Electric Field Mills

On a balloon - a status update

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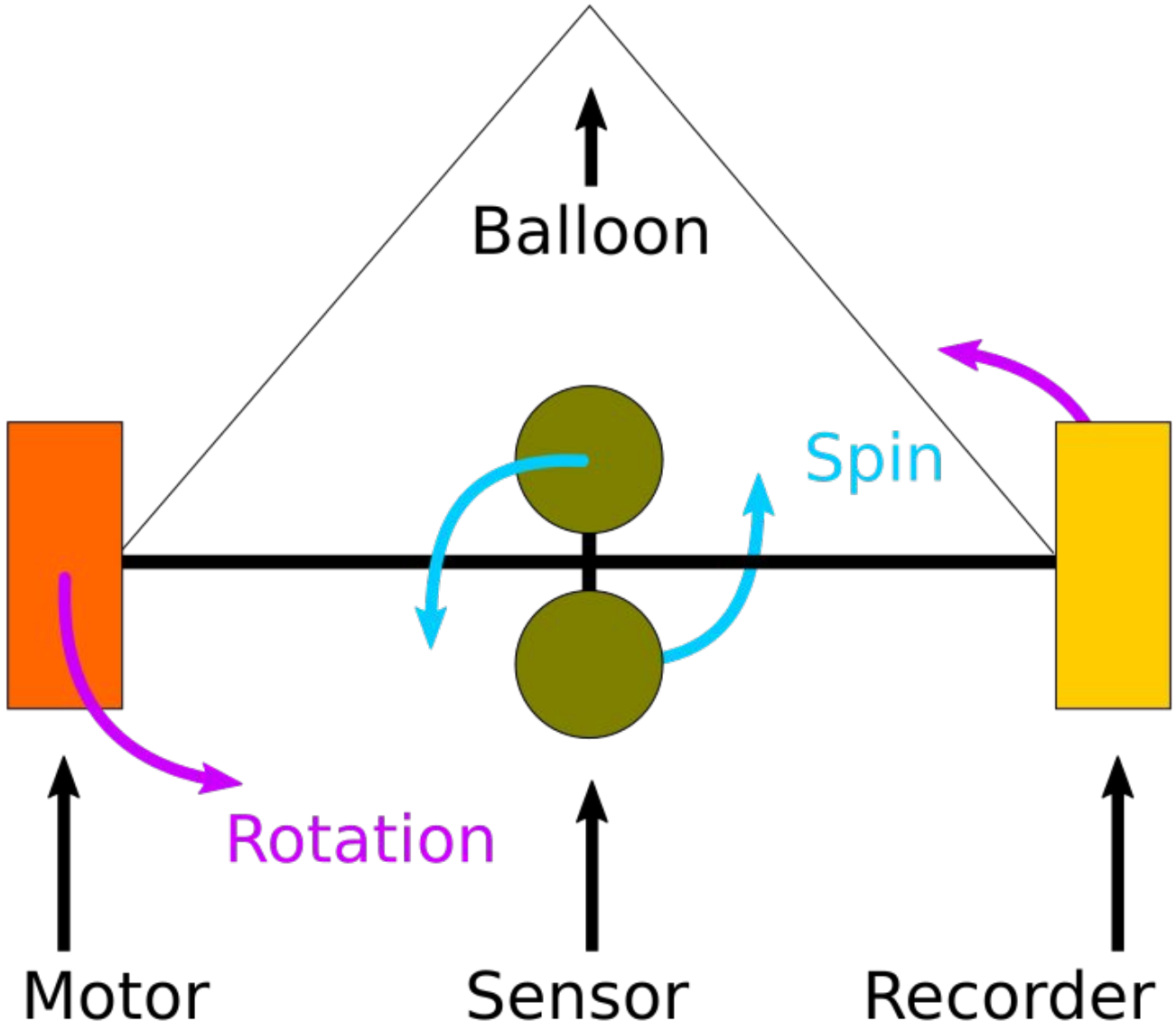
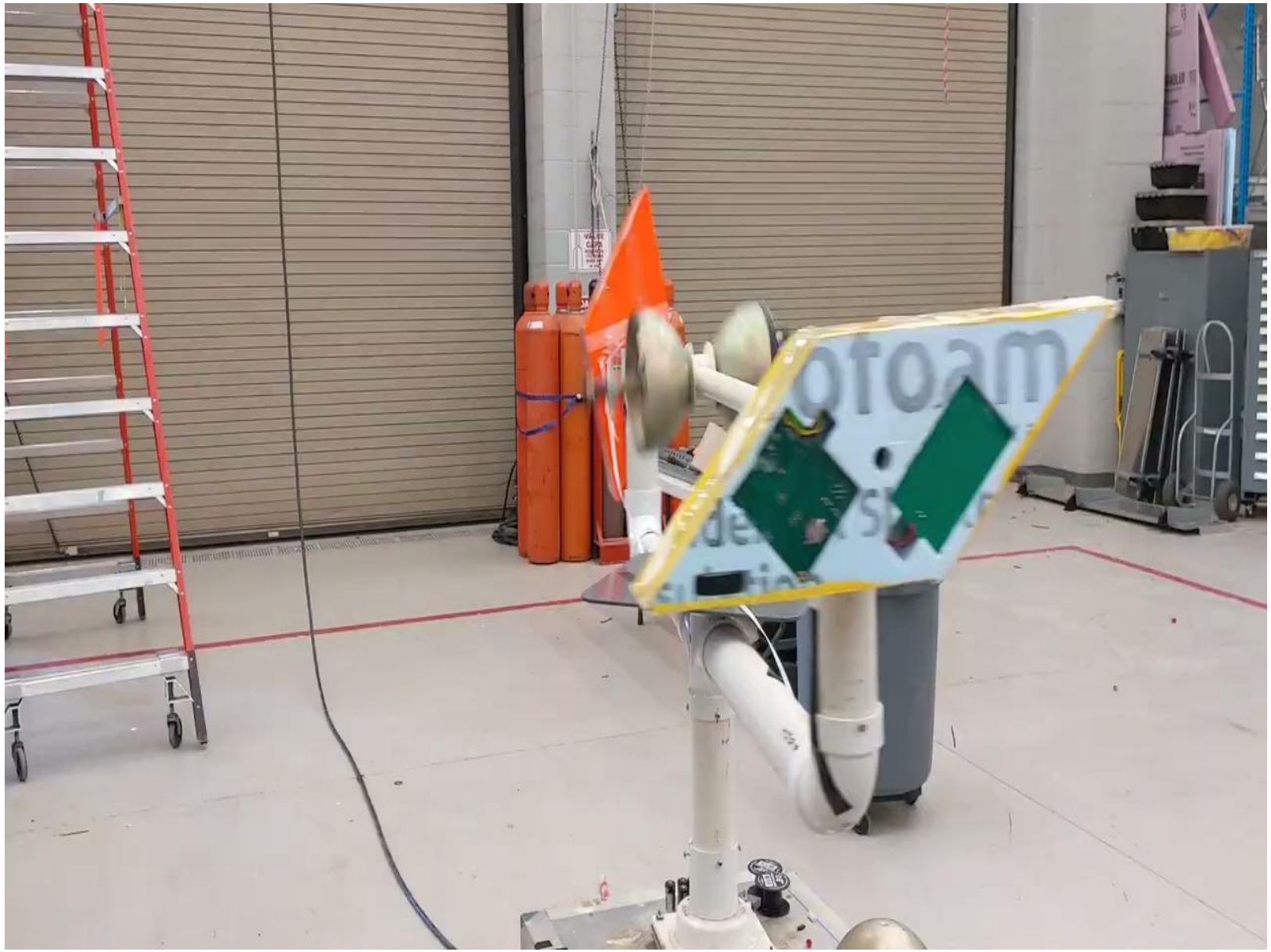
LEE Workshop, Oswego NY
July, 2023

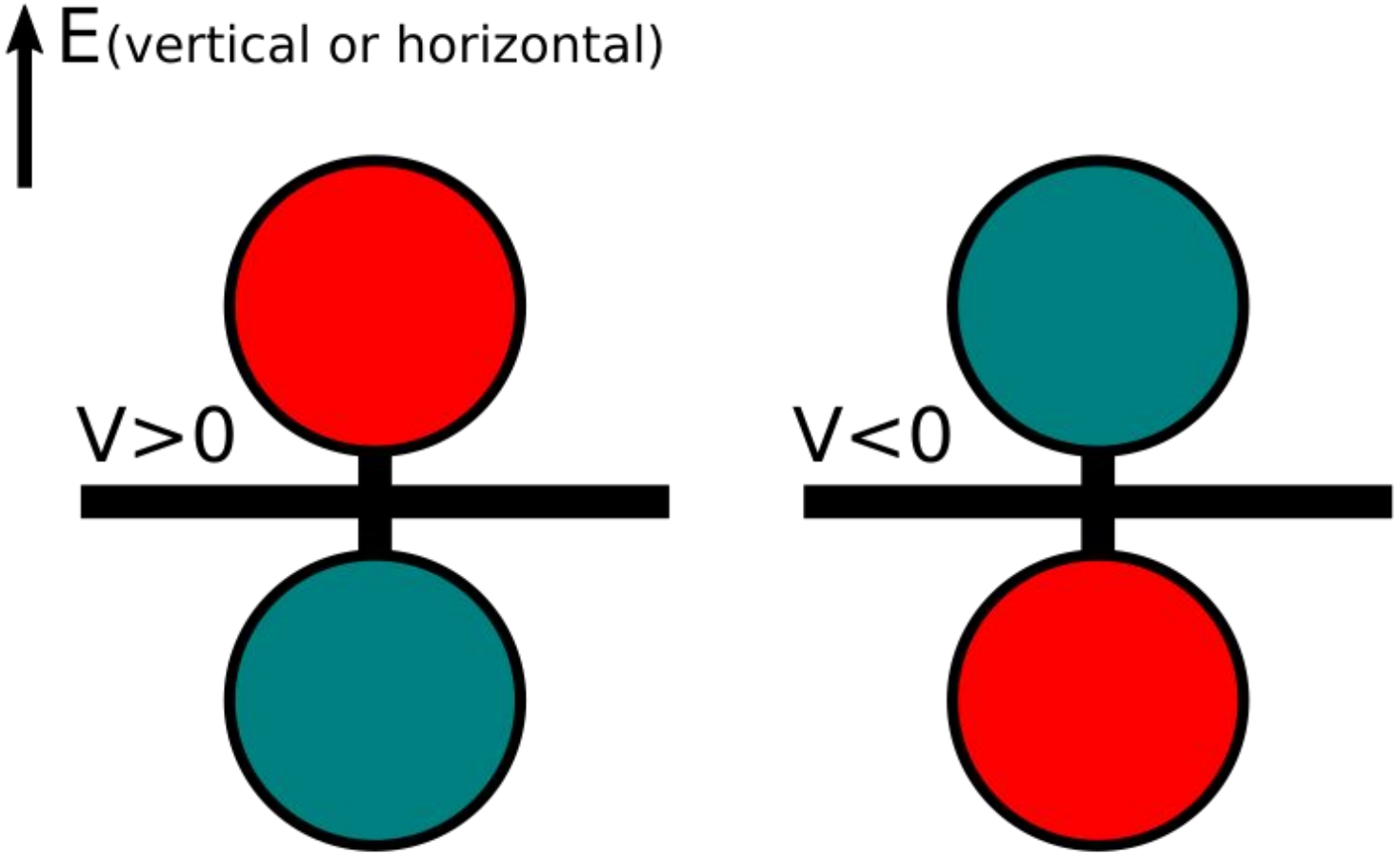
Diagram of the EFM



Testing video on rack



The EFM Signal

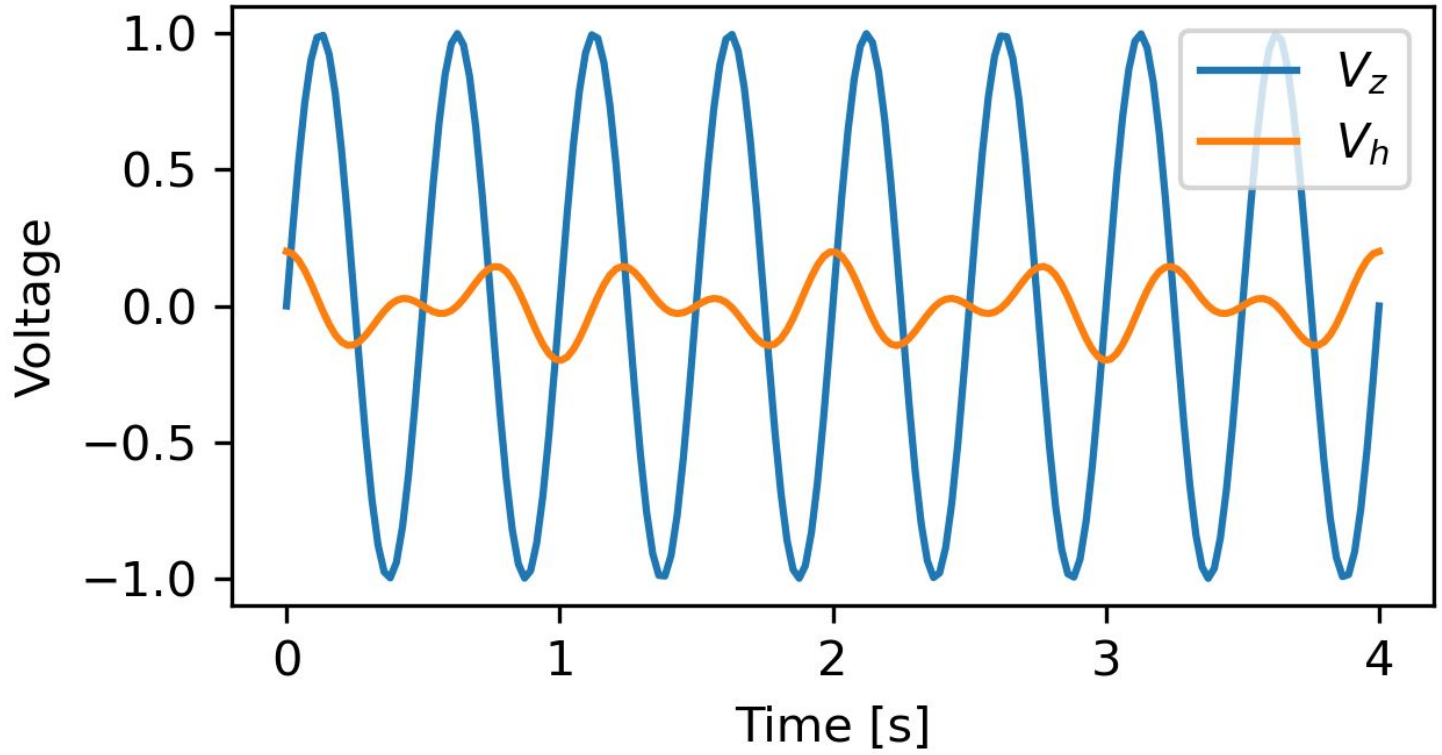


Just Spin

Spin and Rotation

$$V = E_z \sin(\omega_{spin} t) + E_h \cos(\omega_{spin} t) \cos(\omega_{rotation} t)$$

The EFM Signal (simulated)



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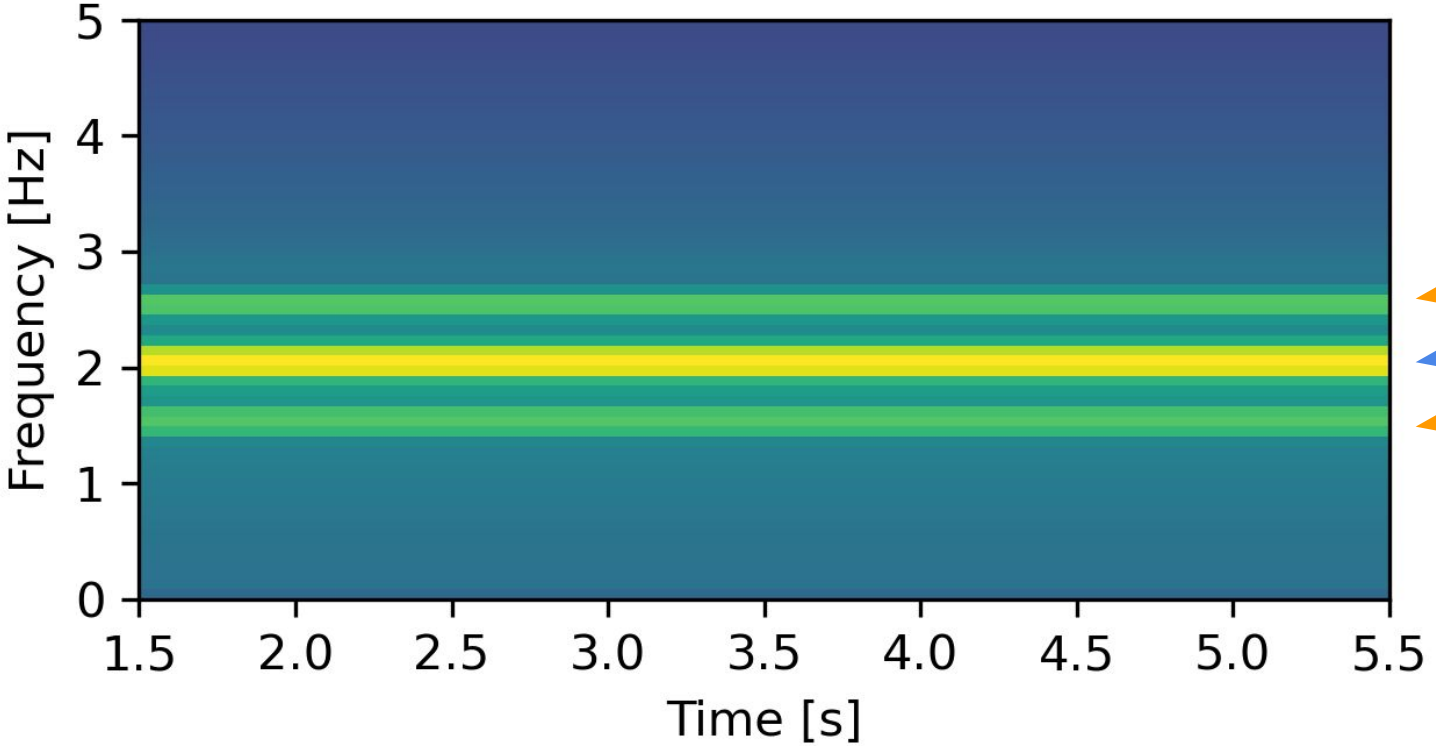


