LI MAG meeting
12-13 October 2021

A geostationary lightning pseudo-observation generator utilizing low frequency ground-based lightning observations

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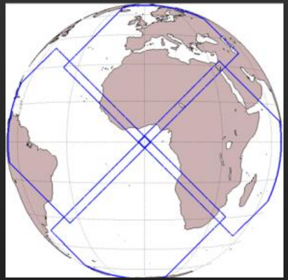
Co-authors
Olivier Caumont (CNRM), Eric Defer (LA)

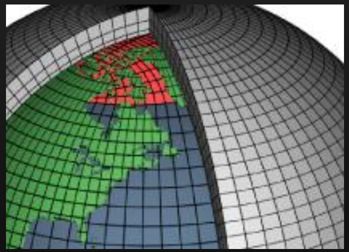
Funding: CNES and Météo-France

I. Project motivation and objective

- Improvement of the **prediction** of deep convection (and related) events and increase of **warning lead times**



- Preparation for using the GEO **MTG-LI** [launch in 2022] data in the NWP
- **Realistic synthetic MTG-LI data** to develop the assimilation scheme



- **Assimilation** of MTG-LI observations in the regional operational model of Météo-France (AROME-France)

Content

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II. Analyzing ground- and space-based lightning observations

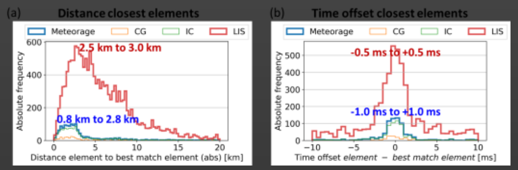
III. GLM and NLDN data - GEO lightning pseudo-observation generator

IV. Pseudo MTG-LI FED

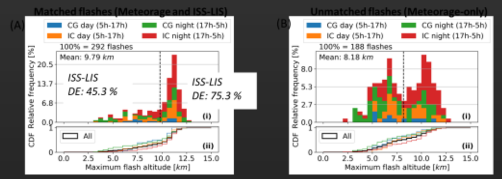
V. Summary

II. Ground- and space-based lightning observations in France

- **Good spatial and temporal agreement**
  (like e.g., Bitzer et al., 2016, Blakeslee et al., 2020)



- **Relative flash DE** of ISS-LIS (Meteorage) of 57.3% (83.3%)
  (similar Blakeslee et al., 2020)
- **Flash altitudes** as important influence
  (altitude dependency in e.g., Thomas, 2000 for TRMM-LIS, or Marchand et al., 2019 for GLM)



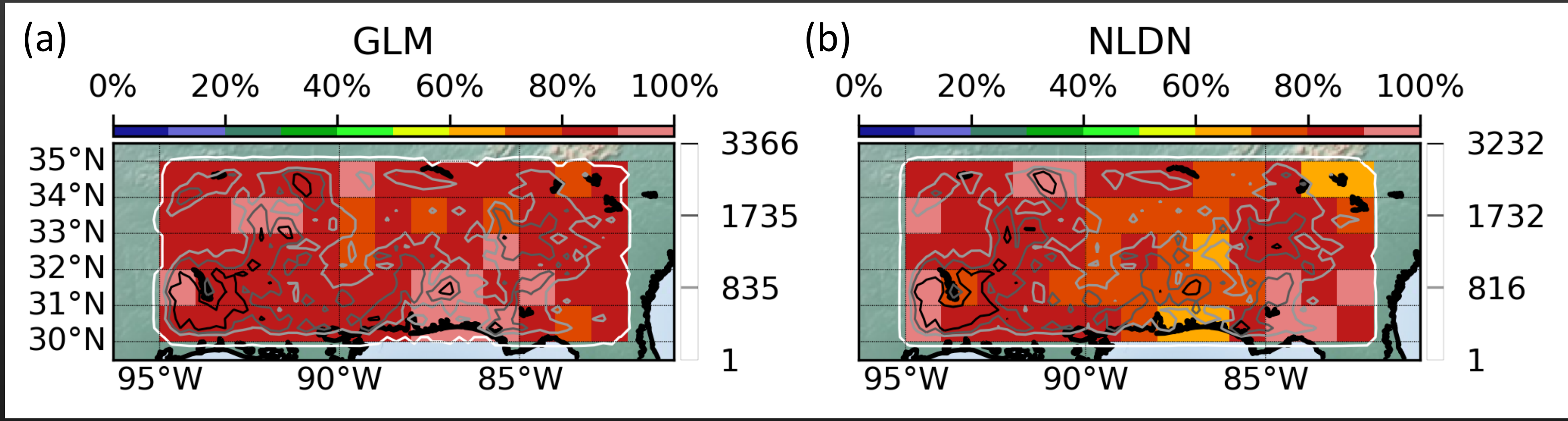
- **Large-extent** and **long-duration flashes** likely observed from space and ground
  (in accordance with Zhang et al., 2020 for GLM flashes)

- **Limited number of cases** due to LEO → GLM and NLDN comparison

- Published AMT paper: **Erdmann et al. (2020)** [Erdmann, F., Defer, E., Caumont, O., Blakeslee, R. J., Pédeboy, S., and Coquillat, S.: Concurrent satellite and ground-based lightning observations from the Optical Lightning Imaging Sensor (ISS-LIS), the low-frequency network Meteorage and the SAETTA Lightning Mapping Array (LMA) in the northwestern Mediterranean region, Atmos. Meas. Tech., 13, 853–875, https://doi.org/10.5194/amt-13-853-2020, 2020.]

II. Lightning observation in the USA – GLM and NLDN records

- Methodology of previous intercomparison now applied for 10 complete storm days
- High **GLM flash DE** of about **87 %** and **NLDN flash DE** of about **84 %**



- Flash DE increases again with longer flash extent, longer flash duration, and higher number of optical (LF) events (strokes+pulses) *(as also, e.g., Zhang et al., 2020)*

- **Flash database** with more than **900,000** coincident flashes:
  Training of the **GEO lightning pseudo-observation generator**

III. GLM and NLDN data - GEO lightning pseudo-observation generator

Ground-based LF stroke-type data

Training Input

- 6 NLDN **features** per flash:
  - Extent,
  - Stroke+pulse number,
  - Duration,
  - Mean absolute current,
  - Maximum current,
  - CG ratio
- 3 observed GLM **targets** per flash:
  - Extent,
  - Event number,
  - Duration

1. Pseudo-GEO target generator

- LF observation flash features
- Machine learning based target generator
- Simulated pseudo-GEO targets

2. Simulation of pseudo-GEO events

- Use simulated pseudo-GEO targets
- Pseudo-GEO events on regular lat-lon grid

Test

- Statistics of distributions of observed and pseudo-GLM flash characteristics
- Comparison of observed GLM FED and simulated FED

GEO Flash Extent Density (FED)

- Submitted paper to JTECH: **Erdmann et al.** [Erdmann, F., Caumont, O., and Defer, E.: A geostationary lightning pseudo-observation generator utilizing low frequency ground-based lightning observations, submitted to the Journal of Atmospheric and Oceanic Technology in October 2020]

III. GLM and NLDN data - GEO lightning pseudo-observation generator

- Trained machine learning model(s) archived at Meteo France
    - Memory usage of recommended generator: 10,2 kB (15 files)
- Requirements: Python3, trained ML model, LF lightning input data
- Input: Meteorage (or any suitable LF) stroke-type lightning data ASCII file

Date and time with deciseconds

Latitude

Longitude

LF current amplitude

Type
- f or C for IC
- t or G for CG

```
2018-08-09 14:32:20.345;46.41212;6.21233;-25.353;f
2018-08-09 14:32:20.612;46.46543;6.37411;-12.421;f
2018-08-09 14:32:21.001;46.51312;6.32341;-101.353;t
...
```

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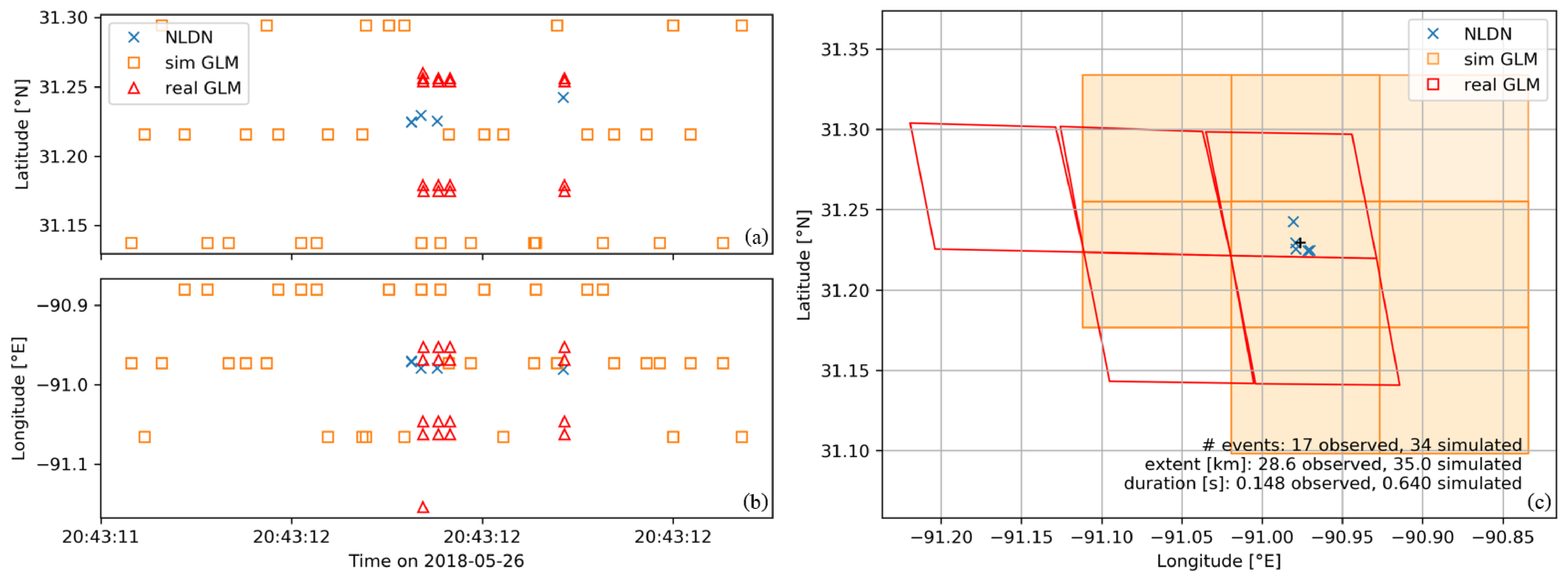
III. GLM and NLDN data - GEO lightning pseudo-observation generator

- Trained machine learning model(s) archived at Meteo France
  - Memory usage of recommended generator: 10,2 kB (15 files)
- Requirements: Python3, trained ML model, LF lightning input data
- Input: Meteorage (or any suitable LF) stroke-type lightning data ASCII file
- Python3 script (generator)
  - Single day processing – date selection
  1. Grouping of LF strokes/pulses to flash level + feature computation – dt and ds for flashes
  2. Selection of region, pseudo-GEO grid, ML model
  3. Simulation of GEO flash targets (1 set of targets for each LF flash)
  4. Simulation GEO pseudo-events for each flash from GEO flash target
  5. Storage of results as binary pickle files
- Shell script for even easier use
  - Uses recommended configuration (no changes)
  - Select the date, region, size of pseudo-GEO lightning events

