VERDE

Product Specifications

Version 1.0 - March 2019

Strictly confidential – Airbus DS proprietary information

AIRBUS

Content

Acknowledgments

We would like to express our deepest gratitude to Hervé Poilvé, senior expert at Airbus, for the years of work he invested in translating satellite imagery pixels into robust, stable characterizations of plant parameters, regardless of the satellite source. This exceptional contribution has been essential to bring all Airbus agriculture services to the level of quality they currently feature. With Verde, Airbus is excited to open the access to this unprecedented capacity to a much wider audience. We hope you will enjoy it as much as we do and join us in increasing sustainability and profitability for farmers around the globe.

We would also like to sincerely thank the six companies who accompanied us in the product development journey as Early Adopters. Their continuous testing, their feedback, their time and above all, their people have been priceless in building this service.

Introduction

Airbus, a global leader in aeronautics and space and the longest-lasting commercial satellite imagery provider has pioneered the use of remote sensing for agriculture. Every day, Airbus delivers ambitious, environmentally friendly solutions to solve today's farming challenges on a global scale.

Leveraging the increasing amount of imaging satellites and the technical opportunities opened by the digital era, Airbus now aims to provide precision agriculture leaders and start-ups with a living reference layer of premium crop analytics, conveniently clipped to the field and accurately de-clouded.

Based on the result of our technological leadership and R&D investment, Verde delivers incomparable vegetation maps based on a unique capability to characterize plant parameters regardless of the satellite source[1]. These quantitative, precise vegetation insights have been designed to simplify the fusion of satellite imagery and agronomy. These physical measures of vegetation are easy to ingest in crop models for seamless fusion with other data sources such as soil, moisture and weather information. They empower the capacity to go beyond observation to establish an agronomic diagnosis, and eventually to release a farming recommendation.

Lastly, API delivery ensures direct integration into any workflow for a seamless experience on the farmers' end.

[1] See *Appendix 1 – Verde processing* for more details about how we process these, and *Appendix 2 – Interest of Verde and of the biophysical parameters approach* for further details about the benefits of this approach.

I. Verde content / layers descriptions

Verde delivers a range of crops analytics[2] derived from satellite imagery, automatically processed, properly de-clouded, clipped to the field and served as an API.

A. LAI

1. LAI description

LAI (Leaf Area Index) is the number of square meters of green leaves present in one square meter of ground (m²/m²). It features the total developed area of green leaves (one-sided) per ground area unit. It is highly correlated to biomass, allowing for the quantification of crop development. It typically ranges from 0 to 7, and canopy closure is reached around 3.5.

- Crops: wheat, barley, corn, soybean, rapeseed, sugar beet, potatoes, rice, sunflower, cotton, almonds, grass, alfalfa, sugarcane.
- Source imagery: Sentinel 2A/2B, Landsat 8, SPOT 6/7, Pléiades 1a/1b.

2. LAI deliverables

ANALYTICS	The output format for computation, post-processing and analysis
File type	GeoTIFF float 32
Range	[0:10]
Pixel size	2.5m
Projection	WGS 84 / EPSG 4326
No data	-1 (inside the boundaries, in case of cloud or cloud shadow, or outside)
DISPLAY_EARLYSTAGE	The output format for visualization of the data at the beginning of the cycle, when vegetation level is low
File type	PNG
Color scale	[0:3]
Pixel size	2.5m
No data	Transparent

[2] See *Appendix 2 – Interest of Verde and of the biophysical parameters approach* for more details about the benefits of these crop analytics.

DISPLAY_FULLCYCLE	The output format for visualization of the data at late stages of growth, after the canopy is closed
File type	PNG
Color scale	[0:6]
Pixel size	2.5m
No data	Transparent
STATS	A file containing main statistics of the layer
File type	JSON
Values	Min, median, variance, validity (percentage of valid pixels)

B. FCOVER

1. FCOVER description

FCOVER (Green Cover Fraction) features the percentage of ground surface covered by the crop, seen from above. It is a simple characterization of the crop development and does not require knowing the crop type. It is also a good backup option for LAI when the budget is limited. It ranges from 0 to 1, from bare soil to complete coverage of the vegetation.

- <u>Crops</u>: any crop.
- <u>Source imagery</u>: Sentinel 2A/2B, Landsat 8, SPOT 6/7, Pléiades 1a/1b.

2. FCOVER deliverables

ANALYTICS	The output format for computation, post-processing and analysis
File type	GeoTIFF float 32
Range	[0:1]
Pixel size	2.5m
Projection	WGS 84 / EPSG 4326
No data	-1 (inside the boundaries, in case of cloud or cloud shadow, or outside)

DISPLAY_FULLCYCLE	The output format for visualization of the data
File type	PNG
Color scale	[0:1]
Pixel size	2.5m
No data	Transparent
STATS	A file containing the main statistics of the layer
File type	JSON
Values	Min, median, variance, validity (percentage of valid pixels)

C. CHL

1. *CHL description*

CHL (Chlorophyll) features the leaf content of chlorophyll A and B per unit area of leaves (µg/cm²). The concentration of chlorophyll is in direct relation with leaf age, plant nutrition (N), and stress. It typically ranges from 20 to 80 µg/cm².

- Crops: wheat, barley, corn, soybean, rapeseed, sugar beet, potatoes, rice, sunflower, cotton, almonds, grass, alfalfa, sugarcane.
- Source imagery: Sentinel 2A/2B.

