Comparison of GPS/GLONASS Clock Solutions

R. Dach[1], S. Schaer[2], and M. Meindl[1]

[1]Astronomical Institute, University of Bern
Sidlerstrasse 5, CH-3012 Bern

[2]Federal Office of Topography swisstopo

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Outline

Comparison of GPS/GLONASS Clock Solutions

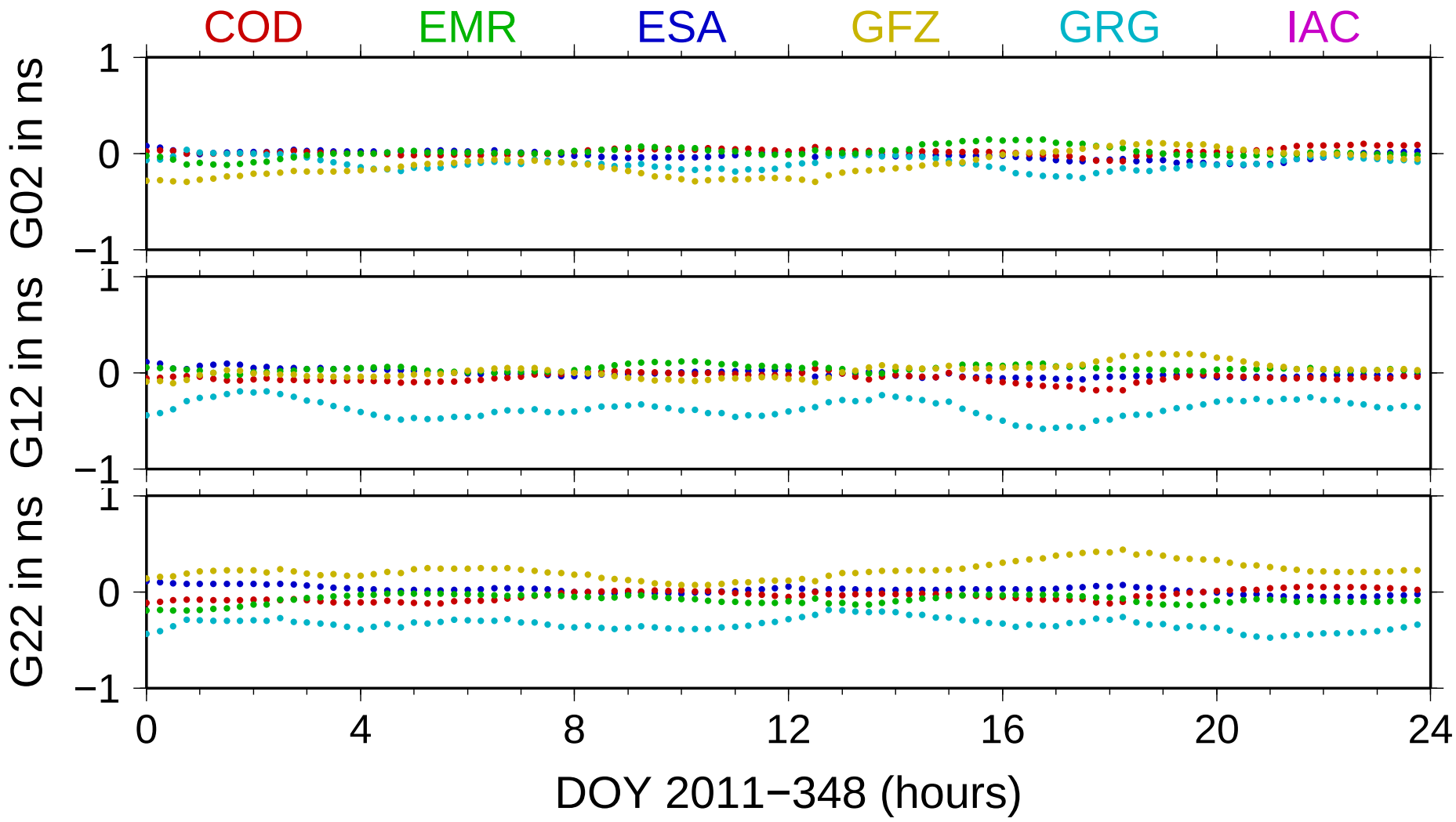
1. Direct comparison of the satellite clocks
2. Comparison of the submitted ISB/IFB
3. Precise Point Positioning solutions

Overview on the Contributions

Analysis Center		Clock Solution Systems	satell.	stations
COD	Center for Orbit Determination in Europe, AIUB, Switzerland	GPS+GLONASS	30 sec	300 sec
EMR	Natural Resources Canada, Canada	GPS+GLONASS	30 sec	—
ESA	European Space Operations Center, ESA, Germany	GPS+GLONASS	30 sec	300 sec
GFZ	GeoForschungsZentrum, Germany	GPS+GLONASS	300 sec	300 sec
GRG	GRGS-CNES/CLS, Toulouse, France	GPS+GLONASS	900 sec	900 sec
IAC	Information-Analytical Centre, Russia	GPS+GLONASS	300 sec	300 sec

Satellite Clock Series (Reference clock: G15)

Deviation from the median



Satellite Clock Series (Reference clock: G15)

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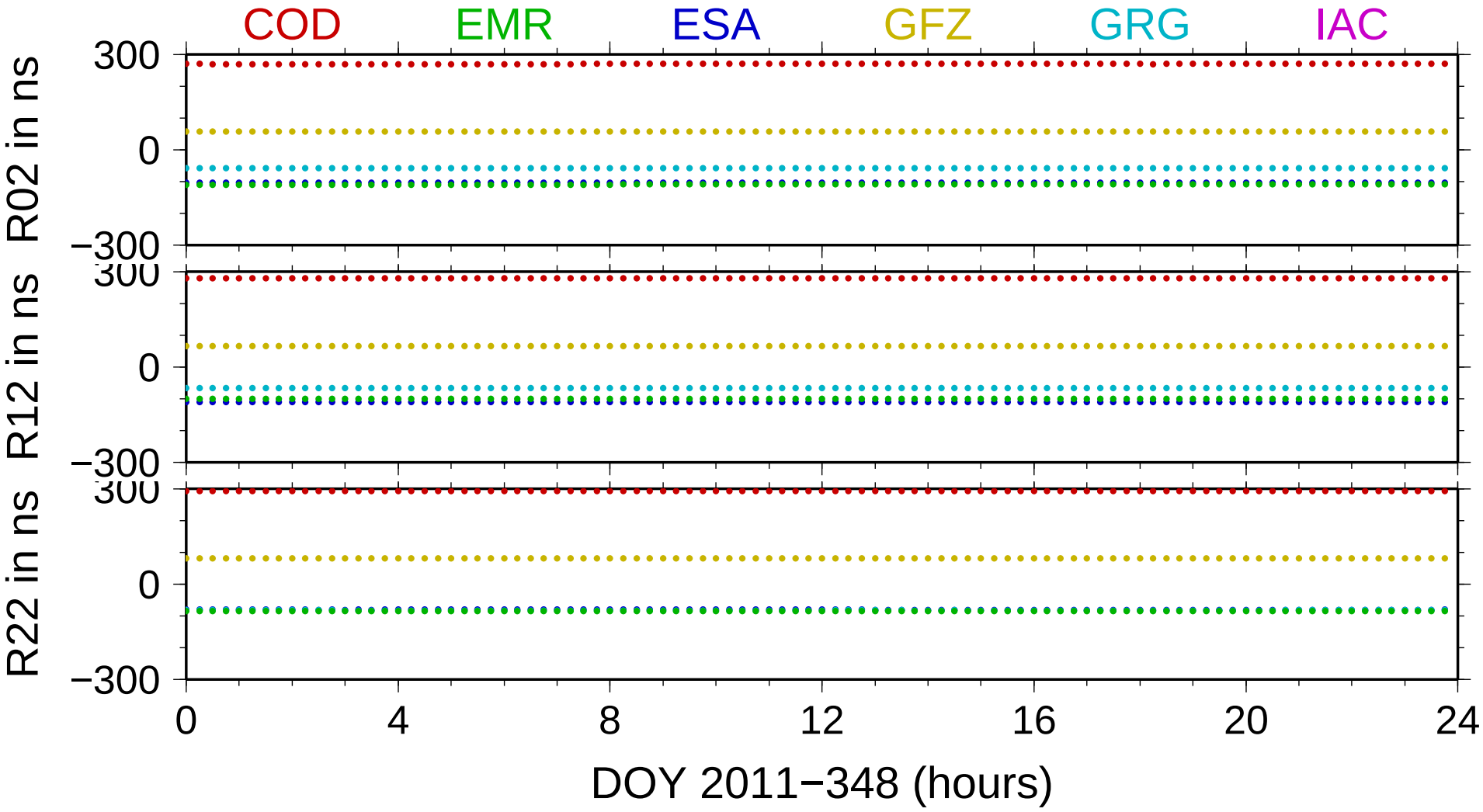
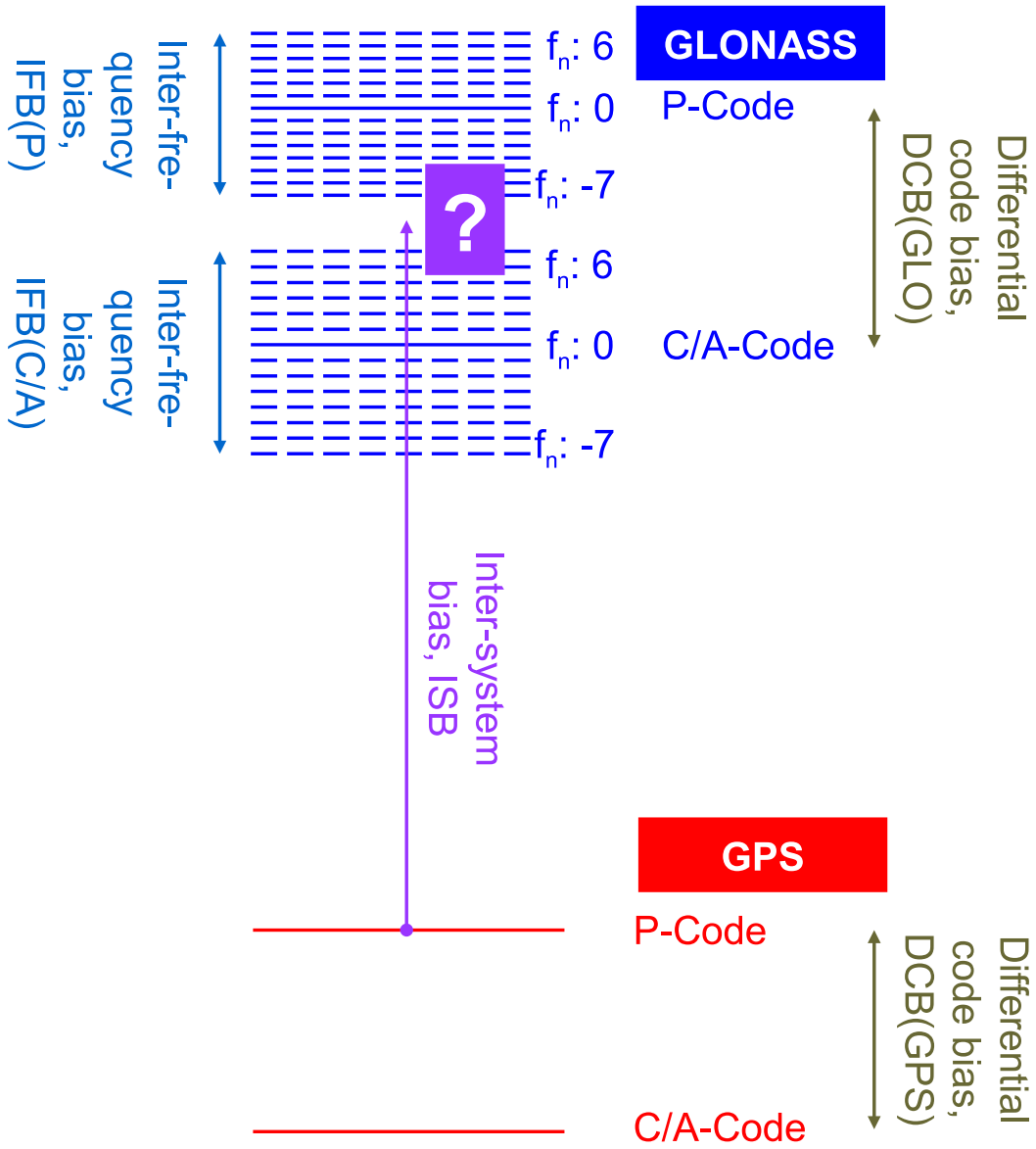


Biases in GPS/GLONASS (Clock) Processing



- **DCB: differential code bias** different hardware delays for P– and C–Code
- **ISB: inter–system bias** different hardware delays for measurements of different GNSS
- **IFB: inter–frequency bias** frequency–dependent hardware delays for the different GLONASS–signals

We can only extract the sum of delays from a GPS/GLONASS data processing.

Biases in GPS/GLONASS (Clock) Processing

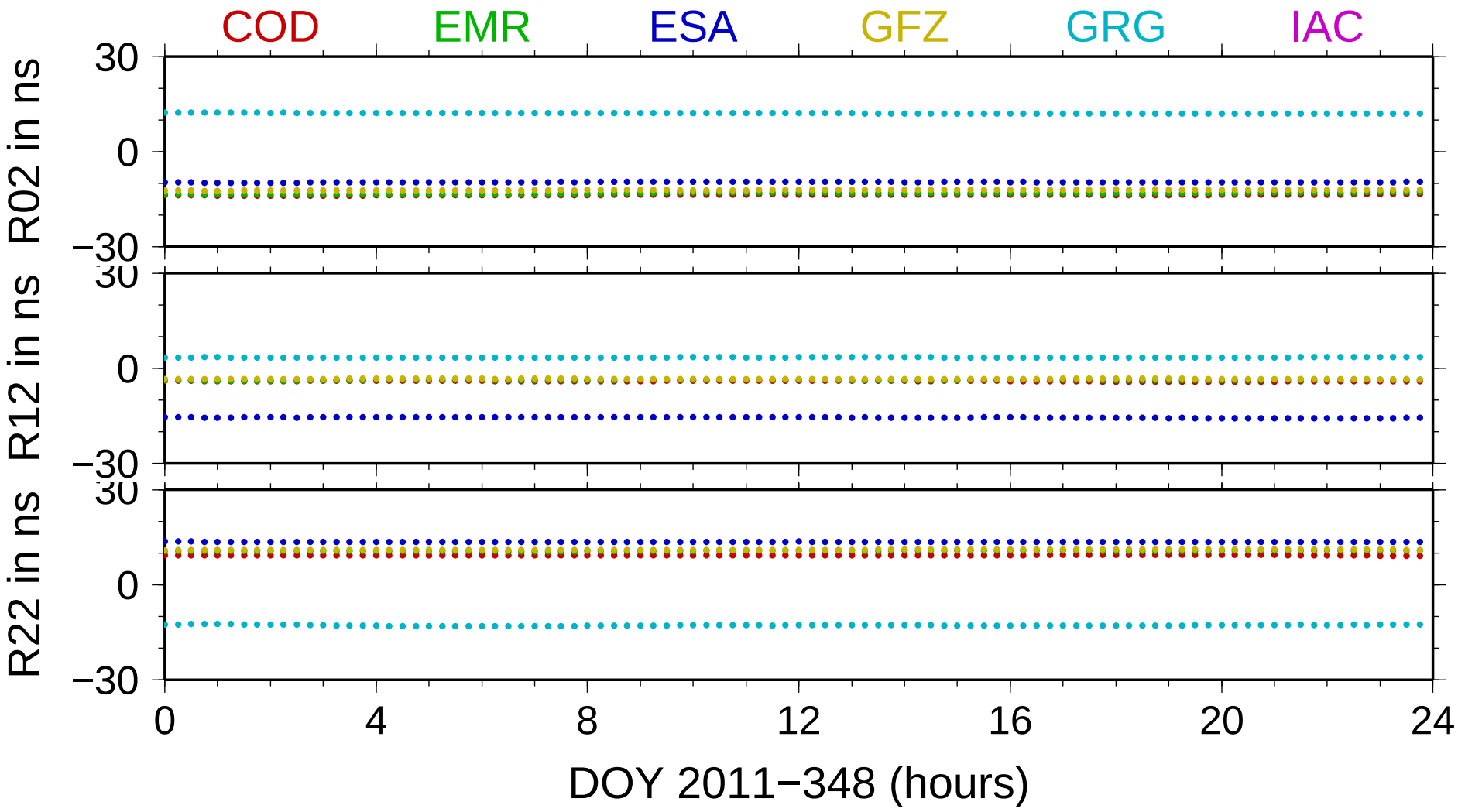
The different biases are realized in different ways in the six contributing solutions. We can extract the following biases from the (satellite) clock time series:

- **ISB: inter–system bias**
  one common offset between all GPS and GLONASS clocks from each of the solutions
- **IFB: inter–frequency bias**
  one offset for each GLONASS clock with respect to all GPS clocks of the solution

Note, all offsets are realized as *median* to be robust against outliers.

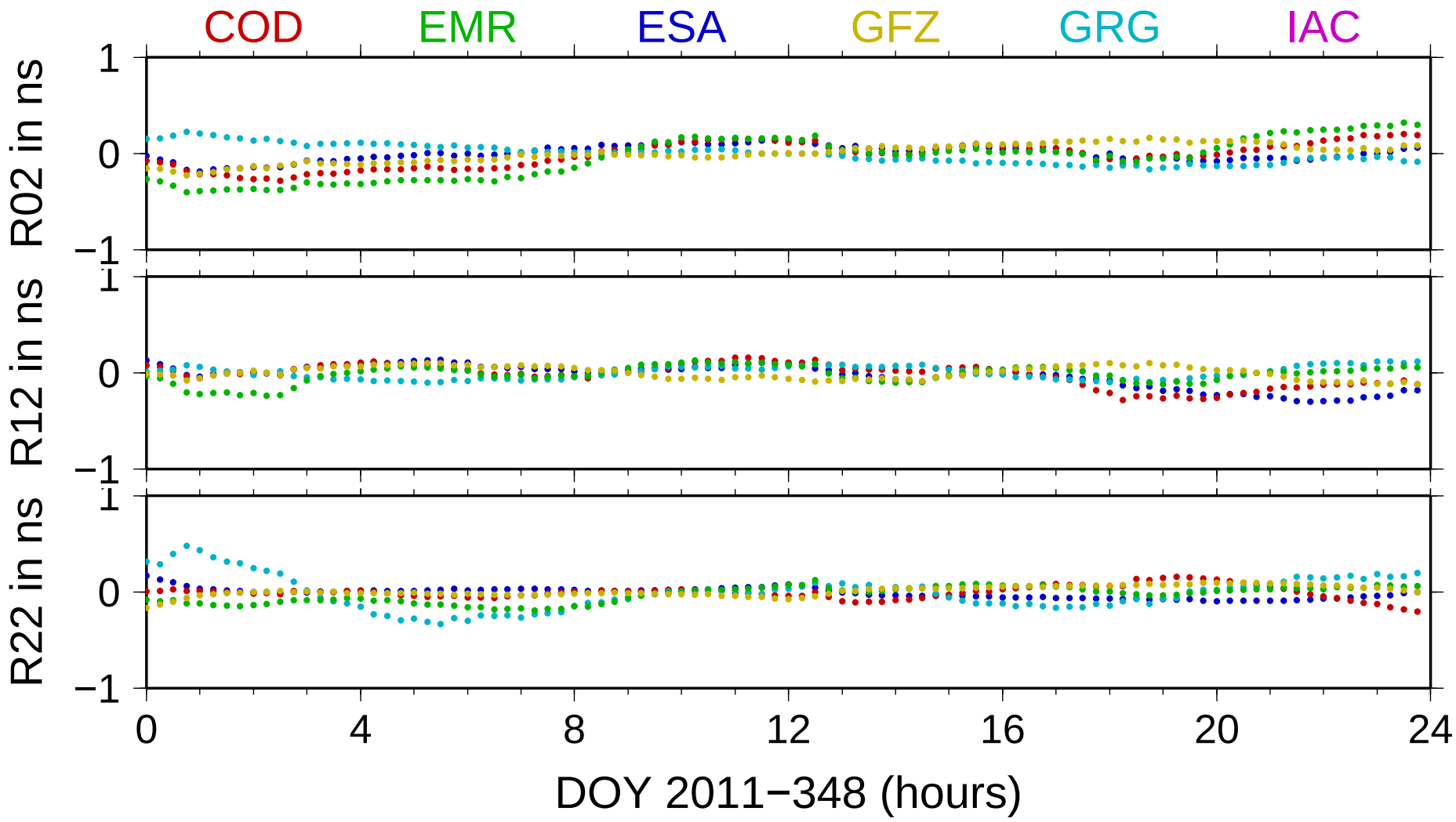
Satellite Clock Series (Reference clock: G15)

Deviation from the median, ISB subtracted

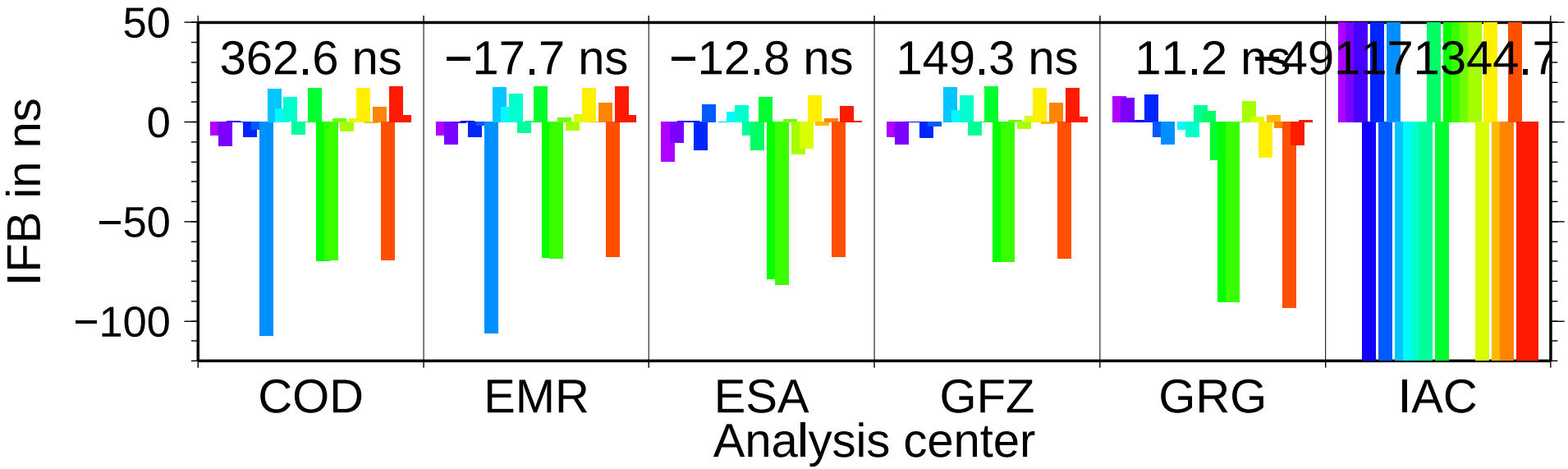


Satellite Clock Series (Reference clock: G15)

