SF2A 2025
A. Siebert, K. Baillié, M. Béthermin, F. Cantalloube, E. Josselin, N. Lagarde, J. Malzac, J. Richard, L. Selliez, O. Venot (eds)

CHARACTERISING LIGHTING PRACTISES IN FRANCE

R. Buhler[1], P. Deverchère[1], C. Plotard[1] and S. Vauclair[1]

Abstract. Over the past decade, DarkSkyLab has been implementing solutions to measure, model and reduce light pollution. In this article we give a brief overview of our activities and proceed to describe some recent developments. We present a new algorithm to detect switch off of public lighting in the middle of the night. These swich offs have been an important tool for light pollution reduction in France. We also present a new algorithm to predict light emission during the middle of the night of towns based on their local infrastructure.

Keywords: Light pollution, Artificial Light At Night

1 Introduction

Since 2014, DarkSkyLab has been developing and implementing solutions to measure, model and map light pollution. To date, more than 150 individual projects have been completed all over the World (DarkSkyLab 2025). In France, which is at the forefront of the reduction of light pollution worldwide (Buhler et al. 2025), thousands of municipalities have been studied. Typically, studies focus on the impact of private or public lighting parks. Another important topic is the analysis of dark ecological networks, which are systems of connected areas where darkness is preserved to protect nocturnal biodiversity. Training and awareness-raising are also fundamental parts of our work. Two areas of expertise are central for most of the projects: the modelling of light pollution from ground radiance measurements and infield measurements of the dark sky quality. In both of them we are constantly improving our tools and developing new approaches.

2 Recent developments

We have recently made a major update to our software *Otus*, which simulates light pollution parameters from satellite radiances or light source information. The main improvement is the addition of a new light pollution indicator, the total ground illuminance. We simulate the total contribution from skyglow and from direct illumination of lights on the ground for the first time. This indicator is in many cases better suited to characterize the nuisance due to light pollution on the biosphere than the traditional zenith luminance. In parallel, we are developing a new version of out Ninox measurement devices, which include lux meters, which will allow us to measure the total illuminance to calibrate the simulations. We have recently described these advances in Buhler et al. (2025) and therefore focus on two other new developments here.

2.1 Detection of public lighting switch off during the night

An important tool for light pollution reduction in France is the switch off of public lighting during the middle of the night. In a study led by the Cerema, we showed that about half of the municipalities in France apply this practice (Cerema 2025). DarkSkyLab has developed a dedicated software called *Asio*, that detects light swich-offs. In order to do this at the scale of France and with sufficient spatial and time resolution, we use satellite radiance data from the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on board the Suomi NPP satellite. The VIIRS pixel size is approximately 500 meters and consistent data which can be used for evolution analysis is available since 2014. Monthly VIIRS data sets are published by the Earth Observation

[1] DarkSkyLab, Pascaou, 31470 Fontenilles, France. E-mail: info@darkskylab.com. Alphabetically ordered author list.

