JPL D-96968

ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)

Level-1B Geo PGE Algorithm Specification Document

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June 11, 2018

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This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

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List of Acronyms

ALEXI	Atmosphere–Land Exchange Inverse
ARS	Agricultural Research Service
ATBD	Algorithm Theoretical Basis Document
Cal/Val	Calibration and Validation
CDL	Cropland Data Layer
CFSR	Climate Forecast System Reanalysis
CONUS	Contiguous United States
DisALEXI	Disaggregated ALEXI algorithm
DPU-IO	Digital Processing Unit Input/Output
ECOSTRESS	ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station
ET	Evapotranspiration
EVI-2	Earth Ventures Instruments, Second call
FPIE	Focal Plane Interface Electronics
FSWT	Flight Software Time (in GPS time)
GET-D	GOES Evapotranspiration and Drought System
GPS	Global Positioning System
HRSL	Hydrology and Remote Sensing Laboratory
ISS	International Space Station
L-2	Level 2
L-3	Level 3
LTAR	Long-Term Agroecosystem Research
MODIS	MODerate-resolution Imaging Spectroradiometer
NASS	National Agricultural Statistics Service
NLCD	National Land Cover Dataset
NOAA	National Oceanographic and Atmospheric Administration
PGE	Product Generation Executive
PM	Penman-Monteith
PSD	Product Specification Document
RMSD	Root Mean Squared Difference
SDS	Science Data System
SEB	Surface Energy Balance
TIR	Thermal Infrared
TSEB	Two-Source Energy Balance
USDA	United States Department of Agriculture

Contents

1 Introduction

The ECOSTRESS mission will provide high-resolution multi-spectral thermal infrared imagery to support field-scale mapping of evapotranspiration (ET) or consumptive water use. The thermal data will be converted to Level 2 (L-2) radiometric land surface temperature (LST) and emissivity products by JPL as described in the Surface Temperature Algorithm Theoretical Basis Document (ATBD).

1.1 Objective

The purpose of this Algorithm Specification Document (ASD) is to describe the computer processing system that will be used to generate Level 1B (L1B) Geolocation files from the ECOSTRESS L1B RAD files.

1.2 Scope

This document describes the L1B Geo Product Generation Executive (PGE) implemented at the ECOSTRESS Science Data System (SDS) to generate L1B Geo files.

1.3 References

Reference 1: ECOSTRESS Level-1B Resampling and Geolocation Algorithm Theoretical Basis Document (ATBD), JPL D-94641

Reference 2: ECOSTRESS Level-1 Product Specification Document (PSD), JPL D-94634

2 Algorithm Description & Software Design

2.1 Data System Context

The ECOSTRESS processing levels are conceptually described as:

- Level 0 Processing prepares incoming datasets for higher-level processing
- Level 1 Processing generates engineering data products and calibrated, geolocated science measurements
- Level 2 Processing generates ECOSTRESS science results
- Level 3 and 4 Processing generate physical retrievals of target variables (ET and reference ET ratio)

2.2 The L1B Geo PGE Role in the ECOSTRESS Data System

The L1B Geo PGE is one of four PGEs within the L1 context (Figure 1). It uses the ephemeris and attitude data from the L1A Raw PGE to produce geolocation, height, solar and view angles and land fraction associated with the L1B Rad generated radiance data. In addition, it uses image matching between the L1B Rad and a reference orthobase (based on Landsat 7 data) to correct for errors in the ISS reported ephemeris and attitude information.

