The scientific payload of the ALOFT mission to chase Terrestrial Gamma-ray Flashes and gamma-ray glows

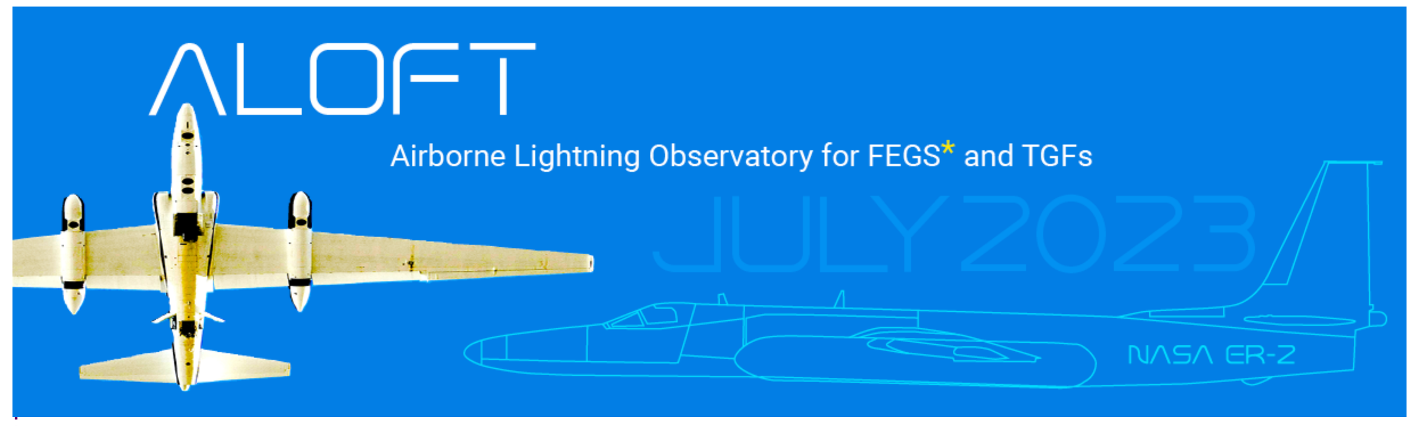
BIRKELAND CENTRE FOR SPACE SCIENCE

EGU General Assembly 2023

9381

Martino Marisaldi[1] (martino.marisaldi@uib.no), N. Østgaard[1], K. Ullaland[1], S. Yang[1], B. H. Qureshi[1], J. Søndergaard[1], A. Mezentsev[1], D. Sarria[1], N. Lehtinen[1], T. J. Lang[2], H. Christian[3], M. Quick[2], R. Blakeslee[2], J. E. Grove[4], and D. Shy[5]

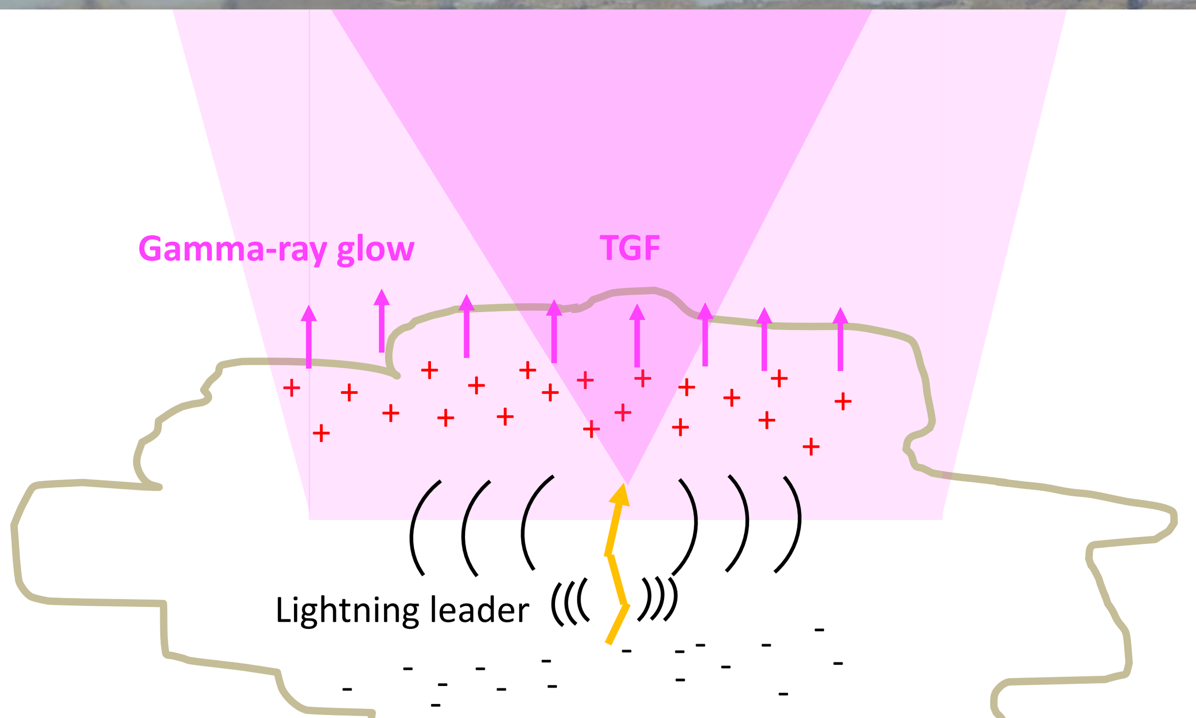
[1]Birkeland Centre for Space Science, University of Bergen, Norway [2]NASA Marshall Space Flight Center, Huntsville, USA [3]Department of Atmospheric Science, University of Alabama in Huntsville, Huntsville, USA, [4]U.S. Naval Research Laboratory, Washington DC, USA, [5]National Research Council Research Associate resident at the U.S. Naval Research Laboratory, Washington DC, 20375, USA

