The thermal and dynamical state of the atmosphere during polar mesosphere winter echoes

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Polar Mesosphere Winter Echoes (PMWE) are very strong VHF radar echoes which are observed in the winter lower and middle mesosphere nearly exclusively during enhanced solar and/or geomagnetic disturbed periods. In general, PMWE occur much more seldom compared to their summer counterparts PMSE (typical occurrence rates at 69° N are 1–3% vs. 80%, respectively). In January 2005, a total of 18 rockets were launched from the Andøya Rocket Range in Northern Norway (69° N) into strong a PMWE event. Our in-situ measurements by falling sphere, chaff, and instrumented payloads provide detailed information about the thermal and dynamical state of the atmosphere and therefore allow an unprecedented study of the background atmosphere during PMWE. There are a number of independent observations indicating that neutral air turbulence has caused PMWE. Ion density fluctuations show a turbulence spectrum within PMWE and no fluctuations outside. Temperature lapse rates close to the adiabatic gradient are observed in the vicinity of PMWE indicating persistent turbulent mixing. The spectral broadening of radar echoes is consistent with turbulent velocity fluctuations. Turbulence also explains the mean occurrence height of PMWE ($\sim$68–75 km): viscosity increases rapidly with altitude and destroys any small scale fluctuations in the upper mesosphere, whereas electron densities are usually too low in the lower mesosphere to cause significant backscatter. The seasonal variation of echoes in the lower mesosphere is in agreement with a turbulence climatology derived from earlier sounding rocket flights. We have performed model calculations to study the radar backscatter from plasma fluctuations caused by neutral air turbulence. We find that volume reflectivities observed during PMWE are in quantitative agreement with theory. Apart from turbulence the most crucial requirement for PMWE is a sufficiently large number of electrons, for example produced by solar proton events. We will present a study of the radar echo sensitivity on various parameters, most important electron number density and turbulence intensity. Our observational and theoretical considerations do not provide any evidence that charged aerosol particles are needed to explain PMWE, in contrast to the summer echoes which owe their existence to charged ice particles.