FLEX DISC

FLuorescence EXplorer Data Innovation and Science Cluster

L1C & L2 IPF Product Format Definition

Document Information

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1	1	19/08/2024	Units of integrated PAR changed to umol photons m-2 s-1. Updates to address MS1 RIDs: • Several minor typos. • MBe-06 and MBe-10: further information about how CAMS meteo data is used (contingency plan). • MBe-07: mention to non-recalibrated TOA radiances in L1C product. • MBe-09: updated caption in Tables 3-1 and 3-7. • MBe-11: size of along-track product updated taking into account margin. • MBe-12 and MBe-17: FLOAT data type changed to USHORT to reduce data volume. • MBe-14 and MBe-15: information regarding UTM tiles in Section 3.2.2. • Revision of file naming convention (Section 4) based on RIDs and discussion with PDGS team. • MT-04: included the approx. number of L2 product UTM tiles within a single L1C slice. • MT-05: clarification note on the suggested spectral sampling for irradiance and SIF.	
1	2	23/10/2024	Updates for MS2 delivery: • Quality flags/indicators included in the L1C and L2 products. • FLORIS-OLCI cross-calibration coefficients included in the L1C product. • PSI/PSII and NPQ added.	

			• Revision of spectral sampling for par, reflectance and SIF • Preliminary MPH section.	
1	3	10/12/2024	Updates according to MS2 RIDs: • MT-45: review of photosynthesis products • MT-47: typo in NPQ variable corrected • MC-26: clarification added regarding the global attribute to identify absence of Sentinel-3 data • MC-27: corrected physical naming of the L1C/L2 products • Consolidation of MPH section	

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1. Introduction

1.1. Scope of the document

In the frame of the FLEX DISC, this document is the Product Format Definition (PFD), prepared during Phase 1 but applicable for all the phases of the DISC project, and is in answer to related applicable documents. The purpose of this document is twofold:

1. To describe the content of the FLEX Level-1C (L1C) and Level-2 (L2) products distributed to the end-users and that are generated by the Level-1C (L1C) and Level-2 (L2) Instrument Processing Facility (IPF).
2. To contain high-level information about the characteristics of the FLEX L1C and L2 products (spacing, resolution, performance summary, data volume).

The content of this document is divided as follows: Section 2 gives an overview of the FLEX mission objectives, processing chain and products. Section 3 describes the main characteristics of the FLEX L1C and L2 products. Section 4 details the product data conventions. Section 5 gives detailed information about the content of the FLEX L1C and L2 products.

1.2. Related documents

1.2.1. Applicable documents

Id.	Ref.	Description	Issue
[AD-01]	ESAEOP-SM/2221/MDru-md	FLEX EE8 Mission Requirements Document	3.0
[AD-02]	FLX-TN-ESA-SYS-0032	FLEX Mission Architecture and Operations Concept	2.0
[AD-03]	FLX-ADD-GMV-FIPS-GPP	FLEX L2 E2E Mission Performance Assessment - Architecture Design Document	2.2.2
[AD-04]	FLX-ICD-GMV-FIPS-GPP	FLEX L2 E2E Mission Performance Assessment - Interfaces Control Document	2.2.3
[AD-05]	ESA-EOPG-PR-0005	EOP-G Security operating procedure (SECOPS) framework	1.0
[AD-06]	GMGT-SENE-EOPG-PD-12-0011	EOP-G Security Incident Handling Policy	1.1
[AD-07]	ESA-EOPG-EOEP-DD-0003	FLEX PDGS System Architecture Document	3.0
[AD-08]	ESA-EOPG-EEGS-ID-0083	Generic Processor ICD	1.4
[AD-09]	ESA-EOPG-EOEP-ID-0009	FLEX PDGS CPF-IPF Interface Control Document	1.5
[AD-10]	ESA-EOPG-EOEP-TN-0015	FLEX PDGS Products Naming Convention and Definition	2.13
[AD-11]	ESA-EOPG-EOEP-TN-0025	FLEX PDGS Main Product Header Definition	1.9

[AD-12]	ESA-EOPG-EOEP-TN-0014	FLEX PDGS Production Model	1.3
[AD-14]	ESA-EOPG-EOPGMQ-SOW-43	FLEX DISC Statement Of Work	1.0

1.2.2. Reference documents

Id.	Ref.	Description	Issue
[RD-01]	EOP-SM-3044-MDru-mdru	FLEX Mission Product Tree & Product Definition	2.0
[RD-02]	EOP-SM/2776	Scientific Readiness Levels (SRL) Handbook	1.1
[RD-03]	FLX-LI-ESA-SYS-0017	FLEX Acronyms, Terms and Definitions (ATD)	1.3
[RD-04]	ECSS-E-HB-40-01A	Agile software development handbook	1.0
[RD-05]	ESA-EOPG-EOEP-TN-0013	FLEX PDGS Product Baseline Definition and Usage	1.1
[RD-06]	ESA-EOPG-EOEP-TN-0026	FLEX PDGS Auxiliary Product Format Definition	2.3
[RD-07]	ESA-EOPG-EOEP-TN-0027	FLEX PDGS RAW Products Format Definition	2.10
[RD-08]	ESA-EOPG-EOEP-TN-0022	FLEX PDGS Level-0 Product Format Definition	2.7
[RD-09]	ESA-ESO-PR-2020-0039	Instructions Regarding the Common Protection of Unclassified Programme/Project Information	2.0
[RD-10]	ISO/IEC 15408D	Common Criteria for Information Technology Security Evaluation	
[RD-11]	FLX-RS-ESA-GS-0043	FLEX Ground Segment Requirements Document (GSRD)	2.1
[RD-12]	MAG-23-PTF-86-Vol1	FLEX DISC Technical Proposal	2.1
[RD-19]	FLEXDISC-PMP-MAG-002	FLEX DISC Project Management Plan	1.1

1.2.3. Other related documents

Id.	Ref.	Description	Issue
[L1-PDS]	FLX-TN-FNM-INS-0047	FLEX L1 Product Specification	2.0
[ATBD-L2A]			
[ATBD-L2B]			
[ATBD-L2C]			

1.2.4. Definitions and Acronyms

The FLEX Acronyms, Terms and Definitions are listed in [RD-03]. Additional definitions and acronyms not covered in [RD-03] are listed below.

AOD	Aerosol Optical Depth	AOT	Aerosol Optical Thickness
CWV	Columnar Water Vapor	DGVM	Dynamic Global Vegetation Models
FAPAR	Fraction of Absorbed Photosynthetic Active Radiation	FLO	FLORIS
FQE	Fluorescence Quantum Efficiency	GPP	Gross Primary Production
HR	High Resolution	ICD	Interface Control Document
IPF	Instrument Processing Facility	L1B	Level-1B
L1C	Level-1C	L2	Level-2
L2PP	L2 Prototype Processor	LAI	Leaf Area Index
LCC	Leaf Chlorophyll Content	LCCAR	Leaf Carotenoids Content
LR	Low Resolution	LST	Land Surface Temperature
MGRS	Military Grid Reference System		
NPQ	Non-Photochemical Quenching	PRI	Photochemical Reflectance Index
RAA	Relative Azimuth Angle	SAA	Solar Azimuth Angle
SIF	Sun Induced Fluorescence	SSA	Single Scattering Albedo
SSD	Spatial Sampling Distance	SYN	Synergy
SWIR	Shortwave Infrared	SZA	Solar Zenith Angle
TIR	Thermal Infrared	TOA	Top of Atmosphere
VIS	Visible	VZA	Viewing Zenith Angle
–	–	–	–

2. Overview of ESA's FLEX mission and products

2.1. Background and scientific justification

Unprecedented ecological shifts driven by climate change, biodiversity loss, nitrogen saturation, and phosphorus deficiencies are altering critical ecosystem services, notably food production, threatening global sustainability (Figure 2-1). This global change scenario underscores the pivotal role of primary productivity in shaping Earth's carrying capacity, as highlighted by the Land Challenges identified in ESA's Earth Observation Living Planet Programme. Yet, the United Nations Food & Agriculture Organization (FAO) warns of a disconcerting trend: while the volume of traded agricultural products surges, global biomass production lags behind. This trend reshapes land-use dynamics (Kastner et al., 2015), fostering a geographic disconnection between places of production and the places where these products are being consumed, driving agricultural displacement across regions. These shifts in land use and land management are reshaping the Earth's surface properties at an unprecedented pace. Indeed, intensive crop expansion contrasts with abandoned agricultural lands reverting to nature, underscoring human-induced geographical transformations outpacing natural vegetation shifts. Desertification, altered precipitation patterns, and rising temperatures further impact plant phenology and terrestrial vegetation distribution. In response, there's a pressing need to pivot towards resource-optimized biological resource production and sustainable plant production systems to align with future bio-based economies.

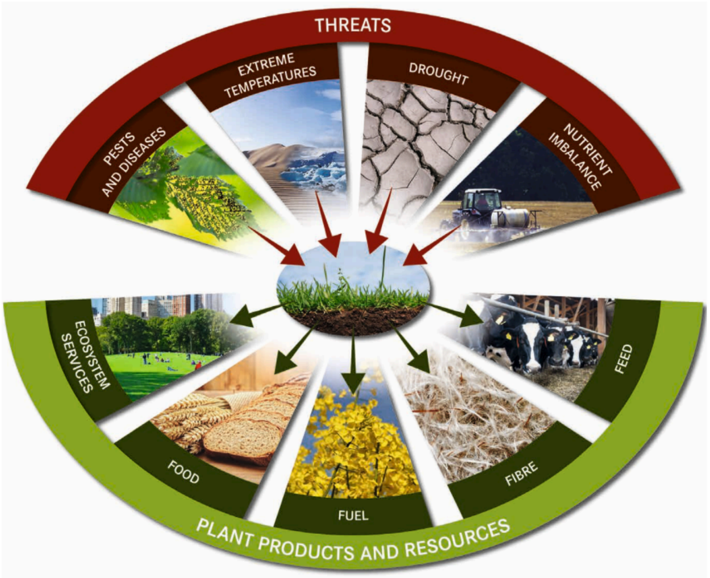

Figure 2-1: Environmental- and anthropogenically-driven changes threaten plan products and services globally. Credit: Forschungszentrum Jülich.

Earth observation emerges as a potent tool for evaluating biospheric metabolism, which hinges on the delicate balance between food production and environmental preservation. Indeed, most of the functions provided by the biosphere are rooted in the physiology of plants. Addressing the status of terrestrial vegetation requires advanced monitoring techniques. While traditional remote sensing relies on analyzing surface reflectance and thermal emission analysis, Sun-induced chlorophyll fluorescence (SIF) provides additional critical information about the functional status of vegetation and thus of photosynthesis.

Photosynthesis is a complex mechanism that relies on sunlight. Under optimal circumstances, a portion of the incoming radiation is absorbed by the plant's photosynthetic pigments (chlorophyll and carotenoids). This absorbed light produces a cascade of biophysical and biochemical reactions fueling the photosynthetic electron transport to drive the splitting of water molecules and, ultimately, converting atmospheric CO_2 into energy-rich carbohydrates (see Figure 2-2). Despite its relatively low efficiency in converting solar energy into biochemical energy, photosynthesis serves as a vital integrative indicator of biosphere dynamics. The residual energy not used for photosynthesis is dissipated as heat or fluorescence emissions, reflecting the plant's functional status. Therefore, the detection of SIF enables the closure of the energy balance and provides a direct indicator of photosynthetic efficiency and stress levels. Understanding this fluorescence emission offers a spectrum of information, with changes reflecting alterations in photosynthetic reactions and stress responses, surpassing current approaches reliant on passive reflectance and vegetation temperature observations, promising a deeper understanding of ecosystem dynamics.

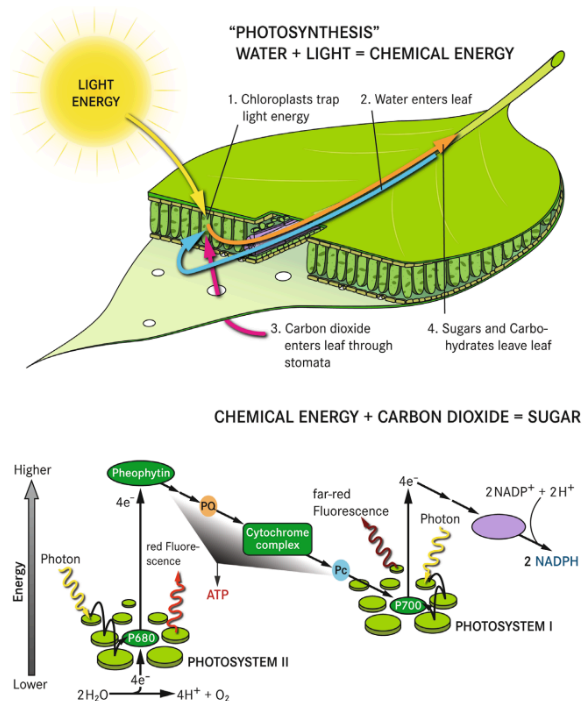

Figure 2-2: Photosynthesis: energy for life. This complex process takes place in plant leaves where atmospheric CO2 is fixed and converted to energy-rich carbohydrates (upper panel). The conversion of solar energy into biochemically usable energy carriers (ATP and NADPH) occurs in the 'light reaction' of photosynthesis, which is a complex and highly regulated cascade of light absorption – electron transfer – biosynthesis (lower panel).

The SIF emission spectrum covers the 640-800 nm spectral range and exhibits two distinctive peaks at nearly 685 nm and 740 nm closely linked to photosystems I and II respectively. Changes in fluorescence emission signatures reflect dynamic regulation of photosystems, especially PS II, under stress conditions (see Figure 2-3). Mechanisms like the xanthophyll cycle and non-photochemical quenching (NPQ) play crucial roles in dissipating excess light energy as heat, influencing fluorescence emissions and spectral reflectance changes around 531 nm (Gamon et al., 1992, Vilfan et al. 2018). Understanding these fluorescence dynamics enhances our ability to accurately assess vegetation physiology and stress levels, complementing traditional reflectance-based observations. By integrating fluorescence data, researchers gain deeper insights into ecosystem dynamics, facilitating more effective monitoring and management strategies for terrestrial vegetation.

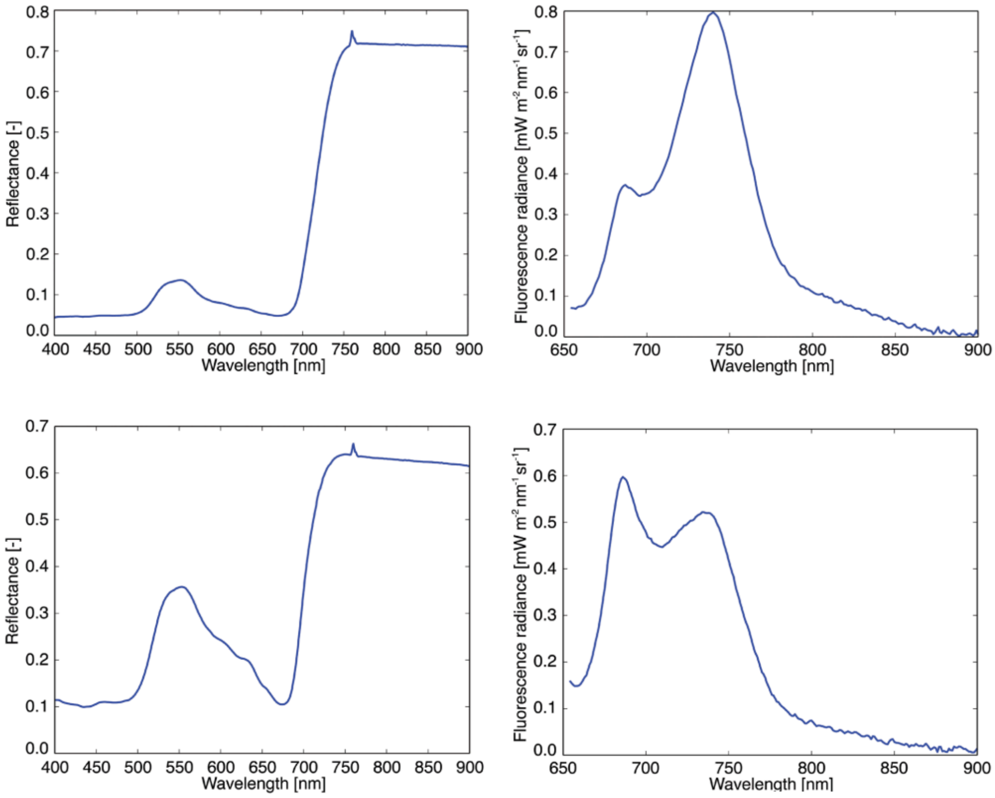

Figure 2-3. Measurements of reflectance (right) and fluorescence (left) spectra corresponding to two different species: (a) dark green ivy leaf (Hedera helix), (b) light green tobaco leaf (Nicotiana tabaccum). Both 'spectral signatures' carry different information about structure and functioning of vegetation types. (University of Valencia)

SIF can be measured passively, leveraging strong atmospheric absorption bands in narrow spectrum regions where vegetation reflectance is predominantly contributed by chlorophyll fluorescence (Malenovský et al 2009, Meroni et al 2009). Recent studies have demonstrated the possibility of detecting the weak fluorescence signal from ground-based, airborne, and satellite systems (Joiner et al 2011, Rascher et al 2015). Moreover, incorporating SIF data has been shown to enhance the modeling of canopy photosynthesis diurnal courses (Damm et al. 2010). Thus, global SIF measurements promise to bridge atmospheric CO2 observations with detailed leaf physiology, facilitating the most direct measurement of land photosynthesis processes at regional to global scales.

