Report on Deliverable 5.4

Online artificial light trends analysis tool

Creator	C.C.M. Kyba (GFZ German Research Centre for Geosciences)
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Executive Summary

The Radiance Light Trends web application was developed in order to make it possible for anyone to quickly analyze trends in Earth's night light emissions. While the data underlying the app were already freely available, downloading and processing the large datasets takes considerable time and expertise. Even for an expert who had already downloaded the data, producing a trend for a selected area used to take between 30 minutes to around one day, depending on the complexity of the area under analysis. With the new webapp, developed as part of the GEOEssential project, this task can now be completed in about 15-30 seconds. In addition to democratizing the data, this tool provides considerable benefit to experts, because of the greatly increased speed.

In addition to providing the raw data, the application produces attractive charts, and optionally performs linear or exponential fitting to the data. The intent is that this will be a useful tool for city managers aiming to better understand trends in light emissions from their areas of responsibility, as well as for activists aiming to raise awareness of unsustainable increases in light (or, more hopefully, to eventually demonstrate progress towards reduction of light pollution). This report briefly outlines the functionality of the web application.

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1   Introduction

This web application allows anyone to examine changes in nighttime light emissions (nearly) worldwide, from 1992 up until the most recent month for which data is available. This document explains the app user interface, and then discusses where the data comes from and what need to know about the data sources to understand the charts that you generate.

2   Using the app

The web application can be accessed at the following website:
https://lighttrends.lightpollutionmap.info/

The landing page is shown in Figure 1, with a few key control elements highlighted with yellow arrows. The "?" icon leads to an in-app tutorial that walks the user through all of the different systems and controls of the application, and provides more detailed instructions than are provided here. The icon at top right allows the user to select from a set of background layers and their opacity. All of the individual night lights products can be selected as a background layer. The two main tools are the "point analysis" and "area analysis" in the top left corner.
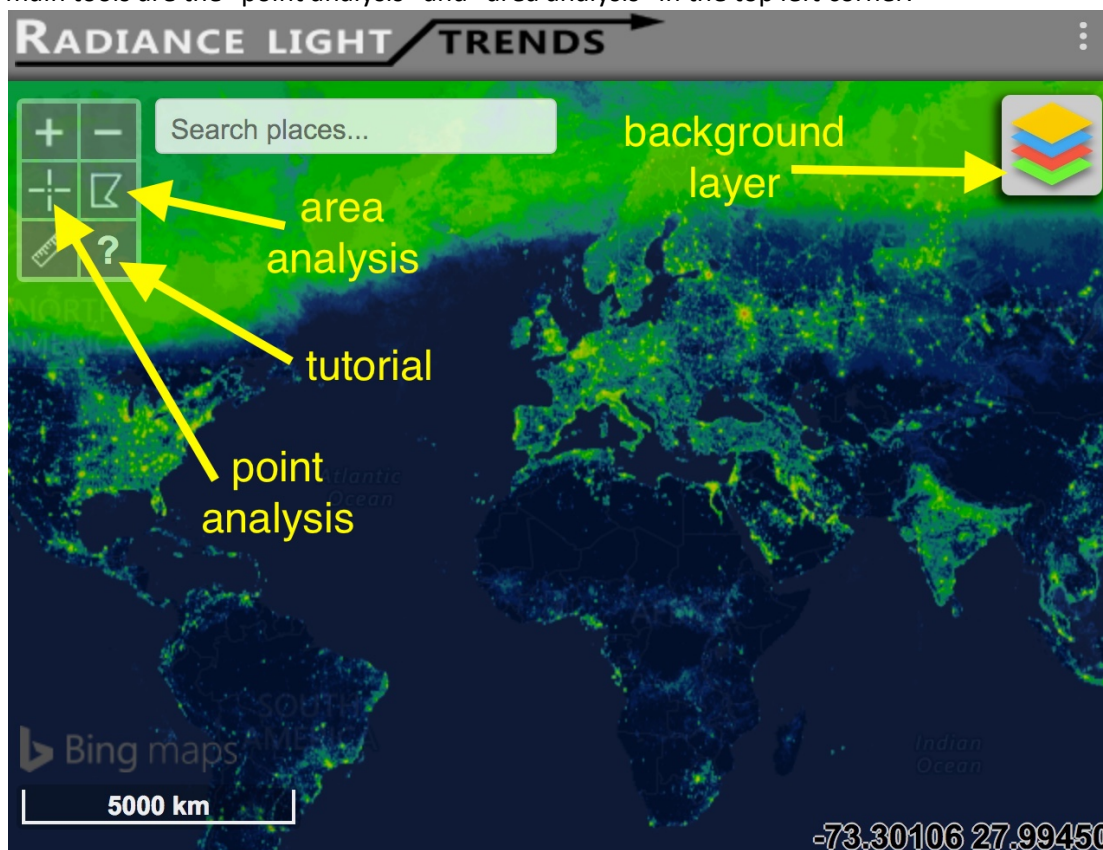