2. *CHL deliverables*

ANALYTICS	The output format for computation, post-processing and analysis
File type	GeoTIFF float 32
Range	[0:120]
Pixel size	2.5m
Projection	WGS 84 / EPSG 4326
No data	-1 (inside the boundaries, in case of cloud or cloud shadow or low vegetation i.e. FCOVER <0.3, or outside)

DISPLAY_FULLCYCLE	The output format for visualization of the data
File type	PNG
Color scale	[20:80]
Pixel size	2.5m
No data	Transparent
STATS	A file containing the main statistics of the layer
File type	JSON
Values	Min, median, variance, validity (percentage of valid pixels)

D. FIELDIMAGE

1. FIELDIMAGE description

The FIELDIMAGE is a compressed, high resolution, view-only version of the satellite imagery ("quicklook"). It is useful to understand/check the other layers derived from the same source imagery.

- Source imagery: Sentinel 2A/2B, Landsat 8, SPOT 6/7, Pléiades 1a/1b.

2. FIELDIMAGE deliverables

DISPLAY	The output format for visualization of the satellite image (RGB)
File type	JPG
Pixel size	2.5m

II. Verde offer

A. In-season vs. Historical

Verde is available to serve two main scenarios of use.

- In-season[3] monitoring is meant for services focusing on daily farming operations. A live stream of information allows rapid reaction in the field during the ongoing crop cycle.
- Historical[4] gives the opportunity to review several cycles, gain return on experience and spot recurring patterns to adjust the farming strategy over the long run.

In the API, you define freely the duration of a season, so it can be adapted to the crop and the region. Maximum duration of a season is 365 days.

B. Layers, sensors, cloud cover

Verde is packaged to allow maximum flexibility in the selection of the sensor(s) and the layer(s) and match a wide range of use cases. FCOVER, LAI can be selected together or alone from the combination of sensors you choose. CHL can only be ordered on top of LAI, and for Sentinel 2A/2B only. The FIELDIMAGE is always delivered on top of any other layer ordered, free of charge.

Layer	Sensors	Comment
FCOVER	Sentinel 2A/2B & Landsat 8	Can be ordered with other layers or on a standalone basis
FCOVER	SPOT 6/7	
FCOVER	Pléiades 1a/1b	
LAI	Sentinel 2A/2B & Landsat 8	
LAI	SPOT 6/7	
LAI	Pléiades 1a/1b	
CHL	Sentinel 2A/2B	Shall be ordered on top of Sentinel 2A/2B LAI
FIELDIMAGE	Sentinel 2A/2B, or Landsat 8, or SPOT 6/7 or Pléiades 1a/1b	Always delivered on top of any other layer, free of charge

[3] In-season with SPOT 6/7 and Pléiades 1a/1b requires satellite tasking activation. With Landsat 8 and Sentinel 2A/2B, the data capture is systematic.
[4] Historical with Landsat 8 and Sentinel 2A/2B is directly accessible through the API. Historical with SPOT 6/7 and Pléiades 1a/1b is available upon request and requires an analysis of archive availability in our catalogs.

You define your own requirement in terms of cloud free coverage[5]. The cloud cover is calculated by intersecting the image with the field boundaries to maximize the number of images retained matching the cloud threshold criteria.

C. Licenses

You have the choice between two licenses:

- Commercial license, for your daily precision agriculture business,
- R&D license, at a discounted rate, including the capacity to do marketing around your R&D results.

The licenses are available for review here: https://www.intelligence-airbusds.com/en/8236-licences-supply-conditions.

[5] See *Appendix 3 - Service Level Agreement*, section *Cloud masking* for further details about our cloud rating performance.

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III. Verde API

Verde is available as a REST API, enabling direct interaction between your platform and our system. It automates data ordering and data retrieval, whether for display or further processing, for anyone with a valid account in our authentication system.

A. Get started

1. Package

A package is one subset of Verde options that you select.

Attributes of a package:

Attribute	Meaning	Possible values
constellation(s)	Family of satellites	SENTINEL, LANDSAT, SPOT, PLEIADES
sensor(s)	Satellites or drone cameras	SENTINEL2A, SENTINEL2B, LANDSAT8, SPOT6, SPOT7, PHR1A, PHR1B
layer(s)	The list of desired outputs	LAI, FCOVER, CHL, FIELDIMAGE
crop(s)		RAPESEED, SOYBEAN, BARLEY, WHEAT, CORN, ALMONDS, COTTON, SUGARBEET, RICE, POTATOES, SUNFLOWER, ALFALFA, GRASS, SUGARCANE, OTHERCROP
startDate	Beginning of the period covered by the package	YYYY-MM-DD
endDate	End of the period covered by the package	YYYY-MM-DD
cloudFree	Requirement of minimum clear pixel percentage within the field	[0:1]

The package(s) you select will be set up for you by the Airbus team in our system so you can subscribe fields to these.

With Verde API, you can:

- Get the list of all your packages, as well as their attributes.

2. *Project*

A project is a vehicle similar to a workspace enabling you to translate the Verde world into your own world. The nature of a project is defined by you so you can include Verde into your workflows as needed. For example, you decide if a project is a given offer package, a dealer, a farmer, or a field.

Attributes of a project:

- Name.

With Verde API, you can:

- Create a project,
- Get the list of all your projects,
- Delete a project.

