南極昭和基地大型大気レーダーによって観測された極域冬期中間圏エコーと高エネルギー降下粒子との対応

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Polar Mesosphere Winter Echo(PMWE) observed by PANSY radar: Implications of highly energetic precipitating particles

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The physical properties of terrestrial atmosphere, such as temperature and composition, change drastically depending on altitudes. In addition, energy injections originated from the solar activity in a variety of temporal scales, such as CME and 11-year solar cycle, are known to disturb terrestrial atmosphere strongly. Therefore, coupling process and energy budget in the middle and upper atmospheres, which have different physical properties, should be taken into account to fully understand the atmospheric environment and short- and long-termed variations. However, it is difficult to measure basic physical quantity of atmosphere (temperature, density, wind velocity and compositions) continuously as a function of time and altitudes from a few tens of km to about 100 km, in the middle and the upper atmosphere. Detailed investigations based on comprehensive observations for the middle and upper atmosphere are required to reveal the nature of plasma-neutral atmospheric coupling process.

In the VIII-th six-year project of the Japanese Antarctic Research Expedition (JARE) from 2010, the middle and upper atmosphere research is one of the sub-projects of the prioritized research project entitled 'Global warming revealed from the Antarctic', and comprehensive ground based observations with various remote sensing instruments for the middle and upper atmosphere have been operating continuously in Syowa station. We analyzed data obtained by PANSY (Program of the Antarctic Syowa MST/IS) radar, which is the core instrument of the project, focusing on Polar Mesosphere Winter Echo (PMWE) in the context of plasma-neutral atmospheric coupling process between the middle and upper atmosphere.

In the lower thermosphere at the altitude of around 100 km, both neutral turbulence and ionization of atmosphere due to solar radiations cause irregularities of reflective index, and as a result back scatter echoes from that altitude are frequently observed by radars on the ground. In the mesosphere, Polar Mesosphere Summer Echo (PMSE) is reported to be a strong echo associated with ice particles, which are produced around the coldest mesopause region in the polar summer, by a number of past radar observations [Cho and Rottger, 1997; Rapp and Lubken, 2004]. It should be also noted that occurrence rate of PMSE is very high (80-90%) [Bremer et al., 2003]. On the other hand, PMWE is also known as back scatter echo from 55 to 85 km in the mesosphere, and it has been observed by MST and IS radar in polar region during winter [e.g., Ecklund and Balsley, 1981; Czechowsky et al., 1989; Lubken et al., 2006; Strelnikova and Rapp, 2013]. Due to the lack of of free electrons and ice particles in the dark and warm mesosphere during winter, it is suggested that PMWE requires strong ionization of neutral atmosphere associated with precipitations of Solar Energetic Particles (SEPs) during geomagnetically disturbed periods [Kirkwood et al., 2002; Zeller et al., 2006]. However, the detailed generation process of PMWE has not been identified yet, partly because the reported PMWE occurrence rate was quite low (2.9%) [Zeller et al., 2006].

PANSY radar is a 47 MHz VHF radar with 125 kW (full system 500 kW) output power, and it is the largest MST radar composed 5,000 m^2 (full system 20,000 m^2) antenna array in Antarctica at the moment. PANSY has already identified a number of PMWE near local noon since operation of mesosphere observation mode was started in June 2012. We would like to show occurrence characteristic of PMWE and its relation to SEPs during geomagnetically disturbed period in June and July 2012, when continuous PMWEs were observed on temporal scales of several days. Highly energetic particle precipitations during this period were investigated based on NOAA satellite particle measurements above Syowa. Unfortunately, particle data around local noon, which can be directly compared with PMWE observed by PANSY radar, does not exist in most case due to the limitation of NOAA satellite orbits. However, we found that the flux of precipitating electrons in the energy ranges 30-300 keV increased in one-two orders of magnitude for normal levels just after/before PMWE appearances. On the other hand, occurrence of PMWE seemed to uncorrelate to the flux of precipitating electrons in the energy more than 300 keV and energetic protons (3-8 MeV), which may suggest that energetic protons associated with Solar Proton Events (SPEs) and relativistic electrons (> MeV) are not necessarily required to generation of PMWE. Therefore, non relativistic electron

precipitations in medium energy range (30-300 keV) play an important role in plasma-neutral atmospheric coupling process in the mesosphere, and such coupling processes via particle precipitations would happen more frequently than past predictions based on MST or IS radar measurements.

References

Cho, J. Y. N., and J. Rottger, An updated review of polar mesosphere summer echoes: Observation, theory, and their relationship to noctilucent clouds and subvisible aerosols, J. Geophys. Res., 102, 2001 – 2020, 1997.

Rapp, M. and Lubken, F.-J., Polar mesosphere summer echoes (PMSE): Review of observations and current understanding, Atmos. Chem. Phys., 4, 2601–2633, 2004

Bremer, J., Hoffmann, P., Latteck, R., Singer, W., Seasonal and long-term variations of PMSE from VHF radar observations at Andenes, Norway. Journal of Geophysical Research 108 (D8), 8438, 2003.

Ecklund, W.L., Balsley, B.B. Long-term observations of the Arctic mesosphere with the MST radar at Poker Flat. Alaska, J. Geophys. Res. 86, 7775–7780, 1981

Czechowsky, P., Reid, I.M., Ruster, R., Schmidt, G. VHF radar echoes observed in the summer and winter polar mesosphere over Andøya, Norway. J. Geophys. Res. 94, 5199–5217, 1989.

Lubken, F.-J., Strelnikov, B., Rapp, M., Singer, W., Latteck, R., Brattli, A., Hoppe, U.-P., and Friedrich, M, The thermal and dynamical state of the atmosphere during polar mesosphere winter echoes, Atmos. Chem. Phys., 6, 13–24, doi:10.5194/acp-6-13-2006, 2006.

Strelnikova, I. and Rapp, M., Statistical characteristics of PMWE observations by the EISCAT VHF radar, Ann. Geophys., 31, 359-375, doi:10.5194/angeo-31-359-2013, 2013.

Kirkwood, S., Barabash, V., Belova, E., Nilsson, H., Rao, T.N., Stebel, K., Osepian, A., Chilson, P.B., Polar mesosphere winter echoes during solar proton events, Adv. in Polar Upper Atmos. Res. 16, 111–125, 2002.

Zeller, O., Zecha, M., Bremer, J., Latteck, R., Singer, W., Mean characteristics of mesosphere winter echoes at mid- and high-latitudes, J. Atmos. Sol. Terr. Phys. 68 (10), 1087–1104, 2006.