Sentinel-3 Product Notice – SLSTR Level-2 Near Real Time (NRT) Fire Radiative Power (FRP)

Processing Baseline (PB) 1.2 – FRP_NR.001.02

Mission	Sentinel-3A & Sentinel-3B
Sensor	SLSTR-A & SLSTR-B

Product	Near Real Time (NRT) Level-2 (L2) Fire Radiative Power (FRP)
	• Operations:
	  ○ SL2_FRP at Near Real Time (NRT) timeliness exclusively.
	  ○ Granules of 5 minutes.
	• Partially Reprocessed:
	  ○ SL2_FRP based on Level-1B (L1B) Near Real Time (NRT) timeliness exclusively.
	  ○ Granules of 3 minutes.
	  ○ Period coverage: 2019-2021.
	  ○ Request to be sent to EUMETSAT for access.

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Version	1.0
Preparation	This Product Notice was prepared by EUMETSAT.
Approval	EUMETSAT Mission Management

Summary

This document is the Product Notice (PN) for the public release of Copernicus Sentinel-3 (S3-A and S3-B) Sea and Land Surface Temperature Radiometer (SLSTR-A and SLSTR-B) Level-2 (L2) Fire Radiative Power (FRP) product **PB 1.2** generated with the **EUMETSAT L2 Instrument Processing Facility (IPF) version 2.01** deployed on 06/05/2021 in the EUMETSAT Sentinel-3 ground segment.

It is exclusively applicable to products generated in Near Real Time (NRT). It runs from the SLSTR Level-1 B (L1B) Processing Baseline (PC) 2.59(A)/1.40(B) IPF v6.17 deployed on 09/06/2020.

This Notice describes the Copernicus S3 L2 NRT FRP current status, the processing baseline, processor capabilities, the product quality status, known limitations for both SLSTR-A and SLSTR-B. Further information about NRT data access, partial reprocessed data access and overall past release history are given at the end of the PN.

The new PB 1.2 includes several new parameters & modifications related to active detection & radiative power computation of all hot-spot types (biomass fires, industrial gas flares, explosions, volcanoes) during night-time.

EUMETSAT L2 Processing Baseline

	S3A	S3B
Processing Baseline (Reference to be used by users)	Processing Baseline: FRP_NR.001.02	
IPFs version	SL_2 IPF v2.01 NRT	
Product Baseline Collection (BC)	BC 1 NRT	

Explanation about the PB nomenclature:

- The collection of BC, IPF version and static Auxiliary Data Files (ADFs) is known as the PB. The PB number is the same for S3A and B..
- The BC 1 is clearly indicated in the SAFE directory name as the last three digits ("*001*") before the extension *.SEN3*.
- The used IPF version is indicated in the Global Attributes of the product netcdf file (FRP_in.nc).

To refer to the product version in their communication, users are encouraged to cite the following PB nomenclature if the NRT FRP 1.2 is used:

FRP_NR_001.02

- NB: The label "FRP_NR.001.02" is not yet explicitly visible in the global attributes of the product. It will appear within some months as part of a general activity scheduled to update global attributes of all the Sentinel-3 L1 & L2 products.

Current Operational Processing Baselines

IPF	IPF Version	Into operations since
S3A SL2	02.01	NRT mode: 06/05/2021 07:07 UTC with early products from 08/04/2020 available only on ODA and the EUMETSAT Data Centre
S3B SL2	02.01	NRT mode: 06/05/2021 07:47 UTC with early products from 08/04/2020 available only on ODA and the EUMETSAT Data Centre

NRT FRP data generated from **2021-05-06** onwards are based on **FRP_NR_001.02** (*i.e.* IPF v02.01, PB 1.2).

FRP NRT data previous to this date are generated from the previous versions. Please check https://www.eumetsat.int/atmospheric-composition or "Off-Line Products Availability" in the next sections for details about the past product versions.

L2 NRT FRP Product Quality Status

The quality of L2 NRT FRP product for the **standard FRP Middle Infrared (MWIR) and ShortWave InfraRed (SWIR)** is declared today as **preliminary operational night-time**. Its scientific quality is considered to be approaching the expected requirements, nevertheless it is considered to have reached a level of maturity which can be safely exploited by users. To confirm the final operational status, a more extensive validation is being performed over longer time series with a larger set of measurements.

The new **Alternative FRP MWIR night-time** introduced in the current PB 1.2 is **Demonstrational**.

The data produced are fully compliant with the Sentinel-3 mission requirements in terms of completeness and timeliness. In case of any data production / dissemination anomaly, users can get the most up to date information via the User Notification Service (UNS) https://uns.eumetsat.int, subscription available at https://eoportal.eumetsat.int. Some known scientific limitations on the mission dataset are described in the following sections. There are no operational product anomalies raised at the moment.

Like for the previous PBs, the current Copernicus S3 NRT FRP is mostly a night-time product. Very little spurious day-time hot-spots are occasionally detected and produced. But users are, at this stage, strongly advised to avoid or to use them with a very high precaution. The reasons are mainly related to 1) a high occurrence of the saturation of SLSTR S7 (3.7 um – low dynamic range) radiances during daytime, 2) a lack of co-registration of the SLSTR F1 (3.7 um – high dynamic range) with the other SLSTR detectors, and 3) frequent F1 radiance over-shooting (see below).

