

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

Timothy Lang
Earth Science Branch, NASA MSFC
ALOFT Project Scientist

Contributors: Nikolai Østgaard, Mason Quick, Christopher Schultz, Douglas Mach, Dennis Buechler, Martino Marisaldi, Eric Grove, Ian Adams, Rachael Kroodsma, Gerald Heymsfield, Hugh Christian, Randall Longenbaugh, Richard Blakeslee, Andrey Mezentsev, David Sarria, Phillip Bitzer, Morris Cohen, Steven Cummer, Martin Fullekrug, Joan Montanya, Marni Pazos, Mark Stanley, Camilo Velosa

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.

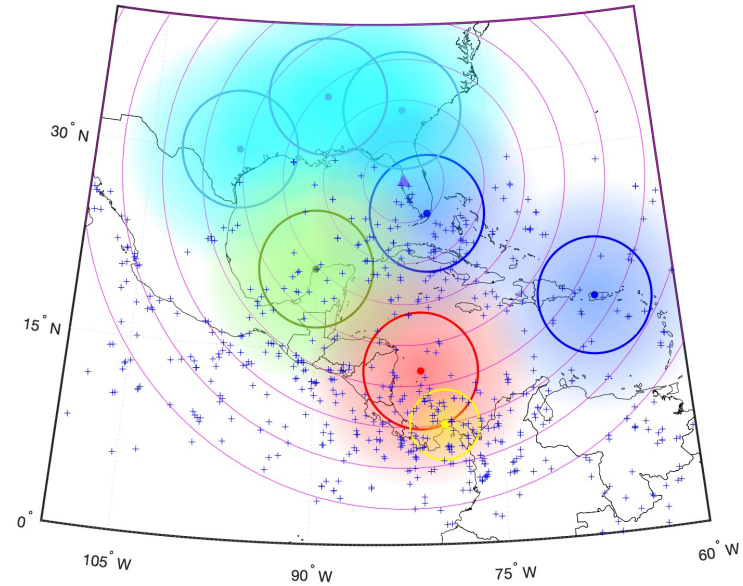
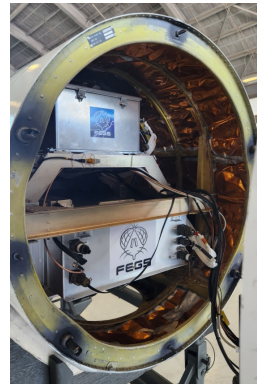


ALOFT Airborne and Ground Instruments



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

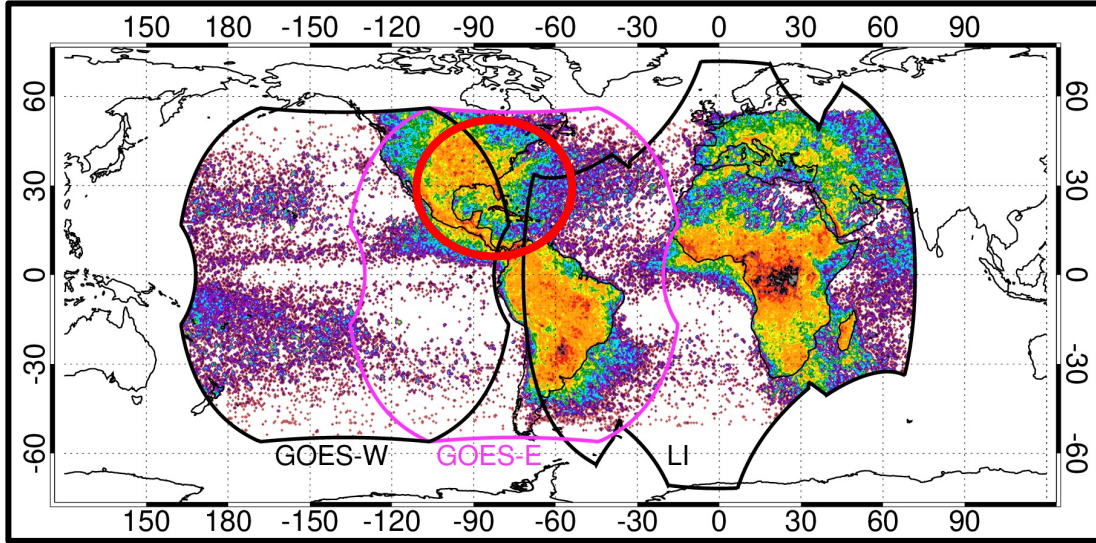
- LF antennas – Mexico, Florida & SE USA, San Andres, Puerto Rico
- VHF interferometers @ KSC, Homestead, and San Andres
- Central Florida LMA – 5-6 stations
- Panama Marx Meter Network
- Additional San Andres – VHF station, high-energy sensor, high-speed cameras, radar



