ANALYZING LONG-TERM ARTIFICIAL LIGHT AT NIGHT USING VIIRS MONTHLY PRODUCT WITH LAND USE DATA: PRELIMINARY RESULT OF HONG KONG

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ABSTRACT

Long-term monitoring of artificial light at night (ALAN) is essential for our understanding of the source of light pollution and developing mechanisms to control it. In this study, based on the VIIRS monthly product and land use data, we analyzed the long-term ALAN in Hong Kong between 2012 and 2019. We could not detect any long-term trend in the level of ALAN of Hong Kong from this dataset over the eight years of observations at the level of detection accuracy of the VIIRS monthly data. We performed a detailed analysis of the ALAN from Hong Kong and its relationship with land use classes. We found that in Hong Kong, the public residential areas are brighter than the private ones, likely the consequence of a combination of population density and lighting designs. Using the clustering method, we were able to identify some persistently bright (or dark) facilities, such as the Hong Kong-Zhuhai-Macau Bridge Port, airport and port facilities. Transient phenomena such as wildfires were identified as well. Finally, we observed a brighter background ALAN associated with an elevated humidity level (R = 0.54), which can possibly be attributed to the dispersing effect of water vapor on radiation. Since large public transportation facilities emitted the most ALAN in Hong Kong, we suggest adopting sustainable design in future transportation projects to reduce the emitted ALAN to the space, thereby reducing light pollution.

Index Terms**—** Light pollution, artificial light at night (ALAN), VIIRS, Hong Kong, wildfire, clustering, humidity

1. INTRODUCTION

Although artificial light at night (ALAN) is essential for human nighttime activities in cities, its usage may cause a series of ecological and environmental problems in the natural environment, such as decreasing the density of sea turtles and seabirds [1, 2]. Several techniques are utilized by scientists to study light pollution [3]. Among them, the most popular ones are via the sky quality meter (SQM) or via nighttime remote sensing data [4, 5]. The Visible Infrared Imaging Radiometer Suite (VIIRS) monthly product with a resolution of 742 m is currently the most popular remote sensing data in examining long-term light pollution, dating back to April 2012. Although data before 2012 can be accessed via the Defense Meteorological Program Operational Line-Scan System (DMSP/OLS), the lack of calibration makes it unsuitable for quantitative analysis. As a result, the monthly VIISS product is current ideal data to study long-term ALAN.

One of the goals in studying ALAN is to identify its sources so that we can control the degree of light pollution. However, several studies pointed out that we are still in the beginning of understanding ALAN [6, 7]. The sources of ALAN in most cases were city lighting related to daily activities, but sometimes were industrial sites, open-pit mines, and gas flares [8]. Within cities, commercial areas were often accounted as the primary ALAN sources [9, 10], while airports were also a major factor [11]. Regression models were often used to analyze the potential variables of ALAN [10, 12], whereas unmixing and clustering methods also played a significant role [13, 14, 15]. Nevertheless, only a limited number of studies have examined ALAN sources, and more detailed studies at the city or local scale should be presented.

Megacities and fast-developing regions tend to be brighter. Hu and Zhang (2020) [16] stated that the increase of ALAN from 1997 to 2017 was mainly concentrated in five regions, four of them in Asia. Hong Kong was reported to be one of the cites that suffered from long-term light pollution [4]. It is relatively small in terms of administrative area but a megacity in terms of population and prosperity. The lack of heavy industries makes it an ideal place to study city lighting without worrying about gas flares. Thanks to the available detailed land use data in Hong Kong, it is possible to analyze long-term ALAN with land use functional zones, e.g., public residential, private residential, and commercial areas. Therefore, in this study, we aim to analyze the long-term ALAN between 2012 and 2019 in Hong Kong using the VIIRS monthly data.

2. DATA AND METHOD

We obtained the VIIRS monthly product (*VCMCFG*) between April 2012 and May 2019 via the NOAA website, in which June 2018 was not available. The monthly product was fil-

