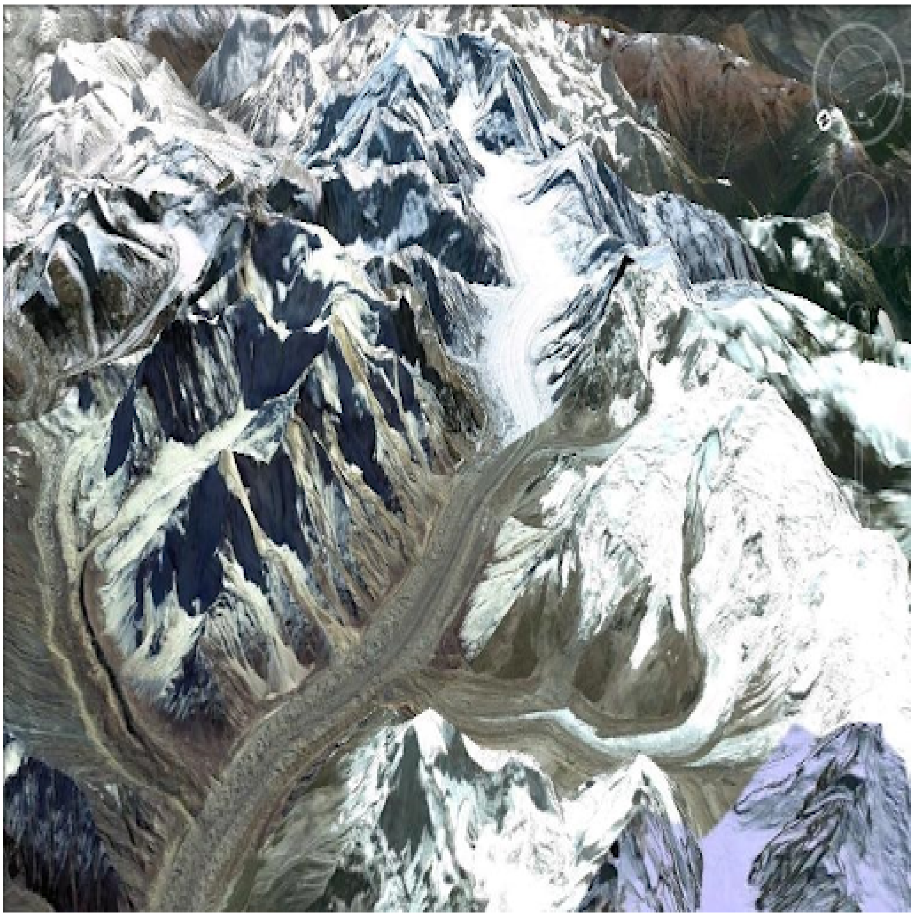
Indian Institute of Technology Bombay

GNR618 : Remote Sensing and GIS Applications to Cryosphere



Project Report

April 11, 2021

Glacier features classification using fully polarimetric SAR (POLSAR)
Data Science and Machine Learning

Group 35
Gaurav Anand, 170070034, Department Of Electrical Engineering
Mayur Ware, 19D070070, Department Of Electrical Engineering
Aayush Shrivastava, 19D070002, Department Of Electrical Engineering
Tanmay Hiremath, 19D070061, Department Of Electrical Engineering
Siddhant Shingade, 19D070057, Department Of Electrical Engineering

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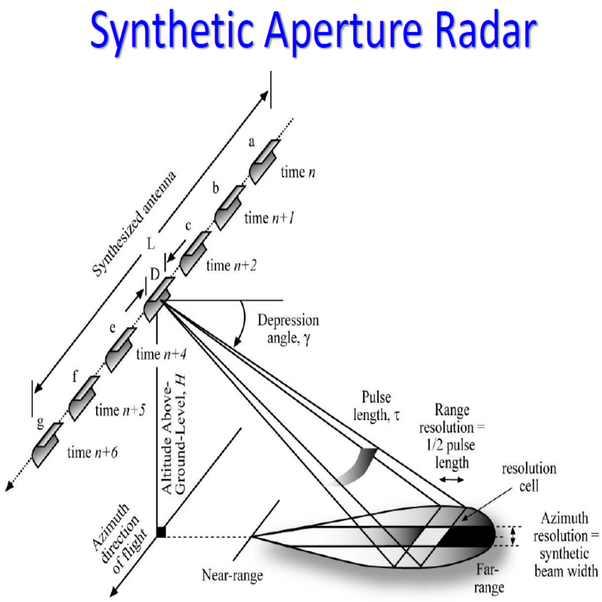
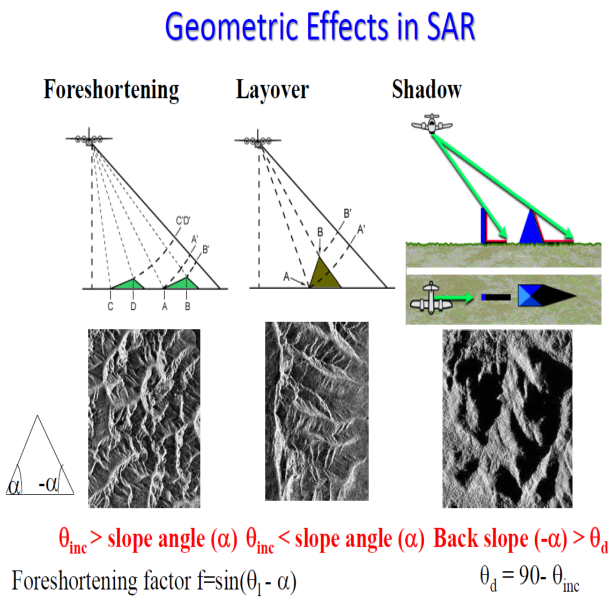
1. Abstract

Glaciers are important indicators of global warming and climate change in several ways. Melting ice sheets contribute to rising sea levels. As ice sheets in Antarctica and Greenland melt, they raise the level of the ocean.
Tons of fresh water are added to the ocean every day. So an important task becomes to study the properties of the glacier and the various features of the Glacier.
Since the study of these is not possible through physical contact as they are located in extreme weather conditions where humans cannot survive often remote sensing techniques are used to study them. Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object and thus is in contrast to on-site observation.



The term is applied especially to acquiring information about the Earth. One of the methods to do so is by using Polarimetric SAR (POLSAR) data and machine learning to extract the various features of a glacier. Our study includes the Gangotri Glacier which is located in Uttarkashi District, Uttarakhand, India in a region bordering Tibet. We have trained three models using POLSAR data and compared the results we get.
We have used two supervised learning models which are Maximum likelihood estimator, Random Forest classifier and one unsupervised learning model of K-Means clustering to classify the various prominent features of the Gangotri Glacier.



2. Introduction

Glaciers are made up of fallen snow that, over many years, compresses into large, thickened ice masses. Glaciers form when snow remains in one location long enough to transform into ice. What makes glaciers unique is their ability to flow. Due to sheer mass, glaciers flow like very slow rivers.

Some glaciers are as small as football fields, while others grow to be dozens or even hundreds of kilometers long. Presently, glaciers occupy about 10 percent of the world's total land area, with most located in polar regions like Antarctica, Greenland, and the Canadian Arctic.

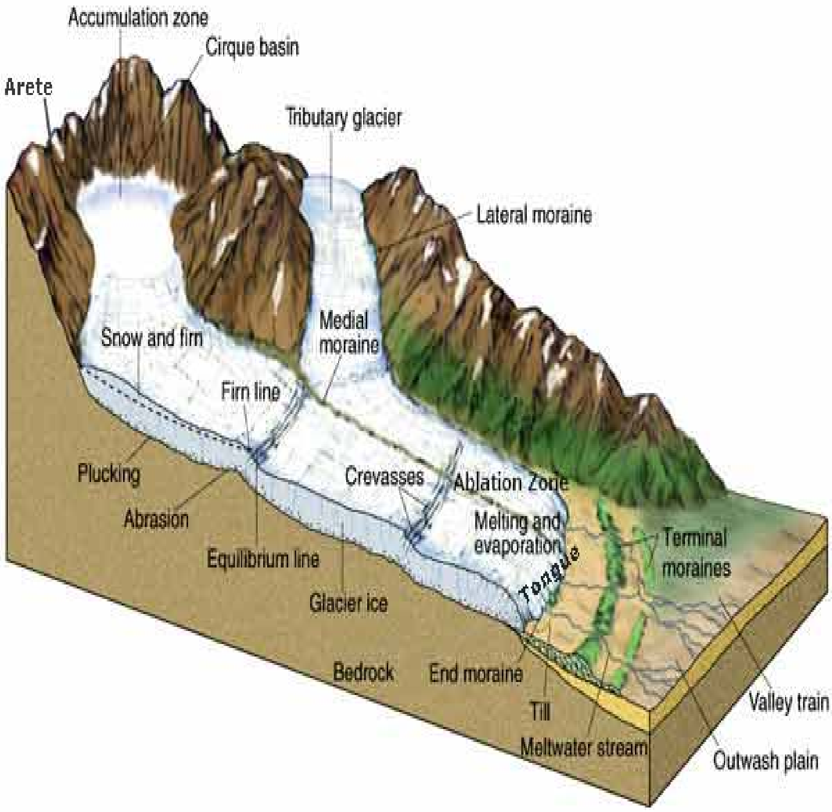
Glaciers are dynamic, and several elements contribute to glacier formation and growth. Snow falls in the accumulation area, usually the part of the glacier with the highest elevation, adding to the glacier's mass. As the snow slowly accumulates and turns to ice, and the glacier increases in weight, the weight begins to deform the ice, forcing the glacier to flow downhill.

Further down the glacier, usually at a lower altitude, is the ablation area, where most of the melting and evaporation occur. Between these two areas a balance is reached, where snowfall equals snowmelt, and the glacier is in equilibrium. Whenever this equilibrium is disturbed, either by increased snowfall or by excessive melting, the glacier either advances or retreats at more than its normal pace.

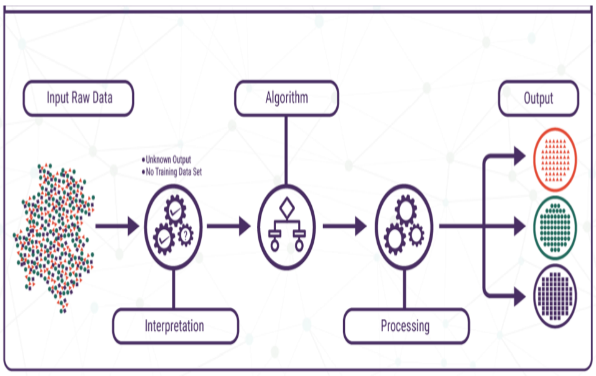
Several visible features are common to most glaciers. At locations where a glacier flows rapidly, friction creates giant cracks called crevasses, which may make travel across a glacier treacherous. Other common glacial features are moraines, created when the glacier pushes or carries rocky debris as it moves.

These long, dark bands of debris are visible on top and along the edges of glaciers. Medial moraines run down the middle of a glacier, lateral moraines along the sides, and terminal moraines are found at the terminus, or snout, of a glacier.

Sometimes one glacier flows into another, creating combined wider moraines. Often these linear deposits of rocks are left behind, almost intact, after the ice in a glacier has melted away. These features are of interest to us and to know about the glacier fully we must study them.



In the field of glaciology, satellite remote sensing allows us to conduct research on remote areas that are hard to access, and to gather data on a spatial extent not possible by fieldwork alone. Thus we use POLSAR data of the Gangotri Glacier located in Himalayas to classify the various features of the glacier.Data acquired by polarimetric SAR (POLSAR) are directly related to physical properties of natural media.



One of the most challenging applications of polarimetry in remote is natural media classification using fully polarimetric SAR images. The classification of POLSAR images, based on targets' backscattering properties, has been a subject of highest interest for the past years. The classification method though dealing with the scattering vectors, implementing targets decomposition to extract classification features is the most popular and effective means of classification currently.
We use three methods in this report, these are Random Forest Classifier, Maximum Likelihood estimator and K-means clustering after processing the data.

3. Method and Data Processing

There are 4 image files. To export data in snap we have to read the LED file and we read volume file for importing data in snap. So we go to snap to do the required processing.
We open snap and navigate to File->Import->SAR Sensors.
Now depending upon the type of data we select ALOS PALSAR CEOS or ALOS 2 CEOS. The type of data can be found by looking up the summary file. Then we give the path to our data and select the volume file to import it. Then we click on bands. There are 4 types of polarisation channel images,**HH HV VH VV**. These stand for horizontal horizontal,horizontal vertical,vertical horizontal,vertical vertical respectively.Then we select the data and select radar for radio calibaration.

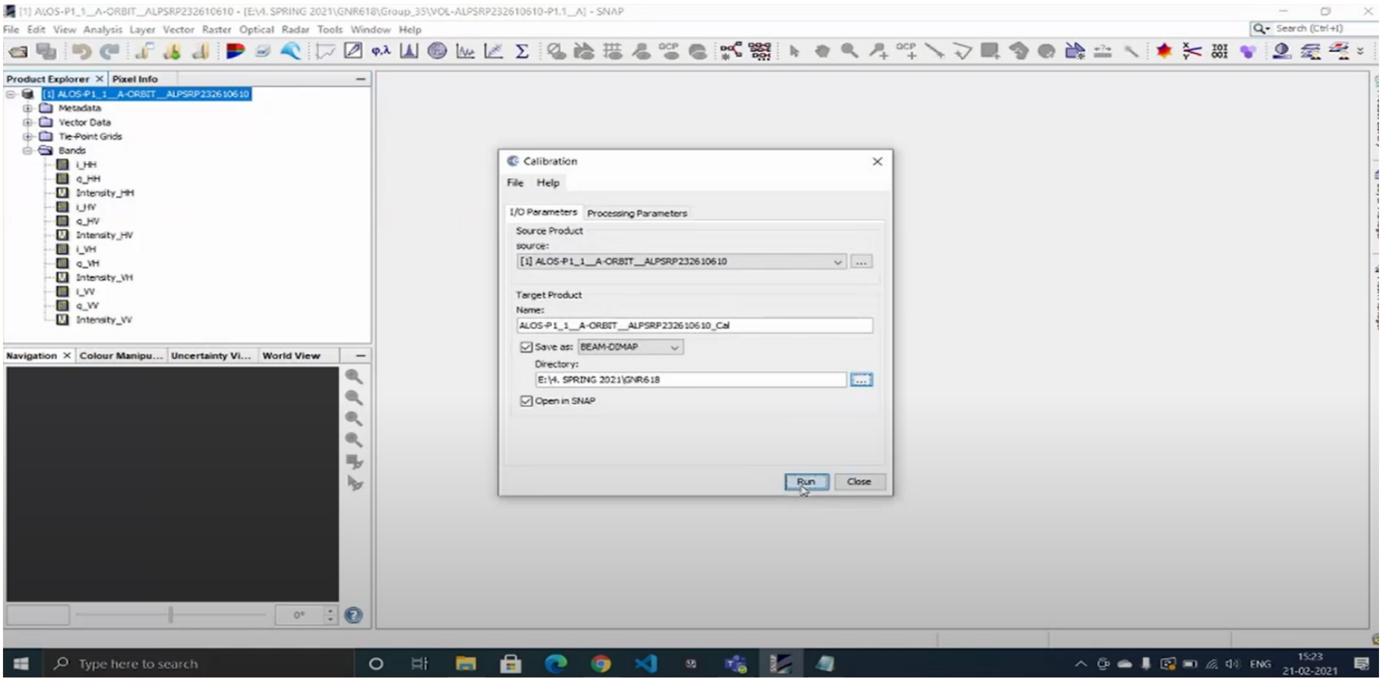


Figure 1 : Calibaration

The calibrated data is just the original data multiplied with calibration factor. After doing this,we have to save the data in complex output. After saving the data, we go to radar to generate polarimatric matrix. We have to generate the T3 matrix. After generating the T3 matrix,we get the band data.Then looking at the bands data, we see that we have 9 independent parameters(which includes real and imaginary). This is an advantage of converting the H to T matrix. T matrix has direct interpretation of target.

