LI Level 2 Data Operational Dissemination Validation Report

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INTRODUCTION

This document is a public version of the full LI L2 Data Operational Dissemination Validation Report. It presents the outcome of the analysis of the Meteosat Third Generation Lightning Imager (MTG-LI) Level 1b and Level 2 products produced by the end-to-end processing of LI observations with the Operational (OPE) Ground Segment at EUMETSAT. The analysis covers the period July 4 – August 22, 2024, for overall performance assessment and the period between August 22, 2024, until the start of the operational dissemination for checking of the processing stability and final performances prior to the beginning of the operational dissemination.

1.1 Scope

This document is in support of the PVRB decision: approval for the activation of the operational dissemination via EUMETSAT data services of LI Level 2 groups (LI-2-LGR), flashes (LI-2-LFL), and accumulated products (LI-2-AF, AFA and AFR). The LI L2 Accumulated Flash Area (AFA) product will be disseminated to the African users via EUMETCast Africa without any additional modification, i.e. it is also covered in this document.

1.2 Reference Documents

	Document Title	**Reference**
[EURD]	MTG End-User Requirements Document	EUM/MTG/SPE/07/0036 and link
[LIL2ATBD]	Algorithm Theoretical Basis Document (ATBD) for L2 processing of the MTG Lightning Imager data	EUM/MTG/DOC/11/0155 Issue 7 and link
[LIL2PUG]	LI L2 Product User Guide [LIL2PUG]	EUM/GEO/TEN/15/828715 Issue 2D and link
[SRD]	MTG System Requirements Document [SRD]	EUM/MTG/SPE/06/0032 Issue 7B

LI LIGHTNING DATA AND PERFORMANCE INDICATORS AND VALIDATION STRATEGY

Since March 7, 2024, LI is being operated to perform continuous lightning detections in OPER mode with acquisitions of background images every 60 sec. Currently, the data acquired by LI are continuously downlinked to ground and processed by end-to-end chain IDPF-I v5.8.2 + L2PF v4.2.2.6 deployed on the OPE Processing Facility at EUMETSAT.
The Level 1b processing, exercised by the IDPF-I, calibrates and navigates LI data. In addition, it flags false lightning events. This allows one to input a sub-set of Level 0 lightning events in the L2PF. This facility completes the filtering of false events and computes groups and flashes and the remaining Level 2 products to be disseminated to users. In detail, the breakdown of the LI products produced by the end-to-end processing chain is:

1. Level 0+ products.
2. Level 1b products:
   a. LI-1B-LE, i.e., Level 1b lightning events,
   b. LI-1B-BCK, i.e., Level 1b background.
3. Level 2 products:
   a. LI-2-LE, i.e, Level 2 events used only for monitoring purpose at EUMETSAT,
   b. LI-2-LEF, i.e., Level 2 events populating Level 2 flashes (LI-2-LFL),
   c. LI-2-LGR, i.e., Level 2 groups populating Level 2 flashes (LI-2-LFL),
   d. LI-2-LFL, i.e., Level 2 flashes,
   e. LI-2-AF, i.e., Level 2 accumulated flashes,
   f. LI-2-AFA, i.e., Level 2 accumulated flash area,
   g. LI-2-AFR, i.e., Level 2 accumulated flash radiance.

Products 3c to 3g will be disseminated to end users. For a high-level description of the end-to-end processing strategy/configuration, the reader can refer to [LIL2PUG]. In addition, a very detailed description of the end-to-end processing with particular focus on Level 2 algorithms/products is available at [LIL2ATBD].

LI is a visible imager with lightning diagnostic capabilities. As any imager, LI is characterised by navigation performances and radiometric performances. In addition (and most importantly), LI is characterized by its lightning detection performances. Lightning detection performances are defined[1] as:

- Detection Efficiency (DE): the percentage of real lightning that are detected by the instrument and that are found in products at a specific step of the end-to-end processing chain (e.g., Level 0, Level 1b and Level 2, respectively);
- False Alarm Rate (FAR): the number of false lightning detections found in products at a specific processing step (e.g., Level 0, Level 1b and Level 2, respectively).

It is worth clarifying that one could reduce FAR to near-zero. However, since this can only be achieved by removing lightning detections “aggressively” from products, a side effect would inevitably be a strong reduction of the DE.
DE and FAR are defined relative to an external reference lightning location system. In detail, these are measured by comparing each LI lightning measurement (i.e., events at Level 1b, and groups/flashes at Level 2) against the strokes and flashes observed by an external reference lightning location system. One can describe the computation of DE and FAR as:

[1] These being purely theoretical definitions.

- DE: the fraction of lightning detections of the reference system that have at least one corresponding LI detection at a specific step of the end-to-end processing chain (e.g., Level 0, Level 1b and Level 2, respectively);
- FAR: the number of LI lightning detections per second (a rate) that are uncorrelated to lightning detections of the reference system. This is also defined at a specific step of the end-to-end processing chain (e.g., Level 0, Level 1b and Level 2, respectively).

The description of the techniques/algorithms used to compute DE and FAR of LI is beyond the scope of this document. However, one can grasp the concept behind such algorithms by thinking about a "matching exercise" meant to look for a correspondence (or lack of correspondence in the case of the FAR) between LI and the reference system within a specified spatial-temporal window. This analysis is executed by means of the same tools used to assess the quality of LI Level 1b data, i.e., LI-STAR (Gitlab repo https://gitlab.eumetsat.int/oi/li-star/li-star-satpy), using GLD360 as the main external reference lightning location system. In addition, performances against GLM are also derived for Level 2 products in the overlap region between the two instruments. Very important by-products of the matching exercise for the computation of DE against GLD360 are:

- Location Accuracy (LA): the median of spatial distances (in km) between matching LI and reference network lightning detections at a specific step of the end-to-end processing chain (e.g., Level 0, Level 1b and Level 2, respectively).
- Timing Accuracy (TA): the median of time difference (in μsec) between matching LI and reference network lightning detections at a specific step of the end-to-end processing chain (e.g., Level 0, Level 1b and Level 2, respectively).

The matching exercise is carried out over the entire LI field of view and the complete time interval covered by the dataset and by accounting for parallax correction of LI data prior to the matching against GLD360.

In this report, we present the main results of the analyses of LI Level 1b and Level 2 products produced by the end-to-end processing chain in the time period July 4-August 22, 2024. This shall be regarded as the reference period for LI performance assessment. The following performances will be presented in this report: DE, FAR, LA and TA at Level 1b and Level 2. In addition, to check the robustness of such measures, and how representative they are of the system performances daily, the analysis of time sequences of both lightning detection and processing performances will also be included. The results of the analyses are presented in two different sections, focusing on Level 1b and Level 2, respectively. It is very important to stress that the scope of this report is to certify the overall readiness of the LI System to support operational dissemination. The investigation of specific results, such as deviating/anomalous results over very short time intervals, is beyond the scope of this document and will be analysed by the LI Science Team in the future. Finally, this report will not include the validation of the LI accumulated products. In fact, the main purpose of this report is to confirm the suitability of LI Level 2 performances for operational dissemination. LI Level 2 accumulated products have no performance requirement [EURD]. The correctness of LI Level 2 Accumulated Products was certified.

In addition, since the kick-off of the operational dissemination of LI Level 2 products to users is planned for the beginning of November 2024. In this report, we include:

1. a section in which we demonstrate that the performances delivered by the LI System right before the kick-off of the dissemination (over about one week) are in line with those assessed over the reference period July-August 2024;
2. a section devoted to the description of the LI System behaviour during the so called "eclipse season" of August-October 2024, focusing processing stability of the soon-to-be LI Operational System.

In Table 1, we present the configuration of the LI Ground Segment on OPE during the reference period and for the kick-off of the operational dissemination.

Table 1: LI System configurations July and the beginning of the operational dissemination.

LI System element	Time period
LI Instrument	LI instrument configuration is: Application software version: ASW v05.01.02 Software patches installed in SDRAM post activation: • LOH BASIC Conf Delta Thresholds update • upload of the adapted RTPP LUT (in relation to EUM/MTG/AR/7656) • ONB22 for Dark objects (in relation to EUM/MTG/AR/7620)
IDPF-I v5.7.1 + L2PF 4.2.2.3	July 4 – August 22, 2024
	IDPF-I v5.7.1 configurations from July 3, 2024: https://gitlab.eumetsat.int/INRC/mtg-iqt-snapshots/-/releases/IDPF-SNAP3-KALM-relaxStar (IDPFI-OPE: 03 Jul 2024) https://gitlab.eumetsat.int/INRC/mtg-iqt-snapshots/-/releases/IDPF-SNAP3-KALM-relaxStar2 (IDPFI-OPE: 09 Jul 2024, FCI RC55) https://gitlab.eumetsat.int/INRC/mtg-iqt-snapshots/-/releases/IDPF-SNAP3-KALM-HOTFIX03 (IDPFI-OPE: 24 Jul 2024 10:20z) With SCCDB V8.1.1 (https://gitlab.eumetsat.int/MTG_SCCDB/mtg-sccdb-i1-iqt-l1pp-if/-/tags/SCCDB-I1-IQT-L1PP-IF-V8.1.1) L2PF v4.2.2.3 Configuration SAD-0.0.x_v3.1.0
IDPF-I v5.8.2 + L2PF v4.2.2.6	October 11 – October 18, 2024
	IDPF-I v5.8.2 configurations from October 11, 2024: https://gitlab.eumetsat.int/INRC/mtg-iqt-snapshots/-/releases/IDPF-SNAP4-KALM-HOTFIX01 ((IDPFI-OPE: 08 Oct 2024) With SCCDB V8.3 (https://gitlab.eumetsat.int/MTG_SCCDB/mtg-sccdb-i1-iqt-l1pp-if/-/releases/SCCDB-I1-IQT-L1PP-IF-V8.3) L2PF v4.2.2.6 Configuration SAD-0.0.x_v3.1.0

LEVEL 1B PERFORMANCES

In Figure 1 the reader finds the DE and LA for LI Level 1b events (LI-1B-LE) computed against GLD360 lightning strokes using the matching exercise.

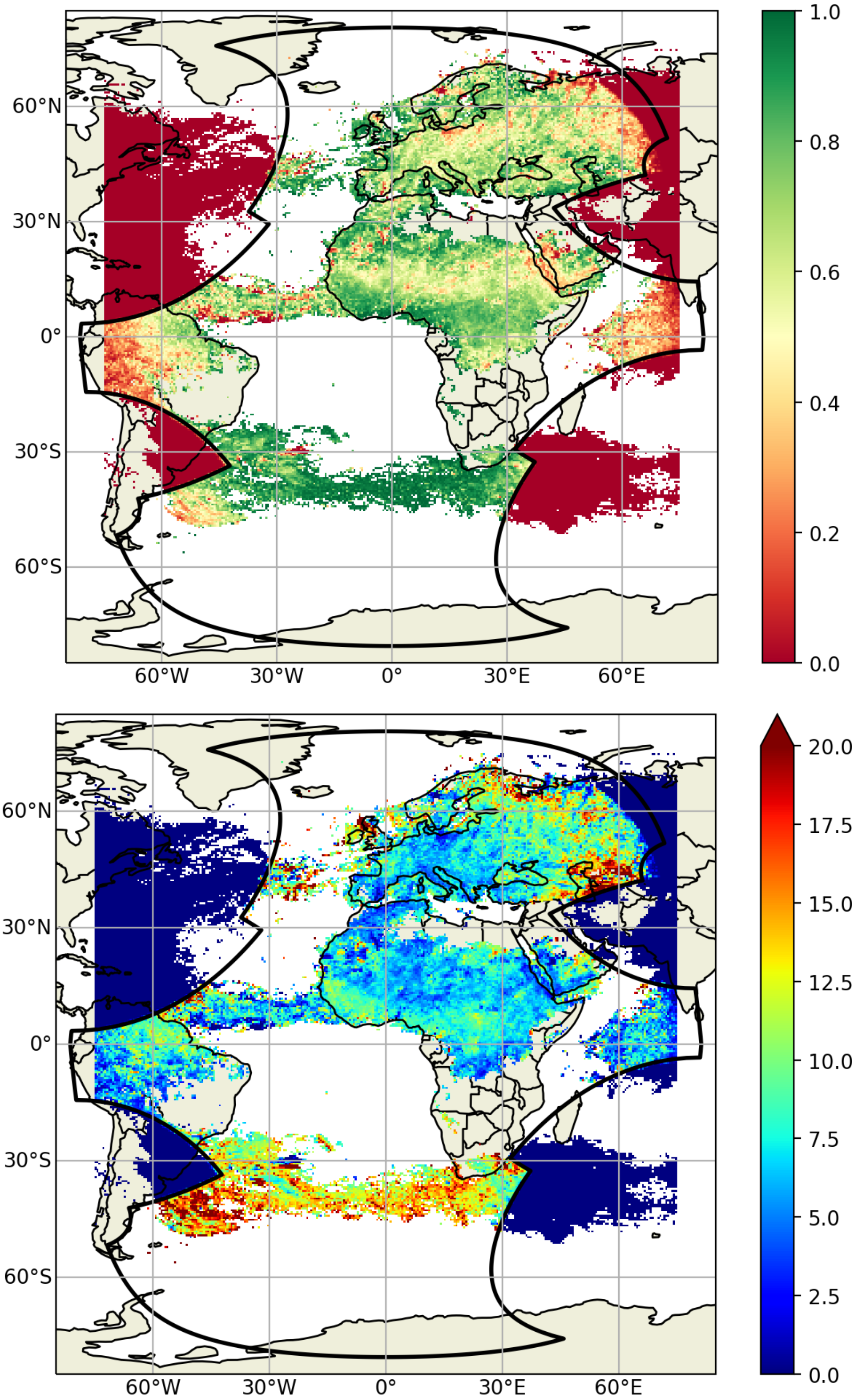


Figure 1: DE at Level 1b (top panel) and LA in km (bottom panel) derived from the matching exercise between LI Level 1b events and GLD360 lightning strokes during the reference time interval July 4, 2024, 00:00 UTC - August 22, 2024, 23:59 UTC.

Table 2: Average (over the LI field-of-view) DE at Level 1b derived from the matching exercise between LI Level 1b events and GLD360 strokes during the reference time interval July 4, 2024 00:00 UTC - August 22, 2024 23:59 UTC.

	LI field-of-view	Central Africa	Southern Europe	South America
Level 1b DE	0.60	0.71	0.66	0.52

Lightning activity is mostly taking place in the northern hemisphere, over central/northern Africa, Europe, part of the Middle East and Russia. In addition, other areas of lightning activity are part of South America and the Atlantic Ocean. Such coverage is the largest so far achieved over a continuous time window by the LI System. Results show the overall good performances at Level 1b. In fact, for most regions in which lightning activity took place, DE is larger than 50% (60% average over the field-of-view; see Table 2). The variability of DE stems from:

1. the performance assessment is done through the comparison between measurements from two systems (LI and GLD360) that perform lightning detection in different ways, i.e., remote sensing of visible photons emitted by lightning channels (LI) and detection of radio waves emitted by lightning strokes (GLD360);
2. the bias of GLD360 towards the detection of cloud-to-ground lightning activity which turns out to be the most challenging type of lightning activity to be detected by LI[2];
3. the impact of the optical properties of the cloud layer between LI and the lightning channels emitting visible photons; optically thick clouds can prevent photons from reaching cloud tops and being detected by LI, in particular when the lightning channel is a cloud-to-ground one (i.e., the vast majority of GLD360 detections)[3];
4. different lightning properties between sea and land, this is exemplified in the systematic higher DE over the southern Atlantic Ocean and Europe (despite the very similar absolute value of the latitude of these two regions).

In addition to the local variability, one can see:

a. the expected degradation of the DE towards the edges of the visible Earth disk (see also the last columns of Table 2). This is most obvious at the north-east edge of the LI field of view (typically starting from 60 deg distance from the sub-satellite point). The drop of the DE is due to the unfavorable observation-geometry, i.e., large angle between the local vertical to the ground and the line of sight of LI;
b. the regions outside the LI field-of-view with DE = 0 % (in dark red); those are regions over which GLD360 (a global lightning location systems) can monitor lightning activity while LI cannot.

With respect to point a, it must be highlighted that despite of the systematic reduction of DE towards the edges of the field-of-view, LI is still very capable of tracking lightning activity in high-latitude regions so far never covered by any lightning imager on a GEO satellite (i.e., above 70°N). Of particular interest are the results obtained over Scandinavian countries.

