



The ALOFT Airborne Campaign: Relevance to Spaceborne Lightning Sensor Validation and Science Applications

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ALOFT Overview



ALOFT means Airborne Lightning Observatory for FEGS [Fly's Eye GLM (Geostationary Lightning Mapper) Simulator] and TGFs [Terrestrial Gamma-ray Flashes]

ALOFT was a collaborative field campaign (NASA + University of Bergen) in July 2023 that used the NASA ER-2 to hunt for gamma-rays and lightning in tropical thunderstorms

GOALS

1. Observe TGFs in one of the most TGF-intense regions on the planet.
2. Observe gamma-ray glows in thunderstorms and their relation to TGFs.
3. **Perform International Space Station Lightning Imaging Sensor (ISS LIS) and GLM validation using improved suborbital instrumentation (including upgraded FEGS).**
4. **Evaluate new design concepts for next-generation spaceborne lightning mappers.**
5. Make measurements of tropical convection from a suborbital platform.

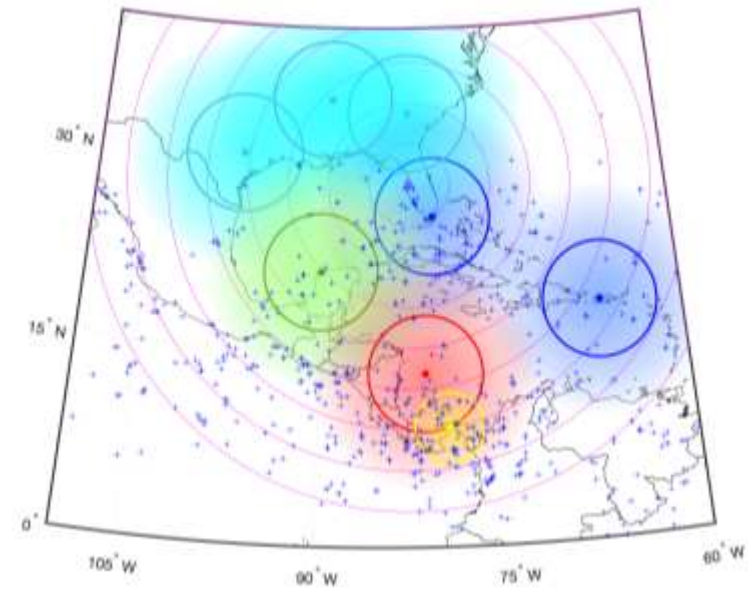


ALOFT Airborne and Ground Instruments



Airborne

- **UIB-BGO** (Univ. of Bergen) - gamma-ray detection
- **iSTORM** (NRL) - gamma-ray detection
- **FEGS** (MSFC) - cloud-top optical emissions from lightning discharges
- **EFCM** (MSFC) - electric field change meter
- **LIP** (MSFC) - 3D electric field of thundercloud
- **CoSSIR** (GSFC) - sub-millimeter-wave radiometer for observing ice clouds (170-684 GHz)
- **AMPR** (MSFC) - low-frequency radiometer for observing convective precipitation (10-85 GHz)
- **EXRAD** (GSFC) - 3D winds and precipitation structure within deep convection (X-band)
- **CRS** (GSFC) - high-cloud structure (e.g., anvils, convective cloud-top height) (W-band)



Ground Network

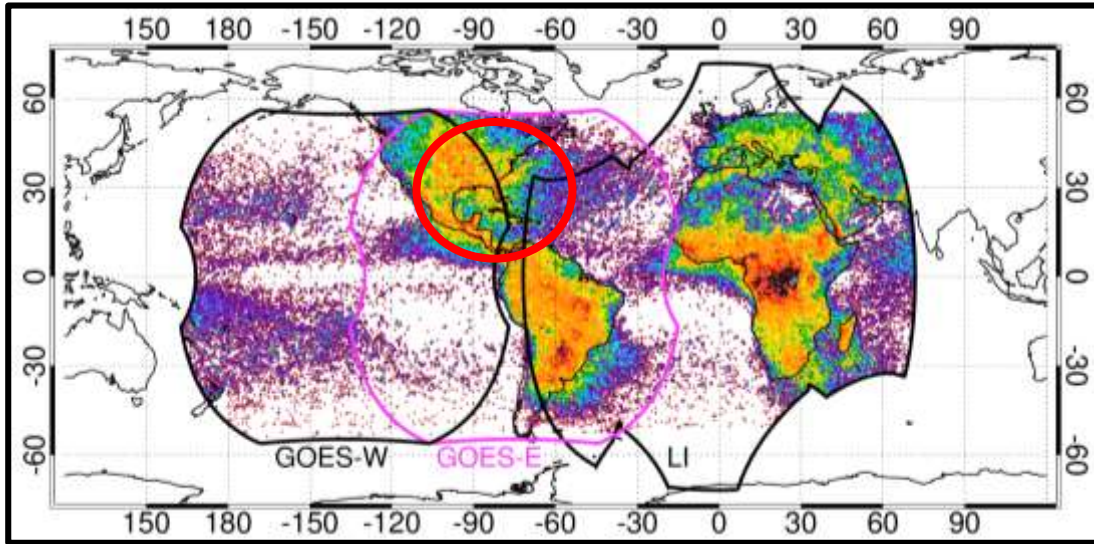
- LF antennas – Mexico, Florida & SE USA, San Andres, Puerto Rico
- VHF interferometers @ KSC, Homestead, and San Andres
- Central Florida LMA – 5-6 stations
- Panama Marx Meter Network
- Additional San Andres – VHF station, high-energy sensor, high-speed cameras, radar



