

# Galileo and its Outage in July 2019 from the IGS-MGEX Perspective

**G. Beutler**

*IAG representative on PNT Advisory Board*

**with contributions from**

*Rolf Dach, Lars Prange, Arturo Villiger*

*Astronomical Institute, University of Bern (AIUB)*

and

**Oliver Montenbruck and Peter Steigenberger**

*German Space Operations Center (DLR), Oberpfaffenhofen*

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**The Hilton Hotel**

**15150 North Atlantic Avenue**

**Cocoa Beach, Fl 32931-3268, USA**

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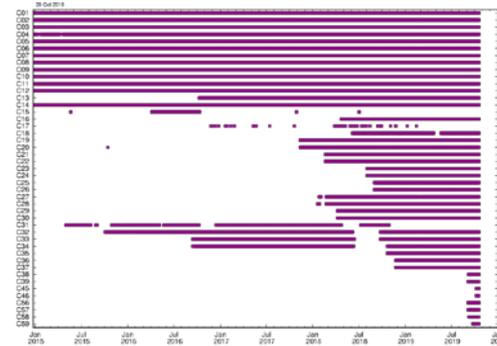
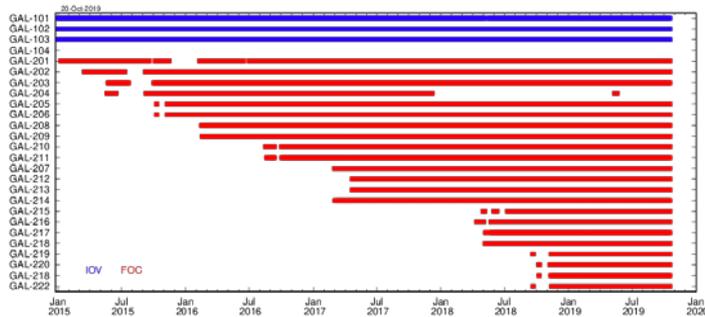
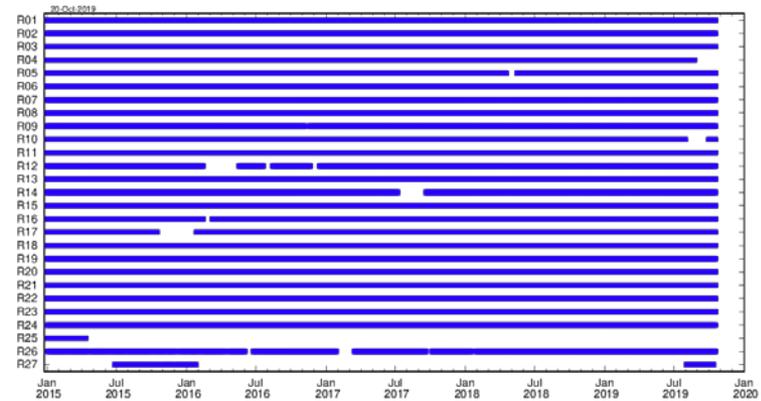
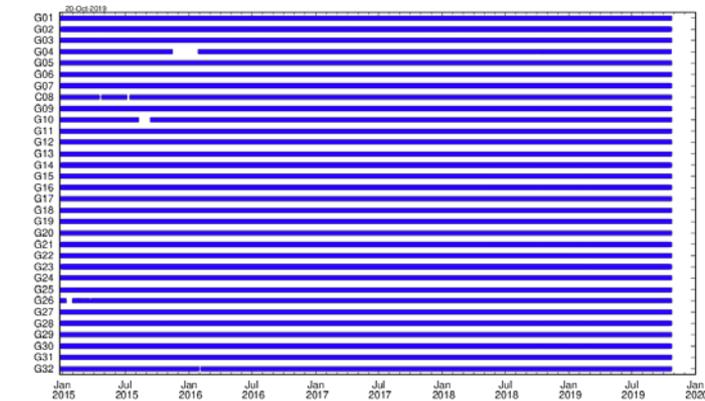


# Content

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# GNSS Status 2019



The Multi-GNSS Experiment (MGEX) of the International GNSS Service (IGS) monitors the performance of all GNSS. The figures show the system-specific data availability since 2015. (Top, left): GPS; (top, right): GLONASS; (bottom, left): Galileo; (bottom, right): BeiDou. **No data gap visible for Galileo in 2019**

