Activities at the CODE Analysis Center

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IGS WS2018: PS01

International GNSS Service Workshop 2018
29 October - 2 November, 2018
Wuhan, China

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.

AIUB — Schweizerische Eidgenossenschaft / Confédération suisse / Confederazione Svizzera / Confederaziun svizra — Bundesamt für Landestopografie swisstopo / Office fédéral de topographie swisstopo / Ufficio federale di topografia swisstopo / Uffizi federal da topografia swisstopo — Bundesamt für Kartographie und Geodäsie — Technische Universität München

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.
Preference is given to RINEX3 data. Since September 2018 the RINEX3 data prevail over the RINEX2 data in the CODE IGS Final processing (Figure 3).
Regular contribution to IGS-MGEX since 2012 with a five-system solution: GPS + GLONASS + Galileo + BeiDou + QZSS (see poster of Prange et al. in session "PS06: MGEX and IGMA").
Continuous parameterization, particularly for Earth orientation parameters (EOP, Figure 4), troposphere zenith path delays (ZPD) and horizontal gradients, as well as for ionosphere parameters (Figure 5), 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 6). 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.
GNSS ambiguity resolution: double-difference 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 based on the combination of clock and ionosphere analysis results.
GLONASS frequency numbers are verified.
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 scripts including instant alerting in case of processing and technical failures, general data flow problems, changes in the GNSS constellations.

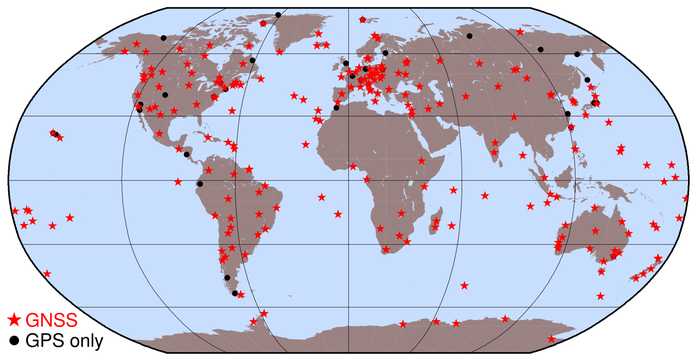

Figure 1: Tracking network as considered in CODE's GNSS final analysis by October 2018. About 88% of the sites support GLONASS.

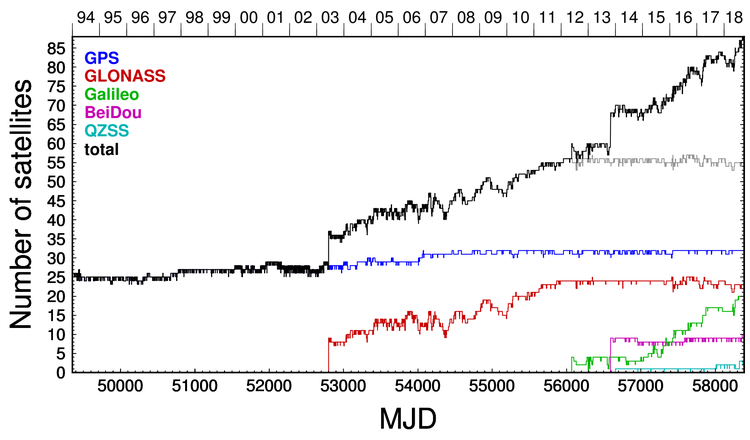

Figure 2: Number of GNSS satellites since 1994 as considered in CODE's final and MGEX analyses.

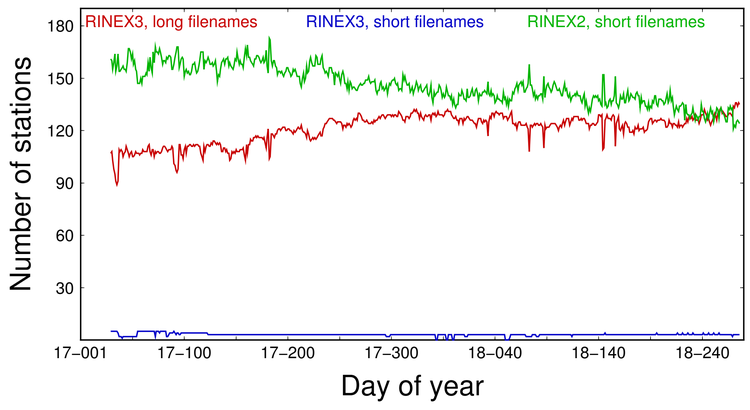

Figure 3: RINEX2 and RINEX3 observation data usage in the CODE IGS final processing.