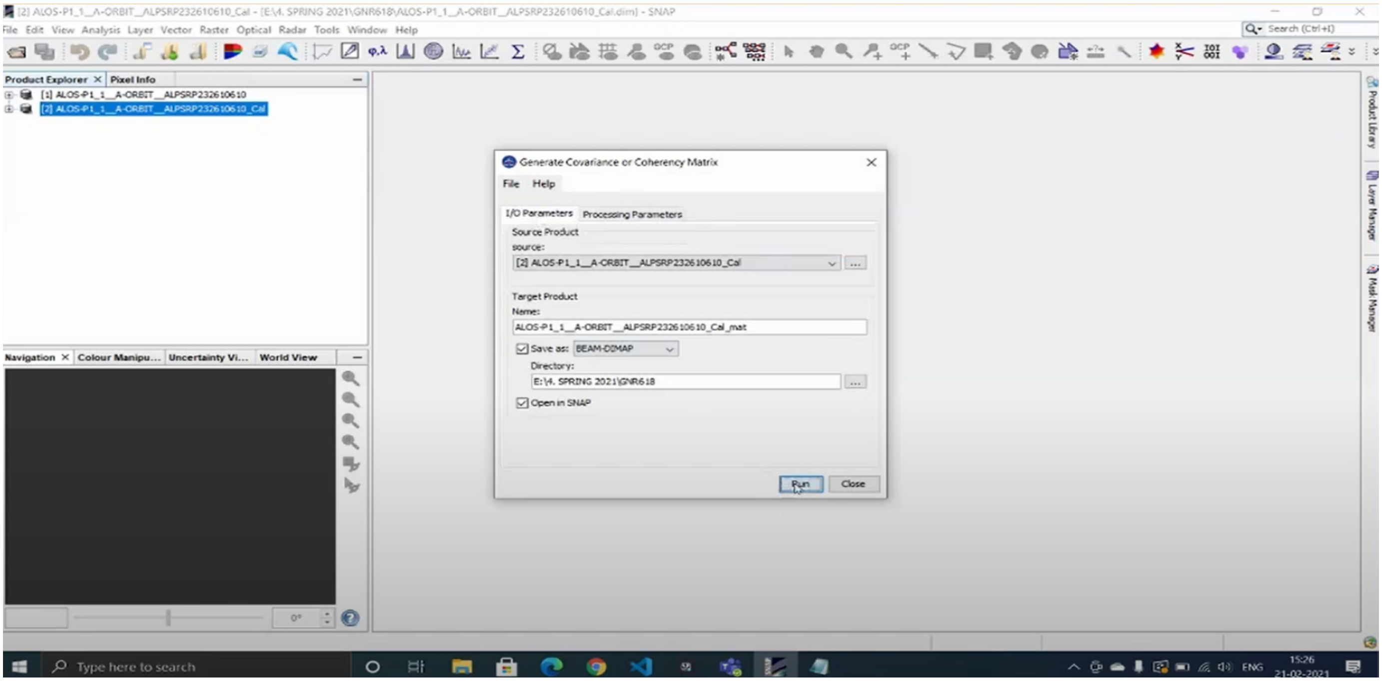


Figure 2 : Matrix Generation

But the data is in single look and we need to convert it to multilook. This is done by going to the radar tab and selecting multilooking. We keep the number of range look to be 2 and mean GR square pixels to be around 42. After this we can clearly see the difference in single look and multilook data. Multilook data is more clear. But this is without Terrain Correction.

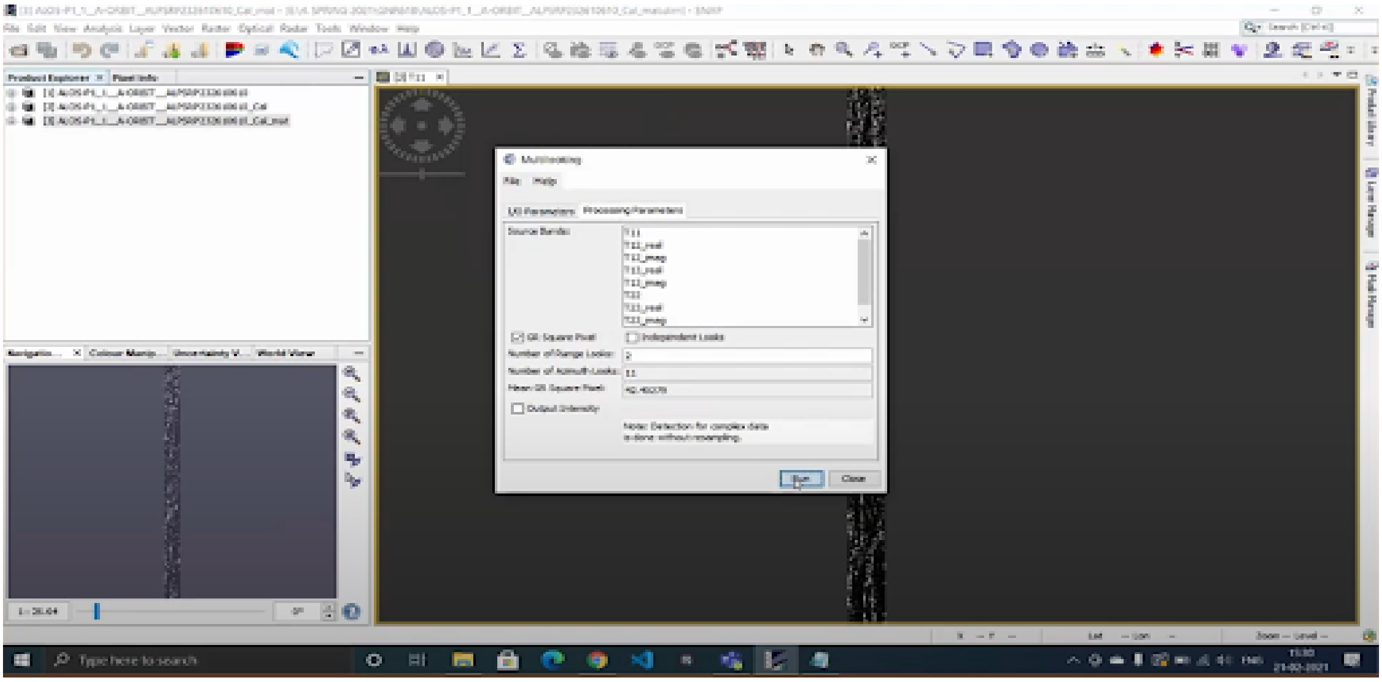


Figure 3 : Multilooking

Terrain correction is needed since we need to correct the geometric effect as the radar is looking sideways. The target at the top and the target at the bottom may have distance shortening when the image is acquired. This can be corrected by applying terrain correction.
Now we go to Radar->Geometric->Terrain Correction->Range Doppler Terrain Correction.

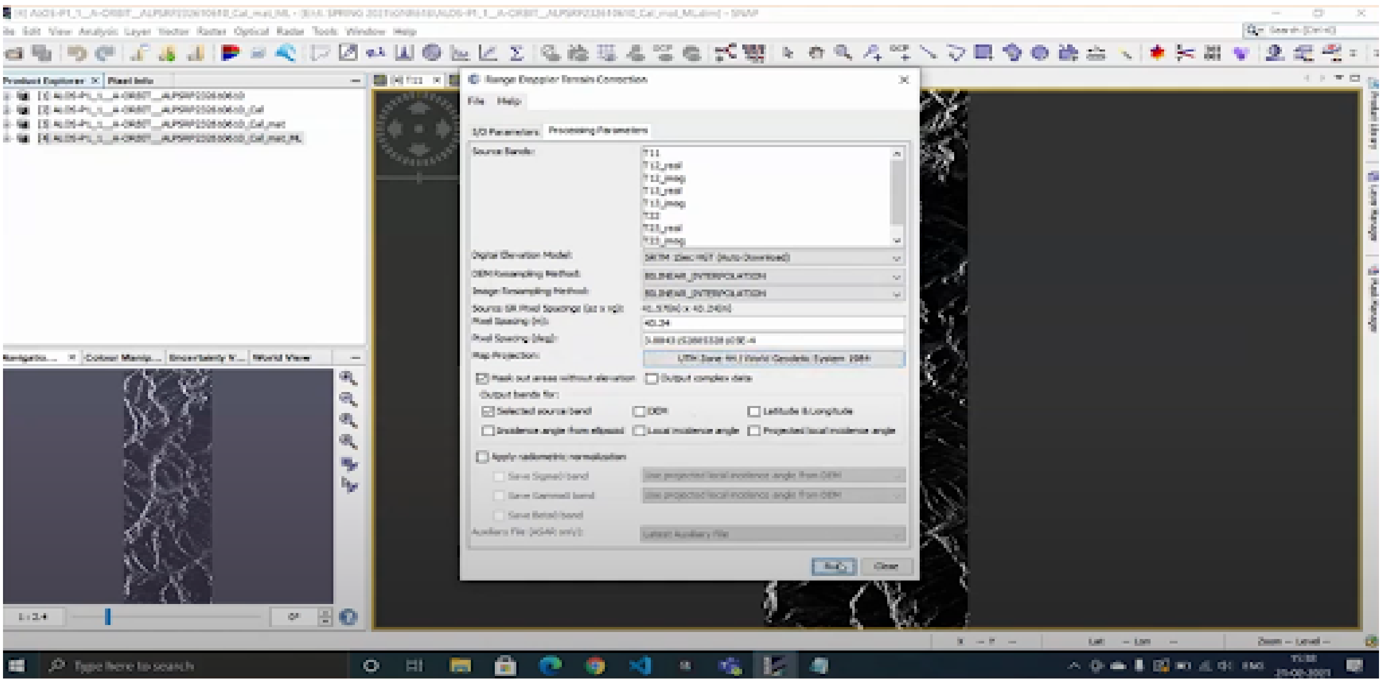


Figure 4 : Range Doppler Terrain Correction

Then SRTM 1 sec HGT (Auto download) can be selected based on internet connectivity . Map projection is selected as UTM/WGS. Then we export this terrain corrected data to PolSARpro for advanced polarimetric decomposition. This can take some time.

Once opened in SNAP, any product or image has a coordinate reference system which helps locating the product on the world map. There are multiple CRS, and the product can be projected to another system, even to define a new custom coordinate reference system.
For this we go to Radar -> Geometric Operations -> Reprojection.

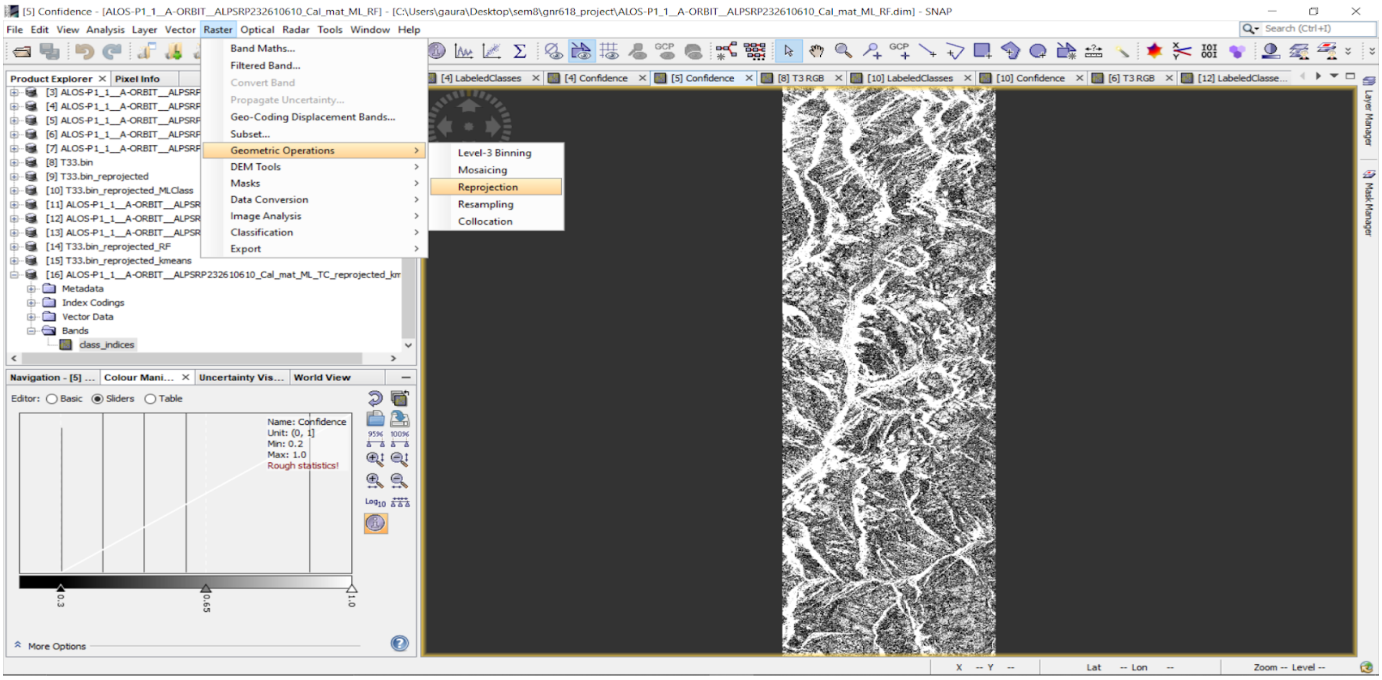


Figure 5 : Reprojection Step 1

And then we select the following parameters :