Deviation from the median, ISB+IFB subtracted



ISB/IFB as Extracted from Satellite Clocks

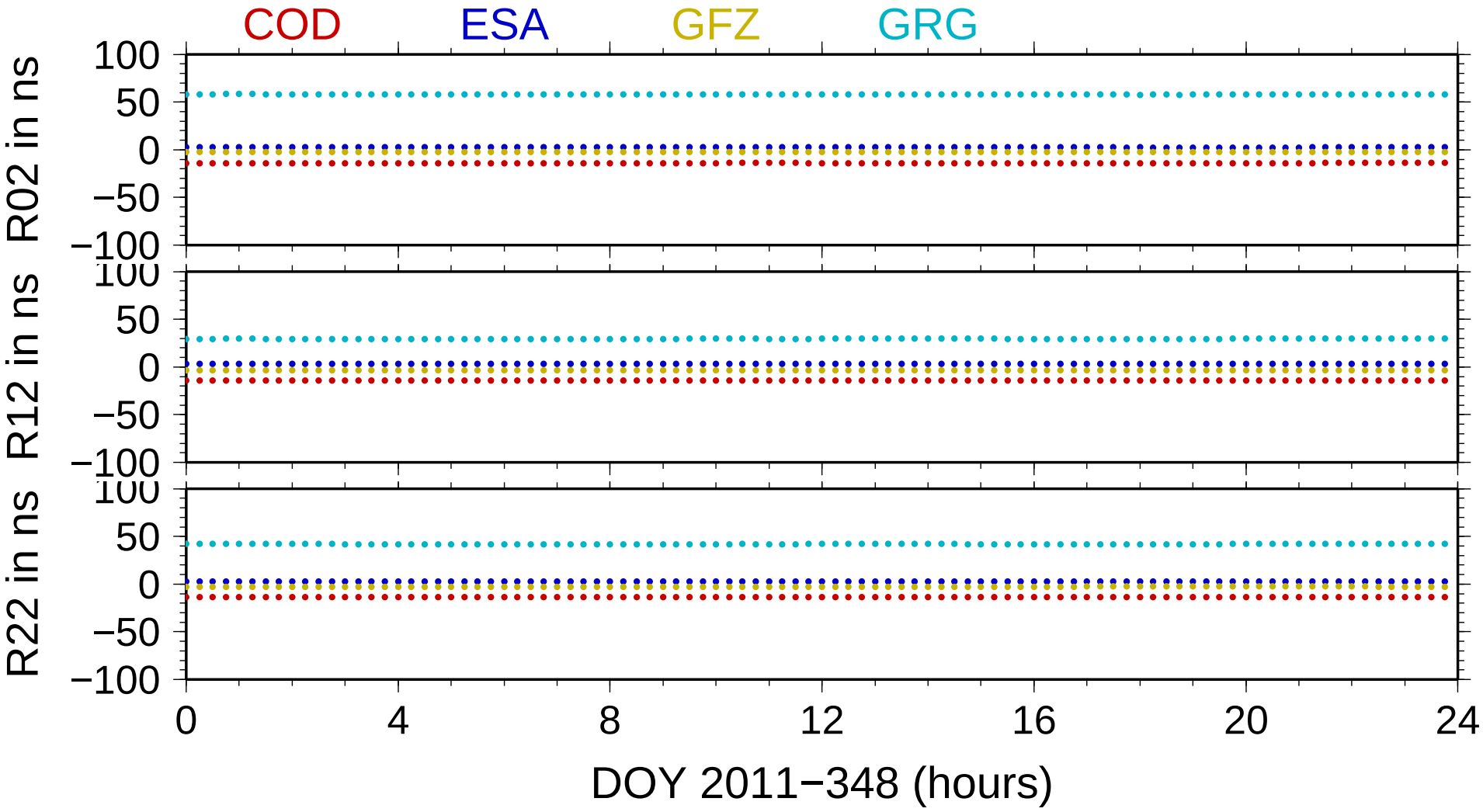


Conclusion

- The ISB/IFB can be estimated from the satellite clock solutions of different ACs.
- Appling these corrections allows for a GLONASS satellite clock combination following the same technology as for GPS.
- The estimated ISB/IFB can be rather inhomogeneous if a satellite is not included in all solutions (which has no influence on a PPP–solution).

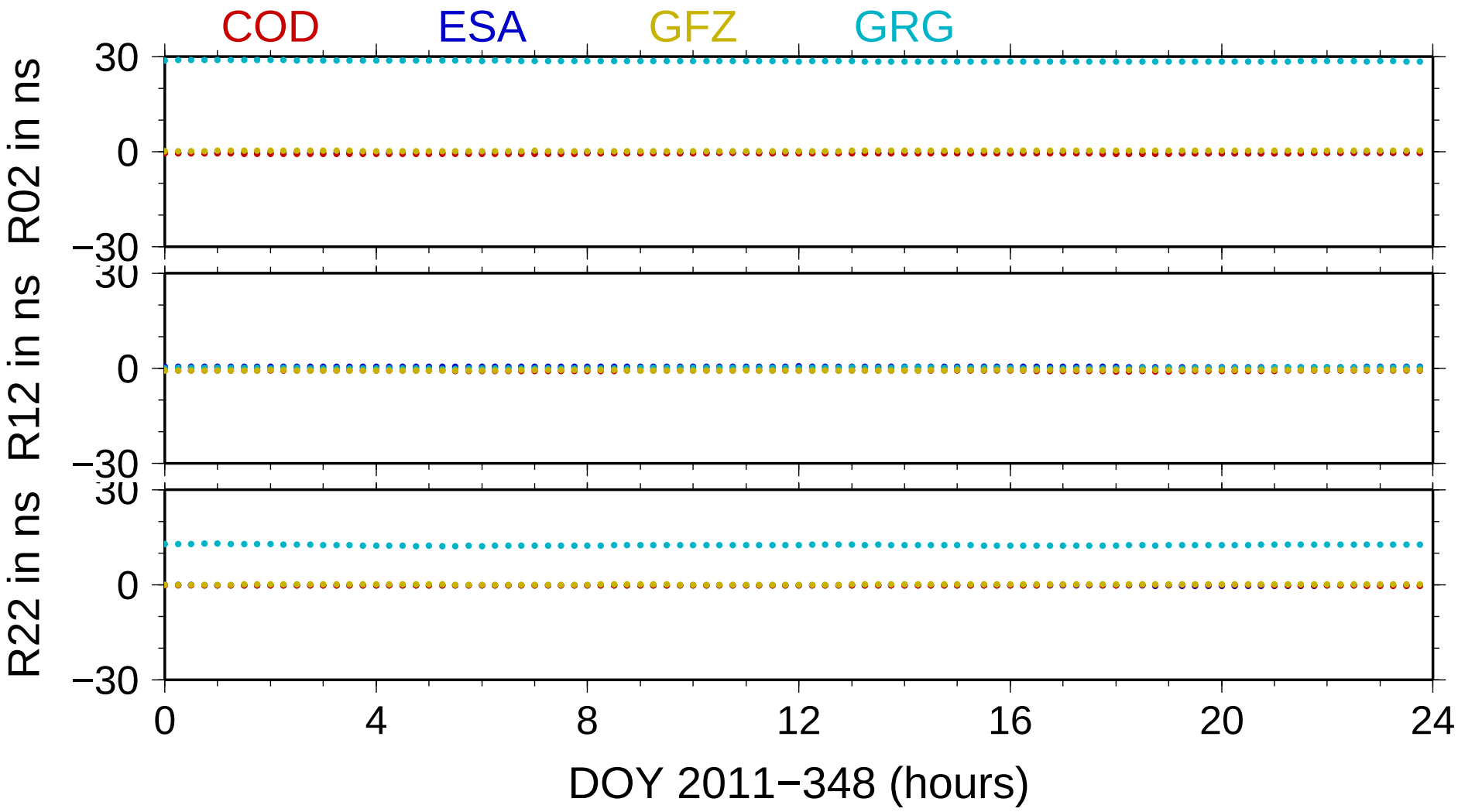
Satellite Clock Series (Reference clock: G15)

Deviation from the median



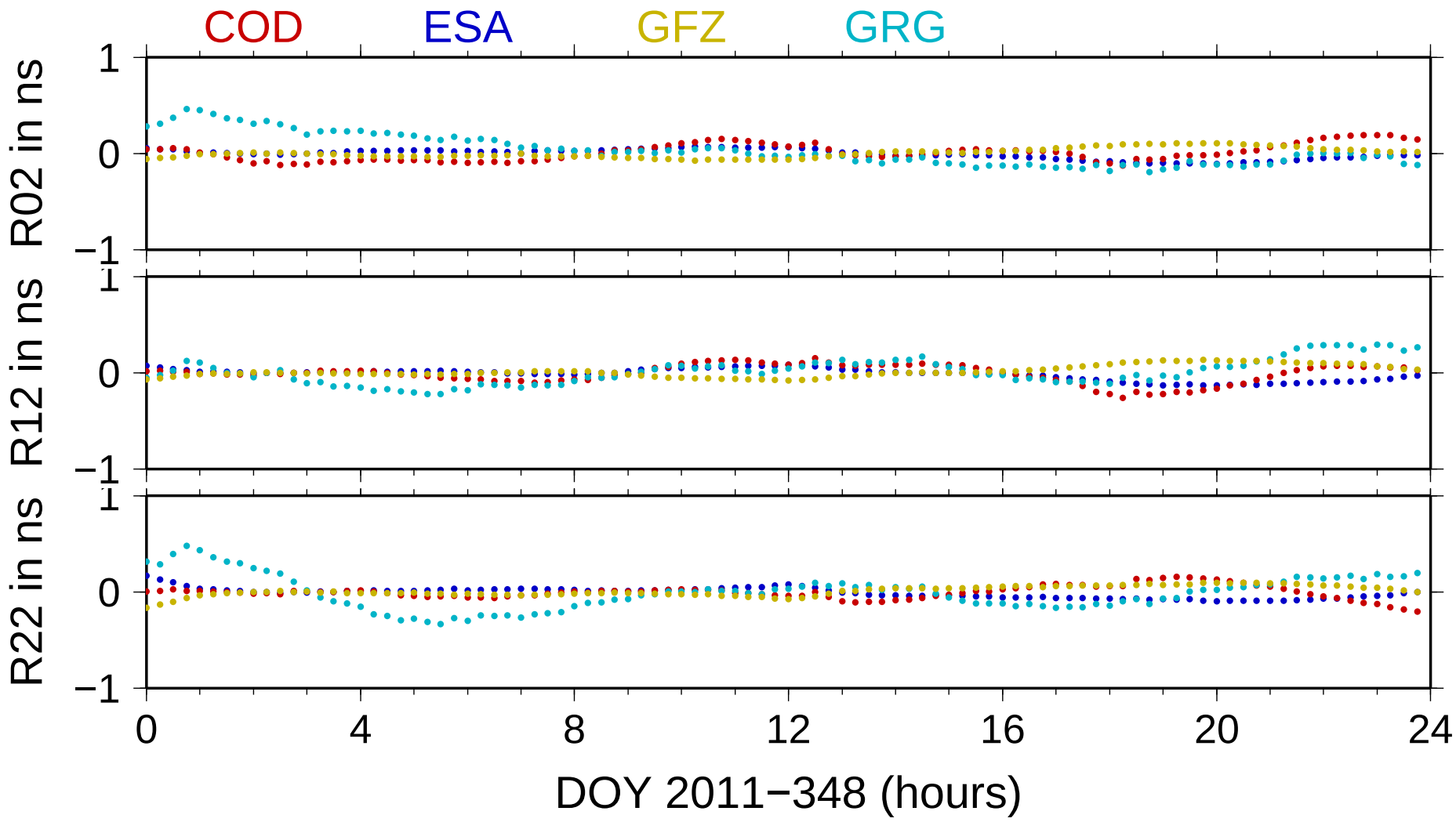
Satellite Clock Series (Reference clock: G15)

Deviation from the median, ISB subtracted

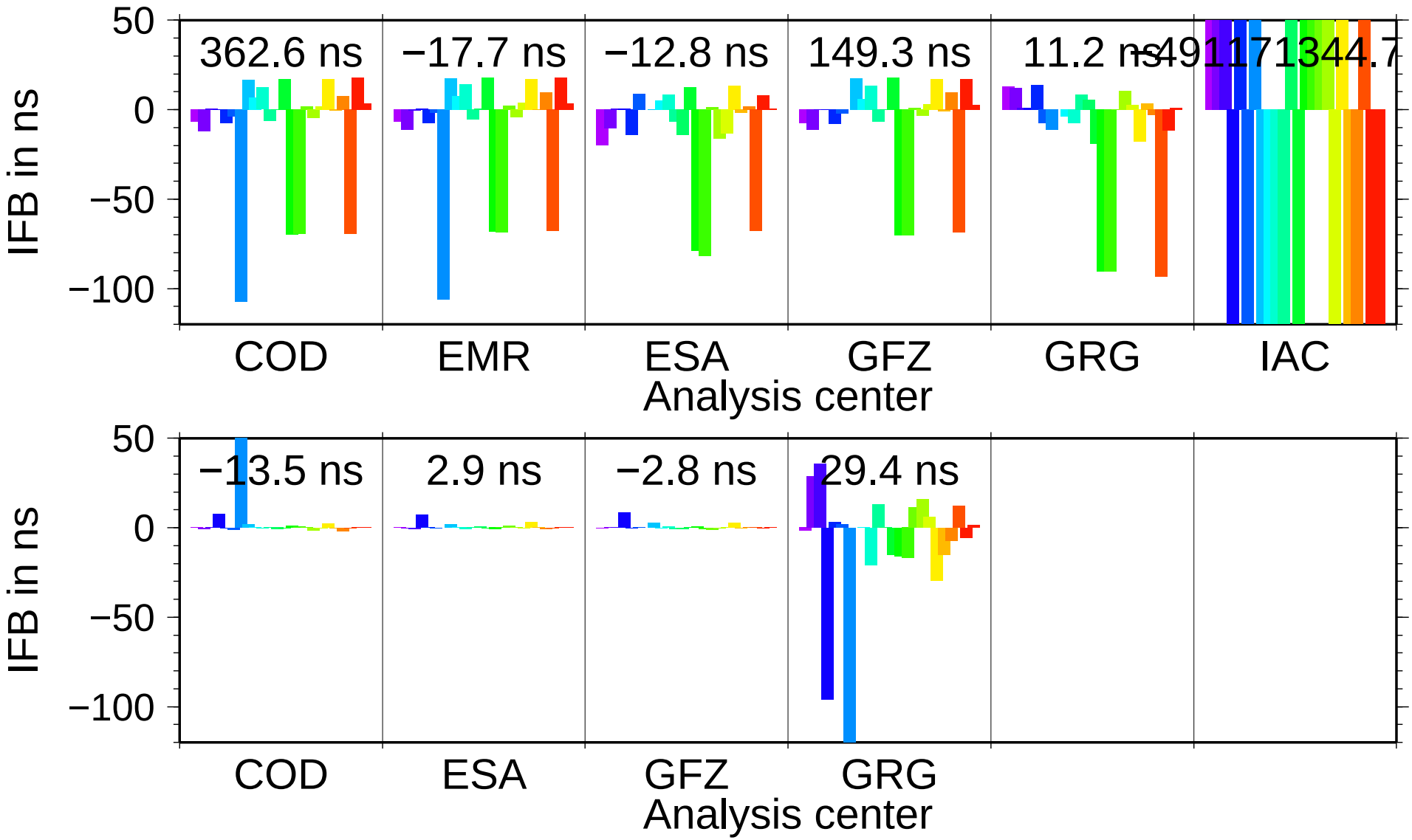


Satellite Clock Series (Reference clock: G15)

Deviation from the median, ISB+IFB subtracted



ISB/IFB as Extracted from Satellite Clocks



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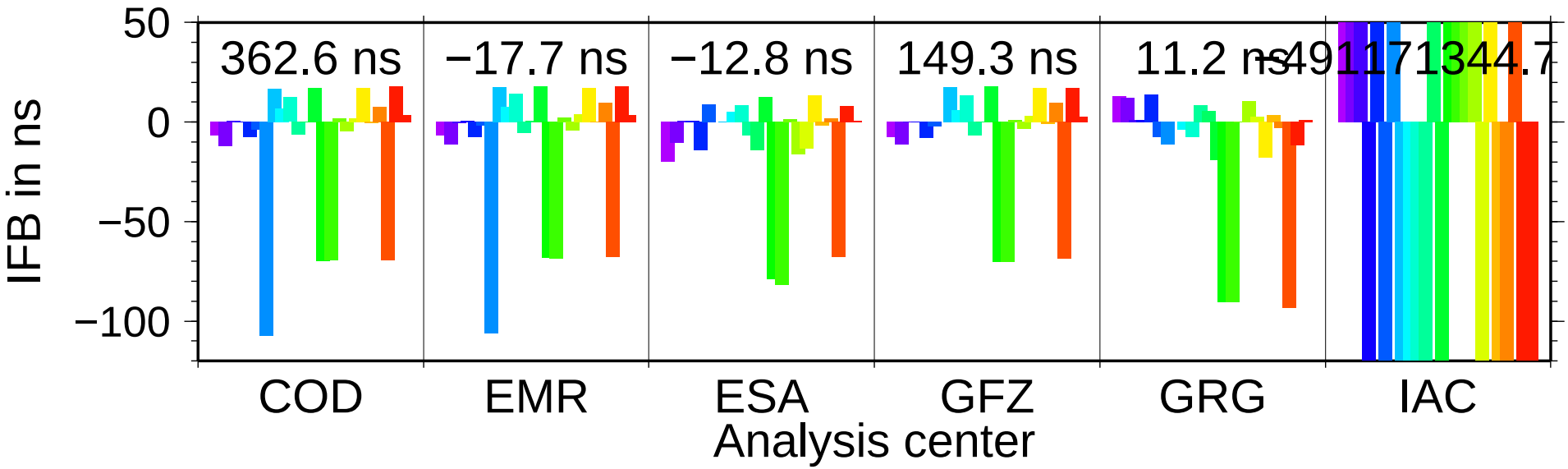
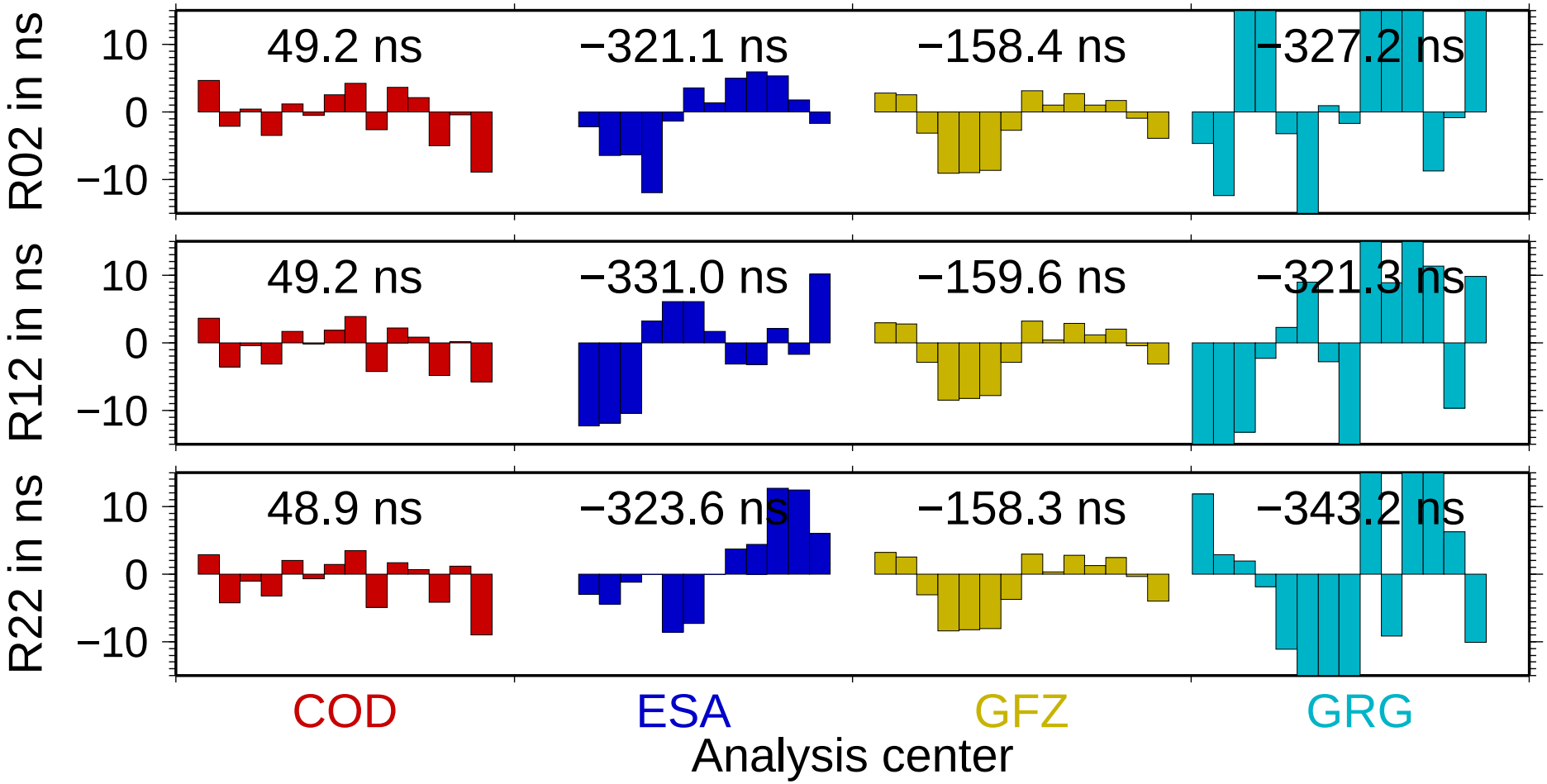


Conclusion – 2

- To apply the mean ISB/IFB per satellite from the satellite clock solutions helps to reduce the differences between the solutions.
- Nevertheless, additional ISB/IFB need to be estimated from the satellite clock solutions of different ACs to achieve the consistency level necessary for the combination.
- The problem of ISB/IFB estimation from satellites not included in all solutions is reduced but not solved.