III. GEO lightning pseudo-observation generator – One simulated flash

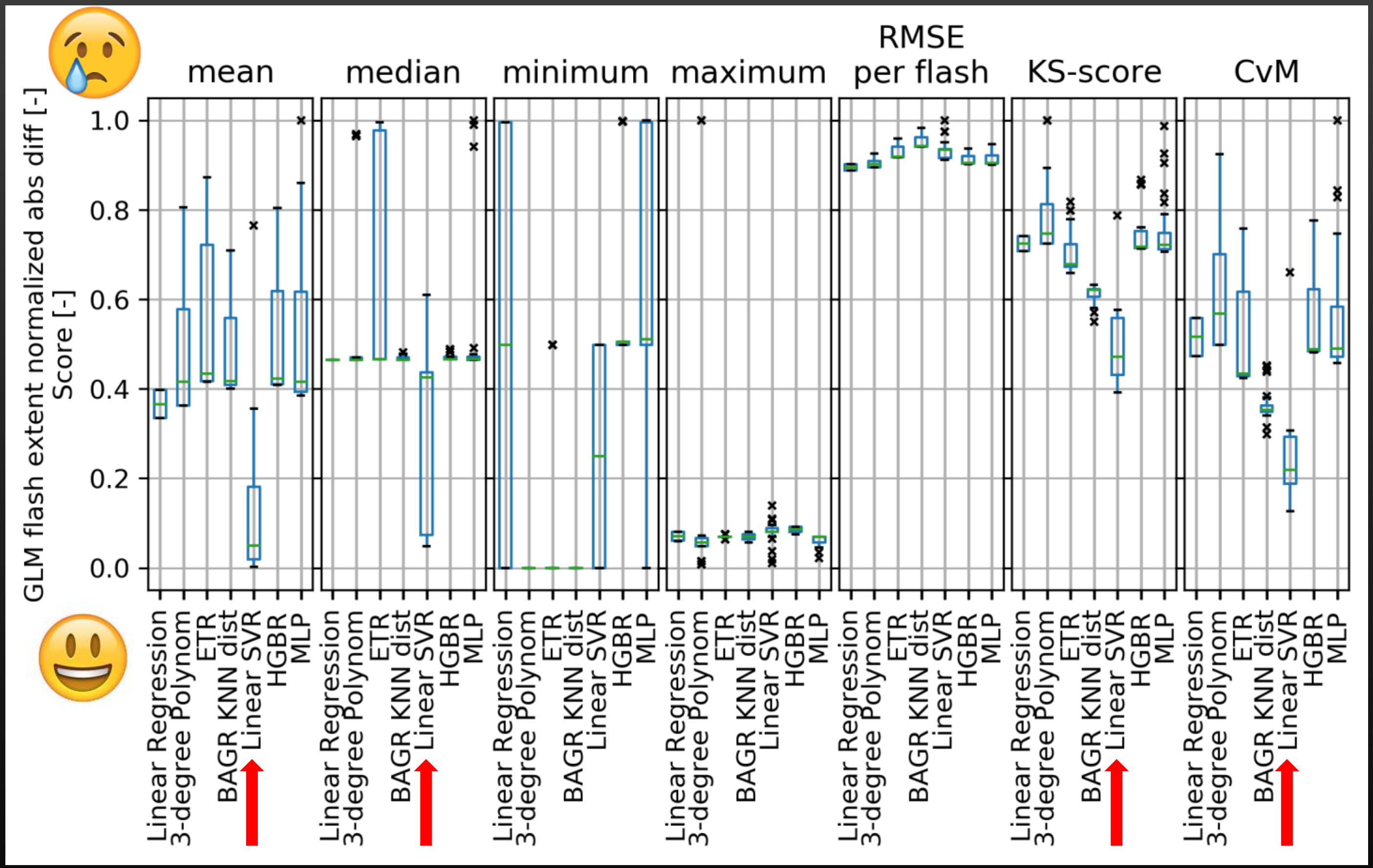
- Event number, flash extent, flash duration – NLDN, GLM observation and simulation
- Real GLM grid (red) vs. regular pseudo-GLM grid (orange shaded)



III. Evaluation of machine learning based part – Example GLM flash extent

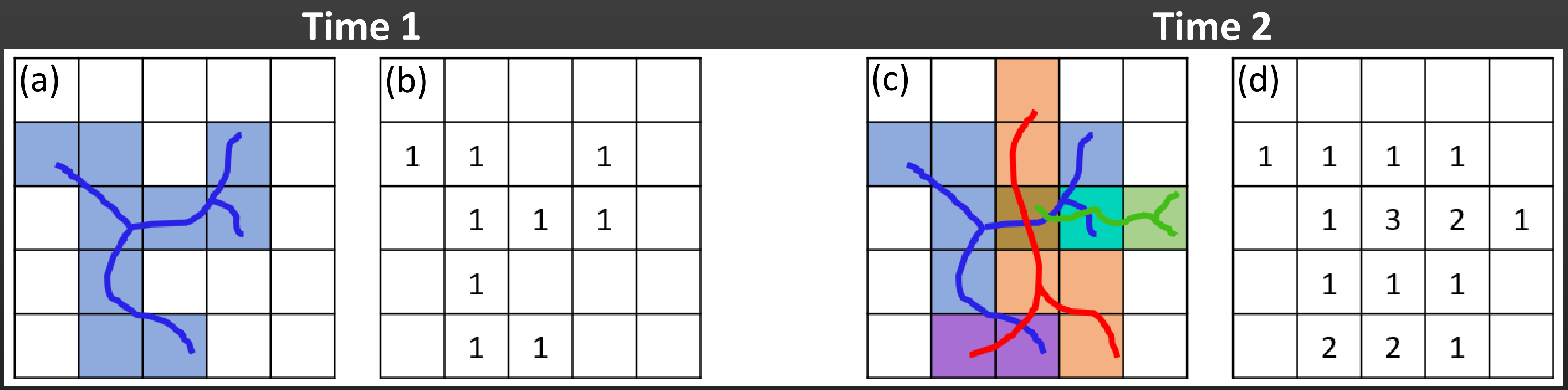
- **196 different configurations** of the generator tested
- 7 machine learning types (x-axis)
- Compare distributions of observed and simulated GLM flash extent
- **Normalized difference** between prediction and observation for 7 statistics
- 1 = worst generator in the comparison
- 0 = observation value
- **Linear SVR (linSVR)** overall best

Normalized difference: all generators grouped by ML model type

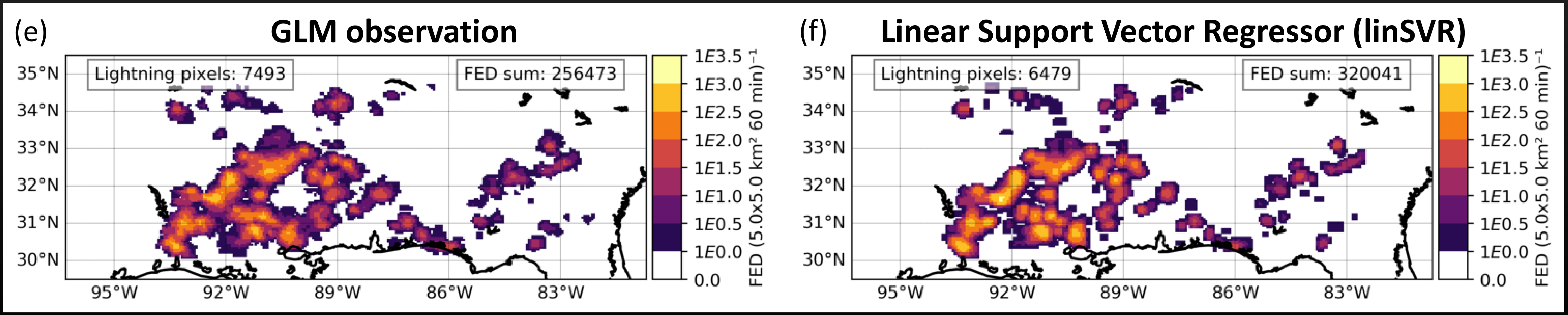


III. GLM and NLDN data - GEO pseudo Flash Extent Density product

- **Flash extent density (FED)** on regular grid and within a given time period

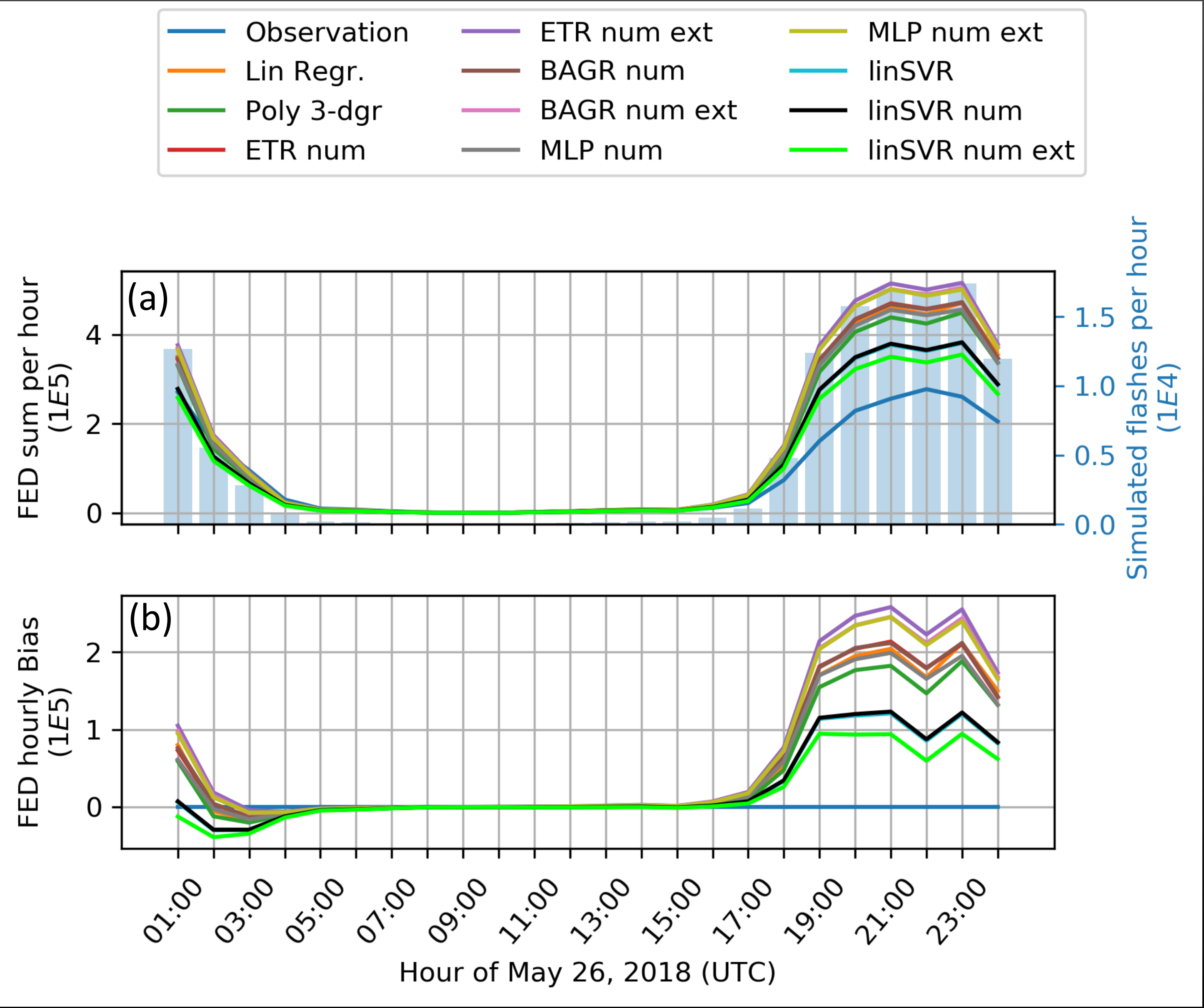


- Example 26 May 2018, 20:00-21:00 UTC, FED on 5km x 5km pixels within 60 min



III. Evaluation of FED product – Difference of hourly FED sum in the region

- Hourly sum of FED values of all pixels within the domain
- **Difference of hourly FED sum** (simulation minus observation)
- Lowest difference: linSVR num ext for most hours
- **Linear Support Vector Machine (linSVR) yields best results**