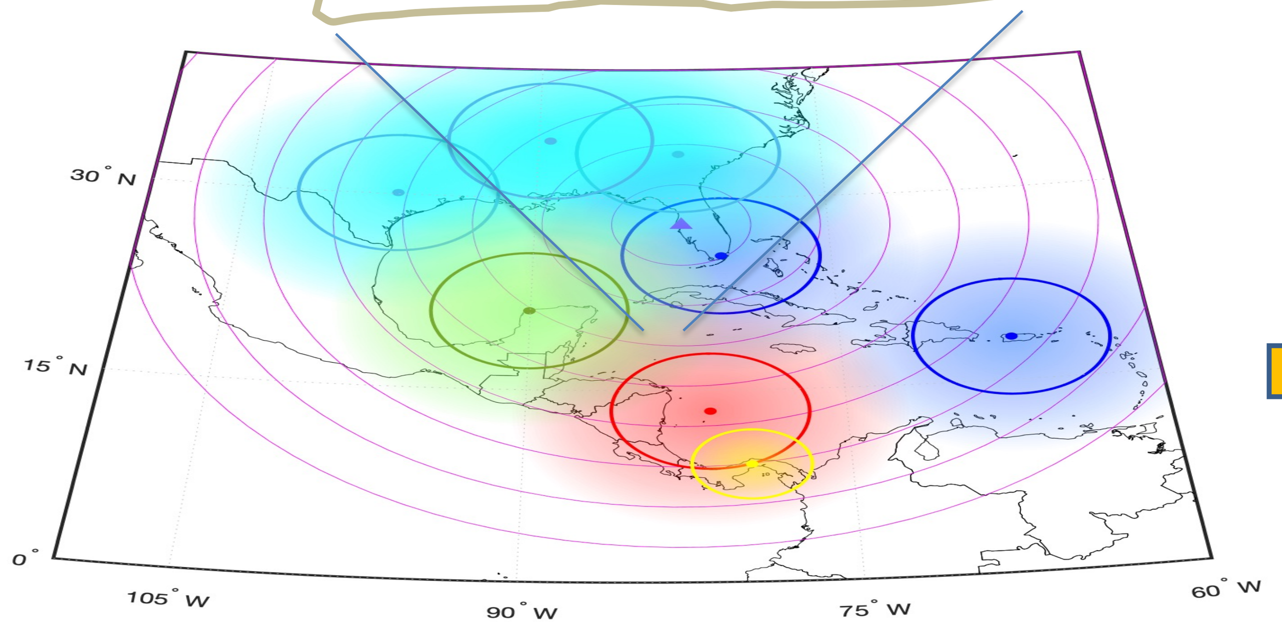


Principal Investigator – Nikolai Ostgaard, University of Bergen, Norway
Project Scientist – Timothy Lang, NASA MSFC
ER-2 Project Manager – Franzeska Becker, NASA AFRC, USA

THE MISSION SCENARIO

Credits: NASA





The network of ground sensors in support of the ALOFT mission

THE ALOFT MISSION

ALOFT (Airborne Lightning Observatory for FEGS and TGFs) is a flight campaign designed to observe Terrestrial Gamma-ray Flashes (TGF) and gamma-ray glows close to their production source. The campaign consists of 60 flight hours of a NASA ER-2 research aircraft taking off from Florida and is scheduled for July 2023. The ER-2 cruise altitude of 20 km allows flying over active thunderstorms in the Gulf of Mexico and Caribbean region, one of the most TGF-active region on the planet. The synergy between airborne gamma-ray, optical and electric field measurements, combined with ground-based radio observations, will provide a unique set of observations to constrain the source properties and their physics.

