

IPPP time transfer for UTC based on IGS continuous products

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UTC : What time is it?



The international reference time scale for all the applications is the

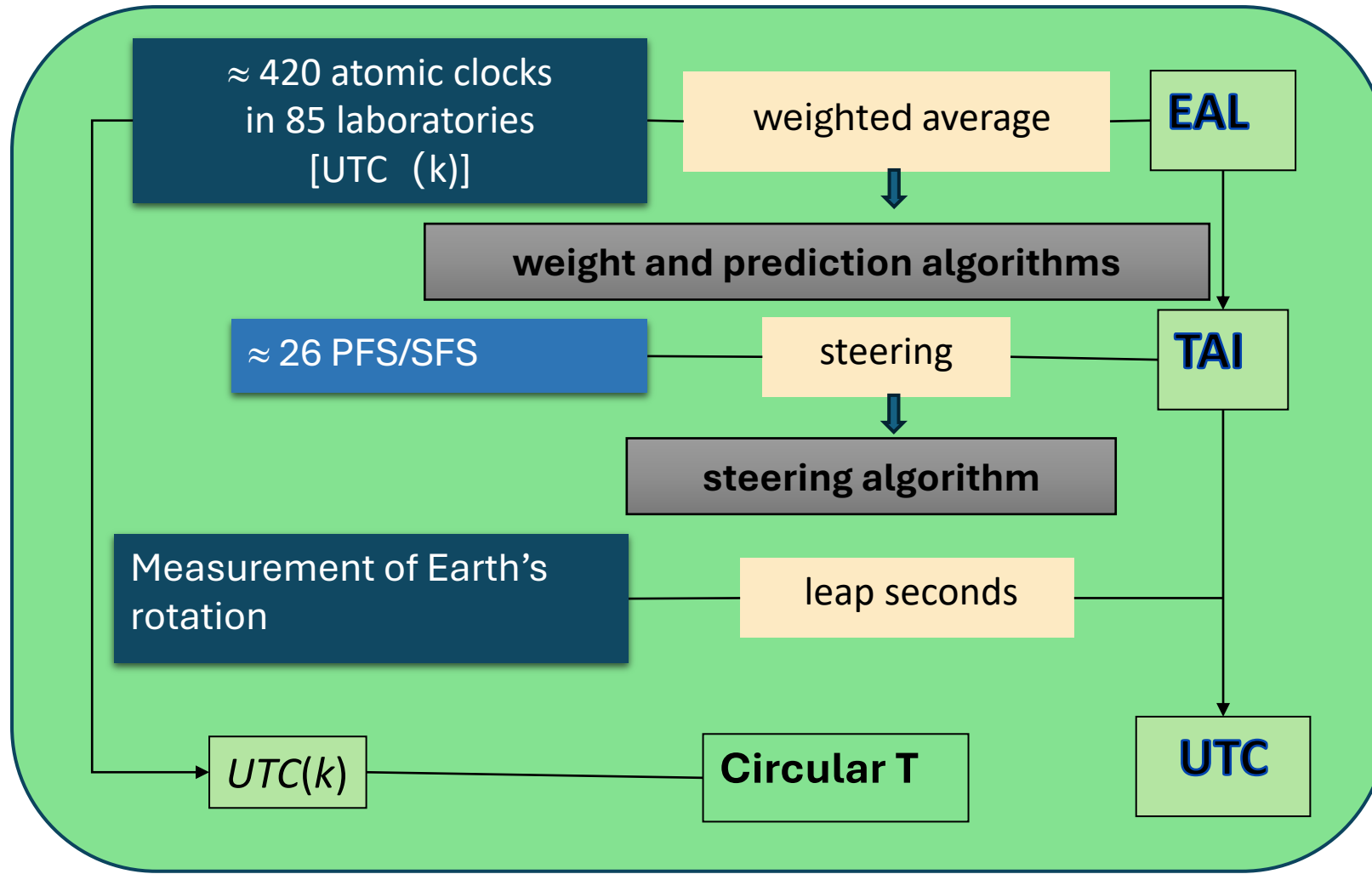
Coordinated Universal Time UTC

computed and distributed by the Bureau International des Poids et Mesures (BIPM) in Sevres, France,

based on the readings of very precise atomic clocks kept all over the world by timekeeping laboratories