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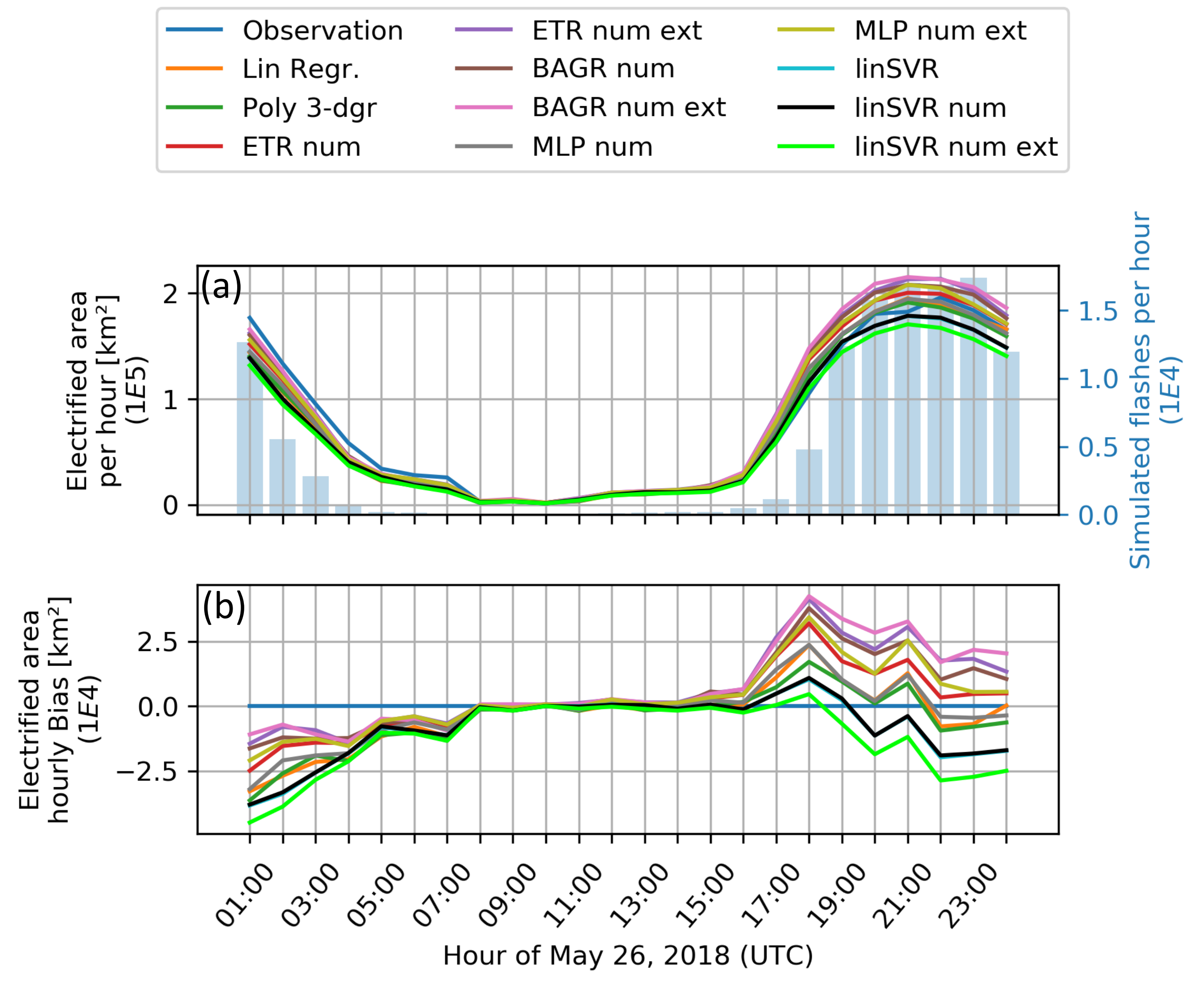
III. Evaluation of FED product – Difference of electrified area

- Electrified area from the number of pixels with FED > 0

- **Difference of electrified area** (simulation minus observation)

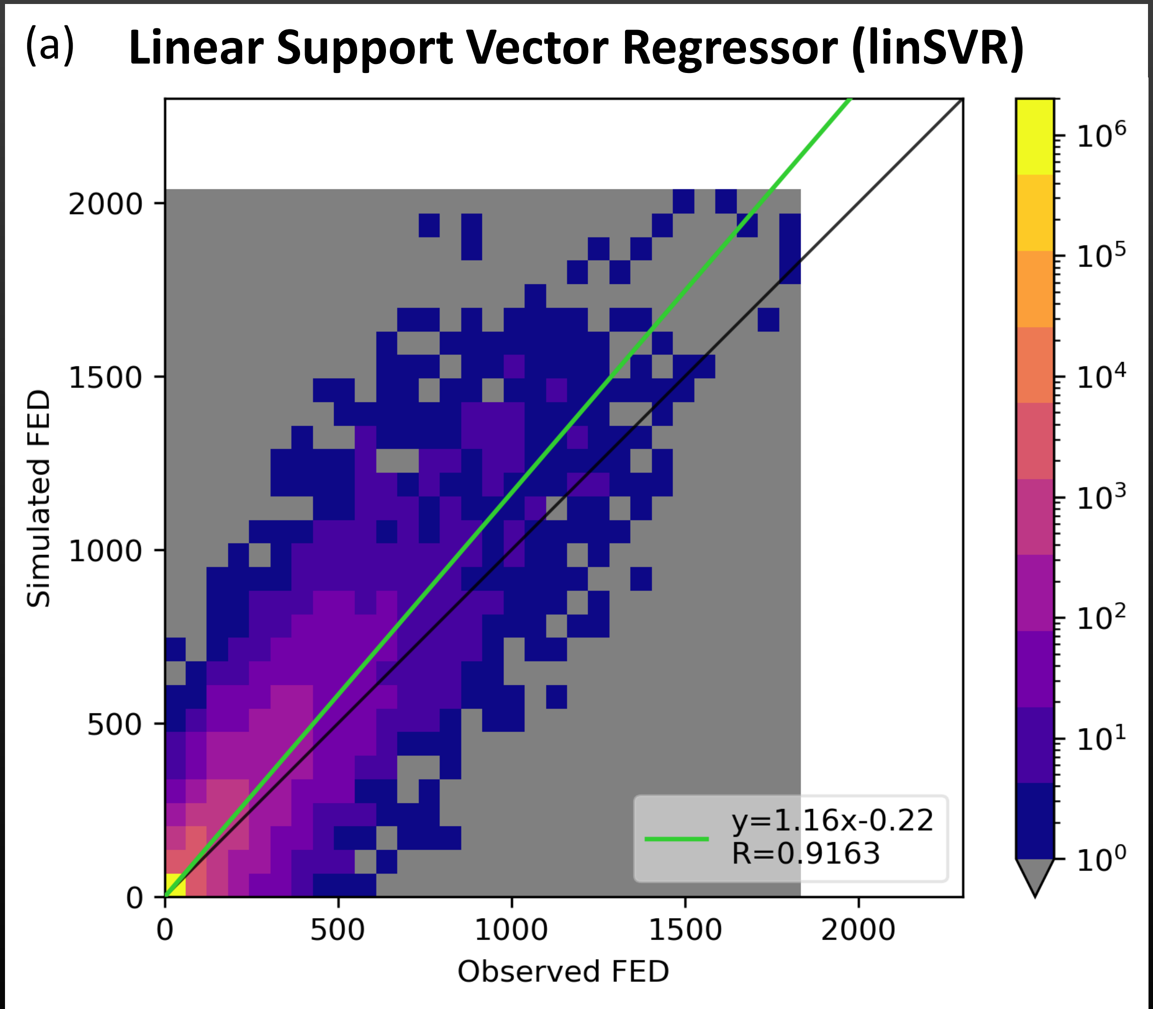
- Lowest difference: MLP num and BAGR num
- Range of outcomes lower than for FED sum

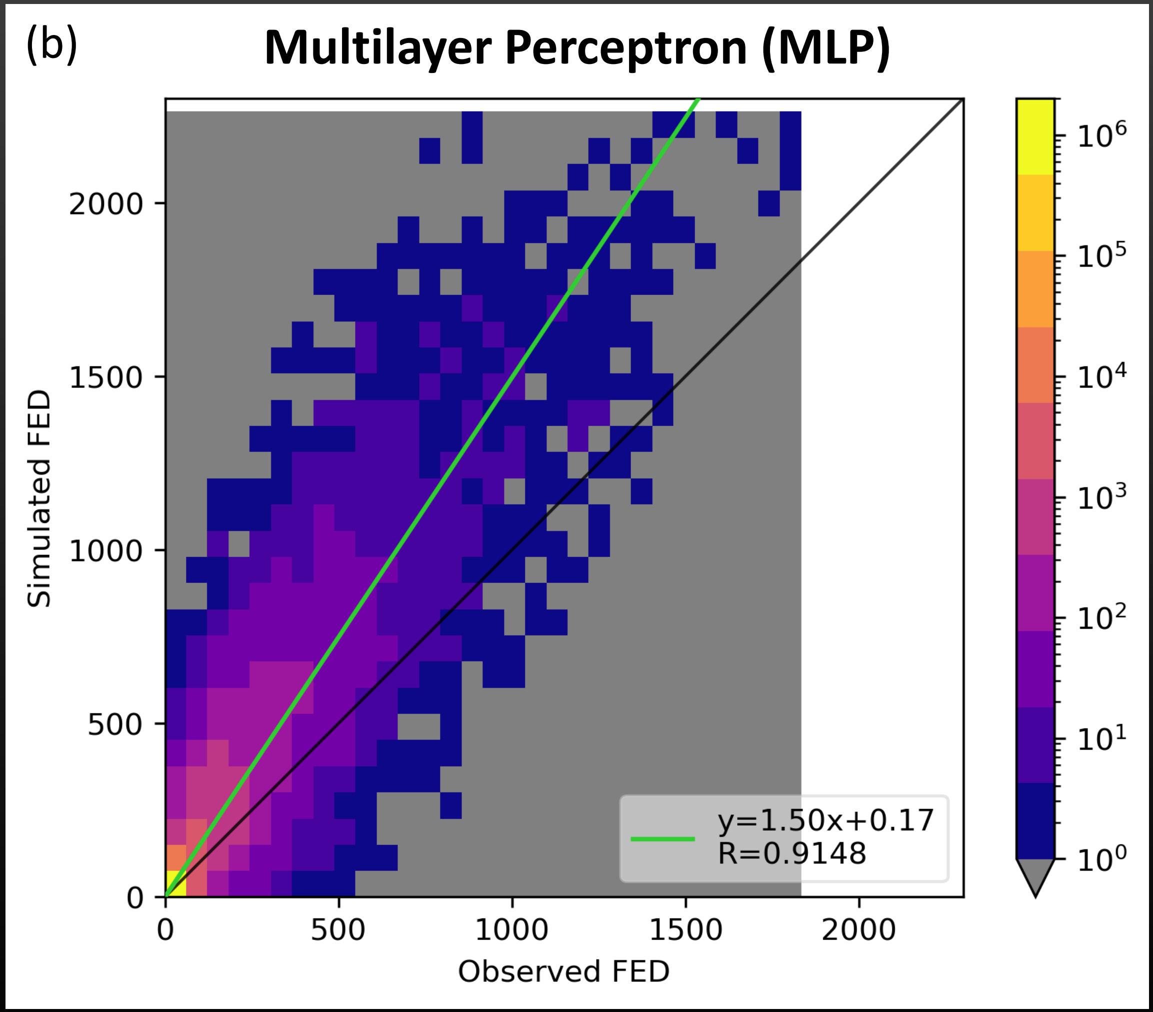
- **Neural Network (MLP)** and **Bagging with k-means clustering yields best results**



III. Evaluation of FED product

- Observed versus simulated GLM-derived FED

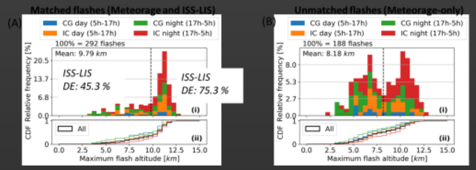




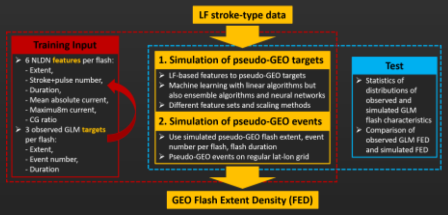
IV. Towards Meteosat Third Generation (MTG) Lightning Imager (LI) data

- 4 steps to develop a **GEO lightning pseudo-observation generator**

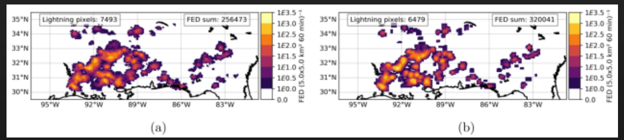
1. Methods to compare **LF network Meteorage, LMA SAETTA,** and **optical ISS-LIS** records in France



