

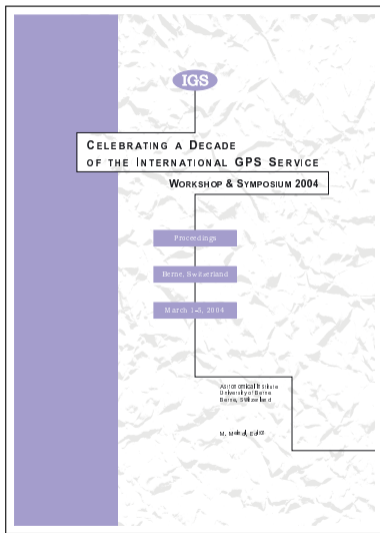
# Earth's Center of Mass Handling for GNSS Orbit Determination and PPP

Rolf Dach, Stefan Schaer, Daniel Arnold, Elmar Brockmann,  
Maciej Kalarus, Martin Lasser, Pascal Stebler, Adrian Jäggi

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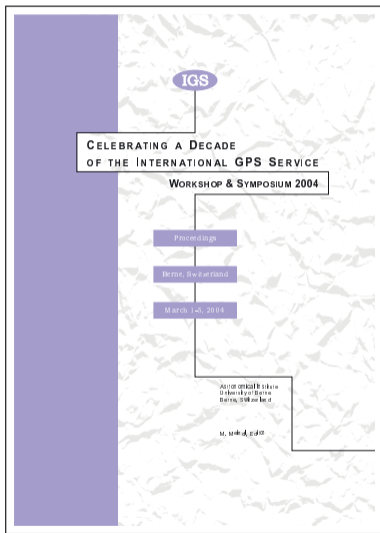
IGS Symposium & Workshop  
1–5. July 2024, Bern Switzerland

# IGS Workshop 2004



Recommendations:

# IGS Workshop 2004



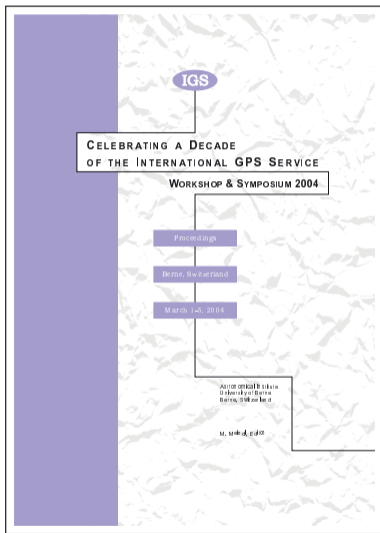
## Recommendations:

- All IGS satellite clocks should be in ITRF center of network. . . .
- The PPP realization of ITRF using IGS products . . .

extract from Recommendation 2.10 – IGS Reference Frame Maintenance

extract from Recommendation 2.11 – IGS Reference Frame Maintenance

# IGS Workshop 2004



## Recommendations:

- All IGS satellite clocks should be in ITRF center of network. . . .

extract from Recommendation 2.10 – IGS Reference Frame Maintenance

- The PPP realization of ITRF using IGS products . . .

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- *Handling of geocenter motion:*

