LAHARZ on QGIS

1. Introduction

LAHARZ creates a series of lahar tif files which can then be loaded into QGIS. The lahars are based on the volumes the user inputs and the initiation points are determined from the energy cone, based on the H/L ratio.

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2. Overview

Laharz Python Program

- Collects user parameters
- Opens DEM, Stream and Flow files
- Determines the energy cone based on the H/L ratio input
- Determines the initiation points where the thalwegs meet the energy cone
- For each initiation point and volume selected, creates a separate file for the lahar flow. Separate files are created for all initiation points for a volume and for all initiation points for all volumes
- Files are also output for the thalwegs, energy cone (raw, filled and line) and the initiation points

3. Setup

Create the following directory structure:

Development: call Laharz from this directory – see below

Working Directory: store input files here; some output files are created in here. Use whatever name for the working directory you wish – usually the volcano name

When it runs, Laharz creates additional directories in the 'Working Directory' directory.

Lahars: lahar files will be output here; program will create directory

Mesh: mesh files will be output here; program will create directory

Install Laharz from Conda by using: `conda install -c keith1815 laharz`

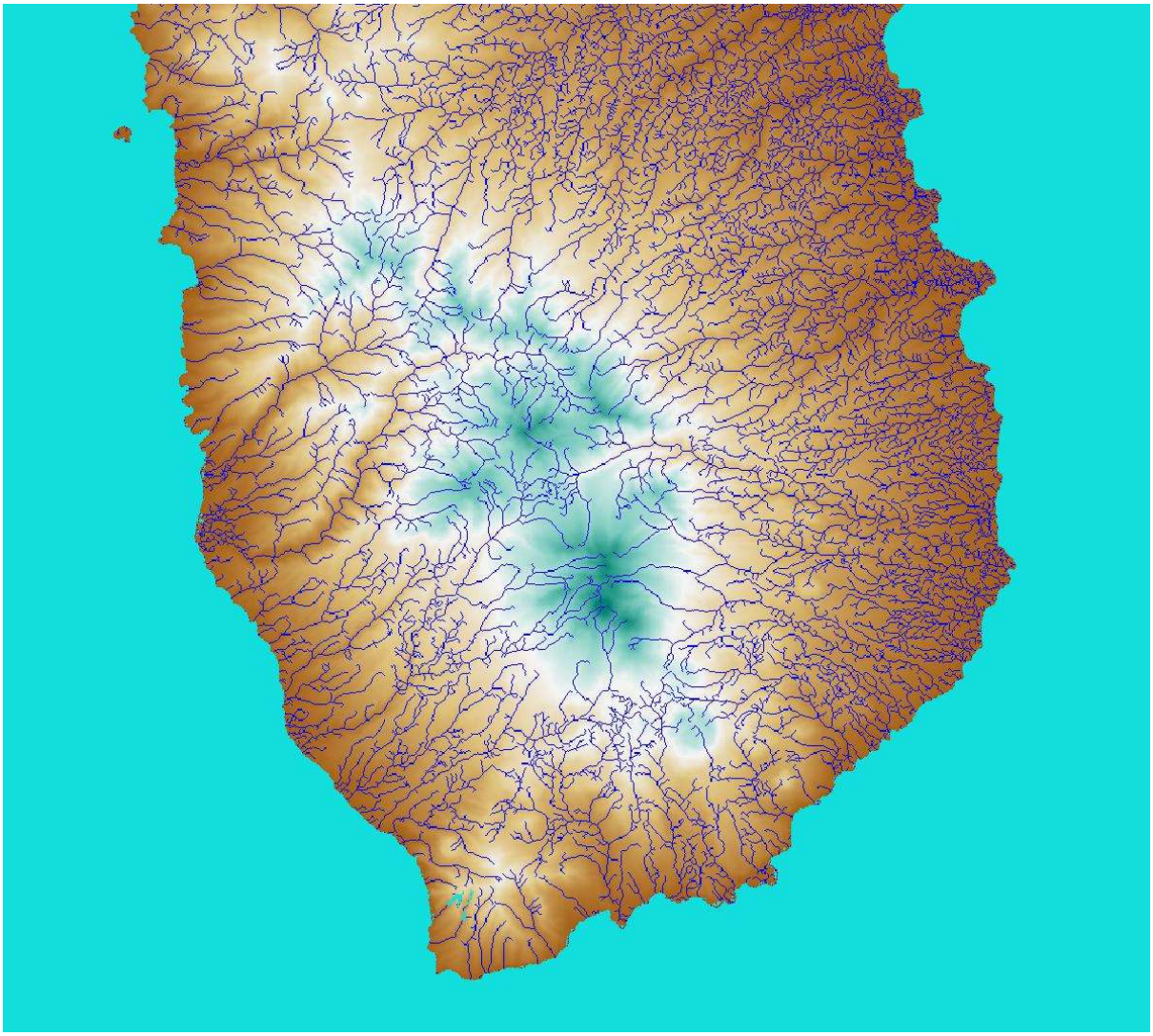
Alternatively, you can manually install the required modules (numpy, rasterio, pillow, scipy, trimesh, pyproj, simplekml) directly using pip or conda. Mixing pip and conda to install can cause issues – better to exclusively use one of the other. You can run the programme laharz.py directly from the Development directory.