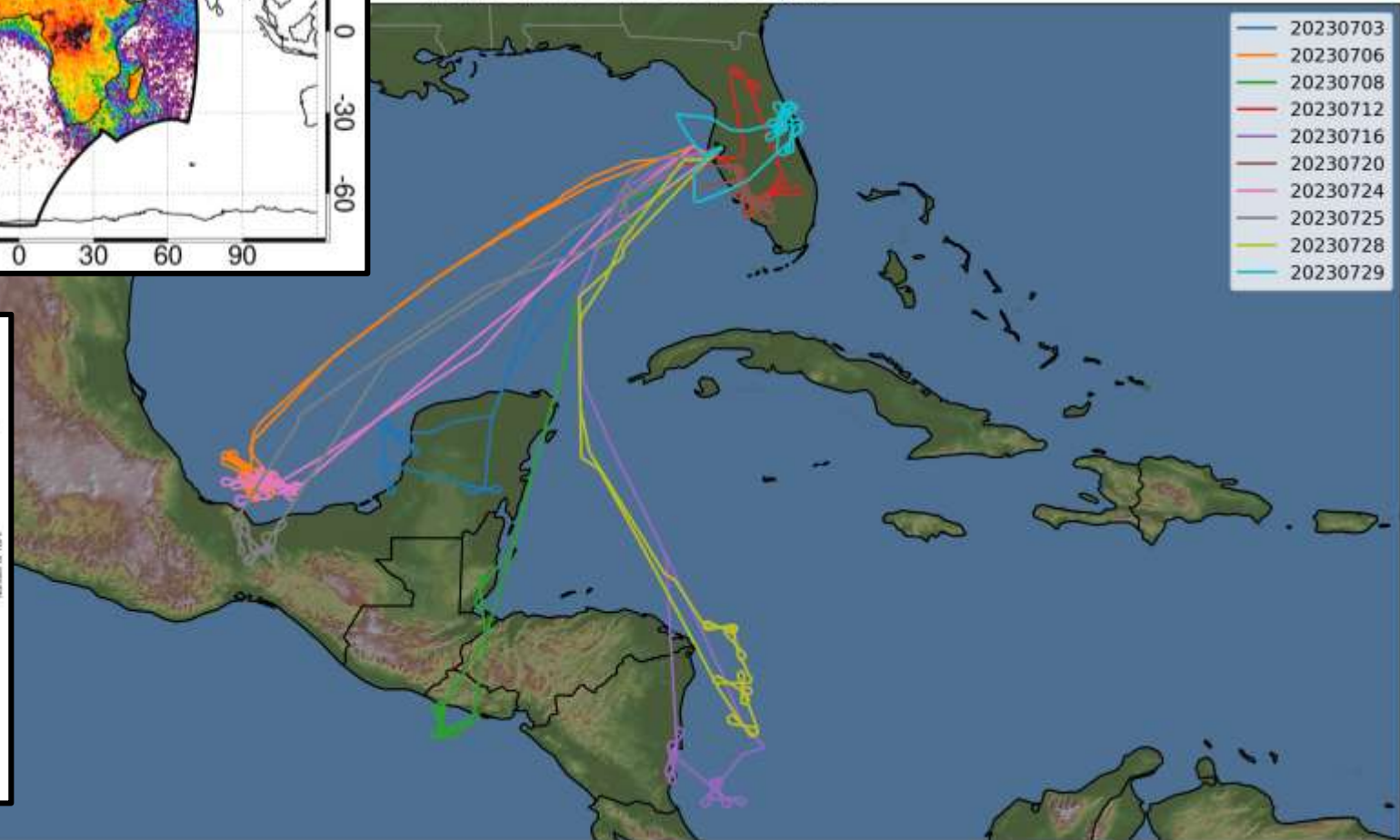
ALOFT Science Flights



- 10 Science Flights (> 60 hours)
- Thunderstorm overflights during both transits



