The EUMETSAT Satellite Application Facility on Land Surface Analysis (LSA SAF)

Product User Manual (PUM)

Normalized Difference Vegetation Index (ENDVI10)

PRODUCTS: LSA-420 AND LSA-454 (ENDVI10)

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1   Introduction

The Satellite Application Facility (SAF) on Land Surface Analysis (LSA) is part of the SAF Network, a set of specialized development and processing centers, serving as EUMETSAT (European organization for the Exploitation of Meteorological Satellites) distributed Applications Ground Segment. The SAF network complements the product-oriented activities at the EUMETSAT Central Facility in Darmstadt. The main purpose of the LSA SAF is to take full advantage of remotely sensed data, particularly those available from **EUMETSAT** sensors, to measure **land surface** variables, which will find primarily applications in meteorology (http://landsaf.ipma.pt/).

The EUMETSAT Polar System (EPS) is Europe's first polar orbiting operational meteorological satellite and the European contribution to a joint polar system with the USA. EUMETSAT will have the operational responsibility for the "morning orbit" with Meteorological-Operational (MetOp) satellites, the first of which was successfully launched on October 19, 2006, the second (MetOp-B) on 17 September 2012, and the third (MetOp-C) on 7 November 2018, which became operational on 3 July 2019. Despite the wide range of sensors on-board MetOp (http://www.eumetsat.int/), most LSA SAF parameters make use of the Advanced Very High Resolution Radiometer (AVHRR) and, to a lesser extent, of the Advanced Scatterometer (ASCAT).

The MetOp-AVHRR S10 ("ENDVI10") are near-global, 10-daily composite images which are synthesized from the "best available" observations registered in the course of every "dekad" by the orbiting earth observation system MetOp-AVHRR, a year composite of 2009 is shown in Figure 1.
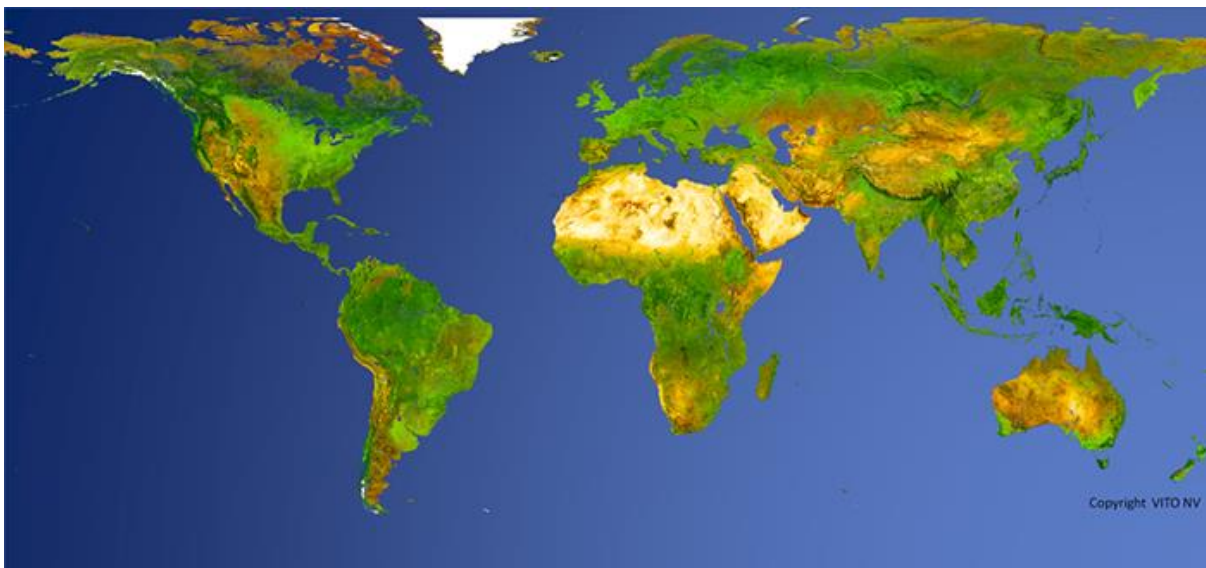
Figure 1: ENDVI10 product example.

On behalf of the JRC-MARS program of EC, the Flemish Institute for Technological Research (VITO) developed a processing chain for the generation of National Oceanic and Atmospheric Administration (NOAA)-AVHRR data over Europe. Individual tracks/orbits are ingested, corrected in different steps (calibration, geometric correction, atmospheric correction, cloud/snow labeling), and then composited into 10-daily "Synthesis" images (S10). With this processing chain, all the daytime-

observed NOAA data registered since 1981 were processed by different European institutes in Europe. Recently, the procedures were adapted for MetOp-AVHRR Level 1b observations. The resulting S10 composites from MetOp-AVHRR are very comparable with the ones delivered by VITO's SPOT-VEGETATION (1998 – 2014) processing chain: 1 km resolution, near-global coverage, frequency of 10 days ("dekad") and similar spectral contents (RED, NIR, SWIR - no BLUE, but two thermal bands). In addition to the basic information layers (surface reflectances, angles of the solar/viewing geometry, status map, etc.), the decadal composites also comprise two "value-added" image layers: NDVI and accompanying Land Surface Temperature (LST).

