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On the interoperability of GNSS clock and bias products for precise point positioning with ambiguity resolution

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United Nations / Fiji Workshop on the Applications of GNSS, 27 June 2019

Canada

GNSS Augmentation

State-space representation (SSR)

Satellite orbit and clock corrections

+

Satellite code and phase biases

Standard PPP

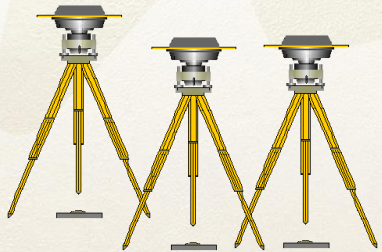
PPP with ambiguity resolution (PPP-AR)

User

Ionosphere

Troposphere

Regional network

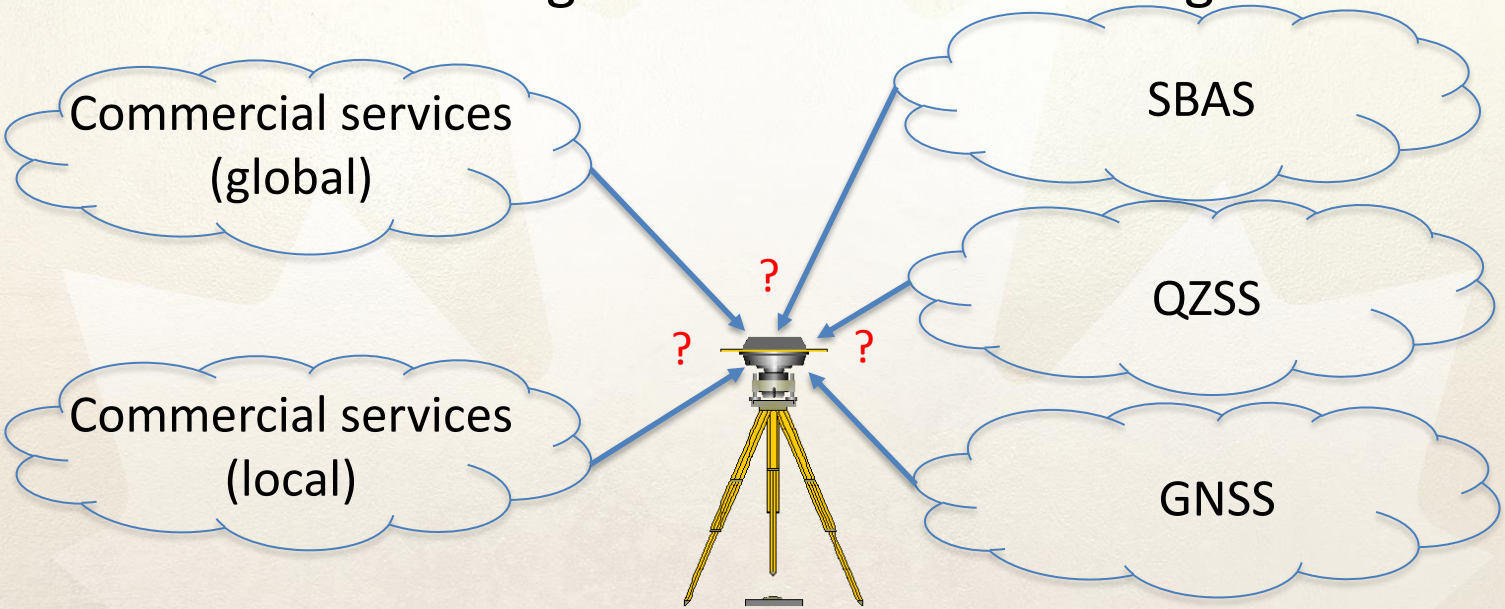


Permanent reference stations

"PPP-RTK" or "Fast PPP"