$$GCRF = P \cdot N \cdot R \cdot W \cdot (ITRF + O(t)) \dots$$

$O(t)$ : “instantaneous” geocenter offset vector

extract from Recommendation 3.5 – Other Reference Issues

The clear theory

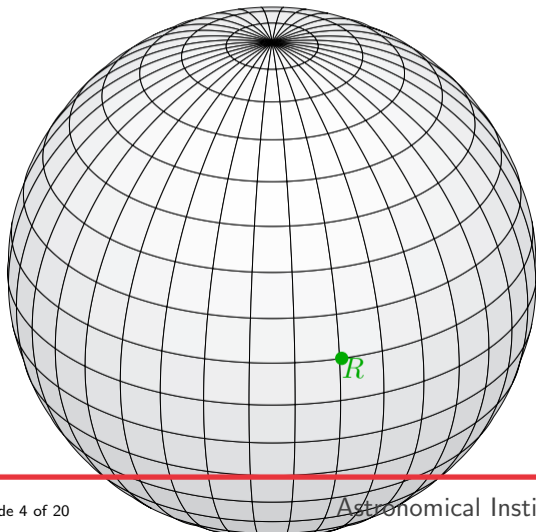
Something unexpected

Explanation for the surprise

Discussion

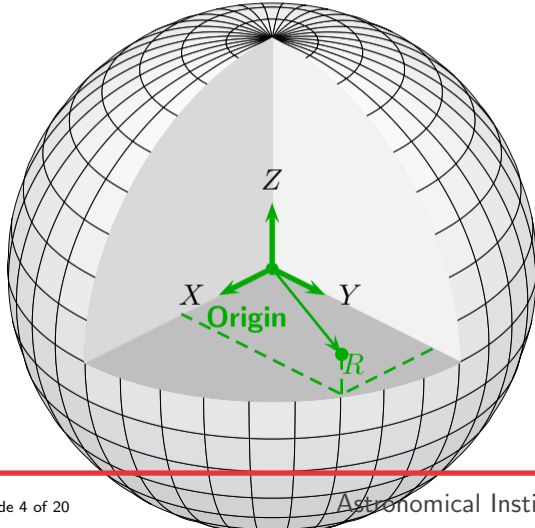
# Illustration of the problem

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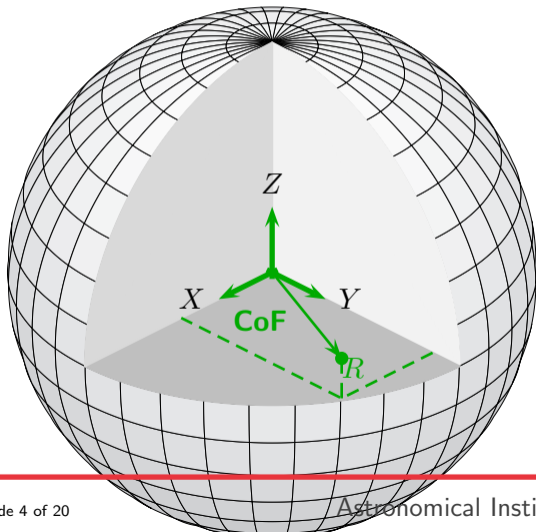


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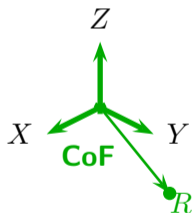
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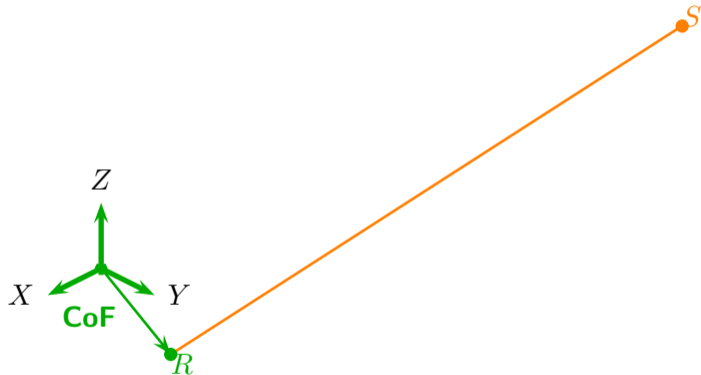
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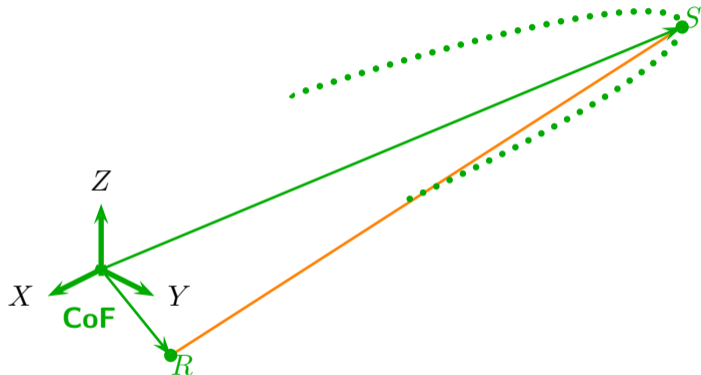


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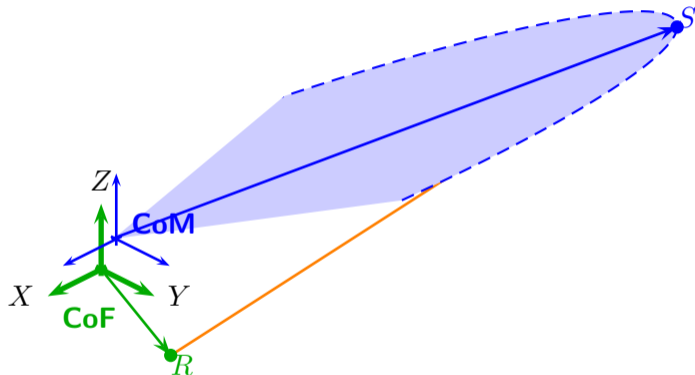
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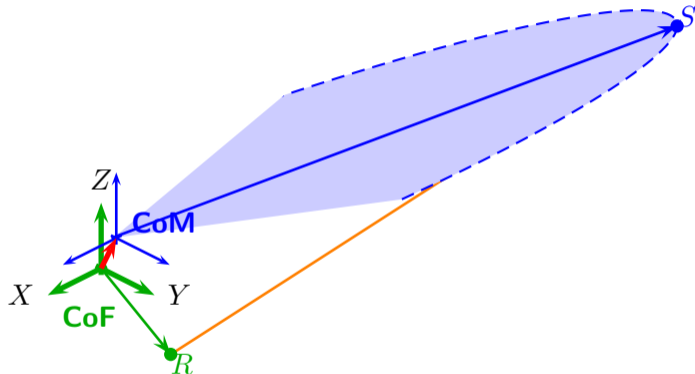
# Illustration of the problem



