Earth Surface Processes and Landscape Evolution
Exploring the OCTOPUS cosmogenic database

The objectives of this practical are:

- To learn how to get hold of erosion rate data from the OCTOPUS cosmogenic database.
- To load these data into a GIS and compare to the topography.
- To compare erosion rates to mean basin slope and channel steepness for some basins in the Great Smoky Mountains, USA.

Background: cosmogenic radionuclides and erosion rates

Cosmogenic radionuclide dating is a common tool that is used to date the age of surfaces exposed on the Earth's surface. It takes advantage of cosmic rays which interact with atoms exposed near to the Earth surface and produce new radionuclides: thus **cosmogenic radionuclide dating**. This is an uncommon process: rates of production of these new nuclides are very low, but predictable and known. The production rates are highest at the Earth's surface and decline exponentially with depth into the Earth, such that we only preserve these cosmogenic radionuclides (CRNs) within the top few metres of the crust.

While this technique is often used to date surfaces and is therefore useful in working out things like the movement of ice sheets, we can also use it to **measure erosion**. You can think of erosion as moving rocks from depth up through the "cosmogenic production zone" which is within the top few metres of the surface. If erosion is happening quickly, rocks move quickly through the production zone and accumulate few CRNs. If we take a sample of that rock, we will have a low concentration of CRNs. However, if erosion is happening slowly, rocks will move slowly through the production zone and our sample will accumulate lots of CRNs – it will have a high measured concentration.

If we did this for an individual surface, we would get an erosion rate at one particular point. What if we want to understand what is happening at a larger scale? To do this, we normally take a *catchment-averaged sample*: we will take a sample of sand at the outlet of a river basin, and analyse the concentration of CRNs to get an estimated erosion rate. We have to assume that the sand that we sample is **representative** of all the erosion processes occurring in the basin!

These samples are pretty expensive to take, but lots of people have taken them for basins around the world. The University of Wollongong has set up the OCTOPUS project which has compiled a lot of these measurements and made them freely available to download. We are going to explore this dataset and download some erosion rate measurements.

Instructions

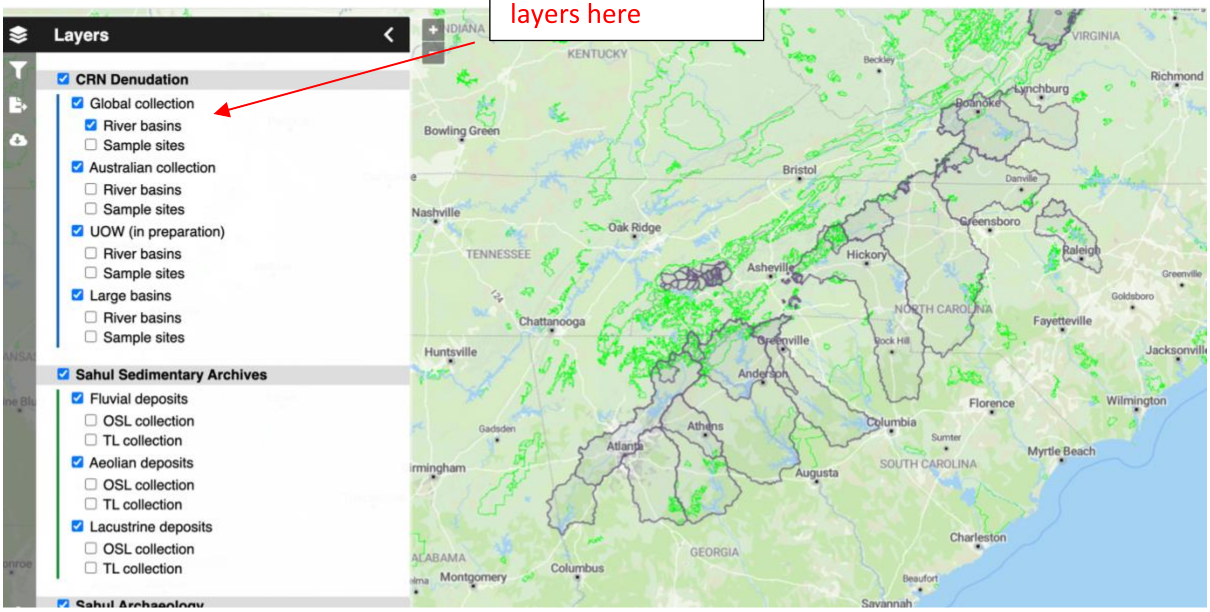
In the practical today we will download CRN data for the Great Smoky Mountains from the OCTOPUS website. You can use these instructions to download data from anywhere (useful for independent projects/dissertations). We will also use OpenTopography to download a DEM: please refer to the instructions from Week 5 for more help, and to your lecture notes as you work through today's practical. Remember that ArcGIS tools all have *Tool Help* and that more detailed *Help Documentation* is also available, so get used to using these to understand how to use tools and carry out analyses.

