D1860, EGU2020-2467:
Source Altitudes of Optical Emissions Associated with TGFs

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Outline of this Presentation

This display follows a slightly different structure compared to a normal talk or presentation: It starts with the summary of the main points and then presents the argumentation. The instrument description and the references are at the end.

Thanks to Hare et al. (D1866, EGU2020-7957) for the idea to this format!

Summary

Optical observations associated with TGFs are always connected to emissions in the 337 nm band

F/MUV (180-230 nm) detections are correlated to higher production altitudes and stronger 337 nm emissions

777 nm emissions are detected in all but 1 case, show absorption and are generally ~3 times weaker than the emissions in 337 nm.

Source altitudes of optical emissions associated with TGF are in the range of 8-14 km

→ Consistent with previous estimates of TGF altitudes from radio measurements (Stanley et al., 2006, Cummer et al., 2015)

Optical Detections Associated to TGFs - A typical Example

Most common sequence of events:

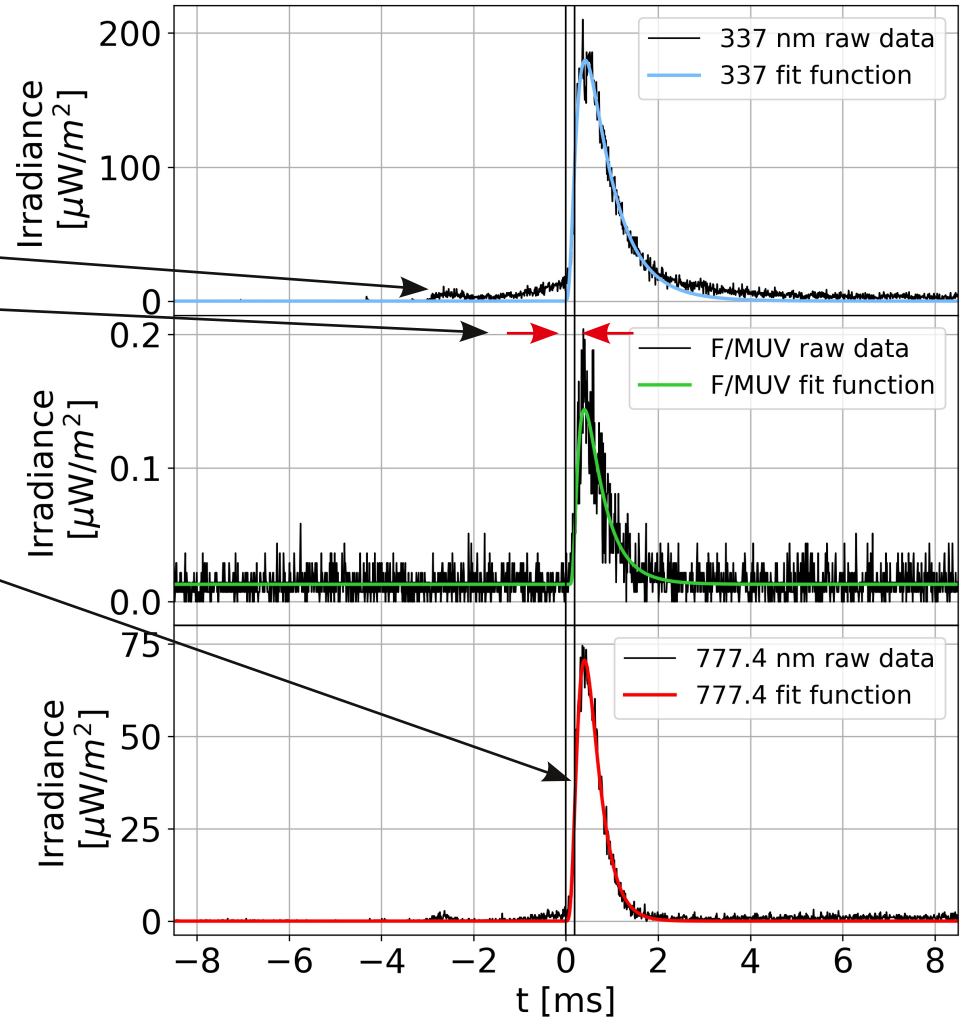
1. Leader activity
2. TGF
3. Main optical pulse

ASIM/MMIA photometers sample with 100 kHz in 3 bands:

→ 337 nm (blue in plot)

→ F/MUV: 180-230 nm (green i.p.)