IFB/ISB Computed by the Analysis Centers

Repeatability of the IFB/ISB (as they are)



Station: MATE – Matera, IT

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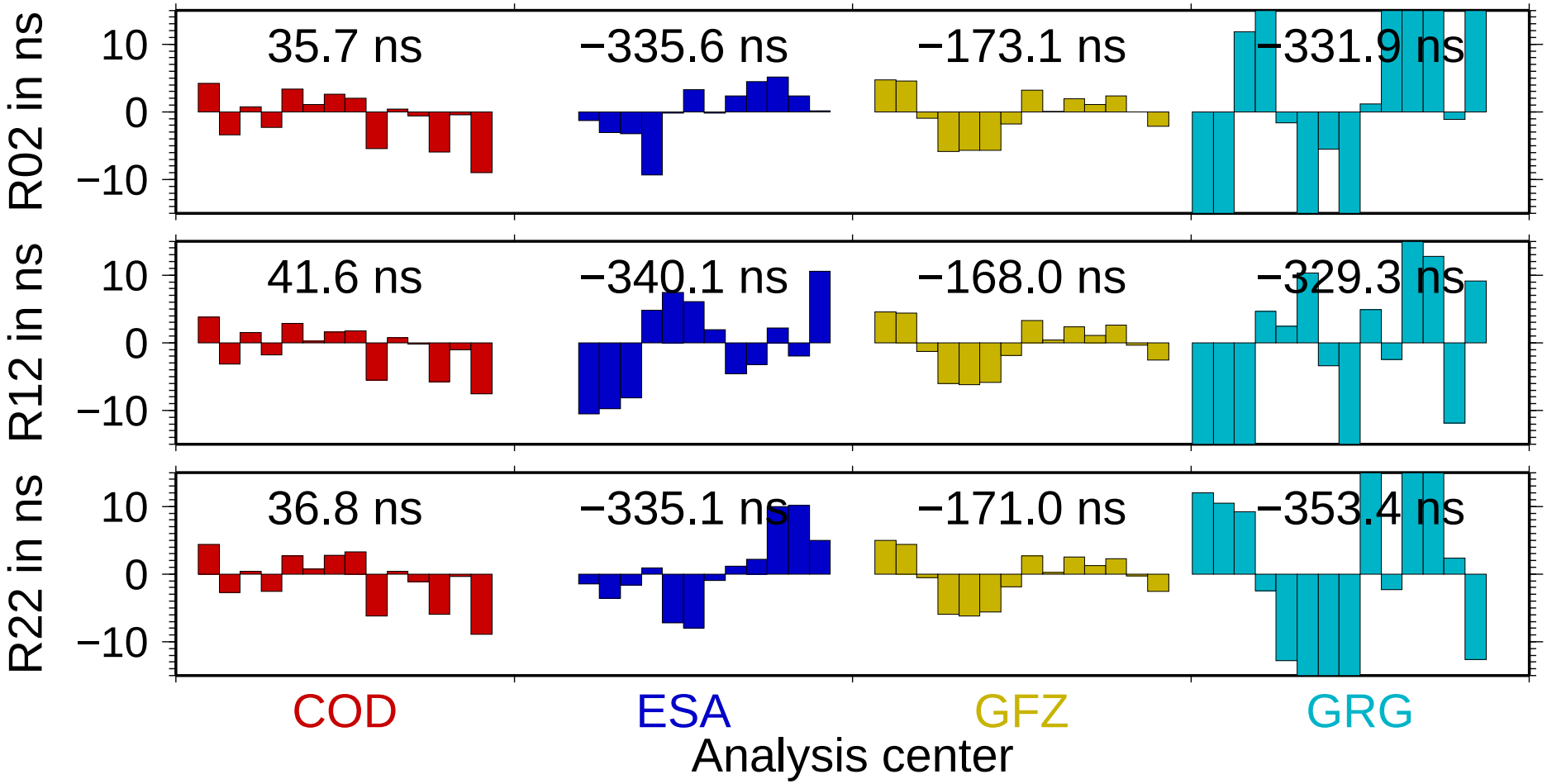
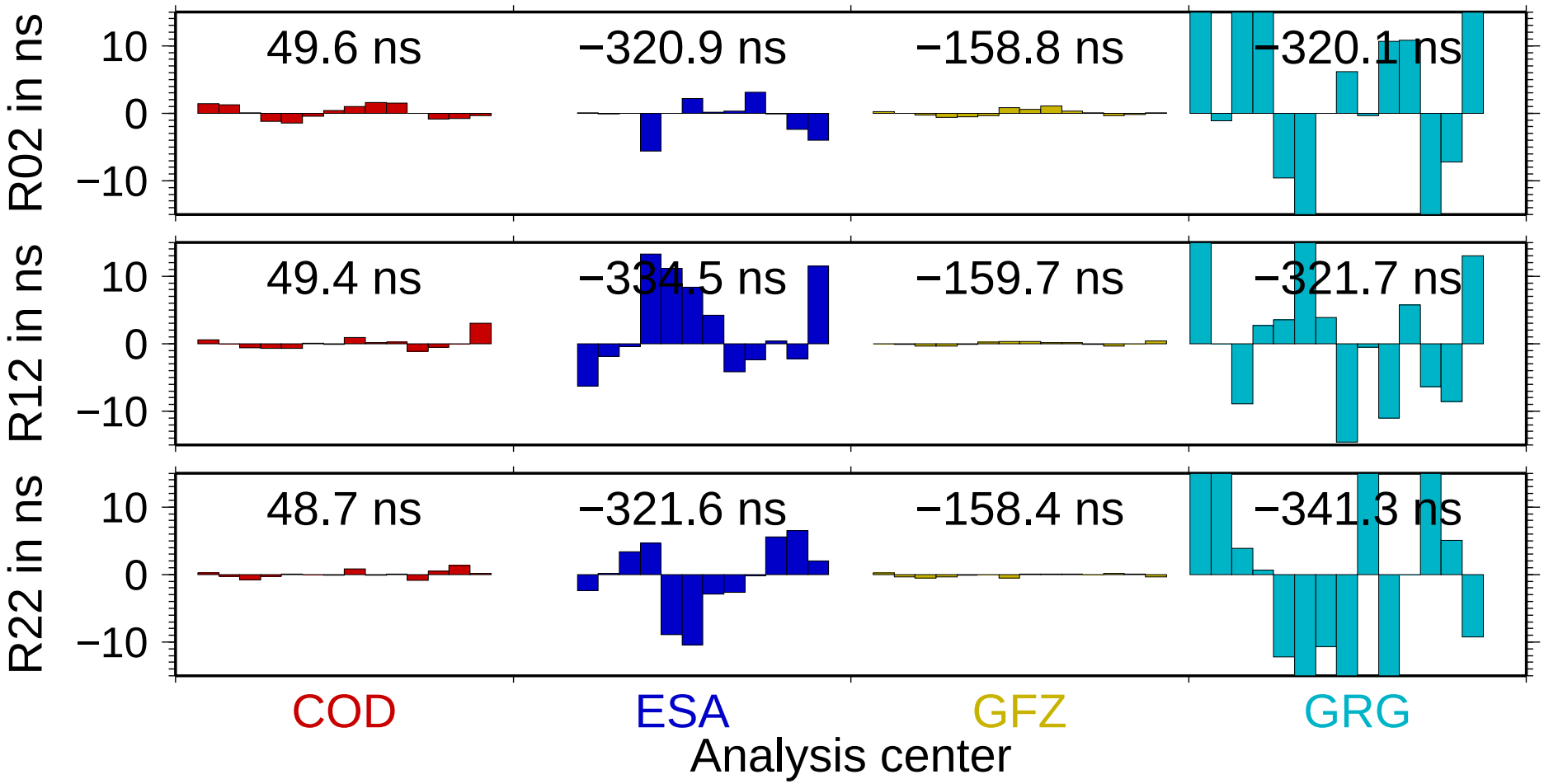


Station: CONZ – Concepcion, CL

IFB/ISB Computed by the Analysis Centers

Repeatability of the IFB/ISB (unified reference)



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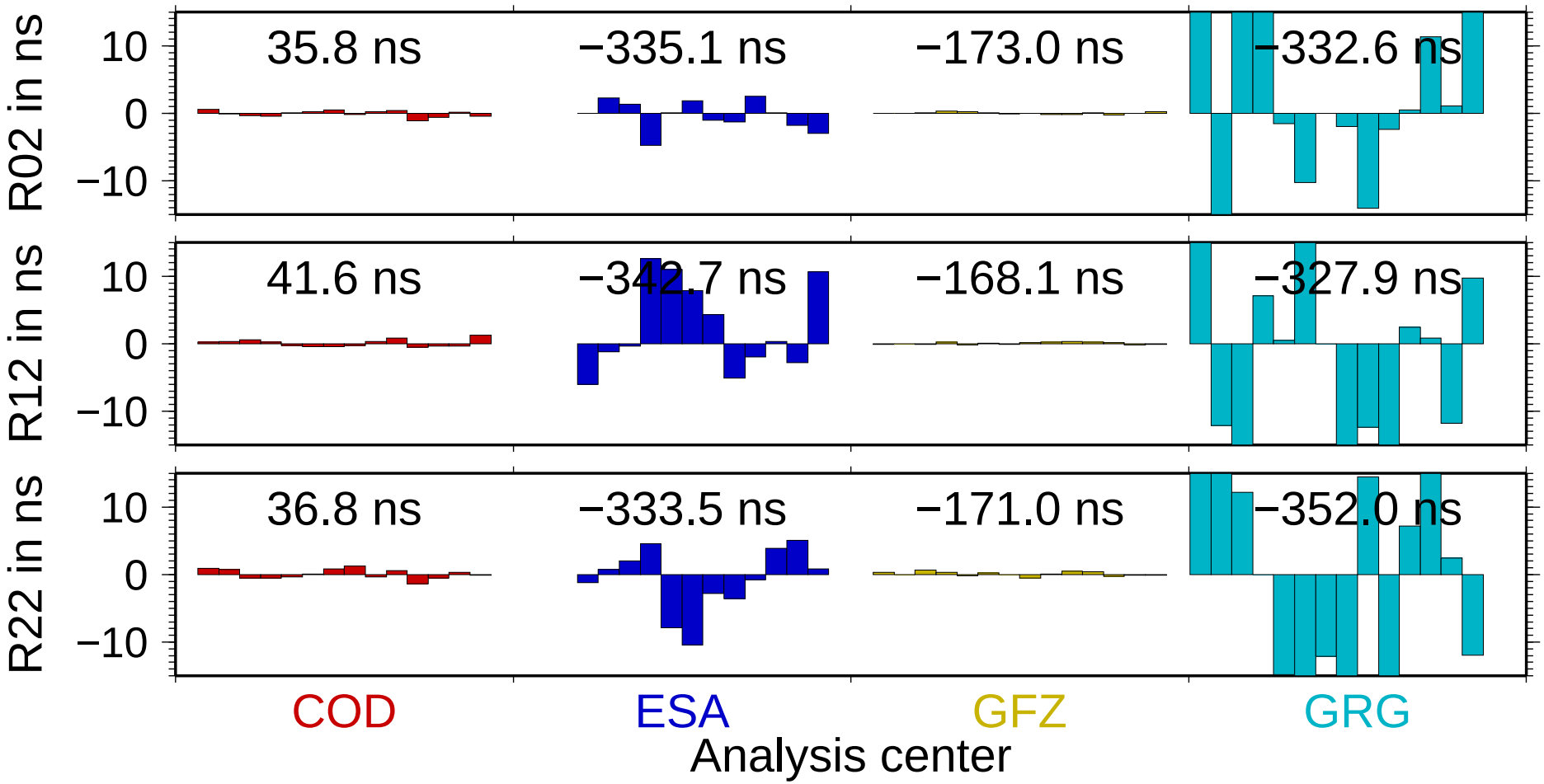


Station: CONZ – Concepcion, CL

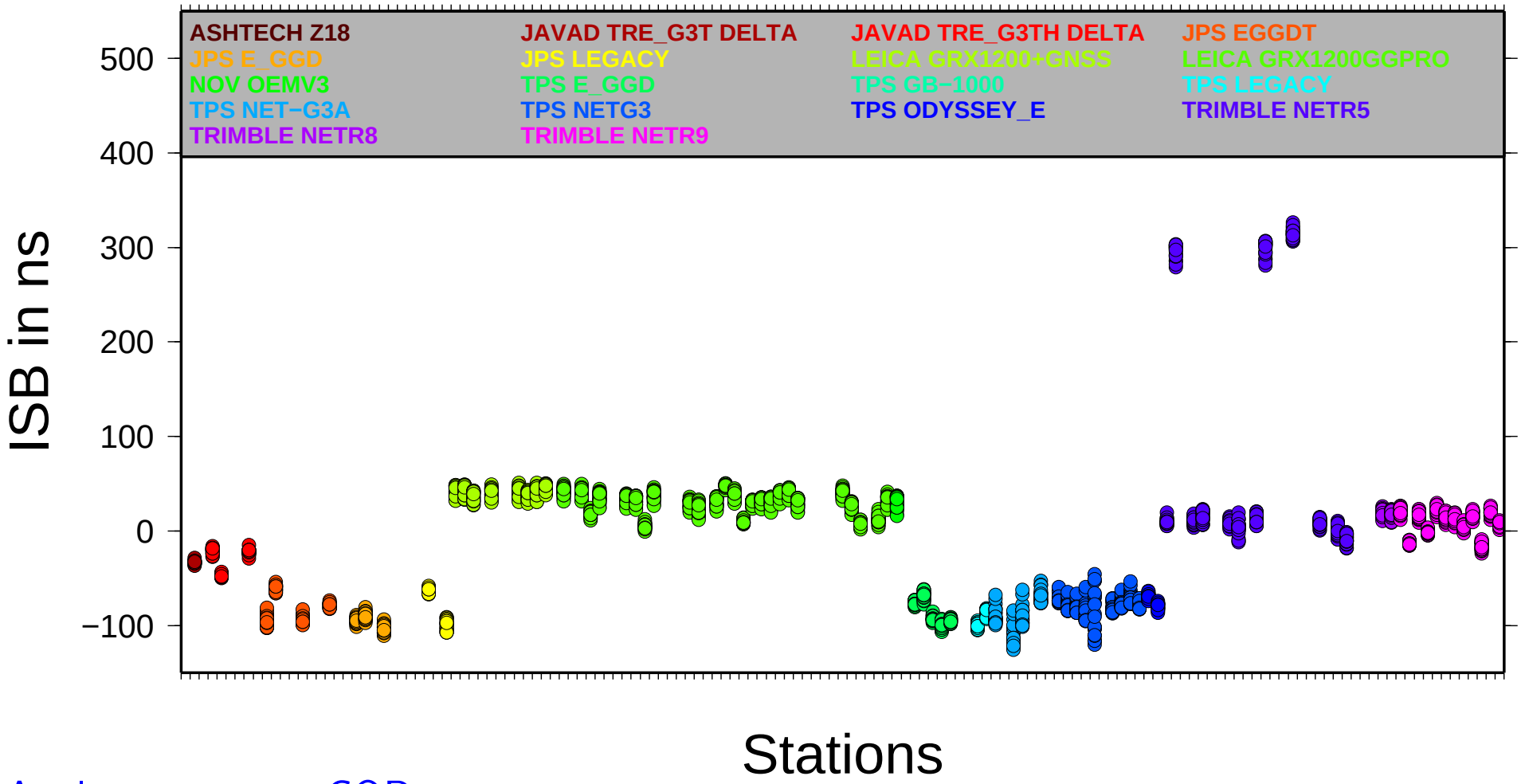
IFB/ISB Computed by the Analysis Centers

Conclusion

- The IFB/ISB series from daily independent solutions need to be unitfied regarding their reference.
- The stability of the IFB with unified reference depend on the stability of the differences between the IFB between two satellites from the day to day in the original series.
- In the best cases we achieve a peak-to-peak stability of 2 to 3 ns.