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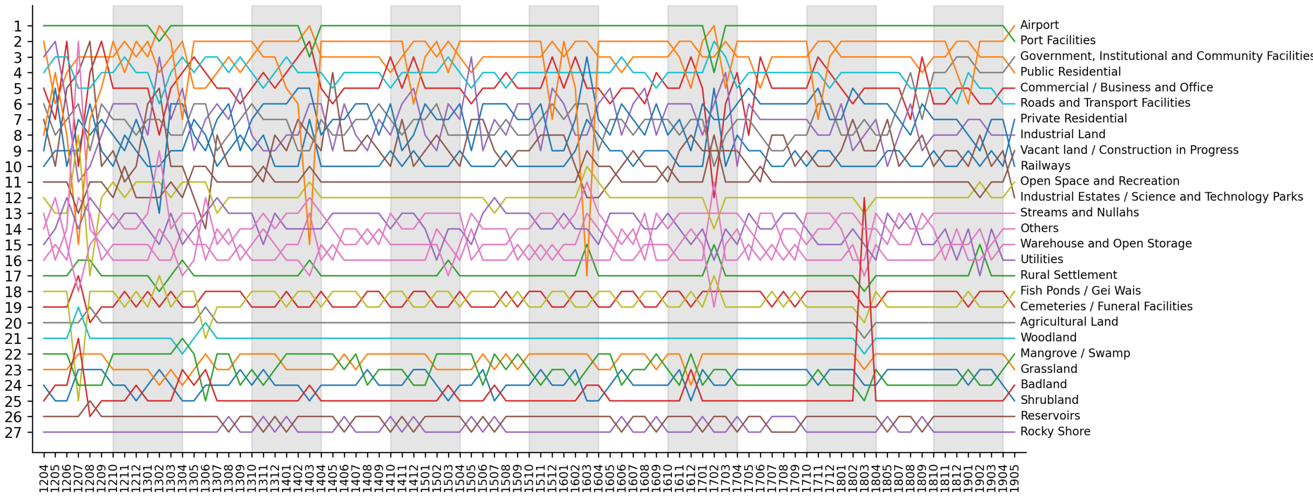

Fig. 1: Trend of monthly land use ranking by ALAN. White background: April to October; gray: October to April.

tered and supposed to be cloudless. Due to the monsoon climate with frequent clouds in Hong Kong, some regions had zero valid observations in some months. We filtered out the non-valid observations.

We obtained the 2018 land use data from the Planning Department[1]. It consisted of 27 land use classes, e.g., airport, port facilities, commercial/business and office, public residential, and private residential. We resampled the data as the size of VIIRS grid using the nearest neighbor method.

To identify brighter or darker regions, we used the agglomerative clustering to cluster time-series VIIRS data into several classes. The Ward's method with Euclidean distance was adopted to minimize the variance of the clusters [17].

To analyze the seasonal variation, we found the top-N months in terms of radiance of each pixel among the 85 months and calculated their frequencies. For each pixel, a larger top-N value of a month indicates that this pixel in the specified natural month tended to be brighter than other months.

3. RESULTS AND DISCUSSION

3.1. Land Use Ranking Between 2012 and 2019

We show monthly land use ranking between 2012 and 2019 in Hong Kong in Fig. 1. Among the 27 classes, port facilities were the brightest in most months, followed by the airport. These two unshaded, open regions emitted ALAN without the blocking of urban canyon. The followings are public residential areas, government facilities, commercial areas, and transportation facilities. Public residential areas were brighter than the private residential areas. In Hong Kong, public residential areas are often located in the core urban areas. Private residential areas are in the mid-levels or islands that are private and far away from city centers, which should explain the relatively low ALAN in private residential areas. The remaining urban land use classes were brighter than the natural ones. Among the natural land use classes, mangroves were brighter than reservoirs and rocky shore, indicating potential ecological light pollution of mangroves. Although variation existed in these land use classes, their relative ranking was similar in the eight years.

3.2. Identifying Brighter/Darker Regions via Clustering

We used the agglomerative clustering to identify potential brighter or darker ALAN patterns, as shown in Fig. 2. We set the number of classes as 36. Most classes fluctuated within a certain range but were not significantly brighter or darker, except for classes 2 and 27. Sudden peak occurred in several classes, with the most distinct in classes 26 and 28 (peaks at February 2016 and March 2018, respectively). The two identified classes located at the Castle Peak and Por Lo Shan, as shown in Fig. 3. Based on online records, wildfires happened in the two regions on February 6-7, 2016, and March 21-23, 2018 (Castle Peak: `https://youtu.be/C1ysPPKxh0s`; Por Lo Shan: `https://youtu.be/I2p1oWD-gYY`).

