ECMWF COPERNICUS REPORT

Copernicus Climate Change Service

Product User Guide and Specification

ICDR Sentinel-3 Active Fire, Fire Radiative Power Night-time Products & Gas Flare Products (v1.2)

Issued by: Brockmann Consult GmbH/ Carsten Brockmann

Date: 08/01/2025

Ref: WP2-ICDR-FRP-NIGHTTIME-2020-2023-SENTINEL3-v1.2_PUGS_v3.1

Official reference number service contract: 2022/C3S2_312a_Lot5_VITO/SC1

PROGRAMME OF THE EUROPEAN UNION

IMPLEMENTED BY ECMWF

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This document is based on the document (D3.3.16-v1.1_PUGS_CDR-ICDR_FRP_SENTINEL3_v1.0.x_PRODUCTS_v1.2) [1]. It has been updated by the consortium in collaboration with the former partners - Prof. M. Wooster & Dr. W. Xu.

History of modifications

Version	Date	Description of modification	Chapters / Sections
V1.0	30/06/2023	First issue	All
V1.1	03/11/2023	Document amended to account for feedback from independent reviewer and finalized for publication	All
V2.0	20/12/2023	Update of the document to include the products of 2022.	Name and version of the document
V3.0	09/12/2024	Document amended to add gas flare product description	All
V3.1	08/01/2025	Document amended to account for feedback from independent reviewer and finalized for publication	All

List of datasets covered by this document

Deliverable ID	Product title	Product type (CDR, ICDR)	Version number	Delivery date
WP2-FDDP-FRP-NIGHTTIME-2021-SENTINEL3-v1.2	CDR and ICDR Sentinel-3 AF &FRP v1.2- 2021	ICDR	1.2	30/06/2023
WP2-ICDR-FRP-NIGHTTIME-2022-SENTINEL3-v1.2	CDR and ICDR Sentinel-3 AF &FRP v1.2- 2022	ICDR	1.2	31/12/2023
WP2-ICDR-FRP-NIGHTTIME-2020-2023-SENTINEL3-v1.2	CDR and ICDR Sentinel-3 AF &FRP v1.2- 2020 - 2023	ICDR	1.2	31/10/2024

[1] *http://dast.data.compute.cci2.ecmwf.int/documents/satellite-fire-radiative-power/D3.3.16-v1.1_PUGS_CDR-ICDR_FRP_SENTINEL3_v1.0.x_PRODUCTS_v1.2.pdf*

Related Documents

Reference ID	Document
[RD - 1]	E.U. Copernicus Climate Change Service (2024) "Algorithm Theoretical Basis Document - CDR and ICDR Sentinel-3 Active Fire, Fire Radiative Power & Gas Flare Night-time Products (v1.2)", E.U. Copernicus Climate Change Service, Document ref: WP2-ICDR-FRP-NIGHTTIME-2020-2023-SENTINEL3-v1.2_ATBD_v2.0 (not yet published)

Acronyms

Acronym	Definition
(A)ATSR	(Advanced) Along track Scanning Radiometer
AF	Active Fire
ASCII	American Standard Code for Information Interchange
ATBD	Algorithm Theoretical Basis Document
AVHRR	Advanced Very High Resolution Radiometer
BT	Brightness Temperature
C3S	Copernicus Climate Change Service
CCI	Climate Change Initiative
CDR	Climate Data Records
CLM	CLoud Mask
CMG	MODIS Climate Modelling Grid
CSV	Comma-separated values
EC	European Commission
ECV	Essential Climate Variable
EO	Earth Observation
ESA	European Space Agency
FRE	Fire Radiative Energy
FRP	Fire Radiative Power
GCOS	Global Climate Observing System
GHG	GreenHouse Gas
GTOS	Global Terrestrial Observing System
ICDR	Intermediate Climate Data Records
LUT	Look-Up Table
LWIR	LongWave InfraRed
MAD	Mean Absolute Deviation
MIR	Middle InfraRed
MODIS	Moderate-Resolution Imaging Spectroradiometer
MWIR	Mid-Wave InfraRed
NetCDF	Network Common Data Form
NetCDF4	Network Common Data Form version 4
NTC	Non-time critical
PSF	Point Spread Function

Acronym	Definition
PUGS	Product User Guide Specification
ROI	Region of Interest
S3A	Sentinel 3A
S3B	Sentinel 3B
SLSTR	Sea and Land Surface Temperature Radiometer
SWIR	Shortwave InfraRed
VIS	Visible spectral region
WGS84	World Geodetic System 84
XML	Extensible Markup Language

General definitions

Active Fire (AF)
A landscape fire that was actively burning when the satellite observations were made.

Satellite 'Active Fire' Products
Those that report information on Active Fires (AF) using thermal remote sensing techniques. AF pixels are pixels classified as containing one or more actively burning fires when the observation was made.

Fire Radiative Power (FRP)
The rate of radiant heat output from a landscape fire, typically expressed in Watts $\times 10^6$ (MW). FRP is typically very well related to a fire´s combustion rate (how much material is being burned per unit time) and rate of smoke emission, and hence remotely-sensed FRP measures are commonly used to estimate these terms. At the pixel scale, a satellite product typically is reporting the total FRP from all fires burning within that pixel at the time the observation was made.

Fire Radiative Energy (FRE)
The temporal integral of fire radiative power calculated over the fire's lifetime, equating to the total amount of energy radiated by the fire. FRE is typically used to estimate how much material was burned in a fire and how much smoke was released.

Granule
In remote sensing, a "granule" refers to a discrete unit of data or imagery acquired by a satellite or sensor during a single overpass or observation. These granules are essentially individual scenes or tiles of data that cover a specific geographic area and time period. They are part of a larger dataset and are used to organize and distribute remote sensing data. For MODIS, the time period for one granule is 5 minutes and for SLSTR its 3 minutes.

Goal (G): Represents the ideal requirement that surpasses the need for further improvements.

Breakthrough (B): An intermediate level between the threshold and the goal, achieving which would result in a significant enhancement for the targeted application. The breakthrough value may vary for different uses within climate monitoring.

Threshold (T): The minimum requirement that must be met to ensure the usefulness of the data

Satellite Data Processing Levels

- **Level 0** (L0) data are reconstructed, unprocessed instrument and payload data at full resolution, with any and all communications artefacts (e.g., synchronization frames, communications headers, duplicate data) removed.
- **Level 1A** (L1A) data are reconstructed, unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric

calibration coefficients and georeferencing parameters (e.g., platform ephemeris) computed and appended but not applied to L0 data.

- **Level 1B** (L1B) data are L1A data that have been processed to sensor units (not all instruments have L1B source data).
- **Level 1C** (L1C) data are L1B data that include new variables to describe the spectra. These variables allow the user to identify which L1C channels have been copied directly from the L1B and which have been synthesized from L1B and why.
- **Level 2** (L2) data are derived geophysical variables at the same resolution and location as L1 source data.
- **Level 2A** (L2A) data contains information derived from the geolocated sensor data, such as ground elevation, highest and lowest surface return elevations, energy quantile heights ("relative height" metrics), and other waveform-derived metrics describing the intercepted surface.
- **Level 2B** (L2B) data are L2A data that have been processed to sensor units (not all instruments will have a L2B equivalent).
- **Level 3** (L3) are variables mapped on uniform space-time grid scales, usually with some completeness and consistency.
- **Level 3A** (L3A) data are generally periodic summaries (weekly, ten-day, monthly) of L2 products.
- **Level 4** data are model output or results from analyses of lower-level data (e.g., variables derived from multiple measurements).

Descriptions of data processing levels ranging from Level 0 to Level 4 have been sourced from the following National Aeronautics and Space Administration (NASA) Earth Observation Data website: https://www.earthdata.nasa.gov/engage/open-data-services-and-software/data-information-policy/data-levels

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Scope of the document

This Product User Guide Specification (PUGS) is the reference for the family of night-time C3S Active Fire (AF) Detection and Fire Radiative Power (FRP) products, including both the thermal infrared-derived 'active fire' products that store information on all detected hotspots, and the night-time gas flare products that relate only to the shortwave-infrared derived gas flare observations. This PUGS describes the data formats, filenames, metadata and thematic content - with the aim of familiarising users with the products and their content. The family of C3S AF & FRP products are all generated from observations made by the Sea and Land Surface Temperature Radiometer (SLSTR) operating onboard the Sentinel-3 satellites, currently as of time of writing (2024) the concurrently operating Sentinel-3A and -3B. A Level 2 AF detection and FRP product is generated in non-time critical (NTC) mode from each Level 1B SLSTR data granule, and the C3S products consist of a family of higher level products that each summarise certain parts of this Level 2 information. The C3S products encompass firstly a Level 2 summary product providing a text-based summary of the thermal infrared derived Level 2 AF detection and FRP data collected over the period of one month across the globe at the locations of active fire pixels detected, along with three Level 3 'synthesis products' which each grid this Level 2 AF detection and FRP data at various spatial and temporal resolutions and provide some adjustments for cloud cover variations. The 'active fire' pixels in these products can be due to any type of hotspot, and there is a geographically-based classification in the Level 2 Summary Product taken from the original L2 dataset. Secondly there are also the same set of Level 2 summary and three Level 3 'synthesis products', but now derived from the shortwave-infrared derived hotspot data contained in the Level 2 products, and filtered to only include information believed to relate to gas flares. Together these night-time C3S products are designed to provide easy and accessible access to the key information held within many individual night-time Level 2 granule-based AF detection and FRP products, for example to support global modelling, trend analysis and model evaluation. As such, this user guide provides information for those wishing to utilize these Level 2 Summary and Level 3 FRP products.

The document is divided into two sections briefly described below:

- Section 1 provides the specifications of the C3S AF & FRP product.
- Section 2 explains how to access the C3S AF & FRP products and provides their terms of use.

Executive summary

The Copernicus Climate Change Service (C3S) provides Intermediate Climate Data Records (ICDRs) for many Essential Climate Variables (ECVs), amongst which is active fire (AF) and fire radiative power (FRP). The C3S AF & FRP products are generated from observations made by the Sea and Land Surface Temperature Radiometer (SLSTR) operating onboard the Sentinel-3 satellites, currently (2024) Sentinel-3A and Sentinel-3B.

Sentinel-3 SLSTR Level 1 data are used to generate a set of granule-based Level 2 Active Fire (AF) Detection and FRP products that each store essential information about pixels believed to contain actively burning fires identified in each 3 minute Universal Time SLSTR Level 1 granule, including their location, fire radiative power (FRP in MW) and FRP uncertainty, along with a SUMMARY FLAG dataset providing information on every pixel in the granule related primarily to the output of the active fire detection tests. These SUMMARY FLAG data are stored as a 2D array bit mask. Each Level 2 FRP product corresponds to a single SLSTR data granule and contains a very large amount of information across a set of eleven measurement and annotation data files, plus an XML manifest (xfdumanifest.xml) that describes the content and metadata of the package. The manifest is the entry point for accessing and processing the package. Whilst these Level 2 FRP product files are extremely comprehensive in the information they contain, use of them at the global scale and over long time periods results in potentially very large numbers of data files. Therefore, the C3S FRP products provide both a Level 2 global summary FRP product that provides a text-based summary of the Level 2 Active Fire Detection and FRP product data collected over the period of one month at the locations of all detected active fire (AF) pixels, plus three Level 3 'synthesis products' which summarize the Level 2 AF detection and FRP data at various spatial and temporal resolutions, and provide some adjustments for cloud cover variations. One set of these four C3S product types relates to the thermal infrared detected "active fire" hotspots in the Level 2 products, which are mostly active fire related but can also be due to other phenomena such as industrial or volcanic heat sources. The other set of four C3S product types relates to the shortwave infrared detected hotspots in the Level 2 products, which are filtered to only contain "gas flare" hotspots in the C3S products. The C3S products are each designed for ease of access and use of the key information held within the Level 2 granule-based FRP products, and for global modelling, trend analysis and model evaluation.

This user guide provides information for those wishing to utilize any of the C3S products and the information they contain. The C3S FRP products have been designed to be relatively similar to those generated from the MOD14 and MYD14 Level 2 Active Fire and Thermal Anomaly products, which are themselves created from observations made by the MODIS sensor operating onboard the Terra and Aqua satellites. The Terra satellite has been operating for more than 20 years and had lowered its orbit in 2022 to save fuel, altering some of the characteristics of the product like overpass time to ~10:15. Ultimately the satellite will cease operation when it reaches its end of life, and since Sentinel-3 has an equatorial crossing time similar to that of Terra, the long-term record of active fire counts and FRP started in the year 2000 using observations made by MODIS on Terra is expected to be continued with Sentinel-3 SLSTR. The similarity of the overpass time of Terra and Sentinel-3 is important to this effort because landscape fires typically show very strong diurnal variability, so any long-term record aiming to be used for trend or anomaly analysis is best made using observations taken at a similar time of day.

1 Active Fire & Fire Radiative Power product description

1.1 Product Description

The requirement for satellite active fire (AF) products is driven by the fact that landscape burning perturbs a greater area over a wider variety of biomes than any other natural disturbance agent (Figure 1-1), and affects the terrestrial biosphere and atmosphere through the combustion of vegetation and organic soils ('fuel'). Upon combustion the vast bulk of the biomass is transferred into the troposphere in the form of smoke comprised of many different gaseous and particulate compounds (Bowman et al., 2009), whilst an approximately fixed amount of thermal energy is released per kg of biomass consumed. A certain proportion of this thermal energy is emitted as (primarily infrared) electromagnetic radiation, and remotely sensed infrared measurements - such as those provided by SLSTR onboard Sentinel-3 - can be used to identify the presence of an actively burning fire based on detection of this thermally emitted energy. At wavelengths in the middle infrared (MIR) atmospheric window (3 – 5 µm; where the SLSTR S7 and F1 channels operate) the thermal energy emission by a landscape fire is so much stronger than that of the ambient background that a fire may be detectable in an SLSTR pixel even though it may cover less than 1% of the pixel area. Based on methods and an algorithm detailed in Wooster et al. (2012) and Xu et al. (2020) the Sentinel-3 Level-2 Active Fire Detection and FRP product uses this approach to provide extremely comprehensive information on the location, timing, and strength (in terms of fire radiative power output) of actively burning fires that were alight at the time the SLSTR observations were made. The C3S FRP products provide two convenient and easy-to-use Level 2 Global Summary Products reporting data collected at (i) all thermal infrared-detected active fire pixels identified SLSTR over the period of one month, and (ii) all shortwave infrared detected gas flare pixels. They also provide a series of three different Level 3 'synthesis' products for the thermal infrared and shortwave infrared derived hotspots, which each contain these same data but gridded at different spatial and temporal resolutions, as detailed below. Note that in the Night-time Sentinel-3 Level 2 FRP products, FRP values are provided that are based on both the middle infrared (MIR) and short-wave infrared (SWIR) observations where possible. However, the FRP data reported in the Level 3 C3S products are those made using the MIR observations for the thermal-infrared derived active fire products, and using the SWIR observation for the gas flare products (Wooster et al., 2005; Fisher and Wooster, 2019). Figure 1-1 shows an example of Active Fire Pixel Count and FRP for July 2022 – derived from SLSTR thermal infrared channel observations and including all hotspots (whether they be landscape fires or not) stored in the FRP_in.nc file of the Level 2 C3S Night-time Active Fire Detection and FRP Product files. It is these data that the C3S Active Fire Detection and FRP products summarises.

The C3S Gas Flare products were produced to reflect the fact that industrial gas flaring represents a significant environmental concern, wasting a valuable economic resource, emitting GHGs (e.g. CO_2 from the burning gas, and potentially unburned methane) and contributing to atmospheric pollution (e.g. NOx and particulate matter) with documented regional health implications. Figure 1-2 shows an example of Gas Flare count and FRP for July 2023 – derived from SLSTR shortwave infrared channel observations and converted to gas flare data stored in the FRP_an.nc file of the Level 2 C3S Night-time Active Fire Detection and FRP Product files. It is these data that the C3S Gas Flare products summarises.

