ECOSTRESS STARS NDVI & Albedo User Guide

Contents

1 ECOSTRESS Collection 3 Level-2 STARS NDVI & Albedo Data Product User Guide

ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)

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This User Guide provides practical information for accessing, understanding, and using the ECOSTRESS Collection 3 Level-2 STARS NDVI & Albedo data products. It covers product specifications, data access procedures, file formats, quality assessment, and recommended processing workflows.

For detailed information on the scientific methodology, mathematical formulations, and algorithm implementation, please refer to the companion ECOSTRESS Collection 3 Level-2 STARS NDVI & Albedo Algorithm Theoretical Basis Document (ATBD).

This guide is designed to be a living document that is updated as the products evolve and user feedback is incorporated.

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1.2 Table of Contents

1.2.1 List of Tables

2 Introduction

2.1 Product Overview

The ECOSTRESS Collection 3 Level-2 STARS NDVI & Albedo product (L2T_STARS) provides high-resolution (70 m) estimates of Normalized Difference Vegetation Index (NDVI) and broad-band shortwave albedo that are temporally and spatially coincident with each ECOSTRESS Land Surface Temperature & Emissivity (L2T_LSTE) observation.

These products are generated using the Spatial Timeseries for Automated high-Resolution multi-Sensor data fusion (STARS) algorithm, which optimally combines: - High spatial resolution data from Harmonized Landsat Sentinel (HLS) 2.0 products (30 m, 3-5 day revisit) - High temporal resolution data from VIIRS VNP09GA products (500 m-1 km, daily coverage)

The result is gap-filled, analysis-ready NDVI and albedo data at ECOSTRESS resolution with quantified uncertainties, essential for evapotranspiration modeling and land surface analysis.

Product Long Name	Product Short Name
STARS NDVI/Albedo	L2T STARS
Surface Energy Balance	L3T SEB
Soil Moisture	L3T SM
Meteorology	L3T MET
Ecosystem Auxiliary Inputs	L3T ETAUX
Evapotranspiration Ensemble	L3T JET
DisALEXI-JPL Evapotranspiration	L3T ET ALEXI
Evaporative Stress Index	L4T ESI
DisALEXI-JPL Evaporative Stress Index	L4T ESI ALEXI
Water Use Efficiency	L4T WUE

Table 1. Listing of ECOSTRESS tiled products long names and short names.

2.2 File Format and Structure

2.2.1 Cloud-Optimized GeoTIFF (COG) Format

All L2T_STARS products are distributed as Cloud-Optimized GeoTIFFs, providing: - Efficient streaming and partial data access - Universal compatibility with GIS software and programming libraries - Built-in pyramids for multi-resolution visualization - Standardized georeferencing with embedded spatial reference information

2.2.2 Tiling System

- Tiling scheme: Modified Military Grid Reference System (MGRS) used by Sentinel-2
- Tile size: 109.8 km × 109.8 km
- Pixel size: 70 m × 70 m
- Array dimensions: 1,568 × 1,568 pixels per tile
- Projection: UTM zone-specific

2.2.3 File Naming Convention

`ECOSTRESS_L2T_STARS_[TileID]_[AcquisitionDateTime]_[ProductionDateTime]_[Version].tif`

Example:

`ECOSTRESS_L2T_STARS_T11SPS_20241008T183000_20241009T120000_02.tif`

2.2.4 File Components

Each L2T_STARS granule contains: - Data files: Individual GeoTIFF files for each data layer - Browse images: JPEG preview images for quick visualization - Metadata file: JSON file with product and standard metadata - Quality layers: Cloud and water masks

2.3 Quality Flags

2.4 Spatial and Temporal Characteristics

2.4.1 Spatial Resolution

- Native resolution: 70 m × 70 m
- Coordinate system: UTM (zone-specific)
- Resampling method: Bilinear interpolation from input sources
- Spatial extent: Global land areas (±60° latitude)

2.4.2 Temporal Resolution

- Observation frequency: Variable based on ISS orbit (typically 3-4 days)
- Temporal coverage: Daytime overpasses only
- Data continuity: Gap-filled using temporal fusion algorithm
- Archive period: 2018-present

