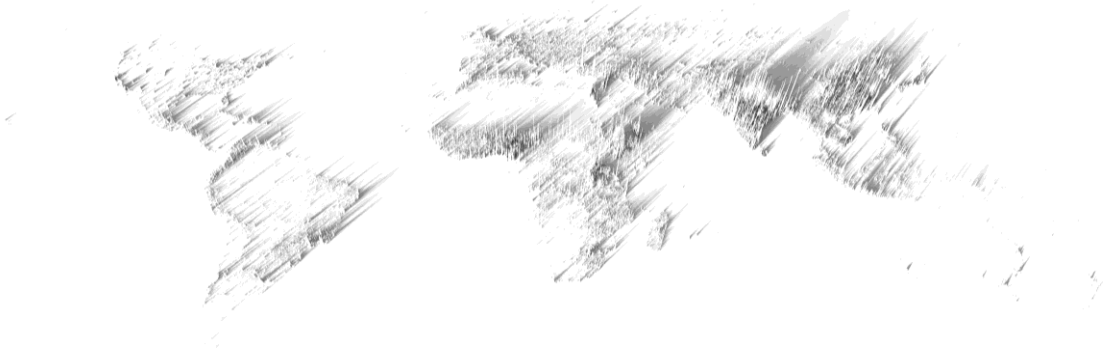
AN INTRODUCTION TO AERIALOD

Creating 3D maps and visualisations in Aerialod

with Alasdair Rae



Aerialod version: Win v0.0.1

Workbook version and date: v1.5, February 2021

Automatic Knowledge Ltd
www.automaticknowledge.co.uk

Contents

A note about Aerialod
The first version of Aerialod was released at the end of 2019, by @ephtracy. It is available in 64- or 32-bit versions for Windows (if you are not sure whether you have the 64- or 32-bit version of Windows, you can find out via > > System > About). Aerialod downloads as a 2.04MB zip archive, which when unzipped is still only 3.34MB in size. Yet it is surprisingly powerful. If you need to adjust the size of the text on the Aerialod interface, go to the *config.txt* file in the *config* folder and change the default *ui_scale* value from 1.0 to a larger number (e.g. try 1.5 and then adjust again if necessary).

This workbook is also available online, at:
https://automaticknowledge.org/training/workbooks

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About Automatic Knowledge

Our philosophy is all about sharing data and knowledge, so that we can all be a bit better informed about the world. The way we do this is mainly through spatial data analysis and visualisation, and as part of this we offer training courses in software like QGIS and Aerialod. Alasdair Rae (pictured) founded Automatic Knowledge in 2019 and also runs the training courses.

Why 'automatic knowledge'?

The idea behind Automatic Knowledge is that we do the hard work of completing the journey from data to knowledge, so that you can then make more informed decisions. These training sessions will hopefully help you do that too.

Other activities (e.g. free stuff)

In addition to training, we provide a range of consultancy services, specialising in data, spatial analysis, the built environment and cartography. We also publish free and open datasets that you may find useful, at:

automaticknowledge.co.uk/resources

We are also a 'sustaining member' of QGIS, and have previously donated to @ephtracy, creator of Aerialod. By taking this course, you're making a contribution too.

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Automatic Knowledge training sessions

The idea behind all our training sessions, and these workbooks, is to help you learn new things in an enjoyable way, without confusing you. We want everyone who takes one of our courses to come away with useful new skills that they can then put into practice in their day-to-day work, and build on in the future.

About this workbook

Following a workbook can be a great way to learn new software skills, but there's also a risk that it turns us into robots, following step-by-step instructions in a linear way. During the session, we'll go off at tangents and do some demos of useful skills – among other things. *The emojis?* I add them in for a bit of colour, but they also serve a practical purpose because they can help us find key sections of the document quickly.

Formatting

Most font is size 14. When switching between screen and workbook this is easier on the eyes. The following format will be used in relation to files/folders, websites, options/tools, click actions and any text I want you to input. I've also added a 'Notes' section on each page where you can jot things down.

Files, folders and suchlike: e.g. scotland_50m_dtm.tif
Websites: e.g. www.automaticknowledge.org/training/data
Aerialod tools, sections, options: e.g. Intensity
Actions - click menu item/ button: e.g. Render > Save As
Text input: e.g. 31839f when entering colour codes

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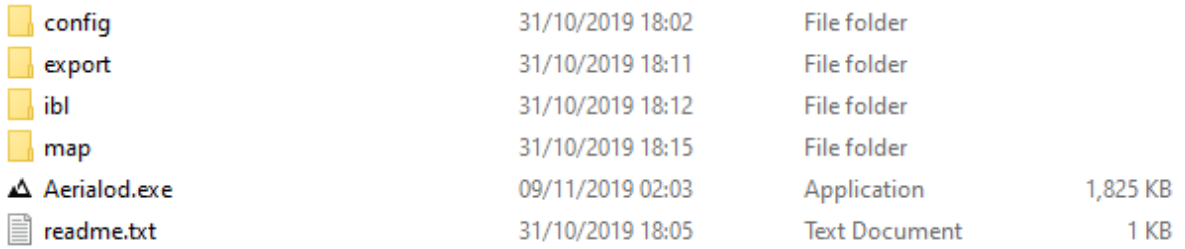
1. The Aerialod interface: how it works, what does what

We'll mostly look at the Aerialod interface in this section, but let's start at the beginning, one step before that.

