ESA's Sentinel-2

Spectral Discovery for Sentinel-2 Imagery

(DOS- and GUI-based Version 2.0)

Software tools to easily and rapidly make colourful and detail-rich **Sentinel-2** imagery composite at **10m**-resolution, with **3** simple button clicks:

- Band Combination
- Image Stretching
- Image Pan-sharpening
- Exploratory Image Feature Extraction

Developers: BigData Earth | GeoSage
http://www.BigDataEarth.com/ | http://www.GeoSage.com/

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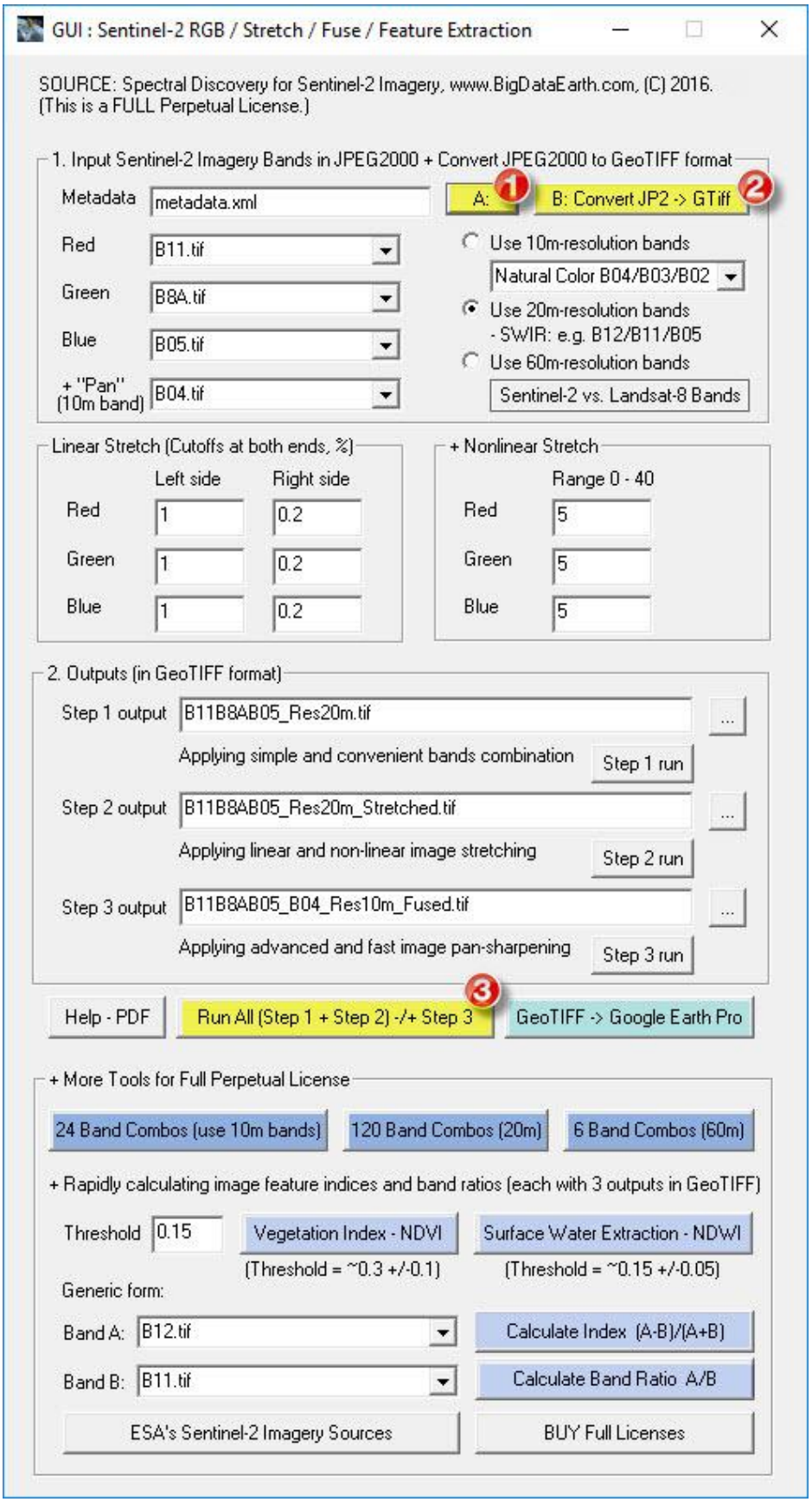
BigDataEarth®


GUI : Sentinel-2 RGB / Stretch / Fuse / Feature Extraction
SOURCE: Spectral Discovery for Sentinel-2 Imagery, www.BigDataEarth.com, (C) 2016.
(This is a FULL Perpetual License.)
1. Input Sentinel-2 Imagery Bands in JPEG2000 + Convert JPEG2000 to GeoTIFF format
Metadata
metadata.xml
A:
1
B: Convert JP2 -> GTiff
2
Red
B11.tif
Green
B8A.tif
Blue
B05.tif
+ "Pan" (10m band)
B04.tif
Use 10m-resolution bands
Natural Color B04/B03/B02
Use 20m-resolution bands
- SWIR: e.g. B12/B11/B05
Use 60m-resolution bands
Sentinel-2 vs. Landsat-8 Bands
Linear Stretch (Cutoffs at both ends, %)
Left side
Right side
Red
1
0.2
Green
1
0.2
Blue
1
0.2
+ Nonlinear Stretch
Range 0 - 40
Red
5
Green
5
Blue
5
2. Outputs (in GeoTIFF format)
Step 1 output
B11B8AB05_Res20m.tif
...
Applying simple and convenient bands combination
Step 1 run
Step 2 output
B11B8AB05_Res20m_Stretched.tif
...
Applying linear and non-linear image stretching
Step 2 run
Step 3 output
B11B8AB05_B04_Res10m_Fused.tif
...
Applying advanced and fast image pan-sharpening
Step 3 run
Help - PDF
Run All (Step 1 + Step 2) -/+ Step 3
3
GeoTIFF -> Google Earth Pro
+ More Tools for Full Perpetual License
24 Band Combos (use 10m bands)
120 Band Combos (20m)
6 Band Combos (60m)
+ Rapidly calculating image feature indices and band ratios (each with 3 outputs in GeoTIFF)
Threshold
0.15
Vegetation Index - NDVI
(Threshold = ~0.3 +/-0.1)
Surface Water Extraction - NDWI
(Threshold = ~0.15 +/-0.05)
Generic form:
Band A:
B12.tif
Band B:
B11.tif
Calculate Index (A-B)/(A+B)
Calculate Band Ratio A/B
ESA's Sentinel-2 Imagery Sources
BUY Full Licenses

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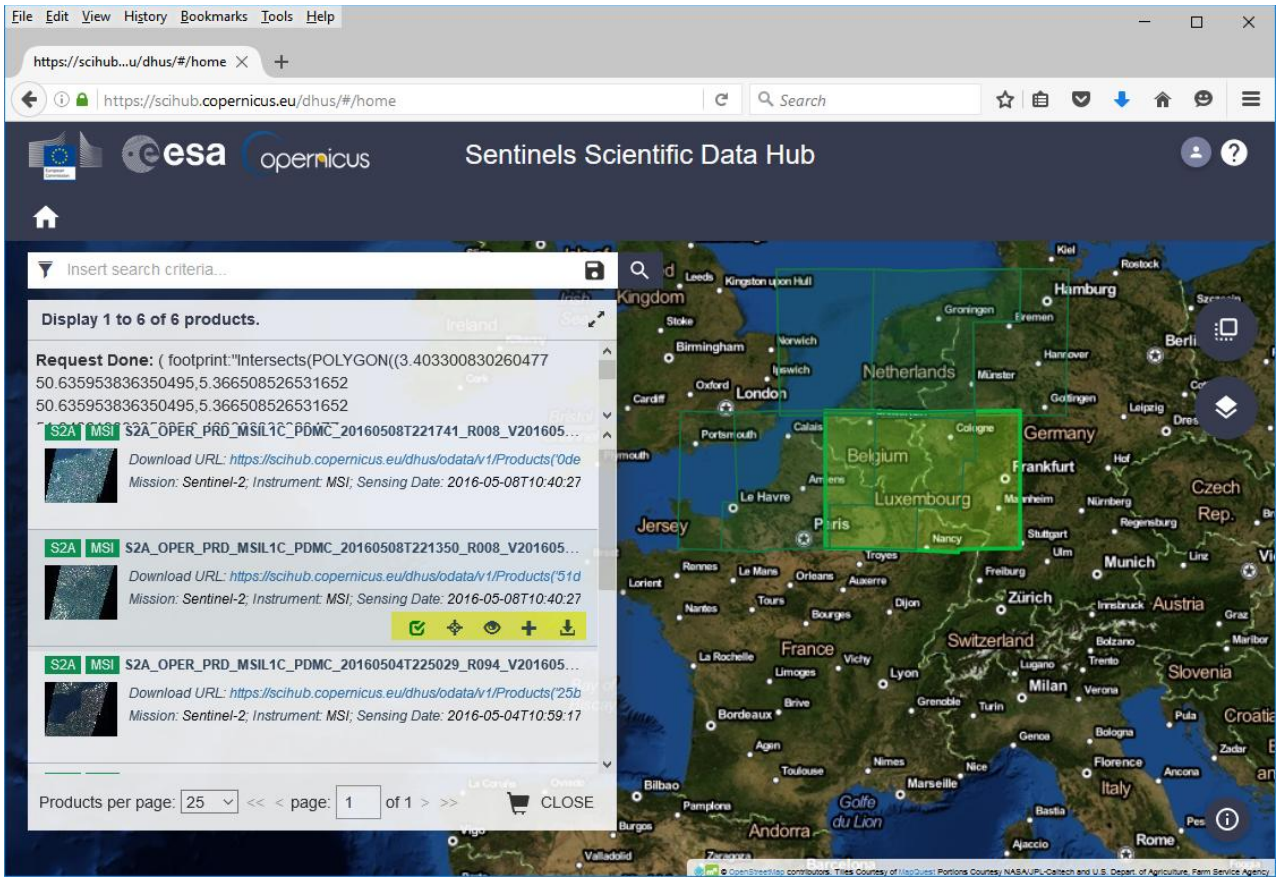
1. Download free Sentinel-2 Level-1C imagery data (4 methods)