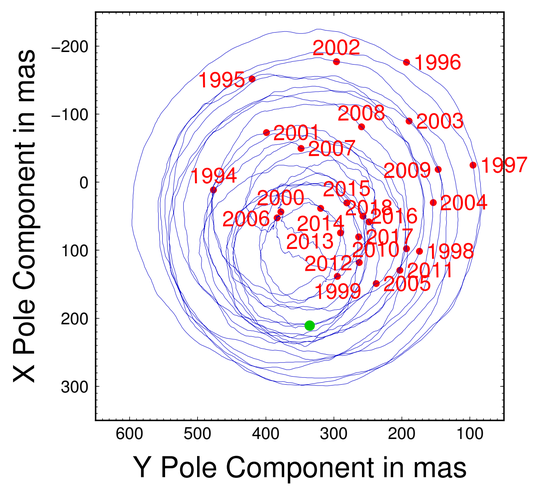

Figure 4: Polar motion from 19-Jul-1993 to 29-Sep-2018 as monitored by CODE.

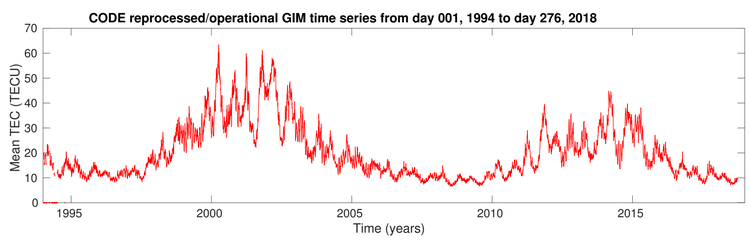

Figure 5: Global mean TEC extracted from the Global Ionosphere Maps (GIMs) produced by CODE. This particular daily time series, meanwhile covering two solar cycles, was created on the basis of hourly GIMs obtained as a by-product from a bias-dedicated GPS/GLONASS reprocessing (1994-2016) effort. Note that those 1994 GIM solutions without global coverage are indicated with zero values.

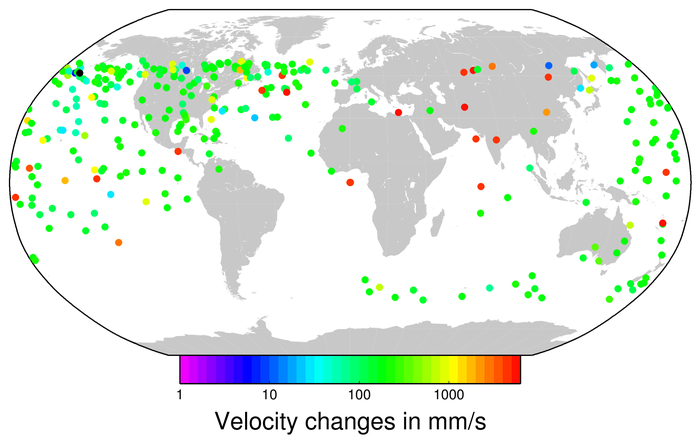

Figure 6: Geographical locations of all repositioning events of GPS satellites since 2004 as determined by CODE.