2.2. FLEX objectives and mission description

To help us understand the health of Earth's vegetation and improve our predicting capability for food security and agriculture, ESA is developing the FLuorescence EXplorer (FLEX) mission (https://earth.esa.int/eogateway/missions/flex). As described in FLEX

Mission Requirements Document [AD-01], the main objective of the FLEX mission is **to provide estimates of the actual photosynthetic activity and early stress indicators in terrestrial vegetation** by measuring the full energy balance i.e., incoming radiation, reflected light, surface temperature and, specially, SIF. End-users who will benefit from FLEX high-level products are: remote sensing scientists, plant physiologists, users working in climate models, aquatic ecosystems scientists, stakeholders in agriculture and land-use.

FLEX is the first mission providing direct measurements of the cause-effect relationships between plant health, photosynthesis and vegetation functioning at spatial scales nearing individual forest and agricultural management units. This direct estimation of photosynthetic efficiency and activation/deactivation status of the photosynthetic machinery provides, for example, a more precise determination of the duration of the growing season in boreal ecosystems than the current satellite-based reflectance measurements. Moreover, understanding the dynamics of plant photosynthesis will result in a more accurate estimates of Gross Primary Production (GPP) and foster the development and improvement of carbon assimilation in dynamic vegetation models:

- To enhance our knowledge of the coupling of the carbon and water cycles and to improve the predictive capability of current model systems.
- To provide an early pre-visual identification of stress effects to help track resilience and recovery of plant photosynthetic function, to delimit compromised vegetation sites from biotic and abiotic stresses to schedule measures to salvage a harvest.
- To support the identification of optimal growing and management strategies for a performance appraisal of vegetation for stress resistance in the context of crop production and food security

In the context of the FLEX satellite mission, *photosynthetic rates* are defined as the rates of electrons transported in light reaction of photosynthesis. These photosynthetic rates are measured in µmol electrons $m^{-2}s^{-1}$ and refer to the processes in light reaction, which provide the first energetic units of photosynthesis. To avoid confusion we refer to CO_2 uptake rates or GPP if we refer to the carbon uptake.

The FLEX mission aims to achieve estimates of photosynthesis efficiency with uncertainties below 30% under environmental conditions characterized by high levels of regulated heat dissipation. This accuracy is necessary for improving the accuracy of dynamic global vegetation models (DGVM), which rely on accurate representations of photosynthesis. Currently, there are significant uncertainties, with variations of at least 25% in predicted gross primary productivity (GPP) among different DGVMs in high light conditions (Rogers et al. 2017). Remote sensing based approaches, based on surface reflectance also face substantial uncertainties when compared to in situ measurements of GPP (Turner et al. 2005). One major challenge is the inadequate description of vegetation stress in numerical models due to limited observational data on regional to continental scales. However, the early responsiveness of fluorescence to various stresses can serve as a bioindicator of vegetation health. Previous research has demonstrated its sensitivity to factors such as plant physiological status, soil composition, water balance, atmospheric chemistry, and human activities. The FLEX mission aims to build upon this research by advancing fluorescence monitoring to scales relevant for identifying and tracking stress effects on terrestrial vegetation.

To achieve these mission objectives, FLEX is conceived as a two-platform satellite mission: the main FLEX platform, hosting the FLuORescence Imaging Spectrometer (FLORIS), flying in tandem with Copernicus' Sentinel-3 mission. The tandem flight follows a Sun-synchronous orbit crossing the equator at 10:00 local time. With a swath of 160 km and nadir-pointing geometry, FLORIS performs consecutive data acquisitions over the same location of the Earth with a repetition cycle of nearly 1 month over the equator (higher frequency at higher latitudes). The modest spatial resolution of 300 m/pixel allows scientists and stakeholders to analyze the plant health, photosynthesis and vegetation functioning at spatial scales of individual forest and agricultural management units.

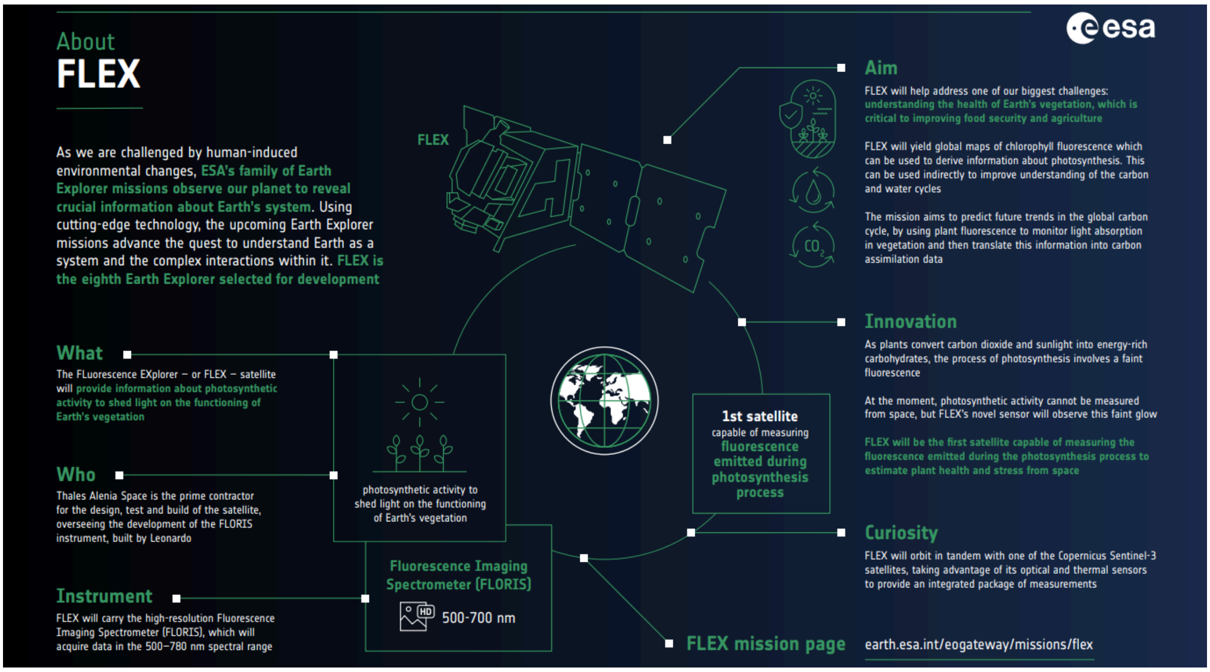

Figure 2-4 Infographics of ESA's FLEX Earth Explorer mission. Credit: ESA

FLEX/FLORIS instrument is divided into three imaging spectrometers: the two FLORIS High-Resolution (FLORIS-HR) spectrometers (focused at observations in the O2A and O2B bands) and the FLORIS Low-Resolution (FLORIS-LR) spectrometer. This configuration has been chosen to achieve by design the stringent spectral and signal-to-noise requirements.

FLEX is flying in tandem with Sentinel-3B (**A, B or C is TBC**), with an orbit separation of 6-15 s, to make use of the additional information obtained from the optical payloads: OLCI and SLSTR. OLCI provides multi-spectral information at an extended spectral range (400-1080 nm) with the same spatial resolution as FLORIS (300 m/pixel). SLSTR provides dual-view capabilities and thermal data. Altogether, Sentinel-3 provides enhanced information to better characterize the atmosphere (aerosols, water vapor, cloud screening), the biophysical properties of the vegetation, and thermal information to close the energy balance.

FLEX/FLORIS and Sentinel-3/OLCI-SLSTR Level-1B products are processed in synergy to derive the FLEX Level-2 (L2) mission products to the final users. The following section gives an overview of the FLEX L2 processing chain.

2.3. Overview of the FLEX L2 processing chain and products

The FLEX mission offers two high-level products for exploitation by end-users: the Level-1C (L1C) and Level-2 (L2). The processing chain implemented in the Instrument Processing Facility (IPF) consists of 5 modules (see Figure 2-5) that process the input Level-1B (L1B) data from FLEX/FLORIS and Sentinel-3/OLCI-SLSTR instruments to produce L1C and L2 products in agreement with the FLEX Product Handbook [RD-01].

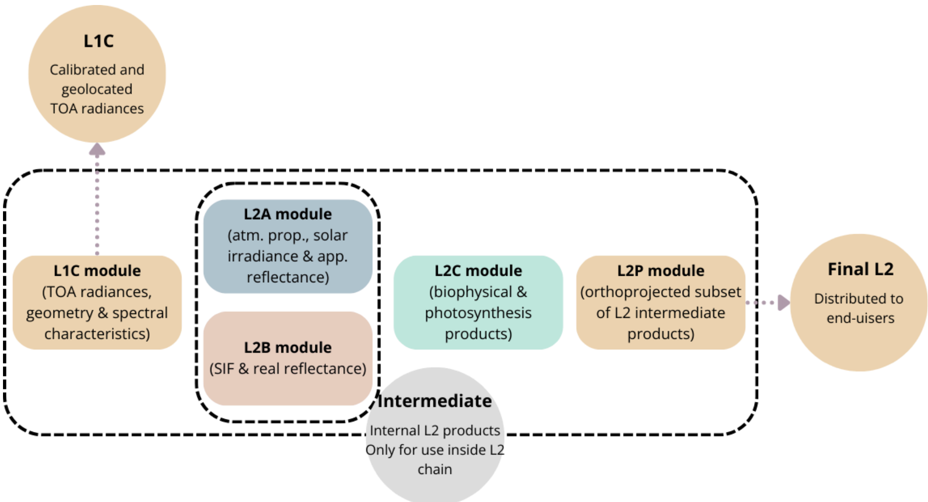

Figure 2-5: High-level architecture of FLEX L2 data processing chain.

The data processing starts with the **L1C module**. In its nominal execution mode, the L1C module is in charge of processing FLORIS (HR and LR spectrometers), OLCI and SLSTR (nadir and oblique) L1B products i.e., calibrated at-sensor top-of-atmosphere (TOA) radiances with appended geometric (i.e., orbit position, platform attitude, instrument lines-of-sight) & spectral information (i.e., wavelengths and resolution of spectral channels), and ancillary meteorological data (i.e. ozone, relative humidity, surface pressure and temperature profile), and generating the L1C product (**L1C**). This module therefore performs the following processing: (1) geometric co-registration between FLORIS, OLCI and SLSTR, and (2) pixel classification and quality flagging. This module gives pixel-wise appended information containing observation/illumination geometry and surface elevation/slope/aspect. In case of unavailable Sentinel-3 L1B products, the same process is carried out on the two FLORIS spectrometers only. It is noted that FLORIS-OLCI radiometric cross-calibration is only applied at the beginning of the L2A processor to harmonize OLCI and FLORIS radiances based on cal/val measurements.

The processing chain continues with the **atmospheric characterization and correction module (L2A)** and the **fluorescence retrieval module (L2B)**. In terms of architecture, these two modules are merged into one single entity, being the L2B module a pixel-wise subroutine within the much larger L2A module. The L2A module aims at characterizing the atmospheric state concurrent to FLEX observations. This includes:

- the aerosol optical properties[1] i.e., Aerosol Optical Thickness (AOT)[2], Angstrom exponent, and asymmetry parameter;
- the columnar water vapor (CWV);
- and a cloud probability mask.

After characterizing the atmospheric conditions, and with the knowledge of illumination geometry, the L2A produces at-surface solar irradiance (separated by its direct and diffuse terms). Finally, the L2A module performs the retrieval of surface apparent reflectance (i.e., the real surface reflectance with the effective contribution of solar induced fluorescence, SIF) from the input L1C TOA radiance product from all instruments (i.e., for FLORIS, OLCI and SLSTR nadir). It is noted that the L2A module exploits nominally the Sentinel-3 data stored in the L1C products but can also run only with FLORIS data in case of absence of Sentinel-3 data with degraded performances.

The L2B module disentangles the SIF signal from the surface apparent reflectance and at-surface solar irradiance coming from the L2A intermediate product. Through this process, the L2B ingests not only the L2A product but also the uncertainties (through a covariance matrix) associated with the L2A data.

Next in the processing chain comes the **biophysical vegetation parameters retrieval module (L2C)**. This module ingests the L2B intermediate product (SIF spectrum and surface real reflectance at FLORIS bands) and the L2A OLCI surface reflectance product to retrieve biophysical variables for a correct interpretation of the fluorescence signal. Moreover, the L2C module is responsible for deriving higher-level products related to vegetation photosynthetic activity.

The last module running in the L2 processing chain is the **Level-2 post-processing module (L2P)**. This module ortho-rectifies a subset of intermediate L2A to L2C products, targeted for scientific applications and derivation of high-level products, and reprojects them in a ground reference frame (Sentinel-2 UTM tiling grid).

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[1] Single Scattering Albedo, SSA, is obtained from climatology.
[2] In this document AOT is sometimes referred to indistinctly as Aerosol Optical Depth (AOD). In both cases, the AOT value is defined at 550 nm.

The following Table 2-2 summarizes the general description of FLEX L1C and L2 products to be distributed to the end-users. Details on these products are given in the following Section 3.

Product	High-level description	Potential users
L1C	Radiometrically and spectrally calibrated TOA radiances for the FLORIS (HR and LR), OLCI, and SLSTR (nadir and oblique) spatially resampled and projected into the FLORIS-HR focal plane geometry with appended information (quality flags, surface topography, geometry, spectral characteristics). Note: a global attribute indicates whether Sentinel-3 is available or not. If Sentinel-3 is not available, this global attribute triggers the execution of a contingency plan, making use of CAMS data in the L2 data processing.	• L2A core products ESL (module). • Expert users interested in developing their own atmospheric correction algorithms. • Expert users interested in testing radiometric cross-calibration between FLORIS & OLCI instruments. • Expert users interested in developing their own standalone L2 data processing externally to the collaborative platform.
L2	• Surface apparent reflectance for the FLORIS instruments. • At-surface solar irradiance (direct and diffuse) at FLORIS spectral resolution • Cloud probability mask. • Land Surface Temperature (LST). • SIF and surface real reflectance spectra. • Biophysical parameters. • Photosynthesis-related parameters. Note: all products are provided with appended uncertainties. Note: a global attribute indicates whether Sentinel-3 is available or not. If Sentinel-3 is not available, this global attribute triggers the execution of a contingency plan, making use of CAMS data in the L2 data processing.	• Scientific end-users. • cal/val ESL.

Table 2-1: High-level description of FLEX L1C/L2 products and users. Although not specified, all products are provided with their corresponding uncertainties.

3. FLEX L1C and L2 product characteristics

This section provides high-level information about the characteristics of the FLEX L1C and L2 products (e.g., spacing, resolution, performance summary, data volume).