IFB/ISB Computed by the Analysis Centers

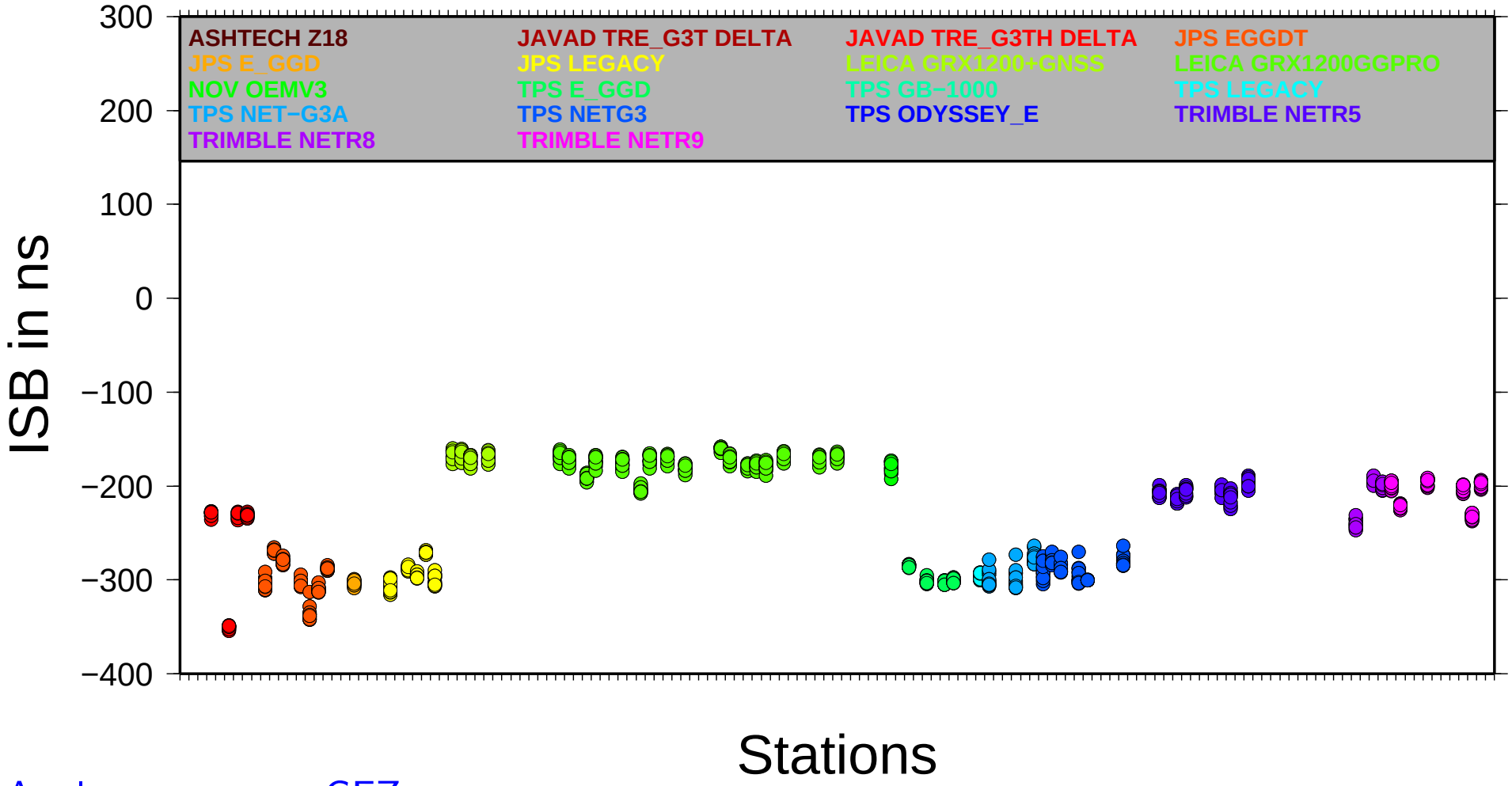
ISB characteristic of the receivers



Analyse centrum: COD

IFB/ISB Computed by the Analysis Centers

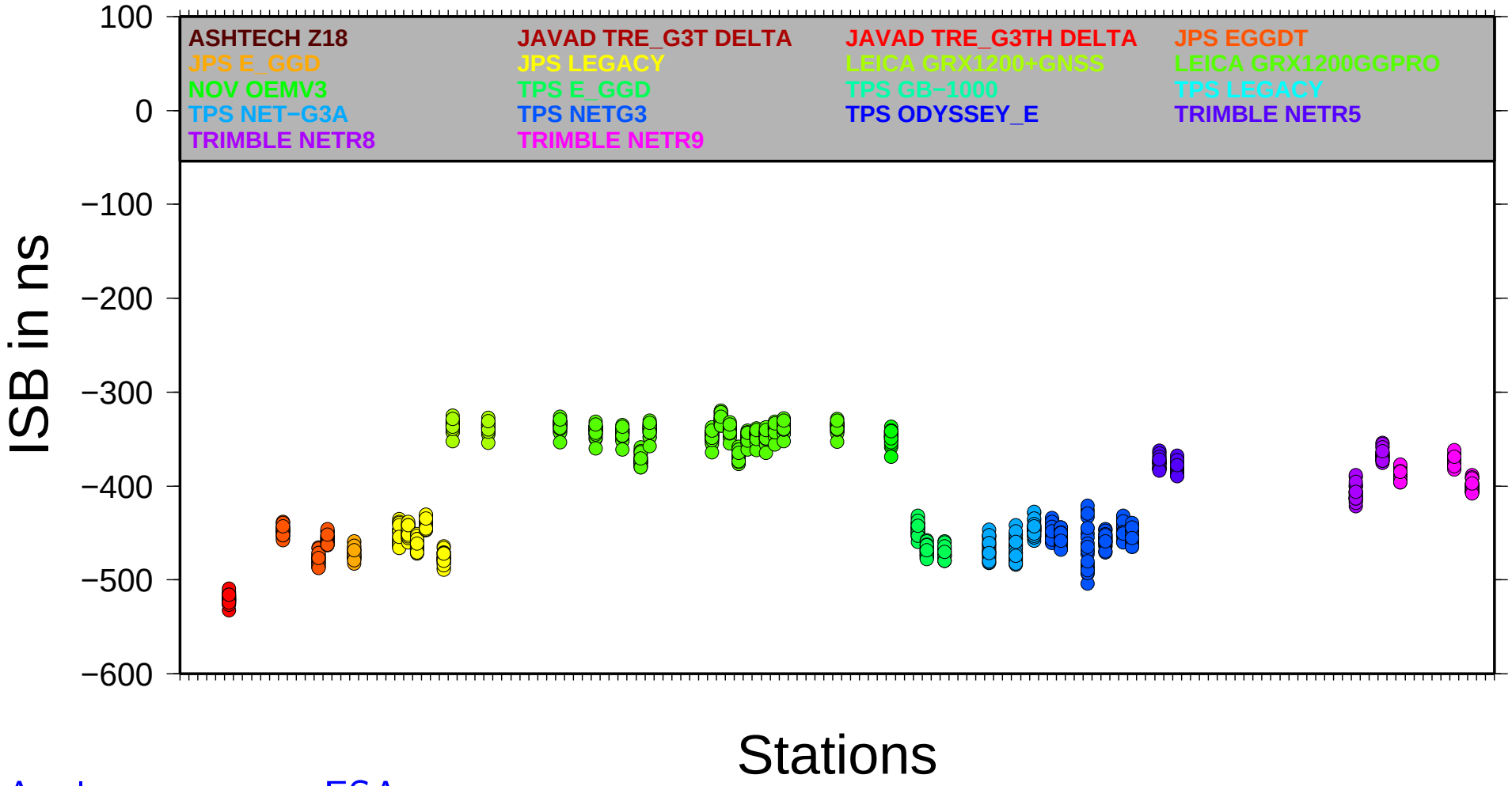
ISB characteristic of the receivers



Analyse centrum: GFZ

IFB/ISB Computed by the Analysis Centers

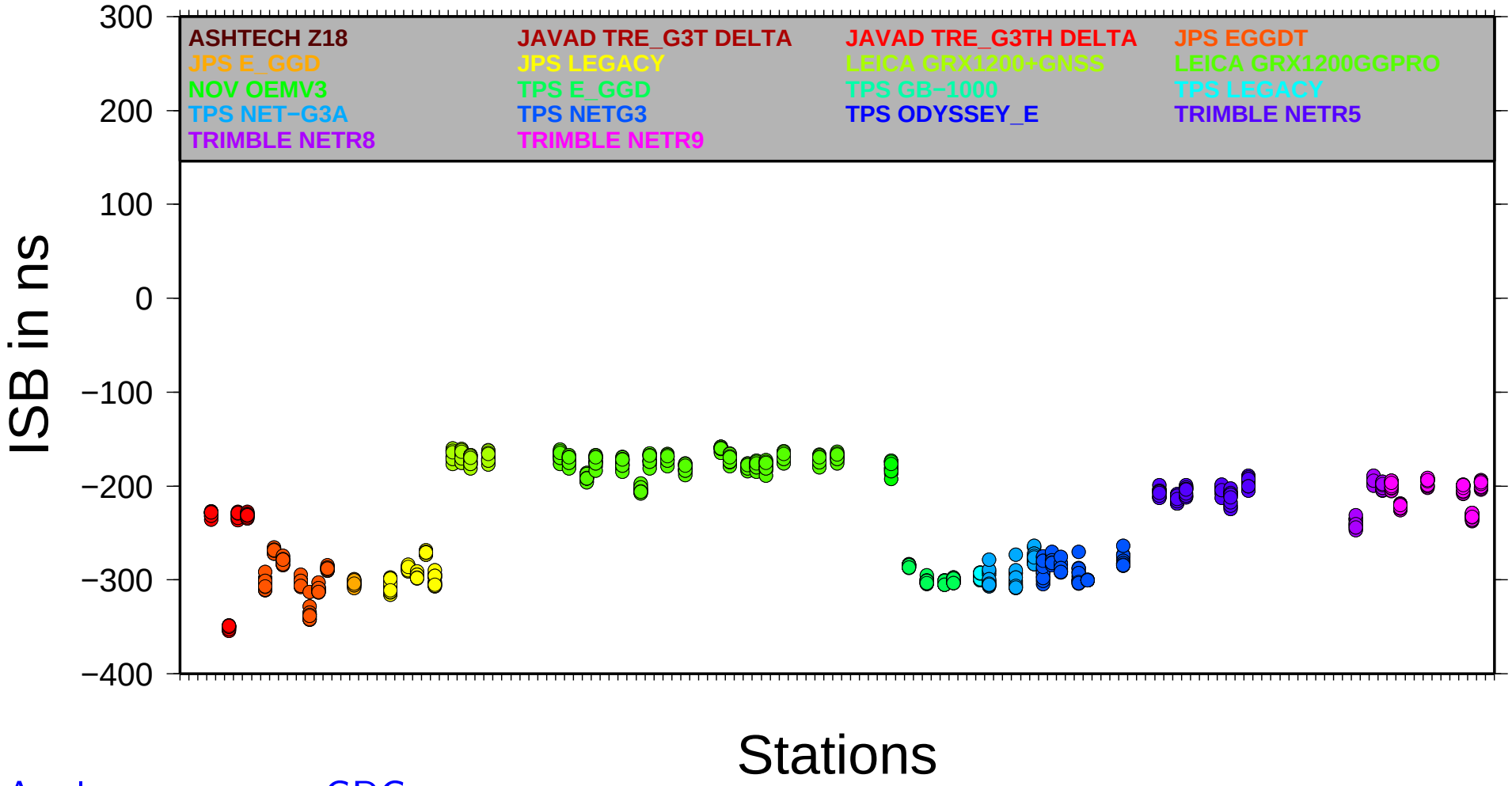
ISB characteristic of the receivers



Analyse centrum: ESA

IFB/ISB Computed by the Analysis Centers

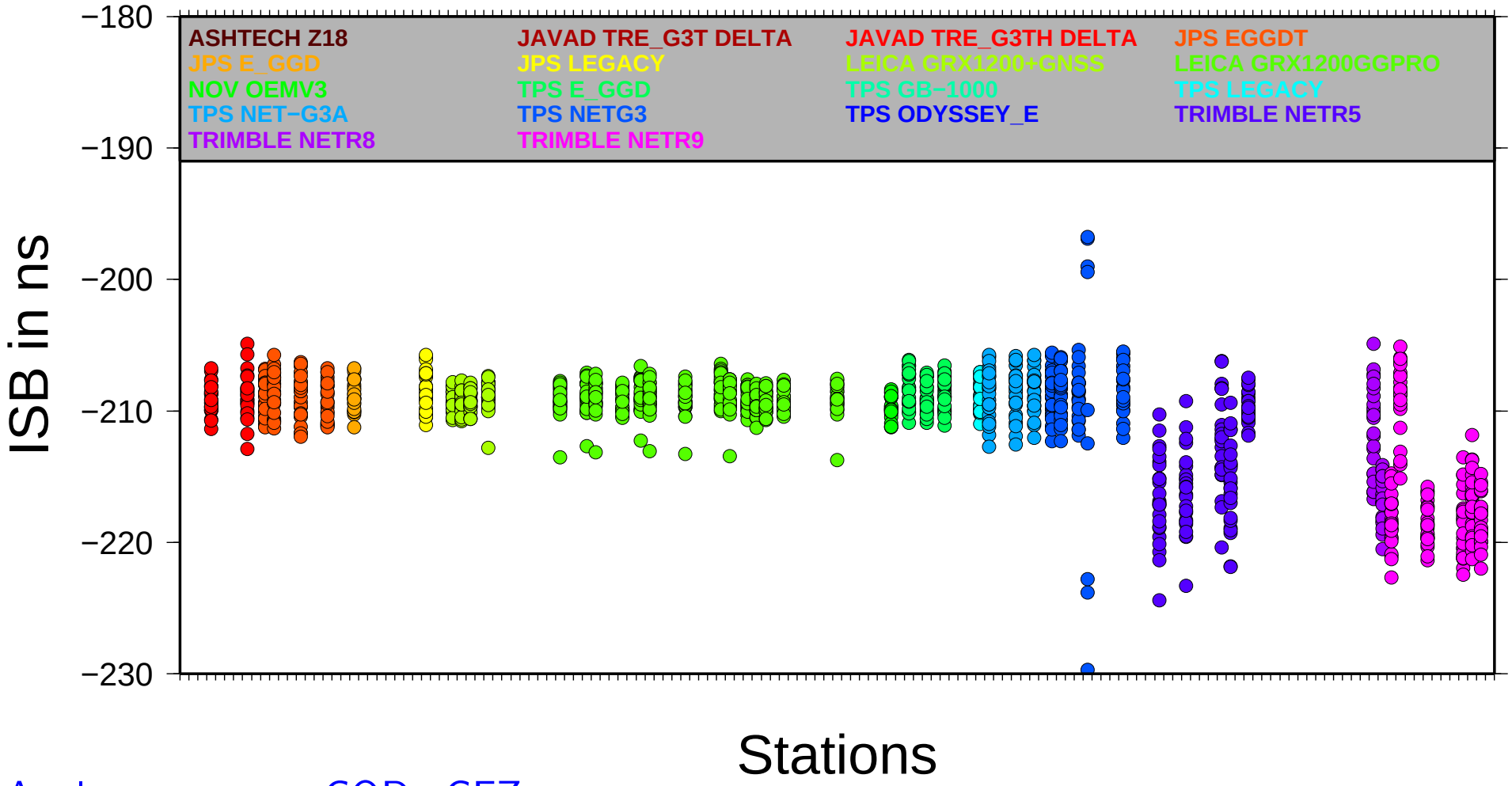
ISB characteristic of the receivers



Analyse centrum: GRG

IFB/ISB Computed by the Analysis Centers

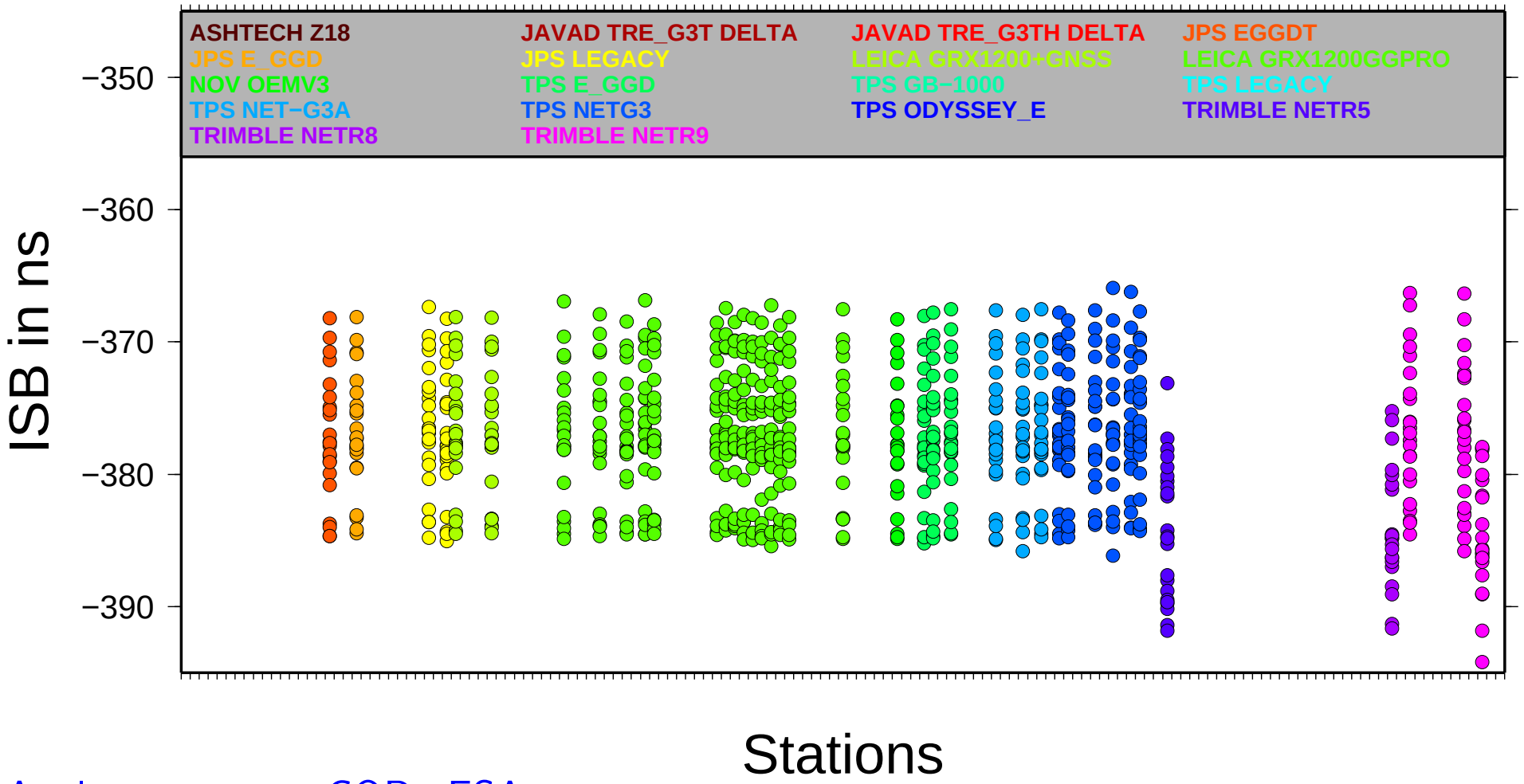
Differences between ISB characteristic of the receivers



Analyse centrum: COD−GFZ

IFB/ISB Computed by the Analysis Centers

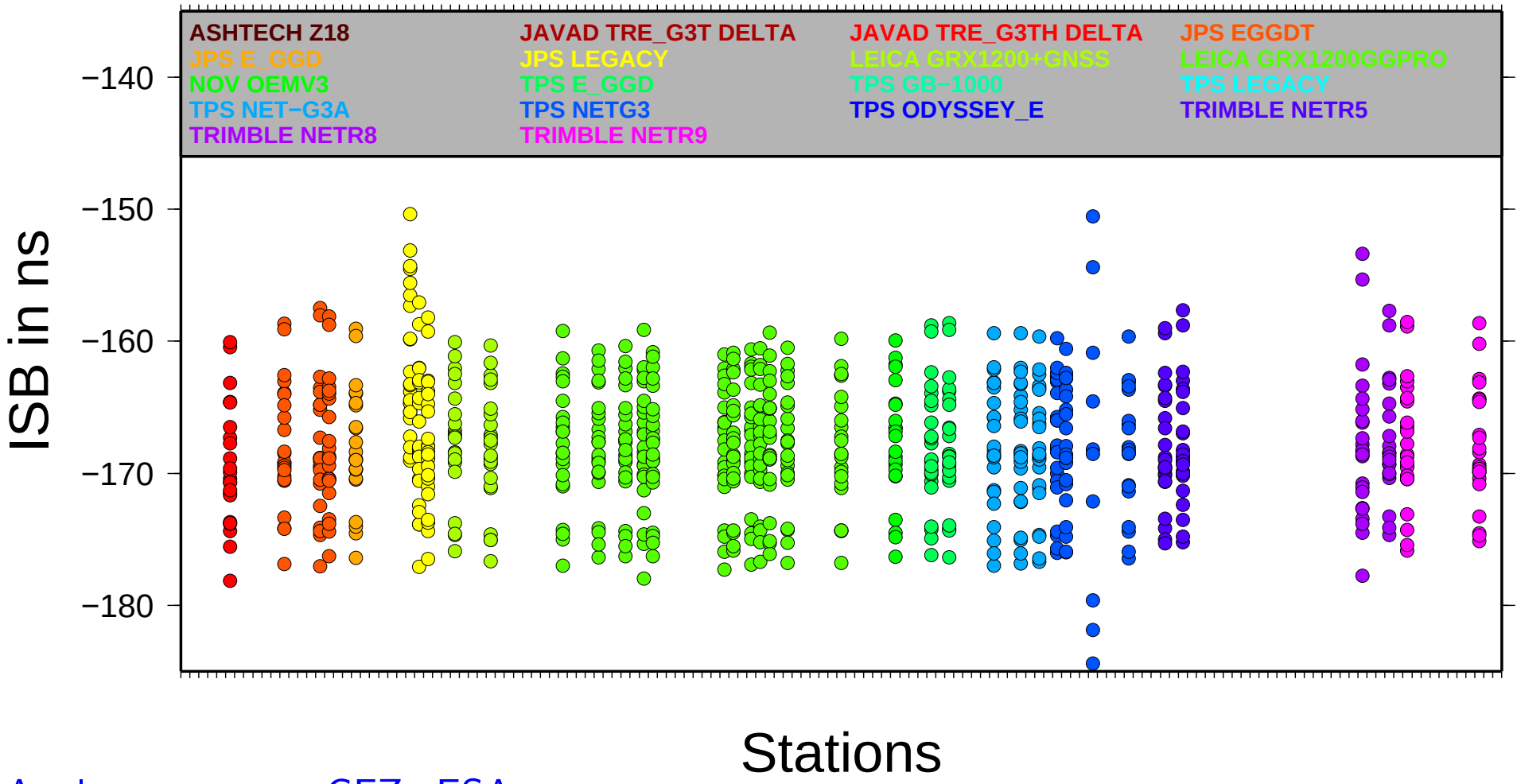
Differences between ISB characteristic of the receivers



Analyse centrum: COD−ESA

IFB/ISB Computed by the Analysis Centers

Differences between ISB characteristic of the receivers



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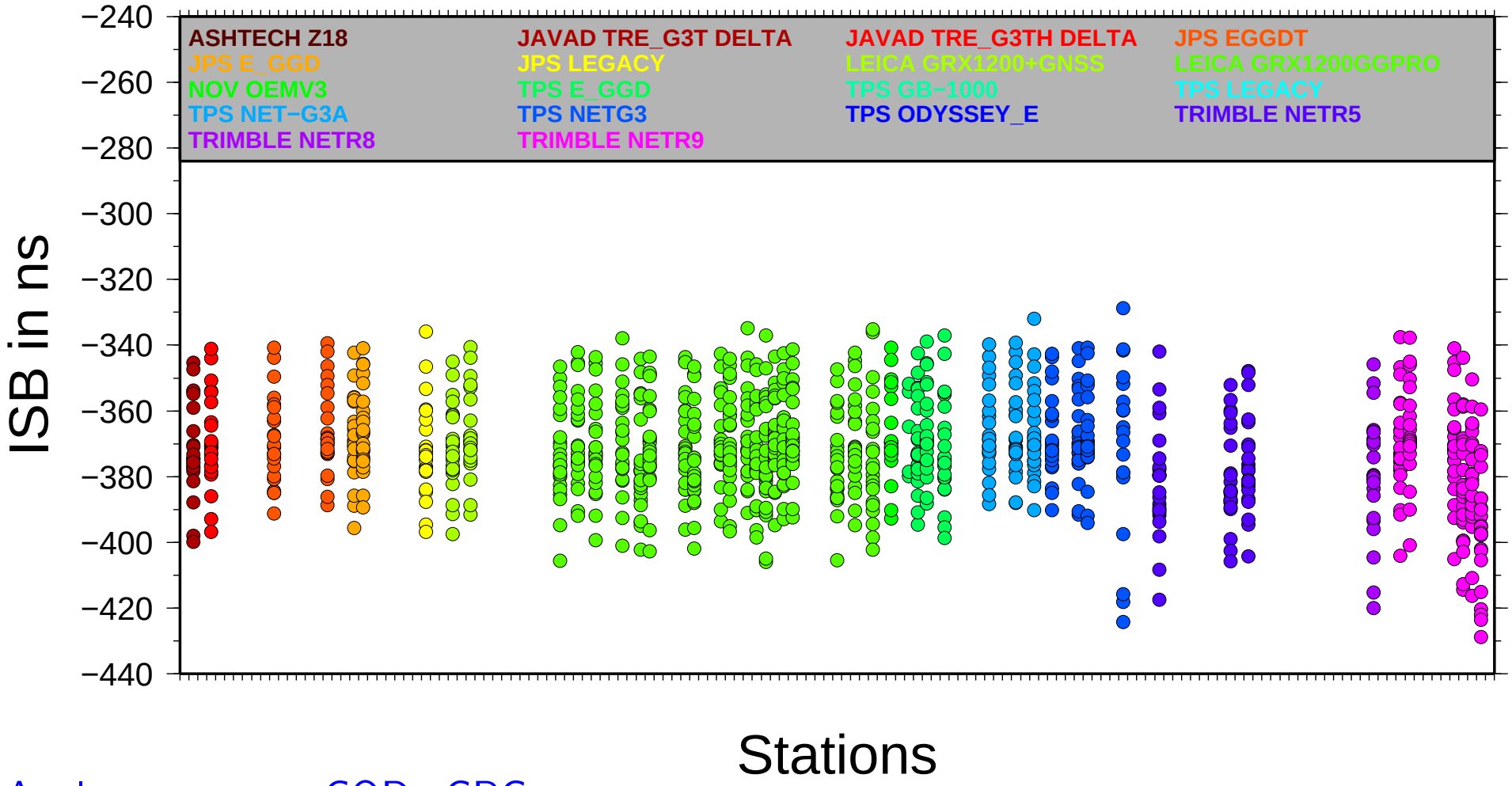

