CE671A HA 1

Aadya Umrao
210003
Civil Engineering
aadyau21@iitk.ac.in

---

1 Introduction

In this assignment, we will go through the process of selecting the most appropriate remote sensing sensors to distinguish between different materials. Starting by downloading spectral data files for five materials of any choice from NASA's ECOSTRESS Spectral Library. After getting familiarized with the data format and relevant documentation, spectral reflectance curves need to be generated using software like MATLAB or Python. By analyzing these curves, compare the spectral signatures of the materials across various wavebands to identify key differences. Based on this analysis, decide which wavebands and sensors are most effective for distinguishing the materials.

2 Methodology

2.1 Procedure-

Data:

- Visit the NASA ECOSTRESS Spectral Library website and review the available resources.
- Download the spectral data files for five selected materials.
- Carefully read the metadata and documentation accompanying the downloaded spectral data.

Generation of Spectral Reflectance Curves:

- Use MATLAB, or Python to generate spectral reflectance curves for these five materials.
- Ensure that the reflectance is plotted as a function of wavelength for each material, and that the graphs are clear, properly labeled, and easy to interpret.

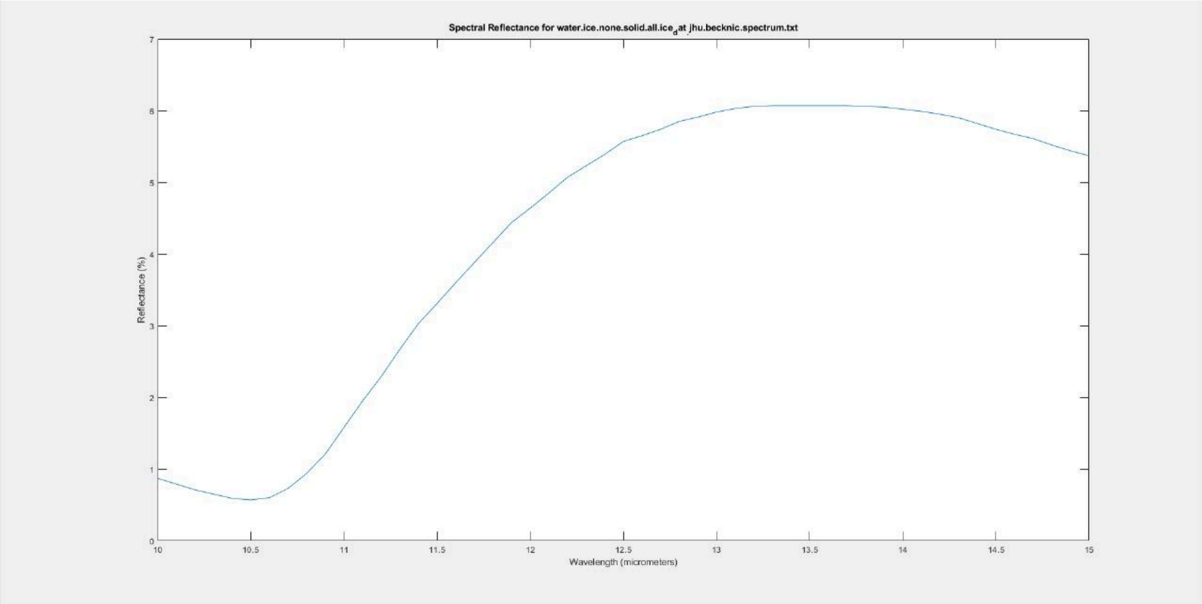
Analysis of Reflectance Curves:

- Compare these spectral reflectance curves to identify key differences and similarities.
- Focus on different wavebands to understand how the spectral signatures of the materials vary across these regions.
- Consider how these variations could impact the selection of remote sensing sensors or wavebands.

