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User Guide: A Curated Dataset of Regional Meteor Events with Simultaneous Optical and Infrasound Observations

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ABSTRACT

This user guide supports a curated dataset of 71 meteor events recorded between 2006 and 2011 in Southwestern Ontario, Canada. Each event was simultaneously observed by ground-based optical cameras and an infrasound array, providing a rare opportunity to examine meteor trajectories and acoustic signals from the same atmospheric entry events. The dataset includes raw and processed optical data, meteor trajectories, photometric light curves, infrasound waveforms, and atmospheric specifications relevant for acoustic modeling. The archive is structured to support reproducible research in meteor physics, atmospheric acoustics, and shock wave analysis. It is organized following transparent file naming conventions and structured folders to facilitate scientific reuse, comparison, and integration across research domains. The dataset is freely available on Zenodo, doi: 10.5281/zenodo.15868512.

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This dataset is intended to support open, reproducible research in meteor physics, atmospheric infrasound, and planetary science. If you use any component of this dataset, please cite the Zenodo record (doi: 10.5281/zenodo.15868512) and associated publications listed in Section 8.

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ACRONYMS AND TERMS

Acronym/Term	Definition
CSS3	Center for Seismic Studies Version 3
CSV	Comma Separated Values
ECEF	Earth-centered Earth-fixed coordinate system
ELFO	Elginfield Infrasound Array
G2S	Ground-to-Space
HWM	Horizontal Wind Model
LC	Light Curve
miniSEED	A compact version of the Standard for the Exchange of Earthquake Data
NCPA	National Center for Physical Acoustics
PNG	Portable Network Graphics
SOMN	Southern Ontario Meteor Network
UKMO	United Kingdom Met Office
UTC	Coordinated Universal Time
WMPG	Western Meteor Physics Group
ZMILI	A file format

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1. INTRODUCTION

Understanding the atmospheric entry of meteoroids and the associated generation of infrasound requires high-quality, simultaneous optical and acoustic measurements [1]. While many meteoroid events are detected globally by individual sensors or networks, few datasets exist where both optical and infrasound observations are available for the same events, particularly at regional ranges (<300 km) where acoustic waveforms retain source-specific characteristics.

This curated dataset [2, 3] addresses that observational gap by providing structured access to a comprehensive archive of 71 meteor events produced by ~cm-sized meteoroids that were simultaneously detected by the Southern Ontario Meteor Network (SOMN) all-sky camera system [4-6] and the nearby Elginfield Infrasound Array (ELFO) [1]. These observations were collected between 2006 and 2011 during a coordinated campaign organized by the Western Meteor Physics Group (WMPG) at Western University in London, Ontario, Canada.

Each event in the dataset includes optical recordings, astrometric and trajectory solutions, and, in many cases light curve data characterizing the meteor's brightness profile. In parallel, infrasound waveform data were collected using ELFO and stored in both CSS3 (Center for Seismic Studies Version 3) and miniSEED (a compact version of the Standard for the Exchange of Earthquake Data) formats to ensure long-term compatibility. Two sets of atmospheric profiles are included: a legacy compilation based on models available at the time of initial analysis, including data from the UK Met Office (UKMO) [7] and the Horizontal Wind Model (HWM) [8], and a more recent set based on the Ground-to-Space (G2S) framework [9, 10].

This dataset is organized to support open, reproducible analysis. It is structured into well-documented directories, adheres to standardized naming conventions, and is compatible with commonly used research tools. It provides a foundation for the empirical evaluation of meteor-generated shock wave generation and infrasound propagation. In addition to supporting empirical studies, the dataset is well suited for methodological work involving acoustic signal detection, classification, and multi-sensor integration. It may also serve as a reference resource for planetary defense applications.

This user guide provides an overview of the dataset's organization and content, offering guidance on technical structure, file types, and usage considerations.

2. DIRECTORY STRUCTURE OVERVIEW

The dataset is organized into major subdirectories, each corresponding to a specific sensor type or data product: optical data, infrasound recordings, and atmospheric specifications. Within each of these, data are grouped by individual meteor events.

Each top-level directory (e.g., `/Optical_Data/`, `/Infrasound_Data/`, `/Atmospheric_Profiles/`) contains these timestamped subfolders for each event. The naming convention is consistent across all data types, allowing users to easily cross-reference data products associated with the same event.

`README` files are included in each main folder to describe the contents, file formats, and usage considerations for that data type. These provide documentation to support reuse of the data.

2.1. Top-Level Directories:

The dataset is organized into the top-level folders shown in Figure 1, each containing a distinct category of data products. A `README` file is included in each main folder to explain its structure, contents, and usage.