3.1. L1C product characteristics

3.1.1. General product description

The FLEX L1C product output by the FLEX L1C Instrument Processing Facility (IPF) contains radiometrically and spectrally calibrated TOA radiances for the FLORIS (merged HR and LR spectrometers), OLCI, and SLSTR (nadir and oblique) instruments projected in the FLORIS-HR grid. The product comes along with appended information (quality flags, surface topography, geometry, spectral characteristics). The L1C product contains a global attribute that indicates whether Sentinel-3 data is available or not. If Sentinel-3 is not available, this global attribute triggers the execution of a contingency plan, making use of CAMS data in the L2 data processing.

The following Table 3-1 gives a summary of the content of the L1C products. Further details are given in Section 5.

L1C product
FLORIS TOA radiance Merged FLORIS-HR and -LR TOA radiance spectral hypercube, spectrally and radiometrically calibrated, with associated uncertainty and appended with central wavelengths and spectral resolution information (also with their uncertainties).
FLORIS instrument flag Per-channel flag identifying the source FLORIS spectrometer after merging FLORIS-HR and -LR TOA radiance data.
OLCI TOA radiance (only if Sentinel-3 data is available) OLCI TOA radiance spectral hypercube, spectrally and radiometrically calibrated, and reprojected to the FLORIS-HR focal plane geometry with appended central wavelength grid information.
SLSTR nadir TOA radiance(only if Sentinel-3 data is available) SLSTR nadir view TOA radiance spectral hypercube, spectrally and radiometrically calibrated, and reprojected to the FLORIS-HR focal plane geometry with appended central wavelength grid information.
SLSTR oblique TOA radiance (only if Sentinel-3 data is available)

SLSTR oblique view TOA radiance spectral hypercube, spectrally and radiometrically calibrated, and reprojected to the FLORIS-HR focal plane geometry.
FLORIS extraterrestrial solar irradiance Solar irradiance spectrum resampled at FLORIS bands.
OLCI extraterrestrial solar irradiance (only if Sentinel-3 data is available) Solar irradiance spectrum resampled at OLCI bands.
SLSTR extraterrestrial solar irradiance (only if Sentinel-3 data is available) Solar irradiance spectrum resampled at SLSTR bands.
Geolocation Latitude and longitude coordinates associated with every pixel in the L1C product with associated geolocation uncertainty.
Surface elevation GETASSE30 surface elevation relative to EGM96 geoid reprojected on FLORIS-HR grid, with associated surface slope and surface aspect.
Geometric information Viewing and Solar Zenith Angles (VZA and SZA), Solar Azimuth Angle (SAA) and Relative Azimuth Angle (RAA) associated with each of the instruments in the L1C product (i.e. FLORIS, OLCI, SLSTR nadir, and SLSTR oblique).
Temperature profile Temperature profile (extracted from FLEX L1B product ECMWF meteorological data) reprojected on FLORIS-HR grid, plus associated pressure grid.
Ancillary meteorological data Preliminary atmospheric characterization (extracted from FLEX L1B product ECMWF meteorological data and CAMS forecasting data) reprojected on FLORIS-HR grid. The following parameters are provided: (i) columnar water vapor, (ii) ozone content, (iii) sea level pressure, (iv) AOT at 550 nm, 670 nm and 865 nm.
Pixel classification Preliminary pixel classification, extracted from FLORIS-HR L1B product and refined based on the TOA radiance measurements.
Quality flags Quality flags as a bitmask identifying good/bad pixels in each instrument (FLORIS, OLCI, SLSTR nadir, SLSTR oblique). **Note:** This description is **TBC**.
Cross-calibration coefficients Cross-calibration coefficients to harmonize FLORIS and OLCI TOA radiances. These coefficients are provided to the L1C processor in an auxiliary file and are passed to (and applied in) the L2 processor.

Table 3-1: List of variables stored in the FLEX L1C product.

Table 3-2 gives a summary of the main L1C product characteristics, which are further described in the following section.

Characteristics	Value/description
Projection	FLORIS-HR focal plane
Size	161 x 1397km^2 (536x4656 pixels) N.B.: the along-track size comes from the 3 min slicing of L1B products (~1241 km) and a margin of twice (before and after) the diagonal of a UTM tile (110x110 km^2) to ensure continuity in the L2 products.
Pixel size	300x300 m^2
Spatial Sampling Distance (SSD)	300 m
Local observation time	10:00 LTDN with variations between 9:00 (south pole) to 12:30 (north pole)
VZA	0º to 7º
Co-registration accuracy	<0.1 SSD
Absolute radiometric accuracy	2-5%
Relative radiometric accuracy (spatial)	<0.5% for all bands in the 500-780 nm spectral range
Relative radiometric accuracy (spectral)	<1% for peak-to-peak spectral variations over the full FOV
SNR@Lref	175-1015 (see Table 3-3 for details)
Spectral range (FLORIS) and number of spectral channels	500-780 nm 580 spectral channels
Spectral Sampling Distance (SSI)	0.1 nm (inside the O2 bands) up to 2 nm (in the 500-677 nm range). See Table 3-4 for details.
Spectral resolution	0.28 nm (inside the O2 bands) up to 3 nm (in the 500-677 nm range). See Table 3-4 for details.
Spectral range (OLCI/SLSTR) and number of spectral channels (only if Sentinel-3 data is available)	OLCI: 400-1020 nm (21 channels) SLSTR: 555-10850 nm (9 channels)
Data types	FLOAT and INT16
Data volume	6.5 GB

Table 3-2: Main characteristics of the FLEX L1C product.

3.1.2. Product characteristics

Geometric characteristics

The FLEX satellite follows a Sun-synchronous orbit with a local time of descending node (LTDN) at 10:00. This implies a variation of the local time ranging from 9:00 to 12:30 (see Figure 3-1). FLEX flies in a tandem orbit with Sentinel-3, sharing the same orbit with a difference of 6-15 seconds. In practice, the FLORIS-HR and -LR spectrometers are nearly concurrent in time and share virtually the same illumination conditions, with maximum differences in SZA<0.1°. Variations due to potential moving clouds are expected to affect at sub-pixel level.

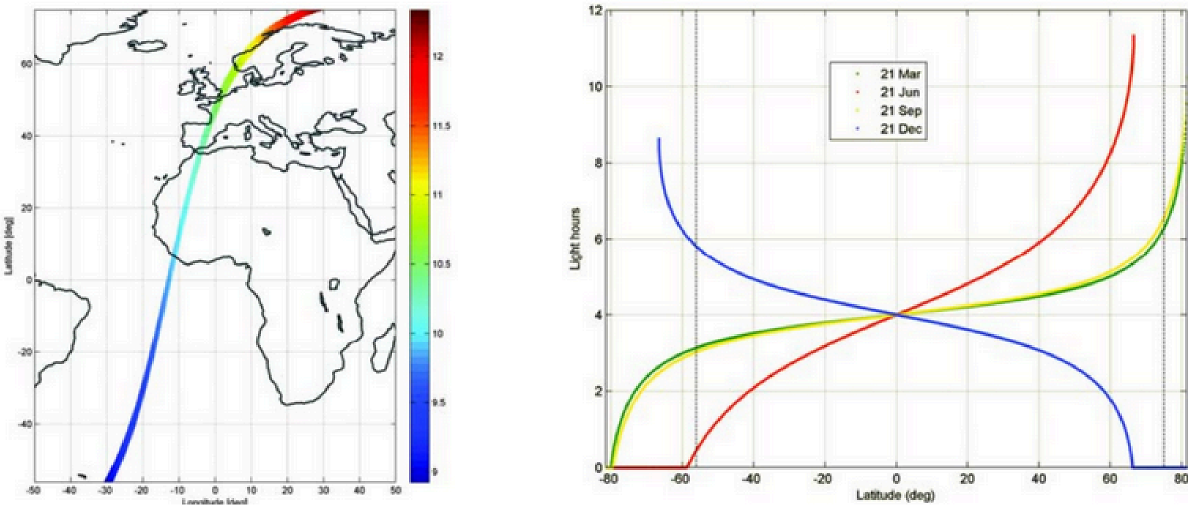

Figure 3-1: Left: Instantaneous time of observation as function of latitude for a 10:00 equatorial crossing for a reference orbit. Right: number of illumination hours over each target at the time of overpass as function of latitude for different seasons. Credit: Elecnor Deimos for ESA

The near-nadir observations from the two FLORIS spectrometers share nearly the same viewing angles (differences in VZA<0.5%).

We note that all instrument-specific geometric information is included in the L1C product to reduce any potential sources of errors when processing at higher levels (particularly atmospheric correction). This is particularly relevant for the SLSTR oblique view, whose VZA (55º) and time of overpass differs considerably from the rest of the nadir pointing instrument.

The continuous acquisition of FLEX data is called a "datatake". The maximum length of an imaging datatake is 15,000 km (e.g. continuous observation from northern Russia to southern Africa). A datatake is subdivided in one or more slices corresponding to continuous segments of nearly 3min. Unlike other missions such as Sentinel-2/MSI, where L1C products are defined in an orthorectified UTM grid, the FLEX L1C products use the FLORIS-HR instrument focal plane as a geometric projection, sharing a nearly one-to-one equivalence with the FLEX L1B product. There are two main differences with respect to the L1B product:

- In the L1C product, all instrument data (OLCI, SLSTR and FLORIS-LR) are spatially resampled and projected into the FLORIS-HR focal plane geometry. The main goal is to avoid any artifacts on the FLORIS-HR TOA radiance that will hamper the quality of the data and the subsequent retrieval of SIF. Moreover, working in FLORIS-HR grid allows the L2 processor to take into account the smile effect within the processing chain.

- A slice of L1C product contains a margin coming from the previous/next L1B product slices to ensure continuity in the later L2 products (UTM tiles). This margin is calculated as twice the diagonal of a UTM tile (i.e. 2*155 km).

The geometric projection of a L1C slice is driven by the near-nadir FLEX observations. Accordingly, a slice covers an area of 161 km across-track and 3 minutes of acquisition time (~1241 km along-track) plus margin (155 km). With a pixel spatial resolution of nearly 300x300 m^2 and a spatial sampling distance (SSD) of ~300 m, this results in matrices of 536x4565 pixels. It is noted that, while FLORIS and OLCI L1B products share similar spatial characteristics, SLSTR pixel size is much larger, ranging from 500 m in nadir view to 1-2 km in oblique views. Therefore, users should note that within the L1C processor, SLSTR L1B TOA data is resampled/interpolated to FLORIS-HR higher spatial resolution grid. Overall, the accuracy of geolocation and co-registration of all instrument data into the FLORIS-HR focal plane geometry is achieved with errors typically below 0.1 SSD.

Radiometric characteristics

The main data sets in the FLEX L1C products are FLORIS, OLCI and SLSTR TOA radiances. Aside from the projection of the L1B data into the FLORIS-HR frame, and with the exception of thermal channels in SLSTR, the input L1B TOA radiances (L) from OLCI need to be renormalized to use the same extraterrestrial solar irradiance (I_0) model as in FLORIS data. That is:

$$L_{L1C}^{OLCI} = L_{L1B}^{OLCI} I_{0,L1C} / I_{0,L1B}$$

Note that this normalization is not necessary if all OLCI, SLSTR and FLORIS L1B products use the same solar irradiance model, which as today is the case (note: TSIS solar irradiance model is used in FLORIS L1B and OLCI L1B, and it is foreseen for SLSTR L1B).

Following the mission requirements [AD-01], the FLORIS TOA radiance data set is characterized by having an absolute radiometric calibration error between 2% and 5%, and a relative radiometric calibration error of ±0.5% (spatial for all bands in the 500-780 nm spectral region) and 1% (peak-to-peak spectral variations over the full field of view). Beyond this potential solar irradiance renormalization, the L1C products will not apply any radiometric re-calibration. It is noted that the OLCI-FLORIS cross-calibration coefficients are stored in an auxiliary file and the cross-calibration is applied at the beginning of the L2A processor.

The noise level presented in Table 3-3 corresponds to the SNR calculated at a reference radiance level (see Figure 3-2).

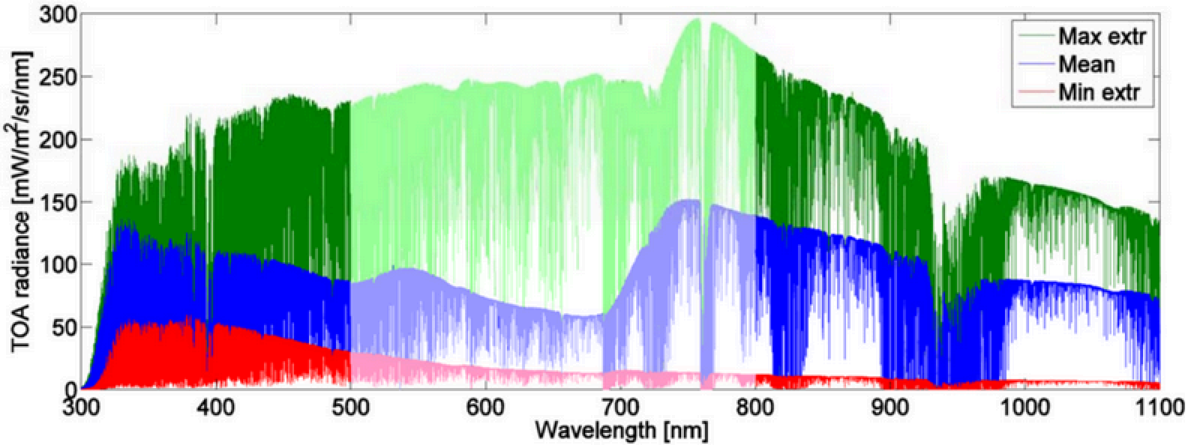

Figure 3-2: Minimum/Mean/Maximum reference TOA radiance spectra. Credit: ESA

	FLORIS-LR		**FLORIS-HR1**		**FLORIS-LR**	**FLORIS-HR2**			
	Pigments and Chlorophyll absorption		O2B band		Red-edge	O2A band			
Range (nm)	500-600	600-677	677-686	686-697	697-740	740 to 748	748 to 759	759 to 769	769 to 780
SNR	245	245	340	175	425	510 to 780	780 to 1015	115 to 455	1015

Table 3-3: FLORIS signal-to-noise (SNR) configuration.

Spectral characteristics

The L1C product contains 4 spectral TOA radiance hypercubes corresponding to FLORIS (merged HR and LR spectrometers), OLCI, and SLSTR (nadir & oblique views). The spectral characteristics of OLCI and SLSTR TOA radiance data sets are directly imported in the L1C processor from the original L1B products without modifications of their spectral characteristics. OLCI data has 21 spectral channels with a typical spectral resolution of 10 nm, ranging from 2.5 nm in the O2A band (band #13) up to 40 nm at 1020 nm (band #21). SLSTR data has 9 spectral channels, 6 in the visible (VIS) and shortwave infrared (SWIR) and 3 in the thermal infrared (TIR). The reader is encouraged to find further information about the band configuration of OLCI and SLSTR in the corresponding ESA websites:

- OLCI: https://sentiwiki.copernicus.eu/web/s3-olci-instrument
- SLSTR: https://sentiwiki.copernicus.eu/web/s3-slstr-instrument

Regarding FLORIS, the spectral data (wavelength and FWHM) is provided in two specific data sets. The FLORIS central wavelengths contain the information about the wavelengths of each spectral channel. It is important to note that the smile effect is not corrected at L1C i.e., spectral data is not resampled to a common spectral grid. Therefore, central wavelengths are provided for each across-track column of the

detector. The same is applicable for the spectral resolution (FWHM), which is provided for all channels and all across-track pixels.
The specific spectral configuration of FLORIS is given in Table 3-3. After merging FLORIS-HR and -LR L1B products in a single hypercube, the FLORIS TOA radiance data contains a total of 580 spectral channels. The spectral configuration is set for specific needs of the L2 products and algorithms:

- 500-600 nm: Pigments absorption in the PRI region related with plant energy regulation and photoprotection.
- 600-677 nm: Chlorophyll absorption feature.
- 677-686 nm: O2B absorption band (outside)
- 686-697 nm: O2B absorption band (inside)
- 697-740 nm: red-edge + H2O absorption band.
- 740-759 nm: O2A absorption band (outside) + Fraunhofer lines.
- 759-769 nm: O2A absorption band (inside).
- 769-780 nm: O2A absorption band (outside)

The spectral region between 670 nm and 780 nm is where the SIF emission takes place. The SIF emission is amplified with respect to the reflected radiance in areas of solar and telluric absorptions (see Figure 3-4). Particularly, the O2B and O2A bands offer an idoneous spectral contrast.