The OCTOPUS website

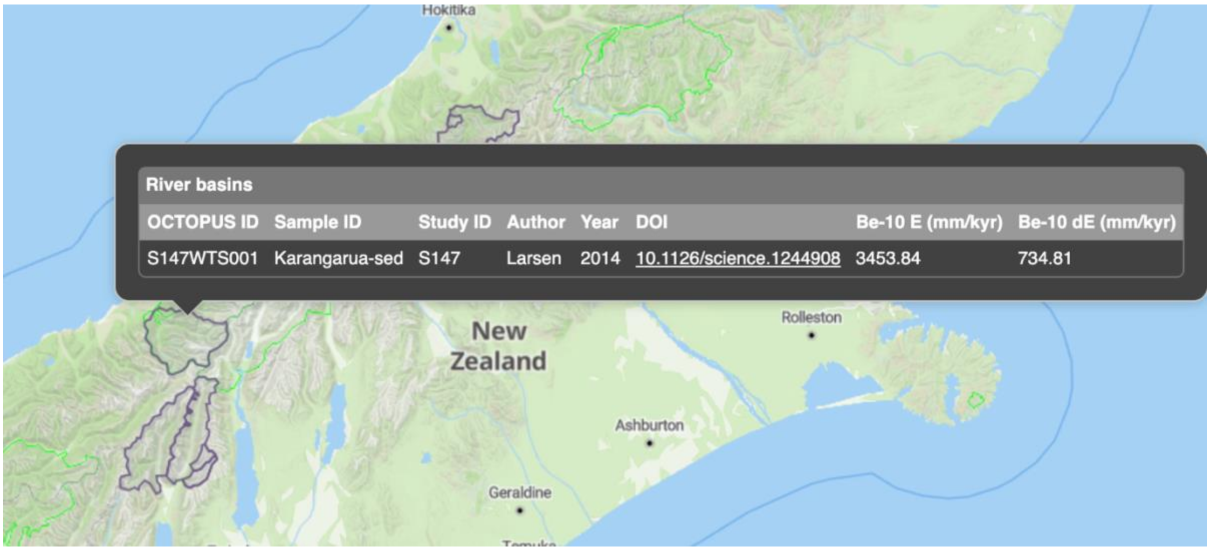
The data we will use are part of a global compilation carried out by the University of Wollongong. You can access the website here: https://octopusdata.org/

1. Explore the OCTOPUS dataset

Use the above link to access the OCTOPUS page. You will see a world map which you can pan and zoom around. The left hand bar gives you different options. We need to click on the top one "Layers" and turn on the river basins option so we can see where the CRN data are available.



Each of the purple outlines shows you the outline of a catchment which has an available erosion rate sample. Spend some time zooming in on different regions and looking at the available data. You can click on a basin to find out information about the sample (here I show an example for a basin in the Southern Alps of New Zealand:



You can see that we have some important information available for each basin:

- OCTOPUS ID, Sample ID, Study ID: various ID markers associated to the sample.
- Author, Year, DOI: details about the paper where the data were taken from. You can use the DOI to find the original reference by pasting it into Google.
- Be-10 E (mm/kyr): the erosion rate of the basin in mm per thousand years. In this case, it is 3453.84 mm/kyr, or 3.4 m/kyr
- Be-10 dE (mm/kyr): the error on the erosion rate measurement (how certain we are about that erosion rate). This tends to be higher for high erosion rates: for this site the error is 734.81 mm/kyr.

