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Radar and photometric meteor mass determination

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Individual meteor mass estimates vary greatly depending on the method of observation and the technique used to calculate the mass. The resulting large uncertainty in the total meteoric mass flux (at least two orders of magnitude) affects the atmospheric community's ability to accurately model densities, composition, and phenomena such as the formation of metal layers. Two common tools for remote observation of meteors are incoherent scatter radar and optical cameras. Historically, comparison between radar and optical measurements has been difficult due to the low number of events observed by both systems. We present mass estimates from a set of 150 meteors observed simultaneously by the MAARSY radar (Andøya, Norway, 53.5 MHz) and an optical camera network (1). Radar masses are calculated using results from finite difference time domain (FDTD) simulations, which model the interaction of a radar pulse with a meteor head plasma (2). The FDTD results are used to generate lookup tables which relate radar cross section (RCS) measurements to physical meteor parameters, which are then used to calculate masses. This method has been validated using a set of meteors observed by two radars, and is now being applied to a set of single-frequency measurements.

Optical masses are calculated using the standard photometric mass relationship:

$$L = \tau \frac{1}{2} \frac{dm}{dt} v^2$$

The meteor's luminosity (L) and velocity (v) along its trajectory are measured by the optical cameras. The photometric masses apply luminous efficiency (τ) results from an experimental laboratory campaign. For many of the optical events, the meteors are captured by multiple cameras. This allows multiple independent optical mass estimates to be made for each event. For both the optical and radar observations, mass estimates are made for the total length of the observation, and for the altitude regime in which both systems are observing the meteor simultaneously. The latter quantity is of interest for determining the mass difference between the two observation systems. Comparing the results of these two mass estimation methods provides insight into the discrepancy between radar and photometric mass estimates, and in the future can be applied to a broader set of observations in order to make an estimate of the meteoric mass flux.

1. P. Brown, G. Stober, C. Schult, Z. Krzeminski, W. Cooke, J. Chau. Simultaneous optical and meteor head echo measurements using the Middle Atmosphere Alomar Radar System (MAARSY): data collection and preliminary analysis Planet. Space Sci., 141 (2017), pp. 25-34, 10.1016/j.pss.2017.04.013

2. Tarnecki, L. K., Marshall, R. A., Stober, G., & Kero, J. (2021). Meteoroid mass estimation based on single-frequency radar cross section measurements. Journal of Geophysical Research: Space Physics, 126, e2021JA029525. 10.1029/2021JA029525