Office of Satellite and Product Operations
Environmental Satellite Processing Center

Leaf Area Index External Users' Manual

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Approval Page

Environmental Satellite Processing Center
Leaf Area Index External Users' Manual

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Changes/Revisions Record

This external users' manual is changed as required to reflect system, operational, or organizational changes. Modifications made to this document are recorded in the Changes/Revisions Record below. This record will be maintained throughout the life of the document.

Version Number	Date	Description of Change/Revision	Section/Pages Affected	Changes Made by Name/Title/ Organization
1.0	03/2025	Initial version	All	Susan Haworth
1.1	04/2025	Added links to product monitoring, visualization	3.5, 3.5.1	Jeff Augenbaum
1.2	04/17/2025	Transfer contents to latest template, perform minor copy editing and formatting	All	Hannah Bowie, Technical Writer, ERT
1.2	04/18/2025	Quality Assurance	All	Clint Sherwood, Quality Assurance Manager, ERT

Preface

This document comprises the National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS), Office of Satellite and Product Operations (OSPO), publication of this Leaf Area Index (LAI) External Users' Manual (EUM). This document reflects current operations for the DOC/NOAA/NESDIS Environmental Satellite Processing Center (ESPC) (NOAA5045) information technology systems. This document describes the established ESPC procedures for external users of LAI in accordance with Federal, DOC, NOAA, NESDIS and OSPO requirements.

Future updates and revisions to this document will be produced and controlled by DOC/NOAA/NESDIS for ESPC information technology systems.

The published version of this document can be found at the OSPO SharePoint Products Library.

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1. Products

1.1. Product Overview

The Leaf Area Index (LAI) External User Manual describes the LAI products and output files. The LAI product system was developed at the Center for Satellite Applications and Research (STAR) and was implemented into operations at the NOAA Office of Satellite and Product Operations (OSPO).

The intended users of the External User Manual (EUM) are end users of the output products and files and the product verification and validation (V&V) teams. The purpose of the EUM is to provide product users and product testers with information that will enable them to acquire the product, understand its features, and use the data. External users are defined as those users who do not have direct access to the processing system.

1.1.1. Product Requirements

The requirements for the LAI product are listed in Table 1-1. For more details concerning the algorithm package's requirements, refer to the ATBD for the algorithm [Leaf Area Index (LAI) Algorithm Theoretical Basis Document (v1.0, February 2023)].

Table 1-1 - LAI Product Requirements

Attribute	Threshold
Geographic Coverage	Clear sky condition, land surface
Vertical Coverage	N/A
Refresh Rate	8-day
Horizontal Cell Size	1 km
Mapping Uncertainty	1 km
Measurement Range	0-10
Accuracy	15%
Precision	18%
Uncertainty	20%

1.1.2. Product Team

The product team consists of members from several organizations. Information including the team member's organizations, roles, and contact information can be found in Table 1-2.

Table 1-2 - Product Team Members

Team Member	Organization	Role	Contact Info
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1.1.3. Product Description

Leaf Area Index (LAI) is defined as one half the total green leaf area per unit horizontal ground surface area. It is an essential climate variable driving water fluxes, carbon fluxes, and energy exchanges, playing an important role in the models of the climate, hydrology, and ecology. As a fundamental attribute of vegetation, LAI is an essential climate variable.

Leaf Area Index (LAI) uses VIIRS Surface Reflectance as the primary input data and geometry data (GITCO) to produce two intermediate products:

- Daily green leaf coverage value (Daily LAI), and
- Weekly green leaf coverage value (Weekly LAI).

Both Daily and Weekly LAI are saved and used to create the final product: a global gap-free LAI end product at 1 km resolution with a step of 8-day.

The LAI product is for daytime observations only.

LAI can benefit users in the following ways:

- Substantially improves the prediction accuracy of NCEP global and mesoscale models (GFS and NAM).
- Substantially improves the impact over land of satellite-measured leaf area index in surface-sensitive satellite channels in the data assimilation in NCEP global and regional data assimilation systems (GDAS and NDAS).
- Provides an important input for many ecological and hydrological models.