# Illustration of the problem



# Illustration of the problem



# Which reference frames are needed for which purpose?

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## GNSS station:

ITRF (CF-based)

- Earth fixed system with stable origin in time

## Satellite positions (for interpolation):

ITRF (CF-based)

- the same frame as the GNSS stations (for user's convenience)
- realized today in the SP3 orbit product files

## Satellite orbits (for orbit modelling):

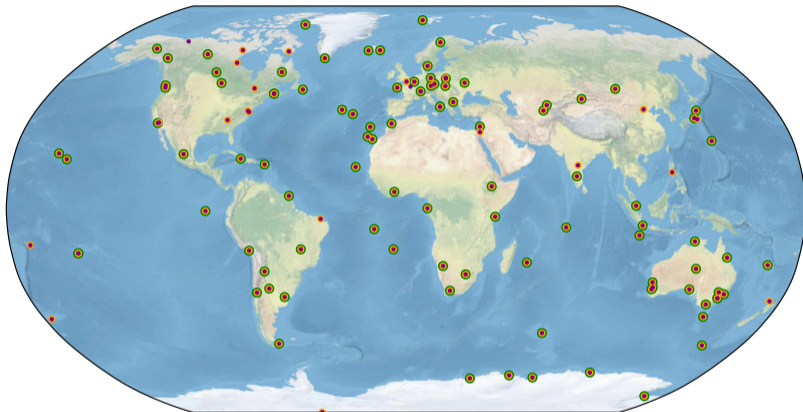
GCRF (CM-based)

- Earth centered system that does not participate in the Earth rotation
- instantaneous center of mass as the origin

We just need a well established ITRF;

GCRF is only needed temporally during the data analysis.

# The experiment setup



Network of 120 IGS stations as used by CODE rapid solution.

# The experiment setup

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Following the CODE processing scheme for the IGS rapid solution:



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- one-day orbit solution
  - day 179 to 190 of year 2023
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  - datum definition: NNR+NNT condition on a verified set of stations in IGS20 frame

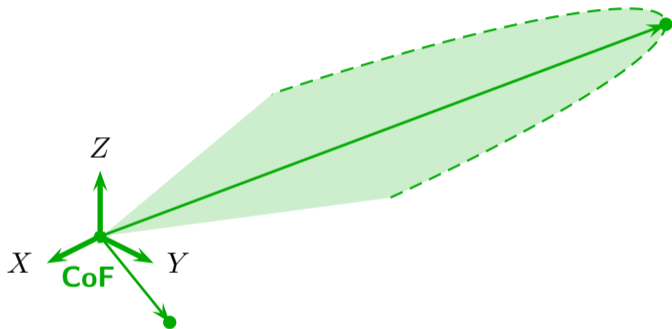
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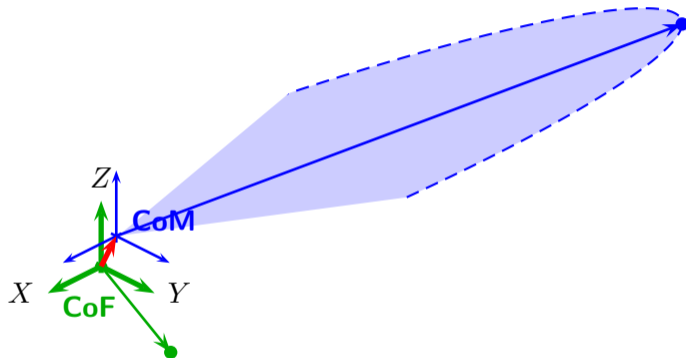
Following the CODE processing scheme for the IGS rapid solution:

- **one-day orbit solution**
  - day 179 to 190 of year 2023
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  - datum definition: NNR+NNT condition on a verified set of stations in IGS20 frame
- **back substitution of the receiver and satellite clock parameter**
  - day 180 to 189 of year 2023
  - geometry from the three-day long-arc solution is introduced

# The experiment setup: Solution CoF



# The experiment setup: Solution CoM



# Comparing the CoF- and CoM-based solutions

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Station coordinates (in IGS20 frame):

- no significant transformation parameters
- agreement: RMS of differences (without transformation parameters)  $< 0.5$  mm

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- exception for satellites with repositioning event or short observed interval

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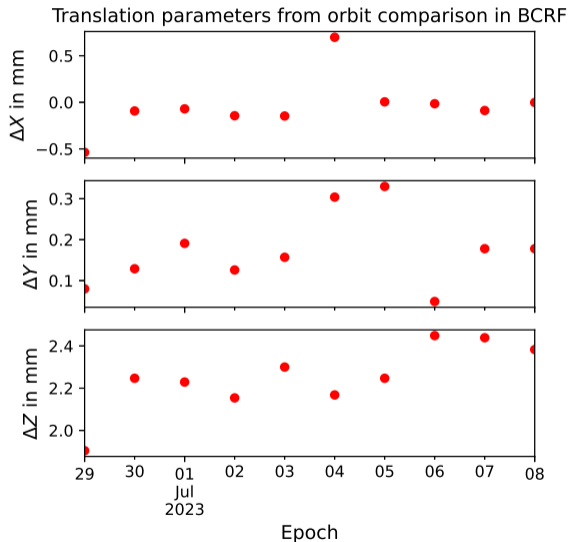
- no significant transformation parameters
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## Satellite positions (in GCRF incl. geocenter vector):

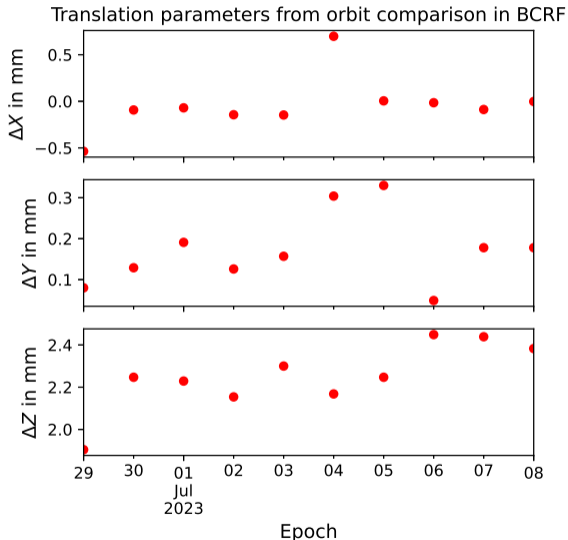
- agreement: RMS of differences (with transformation parameters)  $\approx 5 \dots 7$  mm



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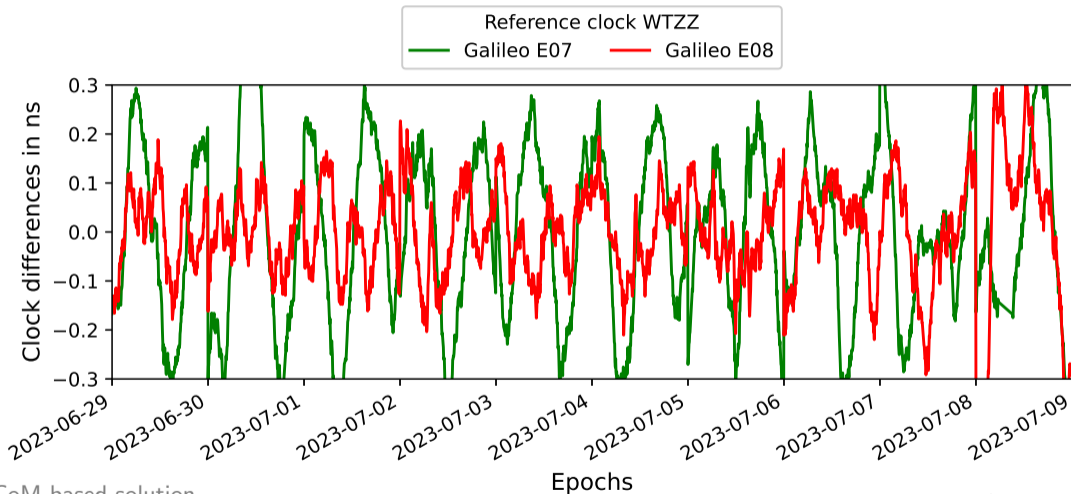
Geocenter correction applied:

- X-component: 0.5 mm
- Y-component: 3.2 mm
- Z-component: 3.2 mm

Geocenter motion model from ITRF2020

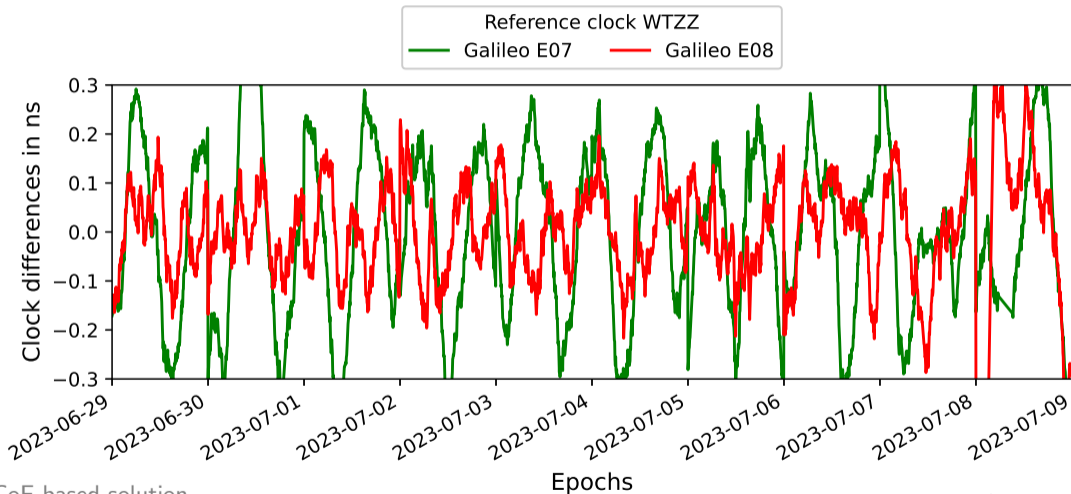
<https://itrf.ign.fr/ftp/pub/itrf/itrf2020/...>  
ITRF2020-geocenter-motion.dat

