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# **Assessment of real time relative GNSS positioning based on the Brazilian CORS Network**

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United Nations/Argentina Workshop on the Applications of  
Global Navigation Satellite Systems

Falda del Carmen, 19-23 March 2018



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# Introduction

- During the past decades, positioning, navigation and timing have been revolutionized by GNSS
  - GPS, GLONASS are fully operational
  - Galileo, BeiDou being implemented, with full operational capability expected to be achieved ~2020
- Large range of users/applications, from navigation to high accuracy positioning, in real time or post-mission modes
  - Relative/differential techniques developed to provide better accuracies
    - ⇒ birth of **CORS Networks**
    - **Real time relative/differential techniques** require base station(s) transmitting observations/corrections in real time
      - ⇒ **real time CORS Networks**

Research motivation:  
Assessment of real time relative/differential GNSS positioning  
based on the real time Brazilian CORS Network



# RBMC – Brazilian Network for Continuous Monitoring of GNSS



Instituto Brasileiro de Geografia e Estatística - IBGE  
Diretoria de Geociências - DGC  
Coordenação de Geodésia - CGED

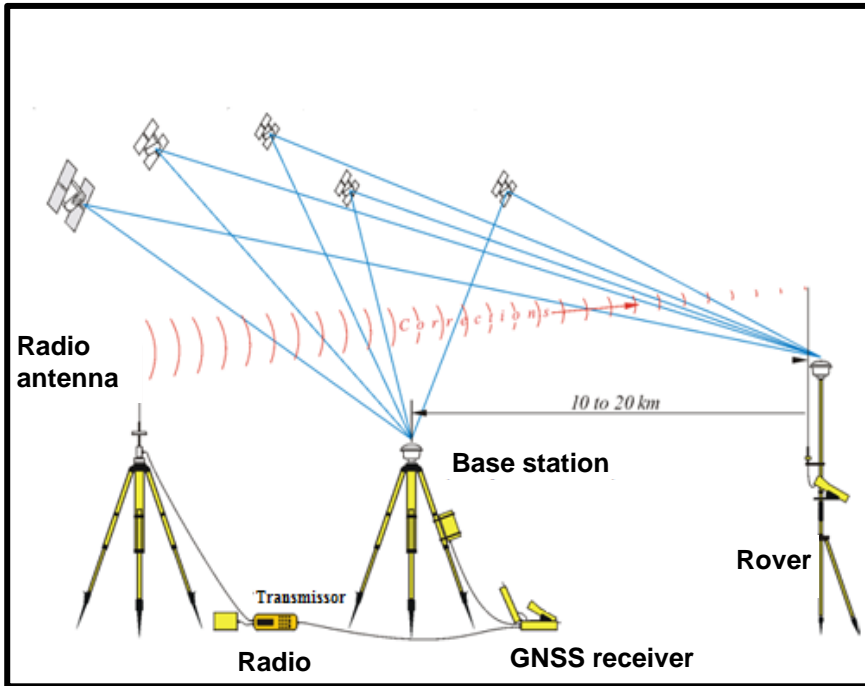
## REDE BRASILEIRA DE MONITORAMENTO CONTÍNUO DOS SISTEMAS GNSS

- Established, operated and managed by the **Brazilian Institute of Geography and Statistics (IBGE)**
- Total of 144 stations (ref. March 2018)
  - **RBMC-IP**: composed by 104 RBMC stations which transmit RTCM observations @1 second in real time through the Internet using the NTRIP protocol
- Provide access to SIRGAS2000 reference frame



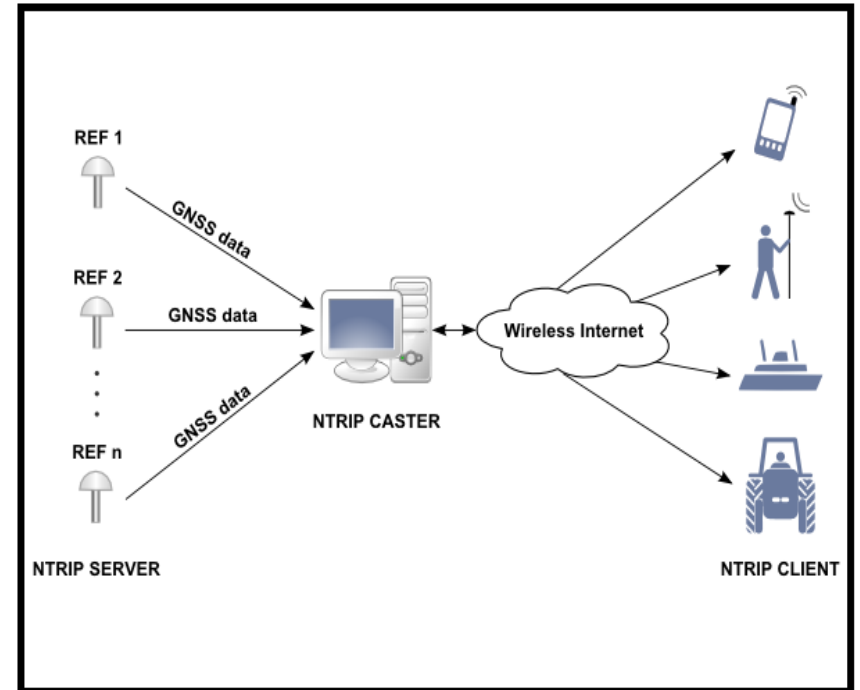
(source: [www.ibge.gov.br](http://www.ibge.gov.br))

# RTK and DGNSS review



## Conventional

(source: adapted from <http://anatumfieldsolutions.com/rtk-gps-explained>)



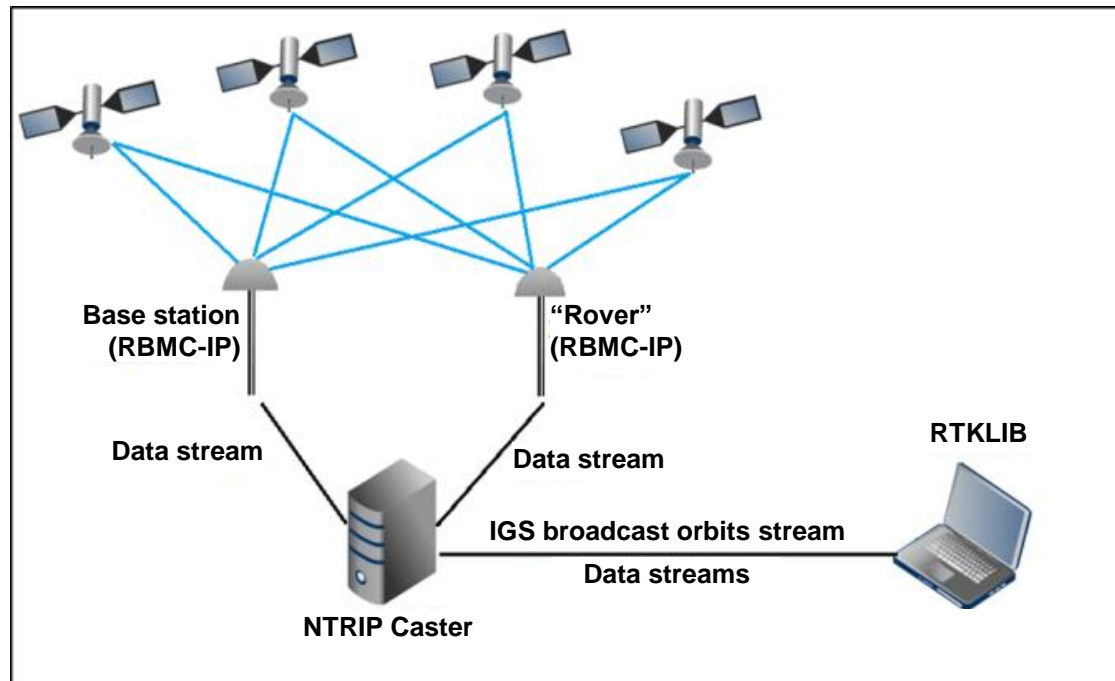
## NTRIP

(source: [//geotronics.es/productos/redes-gnss/dynamic-control](http://geotronics.es/productos/redes-gnss/dynamic-control))

- RTK: uses carrier phase (and pseudorange) observations
- DGNSS: uses pseudorange observations

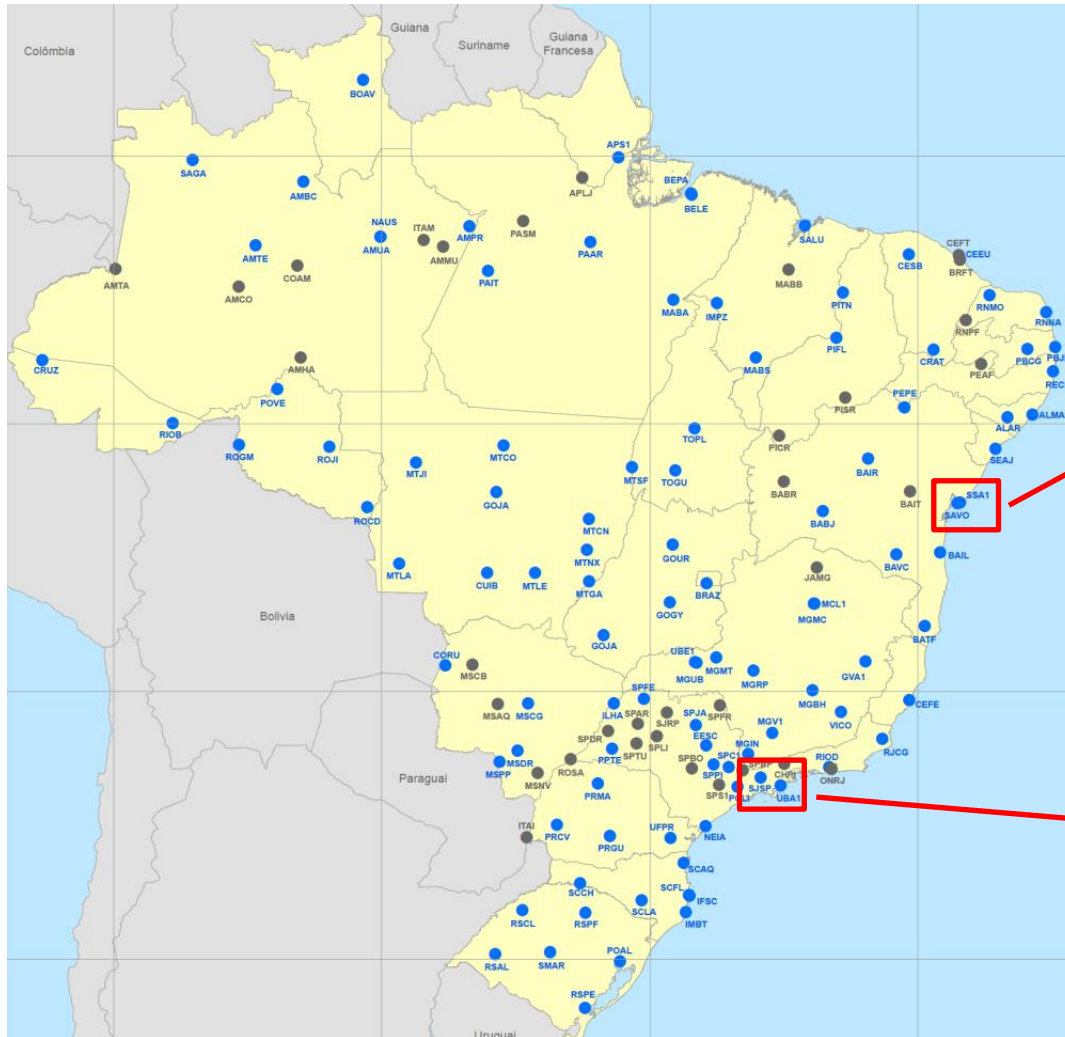
# Methodology (1/3)