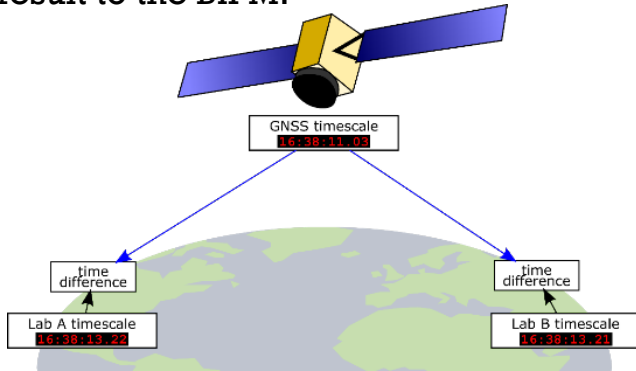
UTC: Calculations



UTC: Time Transfer

Global Navigation Satellite Systems (GNSS)

GNSS are based on time broadcasting from satellites (one-way time transfer). Distant labs equipped with GNSS receivers periodically compare their clocks to the broadcasted timescale and report the result to the BIPM.

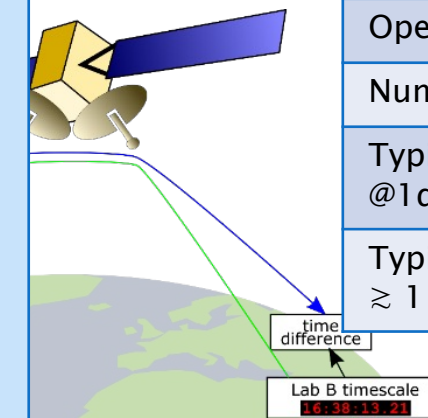


Progress in GNSS measures

GPS+ GLONASS + Beidou + Galileo
IPPP : Precise Point Positioning with
resolution

Two-Way Satellite Time & Freq. Transfer (TWSTFT)

Terminals simultaneously receive and transmit time signals (two-way time transfer) on geostationary telecom satellites. The system cancels out (at first order) the propagation time of the signals.



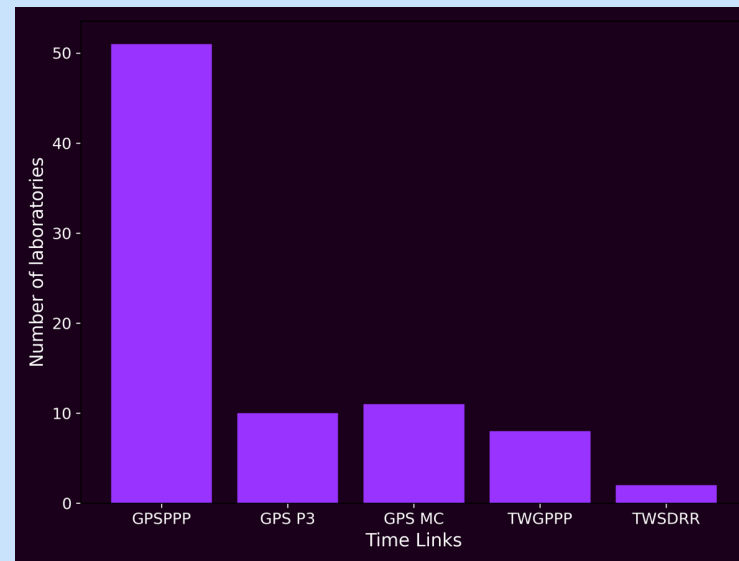
Operational since ~2000

Number of links : 18

Typical freq. transfer accuracy
@1d : a few 10-15

Typical time transfer accuracy :
 ≈ 1 ns

Example: July 2025 Circular T



In development : Optical Fiber links

A growing number of UTC laboratories are gaining access to fiber links dedicated to time and frequency. Although few of them are currently interconnected by operational, high-duty cycle links, this number is expected to grow quickly during the next decade.