# Comparing the obtained satellite clock corrections



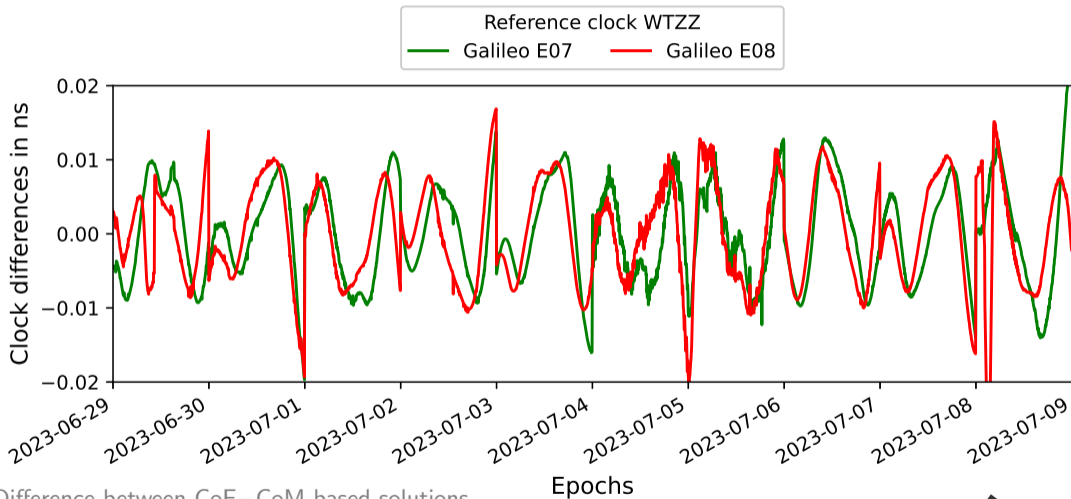
CoM-based solution

# Comparing the obtained satellite clock corrections



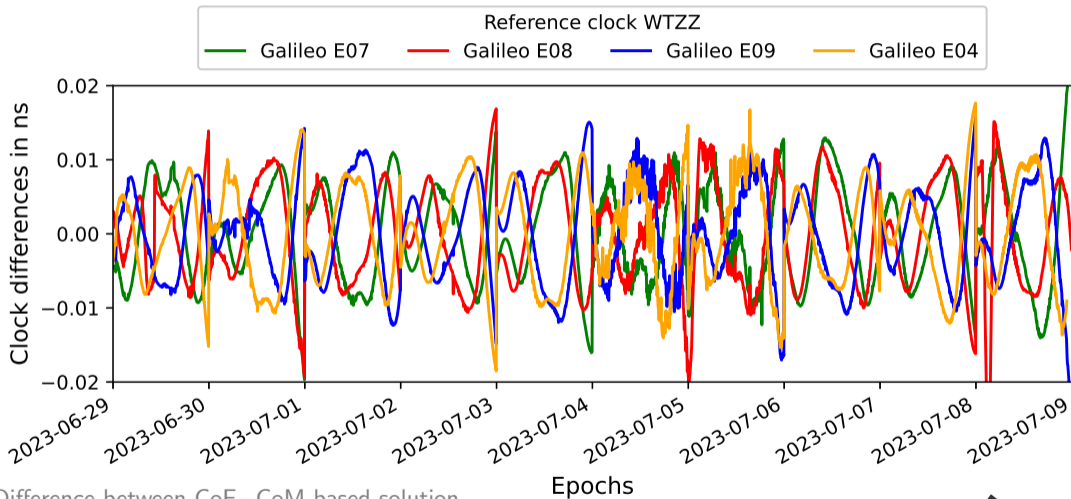
CoF-based solution

# Comparing the obtained satellite clock corrections



Difference between CoF–CoM-based solutions

# Comparing the obtained satellite clock corrections



# Satellite clock corrections do absorb the Geocenter correction

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From the satellite clock differences  
the related geocenter vector is extracted:

- X-component: 0.7 mm
- Y-component: 3.5 mm
- Z-component: 2.6 mm

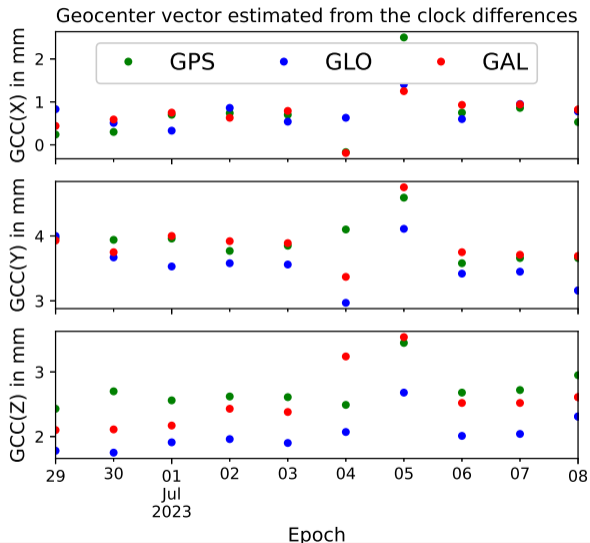
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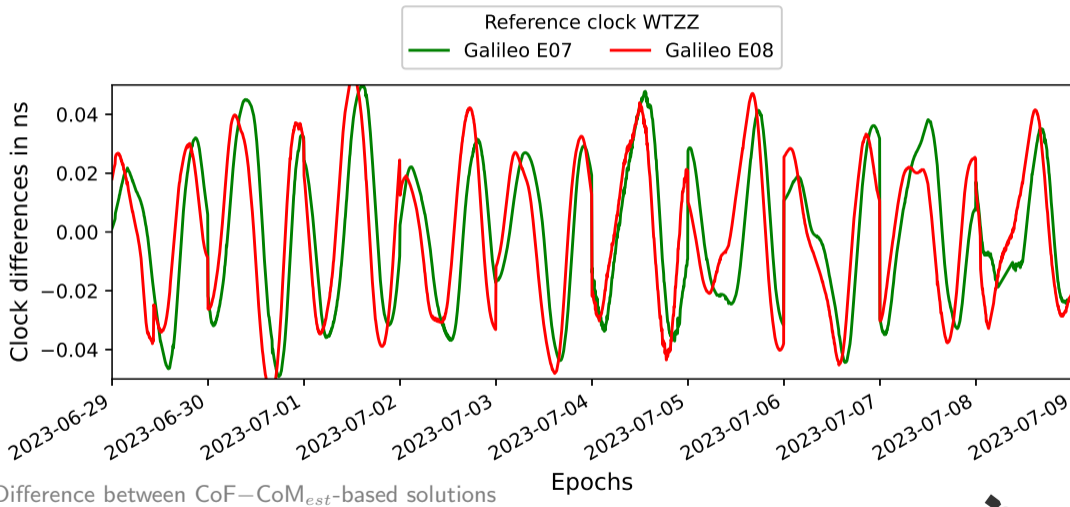
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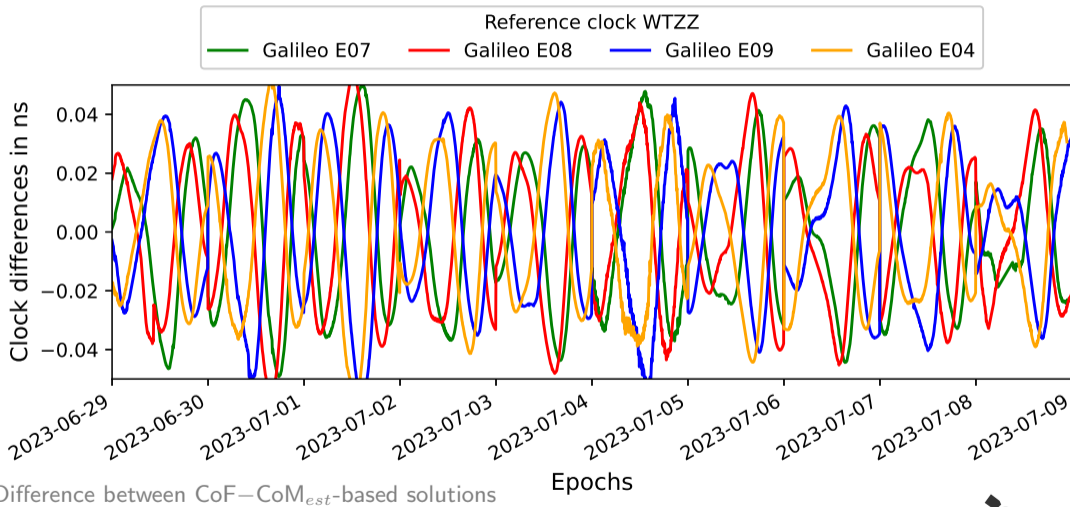
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The procedure was repeated a third time **with estimated translation vector** instead of introducing the ITRF2000-based geocenter corrections.

