FYS3023: Environmental monitoring from satellite, Fall 2018

Assignment 3: Optical Remote Sensing

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Deadline for hand in: 12:00, 20 November, 2 weeks for this exercise

Note:

- In this exercise you will practise processing data of optical satellites.
- Data can be found on Canvas.

The grading will be based on your plots and comments. Therefore, make sure to be clear and precise when plots and comments are asked for!
Code, an important part, should be attached as an appendix, make sure it is well commented and easy to follow. We will read your code to check if you do it individually.

Good luck!

The data is Landsat8 level-1 product. Landsat 8 products combine data acquired by both the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) (11bands in total), and are delivered in 16-bit unsigned integer format. The data consists of the following spectral bands:

Spectral band:	Wavelengths [μm]	Resolution [m]
Band 1 (Coastal aerosol)	0.433 - 0.453	30
Band 2 (Blue)	0.450 - 0.515	30
Band 3 (Green)	0.525 - 0.600	30
Band 4 (Red)	0.630 - 0.680	30
Band 5 (NIR)	0.845 - 0.885	30
Band 6 (SWIR 1)	1.56 - 1.66	30
Band 7 (SWIR 2)	2.10 - 2.30	30
Band 8 (Panchromatic)	0.500 - 0.680	15
Band 9 (Cirrus)	1.36 - 1.38	30
Band 10 (TIR 1)	10.3 - 11.3	100
Band 11 (TIR 2)	11.5 - 12.5	100

Table 1: The spectral bands for Landsat-8.

Bands 1 to 9 are sensed by the Operational Land Imager (OLI) and bands 10 and 11 by the Thermal InfraRed Sensor (TIRS) onboard Landsat-8.

Part 1: Visualising the data

In this part you will visualise the data. Please do the following:

(a) Load the file ”Landsat8.mat”, there are 11 bands, choose one band to display as a grey image. Please notice that the datatype is 16-bit unsigned integer format, what is the range of the data for this datatype? The image you show look dark? Use histogram equalization or some other methods(e.g. imadjust in matlab) to adjust it. (2pt)

(b) Display RGB image using true colour composite. (1pt)

(c) Display RGB image using false colour composite (a common scheme is changing the red band to the near IR band). What type of terrain that differ most between this RGB image and the one you got in (b). And what types are similar on both images. You need to explain it later. (2pt)

Part 2: Calibration

Like what we do in SAR part, the optical data we get needs to be calibrated. For SAR data, the calibration is from Digital Number(DN) values to backscattering coefficients. For optical satellites, the DN values can be converted to spectral radiance or reflectance with physical meaning.

(a) Read the calibration instructions on https://landsat.usgs.gov/using-usgs-landsat-8-product. Explain what is meant by top of atmosphere (TOA) spectral radiance. (2pt)

(b) Calibrate the 11 channels to the TOA spectral radiance. The calibration coefficients can be found in the file "head.txt" (hint: they are the values below GROUP = RADIOMETRIC RESCALING). (1pt)

(c) Find plots of spectral reflectance for vegetation, snow and water on Internet. Use these plots to explain what you get in part1(c). (3pts)

Part 3: Applications

A wide range of value added products can be computed by combing different channels. We shall look at two such products: the normalised difference vegetation index (NDVI)and the normalised difference water index (NDWI), defined as:

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}}$$

$$\mathrm{NDWI} = \frac{\mathrm{TIR} - \mathrm{RED}}{\mathrm{TIR} + \mathrm{RED}}$$

where RED is red (band 4), NIR is near infrared (band 5), SWIR is short wave infrared (here, use band 6) and TIR is thermal infrared (here, use band 10), all given in spectral radiance. It should be noted that we should use surface response to calculate the index. To achieve this, we should do atmospheric corrections to the TOA radiance. Here we don't consider the effects of atmosphere, but in real case the atmosphere may have a great influence.

(a) Compute the NDVI product from the radiance bands. Show an NDVI image with colour bar. Explain why the NDVI can be an index for vegetated areas or healthy vegetation (Hint: consider the spectral responses of vegetation at RED and NIR bands). (3pt)

(b) Compute the NDWI. Use this together with the NDVI to produce a land/sea mask, where land is defined as:

$$\mathrm{NDVI} > -0.45 \;\; \text{and} \;\; \mathrm{NDWI} < -0.3$$

In MATLAB, the mask is easily constructed as a logical map 'LAND', with the following command:

```
>> LAND = (NDVI > -0.45) & (NDWI < -0.30);
```

where 'NDVI' and 'NDWI' are the NDVI and NDWI images. A corresponding sea mask can be defined in MATLAB as:

```
>> SEA = ~LAND;
```

Display the land and sea mask. (3pt)

(c) The last two bands of Landsat8 are also quite useful. We can build the relations between brightness temperature and surface temperature. Please explain the difference between brightness temperature and surface temperature. A widely used method to retrieve surface temperature from brightness temperature is called Split Window. It uses at least two thermal bands to reduce the effects of atmosphere. Here we try to use the bands 10 and 11 to retrieve the sea surface temperature (SST). Apply the sea mask on bands 10 and 11 and calculate the Top of Atmosphere Brightness Temperature (calculation coefficients can be easily found in "head.txt"). Calculate the SST using the equation:

$$SST = 5.1424 + 0.9558 * T_{10} + 0.8365(T_{10} - T_{11});$$

Show the SST image with colour bar. (3pt)