

Coastal Monitoring User Manual Sea Surface Temperature (SST)

Technical Document

June 2026

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- **Data:** CopernicusLAC Chile. (2025). Sea Surface Temperature (0.02°) for Latin America and the Caribbean: 2024 Monthly Level 4 Gap-Free Product (Version 1.0) [Data set]. <https://www.copernicuslac-chile.eu>

1. Executive summary

This manual describes the Sea Surface Temperature (SST) product generated by CopernicusLAC Chile for the Coastal Monitoring Service, based on multi-source nighttime remote sensing observations, validated with *in situ* data for 2024.

The product covers the Latin America and the Caribbean region (33°N, -60°S, -123°W, -25°E), with a spatial resolution of 0.02° (~2 km at the equator) and monthly temporal resolution. It corresponds to processing level 4 (L4): a spatially continuous variable with no gaps, obtained through optimal interpolation and deep-learning-based reconstruction.

SST is recognized by the Global Climate Observing System (GCOS) as an Essential Climate Variable (ECV), given its role in regulating heat exchange between the ocean and the atmosphere. The product is intended for climate and oceanographic research, model validation, coastal thermal characterization, fisheries management, early warning for extreme events (ENSO, tropical cyclones, coral bleaching), and the design of coastal adaptation policies in the region.

2. Introduction

Sea Surface Temperature (SST) plays a central role in regulating sensible heat, latent heat, and momentum fluxes between the ocean and the atmosphere, processes that largely determine the global energy balance and the dynamics of the lower troposphere's atmospheric circulation. Anomalous SST variations, such as those associated with the El Niño-Southern Oscillation (ENSO), modulate the position of the Intertropical Convergence Zone, the intensity of the trade winds, and regional and global precipitation patterns, with direct impacts on agriculture, water availability, and the occurrence of extreme weather events.

From an oceanographic standpoint, SST is a first-order tracer of dynamic processes such as coastal upwelling, thermal fronts, and mesoscale eddies, which sustain primary productivity and structure the distribution of marine species. In the Latin America and Caribbean domain, systems such as the Humboldt Current and the Brazil-Malvinas Confluence depend on surface thermal gradients whose precise characterization is essential for fisheries management and coastal ecosystem conservation.

Likewise, homogeneous satellite records free of instrumental bias, such as the one documented by this product, are a critical input for detecting ocean warming trends, validating and assimilating data into coupled ocean-atmosphere numerical models, and assessing risks associated with the intensification of tropical cyclones and coral reef bleaching (Embury et al., 2024).

For the Latin America and Caribbean region, the availability of a high spatial resolution, temporally continuous SST product is particularly relevant, given the historically low density of *in situ* observations and the high climate vulnerability of its coastal zones. The coastal upwelling systems, such as those in the southeastern Pacific, associated with the Humboldt Current, sustain one of the most productive fisheries on the planet. The dynamics of these resources are strongly conditioned by

ENSO-related SST anomalies: warm episodes (El Niño) are associated with a temporary reduction in primary productivity and catches, while cold episodes (La Niña) tend to favor more productive conditions.

In the Caribbean, persistent positive SST anomalies are the main predictor of mass coral bleaching events, with direct implications for reef biodiversity and local economies dependent on tourism and artisanal fishing. Likewise, monitoring SST in the Gulf of Mexico and the Caribbean basin is critical for assessing the potential for tropical cyclone intensification, since surface temperatures above 26 °C are a necessary condition for their development.

In this context, a gap-free, homogeneous, locally validated L4 product, such as the one described in this manual, provides a robust information base for regional oceanographic research, fisheries management, early warning for extreme climate events, and the design of coastal adaptation policies in Latin America and the Caribbean.

3. Product specifications

The technical specifications of the Sea Surface Temperature (SST) product from the CopernicusLAC Chile Coastal Monitoring Service are organized around the following aspects: general product information, a description of its content and coverage, and the distribution format. This documentation is intended to facilitate the correct download, reading, and integration of the product into oceanographic, climate, and coastal environmental management analysis tools.

3.1 General information

This subsection brings together the technical parameters that define the Sea Surface Temperature (SST) product generated by the CopernicusLAC Chile Coastal Monitoring Service. This information allows the user to understand the product's essential operating characteristics before downloading and using it in ocean climatology studies, model validation, or coastal thermal characterization. Table 1 summarizes the product's general attributes, including name, version, source sensors (SLSTR/Sentinel-3A and 3B, VIIRS/JPSS and NOAA-20, AVHRR/Metop-B and Metop-C), spatial resolution (0.02° , ~2 km), monthly temporal resolution, distribution format (NetCDF4 and ZARR), processing level (L4, gap-free), metadata standard (GHR SST GDS 2.1, CF-1.7, ACDD-1.3), and the product's spatial domain over the Latin America and Caribbean region (Figure 1).