3. *Field*

A field is the exact geographical footprint of a single crop for a single season.

Attributes of a field:

Attribute	Meaning	Possible values
crop(s)		RAPESEED, SOYBEAN, BARLEY, WHEAT, CORN, ALMONDS, COTTON, SUGARBEET, RICE, POTATOES, SUNFLOWER, ALFALFA, GRASS, SUGARCANE, OTHERCROP
name	Name of the field	string
geometry	Extent of the seeded or planted area	Lat; long

A field should be:

- a closed polygon, in valid topology (*mandatory*),
- in GeoJSON (*mandatory*),
- in WGS84 projection (EPSG: 4326) (*mandatory*),
- bigger than 0.4 hectares, and smaller than 1,500 hectares, (*recommended*),
- wider than 20m in all directions (*recommended*).

With Verde API, you can:

- Create fields within a given project,
- Get the list and attributes of your fields for a given project,
- Delete a field.

B. Use

To get data over a field, you need to *subscribe* it to a package.

1. Subscription

A subscription is the functionality to activate a given package for a given field. A subscription can be over past images (*archive subscription*) or for any new images to be collected after the subscription date (*live subscription*).

- For archive subscriptions, each observation (intersection of an image and a field) is processed independently and is released in the API as soon as its individual production is over (production order is random).
- For live monitoring, the processing is done on-the-fly as soon as a new image (matching the package criteria) is available in the satellite image catalog.

Attributes of archive subscriptions:

- startDate: YYYY-MM-DD,
- endDate: YYYY-MM-DD,
- fields: the relevant project(s), and relevant field(s) within each project, to be subscribed to the package.

Attributes of live subscriptions:

- field: the field ID (and its project ID) to be subscribed to the package,
- package: the package ID (and its project ID).

As a result, to get an in-season monitoring over a given field, you may activate

- a live subscription, if your monitoring period is starting the day after the subscription date, or later,
- a live subscription and an archive subscription, if the monitoring period/the growing season has already started when you subscribe the field to the package, and get the observations from the beginning of the season.

Historical monitoring is always composed of archive subscription only.

With Verde API, you can:

- Create an archive or a live subscription,
- Get the list of all live subscription ongoing,
- Delete live subscription.

Now that your fields are subscribed to your packages, we will take you through how to get Verde outputs.

2. Observations

An observation is the resulting data you get from your subscription. This data is the result of the processing applied to the satellite imagery matching all your criteria.

Attributes of observations:

- acquisition: the source image and its metadata (sensor, constellation, sensingDate, sourceID[6]),
- processingDate: the computing date of the observation,
- cloudFreeCover: the percentage of clear pixels within the field [0:1],
- layers: the different outputs, i.e. maps, statistics and metadata (bounding box, format).

With Verde API, you can:

- Get the attributes of observations in JSON format,
- Download the layers, either as ANALYTICS (for computation, post-processing and analysis), DISPLAY (for visualization) or STATS.

Note: for developers, more details are available about the API in the following documents:

- API Documentation: an end-to-end description of the API architecture and a list of all requests is available here: https://api.oneatlas.airbus.com/api-catalog/verde/index.html.
- Tutorial (*coming soon*): an example of the journey of a developer coding software to deliver corn input management solutions to farmers. The code is described, as well as the results, so you can check step-by-step your understanding and implementation.

[6] The ID of the imagery used to compute the layer.

- Guide (*coming soon*): a lighter version of the API documentation, organized per functions. Each function is described and illustrated with some examples of an API call.

Appendix 1 – Verde processing

The Verde service uses the Overland processor, an optical image processing suite developed by Airbus to generate vegetation maps such as Leaf Area Index (LAI) or Leaf Chlorophyll content (CHL). Initial algorithms were developed in the early 2000's and have been constantly improved since that date. Overland is able to process a large range of multispectral images, covering spectral domains 0.4 to 2.5µ from various sources (satellite, airborne, UAV) and spatial resolutions.

The Overland processor uses techniques based on physical models, so called 'biophysical processing'. The SAIL and PROSPECT models are the core elements of the model simulating the reflectance of the crop canopy (Verhoef, 1984, Verhoef, 1985, Jacquemoud & Baret, 1990). The association of SAIL/PROSPECT models is highly successful and has been validated on many crops (Jacquemoud & al, 2009). Satellite observations passing through the whole atmospheric column and the modelling of the atmospheric transfer is performed thanks to the LOWTRAN model (Kneisys et al., 1995) completed with a dedicated cloud model (turbid medium model using cloud optical properties and a Henyey-Greenstein phase function).

The Overland processing principle is to couple the scene and atmospheric models in order to perform inversion of this combined model through minimization techniques, having the satellite image converted to Top of Atmosphere (TOA) radiance as inputs. Advantages of such an approach are discussed in (Verhoef & Bach, 2003). A detailed description of the Overland algorithms can be found in the Algorithm Theoretical Basis Document (ATBD) of the geoland2 MERIS products (Poilvé, 2010). In this case, they were applied to process low-resolution MERIS data (15 VNIR bands / 300 m).

A major Overland feature is the capability to customize the reflectance model for a given canopy type. For the Verde application, this has been done systematically for each individual crop. This means (1) tuning statistics of the model parameters (used as a priori information in the model inversion process) in order to best fit known crop behavior, and (2) adding specific features related to the crop and associated practices such as visible contribution of flower or panicles, possible fallow conditions or presence of residues before/after the crop cycle, etc. Modelling crop reflectance also implies having a spectral signature of the local soil. For the Verde application, such local soil signatures, characterized in dry and unshaded (flat soil) conditions, have been collected into a global soil database covering all cropping regions in the world.

