Creating 3D printable globes: a step-by-step guide

Jeff Winterbourne – February 2021

Blender (https://www.blender.org/) is a highly flexible piece of open source software used by animators and 3D modellers around the world. Its capabilities mean that it is ideal for creating 3D models, but it has a steep learning curve. To explain how Blender works in detail is beyond the scope of this document. However, we describe here in detail the steps that need to be taken to create 3D models to ensure that our method can be followed by a non-expert audience.

1 CONTENTS

2 OVERVIEW

Essentially, we want to apply a height map to the surface of a sphere, such that light areas become higher topography, dark becomes lower topography and mid-grey remains neutral.

In this tutorial, our height map image is assumed to be pre-prepared – see https://github.com/jeffwinterbourne/3D_globes/ for the scripts and workflow required to create this.

In Blender, we need to apply the height map to a sphere using a technique called UV mapping, a procedure that relates the pixels in an image to the geometry of a 3D object. The modified sphere can then be exported in a standard .stl or .obj format generally used by most 3D printing and modelling software.

Some post-processing is required to hollow and divide the globe into 2 hemispheres for easy printing with minimal material usage. We use Autodesk Meshmixer to complete these steps, but this is also possible in Blender.

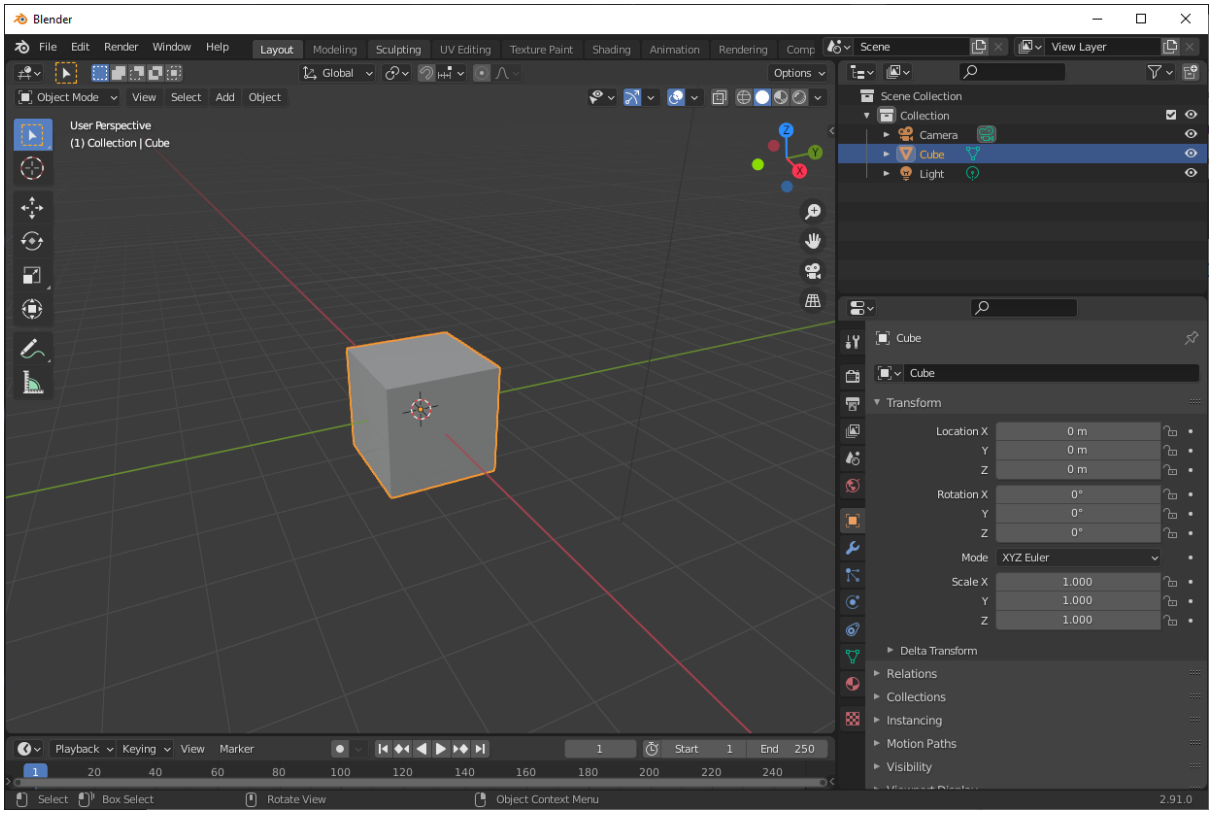
3 CREATING THE GLOBE IN BLENDER

We used Blender 2.91 when creating this tutorial, but the workflow should remain essentially the same in other versions.

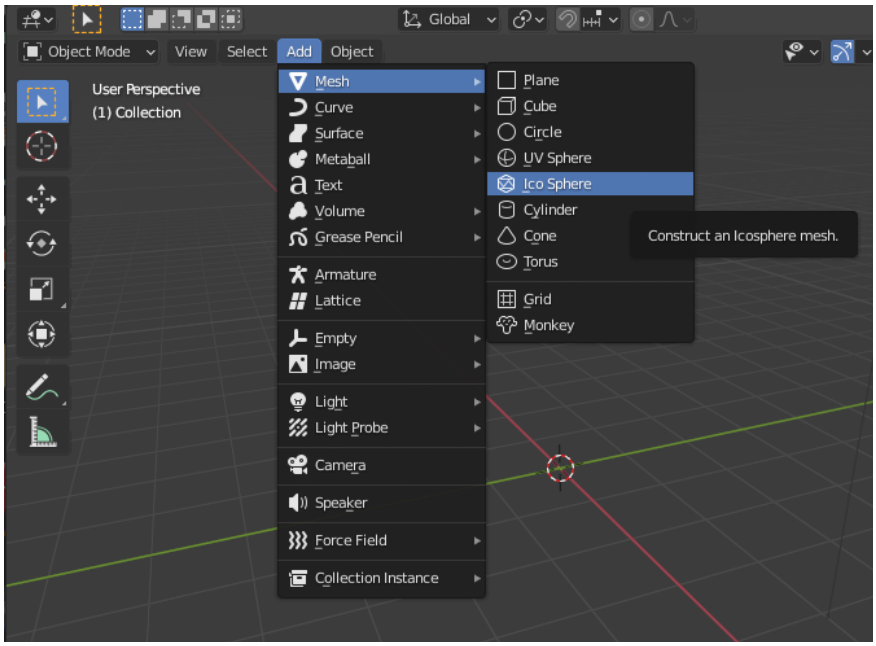
3.1 CREATE A SPHERE

Our goal here is to create a sphere with a high polygon count and a UV map. To do this, we insert a basic sphere, apply a subdivision modifier to increase the resolution and scale it to the desired size.

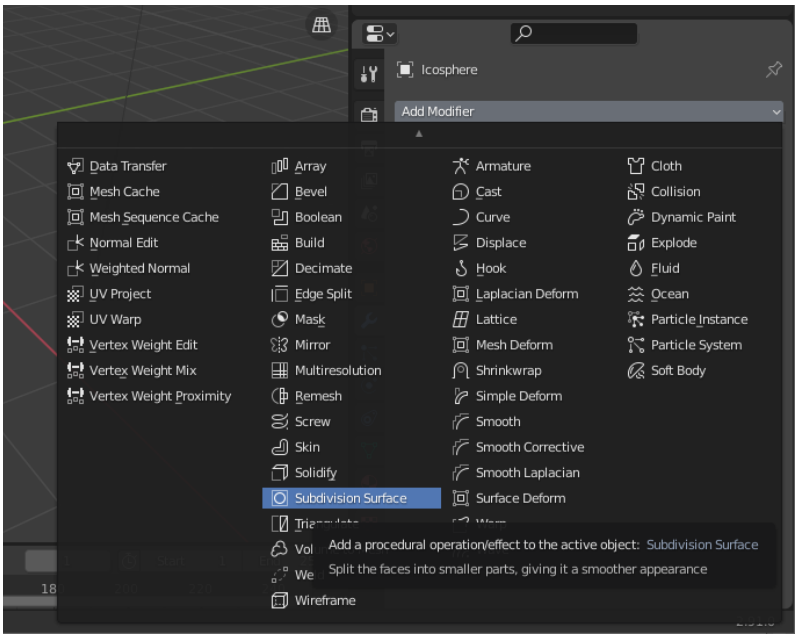
Open Blender. By default a grey cube is already loaded. Delete this by hitting the “Delete” key.



In the main 3D pane, select Add → Mesh → Ico Sphere. A crude “sphere” made of triangles will appear.

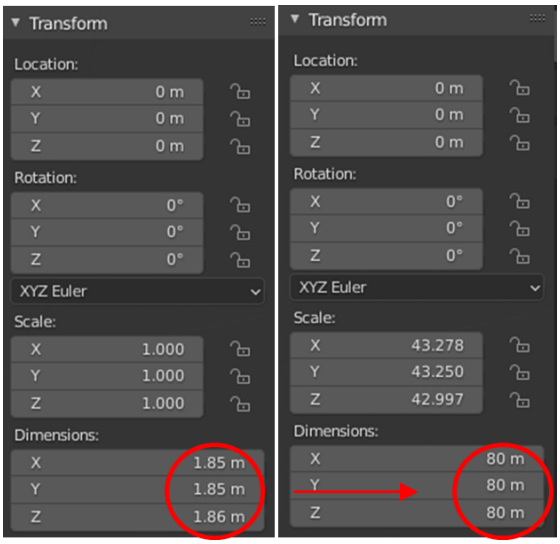


In the bottom right panel, select the modifiers pane () then Click Add Modifier → Subdivision Surface.

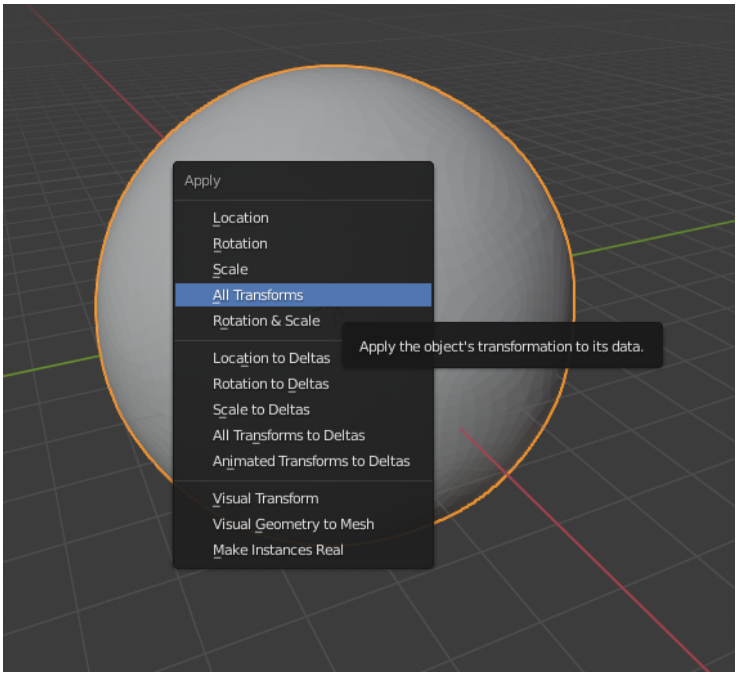


Change “Levels Viewport” and “Render” to 4. As you do this, you should see the crude sphere becoming more refined. “Apply” the subdivision to make it permanent (i.e. does not need to be constantly recalculated) by clicking the down arrow on the first row and clicking “Apply”. Subdividing less will mean artefacts near the poles. Subdividing more will technically improve UV mapping accuracy but should not be necessary.

