Investigation of link between satellite-based lightning detection and severe weather

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Introduction

We investigated the correspondence between satellite-based lightning detection and severe weather reports. We especially wanted to check if severe thunderstorms, characterized by very **strong updrafts** were more likely to produce a **high quantity of relatively small lightning flashes**. To test this, we analyzed data from the Meteosat Third Generation Lightning Imager (**MTG-LI**) and severe weather reports from the European Severe Weather Database (**ESWD**).
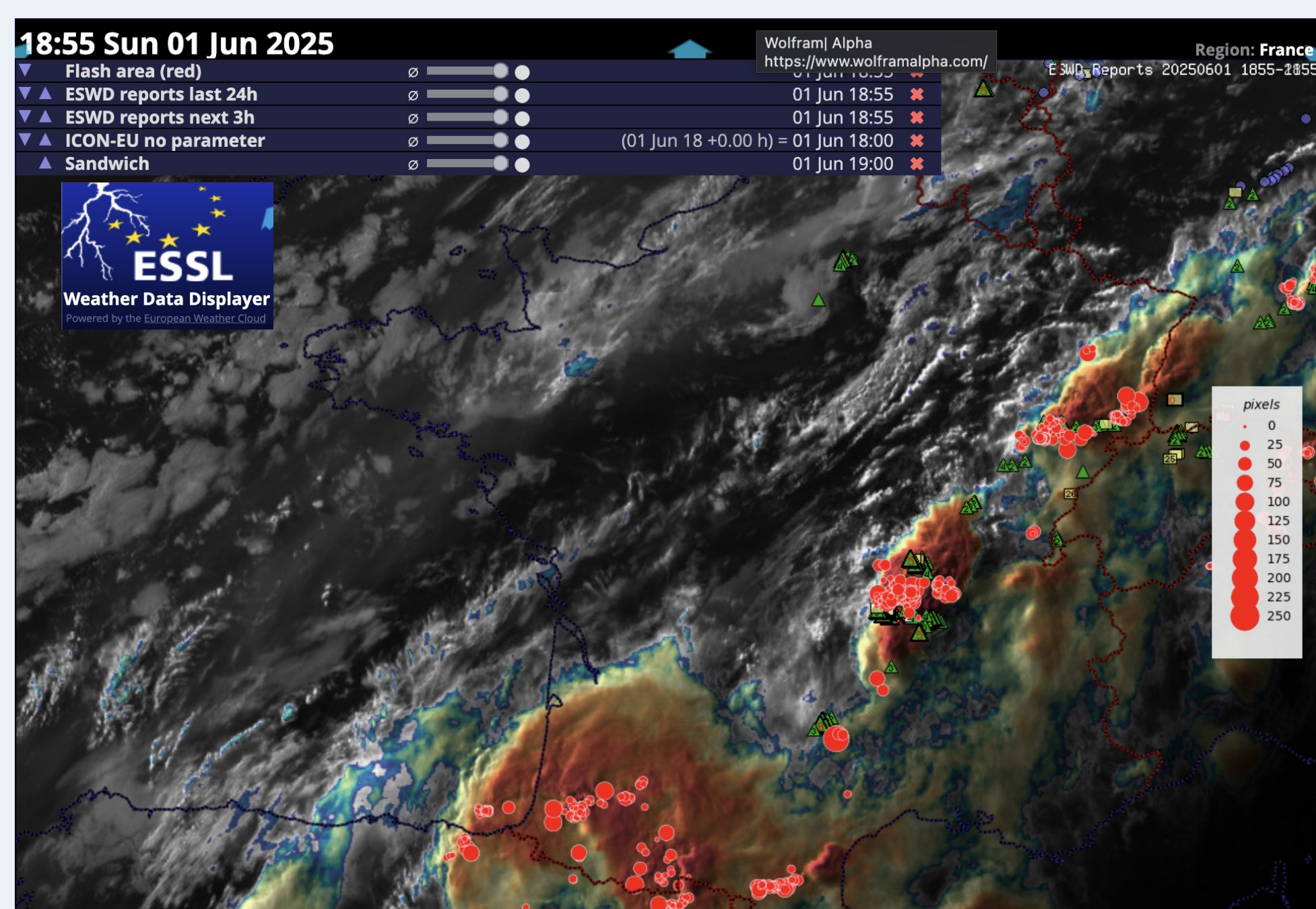
Screenshot of the ESSL Weather Data Displayer

