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# METEOSAT THIRD GENERATION LIGHTNING IMAGER, THE DEVELOPMENT OF FUTURE OPERATIONAL USER ORIENTED APPLICATIONS.

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**Abstract**

The next generation of EUMETSAT geostationary meteorological satellites, Meteosat Third Generation (MTG), will bring in orbit the instrument for optical lightning detection, the Lightning Imager (LI). The LI mission is intended to provide a real time total lightning detection with accurate location capability, for the individuation, surveillance and short term forecast of atmospheric electrical hazards. As lightning is strongly correlated with intensive convection a further objective of the LI mission is to serve as proxy for storm related phenomena like precipitation, hail and gust, serving also as latent heat proxy information source to be assimilated in Numerical Weather Prediction (NWP) models. The paper describes the study for the user readiness and related preparation towards future utilization of LI data into operational applications; Nowcasting (NWC) and Very Short Range Forecast (VSRF) applications are evidenced, discussing the design of systems for the full exploitation of LI real-time data streaming in operational weather centre and in other decision maker headquarters. The presented study is developed in the framework of the Doctoral School in Engineering at University of Rome Tor Vergata.
Keywords: remote sensing, lightning sensing, space-based lightning detection, nowcasting, very short range forecast.

## INTRODUCTION

Lightnings are a limiting factor for aviation, in terms of safety for the crews, passengers and assets, and flight comfort, being lightnings a tracer for stormy weather, severe turbulence, large hails. Near Real Time (NRT) lightning information, in continuous on wider continental scale, is a crucial element and a step forward in forthcoming aviation industry and more generally in operational user oriented applications. EUMETSAT Meteosat Third Generation (MTG), will bring soon into orbit the optical lightnings detection instrument, the Lightning Imager (LI), providing real time total lightning. LI is also a monitoring platform for lightnings related phenomena as precipitation, hail and gust, and as latent heat proxy for NWP.
Our quest: "is the generic user of METEOSAT aware and ready for the forthcoming operational exploitation of LI?"
The arguments presented are partly developed during the studies done by the author in the framework of the Doctoral School in Engineering at University of Rome Tor Vergata.

## THE FUTURE OF OPERATIONS IN AVIATION: LIGHTNING HAZARDS

The study analyzes the most likely scenarios of operational aviation in the next 10 years. In particular the continuous improvement of aeronautical materials and technologies, in a time of increasing air transportation demand, forces the aviation industrial sector towards a new reality based mainly on the automation of aircraft routing and machine supported decision for weather threats avoidance. Aviation traffic volumes in the last decade increased steadily by a plus 5% on a yearly base, and industrial sector experts predicts the doubling of traffic movements within the next 15 years (figure 1). With that in mind it is easy to understand how the current situation, with air traffic managed only in terms of geometrical separation by human air traffic controller (DBS-Distance Based Separation), is destined to saturate soon without the possibility of further operating slots. It is already planned, and now under construction for Europe and North America, a revolution in air traffic management, not more controlled only by human operators, but assisted by Artificial Intelligence - Air Traffic Control (AI-ATC), towards continuous online calculation of Time Based Separation (TBS) to augment up to the double airport terminal capacities, something that can't be done by stand-alone human controllers.

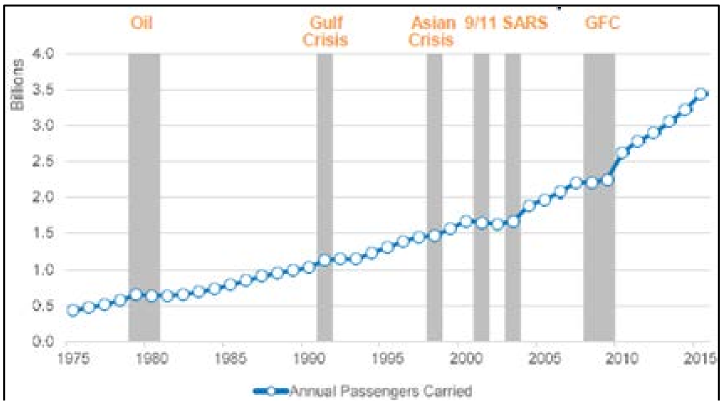


***Figure 1:*** **Aviation traffic volumes in the last decade increased steadily by a plus 5% on a yearly base, and industrial sector experts predicts the doubling of traffic movements within the next 15 years (image World Bank).**

Optimization of flight paths is also crucial for the reduction of environmental impacts, avoiding traffic jamming or re-routing due to adverse weather conditions and low velocity holding in parking areas over major hubs. To maximize the optimization of flight paths a fundamental element is the assimilation in near real time of present meteorological conditions, in particular of the most threating phenomena as thunderstorms elements.