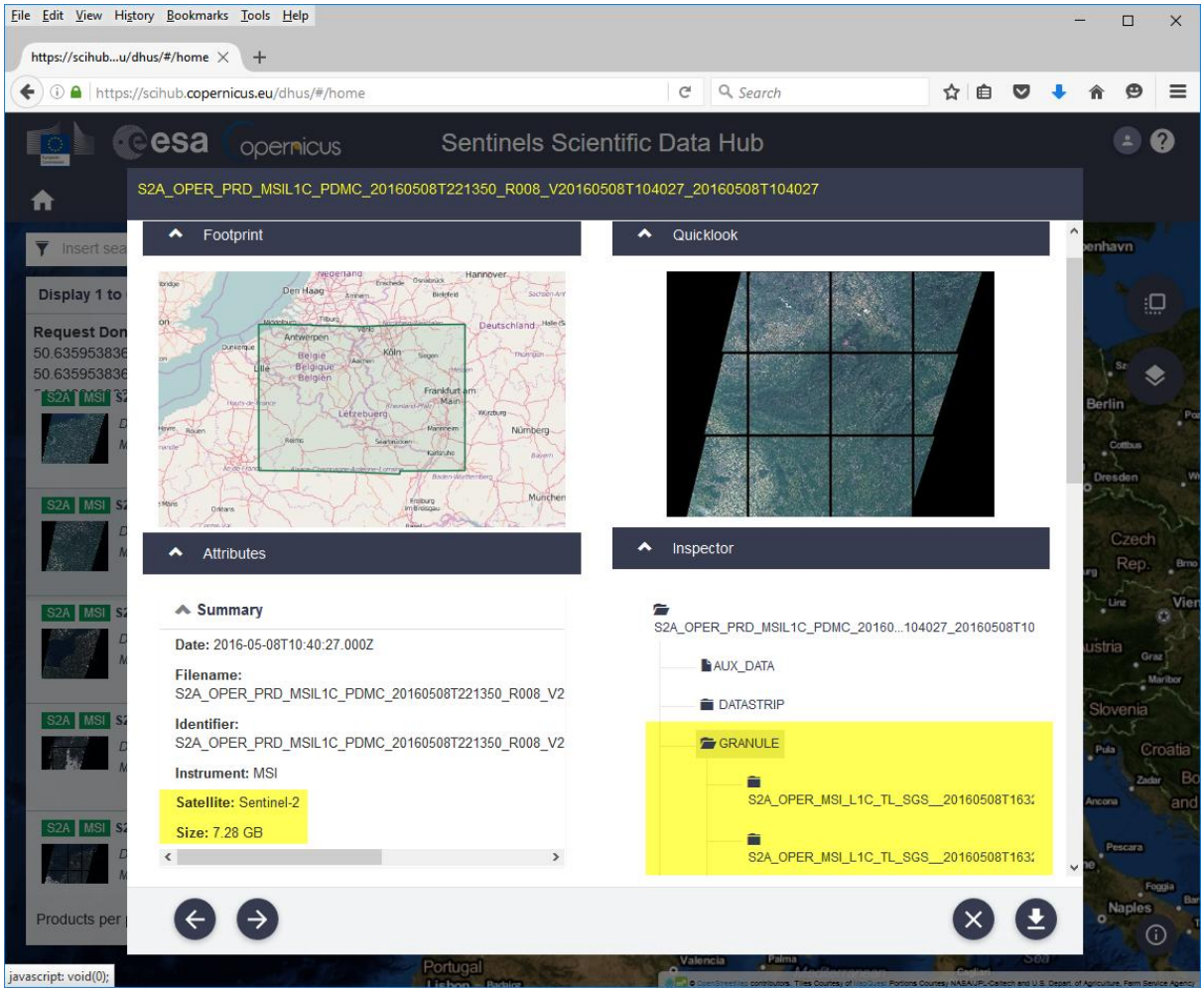
1.1 - Method 1

Through ESA's Sentinels Scientific Data Hub - https://scihub.copernicus.eu/
Or, directly go to map-based imagery search tool: https://scihub.copernicus.eu/dhus/#/home

- Login
- Define AOI
- Define search criteria
- Highlight the scene of interest and preview the imagery

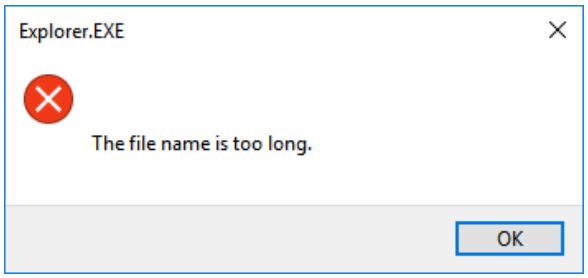


By this method, one can download **individual scenes** of Sentinel-2 imagery. Each scene is quite large given the wide swath of 290 km and the image resolution of 10 m. Each scene at 10m-resolution is about 30,000 x 30,000 pixels. The file size of a single scene (downloadable zip file) could be far greater than 10 GB.

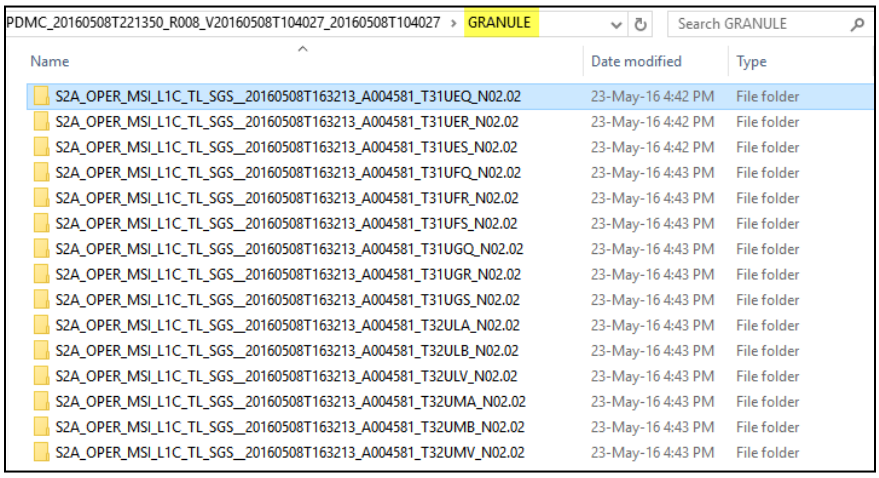


In Sentinel-2 data structure, each scene is actually divided into many (e.g. 12) smaller-sized, overlapping **granules / tiles**, and each granule / tile is 100 x 100 km (not including overlapping areas).

A common issue users often experience when unzipping the downloaded Sentinel-2 data file is that the length of file path exceeds 256 characters. Windows OS might display the following error message. It is up to the user to plan that the length of each input and output file path does not exceed the limit of 256 characters. (*Spectral Discovery for Sentinel-2 Imagery* software automatically appends file name extensions such as "_Res10m_Stretched.tif" and checks the length of file paths.)

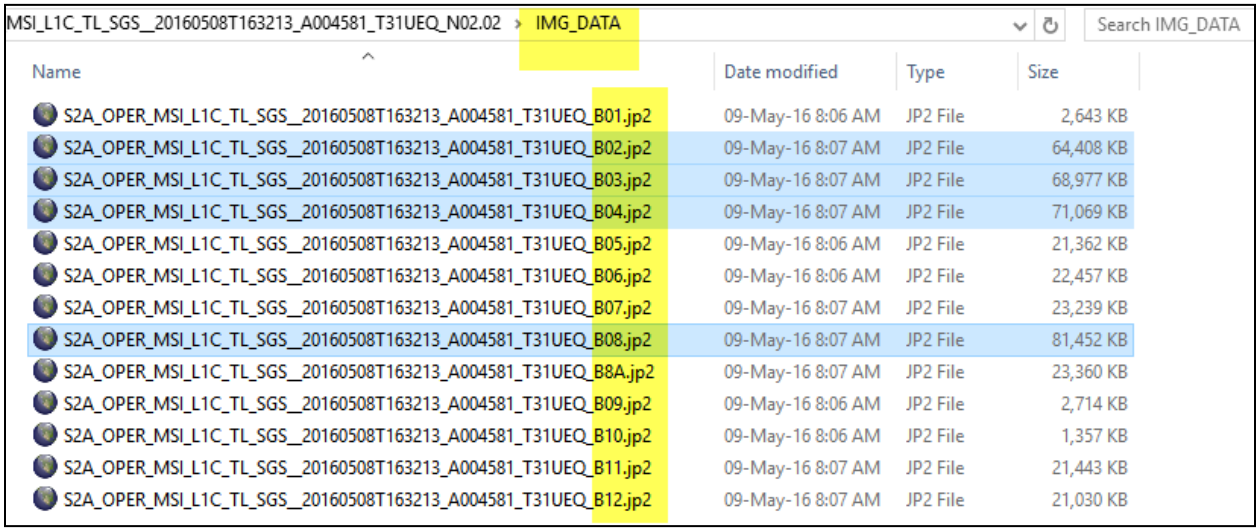


Let's take a look at an example: The following downloaded **scene** contains 15 **granules** under the **\GRANULE** folder: ..\Download\S2A_OPER_PRD_MSIL1C_PDMC_20160508T221350_R008_V20160508T104027_20160508T104027**GRANULE**\



Then, each **granule** contains a metadata file (*.xml), **image data** and others. *Spectral Discovery for Sentinel-2 Imagery* software targets and processes these **granules / tiles**, and the metadata file (*.xml) located here is **the first input to the software**. Please note again what is required is the metadata file (*.xml) specific to the **granule/tile**, not the metadata file (also in *.xml) specific to the **whole scene**.

