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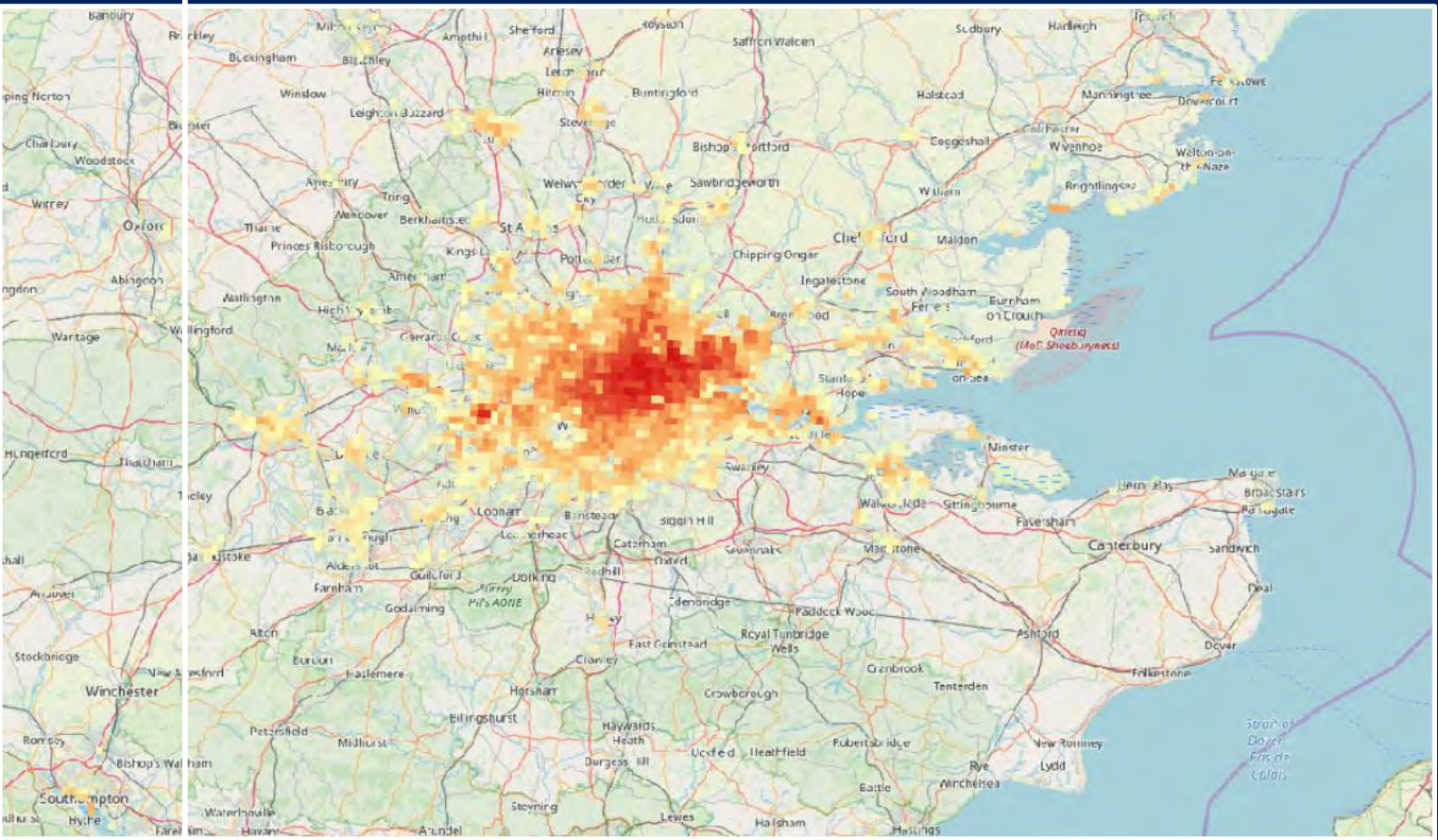

TRAINING KIT – LAND09

URBAN HEAT ISLAND WITH SENTINEL-3

Case Study: London, 2018

serco

NOVELTIS

ALONG-TRACK

ROMANIA

Research and User Support for Sentinel Core Products

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Authors would be glad to receive your feedback or suggestions and to know how this material was used. Please, contact us on training@rus-copernicus.eu

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Table of Contents

1 Introduction to RUS

The Research and User Support for Sentinel core products (RUS) service provides a free and open scalable platform in a powerful computing environment, hosting a suite of open source toolboxes pre-installed on virtual machines, to handle and process data derived from the Copernicus Sentinel satellites constellation.

In this tutorial, we will employ RUS to monitor the urban heat island phenomenon in London (UK) using Sentinel-3 SLSTR sensor as source of information.

2 Urban Heat Island – background

Currently, more than half of the world's population live in urban areas and this number is still rapidly increasing. Since settlements represent the centers of human activity, the environmental, economic, political and cultural impacts of urbanization are far-reaching. They include negative aspects like the loss of natural habitats, biodiversity and fertile soils, climate impacts, waste, pollution, etc., making urbanization one of the most pressing global challenges.

The Urban Heat Island (UHI) phenomenon is one example of the effect of urban areas in the local climate. The effect mainly consists of the heating of urban zones in comparison to its non-urbanized surroundings. The atmospheric air temperature of densely urbanized areas is higher than the one of the nearby rural areas. Its relevance usually appears during the night because of the release of energy that has been stored by built-up surfaces during the day. Among the local impacts and negative effects of the UHI phenomenon, we can highlight thermal stress & deaths, higher energy consumption (due to air-conditioning), atmospheric chemistry (0_3 emissions from energy consumptions), increased water demand amongst others.

3 Training

Approximate duration of this training session is one hour.

The Training Code for this tutorial is LAND09. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the RUS portal and open a User Service request from Your RUS service > Your dashboard.

3.1 Data used

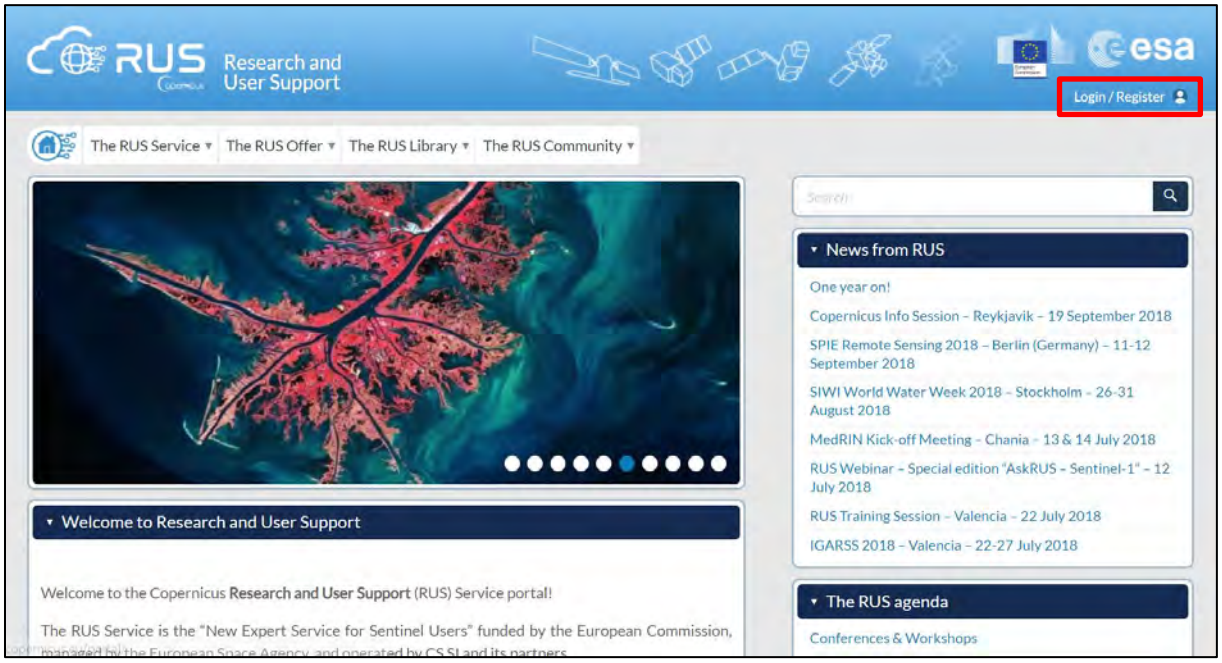
- 2 Sentinel-3A images acquired on 2nd August 2018 [downloadable at https://scihub.copernicus.eu/
- Pre-processed data stored locally *@/shared/Training/LAND09_UrbanHeatIsland_London/AuxData/*

3.2 Software in RUS environment

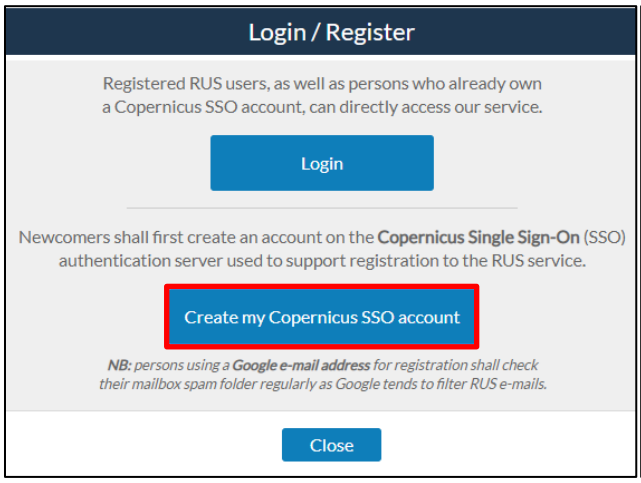
Internet browser, SNAP + S3 Toolbox

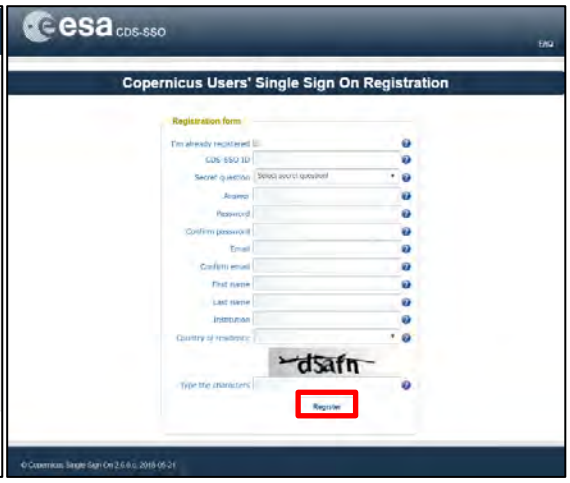
4 Register to RUS Copernicus

To repeat the exercise using a RUS Copernicus Virtual Machine (VM), you will first have to register as a RUS user. For that, go to the RUS Copernicus website (www.rus-copernicus.eu) and click on *Login/Register* in the upper right corner.



