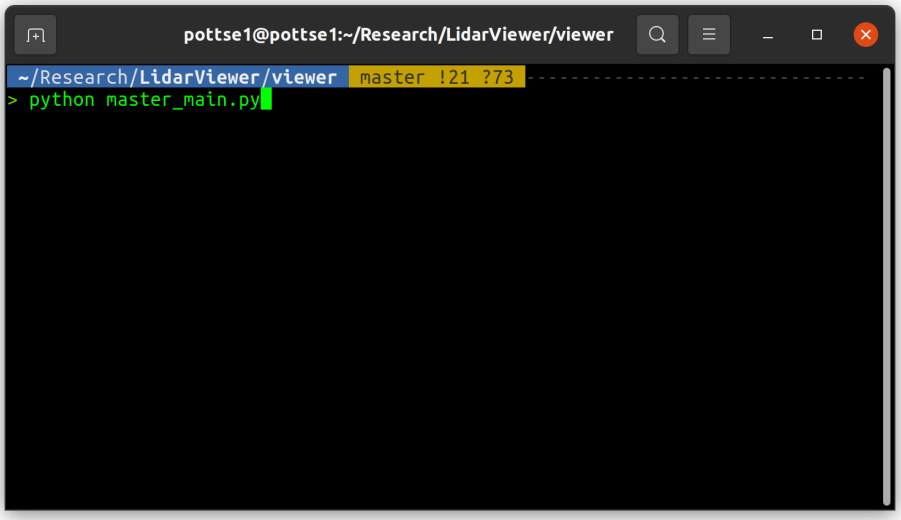
Starting the program:

1. Open the terminal on your computer
2. Navigate to where the program files are located
3. Run: *python master_main.py*



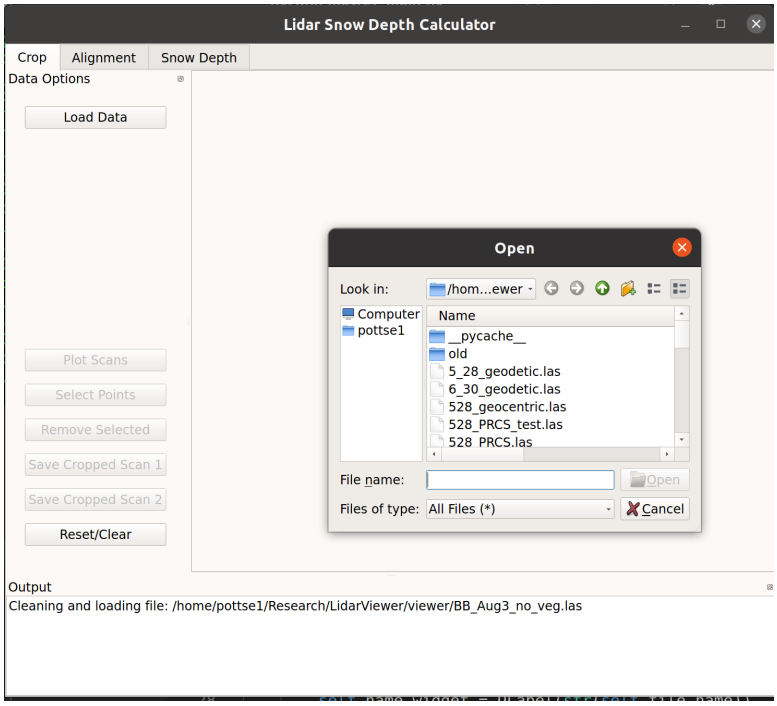
4. This will start the software and the window will appear.

Overall window layout:

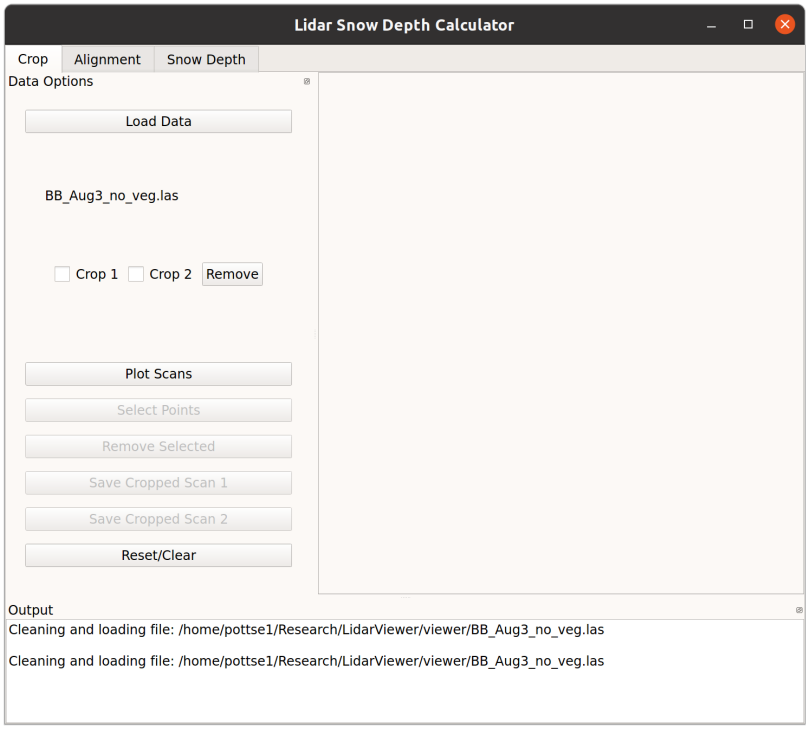
1. Graphical User Interface (GUI) Layout. The orange box in the top left highlights the tabs for navigation between the different windows. The red box highlights the data analysis area of the windows. The green box highlights where the scans will be plotted. The blue box highlights where messages and information will be printed.

