Combined GPS/GLONASS Analysis at the Center for Orbit Determination in Europe (CODE)

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Astronomical Institute, University of Berne, Switzerland

The Center for Orbit Determination in Europe (CODE)

CODE is a joint venture of the following four institutions:

- the Astronomical Institute of the University of Berne (AIUB), Switzerland,
- the Federal Office of Topography (swisstopo), Wabern, Switzerland,
- the Federal Agency of Cartography and Geodesy (BKG), Frankfurt, Germany, and
- the Institut Geographique National (IGN), Paris, France.

The actual analysis center (AC) is located at AIUB. CODE has been contributing to the International GPS Service (IGS) since the beginning.

Outline

- Activities at CODE in terms of GPS/GLONASS (GNSS) POD: (a) *rapid*, (b) *final*, (c) *ultra-rapid/predicted* (or near-real-time) orbit/ERP products
- POD for GPS satellites being repositioned
- Retrieval of GNSS satellite antenna phase center variations
- Global mapping (and prediction) of the Earth‘s ionospheric TEC using GNSS data
- Differential pseudorange biases reponding to P1-P2 and P1-C1 as by-products of the ionosphere/clock analysis
- GNSS satellite and receiver clock estimation – retrieval of frequency- (and receiver-) dependent pseudorange biases
- Summary

CODE Rapid GNSS Orbit Product

- Since the beginning of May 2003, the CODE AC has been computing a rapid orbit product for both the GPS and the GLONASS satellite constellation.
- GPS and GLONASS orbits are generated at the same time in a rigorous GNSS analysis, ensuring best possible consistency between GPS and GLONASS orbits.
- This may be considered as an essential step towards routine analysis of multi satellite navigation systems, specifically in view of the upcoming *European GALILEO system*.
- The CODE rapid orbit/ERP product usually becomes available around 9 UT of the following day.

Motivation for Inclusion of GLONASS Tracking Data

1. First step for routine analysis of tracking data originating from two or more navigation satellite systems.
2. Regular testing of our development version of the Bernese Software in terms of the GLONASS capability.
3. Possible improvement of specific global parameters was definitively *not* a reason for this effort.

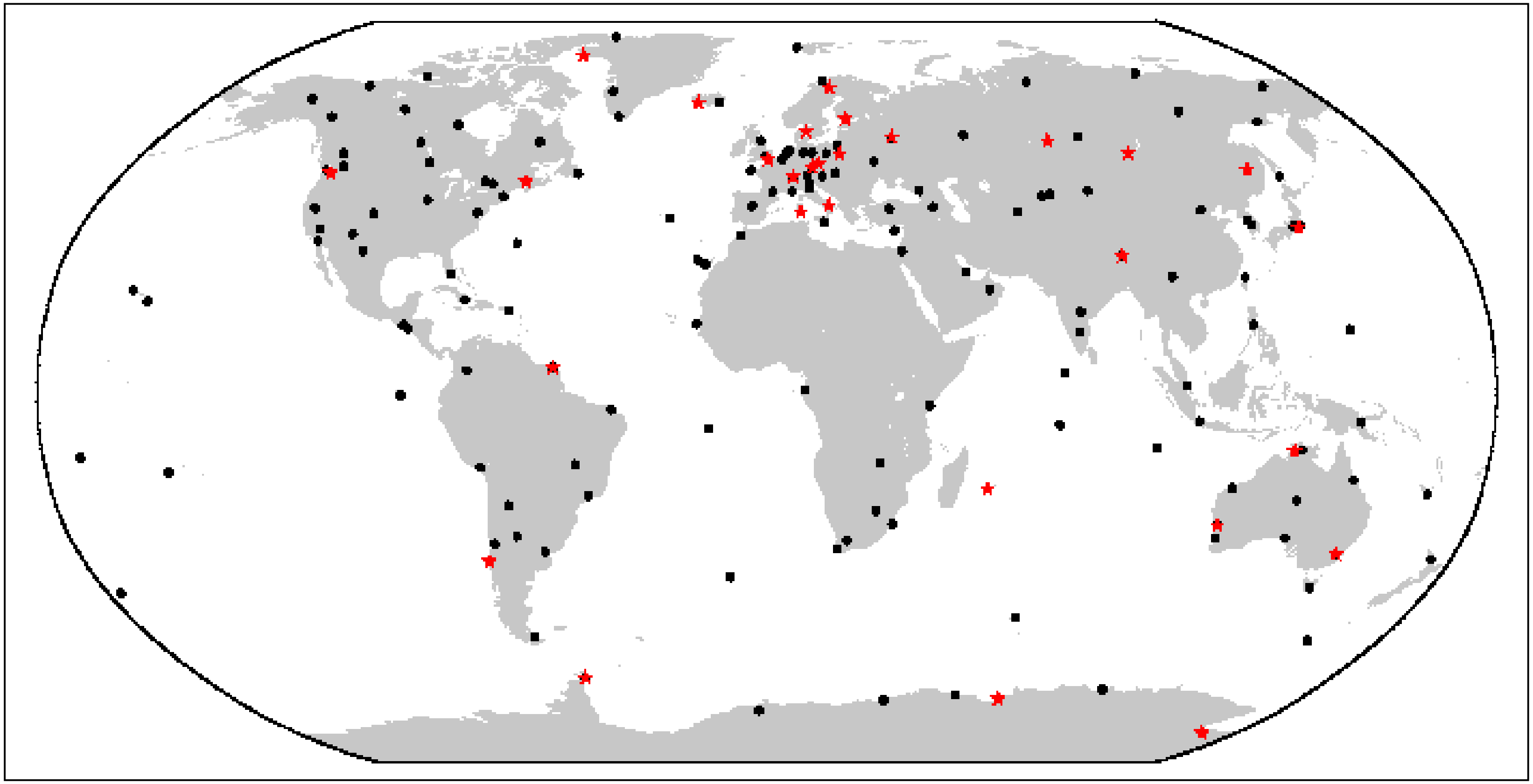
Important remark:

In our final analysis we benefit from products coming from our rapid analysis. It was therefore an absolute requirement for us to include GLONASS data already at the stage of the rapid analysis (to prevent dublicate analysis!). Data availability problems could be anticipated.

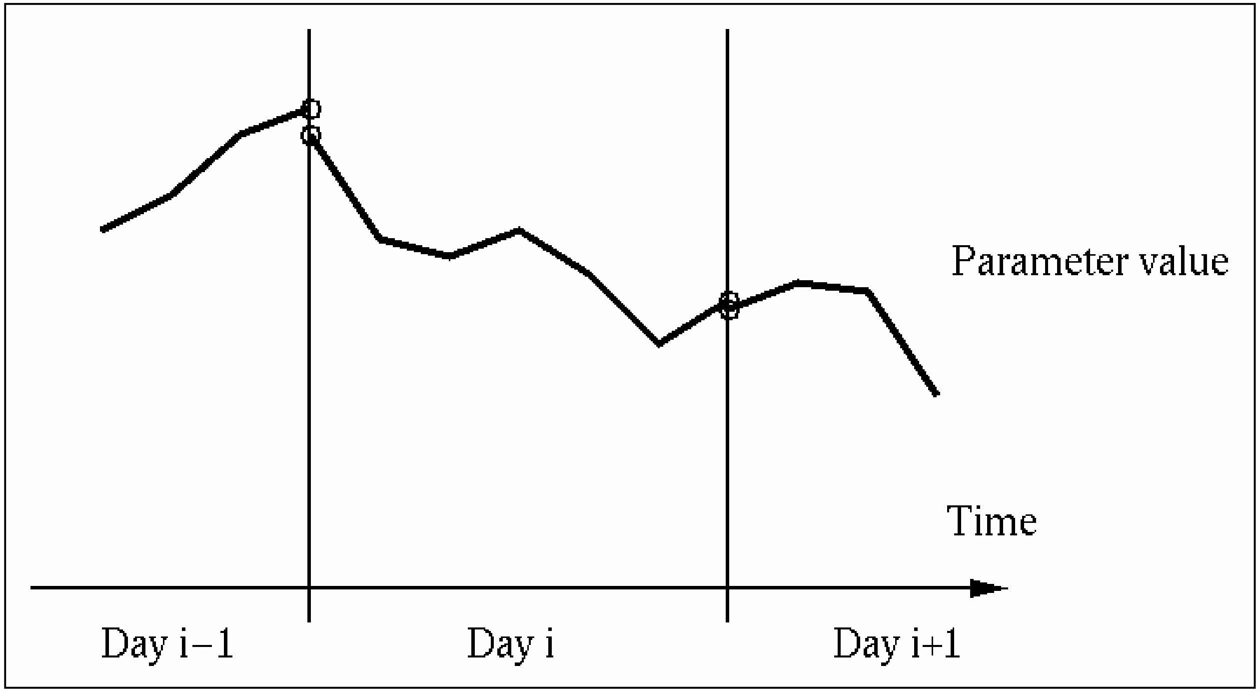
CODE Final GNSS Products

- CODE final analysis extended to GNSS on June 8, 2003 (GPS week 1222) for all products, apart from the clock product.
- Orbits: SP3 orbital positions are consistently referred to ITRF2000 (and the GPS time frame).
- SINEX: Weekly SINEX contributions now include station coordinates for a significant number of GPS/GLONASS tracking stations. GNSS-based ERP parameters (and geocenter coordinates) are the consequence of the common GNSS analysis.

IGS/IGLOS Tracking Network as Considered in CODE´s Final GNSS Analysis

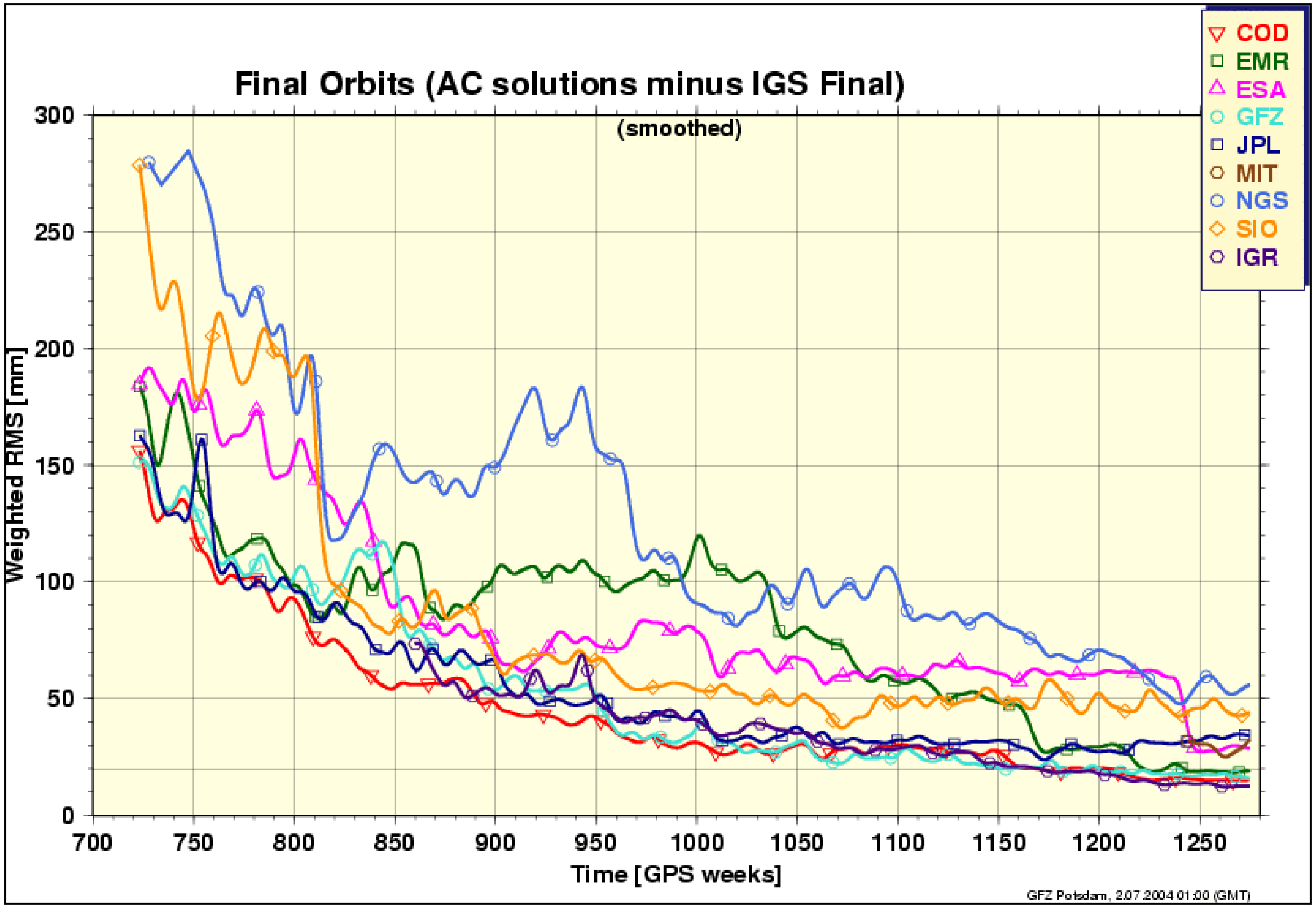


EOP and Troposphere Parameterization Continuous in Time



- 3-day solutions traditionally generated on the NEQ level.
- 1-day NEQ files include on average (explicitly) 4000 unknown parameters each ($8x4000^2 = 128$ Mbytes/file).

