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DE CATALUNYA
BARCELONATECH

Final meeting: Evaluation of ISS-LIS against LMA

EUM/CO/18/4600002153/BV

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June 28th 2019

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Outline

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Introduction

- The EUMETSAT Lightning Imager will be the first global lightning detector in space monitoring Europe and Africa
- Its performance can be evaluated using ground-based detection systems

- Intracloud lightning will be detected much more efficiently
- The only type of detection network capable of intracloud lightning is the Lightning Mapping Array (LMA)

- This study compares the performance of the space-based optical detector ISS-LIS to a ground-based electromagnetic detector, the Ebro LMA in eastern Spain
- Naturally, the two ways of detection are not exactly equal

- We lay out a methodology for evaluation of the performance of future LI

- We provide statistical characteristics of LMA flashes and the occurrence of LIS detections with which a simulation of lightning and optical detections can be built.

Objectives

The tasks of the study shall answer the following questions:

1. How can LMA data be employed to validate and, if needed, correct/complement the information on lightning events, groups, and flashes provided by ISS–LIS?

1. How can LMA data and ISS-LIS data be used to define a new and refined statistical description of lightning pulses, groups, and flashes?

1. What are the performances of ISS-LIS evaluated against LMA measurements?

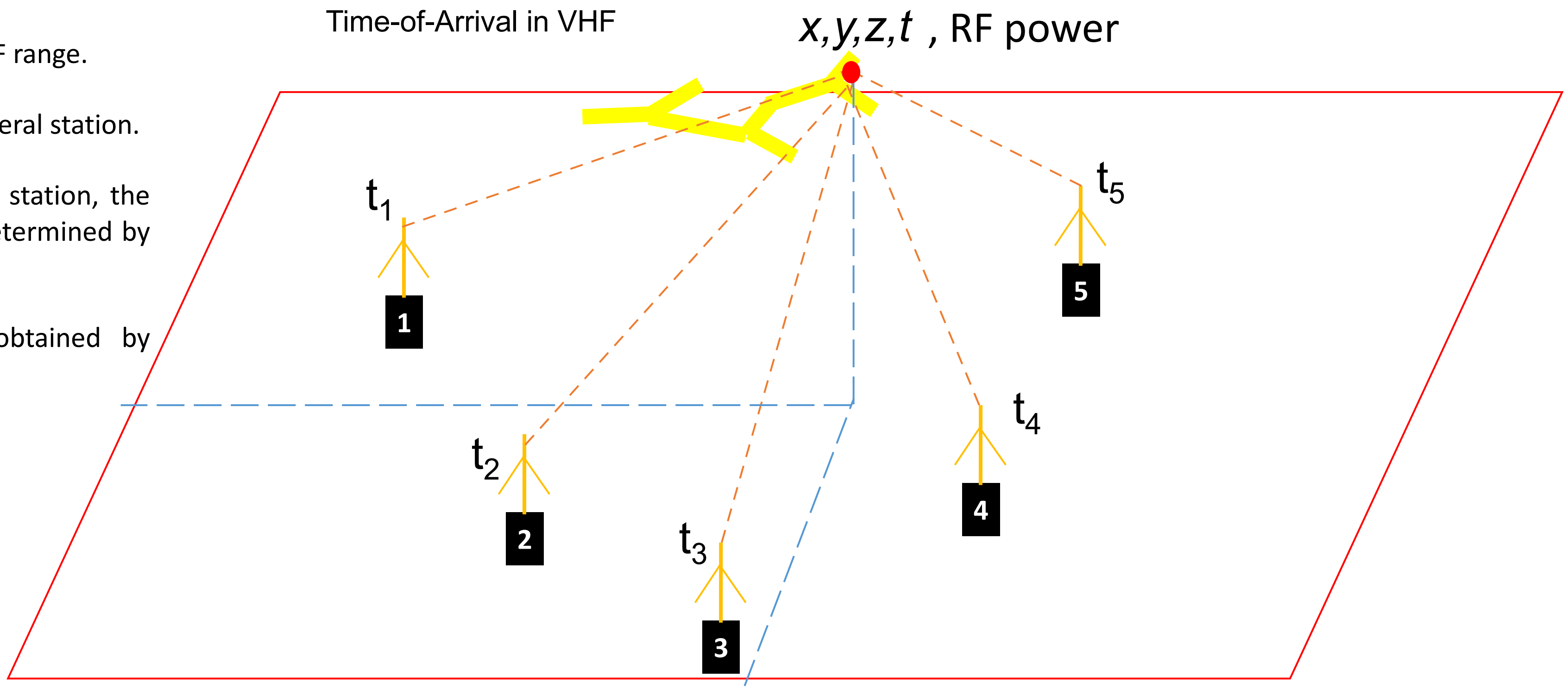
1. How can LMA data and ISS-LIS data be used to define test cases for the EUMETSAT MTG LI end - to - end processor?

1. From the lesson learned by comparing ISS-LIS data against LMA data: how can LMA data be employed in the validation of MTG LI during commissioning and in routine monitoring?

1. Technical description of the LMA

1.2 LMA

- Lightning leaders produce broadband emissions in the VHF range.
- These radio frequency (RF) emissions are measured at several station.
- Knowing the time when the emission is received at the station, the location (X,Y,Z) and t of what is called a **source** can be determined by combining several stations.
- **Source:** a location of a lightning leader emission obtained by combining the detections at individual stations.

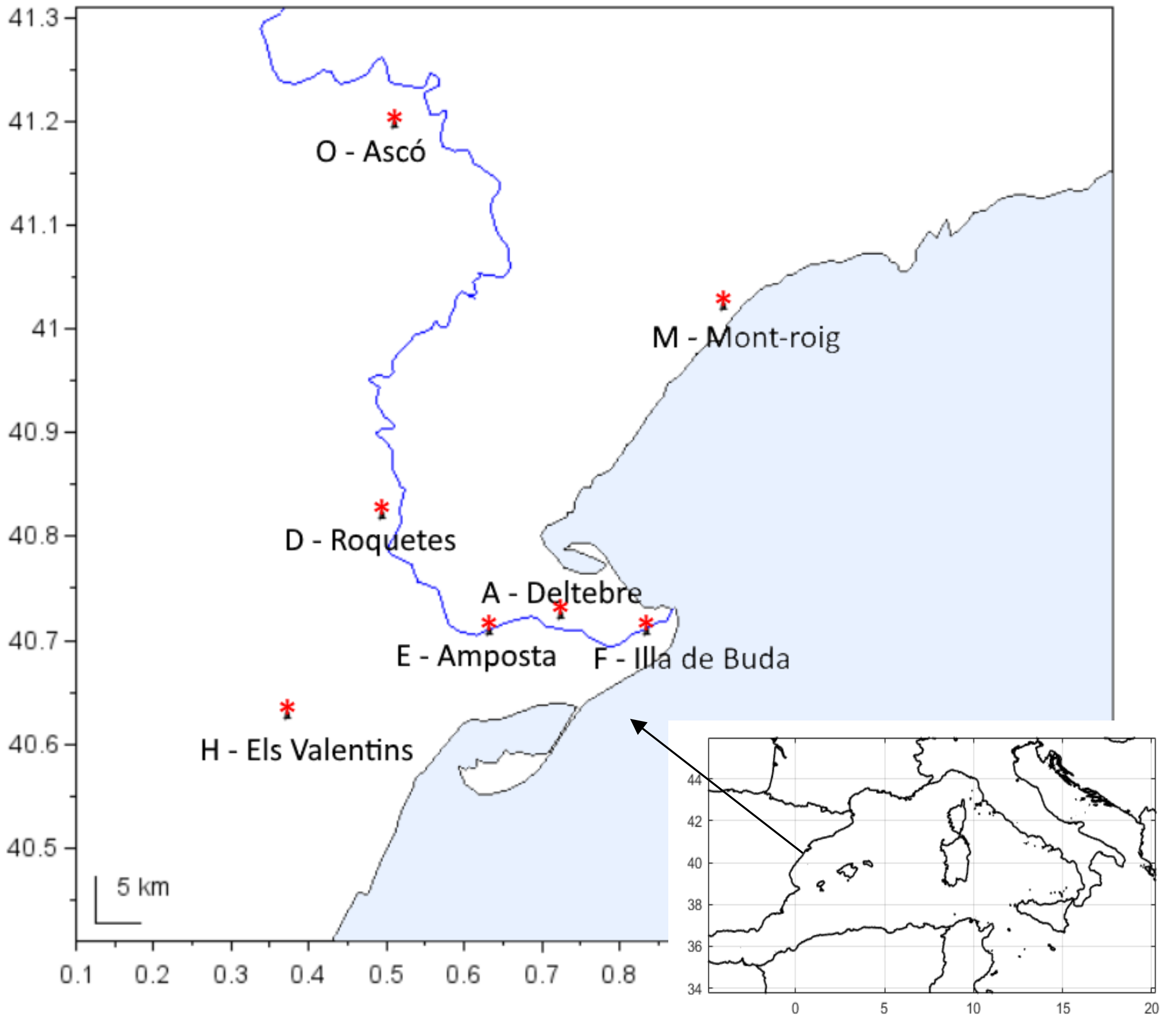


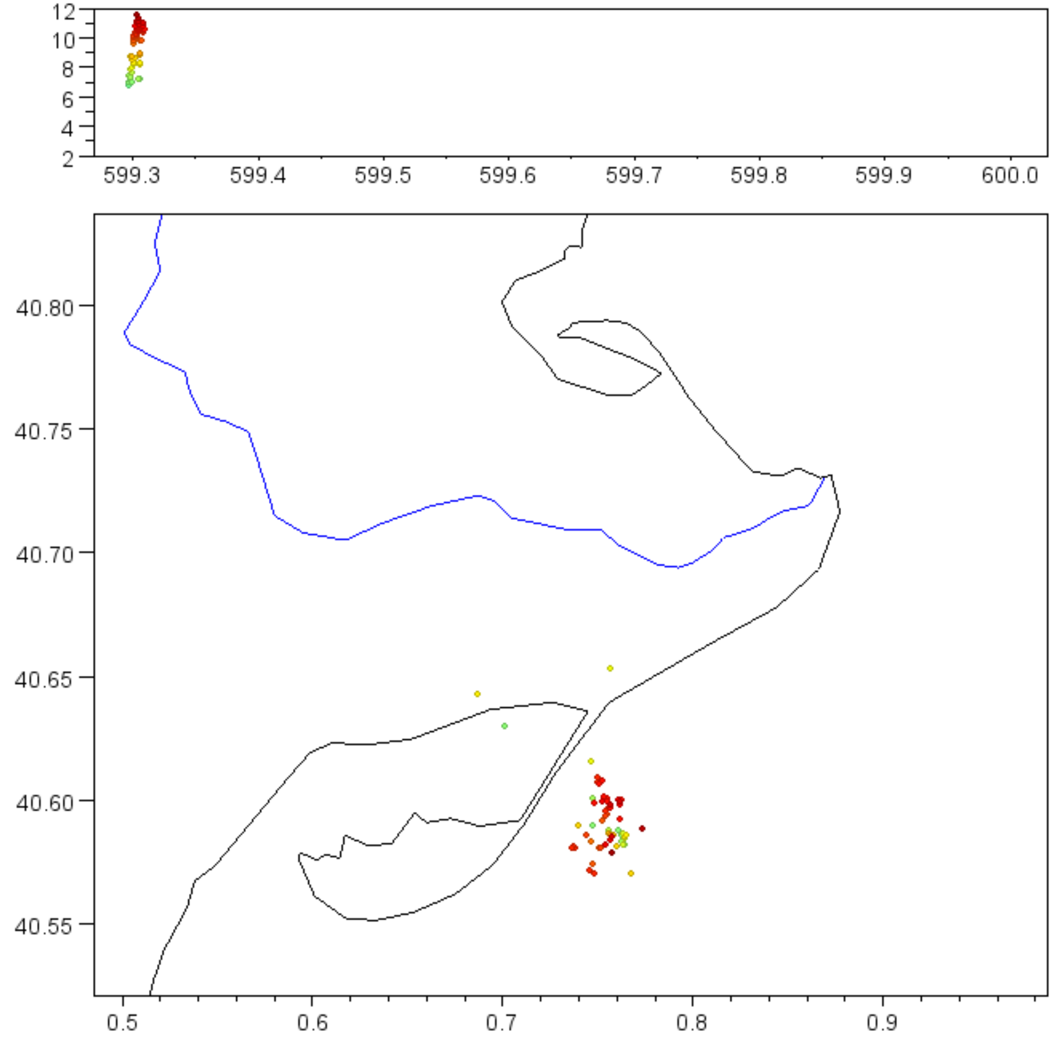
Proctor 1971, 1981, 1991
Proctor et al. 1988
Lennon and Maier 1991

$$t_i = t + \frac{\sqrt{(x-x_i)^2 + (y-y_i)^2 + (z-z_i)^2}}{c}$$

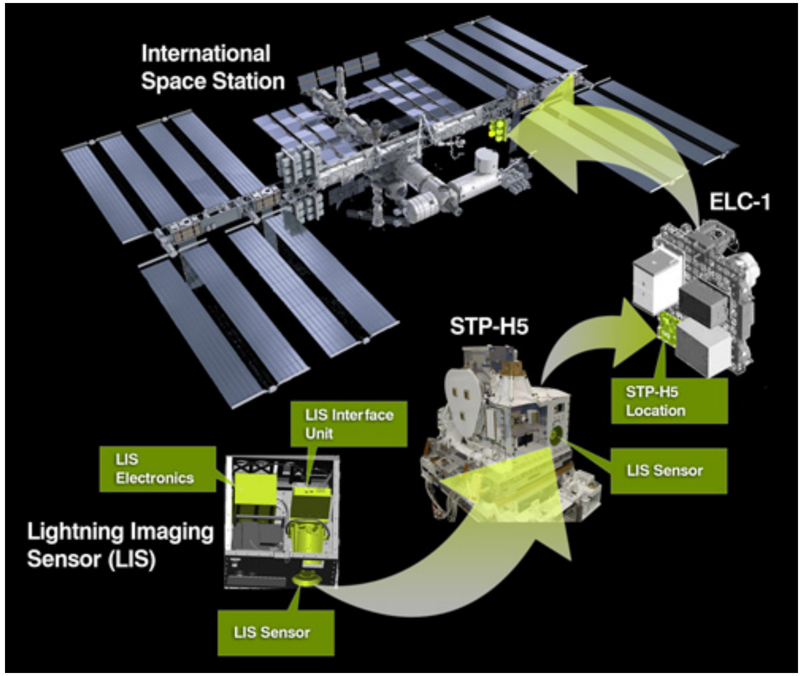
Technical description of the LMA

Ebro-LMA (ELMA) 2017-2018





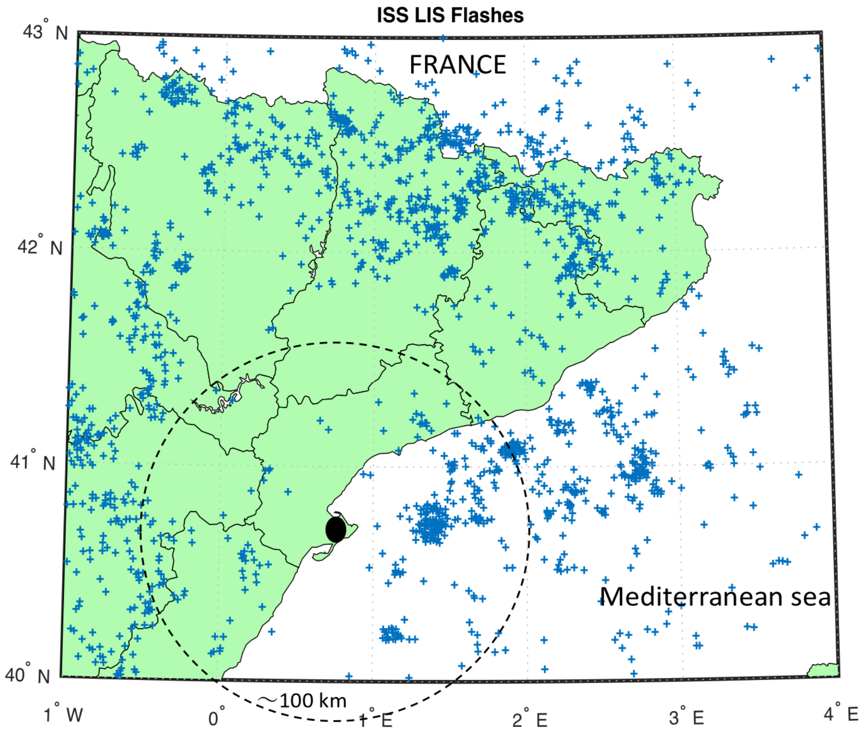
Technical description of the ISS-LIS



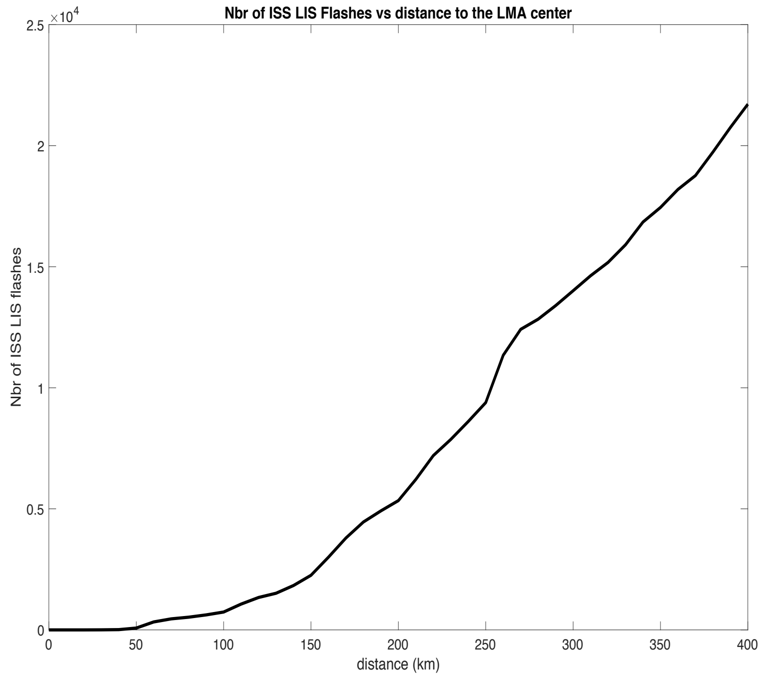
Field-of-View (FOV):	80°x80°
CCD Array Size:	128 x 180 pixels
Dynamic Range:	>100
Pixel IFOV :	4 km (nadir) to 8 km
Interference Filter wavelength:	777.4 nm
Filter bandwidth:	1 nm
Detection threshold:	4.7 µJ m^{-2} sr^{-1}
Signal to noise ratio:	6
Detection Efficiency (DE)	~90 %
False Event Rate (FER)	<5 %
Measurement accuracy	
Location:	1 pixel
Intensity:	10 %
Time:	tag at frame rate
Frame rate (integration time):	2 ms

Source: hhrc.nsstc.nasa.gov

ISS-LIS flashes
(March 2017 – October 2018)