The Verde service uses publicly available imagery that best fits the Agriculture application, i.e. Sentinel 2A/2B and Landsat 8, as well as Airbus images (SPOT 6/7 and Pléiades 1a/1b) in order to improve spatial resolution and revisit. LAI maps can be produced from all these sources, whereas Chlorophyll maps are only provided from the Sentinel 2A/2B data. The spectral richness of the Sentinel 2A/2B sensors (13 bands) allow for robust retrieval of this information. Each sensor data is processed to the best possible resolution (except for Pléiades): 20m for Landsat 8, 10m for Sentinel 2A/2B and 5m for SPOT 6/7. This is achieved by a multi-resolution processing technique that performs spatial enhancement similar to a pan-sharpening technique, but integrated within the biophysical processing. Finally, all maps of the individual field plots are generated at a 2.5m sampling distance, independently of the source sensor, in order to provide time series that are fully stackable.

The Overland processor, with its built-in atmospheric model, performs autonomous atmospheric correction and automatic masking of thick clouds and dark shadows. A map is discarded from the series of observations if field plot masked area exceeds a maximum fraction (e.g. 30%, customizable). Applied quality rules also lead to discarded conditions such as snow cover or a flooded field (except for rice).

For Verde, this processing chain has been migrated to the Cloud (Google Cloud Platform) and can be triggered through API calls. The infrastructure behind the service has been designed for maximum scalability and optimal performance, as the number of virtual machines activated is proportional to the amount of request at a given point in time[7].

References

Jacquemoud, S. & Baret, F. (1990). PROSPECT: A model of leaf optical properties spectra. Remote Sensing of Environment, 34, 75-91.

Jacquemoud, S. & al. (2009). PROSPECT + SAIL models: A review of use for vegetation characterization. Remote Sensing of Environment, 113, S56-S66.

Kneisys F.X., Abreu L.W., Anderson G.P., Chetwynd J.H, & al., (1995). The MODTRAN 2/3 and LOWTRAN 7 Model. Philips Laboratory, prepared by Ontar Corporation, North Andover (MA), 267 pp.

Poilvé, H. (2010). BioPar Methods Compendium of MERIS FR Biophysical Products (report g2-BP-RP-038, EC geoland2 project FP-7-218795). Retrieved from ResearchGate website: https://www.researchgate.net/publication/265728093_geoland2_-_BioPar_Methods_Compendium_of_MERIS_FR_Biophysical_ProductsBioPar

Verhoef, W. (1984). Light scattering by leaf layers with application to canopy reflectance modeling: the SAIL model. Remote Sensing of Environment, 16, 125-141.

Verhoef, W. (1985). Earth observation modelling based on layer scattering matrices. Remote Sensing of Environment, 17, 165-178.

Verhoef, W., & Bach, H. (2003). Simulation of hyperspectral and directional radiance images using coupled biophysical and atmospheric radiative transfer models. Remote Sensing of Environment, 87, 23–41.

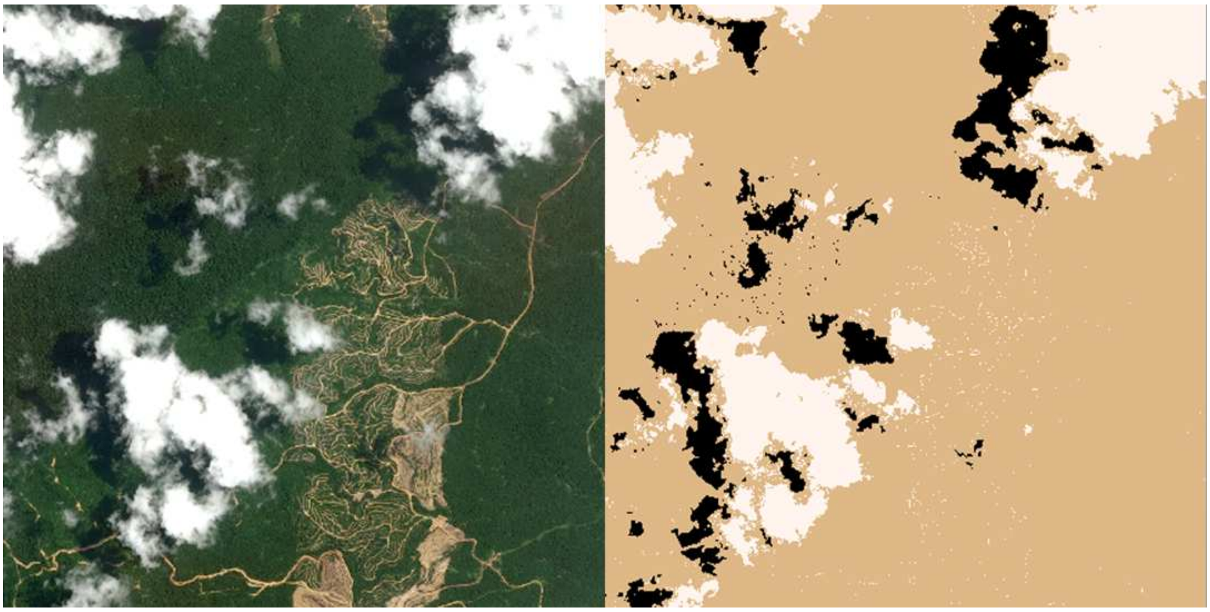
See https://www.intelligence-airbusds.com/biophysicalparameters/ to get the comprehensive list of research papers about this approach and its benefits (at the bottom of the page).

