

ESA's Sentinel-2

# Spectral Discovery for Sentinel-2 Imagery

(DOS- and GUI-based Version 3.1)

Unique software tool to easily and rapidly make colourful and detail-rich **Sentinel-2** imagery composites 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/

Updated 1 March 2020



1. Input Ser	ntinel-2 Image	ry Bands in JPE	G2000 + Co	nvert JPE	G2000 to GeoTI	FF format
Metadata	metadata.xr	nl		A:	B: Convert JP:	2 -> GTiff
Red	B12.tif		•	-	0m-resolution ba Iral Color B04/B0	
Green	B11.tif		•		20m-resolution ba	
Blue	B8A.tif		•		R/NIR - B12/B1 50m-resolution ba	
+ ''Pan'' (10m band)	B04.tif		•		tinel-2 vs. Landsa	
		both ends, %)-		Nonlinea	r Stretch	
	Left side	Right side			Range 0 - 40	
Red	1	0.2		Red	10	
Green	1	0.2		Green	10	
Blue	1	0.2		Blue	10	
Step 2 out	put B12B11	simple and con B8A_Res20m_! linear and non-	Stretched.tif			
Step 2 out Step 3 out	put  B12B11 Applying put  B12B11	B84_Res20m_: linear and non- B84_B04_Res <sup>-1</sup>	venient ban Stretched.tif linear image 10m_Fused.t	stretching	Step 2	run
	put  B12B11 Applying put  B12B11	B8A_Res20m_ linear and non-	venient ban Stretched.tif linear image 10m_Fused.t	stretching	Step 21	run
	put  B12B11 Applying put  B12B11 Applying	B84_Res20m_: linear and non- B84_B04_Res <sup>-1</sup>	venient ban Stretched.tif linear image 10m_Fused.t fast image p	stretching if an-sharpo	Step 2	run run run
Step 3 out Help - PD	put B12B11 Applying put B12B11 Applying F Run A	B8A_Res20m_ linear and non- B8A_B04_Res <sup>-</sup> advanced and	venient ban Stretched.tif linear image 10m_Fused.t fast image p	stretching if an-sharpo	Step 21	run run run
Step 3 out Help - PD + More Tool	put B12B11 Applying put B12B11 Applying F Run A	B8A_Res20m_: linear and non- B8A_B04_Res1 advanced and II (Step 1 + Step etual License	venient ban Stretched.tif linear image 10m_Fused.t fast image p	stretching if an-sharpo 3 3 3	Step 2 i ening Step 3 i eoTIFF -> Google	run
Step 3 out Help - PD + More Tool 24 Band Co	put B12B11 Applying put B12B11 Applying F Run A s for Full Perp	B&A_Res20m_: linear and non- B&A_B04_Res advanced and II (Step 1 + Step etual License - Im bands)	venient ban Stretched.tif linear image 10m_Fused.t fast image p 0 2) -/+ Step 20 Band Con	stretching if an-sharp 3 3 3 6 nbos (20n	ening Step 3 (	run