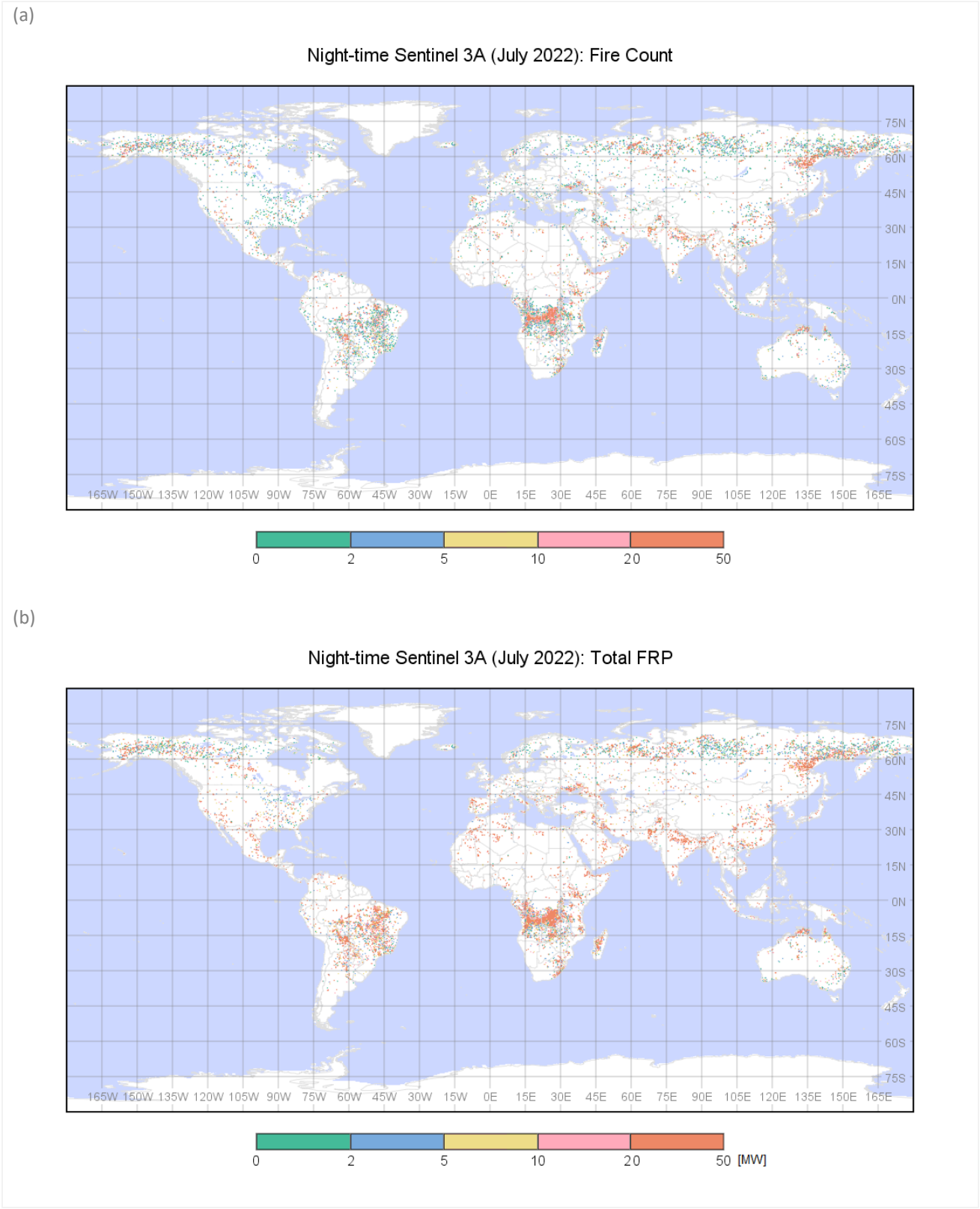


Figure 1-1: Example information contained within the Level 2 Sentinel-3 SLSTR FRP products. Monthly global map of thermal-infrared derived (a) active fire pixel count and (b) total FRP, both derived from around 15,000 Sentinel-3A Level 2 FRP products held within the C3S Level 3 Monthly Summary AF & FRP Night-time S3A Product of July 2022. Grid cell size is 0.25°.

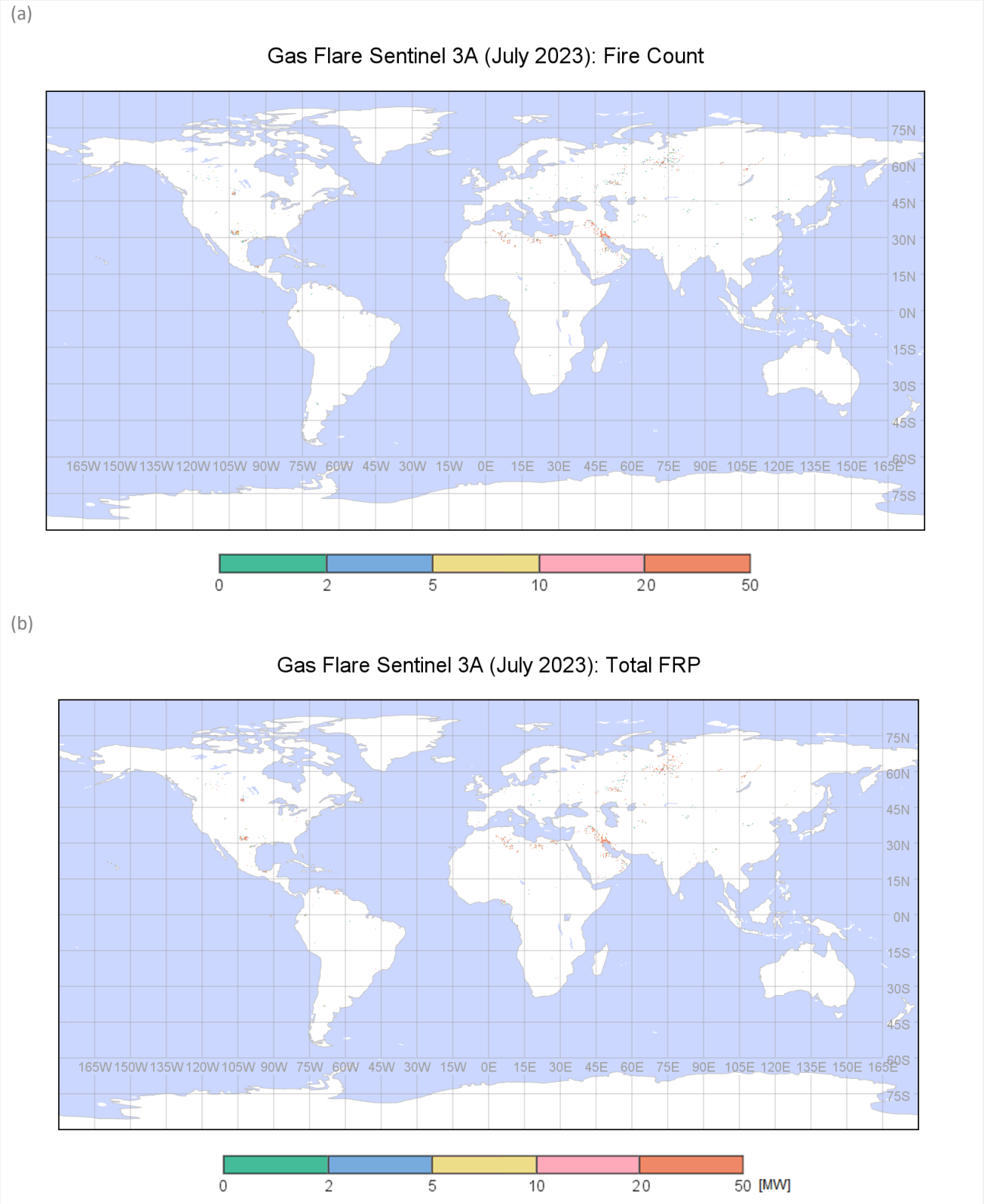


Figure 1-2: Example information contained within the Level 3 monthly Sentinel-3 SLSTR Gas Flare products. Monthly global map of shortwave infrared derived (a) gas flare pixel count and (b) total FRP, both derived from around 15,000 Sentinel-3A Level 2 FRP products held within the C3S Level 3 Monthly grided Gas flare Night-time S3A Product of July 2023. Grid cell size is 0.25°.

1.2 Target Requirements

The Fire Essential Climate Variable (ECV) requirements established by the Global Climate Observing System (GCOS) are outlined in the GCOS ECVs Requirements document (GCOS-245, 2022). Starting from 2016, Fire Radiative Power (FRP) has been designated as a full ECV rather than a supplementary one (GCOS-200, 2016) – and note this specification relates to landscape fires and not to gas flares. However, the specifications for the FRP ECV and the Active Fire (AF) detections presented in *Table 1-1* were updated in the 2022 plan (Table 1-2;

Table 1-3). While the 2016 specifications were mostly attainable using existing sensors, the 2022 specifications introduce a higher level of detail, some of which are not compatible with the currently available observing systems. Consequently, the 2022 specifications are categorized as follows: **Goal (G), Breakthrough (B) and Threshold (T).**

Table 1-1: GCOS requirements (GCOS-200, 2016) for Active Fire detection and FRP.

ECV	Frequency	Horizontal resolution	Required measurement uncertainty
Active Fire Maps	6 hours at all latitudes from Polar-Orbiting and 1 hour from Geostationary	0.25-1 km (Polar-Orbiting); 1-3 km (Geostationary)	5% error of commission 10% error of omission
Fire Radiative Power	6 hours at all latitudes from Polar-Orbiting and 1 hour from Geostationary	0.25-1 km (Polar-Orbiting) 1-3 km (Geostationary)	Based on target detection threshold of 5 MW/km² equivalent integrated FRP per pixel (i.e. for a 0.5 km² pixel the target threshold would be 2.5 MW, for a 9 km² pixel it would be 45 MW).and with the same detection accuracy as the Active Fire Maps.

Table 1-2: GCOS requirements (GCOS-245, 2022) for Active Fire detection.

Item needed	Unit	Metric	Ac[2]	Value	Derivation and References and Standards
Horizontal Resolution	m	Minimum mapping unit to which the AF product refers	G	50	This resolution reflects need to detect small and cool fires (including underground peat fires and fires occurring under forest canopies) and is mostly required by fire which the managers and fire extinction services.
			B	250	Useful for fire risk assessment and better understanding of fire risk factors.

[2] *Ac: 2022 specification terms: G (Goal), B (Breakthrough), T (Threshold)*

Item needed	Unit	Metric	Ac[2]	Value	Derivation and References and Standards
			T	5000	5,000-m threshold reflects experience using legacy AVHRR GAC data. Most climate modelers work at coarse resolution grids, 0.25˚ is the most common. A recent review of users of RS BA products show that most of them work at this level of detail (https://climate.esa.int/media/documents/Fire_cci_D1.1_URD_v5.2_xkSTbGK.pdf , updated by Heil 2019).
Temporal Resolution	min	Minimum temporal period to which the AF product refers (values specified regardless of cloud conditions)	G	5	5-min goal reflects need to detect rapidly moving and short-lived fires. For fire management purposes, active period to fire detection should be done very frequently. the Atmospheric modelers also require updated information.
			B	120	2-hour breakthrough reflects need to monitor diurnal active fire variability.
			T	720	12-hour threshold reflects experience with legacy fire of cloud data sets. Needed by atmospheric and carbon modelers.
Timeliness	day	Time lapse between satellites overpass and AF availability	G	1	Requirement values reflect need to analyse climate anomalies and their effects shortly after fire occurrence. A timeliness of 10 minutes (achievable using new geostationary satellites) will be needed by fire managers and atmospheric modelers of smoke impacts on human.
			B	7	
			T	365	Reporting on fire activity.
Required Measurement uncertainty	%	Average omission and commission errors	G	5%[3]	Based on a questionnaire to atmospheric and carbon modelers done in 2011: (https://climate.esa.int/media/documents/Fire_cci_D1.1_URD_v5.2_xkSTbGK.pdf , updated by Heil 2019).
			B	5%[4]	
			T	5%[5]	
Stability	Measures of omission	Assessment of whether	G	0	Percentage reflects the relative increase or decrease in reported global total count of
			B	1	

[3] *with respect to active fires burning with FRP equal to 5 MW / km-2 in the detector ground footprint*

[4] *with respect to active fires burning with FRP equal to 10 MW / km-2 in the detector ground footprint*

[5] *with respect to active fires burning with FRP equal to 20 MW / km-2 in the detector ground footprint*

Item needed	Unit	Metric	Ac[2]	Value	Derivation and References and Standards
	and commission over the available time period	a monotonic trend exists based on the slope of the relationship between an accuracy measure and time	T	2	active fire detection grid cells over a 10-year period.

Table 1-3: GCOS requirements (GCOS-245, 2022) for Fire Radiative Power.

Item needed	Unit	Metric	Ac[6]	Value	Derivation and References and Standards
Horizontal Resolution	m	Minimum mapping unit to which the FRP product refers	G	50	This resolution reflects need to detect small and cool fires (including underground peat fires and fires occurring under forest canopies) and is mostly required by fire which the managers and fire extinction services.
			B	250	
			T	5000	Reflects experience using legacy AVHRR GAC data.
Temporal Resolution	min	Minimum temporal period to which the FRP product refers (values specified regardless of cloud conditions)	G	5	5-min goal reflects need to detect rapidly moving and short-lived fires.
			B	120	2-hour breakthrough reflects need to monitor diurnal active fire variability.
			T	720	12-hour threshold reflects experience with legacy fire of cloud data sets.
Timeliness	day	Time lapse between satellites overpass and AF availability	G	1	For climate applications timeliness is less critical
			B	7	Requirement values reflect need to analyse climate anomalies and their effects shortly after fire occurrence
			T	365	

[6] *Ac: 2022 specification terms: G (Goal), B (Breakthrough), T (Threshold)*

Required Measure-ment uncertainty	MW/km-2 of detector ground footprint	Average deviation between estimated and observed FRP	G	0.5	Goal based on need to quantify FRP of small and cool smouldering fires
			B	1	
			T	2	
Stability	Measures of omission and com-mission over the available time period	Assessment of whether a monotonic trend exists based on the slope of the relationship between an accuracy measure and time	G	0	Percentage reflects the relative increase or decrease in reported global total FRP of active fire detection grid cells over a 10-year period.
			B	1	
			T	2	

The data contained within the Sentinel-3 Level 2 Active Fire Detection and FRP products is produced from the polar orbiting Sentinel-3 satellites, and in many ways is similar in nature to that provided from MODIS Terra in the MOD14 Level 2 Active Fire and Thermal Anomaly products. However, whilst the SLSTR product includes a shortwave infrared derived data layer of hotspot detections as well as a thermal infrared derived layer, MODIS only has the latter.

MODIS operates onboard the Terra and Aqua satellites and provides radiometrically calibrated and geo-located remote sensing observations of the Earth in 34 spectral bands over a 2330 km swath. The MODIS onboard the Terra satellite provides data at times similar to those provided by the SLSTR sensor onboard Sentinel-3, since the Terra and Sentinel-3 satellites equatorial crossing times occur within 30 mins of one another. Radiometric observations in certain of the MODIS bands are used to generate the MODIS Active Fire and Thermal Anomaly products which are described in detail in Giglio et al. (2016). These products are named MOD14 when generated by MODIS onboard the Terra satellite, and MYD14 when generated by MODIS onboard Aqua. The MODIS AF Products were the first in a family of remotely sensed active fire datasets produced from a new generation of moderate spatial resolution (~1 km) "fire-capable" sensors hosted on-board low Earth orbit (LEO) remote sensing satellites. At the time of writing, the Sentinel-3 Level 2 Active Fire Detection and FRP Products are the latest such products to become available.

As with the Sentinel-3 Level 2 Active Fire Detection and FRP Products, to produce the MODIS MOD14 and MYD14 AF products a contextual AF detection algorithm is used. The MODIS algorithm is thermal infrared based and described in Giglio et al. (2016). It is applied to identify pixels within every MODIS 5-minute level 1b granule which appear to contain sub-pixel active fires burning at the time of the MODIS observation. For each confirmed MODIS AF pixel, the pixel-based FRP is then estimated using the MIR radiance method of Wooster et al., (2003; 2005) - the same approach used within the Sentinel-3 Level 2 FRP product (Wooster et al., 2012). Since their first iteration in 2000, the MODIS AF products have been used to help address a very broad range of scientific questions concerning fire characterisation and the role of biomass burning within the Earth system. Reprocessing of the entire MODIS data product archive is periodically performed to incorporate instrument calibration updates, algorithm refinements, and improved upstream data. The updated MODIS data product archive resulting from each reprocessing is referred to as a Collection. For Terra MODIS, Collection 1

consisted of the first products generated following the Terra satellite launch in 1999. The latest Collection 6 data (Giglio et al., 2016) were first issued in 2015 and are similar to the Sentinel-3 Level 2 Active Fire Detection and FRP Products in that each product contains information on the characteristics of each confirmed active fire pixel present in the Level 1 granule (FRP estimate, AF pixel detection time and position, etc.), along with a 2D image providing a classification of every pixel in the Level 1b MODIS granule, whether or not it was identified as an AF pixel (e.g. surface conditions preventing AF detection (e.g. water), atmospheric conditions preventing AF detection (e.g. cloud), cloud-free land, AF pixel).

As such the polar orbiting specifications from *Table 1-1* are the most relevant. Both Sentinel-3 and Terra have a similar equatorial crossing time, so ultimately the Sentinel-3 FRP product datasets will take over from the MODIS Terra datasets in order for a continued globally consistent data record to be produced. The Sentinel-3 FRP product delivers information from the satellites nighttime (ascending node) passes (S3 satellite equatorial crossing time of ~22:00), and also daytime passes (~10:00 equatorial crossing time) – though with different algorithms due to the additional criteria that have to be considered by day. The shortwave infrared derived information is also only included for night-time observation, and this document is focused on the night-time case only.

In terms of the nighttime AF detections, early evidence indicates that when the Level-2 SLSTR FRP product and MODIS Terra AF products are produced for the same area near simultaneously, from its thermal infrared based detection algorithm the SLSTR product tends to detect more active fire pixels. However, the FRP total from the near-simultaneously observed regions appear to be very similar for SLSTR and MODIS Terra since the additional AF pixels detected by SLSTR tend mostly to be associated with low FRP fires. Early indications suggest that for the majority of the near nadir view SLSTR scan, data from which is used to generate the Level 2 FRP products, the GCOS requirement of a minimum active fire detection limit of 5 MW/km^2 is met.

Note that in relation to the thermal infrared detections - the instantaneous field of view (IFOV) of the SLSTR S7 and F1 middle infrared channels is very different due to their differing detector shapes and matching IFOV. Whilst the IFOV of S7 is very similar to that of the SLSTR long wave infrared (LWIR) channels (S8 and S9), that of F1 is far narrower. At any point around the near nadir scan, the matching S7 and F1 pixels in fact have quite different ground footprint shapes, and with a smaller pixel area for F1. Around the scan, F1 also shows far more limited growth in the area of its pixel footprint compared to S7. A key consideration for the SLSTR AF application is that data from both S7 and F1 must be combined for any production algorithm to be most effective, as detailed in Xu et al. (2020, 2021). This is because MIR channel measurements in excess of 311 K can only be provided by F1, whereas cooler BTs are more precisely measured by the lower-noise S7 channel. For other fire (typically lower FRP) clusters whose S7 channel observations remain unsaturated across all their AF pixels, their FRP can be retrieved in all their AF pixels via either F1 (termed the “F1_ON” option) or S7 (“F1_OFF” option). Before August 2020, the NTC Level-2 FRP product from ESA used the “F1_OFF” option which means for those fire clusters whose S7 channel observations remain unsaturated across all their AF pixels, their position and FRP are from S7, but for those fire clusters having a BT >320 K, their FRP and position will come from F1. There is a “F1_flag” in the C3S Level-2 summary product with 1 indicating the FRP for the Active fire is from F1 channel and 0 means the FRP is from S7. However, for all three Level-3 FRP products, the active fire count and FRP are gridded from all Level-2 SLSTR observations

regardless of whether the AF pixel FRP is retrieved from S7/F1 channel grid. After August 2020, the Level-2 NTC product started to use the “F1_ON” option so all the AF position and FRP will come from the F1 channel.

