

Practical Session- Working with satellite multispectral data

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1. Task

To access a typical ESA Sentinel-2 scene and process using two different methods for atmospheric correction packages:

- [ARCSI](#) (Atmospheric and Radiometric Correction of Satellite Imagery), which is designed for terrestrial environments
- [ACOLITE](#) , which is designed for inland water and coastal environments

2. Dataset

This exercise will use Sentinel-2 data which is operated by ESA with data freely available through Copernicus. For this task, we will be accessing and downloaded data ourselves, outlined in the following sections.

a) Accessing Data

Although the data needed for this practical has already been downloaded, this section documents how this vast resource of freely available ESA satellite data can be accessed.

1. Make an account with Copernicus: <https://scihub.copernicus.eu/dhus/#/self-registration>
2. Access the SciHub Portal: <https://scihub.copernicus.eu/dhus>
3. Make bounding box over area of interest:

Figure 1 shows the SciHub portal. You can navigate by moving the mouse cursor whilst holding a click and zooming with the mouse wheel. Once you have navigated to the area of interest, use the square shaped tool on the right boarder of the portal and click to draw a polygon by clicking where you want vertices to be. Double click to finish the polygon. An example is shown in Figure 1.

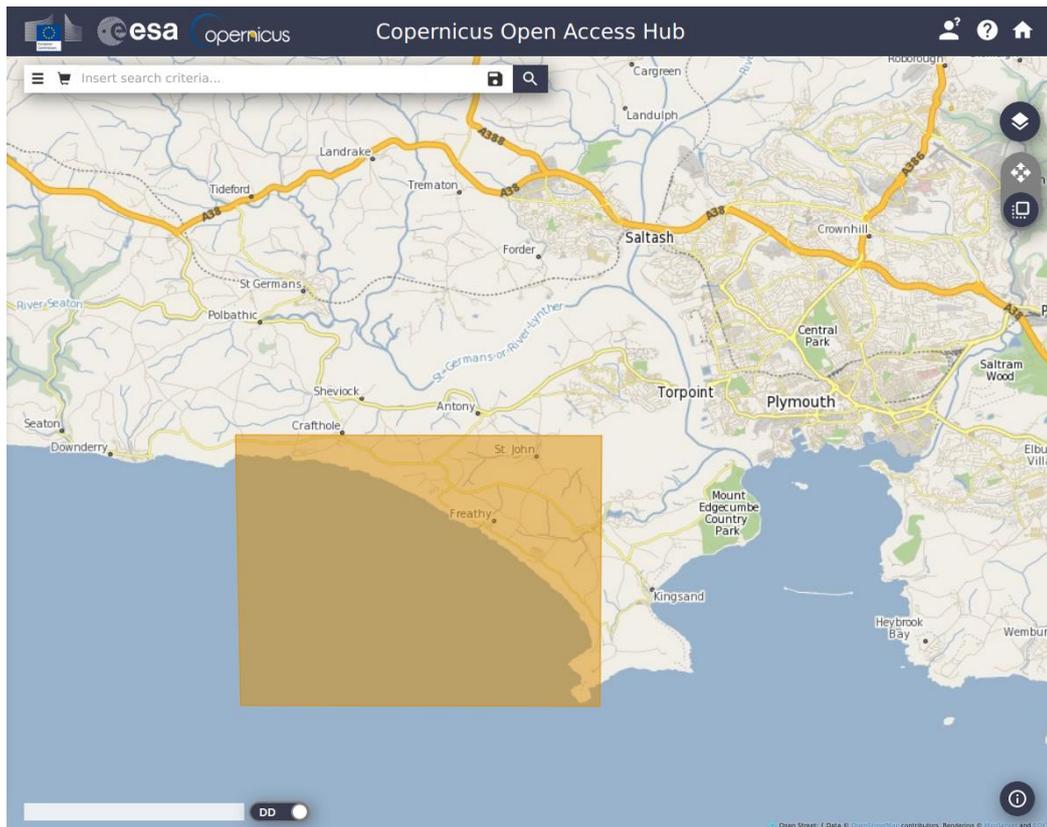


Figure 1. Example of bounding box drawn in SciHub over Whitsand Bay, Cornwall.

4. Search for data products:

The search bar is on the top left of the portal. On the left of the search bar is the Advanced Search option, the menu of which is shown in Figure 2. Enter a 'Sensing Period' for the 27th June 2018. Tick 'Mission: Sentinel-2' and select a 'Product Type' of 'S2MSI1C'.