The MetOp-AVHRR ENDVI S10 processing chain is operated in the LSA SAF System II at VITO. ENDVI10 is available as a Climate Data Record (CDR, LSA-454), covering the period May 2007 – December 2019, and an Interim Climate Data Record (ICDR, LSA-420) performing continuous updates in Near Real Time of LSA-454. In both cases, ENDVI10 consists of composites representing a Normalized Difference Vegetation Index (NDVI) and are distributed together with a set of ancillary dataset layers (surface reflectances, solar and viewing angles, quality indicators). The product and ancillary dataset layers described in this document refer to both LSA SAF products: the ENDVI10 CDR (LSA-454) and the ENDVI10 ICDR (LSA-420). The Land Surface Temperature (LST) ancillary data layer is added on courtesy of VITO, whereof EUMETSAT does not take any liability, responsibility and ownership.

This document is one of the Product Manuals dedicated to LSA SAF users. The algorithm and the main characteristics of the vegetation indices (NDVI and the accompanying LST) generated by the LSA SAF from AVHRR observations are described in the following sections. The characteristics of AVHRR based vegetation indices provided by the LSA SAF are described in Table 1. Further details on the LSA SAF product requirements can be found in the Product Requirements Document (PRD) available at the LSA SAF website http://landsaf.ipma.pt).

Table 1: Product Requirements for ENDVI, in terms of area coverage, resolution, and accuracy.

Product Name	Product Identifier	Coverage	Resolution		Accuracy		
			Temporal	Spatial	Threshold	Target	Optimal
ENDVI10	LSA-454 LSA-420	Global	10-daily	1km	R^2>0.80	R^2>0.90	R^2>0.95

with R^2 = coefficient of determination.

2   Algorithm

2.1   Introduction

The European MetOp satellites were conceived by ESA/EUMETSAT to complement the geostationary Meteosat satellites. In this way, they are analogue to the USA NOAA platforms, which accompany the geostationary GOES-East and -West satellites. Since mid-2007, MetOp thus occupies the "morning orbit", while NOAA occupies the "afternoon orbit": the local solar time of the overpasses is around 08:45 h for MetOp-B, 09:30 h for MetOp-A and -C, respectively, and 14:00 h for NOAA. Both platforms carry the same AVHRR instrument which scans the full earth surface at ±1km resolution in five spectral bands: RED, NIR, SWIR/MIR, TIR$_4$, and TIR$_5$. See Table 2 for the spectral band widths. During the night, band 3 is switched from SWIR (3A) to MIR (3B), but the ENDVI10 only cover daytime registrations.

The 1 km resolution image data registered globally by MetOp-AVHRR are systematically captured by the antenna in Svalbard (Norway) and further transferred to EUMETSAT (Darmstadt, Germany). EUMETSAT immediately applies some crucial pre-processing steps: the raw observations are calibrated and transformed into Top-of-Atmosphere (TOA) radiances, accurate "Lon/Lat-planes" are added with the geographical position of each pixel in the raw segment, and also a mask indicating the status of each observation (clear, cloud, snow) is added. The resulting data stream is cut into 3-minute segments (1080 scanlines), which are distributed in near-real time via the EUMETCast broadcasting system as EPS-formatted Level1b files. At the time of writing, EUMETSAT operates the full suite of three MetOp platforms, known as METOP-A, -B, and -C.

The AVHRR-3 sensor on board MetOp observes in five spectral bands, as shown in Table 2. During the day band 3 operates in the Shortwave Infrared (SWIR, Band 3A), during the night it is switched to Middle Infrared (MIR, 3B).

Table 2: METOP-AVHRR spectral bands.

Band nr.	Bandwidth (µm)	Spectral domain	Band abbreviation
1	0.58 - 0.68	Shortwave	VIS (visual) or RED
2	0.725 - 1.00	Shortwave	NIR (near infrared)
3A	1.58 - 1.64	Shortwave	SWIR (shortwave infrared)
3B	3.55 - 3.93	Middle infrared	MIR
4	10.3 - 11.3	Thermal infrared	TIR$_4$
5	11.5 - 12.5	Thermal infrared	TIR$_5$

The Level1b files always provide the accompanying longitude and latitude on the WGS84 geodetical datum for a subsample of pixels. These "Lon/Lat-planes" are required for the mapping of the raw images towards a geographical projection system.

2.2 Segment Processing

VITO ingests all MetOp-AVHRR EPS Level1b files received through its EUMETCast reception stations. However, for the ENDVI10 production, only daytime segments are used. Each individual segment is then processed as follows:

- *Segment selection*

  The continuous data feed comprises all kinds of MetOp-AVHRR imagery, registered over land and sea, during day and night. But as the focus is on global vegetation monitoring, only the daytime segments with at least some land pixels are retained for further processing and no further processing over sea/ocean is performed. The elimination of the night time registrations implies that band 3 always corresponds with the SWIR spectral range (B3A).

- *Spatial - Remap*

  Using the mentioned Lon/Lat-planes, included by EUMETSAT in the Level1b data, and a "nearest neighbour" resampling scheme, the five AVHRR spectral bands are converted to the WGS84 Geographical Lon/Lat system, with a pixel size of 1°/112 ≈ 1 km along a great circle is used.

