How to generate a digital surface model (DSM)[1]

One essential input data for many of the tools in the Urban Multi-scale Environmental Predictor (UMEP) and urban climate studies in general, is a ground and building DSM. From this data, both morphology parameters can be calculated as well as analysis of surface solar radiation, shadow patterns etc. can be generated. First of all you need to know the different definitions of the various surface models that are used:

- Digital Elevation model (DEM) includes only ground heights. Objects such as buildings, trees and other objects have been removed. This is the most common form of surface model.
- Digital Surface Model (DSM) includes both ground and building heights.
- Canopy Digital Surface Model is a model where vegetation heights are included, either as height above sea level (masl) or meter above ground level (magl). Other pixels are set to zero.
- Digital Terrain Model DSM) is usually the same as a DEM. However it has also been defined as derivative of any of the two models above. For example, a slope image or a shadow map can also be defined as a DTM.

Even though the definition above is the common ones, you should always examine your datasets as discrepancies in definition occur regularly. Sometime, variations of the surface models exist. One example is a building DSM where ground pixels are set to zero and building height are given in magl. Other definitions of surface models could also be found so be aware of discrepancies. Figure 1 shows a ground and building DSM over the central parts of London in the QGIS map canvas. It is a 1 meter resolution geotiff raster generated from LiDAR dataset. Usually, this kind of detailed data is not available and to create a building and ground DSM other data and methods needs to be adapted.