→ 777.4 nm (red i.p.)



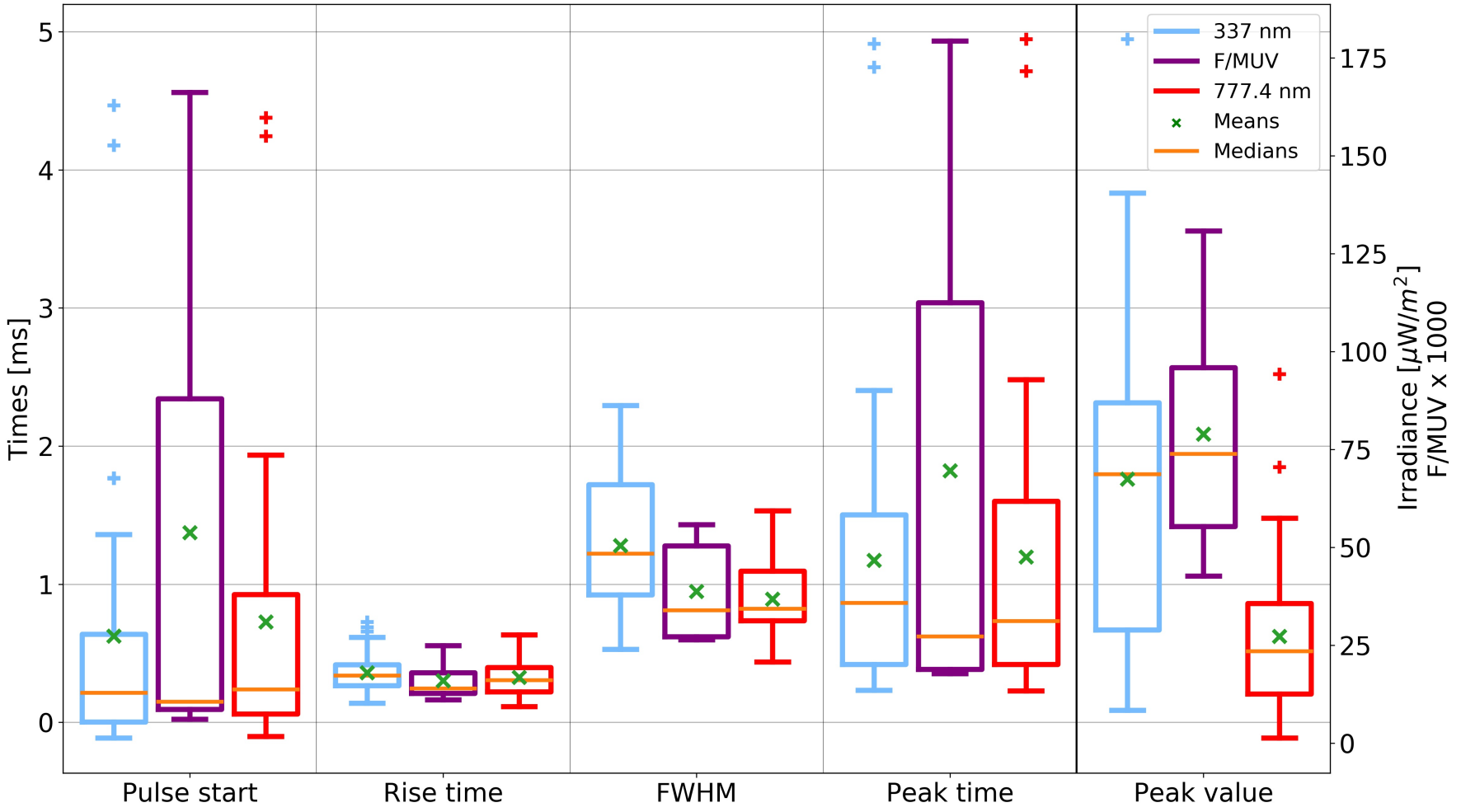
More instrument details can be found on slide 9.

