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The Light Pollution Hunter

Age: 15- 18 years old

Topics: Students will use smartphone sensors to map and acquire georeferenced data about light sources spread on a territory, namely streetlamps.

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Module: Energy Resources & Light Pollution Mitigation

Topic: Light pollution Mapping

Lesson Plan Title: The Light Pollution Hunter	
Duration: 45 minutes	
Short Description of the Lesson	Students will use smartphone sensors to map and acquire georeferenced data about light sources spread on a territory, namely streetlamps.
Learning Goals	• Sensor Technology Proficiency: Understand and demonstrate proficiency in utilizing smartphone sensors for data acquisition, focusing on mapping and acquiring georeferenced data. • Data Analysis Skills: Develop the ability to analyse collected data effectively. • Georeferencing Knowledge: Acquire knowledge and skills in georeferencing, including understanding the principles of mapping data to geographic locations and utilizing geospatial information in analysis. • Map Interpretation and Creation: Develop the competence to interpret and create maps based on the analysed data, showcasing the spatial distribution of the data in the specified territory.
Green Competences Linked	• Valuing sustainability: promote an understanding of the importance of dark skies for both ecological balance and human well-being; discussing the negative impacts of light pollution on wildlife, ecosystems, human health, and astronomical research. • Critical thinking: analyze the various sources of light pollution, such as streetlights, billboards, residential and commercial buildings, and vehicle headlights; understanding the complex interplay between urban development, technological advancement, energy consumption, and light pollution. • Adaptability: research potential solutions to reduce light pollution; this could include the use of energy-efficient lighting, implementation of 'dark sky' policies, and public education campaigns.
Target Group	Secondary school students aged 15-18 years old.
Educational Approach	Learning by project.
Link to School Curricula (if applicable)	Physics, Geography, Technology.

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Facility/ Equipment	• Classroom • Internet access • Personal computer • Smartphone or tablet with GPS sensor
Tools/ Materials	• PhyPhox app • Electronic spreadsheet software
Main Tasks 45 minutes	Mapping the Streetlights
Extracurricular Activities	• Field Trips for Data Collection: Organize field trips to gather real-world data on streetlamps, allowing students to apply sensor technology and georeferencing skills in different urban settings. • Mapathon Events: Host mapathon events where students collaborate to analyse and map data, fostering teamwork and providing a platform for showcasing their findings. • Community Outreach Programs: Engage with local communities to raise awareness about the project, involving residents in the data collection process and discussing the potential benefits of optimizing street lighting. • Project Showcases: Organize exhibitions or presentations to showcase the results of the data analysis and mapping, allowing students to share their findings with peers, teachers, and the community.

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Introduction

Light pollution is damaging to the environment, human health, and other beings. Do you wonder how much light pollution you are exposed to in your everyday life? This activity goal is to use smartphone or tablet sensors to map and acquire georeferenced data from light sources such as streetlamps. To collect the data, you need to use an app that allows access to the sensors and save the measurements in an output file. We suggest the PhyPhox app; it is available in the Play Store (Android) and App Store (iPhone), as well as https://phyphox.org. PhyPhox is free to use, and it allows us to collect a large amount of data from different sensors that smartphones usually have. This is a great tool to use in your classroom that, besides creating awareness about light pollution and energy savings, can exercise different competencies, including data science.

Equipment and Materials

- Cell phone/tablet with GPS sensor.
- PhyPhox app.
- Electronic spreadsheet software.

Suggested Ages

15-18 years old.

Prior Knowledge

The basics of electronic spreadsheet software and Google Maps editor.

Activity

For this task, the smartphone or tablet should have light and GPS sensors activated. The figure 1 below contains screenshots from the PhyPhox app showing the sensors that must be activated to be able to collect light and location data, and then it is possible to acquire the location data and the illuminance of the environment.

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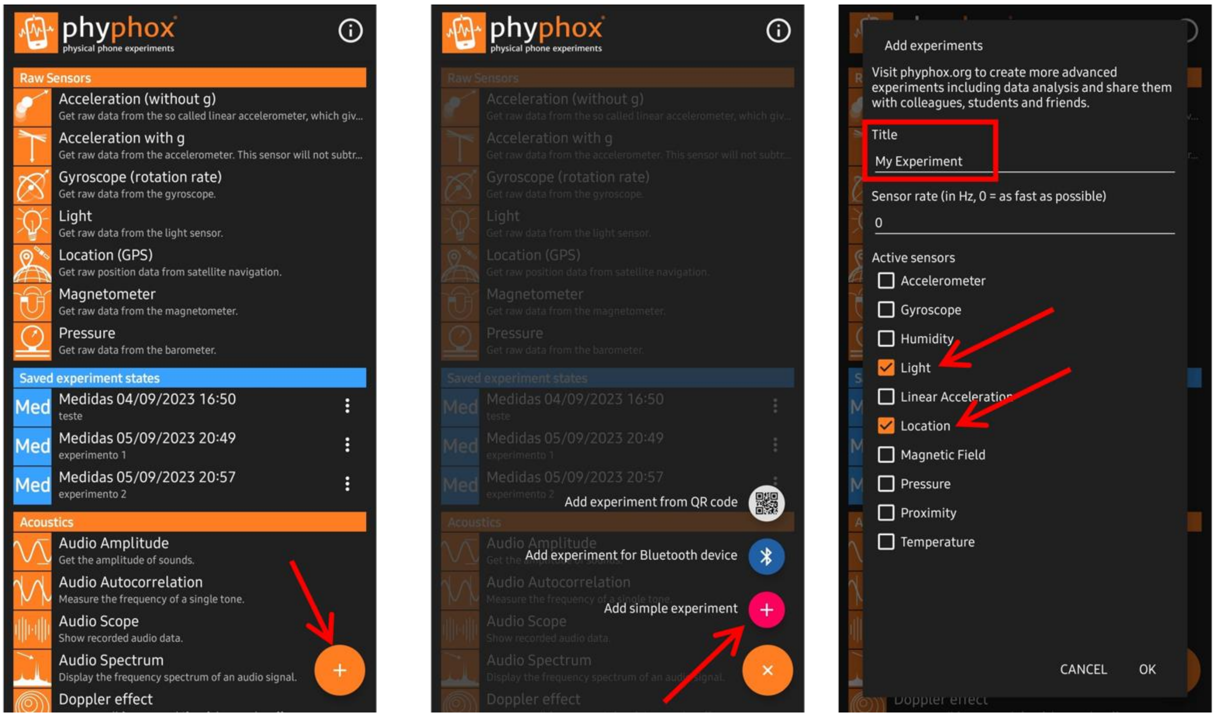