When you download Aerialod from the ephtracy website, this is what you get (my screenshots are from a Windows 10 PC).

When you unzip this archive, this is what you will see inside the Aerialod-0.0.1-win64 folder (you may be using the 32-bit version, in which case the folder will have a different name).



The readme.txt file has information about the software, plus some data credits – I always recommend actually opening and reading readme files!

Remember this

You can browse around different folders if you are interested but if you need to **adjust the font size on the Aerialod interface**, you need to look in the config folder and then change the ui_scale value from 1.0 to a higher number in the config.txt file (try 1.5 or 2.0 at first).

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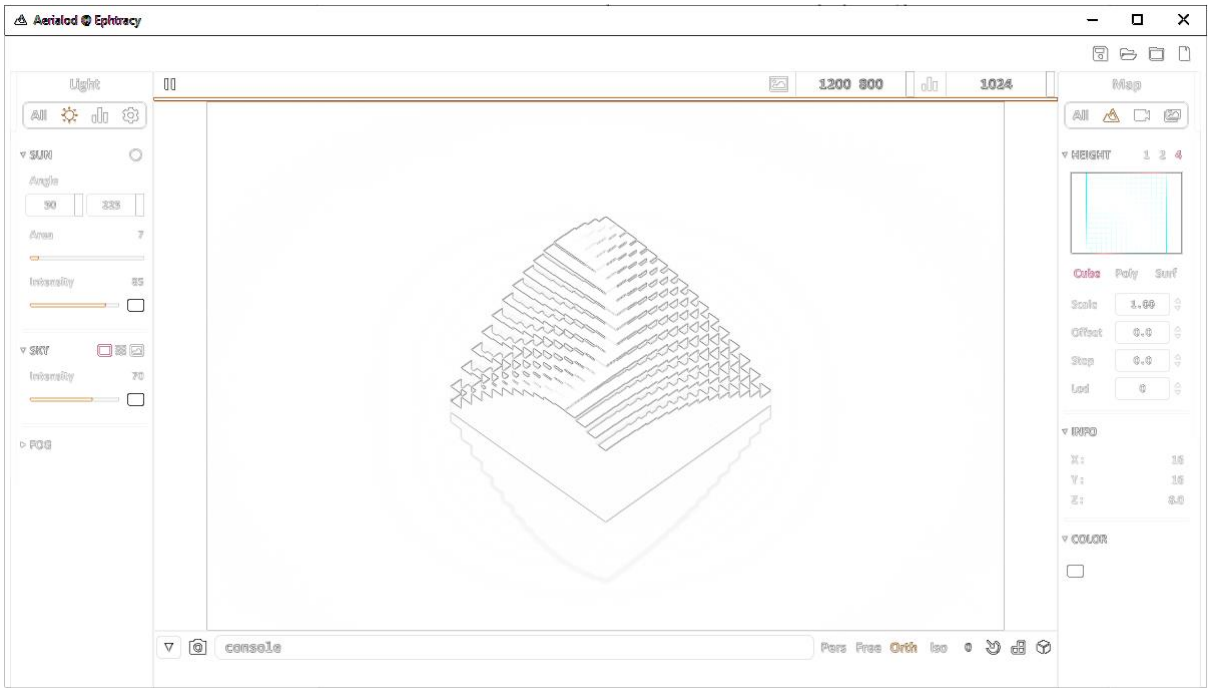
As you may have already discovered, you launch Aerialod by double-clicking the Aerialod.exe icon. 

Then you see something like this, below (you'll see it in dark colours – I have just inverted the colour scheme for printing purposes).



Let's walk through the following controls now.

- Moving the demo map around – pan/zoom etc
- All the Light settings, on the left
- All the Map settings, on the right
- The View settings, along the bottom
- Then we can go through the rest: Sample, Display, Camera, Export and how to save views in memory.

