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Meteor head echo characteristics revealed by MU radar observations

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A meteor head echo is transient, strongly Doppler-shifted and generated by scattering of radio waves from what seems like a compact region of plasma surrounding and moving with the velocity of a meteoroid on an atmospheric trajectory at about 70-140 km altitude. We have developed an automatic analysis scheme for such echoes detected with a multi-channel high power large aperture (HPLA) radar, using the observational data of the Shigaraki 46.5 MHz MU radar. The method's major advantage is the utilization of the meteor head echo phase values obtained from each received pulse. We combine the velocity estimated by target range rate and Doppler shift from a single pulse with the correlation of the phase of each echo pulse-to-pulse. The precision is of the order of a few tens of m/s. The interferometric capability of the radar is utilized to determine the trajectory of the meteoroid and thus also the instantaneous angle between the trajectory and the line-of-sight to the centre of the transmitter/receiver antenna field. This angle is taken into account on a pulse-to-pulse basis to calculate the true meteoroid velocity along its trajectory and determine its deceleration.

The MU radar head echo durations are often a few tenths of a second long. In many cases the whole ionization process takes place inside the radar beam unlike when using other HPLA radars with narrower beams. The precision is high enough to monitor changes in the deceleration rates of meteoroids during their atmospheric flight. This enables us to study and distinguish plausible meteoroid-atmosphere interaction processes as sudden releases of volatile elements when a meteoroid is heated to its boiling temperature and/or disrupted into two or more solid or molten particles.

In addition to the MU radar we have used one co-located ICCD video camera and two video cameras with image intensifiers at remote sites to capture the radar meteors optically. All cameras were equipped with telescopic lenses. In 2009 more than a hundred simultaneous video and radar meteor events were recorded. Comparing the head echo target locations with the leading edge of the streak of light recorded on video we examine systemic parameters such as radar phase offset and validate the head echo analysis methods. The optical magnitude and estimated photometric mass of the meteoroids from video data are compared with the radar head echo characteristics to investigate the atmosphere interaction processes.