Left click on the sphere and hit “n” on the keyboard to show the transform panel. Change the dimensions to the desired size diameter in millimetres, **ignoring the fact that Blender works in metres by default.** 3D printing programs will usually assume dimensions are in millimeters. Zoom out to be able to see the entire sphere by scrolling the mouse wheel. (This menu can be hidden by hitting “n” again).

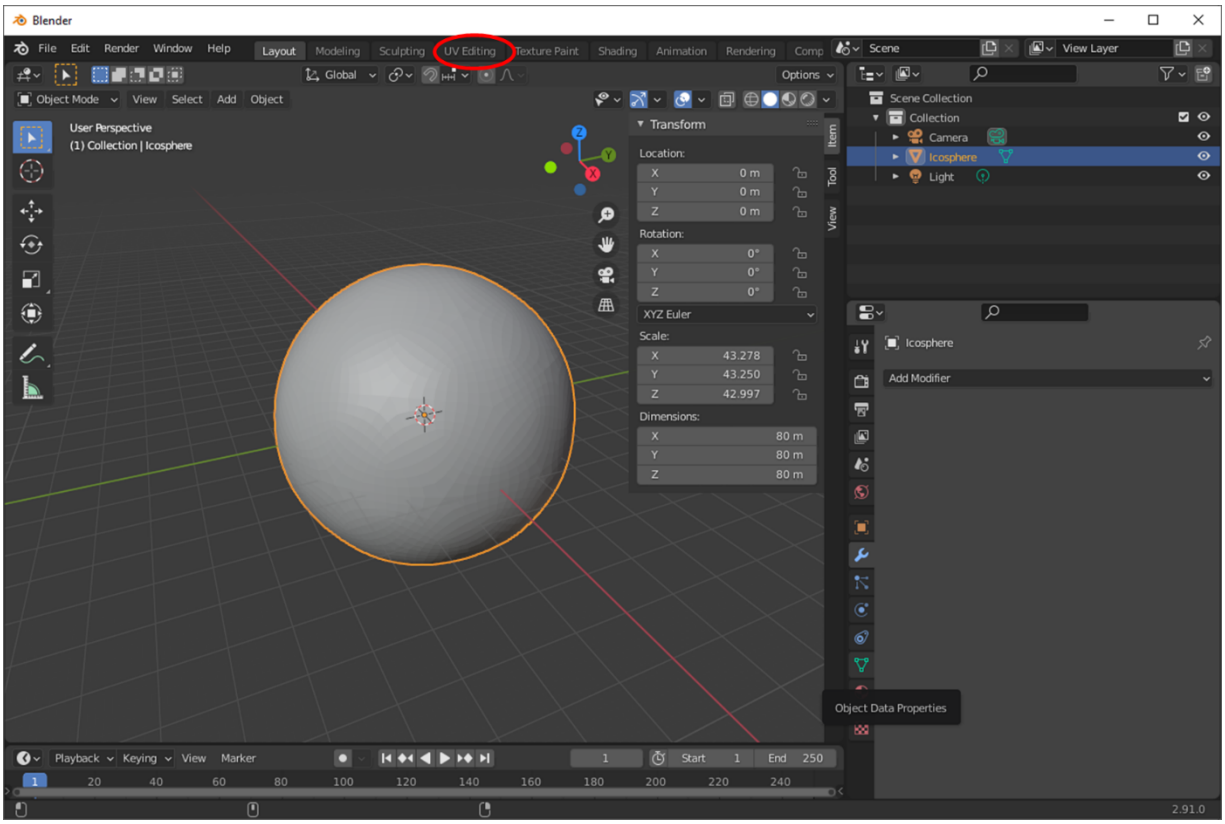


Finally, make this scaling permanent by hitting Ctrl+A (Cmd+A on Mac) and selecting “All Transforms” on the menu that appears.

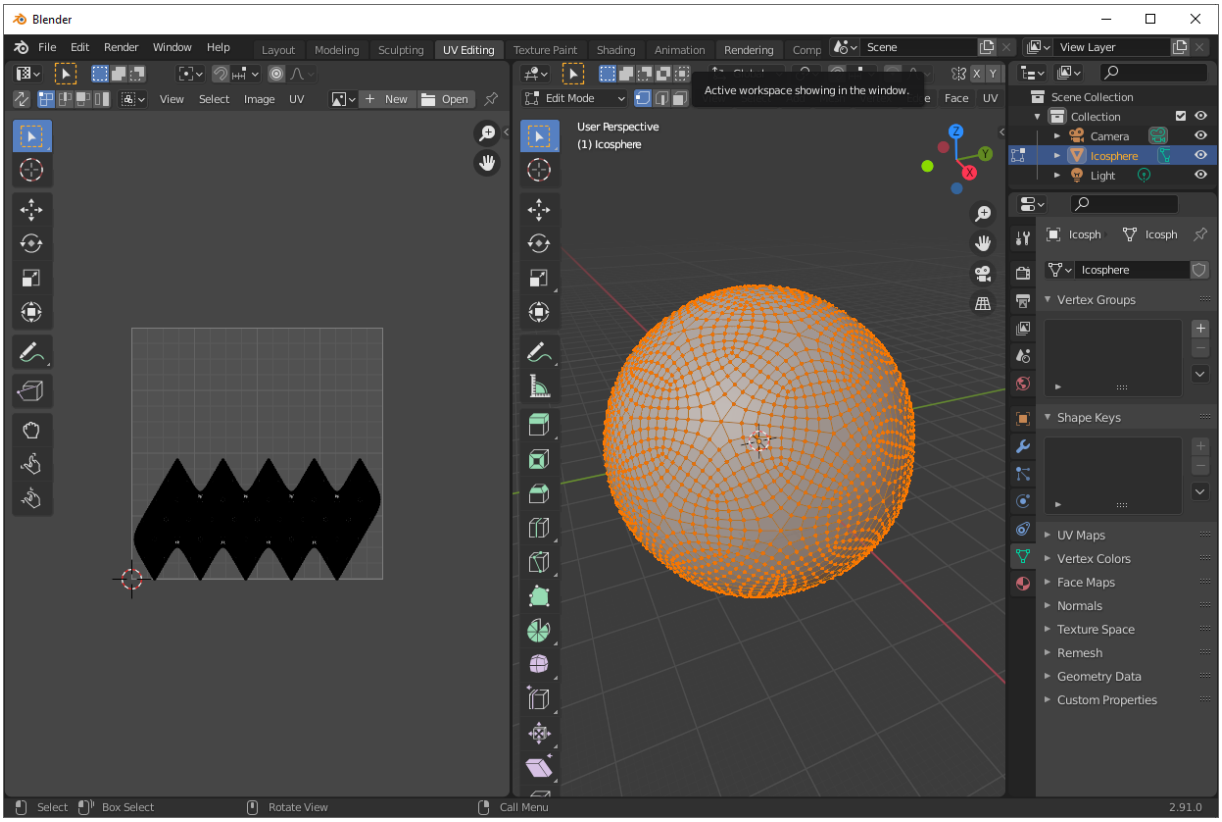


3.2 Create the UV map

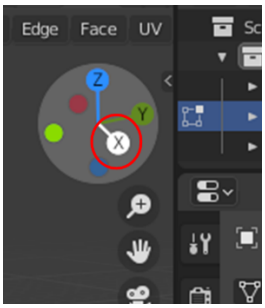
Change from the “Layout” view to the “UV editing” view using the tabs at the top:



A new screen layout appears. Use the mouse scroll wheel to zoom out on the right pane until the whole sphere can be seen.

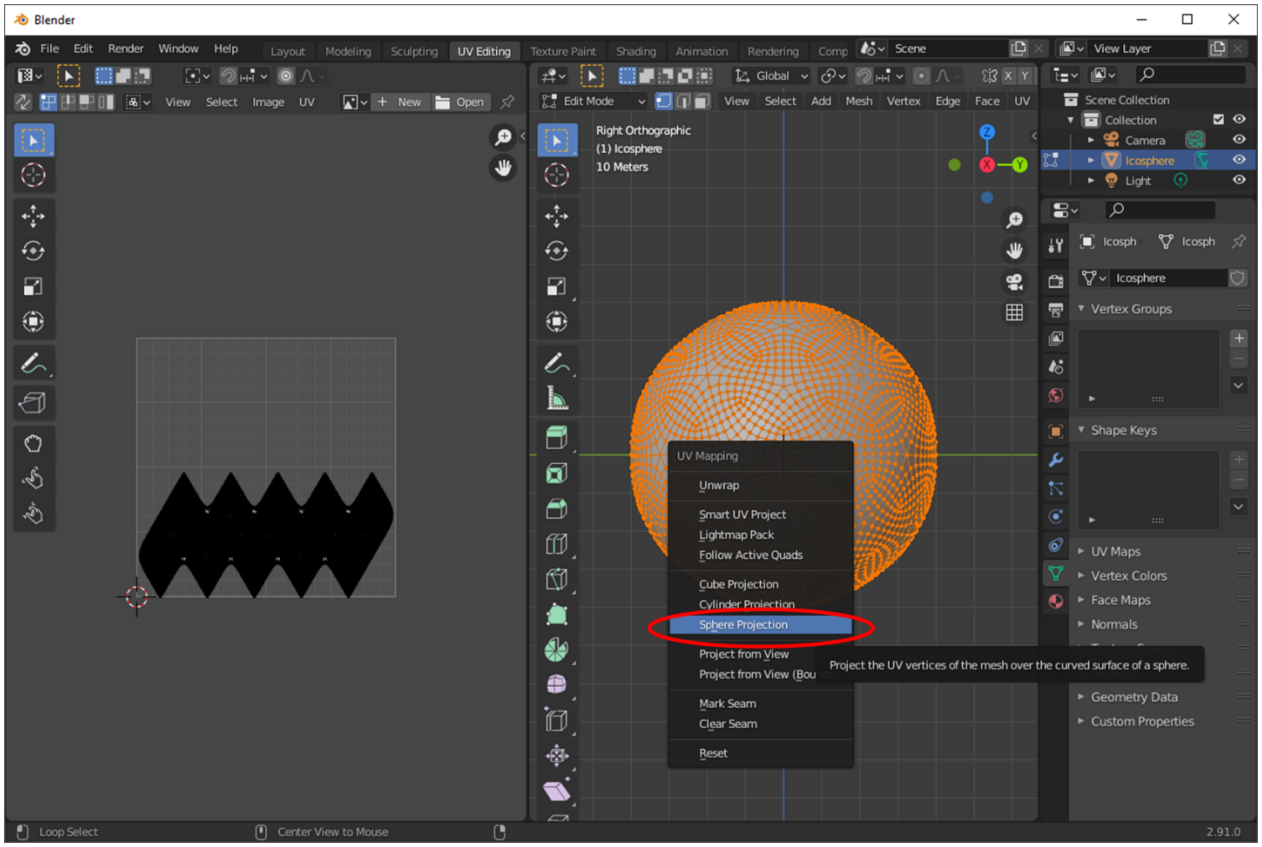


Orient the view in the right pane to look precisely down the X-axis by clicking on the red X on the axes in the top right of the pane, or by pressing “3” on the numpad of your keyboard. (This step is necessary to ensure that the equator comes out on the horizontal plane).

