Assignment 3: Optical Remote Sensing

Candidate 3

November 27, 2018

Introduction

In this assignment various methods of processing optical data from a satellite is presented. The data was made available by Xu Xu and is from a Landsat8 level-1 product, it is described in more detail in the assignment instructions. The data processing was done in MATLAB. The code can be found in the attached *assignment3_1.m* and *assignment3_2_3.m* MATLAB files.

Part 1: Visualizing the Data

1a

All data is in the form of unsigned 16-bit integer (uint16), each value is represented by two bytes, which means it can have values from 0 to $2^{16} = 65535$. To show an image of a channel we first perform histogram equalization to smooth out the contrast in the image. This is done using a MATLAB library function *histeq*, by mapping a roughly equal number of pixels to 6535 bins (since this is the range of the values), so that the histogram is approximately flat. Doing so for channel 5, the near infrared (NIR) band, we get an image as shown in figure 1. In the image we can see that water results in almost zero intensity values, whereas snow is the brightest. Which makes sense because water in its liquid state, has a high absorption coefficient in the NIR spectrum.

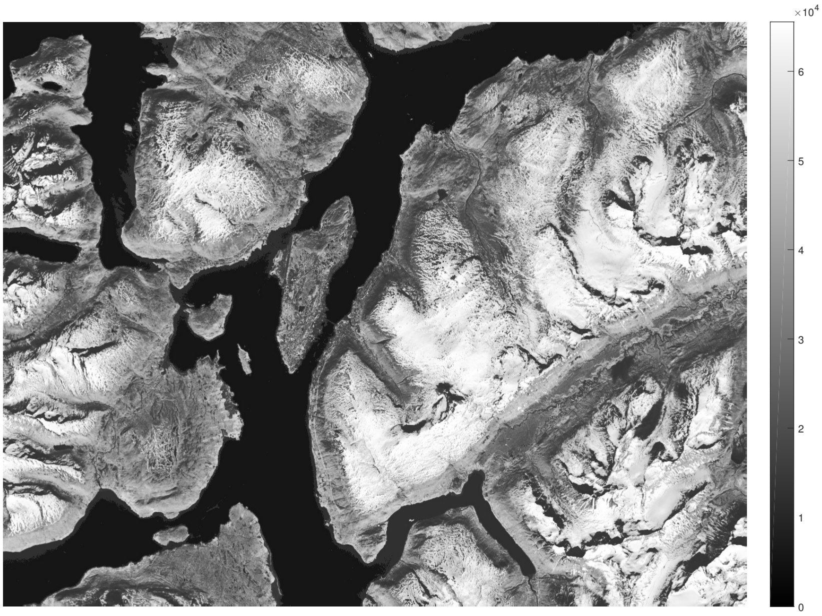

Figure 1: Histogram equalized grey scale image of the near infrared channel 5, in the range 0 to 65535.

1b

An RGB image is formed by using band 2, 3 and 4, respectively B, G and R. Again histogram equalization is applied to each channel as before. Combining the three channels in one RGB image results in figure 2. Compared to other true color satellite images of the area, figure 2 looks realistic.

1c

An RGB image with a false color composite, is created by using the NIR channel as the red band. As usual, histogram equalization is applied to all channels. The image is seen in figure 3. Comparing this image with the real color RGB in figure 2, we see that the ice remain the same, whereas vegetation appear red instead of green and the urban areas appear blue instead of grey. Explanation follows in part 2.c.

