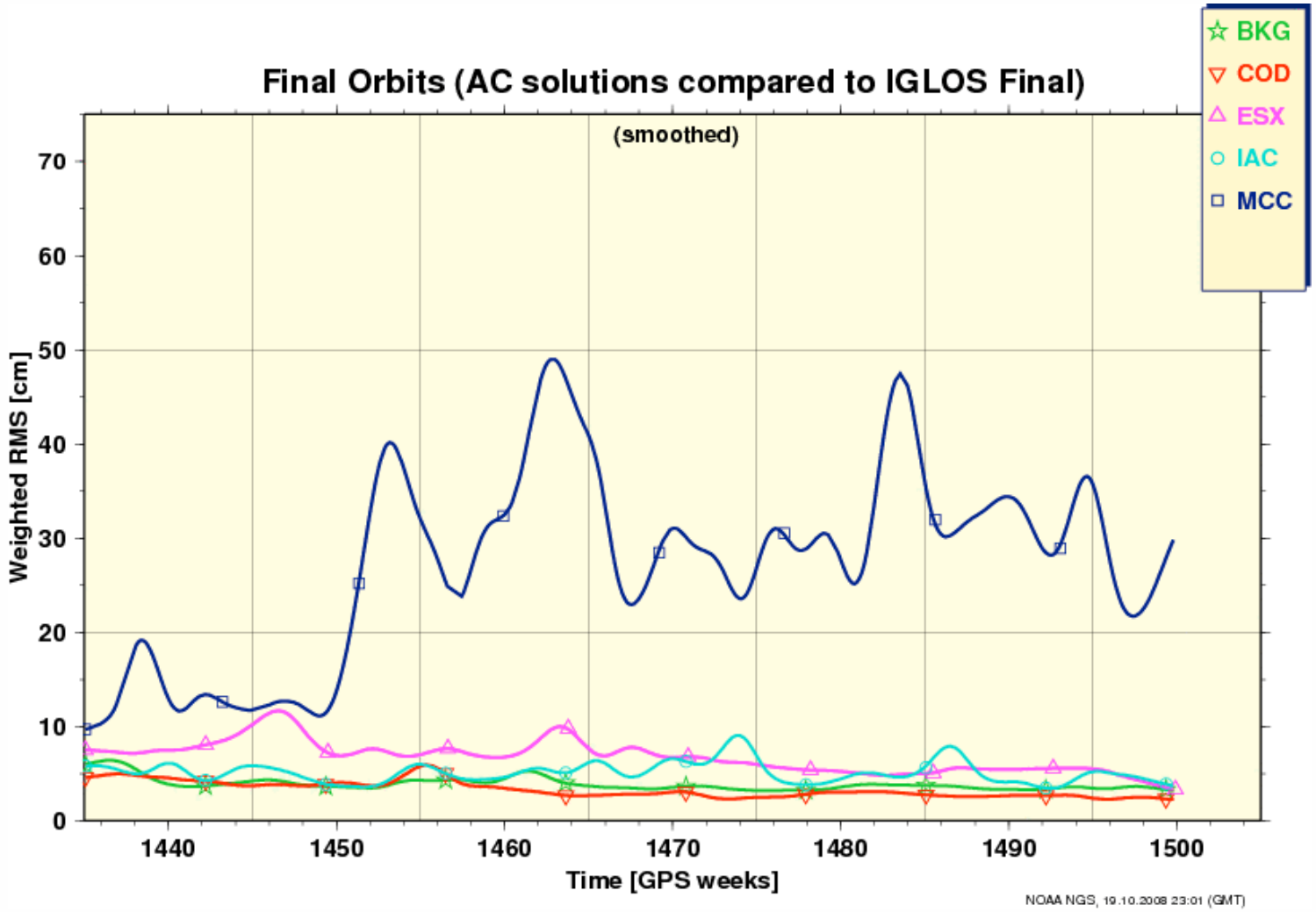


250 GNSS stations:160 GPS-only (64%) + 90 GPS/GLONASS (36%)

Validation of CODE's GLONASS 1-Day Final Orbit Consistency

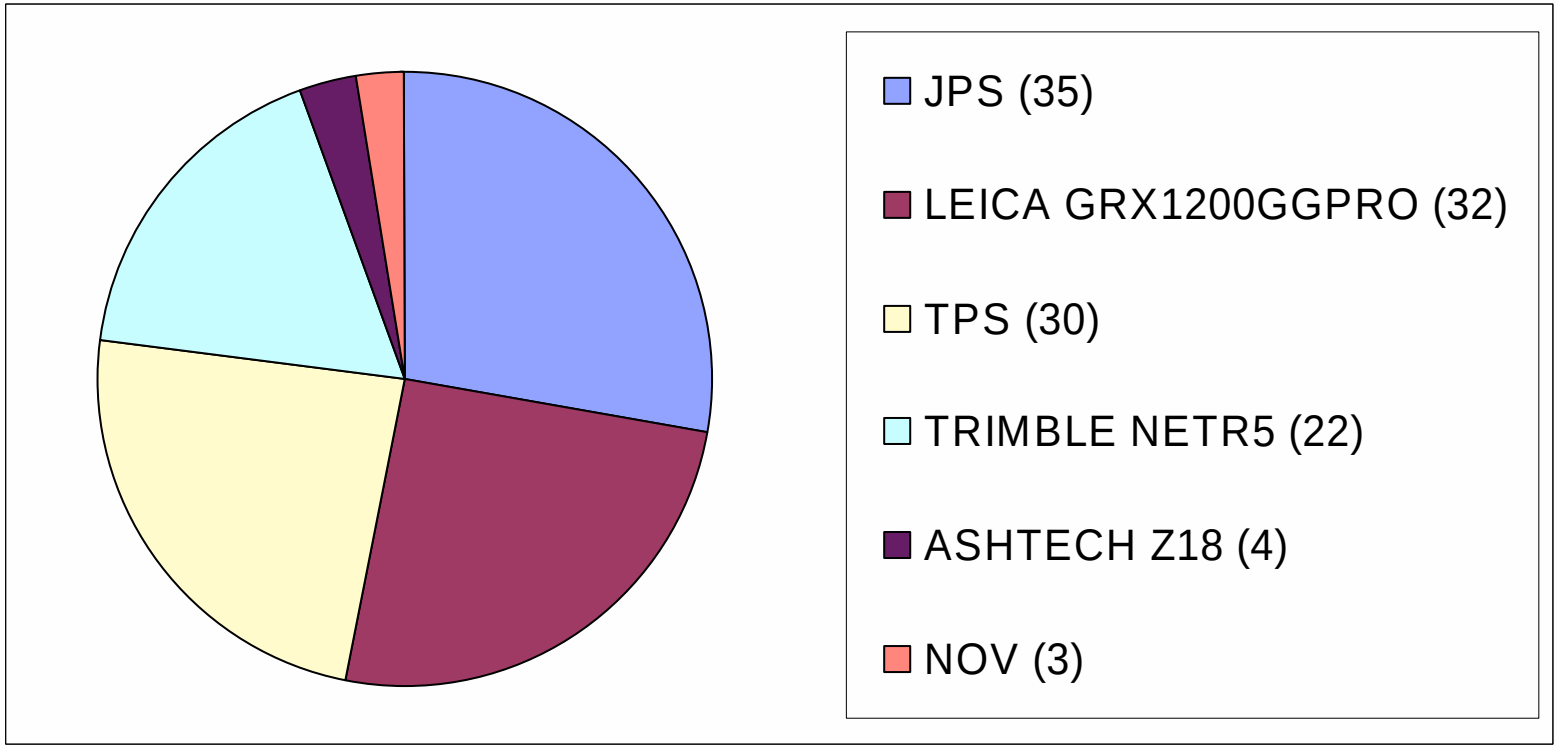


IGLOS Final Orbit Combination

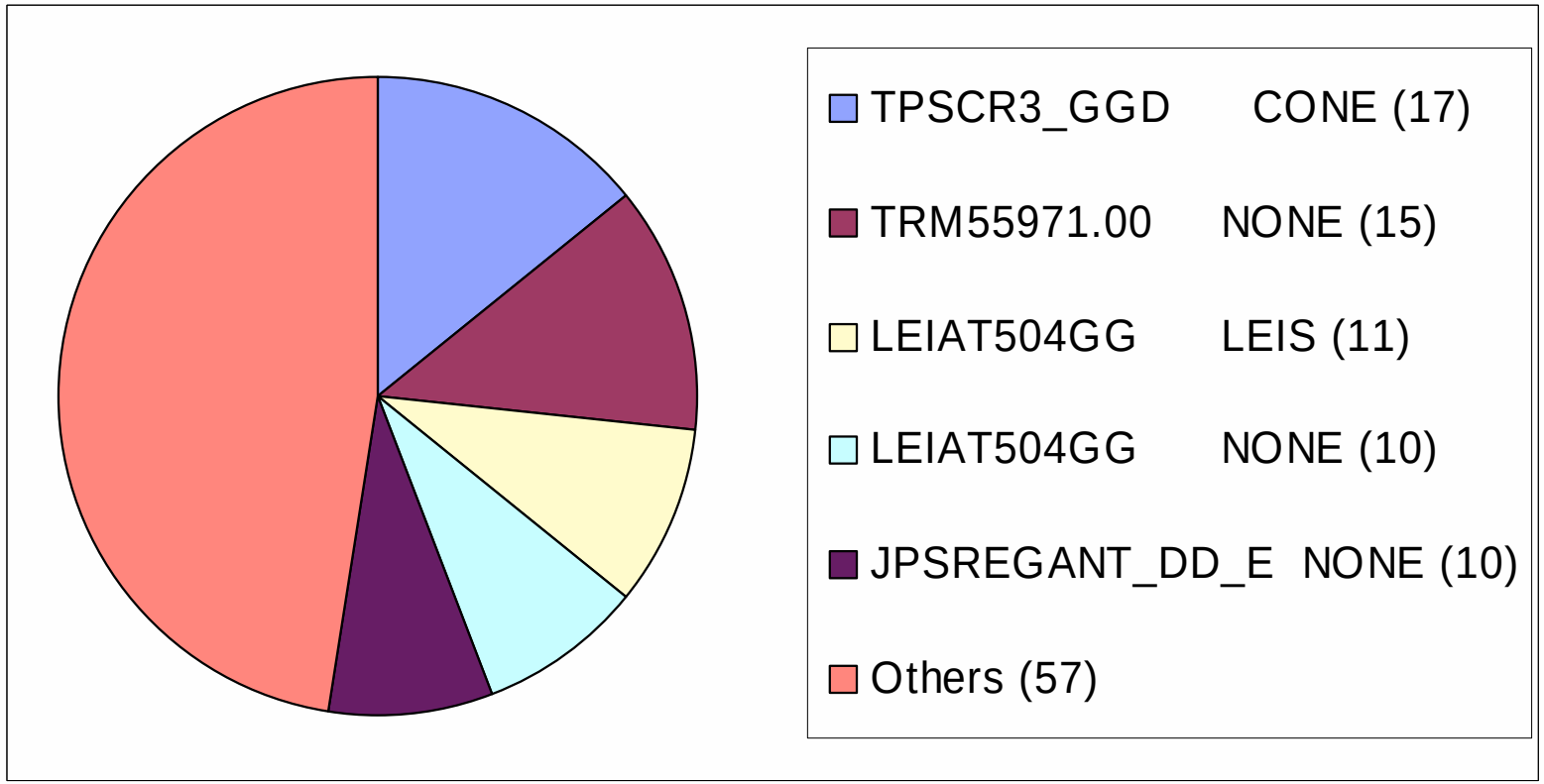


http://www.ngs.noaa.gov/igsacc/WWW/

GNSS Receiver Models



GNSS Antenna/Radome Combinations



GNSS Receiver Antenna Models (1/2)

```
AOAD/M_B        DUTD    1   IGS05_1499 ADOPTED from NONE
AOAD/M_B        OSOD    1   IGS05_1499 ADOPTED from NONE
AOAD/M_T        AUST    1   IGS05_1499 ADOPTED from NONE
AOAD/M_T        DOME    1   IGS05_1499 ADOPTED from NONE
AOAD/M_T        JPLA    1   IGS05_1499 ADOPTED from NONE
AOAD/M_T        NONE    4   IGS05_1499 ROBOT
AOAD/M_T        OSOD    5   IGS05_1499 ADOPTED from NONE
ASH700936C_M    SNOW    1   IGS05_1499 ROBOT
ASH700936D_M    NONE    1   IGS05_1499 ROBOT
ASH701073.1     NONE    1   IGS05_1499 COPIED
ASH701073.1     SCIS    1   IGS05_1499 ADOPTED from NONE
ASH701073.1     SNOW    1   IGS05_1499 ADOPTED from NONE