The two identified classes with increased ALAN are an artificial island of the Hong Kong-Zhuhai-Macau Bridge Port and the Happy Valley, a downtown residential region with distinct sports lighting. However, for most urban areas, we could not detect any long-term tend from the VIIRS data. Although several urban development and renewal projects were being conducted in Hong Kong in recent years (e.g., Kai Tak, Tseung Kwan O), they might be too subtle to be detected using the VIIRS data with a resolution of 742 m. Another possible

[1]`https://www.pland.gov.hk/pland_en/info_serv/statistic/landu.html`

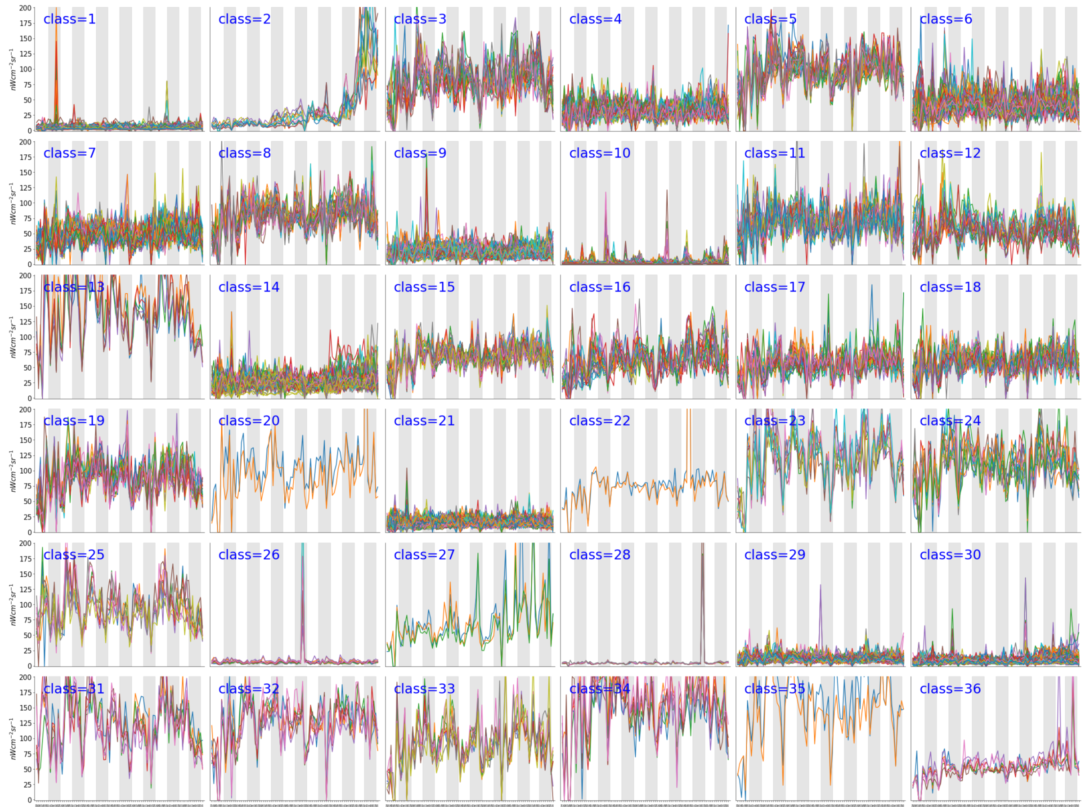

Fig. 2: Clustering result. White background: April to October; gray: October to April. Data range: April 2012 - May 2019.

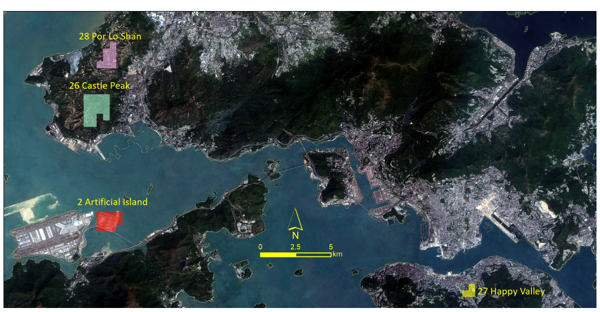

Fig. 3: Special ALAN patterns identified.

reason may be that during early construction, the construction lighting was bright enough and illuminated the entire region. As a result, ALAN increased in the early stage of development. For urban renewal, the consistent ALAN from the construction site and the surrounding regions makes it difficult to detect using this data captured at midnight.