2. Similarity of French **Meteorage** network and US **NLDN**



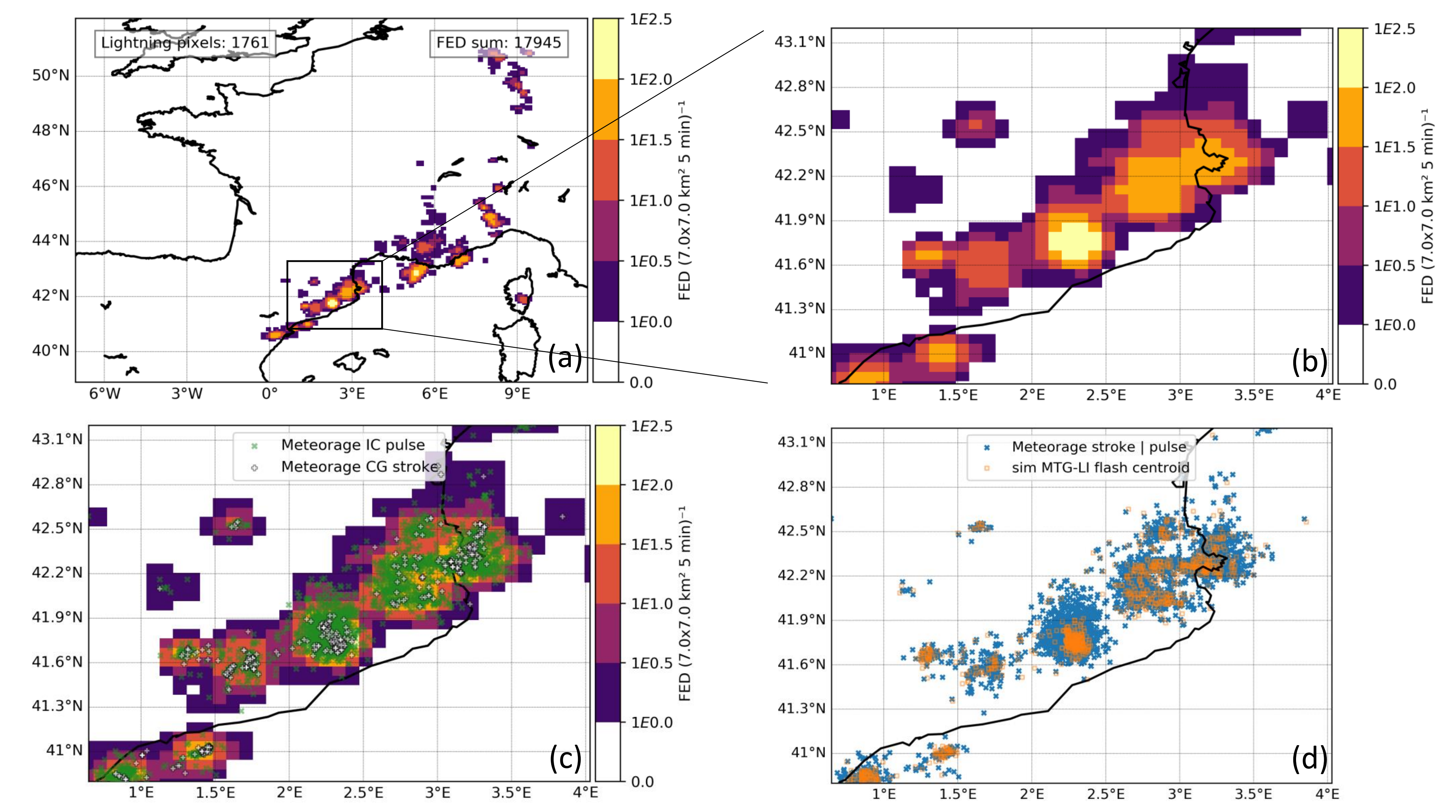
3. **Training** of the GEO lightning pseudo-observation generator with operational US **NLDN** and **GLM**
4. **Testing** of simulated **pseudo-GLM FED** versus GLM observations



- **Recommended** generator uses **linSVR** – out of almost 200 generators
- Next: **Pseudo MTG-LI** data generation over France using Meteorage records

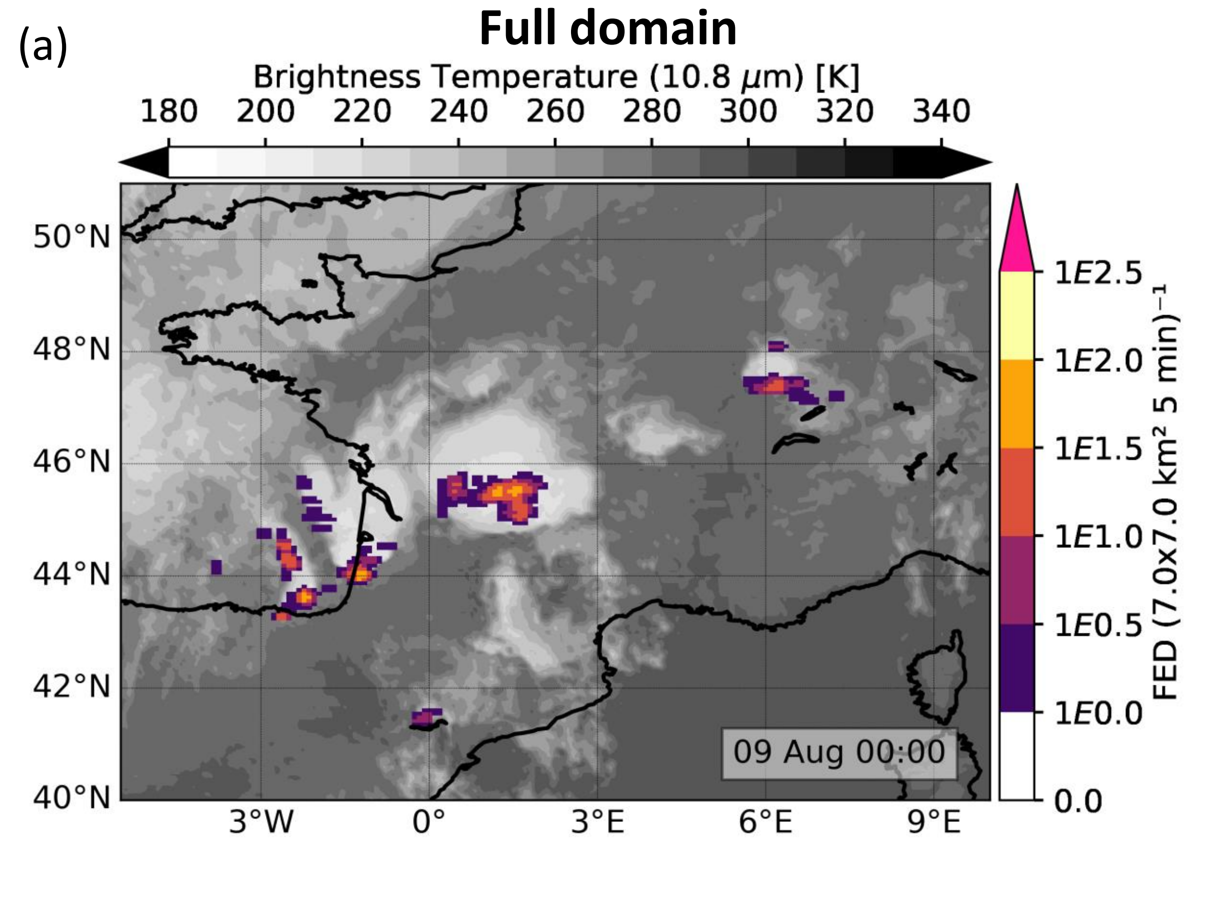
IV. Simulated FED and source Meteorage records

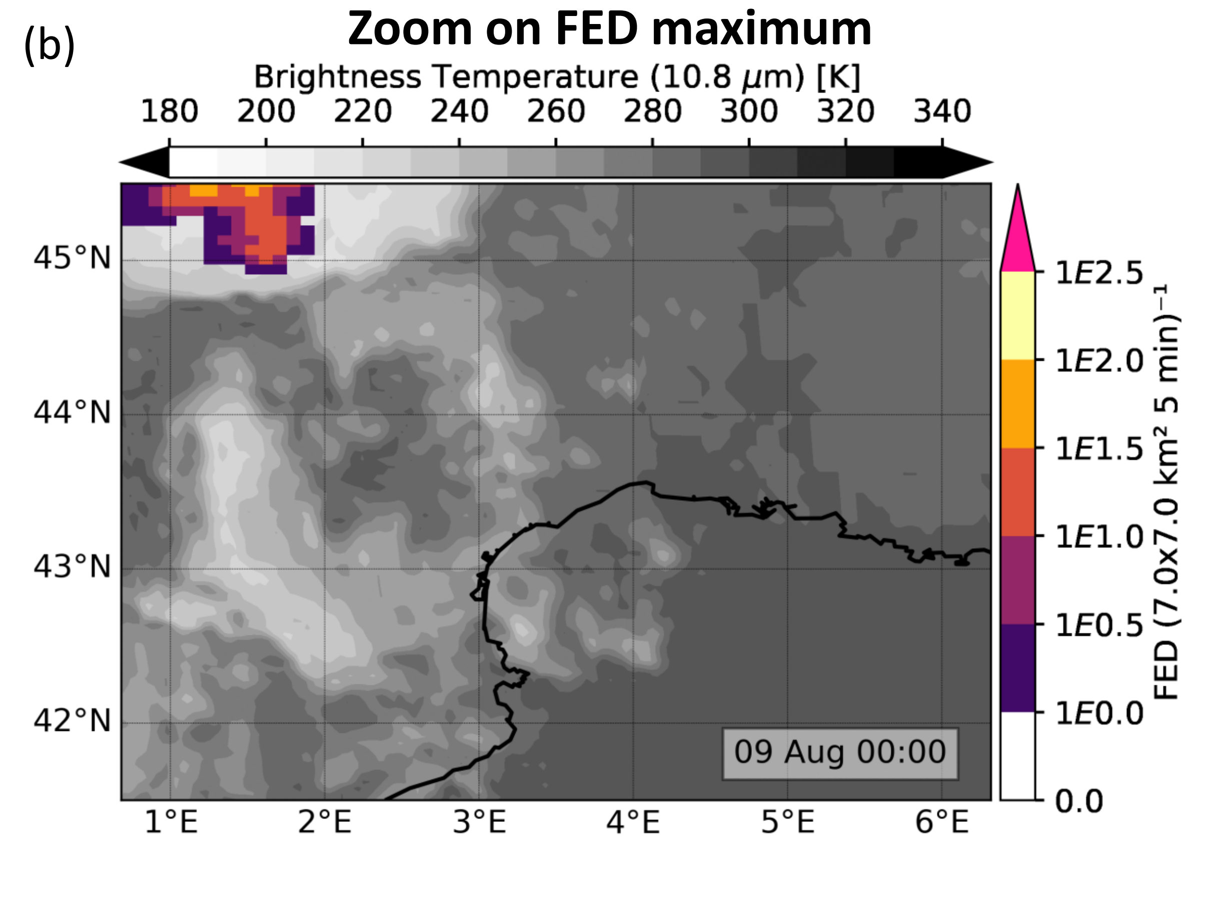
09 Aug 2018, 13:55-14:00 UTC



IV. Pseudo lightning data – MTG-LI flash extent density (FED)

- GEO lightning pseudo-observation generator for **MTG-LI spatial** and **temporal resolution**
- Ex.: Pseudo **MTG-LI FED** based on Meteorage records + IR 10.8 µm MSG – SEVIRI images

