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Low Frequency Waves in HF Heating of the Mid-Latitude Ionosphere

Abstract:
The heating of the ionsosphere by high frequency (HF) radio waves leads to plasma processes with a wide range of scales. In the high-latitude ionosphere, extensive studies using numerical simulations using a Hall-magnetohydrodynamic model and experiments with the HAARP facility have provided a comprehensive understanding of the generation of low frequency hydromagnetic waves, both in the presence and absence of the auroral electrojet. Modulated HF heating in the F-region produces a local modulation of the electron temperature and the resulting pressure gradient give rise to a diamagnetic current, which in turn excites magnetosonic waves that propagate away from the heating region.

In the E-region, where the Hall conductivity is dominant, these waves lead to oscillating Hall currents that produce shear Alfvén waves. These waves propagate along the field lines to the ground, where they are detected by ground-based magnetometers and into the magnetosphere.

The observations of the shear Alfven waves by DEMETER satellite when its trajectory is over the HAARP magnetic zenith have shown the wave propagation to higher altitudes. For the mid latitude ionosphere the simulations use the Earth's dipole magnetic field and the heating region is located at L = 1.6 and altitude of 300 km. With HF waves modulated at 2 – 10 Hz the low frequency waves are generated by essentially the same processes as in the high-latitude case, with additional features arising from the magnetic geometry of the mid-latitude ionosphere.

The shear Alfven waves propagating to the magnetosphere become electromagnetic ion cyclotron (EMIC) waves at higher altitudes but do not propagate beyond the ion cyclotron resonance layer. The heating of the ionosphere generates many plasma modes, viz., the Alfven, magnetosonic, helicon, whistler and electromagnetic ion cyclotron waves, and comparison of their properties with measurements during experiments (Arecibo and Sura) will be presented.