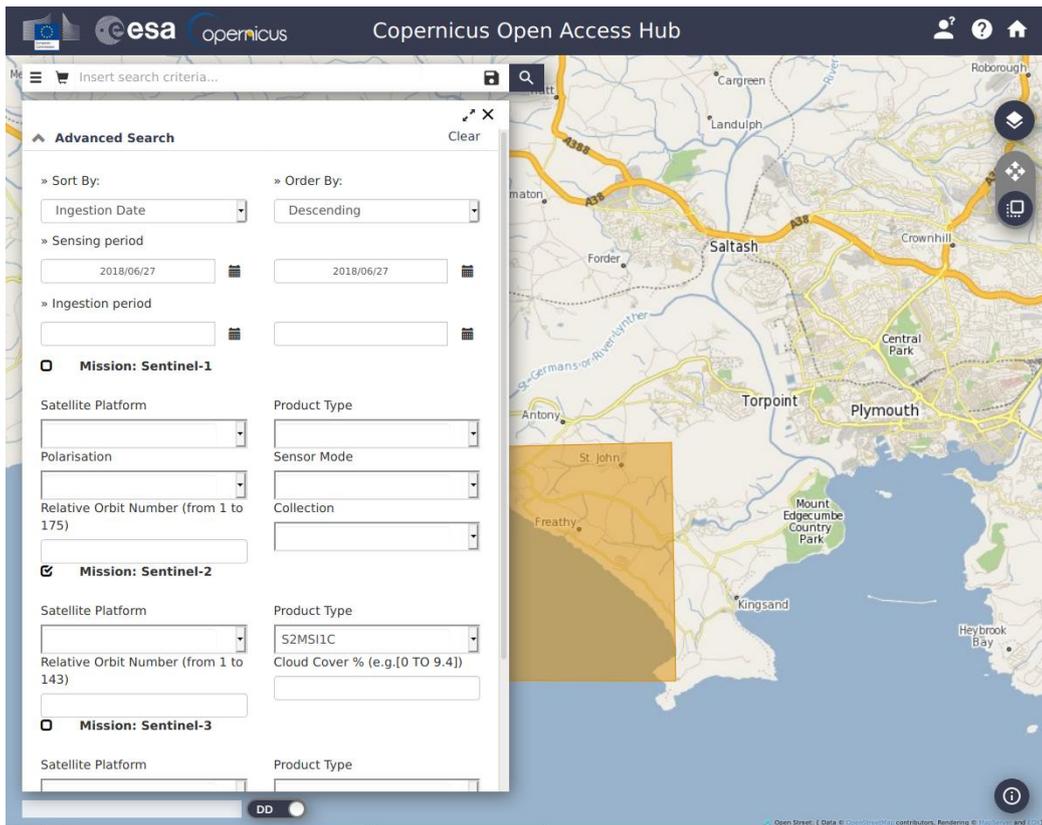


Figure 2. Example of using advance search parameters to find data.

This search criteria produces two results, which are two images from the same Sentinel-2 scene. The data used in the practical is

“S2B_MSIL1C_20180627T113319_N0206_R080_T30UUA_20180627T133731”. This is selected in

Figure 3. For more information on ESA naming conventions visit the [user guides](#) on ESA's website.