Developments led by EUMETSAT are in progress for a Copernicus S3 NRT FRP product addressing these challenges also during daytime. These will be communicated in a near future.

Changes between FRP_NR_001.02 & FRP_NR_001.01

Details about the previous releases are referred in the Section “PB Release history”.

The following elements are maintained with no changes between the previous collections and the current BC 1.2 of the Copernicus S3 NRT FRP product:

- The Standard FRP MWIR (coordinates, FRP & uncertainty values, and other original associated flags) in the key FRP_in.nc file.
- The original flags & indexes related to the Level 1B (L1B) SLSTR pixels in FRP_in.nc.
- The ancillary files flags_in.nc & geodetic_in.nc are still produced.

Many new elements are introduced in the new PB 1.2 of the Copernicus S3 NRT FRP product (moer technical information in Section "Processor capabilities"):

- **Various probabilistic confidence class indexes are now introduced for each fire pixel** identified with the Standard FRP MWIR (3.7 µm). Those include: Clear-Sky Split Window, Clear-Sky Freezing, Absolute S7 Brightness Temperature (BT) value, Relative signal with respect to (w.r.t.) spectral & spatial, and near-neighbouring cloud & water pixels. The higher a Confidence Class value, the more reliable is the detected Standard MWIR fire pixel.

- A new method, named **Alternative FRP MWIR**, is added as an alternative technique for hot-spot detection & FRP computation from the MWIR spectral domain (3.7 µm). The number of hot-spots is generally higher than with the Standard FRP MWIR and shall be considered as an alternative, but not in replacement to the Standard FRP MWIR hot-spots. Over clear-sky scenes with no major temperature gradients (apart due to fires), this technique is expected to detect better weakly radiative hot-spots, *i.e.* "small fires", across the SLSTR swath (Xu *et al.*, 2020, 2021).

- Prior to the Level 2 processing, a **correction of the radiometric calibration is applied to all the SLSTR L1B S5-S6 Top-Of-the-Atmosphere (TOA) radiances** (*i.e.* 1.6 µm & 2.25 µm) at the original sampling of 500 m. The correction is based on multiplicative radiometric coefficients derived from SLSTR-A summarised in S3MPC.RAL.TN.020-i1r0.

- The **FRP SWIR (1 km)** technique principle remains nearly identical as in the previous versions, except:
  - Thanks to the SWIR calibration corrections, a higher number of real SWIR (1 km) hot-spots is detected leading to an increase in regionally integrated FRP between 25%-36% (Persian Gulf gas flares).
  - FRP SWIR value is corrected of a minor error related to the used H_2O transmittance correction.
  - NB: the FRP SWIR(1 km) can be assumed to be reasonably well co-registered with the Standard but not with the Alternative FRP MWIR.

- The **SAA detection parameter associated with the FRP SWIR (1 km)** has evolved from a binary flag to a probabilistic (in %) Confidence Class.

- A **new FRP SWIR is introduced at fine resolution (500 m)**. Contrary to the FRP SWIR (1 km), each SWIR (500 m) hot spot is directly reported onto the L1B fine grid. This is of high relevance for point sources such as gas flares. Over a same region, the number of SWIR(500 m) hot-spots is higher than with SWIR(1 km), while the integrated FRPs are identical.
  - NB: The FRP SWIR (500 m) cannot be assumed as co-registered with the other FRP types.

- The ancillary file **geometry_tn.nc file is not produced anymore** leading to a significant product size reduction.
- **Angles (solar, viewing, zenith, and azimuth) are now directly provided in the key FRP_in.nc file** for each fire pixel identified with the Standard FRP MWIR, Alternative FRP MWIR and/or SWIR (1 km).

Further scientific & technical details are given in the section "Processor Description".

Key recommendations to users about FRP_NR_001.02 (night-time)

The following elements are overall recommended for an optimal exploitation:

- The **Standard FRP MWIR is recommended by EUMETSAT experts as the reference operational MWIR approach on a global & daily basis** thanks to its expected low commission error (*i.e.* low number of false alarms). As of today, most of users shall consider the associated MWIR results by default with the following guidelines:
    - The FRP MWIR hot-spots with the highest confidence are those commonly detected with the FRP SWIR (1 km) & a Confidence Class SAA of 50%.
    - To gain further confidence with the FRP MWIR alone, *i.e.* not common with FRP SWIR (1 km), users shall primarily consider the probabilistic Clear Sky Split Window confidence class to remove potential false alarms caused by unscreened cloud edges. As a 1st attempt, thresholds of 20%-40%-60% are recommended for low-medium-high clear-sky (*i.e.* non cloud-edge) confidence.
    - Users are also very much encouraged to test combinations with all the other Confidence Classes given in the FRP_in.nc file.

- The **Alternative FRP MWIR is primarily recommended to Expert fire users further interested by small hot-spots**. It is expected by EUMETSAT that most of false alarms, that can quite often be caused by the very special radiance behaviour produced by the SLSTR F1 detector, are strongly minimized thanks to the implemented F1 over-shooting risk mask developed by EUMETSAT. Nevertheless, a few may still remain in small & heterogeneous areas. Hence, by safety, expert users shall privilege cases of interest with low temperature gradient in the scene background (*i.e.* cloud-free, not too cold scenes). On the long-term, it is expected this technique may become the reference one upon positive user & expert feedbacks.