For each granule, the **IMG_DATA** folder contains a total of 13 imagery bands in JEPG2000 format.

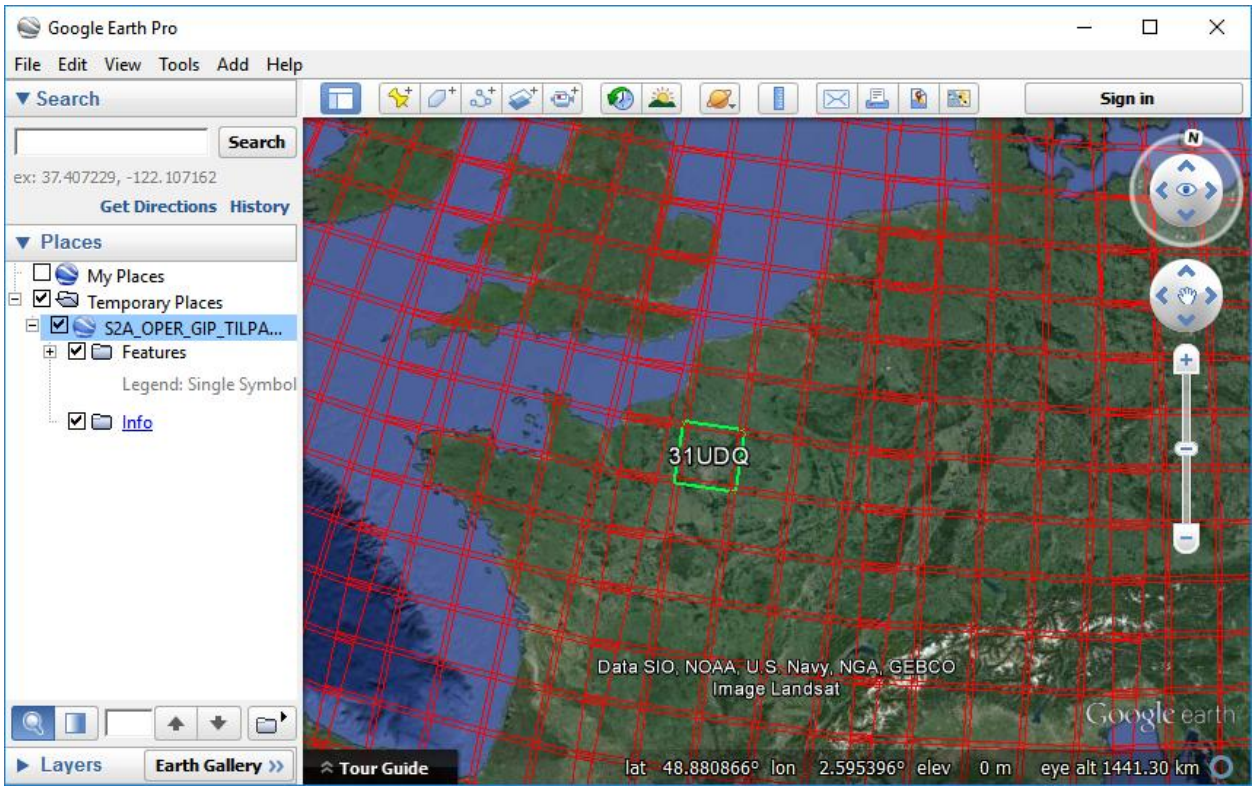


1.2 - Method 2

Sentinel-2 on AWS: "Sentinel-2 data available for anyone to use via Amazon S3"
http://sentinel-pds.s3-website.eu-central-1.amazonaws.com/ (including an easy-to-use map-based image search tool)

This website provides a brief overview about the **granule/tile** system Sentinel-2 uses. It is based on the NATO Military Grid Reference System (MGRS). The **Sentinel-2 Level-1C tiling grid** in Google Earth KML format can be downloaded from ESA - KML file (~103MB); alternatively, a compressed version can be downloaded here (~9 MB).

Open this KML file in Google Earth, and then locate the **[UTM code]/latitude band/square/** for an **Area of Interest (AOI)**. For example, tile name for Paris: 31/U/DQ/ (as shown in the figure below). Each granule/tile is 100 x 100 km (excluding overlapping edges).



Tile name for a few other cities following the tiling grid format: **[UTM code]/latitude band/square/**

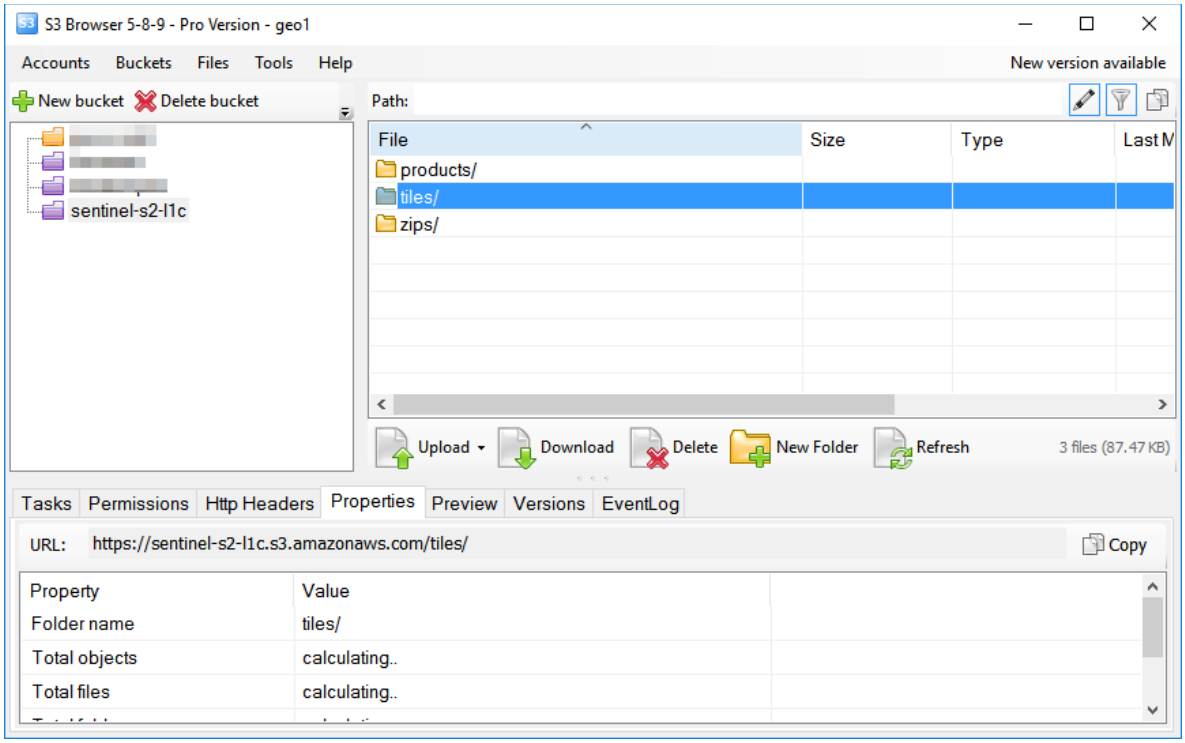
San Francisco, the U.S.: 10/S/EG/
Rio, Brazil: 23/K/PQ/
Beijing, China: 50/T/MK/
Cape Town, South Africa: 34/H/BH/
Rome, Italy: 33/T/TG/
Perth, Australia: 50/H/LK/

After knowing the location (tiling grid) for the AOI, one can start to browse and download individual imagery bands, via **http://sentinel-s2-l1c.s3-website.eu-central-1.amazonaws.com/**

Notes:

We suggest users download Sentinel-2 imagery files from AWS S3 based on **data folders** (not single files, one by one), using tools such as **S3 Browser** (http://s3browser.com/). Many similar tools, including AWS Command Line Tools, can make data download very quickly and efficiently.