IGS AC Final (GPS) Orbit Consistency

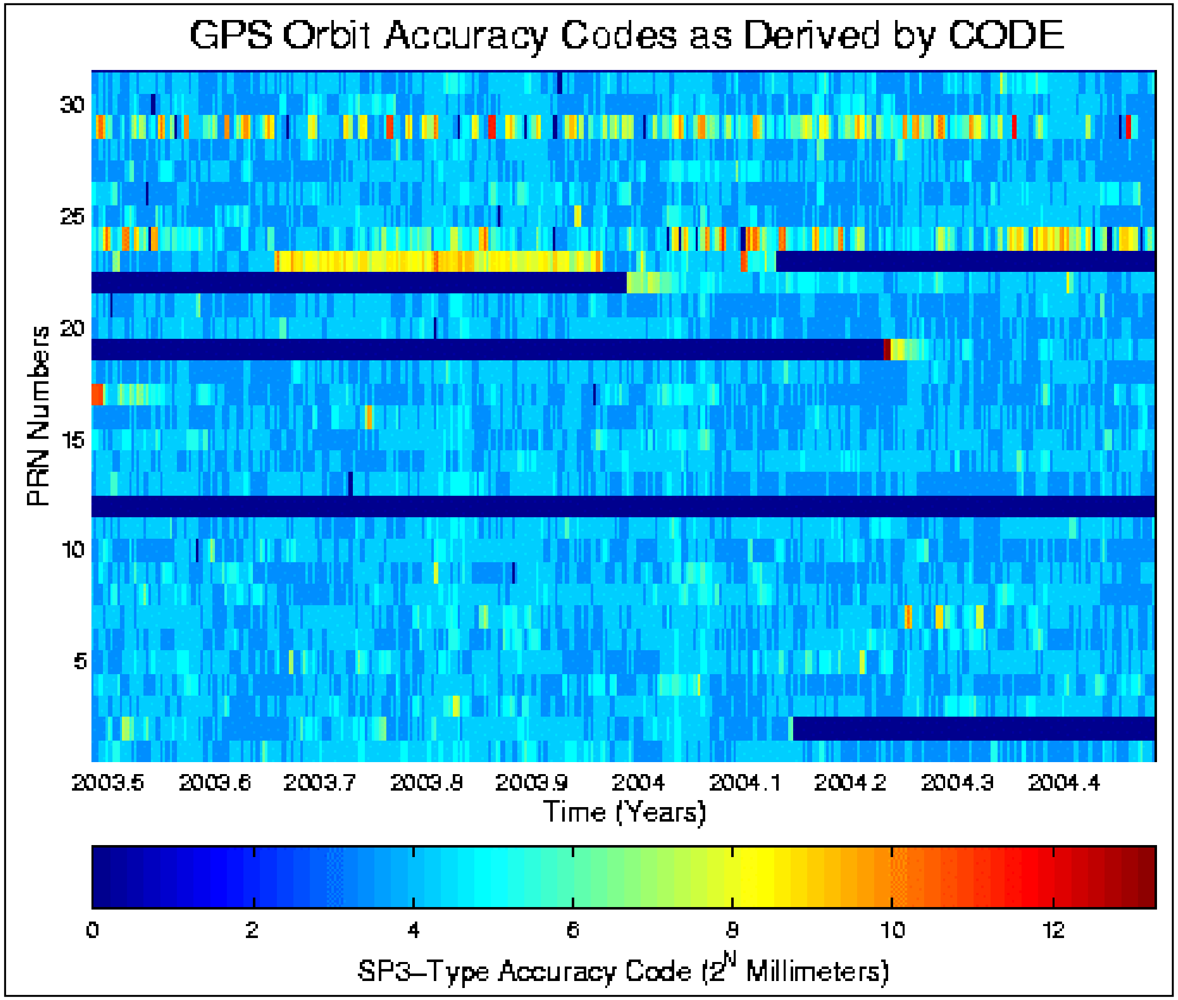


Courtesy: G. Gendt, GFZ, Potsdam, Germany

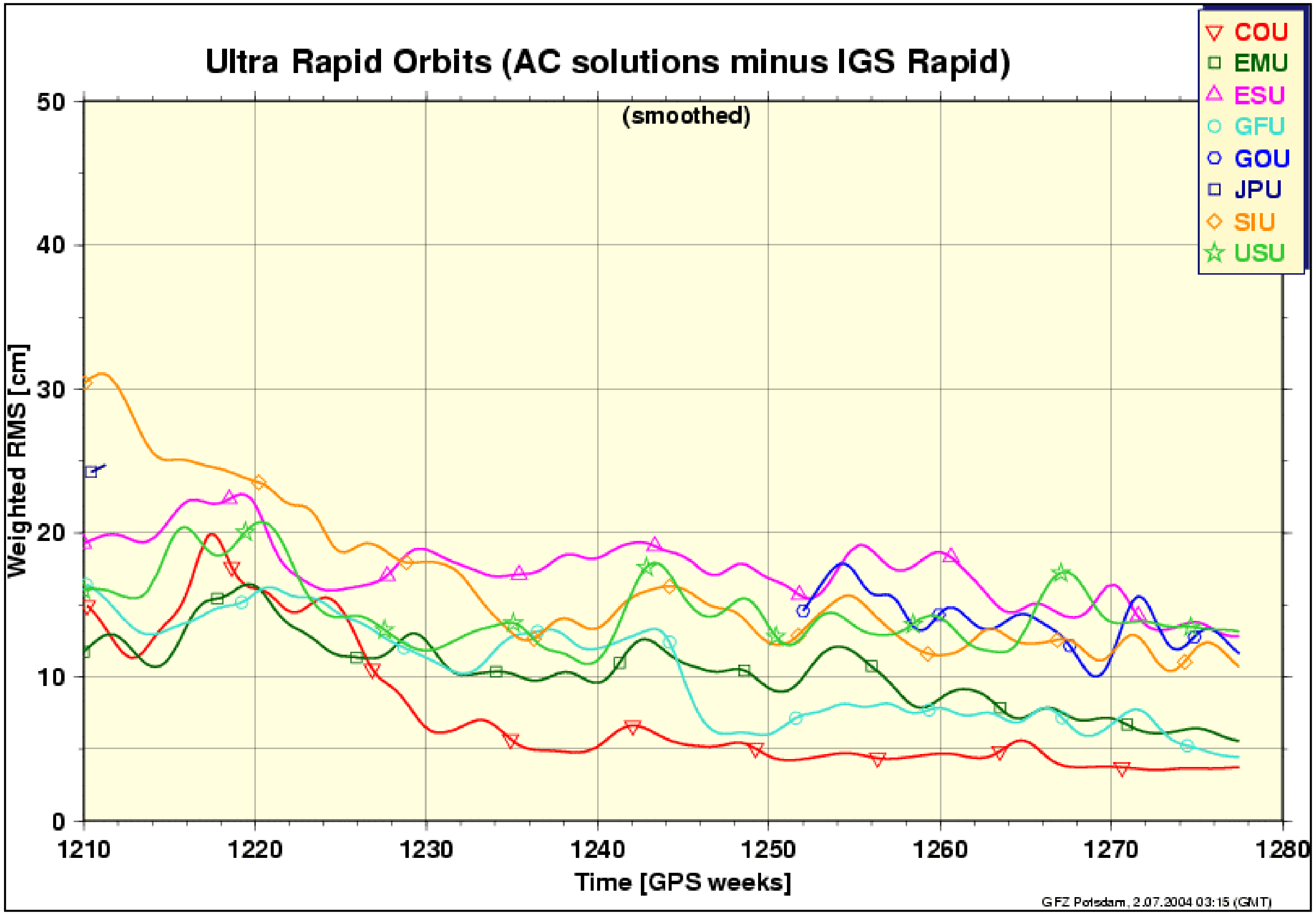
CODE Ultra-Rapid Orbit Product

- Production of CODE ultra-rapid orbits commenced officially on July 30, 2003, now considering near-real-time tracking data.
- From the beginning, this product did cover orbits for the GLONASS satellite constellation.
- Ultra-rapid orbit updates include ambiguity resolution for baselines up to 6000 km length. Historical rapid orbit information is used for long-arc combination on the NEQ level.
- It is complete with respect to all transmitting GNSS satellites (currently 29 GPS plus 11 GLONASS) and has been available *without exception* since the beginning.
- Reliable SP3-type accuracy codes are provided.