It should also be noted that many of modern aircrafts are now made up mostly of composite elements, an engineering solution that has significantly reduced weight and consumption, but at the cost of increasing the risk of damage to aircraft structures in the case of lightning electrocution, an event that, although often extremely confined thanks to passive protection systems present on the aircraft body, triggers an expensive machine stop for detailed maintenance checks.

Finally, the future of aviation is now steered towards the increase of remote controlled assets or automatic pilot schemes, e.g. Unmanned Aircraft System (UAV) or Remotely Piloted Aircraft Systems (RPAS). To guarantee the highest possible level of safety in case of sharing of airspace of these systems with the manned aircrafts, it will be necessary that remote pilots or automatic expert driving systems keep the assets sufficiently far from intense atmospheric electric phenomena.

## WEATHER INFORMATION IN AVIATION

The supply of meteorological information to flight crews is mostly based on the provision of maps and bulletins well before the flight starts. Only recently the provision has been added of updates of the meteorological safety messengers during the flight, better known as SIGMET and AIRMET (SIGnificant METeorologic information and AIRmen's METeorological information), codifying the risky phenomenon together with the area of interest in the form of polygonal, allowing the close in time updating both on aircraft display systems on board, in available, or the listening safety radio frequency, as the example in figure 2.

Given the expertise of the forecasters responsible for the provision of the above security messages, it should be noted that the renewal of the messages occurs at most every 2 hours, with a spatial extension of phenomena frequently of regional scale. This approach is fundamental for the necessary synthesis and effectiveness of the security messages in aeronautical context of the single Flight Information Region (FIR), warning in a generic way the crews crossing an airspace sector. But this is

far from the ideal near real time description of the hazards that is desired by the pilots, who would need informations not older than a few minutes, in order to coordinate as best and as securely as possible the route and altitude with the ground air traffic management centers. The information that permits such frequent update, within a few minutes, is near real time observations of lightning strikes, currently by the ground-based detection networks, and soon from space with the advent of the EUMETSAT Meteosat Third Generation Lightning Imager (MTG-LI).
Thanks to the author's experience, considering among other things 20-years of duty service as an operational aeronautical forecaster for the Italian Air Force, the needs and expectations of the aviation industry regarding the future provision of LI observations can be summarized in the following points:

- Clustering and isocontouring of densities in 4-5 intensity levels, and timeliness in the order of 30 seconds;
- Tracking and nowcast of lightning cells movements, up to 30 minutes, with probability of point of interest impact;
- Early individuation of density trends, evidencing lightning jumps;
- On the fly translation of lightning rates into rate of precipitation, hail risk and gust presence.