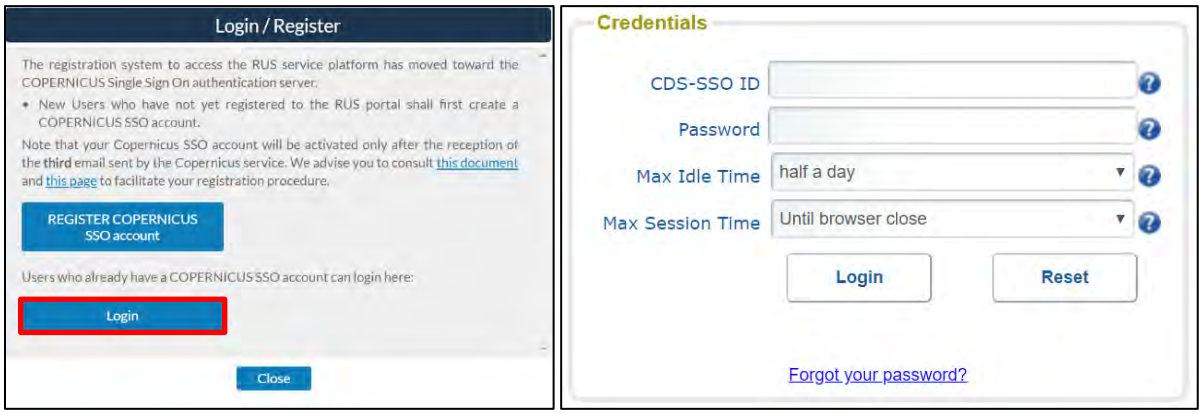
Select the option *Create my Copernicus SSO account* and then fill in ALL the fields on the Copernicus Users' Single Sign On Registration. Click *Register.*



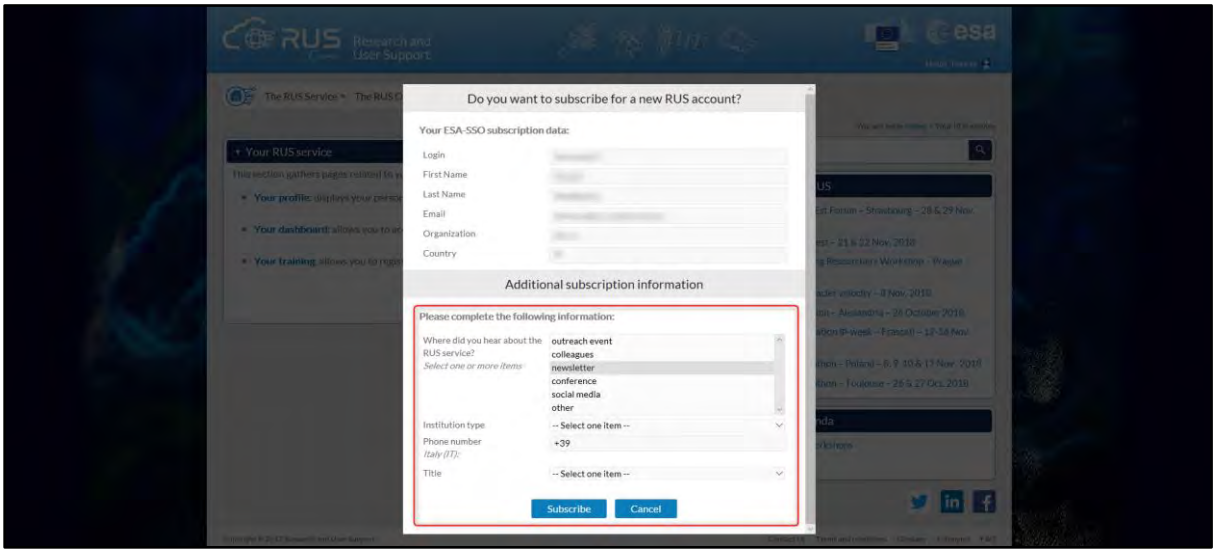


Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.

You can now return to https://rus-copernicus.eu/, click on *Login/Register*, choose *Login* and enter your chosen credentials.

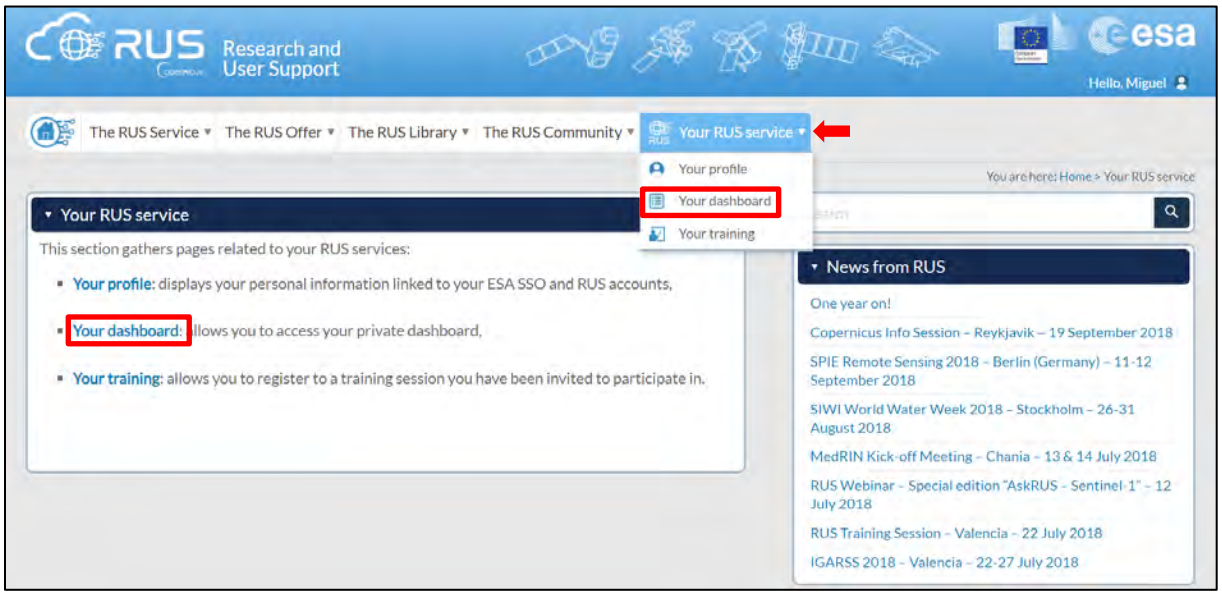


Upon your first login you will need to enter some details. You must fill all the fields.

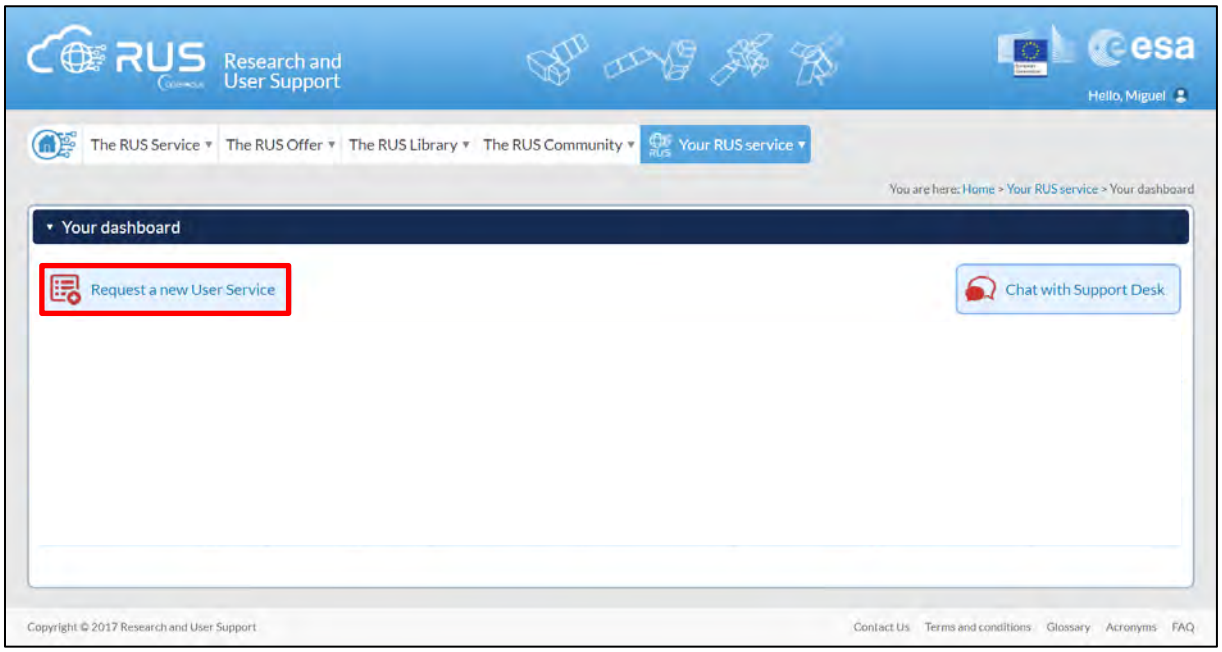


5 Request a RUS Copernicus Virtual Machine

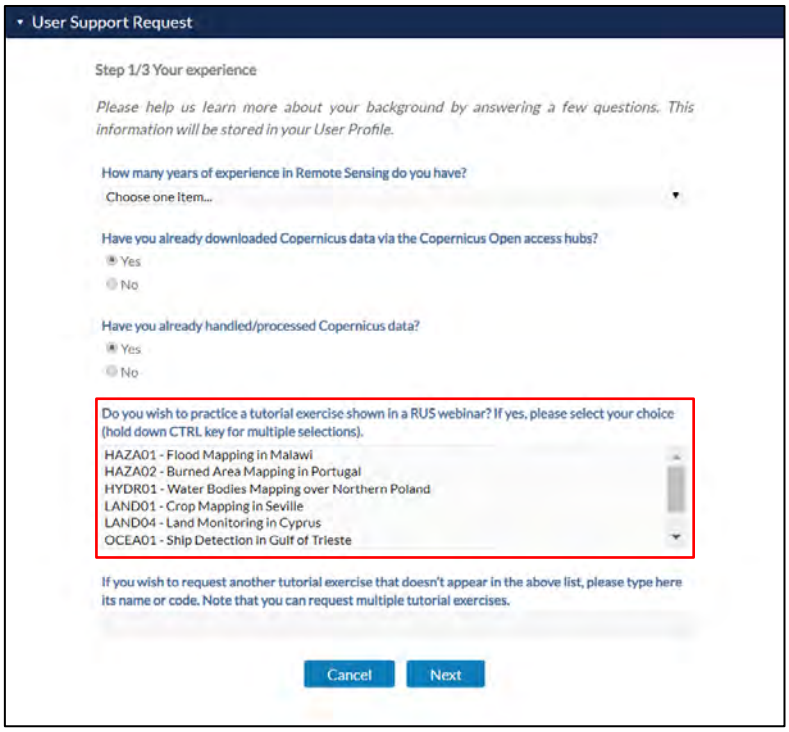
Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on *Your RUS Service* → *Your Dashboard.*



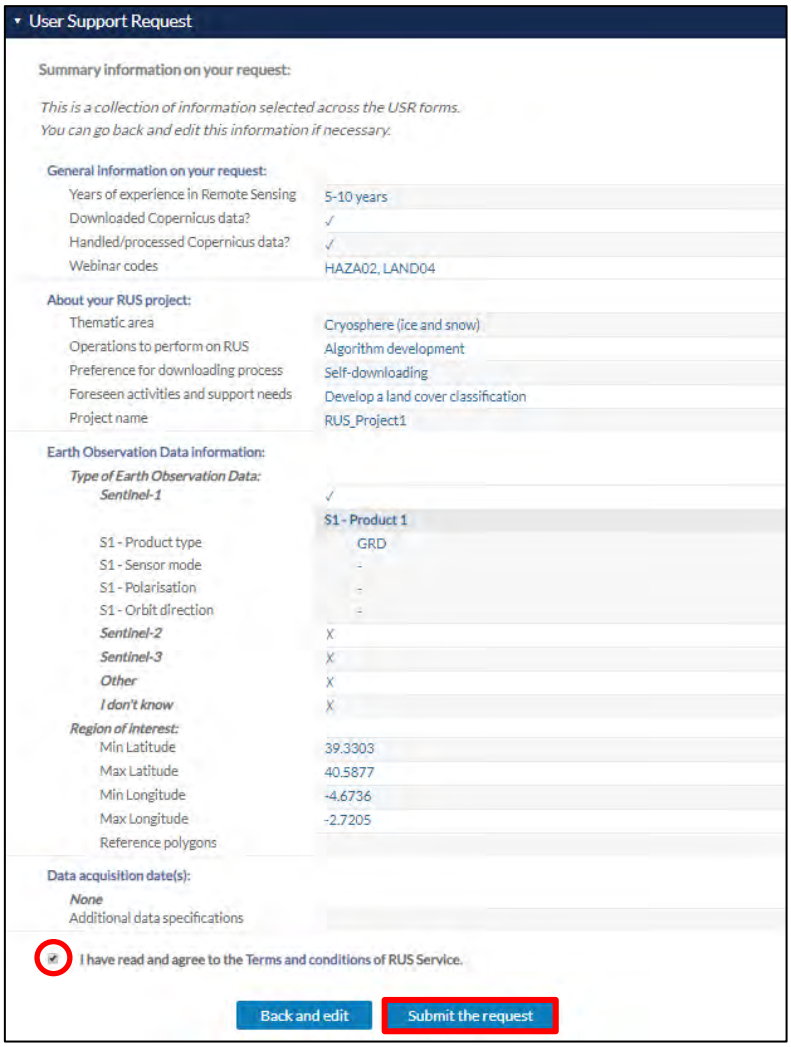
Click on *Request a new User Service* to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.