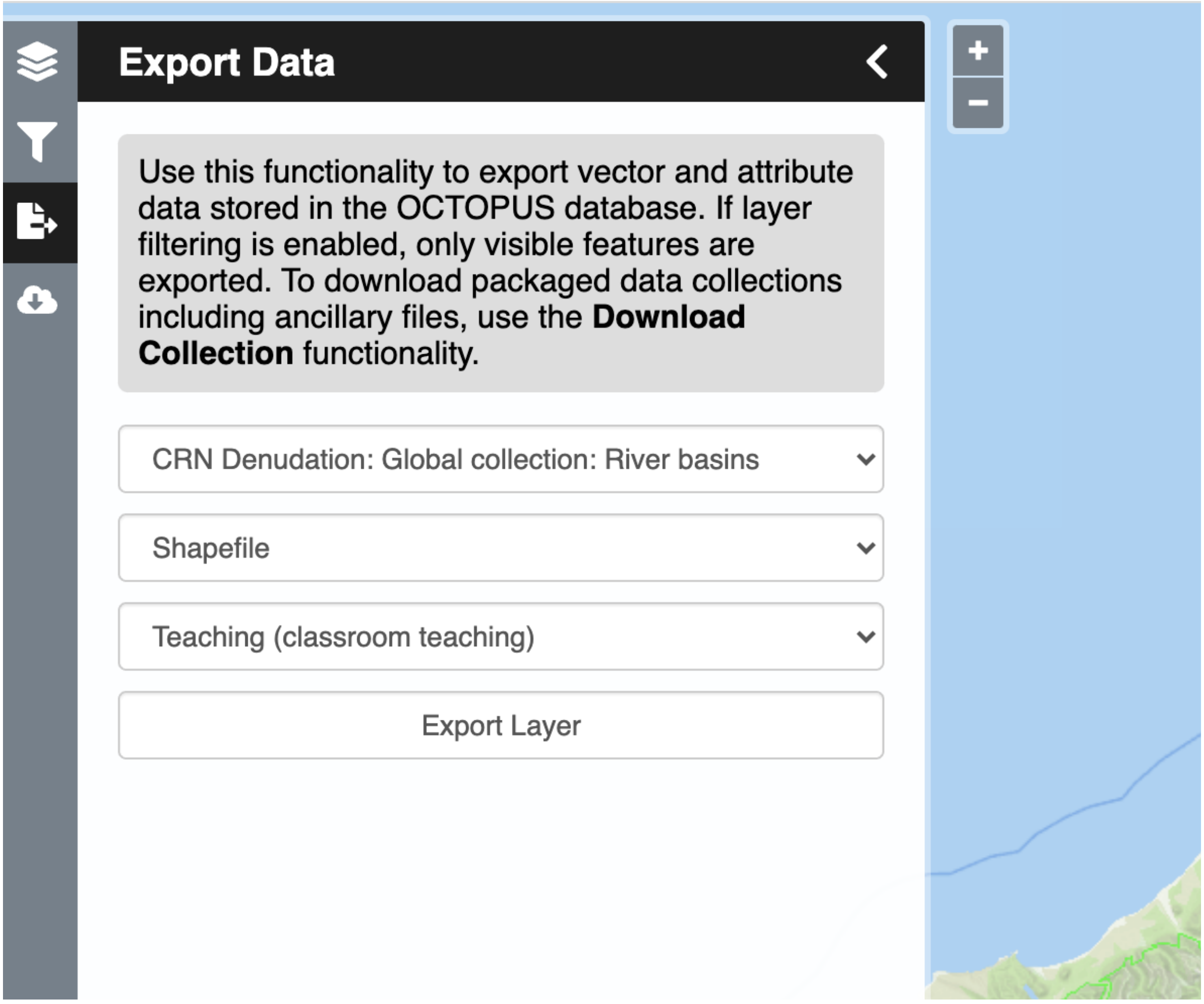
Task: explore some different areas of the world by clicking on different river basins. Write down some of the erosion rates that have been measured. What is the range of erosion rates that you have explored?

Write down the region with the highest erosion rate and lowest erosion rate that you have found.

2. Download some erosion rate data

Now you've explored the dataset a bit, we are going to download some erosion rate data. There are a few ways you can do this from the database, but what we are going to download is a ***global shapefile*** of all the basins with CRN erosion rates. This is a powerful dataset! We will then focus on the Great Smoky Mountains from these data.

To download, click the "Export Data" button in the left hand bar (third button down). Choose the "CRN Denudation: Global collection: River basins" option, and the format "Shapefile". Choose an appropriate area of use ("Teaching: classroom teaching") and then click on **Export Layer.** This will download a zip file with all the basins in it called *crn_int_basins.zip.*



Move the ZIP file that is downloaded somewhere appropriate (like your J drive) and then unzip it. You should find the shapefile with the basins inside.