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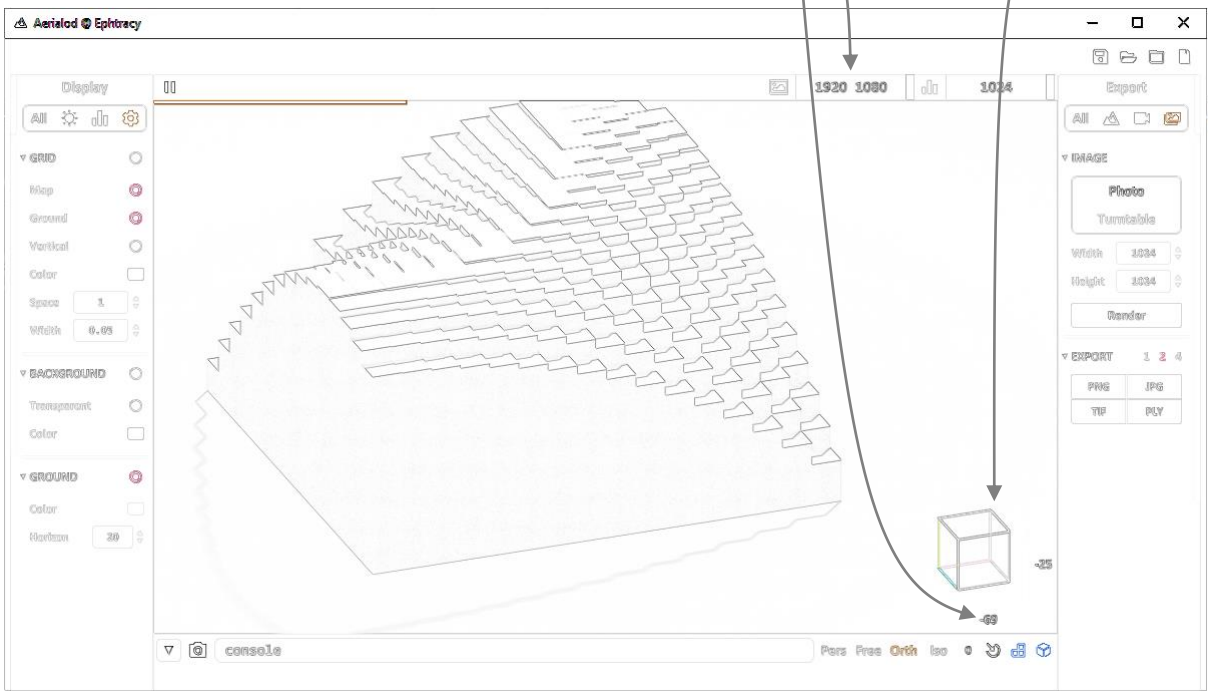
Let's not overlook: Scale, Offset, Step, Lod (level of detail – that's why it's called AeriaLOD), Grid, and so on. And of course the left, right and middle mouse buttons, and the space bar. Also, the model image you are working with here is a very small 16x16 pixel image. That's all it is.

- We can also look at the Camera Ruler and the View Cube, as well as changing the Image Size.



Aerialod is, according to the website, 'An interactive path tracing renderer for height maps', but what does this *actually* mean?

- **Interactive?** Well, this is fairly straightforward. It just means we can interact with it and set the views and options that we want. We interact directly with the 3D model on screen.

- **Path tracing?** This refers to a method of rendering 3D images so that they look realistic, based on the way they are lit. Although Aerialod seems simple, path tracing is

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actually very complex – that's why it may slow your computer down when you try to render large scenes.

- **Height maps?** Normally this will be things like elevation models you import into Aerialod – e.g. the digital terrain model data we're using later on, or some lidar data. In reality, it can be any kind of raster image with pixel values that Aerialod can interpret and extrude and render.

If you want absolute top-end performance when you are working with Aerialod, then you're likely going to need a more expensive graphics card. If you're using a fairly conventional office-type PC setup then you may have to be patient while rendering large, complex images but if you have something like an RTX 3070 graphics card (typically found in gaming PCs) then you will notice a world of difference, with much faster rendering. However, for most jobs you will get on just fine on a fairly typical spec machine.

Remember this

Aerialod supports rendering of height maps up to 16,384^2.

What does this mean? Well, if you try to import an image 20,000 pixels wide in Aerialod it won't work. Feel free to try it and see how you get on. This is rarely a problem but if you were trying to import a 1km global population density raster then you would run out of space and have to resize it before importing it into Aerialod (because the earth is 40,075 km in circumference at the equator).

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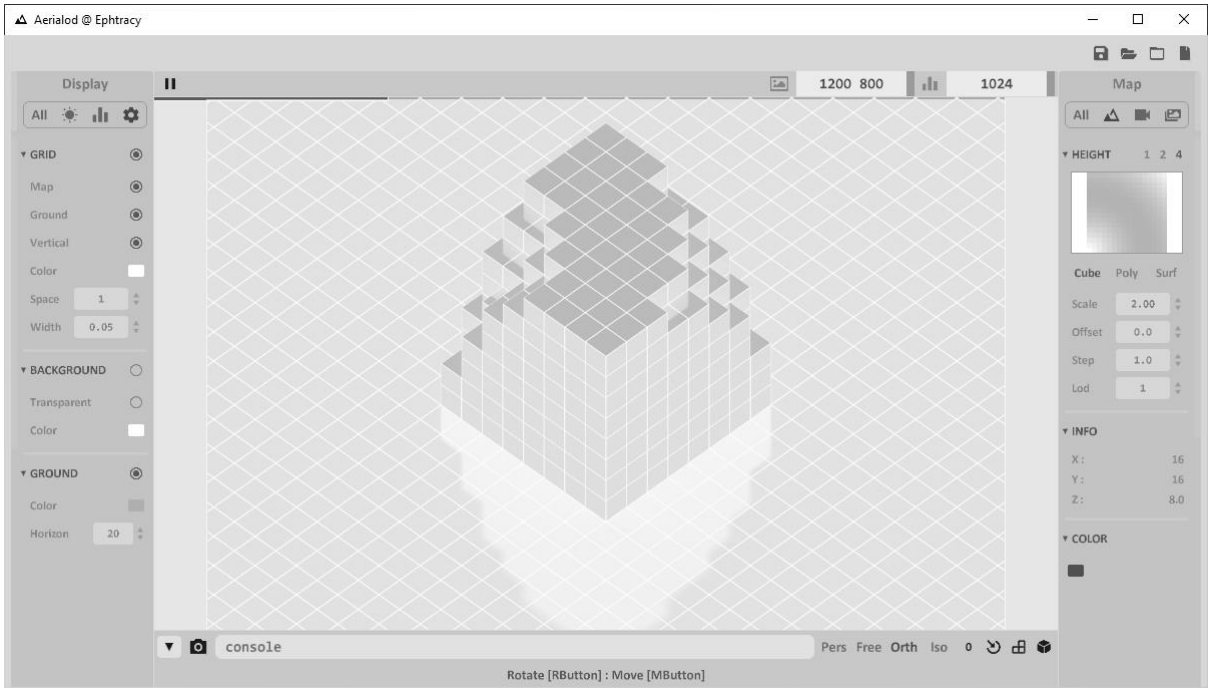