Horizontal Field

Vertical Field

Horizontal Field

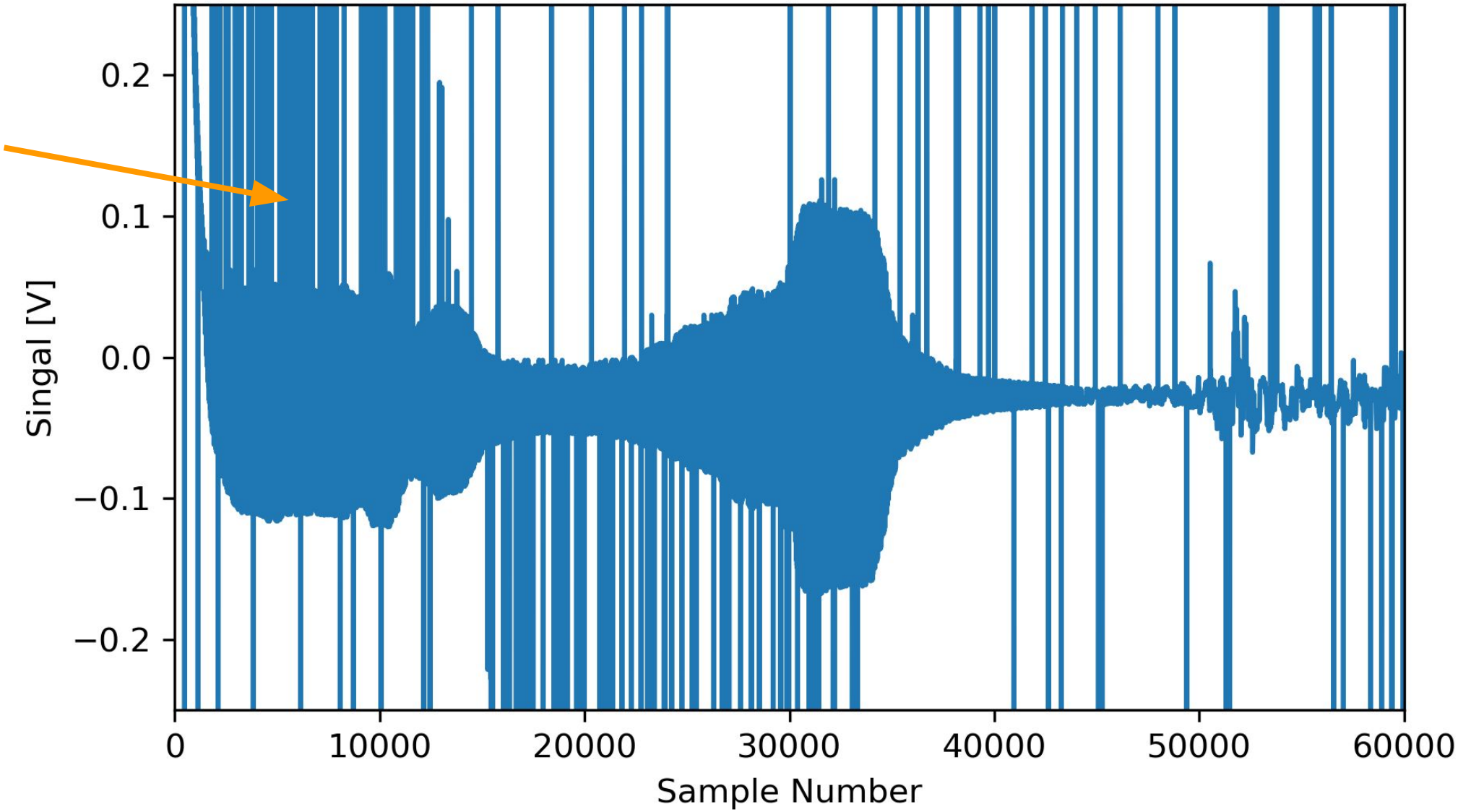
Just Spin

Spin and Rotation

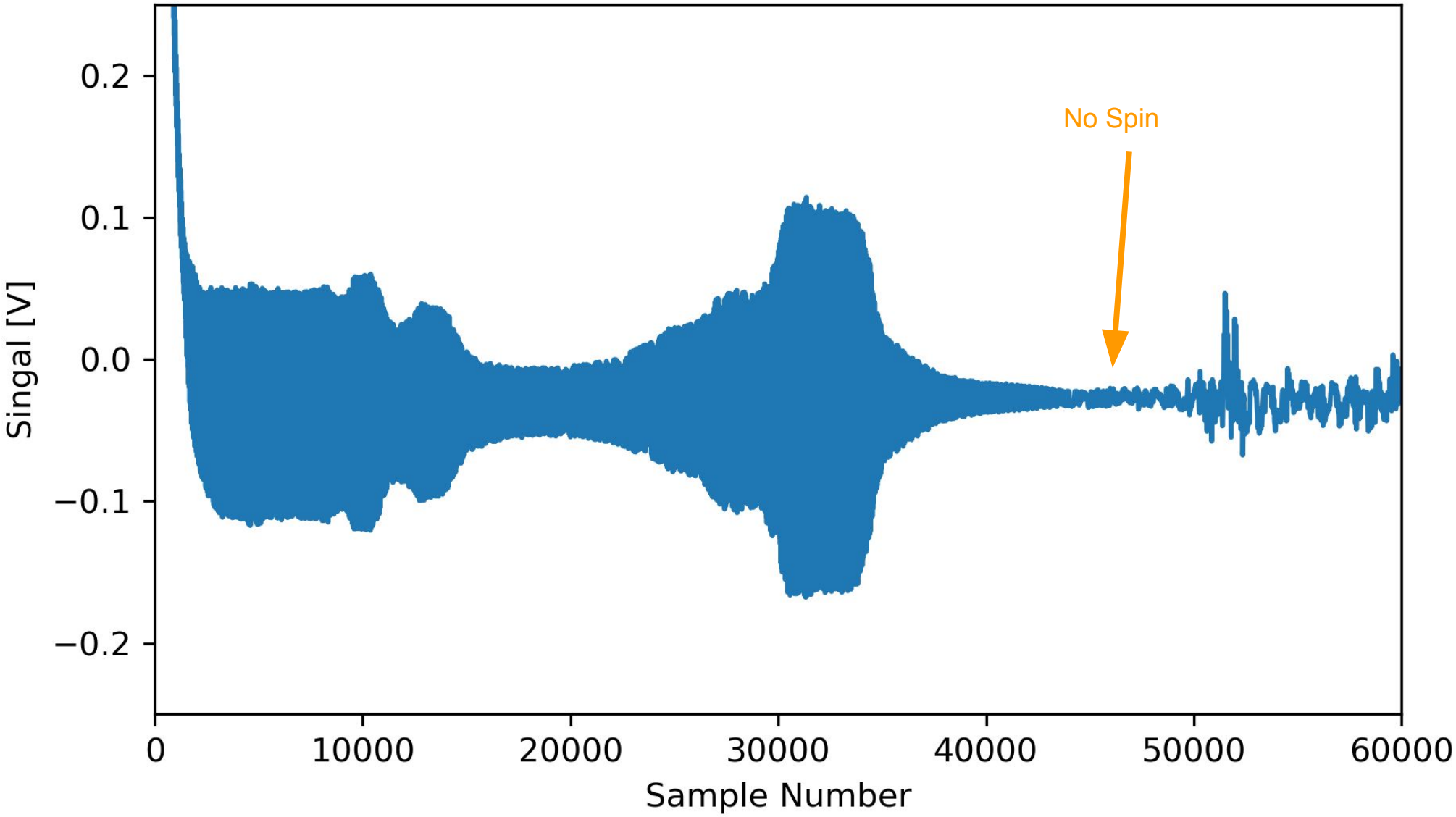
$$V = E_z \sin(\omega_{spin} t) + E_h \cos(\omega_{spin} t) \cos(\omega_{rotation} t)$$

The EFM Signal (IOP2 - Sleet)

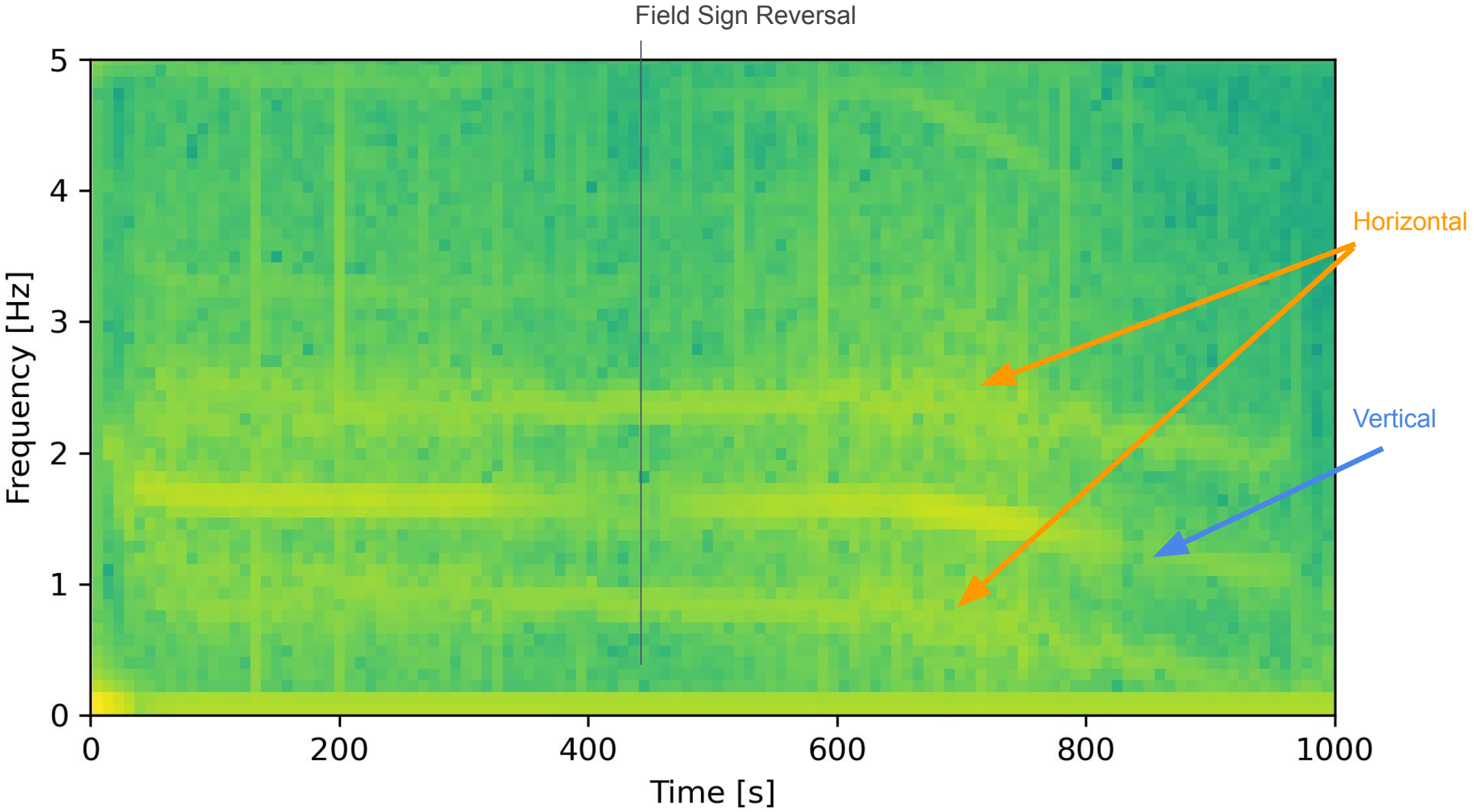
Recording Errors



The EFM Signal (IOP2 - Sleet)



The EFM Signal (IOP2 - Sleet)



EFM flight processing

All preflight lab data checked to confirm field polarity

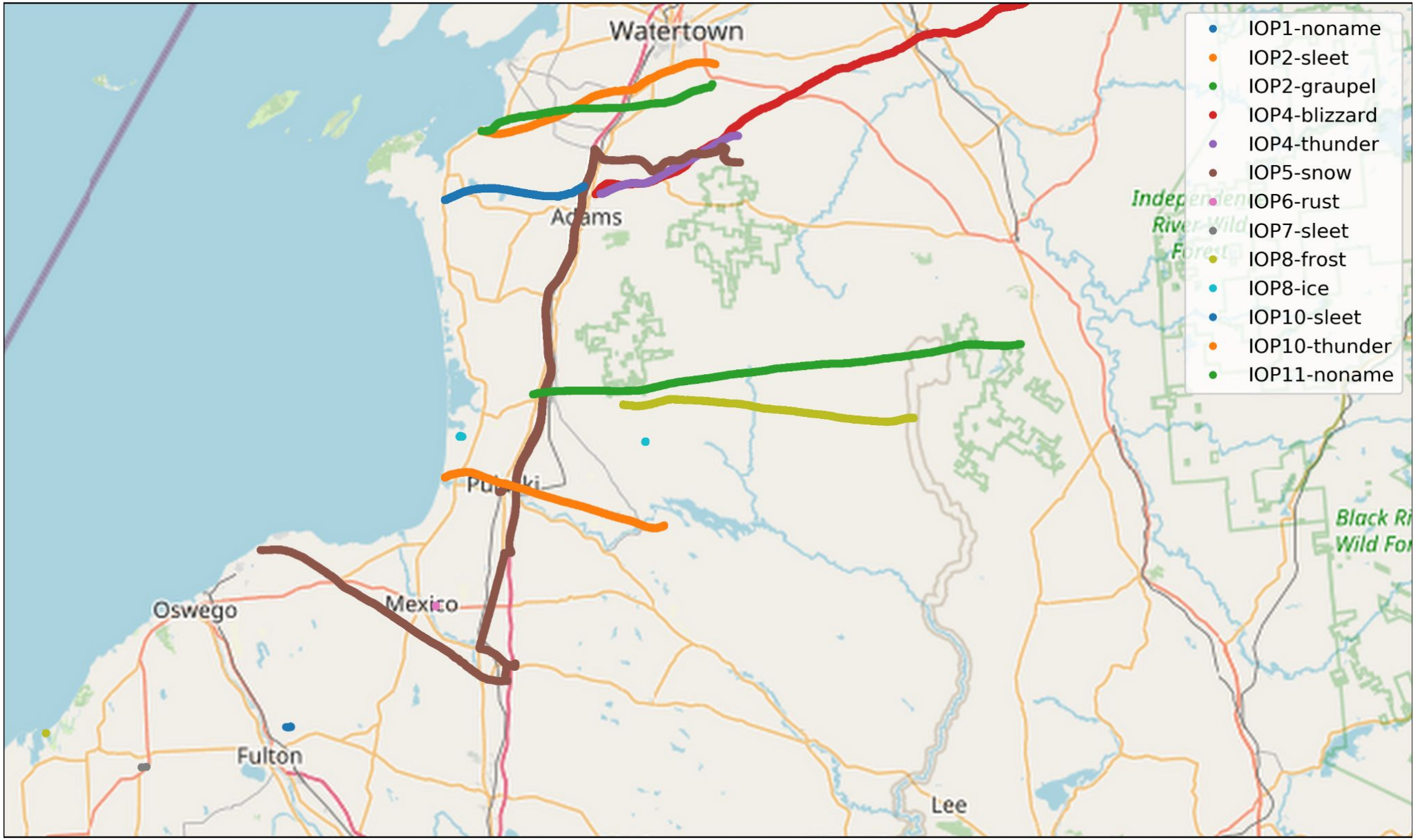
Electric field magnitude and vertical polarity calculated

- Goal is to assess which flights observed large E magnitudes and infer basic charge structure vs. altitude in cloud
- Charge density: look at order of magnitude: 0.1 nC/m^3 is meaningful, 1 nC/m^3 is a dense charge layer
- Signal processing will be refined. Data are noisier than they will be eventually (IOP2-Sleet has our first example)

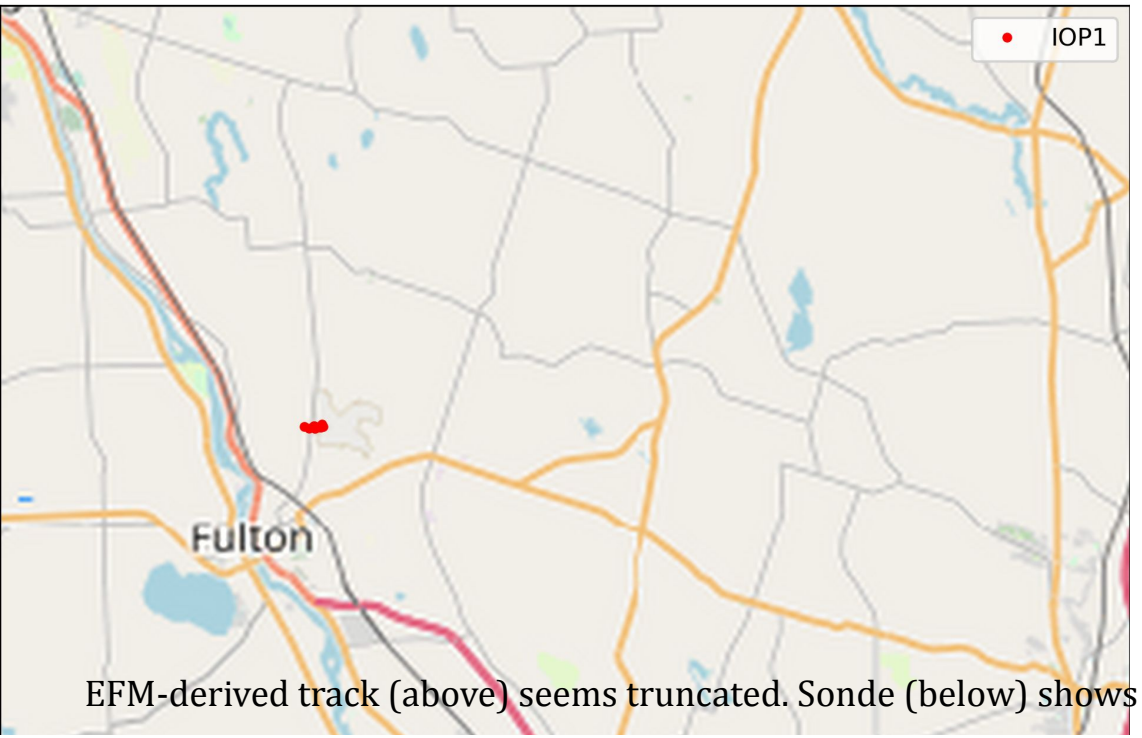
Merged with radiosonde data

- up and down soundings shown
- commonly, instrument partially or not spinning on descent
- check GPS ascent rate: updraft when ascent rate increases above mean ascent rate of ~5 m/s