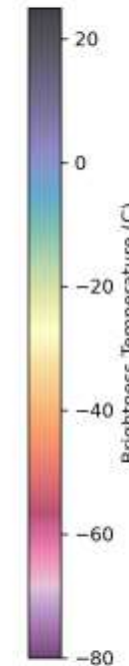
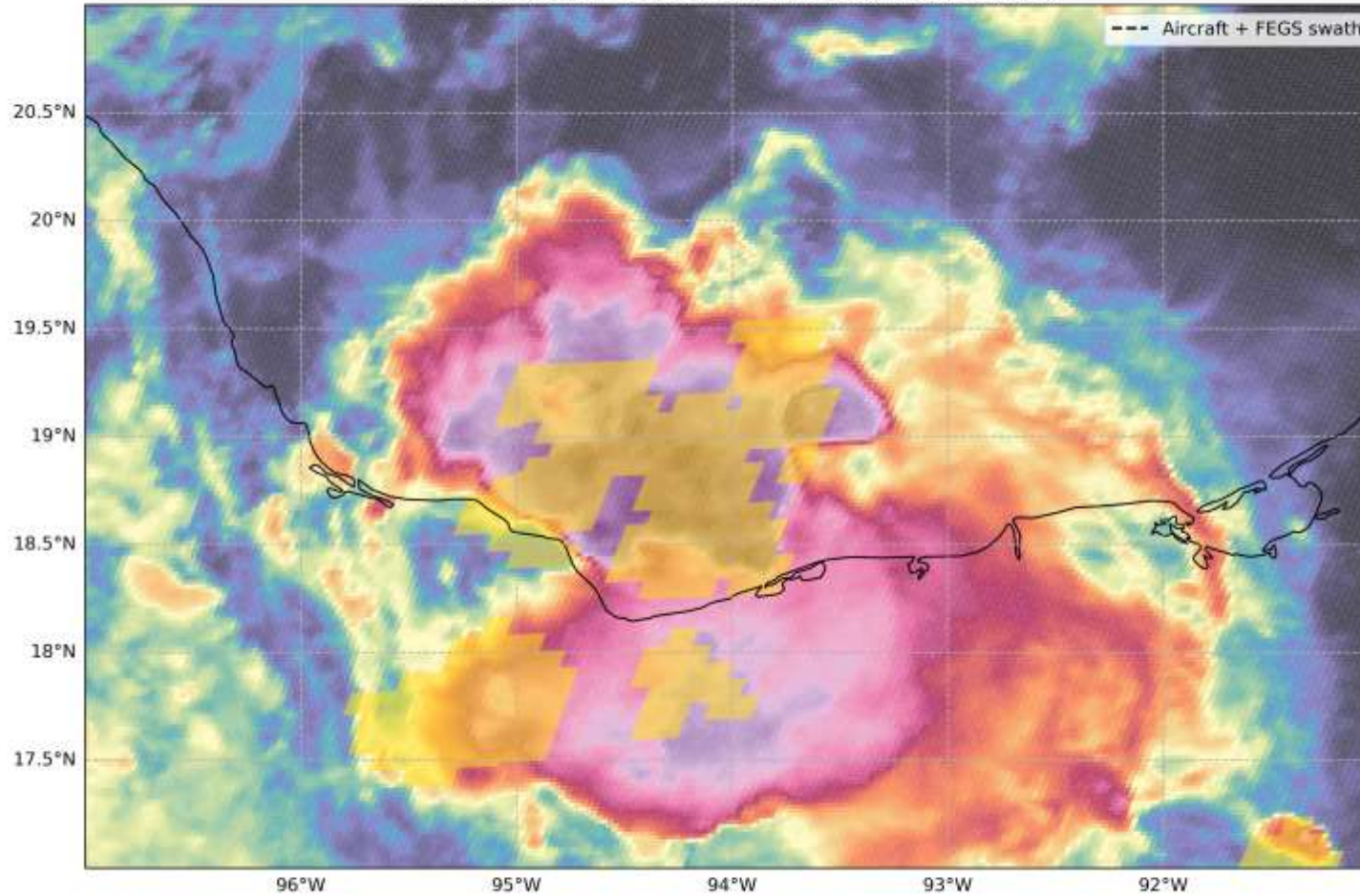
ALOFT Domain - ER-2 Science Flights