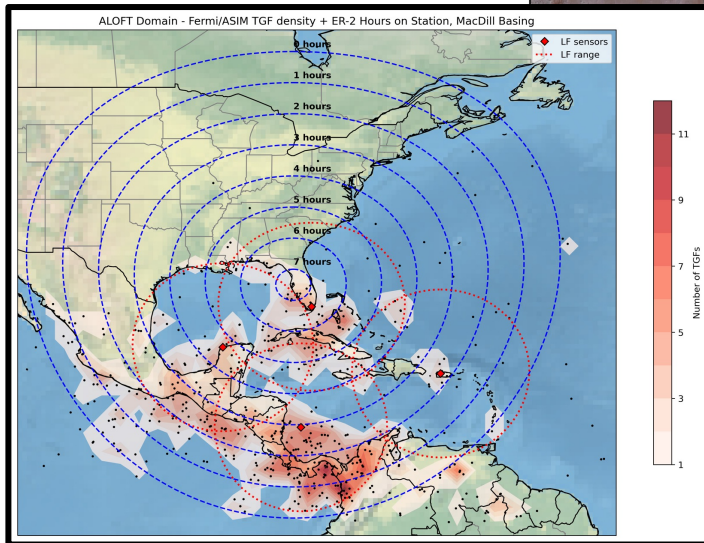
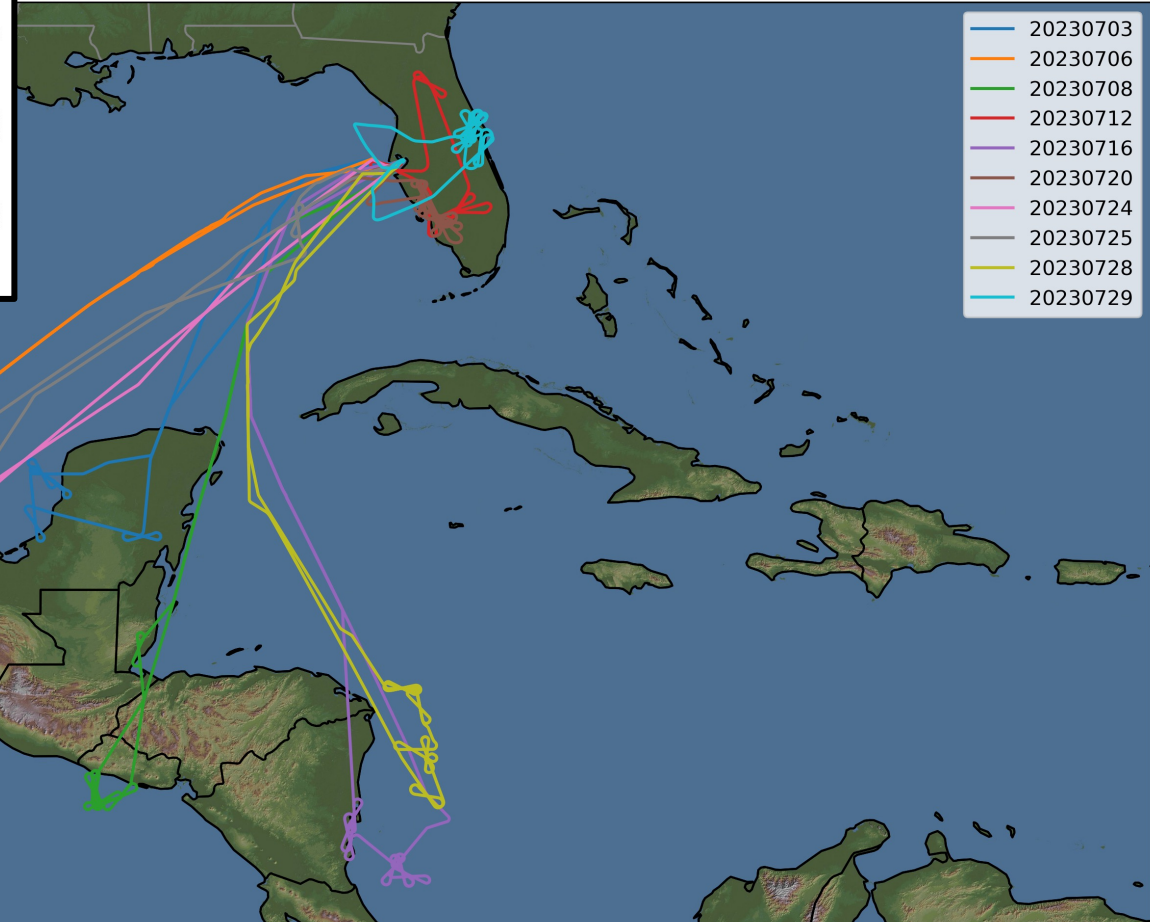
ALOFT Science Flights