ASH701941.B     NONE    1   IGS05_1499 CONVERTED
ASH701941.B     SCIT    1   IGS05_1499 ADOPTED from NONE
ASH701941.B     SNOW    2   IGS05_1499 ADOPTED from NONE
ASH701945B_M    NONE    1   IGS05_1499 COPIED
ASH701945C_M    NONE    4   IGS05_1499 COPIED
ASH701945C_M    OSOD    1   IGS05_1499 ADOPTED from NONE
ASH701945C_M    SNOW    1   IGS05_1499 ROBOT
ASH701945E_M    NONE    2   IGS05_1499 COPIED
ASH701945G_M    AUST    1   IGS05_1499 ADOPTED from NONE
ASH701946.3     NONE    1   IGS05_1499 COPIED
JPLD/M_R        NONE    1   IGS05_1499 CONVERTED
JPSREGANT_DD_E  NONE   10   IGS05_1499 ROBOT
JPSREGANT_SD_E  NONE    5   IGS05_1499 ROBOT
LEIAT504        NONE    1   IGS05_1499 ROBOT
LEIAT504GG      LEIS   11   IGS05_1499 ROBOT
LEIAT504GG      NONE   10   IGS05_1499 ROBOT
LEIAX1202GG     NONE    3   IGS05_1499 FIELD
NOV702GG        NONE    1   IGS05_1499 ROBOT
TPSCR.G3        TPSH    1   IGS05_1499 ROBOT
TPSCR3_GGD      CONE   17   IGS05_1499 FIELD
TPSCR3_GGD      NONE    3   IGS05_1499 FIELD
TPSCR3_GGD      PFAN    1   IGS05_1499 ROBOT
TPSG3_A1        NONE    1   IGS05_1499 FIELD