- Use of **two RBMC-IP stations**: one as a **base station** and the other as a **rover**
  - Possibility of computing the **accuracy** of the solutions, as all coordinates are known
- Base station and rover data streams received in real time through the Internet by a computer running **RTKLIB/RTKNAVI** open source application **in kinematic mode**
- **IGS broadcast orbits** also received in real time through the Internet



# Methodology (2/3)

- Baselines processed
  - SAVO-SSA1: 10 km in Bahia state (Northeastern region)
  - SJSP-UBA1: 82 km in São Paulo State (Southeastern region)





## Methodology (3/3)

- Real time kinematic solutions generated for each baseline:

Technique	System	Signal(s)	# of sessions	Session length (h)
RTK	GPS	L1	2	1
	GPS+GLONASS	L1	2	1
	GPS	L1+L2	2	1
	GPS+GLONASS	L1+L2	2	1
DGNSS	GPS	L1	1	2
	GPS+GLONASS	L1	1	2
	GPS	L1+L2	1	2
	GPS+GLONASS	L1+L2	1	2
Total number of sessions for each baseline			12	

- RTK sessions starting at 11:00-15:00 or 15:00-20:00 local time
- DGNSS sessions within 11:00-22:00 local time
- Sessions were carried out in Jan, Feb, Mar, Jun, Jul 2017

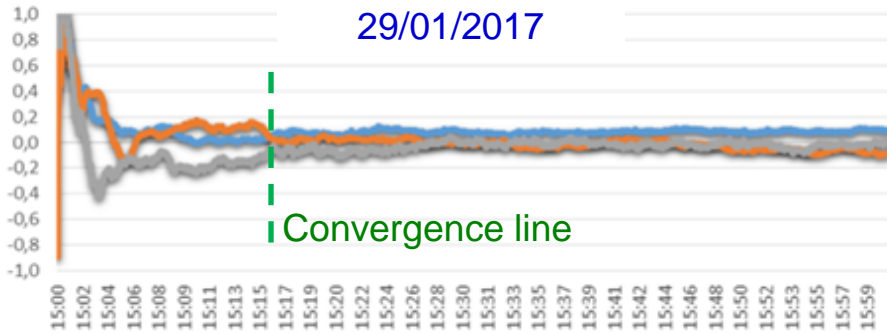




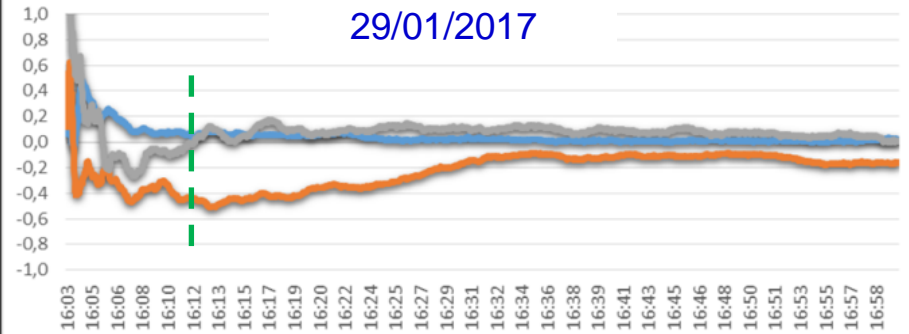
# RTK results (1/6)

SAVO-SSA1: 10-km baseline; Sessions starting 11:00-15:00 local time (m)  
**Latitude**, **Longitude** and **Height** differences (m)  
to rover known coordinates (vertical axis: -1 to +1 m)

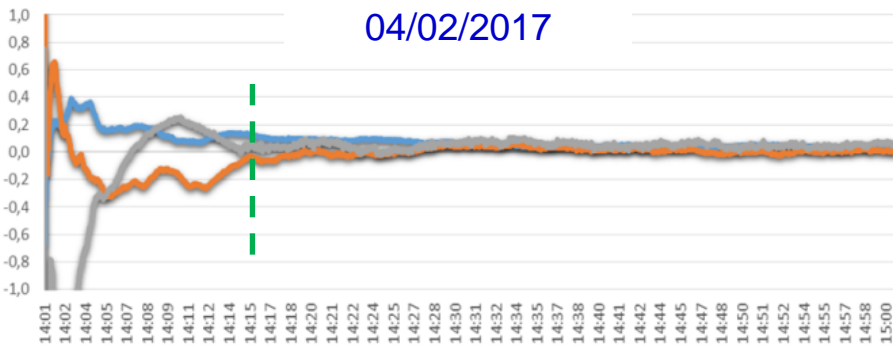
GPS, L1, 12:00→13:00 local time  
29/01/2017



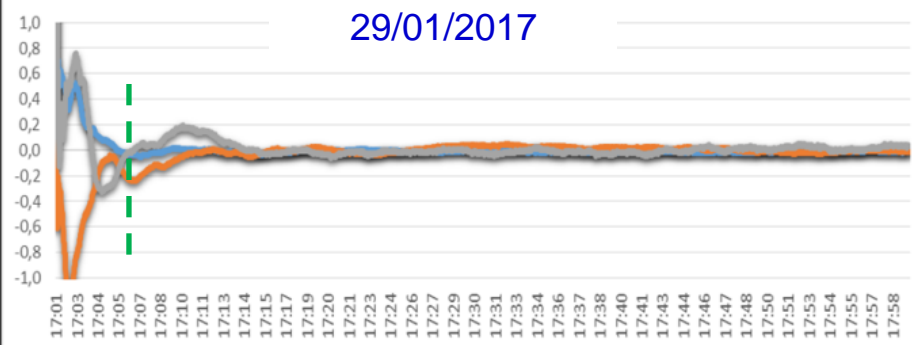
GPS, L1+L2, 13:00→14:00 local time  
29/01/2017



GPS+GLONASS, L1, 11:00→12:00 local time  
04/02/2017



GPS+GLONASS, L1+L2, 14:00→15:00 local time  
29/01/2017

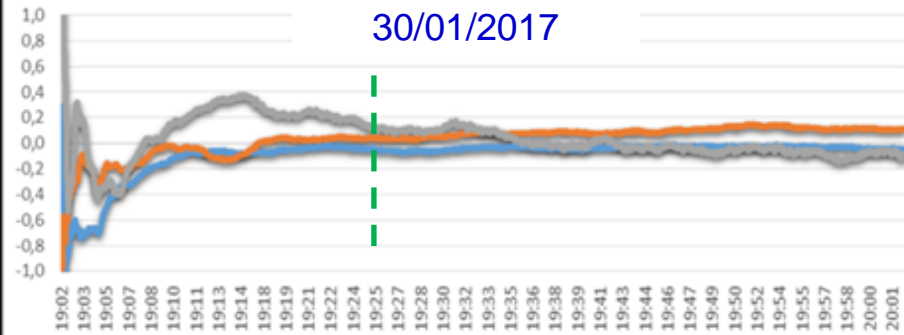




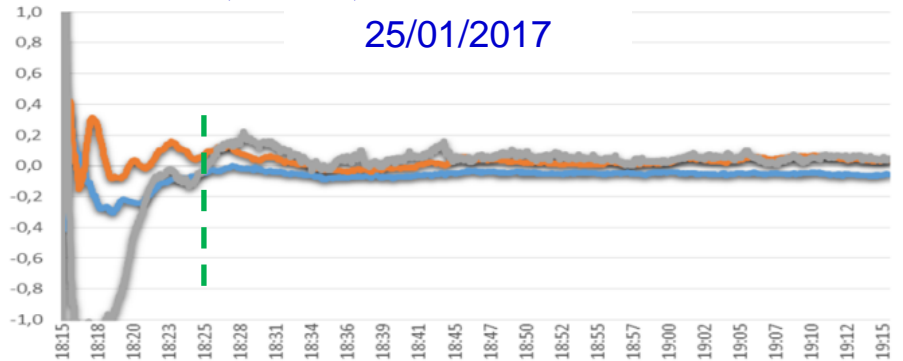
# RTK results (2/6)

SAVO-SSA1: 10-km baseline; Sessions starting 15:00-20:00 local time (m)  
**Latitude**, **Longitude** and **Height** differences (m)  
to rover known coordinates (vertical axis: -1 to +1 m)

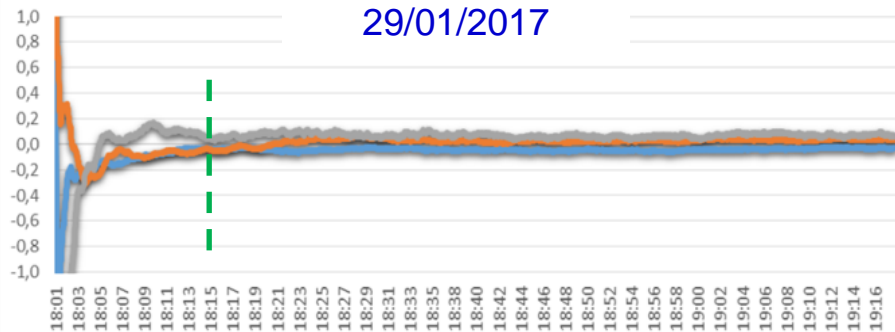
GPS, L1, 16:00→17:00 local time  
30/01/2017



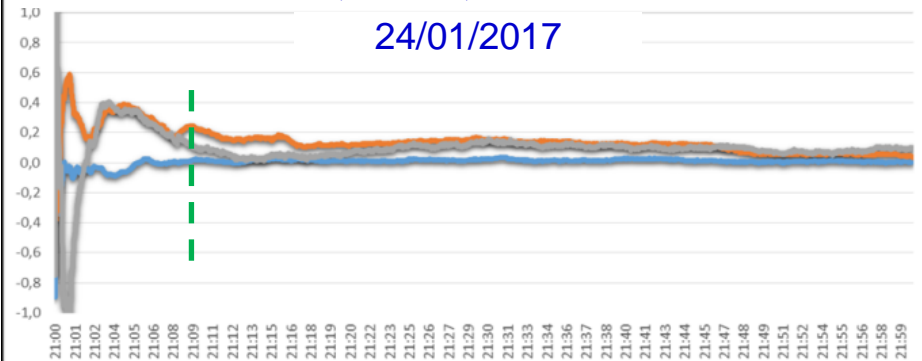
GPS, L1+L2, 15:15→16:15 local time  
25/01/2017



GPS+GLONASS, L1, 15:00→16:00 local time  
29/01/2017



GPS+GLONASS, L1+L2, 18:00→19:00 local time  
24/01/2017





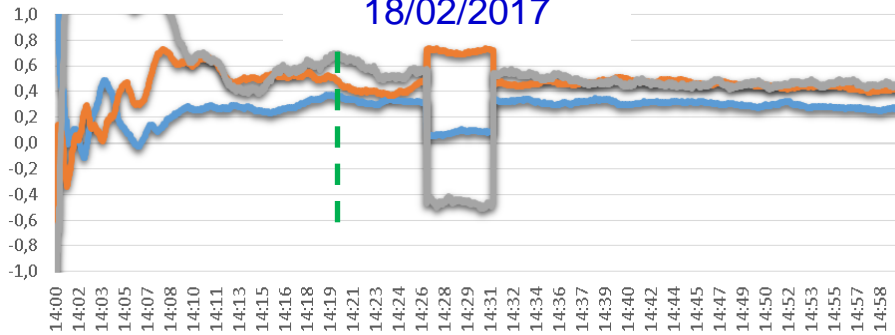
# RTK Results (3/6)

SJSP-UBA1: 82-km baseline; Sessions starting 11:00-15:00 local time (m)