Table 1. General information for the Sea Surface Temperature (SST) product.

Product ID	2024-L4_SST-monthly-GHR SST_v0.1
Spatial resolution	0.02° (~2 km. at the equator)
Temporal resolution	Monthly
Variable	Nighttime Sea Surface Temperature
Format (standard)	NetCDF4, ZARR (GHR SST GDS 2.1)
Geographic coverage	33° north, -60° south, -123° west and -25° east
Temporal coverage	2024

Source: Own elaboration.

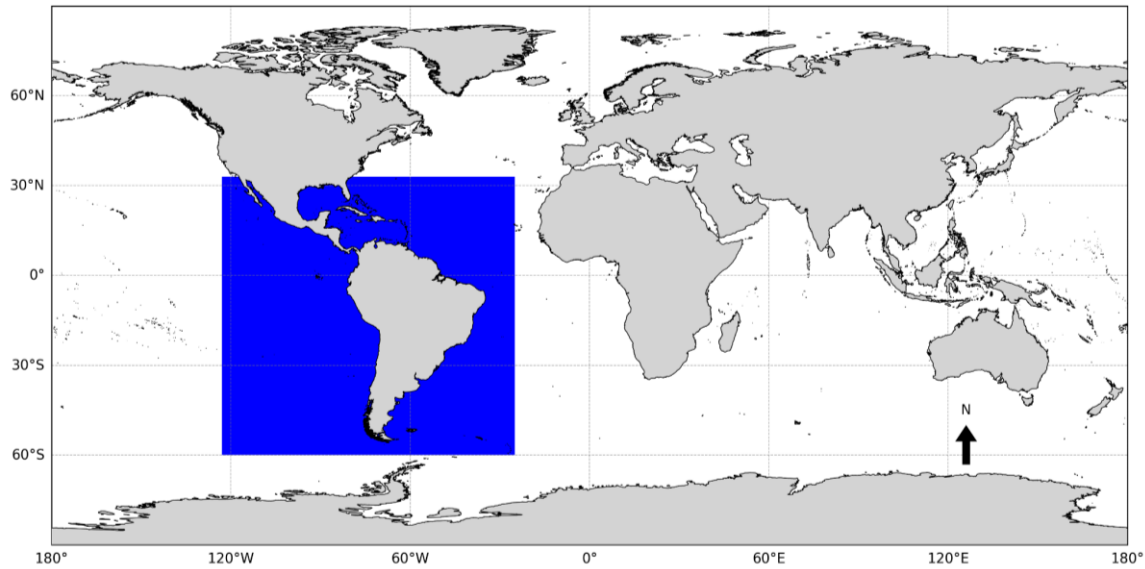


Figure 1. Coverage of Sentinel-2 tiles used per city.

Source: Own elaboration.

3.2 Product description

The Sea Surface Temperature dataset for Latin America and the Caribbean, produced by the CopernicusLAC Chile Coastal Monitoring Service, provides monthly Level 4 (L4) processing products, generated from Level 2 (L2P) satellite observations conforming to the GHR SST standard (Group for High Resolution Sea Surface Temperature) (GHR SST International Project Office, 2025), from the following sensors and platforms: SLSTR (Sentinel-3A and Sentinel-3B), VIIRS (JPSS and NOAA-20), and AVHRR (Metop-B and Metop-C).

These files were processed under the GHR SST standard, the “GHR SST Data Processing Specification” (GDS 2.1) (Piollé et al., 2022). To achieve the product's spatial continuity, a U-Net-based methodology (Zhao et al., 2025) was used, incorporating historical context (1981 to 2022) and auxiliary variables (wind speed and bathymetry), with input

pre checking/harmonization, robust training, tiled inference, and channel-importance analysis.

As a result, Level 4 (L4) products provide high-resolution (0.02°) SST measurements, bias-corrected and free of diurnal variability.

3.3 Product format

The SST product is distributed in NetCDF4 and ZARR format, under the Climate and Forecast Metadata (CF-1.7) (Eaton et al., 2017), Attribute Convention for Data Discovery (ACDD-1.3) (ESIP Federation Metadata Committee, 2015), and Group for High Resolution SST (GHRSSST GDS-2.1) conventions, allowing large volumes of structured data to be stored with easy access for subsequent analysis.

