Activities at the CODE Analysis Center

R. Dach[1], S. Schaer[2], D. Arnold[1], E. Brockmann[1], M. Kalarus[1], C. Kobel[1], M. Lasser[1], P. Stebler[1], A. Jäggi[1], and the Space Geodesy Research Group[1]

[1]Astronomical Institute, University of Bern, Switzerland
[2]Federal Office of Topography swisstopo, Wabern, Switzerland

IGS Symposium 2026: P2-1

International GNSS Service Symposium 2026
01 - 05 June 2026
Santiago de Chile, Chile

The CODE consortium

Four institutions compose the CODE consortium: the Astronomical Institute of the University of Bern (AIUB), Switzerland; the Swiss Federal Office of Topography (swisstopo); 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, GLONASS, and Galileo observations is performed in all operational product lines (GLONASS: since May 2003; Galileo: final since Nov. 2022, rapid since Sep. 2019), see Figures 1 and 2 .

Regular contribution to IGS-MGEX since 2012 with a five-system solution: GPS + GLONASS + Galileo + BeiDou + QZSS is generated and made available as well. Since March 2021, also the BeiDou-3 constellation is considered, see Figure 2 .

Three-day long-arc solutions are preferred for all product lines based on NEQ-stacking. The rapid solution is repeated in the afternoon by including the NEQ by the 12 UTC ultra-rapid.

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 GNSS satellites 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/d 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 IGc20 fiducial sites for consistent datum definition in the final, rapid, and ultra-rapid analysis chains.

GNSS ambiguity resolution: double-difference ambiguities are resolved for CDMA-based GNSS 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/Galileo-GPS bias parameters with respect to station coordinates and troposphere ZPD and gradients.
- Scaling factors for higher-order ionosphere (HOI) and (station-wise) for the deformation models as provided by Dill and Dobslaw (2013),
- 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.

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.

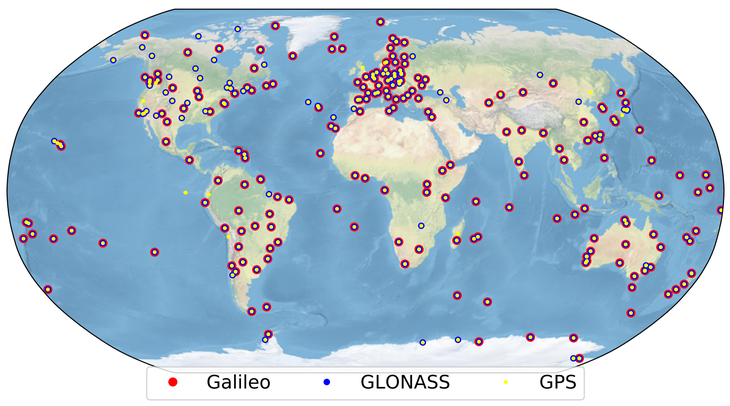

Figure 1: Tracking network as considered in CODE's GNSS final analysis in May 2026. About 74% of the tracking stations support all three systems (with the completely calibrated receiver antenna); about 6% of them only support GPS.

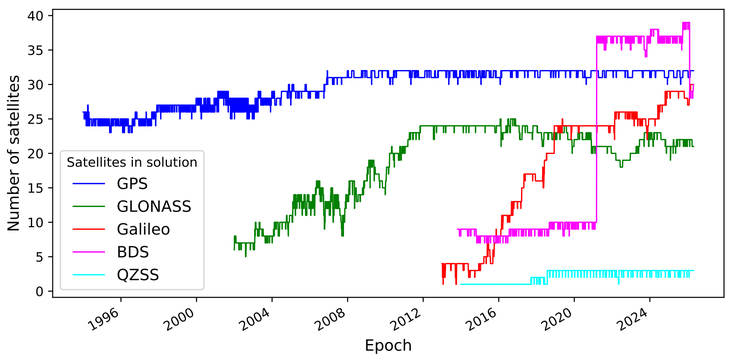

Figure 2: Number of GNSS satellites as considered in CODE's final and MGEX analyses.