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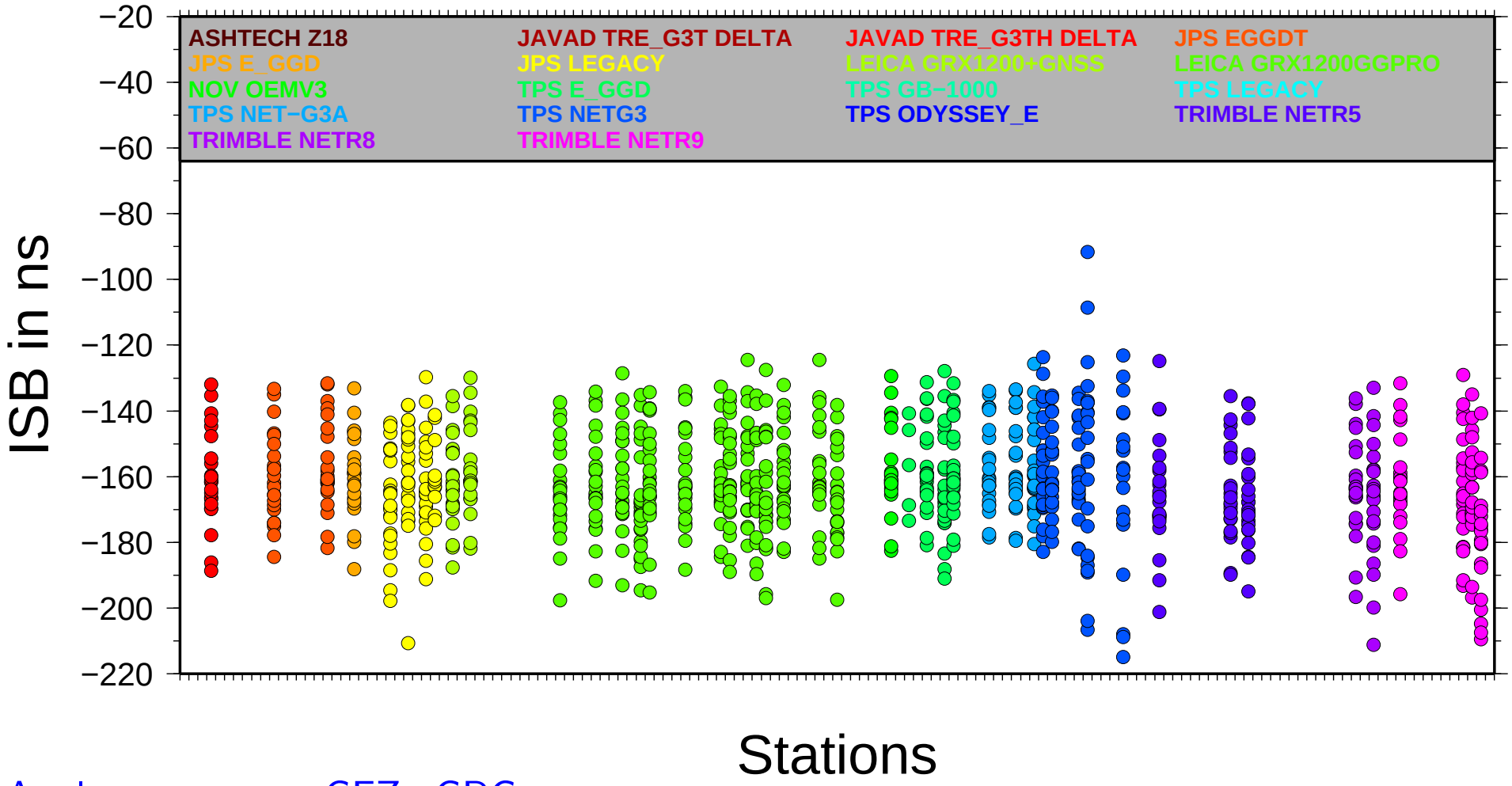

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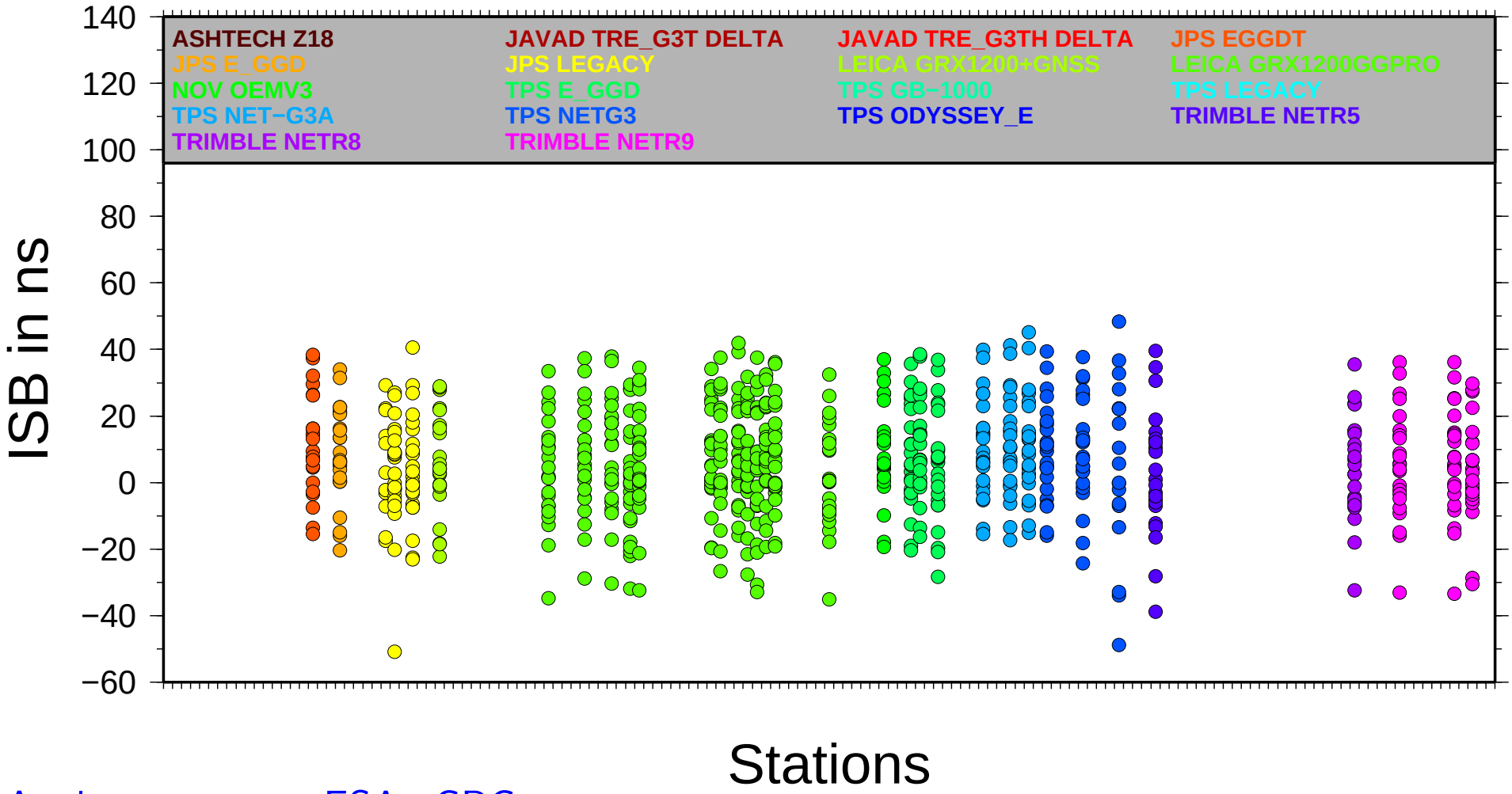


Analyse centrum: ESA−GRG

IFB/ISB Computed by the Analysis Centers

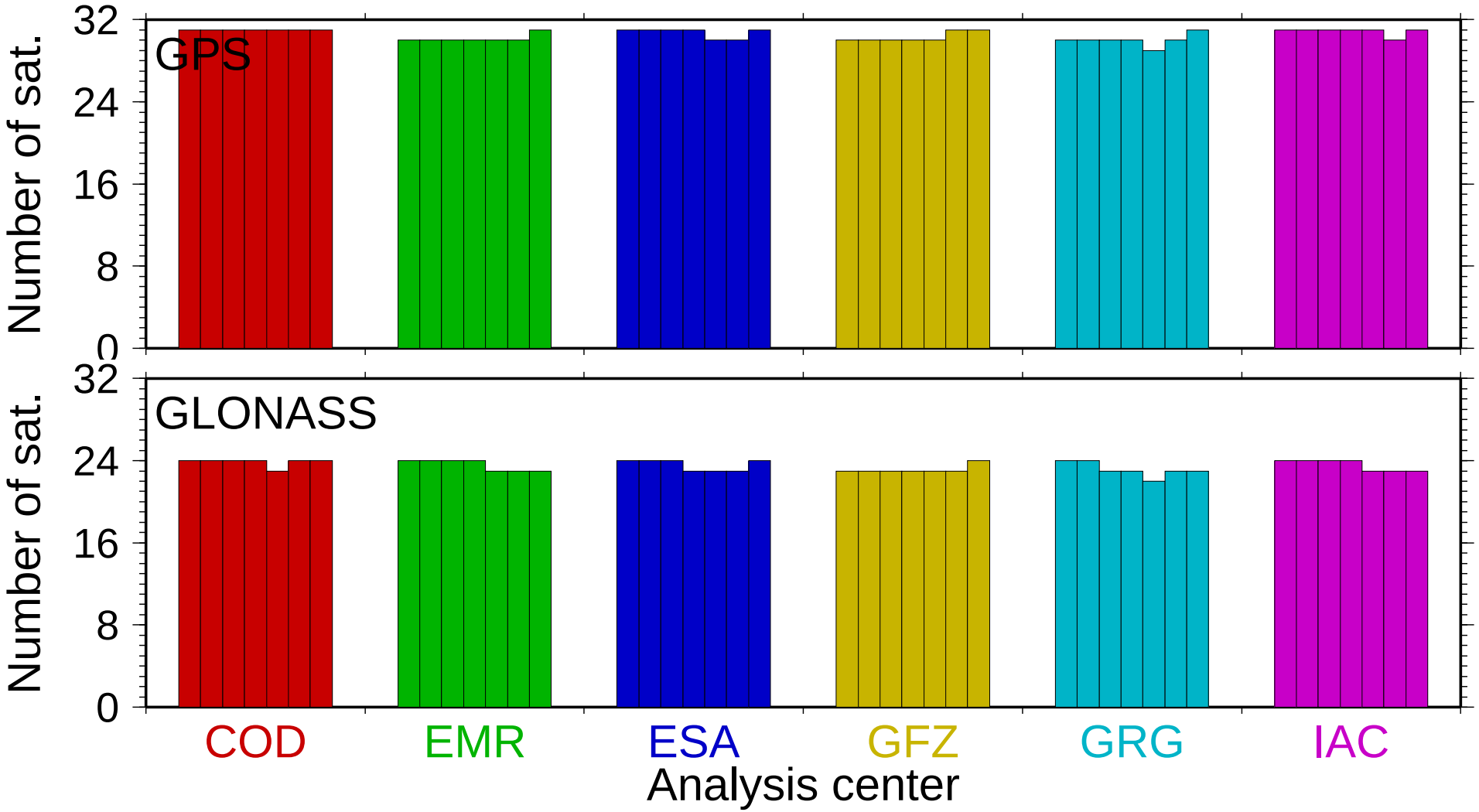
Differences between ISB characteristic of the receivers

Difference	Num. of Stations	Mean in ns	Median in ns	RMS in ns
COD – GFZ	52	−210.6	−209.4	4.9
COD – ESA	39	−377.5	−377.6	5.1
GFZ – ESA	36	−167.7	−168.2	6.1
COD – GRG	50	−371.9	−372.2	18.7
GFZ – GRG	46	−162.1	−163.0	19.2
ESA – GRG	34	6.1	5.8	20.6

- High consistency (low RMS) with a proper IFB–handling (enough weight for the code measurements?)
- Test whether the ACs select the same type of code observations (CODE differs from ESA and GFZ)

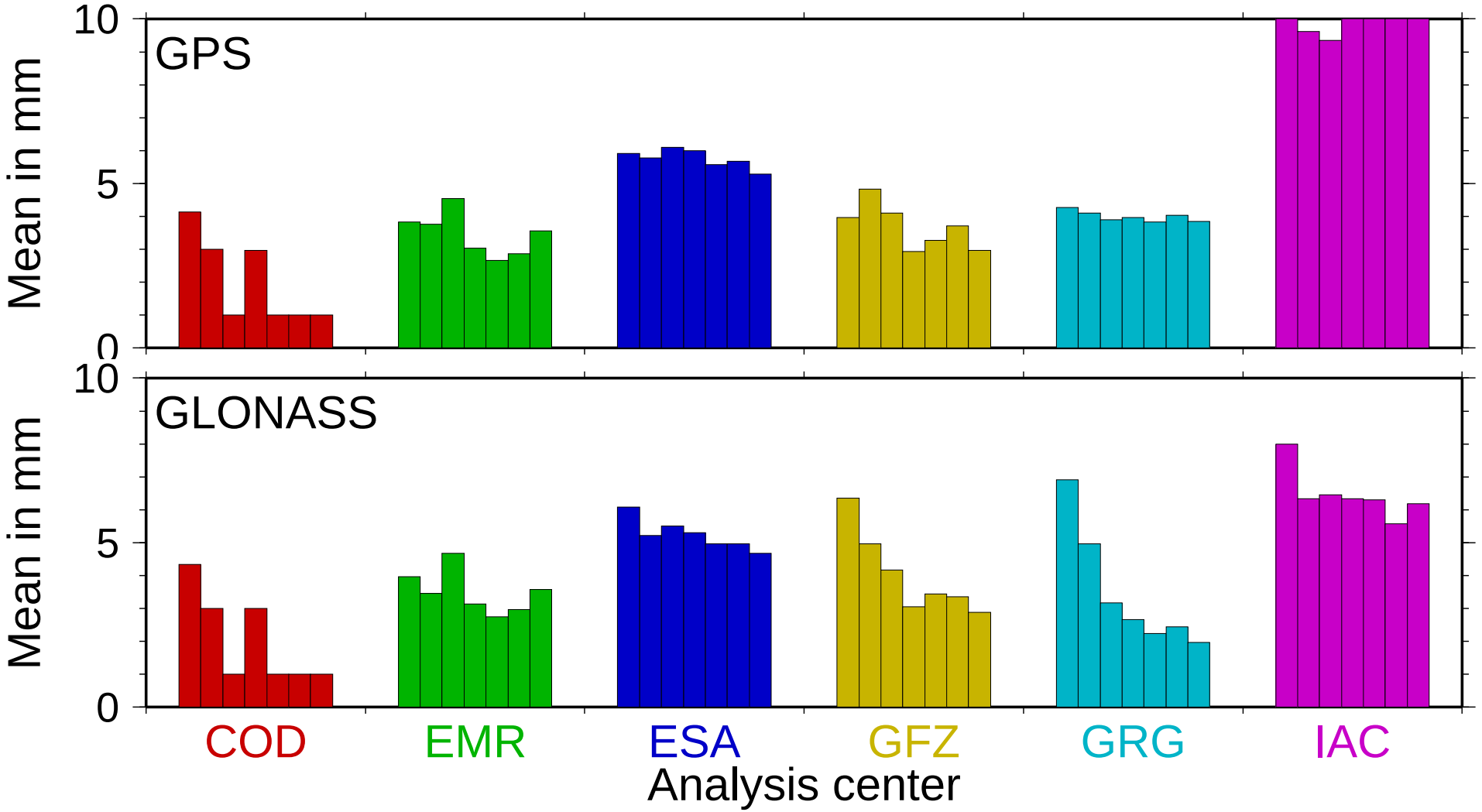
Number of Satellites in the Solutions

Number of satellites per system



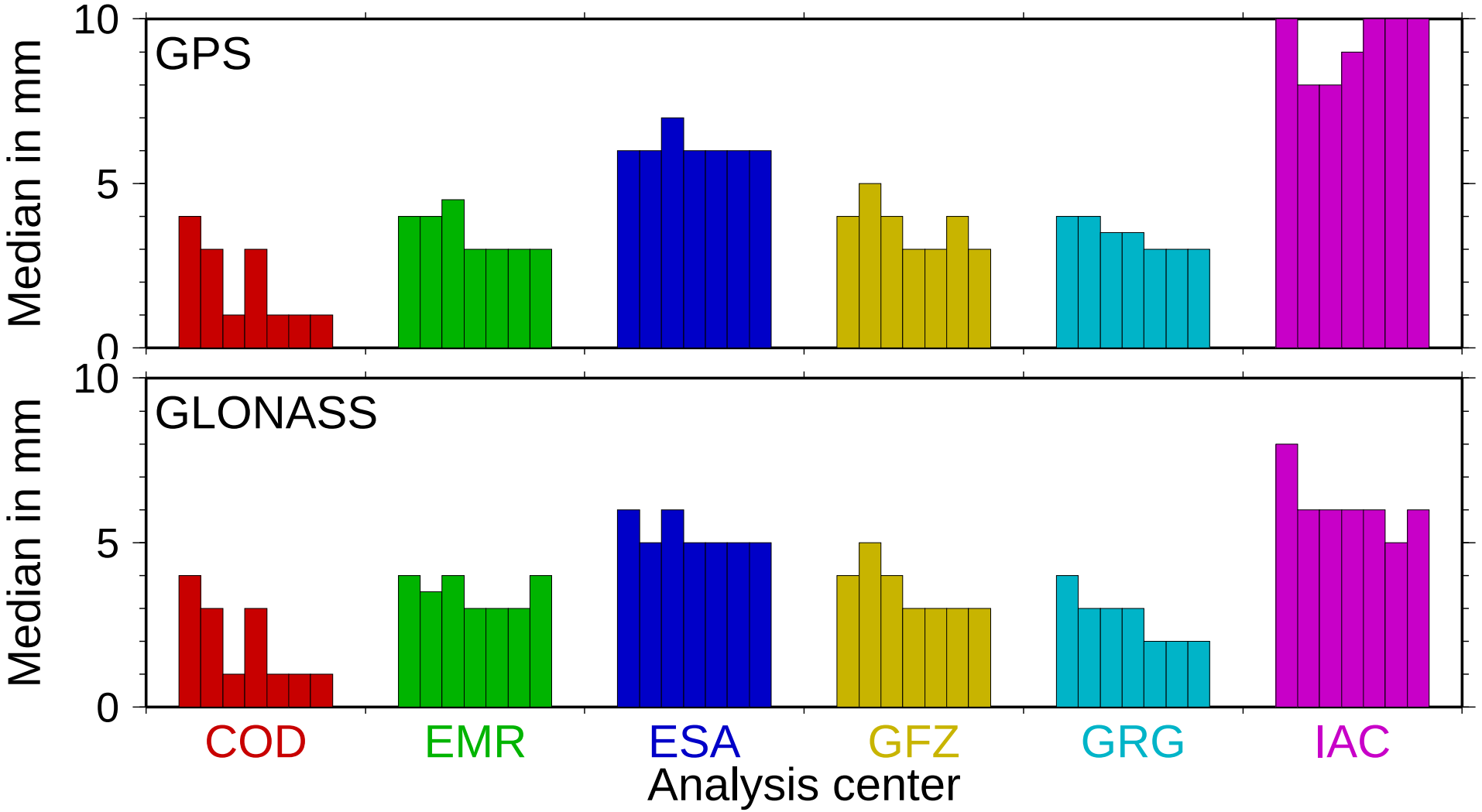
RMS of Orbit–fit using Bernese Software

Mean over all satellites of each system



RMS of Orbit–fit using Bernese Software

Median from all satellites of each system



Comparison in the PPP–Performance

How the following Solutions Have Been Generated?

1. Data import and screening

   (a) **if high–rate satellite clock corrections are available:**
   Phase–data are screened based on PPP with a sophisticated algorithm before the first PPP–solution using post–fit residual screening.

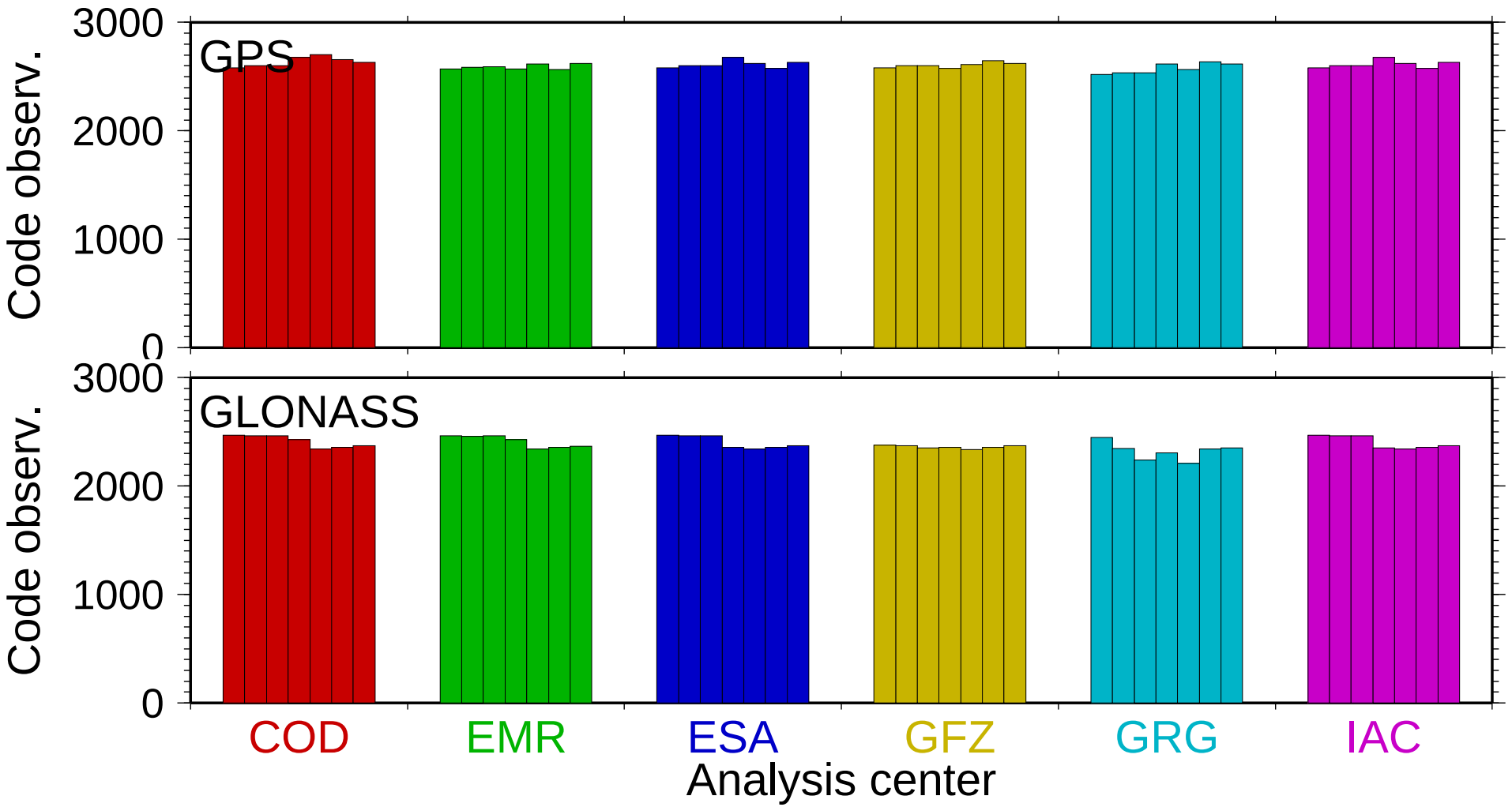
   (b) **without high–rate satellite clock corrections:**
   Only the consistency between code– and phase–data is checked before the first PPP–solution using post–fit residual screening.

