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Diagnosing the Impact of GLONASS Observables on Receiver Bias Estimates

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Overview

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Objectives

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1. What is the impact of GLONASS observables on the ground based receiver bias estimation, and how can we use such a knowledge?

2. Are there any (geographical) trends in the receiver biases?

3. How do JPL-derived receiver biases compare with other centers?

Introduction (1/2)

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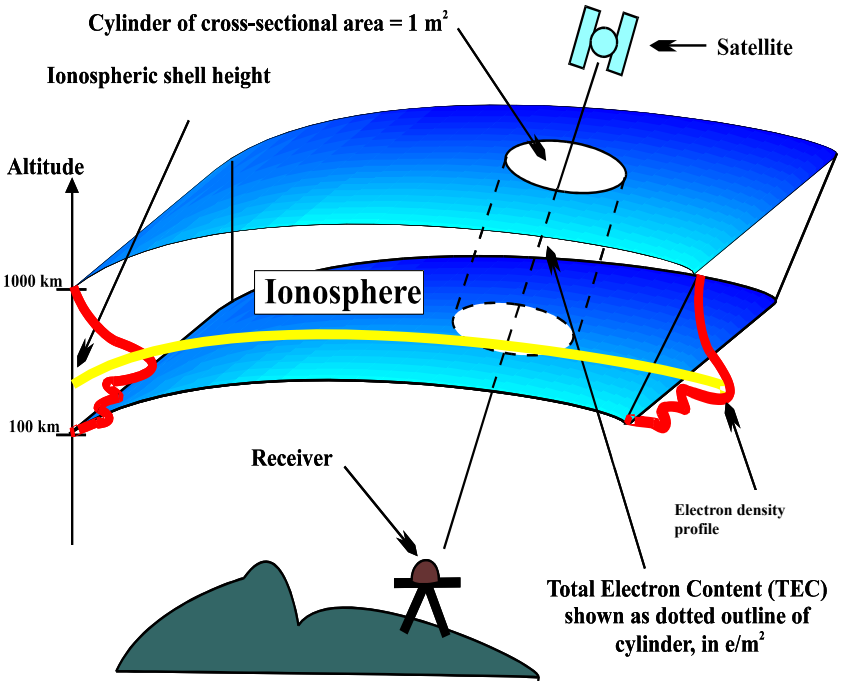

Figure 1: *Schematic depicting the vertical variability of the ionospheric electron number density (red lines) and the integrated total electron content (TEC) (black line) between a GPS satellite and a ground – based receiver link.*

1. Primarily, single-shell ionosphere
2. Integrated electron number density
3. Receiver – Satellite link
4. Available GNSS constellations
5. Globally – distributed GNSS receivers

End product: Global ionosphere maps

Since the advent of the GLONASS constellation, little attention has been given to the impact of such signals on the construction of TEC maps and of the accompanying receiver biases of the ground-based receivers

Introduction (2/2)

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Characteristics of the receiver biases:

1. Nearly constant over several days [e.g., *Wilson and Mannucci*, 1993]
2. Day–to–day variability: <1.0 TECU [e.g., *Montenbruck et al.,* 2014]
3. Estimation accuracy: < 1.5 TECU [e.g., *Sardón and Zarraoa,* 1997; *Ma et al.,* 2005; *Komjathy et al.,* 2005; *Dear and Mitchell,* 2006; *Sarma et al.,* 2008;]

All the abovementioned results used only GPS observations.

Now, let's include GLONASS (transmits in 14 antipodal channeles)

To–date, only a handful of studies quantify the GLONASS satellite – receiver biases [e.g., *Wanninger,* 2012; *Mylnikova et al.*, 2015]. Yet, questions about **the impact of GLONASS on the receiver bias accuracy, daily scatter, and variability still remain.**

Methodology (1/2)

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COMPONENTS OF JPL/GIM SOFTWARE

DATA	FUNDAMENTALS	RETRIEVALS
Data • 200 stations • IGS ground-based stns. • GPS, **GLONASS**	**Ionosphere model approximation** • Single – shell (till 2000) • Three – shell (2000 - present) • Slabs center at 250, 450, 800 km	**Products** • Satellite & receiver biases • STEC & VTEC products
Input variables • Satellite phase and pseudorange observations (dual freq.)	**Global grid specifications** • Basis functions (*Mannuci et al.,* 1998) • Spatial: typical 5x5 or better • Temporal: 15-minute • Kalman-filter capability	**DATA ANALYSIS** 1) Compare receiver bias with and without GLONASS data 2) Assess bias stability and daily variability 3) Compare JPL and CODE