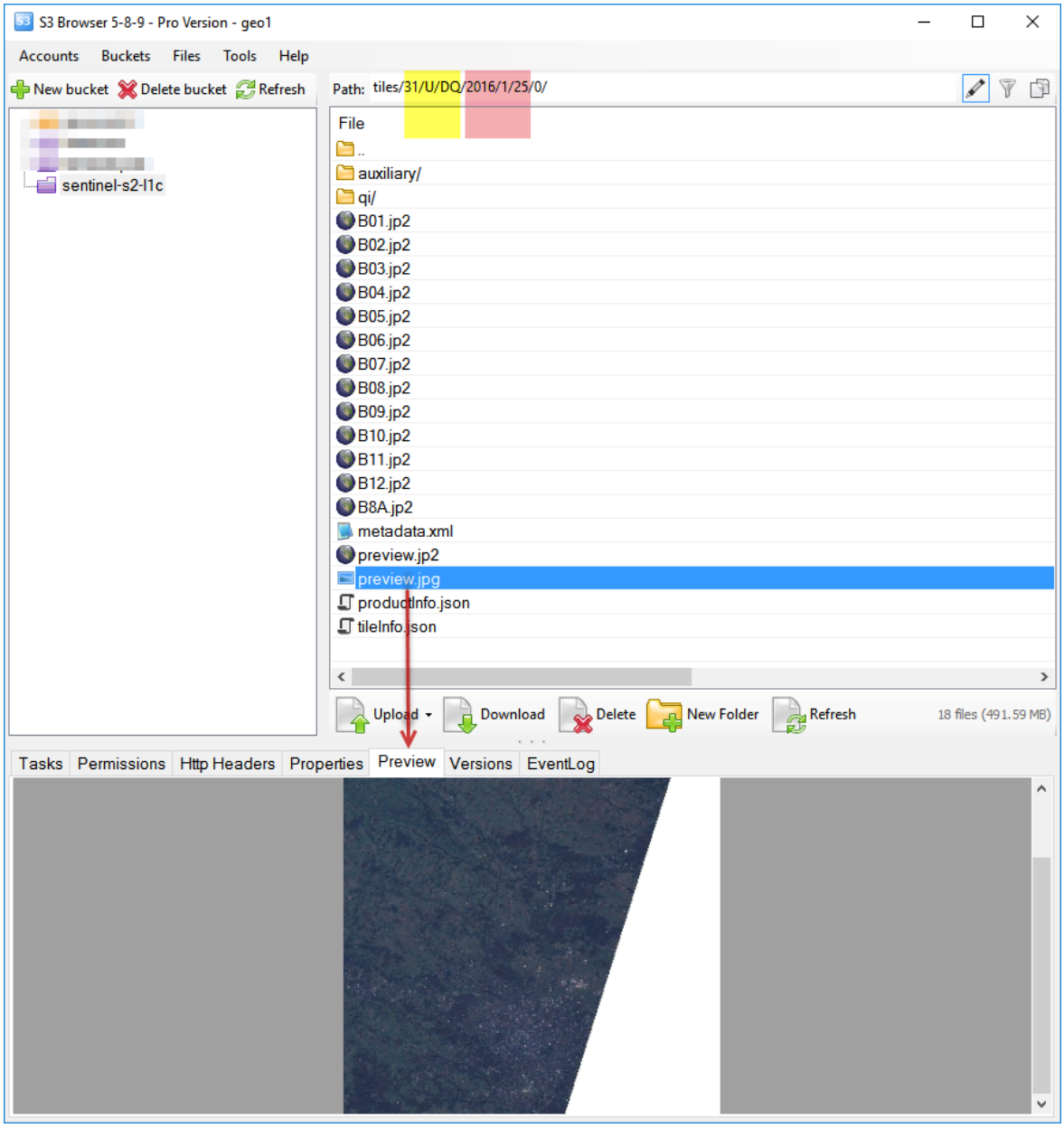
For example, in **S3 Browser**, first add the Sentinel-2 data **public bucket** using the menu **Buckets | Add External Bucket:** sentinel-s2-l1c, and then start to browse and download Sentinel-2 data, folder by folder. (S3 Browser Pro Version promises faster download, e.g. by x5, x10 times.)



Once one gets into the sentinel-s2-l1c bucket, three folders are there so far: **products**, **tiles** and **zips**. In what follows, we briefly demonstrate how to download files by **tiles** and by **zips**.

Tiles

The following figure shows an example of imagery files for Paris: tiling grid 31/U/DQ/, image date 2016-01-25. One may just download the 2016-01-25 folder (containing all imagery files within) to a local hard drive. Each granule/tile is about 500 MB in file size.

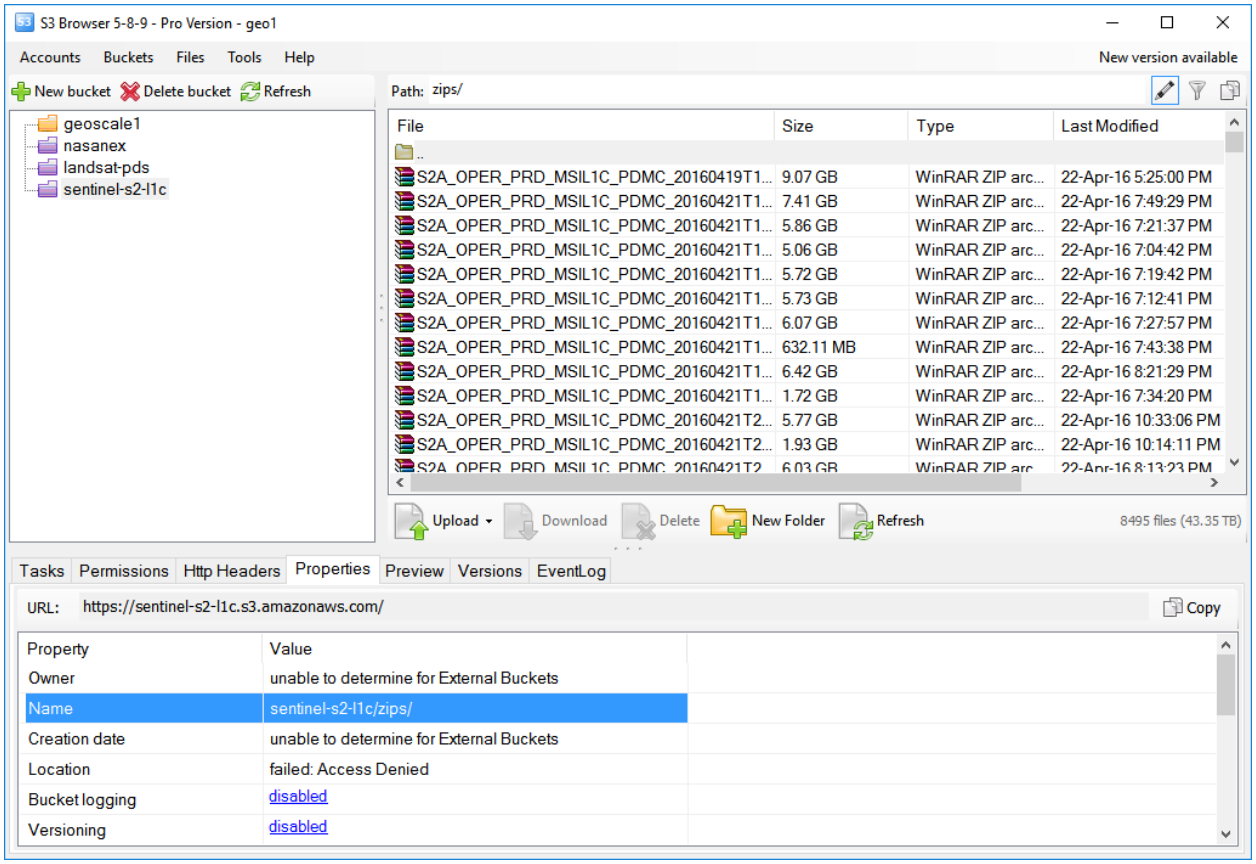


Spectral Discovery for Sentinel-2 Imagery software also processes such granules/tiles directly downloaded from AWS . Note that unlike the imagery data downloaded via **Method 1**, the **metadata.xml** file is **included** in the granule/tile data folder, and each band is indicated by **short file names**. **In this case, the software also reads metadata.xml as the first input.**

Zips

Another option is to download larger-sized imagery data files for a whole Sentinel-2 scene (consisting of multiple granules/tiles), using the zips folder on AWS S3: **sentinel-s2-l1c/zips/**

Each downloaded zip file is similar to those from the Sentinels Scientific Data Hub introduced in Method 1.



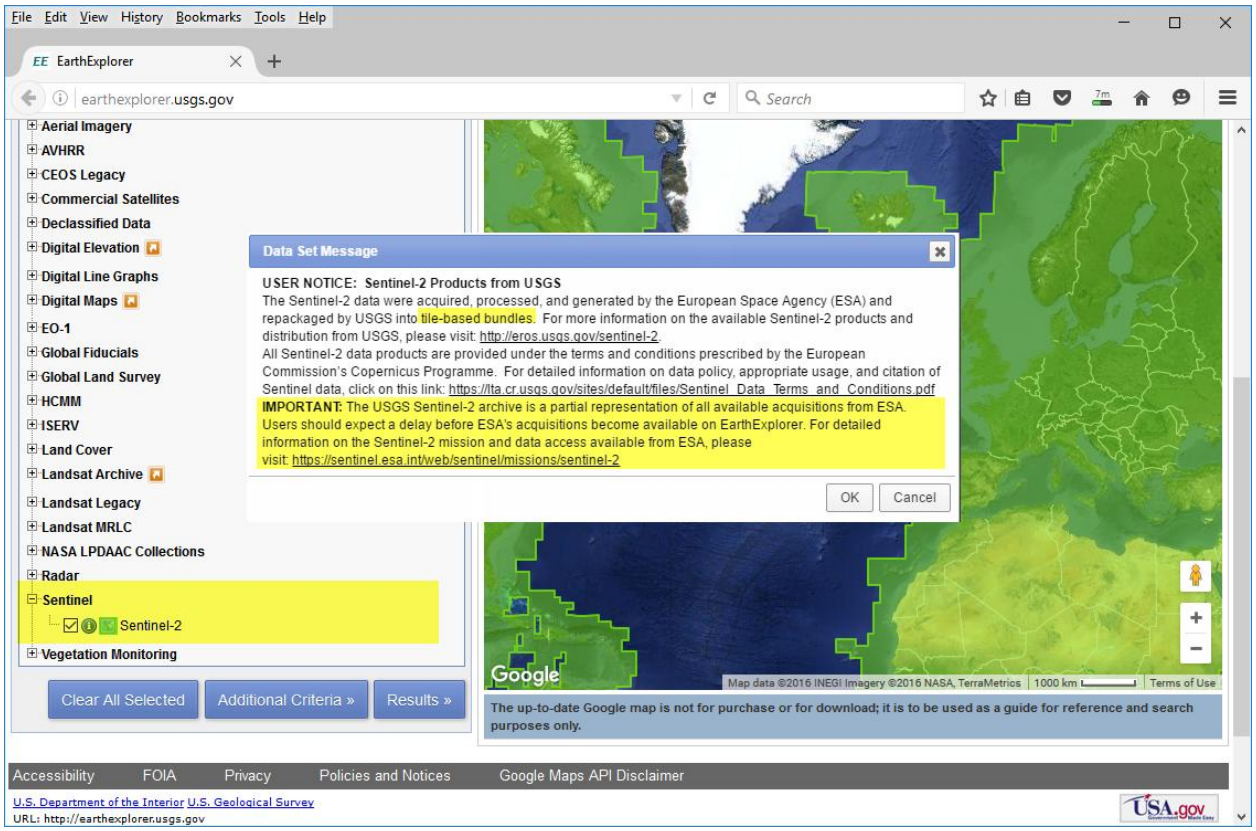
1.3 - Method 3

Through the USGS EarthExplorer and the USGS GloVis

Exciting News - "USGS Partners with European Space Agency to Deliver Copernicus Earth Data"

