IGS-repro3/IGS20 update, changes w.r.t. IGb14

Rolf Dach
with contributions from the CODE AC team

Astronomical Institute, University of Bern, Switzerland

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Conventional model updates

GNSS antenna related changes for IGS-repro3

Generation of the IGS20 reference frame

Other changes in the IGS conventions

Schedule to introduce IGS20 reference frame

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Consistently applied by all techniques (update in the IERS-conventions):

- Mean pole model
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  switched to Desai and Sibois, 2016 in repro for ITRF2020

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- Mean pole model
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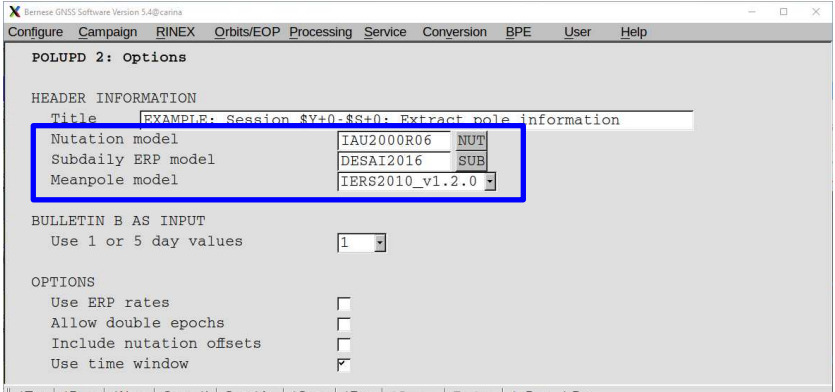
- High-frequency pole model
  switched to Desai and Sibois, 2016 in repro for ITRF2020

- These new model are continued after switching the operational processing.

Polar motion modelling

Bernese GNSS Software 5.4:

- Select the polar motion models when importing ERP information:



Polar motion modelling

Bernese GNSS Software 5.4:

```
EXAMPLE: Session 2019-0440: Extract pole information            14-SEP-22 16:10
------------------------------------------------------------------------------------------ ...
Format:                 1.00
Number of model lines: 3
NUTATION MODEL:         IAU2000R06
SUBDAILY POLE MODEL:    DESAI2016
MEANPOLE:               IERS2010_v1.2.0

    DATE    TIME          X-POLE      Y-POLE      UT1-UTC    GPS-UTC      RMS XP      RMS YP   ...
YYYY MM DD HH MM SS         (")         (")          (S)       (S) REM      (")         (")     ...

2019 02 12 00 00 00  0.03865700  0.32332700 -0.070627200  18. V_2  0.00000700 0.00000700 ...
2019 02 12 12 00 00  0.03822000  0.32354400 -0.071220900  18. V_2  0.00000500 0.00000500 ...
2019 02 13 00 00 00  0.03778300  0.32376200 -0.071796200  18. V_2  0.00000600 0.00000600 ...
...
```

Models are reported in the header of the Bernese formatted pole file.

Polar motion modelling

Bernese GNSS Software 5.4:

For example BPEs just change the PCF variables:

```
# General and model files:
# ------------------------
V_MEANPL = IERS2010;          DESCRIPTION=Mean pole model
V_SUBMOD = IERS2010XY;        DESCRIPTION=Subdaily pole model
V_NUTMOD = IAU2000R06;        DESCRIPTION=Nutation model
...
```

New values:

```
# General and model files:
# ------------------------
V_MEANPL = IERS2010_v1.2.0;   DESCRIPTION=Mean pole model
V_SUBMOD = DESAI2016;         DESCRIPTION=Subdaily pole model
V_NUTMOD = IAU2000R06;        DESCRIPTION=Nutation model
...
```

Polar motion modelling

Bernese GNSS Software 5.2:

High-frequency pole model:

- exchange `IERS2010XY.SUB` by `DESAI2016.SUB` in the panels
- no dedicated variable in the example BPEs from version 5.2

Polar motion modelling

Bernese GNSS Software 5.2:

Mean pole model:

- no support of the secular pole model (IERS convention 2010, v1.2.0)
- polar motion is not fully consistent to satellite orbits
- compensated by stochastic pulses during orbit fit

High-frequency pole model:

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GNSS antenna related changes for IGS-repro3

IGS repro for ITRF2020:

- Receiver antennas
  - Receiver antenna misalignment towards north was considered.
  - New multi-GNSS receiver antenna corrections from Geo++ and chamber at Uni Bonn have been used; no “copy from GPS” was allowed.