Methodology (2/2)

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TEC Observation Equation:

$$TEC = M_1(h_1, E_1)\sum_i C_{1i}B_{1i}(\lambda_1, \phi_1) + M_2(h_2, E_2)\sum_i C_{2i}B_{2i}(\lambda_2, \phi_2) +$$

$$M_3(h_3, E_3)\sum_i C_{3i}B_{3i}(\lambda_3, \phi_3) + b_{s,GPS} + b_{r,GPS} + b_{r,GLONASS_f}(GLONASS_f),$$

Limiting factors affecting the TEC estimation

Basis functions
(functions of lat/lon)

Ground-based receiver differential code biases
GPS and GLONASS satellite biases

Here, we focus on characterizing the behavior of the receiver biases, when including GLONASS observations

Results (1/4)

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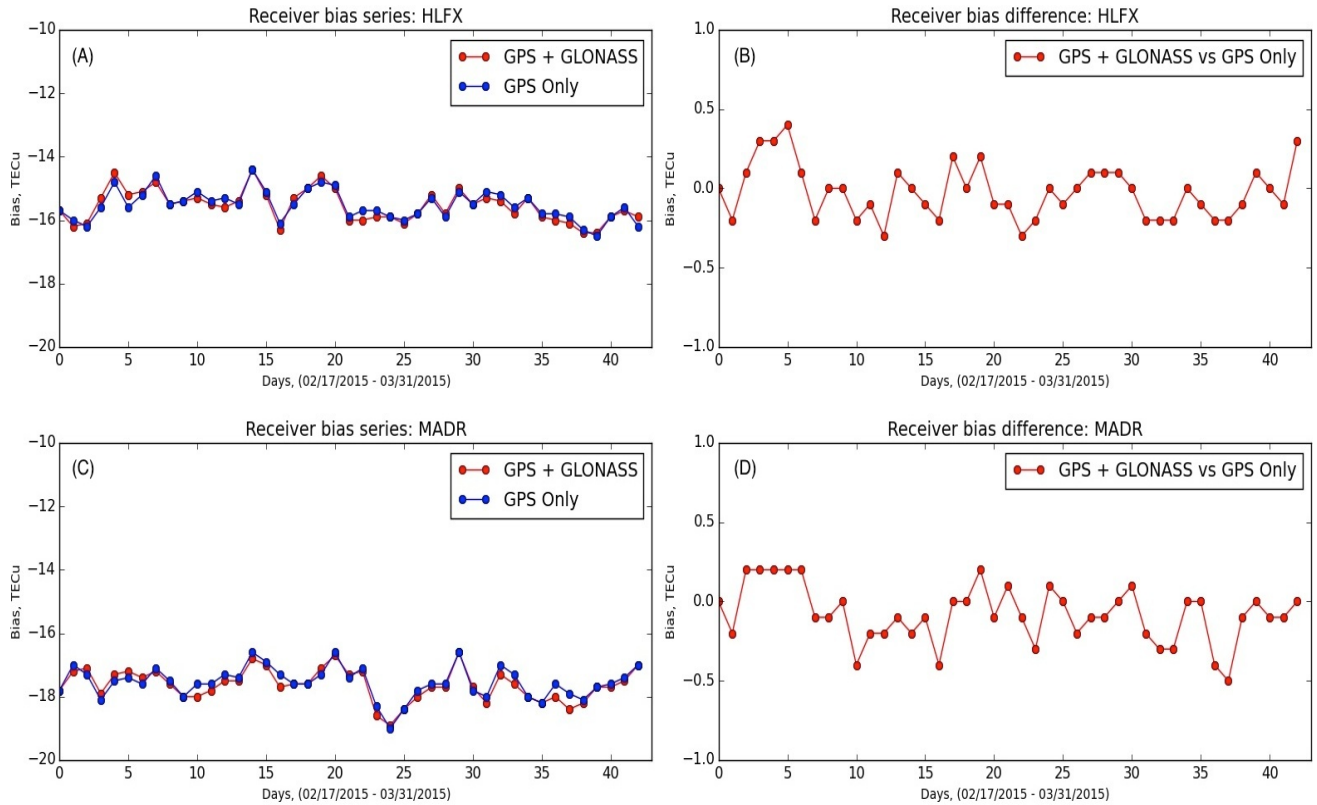
Characterize the GPS receiver biases using GLONASS observables (Vergados et al., 2015)