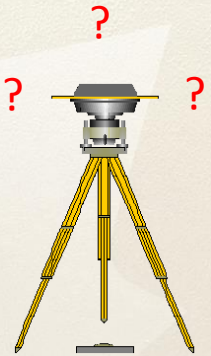
GNSS Augmentation

- Several sources of augmentation are becoming available



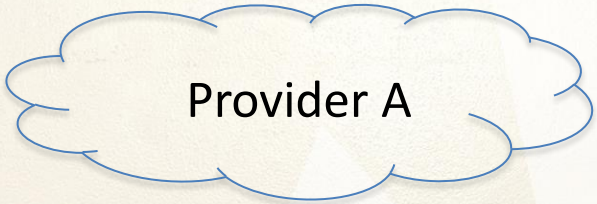
GNSS Augmentation

- Several questions for users:
  - Can we mix streams of SSR corrections?
  - Can we switch from one stream to another when interruptions occur?
  - Can there be provider vs user inconsistencies?
  - …

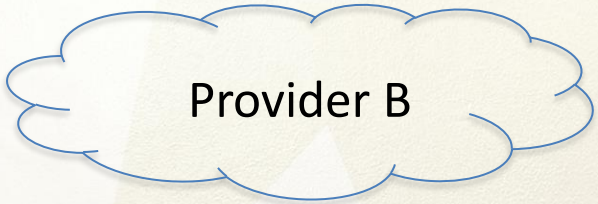


Answers

- Can we mix streams of SSR corrections?



- Very good orbit / clock corrections
- No phase biases for AR

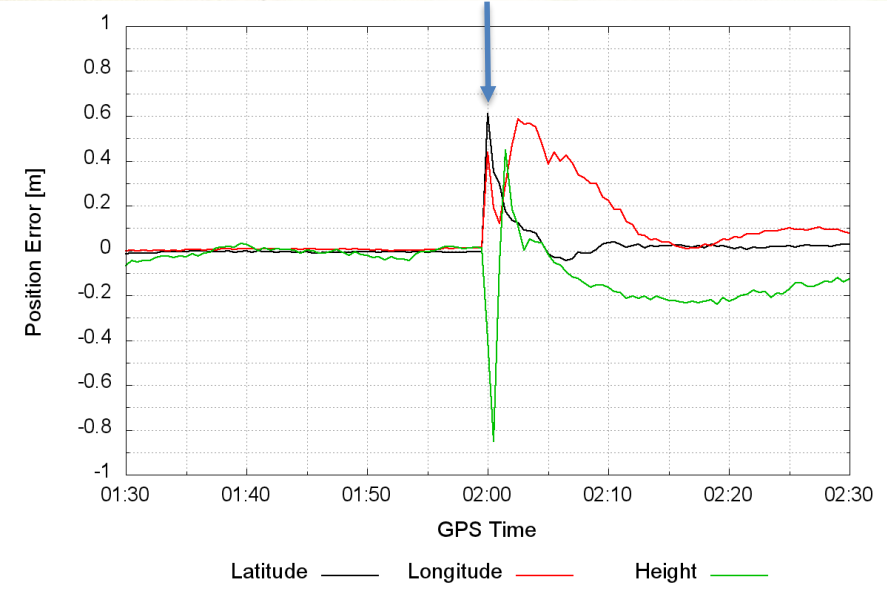


- Good orbit / clock corrections
- Phase biases for AR

Answer: No, orbit / clock / bias corrections need to be used together for consistency

Answers

- Can we switch from one stream to another when interruptions occur?



Answer: Unless sophisticated algorithms are used on the user end, switching correction streams requires a “reset” of the filter

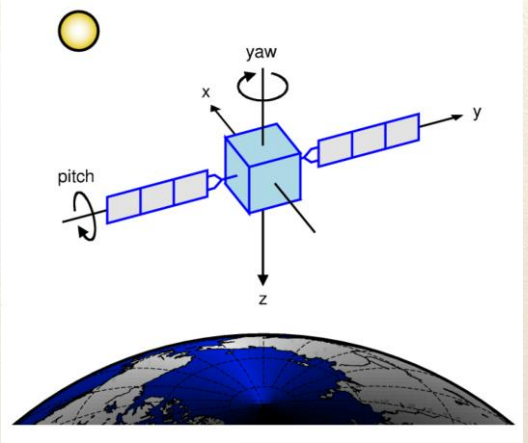
Answers

- Can there be provider vs user inconsistencies?
  - The International GNSS Service (IGS) sets guidelines and recommends models for processing GNSS data (i.e., IERS conventions)
  - But not all error sources are considered which leaves room for inconsistencies

