Lightning activity over central Europe in years 2017-2022 (analysis of ISS LIS data)

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1. Introduction

The main method for obtaining the information about lightning flashes and only way to study the processes inside the thundercloud is an analysis of electromagnetic signals that lightning discharges generate. Combining different measuring techniques – electromagnetic measurements with optical data, or ground-based with satellite data – can provide us with valuable and solid information about specific processes.

For a study of lightning activity, we combine satellite data from optical sensor LIS with ground-based electromagnetic measurements from SLAVIA sensors and lightning location network WWLLN and GLD360. Using the ISS LIS and WWLLN data from March 2017 until November 2022, we studied the global lightning activity and the activity over central Europe - limited by bounding box (54.5° N, 7.5° E) to (44.5° N, 22.5° E). For the territory of Czechia, we combined the data with electromagnetic measurements from SLAVIA sensors and GLD360.

2. Instrumentation

2.1 Lightning Imaging Sensor (LIS)

ISS LIS is a space-based optical lightning sensor aboard the International Space Station (ISS). The ISS coverage ranges from -55° to 55° latitude, with a spatial resolution of ~4km and a temporal resolution of 2 ms. The optical lightning detection is performed at a wavelength of 777.4 nm.

Optical units in the dataset
- event: illuminated pixel
- group: 1 or more events detected within the same time frame and in adjacent pixels
- flash: 1 or more groups occuring within

2.2 Shielded Loop Antenna with a Versatile Integrated Amplifier (SLAVIA)

SLAVIA is a ground-based magnetic loop antenna which detects horizontal components of magnetic field fluctuations in 5 kHz - 90 MHz frequency range, its detection coverage is ~200km. The sensors used in the study are located in the northwestern part of Czechia on Milesovka mountain (50.55° N, 13.93° E).

3. Results

3.1 Yearly flash rate

Similar trend in changes of yearly rates

a) Global

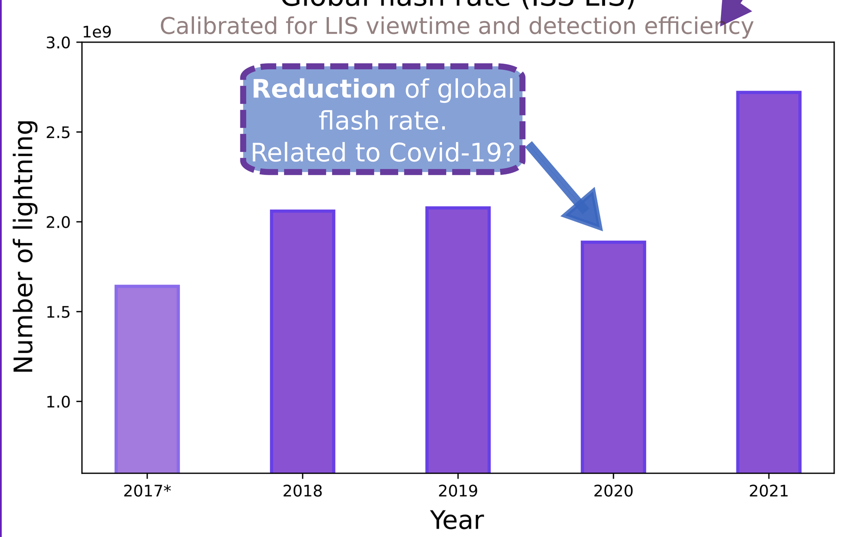


Figure A: Histogram of total number of flashes detected globally in each year by ISS LIS.
*data for year 2017 available from March to December