Note that the programme expects to be run from the Development directory and uses the directory structure above (with relative references) to find the necessary files.

4. Operating Procedure

1. Open QGIS with GRASS. This version works on QGIS 3.16 and is believe to work with later versions. Use of QGIS is very standard and unlikely to be impacted by future releases
2. Load a suitable DEM into QGIS
3. If the DEM is large, use Raster/Extraction/Clip Raster by Extent to reduce the size of the raster file. Larger files can take a long time to process
4. Use the GRASS fill routine to fill any holes in the raster file. Display the tools by selecting Process/Toolbox then select GRASS/Raster/r.fillnulls. Use the default options with the exception of:
    a. Input raster layer to fill – use your raster layer
    b. Interpolation method to use – select 'bilinear'
    c. Filled – save to a file – eg YourDEM-filled.tif
5. Use the GRASS fill routine to calculate the streams. Display the tools by selecting Process/Toolbox then select GRASS/Raster/r.stream.extract. Use the default options with the exception of:
    a. Input map:elevation map – use your filled raster layer eg YourDEM-filled.tif
    b. Minimum flow accumulation for streams – experiment with this value. A larger number gives less stream detail; a smaller one gives more stream detail. Try 3000 to begin with
    c. Unique stream ids (rast) – save to a file – eg YourDEM-streams.tif

d. Unique stream ids (vector) – skip output
e. Flow Direction – save to a file – eg YourDEM-flow.tif