- *Spatial - Angles*

  Similar images are computed, providing for each pixel the angular position (zenith/azimuth) of the sun and the sensor at the moment of the registration.

- *Spectral – Shortwave: Atmospheric Correction*

  The on-board (TOA) registered radiances are converted into surface reflectances (Top-of Canopy, TOC) by applying SMAC algorithm (Rahman and Dedieu, 1994), which corrects for the interaction of solar radiation by atmospheric constituents in both the downward and upward direction. The SMAC coefficients for MetOp's three shortwave channels (RED, NIR, and SWIR) were computed on behalf of the Monitoring Agricultural ResourceS (MARS) project (Berthelot et al., 2008). In addition to these band-specific coefficients, SMAC needs the input of the atmospheric state at registration time, in terms of water vapour, aerosol load and ozone content. In the previous ENDVI10 version (v1), the aerosol optical thickness (AOT) input for SMAC was formulated by a latitudinal function, which has a dynamic range of [0.05,0.2]. Over time, it became clear that physically more representative and more dynamic AOT data could improve the atmospheric correction. Therefore for ENDVI10 v2 a choice was made to compute a 30th percentile AOT 10-day climatology based on 2003 – 2017 Copernicus Atmospheric Monitoring Service (CAMS) re-analysis AOT data and use these as AOT input for SMAC.

  For ozone, climatological values based on Earth Probe Total Ozone Monitoring Instrument (EP-TOMS) are used (long term monthly averages), while for water vapour Numerical

Weather Prediction (NWP) data from the European Centre for Mid-Range Weather Forecasts (ECMWF) are acquired, i.e., global water vapour maps with a spatial resolution of 0.25° × 0.25º and a renewal frequency of six hours (four water vapour images per day) are used.

After the atmospheric correction, the Normalised Difference Vegetation Index (NDVI) is computed from the Top-Of-Canopy (TOC) reflectances: NDVI = (NIR-RED)/(NIR+RED).

- *Spectral - Longwave*

  Land surface temperatures (LST) are derived, separately for land and sea pixels, from the two Thermal Infrared (TIR) brightness temperatures (BT), using the split window technique of Coll and Caselles (1997), which also requires water vapour and TIR emissivity input data. For water vapour, the same six-hourly ECMWF data as in the atmospheric correction step are used. The land pixels' TIR emissivities are assessed via a simple linear equation from the obtained NDVI.

- *Quality - Masking*

  Each pixel's observational state is expressed via subsequent 0/1-switches in a bitmap image. This "status mask" classifies each pixel according to criteria such as: land↔sea, and clear↔cloud↔snow/ice. While the Global Land Cover (GLC) 2000 map (Bartholomé et al., 2005) is used to separate land from sea pixels, the distinction between "clear↔cloud↔snow/ice" is fully based on the results of the cloud/snow detection added by EUMETSAT in the Level1b files (EUMETSAT, 2004).

2.3   S10 synthesis processing

The final ten-daily composites (S10) are created as follows:

- *Spatial aspects*

  The composite images follow the same map system as the corrected segments, i.e., WGS84 Geographical Lon/Lat with a resolution of 1°/112. But while the segments only cover limited zones, the S10 composites always extend over the same near-global area, ranging from -180° to +180° in longitude and from -56° to +75° in latitude (40,320 columns × 14,673 lines). The composites only contain NDVI information for the land pixels. Water pixels are flagged with unique missing values codes.

- *Temporal aspects*

  Every month is divided in three "dekads". The first two always comprise ten days (1-10, 11-20), the third one has variable length, as it runs from day 21 until the end of the month. The procedure starts with the selection of all segments registered within the concerned dekad and overlapping at least partially with the mentioned target zone.

- *Spectral aspects*

  In general, for each composite land pixel , different observations are available, from different segments or registration dates. The compositing selects the "best available" observation and transfers all its components (NDVI, LST, reflectances, temperatures, angles,

status map) to the corresponding S10 synthesis layers. A classification action is performed, as explained further below. After the classification, the best available group is found. If it contains only one observation, this will be the "best" one. If there are more, the one with the highest TOA NDVI is selected. This method favors the near-nadir views and suppresses observations which are still partly affected by clouds, snow, and water (which all have low NDVI).

- *Quality Control*

  NOAA-AVHRR scenes are often affected by radiometric errors (stripes, waves) or geometrical shifts, especially when a platform reaches its nominal lifetime. Hence, after the pre-processing each individual segment is visually checked by an operator who identifies and rejects the bad scenes. Without this measure, the bad segments can decrease the quality of the final composites. After one year of similar checks on MetOp-AVHRR data, no such errors could be detected. So as an alternative, only the daily global composites,, which are produced as well in the background, are checked. This requires less time and is as effective as checking hundreds of individual segments (480 per day).

The compositing is a crucial step. Whereas individual segments contain a lot of clouds and occupy different and scattered areas, the final 10-daily composites have are better spatial coverage , are less contaminated by clouds, and always cover the full area of the "target zone", in this case the majority of the globe. The global S10 composites derived from MetOp-AVHRR have the same spatial characteristics as the S10 of SPOT-VGT − both can even directly be superimposed. As mentioned, all sea pixels are flagged and information is only provided for the land pixels.