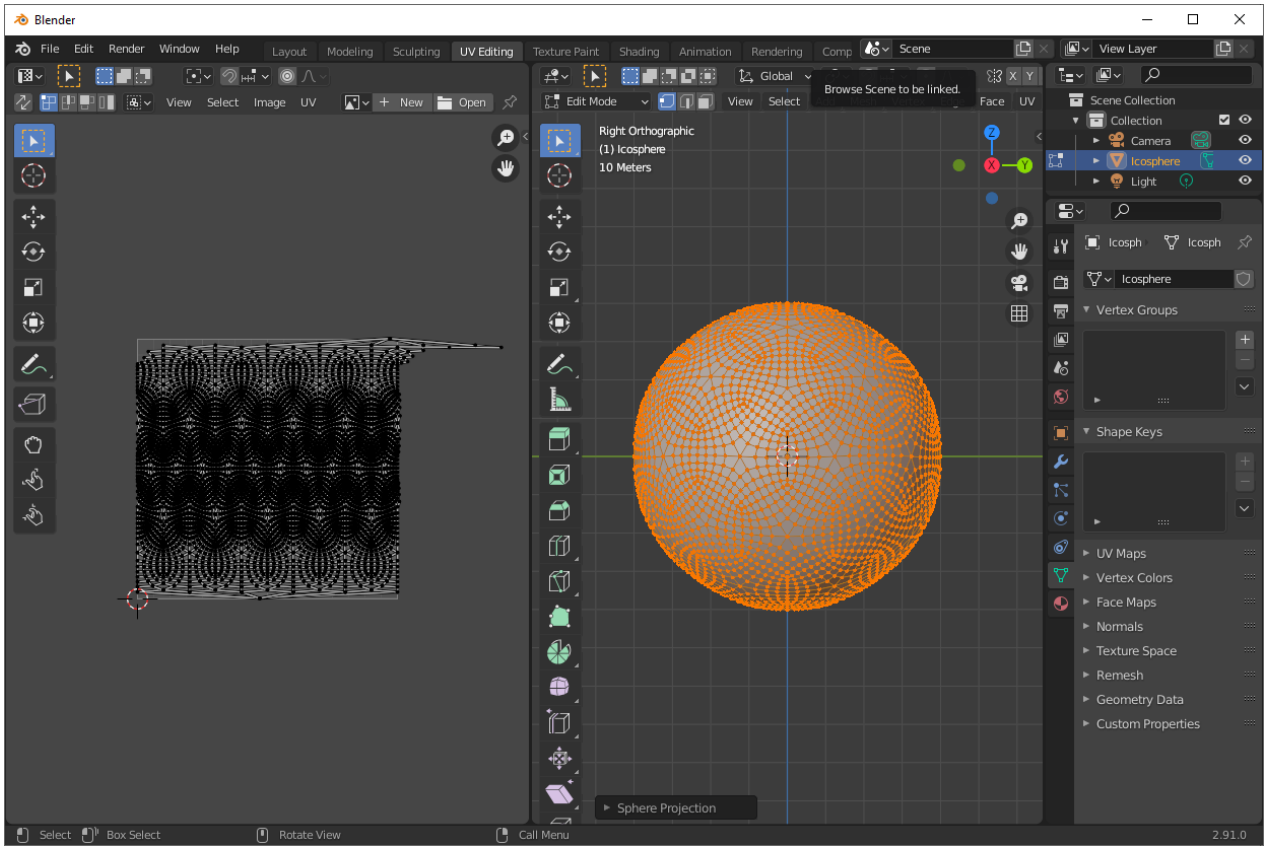


Ensuring the right pane is active, select all the vertices of the Globe by hitting “a” on the keyboard, or by choosing Select→All from the menus at the top of the right pane. Every vertex on the sphere in the right pane should be coloured orange. (By default all vertices are already selected so you may not see a change; this step ensures points that cannot be seen are also selected).

Hit “u” on the keyboard to bring up the UV mapping menu. Select “Sphere Projection”



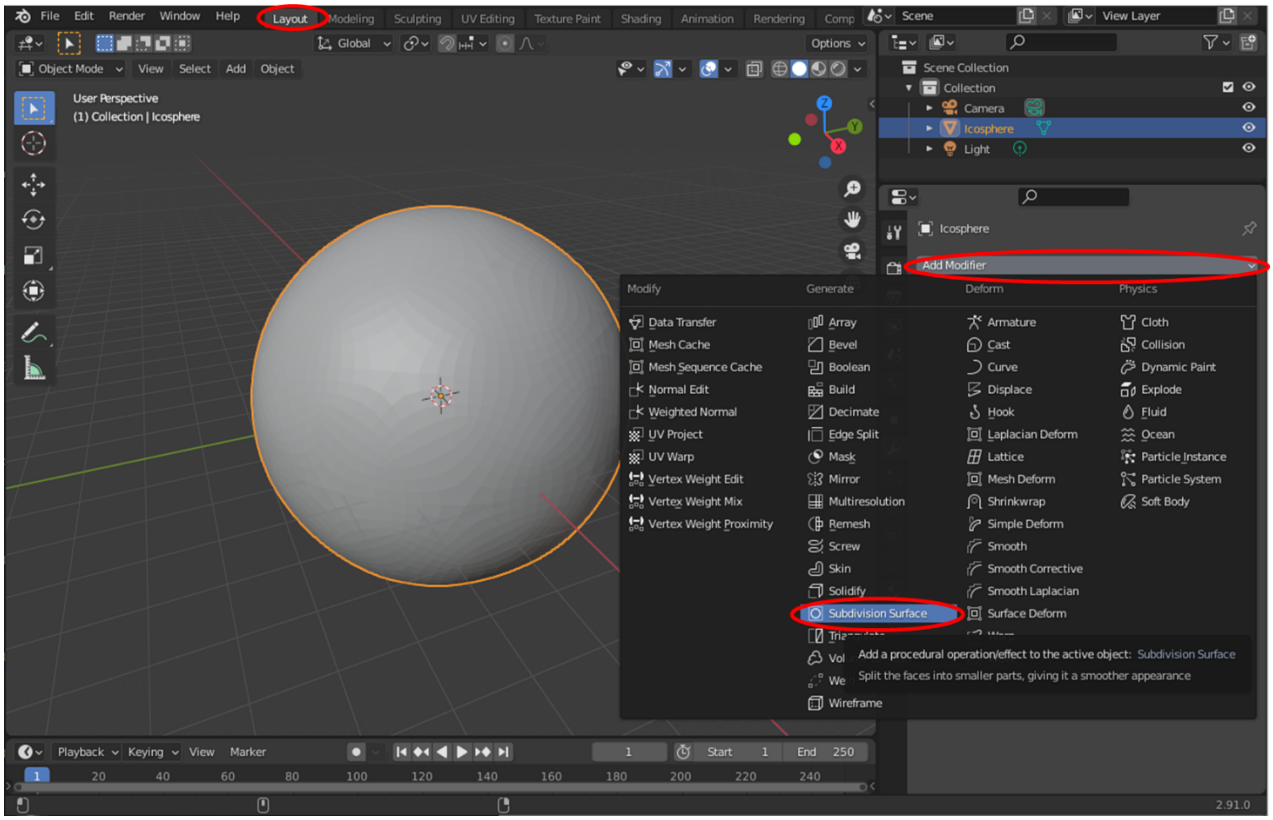
The left hand pane should immediately change to look something like the image below. Our UV map is now correct for use with Cartesian projected height maps.



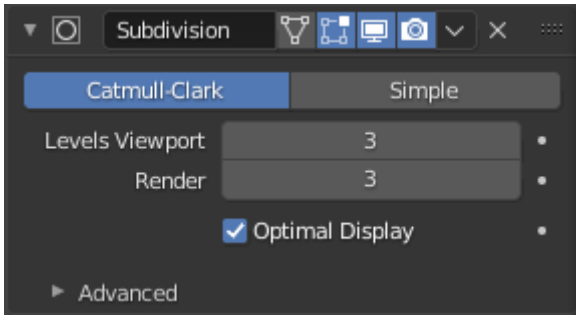
Note – this is perfect time to save a template project if you’re going to make a lot of these globes!

3.3 APPLY THE HEIGHT MAP

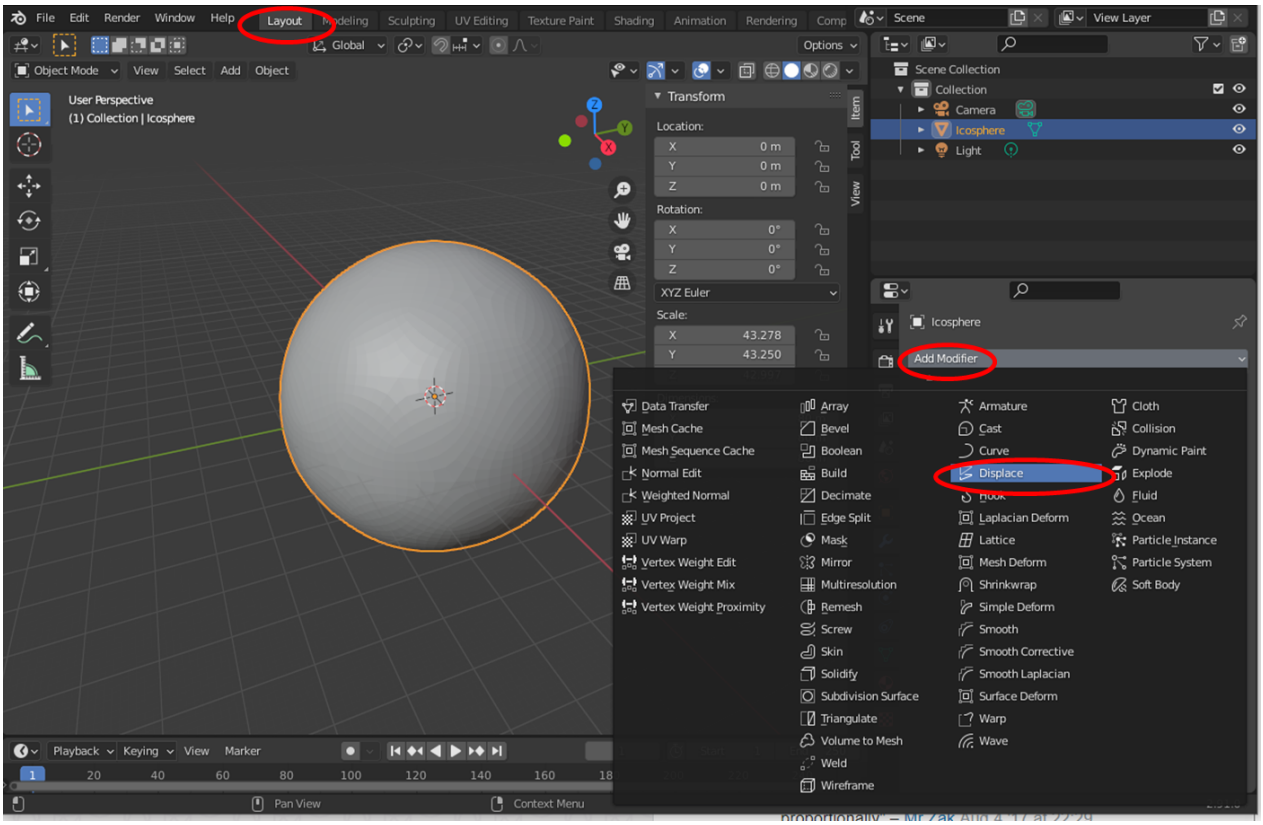
Return to the “Layout” view using the tabs at the very top. We will first add another “subdivide” modifier to get to the final resolution of our output globe. Unlike in step 2.1, we will not “apply” this step, which means it will be recalculated on the fly. This has two benefits – firstly the project file size stays small, and secondly it allows us to tweak the result later to our liking.