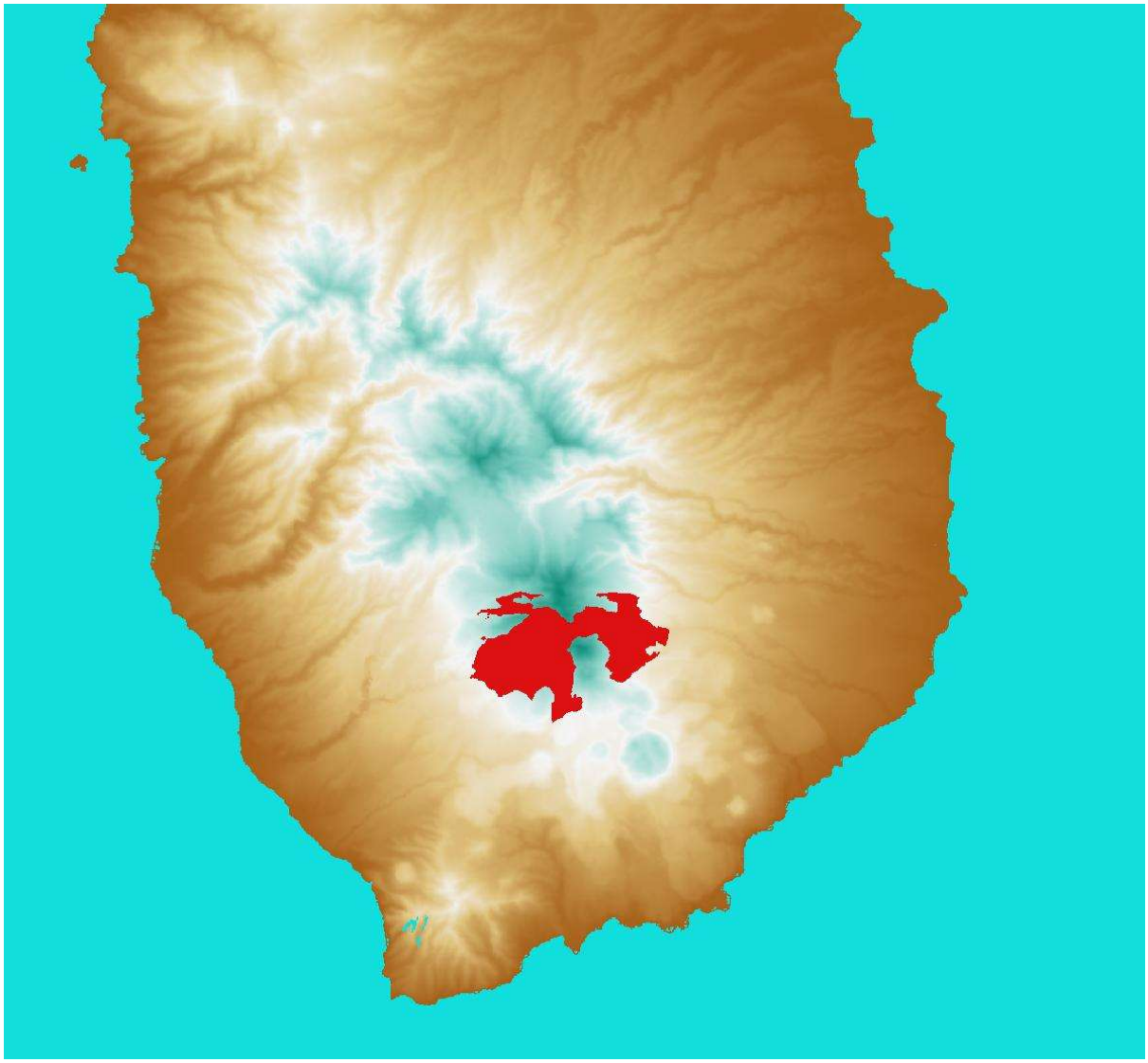
Filled DEM with Streams

6. Optional: The stream raster numbers the streams (ie the pixels in each stream segment have a different number). To create a simpler raster than just shows all streams as '1's use Raster/Raster Calculator with:
    a. Output layer set to a raster name of your choice (eg YourDEM-simplestreams.tif)
    b. An expressions such as ("Stream@1">0)*1 + ("Stream@1"<=0)*0 :ie where the stream value is greater than 0, set it to 1; where the stream value is less than or equal to zero, set it to zero.
7. Run LaharZ by 'import laharz from laharz' in a python command line or script. This will present a GUI window with parameters as follows:
    a. **Working directory** – directory which contains the input files and where the output files will be written to. Useful to use the name of the volcano: eg "Merapi"