The compositing rule is a classical "Maximum TOA NDVI", with constraints on the observation status and the registration geometry. In practice, for each pixel the available observations are first classified as follows (Θ_s=*solar zenith angle*, Θ_v=*viewing zenith angle)*, as shown in Table 3*.

Table 3: Compositing rule.

OBSERVATION STATUS	REGISTRATION GEOMETRY		
	BAD θ_s>75° or θ_v>45°	ACCEPTABLE θ_s<75° and θ_v>40°	GOOD θ_s<75° and θ_v<40°
Cloud	Not used	C2	C1
Snow/Ice	Not used	B2	B1
Clear	Not used	A2	A1

All observations in the BAD category are immediately discarded. The remaining ones (if any) are grouped into six classes with the following hierarchy: A1 > A2 > B1 > B2 > C1 > C2. Then, the highest non-empty class is searched. If it contains only one observation, that one is selected, else it will be the one with the highest TOC NDVI (which promotes the cloud- and snow-free data). If a pixel has no GOOD or ACCEPTABLE observations, its position in the composite is flagged with special codes in all spectral layers. But in all other cases (at least one acceptable measurement), the ENDVI10

composite will contain the values of the best observation (reflectances, angles, etc.), while its nature (clear, cloudy,...) is expressed via the ENDVI10 Status Map (STM).

3 Product Description

3.1 Image format and naming convention

The ENDVI10 LSA SAF product follows the following naming standard:

METOP_AVHRR_<*YYYYMMDD*>_S10_<*www*>_<*vvv*>.<*eee*>

where

- *<YYYYMMDD>* = start date of the concerned dekad. *YYYY, MM, DD* denote the year, the month, and the day, respectively. *DD* can only be 01, 11 or 21, being the start of each dekad.
- *<www>* = the label of the selected geographical window (see Section 3.4).
- *<vvv>* = the label of the concerned image layer (see Table 4).
- *<eee>* = the filename extension (IMG, HDR, TIF or XML).

The ENDVI10 products are distributed as zip archives. The archive uses the following naming convention:

METOP_AVHRR_<*YYYYMMDD*>_S10_<*www*>_V200.zip

with the same convention as described above and 'V200' referring to ENDVI v2. Each zip archive contains 26 files:

- twelve image layers (*.img) represented by an image and the corresponding header information (*.hdr),

- one XML metadata file conform INSPIRE guidelines version 1.0. INSPIRE is a European metadata format description, providing rules to use the ISO-19115 standard. Note that the XML file does not have a label representing the image layer, hence no *<vvv>*. Instead of the *<vvv>* tag, the xml file name contains a version tag. For ENDVI v2, this tag is denoted 'V200'.

  The indication whether the data are from METOP-A, -B or -C is expressed in the metadata file in the element <DS_InitiativeTypeCode>, indicated as either METOP_A, METOP_B or METOP_C.

- one NDVI quicklook (QL) GeoTiff file, with values colored brown to dark green for low to high NDVI. The quicklook is sub-sampled to 25% of the original image size in both horizontal and vertical direction.

The image layers are provided in "flat binary" format without header/trailer bytes. "Flat" means that each layer of a certain composite is stored in a separate image file. These files have the fixed extension *.img. Because all layers have the byte data type (1 pixel = 1 byte), the total number of bytes in each image is equal to the number of pixels. This type of imagery can easily be imported in any standard image processing software.

Associated to each image file is a small ASCII-formatted header annotation file, which uses the same filename as the image, but with extension *.hdr. It provides all the basic ancillary information to

properly import the imagery directly into the ENVI software. Similar annotation files can easily be created for other packages. Figure 2 depicts an example of the NDVI image header file for the ENDVI10 EUR window for the second dekad of February 2010. The sequence "1.5, 1.5, -11, 75" in "map info" specifies that the center of the top-left pixel (Col=1.5, Rec=1.5) is located at the geographical position with Lon=-11°, Lat=75°, while the value "0.0089285714" indicates the spatial resolution in the x and y direction in degrees (~1 km). The "VALUES" fields specify the spectral product's characteristics (see §3.3).

```
ENVI
description = {METOP_A-AVHRR, type=S10_EUR, date=20100211 }
samples = 8176
lines = 5600
bands = 1
file type = ENVI Standard
data type = 1
sensor type = METOP-AVHRR
map info = {Geographic Lat/Lon, 1.5, 1.5, -11, 75, 0.0089285714, 0.0089285714, WGS-84, units=Degrees}
DATE = 20100211
DAYS = 10
FLAGS = { 255=noValue}
SENSOR TYPE = METOP_A-AVHRR
VALUES = { NDVI, -, 0, 250, 0, 250, -0.08, 0.004}
```

Figure 2: Example contents of the header file METOP-AVHRR_20100211_S10_EUR_NDV.hdr.

3.2 Temporal characteristics

Every month is divided into three "dekads". The first two always comprise ten days (1-10, 11-20), while the third has a variable length, as it runs from day 21 until the end of the month.

The distinction between "days" is based on Universal Time Coordinate (UTC) criteria. Every "dekad", a new ENDVI10 is generated. Although MetOp-AVHRR became operational on 21 May 2007, the ENDVI10 time series distributed by VITO are available from 1 May 2007 onwards. The objective is to deliver each new ENDVI10 with a maximum delay of three days, i.e., at the latest on month days 3, 13, and 23.