In the bottom panel of Figure 1 the reader finds the LA for LI Level 1b events (LI-1B-LE) computed against GLD360 strokes. It is important to clarify that GLD360 has overall better

[2] Since LI senses visible photons emerging at cloud-tops, one expects LI to be very capable in monitoring intra-cloud or cloud-to-cloud lightning activity.
[3] EUMETSAT RSP experts successfully performed preliminary tests to relate drops of LI DE (< 20%) and high values of optical thickness of cloud systems.

location accuracy than LI, and it is a suitable reference for location accuracy assessment. In fact, its location accuracy can be as good as 1-2 km in some areas of the LI field-of-view (e.g., Europe). The location accuracy of a single lightning event of LI can be as good as the spatial sampling at sub-satellite point, i.e., 4.5 km. The spatial sampling of a pixel of LI becomes coarser away from the sub-satellite point; for example, over central Europe the LI spatial sampling is of the order of 7-8 km. In the bottom panel of Figure 1, one finds that the LA is always below 10 km, except for few small areas. This means that the LA is always of the order of the pixel spatial sampling, i.e., the best performance obtainable by the system. Currently, the LA assessment against GLD360 is the reference measure of LI INR performances. This can be employed, both during the day and night, despite the availability of the only LI visible channel. It has to be stressed that this method is not bulletproof due to known limitations in the LA of GLD360 over the Atlantic Ocean. This is most likely the main reason for the LI LA degradation visible in the southern Atlantic Ocean and off the coast of the Iberian Peninsula.

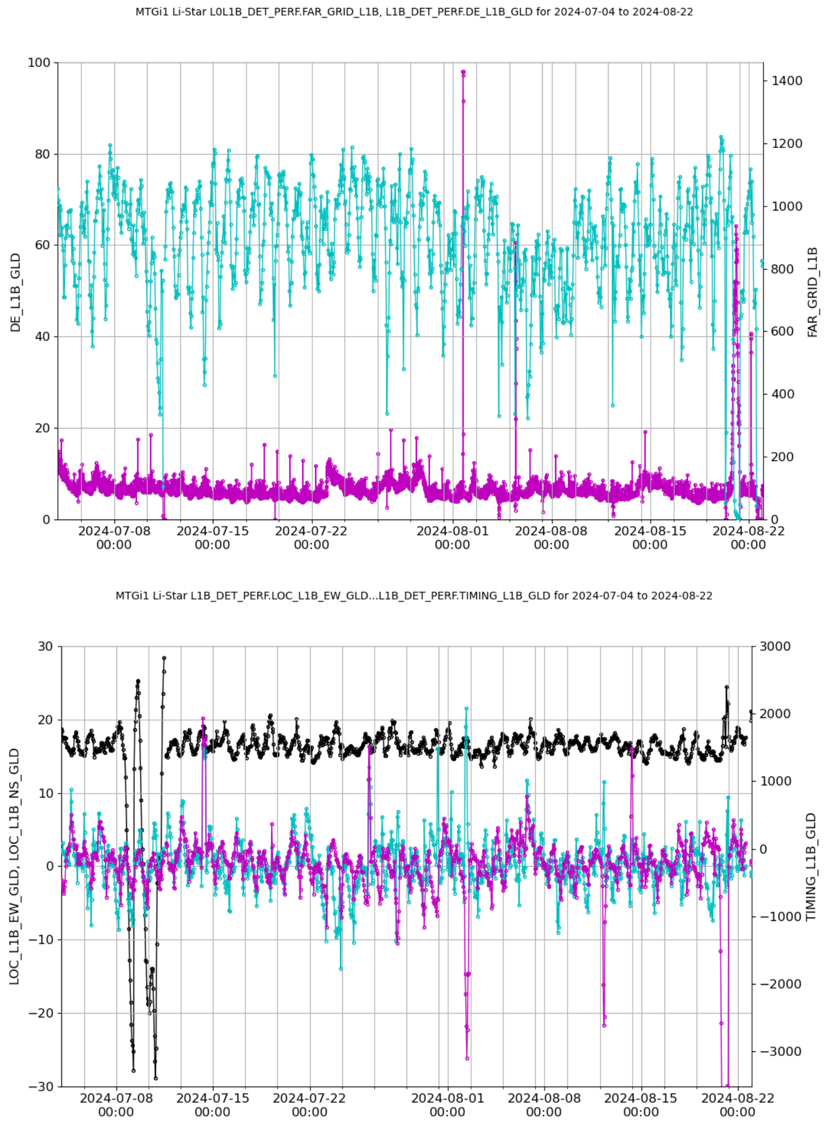


Figure 2: DE and FAR at Level 1b (top panel in cyan and purple, respectively) and North-South and East-West LA in km (bottom panel in purple and cyan, respectively) and TA in µsec (bottom panel in black) derived from the matching exercise between Level 1b events and GLD360 lightning strokes during the reference time interval July

4, 2024, 00:00 UTC - August 22, 2024, 23:59 UTC. In their respective plots, FAR and TA are referred to the y-axis on the right side.

In Figure 2, we present the same results available in Figure 1, but as a function of time. In fact, on the one hand, Figure 1 provides one with average performances over the entire reference time interval as a function of the geographical location in the LI field-of-view. On the other hand, Figure 2 provides one with average performances over the entire LI field-of-view as a function of time. In addition, in Figure 2 one finds: FAR, TA and the north-south and east-west components of LA, respectively.
In the top panel of Figure 2 one can see that the DE presented in Figure 1 have a typical 24h-variation with an additional modulation over longer time-scales (of the order of weeks); the latter with much smaller amplitude with respect to the former. Such result can be explained by considering the changes of illumination conditions through the day combined to the change of location of lightning occurrence within the LI field-of-view (typically over timescales longer than 24h). Both factors impact LI detection capabilities and, consequently, LI DE.
Similarly to the DE, also LA (in Figure 2 bottom panel) presents a regular pattern whose origin is still unclear. However, the most important result from the time sequence of the LA is the evidence of the stability within ±10 km for both north-south and east-west components over about two months. The TA (Figure 2 bottom panel) is very stable and below 2 milliseconds[4], in line with the 1 milliseconds acquisition time.
To complete the assessment of the lightning detection performances at Level 1b, in the top panel of Figure 2 one finds the FAR. This is very stable-in-time, with few short phases of small increase. Only three peaks with very short duration are observed. In addition, one sees the regular “comb” pattern than emerges from the FAR time sequence. This is a known anomaly of the IDPF-I whose solution will soon be available on IDPF-I OPE. The anomaly is impacting the FAR every 2 hours and 10 minutes. The FAR curve is well within the maximum value of 35000 lightning events per second for the FAR. It has to be stressed that this anomaly has no impact on Level 2 products since the Level 2 filtering is effectively removing false events.

In Figure 3, we present the time sequence of key descriptors of the LI Level 1b processing of lightning events. As for Figure 2, the aim of Figure 3 is to prove the stability of the Level 1b processing chain dedicated to the filtering of lightning events. In the top panel of Figure 3, one finds the lightning event rate at Level 0 (i.e., in input to the IDPF-I). The periodic variation of the rate of detections is driven by the change of illumination (already mentioned above to interpret the regular variation of Level 1b DE in Figure 2 top panel). The large variability of the number of lightning detections between daytime and nighttime is due to the different sensitivity of the on-board detection LUTs for different parts of the dynamic range. Since December 2023, the sensitivity over dark scenes (e.g., at nighttime) has been reduced to improve the stability and operability of LI. In the top panel one also finds the lightning event rate at Level 1b (i.e., the output of the IDPF-I). Two main features characterize the Level 1b rate:

1. Strongly reduced rate compared to Level 0 due to the effective lightning event filtering (see bottom panel of Figure 3).
2. Smooth variation with different/shifted temporal cycle (with respect to Level 0) following the lightning activity cycle rather than illumination cycle (i.e., the noise cycle). In detail, maxima are around 16:00 UTC (diurnal lightning activity maximum over Africa and Europe) and

[4] Only for a short time-period, a considerable degradation of TA was observed, this was due to an outage of the data feed of the files used by the IDPF-I to convert OBT into UTC (beginning of July 2024).

minima are around 8:00 UTC during the diurnal minimum of lightning activity in Africa and nighttime dissipation of thunderstorms in South America. On some days, a secondary maximum corresponding to the diurnal lightning activity peak over South America can be seen around midnight[5].

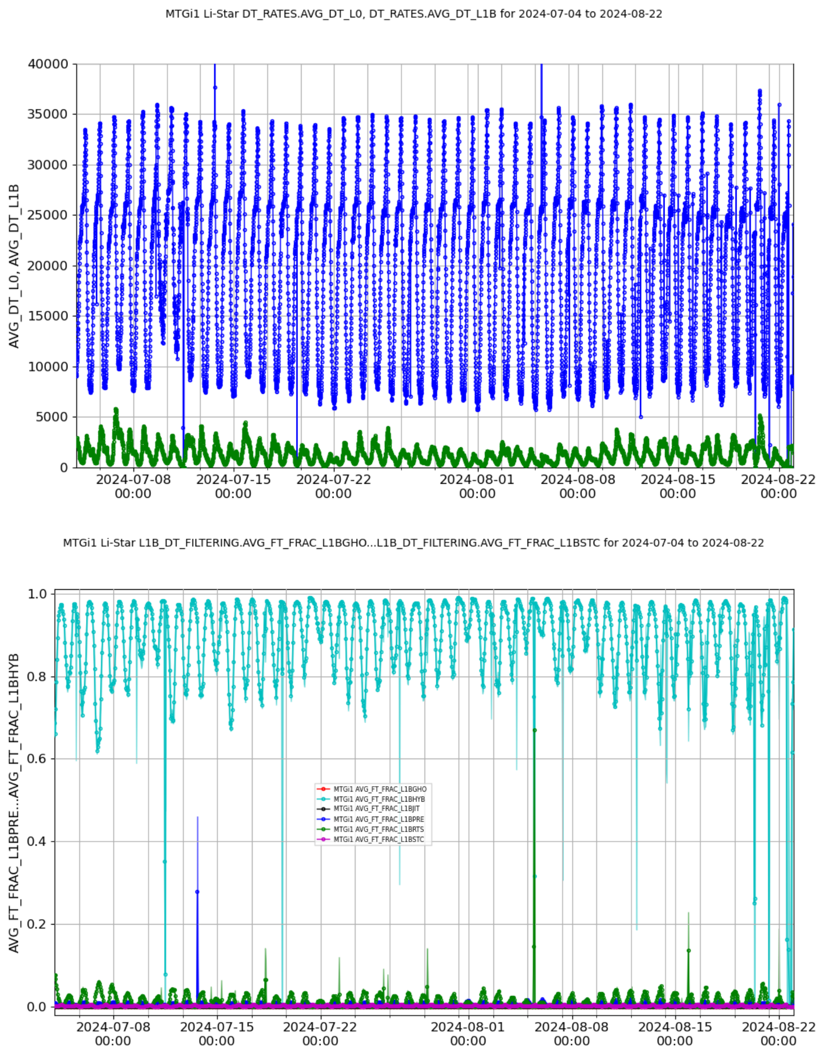


Figure 3: LI lightning event rates per second averaged over 10 min (i.e., each dot in the plot) at Level 0 (i.e., in input to the IDPF-I; top panel in blue) and at Level 1b (i.e., output of the IDPF-I; top panel in green). Fraction of Level 0 events filtered by each Level 1b filter (bottom panel). One can refer to the legend for the interpretation of the colour coding of the Level 1b filters. Each plot is defined during the reference time interval July 4, 2024, 00:00 UTC - August 22, 2024, 23:59 UTC.

In the bottom panel of Figure 3, one learns about the impact of each Level 1b filter to the filtering of false detections. The hybrid (HYB) filter is the main filter for the removal of false detections, with an average fraction of about 90%. The JIT filter has been deactivated following the evidence of very low numbers of false detections due to micro-vibrations. Finally, the use of Level 1b filters may be subject to future tuning/deactivation. In fact, one wants to send to the Spatial-Temporal Coherency filter (STC; currently rejecting less than 1% of Level 0 events) as many events as

[5] Despite LI being capable of detecting lightning activity over South America and Europe, the magnitude of the lightning activity over Africa dictates the temporal cycle observed in the rate of lightning detections.

possible. Differently from the HYB filter that classifies detections one-by-one, the STC filter checks for the correlation between detections, i.e., one of the main properties of lightning activity. In addition, one should not reject about 90% of detections at the beginning of the processing (as we are doing now on OPE), but rather proceed with a stepwise processing that combines different phases of clustering and filtering.

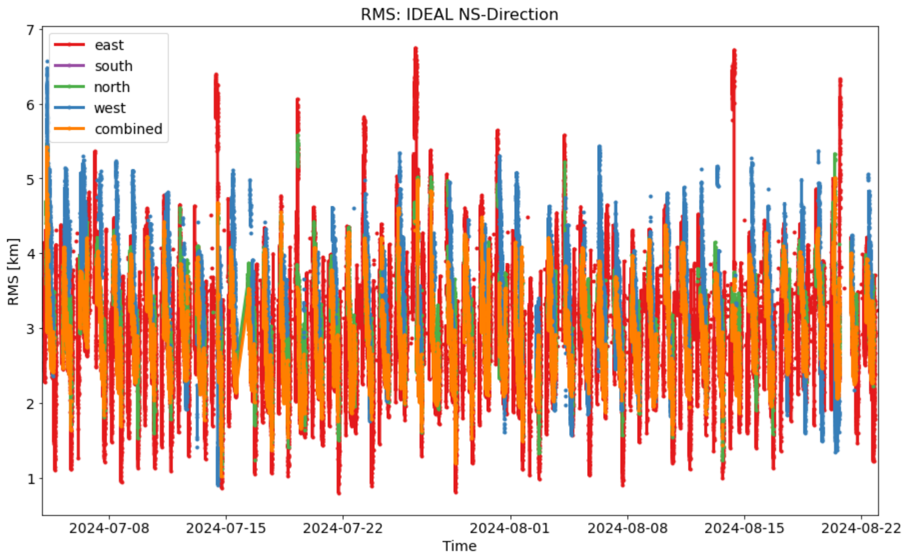
To complement the assessment of INR performances undertaken with LI-STAR, PIQMICS was also employed to certify the minimum geometric quality of the products to enable the operational dissemination of LI Level 2 products. In detail, the objective of the analysis is the validation of requirements for ASPKE) and ASPKE during eclipse period. Here ASPKE stands for Absolute Sample Position Knowledge Error. The original plan was to analyse the ASPKE values provided by the trailer of LI background images. However, as the trailer content is not correct, the test had to be amended to at least achieve some results. The idea now is to complement the missing data with data from other PIQMICS tools:

- ALTO: (ALternative statistics Tool): this takes IDPF observations (via GEOOBS DPP files) and provides additional statistics such as mean values and RMS, but also ASPKE estimates.
- IDEAL (IndepenDEnt Absolute geometry quality tooL): IDEAL works on the background images directly and provides geometric quality information independent of IDPF; however, it is not suitable for ASPKE estimates, but mean values and RMS. This can be used as an alternative metric and is less prone to outliers compared to ASPKE.

Methods based on landmark analysis only work during daytime. Hence, half of the background images analysed cannot provide any useful result. Moreover, there is one trailer per background image i.e. (140 or 141 off). However, there are 10 images in a Level 1b product.

- During the test period, 6983 trailer records were analysed- containing a limited amount of data.
- Due to a problem with the GEOOBS file population, not all of these images can be analysed by ALTO. As a result, only 12935 images could be analysed.
- IDEAL was able to process 68813 images. (Due to a PIQMICS issue, the IDEAL record has a gap between 15.07.2024 14:10 and 16.97.2024 07:40.)

For the sake of shortness, here we focus on the most relevant results, i.e., those from IDEAL RMS (see Figure 4).