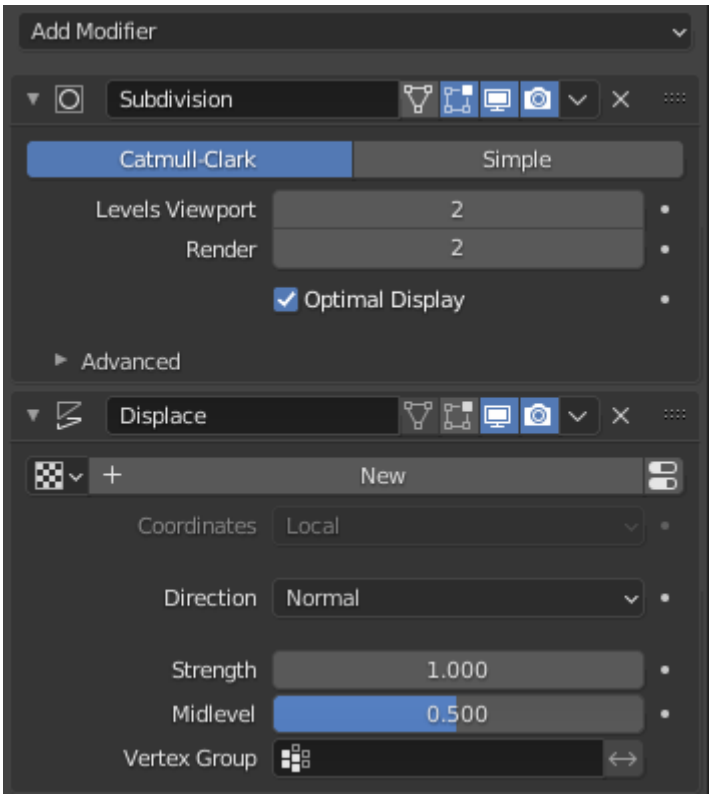


This time, set the values to 3. For higher resolution outputs, simply increment these numbers in steps of 1, but be warned – file sizes increase very quickly, and globes of too high resolution may be impractical to work with in 3D printing software.



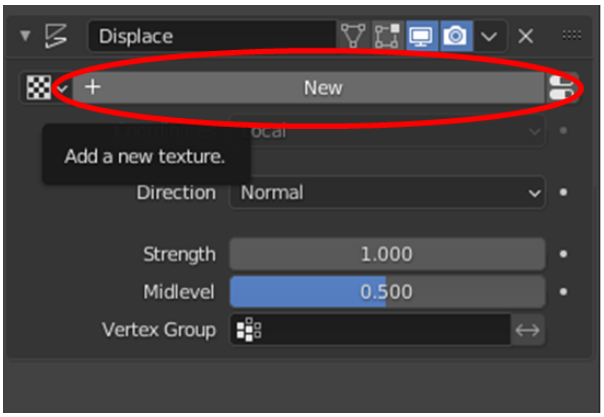
Now we add a second modifier. Click “Add Modifier” and then “Displace”. This is the tool that applies the height map to the sphere. You’ll see it appear below your subdivision modifier, which means that it happens afterwards in the processing chain.

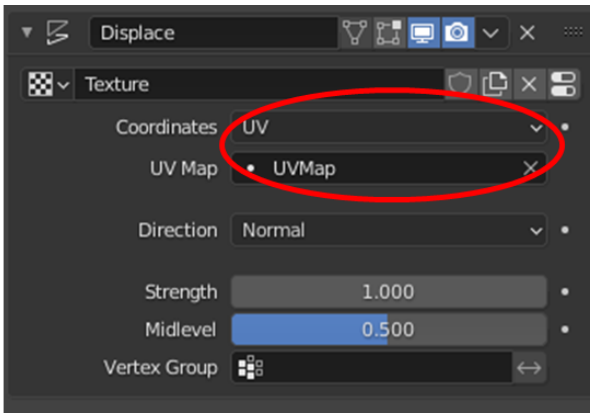




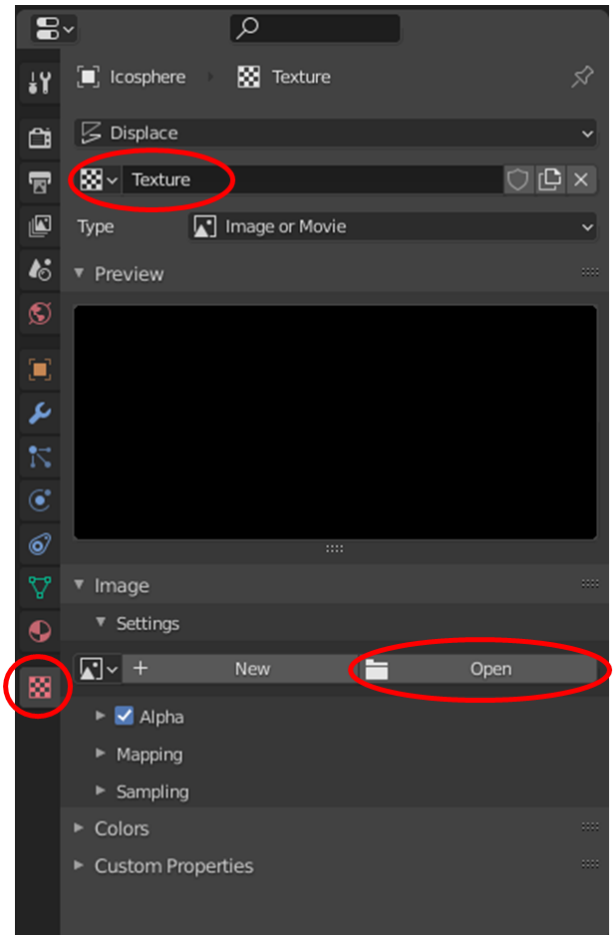
Now we need to create a “texture” – this will be our height map. Click “New”. Select the option “UV” for coordinates and then “UVMap” for the UV Map option that appears. This step tells Blender to use the UV map we defined earlier to wrap our height map around the sphere. Note that if you already have a Texture defined in the project you may see something similar to “Texture.001”. For the remainder of the tutorial, you will need to ensure that this is used where we refer to “Texture”.

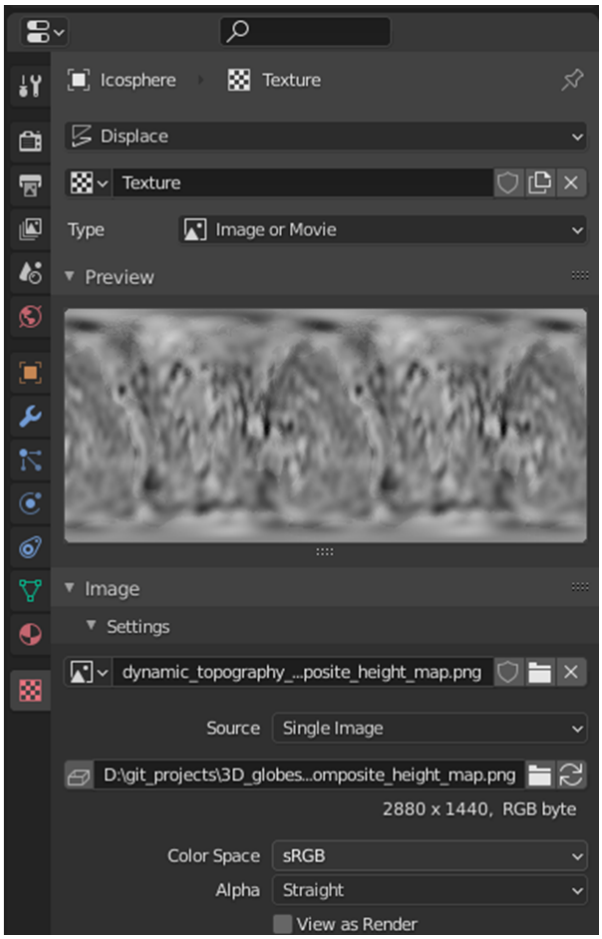
Don’t worry about the rest of the settings yet – we’ll come back to those.



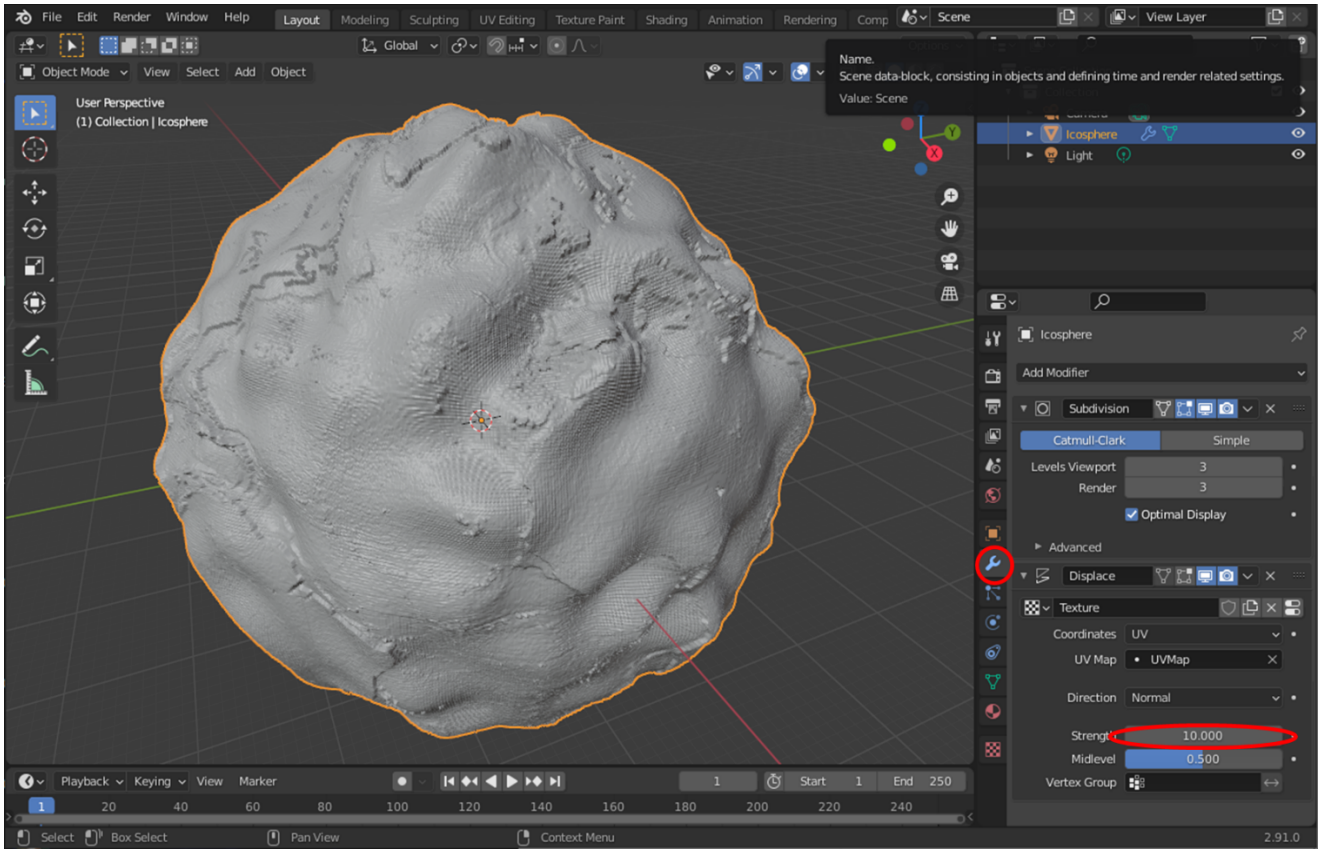


Next, we need to load the height map image. Click onto the textures pane (). In the new menu that appears, ensure that “Texture” is selected in the dropdown menu, which should be the default in this project as it will be the only one. Under “Image”, select “Open”. In the file selector that appears, navigate to your height map image and select “Open Image”. The preview pane should now match your height map image. You might also notice a ghostly impression of your height map appearing in the 3D window.