3.3 Spectral characteristics

Each ENDVI10 composite comprises twelve separate image layers, whose characteristics are listed in Table 4. All layers have data type "8 bit, unsigned byte", so the digital values *V* in the images vary (potentially) between 0 and 255. Note that SR1, SR2, and SR3 are unitless [-], while for LST the unit is [K], which is different from ENDVI v1.

Table 4: Image layers of the ENDVI10 product.

IMAGE	Physical Values Y			Scaling	Digital Values V	
vvv	CONTENT	UNIT	$Y_{lo} \rightarrow Y_{hi}$	Y = A + B*V	$V_{lo} \rightarrow V_{hi}$	V_{flag}
SR1	$R_{s,RED}$	-	$0 \rightarrow 0.625$	Y=0.0025*V	$0 \rightarrow 250$	255
SR2	$R_{s,NIR}$	-	$0 \rightarrow 0.833$	Y=0.00333*V	$0 \rightarrow 250$	255
SR3	$R_{s,SWIR}$	-	$0 \rightarrow 0.625$	Y=0.0025*V	$0 \rightarrow 250$	255
NDV	NDVI	-	$-0.08 \rightarrow 0.92$	Y=-0.08 + 0.004*V	$0 \rightarrow 250$	255
LST	Land surface temperature	K	$223.15 \rightarrow 348.15$	Y=223.15 + 0.5*V	$0 \rightarrow 250$	255
SZA	Solar Zenith Angle	º	$0 \rightarrow 125$	Y=0.5*V	$0 \rightarrow 250$	255
VZA	Viewing Zenith Angle	º	$0 \rightarrow 125$	Y=0.5*V	$0 \rightarrow 250$	255
SAA	Solar Azimuth Angle	º	$0 \rightarrow 360$	Y=1.5*V	$0 \rightarrow 240$	255
VAA	Viewing Azimuth Angle	º	$0 \rightarrow 360$	Y=1.5*V	$0 \rightarrow 240$	255
TCO	Number of Clear observations	-	$1 \rightarrow 255$	Y=V	$1 \rightarrow 255$	0
DAY	Day in dekad	-	$1 \rightarrow 11$	Y=V	$1 \rightarrow 11$	0
STM	Status Map	-	Bit interpretation (see table below)		$1 \rightarrow 255$	0

- NIR=near infrared, SWIR=shortwave infrared.
- R_s=atmospherically corrected "surface" (TOC) reflectance, NDVI=Normalized Difference Vegetation Index=$(R_{s,NIR}-R_{s,RED})/ (R_{s,NIR}+R_{s,RED})$.
- V=digital value as indicated in the image, Y=physical meaning.
- V_{lo}-V_{hi}=Significant V range. The scaling only holds for this range. Values beyond V_{lo}-V_{hi} are flags.
- V_{flag}: Per image, there is only one flag to indicate all "aberrant" states (Sea, NoData, NoValidData, Error). The Status Map image provides more information.

The Status Map bit interpretation (Bit7=Most Significant Bit):

Table 5: Status Map bits and interpretation.

Decimal	128	64	32	16	8	4	2	1
Bit Value	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
1	Land	ValidObs	N/A	AOT ≥ AOT_{max}	Good	Cloud OR shadow	Cloud	Snow
0	Sea	NoValidObs	N/A	AOT < AOT_{max}	Acceptable	none of these	Cloud-free	No Snow

- Bit7 indicates whether a pixel is land or sea/ocean. Note that ENDVI10 NDVI data are only computed for land pixels.
- As in ENDVI v1, Bit5 is unused.

- Bit4 contains information on whether the CAMS re-analysis AOT was higher than a pre-calculated maximum AOT that preserves positive RED TOC reflectances after the SMAC calculations. See for more details the ENDVI v2 ATBD. Bit4 was unused in ENDVI v1.
- No cloud shadow detection is applied, hence always Bit2 = Bit1.
- The compositing processing classifies each pixel's observation in three categories depending on the solar and viewing zenith angles: "good", "acceptable", and "bad". The last group is definitely withdrawn, but in the absence of "good" observations, "acceptable" ones may be included into the composites. This is indicated by Bit3.

Sea/ocean pixels can be easily recognized because all bits are 0 (thus the decimal value is zero). Land pixels with at least one cloud/snow-free observation have decimal value 200 (128+64+8) or 192 (128+64, when Bit3=0).

3.4 Spatial characteristics

In a spatial sense, the near-global ENDVI10 S10s are identical to (and congruent with) those of SPOT-VEGETATION.

Table 6: Spatial overview of ENDVI10.