The 'F1' or 'S7' channel coordinates that are used for the SLSTR L2 FRP products depend on which “F1_flag” is used (on or off), while the 'S7' channel grid is used for other flags such as “cloud” and “water”. Since F1 and S7 channel coordinates are slightly different, this means that the SLSTR L2 FRP products and the other flags have different spatial resolutions and alignments. In the case of the C3S FRP L2 summary product the original AF & FRP and the provided coordinates are applied. But the derivation of the C3S FRP L3 products requires an aggregation of SLSTR L2 FRP products using the corresponding “cloud” and “water” flags. This sometimes leads to an AF & FRP counted in one bin cell and the corresponding “cloud” and “water” flags being counted in the neighbouring cell and makes the C3S FRP L2 summary inconsistent with the other C3S FRP L3 products.

1.3 Data usage information

1.3.1 Level 2 Monthly Global Fire Location and FRP Night-time Summary Product

1.3.1.1 Introduction

The Sentinel-3 Level 2 Active Fire Detection and FRP Products issued in non-time critical (NTC) mode are the source for the C3S FRP products, including the Level 2 Monthly Global Active Fire Location and FRP Summary Product discussed here. Each night-time C3S Level 2 Monthly Global Fire Location and FRP Summary Product is a comma delimited ASCII text CSV file containing the information shown in Table 4-1 that is relevant to the AF pixels detected that month. Each Level 2 Summary Product is based on information from tens of thousands of Level 2 Active Fire Detection and FRP Product files.
Each Level 2 FRP Summary product stores essential information about pixels believed to contain actively burning fires, along with a SUMMARY FLAG dataset providing information on every pixel in the 3-minute Universal time granule related primarily to the output of the active fire detection tests. The Level 2 Monthly Global Active Fire Location and FRP Summary Product provides a text-based summary of the Level 2 Active Fire Detection and FRP Product data collected over the period of one month at the locations of all detected active fire pixels across the globe.

The monthly night-time summary product stores the latitude, longitude, FRP, date, time and associated data of every detected active fire pixel identified worldwide in the Level 2 Active Fire Detection and FRP Products of that month, as detailed in Section 1.3.1.2. The separate summaries of the data records coming from the S3A and S3B satellites are put also into separate text type files stored in CSV format.

1.3.1.2 Date usage information

Each Level 2 Monthly Global Active Fire Location and FRP Summary Product is stored as a space delimited ASCII text CSV file containing a monthly summary of the Level 2 Active Fire Detection and FRP Products data records collected globally over the month, and specifically information related to the location of every detected active fire (AF) pixel. Each Level 2 AF Detection and FRP Product granule

consists of a set of eleven measurement and annotation data files corresponding to information on fires burning at the time the SLSTR observation was made. Information related to the AF detections and their FRP is stored in the Level 2 product as two different datasets: a "LIST" of the characteristics of each confirmed active fire (AF) pixel and a 2-d array "SUMMARY FLAG" dataset. The data stored in each L2 Summary Product include (i) the original SLSTR Level 1 granule pixel sample and line number, (ii) the corresponding latitude and longitude, (iii) the AF pixel FRP and uncertainty (MIR- and SWIR-derived where available), (iv) pixel footprint area of the MIR channel used (F1 or S7), day/night flag, (v) the MIR channel used to retrieval FRP (F1 or S7) and (v) date, time and satellite (e.g., Sentinel-3A or 3B). Further details of this information are provided in Table 1-4.

Table 1-4: Information held within each Level 2 Monthly Global Fire Location and FRP Night-time Summary Product File at the location of each detected active fire (AF) pixel for each Sentinel-3 satellite.

Name	Units	Comment
Column	Pixel	Across-track image grid index for the detected AF pixel
Row	Pixel	Along-track image grid index for the detected AF pixel
Date	Date	Date in the format of YYYYMMDD
Time	hours, minutes and seconds	Time in the format of HHMMSS
Latitude	° (i.e., degrees)	Latitude
Longitude	° (i.e., degrees)	Longitude
sat_zenith	° (i.e., degrees)	Satellite zenith angle
FRP_MWIR	MW	Fire radiative power computed from the MWIR channel observation (either S7 or F1)
FRP_MWIR_uncertainty	MW	Uncertainty of the fire radiative power computed from the MWIR channel observation (either S7 or F1)
FRP_SWIR	MW	Fire radiative power computed from the SWIR channel observation (S6)
FRP_SWIR_uncertainty	MW	Uncertainty of the fire radiative power computed from the SWIR channel observation (S6)
Local solar time	Decimal hour	Based on latitude and solar zenith angle, allowing users to identify AF pixels detected during the descending node (morning) S3 overpass, but classified as night-time pixels due to their extreme solar zenith angle.
BT_MIR	Kelvin	MIR Brightness Temperature from the fire
BT_window	Kelvin	Mean Brightness Temperature of the valid pixels in the background window
F1_flag	Boolean	Boolean flag indicating the data from which channel was used in the FRP calculation, with 0 referring to S7 and 1 to F1

Name	Units	Comment
Day_flag	Boolean	Boolean flag indicating a daytime or night-time AF detection based on pixel solar zenith angle
Area	m^2	Projected area of the pixel footprint on the Earth surface
Platform	-	Sentinel-3A or Sentinel -3B
Land/Ocean	Boolean	Boolean flag indicating the fire over the land or ocean, with 0 referring to Ocean and 1 to Land
Hotspot class	-	Different number indicate hotspot classes with 0 referring to vegetation_fire, 1 to onshore_gas_flare and 2 as offshore_gas_flare[7]

1.3.1.3 Temporal Resolution

The monthly summary product is generated every calendar month, at present the product only includes night-time landscape fires over the land.

1.3.1.4 File format and size

The Level 2 Monthly Global Active Fire Location and FRP Summary Product is a space delimited ASCII text file with 18 columns, stored in CSV format. The definition of each column is shown in Table 1-4. The file size for each file is about 100MB.

1.3.1.5 File naming convention

The C3S Level 2 Monthly Global Active Fire Location and FRP Summary Product files are named as follows: **<Indicative_Date>-C3S-L2-FRP-<Indicative_sensor>-<TempRes>-<Indicative_satellite>-<day/nighttime>-fv<xx.x>.csv**

<Indicative_Date>
The identifying date for this data set:
The format is YYYYMMDD, where YYYY is the four-digit year, MM is the two-digit month from 01 to 12 and DD is the two digit day of the month. As the product is provided in monthly files this is always 01.
<Indicative_sensor>
In this version of the product, it is SLSTR.
< TempRes >
In this version of the product, it is P1M.
<Indicative_satellite>

[7] *Due to an error in the processing chain of the ESA SLSTR L2 FRP NTC products (currently under correction), sometimes fires that are temporarily categorised as 'unclassified' are not reclassified correctly, e.g. as vegetation fires, gas flares, etc. Therefore, the user should use the classification flag in the C3S AF & FRP L2 summary product derived from the ESA SLSTR L2 FRP NTC products with caution and also consider the unclassified fires.*

The identifying sentinel-3 satellite, currently there are two operating sentinel-3 satellites: sentinel-3A and -3B. For sentinel-3A, its S3A, sentinel-3B, its S3B.
<day/nighttime>
Day or night-time product
fv<File_Version>
File version number in the form n{1,}[.n{1,}] (That is 1 or more digits followed by optional . and another 1 or more digits). This version is fv1.2.

Example:
20220701-C3S-L2-FRP-SLSTR-P1M-S3A-nighttime-fv1.2.csv

1.3.1.6 Metadata

The metadata for the FRP maps are provided as global attributes in the NetCDF file. It follows the CCI guidelines (Bennett, 2012).

1.3.2 Level 3a Daily Gridded AF & FRP Night-time Product

1.3.2.1 Temporal Resolution

The Level 3a Daily Gridded AF & FRP Night-time Product is generated on a daily basis, but at present only nighttime landscape fires are included due to the full daytime AF detection algorithm not yet being implemented during the generation of the Level 2 Active Fire Detection and FRP Products files. Active fire data from the different Sentinel satellites (Sentinel-3A and -3B currently) are stored in different products in NetCDF4 format.

1.3.2.2 Spatial Resolution

The Level 3a Daily Gridded AF & FRP Night-time Product file stores daily data on a global 0.1° resolution grid, the grid cell is approximately 10 km by 10 km at the equator and its area decreases with latitude away from the equator.

1.3.2.3 Projection

The Level 3a Daily Gridded AF & FRP Night-time Product file stores data on a global 0.1° resolution grid. A geographic coordinate system based on the World Geodetic System 84 (WGS84) reference ellipsoid is used, with coordinates specified in decimal degrees. Information on product projection, ellipsoid and pixel size is included in the NetCDF file, so the area covered by every grid cell can be geographically referenced without the need of additional specific pixel indicators of geographical position.

1.3.2.4 Product Layer

Each Level 3a Daily Gridded AF & FRP Night-time Product file is a tiled NetCDF file covering the globe at a 0.1° grid cell resolution. The AF & FRP data from different satellite will be put in different files, one for Sentinel-3A, and one for Sentinel-3B. Each file stores information contained in one day of Level 2 Sentinel-3 AF detection and FRP Product files. Only data in grid cells containing land are provided in the Level 3a Daily Gridded FRP Product files in order to make the product most relevant to only vegetation fires and organic soil burning (avoiding oceanic gas flares). Separate products are

provided for the data coming from S3A and S3B, and in each product a grid-cell location stores eight values relevant to SLSTR night-time observations:

1. Number of active fire pixels detected in each land grid cell (grid-cells containing only water are given zero AF detections, since any fires would likely be due to oceanic gas flares rather than biomass burning)
2. Mean FRP of the detected land-based AF pixels
3. Uncertainty of the Mean FRP of the detected land-based AF pixels
4. Total number of pixel observations made within the grid cell
5. Total number of pixels in the grid cell whose surface conditions might impact AF detection (e.g., which contain too great an area of surface water)
6. Total number of pixels on land identified as containing atmospheric phenomena that might interfere with AF detection (e.g., thick cloud cover)
7. The mean "cloud fraction" of the land pixels in a 1.1° × 1.1° grid cell
8. Total active fire pixel count adjusted for atmospheric conditions that impede AF detection (e.g., thick cloud cover).

This adjusted active fire pixel count is based on the assumption that active fires burn with the same frequency under the cloud as they do under cloud free conditions, so for example, if land in a grid cell was 30% covered by cloud during the period then the number of active fire pixels adjusted for cloud cover is simply the detected number of active fire pixels increased by 30%. It is considered that the cloud cover adjustment may work better at coarser spatial resolutions than the AF detections are made at, so cloud cover fraction is calculated at 1.1° grid cell resolution, centered on each 0.1° grid cell.

In terms of frequency of coverage of each grid cell, when combined together the SLSTR instruments on the two concurrently orbiting Sentinel-3 satellites provide data of any equatorial Earth location once by day and once by night, every 24 hours. Therefore, every 24 hours, each individual satellite SLSTR provides night-time data in around half of the equatorial grid cells. However, this frequency of coverage increases at higher latitudes to orbital convergence, providing grid cells sufficiently close to the poles with more observations every 24 hours than those at the equator. Whilst a constantly maintained Sentinel-3 orbit means that the frequency of coverage pattern of any particular grid cell should simply be repeated over time, users may sometimes wish to take into account the differing number of observations made at certain grid cells. The data layer 'Total number of pixel observations made within the grid cell' can be used for this. This parameter will change with latitude due to both 0.1° × 0.1° grid cells at higher latitudes being covered by a different number of SLSTR 1km pixels than at the equator, and also by the fact that grid cells at higher latitudes are observed more often by SLSTR compared to those at lower latitudes. For the Level 3a Daily Gridded FRP Product file, the S3A data layer 's3a_night_pixel' stores the number of pixel observations that were made within each grid cell during nighttime passes. Some values will be zero for the daily gridded product, indicating that no observations of that grid cell were made in the period being considered. Values higher than zero indicate the number of pixel observations that fell within the grid cell, which depends on both the latitudinally-dependent km² area of the grid cell and the number of times SLSTR viewed that grid cell

in the period. Some grid cells that lay at the edge of the SLSTR near nadir swath may only be partly observed during an overpass, and this will also be reflected in their recorded number of pixel observations.

The grid cells will have typically eight data layers, representing information derived from the nighttime (ascending node) Sentinel-3 A or B overpasses. Figure 1-3 shows a Level 3a Daily Gridded AF & FRP Night-time Product as opened in the Panoply Data Viewer[8] with all of the layers shown.

Name	Long Name	Type
20220701-C3S-L3-FRP-SLSTR-P1D-0.1deg-S3A-nighttime-fv1.2.nc	ECMWF C3S Gridded OLCI Fire Radiative Power product	Local File
atmospheric_condition_flag_pixels	Total number of S3A nighttime pixels unprocessed by the AF detection algor…	Geo2D
atmospheric_condition_fraction	Mean unsuitable atmospheric condition fraction of S3A nighttime land pixels i…	Geo2D
fire_pixels	Total number of S3A nighttime active fire pixels	Geo2D
fire_weighted_pixels	Number of S3A nighttime active fire pixels weighted by atmospheric conditio…	Geo2D
frp	Mean Fire Radiative Power measured by S3A during nighttime	Geo2D
frp_unc	Mean Fire Radiative Power uncertainty measured by S3A during nighttime	Geo2D
lat	latitude	1D
lat_bounds	lat_bounds	2D
lon	longitude	1D
lon_bounds	lon_bounds	2D
surface_conditions_flag_pixels	Total number of S3A nighttime pixels unprocessed by the AF detection algor…	Geo2D
time	time	—
time_bounds	time_bounds	1D
total_pixels	Total number of S3A nighttime pixels	Geo2D

Figure 1-3: An example of the layer structure of the C3S Level 3a Daily Gridded AF & FRP Night-time Product for 01 March 2022, as opened in the Panoply Data Viewer.

Figure 1-4 shows the Level 3a Daily Gridded AF & FRP Night-time S3A Product of 01 July 2022 ; (a) the gridded global night-time AF count (fire_pixels) and (b) total FRP, the latter calculated by multiplying together the AF count (fire_pixels) and mean FRP (frp) data layers. Fires are particularly active in parts of South America, Southern Africa and Russia during this period.

[8] https://www.giss.nasa.gov/tools/panoply/

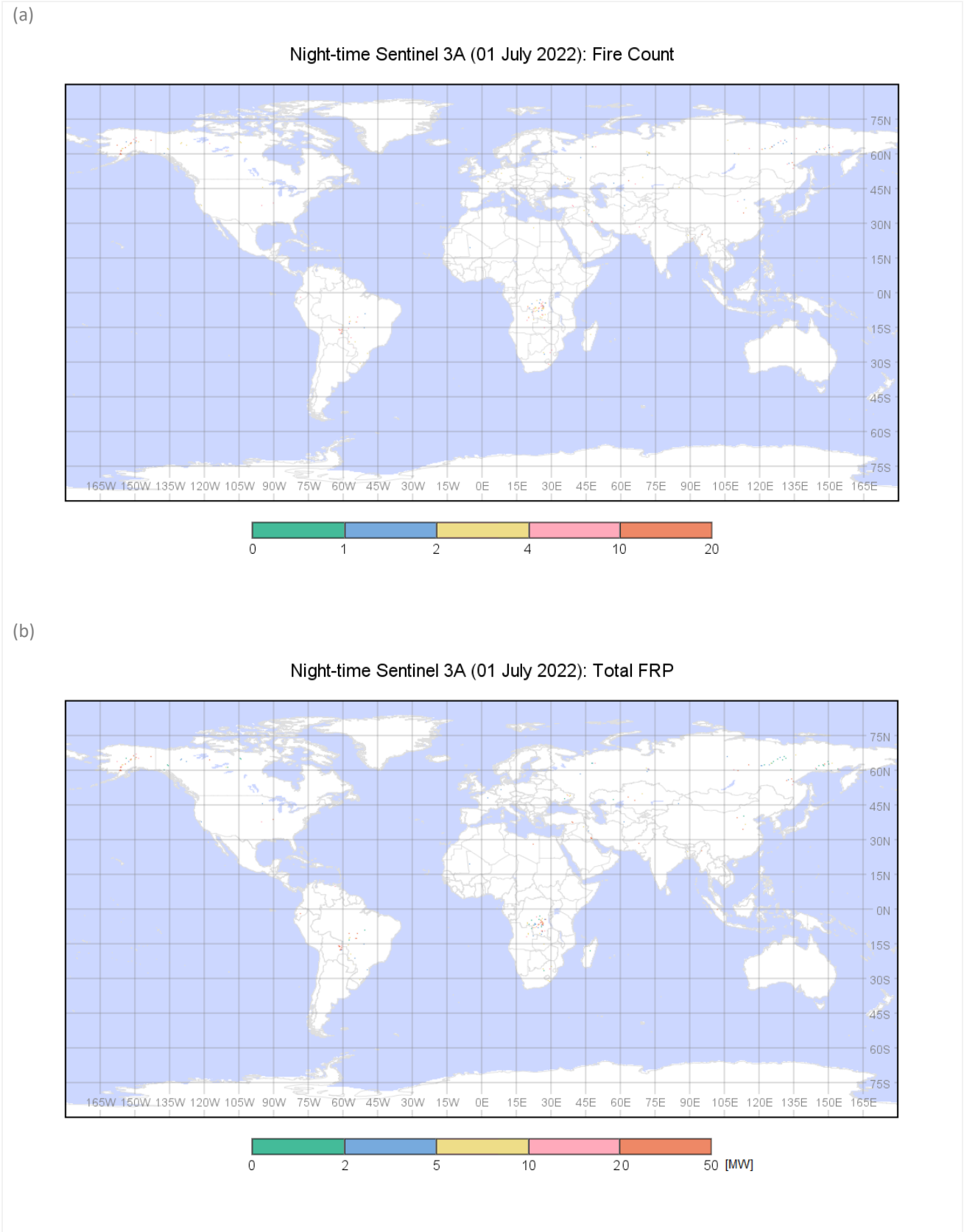


Figure 1-4: Daily global map of (a) AF count and (b) total FRP derived from the Level 3a Daily Gridded AF & FRP Night-time S3A Product of 01 July 2022. Data are from Sentinel-3A in this case.