In this example above I have shown an example with the grid, where it turns things into neatly defined blocks. To get the lines on the vertical side surface of the model I select the Vertical setting on the left, in the Grid settings. And to the right…

- Scale**:** height scale – e.g. if you want to exaggerate elevation, increase this figure.
- Offset**:** if you want your ground level to move up or down, adjust this up or down (e.g. if it's land it will look flooded using a negative value). This is the height offset setting.
- Step**:** this refers to Quantization Step and will basically make your data look more 'stepped' or 'terraced'.
- Lod**:** you'll notice that this will make things more chunky with higher values – LOD stands for 'level of detail'.

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2. Some important principles

The small file size and apparently lightweight nature of Aerialod can be misleading. It is quite powerful and complex and there can be quite a lot to understand. We'll go through some of this step-by-step, but before we get going it's worth highlighting a few more things.

Samples Per Pixel

First of all, if you want to understand what impact increasing the Samples Per Pixel value can have, see this 3-seconds-per-frame gif I created using settings of 512 and then 8192 Samples Per Pixel. The gif switches back and forth between the two.

http://automaticknowledge.org/training/data/raster/aerialod_samples_per_pixel.gif

Put simply, a *higher value* will lead to a crisper, *less noisy* image and – in this case – a smaller file size.

Read this piece about sampling – it's pretty useful.
https://docs.arnoldrenderer.com/pages/viewpage.action?pageId=36110402

Rayleigh

Rayleigh refers to the optical phenomenon of what is known as 'Rayleigh scattering', named after the nineteenth-century British physicist Lord Rayleigh (aka John William Strutt). *Why is the sky*

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blue? The answer is that the blue sky we sometimes see in the daytime is caused by Rayleigh scattering.

There are countless websites and blogs and other resources online about Rayleigh scattering, and you can check them out if you want to find out more. The whole topic is fascinating.

Want to see it in action in Aerialod? Just turn the Sky setting to Atmospheric Scattering and turn Rayleigh all the way down to 0 and then start adjusting it upwards and watch as the blue starts to show, and then change to orange (you'll need to be on Pers camera view and ideally SG for LENS).

Using the default 40 and blue in Aerialod you will see a blue sky when you have the right camera view on. Turn it all the way up to 100 and you'll see a bright orange glow.

Mie

What the heck is this? Well it's also to do with light scattering but it's different from the Rayleigh setting. The Wikipedia page on Mie is actually quite good (if complex) and shows a nice image illustrating the link between Rayleigh and Mie scattering. It is named after the person who first specified the process, the German physicist Gustav Mie.

Leave Rayleigh at the default 40 and turn Mie up to 100 and you'll see that things get somewhat hazy, with the sun getting

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obscured by the haze, if you have it turned on. Turn it to 0 and you'll see a much cleaner, clearer, crisper atmosphere.

Top tip

How do you adjust the numbers accurately in Aerialod?

You can generally just click a value bar and/or slide it back and forth to adjust numerical values for different settings (such as Rayleigh, Mie and Ozone). If you want to enter a specific number quickly all you need to do is double click on the actual number and then type in a different value manually using your keyboard. Just delete the number that is there and enter what you want.

Ozone

We've all heard about the Ozone Layer but in Aerialod this refers to Ozone Density. This is the most confusing of the Sky settings in my opinion. First of all, there's the colour – it seems to turn things purple on the default setting (which uses the default colour of green). Turn it to 100 and you get dark purple everywhere.

The best way to really explain what it does is to leave Rayleigh and Mie at 40 and then put Ozone up to something like 20 in the first instance and you'll see a nice purple glow.

Why does green turn things purple? Look at a colour wheel and you'll see that green shades are opposite the pinks and purples. If you change the Ozone green to orange, for example, then the scene will turn blue – blue is opposite orange on a colour wheel.