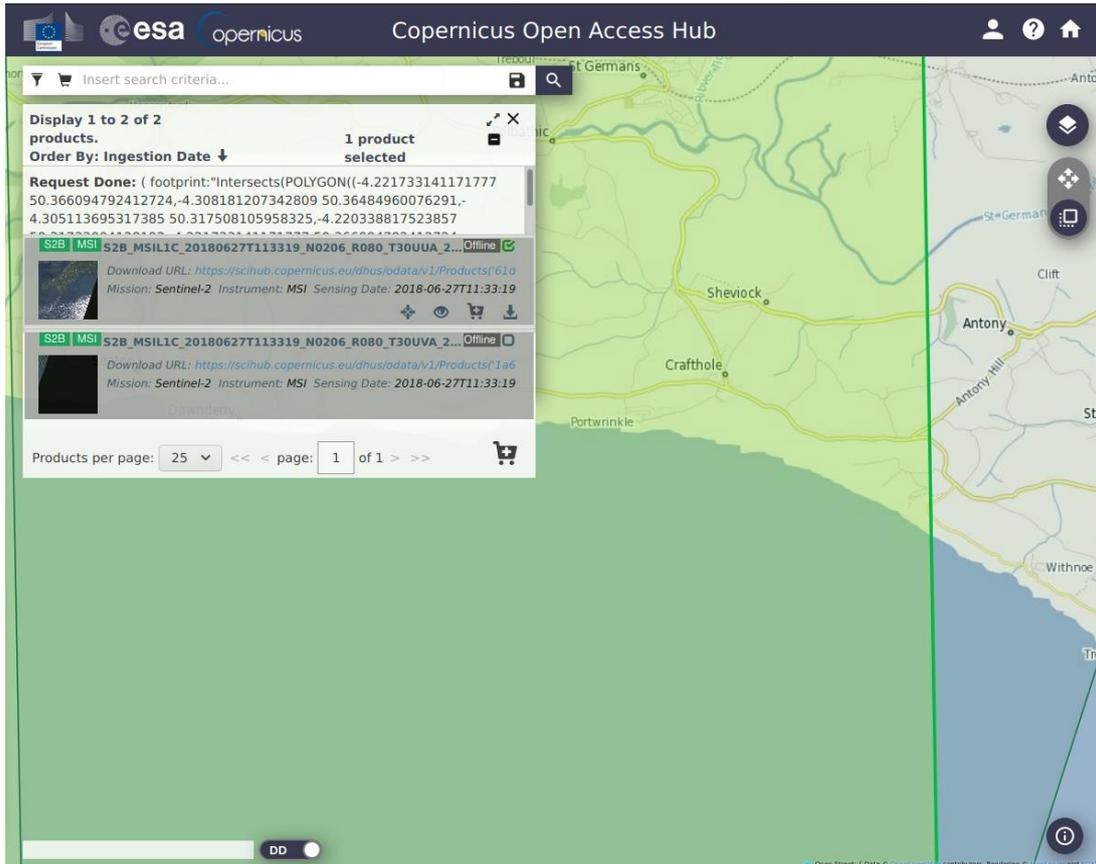


Figure 3. Example of advance search results.

Click the download icon (downwards arrow) whilst the relevant scene is selected. This should start to download from your browser. You will need to log in if you have not already.

5. Download

Download scenes by clicking on the download icon on the right of where the product appears in the search results (Figure 3). This will then be downloaded by your browser. If a large amount of data, or a regular download is required, the [SciHub API](#) can be used.

3. Setup

These steps assume you have already installed Anaconda. If you haven't installed ARCSI as part of the set up process then a create a [new environment](#) called "arcsi" and open a terminal within it.

From within this type:

```
conda install -c conda-forge arcsi
```

This needs to install a lot of packages so will take a while.

Test it is installed OK by typing

arcsi.py

This should print the help for arcsi.py

If you don't already have ACOLITE installed follow [this video](#)

The tutorials mostly use the Command Line Interface (CLI). The CLI requires typing commands into a terminal window rather than using the mouse to select options. Although the CLI is a more 'old school' way of using a computer it can be very powerful and allow you to automate tasks a lot easier. The commands you need to type use a fixed width font it is recommended you try and type them out rather than just copying and pasting. You can use the TAB key to complete file paths, type the first couple of letters of a file or path and press tab to complete. If there are multiple files with the same start you will need to type the additional characters and press tab again, once you get the hang of this using the command line will start to get more efficient.

The command treats a new line as an instruction to execute the command (the same as pressing the 'enter' button). Therefore, to enter commands spanning multiple lines you must break new lines with ^ on Windows (as shown in the examples) or \ on Linux or macOS.

Note, that when copying the commands from the word document sometime extra blank lines are added. It is recommended to copy commands out of the word document and into a text editor (Notepad on windows will work). You might want to save this text file for future reference.

4. Atmospheric Correction using ARCSI

The Atmospheric and Radiometric Correction of Satellite Imagery (ARCSI) is an open source package for atmospheric correction of data from many different sensors (including the Landsat series and Sentinel 2). It was developed by Pete Bunting at Aberystwyth University. It is based on the 6S radiative transfer model, which it uses through [Py6S](#), developed by Robin Wilson. The Py6S package is useful on its own and allows simulating at-sensor radiance from field measured reflectance. If you want to learn more about Py6S we have developed a [Jupyter notebook](#) which you may wish to follow through after this tutorial. You will need to install the jupyter-lab package to run it.

The steps here are described in more detail in the ARCSI Introduction Tutorial ([pdf](#)), please note that some of the install instructions in this guide are slightly out of date.