2.5 Quality Flags

2.5.1 Standard Quality Masks

Two binary quality flags are provided as unsigned 8-bit integer layers:

- cloud: Cloud detection mask from L2_CLOUD product
  - 0 = Clear sky
  - 1 = Cloud detected
- water: Surface water body mask from SRTM DEM
  - 0 = Land surface
  - 1 = Open water surface

2.5.2 Data Quality Indicators

- Fill values: NaN (Not-a-Number) for float32 data layers
- Valid data range:
  - NDVI: -1.0 to 1.0
  - Albedo: 0.0 to 1.0
  - Uncertainties: 0.0 to maximum valid range

2.6 Data Access and Availability

2.6.1 Distribution and Access

The L2T_STARS products are distributed through: - NASA Earthdata: https://earthdata.nasa.gov/ - LP DAAC Data Pool: https://e4ftl01.cr.usgs.gov/ - NASA Worldview: https://worldview.earthdata.nasa.gov/ - AppEEARS: https://appeears.earthdatacloud.nasa.gov/

2.6.2 Data Latency

- Near Real-Time: Products are typically available within 1-3 days of ECOSTRESS observation
- Reprocessing: Historical data are reprocessed as algorithm improvements are implemented

2.6.3 Spatial Coverage

- Global land areas excluding regions poleward of ±60° latitude
- Tiled format using modified MGRS tiling system
- Individual tiles: 109.8 km × 109.8 km at 70 m resolution

2.6.4 Authentication Requirements

- NASA Earthdata Login account required for data access
- Free registration at: https://urs.earthdata.nasa.gov/

3 Product Specifications

3.1 Data Layers

The L2T_STARS product contains eight data layers providing NDVI and albedo estimates with associated uncertainties and bias corrections:

3.1.1 Primary Data Products:

- NDVI: Normalized Difference Vegetation Index estimates
- albedo: Broadband shortwave albedo estimates

3.1.2 Uncertainty Products:

- NDVI-UQ: One-sigma uncertainty of NDVI estimates
- albedo-UQ: One-sigma uncertainty of albedo estimates

3.1.3 Bias Correction Products:

- NDVI-bias: Systematic bias correction applied to NDVI
- albedo-bias: Systematic bias correction applied to albedo
- NDVI-bias-UQ: Uncertainty in NDVI bias correction
- albedo-bias-UQ: Uncertainty in albedo bias correction

Layer Name	Description	Data Type	Units	Valid Range	Fill Value	File Size
NDVI	Normalized Difference Vegetation Index	float32	Dimensionless	-1.0 to 1.0	NaN	12.96 MB
NDVI-UQ	NDVI One-sigma Uncertainty	float32	Dimensionless	0.0 to 1.0	NaN	12.96 MB
NDVI-bias	NDVI Bias Correction	float32	Dimensionless	Variable	NaN	12.96 MB
NDVI-bias-UQ	NDVI Bias Uncertainty	float32	Dimensionless	0.0 to 1.0	NaN	12.96 MB
albedo	Broadband Shortwave Albedo	float32	Dimensionless	0.0 to 1.0	NaN	12.96 MB

Layer Name	Description	Data Type	Units	Valid Range	Fill Value	File Size
albedo-UQ	Albedo One-sigma Uncertainty	float32	Dimensionless	0.0 to 1.0	NaN	12.96 MB
albedo-bias	Albedo Bias Correction	float32	Dimensionless	Variable	NaN	12.96 MB
albedo-bias-UQ	Albedo Bias Uncertainty	float32	Dimensionless	0.0 to 1.0	NaN	12.96 MB

Table 2. L2T_STARS data layer specifications.