2. static PPP using GPS/GLONASS data
   assuming satellite–specific inter–system/inter–frequency code biases without ambiguity resolution for the phase data

3. pseudo–kinematic PPP using GPS/GLONASS data
   (same as above)

Statistics of the PPP Solution (after screening)

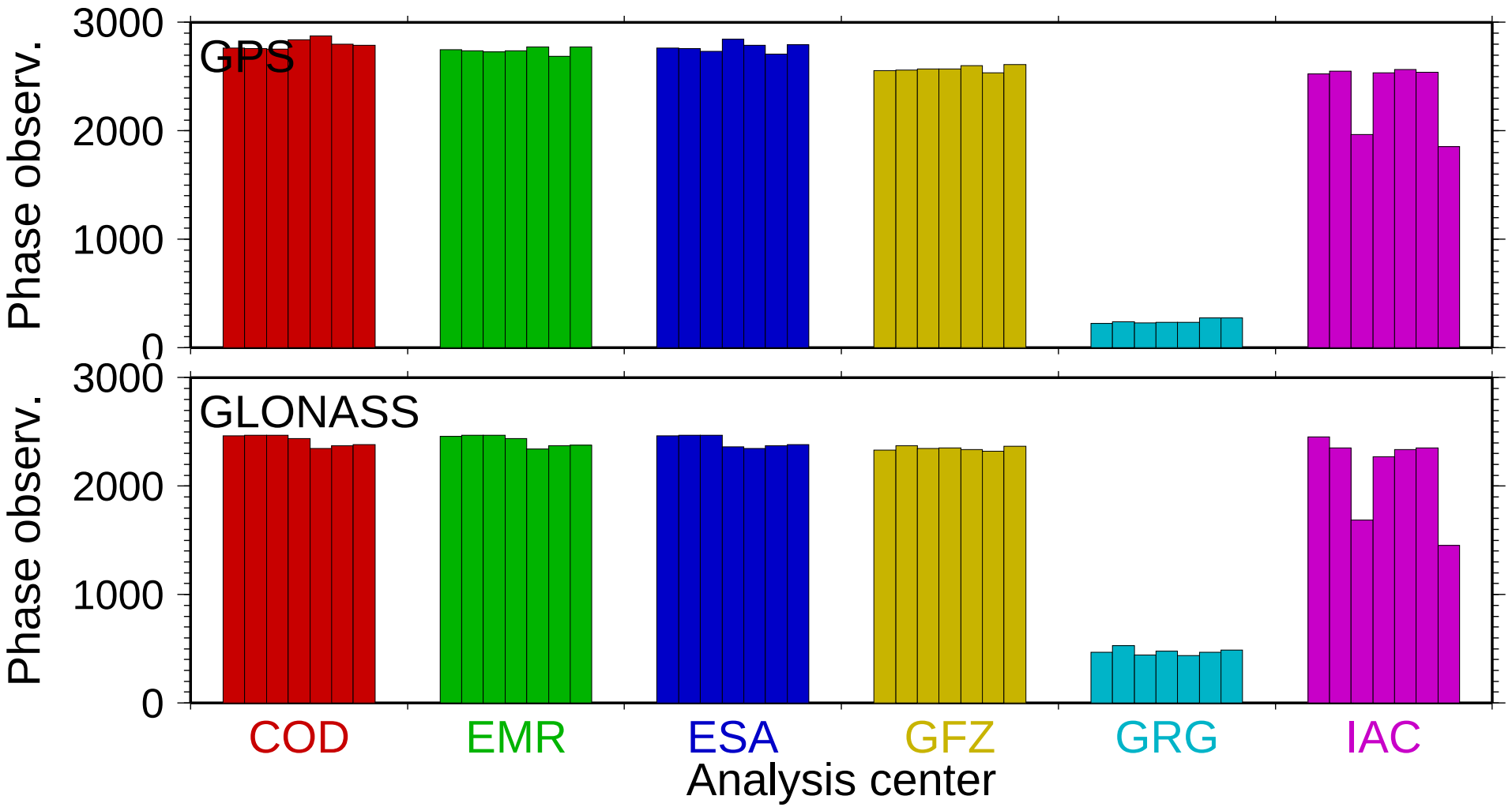
Number of code measurements (300 sec. sampling)



Station: ONSA – Onsala, SE

Statistics of the PPP Solution (after screening)

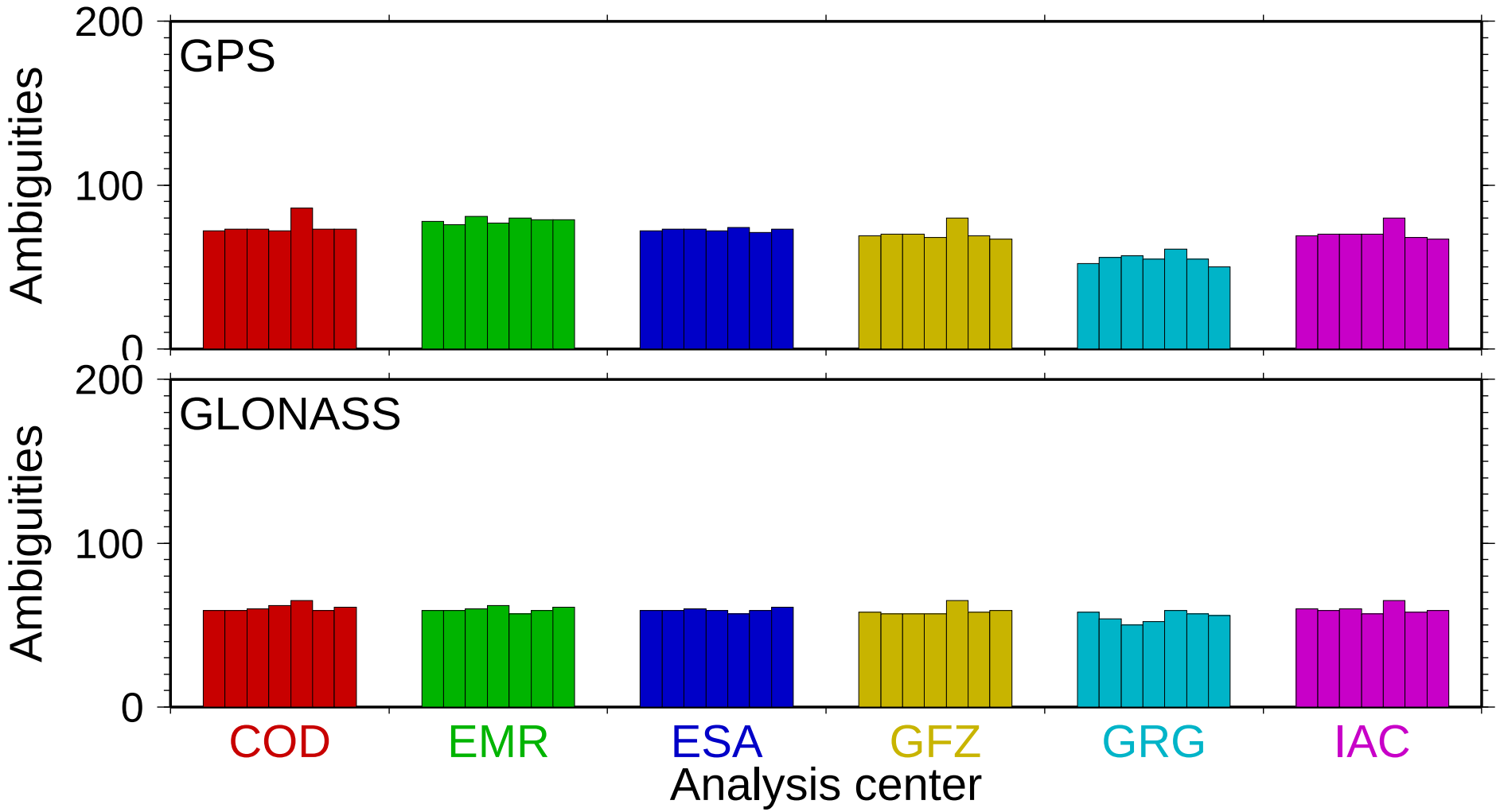
Number of phase measurements (300 sec. sampling)



Station: ONSA – Onsala, SE

Statistics of the PPP Solution (after screening)

Number of ambiguity parameters



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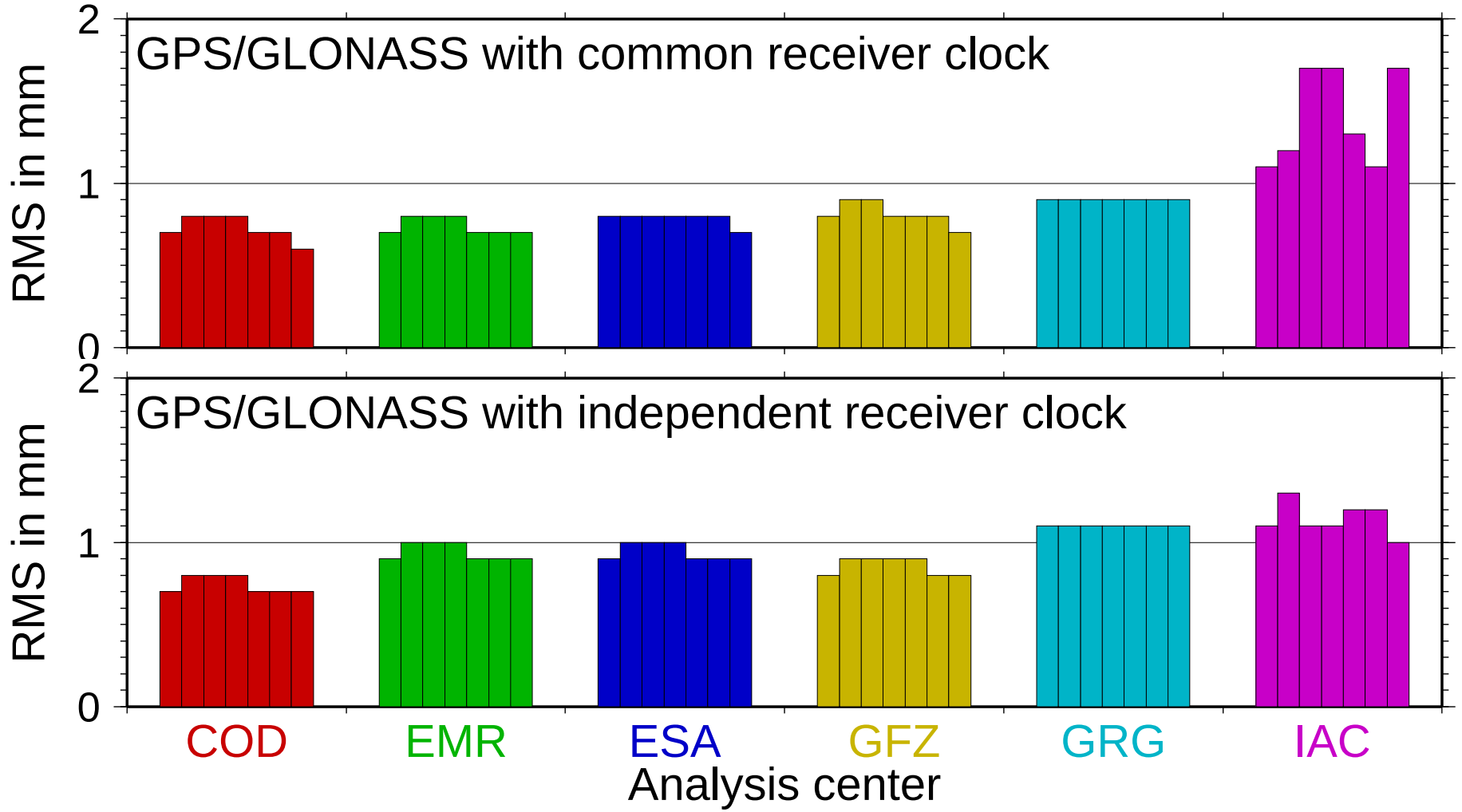
Statistics of the PPP Solution (after screening)

A posteriori unit of weight



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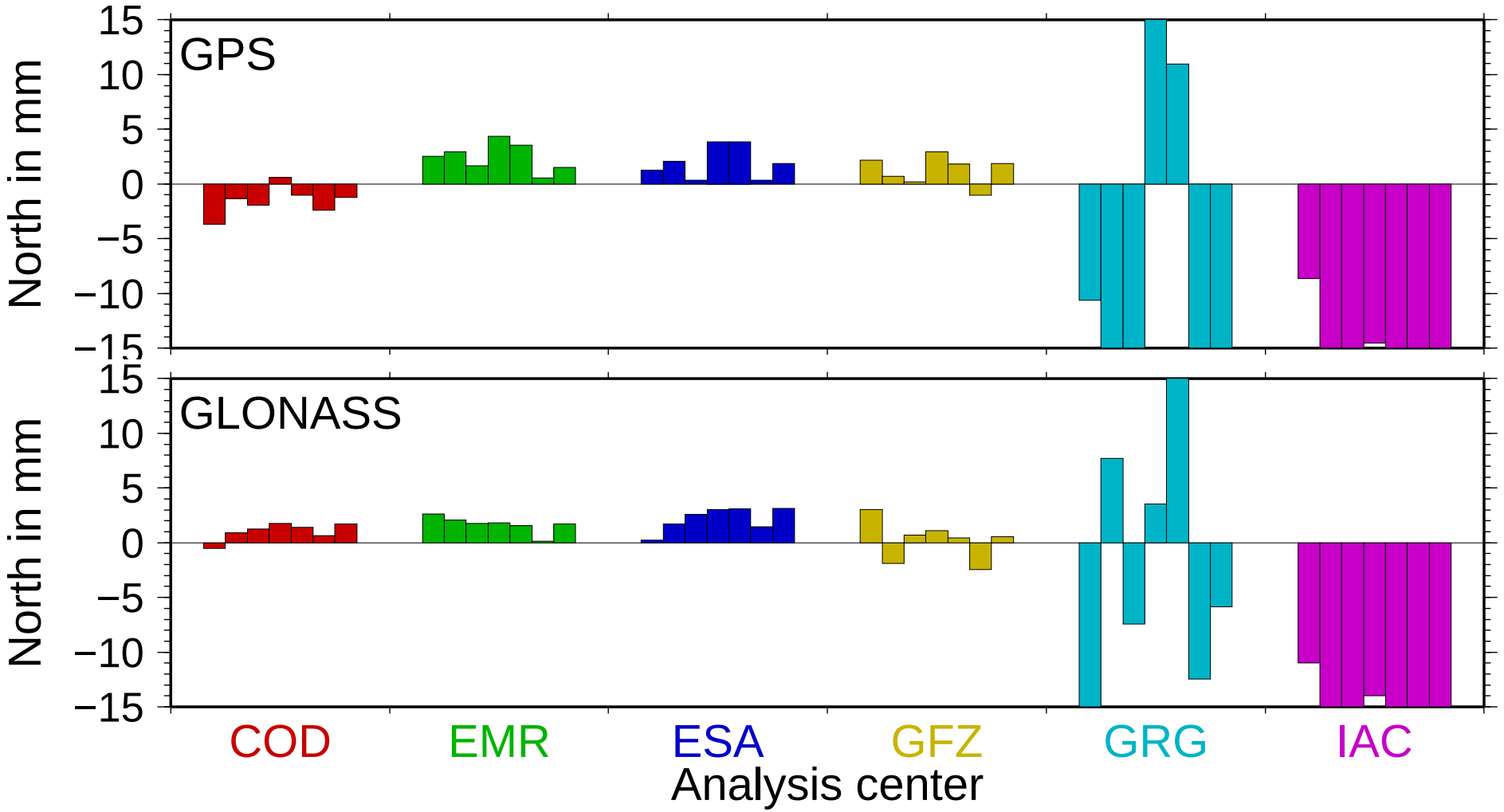
Coordinate Comparison from PPP Solutions

Coordinate difference to IGS08.SNX



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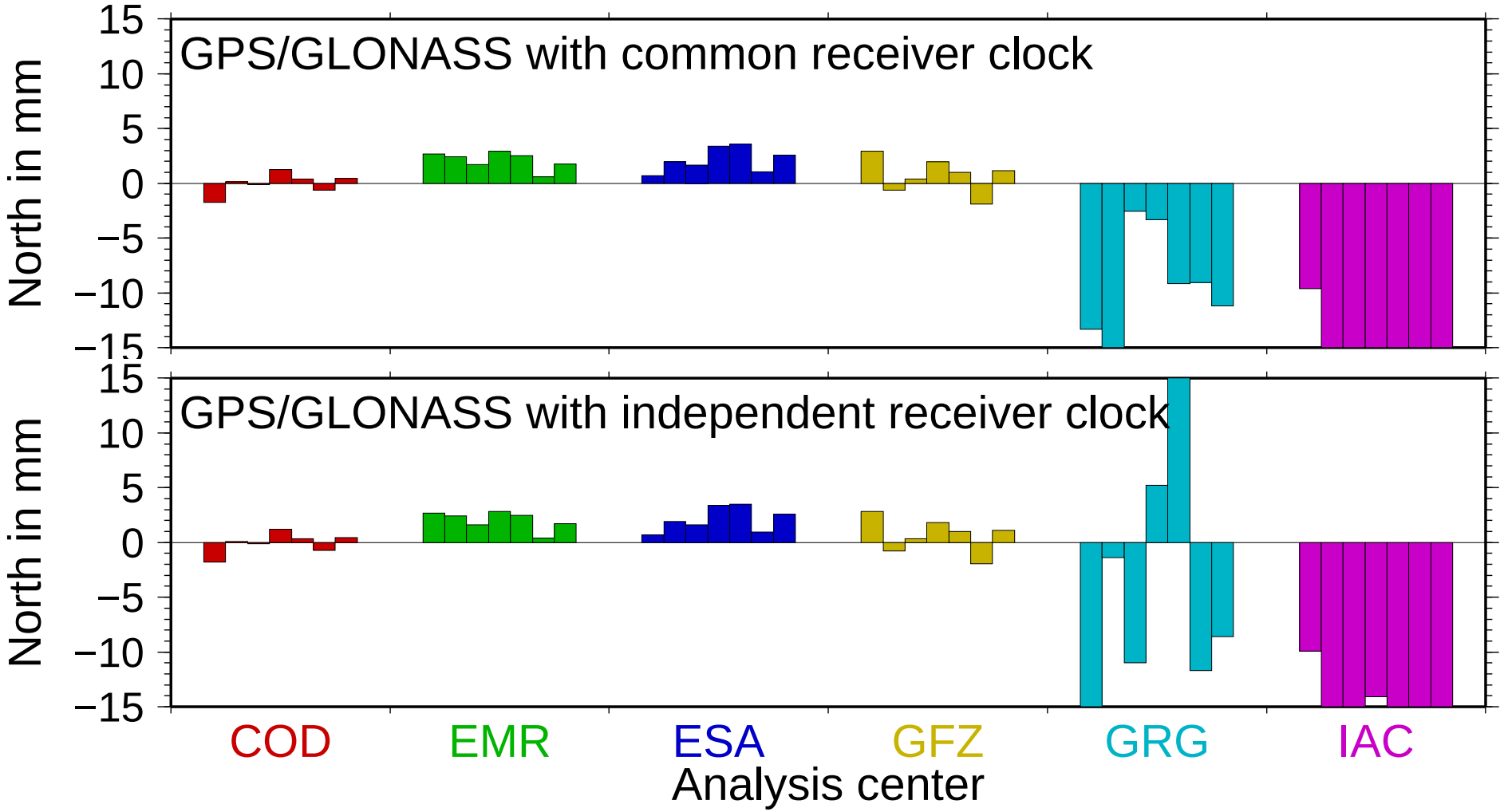

