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Equinoctial Asymmetry in the East-west Distribution of Scintillation Occurrence Observed by GPS Receivers in Indonesia

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ABSTRACT

We used GPS receivers installed in Pontianak (0.02°S, 109.3°E; 9.8°S mag. Lat.) and Bandung (6.9°S, 107.6°E; 16.7°S mag. Lat), Indonesia to observe azimuthal dependence of GPS-L1 scintillation occurrence rate. Crest of the equatorial anomaly region is located between both sites. We focus on analyzing east-west distribution of scintillation occurrences in equinox months. We collected scintillation data as indicated by S_4 index from those receivers for March and September from 2011 to 2015. Our findings statistically emphasized that scintillation occurrence rate is higher in the westward direction than that in eastward direction in March equinox. This east-west difference of scintillation occurrence is more distinct in March equinox than September equinox. In September equinox, the occurrence rate is almost comparable between westward and eastward direction. We can speculate that the equinoctial asymmetry in east-west distribution of scintillation occurrence could be likely caused by westward tilt of plasma bubble extending to higher altitudes/latitude, and that the plasma bubbles are more tilted westward in March equinox than in September equinox. We have analyzed zonal irregularity drift velocity observed by closely-spaced GPS receivers at Kototabang (0.2°S, 100.3°E; 9.9°S mag. Lat.), Indonesia for the same observation period. The results showed that eastward drift velocity decreases with increasing magnetic latitudes, and that the latitudinal gradient of eastward drift in March equinox is larger than in September equinox. In March equinox, the large latitudinal gradient of irregularity drift velocity could be responsible for further westward tilt of plasma bubble extending to higher altitudes/latitudes. Consequently, the equinoctial asymmetry of east-west distribution of scintillation could be caused by the equinoctial asymmetry of tilted westward structure of plasma bubble.

Key words: Equatorial ionosphere, plasma bubble,irregularity, scintillation, equinoctial asymmetry, GPS.

1. **Introduction and Focus**

In the equatorial and low-latitude region, scintillation in GPS signal is caused by irregularities associated with plasma bubble. Thus, scintillation in GPS signal will be affected by morphology and climatology of the occurrence of plasma bubble. One of morphological feature of plasma bubble is that the bubble generally tilted westward as it develops both in vertical and latitude. This structure of the plasma bubble may cause east-west asymmetry of scintillation distribution observed by receiver in the ground, as reported in the study [1]. In climatology, plasma bubble generally occurs in the equinox months (Mar-Apr and Sep-Oct) when solar terminator aligned with geomagnetic meridian. However, there is an interesting in climatology of the plasma bubble so-called equinoctial asymmetry. Previous studies reported that equinoctial asymmetry in the plasma bubble nature can be seen in the asymmetry of the occurrence between two equinoxes. Plasma bubble occurs more frequently in March equinox than in September equinox. Consequently, scintillation occurrence is higher in March equinox than in September equinox [2]. In this study, we have a research question. Can such a equinoctial asymmetry be seen in the east-west distribution of scintillation occurrences? Thus, we investigate east-west distribution of GPS scintillation occurrence at March and September equinoxes using GPS receivers in Indonesia. Additionally, we use closely spaced-GPS receivers to investigate latitudinal gradient of zonal irregularity drift velocity, which can cause westward tilt of plasma bubbles.

2. **Observation and Results**

We have used two GPS receivers of Novatel, which have a specific for observing ionospheric scintillation, installed in Pontianak (PTK; 0.02°S, 109.3°E; 9.8°S mag. Lat.) and Bandung (BDG; 6.9°S, 107.6°E; 16.7°S mag. Lat), Indonesia. S_4 index obtained for March and September from 2011 to 2015 is analyzed to investigate amplitude scintillation. We only used scintillation data during 19:30 to 21:30 LT when plasma bubble grows. Scintillation data with elevation angles lower than 10° are excluded. For removing multipath effects, we use the method from the study [3]. We have revealed azimuth and zenith dependence of the scintillation occurrence in order to see in which direction scintillation most frequently occurs. Fig. 1(a) shows scintillation receiver sites used for this study. Additionally, we have used three single frequency GPS receivers spaced with the mutual distance of approximately 100 m in Kototabang (KTB) (0.2°S, 100.3°E; 9.9°S mag. Lat.), Indonesia, which is same latitude as PTK but separated 9° west in longitude, to measure zonal irregularity drift velocity. Configuration of closely-GPS receivers is also shown in bottom-left of Fig. 1(a). Two of three receivers are aligned with magnetic equator, and the other is in the south of two receivers. Detail for calculating velocity drift is described in the study [2]. We used irregularity drift data with criteria as follows: elevation angle > 30°, S4 index > 0.5, data used in the interval 98-102°E, and the same observation period with scintillation observation. Fig. 1(a) also shows latitudinal profile of plasma density during March from 2011 to 2015 in longitude of 100°E, provided from IRI2012 (http://omniweb.gsfc.nasa.gov/vitmo/iri2012_vitmo.html). Average crest location of EIA (equatorial ionization anomaly), where scintillation mostly occurs, is between PTK and BDG. Furthermore, it can be expected that scintillation mostly occurs in south of PTK and north of BDG, respectively [1].