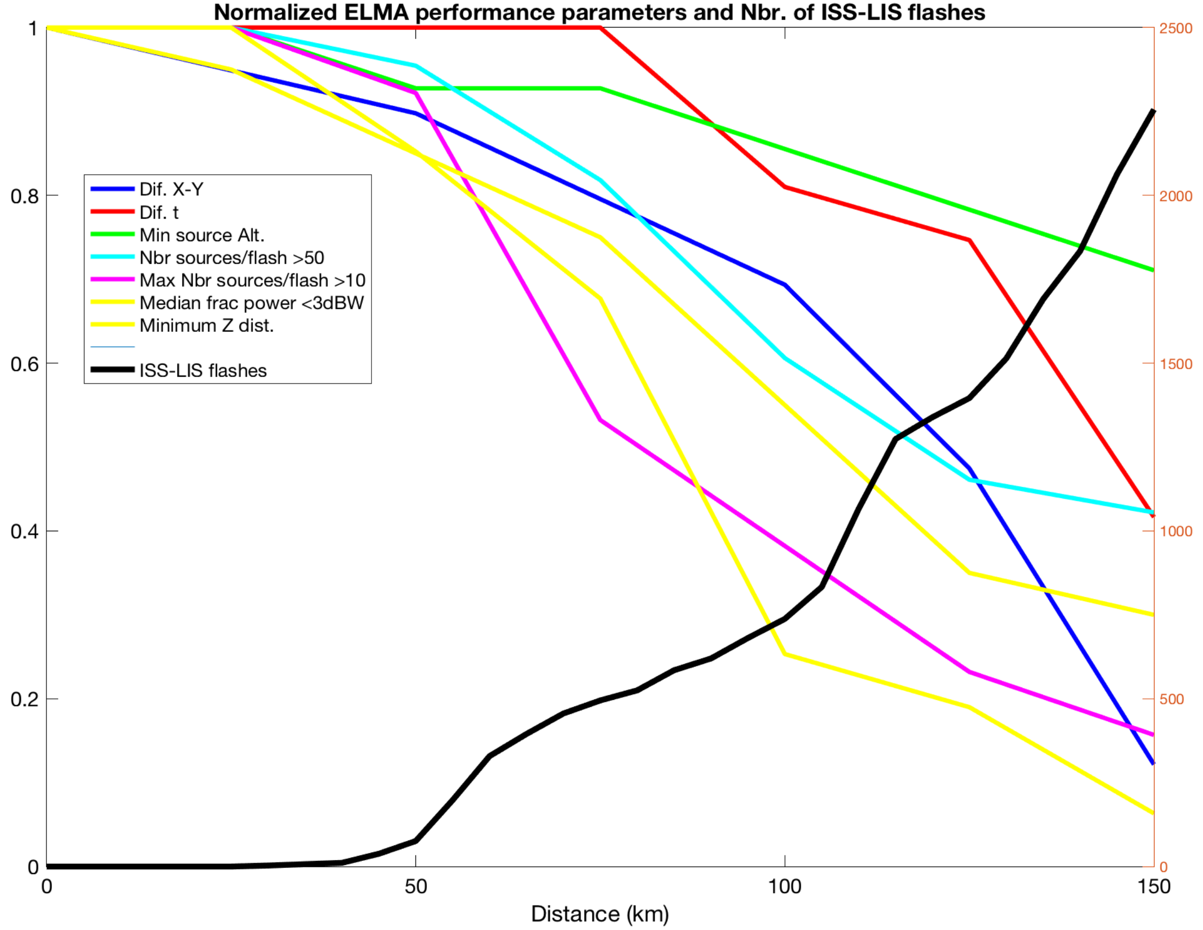


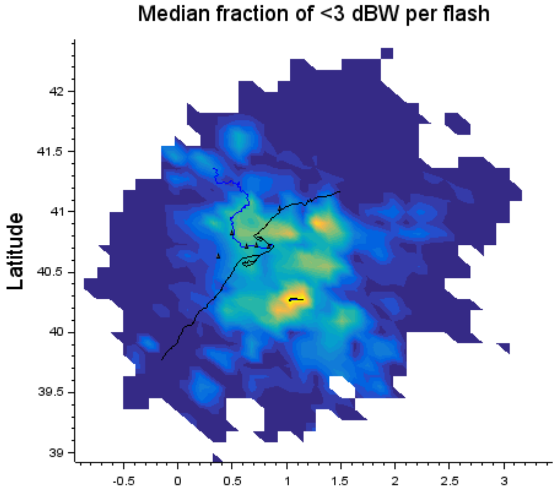
Number ISS-LIS flashes to the ELMA center
(March 2017 – October 2018)



Distance to the center of the ELMA	Number of ISS-LIS flashes
25 km	0
50 km	76
75 km	495
100 km	738
125 km	1396
150 km	2256

LMA Performance

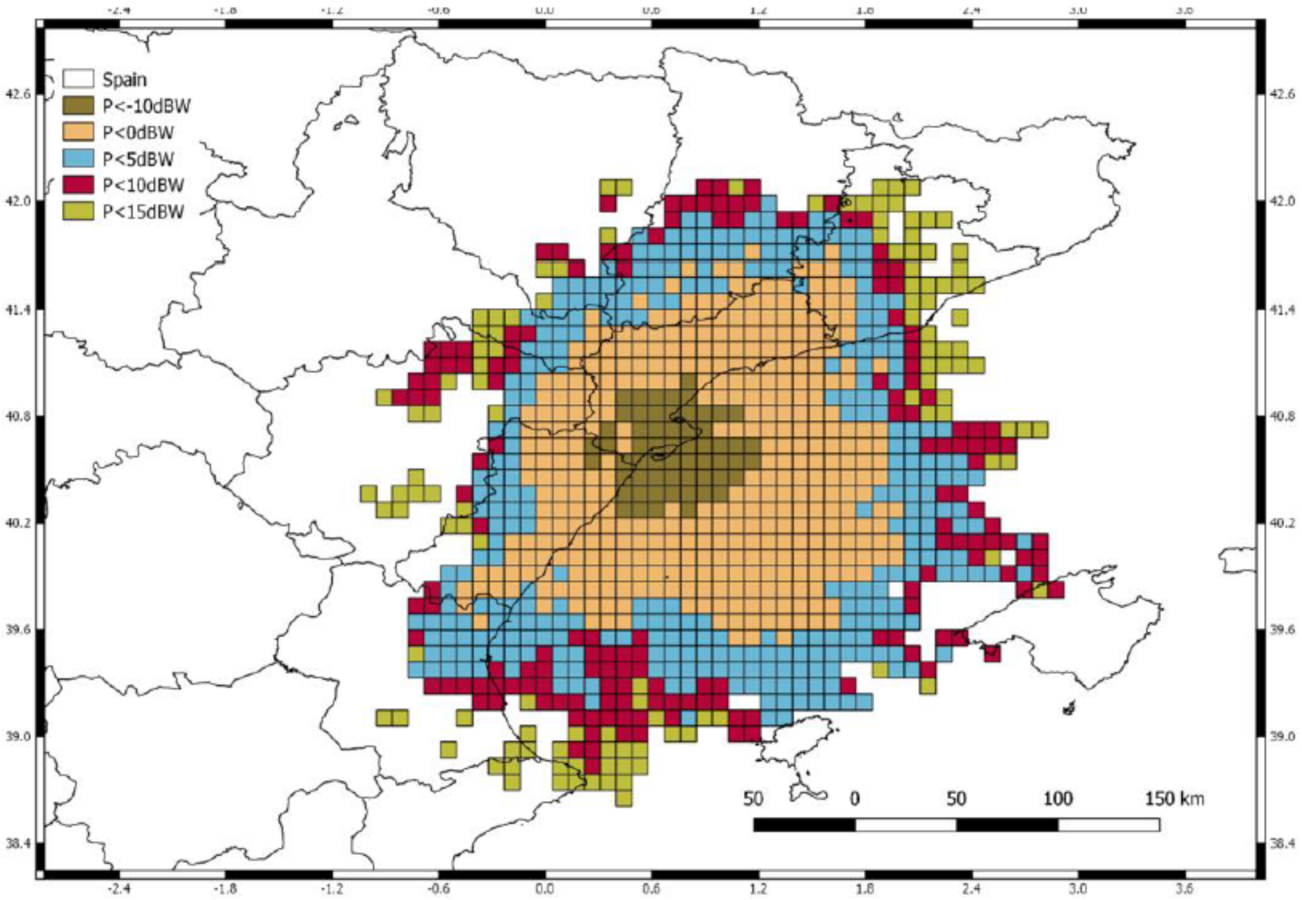




Parameter	Value at the ELMA center	Maximum value
X-Y Distance between consecutive sources	0.26 km	3 km
Median Z distance between consecutive sources	0.167 km	3.5 km
Minimum Z altitude of LMA sources	0.120 km	6.4 km
Time difference between consecutive sources	0.001 ms	3 ms
Number of sources per flash	220	228
Maximum number of sources per flash	1484	2067
Median fraction of number of sources with power < 3dBW	0.23	0.51

LMA Performance

Area where low-power sources can be detected

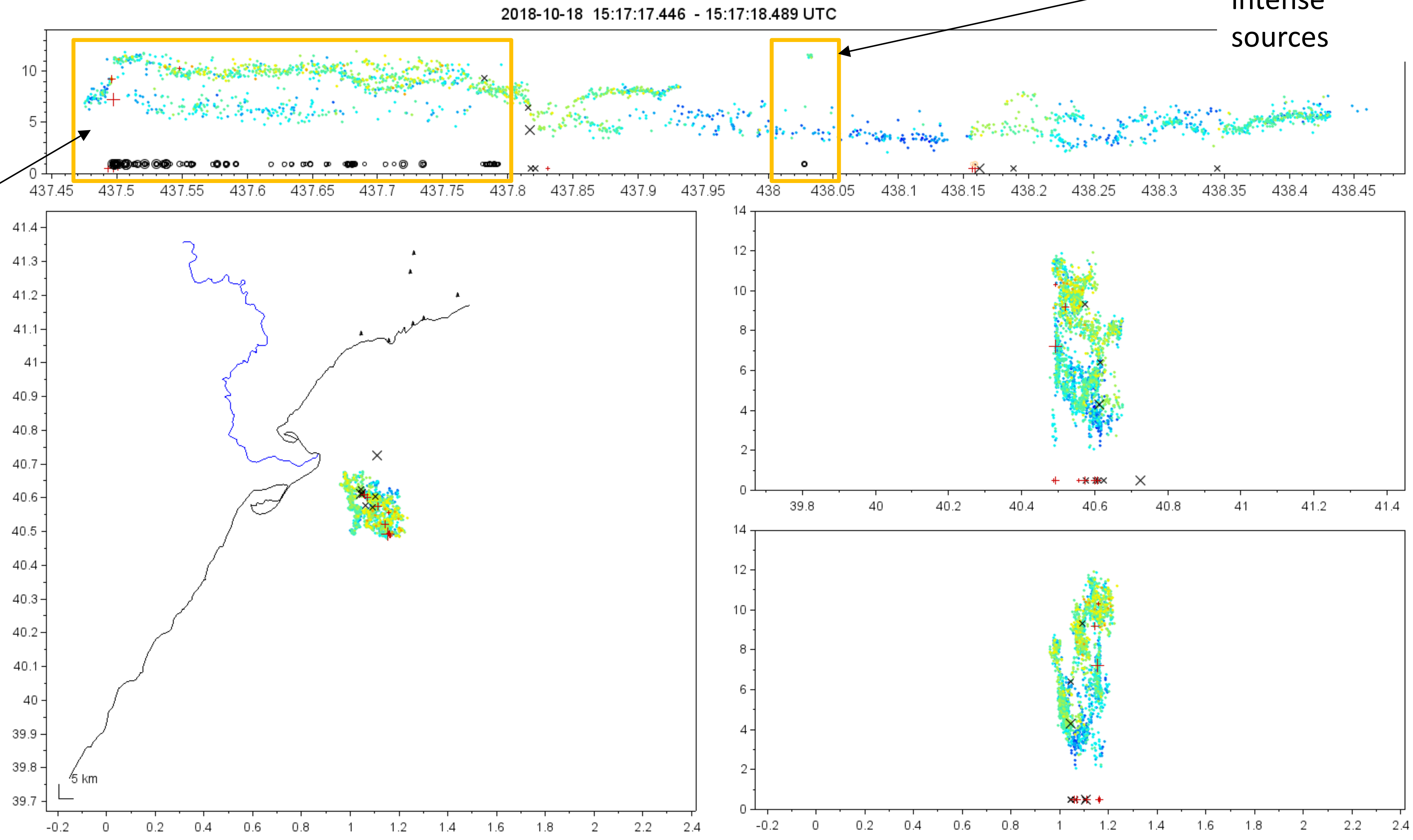


Evaluation of ISS-LIS performance

Example

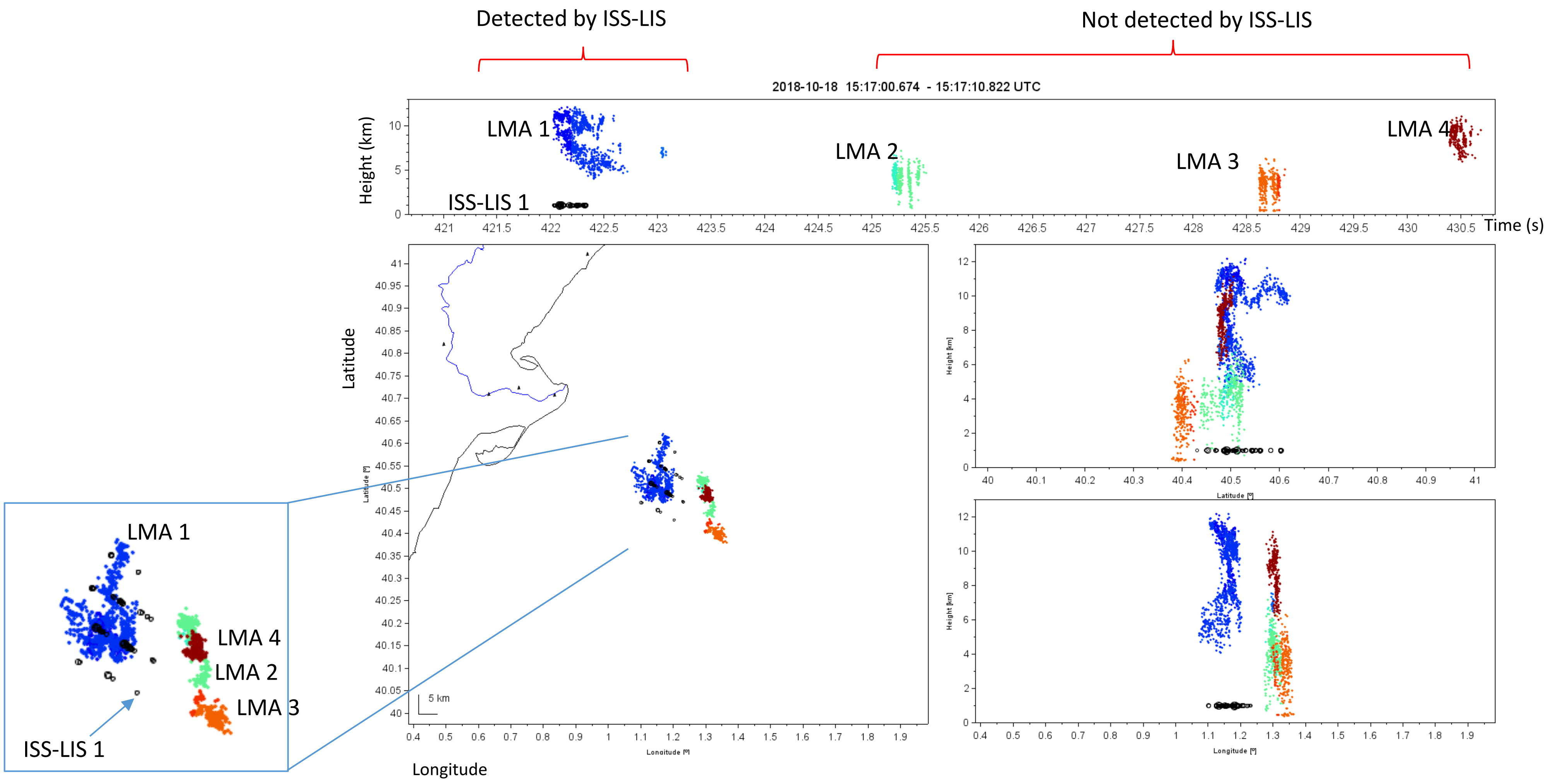
LIS events = isolated intense sources

LIS events = intense sources



Detection Efficiency

An ISS-LIS flash is detected if it matches in time with an LMA flash in the FOV of ISS-LIS.

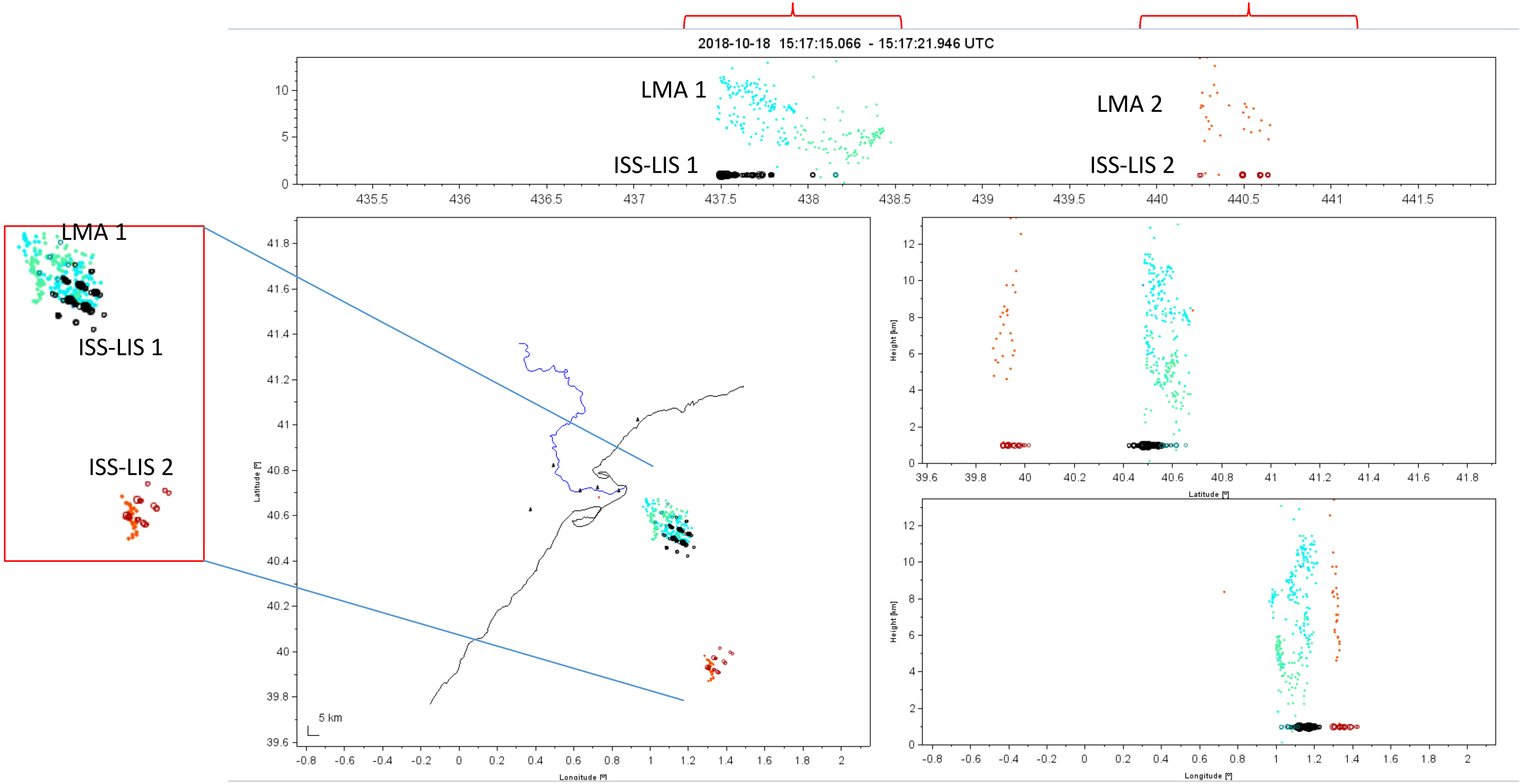


IMPORTANT:
In this case all the LMA flashes are identified as good quality flashes (not noise). So these flashes have an ID.

