ECOSTRESS

ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

L1 Calibration and Geolocation Review
Science Team Meeting
15-17NOV2022

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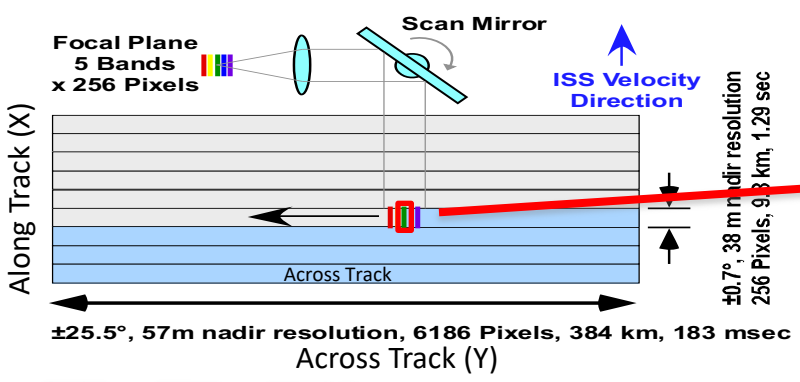
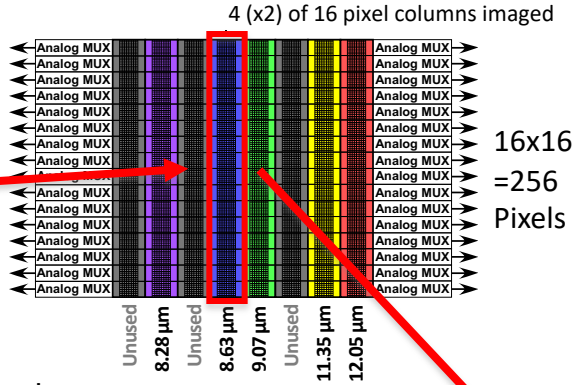
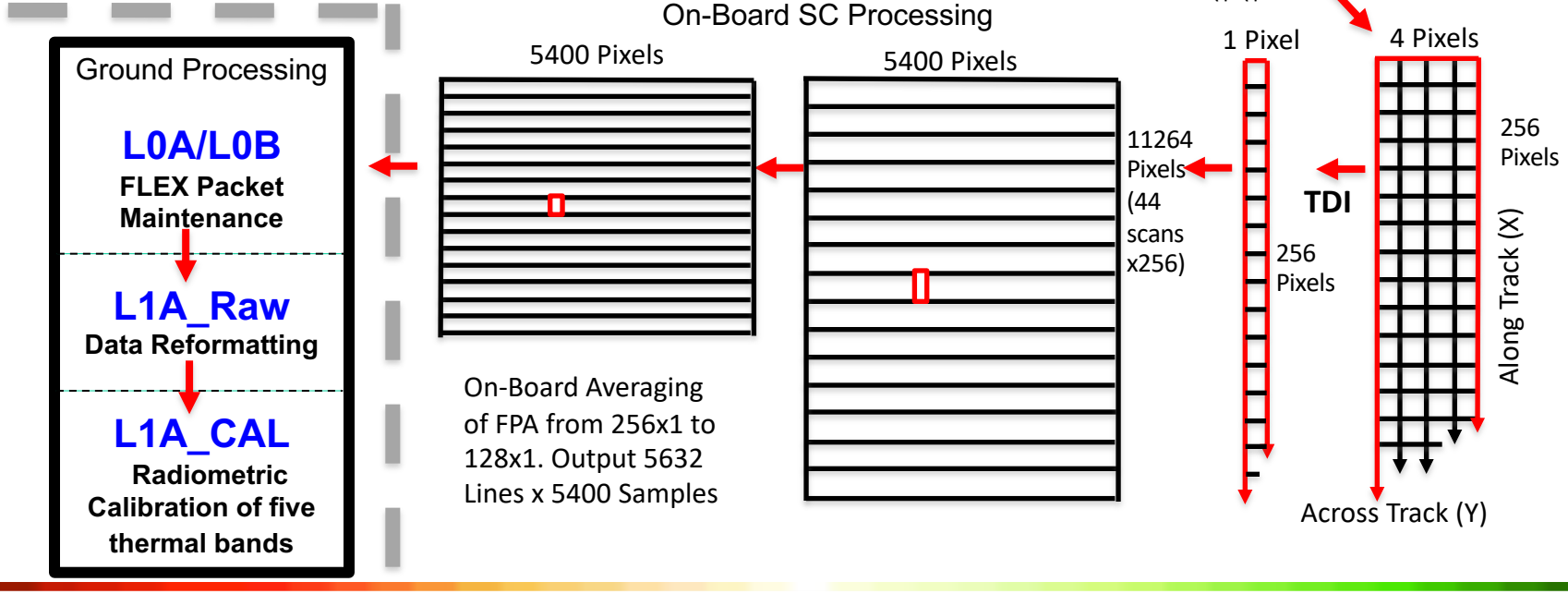
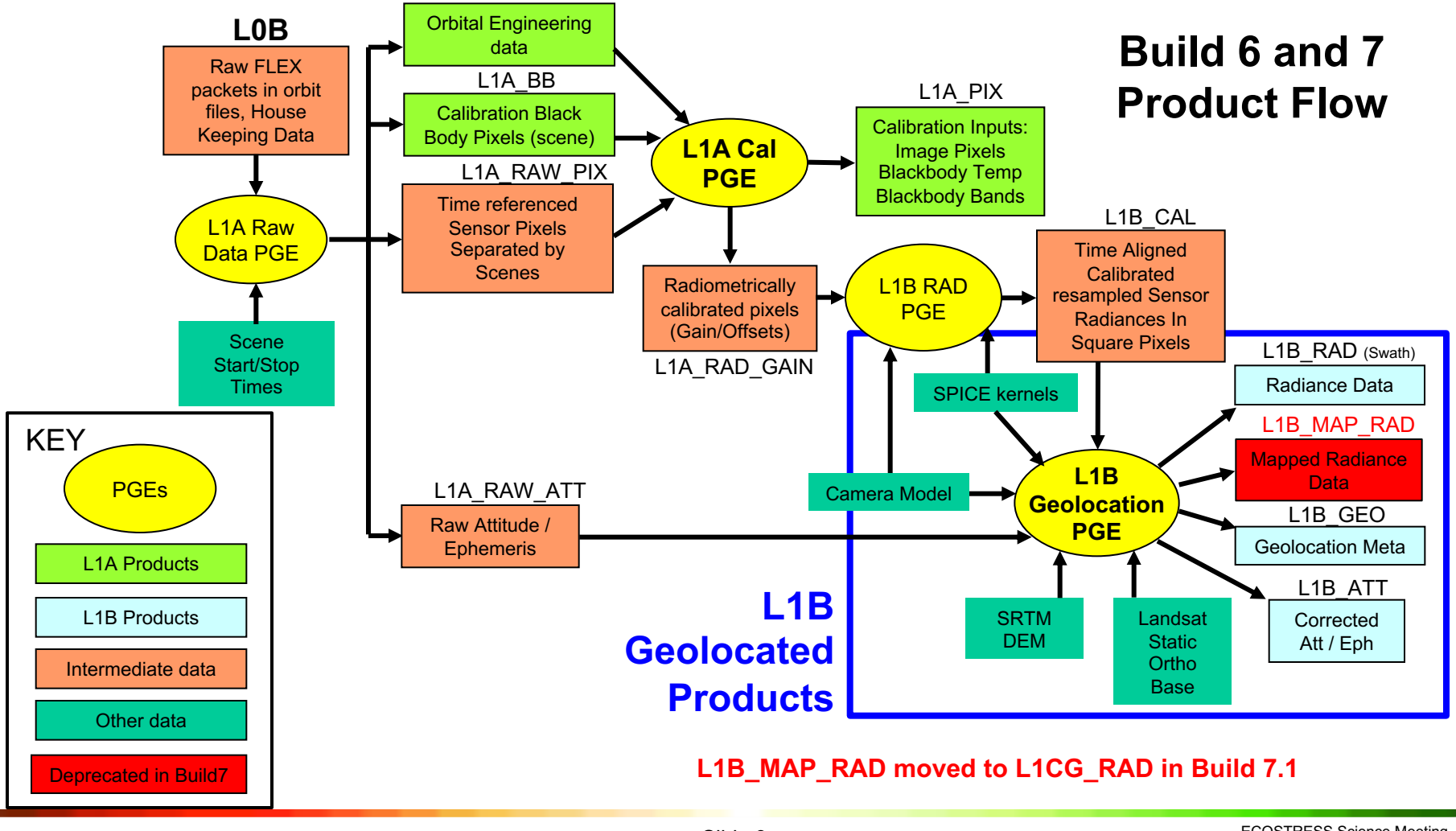
L0 to L1 Travel Path of the ECOSTRESS Pixel