# GNSS News from MGEX

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2019/09/22	Launch of two BeiDou-3 MEO satellites
2019/08/22	Launch of the second GPS III satellite
2019/06/24	Launch of a BeiDou-3 IGSO satellite
2019/05/27	Launch of a GLONASS-M+ satellite
2019/05/17	Launch of a BeiDou-2 GEO satellite
2019/04/20	Launch of first BeiDou-3 IGSO satellite
2018/12/27	Start of BeiDou global service
2018/12/23	Launch of the first GPS III satellite

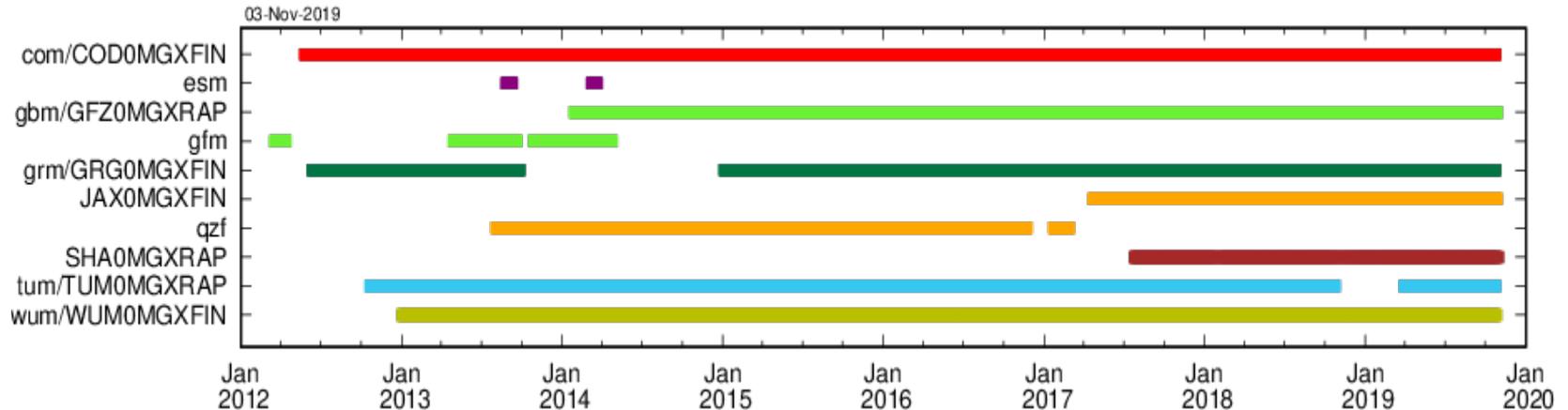
**News concerning all GNSS, broadcast by the IGS-MGEX (see homepage)**

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# IGS/MGEX Analysis Centers



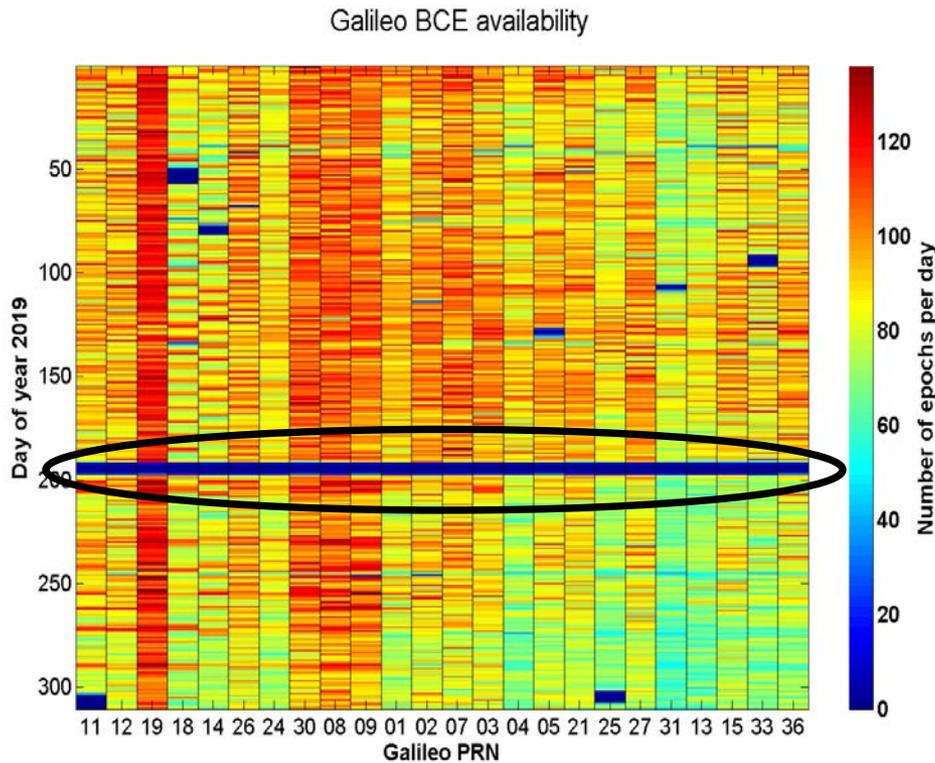
**Seven analysis centers regularly contribute to MGEX.**