TRM29659.00     NONE    4   IGS05_1499 ROBOT
TRM29659.00     TCWD    1   IGS05_1499 ROBOT
TRM29659.00     UNAV    1   IGS05_1499 FIELD
TRM55971.00     NONE   15   IGS05_1499 ROBOT
```

GNSS Receiver Antenna Models (2/2)

```
AOAD/M_B        DUTD    1   IGS05_1499 ADOPTED from NONE
AOAD/M_B        OSOD    1   IGS05_1499 ADOPTED from NONE
AOAD/M_T        AUST    1   IGS05_1499 ADOPTED from NONE
AOAD/M_T        DOME    1   IGS05_1499 ADOPTED from NONE
AOAD/M_T        JPLA    1   IGS05_1499 ADOPTED from NONE
ASH700936C_M    SNOW    1   IGS05_1499 ROBOT
ASH700936D_M    NONE    1   IGS05_1499 ROBOT
ASH701073.1     NONE    1   IGS05_1499 COPIED
ASH701073.1     SCIS    1   IGS05_1499 ADOPTED from NONE
ASH701073.1     SNOW    1   IGS05_1499 ADOPTED from NONE
ASH701941.B     NONE    1   IGS05_1499 CONVERTED
ASH701941.B     SCIT    1   IGS05_1499 ADOPTED from NONE
ASH701945B_M    NONE    1   IGS05_1499 COPIED
ASH701945C_M    OSOD    1   IGS05_1499 ADOPTED from NONE
ASH701945C_M    SNOW    1   IGS05_1499 ROBOT
ASH701945G_M    AUST    1   IGS05_1499 ADOPTED from NONE
