Subionospheric VLF observations of VLF transmitter-induced precipitation of inner radiation belt electrons

K. Graf & U. S. Inan
STAR Laboratory, Stanford University

Energetic electron precipitation induced by controlled injection of VLF signals from a ground based transmitter is monitored via both subionospheric VLF remote sensing and satellite based energetic electron detection. The 21.4 kHz NPM transmitter in Lualualei, Hawaii is keyed ON-OFF for 30 minute periods with periodic sequences (e.g., 5-s ON/5-s OFF). The same periodicity is observed in the amplitude and phase of the subionospherically propagating signals of the 24.8 kHz NLK (Jim Creek, Washington) and 25.2 kHz NLM (LaMoure, North Dakota) transmitters measured at Midway Island, which traverse the ionospheric regions of expected precipitation. The periodicity is only occasionally observed with the >60 keV electron detectors onboard the DEMETER satellite in its 700-km circular polar orbit. Satellite based measurements are made in both the expected precipitation region and its conjugate. Since April of 2006, with occasional schedule breaks, coordinated measurements have been carried out regularly in conjunction with NPM transmissions. NPM transmission formats of 5-s ON/5-s OFF, 3-s ON/2-s OFF, and 10-s ON/10-s OFF were utilized over this time span. The data set is analyzed for correlation between NPM transmission and signs of energetic electron precipitation. Models of wave-induced electron precipitation as well as trans-ionospheric and subionospheric VLF propagation are used for quantitative interpretation of observations in terms of the absolute magnitudes of the precipitation fluxes, with precipitation fluxes induced by the NPM transmitter estimated to peak at L ~ 2. Statistics of observations of precipitation effects are compared with geomagnetic activity, since precipitation fluxes are expected to be directly proportional to the trapped flux levels near the loss cone edge.