b. **Load parameters** – file name that contains parameters to be loaded. Previously created by Save Parameters. The file name is a pickle file stored in Working Directory
c. **DEM file** – file name of a DEM file. Assumed to be in the Working Directory. Eg YourDEM-filled.tif. Best to use the filled version
d. **Stream File** – file name of stream extract (or thalweg) file. Assumed to be in the Working Directory. Eg YourDEM-streams.tif
e. **Flow File** - file name of the flow direction file. Assumed to be in the Working Directory. Eg YourDEM-flow.tif
f. **Volume** – comma separated list of volumes used to calculate the lahars in m^3. Multiple volumes can be set: eg 1e4, 1e5, 1e6
g. **H/L Ratio** - height to length ratio for determining the initiation points. See Schilling 1998. Usually between 0.2 and 0.3
h. **Peak** – program will search in a square box centered on this point to find the highest point which it then uses as the peak – eg: -78.45, -0.66. Latitude, Longitude.
i. **Search Diagonal** – distance NE and SW of peak to search for the highest point (ie the diagonal of the search box) in metres. Eg 10e3. Intention is that the high point is chosen in a region rather than the user entering the exact location, mostly for convenience. If you are confident in the location of the peak, use a very small Search Diagonal
j. **Sea Level** - lahars stop at this sea level value. Otherwise you get streaks across the sea. Usually set to zero
k. **Lahar Directory** - subdirectory of Working Directory where all lahar files are created. Eg. Lahars. The programme will create the directory and overwrite any existing files where the file names clash; if they do not clash the files are ignored
l. **Initiation Points** – the initiation points are written to this file in the Working Directory. Eg. Initiation Points.csv. Also used as the filename to read in initiation points. The file can be edited to remove surplus initiation points are enter new ones
m. **Log file** – a log of the execution of the programme written to this file in the Working Directory. Eg. Log.txt. Useful to as a record of which parameters were used
n. **Raw Energy Cone** - filename where the raw energy cone is output in the Working Directory. Eg ecraw.tif. See Schilling 1998 for definition of the Energy Cone
o. **Filled Energy Cone** - filename where the filled energy cone is output in the Working Directory. Eg ecfilled.tif.
p. **Energy Cone Line** - filename where the energy cone line is output in the Working Directory. Eg ecline.tif.