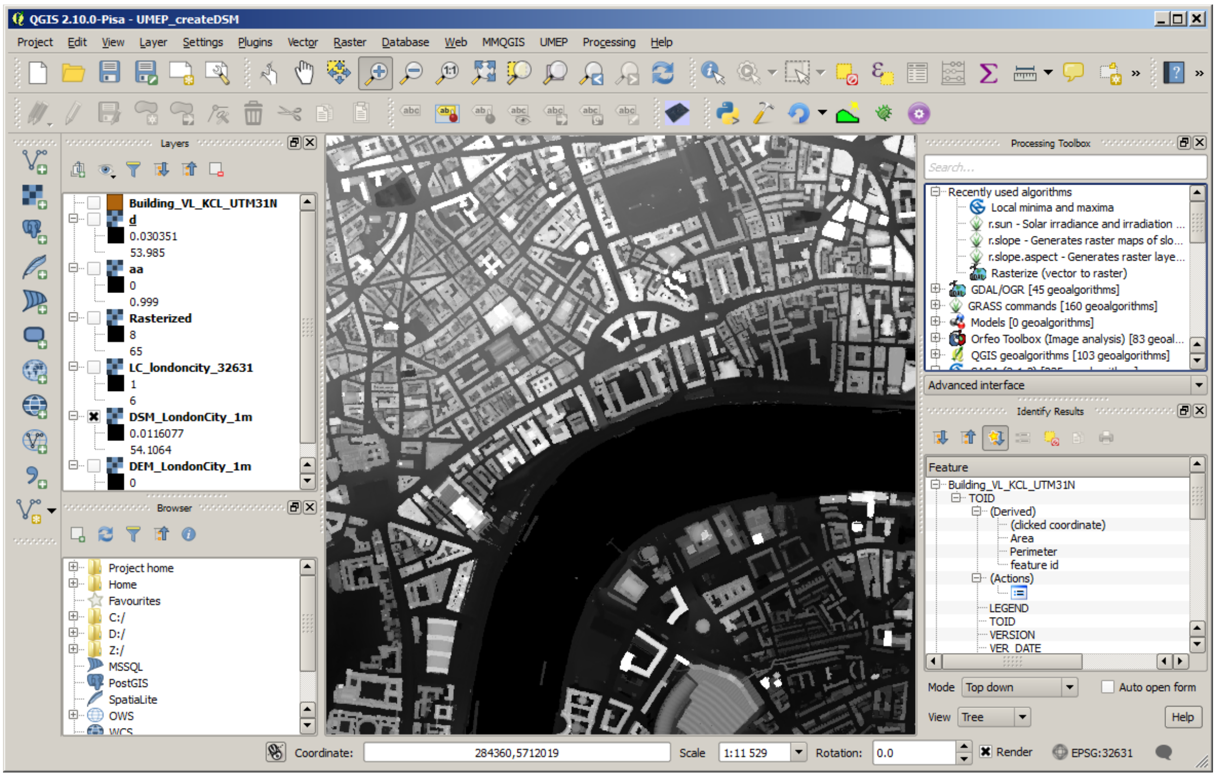


Figure 1: A snapshot of QGIS 2.10. A ground and building DSM over central London is shown in the map canvas.

[1] This tutorial assumes that you have basic QGIS skills.

This tutorial will show how to create a DSM from vector data, which is a much more common data source for 3D building structures in urban areas. This tutorial is based on QGIS version 2.10 (www.qgis.org). The dataset used are shown in figure 2. The vector layer is a polygon building footprint shape file (**Building_VL_KCL_UTM31N.shp**) where height information is found in the accompanying attribute table. This dataset originates from the Virtual London dataset where all buildings within the Greater London Authority (GLA) were attributed heights (Evans, 2003). A raster DEM (**DEM_LondonCity_1m.tif**) is also included as well as another DSM (**DSM_LondonCity_1m.tif**) for comparison. All data is projected in UTM31N (EPSG:32631).

Hand in:

- Answer the questions that can be found throughout the tutorial.
- A map with your newly created DSM including all the items that should be included in an 'accurate' map.

Examining the datasets

Start by adding the two layers to your QGIS project. As you can see, the two layers have different extents. Examine the attribute table of the building polygon footprint layer. The last columns (right) show various information of heights for each of the building footprints (Figure 3). The two columns if interest is **DEM_HGHT** and **DTM_HGHT**. Here DTM is values derived from a terrain model showing average ground heights above ground underneath each building. Just to confuse you the vendor for this dataset gives the average building height (masl) in the **DEM_HGHT**- column. Another column that could be interesting is also **REL_HGHT** which gives building heights above ground.