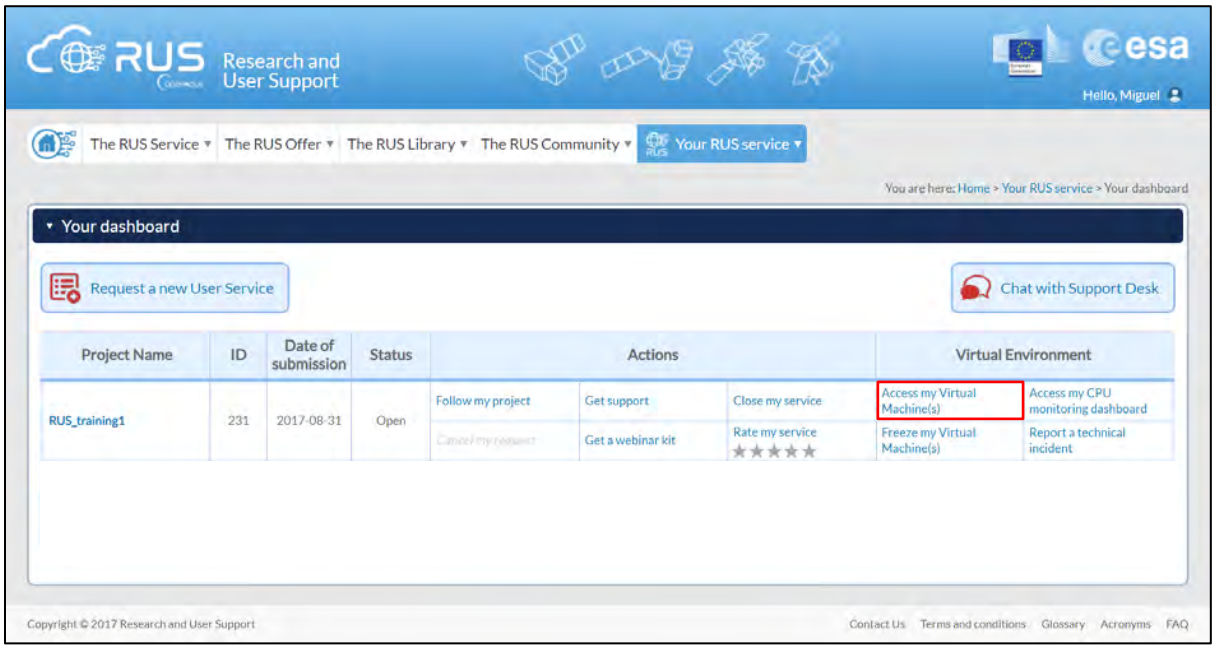
If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.



Complete the remaining steps, check the terms and conditions of the RUS Service and submit your request once you are finished.



Further to the acceptance of your request by the RUS Helpdesk, you will receive a notification email with all the details about your Virtual Machine. To access it, go to *Your RUS Service* → *Your Dashboard* and click on *Access my Virtual Machine.*



Fill in the login credentials that have been provided to you by the RUS Helpdesk via email to access your RUS Copernicus Virtual Machine.

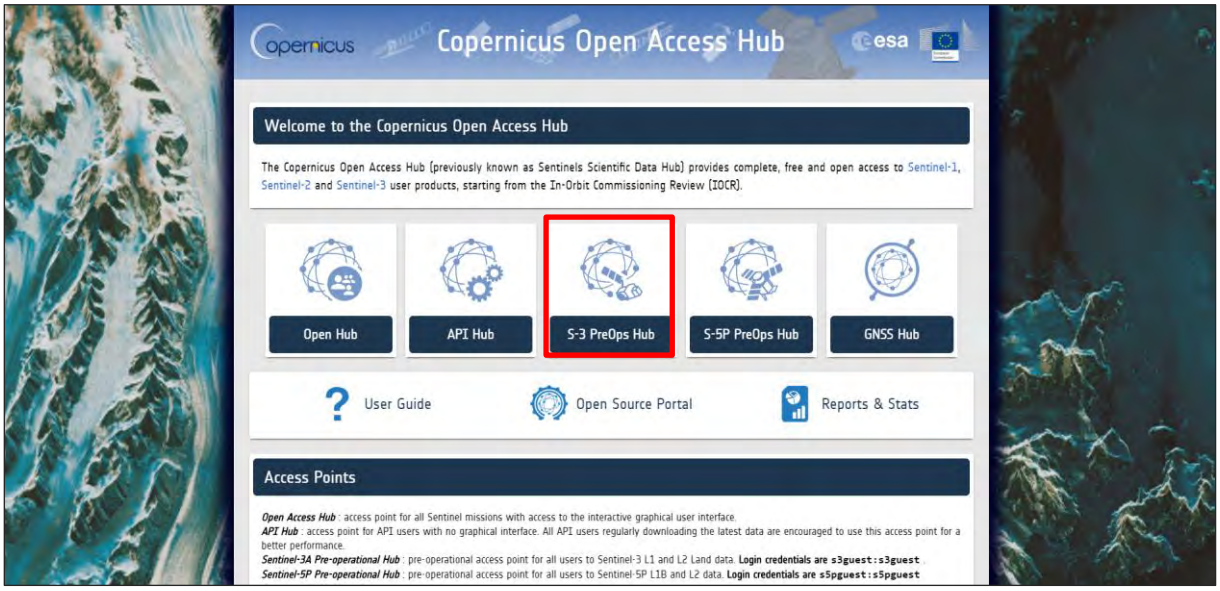
This is the remote desktop of your Virtual Machine.

6 Step by step

6.1 Data download – ESA SciHUB

Before starting the exercise, make sure you are registered in the Copernicus Open Access Hub so that you can access the free data provided by the Sentinel satellites.

Go to https://scihub.copernicus.eu/



Go to *S-3 PreOps Hub*. If you do not have an account, sign up in the upper right corner, fill in the details and click register.

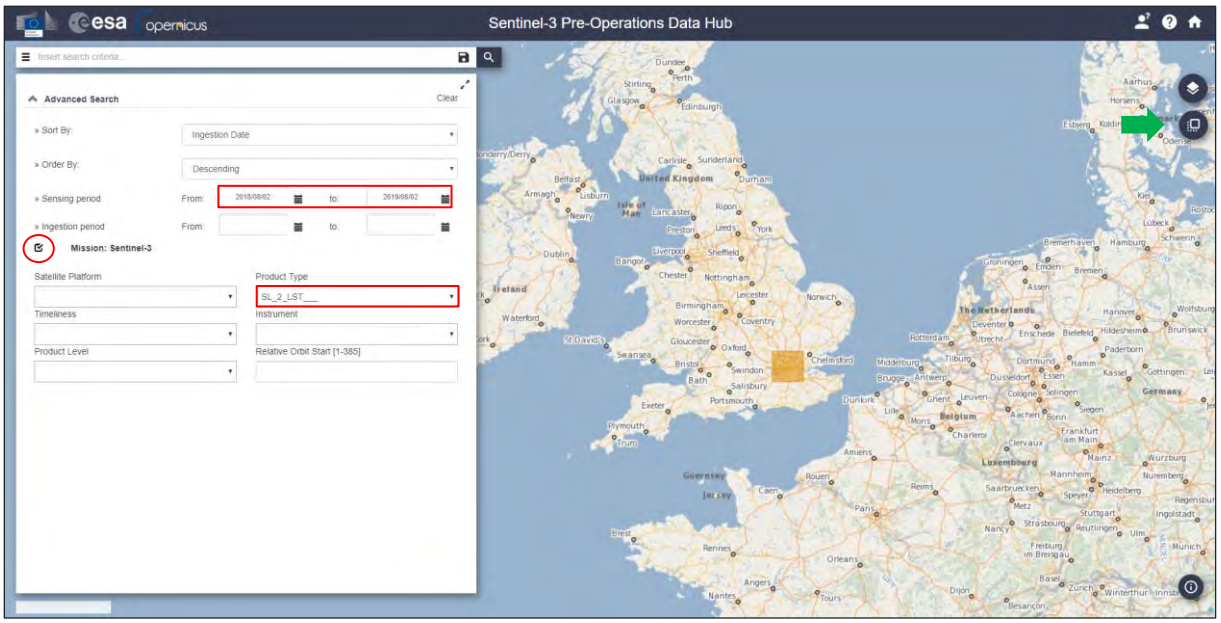
You will receive a confirmation email on the e-mail address you have specified: open the email and click on the link to finalize the registration.

Once your account is activated – or if you already have an account – log in.

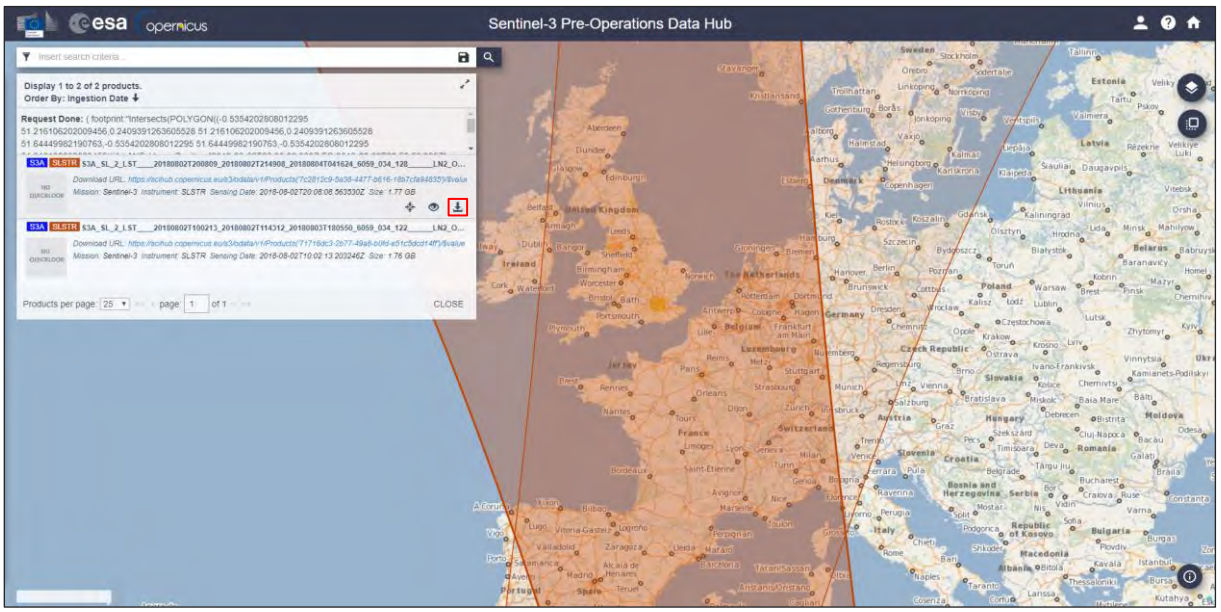
6.2 Download data

In this exercise, we will analyse 2 Sentinel-3A images acquired during August 2018. Navigate to the London area, switch the pan mode to drawing by clicking on the icon in the upper right corner of the map (**Green arrow**) and draw a rectangle as indicated below. Open search menu by clicking at the left of the search bar ( ), specify the following parameters and press the search button ( ):

Sensing period: From 2018/08/02 to 2018/08/02
Check Mission: Sentinel-3 | **Product type**: SL_2_LST__



In our case, the search returns 2 results (day and night acquisitions). Download both products by clicking on the arrow icon . Note the different sensing times of the images: S3A_SL_2_LST____20180802T**100213** and S3A_SL_2_LST____20180802T**200809**



Once downloaded (*@/home/rus/Downloads*), move them to the following path and unzip them (*right click -> Extract Here*).

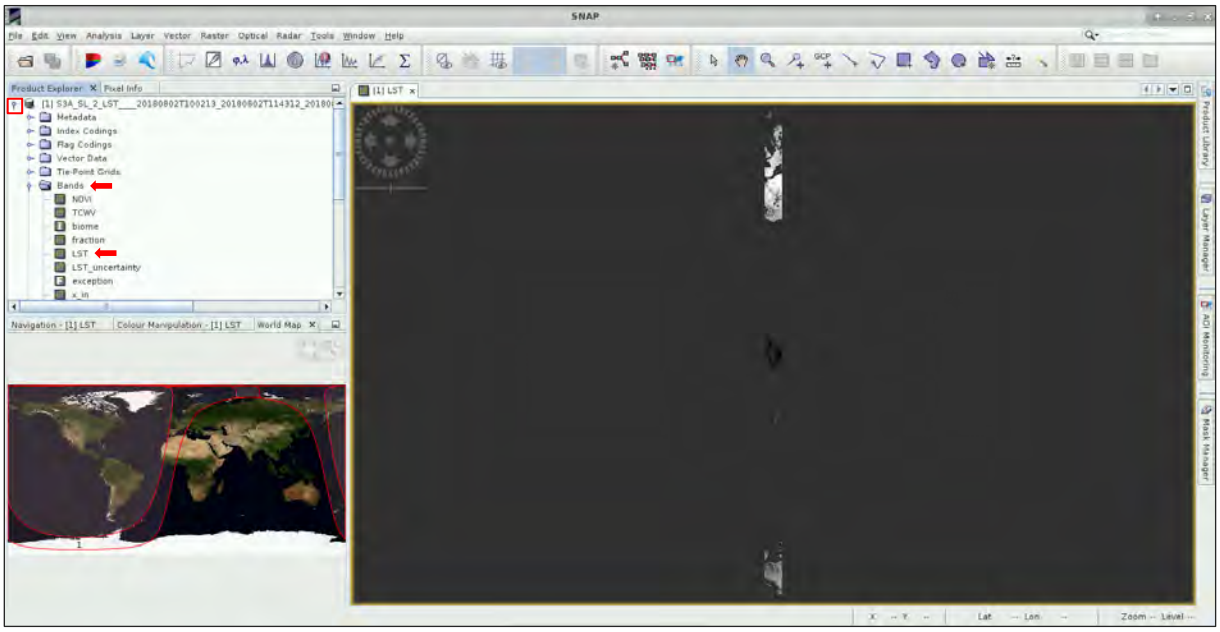
Path: */shared/Training/LAND09_UrbanHeatIsland_London/Original/*

6.3 Sentinel-3 SNAP Processing

Open *SNAP Desktop* from your desktop (or *Applications -> Processing -> SNAP)*, click on the *Open product* icon (), navigate to the following path and open the day-time Sentinel-3 product from 2018-08-02 (S3A_SL_2_LST____20180802T**100213)**. Open the folder and select the file *xfdumanifest.xml.* Then, click *OK*.