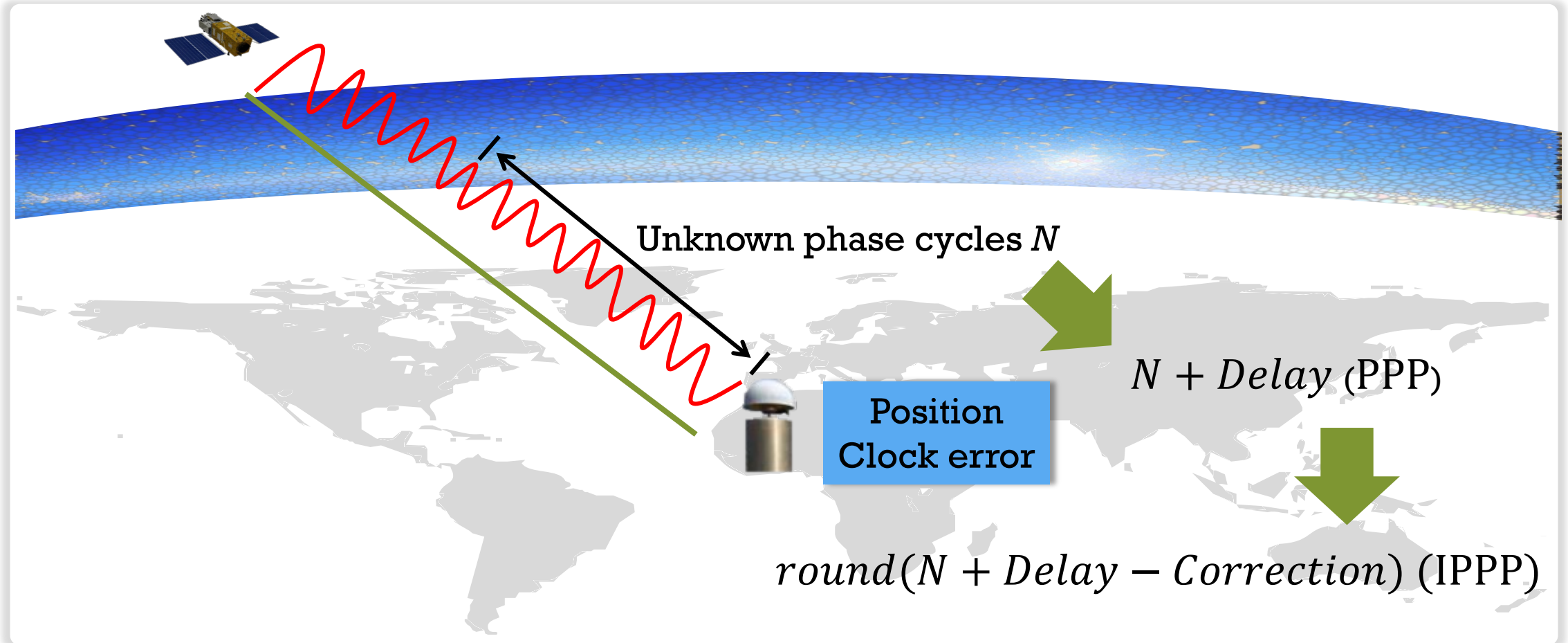


Motivation of applying IPPP

- ❑ PPP is one of the backbone of time transfer used for UTC computation.
- ❑ Is used in Circular T since 2009.
- ❑ In recent years Optically Frequency Standard (10^{-18} frequency stability) have entered the Circular T.
- ❑ Their performance is so good that PPP time transfer errors is one of the limiting factor of UTC quality.
- ❑ **Improving PPP** in Circular T means we **improve UTC**.