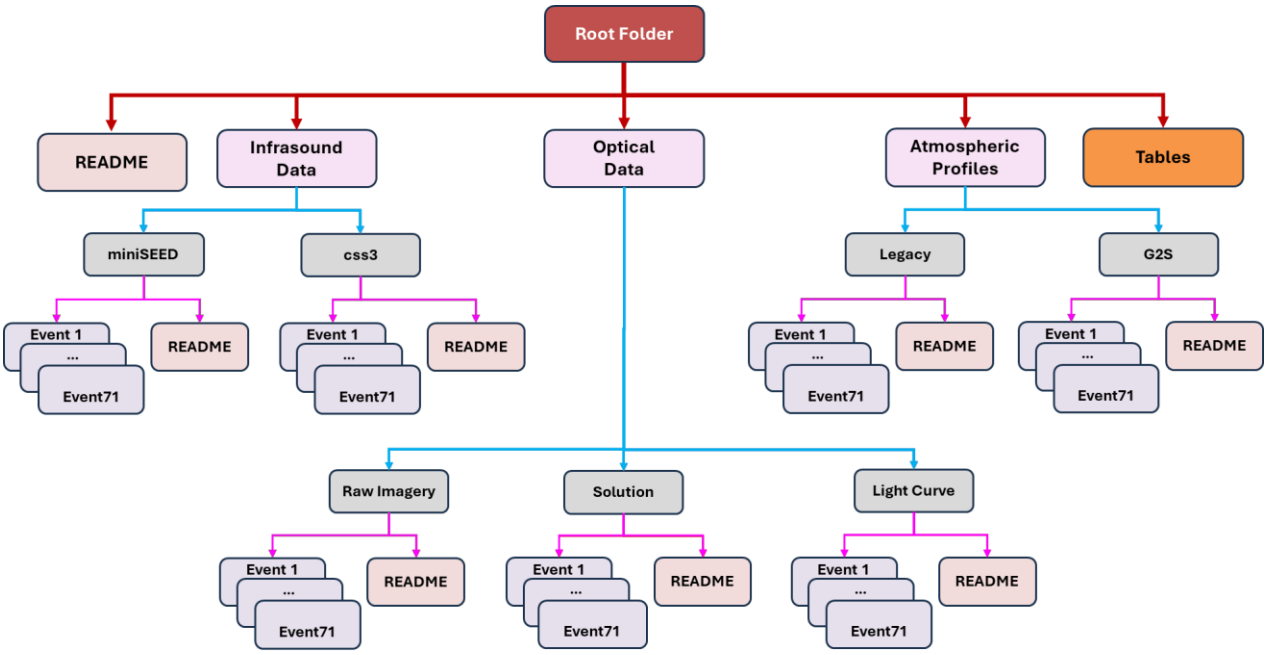

Figure 1. Diagram depicting the folder structure

A brief description of the folders is as follows:

- `/tables`: Summary tables with derived parameters for all events, including trajectory, acoustic arrival times, and energy-related information
- `/Optical_Data/Raw_imagery`: Raw optical imagery, plate files, and metadata from SOMN camera stations
- `/Optical_Data/Solutions`: Reduced trajectory and orbital solutions with supporting diagnostics

- `/Optical_Data/Light_Curves`: Published light curves with classification based on the meteor infrasound taxonomy proposed in Silber and Brown [1] (text and image formats)
- `/Infrasound_Data/Infrasound_CSS3`: Infrasound waveform data and metadata in CSS3 format (`.w, .wfdisc, .site`)
- `/Infrasound_Data/Infrasound_mseed`: Infrasound waveform data in `miniSEED` format (`.mseed`)
- `/Atmospheric_Profiles/Atmosphere_G2S`: High-resolution, event-specific atmospheric profiles in G2S format
- `/Atmospheric_Profiles/Atmosphere_Legacy`: Legacy profiles used in earlier analyses (text, CSV, and optional plots)

3. OPTICAL DATA

3.1. Astrometry Raw Files

Located in `/Optical_Data/Raw_imagery/`, this folder contains the original optical data captured during each meteor event. Files include raw video frames, still images, text logs, and plate solution files. These raw records support independent reprocessing and reanalysis of astrometric solutions.

Folder structure:

`/raw_files/yyyymmdd_hhmmss/`

File types include `.txt`, `.dat`, `.png`, `.avi`, `.m2v`, and `.plt`

3.2. Astrometry Solutions

Found in `/Optical_Data/Solutions/`, this directory contains the trajectory and orbital solutions derived from the raw imagery. Products include position vectors, velocity fits, trajectory reconstructions, orbital elements, and diagnostics.