All 13 flight tracks

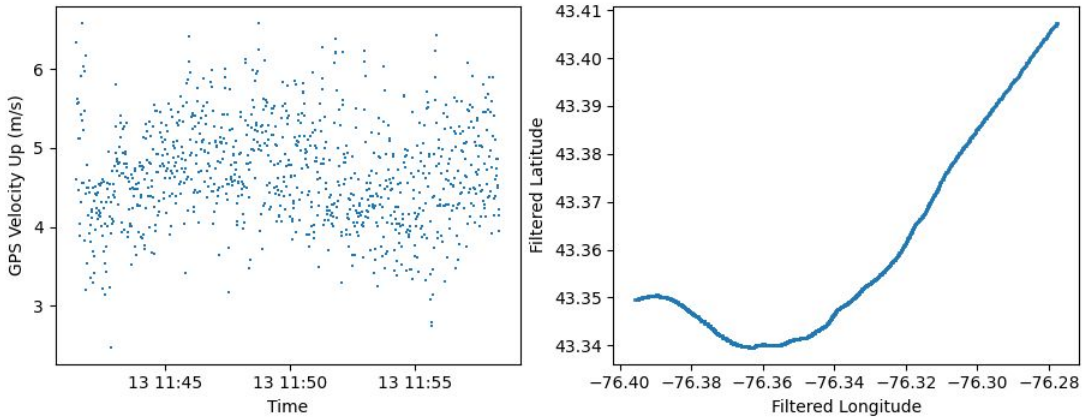


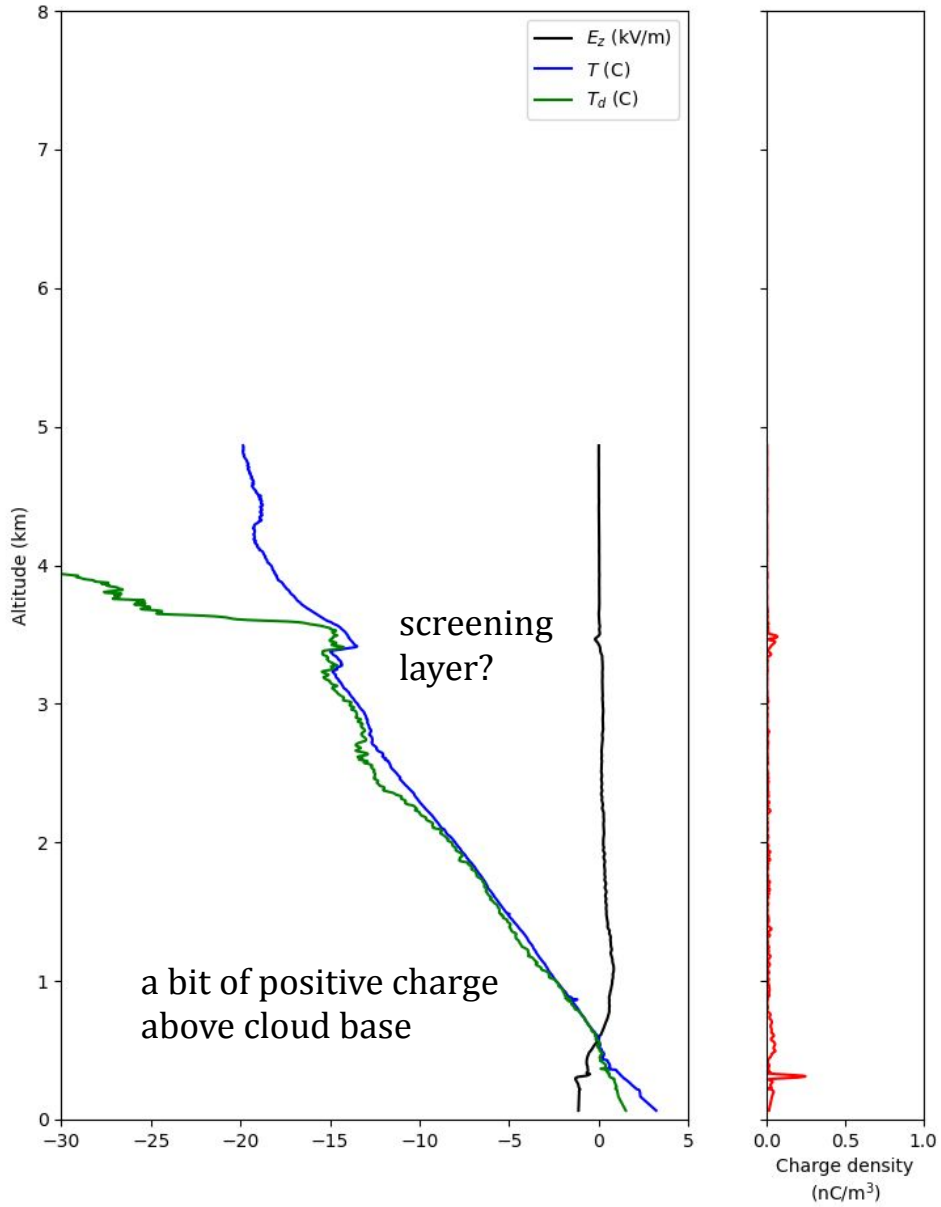
IOP 1 - 13 Nov 1141 UTC



Not much field strength or charge

EFM-derived track (above) seems truncated. Sonde (below) shows more.





IOP 2 - 18 Nov 2022

IOP 2 Rust - 18 Nov 2258 UTC

Charge densities moderately large

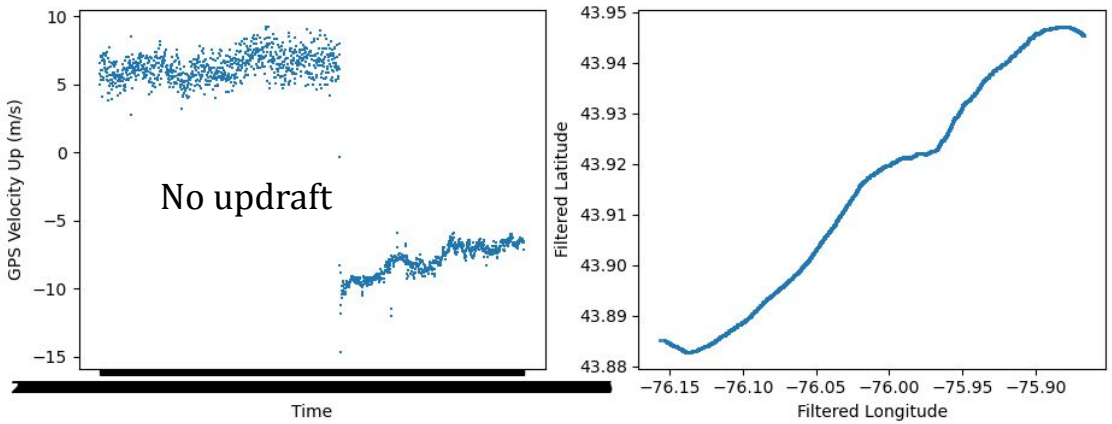
Up:

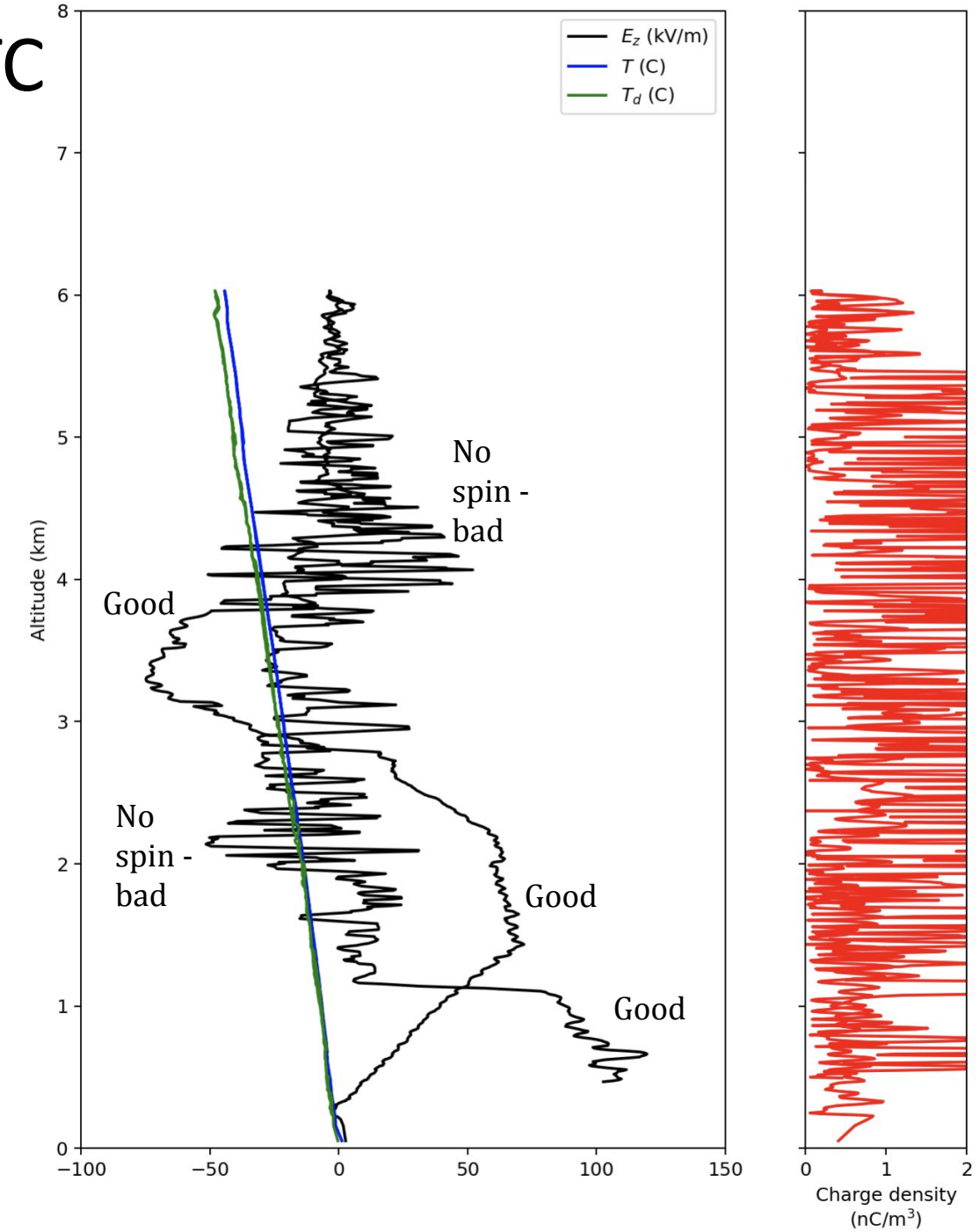
- Positive charge above 3.5 km
- Negative charge from 2.0 to 3.2 km
- Moderately deep (to 1.3 km) and dense lower positive charge

Down:

- No spin for most of descent
- When it returns, **we measured >100 kV/m at about 500 m MSL**!
- Landed about a mile southeast of Watertown.

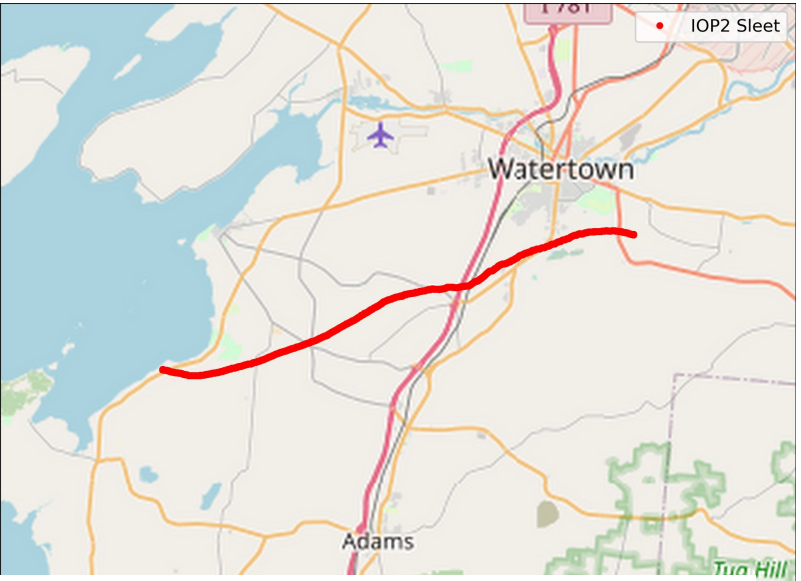
EFM-derived track seems truncated. Sonde (below) shows more.
Landed about a mile southeast of Watertown





IOP 2 Sleet - 19 Nov 0139 UTC

Improved next-gen EFM processing fixes noise problems.

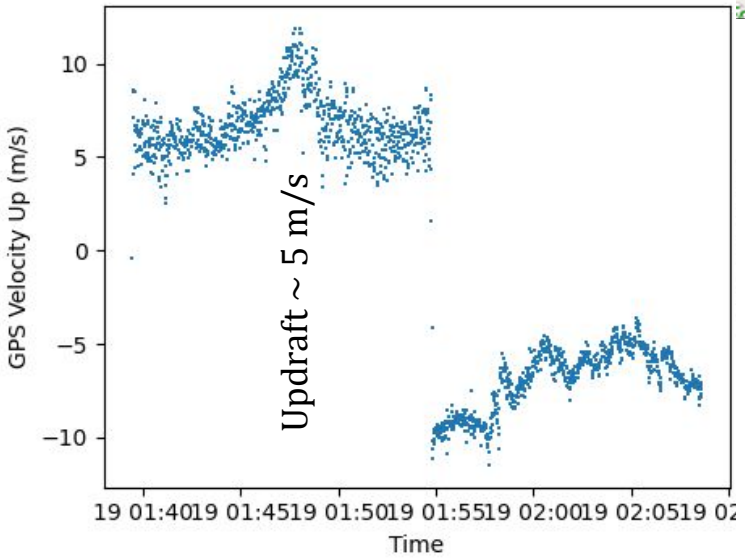


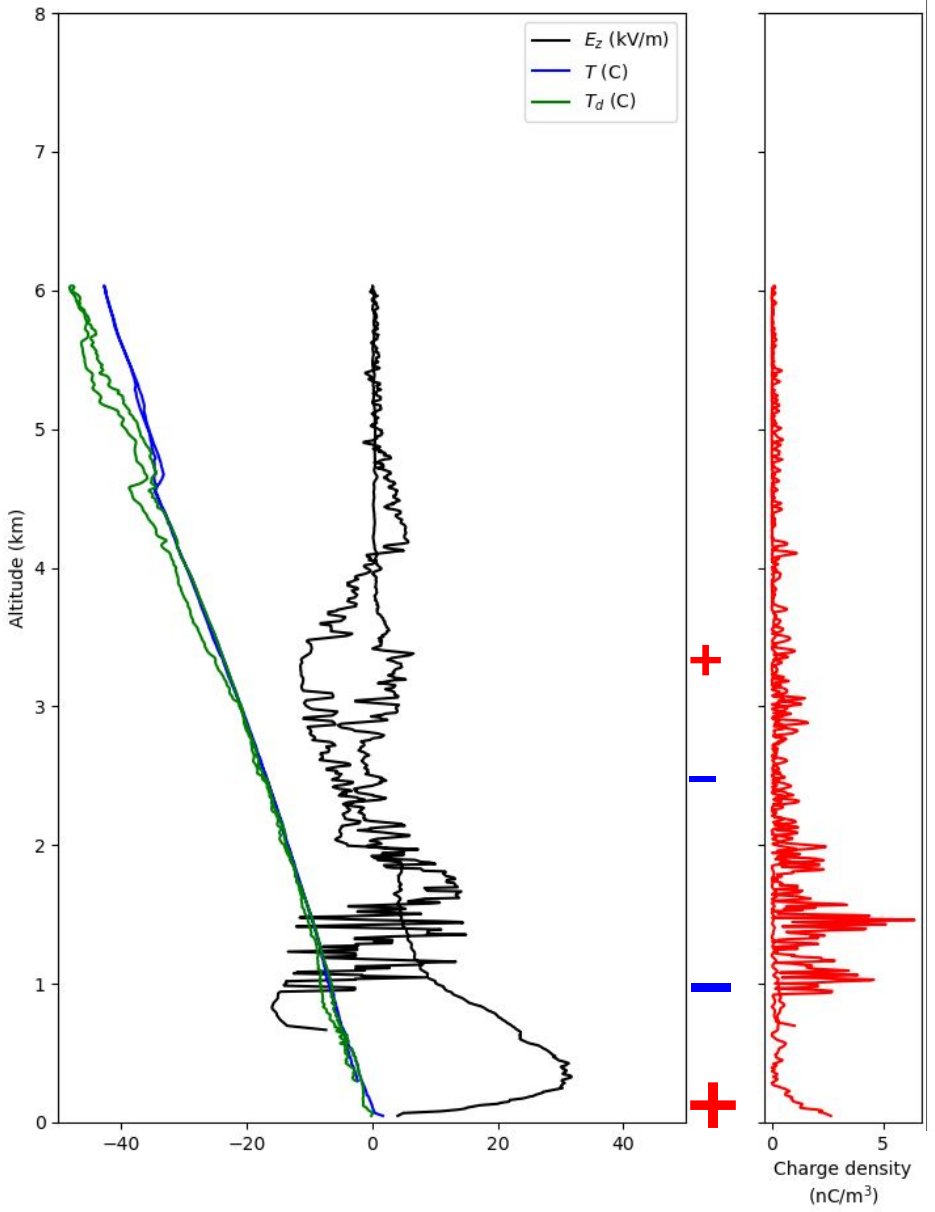
Preliminary charge structure

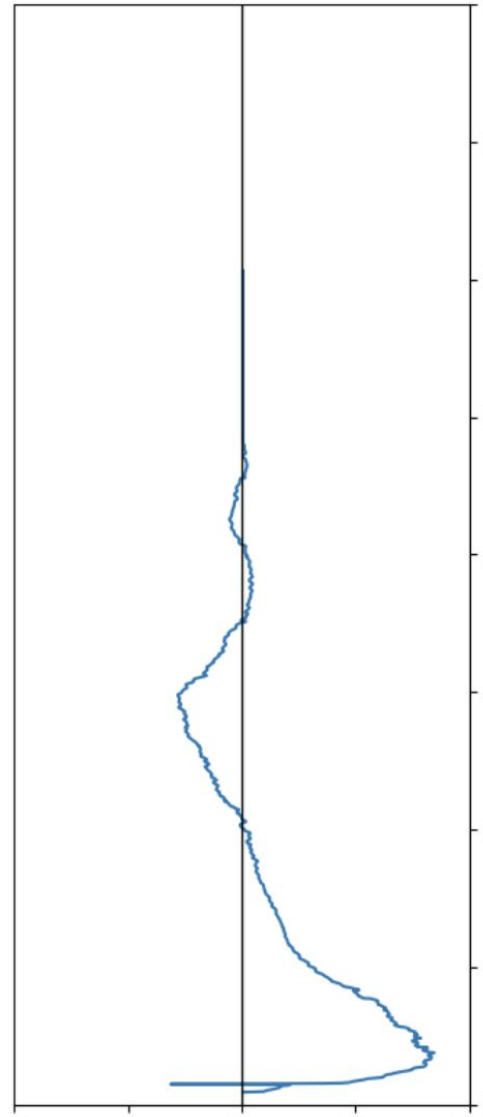
Probable upper positive layer at top of boundary layer