Step 3 out Help - PD + More Tool 24 Band Co	put B12B11 Applying put B12B11 Applying F Run A s for Full Perp ombos (use 10 alculating imag	B&A_Res20m_: linear and non- B&A_B04_Res1 advanced and II (Step 1 + Step etual License Om bands) 12 ge feature indice Vegetation Inc	venient ban Stretched.tif linear image IOm_Fused.t fast image p 0 2) -/+ Step 20 Band Con 20 Band Con 20 Band Con 20 Band Con	stretching if an-sharp 3 3 3 6 3 6 3 6 7 3 6 7 7 8 7 8 7 7 8 7 8 7 8 7 8 7 8 7 8 7	ening Step 2 i ening Step 3 i eoTIFF -> Google n) 6 Band Cor ch with 3 outputs	run run run e Earth Pro nbos (60m) s in GeoTIF on - NDWI
Step 3 out Help - PD + More Tool 24 Band Co + Rapidly ca	put B12B11 Applying put B12B11 Applying F Run A s for Full Perp ombos (use 10 alculating imag	B&A_Res20m_: linear and non- B&A_B04_Res <sup>+</sup> advanced and II (Step 1 + Step etual License Im bands)	venient ban Stretched.tif linear image IOm_Fused.t fast image p 0 2) -/+ Step 20 Band Con 20 Band Con 20 Band Con 20 Band Con	stretching if an-sharp 3 3 3 6 3 6 3 6 7 3 6 7 7 8 7 8 7 7 8 7 8 7 8 7 8 7 8 7 8 7	Step 2 i ening Step 3 i eoTIFF -> Google n) 6 Band Cor ch with 3 outputs	run run run e Earth Pro nbos (60m) s in GeoTIF on - NDWI
Step 3 out Help - PD + More Tool 24 Band Co + Rapidly ca Threshold Generic fo	put B12B11 Applying put B12B11 Applying F Run A s for Full Perp ombos (use 10 alculating imag	B&A_Res20m_: linear and non- B&A_B04_Res1 advanced and II (Step 1 + Step etual License Om bands) 12 ge feature indice Vegetation Inc	venient ban Stretched.tif linear image IOm_Fused.t fast image p 0 2) -/+ Step 20 Band Con 20 Band Con 20 Band Con 20 Band Con	stretching if an-sharp 3 3 3 6 3 6 3 6 1 3 6 1 3 6 1 3 6 1 3 6 1 3 6 1 1 1 1	ening Step 2 i ening Step 3 i eoTIFF -> Google n) 6 Band Cor ch with 3 outputs	run run run e Earth Pro nbos (60m s in GeoTII on - NDW +/-0.05)
Step 3 out Help - PD + More Tool 24 Band Co + Rapidly ca Threshold Generic fo Band A:	put B12B11 Applying put B12B11 Applying F Run A s for Full Perp ombos (use 10 alculating imag [0.15] rm:	B&A_Res20m_: linear and non- B&A_B04_Res1 advanced and II (Step 1 + Step etual License Om bands) 12 ge feature indice Vegetation Inc	venient ban Stretched.tif linear image IOm_Fused.t fast image p o 2) -/+ Step 20 Band Con es and band lex - NDVI 1.3 +/-0.1)	stretching if an-sharp abos (20n ratios (ea Surfac (Th	Step 2 i ening Step 3 i eoTIFF -> Google n) 6 Band Cor ch with 3 outputs ce Water Extraction reshold = ~0.15 -	run run run e Earth Pro mbos (60m) s in GeoTIF on - NDWI +/-0.05) B)/(A+B)