Figure 1 - Screenshot of the cell phone using the app, starting a data collection experiment.

How to start the data collection? Easy, you should create an experiment by tapping the “plus” icon at the bottom right corner of the screen (Figure 1, left) and then creating “Add simple experiment” (figure 1, centre). Now, give it a name, and select which sensors you wish to activate (Figure 1, right). Tap “OK” to open the data collection experiment.

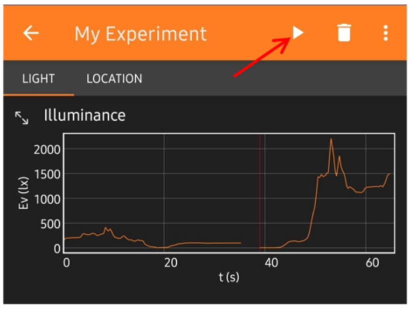

Figure 2 - Screenshot showing the "Play" icon to start the data collection.

To start collecting data from a sensor, tap the sensor name and then the button with the “Play” icon; Figure 2 shows the example for the Light sensor.

Figure 3 shows the screenshots for location data and light measurement, respectively. These screens can be accessed during the data collection; however, it is only controlled because the raw data will be saved in an output file.

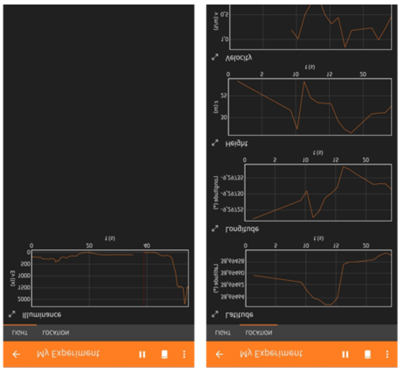

Figure 3 - Screenshot of the working app, marking of the sensors to be used in the data collection experiment.

How to save an output file? You can export the data to Excel format by taping the three dots menu at the top right corner of the screen and then “Export data” (Figure 4). Note you can save it as a CSV file if you want to. CSV file, or Comma Separated Values, is a plain text file that stores data by delimiting data entries with commas. CSV files are often used when data needs to be compatible with many different programs. An optional advantage is the file sizes are usually only a few kilobytes.

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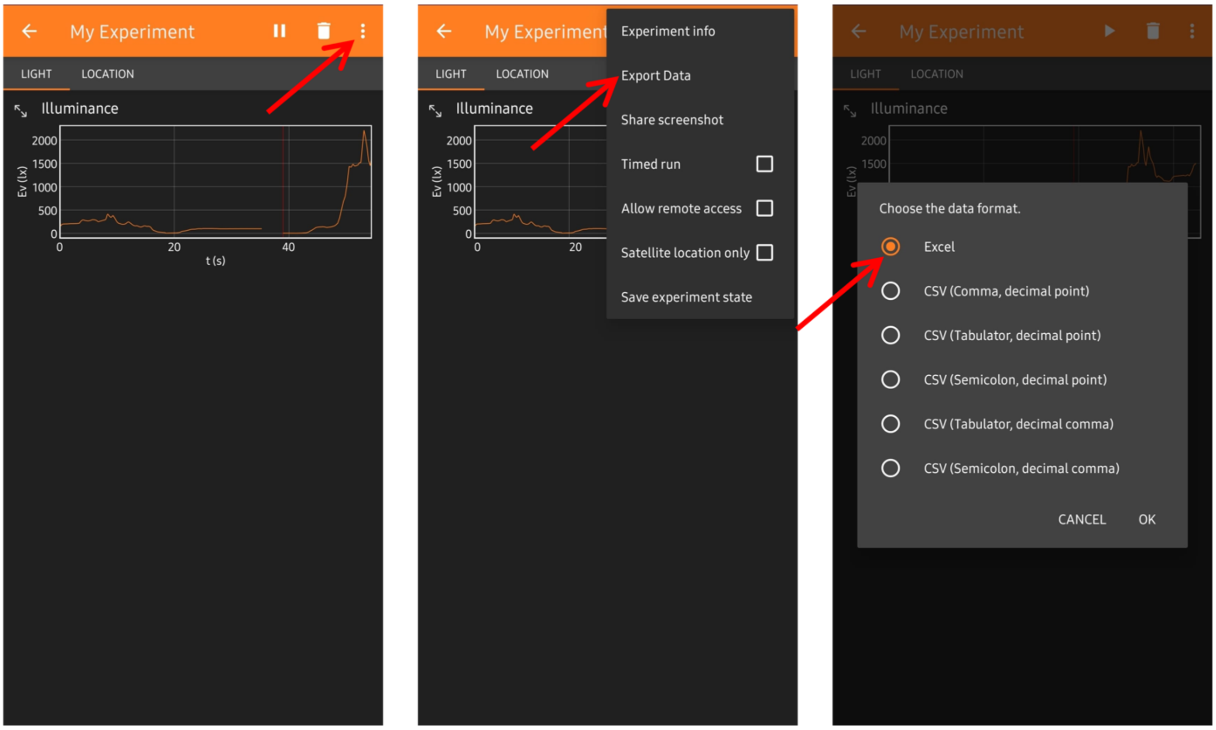

Figure 4 - Screenshot showing how to export your data.

