Ongoing investigations related to ELF radio waves at the HUN-REN Institute of Earth Physics and Space Science (Hungary)

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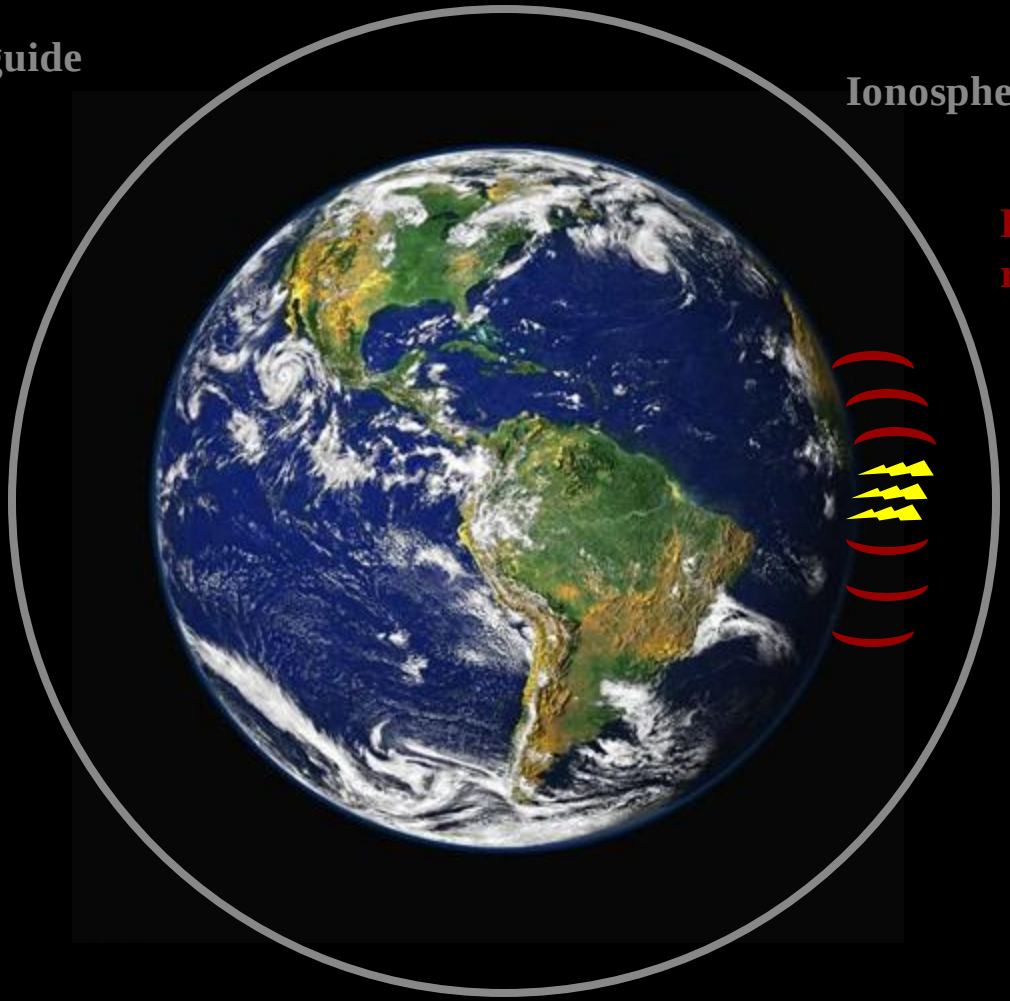
ELF Seminar

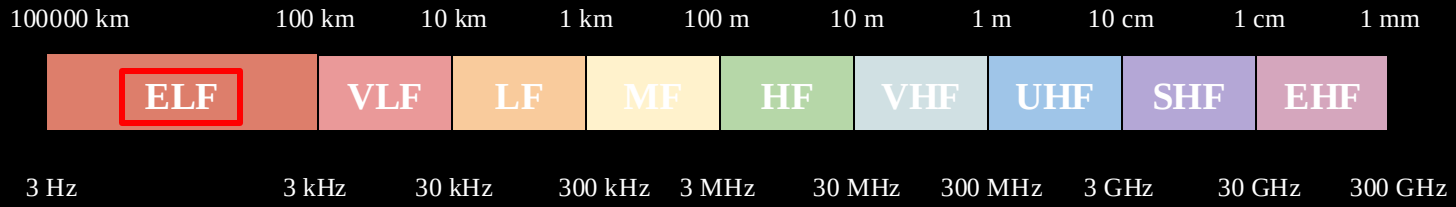
26 February 2025

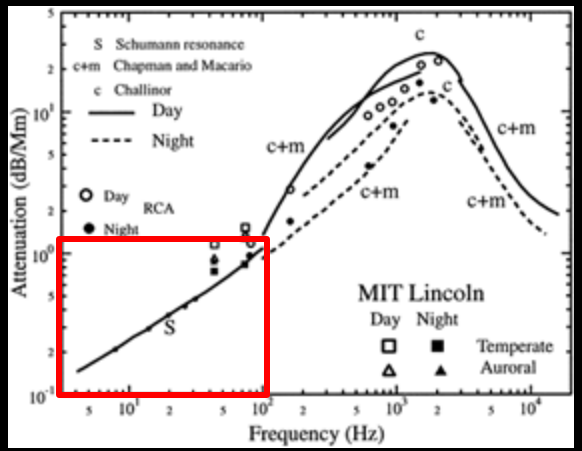
Earth-ionosphere waveguide



Extremely low frequency (ELF) band

The radio spectrum





SR band: f<100 Hz

Attenuation of EM waves: <1 dB/Mm

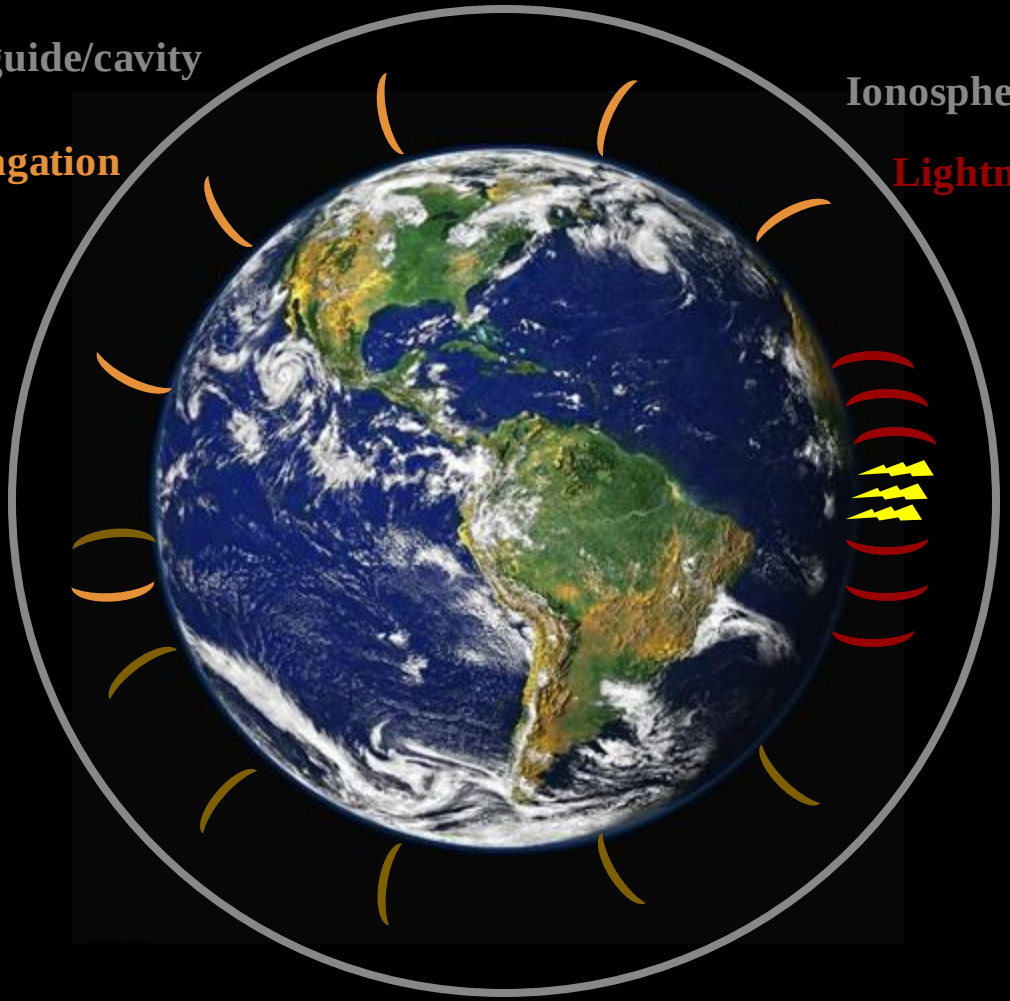
(from Barr et al., 2000)