Representative file types:

- `obs.dat` – raw vectors (ECEF format)
- `milig.txt`, `smets.txt` – trajectory/orbit solutions
- `zmili`, `ZMILI.DAT` – refined or final solutions
- `*.png` – diagnostic plots (e.g., residuals, timing, deviation)

3.3. Light Curves

Stored in `/Optical_Data/Light_Curves/`, this subdirectory includes calibrated light curve data (in `.txt` format) for a subset of events published in Silber et al. (2015), and normalized plots (in `.jpg` format) with infrasound source classifications:

- Green = cylindrical line source
- Red = fragmentation
- Yellow = indeterminate

Folders:

- `/LCs/` – raw light curve data (`ev*.txt`)
- `/figures/` – normalized plots (`*.jpg`)

4. INFRASOUND DATA

4.1. CSS3 Format

Located in `/Infrasound_Data/Infrasound_CSS3/`, this directory contains waveform recordings in CSS3 format. Each waveform file typically represents one hour of digitized array data starting from the time indicated in the filename.

4.2. miniSEED Format

Located in `/Infrasound_Data/Infrasound_mseed/`, this directory contains the same infrasound waveform data as `CSS3`, but in `miniSEED` format. This modern format is widely supported in acoustic and seismic analysis platforms. Each .mseed file contains one hour of data, typically covering one hours before and two hours after each meteor event.

5. ATMOSPHERIC PROFILES

5.1. G2S Atmospheric Specifications

Located in `/Atmospheric_Profiles/Atmosphere_G2S/`, these profiles were generated using the Ground-to-Space (G2S) model [8] developed by the National Center for Physical Acoustics (NCPA) [9]. Profiles are provided at 1-, 3-, or 6-hour intervals depending on availability.
Each `.dat` file contains:

- Altitude [km]
- Temperature [K]
- Pressure [mbar]
- Zonal/meridional wind components [m/s]
- Density [g/cm³]

Naming format: `g2s_yyyymmdd_hh.dat`

5.2. Legacy Atmospheric Profiles

Stored in `/Atmospheric_Profiles/Atmosphere_Legacy/`, these profiles were used in the original studies [1, 11, 12]. Each folder contains:

- `.txt` – profile with detailed header
- `.csv` – same profile in spreadsheet format
- `.png` – optional profile plots (temperature and wind vs. altitude)

These legacy files provide temperature, wind, and pressure structure and remain useful for replicating earlier works [1] and comparison or sensitivity studies.

6. TIMESTAMPS AND FILE NAMING

Each meteor event is indexed using a timestamp based on Coordinated Universal Time (UTC). The naming format used for each event folder is: `yyyymmdd_hhmmss`, where:

- `yyyy` = 4-digit year (e.g., 2006)
- `mm` = 2-digit month (01–12)
- `dd` = 2-digit day of the month (01–31)
- `hh` = 2-digit hour (00–23, in UTC)
- `mm` = 2-digit minute (00–59)
- `ss` = 2-digit second (00–59)

For example, the folder `20060419_042128` corresponds to a meteor event that occurred on April 19, 2006 at 04:21:28 UTC.

All data products use a common UTC-based timestamp:

- Folder names: `yyyymmdd_hhmmss`
- File names: Vary by data type, but typically follow `yyyymmdd_hh0000` to denote the start of a 1-hour data window

7. SOFTWARE COMPATIBILITY

This dataset is compatible with a wide range of scientific software platforms. Examples include:

- `ObsPy` (Python): For reading and processing waveform data and seismic metadata
- `MATLAB`: For numerical modeling, signal processing, data visualization, and working with waveform, trajectory, or atmospheric data
- Excel, Python (`pandas`, `NumPy`, etc.): For handling tabular data, summary files, and custom analysis
- `InfraGA` and other acoustic propagation tools: For modeling wave propagation using atmospheric specifications

These tools are provided as representative examples; users may employ any software that supports the included file formats. No proprietary software is required to access or analyze the dataset.

8. RELATED PUBLICATIONS

Users of this dataset are expected to cite at minimum this user guide (along with the Zenodo repository) and the associated data descriptor paper [3]. These references provide essential context for the structure, processing, and scientific relevance of the dataset. Additional peer-reviewed publications that informed the design and methodology of the archive are listed below for reference and may be cited where relevant.

Required citations:

- Data descriptor paper: Silber, et al. [3], doi: https://doi.org/10.3390/data10090138
- This report: Silber et al., SAND2025-10874
    - Also available at: https://doi.org/10.5281/zenodo.15868512
- Dataset: Silber, et al. [2], https://doi.org/10.5281/zenodo.15868512

Additional supporting publications (optional):

- Silber and Brown [1], https://doi.org/10.1016/j.jastp.2014.07.005
- Silber, et al. [12], https://doi.org/10.1002/2014JE004680

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