Loading in *.las* files:

1. Each window has the ‘Load Data’ Button. Clicking this button will open up another window for the user to navigate to the *.las* file. Select the *.las* file and click ‘Open’



2. The file will now be loaded AND APPEAR IN EVERY WINDOW TAB



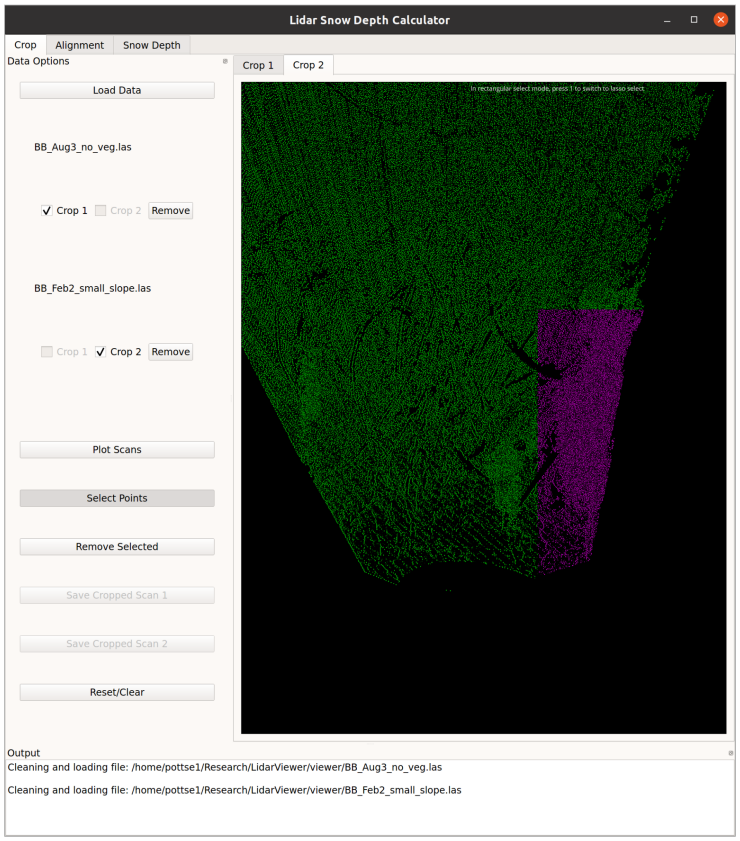
3. To remove a loaded file click the ‘Remove’ button by the file name. IT WILL BE REMOVED FROM EVERY WINDOW.

CROPPING WINDOW

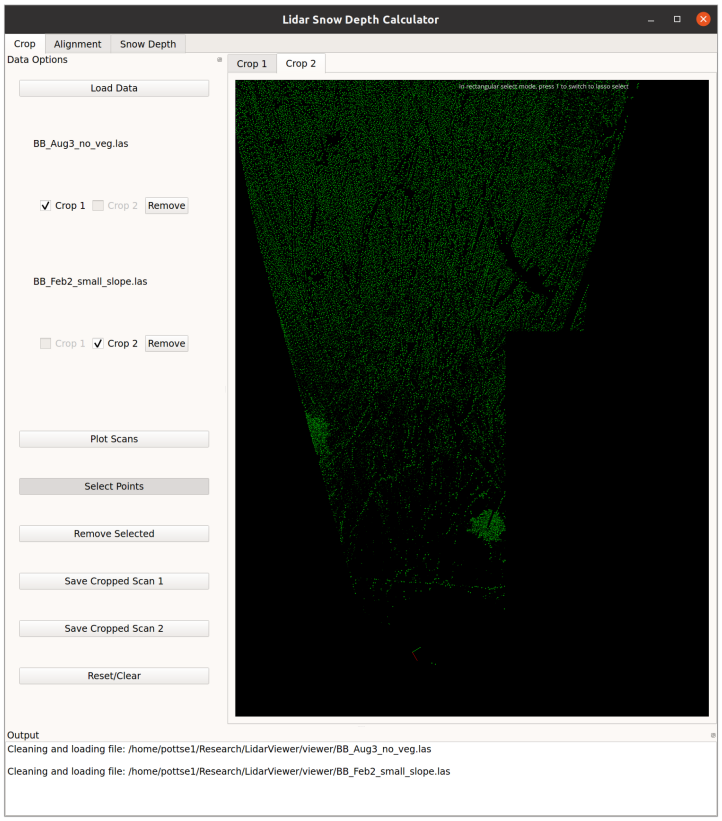
- Alignment is done using an Iterative Closest Point algorithm, meaning the algorithm maps scan 1 onto scan 2, rotates and shifts scan 2 onto scan 1 then repeats this process until the error is very small or not improving
- It is important to match on the most prominent features present in both scans, whether that be cliffs and trees or lift poles