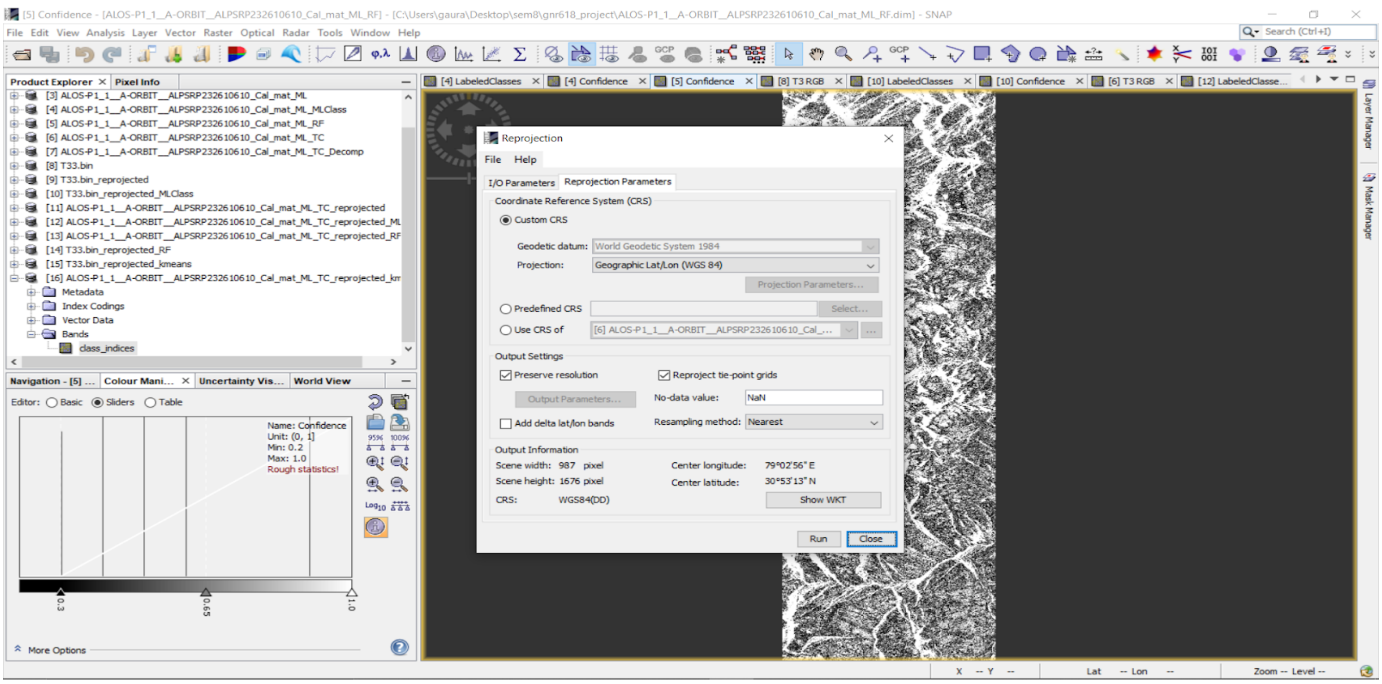


Figure 6 : Reprojection Step 2

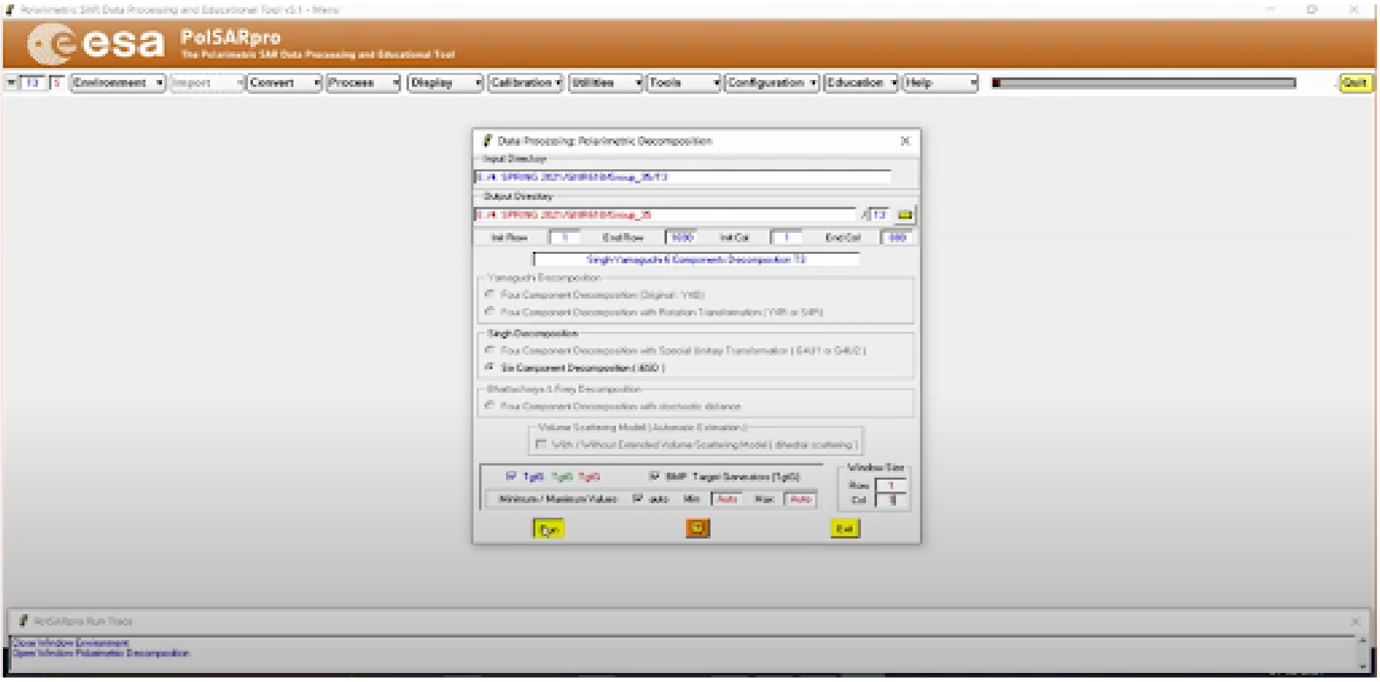


Figure 7 : Decomposition in POLSARPro

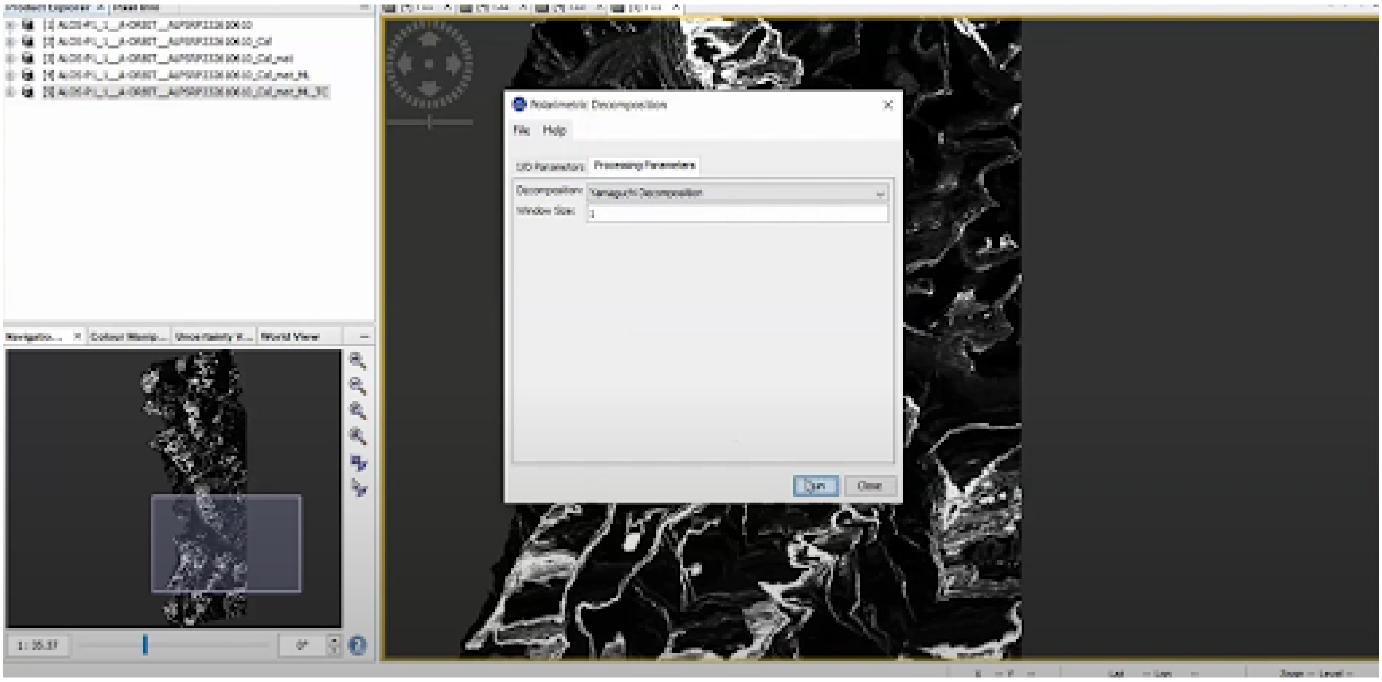


Figure 8 : Decomposition in SNAP

After loading the previous directory of the T3 matrix in POLSARPro, in the Process tab we select Polarimetric Decomposition and select iSSD. Selecting TgtG and BMP and keeping row and column size as 1, we run it.
For RGB we select Blue-> Odd. This is for surface.
Green-> Vol (Volume) and Red-> Dbl (Double Bounce). Then select common and run.
We get the the RGB colour coded image.
The blue area is therefore wet snow covered and the green area is debris covered.
We can thus identify different areas. After this we copy the 6 generated decompostion files (CD, Dbl, Hlx, OD, Odd , Vol) and paste in the original T3 file.

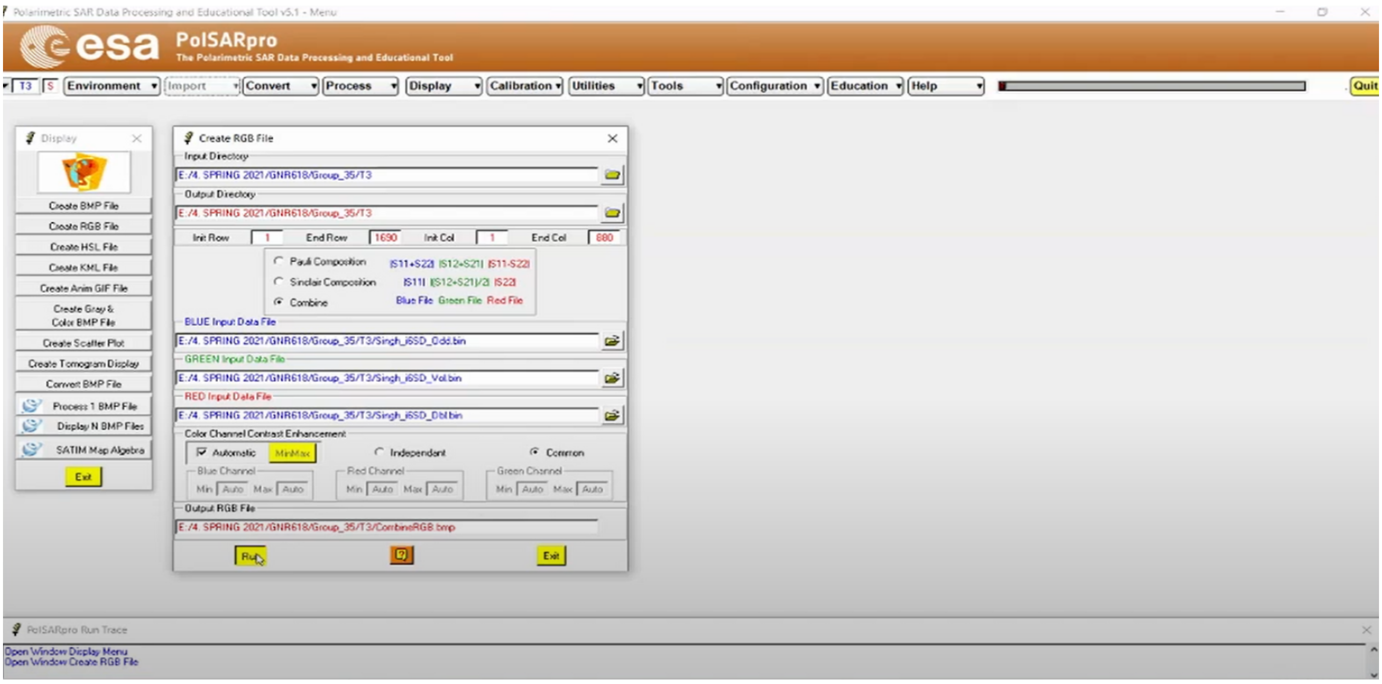


Figure 9 : RGB in POLSARPro

After copying and renaming the hdr T11 file 6 times with the names of the 6 decomposition files, we import them in SNAP.
After opening RGB window we give the same extensions to Red, Blue and Green as earlier.
Then in Raster-> Classification-> Unsupervised Classification-> K-Means Cluster Analysis, we select 5 clusters, 10 iterations we select all the 6 files.
For supervised classification we use vector and in new vector data we give name for eg:wet_snow (We select Dark Bluish area avoiding boundary areas). After doing this for other areas we do supervised classification in raster. Similarly, we created data containers for other glacier features such as debris covered area.