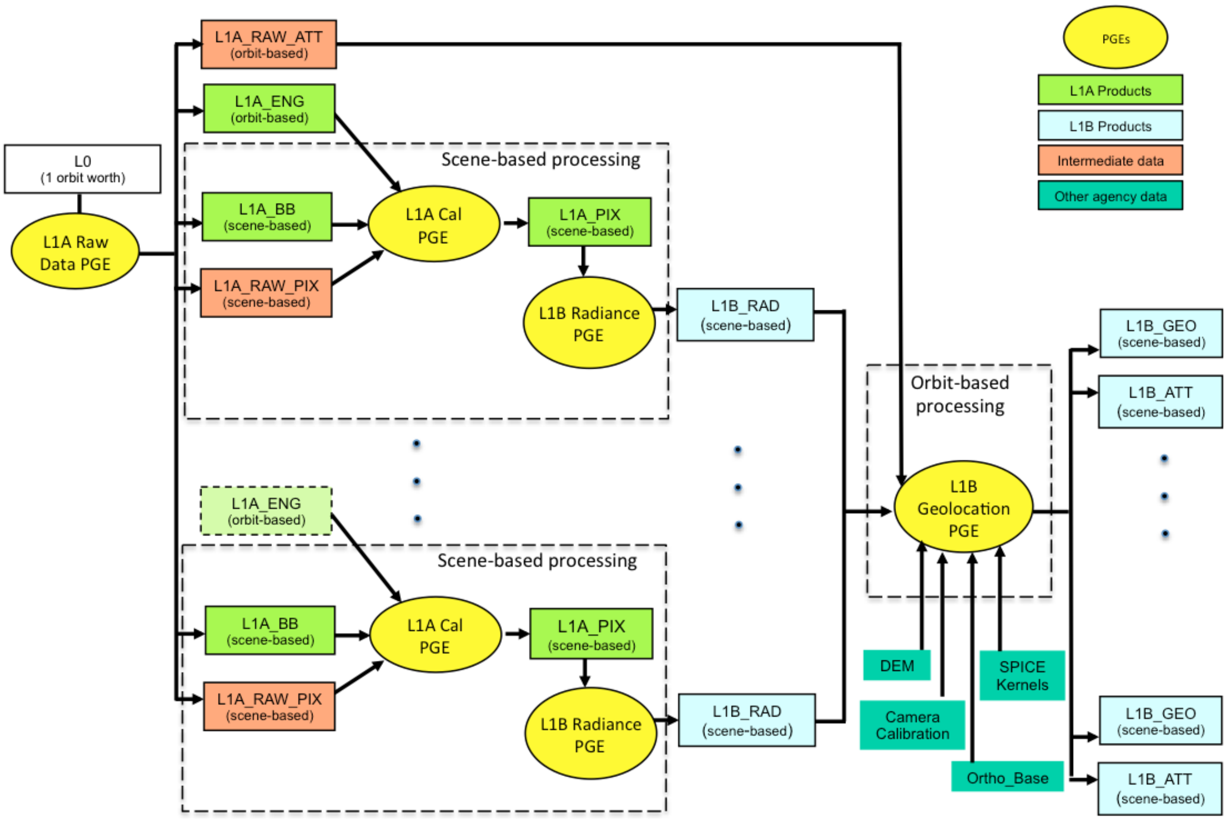

Figure 1: ECOSTRESS Level 1 (L1) Contextual Flow Diagram.

2.3 Input Data Sets

The following input data files are required:

- L1A_RAW_ATT: Ephemeris and Attitude information
  - Ephemeris
  - Velocity
  - Attitude quaternion
- L1B_RAD: Contains the TIR bands as radiance, and the SWIR band as DN
  - 5 co-registered TIR bands as radiance data
  - 5 Data Quality Indicators images
  - SWIR DN image with Dark Current subtracted

2.4 Output Data Sets

The following output data files are created:

- L1B_GEO: Contains the latitude, longitude, and height of each pixel in the L1B_RAD image. Also contains solar and view angles and land fraction
  - Latitude of each pixel in L1B_RAD image
  - Longitude of each pixel
  - Height of each pixel
  - Solar azimuth angle of each pixel
  - Solar zenith angle of each pixel
  - View azimuth angle of each pixel
  - View zenith angle of each pixel

    - Land fraction of each pixel.
- L1B_ATT: Corrected spacecraft ephemeris and attitude data
    - Ephemeris (corrected)
    - Velocity
    - Attitude quaternion (corrected)

3 Overview of Design

The L1B Geo PGE provided location information for each image pixel from L1B_RAD, and also produces the related height, view and solar angles, and land fraction.

As a precursor to this step, we correct the reported ISS ephemeris and attitude information. This is necessary to produce the required 50-meter geolocation accuracy. The reported ISS attitude can contain large static errors, giving as large as a 2.5 km pointing error (see Reference 1).

In addition, the ISS ephemeris position is for the center of the ISS. ECOSTRESS is mounted near the outer edge of the ISS (see Reference 1), and the distance is significant enough that we need to account for it (roughly 22 meters). So, we first correct the ISS ephemeris to give the location of ECOSTRESS rather than ISS center.

