Statistical Investigation of Ionospheric Storm and Substorm Events Using GEC and AE-index

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ABSTRACT

Storm time modelling of Global Electron Content (GEC) calculated from JPL GIM-TEC for 1999 to 2014 is associated with variability of smoothed and normalized Auroral Electrojet index (AEsn). The statistical analysis of DGEC values taking the hourly ratio of instant GEC to 7 preceding days median is made with storm onset determined by a joint analysis of variations in IMF-B magnitude, its derivative (dIMF-B) and direction of IMF-Bz together with sudden increase in AE exceeding 900 nT. The AEsn index is related to DGEC through a polynomial whose coefficients are estimated in the Linear Least Squares sense. The statistics of estimated coefficients for ionospheric storms and substorms between 1999 and 2014 are modelled and classified with respect to the type and intensity of the storms. The positive correlation between the increase of AE and GEC can be a promising precursor of space weather variability.

1. INTRODUCTION

The ionospheric storms and substorms are identified in the Arctic zone (magnetic latitudes Mlat ≥ 60°N) and Antarctic zone (Mlat ≤ -60°S) using the hourly global ionospheric weather W-index maps produced from JPL GIM-TEC for 1999-2014. W-index varies from quiet state, W = 0, to intense storm, W = ±4 [*Gulyaeva and Stanislawska*, 2008*; Gulyaeva et al.*, 2013].

We construct Catalogues of the positive and negative ionosphere substorms in the North (Arctic) and South (Antarctic) zones with the following criteria:
(1) Storm Occurrence Density, SOD, for the zone, in percent, is equal to or greater than 10%. This implies that the surface area equal to or greater than 340 000 km^2 in Arctic or Antarctic zone includes $W^+ = 3, 4$ or $W^- = -3, -4$ storm indices;
(2) the condition (1) is observed during at least 4 consecutive hours.

Global Electron Content (GEC) is equal to the total number of electrons in the ionosphere and plasmasphere up to the height of Global Positioning System (GPS) satellite altitude of 20,200 km [*Afraimovich et al*., 2008; *Gulyaeva and Veselovsky*, 2012]. In the present study GEC is connected to Auroral Electrojet (AE) index, which is a measure of global electrojet activity in the auroral zone [*Davis and Sugiura*, 1966].

2. RESULTS

Figure 1 presents annual substorm occurrence, in percent, for both W^+ and W^- index in the Arctic zone (WNorth) and Antarctic zone (WSouth). The Auroral Electrojet AE-index substorms (AE ≥500 nT) are given for a comparison. Substorm Occurrence Density (SOD) vary with solar cycle (minimum SOD during 2007-2009 solar minimum) with dominant WSouth occurrence in accordance with North/South AE index asymmetry [*Weygand et al.*, 2014] and the annual ionosphere asymmetry [*Gulyaeva et al.*, 2014].

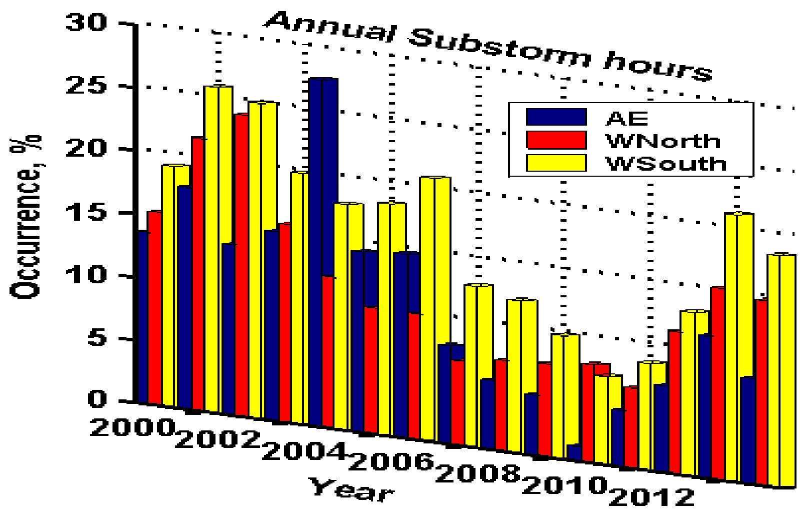

Figure 1. Histogram of the annual ionosphere substorm occurrence in the North and South auroral regions.