Study Period:	July 2024 – September 2025
Flashes:	43.4 million
Severe weather reports:	40,000

Statistics of the MTG LI flash data

What are small flashes ?
In pixels (footprint size)

Mean :	9.94
Median :	7.00
25th percentile :	4.00

What is a lot of flashes?
In number /10 km x 10km / 15min

Mean :	7.42
Median :	2.00
75th percentile :	6.00
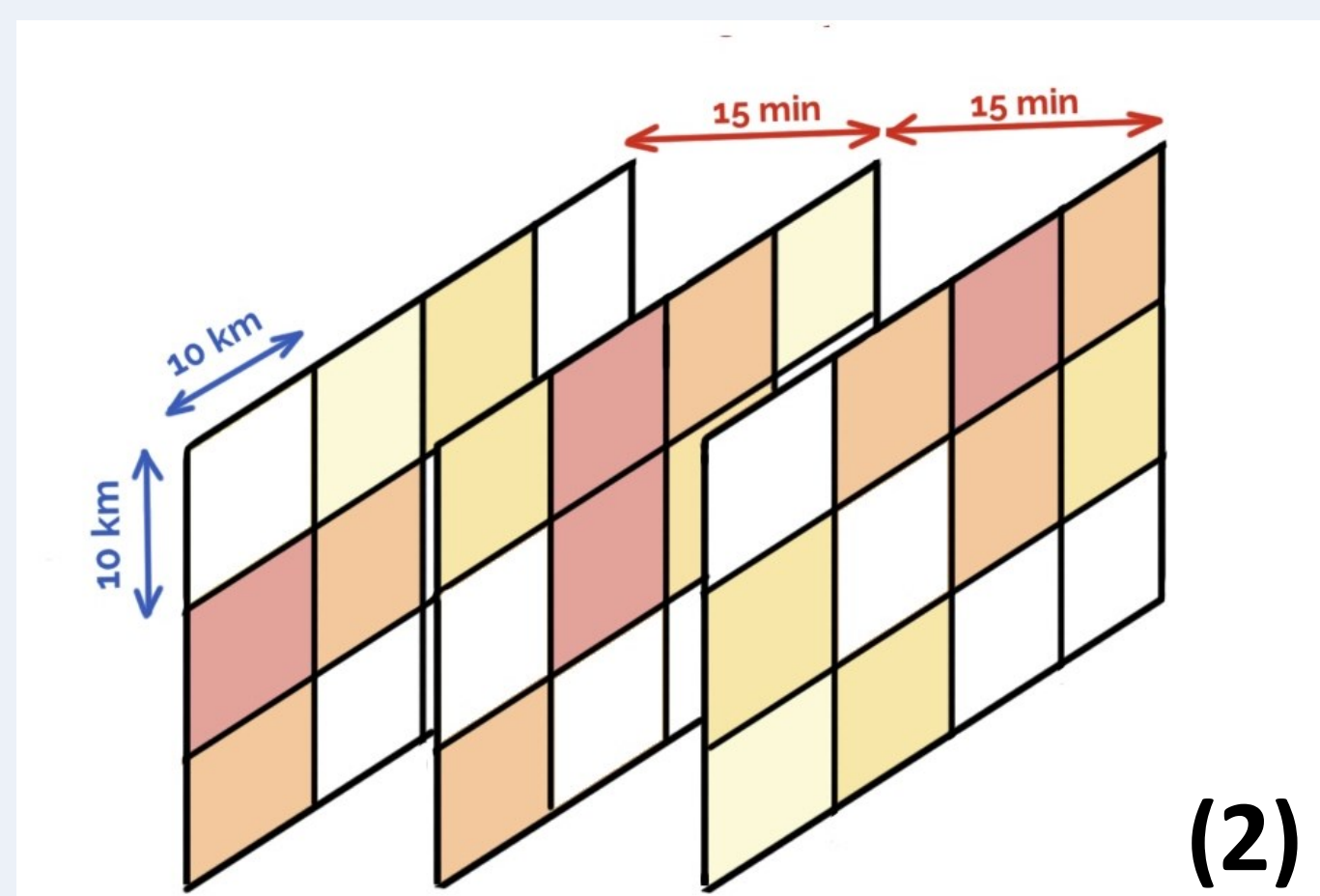
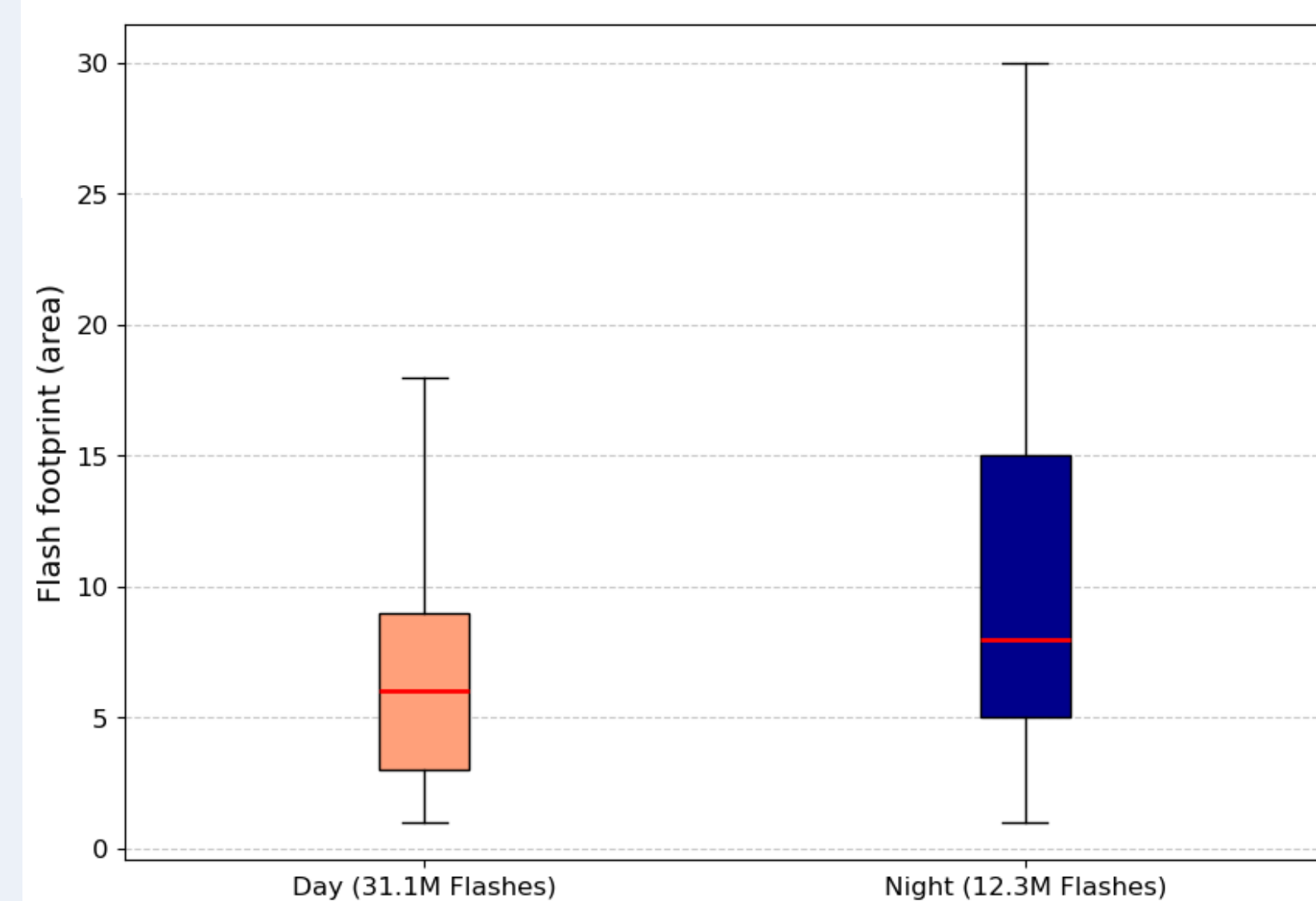*Illustration of the lightning flash density gridding process*

