

Multi-GNSS Working Group Technical Report 2021

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1 Introduction

As in the previous years, the major task of the Multi-GNSS Working Group (MGWG) is the Multi-GNSS Pilot Project (MGEX). Furthermore, the MGWG supported the development of the RINEX 4.00 navigation file format providing additional information included in modernized navigation messages: CNAV and CNAV-2 for GPS and QZSS as well as CNAV-1/2/3 for BeiDou-3. More details are given in the report of the RINEX Working Group. Ningbo Wang joined the MGWG in 2021 as representative for CAS providing differential code biases to MGEX since many years.

2 GNSS Evolution

The GNSS satellite launches of 2021 are given in Table 1. Compared to the previous years, launch activities were pretty low. The fifth GPS III satellite nicknamed *Neil Armstrong* was launched in June 2021 but was still in testing as of December 2021. QZS-1R is the replenishment for the first QZSS satellite in an inclined geo-synchronous orbit (IGSO). It is the first satellite capable of transmitting the L1C/B signal ([IS-QZSS-PNT-004, 2021](#)) that is supported in the RINEX format starting with version 4.00. Whereas L1C/B was transmitted during the in-orbit testing of QZS-1R, regular signal transmission is not expected before 2023. After a break of three years, two Galileo satellites were launched in December 2021. However, transmission of navigation signals did not start in 2021.

In 2021, three GPS Interface Specification documents were updated ([IS-GPS-200M, 2021](#); [IS-GPS-705H, 2021](#); [IS-GPS-800H, 2021](#)). A new version of the Galileo Interface Control Document (ICD) was published in January 2021 ([European Union, 2021c](#)). With this issue, three new

Table 1: GNSS satellite launches in 2021.

Date	Satellite	Type
17 Jun 2021	GPS III	MEO
26 Oct 2021	QZS-1R	IGSO
01 Dec 2021	Galileo FOC FM23/4	MEO

features are introduced to the I/NAV message transmitted within the Galileo E1 Open Service signal (Secondary Synchronisation Pattern, Reduced Clock and Ephemeris and Reed-Solomon Outer Forward Error Correction). The Service Definition Document for the Galileo Open Service was updated in November 2021 (European Union, 2021d).

In May 2021, a test campaign for the Galileo High Accuracy Service (HAS; European GNSS Agency, 2020) started with transmission of corresponding corrections on the data component of the E6 signal. A test campaign was also conducted for the Galileo Open Service Navigation Message Authentication (OSNMA). A dedicated ICD for this test phase was published by European Union (2021a) accompanied by corresponding receiver guidelines (European Union, 2021b).

3 Network

As of January 2022, the IGS multi-GNSS tracking network comprises 370 stations, see Figs. 1 and 2. 10 stations are completely dormant and did not provide any observations in 2021.

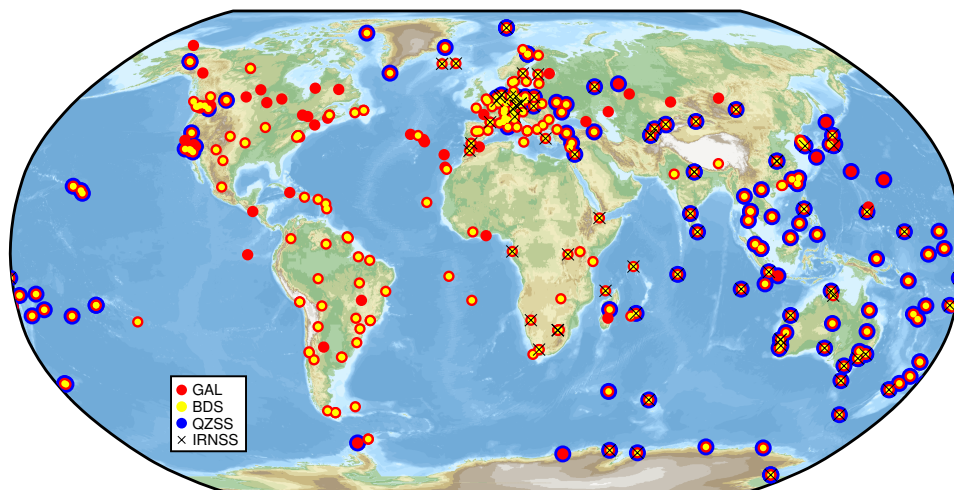


Figure 1: Distribution of IGS multi-GNSS stations supporting tracking of Galileo (red), BeiDou (yellow), QZSS (blue), and IRNSS (black crosses) as of January 2022.