Geodetical datum	WGS84
Projection	Unprojected Geographic Lon/Lat
Resolution	ΔLon=ΔLat=1°/112=0.00892857 (± 1 km along a great circle)
Centre of edge pixels	LON_{min}: -180° $\rightarrow$ LON_{max}+179.991071° LAT_{min}: -56° $\rightarrow$ LAT_{max}+75°
Ncol / Nrec / Npix	40 320 / 14 673 / 591 615 360

However, the near-global imagery is not distributed as such. Users can only select one of the ten pre-defined regions listed in Table 7.
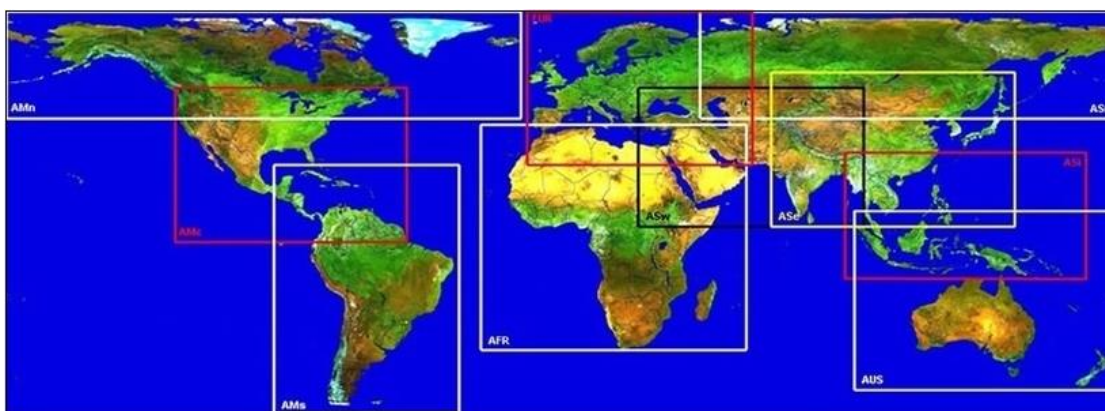

Figure 3: Geographical regions.

Table 7: Geographical regions characteristics.

www	WINDOW	LON_{min}	LON_{max}	LAT_{min}	LAT_{max}	N_{col}	N_{rec}	N_{pix}
AMn	North America	-180	-13	40	75	18704	3920	73 319 680
AMc	Central America	-125	-50	0	50	8400	5600	47 040 000
AMs	South America	-93	-33	-56	25	6720	9072	60 963 840
EUR	Europe	-11	62	25	75	8176	5600	45 785 600
AFR	Africa	-26	60	-35	38	9632	8176	78 751 232
ASw	Asia West	25	98	5	50	8176	5040	41 207 040
ASn	Asia North	45	180	40	75	15120	3920	59 270 400
ASe	Asia East	68	147	5	55	8848	5600	49 548 800
ASi	Asian Islands	92	170	-12	29	8736	4592	40 115 712
AUS	Australasia	95	180	-48	10	9520	6496	61 841 920

The listed Lon/Lat values indicate the geographical longitude and latitude of the center of the edge pixels in each window. 'Ncol' and 'Nrec' are the number of columns and rows in each window and 'Npix' is the total number of pixels (Npix = Nrec x Ncol).

4 Data Access

4.1 Introduction

The ENDVI10 S10 data products are freely available without limitations for non-commercial use and are provided under copyright of EUMETSAT**,** but when used for reports, publications or similar, please mention the reference: "*by courtesy of the LSA SAF project, produced by VITO*" and inform us (helpdesk.landsaf@ipma.pt) for which purpose they are used.

The ENDVI10 data products can be accessed through the LSA SAF website (http://landsaf.ipma.pt/), see Figure 4.

The ENDVI10 products can be ordered via the on-line catalogue and/or via subscription, through the link as expressed on the LSA-SAF website (Product Download hyperlink). Selections can be made in time (*e.g.* the 36 dekads of 2019) and space (*e.g.* one or more of the ten pre-defined windows), but not in a thematic sense (*e.g.* only NDVI and LST). Each individual composite thus always comprises all twelve constituent images (see Section 3.3). The ENDVI10 products are always delivered as ZIP files.
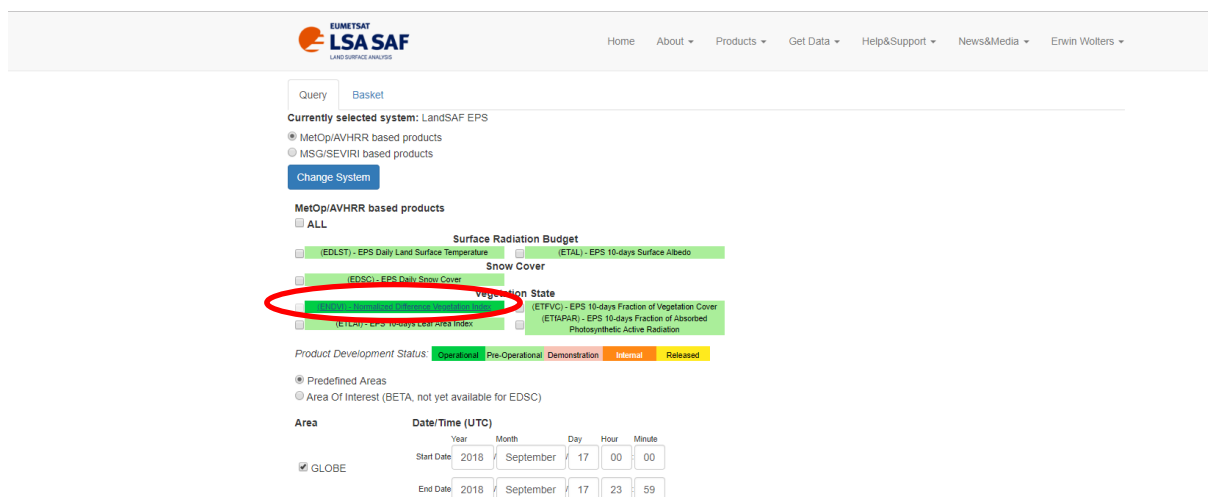
Figure 4: LSA-SAF ENDVI10 home.

