Sentinel-3 Product Notice – SLSTR Level-2 Near Real Time Fire Radiative Power

Mission	Sentinel-3A & Sentinel-3B	
Sensor	SLSTR-A & SLSTR-B	
Product	Near Real Time (NRT) Level-2 (L2) Fire Radiative Power (FRP)	
Product Notice ID	EUM/RSP/DOC/20/1171781	S3.PN-SLSTR-L2FRP-02.00
Issue/Rev Date	09/04/2020	
Version	1.0	
Preparation	This Product Notice was prepared by EUMETSAT.	
Approval	EUMETSAT Mission Management	

Summary

This is the Product Notice (PN) for Sentinel-3A and -3B Sea and Land Surface Temperature Radiometer (SLSTR-A and SLSTR-B) Level-2 (L2) Fire Radiative Power (FRP) product generated with Processing Baseline (PB) 2.46 (-A) and 1.18 (-B), IPF version 2.0 deployed on 08/04/2020. It is exclusively applicable to products generated in Near Real Time (NRT).

This Notice describes the L2 NRT FRP current status, the processing baseline, the product quality and known limitations for both SLSTR-A and SLSTR-B.

Note: This product deployment follows the latest SLSTR Level-1 Processing Baseline, operational since 15.01.2020, that led to major changes in the SLSTR L1B product, which were essential for a high quality SLSTR L2 FRP processing.

Processing Baseline

	S3A	S3B
Processing Baseline	Processing Baseline: 2.64	Processing Baseline: 1.37
IPFs version	SL_2 IPF version: 02.00	

Current Operational Processing Baselines

IPF	IPF Version	Into operations since
S3A SL2	02.00	NRT mode: 21/04/2020 10:15 UTC with early products from 08/04/2020 available only on ODA and the EUMETSAT Data Centre
S3B SL2	02.00	NRT mode: 21/04/2020 10:15 UTC with early products from 08/04/2020 available only on ODA and the EUMETSAT Data Centre

Status of the Processing Baseline

This PN covers preliminary operational Near Real Time (NRT) SLSTR-A & SLSTR-B Level-2 (L2) Fire Radiative Power (FRP) products, generated using PB 2.64 and PB 1.37, respectively, both from Instrument Processing Facility (IPF) version 02.00. The baseline was declared operational in the marine processing centre on 21/04/2020 for both SLSTR-A and SLSTR-B (early products generated from 8/4 are also available only on ODA and in the EUMETSAT Data Centre).

Level 1 Product:

- Please see the Sentinel-3 A and B Product Notice – SLSTR Level-1B, S3.PN-SLSTR-L1.07 v1.0, issued on 15/01/2020.

Level 2 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 current version of the NRT S3 FRP product is considered as "preliminary operational". It is mainly applicable during nighttime, as only few daytime granules with non-saturated background (*i.e.* no fires) radiance are processed at this stage. Further improvements to the NRT S3 FRP product are planned, including the full processing of granules during daytime, a comprehensive global validation, and updates following feedback from experts and users.

Algorithm capabilities:

- Both "active hot-spot detection" and "radiative power quantification" tasks are performed;
- FRP detection and quantification is reported at 1km resolution, on the reference S7 image grid;
- 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);
- The full swath of the SLSTR nadir view is used (no use of the dual-view configuration);
- Cloud mask tests are internal to the FRP processor, *i.e.* not taken from those available in the SLSTR L1B data. Same applies for the Land/Sea mask which comes from the Global Land Cover (GLC) 2000 [https://forobs.jrc.ec.europa.eu/products/glc2000/glc2000.php];
- F1 & S7 differ in terms of dynamic range. F1, called the "hot" channel, does not saturate over hot fires, but may be noisier. By opposition, S7 is less noisy, but becomes highly uncertain above 305 K, and even saturates ~312 K;
- Consequently, scenes with S7 saturated background (*i.e.* non impacted by hot spots) are not processed for now. This essentially occurs during daytime. Note that scenes where only hot-spot pixels are saturated in S7 are processed, thanks to the F1 detector;
- Two types of hot spots are identified:

  - "FRP MWIR", based on 3.7 µm, for warm hot spots with T > 600 K, e.g. vegetation fires – Applicable by day global, by night only over land surfaces (see Fig.2);
  - "FRP SWIR", based on 2.25 µm, 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 (see Fig. 3);
  - Both hot spot types are relevant and shall be considered by users. Some events will be detected by one of the two tests, others will be by both (but only counted once in the overall total number of fires per granule). But the warmer FRP MWIR shall be considered as the most reliable.
- 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;
- A specific flag is added to filter out South Atlantic Anomalies (SAA) and other transient or spurious events, during night-time. Users interested by FRP SWIR are strongly advised to use "FLAG_SWIR_SAA" equal to the value of 0 to optimize their focus on real hot-spots such as fires in Argentina, Bolivia, and others;
- A series of flags, indicating the outcome of each single detection test, is reported for all original L1 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 H2O absorption, potential hot spot type;
- Heating signals from equatorial warm waters are discriminated from real hot spots;
- Current reference processor configuration exclusively computes FRP MWIR, after detection, as follow:
  - for S7 non saturated hot spot pixel : use of S7 radiance;
  - for S7 saturated hot spot pixels : use of F1 radiance;
  - A clustering image correlation technique allows the mapping of consistent F1 and S7 hot-spots onto each other. This technique is hereafter named "Full F1 Off".