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



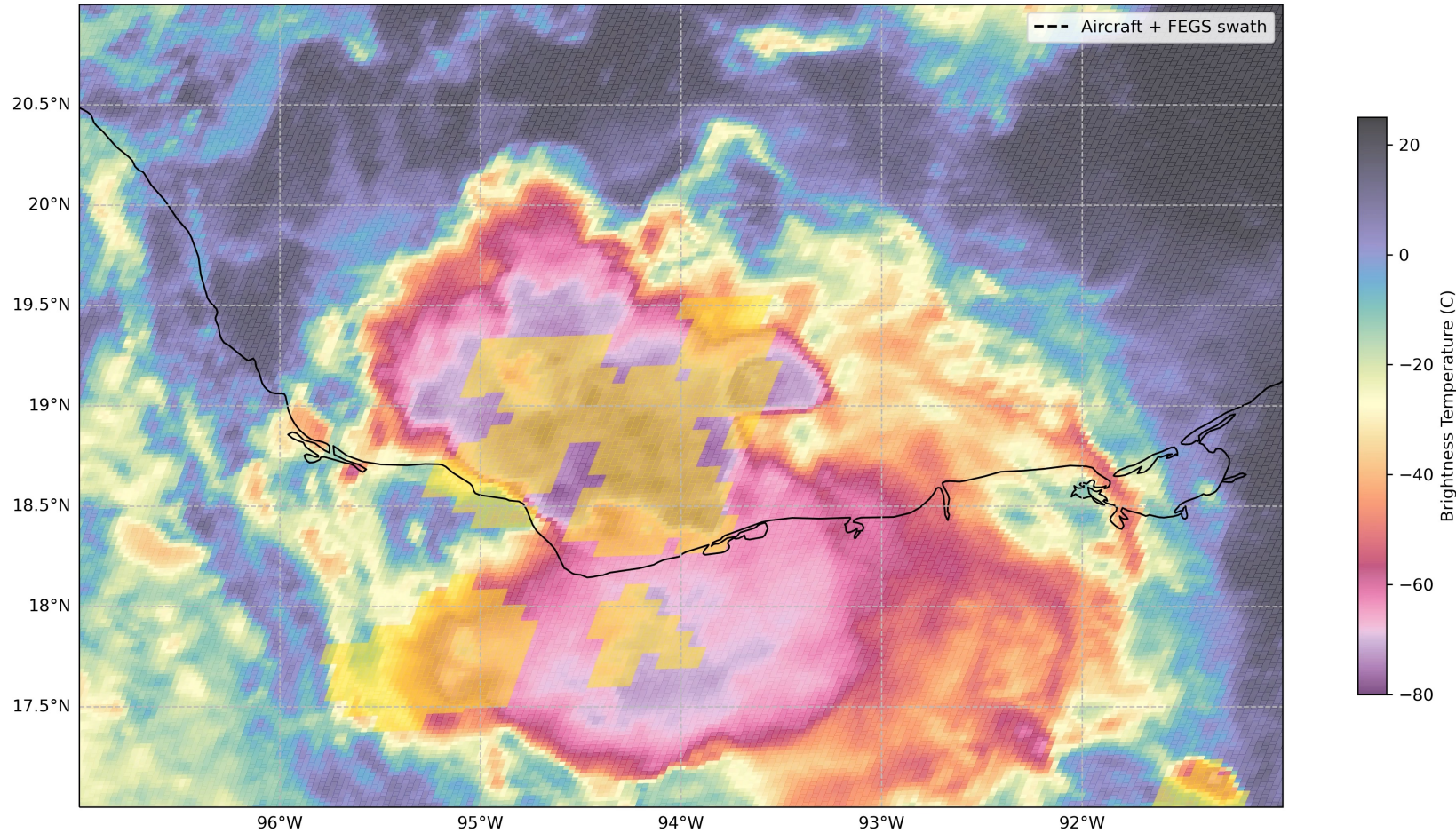
ALOFT Domain - ER-2 Science Flights



24 July 2023 – Highly Electrified and “Radioactive” MCS