The following sections present the general NetCDF file structure (Table 2), global metadata attributes (Table 3), main variables (Table 4), and masks and fill values (Table 5).

Table 2. General structure of the NetCDF file.

Dimension	Description	Type
time	reference time (daily, nighttime average)	double
lat	latitude (degrees north)	double
lon	longitude (degrees east)	double

Source: Own elaboration.

Table 3. Global metadata attributes.

Attribute	Value
title	Monthly L4 Sea Surface Temperature Analysis, 2024
summary	Gap-free monthly SST analysis (L4) built from L3S monthly composites
institution	Coastal Monitoring / RDAC CopernicusLAC Chile
project	CopernicusLAC Chile
processing_level	L4
processing_mode	delayed
license	GHRST protocol: free and open
id	2024-l4_sst-monthly-ghrsst_v0.1.nc
product_version	v0.1
uuid	801414c1-ecf3-4213-b7de-2228e681dcb5
date_created	2025-10-29T17:54:16Z
time_coverage_start / end	2024-01-01 → 2024-12-31
geospatial_lat_min / max	-60 / 33
geospatial_lon_min / max	-123 / -25
geospatial_bounds	POLYGON((-123, -60, -25, 33))
spatial_resolution	0.02° (~2 km)
temporal_resolution	Monthly
instrument / platform	SLSTR / Sentinel-3A
source	L3S monthly multi-sensor composites fused into gap-free L4 analysis (SLSTR reference).

keywords	EARTH SCIENCE > OCEANS > OCEAN TEMPERATURE > SEA SURFACE TEMPERATURE
publisher_name / email / url	CopernicusLAC Chile / info@copernicuslac-chile.eu / https://www.copernicuslac-chile.eu
metadata_link	https://www.copernicuslac-chile.eu/
references	GHR SST GDS-2.1; CF-1.7; ACDD-1.3
file_quality_level	3
acknowledgment	Please acknowledge Copernicus LAC Chile; this product follows GHR SST GDS-2.1 protocols.

Source: Own elaboration.

Table 4. Main variables.

Variable	CF Standard Name	Description	Unit	Type
analysed_sst	sea_surface_foundation_temperature	Analyzed sea surface temperature (complete L4 field, gap-free, free of diurnal cycle).	K	int16
analysis_error	sea_surface_foundation_temperature_standard_error	Standard error of the analyzed temperature. Uncertainty estimate (1σ).	K	int16
sea_ice_fraction	sea_ice_area_fraction	Fraction of the cell covered by sea ice (0 to 1).	-	int16
mask	-	Binary mask: 0 = ocean, 1 = land, 2 = ice.	-	byte
sses_bias	-	Sensor-estimated bias (Sensor Specific Error Statistics).	K	Int8

sses_standard_deviation	-	Standard deviation associated with each SST pixel (random error).	K	int16
sum_sst	-	Cumulative sum of SST for monthly averages.	K	float32
sum_square_sst	-	Sum of squares of SST, used to calculate variances.	K	float32
sst_dtime	-	Time difference (seconds) relative to the UTC reference time (00:00).	s	Int32
wind_speed	wind_speed	Surface wind speed used as an auxiliary variable in interpolation and gap-filling (fundamental to the calculation of diurnal-effect bias).	m s ⁻¹	float32

Source: Own elaboration.

Table 5. Masks and fill values.

Flag	Description
1	Water (open ocean)
2	Land
8	Water with ice

Source: Own elaboration.

The following figure presents an example of the product visualization, illustrating the spatial representation of the variable, the distribution of its values across the study area, and the format in which the information is displayed to the user within the service.