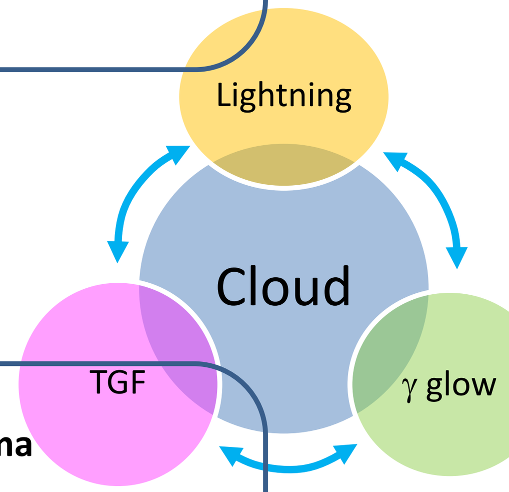
DATA FROM AIRCRAFT

Gamma-rays
Is there a TGF or a glow?

Optical
Are there 'hot' processes? (Blue vs. red disharges)

Electric field
What is the cloud charge structure?

Radar / passive radiometer
What is the cloud structure / microphysics?



SCIENTIFIC OBJECTIVES

- **How and under what conditions are Terrestrial Gamma Flashes (TGF) produced?**
- **How extended in space and time are gamma-ray glows?**
- **Are gamma-ray glows and TGFs interrelated?**

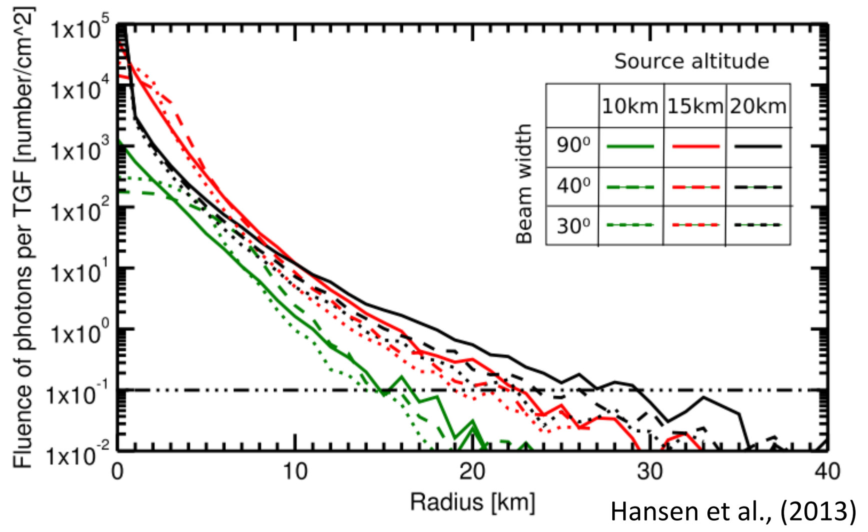
DATA FROM GROUND

LF radio
How much charge is moved?
Are there 'slow' processes?

VHF radio (interferometry)
What is the discharge spatial morphology?
What are the characteristics (length, speed...) of the associated leader?

THE DYNAMIC RANGE CHALLENGE

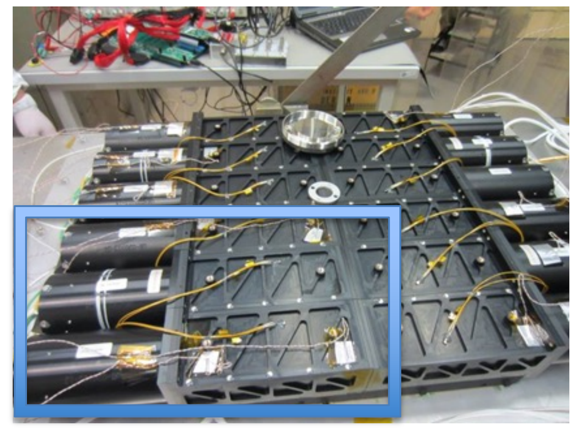
- **4 to 5 orders of magnitude in TGF fluence are expected at aircraft altitude**, depending on radial distance to source (Hansen et al., 2013, JGR 118, 2333)
- The maximum flux that a single gamma-ray detector can stand depends on its dimension, timing performance, and readout logic
- A realistic approach is to use a **suite of gamma-ray detectors sensitive in different flux ranges**, to cover the wide dynamic range requested



Hansen et al., (2013)

