Space Weather Operational Office, Central Weather Administration, Taiwan
Web – https://swoo.cwa.gov.tw/ E-Mail – swoo@cwa.gov.tw

Validation of the Location of Equatorial Plasma Bubbles Around Taiwan Using FORMOSAT-7/COSMIC-2 and GNSS Ground Receivers

Huei-Wen Siao[1,2], I-Te Lee[1,2,3], Jyun-Ying Huang[1], Hsu-Hui Ho[1], Jan-Peter Weiss[4]
[1]Central Weather Administration, Taiwan; [2]Taiwan Group on Earth Observations, Taiwan;
[3]Advanced Research Center for Earth Sciences, National Central University, Taiwan; [4]COSMIC Program, UCAR, USA

Motivation

Equatorial plasma bubbles (EPBs) are the regions with lower plasma density compared to the background ionosphere, leading to significant errors in positioning accuracy. However, determining the precise positions of EPBs poses a significant challenge on both regional and global scales. Our study presented that the validation for FORMOSAT-7/COSMIC-2 scintillation geolocation and Taiwan GNSS ground stations to ensure reliability in the regional area of scintillation geolocation.

Data and Methodology

■ FORMOSAT-7/COSMIC-2 Scintillation Geolocation (scnGeo)

- Using back propagation technique to high-rate phase observations.
- When the POD antennas recorded scintillation index over threshold, the signal is further used to estimate where the scintillation occurred along the ray path.

■ Scintillation Index from Taiwan GNSS Ground Stations

- Setting the ionospheric point at 300 km for observation projection from the satellite signal to the ground receiver stations installed on Taiwan.
- GNSS observation is 1 Hz, and the temporal resolution of product is 5 minutes.

■ Analyzed region:

- Longitude: 118°-124°
- Latitude: 15°-30°

■ Analyzed duration:

- 14 February 2024 - 31 March 2024

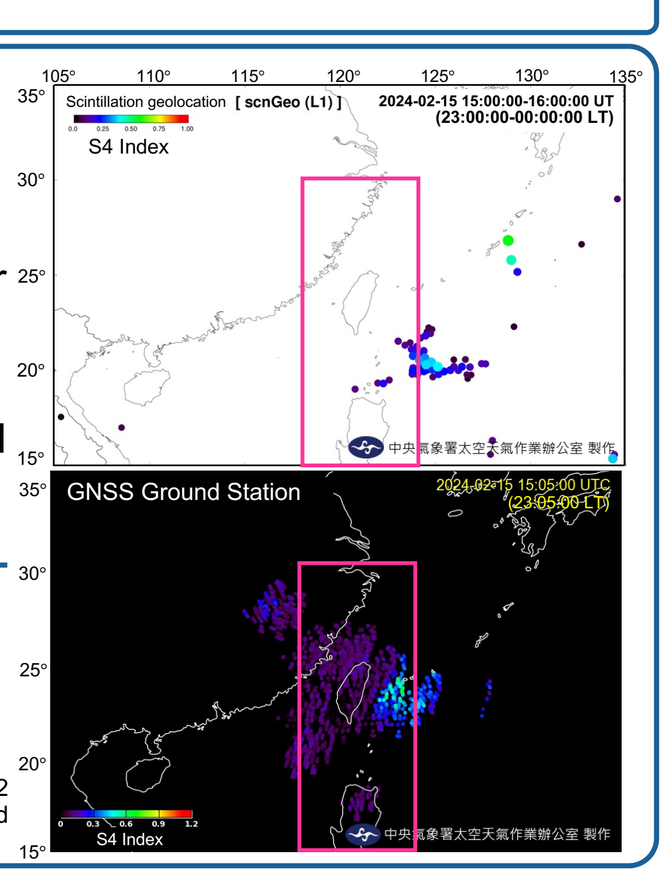

Figure 1. Scintillation index from FORMOSAT-7/COSMIC-2 scintillation geolocation (top) and Taiwan GNSS ground stations (bottom). Pink box is the analyzed region.