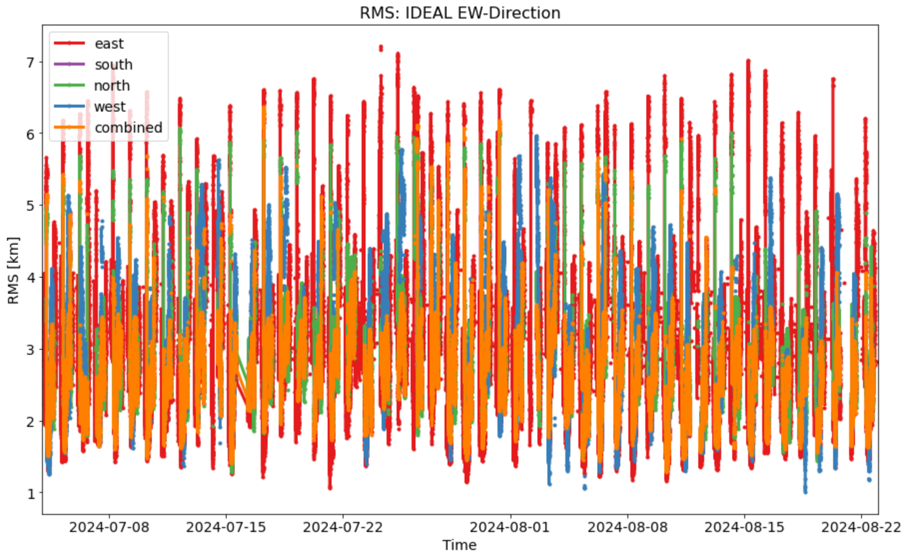


Figure 4: RMS of landmark deviation in NS direction (top panel) and EW direction (bottom panel) from IDEAL during the reference time interval July 4, 2024, 00:00 UTC - August 22, 2024, 23:59 UTC.

LI geometric accuracy suffers significantly over night: night performance cannot be assessed directly, but at dawn-time the observed discrepancies in geometric quality analysis are contributing significantly to the number of non-nominal images. Occasionally, the navigation of LI was significantly out of specification and could only be recovered by a re-start of IDPF. In detail, five occurrences of strong INR degradation were encountered: on July 14 and 26, 2024 and on August 2, 12 and 14, 2024. Such peaks are also found in the bottom panel of Figure 2. Based on IDEAL RMS, 67% of all RCs are nominal, i.e., RMS below 4 km. This may be an overestimation, as during night, where we have no information, the quality might be worse. This percentage is a very low number however, the quality in total is not dramatically bad. If one assesses the percentage of images with an RMS less than 5 km, one finds that nearly 99% of the images satisfy this criterion. It is expected that further tuning of the INR filter, combined with the introduction of the Line-Of-Sight-CALibration algorithm, will be improving these numbers significantly.

In Table 3, we specify the subset of requirements that are verified based on the content of this report. The complete list of requirements are being verified as part of the LI Commissioning

Table 3: LI Level 1b requirements being verified by means of the results included in this report.

Test Procedure	Requirements	Status and/or comment
COM-835500.12-I1 False Alarm Rate at Level 1b – FAR	[SRD] LI-15420	Verified
COM-835500.35-I1 Monitoring Level 1b processing	Cal/Val	Verified
COM-835500.38-I1 Jitter-Reconstruction Filter testing and visualization of the Micro-Vibration Window measurements	Cal/Val	Descoped (see **Error! Reference source not found.**). It was checked that the processing chain does not reject events through the Jitter-reconstruction filter

Test Procedure	Requirements	Status and/or comment
COM-835500.10-I1 DE and triggered events – group-to-stroke analysis	[SRD] LI-15390	This requirement cannot be verified using real data. It has been verified by industry using the LI Simulator. However, in this report EUMETSAT shows the goodness of Level 1b performances by mean of the comparison against an external lightning location system, i.e., GLD360.
COM-835500.30-I1 ASPKE – Monitoring of basic GQA	[SRD] LI-15690	This requirement is specified in terms of ASPKE. However, the Trailers and the GEOOBS files do not contain the information needed for the ASPKE assessment/monitoring. The IDEAL tool is employed for overall quality assessment of INR performances. Results from IDEAL are complemented by those from the matching exercise between LI and GLD360 both at Level 1b and Level 2.

LEVEL 2 PERFORMANCES

In Figure 5 the reader finds DE and LA for Level 2 groups (LI-2-LGR) computed against GLD360 lightning strokes using the matching exercise.

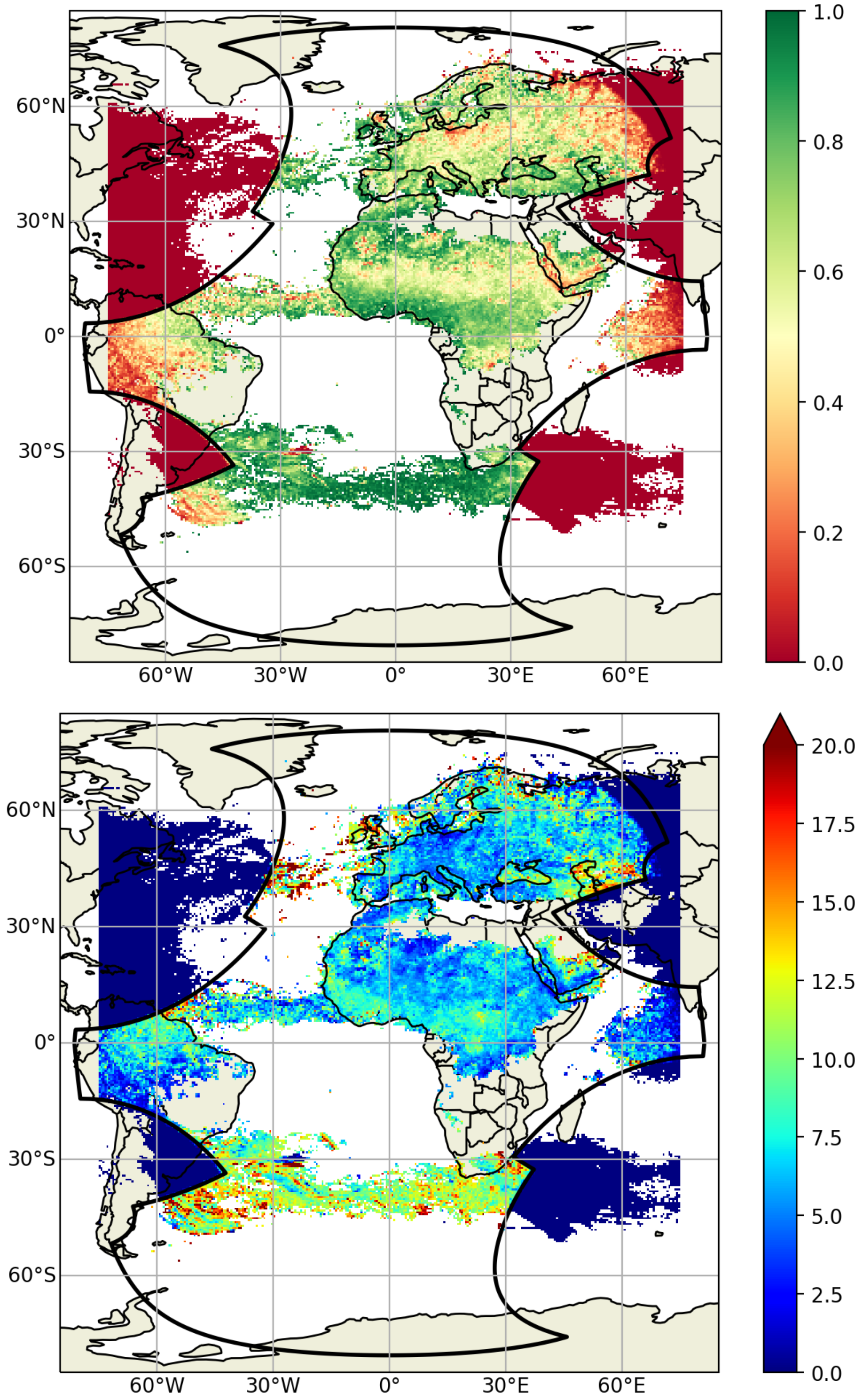


Figure 5: DE at Level 2 (top panel) and LA in km (bottom panel) derived from the matching exercise between LI Level 2 groups and GLD360 lightning strokes during the reference time interval July 4, 2024, 00:00 UTC - August 22, 2024, 23:59 UTC.

Level 2 groups are one of the products that EUMETSAT is disseminating to users and can be used as a “tie-point” between Level 1b and Level 2 to evaluate the quality of flashes. The definition of groups is a collection of neighbouring lightning events acquired at the same time (i.e., in the same acquisition frame; see [LIL2PUG] or [LIL2ATBD]). This means the matching exercises LI-1B-LE (events)-GLD360 strokes and LI-2-LGR (groups)-GLD360 strokes are actually very similar. There is however an important difference: Level 2 groups are the outcome of the Level 2 filtering. To clarify, by configuring the Level 2 processing to exercise no filtering of lightning events, one would find that Level 2 groups contain exactly the lightning events at Level 1b, and the two matching exercises mentioned above would give one almost exactly the same result. This means that when exercising the filtering at Level 2, comparing the outcome of the matching exercises at Level 1b for events and at Level 2 for groups gives one a good understanding of the impact of Level 2 filtering on lightning detection performances. If the Level 2 filtering is effective in removing false detections and keeping true lightning, the detection efficiency for Level 2 groups must be very close to the detection efficiency for Level 1b events. From a direct comparison of the top panels of Figure 1 and Figure 5 one can see that the DE maps are very similar. By comparing Table 2 and Table 4 one finds out that Level 1b DE is 60% while Level 2 DE is 56%. In the time sequence in the top panel of Figure 8, such difference is visualized over time, following the daily cycle. For the LA (bottom panel of Figure 5), one finds that for Level 2 groups the LA is better in some geographical areas than for Level 1b events (bottom panel of Figure 1). This result may stem from the definition of location of Level 2 groups: the average of the locations of the events composing the group weighted by the radiance of each event. When performing the matching exercise between LI and GLD360, one is relating GLD360 detections with optical pulses observed by LI that often illuminate multiple LI pixels in the same acquisition frame (i.e., the definition of a group). The radiance-weighted average of locations tends to put the group location into the “core” region of the corresponding lightning stroke/pulse, and it is also more likely to find the strong radio source in that region.

In Figure 6 and Figure 7 the reader finds DE for Level 2 flashes (LI-2-LFL) from a comparison with GLD360 and GLM, respectively. Although GLD360 uses somewhat different flash definition from the one of LI, the simple fact that a flash is a collection of lightning detections correlated in space and time mitigates the differences in the way different types of lightning systems perform lightning detection and their product definition (see [LIL2ATBD] and [LIL2PUG]). This usually maximises the performances of one system with respect to another one. If one compares the top panel of Figure 5 and Figure 6, it is evident that LI Level 2 DE performances at flash level are systematically higher than those at group level (see also the time sequence in the top panel of Figure 8). Table 4 shows that, over the entire field-of-view, the increase in DE from groups to flashes is of the order of 15%. The LI Level 2 flash detection efficiency with respect to GLD360 is of 72%. For completeness, in Figure 7 one finds the Level 2 detection efficiency for flashes relative to GLM. This result shows that the DE relative to GLM is overall higher than the one against GLD360. This is because LI and GLM perform lightning detection in the same way and the key elements of the processing chains of the two systems are actually very similar (including the definition of lightning flashes). Local minima are still visible in areas with very good detection performances. Those can be due to short outages in the production of LI Level 2 data during the reference period, or temporary drops in Level 2 detection performances. It must be stressed that the performance assessment here presented covers only two months of LI measurements and a complete/exhaustive performance assessment should take place over years.

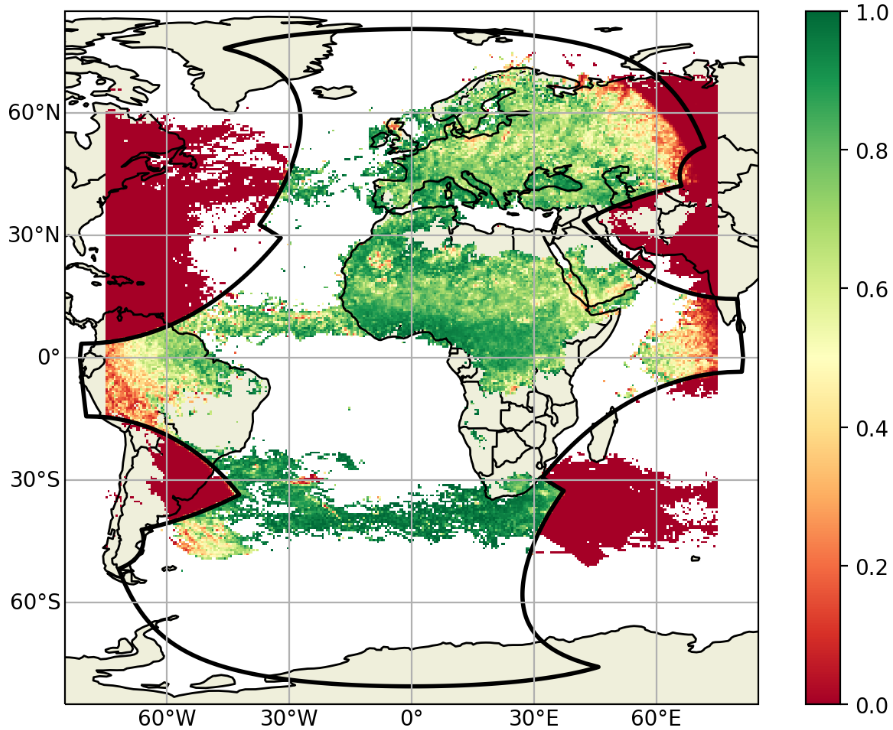


Figure 6: Flash DE at Level 2 derived from the matching exercise between LI Level 2 flashes and GLD360 flashes during the reference time interval July 4, 2024, 00:00 UTC - August 22, 2024, 23:59 UTC.

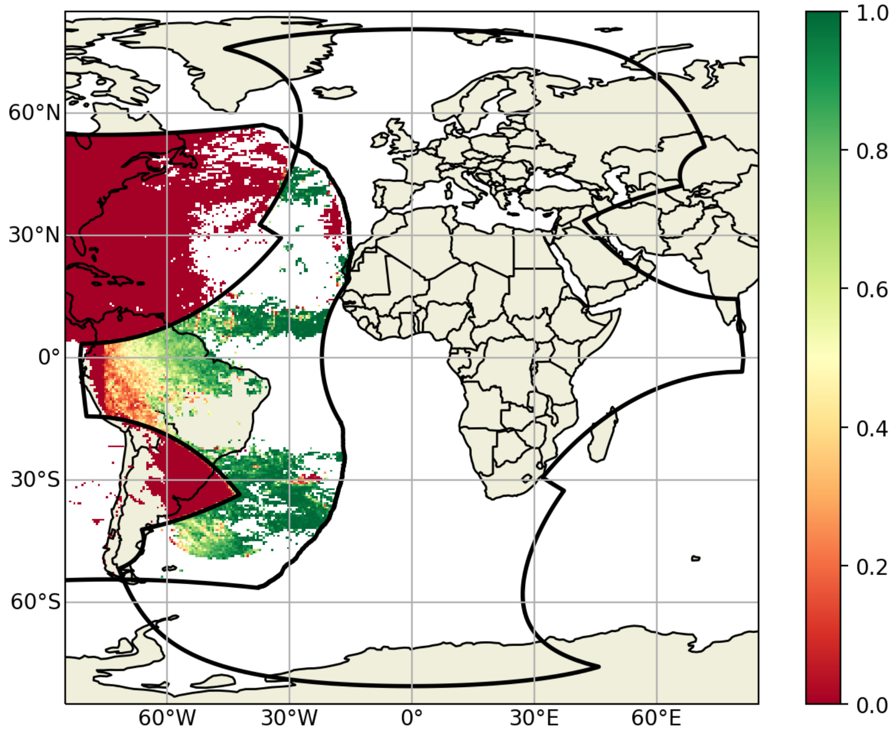


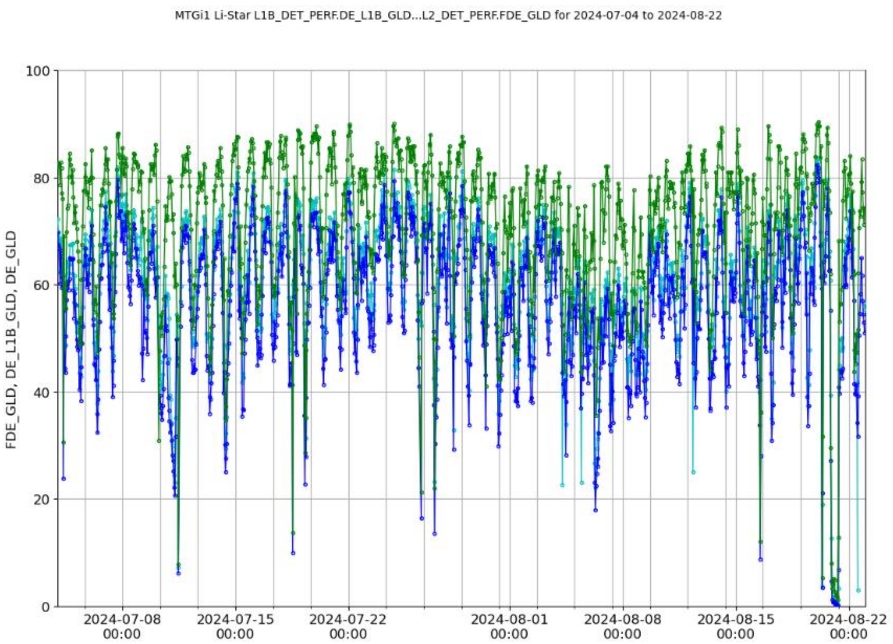
Figure 7: Flash DE at Level 2 derived from the matching exercise between LI Level 2 flashes and GLM-16 flashes during the reference time interval July 4, 2024, 00:00 UTC - August 22, 2024, 23:59 UTC.