Make a folder to store all the files, move the Sentinel-2 scene you have downloaded into it.

ARCSI can use a Digital Elevation Model (DEM) for the atmospheric correction, one for Whitsand Bay, extracted from the SRTM mosaic can be download from [here](#). Once this file has been downloaded also move into this directory.

Then open anaconda and start the 'arcsi' environment.

Use cd to go to the directory containing your data, for example:

```
cd C:\Users\dan\FSEODAAAS\ARCSI
```

Then make two directories for storing outputs and temporary processing files using the following commands:

```
mkdir arcsi_out_fixed_aot
```

```
mkdir arcsi_temp
```

An important parameter in atmospheric correction models is Aerosol Optical Thickness (AOT; also called Aerosol Optical Depth, AOD) . This can be measured using a Sun Photometer either a handheld one at the time of overpass or from a fixed AERONET Station.

For Whitsand Bay at Rame Head:

https://aeronet.gsfc.nasa.gov/cgi-bin/type_one_station_opera_v2_new?site=Rame_Head

This is operated as part of the [Western Channel Observatory](#).

Find the AOT value at a wavelength closest to 550 nm corresponding to 11:33AM on 27th June 2018. On the site, set the 'AERONET Data Type' as 'AOD', select the correct year, month and day. This should display two plots, the plot on the right shows the AOT of several different wavelengths throughout the day (this can be enlarged by double clicking). For this practical we will use the 'AOT_500' (AOT at 500 nm) value at the time of our overpass for use with ARCSI.

```
arcsi.py -s sen2 -f KEA -o arcsi_out_fixed_aot ^
--tmpath arcsi_temp ^
-p RAD SREF METADATA --aot AOT_VALUE --scalefac 10000 ^
-i
S2B_MSIL1C_20180627T113319_N0206_R080_T30UUA_20180627T133731.SAFE\MTD_MSIL1
C.xml
```

Changing **AOT_VALUE** for the value obtained from AERONET. The reflectance values (0 – 1) are scaled by a value so they can be stored as an integer, reducing the file size. While the default of 1000 is normally good for terrestrial applications using a value of 10000 is better for water which has a low reflectance.

The output for ARCSI is a [KEA file](#) which isn't supported by all programs. Therefore, we will convert to a GeoTiff using GDAL translate. As we are only interested in part of the scene we will take a subset to make it more manageable.

```
gdal_translate -of GTiff -co "COMPRESS=LZW" -co "TILED=YES" ^
-co "COPY_SRC_OVERVIEWS=YES" -co "BIGTIFF=YES" ^
-projwin 405200 5586000 409800 5573000 ^
arcsi_out_fixed_aot\SEN2_20180627_latn500lonw50_T30UUA_ORB080_utm30n_vmsk_r
ad_sref.kea ^
arcsi_out_fixed_aot\SEN2_20180627_latn500lonw50_T30UUA_ORB080_utm30n_vmsk_r
ad_sref_aot0_1.tif
```

Open this image in SNAP by running SNAP (see installation instructions if it is not already installed), and selecting 'File', 'Open Product' from the drop-down menu.

Navigate to the subset tif that has been created (to

arcsi_out_fixed_aot\SEN2_20180627_latn500lonw50_T30UUA_ORB080_utm30n_vmsk_rad_sref_aot0_1.tif) and click open.

The filename should now be present in the left hand 'Product Explorer' window as shown in Figure 4.

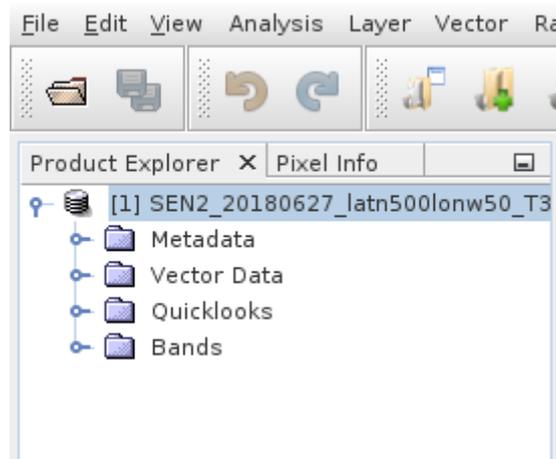


Figure 4. The SNAP 'Product Explorer'.

Right click on the filename in the 'Product Explorer' window and select 'Open RGB Image Window' as shown in Figure 5.

