Activities at the CODE Analysis Center

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IGS WS2017: PS06-02

International GNSS Service Workshop 2017
3 - 7 July, 2017
Paris, France

The CODE consortium

Four institutions compose the CODE consortium: the Astronomical Institute of the University of Bern (AIUB), Switzerland; swisstopo: the Federal Office of Topography of Switzerland; the German Federal Agency for Cartography and Geodesy (BKG) and the Institut für Astronomische und Physikalische Geodäsie (IAPG), Munich, Germany.

Highlights

Rigorously combined processing of GPS and GLONASS observations has been performed since mid of 2003 as an essential step towards multiconstellation analysis (see Figures 1 and 2).
Two consistent solution series, **a clean one-day (COF)** and **a three-day long-arc (COD)** solution, are generated in parallel.
Regular contribution to IGS-MGEX since 2012 with a five-system solution: GPS + GLONASS + Galileo + BeiDou + QZSS (see presentation of Prange et al. in plenary session #01).
Continuous parameterization, particularly for Earth orientation parameters (EOP, Figure 3), troposphere zenith path delays (ZPD) and horizontal gradients, as well as for ionosphere parameters (Figure 4), allows the connection of the parameters at day boundaries.
Completeness of GNSS orbit products with respect to all transmitting GPS and GLONASS satellites without exception with reliable accuracy code information.
Generation of uninterrupted orbit information for the satellites being repositioned (Figure 5). Corresponding events are identified with a maneuver flag in the SP3c orbit files. An orbit initialization procedure is implemented for easy inclusion of brand new GNSS satellites, even if they do not provide broadcast navigation messages.
Automatic verification of IGS14 fiducial sites for consistent datum definition in the final, rapid, and ultra-rapid analysis chains.
Comprehensive CODE analysis summaries with extended orbit validation information and datum verification results.
Independent GNSS orbit validation on the basis of SLR data including MGEX (see poster of Grahsl et al. in session "PS08: Orbit Modelling").
GNSS ambiguity resolution: ambiguities are resolved for GPS and GLONASS observations with a self-calibrating procedure for handling of GLONASS-DPCB (differential phase-code biases).
Monitoring parameters are set up in the final solutions for internal use:

- Satellite(-specific) antenna offsets and patterns.
- GLONASS-GPS bias parameters with respect to station coordinates and troposphere ZPD and (from day 185/2016) gradients.
- Scaling factors for higher-order ionosphere (HOI) and non-tidal atmosphere pressure loading (APL) corrections.
- Geocenter coordinates (GCC).
- Plane-specific ERP and satellite-specific GCC.

Note: These parameters are contained in the daily NEQs that are archived. For efficiency reasons the monitoring parameters are stacked or removed from the NEQs before generating the final solution.
Observable-specific code bias estimation for all GNSS signals (see Figure 6) based on the combination of clock and ionosphere analysis results.
GLONASS frequency numbers are verified on a regular basis.
SINEX result files are generated in all processing lines: final, **rapid and even ultra-rapid.**
Fully automated GNSS data processing with the latest development version of the Bernese GNSS Software (Dach et al., 2015). The processing is embedded in a system of Perl modules. This includes instant alerting in case of processing and technical failures, general data flow problems, changes in the GNSS constellations.

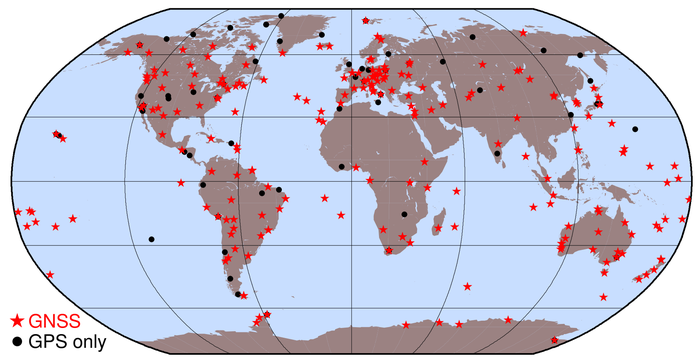

Figure 1: Tracking network as considered in CODE's GNSS final analysis by June 2017. About 75% of the sites support GLONASS.