Path: */shared/Training/LAND09_UrbanHeatIsland_London/Original/*

In the *Product Explorer,* expand the product by clicking in the left arrow. Expand now the *Bands* folder and double click on the band *LST* to visualize it.



6.3.1 Subset

The first step of the methodology will subset the image to reduce its original extent and number of bands. Select the Sentinel-3 SLSTR product in the *Product Explorer* and go to *Raster -> Subset*. In the *Spatial Subset* tab click on *Geo Coordinates* and introduce the following values:

North latitude bound: 54.211

West longitude bound: -6.362

South latitude bound: 49.095

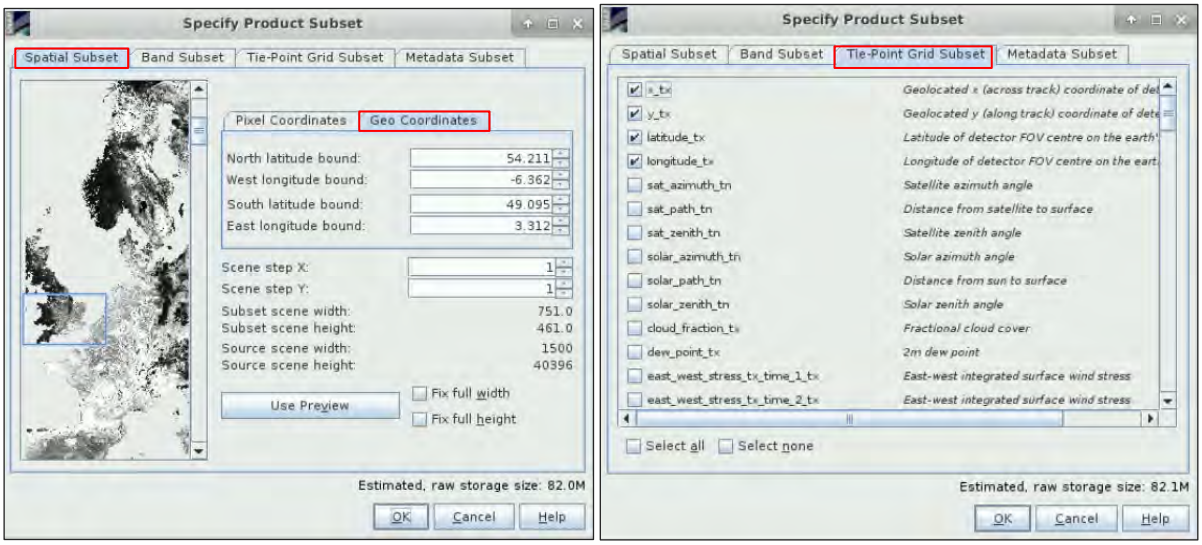
East longitude bound: 3.312

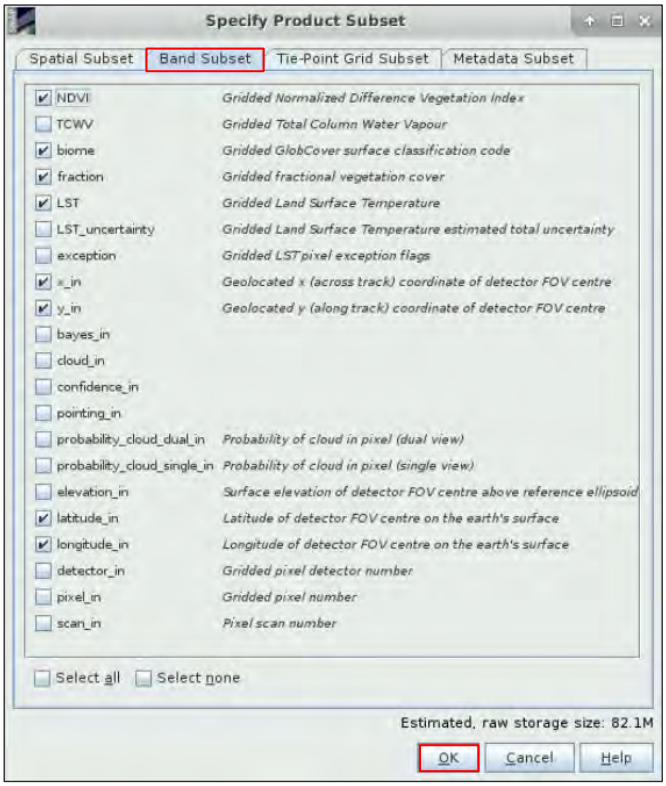
In the *Tie-Point Grid Subset* tab, select only the bands *x_tx, y_tx, latitude_tx, longitude_tx.*

In the *Band Subset* tab, select only the bands *NDVI, biome, fraction, LST, x_in, y_in, latitude_in, longitude_in.* Then, click OK (click *No* in the pop-up flag dataset window).

Once created, the subset product will appear in the *Product Explorer.* Do not forget to save it (right click on it -> Save Product) in the following path (click *YES* in the pop-up window):

Path: */shared/Training/LAND09_UrbanHeatIsland_London/Processing/*



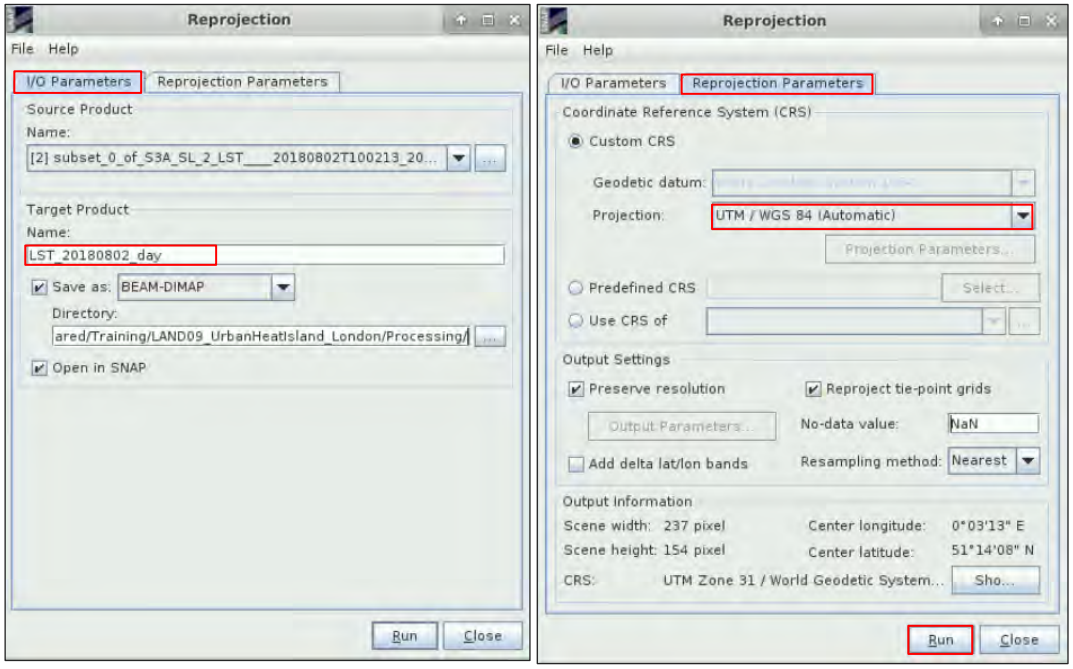


6.3.2 Reproject

Once the product has been saved, we will reproject the Sentinel-3 SLSTR product to an appropriate map projection. Go to *Raster -> Geometric operations -> Reprojection.* In the *I/O Parameters* tab, make sure you select the subset product (index [2]) as input, change the output name to *LST_20180802_day* and make sure you set the output directory to the following path:

Path: */shared/Training/LAND09_UrbanHeatIsland_London/Processing/*

In the *Reprojection Parameters* tab, click on the *Projection* drop-down menu and select *UTM / WGS 84 (Automatic)*. Then, click *Run.*



6.3.3 Subset

After reprojection, we will subset the product to its final extent. For that, select the reprojected product in the *Product Explorer* and go to *Raster -> Subset*. In the *Spatial Subset* tab click on *Geo Coordinates* and introduce the following values:

North latitude bound: 52.372

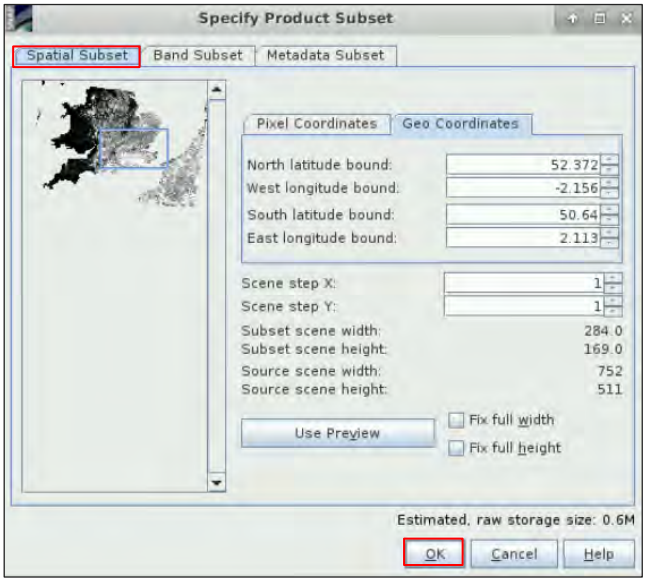
West longitude bound: -2.156

South latitude bound: 50.64

East longitude bound: 2.113

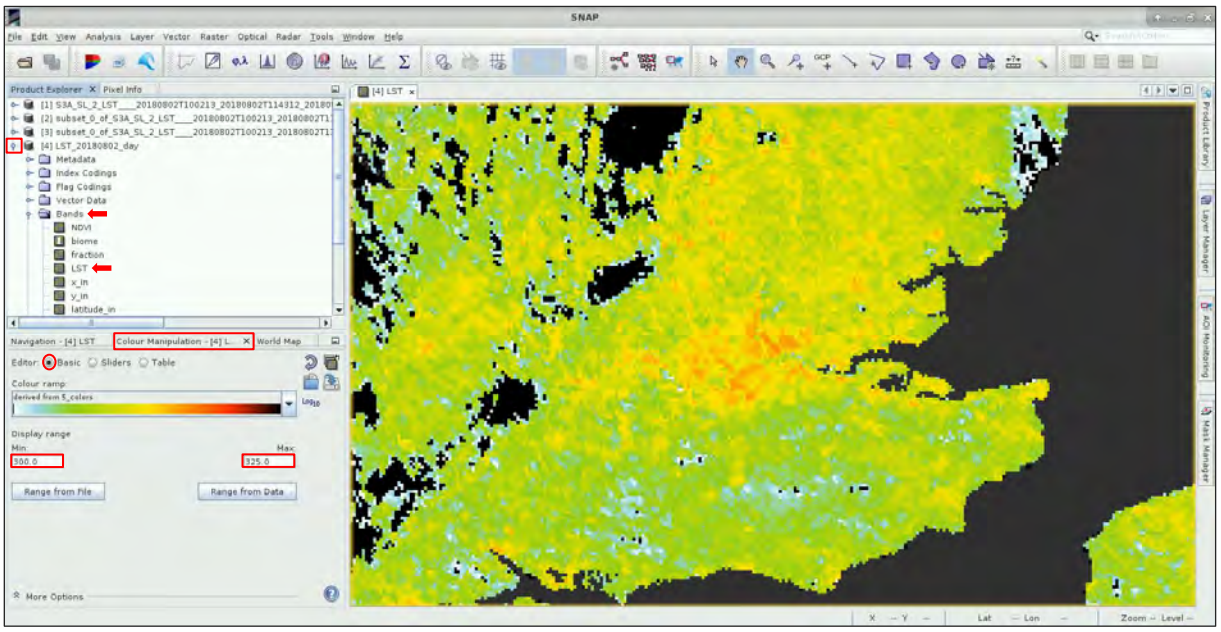
Once created, the subset product will appear in the *Product Explorer.* Do not forget to save it (right click on it -> Save Product) in the following path (click *YES* in the pop-up window) with the name *LST_20180802_day*

Path: */shared/Training/LAND09_UrbanHeatIsland_London/Processing/*



In the *Product Explorer,* expand the reprojected product (index [4]) by clicking in the left arrow. Expand the *Bands* folder and double click on the band *LST* to visualize it.