	FLORIS-LR		**FLORIS-HR1**		**FLORIS-LR**	**FLORIS-HR2**			
	Pigments and Chlorophyll absorption		O2B band		Red-edge	O2A band			
Range (nm)	500-600	600-677	677-686	686-697	697-740	740 to 748	748 to 759	759 to 769	769 to 780
FWHM (nm)	3	3	0.7	0.3	2	0.7	0.3	0.3	0.7
SSI (nm)	2	2	0.5	0.1	1	0.5	0.1	0.1	0.5

Table 3-4: FLORIS spectral configuration.

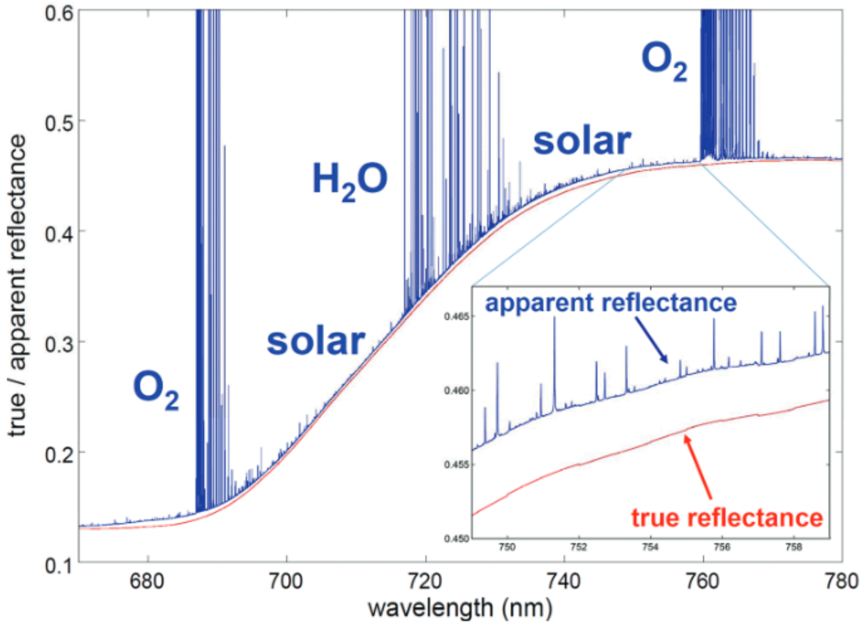

Figure 3-3: Apparent surface reflectance (blue) and actual surface reflectance (red) in the spectral range of fluorescence emission. The differences are dominated by the presence of absorption bands in solar irradiance arriving at the surface, either caused by solar Fraunhofer lines or terrestrial O2 or water vapour absorptions. Inset: Zoom of a spectral region dominated by Fraunhofer lines, which produce much smaller effects than the strong terrestrial absorptions. Credit: University of Valencia

The FLORIS wavelength grid is calibrated inside the O2 bands with an error of 0.01 SSI (~0.001 nm) and the FWHM with an error of 0.1 SSI (0.01 nm). By mission requirements, the spectral characteristics should be stable within 0.1 SSI for every 10 min of orbit. This implies that, within the L1C product, the first and last acquisition lines (3 min of orbit) might deviate <0.003 nm.

Ancillary meteorological data

The retrieval of fluorescence and other biophysical products rely on accurate atmospheric correction. While aerosols and water vapor are retrieved within the L2 processor, temperature profile, total column of ozone, and surface pressure are obtained from meteorological data (ECMWF). These ancillary meteorological data are extracted from the FLEX L1B product and are spatially resampled to the L1C FLORIS grid (i.e. at 300 m/pixel). The units for O3 content are modified in the L1C to atm-cm to be compatible with the atmospheric correction process at L2.
In addition to the ECMWF data coming from the L1B product, the L1C product contains AOT at three wavelengths (550, 670, 865 nm), extracted from CAMS (Copernicus Atmosphere Monitoring Service) forecasting data and interpolated (temporally and spatially) to the L1C grid. The inclusion of CAMS meteorological data in the L1C product serves as a contingency scenario in case of unavailable Sentinel-3 data. In that case, the aerosol retrieval in the L2 processor cannot be initialized with a retrieval based on SLSTR

dual view. Instead, CAMS aerosols parameters are used as first guess in the aerosol retrieval process.
Although CAMS is foreseen for the contingency scenario, CAMS data will be always fetched and provided in the L1C product given its small data volume.

Data quality information

The L1C products come along with several variables providing an insight on the data quality. First, key variables come along with an associated **uncertainty** related with the quality of the data processing. In particular, the following uncertainties are provided:

- Uncertainty in FLORIS TOA radiance.
- Uncertainty in the central wavelengths of FLORIS spectral channels.
- Uncertainty in the FWHM of FLORIS spectral channels.
- Average coregistration uncertainty.

Another layer of quality information comes from the **pixel classification**. This pixel classification is a refinement of the one provided in the L1B, with a redefinition of bright pixels (potential clouds), the addition of potential cloud shadows, and the identification of non-vegetation, sparse vegetation and dense vegetation. The following IDs are used:
0 = Not-valid
1 = Land (non-vegetation: bare soil, manmade…)
2 = Water
3 = Coastline
4 = Tidal region
5 = Cloud/bright
6 = Sun-glint risk
7 = Preliminary cloud shadow
8 = Sparse vegetation
9 = Dense vegetation

In addition, per-pixel **quality flags** are included in the L1C products. This bitmask variable provides information about the validity of each pixel for each instrument (FLORIS, OLCI, SLSTR nadir, SLSR oblique). The validity of a pixel is determined from the related quality flags in the L1B product, identifying a non-valid pixel when at least one spectral channel is identified (in the L1B product) as bad, wrong, dead, invalid, saturated, partially saturated, dubious, or cosmetic. The following Table 3-5 describes the structure of the byte regrouping all quality flags of the L1C products (byte/bit decimal highest value indicates the most significant):

Byte/bit	7	6	5	4	3	2	1	0
0	sp	sp	sp	SLO	SLN	OLC	LR	HR

Table 3-5: Structure of the L1C quality flags

with:

- **HR**: bad FLORIS-HR pixel flag set to '1' if the pixel has poor quality (i.e., bad, dead, saturated, dubious) at any spectral channel in FLORIS-HR spectrometer.
- **LR**: bad FLORIS-LR pixel flag set to '1' if the pixel has poor quality (i.e., bad, dead, saturated, dubious) at any spectral channel in FLORIS-LR spectrometer.
- **OLC**: bad OLCI pixel flag set to '1' if the pixel has poor quality (i.e., invalid, saturated, partially saturated, cosmetic).
- **SLN**: bad SLSTR nadir pixel flag set to '1' if the pixel has poor quality (i.e., bad, dead, saturated, dubious).
- **SLO**: bad SLST oblique pixel flag set to '1' if the pixel has poor quality (i.e., bad, dead, saturated, dubious).
- **sp**: spare bits, to be ignored (set to 0).

Note: while OLCI L1B quality flags are channel independent, FLORIS L1B quality flags are spectral magnitudes i.e., each spatial pixel has a quality flag per spectral channel. It is still under discussion whether to keep a spectral quality flag for FLORIS data in the L1C product or to use a single layer quality flag for each pixel as described in the paragraph above (**TBD**).

Data volume

FLEX L1C product is stored in hierarchical netcdf files following the format detailed in Section 5. The various data sets are mostly stored in FLOAT (4 bytes) except for variables involving integers (e.g., pixel classification) and the variables that take the largest portion of the data volume (mainly radiances and angular information), which are stored in USHORT/INT16 (2 bytes). USHORTs (2 bytes) are used to reduce size and NetCDF packing. NetCDF libraries automatically and transparently do the conversion between USHORT to FLOAT/DOUBLE whenever they find the `add_offset` and `scale_factor` attributes.

The following Table 3-6 gives the size of each variable of one file. Since the NetCDF files generated are not compressed, the total size can be computed from the size of each dimension and the data type. Accordingly, a single L1C netcdf file has a size of 6.5 GB. The table shows that most of the data volume is taken by the FLORIS TOA radiance hypercube and its uncertainty (97%) due to its large number of wavelengths.

variable name	bits	col	row	field	size (MB)	fraction (%)
floris_toa_radiance	16	536	4656	580	2895	46
floris_toa_radiance_uncertainty	16	536	4656	580	2895	46
olci_toa_radiance	16	536	4656	21	105	2
slstr_nadir_toa_radiance	16	536	4656	6	30	0

slstr_oblique_toa_radiance	16	536	4656	6	30	0
slstr_nadir_tir_toa_radiance	16	536	4656	3	15	0
floris_spectral_channel_central_wavelengths	32	536	1	580	1	0
floris_spectral_channel_central_wavelengths_uncertainty	32	536	1	580	1	0
floris_spectral_channel_fwhm	32	536	1	580	1	0
floris_spectral_channel_fwhm_uncertainty	32	536	1	580	1	0
floris_instrument_flag	32	536	1	580	1	0
olci_spectral_channel_central_wavelengths	32	1	100	21	0	0
slstr_vswir_spectral_channel_central_wavelengths	32	1	1	6	0	0
slstr_tir_spectral_channel_central_wavelengths	32	1	1	3	0	0
longitude	32	536	4656	1	10	0
latitude	32	536	4656	1	10	0
average_coregistration_uncertainty	32	1	1	1	0	0
surface_elevation	32	536	4656	1	10	0
surface_slope	32	536	4656	1	10	0
surface_aspect	32	536	4656	1	10	0
viewing_zenith_angle	16	536	4656	4	20	0
sun_zenith_angle	16	536	4656	4	20	0
relative_azimuth_angle	16	536	4656	4	20	0
sun_azimuth_angle	16	536	4656	4	20	0
floris_extraterrestrial_solar_irradiance	32	536	1	580	1	0
olci_extraterrestrial_solar_irradiance	32	1	1	21	0	0
slstr_extraterrestrial_solar_irradiance	32	1	1	6	0	0
crosscalibration_coefficients	32	1	1	8	0	0
pixel_classification	16	536	4656	1	5	0
quality_flags	8	536	4656	1	2.5	0
temperature_profile	32	536	4656	25	250	2
tie_pressure_levels	32	1	1	25	0	0
total_column_water_vapor	32	536	4656	1	10	0
total_ozone	32	536	4656	1	10	0

aerosol_optical_thickness	16	536	4656	3	15	0
				Total L1C_SYN:	**6.5 GB**	

Table 3-6: Size of the L1C product in a single netcdf file (3 min slice + margins).

3.1.3. Geometric ancillary product characteristics

To enable users of the FLEX L1C product to do their own geometric modeling, L1B ancillary geometric data is transferred to the L1C product as ancillary. As FLORIS-LR is optimized to be coregistered on the FLORIS-HR model, only the FLORIS-HR ancillary product is still valid for the FLEX L1C product **TBC**.

Basic information about the content of these ancillary products is provided in the Table 3-7 below:

File	Content	File Format
ANC_ROTLOS	Rotation matrix from the satellite platform to the instrument and the Line Of Sight of the FLORIS instruments for each ACT pixel (FLORIS-HR1, FLORIS-HR2, FLORIS-LR).	NetCDF file (.nc)
ANC_ATTRES	Attitude quaternions in ECEF reference frame, with associated timestamps (sampled at FLORIS integration time in UTC times).	EOF file (.EOF)
ANC_ORBRES	Position and velocity vectors ECEF reference frame, with associated timestamps (sampled at FLORIS integration time in UTC times).	EOF file (.EOF)

Table 3-7: Description of the Geometric ancillary product

The detailed format of these files is detailed in the FLEX L1 Product Specification **[L1-PDS]**.

3.2. L2 product characteristics

3.2.1. General product description

The FLEX L2 product contains bio-/geo-physical variables extracted from processing the input L1C products and orthoprojected in a UTM tile grid compatible with Sentinel-2. The nature of these variables range from typical surface (apparent) reflectance spectra and biophysical parameters to mission-specific products such as fluorescence emission spectra and photosynthesis-related variables. All variables come with appended information (quality flags, geometry, spectral characteristics). The following Table 3-7 gives a summary of the content of the L2 products distributed to end-users. Further details are given in Section 5. It is noted that all these variables in the L2 product are generated regardless of the availability of Sentinel-3 data in the input L1C product. In case of unavailable Sentinel-3 data, a contingency plan is executed producing degraded L2 products.

L2 product
Cloud probability Per-pixel values of cloud probability (0%: no cloud; 100%: fully cloud covered).
Cirrus cloud type map Binary map identifying cirrus clouds.
Atmospheric characteristics Mainly water vapor and aerosol optical properties, obtained as by-products of the atmospheric correction data processing.
FLORIS surface apparent reflectance i.e., actual reflectance with the contribution from fluorescence emission, provided at FLORIS spectral channels in the fluorescence emission spectral region (670-780 nm). This variable is complemented with associated uncertainty and spectral information (central wavelength varying across-track).
OLCI surface reflectance Surface reflectance hypercube obtained from the atmospheric correction of OLCI TOA radiance data.
SLSTR (nadir view) surface reflectance Surface reflectance hypercube obtained from the atmospheric correction of SLSTR (nadir view only) TOA radiance data (VIS-SWIR spectral channels only).
Land surface temperature Surface temperature extracted from the processing of SLSTR TIR spectral channels.
Direct/diffuse at-surface solar irradiance Direct and diffuse solar irradiance spectra from 400 nm to 780 nm with associated uncertainty and with appended spectral information (central wavelengths).
Sun-induced fluorescence (SIF) SIF spectra in the 670-780 nm spectral region at 2 nm (TBD) sampling with associated uncertainty and wavelength grid.
Real surface reflectance

Real surface reflectance spectra (i.e. after decoupling SIF emission) in the 500-780 nm spectral range at 2 nm (TBD) sampling with associated uncertainty and with appended spectral information (central wavelengths).
Leaf Chlorophyll Content (LCC) with associated absolute/relative uncertainties and quality flag
Leaf Carotenoids Content (LCCAR) with associated absolute/relative uncertainties and quality flag.
Leaf Area Index (LAI) with associated absolute/relative uncertainties and quality flag.
Fraction of Absorbed Photosynthetic Active Radiation (FAPAR) Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), integrated over the 400-700 nm region, with associated absolute/relative uncertainties and quality flag.
Non-Photochemical Quenching (NPQ) Non-Photochemical energy dissipation efficiency
Photosynthetic Active Radiation Absorbed by Chlorophyll Total amount of light absorbed by chlorophyll-a, integrated in the wavelength range 400-700 nm, with associated uncertainty.
Fluorescence Quantum Efficiency (FQE) Fluorescence quantum efficiency (FQE) as the dimensionless ratio of SIF_photons over APAR_Chl_photons, plus uncertainty.
Electron Transport Rate (ETR) with associated uncertainty.
Escape probability (fesc) Escape probability of fluorescence in sensor direction times pi.
PSI/PSII PSI/PSII relative contributions to fluorescence emission spectrum.
Geolocation Latitude and longitude coordinates associated with every pixel in the L2 product.
Surface height
Geometric information Viewing and Solar Zenith Angles (VZA and SZA), Solar Azimuth Angle (SAA) and Relative Azimuth Angle (RAA) associated with FLORIS-HR observations.
Quality flags

Quality flags as a bitmask identifying good/bad pixels in each key data processing steps or variables (aerosols, water vapor, reflectance, SIF, LAI, LCC, LCCAR, fAPAR, escape probability, photosynthesis-related products).

Table 3-8: List of variables in the FLEX L2 product.

Table 3–9 gives a summary of the main L2 product characteristics, which are further described in the following section.