1.2. Product History

The final version of LAI, which will be implemented in the NCCF, was delivered in January 2025.

1.3. Product Access

Table 1-3 lists information for the final LAI output files. Intermediate output product files are not included. For more information concerning intermediate output files, refer to the LAI System Maintenance Manual (SMM).

Table 1-3 - LAI Output File Naming Conventions

Description of File	Type of File	Naming Convention
Weekly Global LAI	NETCDF4	WKL-LAI-GLB_v1r0_<sat>_s<YYYYmmddHHMMSSf>_ e<YYYYmmddHHMMSSf>_c<YYYYmmddHHMMSSf>.nc

Where:

<sat>	→	The satellite source: npp, n20, or n21.
s< YYYYmmddHHMMSSf >	→	The start timestamp for the granule in 4-digit year, 2-digit month, 2-digit day, 2-digit hour, 2-digit minute, 2-digit second, and 1-digit microseconds format.
e< YYYYmmddHHMMSSf >	→	The end timestamp for the granule in 4-digit year, 2-digit month, 2-digit day, 2-digit hour, 2-digit minute, 2-digit second, and 1-digit microseconds format.
c< YYYYmmddHHMMSSf >	→	The creation timestamp for the granule in 4-digit year, 2-digit month, 2-digit day, 2-digit hour, 2-digit minute, 2-digit second, and 1-digit microseconds format.

The contents of the NetCDF output file are described in Table 1-4.

Table 1-4 - LAI NetCDF4 Output File Description

Variable	Type	Description	Dim	Units	Range
LAI	16-bit integer	8-Day Global Leaf Area Index	20000 x 40000	m2/m2	N/A
quality_information	String	Total number of retrievals, percentage of optimal retrievals, percentage of sub optimal retrievals, percentage of bad retrievals	1	N/A	N/A

The metadata for the NetCDF output file is described in Table 1-5.

Table 1-5 - LAI NetCDF4 Output File Metadata

Attribute	Description	Type	Array Size
Conventions	A text string identifying the NetCDF conventions followed.	String	Scalar
_NCProperties	NetCDF and HDF version numbers (automatically generated).	String	Scalar
cdm_data_type	The data type, as derived from Unidata's Common Data Model Scientific Data types and understood by THREDDS.	String	Scalar

Attribute	Description	Type	Array Size
creator_email	The email address of the person (or other creator type specified by the creator_type attribute) principally responsible for creating this data.	String	Scalar
creator_name	The name of the person (or other creator type, such as a RDAC, specified by the creator_type attribute) principally responsible for creating this data.	String	Scalar
creator_url	The URL of the of the person (or other creator type specified by the creator_type attribute) principally responsible for creating this data.	String	Scalar
date_created	The date on which this version of the data was created.	String	Scalar
day_night_data_flag	Describes sunlight conditions for observation: day, night, or both.	String	Scalar
geospatial_lat_max	Describes a simple upper latitude limit; may be part of a 2- or 3-dimensional bounding region. Specifies the northernmost latitude covered by the dataset.	64-bit floating-point	1
geospatial_lat_min	Describes a simple lower latitude limit; may be part of a 2- or 3-dimensional bounding region. Specifies the southernmost latitude covered by the dataset.	64-bit floating-point	1
geospatial_lat_resolution	Information about the targeted spacing of points in latitude.	String	Scalar
geospatial_lat_units	Units for the latitude axis described in geospatial_lat_min and geospatial_lat_max attributes.	String	Scalar
geospatial_lon_max	Describes a simple longitude limit; may be part of a 2- or 3-dimensional bounding region. Specifies the easternmost longitude covered by the dataset.	64-bit floating-point	1
geospatial_lon_min	Describes a simple longitude limit; may be part of a 2- or 3-dimensional bounding region. Specifies the westernmost longitude covered by the dataset.	64-bit floating-point	1
geospatial_lon_resolution	Information about the targeted spacing of points in longitude.	String	Scalar
geospatial_lon_units	Units for the longitude axis described in geospatial_lon_min and geospatial_lon_max attributes.	String	Scalar
History	Provides an audit trail for modifications to the original data.	String	Scalar
Id	An identifier for the data set, provided by and unique within its naming authority.	String	Scalar
institution	The name of the institution principally responsible for originating this data.	String	Scalar
instrument	Name of the contributing instrument(s) or sensor(s) used to create this data set or product. I	String	Scalar