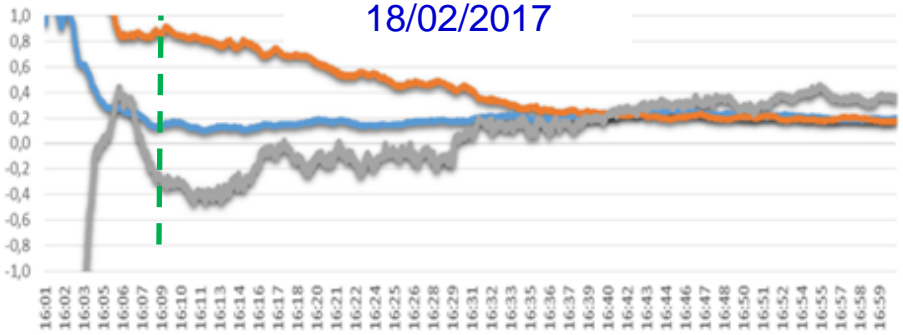
Latitude, Longitude and Height differences (m)

to rover known coordinates (vertical axis: -1 to +1 m)

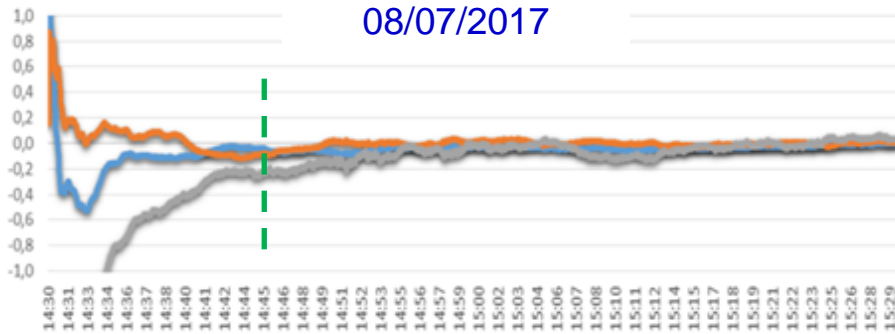
GPS, L1, 11:00→12:00 local time  
18/02/2017



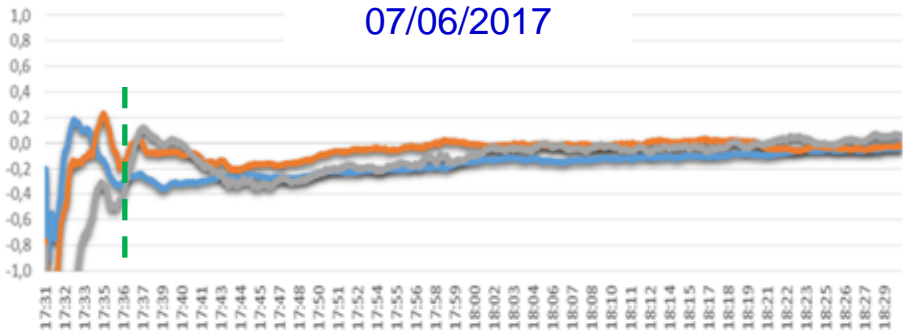
GPS, L1+L2, 13:00→14:00 local time  
18/02/2017



GPS+GLONASS, L1, 11:30→12:30 local time  
08/07/2017



GPS+GLONASS, L1+L2, 14:30→15:30 local time  
07/06/2017

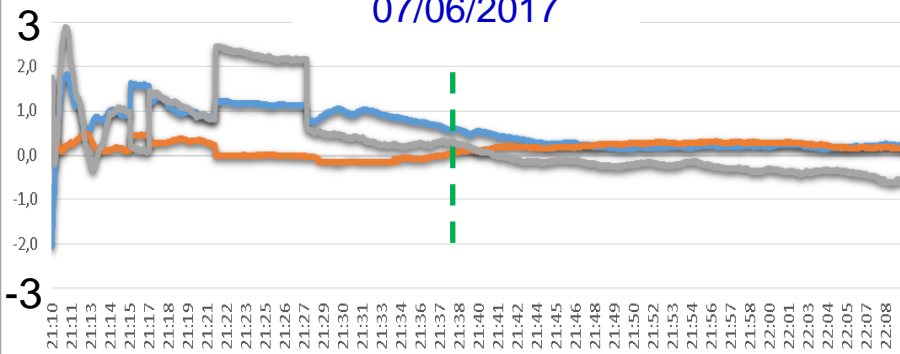




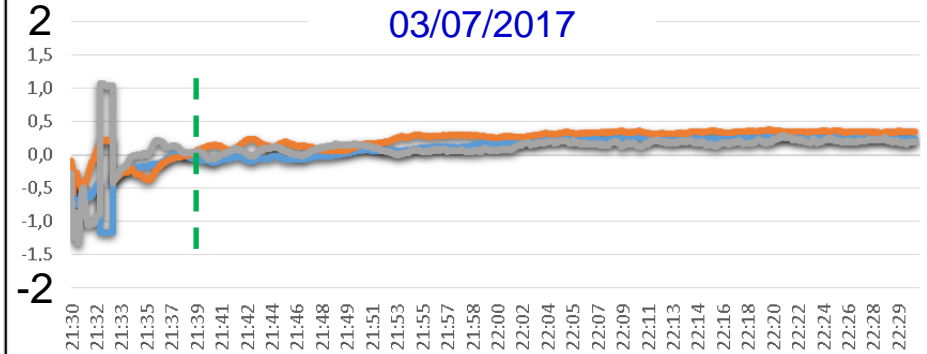
# RTK results (4/6)

SJSP-UBA1: 82-km baseline; Sessions starting 15:00-20:00 local time (m)  
**Latitude**, **Longitude** and **Height** differences (m)  
to rover known coordinates

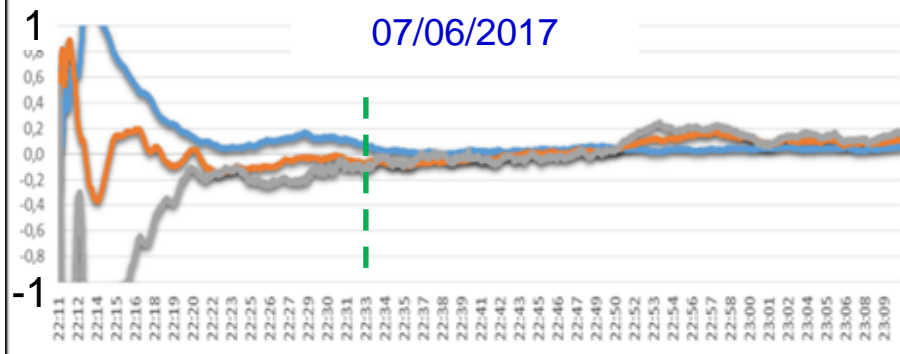
GPS, L1, 18:10→19:10 local time  
07/06/2017



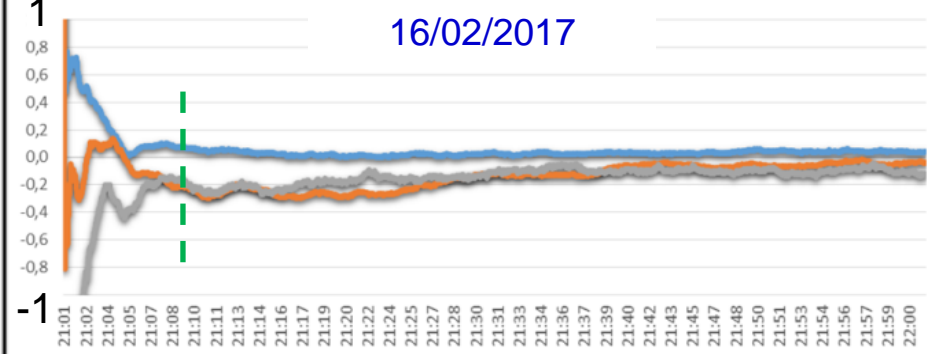
GPS, L1+L2, 18:30→19:30 local time  
03/07/2017



GPS+GLONASS, L1, 19:11→20:11 local time  
07/06/2017



GPS+GLONASS, L1+L2, 18:00→19:00 local time  
16/02/2017



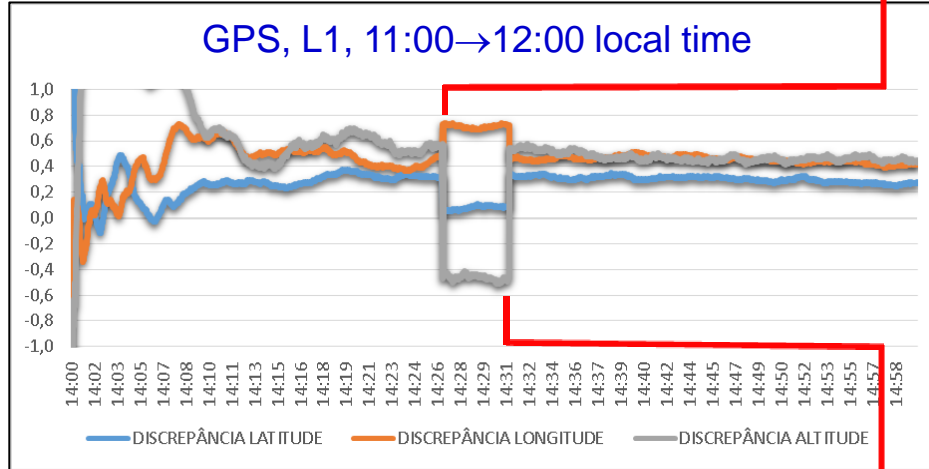


# RTK results (5/6)

Q

Ratio

18/02/2017	14:26:51	-23.500174065	-45.118896817	6.79	2.00	7.00	0.02	0.03	0.05	-0.01	-0.0112000000	0.02	1	2.1
18/02/2017	14:26:52	-23.500174047	-45.118896827	6.78	2.00	7.00	0.02	0.03	0.05	-0.01	-0.0112000000	0.02	0	2.5
18/02/2017	14:26:53	-23.500174035	-45.118896811	6.78	2.00	7.00	0.02	0.03	0.05	-0.01	-0.0114000000	0.02	1	2.8
18/02/2017	14:26:54	-23.500176429	-45.118894355	5.78	1.00	7.00	0.01	0.01	0.03	-0.01	-0.0122000000	0.01	0	3.2
18/02/2017	14:26:55	-23.500176446	-45.118894354	5.78	1.00	7.00	0.01	0.01	0.03	-0.01	-0.0123000000	0.01	1	3.5
18/02/2017	14:26:56	-23.500176448	-45.118894344	5.78	1.00	7.00	0.01	0.01	0.03	-0.01	-0.0123000000	0.01	1	3.9



18/02/2017	14:31:30	-23.500176167	-45.118894452	5.75	1.00	7.00	0.01	0.01	0.03	-0.01	-0.0120000000	0.01	2	3.0
18/02/2017	14:31:31	-23.500176196	-45.118894442	5.75	1.00	7.00	0.01	0.01	0.03	-0.01	-0.0116000000	0.01	0	3.0
18/02/2017	14:31:32	-23.500176190	-45.118894437	5.75	1.00	7.00	0.01	0.01	0.03	-0.01	-0.0117000000	0.01	1	3.0
18/02/2017	14:31:33	-23.500173798	-45.118897088	6.76	2.00	7.00	0.02	0.03	0.04	0.00	-0.0122000000	0.01	1	3.0
18/02/2017	14:31:34	-23.500173827	-45.118897062	6.76	2.00	7.00	0.02	0.03	0.04	0.00	-0.0126000000	0.01	2	3.0
18/02/2017	14:31:35	-23.500173843	-45.118897009	6.75	2.00	7.00	0.02	0.03	0.04	0.00	-0.0121000000	0.01	0	3.0