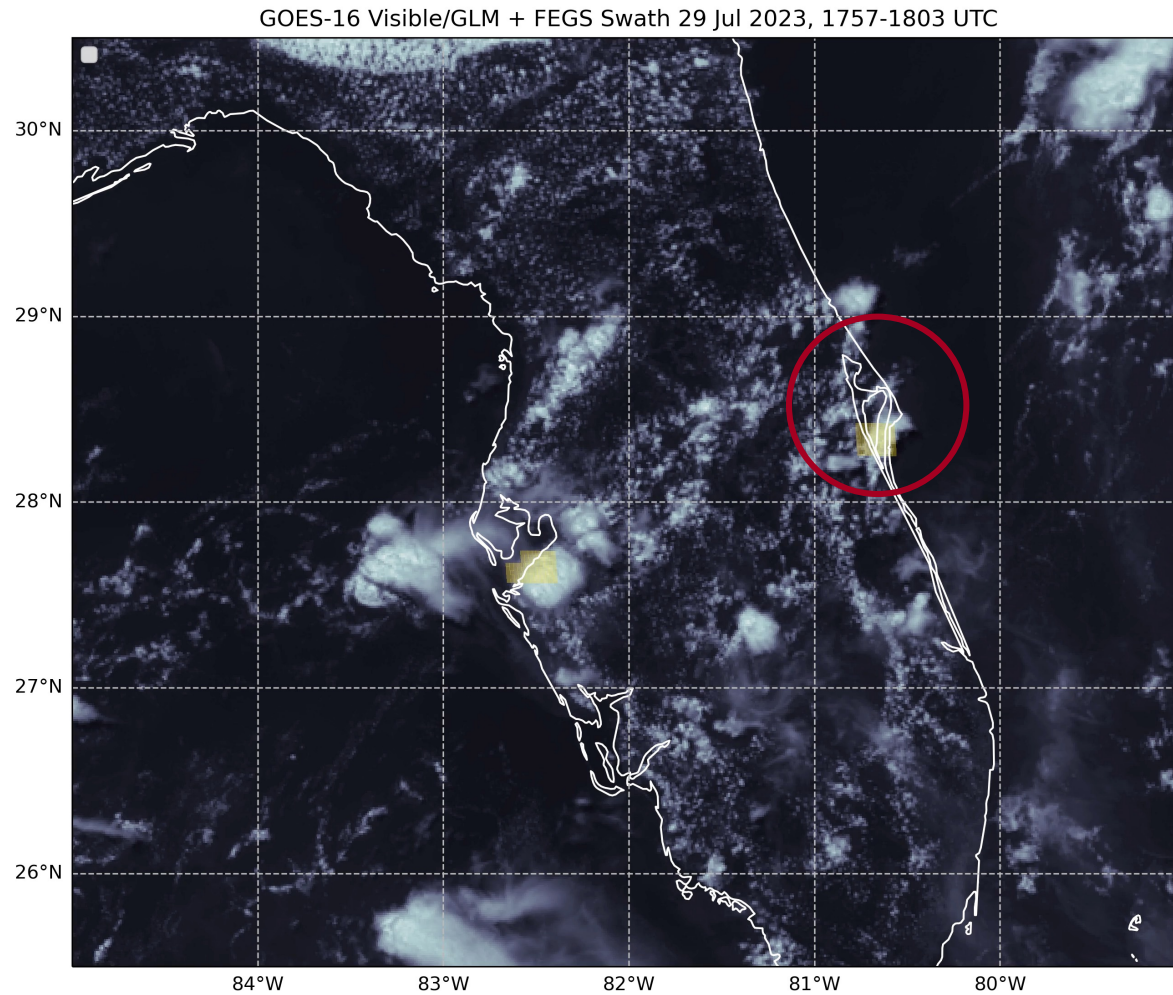
GOES-18 IR/GLM + FECS Swath 24 Jul 2023, 0430-0436 UTC



- ~85 TGFs
- Some EFCM/LIP missing data (~1-2 hours)
- ISS overpass but LIS malfunction