24 July 2023 – Highly Electrified and “Radioactive” MCS



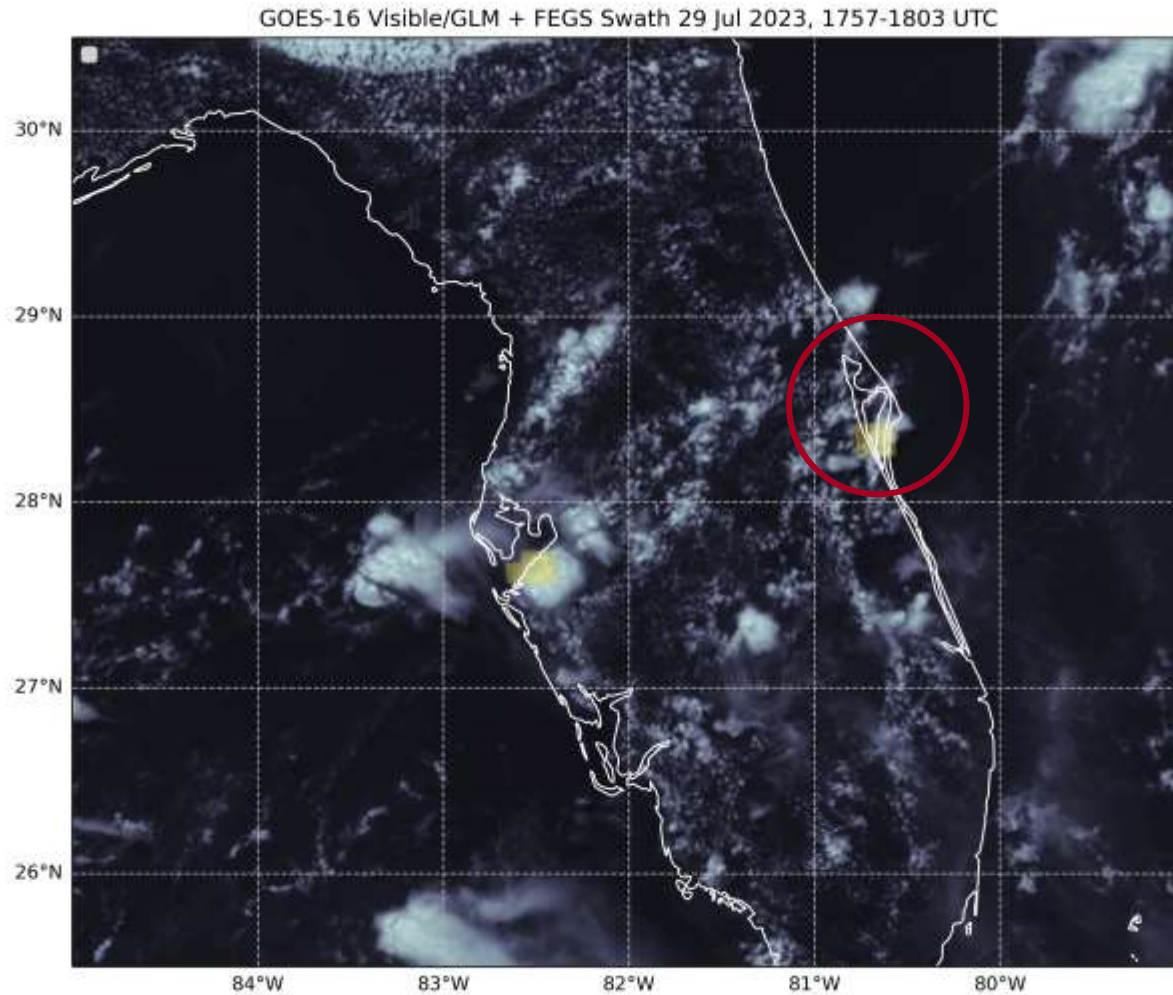
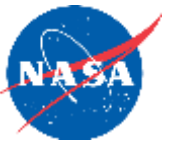
GOES-18 IR/GLM + FECS Swath 24 Jul 2023, 0430-0436 UTC



- ~80 TGFs or similar
- Some EFCM/LIP missing data
- ISS overpass but LIS malfunction