Characteristics	Value/description
Projection	Sentinel-2 UTM tiling
Size (per tile)	110 x 110 km^2 (366x366 pixels)
Number of tiles per L1C slice	18 to 21 (depending on the exact overlapping of L1C slice with UTM tiles and the minimum number of valid pixels in a UTM tile)
Minimum number of valid pixels	1340 (i.e., 1% of a UTM tile)
Pixel size	300x300 m^2
Spatial Sampling Distance (SSD)	300 m
Surface apparent reflectance	500-780 nm at FLORIS resolution/sampling (see Table 3-4 for details)
SIF spectral range, sampling, and number of spectral channels	670-780 nm at 2 nm (TBD) sampling 55 spectral channels
Real surface spectral range, sampling, and number of spectral channels	500-780 nm at 2 nm (TBD) sampling 140 spectral channels
OLCI and SLSTR surface reflectance spectral range, and number of channels	OLCI: 400-1020 nm (21 channels) SLSTR: 550-2250 nm (6 channels)
Data types	FLOAT and INT16
Data volume	950 MB

Table 3-9: Main characteristics of the FLEX L2 product.

3.2.2. Product characteristics

Geometric characteristics

The L2 products are elementary granules, also called tiles, of fixed size, within a single orbit. A granule is the minimum indivisible partition of a product (containing all possible spectral bands). For the FLEX L2 products, the granules follow the Sentinel 2 tile grid rules, which is based on the MGRS grid system. That is, each L2 tile is defined as a 110x110 km² ortho-images in UTM/WGS84 projection.

Unlike the “traditional” latitude/longitude system with the coordinates given in a spherical referential, the UTM coordinates are given in a plane using a cylindrical projection (Transverse Mercator projection). UTM projection uses meters from a reference point as coordinates instead of degrees. Given the fact that the Earth is not flat, the further west or east the data gets from the reference point, the more the projection will be deformed (see Figure 3-4 left). That is why the UTM system divides the Earth in 60 zones, each with a width of 6° of longitude (Figure 3-4 right) and with their own reference point at the equator. In the UTM system, each of these 60 zones corresponds to a spatial reference system and has assigned an EPSG code (e.g., EPSG:32631), which has no physical meaning and only corresponds to an identification number.

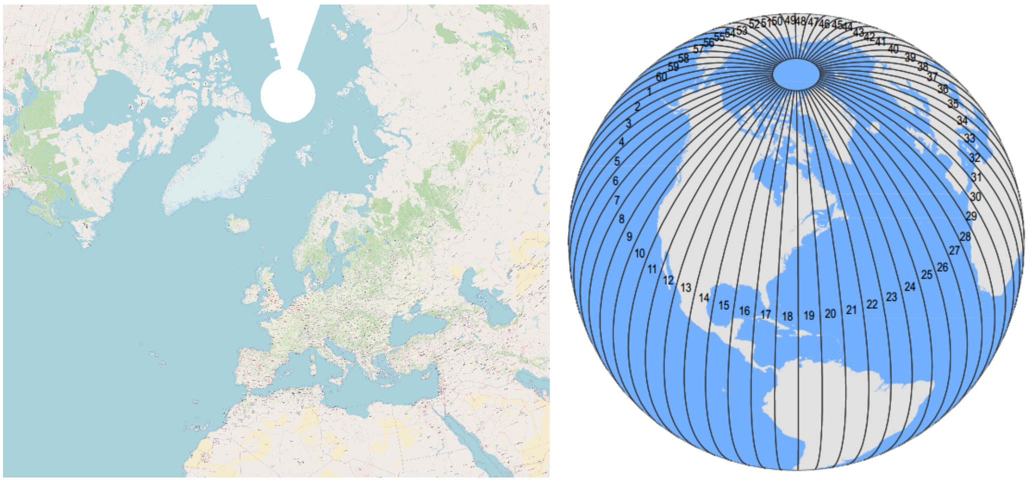

Figure 3-4: Left: The Earth map projected in the UTM zone 31 spatial reference system (EPSG:32631) . Right: The 60 UTM zones

In the FLEX UTM tile grid, the Earth is subdivided on a predefined set of tiles, each defined in UTM/WGS84 projection and using a 100 km step. However, each tile has a surface of 110x110 km² in order to provide large overlap with the neighboring tiles (see e.g. Figure 3-5). With 300 m/pixel, each tile has 366x366 pixels.

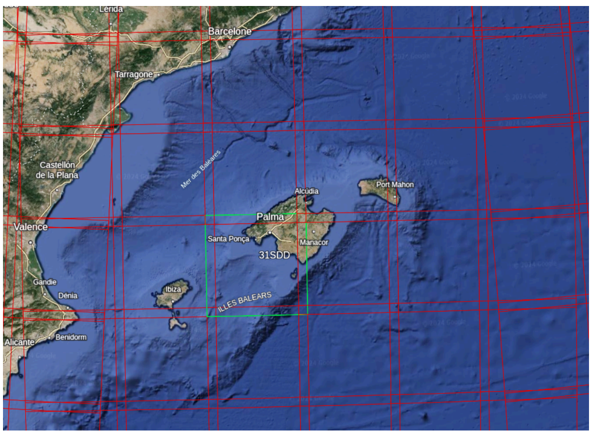

Figure 3-5: Google Earth view of Sentinel-2 UTM tiles

The following Figure 3-6 illustrates how one or more slices of L1C products could cover different parts of the same tile. Representing the consecutive acquisitions as Slice 1 and Slice 2, the UTM tile of interest (here 31TEL) appears on both. To the left, we see the consecutive slices, both containing the tile of interest. To the right, we see a zoomed version of the transition between the slices. In both cases, the 31TEL tile is contained between these two. The figure illustrates how the same tile can be contained on multiple slices, and how different parts of the same tile do not necessarily belong to the same slice.

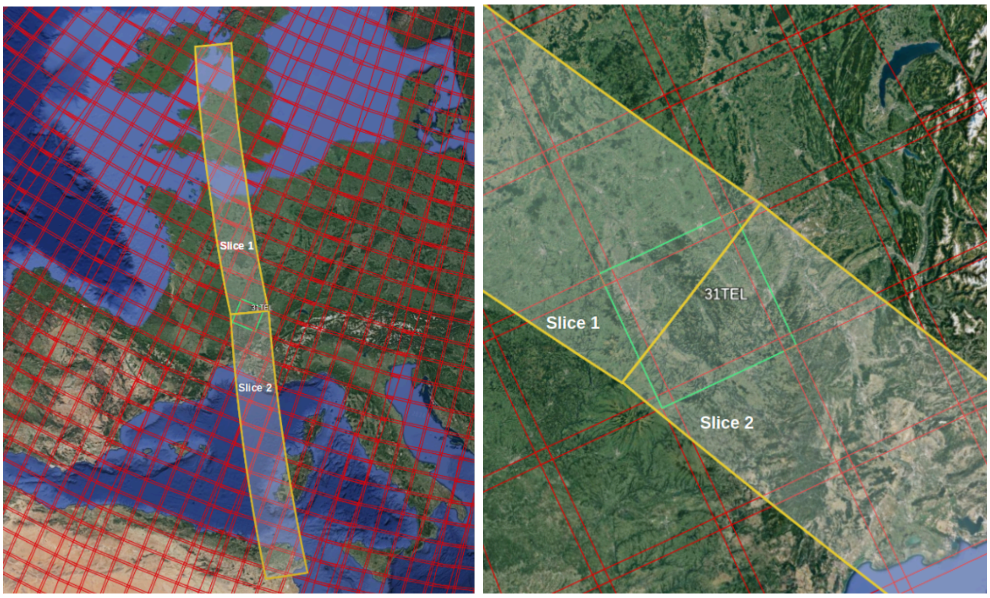

Figure 3-6: In yellow, ground footprint of the L1C products. In red, the UTM tile grid. The central tile (here 31TEL) is highlighted in green.

Surface apparent reflectance

Surface apparent reflectance is defined as the actual (true/real) surface reflectance with the added contribution of the SIF emission normalized to reflectance units. In practice, the apparent reflectance is the product from atmospheric correction i.e., the removal of atmospheric absorption and scattering effects from the at-sensor TOA radiance (Sabater et al., 2017).

$$L = L_0 + \frac{T(E\rho + \pi F)}{\pi(1 - S\rho)} \rightarrow L_0 + \frac{TE\rho_{app}}{\pi(1 - S\rho_{app})}$$

Within the L2 products, three hypercubes of surface apparent reflectance will be distributed to end-users: FLORIS, OLCI, and SLSTR (only nadir and VSWIR channels).

The contribution of SIF into apparent reflectance is limited in the 670-780 nm spectral range. Nonetheless, to provide end-users with the original data, the apparent reflectance is provided in the entire FLORIS spectral range (500-780 nm) at the nominal FLORIS spectral resolution/sampling (580 spectral channels). It is noted that, since the L2 data is projected in UTM coordinates, the notion of sensor columns from the L1C product is lost and thus the possibility of explicitly accounting for the smile effect. Accordingly, surface apparent reflectance is resampled at a fixed spectral grid defined as the nominal spectral grid specified in the MRD requirements at Table 3-4.

The errors in surface apparent reflectance are expected to be within 1% in the 670-780 nm spectral region. The errors will be higher (5-10%) towards shorter wavelengths due to the influence of aerosol scattering/absorption and the typically low values of vegetation reflectance. Uncertainty in FLORIS surface apparent reflectance is also provided in the L2 products.

Beyond FLORIS, surface (apparent) reflectance is also provided for the 21 channels of OLCI and the 6 VIS-to-SWIR channels of SLSTR (only nadir view) to provide complementary information by expanding the spectral range below 500 nm (down to 400 nm) and above 780 nm (up to 2250 nm).

At-surface solar irradiance

Another byproduct of the atmospheric correction is the at-surface solar irradiance. The L2 product provides this spectral magnitude divided into its direct (E_{dir}) and diffuse (E_{dirf}) components. The total at-surface solar irradiance can be calculated as $E_{dir} \cos\theta_{il} + E_{dif}$, where θ_{il} is the illumination angle (angle between the Sun direction and the normal to the surface), which is equivalent to the SZA in case of an horizontal surface.

Given the needs in the L2 processor to extend the solar irradiance in the photosynthetically active region, the solar irradiance is provided in the 400-780 nm spectral range. The spectral grid at which solar irradiance is provided is the following:

- 400-500 nm region at 4 nm sampling (**TBC**), that is 45 spectral channels. A 4 nm sampling is deemed to be sufficient for integrated PAR calculations with a spectral sampling on the same order of the FLORIS-LR binned channels sampling.
- 500-780 nm with the same spectral grid as surface apparent reflectance, i.e. 580 spectral channels.

Based on current performance analysis, solar irradiance is provided with errors <5% in the SIF emission spectral range (670-780 nm). Both direct and diffuse irradiance come along in the L2 product with associated uncertainties.

Fluorescence and real surface reflectance

FLEX is the only satellite mission that provides the full SIF spectrum by decoupling the SIF signal from the reflected light. Given the smoothness of the SIF spectra, SIF is provided in the 670-780 nm spectral range at 2 nm sampling (**TBC**). This spectral sampling is deemed sufficient to balance data volume without degrading the accuracy of the retrieved SIF spectra. In addition to the complete spectrum, key SIF parameters are provided in the L2 products: (1) peak values at ~685 nm and 750 nm (and their precise wavelength position), (2) SIF values in the O2B and O2A bands, and (3) total spectrally-integrated SIF. Both SIF spectra and the key parameters are provided with their corresponding uncertainties.

The current performance of the SIF retrieval indicates that errors are <0.2 $mW \cdot m^{-2} sr^{-1} nm^{-1}$ in the O2B band (687 nm) and between 0.2-0.4 $mW \cdot m^{-2} sr^{-1} nm^{-1}$ in the O2A band (761 nm). The integrated total fluorescence emission has errors that oscillate from 10% to 30%.

Real surface reflectance spectra (i.e. after decoupling SIF emission) is provided in the 500-780 nm spectral range at 2 nm (**TBC**) sampling together with its corresponding uncertainty.

The appended spectral information (central wavelengths) is provided for the SIF and real reflectance spectra.

Biophysical and photosynthesis products

In the FLEX L2 products a set of vegetation parameters are provided to properly interpret the fluorescence signal in the context of vegetation stress and photosynthetic activity. These parameters are provided based on the maturity of the data processing algorithms and of validation protocols. In the current version, the following vegetation parameters are provided:

- Leaf area index.
- Leaf chlorophyll content.
- Leaf carotenoids content.
- Fraction of absorbed photosynthetic radiation.
- PRI index, as a proxy for non-photochemical quenching.
- Fluorescence quantum efficiency.
- Electron transport rate.
- Escape probability.
- Non-photochemical quenching.
- PSI-PSII relative contribution.

All these parameters are provided with associated uncertainties.

Data quality information

The L2 products come along with a set of variables providing an insight on the data quality. First, key variables come along with an associated **uncertainty** related with the quality of the data processing. In particular, the following uncertainties are provided:

- Uncertainty in FLORIS surface reflectance (apparent and real).
- Uncertainty in the at-surface direct/diffuse solar irradiance at FLORIS spectral channels.

- Uncertainty in SIF emission spectrum.
- Uncertainty in biophysical parameters: leaf chlorophyll content, leaf carotenoids content, leaf area index.
- Uncertainty in photosynthesis-related parameters: APAR by chlorophyll, fluorescence quantum efficiency, electron transport rate, SIF escape probability.

Another layer of quality information comes from the **pixel classification**. This pixel classification is extracted from the L1C product and reprojected in the UTM grid of L2 products.

As part of the quality product information, the L2 products provide information about the per-pixel cloud probability and a cirrus cloud mask.

In addition, per-pixel **quality flags** are included in the L2 products. This bitmask variable provides information about the validity of a key variable or processing step. The validity of a pixel is determined from a combination of factors such as out-of-range values, anomalies in the spectral data, failures during a retrieval process, or inconsistencies between variables. See [ATBD-L2A] to [ATBD-L2C] for further details. The following Table 3-10 describes the structure of the byte regrouping all quality flags of the L2 products:

Byte/bit	15-10	9	8	7	6	5	4	3	2	1	0
0	sp	PHT	FES	FAP	LCA	LCC	LAI	SIF	RFL	CWV	AER

Table 3-10: Structure of the L2 quality flags

with:

- **AER**: bad aerosol retrieval.
- **CWV**: bad water vapor retrieval.
- **RFL**: bad retrieval of surface apparent reflectance in FLORIS spectral channels.
- **SIF**: bad fluorescence retrieval.
- **LAI**: bad leaf area index retrieval.
- **LCC**: bad leaf chlorophyll content retrieval.
- **LCA**: bad leaf carotenoids content retrieval.
- **FAP**: bad fAPAR retrieval.
- **FES**: bad fluorescence escape portability retrieval.
- **PHT**: bad retrieval of photosynthesis-related products.
- **sp**: spare bits, to be ignored (set to 0).

Contingency plan for unavailability of Sentinel-3 data

The FLEX mission is designed to operate the FLEX satellite in synergy with Sentinel-3, exploiting the information coming from the OLCI and SLSTR instruments for atmospheric correction, surface temperature, and biophysical parameters retrieval. Nonetheless, in

case of unavailable Sentinel-3 data, a contingency plan is foreseen to enable the production of FLEX L2 products (with expected degraded performances).
The contingency plan relies on the use of meteorological data from ECMWF (columnar water vapor) and CAMS (aerosol optical depth at 550 nm, 680 nm and 865 nm), stored in the L1C product, to bypass the retrieval otherwise performed with OLCI (differential absorption for water vapor retrieval) and SLSTR (dual viewing angle for derivation of first guess aerosol optical properties).

Data volume

FLEX L2 products are stored in hierarchical netcdf files following the format detailed in Section 5. The various data sets are mostly stored in FLOAT (4 bytes) except for variables involving integers and the variables that take the largest portion of the data volume (mainly spectral variables such as reflectance and SIF), which are stored in USHORT/INT16 (2 bytes). USHORTs (2 bytes) are used to reduce size and NetCDF packing. NetCDF libraries automatically and transparently do the conversion between USHORT to FLOAT/DOUBLE whenever they find the `add_offset` and `scale_factor` attributes.