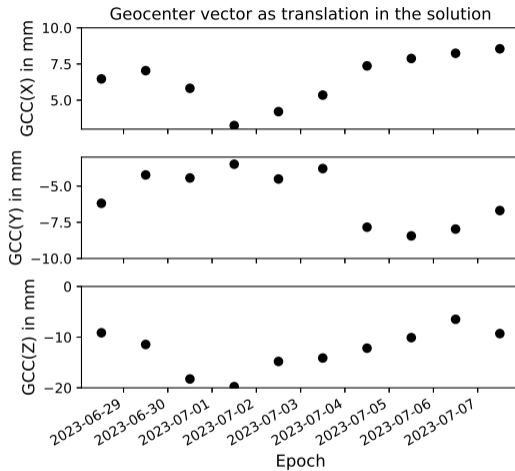
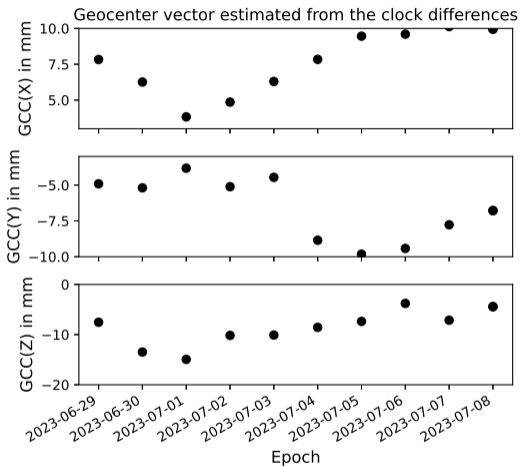
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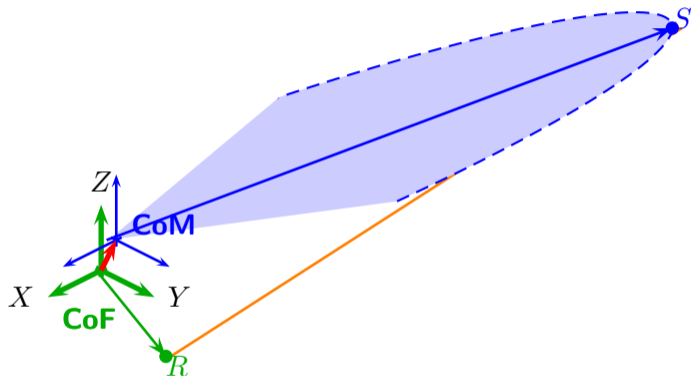
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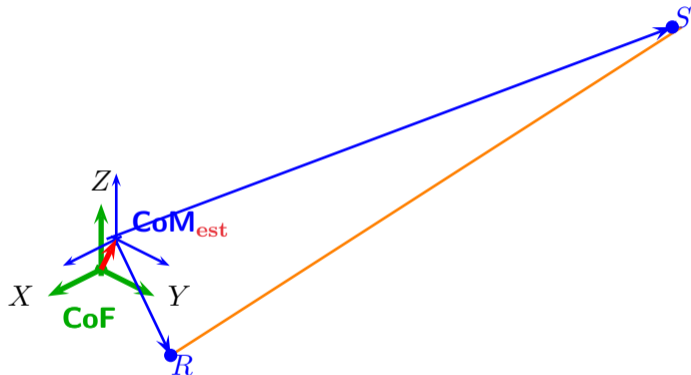
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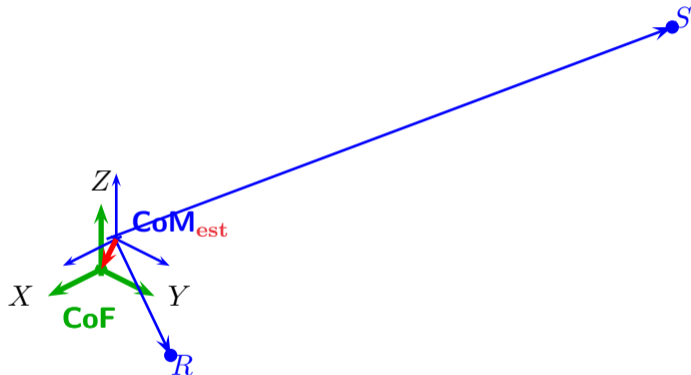