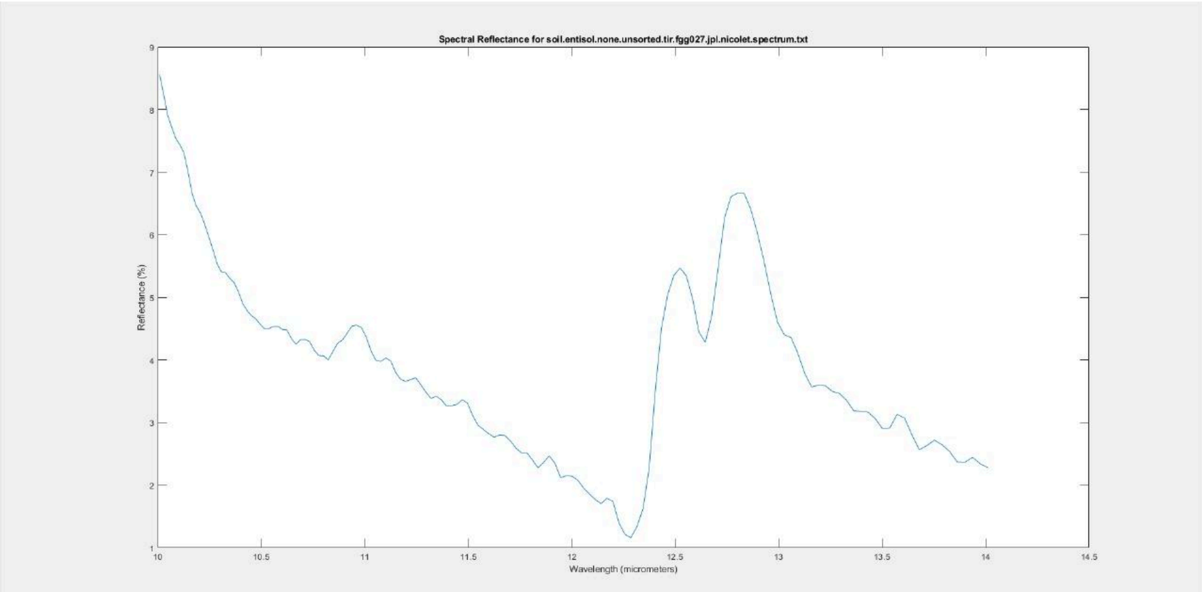
2.2 Results-

1. Mineral- Olivine (Fo92) $(Fe^{+2},Mg)_2SiO_4$
   Rock- Marble, Metamorphic
   Soil- Alluvial soil, Entisol
   Vegetation- Adenostoma fasciculatum 1
   Water- Ice