1.3.2.5 File format and size

The Level 3a Daily Gridded AF & FRP Night-time Product file is stored in a compressed Network Common Data Form version 4 (NetCDF4) file, with metadata attributes compliant with version 1.7 of the Climate and Forecast conventions. AF data coming from observations made by the different Sentinel-3 satellites (Sentinel-3A and -3B currently) have separate layers in the NetCDF file, and ultimately there will be two Sentinel-3A and two Sentinel-3B layers – representing data from the daytime and nighttime overpasses of each satellite (currently a full daytime Level 2 FRP NTC product does not exist with which to create the Level 3 day-time data layers). In each layer of the gridded Level 3a product, each grid cell has eight values stored, as detailed in Section 1.3.2.4. The file size of each Level 3a daily gridded Night-time product NetCDF4 file is around 5MB.

1.3.2.6 File naming convention

The Level 3a Daily Gridded AF & FRP Night-time Product files are named as follows (with TempRes as P1D to differentiate them from other Level 3 Gridded AF & FRP Night-time Product files):

<Indicative_Date>-C3S-L3-FRP-<Indicative_sensor>-<TempRes>-<SpatRes>-<Indicative_satellite>-<day/nighttime>-fv<xx.x>.nc

<Indicative_Date>
The identifying date for this data set:
The format is YYYYMMDD, where YYYY is the four-digit year, MM is the two-digit month from 01 to 12 and DD is the two-digit day of the month.
<Indicative_sensor>
In this version of the product, it is SLSTR.
<TempRes>
In this version of the product, it is P1D.
<SpatRes>
In this version of the product, it is 0.1deg.
<Indicative_satellite>
The identifying sentinel-3 satellite, currently there are two operating sentinel-3 satellites: sentinel-3A and -3B. For sentinel-3A, its S3A, sentinel-3B, its S3B.
<day/nighttime>
Day or night-time product

fv<File_Version>
File version number in the form n{1,}[.n{1,}] (That is 1 or more digits followed by optional . and another 1 or more digits). This version is fv1.2.

Example:
20220701-C3S-L3-FRP-SLSTR-P1D-0.1deg-S3A-nighttime-fv1.2.nc

1.3.2.7 Metadata

The metadata for the Night-time AF & FRP maps are provided as global attributes in the NetCDF file. It follows the CCI guidelines (Bennett, 2012).

1.3.3 Level 3a 27-Day Gridded AF & FRP Night-time Product

1.3.3.1 Temporal Resolution

The Level 3a 27-Day Gridded AF & FRP Night-time Product builds on the Level 3a Daily Gridded AF & FRP Night-time Product by collating and summarising the information contained therein at the same 0.1° grid cell resolution, but now over a 27-day period. This time interval is selected to match the standard Sentinel-3 orbital repeat cycle.

1.3.3.2 Spatial Resolution

The Level 3a 27-Day Gridded AF & FRP Night-time Product builds on Level 2 Active Fire Detection and FRP Products files and stores the information on a global 0.1° resolution grid.

1.3.3.3 Projection

The Level 3a 27-Day Gridded AF & FRP Night-time Product file builds on the Level 2 Active Fire Detection and FRP Products files and is stored on the global 0.1° resolution grid similar to the Level 3a Daily Gridded AF & FRP Night-time Product. A geographic coordinate system based on the World Geodetic System 84 (WGS84) reference ellipsoid is used, with coordinates specified in decimal degrees. Information on product projection, ellipsoid and pixel size is included in the NetCDF file, so the area covered by every grid cell can be geographically referenced without the need of adding specific pixel indicators of geographical position.

1.3.3.4 Product Layer

Similar to the Level 3a Daily Gridded AF & FRP Night-time Product, data from S3A and S3B are stored in separate files, which are calculated over the 27-day period and in each product a grid-cell location stores seven values relevant to SLSTR night-time observations:

1. Number of active fire pixels detected in each land grid cell
2. Mean FRP of the detected land-based AF pixels
3. Total number of pixel observations made within the grid cell
4. Total number of pixels in the grid cell whose surface conditions might impact AF detection (e.g., which contain too great an area of surface water)
5. Total number of pixels on land identified as containing atmospheric phenomena that might interfere with AF detection (e.g., thick cloud cover)
6. The mean “cloud fraction” of the land pixels in a 1.1° × 1.1° grid cell
7. Total active fire pixel count adjusted for atmospheric conditions that impede AF detection (e.g., thick cloud cover).

As with the Level 3a Daily Gridded AF & FRP Night-time Product, for the Level 3a 27-Day Gridded AF & FRP Night-time Product the ‘Total number of pixel observations made within the grid cell’ can be used to understand the differing number of observations made at different grid cells, which changes with latitude due to both 0.1° × 0.1° grid cells at higher latitudes being covered by a different number

of SLSTR 1 km pixels than at the equator, and also by the fact that grid cells at higher latitudes are observed more often by SLSTR compared to those at lower latitudes.

Figure 1-5 shows a Level 3a 27-Day Gridded AF & FRP Night-time Product opened in the Panoply Data Viewer[9], with all of the layers shown. The layer structure is similar to the daily Night-time product.

Name	Long Name	Type
20220624-C3S-L3-FRP-SLSTR-P27D-0.1deg-S3A-nighttime-fv1.2.nc	ECMWF C3S Gridded OLCI Fire Radiative Power product	Local File
atmospheric_condition_flag_pixels	Total number of S3A nighttime pixels unprocessed by the AF detection algor…	Geo2D
atmospheric_condition_fraction	Mean unsuitable atmospheric condition fraction of S3A nighttime land pixels i…	Geo2D
fire_pixels	Total number of S3A nighttime active fire pixels	Geo2D
fire_weighted_pixels	Number of S3A nighttime active fire pixels weighted by atmospheric conditio…	Geo2D
frp	Mean Fire Radiative Power measured by S3A during nighttime	Geo2D
frp_unc	Mean Fire Radiative Power uncertainty measured by S3A during nighttime	Geo2D
lat	latitude	1D
lat_bounds	lat_bounds	2D
lon	longitude	1D
lon_bounds	lon_bounds	2D
surface_conditions_flag_pixels	Total number of S3A nighttime pixels unprocessed by the AF detection algor…	Geo2D
time	time	—
time_bounds	time_bounds	1D
total_pixels	Total number of S3A nighttime pixels	Geo2D

Figure 1-5: An example of the layer structure of the C3S Level 3a 27-Day Gridded AF & FRP Night-time Product starting date of the data is 24 June 2022, as opened in Panoply Data Viewer.

1.3.3.5 File format and size

In the same way as the Level 3a Daily Gridded AF & FRP Night-time Product , the Level 3a 27-Day Gridded AF & FRP Night-time Product stores information in a compressed Network Common Data Form version 4 (NetCDF4) file, with metadata attributes compliant with version 1.7 of the Climate and Forecast conventions. In each layer, each grid cell has eight values stored, as detailed in Section 1.3.3.4. The file size is around 10 MB.

1.3.3.6 File naming convention

The Level 3a 27-Day Gridded AF & FRP Night-time Product files are named as follows (with TempRes as P27D to differentiate them from other Level 3 Gridded AF & FRP Night-time Product files):

<Indicative_Date>-C3S-L3-FRP-<Indicative_sensor>-<TempRes>-<SpatRes>-<Indicative_satellite>-<day/nighttime>-fv<xx.x>.nc

<Indicative_Date>
The identifying date for this data set:
The format is YYYYMMDD, where YYYY is the four-digit year, MM is the two-digit month from 01 to 12 and DD is the two digit day of the month at which the product starts accumulating data.
<Indicative_sensor>
In this version of the product, it is SLSTR.
<TempRes>
In this version of the product, it is P27D.

[9] https://www.giss.nasa.gov/tools/panoply/

<SpatRes>
In this version of the product, it is 0.1deg.
<Indicative_satellite>
The identifying sentinel-3 satellite, currently there are two operating sentinel-3 satellites: sentinel-3A and -3B. For sentinel-3A, its S3A, sentinel-3B, its S3B.
<day/nighttime>
Day or night-time product
fv<File_Version>
File version number in the form n{1,}[.n{1,}] (That is 1 or more digits followed by optional . and another 1 or more digits). This version is fv1.2.

Example:
20220624-C3S-L3-FRP-SLSTR-P27D-0.1deg-S3A-nighttime-fv1.2.nc

1.3.3.7 Metadata

The metadata for the Night-time AF & FRP maps are provided as global attributes in the NetCDF file. It follows the CCI guidelines (Bennett, 2012).

1.3.4 Level 3 Monthly Summary AF & FRP Night-time Product

1.3.4.1 Temporal Resolution

The Level 3 Monthly Summary AF & FRP Night-time Product builds on the Level 2 Active Fire Detection and FRP Products files by collating and summarising the information contained therein over a calendar month.

1.3.4.2 Spatial Resolution

The Level 3 Monthly Summary AF & FRP Night-time Product provides global data at a grid cell size of 0.25°, matching that of the MODIS Climate Modelling Grid (CMG) active fire products.

1.3.4.3 Projection

The Level 3 Monthly Summary AF & FRP Night-time Product stores data on a global 0.25° resolution grid. A geographic coordinate system based on the World Geodetic System 84 (WGS84) reference ellipsoid is used, with coordinates specified in decimal degrees. Information on product projection, ellipsoid and pixel size is included in the NetCDF file, so the area covered by every grid cell can be geographically referenced without the need of adding specific pixel indicators of geographical position.

1.3.4.4 Product Layer

The Level 3 Monthly Summary AF & FRP Night-time Product provides global data at a grid cell size of 0.25°, matching that of the Terra MODIS Climate Modelling Grid (MOD14CMQ) active fire products. Similar to the Level 3a 27-Day Gridded AF & FRP Night-time Product, the Level 3 Monthly Summary

AF & FRP Night-time Product stores the data from S3A and S3B in separate files including seven bands but each calculated over the monthly period at the location of each 0.25° grid cell in question:

1. Number of active fire pixels detected in each land grid cell
2. Mean FRP of the detected land-based AF pixels
3. Total number of pixel observations made within the grid cell
4. Total number of pixels in the grid cell whose surface conditions might impact AF detection (e.g., which contain too great an area of surface water)
5. Total number of pixels on land identified as containing atmospheric phenomena that might interfere with AF detection (e.g., thick cloud cover)
6. The mean "cloud fraction" of the land pixels in a 1.25° × 1.25° grid cell
7. Total active fire pixel count adjusted for atmospheric conditions that impede AF detection (e.g., thick cloud cover).

As with the Level 3a Daily and 27-Day Gridded AF & FRP Night-time Products, for the Level 3 Monthly Summary AF & FRP Night-time Product, the 'Total number of pixel observations made within the grid cell' layer can be used to understand the differing number of observations made at different grid cells, which changes with latitude due to both 0.25° × 0.25° grid cells at higher latitudes being covered by a different number of SLSTR 1 km pixels than at the equator, and also by the fact that grid cells at higher latitudes are observed more often by SLSTR compared to those at lower latitudes.

Figure 1-6 shows a Level 3 Monthly Summary AF & FRP Night-time Product opened in the Panoply Data Viewer[10], with all the layers shown. The layer structure is similar to the daily and 27-Day Night-time product.

Name	Long Name	Type
20220701-C3S-L3-FRP-SLSTR-P1M-0.25deg-S3A-nighttime-fv1.2.nc	ECMWF C3S Gridded OLCI Fire Radiative Power product	Local File
atmospheric_condition_flag_pixels	Total number of S3A nighttime pixels unprocessed by the AF detection algor…	Geo2D
atmospheric_condition_fraction	Mean unsuitable atmospheric condition fraction of S3A nighttime land pixels i…	Geo2D
fire_pixels	Total number of S3A nighttime active fire pixels	Geo2D
fire_weighted_pixels	Number of S3A nighttime active fire pixels weighted by atmospheric conditio…	Geo2D
frp	Mean Fire Radiative Power measured by S3A during nighttime	Geo2D
frp_unc	Mean Fire Radiative Power uncertainty measured by S3A during nighttime	Geo2D
lat	latitude	1D
lat_bounds	lat_bounds	2D
lon	longitude	1D
lon_bounds	lon_bounds	2D
surface_conditions_flag_pixels	Total number of S3A nighttime pixels unprocessed by the AF detection algor…	Geo2D
time	time	—
time_bounds	time_bounds	1D
total_pixels	Total number of S3A nighttime pixels	Geo2D

Figure 1-6: An example of the layer structure of the C3S Level 3 Monthly Summary Gridded AF & FRP Night-time Product of July 2022, as opened in Panoply Data Viewer.

Figure 1-7 shows from the Level 3 Monthly Summary AF & FRP Night-time S3A Product of July 2022 (a) the gridded global night-time AF count from S3A and (b) the total FRP, the latter calculated by multiplying together the AF count and mean FRP data layers.

[10] https://www.giss.nasa.gov/tools/panoply/

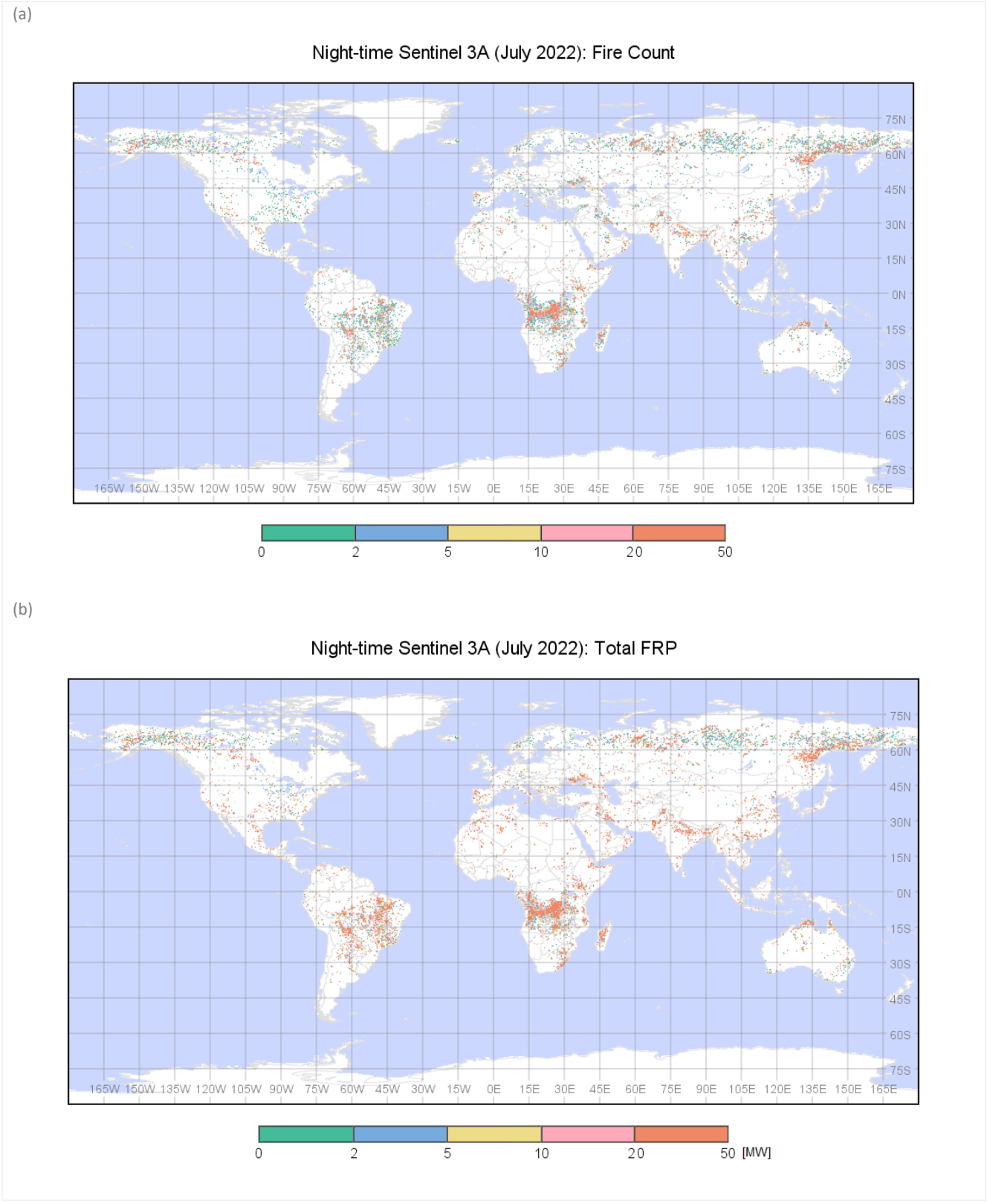


Figure 1-7: Monthly global map of (a) AF count and (b) total FRP derived from the Level 3 Monthly Summary AF & FRP Night-time S3A Product of July 2022. Data are from Sentinel-3A in this case. Compare to the daily Night-time maps of Figure 1-3 produced using data from 01 July 2022 to see the difference the accumulation of data over a one-month period makes.