Identification of Misbehaving, or Badly Predictable GPS Satellites

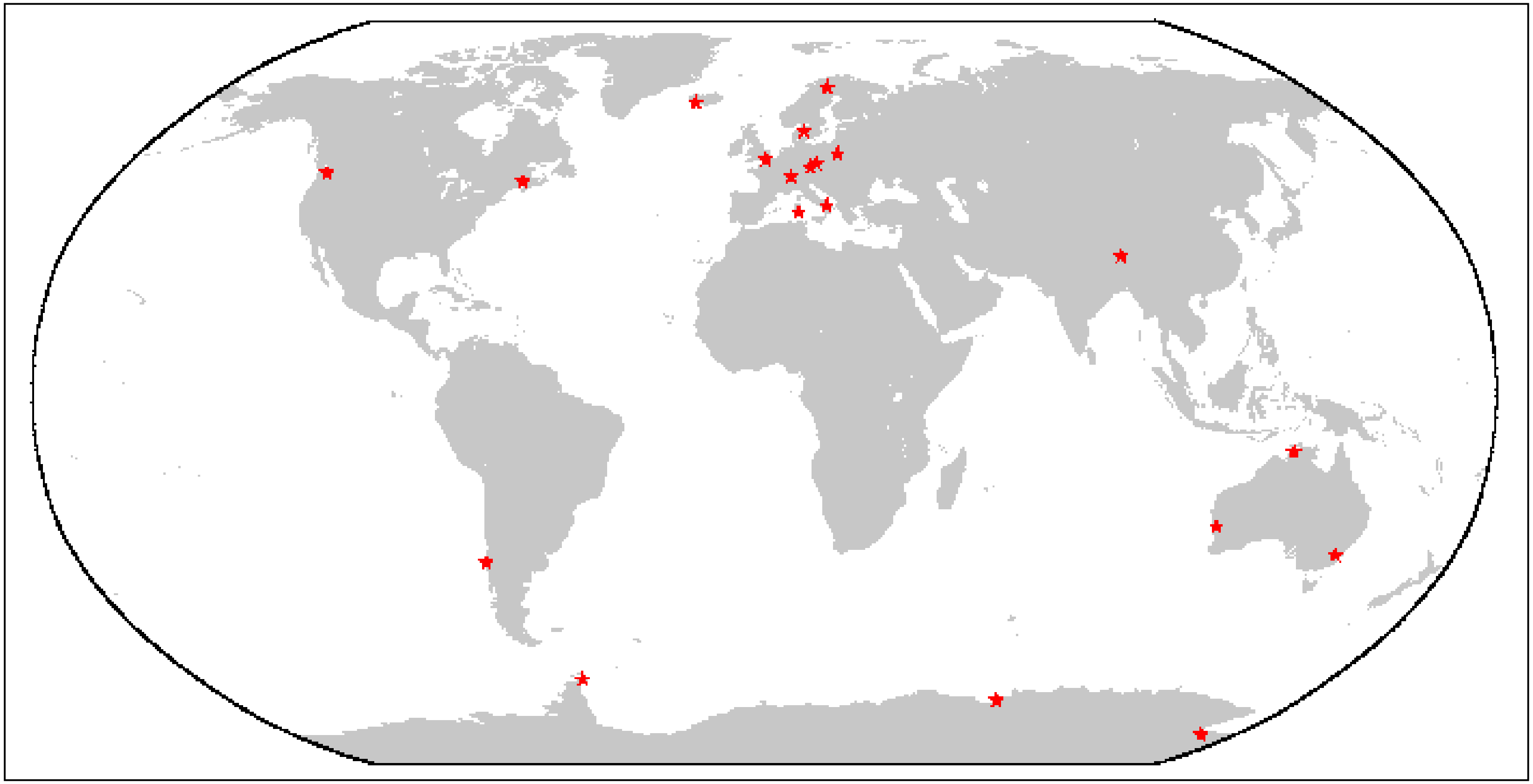


IGS AC Ultra-Rapid (GPS) Orbit Consistency

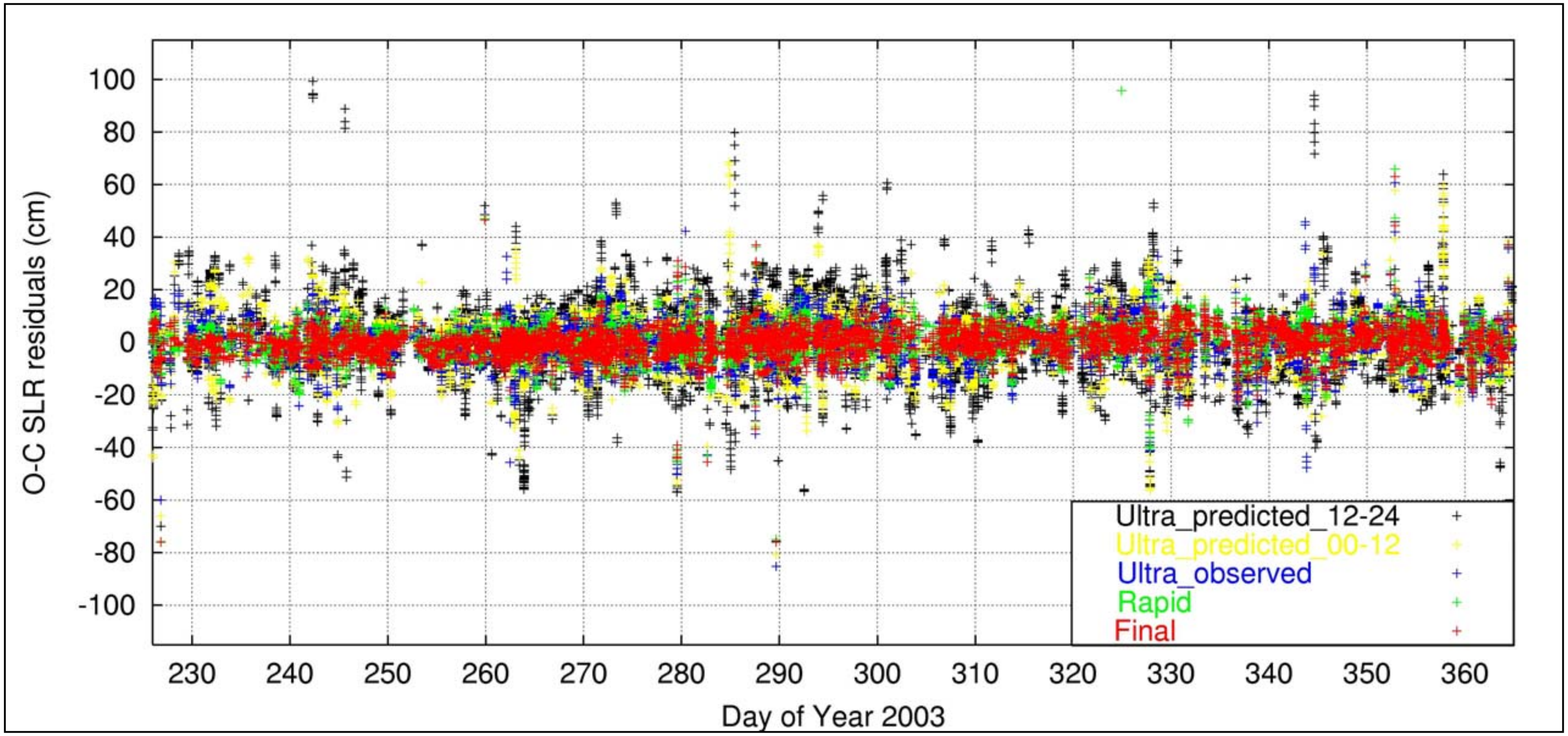


Courtesy: G. Gendt, GFZ, Potsdam, Germany

IGLOS Tracking Network as Considered in CODE´s Ultra-Rapid GNSS Analysis

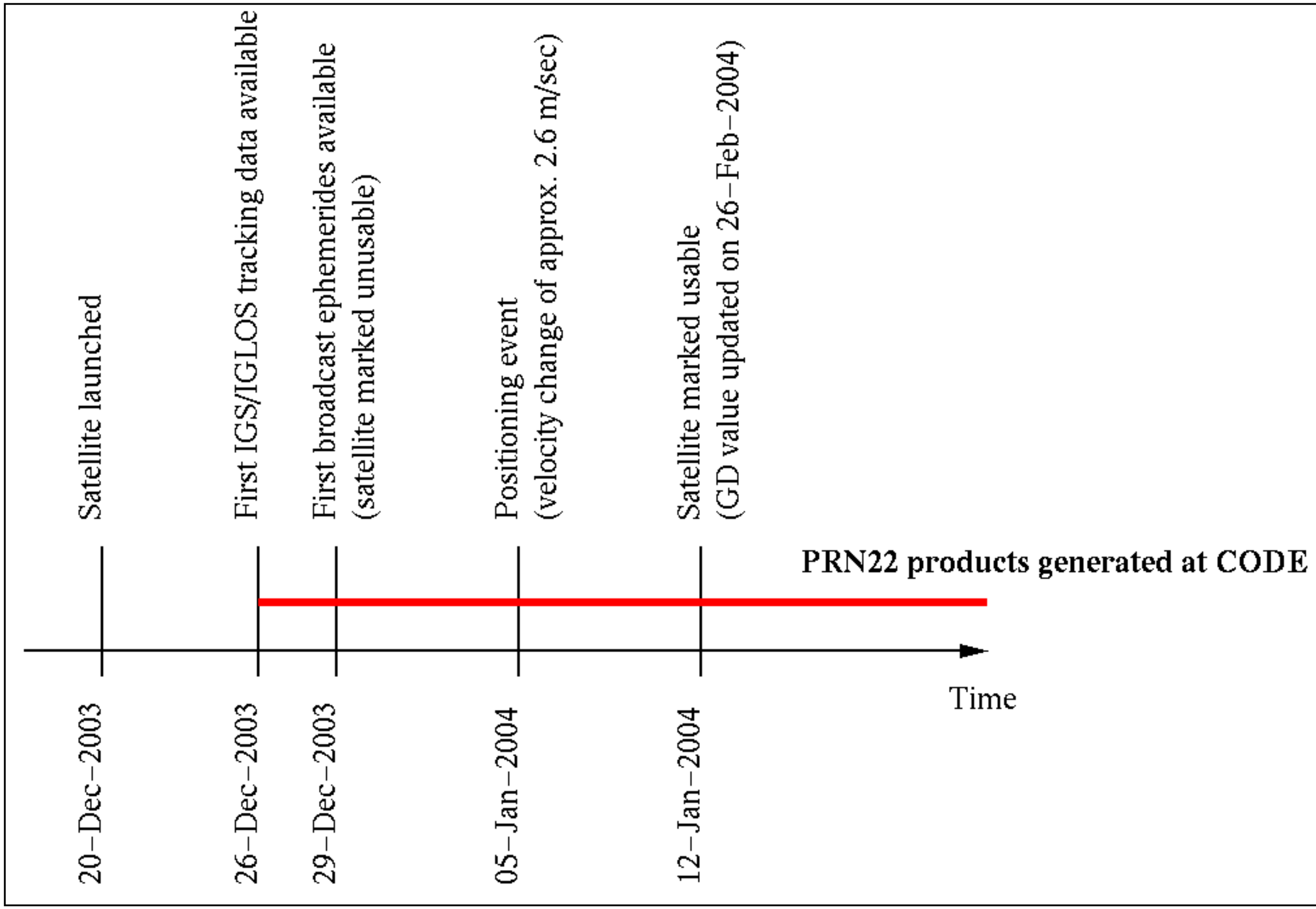


CODE GLONASS Orbit Validation Using SLR Data

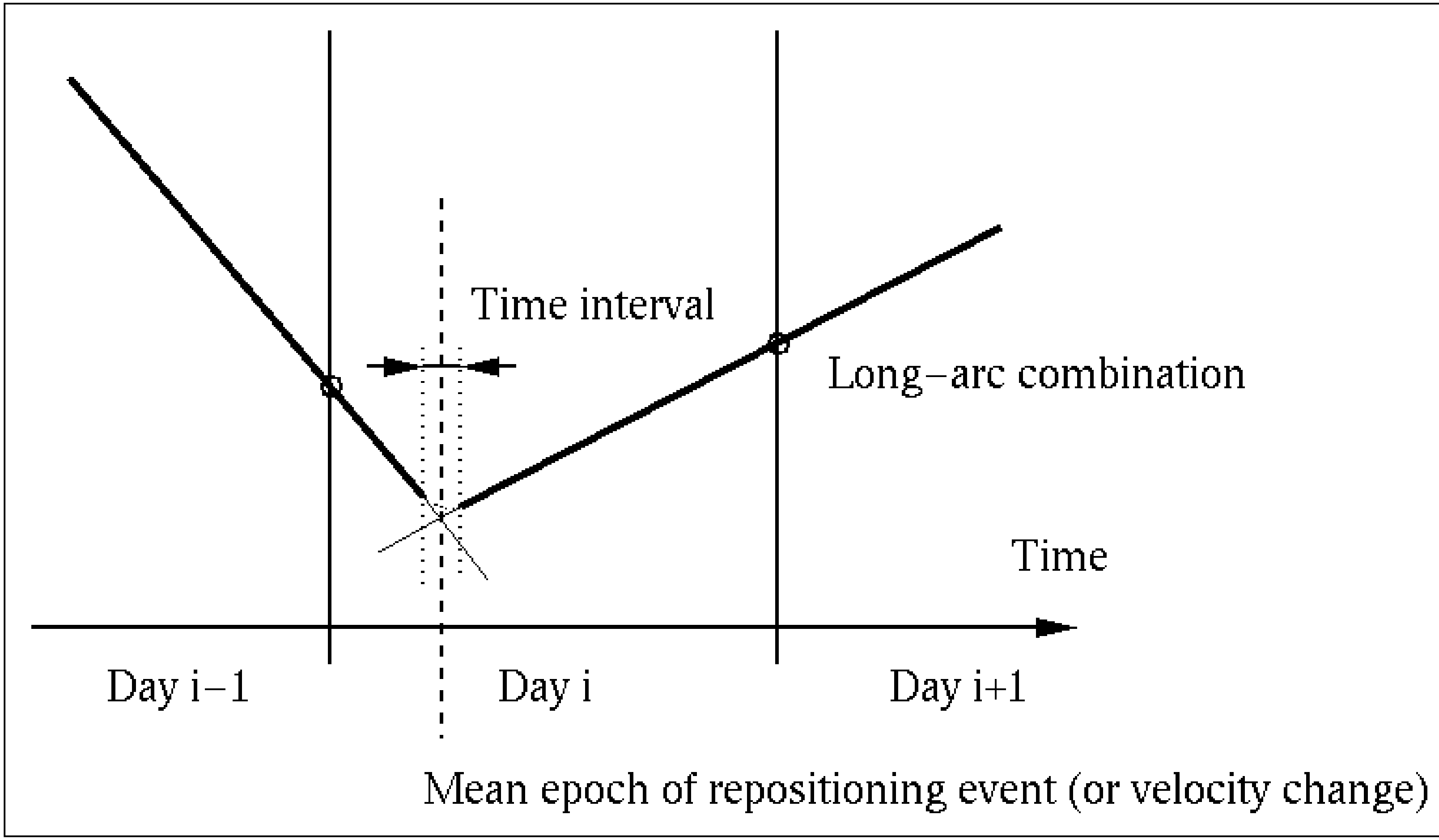


Standard deviation: 13 / 9 / 7 / 6 / 5 cm

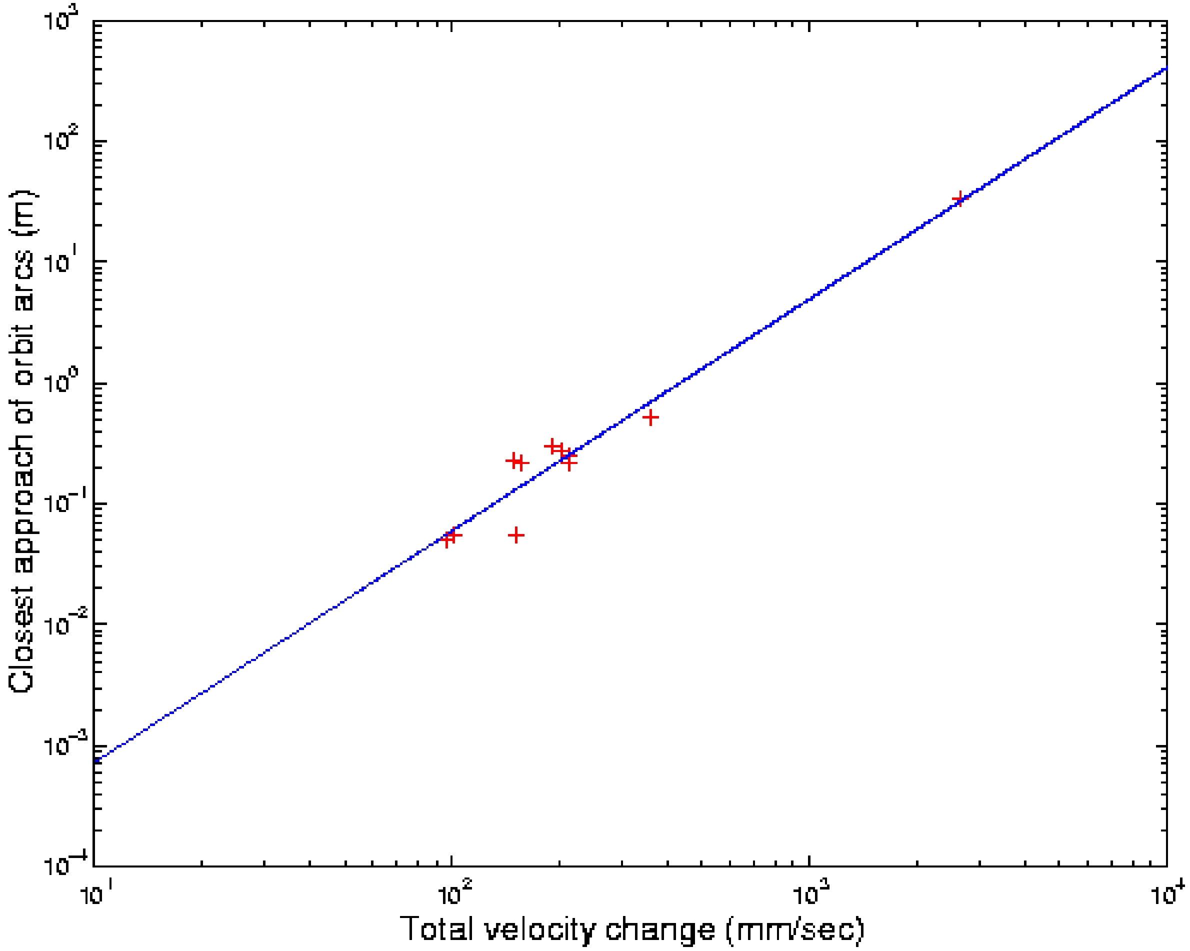
Chronology of a Recent GPS Block-IIR Satellite Launch (PRN22)



Orbit Determination for GPS Satellites Being Repositioned



GPS Satellite Repositioning Events



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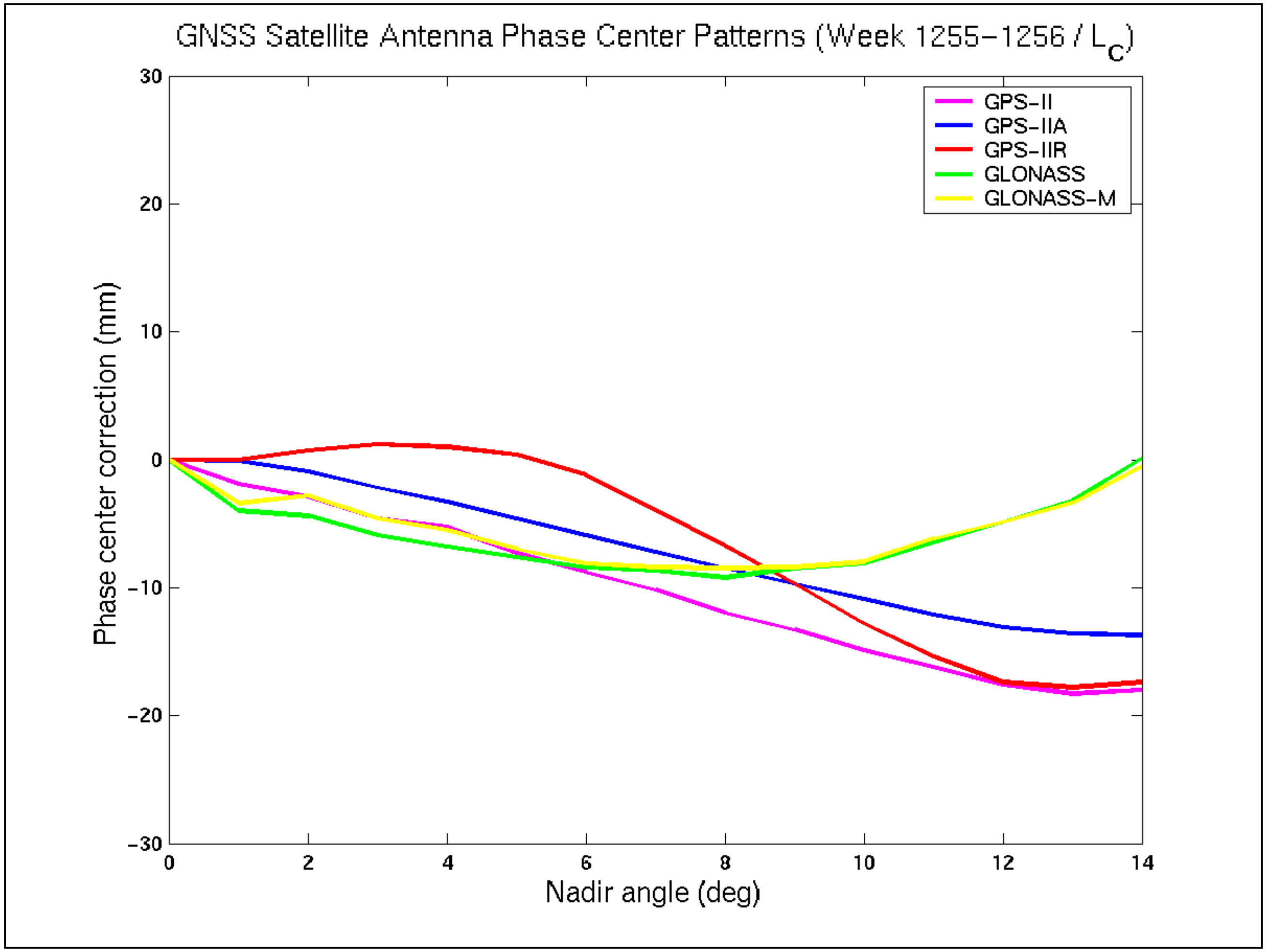
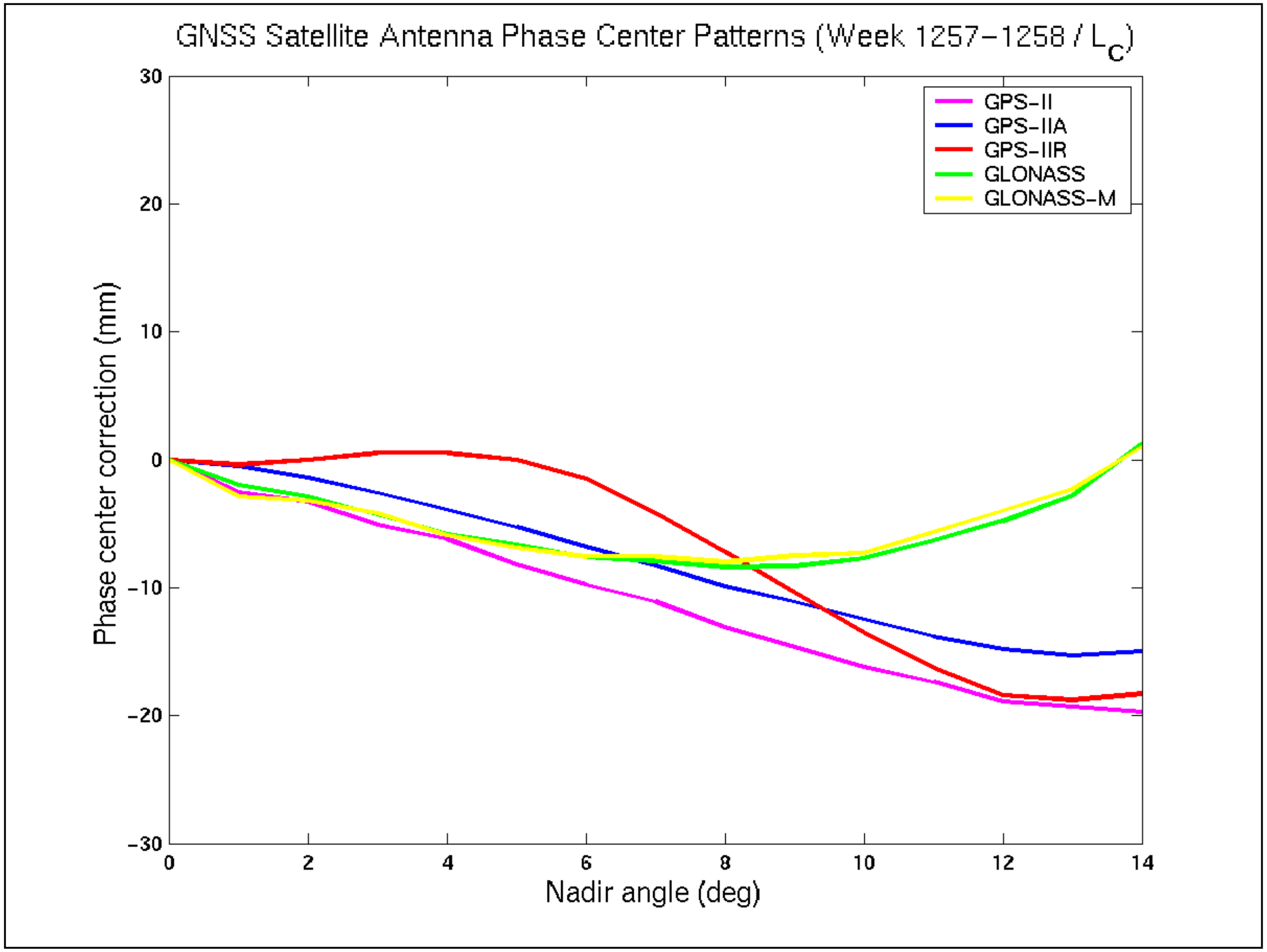
Estimation of GNSS Satellite Antenna Phase Center Patterns and Offsets Responding to the Ionospere-Free LC

- Regular estimation of GNSS satellite antenna phase center patterns for GPS-II, GPS-IIA, GPS-IIR, GLONASS and GLONASS-M satellite types started with GPS week 1254.
- Corresponding patterns are not only available for the ionosphere-free linear combination but also for the geometry-free (L1-L2) linear combination.