3.3. Relationship with Humidity

In Fig. 4, we show the geographic distribution of the brightest N (N=30) records of each month. A large value means the pixel tends to be bright in the specific month. The N value is a smoothing factor and does not change the conclusion. Background ALAN (sea and mountains) with small values tended to be brighter in April, and the urban ALAN with large values brighter in January. We can easily identify the outline of the city as the patterns in April and January are clear. Background ALAN is known to be diffuse light [18]. Hong Kong has the highest humidity level in April and the lowest in December and January (Fig. 4). Atmosphere with high humidity tends to scatter light [19]. Instead of a simple coincidence, this finding seems to be a fact that high humidity causes more background diffuse light. On the contrary, urban ALAN with large values became darker due to the dispersing effect in April but brighter in January when the humidity was low. A linear correlation (R=0.54) was found to support the argument.

4. CONCLUSIONS

In this study, based on the monthly VIIRS product and land use data, we aim to find the brighter or darker areas between 2012 and 2019 in Hong Kong. The Hong Kong-Zhuhai-Macau Bridge Port's artificial island had a dramatic increase of ALAN. But ALAN of the remaining regions from the VIIRS data fluctuated within a certain range and was neither brighter nor darker. We identified two interesting areas with sudden ALAN changes related to wildfires by a clustering method. By analyzing each pixel's top-N months, we found

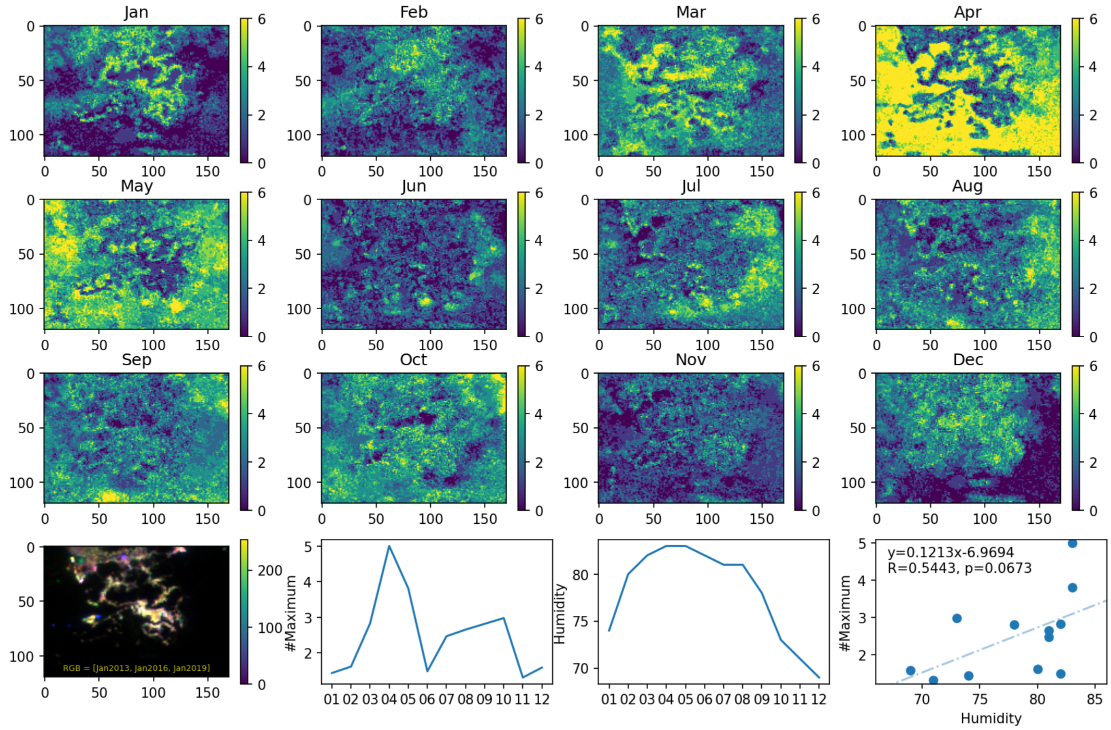

Fig. 4: Locations of top-N months, ALAN image, and the correlation between humidity and background ALAN.

that background ALAN was bright in April when the humidity level was high. A linear correlation (R=0.54) between humidity and the top-N value was found to support the conclusion. Background ALAN is known for its diffuse nature. Our finding should show that it might be related to humidity. Due to the coarse resolution of the VIIRS data, we found only increased ALAN related to large construction and no darker areas. In future studies, high-resolution data will benefit the ALAN study and is worth our investigations.

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