The following Table 3-11 gives the size of each variable of one tile. Since the NetCDF files generated are not compressed, the total size can be computed from the size of each dimension and the datatype. Accordingly, a single L2 netcdf file (tile) has a size of nearly 950 MB. The table shows that the data volume is mostly taken by the spectral variables (surface apparent reflectance, real surface reflectance, solar irradiance, and fluorescence emission).

variable name	bits	row	col	field	size (MB)	fraction (%)
cloud_probabilty	32	366	366	1	0.5	0
cirrus_cloud_mask	32	366	366	1	0.5	0
floris_apparent_reflectance	16	366	366	580	148	13.8
floris_apparent_reflectance_uncertainty	16	366	366	580	148	13.8
olci_apparent_reflectance	32	366	366	21	11.3	1
slstr_apparent_reflectance	32	366	366	6	3.2	0.2
floris_spectral_channel_central_wavelength	32	1	1	580	0.1	0
olci_spectral_channel_central_wavelengths	32	1	1	21	<0.1	0
slstr_vswir_spectral_channel_central_wavelengths	32	1	1	6	<0.1	0
land_surface_temperature	32	366	366	1	0.5	0

direct_irradiance	16	366	366	628	160	15
direct_irradiance_uncertainty	16	366	366	628	160	15
diffuse_irradiance	16	366	366	628	160	15
diffuse_irradiance_uncertainty	16	366	366	628	160	15
irradiance_wavelength_grid	32	1	1	628	0.1	0
integrated_par	32	366	366	1	0.5	0
aerosol_optical_thickness	32	366	366	1	0.5	0
asymmetry_parameter	32	366	366	1	0.5	0
angstrom_exponent	32	366	366	1	0.5	0
columnar_water_vapor	32	366	366	1	0.5	0
sif_emission_spectrum	16	366	366	55	15	2
sif_emission_spectrum_uncertainty	16	366	366	55	15	2
sif_peak_values	32	366	366	2	1.1	0.1
sif_peak_values_uncertainty	32	366	366	2	1.1	0.1
sif_peak_positions	32	366	366	2	1.1	0.1
sif_peak_positions_uncertainty	32	366	366	2	1.1	0.1
sif_O2_bands_values	32	366	366	2	1.1	0.1
sif_O2_bands_values_uncertainty	32	366	366	2	1.1	0.1
total_integrated_sif	32	366	366	1	0.5	0.0
total_integrated_sif_uncertainty	32	366	366	1	0.5	0.0
sif_wavelength_grid	32	1	1	55	<0.1	0.0
floris_real_reflectance	16	366	366	140	37.5	4
floris_real_reflectance_uncertainty	16	366	366	140	37.5	4
reflectance_wavelength_grid	32	1	1	140	<0.1	0
leaf_area_index	32	366	366	1	0.5	0
leaf_area_index_uncertainty	32	366	366	1	0.5	0
leaf_chlorophyll_content	32	366	366	1	0.5	0
leaf_chlorophyll_content_uncertainty	32	366	366	1	0.5	0
leaf_carotenoid_content	32	366	366	1	0.5	0
leaf_carotenoid_uncertainty	32	366	366	1	0.5	0
fraction_of_absorbed_photosynthetically_active_radiation	32	366	366	1	0.5	0

non_physical_quenching	32	366	366	1	0.5	0
apar_chlorophyll_photons	32	366	366	1	0.5	0
apar_chlorophyll_photons_uncertainty	32	366	366	1	0.5	0
fluorescence_quantum_efficiency	32	366	366	1	0.5	0
fluorescence_quantum_efficiency_uncertainty	32	366	366	1	0.5	0
electron_transport_rate	32	366	366	1	0.5	0
electron_transport_rate_uncertainty	32	366	366	1	0.5	0
fluorescence_escape_probability	32	366	366	1	0.5	0
fluorescence_escape_probability_uncertainty	32	366	366	1	0.5	0
PSI_PSII_relative_contribution	32	366	366	1	0.5	0
longitude	32	366	366	1	0.5	0
latitude	32	366	366	1	0.5	0
surface_elevation	32	366	366	1	0.5	0
sun_zenith_angle	32	366	366	1	0.5	0
viewing_zenith_angle	32	366	366	1	0.5	0
relative_azimuth_angle	32	366	366	1	0.5	0
quality_flags	8	366	366	1	0.3	0
				Total	**1.05 GB**	

Table 3-11: Size of the L2 product in one UTM tile.

The volume is mainly taken by variables coming from the atmospheric correction products, specifically the FLORIS apparent reflectance and solar irradiance (with their uncertainties).

4. Product data conventions

4.1. Naming convention

The FLEX product naming conventions are fully described in the FLEX PDGS Products Naming Convention and Definition document [AD-10]. The goal of this section is not to repeat the same information but to provide a summary with key practical elements to end-users of the FLEX L1C and L2 products. The description of the files content is described in Section 5.

Note: after discussion with ESA, the relevant impacted documentation will be updated in Sept. starting from an updated version of the ESA-EOPG-EOEP-TN-0015_[FLEX PDGS Products Naming Convention and Definition]_[2.13] document.

4.1.1. FLEX L1C products

The file naming convention for FLEX L1C product is identified by the sequence of fields described here.

<MMM>_<TTTTTTTTTT>_<instance ID>_<DDDD>.<EXT>

<MMM> is the Mission ID. For FLEX, it is fixed, and equal to "FLX".

<TTTTTTTTTT> is the file type element, which identifies the product, and it consists of 10 characters, either uppercase letters, digits or underscores "_". For FLEX, the File Type is subdivided into two sub-elements of respectively 3 and 6 characters separated by an underscore "_", as follow: <TTTTTTTTTT> = <FFF>_<DDDDDD> where <FFF> is the file category and <DDDDDD> is a semantic description.

- <FFF> is the "File Category" element and it consists of 3 characters (3 uppercase letters, digits or underscores ""). For the FLEX L1C products, this is fixed to <FFF>="L1C" (i.e. Earth Observation L1C products).
- <DDDDDD> is a "Semantic Descriptor" and it is unique and as descriptive as possible. For the L1C products, this will get the value "FLXSYN".

The <instance ID> field consists of a series of characters, either uppercase letters or digits or underscores "_"". For the L1C products, it includes the following:

<instance ID> = yyyymmddThhmmss_yyyymmddThhmmss_YYYYMMDDTHHMMSS_SSSS_CCC_LLL_SSSS_BB

- The first two dates correspond to the sensing start and stop time respectively.
- The following date refers to the product creation date.
- SSSS identifies the duration of the acquisition in seconds. This value is set by the processor and it matches with the difference between start and stop sensing time

described above. For the L1C products this value is typically 0195 to 0200 (i.e., 180 s = 3 min of L1B slices + 15 to 20 seconds of margins).

- CCC is the cycle number at the start sensing time of the product.
- LLL is the relative orbit number within the cycle at the start sensing time of the product.
- SSSS is the elapsed time, in seconds, from the ascending node corresponding to the sensing start time.
- BB is a two digits value field that represents the baseline of the production chain and identifies the version of the processor that computes the product. This value is defined at PDGS level as an input found in the JobOrder (e.g., "01").

The field <DDDD> is the Suffix ID. It is an optional string that allows distinguishing different files composing the same product. In the case of L1C products, the suffix ID is not used.

Finally <EXT> is the filename extension (e.g., .nc for netcdf or xml for hierarchical metadata).

An example of a FLEX L1C product filename is:
`flc_l1c_flxsyn_20270314T101206_20270314T101521_20270314T120248_0195_005_179_2339_01.nc`

It identifies a Level-1C product acquired on the 14th of March, 2027 starting the acquisition at 10:12:06 AM and finishing at 10:15:21. The file was processed on the same day of acquisition at 12:02:48 AM. The file was 195 s of acquisition time, on the cycle number 5, relative orbit number 179 with 2339 s from the ascending node.

4.1.2. FLEX L2 products

The file naming convention for FLEX L2 products follows a similar convention as the L1C product (fully documented in [AD-10]) with a few variations.

The "File Category" element, <FFF>, is fixed to <DDD>="L2_" (i.e. Earth Observation L2 products). The "Semantic Descriptor", <DDDDDD>, is fixed to "FLXSYN".

Regarding the <instance ID> field, the convention applied for the L1C product is adapted for a better suitability in the L2 products. The <instance ID> includes the following:

`<instance ID> = yyyymmddThhmmss_yyyymmddThhmmss_YYYYMMDDTHHMMSS_TTTTT_CCC_LLL_BB`

- The first two dates correspond to the lowest and highest sensing time of the data in a tile.
- The third date refers to the product creation date.

- `TTTTT` is the tile ID (e.g. 31SDD).
- `CCC` is the cycle number at the start sensing time of the product.
- `LLL` is the relative orbit number within the cycle at the start sensing time of the product.
- `BB` is a two digits value field that represents the baseline of the production chain and identifies the version of the processor that computes the product. This value is defined at PDGS level as an input found in the JobOrder (e.g., “01”).

The cycle number and relative orbit number are useful to identify the segment of the orbit that generated the tile, which is often useful for finding out whether the tile is on the edge of a swath or not.

An example of a FLEX L2 product filename is:
`flc_l2_flxsyn_20270314T101206_20270314T101521_20270314T120248_31sdd_005_179_01.nc`

It identifies a Level-2 product whose first and last sensing time were on the 14th of March, 2027 at 10:12:06 AM and 10:15:21 AM respectively. The file was processed on the same day of acquisition at 12:02:48 AM. The file corresponds to the cycle number 5, relative orbit number 179. The L2 product is provided on the UTM tile 31SDD.

4.2. Data formats

A FLEX L1C and L2 product data format refers to a directory with an MPH file (i.e., an .xml file) and one or more scientific data files (in netCDF), as per relevant documentation (e.g. ESA-EOPG-EOEP-TN-0015):

- a product metadata file (MPH) in XML format describes the physical organization and the content of the product;
- and the scientific data files (in netcdf), including the image data, and associated ancillary information (e.g., wavelengths, quality flags, uncertainties), and metadata (e.g., cloud coverage).

4.2.1. Product metadata (MPH)

L1C and L2 MPH will be based on L1B one, by adding the following variables as generic or “vendorSpecific” properties:

- For L1C MPH
  - Preliminary percentage of the cloud coverage (in EarthObservationResult/cloudCoverPercentage node and sibling)
- For L2 MPH
  - Percentage of cloud coverage (in EarthObservationResult/cloudCoverPercentage node and sibling)

- ○ Tile number according to the US-MGRS naming convention

TBW

4.2.2. Scientific data files

The scientific content of the FLEX L1C and L2 products is made available to end-users in NetCDF-4 Classic Model Format. NetCDF (network Common Data Form) is a set of software libraries and machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data. In order to make NetCDF files "self-describing", the names of variables, dimensions, and other attributes playing a vital role in providing ancillary information are described following the CF convention (https://cfconventions.org). The following guidelines are applied for the L1C and L2 product files.

- File name: NetCDF files have the file name extension ".nc".
- A NetCDF dataset contains dimensions, variables, and attributes. The names of dimensions, variables and attributes consist of arbitrary sequences of alphanumeric characters that begin with a letter and can be composed of letters, digits, and underscores. Case is significant in NetCDF names.
- Dimensions: are used to represent a real physical dimension (e.g., time, number of samples). A NetCDF dimension has both a name and a length. A dimension length is an arbitrary positive integer. In a NetCDF-4 dataset, any number of unlimited dimensions can be used.
- Data variables: Variables are used to store the bulk of the data in a NetCDF dataset. A variable represents an array of values of the same type. A scalar value is treated as a 0-dimensional array. A variable has a name, a data type, and a shape described by its list of dimensions specified when the variable is created. A variable has associated attributes such as units, dimensions, or long name.
- Data variables attributes: NetCDF attributes are used to store data about the data (ancillary data or metadata). Most attributes provide information about a specific variable. Regarding the description of the data, the different data variables contain at least the following attributes:
  - Varname: Descriptive and meaningful variable name. Variable names should begin with a letter and be composed of letters, digits, and underscores. Since variable names can be case-insensitive, the same case-insensitive names are not used for multiple variables within a single file.
  - Units: A character array that specifies the units used for the variable's data. Where possible the units attribute are formatted as per the recommendations in the Unidata udunits package.
  - Long name: This attribute is used to include a more detailed description of the data (title). This could be used for labeling plots, for example. By default this field shall contain the same information as the Varname field.
  - Number of dimensions: All netCDF variables are defined on either one, two, three, or four dimensions (the nature of the data will dictate the natural encoding).

Where it makes sense, single point locations are encoded as coordinate variables, for example, the latitude and longitude positions of a vertical profile are natural candidates for single point latitude and longitude coordinate variables.

  - In addition, the netCDF standard attributes add_offset and scale_factor can be used to automatically convert (U)SHORTs to floating-point values during the processing.

- Global attributes (file header): The NetCDF files contain some basic data in global attributes. The FLEX L1C and L2 products include (**TBC**):
  - Product level: using the file type element in the product naming convention i.e., "L1C_FLXSYN" for L1C product, or "L2__FLXSYN" for L2 product.
  - Sentinel-3 availability: a flag indicating whether the L1C or L2 product was generated with Sentinel-3 data (true) or FLORIS only (false) i.e., with the contingency plan .
  - Cloud coverage: percentage of pixels covered by clouds.
  - Source: version of data processing baseline.
  - History: audit trail of processing operations.
  - References: pointers to publications or web documentation.
  - Comment: miscellaneous.

It shall be noted that the output NetCDF files follow the C convention for defining the dimensions. Fortran users (e.g., for codes developed in Matlab) must be aware that dimensions are permuted/reversed with respect to the C convention.

In the following Section 5, the content of the NetCDF files is presented in two tables. The first one summarizes the dimensions while the second table describes the data variables. A template of these two tables is shown below.

Dimension name and default value	Description
Name of dimension	Description associated to this dimension

Name	Value	Type
Global attributes		
Product level	L1C	string
Source	v1.0	string
S3 availability	true (if Sentinel-3 data is available) or false	logical
Cloud coverage	0% to 100%	int16
DOY	1 to 365	int16
History		string

References		string
Comment		string

Group_name

variable_type **variable_name**(*dimension_1, dimension_2*) ;	
standard_name	
short_name	
long_name	
units	
description	
add_offset	
scale_factor	

5. Product structure and format

5.1. Level-1C product

Dimension name and default value	Description
number_of_across_track_samples = 536 ;	Number of row in the product (sensor frame)
number_of_along_track_samples = 4656 ;	Number of columns in the product (sensor frame)
number_of_aot_wavelengths = 3 ;	Number of AOT wavelengths
number_of_floris_spectral_channels = 580 ;	Number of FLORIS spectral channels, after merging the two FLORIS spectrometers (HR & LR)
number_of_geometrical_dimensions = 2 ;	Number of geometrical dimensions (lon, lat)
number_of_instruments = 4 ;	Number of instruments toto
number_of_olci_spectral_channels = 21 ;	Number of OLCI spectral channels
number_of_slstr_tir_spectral_channels = 3 ;	Number of SLSTR spectral channels (only TIR)
number_of_slstr_vswir_spectral_channels = 6 ;	Number of SLSTR spectral channels (only VSWIR)
number_of_tie_pressure_levels = 25 ;	Number of tie pressure levels

number_of_crosscalibration_channels = 8 ;	Number of cross-calibration channels

Name	Value	Type
Global attributes		
Product_level	L1C	string
Source	v1.0	string
S3_availability	true (if Sentinel-3 data is available) or false	logical
Cloud_coverag e	0% to 100%	int16
DOY	1 to 365	int16
History		string
References		string
Comment		string