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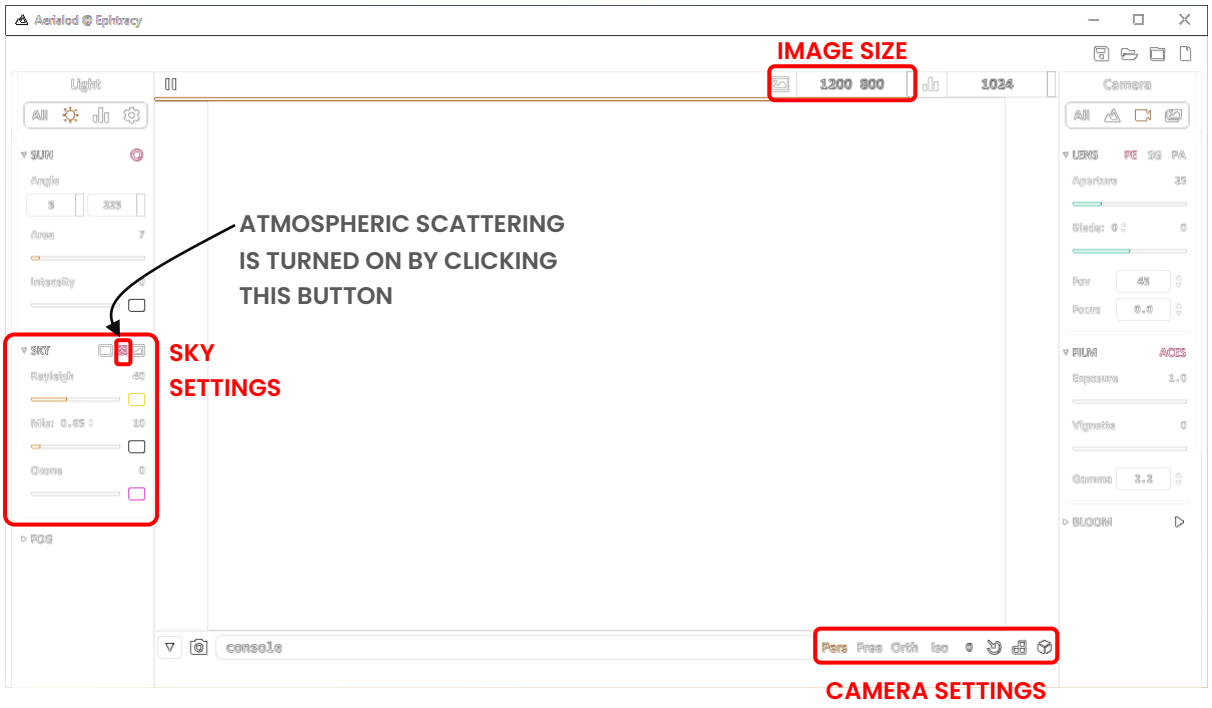
Fog

This can also be confusing. Turn Density up to 100 and you will see your scene look like a very foggy day. Then change the Phase value between the min and max (-0.90 and 0.90) to see what it does – it shifts the fog position in the scene.

Top tip

Spend some time playing with the settings and noting what they do.

The best way to get to the stage where you are able to create stunning visuals with Aerialod is to get to grips with the effects of the different options – there are infinite possibilities!



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3. Scotland digital terrain model

For the rest of the time we're going to experiment with real-world data, instead of the model data that appears when we open in Aerialod.

You'll find the Scotland digital terrain model in the /raster folder for this session. There are multiple different versions but you can just download the png version for now.

http://automaticknowledge.org/training/data/raster/

This is the file you want:
scotland_no_lochs_small_high_compression.png

In your web browser, you may have to right-click and then choose something like Save link as... to download it.

It's a 50 metre resolution digital terrain model that I put together using Ordnance Survey open data (their Terrain 50 product) and you can read more about it at the link below.

https://automaticknowledge.co.uk/resources/

- Once you've downloaded the file, drag and drop it straight into Aerialod and we'll get started. If for any reason it is causing your computer to run slowly then we can just chop a bit out of it and use a smaller portion of it.

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Now we're going to try and make something interesting with Scotland.

I'll do a proper walk-through of it, but here are some of the basic steps we'll take.

1. Image Size to 1920 x 1080.
2. Camera mode on Pers.
3. Sun angle to 3 degrees pitch.
4. Atmospheric Scattering turned on.
5. Sun turned on and Area (size) of 40.
6. Lens on SG.
7. Exposure on 10.0.
8. Gamma on 1.0 (Gamma correction controls the overall brightness of an image – try it).
9. Change the Scale setting to 0.33.
10. Under Bounce, on the left, let's change Diffuse to 3 and Energy to 15 – see the little bar chart icon to the top left.
11. Change the Ground colour to #4564b3.
12. Change the Base colour to #a4af83.
13. Add a Vignette of 15.

From here, I want you to continue to tweak the settings on your own and see what you can come up with. Feel free to share it.

We export by specifying our Width and Height then via Render but I won't do this now as it will take too long. Export just exports a raw raster image, not our rendered scene.

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Angle the scene however you like – and remember that when you move the image it will take a few moments to redraw, possibly longer. You can try to render a small scene if you like, but don't try to export a massive image during the session. You can always take a screenshot of your settings – that's what I normally do.

4. High-resolution Lidar data

Hopefully you've managed to do something interesting with the Scotland DTM data above. That was 50 metre resolution data - and that means each cell in the raster file is 50 metres by 50 metes and has one data value associated with it (in this case it was elevation).

In the UK we now have lots of open lidar data, and this is *much* more detailed – with correspondingly large file sizes.

As per Wikipedia: "lidar was originally a portmanteau of light and radar. It is now also used as an acronym of "light detection and ranging"

For an informative explanation of lidar data and how it is collected, I highly recommend looking at this Environment Agency (UK) explanation.

https://www.arcgis.com/apps/MapJournal/index.html?appid=c6cef6cc642a48838d38e722ea8ccfee

The different spatial resolutions we have in the UK are 2 metre, 1 metre, 50 centimetre and 25 centimetre – but note that the coverage is not complete and can be missing entirely in places.

I have patched together some 1 metre resolution data for you, for a part of Greater Manchester in England. See below for more.