Detection Efficiency

Reported by ISS-LIS and LMA (good quality)

Reported by ISS-LIS and LMA (low quality, e.g. it is far)



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Detection Efficiency

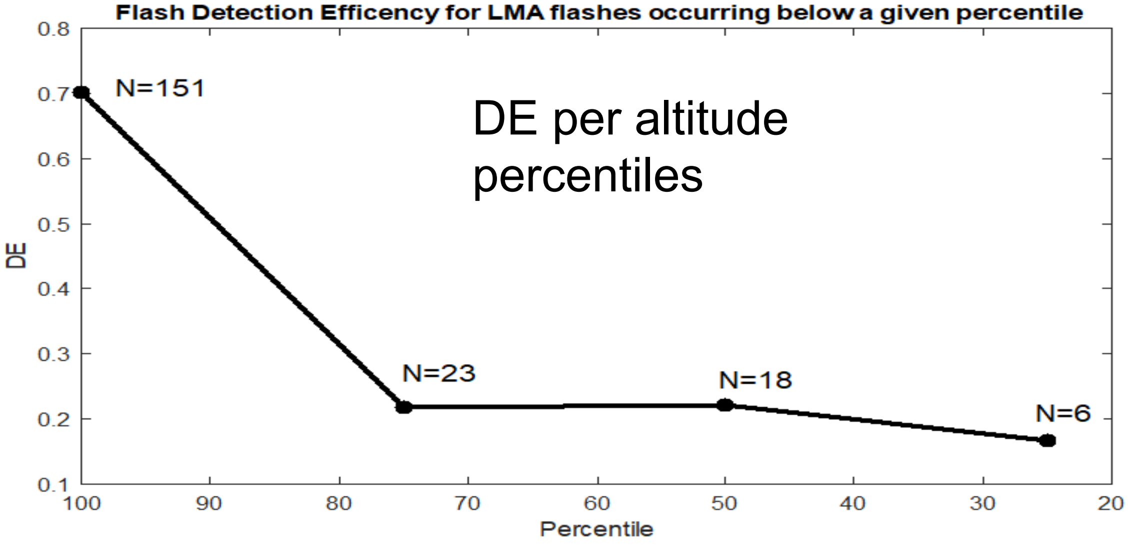
Results

Episodes with high quality LMA data: distance < 150 km NO minimum number of sources per LMA flash						
Date	**Number of flashes**	**Average flash rate [min^{-1}]**	**Average LMA source rate [s^{-1}]**	**Number of flashes detected by ISS-LIS**	**Detection Efficiency DE_f**	**Comments**
20171018-1 ~10:30 UTC	24	16.0	43.2	13	0.54	
20171018-2 ~17:00 UTC	10	5.8	50.3	4	0.40	The flashes occurred in the edge of the CCD.
20180809 ~19:00 UTC	20	12.2	30.7	18	0.90	
20180831 ~04:40 UTC	28	15.7	4.5	24	0.85	Flashes occur far from the network
20180917 ~21:10 UTC	42	21.61	36.3	18	0.43	
20180918 ~03:30 UTC	73	41.3	303.4	60	0.82	Extremely active episode Night time. Average flash rates are not realistic since many flashes cannot be separated
20181014 ~17:00 UTC	43	24.9	225.3	32	0.74	Moderate activity
20181018 ~15:15 UTC	32	18.7	214.3	16	0.50	Moderate flash rate but quite active in terms of LMA sources
Total number of LMA flashes: 272						
Total number of flashes detected by LIS: 185						
DE_f = 0.68						

We analyzed DE for several different ranges and LMA flash criteria

Average DE = 68% to 76%

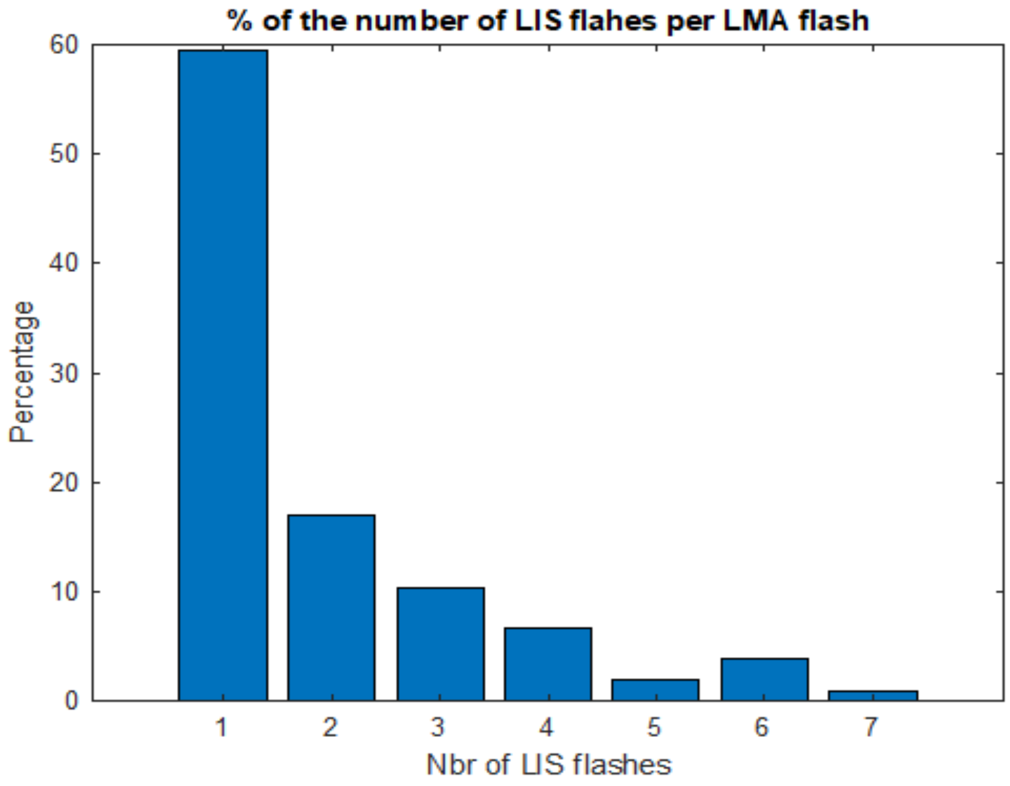
Varies from 40% to 90%



DE per altitude percentiles

Detection Efficiency

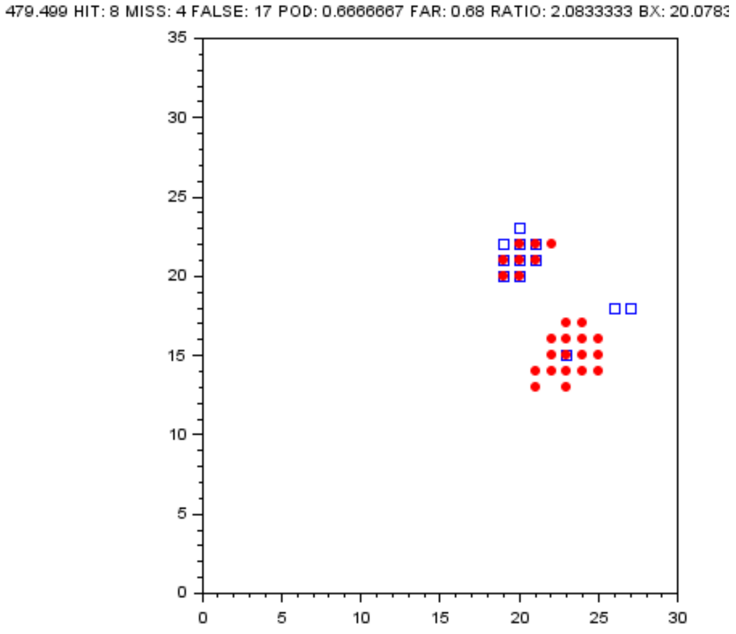
Number of ISS-LIS flashes and events for detected LMA flashes

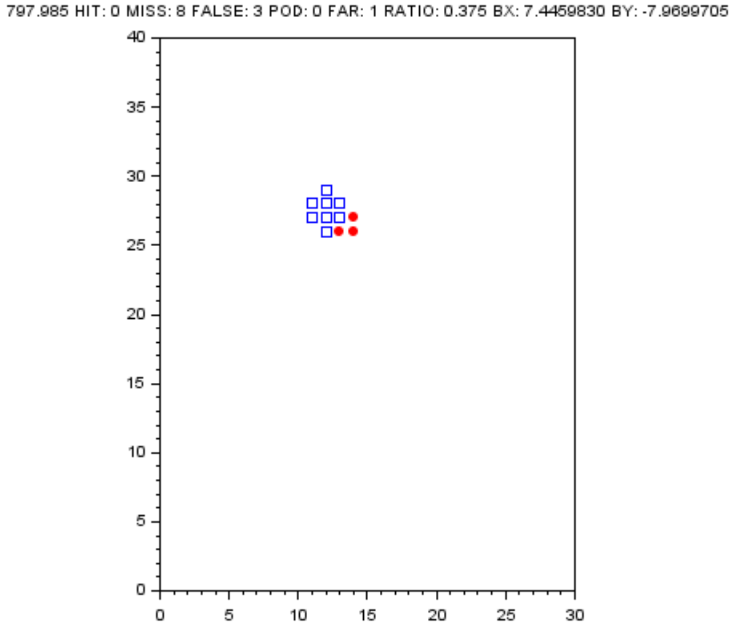


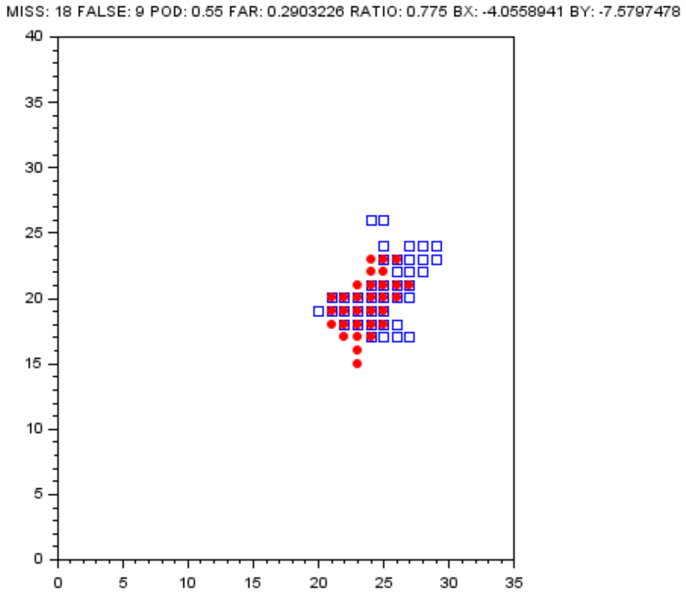
About 60 % of the LMA flashes have one ISS-LIS flash.
About 20 % of the LMA flashes → ISS-LIS assigned two flashes

Location Accuracy

1. Offset in flash position
2. Overlap and size







Blue squares = LMA
Red circles = ISS-LIS

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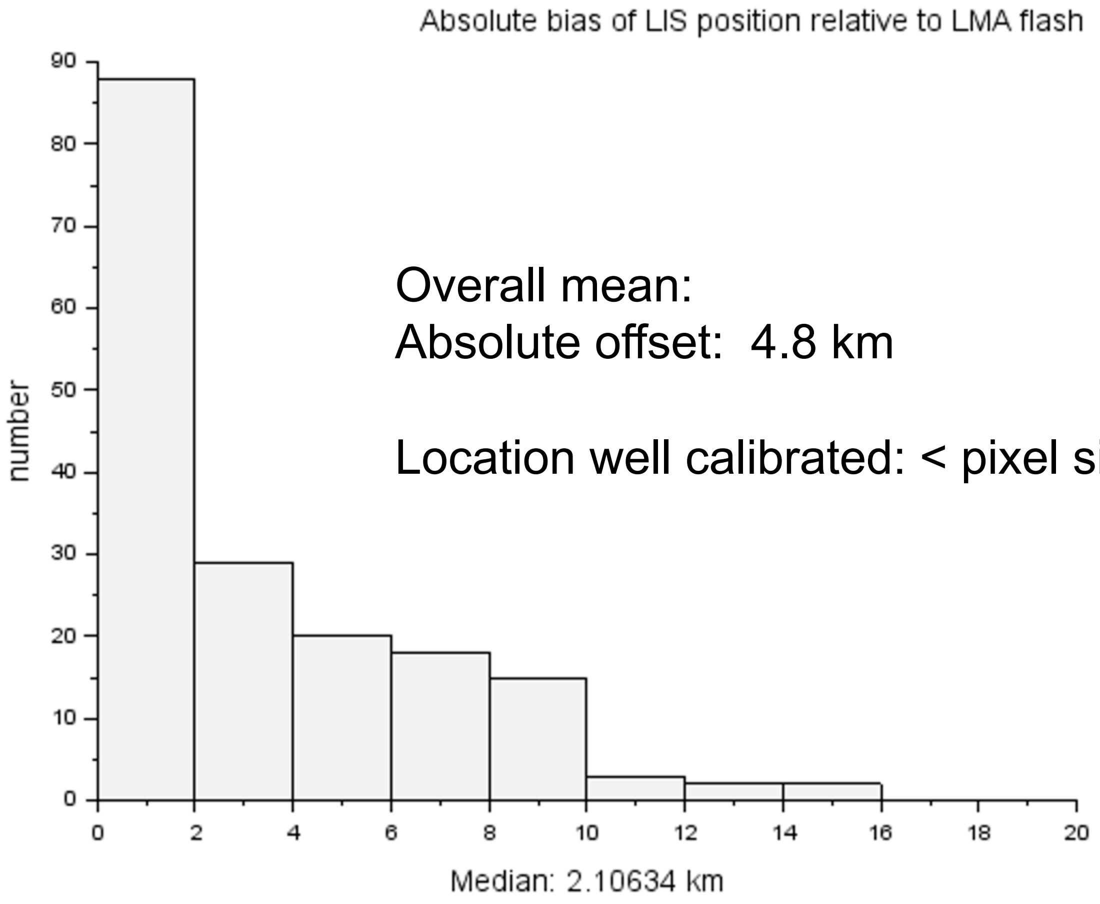
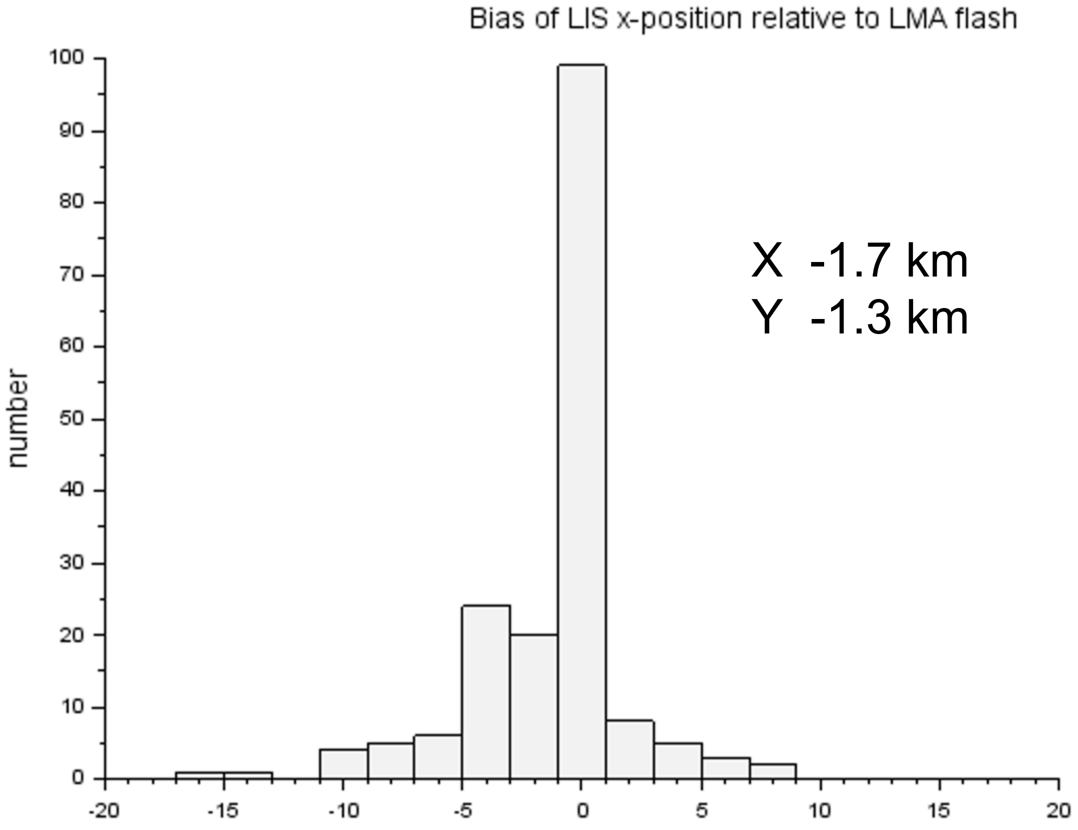
Location Accuracy

Absolute offset between LMA flash center and LIS events
X and Y bias in location



Overall mean:
Absolute offset: 4.8 km

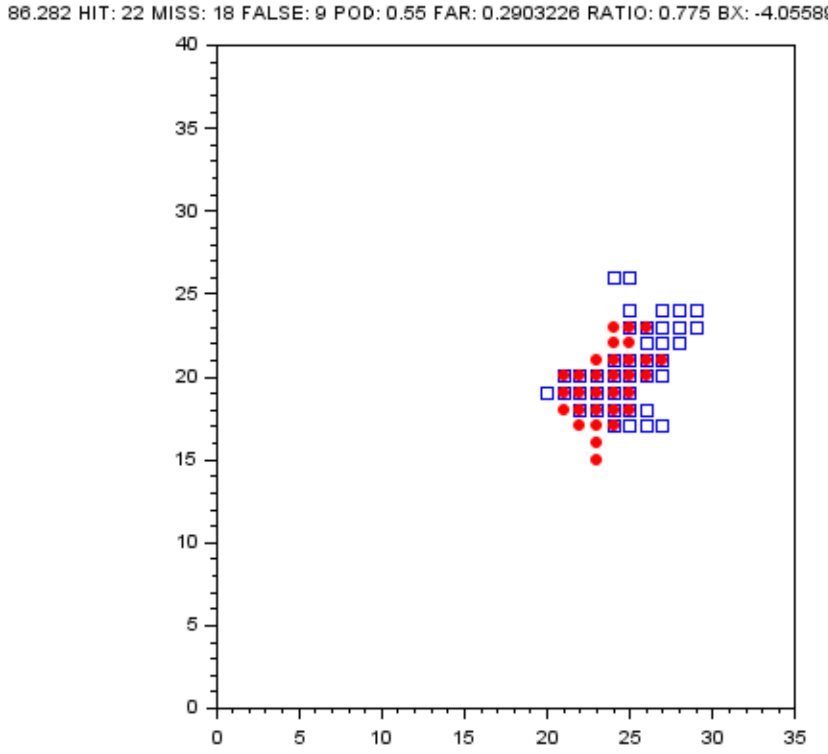
Location well calibrated: < pixel size



X -1.7 km
Y -1.3 km

Location Accuracy

Spatial overlap:
Percentage of LMA flash area detected by ISS-LIS
Percentage of LIS area not matched by LMA underneath



In this example: 55% of LMA detected by LIS
29% of LIS not matched

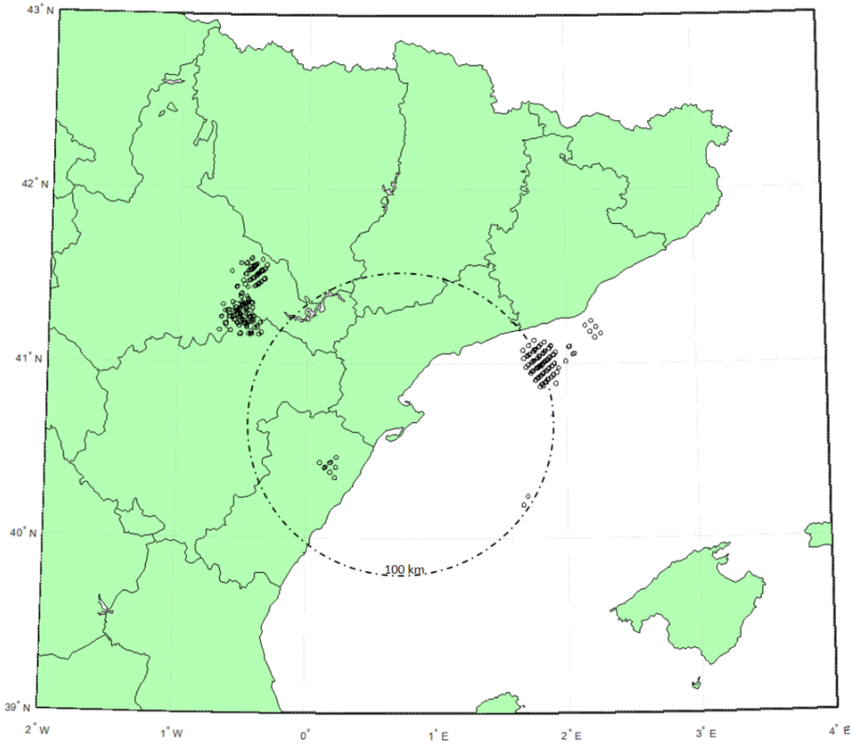
Overall average: 47% of LMA detected by LIS

LMA flashes are on average 200 km^2
corresponding LIS events 207 km^2

Flash “False Alarm”

Candidates not detected by the LMA → candidates to False Alarms

Candidates to ‘false alarm’



The situations where ISS-LIS report a flash and it is not detected by LMA will be called as a candidate for flash ‘False Alarm’ or Flash FAR. These cases need special treatment for definitive confirmation:

- Verification that these cases do not occur in **areas of reduced detection efficiency by the LMA**.
- Verification that these cases might be related to an existing flash but not reported by the LMA due to some **technical issues, e.g.: not enough sensors to compute solutions, high noise at some of the stations**, etc. In that case, raw data of single stations can be inspected to confirm the existence of a flash.
- Additional data can be used: VLF/LF LLS data, satellite and radar to confirm the presence of a storm cell at the location of the false flash.