Earth-ionosphere waveguide/cavity

Round the world propagation

Ionosphere

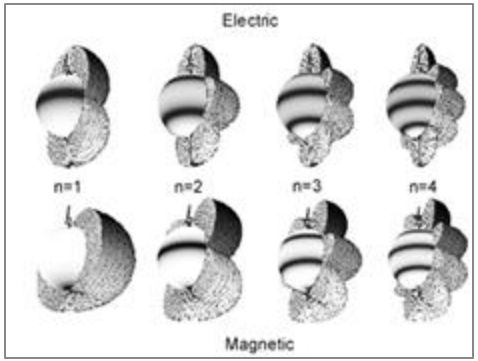
Lightning-radiated EM waves



Lightning

Schumann resonances (SRs)

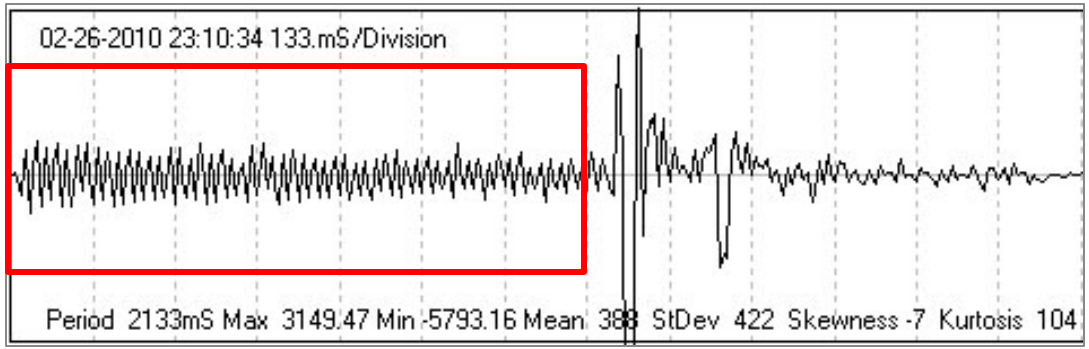
SRs are the **global electromagnetic resonances of the Earth-ionosphere cavity** with resonance frequencies at ~8, ~14, ~20, ~26 etc. Hz excited primarily by lightning-radiated electromagnetic waves.



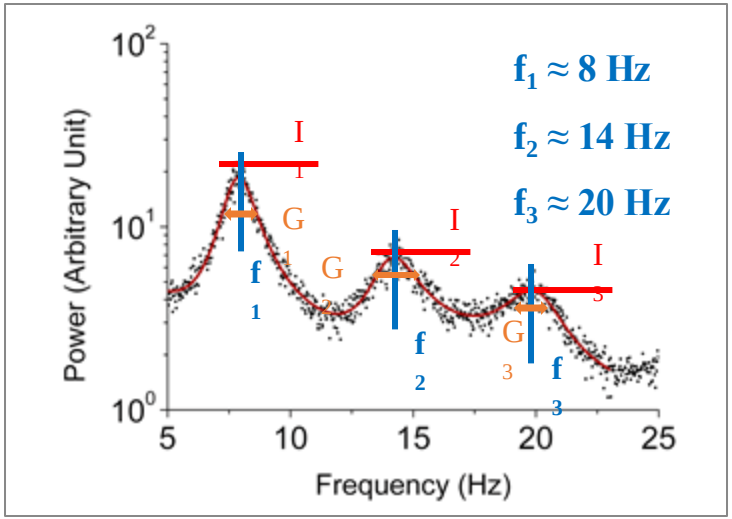
Angular distribution of SR modes (Sentman, 1995).