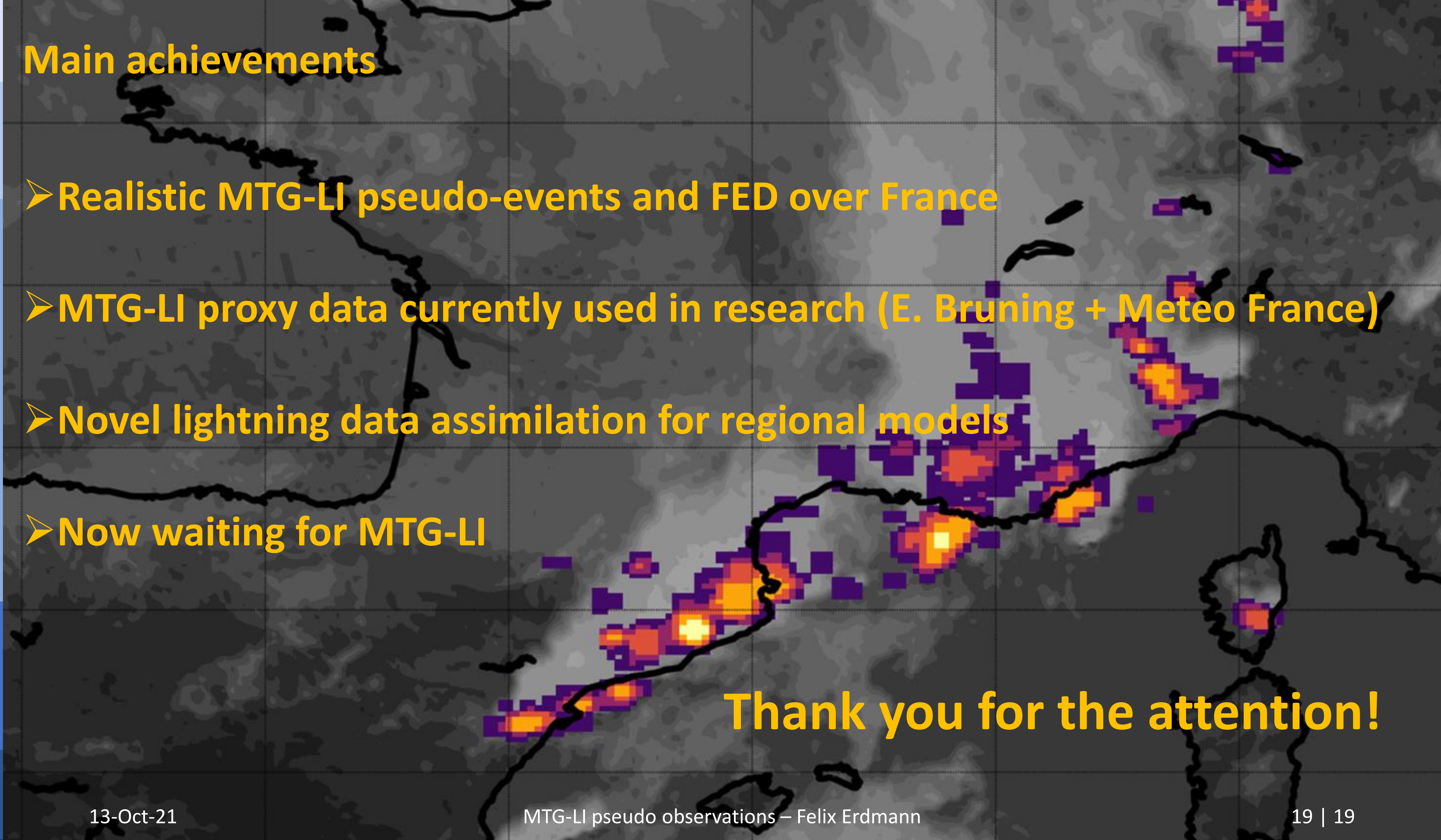




V. Summary: Pseudo MTG-LI data generator

Strengths	• **Most realistic MTG-LI proxy FED known so far** • **Large area data generation** • **MTG-LI pseudo-events are included** • **Gridded products can be derived, e.g., FED** • **Generator handles all kinds of LF stroke-type lightning observations with CG-IC discrimination and LF amplitude**
Weaknesses	• Simulation of MTG-LI pseudo-observation only where LF ground-based records + no approach for *unmatched* flashes • Statistical rather than flash-by-flash accuracy • No realistic MTG-LI pseudo-groups as event times are assigned uniformly during a flash • Only a regular MTG-LI grid – fixed event spacing • Only verified for Meteorage performance

Main achievements



- ➢Realistic MTG-LI pseudo-events and FED over France
- ➢MTG-LI proxy data currently used in research (E. Bruning + Meteo France)
- ➢Novel lightning data assimilation for regional models
- ➢Now waiting for MTG-LI

Thank you for the attention!

Backup Slides

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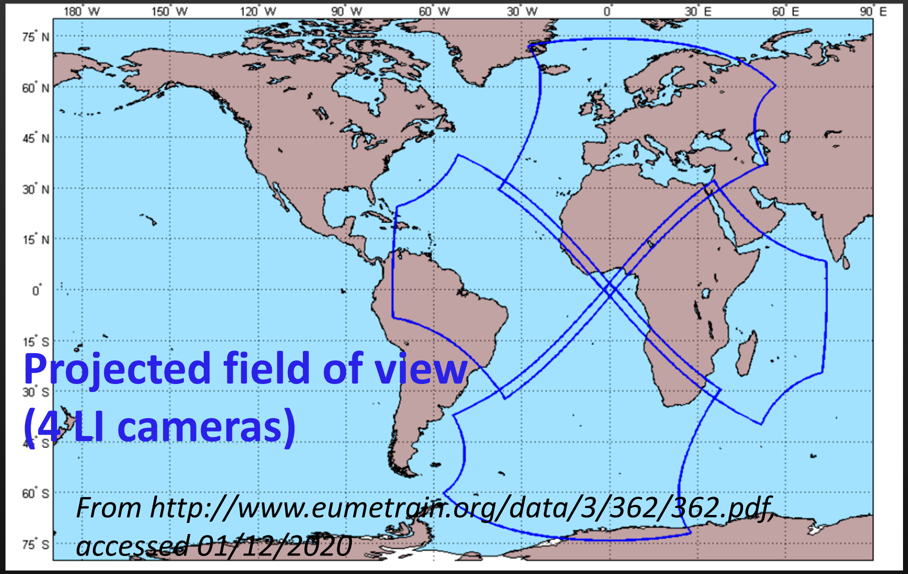
I Use of lightning observations

Spaceborne sensors on Geostationary (GEO) and low Earth orbit (LEO)

- E.g., GEO **Meteosat Third Generation (MTG) Lightning Imager (LI)** coverage

(a)



From http://www.eumetrain.org/data/3/362/362.pdf, accessed 01/12/2020

(b)

(c)

From https://directory.eoportal.org/web/eoportal/satellite-missions/iss-lis, accessed 05/04/2020

(d)

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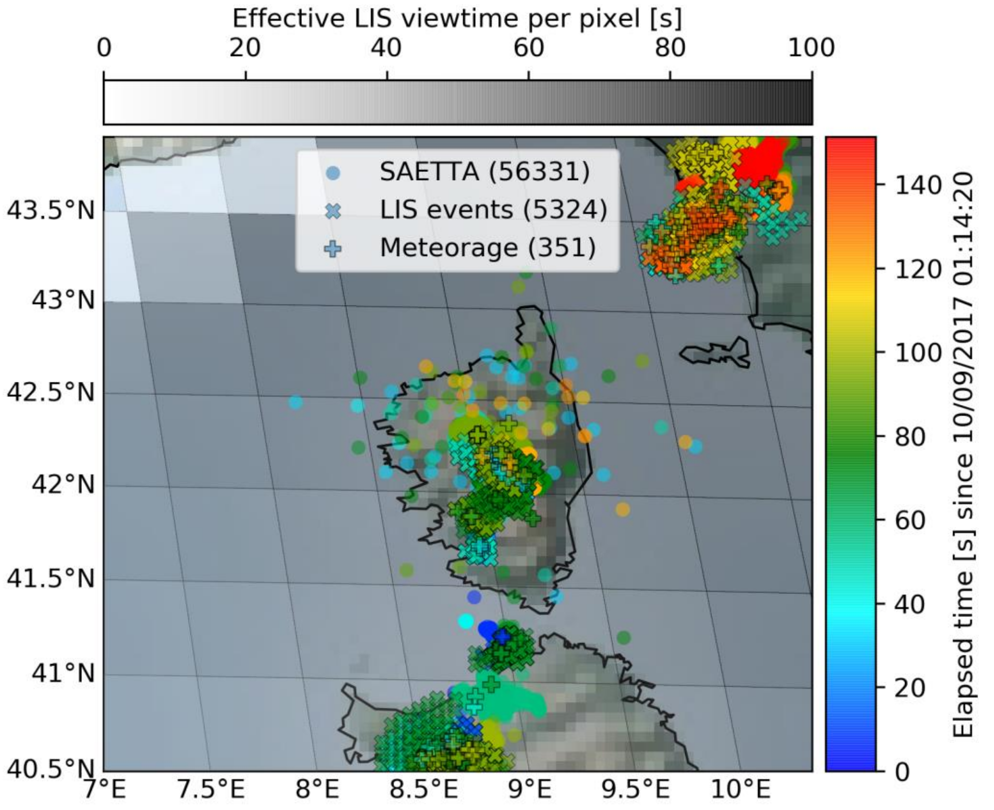
Ground-based lightning locating systems (LLSs)

II. Ground- and space-based lightning observations in France

Region	NW-Mediterranean, Corsica
Period	ISS-LIS *viewtime* periods, March 01, 2017 – March 20, 2018
Data type **- ISS-LIS** **- Meteorage**	 Optical events CG strokes + IC pulses
Algorithms	Merging: Flash level data Matching: Coincident flashes
Notes	Flash altitudes from SAETTA sources

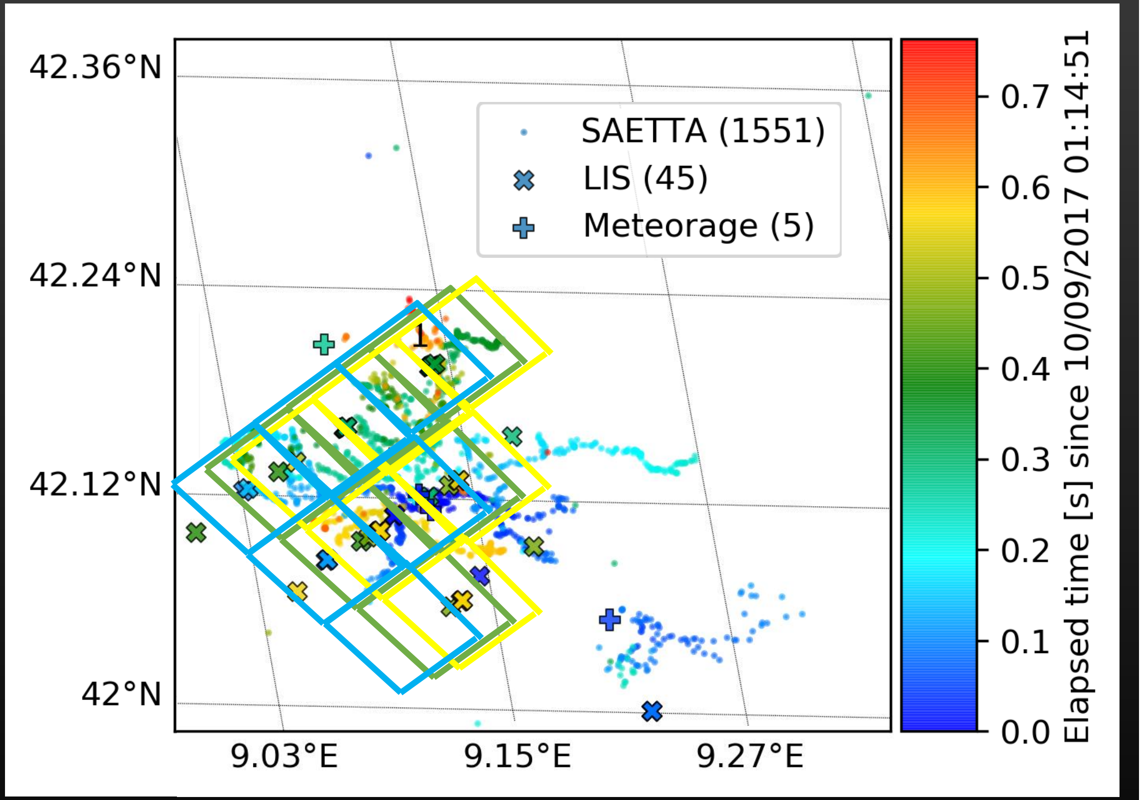
Example of lightning observations during an ISS overpass