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  - Disclosed satellite antenna corrections for Galileo was used as the basis.
  - GPS and GLONASS satellite antenna offsets adjusted to the Galileo defined scale.

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  - Disclosed GPS Block IIIA satellite antenna offsets consistent with the Galileo values.

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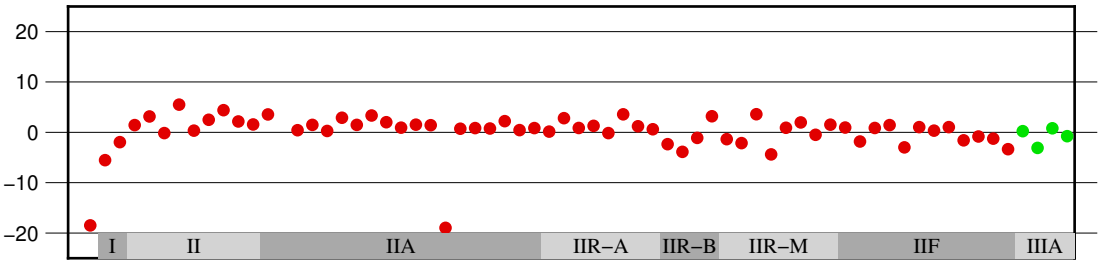
  - Time variable GLONASS horizontal satellite antenna offsets (see Dach et al. 2019).
  - Disclosed GPS Block IIIA satellite antenna offsets consistent with the Galileo values. (Nadir-dependent corrections estimated from ground station network)

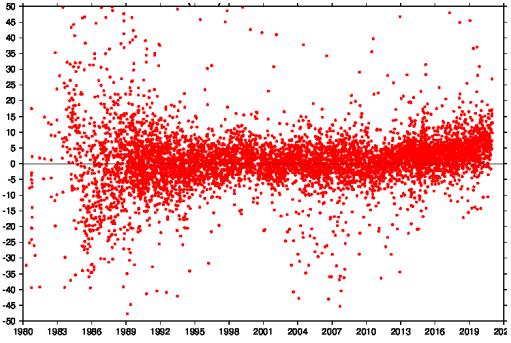
GPS Block IIIA satellite antenna offsets

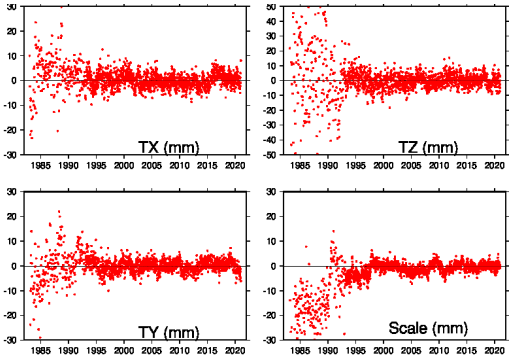


- GPS satellite antenna offsets estimated based on Galileo values
- Differences wrt values used in IGS-repro3 and values published by Lockheed Martin in December 2021 for Block IIIA

Plot provided by A. Villiger

Scale in the ITRF2020 solution

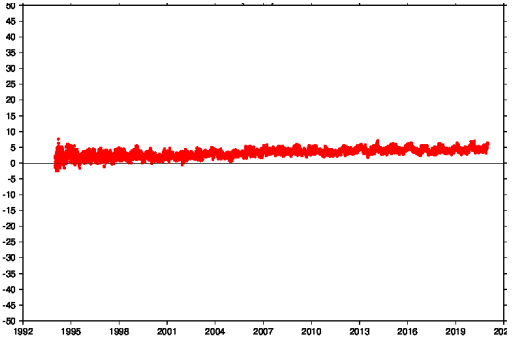




VLBI (scale) SLR (geocenter & scale)