- The **night-time fire pixels shall be optimally identified thanks to the associated Solar Zenith Angles (SZA) larger than 85 deg for SWIR & 100 deg for MWIR given in the FRP_in.nc file**.

- FRP without H_2O transmittance correction can be deduced by multiplying the FRP values with the corresponding H_2O_transmission fields given in FRP_in.nc.

- FRP SWIR (500 m & 1 km) are regularly affected by the SAA which can extend far away from South-America. Hence, users are strongly advised to use it with the associated SAA confidence class available in the FRP_in.nc. For FRP SWIR (1 km), a threshold of 50% seems to be sufficient to remove most of SAA affected while 100%, albeit providing the most reliable FRP SWIR (1 km) pixels, generally tends to over-screen, such as gas-flares in the high-latitude (*e.g.* North-Sea).

Additionally, users are strongly advised to pay attention to the listed detailed asset & limitations of the product in the Sections "Known performance" & "Known Product limitations".

Processor Description

Level 1B Product

- Please see the Sentinel-3 A and B Product Notice – SLSTR Level-1B, S3.PN-SLSTR-L1.07 v1.1, issued on 15/01/2020 & revised on 09/06/2020 for all details.

The following is however worth being highlighted in the context of S3 NRT FRP:

Geometric Calibration:

- SLSTR-A & SLSTR-B nadir and oblique view geolocation accuracy meet the mission requirements (0.5 pixel as per S3 MRTD, 2011).
- The estimated geometric validation for SLSTR-A and SLSTR-B is within 0.1 pixel in nadir view along and across track and in oblique view across track.
  - Smaller offset (still within requirements) is observed in oblique view along track (~0.2 pix) for both satellites.

TIR Radiometric Calibration:

- SLSTR-A & SLSTR-B TIR radiometric accuracy meets the mission requirements (S3 MRTD, 2011).

Level 2 S3 NRT Product

NRT FRP retrieval algorithm - Radiant heating & threat monitoring of fires, gas flares, and volcanoes

The Copernicus Sentinel-3 (S3) FRP product monitors in Near Real Time (NRT) the location and associated threat (*i.e.* total radiative power) of all land and ocean hot-spots detectable on our planet. Hot spot are any "burning" body exhibiting a high temperature (> 650 K), a heating radiative signal within a pixel of 1 km, and posing an immediate threat to our atmosphere, ecosystem and surrounding population. FRP is related to the rate at which combustible is being consumed per unit of time as a direct result of the combustion process.

The original algorithm was specified by M. Wooster & W. Xu from King's College London (KCL), under the reference S3-L2-SD-03-T04-KCL-ATBD_FIREPRODUCT, v4.3. Since the 1st release PB under FRP_NR.001.00 (IPF v2.0) & the next follow-ups, additional developments were specified and added by EUMETSAT.

Processor capabilities:

- **For all FRP techniques**
    - Both "active hot-spot detection" and "radiative power quantification" tasks are performed.
    - The key used SLSTR channels are: S5 (SWIR – 1.6 µm), S6 (SWIR - 2.25 µm), the two S7 & F1 (MWIR – 3.7 µm), and S8 (10.85 µm).
    - From temperature point of view, two types of hot spots are identified:
        - "FRP MWIR" for warm hot spots with T > 650 K, *e.g.* vegetation fires. This FRP is based on 3.7 µm, either from S7 or F1 detectors, combined with the Long WaveInfraRed (LWIR) at 10.8 µm (S8) .
        - "FRP SWIR", based on 2.25 µm (S6), for very warm hot spots with T > 1000 K, *e.g.* gas flares – Applicable by night global, and by day only for ocean gas flares.
    - A series of flags, indicating the outcome of each single detection test, is reported for all original L1B pixels on the S7 image grid (1 km). This allows advanced users to investigate potential omitted events.
    - Additional parameters are provided for each detected hot spot such as FRP uncertainty, radiance value (S6, S7, and/or F1), transmittance corrected from H_2O absorption, potential hot spot type;
    - Heating signals from equatorial warm waters are discriminated from real hot spots;
    - The full swath of the SLSTR nadir view is used (no oblique or dual-view configuration);
    - Cloud mask is internal to the FRP processor & relies on a simple S8 BT test (threshold of 273 K).
    - The reference Land/Sea mask is the Global Land Cover (GLC) 2000 [https://forobs.jrc.ec.europa.eu/products/glc2000/glc2000.php].
    - Scenes with S7 saturated background (*i.e.* non impacted by hot spots) are not processed for now by any FRP MWIR techniques. This essentially occurs during daytime. Note that scenes where only hot-spot pixels are saturated in S7 are nevertheless processed, thanks to the F1 detector.
    - All FRP values are corrected of the H_2O transmittance.