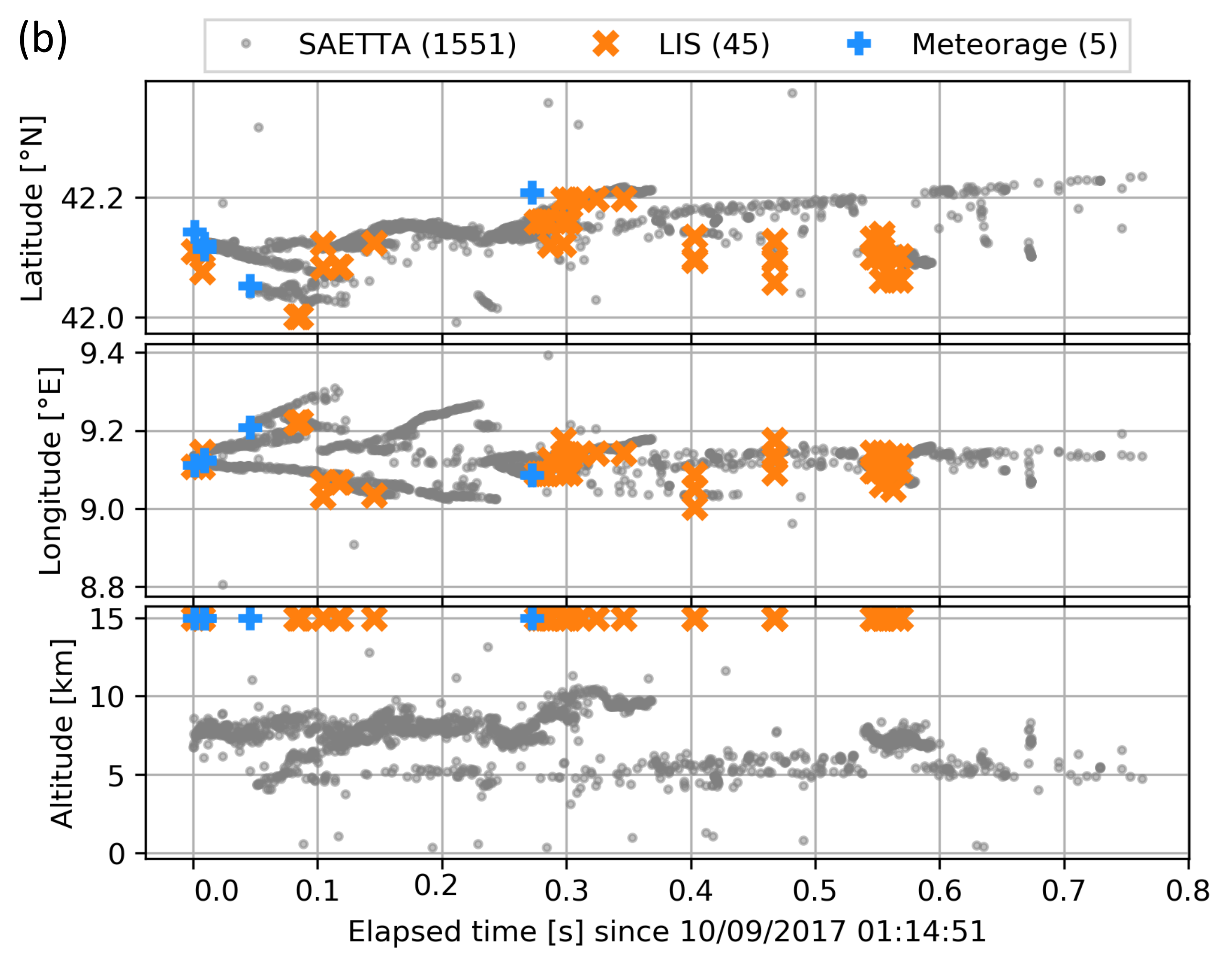
II. Ground- and space-based lightning observations in France

- One flash observed by ISS-LIS, Meteorage, and SAETTA

(a)



(b)

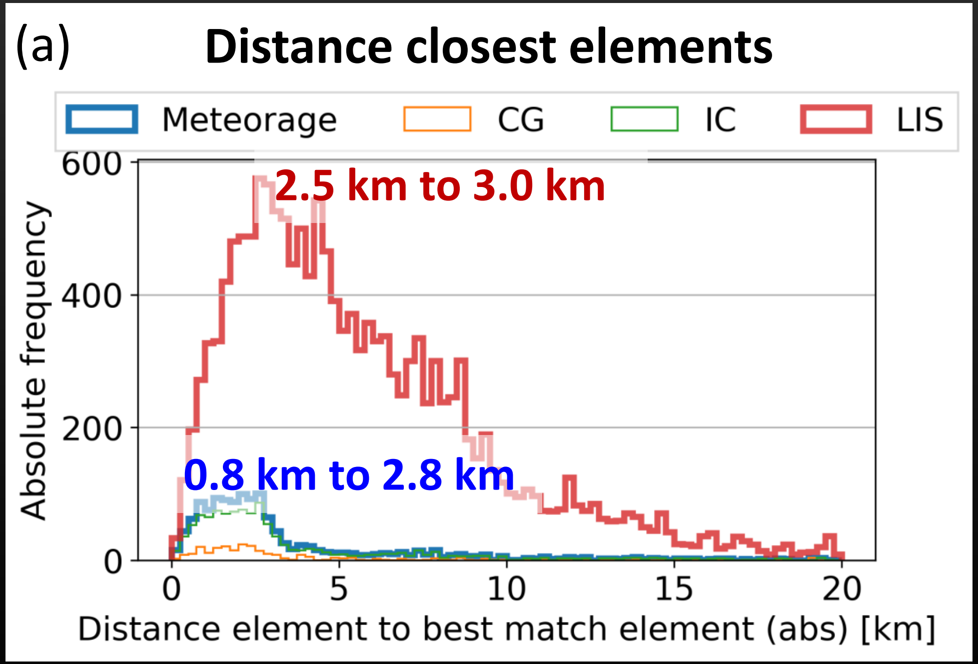


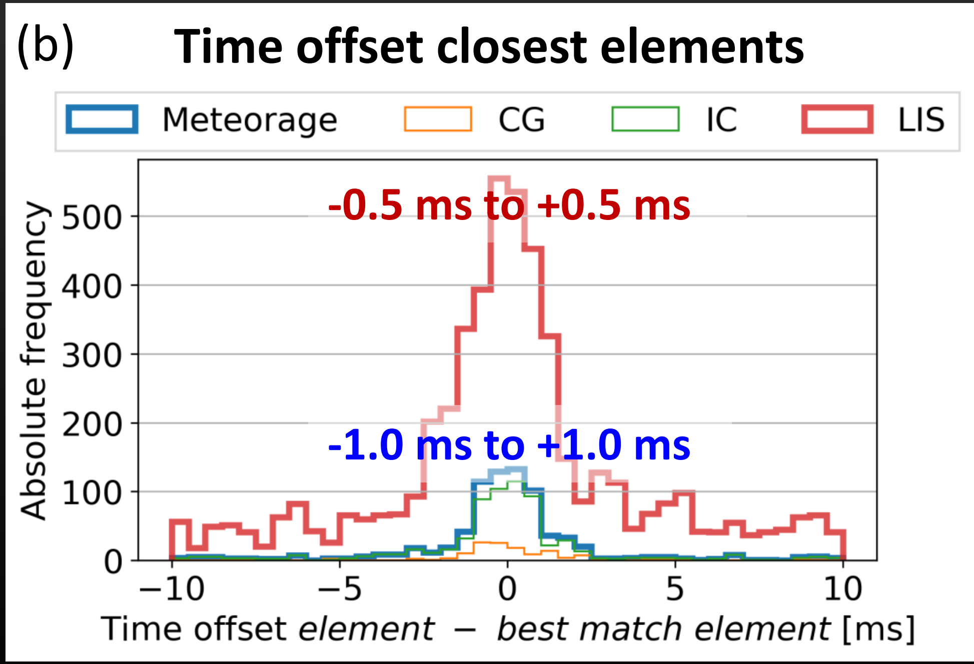
II. Ground- and space-based lightning observations in France

- **Relative flash detection efficiency (DE)** for 26 overpasses with lightning activity

	ISS-LIS	Meteorage
Relative DE [%]	57.3	83.3
Number of flashes	330	569

- Coincident flashes: Closest *flash elements* (=ISS-LIS events, Meteorage strokes + pulses)

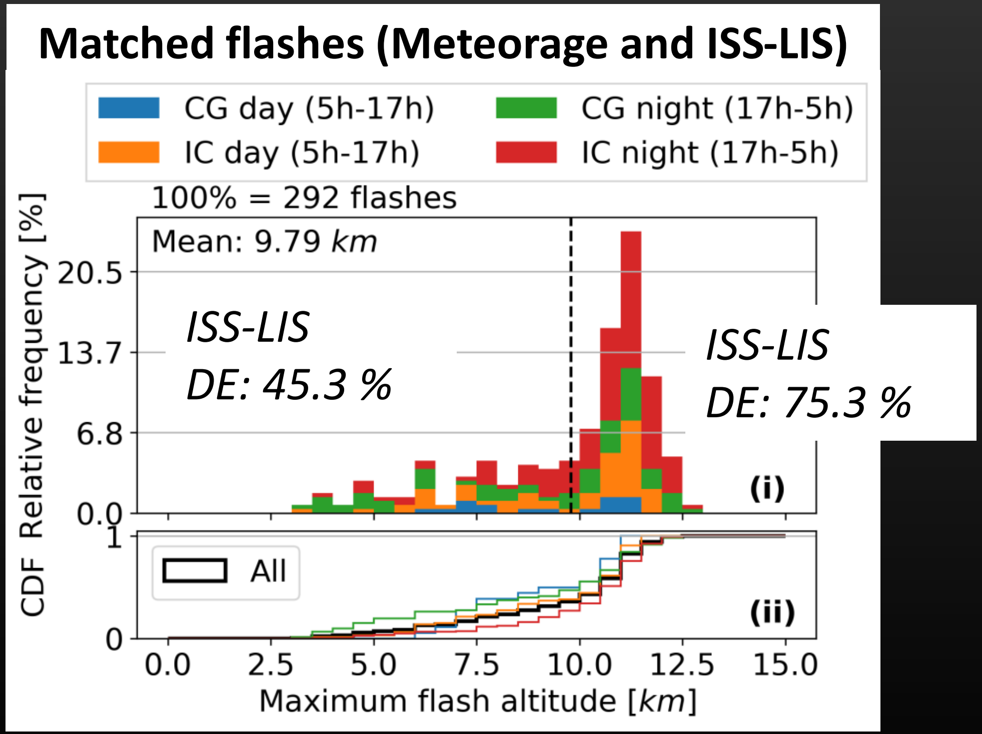




II. Ground- and space-based lightning observations in France

- Comparison of **flash characteristics** (i.e., extent, duration, energetics, altitude)
- Separate ***matched*** (located by ISS-LIS and Meteorage) and ***unmatched*** (located by only one LLS) flashes
- Example: Maximum flash altitude of Meteorage flashes

(a)



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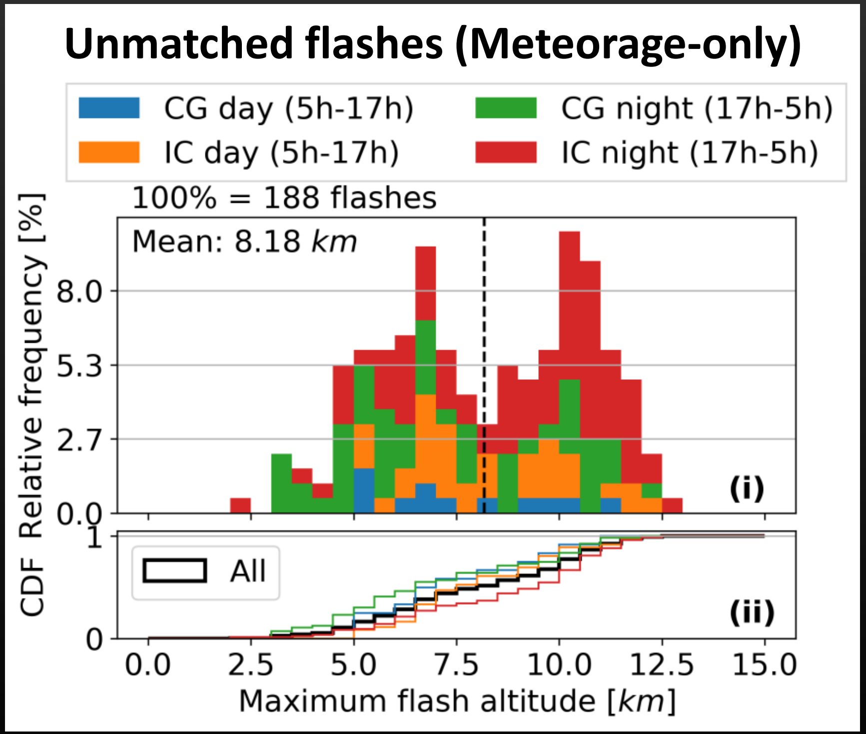