Answer: Yes, see the satellite eclipse example next

Satellite eclipses

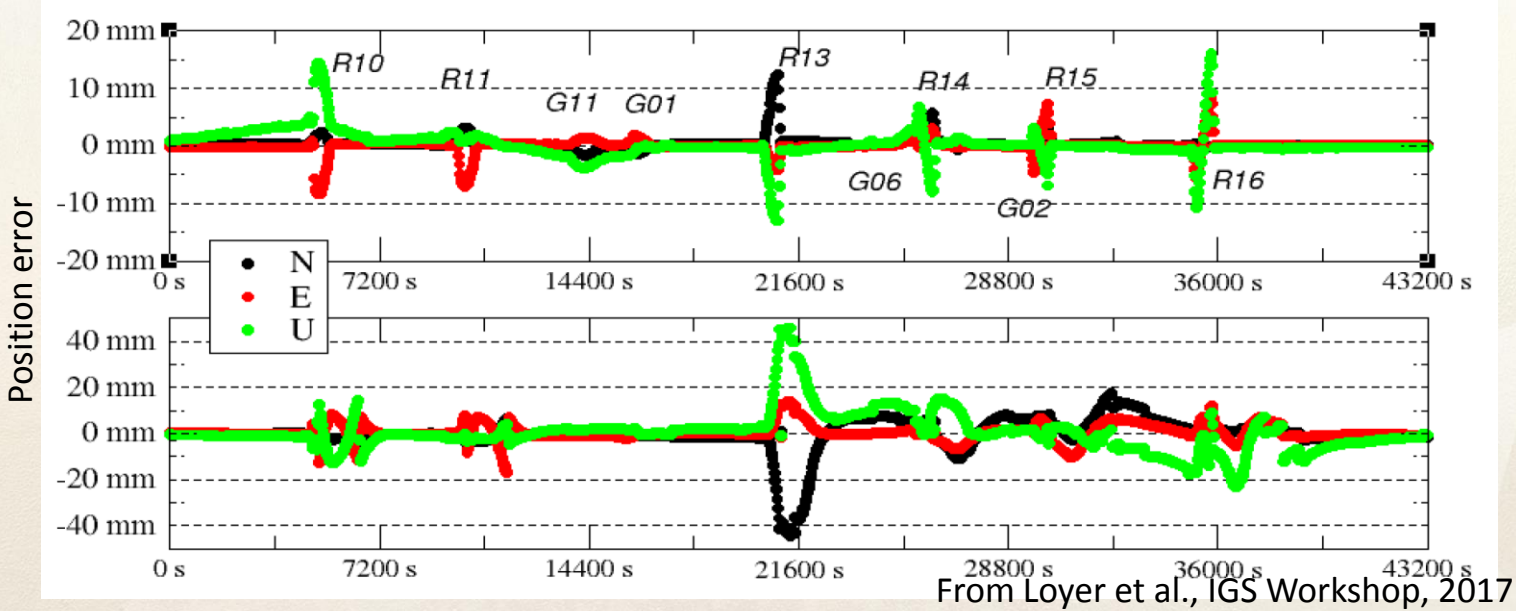
- Satellites continuously try to align their solar panels towards the Sun
- When satellites are in the Earth's shadow, this alignment becomes ambiguous and satellites from different constellations behave differently
- Galileo provided metadata on satellite attitude during eclipses (thanks!)
- For other GNSS, satellite attitude has been reserve-engineered, but each analysis center adopts its own model



From Dilssner et al., AGU 2011

Satellite eclipses

- Impact on user position caused by mismodeled satellite attitude



User-defined attitude modeling

No attitude modeling by user

From Loyer et al., IGS Workshop, 2017

Solutions: 1) satellite attitude from GNSS operators; 2) data format to exchange attitude

Issues

- Users have a “choice overload” in terms of SSR corrections
- They are not allowed to mix correction streams or switch streams without position degradation
- They are subject to further position degradation if inconsistencies exist between the provider implementation and the user implementation

