Calculations of 4278 Å artificial auroral airglow emissions resulting from powerful HF radio transmissions

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Powerful HF electromagnetic waves transmitted into the ionosphere from the High-frequency Active Auroral Research Program (HAARP) facility in Alaska and the European Incoherent Scatter Scientific Association (EISCAT) facility in Norway have induced artificial aurora with ground-measurable 4278 Å wavelength emissions (B. Gustavsson et al., *Ann. Geophys.*, 23, 1747-1754, 2005; T. B. Pedersen et al., *Geophys. Res. Lett.* 37, 2, L02106, 2010). This artificial "blue-line" emission can result from the electronic transition of an $N_2^+(^1N)$ ion to its ground state. The two main sources of $N_2^+(^1N)$ ions in the F region are photoionization and electron-impact ionization of N_2 molecules. Experimental and theoretical evidence suggests that impact ionization of N_2 molecules by electrons accelerated by wave-plasma interactions to energies exceeding 18 eV is responsible at least in part for artificial 4278 Å wavelength emissions observed during ionosphere radio modification experiments at HAARP and EISCAT (H. C. Carlson et al., *J. Atmos. Solar Terr. Phys.*, 44, 12, 1089-1100, 1982; A. V. Gurevich et al., *J. Atmos. Terr. Phys.*, 47, 11, 1057-1070, 1985).

Another significant source of 4278 Å airglow in the twilit ionosphere is resonant scattering of sunlight by N_2^+ ions (A. L. Broadfoot, *Planet. Space Sci.*, 15, 12, 1801-1815, 1967). Resonant scatter is also a significant source of blue-line emissions during auroral activity (K. J. Remick et al., *J. Atmos. Solar Terr. Phys.*, 63, 4, 295-308, 2001). Ionosphere heating by auroral electron precipitation or by HF pumping at HAARP or EISCAT causes changes to temperature-dependent ion chemistry and ambipolar diffusive transport, resulting in vertical redistribution of ion concentrations. In particular, ionosphere plasma heating during twilight is generally expected to increase N_2^+ ion densities above the shadow height and consequently increase 4278 Å emission rates due to resonant scattering of sunlight. Previous reported measurements of artificial blue aurora intensities at HAARP and EISCAT were made during twilight conditions when the F region was still illuminated. Therefore, resonant scattering of sunlight is a significant potential source of artificial 4278 Å emissions in addition to impact ionization of N_2 molecules by HF-accelerated electrons.

This report describes calculations of artificial 4278 Å airglow emission rates resulting from ionosphere electron heating by the HAARP transmitter. A self-consistent ionosphere model is used to simulate the high-latitude ionosphere response to artificial electron heating between the HF pump wave reflection and upper-hybrid resonant heights. Electron heating in the twilit ionosphere above the HAARP facility is shown with model calculations to increase N_2^+ ion number densities above the shadow height. These N_2^+ ion density enhancements then increase 4278 Å emissions from resonantly scattered sunlight by tens of Rayleigh above the background as measured from the ground, comparable to the most intense reported artificial blue-line emissions measured during ionosphere radio modification experiments. Comparisons are made with calculations of artificial 4278 Å emissions from impact ionization of N_2 molecules by HF-accelerated electrons and experiments are proposed to measure the relative importance of impact ionization and resonant scattering sources.