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Validation of CODE-GIM and Regional Ionosphere Model (RIM) for Single Frequency GNSS PPP Solution using Bernese GNSS software - Case Study: Egyptian Nile Delta

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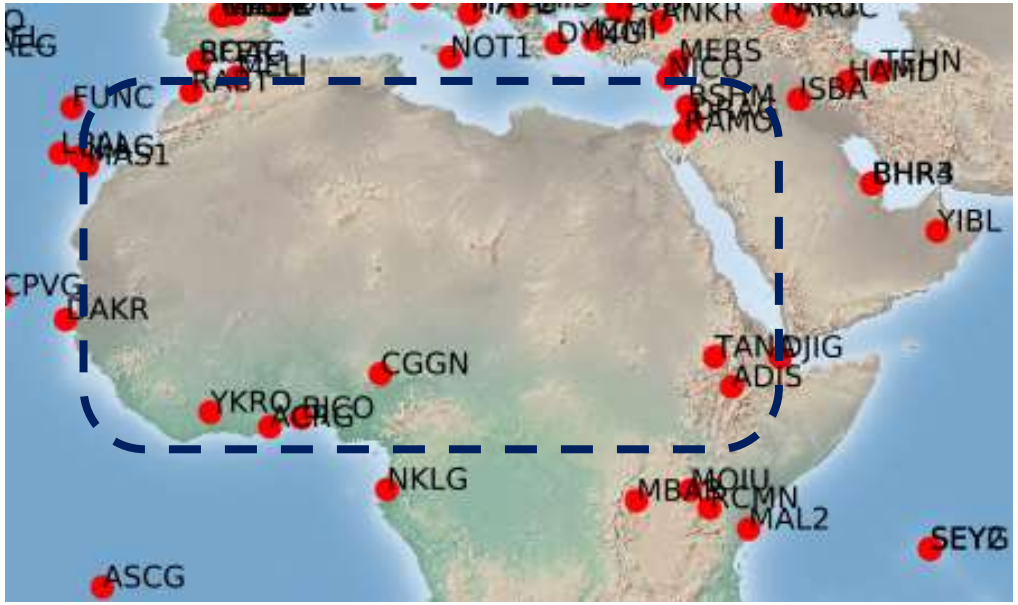
Motivation

- The IGS stations in Africa have many characteristics:
  - The network is mainly situated in the coastal area with long baselines, which affects the accuracy of the network precision,
  - is a sparse network (low density network) and have long base line distances,
  - these stations face high ionospheric activities, which lead to the loss of GNSS data.



Motivation

- In Egypt, the IGS-GIM model has a limitation to obtain a reliable PPP solution for single-frequency (SF) users (caused by low density of IGS station network).

- In 2012, the Egyptian Surveying Authority (ESA) established the first permanent Egyptian Continuously Operating Reference Stations (CORS) network with 40 stations.

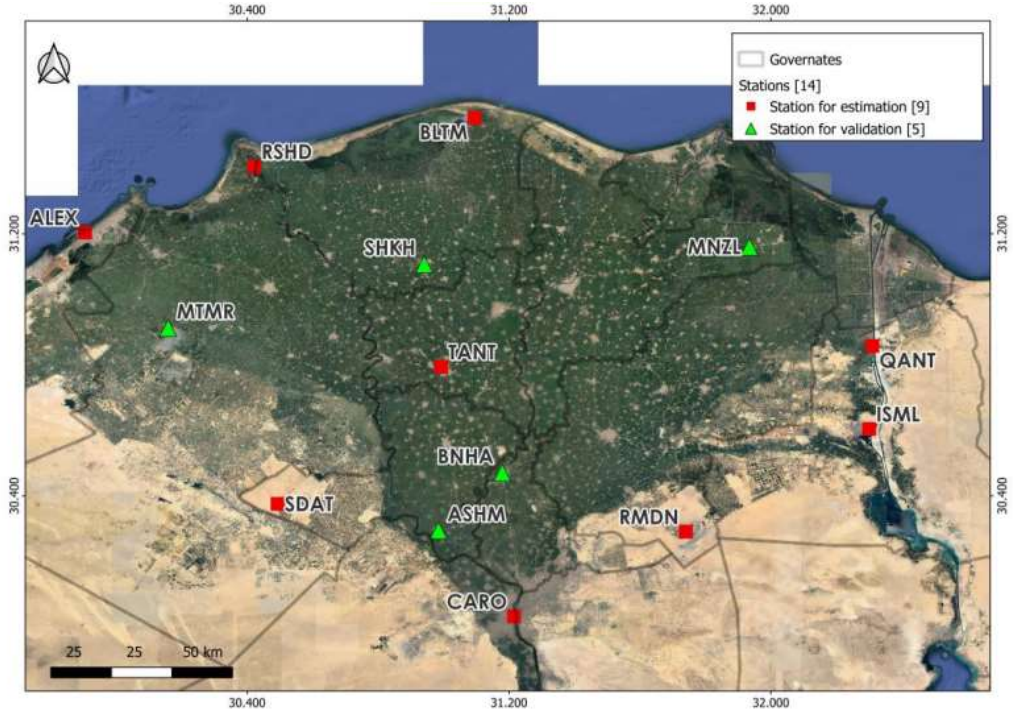
- This paper aims to evaluate the accuracy of the SF-PPP solution using the GIM model provided from CODE, and the modeled Regional Ionospheric Model (RIM) for the area of the Nile Delta.