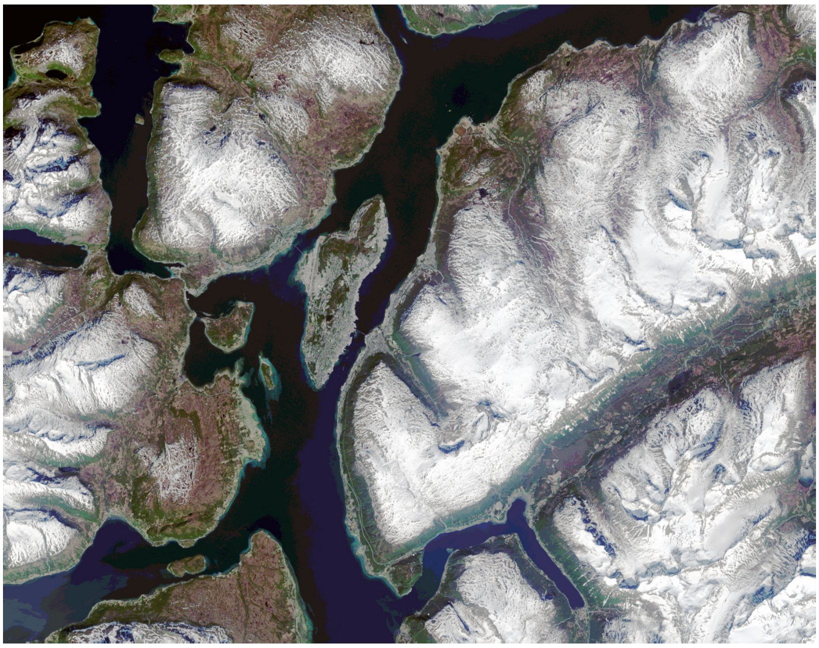

Figure 2: RGB image of the channels 2, 3 and 4.

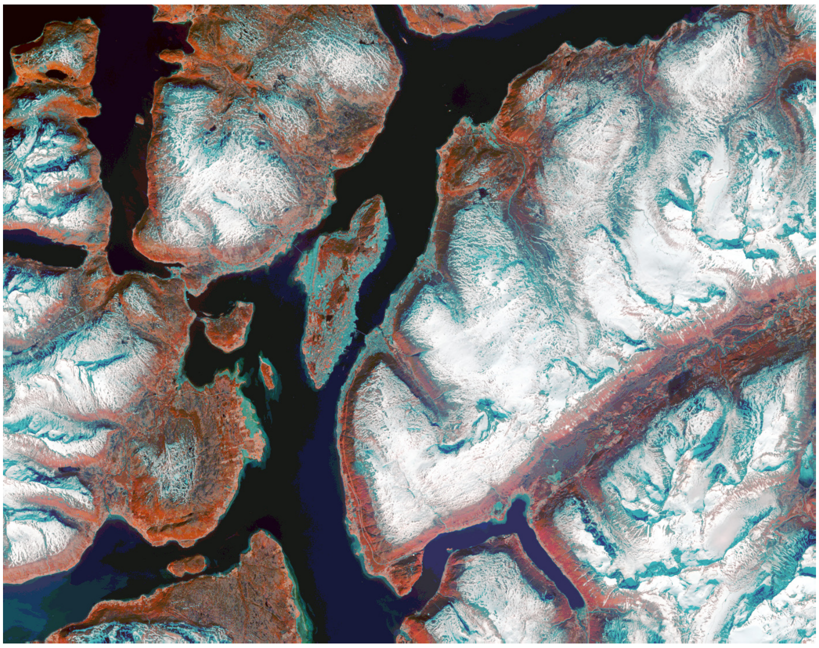

Figure 3: RGB image with false color composite using the NIR channel as the red band.

Part 2: Calibration

2a

Top of the atmosphere (TOA) spectral radiance, is a measure of all light reflected from both the earths surface and atmosphere. Thus it is equivalent to viewing the earth from the top of the atmosphere.

Radiance is dependent on illumination, both in magnitude and direction, however when light travels trough the atmosphere, it is scattered in different directions. TOA provide a way to correct some of these scattering factors.

2b

Using the equation presented by USGS [3], the TOA spectral radiance values for all bands are calculated. The necessary constants for the calculation are found in the provided header file, containing meta data for the measurements.

2c

Looking at spectral reflectance for vegetation [2], one find that it is a good absorber of red and blue light and reflects a lot of green light. This explain why vegetated areas look green to the human eye and in figure 2. Vegetation also has a very high reflection in the NIR spectrum, explaining why the vegetation in figure 3 is red (the NIR channel was chosen as the red band in the image).
Snow is highly reflective in the visible spectrum and also in the NIR spectrum [2], thus the snow appears white in both images in 1.c.
Water is a good absorber over all wavelengths [2], but a little less so for blue light, why it appears black or dark blue in the images.
Reflectance of urban areas vary across the globe. In this case it would appear to be somewhat equally absorbing of visible light, thus the grey/whiteish color in figure 2. In figure 3 the urban area appear blue-green, indicating that it is a better absorber of infrared light than blue and green.