ASH701946.3     NONE    1   IGS05_1499 COPIED
JPLD/M_R        NONE    1   IGS05_1499 CONVERTED
LEIAT504        NONE    1   IGS05_1499 ROBOT
NOV702GG        NONE    1   IGS05_1499 ROBOT
TPSCR.G3        TPSH    1   IGS05_1499 ROBOT
TPSCR3_GGD      PFAN    1   IGS05_1499 ROBOT
TPSG3_A1        NONE    1   IGS05_1499 FIELD
TRM29659.00     TCWD    1   IGS05_1499 ROBOT
TRM29659.00     UNAV    1   IGS05_1499 FIELD
ASH701941.B     SNOW    2   IGS05_1499 ADOPTED from NONE
ASH701945E_M    NONE    2   IGS05_1499 COPIED
LEIAX1202GG     NONE    3   IGS05_1499 FIELD
TPSCR3_GGD      NONE    3   IGS05_1499 FIELD
AOAD/M_T        NONE    4   IGS05_1499 ROBOT
ASH701945C_M    NONE    4   IGS05_1499 COPIED
TRM29659.00     NONE    4   IGS05_1499 ROBOT
AOAD/M_T        OSOD    5   IGS05_1499 ADOPTED from NONE
JPSREGANT_SD_E  NONE    5   IGS05_1499 ROBOT
JPSREGANT_DD_E  NONE   10   IGS05_1499 ROBOT
LEIAT504GG      NONE   10   IGS05_1499 ROBOT
LEIAT504GG      LEIS   11   IGS05_1499 ROBOT
TRM55971.00     NONE   15   IGS05_1499 ROBOT
TPSCR3_GGD      CONE   17   IGS05_1499 FIELD
```