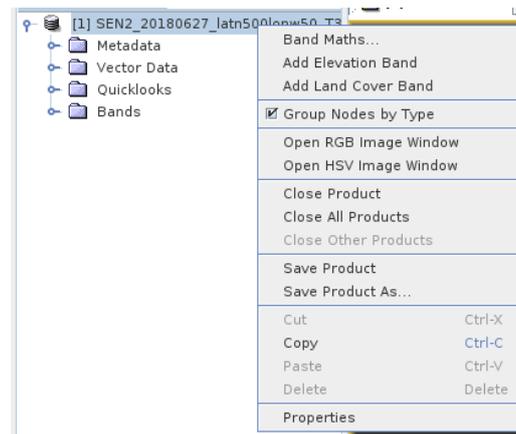


Figure 5. The product drop down menu.

Once 'Open RGB Image Window' is selected, the 'Select RGB-Image Channels' dialogue window should appear. Here we will select which bands to visualise. Figure 6 shows what bands to use for a true colour visualisation with this TIF.

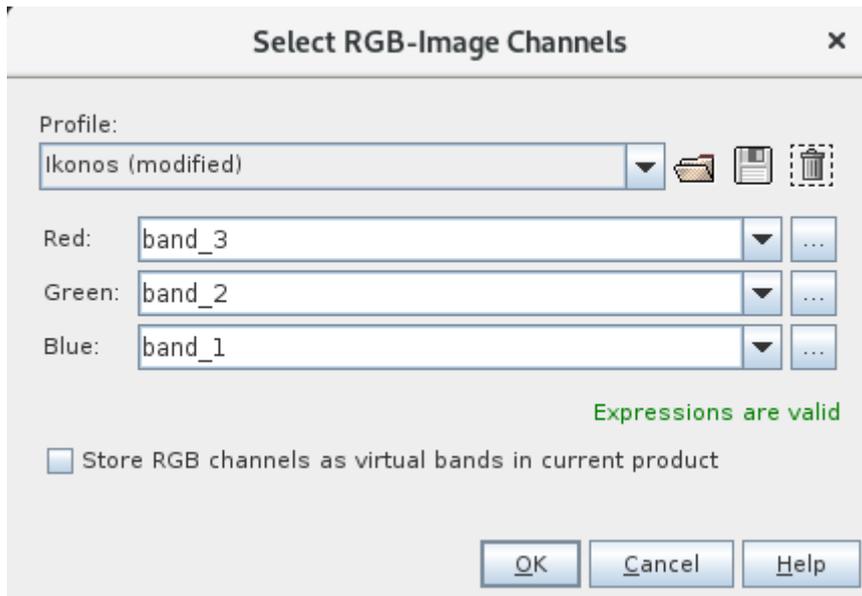


Figure 6. The SNAP 'Select RGB-Image Channels' dialogue box.

This should result in a true colour visualisation of our subset of South East Cornwall, including Whitsand Bay and part of the River Lynher shown in Figure 7.