Level 2 flash detection efficiency shall be regarded well within the expected requirements To be noted, in [EURD] the requirement on the flash detection efficiency is set at 70% over the field-of-

view, i.e., the requirement appears to be verified. However, no reference network is specified in the requirement, i.e., flash detection efficiency should be checked against total lightning activity. This assessment is not possible since there is no system capable of monitoring the entire lightning activity over the LI field-of-view with 100% detection efficiency, i.e., the requirement is ill defined. Starting from the results of Figure 6 and Figure 7, one could assess the upper limit of the flash detection efficiency by means of a Bayesian[6] techniques. This work is currently on-going in cooperation with external experts from the US.
In the last three columns of Table 4, one also finds three values for the detection efficiency derived from three regions of interest within the LI field-of-view. DE values for central Africa and southern Europe are very high. In central and northern Europe, lightning detection performances are in line with the figures obtained over southern Europe (as visible in Figure 7). Performances over South America are below average, and this is due to the expected degradation of the LI sensitivity near the edges of the field of view. These are very promising results derived on samples of matches of the order of 10^6-10^7. In general, compared to the DE map in Figure 1, in Figure 5 one can see that the flash DE is less affected by local/regional variations, rather by variations over large scales, in particular by the drop towards the edge of the field-of-view.

Table 4: Average (over the LI field-of-view) DE at Level 2 derived from the matching exercise between LI Level 2 groups/flashes and GLD360 strokes/flashes during the reference time interval July 4, 2024, 00:00 UTC - August 22, 2024, 23:59 UTC.

	Level 2 Groups	**Level 2 Flashes**	**Level 2 Flashes Central Africa**	**Level 2 Flashes Southern Europe**	**Level 2 Flashes South America**
Level 2 DE	0.56	0.72	0.82	0.78	0.65



[6] Bitzer, Phillip M., and Jeffrey C. Burchfield, "Bayesian techniques to analyse and merge lightning locating system data."; Geophysical Research Letters 43.24 (2016).

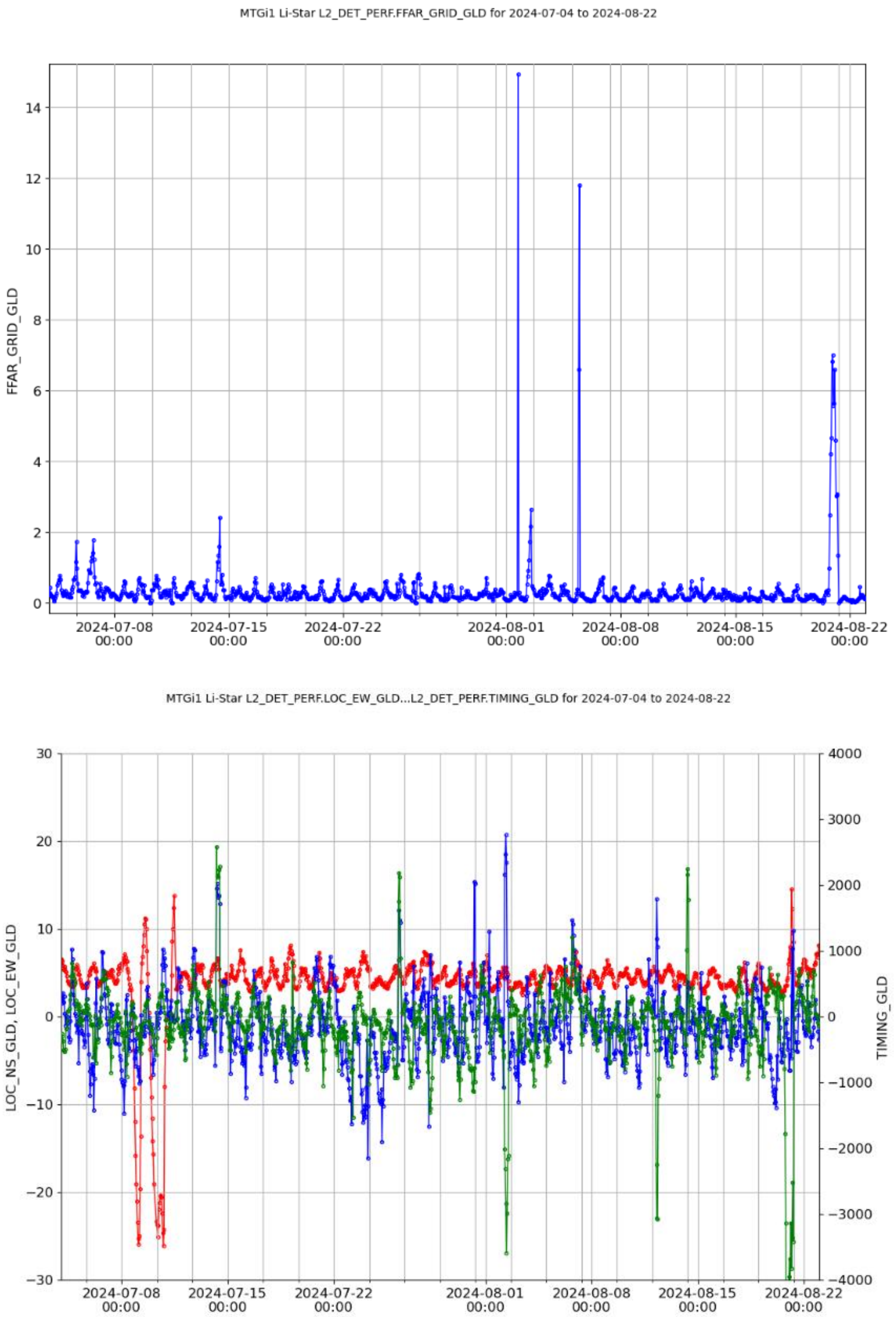


Figure 8: Level 2 Group DE (top panel in blue), Level 1b DE (top panel in cyan; as in Figure 2), and Level 2 Flash DE (top panel in green), Flash False Alarm Rate (FFAR in number of flashes per second; middle panel), East-West LA (bottom panel in blue) and North-South LA (bottom panel in green) in km and Timing Accuracy in µsec (bottom panel in red) derived from the matching exercise between LI Level 2 products and GLD360. Each plot is defined during the reference time interval July 4, 2024, 00:00 UTC - August 22, 2024, 23:59 UTC.

Figure 8 is meant to provide the reader with a different view of Level 2 performances, i.e., their behaviour over time. In particular, the three panels show the temporal stability of Level 2 performances and representativeness of accumulated performances over 24h.

Three comments are due on Figure 8:

1. In the top panel, one can see the variation of Level 2 Flash DE (related to Figure 6), Level 2 Group DE (related to Figure 5) and Level 1b DE (same as Figure 2), respectively. As discussed

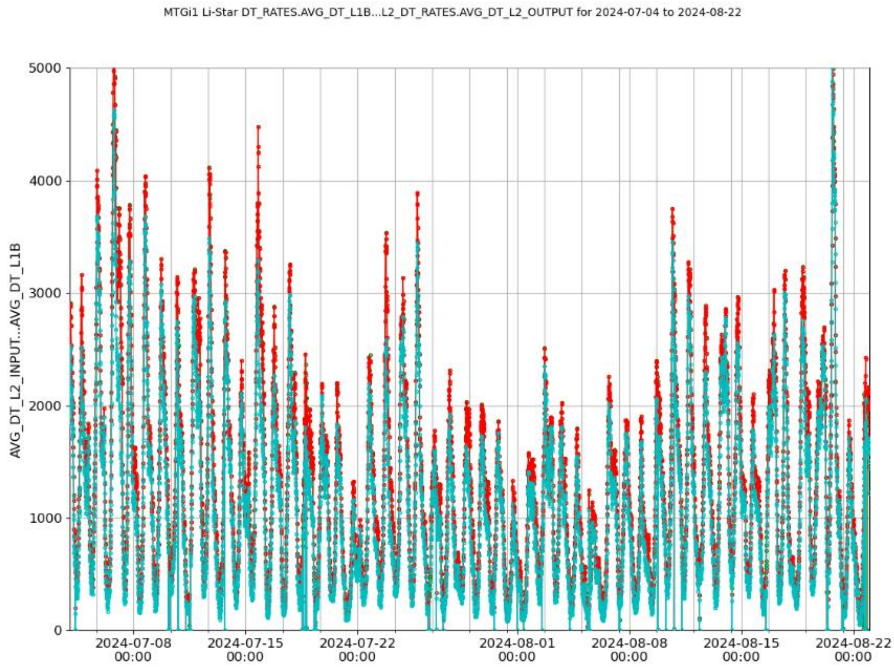
at the beginning of this section, one can see that Level 2 Group DE and Level 1b DE have very similar values along the entire time sequence. In detail, Level 2 Group DE is few percentage points lower than Level 1b DE. This is the measure of the impact of the Level 2 filtering on performances achieved at Level 1b. As expected, Level 2 FDE are systematically higher and generally vary between 90% and 60%. Rarely, Level 2 FDE can be very low due to short gaps in LIL2 processing or large INR issue. As for Figure 2, Level 2 FDE has a clear 24h variation with an additional modulation over longer timescales (of the order of weeks). The key factors impacting Level 2 performances are the variation of illumination conditions through the day combined to the change of location of lightning occurrence within the LI field-of-view (typically over timescales longer than 24h).

2. In the bottom panel, Level 2 LA and TA are very much in line with the same quantities at Level 1b (presented in Figure 2 bottom panel). This result is in contrast with the differences between the LA maps in Figure 1 and Figure 5, i.e., average performances over the entire field of view are not impacted by the difference between events and groups. In fact, average LA over the whole field of view is good for monitoring overall performances and spotting INR anomalies, but not good for highlighting local/“natural” LA variations. In detail, average LA over the entire LI field-of-view as a function of time is very close to the same quantity at Level 1b. The origin of the variation of the TA is still unclear. Most likely this is due to a combination of the following factors: *i)* diurnal changes in the locations of the dominant lightning regions in the FOV (combined to the LA of GLD360 in those regions), *ii)* diurnal changes in the quality of INR (discussed in the previous bullet) and *iii)* some diurnal and regional changes in how well the parallax correction[7] is accounting for the thunderstorm top height.
3. In the middle panel, the origin of the three prominent FFAR peaks is understood. These are due to a short outage of reference GLD360 data (August 1, 2024), an object transiting the LI field-of-view (August 5, 2024) and temporary INR degradation following a station-keeping manoeuvre (August 20-21, 2024), respectively. To be noticed, the on-board detection and data regulation settings designed to prevent the instrument from locking in case of transit of an object in the LI field-of-view worked as expected. Finally, the “comb” regular pattern visible at Level 1b (see Figure 2) is not present at Level 2. The Flash FAR is very stable-in-time and well within the requirement. Finally, the systematic difference of about 1 millisecond between the TA at Level 1b (bottom panel of Figure 2) and Level 2 is still under investigation.

In Figure 9, we present the time sequence of key descriptors of the LI Level 2 processing of lightning groups and flashes. In the top panel of Figure 9, one finds the lightning event rate at Level 1b (i.e., in input to the L2PF). From Level 1b, the diurnal variation of the rate of detections (and groups and flashes) is driven by the temporal evolution of the lightning activity. In fact, as shown in the middle panel of Figure 8, the number of false events at this point of the processing is very small. In line with this, the reduction in the rate of events from Level 1b to Level 2 is much smaller than the reduction observed from Level 0 to Level 1b. From the bottom panel of Figure 9, one learns about the impact of each Level 2 filter to the filtering of false detections. Only few filters of the LI Level 2 baseline are currently employed. For groups, L2PF rejects collections of events associated to particles impacting the focal plane as well as groups containing events with saturated radiances. For flashes, the facility rejects (initially) any flash with less than three groups. After the flash rejection, there is a step of a posteriori re-introduction which can bring back initially filtered flashes if they are found in the same location of true flashes within a certain time window. Finally, L2PF also takes care of handling the duplication of flashes in areas of overlap between

[7] The EUMETSAT LUT for parallax correction is employed to correct the location of LI measurements before executing the matching exercise.

the OCs. The filter with the strongest impact, as expected, is the one rejecting flashes with one group (FSINGLEG).



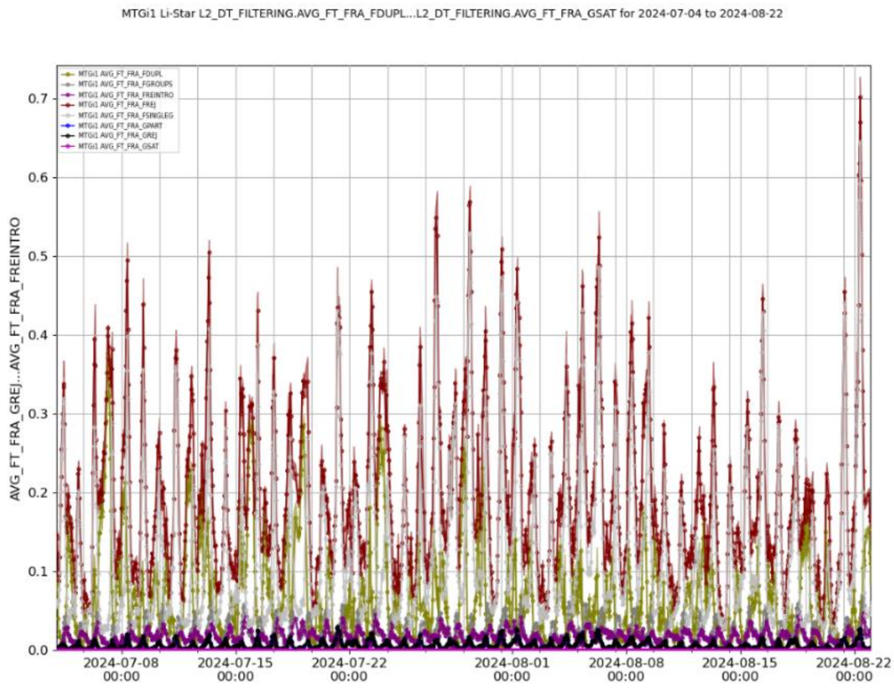


Figure 9: LI lightning event rates per second averaged over 10 min (i.e., each dot in the plot) at Level 1b (i.e., in input to the L2PF; top panel in red), after the Level 2 acceptance step (in green; barely visible below the red) and Level 2 (i.e., output of the L2PF; top panel in cyan). Fraction of Level 1b events filtered by each Level 2 filter (bottom panel). One can refer to the legend for the interpretation of the colour coding of the Level 2 filters. Each plot is defined during the reference time interval July 4, 2024, 00:00 UTC - August 22, 2024, 23:59 UTC.