Experiment set-up: We use a month worth of GPS receiver bias series from a global network, which tracks both GPS and GLONASS signals. We investigate the impact of GLONASS observations on the GPS receiver biases, and analyze our results as function of latitude to identify trends in the receiver behavior (part of the "GPS Ionosphere Support for NASA's Earth Observing Satellites" program).



There is a clear daily variability of the receiver biases, the scatter of which is <0.5 TECU (amplitude).

Figure 2: *Ground–based receiver bias series for HLFX* ***(A)*** *and MADR* ***(C)*** *using JPL's GPS only (blue dotted line) and JPL's GPS+GLONASS (red dotted line) solutions. The red dotted line represents the difference in JPL retrievals with and without GLONASS observables for HLFX* ***(B)*** *and MADR* ***(D)****, respectively.*

Results (2/4)

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Characterize the GPS receiver biases using GLONASS observables

Station Name	Latitude (^{o}N)	Longitude (^{o}E)	Mean bias difference (TECU)
WHIT	60.8	224.8	- 0 .4
PERT	- 31.8	115.9	- 0 .1
ONSA	57.4	11.9	- 0 .1
TSKB	36.1	140.1	- 0.5
CHPI	- 22.7	315.0	+ 0.7
TRO1	69.7	18.9	- 0.7
THTI	- 17.5	210.4	- 0.4
WES2	42.6	288.5	0.0
SUTH	- 32.4	20.8	- 0.7
CORD	- 31.2	295.5	0.0
KIRU	67.9	21.0	0.0
HOLB	50.6	231.9	- 0.2
NRIL	69.4	88.4	- 0.3
NANO	49.3	235.9	- 0.2
TIXI	71.6	128.9	- 0.1
LPGS	- 34.9	302.1	+ 0.3
MORP	55.2	358.3	- 0.2
DAV1	- 68.6	78.0	- 0.2
ISPA	- 27.1	250.7	- 0.1
MAS1	27.8	344.4	- 0.7

Table 1. Example of 20 monthly mean receiver bias differences with and without GLONASS (three–shell ionosphere model) for stations within all different latitude belts.

Conclusions: An ensemble of 84 GPS receivers showed that GLONASS observations systematically reduce the receiver bias by < 1.0 TECU.

Results (3/4)

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Investigating the GPS receiver bias stabilities with and without GLONASS observables