Deep negative layer, larger charge density below 1 km

Significant positive charge just above surface

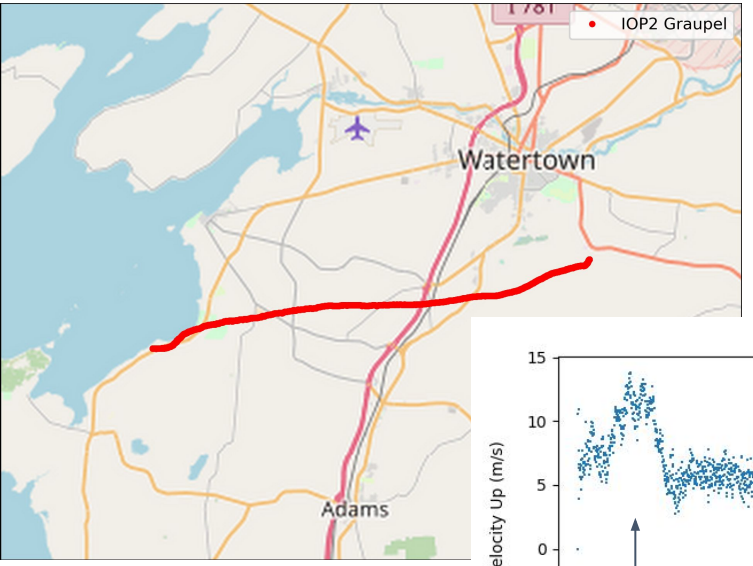


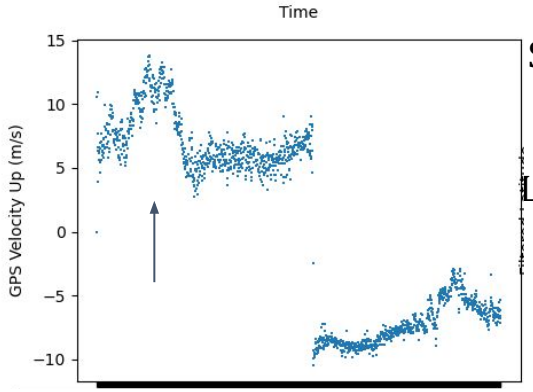




Up sounding only

IOP 2 Graupel - 19 Nov 0252





Preliminary charge structure

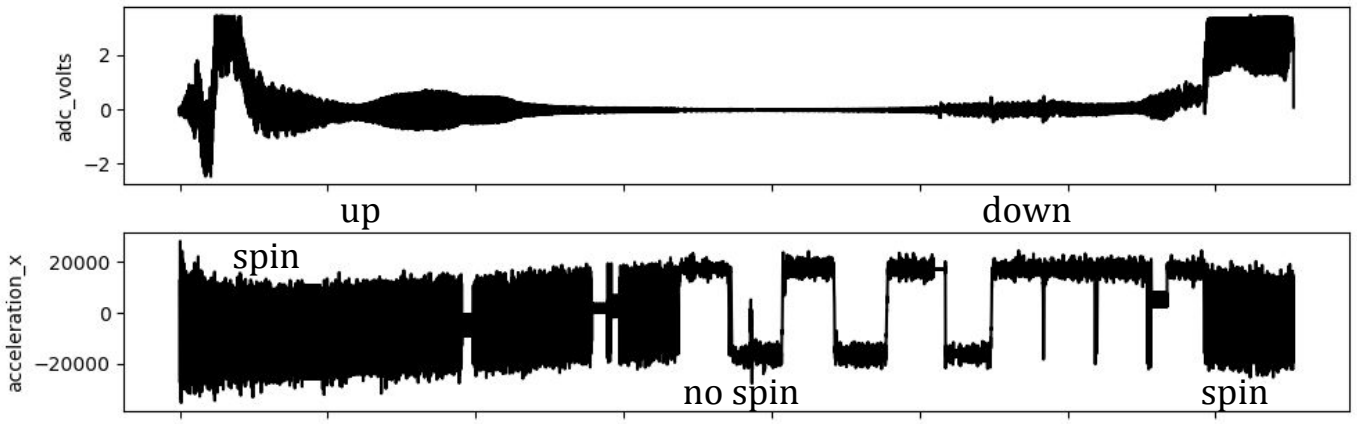
Probable upper positive layer at top of boundary layer

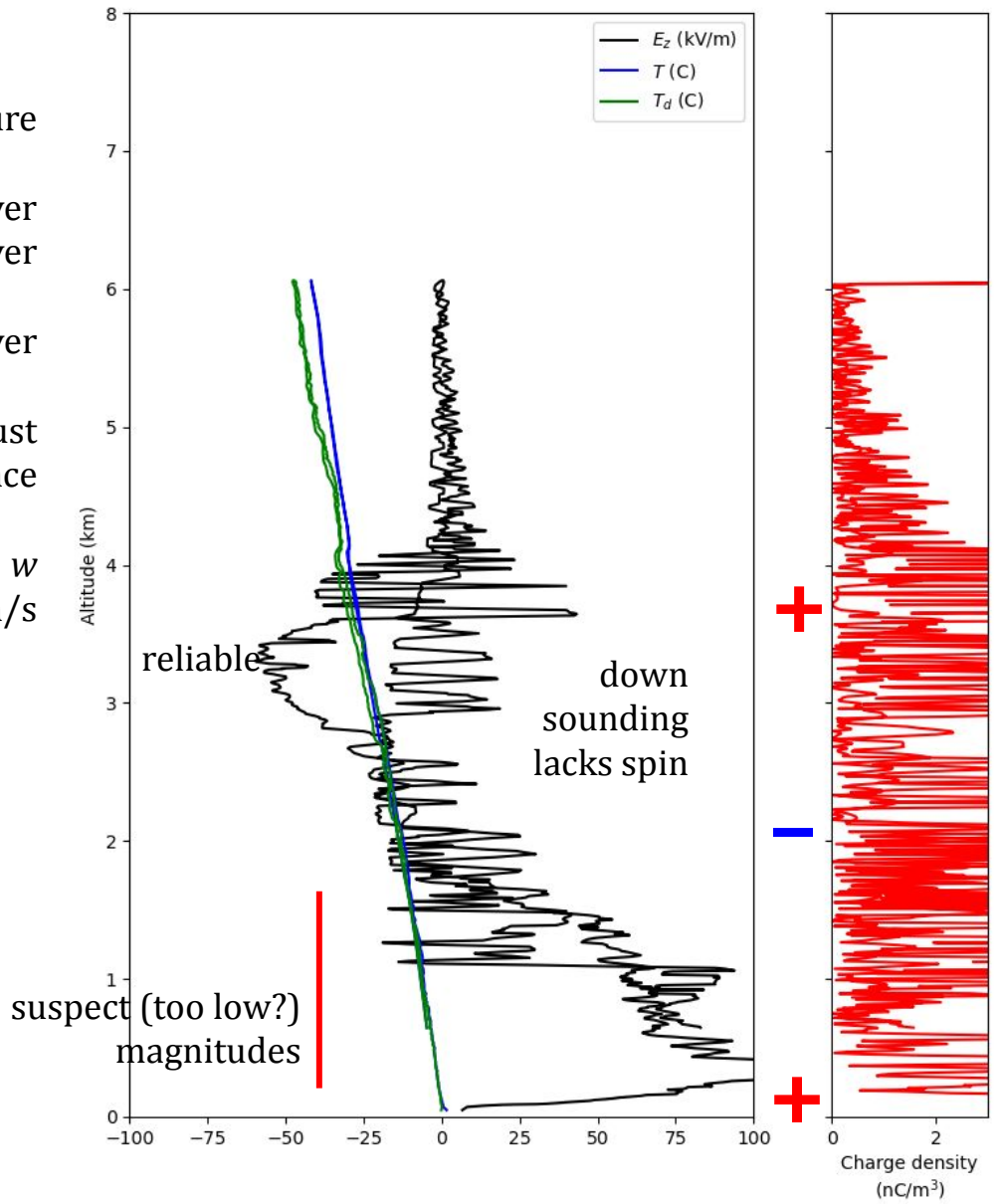
Deep negative layer

Significant positive charge just above surface

Largest updraft in campaign: *w* ~= 8 m/s

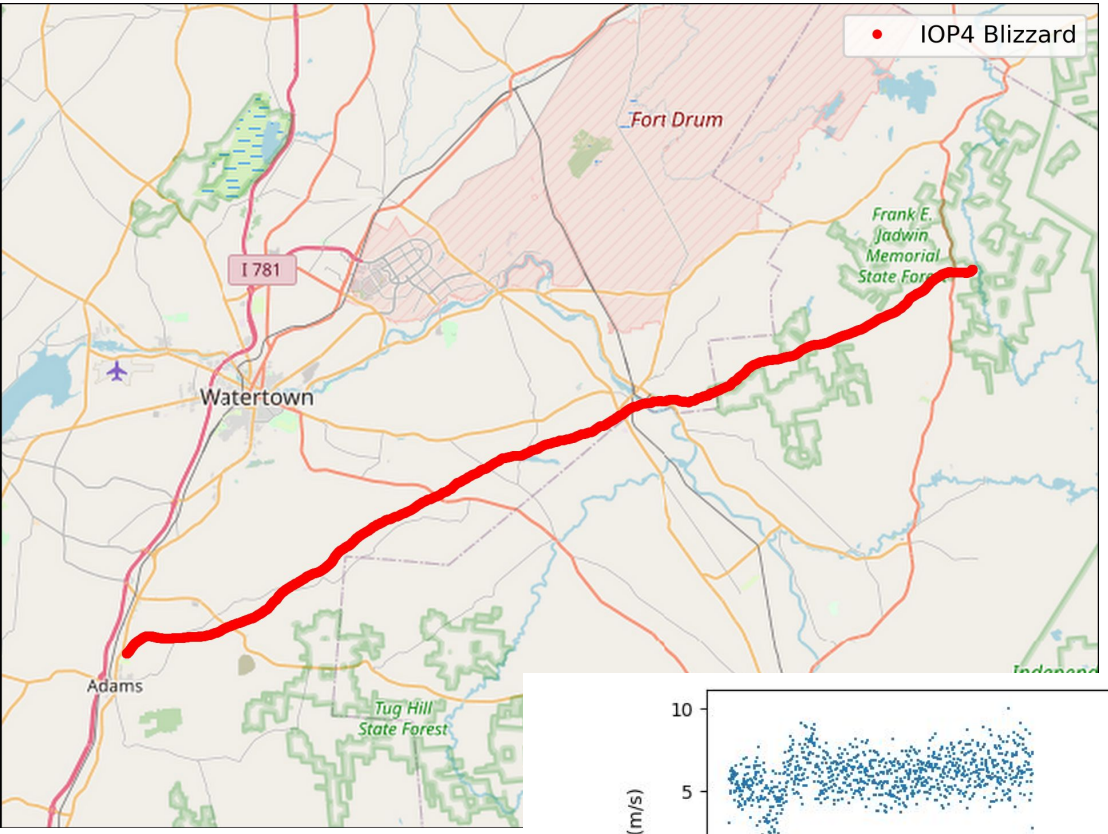
Clipped E due to baseline offset from accumulation of precip across spheres





IOP4 18 Dec 2022

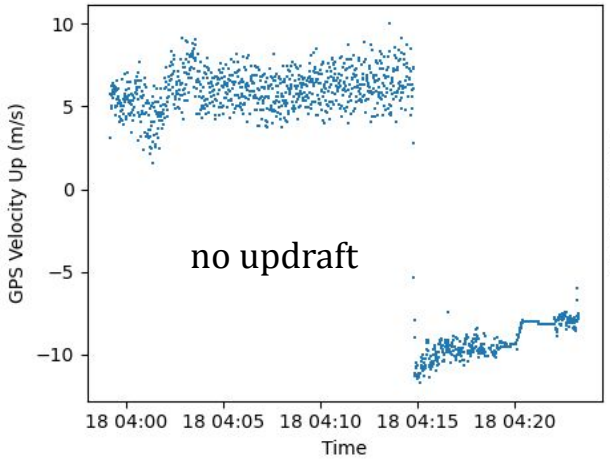
IOP 4 Blizzard - 18 Dec 0356 UTC

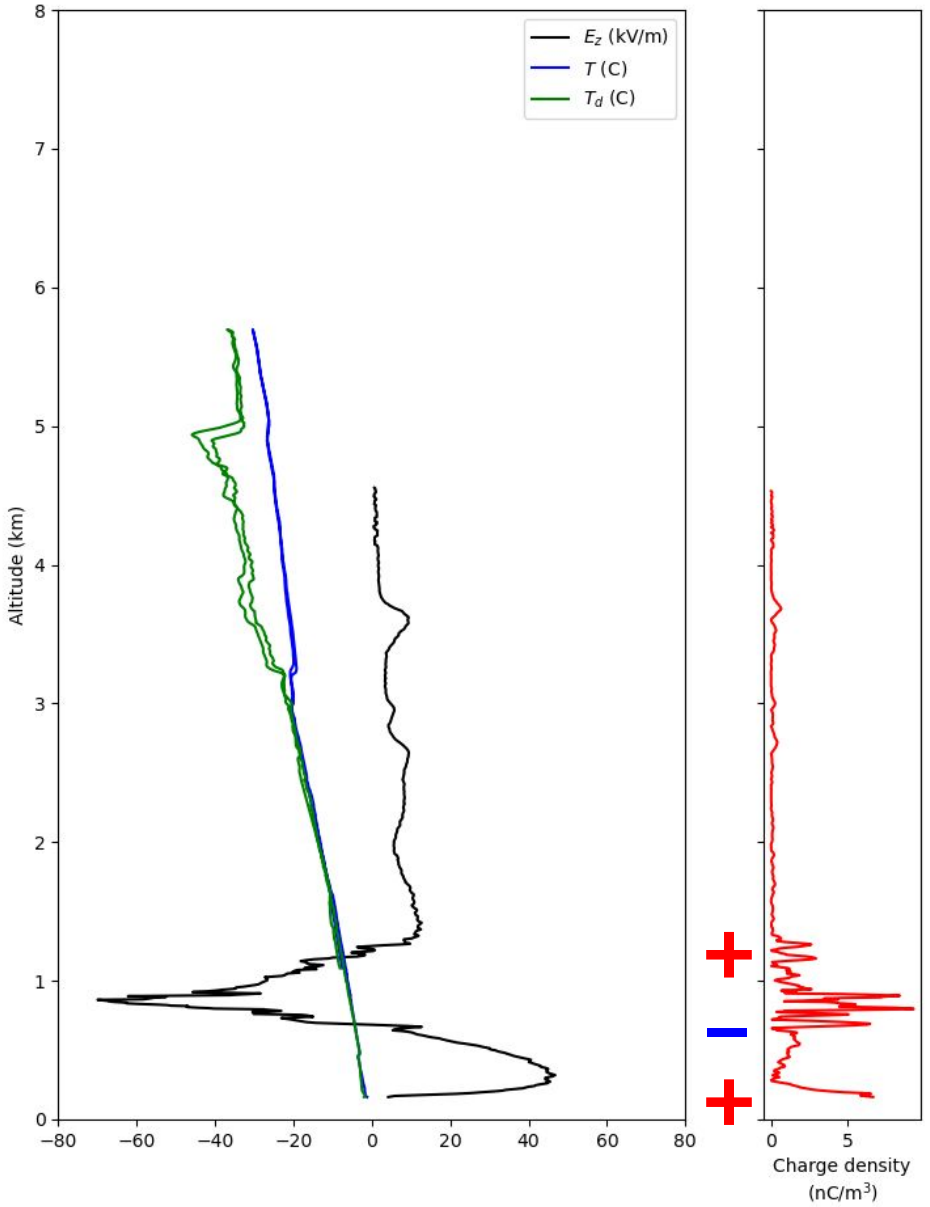


Preliminary charge structure

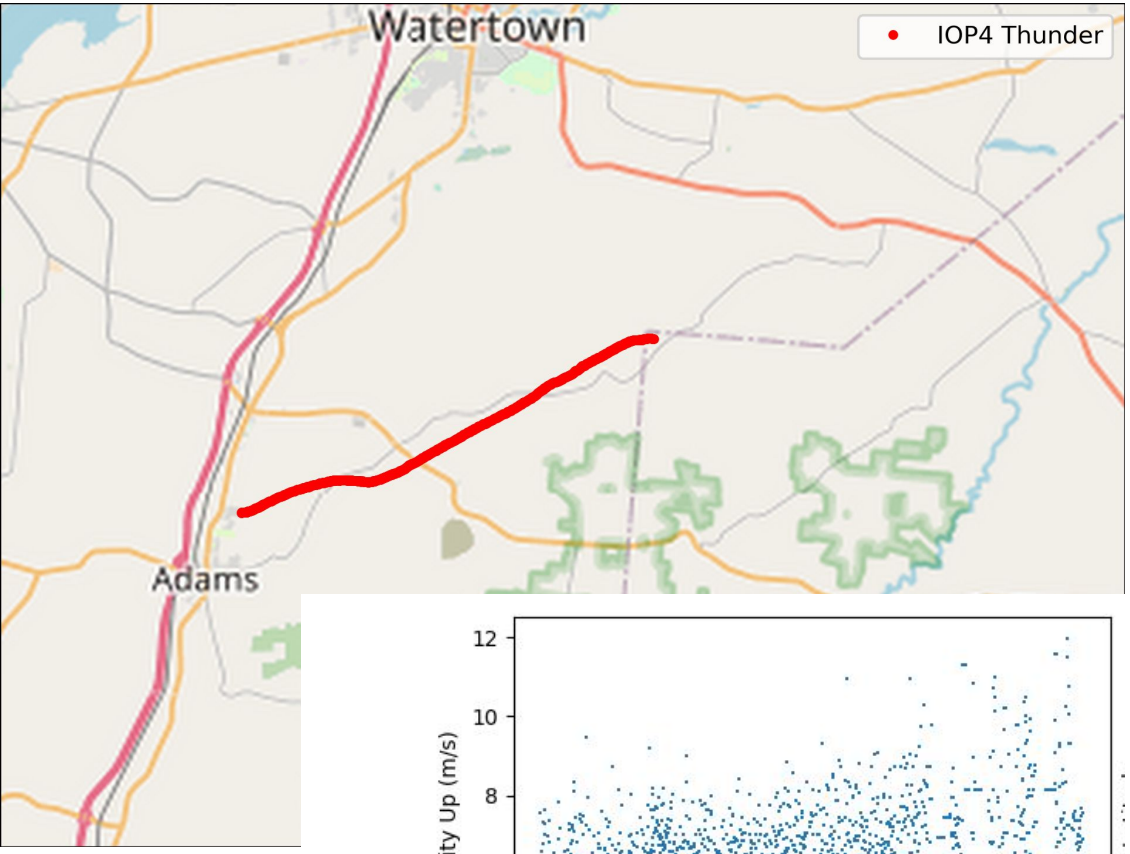
Dense tripolar charge structure, entirely below 1.3 km