Ionosphere modelling

- GNSS-Precise Point Positioning (PPP) solution plays a vital alternative to the differential solution to provide a reliable position accuracy,
- Dual-frequency PPP data is used for the ionosphere-free linear combination for phase and code observations to eliminate the first order of ionosphere errors.
- One of the greatest challenges for the single-frequency PPP (SF-PPP) technique is the modelling of the ionosphere errors.
- Ionosphere error reaches 1 m – 15 m for mid-latitude to near-equatorial region.

Methodology and software

- Data set of 14 stations are involved in the study of six consecutive days 202-207/2019 of the ESA-CORS permanent stations,
  - 9 stations have been considered for RIM estimation ■
  - 5 stations are used for validation ▲
- Bernese GNSS V. 5.2 software has been used for:
  - RIM model estimation,
  - SF-PPP solution

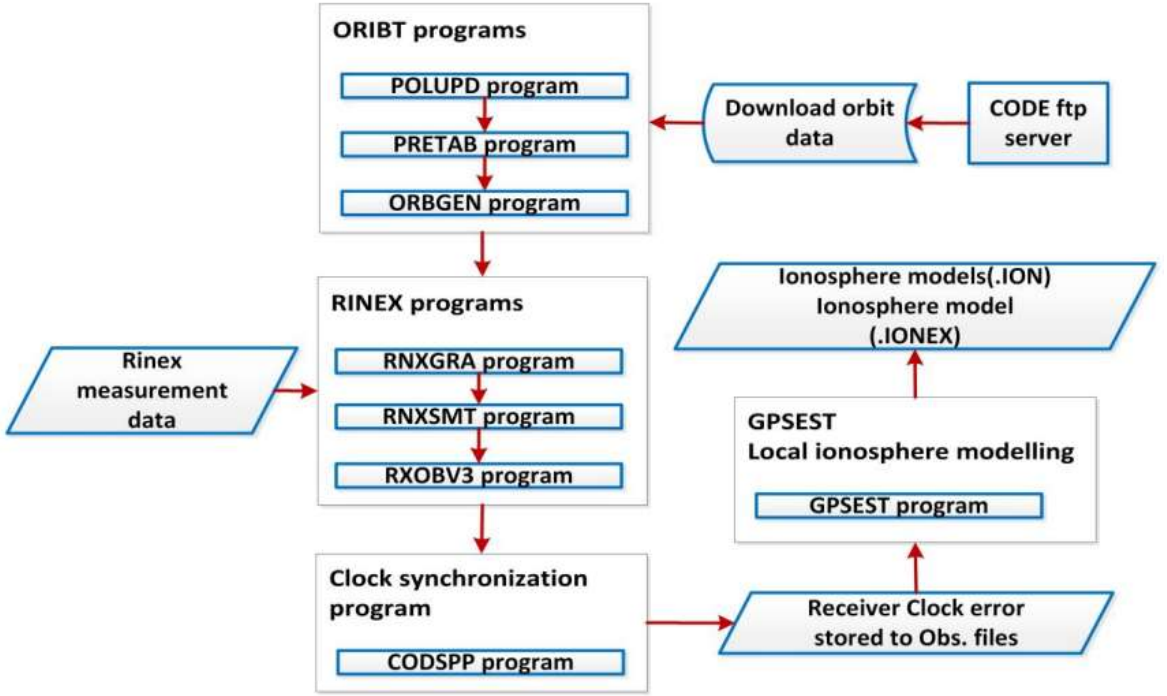