# **Table of Contents**

1. Download Sentinel-2 Level-1C Imagery Data	1
1.1 - Method 1	1
1.2 - Method 2	5
1.3 - Method 3	8
1.4 - Method 4	9
2. Install DOS-/GUI-based Spectral Discovery for Sentinel-2 Imagery	10
3. Run GUI	11
4. Display Stretched and Pan-sharpened Imagery Composites in Google Earth Pro	12
5. Additional Features for Innovative Applications	13
Appendix - Main Steps in DOS-based Spectral Discovery for Sentinel-2 Imagery	15

## 1. Download Sentinel-2 Level-1C Imagery Data

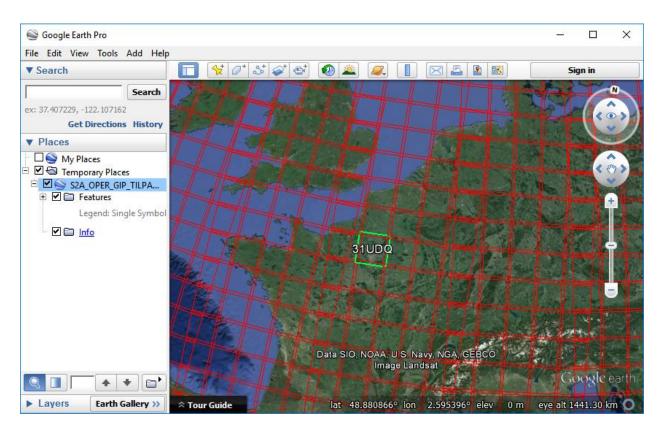
There are many ways to obtain open Sentinel-2 imagery these days. The most convenient way is probably via Amazon Web Services and Google Earth Engine.

### 1.1 - Method 1

Sentinel-2 on AWS: public bucket sentinel-s2-l1c
https://registry.opendata.aws/sentinel-2/

Sentinel-2 imagery uses a **granule/tile** system which is based on the NATO <u>Military Grid Reference</u> <u>System (MGRS)</u>. The **Sentinel-2 Level-1C tiling grid** in Google Earth KML format can be downloaded from ESA - <u>KML file</u> (~103MB); alternatively, a compressed version can be downloaded <u>here</u> (~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/Cape Town, South Africa: 34/H/BH/Rio, Brazil: 23/K/PQ/Rome, Italy: 33/T/TG/Beijing, China: 50/T/MK/Perth, Australia: 50/H/LK/

After knowing the location (tiling grid) for the AOI, you can start to browse and download imagery bands, via the Sentinel-2 public bucket on AWS.

Notes:

We suggest users download Sentinel-2 imagery files from AWS S3 based on **whole data folders** (not single files), using GUI-based tools such as **S3 Browser** (<u>http://s3browser.com/</u>).

Many similar tools, including AWS Command Line Tools, can make data download very quickly and efficiently. FYI – "Accessing Landsat and Sentinel-2 on Amazon Web services" available at <a href="http://earsc.org/news/accessing-landsat-and-sentinel-2-on-amazon-web-services">http://earsc.org/news/accessing-landsat-and-sentinel-2</a> on Amazon Web services" available at <a href="http://earsc.org/news/accessing-landsat-and-sentinel-2-on-amazon-web-services">http://earsc.org/news/accessing-landsat-and-sentinel-2</a> on Amazon Web services" available at <a href="http://earsc.org/news/accessing-landsat-and-sentinel-2-on-amazon-web-services">http://earsc.org/news/accessing-landsat-and-sentinel-2-on-amazon-web-services</a>

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.)

53 Browser 5-8-9 - Pro Version - g	jeo1	- 1	n x
Accounts Buckets Files Too	ls Help	New versi	on available
🖶 New bucket 💥 Delete bucket	<b>₽</b> Path:	đ	/ 7 🗊
sentinel-s2-l1c	File Si products/ tiles/ zips/	ize Type	LastM
	<		> les (87.47 KB)
	Upload 🗸 📄 Download 🗽 Delete 🧱 New Fo	older Refresh 3 fil	les (87.47 KB)
Tasks Permissions Http Hea	ders Properties Preview Versions EventLog		
URL: https://sentinel-s2-l1c.s	3.amazonaws.com/tiles/		🗇 Сору
Property	Value		^
Folder name	tiles/		
Total objects	calculating		
Total files	calculating		
	and a second		¥

In what follows, we briefly demonstrate how to download files by **tiles**.