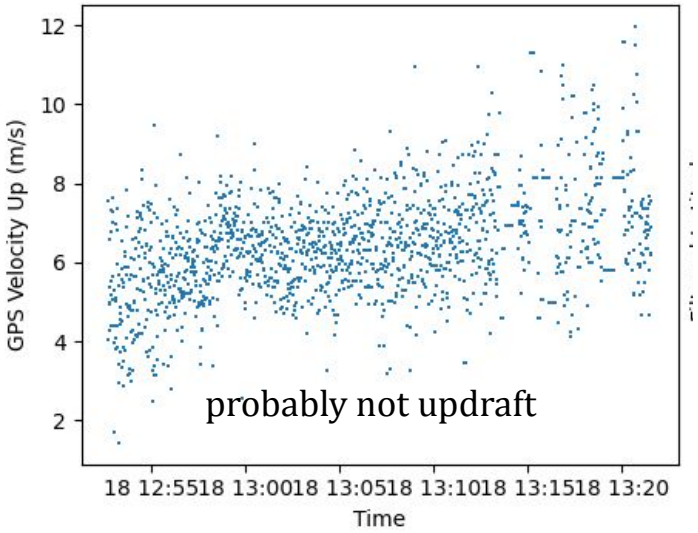
Some other variability above





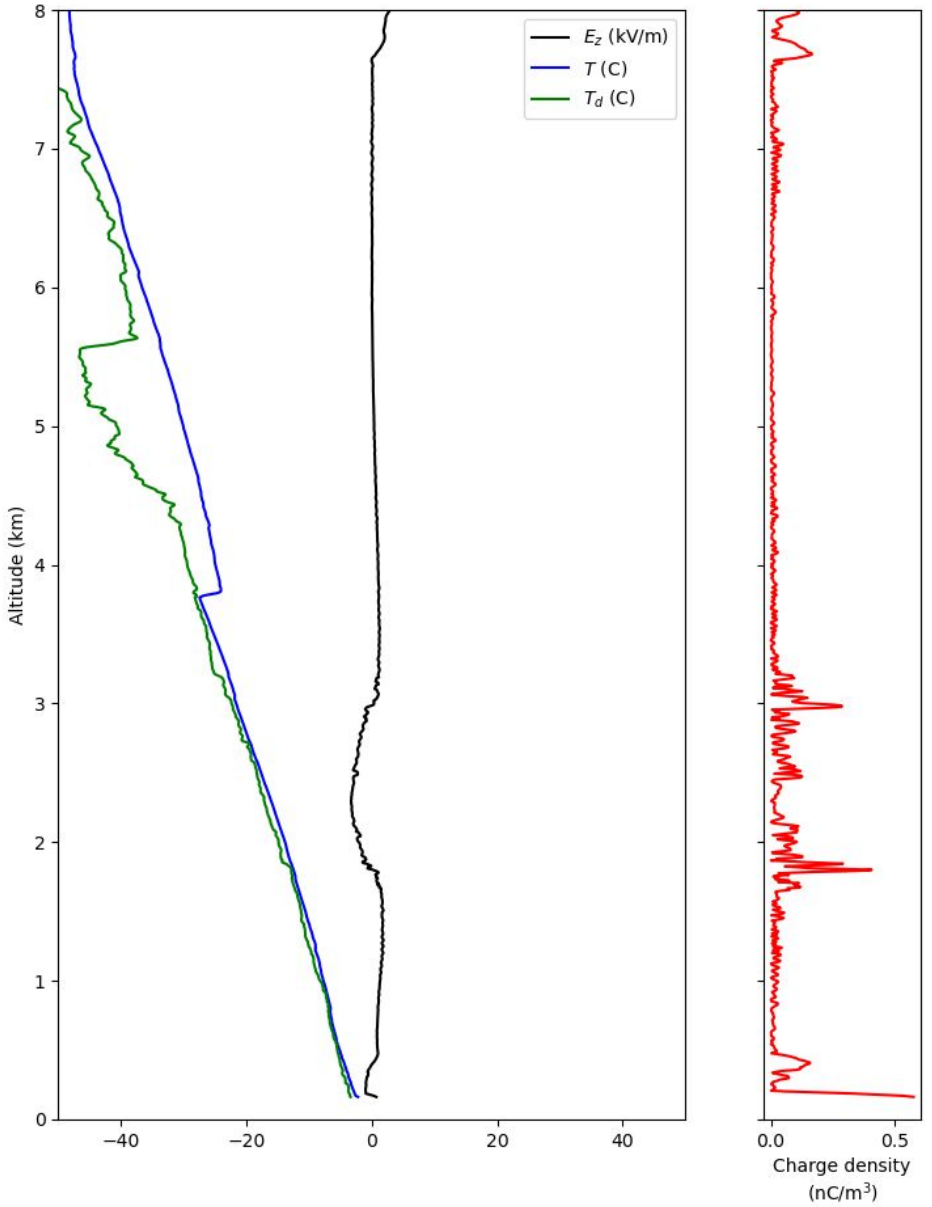
IOP 4 Thunder - 18 Dec 1253 UTC



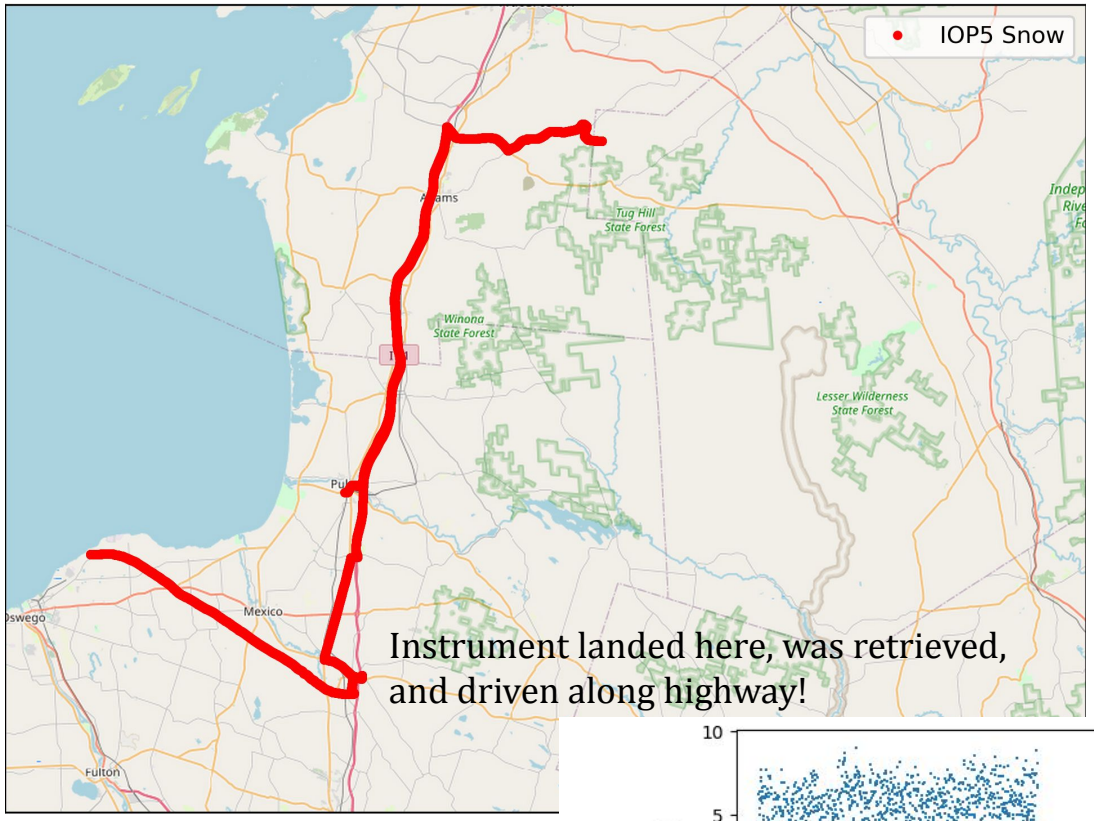


Not much field strength or charge

Cutdown apparently did not work



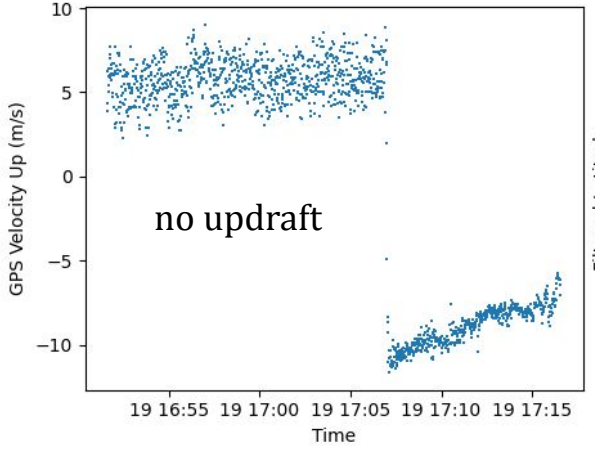
IOP 5 Snow - 19 Dec 1655 UTC

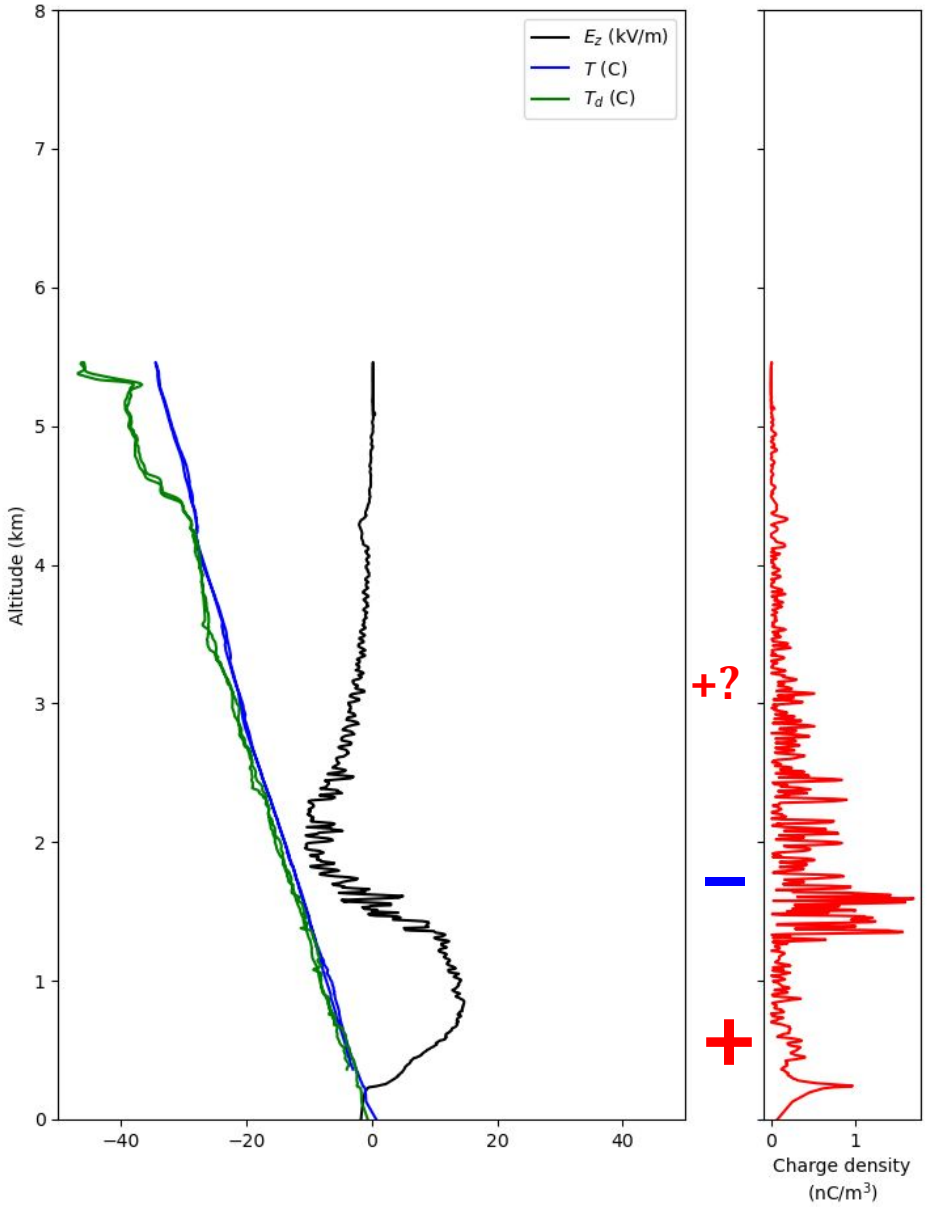


Preliminary charge structure

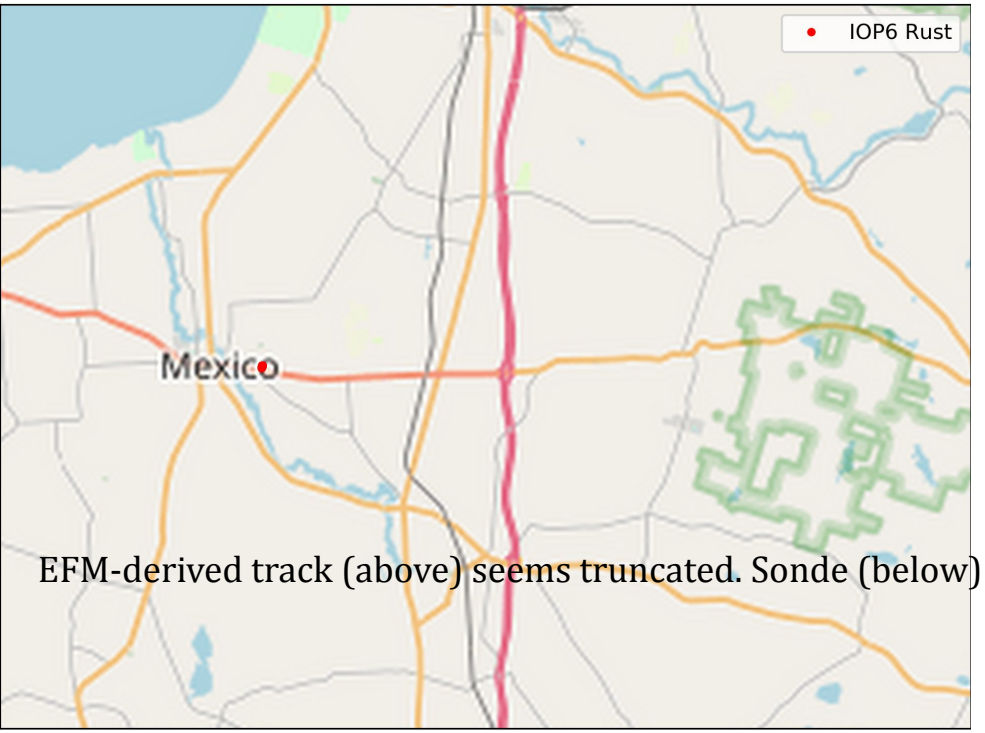
Maybe upper positive charge, but could be moving away from a localized charge

Moderately dense lower positive and middle negative



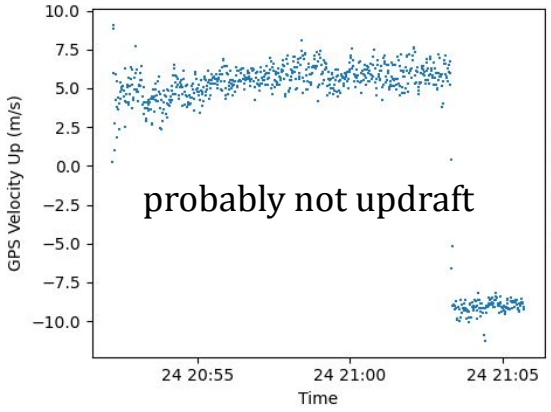


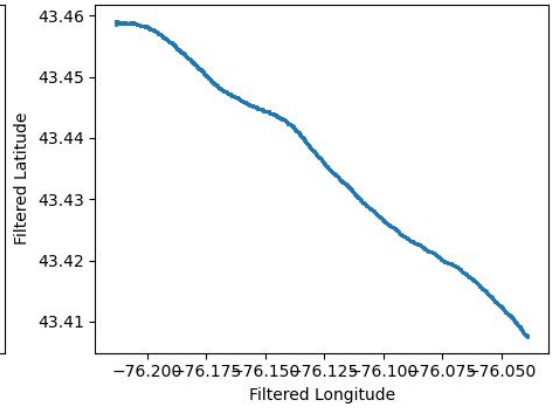
IOP 6 Rust - 24 Jan 2053 UTC

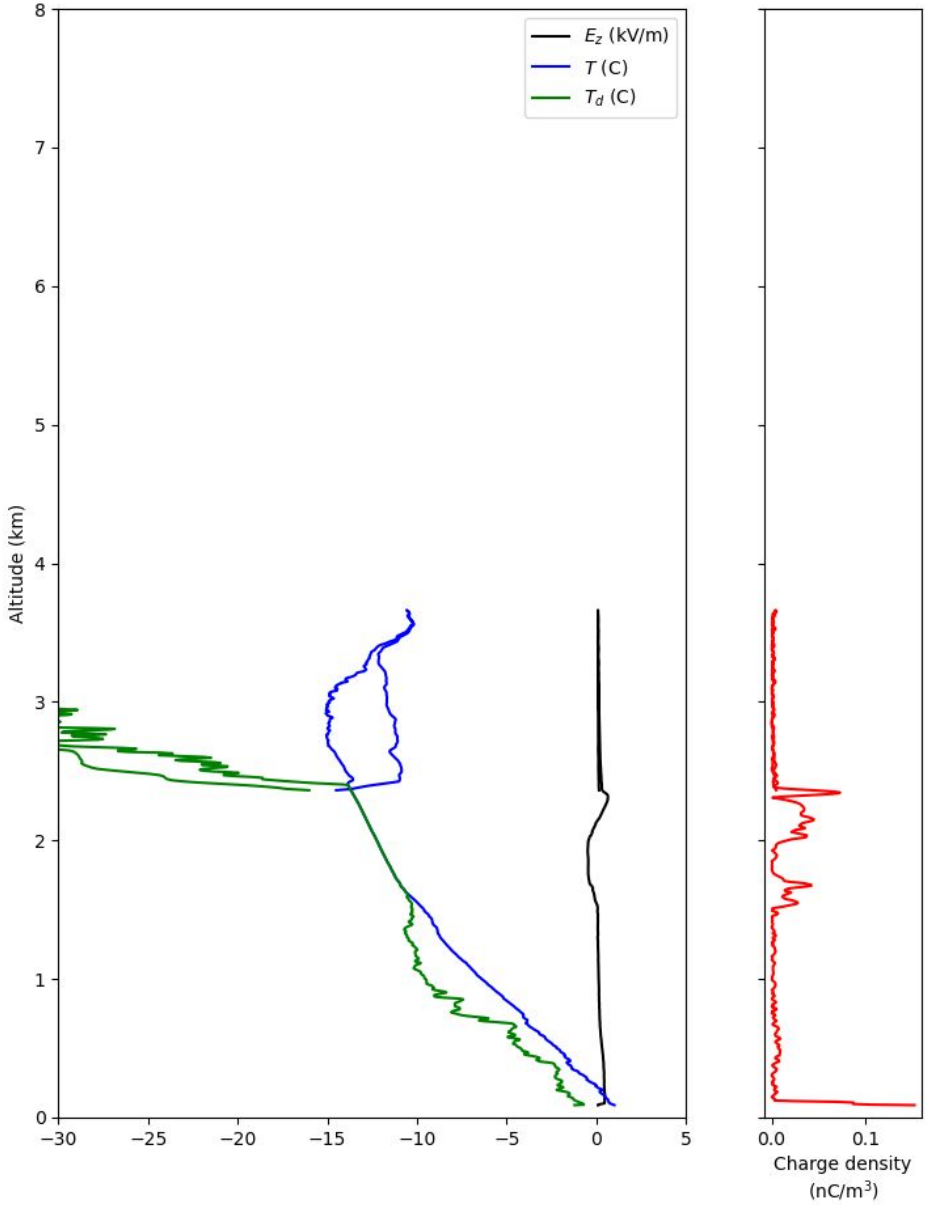


Not much field strength or charge, though clearly the cloud carried some charge. Screening layer at cloud top.