Characteristics of the Main Optical Peak

Absorption in 777.4 nm:
(neglectable in 337 nm)
→ smaller FWHM
→ slightly earlier maxima

337 nm ≈ 3 x 777.4 nm
→ peak ratio
→ pairwise calculated

Emission abundance:
→ 337 nm: 100%
→ F/MUV: 21%
→ 777 nm: 97%



Models and Assumed Cloud Composition

Absorption-diffusion model for propagation of optical emissions through the cloud
→ instantaneous, point-like source
→ planar cloud

} Soler et al., 2020

Cloud composed of water ice droplets:
→ cloud droplet radius: 15-20 µm
→ cloud droplet density: 10^8 m^{-3}

} Dye et al., 2007; Ursi et al., 2019

→ asymmetry factor: 0.88
→ single scattering albedo: ~1

} Light et al., 2001; Koshak et al., 1994; Thomason & Krider, 1982

Cloud top altitudes are approximated by a model of latitude dependent tropopause heights

} Offroy et al. 2015

Altitude Estimation of Optical Emissions I

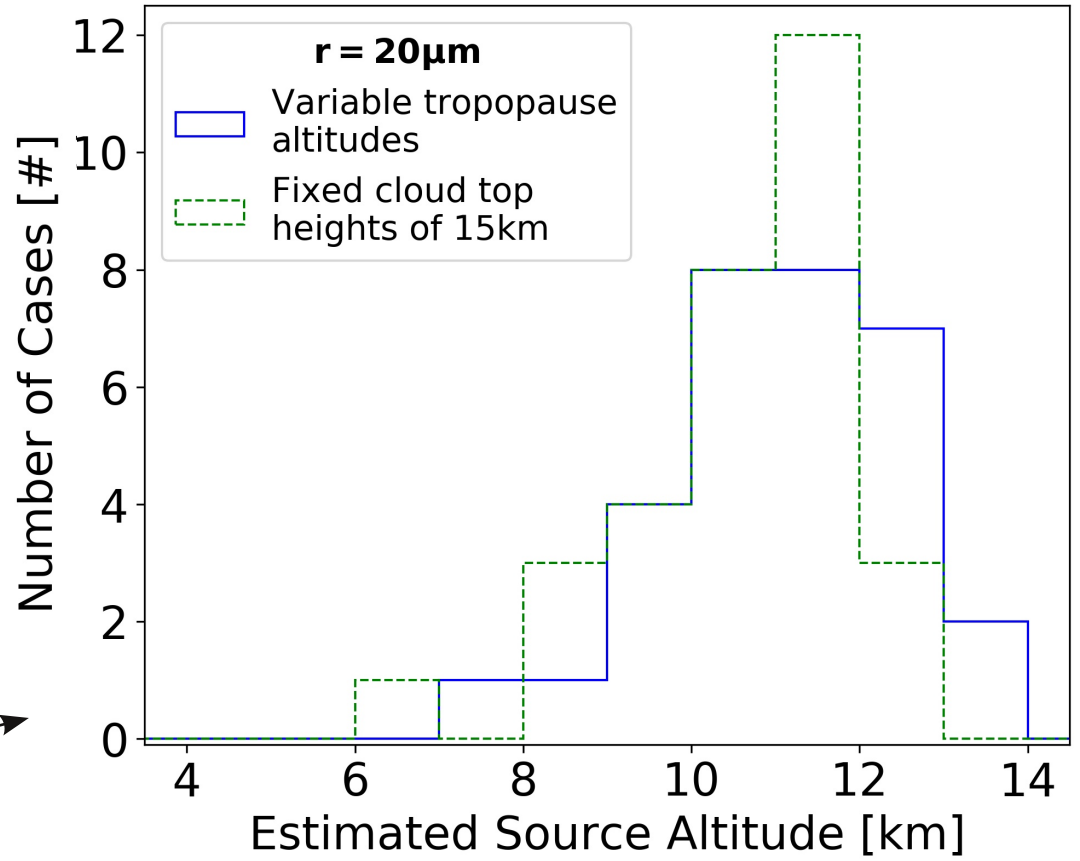
Processing Steps:

1.) Fit results from absorption-diffusion model to optical pulses associated with TGFs

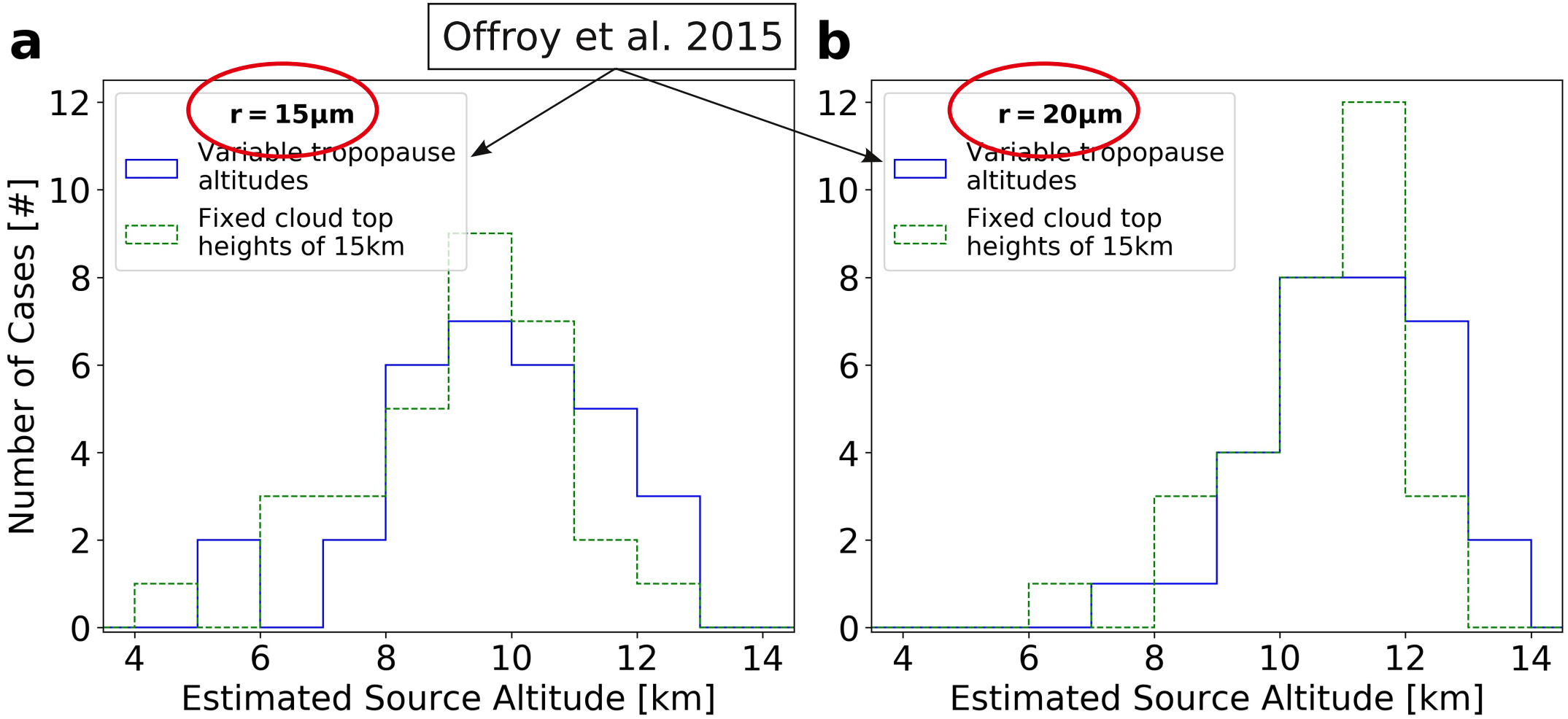
2.) Calculate depth inside the cloud from 337 nm signal based on cloud composition (slide 6)

