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Ground-based estimates of outer radiation belt energetic electron precipitation fluxes into the atmosphere

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Currently there is intense debate as to the ultimate effects of solar activity on tropospheric and stratospheric variability, particularly through direct and indirect effects of chemical changes induced by energetic particle precipitation. However, there are key unresolved questions concerning the understanding of the effects of energetic particle precipitation on the lower atmosphere, one of which is magnitude and temporal variability of precipitating radiation belt energetic electrons. Definitive answers are very difficult to provide from satellite measurements alone because of the complexity in measuring electron fluxes unambiguously in the whole bounce-loss cone without contamination from fluxes in the drift-loss cone or trapped fluxes.

In this study we have used AARDDVARK data from a radiowave receiver in Sodankylä, Finland to monitor transmissions from the very low frequency communications transmitter, NAA, (24.0 kHz, 44°N, 67°W, L=2.9) in USA since 2004. The transmissions are influenced by outer radiation belt (L=3-7) energetic electron precipitation. In this study we have been able to show that the observed transmission amplitude variations can be used to routinely determine the flux of energetic electrons entering the atmosphere. Our analysis of the NAA observations shows that electron precipitation fluxes can vary by three orders of magnitude during geomagnetic storms. Comparison of the ground-based estimates of precipitation flux with satellite observations from DEMETER and POES indicates a broad agreement during geomagnetic storms, but some differences in the quiet-time levels, with the satellites observing higher fluxes than those observed from the ground. Typically when averaging over L=3-7 we find that the >100 keV POES 'trapped' fluxes peak at about 10^6 $el.cm^{-2}s^{-1}str^{-1}$ during geomagnetic storms, with the DEMETER >100 keV drift loss cone showing peak fluxes of 10^5 $el.cm^{-2}s^{-1}str^{-1}$, and both the POES >100 keV 'loss' fluxes and the NAA ground-based >100 keV precipitation fluxes showing peaks of ~10^4 $el.cm^{-2}s^{-1}str^{-1}$. The analysis of NAA amplitude variability has the potential of providing a detailed, near real-time, picture of energetic electron precipitation fluxes from the outer radiation belts.