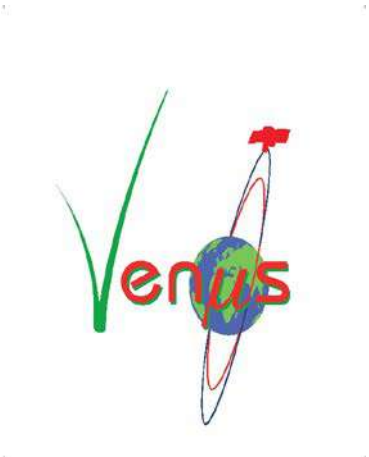
November 7, 2018



VENμS:
Joint Israeli-French micro-Spacecraft for Earth Observation Mission

VENμS
Vegetation and Environment monitoring New Micro Satellite

The VENμS mission and products

https://venus.cnes.fr/en/VENUS/index.htm

Centre National d'Etudes Spatiales – France

Israeli Space Agency – Israel

CESBIO, Toulouse University – France

The Remote Sensing Laboratory, Ben Gurion University of the Negev – Israel

Contents

1. The VENμS Mission 3
2. Camera 5
3. Products 7
3.1 Level 1 9
3.2 Level 2 10
3.3 Level 3 11
3.4 In-situ data 12
3.5 Data distribution for the VENμS Israeli scientific sites 12
3.6 Data distribution for others VENμS scientific sites 12
4. How to order, download and extract the Israeli VENμS products 13
4.1 System registration 13
4.2 Query and Order Images 15
4.3 Download Images 18
4.4 Extract the Images 18

1. The VENµS Mission

VENµS (Vegetation and Environment monitoring New Micro-Satellite) is the first cooperation between Israel and France for the Earth observation using a superspectral camera, dedicated to vegetation monitoring. The Memorandum of Understanding between CNES and ISA (Israeli Space Agency) was signed in April 2005. The satellite was launched in August 2017.

The VENµS satellite will use an IMPS micro-satellite platform (Improved Multi Purpose Satellite) of the IAI /MBT space division (Israeli Aerospace Industries).

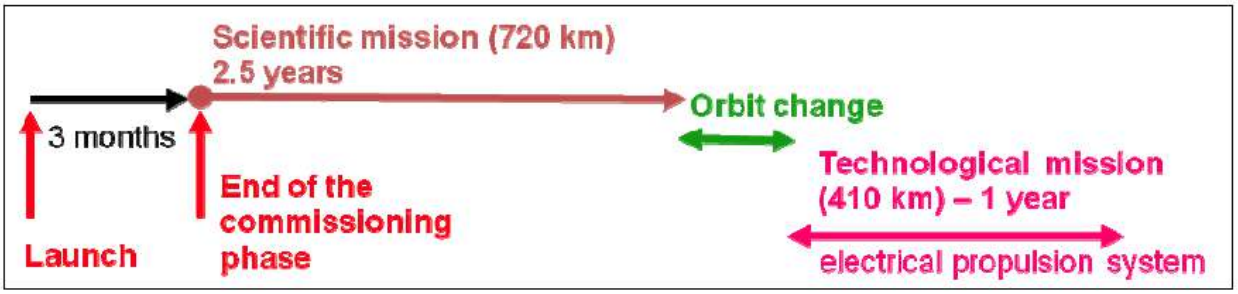
VENµS scientific objective is the provision of data for scientific studies dealing with the monitoring, analysis, and modeling of land surface functioning under the influences of environmental factors as well as human activities. To fulfill this objective, VENµS will acquire **every two days** high resolution and superspectral images of predefined sites of interest all around the world.

Scientific mission requirements have been defined by **CESBIO** (France), **Ben Gurion University of the Negev** (Israel) and CNES.

VENµS technological mission is aimed at validating the IHET (Israeli Hall Effect Thruster): qualification of the IHET thruster for low altitude station keeping and evaluation of the IHET performances in space.

CNES is responsible for supplying the superspectral camera and the science mission center. ISA is responsible for the spacecraft, for the launcher interface and for the satellite control center.

The scientific mission is expected to end about 33 months after launch (so-called VM1 period). At the end of this period, the Technological Mission will begin. The altitude of the spacecraft will be decreased from 720 km to about 410 km. The change of the orbit will take about six months (VM2 period). The 410 km orbit will then be kept during one year, from about 38th month to 50th month after launch (VM3 period). Imaging operation is expected to continue during the technological mission. Due to orbit change, the swath will be reduced to about 15 km, while the ground resolution will increase to about 3m.