Download the DEM

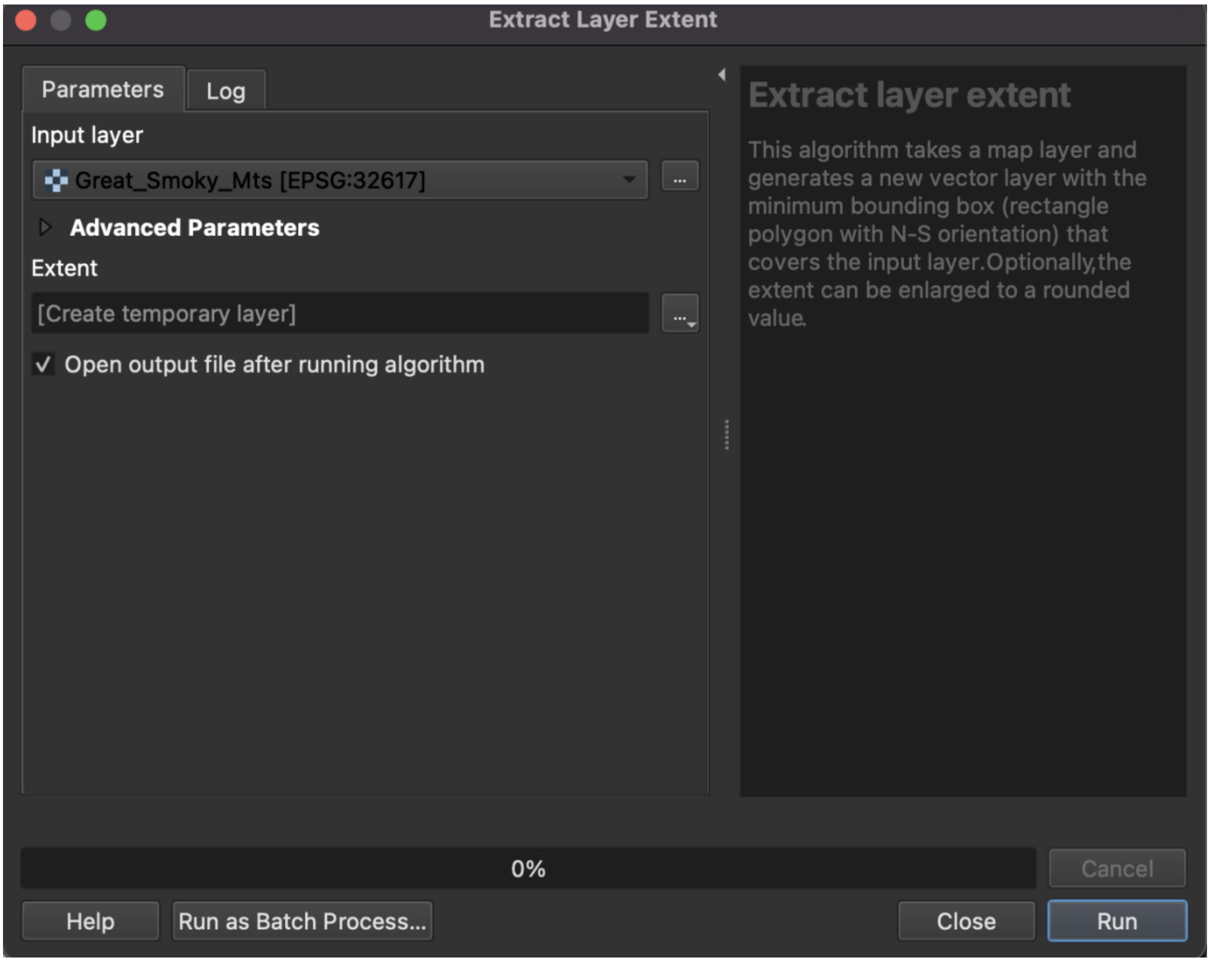
These data give you erosion rates for all the basins available globally, but for the practical we are going to focus on the Great Smoky Mountains on the East coast of the USA. I have downloaded a DEM from this region from OpenTopography using the approach we did last week. To make sure everyone has the same area, I have put this onto Learn Ultra. You should download this from the ESPL page for this practical.