Click on the *Colour Manipulation* tab (in the lower left corner), select *Basic* as *Editor* and click on the *5_colors* colour ramp. Set the *Min* and *Max* values to 300 and 325 respectively. Do not forget to save the product afterwards (right click on it -> *Save Product)*.

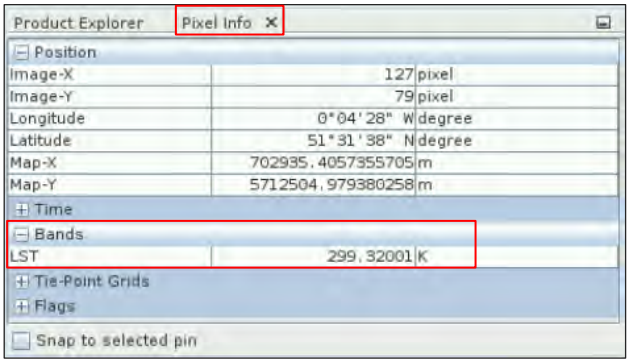


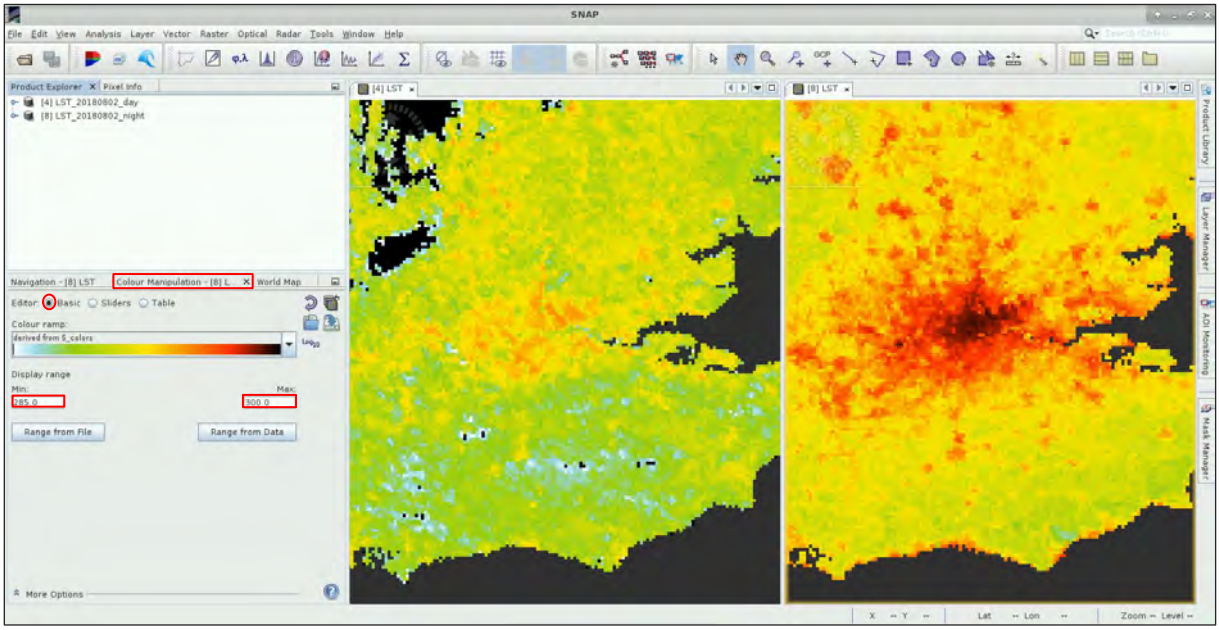
Once the product has been processed, we need to run the same steps (*Subset + Reprojection + Subset*) for the 2018-08-02 night product (S3A_SL_2_LST____20180802T**200809**). Click on the *Open product* icon (), navigate to the following path and open the night-time Sentinel-3 product from 2018-08-02.

Repeat the steps as explained before and named the final product *LST_20180802_night*. For the night product, set the *Min* and *Max* values to 285 and 300 respectively and do not forget to save the product afterwards (right click on it -> *Save Product)*.

Path: */shared/Training/LAND09_UrbanHeatIsland_London/Original/*

Once both products are opened, go to *Windows -> Tile Horizontally* to combine both views and compared the temperatures (K). Click on the *Pixel info* tab and move the mouse over the images to analysis pixel values. To avoid confusion, close now (right click on the product -> *Close product)* all the products except the *LST_20180802_day* and *LST_20180802_night.*



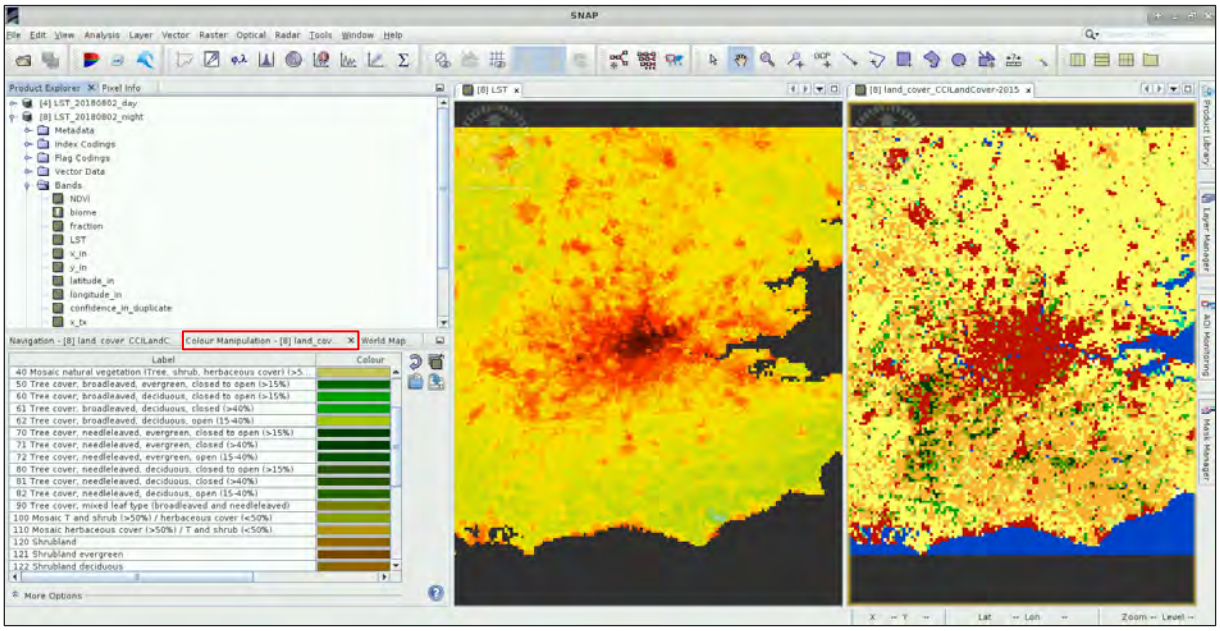


6.3.4 Add Land Cover Band

Once you have compared the different temperature (K) values between the day and night acquisition, close the *LST_20180802_day* product. To better identify the effect of an urban area in the temperature, we will subtract the average temperature of non-urban areas close to London. For that, we first add a land cover band to identify different land cover / land use. Right click on the *LST_20180802_night* product and select *Add Land Cover Band.* In the menu, go down, select *CCILandCover-2015* (See NOTE 1) and click OK. Do not forget to save to product afterwards.

NOTE 1: More information on the CCI Land Cover project can be found here - https://bit.ly/2MGSXdw

In the *Bands* folder of the *LST_20180802_night* product, double click on the land cover band (*land_cover_CCILandCover-2015)* to visualize it. Combine the visualization with the LST band by going to *Windows -> Tile Horizontally.* Use the *Pixel info* tab to identify the land cover code of each pixel.



You can find the legend for the different classes in the color manipulation tab of the land cover band.

6.3.5 Mean temperature

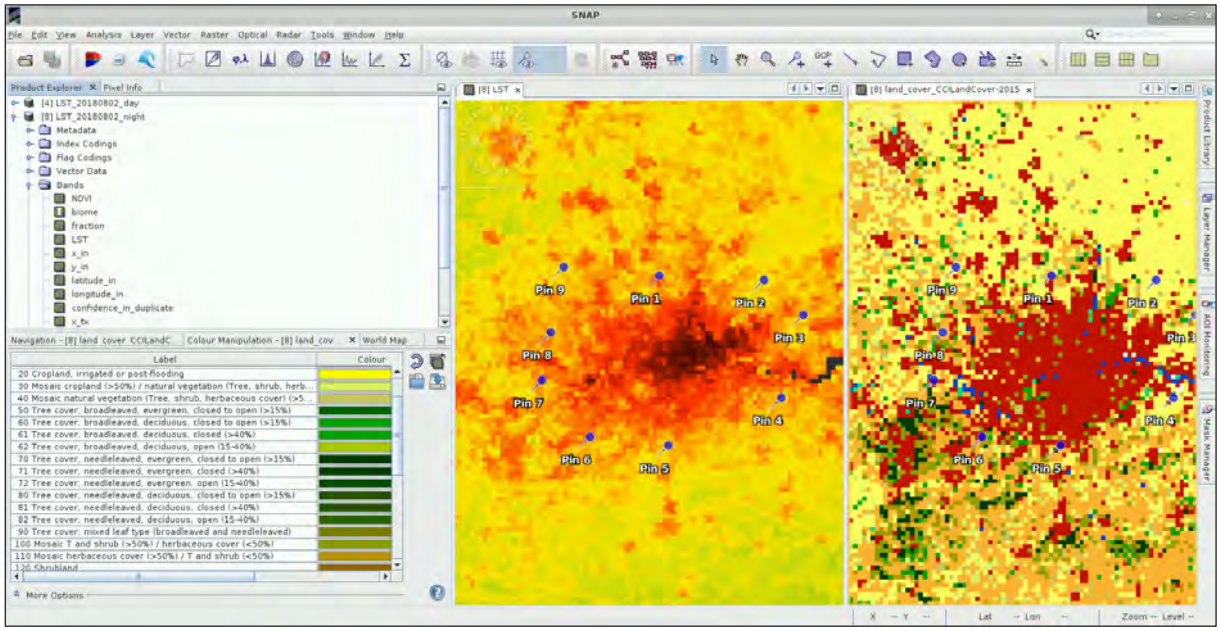
Once the land cover band is added, the next step is to derive the mean temperature in the surroundings of London using specific pixel values identified using the *Pin* tool of SNAP. Instead of creating those pins from scratch, we will load them directly. In the *Product Explorer*, select the *LST_20180802_night* product and go to *Vector -> Import -> ESRI Shapefile*. Navigate to the following path and select the file *pins_Point.shp.*

Path: */shared/Training/LAND09_UrbanHeatIsland_London/AuxData/*

Once loaded, the *pins* are saved in the *Vector* folder of the *LST_20180802_night* product and can be visualized in the LST and Land Cover band (See NOTE 2) (See NOTE 3). Do not forget to save the product afterwards (right click -> *Save Product).*

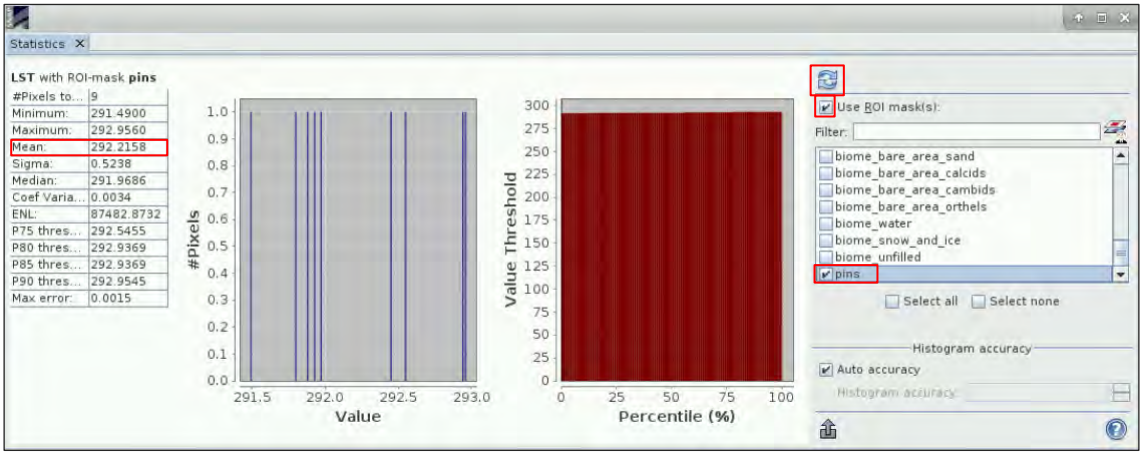
> NOTE 2: If the *pins* are not loaded in the land cover band, close the visualization and open it again to refresh the view.

