Database of Ionospheric Rate of TEC Change Index (ROTI) Map Derived from Indonesian GNSS Receiver Network

Authors: Prayitno Abadi[1,2], Ihsan Naufal Muafiry[1], Teguh N. Pratama[1], Noersomadi[1], Edy Maryadi[3]

Affiliations: [1]Research Center for Climate and Atmosphere (PRIMA), BRIN, Bandung, Indonesia; [2]School of Electrical Engineering, Telkom University, Bandung, Indonesia; [3]Research Center for Artificial Intelligence and Cyber Security, BRIN, Bandung, Indonesia

1. Introduction

Indonesia, located near the magnetic equator in Southeast and East Asia, plays a crucial role in advancing our understanding of ionospheric phenomena, particularly Equatorial Plasma Bubbles (EPBs). These ionospheric disturbances can significantly impact satellite communication and navigation systems, making their study vital. The Indonesian Geospatial Information Agency (Badan Informasi Geospasial/BIG) has established a comprehensive network of Global Navigation Satellite System (GNSS) receivers as part of the Indonesia Continuously Operating Reference Stations (Ina-CORS). This network allows the generation of detailed maps of ionospheric irregularities using the Rate of Total Electron Content (TEC) Change Index (ROTI). These ROTI maps fill critical data gaps in understanding EPBs over Southeast and East Asia.

2. GNSS Network and ROTI Map Generation

The Ina-CORS network comprises almost 300 GNSS receivers strategically distributed across Indonesia, from 95°E to 140°E and 5°N to 10°S. Each station continuously records GNSS observational data at a 30-second interval, stored in the Receiver Independent Exchange (RINEX) file format. This observable GNSS data is processed to calculate the Total Electron Content (TEC) using an open-source software package developed by Seemala (2023). The TEC data is then used to generate ROTI, which is calculated by assessing the standard deviation of the TEC change rate over a 5-minute window (Pi et al., 1997). This index is an essential indicator of ionospheric irregularities at a spatial scale of kilometers within EPBs.

To visualize ionospheric irregularities, the ROTI data is mapped at the Ionospheric Pierce Point (IPP) altitude of 350 km. These 2-dimensional latitude-longitude ROTI maps utilize a grid size of 0.25° × 0.25°. A boxcar average filter of 5 × 5 grid cells is applied to smooth the data. The ROTI maps are generated every 10 minutes between 9:00 and 23:50 Universal Time (UT), offering a detailed temporal snapshot of ionospheric conditions over Indonesia. A detailed flowchart for generating these maps can be found in Abadi et al. (2025). The ROTI map database is accessible at: https://gatotkaca.brin.go.id/petaionosfer/. Each file is named based on the date and time, following the format s_yyyyddd_hh_mm.txt. For example, s_2024122_13_10.txt represents a map generated on the 122nd day of 2024 at 13:10 UT. In the database, an animation of the ROTI map in GIF format existed for each day. The ROTI map grid matrix is 241 × 161, covering longitudes [90:0.25:150] and latitudes [−20:0.25:20], with missing values indicated by “NaN.”

3. Purpose

The ROTI map database aims to provide a freely accessible and high-resolution dataset to support the scientific community in understanding ionospheric irregularities within EPBs. By leveraging GNSS data from the Ina-CORS network, this database offers an alternative to sharing raw RINEX files, which may be restricted due to data-sharing policies. The ROTI maps facilitate educational and research activities related to EPB phenomena, GNSS signal disruptions, and space weather forecasting. The availability of this database encourages collaborative research between Indonesian and international ionospheric scientists, fostering global partnerships.

4. Data Access and Usage

The ROTI map database is freely available for academic, educational, and scientific purposes, supporting a wide range of research on ionospheric irregularities. Users can easily access and download the ROTI maps through the provided link. Researchers are strongly encouraged to cite this database in any publications, presentations, or research outputs derived from its use, ensuring proper acknowledgment of the Indonesian Geospatial Information Agency (Badan Informasi Geospasial) for providing the GNSS data foundational to the ROTI maps over Indonesia, as well as recognizing the research team's efforts in compiling and sharing this resource with the global community. Researchers are also invited to collaborate with Indonesian ionospheric experts to strengthen international partnerships and advance the study of EPBs. We kindly request that users inform us of any publications that utilize this data, as this allows us to highlight these works as indicators of the database's impact and success.

5. Future Work and Updates

The database will be regularly updated to reflect the most recent ROTI maps generated from the Ina-CORS network. Future developments may include expanding the spatial coverage to neighboring regions, refining the map resolution, and incorporating new data from additional GNSS networks. Feedback from the research community is invaluable, and suggestions for improvements or new research applications are welcome.

6. Contact Information

For further inquiries or additional information, please contact:
Dr. Prayitno Abadi
Researcher at Research Center for Climate and Atmosphere, BRIN
Email: pray001[at]brin.go.id (replace "[at]" with "@")

7. References

- Abadi, P., Muafiry, I. N., Pratama, T. N., Putra, A. Y., Suraina, Pramono, G. H., Wibowo, S. T., Chabibi, F. F., Ahmad, U. A., Tresna W. P., Asnawi. (2025). Leveraging ROTI map derived from Indonesian GNSS receiver network for advancing study of Equatorial Plasma Bubble in Southeast/East Asia. Earth Planet. Phys., 9(1), 1–16. http://doi.org/10.26464/epp2025007

- Seemala, G. K. (2023). *Chapter 4 - Estimation of ionospheric total electron content (TEC) from GNSS observations*. In A. K. Singh & S. Tiwari (Eds.), *Earth Observation, Atmospheric Remote Sensing*. Elsevier, pp. 63–84. doi.org/10.1016/B978-0-323-99262-6.00022-5
- Pi, X., Mannucci, A. J., Lindqwister, U. J., & Ho, C. M. (1997). Monitoring of global ionospheric irregularities using the worldwide GPS network. *Geophysical Research Letters, 24*(19), 2283–2286.