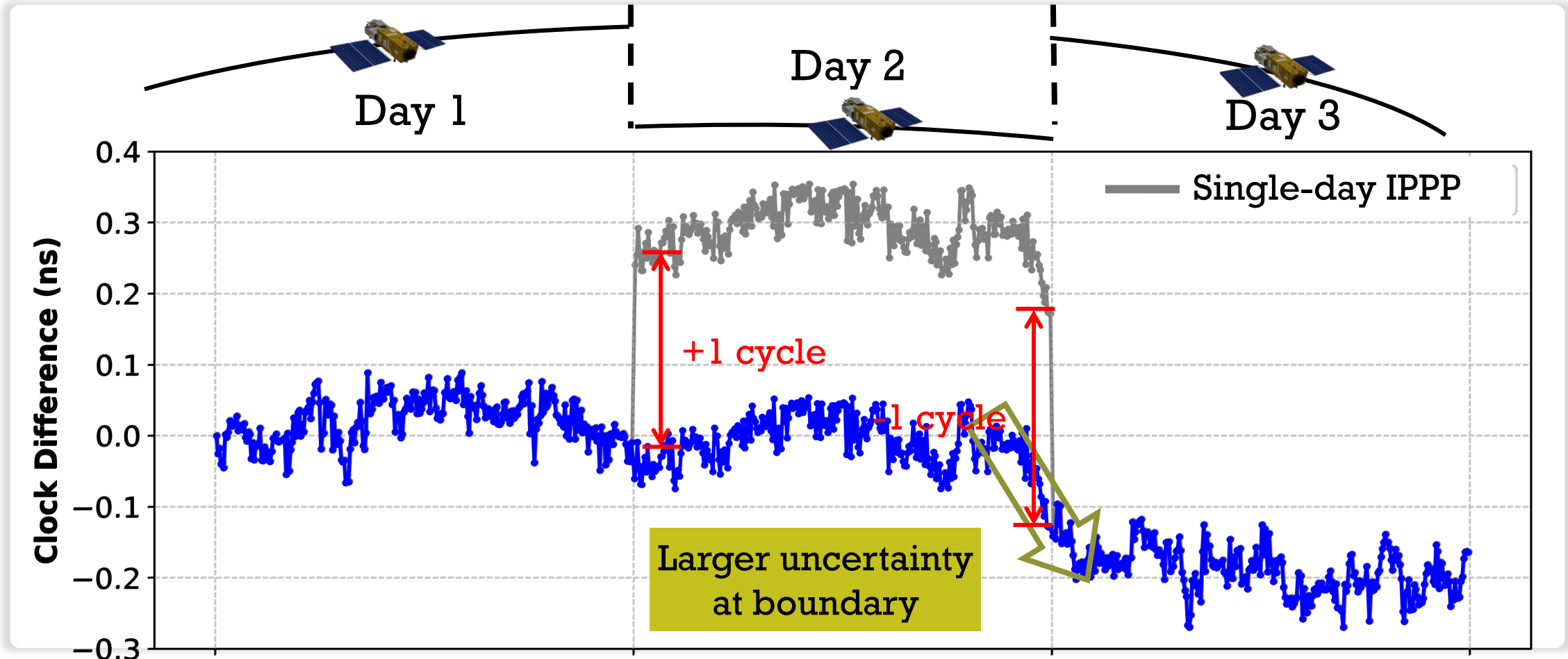
Integer Precise Point Positioning (PPP/IPPP)

- PPP is a technique that enables high-precision positioning and timing globally without any reference station