Visualise the data using ArcGIS or QGIS

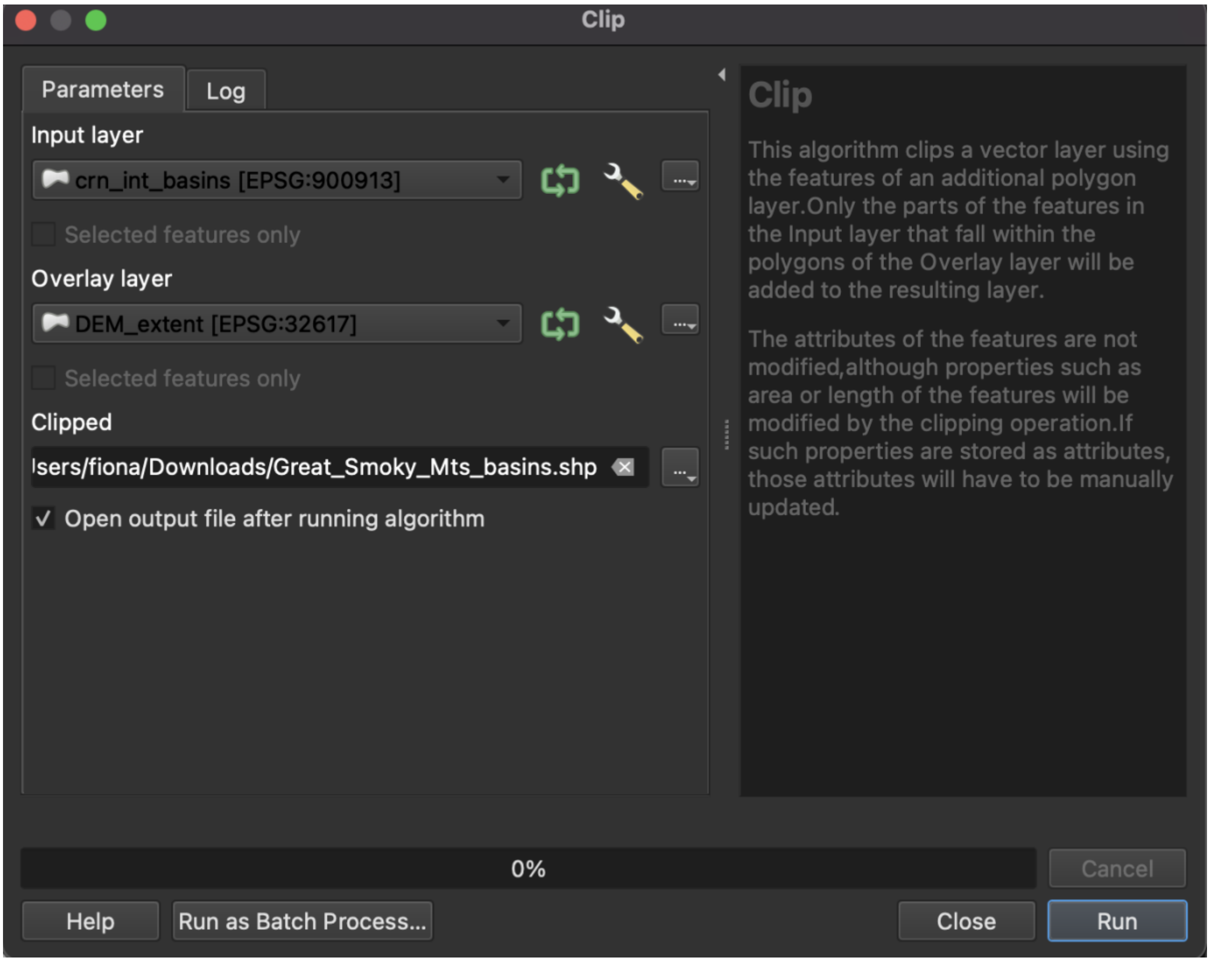
We can use these folders that we have just downloaded to take a look at the data in a GIS. You can use whatever program you are most comfortable with: we are just going to use it to make a map. Here I give instructions for QGIS but you can use the ArcGIS practical from last week to help you if you want. Both of these can be opened from AppsAnywhere, or you can also download QGIS directly (https://www.qgis.org/en/site/forusers/download.html).