Fig. 1(b) and (c) show occurrence rate of scintillation at PTK and BDG, respectively. We point out the difference between southwest (SW) and southeast (SE) direction for PTK and the difference of northwest (NW) and northeast (NE) direction for BDG. For PTK, the occurrence rate in March equinox are 4.0% and 2.9% for SW and SE (the ratio is 1.4), respectively. In September, the occurrence rate in SW and SE direction are 1.9% and 2.3% (ratio is 0.7), respectively, which means scintillation occurrence rate is slightly higher in SE direction. The same situation is also showed for BDG where scintillation occurrence is higher in westward direction in March and slightly higher in eastward direction in September. Even, we see almost twice difference in the scintillation occurrence for BDG between NW (7.0%) and NE (3.6%) (ratio is 1.9) for March. In September, the ratio for NW : NE is 2.2% : 3.1% (0.8).

Fig. 1(d) shows the latitudinal variation of eastward irregularity drift velocity obtained from closely-spaced GPS receivers at KTB. We can see much clearly that eastward drift velocity decreases more rapidly with increasing magnetic latitude for March rather than for September. By applying linear fitting in velocity drift data in Fig. 1(d), latitudinal gradient of the zonal drift velocity is calculated and found that the latitudinal gradient of the zonal drift velocity is 7.3 m/s/° for March equinox and 2.1 m/s/° for September equinox. The ratio of the gradient for March equinox to September equinox is ~3.3. These results suggest that plasma bubble has more westward-tilted structure in March rather than in September. This finding may also imply that equinoctial asymmetry in the plasma bubble nature can be also seen in the latitudinal structure.

3. Discussion and Conclusions

Our observations show statistically that east-west distribution of scintillation in March shows clearly asymmetry (higher in the westward than in eastward direction). For September, it is almost comparable in the scintillation occurrence rate between westward and eastward direction. Comparing with observation for zonal irregularity drift velocity, we can suggest that plasma bubble tilts more westward in March than in September. Because of westward-tilted structure of the plasma bubble, signal propagation between satellite and receiver in the westward direction could be likely more scintillated by irregularities inside the bubble. This geometry effect can explain relation between east-west asymmetry of scintillation occurrence and plasma bubble structure. Hence, we can suggest that the obvious asymmetry of east-west scintillation distribution in March rather than in September could be likely related to more westward-tilted structures of plasma bubble in March rather than in September. We see the consistency between equinoctial asymmetry of east-west scintillation occurrence rate and latitudinal gradient of the zonal drift velocity.

4. References

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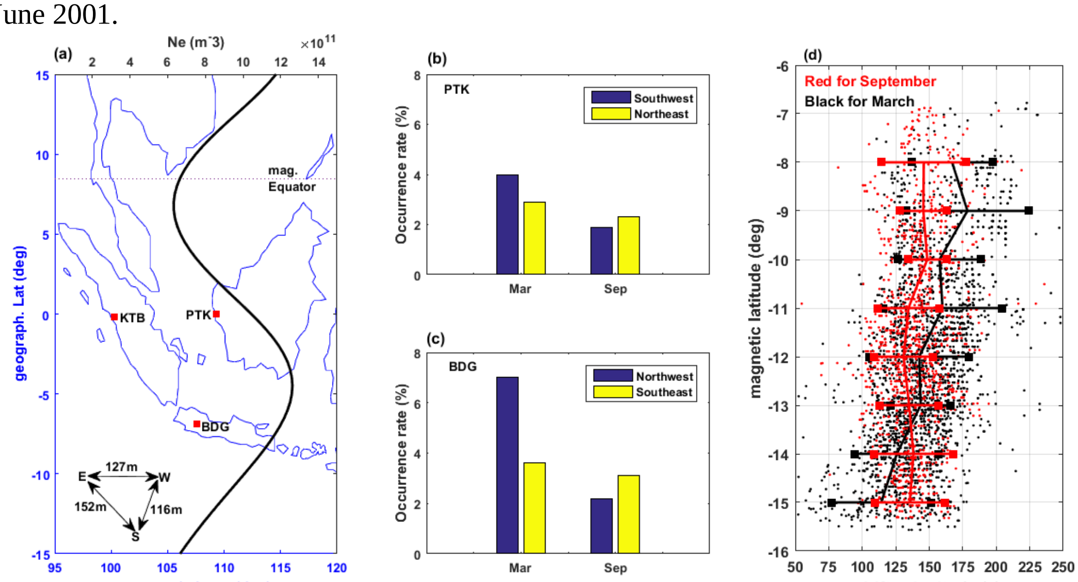

Figure 1. (a) Geographical observation sites for this study and latitudinal profile of electron density (solid black curve) at the longitude of 100°E. Directional occurrence of scintillation is observed by (b) PTK and (c) BDG stations.(d) Latitudinal variation of irregularity drift velocity obtained by closely spaced-GPS receivers at KTB (solid line and error bar indicate average and standard deviation of the drift velocity in 1° latitude, respectively).