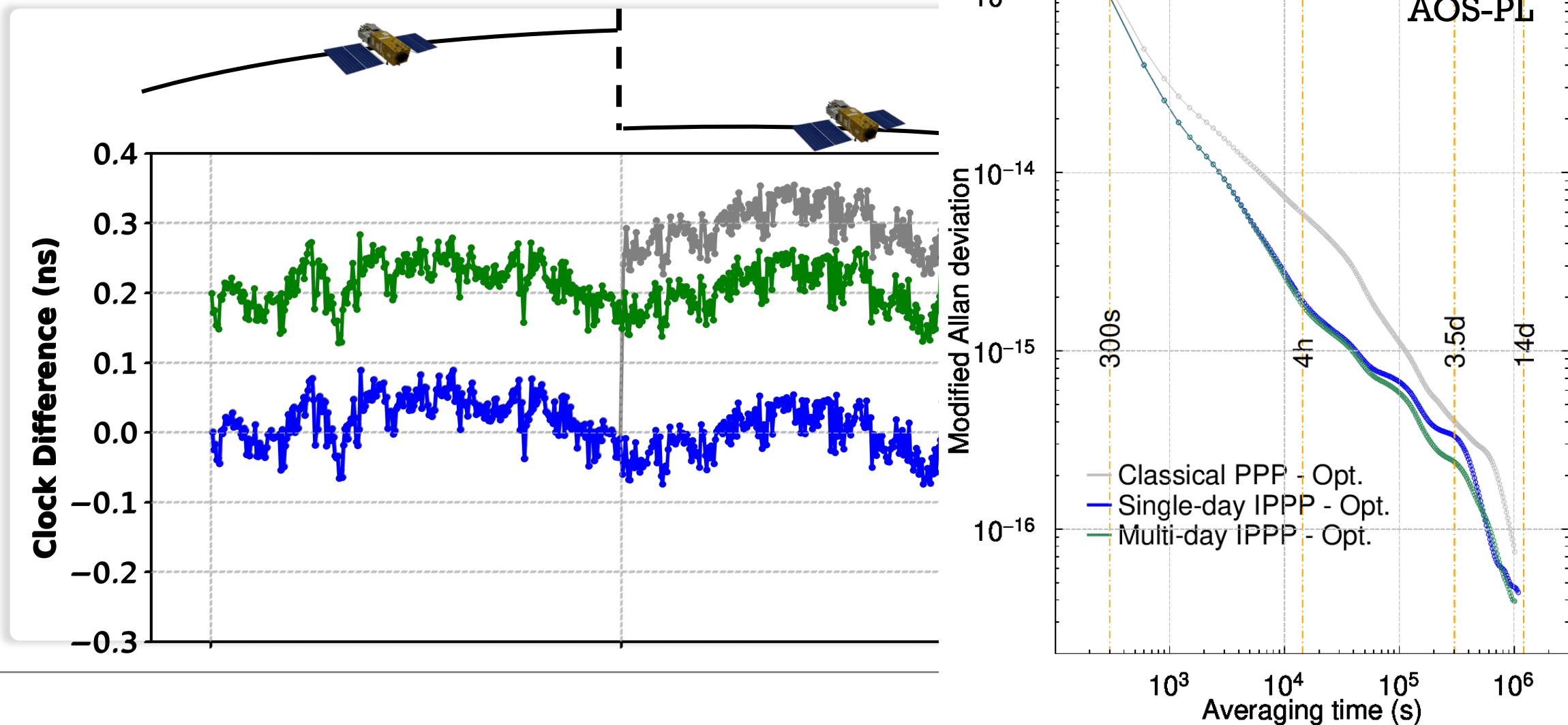
Single-day IPPP

- Classical IPPP employ **24-hour** batch processing to mitigate the impact of inter-day inconsistencies in precise satellite orbit and clock products.



Multi-day IPPP

- Multi-day IPPP eliminates day-boundary uncertainties but demands continuous satellite products across consecutive days (such as Wuhan Period)



Possible rapid IGS products for multi-day IPPP

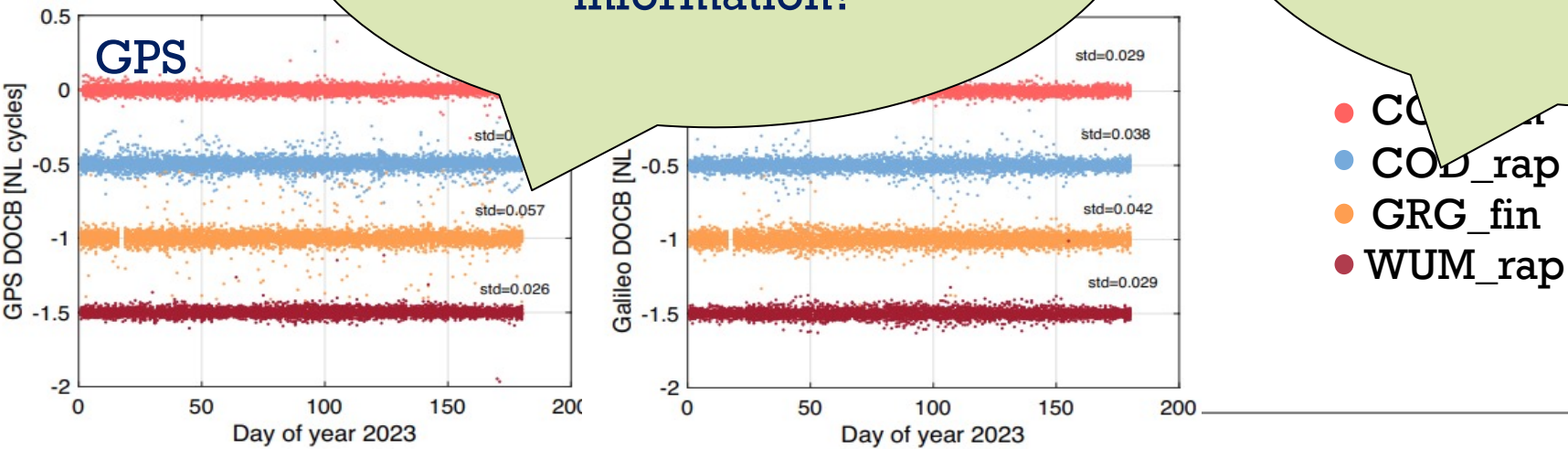
- ❑ Three rapid IGS products are assessed for precision and timeliness performance