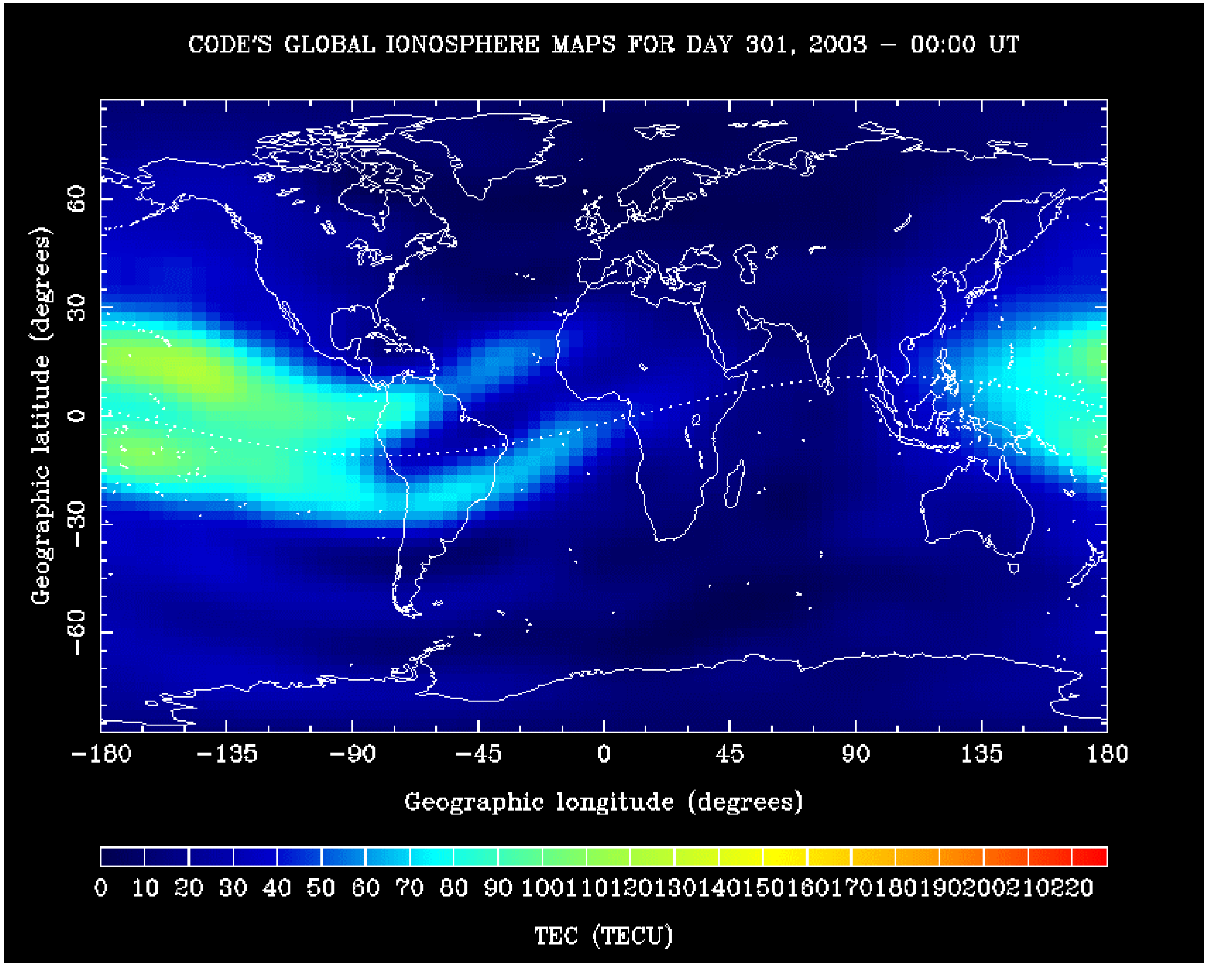
GNSS PCV Patterns – First Results (1)



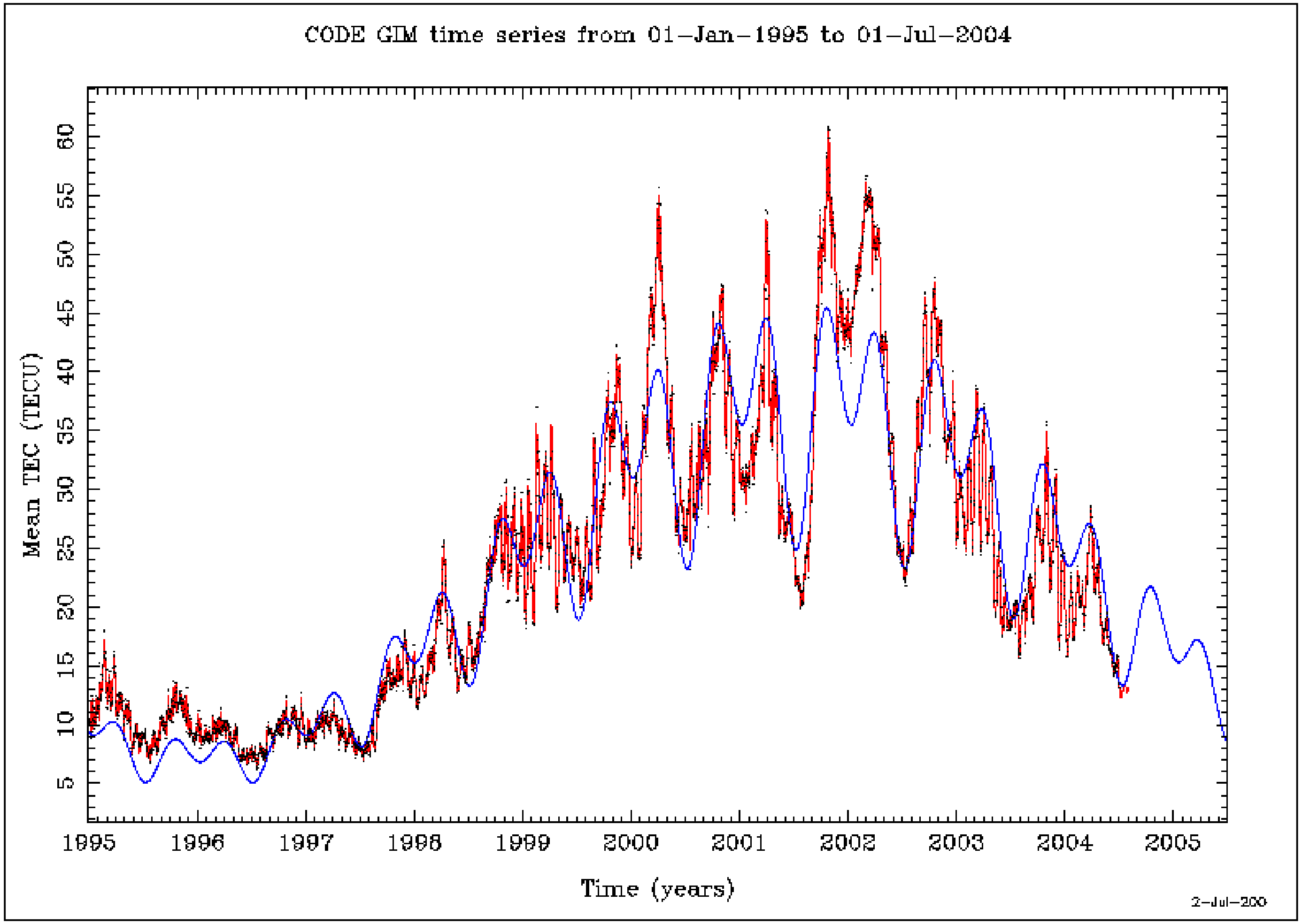
GNSS PCV Patterns – First Results (2)



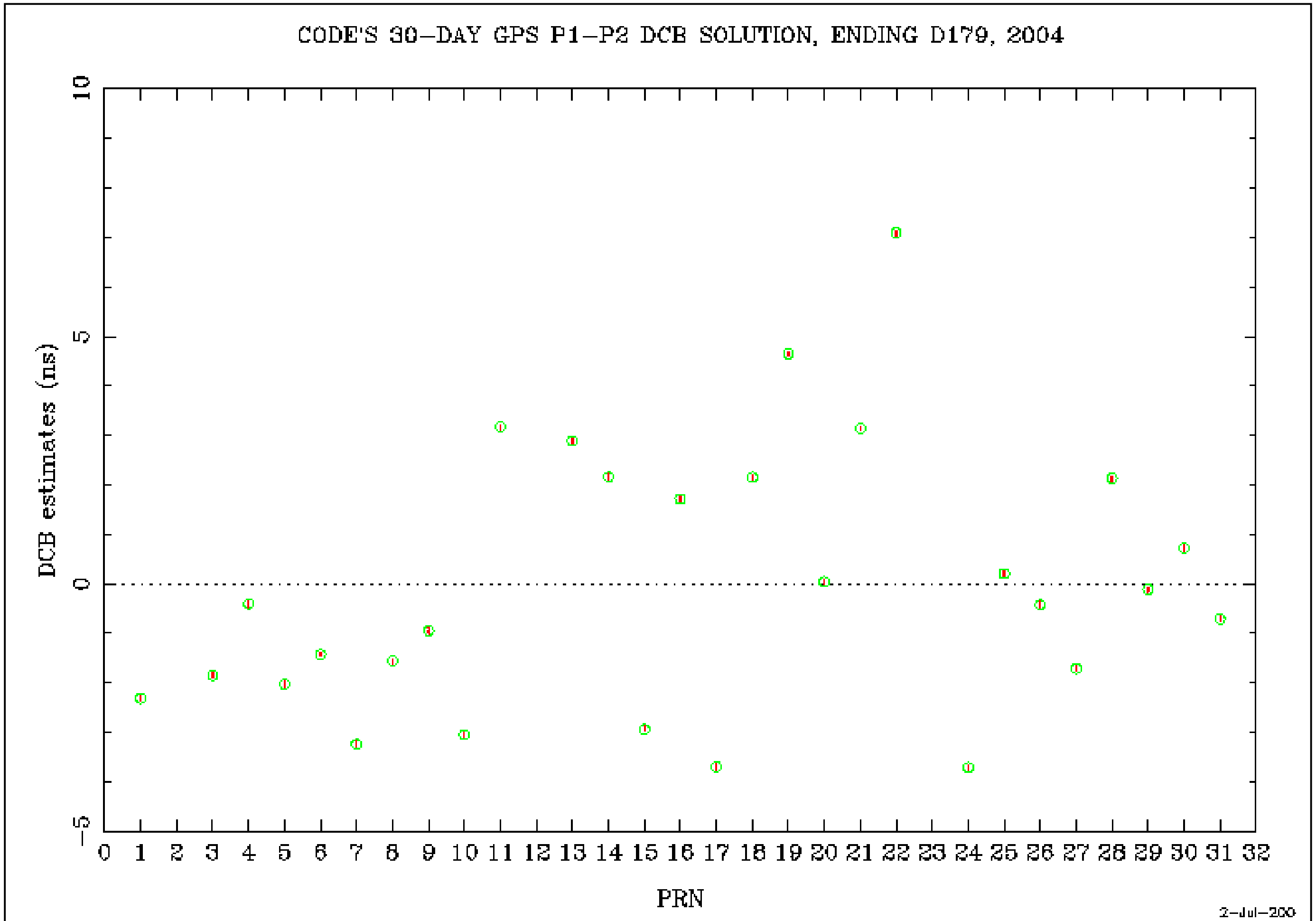
Exceptionally High TEC Levels due to X17.2 Solar Flare (CME)



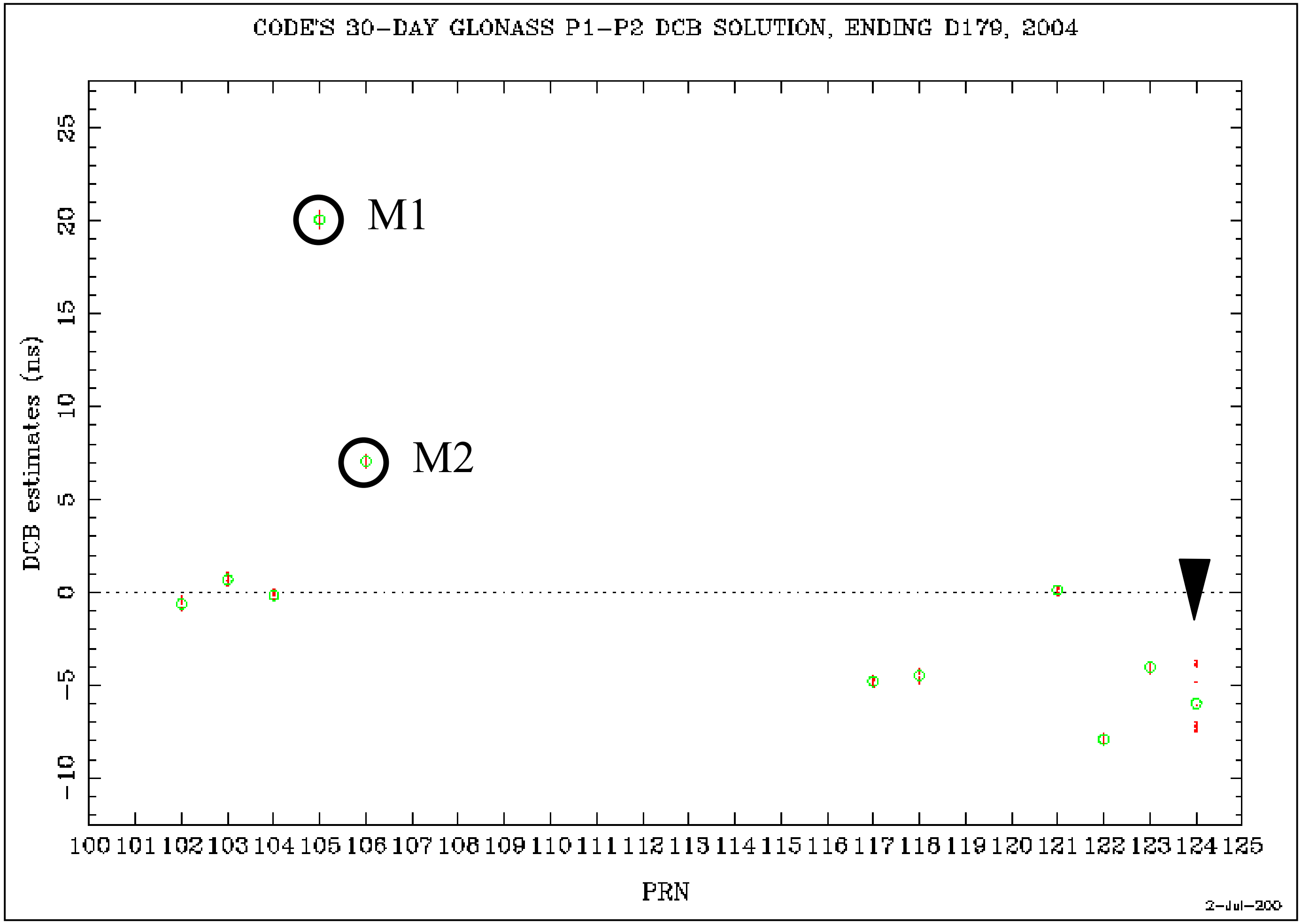
Time Series of Global Mean TEC Covering Nearly One Solar Cycle as Generated at CODE