Opening the raw data file, obtained from the PhyPhox App, in any spreadsheet program you want, it is possible to notice that it includes in one tab the data for illuminance (in Lux units), and in another the location (geographic coordinates). Figure 5 shows an example of raw data collected in Greece during the 2022 Summer School, where it is possible to see the different tabs.

	A	B
1	Time (s)	Illuminance (lx)
2	0	0,425000012
3	0,0549853	0,637499988
4	1,0549853	0,425000012
5	2,0549853	0,425000012
6	3,0549853	0
7	4,0549853	0,425000012
8	5,0549853	0
9	6,0549853	0,425000012
10	7,0549853	0,425000012
11	8,0549853	0,425000012
12	9,0549853	0,425000012
13	10,054985	0
14	11,054985	0,425000012
15	12,054985	0,425000012
16	13,054985	0
17	14,054985	0,425000012
18	15,054985	0,425000012
19	16,054985	0,425000012
20	17,054985	0,637499988
21	18,054985	1,075000048
22	19,054985	1,712499976
23	20,054985	3,212500095

Light | Location | Metadata Device | Metadata Time

	A	B	C	D	E	F	G	H
1	Time (s)	Latitude (°)	Longitude (°)	Height (m)	Velocity (m/s)	Direction (°)	Horizontal Accuracy (m)	Vertical Accuracy (m)
2	0,58522208	38,10823795	23,98162173	7,721183329	0,289999992	355,7000122	10,34704971	22,05681419
3	1,22985854	38,10823627	23,98162137	7,816097446	0,289999992	355,7000122	10,93671227	22,05681419
4	2,23002214	38,1082468	23,98154739	5,43517607	0	0	4,979489803	8,49677372
5	3,22956094	38,10824898	23,98152751	3,475204379	0	0	3,790092468	4,967496872
6	4,22868396	38,10824488	23,9815114	1,916114132	0	0	3,790092468	3,768536568
7	5,2288663	38,10825113	23,98151015	1,01644651	0	0	3,790092468	2,937361956
8	6,2291137	38,10825051	23,98150713	0,148597219	0	0	3,790092468	2,547336578
9	7,22945146	38,10825706	23,98150509	0,354277836	0	0	3,790092468	2,5
10	8,22884594	38,10826024	23,98150446	0,736536211	0	0	3,790092468	2,5
11	9,22913276	38,10826117	23,98150077	1,808321806	0	0	3,790092468	2,5
12	10,2294156	38,10826185	23,98150124	2,139862081	0	0	3,790092468	2,5
13	11,2286465	38,10826113	23,98149885	2,835792998	0	0	3,790092468	2,5
14	12,2288805	38,10826718	23,98149365	2,971048779	0,379999995	353,8999939	3,790092468	2,5
15	13,2293186	38,10826711	23,98149079	2,962694986	0,460000008	353,8999939	3,790092468	2,5
16	14,228523	38,10827449	23,98148704	2,265058293	0,649999976	353,8999939	3,790092468	2,5
17	15,2291262	38,10827707	23,98148648	2,319619956	0,790000022	354,1000061	3,790092468	2,5
18	16,2286828	38,10828428	23,98148728	2,209556527	0,75	354	3,790092468	2,5
19	17,2290593	38,10829003	23,98148612	2,208571327	0,660000026	16,29999924	3,790092468	2,5
20	18,2291573	38,10829573	23,98148752	2,116758864	0,660000026	16,29999924	3,790092468	2,5
21	19,2294354	38,1083001	23,98149576	4,133450803	0,709999979	20,89999962	3,790092468	2,5
22	20,2292001	38,10830549	23,98149997	4,581426159	0,779999971	20,70000076	3,790092468	2,5
23	21,2287286	38,10831276	23,98150224	4,266951819	0,889999986	14,89999962	3,790092468	2,5

Light | Location | Metadata Device | Metadata Time

Figure 5 - Example of raw data collected in Greece in the summer of 2022.

The metadata tab is where the information about sensors onboard the smartphone or tablet is written. This information is not directly useful for this task, so you need to focus on the two first tabs (light and location data).