### 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.

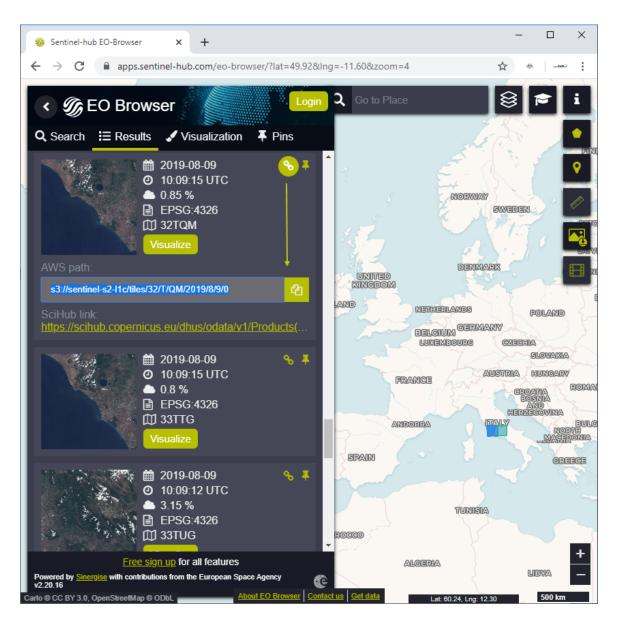
S3 Browser 5-8-9 - Pro Version - geo1		_		×
Accounts Buckets Files Tools Help				
An New bucket W Delete bucket 2 Refresh	Path: tiles/31/U/DO/2016/1/25/0/		1	1 1 1 1
New bucket 💥 Delete bucket 🚰 Refresh	Path: tiles/31/U/DQ/2016/1/25/0/         File            auxiliary/         qi/         B01,jp2         B02,jp2         B03,jp2         B04,jp2         B05,jp2         B06,jp2         B07,jp2         B08,jp2         B08,jp2         B09,jp2         B10,jp2         B11,jp2         B12,jp2         B8A,jp2         metadata.xml         preview.jp2         preview.jp2         preview.jp3         Trouchnfo.json         TileInfo.son			
				>
	Upload - Download	18	files (49	1.59 MB)
Tasks Permissions Http Headers Prop	erties Preview Versions EventLog			
				^

*Spectral Discovery for Sentinel-2 Imagery* software processes granules/tiles directly downloaded from AWS . **metadata.xml** file is **included** in the granule/tile data folder, and each band is indicated by **short file names**. **The software reads metadata.xml as the first input.** 



**FYI -** Search the imagery of interest via easy-to-use web-based mapping App **EO Browser** <u>https://apps.sentinel-hub.com/eo-browser/</u>

After searching imagery for a particular AOI, one can get **AWS path** for the imagery data (as shown the figure below).