- **F1 *vs.* S7**: Although F1 & S7 measure the same spectral range of 3.7 µm with a similar spectral response function, both detector designs & Instantaneous Field Of View (IFOV) differ. Consequently:
    - F1 can measure BTs beyond 450 K, while S7 becomes highly uncertain above 305 K, and even saturates ~312 K.
    - Noise contribution is much higher in F1.
    - S7 & S8 IFOVs highly differ with F1 IFOV in terms of size & shape. F1 IFOV is far narrower and associated geometric deformation is much lower than S7 across the swath: close to 6 km^2 at the edge of the swath for S7 compared to less than 2 km^2 for F1.
    - F1 is not co-registered with any S6-S7-S8 detectors. Signals integrated in F1 & S7 come from different target location. This has a particular significance over heterogeneous

scenes such as local hot-spots or heterogeneous cloud coverage. Consequently, from geometry point-of-view, F1 presents a much better sensitivity to small fires across the swath while S7 pixels show a far greater degree of pixel-to-pixel footprint overlap.
    - Contrary to S7, F1 is very sensitive to high temperature gradient scanned over a scene. Consequently, abnormal very high radiance is very regularly observed after a cold cloud in the scan direction, over a series of 5-15 pixels. Reciprocally, very abnormal low radiance is delivered after a very hot fire in the scan direction. Therefore, from radiance point of view, F1 presents a much higher risk than S7 to activate false alarms if no careful precaution are considered over large scenes with heterogeneous cloud coverage.

- **FRP detection and quantification is reported:**
    - For Standard FRP MWIR: at 1 km resolution (close to nadir – 0 deg – angle) mainly on the reference S7 image grid; sometimes on the F1 grid if a MWIR hot-spot was identified thanks to the F1 absolute test (land only);
    - For Alternative FRP MWIR: at 1 km resolution (close to nadir – 0 deg – angle) on the reference F1 image grid in priority if a S7-F1 cluster of contiguous fire pixels could be detected, else on the S7 grid.
    - For FRP SWIR (1 km): at 1 km resolution (close to nadir – 0 deg – angle) mainly on the reference S7 image grid, after aggregation onto the 1 km grid of the original SWIR 500 m hot-spots.
    - For FRP (500 m): at 500 m resolution (close to nadir – 0 deg – angle) on the original reference S6 grid.

- **Standard FRP MWIR principles**
    - Active detection is based on the S7 radiance & associated grid, even if the S7 fire pixel is saturated. Only when the background is saturated, the active detection cannot be performed and is hence skipped.
    - The FRP computation is based on S7 (both fire & background BTs) as long as the fire BT is not saturated (*i.e.* < 312 K).
    - The FRP computation is based on F1 in case of S7 fire pixel saturation. In that case, in a same cluster, the F1 BTs of equivalent S7 fire pixels are redistributed over the saturated S7 fire pixels.
    - The Confidence Classes Abs_BT_MWIR (*i.e.* S7 BT magnitdue), Rel_BT_MWIR spatial (*i.e.* relative S7 fire signal w.r.t. S7 background), Rel_BT_MWIR_spectral (*i.e.* relative S7-S8 spectral signal), ncloud_vicinity, and nwater_vicinity are based on the S3-L2-SD-03-T04-KCL-ATBD_FIREPRODUCT v 4.3 document (Sect. 3.2.7.2).
    - The Confidence Class Clear-Sky Split Window is based on the traditional BT difference between 11 & 12 μm (*i.e.* S8-S9 BT) & widely used in AVHRR & MODIS (Key, 2002; Ackerman *et al.*, 2010). The main assumption is the higher transmittance at 11 um, and absorption at 12 μm of ice & water clouds. The test is exclusively applied by night over land. Minimum S8-S9 BT difference of zero results to a 100% clear sky confidence. Differences larger than 1.5 K (if S8 BT <= 285 K) or 3 K (if 285 K < S8 BT <= 295 K) result as a 0% clear sky confidence (Key, 2002). The test is not applied to L1B pixels with S8 BT values higher than 295 K.

- The Confidence Class Clear-Sky Freezing is inspired by the S8 BT test applied in MODIS (Ackerman *et al.*, 2010). The minimum & maximum thresholds are 273 K & 297.5 K respectively, leading to the range of 0%:100% clear sky probability.
- All Confidence Classes are determined *a posteriori* of all MWIR hot-spot detection.

- **Alternative FRP MWIR principles**
    - The original idea is recommended by (Xu *et al.*, 2020, 2021).The Alternative FRP MWIR however includes a major modification specified & implemented by EUMETSAT: a mask associated with the F1 L1B pixels, in order to cope carefully with the special F1 radiance behaviour from cold to hot targets in the scan direction.
    - Firstly, the primary active detection is based on the S7 radiance & associated grid, even if the S7 fire pixel is saturated. Only when the background is saturated, the active detection cannot be performed and is hence skipped.
    - Secondly, a F1 over-shooting risk mask is elaborated based on 1) the Cloud Split Window test (See Confidence Clear-Sky in Standard FRP MWIR), and 2) a margin of 20 pixels around the S7 cloud to take into account the spatial offset between S7 & F1..
    - Thirdly, a redetection is done onto the F1 grid thanks to a clustering S7-F1 approach for all individual S7 fire pixels non masked by the F1 over-shooting risk maps. This clustering uses spatially contiguous of active fire pixels in both S7 & F1. For the identified F1 fire pixels, FRP is computed from F1 regardless of the S7 saturation status in the original AF detection.
    - Fourthly, for all S7 fire pixels screened by the F1 over-shooting risk mask, FRP is computed from S7.