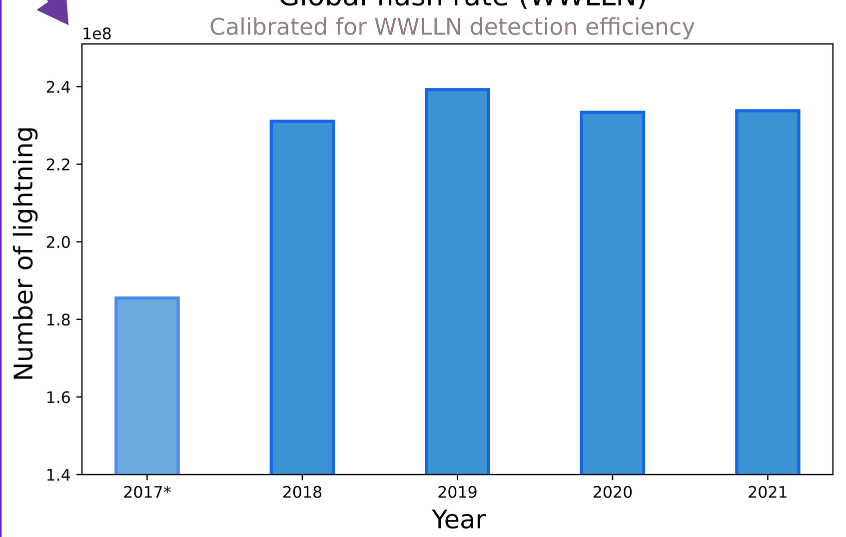


Figure B: Histogram of total number of flashes detected globally in each year by WWLLN.
*for year 2017: data from March to December

b) Central Europe

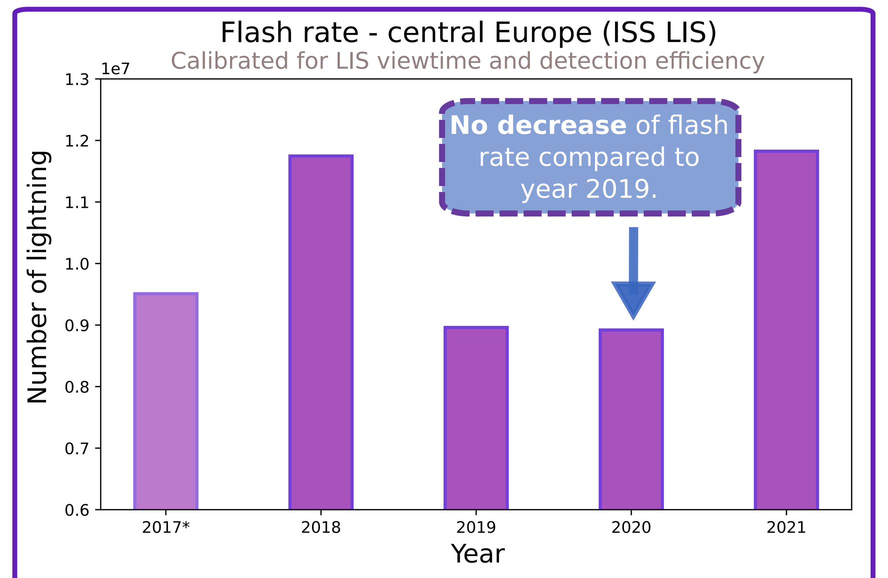


Figure C: Histogram of number of flashes detected in central Europe in each year by ISS LIS.
*data from 2017 available from March to December