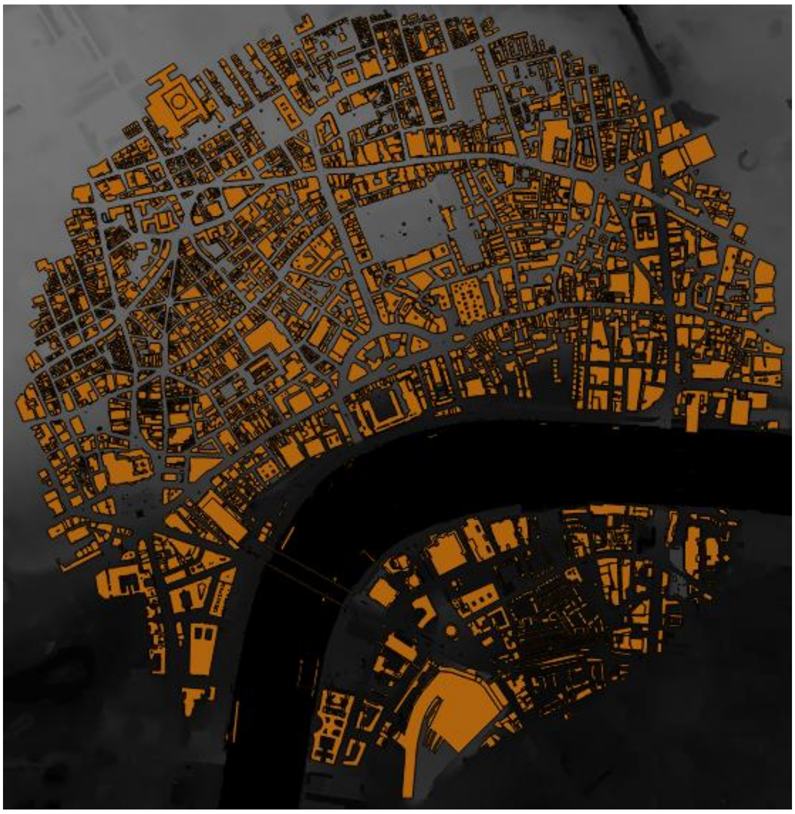
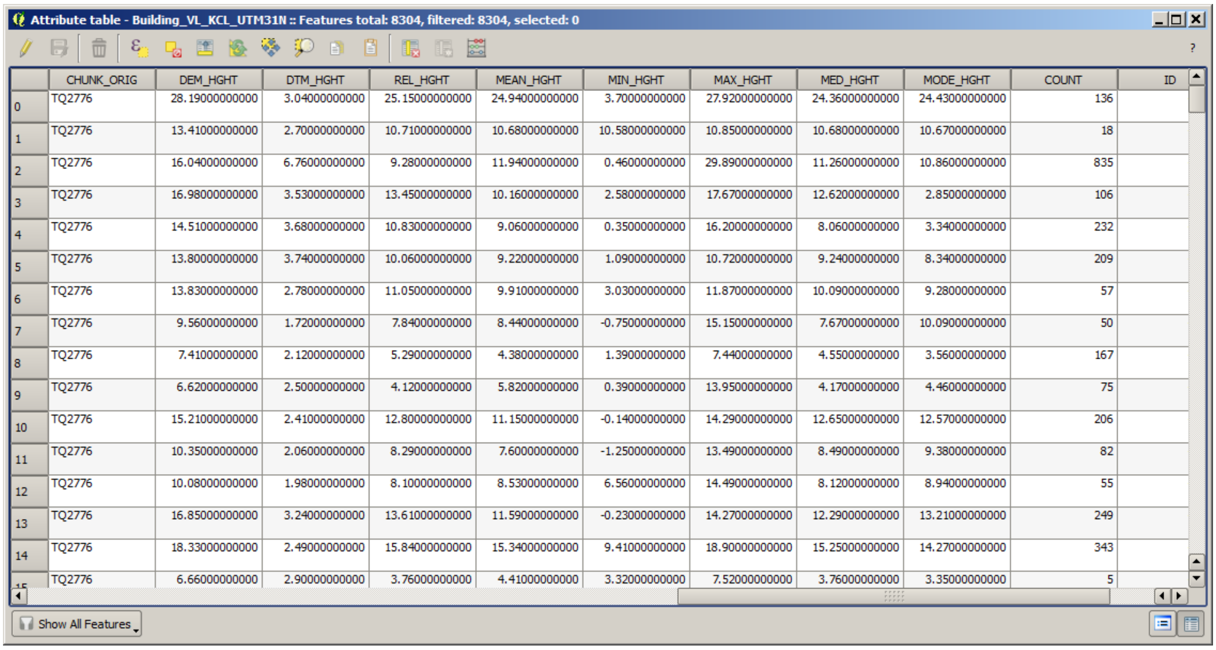


Figure 2: Geodata that will be used to create a DSM, a vector polygon layer and a DEM.

Question 1: What would have been the more 'correct' name for the DEM_HGHT-column?