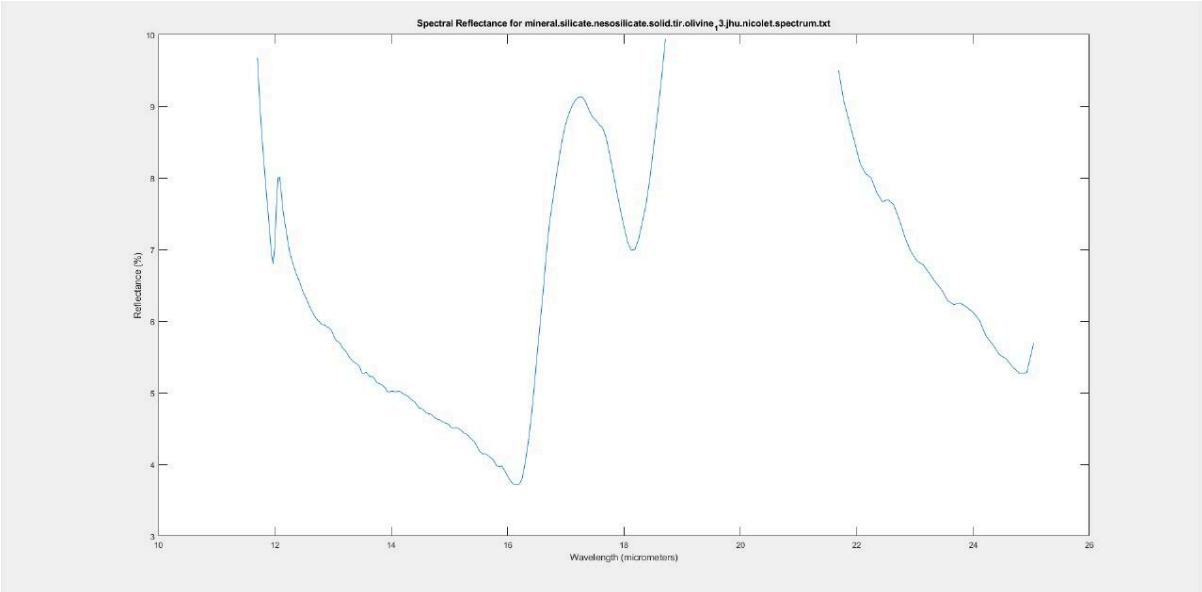
3. Spectral Reflectance curve of Ice



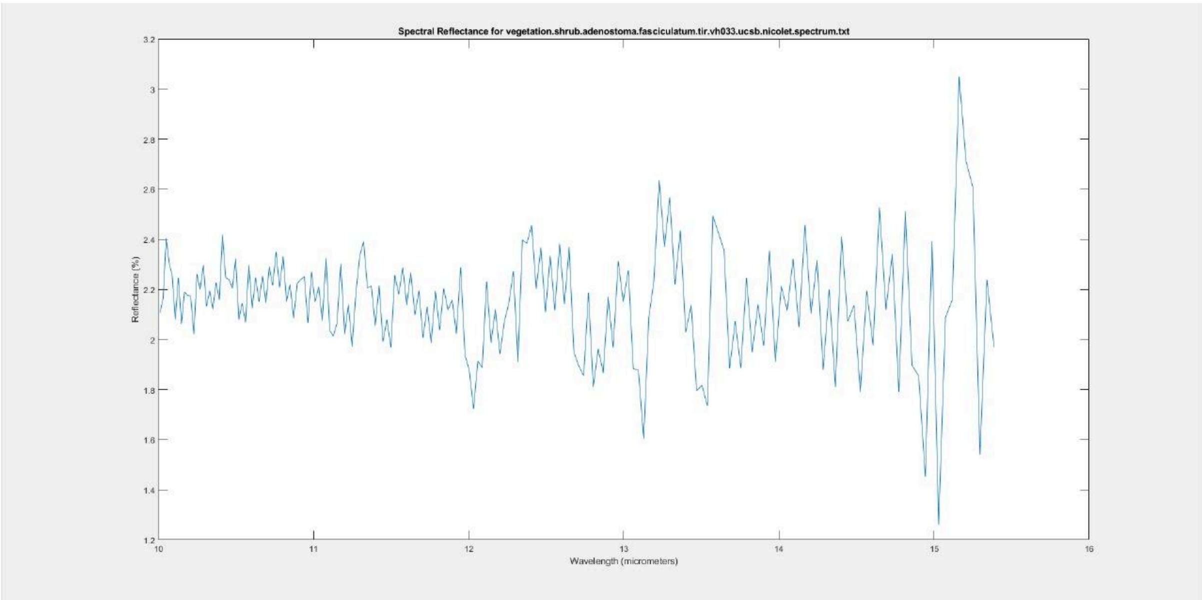
Spectral Reflectance curve of Alluvial Soil



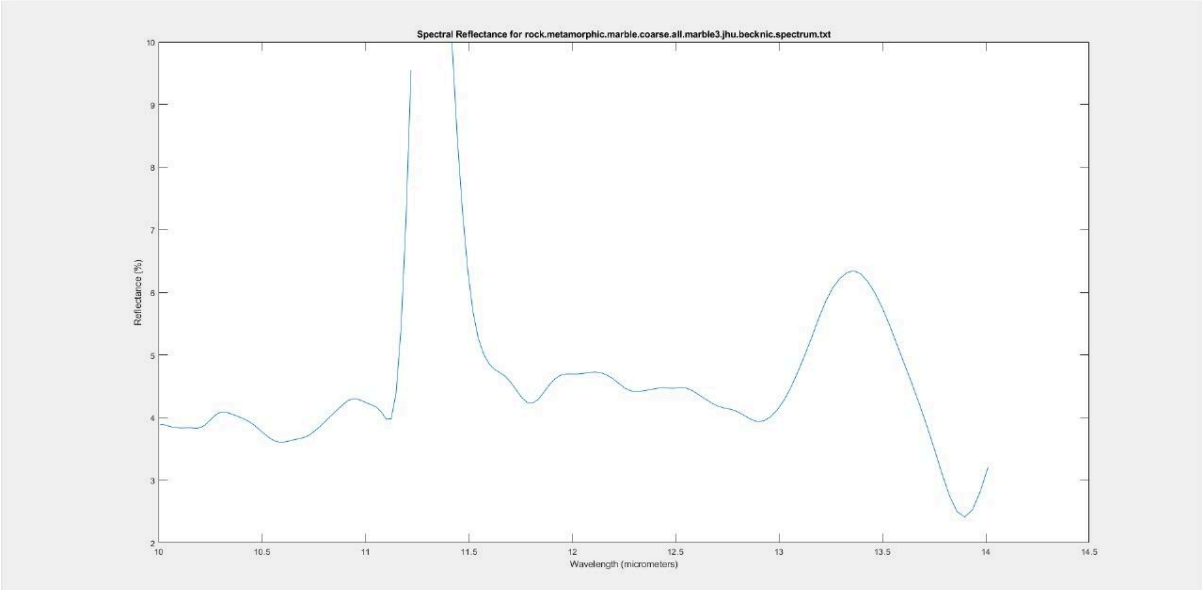
Spectral Reflectance curve of Olivine (Fo92) (Fe+2,Mg)2SiO4



Spectral Reflectance curve of Adenostoma fasciculatum 1



Spectral Reflectance curve of Marble



4.

a) Ice

Curve Characteristics:

The ice reflectance curve shows a smooth, gradual increase in reflectance up to about 12.5 micrometers, after which it flattens out and slightly decreases.