Open your GIS and drag and drop the DEM ('Great_Smoky_Mts.bil') and the basins shapefile ('crn_int_basins.shp') into the window.

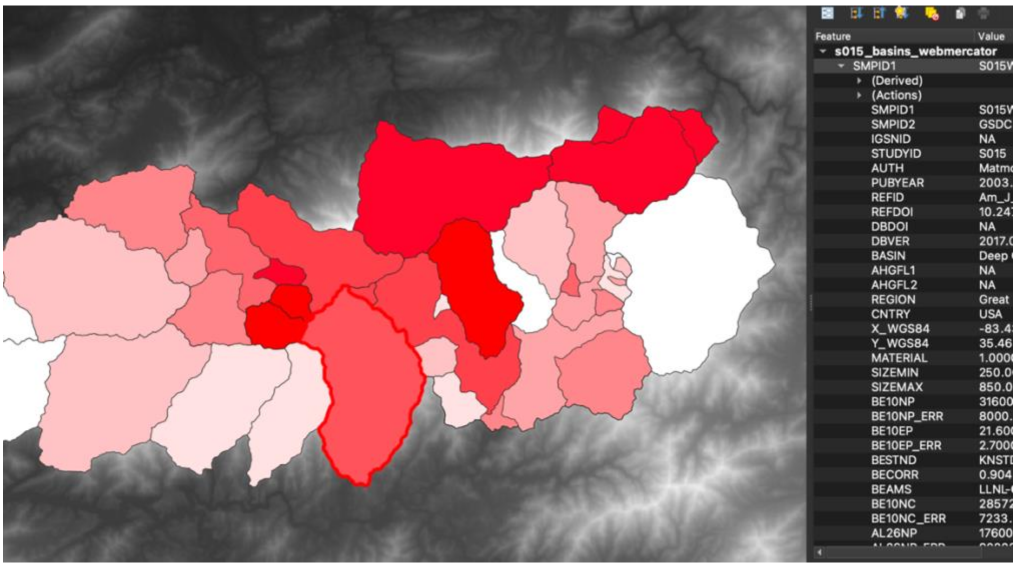
Zoom in on the DEM – you should see a series of basins for this DEM. Let's clip the basins to only the ones that are within the boundaries of the DEM. To do that, we will use the *Extract Layer Extent* tool. In the top menu bar, go to *Vector → Research Tools → Extract Layer Extent.* Choose the DEM as the input layer, and then choose to save the extent somewhere sensible.



This gives us a shapefile with the outline of the raster. We will use this to clip the basin shapefiles to the extent of the DEM. Go to *Vector → Geoprocessing Tools → Clip.* Choose the basins shapefile as the Input layer, and the new DEM extent shapefile as the overlay layer. Then save your shapefile as something sensible (I have called mine "Great_Smoky_Mts_basins.shp") and Run.



You should see a new shapefile that has only got the basins for the area of the DEM! If you click the "Identify" button in the top bar of QGIS or ArcGIS you should be able to click on one of the basins and see lots of information about it.

