Investigation of temperature gradient instability as the source of mid-latitude decameter-scale quiet-time ionospheric irregularities

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SuperDARN HF radars regularly observe decameter-scale ionospheric irregularities at mid-latitudes during quiet geomagnetic conditions. The mechanism responsible for the growth of such common irregularities is still unknown. Previous joint measurements by Millstone Hill Incoherent Scatter Radar (ISR) and SuperDARN HF radar located at Wallops Island, Virginia have identified the presence of opposed meridional electron density and temperature gradients in the region of decameter-scale electron density irregularities period. These gradients have been proposed to be responsible for low velocity Sub-Auroral Ionospheric Scatter (SAIS) observed by SuperDARN radars. Temperature gradient instability (TGI) is investigated as the potential source of irregularities associated with these SuperDARN echoes. The electrostatic dispersion relation for TGI has been extended into the kinetic regime appropriate for SuperDARN radar frequencies by including Landau damping, finite gyro-radius effects, and temperature anisotropy. This dispersion relation has been compared with the fluid model of the TGI proposed by Hudson and Kelley [1976]. The variations of TGI growth rate with electron collision frequency, temperature gradients, density gradients, and the angle between wave vector and magnetic field have been studied. Since temperature and density gradients are a persistent feature in the mid-latitude ionosphere near the plasmapause, the drift mode growth rate at short wavelengths may explain the observed mid-latitude ionospheric irregularities. The calculations of electron temperature and density gradients in the direction perpendicular to the geomagnetic field have shown that the TGI growth is possible in the top-side F-region for the duration of the experiment. A time series for the growth rate has been developed for mid-latitude ionospheric irregularities observed by SuperDARN in the top-side F-region [Greenwald et al., 2006]. This time series is computed for both perpendicular and meridional density and temperature gradients. These observations show the role of TGI is dominant over the gradient drift instability (GDI) in this case. Nonlinear evolution of the TGI has been studied utilizing gyro-kinetic "Particle In Cell" (PIC) simulations with Monte Carlo collisions. This allows detailed study of saturation amplitude, particle flux, heat flux, diffusion coefficient, and thermal diffusivity of the resistive drift wave turbulence. The simulation results have been compared with the linear theory for the short and long wavelength regime. A critical comparison of computational modeling results and experimental observations is discussed.