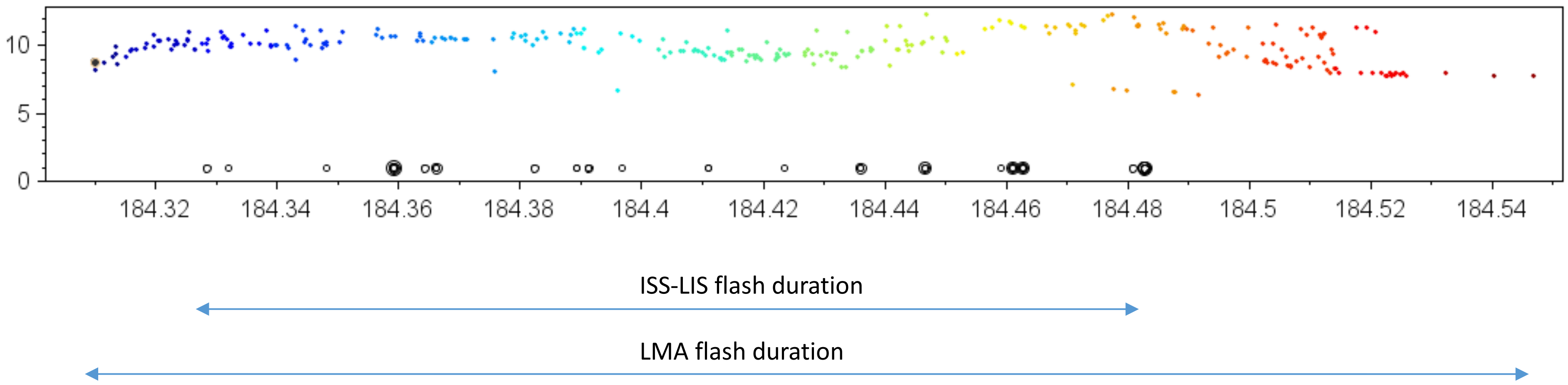
- In this analysis all candidates were due to the distance and/or locations where the LMA has poor DE.
- All cases except one where identified with LMA flashes with low quality due to distance and location.
- **Only one case was not reported by the LMA but it was due to the low number of LMA sensors available that day and unfavorable location**

Flash duration

Flash duration is calculated as:

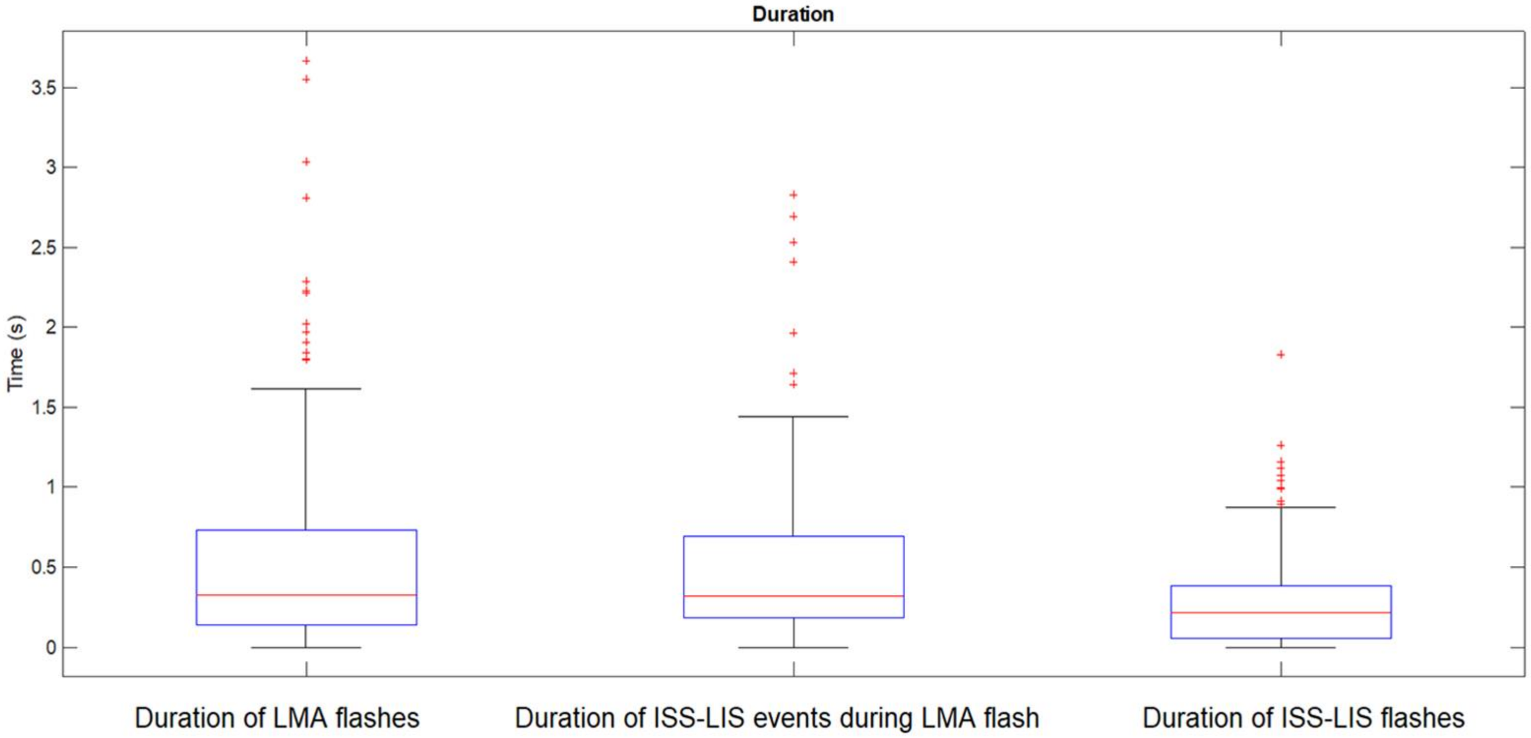
- LMA: time difference between the first and the last source (noise sources are ignored).
- ISS-LIS: time difference between the first and the last event in a LMA flash.

2017-10-18 10:33:04.302 - 10:33:04.552 UTC



Duration (s)	ISS-LIS	LMA
average	0.691	0.860
min	0.107	0.167
max	2.405	2.272

Flash duration



ISS-LIS flash duration is about 70% of the LMA flash duration.

But considering the duration of all the ISS-LIS events during a LMA flash its median is similar to the LMA flash duration.

Median: 0.325 s

Median: 0.319 s

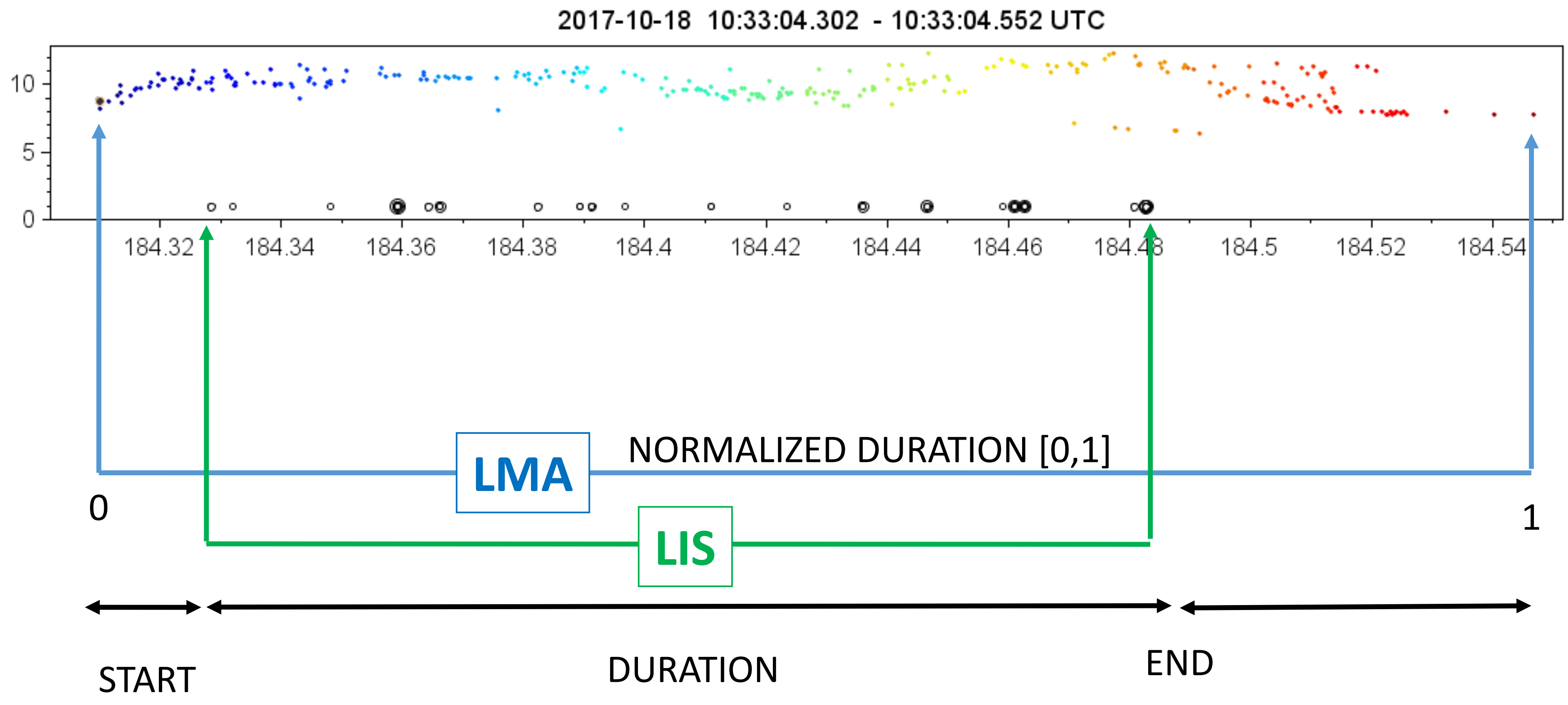
Several ISS-LIS flashes can belong to the same LMA flash

Median: 0.215 s

ISS-LIS flashes according to the ISS-LIS grouping

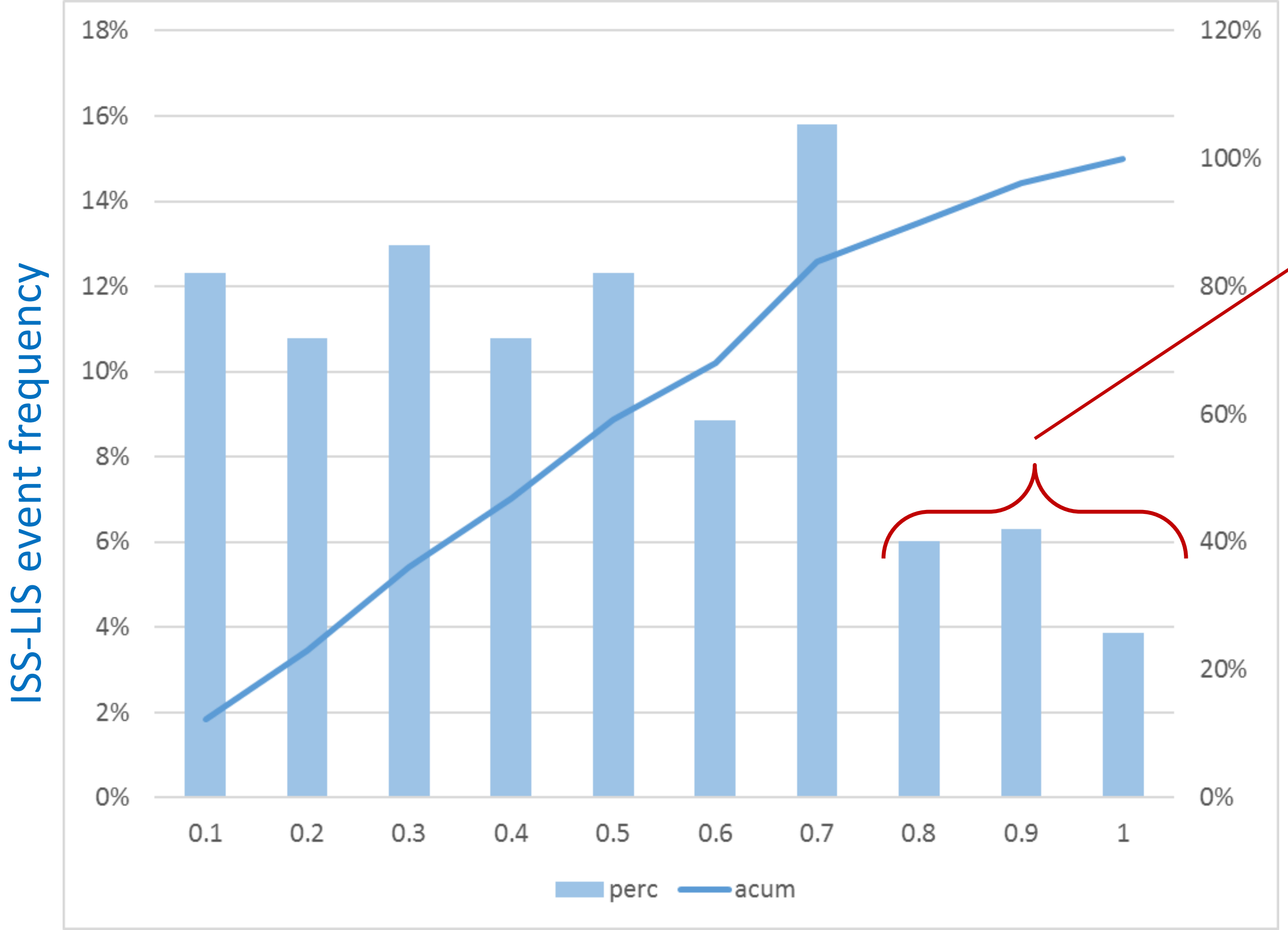
Flash duration

Flash-by-flash duration analysis



Flash duration

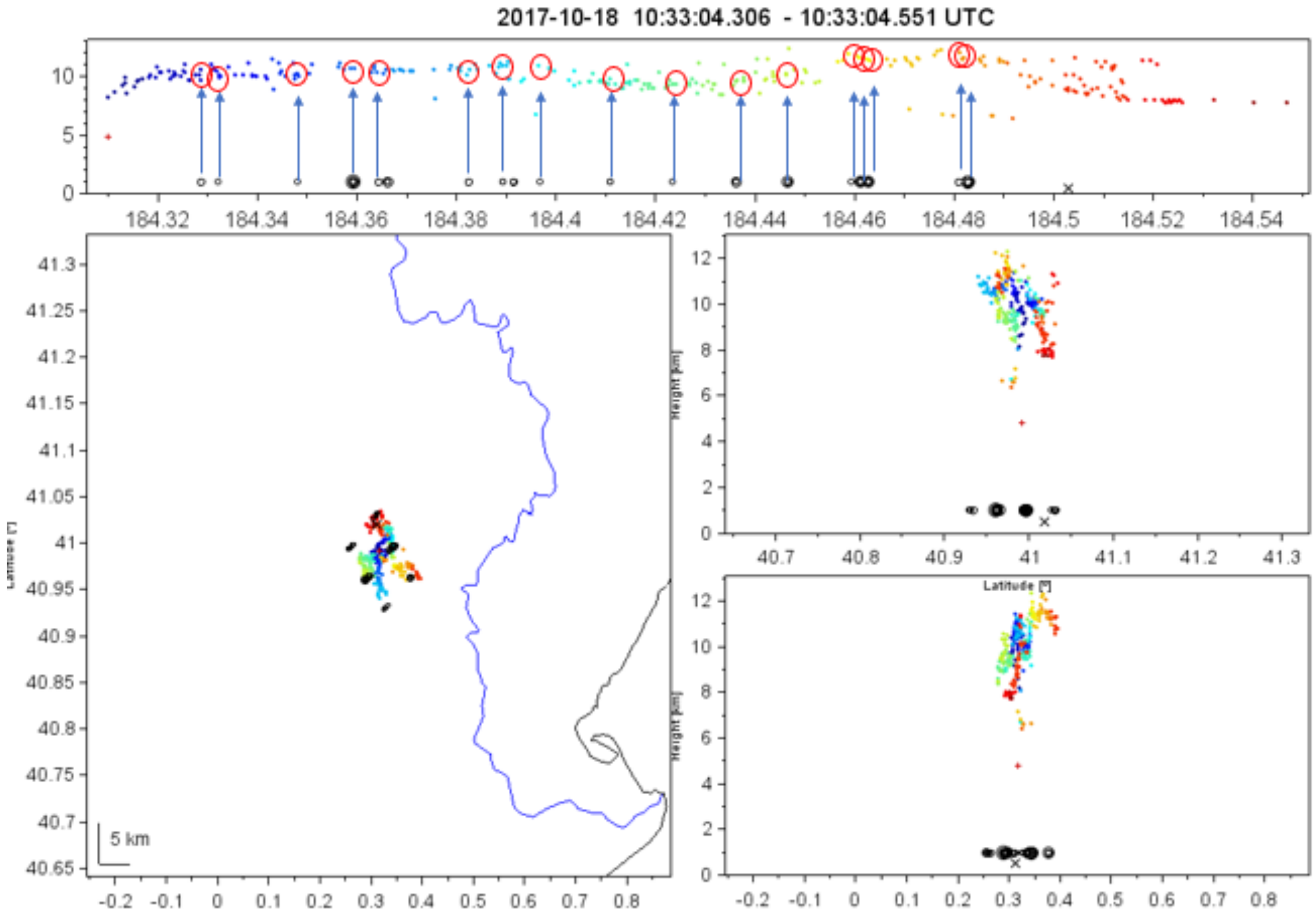
Flash-by-flash duration analysis



ISS-LIS events detected on the last quarter of the flash duration are significantly lower

The normalized LMA flash duration is divided into ten segments

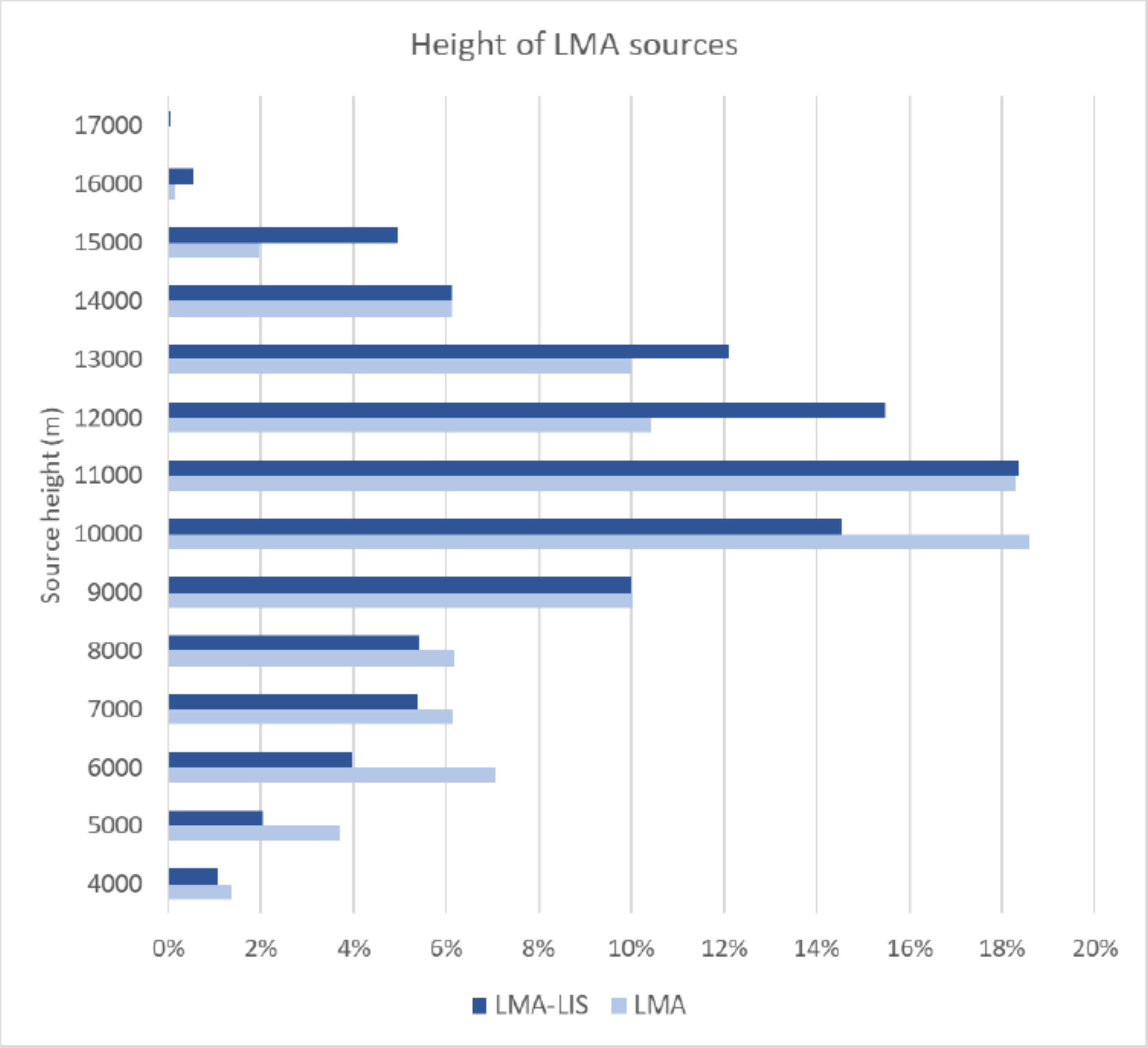
Distribution of Events with height, power and radiance



In this case, events and LMA sources are grouped with a time-distance criteria:

- time difference <10 ms*
- distance <10 km

Distribution of Events with height, power and radiance



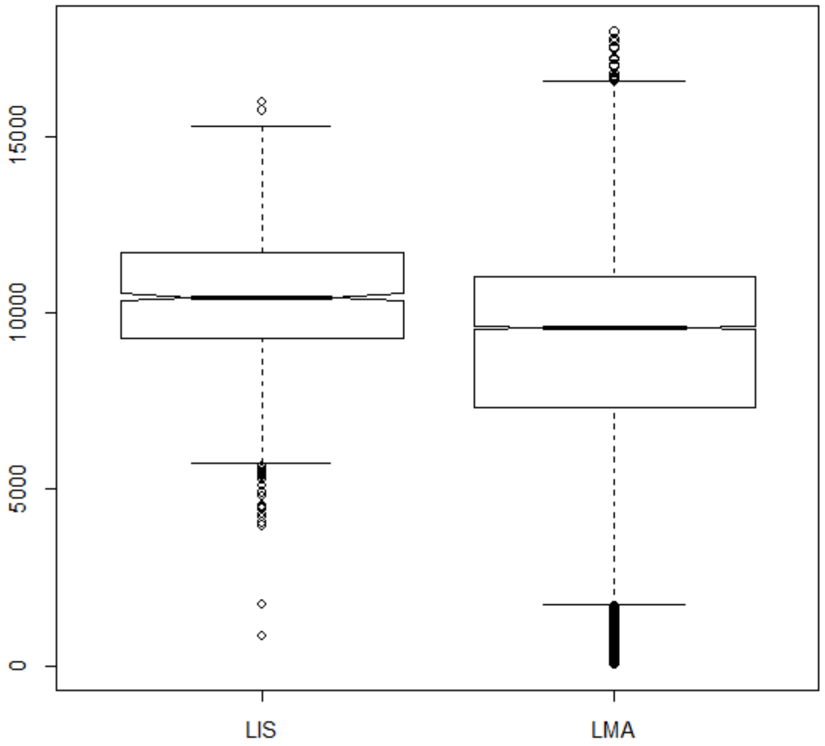
discharges which extend into the upper part of the cloud are better detected by ISS-LIS

11 km

Distribution of Events with height, power and radiance

Results

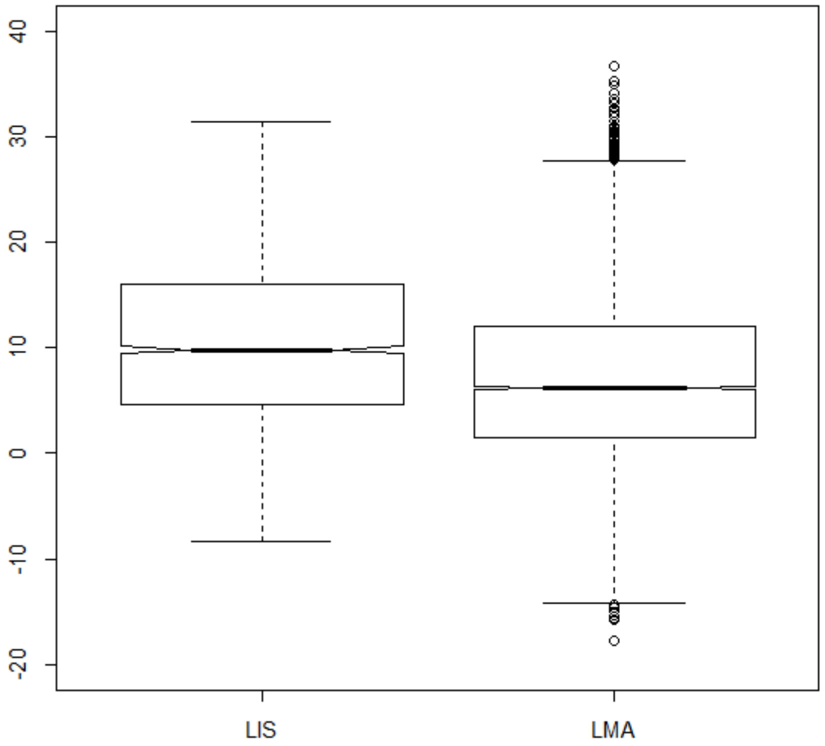
Height (m)



ISS-LIS events matched with LMA sources

LMA source population

Power (dBW)



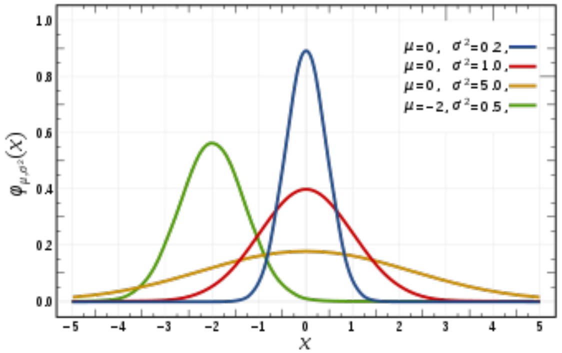
ISS-LIS events matched with LMA sources

LMA source population

Lightning model for test cases

Lightning model for test cases

Statistics based on the LMA data we provide statistics to simulate lightning properties:



source:wikipedia

source:www.ugr.es

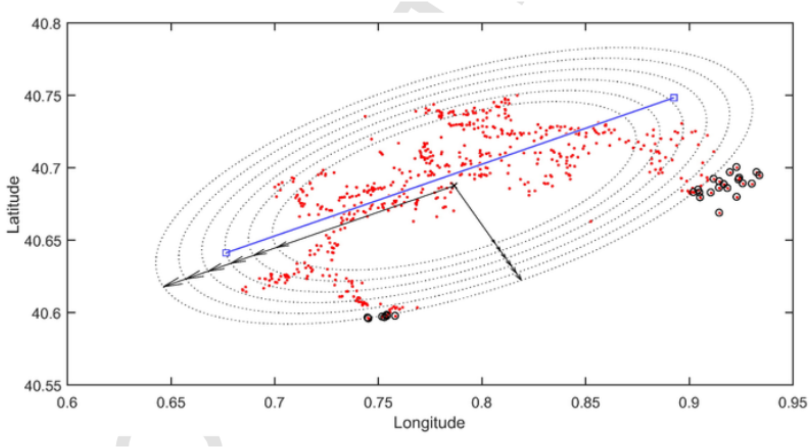
Source: O. van der Velde, UPC

Lightning model for test cases

Statistics based from LMA perspective:

Duration
Summer: Median: 0.35 s Stdev: 0.31 s Winter: Median: 0.41 s Stdev: 0.25 s Maximum 2.39 s Distribution is log-normal Source: López et al. (2016) based on the LMA in Spain.

Size
Summer: Median: 10.3 km Stdev: 13.9 km Maximum 143 km Ellipse eccentricity minor/major axes Median: 0.75 Stdev: 0.154 Winter: Median: 15.6 km Stdev: 10.9 km Maximum 70 km Ellipse eccentricity minor/major axes Median: 0.75 Stdev: 0.147 Distribution is log-normal. Source: López et al. (2016) based on the LMA in Spain.



Lightning model for test cases

Statistics based from LMA perspective:

Inter-flash time

Summer:

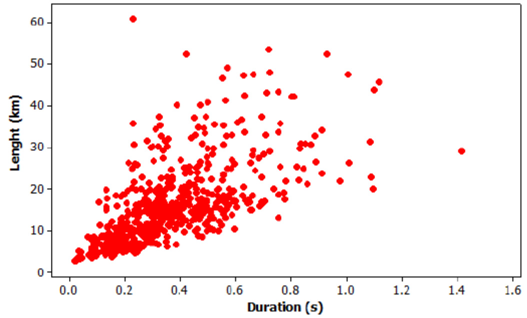
Median: 2.691 s
Stdev: 14.51 s
Min: 0.315 s (this can be as low as few tens of ms for some particular storms)
Max: 150 s (the analysis was time limited up to 150 s)
Nbr. of samples: 17526

Winter:

Median: 24.75 s
Stdev: 29.692 s
Min: 0.55 s
Max: 150 s (the analysis was time limited up to 150 s)
Nbr. of samples: 299

Distribution is log-normal.

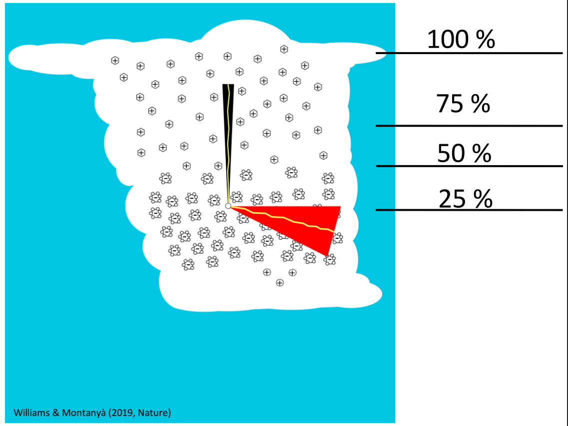
Size vs. duration

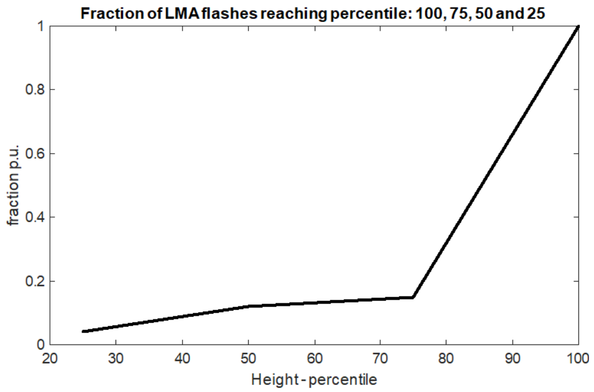


Montanyà et al. (2014) ICLP conference.

Storms with high lightning flash rates tend to produce smaller flashes than storms with lower flash rates (Bruning and MacGorman, 2013).

Maximum height



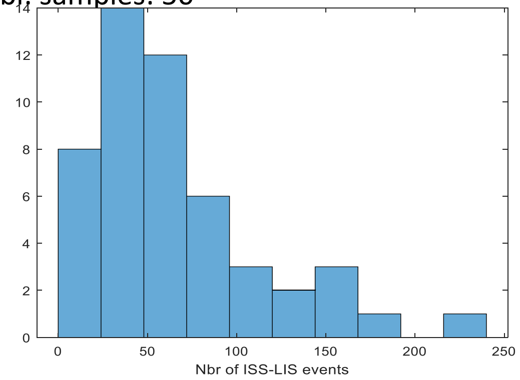


Lightning model for test cases

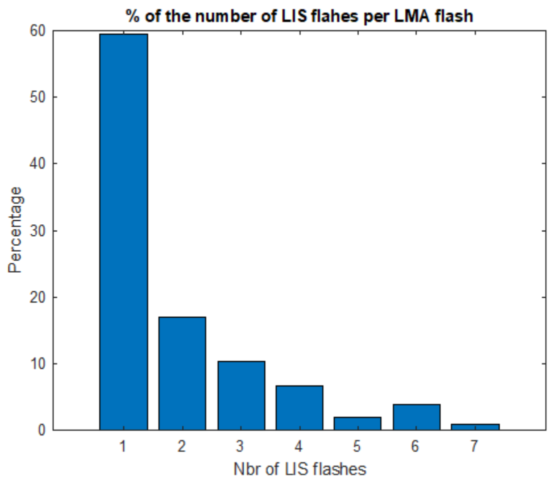
Statistics based from ISS-LIS perspective:

Nbr. events per flash

Median: 55 events per flash
Stdev: 47.18
Distribution: Log-normal
Nbr. samples: 50

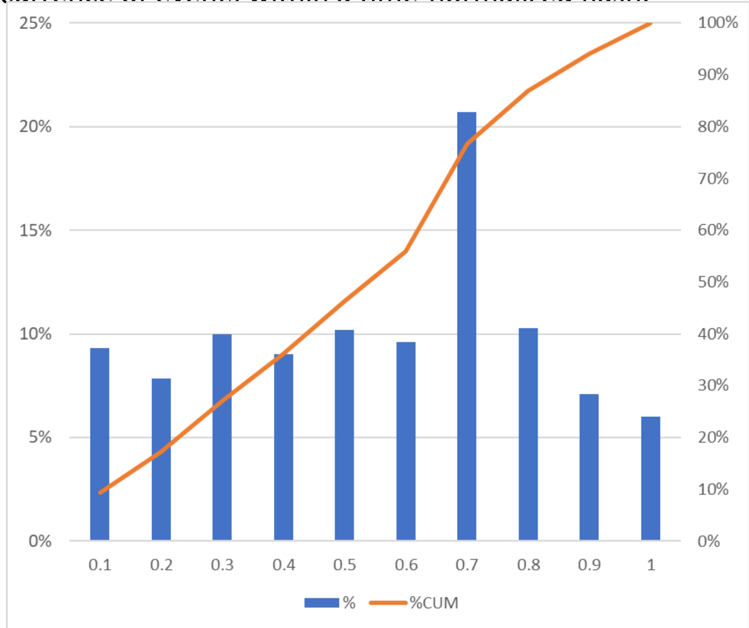


ISS-LIS flashes per flash



Distribution of events

Occurrence of events within a time-normalized flash.



MTG-LI evaluation strategy
Part 1: Metrics

MTG-LI evaluation strategy. Part 1: Metrics

In this part we present the parameters to be used for LI evaluation. Methodology, data and applicability are described.

This part is aligned with the work of the LMA team of the LI-MAG.

Parameters:

- Flash Detection Efficiency (FDE)
- Flash False Alarm (FFAR)
- Absolute Sample Position Knowledge Error (ASPKE)
- Time Accuracy (TA)
- Pulse detection efficiency (PDE)
- Pulse detection false alarm (PFAR)

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MTG-LI evaluation strategy. Part 1: Metrics

Flash Detection Efficiency (FDE)

Summary (FDE)

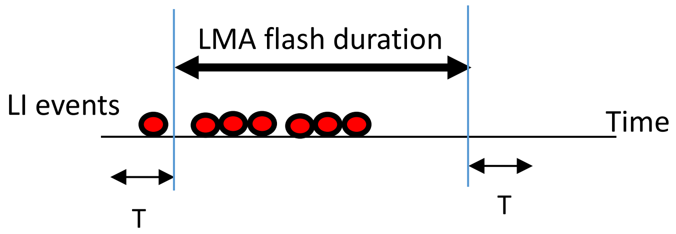
Ratio between the flashes detected by LI versus the total number of LMA flashes.

$$DE_f = \frac{Nbr\ of\ LMA\ flashes\ detected\ by\ \mathrm{LI}}{Total\ number\ of\ LMA\ flashes}$$

Flashes detected by the LMA are used as reference so LMA level-2 data is used. LMA flashes will be restricted to an area defined by sensitivity of <P dBW ensuring that LMA flashes will keep their properties.

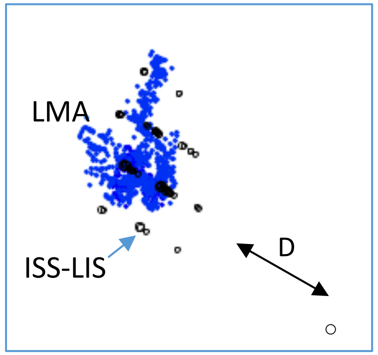
Input data (FDE)

- LI level-2 data: events, groups and flash information.
- LMA level-2 data: VHF sources grouped in flashes.



Configuration parameters (FDE)

- Time tolerance (T) corresponding to the extension of time at the start and at the end of a LMA flash.
- Distance tolerance (D) corresponding to the distance between LMA flash centroid and LI weighted centroid. This is used to discriminate LI flashes occurring at the same time as the reference flash in the LMA but corresponding to another storm.
- Area of evaluation for a given LMA power sensitivity (P): This area will correspond to the area where the LMA can detect lightning sources with power < P dBW. Because this area depends on the status of the network at a given moment (e.g. number of sensors, noise level at each station, etc), this shall be determined for each particular day or episode. The area of <P dBW will be provided in a gridded format.

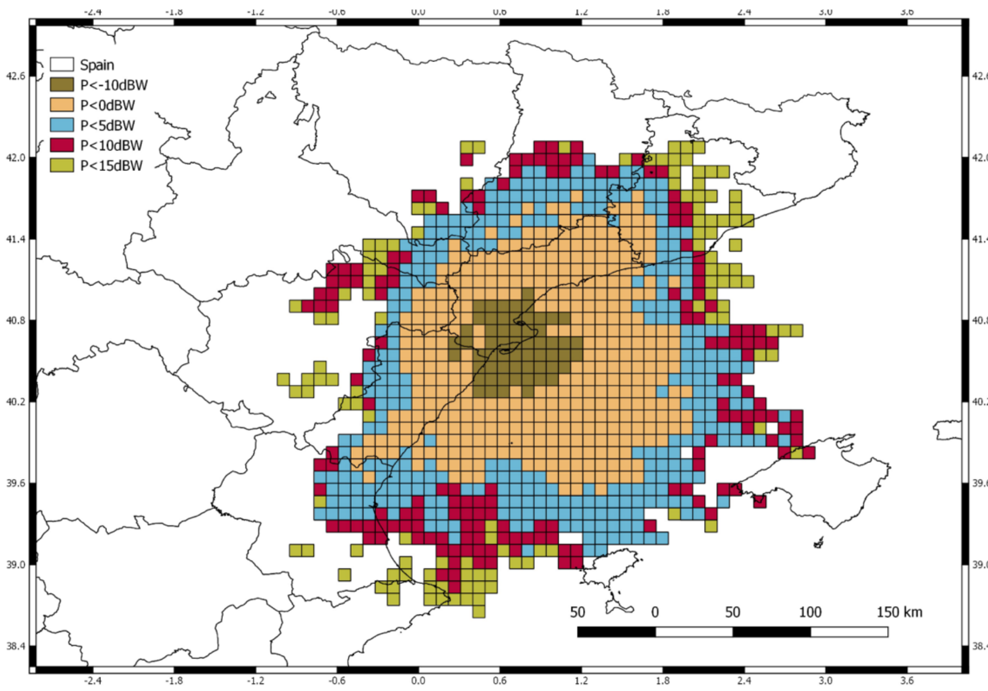


MTG-LI evaluation strategy. Part 1: Metrics

Flash Detection Efficiency (FDE)

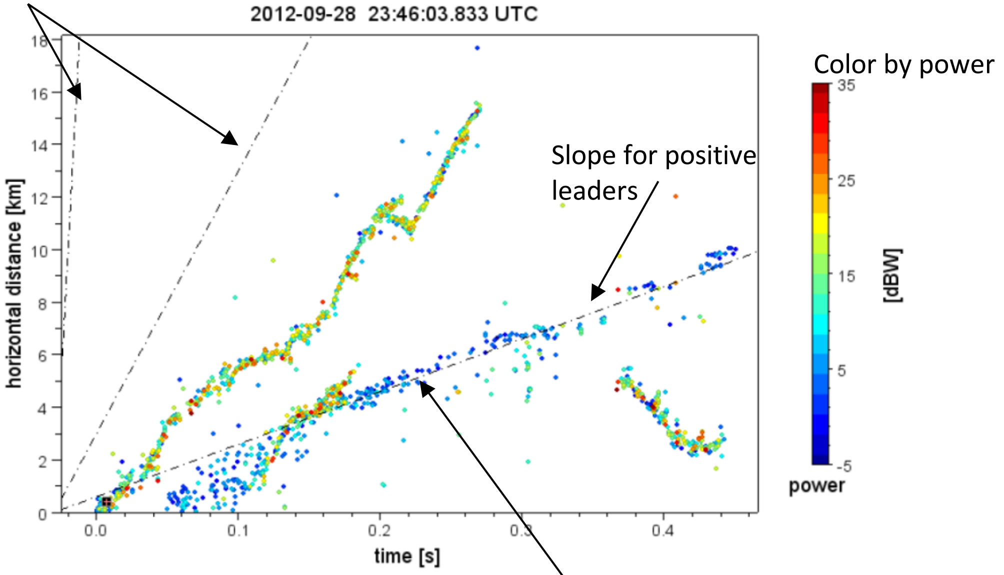
Continue from Configuration parameters: Area of evaluation for a given LMA power sensitivity (P):

LMA sensitivity area



Example of time-distance plot of a LMA flash

Slope for negative leaders



Slope for positive leaders

Required sensitivity threshold P

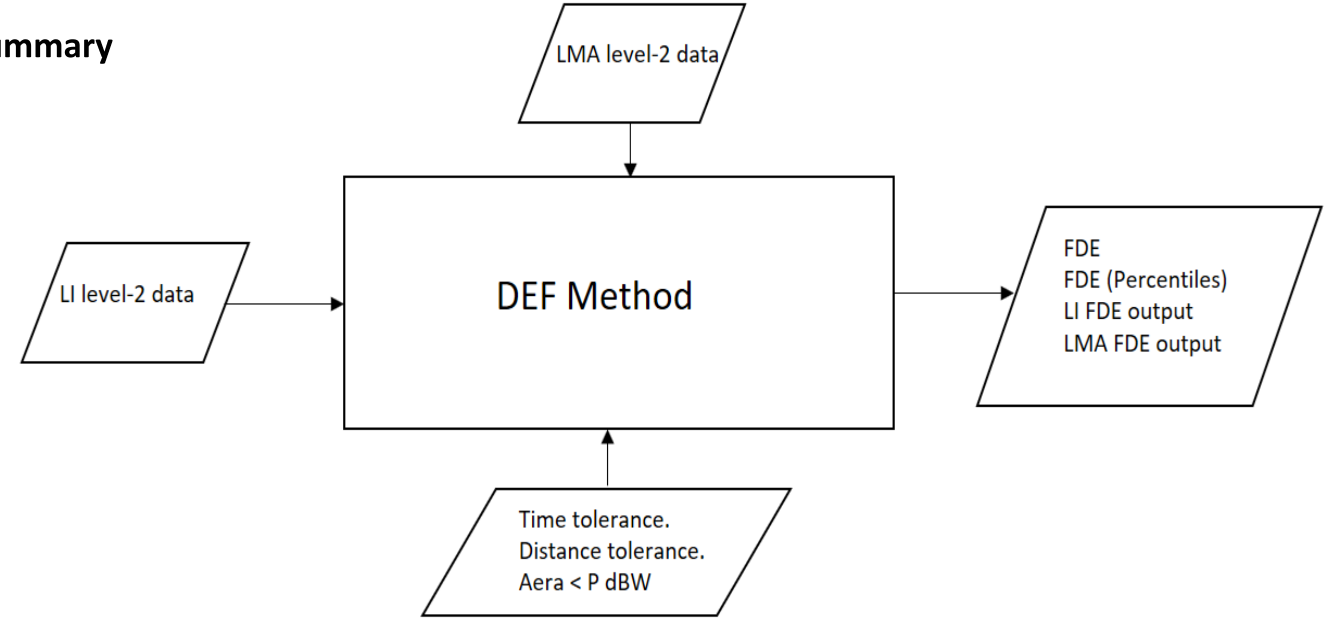
MTG-LI evaluation strategy. Part 1: Metrics

Flash Detection Efficiency (FDE)

Output data (FDE)

-Flash detection efficiency.
-Flash detection efficiency as a function of the maximum height of LMA flashes expressed in percentiles: 90, 75, 50 and 25.
-LI FDE output data indicating these LI flashes that have been associated to LMA flashes. That can/will be used for further analysis, e.g. DE vs. LMA flash duration.
-LMA FDE output data indicating these LMA flashes that have been associated to LI flashes. That can/will be used for further analysis, e.g. DE vs. LMA flash duration.