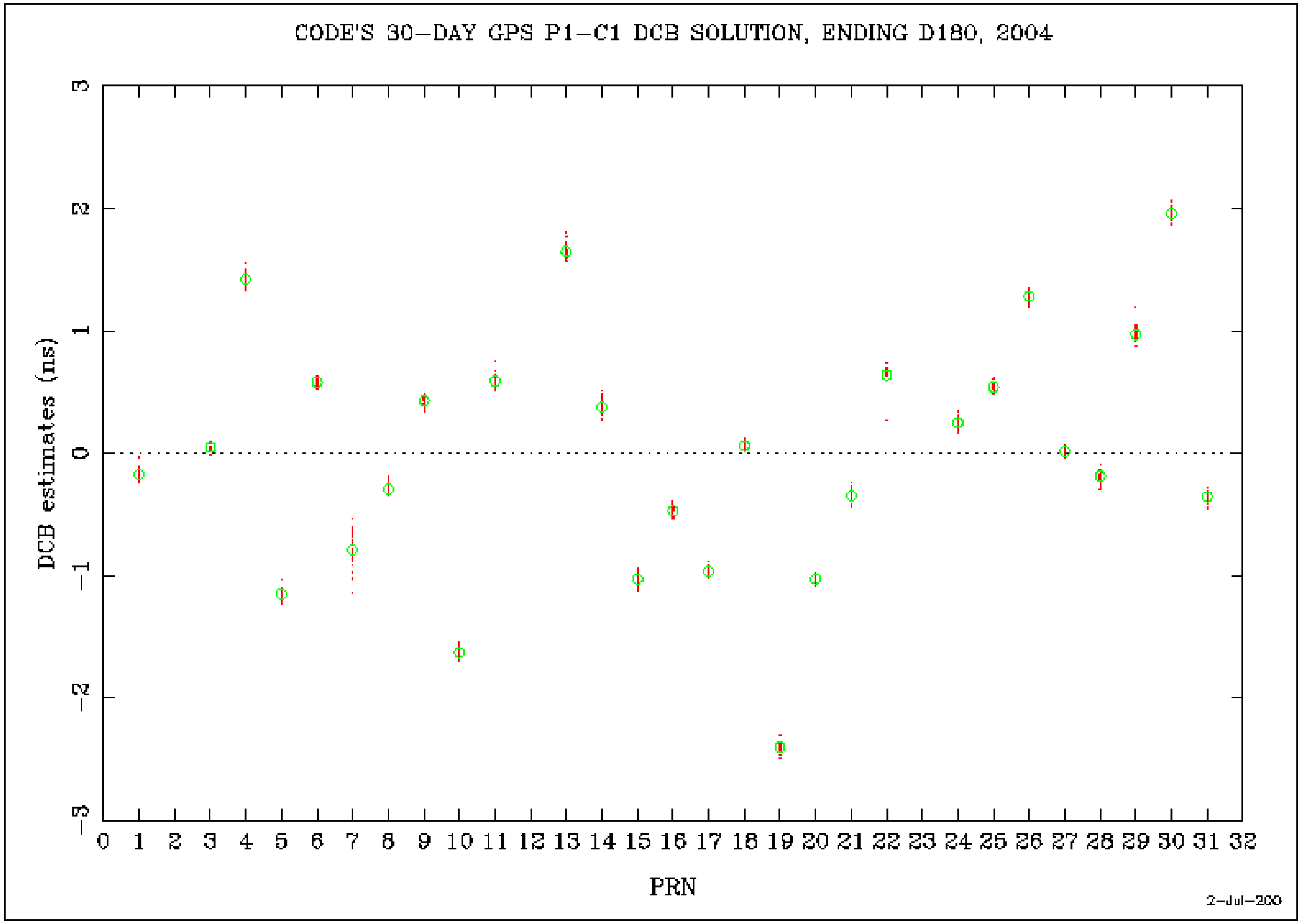
Group Delay (GD), or P1-P2 DCB Values for GPS



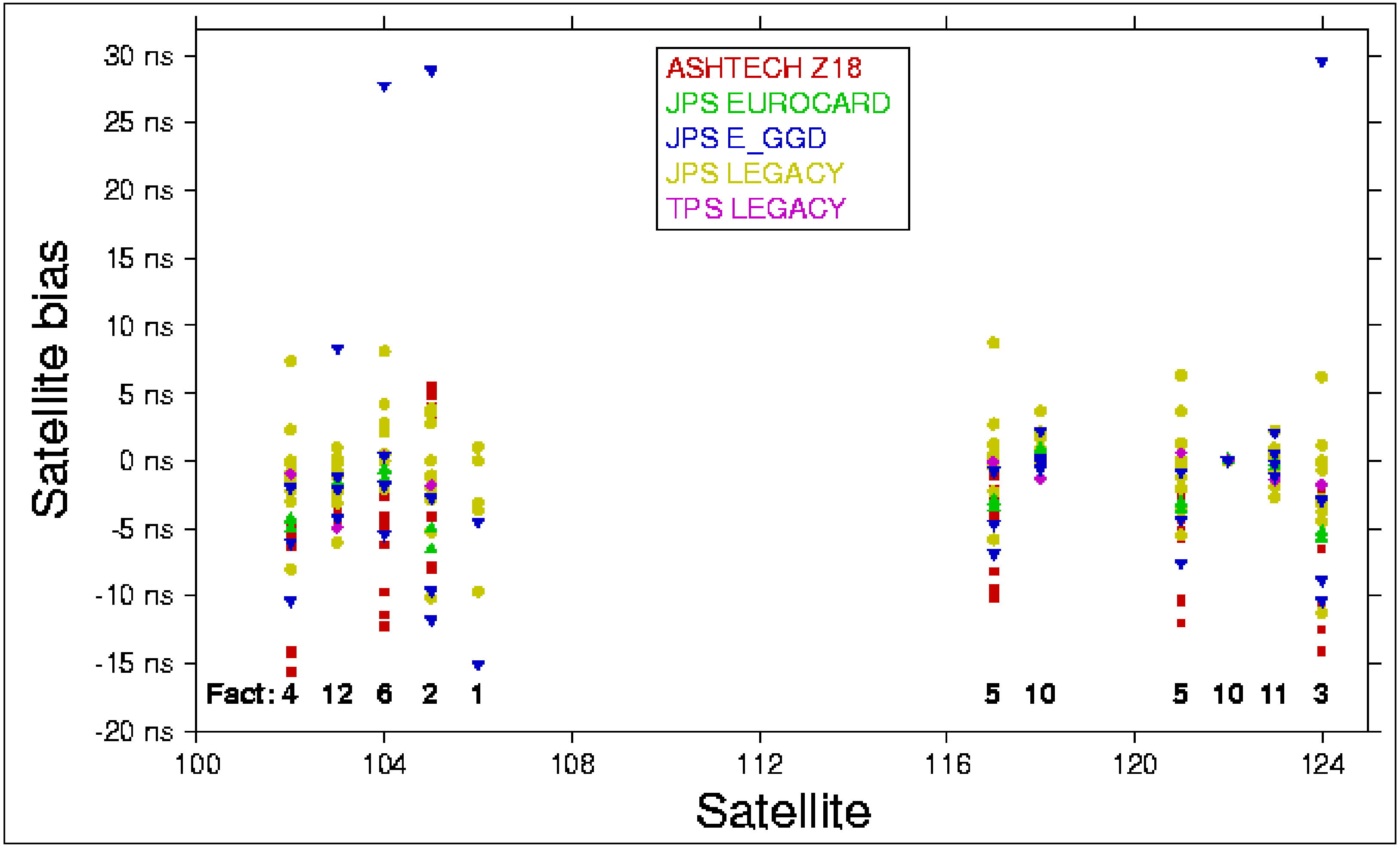
Group Delay (GD), or P1-P2 DCB Values for GLONASS



P1-C1 DCB Values for the GPS Satellite Constellation



GLONASS LC Pseudorange Measurement Biases



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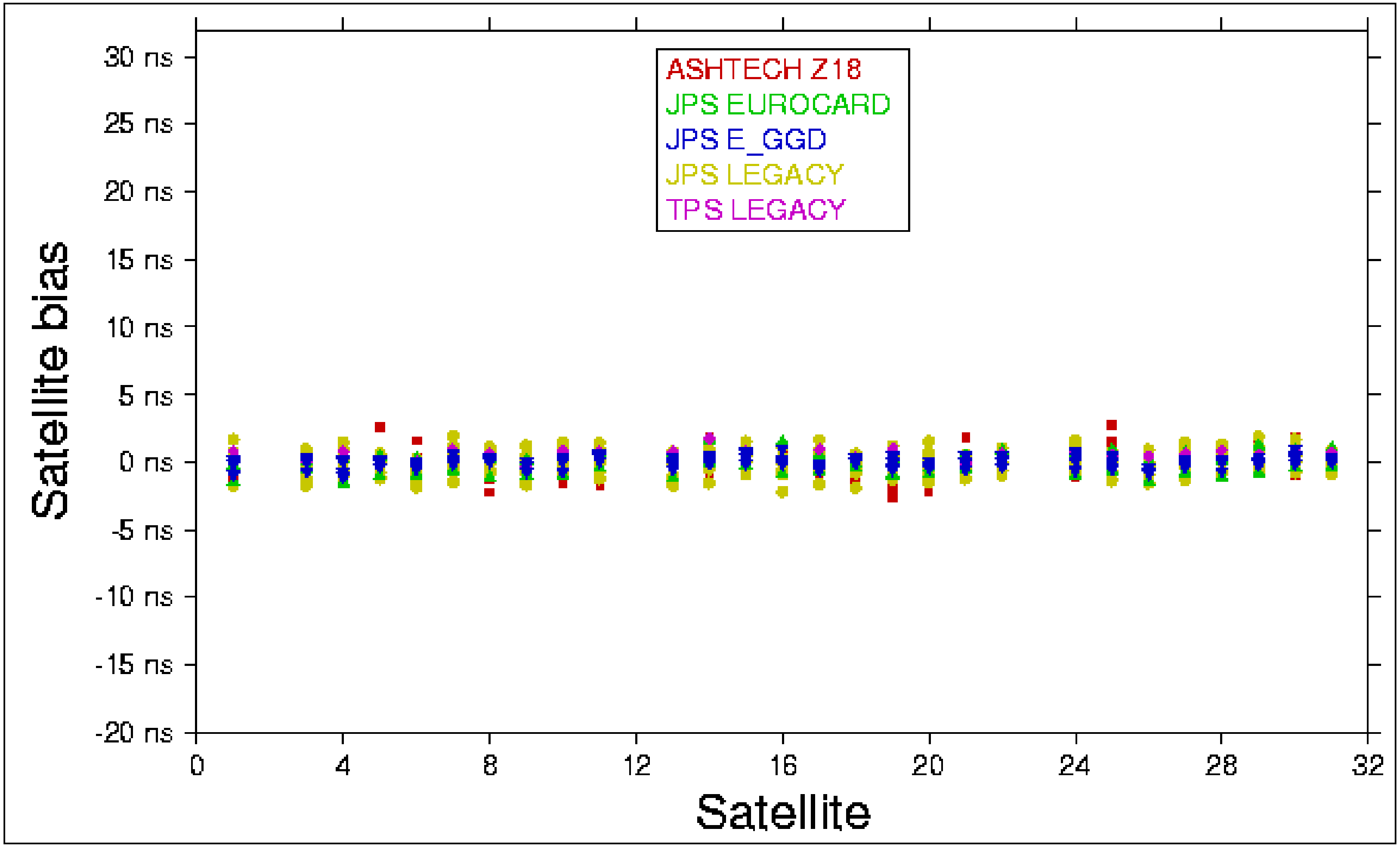
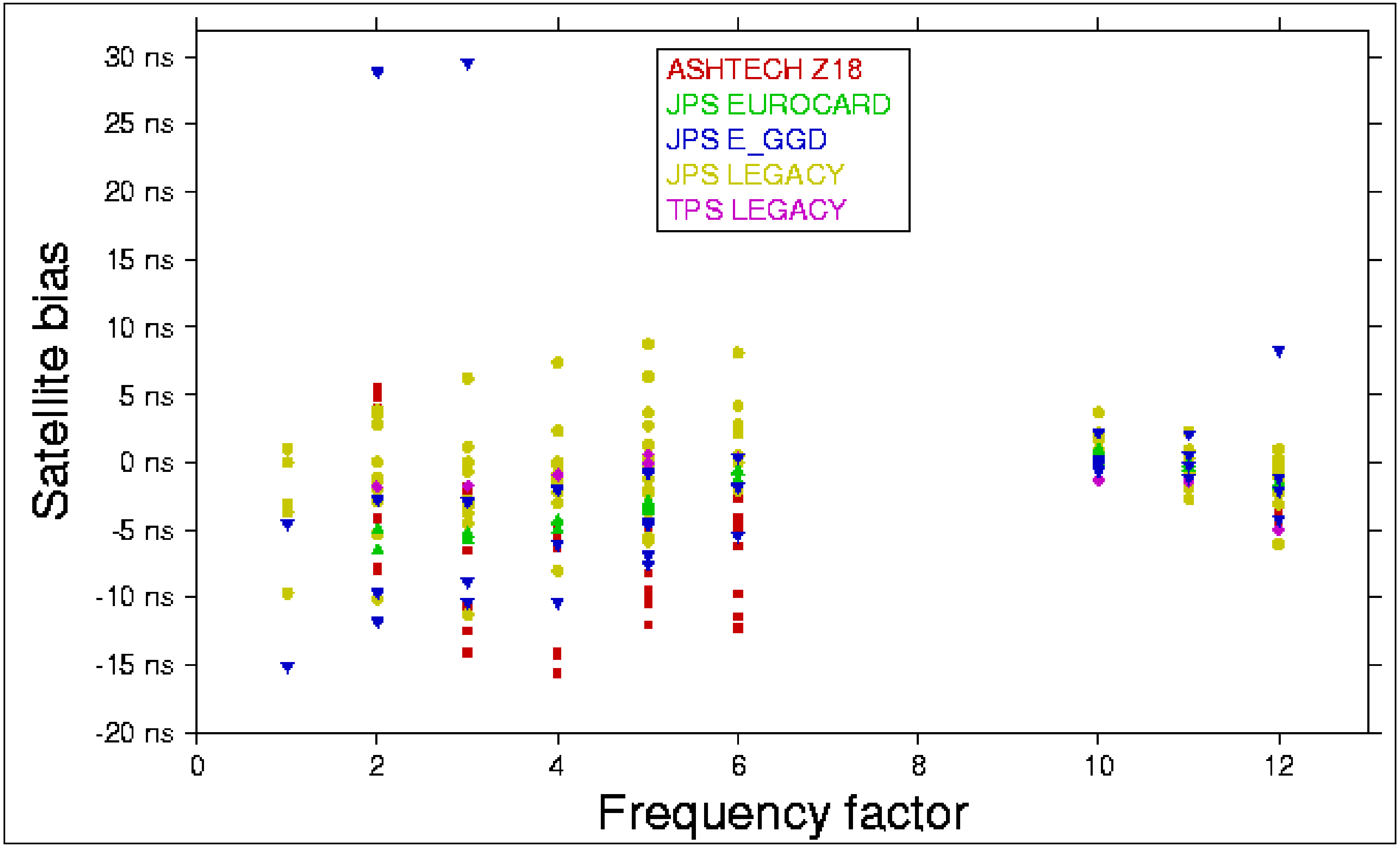
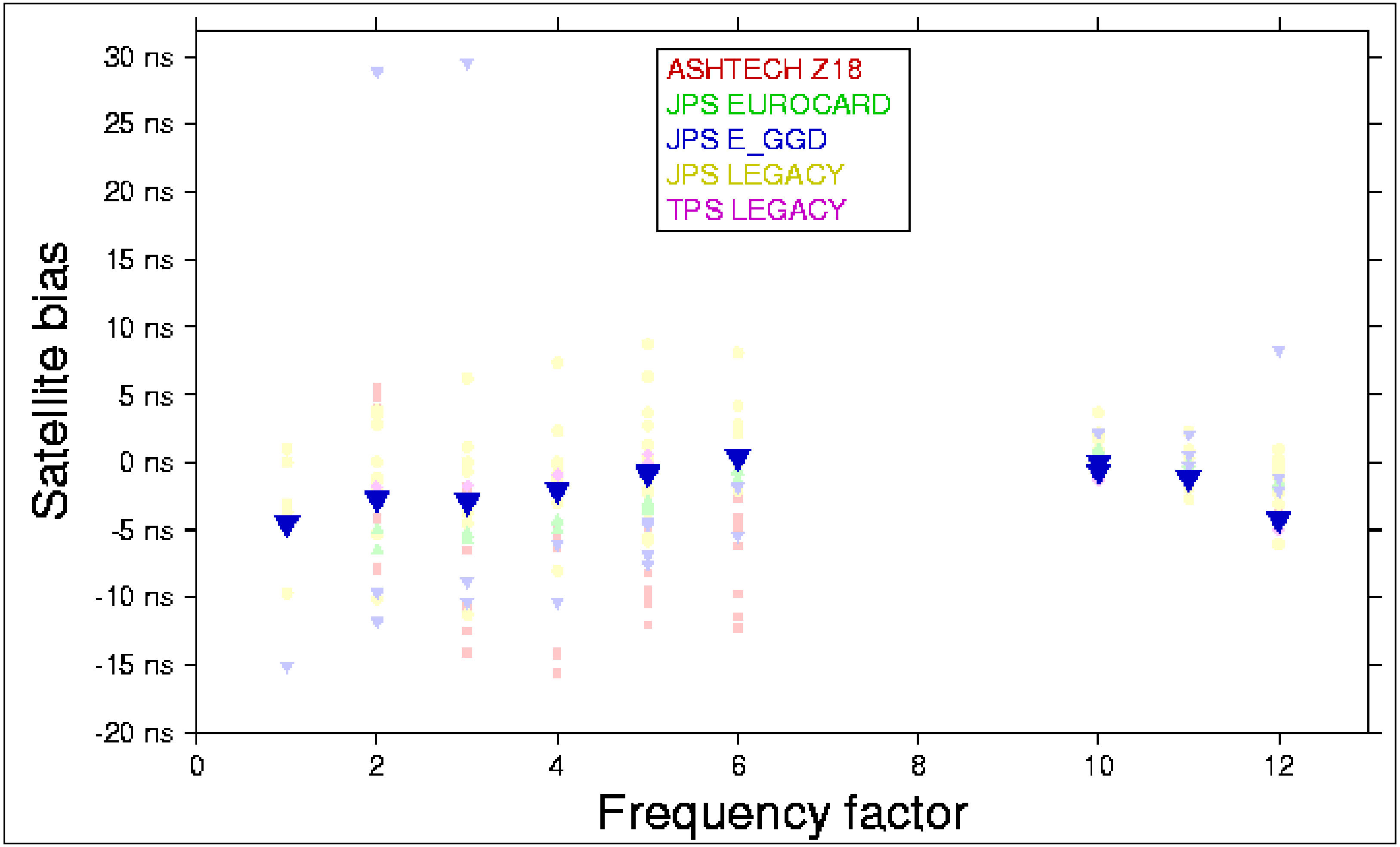
GPS LC Pseudorange Measurement Biases