Possible solutions

- GNSS providers are invited to disclose satellite metadata:
  - Satellite attitude
  - Satellite phase center offsets and variations
  - Satellite weight, shape, signal transmit power, etc.
- Adopting a common format for correction transmission
- Combining SSR corrections from multiple sources can lead to a more robust solution

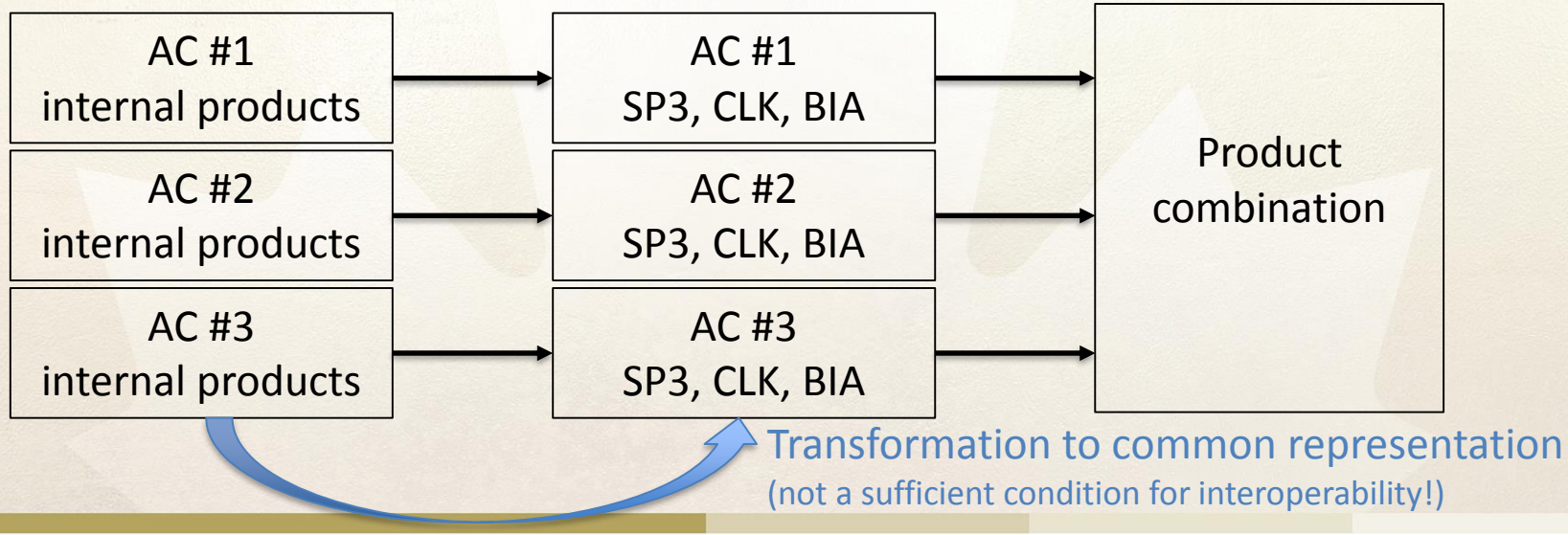
Solution combination