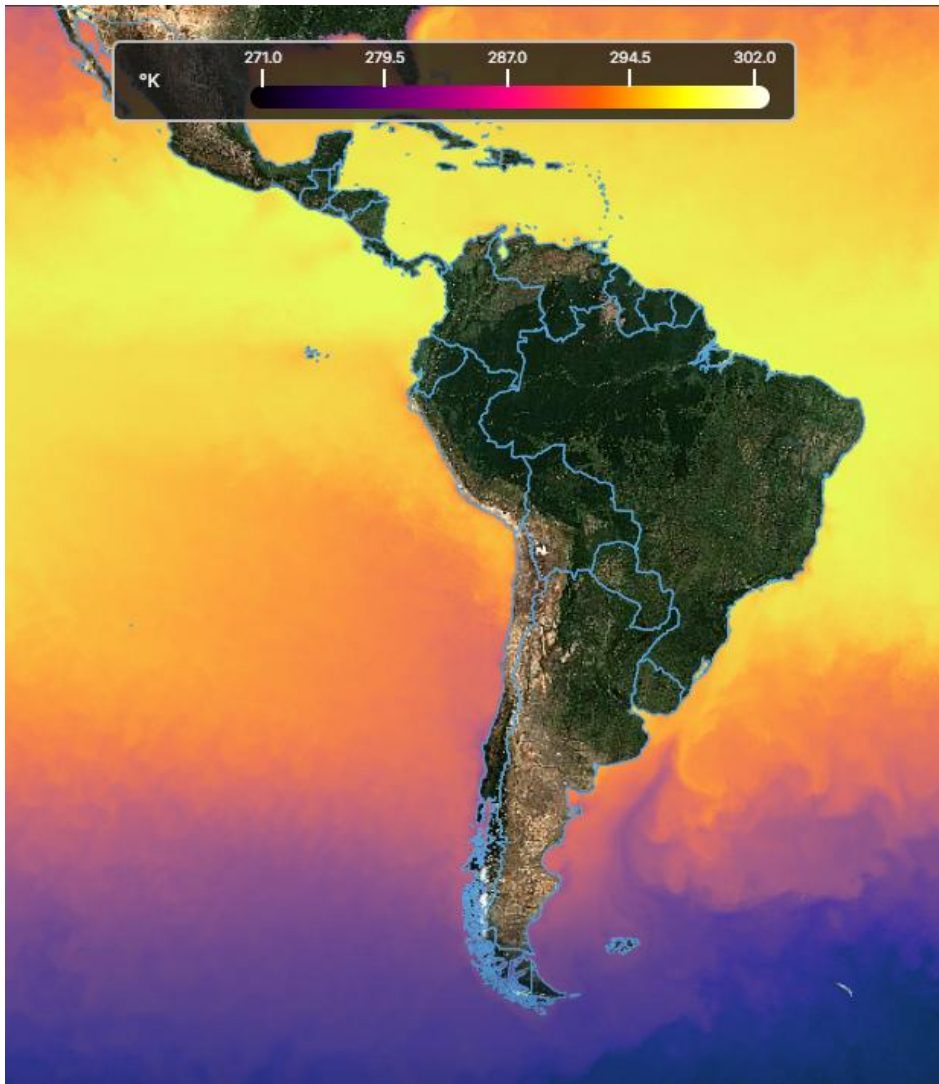


Figure 2. Display of the Sea Surface Temperature (SST) product, January 2024. Source: Own elaboration.

4. Methodological summary

4.1 Production and processing system

The CopernicusLAC Chile SST product's production system is based on the hierarchical structure defined by the GHRSSST GDS 2.1 standard, which establishes the progressive transition from sensor-geometry observations (Level 2, L2P) to fully covered analyzed fields (Level 4, L4). The SLSTR sensor (Sentinel-3 A/B) (EUMETSAT, 2025) is adopted as the absolute radiometric reference for correcting and harmonizing all sensors. Integration is carried out by applying:

- Temporal intercalibration by sensor.
- Bias correction using SLSTR as the reference.
- Cloud and ice masking.
- Reprojection onto a common 0.02° grid.
- Space-time gap-filling using a hybrid model.

Table 6. Satellite data sources.

Platform		Product	Sensor	Level	Provider
Suomi-NPP	NPP	L2P	VIIRS	L2P	OSISAF
NOAA-20	JPSS-1	L2P	VIIRS	L2P	ACSPO
Metop	- A - B	L2P	AVHRR	L2P	IFREMER
Sentinel-3	- 3A - 3B	WST	SLSTR	L2P	EUMETSAT

Source: Own elaboration.

4.2 Filters and Quality Indicators

The filtering process applied to the product follows a strict technical protocol designed to maximize the radiometric integrity and spatial coherence of the satellite observations. The procedure combines the mandatory criteria of the GHR SST GDS 2.1 standard with specific control thresholds defined for the ocean conditions of Latin America and the Caribbean.

Data cleaning begins by restricting observations to nighttime only (`day_night_flag = night`), which removes the influence of daytime surface heating and reduces the dispersion associated with radiative variability. A GHR SST quality filter is then applied, retaining only pixels with `quality_level` ≥ 4 , equivalent to measurements with radiometric and angular error within certified instrument margins. Records with time differences greater than 900 s relative to the nominal time (`sst_dtime`) are also discarded, ensuring temporal coherence between observations.