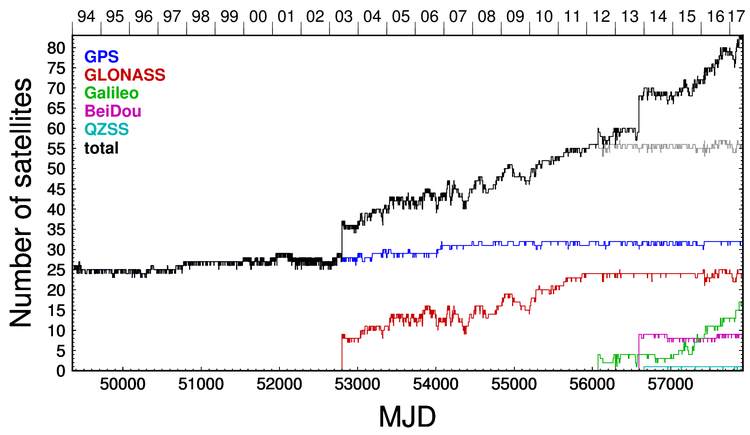

Figure 2: Number of GNSS satellites since 1994 as considered in CODE's final and MGEX analyses.

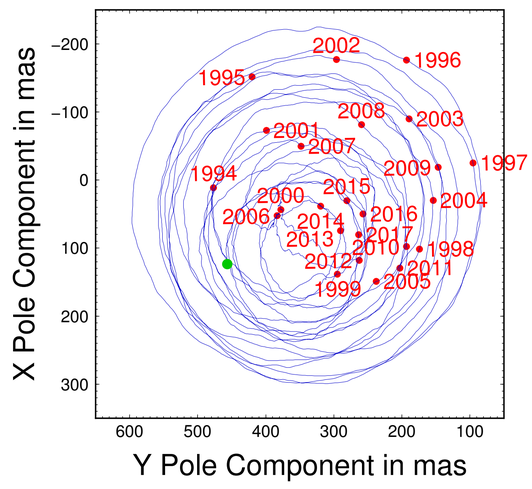

Figure 3: Polar motion from 19-Jul-1993 to 23-Jun-2017 as monitored by CODE.

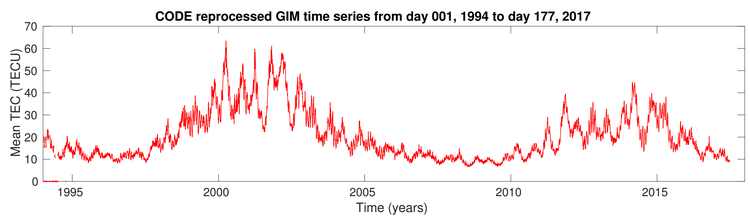

Figure 4: Global mean TEC extracted from the Global Ionosphere Maps (GIMs) produced by CODE. This particular daily time series, meanwhile covering two solar cycles, was created on the basis of hourly GIMs obtained as a by-product from a bias-dedicated GPS/GLONASS reprocessing (1994-2016) effort. Note that those 1994 GIM solutions without global coverage are indicated with zero values.

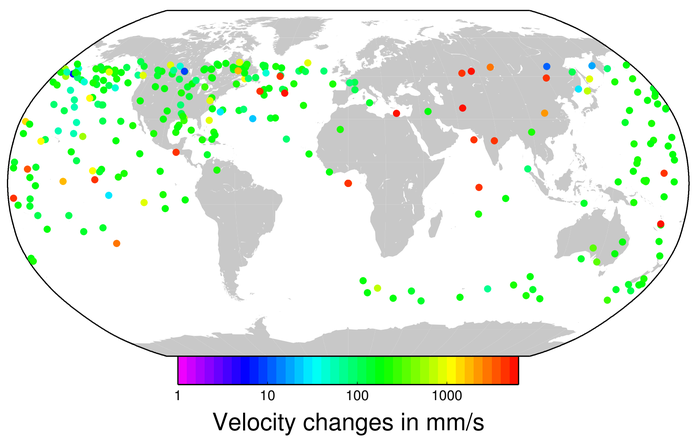

Figure 5: Geographical locations of all repositioning events of GPS satellites since 2004 as determined by CODE.

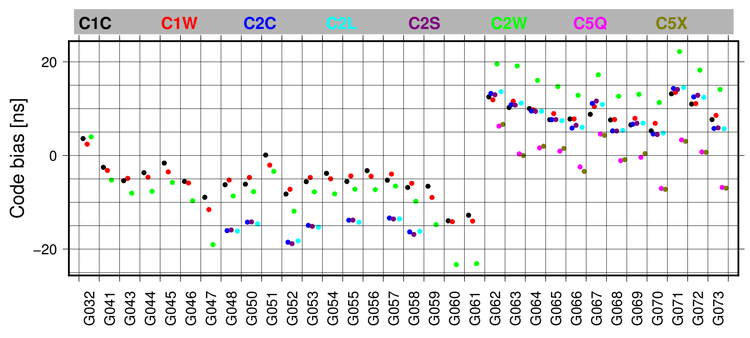

Figure 6: Observable-specific code bias estimates for all available GPS code observable types (using the RINEX3 nomenclature) and GPS SV numbers, computed at CODE. Note that G032-G061 correspond to Block IIA, IIR, IIR-M; G062-G073 correspond to Block IIF satellite generations.