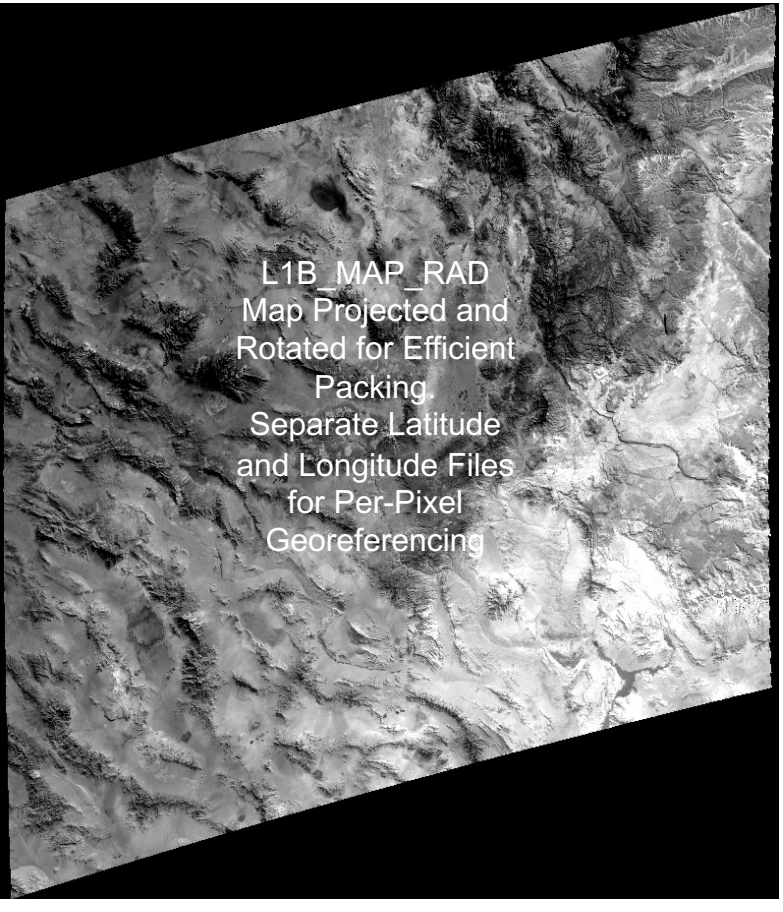


L1 Data Flow Diagram

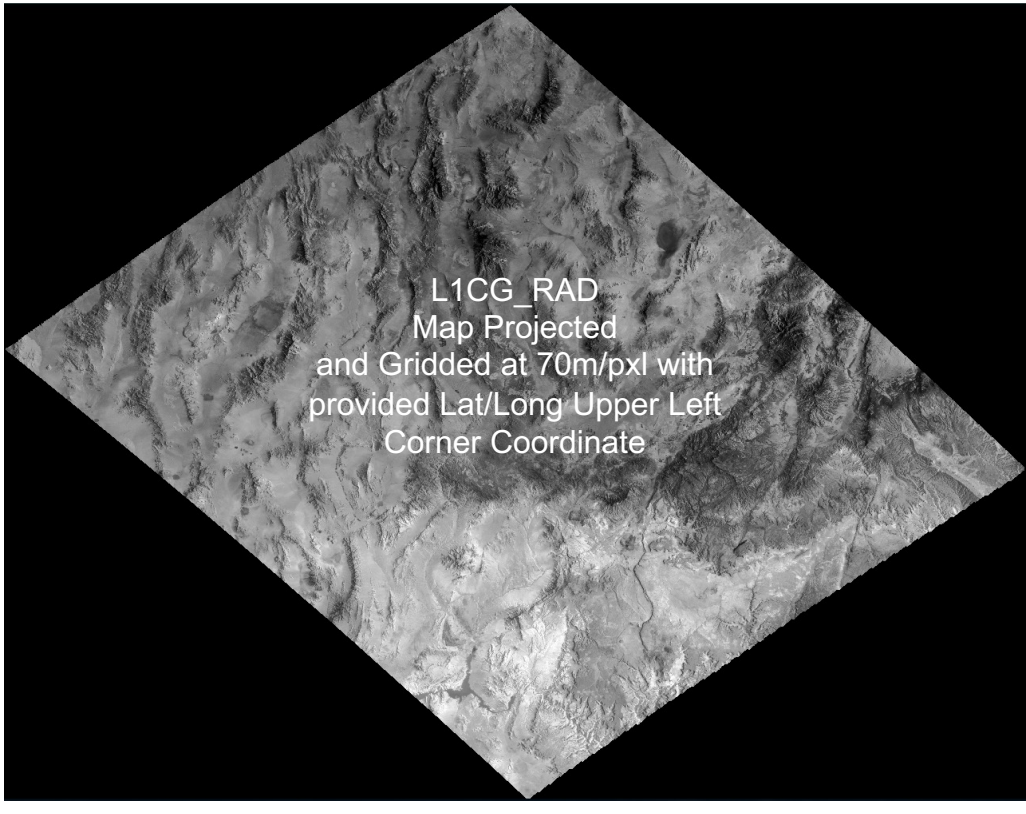


L1 Radiometric Calibration

L1C Gridded Map Radiance Product



L1B_MAP_RAD (TOA) Deprecated Product

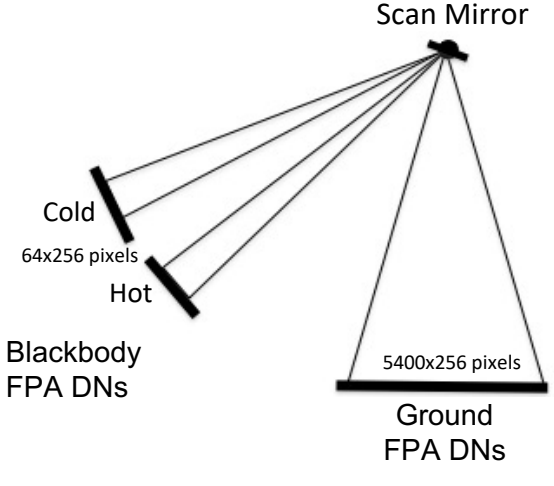


L1CG_RAD (TOA) Replacement Product

L1A Radiometric Two-Point Calibration*

Approach

- Read BB RTD Temperatures.
- Create synthetic FPA 256x1 Blackbody Temperature Images.
- Convert FPA BB Images to Radiances using Planck Function.
- Collect FPA Blackbody and Ground DNs.
- Apply 2pt Algorithm →