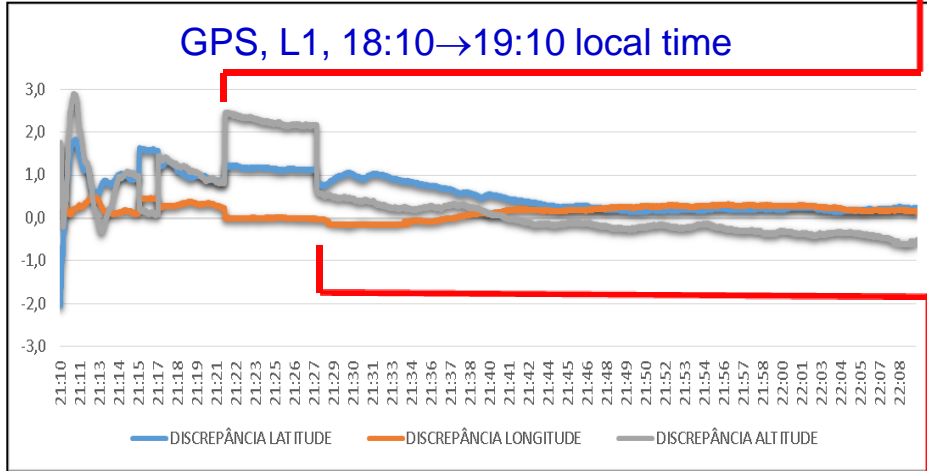


# RTK results (6/6)

Q

Ratio

07/06/2017	21:21:40	-23.50016926200	-45.118899299000	7.01	2	5	0.12	0.06	0.12	-0.06	-0.0298000000	0.09	0	3
07/06/2017	21:21:41	-23.50016932500	-45.118899242000	7.02	2	5	0.12	0.06	0.12	-0.06	-0.0297000000	0.09	-1	3
07/06/2017	21:21:42	-23.50016926200	-45.118899314000	7.01	2	5	0.12	0.06	0.12	-0.06	-0.0297000000	0.09	0	3
07/06/2017	21:21:43	-23.50016612400	-45.118901549000	8.64	1	5	0.03	0.01	0.05	-0.02	0.0052000000	0.02	-1	3
07/06/2017	21:21:44	-23.50016603000	-45.118901522000	8.65	1	5	0.03	0.01	0.05	-0.02	0.0050000000	0.02	0	3
07/06/2017	21:21:45	-23.50016596400	-45.118901572000	8.64	1	5	0.03	0.01	0.05	-0.02	0.0052000000	0.02	1	3



07/06/2017	21:28:01	-23.50016684400	-45.118901754000	8.36	1	5	0.0287	0.0156	0.0447	-0.016	0.0094000000	0.02	0	3
07/06/2017	21:28:02	-23.50016690000	-45.118901727000	8.36	1	5	0.0289	0.0157	0.0449	-0.016	0.0095000000	0.02	1	3
07/06/2017	21:28:03	-23.50016683700	-45.118901770000	8.36	1	5	0.0287	0.0156	0.0447	-0.016	0.0094000000	0.02	0	3
07/06/2017	21:28:04	-23.50016948900	-45.118901868000	6.82	2	5	0.087	0.0487	0.0896	-0.05	-0.0204000000	0.06	-1	3
07/06/2017	21:28:05	-23.50016951600	-45.118901843000	6.82	2	5	0.0868	0.0486	0.0894	-0.05	-0.0205000000	0.06	0	3
07/06/2017	21:28:06	-23.50016953900	-45.118901814000	6.81	2	5	0.0868	0.0487	0.0895	-0.05	-0.0204000000	0.06	1	3



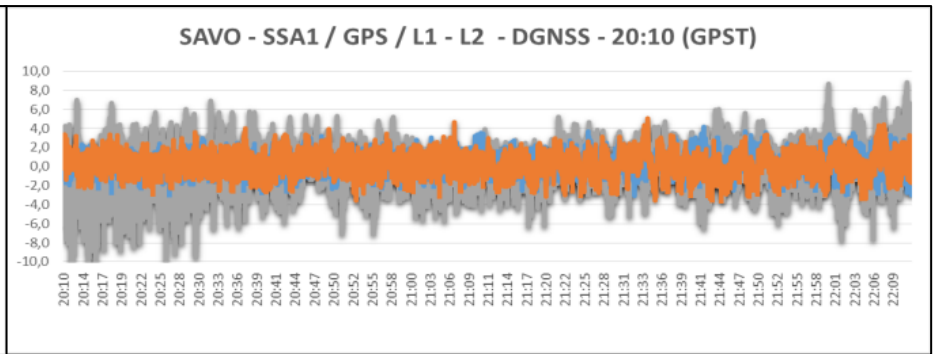
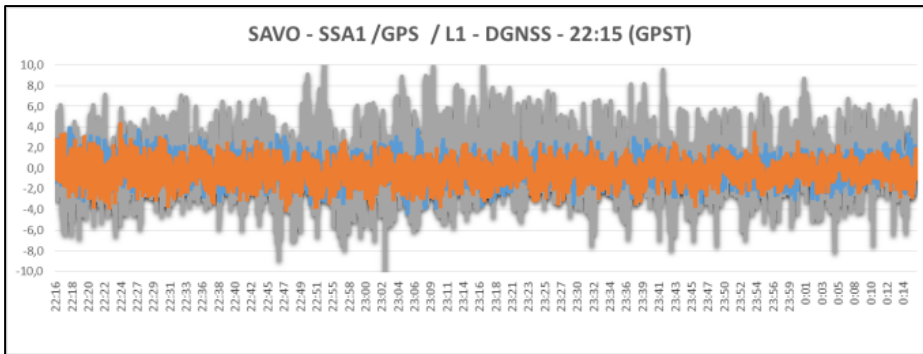
# DGNSS results (1/2)

## SAVO-SSA1: 10-km baseline

Latitude, Longitude and Height differences (m)  
to rover known coordinates (vertical axis: -10 to +10 m)

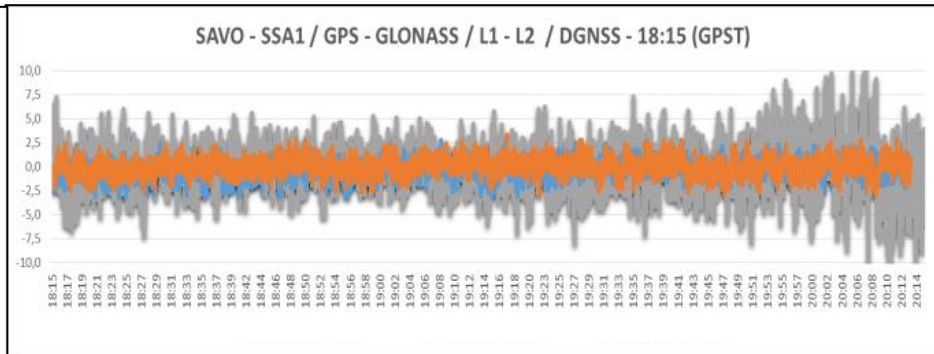
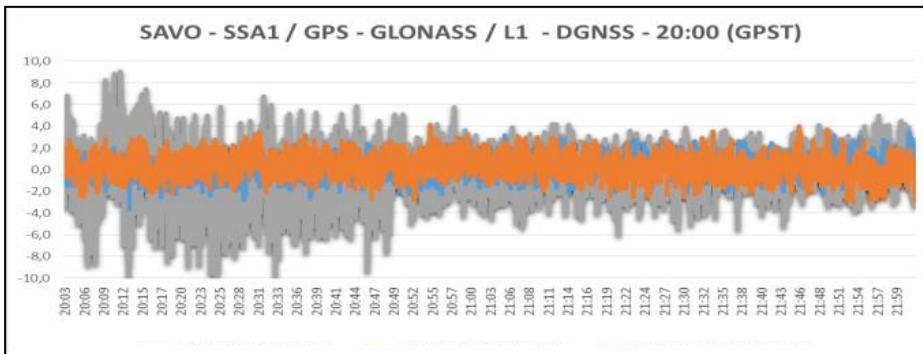
GPS, L1, 19:00→21:00 local time  
30/01/2017

GPS, L1+L2, 17:00→19:00 local time  
02/02/2017



GPS+GLONASS, L1, 17:00→19:00 local time  
01/02/2017

GPS+GLONASS, L1+L2, 15:00→17:00 local time  
02/02/2017





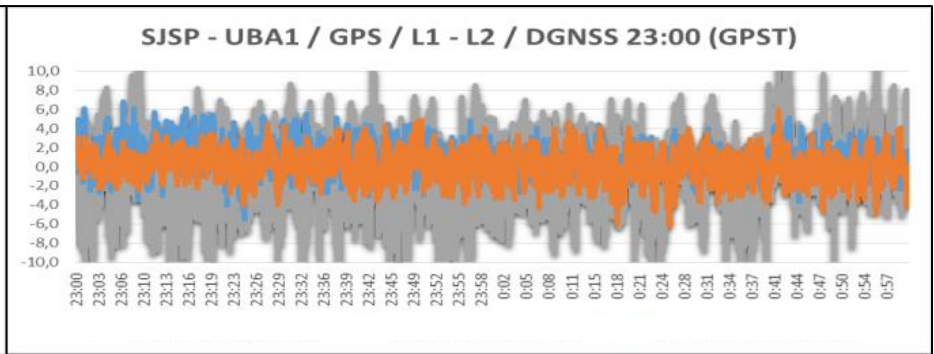
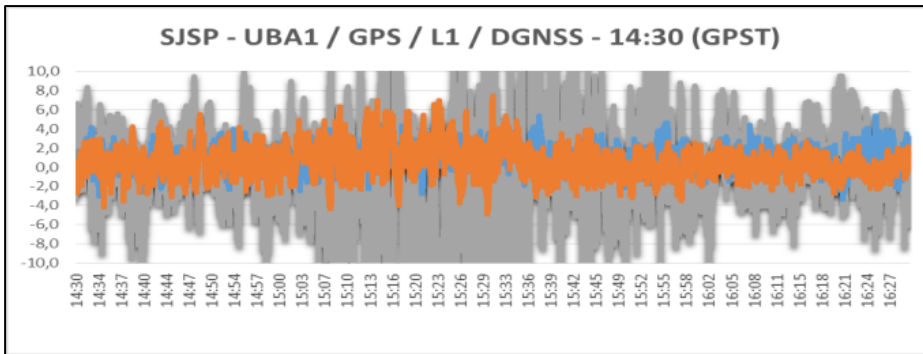
# DGNSS results (2/2)

SJSP-UBA1: 82-km baseline

Latitude, Longitude and Height differences (m)  
to rover known coordinates (vertical axis: -10 to +10 m)

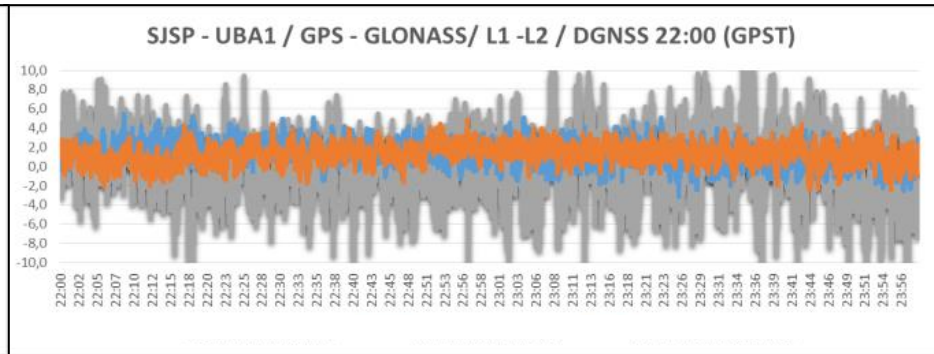
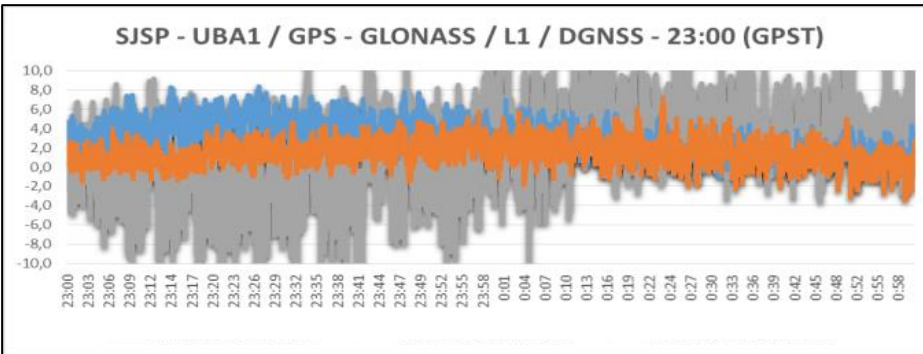
GPS, L1, 11:30→13:30 local time  
21/02/2017

