ECOSTRESS Level-3 Evapotranspiration (JET) Data Products User Guide

ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)

Version 3
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Authors

Gregory Halverson
ECOSTRESS Science Team
Jet Propulsion Laboratory
California Institute of Technology

Kerry Cawse-Nicholson
ECOSTRESS Science Team
Jet Propulsion Laboratory
California Institute of Technology

Margaret Johnson
ECOSTRESS Science Team
Jet Propulsion Laboratory
California Institute of Technology

Claire Villanueva-Weeks
ECOSTRESS Science Team
Jet Propulsion Laboratory
California Institute of Technology

National Aeronautics and Space Administration
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91109-8099
California Institute of Technology

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Note

The users' guide is designed to be a living document that describes the ECOSTRESS data products. The document describes the current state of the art and is revised as progress is made in the development and assessment of the ECOSTRESS data products. The primary purpose of the document is to present an overview of the ECOSTRESS data products to the potential user. For more detailed information on the physical basis and algorithms used to produce these products, please see the Algorithm Theoretical Basis Document (ATBD).

Change History Log

Revision	Effective Date	Prepared by	Description of Changes
Draft	8/24/2022	Gregory Halverson, Kerry Cawse-Nicholson	User Guide first draft
Draft	12/15/2022	Margaret Johnson, Kerry Cawse-Nicholson	STARS Description
Draft	12/15/2022	Gregory Halverson	L1C Processing
Draft	01/12/2023	Gregory Halverson	Editing for URS submission
Draft	11/07/2023	Claire Villanueva-Weeks	Fixed resolution, added logo
Draft	02/27/2024	Claire Villanueva-Weeks, Gregory Halverson	Removed L1CT/L1CG, L2T/L2G LSTE, L3G, L4G products; added product metadata table
Draft	04/23/2024	Claire Villanueva-Weeks, Gregory Halverson	Expanding product layer tables
Draft	06/11/2024	Gregory Halverson	Auxiliary data product bundle
Draft	08/13/2024	Claire Villanueva-Weeks	Removed STARS

Revision	Effective Date	Prepared by	Description of Changes
Version 3	10/07/2025	Gregory Halverson	Updated data layer tables to match code implementation; corrected L3T ETAUX and L3T JET product specifications; fixed product naming consistency; aligned with README documentation; converted all tables to standard markdown format

Contacts

Readers seeking additional information about this product may contact the following:

- Gregory Halverson
  Jet Propulsion Laboratory
  4800 Oak Grove Dr.
  Pasadena, CA 91109
  Email: gregory.h.halverson@jpl.nasa.gov
  Office: (626) 660-6818
- Kerry Cawse-Nicholson

  MS 183-501
  Jet Propulsion Laboratory
  4800 Oak Grove Dr.
  Pasadena, CA 91109
  Email: kerry-anne.cawse-nicholson@jpl.nasa.gov
  Office: (818) 354-1594
- Margaret Johnson
  Jet Propulsion Laboratory
  4800 Oak Grove Dr.
  Pasadena, CA 91109
  Email: maggie.johnson@jpl.nasa.gov

  Office: (818) 354-8885

- Claire Villanueva-Weeks

  Jet Propulsion Laboratory
  4800 Oak Grove Dr.
  Pasadena, CA 91109

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Introduction

This is the user guide for the ECOSTRESS tiled products. ECOSTRESS acquires data within an orbit, and this orbit path is divided into scenes roughly 935 x 935 km in size. The ECOSTRESS orbit/scene/tile products are distributed in Cloud-Optimized GeoTIFF (COG) format. The tiled products are listed in Table 1.

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.

Cloud-Optimized GeoTIFF Orbit/Scene/Tile Products

To provide an analysis-ready format, the ECOSTRESS products are distributed in a tiled form and using the COG format. The tiled products include the letter T in their level identifiers: L1CT, L2T, L3T, and L4T. The tiling system used for ECOSTRESS is borrowed from the modified Military Grid Reference System (MGRS) tiling scheme used by Sentinel 2. These tiles divide the Universal Transverse Mercator (UTM) zones into square tiles 109800 m across. ECOSTRESS uses a 60 m cell size with 1830 rows by 1830 columns in each tile, totaling 3.35 million pixels per tile. This allows the end user to assume that each 60 m ECOSTRESS pixel will remain in the same location at each timestep observed in analysis. The COG format also facilitates end-user analysis as a universally recognized and supported format, compatible with open-source software, including QGIS, ArcGIS, GDAL, the Raster package in R, rioxarray in Python, and Rasters.jl in Julia.