WORKFLOW

1. Load one or more files into the program and then select ‘Crop 1’ and/or ‘Crop 2’ on the files that are to be cropped. The order of ‘Crop 1’ and ‘Crop 2’ does not matter. If only one file is to be edited, ‘Crop 1’ or ‘Crop 2’ can be selected to edit the file.
2. Click ‘Plot Scans’
3. The selected file(s) will be plotted in the plotting area. There will be two tabs above the plotting area for ‘Crop 1’ and/or ‘Crop 2’. You can swap between the scans using those tabs
4. To remove points click the ‘Select Points’ button.
    a. This button acts as a toggle. Click it once to enter ‘Select Points’ mode. Click it again to exit ‘Select Points’ mode.
5. In ‘Select Points’ mode, select points you would like to remove.
    a. Default selection geometry is a rectangle. By pressing the ‘1’ key, the user can switch between rectangular geometry and custom (‘lasso’) selection geometry.
6. Select the points to remove. (They will be highlighted in a purple color)



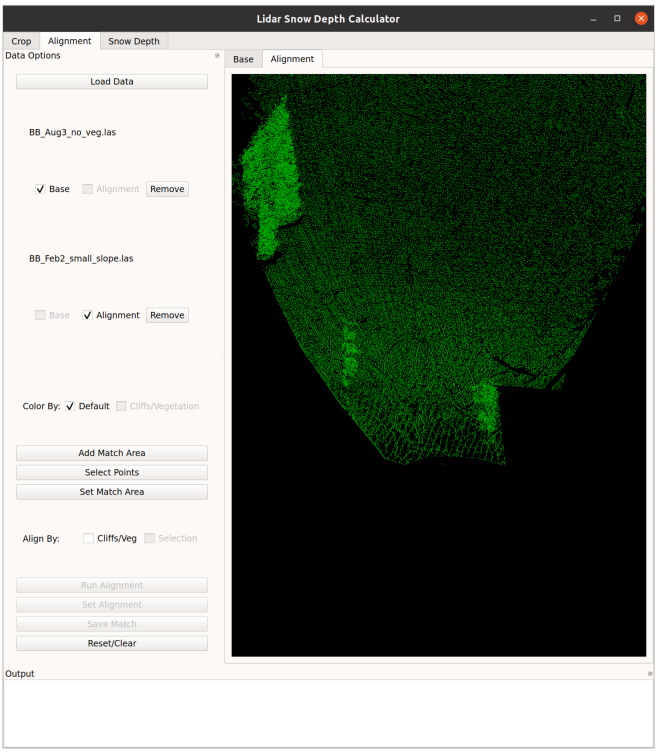
7. If you want to adjust the selection just re-select the desired area. The selected points will reset with each selection. The best practice is to remove small areas at a time to ensure accuracy.
8. Once the user has a selection of points you want to remove, click the ‘Remove Selected’ button.



9. If a mistake was made in the cropping of the file, click the ‘Reset/Clear’ button and the files will be reset to their original points
10. To save the ‘Crop 1’ and/or ‘Crop 2’ files as a new file, click the ‘Save Cropped Scan 1’ or the ‘Save Cropped Scan 2’ button. Type in the new name and make sure to have ‘*.las*’ on the end of the name.

