On Dust Charging Process Associated with Meteoric Smoke Particles (MSP) in the Mesosphere

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***Abstract*—The first study of the modulation of polar mesospheric winter echoes (PMWE) by artificial radiowave heating using computational modeling and experimental observation in different radar frequency bands is presented. The temporal behavior of PMWE response to HF pump heating can be employed to diagnose the charged dust layer associated with Mesospheric Smoke Paricles (MSP). Specifically, the rise and fall time of radar echo strength as well as relaxation and recovery time after heater turn-on and off are distinct parameters that are a function of radar frequency. The second part of this study presents the formation of Polar Mesospheric Summer Echoes PMSE and the associated dust charging process in the course of electron precipitation events. The computational model will be used to investigate the dust parameters in PMSE region by comparing the time evolution of PMSE observed during electron enhancement period.**

I. Introduction

So-called polar mesospheric winter echoes (PMWE) are radar echoes observed during the polar winter at altitudes around 50–80 km and are much weaker than their PMSE (Polar Mesospheric Summer Echoes, e.g. [1]) counterpart and also much less studied. Breaking of gravity waves and the associated turbulence are proposed as the major source for PMWE echoes. The action of neutral turbulence alone does not appear to give a good explanation for PMWE. The close similarity in spectral widths inside and outside the PMWE source region lends evidence to this assertion [2]. It should be noted that so-called PMSE are due to Bragg scatter from electron irregularities which result from charging of free electrons and ions onto subvisible ice particles. While some theories can explain the PMWE characteristics only by the turbulence, there are rocket and radar observations that show the presence of nanometer scale particles throughout PMWE regions [3]. Ablation and evaporation of meteors in the atmosphere between 60 km and 90 km are the main source of Mesospheric Smoke Paricles (MSP). These particles may influence electron density fluctuations through charging and as a result radar echoes. MSPs therefore have been proposed to exist in the PMWE source region and lead to electron irregularities that produce the radar echoes [4]. Most previous PMWE observations were during enhanced electron density conditions. Charging of MSP by free electrons and ion chemical reactions are the two main sources of electron reduction in PMWE region. It should be noted that MSP responsible for PMWE and ice particles associated with PMSE are referred to as dust throughout this paper for simplicity of notation.

II. Remote sensing of mesospheric dust layers using active modulation of PMWE by high-power radiowaves

While sounding rockets only give a brief snapshot of PMSE, a remote sensing technique using high-power radio-waves was developed over the past few years to probe mesopause region. Heating the plasma through High Frequency (HF) radio waves increases the free electron mobility. This process is directly dependent on the radar frequency as well as dusty-parameters within PMSE [5]. This technique has been widely used at the European Incoherent Scatter (EISCAT) facility in Norway, to investigate the dust parameters associated with PMSE. The first PMSE overshoot effect in the VHF radar echoes after the turn-off of the HF heater was reported in 2003 [5]. It has been shown that active modulation of PMSE source region may break down the plasma structuring or enhance them which results in suppression or enhance the radar echoes, respectively [6,7]. The first modulation of HF PMSE at 8 MHz by radio heating of the mesosphere is recenetly observed [8].

Unlike PMSE, PMWE are less studied and understood. The first objective of this work is to consider the temporal variation of PMWE during active modulation using high-power radiowaves to obtain diagnostic information about the source region. Radar frequencies used in this paper are based on the available facilities at EISCAT. Variation of dust-plasma parameters associated with PMWE such as dust radius, dust density, recombination rate, electron- and dust-neutral collision frequencies, and electron temperature enhancement ratio are included. The important role of photo-detachment current and its effects on the agreement of experimental observation with the computational results is investigated. It has been shown for the first time that the dependence of recombination rate on T_e/T_i affects the time evolution of PMWE signal significantly during radiowave heating. Dust radius as small as 1 nm as well as dust radius of 4 nm is used. Computational results derived from different sets of parameters are considered and compared with observations at 224 MHz and 56 MHz. The agreement between the model results and the observations show the high potential of remote sensing of dust and plasma parameters associated with PMWE. Measurement of T_e/T_i using ISR and simultaneous observations in two frequency bands may lead to a more accurate estimation of dust density and radius. Our computational results predicted the enhancement of backscattered signal in the HF band during PMWE heating for the first time. It has been shown that the similarity of the temporal evolution of electron density fluctuation (radar echoes) in the HF band and average charge on the dust particles can be used to study the fundamental physics associated with the dust charging in the PMWE source region [9].

III. Dust charging process associated with PMSE

Another part of our current work is the formation of PMSE and the associated dust charging process in the course of electron precipitation events. The observations were recorded in two consecutive days in July 2012. The experiments started at 8:00 UT on July 10 and 11 lasted for 4 hours (shown in Figure 1). Electron density in PMSE region was measured by EISCAT UHF radar and the EISCAT VHF radar measured PMSE simultaneously. Our data shows the formation of strong PMSE layer subsequent to the electron precipitation event. The strength of the layer is consistent with the time period of electron density increase. In the current work, we are studying the charging process of present ice particle in PMSE and formation of associated electron density fluctuations. Dust parameters including dust radius and density as well as charging characteristics of dust particles will be considered. The formation and enhancement of electron density perturbation in the model will be investigated and compared with the time evolution of VHF PMSE observed in the experiment.

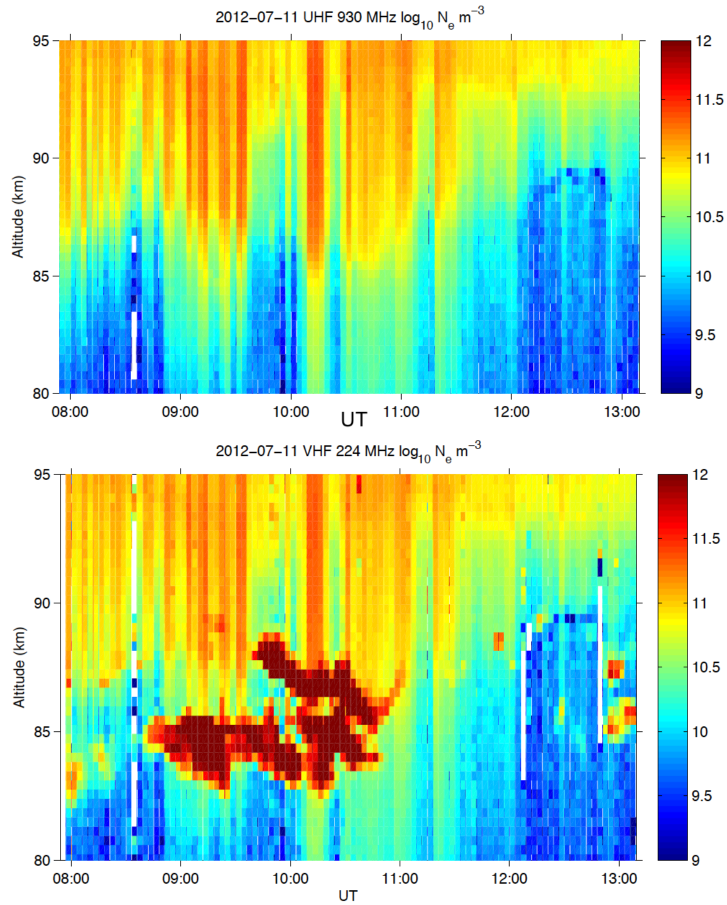

Fig. 1. Experiment conducted on July 11, 2012 a) electron density measured by EISCAT UHF radar b) EISCAT VHF radar and associated PMSE layer.

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