USGS Sentinel-2 portal: https://lta.cr.usgs.gov/sentinel_2

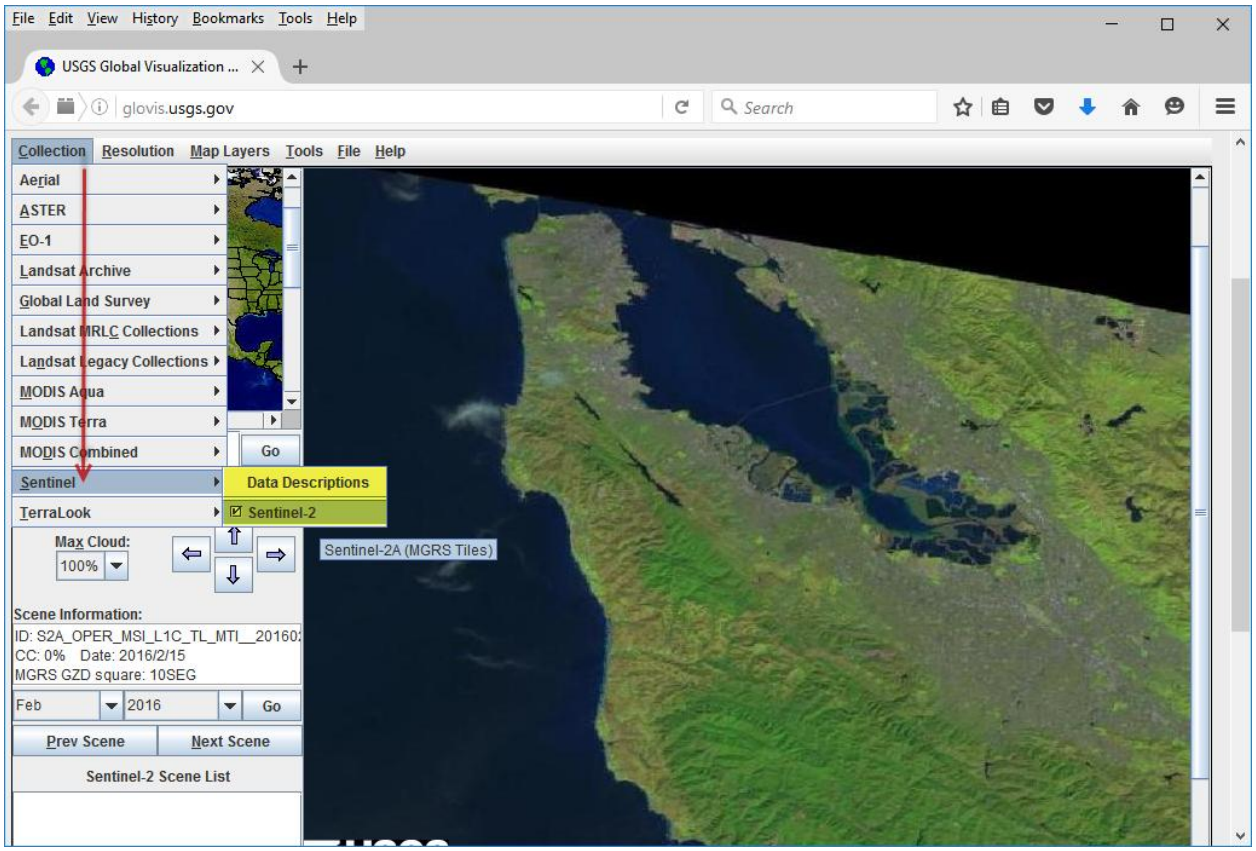
USGS EarthExplorer - http://earthexplorer.usgs.gov/



USGS Earth Explorer includes this Data Set Message:

> **USER NOTICE: Sentinel-2 Products from USGS**
> The Sentinel-2 data were acquired, processed, and generated by the European Space Agency (ESA) and repackaged by USGS into **tile-based bundles**. For more information on the available Sentinel-2 products and distribution from USGS, please visit: http://eros.usgs.gov/sentinel-2.
> All Sentinel-2 data products are provided under the terms and conditions prescribed by the European Commission's Copernicus Programme. For detailed information on data policy, appropriate usage, and citation of Sentinel data, click on this link: https://lta.cr.usgs.gov/sites/default/files/Sentinel_Data_Terms_and_Conditions.pdf
> **IMPORTANT:** The USGS Sentinel-2 archive is **a partial representation** of all available acquisitions from ESA. Users should expect a delay before ESA's acquisitions become available on EarthExplorer. For detailed information on the Sentinel-2 mission and data access available from ESA, please visit: https://sentinel.esa.int/web/sentinel/missions/sentinel-2

USGS GloVis - http://glovis.usgs.gov/



The imagery data downloaded from the **USGS EarthExplorer and GloVis** contain two parts:

- Level-1C Tile in JPEG2000 format
- Full Resolution Browse in GeoTIFF format

Once unzipped, the file structure for each granule/tile is similar to that in **Method 1**; that is, the metadata file (the first input required by the software) is located outside of the **IMG_DATA** folder, **one level up.**

Notes:

As highlighted above, as the Sentinel-2 imagery data on the USGS portal is only a partial collection of the entire Sentinel-2 data sets, and the data sharing between the USGS and ESA has just started, users may try to download more imagery data via Method 2 and Method 1 introduced above.

1.4 - Method 4:

Sentinel-2 Imagery on Google Earth Engine: Source

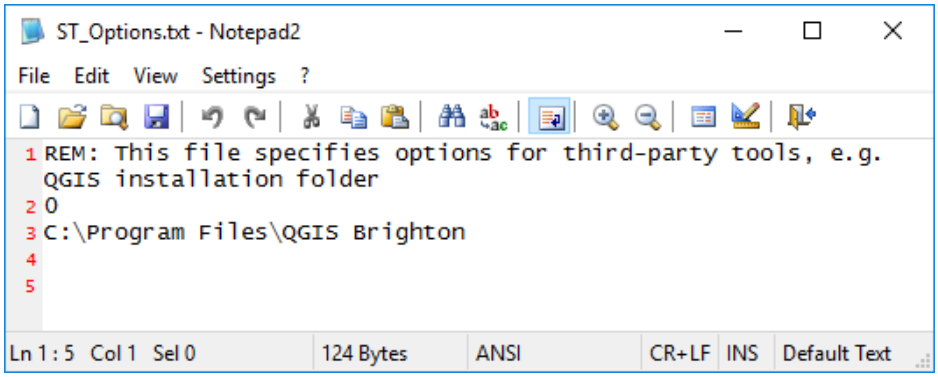
2. Install DOS-/GUI-based Spectral Discovery for Sentinel-2 Imagery

The software is available at http://www.GeoSage.com/

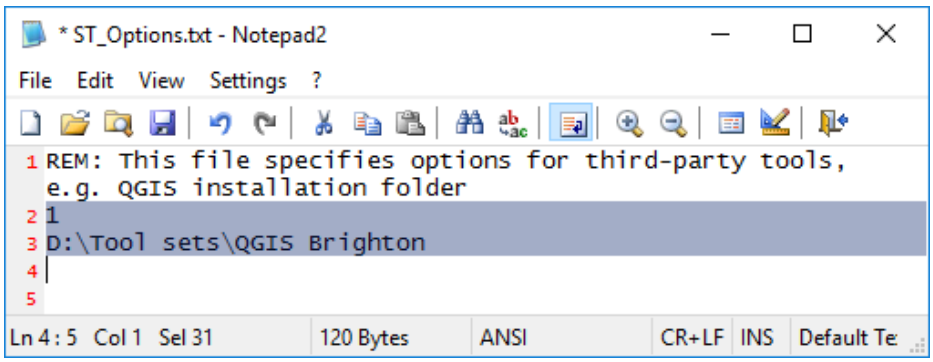
- Prerequisite: Install free Microsoft VC++ 2015 Redistributable (x86)

- Prerequisite: Install the popular open-source GIS software QGIS. *Spectral Discovery for Sentinel-2 Imagery* will use the *GDAL_translate.exe* tool included in QGIS to convert downloaded Sentinel-2 data from compressed JPEG2000 format to uncompressed, analysis-ready popular GeoTIFF format. (Ignore this step if a user has installed QGIS already, or has made such conversions already with other geospatial software.)