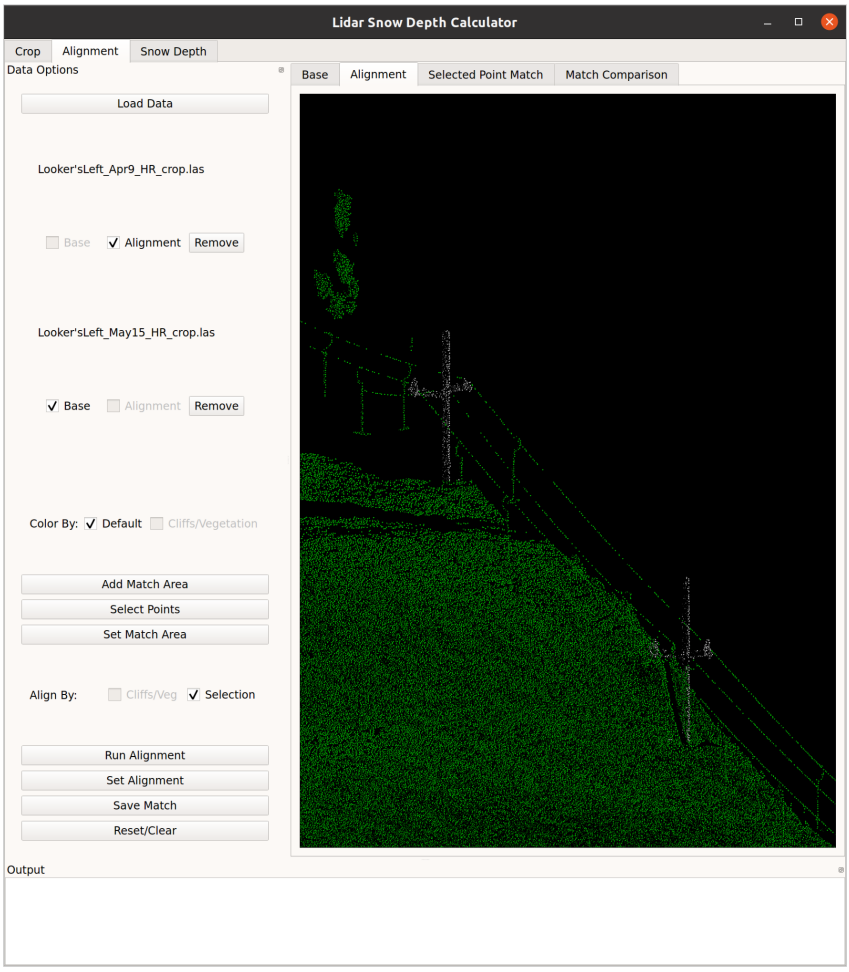
Alignment Window

1. Select which scan to use as the ‘Base’ and which to use as the ‘Alignment’
    a. ‘Base’ scan will not be rotated or translated to match. It will stay the same
    b. ‘Alignment’ scan will be rotated and shifted to match the base scan
2. Select how to color the scans
    a. ‘Default’ will color the ‘Base’ scan red and the ‘Alignment’ scan green
    b. ‘Cliffs/Vegetation’ will color the vegetation and cliffs green and the rest grey
3. Click ‘Add Match Area’
    a. This will plot the ‘Base’ and ‘Alignment’ scans in separate tabs in the plotting area with the selected coloring



4. Decision Point:
    a. If you would like to match the cliffs and vegetation between the scans select the ‘Cliffs/Veg’ checkbox next to the ‘Align By:’ text
    b. If you would like to align a custom selection of points between the scans:
        i. Click ‘Select Points’ to toggle point selection on
        ii. Incrementally select points then click ‘Set Match Area’ to add points to the selection of points to match from.
        iii. Do this for the corresponding area in both scans. It is alright if the same points are selected more than once in the process. They will not be added

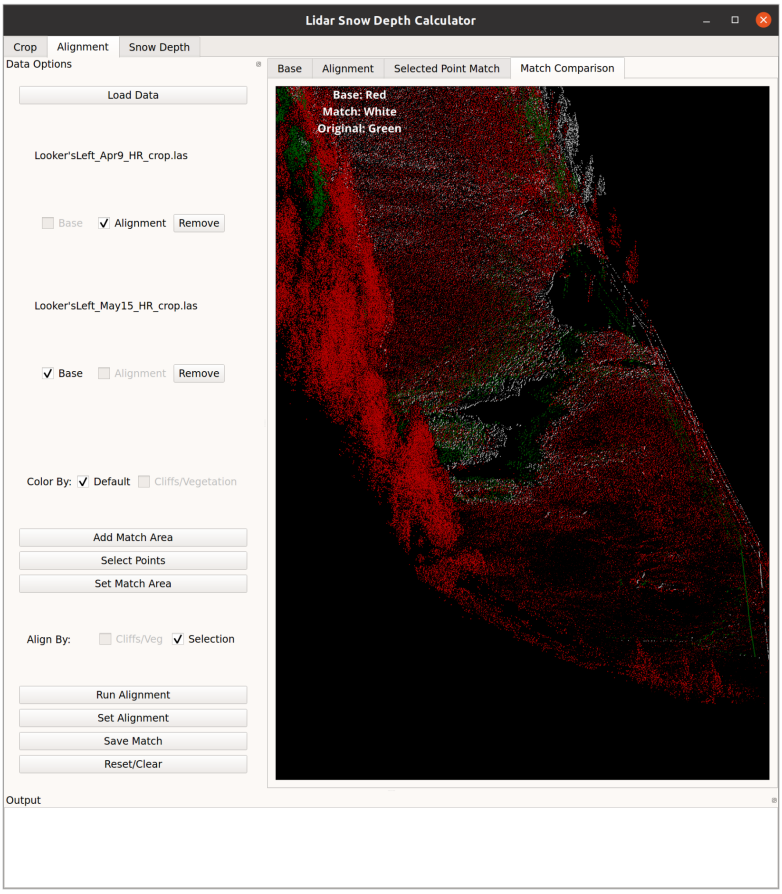
twice.