[7] See *Appendix 3 - Service Level Agreement*, section *API performance*, for further details on this point.

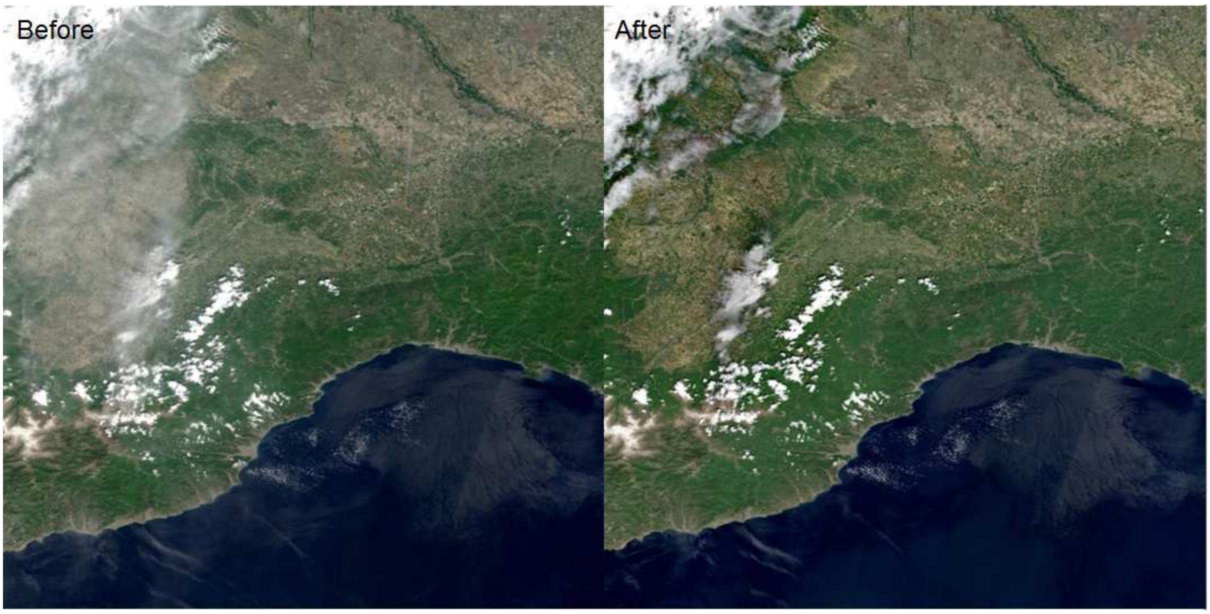
Appendix 2 – Interest of Verde and of the biophysical parameters approach

More useful pixels

With Verde, cloud and cloud shadow are well managed; useless images are filtered out. An accurate detection and removal of haze and veils maximizes the number of useful pixels for the service, resulting in an increased revisit rate.



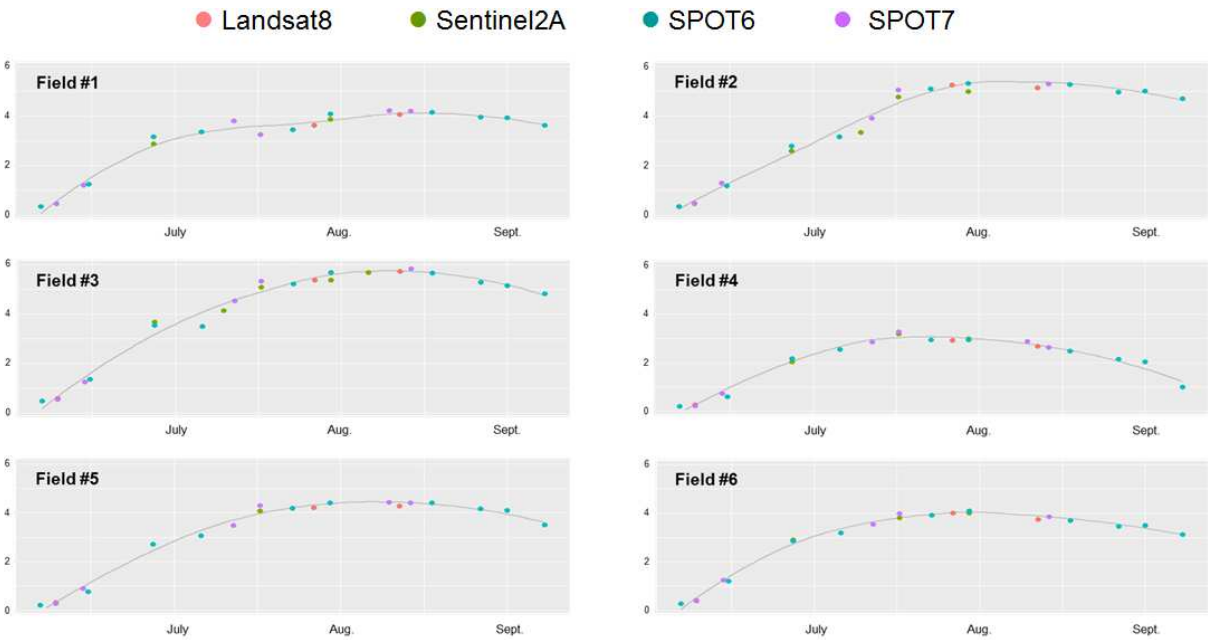
⅄ Example of Verde's cloud and cloud shadow masking