> NOTE 3: To create your own Pins use the *Pin placing tool* (upper toolbar) of SNAP. Click on the Pin tool and add 9 pins around the city where the land use is different from urban areas. Use the land cover band, the *Pixel Info* tab and the *Color Manipulation* tab to help you in the process. Do not forget to save the product afterwards (right click -> Save product).



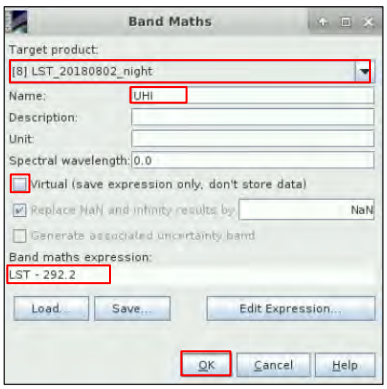
Once the pins are loaded in the image, we can derive the mean value for the pixels identified by the pins using the *Statistics* tool of SNAP. Close the land cover visualization and go to the menu *Analysis -> Statistics*. Select the option *Select ROI Mask(s)*, go down in the list and select *pins*. Finally, press the refresh button.

From the right-side panel, we can extract the mean temperature value (292.2158) using as reference the pins we have just inserted in our image.

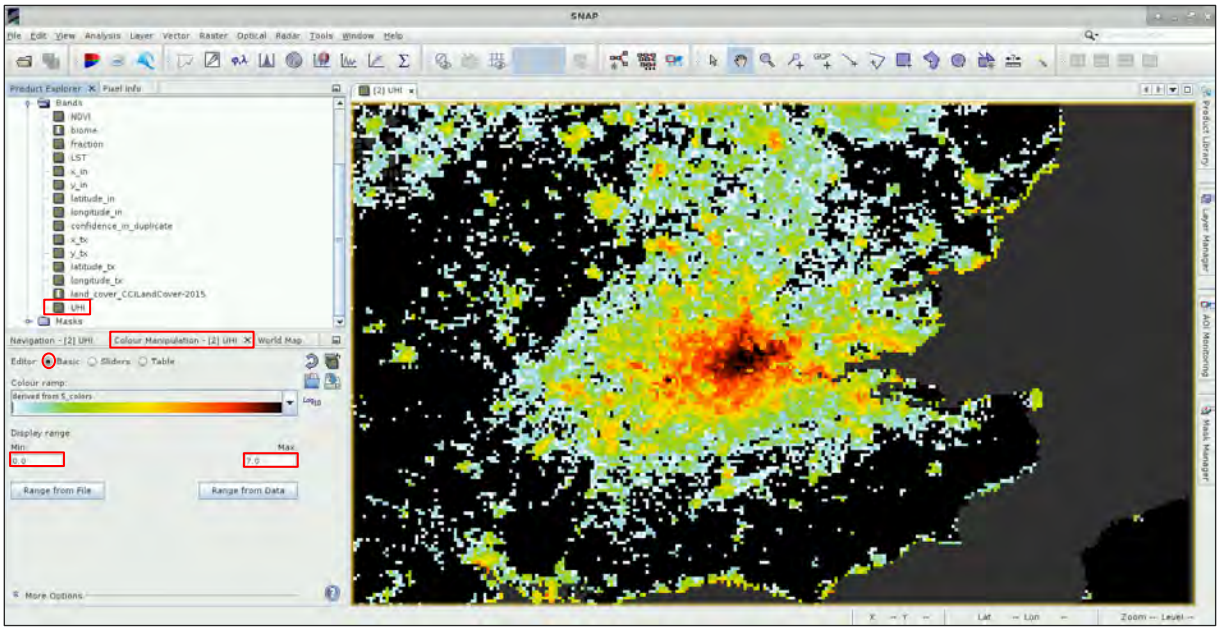


We can now use the *Band Math* operator to subtract this value from the LST measurements. Right click on the *LST_20180802_night* product and select *Band Math.* Change the name to *UHI*, un-select *Virtual* and click on the *Edit Expression button.* Copy-paste the following expression and click *OK*:

```
LST - 292.2
```



Close all previous visualizations except for the newly created *UHI* band. Click on the *Colour Manipulation* tab, select *Basic* as *Editor* and click on the *5_colors* colour ramp. Set the *Min* and *Max* values to 0 and 7 respectively. Do not forget to save the product afterwards (See NOTE 4).

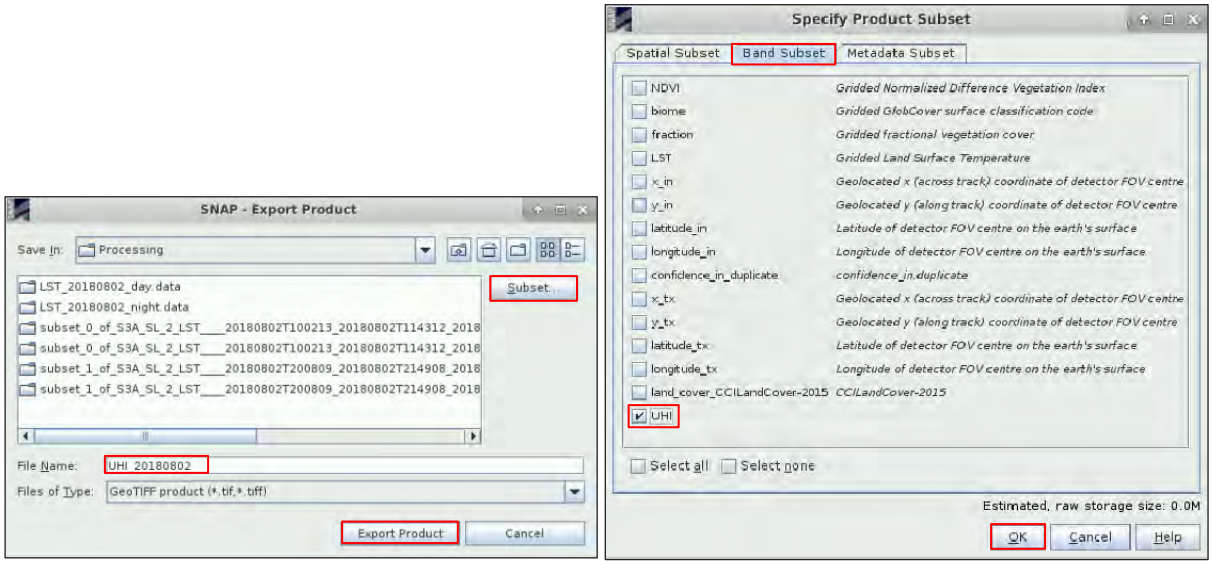


NOTE 4: To remove the *Pins* from the visualization, open the *Layer Manager (Layer -> Layer Manager)* and unselect the option *Vector data.*

6.3.6 Export to QGIS

Once the result is ready, we will export it as GeoTIFF and open it in QGIS. For that, go to *File -> Export -> GeoTIFF*. Click on the *Subset* tab, and in the *Band Subset* menu select only the band *UHI*. Save the file with the name UHI_20180802 in the following path and click *Export Product:*

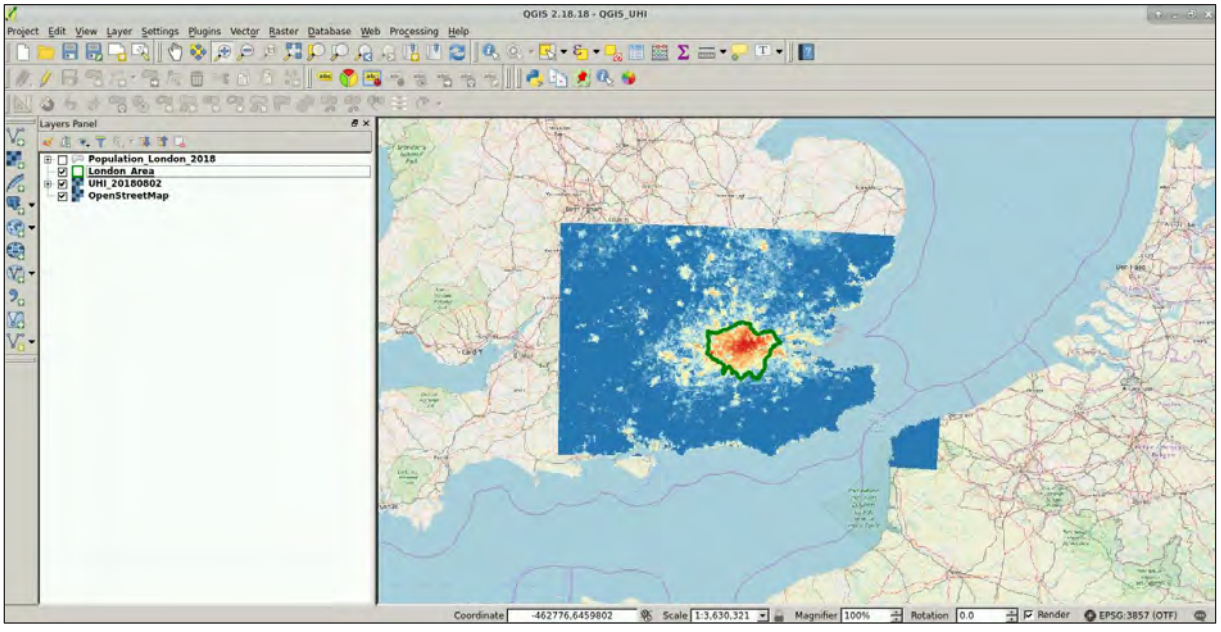
Path: */shared/Training/LAND09_UrbanHeatIsland_London/Processing/*



6.4 QGIS Processing

Once the images are processed in SNAP, we will visualize the results in QGIS. Minimize SNAP and open QGIS, (*Applications -> Processing -> QGIS Desktop*). Although it is possible to open each raster individually, for convenience we will open a pre-saved QGIS session containing all the files. Go to *Project -> Open*, navigate to the following path and open the file *QGIS_UHI.qgs* (See NOTE 5).

Path: */shared/Training/LAND09_UrbanHeatIsland_London/AuxData/*

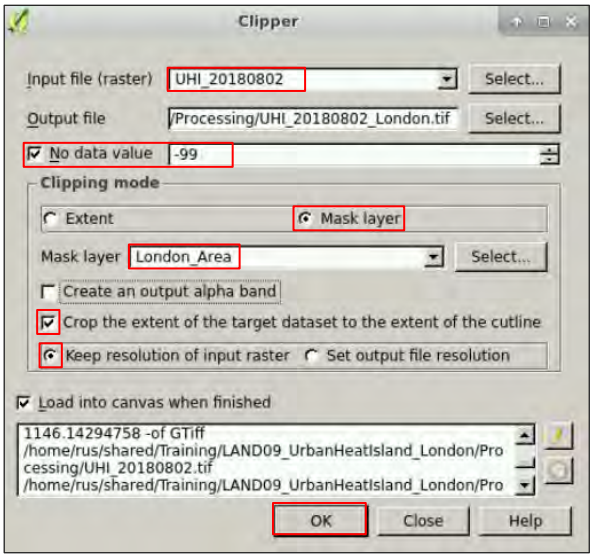


NOTE 5: A basemap from OpenStreetMap will be used in the QGIS visualization. In case the OpenLayers plugin is not installed (not visible in the menu *Web -> OpenLayers plugin)*, click on Plugins -> Manage and Install Plugins. Select the *'All'* tab on the right-side panel and write "OpenLayers plugin" on the search box. Select the plugin on the list and click 'Install Plugin'. Restart QGIS to finalize the installation.