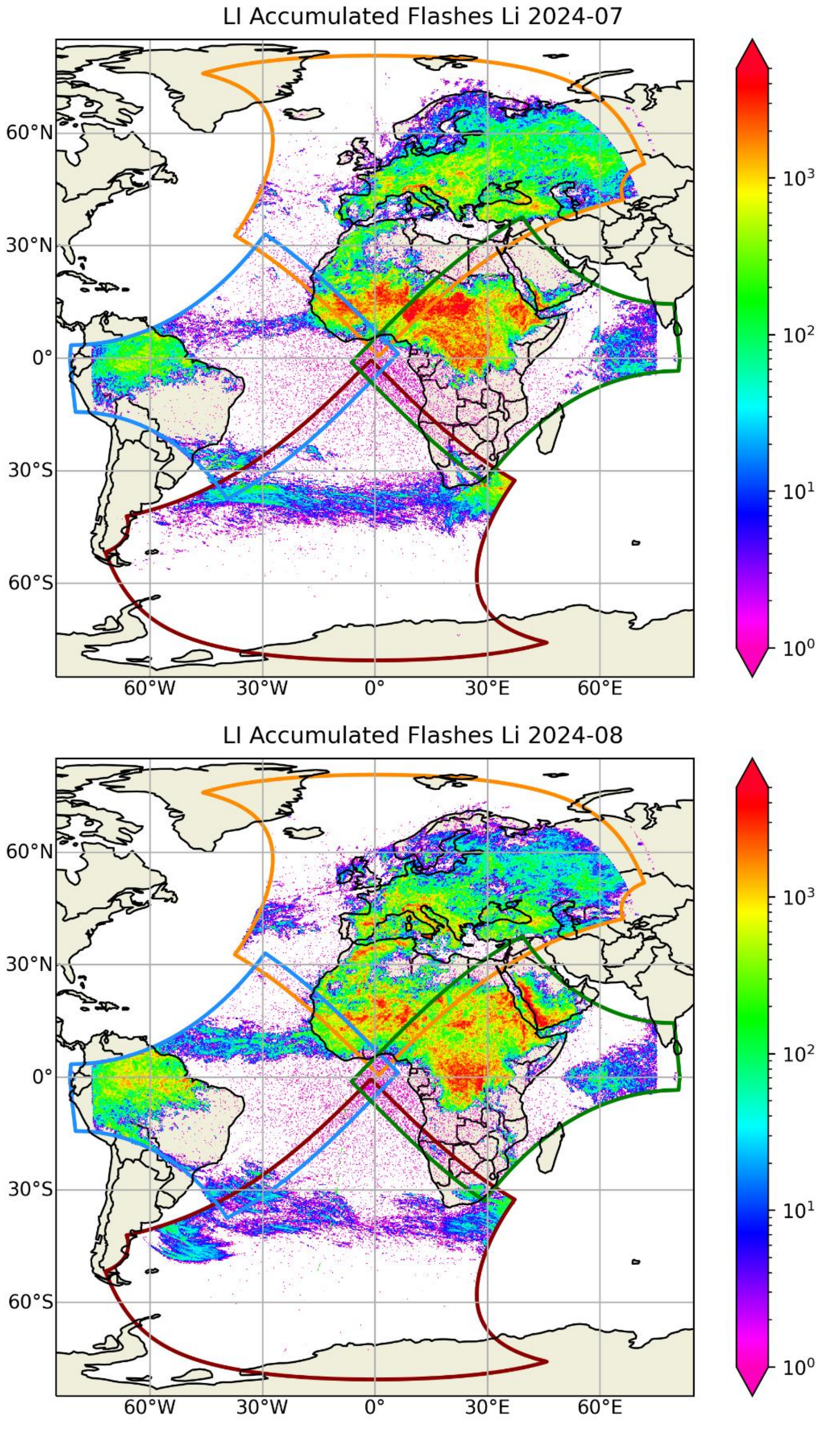


Figure 10: monthly lightning flash climatology from LI during the months of July and August 2024.

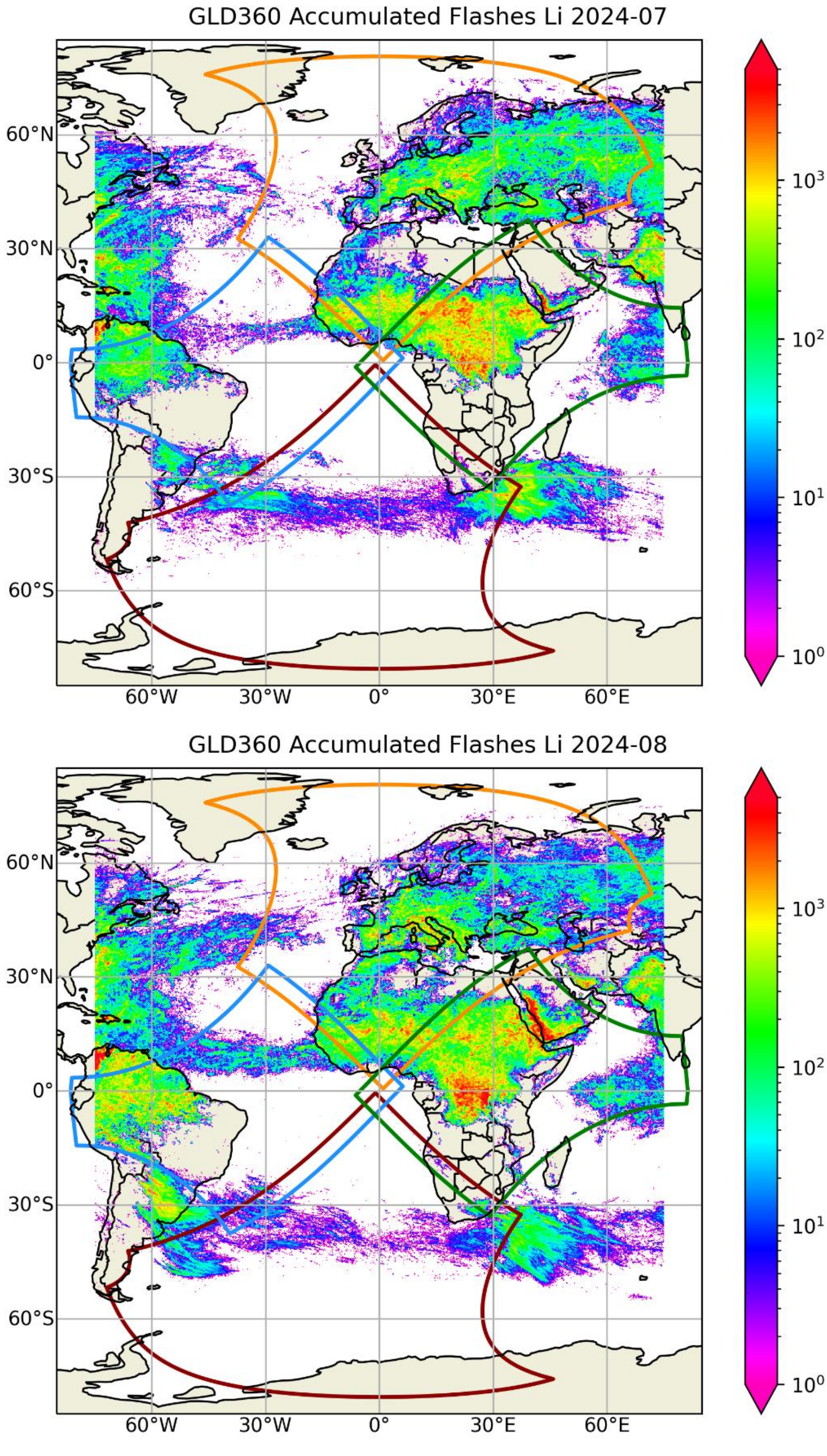


Figure 11: monthly lightning flash climatology from GLD360 during the months of July and August 2024.

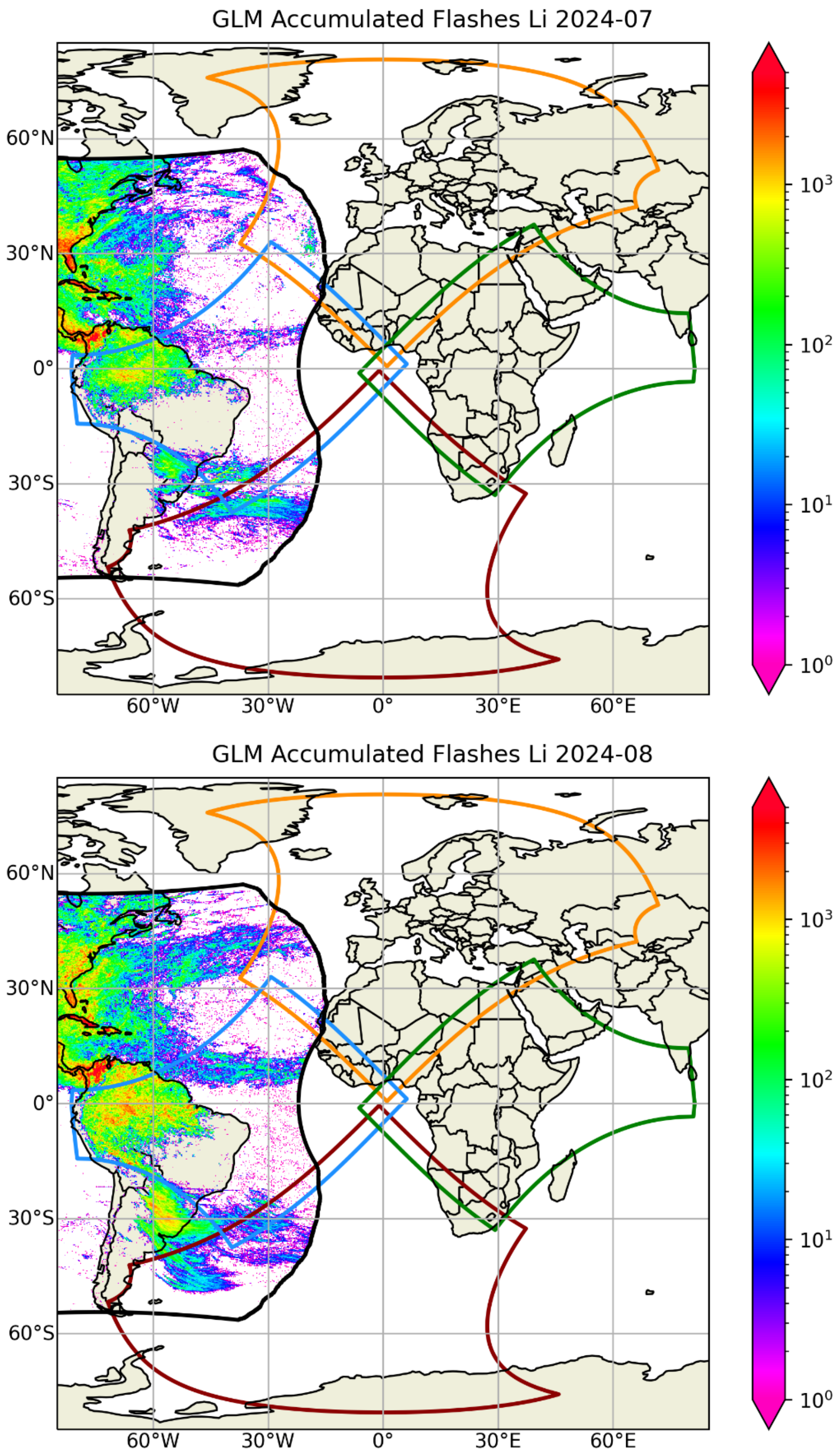


Figure 12: monthly lightning flash climatology from GLM on GOES-16 (GLM-16) during the months of July and August 2024 (only part of the field-of-view is presented in this representation).

Figure 10, Figure 11, and Figure 12 present three different sets of monthly flash climatologies for the months of July and August 2024. From these, one can visually check:

1. The overall agreement between the spatial lightning patterns found within the field of view of the three lightning location systems LI, GLD360 and GLM-16.
2. The considerable larger number of flashes observed by the LI System compared to GLD360. This difference stems from the capability of LI of monitoring the total lightning activity compared to any ground based global lightning detection system. The most striking difference is found in the number of flashes measured over the African continent.
3. The very good agreement between GLM-16 and LI in the overlap region of the field-of-views of the two systems. The agreement is particularly good over the Atlantic Ocean where LI had very high detection efficiency compared to GLM-16 (see Figure 7).
4. The comparable level of FFAR for LI and GLM-16. This is visible as a diffused purple detections covering more or less uniformly the field-of-view of the two instruments. To be noted, the level of false alarm rate in GLD360 is orders of magnitude lower than for the two satellite-based systems. This difference stems from the different nature of the measurements of a visible imager and a very low frequency detection system. The former is strongly impacted by false detections originating from radiometric (shot) noise.

In Table 5, we specify the subset of requirements that are verified based on the content of this report. The complete list of requirements are being verified as part of the LI Commissioning.

Table 5: LI Level 2 requirements being verified by means of the results included in this report.

Test Procedure	Requirements	Status and/or comment
COM-835500.10-I1 DE and triggered events – group-to-stroke analysis	[SRD] LI-15460	Verified
COM-835500.13-I1 False Alarm Rate – FAR and FFAR	[SRD] LI-15450	Verified
COM-835500.14-I1 DE and triggered events – flash-to-flash analysis	[SRD] LI-15460	Verified
COM-835500.33-I1 Climatology of lightning detection	Cal/Val	Verified
COM-835500.39-I1 Monitoring of the Level 2 data	Cal/Val	Verified
COM-835500.46-I1 Filtering Parameters Configuration	[SRD] LI-15450 [SRD] LI-15460	Verified

LI SYSTEM DURING ECLIPSE SEASON

Starting from August 22, 2024, the Sun is transiting in proximity of inside the LI field-of-view. During this period, the LI System is put “under stress” due to very specific observational conditions that produce considerable increase of false detections around 00:00 UTC. In addition, when the Sun transits in a specific location of the deep space corner of OC2, EUMETSAT has been instructed by ESA and Industry to interrupt the detection of lightning events over a time window of about 2 hours only for LI OC2. In this section we provide the reader with a high-level description of the behaviour of the LI System during this time of the year with the aim of demonstrating that a good level of stability through eclipse season has been achieved, i.e., the LI System is suited for operational dissemination.

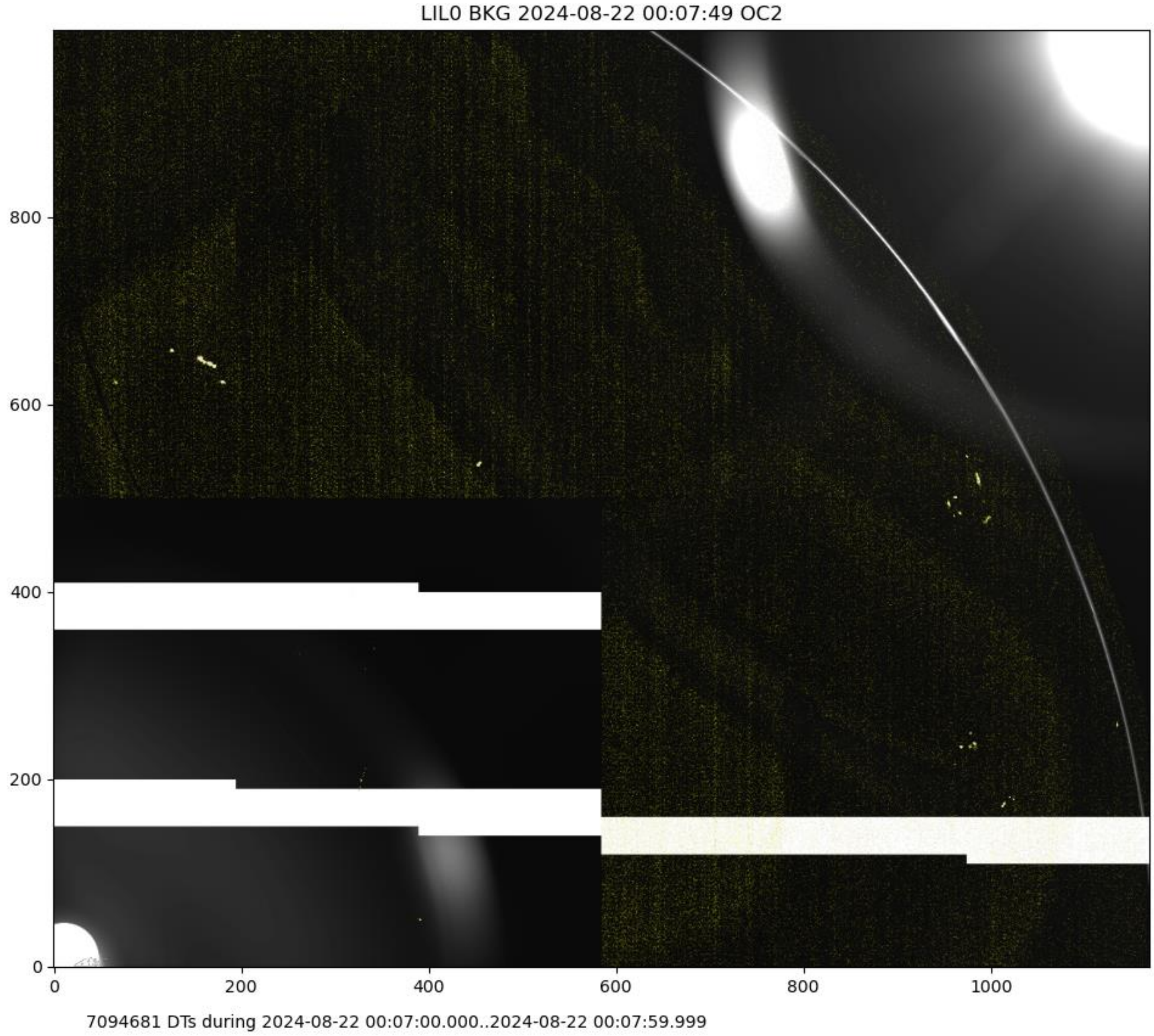


Figure 13: LI Level 0 lightning events accumulated over one minute (yellow pixels) overlaid on Level 0 background image for OC2. The time of the background image is presented at the top of the image, while the number of lightning detections (detected transients DTs) is presented at the bottom.