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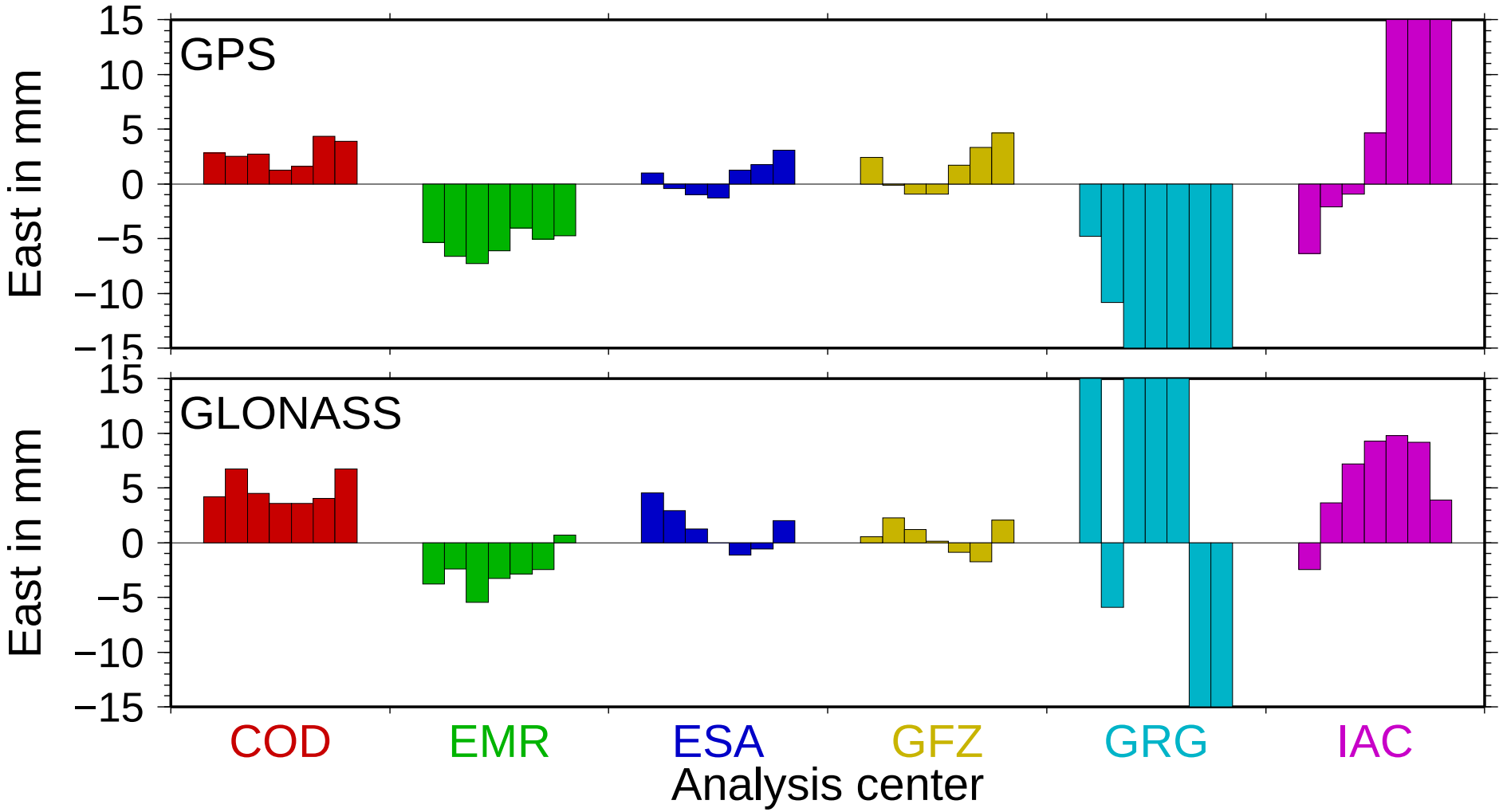

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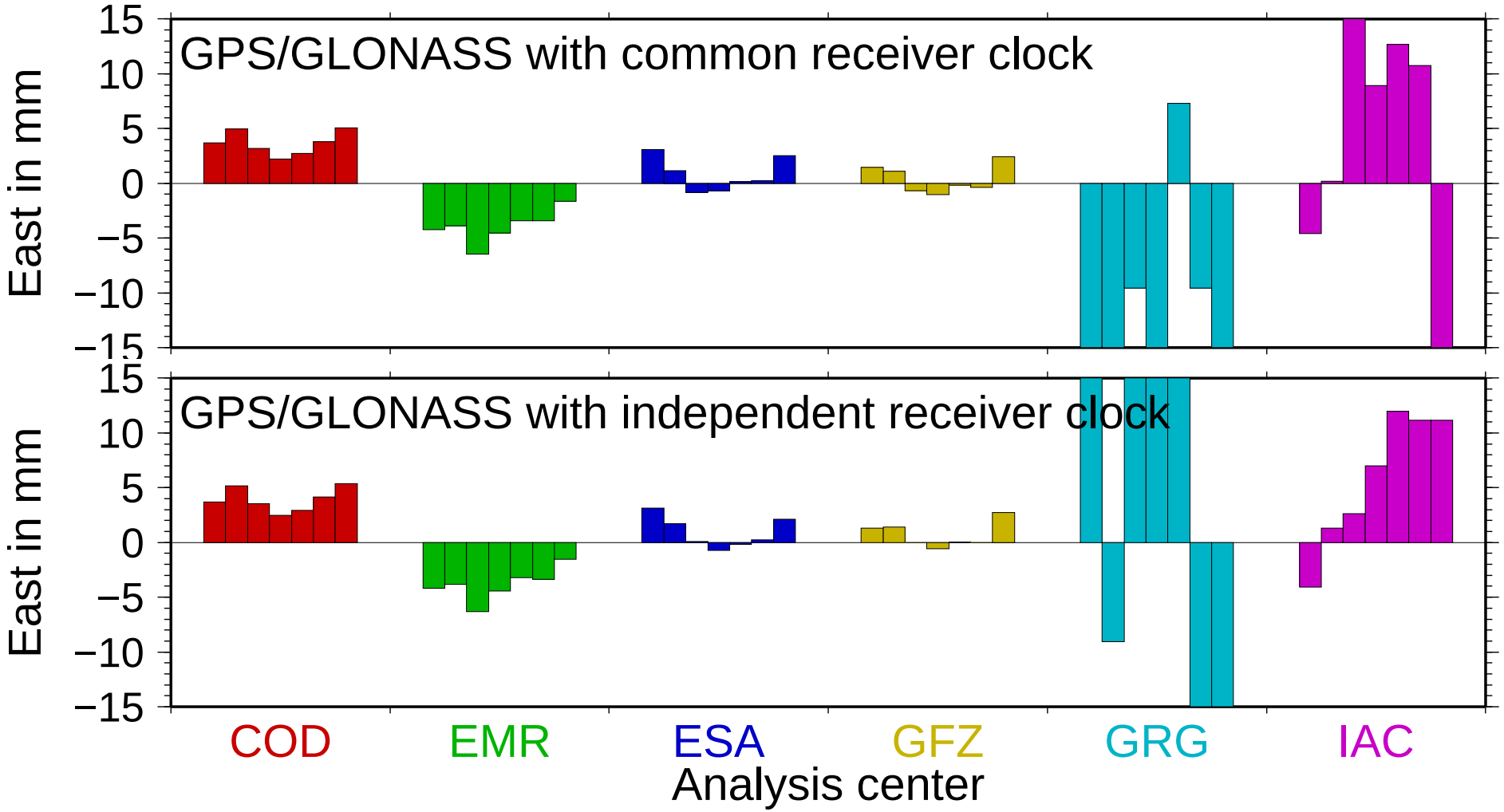

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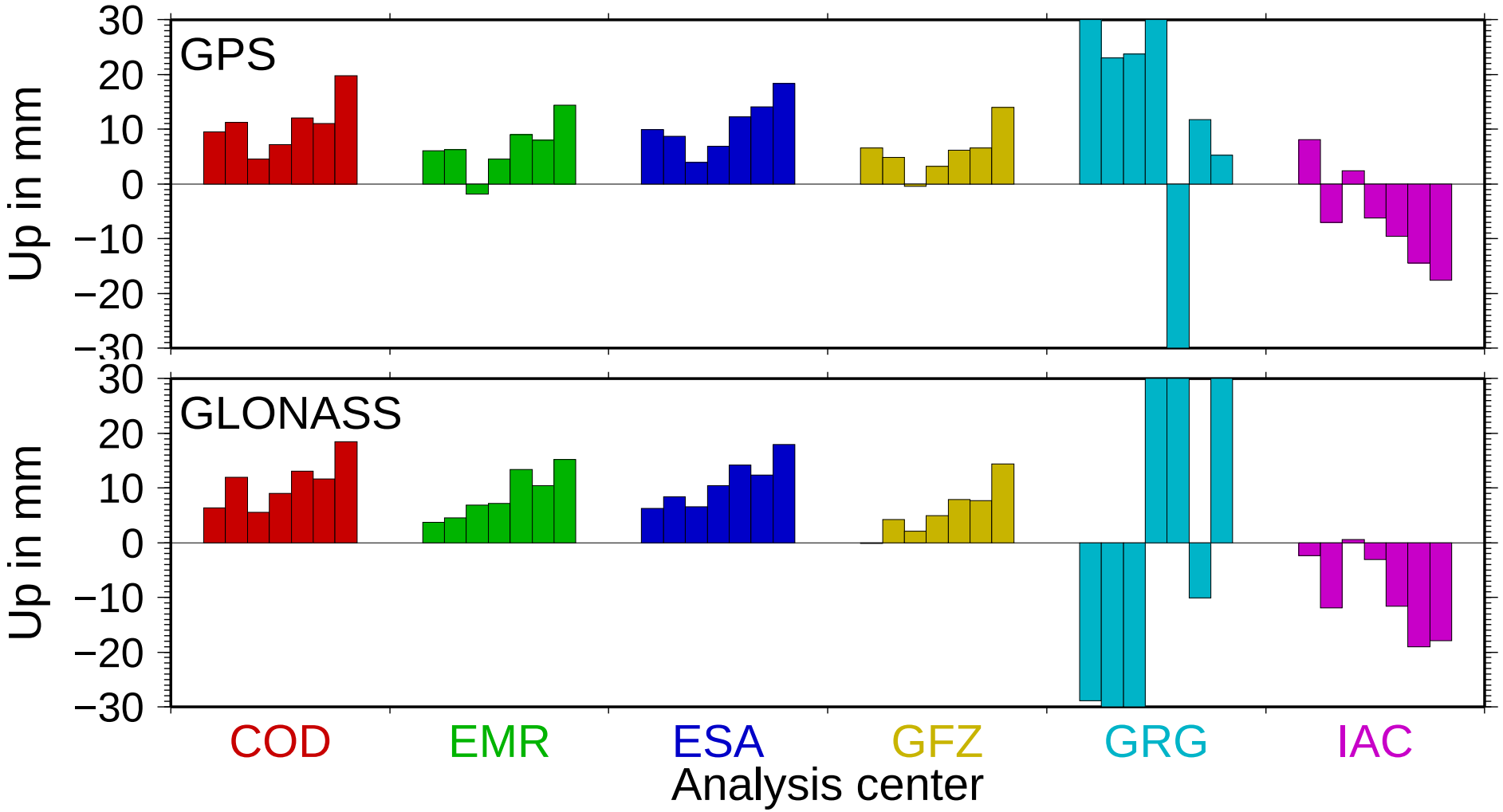

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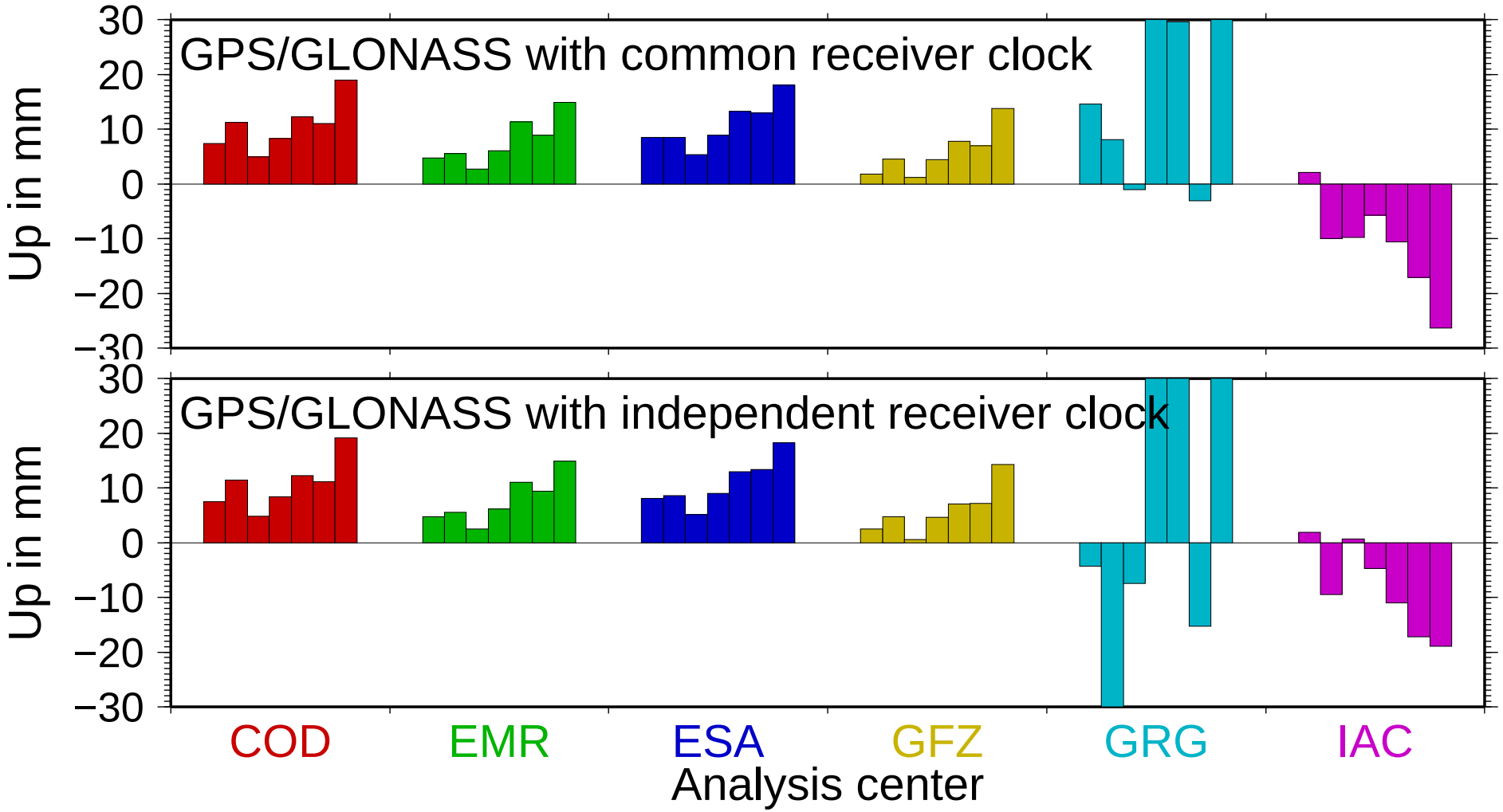

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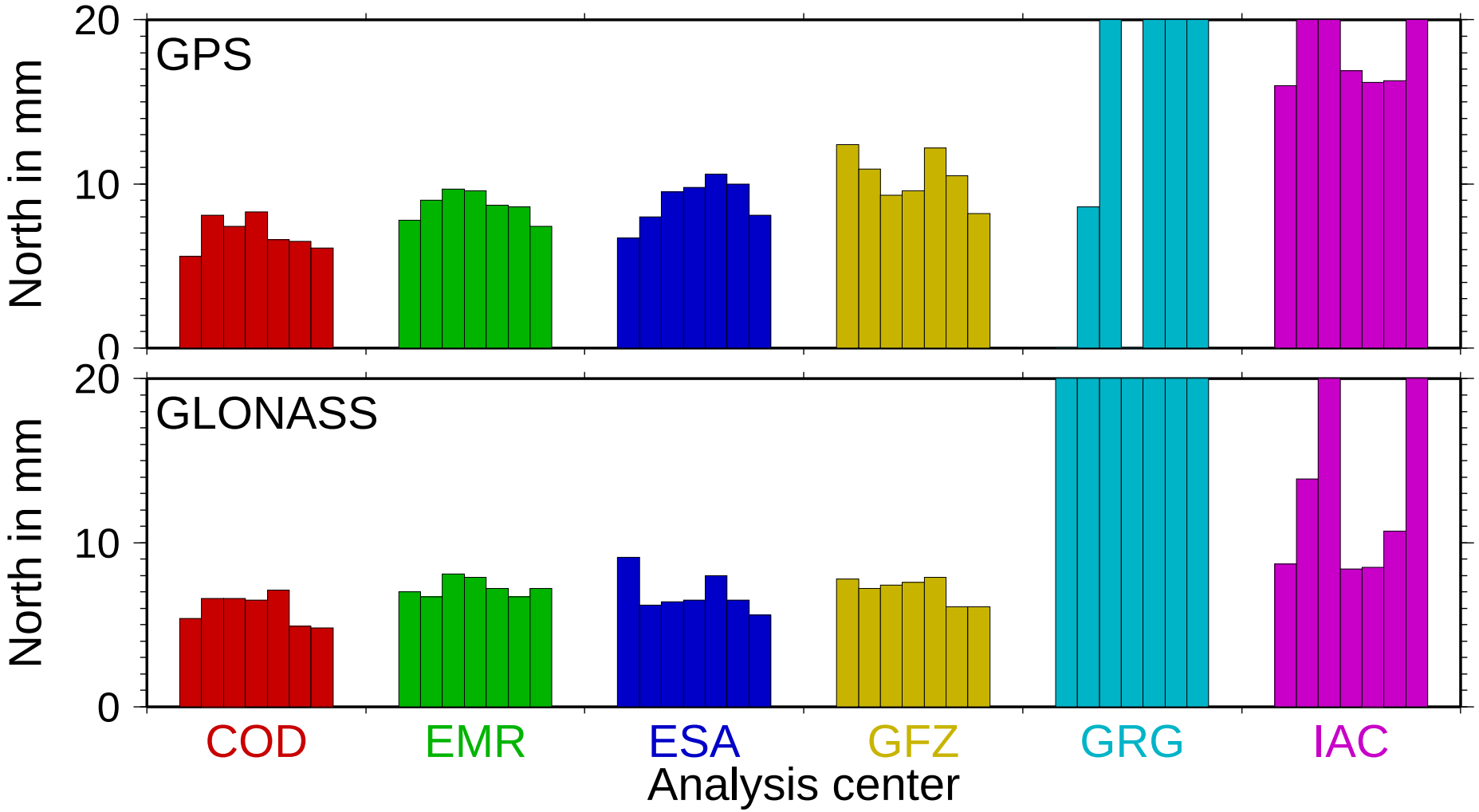
Pseudo–Kinematic PPP Solutions

RMS of the differences w.r.t. the static solutions



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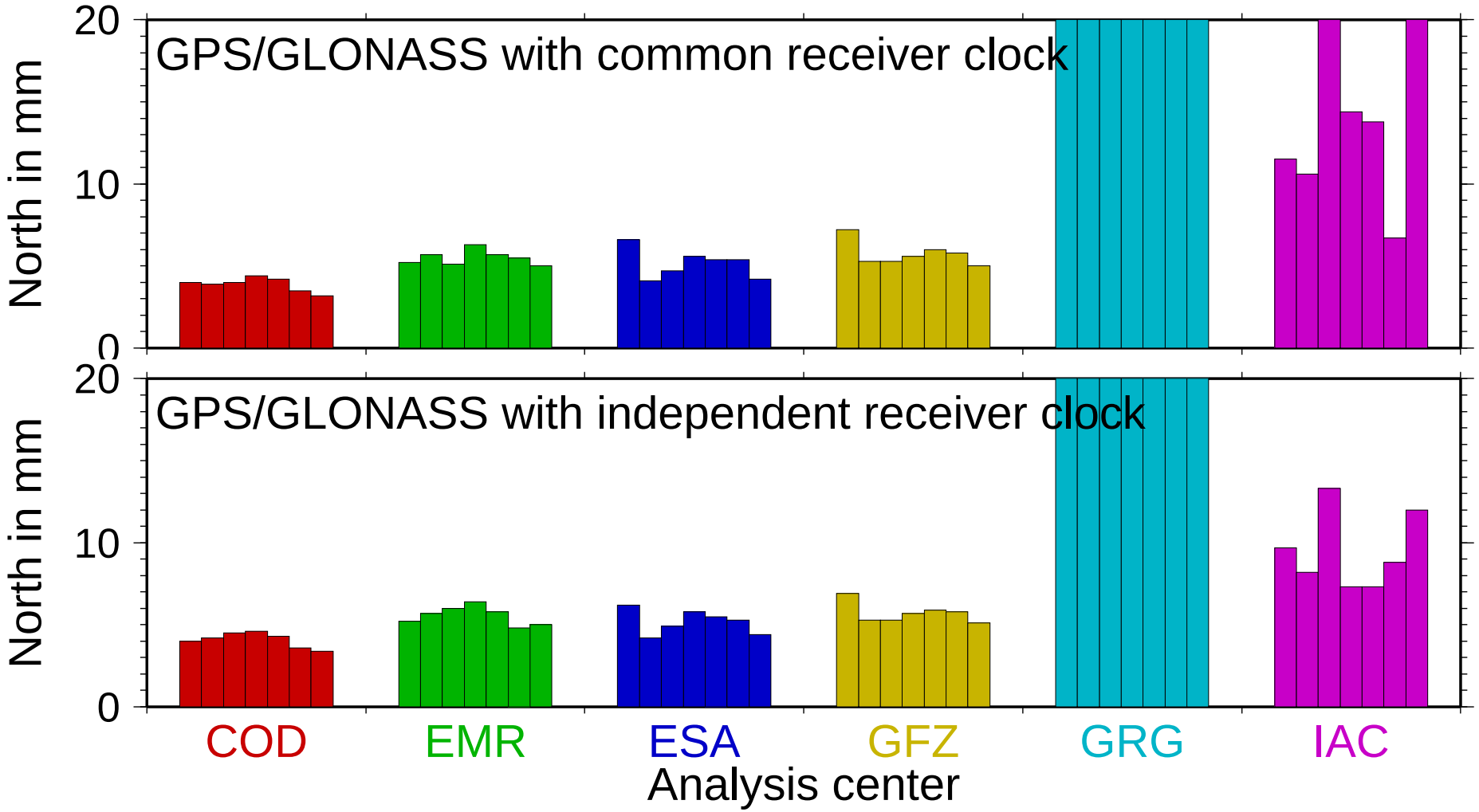