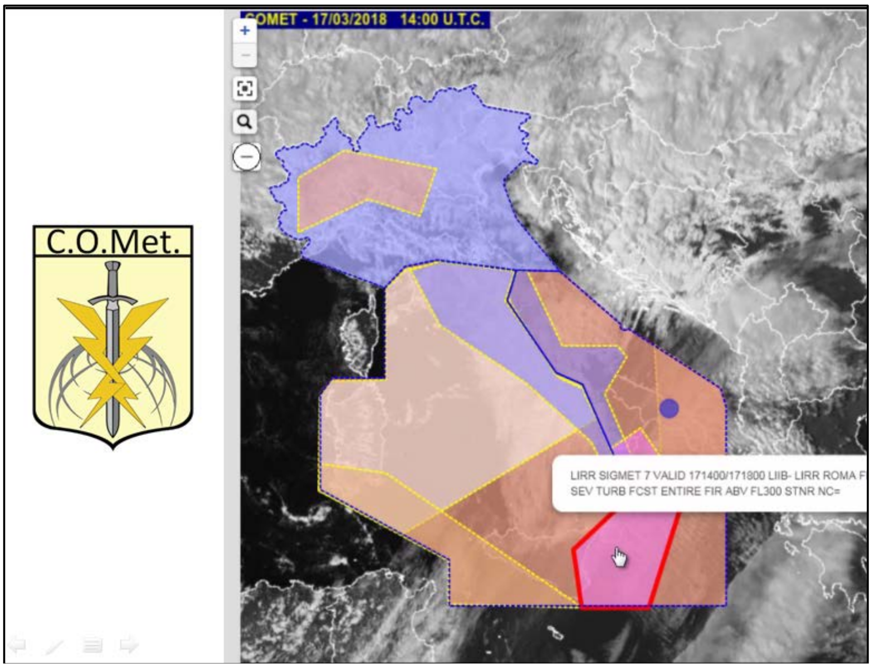


***Figure 2:*** **Plot with an example of the 3 Italian Flight Information Regions SIGMET messages (image Italian Air Force).**

## THE USER EXPECTATIONS ON LI DATA

In the study it has been analyzed the architecture of LI data flow: form the optical detection of lightning brightness up to the delivery of service towards the users. LI design follows the concept of converting optical emission of atmospheric lightning in the Near Infrared (NIR, around 777 nm) into reliable digital information of positions and dimensions of strokes. It has been also studied the functioning of LI instrument, made by optics and proximity electronics, together with the early stages of signal processing on board MTG, including thresholding, filtering and sampling technique at detection matrix level, to minimize false alarm rate creating the so called Level 0 dataset (L0), that is the only data to be transmitted from the platform to the main ground stations and then transferred in EUMETSAT for further processing. Once collected by the EUMETSAT, L0 data are processed in order to remove all residual false signals and noise remnants, mainly due to microvibrations on board satellite or particles noise or stray light effects and similar, generating a dataset that is rich of true signals, georeference and calibrated at detection matrix level, so called Level 1 (L1).
L1 data are not intended to be delivered in near real time to the user, remaining internally in

EUMETSAT processing facility, and accessible offline by interested users, minutes to hours after the detection. In EUMETSAT again there will be a system designed and operated to convert L1 in Level 2 (L2) data, fusing together induvial L1 events, as the trigger of a single matrix pixel in a single integration time, into flashes information by collection of events relatively close in space and time, belonging to the same optical and physical phenomena.

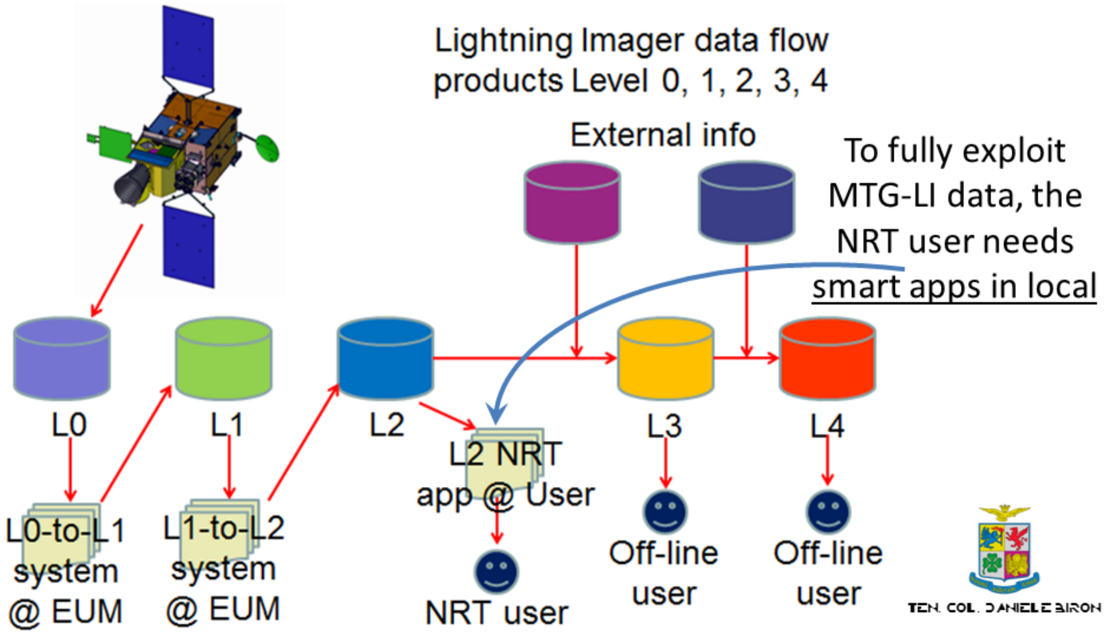


***Figure 3:*** **EUMETSAT Meteosat Third Generation Lightning Imager (MTG-LI) data levels and data flow chart (image Daniele Biron).**

L2 are subsequently sent to the user in NRT for the operations. Offline L2 data will be also processed together with other MTG instruments informations and external datasets, generating Level 3 and Level 4 data for various applications, e.g. climatology or statistics.