Summary



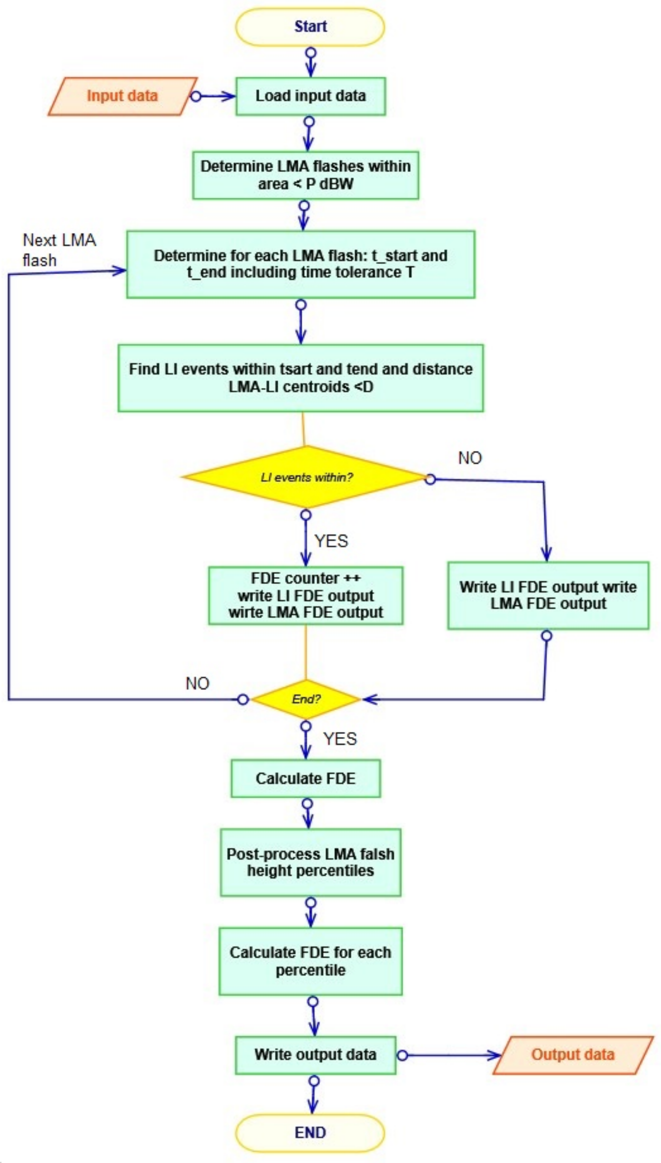
Output FDE data will also allow to evaluate LI flash grouping criteria.

Output FDE data is required as input for some other parameters.

MTG-LI evaluation strategy. Part 1: Metrics

Flash Detection Efficiency (FDE)

Method



Assumptions	• **LMA is the reference network (DE_f LMA = 100 %).** • LMA flashes are taken as reference. It can happen that one LMA flash has assigned several LI flashes. • Constant performance of the LI during the studied period and over the domain of interest. • Constant performance of LMA for a giving period. This is provided as the area of <P dBW for a giving period (typical one day).
Limitations	• **Small areas due to the limited range of the LMA.** • **Episodes with high flash rates** difficult the identification of individual flashes. E.g. some storms present almost continue flash activity. A more complex flash identification would be necessary for these cases. • **LMA data needs to be transferred.** Full data (science data) cannot be transferred and processed in real time. For continuous analysis periodicity should be defined.
Key configuration parameters	• LMA flash definition. In special for high lightning flash rates where identification of individual flashes can be difficult. • Area of analysis. Areas where LMA has low power detection capability (high sensitivity) are convenient in order to keep flash properties (e.g. size and duration). But this limits the evaluation range. Larger areas can be used for only FDE computation.
Confidence of success	• High.
Applicability	• High in terms of implementation of the method and conduction of the analysis. • For continuous evaluation a periodicity shall be defined according to the LMA data availability.

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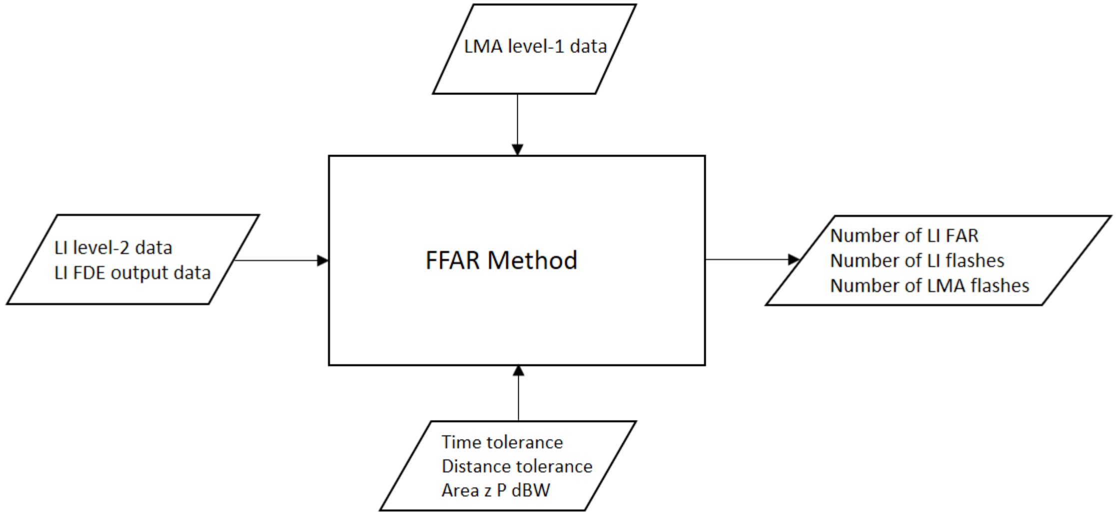
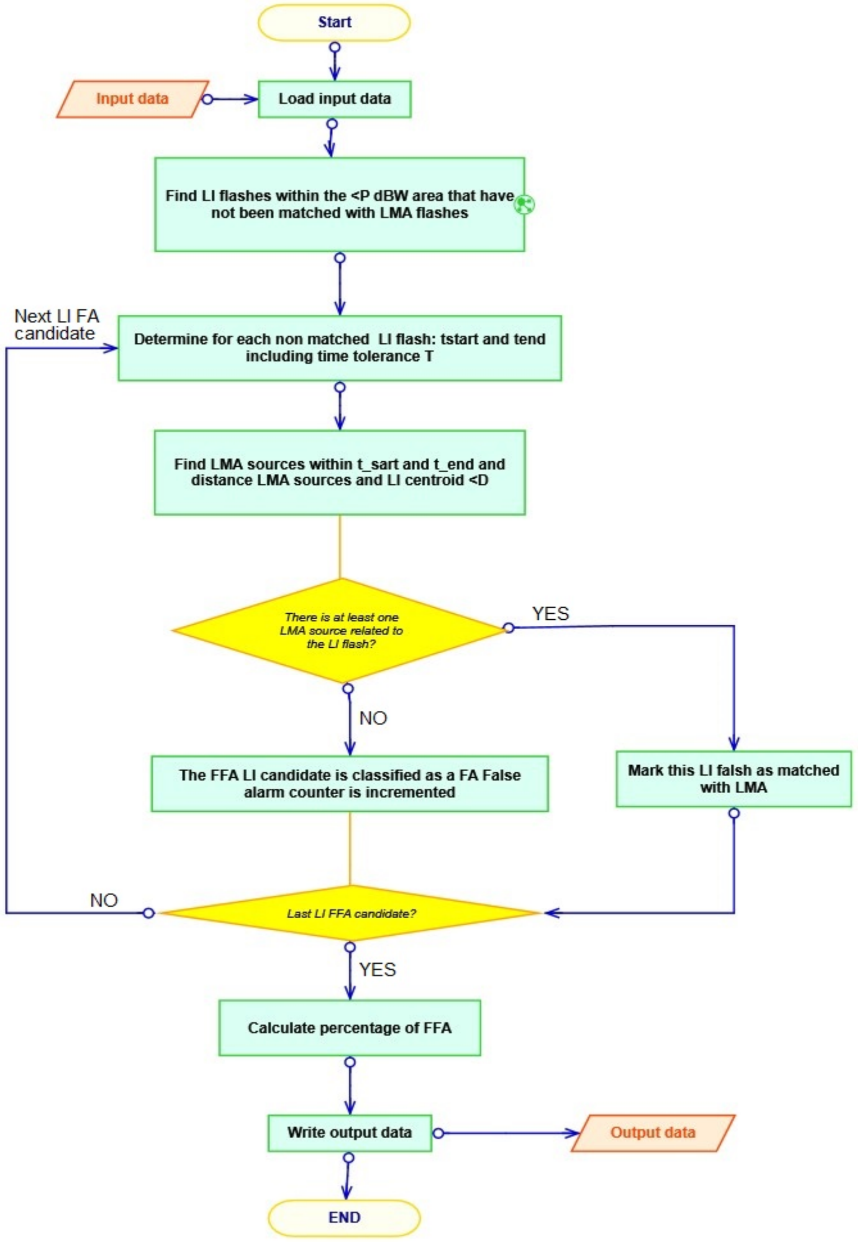
MTG-LI evaluation strategy. Part 1: Metrics

Flash False Alarm Rate (FFAR)

Summary (FFAR)

Flash False Alarm (FFAR) corresponds to the identification of false LI flash detections. In this case, LI flashes not matched with LMA flashes are identified as candidates to False Alarm (FFA). For these candidates, LMA source data (LMA level-1 data) will be used to confirm false detections.



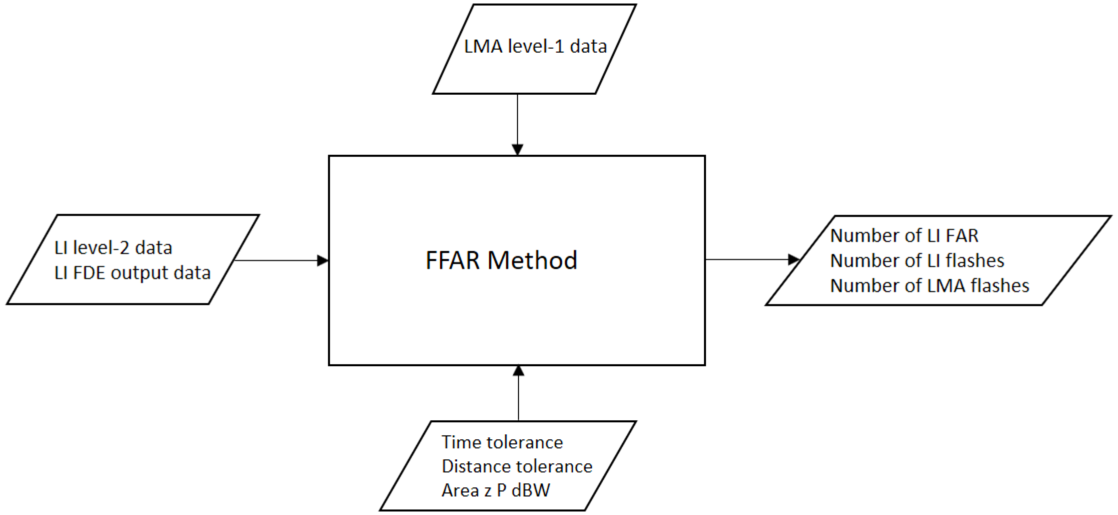


MTG-LI evaluation strategy. Part 1: Metrics

Flash False Alarm Rate (FFAR)

Summary (FFAR)

Flash False Alarm (FFAR) corresponds to the identification of false LI flash detections. In this case, LI flashes not matched with LMA flashes are identified as candidates to False Alarm (FFA). For these candidates, LMA source data (LMA level-1 data) will be used to confirm false detections.



Assumptions	• LMA is the reference network (DE_f LMA = 100 %). • LMA sources are taken as reference. • High performance of the LMA within the <P dBW area.
Limitations	• Small areas due to the limited range of LMA. • LMA data needs to be transferred. Full data (science data) cannot be transferred and processed in real time. For continuous analysis periodicity should be defined.
Key configuration parameters	• Area of analysis. Area of high sensitivity where LMA has low power detection capability (< P dBW) must be considered. This area shall correspond to the analysed day or episode. • Time tolerance (T) This is important in order to avoid cases of LI FFA candidates that happen very close in time (e.g. less than 1 s) to LMA flashes.
Confidence of success	• **Moderate.** Even there is low probability that using **LMA level-1 data** it will not be any source of a flash within the high sensitivity data. For those resulting FFA LI flashes, **LMA level-0** data should be inspected to finally confirm a FA flash.
Applicability	• High, in terms of implementation of the method and conduction of the analysis for LMA level-1 data. • For the use of LMA level-0, this is recommended to carried out by the LMA network operator. • For continuous evaluation periodicity needs to be defined according to the LMA data availability.

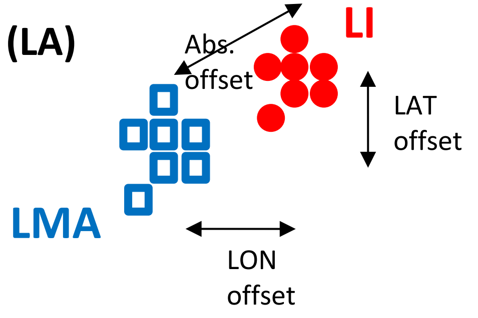
MTG-LI evaluation strategy. Part 1: Metrics

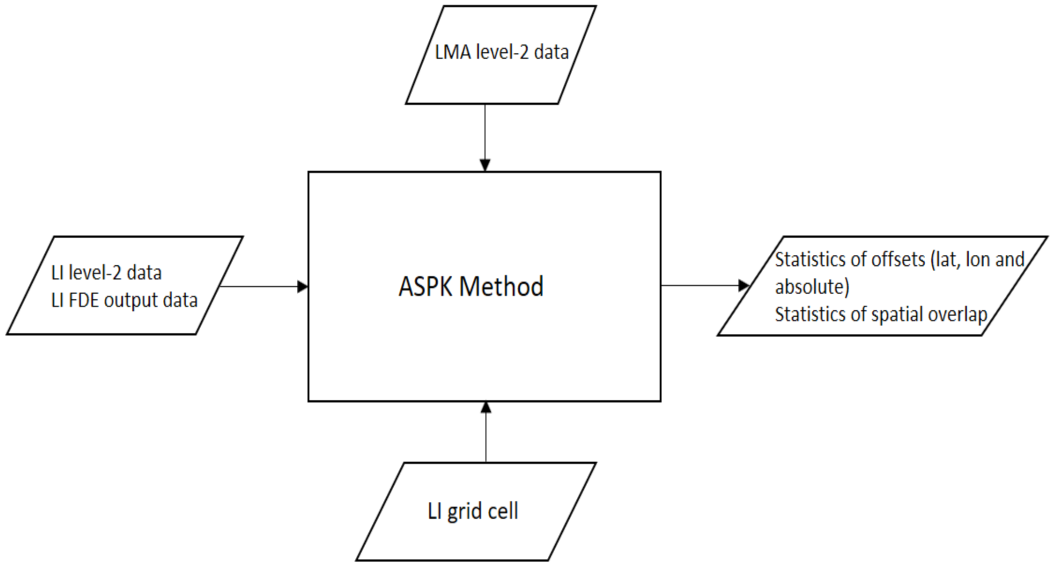
Absolute Sample Position Knowledge Error (ASPKE) – Location Accuracy-

Summary (ASPKE)

Location accuracy (ASPK) is proposed to be conducted using a gridded approach in which cells containing LMA sources of flashes are compared to the cells containing LI events.

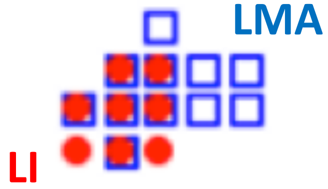
Offset (LA)





Spatial overlap

Area km^2



		LI	
LMA		**YES**	**NO**
	YES	Hit	Miss
	NO	False	Correct negative

$$Fraction\ of\ LMA\ grid\ cells\ correctly\ mapped\ by\ LI = \frac{hits}{hits + misses}$$

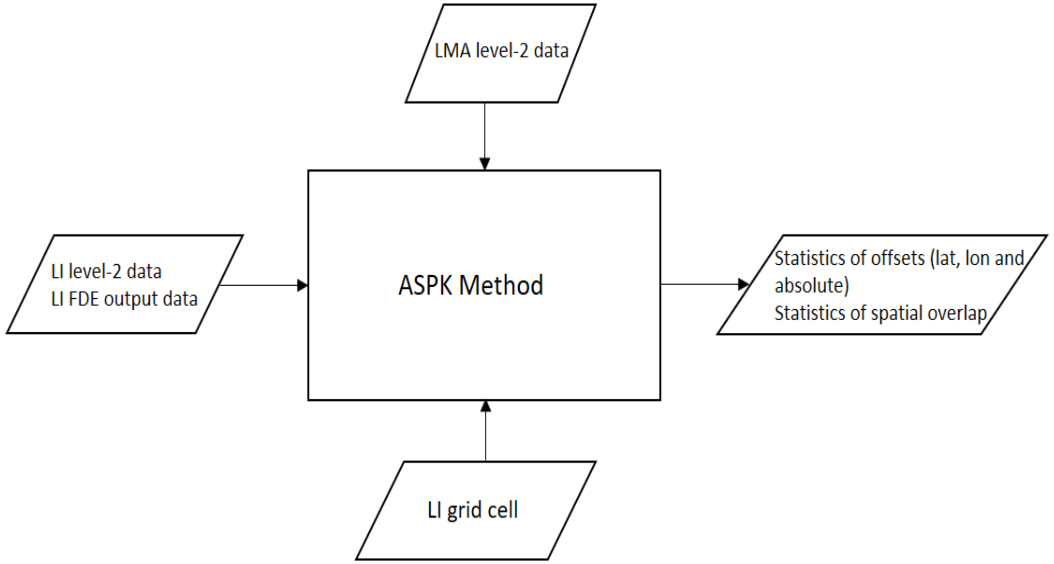
$$Fraction\ of\ LI\ grid\ cells\ not\ corresponditn\ to\ LMA = \frac{false}{hits + false}$$

MTG-LI evaluation strategy. Part 1: Metrics

Absolute Sample Position Knowledge Error (ASPKE) – Location Accuracy-

Summary (ASPKE)

Location accuracy (ASPK) is proposed to be conducted using a gridded approach in which cells containing LMA sources of flashes are compared to the cells containing LI events.