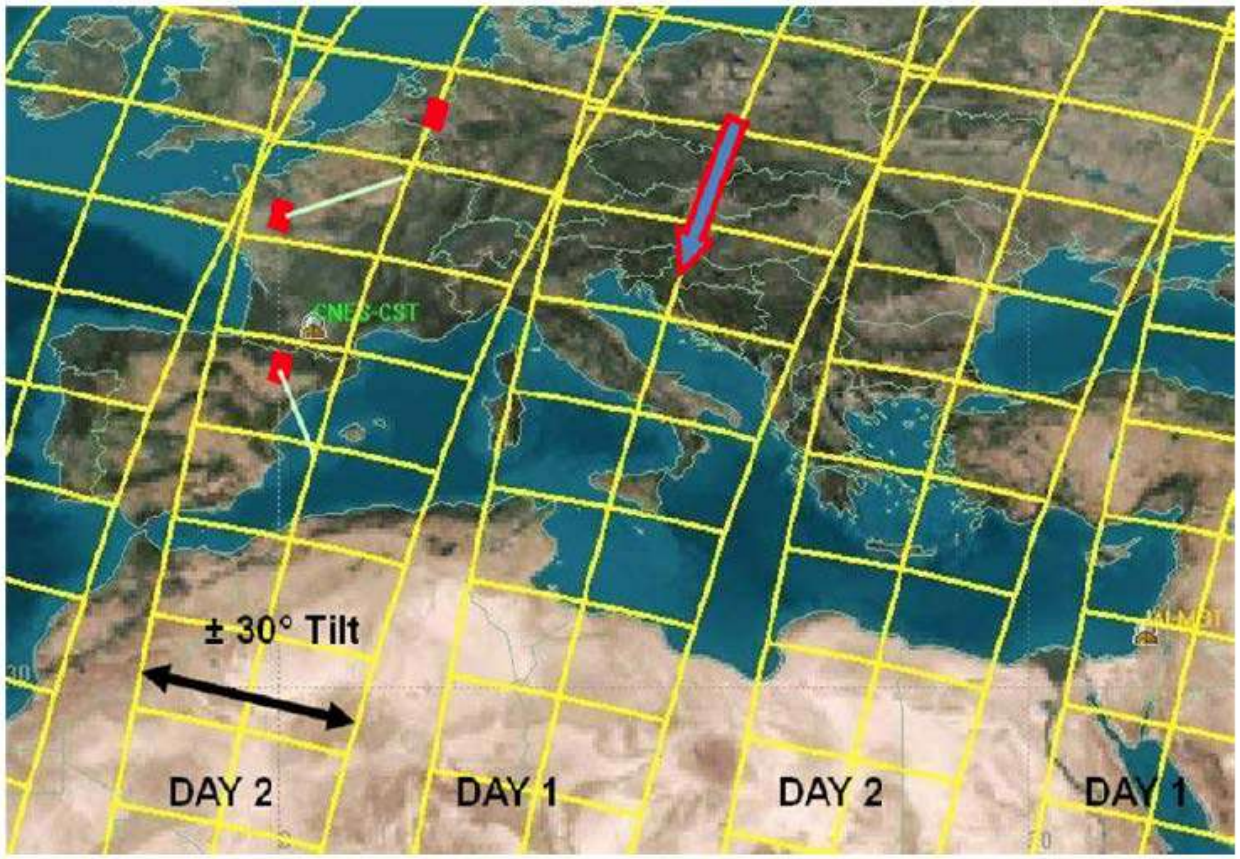
To fulfill its scientific objectives, VENµS will acquire frequent, high resolution, multi-spectral images of over 100 sites of interest all around the world, plus 10 sites for calibration purposes. The satellite will fly in a near polar **sun-synchronous** orbit at 720 km height, 98° inclination. The orbit will be controlled such as to maintain the local time of overpass at +5 minutes.

The whole system will be able to be tilted up to 30 degree along and across track. This configuration will result in a 2-days revisit time, 27 km swath, a camera resolution of 5.3 m at nadir, and the capability to observe any site under a constant view angle. The system will cross the equator at around 10:30 AM.

The satellite will carry a super-spectral camera characterized by 12 narrow spectral bands ranging from 415 nm to 910 nm. The band setting was designed to characterize vegetation status, including through red-edge bands, and to estimate the aerosol optical depth and the water vapour content of the atmosphere for accurate atmospheric corrections. The spectral band setting could also prove useful for coastal areas and inland waters studies.

The science mission center will deliver three levels of products, described in section 3.

Each site will be observed during the whole period of 2.5 years and will be imaged every second day, except under some circumstances such as during polar night.



View of a possible coverage

2. Camera

The satellite will carry a super-spectral camera characterized by 12 narrow spectral bands (B1 – B12). The radiometric resolution for all bands is 10 bits.

At the camera level, each spectral line of an image is made of 5200 pixels. At nadir, the field of view is 27 km with a ground resolution of 5.3 m, but the SNR requirements are only met at 10.6 m. When an image is acquired with an oblique viewing, the native ground resolution decreases a little and the field of view increases.

The data will be acquired over existing or planned experimental sites with size ranging from 27 x 27 km² kilometers to 27 x 54 km² or more. All data for a given site will be acquired with the same observation angle in order to minimize directional effects.

Bands	Central Wavelength (nm)	Bandwidth (nm)	Main Driver
B1	423.9	40	Atmospheric correction
B2	446.9	40	Aerosol, clouds
B3	491.9	40	Atmospheric correction
B4	555.0	40	Land
B5	619.7	40	Land
B6	619.5	40	DEM, image quality
B7	666.2	30	Land
B8	702.0	24	Land
B9	741.1	16	Land
B10	782.2	16	Land
B11	861.1	40	Land
B12	908.7	20	Water vapor

The set of bands includes 4 bands for atmospheric effects removal. The 620 nm band is duplicated with a difference in viewing angle of 1.5°. It is aimed at deriving Digital Elevation Models (DEMs) and image quality assessment. It will also be used to detect clouds using their altitude. Note that most VENμS spectral bands (B1 to B9) are also suited for water color applications, in situations which do not require a very high SNR.

A brief summary of the interest of every band is given below.

B1, B2, and B3: These bands are sensitive to the scattering of light due to particles (aerosols) and molecules, those effects depend on the wavelength. They will allow estimating the turbidity (aerosols) of the atmosphere, which is then used to apply atmospheric correction. In addition, these bands are very efficient to detect clouds and cloud edges over land and water. This is important for automatic processing of image time series. Cloud screening and aerosol characterization do not require the use of full resolution data. Working with data averaged over

4x4 pixels or even more is sufficient. Therefore, the SNR (Signal to Noise Ratio) at full resolution can be lower than for the other bands.

B4: This band is located in the green peak of vegetation and is useful to characterize vegetation status (LAI, chlorophyll).

B5: Vegetation chlorophyll absorption. Used with B11 to compute vegetation indices

B6: this band is a duplication of B5, and is implemented in the camera focal plane such as the difference of viewing angle is 1.5 degree.
The interests of the duplicated B5 band are:

- From the small stereoscopic effect it will be possible i) to generate a coarse DEM ii) to help to detect clouds by their altitudes.
- Having a duplicated band has proved to be very useful with Polder mission for image quality purposes.

B7, B8, B9, and B10: these red-edge bands are designed for detecting the blue shift of the red edge when vegetation is stressed. They can be useful for computing the chlorophyll index.