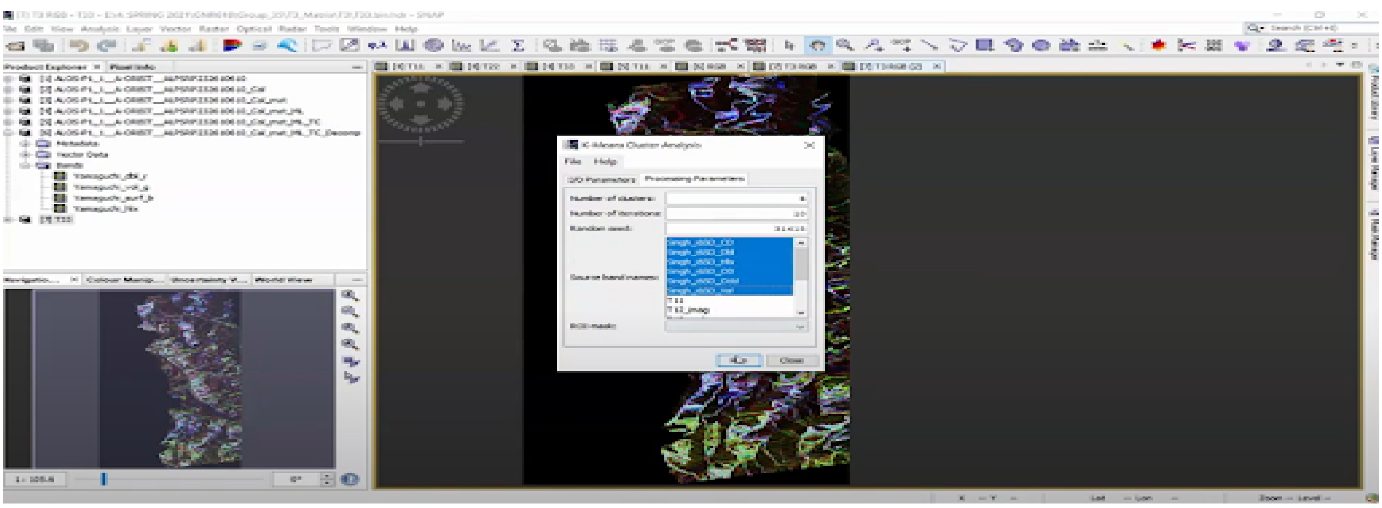


Figure 10 : K-Means Cluster Analysis

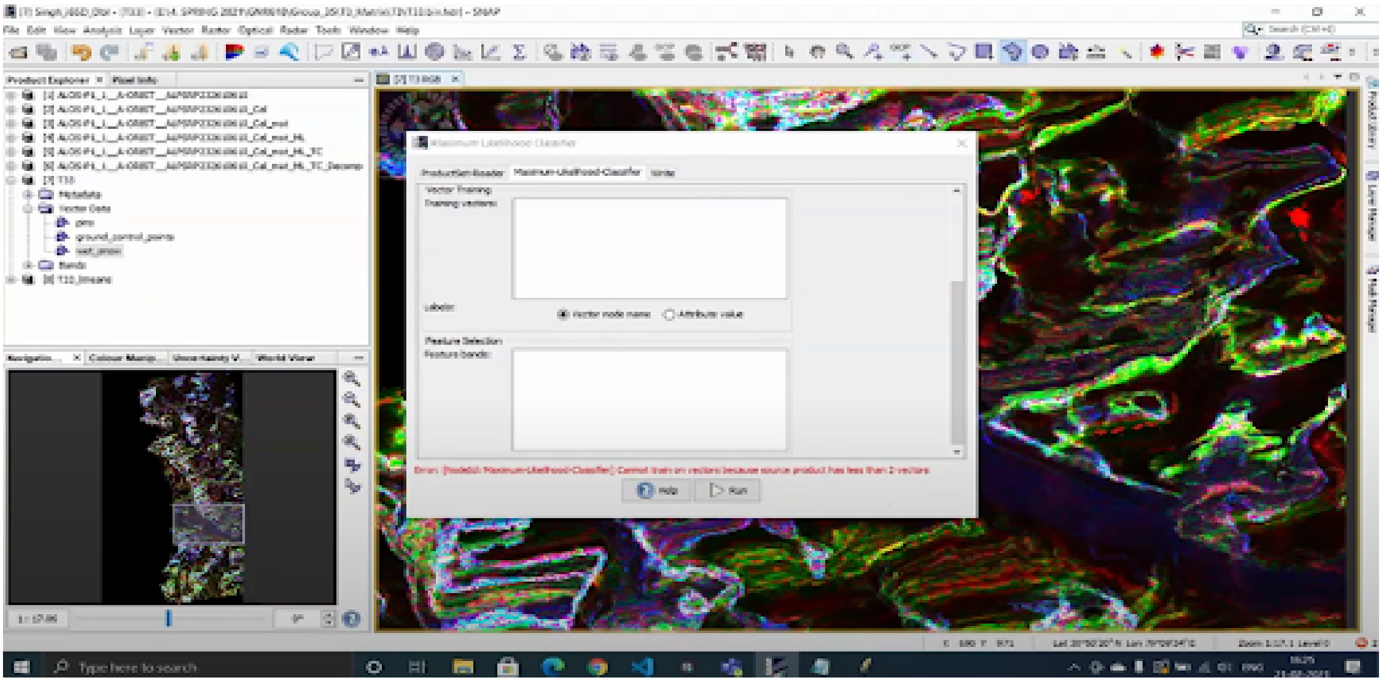


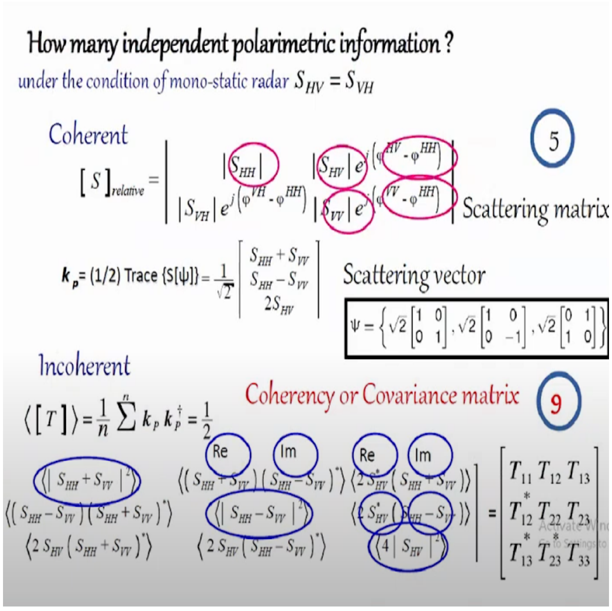
Figure 11 : Vectors

Explanation of few terms :
Polarization refers to the direction of travel of an electromagnetic wave vector's tip. It can be of various types such as :
1) Horizontal(H) - Electromagnetic wave vector's tip oscillates left to right.
2) Vertical(V) - Electromagnetic wave vector's tip oscillates top to bottom.
3) Circular - Rotating in a constant plane left or right.
The direction of polarization is defined by the orientation of the wave's electric field, which is always 90° or perpendicular to its magnetic field.
Electromagnetic waves with a well-defined polarization can be sent through specially designed radar antenna. By varying the polarization of the transmitted signal and receiving several different polarized images from the same series of pulses, SAR systems can gather detailed information on the polarimetric properties of the observed surface.
Now,
The four types of Polarisation Channel Images (HH,HV,VH,VV) simply tell us that :
HH - Horizontal waves transmitted, Horizontal waves received by the system.
HV - Horizontal waves transmitted, Vertical waves received by the system.
VH - Vertical waves transmitted, Horizontal waves received by the system.
VV - Vertical waves transmitted, Vertical waves received by the system.
Scattering Matrix :
When a horizontally or a vertically polarised wave is incident upon a target, the backscattered wave can have vertical or horizontal polarisations. The scattering matrix 'S' describes the backscattering properties of the target :

$$\begin{bmatrix} E_h^s \\ E_v^s \end{bmatrix} = \begin{bmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{bmatrix} \begin{bmatrix} E_h^i \\ E_v^i \end{bmatrix}$$

Here, i refers to incident wave and s refers to reflected wave. The 4 elements are complex. Having measured this matrix, the strength and polarization of the scattered wave for an arbitrary polarization of the incident wave can be computed. The 4 elements of the scattering matrix are complex. They can be measured from the magnitudes and phases measured by the four channels of a polarimetric radar.

Coherent and Incoherent Matrices :
They are defined as shown in the picture. As a result, the elements of the T3 Matrix are generated.



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4. Study Area

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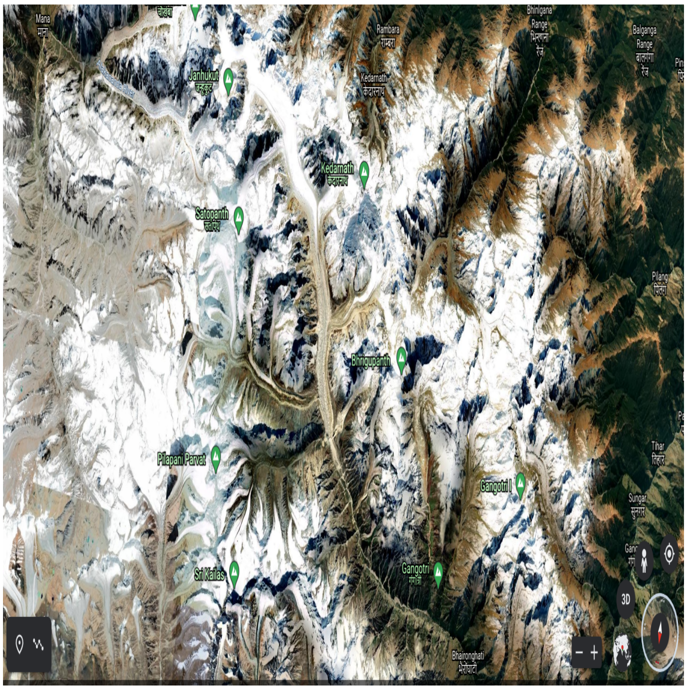
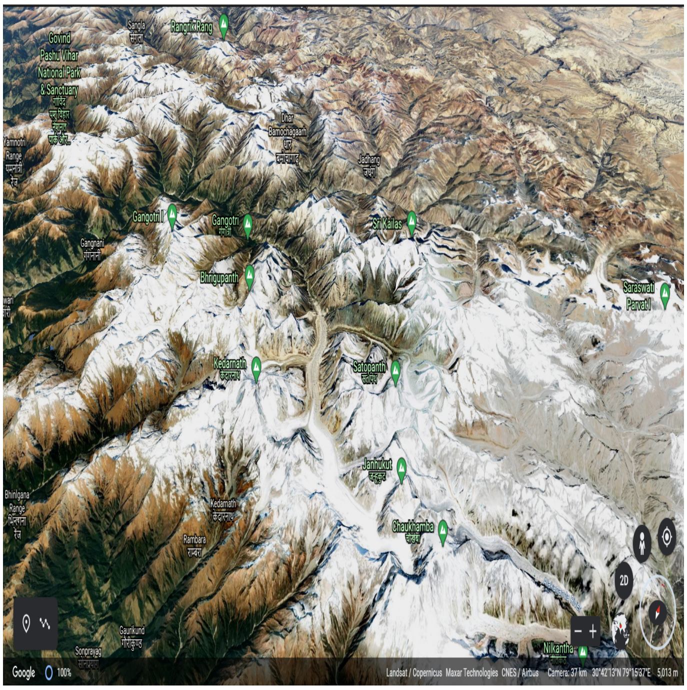
Study area of our project is Gangotri Glacier, the longest glacier in the Indian Himalaya. It is located in Uttarkashi District, Uttarakhand, India in a region bordering Tibet. This glacier is bound between 30°43'22"–30°55'49" (lat.) and 79°4'41"–79°16'34" (long.), extending in height from 4120m to 7000m above sea level.



The glacier is composed of a variety of depositional features such as talus cones, snow-avalanche fans, snow-bridges, and dead ice mounds and erosional features like pyramidal and conical peaks, serrated ridge crests, glacial troughs, smooth rock walls, crags and tails, waterfalls, rock basins, gullies and glacial lakes. All along the Gangotri glacier, several longitudinal and transverse crevasses are formed along which ice blocks have broken down.
The ablation zone of the Gangotri glacier is covered by a thick pile of supraglacial moraines and is characterized by several ice sections, melting into pools of supraglacial lakes. Because of subsidence and the fast

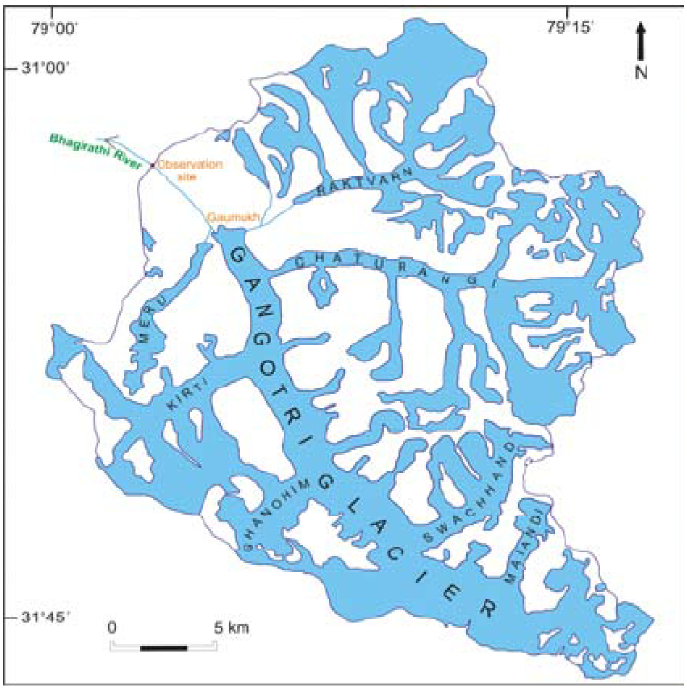
degenerating nature of the glacier, its centre is full of supraglacial lakes. In this part of higher Himalaya, glacial melt-water dominates the fluvial system.

Glacier's main trunk is 26 km long, and the overall ice surface of Gangotri Glacier and its tributaries covers an area of a little more than 200 km2 . It is estimated to contain about 20 km3 of ice. Its meltwater stream becomes a high-volume river after emerging from a sub-glacier tunnel at the glacier terminus — the holy "Gaumukh" (cow's mouth) of Hindu mythology. Kedarnath Temple is also situated in this area which is also an important religious place of Hindus.



The river coming from the Gangotri Glacier is called Bhāgīrathi River, and it is considered to be the primary source of the Ganga (Ganges River). All of the glaciers in the Gangotri area receive nourishment from the monsoon and westerly winter precipitation.

The overall geosystem is made up of various small glaciers as well as mountains, rivers and many valleys. Other important glaciers in the area are Chaukhamba, Janhukut, Satopanth, Bhrigupanth and Ragrik Rang. Major rivers in the area which contribute to the Bhagirathi river are Maindi, Swachand, Ganohim, Kirti, Raktavarn, Chaturangi and Medu.



The glacier originates from the south direction from the Chaukhamba area. It moves towards the north direction and meets other rivers. All the area is mostly covered by dry or wet snow. Glaciers also contain

debris in them.
Yamunotri mountain range in which the Yamuna river originates is in the north direction. This area has a very low population due to extreme weather conditions. But, this area is amongst one of the favorite destinations in India because of religious importance as well as beautiful natural scenery.

