How effective the mirror force makes a difference in atmospheric ionization and electron density?

Tomotaka Tanaka [1], Yasunobu Ogawa [1,2], Yuto Katoh[3], Mizuki Fukizawa[2],
Anton Artemyev[4], Vassilis Angelopoulos[4], and Xiaojia Zhang[5]
[1] *The Graduate University for Advanced Studies*
[2] *National Institute of Polar Research,* [3]*Tohoku University,*
[4]*University of California, Los Angeles,* [5]*University of Texas at Dallas*

Energetic Electron Precipitation (EEP) causes various phenomena, such as aurora emissions and variations in atmospheric compositions via collisions with the atmosphere. To quantitatively study the effects of EEPs on the atmosphere is one of the essential fundamentals for understanding how precipitating electrons with various pitch angle distributions ionize the atmosphere. However, the basic processes involved in the propagation of precipitating electrons and the production of secondary electrons still need to be well understood. Katoh et al.(2023) recently suggested by numerical simulations that the magnetic mirror effect can vary the altitude profile of atmospheric ionization. Therefore, the purpose of this study is to understand observationally the mirror effects on atmospheric ionization so that we would verify the numerical simulation results.

In this study, we used simultaneous observation data of ELFIN satellites and EISCAT radars as well as numerical simulation data for connecting them. The ELFIN satellites consist of two CubeSats flying in formation on nearly identical orbits at an altitude of around 450 km, observing pitch-angle resolved fluxes of electrons in the 50 -7000 keV energy range from September 2018 to September 2022. We used altitude profiles of electron density at altitudes of 60 - 170km observed with the EISCAT Tromsø UHF/VHF radars. We found 42 events which are simultaneously observed by EISCAT radar in Tromsø [19.2 E, 69.6N] and ELFIN satellite in the region within ±2 degree latitude and ±5 degree longitude from Tromsø. Among them, 33 events had significant ionization by EEP at altitudes below 100 km. We adopted the numerical simulation used in Katoh et al., which is a particle transport simulation using the Monte Carlo method. This simulation allows us to quantitatively investigate how the mirror force could affect the atmospheric ionization rate and production of secondary electrons, especially backscattering electrons. Specifically, we calculated, with the numerical simulation, the altitude profile of the collision rate of all the precipitating electrons under two conditions, with/without the mirror effect. Inputs of the energy and pitch-angle profiles of electron flux were used for the data observed by ELFIN satellites. We plan to compare and verify the characteristic of the altitude profile of the ionization-rate/electron-density based on that collision rate with that of electron density simultaneously observed by EISCAT radars.

First, we studied how the mirror effect varied the altitude profile of collision rate below 100 km using the 7th January 2021 simultaneous event. We found that the mirror effect made a difference in the collision rate if we considered the energy and pitch-angle profile of precipitating electron flux observed with ELFIN satellites. The collision rate with the mirror effect was about half of that without the mirror effect. As Katoh et al. suggested, electrons out of the loss cone reduce the collision rate at altitudes between 60 and 80km because they are bounced at a mirror point so that the number of electrons penetrating the low-altitude atmosphere decreases.

According to the result of the numerical simulation, it is useful to verify differences between with and without the mirror effect on the atmospheric ionization and the production of secondary electrons if many precipitating electrons have pitch angles above the loss cone angle. We found 4 events, 5th October, 27th November, 16th December in 2021, and 29th March in 2022, have distributions as mentioned.

We also calculated the altitude profile of electron density in the atmosphere using ELFIN data of these events as initial conditions. Then, we will verify how effective the effect of mirror force is by comparing it with EISCAT data.

In this presentation, we will show the result and discuss how effective the mirror force makes a difference in atmospheric ionization and electron density.

References

Y.Katoh, P.S.Rosendahl, Y.Ogawa, Y.Hiraki and H.Tadokoro, Effect of the mirror force on the collision rate due to energetic electron precipitation: Monte Carlo simulations. Earth, Planet and Space, 75:117, 2023.