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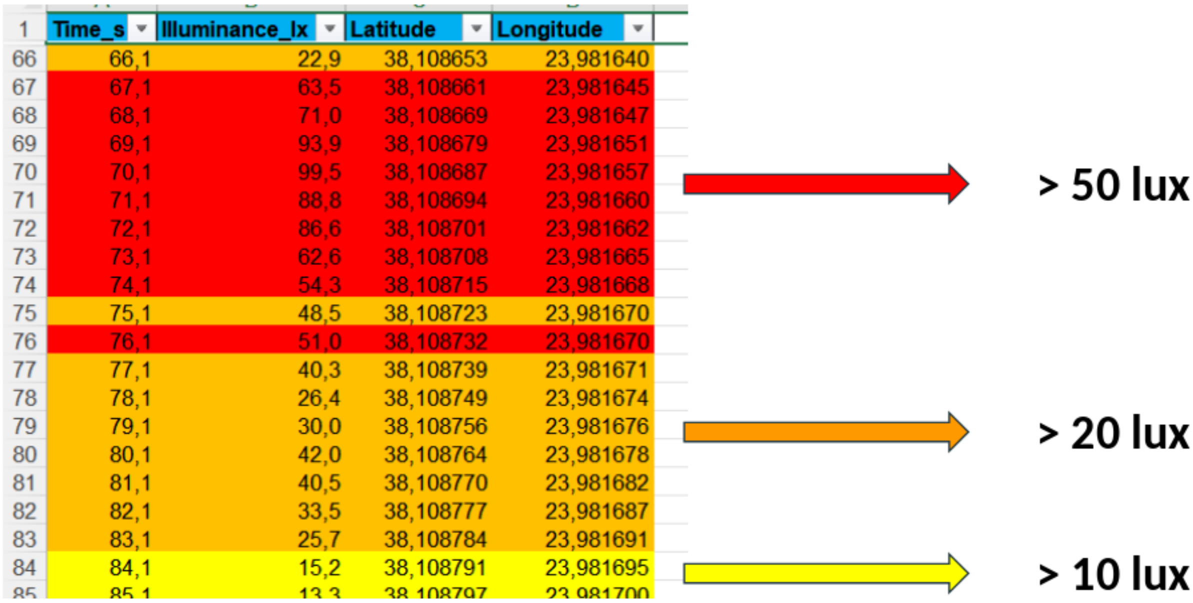
At this point, you should create a new spreadsheet file, where the final data will be saved. This new file should have four columns: Time(s), Iluminance_lx, Latitude, and Longitude; the data values are from the original file. Use the column Time (s), common in the two original tabs, to relate the measurement of light and location in the same new tab.

Now, take a good look at your data file and note the details and the variation in the illuminance. Then, considering a qualitative analysis, the illuminance data should be reclassified because the values are in a vast range. For this specific case, it is suggested that the data be reclassified into three bands: 10-20 lux, 21-50 lux, and 50 lux or higher. Figure 6 shows this reclassification using different colours for each band.



1	Time_s	Illuminance_lx	Latitude	Longitude
66	66,1	22,9	38,108653	23,981640
67	67,1	63,5	38,108661	23,981645
68	68,1	71,0	38,108669	23,981647
69	69,1	93,9	38,108679	23,981651
70	70,1	99,5	38,108687	23,981657
71	71,1	88,8	38,108694	23,981660
72	72,1	86,6	38,108701	23,981662
73	73,1	62,6	38,108708	23,981665
74	74,1	54,3	38,108715	23,981668
75	75,1	48,5	38,108723	23,981670
76	76,1	51,0	38,108732	23,981670
77	77,1	40,3	38,108739	23,981671
78	78,1	26,4	38,108749	23,981674
79	79,1	30,0	38,108756	23,981676
80	80,1	42,0	38,108764	23,981678
81	81,1	40,5	38,108770	23,981682
82	82,1	33,5	38,108777	23,981687
83	83,1	25,7	38,108784	23,981691
84	84,1	15,2	38,108791	23,981695
85	85,1	13,3	38,108797	23,981700

Figure 6 – An example of data reclassification.

You can originate a new column (Reclass) with a unique value for each band, the lower value, for example, from the reclassification method. As the following figure suggests. This procedure will make the next processes easier.

Tips: In Excel, use the function *Custom AutoFilter* to select only the rows in each band chosen and write its specified value (Figure 7).

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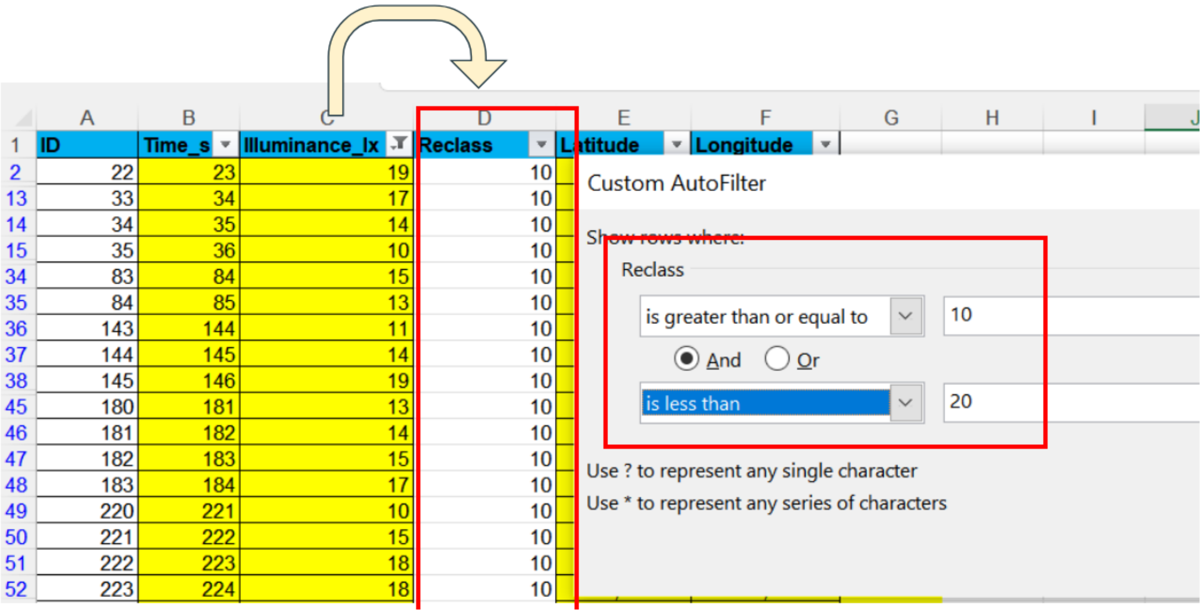

	ID	Time_s	Illuminance_lx	Reclass	Latitude	Longitude
2	22	23	19	10		
13	33	34	17	10		
14	34	35	14	10		
15	35	36	10	10		
34	83	84	15	10		
35	84	85	13	10		
36	143	144	11	10		
37	144	145	14	10		
38	145	146	19	10		
45	180	181	13	10		
46	181	182	14	10		
47	182	183	15	10		
48	183	184	17	10		
49	220	221	10	10		
50	221	222	15	10		
51	222	223	18	10		
52	223	224	18	10		

Figure 7 - Screenshot showing the use of Excel's Custom AutoFilter.