iv. Select the ‘Selection’ checkbox next to the ‘Align By:’ text

5. Click ‘Run Alignment’
    a. 2 more plot tabs will appear
    b. The first will plot three sets of the points used to run the alignment for comparison. The coloring is:
        i. ‘Base’ - red
        ii. matched ‘Alignment’ - White
        iii. original ‘Alignment’ - Green
    c. The first will plot three sets of the full scans for comparison. The coloring is:
        i. ‘Base’ - red
        ii. matched ‘Alignment’ - White

iii. original ‘Alignment’ - Green



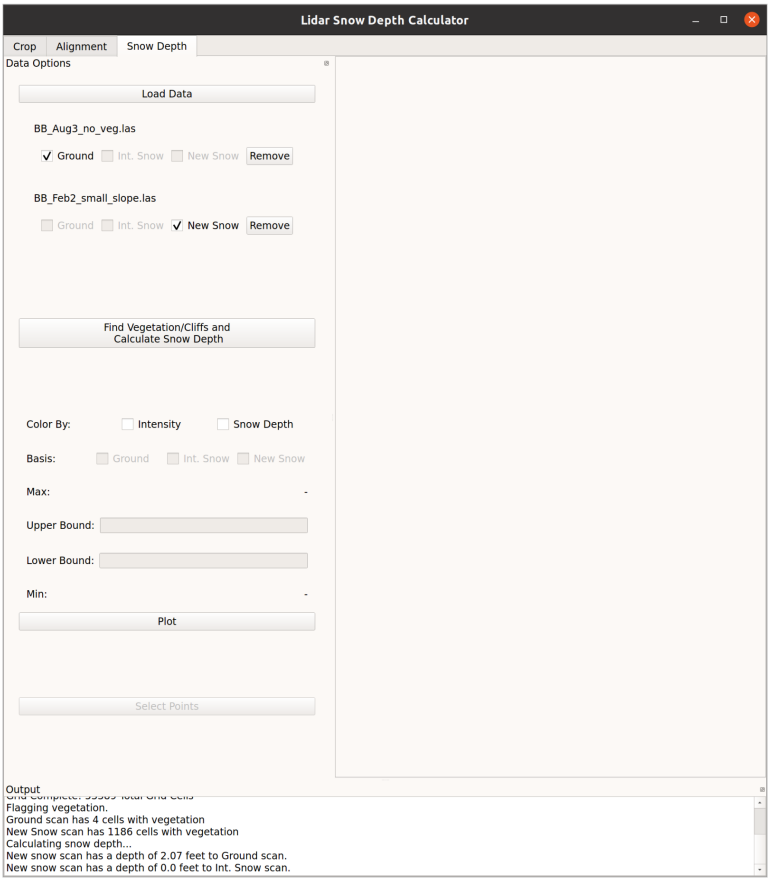
6. If you want to keep the new alignment, click ‘Set Alignment’
7. To save a new file with the new alignment click ‘Save Match’ and type in the new name and make sure to have ‘*.las*’ on the end of the name.

SNOWDEPTH WINDOW

- There are 3 scan selection options, ‘Ground’, ‘Int. Snow’, ‘New Snow’
- The depth is always calculated in reference to the ‘New Snow’. This mean that the depth change will be calculated between the ‘Ground’ and ‘New Snow’ and/or the ‘Int. Snow’ and ‘New Snow’. The snow depth will not be calculated between the ‘Ground’ and ‘Int. Snow’. The ‘Ground’ scan does not have to be a bare ground scan, it can be an earlier season snow scan. The ‘Int. Snow’ option is meant to give some flexibility in visualizing the difference between a mid season scan and the newest scan. For example, this mid season scan could correspond to a weak layer of interest so that the amount of snow that has accumulated on it can be visualized.
- The intensity returns of the lidar scan can also be visualized for any of the scans. This is meant to help with snow surface identification and can be incorporated into future work.