During the study it has been focused the interaction of the NRT operational user with L2 datasets. The overwhelming volume of L2 data could be managed in a very simple but ineffective way, displaying all informations in front of the operators, without any discretization layer or decision support analysis. But this approach does not allow the evidencing of phenomena where lightning threat is probably of interference to the operations. During the study it was simulated realistic LI data flow, using an LI simulator base on Matlab code, based on the author's heritage of past EUMETSAT studies as a member of Lightning Imager Science Team (LIST), now Lightning Imager Mission Advisory Group (LIMAG). The LI simulator is driven in generating optical bolts by regional ground based lightning networks or MSG infrared images, considering lightnings historical occurrence statistics. From simulations is evident that the expected LI L2 data volume cannot be managed directly in operational decision support processes, but dedicated applications "*apps*" at user level need to be built to filter, reduce and optimize significant information content towards the NRT service.

The LI datasets generated during multiple simulations have been analyzed considering user expectations, also comparing them to real threatening weather phenomena. During the study it was developed a computing code that collects and process simulated lightning strikes in a similar way that will be in place with the MTG NRT distribution to the users. The goal is to demonstrate that in few seconds LI L2 flashes could be clustered and isocontoured resulting in densities areas of 4-5 levels of intensity, and after extensive calibration by real measurement and verification by direct observation, these densities could be also mapped in level of threats severity.

An example of what reached during the study is in figure 4, where by the analysis of data from the Italian Air Force Weather Service Lightning Network LAMPINET, data are clustered in space within densities levels by trained algorithm, considering the last 5 minutes chunk of data and the 2 previous 5 minutes chunks, also extrapolating trends in time, finally assigning a phenomena severity level corresponding to the aeronautical expectation in those highlighted regions.

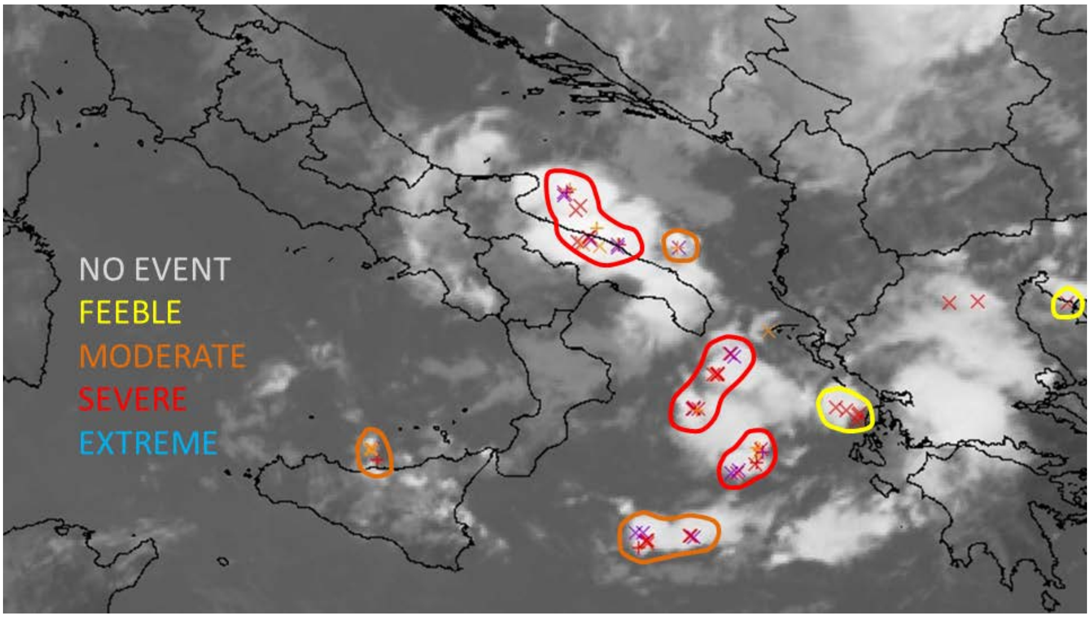


***Figure 4:*** **After the processing of LAMPINET data, discretization of lightning densities and level aeronautical impacts (image Daniele Biron).**