5. Results and Discussion

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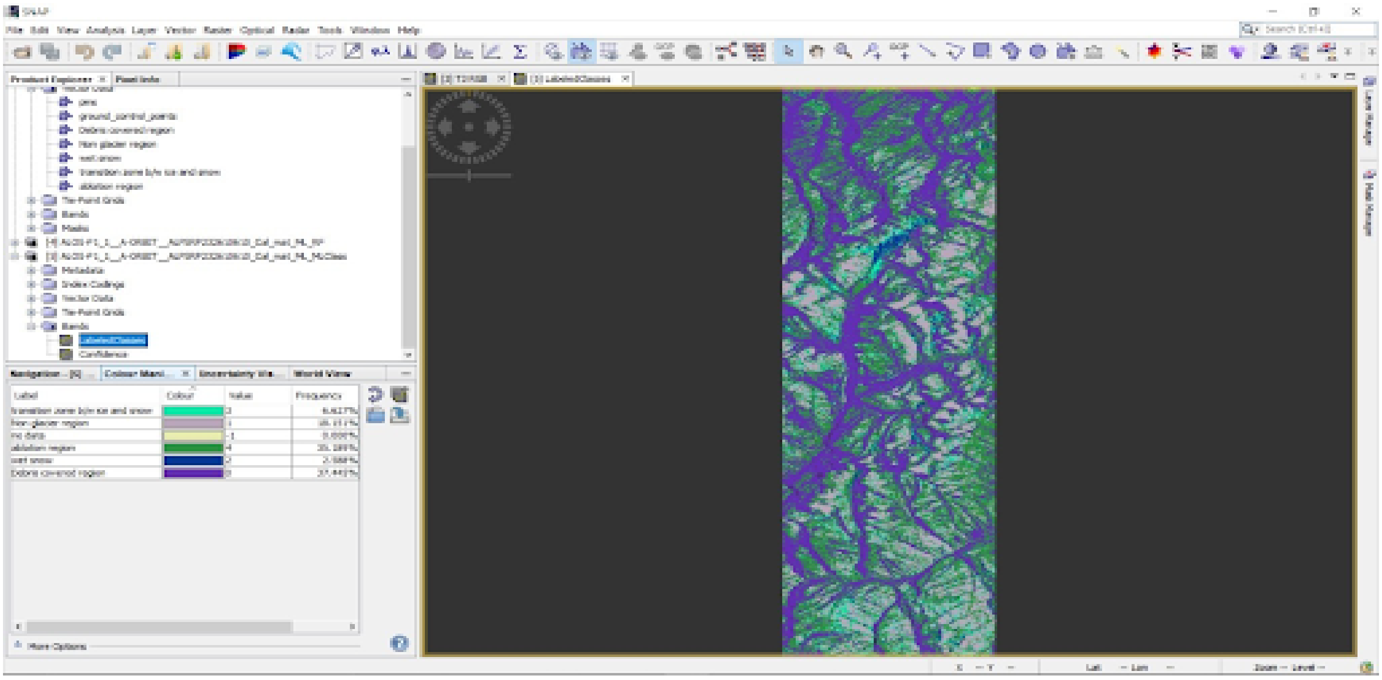
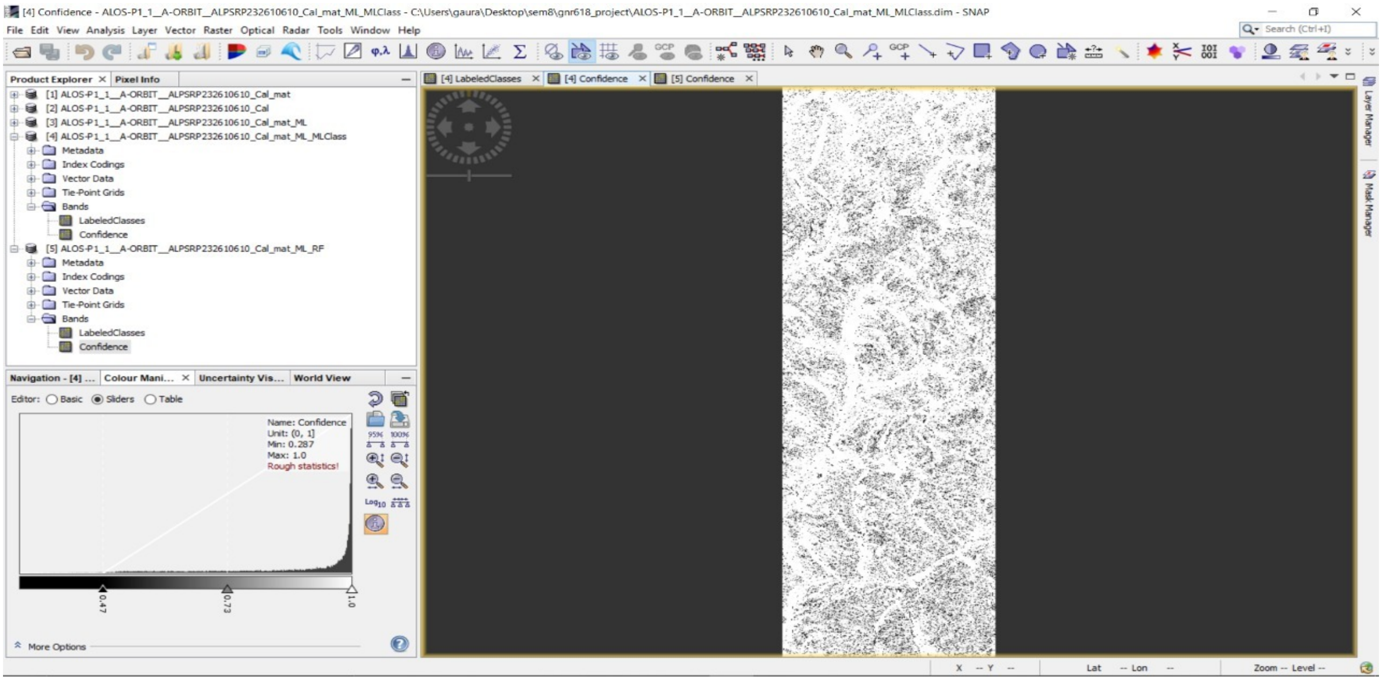
We have used the data to train three models. These models are the Maximum Likelihood Classifier, Random Forest Classifier and Unsupervised Classifier.
First we train on the multilook data without terrain correction then terrain corrected data without decomposition and then we train on the terrain corrected data with Singh Yamaguchi decomposition of the Gangotri glacier and the vector data containers that we created.
1) Multilook Data : On training the Maximum Likelihood Classifier on multilook data without terrain correction we get the following image as result :



Maximum Likelihood Classifier on Multilook Data

We can observe that the model has classified the five classes :
Wet Snow Region (Deep Violet colored area), Ablation Region (Dark Green colored area), Debris Covered Region of Glacier (Blue-Violet colored area), Non Glacial Region (Pink colored area), Transition Zone (Light Green colored area).
Frequency of these classes are 2.588%, 35.189%, 37.445%, 18.151% and 6.627% respectively. This model predicts almost the same frequencies for Ablation Region and Debris Covered Area, higher than others.

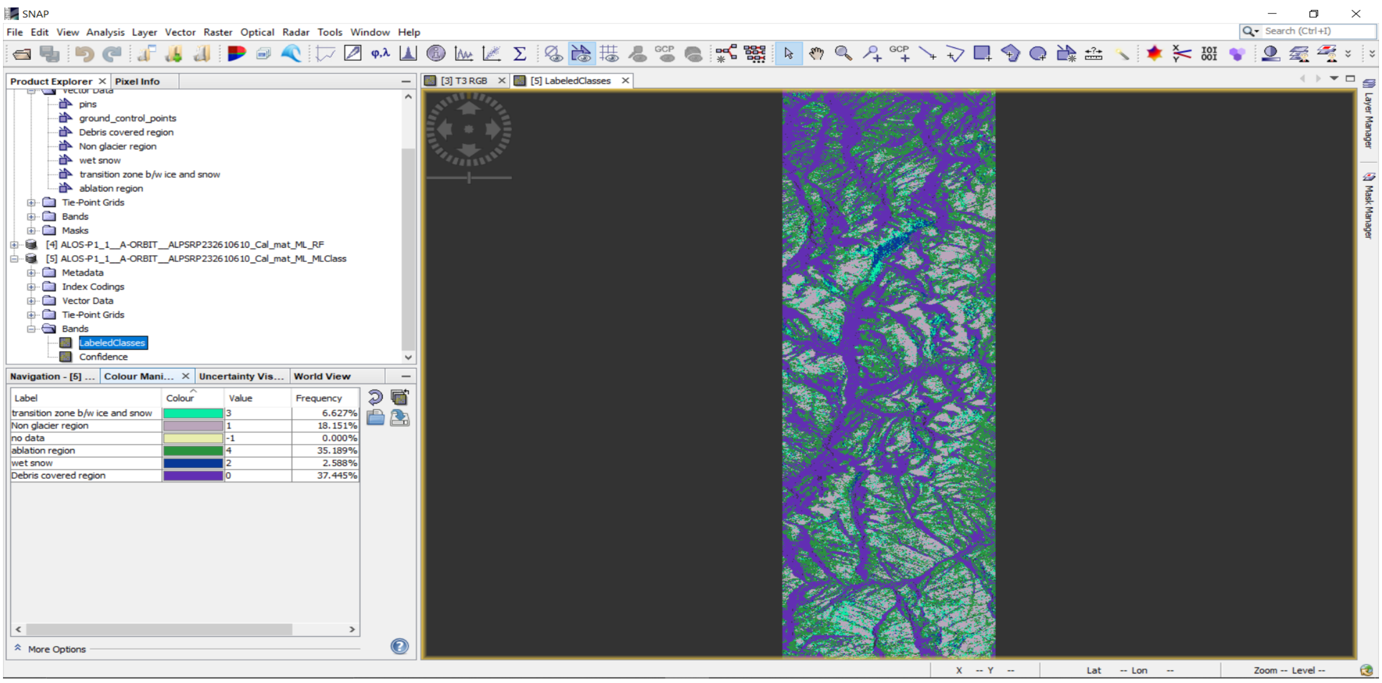
The confidence with which the model predicts the class at each region in the image is given by the following image :



Confidence : Maximum Likelihood Classifier on Multilook Data

As we can see in the image most of the region is white which indicates the confidence level of prediction of our model is very high in all the regions. The min confidence we get is 0.287 and the max confidence we get is 1.00. The most of the region is above 0.9 as we can see in the graph that the peak is very close to 1.

On training the Random Forest Classifier on multilook data without terrain correction we get the following image as result :

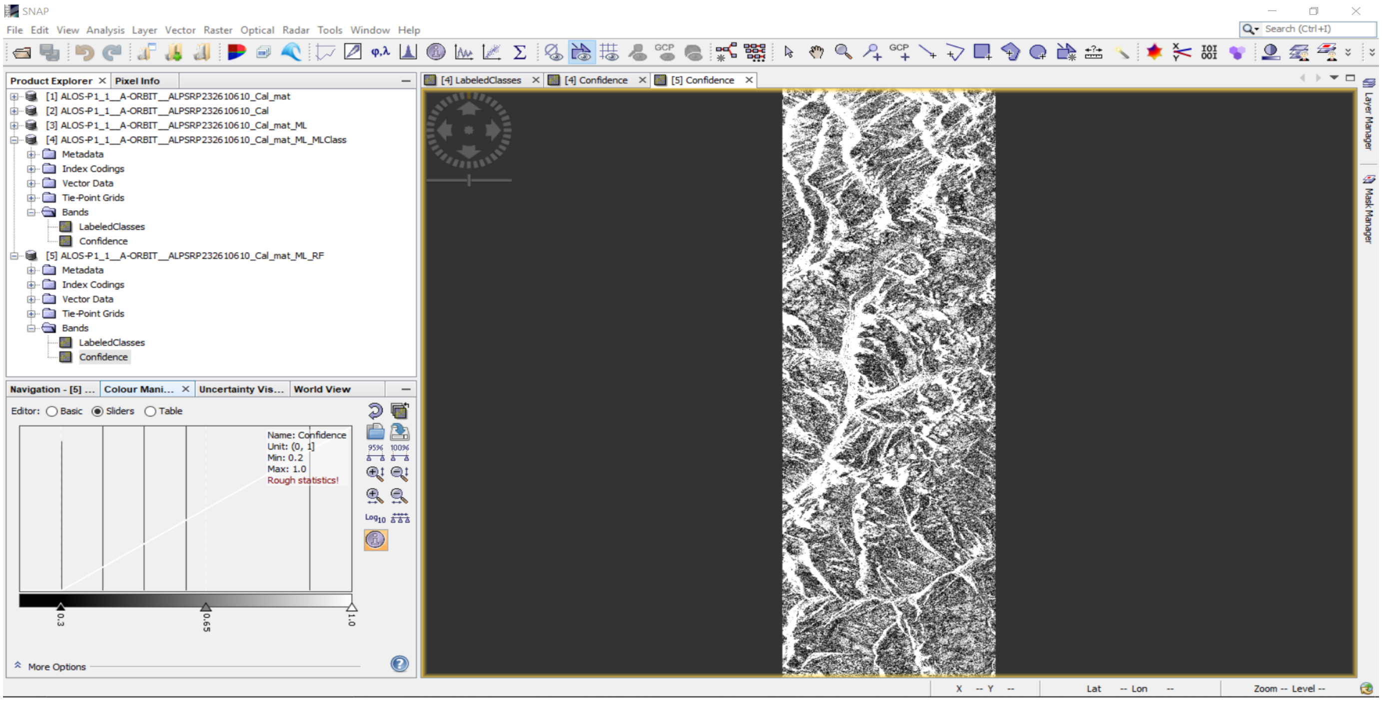


Random Forest Classifier on Multilook Data

We can observe that the model has classified the five classes : Wet Snow Region (Deep Violet colored area) , Ablation Region (Dark Green colored area), Debris Covered Region of Glacier (Blue-Violet colored area), Non Glacial Region (Pink colored area) and Transition Zone (Light Green colored area).

Frequency of these classes are 4.802%, 21.751%, 46.009%, 25.139% and 2.300% respectively. This model predicts higher frequency for Debris Covered Area than others.