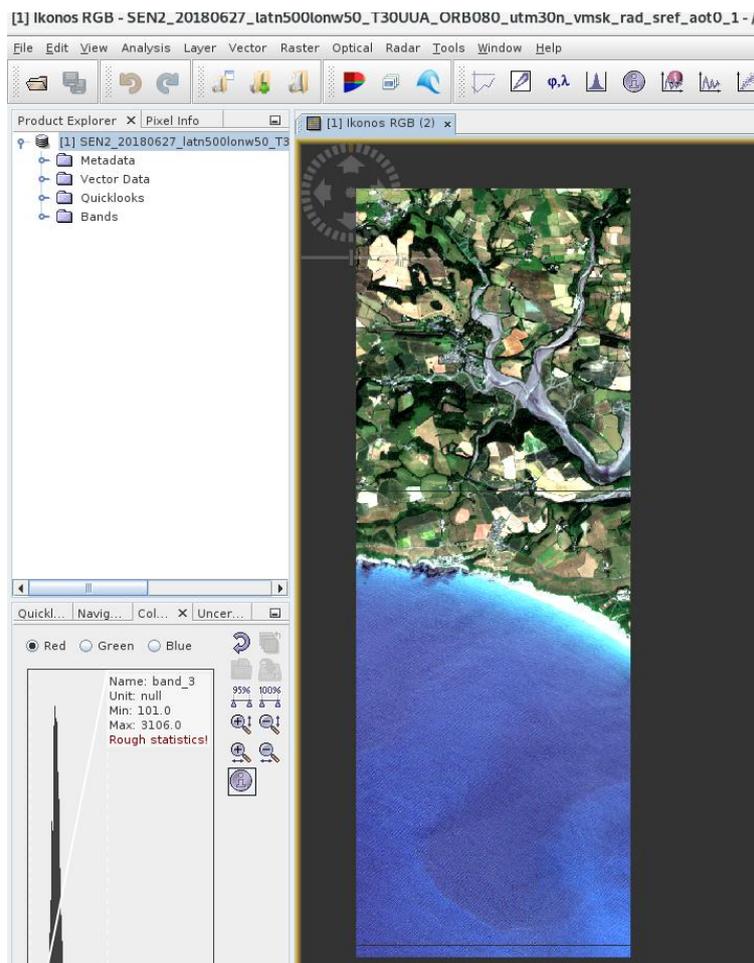


Figure 7. True colour visualisation of an ARCSI output in SNAP.

If reliable AOT data is not available, it is possible to estimate from the image in ARCSI using a dark object subtraction (DOS) to estimate the surface reflectance in blue channel. 6S is then numerically inverted to identify an AOT value which derives a surface reflectance value as close as possible to the estimated. This process requires the DEM downloaded earlier.

Make a new directory for the output:

```
mkdir arcsi_out_dos
```

Run the command using:

```
arcsi.py -s sen2 -f KEA -o arcsi_out_dos \  
--tmpath arcsi_temp ^  
--dem whitsand_bay_srtm_30m.tif ^  
-p RAD DOSAOTSGL SREF METADATA ^  
--scalefac 10000 ^  
-i ^  
S2B_MSIL1C_20180627T113319_N0206_R080_T30UUA_20180627T133731.SAFE\MTD_MSIL1  
C.xml
```

Again convert the output to a GeoTiff, subsetting to the area of interest:

```
gdal_translate -of GTiff -co "COMPRESS=LZW" -co "TILED=YES" ^  
-co "COPY_SRC_OVERVIEWS=YES" -co "BIGTIFF=YES" ^  
-projwin 405200 5586000 409800 5573000 ^  
arcsi_out_dos\SEN2_20180627_latn500lonw50_T30UUA_ORB080_utm30n_vmsk_rad_sre  
fdem.kea ^  
arcsi_out_dos\SEN2_20180627_latn500lonw50_T30UUA_ORB080_utm30n_vmsk_rad_sre  
fdem_dos.tif
```

We can also add CLOUDS to the products list to perform cloud masking, this takes a while to run so as our scene is cloud free we will skip for this practical but you may need to use it for your own data.

Add in some band indices (e.g., NDVI), can use gdal_calc.py (as in hyperspectral practical).

```
mkdir ndvi
```

```
gdal_calc.py --calc='(A.astype(numpy.float32) ^  
- B.astype(numpy.float32))/(A.astype(numpy.float32) + B.astype(numpy.float32))' ^  
--  
outfile=ndvi\SEN2_20180627_latn500lonw50_T30UUA_ORB080_utm30n_vmsk_rad_sref_aot0_1  
_NDVI.tif ^  
-A ^  
arcsi_out_fixed_aot\SEN2_20180627_latn500lonw50_T30UUA_ORB080_utm30n_vmsk_rad_sref  
_aot0_1.tif ^
```

```
--A_band=7 ^  
-B ^  
arcsi_out_fixed_aot\SEN2_20180627_latn500lonw50_T30UUA_ORB080_utm30n_vmsk_rad_sref  
_aot0_1.tif ^  
--B_band=3 --type=Float32
```

When you start using scenes from other locations you will also need to obtain a DEM. A good option for a DEM with global coverage between 60°N – 60°S is the Shuttle Radar Topography Mission ([SRTM](#)). For this workshop we have made the 90 m resolution SRTM available on our server, the entire thing is large (18 GB) but it is possible for ARCSI to just download the area you are interested in as it is running by using:

```
--dem ^  
/vsicurl/http://data.neodaas.ac.uk/files/dem/srtm_global_mosaic_90m.tif
```

If you are interested in Sentinel-2 data for the UK, you can download scenes which already been processed using ARCSI, following a similar method to that described above, from CEDA see <https://catalogue.ceda.ac.uk/uuid/bf9568b558204b81803eeebcc7f529ef>

Comparison with Airborne Hyperspectral Data

If you have already completed the hyperspectral practical, you can compare the Sentinel-2 data with the hyperspectral airborne data what has been mapped to UTM30N.