- **FRP SWIR (1 km)**
    - Active detection is achieved on the S6 TOA radiance at the fine L1B pixel resolution (500 m) on the SWIR a stripe only.
    - FRP is then integrated onto the 1 km grid.
    - A SAA or spurious SWIR signal detection is attempted with 2 independent tests: 1) spectral consistency (assumption that a SWIR hot-spot shall be commonly found in both S5 & S6 detectors in a stripe), 2) spatial consistency at 1 km (assumption that a SWIR hot-spot shall be found in both S6 a and b stripes).
    - A Confidence SAA (1 km), or spurious SWIR signal, class detection is computed as a probability based on the 2 tests: 0% = no anomaly suspicion (no detection by any tests), 50% = anomaly suspected by only 1 test, 100% = anomaly suspected by the 2 tests simultaneously.

- **FRP SWIR (500 m)**
    - Contrary to FRP SWIR (1 km), it is computed and produced directly at the L1B pixel resolution (500 m), and reported on the original S6 L1B grid.
    - The SAA or spurious SWIR signal at fine resolution is exclusively based on the spectral consistency test based on S5 & S6 a stripe.
    - A suspected anomaly directly results as a Confidence SAA (500 m) 100% result.

- **Nearly co-registered Standard FRP MWIR / FRP SWIR (1 km)**
    - While identification techniques are independent, Standard FRP MWIR & FRP SWIR (1 km) are almost always reported on the assumed co-registered 1 km grid. Both hot spot types are relevant and shall be considered by users. Some events will be detected by one of the two tests (*i.e.* FRP MWIR or SWIR Only), others will be by both (*i.e.* FRP MWIR/SWIR Only).
    - However, the overall total number of fires per granule s only counted twice in case of common FRP MWIR/SWIR. In such a case, the warmer FRP value shall be considered as the most reliable.

- **FRP SWIR (500 m & 1 km) - Since the 1st deployment of PB FRP_NR.001.00 with the IPF v2.0**
    - Detection of gas flares & other very warm fires, "outshining" by night, are further optimized thanks to a better discrimination of the S6 radiometric signal and high occurrence of S6 background noise in the absence of Sun irradiance.
    - A tuning has been done to minimize SWIR false alarms due to Solar irradiance residuals in the northern latitudes from end of Autumn to end of Winter in twilight conditions;
    - Additionally, the channel S5 (1.6 µm) is used by night to improve the reliability of very warm FRP SWIR.

<u>Known performances (night time only):</u>

- **For all FRP types:**
    - The expected uncertainty per individual FRP hot spot pixel should be of the order of 10%.

- **Standard FRP MWIR**
    - Deforestation, tropical peats, Savanah and other vegetation fires are well detected by MWIR tests in South-America, Central Africa, India, Thailand, Indonesia, and Australia areas.
    - Globally, ~60-65% of FRP MWIR values are derived from unsaturated S7 BT.
    - ~60-70% of global FRP MWIR are not common with FRP SWIR (1 km). They are mainly associated with low average radiative power: ~7-8 MW.
    - FRP MWIR common with SWIR(1 km) represent stronger hot-spot radiative with average FRP values in the range of 12-15 MW.
    - Every day, 1 single SLSTR finds about 2000 (globally) / 200 (East Asia) more MWIR hot-spots than MODIS Terra. This leads to a daily global difference of ~8000 MW (globally) on the total integrated FRP MWIR between 1 SLSTR & MODIS Terra. These are primarily expected to be related to the enhanced capability of the Copernicus S3 NRT FRP to detect weakly radiative fires than NASA MODIS Terra fire product.
    - The FRP MWIR common with SWIR(1 km) overall show a closer consistency with the MODIS Terra FRP: global differences are reduced to ~200 for the number of AF & ~200 MW for the total integrated FRP.
    - Over Africa, based on a strict matching collocation window of 1x1 pixel, it is found that about 50% of Meteosat Second Generation (MSG)/SEVIRI hot-spots (EUMETSAT Land-

SAF FRP-PIXEL product) are common with SLSTR-A & -B over December 2019 – October 2020. Seasonal variability lies in the range of 47.3%-64.5%. The average of SLSTR FRP MWIR common with MSG SEVIRI is larger than 10 MW. The SLSTR FRP non-common with MSG/SEVIRI has an average lower than 10 MW. Similarly as the comparison with MODIS Terra, this is again assumed to represent the enhanced capability of the Copernicus S3 NRT FRP product to detect weaker radiative hot-spots. The SLSTR *vs.* MSG/SEVIRI inter-comparisons is routinely performed by EUMETSAT based on an in-house Low Earth Orbit (LEO) / GEOstationarry fire CalVal & Collocation tool.

- Overall, SLSTR MWIR hot spot detectability from SLSTR by night is expected to be close to 5-7 MW (under confirmation).
- Real hot spot signals from equatorial warm waters in the vicinity are discarded.