4.3 Grid Information

All products and levels are interpolated onto a regular 0.02° grid, with coordinates at the center of each cell (`lat`, `lon`). The domain extends from -123° W to -25° E and from -60° S to 33° N (Figure 3).

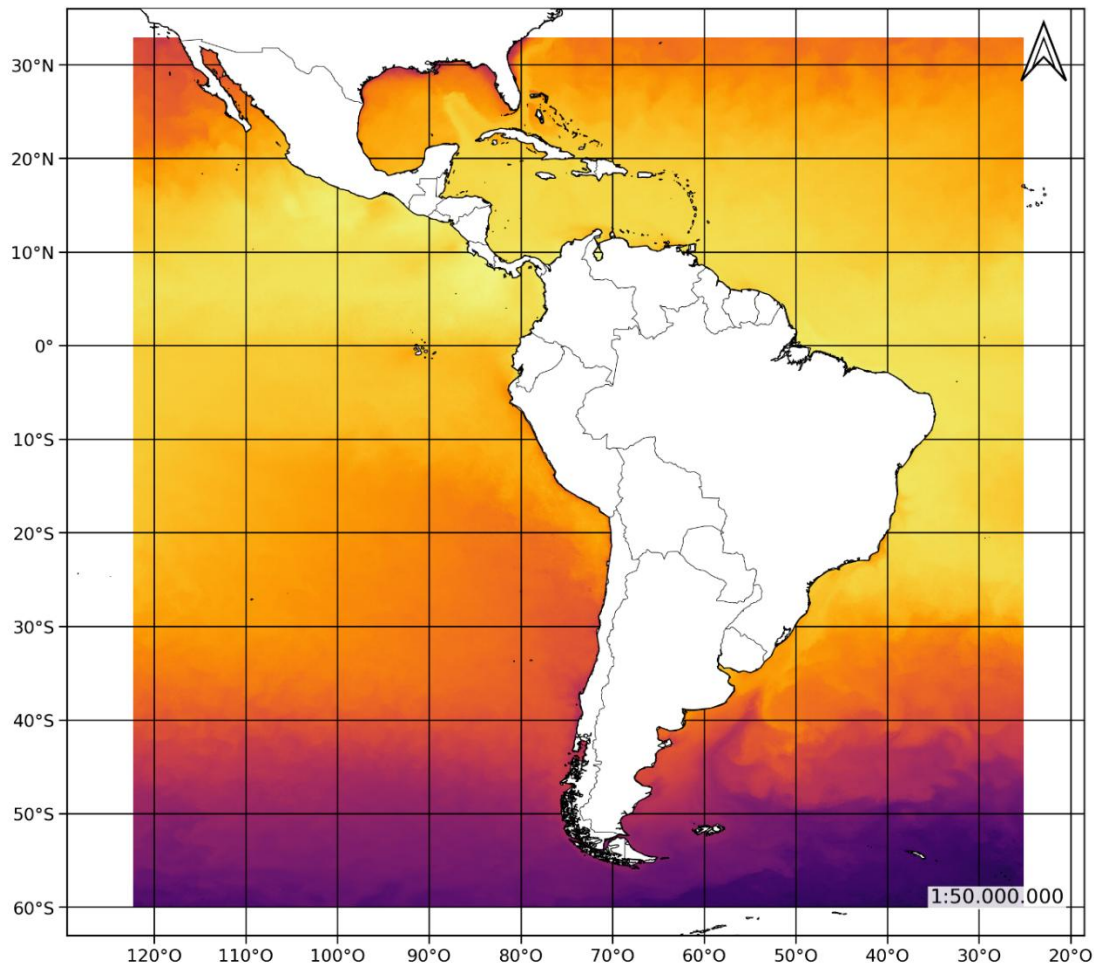


Figure 3. Spatial domain of the Sea Surface Temperature (SST) product, January 2024.

Source: Own elaboration.

4.4 Processing Chain

Processing is organized into five main stages, from the L2P products to the monthly L4 field, ensuring radiometric consistency and spatial continuity (Figure 4).