Now switch back to ‘airborne’ anaconda environment in order to use TuiView. The hyperspectral data can be opened with the true colour bands using the following command. Edit the following so the location of the mapped airborne data is correct:

```
tuiview --rgb --stddev --bands 153,94,53 ^  
hyperspectral_practical\outputs\sf177a023_elc_utm_wgs84N30_mapped_subset.tif
```

Once TuiView has launched, use the ‘Add Raster’ icon in the top left to add the Sentinel-2 data that has had atmospheric correction applied by ARCSI. You can choose what bands to visualise the Sentinel-2 data with by right clicking on the data’s filename in the ‘Layers’ window on the left of TuiView and selecting ‘Edit Stretch’. Then selecting what bands to assign to the red, green and blue channel is possible. Figure 8 shows the true colour visualisations of Sentinel-2 data overlaid by a subset of FENIX data.

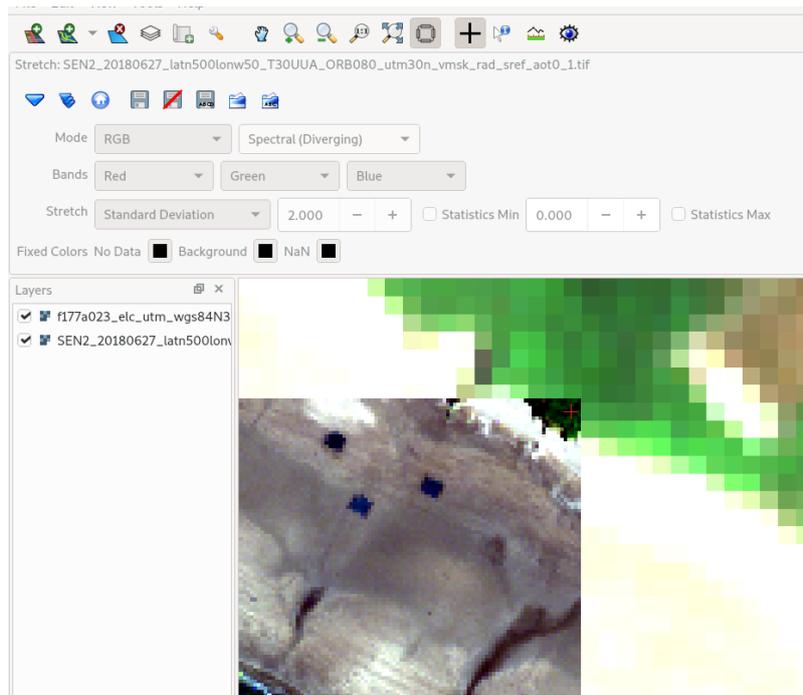


Figure 8. True colour visualisations of FENIX and Sentinel-2b level 3 products.

This should give a good idea of the differences in swaths and spatial resolutions between satellite-borne and airborne instruments. Comparing the Level 3 data will show the differences in spectral resolution, which can be shown by comparing the spectral profiles of the same location in Figure 9.