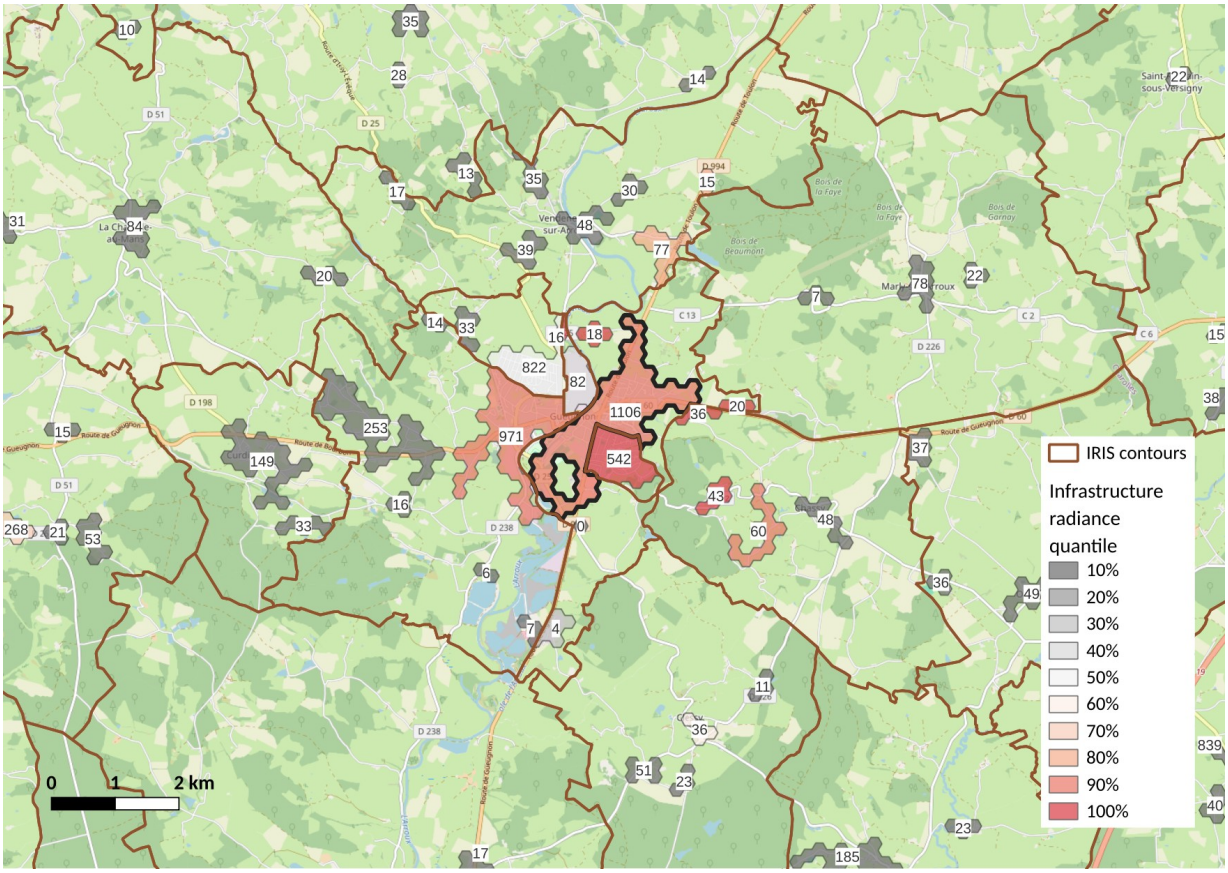

Fig. 1. Clusters of the town of Geugnon and the municipalities around. Some of the clusters are contiguous and split by the IRIS boundaries while others are isolated and correspond to villages and hamlets. The number of housing in each cluster is displayed in the map with a white background. The monthly radiance history for the cluster contoured by the thick black line is shown in figure 2.

Group (Earth Observation Group 2025) and can be used to detect a sustained change of radiance at a given location, e.g. a sudden drop of radiance due to an extinction of the public lighting. However, in order to obtain meaningful results, we have to restrict the monthly radiance analysis to urban areas and figure out the administrative or geographical entity on which the extinction analysis can be carried out. A thorough analysis has led DarkSkyLab to extract continuous urban areas bounded by municipal limits and IRIS units (IRIS, which stands for *Ilots Regroupés pour l'Information Statistique*, are homogeneous entities defined by the IGN for census purposes). This ensures that the radiance analysis to detect extinctions, and more globally private and public lighting changes and evolutions, is performed on meaningful and homogeneous entities. The resulting elementary entity on which radiance evolution analysis is performed is called a **cluster**.

Asio is able to produce all the clusters of Metropolitan France. Clusters are built starting from a grid of 200 meter hexagons that covers the full country. In a first step, the hexagons that do not contain a minimum number of housing, industries or stores are filtered out. This data is obtained from the IGN BD TOPO V3 and is spatially matched with the hexagons. As a second step, the remaining hexagons are recursively merged to form continuous polygons which are in turn cut along the boundaries of municipalities and IRIS. The clusters are the resulting polygons which have specific attributes attached to them such as the number of housing, stores, industries as well as the street length, cluster area, population, etc. For Metropolitan France, a total of 175,824 clusters have been found using the December 2024 IGN BD TOPO version 3.4. Since there are 34,955 municipalities in Metropolitan France, this represents an average of 5 clusters per municipality.

Figure 1 shows an example of clusters on several adjacent municipalities including Gueugnon in Saône-et-Loire, France. One can see that this city has 16 distinct clusters, some of them are isolated (i.e. they correspond to separated urban areas) and some others are contiguous (they are split because of the IRIS boundaries even if they are part of the same urban continuum). The number of housing in each cluster is indicated in the clusters