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4 Data Usage Guidelines

4.1 Recommended Processing Workflow

4.1.1 1. Data Discovery and Download

```python
# Example using Python
import requests
from pathlib import Path

# Search for L2T_STARS data using CMR API
# Download data using NASA Earthdata authentication
```

4.1.2 2. Data Loading and Inspection

```python
# Example using rioxarray
import rioxarray as rxr
import numpy as np

# Load NDVI data
ndvi = rxr.open_rasterio('ECOSTRESS_L2T_STARS_*_NDVI.tif')
ndvi_unc = rxr.open_rasterio('ECOSTRESS_L2T_STARS_*_NDVI-UQ.tif')

# Check data quality
```

```python
valid_data = ~np.isnan(ndvi.values)
print(f"Valid pixels: {valid_data.sum()} / {valid_data.size}")
```

4.1.3 3. Quality Assessment

```python
# Apply quality filters
cloud_mask = rxr.open_rasterio('ECOSTRESS_L2T_STARS_*_cloud.tif')
water_mask = rxr.open_rasterio('ECOSTRESS_L2T_STARS_*_water.tif')

# Create combined quality mask
quality_mask = (cloud_mask == 0) & (water_mask == 0)
filtered_ndvi = ndvi.where(quality_mask)
```

4.2 Software Compatibility

4.2.1 Python Libraries

- rioxarray: Recommended for xarray-based analysis
- GDAL/rasterio: Low-level raster operations
- xarray: Multi-dimensional data analysis
- matplotlib/cartopy: Visualization and mapping

4.2.2 R Packages

- terra: Modern raster data handling
- raster: Traditional raster operations
- stars: Spatiotemporal data cubes
- sf: Spatial data manipulation

4.2.3 Desktop GIS Software

- QGIS: Free, open-source GIS
- ArcGIS: Commercial GIS software
- ENVI: Specialized remote sensing software

4.2.4 Command Line Tools

- GDAL utilities: gdalinfo, gdal_translate, gdalwarp
- NCO operators: For netCDF-like operations

4.3 Quality Assessment

4.3.1 Uncertainty Interpretation

- Low uncertainty (< 0.1): High confidence in estimates
- Moderate uncertainty (0.1 - 0.3): Reasonable confidence
- High uncertainty (> 0.3): Use with caution

4.3.2 Recommended Quality Filters

1. Remove cloudy pixels: Use cloud mask
2. Consider water pixels: Apply water mask if studying land only
3. Check uncertainty values: Filter based on application requirements
4. Validate against field data: When available for your study area

4.3.3 Common Quality Issues

- High uncertainty near cloud edges
- Potential artifacts in mountainous terrain
- Reduced accuracy in very dense canopies
- Seasonal bias in high-latitude regions

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5 Common Applications

5.1 Scientific Research

- Evapotranspiration modeling: Primary input for ET algorithms
- Vegetation monitoring: Phenology and health assessment
- Land surface energy balance: Albedo for radiation modeling
- Climate studies: Surface property characterization

5.2 Agricultural Applications

- Crop health monitoring: NDVI time series analysis
- Irrigation management: Water stress detection
- Yield prediction: Vegetation vigor assessment
- Precision agriculture: Field-scale variability mapping

5.3 Environmental Monitoring

- Drought assessment: Vegetation stress indicators

- Ecosystem health: Biodiversity and conservation
- Land cover change: Deforestation and urbanization
- Fire risk assessment: Vegetation moisture content

5.4 Operational Uses

- Water resource management: ET-based water budgets
- Natural resource inventory: Forest and rangeland assessment
- Disaster response: Rapid vegetation assessment
- Policy support: Environmental compliance monitoring

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6 Troubleshooting

6.1 Common Issues and Solutions

6.1.1 Data Access Problems

Issue: Cannot download data from LP DAAC Solution: - Verify Earthdata Login credentials - Check network connectivity - Ensure proper authentication in download scripts

Issue: Files appear corrupted or incomplete Solution: - Re-download the file - Verify file size matches expected size - Check MD5 checksums if provided

6.1.2 Data Processing Issues

Issue: Cannot open GeoTIFF files Solution: - Update GDAL to version 3.0 or higher - Verify file integrity with `gdalinfo` - Check for proper file extension (.tif)

Issue: Unexpected NaN values Solution: - Check cloud and water masks - Verify data is within valid range - Consider seasonal data availability