Attribute	Description	Type	Array Size
keywords	A comma-separated list of key words and/or phrases. Keywords may be common words or phrases, terms from a controlled vocabulary (GCMD is often used), or URIs for terms from a controlled vocabulary.	String	Scalar
metadata_link	A URL that gives the location of more complete metadata.	String	Scalar
naming_authority	The organization that provides the initial id for the dataset.	String	Scalar
Platform	Name of the platform(s) that supported the sensor data used to create this data set or product. Platforms can be of any type, including satellite, ship, station, aircraft or other.	String	Scalar
processing_level	A textual description of the processing (or quality control) level of the data. Options are: L2P, L3U, L3C, L3S, L4 and GMPE.	String	Scalar
production_environment	Processing string responsible for generating the product.	String	Scalar
production_site	Processing site for the product.	String	Scalar
Project	The name of the project(s) principally responsible for originating this data.	String	Scalar
publisher_email	The email address of the person (or other entity specified by the publisher_type attribute) responsible for publishing the data file or product to users, with its current metadata and format.	String	Scalar
publisher_name	The name of the person (or other entity specified by the publisher_type attribute) responsible for publishing the data file or product to users, with its current metadata and format.	String	Scalar
publisher_url	The URL of the person (or other entity specified by the publisher_type attribute) responsible for publishing the data file or product to users, with its current metadata and format.	String	Scalar
Source	The method of production of the original data.	String	Scalar
standard_name_vocabulary	The name and version of the controlled vocabulary from which variable standard names are taken.	String	Scalar
summary	A paragraph describing the dataset, analogous to an abstract for a paper.	String	Scalar
time_coverage_end	Describes the time of the last data point in the data set.	String	Scalar
time_coverage_start	Describes the time of the first data point in the data set.	String	Scalar
Title	A short phrase or sentence describing the dataset.	String	Scalar

2. Algorithm

2.1. Algorithm Overview

Satellite LAI datasets, recorded over the past two decades, have been utilized extensively across various applications. Leveraging the legacy of established satellite products like the Moderate Resolution Imaging Spectroradiometer (MODIS), Global Land Surface Satellite (GLASS), and Geoland2/BioPar (GEOV2) LAI products, a data-driven methodology has been developed to obtain near-real-time LAI from VIIRS observations. Prior to implementation, a machine learning algorithm is tuned and trained based on a comprehensive suite of representative datasets.

The VIIRS LAI product is designed to be a temporally smoothed, global, gap-free dataset. The operational procedure is segmented into three phases, as depicted in Figure 2-1. The first two steps are daily processing, with up to 8 days' data being sustained for the weekly processing, which will be run every 8 days.

1. **Daily Surface Reflectance Generation**: Utilizing the VIIRS gridding tool, granule data is mapped onto a global grid in a sinusoidal projection. The surface reflectance (SR) compositing process then identifies and selects the highest quality SR and corresponding angles for each grid cell.
2. **Daily LAI Retrieval**: A previously trained machine learning algorithm performs the clear-sky LAI retrieval, leveraging the daily SR together with auxiliary data.
3. **8-Day LAI Compositing and Post-Processing**: From the daily LAI outputs, the optimal quality LAI is chosen for each 8-day interval. Subsequently, a temporal smoothing and gap-filling (TSGF) procedure is applied to produce the final, gap-free product.