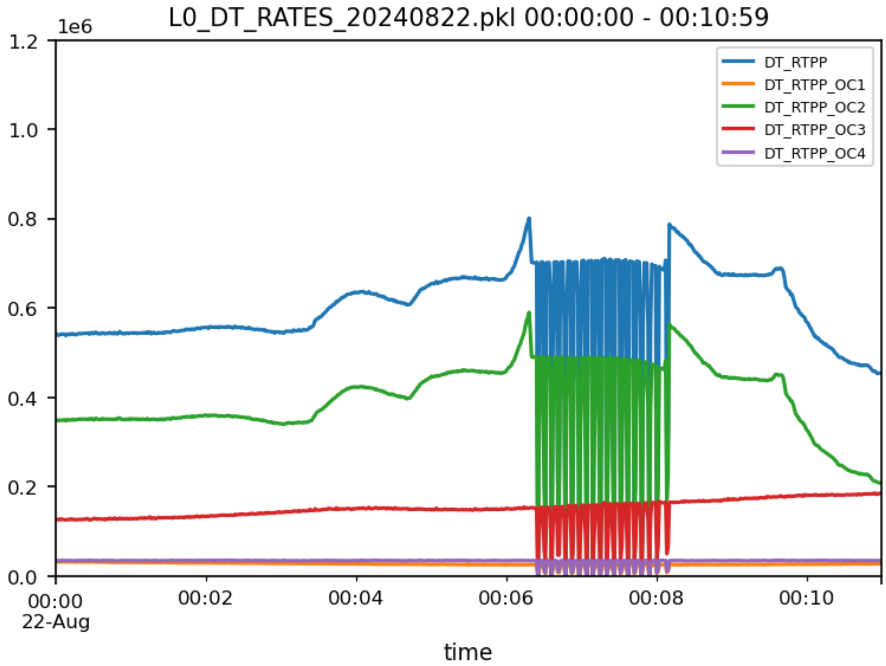


Figure 14: LI Real Time Pixel Processor (RTPP) counter of LI detections for all LI OCs. The time interval of the plot is provided at the top and it encompasses the time of the observation of Figure 13.

Figure 13 and Figure 14 present the observation conditions of the first day of direct Sun imaging in LI OC2. Both representations show a time interval of about 1-2 minutes around 00:07 UTC during which there is an on-board buffer saturation which causes missing information in the downlinking to the ground. This is clearly visible in the background image of Figure 13 in which portions of the image are missing.

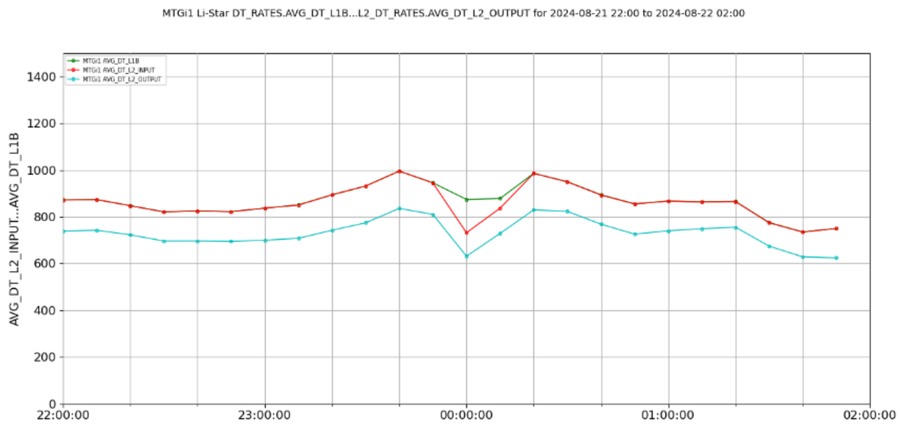


Figure 15: LI detection rates per second averaged over 10 min (i.e., each dot in the plot) at Level 1b (i.e., in input to the L2PF; in green, barely visible below the red), after the Level 2 acceptance step (in red) and Level 2 (i.e., output of the L2PF; in cyan). The plot is defined during the reference time interval August 21, 2024, 22:00UTC and August 22, 2024, 02:00UTC.

Figure 15 shows that the LI end-to-end processing chain can handle the direct Sun imaging without any processing interruption and/or transition to unstable behaviour with a small deviation from the nominal behaviour around midnight. The affected time window is between 23:40UTC and

00:20UTC. A few details about the data production report during the nights of August 22-September1, 2024, are provided in the following: *a small number of intermittent missing Level 1b LE chunks (#28, 30, 32 and 34) is observed when the Sun is imaged by LI. There is no extended impact on production. In fact, nominal production resumes once the Sun leaves the field-of-view.. The same anomaly was observed for all the nights between August 22 and September 1, 2024. The system kept processing through the critical phase.*

During part of the eclipse season, OC2 covers Europe. OC2-based lightning detection will have to be interrupted as a planned activity. Regarding the days in which the lightning detection for OC2 is interrupted, the following report on data production is available: *for four consecutive nights (September 3-7, 2024), OC2 lightning detections were disabled, each night the impact was the following one:*

- *Level 1b: one incomplete LI-1B-LE RC at the time lightning detections is re-enabled..*
- *Level 2: missing accumulated products for the complete duration that LOC2 DTs are disabled (from about 23:30UTC to 02:00UTC) each night..*

It is worth stressing that the non-nominal increase of detections of events was observed for only one night of the four. Figure 16 presents one with the magnitude of the non-nominal detections. The same type of issue occurred between October 5 and 7, 2024.

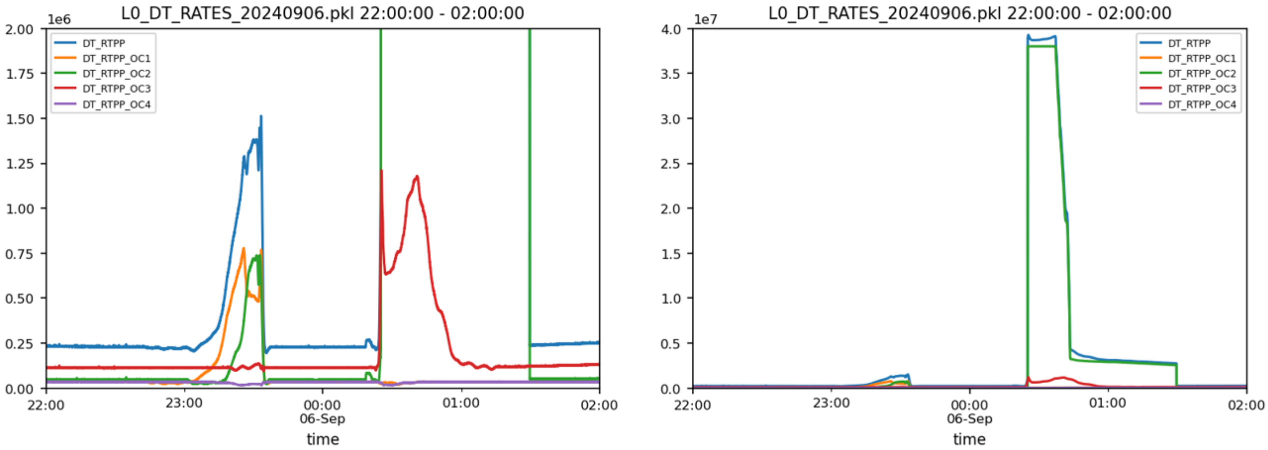


Figure 16: LI Real Time Pixel Processor (RTPP) counter of LI detections for all LI OCs. The time interval of the plot is provided at the top and it encompasses the time of the non-nominal increase of detections. The two plots are meant to capture the difference in dynamic range for OC1, 3, and 4 (left) and OC2 (right), respectively.

To conclude, the combination of LI instrument operations and system stability during eclipse season shall be regarded good to support operational dissemination of LI Level 2 products to users.

LI SYSTEM DURING OBJECTS TRANSITING THE FIELD OF VIEW

During the last two years, several occurrences of objects transiting the LI field-of-view have been observed. This specific type of observation is known to cause a sudden increase in the number of detections that is then propagated at the end of the processing chain into Level 2 products. Figure 17 shows a recent occurrence of an object transiting the LI field-of-view from east to west seen in LI OC2 and OC3.

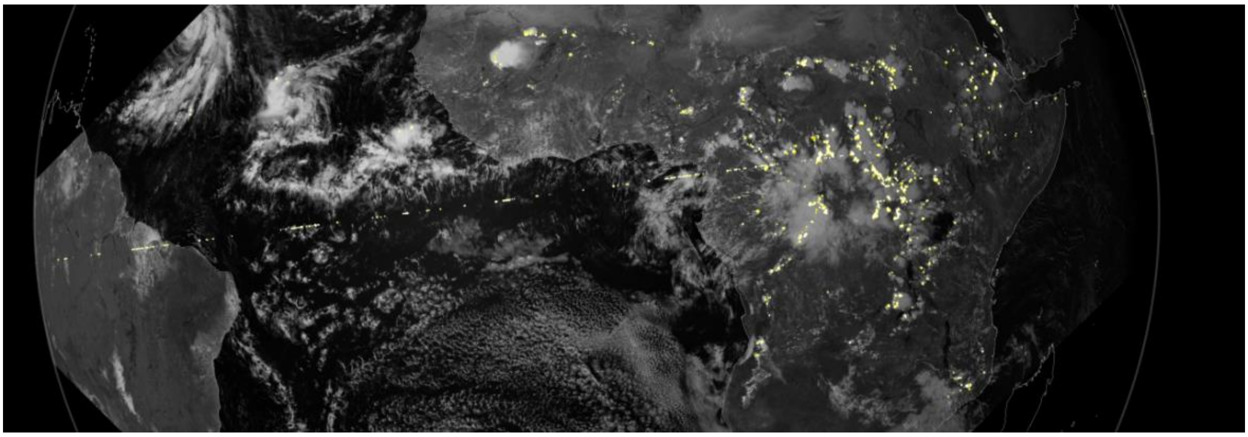


Figure 17: LI Level 1b events overlaid on LI Level 1b background images for October 2, 2024, at 13:35UTC. The transit of the object in the LI field of view generates a streak of false events almost parallel to the equator.

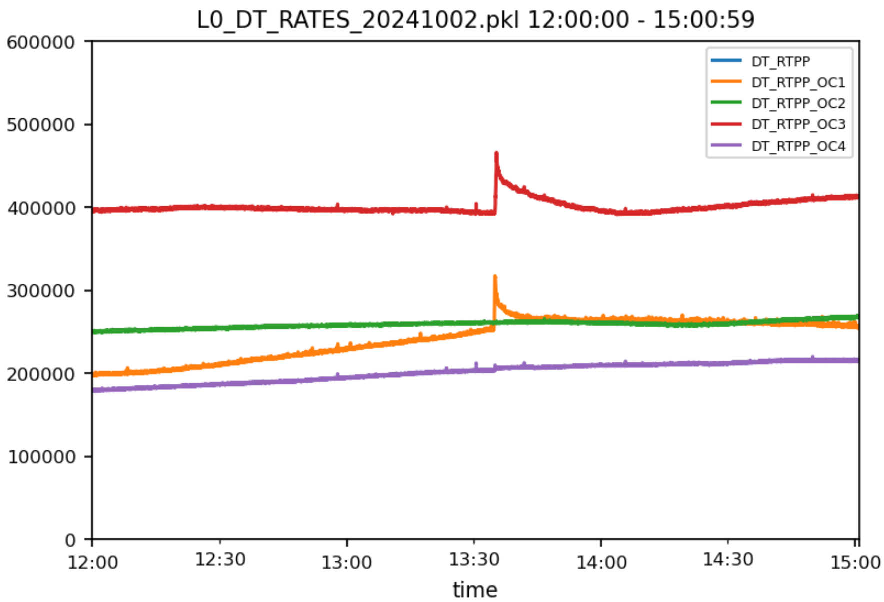


Figure 18: LI Real Time Pixel Processor (RTPP) detection rate during October 2, 2024, 12:00UTC – 15:00UTC. The sudden increase and slow "decay" is visible around 13:30UTC.

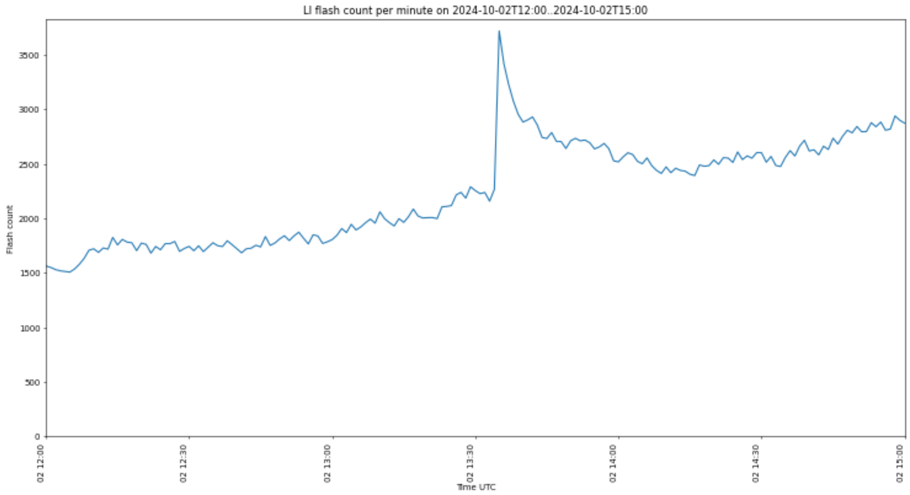


Figure 19: LI Level 2 Flash rate during October 2, 2024, 12:00UTC – 15:00UTC. The sudden increase and slow decrease are visible around 13:30UTC.

Figure 18 and Figure 19 present the reader with the end-to-end impact of the transit. In the former figure, one sees the increase of the on-board detections first in OC1 (pointing east) and after in OC3 (pointing west). In the latter figure the impact of the detections is propagated into Level 2 products, namely into the LI Level 2 flashes. The slow decay observed in both figures is due to the time needed by the LI instrument to recover a nominal background level for those pixels affected by the transit. Currently, the LI end-to-end processing cannot reject the false events generated by such occurrences. In the future, a dedicated/new filtering step may be designed to remove this type of false flashes.

Finally, it is worth stressing that in the past, objects transiting in the LI field-of-view would have caused the “instrument lock” and the consequent interruption of observations for several days. The combination of on-board detection LUTs, data regulation settings and new processing chain makes the LI System stable during such events and suitable to support operational dissemination of LI Level 2 products to users.

