POLA-06

Geonhwa Jee, ghjee@kopri.re.kr
Korea Polar Research Institute (KOPRI)

Occurrence of ion upflow associated with ion/electron heating in the polar cap and cusp regions

Eun-Young Ji[1], Geonhwa Jee[1*], and Young-Sil Kwak[2],

[1]Korea Polar Research Institute, Incheon, Republic of Korea, [2]High Korea Astronomy and Space Science Institute, Daejeon Republic. of Korea

Korea Polar Research Institute

Abstract

In this study, we investigate the occurrence frequency of ion upflow associated with ion/electron heating in the polar cap and cusp regions, using the data obtained from the European Incoherent Scatter Svalbard radar (ESR) during the period of 2000 to 2010. We classify the upflow events by four cases: they are accompanied by ion heating (Case 1), electron heating (Case 2), both ion and electron heatings (Case 3), and without any heating (Case 4). The statistical analysis of the data shows that the upflow normally starts at around 350 km altitude and the occurrence frequency seems to peak at 10 MLT. Among the four cases, the occurrence frequency of the upflow is maximized for the Case 3 and then followed by Case 2, Case 1 and Case 4. We also investigate the dependence of the occurrence frequency on Kp and F10.7 indices, which shows that it slightly increases with Kp. As for the solar activity, the occurrence frequency becomes larger with increasing altitude as F10.7 increases. The results of this study suggest that the ion upflow events occurring in the polar cap and cusp region are associated with both ion and electron heatings.

Introduction

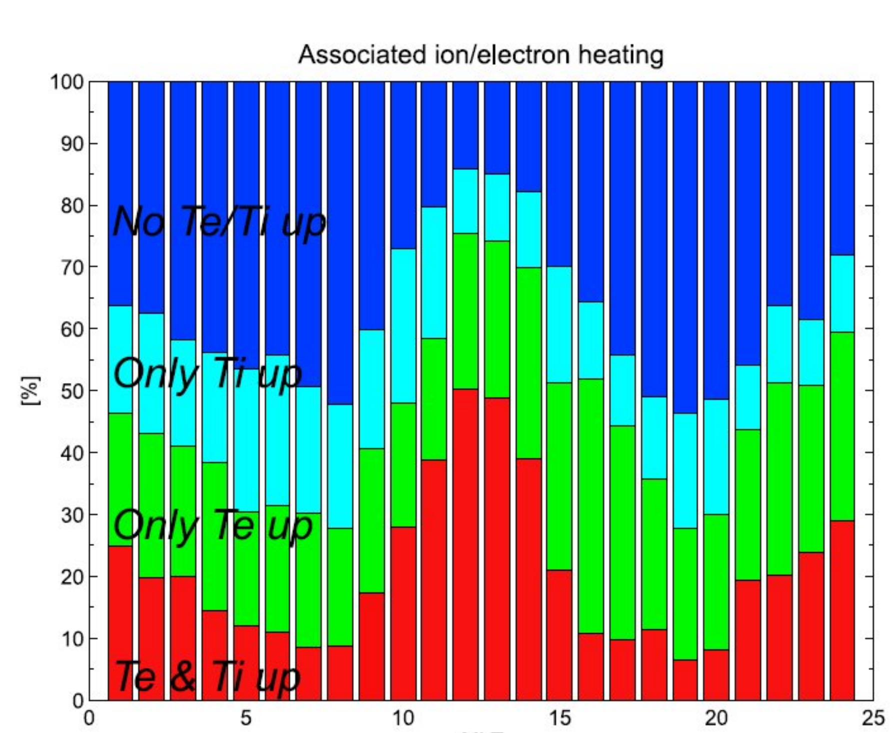
- An important phenomenon of the ionosphere-magnetosphere coupling is the formation of ions flowing upward from the ionosphere, which can be a significant source of the magnetospheric plasmas.
  - Ions, particularly in the polar ionosphere, obtain energy and momentum through particle precipitation, heat flux, propagation of electric fields, and plasma waves from the magnetosphere
  - Consequently, ions in the polar ionosphere can move up to higher altitudes and subsequently flow into the magnetosphere and interplanetary space
  - Ion upflow may be related to outflowing ions found in the magnetosphere
- Ion upflow in the polar ionosphere occurs with upward velocities of a about 100~1000 m/s [Endo et al., 2000; Ogawa et al., 2000, 2008; Skjæveland et al., 2014]
- In this study, the occurrence of ion upflow was investigated in association with ion and electron heatings in the polar region, using the ion drift measurements of EISCAT radar in Svalbard during the period of 2000-2010.