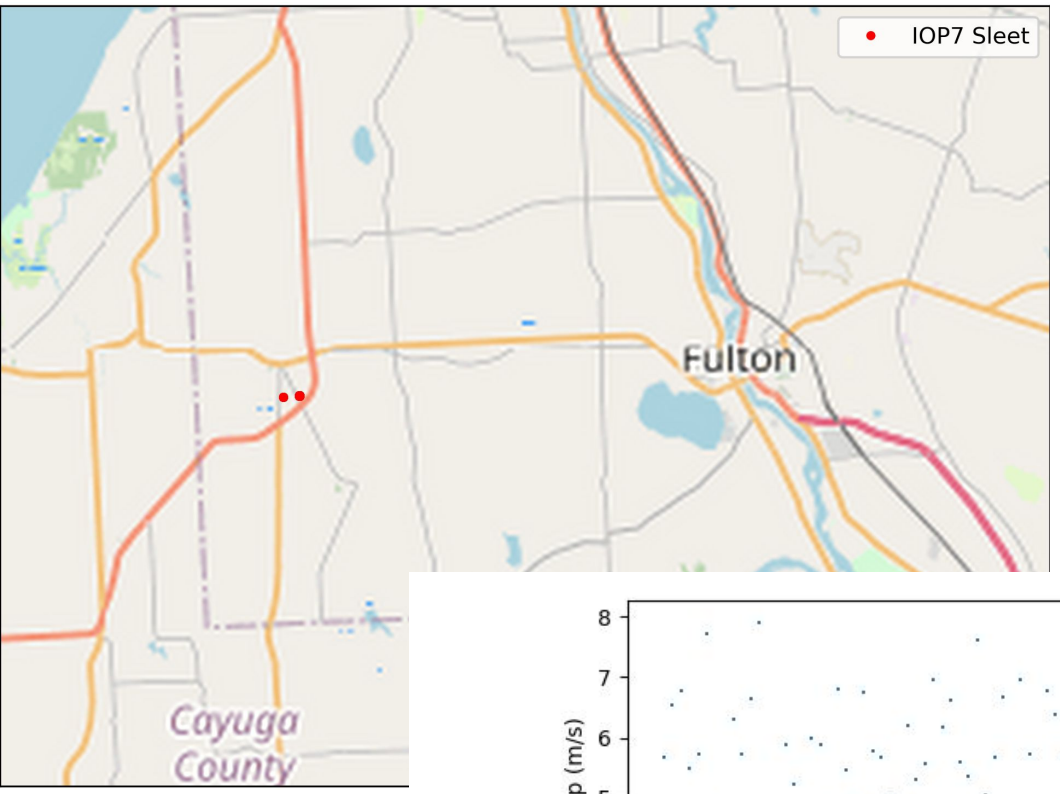
EFM-derived track (above) seems truncated. Sonde (below) shows more.



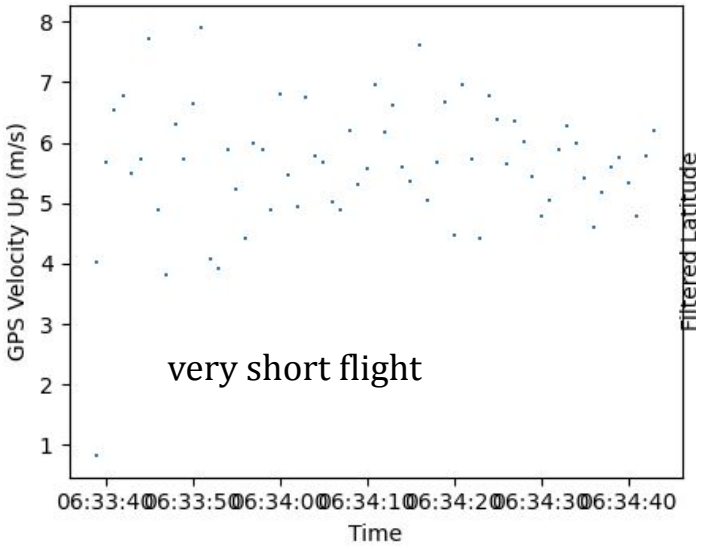


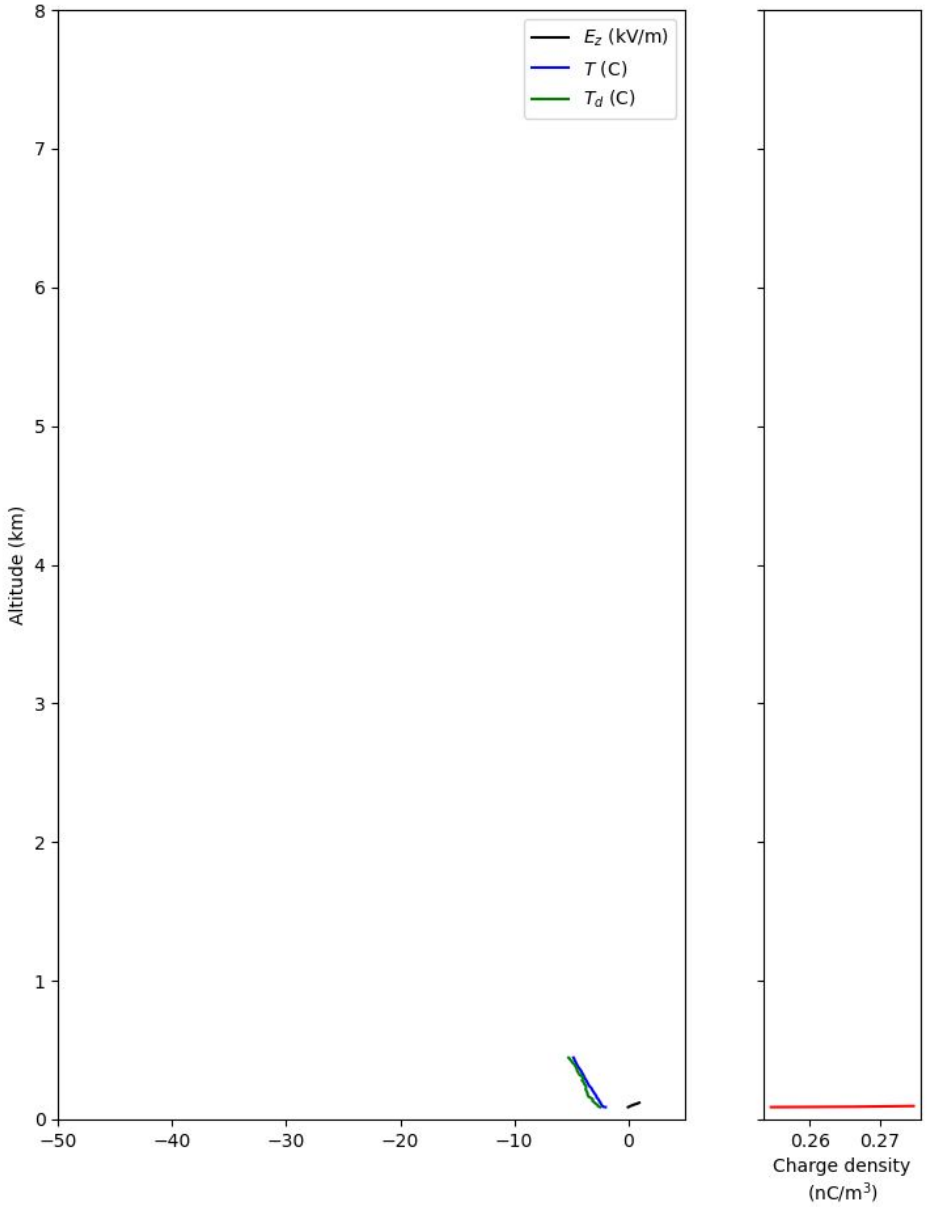


IOP 7 Sleet - 27 Jan 0634 UTC

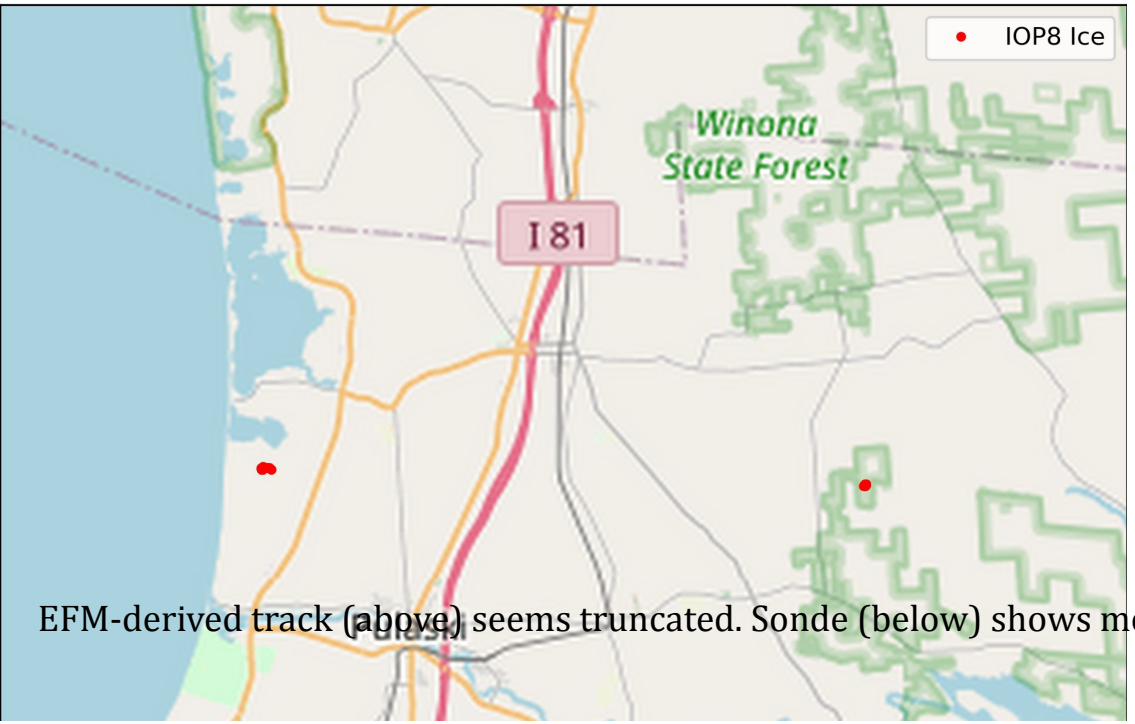


Geofence error triggered an early cutdown



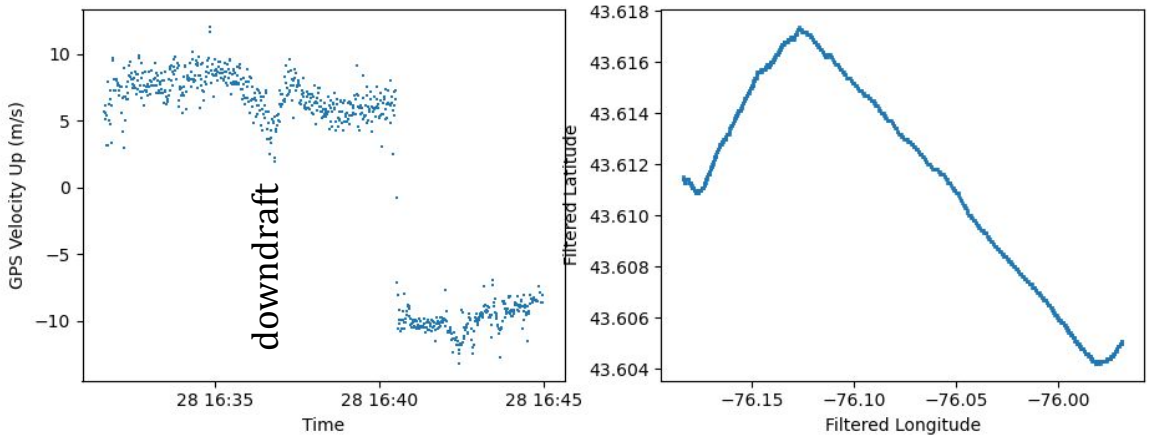


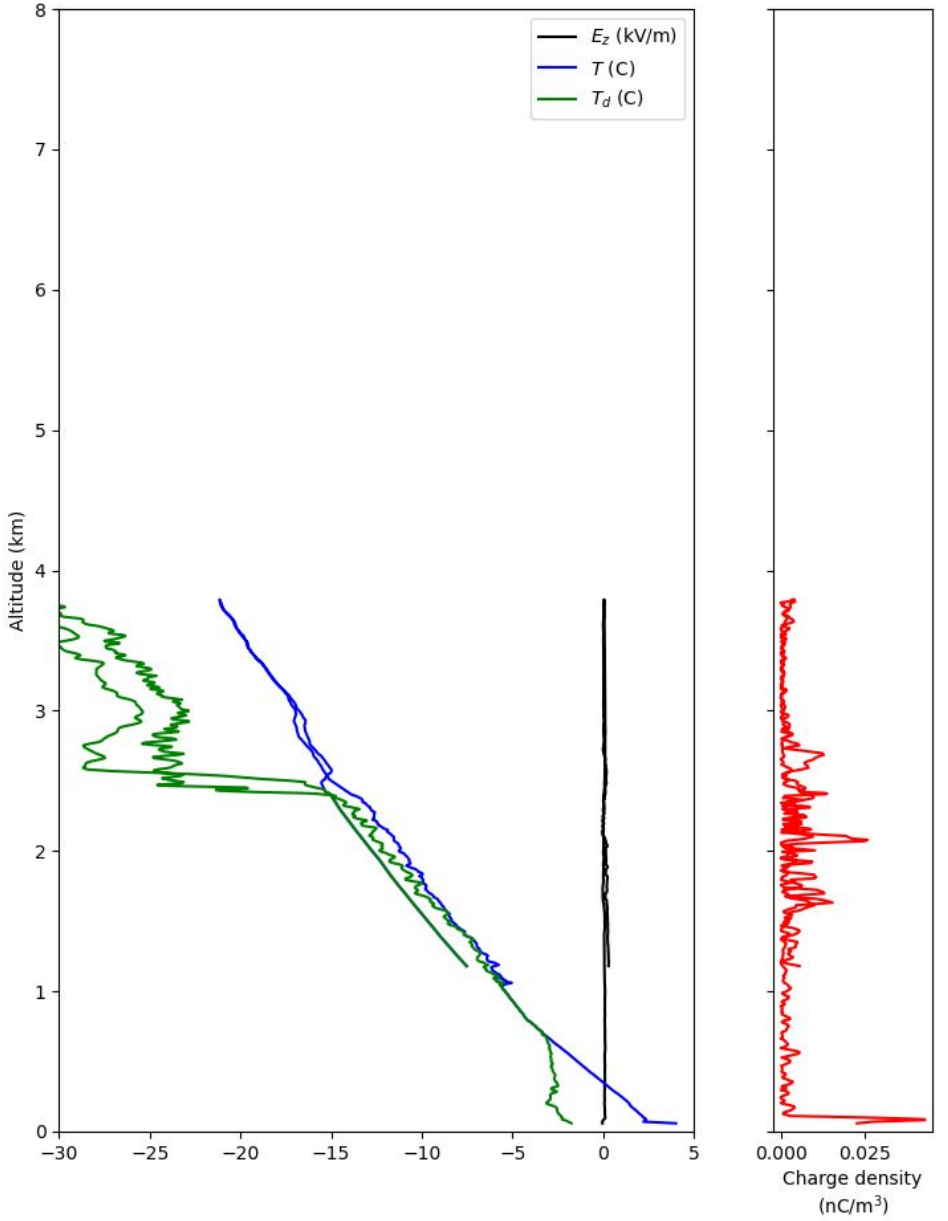
IOP 8 Ice - 28 Jan 1631



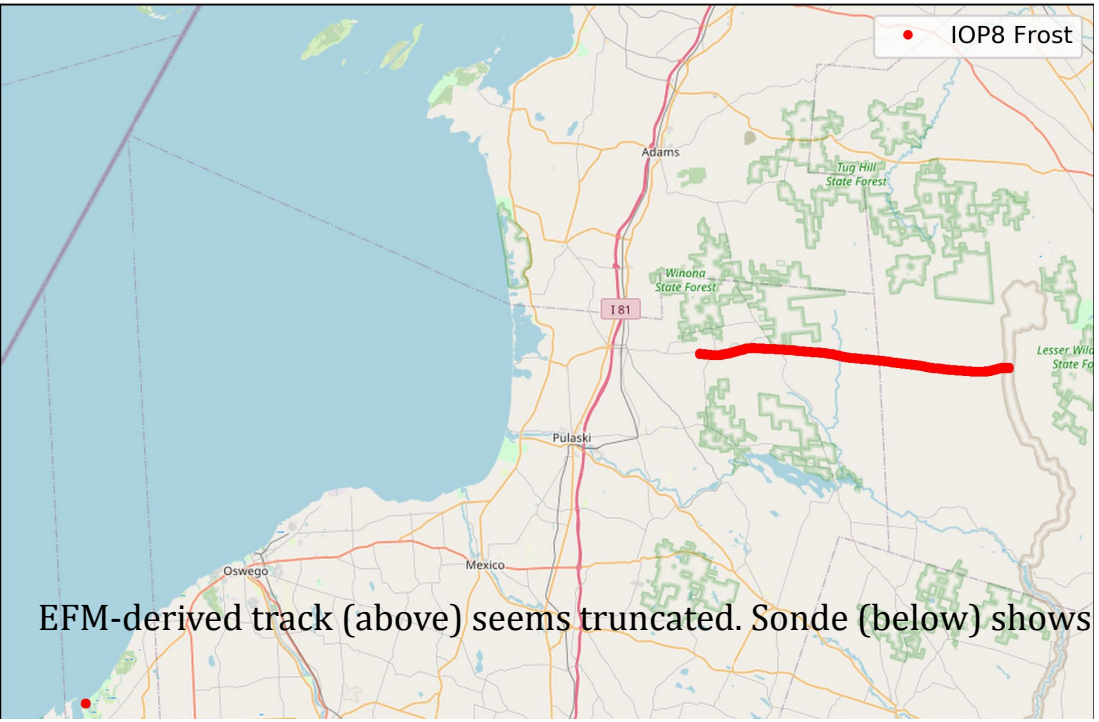
Not much field strength or charge.