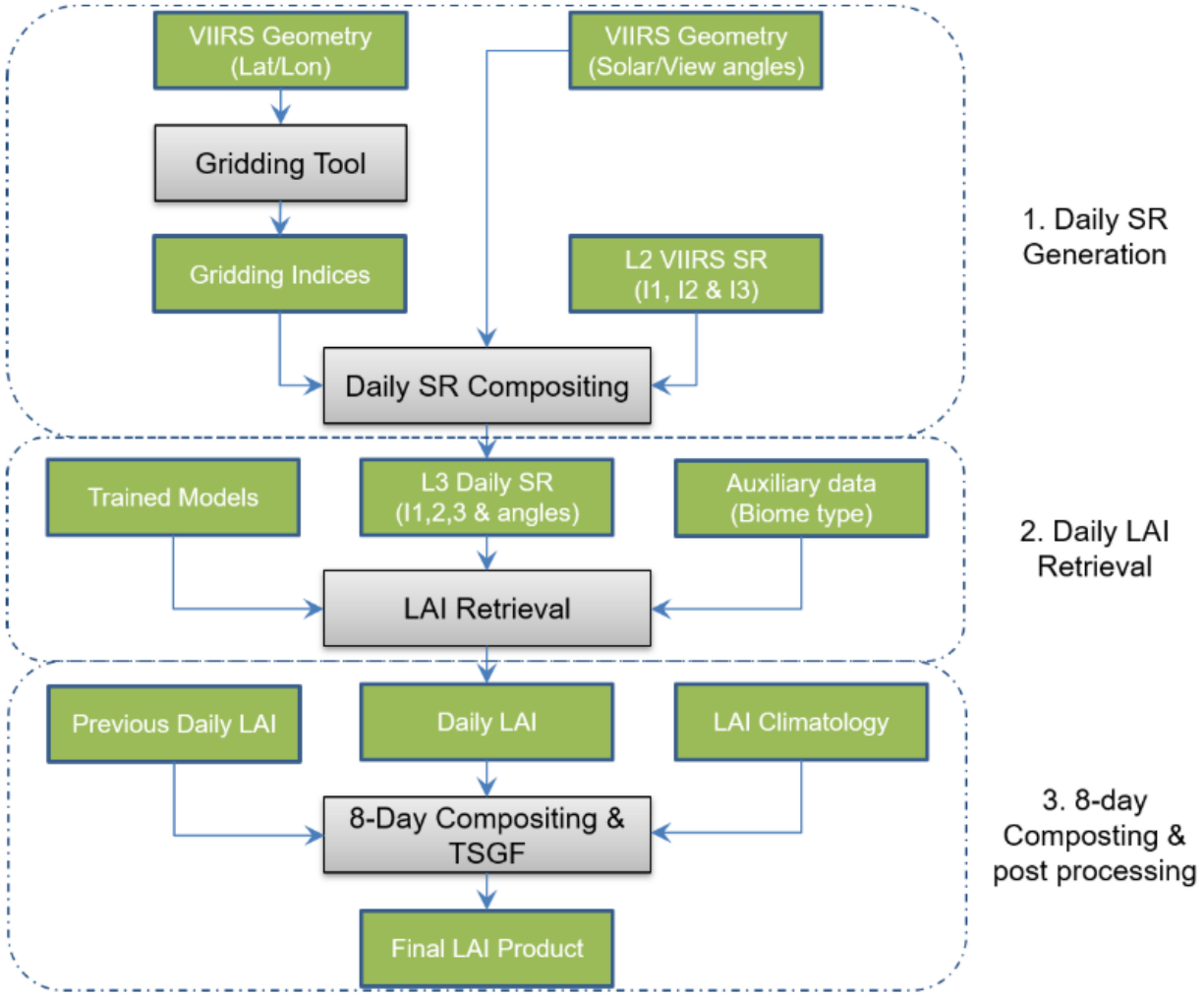

Figure 2-1 - LAI Processing Architecture

2.2. Input Satellite Data

The LAI algorithm primarily uses the data from the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on the Suomi National Polar-orbiting Partnership (S-NPP) platform and on subsequent satellites of the Joint Polar Satellite System (JPSS).