**Five centers generate Galileo products: CODE, GFZ, CNES (GRG), Shanghai Observatory (SHA0), Wuhan University (WUM).**

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# Broadcast Messages from MGEX



From Peter Steigenberger, private communication

IGS-MGEX operates a repository for all broadcast messages of all GNSS.

The figure documents that no broadcast ephemerides (**BCE**) are available for Galileo from July 12 to July 17 (doy 193-198).

Galileo sends out broadcast messages at maximum at a rate of 1 message/10 min, corresponding to 144 messages per day.

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# Galileo Outage 2019

<https://www.gsc-europa.eu/system-status/user-notifications-archive>  
<https://www.gsc-europa.eu/about-the-gsc/news>

<a href="#">NAGU Number</a>	<a href="#">Satellite Name</a>	<a href="#">Date of start event (UTC)</a>	<a href="#">NAGU date of publication (UTC)</a>	<a href="#">NAGU Type</a>	<a href="#">NAGU Subject</a>
<a href="#">2019028</a>	ALL	2019-07-22 18:00	2019-07-22 18:50	GENERAL	SERVICE RESTORED
<a href="#">2019027</a>	ALL	2019-07-17 21:52	2019-07-18 09:20	GENERAL	SERVICE RESTORED (POTENTIAL INSTABILITY)
<a href="#">2019026</a>	ALL	2019-07-12 02:50	2019-07-13 21:15	GENERAL	SERVICE OUTAGE
<a href="#">2019025</a>	ALL	2019-07-11 02:00	2019-07-11 15:45	GENERAL	SERVICE DEGRADATION

**Galileo outage 2019 July 11 to July 18(22), 2019, according to Galileo NAGUs: System "dead" for users relying on broadcast messages!**

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# Galileo Outage 2019

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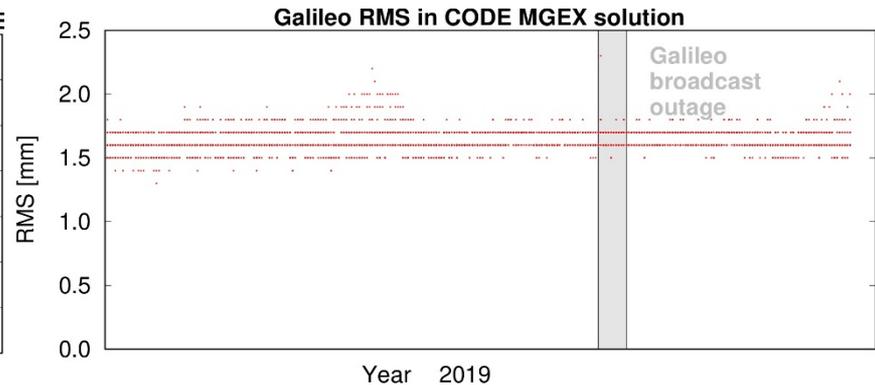
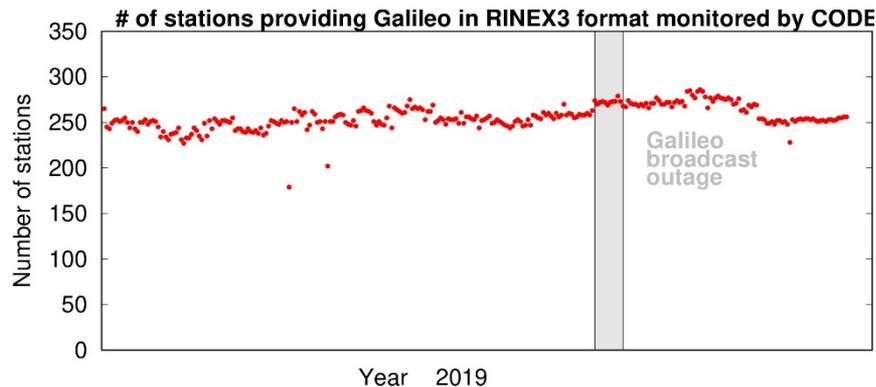
How was the Galileo incident experienced by the scientific users of Galileo? Key differences of "science" vs. "normal" use:

- the phase (and code) measurements on at least two carriers are used.
- the GNSS broadcast messages are skipped and replaced by the IGS-MGEX precise satellite orbit and clock information.

The **quality of the IGS/MGEX orbits** emerges, e.g., from **orbit misclosures** at day boundaries.

The **quality of the satellite clock** emerges, e.g., from the **standard deviation of a linear fit of the satellite-specific clock corrections** over one day.

# Galileo Measurements



**Left:** Number of stations tracking Galileo available in CODE analysis.

**Right:** Galileo-specific standard deviation of double-difference phase observable (ionosphere-free linear combination) in CODE MGEX 1-day analysis.

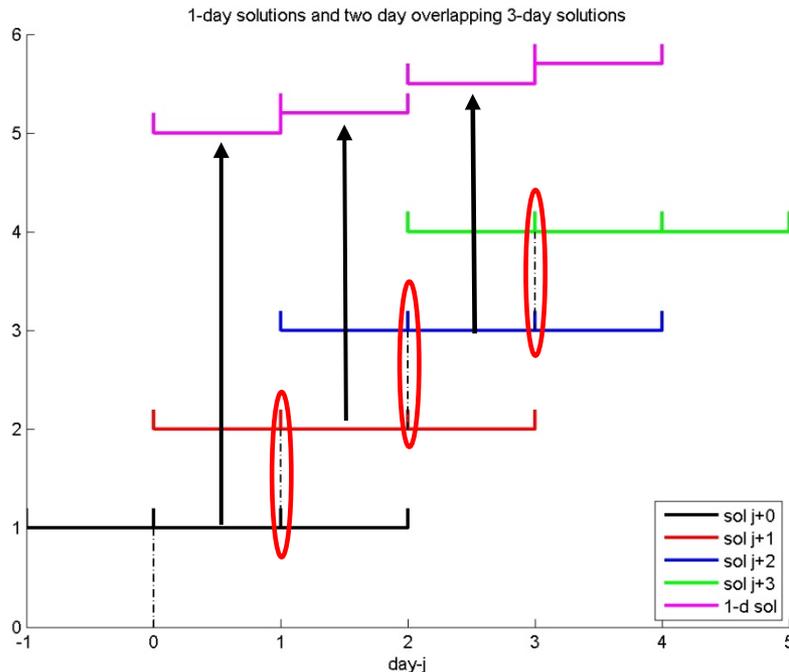
**→ No variations exceeding normal fluctuations.**

