Abstract

The ionosphere’s response to the annular solar eclipse on 26 December 2019 was analyzed using GNSS TEC, in situ Ne/Te measurements from DMSP and Swarm satellites, and local magnetometer data. The main results are as follows: (1) a local TEC reduction of ∼4–6 TECU (30–50%) was identified along the annular eclipse path, with larger depletion and longer recovery periods in the morning eclipse compared to midday. (2) In the morning sector, the equatorial electrojet (EEJ) was significantly weakened when the eclipse trajectory crossed the magnetic equator, causing large and prolonged TEC depletion therein. (3) At midday, the EIA crests exhibited 20–40% enhancements and 3–4° poleward shifting, likely triggered by modified neutral wind and electrodynamics patterns. (4) Ne exhibited ∼30% reduction at ∼500 km but ∼30% enhancement at ∼850 km with 300–500 K Te reduction.

1. Eclipse local time asymmetry

For morning eclipse at IISC/SGOC, the ionosphere was still forming with photo-chemical processes being more dominant than transportation. The TEC depletion was large: -6.5 TECU (-49.1%) at IISC and -7.9 TECU (-46.9%) at SGOC. Both stations exhibited an extended recovery time of ∼4–6 hours after local eclipse end. By contrast, for midday eclipse at NTUS, the daytime ionosphere was well-established and plasmaspheric transport process were already dominant over production. The midday eclipse at NTUS generated a smaller TEC depletion peak of -6.4 TECU (-38.2%) and shorter recovery time.

2. EEJ variation

Eclipse-induced low pressure systems can trigger a local neutral wind dynamo that flows in a direction opposite to the normal daytime solar quiet (SQ) current. This counter-SQ current greatly inhibits the EEJ when eclipse totality crossed the magnetic equator. This figure shows ∆H variation at Alibag (Kototabang) during morning (midday) eclipse, with a significant ∆H reduction at Alibag after the maximum eclipse (vertical line), continuing for 6-8 hours before recovery. The EEJ inhibition intensified the eclipse-induced ionization decrease, causing a pronounced/prolonged local TEC depletion.

3. EIA Crest Enhancement

The ∆TEC and absolute TEC keogram figure below shows a notable midday-eclipse feature: TEC enhancements over the equatorial ionization anomaly (EIA) crests at both hemispheres between 100°–130°E. TECs showed some early ascension before the arrival of maximum obscuration, likely due to day-to-day variability. However, this minor early ascension was greatly amplified during the eclipse, reaching 4–7 TECU (∼20–40%), possibly due to eclipse-induced eastward perturbation electric field and equatorward neutral wind convergence. Moreover, the EIA crests exhibited a slight poleward shifting of ∼3° during the eclipse.

4. Spaceborne observations: opposite altitudinal behavior between F region and topside Ne

The ionospheric Ne behavior before the maximum eclipse exhibited a noticeable altitude difference over the equatorial region, with a considerable depletion around 500 km but an enhancement around 850 km, likely driven by (1) Enhanced zonal E-field. The eclipse-induced E-region conductivity reduction and associated F-region dynamo drove an enhanced eastward E-field in the heading region (Left panel) to amplify the equatorial fountain effect, which evacuated F-region and pushed plasma upward to the topside ionosphere, generating plasma reduction near F2 peak and enhancements in the EIA crest and in topside ionosphere. (2) Eclipse-induced equatorward neutral wind. Thermospheric cooling and composition change can drive neutral wind toward eclipse totality, especially in the eclipse tailing region (right panel). The equatorward wind in this event also pushed the low and mid-latitudes plasma near F2 region upward and equatorward along field line, contributing to the EIA crest and topside Ne/TEC enhancement.

5. Conclusions

1. EEJ inhibition caused significant TEC depletion and prolonged recovery in the morning
2. EIA crests showed 20–40% enhancement and 3–4° poleward shifting
3. Topside Ne showed considerable reduction at 500 km but enhancement at 850 km

6. Reference

Aa, E. et al. (2020). Coordinated ground-based and space-borne observations of ionospheric response to the annular solar eclipse on 26 December 2019. JGR Space Physics, 125, e2020JA028296