Primary and backup data sources are determined by NOAA.

2.2.1. Satellite Instrument Overview

Table 2-1 provides detailed information about the surface reflective bands and configurations for VIIRS.

Table 2-1 - VIIRS Surface Reflective Bands and Configurations

VIIRS Band	Wavelength (µm)	Bandwidth (µm)	Signal-to-Noise Ratio (SNR)	Spatial Resolution (m)
M1	0.412	0.402-0.422	352/316	750m
M2	0.445	0.436-0.454	380/409	
M3	0.488	0.478-0.488	416/414	
M4	0.555	0.545-0.565	362/315	
M5	0.672	0.662-0.682	242/360	
M7	0.865	0.846-0.885	215/340	
M8	1.240	1.23-1.25	74	
M10	1.61	1.58-1.64	83	
M11	2.25	2.23-2.28	10	
I1	0.64	0.6-0.68	119	375m
I2	0.865	0.85-0.88	150	
I3	1.61	1.58-1.64	6	

2.2.2. Satellite Data Preprocessing Overview

No preprocessing is performed on satellite data for the LAI products. The LAI CCAP accepts the satellite data as input in the format from NCCF.

2.2.3. Input Satellite Data Description

Information concerning the file naming conventions associated with the primary input data for the LAI algorithm package is listed in the following tables.

Table 2-2 lists information for the LAI input files.

Table 2-2 - Primary Input File Naming Conventions

Description of File	Type of File	Naming Convention
L1B VIIRS Geometry	Primary Input	GITCO_<sat>_d<YYYYmmdd>_t<HHMMSSf>_ e<HHMMSSf>_b<orbit>_c<YYYYmmddHHMMSSssssss>_<source>.h5
L2 VIIRS Surface Reflectance	Primary Input	SurfRefl_v<x>r<y>_<sat>_s<YYYYmmddHHMMSSf>_ e<YYYYmmddHHMMSSf>_c<YYYYmmddHHMMSSf>.nc

Where:

<sat>	→	The satellite source: npp, n20, or n21.
d<YYYYmmdd>	→	The date of the start of the granule in 4-digit year, 2-digit month, and 2-digit day format.
t<HHMMSSf>	→	The start time of the granule in 2-digit hour, 2-digit minute, 2-digit second, and 1-digit microseconds format.

e<HHMMSSf>	→	The end time of the granule in 2-digit hour, 2-digit minute, 2-digit second, and 1-digit microseconds format.
<orbit>	→	The satellite orbit number.
c<YYYYmmddHHMMSSssssss>	→	The creation timestamp for the granule in 4-digit year, 2-digit month, 2-digit day, 2-digit hour, 2-digit minute, 2-digit second, and 6-digit microseconds format.
<source>	→	The source of the file, including, but not limited to, noac_ops and oeac_ops.
<x>	→	The version number of the Surface Reflectance file.
<y>	→	The revision number of the Surface Reflectance file.
s<YYYYmmddHHMMSSf>	→	The start timestamp for the granule in 4-digit year, 2-digit month, 2-digit day, 2-digit hour, 2-digit minute, 2-digit second, and 1-digit microseconds format.
e<YYYYmmddHHMMSSf	→	The end timestamp for the granule in 4-digit year, 2-digit month, 2-digit day, 2-digit hour, 2-digit minute, 2-digit second, and 1-digit microseconds format.

2.3. Input Ancillary Data

Dynamic Ancillary Data

Dynamic ancillary data is not used for the LAI product.