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II. Flash merging algorithms

NASA GLM (ISS-LIS)

- Events < groups < flashes (< areas)
- ds=16.5 (5.5) km | dt=330 ms Weighted Euclidean Distance for groups of a flash
- $WED^2 = (X/ds)^2+(Y/ds)^2+(T/dt)^2<1$
- X: lat distance of group borders (centroids)
- Y: lon distance of group borders (centroids)
- T: time difference of groups [ms]

Mach et al. (2020) (2007)

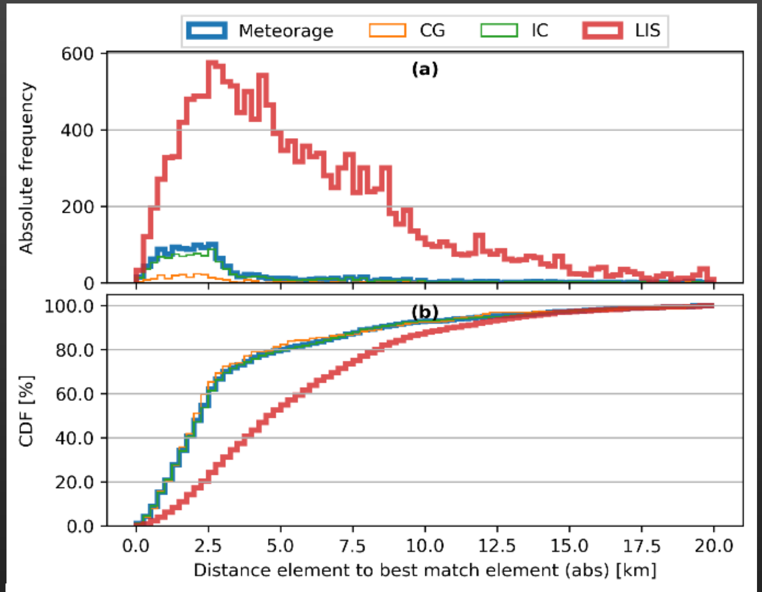
In-house LF networks (ISS-LIS)

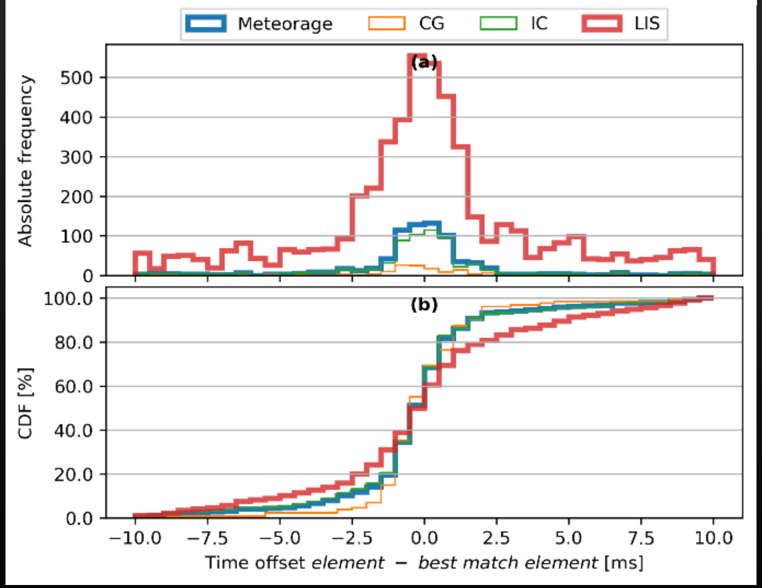
- Strokes|pulses (events) < flashes
- ds=20 (15) km | dt=400 (300) ms for strokes|pulses (events) of a flash
- Both ds and dt must be met to assign two strokes|pulses (events) to the same flash

Erdmann et al. (2020)

II. ISS-LIS versus Meteorage and NLDN – Matched flashes accuracy

LIS-Meteorage

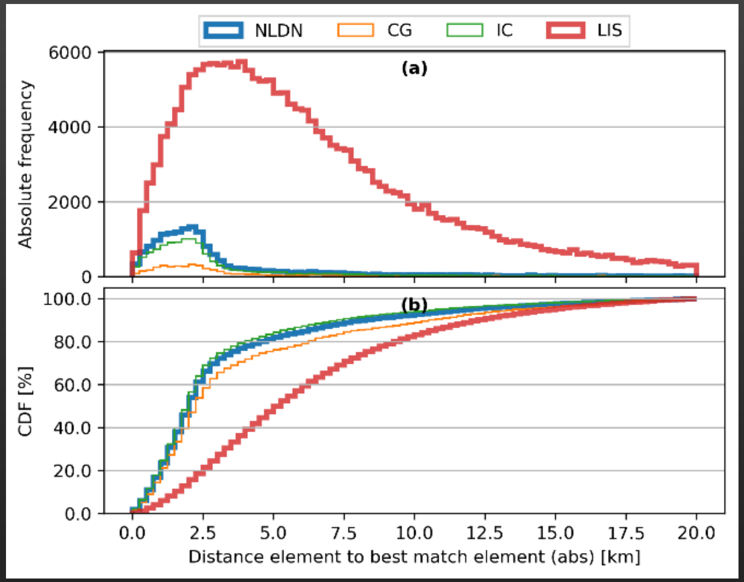


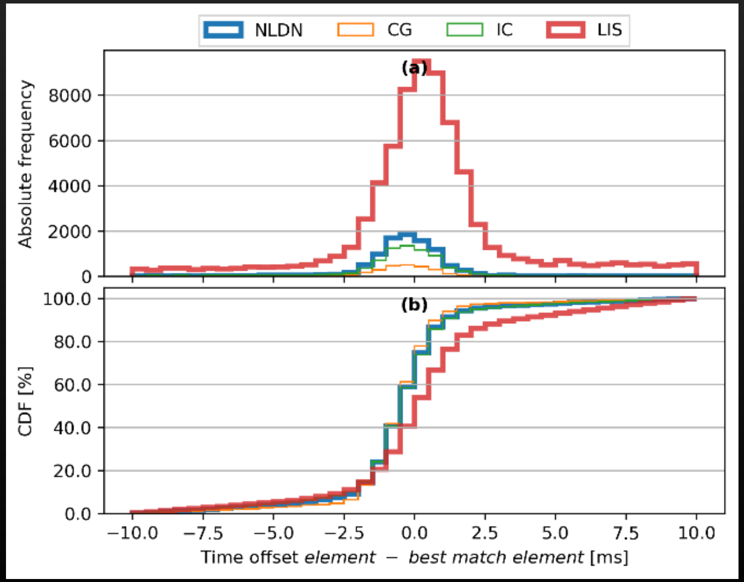


Distance:
Similar shape

Time Offset:
NLDN detected lightning earlier

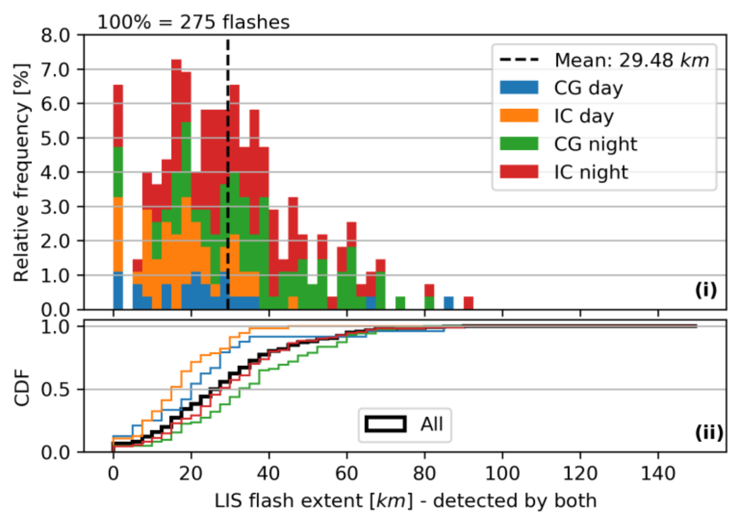
LIS-NLDN

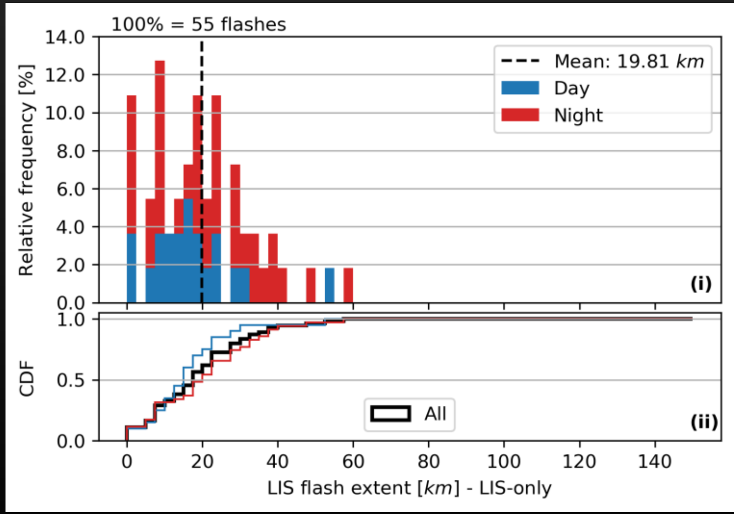




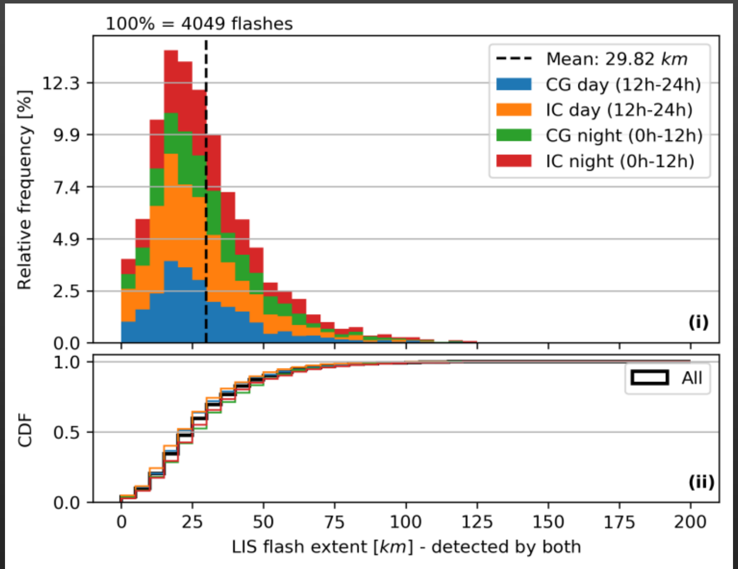
II. ISS-LIS versus Meteorage and NLDN – Example LIS flash extent