Q-burst/SR-transient/ELF-transient

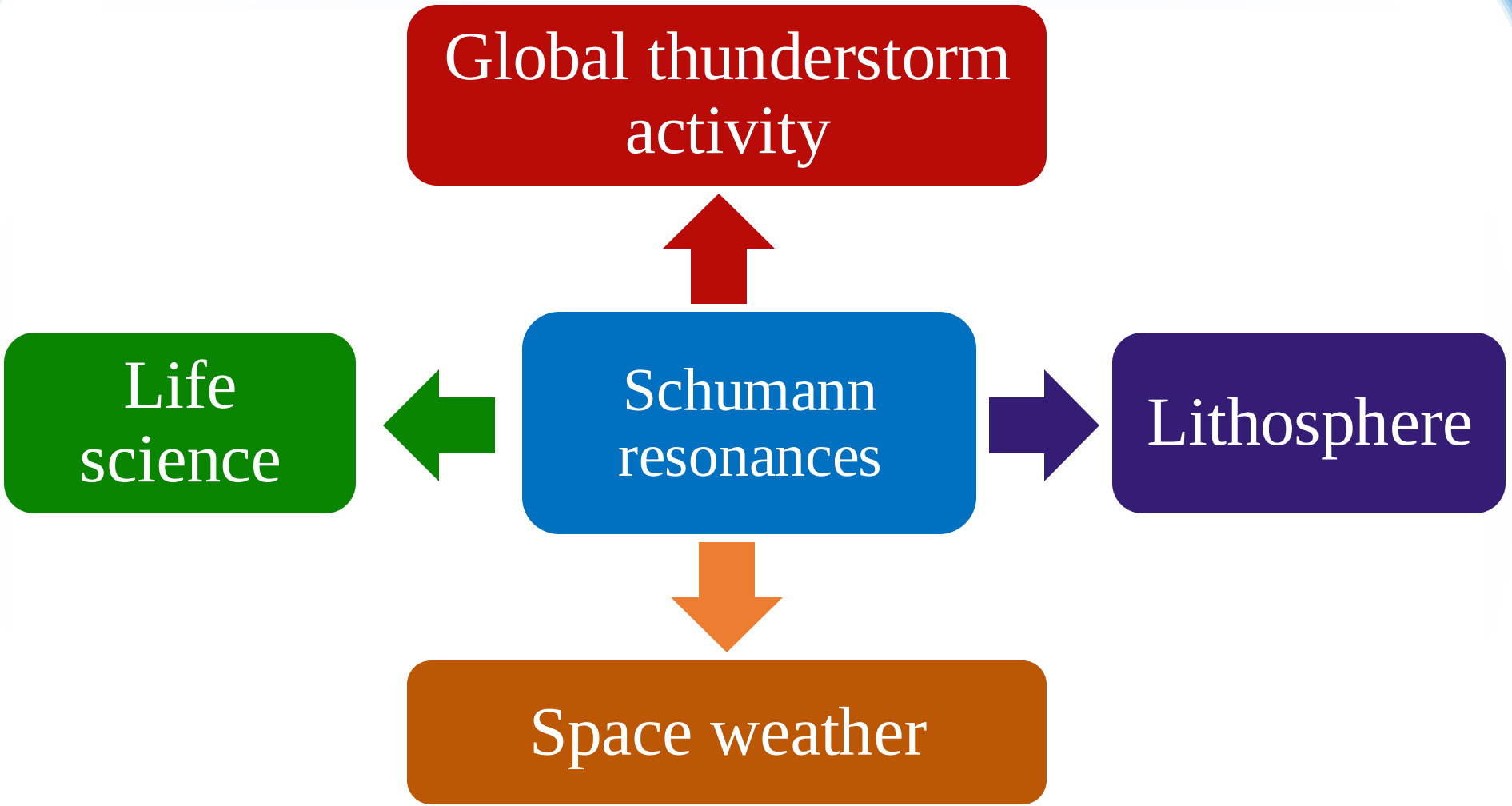
"Background" field

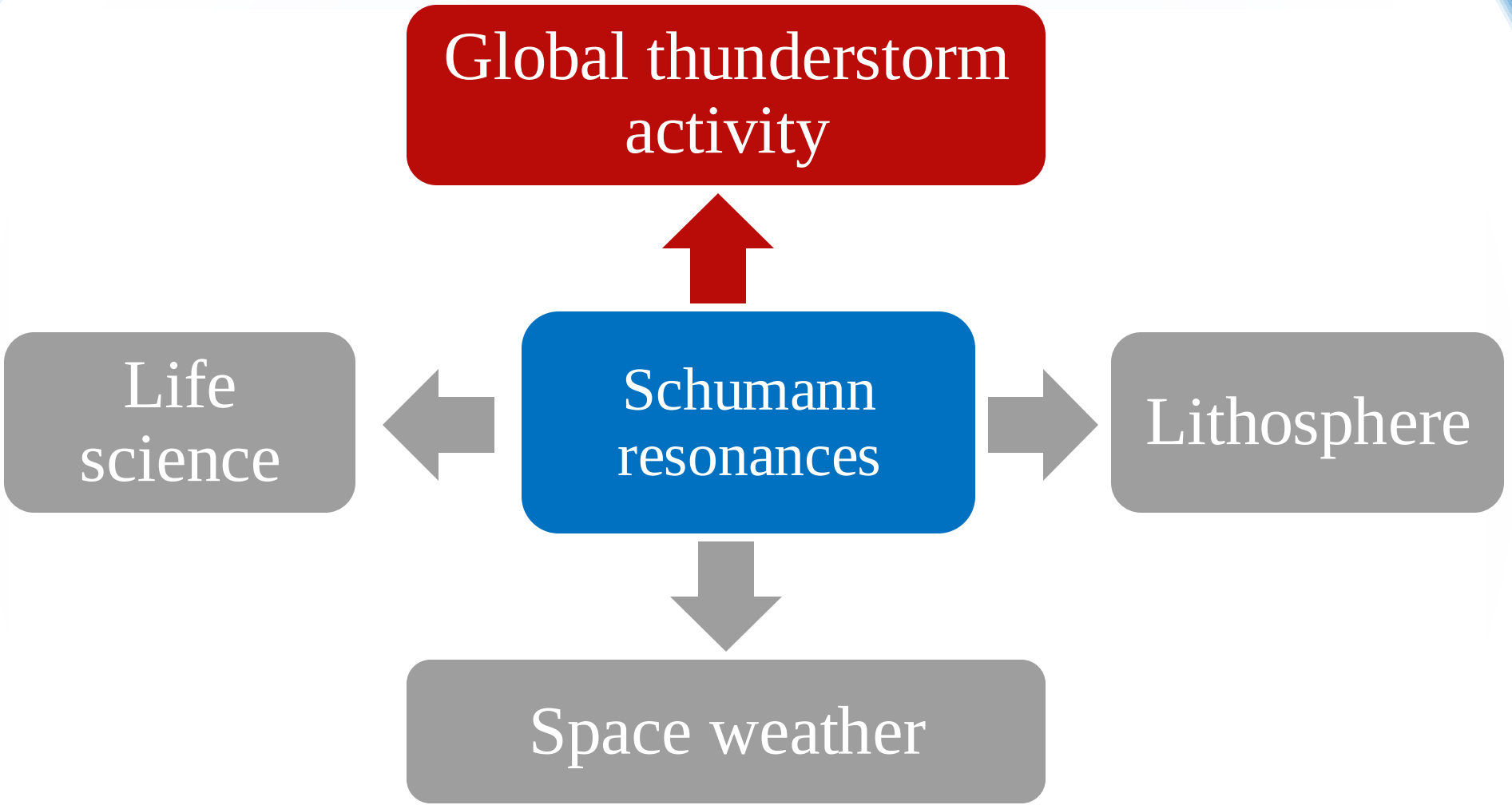


The appearance of a Q-burst and the "background" field in a time series.



Power spectrum of the "background" field.


Global thunderstorm activity
Life science
Schumann resonances
Lithosphere
Space weather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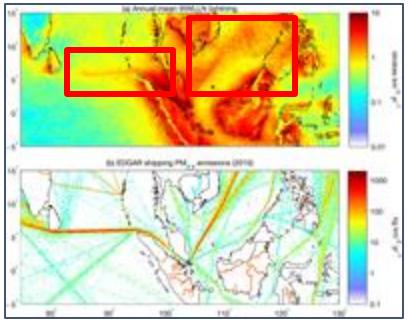
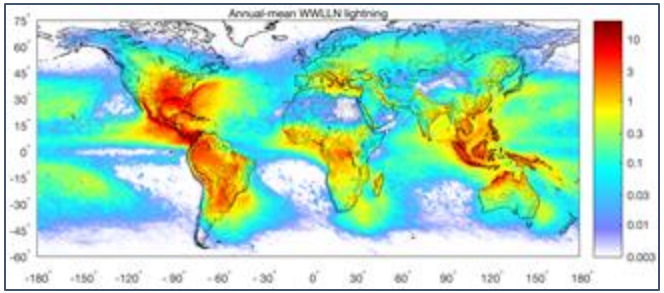
Lightning and climate

- The World Meteorological Organization (WMO) has declared lightning as one of the **essential climate variables**.
- Lightning activity can provide essential information about the **state of the atmosphere** (temperature, humidity, aerosols).
- Due to the **nonlinear relationship**, surface temperature changes on the order of 1°C can result in a significant change in lightning frequency (up to 10% per 1°C).

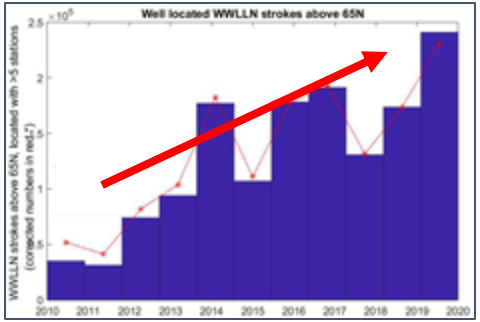


Lightning along ship tracks (Thornton et al., 2017).



Global distribution of lightning activity (Aich et al., 2018).

Lightning as an essential climate variable (https://gcos.wmo.int/en/essential-climate-variables/lightning).

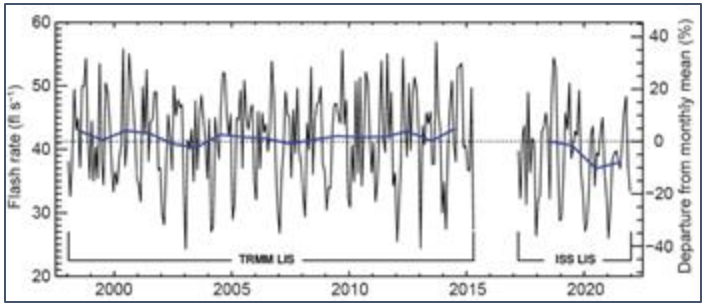


Lightning in the Arctic (Holzworth et al., 2021).

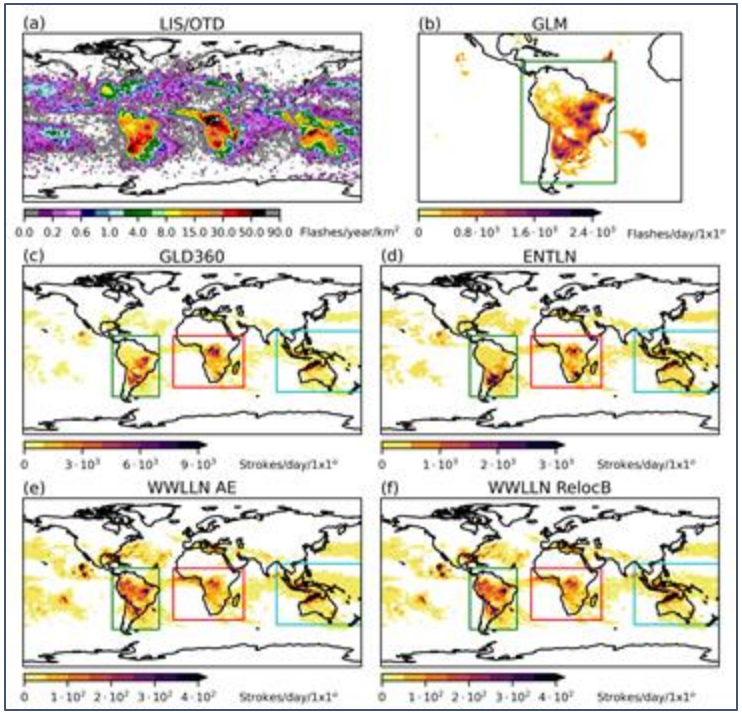
Lightning and climate - main challenges

Yearly report of the American Meteorological Society.