The Catalogue refers to the VITO Product Distribution Portal (www.vito-eodata.be), which provides access to several datasets provided by VITO, amongst them the ENDVI10 product, see Figure 5.

Figure 5: ENDVI10 Product Catalogue on VITO's Product Distribution Portal.

4.2 Data Catalogue Discover and Order

The catalogue can be consulted to discover and order available products online. Specific queries can be defined, as shown in Figure 6.
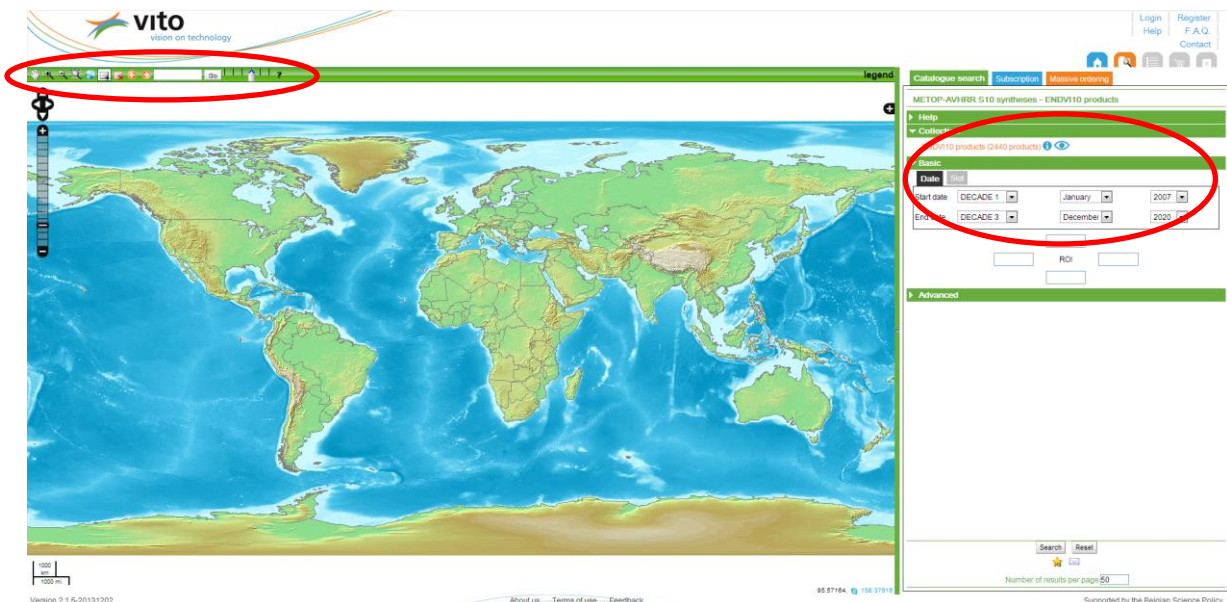

Figure 6: Product discovery.

- A time interval can be specified via the fields 'Start Date' and 'End Date'.
- One of the ten pre-defined windows can be selected by activating the "Draw region of interest" command (icon in top left area). Clicking on the "Search" button then shows the

window(s) covering this region. Some AOIs may intersect only one window (*e.g.* Canada in *www*=AMn), others may even be covered by three different windows (*e.g.* Iraq in *www*=ASw, EUR and AFR).

After submitting the query by clicking the 'search' button, the result pages are shown with an overview of the matching products.

Users must be registered at the portal before downloading data and need to be logged in before the actual order can be set.

