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Polar mesosphere summer echoes (PMSE): Review of observations and current understanding

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Abstract. Polar mesosphere summer echoes (PMSE) are very strong radar echoes primarily studied in the VHF wavelength range from altitudes close to the polar summer mesopause. Radar waves are scattered at irregularities in the radar refractive index which at mesopause altitudes is effectively determined by the electron number density. For efficient scatter, the electron number density must reveal structures at the radar half wavelength (Bragg condition for monostatic radars; ~3 m for typical VHF radars). The question how such small scale electron number density structures are created in the mesopause region has been a longstanding open scientific question for almost 30 years. This paper reviews experimental and theoretical milestones on the way to an advanced understanding of PMSE. Based on new experimental results from in situ observations with sounding rockets, ground based observations with radars and lidars, numerical simulations with microphysical models of the life cycle of mesospheric aerosol particles, and theoretical considerations regarding the diffusivity of electrons in the ice loaded complex plasma of the mesopause region, a consistent explanation for the generation of these radar echoes has been developed. The main idea is that mesospheric neutral air turbulence in combination with a significantly reduced electron diffusivity due to the presence of heavy charged ice aerosol particles (radii ~5–50 nm) leads to the creation of structures at spatial scales significantly smaller than the inner scale of the neutral gas turbulent velocity field itself. Importantly, owing to their very low diffusivity, the plasma structures acquire a very long lifetime, i.e., 10 min to hours in the presence of particles with radii between 10 and 50 nm. This leads to a temporal decoupling of active neutral air turbulence and the existence of small scale plasma structures and PMSE and thus readily explains observations proving the absence of neutral air turbulence at PMSE altitudes. With this explanation at hand, it becomes clear that PMSE are a suitable tool to permanently monitor the thermal and dynamical structure of the mesopause region allowing insights into important atmospheric key parameters like neutral temperatures, winds, gravity wave parameters, turbulence, solar cycle effects, and long term changes.

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