6.1.3 Quality Assessment Problems

Issue: High uncertainty values everywhere Solution: - Check input data availability for that time period - Verify geographic location (polar regions excluded) - Consider atmospheric conditions (heavy aerosols, persistent clouds)

Issue: NDVI values seem unrealistic Solution: - Verify units (should be -1 to 1) - Check for scaling issues in your software - Compare with concurrent Landsat/Sentinel-2 data

6.1.4 Performance Issues

Issue: Slow data loading Solution: - Use COG-aware libraries (rioxarray, GDAL 3.x) - Implement spatial/temporal subsetting - Consider using lower resolution overviews for exploration

6.2 Getting Help

6.2.1 Support Resources

- LP DAAC User Services: https://lpdaac.usgs.gov/contact-us/
- ECOSTRESS Documentation: https://ecostress.jpl.nasa.gov/
- Earthdata Forum: https://forum.earthdata.nasa.gov/

6.2.2 Reporting Issues

When reporting data quality issues, please provide: - Product name and version - Specific tile ID and date - Geographic coordinates of the issue - Screenshots or data examples - Description of expected vs. observed behavior

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7 Metadata

Each ECOSTRESS product bundle contains two sets of product metadata:

- ProductMetadata
- StandardMetadata

Each product contains a custom set of ProductMetadata attributes, as listed in Table 4. The StandardMetadata attributes are consistent across products at each orbit/scene, as listed in Table 3.

Name	Type
AncillaryInputPointer	string
AutomaticQualityFlag	string
AutomaticQualityFlagExplanation	string
BuildID	string
CRS	string
CampaignShortName	string
CollectionLabel	string
DataFormatType	string
DayNightFlag	string
EastBoundingCoordinate	float

Name	Type
FieldOfViewObstruction	string
ImageLines	float
ImageLineSpacing	integer
ImagePixels	float
ImagePixelSpacing	integer
InputPointer	string
InstrumentShortName	string
LocalGranuleID	string
LongName	string
NorthBoundingCoordinate	float
PGEName	string
PGEVersion	string
PlatformLongName	string
PlatformShortName	string
PlatformType	string
ProcessingEnvironment	string
ProcessingLevelDescription	string
ProcessingLevelID	string
ProducerAgency	string
ProducerInstitution	string
ProductionDateTime	string
ProductionLocation	string
RangeBeginningDate	string
RangeBeginningTime	string
RangeEndingDate	string
RangeEndingTime	string
RegionID	string
SISName	string
SISVersion	string
SceneBoundaryLatLonWKT	string
SceneID	string
ShortName	string
SouthBoundingCoordinate	float
StartOrbitNumber	string
StopOrbitNumber	string
WestBoundingCoordinate	float

Table 3. Name and type of metadata fields contained in the common StandardMetadata group in

each L2T/L3T/L4T product.

Name	Type
BandSpecification	float
NumberOfBands	integer
OrbitCorrectionPerformed	string
QAPercentCloudCover	float
QAPercentGoodQuality	float
AuxiliaryNWP	string

Table 4. Name and type of metadata fields contained in the common ProductMetadata group in each L2T/L3T/L4T product.

8 Acknowledgements

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9 References

9.1 Primary Algorithm Reference

Johnson, M. C., G. Halverson, J. Susiluoto, K. Cawse-Nicholson, G. Hulley, and J. B. Fisher (2022), STARS: Spatial Timeseries for Automated high-Resolution multi-Sensor data fusion [Presentation], ECOSTRESS Science and Applications Team Meeting, Nov 2022, Ventura, CA.

9.2 Related Documentation

- ECOSTRESS L2T_STARS ATBD: Algorithm Theoretical Basis Document for detailed methodology
- HLS User Guide: https://lpdaac.usgs.gov/documents/1698/HLS_User_Guide_V2.pdf
- VIIRS Surface Reflectance Guide: https://viirsland.gsfc.nasa.gov/PDF/VIIRS_Surf_Refl_UserGuide_v1.3.pd

9.3 Supporting References

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