As soon as the products are ready for download over FTP, you will receive an e-mail. Please notice that you can use the same username and password to download the products from the FTP server, as the one you use to log on to the portal.
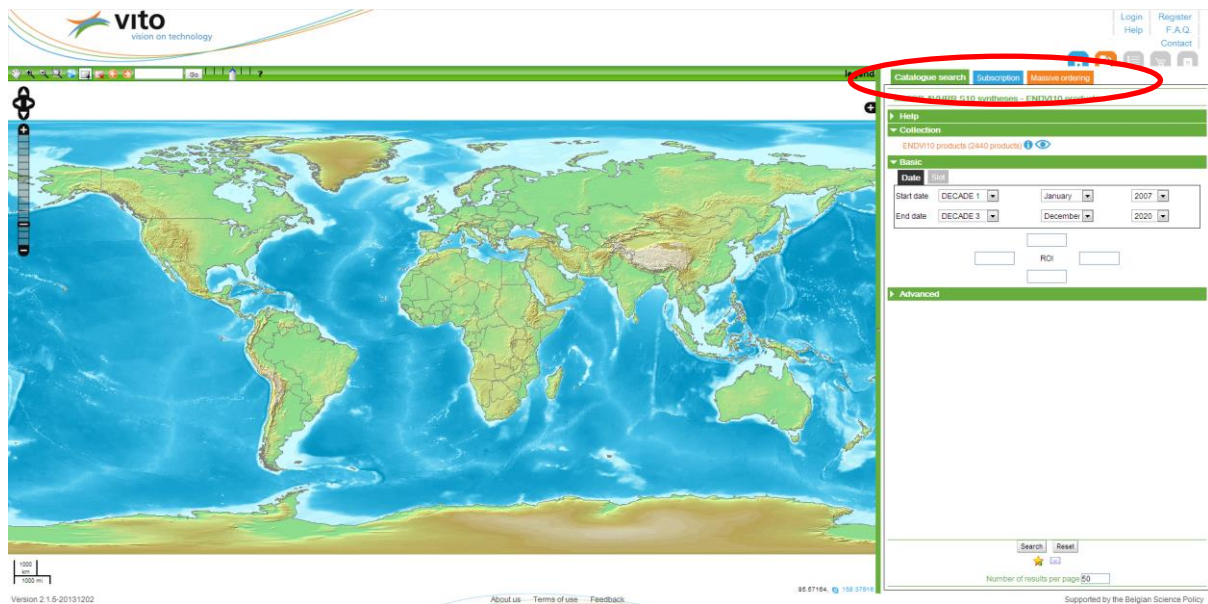
5   Validation

The ENDVI10 v2 data have been validated with corresponding NDVI retrievals obtained from PROBA-V. The reports are available from the LSA SAF website at https://landsaf.ipma.pt/en/products/vegetation/endvi/.

The Validation Report (VR) focuses on product completeness, spatial, statistical and temporal consistency of the ENDVI10 v2, by comparison data over 2016 - 2018 with the previous ENDVI10 v1 and an external NDVI reference dataset from CGLS NDVI v2.2. The main findings are summarized here:

- **Product completeness**

ENDVI10 v2 shows very similar product completeness to ENDVI10 v1 in terms of temporal evolution, spatial distribution and gap length frequency. The average amount of good observations of 71%, with largest occurrence of gaps in Northern hemisphere winter months and at higher latitudes.

- **Spatial consistency**

Compared to ENDVI10 v1, over dense forests, ENDVI10 v2 shows slightly lower frequencies of the highest NDVI ranges. There is a slight shift towards lower NDVI values for biomes with lower NDVI values. Systematic differences are most pronounced over areas where the difference between CAMSCLIM AOT and the static latitudinal function are largest. Differences with CGLS NDVI v2.2 are resulting from a complex combination of differences in sensor characteristics, absolute calibration, processing choices and directional effects that are difficult to separate.

- **Statistical consistency**

ENDVI10 v2 and ENDVI10 v1 show very high statistical consistency, with slightly lower values of high ENDVI10 v2 compared to v1 over densely forested areas and slight skewedness towards higher ENDVI10 v2, related to differences in input AOT.

- **Temporal consistency**

Temporal profiles over BELMANIP2/Direct sites show in general very good agreement between ENDVI10 v2 and ENDVI10 v1. ENDVI10 v2 shows slightly lower temporal smoothness than ENDVI10 v1.

Also the consistency between the MetOp-A, -B and -C sensors was investigated. To evaluate the radiometric consistency between MetOp-A, -B and -C, statistical consistency is analyzed between ENDVI10 v2 derived from MetOp-A and -B over January-December 2016, and between ENDVI10 v2 derived from MetOp-B and -C over the period July-September 2019. Geometric accuracy is evaluated based on the comparison of the geolocation the ENDVI10 v2 to a number of globally distributed Ground Control Points (CGPs).

- **Radiometric consistency**

ENDVI10 v2 shows large agreement between MetOp-A and MetOp-B, and MetOp-B and MetOp-C. The ENDVI10 v2 of MetOp-A is slightly higher than that of MetOp-B, which is in line with what was observed for ENDVI10 v1 in the past (Swinnen and Dierckx, 2015). Bias between MetOp-B and MetOp-C ENDVI10 v2 is smaller. Seasonal variation of the differences between a combined

ENDVI10 v2 dataset based on MetOp-A/B/C and CGLS NDVI v2.2 shows a stable pattern over the years. ENDVI10 v2 thus provides a consistent time series over the different sensors.

- **Geometric accuracy**

Time series analysis of geolocation accuracy shows that MetOp-A and -C have a more accurate geolocation compared to MetOp-B, which is in agreement with the findings of Wu et al. (2019, in review). For all three platforms, latitudinal geolocation is considerably better than longitudinal geolocation.

In conclusion, based on the findings of the validation of ENDVI10 v2 and the consistency analysis between sensors, ENDVI10 v2 is of sufficiently good quality to be distributed in operational mode to the users. Differences between ENDVI10 v2 and ENDVI10 v1 are very small, and can be attributed to the different AOT input (CAMSCLIM vs. static AOT) used in the atmospheric correction. The temporal profiles over BELMANIP2/DIRECT sites show slightly improved consistency of ENDVI10 v2 with CGLS NDVI v2.2, in comparison to ENDVI10 v1, although from the statistical consistency analysis these differences appear to be not significant.

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Appendix A. Acknowledgements