  It is expected that a version of QGIS will be installed under the default "Program Files" or "Program Files (x86)" folder. *Spectral Discovery for Sentinel-2 Imagery* software can automatically detect its location. However, if a user has installed QGIS under a folder other than the above, the following change is required for the "ST_Options.txt" file located in the program folder: for the last two lines, from the current



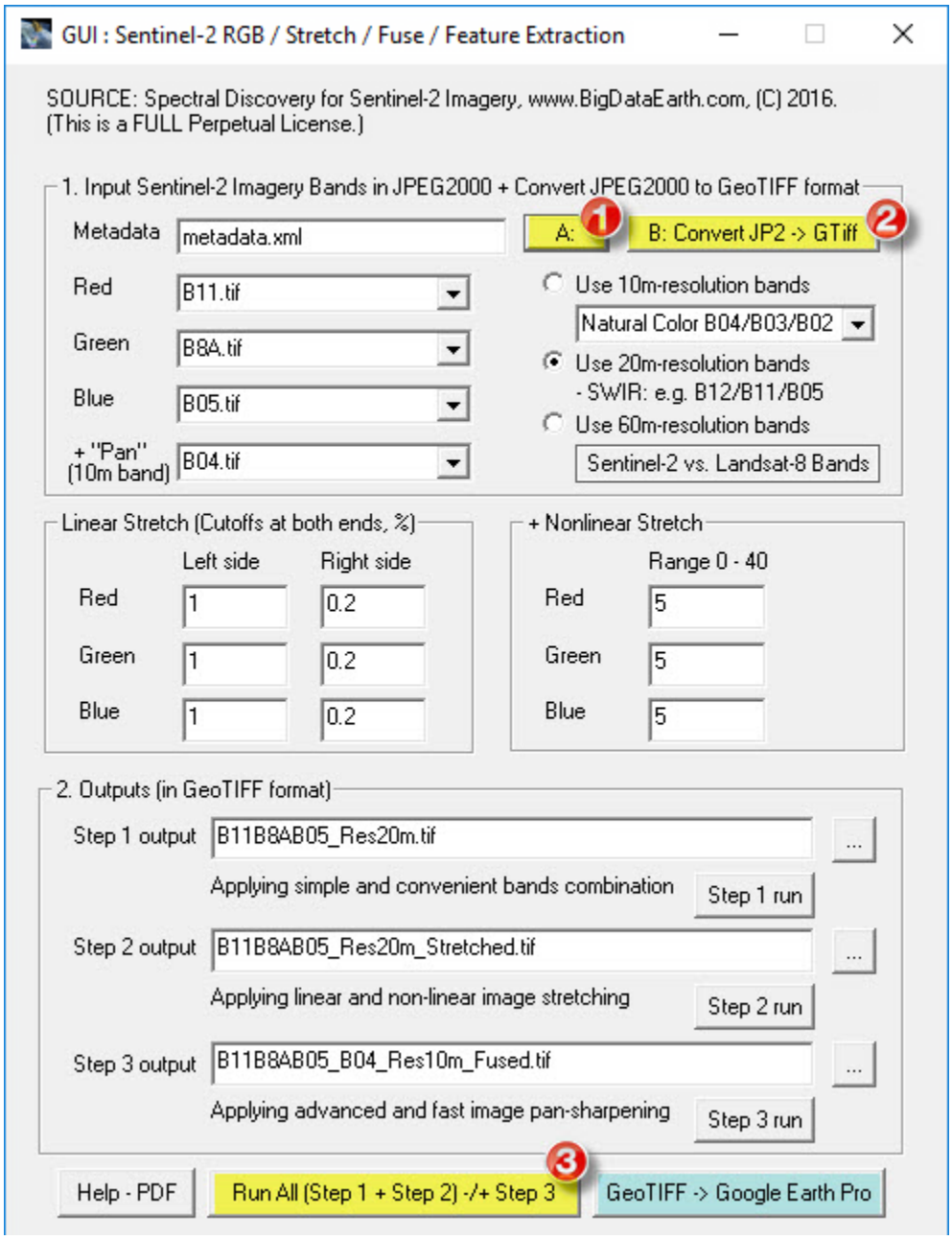
  to something like this indicating where QGIS is installed:



- Optional: Install free Google Earth Pro for displaying and verifying outputs

3. Run GUI (with three simple button clicks)

- **Button 1**: Select metadata file (*.xml) of your downloaded Sentinel-2 granule / tile, and the rest of GUI fields will be automatically populated.
- **Button 2:** Convert downloaded imagery data in JPEG2000 format to uncompressed, analysis-ready GeoTIFF format.
- **Button 3**: Run three steps altogether (Band Combination, Image Stretching, and Image Pan-sharpening) and output files in GeoTIFF format.



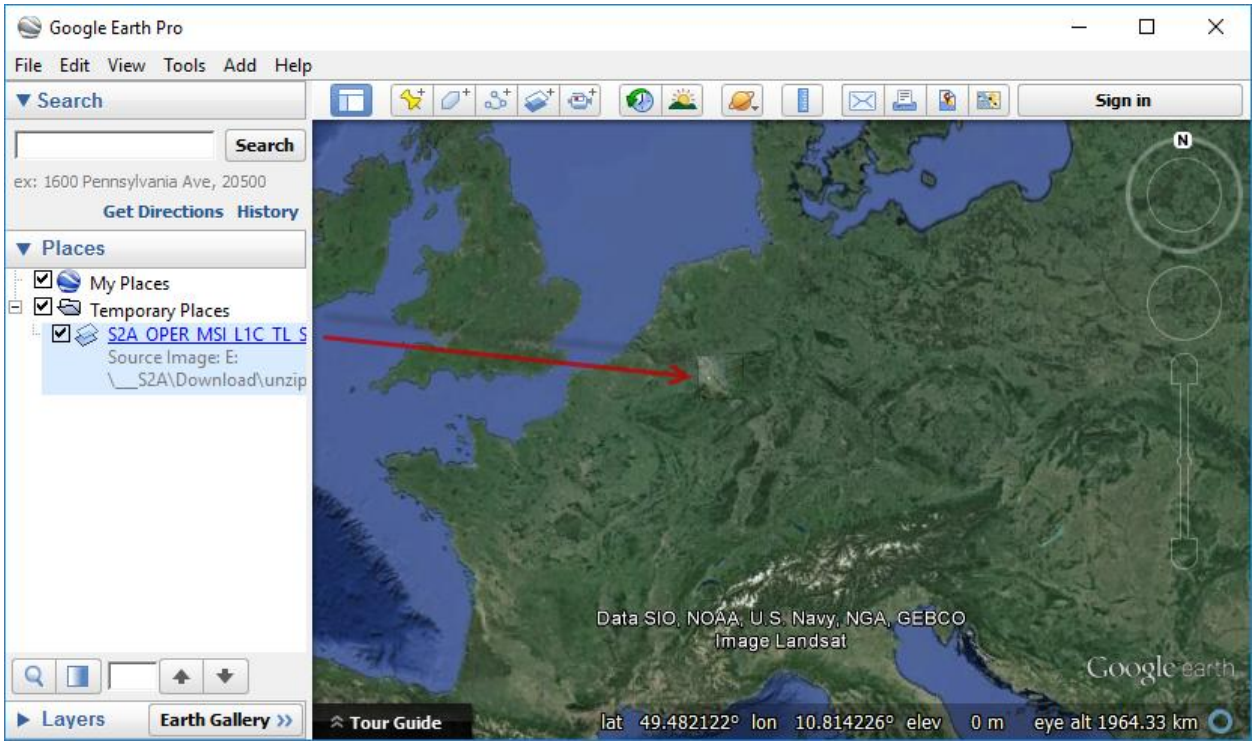
Users may modify and optimise image stretching parameters for various visual styles of the output.

The command-line of each run is stored in a **log.txt** file under the data folder. Users who are experienced with DOS batch runs will find this file very handy (e.g. with this file the runs can be repeated entirely in DOS console without the GUI). Users may also use the log file to edit DOS batch command-lines for more efficient implementation when dealing with 100s or 1,000s of Sentinel-2 granules/tiles.

4. Display stretched and pan-sharpened imagery composites (GeoTIFF format) directly in Google Earth Pro

Google Earth Pro can import geospatial data of a wide array of formats, including GeoTIFF. Users can just simply drag the stretched or pan-sharpened imagery composite into Google Earth Pro, for easy display and comparison with the rich basemaps provided by Google. (The imported imagery may be exported to KMZ format in Google Earth Pro.)

Google Earth Pro is now free (since 30 January 2015) and a copy can be downloaded from Google: http://www.google.com/earth/



Example: Rapidly-processed daily fresh Sentinel-2 imagery easily displayed in Google Earth Pro

5. Additional features for innovative applications

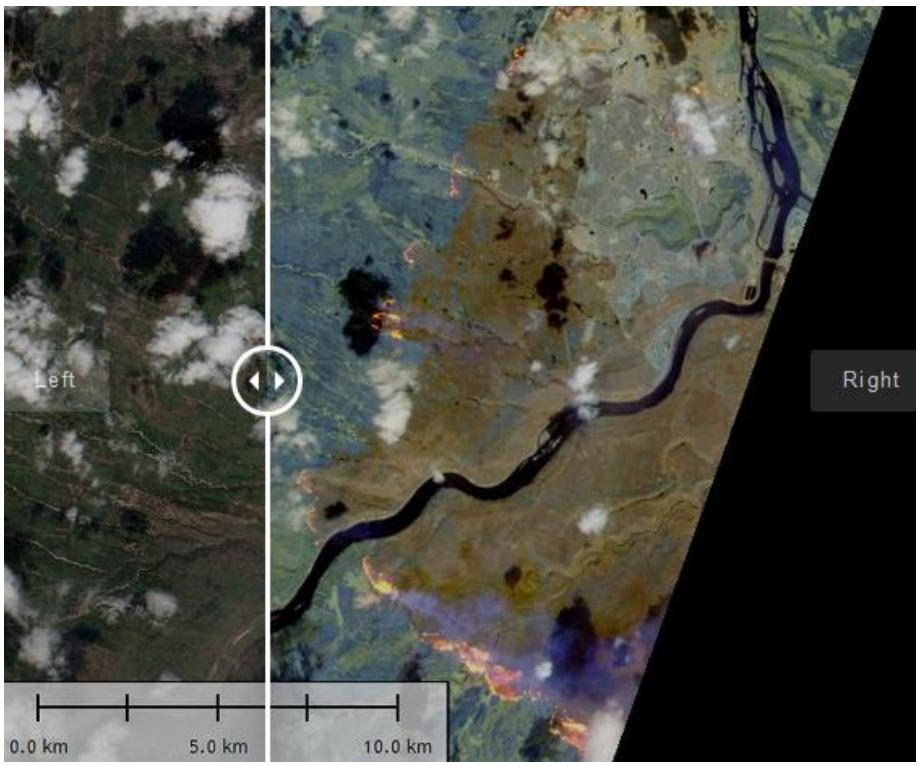
5.1 Batch processing To rapidly make many band combinations using Sentinel-2's full spectral bands in a batch mode:

- 24 = 4x3x2, using 4 multispectral bands at 10m-resolution - Bands 02, 03, 04, 08 (~10 GB disk space required for each granule / tile)
- 120 = 6x5x4, using 6 multispectral bands at 20m-resolution - Bands 05, 06, 07, 8a, 11, 12 (~12GB disk space required for each granule / tile)
- 6 = 3x2x1, using 3 multispectral bands at 60m-resolution - Bands 01, 09, 10 (~0.1 GB disk space required for each granule / tile)

A simple yet extremely powerful way of image (visual) analysis: Through rapid, various band combinations, important features/phenomena of interest on Earth land surface can be **better highlighted and revealed**.