Two-Point Calibration Formula

$$R_\lambda = a + bD_\lambda$$

$$a = \frac{R_h D_c - R_c D_h}{D_c - D_h} \qquad b = \frac{R_c - R_h}{D_c - D_h}$$

Where:

R = *Calculated Radiance of an input Digital Number (DN)*

a = *Offset Term*

b = *Gain Term*

D = *Input Earth Digital Number (DN)*

R_c = *Radiance of the Cold Blackbody (Section 3.3.2)*

R_h = *Radiance of the Hot Blackbody (Section 3.3.2)*

D_c = *Digital Number (DN) from the Cold Blackbody Calibration File (Section 3.3.3)*

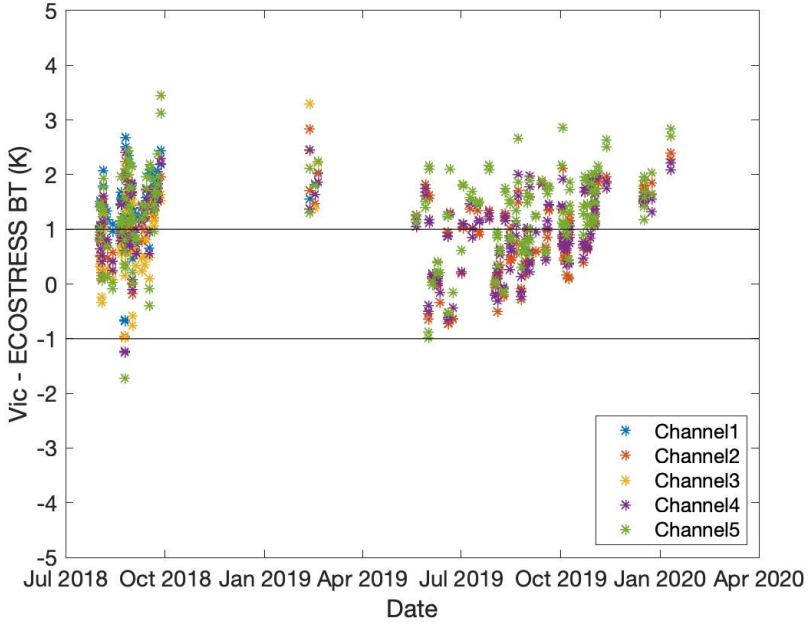
D_h = *Digital Number (DN) from the Hot Blackbody Calibration File (Section 3.3.3)*

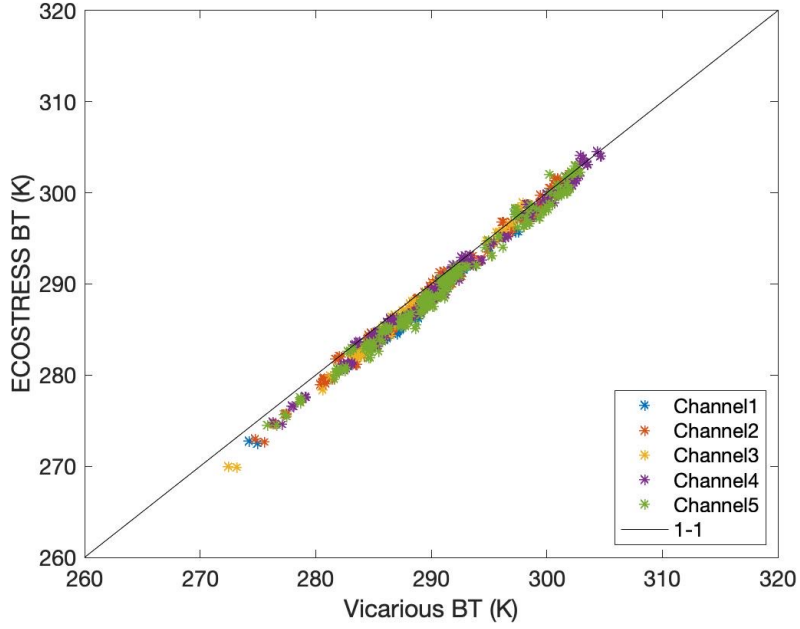
*Documented in: "Level-1 Focal Plane Array and Radiometric Calibration Algorithm Theoretical Basis Document (ATBD)," JPL D-94803.