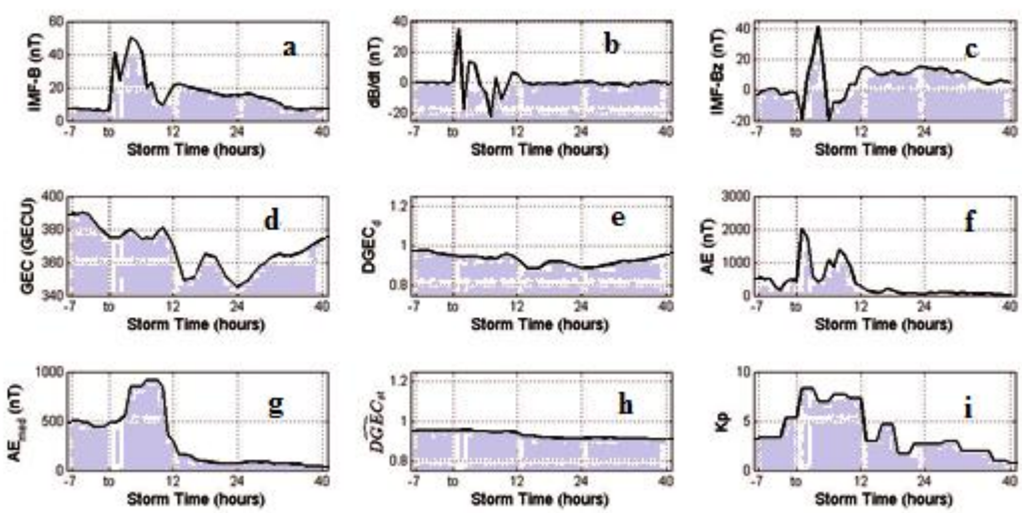

Figure 2. Example of global storm period with t_0 specifying the storm onset: a) IMF-B, b) dB/dt, c) IMF-Bz, d) GEC, e) DGEC, f) AE, g) AE_{med}, h) $\widehat{DGEC}_{st}$, i) K_p index.

The statistical analysis of DGEC values taking the hourly ratio of instant GEC to 7 preceding days median is made with storm onset determined by a joint analysis of variations in IMF-B magnitude, its derivative (dIMF-B) and direction of IMF-Bz together with sudden increase in AE_{med} exceeding 900 nT. AE_{med} is AE index smoothed with 7h sliding window centred on a given day. GEC database has been produced from GIM-TEC and processed for a period from 1999 to 2013. The results presented in Figure 2 refer to a Positive Arctic storm with IMF-B having double peak during storm period. Kp is larger than 8 and Dst index (not shown here) gets as low as -221 nT. DGEC is gradually decreasing during 24 hrs of the main phase of the storm with subsequent recovery afterwards.

3. CONCLUSIONS

In this study, the variability of GEC is related to smoothed and normalized proxy AE index through a polynomial model. The storm/substorm onset times are determined with respect to the sudden increases in the magnitudes of IMF-B, dB/dt and the negative inflection of IMF-Bz. In order to separate the storms that affect AE, an extra condition is imposed by choosing the storms during which AE_{med} becomes larger than 900 nT. The analysis is based on DGEC values computed from the GEC by taking the hourly ratio of 7 day median prior to the day of investigation. 7 hour sliding window median filter of AE provides a smoothed trend that indicates the increase in storm conditions.

The ionosphere reacts to the space weather impact in local, regional or global scale. An advantage of GEC parameterization is that it allows detecting global ionosphere changes due to the external forces. In this respect the results of the present study confirm capability of the ionosphere to react globally in the framework of the solar – interplanetary – magnetosphere – plasmasphere - ionosphere chain. The positive correlation between the increase of AE and GEC driven by the interplanetary parameters can be a promising precursor of the ionosphere variability.

ACKNOWLEDGEMENTS

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REFERENCES

Afraimovich, E.L., Astafyeva, E.I., Oinats, A.V., Yasukevich, Y.V. & Zhivetiev, I.V. (2008). Global electron content: A new conception to track solar activity, Annales Geophysicae, 26(2), 335-344.

Davis, T. N. & Sugiura, M. (1966). Auroral electrojet activity index AE and its universal time variations, J. Geophys. Res., 71, 785-801.

Gulyaeva, T.L. & Stanislawska, I. (2008). Derivation of a planetary ionospheric storm index. Annales Geophysicae, 26, 2645-2648.

Gulyaeva, T. L. & Veselovsky, I.S. (2012). Two-phase storm profile of global electron content in the ionosphere and plasmasphere of the Earth, J. Geophys. Res. Space Physics, 117, A09324.

Gulyaeva, T.L., Arikan, F., Hernandez-Pajares, M. & Stanislawska, I. (2013). GIM-TEC adaptive ionospheric weather assessment and forecast system. J. Atmosph. Solar-Terr. Phys., 102, 329-340.

Gulyaeva, T.L., Arikan, F., Hernandez-Pajares, M. & Veselovsky, I.S. (2014). North-south components of the annual asymmetry in the ionosphere, *Radio Sci*., 49(7), 485-496.

Weygand, J. M., Zesta, E. & Troshichev, O. (2014). Auroral electrojet indices in the Northern and Southern Hemispheres: A statistical comparison, J. Geophys. Res. Space Physics, 119, 4819–4840.