Layout of ESA-CORS stations based on Google Earth platform

Methodology and software

Parameters for RIM modeling using Bernese GNSS software

Parameter	Value
Satellite system	GPS & GLONASS
Differential level	Zero-difference
Frequency	P_4
Elevation angle	10°
Sampling interval	30 s
Temporal resolution	2 h
Max. degree of spherical harmonics (n_{max})	6
Max. order of spherical harmonics (m_{max})	6
Height of single layer (H)	450 km
Reference frame definition	geomagnetic
Latitude of the geomagnetic pole	79°
Longitude of the geomagnetic pole	-71°
Ionosphere grid (*Lat.*×*Long.*)	2.5°×5°

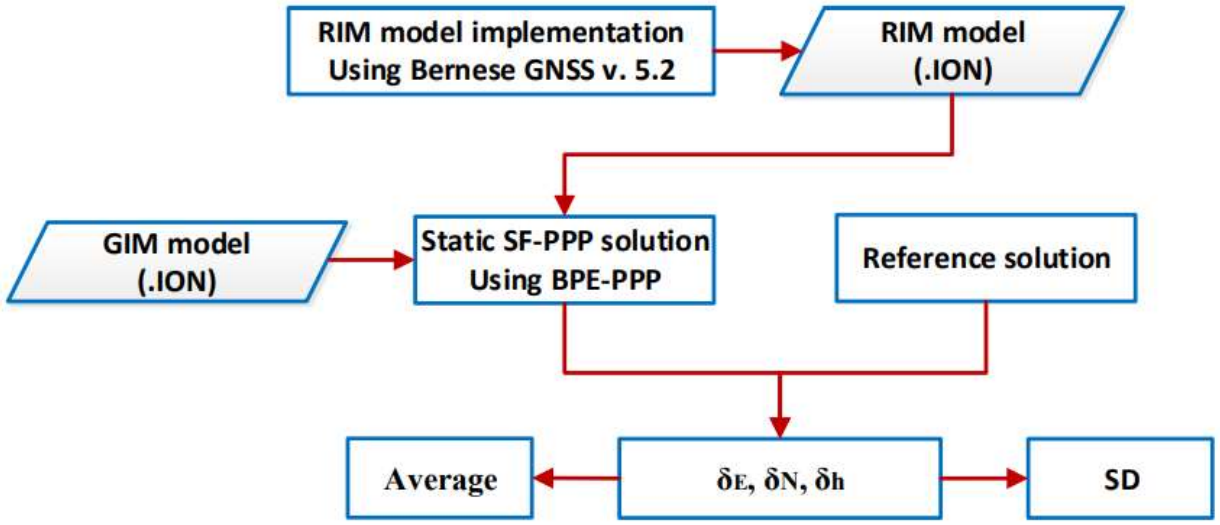


Flowchart of regional ionosphere modeling

Results and analysis

- The evaluation strategy is based on error calculation (δ) between the reference network solution and SF-PPP solution in East, North, and height directions.

- Mean value ($\bar{x}$) and the *RMS* values are estimated in addition to the standard deviation (*SD*).