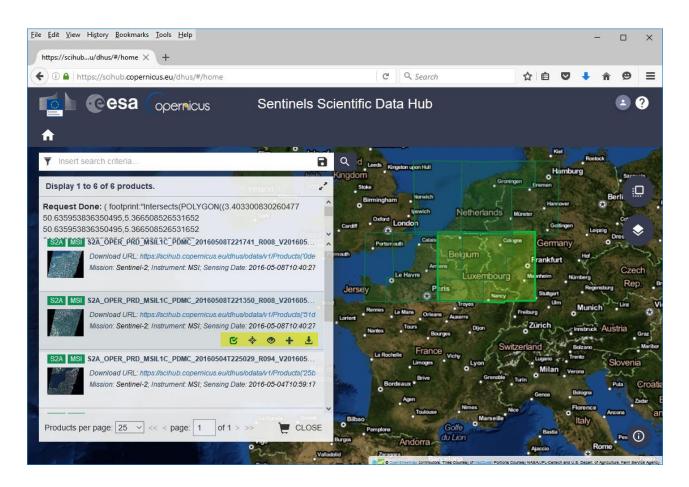


### 1.2 - Method 2

### Via ESA's Sentinels Scientific Data Hub - https://scihub.copernicus.eu/

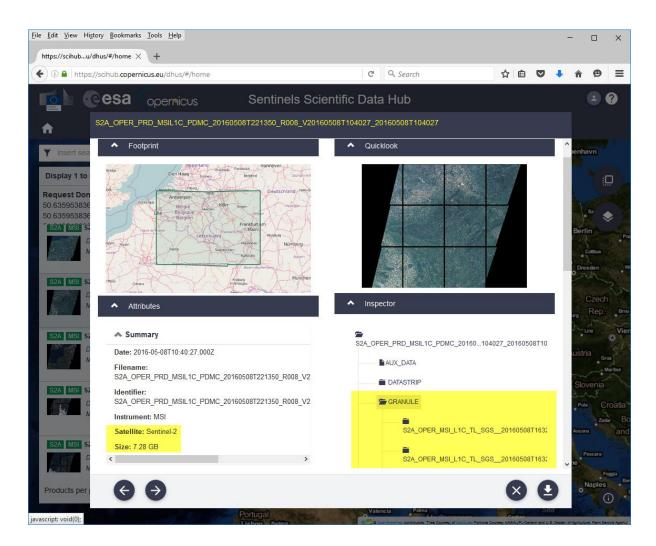
Or, directly go to map-based imagery search tool: https://scihub.copernicus.eu/dhus/#/home

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



By this method, one can download Sentinel-2 imagery **scenes** (made up of ~12 **granules** / **tiles**, as seen in Method 1 above). 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 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 imagery scene 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.)

Explorer.EXE	×
The file name is too long.	
	ОК



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**\

PDMC_20160508T221350_R008_V20160508T104027_20160508T104027 > GRANULE	✓ Ö Search	GRANULE	ς
Name	Date modified	Туре	
S2A_OPER_MSI_L1C_TL_SGS_20160508T163213_A004581_T31UEQ_N02.02	23-May-16 4:42 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T31UER_N02.02	23-May-16 4:42 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T31UES_N02.02	23-May-16 4:42 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T31UFQ_N02.02	23-May-16 4:43 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T31UFR_N02.02	23-May-16 4:43 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T31UFS_N02.02	23-May-16 4:43 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T31UGQ_N02.02	23-May-16 4:43 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T31UGR_N02.02	23-May-16 4:43 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T31UGS_N02.02	23-May-16 4:43 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T32ULA_N02.02	23-May-16 4:43 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T32ULB_N02.02	23-May-16 4:43 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T32ULV_N02.02	23-May-16 4:43 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T32UMA_N02.02	23-May-16 4:43 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T32UMB_N02.02	23-May-16 4:43 PM	File folder	
S2A_OPER_MSI_L1C_TL_SGS20160508T163213_A004581_T32UMV_N02.02	23-May-16 4:43 PM	File folder	

Then, each **granule** contains a metadata file (\*.xml), **image data** and other folders. *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**.

Name	Date modified	Туре
AUX_DATA	23-May-16 4:42 PM	File folder
IMG_DATA	23-May-16 4:42 PM	File folder
QI_DATA	23-May-16 4:42 PM	File folder
S2A_OPER_MTD_L1C_TL_SGS_20160508T163213_A004581_T31UEQ.xml	09-May-16 8:06 AM	XML File