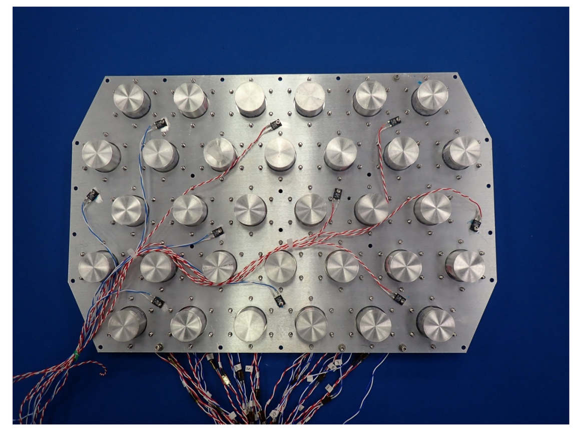
THE GAMMA-RAY PAYLOAD

UiB-BGO – PI: Nikolai Østgaard, University of Bergen, Norway



Type / readout	Geometrical area (cm²)	Usage	Fluence range in 100 µs (distance range)
BGO + PMT	225	Spectroscopy 0.3 – 40 MeV	0.05 - 1 cm^{-2} (~15 – 25 km)
LYSO + SiPM	25	Spectroscopy 0.3 – 40 MeV	0.5 - 50 cm^{-2} (~8 – 20 km)
LYSO + PMT	1	Counter > 0.3 MeV	10 - 1000 cm^{-2} (~12 – 5 km)
LYSO + SiPM	0.09	Counter > 0.3 MeV	500 - 10000 cm^{-2} (<~6 km)

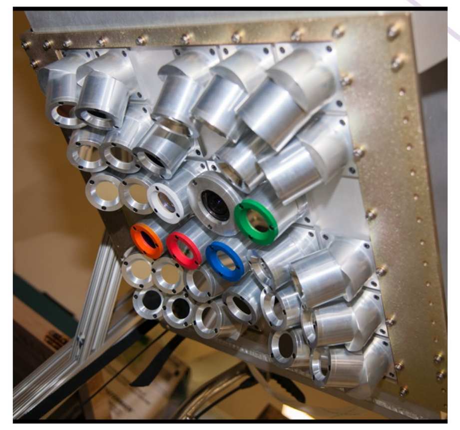
iSTORM – PIs: Eric J. Grove / Daniel Shy, U.S. Naval Research Laboratory, USA



- 32 $CeBr_3$ scintillators with SiPM readout
- 100 keV – 8 MeV energy range
- High spectral resolution

THE OPTICAL PAYLOAD

Fly's Eye Geostationary Lightning Mapper (GLM) Simulator (FEGS)
PI Mason Quick, NASA MSFC, USA



- Array of optical photometers (100 kHz sampling) 10x10 km field of view:
  - 25x 780 nm
  - 1x 340 nm
  - 1x 500 nm
  - 1x 870 nm
  - 1x 1600 nm
  - 1x 400-1100 nm (VNIR)
- 1.6 µm photometer from Sandia Lab (Pis: R. Longenbaugh and T. Edwards, Sandia National Laboratory, USA)
- 400-1000 nm HD camera
- FEGS Spectrometer:
  - Range: 200-850 nm
  - Resolution: 1.5 nm
  - Rate: 500 spectra/second (2ms integration)

THE ELECTRICAL ENVIRONMENT PAYLOAD

Electric Field Change Meter (EFCM) – PI: Hugh Christian, University of Alabama Huntsville, USA

- Fast channel: 10 MHz sampling rate, 100 µs decay time constant
- Slow channel: 1 MHz sampling rate, 150 ms decay time constant

Lightning Instrument Package (LIP) - PI: Chistofer J. Schultz, NASA MSFC

- Three component Electric field, 0.1 s time resolution

THE CLOUD CHARACTERIZATION PAYLOAD

Advanced Microwave Precipitation Radiometer (AMPR) - PI: Timothy Lang, NASA MSFC, USA
- 10-85 GHz microwave radiometer, ~40-km wide swath

Conically Scanning Sub-millimeter-wave Imaging Radiometer (CoSSIR) - PI: Rachael Kroodsma, NASA Goddard SFC, USA
- 16-channel total power imaging radiometer in 170-684 GHz microwave band

Cloud Radar System (CRS) - PI: Gerry Heymsfield, NASA Goddard SFC, USA
- 94 GHz (W-band) doppler radar

X-band Radar (EXRAD) - PI: Gerry Heymsfield, NASA Goddard SFC, USA
- X-band Doppler radar

REFERENCES

The ALOFT webpage

Attend the ALOFT presentation by N. Østgaard et al. (EGU23-3116): **Tue, 25 Apr, Room M2, 10:00–10:10**

Sharing is encouraged