Most important new developments and model changes

New ambiguity-fixed clock products. The generation of a high-quality signal-specific phase bias product and a fully consistent ambiguity-fixed clock product could be established within the IGS-related processing at CODE. The new clock products have been submitted to the IGS starting with GPS week 2004 (June 3, 2018) for our IGS rapid and final product lines and starting with GPS week 2006 (July 17, 2018) for our multi-GNSS clock product contribution to MGEX. The CODE MGEX (COM) clock product does include ambiguity fixing not only for GPS but also for Galileo.
This quantum leap in GNSS clock analysis at CODE could be accomplished due to successful between-satellite ambiguity fixing using undifferenced observation data of the IGS receiver network. The new CODE clock products reveal a notably improved quality (see Figure 7) and, in the end, allow for single-receiver ambiguity resolution, thus enabling integer-PPP (IPPP).
Our new clock and bias products are conditioned in a way that maximum consistency may be ensured for ambiguity-float, ambiguity-fixed, and pseudorange-supported PPP applications. In any case, the clock product has to be used in conjunction with the associated phase and pseudorange bias product (generated in Bias-SINEX V1.00) in order to achieve best possible performance. All described GNSS clock and bias product features are accomplished using our development version of Bernese GNSS Software (V5.3).

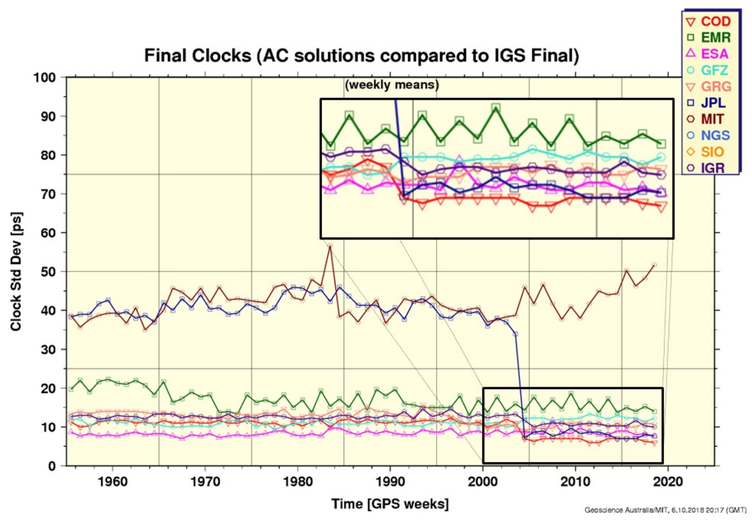

Figure 7: IGS Final clock comparison (`http://acc.igs.org`). The Clock Std Dev plot shows the standard deviations (ps) of the individual AC clock solutions with respect to the IGS Final products. Ambiguity fixing is accomplished in the CODE final clock product starting with GPS week 2004.

Model changes with respect to MGEX:

- Attitude law for Galileo, albedo and antenna thrust for Galileo and QZSS activated since August 2017.
- Consideration of orbit normal (ON) mode and related SRP model for QZSS and BeiDou since July 2018 (see poster of Prange et al. in session PS06).

Details on recent developments at the CODE AC are available in the latest IGS Technical Reports.

Referencing CODE products

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

Dach, R., Schaer, S., Arnold, D., Prange, L., Sidorov, D., Stebler, P., Villiger, A. and Jäggi, A. (2018). CODE ultra-rapid product series for the IGS. Published by Astronomical Institute, University of Bern.
DOI: 10.7892/boris.75676.2
URL: `http://www.aiub.unibe.ch/download/CODE`

Dach, R., Schaer, S., Arnold, D., Prange, L., Sidorov, D., Stebler, P., Villiger, A. and Jäggi, A. (2018). CODE rapid product series for the IGS. Published by Astronomical Institute, University of Bern.
DOI: 10.7892/boris.75854.2
URL: `http://www.aiub.unibe.ch/download/CODE`

Dach, R., Schaer, S., Arnold, D., Prange, L., Sidorov, D., Stebler, P., Villiger, A. and Jäggi, A. (2018). CODE final product series for the IGS. Published by Astronomical Institute, University of Bern.
DOI: 10.7892/boris.75876.3
URL: `http://www.aiub.unibe.ch/download/CODE`

Prange, L., Arnold, D., Dach, R., Schaer, S., Sidorov, D., Stebler, P., Villiger, A. and Jäggi, A. (2018). CODE product series for the IGS-MGEX project. Published by Astronomical Institute, University of Bern. **DOI: 10.7892/boris.75882.2**
URL: `http://www.aiub.unibe.ch/download/CODE_MGEX`

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