⅄ Example of Verde's dehazing

Easy data fusion

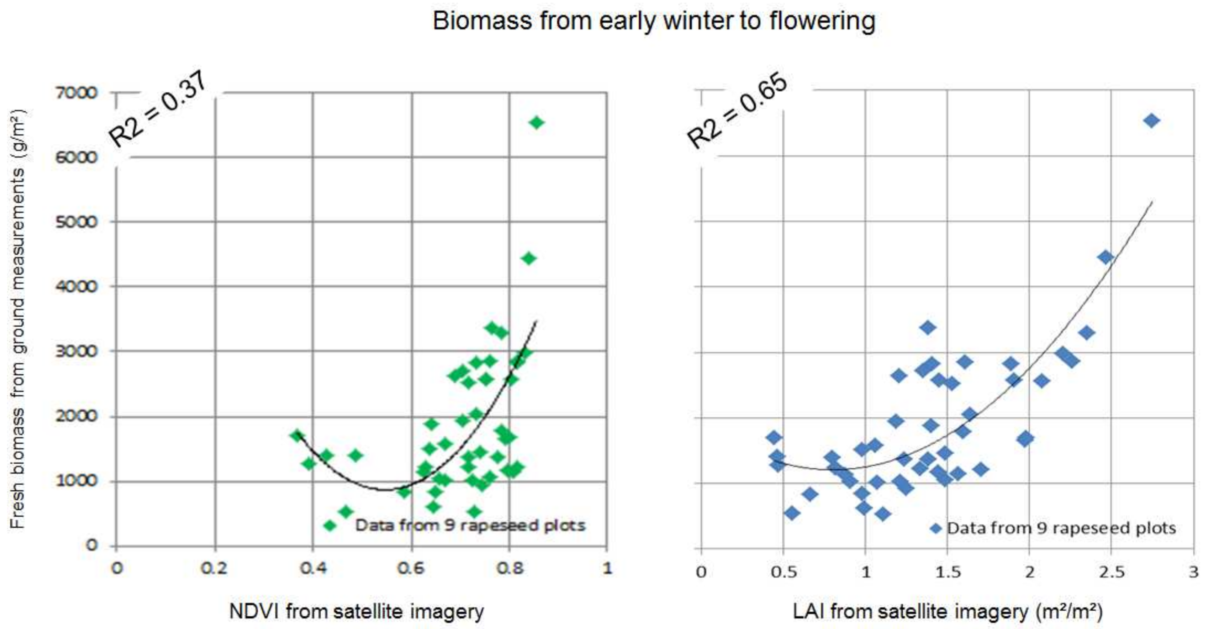
Verde’s analytics provide consistent results regardless of the sensor and the conditions of acquisition, without any ground sampling or image calibration. This eases the merge with agro-meteorology models and machinery/in-field data.



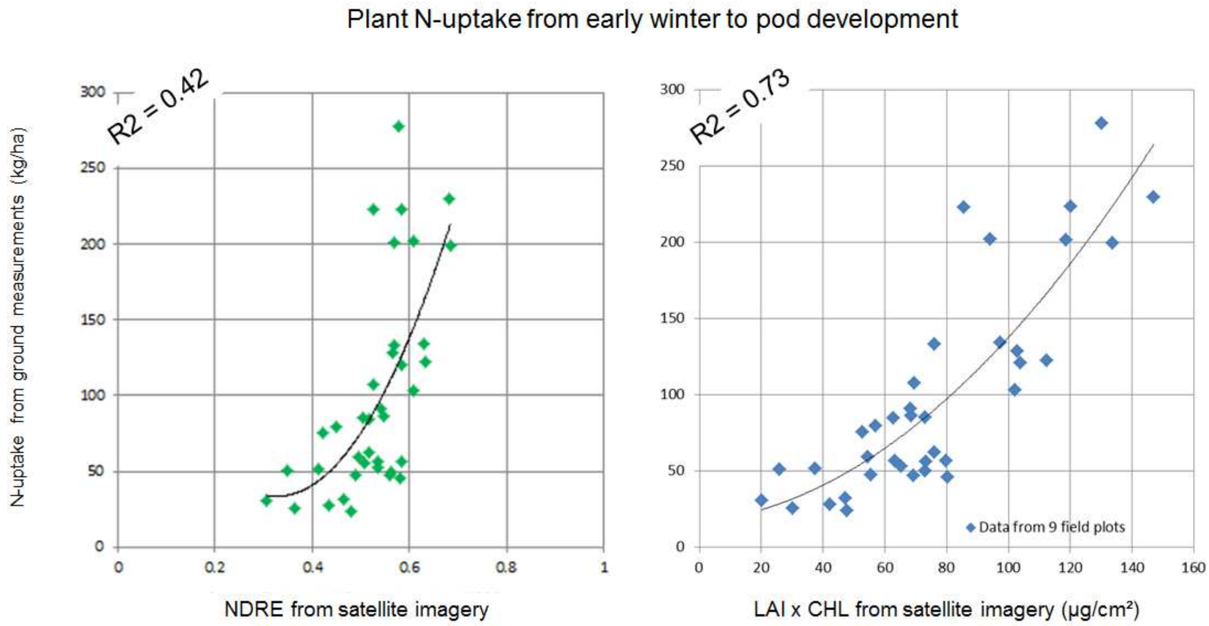
⅄ Example of LAI over corn fields from different types of satellite imagery featuring a consistent crop cycle without ground calibration

