Ionospheric Hall Polarization and Deformation of the Ionospheric Potential Pattern

Aoi Nakamizo[1] and Akimasa Yoshikawa[2,3]
[1]*National Institute of Information and Communications Technology (NICT)*
[2]*Faculty of Science, Kyushu University*
[3]*International Center for Space Weather Science and Education (ICSWSE), Kyushu University*

Whereas it is generally thought that the ionospheric high-latitude convection field reflects the convection field in the magnetosphere, we present the possibility that the ionospheric conductance distribution largely affects the formation of the convection field in the magnetosphere-ionosphere system. We focus on the ionospheric Hall polarization that has a role to rotate the electric field from the background electric field, causing a meandering of equipotentials in a region where the Hall conductance has a spatial gradient [*Yoshikawa et al*., 2013a, 2013b; *Yoshikawa and Fujii*, 2018].

By applying a simplified version of 'Hall-conjugate method' [*Yoshikawa et al*., 2008JpGU] to an ionospheric potential solver (2-D solver so-called thin sheet model), which calculates the electrostatic field under given field-aligned currents (FACs) and conductance distributions, we separate the total field (Φ, the ionospheric total potential) into the primary field (Φ1, including the background and Pedersen polarization field) and secondary field (Φ2, the Hall polarization field generated by the Hall current divergence). We call this method the 'Hall polarization field separation (HPFS)'.

We performed the HPFS by changing the conductance distribution step-by-step from a simplified one (uniform distribution) to a more realistic one. In order to focus on the effects of conductance distribution on the potential pattern, we used a north-south and dawn-dusk symmetric R1 FAC as an input of the solver. We also set north-south and dawn-dusk symmetric conductance distributions to eliminate asymmetries arising from that of the conductance distribution itself.

We found the relationship between the conductance nonuniformity and potential deformation as follows. (a) Under the uniform conductance distribution no Hall polarization field is generated and thus the total potential is completely symmetric with respect to both the noon-midnight and dawn-dusk meridians as well as the primary field. (b) The equatorward enhancement of the Hall conductance owing to solar illumination generates the positive/negative Hall polarization field at the pre-noon/pre-midnight sectors. As the result the total potential rotates clockwise. (c) The day-night conductance difference not only shifts the potential centers toward night due to Pedersen polarization effect (in other words, current continuity), but also generates the Hall polarization field along the terminator due to the sharp conductance gradient there, causing the convex/concave of the total potential along the terminator. (d) Auroral conductance enhancement generates the Hall polarization field around edges of high-conductance band. Especially, a nested structure at the equatorward edge of the high-conductance band in the midnight sector well resembles the Harang Reversal.

These results well explain the characteristics of the observed ionospheric potential pattern, which cannot be completely explained by the external causes (e.g., IMF-By).

References

Yoshikawa, A., O. Amm, H. Vanhamäki, A. Nakamizo, and R. Fujii, Theory of Cowling channel formation by reflection of shear Alfven waves from the auroral ionosphere, J. Geophys. Res. Space Physics, 118, 6416–6425, 2013a.
Yoshikawa, A., O. Amm, H. Vanhamäki, and R. Fujii, Illustration of Cowling channel coupling to the shear Alfvén wave, J. Geophys. Res. Space Physics, 118, 6405–6415, 2013b.
Yoshikawa, A. and R., Fujii (2018). Earth's Ionosphere: Theory and Phenomenology of Cowling Channels. In Electric Currents in Geospace and Beyond (eds A. Keiling, O. Marghitu and M. Wheatland), 2018.