#### For each granule, the **IMG\_DATA** folder contains a total of 13 imagery bands in JEPG2000 format.

ISI_L1C_TL_SGS20	160508T163213_A004581_T31UEQ_N02.02	IMG_DATA			✓ Ö Searc	h IMG_DATA
Name	^		Date modified	Туре	Size	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581_	T31UEQ_ <mark>B01.jp2</mark>	09-May-16 8:06 AM	VI JP2 File	2,643 KB	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581	T31UEQ_ <mark>B02.jp2</mark>	09-May-16 8:07 AM	/ JP2 File	64,408 KB	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581	T31UEQ_ <mark>B03.jp2</mark>	09-May-16 8:07 AM	VI JP2 File	68,977 KB	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581	T31UEQ_ <mark>B04.jp2</mark>	09-May-16 8:07 AM	VI JP2 File	71,069 KB	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581	_T31UEQ_ <mark>B05.jp2</mark>	09-May-16 8:06 AM	/I JP2 File	21,362 KB	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581	_T31UEQ_ <mark>B06.jp2</mark>	09-May-16 8:06 AM	/I JP2 File	22,457 KB	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581	_T31UEQ_ <mark>B07.jp2</mark>	09-May-16 8:07 AM	/I JP2 File	23,239 KB	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581	_T31UEQ_ <mark>B08.jp2</mark>	09-May-16 8:07 AM	∕I JP2 File	81,452 KB	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581	_T31UEQ_ <mark>B8A.jp2</mark>	09-May-16 8:07 AM	∕I JP2 File	23,360 KB	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581	_T31UEQ_ <mark>B09.jp2</mark>	09-May-16 8:06 AM	/I JP2 File	2,714 KB	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581	_T31UEQ_ <mark>B10.jp2</mark>	09-May-16 8:06 AM	/ JP2 File	1,357 KB	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581	_T31UEQ_ <mark>B11.jp2</mark>	09-May-16 8:07 AM	/ JP2 File	21,443 KB	
S2A_OPER_MS	I_L1C_TL_SGS20160508T163213_A004581	_T31UEQ_ <mark>B12.jp2</mark>	09-May-16 8:07 AM	/ JP2 File	21,030 KB	

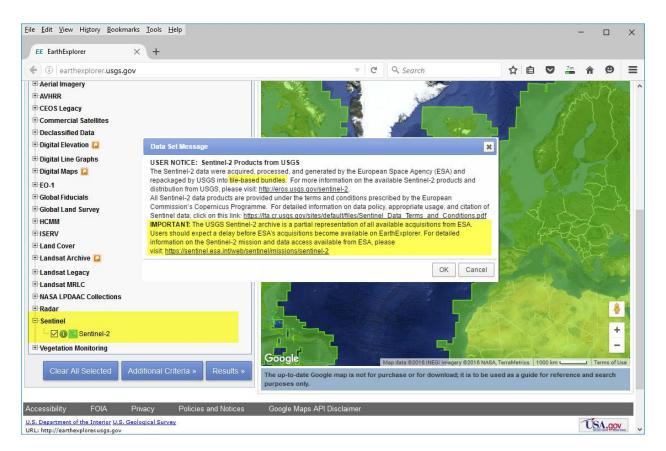


### 1.3 - Method 3

### Via the USGS EarthExplorer and the USGS GloVis

<u>News</u> - "USGS Partners with European Space Agency to Deliver Copernicus Earth Data" USGS Sentinel-2 portal: <u>https://www.usgs.gov/centers/eros/science/usgs-eros-archive-sentinel-2</u>

### USGS EarthExplorer - <a href="http://earthexplorer.usgs.gov/">http://earthexplorer.usgs.gov/</a>



#### 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: <u>http://eros.usgs.gov/sentinel-2</u>. **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: <u>https://sentinel.esa.int/web/sentinel/missions/sentinel-2</u>



### USGS GloVis - <u>http://glovis.usgs.gov/</u>

<u>File Edit View Higtory Bookmarks Iools H</u> elp			_	
← ■ ) ①   glovis.usgs.gov	C Q Search	☆ 🖻 🛡	♣ ♠	⊜ ≡
Collection Resolution Map Layers Tools File Help				^
Aerial				-
ASTER	A BRANN			
E0-1	1 30	A Providence		
Global Land Survey			Poter	
Landsat IIRLC Collections			-	
Landsat Legacy Collections >		The second		
MODIS Aqua				
MODIS Terra	1000	a man		6
MODIS Combined > Go	A 122	Par and the second		
Sentinel Data Descriptions TerraLook Ø Sentinel-2		R. Start	C	
Max Cloud:		In Chiles		
100% ▼ ← → Sentinel-2A (MGRS Tiles)	TAR CONTRACT			
Scene Information:				5
ID: S2A_OPER_MSI_L1C_TL_MTI20160:	The state			
CC: 0% Date: 2016/2/15 MGRS GZD square: 10SEG				
Feb 👻 2016 👻 Go	Charles The	de la		
Prev Scene Next Scene		The Art Star	-	
Sentinel-2 Scene List		Let "		
	Called and the second	ALL PROPERTY	and a	
	and and the state of the			

The imagery data downloaded from the USGS EarthExplorer and GloVis contains 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 2**; that is, the metadata file (the first input required by the software) is located along with the **IMG\_DATA** folder.