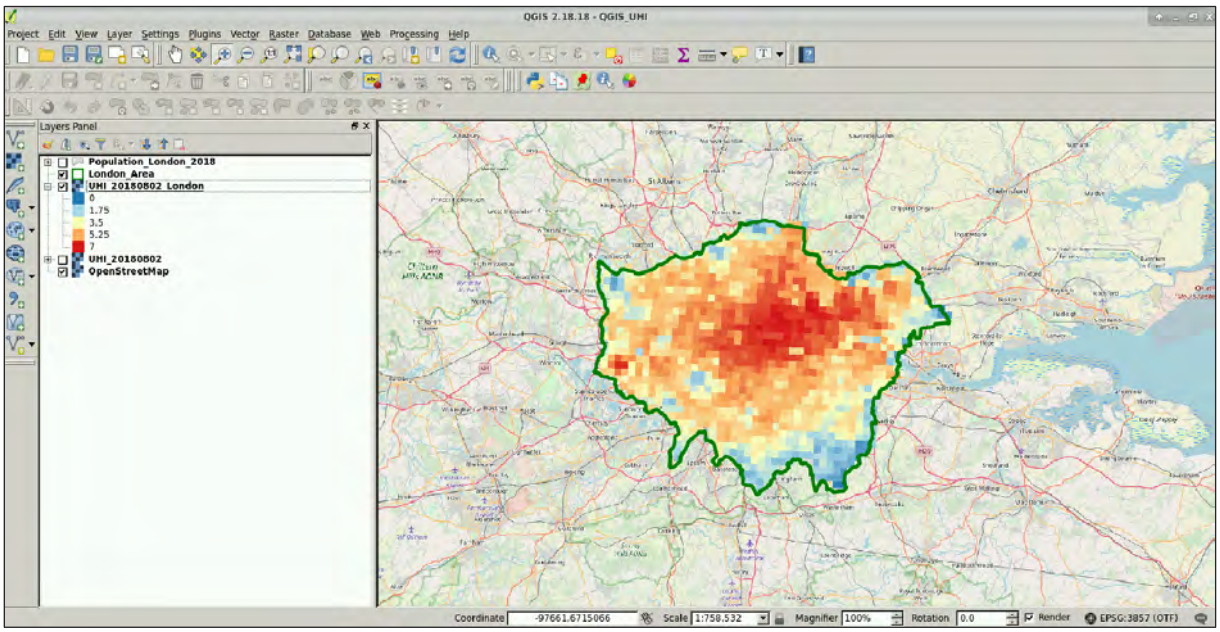
Once the products are opened in QGIS, we will clip the UHI_20180802 raster using as reference the shapefile of the extent of Greater London (*London_area.shp).* For this, go to *Raster -> Extraction -> Clipper.* Select *UHI_20180802* as input file (raster) and set the output file to the following path:

Path: */shared/Training/LAND09_UrbanHeatIsland_London/Processing/UHI_20180802_London.tif*

Select the option *No data value* and set it to -99. As *clipping mode* select *Mask layer* and select *London_Area* as mask. Select the option *Crop the extent of the target dataset to the extent of the cutline* and the option *Keep resolution of input raster.* Finally, click *Ok.*

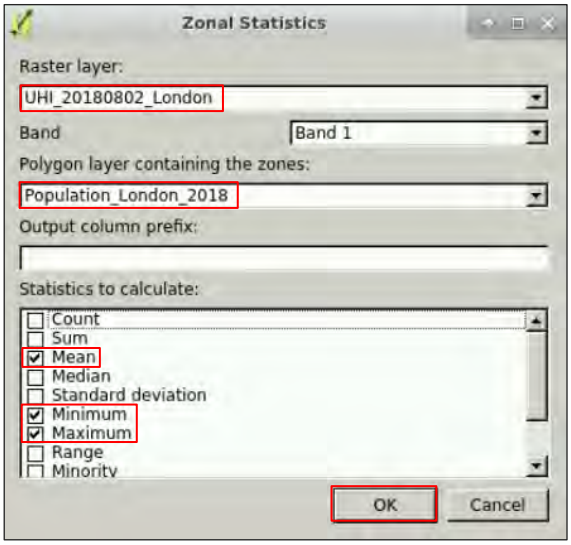


Once the raster is clipped, we have to change its visualization to match the original one. Right click on the raster file *UHI_20180802* and go to *Styles -> Copy Style.* Next, right click on the clipped raster (*UHI_20180802_London*) and go to *Styles -> Paste Style.*

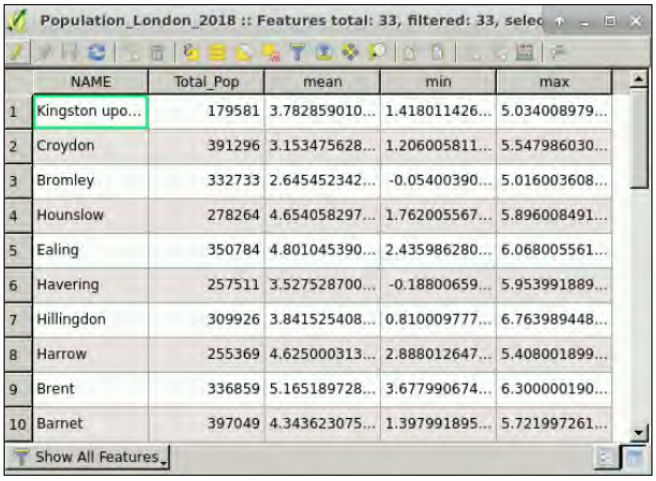


In the last step, we will derive the mean temperature (and other statistics) per boroughs due to the Urban Heat Island effect. For this, we will use the *Zonal* Statistics tool to combine the information of the clipped raster with the shapefile of London's boroughs (*Population_London_2018.shp*).

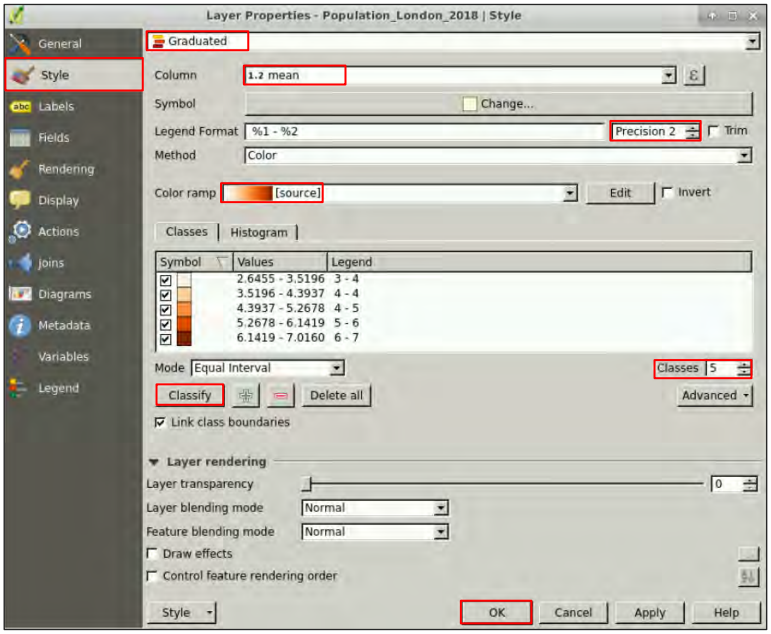
Go to *Raster -> Zonal Statistics -> Zonal Statistics.* Select *UHI_20180802_London* as raster layer, select, *Population_London_2018* as *Polygon layer containing zones,* set _ as *Output column prefix* and select *Mean, Minimum and Maximum* as statistics to calculate.

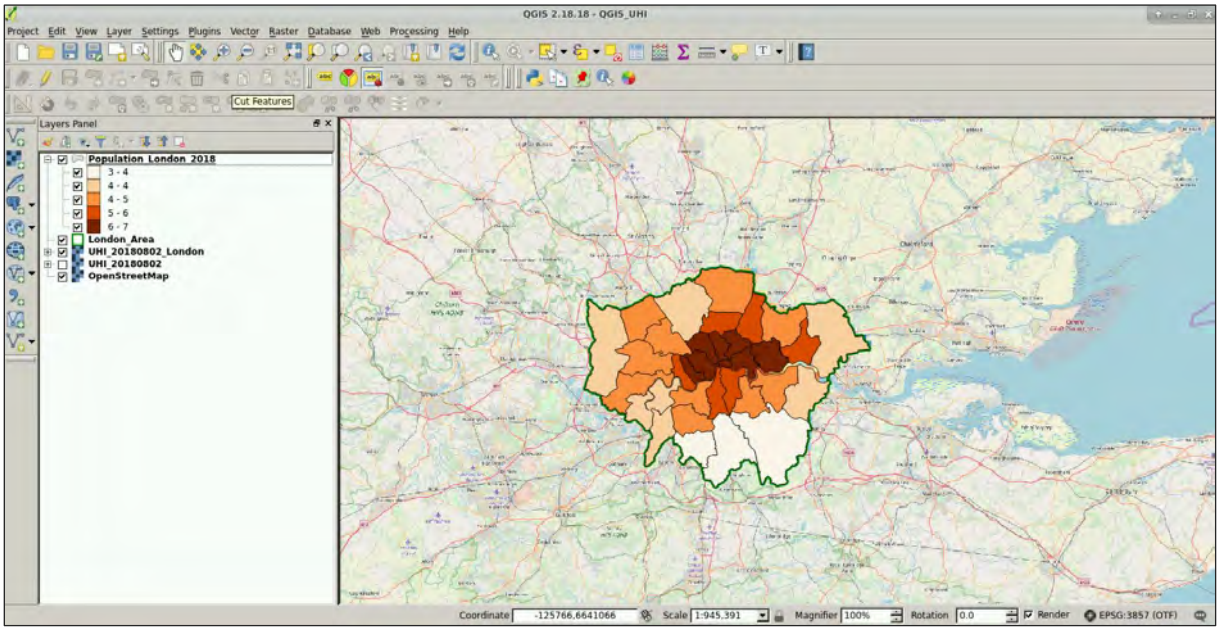


The statistics will be added to the attribute table of *Population_London_2018.* To visualize it, right click on the layer and select *Open Attribute Table.*



We can now visualize the mean temperature per neighborhood due to the Urban Heat Island effect. For this, activate the *Population_London_2018* layer on the *Layers Panel*, right click on it and go to *Properties.* In the right-side menu, go to *Style.* In the top part, select *Graduated* as display method, select *mean* as the column to be represented, set the precision parameter to 2 change the color ramp to *Oranges,* set the number of classes to 5 and click *Classify.* Finally, click *Ok* in the lower part.



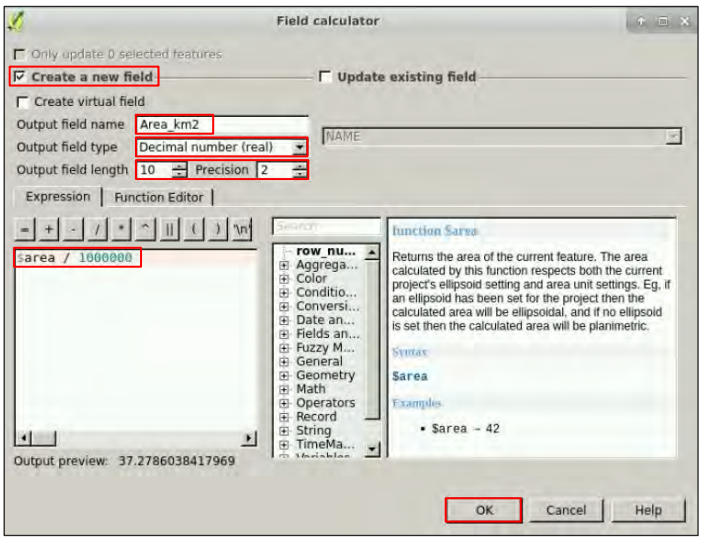


To produce our final visualization, we first need to derive the population density. For this, we will use the *Raster calculator* tool available in QGIS to derive the area of each neighborhood (in km^2) and divide the total population by this parameter. Right click on the *Population_London_2018* and select *Toggle Editing* to start the edition of this layer. In the toolbar, click on the *Open Field Calculator* icon - (See NOTE 6).

> NOTE 6: If not visible, go to *View -> Toolbars -> Attributes toolbar* to active the tools.