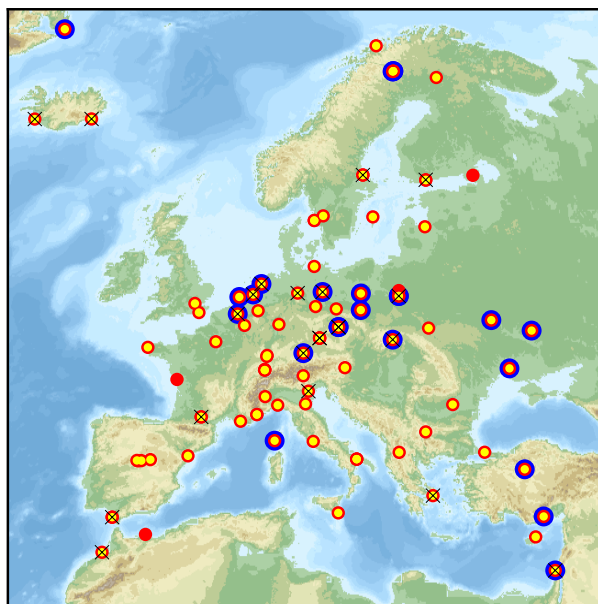


Figure 2: Distribution of European IGS multi-GNSS stations as of January 2022. See Fig. 1 for explanation of individual station labels.

4 Products

As of December 2021, five MGEX analysis centers (CODE, GFZ, IAC, SHAO, WU) provide orbit and clock products for the full range of global navigation systems, namely GPS, GLONASS, Galileo and BeiDou. Four of them, in addition, include the regional QZSS, see Table 2.

Table 2: Analysis centers contributing to IGS MGEX.

Institution	Abbr.	GNSS
CNES/CLS	GRG0MGXF IN	GPS+GLO+GAL
CODE	COD0MGXF IN	GPS+GLO+GAL+BDS2+BDS3+QZS
GFZ	GFZ0MGXRAP	GPS+GLO+GAL+BDS2+BDS3+QZS
IAC	IAC0MGXF IN	GPS+GLO+GAL+BDS2+BDS3+QZS
JAXA	JAX0MGXRAP	GPS+GLO+QZS
SHAO	SHA0MGXRAP	GPS+GLO+GAL+BDS2+BDS3
Wuhan University	WUM0MGXF IN	GPS+GLO+GAL+BDS2+BDS3+QZS

Changes in MGEX products:

- 024/2021: switch from 15 min to 5 min orbit sampling for CNES/CLS
- 066/2021: inclusion of BDS-3 in CODE products

- Switch of **CODE** products from IGB14 reference frame and igs14.atx antenna calibrations to repro3 reference frame (IGS14R3) and extended igsR3.atx file including BeiDou and QZSS antenna calibrations as well as antenna phase center offsets for all GPS III satellites provided by the manufacturer Lockheed Martin.
- 136/2021: **CNES/CLS** starts provision of observable-specific biases compatible with their MGEX orbit and clock products ([Loyer, 2021](#))
- 167/2021: **GFZ** provides uncalibrated phase delays as comment line in their clock products allowing for un-differenced ambiguity resolution ([Deng, 2021](#)). In addition, attitude information for all GPS, GLONASS, Galileo, BeiDou and QZSS satellites are provided in ORBEX format ([Loyer et al., 2019](#)).

Multi-GNSS differential code bias (DCB) products are generated by **CAS** (daily rapid product) and **DLR** (quarterly final product). Inclusion of BeiDou DCBs related to the BDS-3 signals B1C, B2a, and B2b, namely C2I-C1P, C2I-C5P, C2I-C7D DCBs started with the fourth quarter for the DLR product.

5 Satellite Metadata

The MGWG maintains the IGS satellite metadata file available at https://files.igs.org/pub/station/general/igs_satellite_metadata.snx. Cabinet Office, Government of Japan released detailed metadata for the new QZS-1R satellite three weeks after launch ([Cabinet Office, 2021](#)). Metadata for the two Galileo satellites launched in December 2021 are not yet available at the European GNSS Service Centre but mass and center of mass values are published on the website of the International Laser Ranging Service (ILRS) at https://ilrs.cddis.eosdis.nasa.gov/missions/satellite_missions/current_missions/galileo_all_com.html. However, SLR tracking of these satellites has not yet started as of January 2022.

Acronyms

CAS	Chinese Academy of Sciences
CLS	Collecte Localisation Satellites
CNES	Centre National d'Etudes Spatiales
CODE	Center for Orbit Determination in Europe
DLR	Deutsches Zentrum für Luft- und Raumfahrt
GFZ	Deutsches GeoForschungsZentrum
IAC	Information and Analysis Center for Positioning, Navigation and Timing
JAXA	Japan Aerospace Exploration Agency
SHAO	Shanghai Observatory

WU Wuhan University

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