Results

■ Altitude

Our analysis shows that the altitude for most of scintillation geolocation (94%) is below 800 km. Besides, the median altitude is about 400 km which might corresponds to the altitude of ionospheric F2 region.

■ Universal Time

Most of scintillation geolocation occur between UT 11:00 and UT 22:00 corresponding to the evening to midnight local period in the nearby Taiwan region, which could usually observe the EPBs.

■ QCd value

In definition, QCd value starts from 1.2. A larger QCd value of scintillation geolocation indicates greater reliability. The results display that the maximum QCd value could be up to 20. Around 60% of the total QCd values are less than 3 and only 10% are higher than 7.

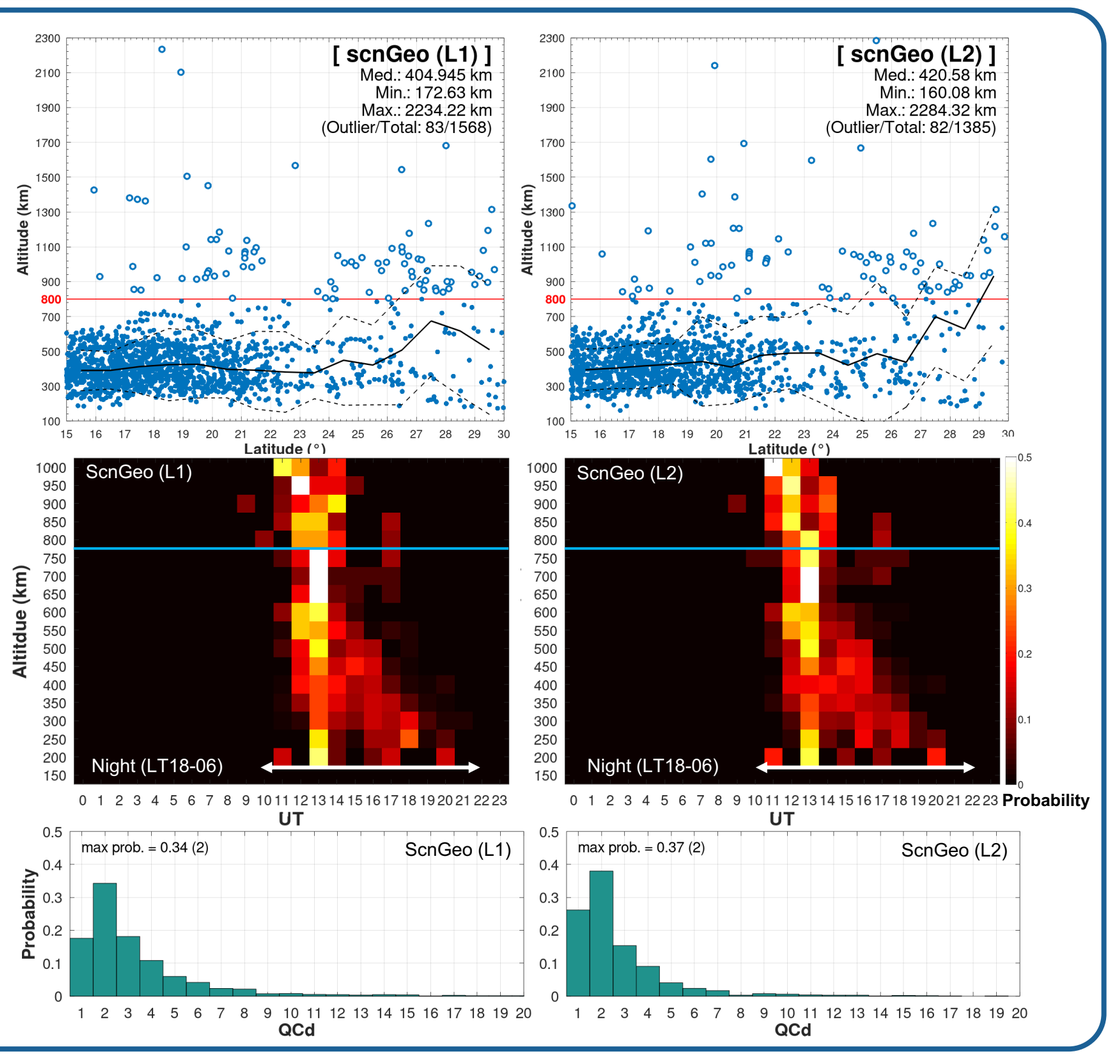

Figure 2. Upper panel depicts latitude against altitude. Left plot is from L1 product, right one is from L2 product. The black line represents the median altitude for each latitude, with one standard deviation marked by a black dashed line. The red line indicates 800 km altitude. Altitudes above 800 km are indicated by hollow dots. Middle panel shows the probability for the universal time with altitude. The probability is calculated from analyzed region at intervals of 50 km, starting from 150 km and extending up to 1000 km. The blue line indicates 800 km altitude. Lower panel illustrates the histogram for the QCd value. In definition, QCd value is started from 1.2. The bar for QCd value 1 is calculated from Qcd value 1.2 to 2.

