The gravity waves in space dusty plasma and PMSE

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Polar Mesospheric Summer Echoes, (PMSE), are very strong radar echoes from the mesosphere in summer at high latitudes (north and south). The source of radar echoes from the atmosphere/ionosphere are electron density irregularities with a scale length matching the radar wavelength (Bragg condition) which are typically of the order of a few tens of centimeters to a few tens of meters corresponding to VHF radars. Experiments and theory seem to support the idea that the physical mechanism that causes PMSE is electron density fluctuations driven by neutral air turbulence. Gravity waves are known to exist in the PMSE region. Thus, the properties of gravity waves propagating in the lower ionospheric dusty plasma are investigated in this paper. It is found that gravity wave turbulence in the dusty plasma layer could be responsible for the abnormal radar scattering observed in PMSE.

In the derivation of the gravity wave dispersion relation, the dusty plasma and the neutral gas are treated as a two-component fluid. Since the collision frequencies between ions, neutrals and electrons are much greater than that of dust with ions, electrons and neutrals, the ions, neutrals and electrons are treated as one component, and the dust as another. The dispersion relation of gravity waves in such dusty plasma is

$$\frac{n_z^2}{\frac{1-[1-1/\alpha-\beta(1-1/\alpha)/\alpha]\omega_a^2/\omega^2+2/\alpha^2-3/\alpha+\beta(1-1/\alpha)^2/\alpha}{[1-1/\alpha+\beta(1-1/\alpha)/\alpha]}}+$$
$$+\frac{n_z^2}{\frac{1-(1-\beta/\alpha)\omega_a^2/\omega^2-2/\alpha+\beta(1-1/\alpha)/\alpha}{1-\omega_b^2/\omega^2}}=1$$

The propagation of gravity waves in a vertically stratified dusty plasma has been analyzed using ray tracing. The result shows that wave reflection can happen in situations: ćÙ$k_z(t=0)<0$ and $\frac{\partial\omega_p^2}{\partial z}>0$or ćÚ$k_z(t=0)>0$ and $\frac{\partial\omega_p^2}{\partial z}<0$. The dust particles lead to stratified structures of ω_p in the dust layer located at 80-90 km in the polar regions. The waves of frequency $\omega>\frac{\omega_b}{(\omega_{p\max}/k_xC)^2+1}$ propagating up or down will be both reflected in the dust layer when the distribution of ω_p is protruded. When the distribution is concave, the waves of frequency $\omega>\frac{\omega_b}{(\omega_{p\max}/k_xC)^2+1}$ will be trapped in the dust layer. In this case, the gravity wave induced strong turbulence could cause PMSE.