GPS, L1+L2, 20:00→22:00 local time  
23/02/2017



GPS+GLONASS, L1, 20:00→22:00 local time  
22/02/2017

GPS+GLONASS, L1+L2, 14:00→15:00 local time  
03/03/2017

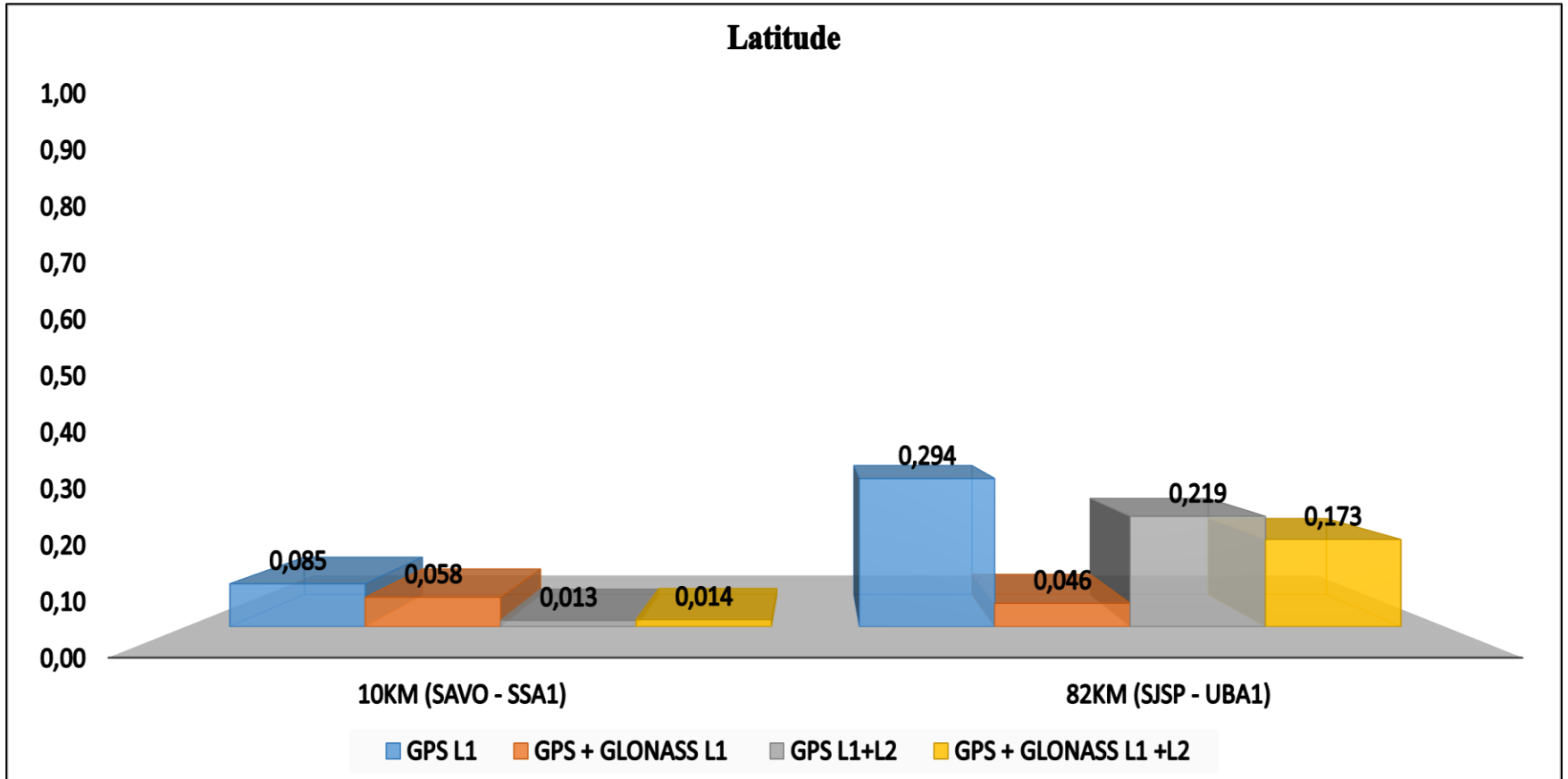






# RTK RMS (1/87)

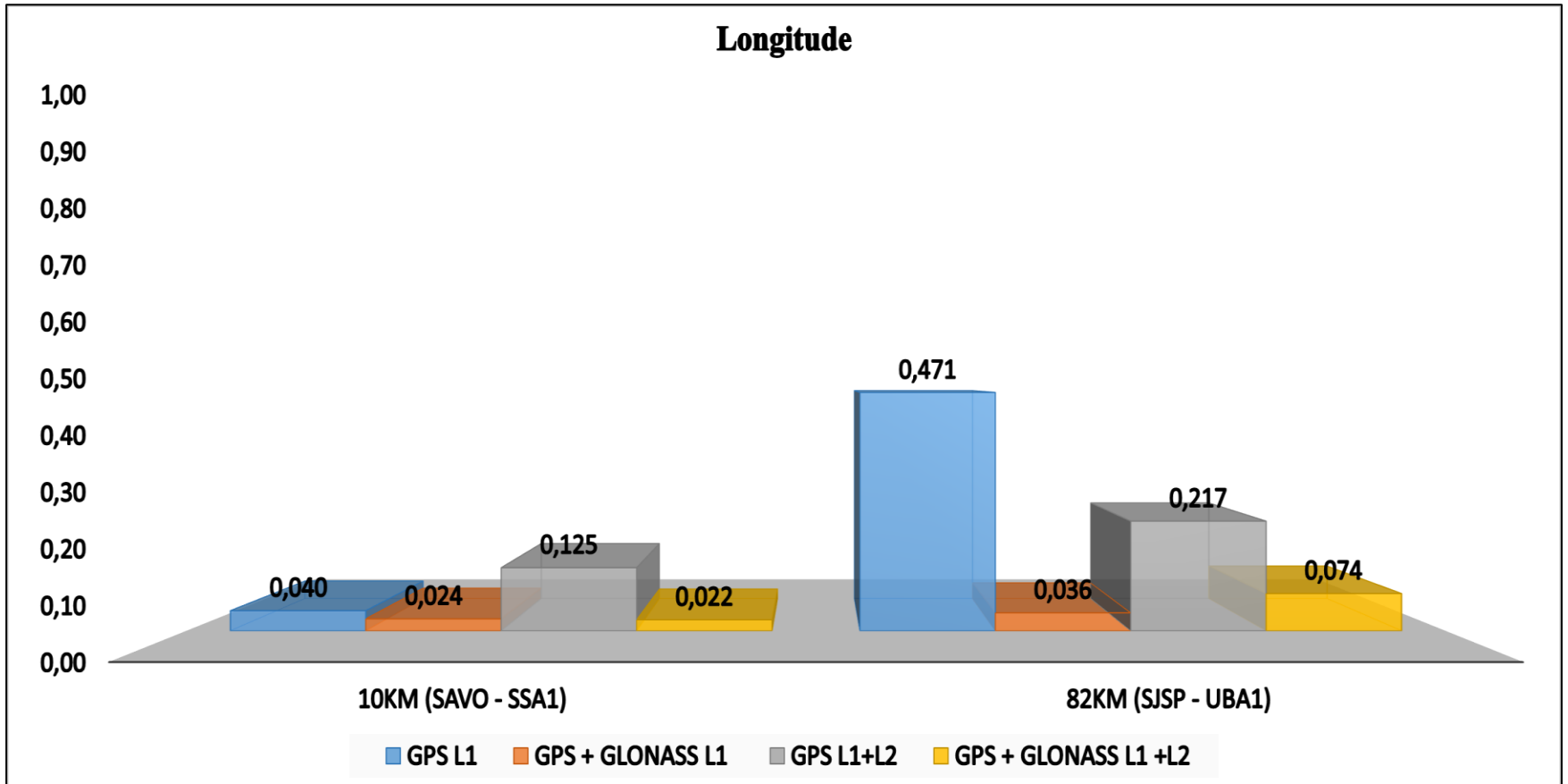
Sessions starting 11:00-15:00 local time (m)





# RTK RMS (2/8)

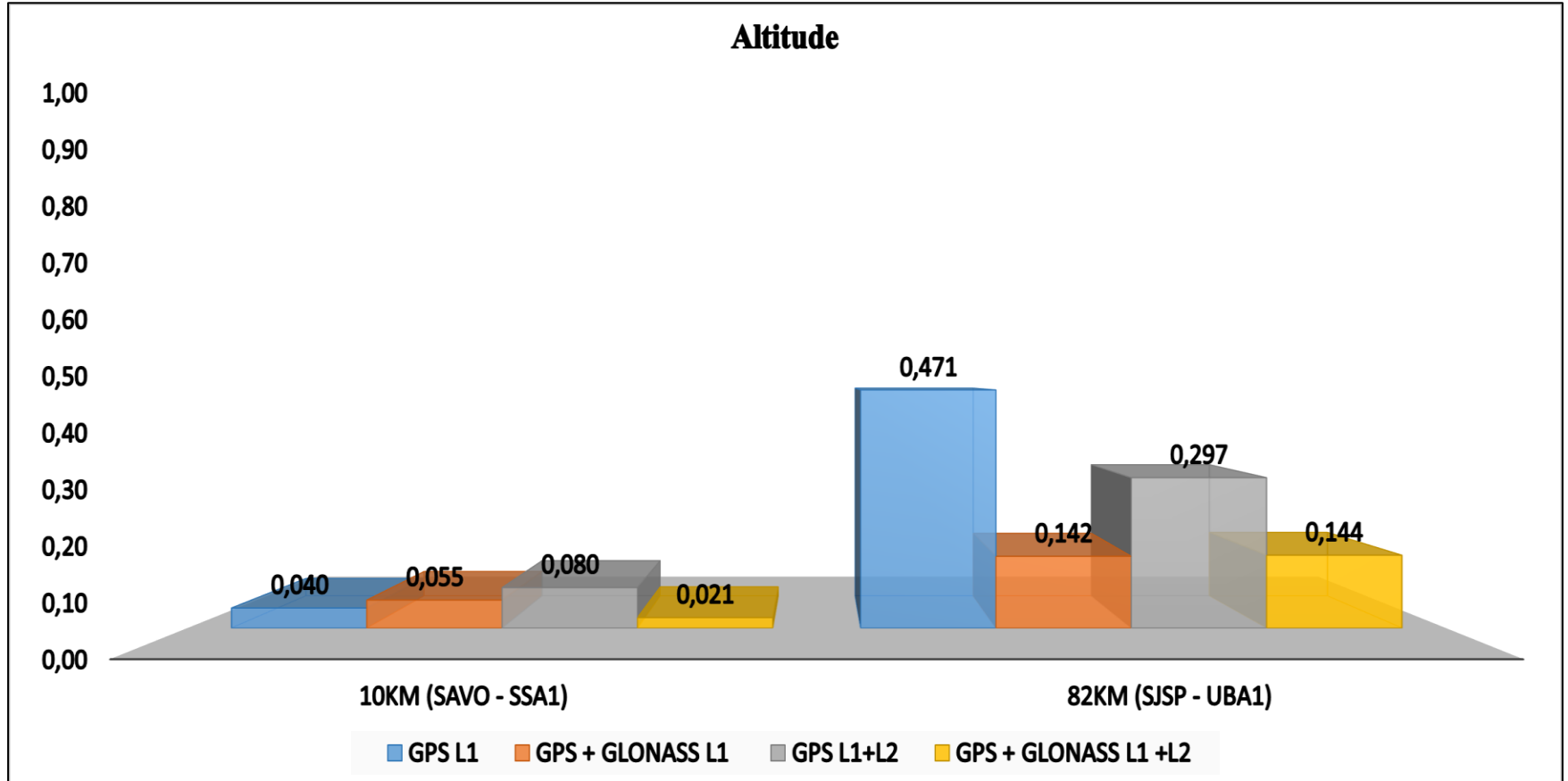
Sessions starting 11:00-15:00 local time (m)