B11: near infrared band, e.g. for NDVI and other vegetation indices computation

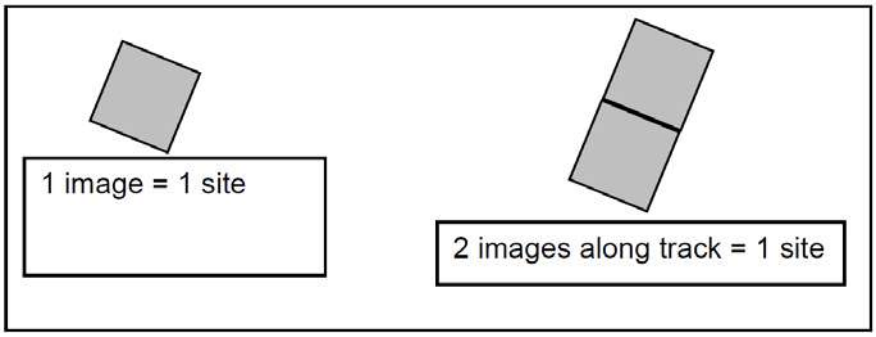
B12: water vapor absorption, to help correcting absorption effects on other bands

3. Products

The VENμS ground segment will deliver three levels of products. The products will be delivered within one month after the acquisition date. No near real time delivery is planned. Products will be available to the users through a web interface and ftp download. At the camera level, each spectral line of an image is made of 5200 pixels. At nadir, the field of view is 27 km with a ground resolution of 5.3 m, but the SNR requirements are only met at 10.6 m. When an image is acquired with an oblique viewing, the native ground resolution decreases a little and the field of view increases. The following definitions apply in the rest of the text:

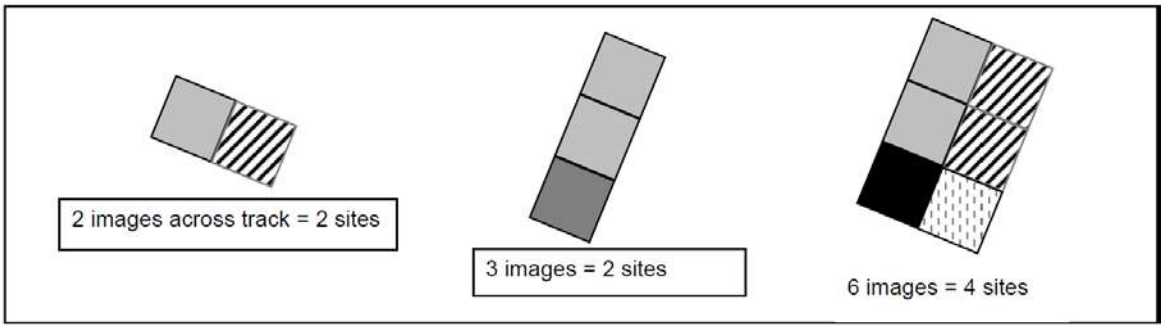
- An **image** corresponds to the acquisition of 5200 rows by 5200 pixels in the twelve spectral bands. At nadir, it corresponds to an area on ground of approximately 27x27km^2. This is the minimal product size which will be delivered to the users.

- The baseline definition of a **site** is: "an area on the Earth covered by one to two along track contiguous images". A site corresponds to 5200x5200 pixels (1 image) or 5200x10400 pixels (2 images) in the focal plane. Therefore, the minimum size of a site is 27x27 km^2, the maximum size being 27x54 km^2 at nadir.



Baseline definition of a site and standard VENμS image acquisitions

However, this definition has to be extended to more complex situations since the same area can also be observed with different view angles, for example nadir, forward and backward viewing from the same orbit and/or from different orbits. In that case, the area of interest is covered by several **acquisitions** of one to two images each with different view angles.



Site definitions for non standard VENμS image acquisitions

When a project requires images which depart from the baseline definition of a site, several sites of one to two images have to be defined. This could occur in the following situations:

- More than two along track contiguous images are needed to cover the area of interest
- Two or more across track images are needed. In that case, the images are acquired with different viewing angles, possibly from different orbits.
- Two or three images of the same area are acquired from different viewing angles. Each viewing direction corresponds to one site (e.g. 3 viewing directions = 3 sites)

Since the VENµS ground segment will only manage and deliver sites of one or two images, the mosaicking of several sites to cover the project area of interest will have to be done by the proponents.

Each site will be observed during the whole period of 2.5 years and will be imaged every second day, except under some circumstances such as during polar night.

The three levels of products, which will be made available to the users, are summarized in the table below.

Product Level	**Temporal characteristics**	**Content**	**Ground resolution**
Level 1	Single date and single angle acquisition	Top of the atmosphere reflectance, map projection	5 m
Level 2	Single date and single angle acquisition	Surface reflectance, map projected	10 m
Level 3	10 days time composite of a single date and single angle acquisition	Surface reflectance, map projected	10 m

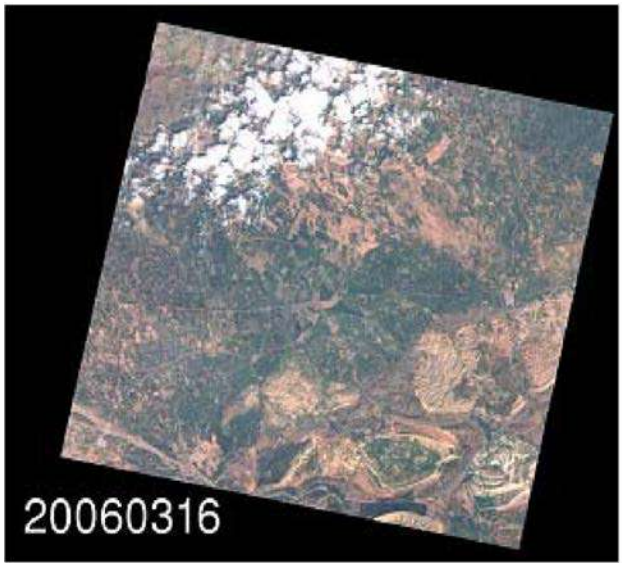
There is one set of products per site, namely levels 1, 2 and 3. Therefore a product is made of 1 (5200x5200 pixels) or 2 images (5200*10400 pixels).