	CHUNK_ORIG	DEM_HGHT	DTM_HGHT	REL_HGHT	MEAN_HGHT	MIN_HGHT	MAX_HGHT	MED_HGHT	MODE_HGHT	COUNT	ID
0	TQ2776	28.19000000000	3.04000000000	25.15000000000	24.94000000000	3.70000000000	27.92000000000	24.36000000000	24.43000000000	136	
1	TQ2776	13.41000000000	2.70000000000	10.71000000000	10.68000000000	10.58000000000	10.85000000000	10.68000000000	10.67000000000	18	
2	TQ2776	16.04000000000	6.76000000000	9.28000000000	11.94000000000	0.46000000000	29.89000000000	11.26000000000	10.86000000000	835	
3	TQ2776	16.98000000000	3.53000000000	13.45000000000	10.16000000000	2.58000000000	17.67000000000	12.62000000000	2.85000000000	106	
4	TQ2776	14.51000000000	3.68000000000	10.83000000000	9.06000000000	0.35000000000	16.20000000000	8.06000000000	3.34000000000	232	
5	TQ2776	13.80000000000	3.74000000000	10.06000000000	9.22000000000	1.09000000000	10.72000000000	9.24000000000	8.34000000000	209	
6	TQ2776	13.83000000000	2.78000000000	11.05000000000	9.91000000000	3.03000000000	11.87000000000	10.09000000000	9.28000000000	57	
7	TQ2776	9.56000000000	1.72000000000	7.84000000000	8.44000000000	-0.75000000000	15.15000000000	7.67000000000	10.09000000000	50	
8	TQ2776	7.41000000000	2.12000000000	5.29000000000	4.38000000000	1.39000000000	7.44000000000	4.55000000000	3.56000000000	167	
9	TQ2776	6.62000000000	2.50000000000	4.12000000000	5.82000000000	0.39000000000	13.95000000000	4.17000000000	4.46000000000	75	
10	TQ2776	15.21000000000	2.41000000000	12.80000000000	11.15000000000	-0.14000000000	14.29000000000	12.65000000000	12.57000000000	206	
11	TQ2776	10.35000000000	2.06000000000	8.29000000000	7.60000000000	-1.25000000000	13.49000000000	8.49000000000	9.38000000000	82	
12	TQ2776	10.08000000000	1.98000000000	8.10000000000	8.53000000000	6.56000000000	14.49000000000	8.12000000000	8.94000000000	55	
13	TQ2776	16.85000000000	3.24000000000	13.61000000000	11.59000000000	-0.23000000000	14.27000000000	12.29000000000	13.21000000000	249	
14	TQ2776	18.33000000000	2.49000000000	15.84000000000	15.34000000000	9.41000000000	18.90000000000	15.25000000000	14.27000000000	343	
15	TQ2776	6.66000000000	2.90000000000	3.76000000000	4.41000000000	3.32000000000	7.52000000000	3.76000000000	3.35000000000	5	

Figure 3: Height attributes available in for the building footprint vector dataset.

DSM creation

First we need to convert the building vector layer into a raster dataset. There are several options to do this in QGIS but to make sure there options are available you need to install and activte the ***GdalTools*** or the ***Processing*** plugin. If you are unfamiliar on how plugins are installed and maintained please go through the tutorial 'Getting started with UMEP and QGIS' found at the UMEP official website (www.bla.bla.ac.uk). When creating new rasters it is important to alling them to other rasters used in the process. Therefore, an empty raster alligned with the DEM is needed. Go to ***Raster -> Raster Calculator*** and make the settings according to Figure 4. The Raster Calculator can be used to numerus thing when dealing with raster images. To get the correct extents, highlight your DEM in the *Raster bands* window and click on *Current layer extent*. Click OK. As you can see, this raster is not that exiting as it only consists of zeros. To reduce the size of your new raster you can clip it based on the extent from your building vector layer. Name the outputlayer **BuildingHeights.tif** and let the no data value be zero. The clip function is found at ***Raster -> Extraction -> Clipper***. You can also clip based on a box that you draw in the map canvas. If you use the vactor layer as mask your new raster will look a bit strange as it has cliped according to the geometries in the vector layer. This will be taken care of in the next step.

Now you will populate building pixels with heights from the vector layer. We will make use of the GdalTools plugin which is a build-in plugin that is included in the QGIS installation package. Go to ***Raster-> Coversion -> Rasterize (Vector to Raster)***. Use the DEM_HGHT attribute and overwrite your BuildingHeights raster. Keep existing raster size and resolution and click OK. As you see in your layers window you now have two BuildingHeightsRaster. These are duplicates. Remove the bottom one.

Question 2: Why are you creating the DSM in such a complicated matter? Why just not add the REL_HGHT column to the DEM to get a ground and building DSM?