Group: Measurement_data

ushort **floris_toa_radiance**(*number_of_along_track_samples, number_of_across_track_samples, number_of_floris_spectral_channels*) ;	
standard_name	floris_toa_radiance
short_name	FLORIS TOA rad.
long_name	FLORIS Top of Atmosphere radiance
units	mW.m-2.sr-1.nm-1
description	FLORIS TOA radiance spectral hypercube, spectrally and radiometrically calibrated
add_offset	
scale_factor	
ushort **floris_toa_radiance_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples, number_of_floris_spectral_channels*) ;	
standard_name	floris_toa_radiance_uncertainty
short_name	FLORIS TOA rad. unc.
long_name	Uncertainties of FLORIS Top of Atmosphere radiance

units	mW.m-2.sr-1.nm-1
description	Radiance uncertainty associated to floris_toa_radiance_uncertainty
add_offset	
scale_factor	
ushort **olci_toa_radiance**(*number_of_along_track_samples, number_of_across_track_samples, number_of_olci_spectral_channels*) ;	
standard_name	olci_toa_radiance
short_name	OLCI TOA rad.
long_name	OLCI Top of Atmosphere radiance
units	mW.m-2.sr-1.nm-1
description	OLCI TOA radiance spectral hypercube, reprojected into FLORIS geometrical frame
add_offset	
scale_factor	
ushort **slstr_nadir_toa_radiance**(*number_of_along_track_samples, number_of_across_track_samples, number_of_slstr_vswir_spectral_channels*) ;	
standard_name	slstr_nadir_toa_radiance
short_name	SLSTR nad. TOA rad.
long_name	SLSTR Nadir Top of Atmosphere radiance
units	mW.m-2.sr-1.nm-1
description	SLSTR_nadir TOA radiance spectral hypercube (VSWIR channels), reprojected into FLORIS geometrical frame
add_offset	
scale_factor	
ushort **slstr_nadir_tir_toa_radiance**(*number_of_along_track_samples, number_of_across_track_samples, number_of_slstr_tir_spectral_channels*) ;	
standard_name	slstr_nadir_tir_toa_radiance
short_name	SLSTR TIR TOA rad.
long_name	SLSTR TIR Top of Atmosphere radiance
units	mW.m-2.sr-1.nm-1
description	SLSTR_nadir TOA radiance spectral hypercube (TIR channels), reprojected into FLORIS geometrical frame
add_offset	
scale_factor	
ushort **slstr_oblique_toa_radiance**(*number_of_along_track_samples,*	

number_of_across_track_samples, number_of_slstr_vswir_spectral_channels) ;	
standard_name	slstr_oblique_toa_radiance
short_name	SLSTR obl. TOA rad.
long_name	SLSTR Oblique Top of Atmosphere radiance
units	mW.m-2.sr-1.nm-1
description	SLSTR_oblique TOA radiance spectral hypercube (VSWIR channels), reprojected into FLORIS geometrical frame
add_offset	
scale_factor	

Group: Annotation_data/Instrumental_information

float **floris_spectral_channel_central_wavelengths**(*number_of_across_track_samples, number_of_floris_spectral_channels*) ;	
standard_name	floris_spectral_channel_central_wavelengths
short_name	wvl_floris
long_name	Central wavelengths of the FLORIS instrument
units	nm
description	Central wavelengths of the FLORIS spectral channels, detailed for each column to take into account the smile effect
float **floris_instrument_flag**(*number_of_across_track_samples, number_of_floris_spectral_channels*) ;	
standard_name	floris_instrument_flag
short_name	floris_instrument_flag
long_name	Floris instrument flag
units	-
description	Identification of the source spectrometer & binning flag after merging FLORIS-HR and -LR TOA radiance data. 1: FLORIS-LR unbinned 2: FLORIS-LR binned 3: FLORIS-HR1 unbinned 4: FLORIS-HR1 binned 5: FLORIS-HR2 unbinned 6: FLORIS-HR2 binned
float **floris_spectral_channel_fwhm**(*number_of_across_track_samples, number_of_floris_spectral_channels*) ;	

standard_name	floris_spectral_channel_fwhm
short_name	fwhm_floris
long_name	Full Width Half-Maximum (FWHM) of the FLORIS instrument
units	nm
description	FWHM (spectral resolution) of the FLORIS spectral channels
float **floris_spectral_channel_central_wavelengths_uncertainty**(*number_of_across_track_samples, number_of_floris_spectral_channels*) ;	
standard_name	floris_spectral_channel_central_wavelengths_uncertainty
short_name	wvl_floris_unc
long_name	Central wavelengths uncertainty of the FLORIS instrument
units	nm
description	Uncertainty associated to FLORIS central wavelengths
float **floris_spectral_channel_fwhm_uncertainty**(*number_of_across_track_samples, number_of_floris_spectral_channels*) ;	
standard_name	floris_spectral_channel_fwhm_uncertainty
short_name	fwhm_floris_unc
long_name	Full Width Half-Maximum (FWHM) uncertainty of the FLORIS instrument
units	nm
description	Uncertainty associated to FLORIS FWHM
float **olci_spectral_channel_central_wavelengths**(*number_of_olci_spectral_channels*) ;	
standard_name	olci_spectral_channel_central_wavelengths
short_name	wvl_olci
long_name	Central wavelengths of the OLCI instrument
units	nm
description	Central wavelengths of the OLCI spectral channels
float **slstr_vswir_spectral_channel_central_wavelengths**(*number_of_slstr_vswir_spectral_channels*) ;	
standard_name	slstr_vswir_spectral_channel_central_wavelengths
short_name	wvl_slstr_vswir
long_name	Central wavelengths of the SLSTR instrument (VSWIR channels)
units	nm
description	Central wavelengths of the SLSTR VSWIR spectral channels

float **slstr_tir_spectral_channel_central_wavelengths**(*number_of_slstr_tir_spectral_channels*) ;	
standard_name	slstr_tir_spectral_channel_central_wavelengths
short_name	wvl_slstr_tir
long_name	Central wavelengths of the SLSTR instrument (TIR channels)
units	nm
description	Central wavelengths of the SLSTR TIR spectral channels
float **crosscalibration_coefficients**(*number_of_crosscalibration_channels*) ;	
standard_name	crosscalibration_coefficients
short_name	crosscalibration_coeff
long_name	Crosscalibration coefficients
units	-
description	Multiplicative crosscalibration coefficients between OLCI and FLORIS

Group: Annotation_data/Meteorology

ushort **aerosol_optical_thickness**(*number_of_along_track_samples, number_of_across_track_samples, number_of_aot_wavelengths*) ;	
standard_name	aerosol_optical_thickness
short_name	AOT
long_name	Aerosol Optical Thickness
units	-
description	Aerosol Optical Thickness at three wavelengths (550, 670, 865) coming from CAMS forecasting
meaning	550, 670, 865
add_offset	
scale_factor	
float **total_columnar_water_vapor**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	total_columnar_water_vapor
short_name	CWV
long_name	Total Columnar Water Vapor (CWV)
units	g.m-2

description	Total Columnar Water Vapor (CWV), ECMWF data resampled to FLORIS-HR geometry
float **tie_pressure_levels**(*number_of_tie_pressure_levels)* ;	
standard_name	tie_pressure_levels
short_name	tie_pressure_levels
long_name	Tie pressure levels
units	hPa
description	Pressure levels at which the temperature profile is provided
float **total_ozone**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	total_ozone
short_name	O3
long_name	Total Ozone (O3)
units	atm-cm
description	Total Ozone (O3), ECMWF data resampled to FLORIS-HR geometry
float **temperature_profile**(*number_of_along_track_samples, number_of_across_track_samples, number_of_tie_pressure_levels*) ;	
standard_name	temperature_profile
short_name	temp_profile
long_name	Temperature profile
units	K
description	Temperature profile coming from ECMWF at the location and time of observation

Group: Annotation_data/Geometry

float **surface_slope**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	surface_slope
short_name	surface_slope
long_name	Surface slope
units	degrees
description	Surface slope
float **surface_aspect**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	surface_aspect

short_name	aspect
long_name	Surface aspect
units	degrees
description	Surface aspect
float **surface_elevation**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	surface_elevation
short_name	elevation
long_name	Surface elevation over geoid EGM96
units	m
description	Surface elevation over geoid EGM96, from GETASSE30 DEM
ushort **sun_zenith_angle**(*number_of_along_track_samples, number_of_across_track_samples, number_of_instruments*) ;	
standard_name	sun_zenith_angle
short_name	SZA
long_name	Sun Zenith Angle (SZA)
units	degrees
description	Sun Zenith Angle for all instruments after projection in the FLORIS-HR frame. In the following order: FLORIS, OLCI, SLSTR nadir, SLSTR oblique
meaning	FLORIS, OLCI, SLSTR_nad, SLSTR_obl
add_offset	
scale_factor	
ushort **viewing_zenith_angle**(*number_of_along_track_samples, number_of_across_track_samples, number_of_instruments*) ;	
standard_name	viewing_zenith_angle
short_name	VZA
long_name	Viewing Zenith Angle (VZA)
units	degrees
description	Viewing Zenith Angle for all instruments after projection in the FLORIS-HR frame. In the following order: FLORIS, OLCI, SLSTR nadir, SLSTR oblique
meaning	FLORIS, OLCI, SLSTR_nad, SLSTR_obl
add_offset	
scale_factor	
ushort **sun_azimuth_angle**(*number_of_along_track_samples, number_of_across_track_samples, number_of_instruments*) ;	

standard_name	sun_azimuth_angle
short_name	SAA
long_name	Sun Azimuth Angle (SAA)
units	degrees
description	Sun Azimuth Angle for all instruments after projection in the FLORIS-HR frame. In the following order: FLORIS, OLCI, SLSTR nadir, SLSTR oblique
meaning	FLORIS, OLCI, SLSTR_nad, SLSTR_obl
add_offset	
scale_factor	
ushort **relative_azimuth_angle**(*number_of_along_track_samples, number_of_across_track_samples, number_of_instruments*) ;	
standard_name	relative_azimuth_angle
short_name	RAA
long_name	Relative Azimuth Angle (RAA)
units	degrees
description	Relative Azimuth Angle for all instruments after projection in the FLORIS-HR frame. In the following order: FLORIS, OLCI, SLSTR nadir, SLSTR oblique
meaning	FLORIS, OLCI, SLSTR_nad, SLSTR_obl
add_offset	
scale_factor	
float **latitude**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	latitude
short_name	lat
long_name	Latitude
units	degrees_north
description	Latitude ground coordinate associated to each pixel in WGS84 convention (geographic)
float **longitude**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	longitude
short_name	lon
long_name	Longitude
units	degrees_east
description	Longitude ground coordinate associated to each pixel in WGS84 convention (geographic)

float **average_coregistration_uncertainty**(*number_of_instruments*, *number_of_geometrical_dimensions*) ;	
standard_name	average_coregistration_uncertainty
short_name	avg_coregis_unc
long_name	Average Coregistration Uncertainty
units	degrees
description	Global coregistration uncertainty, longitude and latitude component describing the uncertainty ellipse

Group: Annotation_data/Quality

short **quality_flags**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	quality_flags
short_name	qc_flags
long_name	Quality flags map for all the instruments
units	-
description	List of bit fields describing boolean flags: 1 2 4 8 16 32 64 128
meaning	"invalid FLORIS-HR, invalid FLORIS-LR, invalid OLCI, invalid SLSTR nadir, invalid SLSTR oblique, speare1, speare2, speare3, speare4"

Group: Annotation_data/Datation

float **time_stamp**(*number_of_along_track_samples*) ;	
standard_name	time_stamp
short_name	t
long_name	Time stamp
units	µs
description	Elapsed time since 01 Jan 2000

Group: Annotation_data/Ancillary_data

float **floris_extraterrestrial_solar_irradiance**(*number_of_across_track_samples, number_of_floris_spectral_channels*) ;	
standard_name	floris_extraterrestrial_solar_irradiance
short_name	floris_Iext
long_name	FLORIS extraterrestrial solar irradiance
units	mW.m-2.nm-1
description	Extraterrestrial solar irradiance at FLORIS spectral channels
float **olci_extraterrestrial_solar_irradiance**(*number_of_olci_spectral_channels*) ;	
standard_name	olci_extraterrestrial_solar_irradiance
short_name	olci_Iext
long_name	OLCI extraterrestrial solar irradiance
units	mW.m-2.nm-1
description	Extraterrestrial solar irradiance at OLCI spectral channels
float **slstr_extraterrestrial_solar_irradiance**(*number_of_slstr_vswir_spectral_channels*) ;	
standard_name	slstr_extraterrestrial_solar_irradiance
short_name	slstr_Iext
long_name	SLSTR extraterrestrial solar irradiance
units	mW.m-2.nm-1
description	Extraterrestrial solar irradiance at SLSTR spectral channels
short **pixel_classification**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	pixel_classification
short_name	pixel_classification
long_name	Pixel classification
units	-
description	Pixel classification. The following IDs are used : 0 = Not-valid, 1 = Land (non-vegetation: bare soil, manmade…) 2 = Water 3 = Coastline 4 = Tidal region 5 = Cloud/bright 6 = Sun-glint risk 7 = Preliminary cloud shadow 8 = Sparse vegetation 9 = Dense vegetation
meaning	Not-valid, Land (non-vegetation: bare soil, manmade…), Water, Coastline, Tidal region, Cloud/bright, Sun-glint risk, Preliminary cloud shadow, Sparse vegetation, Dense vegetation" ;

Table 5-1: FLEX L1C product data file format

5.2. Level-2 product

Dimension name and default value	Description
number_of_along_track_samples = 366 ;	Number of row in the product (UTM frame)
number_of_across_track_samples = 366 ;	Number of columns in the product (UTM frame)
number_of_apparent_reflectance_spectral_channels = 580;	Number of FLORIS spectral channels, after merging the two FLORIS spectrometers (HR & LR)
number_of_olci_spectral_channels = 21 ;	Number of OLCI spectral channels
number_of_slstr_vswir_spectral_channels = 6 ;	Number of SLSTR spectral channels (only VSWIR)
number_of_par_spectral_samples = 628;	Number of solar irradiance spectral channels
number_of_real_reflectance_spectral_samples = 140 ;	Number of real reflectance spectral channels
number_of_sif_spectral_samples = 55 ;	Number of fluorescence spectral channels
number_of_sif_peaks = 2 ;	Number of SIF peak values (red and far-red)

Global attributes			
Product level	L2__FLXSYN	string	1
Source	v1.0	string	1
S3 availability	true (if Sentinel-3 data is available) or false	logical	1
Cloud coverage	0% to 100%	int16	1
History		string	1
References		string	1
Comment		string	1