29 July 2023 – 7 TGFs in range of KSC Interferometer and Central FL LMA



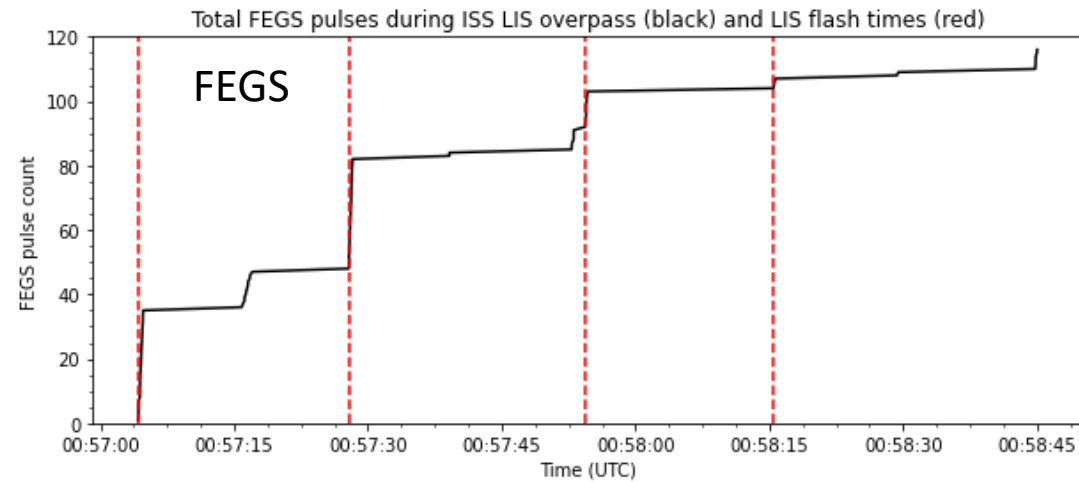
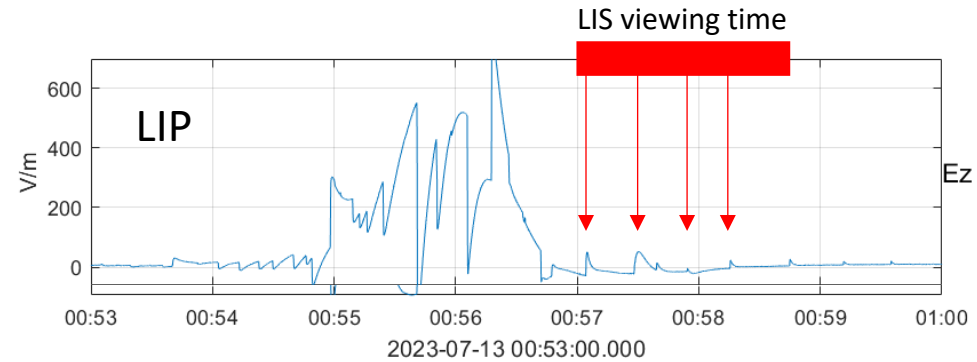
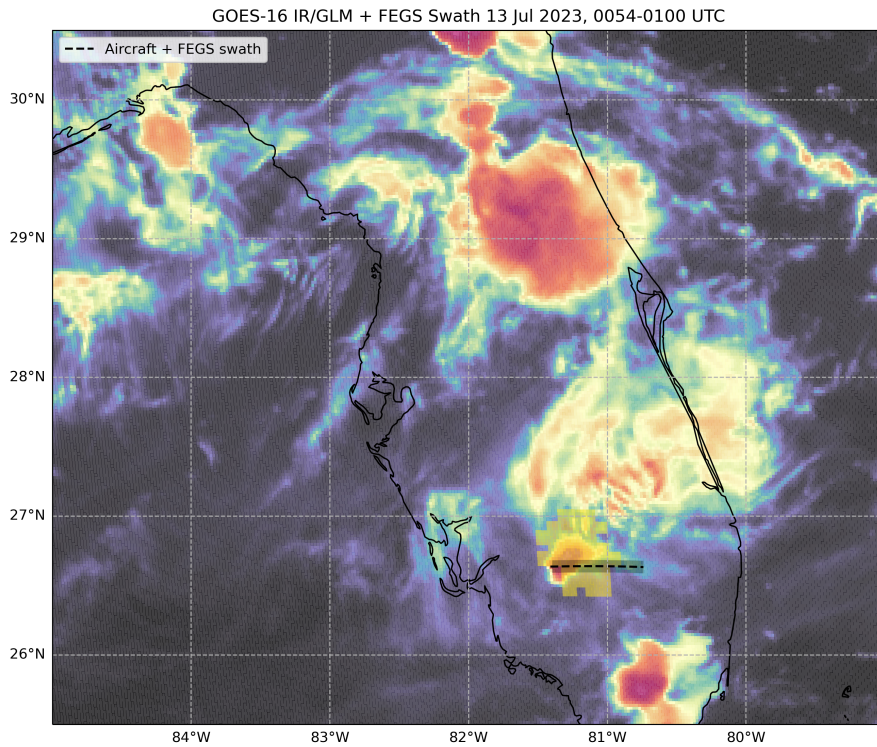
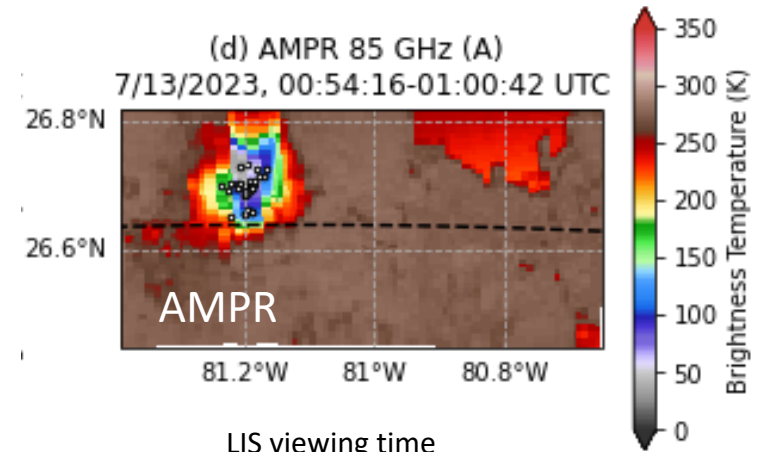
Bowties centered on strongest cells were the most common flight pattern during ALOFT