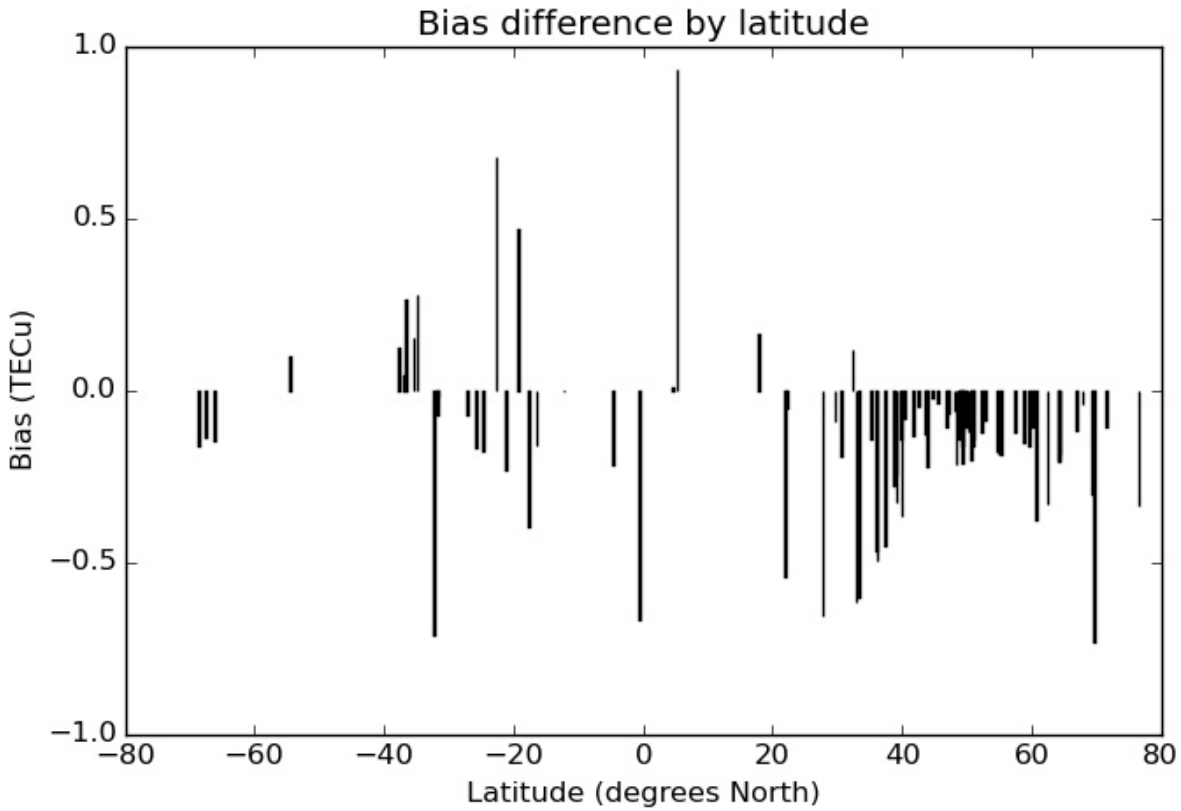

Figure 3. *Ground–based receiver bias differences, between the JPL GPS+GLONASS and GPS–only solutions averaged over 02/17/2015–03/31/2015, for 84 GNSS dual-tracking globally–distributed stations as a function of latitude. Each solid black line represents a station.*

Results: GPS receivers inside the tropical belt (±30°) and higher than 60° pole-ward exhibit higher differences than middle latitude stations, with magnitudes (systematically) lower than 1.0 TECU.

Results (3/3)

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Investigating the GPS receiver stability