Notes:

As indicated above, because Sentinel-2 imagery data on the USGS portal is only a partial collection of the entire Sentinel-2 data sets, users may try to download complete imagery data via Method 1 and Method 2 introduced above.

### 1.4 - Method 4

Sentinel-2 imagery on Google Earth Engine and Google Cloud Platform: https://cloud.google.com/storage/docs/public-datasets/sentinel-2

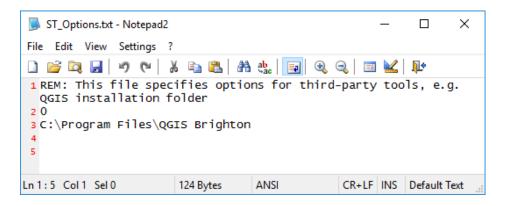


# 2. Install DOS-/GUI-based Spectral Discovery for Sentinel-2 Imagery

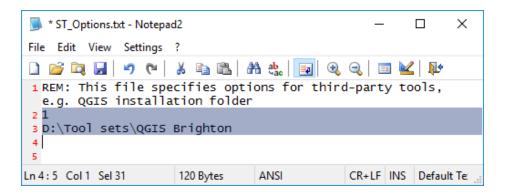
The software is available at <a href="http://www.GeoSage.com/">http://www.GeoSage.com/</a>

- Prerequisite: Install free Microsoft VC++ 2015 Redistributable (x86)
- Prerequisite: Install the most 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 GeoTIFF format. (Ignore this step if a user 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 3 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.

– 1. Input Sen Metadata		000 + Convert JPEG2000 to GeoTIFF format
Red	B12.tif	C Use 10m-resolution bands Natural Color B04/B03/B02
Green Blue		Use 20m-resolution bands     SWIR/NIR - B12/B11/B8A
+ "Pan" (10m band)		Use 60m-resolution bands     Sentinel-2 vs. Landsat-8 Bands
- Linear Streto	ch (Cutoffs at both ends, %) Left side Right side	+ Nonlinear Stretch Range 0 - 40
Red	1 0.2	Red 10
Green	1 0.2	Green 10
Blue	1 0.2	Blue 10
– 2. Outputs (ir	n GeoTIFF format)	
Step 1 outp	put B12B11B8A_Res20m.tif	inthe section in the section of the
Step 2 out;	Applying simple and conve	
Step 2 out	Applying linear and non-line	
Step 3 outp	put B12B11B8A_B04_Res10r	n_Fused.tif
	Appluing advanced and far	st image pan-sharpening Step 3 run



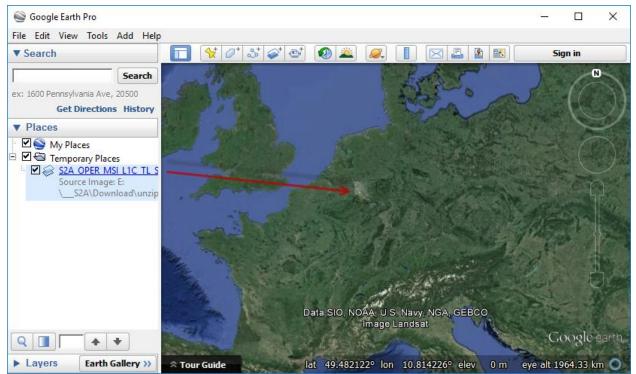
Users may modify and optimise image stretching parameters for various visual styles of the output.