Figure 1: The web application interface when first logging in.

The search bar can be used to zoom to a particular location, either by place name or by specifying the latitude and longitude. In the case of Figure 2, we have selected a region encompassing the Indonesian island of Lombok.
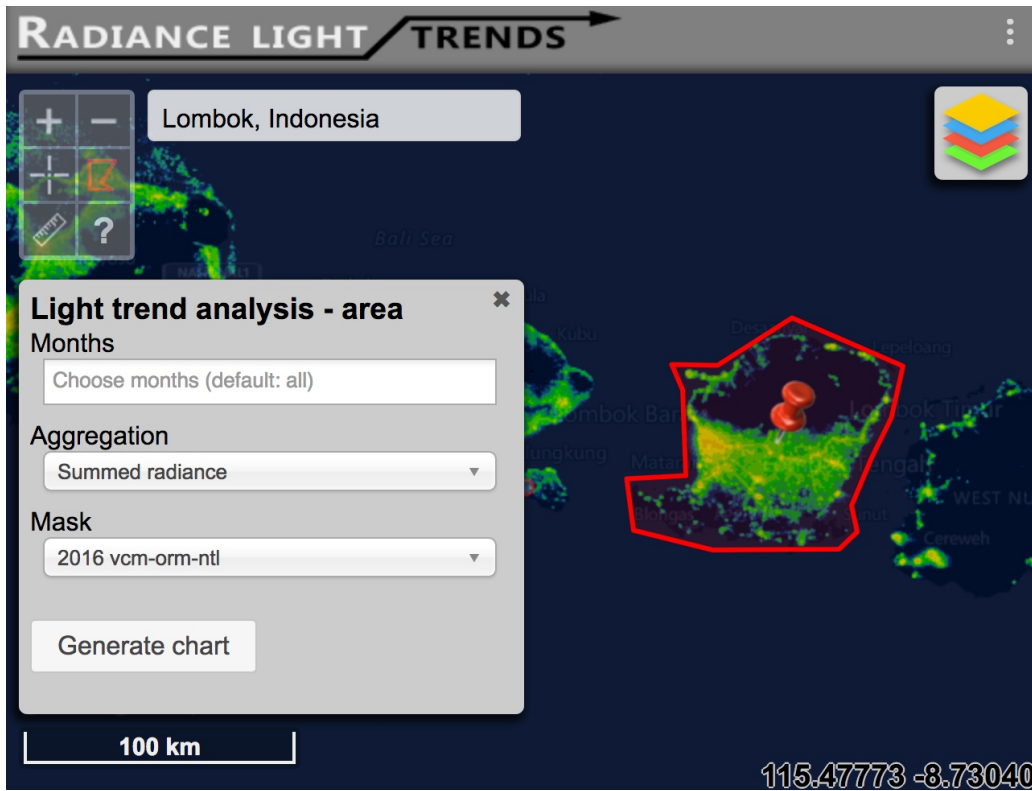
Figure 2: Users can draw a polygon shape to select a region of interest. Polygons can be saved to a local computer, and uploaded again to repeat an analysis at a later date.