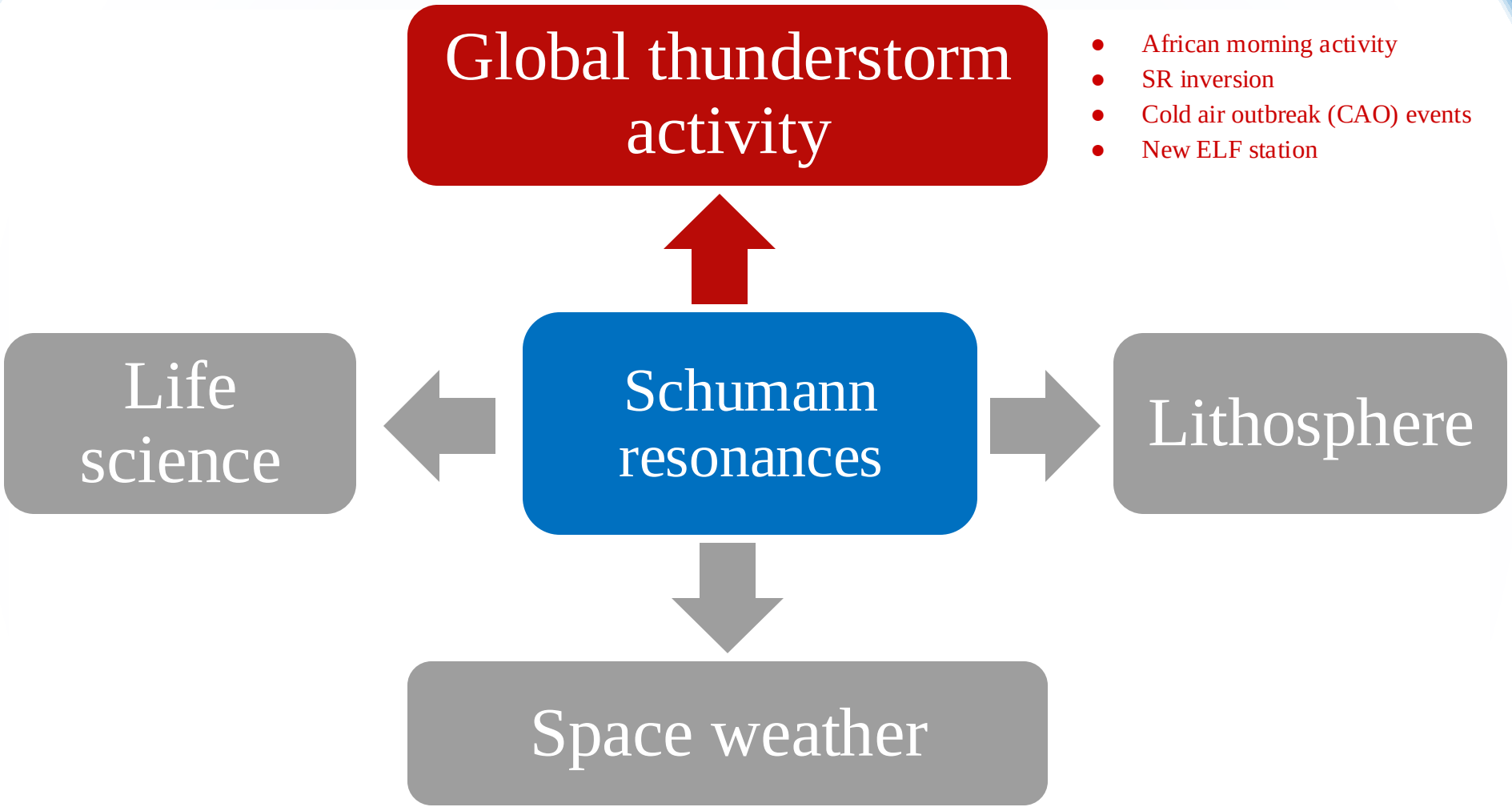
Lightning in the Arctic (Holzworth et al., 2021).

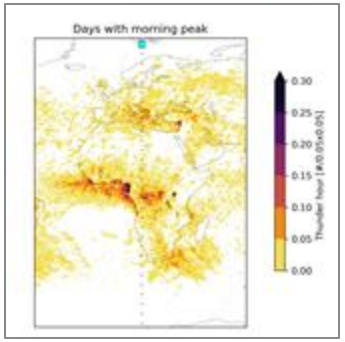


Monthly (solid black) and annual (blue) mean lightning flash rates observed by the TRMM and ISS LIS instruments (Füllekrug et al., 2022).

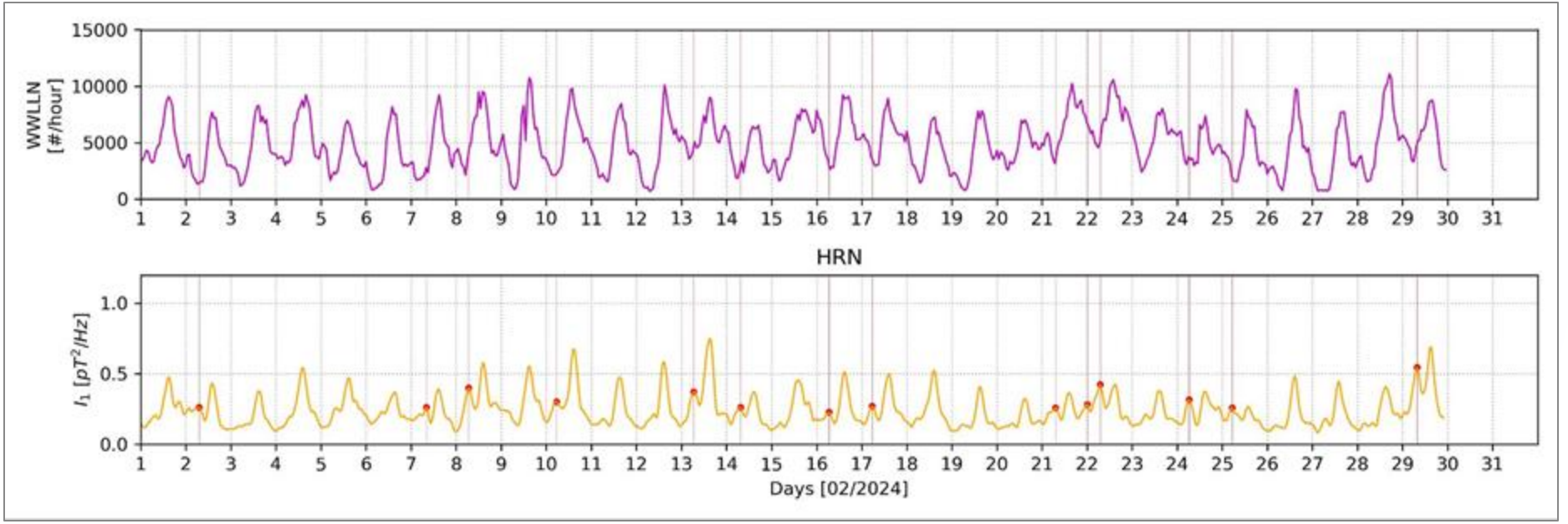


19 days of lighting activity as observed by different lighting detection systems (Bozóki et al., 2023).