Most important new developments and model changes

- **A refined GNSS bias handling** (see presentation by Schaer et al. in plenary session #03) to cope with all available GNSS systems and signals has been implemented and activated (in May 2016) in all IGS analysis lines. Bias results from clock and ionosphere analyses are combined at NEQ level. Coherent long-term code bias solutions are also computed and provided in Bias-SINEX V1.00.
- On day 206/2016 **satellite attitude modelling** according to Kouba (2009) for GPS and Dilssner et al. (2011) for GLONASS satellites was activated. The use of the aforementioned models improves quality of the CODE products for eclipsing satellites.
- In agreement with IGSMAIL-7399, the CODE routine processing was **switched from IGb08 to IGS14** reference frame together with the respective phase center corrections and station post-seismic deformation (PSD) models on day 030/2017. The switch was combined with addition of new mainly multi-GNSS stations to the CODE processing network.
- GPS **and GLONASS final clock corrections** starting from day 030/2017 (now based on one cluster).
- **SLR Quick-Look validation for ILRS extended** (from GR) **to GRECJ** satellite constellations.
- **Preference is now given to RINEX3 data**.

```
Extract from COD19547.SUM:
RINEX OBSERVATION FILES USED FOR ANALYSIS:
-------------------------------------------------------------------------
Data source          169  170  171  172  173  174  175  Average
-------------------------------------------------------------------------
RINEX 3 RECEIVER     117  116  117  116  116  116  116     41.5%
RINEX 3 SHORT          3    3    3    3    3    3    3      1.1%
RINEX 2 FILES        161  163  163  162  160  159  160     57.5%
RINEX 3 STREAM         0    0    0    0    0    0    0      0.0%
RINEX 3 UNKNOWN        0    0    0    0    0    0    0      0.0%
-------------------------------------------------------------------------
Total                281  282  283  281  279  278  279    100.0%
-------------------------------------------------------------------------
Data sources are listed according to their preference.
```

- **The CODE IGS-MGEX processing is now part of the routine analysis**.

More details on recent developments at the CODE AC are available in the IGS Technical Report 2016.

Reprocessing activities at CODE

- **Repro15 - GNSS orbits and clock corrections** in IGb08/IGS08.atx reference frame. Orbits for GPS (since 1994) and GLONASS (since 2002), 30 s satellite clock corrections (GPS since 2000, GLONASS since 2008) and 5 s clock corrections (GPS since 2003, GLONASS since 2010).
- **A bias-dedicated reprocessing (1994-2016)**. Daily NEQ files containing GPS/GLONASS code bias parameters were collected for long-term code bias combination and subsequent realignment of the daily code bias estimates. A consistent time series of GIMs with a 1-hour resolution is an important by-product of this extra reprocessing effort.

Referencing CODE products

The products from CODE (ultra-rapid, rapid, final, MGEX and Repro15 series) are referable as:

Dach, R., Schaer, S., Arnold, D., Prange, L., Sidorov, D., Sušnik, A., Villiger, A. and Jäggi, A. (2017). CODE ultra-rapid product series for the IGS. Published by Astronomical Institute, University of Bern.
DOI: 10.7892/boris.75676.1
URL: `http://www.aiub.unibe.ch/download/CODE`

Dach, R., Schaer, S., Arnold, D., Prange, L., Sidorov, D., Sušnik, A., Villiger, A. and Jäggi, A. (2017). CODE rapid product series for the IGS. Published by Astronomical Institute, University of Bern.
DOI: 10.7892/boris.75854.1
URL: `http://www.aiub.unibe.ch/download/CODE`

Dach, R., Schaer, S., Arnold, D., Prange, L., Sidorov, D., Sušnik, A., Villiger, A. and Jäggi, A. (2017). CODE final product series for the IGS. Published by Astronomical Institute, University of Bern.
DOI: 10.7892/boris.75876.2
URL: `http://www.aiub.unibe.ch/download/CODE`

Prange, L., Sušnik, A., Arnold, D., Dach, R., Schaer, S., Sidorov, D., Villiger, A. and Jäggi, A. (2017). CODE product series for the IGS-MGEX project. Published by Astronomical Institute, University of Bern. **DOI: 10.7892/boris.75882.1**
URL: `http://www.aiub.unibe.ch/download/CODE_MGEX`

Sušnik, A., Dach, R., Villiger, A., Maier, A., Arnold, D., Schaer, S. and Jäggi, A. (2016). CODE reprocessing product series. Published by Astronomical Institute, University of Bern.
DOI: 10.7892/boris.80011
URL: `http://www.aiub.unibe.ch/download/REPRO_2015`

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