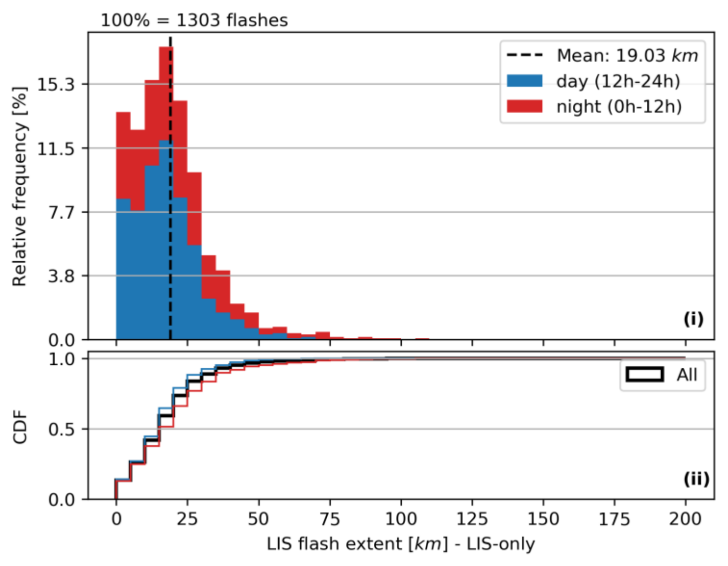
LIS-Meteorage





LIS-NLDN

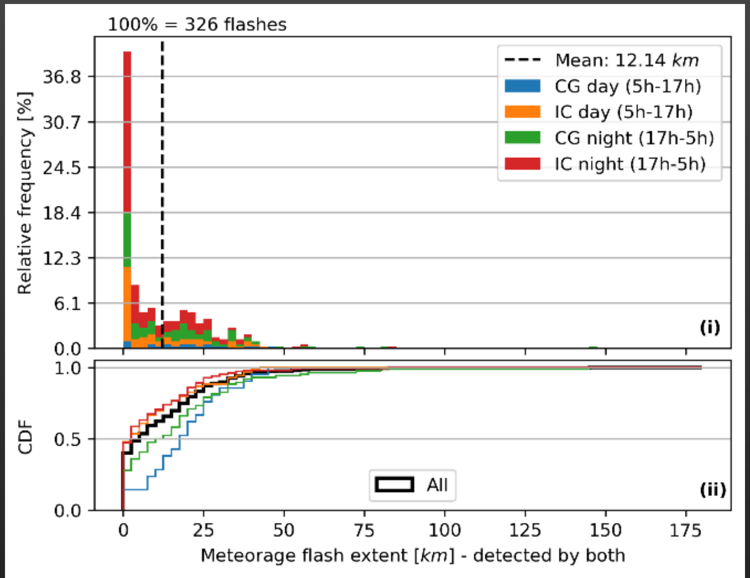




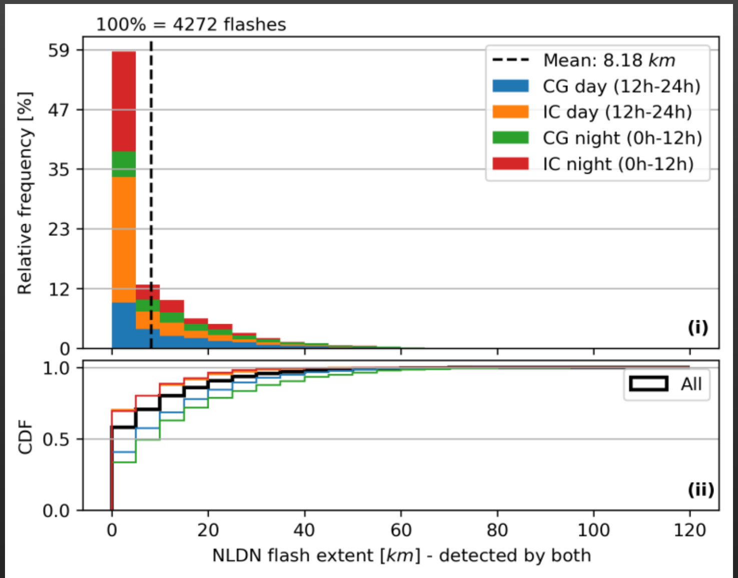
LIS flashes with similar extent in the two region around Corsica and over the SE US

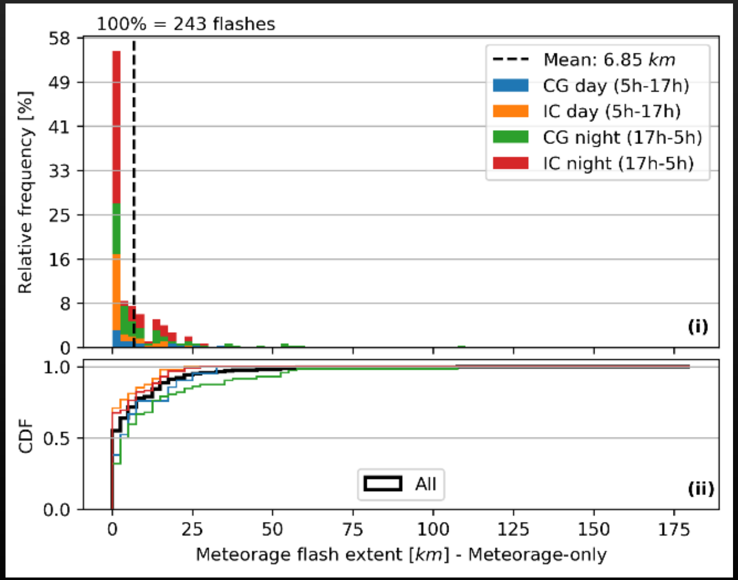
II. ISS-LIS versus Meteorage and NLDN – Example LF flash extent

LIS-Meteorage



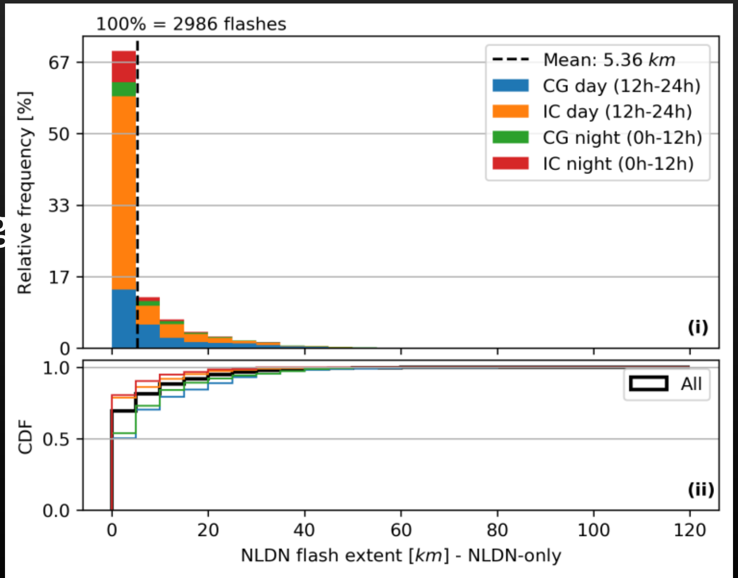
LIS-NLDN





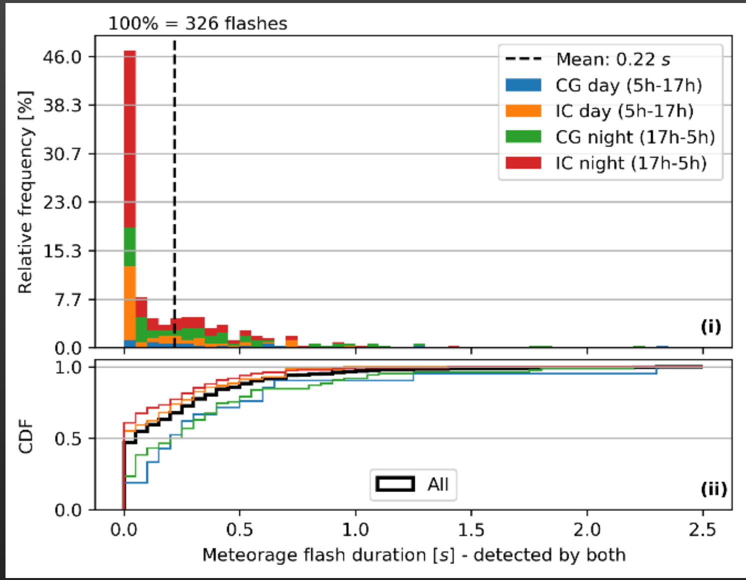
NLDN flashes are smaller than Météorage flashes – Merging criteria?

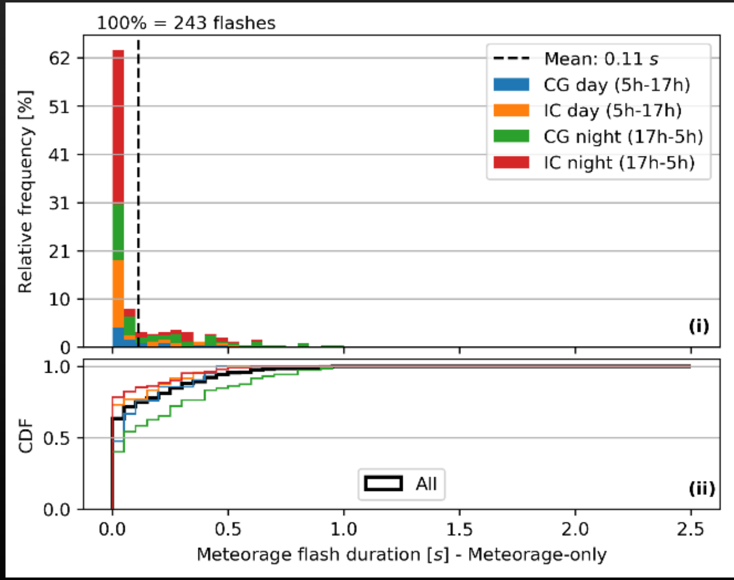
Consider few very extended flashes increasing the mean for Meteorage



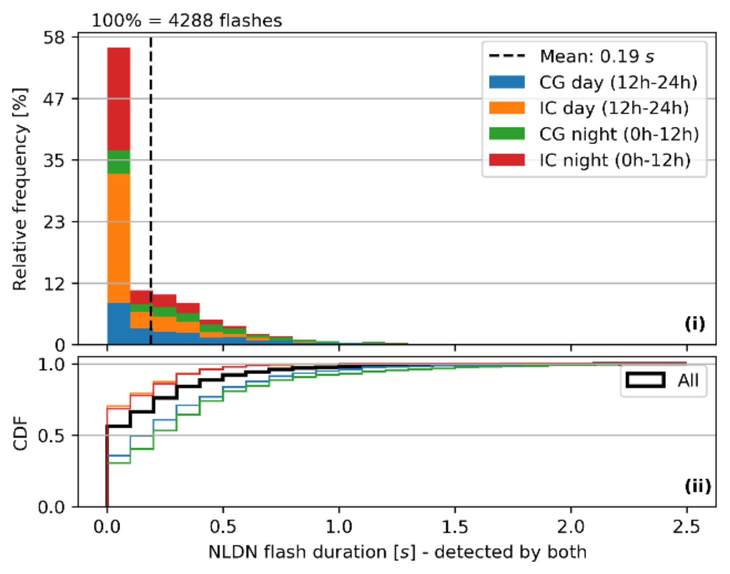
II. ISS-LIS versus Meteorage and NLDN – Example LF flash duration

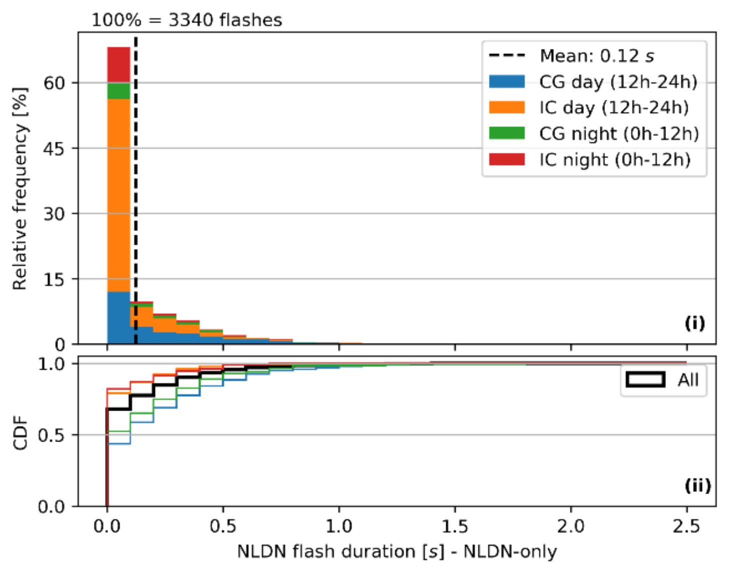
LIS-Meteorage





LIS-NLDN





NLDN flashes **NOT** shorter in time than Météorage flashes
→ Merging criteria seem to be fine

III. GEO lightning pseudo observation generator development data