From `https://itrf.ign.fr/en/solutions/ITRF2020`

Scale in the ITRF2020 solution



GNSS (scale)

From `https://itrf.ign.fr/en/solutions/ITRF2020`

Scale offset of $4\,\mathrm{mm}$ at epoch 2015.0 with a rate of $0.15\,\mathrm{mm/year}$

Generation of the IGS20 reference frame

- Scale difference between ITRF2020 and the IGS repro solution:
  - one scale offset for all Galileo satellites
  - one scale offset for all GPS Block IIIA satellites
  - individual antenna offsets for all other GPS- and GLONASS satellites

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- Update of selected, additional receiver antenna calibration values related correction to the station coordinate is considered

- At the end we confronted three different scales:

  scale(IGb14) = scale(ITRF2014)
  scale(repro3) = scale(Galileo)
  scale(IGS20) = scale(Galileo adjusted to ITRF2020)

Using the reference frames

Bernese GNSS Software 5.4:

- IGb14 – antenna files:
  - `http://ftp.aiub.unibe.ch/BSWUSER54/CONFIG/SATELLIT_I14.SAT`
  - `http://ftp.aiub.unibe.ch/BSWUSER54/REF/ANTENNA_I14.PCV`
  - `http://ftp.aiub.unibe.ch/BSWUSER54/REF/I14.ATX`
- IGb14 – reference frame for operational use (after epoch 2015.0):
  - `http://ftp.aiub.unibe.ch/BSWUSER54/REF/IGB14_R.CRD`
  - `http://ftp.aiub.unibe.ch/BSWUSER54/REF/IGB14_R.VEL`
  - `http://ftp.aiub.unibe.ch/BSWUSER54/REF/IGB14.FIX`
  - `http://ftp.aiub.unibe.ch/BSWUSER54/REF/IGS14.PSD`
- IGb14 – reference frame for reprocessing (before epoch 2015.0):
  - Extract coordinates and velocities for the epoch to be processed using program SNX2NQ0 from `ftp://igs-rf.ign.fr/pub/IGb14/IGb14.snx`
  - Same PSD-file as above applied.

Using the reference frames

Bernese GNSS Software 5.4:

- IGS20 – antenna files:
  - `http://ftp.aiub.unibe.ch/BSWUSER54/CONFIG/SATELLIT_I20.SAT`
  - `http://ftp.aiub.unibe.ch/BSWUSER54/REF/ANTENNA_I20.PCV`
  - `http://ftp.aiub.unibe.ch/BSWUSER54/REF/I20.ATX`
- IGS20 – reference frame for operational use (after epoch 2021.0):
  - `http://ftp.aiub.unibe.ch/BSWUSER54/REF/IGS20_R.CRD`
  - `http://ftp.aiub.unibe.ch/BSWUSER54/REF/IGS20_R.VEL`
  - `http://ftp.aiub.unibe.ch/BSWUSER54/REF/IGS20.FIX`
  - `http://ftp.aiub.unibe.ch/BSWUSER54/REF/IGS20.PSD`
- IGS20 – reference frame for reprocessing (before epoch 2021.0):
  - Extract coordinates and velocities for the epoch to be processed using program SNX2NQ0 from `ftp://igs-rf.ign.fr/pub/IGS20/IGS20.snx.gz`
  - Same PSD-file as above applied.

Using the reference frames

Bernese GNSS Software 5.4:

For example BPEs the PCF variables for using IGb14:

```
# General and model files:
# ------------------------
...
V_PCV    = I14;            DESCRIPTION=Antenna phase center (PCV) model
V_PCVINF = ANTENNA;        DESCRIPTION=PCV information file
V_SATINF = SATELLIT;       DESCRIPTION=Satellite information file
...
# Reference frame and station related files:
# ------------------------------------------
V_REFDIR = ${D}/REF54;     DESCRIPTION=Directory with basic Bernese files
V_REFINF = IGB14;          DESCRIPTION=Master/reference CRD/VEL filename
V_REFPSD = IGB14;          DESCRIPTION=PSD corrections (ITRF2014 or higher)
V_REFEPO = 2010 01 01;     DESCRIPTION=Epoch of coordinates in reference CRD
...
```