3.1 Level 1

The VENµS level 1 will provide:

- Geolocated top of atmosphere reflectances (possibility to use a different geographic projection for each site, but only one per site), with a subpixel (objective 3m) multidate registration.

The level 1 geometric ground resolution is 5 m. Level 1 is used as input to level 2 processors.



Level 1: Top of the Atmosphere reflectances calibrated & geocoded (orthoimage). Formosat-2 data, 8m ground resolution.

The following table details the level 1 product content.

	Code	description	Res.	bands	Format Entête	Format Donnée	bits
Public		Global description of the product	-	-		XML	-
	-	TOA reflectance and masks	5	15	HDR	GEOTIFF	16
		B1=>B12 TOA reflectance					
		SAT Saturated pixels mask					
		PIX aberrant pixels mask					
		CLD clouds mask					
	CLA	Cloud altitude	20	1	HDR	GEOTIFF	16
	SOL	Solar angles grid	100	8 (B05-10-07-06)	HDR	HDF	-
	VIE	Viewing angles grid	500	4 (3000-8000m)	HDR	HDF	-
	QLK	Quick look	100	3	HDR	JPEG	8

The following document shows the formula used to compute the VENµS TOA reflectance from the VENµS TOA radiance:
https://theia.cnes.fr/atdistrib/documents/Level_1_processing_Venus.pdf

Additional information on level 1 product format can be found at the following URLs:

http://www.cesbio.ups-tlse.fr/multitemp/?page_id=12984

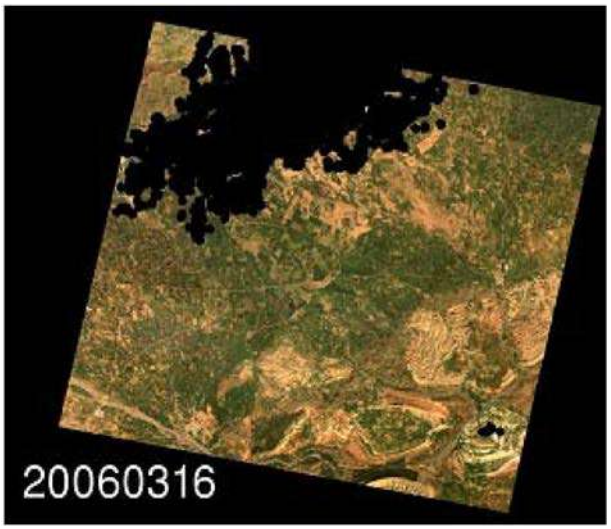
https://theia.cnes.fr/atdistrib/rocket/#/documents

3.2 Level 2

The VENµS level 2 products will provide:

- a fine cloud and cloud shadow mask, and a water mask
- surface reflectance after atmospheric corrections for all spectral bands (still geolocated)

The level 2 geometric resolution is 10 m.



Level 2: Single date surface reflectances after cloud masking and atmospheric correction on level 1 product. Formosat-2 data, 8m ground resolution.

The following table details the level 2 product content.

	Code	description			Res. en m.	Nb. bands	bits signif.	bits write	Format Entête	Format Donnée
Public	-	Global description of the product								XML
	SRE	Surface reflectance without slope correction			10	12	16	16	HDR	GEOTIFF
	FRE	Surface reflectance with slope correction = « Flat reflectance »			10	12	16	16	HDR	GEOTIFF
	ATB	Atmospheric parameters			10	2	8	8	HDR	GEOTIFF
		VAP	Water vapour content							
		AOT	Aerosol optical thickness							
	CLD	Cloud and cloud shadow mask			10	1	8	8	HDR	GEOTIFF
		(*)	*ALL*	*Summary Logical or of All cloud and shadow masks*		*8*	*8*			
			ALL_CLOUDS	*Logical or of All cloud masks*						
			SHADOWS	*Shadows mask from clouds within image*						
			SHADVAR	*Shadows mask from clouds outside image*						
			REFL	*Reflectance threshold*						
			REFL_VAR	*Reflectance variation threshold*						
			EXTENSION	*Extension of the cloud mask*						
			ALT	***Stereoscopic mask***						
	MSK	Geophysical masks			10	1	5	8	HDR	GEOTIFF
			WAT	*Water mask*		*5*	*5*			
			HID	*hidden surfaces*						
			SHD	*shadowed by topography mask*						
			STL	*sun too low flag*						
			TGS	*tangent sun flag*						
	QLT	Quality masks			10	3	12	16	HDR	GEOTIFF
		SAT	Saturation mask copied from L1 (12 useful values)				*12*			
		PIX	aberrant pixels channel copied from level 1 (12 useful values)				*12*			
		OTH	*EDG*	*Edge mask*		*3*	*3*			
			IAO	*AOT pixel mask (0 if computed, 1 if interpolated)*						
			IWC	***VAP pixel mask (0 if computed, 1 if interpolated)***						
	SOL	Solar angles grid (identical to L1 one at L2 scale)			-	-	32	32	HDR	HDF
	VIE	Viewing angles grid (identical to L1 one at L2 scale)			-	-	32	32	HDR	HDF
	-	Quick look			100	3	8	8	HDR	JPEG

The VENμS level 2 products are produced using the MAJA processor, which detects the clouds and their shadows, and estimates aerosol optical thickness (AOT), water vapor and corrects for the atmospheric effects. The processor was jointly developed by CESBIO, CNES and DLR.