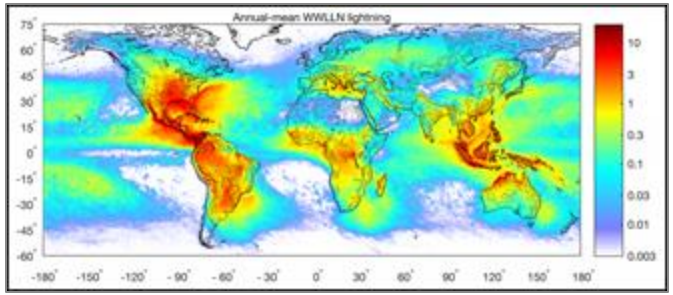

Global thunderstorm activity
African morning activity
SR inversion
Cold air outbreak (CAO) events
New ELF station
Life science
Schumann resonances
Lithosphere
Space weather



African morning activity



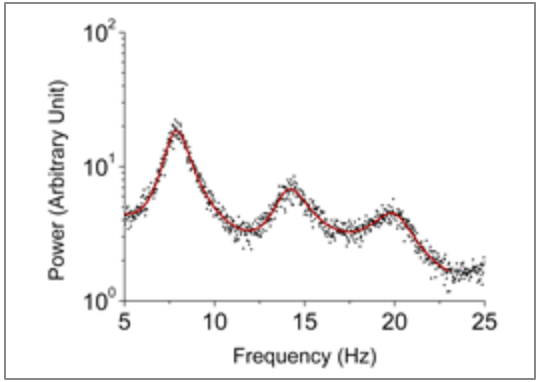
SR inversion

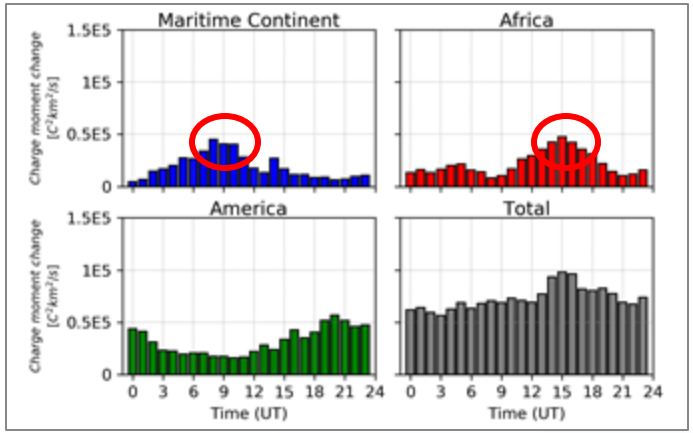


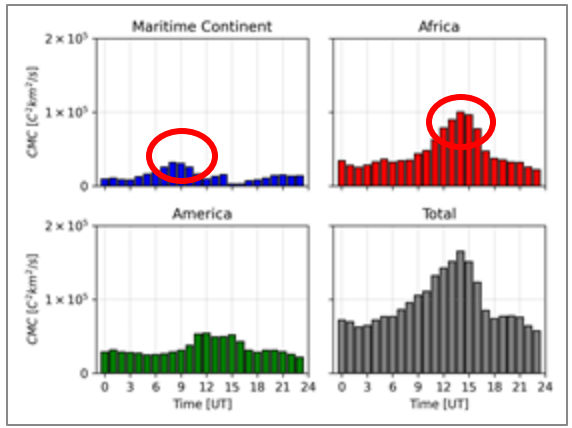
(Aich et al., 2018)