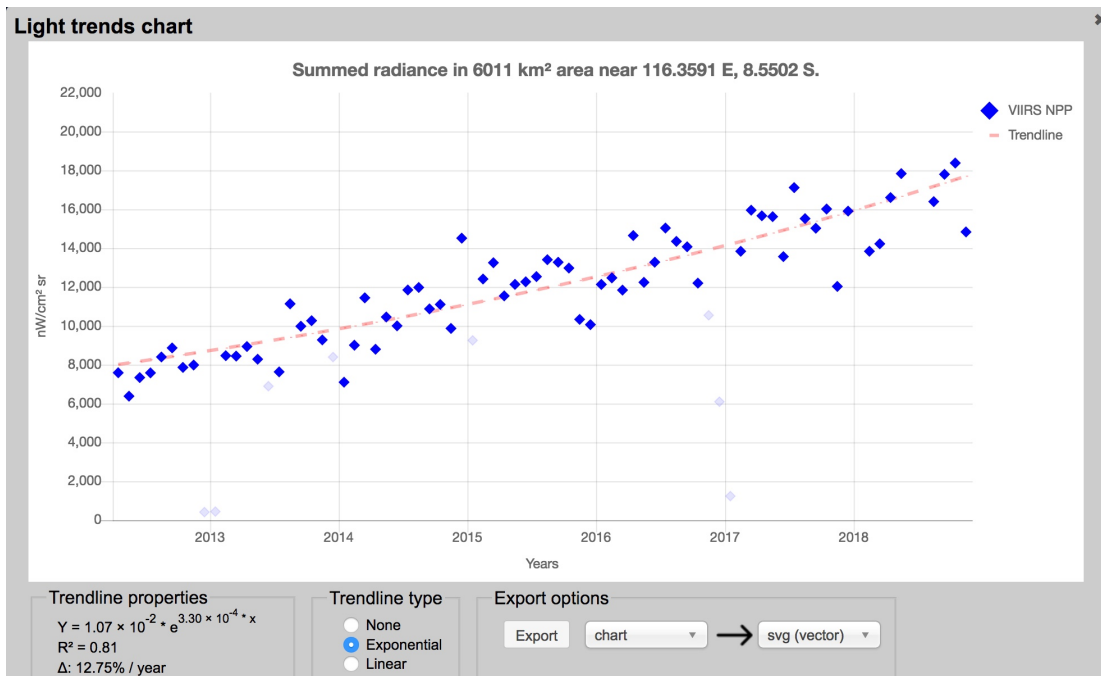When "Generate chart" is clicked, a new interface pops up, as shown in Figure 3:

Figure 3: Screenshot showing the upward light emission trend for the Indonesian island of Lombok. Users can select between an exponential or linear fit, and export the chart and underlying data.

This interface allows the user to select which type of trend to fit, and displays the results of the fit. In this case, we see that from 2012-2019, the island of Lombok brightened at a rate of nearly 13% per year, or in other words a doubling of total upward light emissions every 6 years. This interface allows

the user to export the chart in multiple formats, or to export the data itself. Because analyzing large areas can take several seconds, we currently limit analyses to 5,000 square kilometers for the general public. This limit will be revisited once we have a better understanding of the usage when the app goes public.

The remainder of this document describes the data sources and aspects of the data that are important to be aware of before drawing conclusions based on the data.

3 Data sources

The emissions data come from two satellite sensors. From 1992 to 2013, data comes from the Operational Linescan System of the Defense Meteorological Satellite Program (DMSP) satellites. From 2012 to the present, data comes from the Day/Night Band of the Visible Infrared Imaging Radiometer Suite instrument (VIIRS DNB). The instruments have a number of important differences, and for that reason it is not possible to have a single record running from 1992 to today.

Both of the satellite instruments scanned (nearly) the entire Earth each night, but the DMSP typically passed overhead around 8:30 pm, while VIIRS DNB passes over much later, around 1:30 am. Several days per month, areas of the Earth will be covered in clouds or illuminated by moonlight. For more than two decades, the team of Chris Elvidge and Kimberly Baugh have produced global annual satellite observed nighttime lights data products. They were based initially at the U.S. National Oceanic and Atmospheric Adminsitration's National Geophysical Data Center in Boulder, Colorado. In 2019 they relocated the Payne Institute at the Colorado School of Mines, Golden, Colorado. As the link to obtain the data will soon change, we do not list it here, but will provide an updated link in the "about" tab at the top right of the web application.