L1A Radiometric Calibration

On-Orbit Vicarious Performance

Tahoe and Salton Sea Cal/Val Sites





Build 6 Temperature Bias Corrected in Build 7

Kerry Cawse-Nicholson & Robert Radocinski

L1A Updates for Build 7

- A new “FieldOfViewObstruction” Flag is provided in the Standard Metadata.
  - “Yes/No” codes identify View Obstruction due to ISS Solar Panels.

- Two underperforming focal plane (FPA) pixels have been identified in the 10.5micron band.
  - They correspond to product scan Lines 1 and 110, repeating in 128 line intervals:
    - Lines 1, 129, 257, 385, 513, 641, etc.
    - Lines 110, 238, 366, 494, 622, 750, etc.
  - These scan lines are now marked as “Bad Data” code -9999.
    - Bad Data lines are not interpolated.
  - Users of Build 6 data should be aware of quality issues with these lines in L2 Products.

L1B Updates for Build 7

- A variety of miscellaneous L1B Upgrades.
  - New Radiance gain/offset adjustment parameters have been implemented, and will be managed by the Science Team.
  - Added HDF5 product compression.
  - L1B_Map_RAD product has been moved to the L1C product line.

- Geolocation and Co-Registration Improvements:
  - New Expanded Co-Registration Metadata.
  - New Co-Registration improvements.

L1B Geolocation

- Geolocation calculates the Latitude and Longitude of each image pixel.

- Latitude and Longitude are calculated from Spacecraft Attitude or Attitude corrected by an Orthobase (i.e., Earth Map Image).
  - ECOSTRESS does **not** have a Star Tracker for attitude/orientation correction.
  - ECOSTRESS extrapolates ephemeris/pointing/timing (BAD*) information from the ISS to the camera system on the JEM module and 1553 HK/Telemetry Data.
    - Errors include ISS altitude, ISS orientation, camera focal length, scan mirror calibration.
      - Most errors are corrected through in-orbit calibration, except attitude.
    - Composite errors at the ECOSTRESS module are estimated as:
      - 2.5km error at 1-sigma**
      - 7.5km error at 3-sigma
  - Attitude correction is performed by co-registration/matching an ECOSTRESS image with a similar wavelength ortho-rectified Landsat map mosaic.
    - The ortho-mosaic map is based on Landsat7 imagery circa 2000.
    - The estimated positional accuracy of the map mosaic is 0.5-0.8 pixel.

- Pixel Latitude and Longitude coordinate files are passed to L2 processing.

* BAD: ISS Broadcast Ancillary Data

**Documented in: “Level-1B Resampling and Geolocation Algorithm Theoretical Basis Document (ATBD),” JPL D-94641

L1B Geolocation

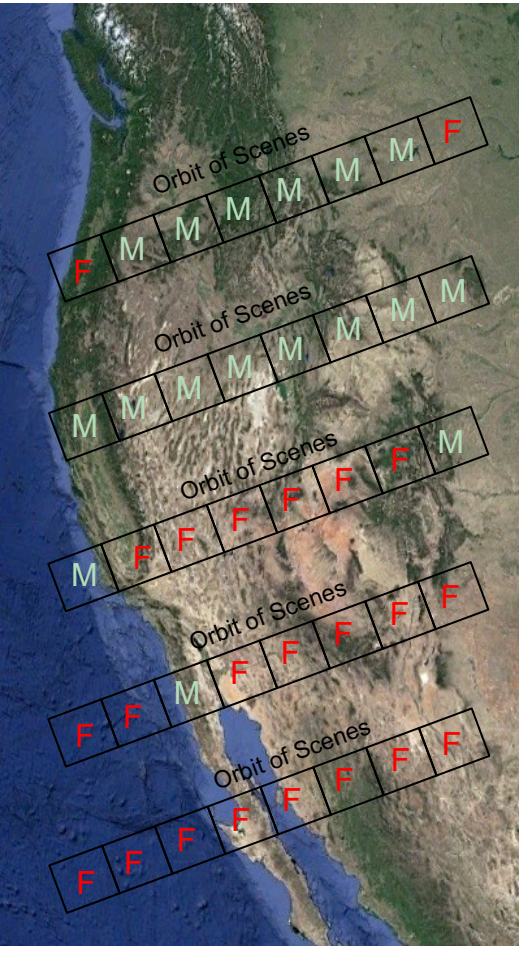
Landsat7 Orthobase (Mosaic) Band 62 (TIR 10.4-12.5u).

Near Global Earth Coverage Excluding Antarctica, Minor Islands, and Miscellaneous Locations

Geolocation From Co-Registration

- Geolocation correction is only possible for scenes where image matching with the Orthobase can be performed.
- Automated Image Matching is performed by a grid of FFTs between the ECOSTRESS Scene and the Landsat Orthobase.
- Automated Image Matching may fail for a variety of reasons:
  - Image is over water/ocean.
  - Image is cloudy.
  - Image lacks ground features that can be matched
    - Fog; Non-Descript Terrain; Ground Temperature transitions
- Images without Geolocation Matching use the available ISS positioning information which can be 2.5km to 7.5km from true geographic location.

