ESTIMATION OF METEORITE FALL MASS AND OTHER PROPERTIES FROM WEATHER RADAR DATA.

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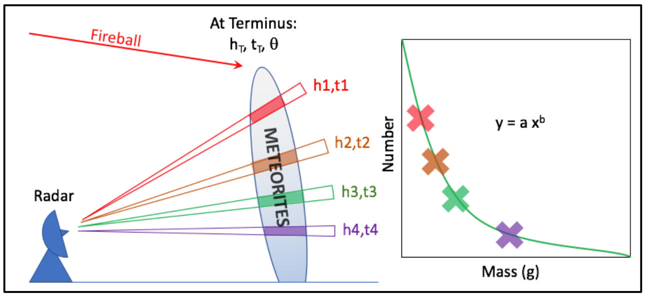
Introduction: Weather radar data can be used to identify meteorite falls for rapid recovery. To date two dozen meteorite falls have been identified on radar in the U.S. and Canada [e.g.1-3]. There are another ten probable, but unrecovered, falls to include three into the Gulf of Mexico and Atlantic Ocean, and one into Lake Michigan. Radar data products such as reflectivity are functions of a variety of factors. These include physical properties of the meteorites and fall dynamics, and in principle it should be possible to discern, or at least constrain properties such as mass, size distribution, and mechanical toughness. Knowing these properties facilitates the rapid recovery of meteorite falls by refining dark flight model results, allows estimates of total mass and meteorite type, supports statistical analyses of large numbers of meteorite falls, and provides information about falls that are unrecoverable such as falls into water. The work shown here describes efforts to extract total mass, size distribution, and mechanical toughness information from radar data.

Methods: NOAA operates the NEXRAD weather radar network to provide nonstop coverage of the U.S. and disseminates realtime and archived radar data for public use. While the network is designed to monitor weather, any meteorite falls which occur within range must fall through its interaction volume and may be detected. Meteorite falls are found in radar data by searching radar imagery at the time/date of candidate events cued by eyewitness reports collected by the American Meteor Society (www.amsmeteors.org), news reports, social media, or other sources.

At the terminus of the luminous phase of a fireball, surviving meteorites fall ~18-30 km to the ground and are aerodynamically size sorted. Meteorites 10 kg in mass reach the ground in ~120s, while 0.1g fragments take ~720s. Radar sweeps then intersect this size-sorted curtain of falling meteorites (Figure at right). Each radar sweep measures reflected radar power (in decibels; dBZ) which is proportional to the total radar cross section (RCS, σ) area of the meteorites in that sweep volume.



Previous studies of meteorite fragmentation dynamics show that meteorite size distribution follows a power law function [e.g. 4,5], and so measuring that function will yield the mass and other properties. The fireball terminus height (h_T), time (t_T), and entry angle (θ) can be measured or estimated, and since h_i and t_i are known for each radar sweep, the mass of the meteorite(s) that traveled across Δh in Δt can be calculated with a dark flight model (e.g. Jörmungandr, v.42). The number (n_i) of meteorites per mass (m_i) is a function of total radar reflectivity recorded in a given sweep. Finding n_i requires a series of steps which, 1) correct the radar's assumption that it is observing water droplets, 2) re-calculate the measured reflectivity value as if it were arising from a single flat-plate reflector with a calculated radar cross section (σ_i), 3) calculating the RCS of each m_i (σ_{MET}) while incorporating Rayleigh, Mie, or Optical reflection behavior as required, and finally 4) finding $n_i = \sigma_i/\sigma_{MET}$. Data from multiple radar sweeps yields a set of points on the size distribution graph (Figure, above) which is fit with a power-law curve to yield the mass/size distribution of the fall. Subsequent data analysis can generate measures of relative size distribution, mechanical toughness, total mass, and "findable mass" or the portion between 1g and 1,000g that is most commonly retrieved.

Initial results indicate that the recent (06 Feb 2017) fall into Lake Michigan ranks among the largest falls of the past 20 years. Interesting trends appear in the data, to include fragmentation behavior of small falls such as Grimsby and Lorton, and of different meteorite types. Additional work is needed to reduce analytical uncertainties. Measurements of the dielectric constant of fusion-crusted meteorites are needed. Accurate determination of h_T, t_T, and θ is needed from future meteorite falls, and a calibration of fall dynamics and radar reflectivity per mass of meteorites would appreciably refine results for all past and future meteorite falls.

References: [1] Fries, M., et al *79th MetSoc* (2016) Abstract #6536. [2] Jenniskens P. et al *Science* **338** 6114 (2014) 1583-1587. [3] Fries M. and Fries J., *MAPS* **45**,9 (2010) 1476-1487. [4] Ceplecha, Z., et al. *Astronomy and Astrophysics* 279 (1993): 615-626. [5] Borovička J. and Kalenda, P. *MAPS*, *38*,7 (2003) 1023-1043.