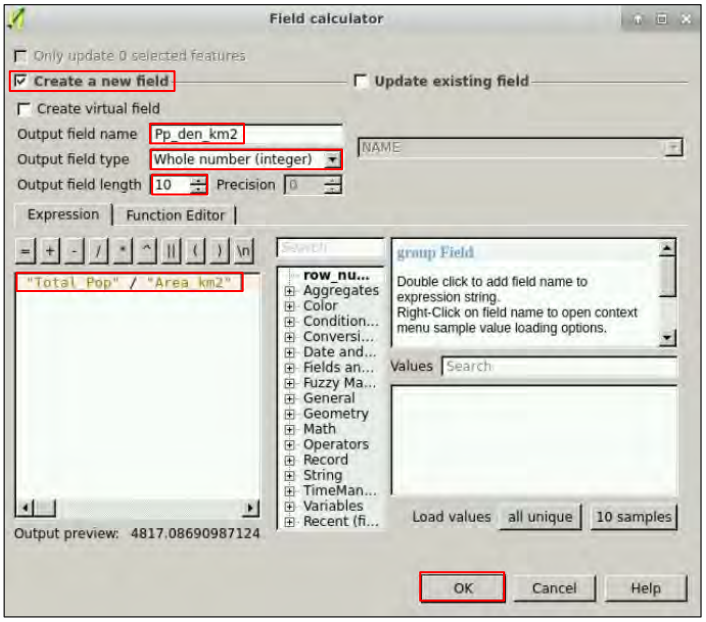
Make sure the option *Create a new field* is selected. Set the *Output field name* to Area_km2, change the *Output field type* to *Decimal number (real)* and set the *Precision* to 2. In the expression editor copy-paste the following expression and click *OK.*

```
$area / 1000000
```

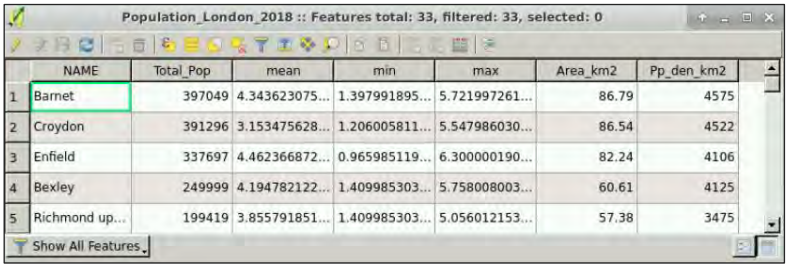


Next, open again the *Field Calculator.* Make sure the option *Create a new field* is selected. Set the *Output field name* to *Pp_den_km2* and leave the *Output field type* to *Whole number (integer)*. In the expression editor copy-paste the following expression and click *OK.*

```
"Total_Pop" / "Area_km2"
```



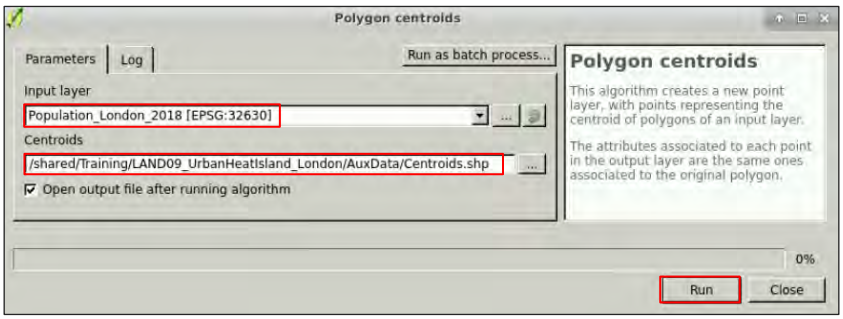
The new fields have been added to the attribute table of *Population_London_2018.* To visualize it, right click on the layer and select *Open Attribute Table.* Before continuing, right click on the *Population_London_2018* layer and click again in the *Toggle Editing* menu to stop the edition. Save the changes when asked.

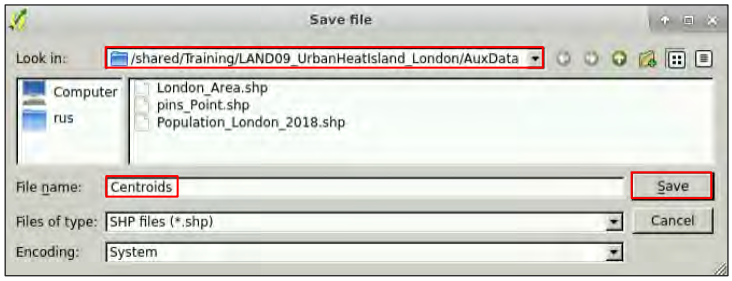


	NAME	Total_Pop	mean	min	max	Area_km2	Pp_den_km2
1	Barnet	397049	4.343623075...	1.397991895...	5.721997261...	86.79	4575
2	Croydon	391296	3.153475628...	1.206005811...	5.547986030...	86.54	4522
3	Enfield	337697	4.462366872...	0.965985119...	6.300000190...	82.24	4106
4	Bexley	249999	4.194782122...	1.409985303...	5.758008003...	60.61	4125
5	Richmond up...	199419	3.855791851...	1.409985303...	5.056012153...	57.38	3475

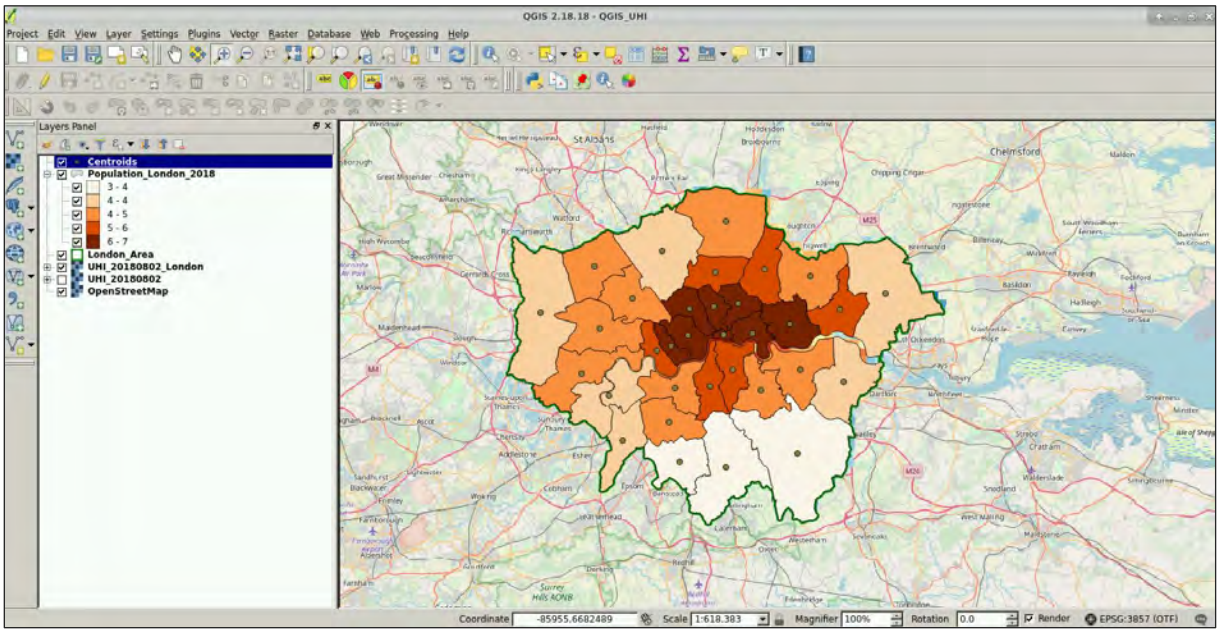
For the final visualization, we will combine the information of the mean temperature with the population density per neighborhood. For this, we will first derive the centroids of each polygon. Go to *Vector -> Geometry Tools -> Polygon Centroids*. Select *Population_London_2018* as input layer and save the output as *Centroids.shp* in the following path (click … and select *Save to file)*. Then, click *Run.*

Path: */shared/Training/LAND09_UrbanHeatIsland_London/AuxData/*

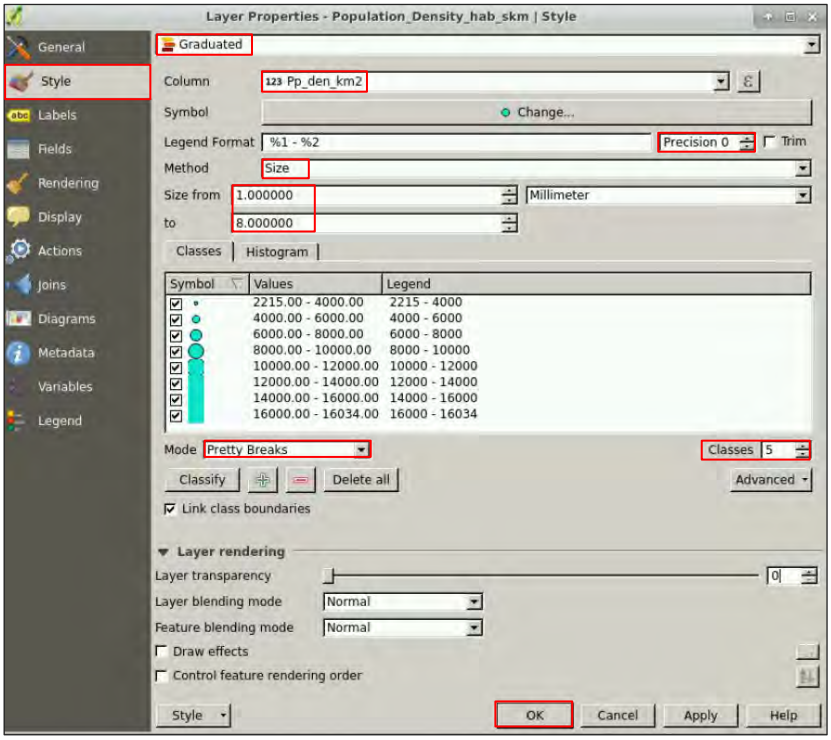




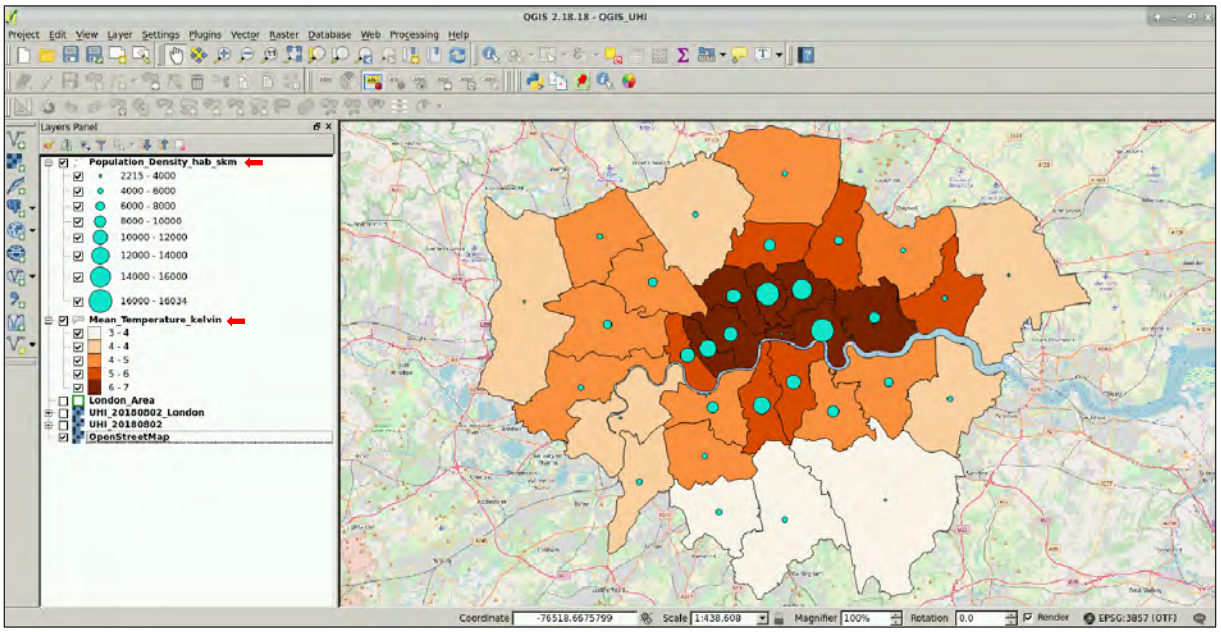
A new point shapefile has been added now to the *Layers Panel*. We will know link the size of the points to the population density of each area.



Right click on the *Centroids* layer and select *Properties.* In the right-side menu, go to *Style.* In the top part, select *Graduated* as display method, select *Pp_den_km2* as the column to be represented and click on the *Change* icon to set the color to light blue. Next, set the precision parameter to 0, change the *Method* to *Size* and make sure the size ranges from 1 to 8. Finally, select *Pretty intervals* as *Mode*, set the number of classes to 5, click *Classify* and *Ok.*



Finally, for visualization purposes, change the name of the *Centroids* and *Population_London_2018* to *Population_Density_hab_skm* and *Mean_Temperature_kelvin*



THANK YOU FOR FOLLOWING THE EXERCISE!

7 Further reading and resources

Sentinel-3 SLSTR User Guide

https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-slstr

Sentinel-3 SLSTR Technical Guide

https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-3-slstr

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