Each float32 data layer occupies 4 bytes of storage per pixel, which amounts to an uncompressed size of 13.4 mb for each tiled data layer. The uint8 quality flag layers occupy a single byte per pixel, which amounts to an uncompressed size of 3.35 mb per tiled data quality layer.

Each .tif COG data layer in each L2T/L3T/L4T product additionally contains a rendered browse image in GeoJPEG format with a .jpeg extension. This image format is universally recognized and supported, and these files are compatible with Google Earth. Each L2T/L3T/L4T tile granule includes a .json file containing the Product Metadata and Standard Metadata in JSON format.

Quality Flags

Two high-level quality flags are provided in all gridded and tiled products as thematic/binary masks encoded to zero and one in unsigned 8-bit integer layers. The cloud layer represents the final cloud test from L2 CLOUD. The water layer represents the surface water body in the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model. For both layers, zero means absence, and one means presence. Pixels with the value 1 in the cloud layer represent detection of cloud in that pixel. Pixels with the value 1 in the water layer represent open water surface in that pixel. All tiled product data layers written in float32 contain a standard not-a-number (NaN) value at each pixel that could not be retrieved. The cloud and water layers are provided to explain these missing values.

Product Availability

The ECOSTRESS products are available at the NASA Land Processes Distribution Active Archive Center (LP-DAAC), https://earthdata.nasa.gov/ and can be accessed via the Earthdata search engine.

L2T STARS NDVI and Albedo Product

L3T ETAUX Ecosystem Auxiliary Inputs Product

The ECOSTRESS JET processing chain is designed to be independently reproducible. To facilitate open science, the auxiliary data inputs that are produced for evapotranspiration processing are distributed as a data product, such that the end user has the ability to run their own evapotranspiration model using ECOSTRESS data. The data layers of the L3T ETAUX product are described in Table 3.

Name	Description	Type	Units	Fill Value	No Data Value	Valid Min	Valid Max	Scale Factor	Size
Ta	Near-surface air temperature	float32	°C	NaN	N/A	N/A	N/A	N/A	12.06 mb
RH	Relative Humidity	float32	Ratio	NaN	N/A	0	1	N/A	12.06 mb
Rg	Global Radiation	float32	$W\ m^{-2}$	NaN	N/A	0	N/A	N/A	12.06 mb
Rn	Net Radiation	float32	$W\ m^{-2}$	NaN	N/A	0	N/A	N/A	12.06 mb
SM	Soil Moisture	float32	Ratio	NaN	N/A	0	1	N/A	12.06 mb

Name	Description	Type	Units	Fill Value	No Data Value	Valid Min	Valid Max	Scale Factor	Size
cloud	Cloud mask	uint8	Mask	255	N/A	0	1	N/A	3.24 mb
water	Water mask	uint8	Mask	255	N/A	0	1	N/A	3.24 mb

Table 3. Listing of the L3T ETAUX data layers.

Downscaled Meteorology

Coarse resolution near-surface air temperature (Ta) and relative humidity (RH) are taken from the GEOS-5 FP tavg1_2d_slv_Nx product. Ta and RH are down-scaled using a linear regression between up-sampled ST, NDVI, and albedo as predictor variables to Ta or RH from GEOS-5 FP as a response variable, within each Sentinel tile. These regression coefficients are then applied to the 60 m ST, NDVI, and albedo, and this first-pass estimate is then bias-corrected to the coarse image from GEOS-5 FP. These downscaled meteorology estimates are recorded in the L3T ETAUX product listed in Table 3. Areas of cloud are filled in with bi-cubically resampled GEOS-5 FP.

Downscaled Soil Moisture

This same down-scaling procedure is applied to soil moisture (SM) from the GEOS-5 FP tavg1_2d_lnd_Nx product, which is recorded in the L3T ETAUX product listed in Table .