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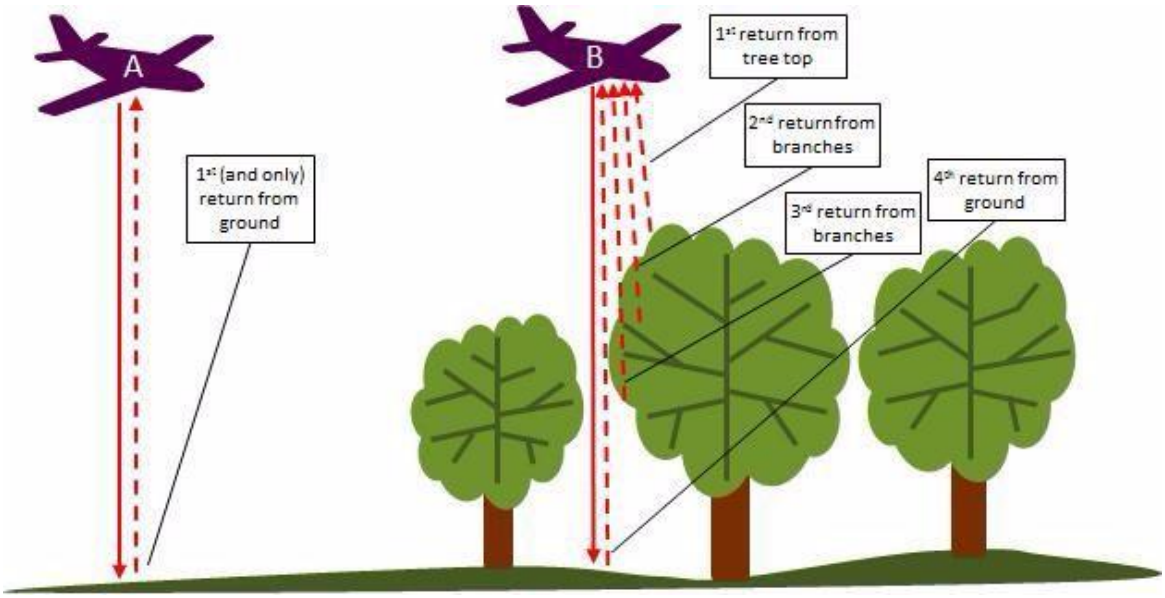
"Laser pulses emitted from a LIDAR system reflect from objects both on and above the ground surface. Each laser pulse can return to the LIDAR sensor as one or many returns, as it encounters multiple reflections from surface objects as it travels to the ground. Our current sensors can have up to 8 returns per laser pulse.

All derived DTM and DSM products have been generated from the last return of the laser pulse or the only returned single reflection, as this provides the optimum chance of the laser reaching the 'true' ground surface. In the diagram below for example the last return used in the DTM and DSM products for Plane A would be the first and only return recorded and for Plane B would be the fourth return."



Source: Environment Agency

The area you have been given data for is tile SJ89NW of the British National Grid. You can find it here if you want to.

https://britishnationalgrid.uk/

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Once again, the file you need to download is in the /raster folder for today's session.

http://automaticknowledge.org/training/data/raster/

I have prepared slightly different versions of this dataset but the one to use right now is sj89nw_1m_rendered_no_water.png

If you just open it up in your web browser you'll see that it is a greyscale image that goes from black (no data) to white (the highest values, which are for the highest elevations).

- Open a new, clean Aerialod session (or close it and then open again) and then drop this lidar data straight in.

- Then spend some time exploring and looking around, switching to a web map of the area if you need to get your bearings or figure out what's what.

Now I want us to make something interesting out of this, using what we have learned so far about the settings.

Example: you could reduce the offset value to -15.0 and set the Ground colour to blue if you want to do a little flood simulation.

The options are almost endless. Try a low sun, but without Atmospheric Scattering. This can also be quite pleasing.

Notes

Try: leave everything at the default settings, except sun Angle of 5, Ground colour of #8399d2, Offset of -15.0 and then zoom in so you can see the detail of this 'flooded' scene. Then set the Ruler values to -25 on the vertical and +40 on the horizontal.

5. Global population density

Okay, so far - so good. But do you REALLY understand what is happening so far? How about the Info panel on the right of Aerialod? For the Manchester lidar data that looked like this (below).

This told us that our image was 5000 units on the x axis, 5000 on the y axis, and 100 on the z axis. That's because it was an area of 5km x 5km so there were 5,000 pixels on both the x and y dimension that Aerialod could read. The Z values ranged from 0 to 100 because instead of this being a true elevation dataset, I converted it to a rendered image with values from 0 to 100 – to create a smaller file size.

When I download the original asc files from the Environment Agency Lidar website and load them in to Aerialod, I still get values of 5,000 for the X and Y dimension but for the Z I get 195.6, which tells me that the highest value in my image is 195.6 metres high. Notice that this has a decimal place as well, so it's more accurate (and takes up more disk space – so we get bigger file sizes).

If you're doing proper analysis, the original asc full resolution data is what you should use. If it's just for visualisation, then the simplified files are usually better as they are easier to work with.