Using the reference frames

Bernese GNSS Software 5.4:

For example BPEs the PCF variables for using IGS20:

```
# General and model files:
# ------------------------
...
V_PCV    = I20;            DESCRIPTION=Antenna phase center (PCV) model
V_PCVINF = ANTENNA;        DESCRIPTION=PCV information file
V_SATINF = SATELLIT;       DESCRIPTION=Satellite information file
...
# Reference frame and station related files:
# ------------------------------------------
V_REFDIR = ${D}/REF54;     DESCRIPTION=Directory with basic Bernese files
V_REFINF = IGS20;          DESCRIPTION=Master/reference CRD/VEL filename
V_REFPSD = IGS20;          DESCRIPTION=PSD corrections (ITRF2014 or higher)
V_REFEPO = 2015 01 01;     DESCRIPTION=Epoch of coordinates in reference CRD
...
```

Using the reference frames

Bernese GNSS Software 5.2:

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- The files for version 5.2 are located in the corresponding directories at `http://ftp.aiub.unibe.ch/BSWUSER52/`

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- The files for version 5.2 are located in the corresponding directories at `http://ftp.aiub.unibe.ch/BSWUSER52/`
- You need to install the following patches:
  - B_108: Additional PSD-correction model for ITRF 2020

Using the reference frames

Bernese GNSS Software 5.2:

- The files for version 5.2 are located in the corresponding directories at `http://ftp.aiub.unibe.ch/BSWUSER52/`

- You need to install the following patches:
  - B_108: Additional PSD-correction model for ITRF 2020
  - B_109: The consistency check in ATX2PCV needs to be adapted because of an additional digit for satellite antenna offsets in `I20.ATX`.

Using the reference frames

Bernese GNSS Software 5.2:

- The files for version 5.2 are located in the corresponding directories at `http://ftp.aiub.unibe.ch/BSWUSER52/`
- You need to install the following patches:
  - B_108: Additional PSD-correction model for ITRF 2020
  - B_109: The consistency check in ATX2PCV needs to be adapted because of an additional digit for satellite antenna offsets in `I20.ATX`.
- PCF variables for the example BPEs need to be adjusted analogue to version 5.4.

Using the reference frames

Bernese GNSS Software:

- repro3 – antenna files:
  - `http://ftp.aiub.unibe.ch/REPRO_2020/BSWUSER54/CONFIG/SATELLIT_R20.SAT`
  - `http://ftp.aiub.unibe.ch/REPRO_2020/BSWUSER54/CONFIG/SATELLIT_R20_V52.SAT`
  - `http://ftp.aiub.unibe.ch/REPRO_2020/BSWUSER54/REF/ANT_COD_R20.PCV`
  - `http://ftp.aiub.unibe.ch/REPRO_2020/BSWUSER54/REF/R20.ATX`

  The files are also accessible as R20-files in the standard directories `http://ftp.aiub.unibe.ch/BSWUSER54/` and `BSWUSER52`.

- repro3 – reference frame files:
  - Extract coordinates and velocities for the epoch to be processed using program SNX2NQ0 from `http://ftp.aiub.unibe.ch/REPRO_2020/BSWUSER54/REF/IGS14R3.SNX`
  - Same PSD-file as for IGS14 applied: `http://ftp.aiub.unibe.ch/BSWUSER54/REF/IGS14.PSD`

Receiver antenna misalignment towards north

Bernese GNSS Software 5.4:

- Station guidelines require orientation of the antenna towards north
- Supported by a new column in the station information files:

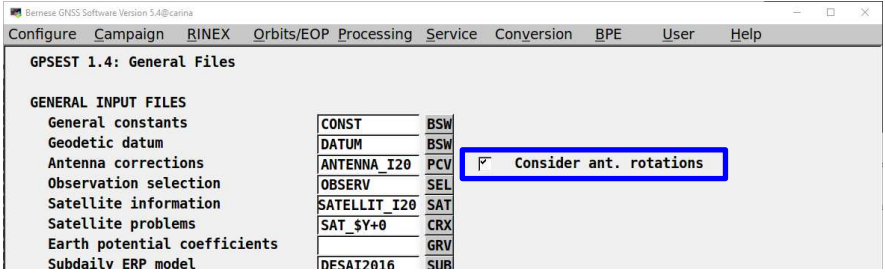
```
TYPE 002: STATION INFORMATION
-----------------------------

STATION NAME      FROM    TO      ...    UP      AZIMUTH  LONG NAME   ...
****************                  ... ***.****   ******   *********   ...
LAMA 12209M001    ...     ...     ...    0.0600           LAMA00POL   ...
MATE 12734M008    ...     ...     ...    0.1010         0 MATE00ITA   ...
MIKL 12335M001    ...     ...     ...    0.0237        45 MIKL00UKR   ...
```

Receiver antenna misalignment towards north

Bernese GNSS Software 5.4:

- Station guidelines require orientation of the antenna towards north
- If not: list azimuth in station information file, activate correction in processing programs; no change in ADDNEQ2 possible!



Receiver antenna misalignment towards north

Bernese GNSS Software 5.4:

- Station guidelines require orientation of the antenna towards north
- Finally the applied azimuth corrections are reported in the SINEX file:

```
*-------------------------------------------------------------------------------
+SITE/ANTENNA
*SITE PT SOLN T DATA_START__ DATA_END____ DESCRIPTION_________ S/N__ DAZI
 BRST  A     1 P 21:095:00000 21:095:86370 TRM57971.00      NONE -----
 GANP  A     1 P 21:095:00000 21:095:86370 TRM59800.00      SCIS -----
 HERT  A     1 P 21:095:00000 21:095:86370 LEIAT504GG       NONE -----
 JOZ2  A     1 P 21:095:00000 21:095:86370 TRM59800.00      NONE -----
 LAMA  A     1 P 21:095:00000 21:095:86370 LEIAT504GG       LEIS -----
 MATE  A     1 P 21:095:00000 21:095:86370 LEIAR20          NONE -----
 MIKL  A     1 P 21:095:00000 21:095:86370 LEIAR10          NONE -----    45
 ONSA  A     1 P 21:095:00000 21:095:86370 AOAD/M_B         OSOD -----
 ORID  A     1 P 21:095:00000 21:095:86370 LEIAR25.R4       LEIT -----
 ....
 -SITE/ANTENNA
*-------------------------------------------------------------------------------
```

Receiver antenna misalignment towards north

Bernese GNSS Software 5.2:

- A rotation of the antenna can be introduced via the AZI file:
  (Station identification via reicever, antenna, internal number)

```
RECEIVER ANTENNA ORIENTATIONS                                          03-NOV-22
------------------------------------------------------------------------------

RECEIVER TYPE           ANTENNA S/N    SESS   AZIMUTH
ANTENNA  TYPE           FROM     TO             DEG
********************  ****** ******  ****     ***

LEICA GR10               2104   2104            35
LEIAR10         NONE
```

- With B_110 the session field can be empty.
- No reporting in SINEX file is supported.

Other changes in the IGS conventions

Antenna corrections are applied when analyzing Melbourne-Wübbena linear combination:

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Frequency-dependent satellite antenna corrections as they are applied for the first time in IGS20 antenna model have an impact on the resulting biases. In particular when using the phase biases the consistent use for PPP ambiguity resolution is essential.

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The IGS changes its convention to apply these antenna corrections when computing these biases starting with the switch to the IGS20 antenna model.

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- Berneses GNSS Software 5.2:
  Not relevant because no PPP ambiguity resolution is supported.