Now, create a new file to do the visual analysis. This new one should have only three columns: **Reclass**, **Latitude**, and **Longitude**. When this new file is complete, it will be possible to map that data using Google Maps, for example. Remember, the geographic coordinates should be registered as decimal degrees to ease the mapping process (usually they are already in this format). Figure 8 shows a visual scheme for this step.

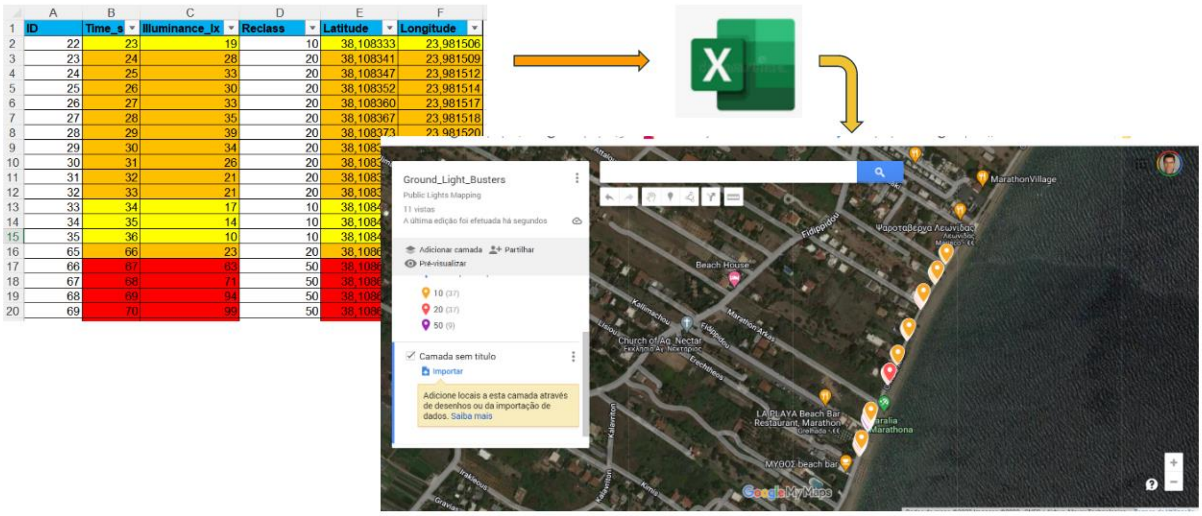

Figure 8 - Representation of the last step: from a data file to the maps.

After mapping the data, it is possible to see where the regions with more light are in the chosen territory. Of course, the measurements are taken on the street, where the light must illuminate. However, this activity can show the irregular distribution of light spots in the street. A possible result is a clever distribution of streetlights. At the same time, you can discover regions with excess streetlights in full power all the time at night, a typical situation of light pollution.

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ANNEXES

Illuminance and Luminous Flux

The measure of the quantity of luminous flux spreads over a given area is known by Illuminance (Fig. 9). One can think of luminous flux (measured in lumens) as a measure of the total "amount" of visible light present and the illuminance as a measure of the intensity of illumination on a surface. The relation between these quantities can be shown by:

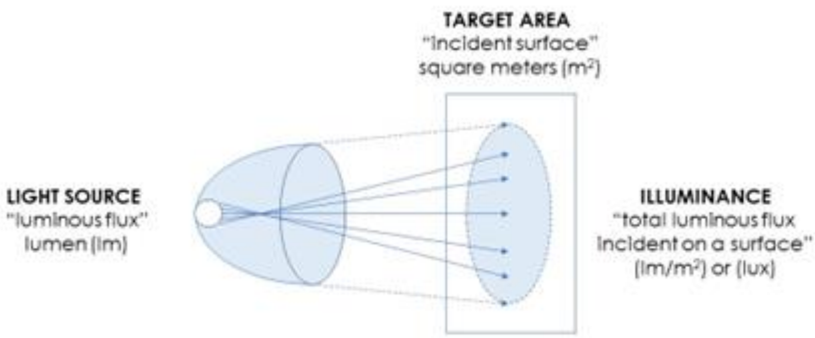

Figure 9 - Visual representation of lumens per square meter.

$$1\ lux\ =\ 1\ {}^{lumens}/_{m^2} \quad (1)$$

where

- Lux: SI unit of illuminance
- Lumens: SI unit of luminous flux
- m^2: square meter, unity of area

Location Sensor

The Location Sensor is used to communicate with the global positioning satellite receiver (GPS) in your phone/tablet. When the Location Sensor communicates with the built-in GPS receiver, the GPS determines the location of your device.

The measuring units employed in the Location Sensor for distance are meters (with 3 meters precision or less). Time is measured in milliseconds (ms). Be aware that **1 second = 1000 ms**.