ISS Underflights

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

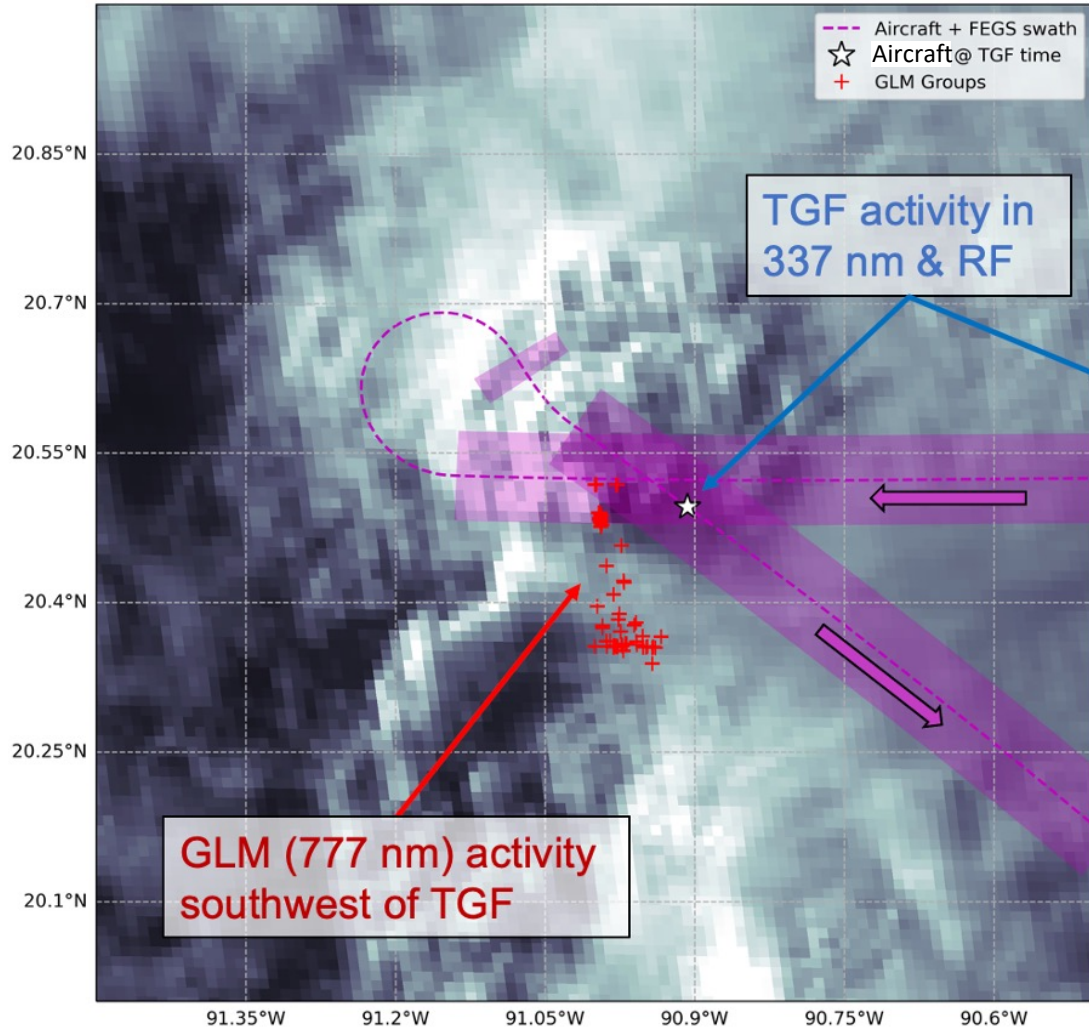
- 7/12-13 was only fully successful underflight
- 7/20 was partially successful (aircraft turning)
- Others had no lightning or LIS malfunctioned (noise)



