ECOv003 L3 JET Algorithm Theoretical Basis Document

Jet Propulsion Laboratory

Authors: Simon Hook, Kerry Cawse-Nicholson, Gregory Halverson, Maggie Johnson, Madeleine Pascolini-Campbell, AJ Purdy, Munish Sikka, Claire Villanueva-Weeks

Affiliation: ECOSTRESS Science Team, Jet Propulsion Laboratory, California Institute of Technology

Date: August 2024

Document Number: ECOSTRESS Science Document no. D-1001467

Table of Contents

1. Introduction
    - Purpose
    - Scope and Objectives
2. Parameter Description and Requirements
3. Evapotranspiration Retrieval
    - PT-JPL$_{SM}$: General Form
    - STIC: General Form
    - MOD16: General Form
    - BESS: General Form
4. Calibration/Validation
5. Acknowledgements
6. References

Introduction

Purpose

Evapotranspiration (ET) is one of the main science outputs from the ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS). ET is a Level-3 (L-3) product constructed from a combination of the ECOSTRESS Level-2 (L-2) Land Surface Temperature (LST) product and auxiliary data sources. The rate of ET is controlled by many environmental and biological factors, including:

- Incoming radiation
- Atmospheric water vapor deficit
- Soil water availability
- Vegetation physiology and phenology

Scope and Objectives

This document provides:

1. A description of the ET parameter characteristics and requirements.
2. An overview of the general form of the ET algorithms in the JET ensemble.
3. Algorithm-specific adaptations for the ECOSTRESS mission.
4. Required auxiliary data products and their sources.
5. A plan for calibration and validation (Cal/Val) of the ET retrieval.

Parameter Description and Requirements

Attributes of ET Data

- Spatial resolution: 70 m x 70 m
- Temporal resolution: Diurnally varying to match ISS overpass characteristics
- Latency: As required by the ECOSTRESS Science Data System (SDS)

Auxiliary Variables

Auxiliary Variable	Equation	Source
Near-surface air temp.	L3G MET	GEOS-5 FP tavg1_2d_slv_Nx
Near-surface dew point	Net radiation	GEOS-5 FP tavg1_2d_slv_Nx
Relative humidity (RH)	L3G MET	GEOS-5 FP tavg1_2d_slv_Nx
Soil moisture (SM)	L3G SM product	GEOS-5 FP tavg1_2d_lnd_Nx

Evapotranspiration Retrieval

PT-JPL$_{SM}$: General Form

The PT-JPL$_{SM}$ model relies on the Priestley-Taylor equation to resolve potential ET (PET):

$$PT = \alpha \frac{\Delta}{\Delta + \gamma} R_N - G$$

Where: - Δ: Slope of the saturation-to-vapor pressure curve - γ: Psychrometric constant - R_N: Net radiation (W/m²) - G: Ground heat flux (W/m²)

To reduce PET to actual ET (AET), ecophysiological constraint functions are applied based on atmospheric moisture and vegetation indices.

STIC: General Form

The Surface Temperature Initiated Closure (STIC) model integrates LST into the Penman-Monteith Shuttleworth-Wallace system of ET equations. The general approach involves:

1. Solving state equations to find analytical solutions for aerodynamic temperature (T_0) and conductances (g_a, g_{cs}).
2. Iteratively estimating unknowns using Penman-Monteith and Shuttleworth-Wallace equations.

MOD16: General Form

The MOD16 algorithm is based on the Penman-Monteith equation with environmental constraints from vegetation cover, temperature, and atmospheric moisture deficits. It resolves evaporative fluxes from the soil, canopy, and intercepted water separately.

BESS: General Form

The Breathing Earth System Simulator (BESS) couples atmospheric and canopy radiative transfer processes with photosynthesis, stomatal conductance, and transpiration. It uses a quadratic representation of the Penman-Monteith model to estimate transpiration.

Calibration/Validation

ET Evaluation

Eddy covariance (EC) towers provide year-round observations at frequencies (~30 minutes) and spatial scales (10s-100s m) necessary to evaluate the JET ensemble. This analysis uses EC data from the Ameriflux network.