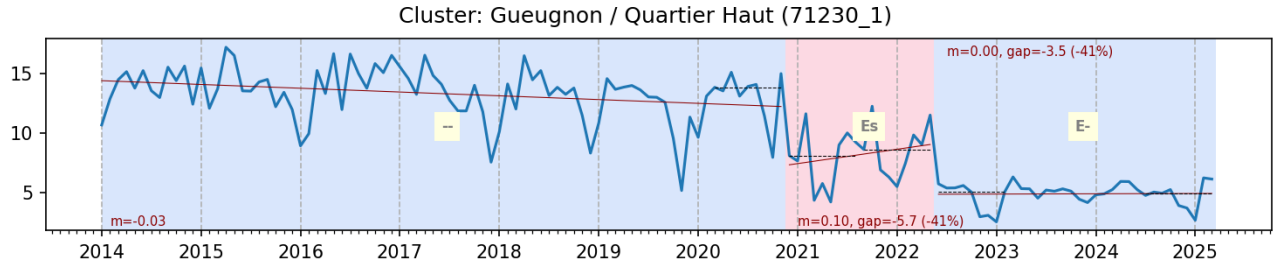

Fig. 2. Monthly radiance history for a cluster of the city of Gueugnon in Saône-et-Loire, marked by thick contours in figure 1. Two change points have been automatically detected in the radiance signal, one in November 2020 and a second one in May 2022. They very likely correspond to two significant extinctions of the public lighting at two different dates (for more details, see the main text). One can notice that the monthly radiance signal is quite noisy since the determination of the mean radiance for a given month is heavily dependant on weather conditions and in particular the number of cloud-free measures by the satellite. There is a very frequent pattern of radiance decrease at the end of most of the years which is likely caused by a low number of clear nights in November and December.

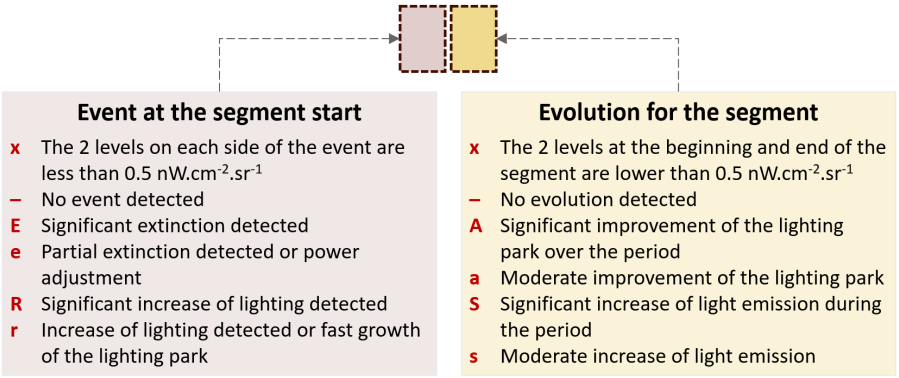

Fig. 3. Convention used to represent events (sudden changes in the radiance signal) and evolutions (progressive changes over several months) in the monthly radiance history of each cluster. Specific heuristics have been developed by DarkSkyLab to determine the thresholds for event and evolution detections.

with a yellow background. Villages around Gueugnon typically have just a few small clusters that correspond to the main village and some hamlets. This territorial organization of urbanized areas is typical of France.

Once the clusters have been obtained, it is possible to calculate for each cluster the mean radiance for every month between January 2014 and August 2025 (at the time of the writing). This radiance is expressed in $nW\ cm^{-2}\ sr^{-1}$. The Asio software makes use of the Python library *rupture* (Truong et al. 2020) to automatically detect change points in the radiance signal that can potentially correspond to lighting extinctions or sudden light emission increases. Once sustained change points have been detected, Asio is also going to analyse a possible progressive evolution on each segment between each pair of change points. To facilitate the visualization of the events end evolutions in the radiance history, Asio produces for each cluster a diagram as the one presented in figure 2. As an example, this diagram provides the radiance history for the main cluster of the city of Gueugnon for each month between January and March 2025 (this cluster is the largest one with 1,106 housing in the map of figure 1). Two change points have been detected by the *rupture* library in November 2020 and May 2022 that very probably correspond to significant public lighting extinctions. The convention described in figure 3 is used to report in the radiance history diagrams the **events** (sudden changes in radiance history) and **evolutions** (progressive changes over several months) detected by Asio. For each segment, two characters are used: the first one reports an event at the beginning of the segment and the second one reports an evolution over the segment. In addition, the slope of the regression line for each segment is provided (parameter m at the beginning of the segment) as well as the gap in $nW\ cm^{-2}\ sr^{-1}$ and % for each event. For the main cluster of Gueugnon in figure 2, the first extinction (E) has a gap of $-5.7\ nW\ cm^{-2}\ sr^{-1}$ (-41%) and the second one has a gap of $-3.5\ nW\ cm^{-2}\ sr^{-1}$ (-41% again). In terms of evolution, a moderate increase of light emission (s) is detected

with a slope of $+0.1 nW\ cm^{-2}\ sr^{-1}\ month^{-1}$ which is the lower limit of the heuristic used by Asio and probably corresponds to noise in the data.