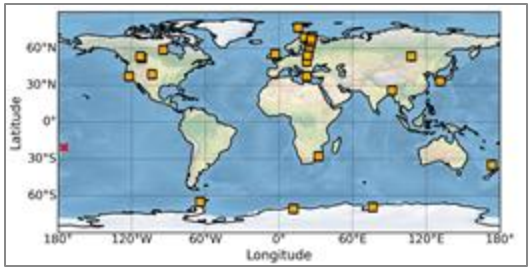
Forward modeling

Inversion

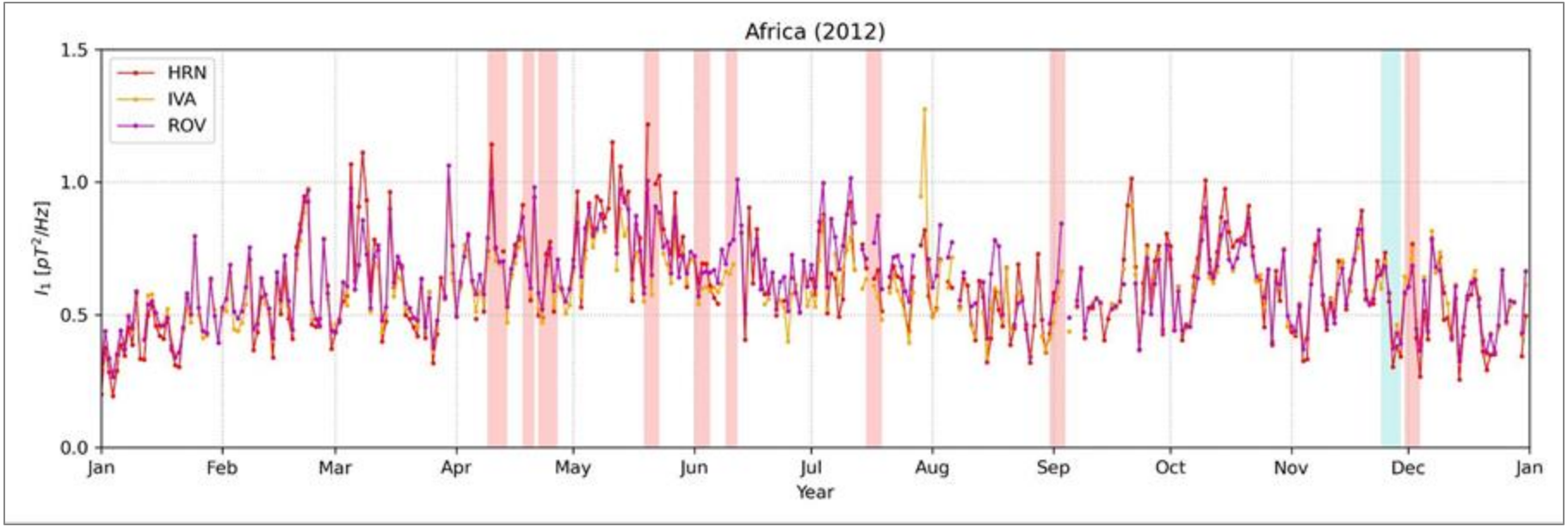




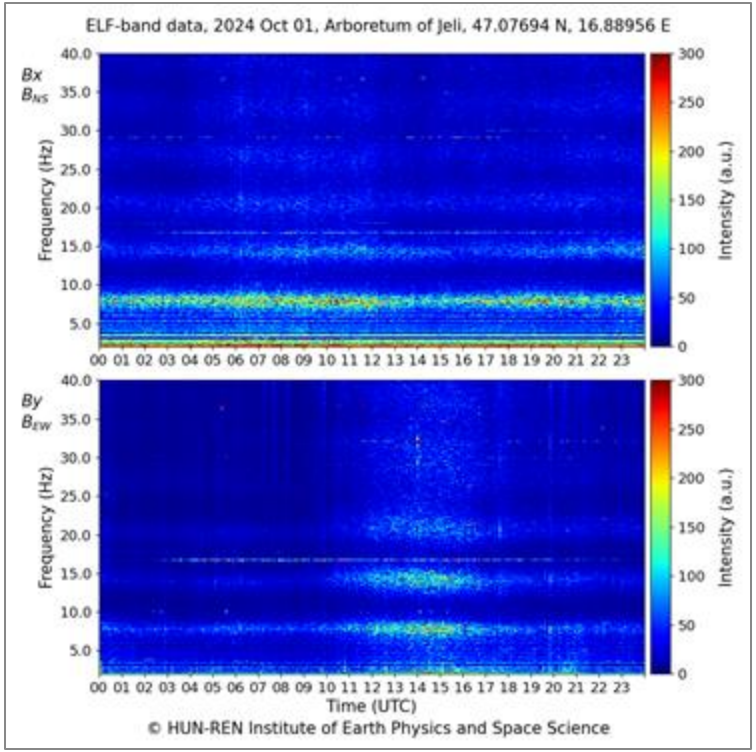


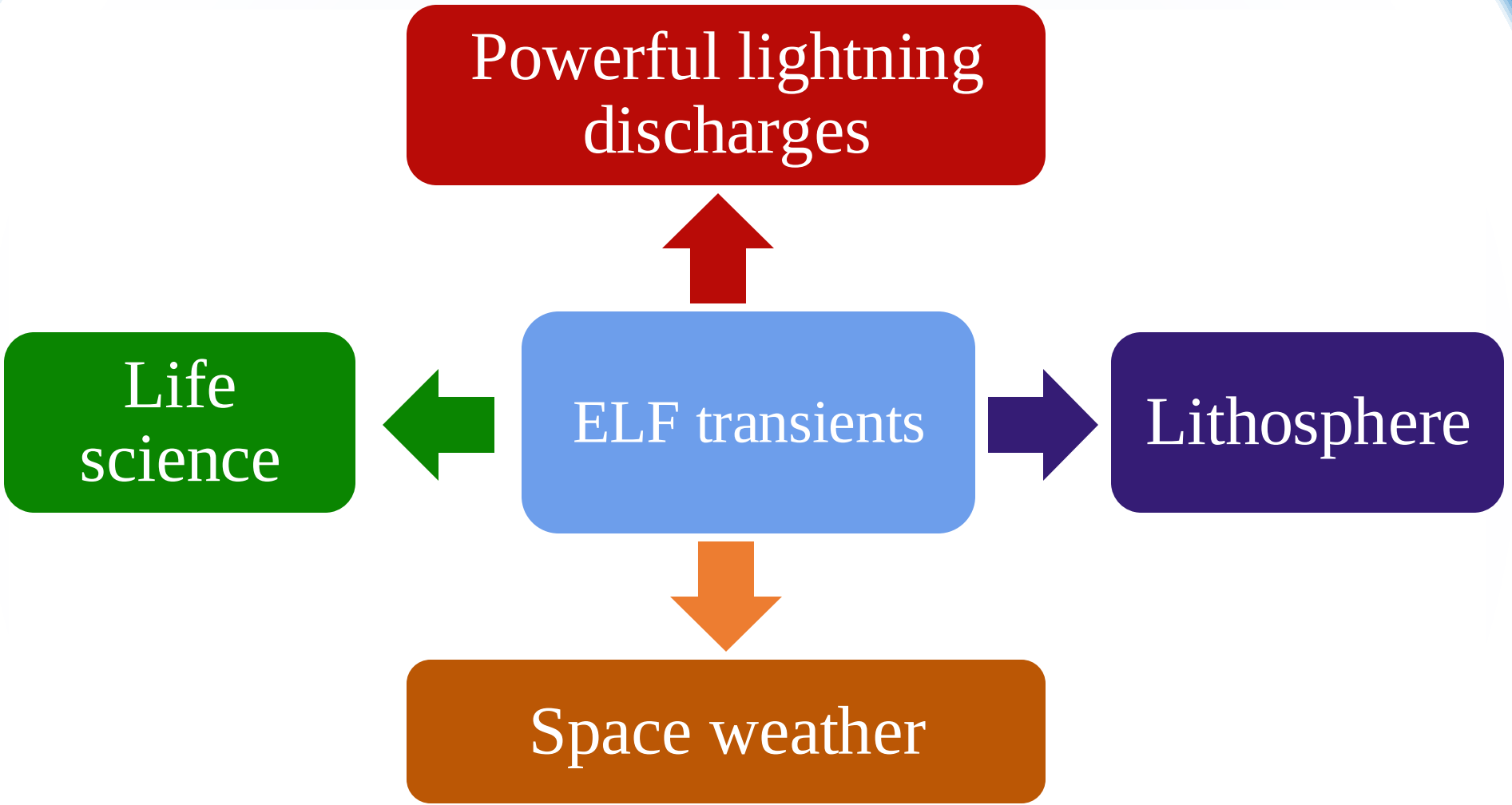


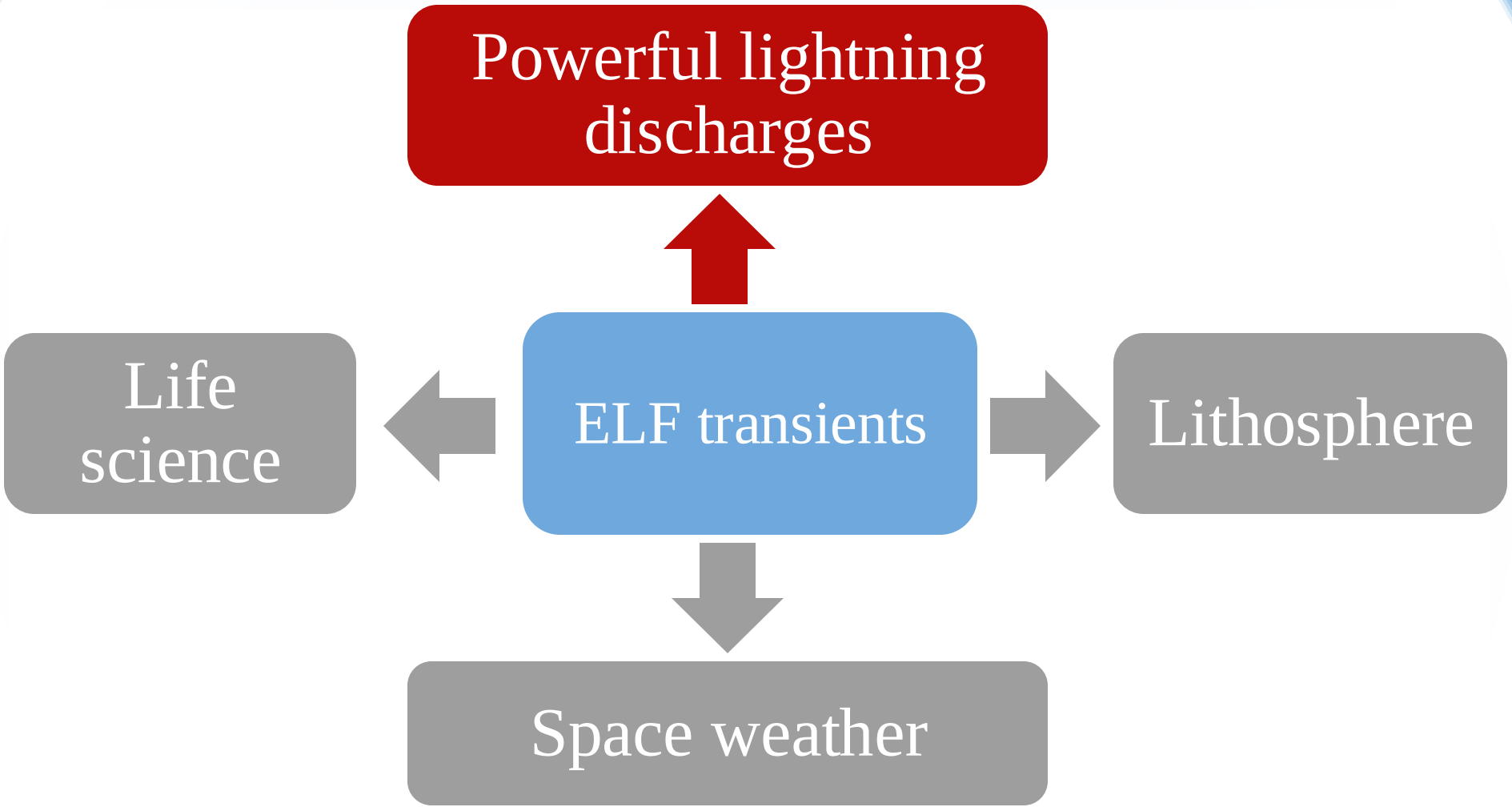
Cold air outbreak (CAO) events



New ELF station at the Jeli Arboretum




Powerful lightning discharges
Life science
ELF transients
Lithosphere
Space weather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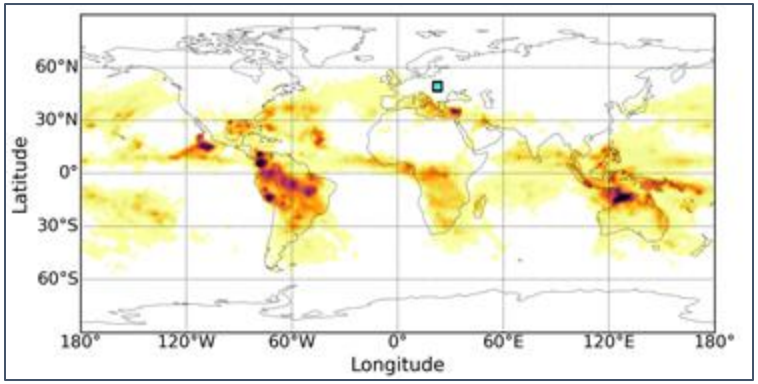
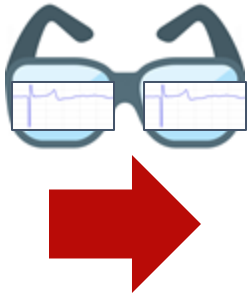
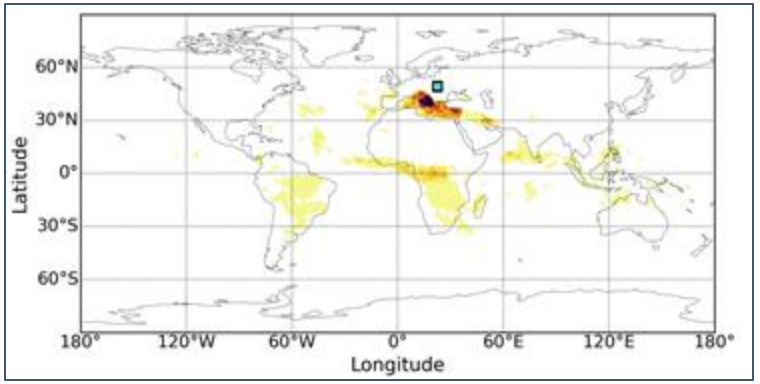
A specific view on (global) lightning activity

The “ELF power” of a lightning stroke is determined by its **vertical charge moment change**. Thus, by investigating SR-transients and their parent lightning strokes, we obtain a view on a specific subset of (global) lightning activity.