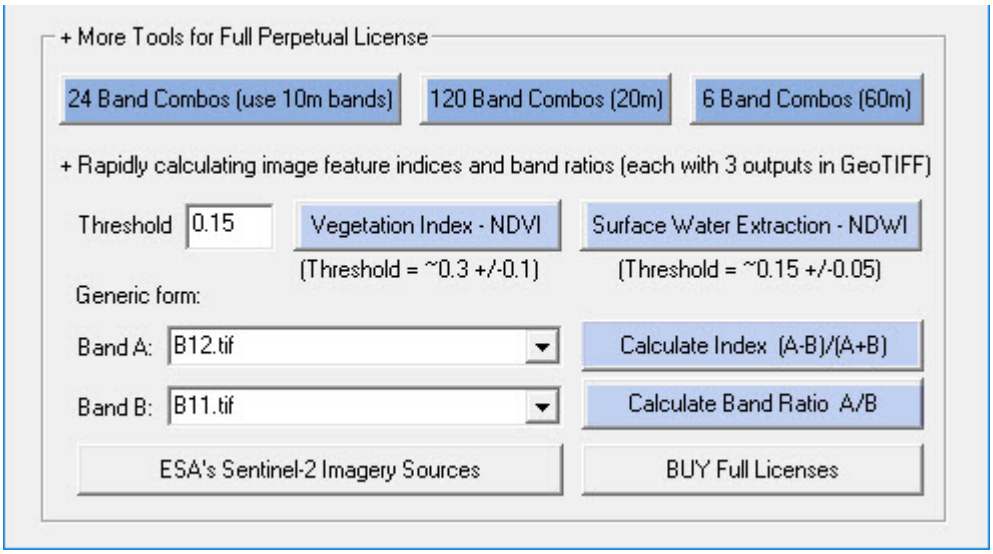
5.2 See the invisible

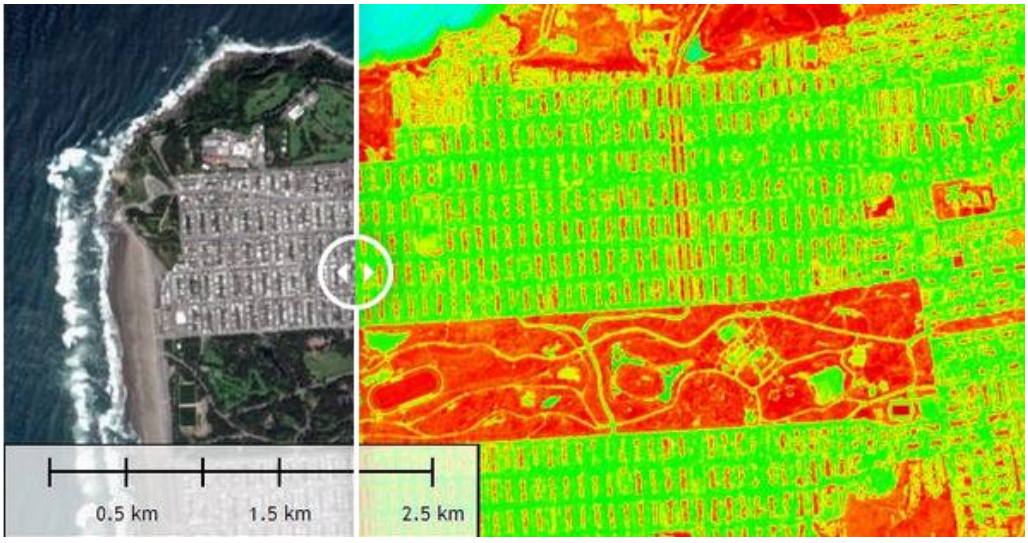
Sentinel-2 short-wave infrared (SWIR) bands are capable of revealing hidden wildfire hot spots and lava flows/heat through thick smokes.



Example: The May 2016 Fort McMurray Fire, Alberta, Canada. Left: Natural colour imagery showing full smoke; Right: False-colour SWIR imagery. Tile name: 12/V/VH; Date: 2016/5/5.

5.3 Exploratory image feature extraction with image feature indices and band ratios

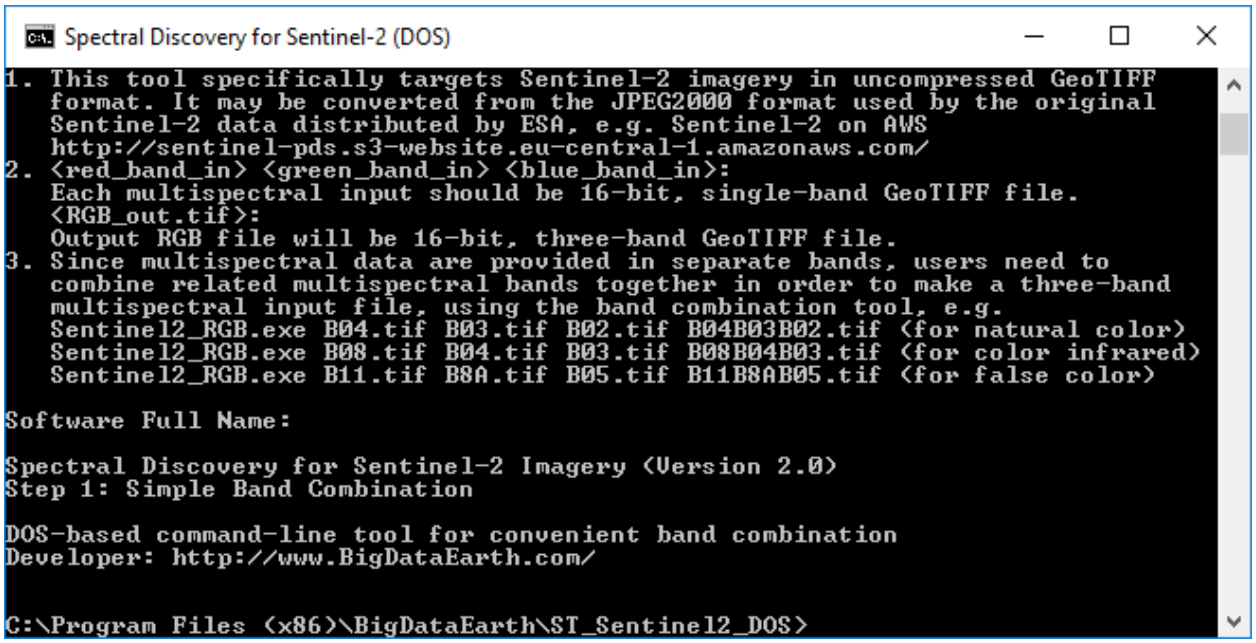




Example: Calculating feature indices with three types of outputs automatically from the software. Left: Natural colour imagery; Right: NDVI. Tile name: 10/S/EG; Date: 2016/4/15. Location: San Francisco.

Appendix

Main Steps in DOS-based *Spectral Discovery for Sentinel-2 Imagery*



Step 1: Simple Band Combination

DOS-based command-line tool for simple and convenient band combinations

Sentinel2_RGB.exe
<red_band_in> <green_band_in> <blue_band_in> <RGB_out.tif>

Help

1. This tool specifically targets Sentinel-2 imagery in uncompressed GeoTIFF format. It may be converted from the JPEG2000 format used by the original Sentinel-2 data distributed by ESA, e.g. Sentinel-2 on AWS http://sentinel-pds.s3-website.eu-central-1.amazonaws.com/
2. <red_band_in> <green_band_in> <blue_band_in>:
   Each multispectral input should be 16-bit, single-band GeoTIFF file.
   <RGB_out.tif>:
   Output RGB file will be 16-bit, three-band GeoTIFF file.
3. Since multispectral data are provided in separate bands, users need to combine related multispectral bands together in order to make a three-band multispectral input file, using the band combination tool, e.g.
   Sentinel2_RGB.exe B04.tif B03.tif B02.tif B04B03B02.tif (for natural color)
   Sentinel2_RGB.exe B08.tif B04.tif B03.tif B08B04B03.tif (for color infrared)
   Sentinel2_RGB.exe B11.tif B8A.tif B05.tif B11B8AB05.tif (for false color)

Step 2: Adaptive Image Stretching

DOS-based command-line tool for adaptive linear and nonlinear image stretching

Sentinel2_Stretch.exe
<red_band_order> <green_band_order> <blue_band_order> -s
<image_stretch_band1_left_cut> <image_stretch_band1_right_cut>
<image_stretch_band2_left_cut> <image_stretch_band2_right_cut>
<image_stretch_band3_left_cut> <image_stretch_band3_right_cut>
<nonlinear_stretch_band1> <nonlinear_stretch_band2> <nonlinear_stretch_band3>
<RGB_in.tif> <RGB_stretched_out.tif>

Parameters - Band order

<red_band_order>:
Order of the Red band in the multi-band input file, range [1-3]
<green_band_order>:
Order of the Green band in the multi-band input file, range [1-3]
<blue_band_order>:
Order of the Blue band in the multi-band input file, range [1-3]

Parameters - Specific to adaptive image stretching
The following parameters are used for both linear and non-linear image histogram stretching.