Surface Energy Balance

The surface energy balance processing for ECOSTRESS begins with an artificial neural network (ANN) implementation of the Forest Light Environmental Simulator (FLiES) radiative transfer algorithm (Kobayashi & Iwabuchi, 2008), following the workflow established by Dr. Hideki Kobayashi and Dr. Youngryel Ryu. GEOS-5 FP provides sub-daily Cloud Optical Thickness (COT) in the tavg1_2d_rad_Nx product and Aerosol Optical Thickness (AOT) from tavg3_2d_aer_Nx. Together with STARS albedo, these variables are run through the ANN implementation of FLiES to estimate incoming shortwave radiation (Rg), bias-corrected to Rg from the GEOS-5 FP tavg1_2d_rad_Nx product.

The Breathing Earth System Simulator (BESS-JPL) algorithm (Ryu et al., 2011; Jiang & Ryu, 2016), contributed by Dr. Youngryel Ryu, iteratively calculates net radiation (Rn), ET, and Gross Primary Production (GPP) estimates. The BESS-JPL Rn is used as the Rn input to the remaining ET models and is recorded in the L3T ETAUX product listed in Table 3.

L3T JET Evapotranspiration Product

Following design of the L3T JET product from ECOSTRESS Collection 2, the Collection 3 L3T JET product uses an ensemble of evapotranspiration models to produce a daily evapotranspiration estimate.

The PT-JPL-SM model (Purdy et al., 2018), developed by Dr. Adam Purdy and Dr. Joshua Fisher was designed as a SM-sensitive evapotranspiration product for the Soil Moisture Active-Passive (SMAP) mission, and then reimplemented as an ET model in the ECOSTRESS and SBG processing chain, using the downscaled soil moisture from the L3T ETAUX product. Similar to the PT-JPL model used in ECOSTRESS Collection 1, The PT-JPL-SM model estimates instantaneous canopy transpiration, leaf surface evaporation, and soil moisture evaporation using the Priestley-Taylor formula with a set of constraints. These three partitions are combined into total latent heat flux in watts per square meter for the ensemble estimate.

The Surface Temperature Initiated Closure (STIC-JPL) model (Mallick et al., 2018), contributed by Dr. Kaniska Mallick, was designed as a ST-sensitive ET model, adopted by ECOSTRESS and SBG for improved estimates of ET reflecting mid-day heat stress. The STIC-JPL model estimates total latent heat flux directly. This instantaneous estimate of latent heat flux is included in the ensemble estimate.

The PM-JPL (Penman-Monteith) algorithm (Mu et al., 2011; Running et al., 2017) was designed as the ET product for the Moderate Resolution Imaging Spectroradiometer (MODIS) and then continued as a Visible Infrared Imaging Radiometer Suite (VIIRS) product. PM-JPL uses a similar approach to PT-JPL and PT-JPL-SM to independently estimate vegetation and soil components of instantaneous ET, but using the Penman-Monteith formula instead of the Priestley-Taylor. The PM-JPL latent heat flux partitions are summed to total latent heat flux for the ensemble estimate.

The BESS-JPL model (Ryu et al., 2011; Jiang & Ryu, 2016) is a coupled surface energy balance and photosynthesis model. The latent heat flux component of BESS-JPL is also included in the ensemble estimate.

The median of total latent heat flux in watts per square meter from the PT-JPL-SM, STIC-JPL, PM-JPL, and BESS-JPL models is upscaled to a daily ET estimate in millimeters per day and recorded in the L3T JET product as ETdaily. The standard deviation between these multiple estimates of ET is considered the uncertainty for the SBG evapotranspiration product, as ETinstUncertainty. The layers for the L3T JET products are listed in Table 4. Note that the ETdaily product represents the integrated ET between sunrise and sunset.

Name	Description	Type	Units	Fill Value	No Data Value	Valid Min	Valid Max	Scale Factor	Size
PTJPLSMinst	PT-JPL-SM Instantaneous	float32	W m⁻²	NaN	N/A	N/A	N/A	N/A	12.06 mb
PTJPLSMdaily	PT-JPL-SM Daily	float32	mm day⁻¹	NaN	N/A	N/A	N/A	N/A	12.06 mb
STICJPLdaily	STIC-JPL Daily	float32	mm day⁻¹	NaN	N/A	N/A	N/A	N/A	12.06 mb
BESSJPLdaily	BESS-JPL Daily	float32	mm day⁻¹	NaN	N/A	N/A	N/A	N/A	12.06 mb
PMJPLdaily	PM-JPL (MOD16) Daily	float32	mm day⁻¹	NaN	N/A	N/A	N/A	N/A	12.06 mb
ETdaily	Daily Evapotranspiration	float32	mm day⁻¹	NaN	N/A	N/A	N/A	N/A	12.06 mb
ETinstUncertainty	Instantaneous Evapotranspiration Uncertainty	float32	W m⁻²	NaN	N/A	N/A	N/A	N/A	12.06 mb
PTJPLSMcanopy	PT-JPL-SM Canopy	float32	proportion	NaN	N/A	N/A	N/A	N/A	12.06 mb
STICJPLcanopy	STIC-JPL Canopy	float32	proportion	NaN	N/A	N/A	N/A	N/A	12.06 mb