1.3.4.5 File format and size

In the same way as for the Level 3a 27-Day Gridded AF & FRP Night-time Products, the Level 3 Monthly Summary AF & FRP Night-time Product stores data in a compressed Network Common Data Form version 4 (NetCDF4) file, with metadata attributes compliant with version 1.7 of the Climate and Forecast conventions. In each layer each grid cell has eight values stored, as detailed in Section 1.3.8.4. The file size is around 3 MB.

1.3.4.6 File naming convention

The Level 3 Monthly Summary AF & FRP Night-time Product files are named as follows (with TempRes as P1M to differentiate them from other Level 3 Gridded AF & FRP Night-time Product files):

<Indicative_Date>-C3S-L3-FRP-<Indicative_sensor>-<TempRes>-<SpatRes>>-<Indicative_satellite>-<day/nighttime>-fv<xx.x>.nc

<Indicative_Date>
The identifying date for this data set:
The format is YYYYMMDD, where YYYY is the four-digit year, MM is the two-digit month from 01 to 12 and DD, as the product is provided in monthly files, is always 01.
<Indicative_sensor>
In this version of the product, it is SLSTR.
<TempRes>
In this version of the product, it is P1M.
<SpatRes>
In this version of the product, it is 0.25deg.
<Indicative_satellite>
The identifying sentinel-3 satellite, currently there are two operating sentinel-3 satellites: sentinel-3A and -3B. For sentinel-3A, its S3A, sentinel-3B, its S3B.
<day/nighttime>
Day or night-time product
fv<File_Version>
File version number in the form n{1,}[.n{1,}] (That is 1 or more digits followed by optional . and another 1 or more digits). This version is fv1.2.

Example:
20220701-C3S-L3-FRP-SLSTR-P1M-0.25deg-S3A-nighttime-fv1.2.nc

1.3.4.7 Metadata

The metadata for the Night-time AF & FRP maps are provided as global attributes in the NetCDF file. It follows the CCI guidelines (Bennett, 2012).

1.3.5 Level 2 Monthly Global Gas Flare Night-time Summary Product

1.3.5.1 Introduction

The Sentinel-3 Level 2 Active Fire Detection and FRP Products issued in non-time critical (NTC) mode are the source for the C3S FRP products, including the Level 2 Monthly Global gas flare Location and FRP Summary Product discussed here. Each night-time C3S Level 2 Monthly Global Gas Flare Location and FRP Summary Product is a comma delimited ASCII text CSV file containing the information shown in Table 1-5 that is relevant to the gas flare pixels detected that month. Each Level 2 Summary Product is based on information from the shortwave-infrared derived data layer contained in tens of thousands of Level 2 Active Fire Detection and FRP Product files.

Each Level 2 FRP Summary product stores essential information about pixels believed to contain active gas flares, along with a SUMMARY FLAG dataset providing information on every pixel in the 3-minute Universal time granule related primarily to the output of the active fire detection tests. The Level 2 Monthly Global Gas Flare Location and FRP Summary Product provides a text-based summary of the Level 2 Active Fire Detection and FRP Product data collected over the period of one month at the locations of all detected active fire pixels across the globe.

The monthly night-time gas flare summary product stores the latitude, longitude, FRP, date, time and associated data of every detected active fire pixel identified worldwide in the Level 2 Gas Flare Detection and FRP Products of that month, as detailed in Section 1.3.1.2. The separate summaries of the data records coming from the S3A and S3B satellites are put also into separate text type files stored in CSV format.

1.3.5.2 Date usage information

The original Sentinel-3 Level 2 Active Fire Detection and FRP Product files contain a shortwave infrared derived data layer that includes all detected hotspot types, but these are filtered by the C3S algorithm to only leave in the S3S Gas Flare products information related to gas flare hotspots.

The FRP of gas flares is best derived from SWIR rather than MIR observations, and so information related to the gas flare pixel detections and their SWIR-derived FRP stored in each L2 Summary Product includes (i) the original SLSTR Level 1 granule pixel sample and line number, (ii) the corresponding latitude and longitude, (iii) the gas flare pixel SWIR-derived FRP and uncertainty, (iv) pixel footprint area of the SWIR channel used (S6) for FRP derivation, day/night flag, and (v) date, time and satellite (e.g., Sentinel-3A or 3B). Further details of this information are provided in Table 1-4.

Table 1-5: Information held within each Level 2 Monthly Global Gas Flare Night-time Summary Product File at the location of each detected gas flare (GF) pixel for each Sentinel-3 satellite.

Name	Units	Comment
Column	Pixel	Across-track image grid index for the detected GF pixel
Row	Pixel	Along-track image grid index for the detected GF pixel

Name	Units	Comment
Date	Date	Date in the format of YYYYMMDD
Time	hours, minutes and seconds	Time in the format of HHMMSS
Latitude	° (i.e., degrees)	Latitude
Longitude	° (i.e., degrees)	Longitude
FRP_SWIR	MW	Fire radiative power computed from the SWIR channel observation (S6)
Sat_Zenith	° (i.e., degrees)	Satellite Zenith Angle
FRP_SWIR_uncertainty	MW	Uncertainty of the fire radiative power computed from the SWIR channel observation (S6)
S56_cluster_ratio	$(Wm^{-2}sr^{-1}\mu m^{-1})(Wm^{-2}sr^{-1}\mu m^{-1})^{-1}$	The S5 to S6 spectral radiance ratio, calculated at the cluster level (therefore all hotspot pixels within a cluster will have the same value)
Local solar time	Decimal hour	Based on latitude and solar zenith angle, allowing users to identify AF pixels detected during the descending node (morning) S3 overpass, but classified as night-time pixels due to their extreme solar zenith angle.
Day_flag	Boolean	Boolean flag indicating a daytime or night-time detection based on pixel solar zenith angle
Area	m^2	Projected area of the pixel footprint on the Earth surface
Platform	-	Sentinel-3A or Sentinel -3B
Land/Ocean	Boolean	Boolean flag indicating the gas flare (GF) over the land or ocean, with 0 referring to Ocean and 1 to Land

1.3.5.3 Temporal Resolution

The monthly summary product is generated every calendar month, at present the product only includes night-time gas flares over the land.

1.3.5.4 File format and size

The Level 2 Monthly Global Gas Flare Night-time Summary Product is a space delimited ASCII text file with 18 columns, stored in CSV format. The definition of each column is shown in Table 1-4. The file size for each file is about 3 MB.

1.3.5.5 File naming convention

The C3S Level 2 Monthly Global Gas Flare Summary Product files are named as follows:
<Indicative_Date>-C3S-L2-FRP-<Indicative_sensor>-<TempRes>-<Indicative_satellite>-<day/nighttime>-fv<xx.x>.csv

<Indicative_Date>
The identifying date for this data set:
The format is YYYYMMDD, where YYYY is the four-digit year, MM is the two-digit month from 01 to 12 and DD is the two digit day of the month. As the product is provided in monthly files this is always 01.
<Indicative_sensor>
In this version of the product, it is SLSTR.
< TempRes >
In this version of the product, it is P1M.
<Indicative_satellite>
The identifying sentinel-3 satellite, currently there are two operating sentinel-3 satellites: sentinel-3A and -3B. For sentinel-3A, its S3A, sentinel-3B, its S3B.
<day/nighttime>
Day, night-time or gas flare product
fv<File_Version>
File version number in the form n{1,}[.n{1,}] (That is 1 or more digits followed by optional . and another 1 or more digits). This version is fv1.2.

Example:
20220701-C3S-L2-FRP-SLSTR-P1M-S3A-gasflares-fv1.2.csv

1.3.5.6 Metadata

The metadata for the FRP maps are provided as global attributes in the NetCDF file. It follows the CCI guidelines (Bennett, 2012).

1.3.6 Level 3a Daily Gridded Gas Flare Night-time Product

1.3.6.1 Temporal Resolution

The Level 3a Daily Gridded Gas Flare Night-time Product is generated on a daily basis.

1.3.6.2 Spatial Resolution

The Level 3a Daily Gridded Gas Flare Night-time Product file stores daily data on a global 0.1° resolution grid, the grid cell is approximately 10 km by 10 km at the equator and its area decreases with latitude away from the equator.

1.3.6.3 Projection

The Level 3a Daily Gridded Gas Flare Night-time Product file stores data on a global 0.1° resolution grid. A geographic coordinate system based on the World Geodetic System 84 (WGS84) reference ellipsoid is used, with coordinates specified in decimal degrees. Information on product projection,

ellipsoid and pixel size is included in the NetCDF file, so the area covered by every grid cell can be geographically referenced without the need of additional specific pixel indicators of geographical position.

1.3.6.4 Product Layer

Each Level 3a Daily Gridded Gas Flare Night-time Product file is a tiled NetCDF file covering the globe at a 0.1° grid cell resolution. The AF & FRP data from different satellite are put in different files, one for Sentinel-3A, and one for Sentinel-3B. Each file stores information contained in one day of Level 2 Sentinel-3 AF detection and FRP Product files. Data in grid cells containing land or water are provided, since gas flares can be present in both environments. In each product a grid-cell location stores six values relevant to SLSTR night-time observations classed as gas flares:

1. Total number of shortwave-infrared detected hotspots identified as gas flare pixels
2. Mean FRP (derived from SWIR channel observations) of all detected gas flare pixels
3. Uncertainty on this SWIR-derived mean FRP
4. Total number of detected gas flare pixels when the cell was fully observed cloud-free
5. Mean SWIR-derived FRP derived from the flare pixels detected when the cell was fully observed cloud-free
6. Uncertainty on this SWIR-derived mean FRP

The grid cells will have typically six data layers, representing information derived from the nighttime (ascending node) Sentinel-3 A or B overpasses. Figure 1-8 shows a Level 3a Daily Gridded Gas Flare Night-time Product as opened in the Panoply Data Viewer[11] with all of the layers shown.

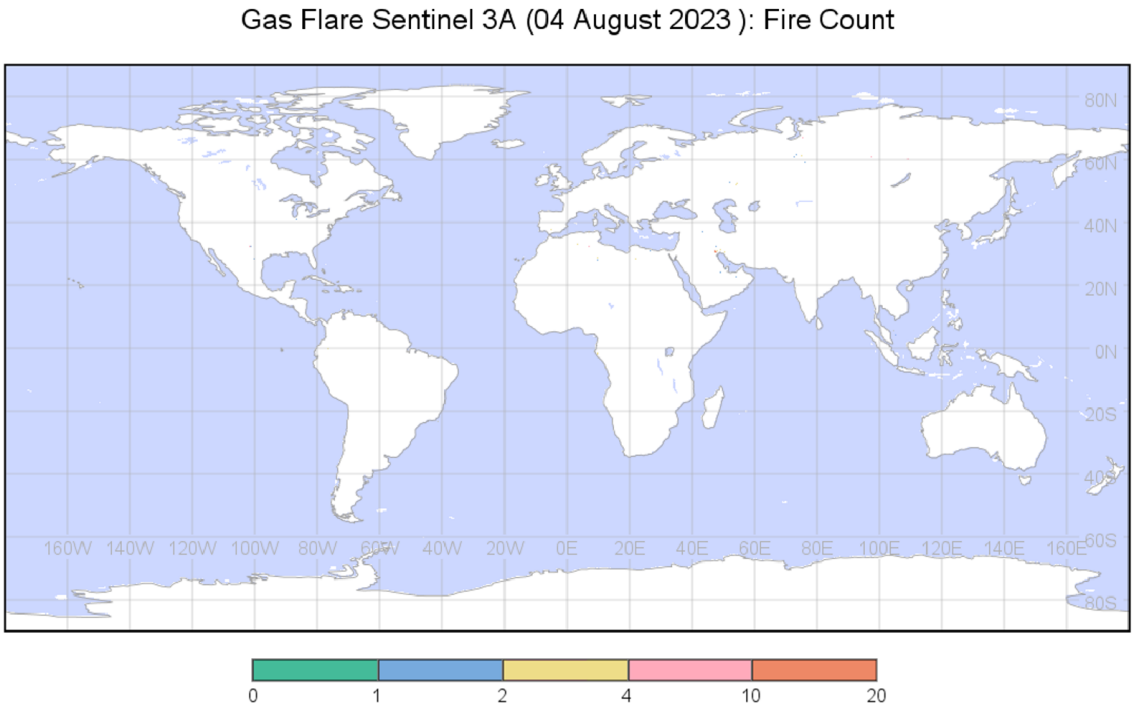
Name	Long Name	Type
20230804-C3S-L3-FRP-SLSTR-P1D-0.1deg-S3A-gasflares-fv1.2.nc	ECMWF C3S Gridded OLCI Fire Radiative Power product	Local File
fire_pixels	Total number of S3A at gasflares active fire pixels	Geo2D
fire_pixels_cloudfree	Total number of S3A at gasflares active fire pixels of cloud-free grid cell con…	Geo2D
frp	Mean Fire Radiative Power measured by S3A at gasflares	Geo2D
frp_cloudfree	Mean Fire Radiative Power of cloud-free grid cell contributions measured by …	Geo2D
frp_unc	Mean Fire Radiative Power uncertainty measured by S3A at gasflares	Geo2D
frp_unc_cloudfree	Mean Fire Radiative Power uncertainty of cloud-free grid cell contributions …	Geo2D
lat	latitude	1D
lat_bounds	lat bounds	2D
lon	longitude	1D
lon_bounds	lon bounds	2D
time	time	—
time_bounds	time bounds	1D

Figure 1-8: An example of the layer structure of the C3S Level 3a Daily Gridded Gas Flare Night-time Product for 04 August 2023 derived from Sentinel-3A, as opened in Panoply Data Viewer.

Figure 1-9 shows the Level 3a Daily Gridded Gas Flare Night-time S3A Product of 04 August 2023; (a) the gridded global night-time Gas Flare count (fire_pixels) and (b) total FRP, the latter calculated by multiplying together the Gas Flare count (fire_pixels) and mean FRP (frp) data layers. Gas Flare Fires are particularly active in parts of North America, North Africa, Arabian Peninsula and Russia during this period.

[11] https://www.giss.nasa.gov/tools/panoply/

(a)



(b)

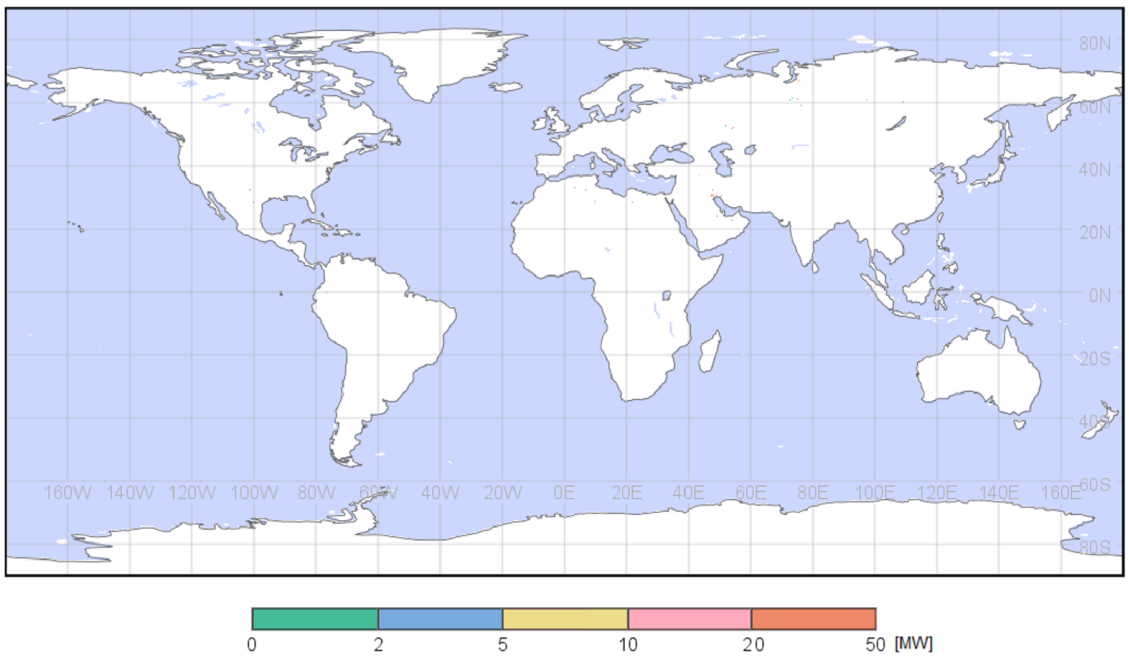


Figure 1-9: Daily global map of (a) AF count and (b) total FRP derived from the Level 3a Daily Gridded AF & FRP Gas Flare Night-time S3A Product of 04 August 2023. Data are from Sentinel-3A in this case.

1.3.6.5 File format and size

The Level 3a Daily Gridded Gas Flare Night-time Product file is stored in a compressed Network Common Data Form version 4 (NetCDF4) file, with metadata attributes compliant with version 1.7 of the Climate and Forecast conventions. AF data coming from observations made by the different Sentinel-3 satellites (Sentinel-3A and -3B currently) have separate layers in the NetCDF file, and ultimately there will be two Sentinel-3A and two Sentinel-3B layers – representing data from the daytime and nighttime overpasses of each satellite (currently a full daytime Level 2 FRP NTC product does not exist with which to create the Level 3 day-time data layers). In each layer of the gridded Level 3a product, each grid cell has eight values stored, as detailed in Section 1.3.2.4. The file size of each Level 3a daily gridded Night-time product NetCDF4 file is around 0.4 MB.