The following document provides a detailed description of the methods used in MAJA:

http://www.cesbio.ups-tlse.fr/multitemp/?p=12432

The following URL present a shorter description of MAJA:

http://www.cesbio.ups-tlse.fr/multitemp/?p=6203

Additional information on level 2 product format can be found at the following URLs:

http://www.cesbio.ups-tlse.fr/multitemp/?page_id=13803

https://theia.cnes.fr/atdistrib/rocket/#/documents

References:

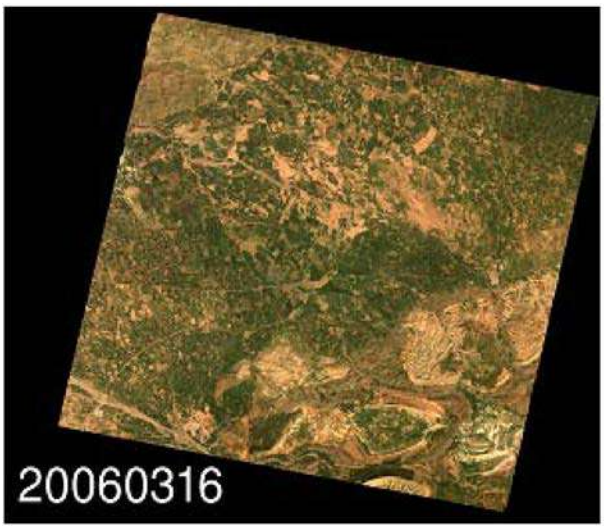
Hagolle, O., G. Dedieu, B. Mougenot, V. Debaecker, B. Duchemin and A. Meygret, 2008, Correction of aerosol effects on multi-temporal images acquired with constant viewing angles: Application to Formosat-2 images. *Remote Sensing of Environment*, Vol. 112, n°4, 1689-1701.

Hagolle O., M. Huc, D.Villa Pascual, and G. Dedieu, "A multi-temporal method for cloud detection, applied to FORMOSAT-2, VENμS, LANDSAT and SENTINEL-2 images," *Remote Sensing of Environment*, vol. 114, Aug. 2010, pp. 1747-1755.

3.3 Level 3

The VENμS level 3 will provide the same variables as level 2, every week, maximizing the number of cloud free pixels. Level 3 will be based on level 2 data acquired under the same viewing angle.

The level 3 geometric resolution is 10 m.



Level 3: 10 days time composite of level 2. Formosat-2 data, 8m ground resolution.

The following table details the level 3 product content.

	Code	description	Res.	bands	bits signif.	bits	Format Entête	Format Donnée
Public	-	Global description of the product	-	-		-		XML
	SRE	Surface reflectance without slope correction	10	12	10	16	HDR	GEOTIFF
	FRE	Surface reflectance with slope correction = « Flat reflectance »	10	12	10	16	HDR	GEOTIFF
	-	Quick look	100	3	8	8	HDR	JPEG
	MSK	Geophysical masks	10	4		16	HDR	GEOTIFF
		CLD Cloud mask						
		CIR Cirrus mask						
		WAT Water mask						
		RAI Rain mask						
	QLT	Quallity/Masks	10	2		16	HDR	GEOTIFF
		SAT Saturated pixel mask						
		PXD Pixel dates						

3.4 In-situ data

For operational reasons, it is not possible to incorporate in-situ data, such as local aerosol measurements, in the operational level 2 and 3 processing.

3.5 Data distribution for the VENμS Israeli scientific sites

The VENμS product of the Israeli scientific site are available at the following URL:

https://venus.bgu.ac.il/venus/

3.6 Data distribution for others VENμS scientific sites

The data over all VENμS scientific sites (except Israel) are available for free download using the following URL:

https://theia.cnes.fr/atdistrib/rocket/#/home

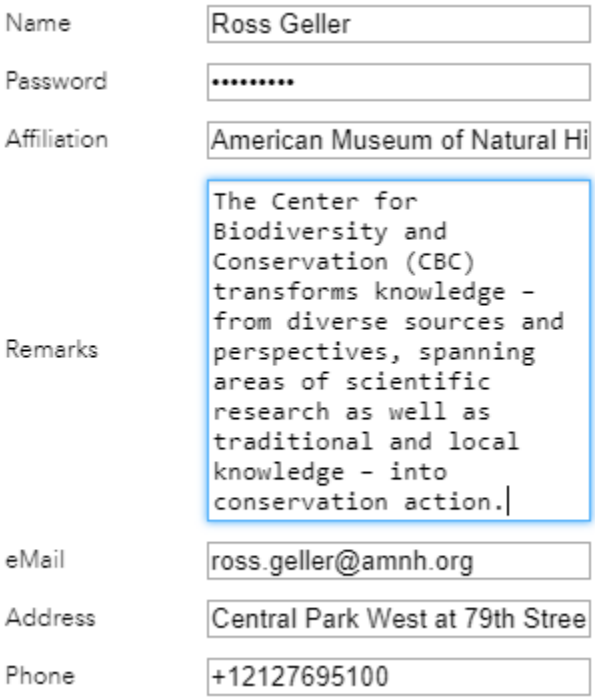
4. How to order, download and extract the Israeli VENμS products

Connect to the website https://venus.bgu.ac.il/venus/

4.1 System registration

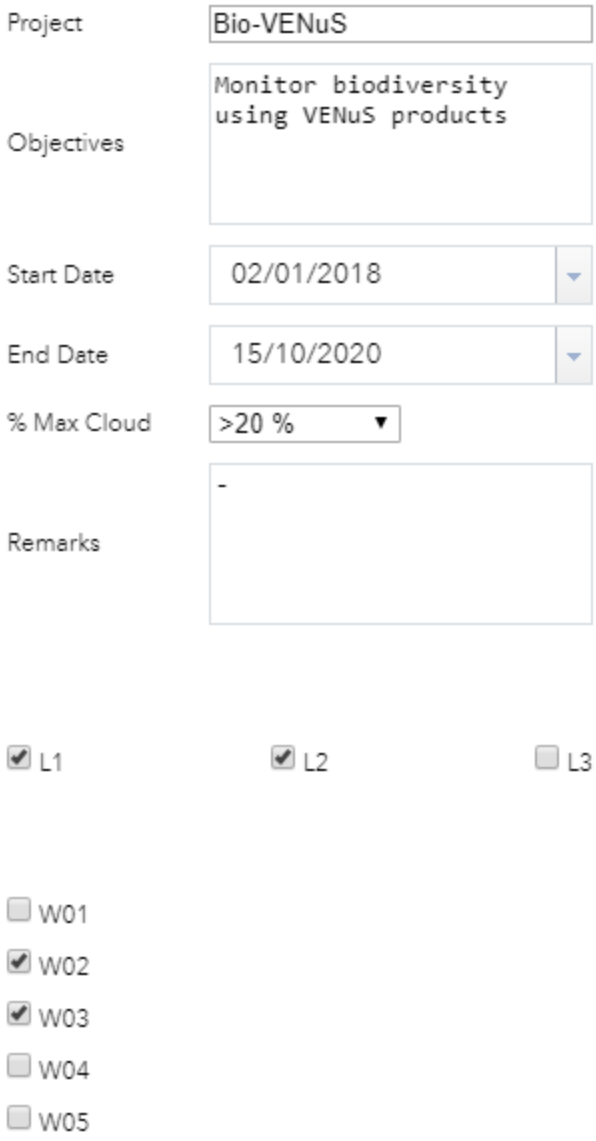
- Click on the “System registration” icon  and fill out all the information in English (**please, don’t write in Hebrew**).