Next, to correct for attitude and ephemeris knowledge errors we first product an ortho-rectified image of the a selected band (SWIR for daytime images, Band 5 – TIR 12.001-micron for nighttime images). This image is based on the ISS reported navigation information, so this will potentially contain large geolocation errors. We then do image matching between the ortho-rectified image and a reference orthobase (Landsat 7 cloud free mosaic). This produced tie-points. We then repeat this for each of the scenes that make up an orbit, producing tie-points for each scene.

A simultaneous bundle adjustment (SBA) is then performed to determine the attitude and ephemeris corrections which best match the collected tie-points.

This corrected ephemeris and attitude is written at as a L1B_ATT files.

The corrected ephemeris and attitude is used to calculate the latitude, longitude, height, view and solar angles, and land fraction. The output is written as a set of L1B_GEO files, one per scene.

4 Detailed descriptions

The following describes how the L1B Geo PGE processing is done.

4.1 Ephemeris Correction from ISS Center to ECOSTRESS Location

The shift from the ISS center to the ECOSTRESS instrument location is a fixed offset in spacecraft coordinate system. We apply the shift by:

1. For each ephemeris value:
    a. Convert x_offset_iss from spacecraft coordinate system to ECI
    b. Replace ephemeris pos_eci with pos_eci + x_offset_iss_eci

4.2 Initial Ortho-rectified images

We create initial ortho-rectified images by:

1. For each scene
    a. Determine band we will match. If the scene is marked as "Day" in L1B Rad, then we use the SWIR channel for ECOSTRESS, matching against Landsat 7 SWIR 1 band. If "Night" we use the 12 micron band for ECOSTRESS (band 5) and Landsat 7 high gain thermal band.
    b. Scale the ortho base map information to roughly 60 meter resolution:

       ortho_scale = round(60.0 / b.map_info.resolution_meter)
    c. Determine the latitude/longitude of each pixel in the scene for the desired band using ray tracing
    d. Do a bilinear interpolation of the latitude/longitude to give the configured number of subpixels (default is 3x3 subpixels)
    e. Resample the L1B Rad radiance (12 micron band) or DN (SWIR band) using the interpolated latitude/longitude to produce an orthorectified image

4.3 Tie-point Collection

We generate tie-points by:

1. For each scene
    a. Select points from an evenly spaced grid of desired size in the ortho-rectified image (nominally 20x20)
    b. Image match with the ortho-base Landsat 7 image use a phase correlation matcher. The initial guess for the location of the point is the point at the corresponding latitude/longitude
    c. Do blunder detection to remove bad image matching points. We do a linear fit to predict the location in the ortho-base from the given location in the ortho-base image. We then predict the location of each tie-point in the ortho-base image and calculate the difference with the image matching location. We throw out tie-points with a residual larger than a given threshold (default 1.5 pixels).

4.4 Ephemeris and Attitude Correction

We correct the ephemeris and attitude by:

1. Create a parameters model to correct ephemeris and attitude.

   a. Current best guess is that we will have 2 attitude correction quaternions, one and the beginning and one at the end of the first and last scene. We will then interpolate the quaternions to correct the attitude in between these 2 times. No correction to ephemeris (other than the ISS to ECOSTRESS center offset we have already performed).
   b. However, we may adjust the error model used once we have real ECOSTRESS orbit data, to more closely model the errors we encounter.
2. Perform a simultaneous bundle adjustment to adjust the orbit parameters to best match the set of tie-points we collected
3. Write out the uncorrected and corrected ephemeris and attitude to produce the L1B_ATT file.

4.5 Latitude, Longitude, Height, View and Solar Angle, Land fraction calculation

We generate data by:

1. For each scene
   a. Use ray tracing and the corrected ephemeris/attitude to determine the ground location and height for each pixel
   b. Use the ephemeris and ground location to calculate the view azimuth and zenith
   c. Use the time of each pixel and ground location to calculate the solar angle using the SPICE toolkit.
   d. Use the ground location to determine the land fraction from the global land/water mask dataset (part of the ortho-base dataset).

4.6 Generating metadata

The PGE will generate both standard and product-specific metadata for use by the PCS to catalog and track each scene file.

5 Other Considerations

5.1 Error handling

The L1B Geo PGE was designed to handle all L1B-expected problems, and to terminate with exit codes for other unexpected conditions. The PGE will return a value of "1" and exit if it finds conditions that prevent it from processing. It will return a value of "0" if the processing is successful. In addition to the standard SYSOUT log file, a formatted log file is created that summarizes the internal processing and provides additional details when a problem occurs.