1.3.6.6 File naming convention

The Level 3a Daily Gridded Gas Flare Night-time Product files are named as follows (with TempRes as P1D to differentiate them from other Level 3 Gridded Gas Flare Night-time Product files):

<Indicative_Date>-C3S-L3-FRP-<Indicative_sensor>-<TempRes>-<SpatRes>-<Indicative_satellite>-<day/nighttime>-fv<xx.x>.nc

<Indicative_Date>
The identifying date for this data set:
The format is YYYYMMDD, where YYYY is the four-digit year, MM is the two-digit month from 01 to 12 and DD is the two-digit day of the month.
<Indicative_sensor>
In this version of the product, it is SLSTR.
<TempRes>
In this version of the product, it is P1D.
<SpatRes>
In this version of the product, it is 0.1deg.
<Indicative_satellite>
The identifying sentinel-3 satellite, currently there are two operating sentinel-3 satellites: sentinel-3A and -3B. For sentinel-3A, its S3A, sentinel-3B, its S3B.
<day/nighttime>
Day, night-time or gas flare product

fv<File_Version>
File version number in the form n{1,}[.n{1,}] (That is 1 or more digits followed by optional . and another 1 or more digits). This version is fv1.2.

Example:
20230804-C3S-L3-FRP-SLSTR-P1D-0.1deg-S3A-gasflares-fv1.2.nc

1.3.6.7 Metadata

The metadata for the Night-time AF & FRP maps are provided as global attributes in the NetCDF file. It follows the CCI guidelines (Bennett, 2012).

1.3.7 Level 3a 27-Day Gridded Gas Flare Night-time Product

1.3.7.1 Temporal Resolution

The Level 3a 27-Day Gridded Gas Flare Night-time Product builds on the Level 3a daily product by collating and summarising the information contained therein at the same 0.1° grid cell resolution, but now over a 27-day period. This time interval is selected to match the standard Sentinel-3 orbital repeat cycle.

1.3.7.2 Spatial Resolution

The Level 3a 27-Day Gridded Gas Flare Night-time Product builds on the Level 3a daily product and stores information on a global 0.1° resolution grid.

1.3.7.3 Projection

The Level 3a 27-Day Gridded Gas Flare Night-time Product file builds on the Level 2 Active Fire Detection and FRP Products files and is stored on the global 0.1° resolution grid similar to the Level 3a Daily Gridded Gas Flare Product. A geographic coordinate system based on the World Geodetic System 84 (WGS84) reference ellipsoid is used, with coordinates specified in decimal degrees. Information on product projection, ellipsoid and pixel size is included in the NetCDF file, so the area covered by every grid cell can be geographically referenced without the need of adding specific pixel indicators of geographical position.

1.3.7.4 Product Layer

Similar to the Level 3a Daily Gridded Gas Flare Product, data from S3A and S3B are stored in separate files, which are calculated over the 27-day period and in each product a grid-cell location stores seven values relevant to SLSTR night-time observations:
The Level 3a 27-Day Gridded Gas Flare Night-time Product builds on the Level 3a Daily Gridded Gas Flare Night-time Product by collating and summarising the information contained therein at the same 0.1° grid cell resolution, but now over a 27-day period. This time interval is selected to match the standard Sentinel-3 orbital repeat cycle. Data from S3A and S3B are stored in separate files, which are calculated over the 27-day period including the following bands:

1. Total number of detected gas flare pixels
2. Mean FRP (derived from SWIR channel observations) of all detected gas flare pixels
3. Uncertainty on this SWIR-derived mean FRP
4. Total number of detected gas flare pixels when the cell was fully observed cloud-free
5. Mean SWIR-derived FRP derived from the flare pixels detected when the cell was fully observed cloud-free
6. Uncertainty on this SWIR-derived mean FRP

As with the Level 3a Daily Gridded Night-time Gas Flare Product, for the Level 3a 27-Day Gridded Gas Flare Product the ‘Total number of pixel observations made within the grid cell’ can be used to understand the differing number of observations made at different grid cells, which changes with

latitude due to both 0.1° × 0.1° grid cells at higher latitudes being covered by a different number of SLSTR 1 km pixels than at the equator, and also by the fact that grid cells at higher latitudes are observed more often by SLSTR compared to those at lower latitudes.

Figure 1-10 shows a Level 3a 27-Day Gridded Gas Flare Night-time Product opened in the Panoply Data Viewer[12], with all of the layers shown. The layer structure is similar to the daily Night-time product.

Name	Long Name	Type
20230803-C3S-L3-FRP-SLSTR-P27D-0.1deg-S3A-gasflares-fv1.2.nc	ECMWF C3S Gridded OLCI Fire Radiative Power product	Local File
fire_pixels	Total number of S3A at gasflares active fire pixels	Geo2D
fire_pixels_cloudfree	Total number of S3A at gasflares active fire pixels of cloud-free grid cell con...	Geo2D
frp	Mean Fire Radiative Power measured by S3A at gasflares	Geo2D
frp_cloudfree	Mean Fire Radiative Power of cloud-free grid cell contributions measured by ...	Geo2D
frp_unc	Mean Fire Radiative Power uncertainty measured by S3A at gasflares	Geo2D
frp_unc_cloudfree	Mean Fire Radiative Power uncertainty of cloud-free grid cell contributions ...	Geo2D
lat	latitude	1D
lat_bounds	lat bounds	2D
lon	longitude	1D
lon_bounds	lon bounds	2D
time	time	—
time_bounds	time bounds	1D

Figure 1-10: An example of the layer structure of the C3S Level 3a 27-Day Gridded Gas Flare Night-time Product starting date of the data is 03 August 2023, as opened in Panoply Data Viewer.

1.3.7.5 File format and size

In the same way as the Level 3a Daily Gridded Gas Flare Night-time Product, the Level 3a 27-Day Gridded Gas Flare Night-time Product stores information in a compressed Network Common Data Form version 4 (NetCDF4) file, with metadata attributes compliant with version 1.7 of the Climate and Forecast conventions. In each layer, each grid cell has eight values stored, as detailed in Section 1.3.3.4. The file size is around 0.4 MB.

1.3.7.6 File naming convention

The Level 3a 27-Day Gridded Gas Flare Night-time Product files are named as follows (with TempRes as P27D to differentiate them from other Level 3 Gridded Gas Flare Night-time Product files):

<Indicative_Date>-C3S-L3-FRP-<Indicative_sensor>-<TempRes>-<SpatRes>-<Indicative_satellite>-<day/nighttime>-fv<xx.x>.nc

<Indicative_Date>
The identifying date for this data set:
The format is YYYYMMDD, where YYYY is the four-digit year, MM is the two-digit month from 01 to 12 and DD is the two digit day of the month at which the product starts accumulating data.
<Indicative_sensor>
In this version of the product, it is SLSTR.
<TempRes>

[12] https://www.giss.nasa.gov/tools/panoply/

In this version of the product, it is P27D.
<SpatRes>
In this version of the product, it is 0.1deg.
<Indicative_satellite>
The identifying sentinel-3 satellite, currently there are two operating sentinel-3 satellites: sentinel-3A and -3B. For sentinel-3A, its S3A, sentinel-3B, its S3B.
<day/nighttime>
Day, night-time or gas flare product
fv<File_Version>
File version number in the form n{1,}[.n{1,}] (That is 1 or more digits followed by optional . and another 1 or more digits). This version is fv1.2.

Example:
20230803-C3S-L3-FRP-SLSTR-P27D-0.1deg-S3A-gasflares-fv1.2.nc

1.3.7.7 Metadata

The metadata for the Night-time Gas Flare maps are provided as global attributes in the NetCDF file. It follows the CCI guidelines (Bennett, 2012).

1.3.8 Level 3 Monthly Summary Gas Flare Night-time Product

1.3.8.1 Temporal Resolution

The Level 3 Monthly Summary Gas Flare Night-time Product builds on the Level 2 Active Fire Detection and FRP Products files by collating and summarising the shortwave infrared derived information contained therein related to gas flares over a calendar month.

1.3.8.2 Spatial Resolution

The Level 3 Monthly Summary Gas Flare Night-time Product provides global data at a grid cell size of 0.25°, matching that of the MODIS Climate Modelling Grid (CMG) active fire products.

1.3.8.3 Projection

The Level 3 Monthly Summary Gas Flare Night-time Product stores data on a global 0.25° resolution grid. A geographic coordinate system based on the World Geodetic System 84 (WGS84) reference ellipsoid is used, with coordinates specified in decimal degrees. Information on product projection, ellipsoid and pixel size is included in the NetCDF file, so the area covered by every grid cell can be geographically referenced without the need of adding specific pixel indicators of geographical position.

1.3.8.4 Product Layer

The Level 3 Monthly Summary Gas Flare Night-time Product provides global data at a grid cell size of 0.25°, matching that of the Terra MODIS Climate Modelling Grid (MOD14CMQ) active fire products. Similar to the Level 3a 27-Day Gridded Gas Flare Night-time Product, the Level 3 Monthly Summary

Gas Flare Night-time Product stores the data from S3A and S3B in separate files including six bands but each calculated over the monthly period at the location of each 0.25° grid cell in question:

1. Total number of detected gas flare pixels
2. Mean FRP (derived from SWIR channel observations) of all detected gas flare pixels
3. Uncertainty on this SWIR-derived mean FRP
4. Total number of detected gas flare pixels when the cell was fully observed cloud-free
5. Mean SWIR-derived FRP derived from the flare pixels detected when the cell was fully observed cloud-free
6. Uncertainty on this SWIR-derived mean FRP

As with the Level 3a Daily and 27-Day Gridded Gas Flare Night-time Products, for the Level 3 Monthly Summary Gas Flare Night-time Product, the 'Total number of pixel observations made within the grid cell' layer can be used to understand the differing number of observations made at different grid cells, which changes with latitude due to both 0.25° × 0.25° grid cells at higher latitudes being covered by a different number of SLSTR 1 km pixels than at the equator, and also by the fact that grid cells at higher latitudes are observed more often by SLSTR compared to those at lower latitudes.

Figure 1-11 shows a Level 3 Monthly Summary Gas Flare Night-time Product opened in the Panoply Data Viewer[13], with all the layers shown. The layer structure is similar to the daily and 27-Day Night-time product.

Name	Long Name	Type
20230801-C3S-L3-FRP-SLSTR-P1M-0.25deg-S3A-gasflares-fv1.2.nc	ECMWF C3S Gridded OLCI Fire Radiative Power product	Local File
fire_pixels	Total number of S3A at gasflares active fire pixels	Geo2D
fire_pixels_cloudfree	Total number of S3A at gasflares active fire pixels of cloud-free grid cell con…	Geo2D
frp	Mean Fire Radiative Power measured by S3A at gasflares	Geo2D
frp_cloudfree	Mean Fire Radiative Power of cloud-free grid cell contributions measured by …	Geo2D
frp_unc	Mean Fire Radiative Power uncertainty measured by S3A at gasflares	Geo2D
frp_unc_cloudfree	Mean Fire Radiative Power uncertainty of cloud-free grid cell contributions …	Geo2D
lat	latitude	1D
lat_bounds	lat bounds	2D
lon	longitude	1D
lon_bounds	lon bounds	2D
time	time	—
time_bounds	time bounds	1D

Figure 1-11: An example of the layer structure of the C3S Level 3 Monthly Summary Gridded Gas Flare Night-time Product of August 2023, as opened in Panoply Data Viewer.

Figure 1-12 shows from the Level 3 Monthly Gridded Gas Flare Night-time S3A Product of July 2023 (a) the gridded global night-time Gas Flare count from S3A and (b) the total FRP, the latter calculated by multiplying together the AF count and mean FRP data layers.

[13] https://www.giss.nasa.gov/tools/panoply/

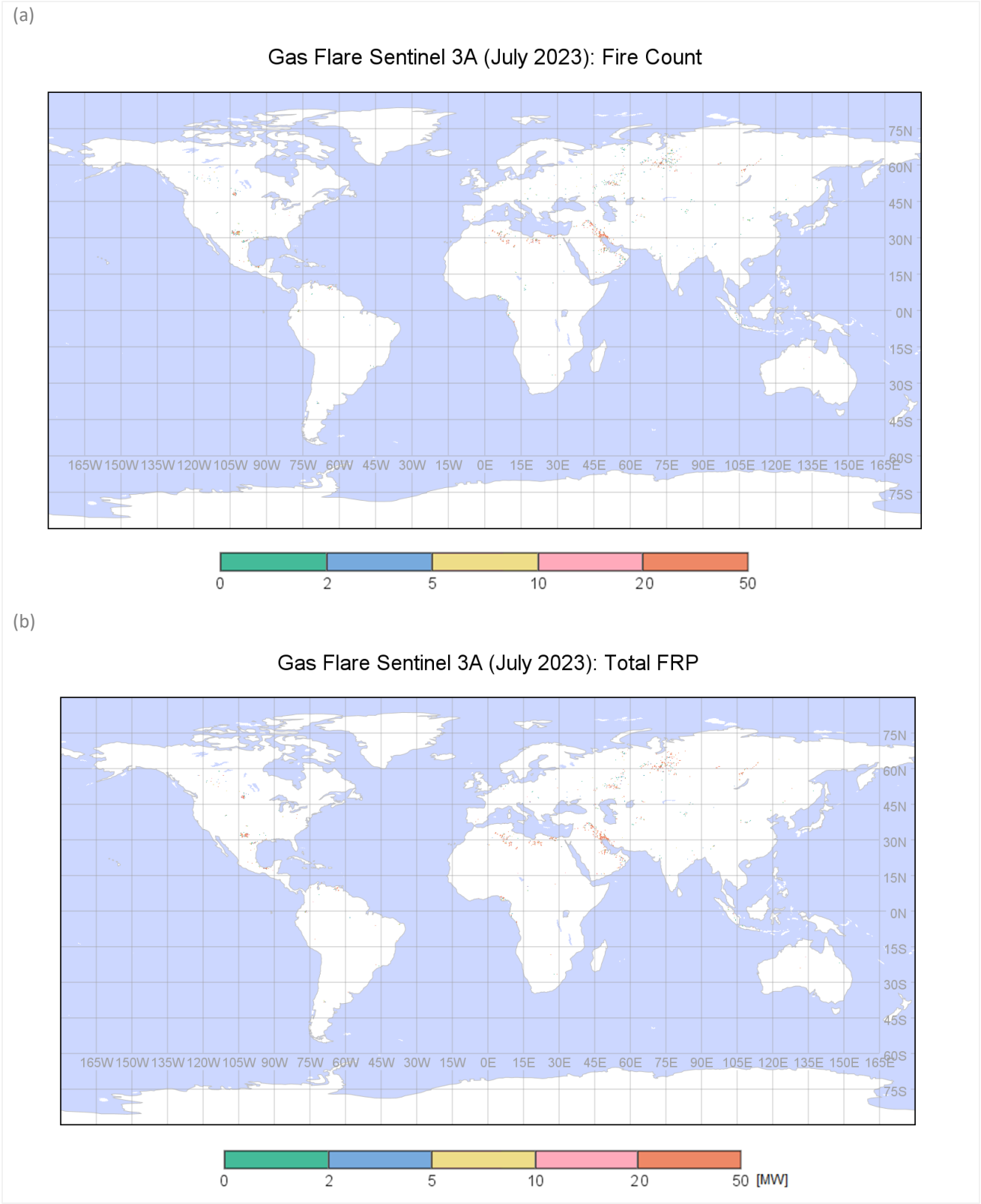


Figure 1-12: Monthly global map of (a) Gas Flare pixel count and (b) total FRP derived from the Level 3 Monthly Summary Gas Flare Night-time S3A Product of July 2023.

1.3.8.5 File format and size

In the same way as for the Level 3a 27-Day Gridded Gas Flare Night-time Products, the Level 3 Monthly Summary Gas Flare Night-time Product stores data in a compressed Network Common Data Form version 4 (NetCDF4) file, with metadata attributes compliant with version 1.7 of the Climate and Forecast conventions. In each layer each grid cell has eight values stored, as detailed in Section 1.3.8.4. The file size is around 0.15 MB.

1.3.8.6 File naming convention

The Level 3 Monthly Summary Gas Flare Night-time Product files are named as follows (with TempRes as P1M to differentiate them from other Level 3 Gridded Gas Flare Night-time Product files):

<Indicative_Date>-C3S-L3-FRP-<Indicative_sensor>-<TempRes>-<SpatRes>>-<Indicative_satellite>-<day/nighttime>-fv<xx.x>.nc

<Indicative_Date>
The identifying date for this data set:
The format is YYYYMMDD, where YYYY is the four-digit year, MM is the two-digit month from 01 to 12 and DD, as the product is provided in monthly files, is always 01.
<Indicative_sensor>
In this version of the product, it is SLSTR.
<TempRes>
In this version of the product, it is P1M.
<SpatRes>
In this version of the product, it is 0.25deg.
<Indicative_satellite>
The identifying sentinel-3 satellite, currently there are two operating sentinel-3 satellites: sentinel-3A and -3B. For sentinel-3A, its S3A, sentinel-3B, its S3B.
<day/nighttime>
Day, night-time or gasflare product
fv<File_Version>
File version number in the form n{1,}[.n{1,}] (That is 1 or more digits followed by optional . and another 1 or more digits). This version is fv1.2.

Example:
20230801-C3S-L3-FRP-SLSTR-P1M-0.25deg-S3A-gasflares-fv1.2.nc

1.3.8.7 Metadata

The metadata for the Night-time Gas Flare maps are provided as global attributes in the NetCDF file. It follows the CCI guidelines (Bennett, 2012).

2 Data Access Information

2.1 Access to the users through the CDS

The data can be accessed through the CDS using this link: https://cds.climate.copernicus.eu/ and searching for Active Fire & Fire Radiative Power.

The Sentinel-3 SLSTR Level 2 Active Fire Detection and FRP Products from which the C3S products are derived are based on the SLSTR Level 2 FRP product algorithm described in Xu et al. (2020) and the ATBD [RD - 1].

2.2 Data provider

The C3S FRP products are produced by Brockmann Consult GmbH based on the ATBD [RD - 1]. Brockmann Consult GmbH are responsible for the distribution of the datasets.