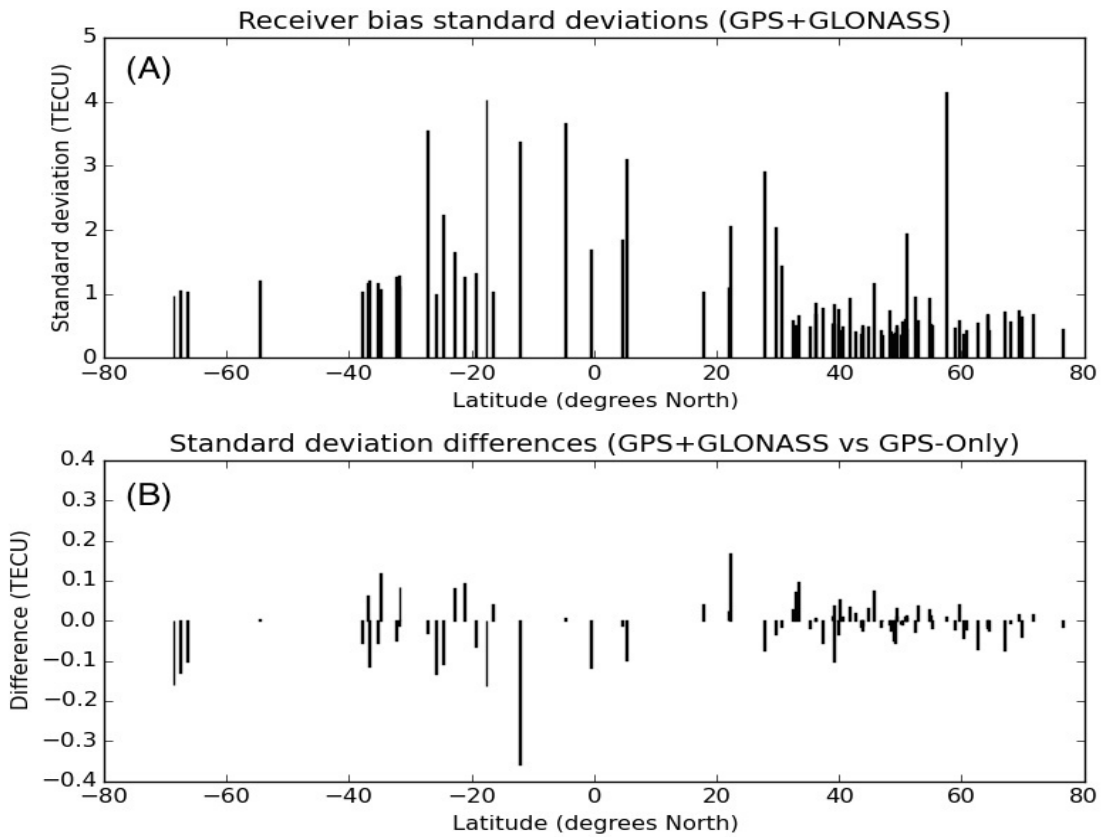

Figure 4. ***(A)*** *Standard deviation of JPL's GPS+GLONASS receiver biases as a function of latitude for all 84 stations.* ***(B)*** *Absolute difference of standard deviation with respect to the GPS–only solution.*

Results: The GPS receivers bias scatter is large for stations inside the tropical belt (±30°) and decreases with latitude. In particular, GLONASS observations affect the bias scatter by maximum of ± 0.15 TECU in a random fashion (no latitudinal dependency is observed).

Results (3/3)

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JPL versus CODE receiver bias characteristics' comparisons

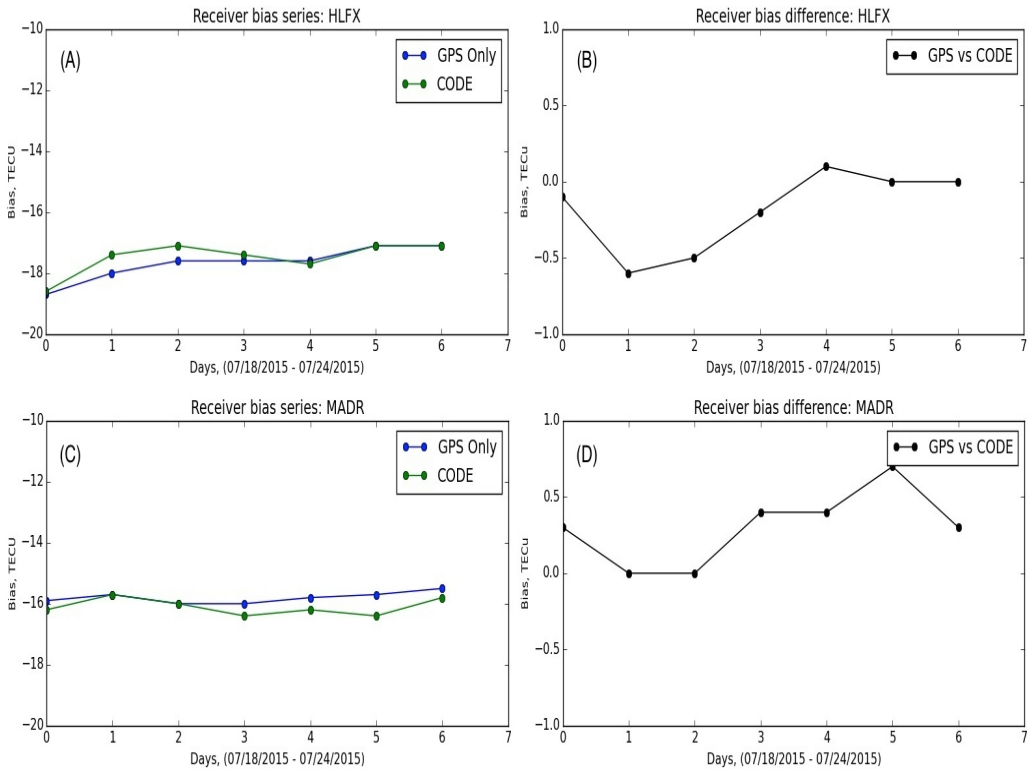

Figure 5. ***(A)*** *Standard deviation of JPL's GPS+GLONASS receiver biases as a function of latitude for all 84 stations.* ***(B)*** *Absolute difference of standard deviation with respect to the GPS–only solution.*