GLONASS LC Pseudorange Measurement Biases (as a Function of the Signal Frequency)



GLONASS LC Pseudorange Measurement Biases (as a Function of the Signal Frequency)



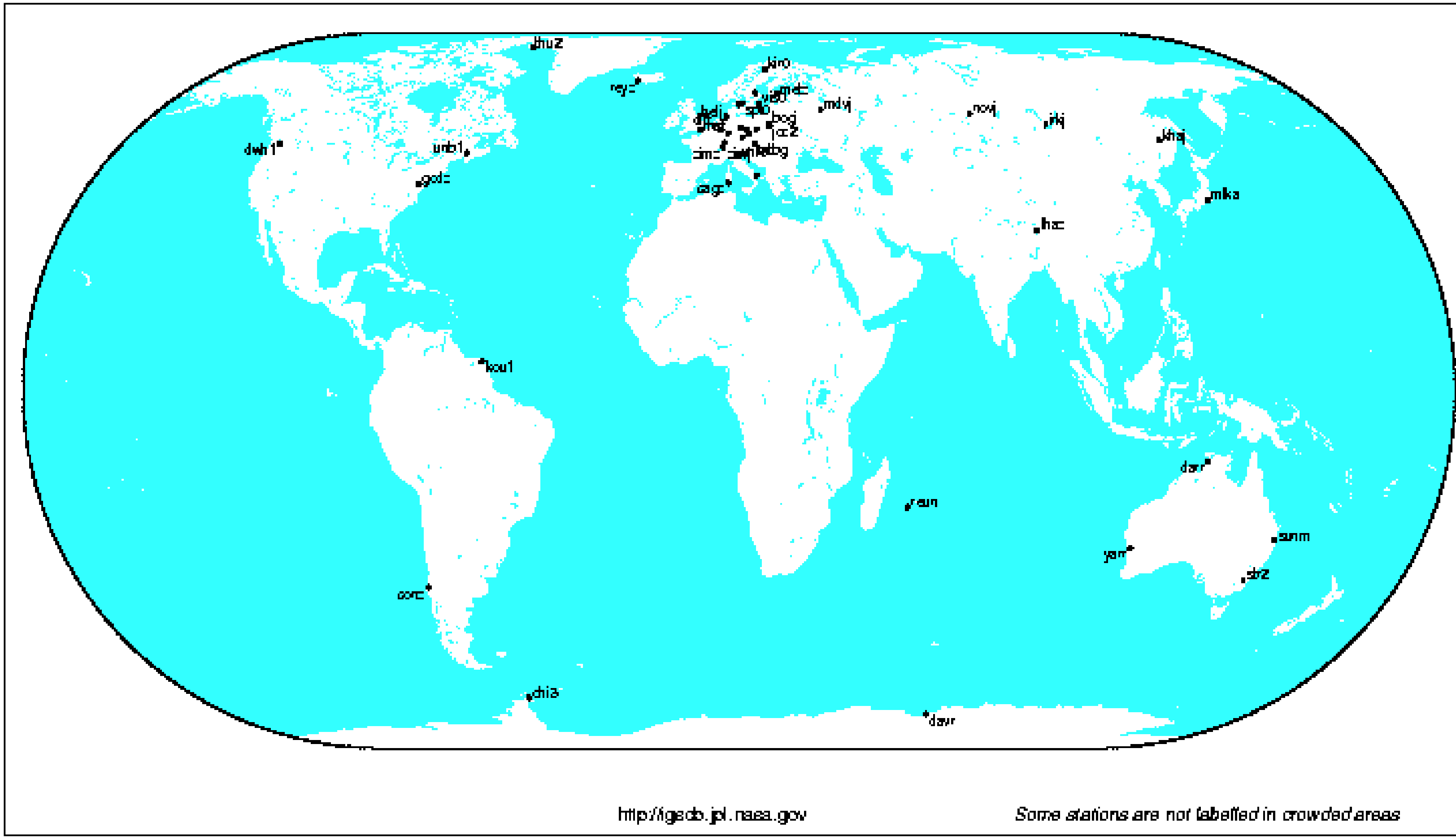
Summary (1)

- Final (>150), rapid (100), as well as ultra-rapid (65) orbit products computed at CODE do *generally* include both GPS and GLONASS. Our GLONASS results get automatically filtered out in all IGS combination processes.
- CODE GNSS orbit information is provided in SP3c format.
- By submitting additional backup ultra-rapid orbit solutions, a 100% reliability could be reached until now.
- We demontrate that operational GNSS POD is possible, even for satellites being repositioned.
- All CODE ionosphere products are based on GNSS data.
- Generation of final as well as rapid (phase-consistent) high-rate (30-sec) GPS clock products. Extension to GLONASS data is intended.

Summary (2)

- Use of new, powerful BPE (Bernese Processing Engine) V5.0 for automated and efficient GNSS data processing.
- Implementation of alerting via e-mail, computer terminal, and SMS messages in case of BPE processing failures, computer, or disk problems, ftp connection problems, general IGS/IGLOS data flow problems, GNSS satellite constellation changes, IGS/IGLOS tracking stations becoming active or inactive (concerning both hourly and daily data flow).
- Last but not least, it is worth mentioning that there is a serious interest from the EUREF/EPN analysis community in estabishment of an (official) IGS final GPS/GLONASS orbit product.

GPS/GLONASS Tracking Network of the IGS

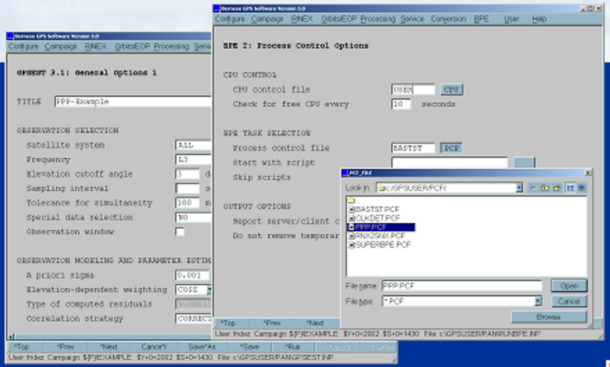


New Version 5.0
Bernese GPS Software

The Bernese GPS Software Version 5.0 continues in the tradition of its predecessors as a high performance, high accuracy, and highly flexible reference GPS/GLONASS (GNSS) post-processing package. State-of-the-art modeling, detailed control over all relevant processing options, powerful tools for automatization, the adherence to up-to-date, internationally adopted standards, and the inherent flexibility due to a highly modular design are characteristics of the Bernese GPS Software.

New Features

- Available on UNIX/Linux and Windows platforms
- User-friendly GUI
- File naming using session variables
- Built-in html-based help system
- New front-end for automatization (*Bernese Processing Engine, BPE*)
- Multi-session parallel processing
- PERL as BPE script language
- New, elaborate BPE examples for basic applications: RINEX-to-SINEX, comprehensive PPP (also relying on IGS products)
- POD not only for GNSS but also for LEO satellites
- GPS satellite parameters available for complete constellation history
- Sophisticated tool (ADDNEQ2) for efficient combination and manipulation of analysis results on the normal equations level
- Improved troposphere modeling
- Real kinematic analysis capability
- IERS 2000 conventions compliance
- Supports GNSS antenna PCV patterns
- Further refinements concerning, e.g., undifferenced processing, handling of pseudorange biases



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Outlook

- Consideration of higher-order ionosphere correction terms
- Use of new, meteo-model-based tropospheric mapping functions
- Validation of atmospheric pressure loading models
- Inclusion of the (fast moving) South Pole permanent station Amundsen-Scott (AMUN)

Current GPS/GLONASS Satellite Constellation

List of GNSS satellites active within the last 30 days:

- 29 GPS satellites: G01, G03, G04, G05, G06, G07, G08, G09, G10, G11, G13, G14, G15, G16, G17, G18, G19, G20, G21, G22, G23[1], G24, G25, G26, G27, G28, G29, G30, G31

- 11 GLONASS satellites: R02, R03, R04, R05[2], R06[1,2], R17, R18, R21, R22, R23, R24

[1]Satellite currently marked unusable

[2]Satellite of GLONASS-M modernization program

Tracking Situation Concerning G09 Being Repositioned, G23 Marked Unusable, and Eclipsing R18 and R24

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DATE : 2003  11  18

   1 |************************************************************************
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   9 |******7545989989*97669**************************************************
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  21 |************************************************************************
  23 |****************765587******************7645589***9778******************
  24 |************************************************************************
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  31 |************************************************************************
 103 |23222323333321112457***********954344433322221-3************964544333222
 105 |*****754122233333332332334769*******976434344444333332359**************8
 117 |233345568******855544434444444444436*****************7422223333333323333
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 122 |********54344433322221-3************975544333233333333333244455*********
 123 |8*********854433444333332-25**************65554432223333333331112567****
 124 |24669*******9   -334444333333315**************-   -332233333333312123457
-----+-----------------+-----------------+-----------------+-----------------+
     0                                  12                                  24
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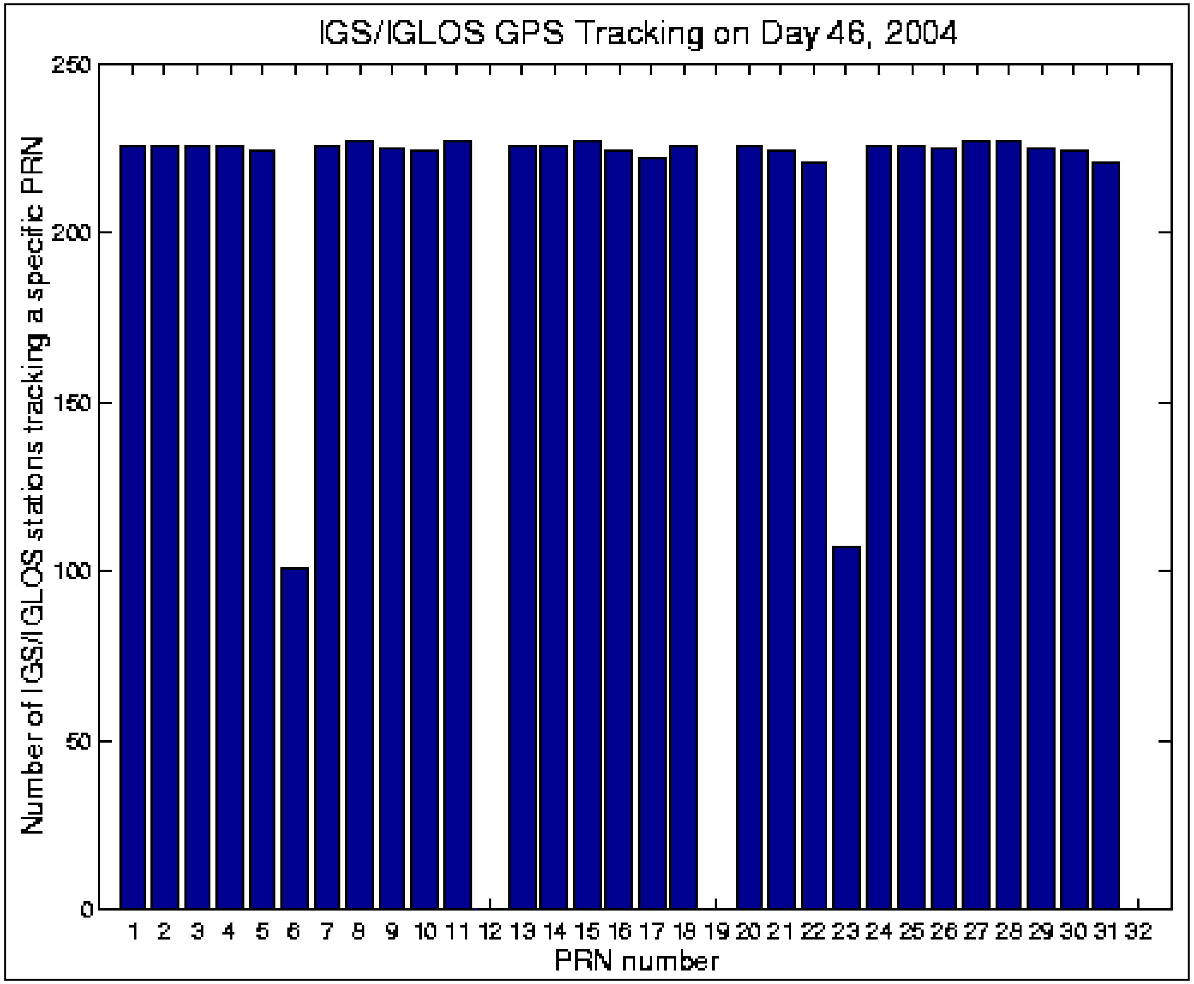
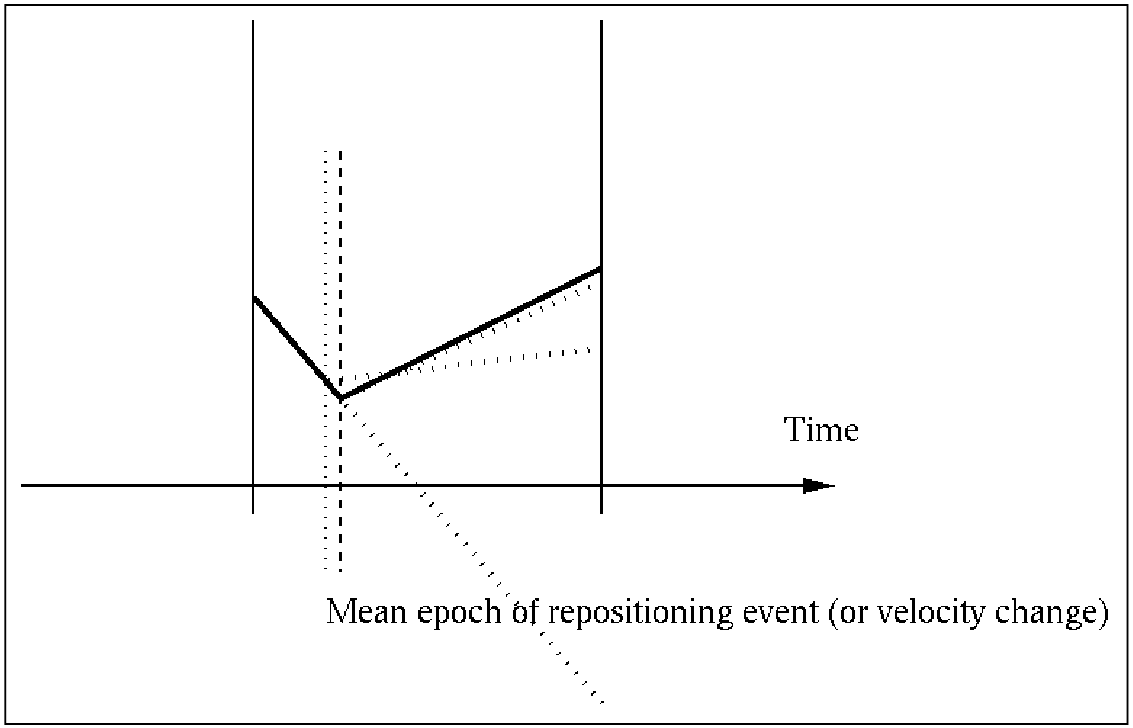
IGS/IGLOS Tracking of GPS Satellites Marked Unhealthy