Orbital Geolocation from Scene Matching



Orbital Attitude Geolocation extrapolated from Matched Scenes

Every Scene Matched and contributes to orbital Attitude

Geolocation for Failed Scenes interpolated from Between Matched Scenes

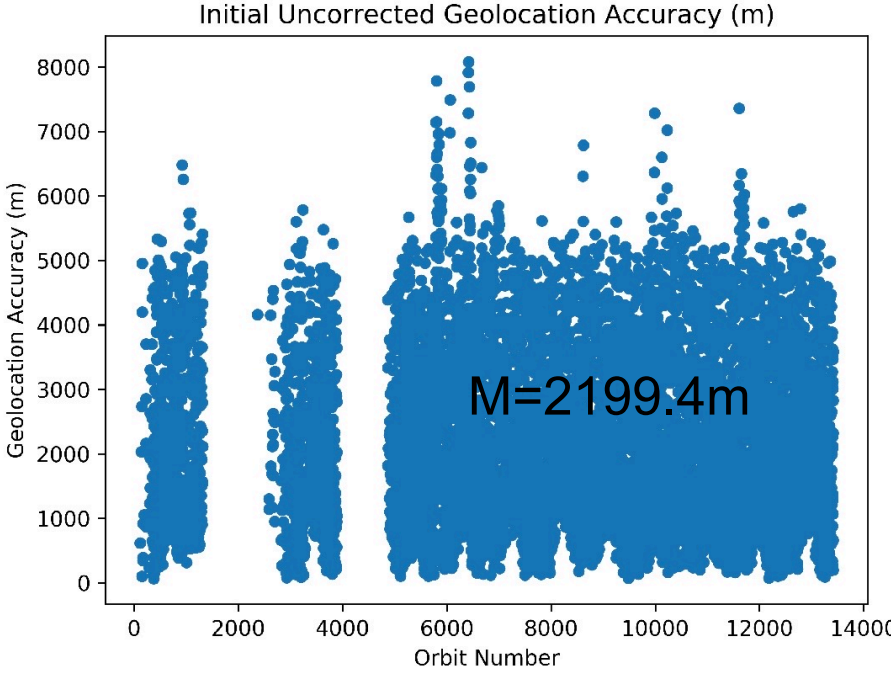
Orbital Attitude extrapolated from Single Matched Scene

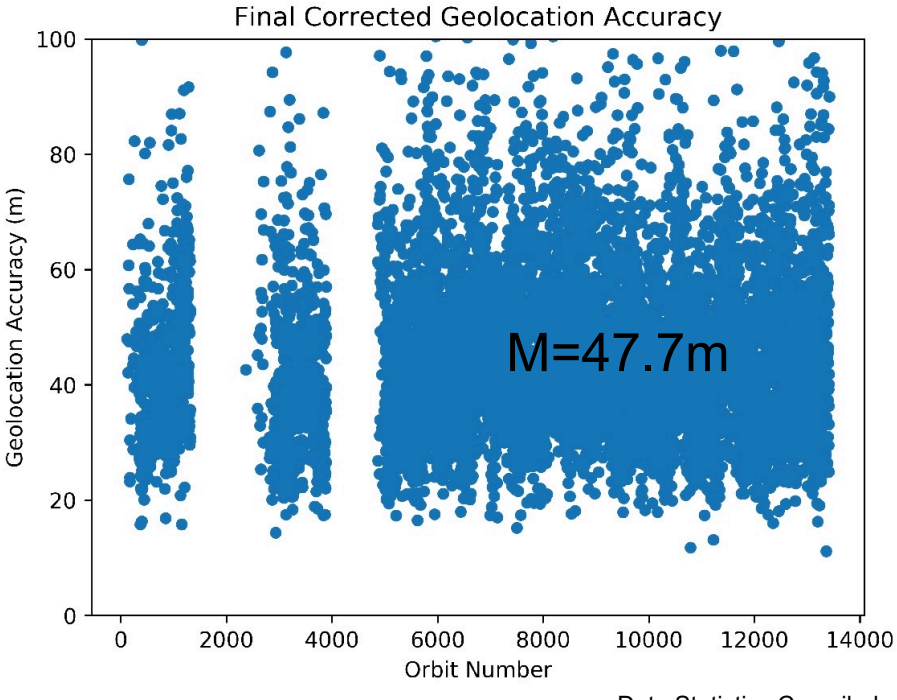
Geolocation Failed; Using ISS Attitude information

Matched Scene to orthobase
Failed Scene Matching due to Water, Clouds, Other

Typical Orbital Error Correction

- Plots of Individual Scene Errors Before and After Geolocation Correction
  - Average 2.2 kilometer Error Reduces to 48 meters