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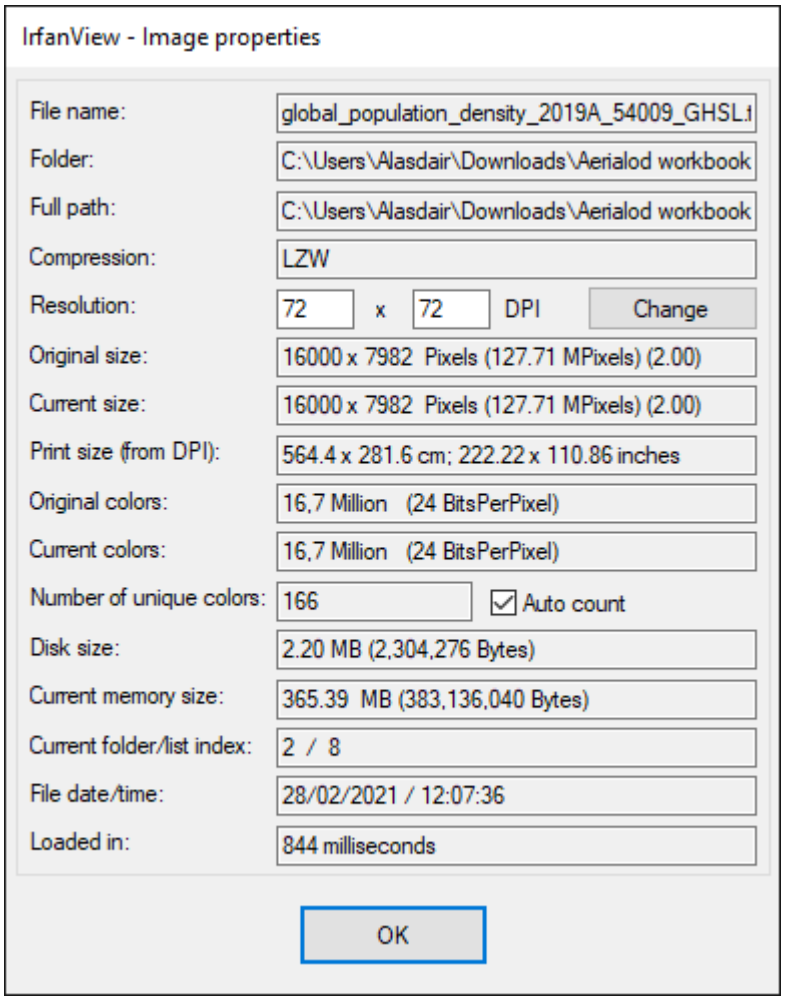
I began this section on 'Global population density' by talking about the lidar data for Manchester on purpose.

Before we add it, it's really important to understand what it is we're working with. This helps us make sure that we know what we're visualising but it can also help us when things go wrong. Okay, so here are the characteristics of the next image (below).

Yes, you are reading this correctly. This is an image of 16,000 x 7,982 pixels of the whole world's population density that is only 2.20MB in size.



What about DPI? You can look into that more yourself but it's not actually what people often think it is, that's all I'll say for now.

Add this file to Aerialod now and see what it looks like – then I'll explain how I put it together. **Please remind me if I forget to explain this.**

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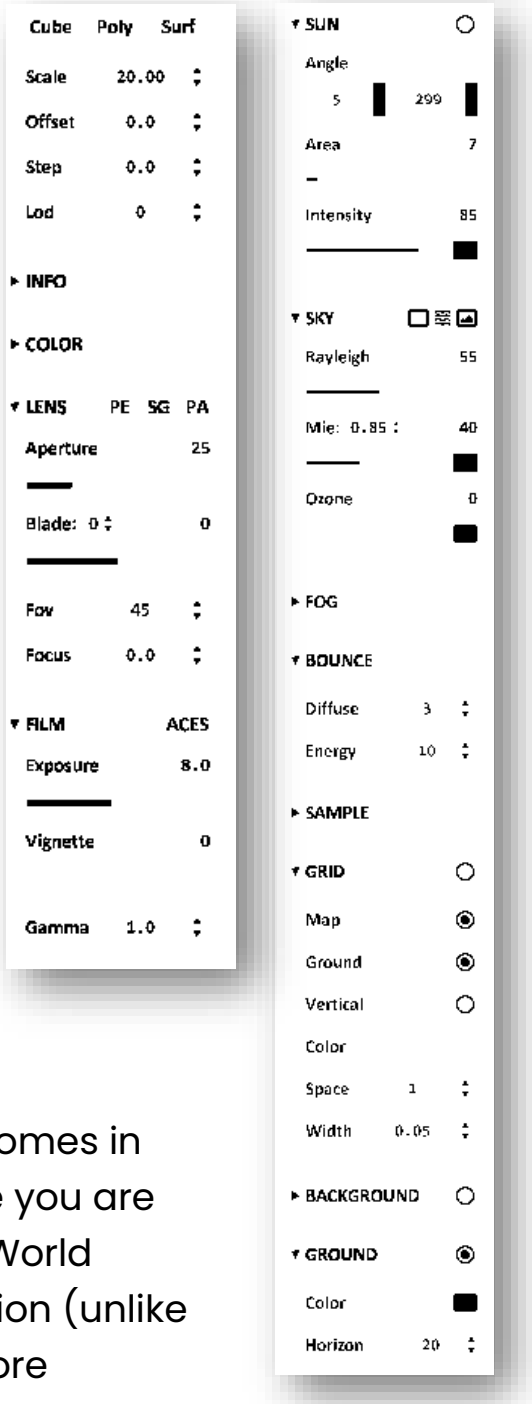
Explore the data for a bit, zoom in, pan and all that.