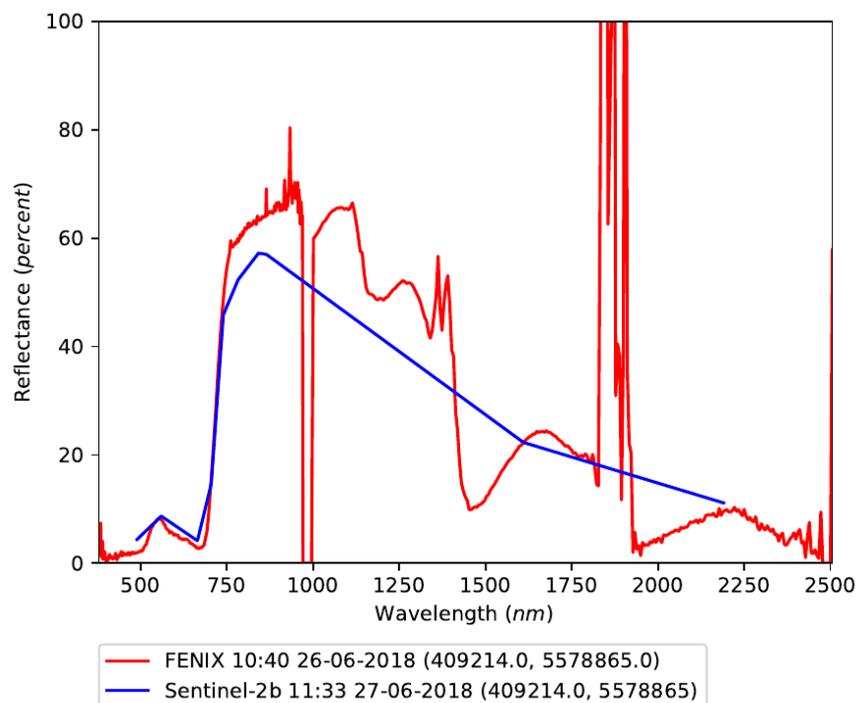


Figure 9. Comparison of vegetation at the same location in FENIX and Sentinel-2b data with different methods of atmospheric correction applied. Note that values have been scaled for this plot.

When examining the spectra from Sentinel-2 and the FENIX sensor. Think about what the reasons for differences between this location's spectra from these two datasets might be.

Figure 8 shows the mapped FENIX NDVI data over the Sentinel-2 NDVI data in TuiView. You may want to manually edit the stretch of each layer so values use the same shades in the colourmap selected.

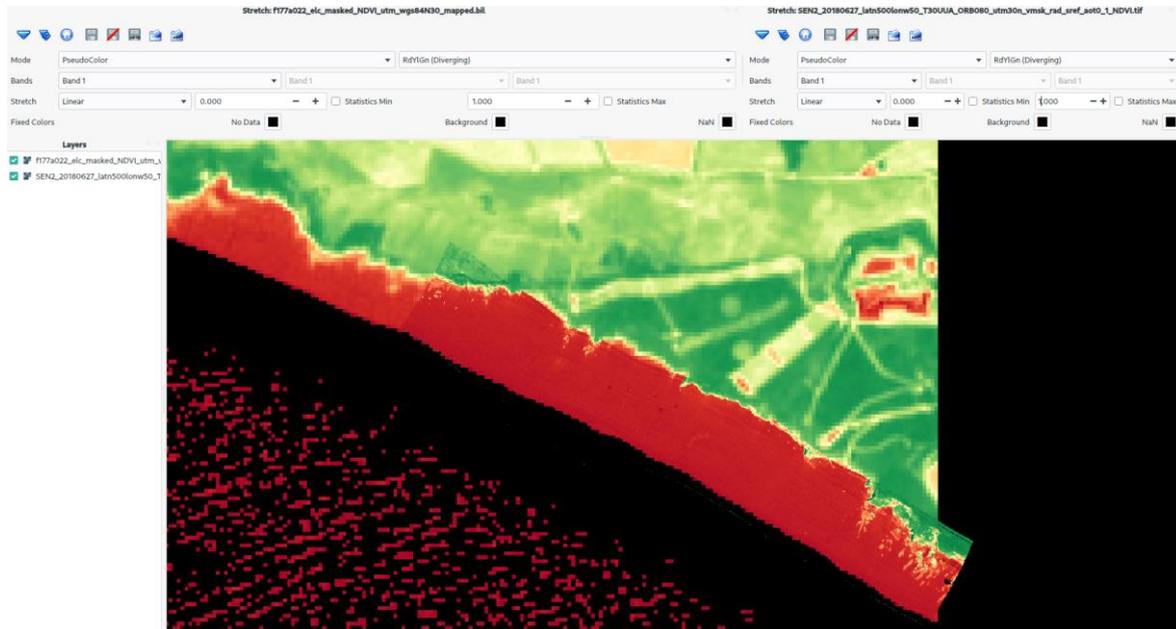


Figure 8. NDVI data from FENIX and Sentinel-2 displayed in TuiView. A Red-Yellow-Green colourmap has been used. The stretches of both datasets have been stretched between 0 and 1 instead of the TuiView default minimum value to maximum value in the image.

5. Atmospheric Correction using ACOLITE

Please follow through the video from:

https://data.neodaas.ac.uk/files/training_october_2020/videos/ACOLITE.mp4

6. Applying to your own site

Now try to find a scene from where you are interested in.

- What time should you use, are you interested in the most recent, data for a specific date, data showing particular conditions (e.g., low tide)?
- Which of the methods for atmospheric correction is most appropriate?
- Are there other band indices apart from NDVI which would be useful to calculate?
- If you had to download 10s or even 100s of scenes what would you need to consider?