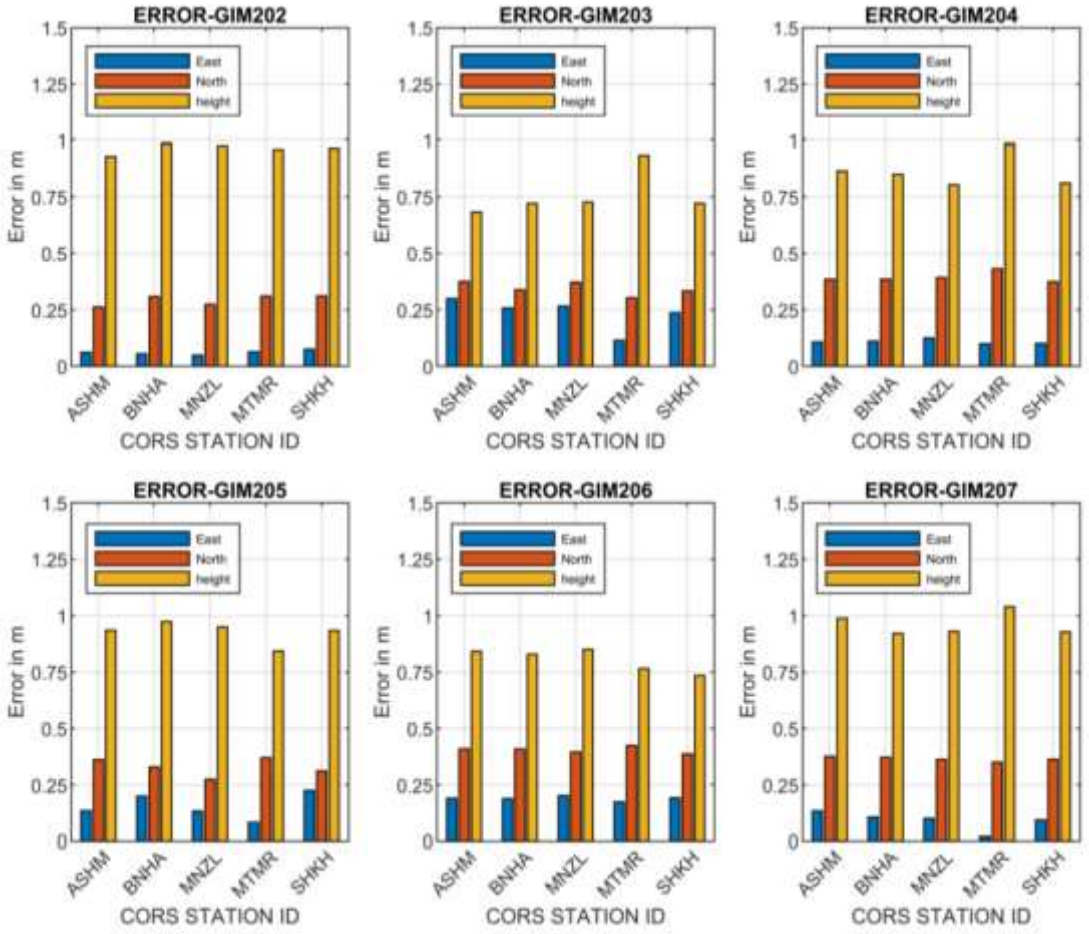


Flowchart of evaluation procedure

Results and analysis

SF-PPP using GIM model

- North direction, the results show an error range of 0.26 – 0.43m (average = 0.35 m),
- East direction, the accuracy shows an error range of 0.02 – 0.29 m (average = 0.14 m),
- Height component provides an error of 0.68 – 1.04 (average = 0.88 m).