3.) Subtract depth from tropopause altitude and a fixed value of 15 km

4.) Compare results for the different TGFs cases

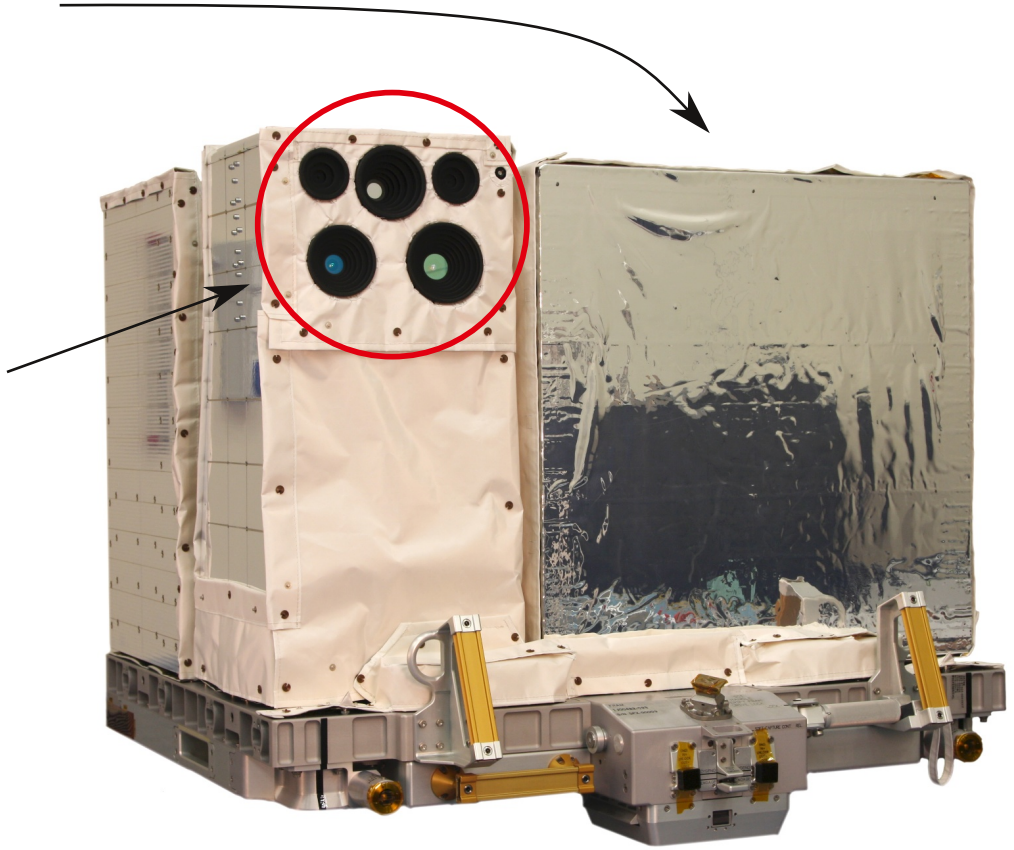


Altitude Estimation of Optical Emissions II



The Atmosphere-Space Interactions Monitor

Modular X- and Gamma-ray Sensor (MXGS)
- low-energy detector 50 to 400 keV
- high-energy detector 0.3 to >30 MeV
- detects TGFs