Static Ancillary Data

There are several static ancillary datasets used to generate the LAI products. All static ancillary datasets for LAI must be located in the following directory:

- $home/CODE/leaf-area-index/ancillary_data

3. Performance

3.1. Product Testing

3.1.1. Test Data Description

Test cases are provided with each algorithm package for product verification before transition to operations. The test cases provide input, static ancillary data, and other resulting product datasets for verification. All specified requirements must be met during testing. Only after end users are satisfied that all the requirements are met will the LAI algorithm package's products be transitioned into operations.

3.1.2. Unit Test Plans

Testing of the algorithm package's products occurs with each update to the algorithm package. The science teams, who develop the products, test them for accuracy and validation. The STAR group tests the algorithm and scripts to ensure that requirements are met. Then, operations must test the products to make sure that they run successfully on their systems. If there are problems in any one of the testing procedures, then the relevant groups must work together to correct any issues.

3.2. Product Accuracy

3.2.1. Test Results

3.2.2. Product Accuracy

3.3. Product Quality Output

Details about program execution can be found in the log files produced by the algorithm package. Each run produces multiple logs that can be used to determine if the run was successful or if there were errors.

Details about product quality can be found in the **quality_information** variable contained within the output files (see **Error! Reference source not found.**).

3.4. External Product Tools

There are no external product tools associated with the LAI algorithm package. External users can choose their own preferred tools to display and analyze these output files.

3.5. Output Files

LAI final products are available on PDA for user subscription. The data retention time on PDA is the standard 7 days.

3.5.1. Product Monitoring and Visualization

Product quality is monitored using the NCCF Product Monitoring Tool at https://nccf-prod-dashboard.nccf.nesdis.noaa.gov/mtool/index.html.

Users can use this page to monitor summaries of the LAI quality based on parameter thresholds determined by the PAL.

The NCCF Products Visualization Page is located at https://www.ospo.noaa.gov/products/land/vegetation/lai/.

LAI products are generated weekly.

4. Product Status

4.1. Operations Documentation

Leaf Area Index (LAI) System Maintenance Manual (v1.0, March 2025)

Leaf Area Index (LAI) Algorithm Theoretical Basis Document (v1.0, February 2023)

Leaf Area Index (LAI) Delivery Documents

- Readme (v1-1, June 2024)
- Delivery Memo (v1-2, January 2025)
- Production Rules (v1-1, June 2024)

4.2. Maintenance History

END OF DOCUMENT

5. Acronyms

Acronym	Definition
ASSISTT	Algorithm Scientific Software Integration and System Transition Team
ATBD	Algorithm Theoretical Basis Document
CCAP	Cloud Containerized Algorithm Package
DOC	Department of Commerce
ERT	Earth Resources Technology, Inc.
ESPC	Environmental Satellite Processing Center
EUM	External Users' Manual
GDAS	Global Data Assimilation System
GEOV2	Geoland2
GFS	Global Forecast System
GLASS	Global Land Surface Satellite
JPSS	Joint Polar Satellite System
LAI	Leaf Area Index
MODIS	Moderate-resolution Imaging Spectroradiometer
NCCF	NESDIS Common Cloud Framework
NCEP	National Centers for Environmental Prediction
NDAS	North American Model Data Assimilation System
NESDIS	National Environmental Satellite, Data, and Information Service
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
OCS	Office of Common Services
OMS	Operations, Maintenance, and Sustainment
OSPO	Office of Satellite and Product Operations
PAL	Product Area Lead
PDA	Product Distribution and Access
PIB	Product Implementation Branch
PPM	Project Portfolio Management
QA	Quality Assurance
SMM	System Maintenance Manual
S-NPP	Suomi National Polar-orbiting Partnership
SNR	Signal-to-Noise Ratio
SR	Surface Reflectance
STAR	Center for Satellite Applications and Research
TSGF	Temporal Smoothing and Gap-Filling
V&V	Verification and Validation
VIIRS	Visible Infrared Imaging Radiometer Suite