Error Budget

The ECOSTRESS ET products target an error value of 1 mm/day, consistent with established literature. For example:

- PT-JPL ET: RMSE of 6%, $R^2 = 0.88$
- MOD16: RMSE of 0.84 mm/day

Acknowledgements

We thank Gregory Halverson, Laura Jewell, Gregory Moore, Caroline Famiglietti, Munish Sikka, Manish Verma, Kevin Tu, Alexandre Guillaume, Kaniska Mallick, Youngryel Ryu, and Hideki Kobayashi for their contributions.

References

Allen, R. G., M. Tasumi, and R. Trezza (2007), Satellite-based energy balance for mapping evapotranspiration with internalized calibration (METRIC)-model, J. Irrig. Drain. E., 133, 380-394. doi: https://doi.org/10.1061/(ASCE)0733-9437(2007)133:4(380)

Anderson, M. C., J. M. Norman, J. R. Mecikalski, J. A. Otkin, and W. P. Kustas (2007), A climatological study of evapotranspiration and moisture stress across the continental United States based on thermal remote sensing: 1. Model formulation, J. Geophys. Res., 112(D10), D10117. doi: https://doi.org/10.1029/2006JD007506

Anderson, M. C., W. P. Kustas, C. R. Hain, C. Cammalleri, F. Gao, M. Yilmaz, I. Mladenova, J. Otkin, M. Schull, and R. Houborg (2013), Mapping surface fluxes and moisture conditions from field to global scales using ALEXI/DisALEXI, Remote Sensing of Energy Fluxes and Soil Moisture Content, 207-232. doi: https://doi.org/10.3390/rs13040773

Baldocchi, D. (2008), 'Breathing' of the terrestrial biosphere: lessons learned from a global network of carbon dioxide flux measurement systems, Australian Journal of Botany, 56, 1-26. doi: https://doi.org/10.1071/BT07151

Baldocchi, D., E. Falge, L. H. Gu, R. J. Olson, D. Hollinger, S. W. Running, P. M. Anthoni, C. Bernhofer, K. Davis, R. Evans, J. Fuentes, A. Goldstein, G. Katul, B. E. Law, X. H. Lee, Y. Malhi, T. Meyers, W. Munger, W. Oechel, K. T. P. U, K. Pilegaard, H. P. Schmid, R. Valentini, S. Verma, T. Vesala, K. Wilson, and S. C. Wofsy (2001), FLUXNET: A new tool to study the temporal and spatial variability of ecosystem-scale carbon dioxide, water vapor, and energy flux densities, Bulletin of the American Meteorological Society, 82(11), 2415-2434. doi: https://doi.org/10.1175/1520-0477(2001)082%3C2415:FANTTS%3E2.3.CO;2

Bi, L., P. Yang, G. W. Kattawar, Y.-X. Hu, and B. A. Baum (2011), Diffraction and external reflection by dielectric faceted particles, J. Quant. Spectrosc. Radiant. Transfer, 112, 163-173. doi: https://doi.org/10.1016/j.jqsrt.2010.02.007

Bisht, G., V. Venturini, S. Islam, and L. Jiang (2005), Estimation of the net radiation using MODIS (Moderate Resolution Imaging Spectroradiometer), Remote Sensing of Environment, 97, 52-67. doi: https://doi.org/10.1016/j.rse.2005.03.014

Bouchet, R. J. (1963), Evapotranspiration réelle evapotranspiration potentielle, signification climatique Rep. Publ. 62, 134-142 pp, Int. Assoc. Sci. Hydrol., Berkeley, California.

Chen, X., H. Wei, P. Yang, and B. A. Baum (2011), An efficient method for computing atmospheric radiances in clear-sky and cloudy conditions, J. Quant. Spectrosc. Radiant. Transfer, 112, 109-118. doi: https://doi.org/10.1016/j.jqsrt.2010.08.013

Chen, Y., J. Xia, S. Liang, J. Feng, J. B. Fisher, X. Li, X. Li, S. Liu, Z. Ma, and A. Miyata (2014), Comparison of satellite-based evapotranspiration models over terrestrial ecosystems in China, Remote Sensing of Environment, 140, 279-293. doi: https://doi.org/10.1016/j.rse.2013.08.045

Coll, C., Z. Wan, and J. M. Galve (2009), Temperature-based and radiance-based validations of the V5 MODIS land surface temperature product, Journal of Geophysical Research, 114(D20102), doi: https://doi.org/10.1029/2009JD012038.