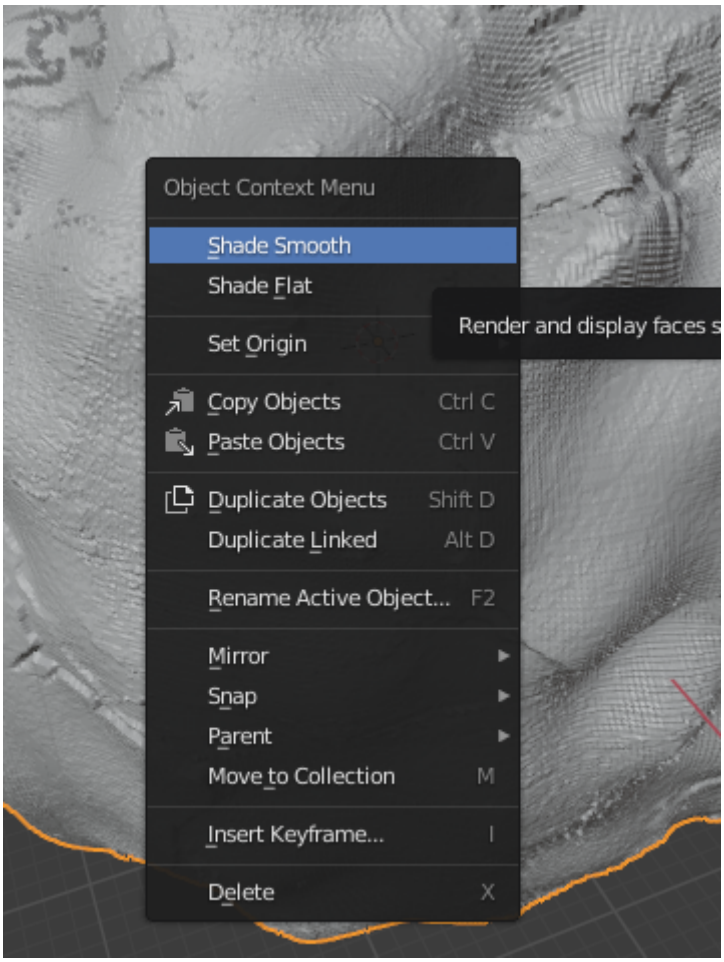


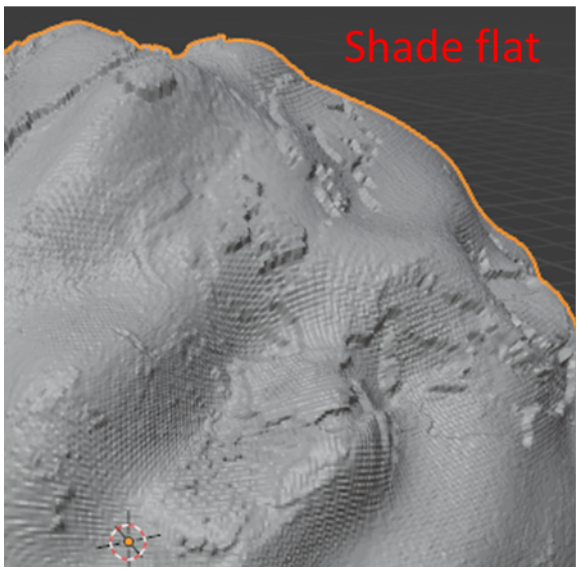
Return to the modifiers menu by clicking the spanner icon. Set “Strength” to 10, and, voila! A 3D globe!

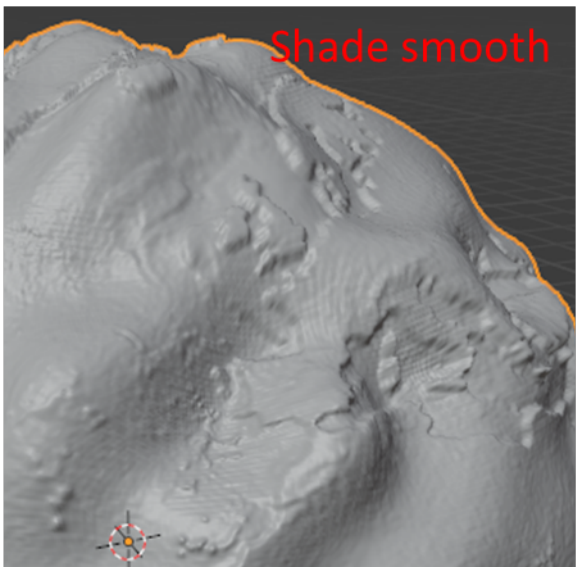


Note that a strength of “10” means that we are raising the highest point by 10 units (for us, millimetres), **and** depressing the lowest point by 10. Thus, this is really a “half strength”. Midlevel is set to 0.5, which means 50% of the way along the brightness values in our height map, so that mid grey means “do not alter”. 10 is a good starting value.

You may notice that the image looks a bit aliased, or “artefacty” – this is because Blender is rendering everything as tiny individual triangles. To get a better idea of how a 3D printed globe will look (which is also more aesthetically pleasing) right click on the globe and hit “shade smooth”. Note that this doesn’t affect the output model.

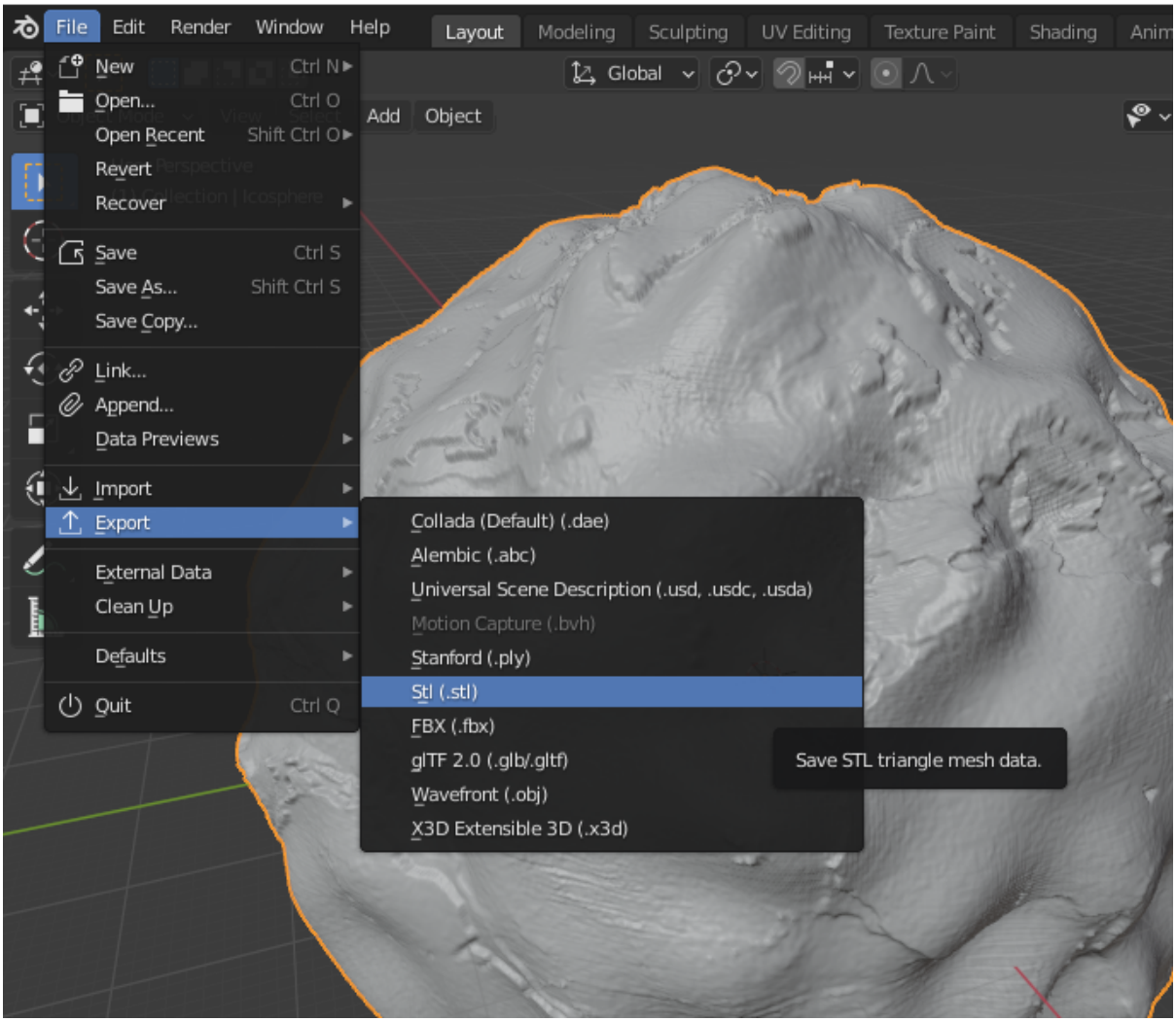






…and that's it! The basic globe is done.

Now we just need to save the model. Making sure the globe is selected (has an orange outline, simply click it if not), hit File → Export → Stl (or Wavefront obj – a technically superior but less common format).



Navigate to your output folder in the window which appears, give your output globe a filename and hit “Export STL”, and you’re done!

4 OPTIMISING THE MODEL FOR 3D PRINTING

The file you just created is already compatible with 3D printing software, but it is not yet ideal for 3D printing. Printing in one piece is particularly challenging, requiring lots of support material and inevitably leading to poor surface quality on areas that faced downwards during printing. It would also waste a lot of plastic, since the model is still solid (as opposed to hollow).