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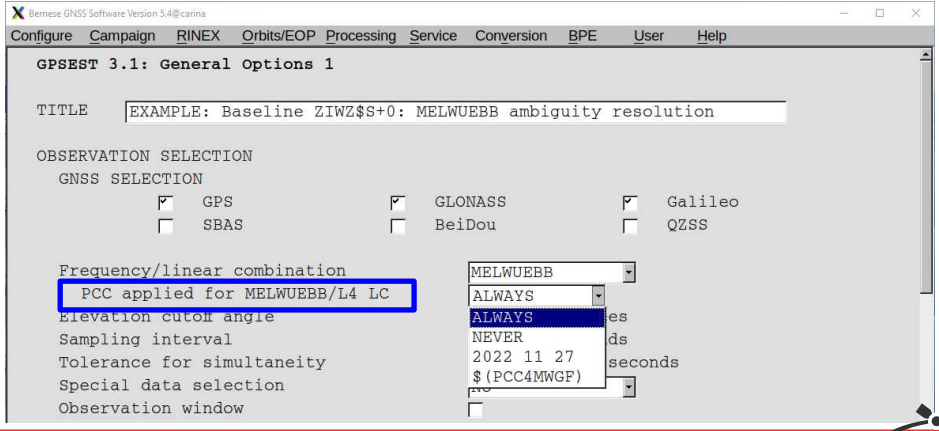
Berneses GNSS Software 5.4:



Other changes in the IGS conventions

Long product filenaming:

Other changes in the IGS conventions

Long product filenaming:

- As applied already for repro3 the products will be provided with the new naming scheme on the IGS databases:

```
COD0OPSFIN_20190440000_01D_05M_ORB.SP3.gz
COD0OPSFIN_20190440000_01D_01D_ERP.ERP.gz
COD0OPSFIN_20190440000_01D_30S_CLK.CLK.gz
COD0OPSFIN_20190440000_01D_05S_CLK.CLK.gz
COD0OPSFIN_20190440000_01D_01D_OSB.BIA.gz
```

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  `COD0OPSFIN_20190440000_01D_05M_ORB.SP3.gz`
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  `COD0OPSFIN_20190440000_01D_05S_CLK.CLK.gz`
  `COD0OPSFIN_20190440000_01D_01D_OSB.BIA.gz`

- On `http://ftp.aiub.unibe.ch/` we will realize the following naming scheme:
  - `.../CODE`: same naming scheme as for the IGS
  - `.../BSWUSER52`: nothing will change
  - `.../BSWUSER54`: naming scheme as used in the examples `COD_20190440.PRE.gz`

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  `COD0OPSFIN_20190440000_01D_05S_CLK.CLK.gz`
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  - `.../BSWUSER54`: naming scheme as used in the examples `COD_20190440.PRE.gz`
  - `.../CODE_TEST`: temporary for testing the upload and download

Schedule to introduce IGS20 reference frame

- July 2022: Publication of IGS20 reference frame and related antenna model
- Since August 2022/week 2222: Parallel generation of the final product series using the IGS reference frame available for test purposes from https://cddis.nasa.gov/archive/gnss/products/wwww/igs20/
- 27. November 2022/week 2238: Switch of the operational product lines
  - IGS products shall be produced by the legacy orbit combination software.
  - GLONASS-products shall be replaced by new multi-GNSS combination procedure on an experimental stage.
- January 2023: The period between end of repro3 and switch of the operational product generation shall be filled with an extension of the repro3 solutions from the IGS analysis centers.

Changes in the CODE processing

When introducing the IGS20:

- All operational products including the final series will cover three systems: GPS, GLONASS, Galileo
- The precise orbit files (SP3) will have a sampling of 5 minutes.

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- All operational products including the final series will cover three systems: GPS, GLONASS, Galileo
- The precise orbit files (SP3) will have a sampling of 5 minutes.
- EPN-final solution will also include Galileo because related antenna corrections are available with IGS20 antenna model.

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Changes in the CODE processing

Summary of recent changes:

- troposphere model based on VMF3 (old VMF1)
- ocean tidal model (gravitational force and crustal deformation): FES2014b (old FES2004)
- final solution is again a three-day long-arc solution
- stochastic orbit parameters (pulses) at orbit midnight (instead of every 12 hours) in the final long-arc solution

Changes in the CODE processing

Summary of recent changes:

- troposphere model based on VMF3 (old VMF1)
- ocean tidal model (gravitational force and crustal deformation): FES2014b (old FES2004)
- final solution is again a three-day long-arc solution
- stochastic orbit parameters (pulses) at orbit midnight (instead of every 12 hours) in the final long-arc solution

(The course tutorial demonstrates how these orbits can be reproduced with version 5.4 of the Bernese GNSS Software.)

THANK YOU
for your attention

Publications of the satellite geodesy research group:

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