The confidence with which the model predicts the class at each region in the image is given by the following image :



Confidence : Random Forest Classifier on Multilook Data

We can observe that the confidence levels are low for most of the regions. Moreover the confidence levels are discrete. So we can say that the model is not that confident in the class which it predicts. The max confidence we get is 1.00 and the min confidence we get is 0.2.
For Random Forest Classifier on Multilook Data, we get following metrics :

*random forest classfier data.txt - Notepad
File Edit Format View Help

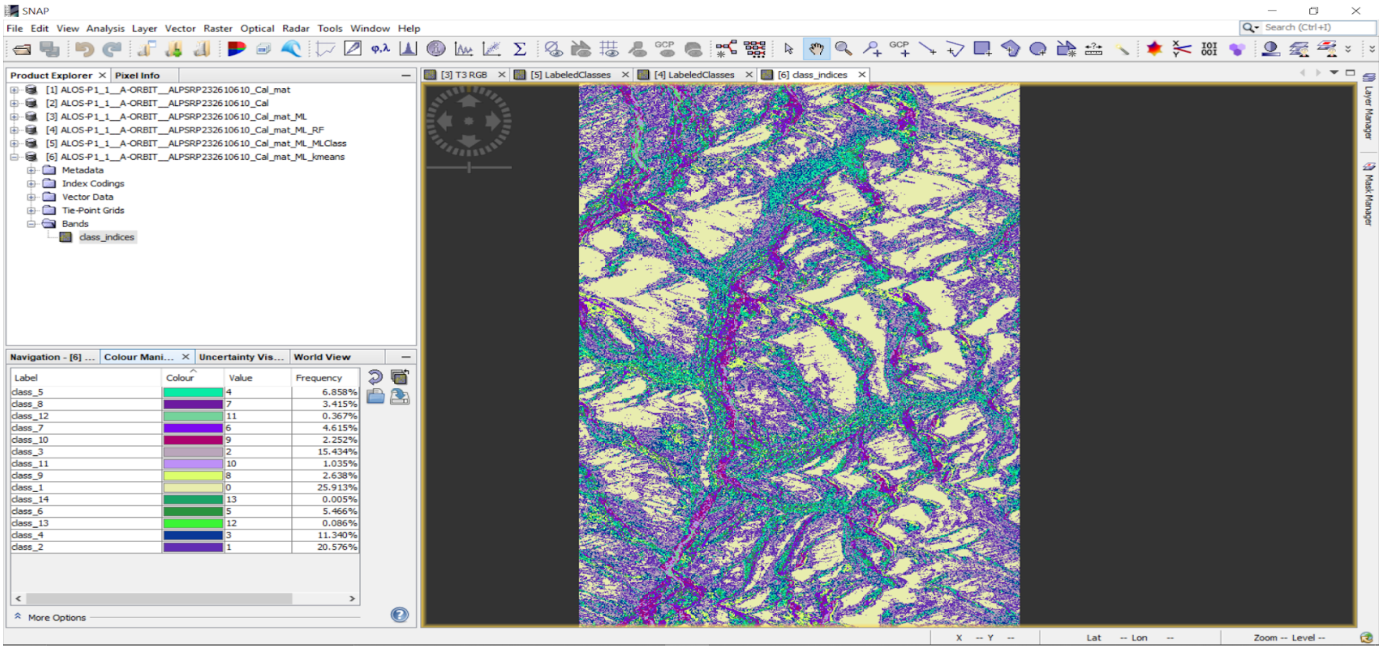
```
RandomForest classifier newClassifier

Cross Validation
Number of classes = 4
   class 0.0: wet snow
    accuracy = 0.9256 precision = 0.8686 correlation = 0.8544 errorRate = 0.0744
    TruePositives = 410.0000 FalsePositives = 62.0000 TrueNegatives = 685.0000 FalseNegatives = 26.0000
   class 1.0: transition zone b/w ice and snow
    accuracy = 0.9256 precision = 0.7949 correlation = 0.7185 errorRate = 0.0744
    TruePositives = 124.0000 FalsePositives = 32.0000 TrueNegatives = 971.0000 FalseNegatives = 56.0000
   class 2.0: Debris covered region
    accuracy = 0.9882 precision = 0.9923 correlation = 0.9737 errorRate = 0.0118
    TruePositives = 388.0000 FalsePositives = 3.0000 TrueNegatives = 781.0000 FalseNegatives = 11.0000
   class 3.0: Non glacier region
    accuracy = 0.9797 precision = 0.9390 correlation = 0.9177 errorRate = 0.0203
    TruePositives = 154.0000 FalsePositives = 10.0000 TrueNegatives = 1005.0000 FalseNegatives = 14.0000

Using Testing dataset, % correct predictions = 90.9552
Total samples = 2369

Distribution:
   class 0.0: wet snow                           873      (36.8510%)
   class 1.0: transition zone b/w ice and snow   361      (15.2385%)
   class 2.0: Debris covered region              799      (33.7273%)
   class 3.0: Non glacier region                 336      (14.1832%)
```

Then, we trained the Unsupervised Classifier model with the same dataset and got the following information as result :

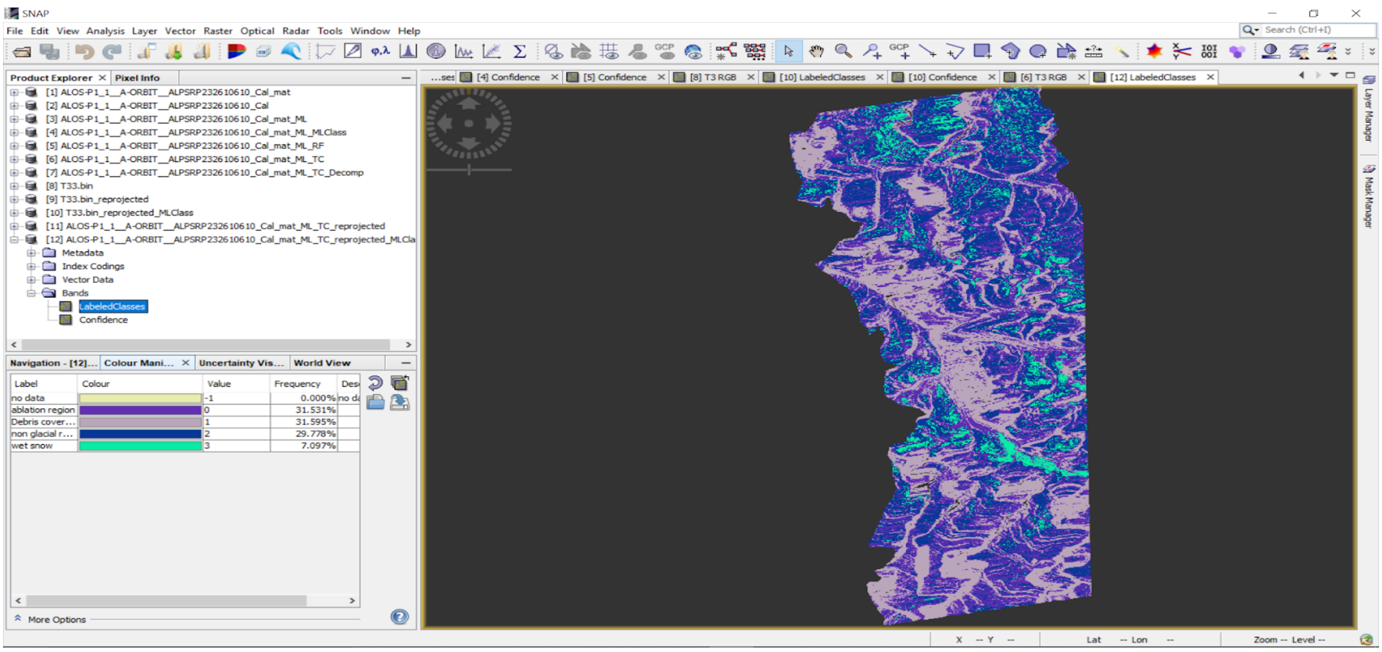


Unsupervised Classifier on Multilook Data

We can observe that this classier has classified the data in multiple classes generated by itself. It has further breaked the supervised classes into two or three classes. Unsupervised Classifier predicts more classes according to diversities in supervised classes.

2) Terrain Corrected Data without Decomposition :

On training the Maximum Likelihood Classifier on the terrain corrected data without decomposition we get the following image as the result :

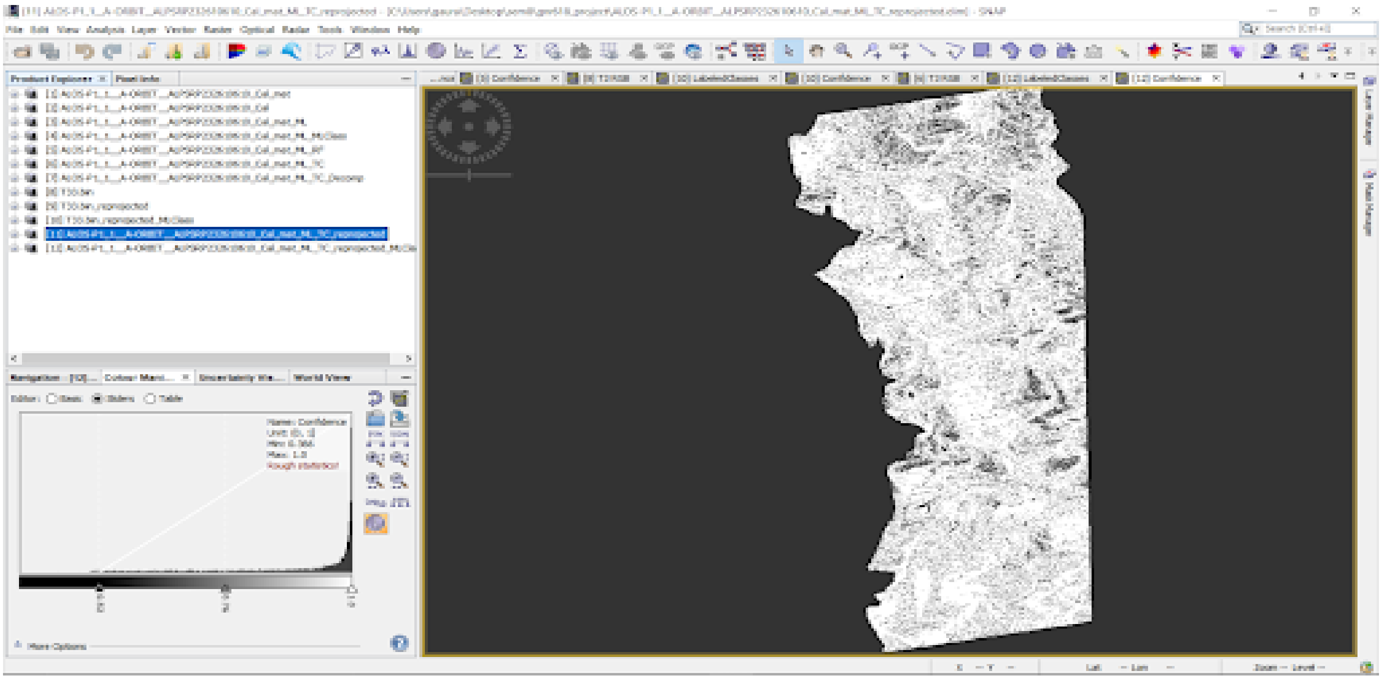


Maximum Likelihood Classifier on Terrain Corrected Data without Decompostion

As we can see in the image we can see the model has classified the four classes - Wet Snow Region (Greenish coloured area) , Ablation Region (Blue-Violet coloured area), Debris Covered Region of Glacier (Pink coloured area) and Non Glacial Region (Deep violet coloured area).

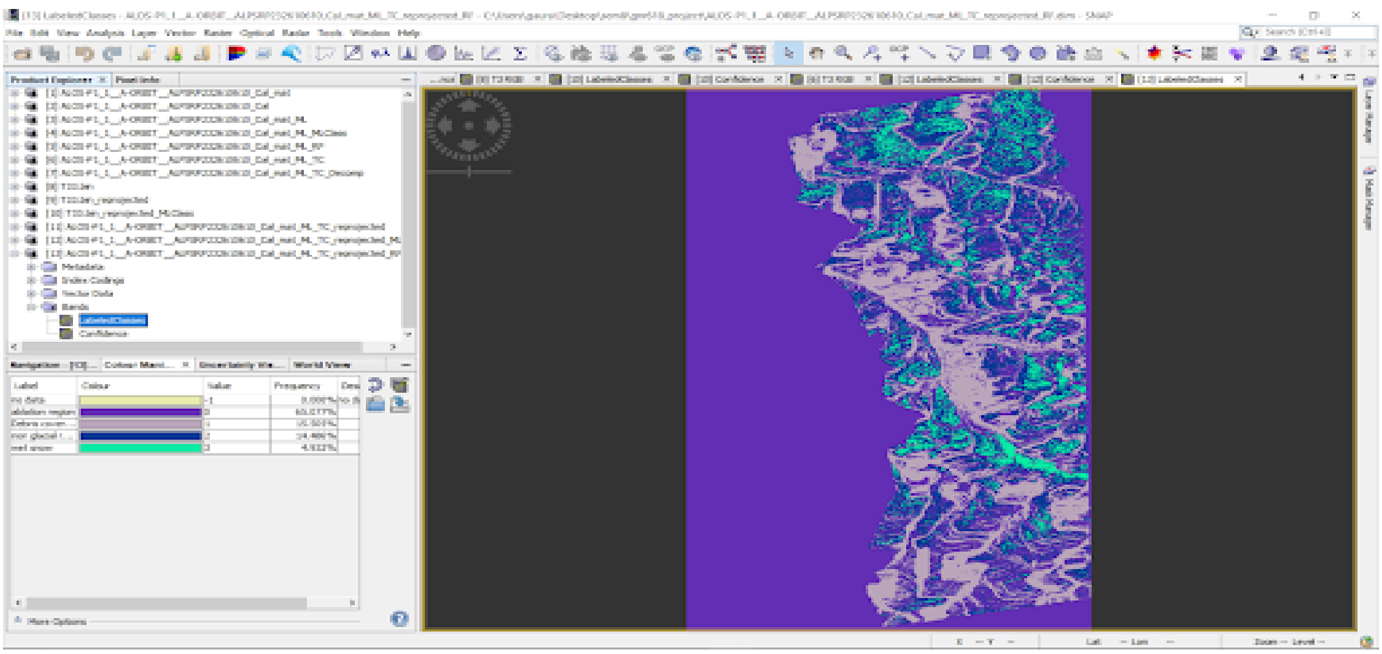
Frequency of these classes are 7.097%, 31.531%, 31.595% and 29.778% respectively. This model predicts almost the same frequencies for Ablation Region, Debris Covered Area and Non Glacial Region.