The point of contact is:

- Email: copernicus-support@ecmwf.int
- Website: http://climate.copernicus.eu/contact-us

2.3 Data visualization and analysis

ECMWF's **earthkit**[14] is an open-source Python project that provides powerful tools for weather and climate science workflows. It simplifies various aspects of data handling, including access, processing, analysis, and visualisation. Key Features of earthkit are data access, data analysis, interoperability and visualization. In addition, earthkit is integrated with **WEkEO**[15]. WEkEO, as one of the Copernicus DIAS (Data and Information Access Services), provides a platform on which users can utilise the capabilities of earthkit. WEkEO is also committed to educating users and making them familiar with its data and processing environment via training sessions[16], use cases[17] and Jupyter Notebooks[18].

Complementary, numerous programming languages exist that can be used for reading and analyzing netCDF files. These include both compiled languages such as Java, Fortran and C, and languages that allow interactive analysis and plotting of data. Some examples of the latter are:

- Python (https://www.python.org/) with add on modules such as:
  - netCDF4: https://unidata.github.io/netcdf4-python/
  - NumPy: https://numpy.org/
  - matplotlib https://matplotlib.org/
  - Iris: https://scitools-iris.readthedocs.io/en/stable/
  - Cartopy: https://scitools.org.uk/cartopy/docs/latest/
- IDL https://www.l3harrisgeospatial.com/Software-Technology/IDL

[14] https://earthkit.readthedocs.io/en/latest/
[15] https://www.wekeo.eu/
[16] https://events.wekeo.eu/
[17] https://www.wekeo.eu/use-cases
[18] https://notebooks.prod.wekeo2.eu/

- MATLAB https://www.mathworks.com/products/matlab.html
- Grid Analysis and Display System (GrADS) http://cola.gmu.edu/grads/
- NCAR Command Language (NCL) https://www.ncl.ucar.edu/

2.4 Copyright notice: EC C3S FRP

Should you write any scientific publication on the results of research activities that use one or several C3S products as input, you shall acknowledge the EC C3S FRP project in the text of the publication and provide the project with an electronic copy of the publication (copernicus-support@ecmwf.int).

If you wish to use one or several FRP products in advertising or in any commercial promotion, you shall acknowledge the EC C3S FRP project and you must submit the layout to the project for approval beforehand (copernicus-support@ecmwf.int).

References

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Wooster, M. J., Xu, W., & Nightingale, T. (2012). Sentinel-3 SLSTR active fire detection and FRP product: Pre-launch algorithm development and performance evaluation using MODIS and ASTER datasets. Remote Sensing of Environment, 120(0), 236–254

Xu, W., Wooster, M. J., He, J., & Zhang, T. (2020). First study of Sentinel-3 SLSTR active fire detection and FRP retrieval: Nighttime algorithm enhancements and global intercomparison to MODIS and VIIRS AF products. Remote Sensing of Environment, 248, 111947.

Xu, W., Wooster, M. J., Polehampton, E., Yemelyanova, R., & Zhang, T. (2021). Sentinel-3 active fire detection and FRP product performance-Impact of scan angle and SLSTR middle infrared channel selection. Remote Sensing of Environment, 261, 112460.

3 Annex

3.1 Annex A - Level 3a Daily Gridded AF & FRP Night-time Product metadata

```
netcdf file:/D:/grit/Downloads/20220701-C3S-L3-FRP-SLSTR-P1D-0.1deg-S3A-
nighttime-fv1.2.nc {
  dimensions:
    lon = 3600;
    lat = 1800;
    time = 1;
    bounds = 2;
  variables:
    float lon(lon=3600);
      :units = "degrees_east";
      :standard_name = "longitude";
      :long_name = "longitude";
      :bounds = "lon_bounds";

    float lat(lat=1800);
      :units = "degrees_north";
      :standard_name = "latitude";
      :long_name = "latitude";
      :bounds = "lat_bounds";

    double time(time=1);
      :units = "days since 1970-01-01 00:00:00";
      :standard_name = "time";
      :long_name = "time";
      :bounds = "time_bounds";
      :calendar = "standard";

    float lon_bounds(lon=3600, bounds=2);

    float lat_bounds(lat=1800, bounds=2);

    double time_bounds(time=1, bounds=2);

    uint fire_pixels(time=1, lat=1800, lon=3600);
      :_FillValue = 4294967295U; // uint
      :units = "1";
      :long_name = "Total number of S3A nighttime active fire pixels";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    float frp(time=1, lat=1800, lon=3600);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power measured by S3A during nighttime";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    float frp_unc(time=1, lat=1800, lon=3600);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power uncertainty measured by S3A during
       nighttime";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    uint total_pixels(time=1, lat=1800, lon=3600);
```

```
      :_FillValue = 4294967295U; // uint
      :units = "1";
      :long_name = "Total number of S3A nighttime pixels";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    uint surface_conditions_flag_pixels(time=1, lat=1800, lon=3600);
      :_FillValue = 4294967295U; // uint
      :units = "1";
      :long_name = "Total number of S3A nighttime pixels unprocessed by the AF
       detection algorithm due to them being considered unsuitable surfaces, e.g.
       permanent water";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    uint atmospheric_condition_flag_pixels(time=1, lat=1800, lon=3600);
      :_FillValue = 4294967295U; // uint
      :units = "1";
      :long_name = "Total number of S3A nighttime pixels unprocessed by the AF
       detection algorithm due to them being considered to have unsuitable
       atmospheric conditions for FRP product processing, e.g. certain types of
       cloud";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    float atmospheric_condition_fraction(time=1, lat=1800, lon=3600);
      :_FillValue = NaNf; // float
      :units = "1";
      :long_name = "Mean unsuitable atmospheric condition fraction of S3A
nighttime land pixels in a macro pixel of 1.1 degrees";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    float fire_weighted_pixels(time=1, lat=1800, lon=3600);
      :_FillValue = NaNf; // float
      :units = "1";
      :long_name = "Number of S3A nighttime active fire pixels weighted by
       atmospheric condition fraction";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

  // global attributes:
  :title = "ECMWF C3S Gridded OLCI Fire Radiative Power product";
  :institution = "King\'s College London, Brockmann Consult GmbH";
  :source = "ESA Sentinel-3 A+B SLSTR FRP";
  :history = "Created on 20221216T000849Z";
  :references = "See https://climate.copernicus.eu/";
  :tracking_id = "300ab1a5-8502-48f5-92e0-88319b2a411a";
  :Conventions = "CF-1.7";
  :summary = "The Copernicus Climate Change Service issues three Level 3 Fire
    Radiative Power (FRP) Products, each generated from Level 2 Sentinel-3 Active
    Fire Detection and FRP Products issued in NTC mode, which themselves are
    based on Sentinel 3 SLSTR data. The global Level 3 Daily FRP Products
    synthesise global data from the Level 2 AF Detection and FRP Product granules
    at 0.1 degree spatial and at 1-day temporal resolution, and also provide some
    adjustments for unsuitable atmospheric condition since e.g clouds can mask
    actively burning fires from view. These products are primarily designed for
    ease of use of the key information coming from individual granule-based Level
    2 Products, for example in global modelling, trend analysis and model
    evaluation. Each product is available in separate files per platform (S3A,
    S3B, ...) and per nighttime and daytime observations.";
  :keywords = "Fire Radiative Power, Climate Change, ESA, C3S, GCOS";
  :id = "20220701-C3S-L3-FRP-SLSTR-P1D-0.1deg-S3A-nighttime-fv1.2.nc";
```

```
  :naming_authority = "org.esa-cci";
  :keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science
keywords";
  :cdm_data_type = "Grid";
  :comment = "These data were produced as part of the Copernicus Climate Change
       Service programme.";
  :date_created = "20221216T000849Z";
  :creator_name = "Brockmann Consult GmbH";
  :creator_url = "https://www.brockmann-consult.de";
  :creator_email = "info@brockmann-consult.de";
  :contact = "http://copernicus-support.ecmwf.int";
  :project = "EC C3S Fire Radiative Power";
  :geospatial_lat_min = "-90";
  :geospatial_lat_max = "90";
  :geospatial_lon_min = "-180";
  :geospatial_lon_max = "180";
  :geospatial_vertical_min = "0";
  :geospatial_vertical_max = "0";
  :time_coverage_start = "20220701T000000Z";
  :time_coverage_end = "20220701T000000Z";
  :time_coverage_duration = "P1D";
  :time_coverage_resolution = "P1D";
  :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata
       Convention";
  :license = "EC C3S FRP Data Policy";
  :platform = "S3A";
  :night_or_day = "night";
  :sensor = "SLSTR";
  :spatial_resolution = "0.1 degrees";
  :geospatial_lon_units = "degrees_east";
  :geospatial_lat_units = "degrees_north";
  :geospatial_lon_resolution = "0.1";
  :geospatial_lat_resolution = "0.1";
}
```

3.2 Annex B - Level 3a 27-Day Gridded AF & FRP Night-time Product metadata

```
netcdf file:/D:/grit/Downloads/20220624-C3S-L3-FRP-SLSTR-P27D-0.1deg-S3A-
nighttime-fv1.2.nc {
  dimensions:
    lon = 3600;
    lat = 1800;
    time = 1;
    bounds = 2;
  variables:
    float lon(lon=3600);
      :units = "degrees_east";
      :standard_name = "longitude";
      :long_name = "longitude";
      :bounds = "lon_bounds";

    float lat(lat=1800);
      :units = "degrees_north";
      :standard_name = "latitude";
      :long_name = "latitude";
      :bounds = "lat_bounds";

    double time(time=1);
      :units = "days since 1970-01-01 00:00:00";
      :standard_name = "time";
      :long_name = "time";
      :bounds = "time_bounds";
      :calendar = "standard";

    float lon_bounds(lon=3600, bounds=2);

    float lat_bounds(lat=1800, bounds=2);

    double time_bounds(time=1, bounds=2);

    uint fire_pixels(time=1, lat=1800, lon=3600);
      :_FillValue = 4294967295U; // uint
      :units = "1";
      :long_name = "Total number of S3A nighttime active fire pixels";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    float frp(time=1, lat=1800, lon=3600);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power measured by S3A during nighttime";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    float frp_unc(time=1, lat=1800, lon=3600);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power uncertainty measured by S3A during
       nighttime";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    uint total_pixels(time=1, lat=1800, lon=3600);
      :_FillValue = 4294967295U; // uint
      :units = "1";
```

```
    :long_name = "Total number of S3A nighttime pixels";
    :_ChunkSizes = 1U, 18U, 3600U; // uint

  uint surface_conditions_flag_pixels(time=1, lat=1800, lon=3600);
    :_FillValue = 4294967295U; // uint
    :units = "1";
    :long_name = "Total number of S3A nighttime pixels unprocessed by the AF
     detection algorithm due to them being considered unsuitable surfaces, e.g.
     permanent water";
    :_ChunkSizes = 1U, 18U, 3600U; // uint

  uint atmospheric_condition_flag_pixels(time=1, lat=1800, lon=3600);
    :_FillValue = 4294967295U; // uint
    :units = "1";
    :long_name = "Total number of S3A nighttime pixels unprocessed by the
     detection algorithm due to them being considered to have
     atmospheric conditions for FRP product processing, e.g. certain types
     cloud";
    :_ChunkSizes = 1U, 18U, 3600U; // uint

  float atmospheric_condition_fraction(time=1, lat=1800, lon=3600);
    :_FillValue = NaNf; // float
    :units = "1";
    :long_name = "Mean unsuitable atmospheric condition fraction of S3A
     nighttime land pixels in a macro pixel of 1.1 degrees";
    :_ChunkSizes = 1U, 18U, 3600U; // uint

  float fire_weighted_pixels(time=1, lat=1800, lon=3600);
    :_FillValue = NaNf; // float
    :units = "1";
    :long_name = "Number of S3A nighttime active fire pixels weighted by
     atmospheric condition fraction";
    :_ChunkSizes = 1U, 18U, 3600U; // uint

// global attributes:
:title = "ECMWF C3S Gridded OLCI Fire Radiative Power product";
:institution = "King\'s College London, Brockmann Consult GmbH";
:source = "ESA Sentinel-3 A+B SLSTR FRP";
:history = "Created on 20221216T022306Z";
:references = "See https://climate.copernicus.eu/";
:tracking_id = "b43e9d78-e5ac-426a-97db-22ae4dd2be4f";
:Conventions = "CF-1.7";
:summary = "The Copernicus Climate Change Service issues three Level 3 Fire
  Radiative Power (FRP) Products, each generated from Level 2 Sentinel-3 Active
  Fire Detection and FRP Products issued in NTC mode, which themselves are
  based on Sentinel 3 SLSTR data. The global Level 3 27-Day FRP Products
  synthesise global data from the Level 2 AF Detection and FRP Product granules
  at 0.1 degree spatial and at 27-day temporal resolution, and also provide
  some adjustments for unsuitable atmospheric condition since e.g clouds can
  mask actively burning fires from view. These products are primarily designed
  for ease of use of the key information coming from individual granule-based
  Level 2 Products, for example in global modelling, trend analysis and model
  evaluation. Each product is available in separate files per platform (S3A,
  S3B, ...) and per nighttime and daytime observations.";
:keywords = "Fire Radiative Power, Climate Change, ESA, C3S, GCOS";
:id = "20220624-C3S-L3-FRP-SLSTR-P27D-0.1deg-S3A-nighttime-fv1.2.nc";
:naming_authority = "org.esa-cci";
```

```
  :keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science
keywords";
  :cdm_data_type = "Grid";
  :comment = "These data were produced as part of the Copernicus Climate Change
       Service programme.";
  :date_created = "20221216T022306Z";
  :creator_name = "Brockmann Consult GmbH";
  :creator_url = "https://www.brockmann-consult.de";
  :creator_email = "info@brockmann-consult.de";
  :contact = "http://copernicus-support.ecmwf.int";
  :project = "EC C3S Fire Radiative Power";
  :geospatial_lat_min = "-90";
  :geospatial_lat_max = "90";
  :geospatial_lon_min = "-180";
  :geospatial_lon_max = "180";
  :geospatial_vertical_min = "0";
  :geospatial_vertical_max = "0";
  :time_coverage_start = "20220624T000000Z";
  :time_coverage_end = "20220720T000000Z";
  :time_coverage_duration = "P27D";
  :time_coverage_resolution = "P27D";
  :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata
       Convention";
  :license = "EC C3S FRP Data Policy";
  :platform = "S3A";
  :night_or_day = "night";
  :sensor = "SLSTR";
  :spatial_resolution = "0.1 degrees";
  :geospatial_lon_units = "degrees_east";
  :geospatial_lat_units = "degrees_north";
  :geospatial_lon_resolution = "0.1";
  :geospatial_lat_resolution = "0.1";
}
```

3.3 Annex C - Level 3 Monthly Summary AF & FRP Night-time Product metadata

```
netcdf file:/D:/grit/Downloads/20220701-C3S-L3-FRP-SLSTR-P1M-0.25deg-S3A-
nighttime-fv1.2.nc {
  dimensions:
    lon = 1440;
    lat = 720;
    time = 1;
    bounds = 2;
  variables:
    float lon(lon=1440);
      :units = "degrees_east";
      :standard_name = "longitude";
      :long_name = "longitude";
      :bounds = "lon_bounds";

    float lat(lat=720);
      :units = "degrees_north";
      :standard_name = "latitude";
      :long_name = "latitude";
      :bounds = "lat_bounds";

    double time(time=1);
      :units = "days since 1970-01-01 00:00:00";
      :standard_name = "time";
      :long_name = "time";
      :bounds = "time_bounds";
      :calendar = "standard";

    float lon_bounds(lon=1440, bounds=2);

    float lat_bounds(lat=720, bounds=2);

    double time_bounds(time=1, bounds=2);

    uint fire_pixels(time=1, lat=720, lon=1440);
      :_FillValue = 4294967295U; // uint
      :units = "1";
      :long_name = "Total number of S3A nighttime active fire pixels";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

    float frp(time=1, lat=720, lon=1440);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power measured by S3A during nighttime";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

    float frp_unc(time=1, lat=720, lon=1440);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power uncertainty measured by S3A during
       nighttime";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

    uint total_pixels(time=1, lat=720, lon=1440);
      :_FillValue = 4294967295U; // uint
      :units = "1";
```

```
      :long_name = "Total number of S3A nighttime pixels";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

    uint surface_conditions_flag_pixels(time=1, lat=720, lon=1440);
      :_FillValue = 4294967295U; // uint
      :units = "1";
      :long_name = "Total number of S3A nighttime pixels unprocessed by the AF
       detection algorithm due to them being considered unsuitable surfaces, e.g.
       permanent water";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

    uint atmospheric_condition_flag_pixels(time=1, lat=720, lon=1440);
      :_FillValue = 4294967295U; // uint
      :units = "1";
      :long_name = "Total number of S3A nighttime pixels unprocessed by the
       detection algorithm due to them being considered to have unsuitable
       atmospheric conditions for FRP product processing, e.g. certain types of
       cloud";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

    float atmospheric_condition_fraction(time=1, lat=720, lon=1440);
      :_FillValue = NaNf; // float
      :units = "1";
      :long_name = "Mean unsuitable atmospheric condition fraction of S3A
       nighttime land pixels in a macro pixel of 1.25 degrees";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

    float fire_weighted_pixels(time=1, lat=720, lon=1440);
      :_FillValue = NaNf; // float
      :units = "1";
      :long_name = "Number of S3A nighttime active fire pixels weighted by
       atmospheric condition fraction";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

  // global attributes:
  :title = "ECMWF C3S Gridded OLCI Fire Radiative Power product";
  :institution = "King\'s College London, Brockmann Consult GmbH";
  :source = "ESA Sentinel-3 A+B SLSTR FRP";
  :history = "Created on 20230614T175255Z";
  :references = "See https://climate.copernicus.eu/";
  :tracking_id = "65a33220-c29d-4358-9379-a8290cf9c778";
  :Conventions = "CF-1.7";
  :summary = "The Copernicus Climate Change Service issues three Level 3 Fire
    Radiative Power (FRP) Products, each generated from Level 2 Sentinel-3 Active
    Fire Detection and FRP Products issued in NTC mode, which themselves are
    based on Sentinel 3 SLSTR data. The global Level 3 Monthly Summary FRP
    Products synthesise global data from the Level 2 AF Detection and FRP Product
    granules at 0.25 degree spatial and at 1 month temporal resolution, and also
    provide some adjustments for unsuitable atmospheric condition since e.g
    clouds can mask actively burning fires from view. These products are
    primarily designed for ease of use of the key information coming from
    individual granule-based Level 2 Products, for example in global modelling,
    trend analysis and model evaluation. Each product is available in separate
    files per platform (S3A, S3B, ...) and per nighttime and daytime
    observations.";
  :keywords = "Fire Radiative Power, Climate Change, ESA, C3S, GCOS";
  :id = "20220701-C3S-L3-FRP-SLSTR-P1M-0.25deg-S3A-nighttime-fv1.2.nc";
  :naming_authority = "org.esa-cci";
```

```
  :keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science
keywords";
  :cdm_data_type = "Grid";
  :comment = "These data were produced as part of the Copernicus Climate Change
       Service programme.";
  :date_created = "20230614T175255Z";
  :creator_name = "Brockmann Consult GmbH";
  :creator_url = "https://www.brockmann-consult.de";
  :creator_email = "info@brockmann-consult.de";
  :contact = "http://copernicus-support.ecmwf.int";
  :project = "EC C3S Fire Radiative Power";
  :geospatial_lat_min = "-90";
  :geospatial_lat_max = "90";
  :geospatial_lon_min = "-180";
  :geospatial_lon_max = "180";
  :geospatial_vertical_min = "0";
  :geospatial_vertical_max = "0";
  :time_coverage_start = "20220701T000000Z";
  :time_coverage_end = "20220731T000000Z";
  :time_coverage_duration = "P1M";
  :time_coverage_resolution = "P1M";
  :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata
       Convention";
  :license = "EC C3S FRP Data Policy";
  :platform = "S3A";
  :night_or_day = "night";
  :sensor = "SLSTR";
  :spatial_resolution = "0.25 degrees";
  :geospatial_lon_units = "degrees_east";
  :geospatial_lat_units = "degrees_north";
  :geospatial_lon_resolution = "0.25";
  :geospatial_lat_resolution = "0.25";
}
```