- **Alternative FRP MWIR**
  - The number of global detected hot-spots with Alternative FRP MWIR is on average 20-25% higher than with Standard FRP MWIR, thanks to the lower F1 FOV size across the SLSTR swath. It can be much larger regionally (*e.g.* Central Africa, India).
  - Globally, ~75-80% of Alternative FRP MWIR values are based on F1 fire BT. The remaining 20%-25% FRP MWIR values are based on unsaturated S7 BT due to high risk of F1 over-shooting radiance detected by the associated mask.
  - The average Alternative FRP MWIR is ~ 5-8 MW lower than the average Standard FRP MWIR.
  - Potential commission error (*i.e.* false alarms) due to the special F1 BT behaviour is expected to be quite minimized thanks to the F1 over-shooting risk mask. It should remain relative close to (if not lower) the Standard FRP MWIR commission error.

- **FRP SWIR (500 m & 1 km)**
  - Dominance of S6 background noise, over all surface types, is discriminated from actual S6 signal caused by "shining" radiative flames;
  - Most of industrial gas flares in Persian gulf, Algeria, and North Sea areas are frequently well detected, by both SWIR and MWIR tests. It is expected that FRP SWIR better captures hotter flames, while those at medium temperatures shall be found common between FRP SWIR and MWIR. Accuracy of FRP detection & estimation is under assessment.
  - Over Persian Gulf during December 2019, 56% of industrial gas are detected by SWIR tests. Temporally & spatially integrated 1 deg FRP (IFRP) SWIR & MWIR highly correlate (0.99). IFRP SWIR is overall much higher by 468.3 MW, confirming a high dominance of extremely warm flaming industries which heating signal peaks more in the SWIR than in the MWIR.
  - Between 15% and 45% of FRP SWIR (1 km) may be suspected related to SAA or other SWIR anomalies with a probability of 50% or 100% respectively (based on the probabilistic Confidence SAA Class).

- **Comparison Standard FRP MWIR & SWIR (1 km)**
  - Over Australia continent (with bush fires) during December 2019, 89.6% of individual hot spots are detected by MWIR tests. IFRP SWIR & MWIR very well correlate (0.97). IFRP MWIR is overall much higher by 1070.2 MW, confirming a high dominance of vegetation fires which heating signal peaks more in the MWIR than in the SWIR.
  - During December 2019: common identified hot spots (MWIR-SWIR) vary between 15.1% (worldwide) and 35.9% (Australia continent). Between 2.2% (Persian Gulf industrial gas flares) and 15.1% (worldwide) individual SWIR hot spots are screened with the "FLAG_SWIR_SAA" equal to the value of 0.

Known Product Quality Limitations

Limitations on L1B inputs

SLSTR-A L1B PB 2.59 and SLSTR-B L1B PB 1.40 have the following known limitations relevant to Fire Radiative Power:

S7, S8, S9 co-registration:

- A small sub-pixel mis-alignment has been observed between S7 and co-registered S8/S9 pixels (~250 m for SLSTR-A and ~120 m for SLSTR-B).

Fire Channel co-registration:

- A dedicated F1 geolocation module with computation of the specific line-of-sight associated with the F1 detector has been introduced to improve the geo-referencing of the F1 channel. Note that the geolocation approach remains unchanged for the other channels;
- The combination of both the new-regridding approach for all channels and the F1 geo-referencing leads to a significant reduction of the spatial offset between F1 and S7 channels in nadir view, from ~2 km to less than 1 km in case of low satellite zenith angles. However, for increasing angles (above 40 deg), the off-set remains larger than 1 km. The geo-referencing of F1 in oblique view is, however, not reduced at this stage and further works continue. The users are advised to use F1 in oblique view with high precaution.

S7 BT upper limit:

- The maximum brightness temperature of the S7 channel in the files has been increased beyond 305 K as a pre-requisite for fire applications based on SLSTR measurements (including the forthcoming SLSTR FRP processor). All S7 BTs above 305 K (except for S3B oblique view pixels above 311K) are flagged as "S7 invalid radiances" as the values are beyond the nominal limits of the detector and related radiometric calibration performance;

- Users should be aware of this limitation. S7 BT larger than 305 K is to be used with caution depending on the user application and associated quality requirements.

VIS/SWIR Radiometric Calibration Information:

- SLSTR-A/B: Currently all solar channels (S1-S6) are undergoing a vicarious calibration assessment to quantify their radiometric calibration. The calibration factors communicated in S3MPC.RAL.TN.020-i1r0 are highly recommended.
- Non-linearity issues may remain & are under further investigation.
- The root cause of the discrepancy has not yet been determined but is under investigation.

Limitations from the level-2 retrieval

Limitations about the Copernicus S3 NRT FRP PB FRP_NR.001.02 are detailed below. New or modified limitations, with respect to (w.r.t.) previous PBs, are indicated in **Purple.** Unchanged ones are indicated in **Black.**

The limitations associated only with the previous PB & not valid anymore here are detailed in the corresponding previous PN documents (see Section "PB Release history").