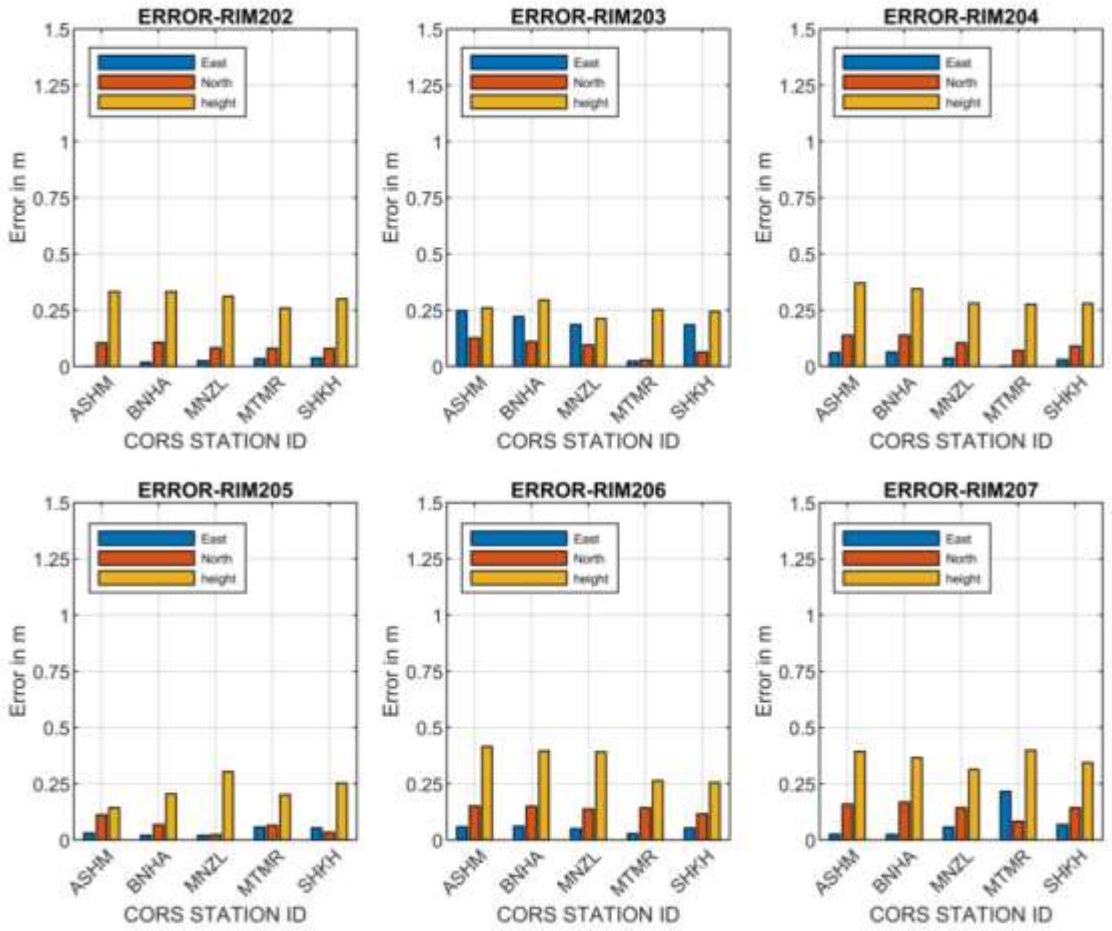


SF-PPP errors using CODE-GIM model

Results and analysis

SF-PPP using RIM model

- North direction, the results show an error range of 0.02 – 0.17 m (average = 0.10 m),
- East direction, the accuracy shows an error range of 0 – 0.24 m (average = 0.06 m),
- Height component provides an error of 0.14 – 0.41 (average = 0.30 m).



SF-PPP errors using CODE-RIM model

Results and analysis

ID	$ASHM_{GIM}$			$BNHA_{GIM}$			$MNZL_{GIM}$			$MTMR_{GIM}$			$SHKH_{GIM}$		
	E	N	h	E	N	h	E	N	h	E	N	h	E	N	h
min	0.06	0.26	0.68	0.05	0.30	0.72	0.05	0.27	0.73	0.02	0.30	0.77	0.07	0.31	0.72
max	0.29	0.40	0.98	0.25	0.40	0.98	0.26	0.39	0.97	0.17	0.43	1.04	0.24	0.39	0.96
Avg.	0.15	0.36	0.87	0.15	0.35	0.88	0.14	0.34	0.87	0.09	0.36	0.92	0.15	0.35	0.85
SD	0.08	0.05	0.10	0.07	0.04	0.10	0.08	0.05	0.10	0.05	0.05	0.10	0.07	0.03	0.10
ID	$ASHM_{RIM}$			$BNHA_{RIM}$			$MNZL_{RIM}$			$MTMR_{RIM}$			$SHKH_{RIM}$		
	E	N	h	E	N	h	E	N	h	E	N	h	E	N	h
min	0.00	0.10	0.14	0.02	0.07	0.20	0.02	0.02	0.21	0.00	0.03	0.20	0.03	0.03	0.24
max	0.25	0.16	0.42	0.22	0.17	0.40	0.19	0.14	0.39	0.22	0.14	0.40	0.18	0.14	0.34
Avg.	0.07	0.13	0.32	0.07	0.12	0.32	0.06	0.10	0.30	0.06	0.08	0.28	0.07	0.09	0.28
SD	0.08	0.02	0.10	0.08	0.04	0.07	0.06	0.04	0.06	0.07	0.04	0.07	0.06	0.04	0.05

Summary of SF-PPP solution for CODE-GIM and RIM models

Conclusions

- This paper investigates the SF-PPP solution using the CODE-GIM model and a developed RIM model for the Egyptian Nile Delta.
- The regional model is designed using six sequences days with a spatial resolution of 2.5°×5° and a temporal resolution of 2 h,
- Bernese GNSS V. 5.2 software has been used for the modelling using code phase geometry-free linear combination (*P4*),
- The results showed that the accuracy obtained by the RIM model has provided approximately a mean error of 0.06 m, 0.10 m, and 0.30 m in east, north, and height,
- In comparison to the CODE-GIM model, the average error of the SF-PPP solution has improved by the RIM model by about 60% in the east, 70% in the north, and 67% in height.

Thank you for your attention!