2.2 *Light emission prediction based on local infrastructure*

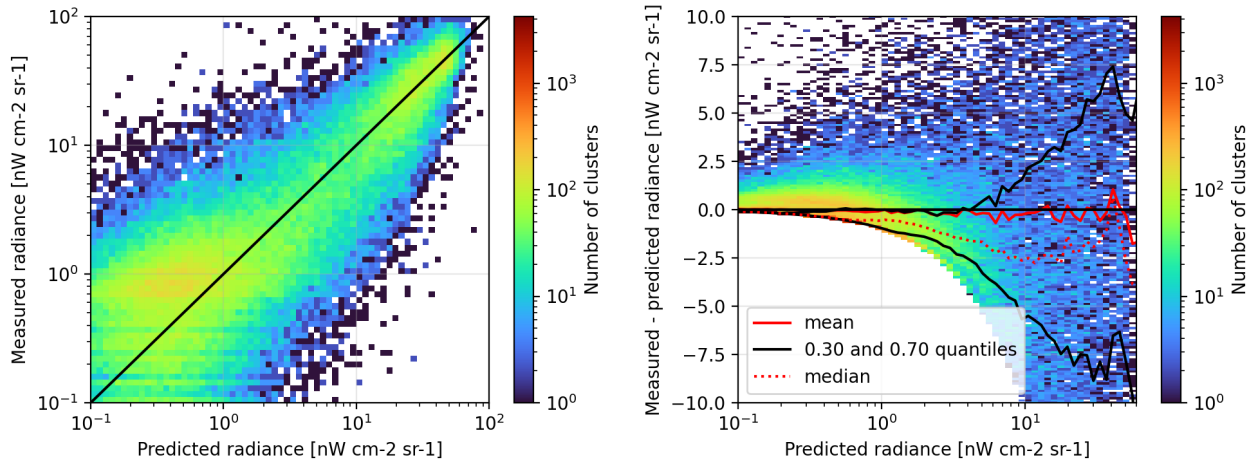

Fig. 4. Left: Measured radiance as a function of predicted radiance for Metropolitan France in 2024. **Right:** Difference of measured to predicted radiance as a function of predicted radiance.

Another path to reduce light pollution is to install more efficient lighting. Efficient in the sense that low-energy-consumption lights are installed, but also in the sense that only areas in which light is needed are illuminated. In order to guide this process, it is useful to characterize how much light is seen on the ground by VIIRS-DNB, in comparison to other areas with similar infrastructure properties. We therefore trained a Random Forest Regressor using the infrastructure information of the BD TOPO. We split the cluster sample randomly in half and used the regressor trained with the other half of the clusters to predict their expected radiance. The rating of feature importance of the regressor shows that the density of roads is by far the most important parameter to predict the radiance. Secondary parameters are the total area of the cluster, the population density and the density of business and industries.

The comparison between predicted and measured radiances is shown in figure 4. One can see a good correlation between the predicted and measured radiance. Generally, the distributions of measured variance for a predicted one are highly asymmetric, as can be seen by the difference between the median and mean predicted variance. The reason is that for low predicted radiances negative fluctuations are suppressed, as measured radiances cannot be negative. In order to characterize how the radiance of a given cluster compares with the prediction, we classified them in 10 quantiles: the lowest quantile indicates that this cluster is among the dimmest 10% of clusters, the highest that it is among the brightest 10%. As an example, the infrastructure quantiles are shown in figure 1. For the highlighted cluster in Gueugnon, also shown in figure 2, one can see that even though light swich-off is practised, the light levels remain high compared to areas with a similar infrastructure.

References

Buhler, R., Deverchère, P., Plotard, C., & Vauclair, S. 2025, Multi-faceted light pollution modelling and its application to the decline of artificial illuminance in France, submitted for publication

Cerema. 2025, Extinction de l'éclairage public : une étude sur les pratiques des collectivités, `https://www.cerema.fr/fr/actualites/extinction-eclairage-public-etude-pratiques-collectivites`, [Online; accessed August-2025]

DarkSkyLab. 2025, Our projects and references, `https://darkskylab.com/www/en/projects/`

Earth Observation Group. 2025, VIIRS Nighttime Lights, `https://eogdata.mines.edu/products/vnl/`

Truong, C., Oudre, L., & Vayatis, N. 2020, Signal Processing, 167, 107299