29 July 2023 – 7 Gamma Events near KSC Interferometer and Central FL LMA



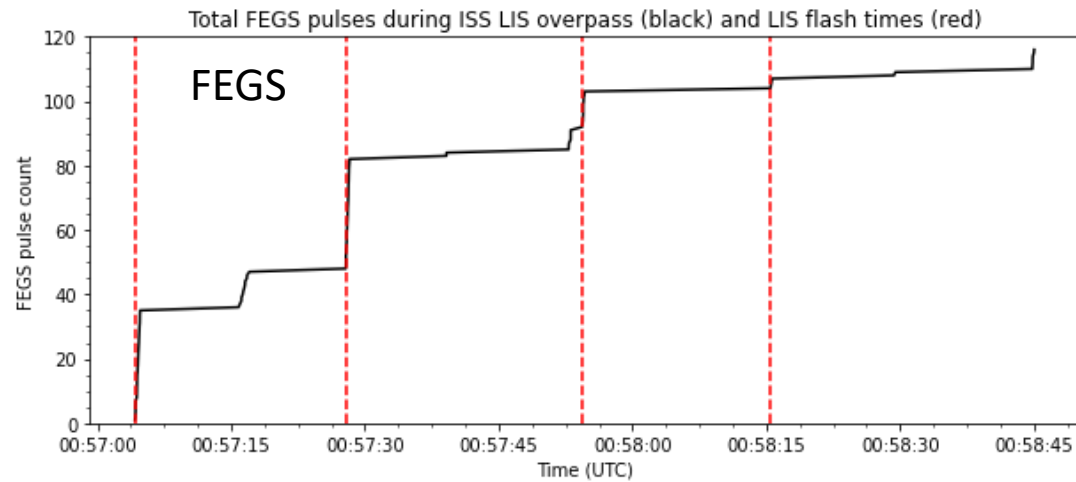
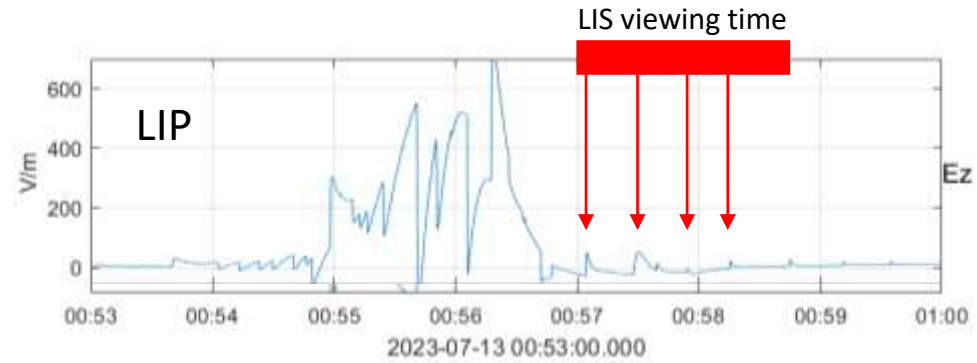
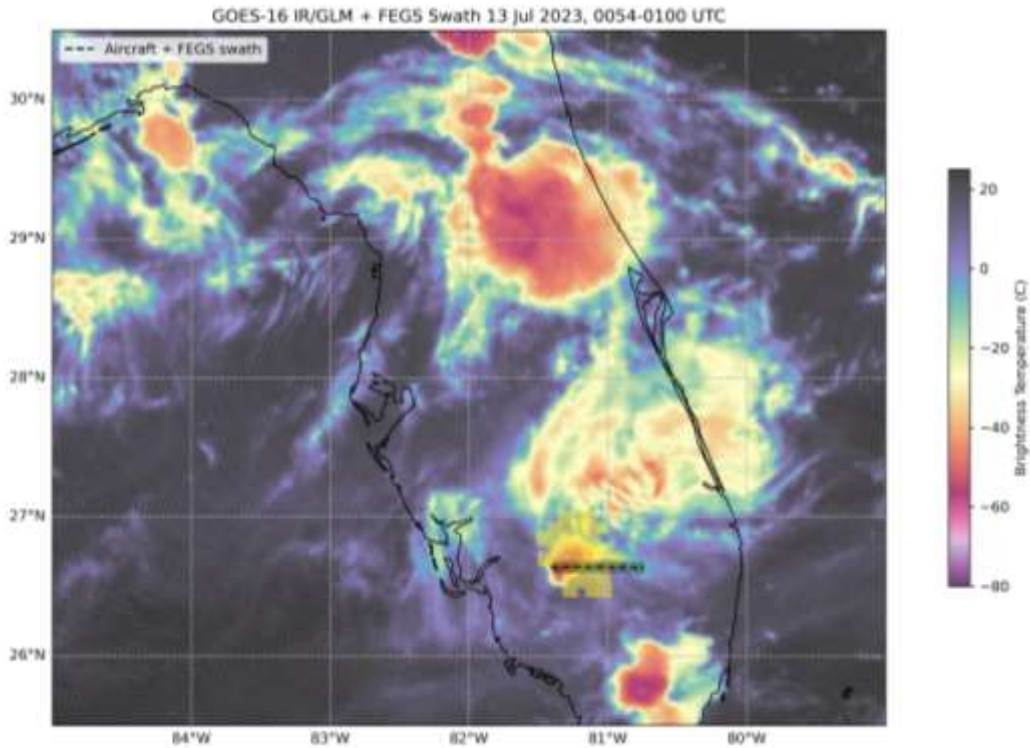
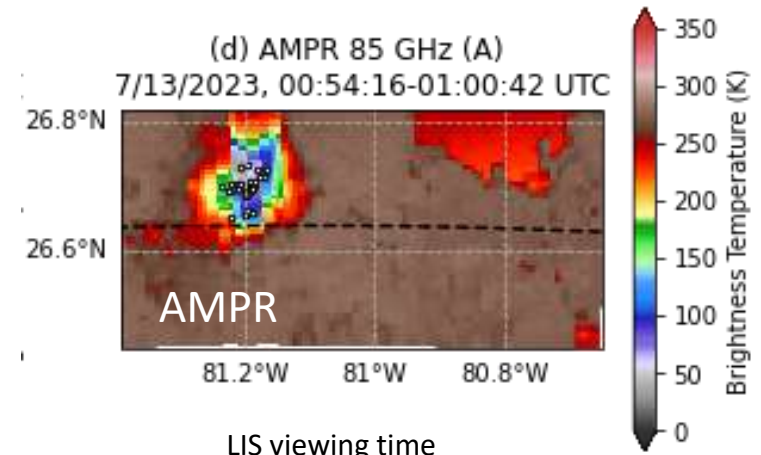
Bowties centered on strongest cells were the most common flight pattern during ALOFT