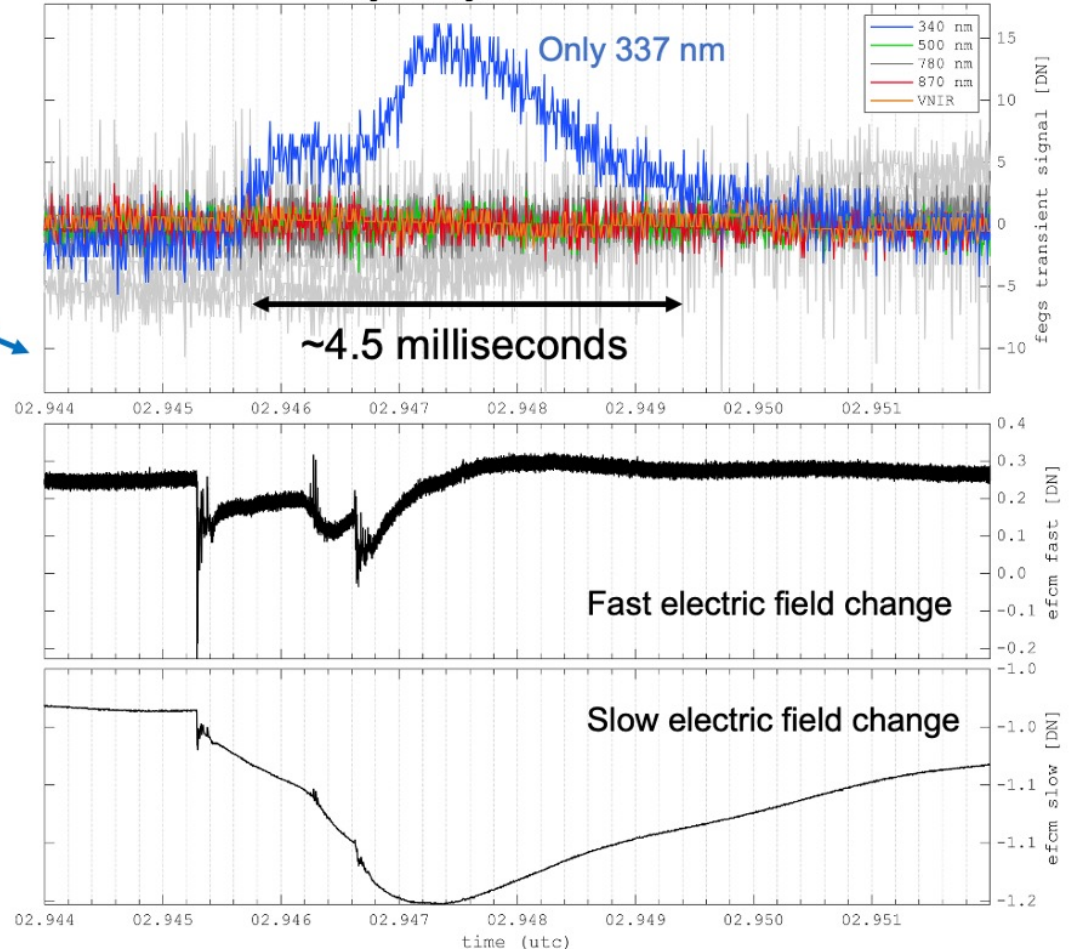
Complementarity of 337-nm Measurements



03 Jul 2023 GOES-16 VIS @ 2320 + GLM Groups (2019-2021) & FECS Swath 2305-2325 UTC



FECS and EFCM TimeSeries | 2023/07/03 23:20:02.944 - 23:20:02.952
fecs background subtracted



