Atmospheric responses in both hemispheres to relativistic electron precipitation

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Relativistic electron precipitation (REP) in the polar atmosphere has been paid attention to because it changes atmospheric composition, causing ozone depletion after migrating to the lower altitude during polar winter. A plausible mechanism for REP is the interaction with magnetospheric plasma waves, such as electromagnetic ion cyclotron (EMIC) waves and whistler-mode chorus waves. Previous studies have already shown that EMIC waves can effectively drive REP, however, observational evidence that chorus waves can drive REP was lacking. In this study we present direct comparison between magnetospheric plasma waves and polar mesosphere winter echoes (PMWE) simultaneously observed with the Arase satellite and high-power Mesosphere, Stratosphere and Troposphere (MST) radars in both hemispheres, PANSY and MAARSY. PMWE can be related to the ionization in the mesosphere due to REP. The PMWE were observed at 03-07 UT on March 21, 2017 during the passage of corotating interaction region (CIR), during which the Arase footprints were close to Syowa Station (SYO; −69.00S, 39.58E), Antarctica, and Husafell (HUS; 65.67N, −21.03E), Iceland.

The observational results are summarized as follows. (1) EMIC waves and whistler-mode chorus waves were observed by Arase near the equatorial magnetosphere during 02:30-04:45 UT and 04:45-07:00 UT, respectively. (2) PMWE were detected with both the MAARSY radar at Andøya (AND; 69.30N, 16.04E), Norway, and the PANSY radar at SYO, Antarctica, during 04:45-07:00 UT, which was the recovery phase of an isolated substorm. We believe this is the first time PMWE have been observed in both hemispheres at exactly the same time. (3) During 04:45-07:00 UT, the temporal variation of the chorus wave power was similar to those of the PMWE power in the both hemispheres. (4) The PMWE observed at SYO during 03:00-04:00 UT before the substorm onset was consistent with the occurrence of the EMIC waves. The item (2) shows direct evidence that chorus waves during the substorm recovery phase cause REP. We estimated the resonance energy of electrons interacting with the observed LBC waves, however, the estimated energy was too low to cause PMWE at an altitude lower than 70 km. However, we found that the resonance energy becomes greater than 1 MeV, if LBC waves propagate to the magnetic latitude greater than 30 degrees and resonate with energetic electrons there. As for item (4), the PMWE observed at SYO during 03:00-04:00 can be related to wave-particle interaction with EMIC waves, which may be generated inside the plasmapause by ring-current hot ions with temperature anisotropy. This anisotropy

was caused by magnetospheric compression due to increasing solar wind dynamic pressure during 01:00–06:00 UT just after the arrival of the CIR. Since CIRs are main sources of geomagnetic disturbances during the declining phase of the solar cycle and solar minimum, this event is not rare but rather a common atmospheric response caused by interaction between recurrent large-scale solar wind structures and geospace.

Keywords: Polar Mesosphere Winter Echoes, Arase satellite, PANSY radar, MAARSY radar, relativistic electron precipitation, magnetospheric plasma waves