3.1 About the DMSP

Observing night lights was not the main purpose of the DMSP, and the 1992-2013 data record therefore have a number of limitations. The instrument was not calibrated, and therefore the results are displayed in "digital numbers" ranging from 0-63. In city centers, the satellite data was often "saturated" (too bright to measure), and therefore each year will just show a value of 63. The team of Chris Elvidge and Kim Baugh worked to produce approximately radiometrically calibrated data for specific years, and this can be accessed by selecting "Radiance Calibrated DMSP" on the "satellite" dropdown menu.

The spatial resolution of the satellite was several kilometers, and is in fact larger than the pixels displayed by the app. Because the overpass time of the DMSP was so early in the evening, at high latitudes most of the data is acquired during winter. Care should therefore be taken in comparing results from high latitude countries to lower latitude countries.

3.2 About VIIRS DNB

The VIIRS DNB was the first satellite instrument intentionally designed to image human lights on the worldwide scale, and is therefore a major improvement over DMSP. The satellite resolution is about 750 meters (or 0.5 square km). This data has been reprojected onto a grid, so in some places (especially high latitudes) the pixels are displayed at finer detail than the satellite's actual resolution. Because of the higher data quality, it is possible to display DNB data on a monthly timescale.

3.3 Limitations of satellite data

Night lights imagery can provide useful data, but it is important to be clear about exactly what it represents. For example, the data presented here should not be understood as (directly) representing energy consumption, community wealth, or light pollution. While each of those are often closely related to light emissions, the satellite does not measure them directly.

The satellites measure light in the spectral range of about 500-900 nm. This is not the same as human vision, which runs from 400-700 nm. The satellite data is therefore less sensitive to white light than the human eye, and has sensitivity at infrared wavelengths that the human eye cannot see. For this reason, when communities switch from orange high pressure sodium lamps to white LED, the satellites often report a drop in brightness even if a human would say that the white LEDs look brighter. Since cities worldwide are changing to white LEDs, it is important to keep this in mind. This is discussed further in Sánchez de Miguel et al. (2019).

Even far away from artificial lights, the world is not entirely dark. It is lit by starlight, aurora light, and "airglow", and the satellite has some sensitivity to this light, especially around the polar regions. In areas that are mainly unlit, changes in airglow or the satellite calibration may affect all of the pixels similarly. Fires can also produce very bright temporary light emissions, and false signals caused by solar radiation appear over a certain region near the southern Atlantic. It is therefore not advisable to include large areas that have little or no installed lighting in your analyses. To some extent, this problem can be reduced by applying a mask. For example, if you select "2016 vcm-orm-ntl", this will remove areas that were not lit consistently during 2016.

The emissions observed from any given area change from month to month for a number of reasons. To some extent, and over the long term, this is due to actual changes in the installed lighting. But on shorter time scales, variation is due to a number of other reasons, such as the imaging angles that made up the monthly composite (see Coesfeld et al. 2018). Many areas, especially those at high latitudes, also display seasonal cycles. In areas that receive snow, it is advisable to restrict analyses to months that are unlikely to have snow on the ground. In addition, at high latitudes there is no data during the summer due to stray light shining on the satellite sensor.

Some of the light emitted upwards can scatter off of molecules and particles in the atmosphere, producing "skyglow", a type of light pollution. Because of this, the satellites often report light emissions from unlit areas near bright light sources. This can be very easily seen in cities that are on coasts. Because this light is regularly present, it will not entirely be removed by the "vcm-orm-ntl" mask.

4 Conclusion

This document has presented the features of the web application that is deliverable 5.4 of the GEOEssential project. In addition to all of the planned features, a number of extra features were added during the development. We thank the Horizon 2020 programme for providing the funding for the development of this application, and also thank Deneb, Geoinformation solutions, Jurij Stare s.p., for their professional coding work on the project. The code related to the app is released under the EUPL, a link to the code is available on the "about" tab of the web application.

5 References

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