**(Information from CODE analysis)**

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# Orbit Quality

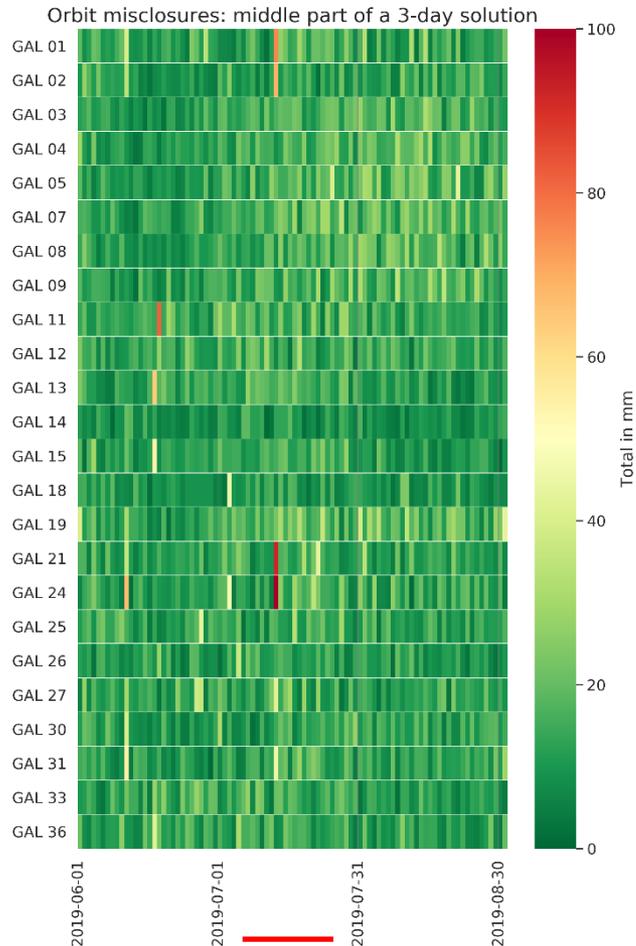


Central days from overlapping  
3-day orbits (**magenta**):

3-day orbits (e.g., black, **red**,  
**blue**) are generated for  
each day by the CODE  
Analysis Center of the IGS.

**Orbit Misclosure**: difference  
of satellite positions at day  
boundaries, e.g., red-black  
@ day 1, blue-red @ day 2,  
etc.

# Galileo Orbit Misclosures Jun-Aug 2019



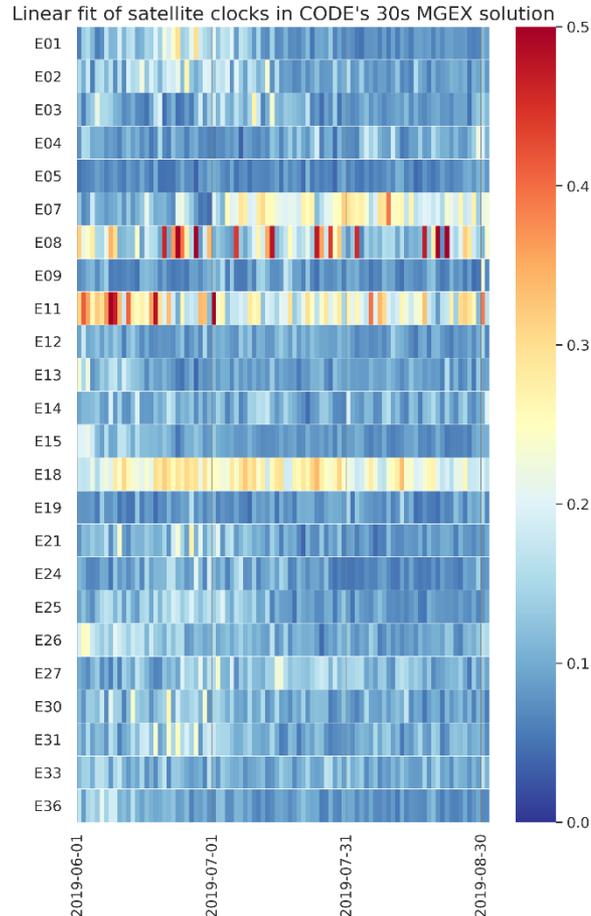
**Daily 3-day solutions from  
CODE Analysis Center**