Conclusion

- The occurrence time and altitude of scintillation geolocation are roughly consistent with EPBs, which also agrees the results of ground-based GNSS observation.
- Since scintillation geolocation relies on the ray paths between FORMOSAT-7/COSMIC-2 and GNSS, these paths do not constantly scan the Taiwan nearby region. However, this property allows us to detect the EPBs which located without ground GNSS stations, such as over the sea.
- Ground-based observation could trace the movement of EPBs within the monitoring region. While outside the region, the tracking can be combined with FORMOSAT-7/COSMIC-2 scintillation geolocation.

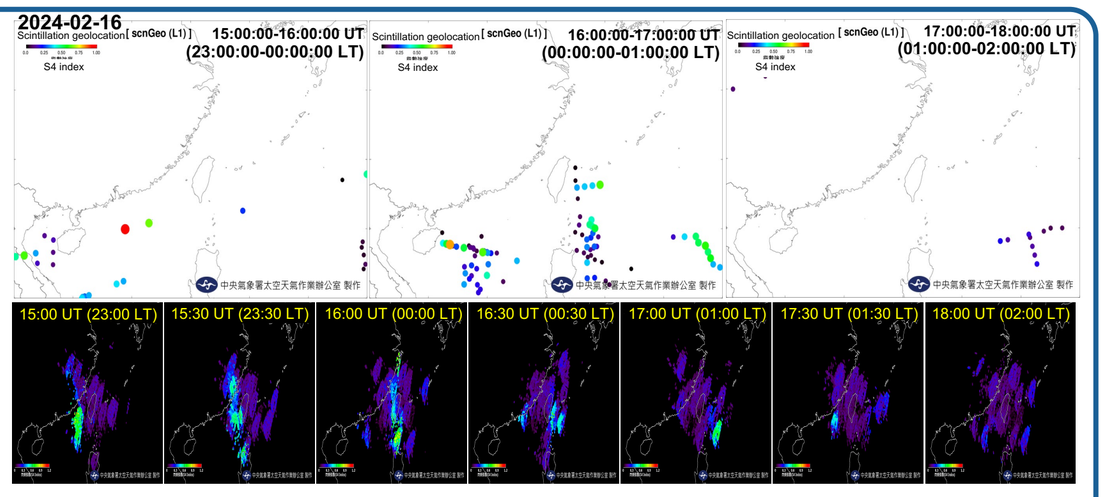

Figure 3. Compared with FORMOSAT-7/COSMIC-2 scintillation geolocation (top) and Taiwan GNSS ground stations (bottom) during 15:00 to 18:00 UTC on 16 February 2024. Upper panel displays high S4 index for Taiwan nearby region throughout this duration. The movement seems from west to east. Lower panels shows high S4 index signals propagating distinctly from southwest to east in the Taiwan nearby region over time.

Future Works

- Conducted case studies for the altitude of scintillation geolocation above 800 km.
- Find the threshold for QCd value.

References and Acknowledgements

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