LI NOISE INSTABILITIES

During the LI Commissioning (in detail, from August 2023 on), several occurrences of noise instabilities of LI OCs were observed. These have impact on instrument operations and LI System end-to-end processing/performances. There is an anomaly that documents the occurrence of such instabilities and actions that were taken to recover the nominal functioning of LI:

On August 25, 2023, after a LI power-cycle, LI started detecting an unusually high number of lightning events (false events due to noise) and was brought in WAIT mode by the instrument operator. Following the yaw-flip manoeuvre of September 17, 2023, it became clear that the dependency of the noise of the LI OCs on the FPA temperature had to be assessed/characterized. Between September 22, 2023, and October 13, 2023, several tests on the dependency of the noise level of OC2 on the FPA temperature took place, these were followed by the first thermal characterization of the LI noise of all OCs (hereafter, T-sweep; as per SOI_0176 and PST MTGI1-COM-PST-REC-0085). The T-sweep allows one to find the combination of FPA temperatures that minimizes the noise of the OCs.
In the list of days that follows, the T-sweep had to be performed to re-establish nominal LI noise performances to remove noise instabilities:

1. November 24, 2023: T-sweep took place and thermal configuration set to OC1=26 deg, OC2=26 deg, OC3=26 deg, and OC4=26 deg.
2. November 27, 2023: T-sweep took place and thermal configuration set to OC1=14 deg, OC2=14 deg, OC3=14 deg, and OC4=14 deg.
3. November 28, 2023: T-sweep took place and thermal configuration set to OC1=16 deg, OC2=16 deg, OC3=16 deg, and OC4=16 deg.
4. December 12, 2023: T-sweep took place and thermal configuration set to OC1=23 deg, OC2=25 deg, OC3=23 deg, and OC4=23 deg.
5. February 8, 2024: T-sweep took place and thermal configuration set to OC1=23 deg, OC2=17 deg, OC3=23 deg, and OC4=17 deg.
6. February 21, 2024: T-sweep took place and thermal configuration set to OC1=26 deg, OC2=26 deg, OC3=26 deg, and OC4=26 deg.

Since February 2024, following a new recommendation from PST (MTG-ROS-REC-0006), as per SOI_0238, the approach to minimize the noise of the OCs is to execute a camera reset. The rationale for this is that there is a very high probability of minimizing the noise of an OC by performing sequences of resets and such sequences take much less time than a T-sweep + data analysis and thermal configuration. The standard/fixed LI thermal configuration is OC1 = 26 deg, OC2=26 deg, OC3=26 deg, and OC4=26 deg.

In the list of days that follows, the camera reset had to be performed to re-establish nominal LI noise performances to remove noise instabilities:

1. June 18, 2024, 19:30UTC: OC2 reset successful after the first attempt.
2. July 2, 2024, 19:13UTC: OC4 reset successful after three attempts.
3. July 9, 2024, 13:40 UTC: OC4 reset successful after the first attempt.
4. September 17, 2024, 14:10 UTC: OC4 reset successful after the first attempt.
5. September 26, 2024, 18:52 UTC: OC4 reset successful after the first attempt.
6. October 1, 2024, 01:00 UTC: OC4 reset successful after four attempts (see Figure 20).

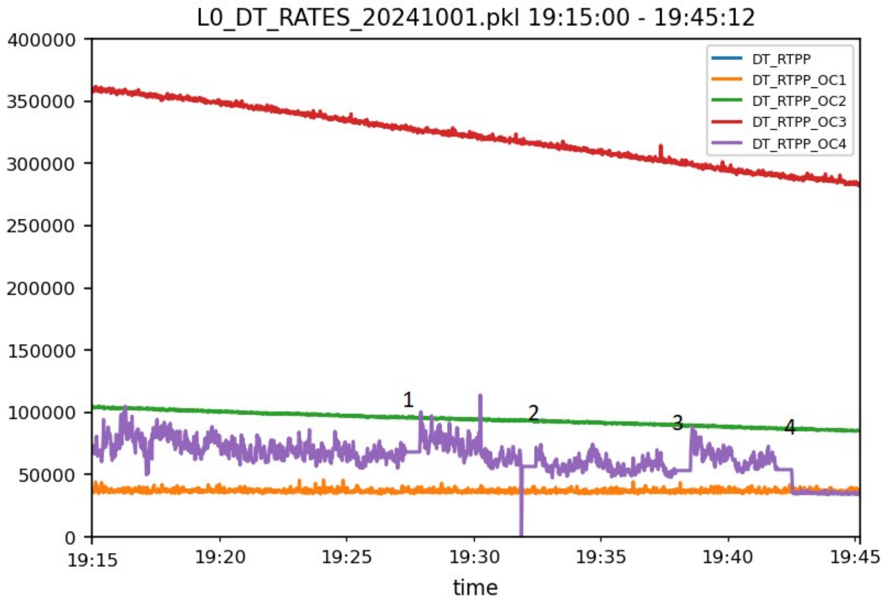


Figure 20: evidence of the impact of the resets of OC4 during October 1, 2024 from the on-board lightning detection counter; after four attempts the noisy/unstable signature observed for OC4 is cleared.

It is now clear that most of the noise instabilities observed in the last two years are following autonomous power cycles of LI OCs whose origins are currently under investigation. EUMETSAT has in place a solid approach for monitoring the occurrence of such instabilities that combines the use of monitoring tools used by instrument operators and the LI Science Team. The reaction time to plan and execute a camera reset is less than 24h during working days. The time needed to execute the camera reset can vary depending on the number of reset attempts. In Figure 20, one learns that in the worst case so far encountered (i.e., four reset attempts) the time needed to re-establish the nominal noise level for OC4 was of about 20 min. It is important to stress that during the reset attempts, the LI end-to-end processing does not stop. Only a temporary data degradation is observed.

CONTENT PROPOSED FOR PUBLISHING AND KNOWN LIMITATIONS

LI Level 2 products shall be disseminated to users in an operational way with the following known limitations:

1. LI Level 2 data trailer chunks not completely/correctly populated.
2. Possible degradation of LI navigation performances after spacecraft manoeuvres, during the eclipse season, and early mornings.
3. Possible degradation of LI detection performances during the nights of the eclipse season.
4. Occasional increase of the Level 2 Flash False Alarm Rate (eg in case of objects transiting in the LI field of view).
5. Non nominal repeat cycles may occur with duplicated or missing chunks.
6. Incomplete quality flagging of degraded LI performance.

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APPENDIX A LEVEL 1B PERFORMANCES UPDATED

This Annex is meant to report on the Level 1b performances achieved in October 2024 through the processing of the LI data with IDPF-I v5.8.2 in the EUMETSAT OPE processing environment. The rationale for the presentation of the results is the following: show that the good performances achieved with the data of July-August 2024 are also achieved with the new data.

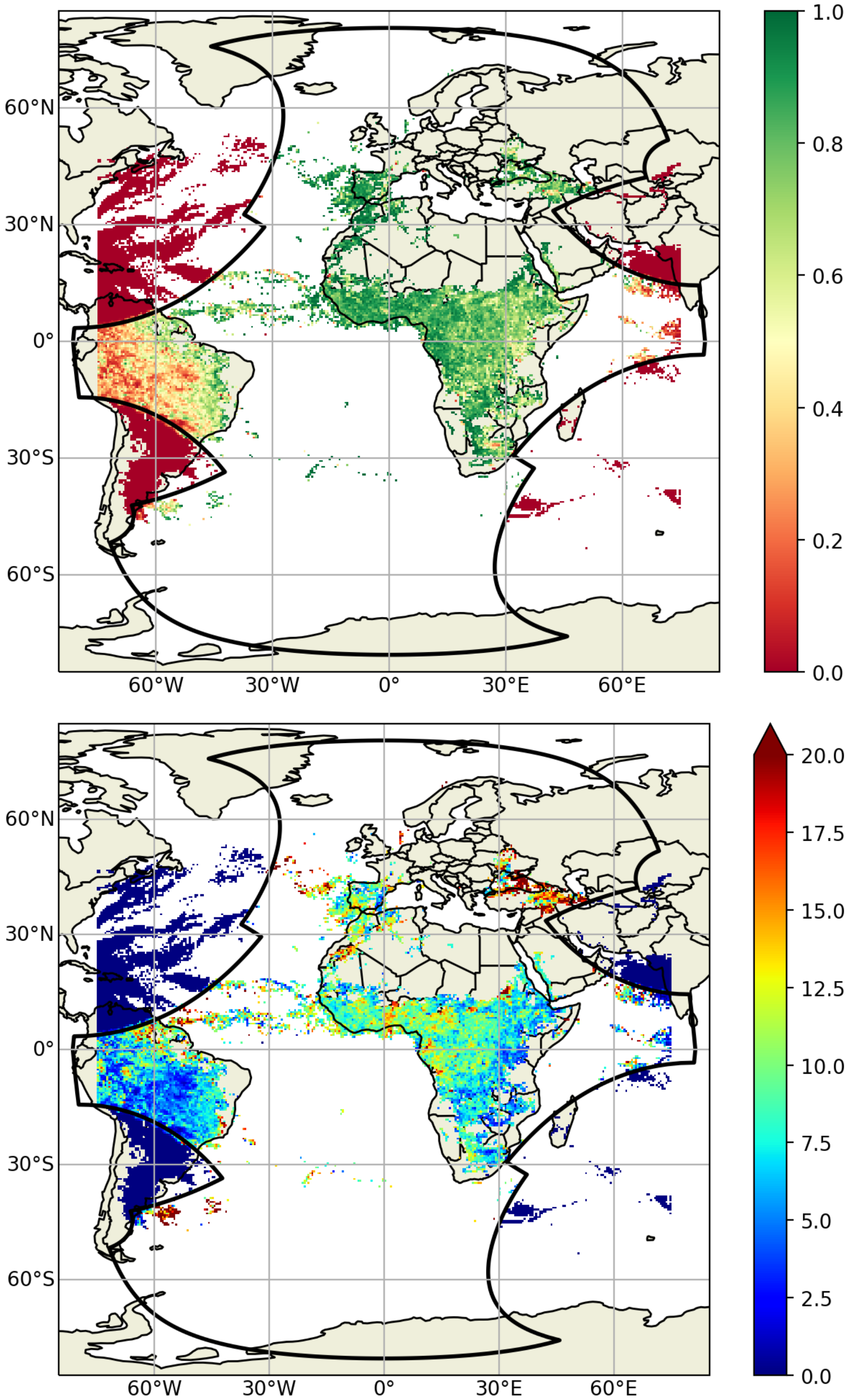
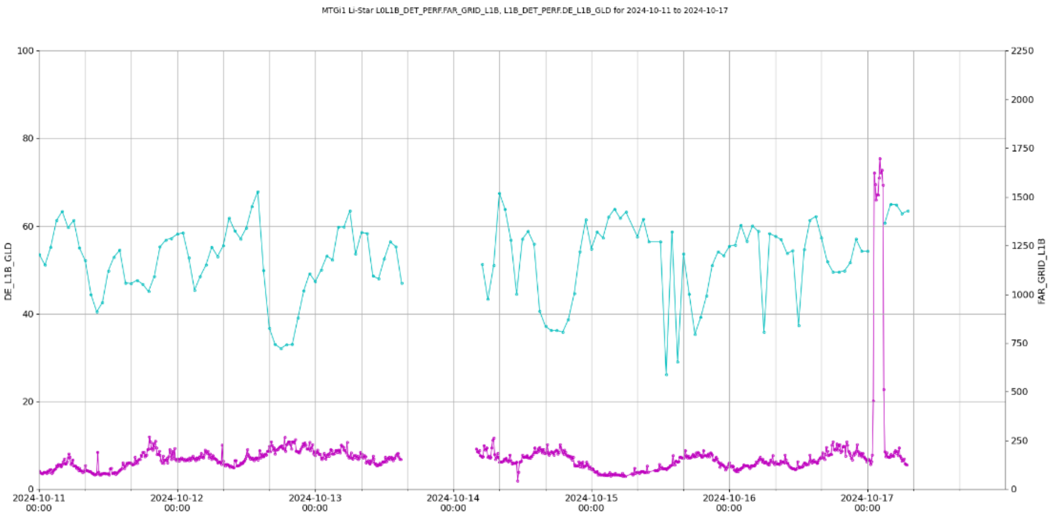


Figure 21: DE at Level 1b (top panel) and LA in km (bottom panel) derived from the matching exercise between LI Level 1b events and GLD360 lightning strokes during the time interval October 11-17, 2024.

Figure 21 shall be compared directly to Figure 1. The upper panel of Figure 21 shows that good Level 1b performances are being achieved from the IDPF-I v5.8.2. The average Level 1b DE over the entire field-of-view from the upper panel of Figure 1 is of 60%, while the value over the upper panel of Figure 21 is 49%. The drop in average performances can be understood by considering the difference in the lightning coverage between the reference time interval and October 11-17, 2024. During the latter period, lightning activity over Europe is low, while lightning activity over South America is very strong and spreads over the entire land area observed by LI. Referring to Table 6 one learns that performances over Africa are actually better during October 11-17, 2024 than the reference period, while over South America performances are considerably worse (-10%). This explains the drop of the average DE. LA values in Figure 1 and Figure 21 are comparable (see also the bottom panel of Figure 22). To be noted though, a small degradation over Africa.

Table 6: Average (over the LI field-of-view) DE at Level 1b derived from the matching exercise between LI Level 1b events and GLD360 strokes during the time interval October 11-17, 2024, and between parentheses during the reference time interval July 4, 2024, 00:00 UTC - August 22, 2024, 23:59 UTC.

	LI field-of-view	**Central Africa**	**Southern Europe**	**South America**
Level 1b DE	0.49 (0.60)	0.74 (0.71)	0.78 (0.66)	0.41 (0.52)



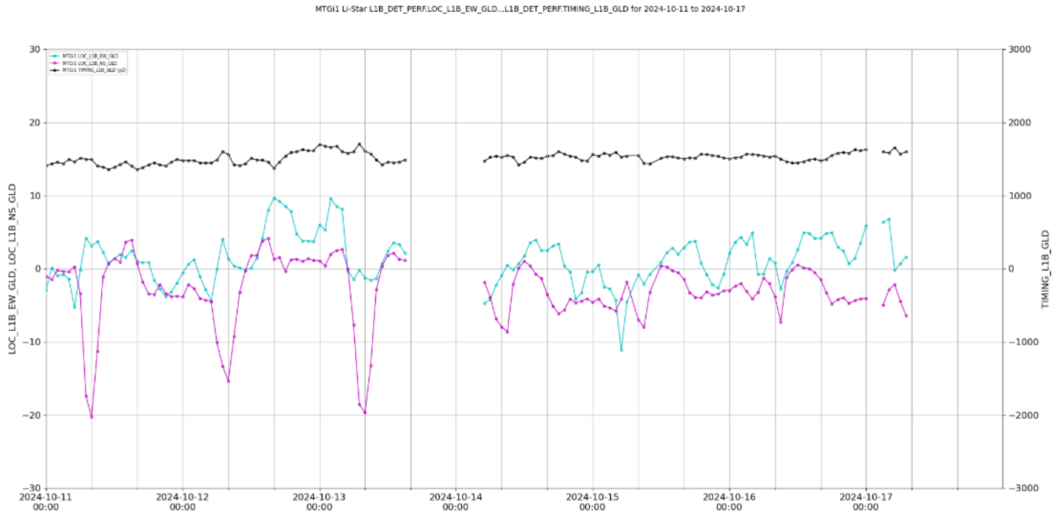


Figure 22: LI lightning event rates per second averaged over 10 min (i.e., each dot in the plot) at Level 0 (i.e., in input to the IDPF-I; top panel in blue) and at Level 1b (i.e., output of the IDPF-I; top panel in green). Fraction of Level 0 events filtered by each Level 1b filter (bottom panel). One can refer to the legend for the interpretation of the colour coding of the Level 1b filters. Each plot is defined during the reference time interval October 11-18, 2024.

Figure 22 shall be compared with Figure 2. Comments to the latter figures apply to the former. Performances during October 11-17, 2024, are comparable to the days around August 8, 2024. LA is slightly more unstable during October 11-17, 2024, than during the reference period. Good LA stability is recovered after October 14, 2024. The TA is very stable and below 2 milliseconds in both figures. FAR is also in line with the values over the reference period, with the large peak of October 17, 2024, due to a temporary outage of reference GLD360 data (i.e., the reference employed to derive the FAR).