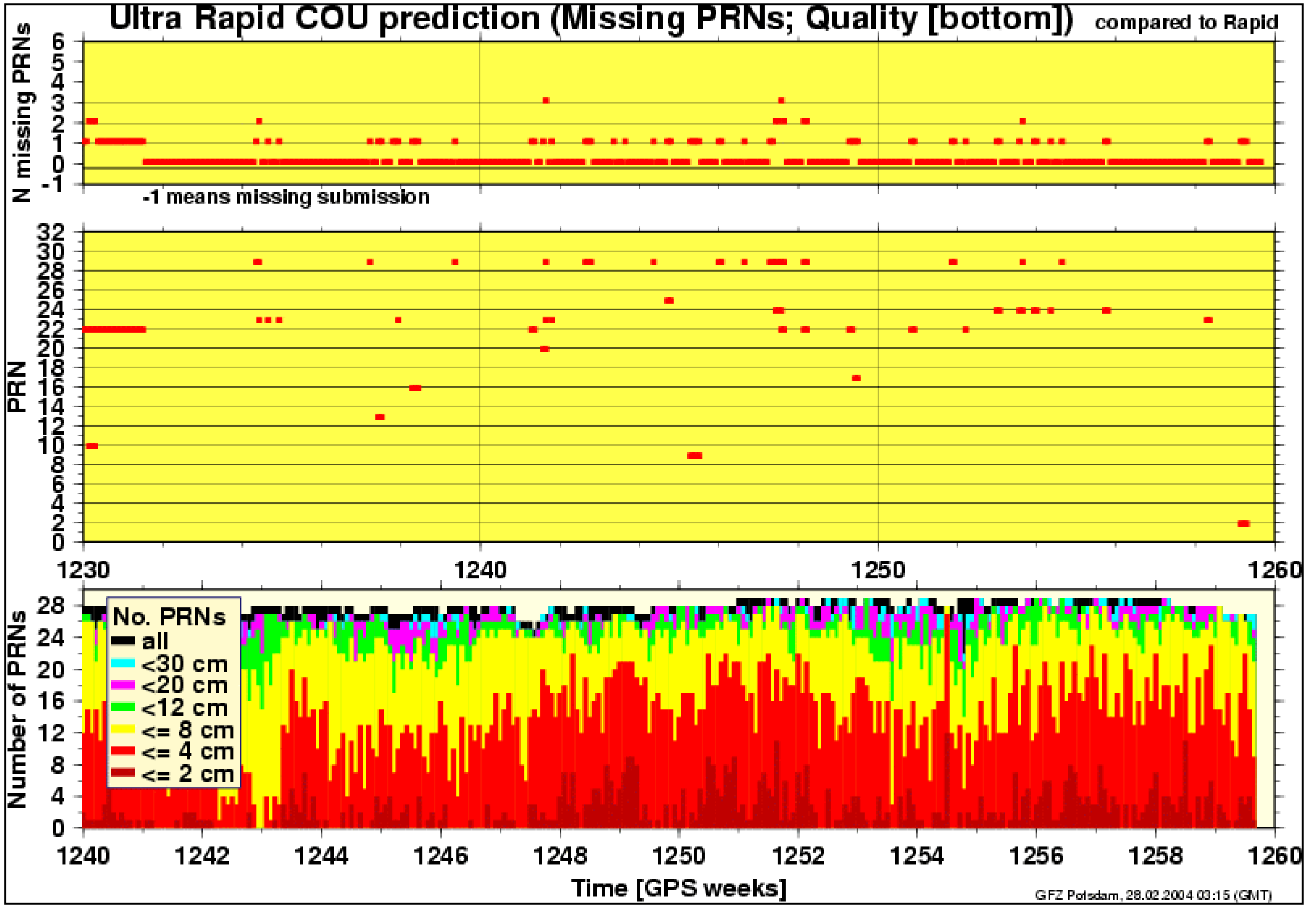


Orbit Initialization for GPS Satellites Being Repositioned



- Data used: double-difference pseudorange measurements
- Parameters solved for: Keplerian orbit elements and inter-system (GPS-GLONASS) receiver DCB parameters

Missing Satellites and Submissions Concerning CODE Ultra-Rapid Product



Courtesy: G. Gendt, GFZ, Potsdam, Germany

Detailed GNSS Data Monitoring

- Detailed monitoring concerning completeness and availability of IGS/IGLOS tracking data initiated at CODE.
- Corresponding charts are regularly posted to http://www.aiub.unibe.ch/download/igsdata/.
- Numerous e-mails sent to achieve improvement in terms of both completeness and availability of GNSS data.

Monitoring of Completeness of IGS/IGLOS GNSS Data (1)

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bogi0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS EUROCARD
conz0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  JPS LEGACY
crar0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  TPS LEGACY
darr0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
dlft0310.04o: G01 G02 G03             G07 G08         G11     G14 G15 G16     G18 G20         G23 G24 G25     G27 G28         G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
drej0310.04o: G01 G02 G03 G04         G07 G08 G09 G10     G13     G15 G16 G17 G18     G21         G24     G26 G27 G28 G29     G31 R03 R04 R05             R21 R22 R23 R24  JPS LEGACY
dwh10310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  JPS LEGACY
ffmj0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
godz0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
gope0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17     R21 R22 R23 R24  ASHTECH Z18
helj0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
hert0310.04o: G01         G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
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joz20310.04o: G01 G02     G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17     R21 R22 R23 R24  ASHTECH Z18
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kir00310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS E_GGD
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mdvj0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
metz0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS EUROCARD
mtbg0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
mtka0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
novj0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22         G25 G26 G27 G28 G29 G30     R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  JPS LEGACY
ohi30310.04o: G01 G02     G04 G05 G06 G07     G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
onsa0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
reun0310.04o: G01 G02 G03 G04     G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
reyz0310.04o: G01         G04 G05 G06 G07     G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17     R21 R22 R23 R24  ASHTECH Z18
spt00310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
str20310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  TPS LEGACY
thu20310.04o: G01         G04 G05 G06 G07     G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
titz0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
unb10310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  TPS LEGACY
vis00310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS E_GGD
wroc0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
wtzj0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
wtzz0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  JPS E_GGD
yarr0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
zimj0310.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  JPS LEGACY
```

Monitoring of Completeness of IGS/IGLOS GNSS Data (2)

```
bogi0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS EUROCARD
conz0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  JPS LEGACY
crar0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  TPS LEGACY
darr0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
dlft0300.04o: G01 G02 G03             G07 G08         G11     G14 G15 G16     G18 G20         G23 G24 G25     G27 G28         G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
drej0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
dwh10300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
ffmj0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
godz0300.04o: G01         G04 G05     G07         G10     G13             G17     G20             G24     G26 G27 G28 G29 G30     R03 R04         R17 R18         R23 R24  ASHTECH Z18
gope0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17     R21 R22 R23 R24  ASHTECH Z18
helj0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
hert0300.04o: G01 G02     G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
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joz20300.04o: G01 G02     G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17     R21 R22 R23 R24  ASHTECH Z18
khaj0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22     G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  JPS LEGACY
kir00300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS E_GGD
kou10300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
leij0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
lhaz0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  JPS LEGACY
mar60300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
mat10300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
mdvj0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
metz0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS EUROCARD
mtbg0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
novj0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22         G25 G26 G27 G28 G29 G30     R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  JPS LEGACY
ohi30300.04o: G01 G02     G04 G05 G06 G07     G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
onsa0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
reun0300.04o: G01 G02 G03 G04     G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
reyz0300.04o: G01         G04 G05 G06 G07     G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17     R21 R22 R23 R24  ASHTECH Z18
spt00300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
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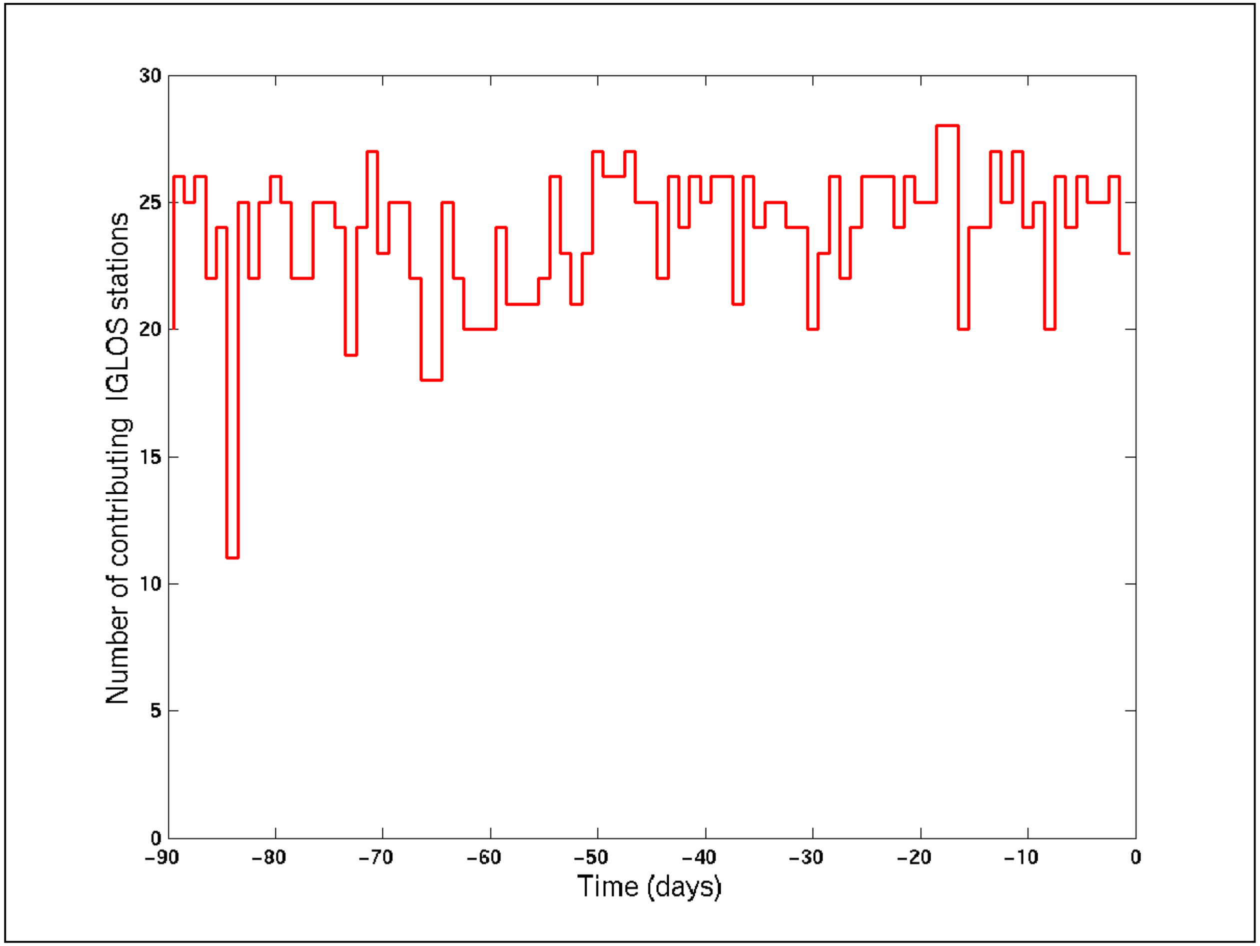
thu20300.04o: G01         G04 G05 G06 G07     G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
titz0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
unb10300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  TPS LEGACY
vis00300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS E_GGD
wroc0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
wtzj0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05     R17 R18 R21 R22 R23 R24  JPS LEGACY
wtzz0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  JPS E_GGD
yarr0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03     R05     R17 R18 R21 R22 R23 R24  ASHTECH Z18
zimj0300.04o: G01 G02 G03 G04 G05 G06 G07 G08 G09 G10 G11 G13 G14 G15 G16 G17 G18 G20 G21 G22 G23 G24 G25 G26 G27 G28 G29 G30 G31 R03 R04 R05 R06 R17 R18 R21 R22 R23 R24  JPS LEGACY
```

IGLOS Daily Data Availability for Rapid and Final Analysis

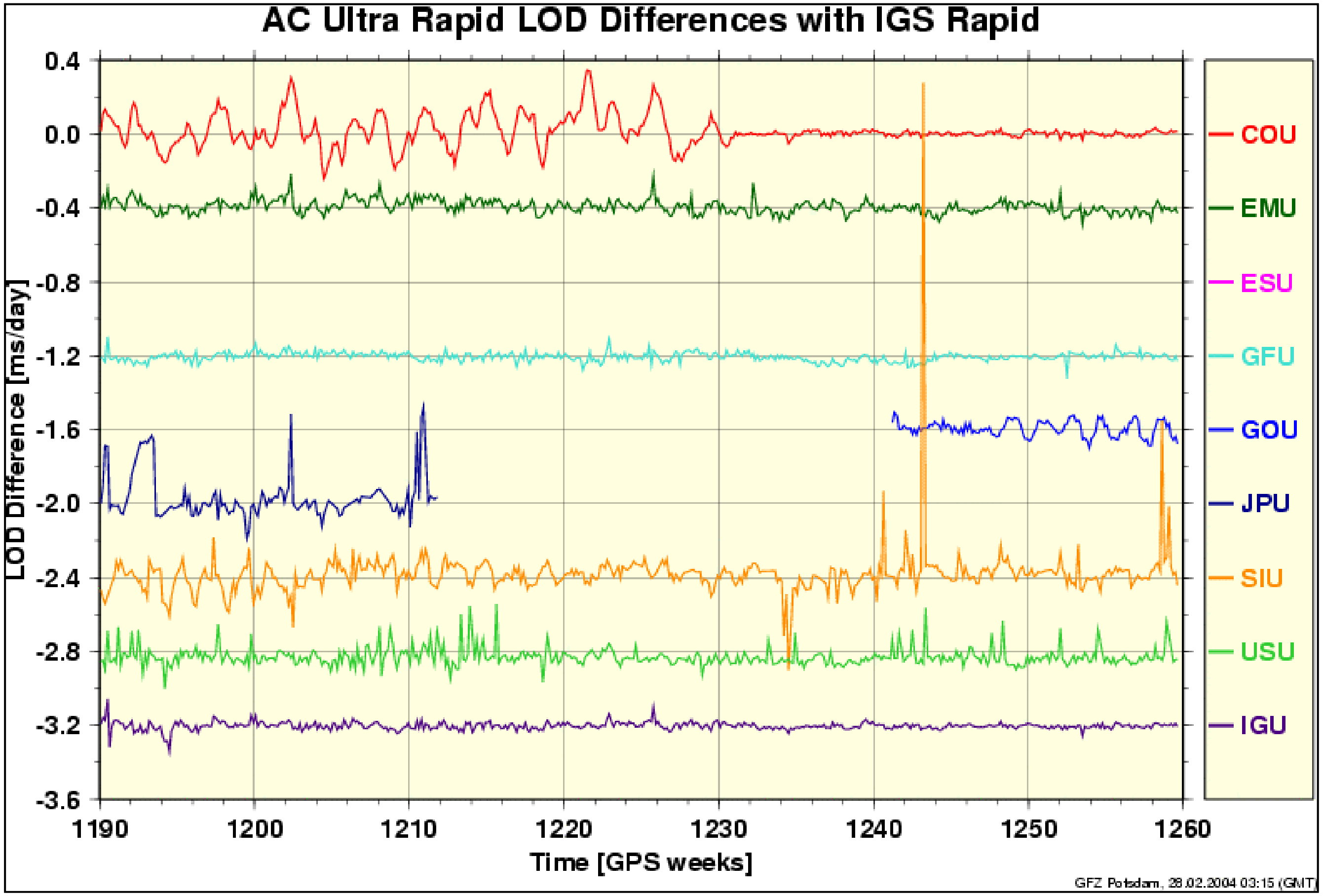
```
DoY      032     039     046     053
Week     1256    1257    1258    1259
DoW   56 0123456 0123456 0123456 0123456
-----------------------------------------------
crar: ** ******* ******* ******* ******* 100.0%
dwh1: ** ******* ******* ******* ******* 100.0%
hert: ** ******* ******* ******* ******* 100.0%
joz2: ** ******* ******* ******* ******* 100.0%
mat1: ** ******* ******* ******* ******* 100.0%
onsa: ** ******* ******* ******* ******* 100.0%
zimj: ** ******* ******* ******* ******* 100.0%
darr: ** ******* ******* ****L** *******  96.7%
gope: ** ******* ******* ******* *L*****  96.7%
ohi3: ** ******* ******* L****** *******  96.7%
reyz: ** ******* ******* L****** *******  96.7%
unb1: ** L****** ******* ******* *******  96.7%
cagz: -- -****** ****L** ******* *******  96.3%
irkj: ** ***L*** ******* ******* *L*****  93.3%
conz: ** ******* ******* L*****L L******  90.0%
kou1: ** L*L**** ******* -****** *******  90.0%
mdvj: ** ***LL** ******* ******* *L*****  90.0%
wtzz: ** ***LL** ******* L****** *******  90.0%
str2: LL L*-**** ****L** L****** *******  88.9%
kir0: ** *L**L** ***L*** ******* *L*****  86.7%
metz: ** *L*L*** LL***** *L***** *******  83.3%
reun: ** ****L** ******* ******- **-**--  83.3%
thu2: ** LL***** ******* ***LL** ****L**  83.3%
yarr: ** ******* *L***** *L-**** ***--**  83.3%
novj: ** LL*L*** ******* LLL**** *L*****  76.7%
mtka: -* L*L**LL *---L** ****-** *-*L***  62.1%
khaj: *L ***L*LL L**L*** **L**LL LL*L*L-  53.3%
davr: -L -L*L*L* *LL**** LLL***L LLLL*--  46.2%
lhaz: LL LL**L*- ------- ------- -------  11.5%
-----------------------------------------------
```