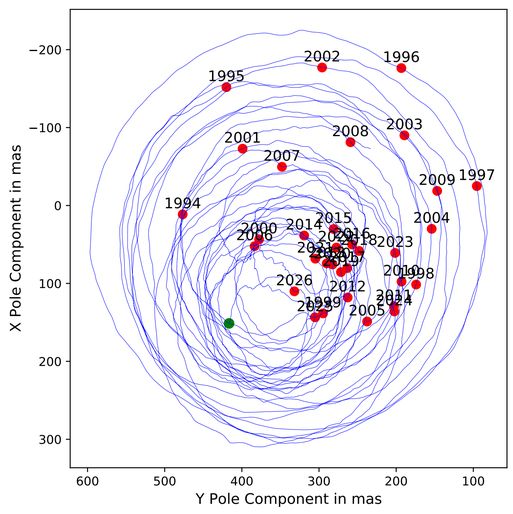

Figure 3: Polar motion from 19-Jul-1993 to 23-April-2026 as monitored by CODE.

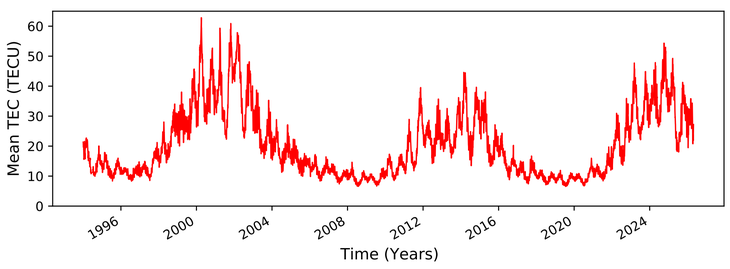

Figure 4: Global mean TEC extracted from the Global Ionosphere Maps (GIMs) produced by CODE. This particular daily time series, meanwhile covering nearly three solar cycles, was created on the basis of hourly GIMs obtained as a by-product from a bias-dedicated GNSS reprocessing effort.

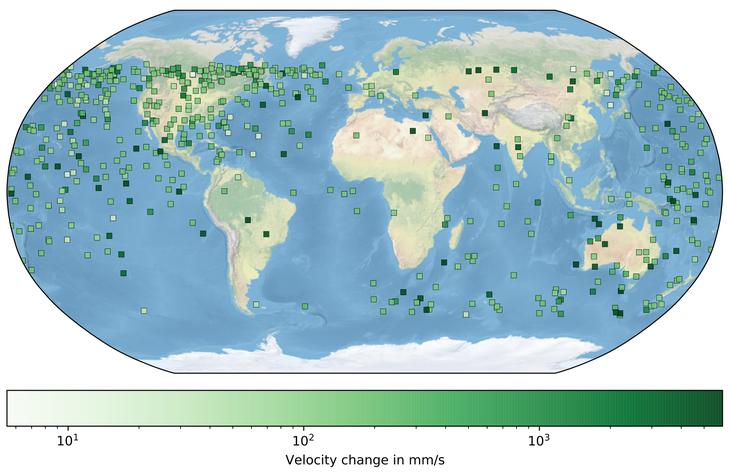

Figure 5: Geographical locations of all repositioning events of GPS satellites as determined by CODE since 2004.

CODE analysis product overview

	GNSS/Satellites	Stations
Ultra-rapid	**GPS+GLONASS+Galileo**; orbits: 5 min usually updated every 3 hours; including 24 h prediction	max. 100 sta; SINEX: CRD, ERP, GCC, SATA tropo SINEX: 2 h
Rapid	**GPS+GLONASS+Galileo**; orbits: 5 min; attitude: 30 sec satellite clocks: 30 sec; phase biases for PPP-AR (GE)	120 sta; SINEX: CRD, ERP, GCC, SATA station clocks: 5 min; tropo SINEX: 2 h
Final	**GPS+GLONASS+Galileo**; orbits: 5 min; attitude: 30 sec satellite clocks: 30&5 sec; phase biases for PPP-AR (GE)	ca. 320 sta; SINEX: CRD, ERP, GCC, SATA station clocks: 5 min; tropo SINEX: 2 h
MGEX	**GPS+GLO+GAL+BDS+QZSS**; orbits: 5 min; attitude: 30 sec satellite clocks: 30 sec; phase biases for PPP-AR (GECJ)	140 stations station clocks: 5 min

Selected recent developments, activities, and model changes

Updates concerning multi-GNSS PPP-AR

PPP-AR has been successfully provided for the operational CODE products for GPS and Galileo since-June 2018. QZSS was included in this regard from week May 2024 and BeiDou-3 finally from Feb. 8th, 2026 (together with the change from L2/L6 to L1/L5). QZSS has undergone a significant update on CODE side since beginning of March 2026 regarding the reference observables and the priority list of signal types. **A key element is that CODE generally generates phase-aligned phase biases**, specifically for all CDMA GNSS considered for PPP-AR:

G:	L1C/L1L/**L1W**/L2X	and L2L/L2S/**L2W**/L2
E:	**L1C**/L1X	and **L5Q**/L5X
C:	**L1P**/L1X	and **L5P**/L5X
J:	L1C/**L1L**/L1X	and L5P/**L5Q**/L5X

IGS ANTEX model updates at CODE

CODE is able to switch to updated IGS-ATX models on a daily basis (generally at the start day of a GPS week), declares the full model identifier used (IGS20_WWWW) in the analysis products, and also provides users with a corresponding (machine-readable) overview:

```
# PCV model   CODE ATX      ITRF   Year-day  Week  F  Remarks            20-May...
# ------------------------------------------------------------------------------
  IGS20       I20_2388      IGS20  2022-331  2238  U  IGS20_2353: G079 E227 E2...
  IGS20_2388  I20_2388      IGb20  2022-331  2238  U  IGS20_2353: G079 E227 E2...
  IGS20_2401  I20_2401      IGc20  2026-011  2401  C
  IGS20_2405  I20_2417      IGc20  2026-039  2405  C
  IGS20_2408  I20_2417      IGc20  2026-060  2408  U
  IGS20_2415  I20_2417      IGc20  2026-116  2416  U
  IGS20_2417  I20_2417/I20  IGc20  2026-130  2418  U  Current PCV model (I20.ATX)
#
# Legend:
#   F=Flag:
#     U=Updated (only new entries added)
#     C=Changed (existing entries modified)
```

Important note: The ATX files made available by CODE have for some time now also included a C05 extension for a significant number of receiver antenna calibrations (which is considered significant after the IGS-coordinated switch to L1/L5 for BeiDou-3 starting with GPS week 2405).

CODE OSB bias reference frame

As part of the work for [Villiger et al. 2019; DOI 10.1007/s00190-019-01262-w], the daily calculation of a NEQ-based long-term OSB combination solution (from 1994 onwards) was set up at CODE. Once a week, all daily bias NEQs are used to obtain uniformly aligned OSB values for the main signal types, specifically for all satellites and ground stations considered. This long-term cumulative solution can be addressed as OSB bias reference frame.

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

Dach, R., S. Schaer, et. al (2026). **Center for Orbit Determination in Europe (CODE) Analysis Center Technical Report 2025**. IGS Central Bureau and University of Bern, Bern Open Publishing, pp 65-81, May 2026. **DOI: 10.48350/93805**

Referencing CODE products

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

Dach, R., S. Schaer, D. Arnold, E. Brockmann, M. Kalarus, C. Kobel, M. Lasser, P. Stebler, A. Jäggi (2026). CODE ultra-rapid product series for the IGS. Published by Astronomical Institute, University of Bern. **DOI: 10.48620/97774**
URL: `http://www.aiub.unibe.ch/download/CODE`

Dach, R., S. Schaer, D. Arnold, E. Brockmann, M. Kalarus, C. Kobel, M. Lasser, P. Stebler, A. Jäggi (2026). CODE rapid product series for the IGS. Published by Astronomical Institute, University of Bern. **DOI: 10.48620/97772**
URL: `http://www.aiub.unibe.ch/download/CODE`

Dach, R., S. Schaer, D. Arnold, E. Brockmann, M. Kalarus, C. Kobel, M. Lasser, P. Stebler, A. Jäggi (2026). CODE final product series for the IGS. Published by Astronomical Institute, University of Bern. **DOI: 10.48620/97773**
URL: `http://www.aiub.unibe.ch/download/CODE`

Dach, R., S. Schaer, D. Arnold, E. Brockmann, M. Kalarus, C. Kobel, M. Lasser, P. Stebler, A. Jäggi (2026). CODE product series for the IGS MGEX project. Published by Astronomical Institute, University of Bern. **DOI: 10.48620/97775**
URL: `http://www.aiub.unibe.ch/download/CODE_MGEX`

Poster compiled by R. Dach, May 2026
Astronomical Institute, University of Bern, Bern
rolf.dach@unibe.ch

Contact address
Rolf Dach
Astronomical Institute, University of Bern
Sidlerstrasse 5
3012 Bern (Switzerland)
code@aiub.unibe.ch

Posters and other publications from the AIUB Space Geodesy Group:
http://www.bernese.unibe.ch/publist