Comparing daytime and nighttime statistics

MTG-LI detection efficiency slightly lower at daytime because of solar contamination
→ Splitting data depending on solar elevation :   • day = solar elevation > -6°
                                                      • night = below -6° under the horizon

→ Quantifying **day VS night thunderstorm characteristics**

Size distribution DAY

- mean   7.93
- 25%   3.00
- 50%   6.00
- 75%   9.00
- max   62

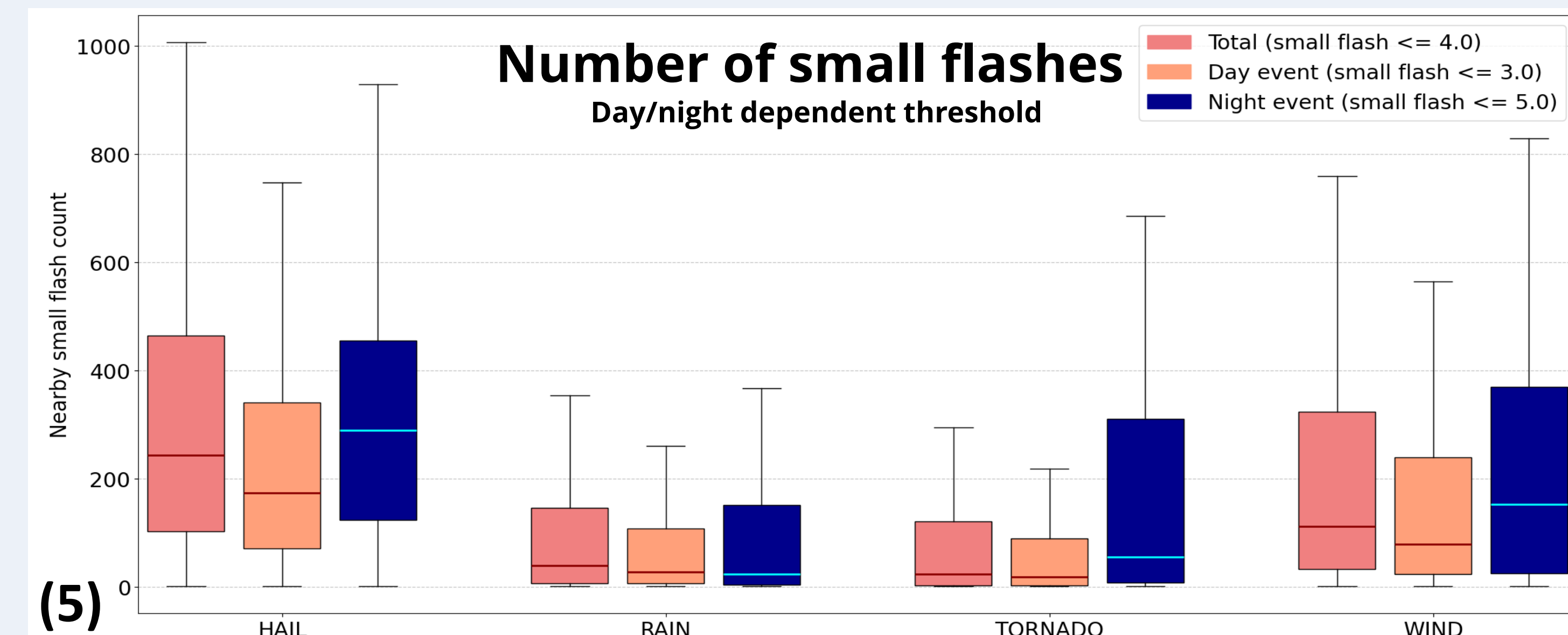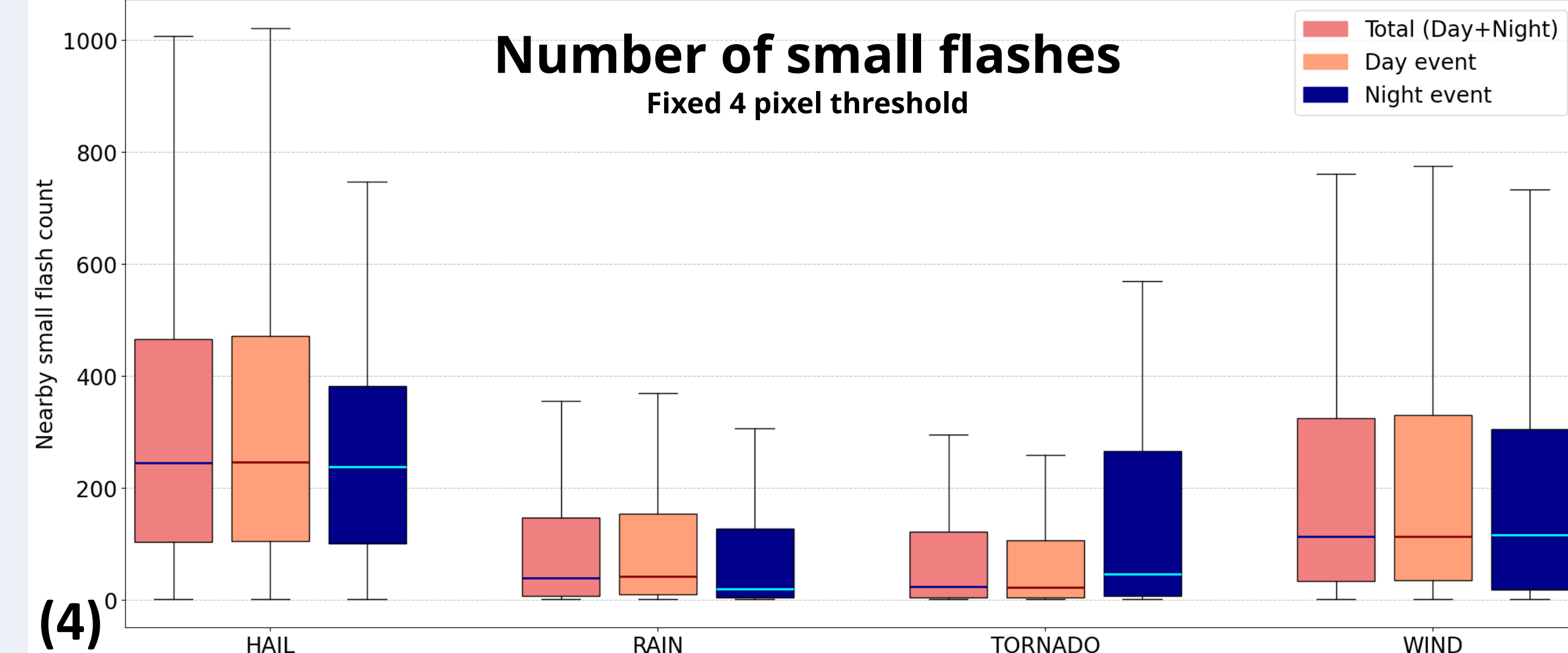**Size distribution NIGHT**