```
DoY         032     039     046     053
Week        1256    1257    1258    1259
DoW   23456 0123456 0123456 0123456 0123
-----------------------------------------------
conz: ***** ******* ******* ******* **** 100.0%
crar: ***** ******* ******* ******* **** 100.0%
darr: ***** ******* ******* ******* **** 100.0%
dwh1: ***** ******* ******* ******* **** 100.0%
gope: ***** ******* ******* ******* **** 100.0%
hert: ***** ******* ******* ******* **** 100.0%
irkj: ***** ******* ******* ******* **** 100.0%
joz2: ***** ******* ******* ******* **** 100.0%
khaj: ***** ******* ******* ******* **** 100.0%
kir0: ***** ******* ******* ******* **** 100.0%
mat1: ***** ******* ******* ******* **** 100.0%
mdvj: ***** ******* ******* ******* **** 100.0%
novj: ***** ******* ******* ******* **** 100.0%
ohi3: ***** ******* ******* ******* **** 100.0%
onsa: ***** ******* ******* ******* **** 100.0%
reyz: ***** ******* ******* ******* **** 100.0%
thu2: ***** ******* ******* ******* **** 100.0%
unb1: ***** ******* ******* ******* **** 100.0%
wtzz: ***** ******* ******* ******* **** 100.0%
zimj: ***** ******* ******* ******* **** 100.0%
kou1: ***** ******* ******* -****** ****  96.7%
metz: ***** ******* ******* *L***** ****  96.7%
str2: ***L* **-**** ******* ******* ****  93.3%
yarr: ***** ******* ******* **-**** ***-  93.3%
cagz: ***-- -****** ******* ******* ****  90.0%
reun: **-** ******* ******* ******- **-*  90.0%
mtka: ***-* ******* *---*** ****-** *-**  80.0%
davr: ----L -****** **LL*** LL**LLL L***  66.7%
lhaz: LLLLL ******- ------- ------- ----  24.0%
-----------------------------------------------
```

Number of IGLOS Stations Contributing to the CODE Rapid Orbit Product



IGS AC Ultra-Rapid LOD Consistency



Courtesy: G. Gendt, GFZ, Potsdam, Germany

Concluding Remarks on IGS/IGLOS Tracking

Let us remind once more that GNSS tracking data, the primary product line of the IGS, is the basis for all IGS analysis products and consequently a crucial factor for their quality!

From our point of view, each GNSS station of the IGS/IGLOS ground network should, as far as possible, *sample all transmitting satellites from horizon to horizon* (barring obstructions).

This implies that a GPS/GNSS receiver being operated as continous station should allow for an *all-in-view* tracking mode (at the station operator´s specific request).

IGS-Combined Final GNSS Orbit Product?

- In addition to CODE´s final GNSS orbit product, GLONASS-only products computed at BKG and at ESA/ESOC are meanwhile regularly available with nominal delay as applied to the final GPS orbit product, in principle enabling synchronous GPS and GLONASS orbit combination.
- In this context, it is worth mentioning that there is a serious interest from the EUREF/EPN analysis community in estabishment of an IGS-combined final GPS/GLONASS orbit product.

Example of Hourly Data Availability for Recent 24UT Ultra-Rapid Update (1)

```
DATE : 2004   2  28

GPS SATELLITES :

ALBH |98878888788664556666566677676668788888778876777665655777787877878767899899
ALGO |9*888867776799766755677656765766778878887877765576666775689998887767788888
ALIC |666777788788***77788888877879999898878887889978**8999998888897
AMC2 |****898889**98786787766568777787788899999888779889778887889977778999*99*9
AREQ |66675577676667765557665677655576665655467778777665678866
ARTU |*988*99*98767777788877779**9897779**999*8998899866678888777789996898 9
AUCK |78776566678777776898799888789998677887888988989 9*9999***99888889*9988766
BOR1 |777677778887677776788886788776866778888786787887776677777677778787 75778
BRST |88989*98887898766789987778779*96678788899677777677667777877789898
BRUS |887787888887888666689987777779987866788 8*8867677666765677777766789988 8897
CAGZ |776778897887      899888   889898876777   8678777777667778776779988 89
CAS1 |989878***9**99*9*********99997777 88**9*88****9899*******9*99888866
CHAT |776776677688666788989898888777767777878899888**8898889**9
CHPI |98898899*99***8898998898999878999988776777 78899*****89888888889 7999*9
COCO |876788898889**99*899999887788 79*****887249*989**9998887887888899778 88888
CONZ |8888887668877897766778788667766667666677766678887788888666778877767678 78
CORD |88767877655657676765776656678767666666556756777668666668766677765656 6567
CRAR |97889***9*88**8********9***9777787799999*****99798******9***9*9988679888
CRO1 |88787666778897776566665455566556777776544444555555444-4445555565667666 77
DAKA |8899*9***9*9888         9998*9*99898887888778776787788989 99**99*99*88999
DAV1 |9*99989*99******9************9*87988999****8**98**8*****9***9*9988867
DWH1 |87777888777554446556544565555556766777578876666344466567657766667698 8889
FAIR |***9768898778566788666677899898897**9*998798888775677878877897**97578*99
GLPS |**99*****9**767989888998888887779888889999988999 9*9*9****999999***99****
GOPE |766655577788755676899977798778855567775565787776666656777776779878886788
GUAM |877866777777 89**98788788889999887899899978988 8**999*7677778997667877 7788
HERT |798678867888876456888777877799856677877776788878678767777877679888878897
HOB2 |677777787787988888899*987678887876677888989888 7*****9999*99888889977776 6
HOFN |******9899*98866879779**78**99*88989*****98988887658887*99888999***99789
IISC |8888688988888899888888799899*******99**888898988987998767887886788878 8998
JOZ2 |766665567777545777788876789778965577787656787776667666777767778987876677
KERG |676666877879 9*878878788889977787656566567676778776467887998876675566 5
KIR0 |****99**8999777789**9*88*****979*******9*999998887668999987 89**9**9**9**
KOKB |6767767877566654567755778777787789 88*--667   8--6----777888887676888 9
KOUR |777887896788877777888667765566666777756777677789997786667666778887766776
```

Example of Hourly Data Availability for Recent 24UT Ultra-Rapid Update (2)

```
MAC1 |778768889*966889*79**989889778889877889*9****889***9***97999*97889997
MALI |57767879999868788999-   ---      ----886776568865---898-8776668899
MAS1 |788878886688778877668767676787756688777677554456656776776667887678898887
MAT1 |866667798777766667888877778878887877777789877676765556566778678888777876 7
MAW1 |7999988889899**77899****77788787665788 88*877889999 7868**8**9876787766
MKEA |788788666889887666667668876678   7878997767776766899887789999 89997788
NLIB |777667675555676666675644456666667767674777887465766776567667875366766544
NOT1 |877877896677989988889898877999788777777887767786777776677878688799988889
OHI3 |765577664675444645677664448753325565875554444256775455446654556765   677
ONSA |*9899*988899877678**98779-                  -88877767778897678***998799*
PERT |666656767877668776666666676765768657788778877688888777767877766677776656
PIMO |776776657888776886776         7898777987878667988897888655655568766 68886
QAQ1 |*****998899989877668*99888889**99899******6697767788 68999**8988*****978
REYZ |888898977967787   788988568977975677879668676678767877898997767999889757
RIOG |89998879*978997         789899767666788767878*99987****9889978*998776778
SANT |888998877898789977677898877778777777677877988889999989997777898778 87*988
SCH2 |89*8988876678876565667776666677788887789*98755756667756698999977 88999
SCUB |99*99*988999887         66777799*9897888778977778677789998799**9999**999
STJO |98*898899887787766777677776776899889787887787766655568877899 98889*989998
STR2 |776678877998   88898***9779889998876798889977 89*****999*9*98889*98777976
SUTH |9*989899**9*989***89**798888998887677776777777778887999887677777886785 68
THTI |766676667886778898878775667888767877777888899998889888 9999*888888 9998
THU3 |********999877999877999***889*99************976777878 8988******988******
TIDB |765667866688888888778*887778779876667888886887799***8899987888898777676
TOW2 |965699889***88888999*99*9888888*****898888 9***99***99*9**999998889889***
UNB1 |***99999888778886678677777777779988988988*997777876678877*999*999**99999*
UNSA |666677666675887         656646776556555566566777566555445666655555565466
USUD |78877687765555556667666688888*888778989888989777677886655555887767888 66
WHIT |99*978899986666778877677 78*99-89899***9*89*9997866678 89*977999*997589***
WTZZ |988*888888889887888999888**888*97799*99897787887687767777797779*9999899*
YELL |989898*898775778777766 7888*868888989*989999*885468777878879***7888679***
ZAMB |567777888786677668887776444356776676664566447765677775766644467777666776
ZIMJ |8878888878888889788999788998 88*98777887678767877788767777798679*9998999*
ZWEN |*89998999986766            99768*99*8**8789999667666787976677898 9999889*
-----+-----------------+-----------------+-----------------+-----------------+
     0                                  12                                  24
```

Example of Hourly Data Availability for Recent 24UT Ultra-Rapid Update (3)

```
GLONASS SATELLITES :

 CAGZ |1111-1122333      212222   222333455556   5544444323333333211-
 CONZ |2221222221223333344556655554334332233333221111-   ---   -22333343321112
 CRAR |544442333222222333233233335443544444433322222222223443344434444443355444
 DWH1 |333334444333333223332222212221222221111111111113333332221111222244443335
 GOPE |2111111222444343333312222222222223334555455554444443333444433111--11-111111
 HERT |21111222223444444343332222222222344555445555544444333344333211 1-111211212
 JOZ2 |2111121222343333333312222212222333455544555434443433334443211--1111121111
 KIR0 |222222234334544544443332222222222344444444544444444444444432122122223 22232
 MAT1 |11111-222333322222222222221223333455556555544444442233443311 1  -   -1111
 OHI3 |443321112222222334444444454444322345444432221222223122122222 1134544   432
 ONSA |2211222223344333333333222-                  -4444433444433112111112222212
 REYZ |111211122333555   44333322222222223323333433323344334443333211221222 22122
 STR2 |333333234434   2211111211112222223332221112222334333444555655554443333332
 UNB1 |2333332332224455544445534422233332222333344344443333433333222222222222233333
 WTZZ |21111222224443433433322222222222333455554555544444444333444433211-1112112111
 ZIMJ |211112222244444434333222232222233345555555556444443333444331111-112112111
-----+-----------------+-----------------+-----------------+-----------------+
     0                                  12                                  24
```