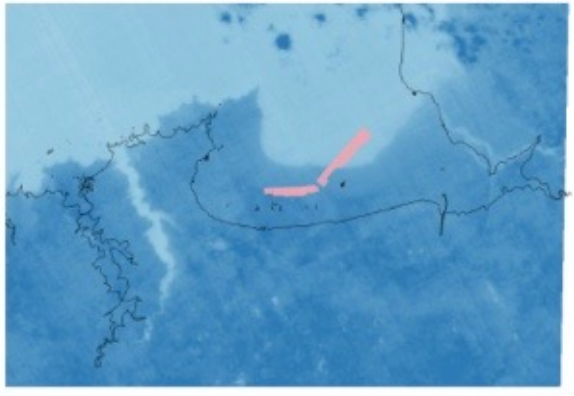




Data Statistics Compiled
17NOV2020

User Test Case

- Early morning scenes can be difficult to register to the Landsat TIR orthobase because of variable overnight temperature cooling effects upon the local terrain. A few false starting matches (bad seed) can then produce mis-registration errors.

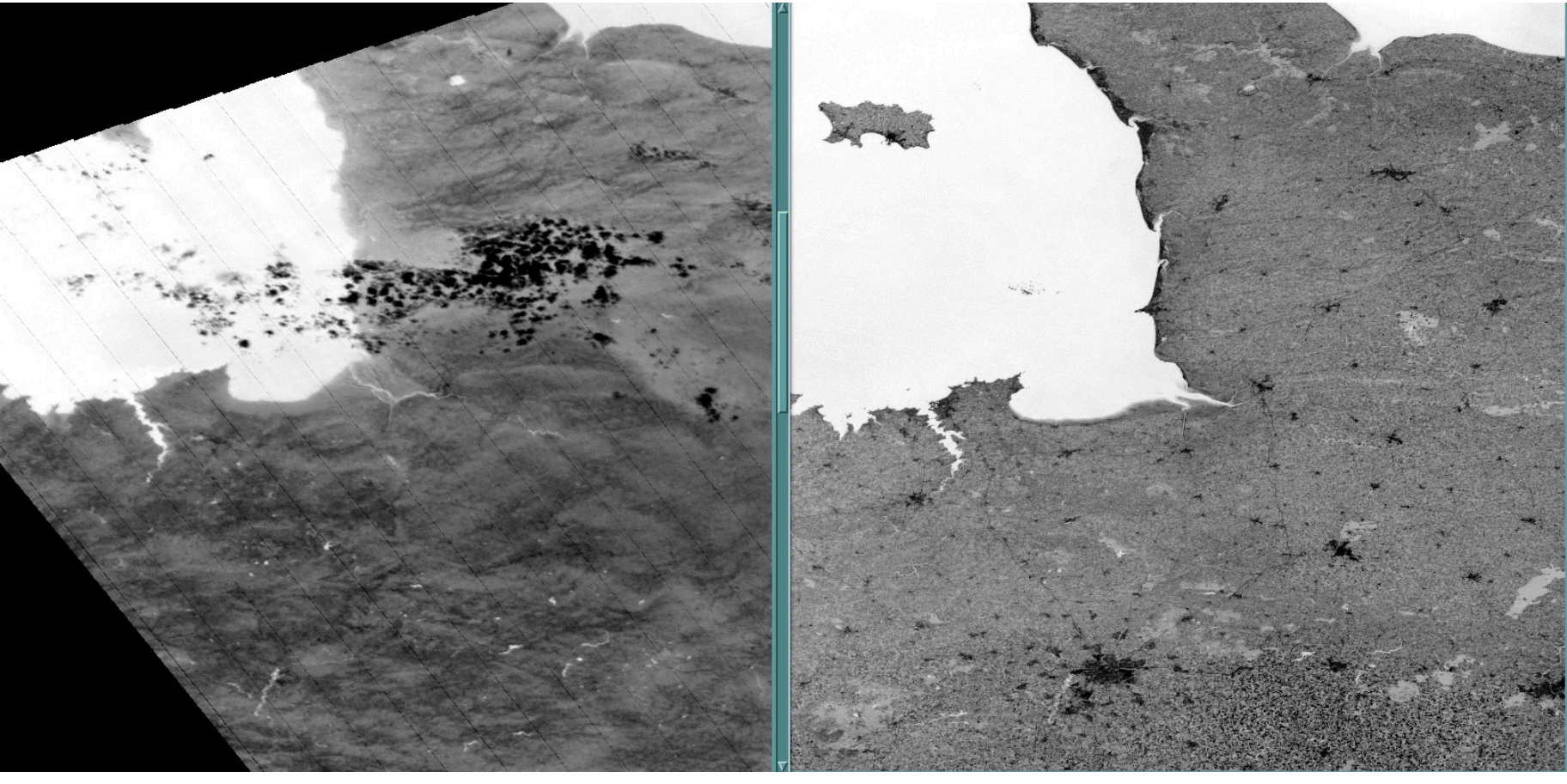


3798_001 No clouds **8.8 km error**
Build ID 0503
Orbit Correction TRUE

(User-Supplied Picture)

L1B Geolocation

Early Morning Scenes Look the Least Like the Orthobase



ECOSTRESS 03798_001 B4 Scene Detail

Landsat7 TIR Orthobase Detail (inverted)