Products	Constellations	Continuity	Latency
CODE (COD)	GPS (GPS)	Not always	5 days
CNES (GRG)	GPS (GPS)	Not always	
Wuhan (WUM)	GPS (GPS)	Not always	

Is it possible to have another aligned rapid products? More ACs provide the DOCB information?

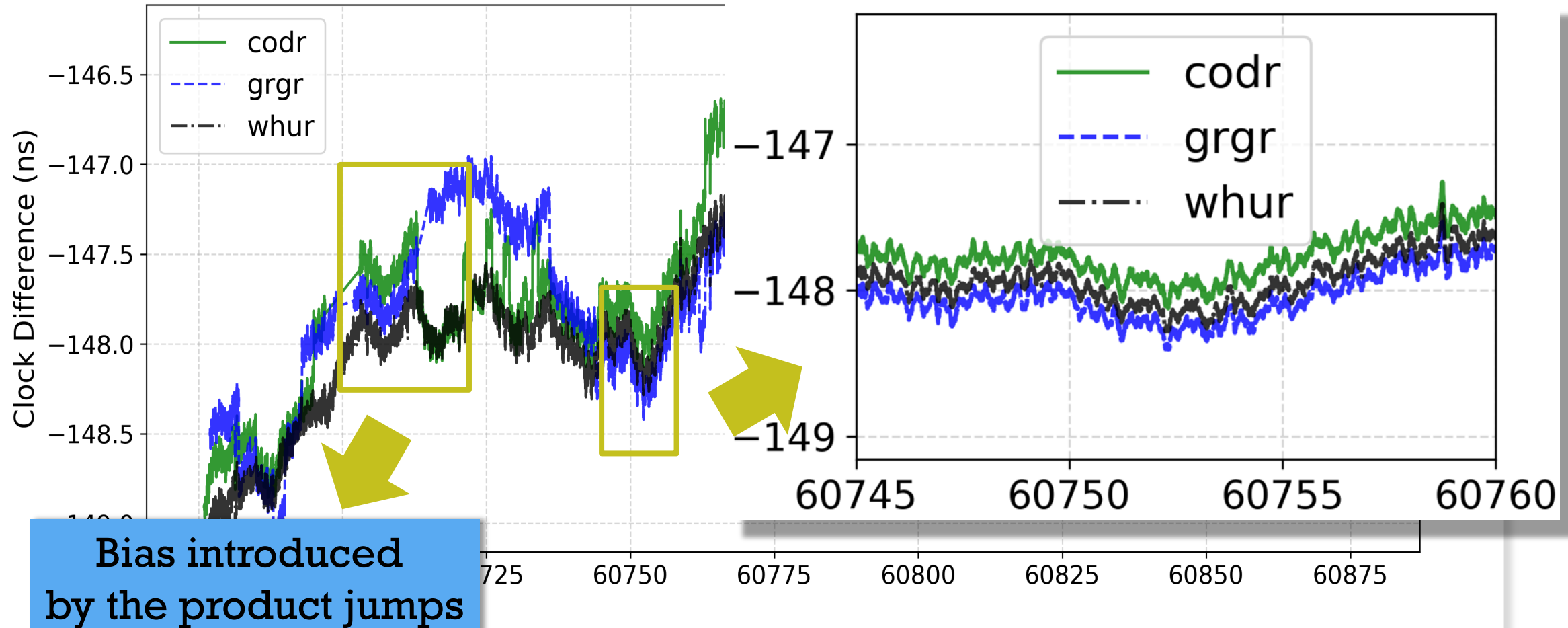
A recommendation was passed at ICG 19 last week. Encouraging the production of continuous clock products.