- In November 2018, the IGS has initiated a new working group (WG) on PPP-AR

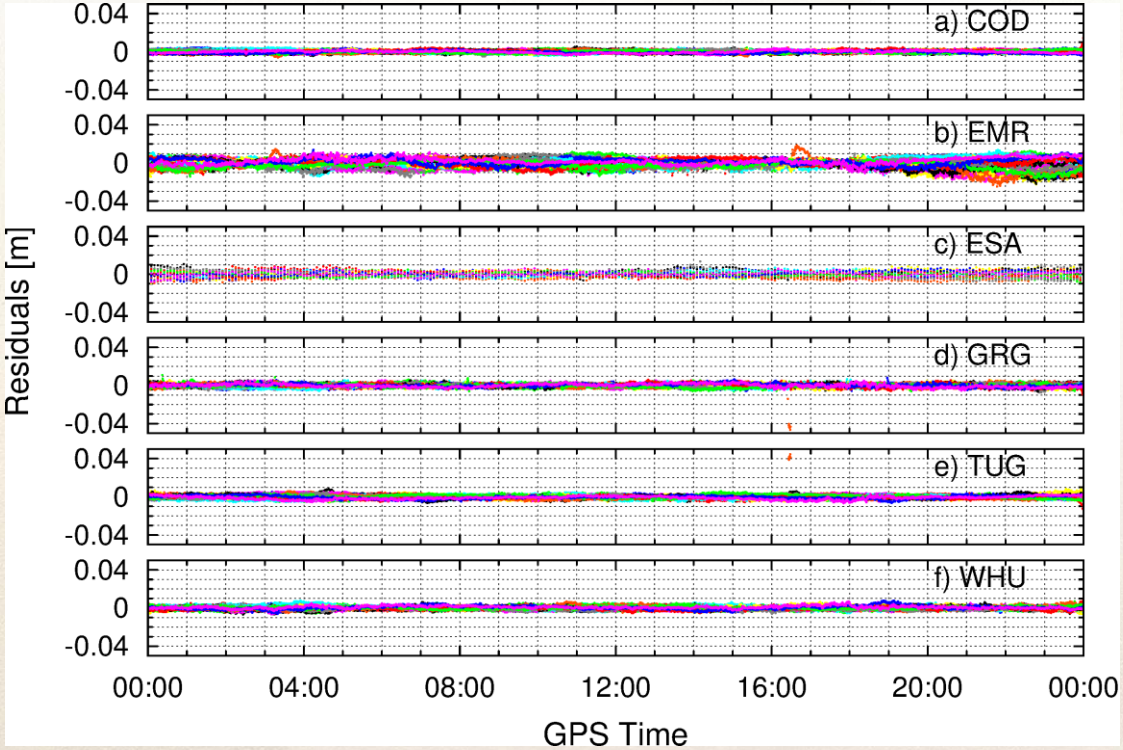
- The main goals of the PPP-AR WG are to:
  - Analyze the interoperability of clock/bias products among IGS analysis centers
  - Assess current data formats for completeness (satellite attitude)

Solution combination

- IGS analysis centers (ACs) use different methodologies and formats when generating PPP-AR products