# RTK RMS (3/8)

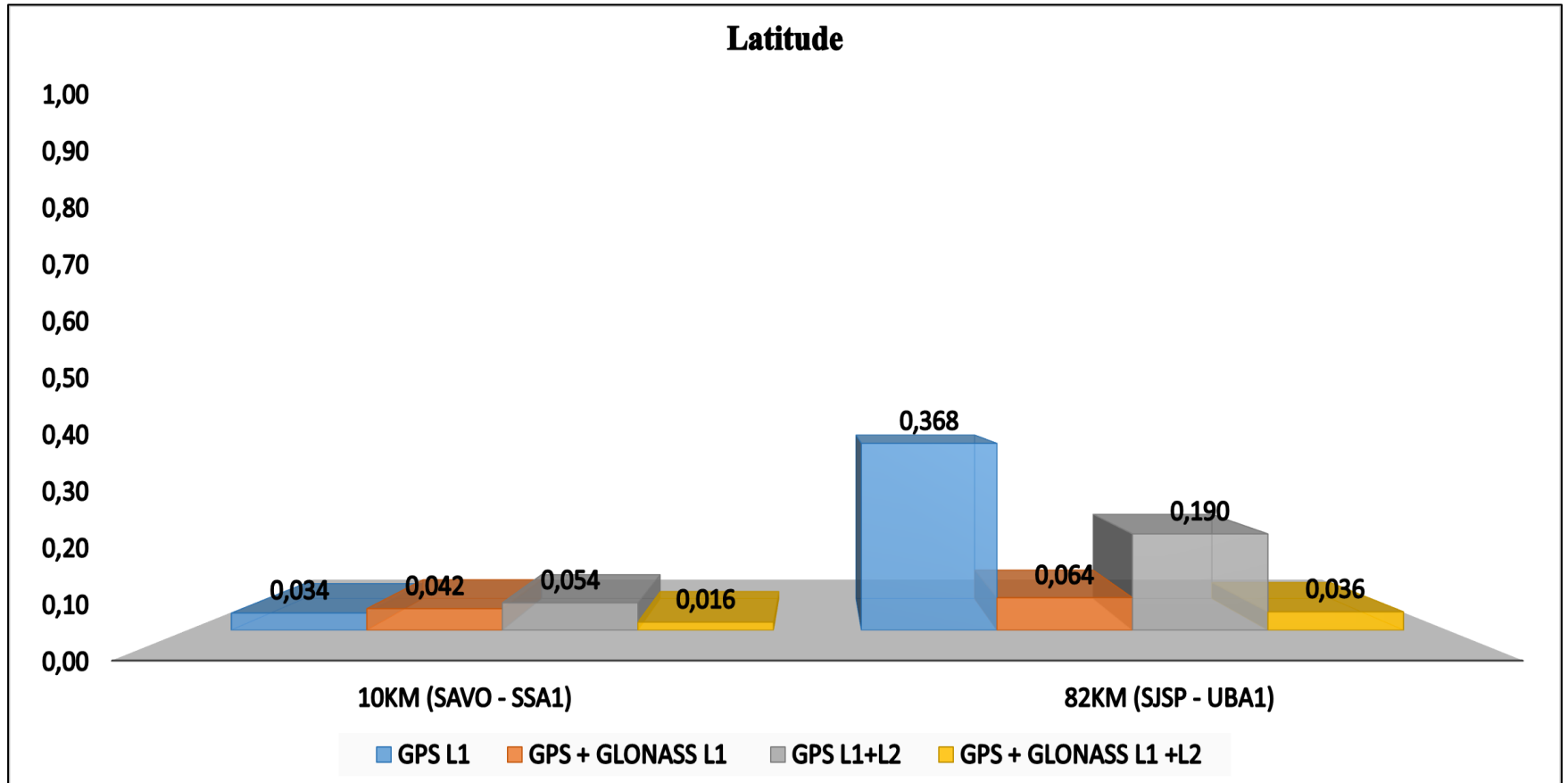
Sessions starting 11:00-15:00 local time (m)





# RTK RMS (4/8)

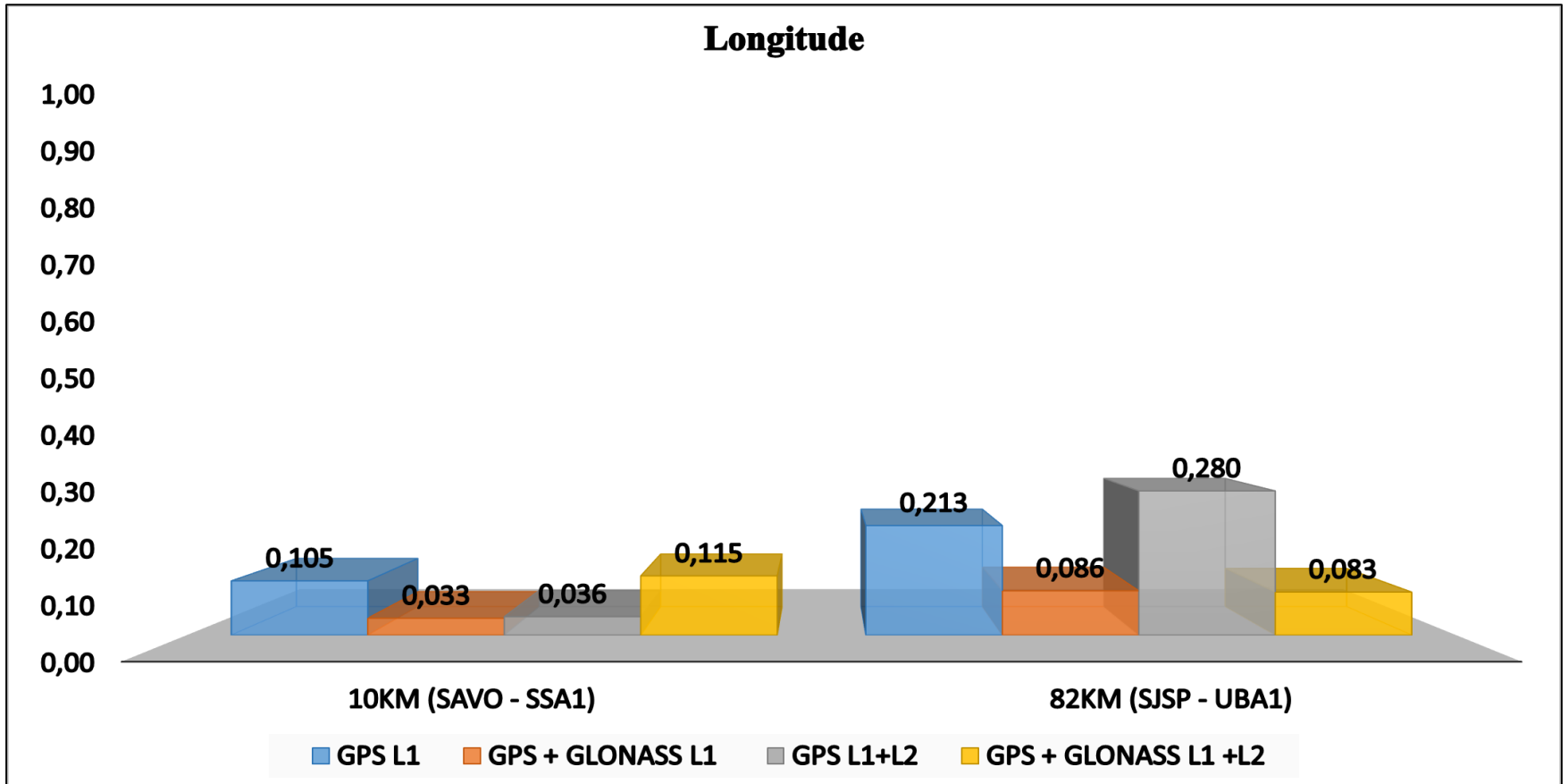
Sessions starting 15:00-20:00 local time (m)





# RTK RMS (5/8)

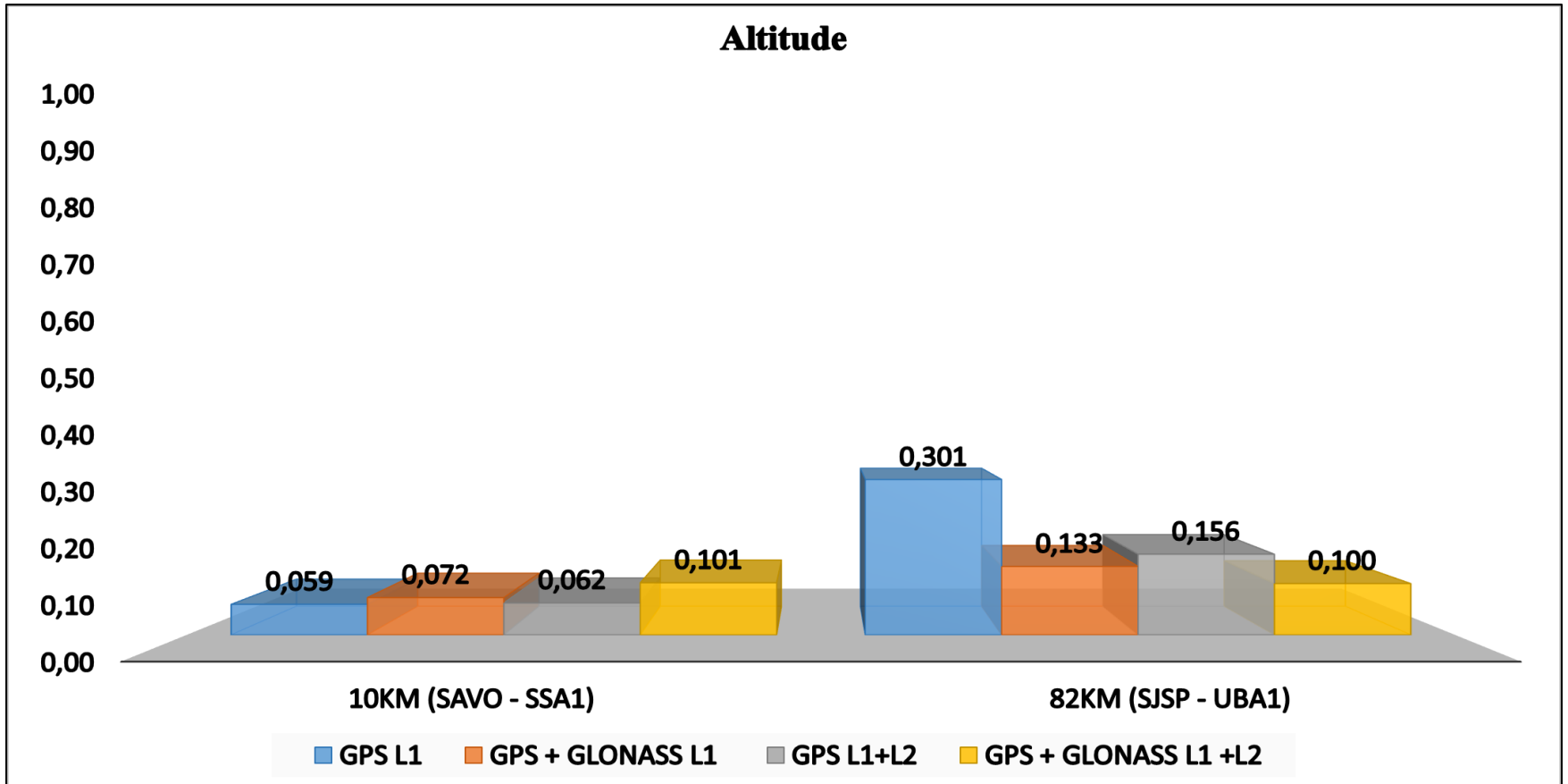
Sessions starting 15:00-20:00 local time (m)