APPENDIX B LEVEL 2 PERFORMANCES UPDATED

This Annex is meant to report on the Level 2 performances achieved in October 2024 through the processing of the LI data with the chain IDPF-I v5.8.2 + L2PF v4.2.2.6 in the EUMETSAT operational processing environment.

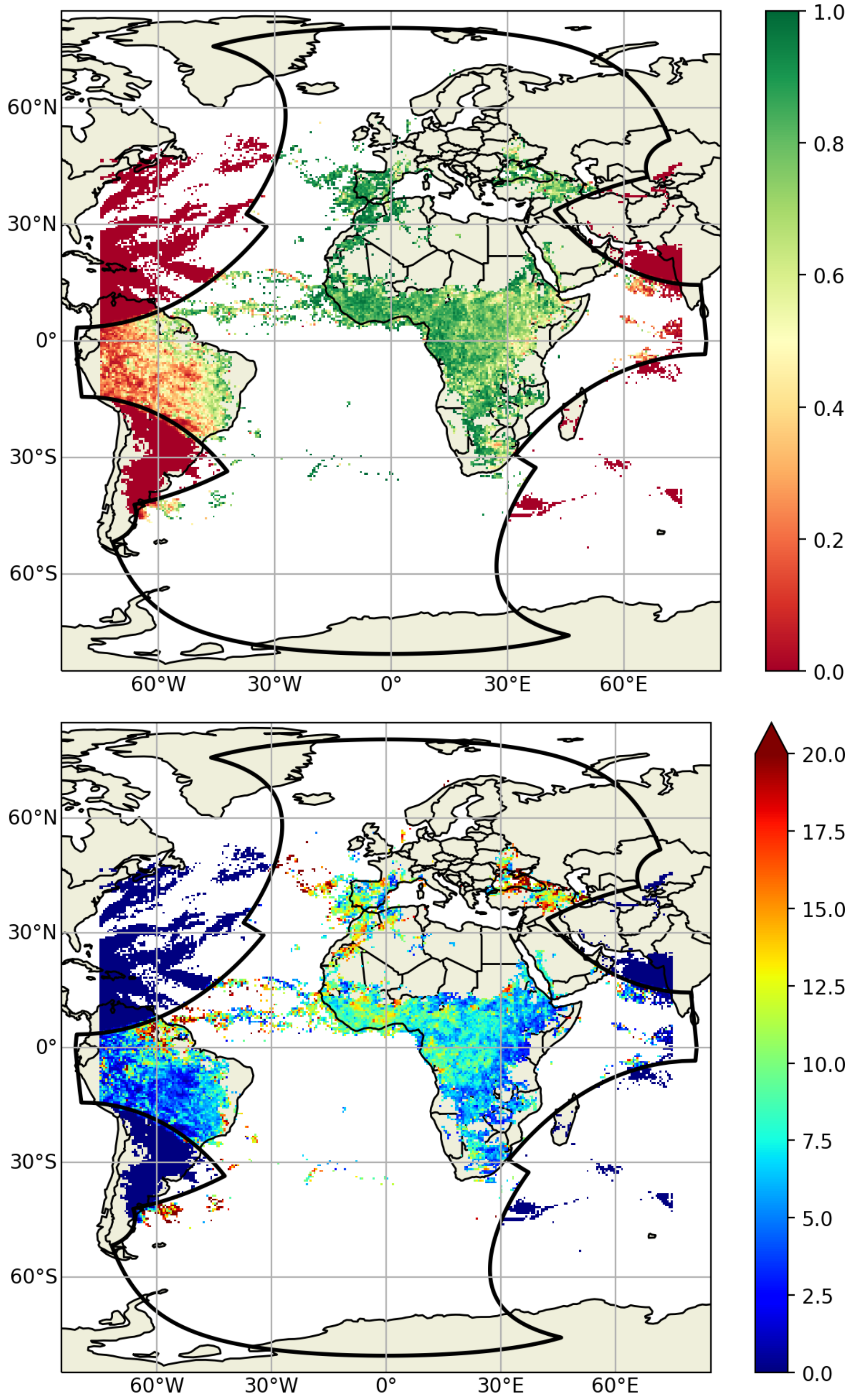


Figure 23: DE at Level 2 (top panel) and LA in km (bottom panel) derived from the matching exercise between LI Level 2 groups and GLD360 lightning strokes during the time interval October 11-17, 2024.

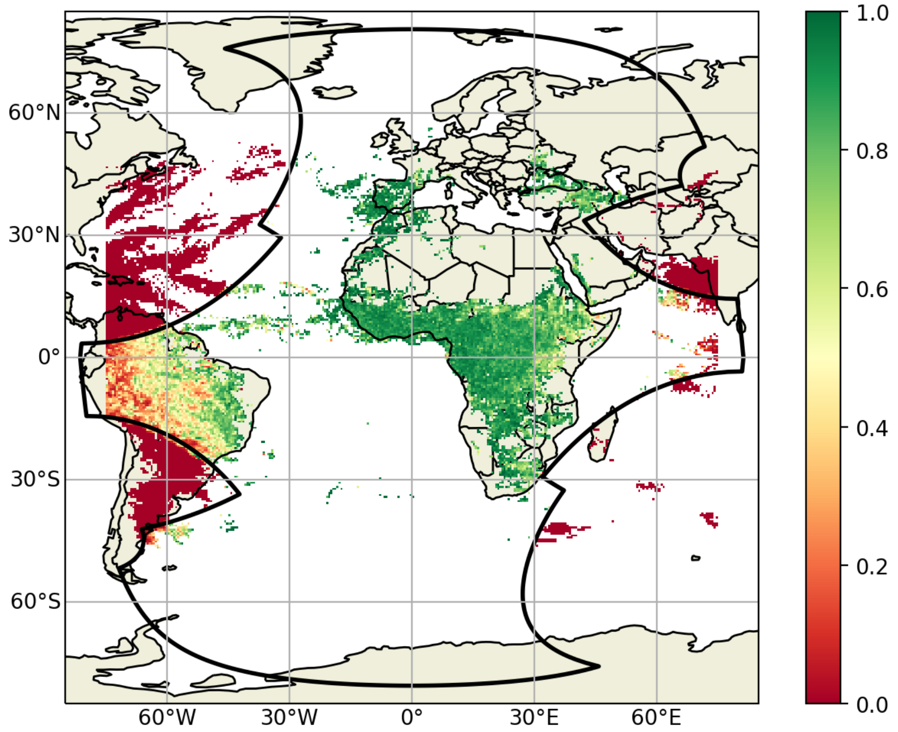


Figure 24: Flash DE at Level 2 derived from the matching exercise between LI Level 2 flashes and GLD360 flashes during the time interval October 11-17, 2024.

Table 7: Average (over the LI field-of-view) DE at Level 2 derived from the matching exercise between LI Level 2 groups/flashes and GLD360 strokes/flashes during the time interval October 11-17, 2024, and between parentheses during the reference time interval July 4, 2024, 00:00 UTC - August 22, 2024, 23:59 UTC

	Level 2 Groups	**Level 2 Flashes**	**Level 2 Flashes Central Africa**	**Level 2 Flashes Southern Europe**	**Level 2 Flashes South America**
Level 2 DE	0.46 (0.56)	0.60 (0.72)	0.84 (0.82)	0.87 (0.78)	0.54 (0.65)

Figure 23, Figure 24 and Table 7 shall be compared with Figure 5, Figure 6 and Table 4, respectively. In general, there is an overall agreement between the results. The decrease in average performances (see Table 4 and Table 7) stems from the decrease in average performances at Level 1b; this being due to the low performances over South America. When considering performances over time (Figure 25 compared with Figure 8), results are reflecting the overall performance reduction compared to the reference time. LA and TA are in line with the reference time. One result worth noting is the small increase in FFAR: this is now reaching values above one flash per second around 12:00UTC. This is not a blocking point to start operational dissemination. Nevertheless, some investigation is due to assess the origin of such increase.

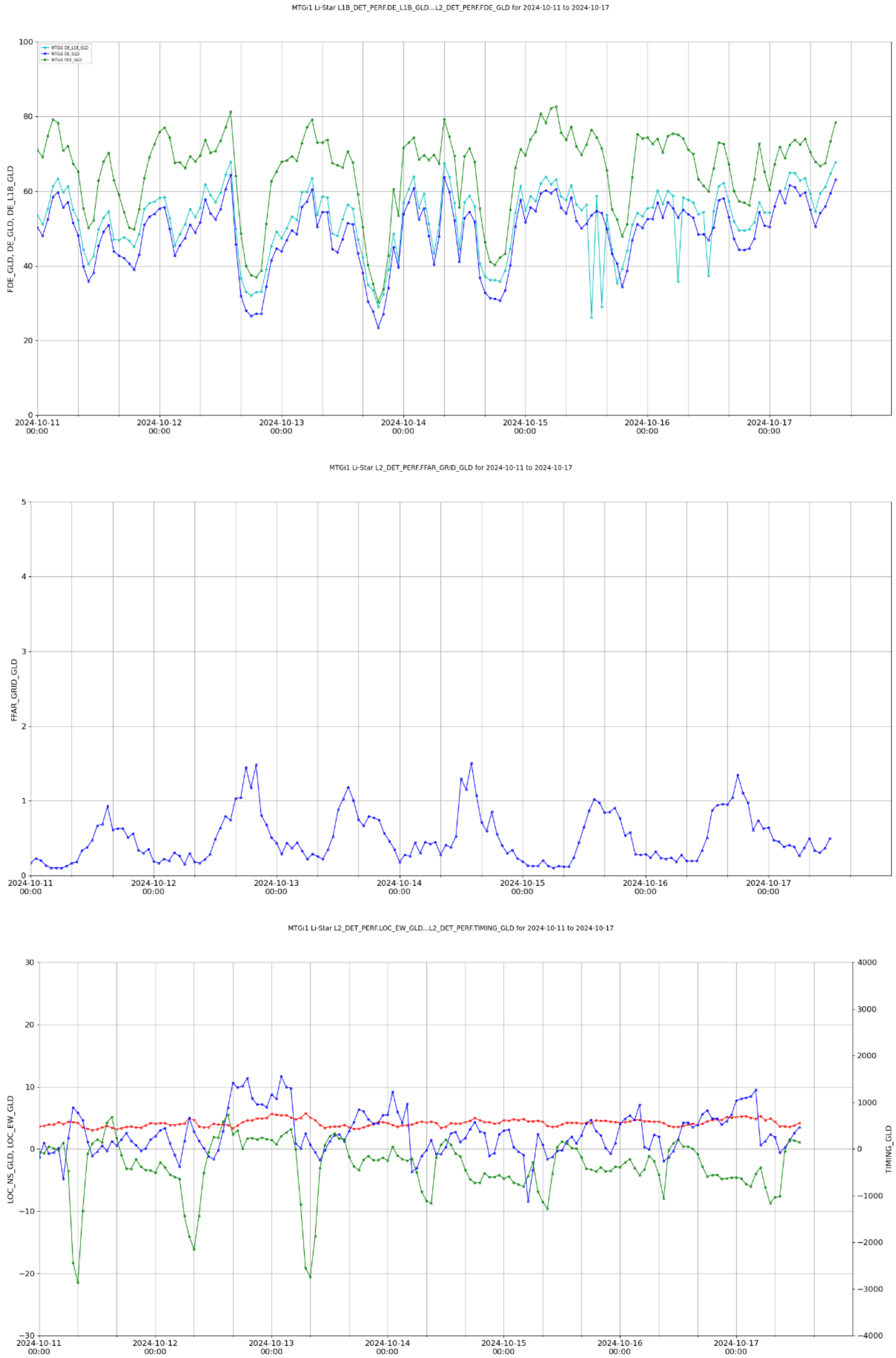


Figure 25: Level 2 Group DE (top panel in blue), Level 1b DE (top panel in cyan; as in Figure 2), and Level 2 Flash DE (top panel in green), Flash False Alarm Rate (FFAR; middle panel), East-West LA (bottom panel in blue) and North-South LA (bottom panel in green) in km and Timing Accuracy in µsec (bottom panel in red) derived from the matching exercise between LI Level 2 products and GLD360. Each plot is defined during the reference time interval October 11-17, 2024.

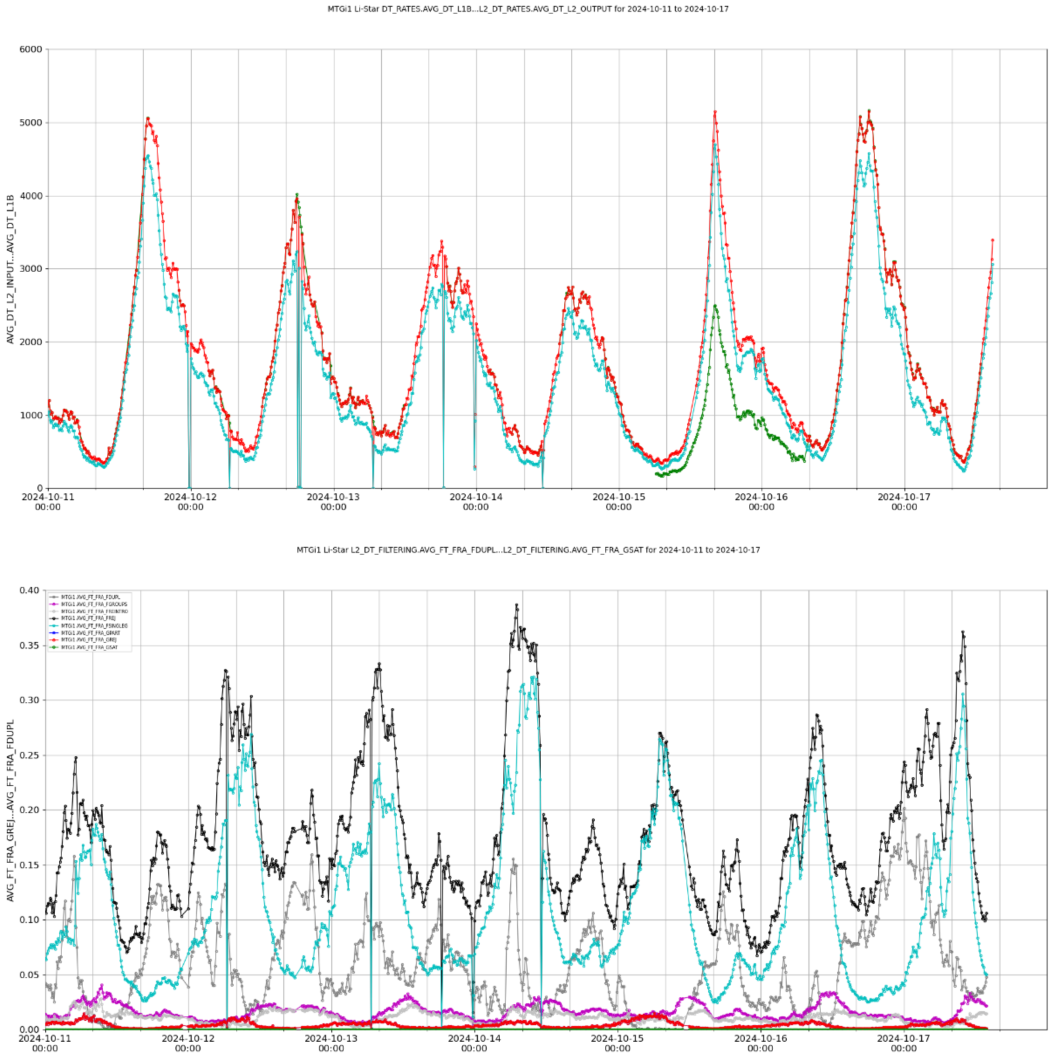


Figure 26: LI lightning event rates per second averaged over 10 min (i.e., each dot in the plot) at Level 1b (i.e., in input to the L2PF; top panel in red), after the Level 2 acceptance step (in green; barely visible below the red) and Level 2 (i.e., output of the L2PF; top panel in cyan). Fraction of Level 1b events filtered by each Level 2 filter (bottom panel). One can refer to the legend for the interpretation of the colour coding of the Level 2 filters. Each plot is defined during the reference time interval October 11-17, 2024.

Figure 26 shall be compared with Figure 9. Overall, data rate reduction from Level 1b to Level 2 as well as the impact of Level 2 filters does not deviate from the reference time. The temporal discrepancy between Level 1b output (green) and Level 2 input (red) observed on October 16, 2024, is due to an issue with the monitoring tool.