Modular Multi-Imaging Assembly (MMIA)
- 3 photometers
  100 kHz sampling
  337/4 nm, 180 - 230 nm and 777.4/5 nm

- 2 cameras @ 12 fps:
  1024 x 1024 pixel
  400 x 400 m resolution
  337/5 nm and 777.4/3 nm

References: Neubert et al., 2019;
Chanrion et al., 2019; Østgaard et al., 2019;

Related Presentations

Köhn et al. (D1865, EGU2020-4645): Modelling the production of terrestrial gamma-ray flashes during the final leader step

Luque et al. (D1898, EGU2020-19506): Scattering of lightning optical radiation by complex, inhomogeneous clouds

Mezentsev et al. (D1887, EGU2020-8157): Lightning optical context associated with ASIM TGFs

Bjørge-Engeland et al. (D1888, EGU2020-7113): Time sequence of TGFs and optical pulses detected by ASIM

Skeie et al. (D1886, EGU2020-6967): Assessing the relationship between the TGF durations and the onset times of the TGFs and the main optical pulses as detected by ASIM

Chanrion et al. (D1855, EGU2020-17913): Analysis of Elves observations from about 2 years of ASIM operation.

References

- Chanrion, O., et al. 2019: The Modular Multispectral Imaging Array (MMIA) of the ASIM Payload on the International Space Station. Sp. Sci. Revs., 215 (4), 28. doi: 10.1007/s11214-019-0593-y
- Cummer, S. A., et al., 2015: Lightning leader altitude progression in terrestrial gamma-ray flashes. GRL, 42(18), 7792-7798. doi: 10.1002/2015GL065228
- Dye, J. E., et al., 2007: Electric fields, cloud microphysics, and reflectivity in anvils of Florida thunderstorms. JGR, 112(D11), D11215. doi: 10.1029/2006JD007550
- Koshak, W. J., et al., 1994: Diffusion model for lightning radiative transfer. JGR, 99(D7), 14361-14371.
- Light, T. E., et al., 2001: Simulations of lightning optical waveforms as seen through clouds by satellites. JGR Atmospheres, 106(D15), 17103-17114. doi: 10.1029/2001JD900051
- Neubert, T., et al., 2019: The ASIM Mission on the International Space Station. Sp. Sci. Revs., 215 (2), 26. doi: 10.1007/s11214-019-0592-z
- Offroy, M., et al., 2015: Temporal and radiometric statistics on lightning flashes observed from space with the ISUAL spectrophotometer. JGR 120(15), 7586-7598. doi: 10.1002/2015JD023263
- Østgaard, N., et al., 2019: The Modular X- and Gamma-Ray Sensor (MXGS) of the ASIM Payload on the International Space Station. Sp. Sci. Revs., 215 (4), 23. doi: 10.1007/s11214-018-0573-7
- Soler, S., et al., 2020: Blue optical observations of narrow bipolar events by ASIM confirm corona streamer activity in thunderstorms. Submitted to JGR Atmospheres.
- Stanley, M. A., et al., 2006: A link between terrestrial gamma-ray flashes and intracloud lightning discharges. GRL, 33(6), L06803. doi: 10.1029/2005GL025537
- Thomason, L. W., Krider, E. P., 1982: The Effects of Clouds on the Light Produced by Lightning. Journal of the Atmospheric Sciences, 39(9), 2051-2065. doi: 10.1175/1520-0469(1982)039h2051:TEOCOTi2.0.CO;2
- Ursi, A., et al., 2019: Analysis of Thunderstorms Producing Terrestrial Gamma Ray Flashes With the Meteosat Second Generation. JGR Atmospheres, 124(23), 12667-12682. doi: 10.1029/2018JD030149

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Thank you for reading through this presentation!

Please use the provided feature for questions and comments or contact me via heumat@space.dtu.dk