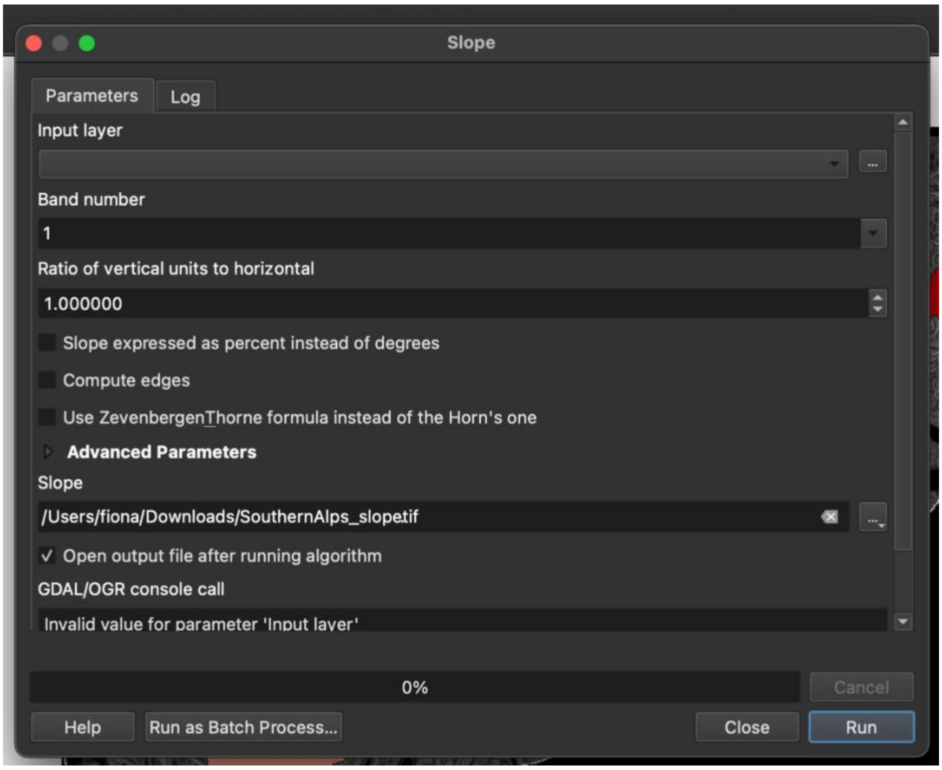


Look at some of the information: you can see the name of the basin ("BASIN"), the latitude ("Y_WGS84") and the longitude ("X_WGS84"). We also have information about the erosion rate (“EBE_MMKYR”) and the error on the erosion rate (“EBE_ERR”). The bottom columns tell us about the basin: we have information like the basin area (“AREA”) and the mean elevation (“ELEV_AVE”).

Exercise 1: In QGIS or ArcGIS, make a hillshade from the DEM and overlay the basin shapefile coloured by erosion rate. Output as a figure and write a short caption that describes how erosion rates vary across these basins in the Great Smoky Mountains.

3. Erosion rates and mean basin slope

One thing that we might want to look at is whether the slope of the topography reflects erosion rates. We have 57 data points for erosion rate (this is quite a lot for CRN erosion rates, because analysing the samples is very expensive). To add the mean slope to each of the basins, we first of all need to calculate a slope map. Refer to the instructions from last week for how to do this in ArcGIS. In QGIS, it is very simple – click on “Raster” in the top menu bar, then “Analysis” → “Slope”. Choose the layer “Great_Smoky_Mts” as the input layer, and then click the 3 dots next to the “Slope” box → “Save to File” → Save to an appropriate filename.



Click “Run”. You will find your slope map in the Layers tab. The next step is to get the mean slope in each basin from our shapefile layer. To do this we will use “Zonal Statistics”. This is called the same thing in both ArcGIS and QGIS: the instructions below are for QGIS.

Open the Processing Toolbox Panel and search for “Zonal Statistics”. In the resulting window put the basins shapefile as the input layer (“Great_Smoky_Mts_basins”) and then the slope as the raster layer. In the output column prefix, put “Slope_” Then click on the “Statistics to calculate" button. You will see that we automatically calculate the count, sum and mean of the slopes. Get rid of count and sum, so we just calculate the mean. Then add the "St dev" so we get our standard deviation. Click the 3 dots to Save to file, and make sure to save it as a **shapefile** (ends in ".shp").

You will see we have a new shapefile that we just created: mine is called "Basins_slope.shp". You can click on this and colour by the mean basin slope: it is the column called "Slope_mean".

Exercise 2: Make a map plot of the basins coloured by the mean basin slope and save as a figure. Compare to your plot of erosion rates. Does it look like the basins with the highest mean slope have the highest erosion rates?

Look at the following paper to find out why slope and erosion rate might not be correlated:

Steven A. Binnie, William M. Phillips, Michael A. Summerfield, L. Keith Fifield; Tectonic uplift, threshold hillslopes, and denudation rates in a developing mountain range. *Geology* 2007; 35 (8): 743–746. doi: https://doi.org/10.1130/G23641A.1

4. Reading the data into python for plotting and further analysis

In this section we will read in the DEM and the basins shapefile into Python to make some additional plots and to do some further analysis (e.g. channel steepness analysis). I recommend you do this section if you want to use these data for your independent projects. To do this section, open the Google Colab notebook using the link under Practical 6 on Learn Ultra.

5. Summary

Today we have looked at how we can download erosion rate and DEM data for anywhere in the world where a sample is available. This is a good resource that you can use for your independent projects! For the rest of the session, you can use the time to work on your projects and ask for help if you need it.