# RTK RMS (6/8)

Sessions starting 15:00-20:00 local time (m)

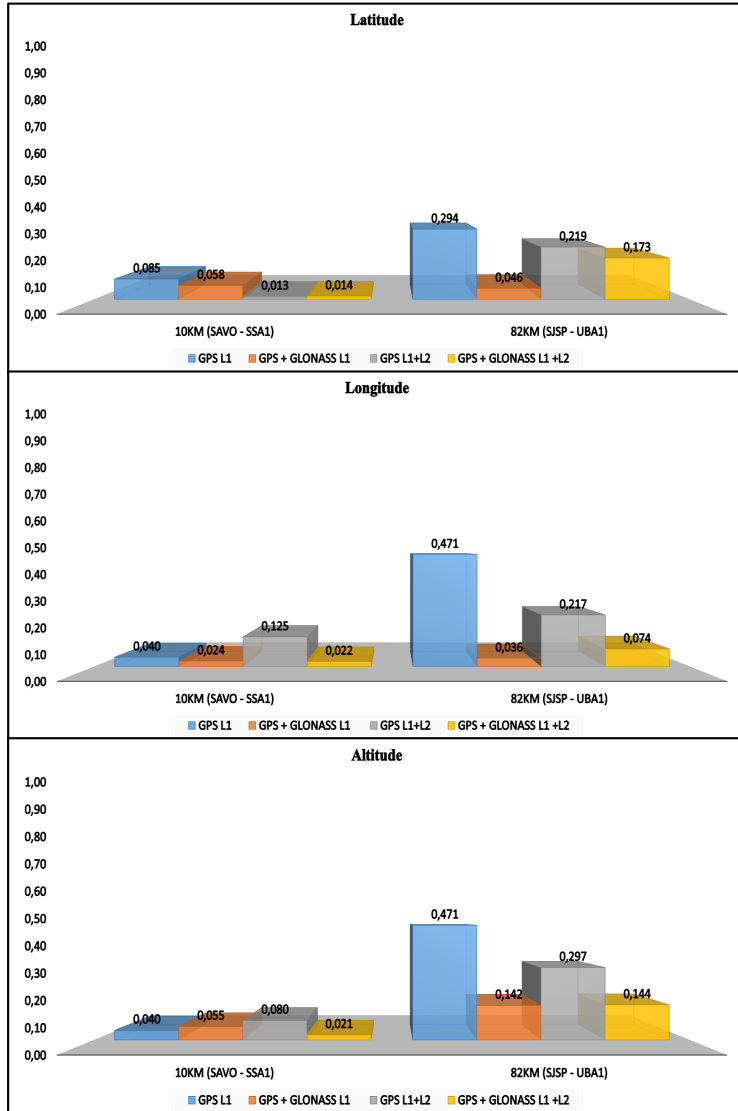




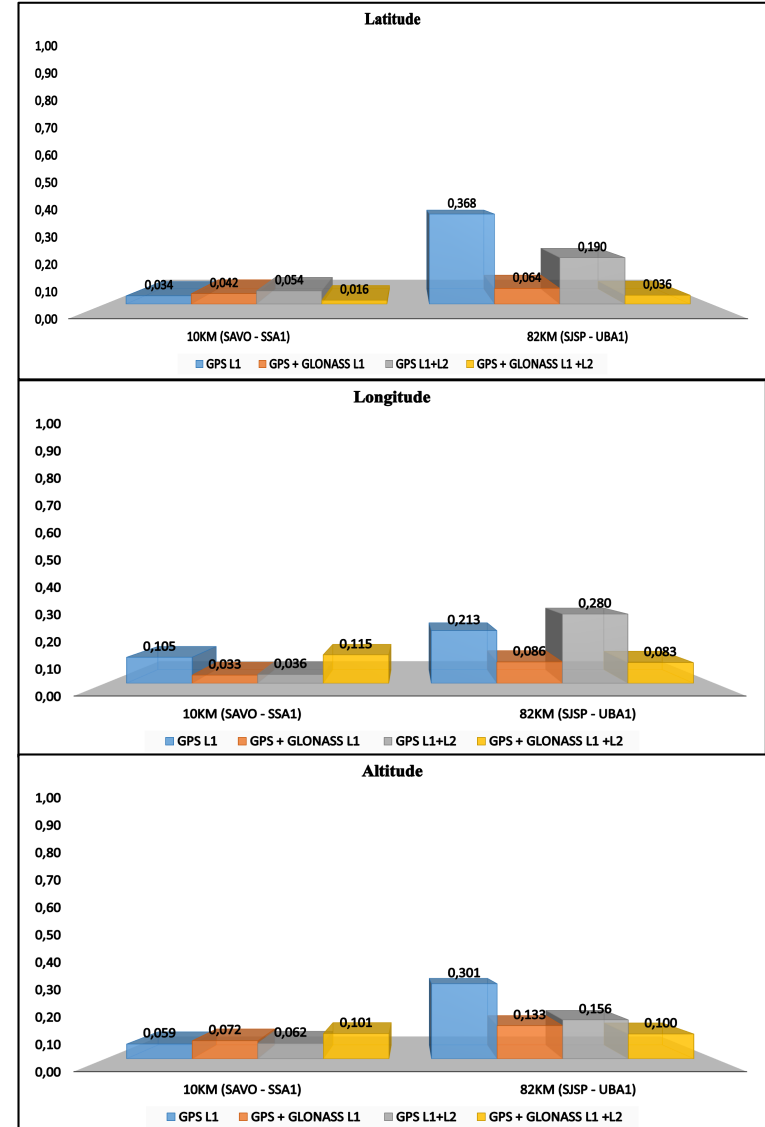
# RTK RMS (7/8)

## Summary

### Sessions starting 11:00-15:00 local time



### Sessions starting 15:00-20:00 local time





# RTK RMS (8/8)

Convergence time (CT) of RTK sessions considered for RMS computation

Sessions starting 11:00-15:00 local time

CIDADE: SALVADOR		LINHA DE BASE: SAVO - SSA1			
SISTEMA DE POSICIONAMENTO	FREQUÊNCIA	SOLUÇÃO	DATA (1º sessão)		TEMPO APROX. DE CONVERGÊNCIA
GPS	L1	RTK	29/01/2017	15:00	16 Min
GPS +GLONASS	L1	RTK	04/02/2017	14:00	14 Min
GPS	L1+L2	RTK	29/01/2017	16:00	9 Min
GPS + GLONASS	L1 + L2	RTK	29/01/2017	17:00	5 Min
CIDADE: S. J. DOS CAMPOS - UBATUBA		LINHA DE BASE: SJSP - UBA1			
GPS	L1	RTK	18/02/2017	14:00	20 Min
GPS +GLONASS	L1	RTK	08/07/2017	14:30	15 Min
GPS	L1+L2	RTK	18/02/2017	16:00	8 Min
GPS + GLONASS	L1 + L2	RTK	07/06/2017	17:30	5 Min

Sessions starting 15:00-20:00 local time

CIDADE: SALVADOR		LINHA DE BASE: SAVO - SSA1			
SISTEMA DE POSICIONAMENTO	FREQUÊNCIA	SOLUÇÃO	DATA (2º sessão)	GPST	TEMPO APROX. DE CONVERGÊNCIA
GPS	L1	RTK	30/01/2017	19:00	23 Min
GPS +GLONASS	L1	RTK	29/01/2017	18:00	14 Min
GPS	L1+L2	RTK	25/01/2017	18:15	10 Min
GPS + GLONASS	L1 + L2	RTK	24/01/2017	21:00	9 Min
CIDADE: S. J. DOS CAMPOS - UBATUBA		LINHA DE BASE: SJSP - UBA1			
GPS	L1	RTK	07/06/2017	21:10	28 Min
GPS +GLONASS	L1	RTK	07/06/2017	22:11	22 Min
GPS	L1+L2	RTK	03/07/2017	21:30	9 Min
GPS + GLONASS	L1 + L2	RTK	16/02/2017	21:00	8 Min

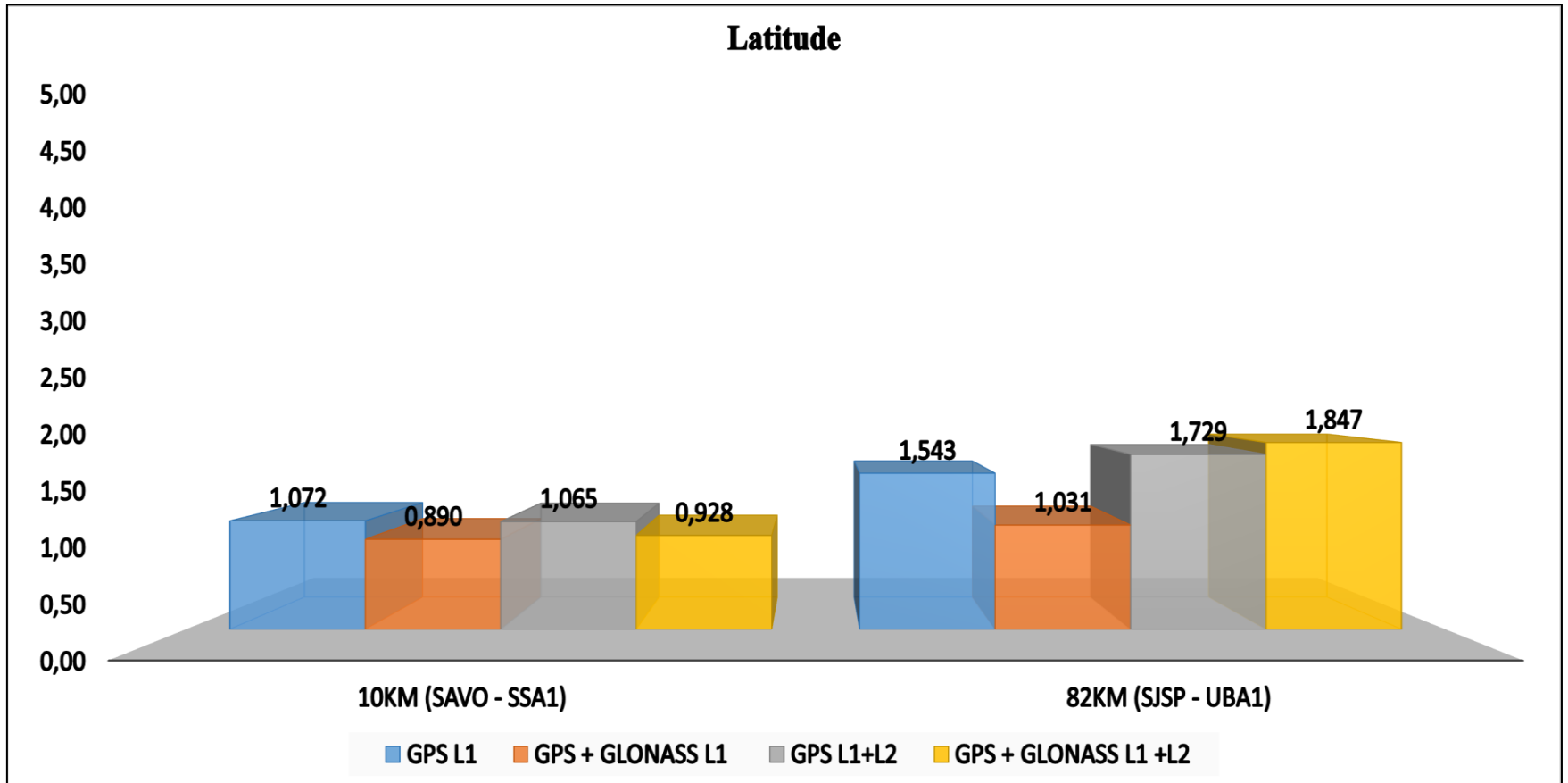
Note: CT defined when differences get close to 0m for the first time → subjective to some extent, which may have affected some of the RMS results