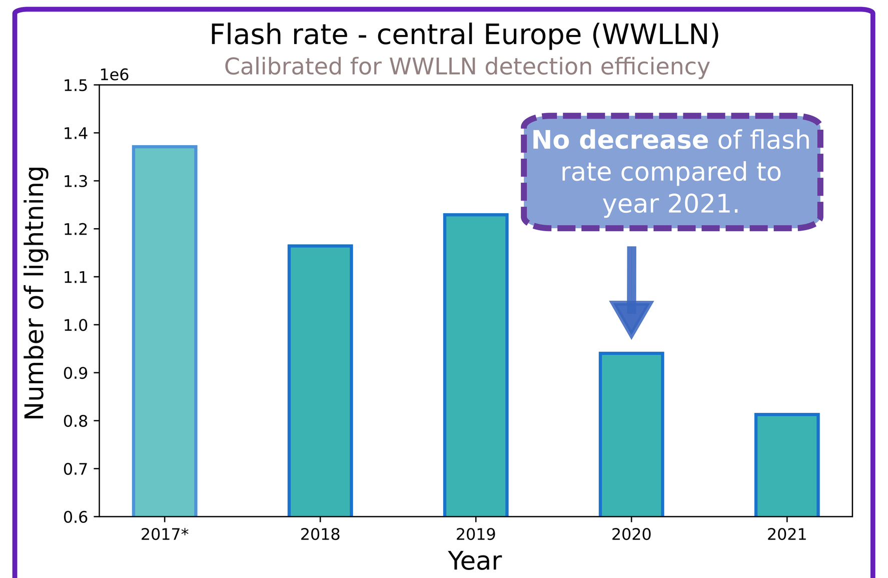


Figure D: Histogram of number of flashes detected in central Europe in each year by WWLLN.
*for year 2017: data from March to December