Part 3: Applications

3a

The normalized difference vegetation index (NDVI) is calculated as described in the assignment:

$$NDVI = \frac{NIR - RED}{NIR + RED}, \tag{1}$$

with NIR and RED representing channel 5 and 4. The function is applied after converting the channels to the TOA spectral radiance values. A histogram equalized image of the NDVI values are shown in figure 4. It does seem to highlight vegetated areas well. Both NIR and red light is well absorbed by water, thus the fraction in equation 1 will be a small number, therefore water appear dark as usual. For snow both NIR and red light is mostly reflected, almost equally, thus the nominator in equation 1 will be close to 0, resulting in a dark area for snow covered parts. Finally vegetation is highly reflective in the NIR spectrum, resulting in high values for the vegetated part. To sum up; the NDVI, as defined in equation 1, therefore highlights vegetated areas while extinguishing water and snow.

3b

The Normalized difference water index (NDWI) is calcualted as described in the assignment:

$$NDWI = \frac{TIR - RED}{TIR + RED}, \tag{2}$$

with TIR being the thermal infrared band (channel 10) and RED the red band (channel 4). The function is applied after converting the channels to the TOA spectral radiance values. Based on the NDVI and NDWI values, a land mask is constructed, as defined in the assignment, by a 1 if a value satisfy the condition $NDVI > -0.45 \quad \text{and} \quad NDWI < -0.3$ and 0 if not. A sea mask is defined as the inverse of

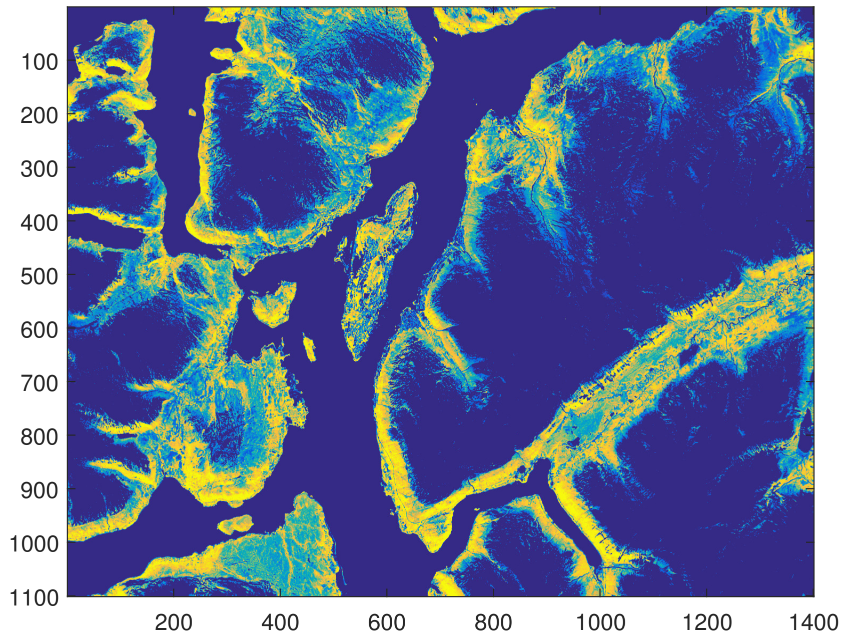

Figure 4: Image if the NDVI values after applying histogram equalization.

the land mask. A visual representation of the land and sea mask can be found in figure 5 and 6. The mentioned condition on NDVI and NDWI appears to be sufficient for defining water and land pixels, as seen in figure 5 - 6.