The confidence with which the model predicts the class at each region in the image is given by the following image :



Confidence : Maximum Likelihood Classifier on Terrain Corrected Data without Decomposition

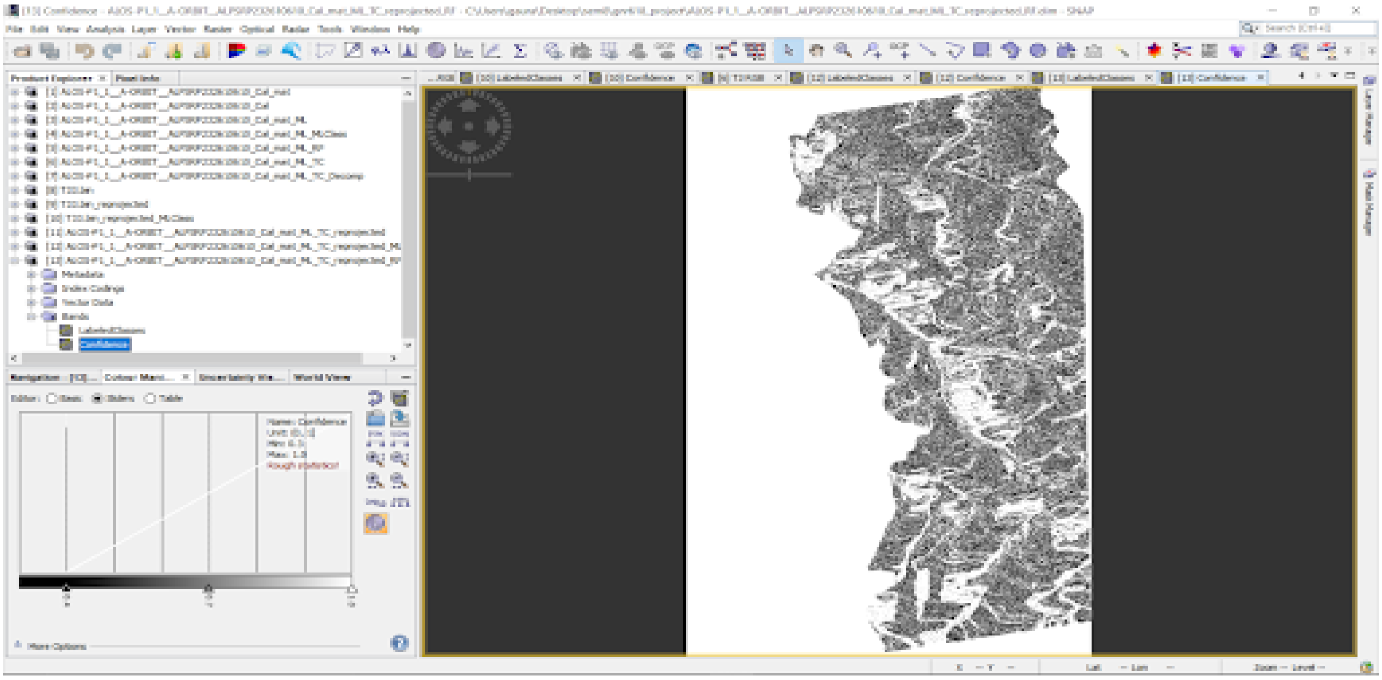
As we can see in the image most of the region is white which indicates the confidence level of prediction of our model is very high in all the regions. The min confidence we get is 0.366 and the max confidence we get is 1.00. The most of the region is above 0.9 as we can see in the graph that peak is very near to 1. On training the Random Forest classifier on the same terrain corrected data without decomposition we get the following classified image :



Random Forest Classifier on Terrain Corrected Data without Decomposition

We can observe that the model has been classified into four classes - Wet Snow Region (Greenish coloured area) , Ablation Region (Blue-Violet coloured area), Debris Covered Region of Glacier (Pink coloured area) and Non Glacial Region (Deep violet coloured area).
Frequency of these classes are 4.932%, 65.077%, 15.505% and 14.486% respectively. This model predicts higher frequency for the Ablation Region than other regions.

The confidence with which the model predicts the class at each region in the image is given by the following image :



Confidence : Random Forest Classifier on Terrain Corrected Data without Decomposition

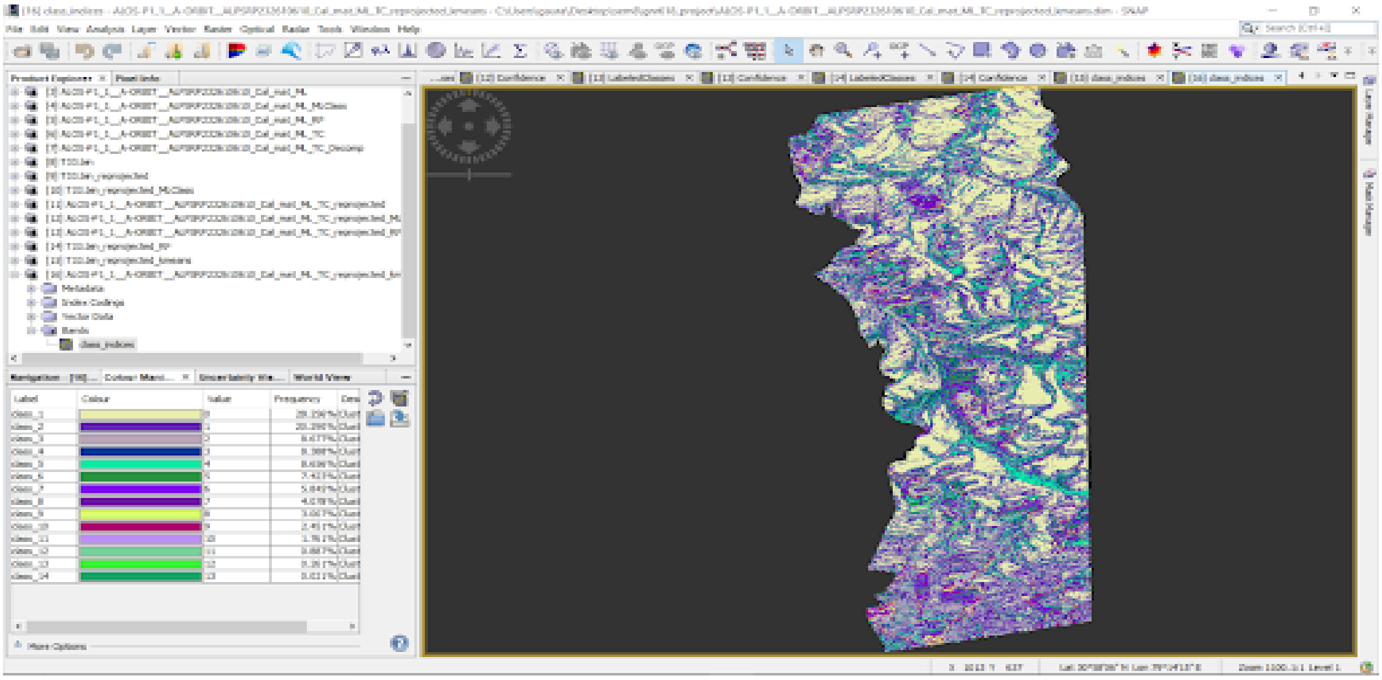
In this model we can see the confidence levels are low for most of the regions. Moreover the confidence levels are discrete. So we can say that the model is not that confident in the class which it predicts. The max confidence we get is 1.00 and the min confidence we get is 0.3.
For Random Forest Classifier on Terrain Corrected Data without Decomposition, we get following metrics :

```
Number of classes = 4
   class 0.0: ablation region
    accuracy = 0.9255 precision = 0.8268 correlation = 0.8018 errorRate = 0.0745
    TruePositives = 148.0000 FalsePositives = 31.0000 TrueNegatives = 585.0000 FalseNegatives = 28.0000
   class 1.0: Debris covered region
    accuracy = 0.9533 precision = 0.9296 correlation = 0.9008 errorRate = 0.0467
    TruePositives = 251.0000 FalsePositives = 19.0000 TrueNegatives = 504.0000 FalseNegatives = 18.0000
   class 2.0: non glacial region
    accuracy = 0.9684 precision = 0.9091 correlation = 0.8831 errorRate = 0.0316
    TruePositives = 110.0000 FalsePositives = 11.0000 TrueNegatives = 657.0000 FalseNegatives = 14.0000
   class 3.0: wet snow
    accuracy = 0.9912 precision = 0.9865 correlation = 0.9783 errorRate = 0.0088
    TruePositives = 219.0000 FalsePositives = 3.0000 TrueNegatives = 566.0000 FalseNegatives = 4.0000

Using Testing dataset, % correct predictions = 91.9192
Total samples = 1586

Distribution:
   class 0.0: ablation region          353     (22.2573%)
   class 1.0: Debris covered region    538     (33.9218%)
   class 2.0: non glacial region       249     (15.6999%)
   class 3.0: wet snow                 446     (28.1211%)
```

Then, we trained the Unsupervised Classifier model with the same dataset and got the following information as result :



Unsupervised Classifier on Terrain Corrected Data without Decomposition

We can observe that this classier has classified the data in multiple classes generated by itself. It has further breaked the supervised classes into two or three classes. Unsupervised Classifier predicts more classes according to diversities in supervised classes.

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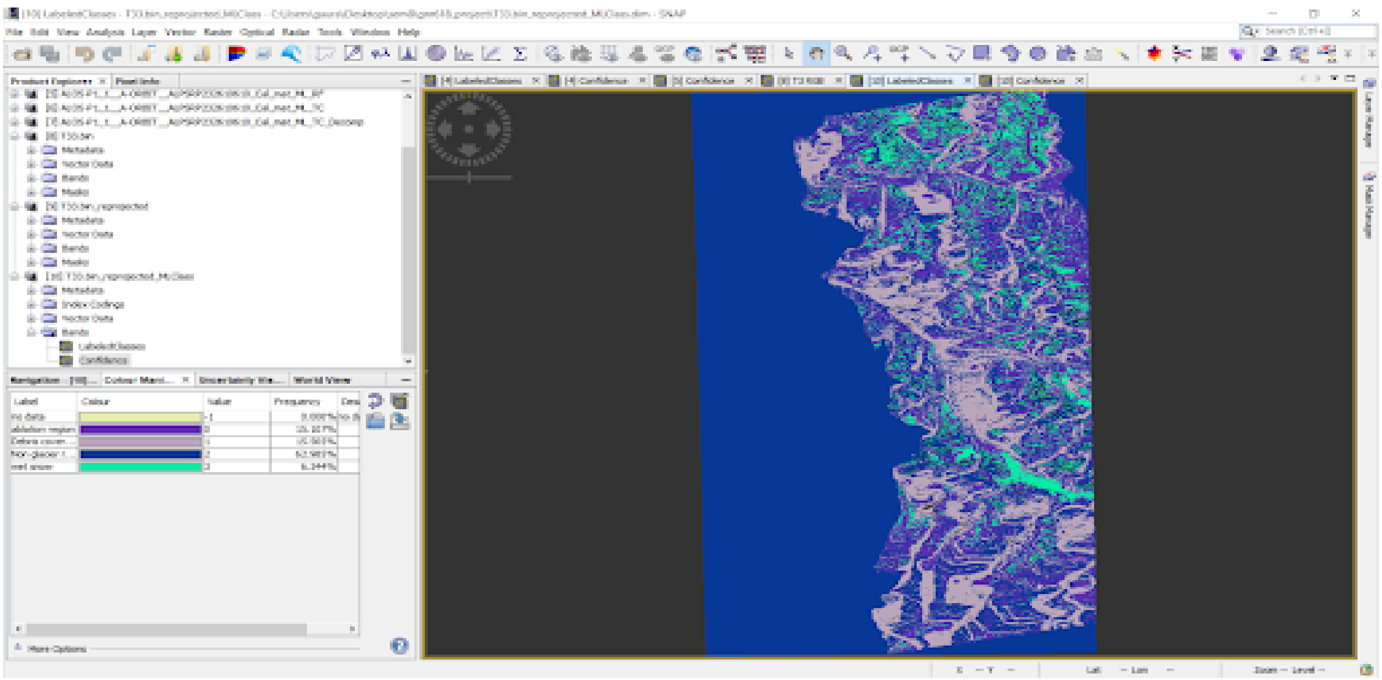
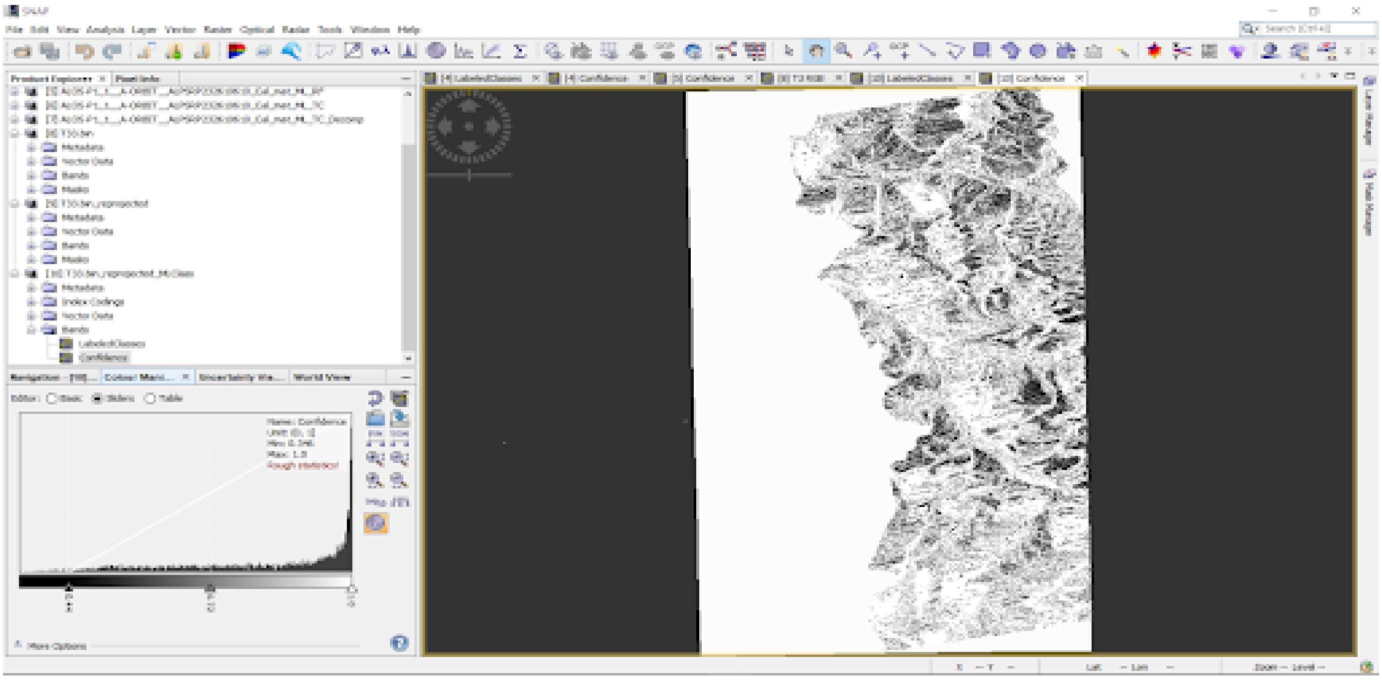
3) Terrain Corrected Data with Decomposition :
Now after decomposing the terrain corrected data using Singh-Yamaguchi Decomposition using PolSARPro Software and training the model on these data we get the following results.
On training the Maximum Likelihood classifier we get the following the image as the result :