3.2 Flash distribution over central Europe and Czechia

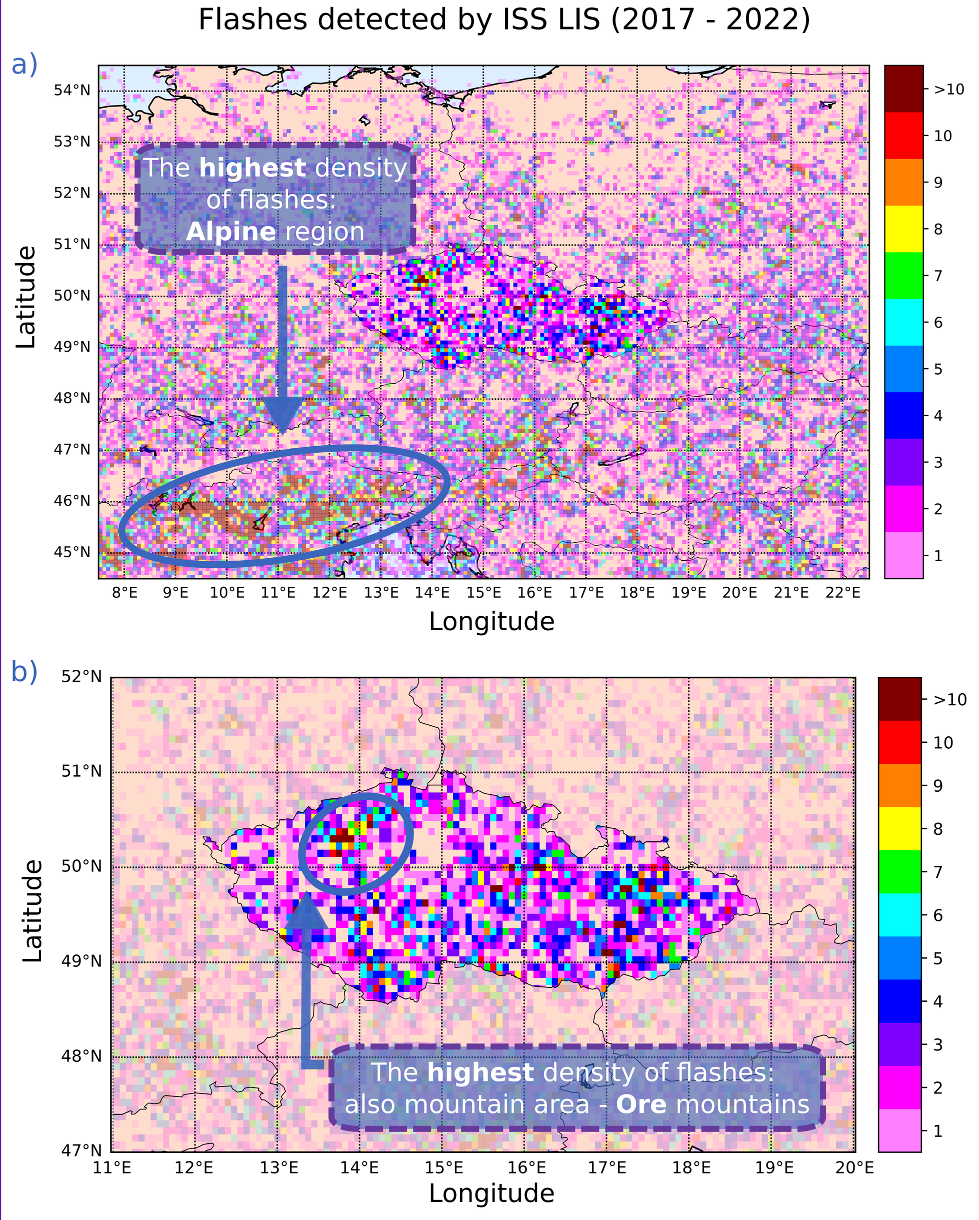


Figure E: 2D histograms of flashes detected by ISS LIS (March 2017 - December 2022); a) Central Europe, b) Czechia

3.3 Lightning analysis on LIS group level (ground based radio wave measurements and LIS optical data from space)

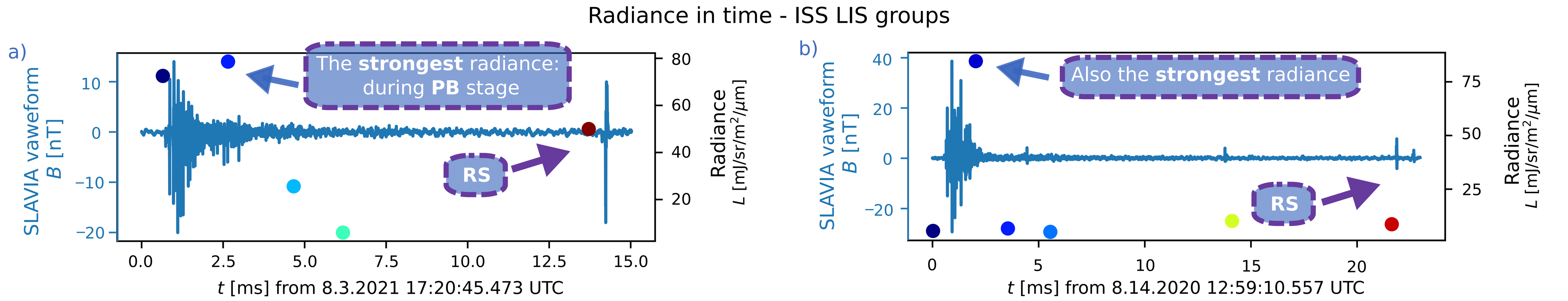


Figure F: Flashes detected near Milesovka mountain, Czechia: SLAVIA waveform (blue) with groups detected by ISS LIS (color coded by time - corresponding to color bar in Figure G). a) flash from August 3rd 2021; b) flash from August 14th 2020