1. **Data ingestion and filtering (L2P):** L2P files are automatically downloaded from the corresponding platform, verifying integrity via checksum and time, orbit, and sensor metadata:

- Selection of nighttime observations ($\text{day_night_flag} = \text{night}$),
- $\text{quality_level} \geq 4$ and $\text{sst_dtime} \leq 900$ s,
- Exclusion of pixels flagged as cloud, glint, fire, ice, invalid, land,
- Physical range $-2^\circ\text{C} \leq \text{SST} \leq 35^\circ\text{C}$,
- Removal of thermal gradients $> 4 \text{ K}\cdot\text{km}^{-1}$ and SSES errors $> 0.8 \text{ K}$,
- Angular restriction: for SLSTR, observations with angles $> 50^\circ$ are discarded, and for VIIRS/AVHRR, $\text{DQF} < 3$ is applied.

The result is a cleaned, physically consistent L2P dataset.

2. **Reprojection and generation (L3U):** Valid observations are resampled onto a regular 0.02° ($\sim 2 \text{ km}$) grid using bilinear interpolation. Each sensor generates its own L3U product (single-sensor, uncollated) without fusion or averaging—only reprojected and filtered.
3. **Temporal compositing (L3C):** The daily L3U mosaics for each sensor are combined into L3C (collated) composites using a quality-weighted average. The result is a radiometrically stable monthly field per sensor.
4. **Multi-sensor fusion (L3S, SLSTR reference):** The L3C products from all sensors are harmonized onto the same spatial grid using SLSTR as the radiometric reference sensor. For each sensor, the mean monthly bias relative to SLSTR is calculated and the correction is applied. Multi-sensor fusion (L3S) is then carried out using an inverse-variance weighted average. This produces a homogeneous mosaic with radiometric coherence and no inter-sensor discontinuities.
5. **Analysis and reconstruction (L4, gap-free field):** The L3S mosaics are integrated with the results of a hybrid model that combines:
 - Deterministic optimal space-time interpolation, applied to the SST anomalies derived from the L3S mosaics. This stage generates an initial continuous field, weighting each observation by its uncertainty ($\text{sses_standard_deviation}$) and its spatial distance, while preserving regional thermal coherence.

- Nonlinear reconstruction based on a 2D Hann U-Net neural network, trained on multi-year historical series and auxiliary variables (surface wind, bathymetry, and the observation mask). This phase refines the field's thermal structure, fills residual gaps, and maintains spatial continuity in coastal zones or areas of high variability.

The final result is the analysed_sst field, accompanied by its uncertainty estimate, analysis_error.

The final product represents the monthly foundation temperature (foundation SST), free of diurnal effects and suitable for climate studies, model validation, and operational applications.