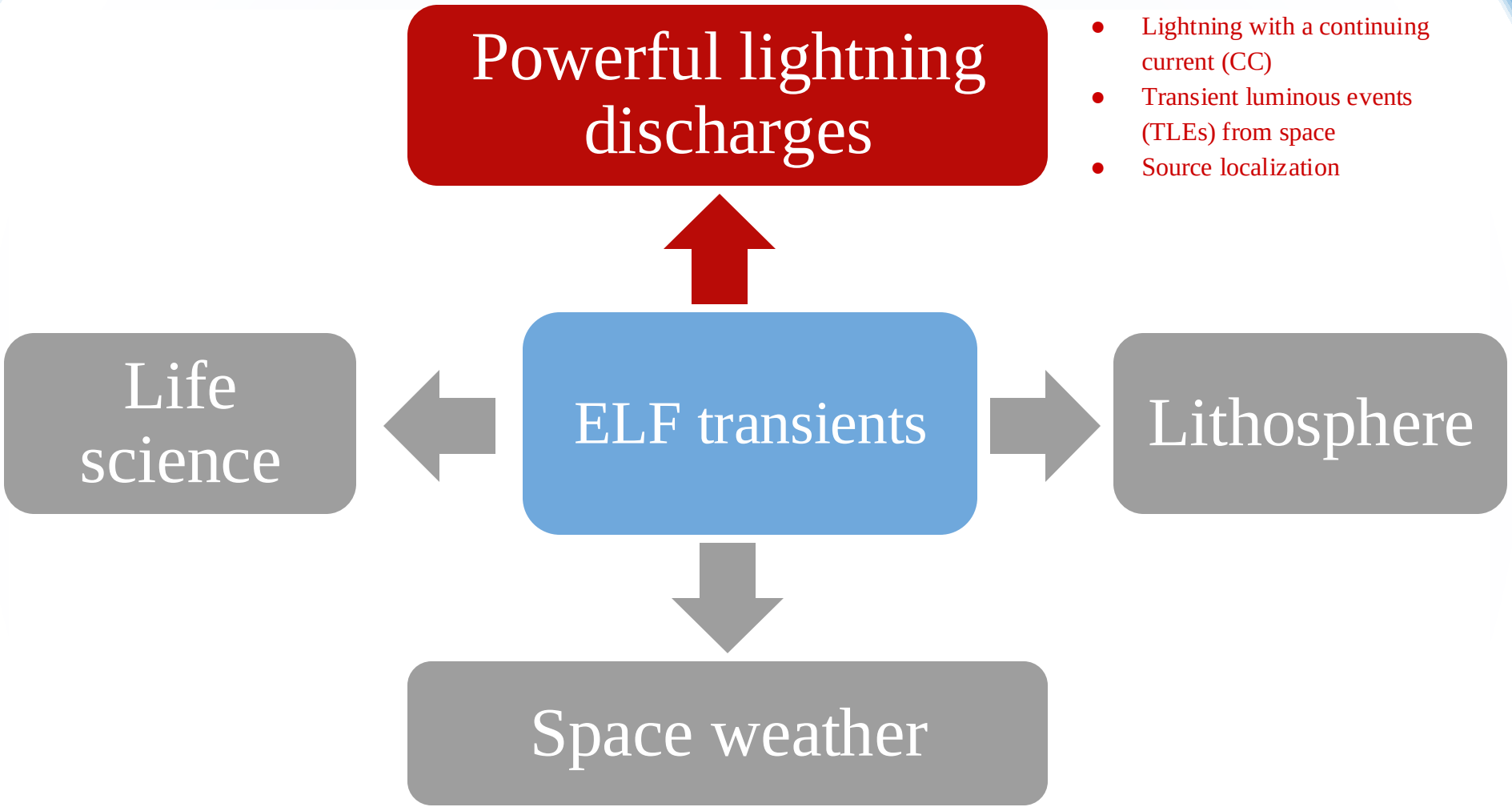
The global distribution of WWLLN-detected lightning strokes in the 1-18 December 2020 period.



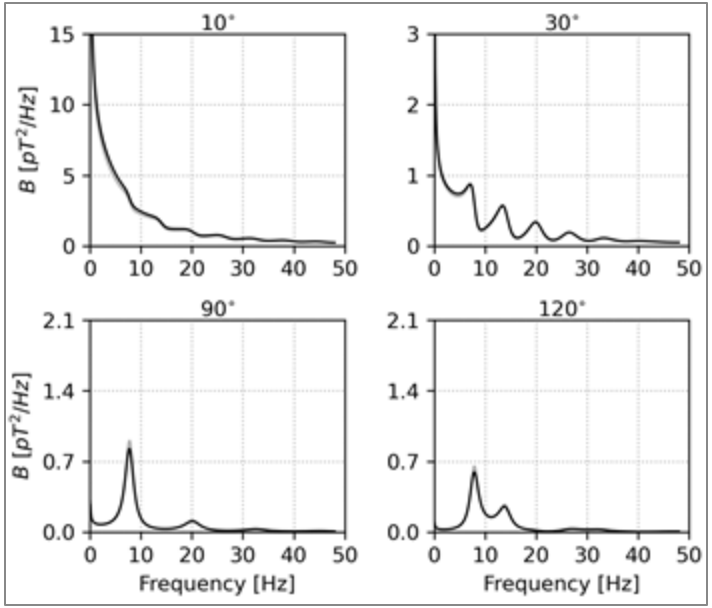


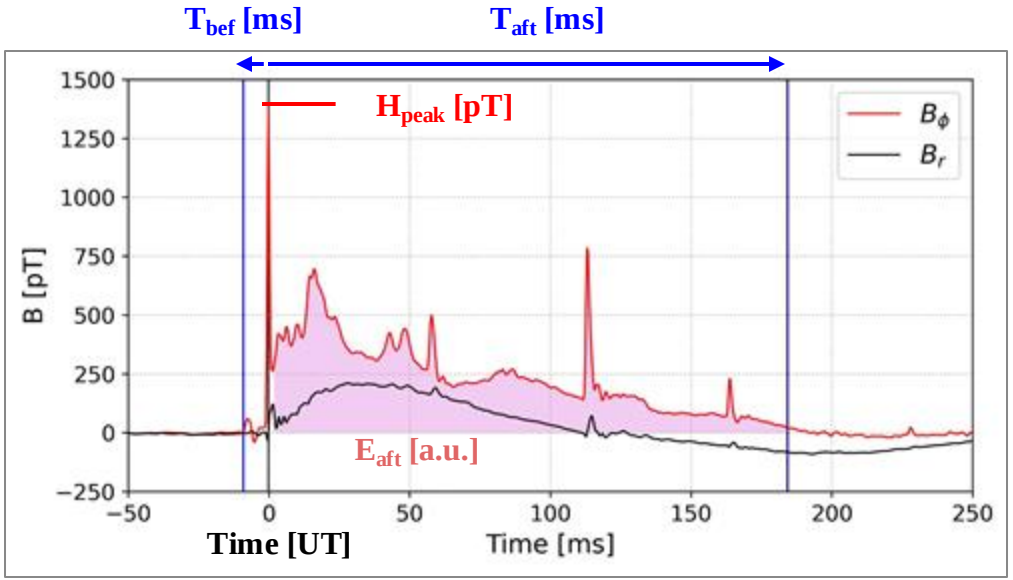
The global distribution of WWLLN-detected lightning strokes producing SR-transients at the Hylaty station in the same time interval.