Suggested physical mechanisms for ion upflow

- Convection-driven frictional ion heating which causes the ion gas to expand upward [e.g., Gombosi and Killeen, 1987; Korosmezey et al., 1992]
- Enhancements of ionospheric electron temperatures and the consequent increased upward ambipolar electric field [Whitteker, 1997]
- Convection shear-driven ion instabilities which may produce "anomalous" ion heating [Ganguli et al., 1994; Liu and Lu, 2004]
- Ring current heavy ion precipitation [Yeh and Foster, 1990]

Classification of ion upflow

- Type 1: Upflows dominated by enhanced T_i
  - Ion temperature is increased by convection-driven frictional ion heating
  - Ion joule heating and atmospheric upwelling may well contribute to ion upflow
- Type 2: Upflows dominated by enhanced T_e
  - Ionospheric electrons are heated by the ionization processes and by collisions with precipitating particles
  - Precipiting electrons collisionally heat ionospheric electrons and create electron pressure gradients that establish the field-aligned ambipolar electric field, which accelerates ions and generates upflow

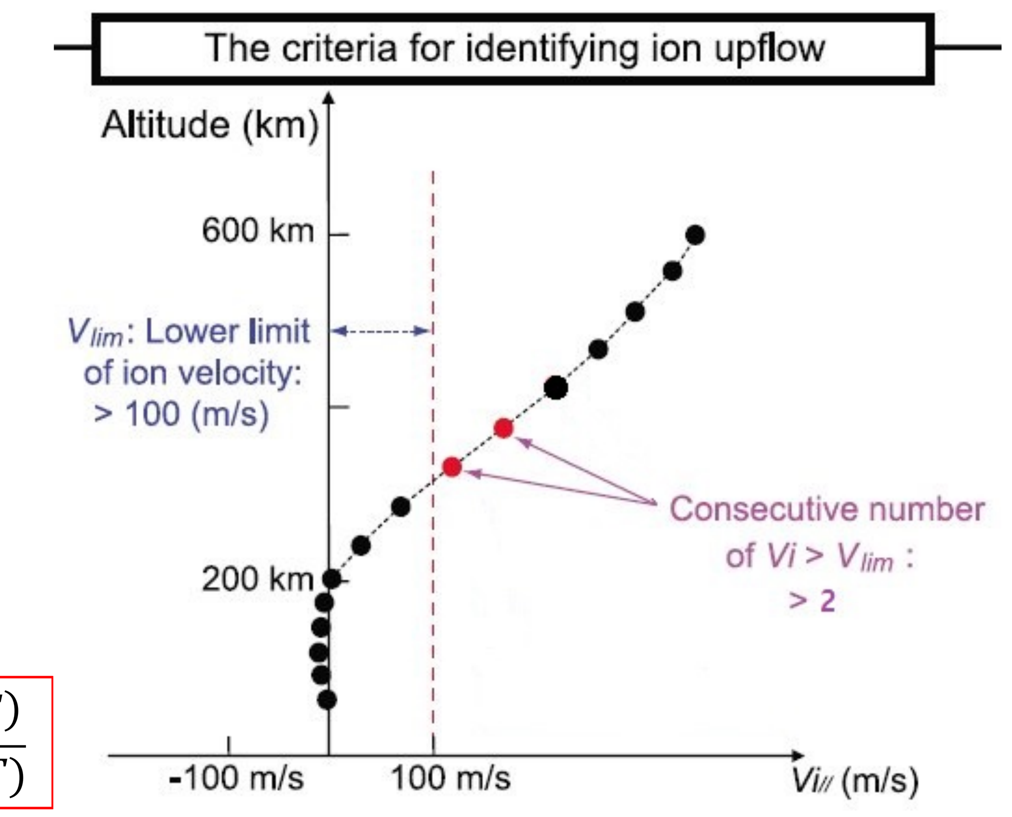


Local time variations of ion/electron heating associated with ion upflows [Ogawa et al. 2009]