Notice the Info characteristics? The image is 16,000 pixels wide and 7,982 pixels high. Think about how these figures compare to the size of the earth and then what that means for the size/area of each pixel.



Then change the Scale to 50 and change the light settings! Then try to match the settings I have pasted on this page →. The settings not shown remain at their default values. Don't worry if your computer takes a while to apply these. The ground colour I used was #5f88d5 (a nice blue).

This data comes from the Global Human Settlement Layer project of the European Commission.

The data on world population density comes in two different map projections – the one you are using here is the EPSG 54009 one – i.e. World Mollweide. This is an equal area projection (unlike WGS84) but as you can see, you get more distortion than you might want.

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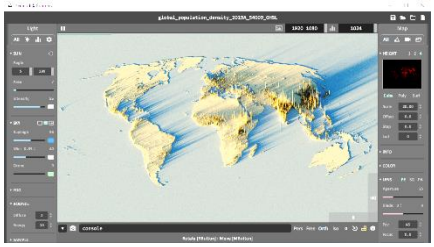
This little thumbnail image → is more or less what you get if you apply the settings I used above (I've lightened it for printing purposes here though).



Once you get something looking just how you like it, you can save screenshots of the settings. This is not ideal, but considering how great Aerialod is, I think it's a small price to pay.

We're going to move on now, so if you want to recreate the world image above then just save the settings you have.

If you want a more full-blown tutorial on how to create a population density map of any country in the world, using a similar dataset, then see my earlier blog post on the topic.

http://www.statsmapsnpix.com/2020/11/how-to-make-3d-population-density.html

Remember this

When you're working with population, just remember that it's different. Unlike elevation data, which typically only has individual pixel values into the hundreds or thousands (e.g. 8,848m for Mount Everest), population values for single cells can be in the tens of thousands, and even more than 100,000. This can cause problems in Aerialod, so I often scale the data first – for example in QGIS, as in the blog link above.

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6. Turntable – for creating frames for animation

Okay, let's look at how we might animate a view in Aerialod. This is what the Turntable export options do. Follow these steps (we're making the image small for this experiment so that it doesn't run too slowly). Use the default Aerialod 16x16 pixel model data and make sure Atmospheric Scattering is turned off and you don't have any fancy effects on.

- Image Size of 320 x 180.
- Samples Per Pixel of 512 (the minimum).
- Go to Export and then with Turntable selected we want 10 Frames, 90 for Angle and 0 for Blur.
- Then we can hit Render and choose a folder to save it to.

You should now see a series of individual frames. If you open your file browser and flick back and forth, you'll get a kind of animation effect. If you want to turn these frames into a gif or an mp4, you can do so with tools like ffmpeg, ImageMagick (both command-line) or GIMP.

Here's a little example (below) I made using dimensions of 320x180 and 90 frames turning 90 degrees and then back – and looping forever back and forth 90 degrees.

https://automaticknowledge.org/training/data/animation/model-30fps.gif

More complex scenes can take a *long* time to render.

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7. Other experiments

In the examples above, we used the built in model data in Aerialod, the Scotland digital terrain model, the Manchester lidar data and the GHSL global population density layer.

If you look in the /raster folder you will also find some variations of these datasets, plus one other, as follows.

- A Manchester lidar layer with border and text round it. You can open this in the browser to see it, and even make your own version with your own text, using the blank border version I also provided. See the file names that end in _border... here.

- Try downloading lds-tile-sd-GTiff.zip and then unzip and load into Aerialod. Perhaps your computer will not be able to handle it, but if it does you'll see some lovely 8m resolution New Zealand terrain data. You will have to adjust the Z factor though. Can you figure out what the correct value of Z should be here? (hint: it's 0.125, but why?)

- Another great source of terrain data, from 1 March 2021 is swisstopo: shop.swisstopo.admin.ch/en/products/free_geodata

- Try making a simple chart in Excel or something else and then saving it as an image and dragging it into Aerialod.

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8. Credits

Aerialod An interactive path tracing renderer for height maps, and a truly great piece of software.
https://ephtracy.github.io/index.html?page=aerialod

Environment Agency Lidar data, available under the Open Government Licence, v3.0.
https://environment.data.gov.uk/DefraDataDownload/?Mode=survey

GHSL - Global Human Settlement Layer Global population density data (GHS-POP R2019A), produced by the European Commission.
https://ghsl.jrc.ec.europa.eu/ghs_pop2019.php

> **Dataset**
> Schiavina, Marcello; Freire, Sergio; MacManus, Kytt (2019): GHS population grid multitemporal (1975, 1990, 2000, 2015) R2019A. European Commission, Joint Research Centre (JRC) DOI: 10.2905/42E8BE89-54FF-464E-BE7B-BF9E64DA5218 PID: http://data.europa.eu/89h/0c6b9751-a71f-4062-830b-43c9f432370f
>
> **Concept & Methodology**
> Freire, Sergio; MacManus, Kytt; Pesaresi, Martino; Doxsey-Whitfield, Erin; Mills, Jane (2016): Development of new open and free multi-temporal global population grids at 250 m resolution. Geospatial Data in a Changing World; Association of Geographic Information Laboratories in Europe (AGILE). AGILE 2016.

Scotland DTM (50m resolution) created using Ordnance Survey open data (their Terrain 50 product), and compiled by Automatic Knowledge Ltd.
https://automaticknowledge.co.uk/resources/

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https://twemoji.twitter.com/

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