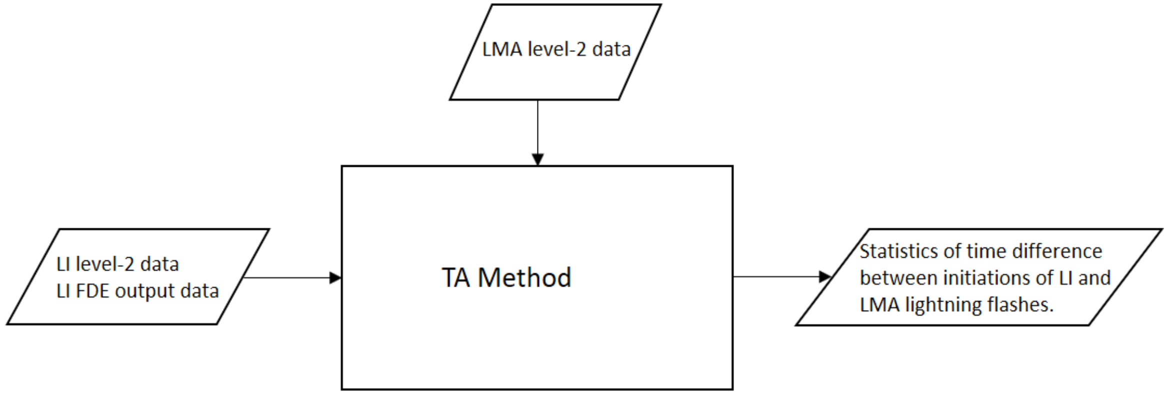
Assumptions	• LMA is the reference network (assumed no location error). • High performance of the LMA within the <P dBW area.
Limitations	• Small areas due to the limited range of LMA. • LMA data needs to be transferred. Full data cannot be transferred and processed in real time. For continuous analysis periodicity should be defined.
Key configuratio n parameters	• Area of analysis. Area of high sensitivity where LMA has low power detection capability (< P dBW) must be considered. This area shall correspond to the analyzed day or episode. • LI grid.
Confidence of success	• High
Applicability	• High

MTG-LI evaluation strategy. Part 1: Metrics

Time Accuracy (TA)

Summary (TA)

Time accuracy at flash level is computed as the difference between the time of the initiation of a LMA flash (first source) and the time of the first event detected by LI.



Assumptions	• LMA is the reference network (DE_f LMA = 100 %). • LMA detects the whole flash. • LMA sources are taken as reference. • High performance of the LMA within the <P dBW area.
Limitations	• The evaluation is limited to areas due to the limited range of LMA. • LMA data needs to be transferred. Full data cannot be transferred and processed in real time. For continuous analysis periodicity should be defined.
Key configuration parameters	• Area of analysis. Area of high sensitivity where LMA has low power detection capability (< P dBW) must be considered. This area shall correspond to the analyzed day or episode.
Confidence of success	• High.
Applicability	• Easy.

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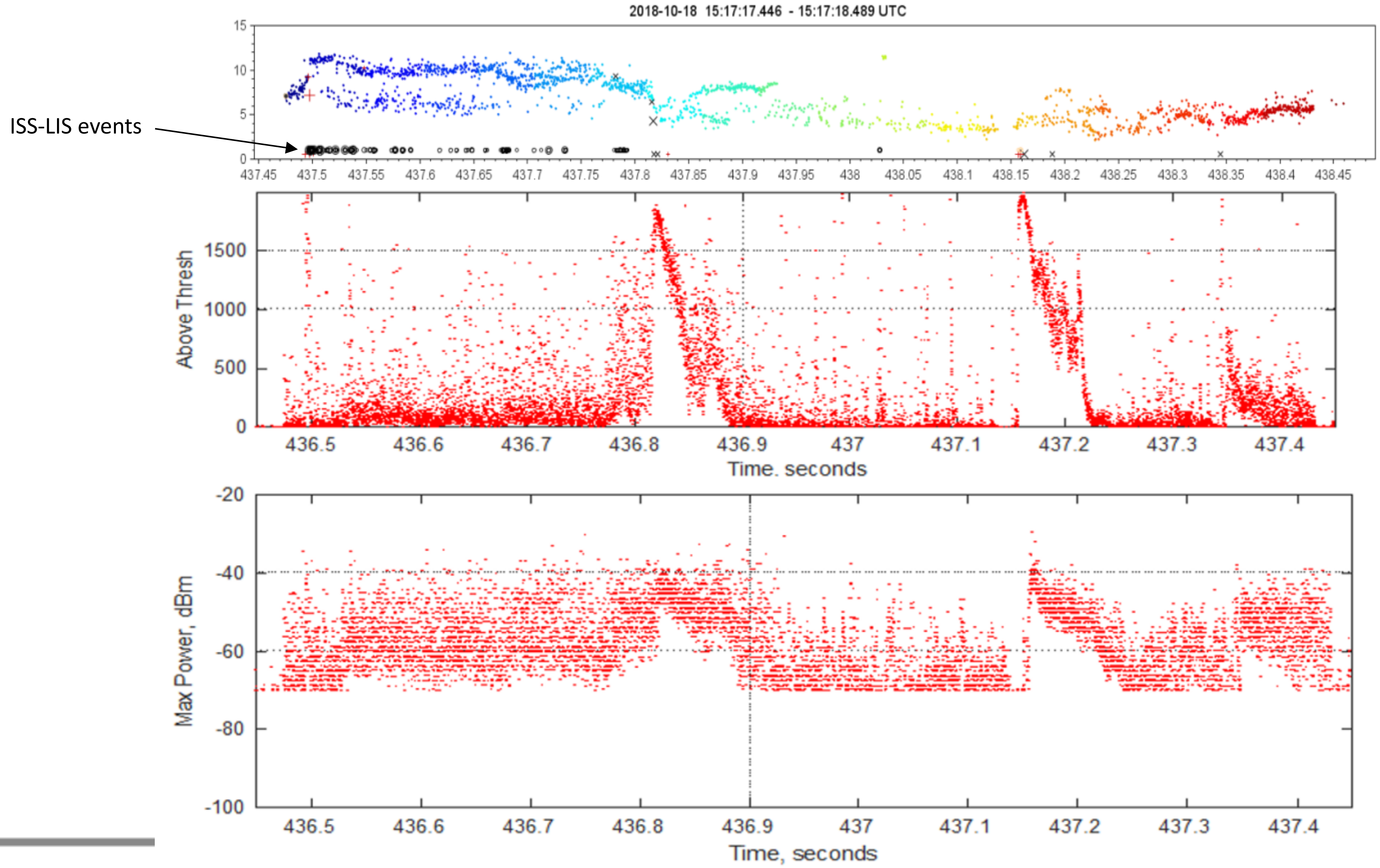
MTG-LI evaluation strategy. Part 1: Metrics

LI L1b L2 Pulse detection efficiency (PDE)



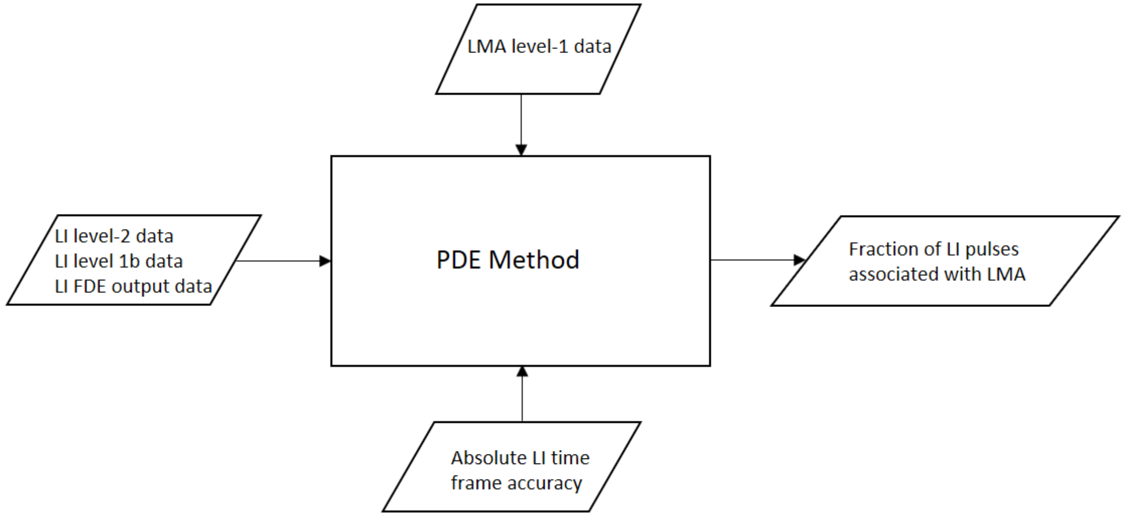
LMA sources

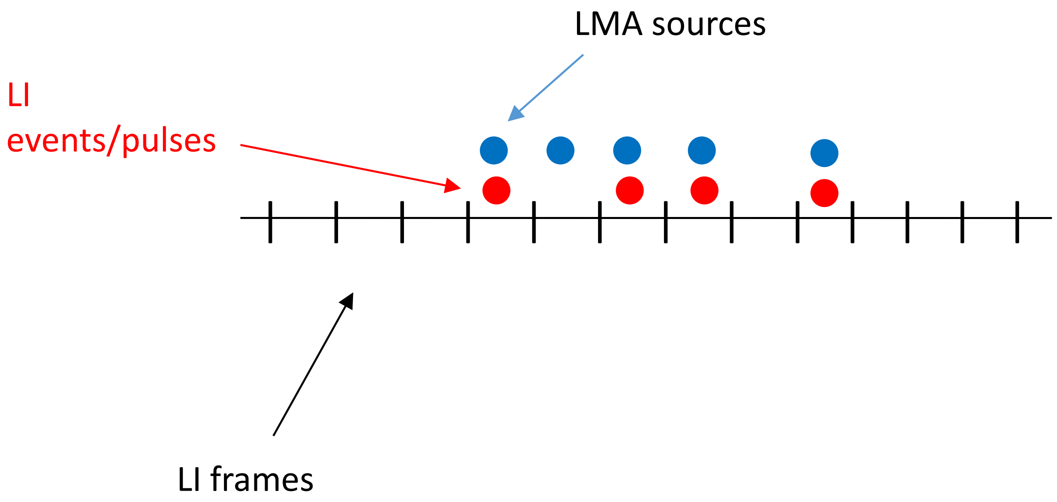
LMA raw data
Nbr of detections above threshold

LMA raw data
VHF RF power for each detection

MTG-LI evaluation strategy. Part 1: Metrics

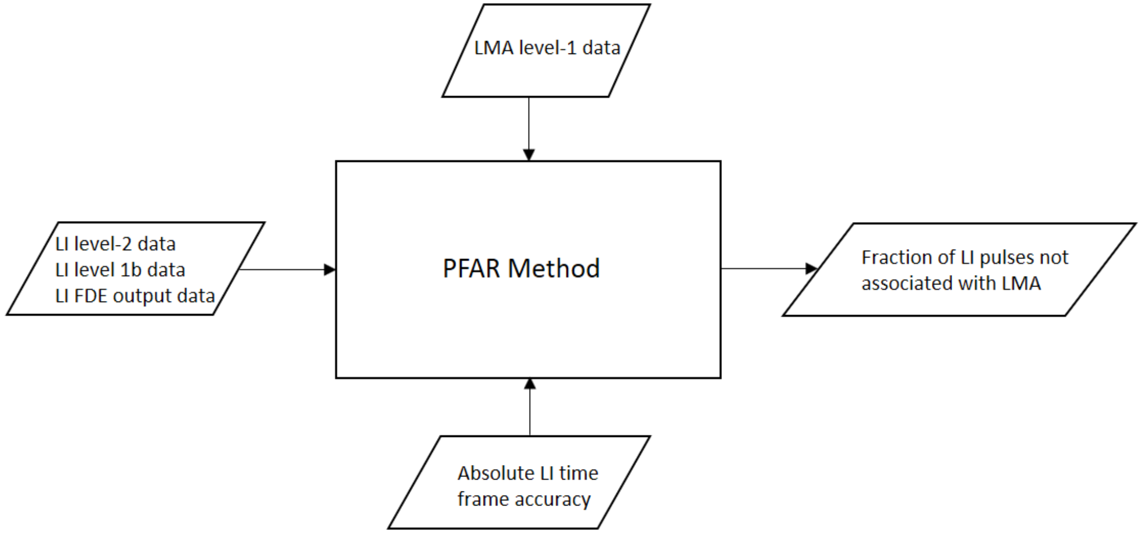
LI L1b L2 Pulse detection efficiency (PDE)

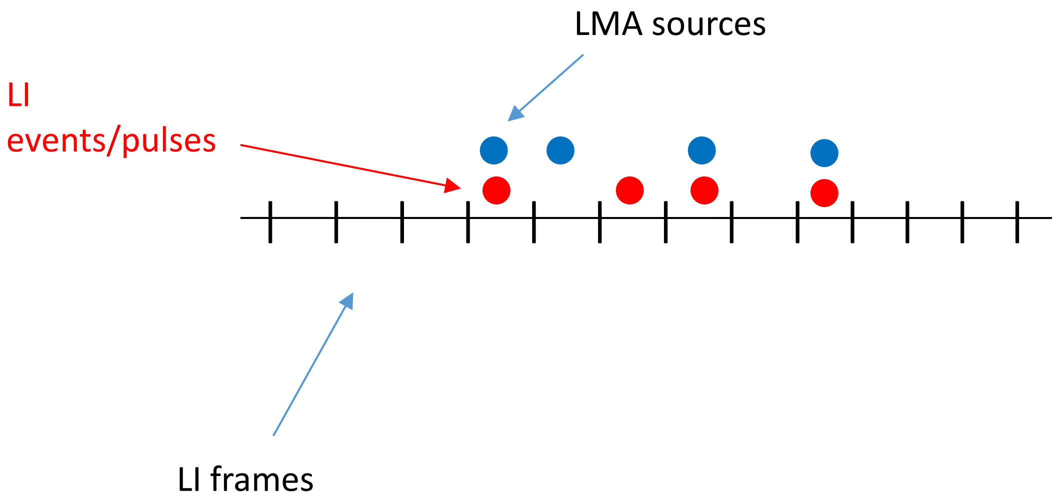




MTG-LI evaluation strategy. Part 1: Metrics

LI L1b L2 Pulse false alarm (PFAR)





MTG-LI evaluation strategy. Part 1: Metrics

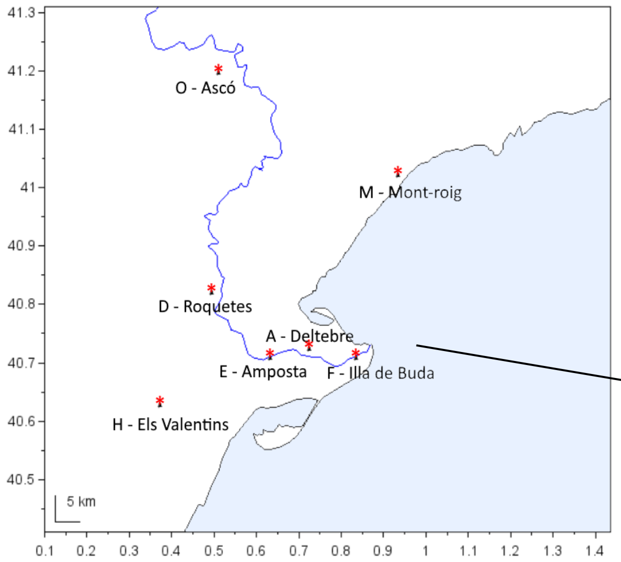
LI L1b L2 Pulse detection efficiency (PDE)
LI L1b L2 Pulse false alarm (PFAR)

Assumptions	• LMA is the reference network (DE_f LMA = 100 %). • LMA sources are related to optical events. This affirmation has not been proved yet. • High performance of the LMA within the <P dBW area.
Limitations	• The evaluation is limited to areas due to the limited range of LMA. • LMA data needs to be transferred. Full data cannot be transferred and processed in real time. For continuous analysis periodicity should be defined. • **Since it is not proved the relation between LMA sources and optical pulses, the results might be not representative**. • The analysis is restricted to those flashes detected by LI and LMA.
Key configuration parameters	• Area of analysis. Area of high sensitivity where LMA has low power detection capability (< P dBW) must be considered. This area shall correspond to the analysed day or episode. • Time uncertainty to include at the LI frame time period.
Confidence of success	• **Low.**
Applicability	• Easy.

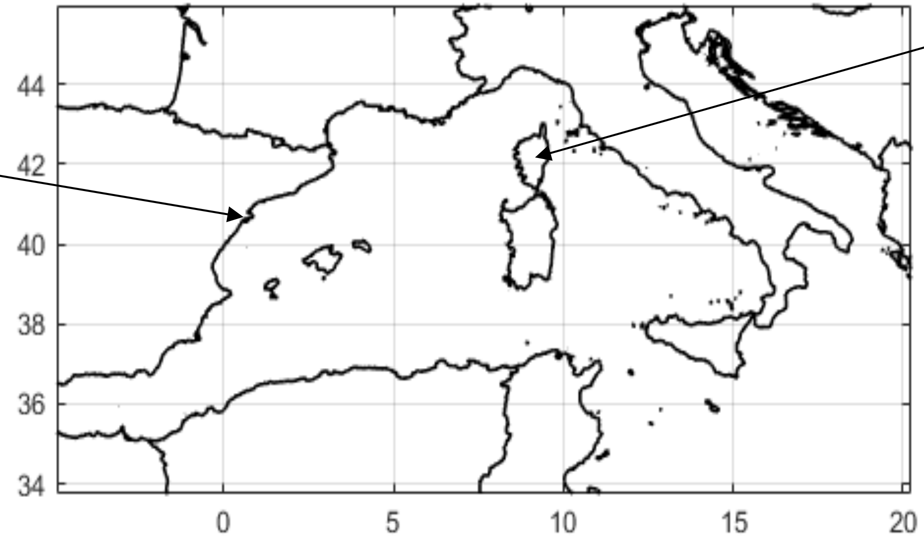
MTG-LI evaluation strategy
Part 2: Strategy

MTG-LI evaluation strategy. Part 2: Strategy

Where? Locations of LMAs and experience in campaigns



LMA networks in Europe



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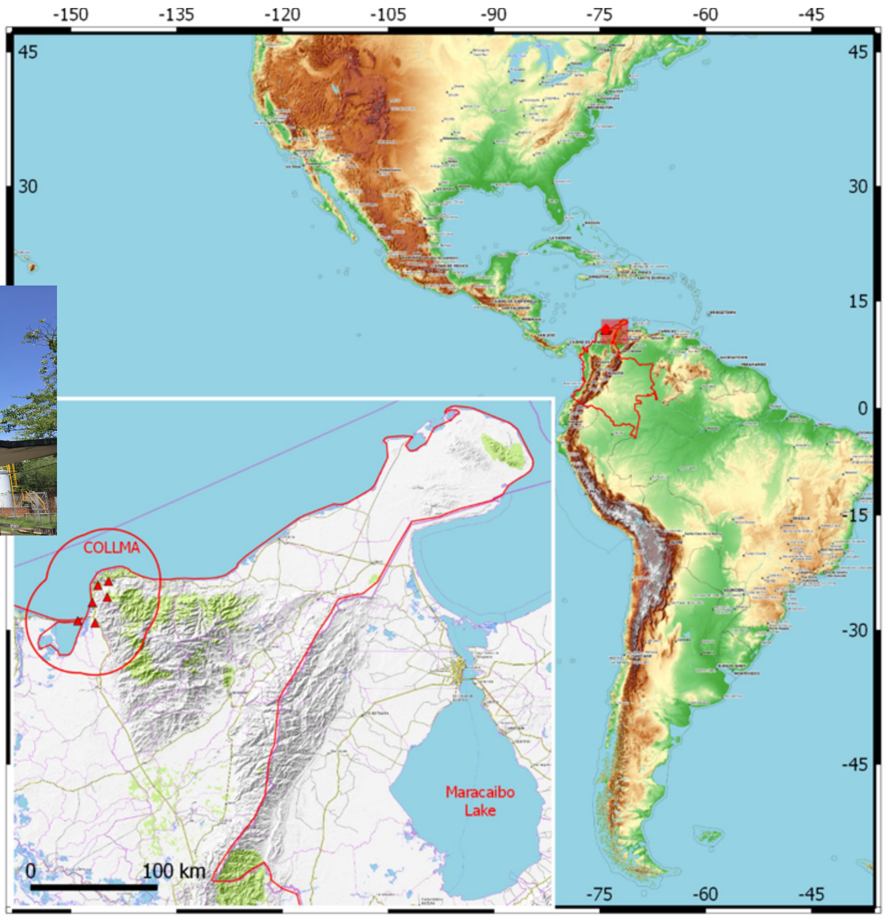
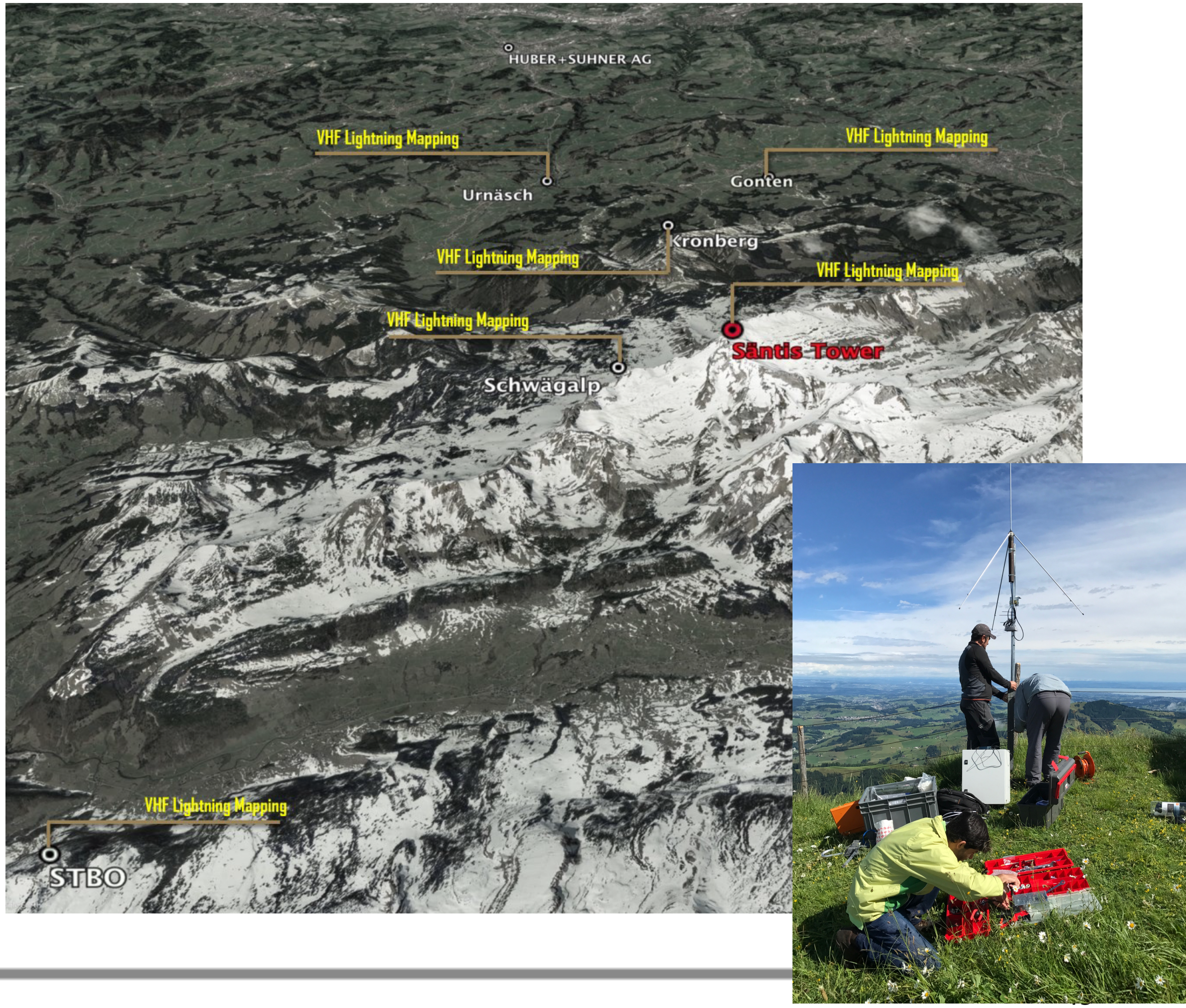
MTG-LI evaluation strategy. Part 2: Strategy