Key Observations:

Ice has a generally low reflectance across the spectrum with a slight increase in the longer wavelengths.

Alluvial Soil

Curve Characteristics:

The alluvial soil reflectance curve exhibits a more complex pattern with several peaks and troughs. Reflectance starts relatively high, decreases, then shows a prominent peak around 12 micrometers, followed by fluctuations.

Key Observations:

The variability in the curve, including the peaks and troughs, suggests soil's diverse composition (e.g., organic matter, minerals) and its interaction with different wavelengths.

Marble

Curve Characteristics:

The reflectance curve for marble shows distinct, sharp peaks around 11.2 micrometers and 12.5 micrometers, with a notable drop in reflectance between these peaks.

Key Observations:

The sharp peaks likely correspond to specific mineralogical features of the marble, making this material's spectral signature quite distinctive.

Olivine (Fo92) (Fe+2,Mg)2SiO4

Curve Characteristics:

The reflectance curve shows a downward trend from 10 to 25 micrometers, with notable peaks around 12 and 18 micrometers, and a trough around 16 micrometers. Reflectance values range from approximately 3.5% to 9.5%.
Key Observations:
The peaks and troughs likely indicate specific absorption features typical of silicate minerals, particularly olivine. The curve's distinct features could help identify the material's composition through comparison with known spectral libraries.

Adenostoma fasciculatum 1
Curve Characteristics:
The reflectance curve fluctuates between 1.2% and 3.0% across wavelengths from 10 to 15 micrometers. It exhibits multiple peaks and troughs, indicating varying reflectance and absorption features.
Key Observations:
The high variability and noise in the curve suggest complex interactions, likely due to the material's composition, possibly vegetation. Smoothing and comparison with spectral libraries may help identify specific material properties.

b)
Key Differences:
Ice has a smooth, low-reflectance curve, whereas alluvial soil shows more complexity with multiple peaks and troughs. This suggests that ice and alluvial soil can be easily distinguished in the infrared spectrum. Alluvial Soil and marble both exhibit peaks, but the sharpness and location of these peaks differ. Marble’s sharp peaks around 11.2 and 12.5 micrometers make it distinguishable from soil, which has broader, less pronounced peaks.
There is a highly variable reflectance curve with lower reflectance values (1.2% to 3.0%) over a shorter wavelength range (10-15 micrometers), suggesting complex interactions, likely from vegetation in Adenostoma fasciculatum 1 . The Olivine has a smoother, more defined curve with higher reflectance values (3.5% to 9.5%) over a broader wavelength range (10-25 micrometers), characteristic of mineral reflectance, particularly silicates like olivine.

Similarities:
All materials show some form of reflectance, but water’s smooth curve and Adenostoma fasciculatum 1’s rough curve make them the most distinct compared to the other complex signatures.

c)Impact on Sensor/Waveband Selection
Visible Spectrum:
Water and soil might have less distinction here, but the contrast increases in the infrared range.
Near-Infrared (NIR):
This region is particularly useful for distinguishing water due to its low reflectance, while soil and rock show more variability.
Shortwave Infrared (SWIR):
The differences become even more pronounced, with marble's sharp peaks making it identifiable, while soil shows more variability.
Since vegetation exhibits complex interactions in specific wavebands, particularly in the mid-infrared (10-15 micrometers), sensors should focus on these narrow bands to differentiate between vegetation types and conditions.For minerals like olivine, wavebands in the mid-to-far infrared (12-25

micrometers) are critical. Sensors should target these broader bands to capture the distinct absorption features and differentiate between various silicate minerals.
Hyperspectral sensors, which offer narrow and contiguous wavebands, are better suited for capturing the detailed spectral signature of vegetation. Multispectral sensors, with broader wavebands, may suffice for mineral detection, as the key absorption features are more pronounced and less susceptible to fine spectral variations.