Another example is in the upper part of figure 5, both on the left and on the right, where again by the analysis of LAMPINET data, considering the last 5 minutes chunk of data and only the previous chunk, it is possible to identify by specifically developed algorithms risk areas for moderate or severe hail or turbulence, respectively.

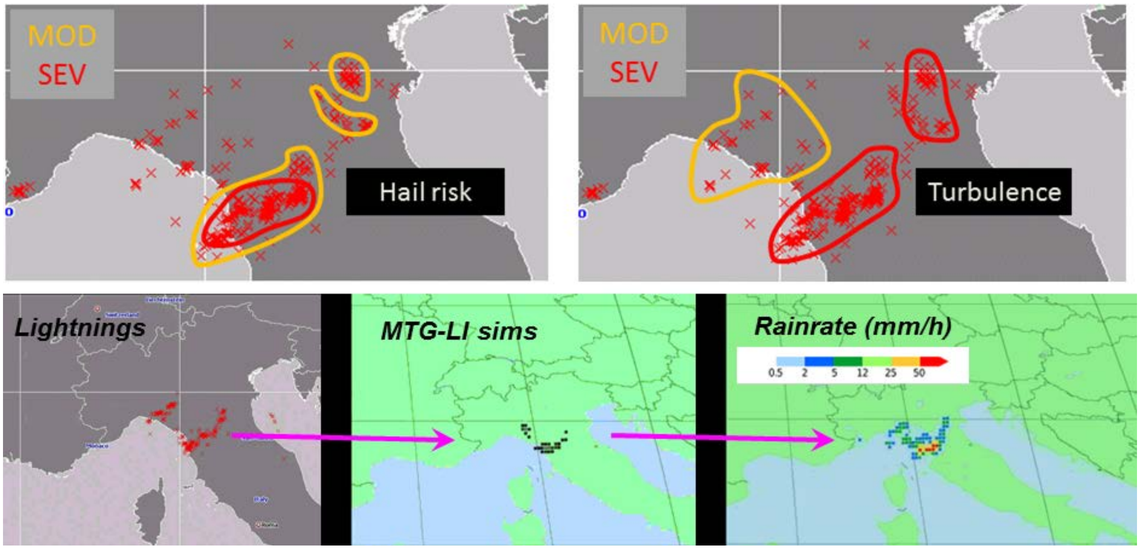


***Figure 5:*** **After the processing of simulated LI data, discretization of possible aeronautical turbulence presence with levels of severity (image Daniele Biron).**

Finally in the lower part of figure 5, MTG-LI simulator has been driven by LAMPINET locations to generate optical pulses and events as detected by LI telescope active matrix, processing the simulated data up to the realistic L2 information that one day will come in the user applications. That type of simulated lightning density it has been regressively correlated with real rainrate measurements from high density rain gauge ground network, establishing an end-to-end chain from real lightning-rate detection to rain-rate estimation by means of simulation of LI behavior and L0-L1-L2 data processing.

## CONCLUSIONS

The next generation of EUMETSAT geostationary meteorological satellites, Meteosat Third Generation (MTG), will bring in orbit the instrument for optical lightning detection, the Lightning Imager (LI). The LI mission is intended to provide a real time total lightning detection with accurate location capability, for the individuation, surveillance and short term forecast of atmospheric electrical hazards. As lightning is strongly correlated with intensive convection a further objective of the LI mission is to serve as proxy for storm related phenomena like precipitation, hail and gust, serving also as latent heat proxy information source to be assimilated in Numerical Weather Prediction (NWP) models. In the framework of the Doctoral School in Engineering at University of Rome Tor Vergata the author has described studies and activities meant for the user readiness and related preparation towards future utilization of LI data into operational applications, in particular Nowcasting (NWC) and Very Short Range Forecast (VSRF) applications in operational weather centre and in analogous decision maker headquarters.