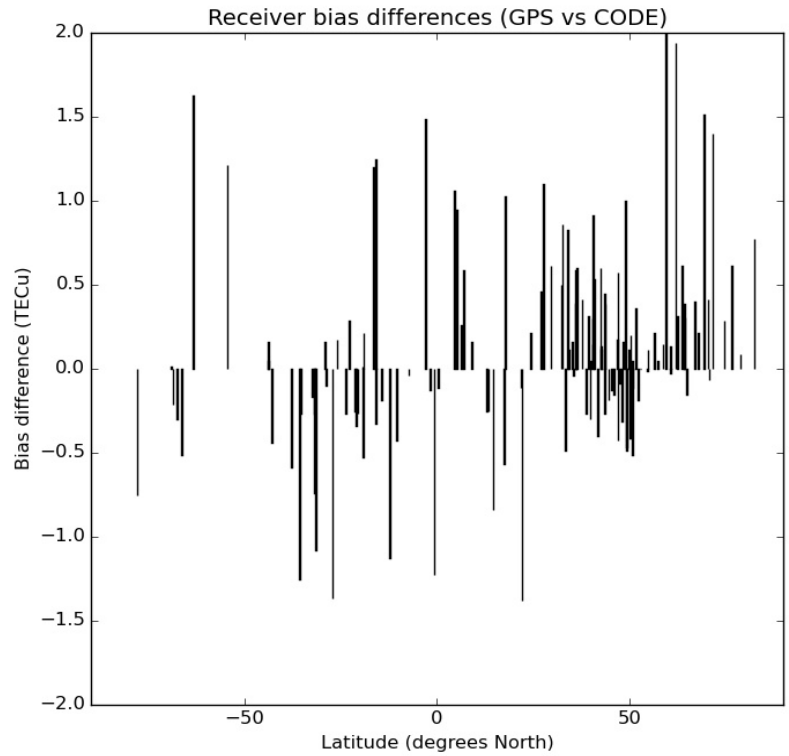

Figure 6. Monthly mean receiver bias differences as a function of latitude (JPL minus CODE).

Results (3/3)

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JPL versus CODE receiver bias differences

Station Name	Latitude (°N)	Longitude (°E)	Mean bias difference (TECU)
WHIT	60.8	224.8	0.0
PERT	- 31.8	115.9	- 0.3
ONSA	57.4	11.9	0.0
TSKB	36.1	140.1	+ 0.6
CHPI	- 22.7	315.0	+ 0.3
HOLM	70.7	242.2	- 0.1
NKLG	0.3	9.7	- 0.1
WES2	42.6	288.5	+ 0.1
SUTH	- 32.4	20.8	- 0.2
CORD	- 31.2	295.5	- 1.1
KIRU	67.9	21.0	+ 0.2
HOLB	50.6	231.9	- 0.4
NRIL	69.4	88.4	+ 1.5
NANO	49.3	235.9	- 0.5
TIXI	71.6	128.9	+ 1.4
GOLD	35.4	243.1	0.0
NANO	49.3	235.9	- 0.5
DAV1	- 68.6	78.0	- 0.2
ISPA	- 27.1	250.7	- 1.4
MAS1	27.8	344.4	+ 1.1

Table 2. An example of 20 monthly mean differences of the receiver biases: JPL versus CODE (GPS–only data using the single–shell ionosphere model approximation)

Conclusions: We observe that the receiver biases between JPL and CODE are systematically smaller than < 0.5 TECU (except with a few exceptions).

Conclusions

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1) The GIM products indicate that GLONASS observations systematically reduce the receiver bias → stronger ionosphere than when GPS – only observations are used by < 1.0 TECU

2) GLONASS observations affect the scatter of the receiver biases by < 0.3 TECU (except a few occasions) without showing a systematic pattern

3) The receiver bias scatter is < 1.0 TECU (in the majority of the stations) with those located inside the tropical belt exhibiting higher values.

4) Cross – center evaluations show a < 0.5 TECU differences in the receiver bias estimation.

Acknowledgments

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THANK YOU