A **user** is defined by “Name”, “Password”, “Affiliation”, “eMail, “Address” and “Phone”.



A **project** is defined by “Name of the Project”, “Objectives”, “Dates”, “% Max. cloud”, “Level of products” (L1, L2, L3) and “name of tiles” (W01, W02, … S10).

More projects can be attached to a single user.



If you are going to create more projects (for a single user), please assure you to fill out correctly all the information of the user, i.e “Name”, “Password”, “Affiliation”, “eMail, “Address” and “Phone”.

The name of the user and the eMail are unique, this means that it is not possible to have more than one user with the same eMail.

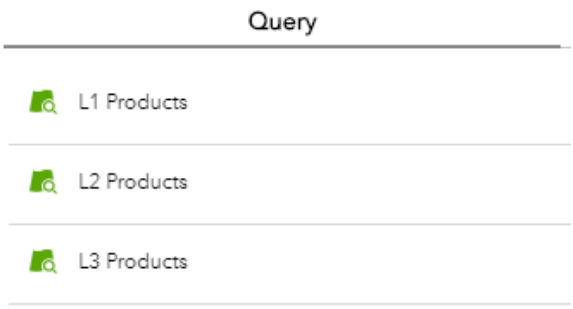
- Fill out the end user agreement form and sent it to venus@post.bgu.ac.il (if not already done).

- You will receive an email from venus@post.bgu.ac.il when your registration will be accepted by the VENμS PI.

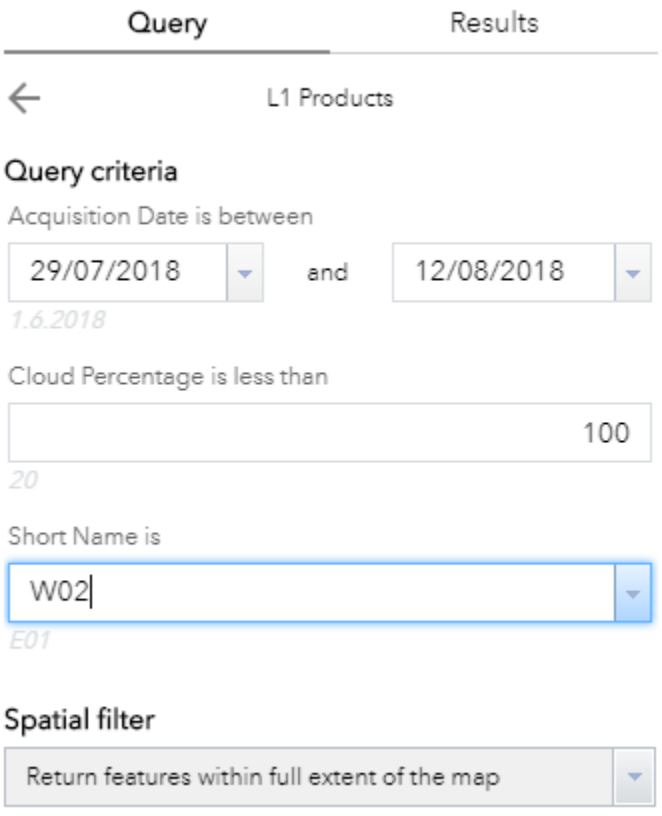
4.2 Query and Order Images

- Click on the “Query and Order Images” icon  .

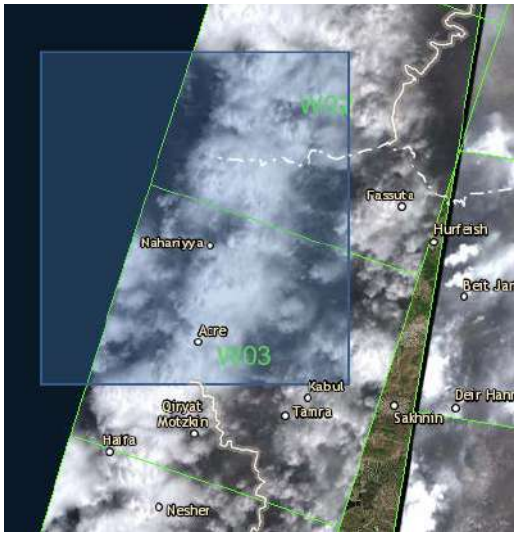
- Select the level of product that you want to query:

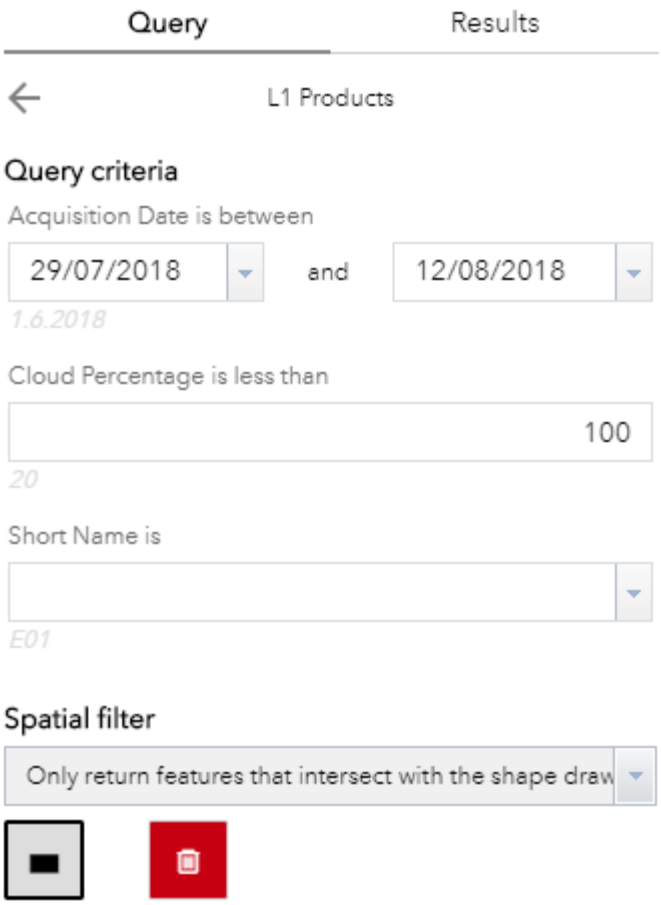


- Fill out the query request information and click “Apply”.

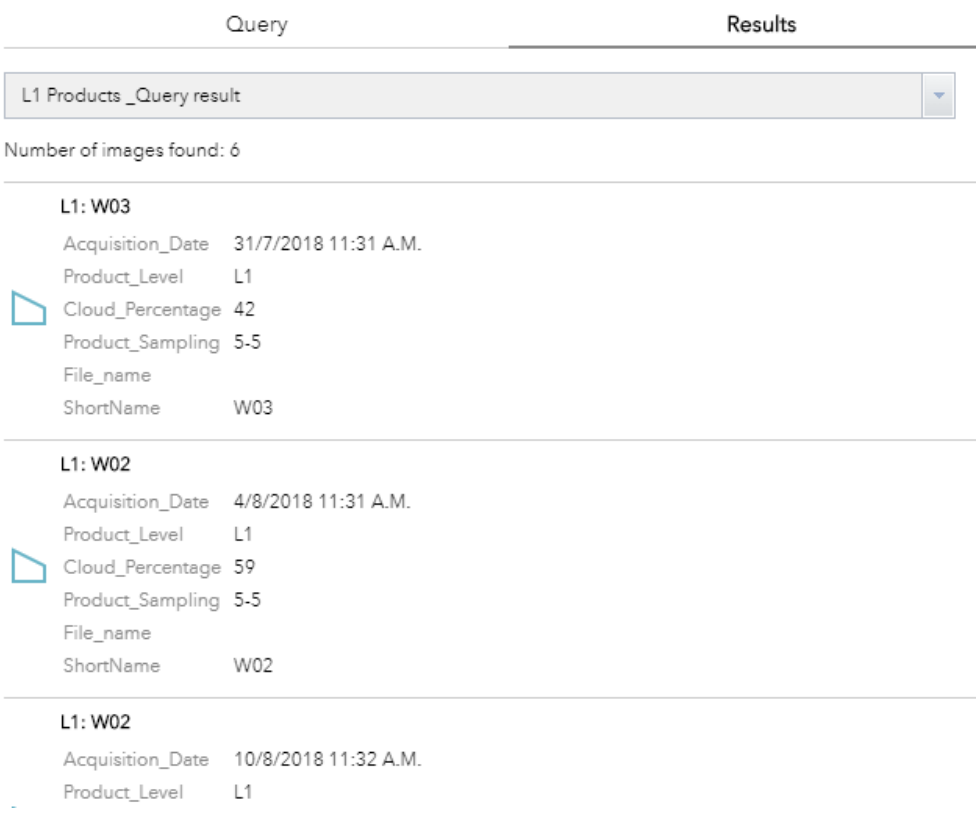


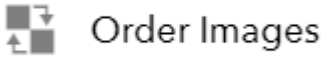
You have the choice to indicate the area of your interest selecting the nickname (E01, E02, ect) or you can do spatial filter and draw rectangle on the map.





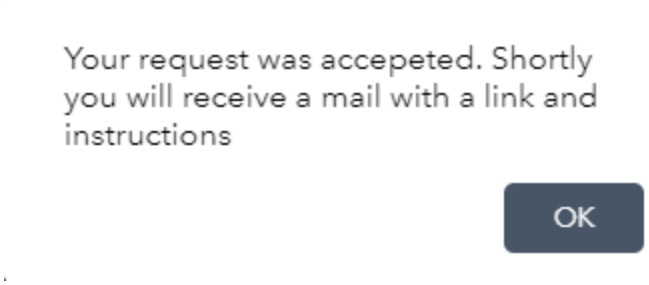
- In “Results” you have the products found in the VENμS archive that correspond to your query request.



- Click on 

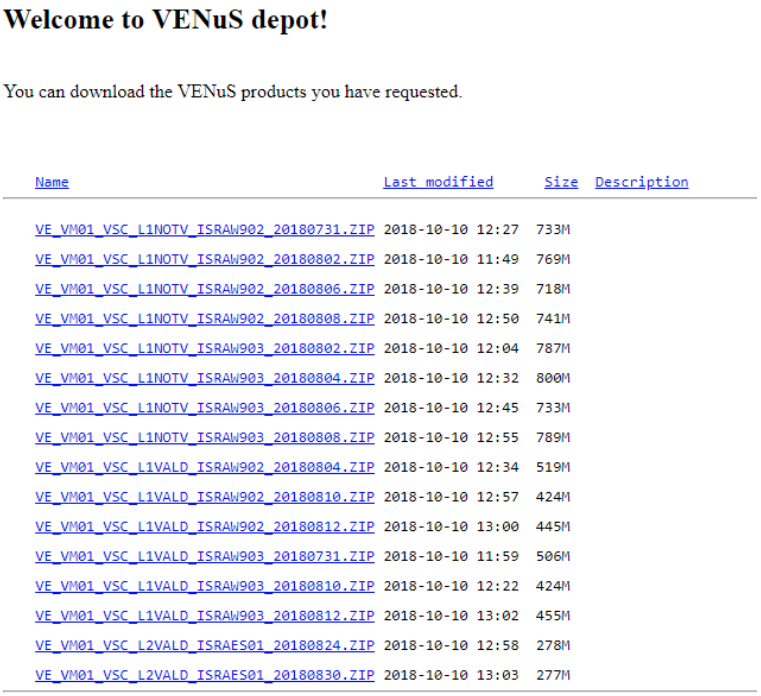
inside the three-dot icon to order all the products of your query.