Maximum Likelihood Classifier on Terrain Corrected Data with Decomposition

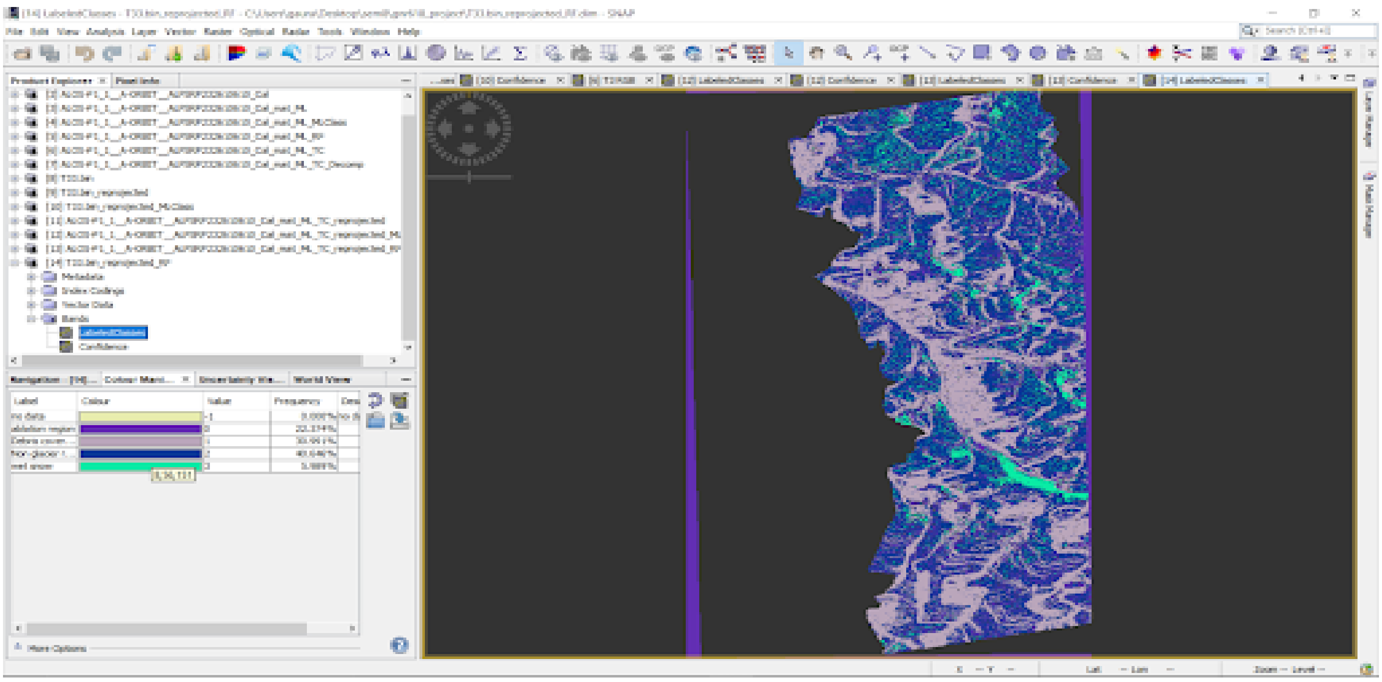
We can observe that the model has been classified into four classes - Wet Snow Region (Greenish coloured

area) , Ablation Region (Blue-Violet coloured area), Debris Covered Region of Glacier (Pink coloured area) and Non Glacial Region (Deep violet coloured area).
Frequency of these classes are 6.344%, 15.107%, 15.565% and 62.985% respectively. This model predicts higher frequency for the Non Glacial Region than other regions.
The confidence with which the model predicts the class at each region in the image is given by the following image :



Confidence : Maximum Likelihood Classifier on Terrain Corrected Data with Decomposition

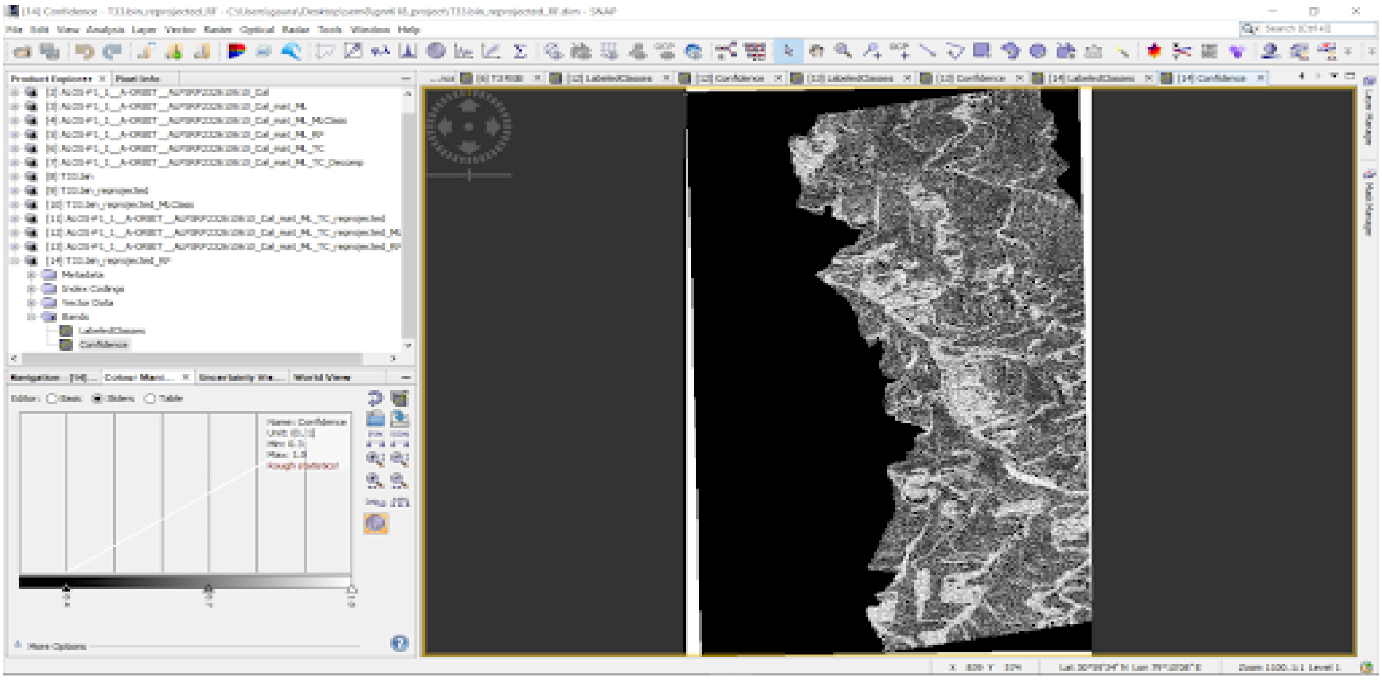
Now this time the maximum likelihood classifier predicts the class with a not as good confidence as before the decomposition as we can see in the image, a lot of black areas. The minimum confidence we get is 0.346 and maximum confidence is 1.00.
When we train the Random forest classifier on the decomposed data we get the following result :



Random Forest Classifier on Terrain Corrected Data with Decomposition

We can observe that the model has been classified into four classes - Wet Snow Region (Greenish coloured area) , Ablation Region (Blue-Violet coloured area), Debris Covered Region of Glacier (Pink coloured area)

and Non Glacial Region (Deep violet coloured area).
Frequency of these classes are 5.989%, 22.374%, 30.991% and 40.646% respectively. This model predicts lower frequency for the Wet Snow Region than other regions.
The confidence with which the model predicts the class at each region in the image is given by the following image :



Confidence : Random Forest Classifier on Terrain Corrected Data with Decomposition

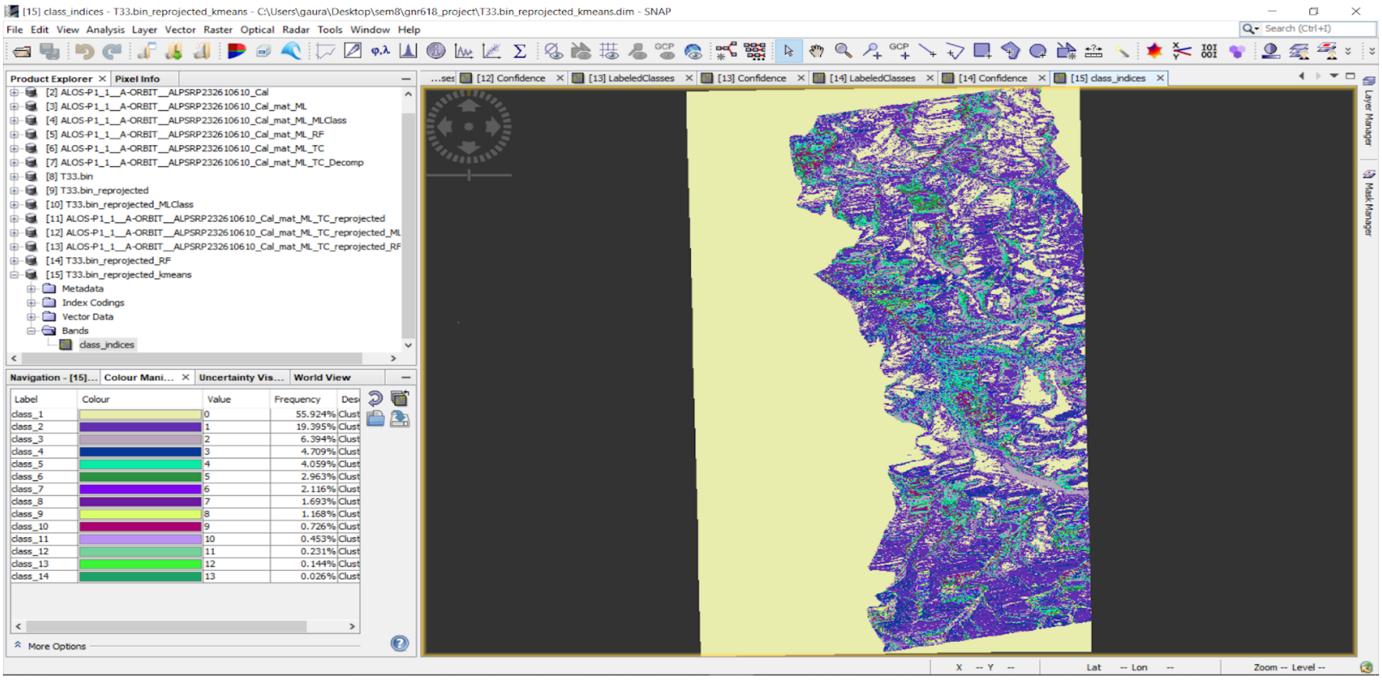
For Random Forest Classifier on Terrain Corrected Data with Decomposition, we get following metrics :

```
Number of classes = 4
   class 0.0: ablation region
    accuracy = 0.9255 precision = 0.6791 correlation = 0.6832 errorRate = 0.0745
    TruePositives = 91.0000 FalsePositives = 43.0000 TrueNegatives = 878.0000 FalseNegatives = 35.0000
   class 1.0: Debris covered region
    accuracy = 0.9656 precision = 0.8945 correlation = 0.9082 errorRate = 0.0344
    TruePositives = 229.0000 FalsePositives = 27.0000 TrueNegatives = 782.0000 FalseNegatives = 9.0000
   class 2.0: Non glacier region
    accuracy = 0.9102 precision = 0.7597 correlation = 0.6597 errorRate = 0.0898
    TruePositives = 98.0000 FalsePositives = 31.0000 TrueNegatives = 855.0000 FalseNegatives = 63.0000
   class 3.0: wet snow
    accuracy = 0.9733 precision = 0.9678 correlation = 0.9479 errorRate = 0.0267
    TruePositives = 511.0000 FalsePositives = 17.0000 TrueNegatives = 508.0000 FalseNegatives = 11.0000

Using Testing dataset, % correct predictions = 88.7297
Total samples = 2094

Distribution:
   class 0.0: ablation region           252     (12.0344%)
   class 1.0: Debris covered region     476     (22.7316%)
   class 2.0: Non glacier region        322     (15.3773%)
   class 3.0: wet snow                  1044    (49.8567%)
```

Also,
After training the Unsupervised Classifier on the terrain corrected data with decomposition we get the following classified image. This is also called K-means clustering.



Unsupervised Classifier on Terrain COrrected Data with Decomposition

We can observe that this classier has classified the data in multiple classes generated by itself. It has further breaked the supervised classes into two or three classes. Unsupervised Classifier predicts more classes according to diversities in supervised classes.

6. Conclusion

Glaciers are important indicators of global warming and climate change in several ways. Melting ice sheets contribute to rising sea levels. So studying them becomes a crucial part.
Since these are located in the regions where in field work is not possible we rely on remote sensing to gather all the information we can. Remote sensing helps us locate glaciers and gather data related to them which we can use to implement other techniques to extract information about them.
We in this project, applied Machine Learning techniques after processing the data. We saw how machine learning can help in classifying various features of glaciers. We tried two supervised learning models and one unsupervised learning model to segregate the features of the glacier.
We trained the models on the three steps of the processed data. First we trained on the multilook data, in the multilook data we get the models get the best confidence, after that we trained on the terrain corrected data as multilook had no information regarding the 3rd dimension in this result we still get good confidence from the models but as we go to the Singh yamaguchi decomposed data the confidence of the models drop more down on the predictions it make.
Moreover, the maximum likelihood classifier predicts the classes with more confidence than the random forest classifier. After this we also tried to train an unsupervised learning model K-means clustering which gave us a total of 12 classes which tell us that there can be a lot more features of the glacier that can be predicted using Machine Learning if we give proper labelled data.
Thus machine learning gives us a lot of useful techniques through which we can extract the information of not only Glaciers but also Ice Sheets and Icebergs from the PolSAR data or optical data.

7. References

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