Known performances (night time):

- Hot spot detectability from SLSTR by night seems to be lower than 10 MW, perhaps even below 5 MW (under confirmation);
- The expected uncertainty per individual FRP hot spot pixel should be of the order of 10%;
- Real hot spot signals from equatorial warm waters in the vicinity are discarded;
- 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;
- Deforestation, tropical peats, Savanah and other vegetation fires are overall well detected by MWIR tests in South-America, Central Africa, India, Thailand, Indonesia, and Australia areas;
- 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;
- On a daily basis, SLSTR-A detects a higher number of hot spots with low FRP (*i.e.* smaller than 10 MW) than MODIS. This might be an asset as frequency of low radiative hot spots on Earth is much more probable (to be confirmed);
- On a spatio-temproal average basis at 2 deg resolution, during December 2019, SLSTR-A and MODIS Terra FRP MWIR differences are between -5 MW (Australia continent) and 2.74 MW (Persian Gas Flares), with correlations up to 0.74.

Known Product Quality Limitations

SLSTR-A Level-1b Processing Baseline 2.37 and SLSTR-B Level-1b Processing Baseline 1.12 have the following known limitations relevant to Fire Radiative Power:

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 the last product notices are still valid and new estimates will be communicated in a few months;
- These corrections should be used with caution as it is possible that the differences are scene dependent;
- The root cause of the discrepancy has not yet been determined but is under investigation.

SLSTR-A Level 2 FRP Processing Baseline 2.64 and SLSTR-B Level 2 FRP Processing Baseline 1.37 have the following known limitations:

FRP SWIR:

- S5 & S6 radiometric channels mis-calibration may not dramatically impact the SWIR detection, but may affect both FRP estimation & SAA filtering. Exact impacts are under characterization;
- Some twilight residuals in FRP SWIR have been detected by EUMETSAT in the northern Arctic Sea starting just after Spring equinox (first time observed on 24.03.2020). Resulting false alarms are for now minor and under a strict monitoring. They are not expected to overlap with actual detection of ocean gas flares in the North Sea, and close to Southern Norway coasts. Hence, associated FRP SWIR in these areas can be considered as reliable. These residuals will be corrected soon by EUMETSAT in a coming upgrade of the NRT processor.

FRP MWIR – S7 *vs.* F1:

- 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;
- BTs from F1 are expected to be noisier than those from S7;
- S7 and F1 are two different detectors, with separated focal planes. Although much improved in the latest deployed L1B PB, the geo-referencing of F1 is not yet perfect with a remaining spatial off-set of 1 km on average w.r.t S7. However, its impact is expected to be partially mitigated thanks to the S7-F1 clustering technique;
- S7 and F1 present different behaviours in terms of geometric deformation across-swath. A S7 pixel increases from 1.1 km^2 to 6 km^2 at the far-left swath edge, while a F1 pixel is more consistent, increasing from 0.9 km^2 to 1.8 km^2. Consequently, S7 may oversample hot-spots in a similar manner to the MODIS "bow-tie effect (Giglio *et al.*, 2013);
- To tackle the latest challenging point, a possibility of using exclusively F1 radiance over all S7 hot-spot pixels (regardless of their saturation status) is implemented in the processor. This

technique, named hereafter "Full F1 On", is currently under evaluation based on a full off-line reprocessing of SLSTR-A and B data from 1st December 2019 to onwards;

- 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).

Fire Confidence:

- Users shall use with great caution the "Fire_Confidence" value, which is systematically too low as it is for now based on S7 instead of F1 BT. An upgrade is expected a short-term evolution.

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

- Challenges are anticipated to handle very low numerical values associated low SNR. 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 SST	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 produced off-line from the same EUMETSAT processor v2.0 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, based on the "Full F1 Off" configuration. It is reminded that is the current reference configuration disseminated in NRT;
- Complete worldwide reprocessing of past (up to 1st of December 2019) and present S3 FRP dataset, based on the "full F1 On" configuration. Users are advised this configuration is currently under evaluation, and hence not yet part of the reference NRT configuration. However, any user is welcome to evaluate it and give feedbacks to EUMETSAT;
- Specific regionally and/or temporally limited reprocessing may be addressed;
- Possible other ancillary data and/or expert advice support.

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 P. 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

End of Product Notice