FRP SWIR (night-time):

- **#SWIR - 1 – S5 & S6 radiometric calibration residual errors may persist** in spite of the absolute & inter band correction applied at the beginning of L2 NRT FRP processor. Key remaining uncertainties are related to non-linearity at low radiance levels and between SLSTR-A and –B. This may not dramatically impact the SWIR detection, but may affect both FRP estimation & SAA filtering. Exact impacts are under characterization.
- **# SWIR - 2 – A value of 100% of the Confidence Class SAA suspicion associated with FRP SWIR (1 km) is likely too conservative** and shall be considered with caution. Indeed, it is observed it tends to over-screen real SWIR hot-spots such as industrial gas flares in the North Sea.
- **#SWIR – 3 – SAA detection seems to be ~5% more frequent with SLSTR-A than –B.** Exact root cause is under analyses.
- **#SWIR - 4 – FRP SWIR (500 m) is not yet comprehensively validated**, although several internal analyses have reported a very high quality & similar good performance with FRP SWIR (1 km). Users are very welcome to report any feedbacks to EUMETSAT.
- **#SWIR – 5 – Spectral consistency test for SAA detection assumes a reasonable co-registration of both S5 & S6 a stripe over 1 km^2 area.** This is however uncertain on a global scale and may trigger false SAA detection, hence contributing to the over-screening mentioned in #SWIR – 2.
- **#SWIR – 6 – Spatial consistency test for SAA detection assumes a reasonable co-registration of both a and b strips of S6 over 1-2 km^2.** This is however uncertain on a global scale and may trigger false SAA detection, hence contributing to the over-screening mentioned in #SWIR – 2.

FRP MWIR (night-time):

- **#MWIR - 1 – All S7 BTs above 305 K are known to present non-linear behaviour** as the values are beyond the nominal limits of the detector and related radiometric calibration performance. Furthermore, no BT beyond 313 K can be obtained from S7 ("saturation"), contrary to F1.
- **#MWIR - 2 – BTs from F1 are expected to be noisier than those from S7**. This may affect the precision of the associated FRP MWIR computation in some cases.
- **#MWIR – 3 – The commission error of the Alternative FRP MWIR remains to be carefully confirmed**, while maximum efforts have been implemented to minimise false alarms thanks to the F1 over-shooting risk map.
- **#MWIR – 4 – The F1 over-shooting risk map used in the Alternative FRP MWIR may be too conservative**. Users are strongly encouraged to report recommendations on the way to relax its criteria such that it would allow to detect a higher number of true weakly radiative hot-spots / fires.
- **#MWIR – 5 – Between 15% & 30% (max) of global Standard FRP MWIR hot-spots may be false alarms caused by under screened cloud edges.** The reason is due to the high similarity of their spectral signatures with weakly radiative ("small") fires across S7 & S8. Most of them can be identified *a posteriori* as 1) non-common hot-spots with SWIR (1 km) and/or 2) low Clear-Sky Confidence class. Exact techniques to remove eventually such false alarms in a future evolution are under investigation.
- **#MWIR - 6 – Specific FRP MWIR pixels are under investigations to understand better the exact mechanisms triggering these positive detections.** These include few but systematic FRP MWIR pixels appearing in Siberia, very small number of spurious pixels in Western Europe and Western Canada in Winter and Spring. The first one might be caused by local hot bodies (plants or others) surrounding by wide frozen surfaces leading to a locally very strong thermal gradient (to be confirmed).
- **#MWIR – 7 – Uncertainty remains about the few MWIR hot-spots found sometimes in coastal waters such as South-America, India & Japan.** It is very likely related to the capability to detect oceanic industrial gas flares, but this remains to be exactly confirmed. Their occurrence is however very rare.
- **#MWIR – 8 – SLSTR S7 & S8-S9 sub-offset inter-registration may trigger false alarms.** Exact impacts are under investigation. It may be related to the issue #MWIR – 5 & affect the Confidence Clear-Sky Split-Window Class.

Fire Confidence:

- **#Confidence - 1 – Most of the new Confidence Classes associated with the Standard FRP MWIR remain to be comprehensively validated.** However, internal analyses have not shown anomalies at the moment.
- **#Confidence - 2 – Alternative FRP MWIR does not have Confidence Class at the moment.** The reason is the lack of co-registration of F1 with any other S measurements that are needed to compute the probabilities.
- **#Confidence - 2 – FPR uncertainty have not yet been comprehensively validated.** Although they can be reasonably used for further confidence in the FRP MWIR and SWIR, users are encouraged to report to EUMETSAT any feedbacks.

Very low Signal-to-Noise-ratio (SNR):

- **#Processor - 1 – Optimized processor code evolution is under planning to improve the processing of very low hot spot signals.**

Products Availability

☒ Copernicus Online Data Access (https://coda.eumetsat.int/), NRT

☒ EUMETCast (https://eoportal.eumetsat.int/), NRT

☒ EUMETSAT Data Centre (https://eoportal.eumetsat.int/), NRT

☐ FTP server address login: login password: password

☐ Other

Product	EUMETCast	ODA*	CODA**	EUMETSAT Data Centre
L2 FRP	NRT	NRT	NRT	NRT

*** ODA** is available only for Copernicus Services and S3VT users
**** CODA** is the service Copernicus Online Data Access and is available to all users

Off-line Products Availability

A series of S3 FRP dataset partially reprocessed off-line from the same EUMETSAT processor v2.01 & with L1B NRT data can be made available upon request (see EUMETSAT point of contact below). This includes the following:

- Complete worldwide reprocessing of past S3 FRP dataset up to 1st of December 2019.
- Specific regionally and/or temporally limited reprocessing may be addressed.
- Possible other ancillary data and/or expert advice support.