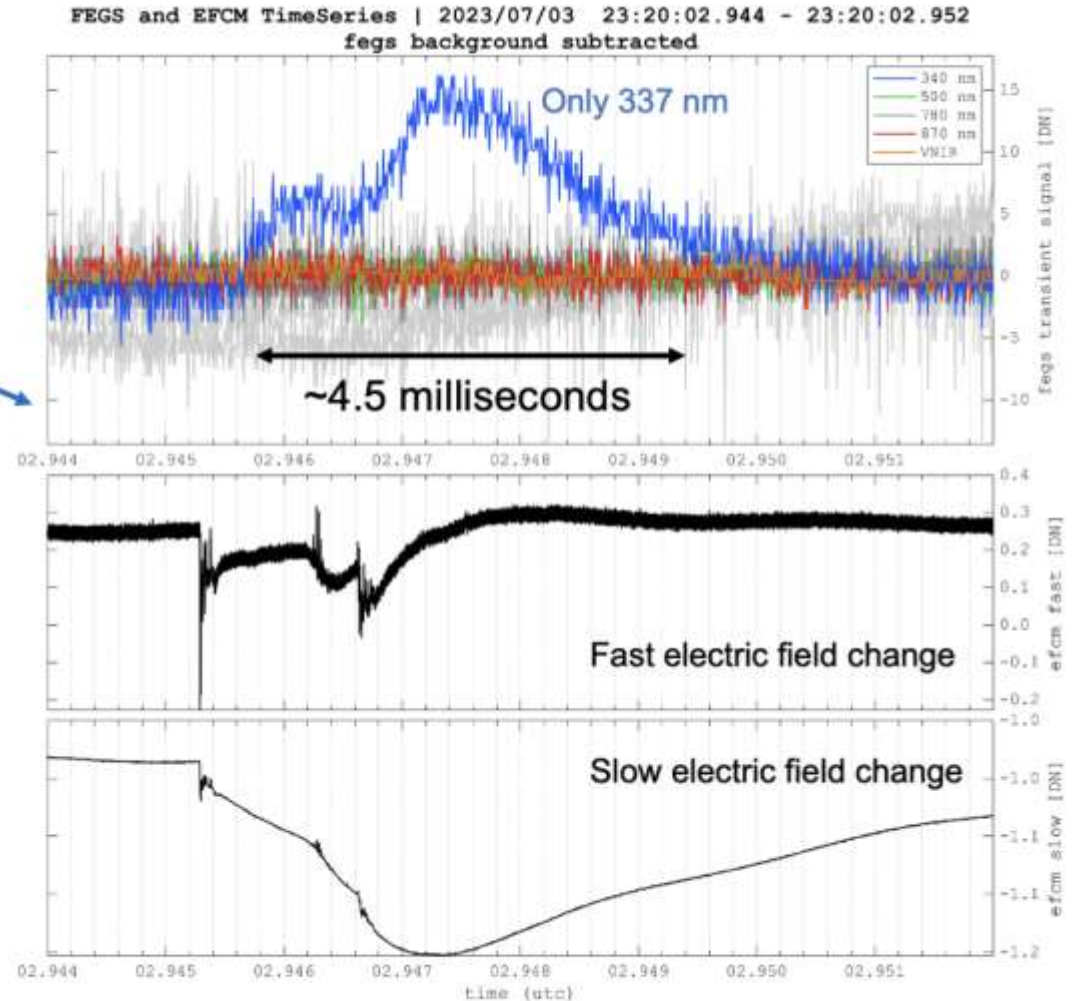
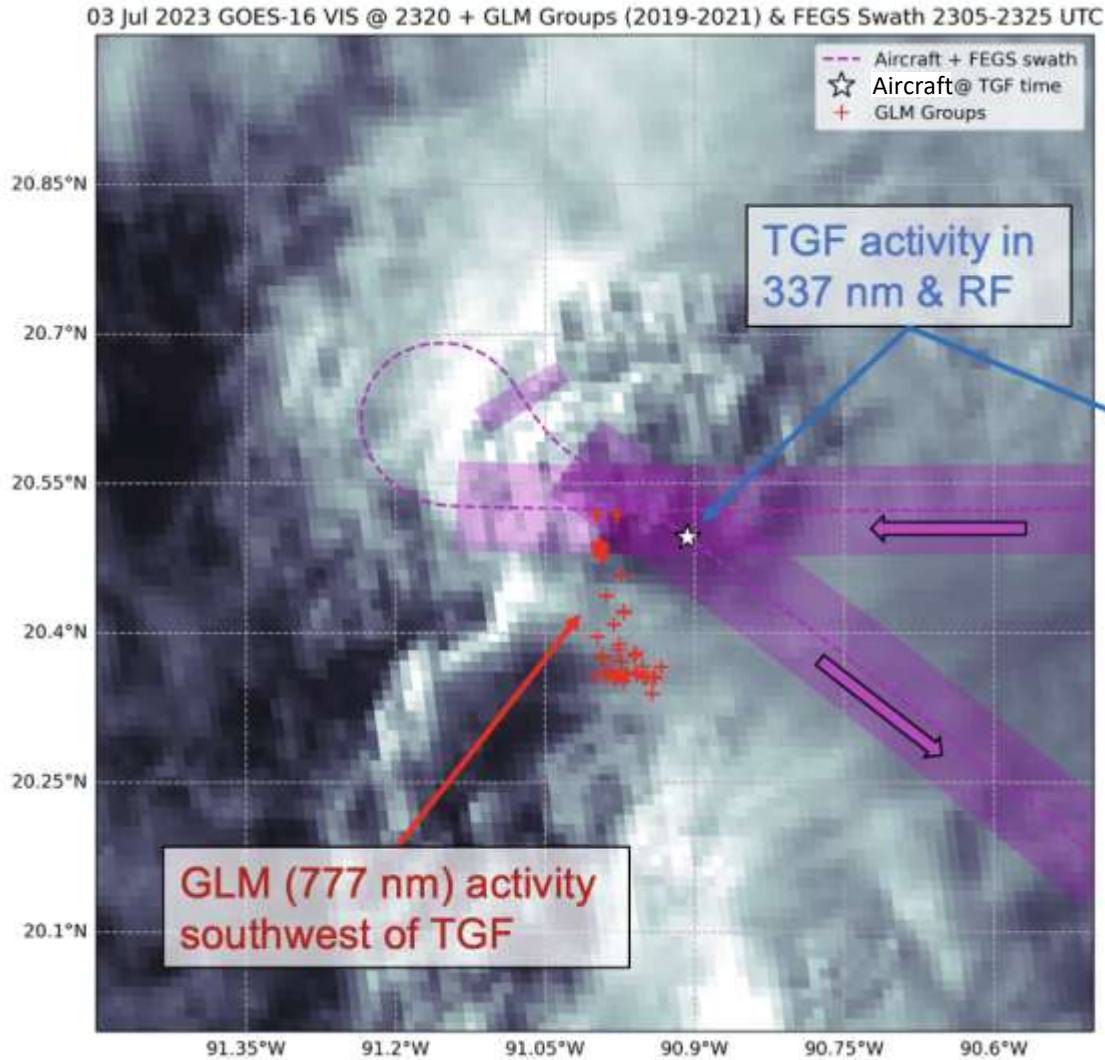
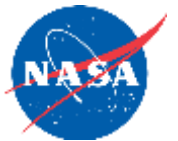
ISS Underflights