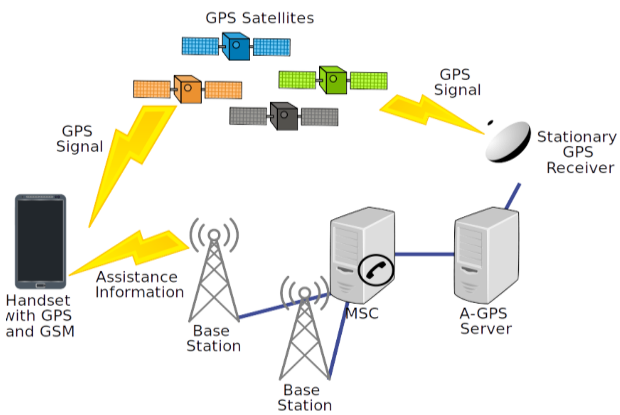

Figure 10 - Assisted GPS (aGPS) scheme.

However, a point to consider here is that the power from a smartphone is not enough for an excellent connection to GPS satellites, so we usually have an assisted GPS (aGPS). For short, in an aGPS system, the network operator deploys an aGPS server, which downloads the orbital information from the satellite and stores it in the database. An aGPS-capable device can connect to

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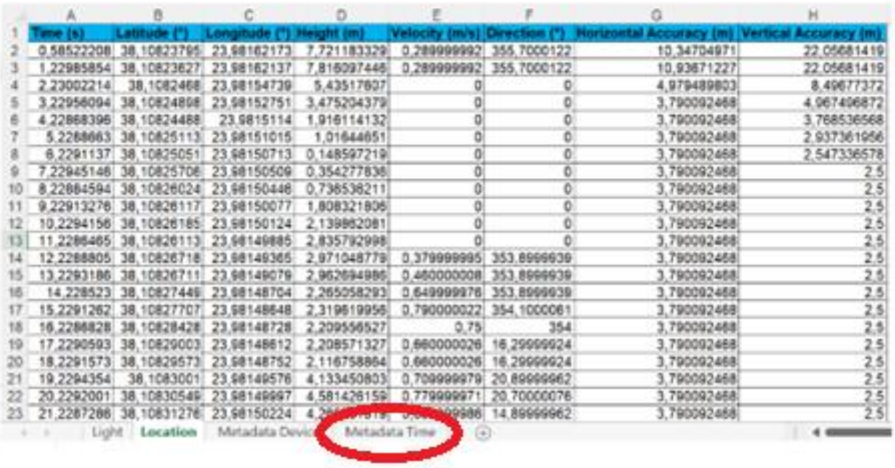
these servers and download this information using a mobile network. Ultimately, the location data are downloaded from this server, saving energy from the smartphone/tablet. So, an internet connection is essential during the data collection.

The Metadata File

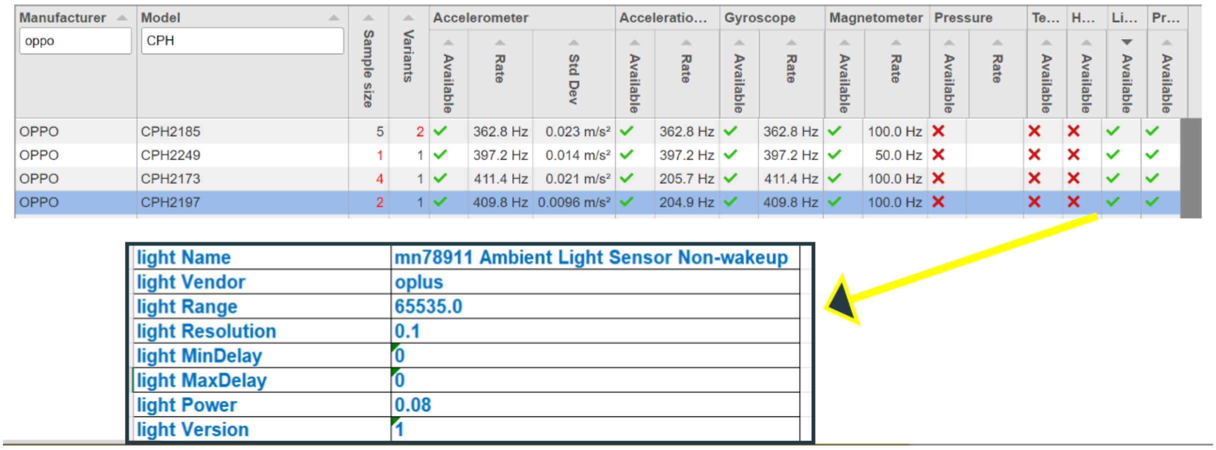
The output file of the PhyPhox app has a special tab named **Metadata**, as is shown in Figure 11.