- mean   12.1
- 25%   5.00
- 50%   8.00
- 75%   15.0
- max   1012

How to define a small flash? → 2 different strategies:

Fig.(4) One unique threshold = the total's 25th percentile = **4.00 pixels**

Fig.(5) Different threshold for day and night = 25th percentile of each distribution:
   Day = 3.00 and **Night 5.00**

Distribution by severe weather event type

→ **Hail** and **wind** events are associated with the **most small flashes**
→ **Rain** and **tornadoes** with **fewer** (except night-time tornadoes)
→ Day/Night difference **not just sensor bias :** nighttime **flashes physically larger** BUT when artificially normalized by choosing a "small flash" threshold consistent with the relative distributions of day and night (*fig. (5)*) there is still a big difference
⤳ **the underlying meteorology and thunderstorm characteristics seem different**

Lightning around severe weather events

We analyzed the lightning environment around ESWD reports →
dataset was filtered to include only thunderstorm-associated events (i.e., at least one flash within a 20 km radius and 45-minute time window) :

- **75.7%** of **severe events** were associated with **a high density of small flashes.**
- **92.3%** of **severe hail reports** were associated with **a high density of small flashes.**

Flash rates VS increasing severity
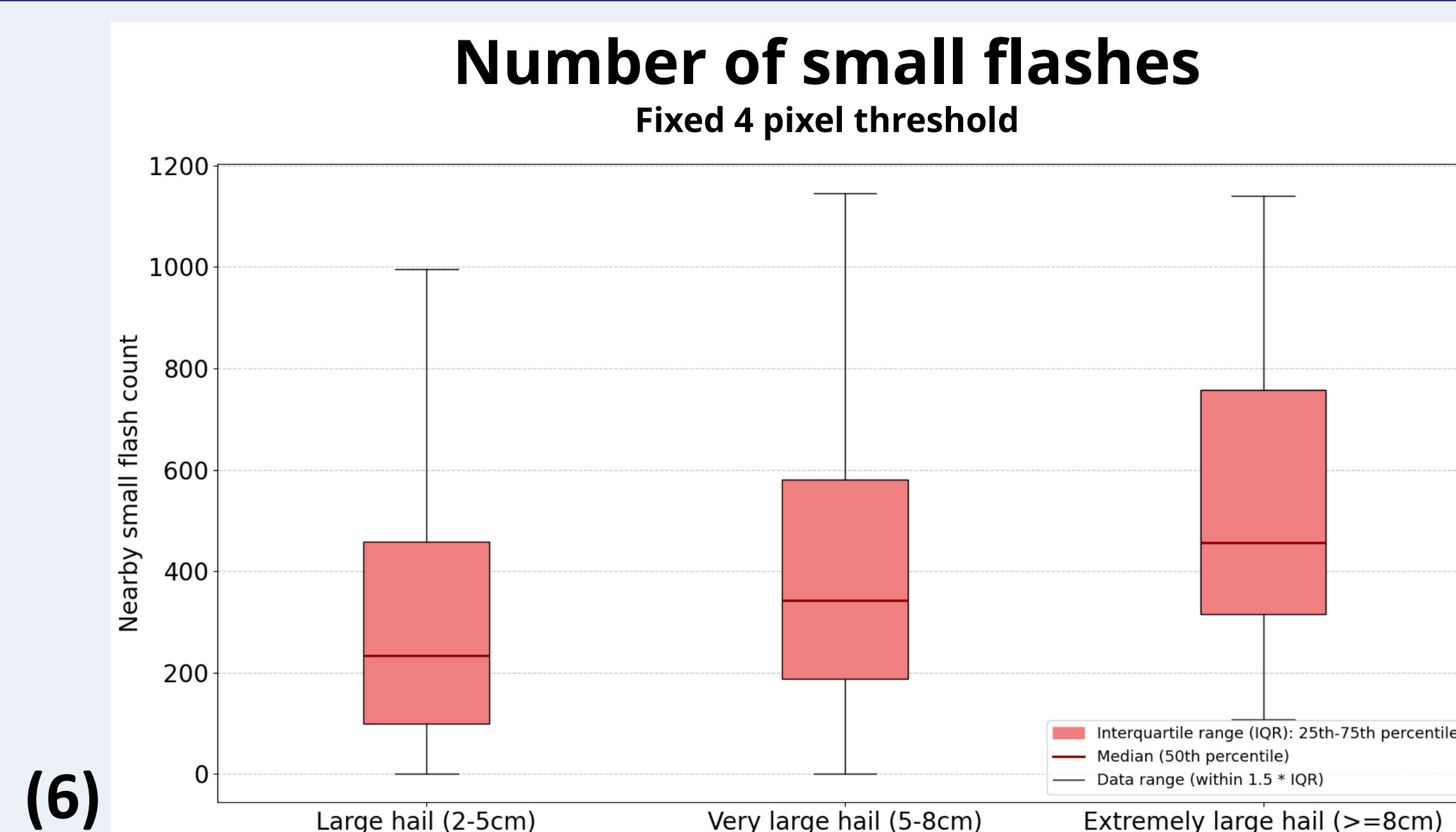
→ Storms producing **larger hail** are also producing **larger amounts of small flashes**

Conclusions

- **High frequency of "small" lightning flashes** is a **robust signature for severe thunderstorms**, found to be co-located with **75.7%** of associated severe weather reports and **92.6 % of severe hail reports.**
- The **number of small-flash signature** is strongly **correlated** with hail size: the number of nearby small flashes increases significantly as reported hail size grows from 2 cm to 8 cm+
- We found a **difference** in flash size spectrum between **day and night MTG-LI data: nighttime small flashes are a bit larger** → we need to investigate further

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