Title: NSSL Balloon-Borne Electric Field Meter Data

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1.0 Data Set Description

- Introduction: Balloon-borne Electric Field Meters (EFMs) were launched into lake effect snow bands during LEE to measure the electric field associated with these storms.
- The balloon-borne EFM provides in-situ measurements of a storm's vertical and horizontal electric field. The combination of the spin (powered by the instrument) and rotation (caused by lift through the storm) provides the modulation that enables measurement of the electric field.
- 8 different EFMs, flown multiple times, were developed and maintained by the National Oceanic and Atmospheric Administration / Office of Atmospheric Research / National Severe Storms Laboratory, OU / CIWRO, and TTU staff.
- Data set includes binary data files for each launch during the field project.
- Creation date: 9 November 2023
- Data Status: Final raw data; see usage note below.
- Time period:. All Intensive Operation Periods (IOPs) from 13 Nov 2022 through 11 Feb 2023.
- Physical location of the measurements: As listed in both the filename and contained in the data Latitude Longitude measurements within each file.
- Data file length: 2 min to 3 hrs

2.0 Instrument Description (Fig. 1)

- The balloon-borne EFM measures the charge induced by the background electric field on two rotating metal spheres.
- The component of the electric field is dependent on the orientation of the spheres. By spinning and rotating the instrument, the horizontal and vertical electric field gets modulated into the signal.
- Shortly after launch, a letdown system lets out additional line to separate the instrument from the balloon package by an additional 100 ft.
- In addition to the EFM, a GPS tracking system and a vaisala sonde were included in the flight.

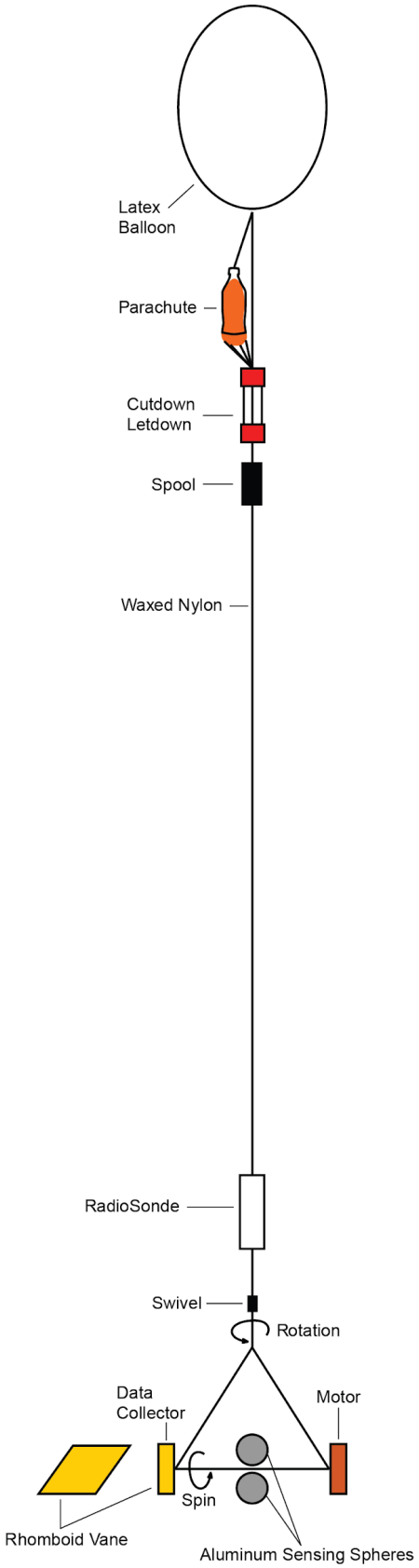

Fig. 1: Schematic of balloon train in flight. EFM package is below the swivel.

- Instrument package is retrieved manually from the landing location and data uploaded from the onboard SD card storage of the instrument.
- Estimated performance: The EFM instrument sample rate is 45.45Hz, but has an effective time resolution for the electric field much lower than this because of the modulation. For the vertical field, the time resolution is around 1Hz, and for the horizontal it is around 0.2 Hz.

3.0 Data Collection and Processing

- EFMs were tracked using GPS locations throughout flight and retrieved from their landing location following each IOP.

3.1 Usage note

As described below, the EFM data are in the raw binary format written by the instrument, and require significant QC and postprocessing to obtain measurements of the electric field. While the code referenced below may be used to process the data, ***interaction with the authors listed above is strongly advised***. As of this writing a merged radiosonde/EFM dataset is planned that will be more appropriate for science uses.

4.0 Data Format

The binary data includes all data measured once an instrument is turned on including pre-launch, flight, and post-landing .