WORKFLOW

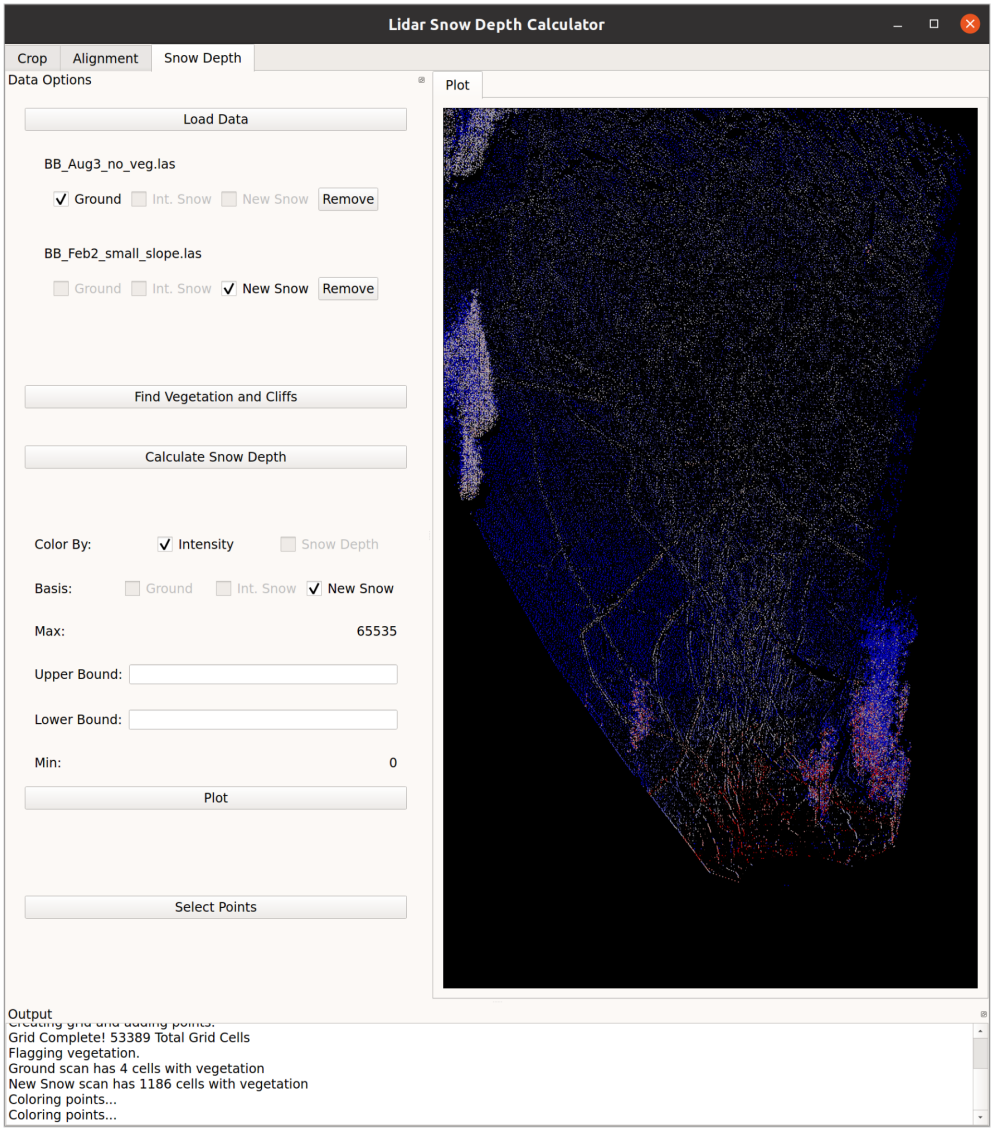
1. Select which scans to use as ‘Ground’, ‘Int. Snow’, and ‘New Snow’ (‘New Snow’ and at least one of ‘Ground’ and ‘Int. Snow’ must be selected to vusialize snow depth)
2. Click ‘Find Vegetation/Cliffs and Calculate Snow Depth’
    a. This will grid the selected scans and then identify grid cells that contain cliffs or trees
    b. Snow Depth will only be calculated if a ‘New Snow’ and at least one of ‘Ground’ and ‘Int. Snow’ is selected



3. **Option 1:** Plot default

    a. If a ‘Color By:’ checkbox is not selected the scan will be colored green where there are cliffs are trees and the rest of the scan will be gray/white
        i. Default hierarchy for plotting is: ‘New Snow’ -> ‘Int. Snow’ -> ‘Ground’
4. **Option 2:** ‘Color By:’ ‘Intensity”
    a. Click checkbox next to ‘Intensity’
    b. Select the ‘Basis:’ for the ‘Intensity’ coloring
        i. ‘Ground’, ‘Int. Snow’, and ‘New Snow’ can all be plotted and colored by their intensity return
        ii. If one of the basis was not selected originally for the gridding it will not be selectable for the plotting
    c. Once the basis is chosen, the ‘Max:’ and ‘Min:’ fields will be populated with the maximum and minimum intensity values in the scan
    d. The ‘Upper Bound:’ and ‘Lower Bound:’ can be specified if desired for a more detailed look or left blank and the software will automatically use the ‘Max:’ and ‘Min:’