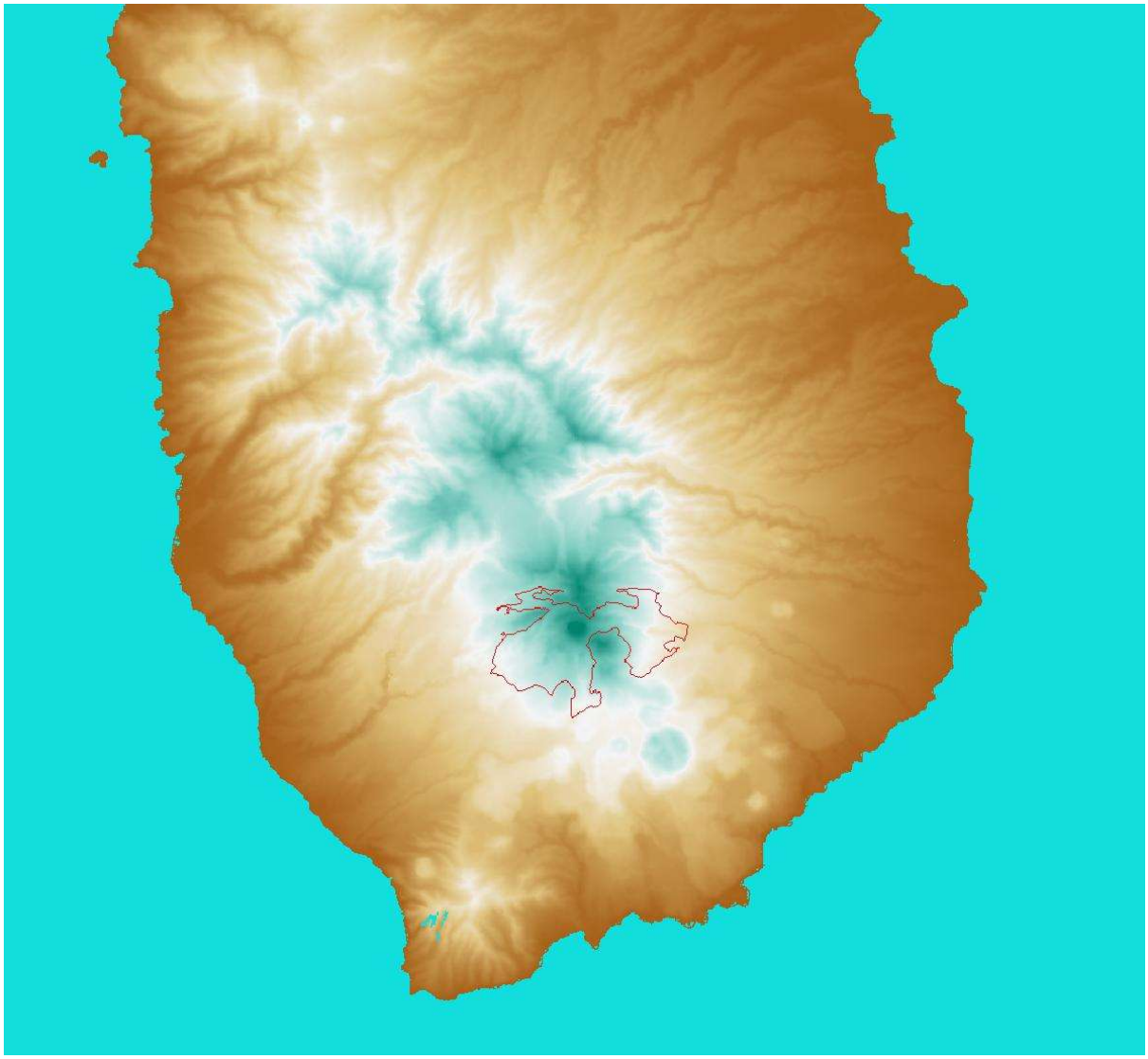
q. **Mesh Directory** - subdirectory of Working Directory where mesh files are created, eg. Mesh, if the Plot Mesh check box is ticked. The programme will create a 3D mesh file (in .vtk format which can be read in Paraview) of the surface and the energy cone, which can be useful for visualizing how the initiation points are determined. The file names are Surface.vtk and Cone.vtk and will be overwritten in each execution of the program.
r. **Mesh Resolution** – number of points in the x and y direction of the mesh. Eg 200
s. **Mesh Extent** - how much of the landscape to include in the mesh. The program calculates the maximum distance from the peak where the energy cone intersects the landscape as 1. Setting a value of 1.2 will create mesh files that are 20% bigger than the this maximum distance. Normal value is 1.3.
t. **Calculate/Load Initiation Points –** if calculate is selected a new set of initiation points are calculated; if load is selected the initiation points in **Initiation Points** are loaded in. It is possible to edit the initiation points in the the file. Retain the header line and ensure the list of points is contiguous (ie no blank lines)
u. **Use Row/Col –** the initiation points are listed with their Latitude & Longitude and their Row & Column. When the points are loaded in, the programme will use Row & Column if **Row/Col** is selected; otherwise it will use Latitude and Longitude
v. **Initiation Points Only** – the programme will calculate the initiation points only and not carry on to determine the lahar files
w. **Save Parameters** – will save the parameters (as a pickle file) in the file name entered
x. **Submit** – will execute the program

8. Output files are created as follows:
    a. The raw energy cone – eg ecraw.tif
    b. The filled energy cone – eg ecfilled.tif