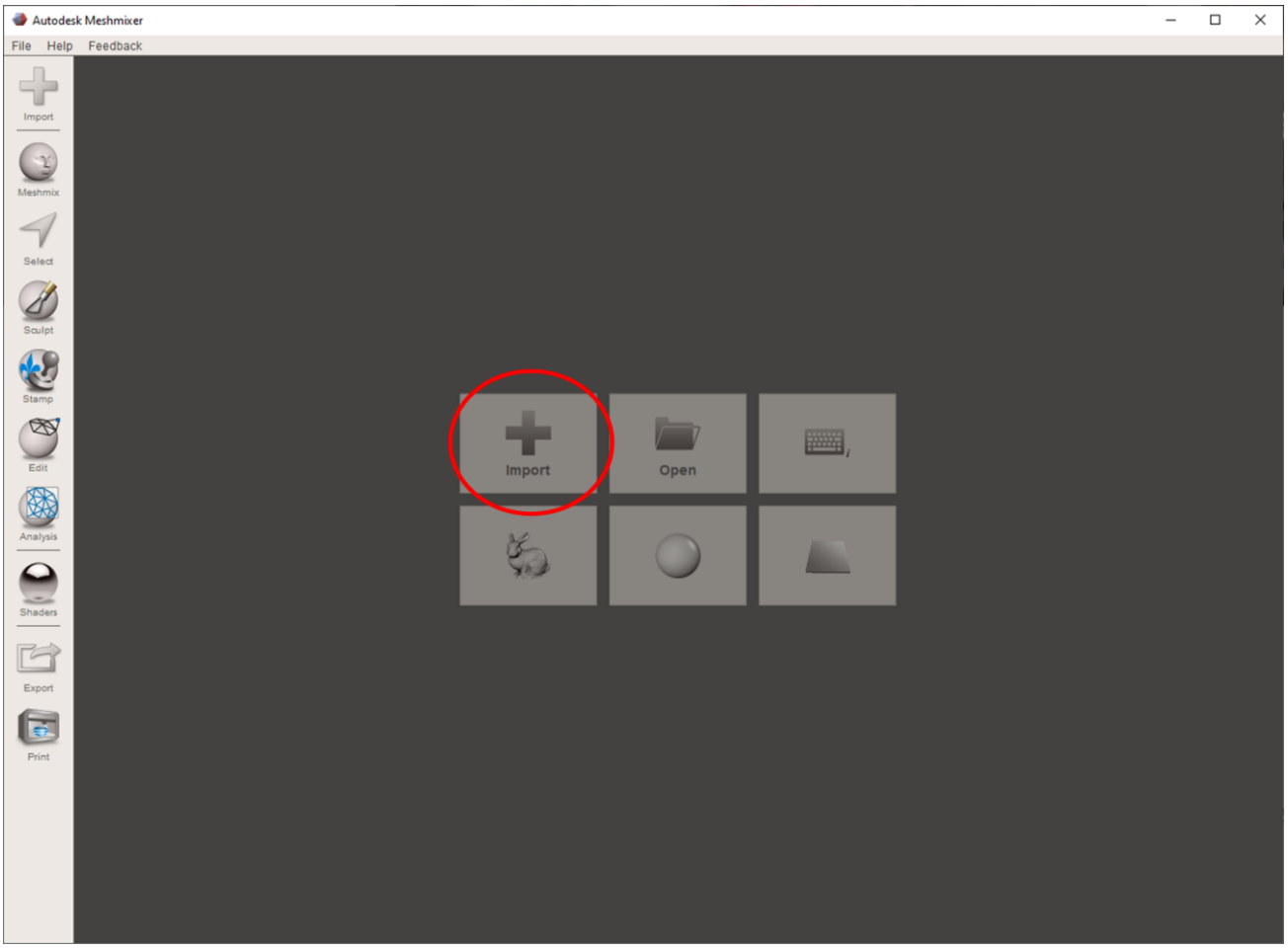
In this section we will use Autodesk Meshmixer (https://www.meshmixer.com/) to hollow the globe and to slice it into 2 separate hemispheres that can be printed separately and later glued together. We use Meshmixer because it is designed for use with 3D printing and has useful tools for assessing printability. Meshmixer is not open source but is free to use. It runs on Windows and Mac OSX, but sadly has no version available for Linux. Linux users should follow a similar workflow in Blender.

There are 3 steps to follow:

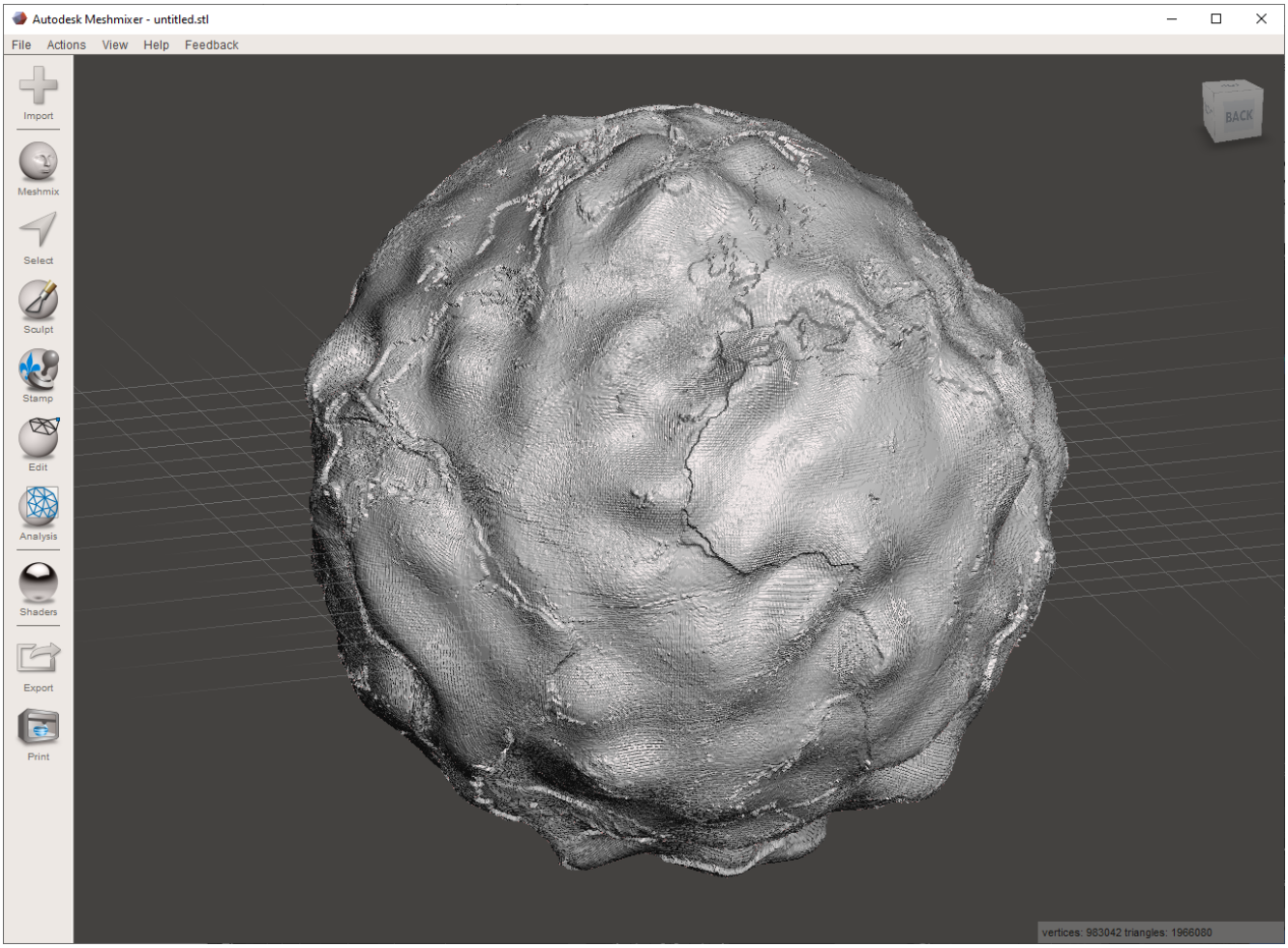
1) Make the model hollow
2) Slice into hemispheres
3) Rotate the southern hemisphere into a printable orientation

4.1 LOAD AND HOLLOW THE MODEL

Open Meshmixer. On the screen that appears, click “Import”. Use the file picker that appears to navigate to your globe file exported from Blender and hit “Open”.

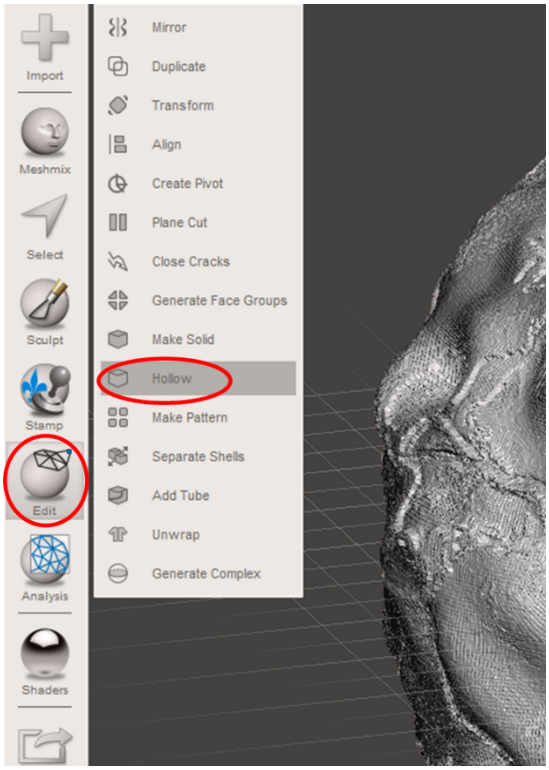


After a bit of processing (which can be slow, particularly if you chose to create a high resolution globe) a 3D representation of our model appears.

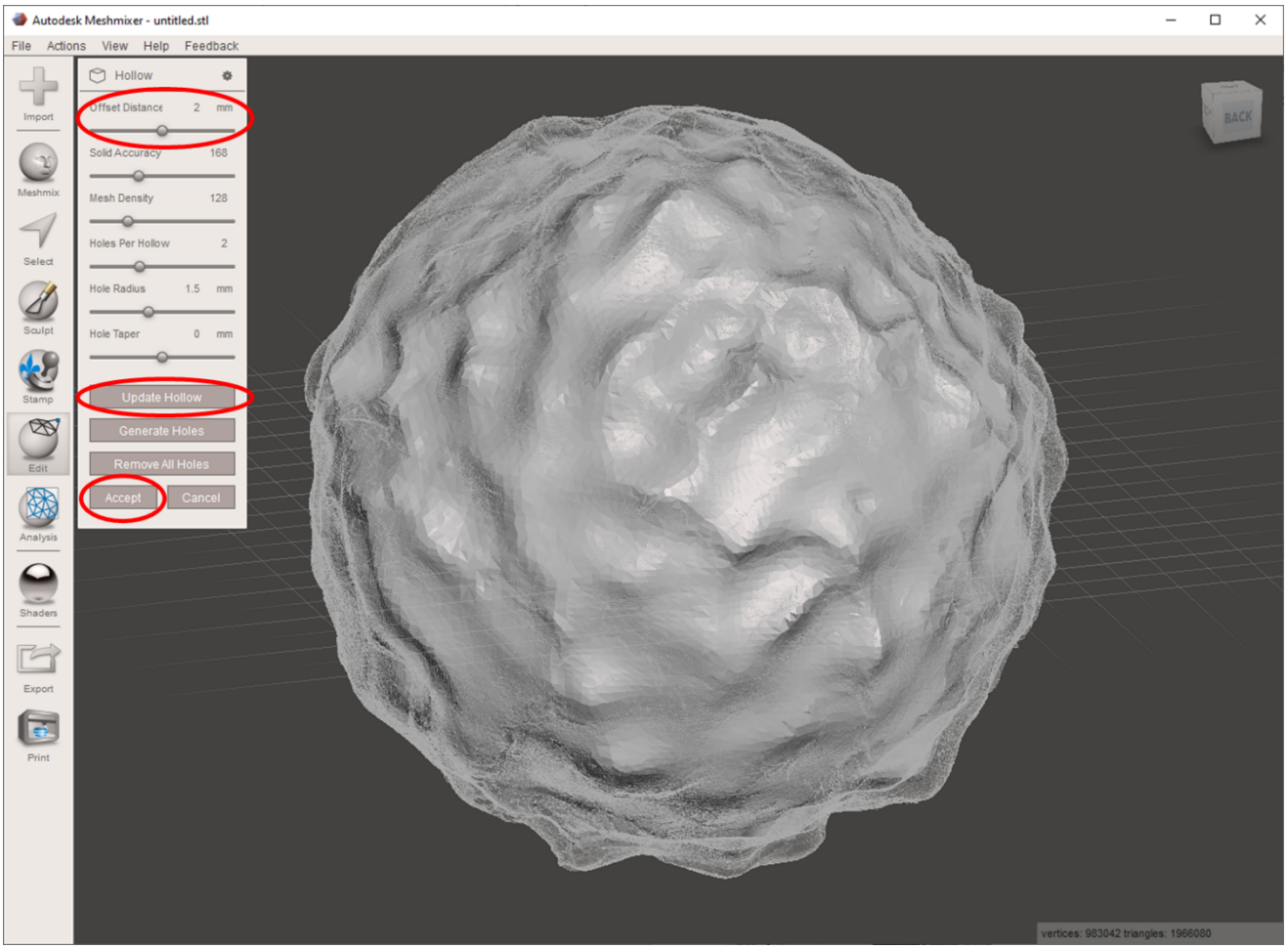


Note that the model is perfectly bisected along the equator by the reference plane – this works because the original icosphere we created right at the start of the Blender section defaults to having its centre at the origin.