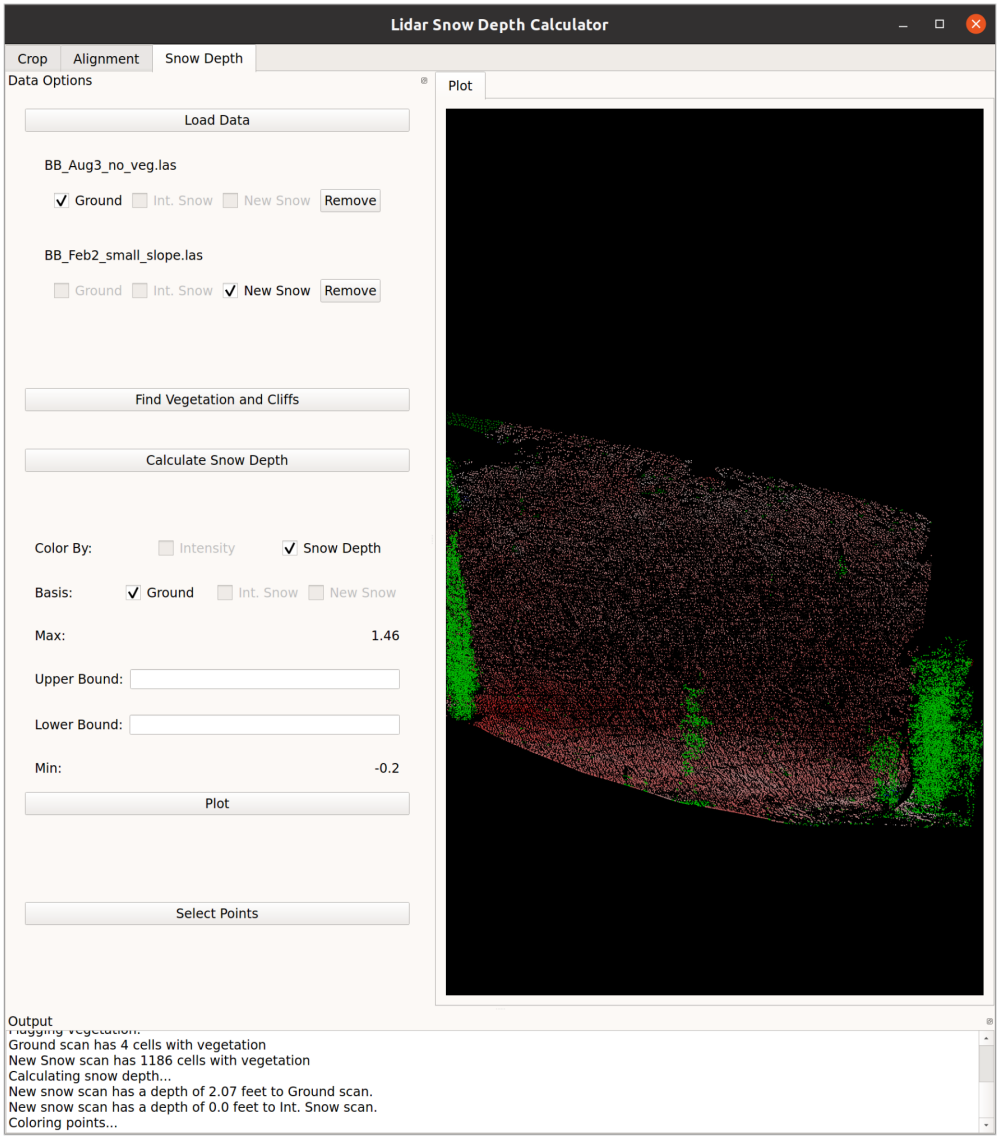
e. Click the ‘Plot’ button to visualize the scan



f. If you would like to replot with different bounds, simply enter the value of the desired ‘Upper Bound:’ and ‘Lower Bound:’ and click the ‘Plot’ button again

5. **Option 3:** Snow Depth Calculation and Visualization
   a. Select ‘Snow Depth’ checkbox for ‘Color By:’
   b. Select ‘Ground’ or ‘Int. Snow’ for ‘Basis:’ of snow depth coloring (‘New Snow’ is unselectable)
   c. Once the basis is chosen, the ‘Max:’ and ‘Min:’ fields will be populated with the maximum and minimum snow depth values between the scans
   d. The ‘Upper Bound:’ and ‘Lower Bound:’ can be specified if desired for a more detailed look or left blank and the software will automatically use the ‘Max:’ and ‘Min:’