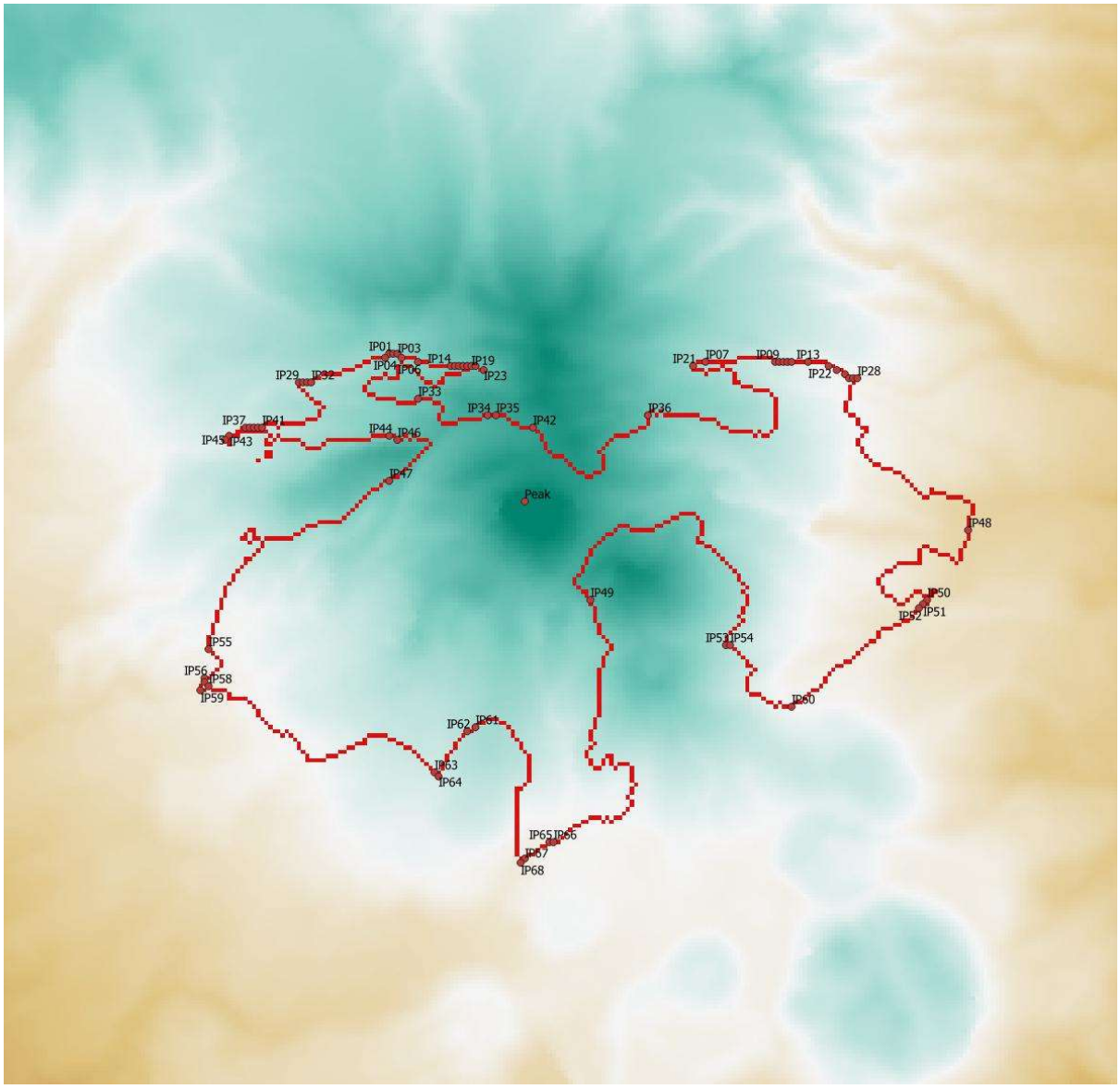
Filled Energy Cone (EC-Filled.tif)

c. The energy cone line – eg ecline.tif



Energy Cone Line (EC-Line.tif)