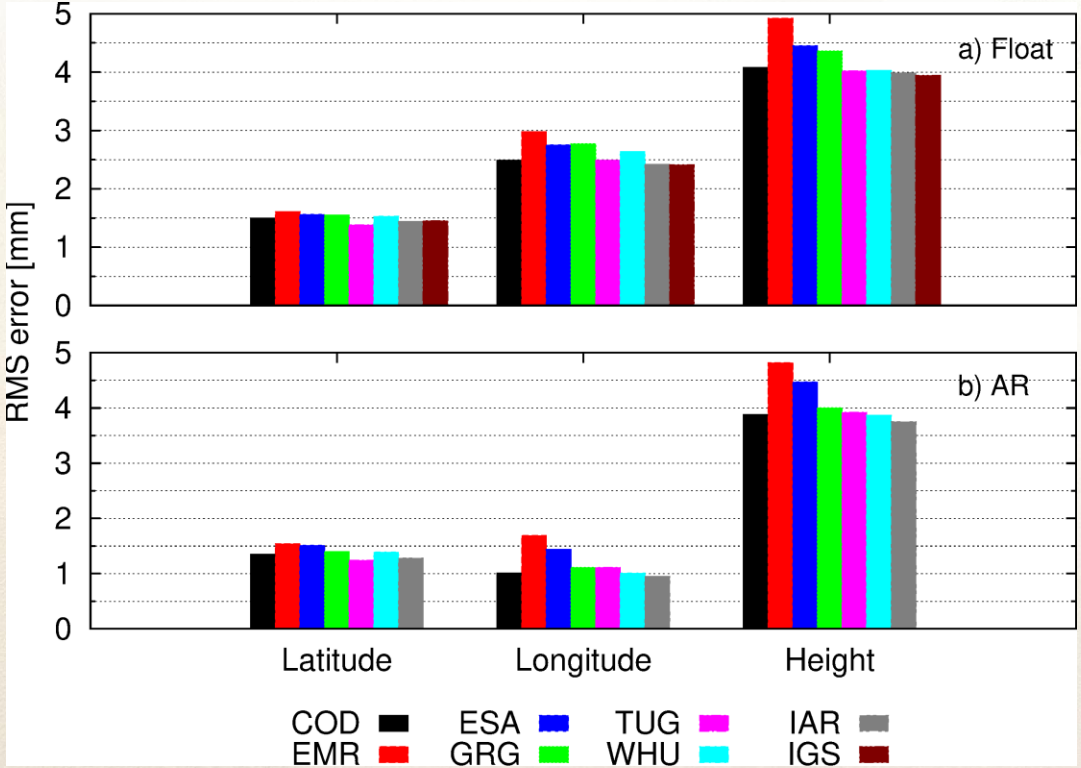
Solution combination



- Six analysis centers participated in a one-week experiment to combine PPP-AR products (orbit / clock / biases)
- Clock residuals from the combination have an RMS of about 1-2 mm, showing excellent agreement despite the differences in analysis center processing strategies

From Banville et al., Journal of Geodesy, 2019

Solution combination



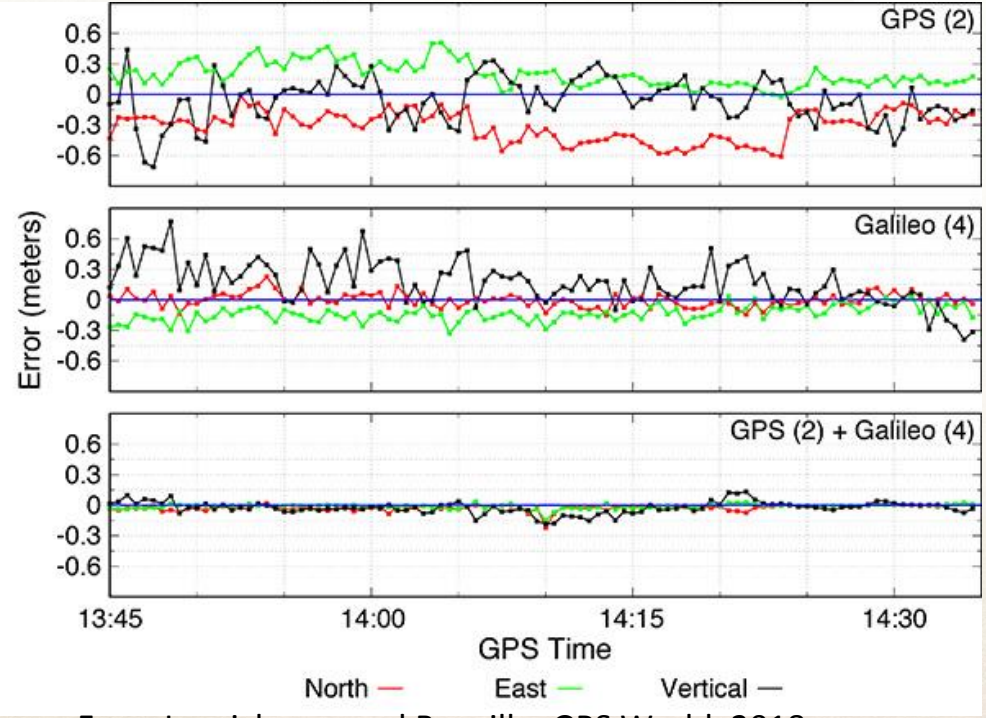
- All products were tested using >200 user stations (static, 24h)
- The combined products (IAR) perform well, confirming the interoperability of the products
- Ambiguity resolution (bottom plot) shows an improvement of ~60% in longitude component

From Banville et al., Journal of Geodesy, 2019

Summary

- Increased transparency by GNSS providers can help in defining standard models for improved interoperability among correction providers and users
- A common data format utilized by all correction providers is recommended for user integration
- Combining corrections can help users in terms of robustness and in reducing the “choice overload”

Benefits of interoperability



From Laurichesse and Banville, GPS World, 2018

- Instantaneous centimeter-level PPP solutions can be obtained by combining multi-frequency GPS and Galileo signals
- Users only need access to precise satellite orbit, clock and bias corrections
- Very promising for end users!

Contact

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This work is published as NRCan contribution number 20190110