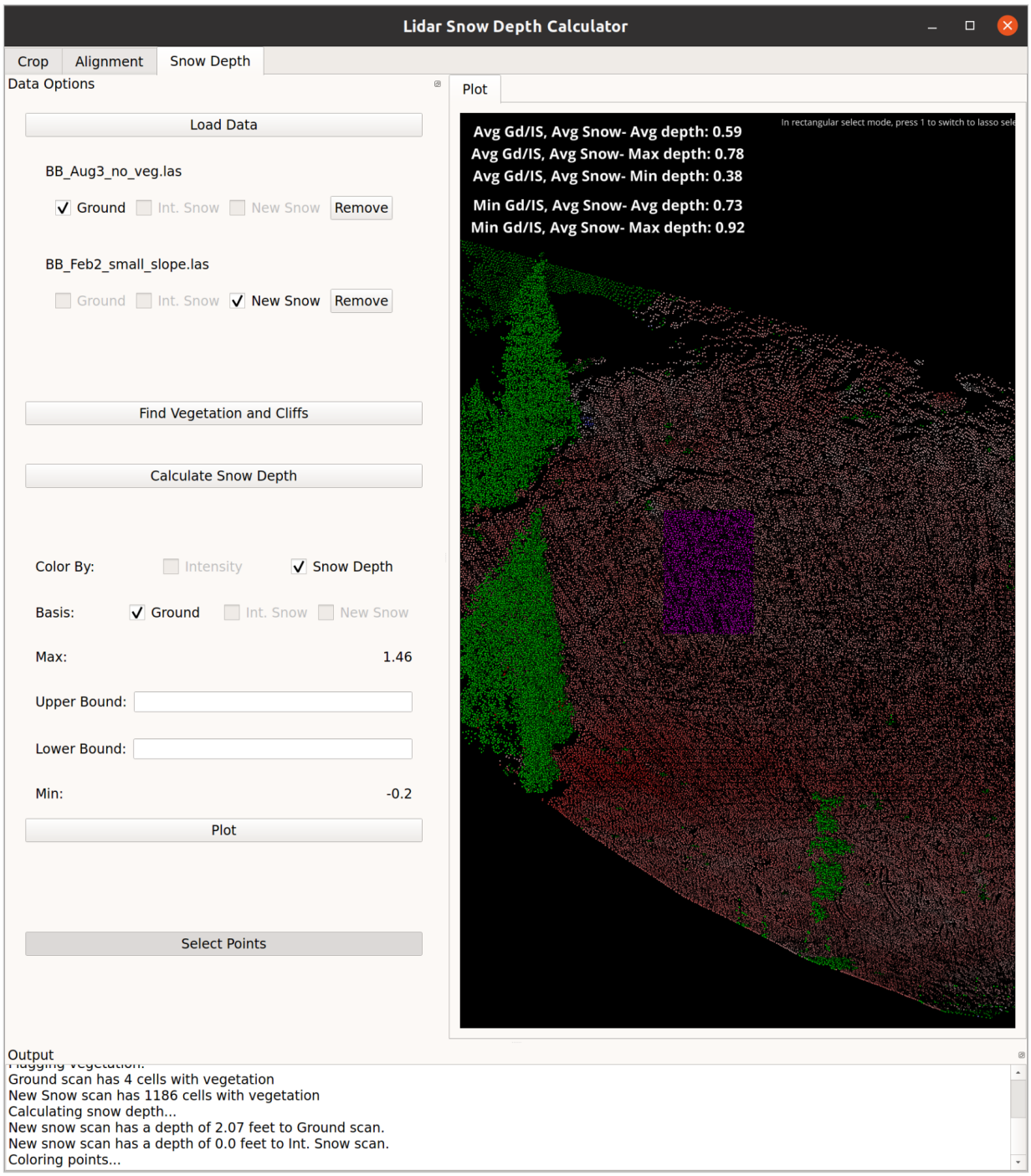
e. Click the ‘Plot’ button to visualize the scan



f. If you would like to replot with different bounds, simply enter the value of the desired ‘Upper Bound:’ and ‘Lower Bound:’ and click the ‘Plot’ button again

6. Once snow depth or intensity has been plotted, more detailed inspection can be done by selecting points
    a. Click the ‘Select Points’ button to toggle point selection on
    b. Rectangular and lasso selected can be swapped between by pressing the ‘1’ key
    c. Select points that you would like more information about and a summary of the snow depth or intensity values of the area selected will be displayed in the top left

of the plot area



d. The depths are in meters. ‘Avg Gd/IS’ uses the average z-coordinate of the ‘Ground’ or ‘Int. Scan’ to calculate the snow depth in the grid cell while ‘Min Gd/IS’ uses the minimum z-coordinate to calculate the snow depth in the grid cell
    i. Average z-coordinate is best used when the scan for comparison has a smooth surface such as an early season snow scan

ii. Minimum z-coordinate is best used when the scan for comparison has a non smooth surface such as a summer scan with grass or rocks/bounders that are too small to be caught by the cliff/vegetation identification algorithm, but can still artificially raise the ground surface by causing the lidar to not be able to penetrate to true ground in the scan.