From observation to diagnosis and recommendation

Verde analytics are accurately correlated to biomass and nitrogen uptake all along the growing season and with no saturation effect even after canopy has closed (see illustrations below). As such, they are a solid basis for use cases such as variable rate distribution of a given input, irrigation recommendation, lodging risk map and nitrogen recommendation.



⅄ Comparison between NDVI and LAI vs. ground measurements of biomass.
NDVI saturates and misses correlation to biomass
whereas LAI captures variability even late in the cycle



⅄ Comparison between NDRE and LAIxCHL vs. ground measurements of N-uptake.
LAI/CHL features a much better correlation
to actual N-Uptake by the crop all along the growing cycle.

See https://www.intelligence-airbusds.com/biophysicalparameters/ for more details and to download research papers on this approach (at the bottom of the page).

Appendix 3 - Service Level Agreement

A. Analytics accuracy

While images from different sensors are processed with the same processing chain in order to generate Verde analytics, these sensors do not have the same characteristics (in particular, spectral bands). As a result, derived products do not have the same intrinsic performance.

Verde maps are currently produced independently from each satellite image. Current performances estimated from the different sensors are presented in the tables below.

Sensor	LAI performance
Sentinel 2A/2B	LAI > 1 : 10-15% (RMS) ; LAI ≤ 1 : 0.1-0.15 (RMS)
Landsat 8	LAI > 1 : 15-20% (RMS) ; LAI ≤ 1 : 0.15-0.2 (RMS)
SPOT 6/7	LAI > 1 : 15-20% (RMS) ; LAI ≤ 1 : 0.15-0.2 (RMS)
Pléiades 1a/1b	LAI > 1 : 15-20% (RMS) ; LAI ≤ 1 : 0.15-0.2 (RMS)

Sensor	CHL performance
Sentinel 2A/2B	2-3 $\mu g/cm^2$ (RMS)

Sensor	FCOVER performance
Sentinel 2A/2B	< 0.03 (RMS)
Landsat 8	< 0.05 (RMS)
SPOT 6/7	< 0.05 (RMS)
Pléiades 1a/1b	< 0.05 (RMS)

Known limitations:

- Indicated performances for LAI and CHL assume that the declared crop is correct.
- Despite the objective to systematically identify and discard cloudy images, some cloud conditions not correctly detected may result in outliers. Future developments

include systematic analysis across the full time series of analytics to spot such outliers automatically and provide filtered evolution profiles.

- CHL is only provided if the FCOVER reaches a minimal value that has been set to 0.35 (as it is indeed unreliable to estimate leaf chlorophyll content if green leaves are not developed enough). Chlorophyll maps are masked accordingly, so mean and median values refer only to the areas within the field that have reached such level (i.e. not to the whole, cloud-free and cloud-shadow-free field area).
- On small or narrow fields, the provision of mean and median information may be affected by borders and neighboring fields and is affected differently depending on native spatial resolution of the different images (i.e. maps produced from Landsat 8 are more affected than other maps).
- On fields showing high heterogeneity (e.g. partially planted fields or even fields planted with two different crops), the single information of the field mean or median value is not exploitable.

B. Cloud masking

Verde performs automatic masking of thick clouds and dark shadows.

- In 7% of the cases, thick clouds and cloud shadows are not detected[8] (average global performance).
- The number of false detections (cloud detected by Verde while there was no actual cloud) is insignificant[8], and these few occurrences happen on bare soil/very low vegetation context outside traditional seasons for crop monitoring.

C. Image frequency

With programs like Sentinel and Landsat providing free and regular coverage of the fields globally, satellite imagery has become much more available. The challenge today is to complement these sources with extra revisit rate or higher resolution, depending on the use case – both features that Airbus can bring thanks to its constellation of satellites. On average, using Sentinel 2A/2B, Landsat 8, and SPOT 6/7, a revisit of every 5 to 10 days is achieved globally. This performance can change locally depending on the climatology and the number of competing requests for SPOT. For a more precise estimation over your area of interest, please contact Intelligence-verde@airbus.com.

[8] Performance assessment has been performed during an entire year over a sample of 200 fields scattered globally across the crop lands.

D. API performance

Our API allows you to request processing on your area of interest and to download the results at any time[9]. API performance is highly linked to the way the API calls are structured. Our technical team is available to provide guidance or advice on this matter[10].
API performance encompasses two sides:

- The Verde performance in terms of analytics availability,
- The Verde performance in terms of analytics computation.

1. Availability of the service

The expected availability level of the service at its opening is above 99%. Dedicated virtual machines in Google Cloud Platform can be subscribed if you want a higher confidence in Verde availability. In case of unavailability, the standard recovery time from an incident is less than 2 hours[11].

Users are notified about planned technical maintenance or system upgrades. Nominally, the architecture of the service allows for no interruption in delivery and availability.