**Galileo orbit misclosures** at day  
boundaries of central day  
between subsequent days.

**Misclosures are of the order of  
1.5-2.5 cm, very few outliers**

→ **No problems between July 11  
and July 22 (red bar)**

# Galileo Clock Performance 2019



**Standard deviation of linear fit of Galileo satellite clocks over central day (from CODE 3-day solutions)**

**Standard deviations are of the order of 0.1 ns \*) or below.**

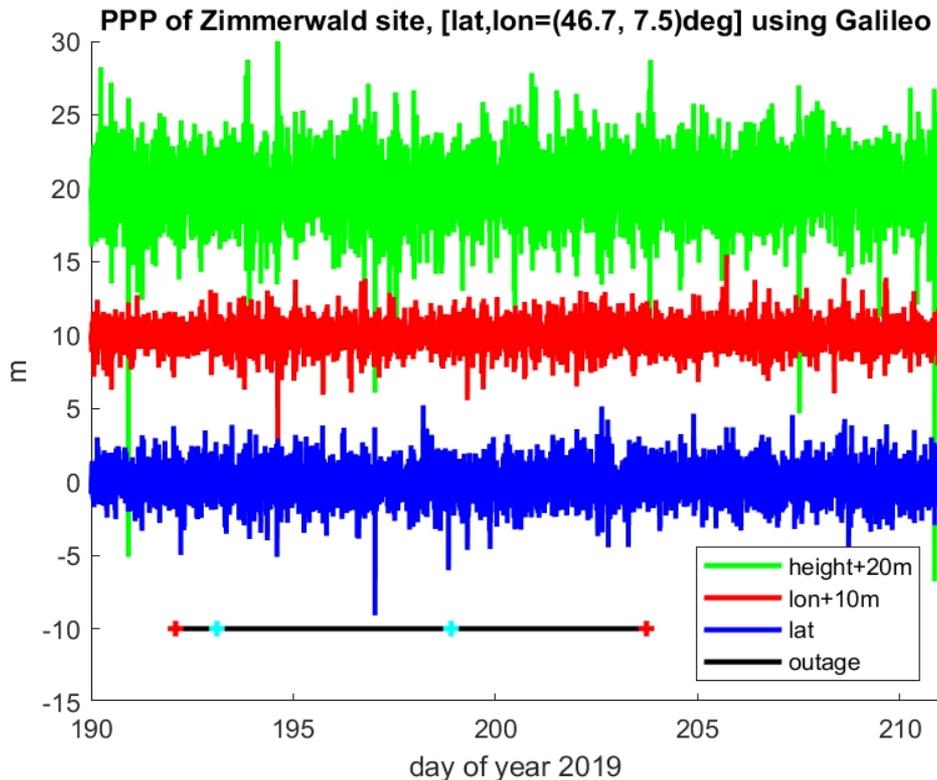
**The performance is typical for the Galileo Masers +)**

**No problems between July 11 and 22 (red bar)**

**\*) 1 ns =  $10^{-9}$ s**

**+ ) E11 runs on a rubidium clock**

# PPP with Galileo Code



Point Positioning with Galileo code observations, MGEX orbits & clocks.

Differences w.r.t. to mean position in **latitude**, **longitude(+10m)**, **height(+20m)**.

"+"-symbols mark time of outage according to NAGU subject:

- "+" : degradation and restored,
- "+": service outage, restored (potential instability)

→ MGEX products and solutions are ok!

# Galileo Outage 2019: Summary

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The **Galileo outage** in July 2019 was **not visible to the high-accuracy, post-processing user of Galileo**, implying that the **Galileo Space Segment was not affected**.

The **IGS-MGEX products** available through the IGS or through the IGS Analysis Centers **show no degradation of the Galileo orbit and satellite clock quality in July 2019**.

As opposed to the GLONASS incident in 2014 (Beutler et al., 2014), the **2019 Galileo BCE problem had no impact on the receiver tracking**.

Official information concerning the Galileo Status 2019 was presented at the ION-GNSS+ 2019 meeting (**Chartre & Benedicto, 2019**). The Galileo ground segment was identified as the source of problems.

**Galileo is included in CODE's Ultra- and Rapid- Product series since September 2019**.

**Galileo will soon leave the IGS-MGEX environment to become part of the IGS legacy/traditional solutions**, together with GPS & GLONASS.

# Acknowledgements & References

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## Acknowledgements:

Figures from slides 3—6 stem from IGS-MGEX

(<http://mgex.igs.org/>)

Figures on slides 9—13 were generated by the CODE Analysis Center of IGS

CODE stands for Center for Orbit Determination in Europe.

## References:

Beutler G, Dach R, Hugentobler U, Montenbruck O, Weber G, Brockmann E (2014). *The GLONASS April Fools' Event: What Went Wrong*. GPS World, June 24, 2014.

Chartre E, Benedicto J (2019). *2019 – Galileo Programme Update*. ION GNSS+ 2019, Miami, September 2019