- Enter your username and password.



4.3 Download Images

- In the next few hours, you will receive an email with the instructions on how to download your products. The products will be available on the server, for a period of 7 days, in a dedicated space for each user. So it may happen that older images are displayed, which have not yet been deleted.



Welcome to VENuS depot!

You can download the VENuS products you have requested.

Name	Last modified	Size	Description
VE_VM01_VSC_L1NOTV_ISRAW902_20180731.ZIP	2018-10-10 12:27	733M	
VE_VM01_VSC_L1NOTV_ISRAW902_20180802.ZIP	2018-10-10 11:49	769M	
VE_VM01_VSC_L1NOTV_ISRAW902_20180806.ZIP	2018-10-10 12:39	718M	
VE_VM01_VSC_L1NOTV_ISRAW902_20180808.ZIP	2018-10-10 12:50	741M	
VE_VM01_VSC_L1NOTV_ISRAW903_20180802.ZIP	2018-10-10 12:04	787M	
VE_VM01_VSC_L1NOTV_ISRAW903_20180804.ZIP	2018-10-10 12:32	800M	
VE_VM01_VSC_L1NOTV_ISRAW903_20180806.ZIP	2018-10-10 12:45	733M	
VE_VM01_VSC_L1NOTV_ISRAW903_20180808.ZIP	2018-10-10 12:55	789M	
VE_VM01_VSC_L1VALD_ISRAW902_20180804.ZIP	2018-10-10 12:34	519M	
VE_VM01_VSC_L1VALD_ISRAW902_20180810.ZIP	2018-10-10 12:57	424M	
VE_VM01_VSC_L1VALD_ISRAW902_20180812.ZIP	2018-10-10 13:00	445M	
VE_VM01_VSC_L1VALD_ISRAW903_20180731.ZIP	2018-10-10 11:59	506M	
VE_VM01_VSC_L1VALD_ISRAW903_20180810.ZIP	2018-10-10 12:22	424M	
VE_VM01_VSC_L1VALD_ISRAW903_20180812.ZIP	2018-10-10 13:02	455M	
VE_VM01_VSC_L2VALD_ISRAES01_20180824.ZIP	2018-10-10 12:58	278M	
VE_VM01_VSC_L2VALD_ISRAES01_20180830.ZIP	2018-10-10 13:03	277M	

4.4 Extract the Images

Each ZIP file contains the metadata (HDR) and a TAR file (DBL) with the images for a specific VENμS product (L1, L2 or L3), date and site.

Un-zip the file.

The HDR is an XML file, which contains the necessary metadata, and can be read with any text editor (e.g. Notepad++), and the DBL file (DataBLock) is a tar.bz2 file.

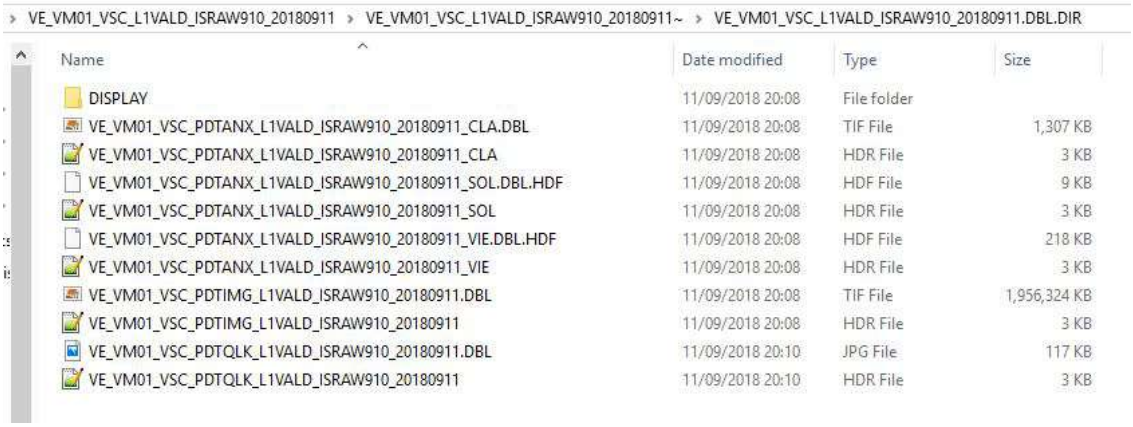
In **Linux**, you can un-zip the DBL file with the following command:

```
tar xvf filename.DBL
```

In **Windows**, you can un-zip the DBL file trough 7Zip (or with others similar software).

ATTENTION: Once you un-zip the file trough 7Zip, a directory that contains another compressed file is created. **You have to un-zip also this file!**

After this **second un-zip** you will obtain all the files of the products in a dedicated directory. For instance:



From now on, you get a good format, but don't forget to remove the ZIP and DBL files, otherwise, VENµS data will occupy a large volume on your disk.

More information on the algorithms, products and uses can be found on the dedicated blog:

http://www.cesbio.ups-tlse.fr/multitemp/?p=6203

http://www.cesbio.ups-tlse.fr/multitemp/?cat=56

For any information, please do not hesitate to contact us at the following address:

venus@post.bgu.ac.il