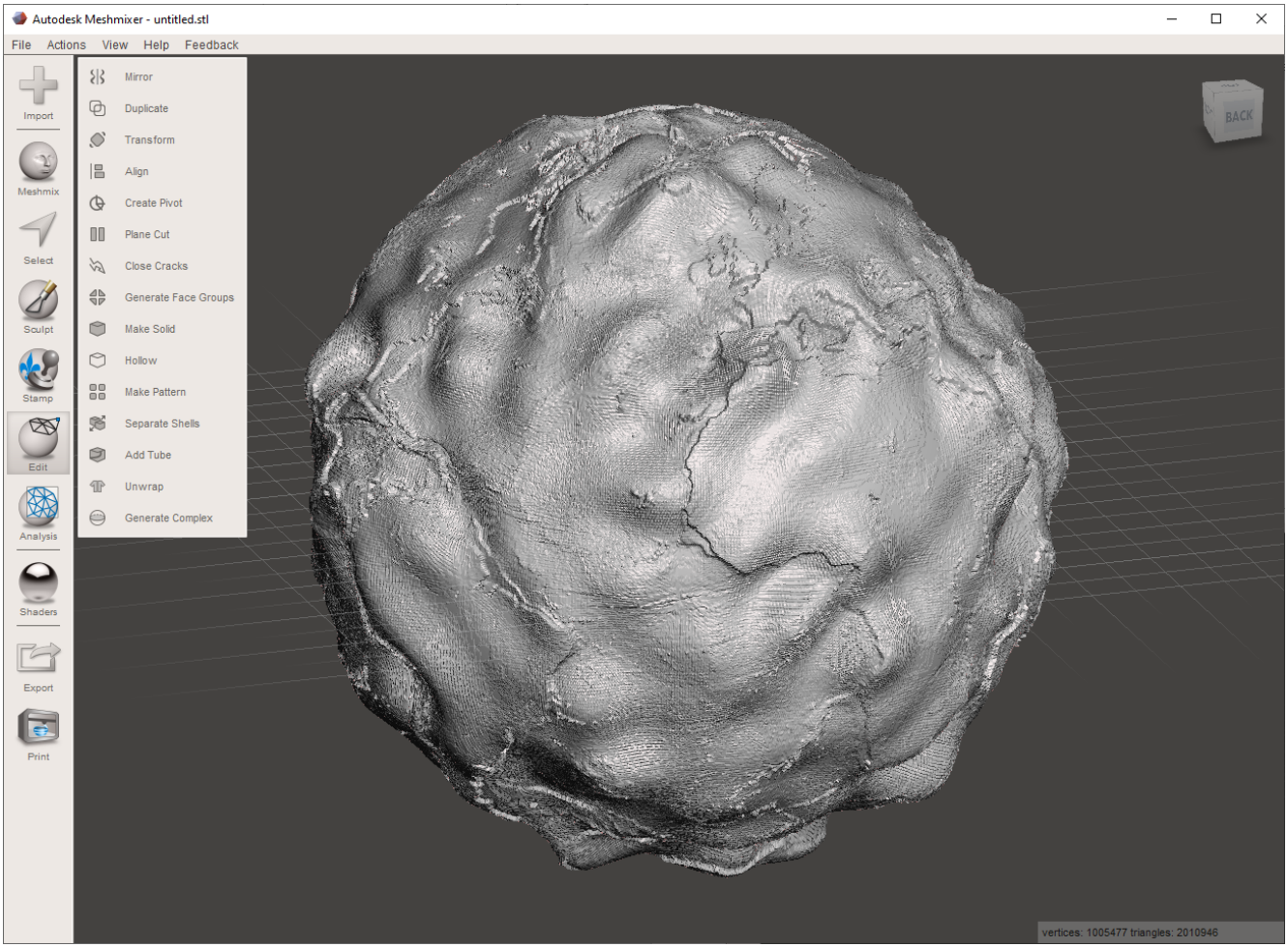
Now we want to make the globe hollow. From the toolbar on the left, click “Edit” → “Hollow”.



After more pre-processing (slow, potentially), a new menu and a preview of the shape that will be the interior of our globe appears.



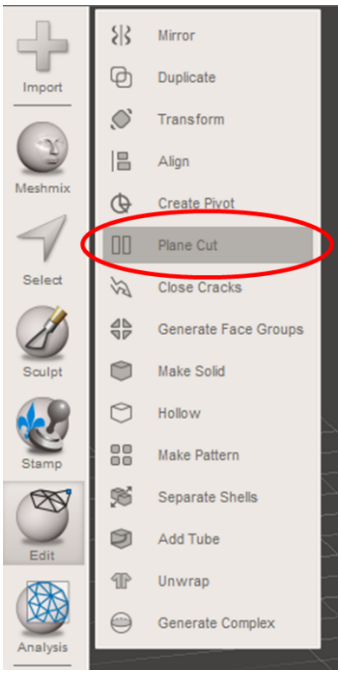
Set the offset distance to the thickness you want your final globe to have. For our 80 mm diameter globe, I recommend 6 to 8 mm as a good starting thickness – it won't waste too much material, but has plenty of thickness to get good bed adhesion in the 3D printing step. Optionally, "Solid Accuracy" and "Mesh density" can be altered to change the details of the result, but generally the default options are fine. Hit "Update hollow", wait for the processing step to complete and then hit "Accept" to finalise the result.



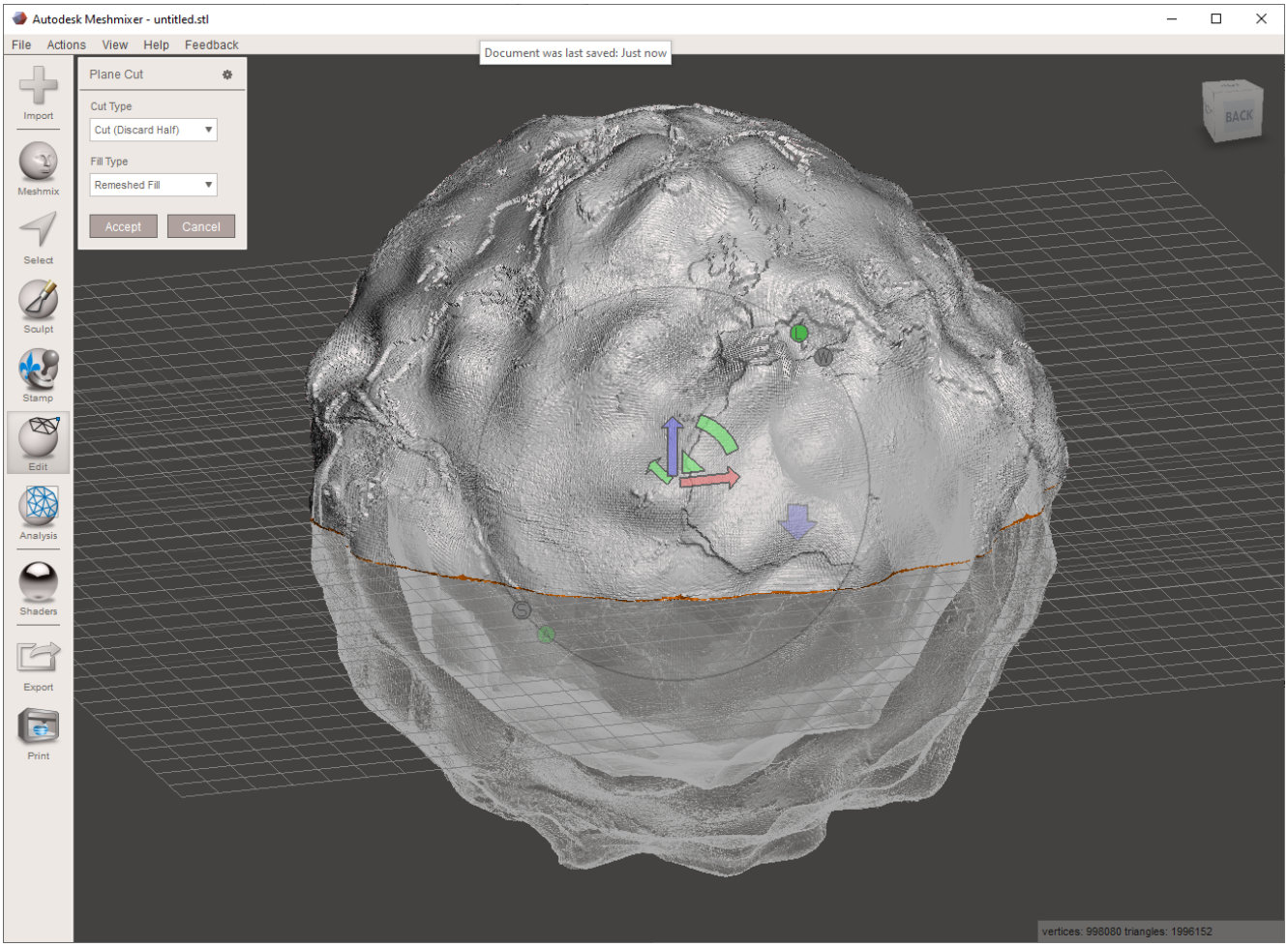
Superficially, nothing has changed – however, our model is now hollow. We just can't see through it!