3c

Surface temperature can not be directly derived from thermal measurements. Measurements will include not only radiation from the surface, but also from the surrounding environment, particularly the atmosphere. Instead we can try and estimate it from the brightness temperature. Brightness temperature is a measure of radiation travelling upwards from the atmosphere to the satellite. It is expressed in units of temperature equivalent to that of a black body in thermal equilibrium with its surroundings if it were to duplicate the measured intensity.
We will try to estimate the sea surface temperature (SST) from the thermal infrared bands 10 and 11, based on the equation given in the assignment:

$$SST = 5.1424 + 0.9558 \cdot T_{10} + 0.8365(T_{10} - T11).$$

We use the TOA corrected values for band 10 and 11, resulting in the image found in figure 7. The temperature of the water is in the range from 11 to 14 degree Celsius. According to the header file, the data was acquired June 1st, in this month the average water temperature around Troms is about 9 degree Celsius, with a max value of about 11 degree Celsius [1]. Thus the measured values might seem to be somewhat overestimated. However if the surface in this case is only a few millimeters in depth, the temperatures are not unlikely, though I am not sure what defines surface for this data.

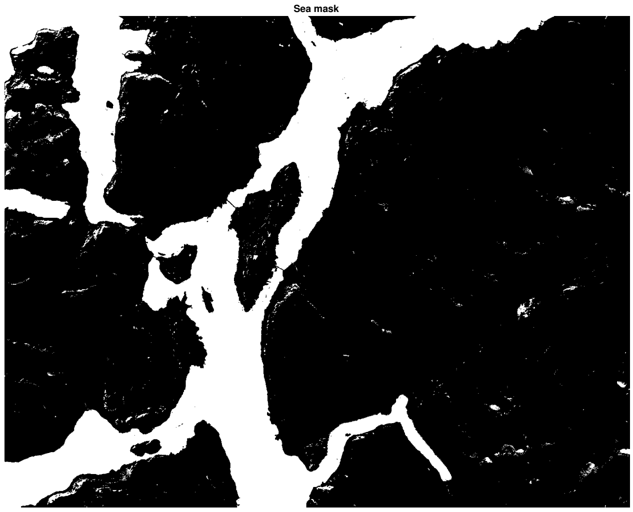

Figure 5: Land mask. White represent presence of land, black is absence.

Figure 6: Sea mask. White represent presence of sea, black is absence.

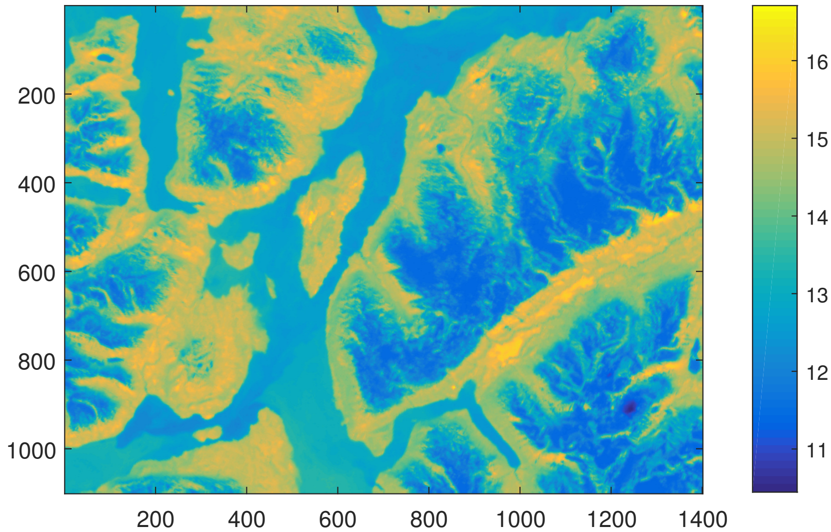

Figure 7: Sea surface temperature.

References

[1] seatemperature.org. Troms average June sea temperature. `https://www.seatemperature.org/europe/norway/tromso-june.htm`. [Online; accessed 22-November-2018].

[2] Humboldt State University. Spectral Reflectance. `http://gsp.humboldt.edu/OLM/Courses/GSP_216_Online/lesson2-1/reflectance.html`. [Online; accessed 21-November-2018].

[3] USGS. Using the USGS Landsat Level-1 Data Product. `https://landsat.usgs.gov/using-usgs-landsat-8-product`. [Online; accessed 21-November-2018].