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PB Release History

Details about the release history of the Copernicus S3 NRT FRP product are given in the table below:

S3 NRT FRP PB	Installation date	Summary	Product Notice
FRP_NR.001.02 IPF v2.01	2021.05.06	Current release.	EUM/SEN3/DOC/21/1225813
FRP_NR.001.01 IPF v2.0	2020.07.16	Removal of twilight contamination in the Standard FRP MWIR & FRP SWIR (1 km) night-time in high North latitude areas. ○ Update via increase Solar Zenith Angle (SZA) threshold.	EUM/SEN3/DOC/20/1194754 v1.0
FRP_NR.001.00 IPF v2.0	2020.04.08	First release	EUM/SEN3/DOC/20/1194716 v2.0

All documents & further description are available at: https://www.eumetsat.int/atmospheric-composition

To form a consistent set of NRT FRP dataset worldwide from both SLSTR-A and –B, users are advised to use the following data:

- Standard FRP MWIR & FRP SWIR (1 km): combining both NRT PB 1.1 & PB 1.2 from 2020.07.16 onwards.
- Confidence classes with Standard FRP MWIR: NRT PB 1.2 from 2021.05.06.
- Alternative FRP MWIR & FRP SWIR (500 m): NRT PB 1.2 from 2021.05.06.

For data before the mentioned dates, partially reprocessed data shall be considered (see Section "Off-line Products availability").

References

- Operational Algorithm Web - Copernicus Sentinel-3 Fire Radiative Power (FRP) – Radiant heating & threat monitoring of fires, gas flares, and volcanoes: https://www.eumetsat.int/website/home/Data/ScienceActivities/OperationalAlgorithms/CopernicusSentinel3NRTFireRadiativePowerFRP/index.html;

- Daily monitoring of FRP hot-spot situations from S3A and S3B via the EUMETSAT Monitoring & Evaluation of Thematic Information from Space (METIS) FRP website: http://metis.eumetsat.int/frp/index.html#;

- Sentinel-3 Atmospheric Composition webpage: https://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Sentinel3/AtmosphericComposition/index.html

- Sentinel-3 Mission Requirements Traceability Document (MRTD), C. Donlon, EOP-SM/2184/CD-cd, 2011: https://sentinel.esa.int/documents/247904/1848151/Sentinel-3-Mission-Requirements-Traceability

- Product Data Format Specification – SLSTR Level 1 & 2 Instrument Products, Ref: S3IPF.PDS.005.1, Issue: 2.7, Date: 06/02/2018: https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-slstr/document-library https://www.eumetsat.int/website/home/Data/TechnicalDocuments/index.html

- SLSTR NRT FRP ATBD "Sentinel-3 Optical Products and Algorithm Definition - Active Fire: Fire Detection and Fire Radiative Power Assessment" written by M. Wooster & W. Xu from King's College London (KCL), under the reference S3-L2-SD-03-T04-KCL-ATBD_FIREPRODUCT, v4.3, on 31/10/2019: https://wwwc.eumetsat.int/website/home/Satellites/CurrentSatellites/Sentinel3/AtmosphericComposition/index.html

- EUMETSAT - SLSTR L2 NRT FRP Product Data Format (PDF) Specification, EUM/RSP/DOC/20/1169482 v1.A, written by J. Chimot, 30/03/2020: https://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Sentinel3/AtmosphericComposition/index.html

- EUMETSAT - SLSTR L2 NRT FRP Auxiliary Data Format (ADF) Specification, EUM/RSP/DOC/20/1169484 v1.A, written by J. Chimot, 30/03/2020: https://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Sentinel3/AtmosphericComposition/index.html

- Further information and documentation can be found at: https://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Sentinel3/SeaSurfaceTemperatureServices/index.html

- S3MPC.RAL.TN.020-i1r0 - S3 SLSTR Visible and Short Wavelength Radiometric Calibration Adjustments – issue 1.0, written by Dave Smith (RAL), 16/07/2020.

- Ackerman Steve, Frey Richard, Strabala Kathleen, Liu Yinghui, Gumley Liam, Baum Bryan, Menzel Paul, Discriminating Clear-Sky from Cloud with MODIS – Algorithm Theoretical Basis Document (MOD35), Cooperative Institute for Meteorological Satellite Studies, university of Wisconsin – Madison, v6.1, October 2010.

- Key Jeffrey R., The Cloud and Surface Parameter Retrieval (CASPR) System for Polar AVHRR, User's Guide, NOAA/NESDIS/ORA/ARAD/ASPT, v4.0, 2002.

- 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 Sens. Environ. 120 (0), 236–254.
- Weidong Xu, Martin J. Wooster, Jiangping He, Tianran Zhang, First study of Sentinel-3 SLSTR active fire detection and FRP retrieval: Night-time algorithm enhancements and global intercomparison to MODIS and VIIRS AF products, Remote Sensing of Environment, Volume 248, 111947, ISSN 0034-4257, https://doi.org/10.1016/j.rse.2020.111947, 2020.
- Weidong Xu, Martin J. Wooster, Edward Polehampton, Rose Yemelyanova, Tianran Zhang, Sentinel-3 Active Fire Detection and FRP Product Performance – Impact of Scan Angle and SLSTR Middle InfraRed Channel Selection, Accepted in Remote Sensing of Environment, 2021.

End of Product Notice