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Airglow altitude variation and its impact on measuring Equatorial Spread F

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Equatorial spread F (ESF) is the name commonly given to low density plasma structures and associated irregularities that occur at low-latitudes in the Earth's ionosphere. All-sky imagers (ASIs) measure the airglow signature of this instability. Emission at 630.0 nm occurs in the F-region and is dependent on the altitude of the ionosphere and its density. As a result, low density regions of the ionosphere, such as ESF structures, are visible as dark regions against a brighter background. ASI images provide a two-dimensional view, of about 10^6 sq. km, of the ionosphere and thus are useful for observing the large-scale features of ESF. These observations are useful for investigating many aspects of ESF in addition to determining their presence. For example, these observations can be used to measure the latitudinal extent, evolution, and velocity of ESF structures. They can also be combined with instruments such as GPS receivers and coherent scatter radars to determine the location of small-scale irregularities within large-scale features. To accurately measure ESF characteristics using an ASI and to compare them to other instruments, the 630.0 nm altitude of emission must be well known.

Our recent work has shown that there are variations in airglow altitude from day to day, throughout the night, and throughout the field of view that can impact the type of work described above. Sau *et al.* [1] showed an apparent interhemispheric asymmetry of plasma bubbles observed with an ASI during the St. Patrick's Day geomagnetic storm of 2015. Our results indicate that this asymmetry is actually due to a variation in airglow altitude across the field of view of the ASI. We found that a variation in airglow altitude, due to a variation in ionospheric altitude, is possible on this night and can fully explain the observed asymmetry. Nearby ionosonde measurements provide more evidence for this ionospheric altitude variation. In addition to the airglow altitude variation on this night, our analysis has found that this variation can occur across the field of view of an imager at other ASI locations around the world and during geomagnetically quiet times.

Other instruments can be used to better constrain airglow altitudes. Empirical models are often used for determining airglow altitude but they often vary from what the actual ionosphere and thermosphere are doing. Incoherent scatter radars, ionosondes, ground receiver GPS, and radio occultation GPS can all be used to better constrain the ionospheric parameters used to calculate airglow altitude. Combining these with assimilative and physics-based models can also be useful.

The impacts of this airglow variation on analysis of ESF can be significant. A variation in airglow altitude of 35 km can change the apparent size of the features in the image by around 12.5 %. ESF depletions can appear too thin or too wide and their latitudinal extent, and resulting apex altitude, can be incorrect. The measured velocity of structures depends on the altitude. When comparing with coherent scatter radar and GPS receiver measurements, small scale irregularities can appear to occur in different locations of the depletions depending on what altitudes are used. This variation can also have broader impacts on our understanding of the ionosphere because ionospheric altitude variations on this scale are not well studied due to the lack of instrument density. These variations can also impact the development of ESF [2].

In this work we present evidence for a variation in airglow altitude to explain previously unexplained results. We show that this variation is not uncommon. We provide information on ways to better constrain the altitude. Finally, we discuss the impacts of this variation on ESF observations and broader impacts.

References

[1] Sau, S., Narayanan, V. L., Gurubaran, S., Ghodpage, R. N., and Patil, P. T. (2017), First observation of interhemispheric asymmetry in the EPBs during the St. Patrick's Day geomagnetic storm of 2015, J. Geophys. Res. Space Physics, 122, 6679– 6688, doi:10.1002/2017JA024213.
[2] Tsunoda, R. T., and White, B. R. (1981), On the generation and growth of equatorial backscatter plumes 1. Wave structure in the bottomside F layer, J. Geophys. Res., 86(A5), 3610– 3616, doi:10.1029/JA086iA05p03610.