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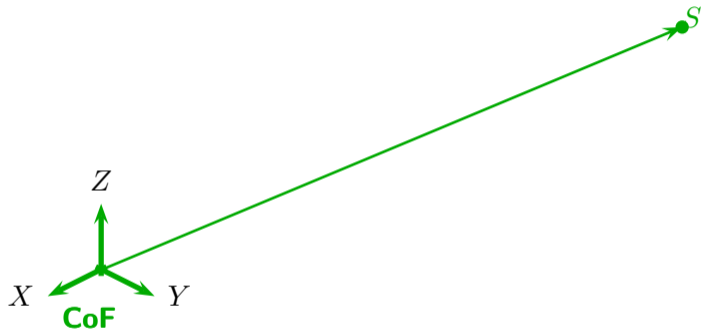


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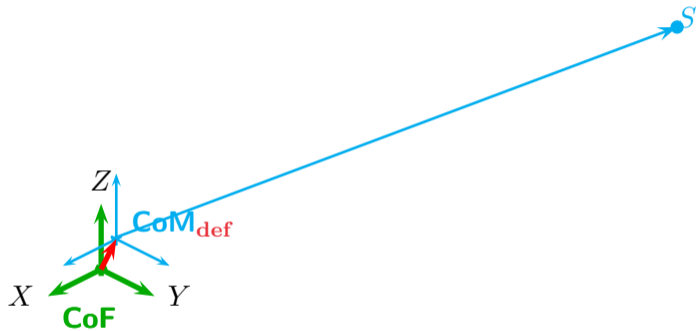


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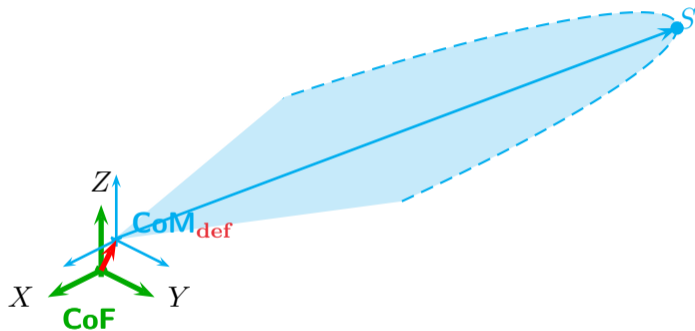
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  - Satellite positions are w.r.t.  $COM_{def}$
  - back substitution of the receiver and satellite clock parameter
- } differences: 1 ... 5 mm
- } differences: 1 ... 2 mm

# What about LEOs?

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- For LEOs, the geocenter vector cannot be absorbed by the satellite clocks.
- They have to be modelled w.r.t. the CoM.

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- For LEOs, the geocenter vector cannot be absorbed by the satellite clocks.
- They have to be modelled w.r.t. the CoM.
- Applying the same geocenter vector for GNSS and LEO orbits, solves the issue: all satellites – in particular the LEO – are flying around the CoM.

# Conclusions

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- For PPP one has to be careful regarding the consistency.
- Any PPP solution has to end up in the ITRF (CF-based frame).
- There exist alternatives for specific applications, like LEO-POD.



# THANK YOU

## for your attention

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<http://www.bernese.unibe.ch/publist>