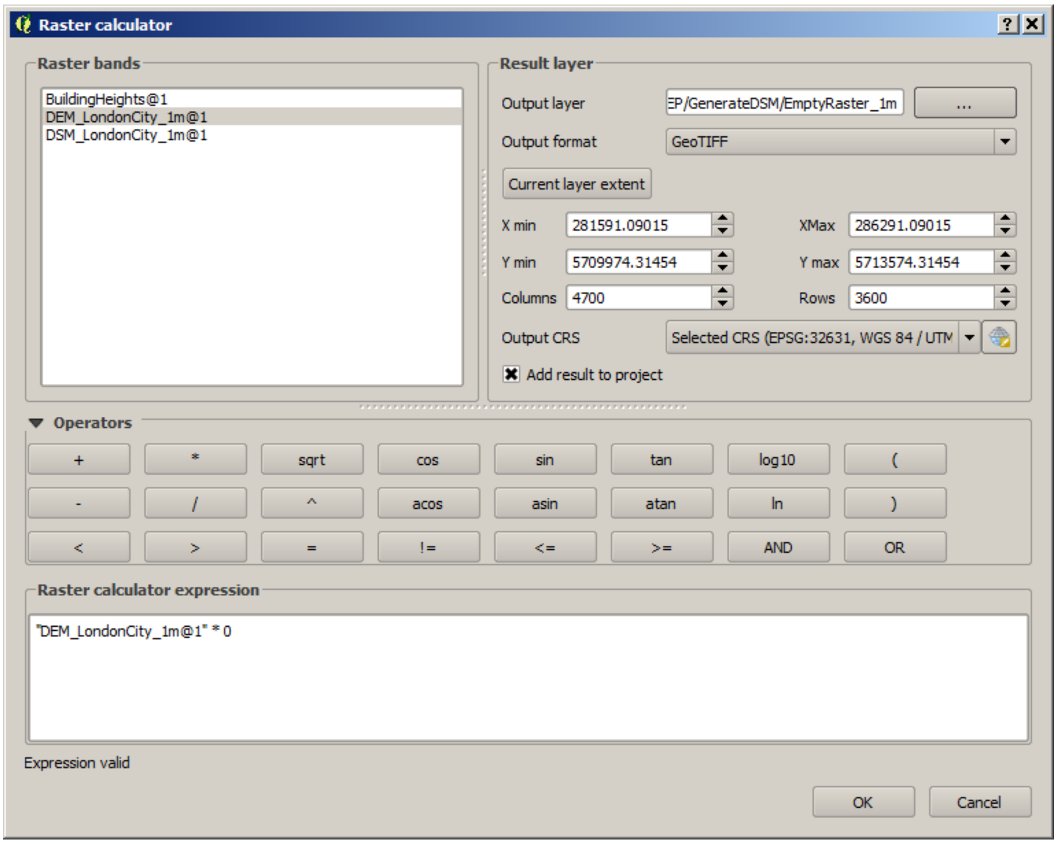


Figure 4: The settings in the raster calculator for creating an empty and aligned grid.

The last step is to populate the ground pixels with heights from your DEM. To do this you need to create a boolean image where building pixels are set to 0 and ground pixels are set to 1. This can easily be done in the Raster Calcualtor. Now we would like to use the zeros as we set to nodata before. Right-click on **BuildingHeights** in your layer window and go to *Properties*. Go to the *Transparency* tab and tick off *No data value: 0*. Now use the ***Raster Calculator*** and use the following expression in the *Raster calcualtor expression* window:

"BuildingHeights@1" = 0

Name your output **GroundBoolean.tif**.

Now you can make an expression where you combine all your datasets. Use the following expression:

"GroundBoolean@1" * "DEM_LondonCity_1m@1" + "BuildingHeights@1"

Name your output **GroundBoolean.tif**. the final product is shown in Figure 5.

Question 3: To save time, how would a combined expression look like using the two expressions above?