Occurred during 5 flights – 7/12-13, 20, 24, 25-26, 28

- 7/12-13 was only fully successful underflight
- 7/20 was partially successful (aircraft turning)
- Others had no lightning or LIS malfunctioned (noise)



Complementarity of 337-nm Measurements



Mason Quick, "FECS Measurements During the 2023 ALOFT Campaign", 1040 ET on Wednesday



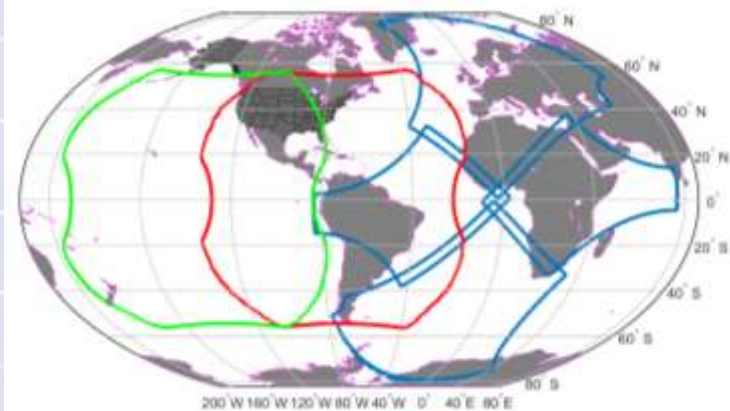
ALOFT Mission Scorecard



Most entries = Number of *flights* that met the requirements

| Highest Priority | | ALOFT Science Baseline | | Supports Additional Instruments or Science | |
|--|---------------------------------------|---|---------------------------------------|---|----------|
| Minimum Requirement | Metric | Enhanced Requirement | Metric | Extended Requirement | Metric |
| Observe TGF with UIB-BGO and/or iSTORM within GLM FOV (total ≥ 1) | UIB-BGO: 9 iSTORM: 5 | Observe TGF with UIB-BGO and/or iSTORM within FECS FOV (total ≥ 1) | UIB-BGO: 5 iSTORM: 3 | Observe TGF within range of 3D-resolving ground sensor (e.g., interferometer) | 1 |
| Observe glow from thundercloud in realtime with UIB-BGO and perform a successful return overpass by the aircraft (total ≥ 1) | 9 | Observe TGF in connection with a glowing thundercloud | 9 | Perform set of radar calibration wing waggles with clear skies near buoy (total ≥ 1) | 4 |
| ISS underflight with FECS + UIB-BGO/iSTORM | 5 | Observe TGF within range of 2D-resolving ground sensor (e.g., LF) | 7 | Perform straight-and-level flight with clear skies near buoy for radiometer calibration (total ≥ 1) | 8 |
| GLM-18 or MTG-LI underflight w/ FECS (indicate which underflown, overall total must be ≥ 1) | GLM-18: 12 MTG-LI: | GLM-18 <u>and</u> MTG-LI underflown w/ FECS (indicate yes/no to right, total numbers to left) | | | |
| Daytime overflight of thunderstorm(s) with FECS (indicate active high-priority channels, total ≥ 1) | 337: 7 777: 7 | Daytime thunderstorm with FECS 337 nm active (indicate yes/no to right, total number to left) | Yes | | |
| Nighttime overflight of thunderstorm(s) with FECS (indicate active high-priority channels, total ≥ 1) | 337: 3 777: 3 | Day/night thunderstorms w/ FECS 868 nm active (each ≥ 1) | Day: 7 Night: 3 | | |
| Total number of flashes observed by FECS (500 Minimum, 2k Enhanced, 5k Extended) | 7000+ | LIP operational (4+ mills up) on thunderstorm flight (total ≥ 1) | 12 | | |
| Overfly thunderstorms over primarily land and primarily ocean (each ≥ 1) | Land: 5 Ocean: 7 | Short-duration flight in FL/Bahamas region (mission science training; indicate date, earlier ideal) | 12-Jul | | |
| Total thunderstorm flights (including transits) | 12 | Overfly thunderstorm with FECS during day/night transition (e.g., dusk) | 2 | | |
| Total science flight hours used | 63.8 | Overfly thunderstorm(s) in range of 3D-resolving ground sensor (e.g., interferometer) | 1 | | |
| Total TGFs observed | 134+ | Fermi underflight while hunting for TGFs | | | |

← No MTG-LI

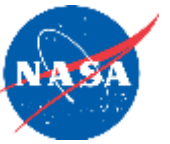


= Very likely to increase with additional analysis



Summary and Conclusions

- ALOFT was incredibly successful relative to original expectations (~130 TGFs or similar, dozens of glows)
- 10 science flights (plus two thunderstorms overflowed during transits), over 60 flight hours, essentially all within stereo GLM-16/18 region (plus ABI MDS for 7 of 10 flights!)
- ~7000 flashes observed by FEGS/EFCM
- 5 underflights of ISS, 1 with coincident FEGS, EFCM, and LIP (another 1 without good FEGS)
- FEGS 337-nm channel detected lightning during both day and night, and detected additional lightning compared to 777 nm



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Requiem for ISS LIS

- LIS is being replaced on the ISS by the Atmospheric Waves Experiment (AWE) space weather instrument
- AWE was launched by the SpaceX CRS-29 mission
- Thus ends a 28-year set of missions that documented global lightning from space, but we are seeking future mission opportunities

Patrick Gatlin, "Efforts Towards Developing a New Low-Earth Orbiting Lightning Mapper", 1050 ET on Wednesday

January Lightning Activity Observed from the Space Station