3.4 Annex D - Level 3a Daily Gridded Gas Flare Night-time Product metadata

```
netcdf file:/E:/C3SLOT5/c3sLot5_FRP/GasFlares/20230804-C3S-L3-FRP-SLSTR-P1D-
0.1deg-S3A-gasflares-fv1.2.nc {
  dimensions:
    lon = 3600;
    lat = 1800;
    time = 1;
    bounds = 2;
  variables:
    float lon(lon=3600);
      :units = "degrees_east";
      :standard_name = "longitude";
      :long_name = "longitude";
      :bounds = "lon_bounds";

    float lat(lat=1800);
      :units = "degrees_north";
      :standard_name = "latitude";
      :long_name = "latitude";
      :bounds = "lat_bounds";

    double time(time=1);
      :units = "days since 1970-01-01 00:00:00";
      :standard_name = "time";
      :long_name = "time";
      :bounds = "time_bounds";
      :calendar = "standard";

    float lon_bounds(lon=3600, bounds=2);

    float lat_bounds(lat=1800, bounds=2);

    double time_bounds(time=1, bounds=2);

    uint fire_pixels(time=1, lat=1800, lon=3600);
      :_FillValue = 0U; // uint
      :units = "1";
      :long_name = "Total number of S3A at gasflares active fire pixels";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    float frp(time=1, lat=1800, lon=3600);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power measured by S3A at gasflares";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    float frp_unc(time=1, lat=1800, lon=3600);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power uncertainty measured by S3A at
                    gasflares";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    uint fire_pixels_cloudfree(time=1, lat=1800, lon=3600);
      :_FillValue = 0U; // uint
      :units = "1";
```

```
    :long_name = "Total number of S3A at gasflares active fire pixels of cloud-
                  free grid cell contributions";
    :_ChunkSizes = 1U, 18U, 3600U; // uint

  float frp_cloudfree(time=1, lat=1800, lon=3600);
    :_FillValue = NaNf; // float
    :units = "MW";
    :long_name = "Mean Fire Radiative Power of cloud-free grid cell
                 contributions measured by S3A at gasflares";
    :_ChunkSizes = 1U, 18U, 3600U; // uint

  float frp_unc_cloudfree(time=1, lat=1800, lon=3600);
    :_FillValue = NaNf; // float
    :units = "MW";
    :long_name = "Mean Fire Radiative Power uncertainty of cloud-free grid cell
                  contributions measured by S3A at gasflares";
    :_ChunkSizes = 1U, 18U, 3600U; // uint

// global attributes:
:title = "ECMWF C3S Gridded OLCI Fire Radiative Power product";
:institution = "King\'s College London, Brockmann Consult GmbH";
:source = "ESA Sentinel-3 A+B SLSTR FRP";
:history = "Created on 20241018T232559Z";
:references = "See https://climate.copernicus.eu/";
:tracking_id = "41c46cc0-20ee-4613-8389-8af8e452b608";
:Conventions = "CF-1.7";
:summary = "The Copernicus Climate Change Service issues three Level 3 Fire
   Radiative Power (FRP) Products, each generated from Level 2 Sentinel-3
   Active Fire Detection and FRP Products issued in NTC mode, which themselves
   are based on Sentinel 3 SLSTR data. The global Level 3 Daily FRP Products
   synthesise global data from the Level 2 AF Detection and FRP Product
   granules at 0.1 degree spatial and at 1-day temporal resolution, and also
   provide some adjustments for unsuitable atmospheric condition since e.g
   clouds can mask actively burning fires from view. These products are
   primarily designed for ease of use of the key information coming from
   individual granule-based Level 2 Products, for example in global modelling,
   trend analysis and model evaluation. Each product is available in separate
   files per platform (S3A, S3B, ...) and per nighttime and daytime
   observations.";
:keywords = "Fire Radiative Power, Climate Change, ESA, C3S, GCOS";
:id = "20230804-C3S-L3-FRP-SLSTR-P1D-0.1deg-S3A-gasflares-fv1.2.nc";
:naming_authority = "org.esa-cci";
:keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science
                        keywords";
:cdm_data_type = "Grid";
:comment = "These data were produced as part of the Copernicus Climate Change
            Service programme.";
:date_created = "20241018T232559Z";
:creator_name = "Brockmann Consult GmbH";
:creator_url = "https://www.brockmann-consult.de";
:creator_email = "info@brockmann-consult.de";
:contact = "http://copernicus-support.ecmwf.int";
:project = "EC C3S Fire Radiative Power";
:geospatial_lat_min = "-90";
:geospatial_lat_max = "90";
:geospatial_lon_min = "-180";
:geospatial_lon_max = "180";
:geospatial_vertical_min = "0";
```

```
  :geospatial_vertical_max = "0";
  :time_coverage_start = "20230804T000000Z";
  :time_coverage_end = "20230804T000000Z";
  :time_coverage_duration = "P1D";
  :time_coverage_resolution = "P1D";
  :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata
                               Convention";
  :license = "EC C3S FRP Data Policy";
  :platform = "S3A";
  :night_or_day = "gasflares";
  :sensor = "SLSTR";
  :spatial_resolution = "0.1 degrees";
  :geospatial_lon_units = "degrees_east";
  :geospatial_lat_units = "degrees_north";
  :geospatial_lon_resolution = "0.1";
  :geospatial_lat_resolution = "0.1";
}
```

3.5 Annex E - Level 3a 27-Day Gridded Gas Flare Night-time Product metadata

```
netcdf file:/E:/C3SLOT5/c3sLot5_FRP/GasFlares/20230830-C3S-L3-FRP-SLSTR-P27D-
0.1deg-S3A-gasflares-fv1.2.nc {
  dimensions:
    lon = 3600;
    lat = 1800;
    time = 1;
    bounds = 2;
  variables:
    float lon(lon=3600);
      :units = "degrees_east";
      :standard_name = "longitude";
      :long_name = "longitude";
      :bounds = "lon_bounds";

    float lat(lat=1800);
      :units = "degrees_north";
      :standard_name = "latitude";
      :long_name = "latitude";
      :bounds = "lat_bounds";

    double time(time=1);
      :units = "days since 1970-01-01 00:00:00";
      :standard_name = "time";
      :long_name = "time";
      :bounds = "time_bounds";
      :calendar = "standard";

    float lon_bounds(lon=3600, bounds=2);

    float lat_bounds(lat=1800, bounds=2);

    double time_bounds(time=1, bounds=2);

    uint fire_pixels(time=1, lat=1800, lon=3600);
      :_FillValue = 0U; // uint
      :units = "1";
      :long_name = "Total number of S3A at gasflares active fire pixels";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    float frp(time=1, lat=1800, lon=3600);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power measured by S3A at gasflares";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    float frp_unc(time=1, lat=1800, lon=3600);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power uncertainty measured by S3A at
                    gasflares";
      :_ChunkSizes = 1U, 18U, 3600U; // uint

    uint fire_pixels_cloudfree(time=1, lat=1800, lon=3600);
      :_FillValue = 0U; // uint
      :units = "1";
```

```
    :long_name = "Total number of S3A at gasflares active fire pixels of cloud-
                 free grid cell contributions";
    :_ChunkSizes = 1U, 18U, 3600U; // uint

  float frp_cloudfree(time=1, lat=1800, lon=3600);
    :_FillValue = NaNf; // float
    :units = "MW";
    :long_name = "Mean Fire Radiative Power of cloud-free grid cell
                  contributions measured by S3A at gasflares";
    :_ChunkSizes = 1U, 18U, 3600U; // uint

  float frp_unc_cloudfree(time=1, lat=1800, lon=3600);
    :_FillValue = NaNf; // float
    :units = "MW";
    :long_name = "Mean Fire Radiative Power uncertainty of cloud-free grid cell
                  contributions measured by S3A at gasflares";
    :_ChunkSizes = 1U, 18U, 3600U; // uint

// global attributes:
:title = "ECMWF C3S Gridded OLCI Fire Radiative Power product";
:institution = "King\'s College London, Brockmann Consult GmbH";
:source = "ESA Sentinel-3 A+B SLSTR FRP";
:history = "Created on 20241019T012411Z";
:references = "See https://climate.copernicus.eu/";
:tracking_id = "c83be3a0-ee13-45d2-888a-6cac2cde113d";
:Conventions = "CF-1.7";
:summary = "The Copernicus Climate Change Service issues three Level 3 Fire
   Radiative Power (FRP) Products, each generated from Level 2 Sentinel-3
   Active Fire Detection and FRP Products issued in NTC mode, which themselves
   are based on Sentinel 3 SLSTR data. The global Level 3 27-Day FRP Products
   synthesise global data from the Level 2 AF Detection and FRP Product
   granules at 0.1 degree spatial and at 27-day temporal resolution, and also
   provide some adjustments for unsuitable atmospheric condition since e.g
   clouds can mask actively burning fires from view. These products are
   primarily designed for ease of use of the key information coming from
   individual granule-based Level 2 Products, for example in global modelling,
   trend analysis and model evaluation. Each product is available in separate
   files per platform (S3A, S3B, ...) and per nighttime and daytime
   observations.";
:keywords = "Fire Radiative Power, Climate Change, ESA, C3S, GCOS";
:id = "20230830-C3S-L3-FRP-SLSTR-P27D-0.1deg-S3A-gasflares-fv1.2.nc";
:naming_authority = "org.esa-cci";
:keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science
                keywords";
:cdm_data_type = "Grid";
:comment = "These data were produced as part of the Copernicus Climate Change
          Service programme.";
:date_created = "20241019T012411Z";
:creator_name = "Brockmann Consult GmbH";
:creator_url = "https://www.brockmann-consult.de";
:creator_email = "info@brockmann-consult.de";
:contact = "http://copernicus-support.ecmwf.int";
:project = "EC C3S Fire Radiative Power";
:geospatial_lat_min = "-90";
:geospatial_lat_max = "90";
:geospatial_lon_min = "-180";
:geospatial_lon_max = "180";
:geospatial_vertical_min = "0";
```

```
  :geospatial_vertical_max = "0";
  :time_coverage_start = "20230830T000000Z";
  :time_coverage_end = "20230925T000000Z";
  :time_coverage_duration = "P27D";
  :time_coverage_resolution = "P27D";
  :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata
Convention";
  :license = "EC C3S FRP Data Policy";
  :platform = "S3A";
  :night_or_day = "gasflares";
  :sensor = "SLSTR";
  :spatial_resolution = "0.1 degrees";
  :geospatial_lon_units = "degrees_east";
  :geospatial_lat_units = "degrees_north";
  :geospatial_lon_resolution = "0.1";
  :geospatial_lat_resolution = "0.1";
}
```

3.6 Annex C - Level 3 Monthly Summary Gas Flare Night-time Product metadata

```
netcdf file:/E:/C3SLOT5/c3sLot5_FRP/GasFlares/20230801-C3S-L3-FRP-SLSTR-P1M-
0.25deg-S3A-gasflares-fv1.2.nc {
  dimensions:
    lon = 1440;
    lat = 720;
    time = 1;
    bounds = 2;
  variables:
    float lon(lon=1440);
      :units = "degrees_east";
      :standard_name = "longitude";
      :long_name = "longitude";
      :bounds = "lon_bounds";

    float lat(lat=720);
      :units = "degrees_north";
      :standard_name = "latitude";
      :long_name = "latitude";
      :bounds = "lat_bounds";

    double time(time=1);
      :units = "days since 1970-01-01 00:00:00";
      :standard_name = "time";
      :long_name = "time";
      :bounds = "time_bounds";
      :calendar = "standard";

    float lon_bounds(lon=1440, bounds=2);

    float lat_bounds(lat=720, bounds=2);

    double time_bounds(time=1, bounds=2);

    uint fire_pixels(time=1, lat=720, lon=1440);
      :_FillValue = 0U; // uint
      :units = "1";
      :long_name = "Total number of S3A at gasflares active fire pixels";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

    float frp(time=1, lat=720, lon=1440);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power measured by S3A at gasflares";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

    float frp_unc(time=1, lat=720, lon=1440);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power uncertainty measured by S3A at
                   gasflares";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

    uint fire_pixels_cloudfree(time=1, lat=720, lon=1440);
      :_FillValue = 0U; // uint
      :units = "1";
```

```
      :long_name = "Total number of S3A at gasflares active fire pixels of cloud-
                   free grid cell contributions";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

    float frp_cloudfree(time=1, lat=720, lon=1440);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power of cloud-free grid cell
                   contributions measured by S3A at gasflares";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

    float frp_unc_cloudfree(time=1, lat=720, lon=1440);
      :_FillValue = NaNf; // float
      :units = "MW";
      :long_name = "Mean Fire Radiative Power uncertainty of cloud-free grid cell
                   contributions measured by S3A at gasflares";
      :_ChunkSizes = 1U, 45U, 1440U; // uint

  // global attributes:
  :title = "ECMWF C3S Gridded OLCI Fire Radiative Power product";
  :institution = "King\'s College London, Brockmann Consult GmbH";
  :source = "ESA Sentinel-3 A+B SLSTR FRP";
  :history = "Created on 20241019T000606Z";
  :references = "See https://climate.copernicus.eu/";
  :tracking_id = "a3a25bc5-6465-414f-b3f3-65e6c9ff1f38";
  :Conventions = "CF-1.7";
  :summary = "The Copernicus Climate Change Service issues three Level 3 Fire
     Radiative Power (FRP) Products, each generated from Level 2 Sentinel-3
     Active Fire Detection and FRP Products issued in NTC mode, which themselves
     are based on Sentinel 3 SLSTR data. The global Level 3 Monthly Summary FRP
     Products synthesise global data from the Level 2 AF Detection and FRP
     Product granules at 0.25 degree spatial and at 1 month temporal resolution,
     and also provide some adjustments for unsuitable atmospheric condition since
     e.g clouds can mask actively burning fires from view. These products are
     primarily designed for ease of use of the key information coming from
     individual granule-based Level 2 Products, for example in global modelling,
     trend analysis and model evaluation. Each product is available in separate
     files per platform (S3A, S3B, ...) and per nighttime and daytime
     observations.";
  :keywords = "Fire Radiative Power, Climate Change, ESA, C3S, GCOS";
  :id = "20230801-C3S-L3-FRP-SLSTR-P1M-0.25deg-S3A-gasflares-fv1.2.nc";
  :naming_authority = "org.esa-cci";
  :keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science
                          keywords";
  :cdm_data_type = "Grid";
  :comment = "These data were produced as part of the Copernicus Climate Change
                Service programme.";
  :date_created = "20241019T000606Z";
  :creator_name = "Brockmann Consult GmbH";
  :creator_url = "https://www.brockmann-consult.de";
  :creator_email = "info@brockmann-consult.de";
  :contact = "http://copernicus-support.ecmwf.int";
  :project = "EC C3S Fire Radiative Power";
  :geospatial_lat_min = "-90";
  :geospatial_lat_max = "90";
  :geospatial_lon_min = "-180";
  :geospatial_lon_max = "180";
  :geospatial_vertical_min = "0";
```

```
  :geospatial_vertical_max = "0";
  :time_coverage_start = "20230801T000000Z";
  :time_coverage_end = "20230831T000000Z";
  :time_coverage_duration = "P1M";
  :time_coverage_resolution = "P1M";
  :standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata
Convention";
  :license = "EC C3S FRP Data Policy";
  :platform = "S3A";
  :night_or_day = "gasflares";
  :sensor = "SLSTR";
  :spatial_resolution = "0.25 degrees";
  :geospatial_lon_units = "degrees_east";
  :geospatial_lat_units = "degrees_north";
  :geospatial_lon_resolution = "0.25";
  :geospatial_lat_resolution = "0.25";
}
```

Copernicus Climate Change Service

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Contact: https://support.ecmwf.int

climate.copernicus.eu copernicus.eu ecmwf.int