Question 4: Compare your newly produced raster with the **DSM_LondonCity_1m.tif** by making a difference raster in the Raster Calculator. What are the main differences between the two raster images?

References

Evans S, Hudson-Smith A, Batty M (2006) 3-D GIS: Virtual London and beyond. An exploration of the 3-D GIS experience involved in the creation of Virtual London. Cybergeo Eur J Geogr 359

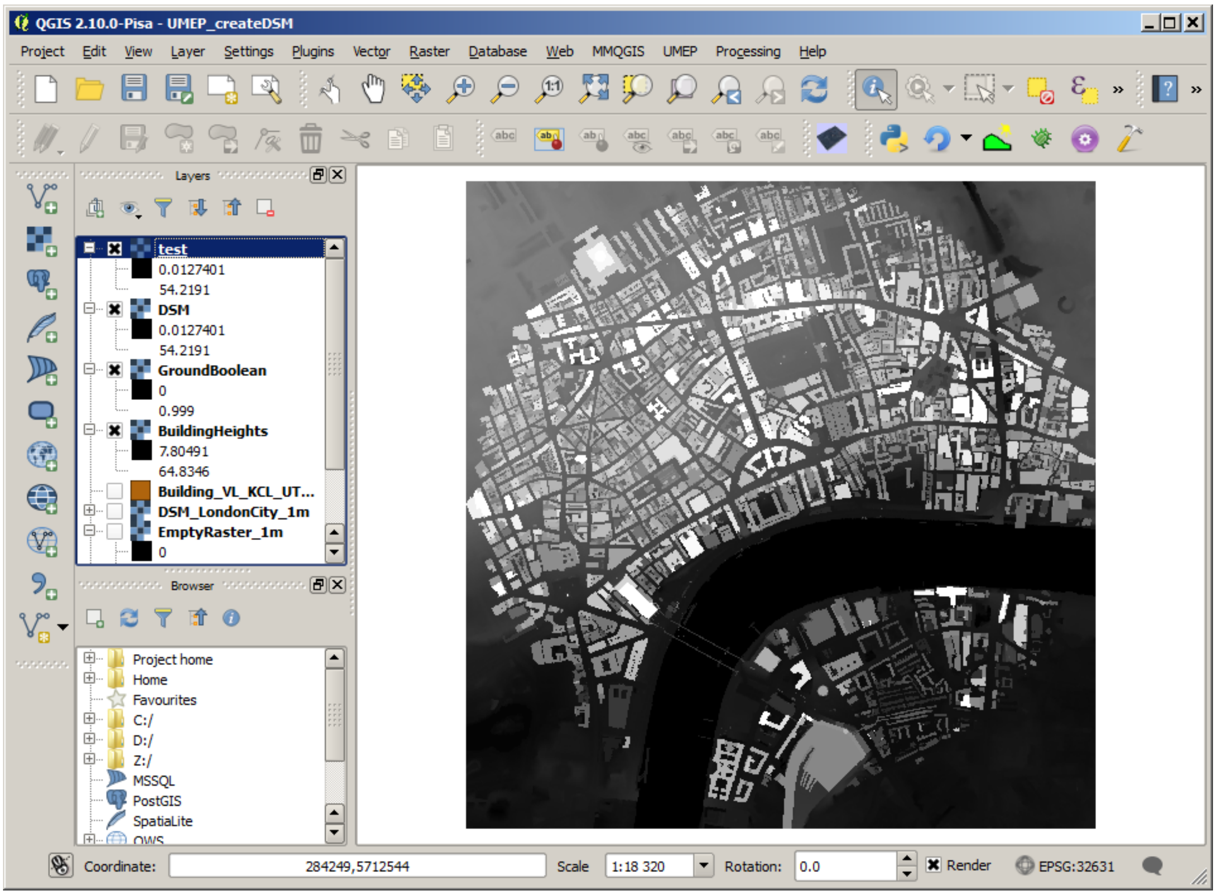


Figure 5: The final DSM