Quarter-Cycle Issue: Identified Problems

- Observation codes cannot distinguish between L2(P) and L2(L2C)
- Problem because of ¼-cycle phase shift of L2(L2C) w/r to L2(P)
  - If L2C- and P-code derived L2 phases are combined in an analysis, ambiguity-resolution can be jeopardized, if these phase shifts are not taken into account
- Need some agreement for version 2.11 how to handle this

Quarter-Cycle Issue: Controversial Discussion

- Should all phases be shifted to a common reference, if necessary, before generating RINEX files?

or

- Should all phase observations be stored in the "original" state and leave the task to do the necessary corrections to the user?

- E-Mail discussion in "RINEX group" (distribution list of ~45 addresses):
  http://www.aiub.unibe.ch/download/rinex/L2C/

Quarter-Cycle Issue: Phase Corrections: Pros

- The receiver knows what it is doing, i.e. it knows its tracking mode.
  → It can do the corrections to an accepted standard
- The manufacturer-provided RINEX converter knows what the receiver did store in the proprietory format: The converter can do the corrections
- The user does not have to deal with these corrections. He can freely mix observables without having to bother with corrections.
- No changes to many existing programs
- Keep things simple for the user. Modern GNSS signals will be complicated enough to deal with
- If the receiver just stores what comes out of its tracking loops: Is it sure that this phase really follows the general assumptions?

Quarter-Cycle Issue: Phase Corrections: Cons

- RINEX philosophy till now: No "external" corrections to the data
- Are we sure that the corrections have been applied correctly? Or applied at all?
- How to apply a priori corrections if the RINEX converter does not know the tracking mode or the signal-generation mode of the satellite ("flex power")?
  - → Same problem, of course, holds for the users!
  - Flex power will not generate phase shifts (statement in recent presentation in Los Angeles)
- Who is setting the standards?
- What happens with the existing data?

Quarter-Cycle Issue: Phase Corrections: Current Status

- Trimble:
  - Shifts L2(L2C) by ¼ cycle
  - Correction procedure for all currently tracked signals available
- Leica/Novatel
  - Probably no corrections to L2C for the time being
- Septentrio
  - Currently no corrections for RINEX 3.0
  - Proposes to correct to standard
- RTCM: Discussions under way. Probably going for a standard
- Geo++
  - Proposes to store unchanged phases into RINEX

Quarter-Cycle Issue: Some Facts

- No corrections are necessary for a specific receiver/station if only one tracking mode per frequency for all satellites
- It's not important if all phases observed by a receiver in mode A are aligned to mode B or if all phases of mode B are aligned to mode A
  - Double-difference processing (ambiguity resolution OK)
  - Zero-difference processing (ambiguity resolution OK, if possible...)
  - PPP
- If one decides to apply corrections, do them
  - either to a commonly accepted, general standard
  - or to a "*receiver-internal standard*" in case of mixed modes

Quarter-Cycle Issue: Decision

- Should be taken by the RINEX group in the very next future
- Comments to gurtner@aiub.unibe.ch
- Hopefully in agreement with RTCM (…)

→ **Correction for Bernese SW 5.0**

Summary

- Current GNSS satellite constellation → GLONASS (??)
- GLONASS negative frequency channels → GNSS receiver firmware updates (and “antiquated” receiver models)
- Improved IGS GNSS receiver coverage → significantly improved GLONASS orbit quality
- Quarter-cycle issue (RINEX/RTCM) → consensus not yet reached

Baseline Vector Repeatability on the Basis of GPS-Only or GPS/GLONASS