EFM-derived track (above) seems truncated. Sonde (below) shows more.



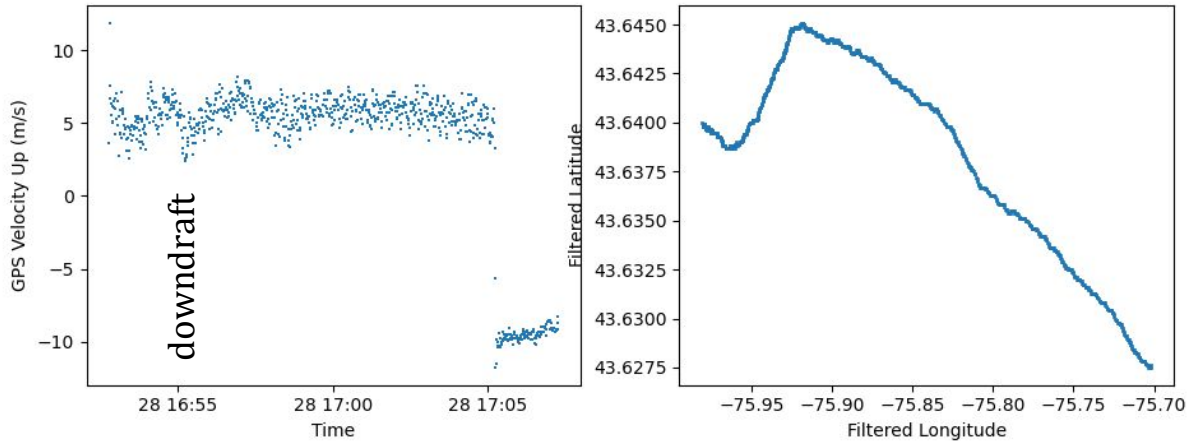


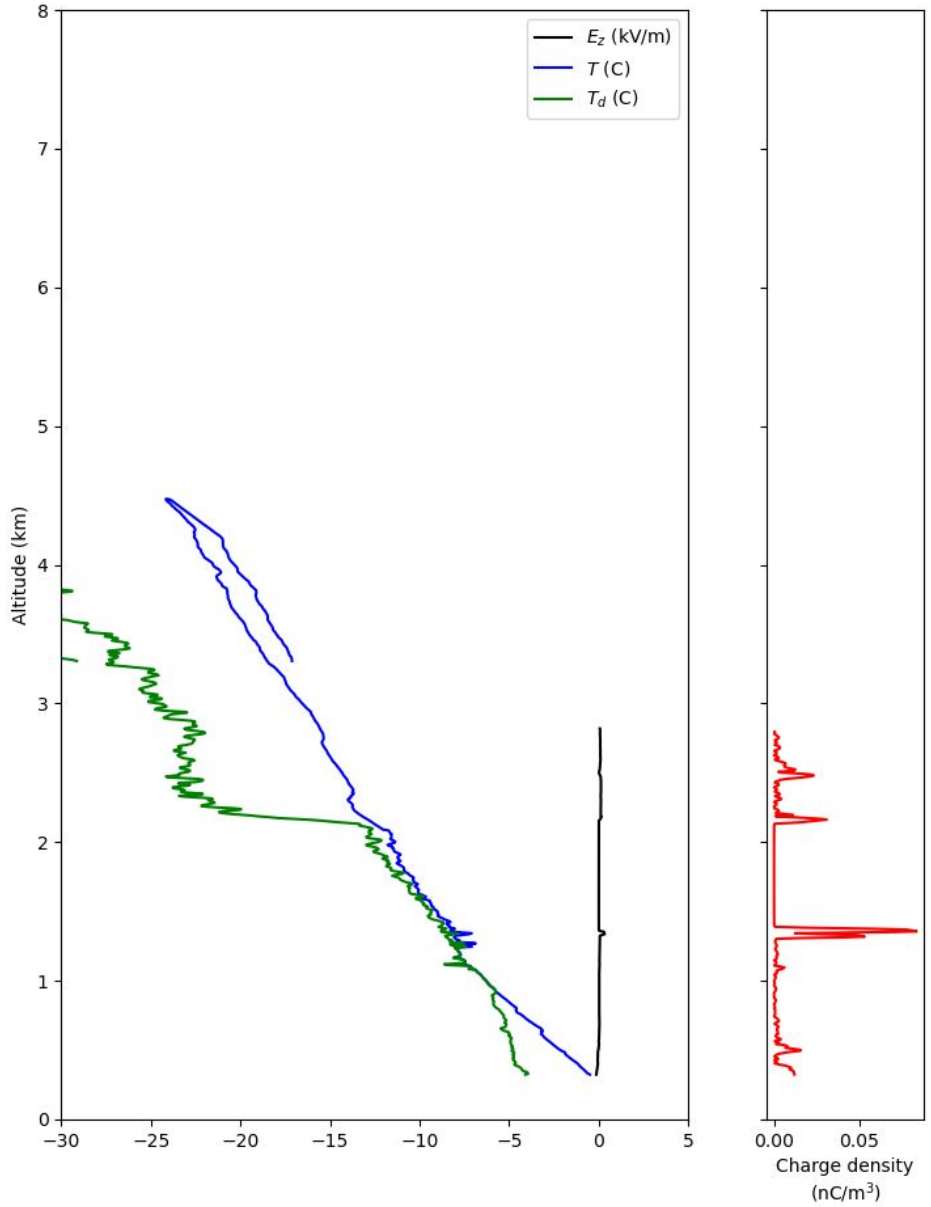
IOP 8 Frost - 28 Jan 1653 UTC



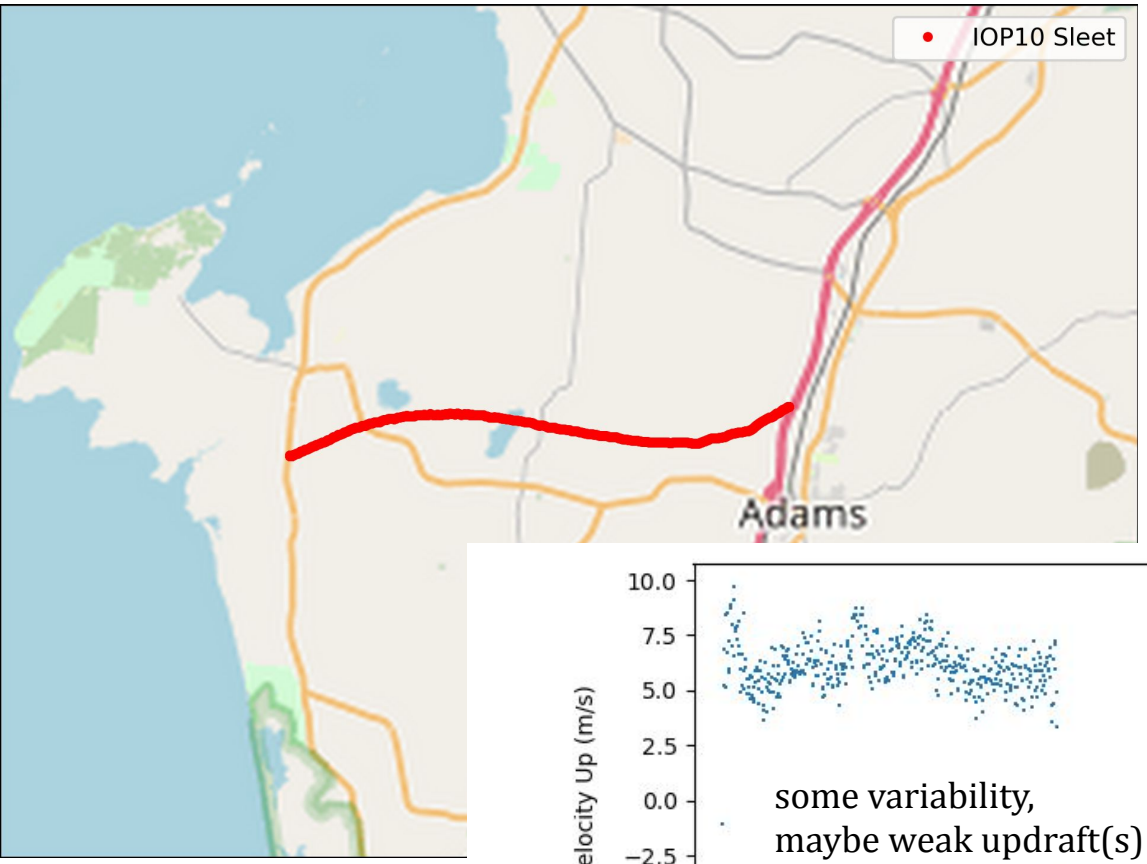
Not much field strength or charge.

EFM-derived track (above) seems truncated. Sonde (below) shows more.



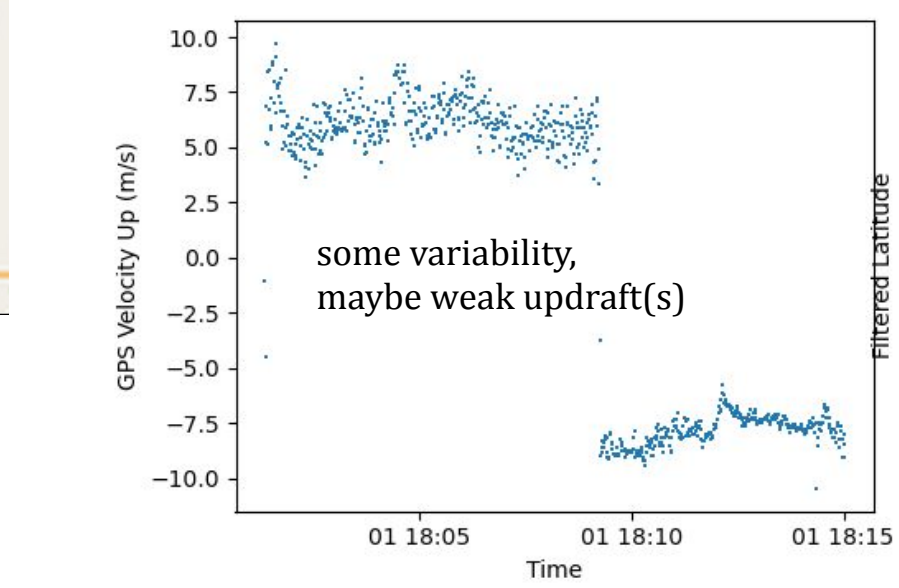


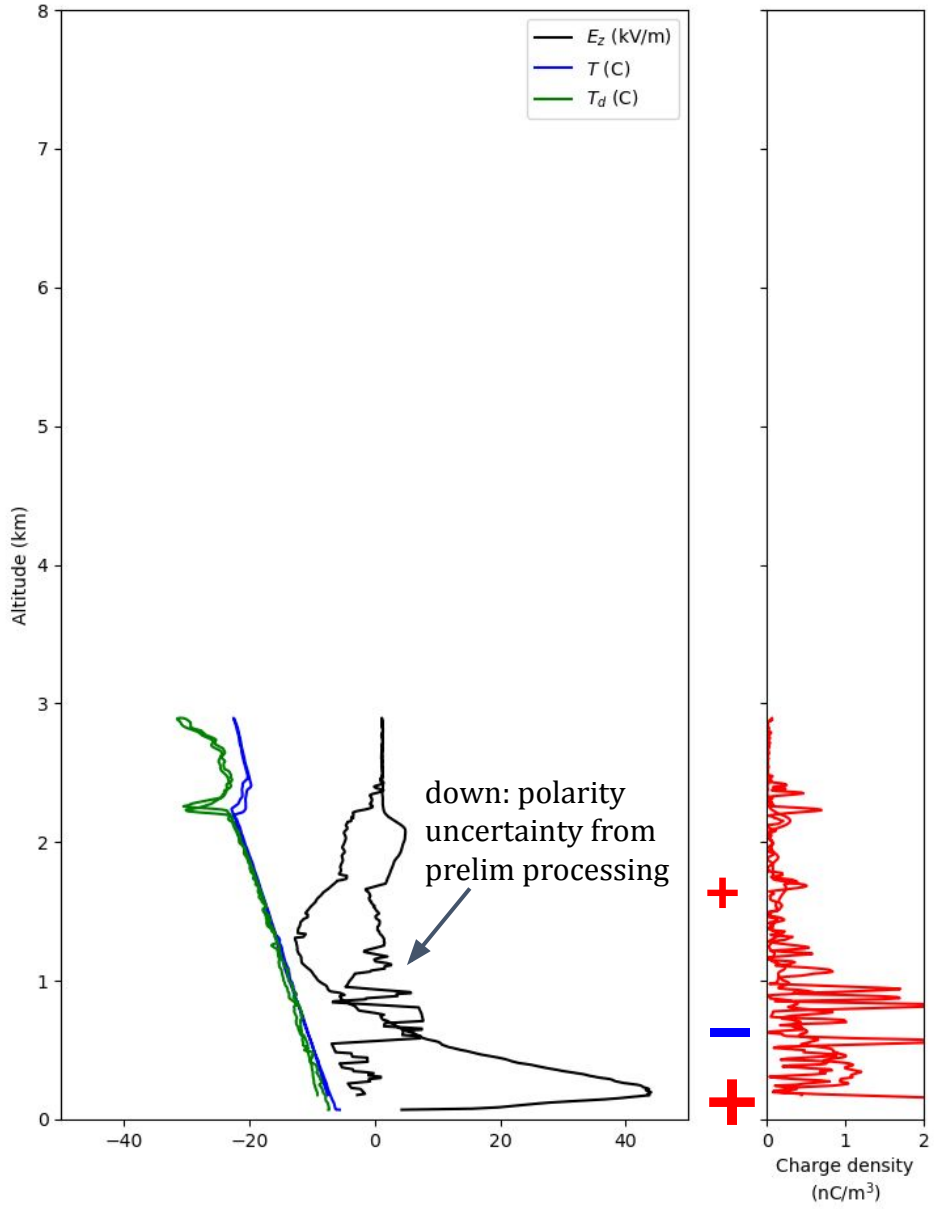
IOP 10 Sleet - 1 Feb 1805 UTC



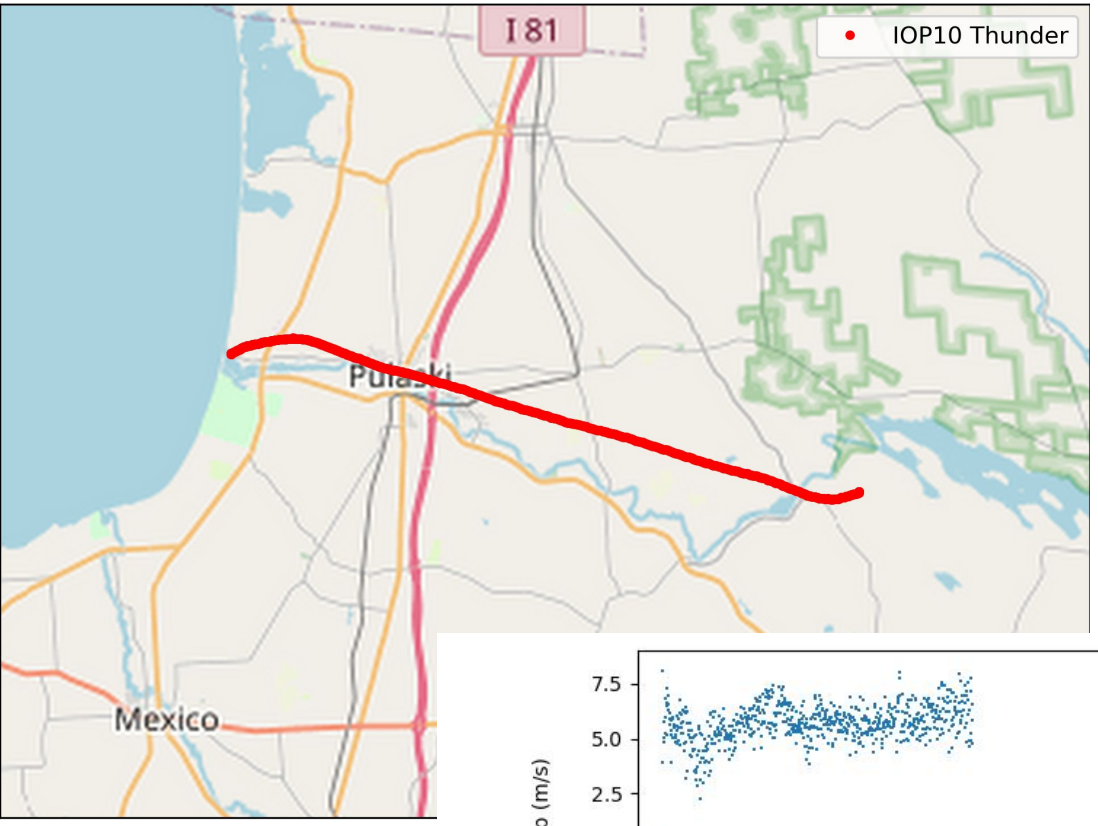
Preliminary charge structure

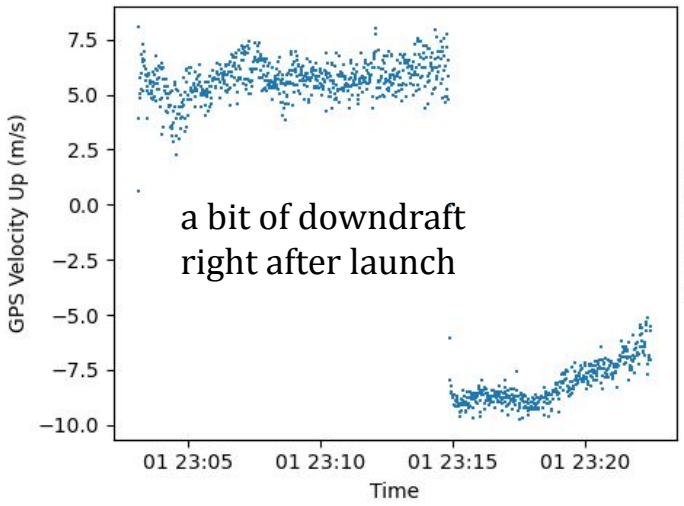
Dense tripolar charge structure spread across boundary layer