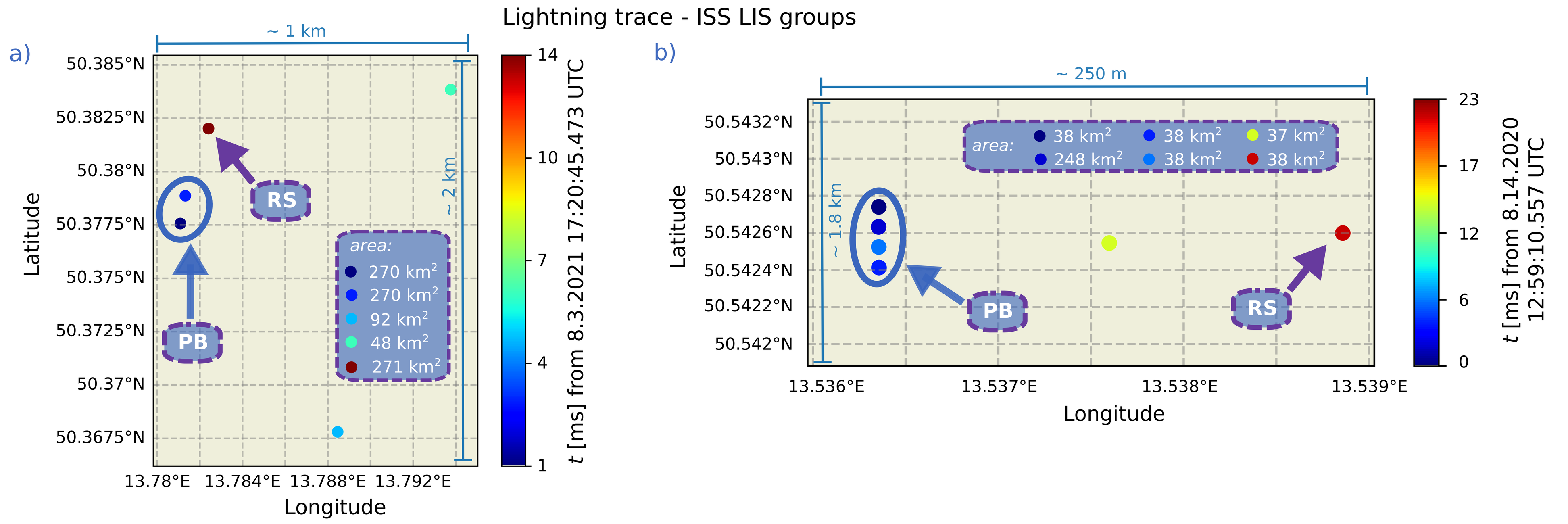
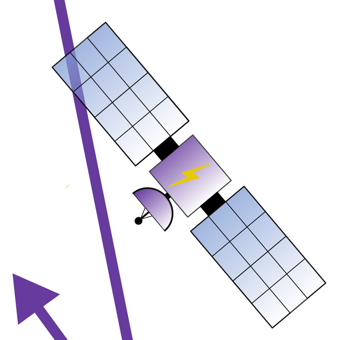


Figure G: Map of groups detected by ISS LIS near Milesovka mountain: a) flash from August 3rd 2021; b) flash from August 14th 2020.
Waveforms and radiances in figure F a,b respectively.



PB stage clearly visible from orbit

5. Conclusion

1. Yearly flash rates (2017- 2021) obtained from ISS LIS and WWLLN were compared, in order to find any possible impact of COVID-19 lockdowns on lightning activity
- data calibrated for detection efficiency, ISS LIS data also calibrated for the viewtime

a) Global: ISS LIS - visible reduction of global flash rate in 2020 (fig. A)
- *might be connected to the drop of aerosol concentration in the atmosphere*

No conclusion can be made - reduction not confirmed by WWLLN data (fig. B).

b) Central Europe: no decrease in 2020 compared to different years (fig. C, fig. D)

2. In years 2017 - 2022, total number of 68192 flashes was detected over central European region during 1805 ISS overpasses

a) Cental Europe: the highest flash density in the Alpine region (fig. E a)
- *strong updrift → formation of thunderclouds*

b) Czechia: the highest flash density in the Ore mountains (fig. E b); location of SLAVIA sensors
- *strong updrift + prevailing western winds*

3. Data from SLAVIA sensors were searched for lightning activity overlapping flashes detected by ISS LIS
- for every overlapping flash: location and time of RS checked with WWLLN and GLD360 data

2 such flashes with visible PB pulses were found

- PB phase: the highest radiance and the largest area of lightning group footprint (fig. F, fig. G)

→ optical radiance from PB stage clearly visible from Earth orbit (same as RS) (affected by scattering of light in the thundercloud)

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