- ❑ Differences



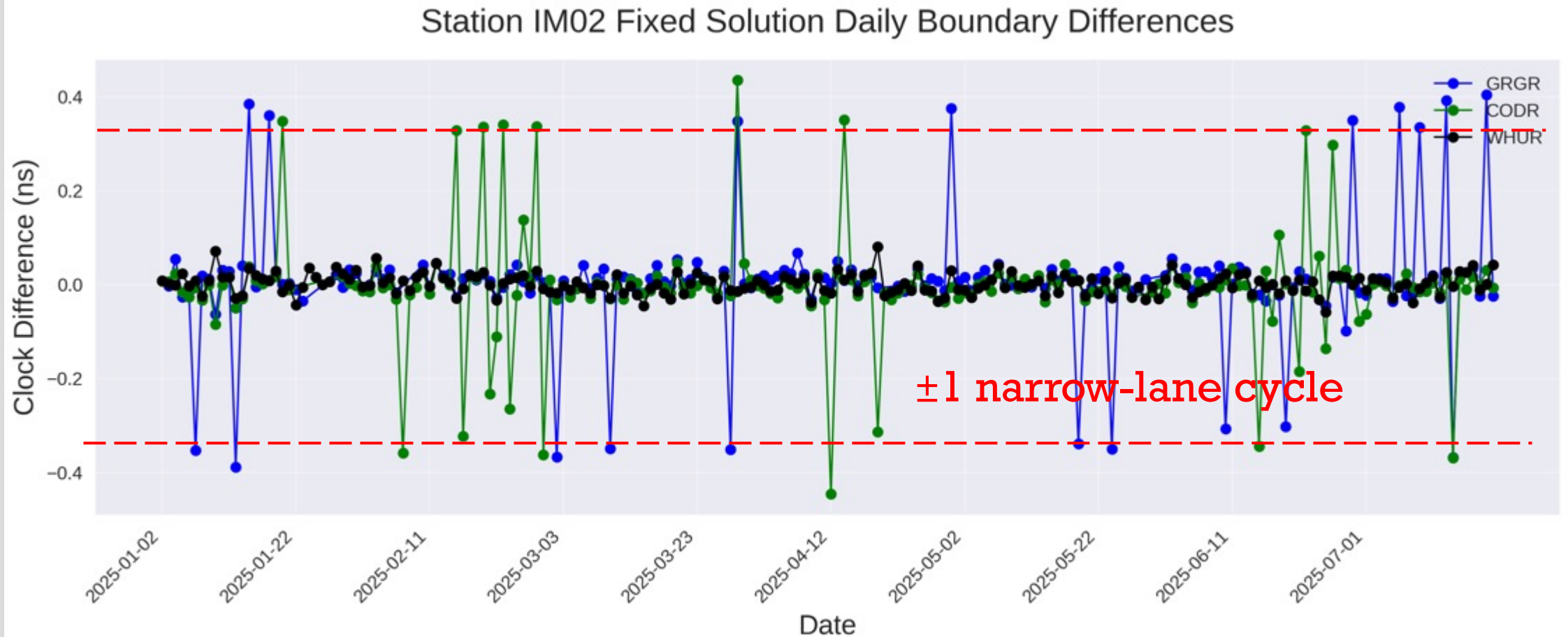
Multi-day IPPP based on different IGS products

200-day time transfer link between PTBB and IM02



Multi-day IPPP based on different IGS products

□ Day boundary discontinuities of multi-day IPPP links



IPPP – Software

Many PPP software packages exist, mainly for precise positioning, but few of them have been extensively tested for timing.

For the future of IPPP we are currently testing two solutions:

- Atomium by ROB (<https://betime.be/en/research/atomium.php>)
- Pride PPPAR by Wuhan University (<https://github.com/PrideLab/PRIDE-PPPAR>)

Conclusions

- ❑ PPP time transfer is one of the backbone of UTC maintenance.
- ❑ BIPM is trying to implement multi-constellation Time transfer with ambiguity resolution in Circular T.
- ❑ This critically depends on IGS precise Ephemerids.
- ❑ Only WUMRAP products are available for multi-day processing.
There is a lack of rapid products with continuous satellite clock.

Thank you for your attention!



C E L E B R A T I N G

150

BIPM

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Multi-day IPPP

- ❑ Multi-day IPPP enables continuous processing near day boundaries
- ❑ Multi-day observations are not truncated at day boundaries, leading to higher reliability of parameter estimation