Filename convention for flight data is “EFM_YYYYMMDD_HHMM_IOP#_location_NAME” provides the instrument name (EFM), date and time of launch (UTC), number Intensive operation period of LEE, the closest city/town to location of the launch, and the specific EFM launched. Filename convention for the calibration data is “EFM-CAL_YYYYMMDD_preIOP#_NAME”, where the date is the testing date of that EFM andthe IOP listed on calibration files is for the most recent record of when the instrument was tested, not when it was flown.

Two files are provided for each flight:

- Pre-flight instrument checkout data (“calibration”) that can be used to confirm the polarity of the processed electric field. During these checkouts, a charged sheet of foam was held in known compass-relative positions with respect to the instrument: typically above, below, north, then east of the instrument. North and east magnitudes are usually much lower. See the calibration notebooks linked below for a description of what was done on each day, as the procedure was not uniform across the campaign.
- Flight data

Code for processing balloon-borne EFM data is available here:
https://github.com/deeplycloudy/efmlib
Draft data processing notebooks for flight and checkout data are included in a branch under

development at the time of this writing:
https://github.com/deeplycloudy/efmlib/tree/max_e_dev/cases-LEE
These case notebooks will be updated as better processing is developed.

5.0 Data Remarks

- PI's assessment of the data during IOPs:
    - IOP 1, 20221113:
        - Launched EFM-Ice. Primarily a test flight; rain with mixed light snow. Little electric field.
    - IOP 2, 20221118-20221119:
        - Launched EFM-Rust, EFM-Sleet, and EFM-Graupel.
        - EFM-Sleet and EFM-Graupel had Analog Board orientation reversed. See pre-launch calibration notes below.
    - IOP 4, 20221218:
        - Launched EFM-Blizzard and EFM-Thunder.
        - Problem with the letdown/cutdown system on EFM-Blizzard. Instrument was closer to the balloon than ideal.
        - Neither EFM (Blizzard and Thunder) cut down automatically. EFM-Blizzard ascended until the balloon popped and Thunder was cut down by a manually triggered signal to the system.
    - IOP 5, 20221219:
        - Launched EFM-Snow. Only let down 25 ft.
    - IOP 6, 20230124:
        - Launched EFM-Rust. Graupel was at site during launch, but the snow band dissipated shortly after EFM was in the air.
    - IOP 7, 20230127:
        - Launched EFM-Sleet. Instrument cutdown system triggered 30 sec after launch by geofence boundary.
    - IOP 8, 20230128:
        - Launched EFM-Frost and EFM-Ice.
        - Problem with the letdown/cutdown system on EFM-ICE. Instrument was closer to the balloon than ideal.
    - IOP 10, 20230201:
        - EFM-Sleet – Difficulty during initial launch so instrument was shutdown while launch team reset. Instrument was restarted for a second launch and was cut down using the geofence boundary.
        - EFM-Thunder – Spin issues at start, batteries changed in field.
    - IOP 11, 20230203:
        - Launched EFM-Snow. Line letdown system failed and EFM remained too close to the balloon.
- Pre-launch calibration notes:

- On two instruments, the orientation of the circuit boards in the instrument were flipped, causing the interpretation of the electric field polarity to be reversed . These instruments are:
  - EFM-Sleet and EFM-Graupel during IOP2. Board orientation was corrected on 20221219 for EFM-Sleet (pre-IOP5); EFM-Graupel was not flown again due to damage from flight/landing during IOP2.

6.0 References

- Winn, W.P. and Byerley, L.G., III (1975), Electric field growth in thunderclouds. *Q.J.R. Meteorol. Soc.*, 101: 979-994. https://doi.org/10.1002/qj.49710143017
- Marshall, T. C., McCarthy, M. P., and Rust, W. D. (1995), Electric field magnitudes and lightning initiation in thunderstorms, *J. Geophys. Res.*, 100(D4), 7097–7103, doi:10.1029/95JD00020.
- Marshall, T. C., Rison, W., Rust, W. D., Stolzenburg, M., Willett, J. C., and Winn, W. P. (1995), Rocket and balloon observations of electric field in two thunderstorms, *J. Geophys. Res.*, 100(D10), 20815–20828, doi:10.1029/95JD01877.
- Rust, W. D., D. R. MacGorman, E. C. Bruning, S. A. Weiss, P. R. Krehbiel, R. J. Thomas, W. Rison, T. Hamlin, and J. Harlin (2005): Inverted-polarity electrical structures in thunderstorms in the Severe Thunderstorm Electrification and Precipitation Study. *Atmos. Res.*, 76:247–271..
- MacGorman, D. R., Biggerstaff, M. I., Waugh, S., Pilkey, J. T., Uman, M. A., Jordan, D. M., Ngin, T., Gamerota, W. R., Carrie, G., and Hyland, P. (2015), Coordinated lightning, balloon-borne electric field, and radar observations of triggered lightning flashes in North Florida, *Geophys. Res. Lett.*, 42, 5635–5643, doi:10.1002/2015GL064203.

7.0 Appendix

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