4.2 SLICE THE MODEL INTO HEMISPHERES

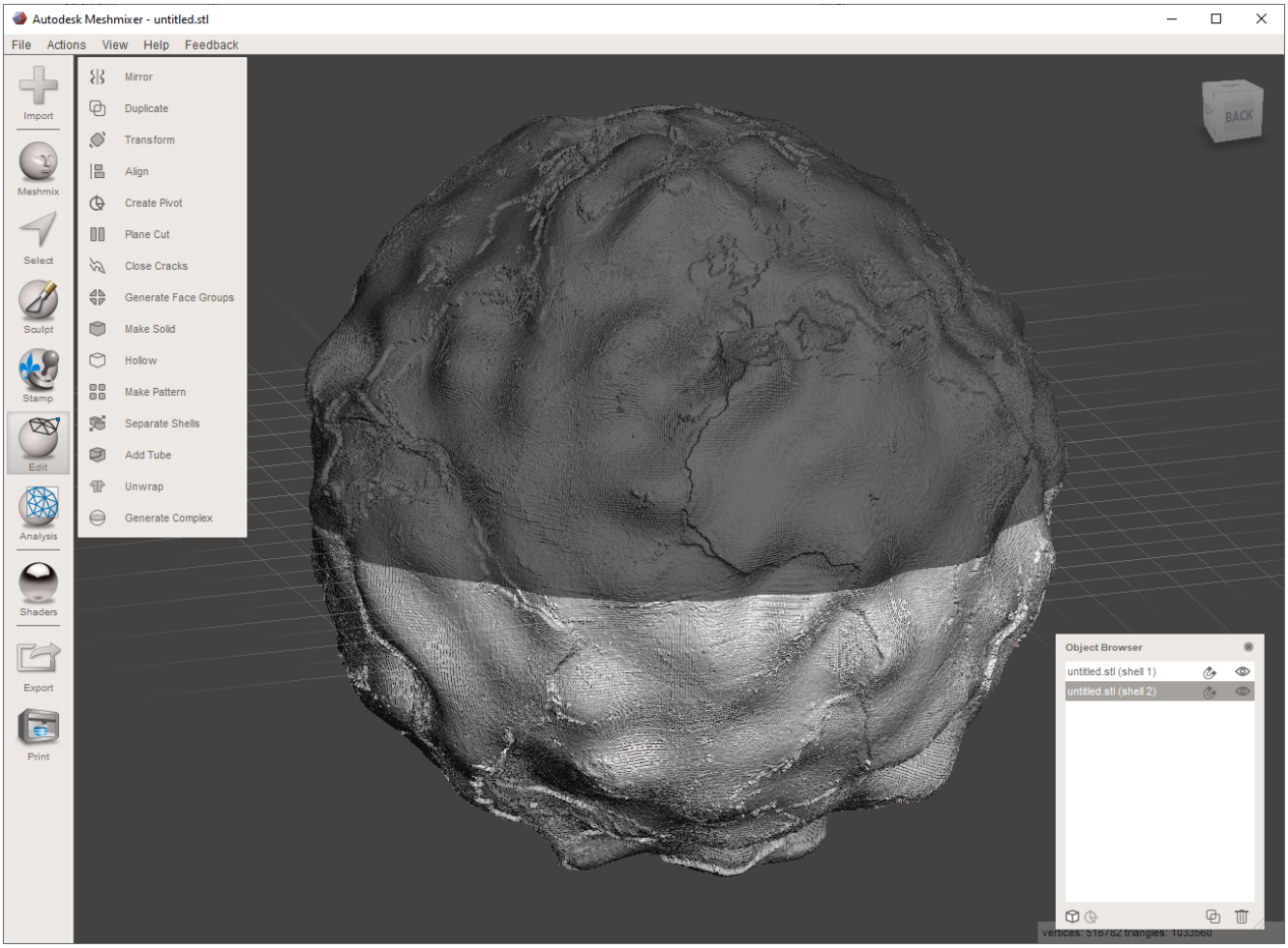
Next, again from the edit tools, click “Plane cut”



Immediately, half of the globe will become transparent, and a menu will appear. You should be able to see a ghostly impression of the hollow interior.

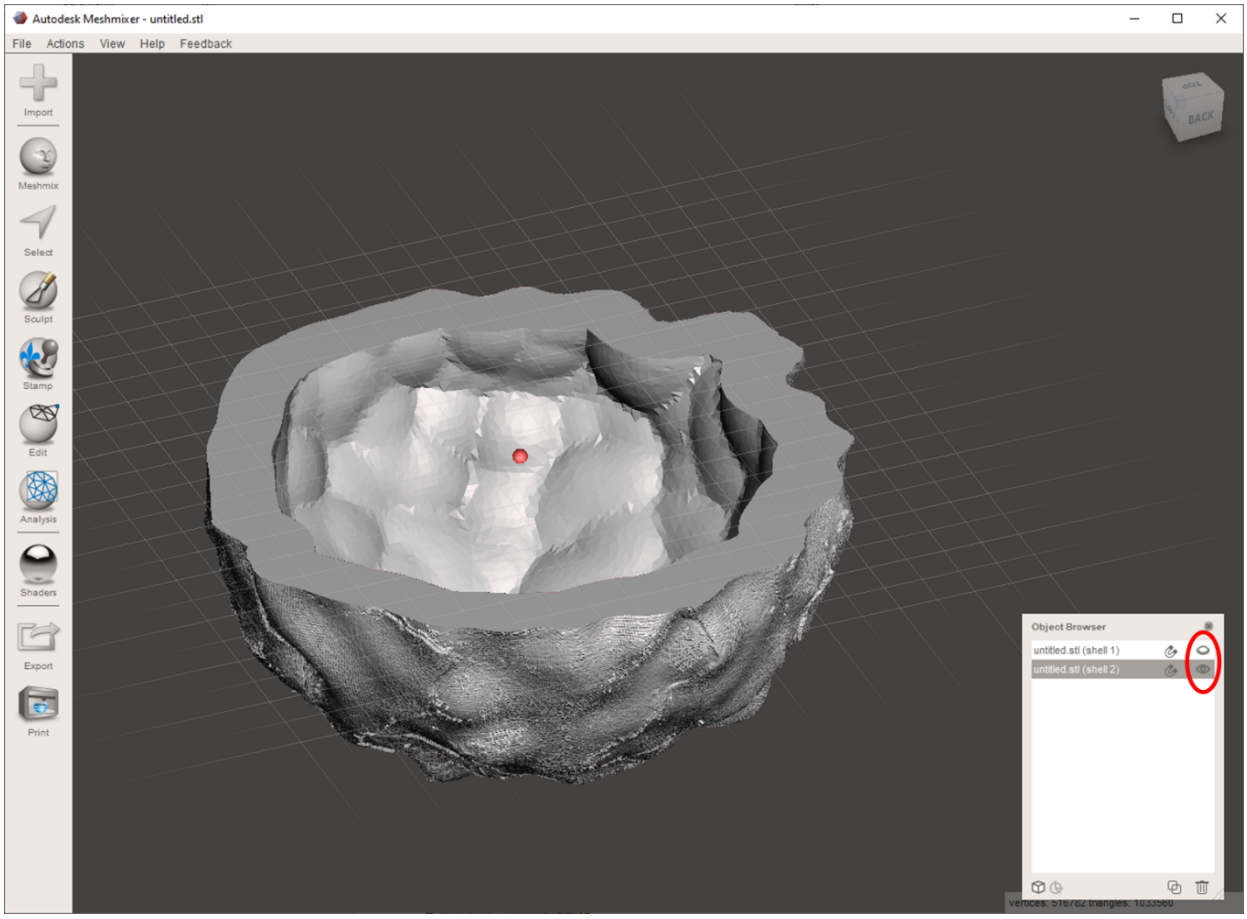


Change cut type to “Slice (Keep Both)” and hit “Accept”. Once again, the globe should appear unaltered; however, it is now in two pieces. To separate these, hit “Separate Shells” on the edit menu.



Half the globe should become dark, and an object browser should appear. (Note that there is a bug that sometimes means that this does not appear. If this happens, try using the “view” menu toggle to ensure that it is displayed and maximise the window).

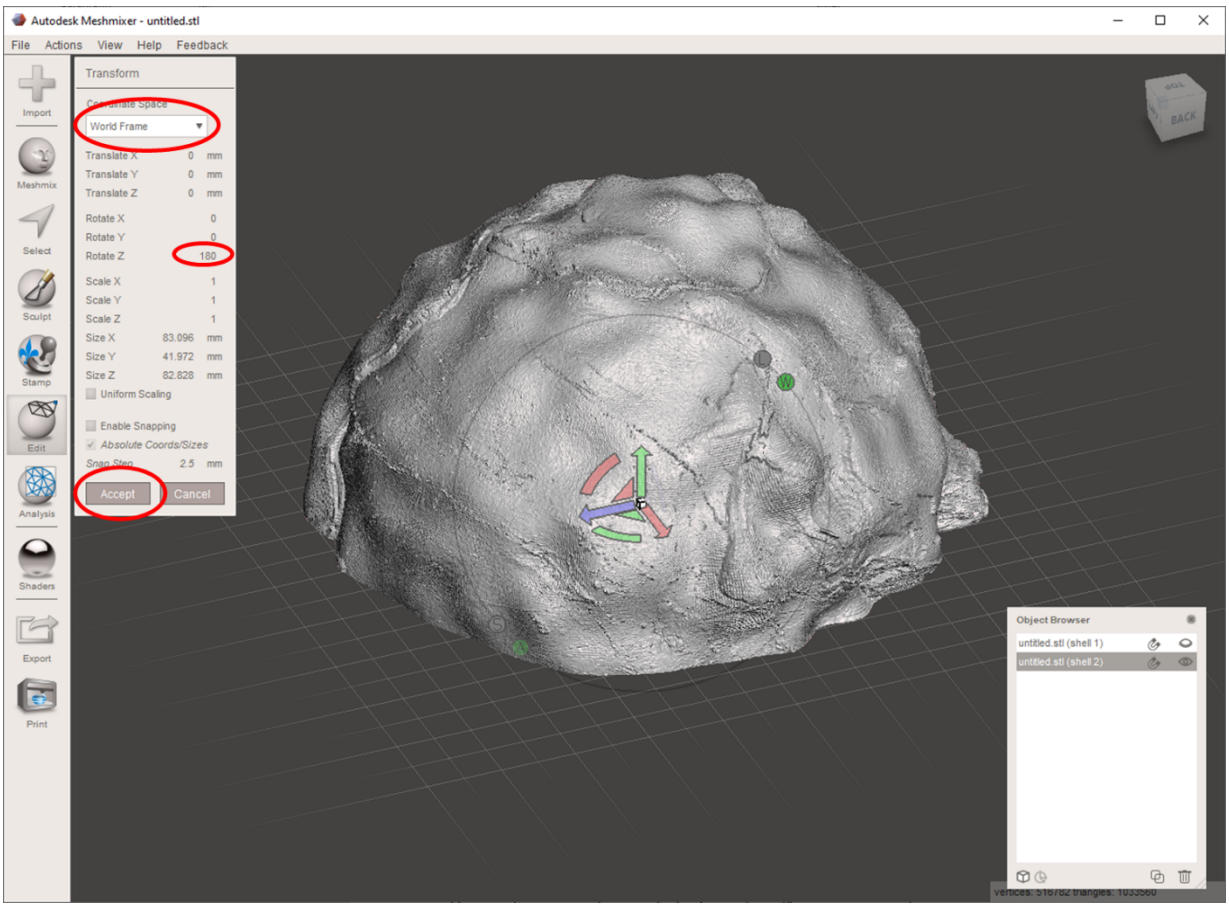
The eye icons can be used to toggle the visibility of the hemispheres. Toggle the upper hemisphere off to check that the interior of the globe looks as expected.



4.3 ROTATE AND EXPORT THE FINAL 3D MODELS

The upper hemisphere is already oriented properly for 3D printing, but the lower hemisphere is not. While it is easy to rotate a model in most 3D printing slicers, it's easier to get that step out of the way here.

With the lower hemisphere selected in the object browser, hit "Edit" (if the menu isn't already visible) and "Transform". Select "World frame" for the coordinate space and set "Rotate Z" to 180. The model should flip on the screen.



That's it! We're done! All that is left is to export the models. Select each of the hemispheres in turn using the object browser and hit "Export" near the bottom of the sidebar. Choose an output location, give the model a sensible name, and hit "Save".

5 3D PRINTING SETTINGS

The 3D printing process is different for every printer, and there are many different slicers and settings to choose from. If you are a beginner at 3D printing, Slicers such as PrusaSlicer (https://www.prusa3d.com/prusaslicer/) and Cura (https://ultimaker.com/software/ultimaker-cura) have excellent default settings for many printers, and there are a large numbers of tutorials online.

For printing globes successfully, we recommend the following settings:

- Use PLA filament. It's sustainable, cheap, easy to print, looks great and it's even biodegradable (in certain circumstances).
- Don't use support material. The interior of the globe might look slightly rough near the top, but that doesn't matter as it will be on the inside, and it will save you a lot of time / material.
- Print the external perimeter slowly (as low as 20-25 mm/s). This will maximise detail and minimise ghosting artefacts from vibrations.
- Calibrate the first layer CAREFULLY. I can't emphasise this enough – it will give you good adhesion and ensure that you don't get a ridge at the equator from being too close to the bed.

Finally, glue the two halves together using standard superglue. Try not to get glue on the outside, as it sometimes discolours PLA.