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)		No MTG-LI	
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	# = Very likely to increase with additional analysis	
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			



Summary and Conclusions

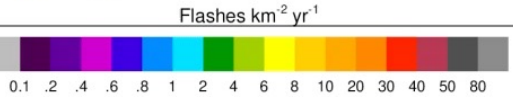
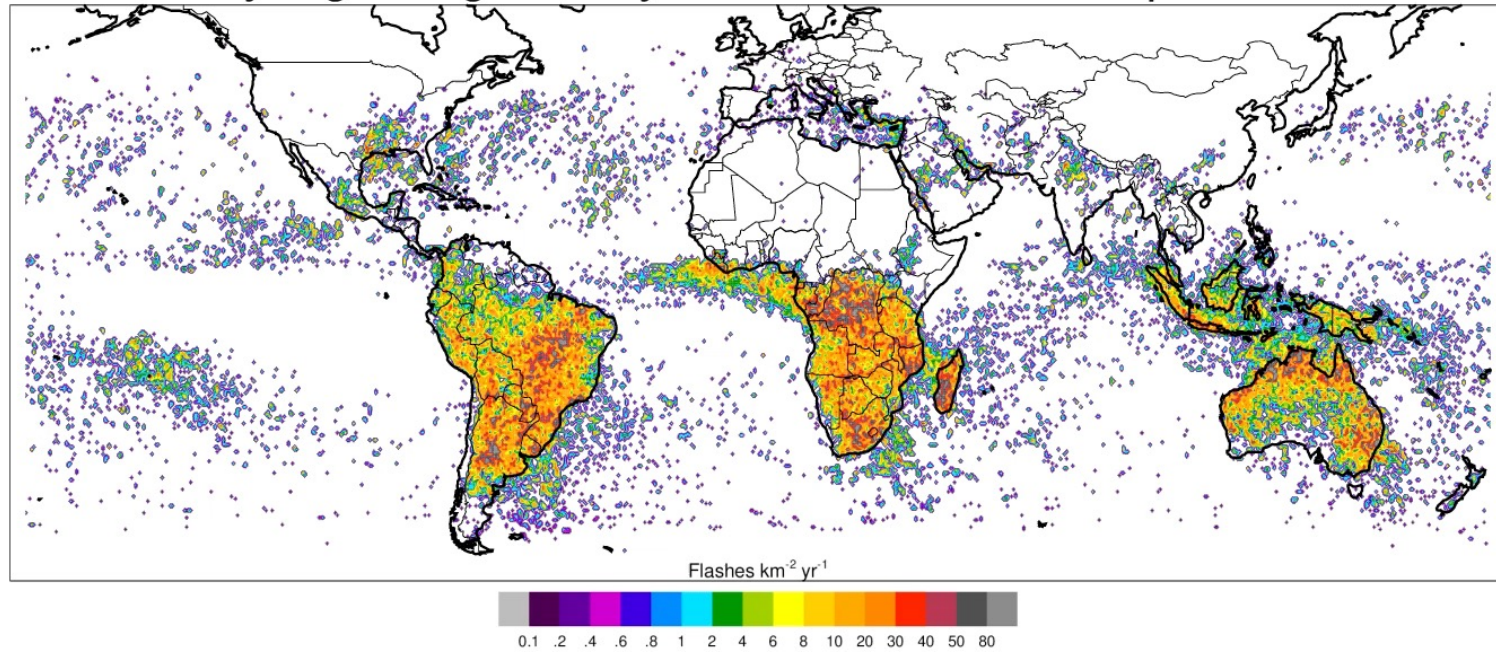
- ALOFT was incredibly successful relative to original expectations (> 130 TGFs, dozens of glows)
- 10 science flights (plus two thunderstorms overflowed during transits), over 60 flight hours, essentially all within stereo GLM-16/18 region
- More than 7000 flashes observed by FEGS/EFCM
- 5 underflights 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



Requiem for ISS LIS

- LIS is being replaced on the ISS by the Atmospheric Waves Experiment (AWE) space weather instrument
- AWE is being 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

January Lightning Activity Observed from the Space Station



Monthly TRMM and ISS LIS Flash Rate