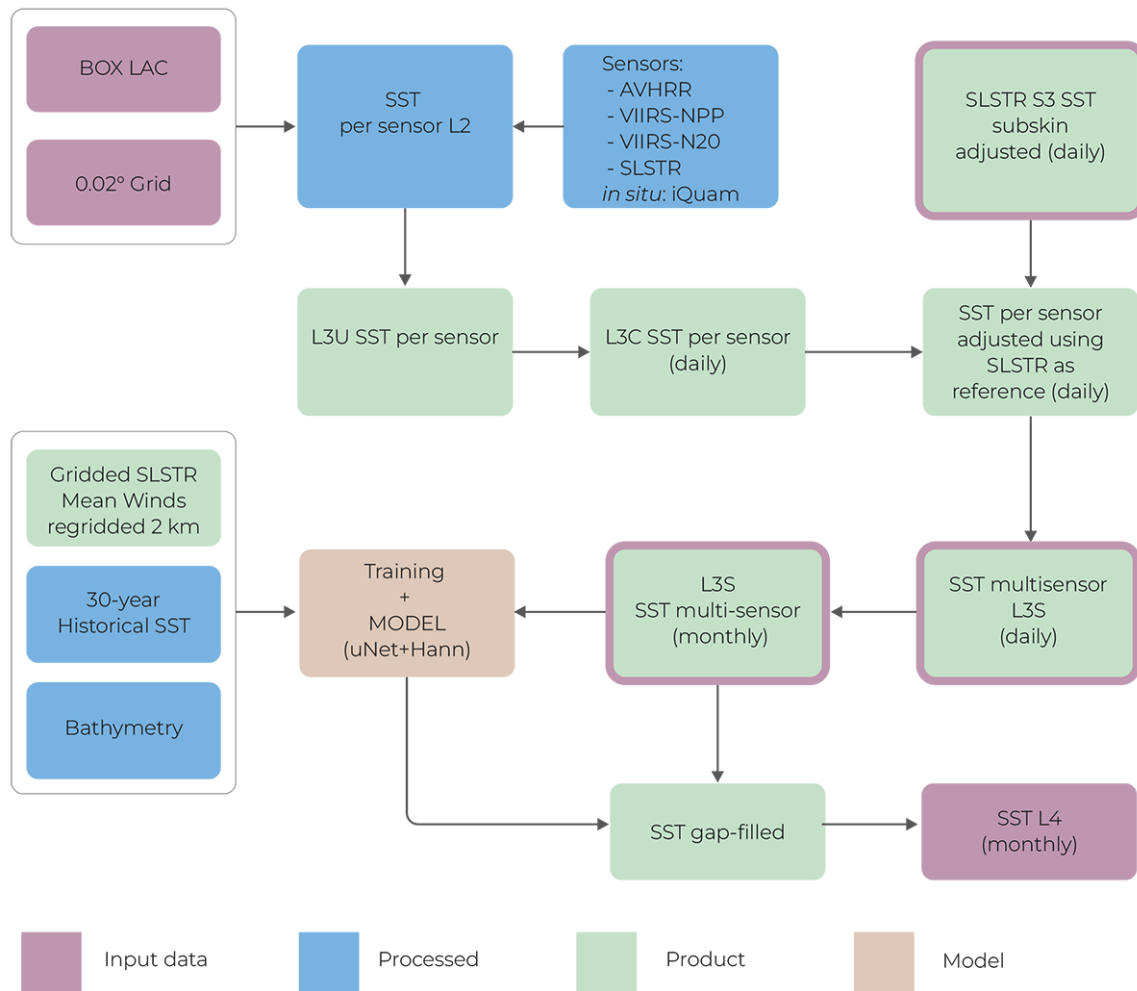


Figure 4. Processing chain for the Sea Surface Temperature (SST) product.

Source: Own elaboration.

5. Limitations

The main known limitations of the CopernicusLAC Chile L4 Sea Surface Temperature (SST) product are inherent to the technical characteristics of the sensors used, the defined geographic domain, and the reconstruction and spatial gap-filling processes applied to ensure the field's continuity (gap-free). Understanding them is essential for correctly interpreting and using the product, especially in applications requiring precision in high-latitude regions, inland water areas, or periods of persistent cloud cover. The main limitations identified are as follows:

- **Coverage:** The polar area is not included due to satellite limitations and the sensors' orbital geometry.
- **Atmospheric conditions:** Clouds and other atmospheric conditions can affect data quality. However, quality flags allow these values to be identified and filtered.
- **Gap-filling errors:** Although gap-filling based on spatial and temporal interpolation is applied, small inaccuracies may exist in data-void areas.
- **Representativeness:** The product is not representative of inland waters or glacial areas.

6. Quality Control and Evaluation

This chapter describes the validation methodological framework and quality control procedures applied to the CopernicusLAC Chile L4 Sea Surface Temperature (SST) product. It is organized into three components: the general validation framework following GHRST/SST-TAC guidelines, including performance metrics and internal quality control, and the evaluation of the analyzed field's coverage and spatial consistency over the Latin America and Caribbean domain.

6.1 General Validation Framework

The validation process for the CopernicusLAC Chile SST product follows the guidelines established by the GHRST group and the practices of the Copernicus SST Thematic Assembly Center (TAC).

The procedure uses *in situ* buoy measurements from the iQuam v2 dataset (NOAA STAR) (NOAA/NESDIS/STAR, 2025) as an independent reference. Only nighttime observations are considered, in order to maintain consistency with the filtering policy applied to the satellite data.

The product's quality control is based on the statistical validation of the analysed_sst field and its associated uncertainty variable, analysis_error. The comparison is performed by bilinearly interpolating the product's SST field (L4) to the position and time of the *in situ* observation. For each matchup, the product–observation difference is calculated, and bias (BIAS), standard deviation (STD), and root mean square error (RMSE) statistics are obtained.

The system also incorporates internal quality indicators (sses_bias, sses_standard_deviation, mask) and global metadata documenting the validation level (file_quality_level > 4). The quality process integrates three components:

1. **Radiometric control:** verification of bias and dispersion against *in situ* observations (iQuam v2).
2. **Spatial control:** analysis of regional thermal coherence and coastal gradients.
3. **Temporal control:** month-to-month consistency of the analyzed SST and series stability.

The process incorporates internal quality indicators derived from multi-sensor processing: the `sses_bias` and `sses_standard_deviation` variables, which characterize the estimated bias and dispersion for each pixel of the analyzed field, and the `mask` variable, which identifies regions of land, ice, or insufficient quality. The `file_quality_level ≥ 4` metadata certifies that the file meets the quality criteria defined by the GHR SST GDS 2.1 standard. These internal indicators complement the external statistical validation and allow the user to assess the product's local reliability before applying it.