5.
Selecting the Best Wavebands
-10.5 to 12.5 micrometers (SWIR): This range is critical for distinguishing marble (rock) due to its sharp peaks.
-8 to 12 micrometers (NIR/SWIR): Effective for differentiating ice from other materials because of ice's low reflectance.
-Visible to Near-Infrared: Can be used to distinguish soil, especially when combined with SWIR.
- 10-15 micrometers: For Adenostoma fasciculatum 1
- 12-25 micrometers (thermal to far-infrared): For Olivine

Justification:
-Ice: Best distinguished using NIR/SWIR because of its smooth, low reflectance curve.
-Alluvial Soil: The variability across NIR and SWIR makes it distinguishable from both ice and marble.
-Marble: Sharp peaks in the SWIR region make this material identifiable, supporting the selection of sensors that capture this wavelength range.
-Adenostoma fasciculatum 1: The vegetation reflectance curve shows high variability within this range, indicating that fine spectral resolution in these wavebands is essential to detect the subtle absorption features associated with plant materials.
-Olivine: The mineral reflectance curve, especially for silicates like olivine, exhibits distinct absorption features in the 12-25 micrometer range. A sensor that captures these broader and smoother features can effectively differentiate minerals.

6.
The five materials (Ice, Alluvial Soil, Marble, Olivine, and Adenostoma fasciculatum 1) were chosen due to

- Ice: Important in climate monitoring, with distinct spectral behavior in the infrared range.
- Alluvial Soil: Crucial for understanding soil composition, fertility, and erosion.
- Marble: Used in geological studies and construction, with sharp spectral peaks.
- Olivine: A common mineral in geology, with characteristic absorption features making it essential for mineral exploration.
- Adenostoma fasciculatum 1: A type of vegetation, relevant in ecological and land use studies.

MATLAB Code-

```
% Directory where the files are located
folderPath = 'C:\Users\dell\Pictures\ce671\ecospeclib-1723904427676\';

% List of files to process (with .spectrum extension)
files = {'mineral.silicate.nesosilicate.solid.tir.olivine_13.jhu.nicolet.spectrum.txt',
```

```
    'rock.metamorphic.marble.coarse.all.marble3.jhu.becknic.spectrum.txt',
    'soil.entisol.none.unsorted.tir.fgg027.jpl.nicolet.spectrum.txt',
    'vegetation.shrub.adenostoma.fasciculatum.tir.vh033.ucsb.nicolet.spectrum.txt',
    'water.ice.none.solid.all.ice_dat_.jhu.becknic.spectrum.txt'};

% Initialize cell array to hold data and labels for plotting
data = cell(length(files), 1);
labels = cell(length(files), 1);

% Create a figure for plotting
fig = figure('Name', 'Spectral Reflectance Curves');

% Create a tab group in the figure
tabGroup = uitabgroup('Parent', fig);

% Loop through each file
for i = 1:length(files)
  % Full path to the file
  filePath = fullfile(folderPath, files{i});

  % Check if file exists
  if isfile(filePath)
    try
      % Read the data from the .spectrum file
      data{i} = readmatrix(filePath, 'Delimiter', ' ', 'NumHeaderLines', 21);
      labels{i} = files{i}; % Store the filename for the legend

      % Create a new tab for each file
      tab = uitab('Parent', tabGroup, 'Title', files{i});

      % Create an axes in the current tab
      ax = axes('Parent', tab);

      % Plot the data for this file
      plot(ax, data{i}(:,1), data{i}(:,2));
      xlabel(ax, 'Wavelength (micrometers)');
      ylabel(ax, 'Reflectance (%)');
      title(ax, sprintf('Spectral Reflectance for %s', files{i}));

    catch
      warning('Failed to read file: %s', files{i});
    end
  else
    warning('File does not exist: %s', files{i});
  end
end

% Set figure properties
```

```
set(fig, 'NumberTitle', 'off', 'MenuBar', 'none', 'ToolBar', 'none');
```

3 Discussion

The results show a clear understanding of how materials interact with electromagnetic radiation, particularly in the infrared spectrum. Ice's smooth, low-reflectance curve reflects its high transparency and low absorption, while marble's sharp peaks match its mineral composition. The complex reflectance of alluvial soil highlights its heterogeneous nature. Also the highly complex plot of Adenostoma fasciculatum 1highlights how vegetation can easily be distinguished. These findings emphasize the need for selecting appropriate wavebands and sensors for accurate material differentiation, underscoring the importance of spectral analysis in remote sensing for geology, ecology, and climate studies.

4 Conclusion

The study focused on five materials—Ice, Alluvial Soil, Marble, Olivine, and Adenostoma fasciculatum 1—chosen for their distinct spectral characteristics and applications. Spectral data across 8 to 25 micrometers were collected, revealing unique features like Ice's low reflectance, Alluvial Soil's complex curve, Marble's sharp peaks, Olivine's absorption features, and the vegetation's variability. The analysis led to tailored recommendations for wavebands and sensors: NIR/SWIR for Ice, SWIR for Alluvial Soil and Marble, and Thermal/Far-Infrared for Olivine, with fine spectral resolution advised for Adenostoma fasciculatum 1. This approach ensures accurate material differentiation in remote sensing.