IOP 10 Thunder - 1 Feb 2302 UTC

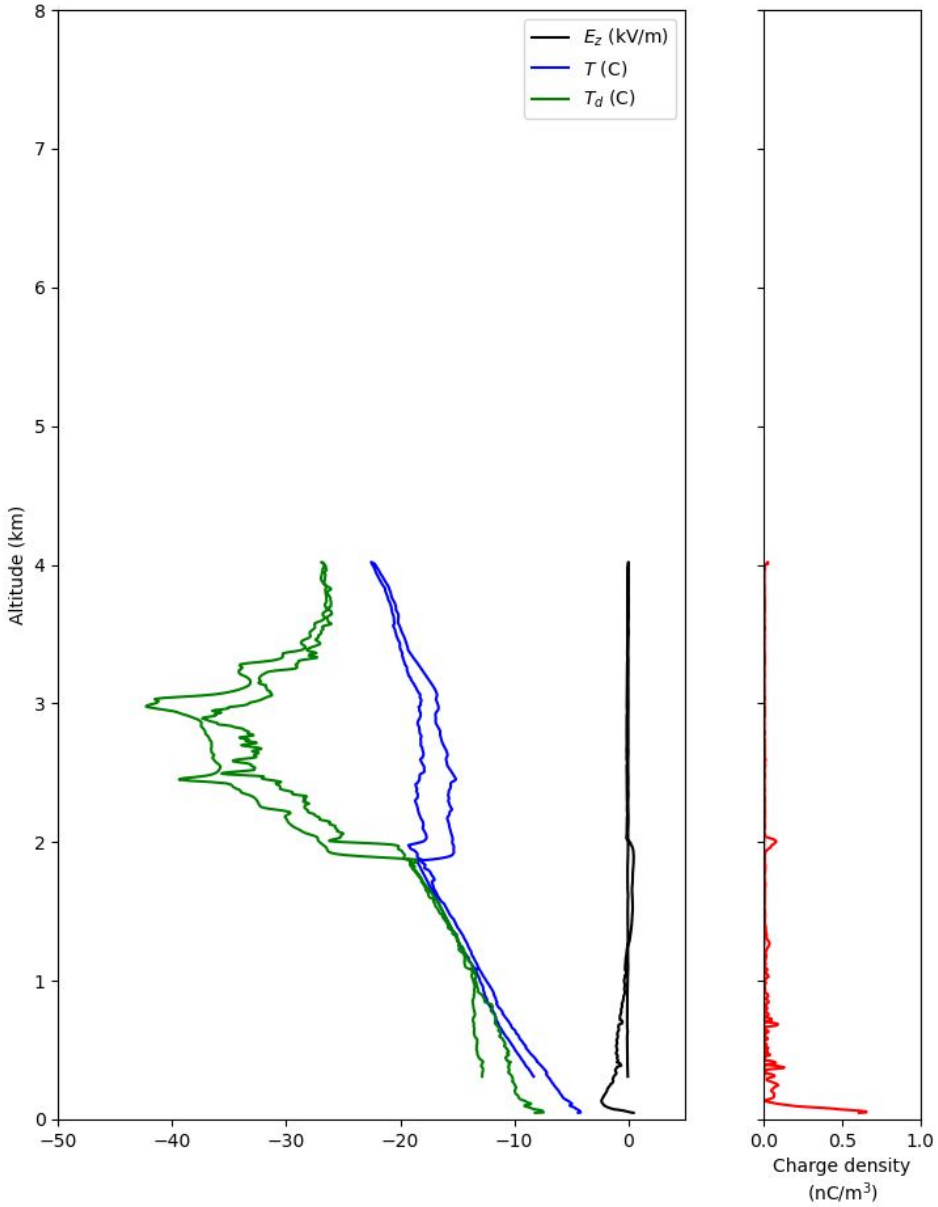




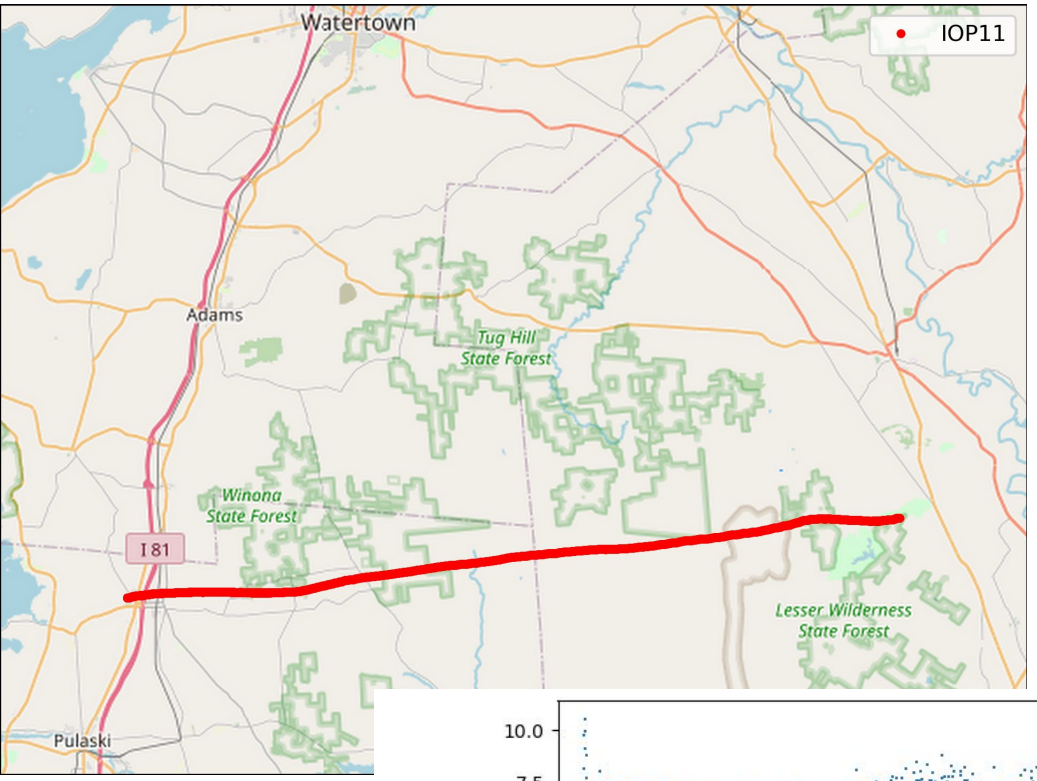
a bit of downdraft right after launch

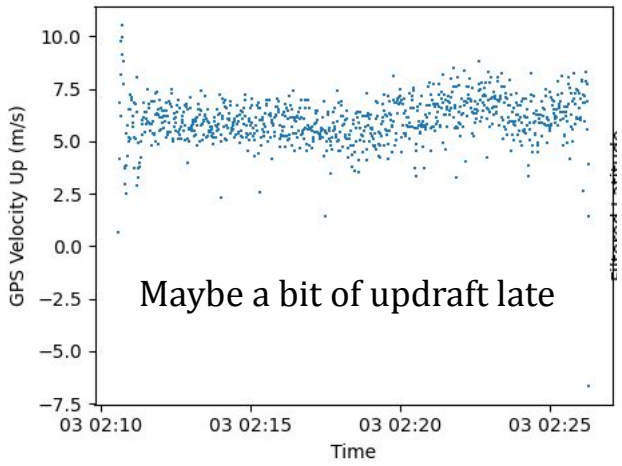
Not much field strength or charge.

Some low-density positive charge in and below the cloud layer.



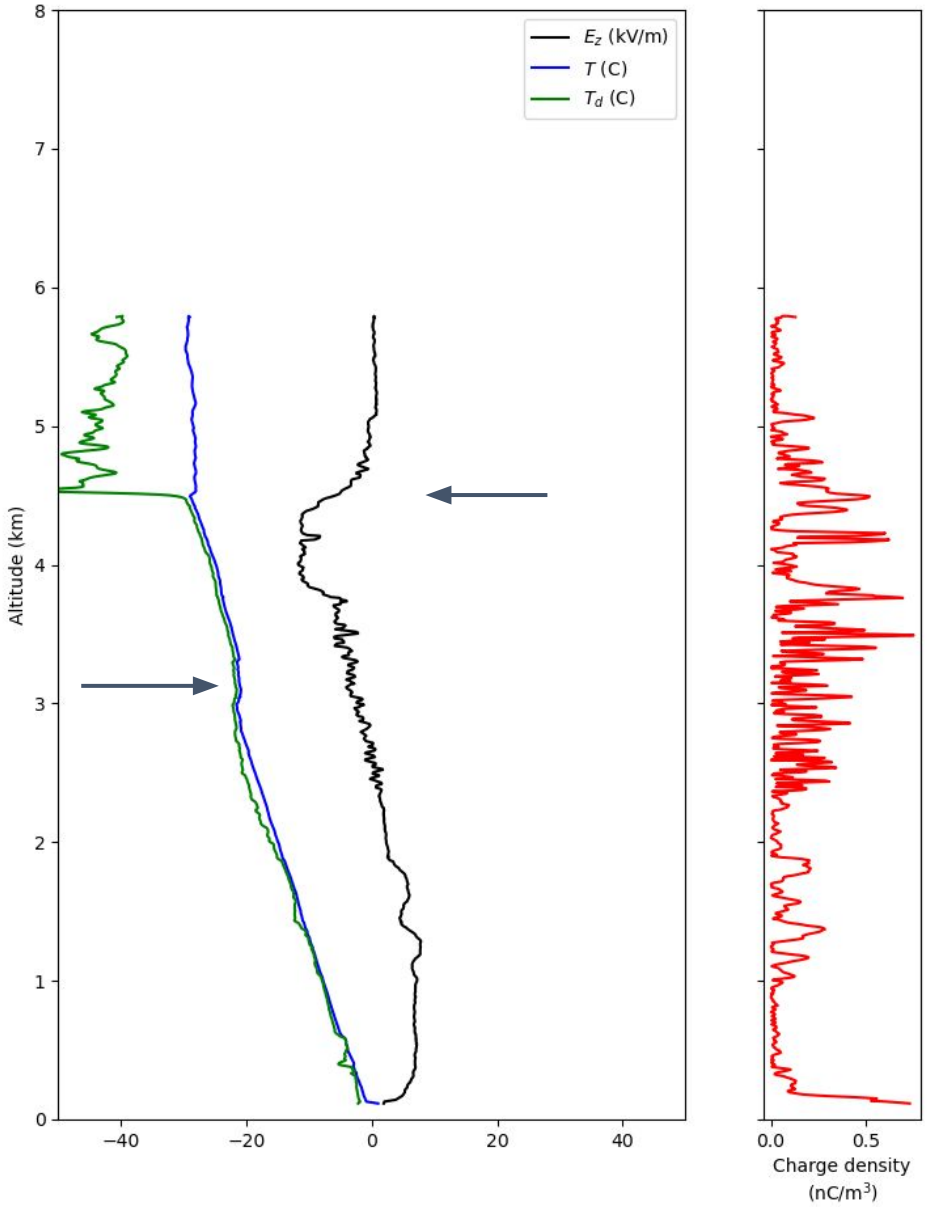
IOP 11 - 3 Feb 0211 UTC





Some field strength and charge, mostly low-density negative.

Note lake-induced boundary layer, then secondary saturated layer, perhaps associated with synoptic system? Most dense charge was in this upper cloud layer.



Summary

Challenges

- Supply chain challenges resulted in launches primarily limited to near the lakeshore.
- The new EFM design proved to be more of a learning experience than expected.
  - There were problems with spin at low temperatures.
  - EFM sample quality required significant QC, and signal processing challenges remain (though solvable).
  - Revisions are needed before we can be confident in asking NSF to fly again.
- Contracting for new EFM revisions is subject to federal purchasing timelines and the amount of post-revision testing we will need to do is significant.

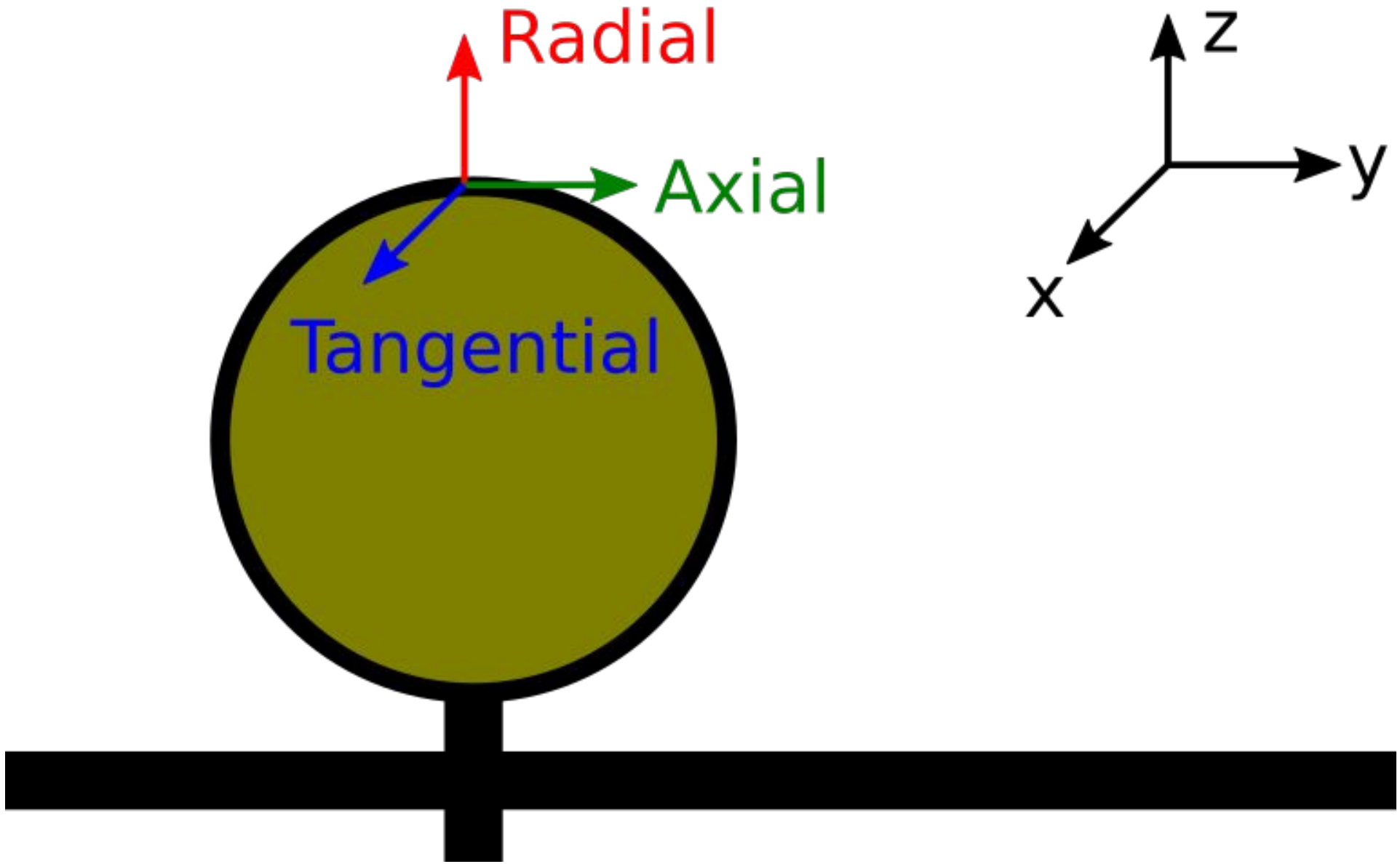
- EFM data still require expert attention to processing and cleanup, and probably are not ready for wide dissemination.

Successes

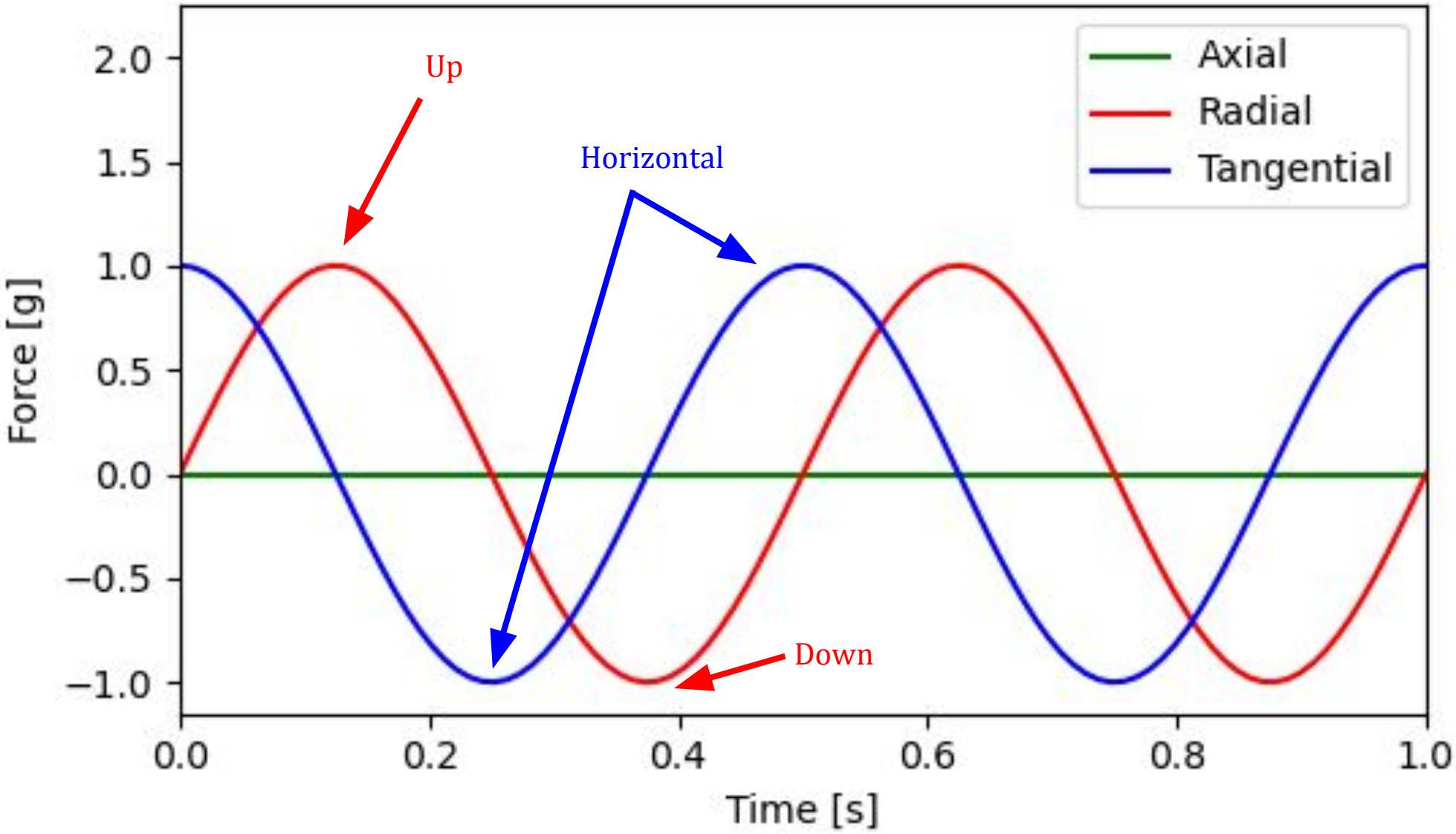
- By operating in real field conditions, we learned a significant amount about how to improve the EFMs.
  - Revisions to the EFMs and a test plan are under way.

- **We collected a first of its kind dataset that establishes a benchmark electrical structure for near-shore lake effect clouds.**
  - Five soundings were collected with $|\mathbf{E}| > 10$ kV/m, and all exhibited the same basic electrical structure.
  - Charge layers are very close to the surface.
  - Significant science will result from assessing the microphysics of electrification in these cases.

Coordinate Systems



Accelerometer Measurements if Inertial



Accelerometer Measurements actual