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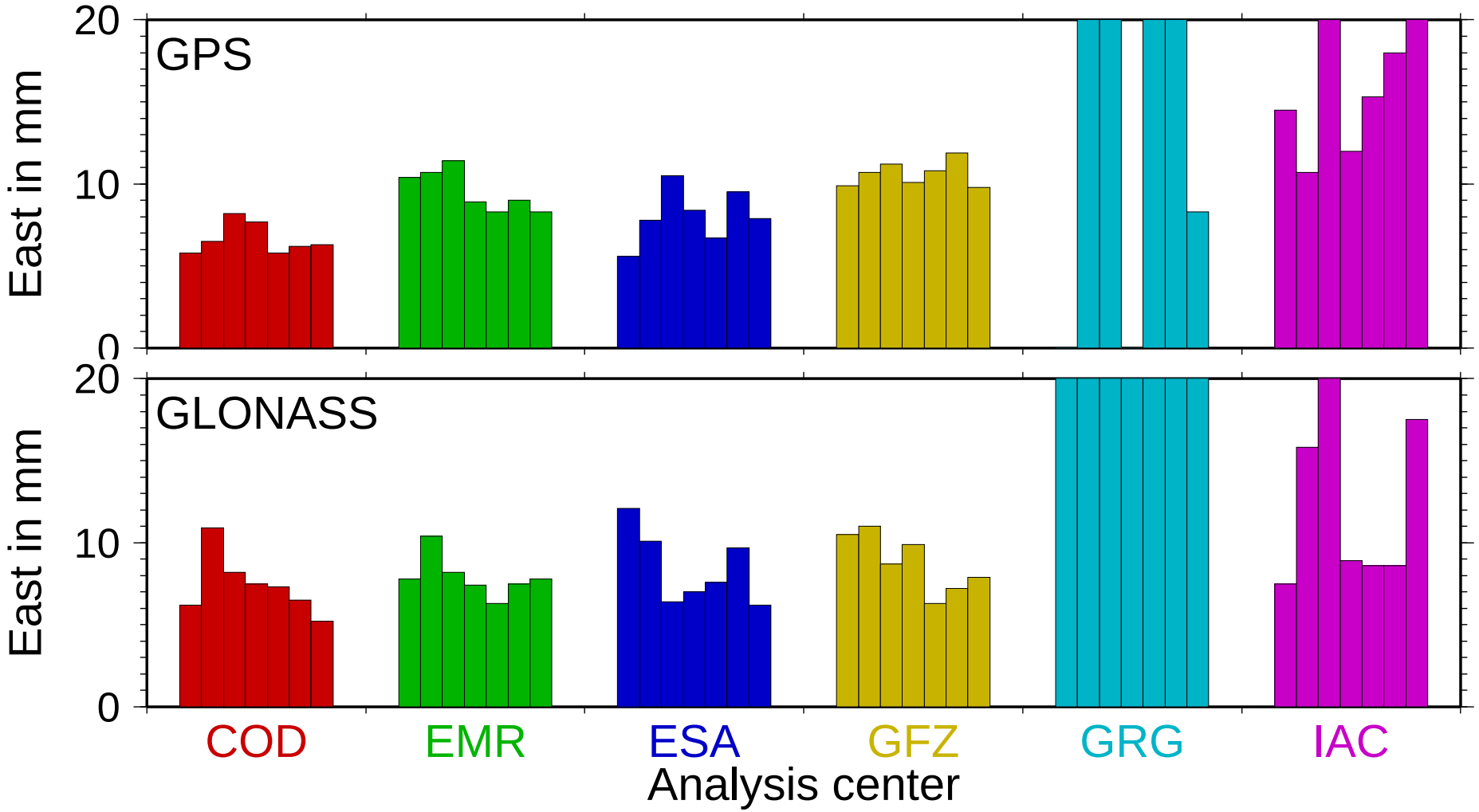

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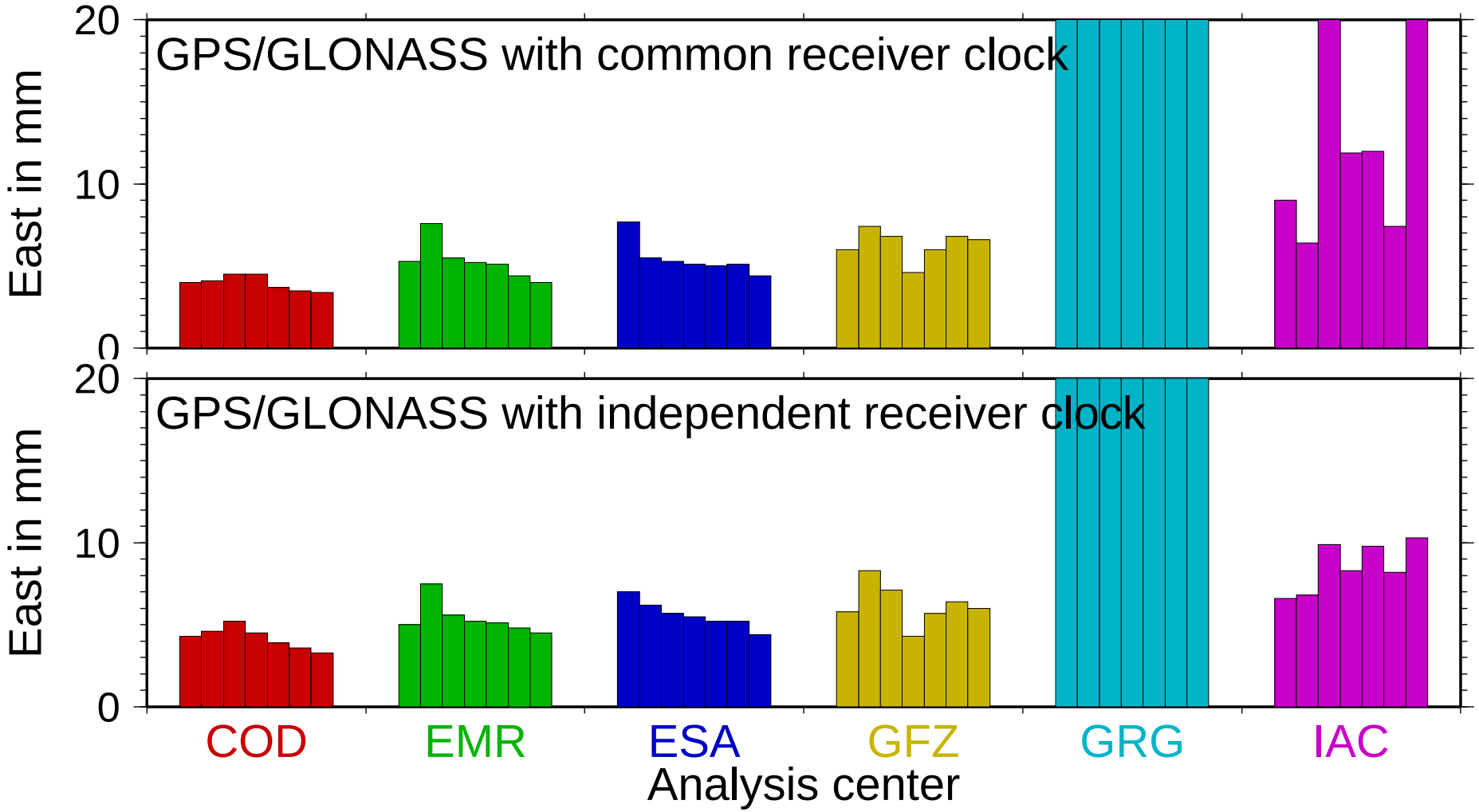

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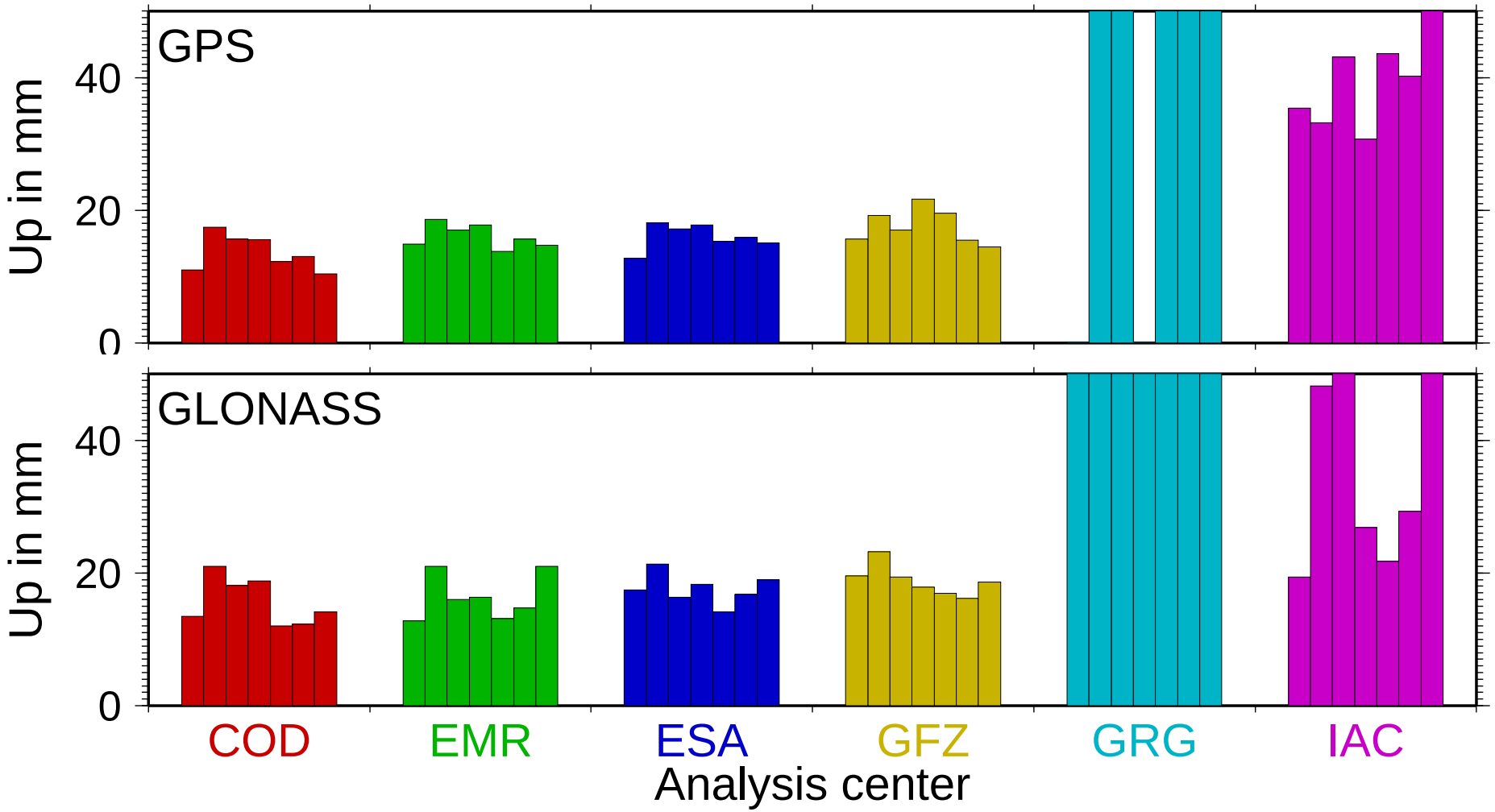

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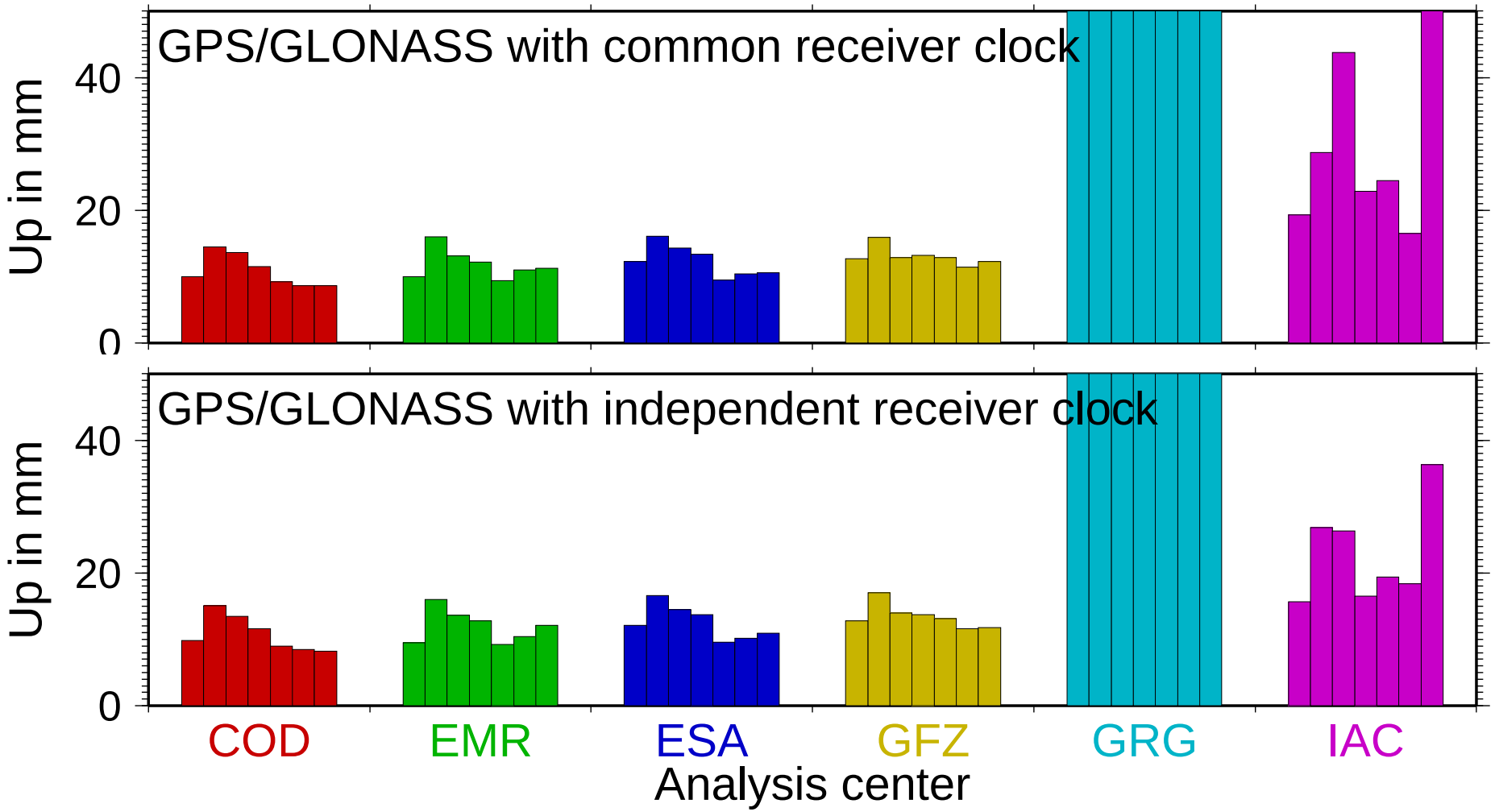
Pseudo–Kinematic PPP Solutions

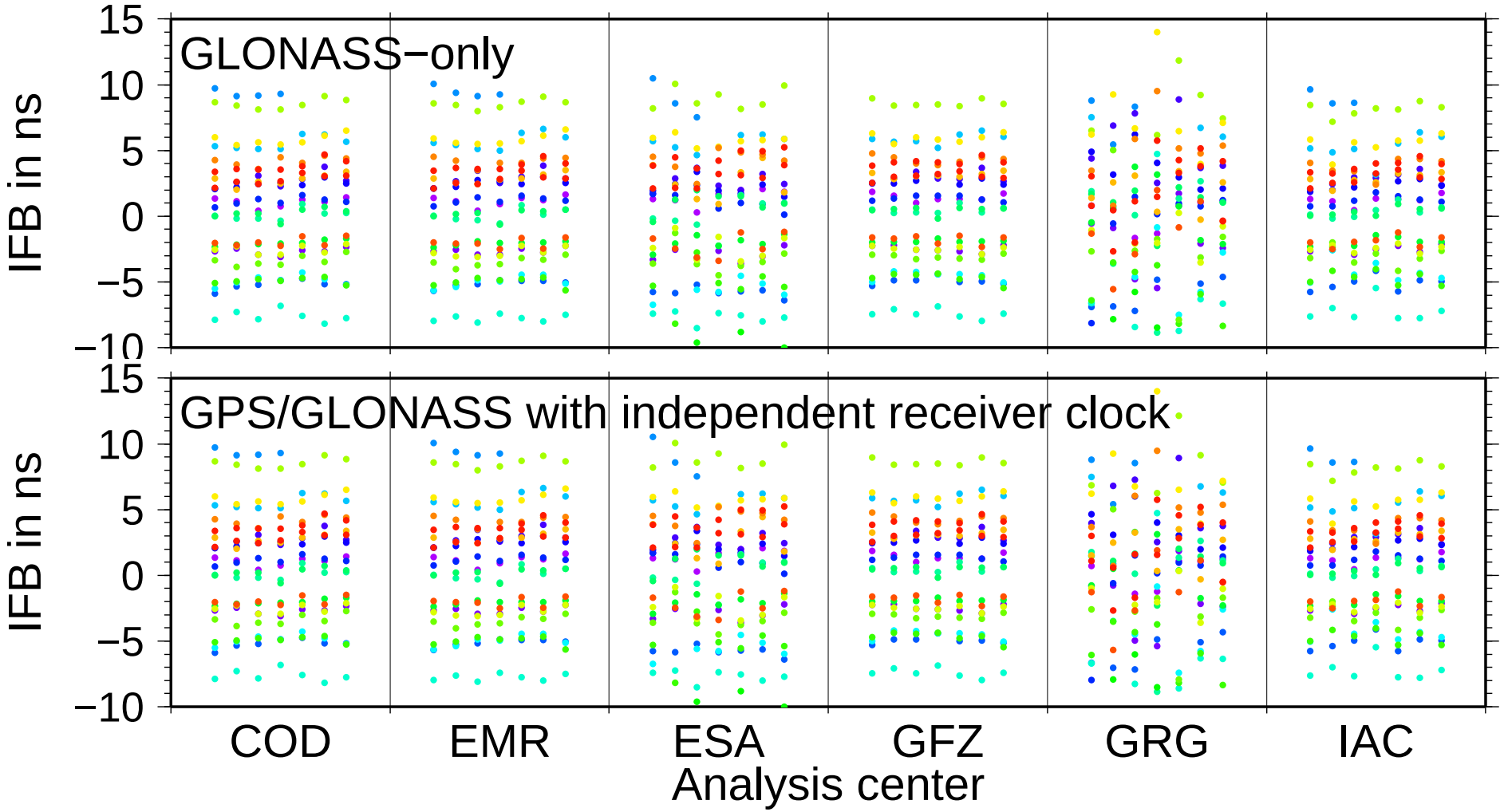
RMS of the differences w.r.t. the static solutions



Station: ONSA – Onsala, SE

GLONASS: Interfrequency–Biases

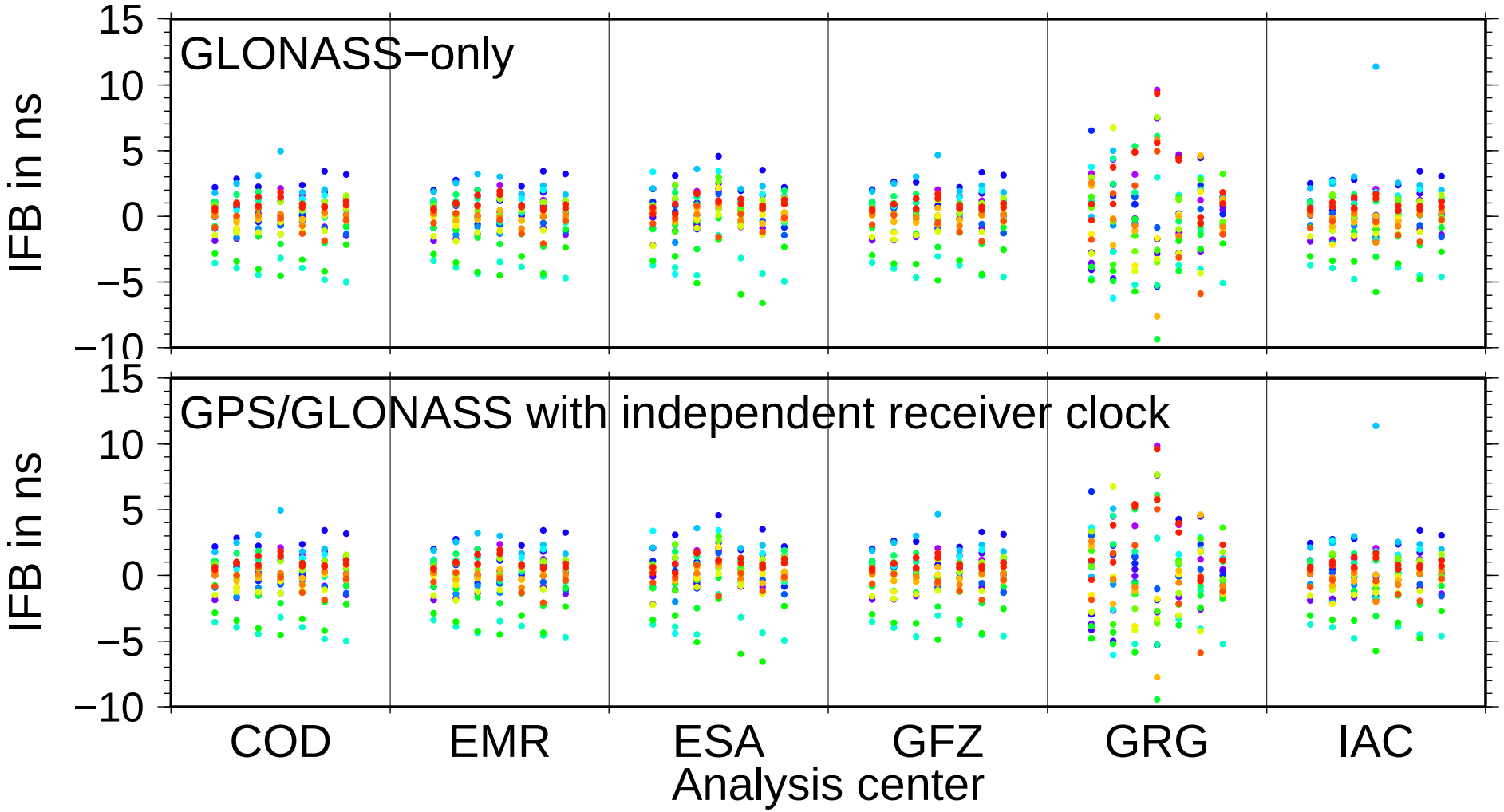
IFB as they are estimated in the static PPP–solution



Station: ONSA – Onsala, SE

GLONASS: Interfrequency–Biases

IFB as they are estimated in the static PPP–solution



Station: MATE – Matera, IT