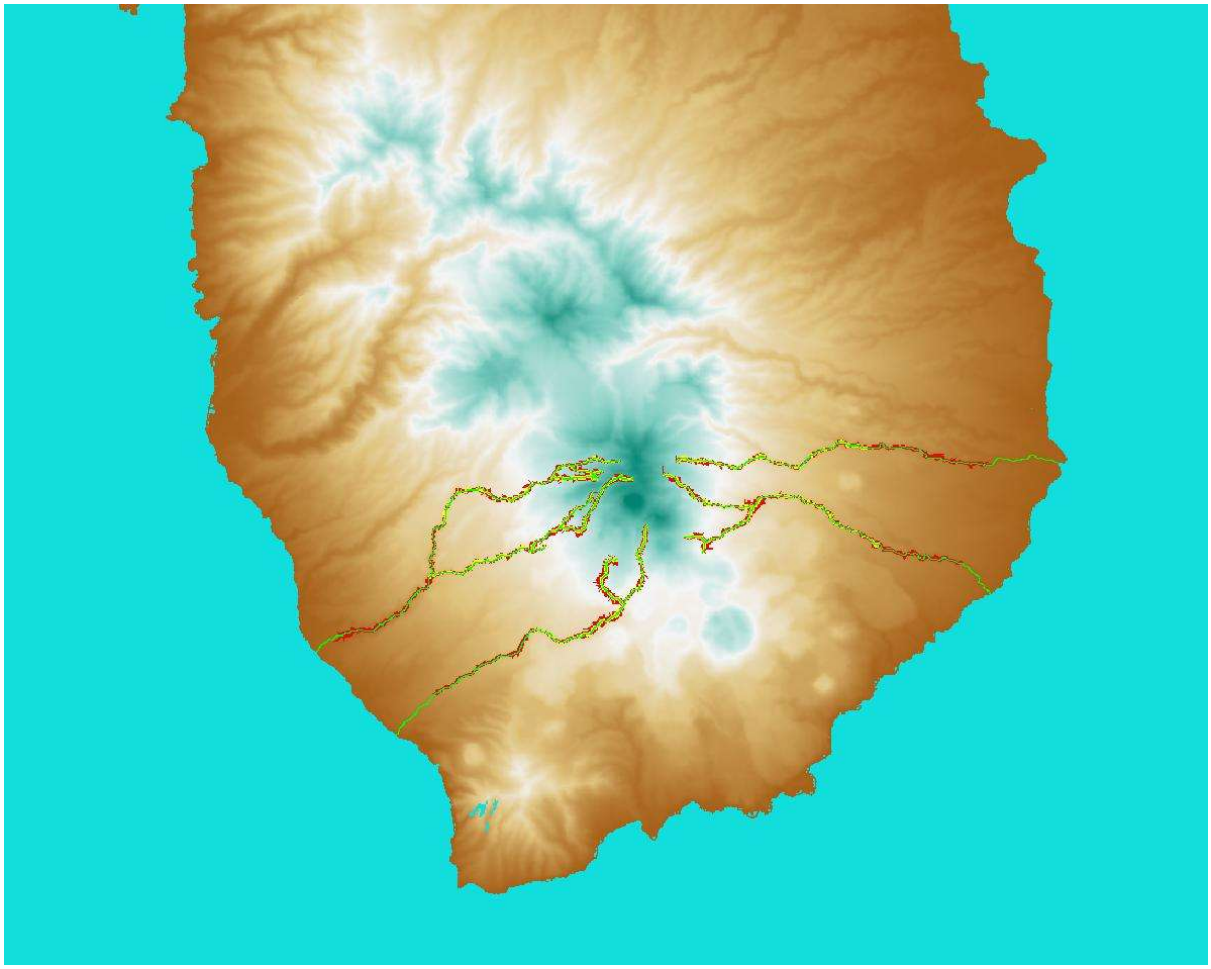
d. Initpoints.csv – list of all initiation points. This can be edited and run with **Load Initiation Points** to use this list of initiation points in the program. Initiation points can be loaded directly into QGIS by Open Data Source Manager/Delimited Text and labelled by Properties/Control Feature Labelling/Single Label



Labelled initiation points

e. In folder **Lahar Directory**:
   i. A file for each volume/initiation point eg IP07-V1-00e04.tif
   ii. A file for all initiation points for a particular volume eg V1-00e05.tif. The value of each point is the number of the initiation point
   iii. A file for all initiation points and volumes. Eg Total.tif. The value of each point is the volume. The total file is best for an overall representation