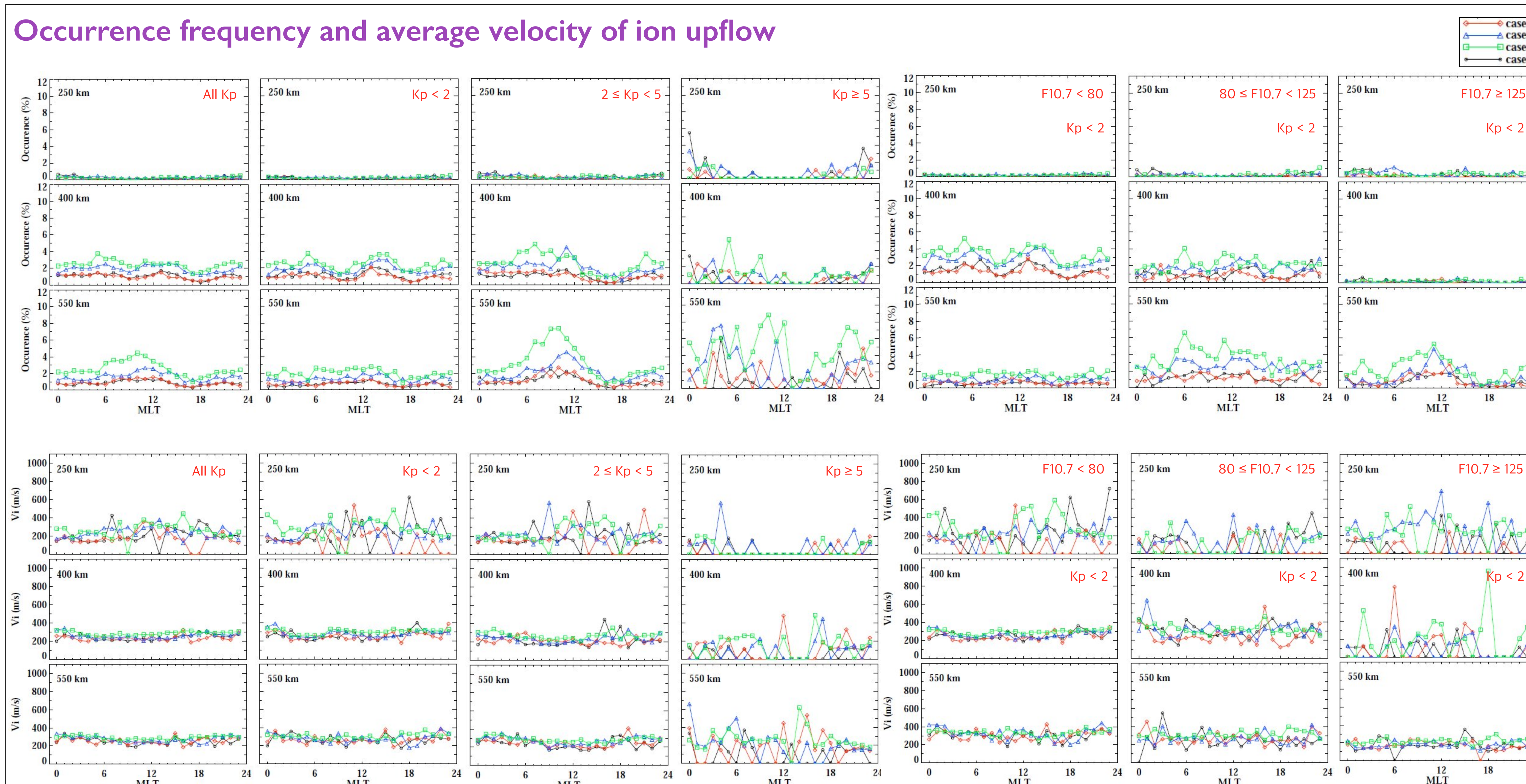
Statistical analysis

- Occurrence frequency and average velocity of ion upflow in association with ion/electron heating
  - Case 1: ion upflow with T_i enhancement
  - Case 2: ion upflow with T_e enhancement
  - Case 3: ion upflow with both T_i and T_e enhancements
  - Case 4: ion upflow without heating
- Identification of ion upflow
  - Lower limit of ion velocity: 100 m/sec
  - 100 m/s $\leq V_i \leq$ 1000 m/s
- Identification of ion/electron heating
  - $T_{i,e} - T_{i,e}(0) \geq 200$ K
  - Background temperature, $T_{i,e}(0)$: 2-h running mean of the temperatures at each height
- Occurrence frequency of ion upflow
  - n = the number of ion upflow events
  - N = the total number of profiles in each bin

$$F\,(h, MLT) = \frac{n\,(h, MLT)}{N\,(h, MLT)}$$



Occurrence frequency and average velocity of ion upflow



Summary

- Results of statistical analysis
  - Occurrence frequency : Case 3 > Case 2 > Case 1 ≈ Case 4
  - Average velocity: Case 3 > Case 2 > Case 1 ≈ Case 4, but the differences are very small
  - Ion upflow more frequently occurs at higher altitude and the occurrence peak is approximately 10 MLT
  - Occurrence frequency seems to increase with Kp
  - Ion upflow occurs at higher altitude as F10.7 increases
  - On average, the upflow velocity is larger at lower altitude, but during magnetically disturbed period (Kp > 5), the velocity becomes larger at higher altitude
  - As F10.7 increases, the upflow velocity seems to become larger but noisy at the same time, especially at lower altitudes
- The results of this study suggest that ion upflow events occurring in the polar region are mostly accompanied by both ion and electron heatings

References

- Ganguli, G., M. J. Keskinen, H. Romero, R. Heelis, T. Moore, and C. Pollock (1994), Coupling of microprocesses and macroprocesses due to velocity shear: An application to the low-altitude ionosphere, J. Geophys. Res., 99(A5), 8873–8889, doi:10.1029/93JA03181.
- Gombosi, T. I., and T. L. Killeen (1987), Effects of thermospheric motions on the polar wind: A time-dependent numerical study, J. Geophys. Res., 92(A5), 4725–4729, doi:10.1029/JA092iA05p04725.
- Korosmezey, A., C. E. Rasmussen, T. I. Gombosi and G.V. Khazanov (1992), Anisotropic ion heating and parallel O+ acceleration in regions of rapid E × B convection, Geophys. Res. Lett., 19, 2289-2292.
- Yeh, H.-C., and J. C. Foster (1990), Storm-time heavyion outflow at midlatitudes, J. Geophys.Res., 95, 7881-7891.
- Liu, H., and G. Lu (2004), Velocity shear-related ion upflow in the low-altitude ionosphere, Ann. Geophys., 22, 1149.