6.1.1 Performance Metrics

Performance metrics quantify the agreement between the CopernicusLAC Chile L4 Sea Surface Temperature (SST) product and *in situ* buoy observations from the iQuam v2 dataset (NOAA STAR). The comparison is performed on coincident nighttime observations (matchups), bilinearly interpolating the analyzed field (`analysed_sst`) to the position and time of each reference measurement. Table 8 presents the mean bias (BIAS), standard deviation (STD), and root mean square error (RMSE) statistics obtained during the 2024 evaluation period over the Latin America and Caribbean domain. These indicators characterize the product's systematic tendency relative to the reference measurements, quantify the random error dispersion, and assess the overall performance of the analyzed field in accordance with GHR SST group standards.

Table 8. Performance metrics.

Metric	Description	Formula	Unit
Bias (BIAS)	Average of the differences between product and <i>in situ</i> SST.	$BIAS = SST_{sat} - SST_{insitu}$	K
Standard deviation (STD)	Variability of the differences relative to the mean bias.	$STD = \sqrt{\frac{1}{N} \sum_{i=1}^N (D_i - BIAS)^2}$	K
RMSE	Total root mean square error.	$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (d_i)^2}$	K
R (Pearson)	Linear correlation between satellite and <i>in situ</i> SST.	$r = \frac{\sum_{i=1}^N (SST_{sat,i} - \overline{SST_{sat}}) (SST_{insitu,i} - \overline{SST_{insitu}})}{\sqrt{\frac{1}{N} \sum_{i=1}^N (SST_{sat,i} - \overline{SST_{sat}})^2} \sqrt{\frac{1}{N} \sum_{i=1}^N (SST_{insitu,i} - \overline{SST_{insitu}})^2}}$	-

Source: Own elaboration.

6.1.2 Internal Quality Control

Each NetCDF file includes metadata documenting:

- **file_quality_level:** 4 (validated analysis, GHRSSST-compliant).
- **history and processing_date:** record the complete processing workflow.
- **uuid:** unique dataset identifier.

Automated controls are applied during processing:

- **Integrity check:** verification of MD5 hashes and NetCDF structure.
- **Spatial coherence control:** removal of gradients > 4 K/km.
- **Physical range control:** validation of thermal limits (271 K to 309 K, or -2 °C to 35 °C).
- **Temporal audit:** detection of discontinuities in the monthly series.

- **Post-gap-filling verification:** comparison of the L4 field against historical climatologies and error-distribution analysis.

The results of the post-gap-filling control are compared against long-term historical climatologies derived from the ESA CCI SST dataset (1981–2022) and the NCEI OISST v2.1 product, allowing systematic anomalies or non-physical artifacts introduced by the U-Net reconstruction model to be detected. In coastal zones and regions of high thermal variability, stricter consistency thresholds against local climatologies are applied, in order to preserve the integrity of the regional thermodynamic structures in the final analyzed field.

6.2 Coverage and Consistency Evaluation

The L4 product provides continuous spatial coverage across the entire LAC domain thanks to the hybrid model, with thermal coherence above 95%. Coastal and upwelling zones (e.g., the southern Pacific, the Colombian Caribbean) maintain local deviations below ± 0.6 K.

At the regional scale, the L4 SST field exhibits high spatial coherence with respect to the known thermodynamic structures of the LAC domain. The southeastern Pacific upwelling system, associated with the Humboldt front, adequately reproduces the meridional temperature gradients and the interannual variability linked to ENSO events. The Brazil-Malvinas front is one of the most dynamic ocean boundaries in the South Atlantic. In the Caribbean basin, the product preserves the structure of the Caribbean Current and the anticyclonic gyres of the Gulf of Mexico, with deviations from the external reference below ± 0.4 K on a monthly average basis. The temporal consistency evaluation confirms the product's month-to-month stability during the 2024 analysis period, with no non-physical discontinuities detected in the series. Comparisons with *in situ* measurements from the iQuam v2 dataset in coastal areas, including stations in central Chile, Colombia, and southwestern Atlantic Brazil, show bias (BIAS) within the ± 0.3 K range and RMSE below 0.6 K, consistent with GHRSSST

system quality standards. In regions with persistent cloud cover, the U-Net hybrid reconstruction model maintains spatial coherence without introducing excessive smoothing, preserving the coastal gradients relevant to regional environmental management.

7. References

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