2. Processing performance

The standard processing performance is 5 minutes for 100 observations over a single field of 300 hectares during a growing season of 9 months[12].

- This performance can increase or decrease depending on the source image resolution. The higher the number of high/very high-resolution images, the longer the processing time.
- This performance improves when the density of fields intersecting a given image increases.
- This performance increases for shorter seasons as the number of observations to process diminishes.
- This performance changes depending on the number of machines turned on in Google Cloud Platform. New subscription requests can be added with the same overall performance for all fields until the maximum processing capacity of the running machines is reached. Once it is reached, a queueing list is started, degrading

[9] Results are stored for 30 days after processing.
[10] Please contact Intelligence-verde@airbus.com.
[11] Working days, working hours, Paris, France time.
[12] Supposing the source satellite imagery (ortho level) is ready for input in the Verde processing chain. Depending on the areas and the desired timespan, historical requests on SPOT and Pléiades may require extra time to perform archive search and ortho processing beforehand.

the processing turnaround of the requests above the threshold. However, we monitor this phenomenon. In case of overload, we can increase quickly and responsively the number of machines used (hence, increasing the threshold).

E. Delivery timeframes after image acquisition (live monitoring)

Sentinel 2 and Landsat 8 products are made available in GCP by ESA and USGS in typically one to two days after image acquisition. Verde scans those catalogs every hour and as soon as a new image is detected on GCP, it is referenced by Verde, and the system triggers production and delivery of the new observations for all live subscriptions.
SPOT 6/7 and Pléiades 1a/1b are typically available less than 24 hours after image acquisition.

F. Storage of the products

Verde observations are stored for 30 days after processing.

Appendix 4 - Source imagery

Verde v1.0 leverages four different families of sensors.

A. SPOT 6/7

For intra-field surveillance and fragmented landscapes	
Spectral bands	PAN, B, G, R, NIR
Product resolution	1.5m – 6m
Swath	60 km
Revisit	Daily (if tasked)

B. Pléiades 1a/1b

For orchard and vineyards and fragmented landscapes	
Spectral bands	PAN, B, G, R, NIR
Product resolution	0.5m – 2m
Swath	20 km
Revisit	Daily (if tasked)

C. Sentinel 2A/2B

For frequent measurements of nitrogen content and high biomass values	
Spectral bands	13, including three red edge bands
Product resolution	10m – 20m – 60m
Swath	290 km
Revisit	5 days

D. Landsat 8

For increased revisit over large parcels	
Spectral bands	9
Product resolution	15m – 30m
Swath	185 km
Revisit	16 days

AIRBUS

Definitions

ANALYTICS: the Verde output format for computation, post-processing and analysis.

API (Application Programming Interface): a set of clearly defined methods of communication between various systems. In the case of Verde, this communication is between the portal of a precision agriculture service provider, and Airbus' imagery and processing chains. It allows direct and automatic communication between the two systems that can interact together, exchanging inputs and outputs, 24/7, in full autonomy.

Archive subscription: the functionality to activate a given package for a given field over a past time period.

CHL (Chlorophyll): the leaf content of chlorophyll A and B per unit area of leaves (µg/cm²). The concentration of chlorophyll is in direct relation with leaf age, plant nutrition (N), and stress. It typically ranges from 20 to 80 µg/cm².

DISPLAY: the output format for visualization of the data.

FCOVER (Green Cover Fraction): the percentage of ground surface covered by the crop, seen from above. It is a simple characterization of the crop development and does not require knowing the crop type. It is also a good backup option for LAI when the budget is limited. It ranges from 0 to 1, from bare soil to complete coverage of the vegetation.

FIELDIMAGE: a compressed, high resolution, view-only version of the satellite imagery ("quicklook"). It is useful to understand/check the other layers derived from the same source imagery.

GeoJSON: an open standard format designed for representing simple geographical features, along with their non-spatial attributes.

LAI (Leaf Area Index): the number of square meters of green leaves present in one square meter of ground (m²/m²). It features the total developed area of green leaves (one-sided) per ground area unit. It is highly correlated to biomass, allowing for the quantification of crop development. It typically ranges from 0 to 7, and canopy closure is reached around 3.5.

Live subscription: the functionality to activate a given package for a given field over a future time period.

N: Nitrogen.

NDVI (Normalized Difference Vegetation Index): a simple indicator that can be used to analyze remote sensing measurements, typically from a space platform, and assess whether the target being observed contains live green vegetation or not. It is a basic computation of spectral band response without modeling of the actual conditions of the crop.

NDRE (Normalized Difference Red Edge): a metric similar to NDVI but uses the ratio of Near Infrared and Red Edge bands to better take into account the chlorophyll contribution. It is sometimes used to analyze whether images obtained from multispectral sensors contain healthy vegetation or not. It is a basic computation on spectral band responses, without modeling of the actual conditions of the crop.

Observation: the resulting data you get from your subscription. This data is the result of the Verde processing applied to the satellite imagery matching all your criteria.

Package: one subset of Verde options you select.

Project: a vehicle similar to a workspace, enabling you to translate the Verde world into your own world. The nature of a project is defined by you so you can include Verde into your workflows. For example, you can decide if a project is a given offer package, a dealer, a farmer, or a field.

SourceID: the ID of the imagery used to compute the layer.

STATS: an output file of Verde containing the main statistics of the layer.

Subscription: the functionality to activate a given package for a given field.