<image_stretch_band1_left_cut>
Linear stretching, % of pixels to be excluded at left-end for band1
Value range [0.0-40.0], typical value 2.0
<image_stretch_band1_right_cut>
Linear stretching, % of pixels to be excluded at right-end for band1
Value range [0.0-40.0], typical value 0.2
<image_stretch_band2_left_cut>
Linear stretching, % of pixels to be excluded at left-end for band2
Value range [0.0-40.0], typical value 2.0
<image_stretch_band2_right_cut>
Linear stretching, % of pixels to be excluded at right-end for band2
Value range [0.0-40.0], typical value 0.2
<image_stretch_band3_left_cut>
Linear stretching, % of pixels to be excluded at left-end for band3
Value range [0.0-40.0], typical value 2.0
<image_stretch_band3_right_cut>
Linear stretching, % of pixels to be excluded at right-end for band3
Value range [0.0-40.0], typical value 0.2

<nonlinear_stretch_band1>
Nonlinear stretching coefficient/weight for band1
Value range [0.0-40.0], typical values 5, 10, 15, ...
<nonlinear_stretch_band2>
Nonlinear stretching coefficient/weight for band2
Value range [0.0-40.0], typical values 5, 10, 15, ...
<nonlinear_stretch_band3>
Nonlinear stretching coefficient/weight for band3
Value range [0.0-40.0], typical values 5, 10, 15, ...

Parameters - Specific to input and output in GeoTIFF format

<RGB_in.tif>
Multispectral input prepared in Step 1 (band combination).
It must contain 16-bit, three-band data.
<RGB_stretched_out.tif>
Stretched output file name. Output will be 8-bit, three-band GeoTIFF file.

Examples/Tips

1. This tool specifically targets Sentinel-2 imagery in uncompressed GeoTIFF format. It may be converted from the JPEG2000 format used by the original Sentinel-2 data distributed by ESA, e.g. Sentinel-2 on AWS http://sentinel-pds.s3-website.eu-central-1.amazonaws.com/
2. Since multispectral data are provided in separate bands, users need to combine related multispectral bands together in order to make a three-band multispectral input file, using the band combination tool in Step 1, e.g.
   Sentinel2_RGB.exe B04.tif B03.tif B02.tif B04B03B02.tif (for natural color)
   Sentinel2_RGB.exe B08.tif B04.tif B03.tif B08B04B03.tif (for color infrared)
   Sentinel2_RGB.exe B11.tif B8A.tif B05.tif B11B8AB05.tif (for false color)
3. Typical image stretching command-line:
   Sentinel2_Stretch.exe 1 2 3 -s 1 0.2 1 0.2 1 0.2 10 10 10
   B04B03B02.tif B04B03B02_stretched_res10m.tif
4. If a scene contains a large proportion of white areas (e.g. cloud and snow), try to increase the right-end cut-off values for their exclusion. This may be automated along with the estimated % of cloud cover of the scene.
5. For more examples and tips, please refer to software features and tutorials on the website.

Step 3: Advanced Image Pan-sharpening

DOS-based command-line tool for rapidly pan-sharpening the 20m- or 60m-resolution Sentinel-2 satellite imagery into sharp 10m-resolution

Sentinel2_Fuse.exe
<pan-sharpening_method> -s
<image_stretch_band1_left_cut> <image_stretch_band1_right_cut>
<image_stretch_band2_left_cut> <image_stretch_band2_right_cut>
<image_stretch_band3_left_cut> <image_stretch_band3_right_cut>
<nonlinear_stretch_band1> <nonlinear_stretch_band2> <nonlinear_stretch_band3>
<pan_band_in.tif> <ms_in.tif> <fused_out.tif>

Parameters - Specific to algorithms

<pan-sharpening_method>
1 - Optimization 1 (recommended); 2 - Optimization 2

Parameters - Specific to adaptive image stretching

The following parameters are used for both linear and non-linear image stretching, identical to those of the image stretching tool (Step 2) included in this package. Type Sentinel2_Stretch.exe for more information.

<image_stretch_band1_left_cut>
Linear stretching, % of pixels to be excluded at left-end for band1
Value range [0.0-40.0], typical value 2.0
<image_stretch_band1_right_cut>
Linear stretching, % of pixels to be excluded at right-end for band1
Value range [0.0-40.0], typical value 0.2
<image_stretch_band2_left_cut>
Linear stretching, % of pixels to be excluded at left-end for band2
Value range [0.0-40.0], typical value 2.0
<image_stretch_band2_right_cut>
Linear stretching, % of pixels to be excluded at right-end for band2
Value range [0.0-40.0], typical value 0.2
<image_stretch_band3_left_cut>
Linear stretching, % of pixels to be excluded at left-end for band3
Value range [0.0-40.0], typical value 2.0
<image_stretch_band3_right_cut>
Linear stretching, % of pixels to be excluded at right-end for band3
Value range [0.0-40.0], typical value 0.2

<nonlinear_stretch_band1>
Nonlinear stretching coefficient/weight for band1
Value range [0.0-40.0], typical values 5, 10, 15, ...
<nonlinear_stretch_band2>
Nonlinear stretching coefficient/weight for band2
Value range [0.0-40.0], typical values 5, 10, 15, ...
<nonlinear_stretch_band3>
Nonlinear stretching coefficient/weight for band3
Value range [0.0-40.0], typical values 5, 10, 15, ...

Parameters - Specific to input and output in GeoTIFF format

<pan_band_in.tif>
Higher resolution (10m) gray band of Sentinel-2 imagery, typically use Band 4 (red band).
This band must contain 16-bit, single-band data.
<ms_in.tif>
Multispectral input prepared in Step 1 (band combination).
It must contain 16-bit, three-band data.
<fused_out.tif>
Pan-sharpened output file name. Output will be 8-bit, three-band GeoTIFF file.

Examples/Tips

1. This tool specifically targets Sentinel-2 imagery in uncompressed GeoTIFF format. It may be converted from the JPEG2000 format used by the original Sentinel-2 data distributed by ESA, e.g. Sentinel-2 on AWS http://sentinel-pds.s3-website.eu-central-1.amazonaws.com/
2. Since multispectral data are provided in separate bands, users need to combine related multispectral bands together in order to make a three-band multispectral input file, using the band combination tool in Step 1, e.g.
   Sentinel2_RGB.exe B04.tif B03.tif B02.tif B04B03B02.tif (for natural color)
   Sentinel2_RGB.exe B08.tif B04.tif B03.tif B08B04B03.tif (for color infrared)
   Sentinel2_RGB.exe B11.tif B8A.tif B05.tif B11B8AB05.tif (for false color)
3. Before pan-sharpening, users may produce stretched RGB file in Step 2:
   Sentinel2_Stretch.exe 1 2 3 -s 1 0.2 1 0.2 1 0.2 10 10 10
   B04B03B02.tif B04B03B02_stretched_res10m.tif
4. Typical pan-sharpening command-line:
   Sentinel2_Fuse.exe 1 -s 1 0.2 1 0.2 1 0.2 10 10 10
   B04.tif B11B8AB05.tif B11B8AB05_B04_fused_res10m.tif
5. For more examples and tips, please refer to software features and tutorials on the website.

Step 4: Calculating image feature indices and band ratios

DOS-based command-line tool for rapidly calculating image feature indices and band ratios, with the 10m-, 20m- and 60m-resolution Sentinel-2 satellite imagery

Sentinel2_Feature.exe
<calculation_method> <input_band1.tif> <input_band2.tif> <threshold>

Parameters

<calculation_method>
1 - Normalized Difference Image Feature Indices (A-B)/(A+B), e.g.
NDVI (Normalized Difference Vegetation Index) = (NIR-RED)/(NIR+RED)
NDWI (Normalized Difference Water Index) = (GREEN-SWIR1)/(GREEN+SWIR1)
2 - Calculating simple band ratios in the form of A/B

<input_band1.tif> <input_band2.tif>
For NDVI calculation, <input_band1.tif> should be Sentinel-2 Band 8 (NIR band)
<input_band2.tif> should be Sentinel-2 Band 4 (RED band).

<threshold>
The threshold value to be used for making a binary output image that shows classified features. E.g. in NDWI calculation, if a pixel value is greater than a defined threshold say 0.1, it is classified as water.

Help

1. This tool specifically targets Sentinel-2 imagery in uncompressed GeoTIFF format. It may be converted from the JPEG2000 format used by the original Sentinel-2 data distributed by ESA, e.g. Sentinel-2 on AWS http://sentinel-pds.s3-website.eu-central-1.amazonaws.com/
2. Three output files are automatically generated by the program. Each is a single-band GeoTIFF file, ready to be displayed in Windows Photo Viewer, GIS and remote sensing software (e.g. QGIS), or Google Earth Pro.
   - First output: 32-bit Float data type, useful for further analyses.
   - Second output: 8-bit Byte data type, a color palette is applied.
   - Third output: 8-bit Byte data type, a binary image to show classified features after a user-defined threshold is applied.

3. For NDVI and the generic form, a general color palette ("rainbow" shown below, from min to max) is used to highlight the wide distribution of pixel values. In the case of Sentinel-2 NDVI, the warmer color the pixel, the more dense vegetation is present.