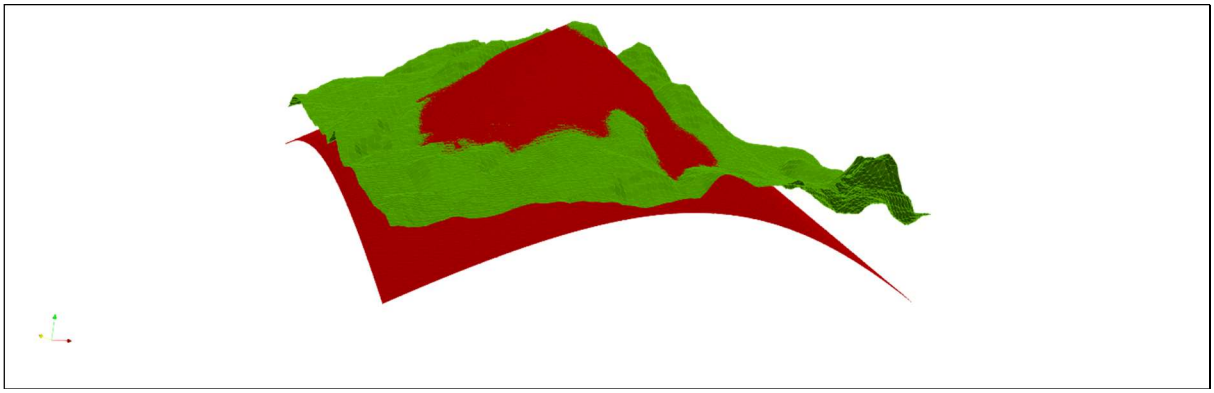
   Each file will need to be colour coded when loaded in QGIS.



Lahars - Total.tif

f. In folder **Mesh Directory**:
   i. Surface.ply – mesh of the surface in 3D
   ii. Cone.ply – mesh of the energy cone in 3D

   Note the .ply files can be displayed using Paraview.



Mesh of surface and energy cone displayed in Paraview

g. Log.txt – log of the execution of the programme

5. Notes

H/L Ratio

The H/L ratio is ratio of the height (between the current point and the highest point) and the horizontal distance (length) from the current point to the highest point. It can be considered the intersection of the volcano's slope with a cone of angle $\tan^{-1}(H/L)$ (sharing a common apex). It is at this intersection point that lahars initiate as it is the furthest extent that material falls through landslides. LaharZ allows the user to select an area where the highest point is to be determined.

Energy cone

The energy cone is the line where the line where the theoretical cone meets the surface. In a classically conically shaped volcano, this will be a rough circle around the peak. More complex volcanic shapes will provide a more complex energy cone line and in some cases, multiple shapes and lines. LaharZ will process multiple shapes and lines and create initiation points accordingly.

The algorithm simply considers where a point is above or below the H/L ratio (ie above or below the theoretical cone) and creates a shape for the energy cone (output as ecraw.tif). This basic approach can give rise to unnecessary complications - such as small holes in the shape. These are filled in and the output is ecfilled.tif. Both shapes can be reviewed to see if there are any issues

The energy cone line (ecline.tif) is line of the edge of the energy cone shape which can similarly be reviewed.

The energy cone and its intersection with the surface can be explored in the output mesh files.

Initiation points

The initiation points are the intersection between the thalweg and the energy cone line. These points are output in an excel file (initpoints.csv) which can be reviewed and edited, to limit the number of initiation points to use.

If LaharZ is run in 'Create Initiation Points only' mode, then the user can review the initiation points and edit initpoints.csv to remove redundant initiation points, adjust or create new ones. In some cases, the intersection will be inappropriate and adjustments will have to be made: eg different H/L ratios; removing bogus initiation points; editing and combining points from multiple runs

6. And finally

Comments, suggestions, issues all welcome. Please report on GitHub to help track.

7. Change Log

Version	Comment
1.0.0a	First release
1.0.1a	Updated release to match version 1.0.1 of LaharZ. Reference to installation guide otherwise no changes to documentation
1.0.2a	Updated to show how to install using conda
1.0.3a	No updates. Version incremented to match programme.

8. References

Schilling, S.P., 1998, LAHARZ—GIS Programs for automated mapping of lahar-inundation hazard zones: U.S. Geological Survey Open-File Report 98-638, 80 p.