NIMROD UK Radar Data Use in Tracking and Locating UK Meteorites Falls

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Introduction: Many meteorites in the extraterrestrial sample collection are collected via expeditions to deserts. These expeditions do not provide orbital information of the meteorites recovered, with other issues such as terrestrial contamination during the meteorites' terrestrial residence. In recent years, the use of weather radar data has been used in both the USA [e.g., 1] and Australia [e.g., 2] utilizing the open-source NOAA NEXRAD data, with over 3 dozen falls recovered so far. In the UK, after the collection of the Winchcombe meteorite in 2021 hours after landing [3] following observation by UK meteor camera networks – UK Fireball Alliance (UKFAll), successful retrieval has not been repeated due to the large search areas calculated, notably the Shropshire fireball in 2022, where field searches failed to locate any material. This study aims at utilising UK radar data at tracing a fireball's "dark flight", when it no longer emits light, using Winchcombe fireball observation as a training model, and refining the strewn fields of the potential meteorites of the Shropshire and South Wales fireballs.

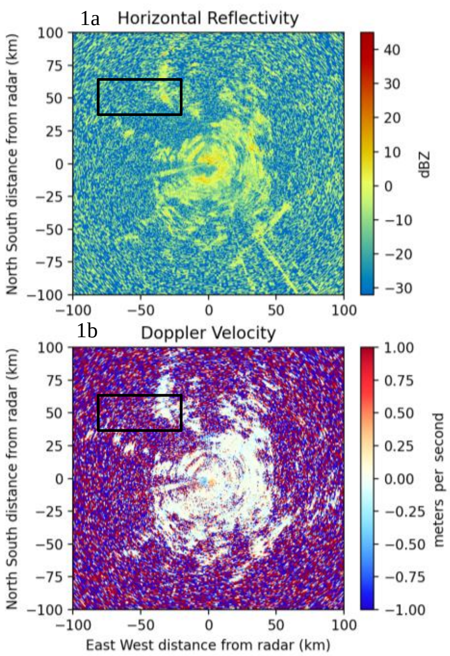

Fig 1a: Reflectivity that would reflect off meteoritic material. 1b: Doppler Velocity that would show movement and direction of material. Area of interest is marked.

Method: We used UK Meteor Data Archive [4] to collate candidates of recent fireballs. Factors for candidate selection are: (1) photometric mass calculated, (2) deceleration from entry to under 5km/s, (3) lowest observed altitude as survival of atmospheric entry as meteorite sample is only likely when ablation finishes below 30km, and (4) possible landing destination (on land rather than at sea). The following candidates have been identified: (1) Winchcombe (2021), (2) Shropshire (2022), (3) South Wales (2022). The turbulent path a hot meteorite material leaves during descent as it moves in an aerodynamically limited velocity can be visible on Doppler radar for approximately 2-5 minutes [1]. This turbulent signature can be traced on Doppler scans and is generated by fast moving large meteorites [1]. Out of the 18 stations operated by the Met Office, the closest 2-3 stations to each meteorite are coincidentally Clee Hill, Chenies, and Hameldon Hill. Plots were generated that covered the path of a meteorite from the last known location through the 5 volumes. These volume scans are taken at 0.5°, 1°, 2°, 3°, and 4° above ground level to cover up to 60km altitude at 200km distance from the radar station. These locations and times of weather radar data were used which include one hour either side of an observed fireball event, shown here using Clee Hill radar data of the Shropshire fireball observed at 23:45, at an elevation of 3° (Fig 1). We used the Doppler and reflectivity plots taken every 5 min for long pulse and 10 min for short pulse to increases short range detail.

Results and Discussion: Sweeps at 0.5° are not usually useful due to the contamination buildings, trees and wildlife can cause [1], and the "noise" seen in Fig 1 can be attributed to these factors despite taken at 3°. Met Office's ground filtered data that has had much of this superfluous data reduced by removing known features such as ground topography. The reflectivity data (Fig 1a) will show scattering of dust to meteorite fragments as yellow or orange signatures, up 20dBZ, usually moving along a line, and the Doppler data (Fig 1b) will show the movement and direction of an object. The strewn field calculated based on trajectory and mass is shown as black boxes in Fig 1. This means the reflectivity and Doppler plots can be used to trace the meteorite signatures through its atmospheric entry. Although we have not yet identified a meteorite on these scans, the Doppler velocity plots and reflectivity plots can be used to identify the debris and turbulence generated closely behind the Shropshire meteorite and can be traced through the volumes to near ground level. This is where dark flight calculations are utilized to create a likely landing location. The weather data will also be used to assess the likelihood of a successful retrieval along with a retrieval window, so future falls may have search teams mobilised within a time frame to limit terrestrial contamination (e.g. collect before a meteorite is rained on).

Conclusion: Further examination of the ground filtered data following fireball events through refinement of the program will result in strewn field confinement that can then be assessed for meteorite sample retrieval probability.

References: [1] Fries M. and Fries J. (2010) *MAPS*, 45(9), pp. 1476–1487 [2] Anderson, S.L. *et al.* (2022) *The Astrophysical Journal Letters*, 930(2) [3] King, A.J. *et al.* (2022) *Science Advances*, 8(46) [4] UK Meteor Data Archive (2013-)