Where? Locations of LMAs and experience in campaigns

LMA in Colombia (permanent since 2015, ASIM ground support)

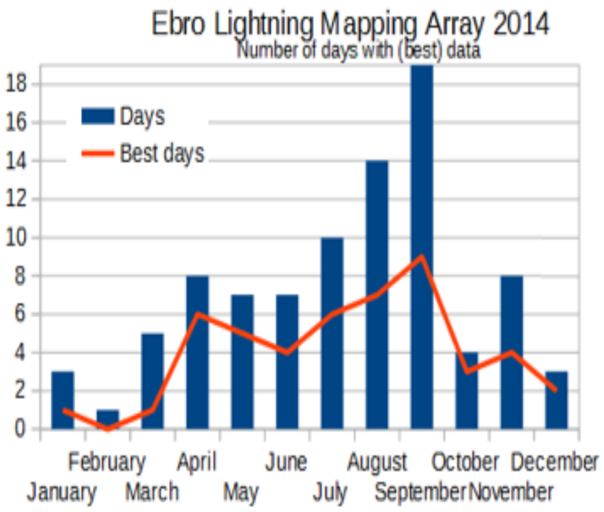


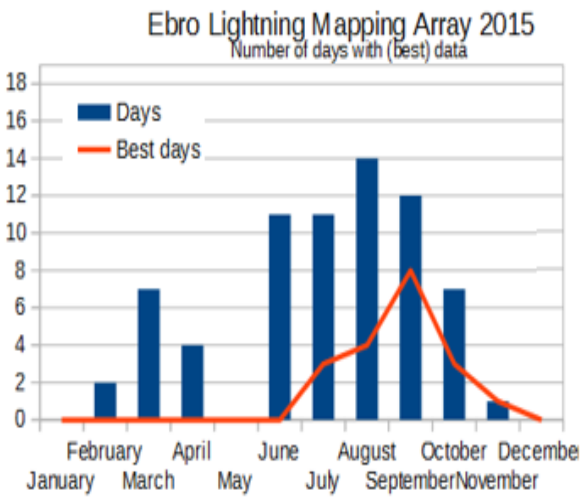
LMA in Switzerland (2017campaign)

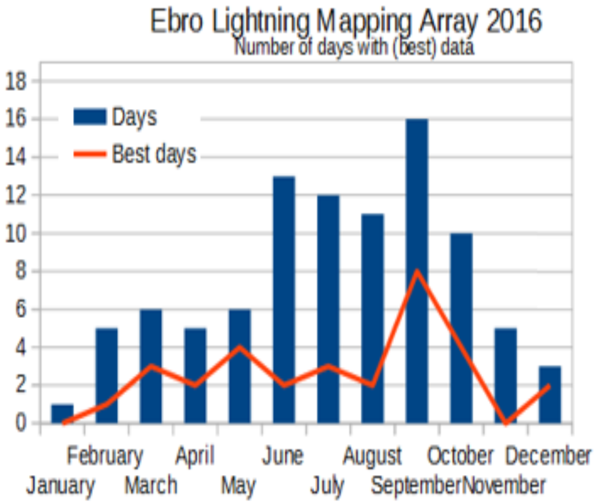


MTG-LI evaluation strategy. Part 2: Strategy

How much data? Expected number of thunderstorms (Ebro-LMA)





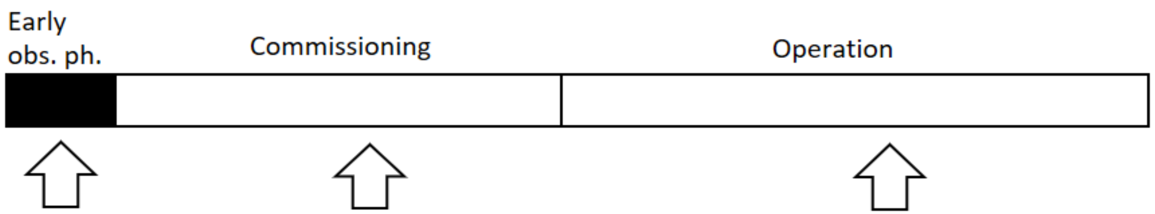


~90 days with storms per year

Expected 1 million flashes per year in the range of the LMA

MTG-LI evaluation strategy. Part 2: Strategy

Strategy



Data delivery:

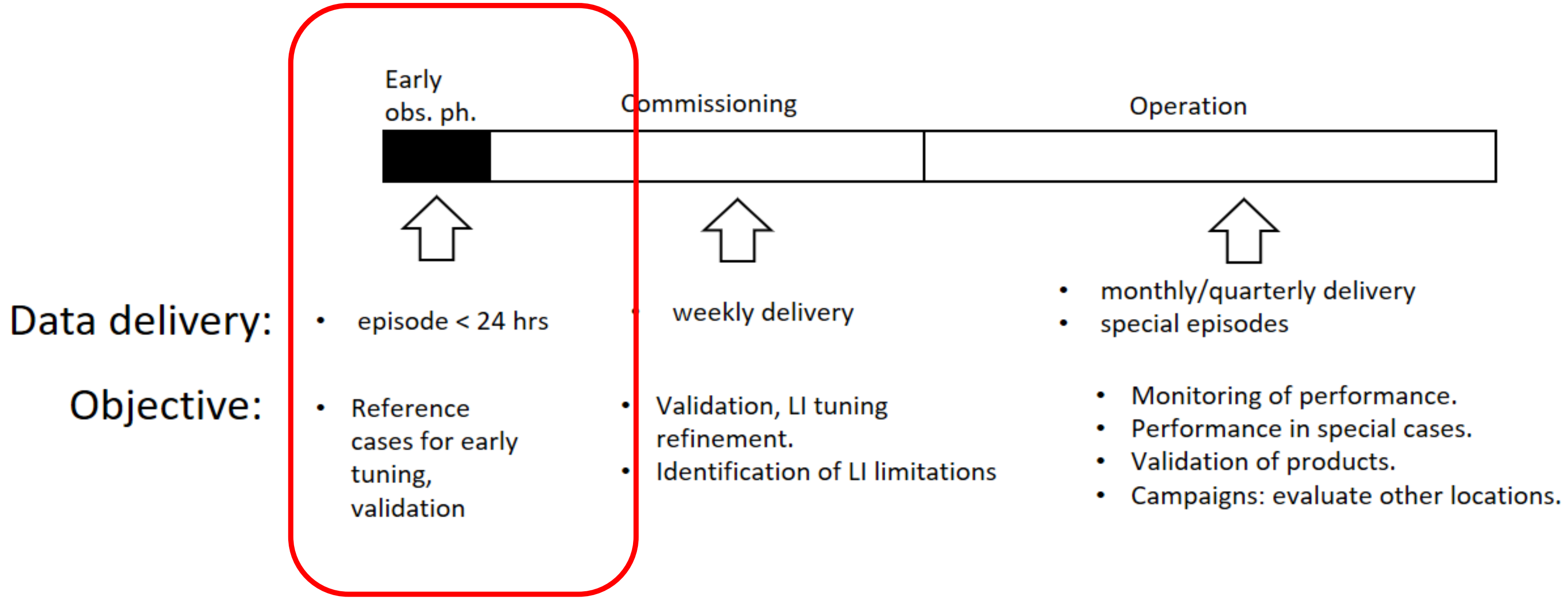
- Early obs. ph.:
  - episode < 24 hrs
- Commissioning:
  - weekly delivery
- Operation:
  - monthly/quarterly delivery
  - special episodes

Objective:

- Early obs. ph.:
  - Reference cases for early tuning, validation
- Commissioning:
  - Validation, LI tuning refinement.
  - Identification of LI limitations
- Operation:
  - Monitoring of performance.
  - Performance in special cases.
  - Validation of products.
  - Campaigns: evaluate other locations.

MTG-LI evaluation strategy. Part 2: Strategy

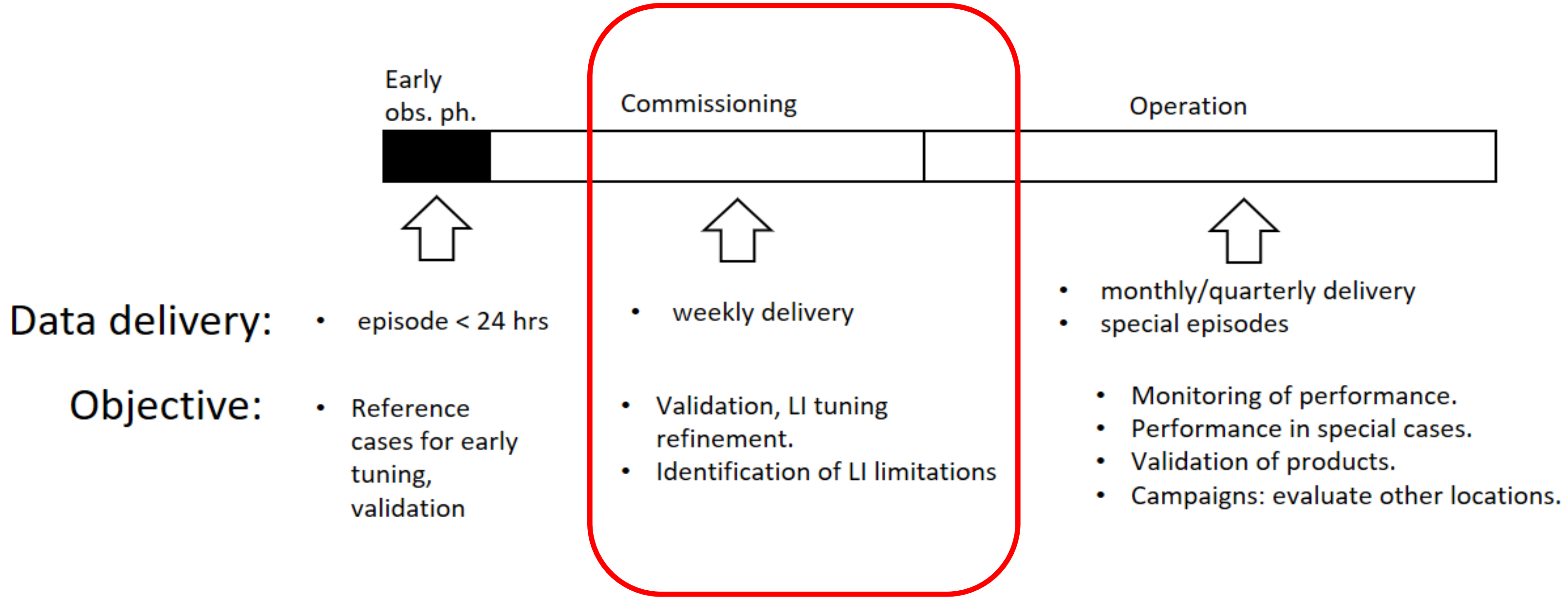
Strategy



Early observation phase LMA can offer reference episodes for validation of initial tunings or verifications of the MTG-LI. Science data can be delivered in less than 24 h.

MTG-LI evaluation strategy. Part 2: Strategy

Strategy

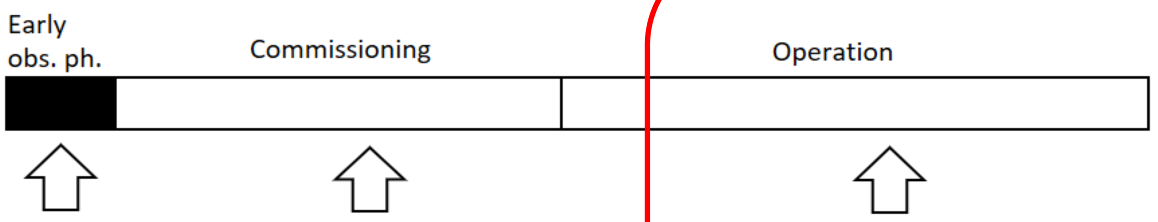


Commissioning phase, data can be delivered periodically and used for validation of the MTG-LI.
In this phase limitations of MTG-LI can be identified or evaluated e.g.:

- Cloud depth occurrence of a lightning flash in order to be detected.
- Duration of a lightning flash in order to be detected.
- Minimum size of a lightning flash in order to be detected.
- Capability of LI to classify/separate lightning flashes.

MTG-LI evaluation strategy. Part 2: Strategy

Strategy



Data delivery:

- Early obs. ph.: episode < 24 hrs
- Commissioning: weekly delivery
- Operation: monthly/quarterly delivery; special episodes

Objective:

- Early obs. ph.: Reference cases for early tuning, validation
- Commissioning:
  - Validation, LI tuning refinement.
  - Identification of LI limitations
- Operation:
  - Monitoring of performance.
  - Performance in special cases.
  - Validation of products.
  - Campaigns: evaluate other locations.

During operation, monitoring of performance of the MTG-LI based on the LMA can routinely performed with attention to those special cases.
At this stage also validation of products derived from the LI can be conducted using LMA data as reference.
Campaigns can be programmed to evaluate MTG-LI performance in locations of interest.

Conclusions

Conclusions

Lightning Mapping Arrays (LMAs) provide the most comprehensive pictures of lightning flashes.

LMA benefits:

- Full 3D-time picture of lightning leaders. So the total size, altitude and duration is very well described compared to cloud-to-ground and/or intra-cloud VLF/LF detections by LLS.
- Typically, hundreds to thousands of sources per lightning flash.
- Discrimination of lightning leader polarity.
- Allows the identification of thundercloud charge regions.
- Easy to setup for campaigns.

Cons:

- Limited range, typically 100 km.
- Large amount of data to be processed in real-time. Data needs to be transferred and/or collected.
- Decimated data is used for the real-time. But this data does not have all the properties of the flashes.
- Lightning return stroke processes are not detected by the LMA.
- LMAs are commonly operated by research institutes and universities where funding is limited.

Conclusions

LMA performance → evaluation domain

- Several parameters have been analyzed.
- Network sensitivity maps are created by analyzing the minimum VHF source power detected in a particular location.
- A gridded method using the same LI grid will be more convenient in order to define the region of analysis.
- Moreover, sensitivity maps can be created per day or even for the evaluated event.

LMA data and processing need to be defined and standardized:

- <u>LMA level-0 data:</u> that corresponds to the raw data for each individual station. In the regular LMA operation, the RF power (dBm) is provided for each detection every 80 µs.
- <u>LMA level-1 data:</u> from level-0 data, the LMA processor obtains the sources. Sources are locations (x,y,z) and power (dBW).
- <u>LMA level-2 data:</u> sources from level-1 data are grouped to form lightning flashes. This grouping is conducted by post processing according to the experience of each LMA operator.

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Conclusions

ISS-LIS evaluation

- Average **flash detection efficiency** resulted to be >75 %. For some episodes the efficiency is very high >90 % but for some particular episodes the efficiency has dropped to <50 %.

- LIS – LMA matches:
  LMA presents sources at higher altitudes.
  Higher number of LMA sources.
  No relation (flash) with power.

- Detection efficiency drops to ~20% when lightning flashes occur below the 75 % altitude for a giving episode

- No **flash false alarm** cases have been found.

- **Flash duration:** typical durations of ISS-LIS flashes are ~ 30 % shorter than the LMA. First ISS-LIS events are typically detected within the initial 20 % of the flash. Last events typically at 85% of the flash.

Conclusions

ISS-LIS evaluation

Location Accuracy:

Mean absolute offset between ISS-LIS and LMA flash are 4.8 km.
In longitude bias is -1.7 km and latitude -1.3 km.
Location accuracy is really correct.
Pixel overlap: 47 %
Flash area: ISS-LIS flashes typically larger than LMA

In section five of this report we have provided some statistical data and plots useful for generating stochastic lightning.

Section six has presented the strategy for the future validation and monitoring of the MTG-LI. Based on the experience in this work and the activity of the LI-MAG group we have described the method for different parameters: Flash Detection Efficiency, Flash False Alarm, Absolute Sample Position Knowledge Error, Time Accuracy, Pulse Detection Efficiency and Pulse False Alarm.

Conclusions

Statistics to generate simulated lightning flashes

Based on LMA some statistical data and plots useful for generating stochastic lightning:

- Flash duration
- Flash size
- Inter-flash time
- Relation size-duration
- Height

From ISS-LIS perspective:

- Events per flash.
- ISS-LIS flashes per flash
- Distribution of occurrence of events within the flash.

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Conclusions

Strategy

Early observation phase: To provide particular storm episodes to be used as reference. Delivery in <24h

Commissioning phase (after the early observation phase): LMA science data can be provided weakly.
Evaluation and validate MTG-LI.
Identification of limitations.

Operation phase: Periodic monitoring of performance.
Evaluation of special cases (e.g. severe thunderstorms)
Validation of derived LI products.
Field campaigns.

Conclusions

Strategy: metrics

Description of the methods, applicability, confidence, etc of:

- Flash Detection Efficiency.
- Flash False Alarm.
- Absolute Sample Position Knowledge Error.
- Time Accuracy.
- Pulse Detection Efficiency and Pulse False Alarms.

Post processing will allow to evaluate other parameters such as the LI flash grouping criteria.

The grade of success is high in most of the parameters except the pulse level parameters.

Evaluation region need to be restricted according to the sensitivity of the network for each particular day or episode.

LMA data delivery is not immediate. Although LMA can produce decimated data for real time, evaluation will need science data level-1 and level-2 that require the transfer of large amounts of data and data processing.

End

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Questions SOW

1. **How can LMA data be employed to validate and, if needed, correct/complement the information on lightning events, groups, and flashes provided by ISS–LIS?**

    - LMA provides reference at flash level.
    - We have seen that there is not a straight relationship between LMA VHF RF/sources and optical pulses.
    - LMA can be used to correct position offsets.

    - LMA can be used to provide uncertainties of different parameters, e.g.: duration, area,….

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Questions SOW

2. How can LMA data and ISS-LIS data be used to define a new and refined statistical description of lightning pulses, groups, and flashes?

- Current flash grouping criteria of ISS-LIS matches ~60 %.
- We provided statistics of flash extension and duration.

Questions SOW

3. What are the performances of ISS-LIS evaluated against LMA measurements?

- Results in the report and summarized in this presentation.

4. How can LMA data and ISS-LIS data be used to define test cases for the EUMETSAT MTG LI end - to - end processor?

- LMA extends typical lightning detection systems from one ‘point’ corresponding to cloud-to-ground lightning strokes to a 3D and time characteristics of lightning flashes.
- Since the LMA detects ‘all’ flashes, storms are better described (e.g. flash rates, …)
- Statistical data has been provided.

Questions SOW

5. From the lesson learned by comparing ISS-LIS data against LMA data: how can LMA data be employed in the validation of MTG LI during commissioning and in routine monitoring?

See evaluation strategy in the report and in this presentation.