Group: L2 Atmosphere

float **cloud_probability**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	cloud_probability
short_name	P_cloud
units	-
long_name	Cloud probability
description	Cloud probabilty map
short **cirrus_cloud_mask**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	cirrus_cloud_mask
short_name	cirrus_mask
units	-
long_name	Cirrus cloud mask
description	Cirrus cloud mask
ushort **floris_apparent_reflectance**(*number_of_along_track_samples, number_of_across_track_samples, number_of_apparent_reflectance_spectral_channels*) ;	
standard_name	floris_apparent_reflectance
short_name	rho_app_floris
units	-
long_name	FLORIS apparent reflectance
description	Apparent reflectance measured with FLORIS spectrometers in the 680-780 nm spectral region
add_offset	
scale_factor	
ushort **floris_apparent_reflectance_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples, number_of_apparent_reflectance_spectral_channels*) ;	
standard_name	floris_apparent_reflectance_uncertainty
short_name	rho_app_floris_unc
units	-
long_name	FLORIS apparent reflectance uncertainty
description	Per pixel reflectance uncertainty associated to the FLORIS apparent reflectance measurement
add_offset	
scale_factor	
float **olci_apparent_reflectance**(*number_of_along_track_samples, number_of_across_track_samples, number_of_olci_spectral_channels*) ;	
standard_name	olci_apparent_reflectance
short_name	rho_app_olci
units	-

long_name	OLCI apparent reflectance
description	Apparent reflectance measured with OLCI instrument
float **slstr_apparent_reflectance**(*number_of_along_track_samples, number_of_across_track_samples, number_of_slstr_vswir_spectral_channels*) ;	
standard_name	slstr_apparent_reflectance
short_name	rho_app_slstr
units	-
long_name	SLSTR apparent reflectance
description	Apparent reflectance measured with SLSTR instrument (nadir)
float **floris_spectral_channel_central_wavelength**(*number_of_apparent_reflectance_spectral_channels*) ;	
standard_name	floris_spectral_channel_central_wavelength
short_name	wvl_floris
units	nm
long_name	Central wavelengths of the FLORIS instrument spectral channels
description	Central wavelengths of the FLORIS spectral channels
float **olci_spectral_channel_central_wavelength**(*number_of_olci_spectral_channels* ;	
standard_name	olci_spectral_channel_central_wavelengths
short_name	wvl_olci
units	nm
long_name	Central wavelengths of the OLCI instrument
description	Central wavelengths of the OLCI spectral channels
float **slstr_vswir_spectral_channel_central_wavelengths**(*number_of_slstr_vswir_spectral_channels*) ;	
standard_name	slstr_vswir_spectral_channel_central_wavelengths
short_name	wvl_slstr_vswir
units	nm
long_name	Central wavelengths of the SLSTR instrument (VSWIR channels)
description	Central wavelengths of the SLSTR VSWIR spectral channels
float **land_surface_temperature**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	land_surface_temperature
short_name	LST
units	K
long_name	Land Surface Temperature (LST)
description	Land Surface Temperature measured with SLSTR thermal channels
ushort **direct_irradiance**(*number_of_along_track_samples, number_of_across_track_samples, number_of_par_spectral_samples*) ;	
standard_name	direct_irradiance
short_name	E_dir

units	mW.m-2.nm-1
long_name	At-surface direct solar irradiance at FLORIS channels
description	Surface direct solar irradiance measured with FLORIS instrument and resampled to par_spectral_sampling, weighted with the cosinus of the illumination angle
add_offset	
scale_factor	
ushort **direct_irradiance_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples, number_of_par_spectral_samples*) ;	
standard_name	direct_irradiance_uncertainty
short_name	E_dir_unc
units	mW.m-2.nm-1
long_name	Uncertainty of at-surface direct solar irradiance at FLORIS channels
description	Per pixel irradiance uncertainty associated to the FLORIS at surface direct solar irradiance measurement
add_offset	
scale_factor	
ushort **diffuse_irradiance**(*number_of_along_track_samples, number_of_across_track_samples, number_of_par_spectral_samples*) ;	
standard_name	diffuse_irradiance
short_name	E_diff
units	mW.m-2.nm-1
long_name	At-surface diffuse solar irradiance at FLORIS channels
description	Surface diffuse solar irradiance measured with FLORIS instrument and resampled to par_spectral_sampling, weighted with the cosinus of the illumination angle
add_offset	
scale_factor	
ushort **diffuse_irradiance_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples, number_of_par_spectral_samples*) ;	
standard_name	diffuse_irradiance_uncertainty
short_name	E_diff_unc
units	mW.m-2.nm-1
long_name	Uncertainty of at-surface diffuse solar irradiance at FLORIS channels
description	Per pixel irradiance uncertainty associated to the FLORIS at surface diffuse_solar_irradiance measurement
add_offset	
scale_factor	
float **irradiance_wavelength_grid**(*number_of_par_spectral_samples*) ;	

standard_name	irradiance_wavelength_grid
short_name	wvl_irr
units	nm
long_name	Spectral sampling associated to at-surface solar irradiance
description	Spectral grid associated with the solar irradiance
float **integrated_par**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	integrated_par
short_name	par_int
units	µmol.photons.m-2.s-1
long_name	Integrated at surface solar irradiance in the 400-700 nm region
description	Integrated Photosynthetically Active Radiation (PAR), resulting from the integration of the total at-surface solar irradiance in the spectral range 400-700 nm.
float **aerosol_optical_thickness**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	aerosol_optical_thickness
short_name	AOT
units	-
long_name	Aerosol optical thickness at 550 nm
description	Aerosol optical thickness at 550 nm
float **asymmetry_parameter**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	asymmetry_parameter
short_name	ASY
units	-
long_name	Asymmetry parameter
description	Spectrally-constant aerosol asymmetry parameter assuming Henyey-Greenstein phase function
float **angstrom_exponent**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	angstrom_exponent
short_name	ANG
units	-
long_name	Angstrom exponent
description	Angstrom exponent of boundary later aerosols
float **columnar_water_vapor**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	columnar_water_vapor
short_name	CWV
units	g.cm-2
long_name	Columnar water vapor
description	Columnar water vapor

Group: L2 Fluorescence

ushort **sif_emission_spectrum**(*number_of_along_track_samples, number_of_across_track_samples, number_of_sif_spectral_samples*) ;	
standard_name	sif_emission_spectrum
short_name	sif_spectrum
units	mW.m-2.sr-1.nm-1
long_name	Solar Induced Fluorescence emission spectrum
description	Solar Induced Fluorescence emission
add_offset	
scale_factor	
ushort **sif_emission_spectrum_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples, number_of_sif_spectral_samples*) ;	
standard_name	sif_emission_spectrum_uncertainty
short_name	sif_spectrum_unc
units	mW.m-2.sr-1.nm-1
long_name	Solar Induced Fluorescence emission spectrum uncertainty
description	Uncertainty associated to the Solar Induced Fluorescence emission
add_offset	
scale_factor	
float **sif_wavelength_grid**(*number_of_sif_spectral_samples*) ;	
standard_name	sif_wavelength_grid
short_name	wvl_sif
units	nm
long_name	SIF wavelength grid
description	Spectral sampling grid of the sif product (670-780 nm)
float **total_integrated_sif**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	total_integrated_sif
short_name	sif_tot
units	mW.m-2.sr-1
long_name	Total integrated Solar-Induced Fluorescence
description	Total integrated Solar-Induced Fluorescence over the sif spectral samples
float **total_integrated_sif_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	total_integrated_sif_uncertainty

short_name	sif_tot_unc
units	mW.m-2.sr-1
long_name	Total integrated Solar-Induced Fluorescence uncertainty
description	Uncertainty associated to the total integrated Solar-Induced Fluorescence over the sif spectral samples
float **sif_peak_values**(*number_of_along_track_samples, number_of_across_track_samples, number_of_sif_peaks*) ;	
standard_name	sif_peak_values
short_name	sif_values
units	mW.m-2.sr-1.nm-1
long_name	SIF peak maximum value
description	Maximum value of the sif peaks (red, far-red)
meaning	"Red Peak", "Far-red Peak"
float **sif_peak_values_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples, number_of_sif_peaks*) ;	
standard_name	sif_peak_values_uncertainty
short_name	sif_values_unc
units	mW.m-2.sr-1.nm-1
long_name	SIF peak maximum value uncertainty
description	Uncertainty associated to the maximum value of the sif peaks (red, far-red)
meaning	"Red Peak", "Far-red Peak"
float **sif_peak_positions**(*number_of_along_track_samples, number_of_across_track_samples, number_of_sif_peaks*) ;	
standard_name	sif_peak_postitions
short_name	sif_positions
units	nm
long_name	SIF peak maximum position
description	Position of the maximum value of the sif peaks (red, far-red)
meaning	"Red Peak", "Far-red Peak"
float **sif_peak_positions_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples, number_of_sif_peaks*) ;	
standard_name	sif_peak_postitions_uncertainty
short_name	sif_positions_unc
units	nm
long_name	SIF peak maximum position uncertainty
description	Uncertainty associated to the position of the maximum value of the sif peaks (red, far-red)
meaning	"Red Peak", "Far-red Peak"

float **sif_O2_bands_value**(*number_of_along_track_samples, number_of_across_track_samples, number_of_sif_o2_values*) ;	
standard_name	sif_O2_bands_value
short_name	sif_O2
units	mW.m-2.sr-1.nm-1
long_name	Solar Induced Fluorescence value in the O2 bands
description	Value of the Solar Induced Fluorescence in the O2B bands
meaning	"O2B band (684nm)", "O2A band (761nm)"
float **sif_O2_bands_value_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples, number_of_sif_peaks*) ;	
standard_name	sif_O2_bands_value_uncertainty
short_name	sif_O2_unc
units	mW.m-2.sr-1.nm-1
long_name	Solar Induced Fluorescence value in the O2 bands uncertainty
description	Uncertainty associated to the value of the Solar Induced Fluorescence in the O2B bands
meaning	"O2B band (684nm)", "O2A band (761nm)"
ushort **floris_real_reflectance**(*number_of_along_track_samples, number_of_across_track_samples, number_of_real_reflectance_spectral_samples*) ;	
standard_name	floris_real_reflectance
short_name	real_refl
units	-
long_name	FLORIS real reflectance
description	Real reflectance retrieved from FLORIS measurements
add_offset	
scale_factor	
ushort **floris_real_reflectance_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples, number_of_real_reflectance_spectral_samples*) ;	
standard_name	floris_real_reflectance_uncertainty
short_name	real_refl_unc
units	-
long_name	FLORIS real reflectance uncertainty
description	Per pixel Fluorescence uncertainty associated to the sif_emission_spectrum measurement
add_offset	
scale_factor	
float **reflectance_wavelength_grid**(*number_of_along_track_samples, number_of_across_track_samples, number_of_real_reflectance_spectral_samples*) ;	

standard_name	reflectance_wavelength_grid
short_name	wvl_refl
units	nm
long_name	Real Reflectance wavelength grid
description	Spectral sampling grid of the real reflectance product. Spectral range from 500 to 780 nm

Group: L2 Vegetation

float **leaf_area_index**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	leaf_area_index
short_name	LAI
units	m2.m-2
long_name	Leaf Area Index
description	Leaf Area Index (LAI), mean retrieved from GPR algorithm
float **leaf_area_index_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	leaf_area_index_uncertainty
short_name	LAI_unc
units	m2.m-2
long_name	Leaf Area Index uncertainty
description	Uncertainty associated with Leaf Area Index measurement, standard deviation retrieved from GPR algorithm
float **leaf_chlorophyll_content**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	leaf_chlorophyll_content
short_name	LCC
units	µg.cm-2
long_name	Leaf Chlorophyll Content
description	Leaf Chlorophyll Content (LCC) mean retrieved from GPR algorithm
float **leaf_chlorophyll_content_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	leaf_chlorophyll_content_uncertainty
short_name	LCC_unc
units	µg.cm-2
long_name	Leaf Chlorophyll Content uncertainty
description	Uncertainty associated with Leaf Chlorophyll Content measurement, standard deviation retrieved from GPR algorithm
float **leaf_carotenoid_content**(*number_of_along_track_samples, number_of_across_track_samples*) ;	

standard_name	leaf_carotenoid_content
short_name	LCCAR
units	μg.cm-2
long_name	Leaf Carotenoid Content
description	Leaf carotenoid content (LCCAR) mean retrieved from GPR algorithm
float **leaf_carotenoid_content_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	leaf_carotenoid_content_uncertainty
short_name	LCCAR_unc
units	μg.cm-2
long_name	Leaf Carotenoid Content uncertainty
description	Uncertainty associated with Leaf Carotenoid Content measurement, standard deviation retrieved from GPR algorithm
float **fraction_of_absorbed_photosynthetically_active_radiation**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	fraction_of_absorbed_photosynthetically_active_radiation
short_name	FAPAR
units	μmol.μmol-1
long_name	Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
description	Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), integrated over the 400-700 nm region. Mean retrieved from GPR algorithm
float **fraction_of_absorbed_photosynthetically_active_radiation_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	fraction_of_absorbed_photosynthetically_active_radiation_uncertainty
short_name	FAPAR_unc
units	μmol.μmol-1
long_name	Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) Uncertainty
description	Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), integrated over the 400-700 nm region. Standard deviation retrieved from GPR algorithm
float **non_photochemical_quenching**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	non_photochemical_quenching
short_name	npq
units	-
long_name	Non-Photochemical Quenching

description	Non-Photochemical Quenching
float **apar_chlorophyll_photons**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	apar_chlorophyll_photons
short_name	apar_chl_photons
units	µmol.photons.m-2.s-1
long_name	Chlorophyll-Absorbed PAR photons
description	Total amount of light absorbed by chlorophyll a, expressed in absorbed photons per second, integrated in the wavelength range 400-780 nm
float **apar_chlorophyll_photons_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	apar_chlorophyll_photons_uncertainty
short_name	apar_chl_photons_unc
units	µmol.photons.m-2.s-1
long_name	Chlorophyll-Absorbed PAR photons uncertainty
description	Uncertainty associated with apar_chlorophyll_photons
float **fluorescence_quantum_efficiency**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	fluorescence_quantum_efficiency
short_name	FQE
units	µmol.µmol-1
long_name	Fluorescence Quantum Efficiency (FQE)
description	Fluorescence quantum efficiency (FQE) as the dimensionless ratio of SIF_photons over APAR_Chl_photons
float **fluorescence_quantum_efficiency_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	fluorescence_quantum_efficiency_uncertainty
short_name	FQE_unc
units	µmol.µmol-1
long_name	Fluorescence Quantum Efficiency (FQE) Uncertainty
description	Uncertainty associated with fluorescence_quantum_efficiency
float **electron_transport_rate**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	electron_transport_rate
short_name	ETR
units	µmol.m-2.s-1
long_name	Electron Transport Rate (ETR)
description	Electron Transport Rate (ETR)
float **electron_transport_rate_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples*) ;	

standard_name	electron_transport_rate_uncertainty
short_name	ETR_unc
units	µmol.m-2.s-1
long_name	Electron Transport Rate (ETR) uncertainty
description	Uncertainty associate with electron_transport_rate
float **fluorescence_escape_probabilty**(*number_of_along_track_samples, number_of_across_track_samples, number_of_sif_spectral_samples*) ;	
standard_name	fluorescence_escape_probability
short_name	fesc
units	-
long_name	Fluorescence Escape Probabilty
description	Escape probability of fluorescence in sensor direction times pi.
float **fluorescence_escape_probability_uncertainty**(*number_of_along_track_samples, number_of_across_track_samples, number_of_sif_spectral_samples*) ;	
standard_name	fluorescence_escape_probability_uncertainty
short_name	fesc_unc
units	-
long_name	Fluorescence Escape Probabilty uncertainty
description	Uncertainty associated with fluorescence_escape_probability
float **PSI_PSII_relative_contribution**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	PSI_PSII
short_name	PSI_PSII
units	-
long_name	PSI PSII relative contribution
description	PSI PSII relative contribution to fluorescence.

Group: Ancillary_information

float **longitude**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	longitude
short_name	lon
units	degrees_east
long_name	Longitude
description	Longitude ground coordinate associated to each pixel in WGS84 convention (geometric)
float **latitude**(*number_of_along_track_samples, number_of_across_track_samples*) ;	

standard_name	latitude
short_name	lat
units	degrees_north
long_name	Latitude
description	Latitude ground coordinate associated to each pixel in WGS84 convention (geometric)
float **elevation**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	surface_elevation
short_name	elevation
units	m
long_name	Surface elevation over geoid EGM96
description	Surface elevation over geoid EGM96, GETASSE30 DEM
float **sun_zenith_angle**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	sun_zenith_angle
short_name	SZA
units	degrees
long_name	Sun Zenith Angle (SZA)
description	Sun Zenith Angle associated to FLORIS observations
float **viewing_zenith_angle**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	viewing_zenith_angle
short_name	VZA
units	degrees
long_name	Viewing Zenith Angle (VZA)
description	Viewing Zenith Angle associated to FLORIS observations
float **relative_azimuth_angle**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	relative_azimuth_angle
short_name	RAA
units	degrees
long_name	Relative Azimuth Angle (RAA)
description	Relative Azimuth Angle associated to FLORIS observations

Group: Quality

ushort **quality_flags**(*number_of_along_track_samples, number_of_across_track_samples*) ;	
standard_name	quality_flags
short_name	qc_flags

units	-
long_name	Quality flags
description	Quality flags depending on the processor - 1 = Aerosols - 2 = Water vapor - 4 = Apparent reflectance - 8 = Fluorescence - 16 = Leaf area index - 32 = Leaf chlorophyll content - 64 = Leaf carotenoids content - 128 = FAPAR - 256 = escape probability - 512 = Photosynthesis parameters - 1024 = spare0 - 2048 = spare1 - 4096 = spare2 - 2048 = spare3 - 8192 = spare4 - 16384 = spare5 - 32768 = spare6 - 65536 = spare7
flag_masks	List of bit fields describing boolean or enumerated flags
meaning	"Aerosols, Water vapor, Apparent reflectance, Fluorescence, Leaf area index, Leaf chlorophyll content, Leaf carotenoids content, FAPAR, escape probability, Photosynthesis parameters"

Table 5-3: FLEX L2 products data file format

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