	A	B	C	D	E	F	G	H
1	Time (s)	Latitude (°)	Longitude (°)	Height (m)	Velocity (m/s)	Direction (°)	Horizontal Accuracy (m)	Vertical Accuracy (m)
2	0,58522208	38,10823795	23,98162173	7,721183329	0,289999992	355,7000122	10,34704971	22,05681419
3	1,22985854	38,10823627	23,98162137	7,816097446	0,289999992	355,7000122	10,93671227	22,05681419
4	2,23002214	38,1082468	23,98154739	5,43517607	0	0	4,979489803	8,49677372
5	3,22956094	38,10824898	23,98152751	3,475204379	0	0	3,790092468	4,967406872
6	4,22868396	38,10824488	23,9815114	1,916114132	0	0	3,790092468	3,768536568
7	5,2288663	38,10825113	23,98151015	1,01644651	0	0	3,790092468	2,937361956
8	6,2291137	38,10825051	23,98150713	0,148597219	0	0	3,790092468	2,547336578
9	7,22945148	38,10825706	23,98150509	0,354277838	0	0	3,790092468	2,5
10	8,22884594	38,10826024	23,98150446	0,738538211	0	0	3,790092468	2,5
11	9,22913276	38,10826117	23,98150077	1,808321806	0	0	3,790092468	2,5
12	10,2294156	38,10826185	23,98150124	2,139862081	0	0	3,790092468	2,5
13	11,2286465	38,10826113	23,98149885	2,835792998	0	0	3,790092468	2,5
14	12,2288805	38,10826718	23,98149365	2,971048779	0,379999995	353,8999939	3,790092468	2,5
15	13,2293186	38,10826711	23,98149079	2,962694986	0,460000008	353,8999939	3,790092468	2,5
16	14,228523	38,10827446	23,98148704	2,265058293	0,649999976	353,8999939	3,790092468	2,5
17	15,2291262	38,10827707	23,98148648	2,319619956	0,790000022	354,1000061	3,790092468	2,5
18	16,2286828	38,10828428	23,98148728	2,209556527	0,75	354	3,790092468	2,5
19	17,2290593	38,10829003	23,98148612	2,208571327	0,660000026	16,29999924	3,790092468	2,5
20	18,2291573	38,10829573	23,98148752	2,116758864	0,660000026	16,29999924	3,790092468	2,5
21	19,2294354	38,1083001	23,98149576	4,133450803	0,709999979	20,89999962	3,790092468	2,5
22	20,2292001	38,10830549	23,98149997	4,581426159	0,779999971	20,70000076	3,790092468	2,5
23	21,2287288	38,10831276	23,98150224	4,2[illegible]	[illegible]	14,89999962	3,790092468	2,5

Figure 11 - An example of raw data collected in Greece in summer 2022, it is highlighted the Metadata.

The metadata tab brings all the information about the smartphone and the sensors on-board, which allows for the understanding of the data acquired. The figure 12 is an example of this metadata.



Manufacturer	Model	Sample size	Variants	Accelerometer			Acceleratio...		Gyroscope		Magnetometer		Pressure		Te...	H...	Li...	Pr...
oppo	CPH			Available	Rate	Std Dev	Available	Rate	Available	Rate	Available	Rate	Available	Rate	Available	Available	Available	Available
OPPO	CPH2185	5	2	✓	362.8 Hz	0.023 m/s²	✓	362.8 Hz	✓	362.8 Hz	✓	100.0 Hz	✗		✗	✗	✓	✓
OPPO	CPH2249	1	1	✓	397.2 Hz	0.014 m/s²	✓	397.2 Hz	✓	397.2 Hz	✓	50.0 Hz	✗		✗	✗	✓	✓
OPPO	CPH2173	4	1	✓	411.4 Hz	0.021 m/s²	✓	205.7 Hz	✓	411.4 Hz	✓	100.0 Hz	✗		✗	✗	✓	✓
OPPO	CPH2197	2	1	✓	409.8 Hz	0.0096 m/s²	✓	204.9 Hz	✓	409.8 Hz	✓	100.0 Hz	✗		✗	✗	✓	✓

light Name	mn78911 Ambient Light Sensor Non-wakeup
light Vendor	oplus
light Range	65535.0
light Resolution	0.1
light MinDelay	0
light MaxDelay	0
light Power	0.08
light Version	1

Figure 12 - An example of Metadata collected in Greece in summer 2022.

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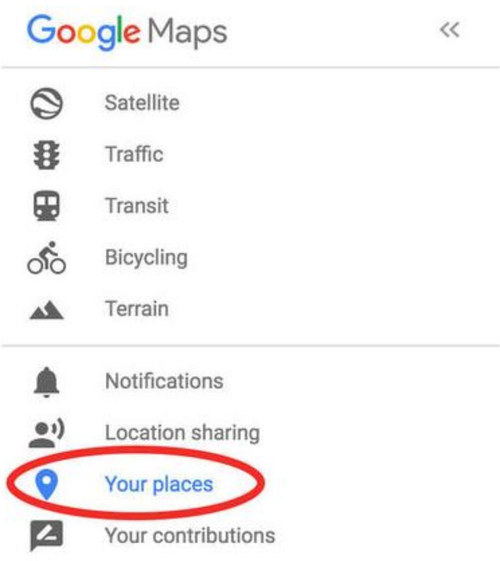
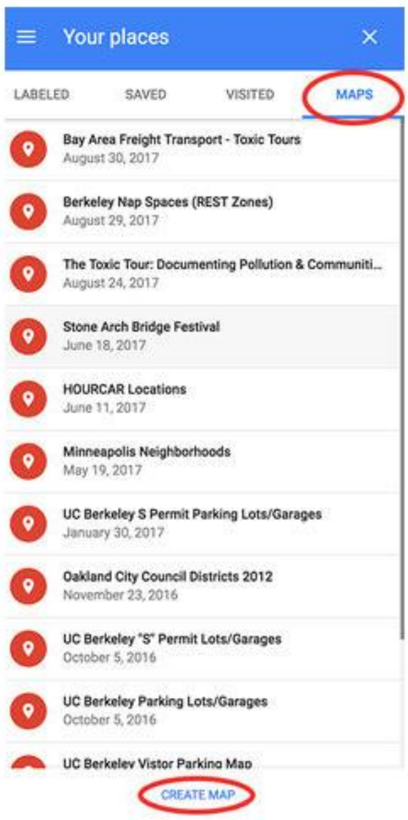
Google Maps Editor



Log in to your Google Account and open Google Maps. So, click on the menu icon on the top left-hand side of the screen and select "Your Places.".



Select the maps tab. Navigate to the very bottom of that window and select "Create a Map.".