Name	Description	Type	Units	Fill Value	No Data Value	Valid Min	Valid Max	Scale Factor	Size
PTJPLSMsoil	PT-JPL-SM Soil	float32	proportion	NaN	N/A	N/A	N/A	N/A	12.06 mb
PTJPLSMinterception	PT-JPL-SM Interception	float32	proportion	NaN	N/A	N/A	N/A	N/A	12.06 mb
cloud	Cloud mask	uint8	Mask	255	N/A	0	1	N/A	3.24 mb
water	Water mask	uint8	Mask	255	N/A	0	1	N/A	3.24 mb

Table 4. Listing of the L3T JET data layers.

L4T ESI & WUE Products

The PT-JPL-SM model generates estimates of both actual and potential instantaneous ET. The potential evapotranspiration (PET) estimate represents the maximum expected ET if there were no water stress to plants on the ground. The ratio of the actual ET estimate to the PET estimate forms an index representing the water stress of plants, with zero being fully stressed with no observable ET and one being non-stressed with ET reaching PET. These ESI and PET estimates are distributed in the L4T ESI product as listed in Table 5.

Name	Description	Type	Units	Fill Value	No Data Value	Valid Min	Valid Max	Scale Factor	Size
ESI	Evaporative Stress Index	float32	Ratio	NaN	N/A	0	1	N/A	12.06 mb
PET	Potential Evapotranspiration	float32	mm day^{-1}	NaN	N/A	N/A	N/A	N/A	12.06 mb
cloud	Cloud mask	uint8	Mask	255	N/A	0	1	N/A	3.24 mb

Name	Description	Type	Units	Fill Value	No Data Value	Valid Min	Valid Max	Scale Factor	Size
water	Water mask	uint8	Mask	255	N/A	0	1	N/A	3.24 mb

Table 5. Listing of the L4T ESI data layers.

The BESS-JPL GPP estimate represents the amount of carbon that plants are taking in. The transpiration component of PT-JPL-SM represents the amount of water that plants are releasing. The BESS-JPL GPP is divided by the PT-JPL-SM transpiration to estimate water use efficiency (WUE), the ratio of grams of carbon that plants take in to kilograms of water that plants release. These WUE and GPP estimates are distributed in the L4T WUE product as listed in Table 6.

Name	Description	Type	Units	Fill Value	No Data Value	Valid Min	Valid Max	Scale Factor	Size
WUE	Water Use Efficiency	float32	g C kg^{-1} H_2O	NaN	N/A	0	1	N/A	12.06 mb
GPP	Gross Primary Production	float32	μmol m^{-2} s^{-1}	NaN	N/A	N/A	N/A	N/A	12.06 mb
cloud	Cloud mask	uint8	Mask	255	N/A	0	1	N/A	3.24 mb
water	Water mask	uint8	Mask	255	N/A	0	1	N/A	3.24 mb

Table 6. Listing of the L4T WUE data layers.

Standard Metadata

Each SBG product bundle contains two sets of product metadata:

- ProductMetadata
- StandardMetadata

Each product contains a custom set of ProductMetadata attributes, as listed in Table 7. The StandardMetadata attributes are consistent across products at each orbit/scene, as listed in Table 8.

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

Name	Type
SISName	string
SISVersion	string
SceneBoundaryLatLonWKT	string
SceneID	string
ShortName	string
SouthBoundingCoordinate	float
StartOrbitNumber	string
StopOrbitNumber	string
WestBoundingCoordinate	float

Table 7. 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 8. Name and type of metadata fields contained in the common ProductMetadata group in each L2T/L3T/L4T product.

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We would like to thank Youngryel Ryu for contributing the BESS-JPL model.

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