These lightning strokes are either close to the observer, or **very powerful** compared to the average charge momentum change of ordinary lightning strokes. Note, that the transient signal of the most powerful strokes can be observed anywhere on Earth (often called "**bell ringers**").


Powerful lightning discharges
Lightning with a continuing current (CC)
Transient luminous events (TLEs) from space
Source localization
Life science
ELF transients
Lithosphere
Space weather

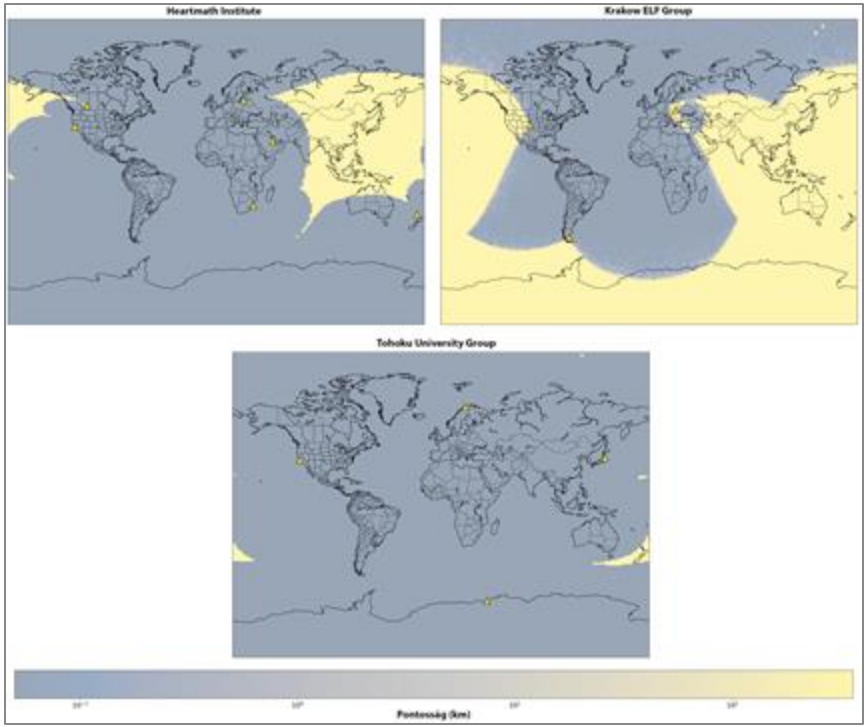
Lightning with a continuing current (CC)

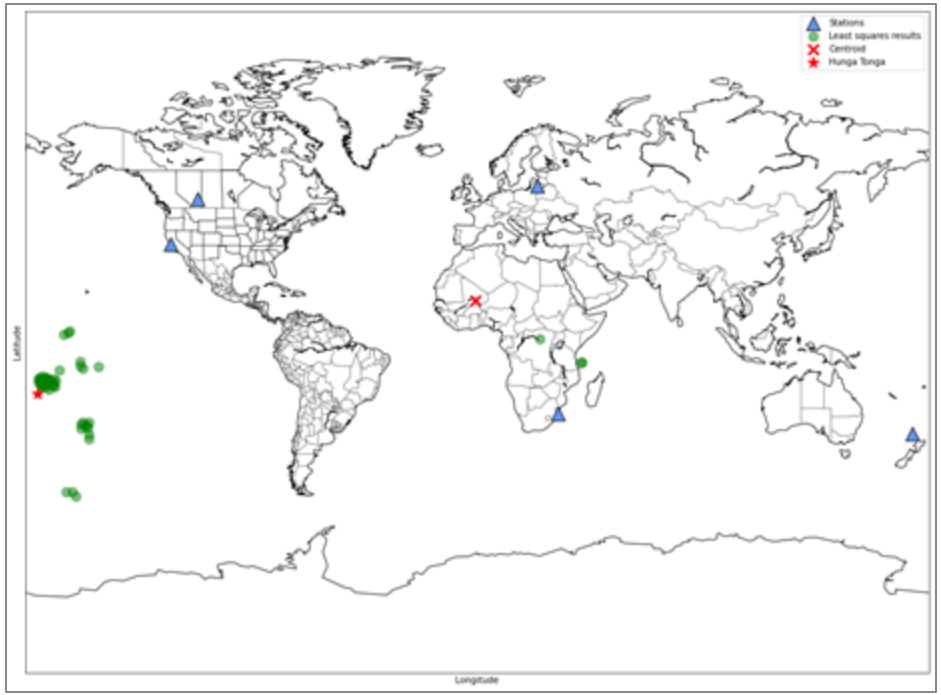




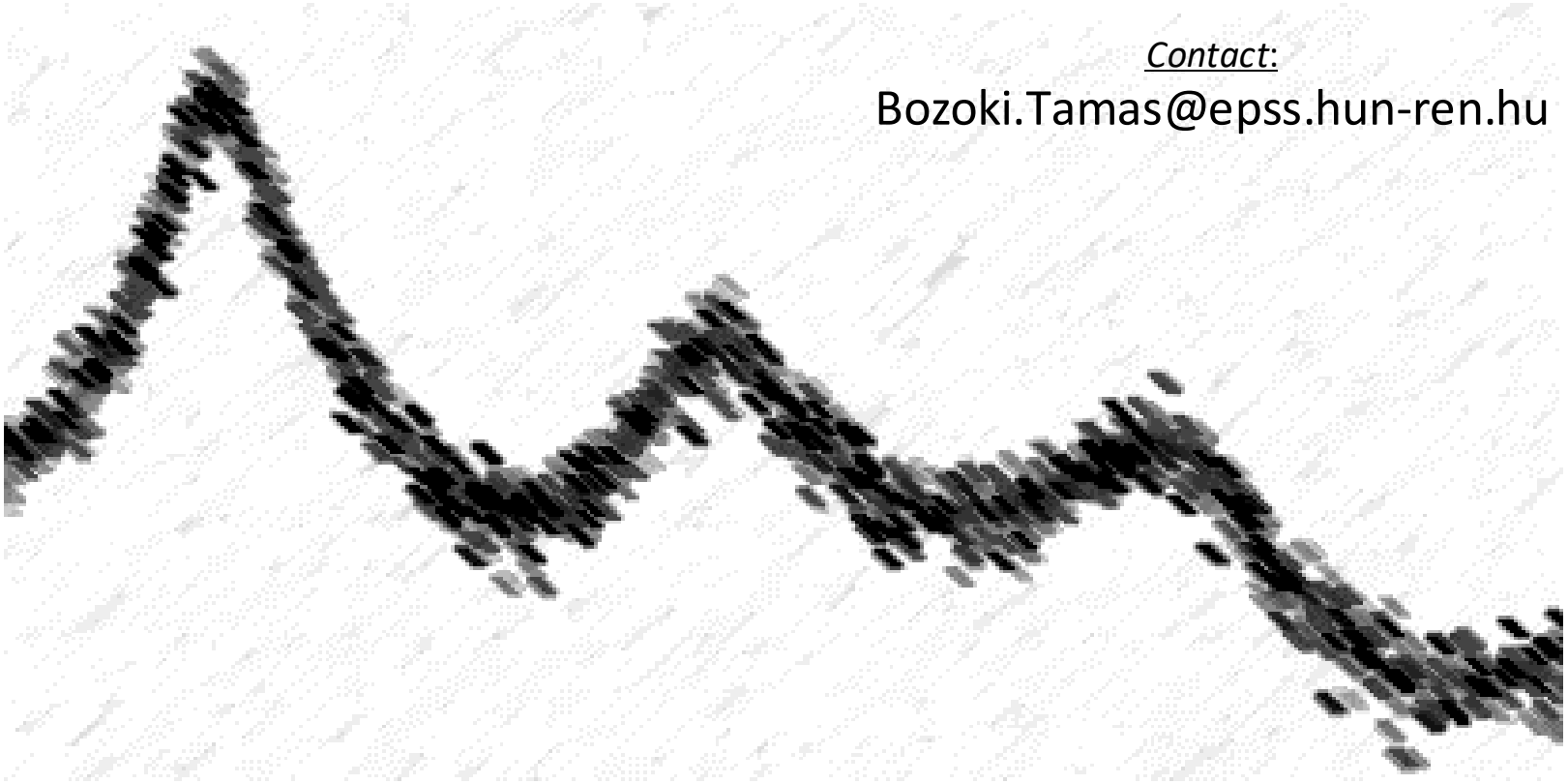
Transient luminous events (TLEs) from space

Source localization





Thank you for your attention!



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