# DGNSS RMS (1/4)

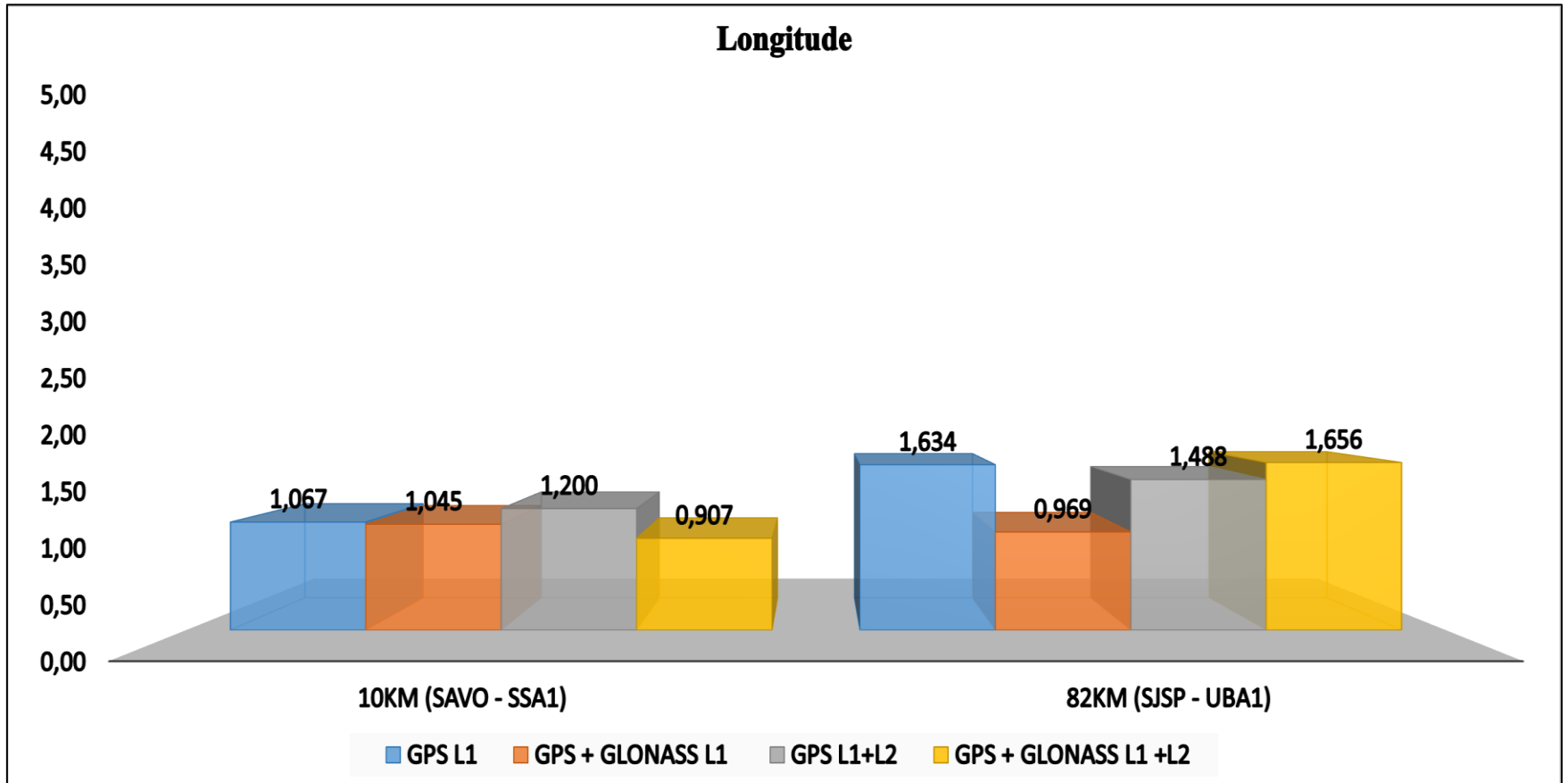
Sessions within 11:00-22:00 local time (m)





# DGNSS RMS (2/4)

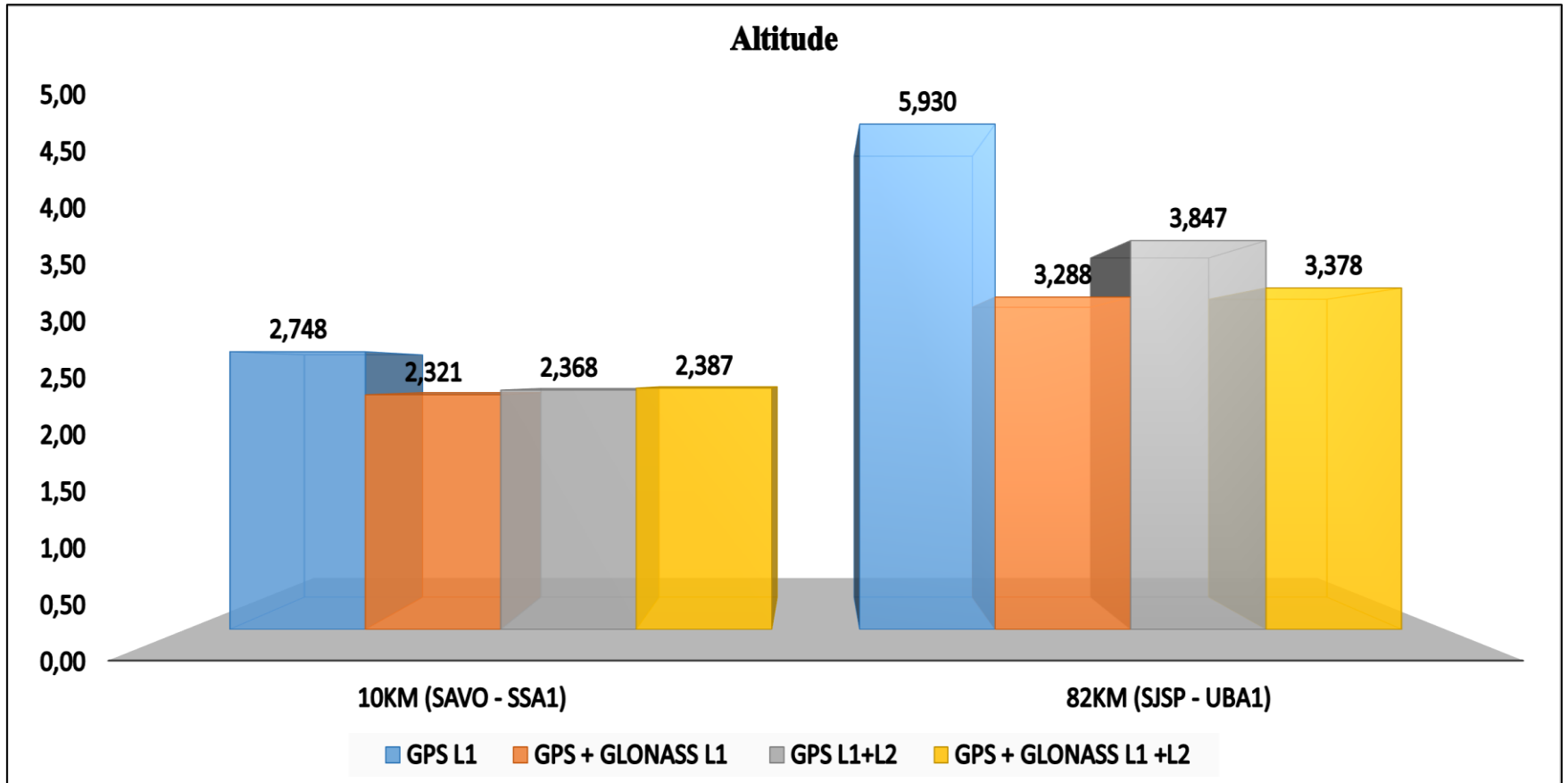
Sessions within 11:00-22:00 local time (m)





# DGNSS RMS (3/4)

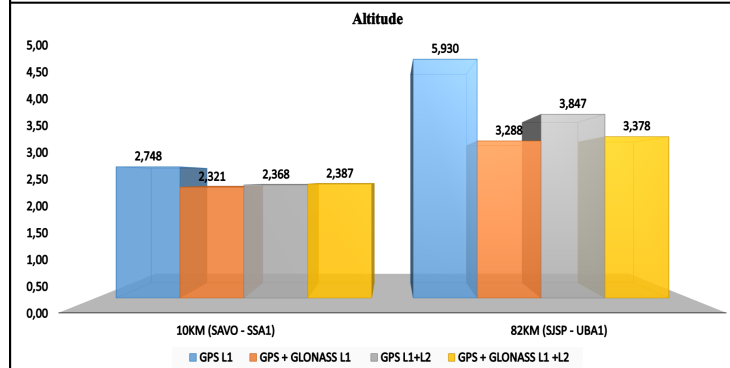
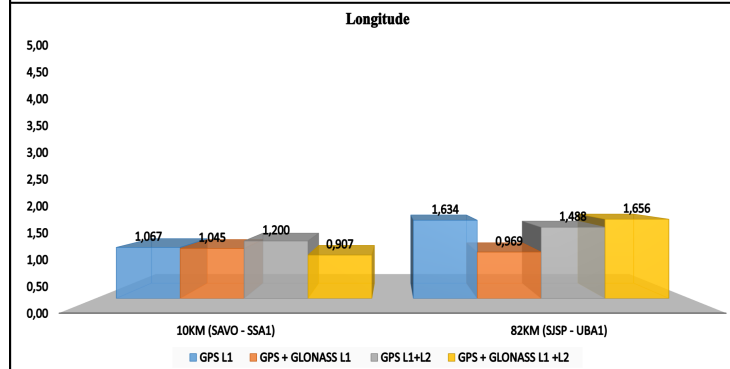
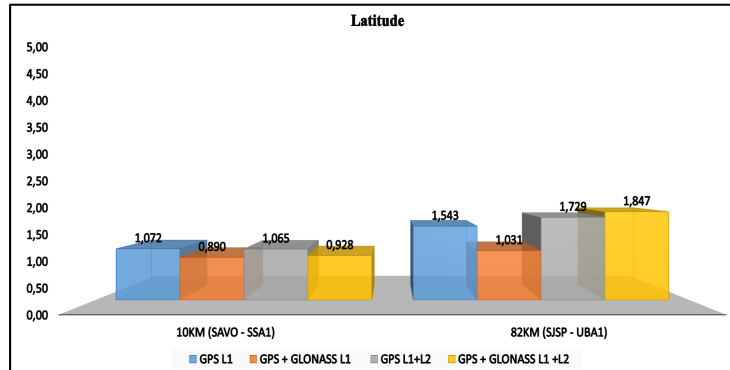
Sessions within 11:00-22:00 local time (m)





# DGNSS RMS(4/4)

## Summary





# Conclusions

- Goal was to assess the **quality** of RTK and DGNSS positioning based on RBMC-IP using **RTKLIB** with **default processing parameters**
- **Unconventional** method using two RBMC-IP stations corresponds to a **unfavorable scenario**, as both base station and rover data were received through the Internet and as such were subjected to communication delays/problems
- RTK achieved **centimeter level** RMS for the **10-km baseline** and **decimeter level** RMS for the **82-km baseline**
- DGNSS reached **meter accuracy**, as multipath and receiver noise contaminate pseudorange observations
  - **~30%** of GPS SPS Position Accuracy Standard
- Using **GPS+GLONASS** data reduced the convergence time and RMS of **RTK solutions** when comparing to **GPS-only solutions**
- In general, using **L1+L2** data improved **RTK solutions**, specially in the 82-km baseline
- Mostly **GPS+GLONASS L1+L2** RTK solutions were the best ones, as expected
  - Some better **GPS+GLONASS L1** results when comparing to **GPS L1+L2** ones in the 82-km baseline may indicate that the benefit of using more L1 observations (which imply better geometry) surpassed the benefit of using L1+L2 data (in this research)