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 in many 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 Earth. (The imported imagery may be exported to KMZ format in Google Earth Pro.)

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



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



# **5. Additional Features for Innovative Applications**

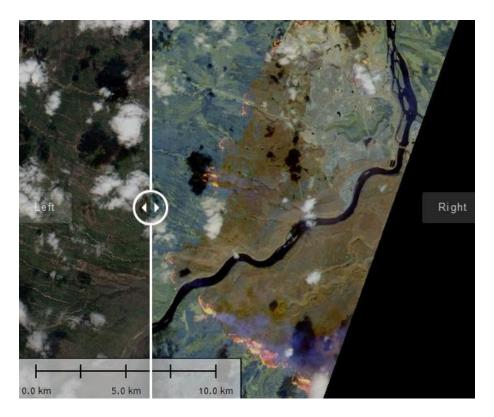
**5.1 Batch processing** To rapidly make many band combinations using the full spectral bands of Sentinel-2 imagery in a batch mode:

- 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 wildfire hotspots and lava flows/heat through thick smokes.

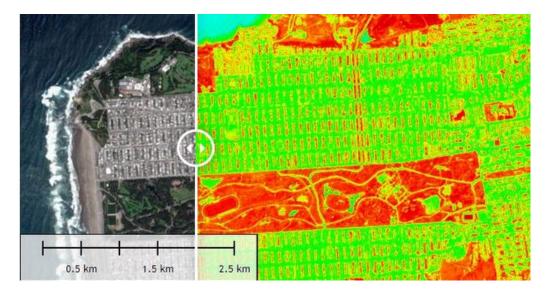


Example: The May 2016 Fort McMurray Fire, Alberta, Canada. Left: Natural colour imagery showing full smoke; Right: False-colour SWIR imagery. Tile name: 12/V/VH; Date: 5/5/2016.



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

24 Band Combos (us	e 10m bands)	120 Band Com	nbos (20m)	6 Band Combos (60m)
+ Rapidly calculating	image feature inc	lices and band I	ratios (each i	with 3 outputs in GeoTIF
Threshold 0.15	Vegetation	Index - NDVI	Surface V	Vater Extraction - NDWI
Generic form:	(Threshold =	~0.3 +/-0.1)	(Threst	nold = ~0.15 +/-0.05)
Band A: B12.tif		-	Calcula	ate Index (A-B)/(A+B)
Band B: B11.tif		-	Calcu	late Band Ratio A/B
ESA's Sen	tinel-2 Imagery So		BI	JY Full Licenses



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



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

Spectral Discovery for Sentinel-2 (DOS)	-	×
<ul> <li>Sentinel2_RGB.exe B11.tif B8A.tif B05.tif B11B8AB05.tif (for false color</li> <li>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</li> <li>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</li> <li>For more examples and tips, please refer to software features and tutori on the website.</li> </ul>		^
Software Full Name:		
Spectral Discovery for Sentinel-2 Imagery (Version 3.1) Step 3: Advanced and Fast Image Pan-sharpening		
DOS-based command-line tool for rapidly pan-sharpening the medium-resolutio Sentinel-2 satellite imagery in GeoTIFF format. Developer: http://www.BigDataEarth.com/	n	
C:\Program Files (x86)\BigDataEarth\ST_Sentinel2_DOS>		~

### **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 imagery in JPEG2000 format used by the ESA Sentinel-2 program, e.g. Sentinel-2 imagery on AWS.

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 imagery in JPEG2000 format used by the ESA Sentinel-2 program, e.g. Sentinel-2 imagery on AWS.

- 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)
- 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 imagery in JPEG2000 format used by the ESA Sentinel-2 program, e.g. Sentinel-2 imagery on AWS.

- 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 imagery in JPEG2000 format used by the ESA Sentinel-2 program, e.g. Sentinel-2 imagery on AWS.

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.