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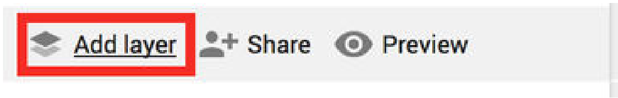
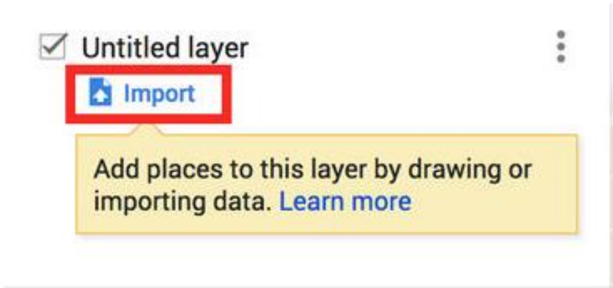
This will open a map in a new tab that you can customize by importing a spreadsheet file. For any map you make, you will need at least one column of the spreadsheet file containing location data. That location data can be a simple list of addresses, or it can include latitude and longitude coordinates, separated by a comma in decimal if they are in the same column.



The spreadsheet file final for this project has three columns: RECLASS, Latitude, and Longitude, so it is possible to use it. To upload the spreadsheet to your map, you must first create a layer by clicking “Add a layer” in the left-hand box.

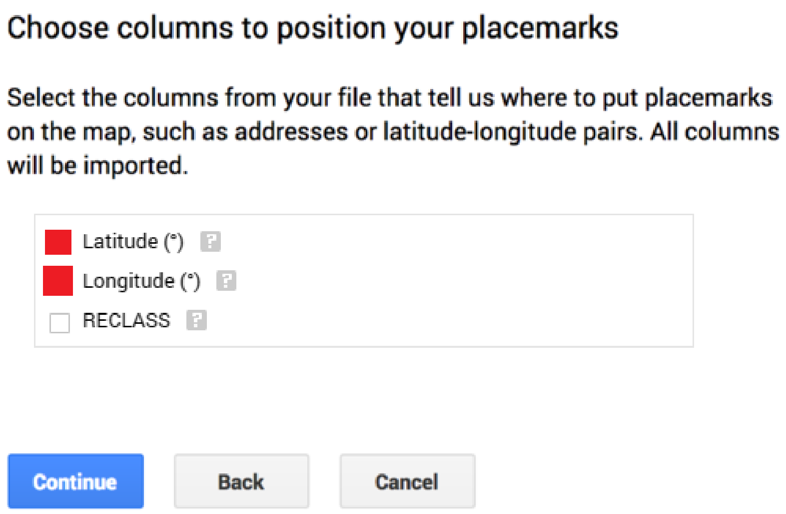
Under the new “Untitled Layer” you have created, click import.



Then find and select the file to import.

Google will prompt you to select the column that contains the location data. This is what Google will use to place the markers on the map. In this case, the location data is in two columns: Latitude and Longitude, so you will select that.

Attention: Probably you will have an extra step here. Google would ask you to select the appropriate order of your coordinates: “latitude, longitude” or “longitude, latitude.”



Then, Google will prompt you to select the title for your markers. In this case, you should select the “RECLASS” column.

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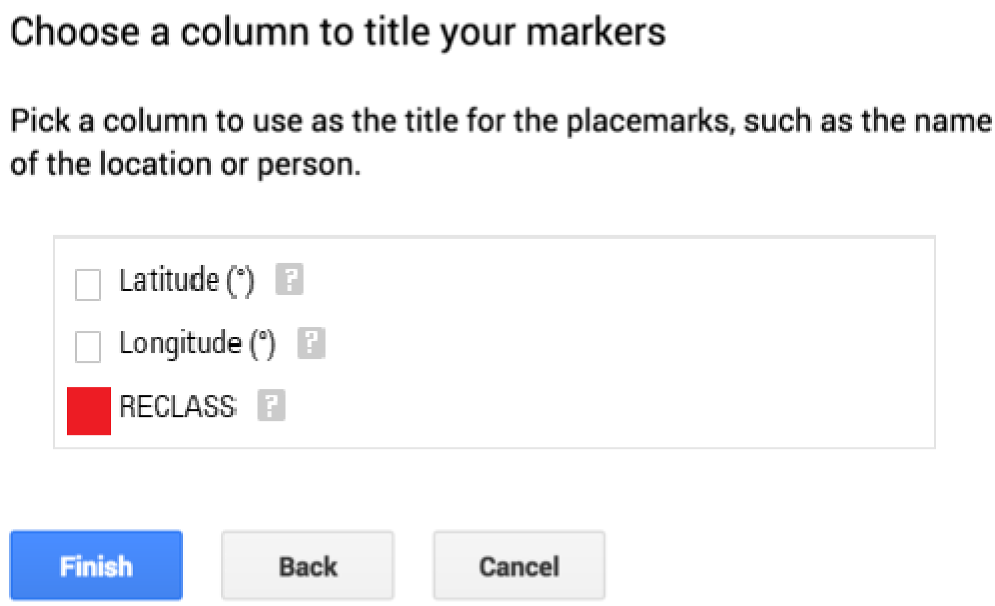

Hit finish and Google will automatically generate your map with the appropriate markers. However, if you look at the newly created map, notice that all markers are the same style: a blue pin.

What can you do? You need to adjust the style using the RECLASS column. Click on the “Group places by” dropdown menu selects “Style by data column” option and select “RECLASS”. Google will automatically choose three different colors for each RECLASS group. If you want to change the color or icon style for each of the groups just hover over each group and click the paint bucket to customize.

Reference

Adapted from: [How to Create Custom Maps in Google Maps | Tutorial | UC Berkeley]

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