Build 7 Geolocation Improvements

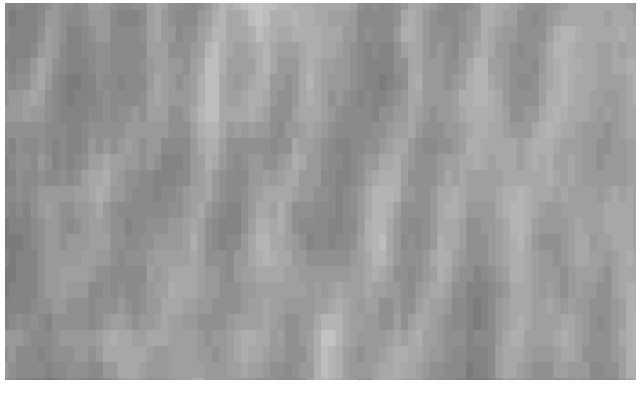
- Improved Geolocation QA Metadata:
  - Build6 Geolocation QA is binary: Match / No Match in Orbit
    - /L1GEOMetadata/OrbitCorrectionPerformed="TRUE"
    - A single metadata value represented the entire orbit.
    - Value indicates if matching occurred somewhere in the orbit, or failed everywhere.
    - Does not provide information as to the quality of the match.
  - Build7 Provides a more descriptive QA flag:
    - Best – Image matching was performed for this scene, expect good geolocation accuracy.
    - Good – Image matching was performed on a nearby scene, and correction has been interpolated/extrapolated. Expect good geolocation accuracy.
    - Suspect – Matched somewhere in the orbit. Expect better geolocation than orbits w/o image matching, but may still have large errors.
    - No Match – No matches in the orbit. Expect largest geolocation errors.

Build7 Geolocation Improvements (cont.)

- Improved Co-Registration and Geolocation:
  - Increased the number of FFTs attempts per image scene to obtain more Tiepoints (~4400). At least 20 good (final) tiepoint matches are required.
  - On Fail, adjust specific parameters and try again.
  - **Up to 4 full-scene co-registration re-tries** are attempted.
  - Parameter modifications include:
    - Changing the initial spatial matching location (seed).
    - Increase/decrease the areal size of the FFT.
    - Relax least-squares tolerance.
- Initial Geolocation Improvement Results:
  - From 3,205 Build 7.0/7.1 orbits (07MAR2022 - 03NOV2022), 57,119 scenes were collected.
    - 16,074 scenes matched the first time.
    - 5,767 additional scenes matched after subsequent “on-fail” attempts.
      - 35% increase in total matched scenes.
    - 35,278 scenes were cloudy, ocean, or otherwise did not register.

Scan-to-Scan Alignment Issue

- A mis-alignment between adjacent Line Scan (swath segments) has been discussed and investigated.
  - Each Scan Swath Segment is 128 lines by 5400 samples and overlaps with it's adjacent top/bottom segments by 15-30 lines depending upon ISS altitude.
  - Studies suggest the average offset is ~1 pixel occurring near the ends of the mirror scan.
  - This may be due to a slight mis-alignment between the two sides of the mirror, and given its' small size and variable occurrence, is difficult to correct.
  - The situation will be monitored for future changes and possible correction.



Faint Scan Line Offset in L1B Data?

"Checkerboard" Issue

- The "checkerboard" pattern occurs in the (1-30 pixel) overlap area between adjacent scan swath segments.
  - It is due to a non-uniformity in the focal plane array (FPA), where the FPA 'beginning' and 'ends' have a slightly different bias.
  - When processed as L2+ products, the top and bottom overlap areas between the two adjacent FPAs process to a *slightly different* model value (due to the bias).
  - The very close mapping between FPAs results in the nearest-neighbor remapping algorithm picking alternate pixels from the two FPAs producing the "checkerboard."
  - To avoid averaging or interpolating data pixels (a mission priority), users will need to apply their own local solution as necessary.

"Checkerboard" Pattern in L2/LSTE Data

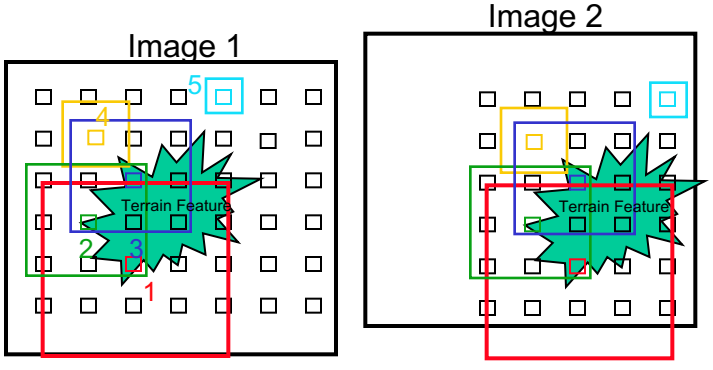
Backup

FFT Co-Registration Approach

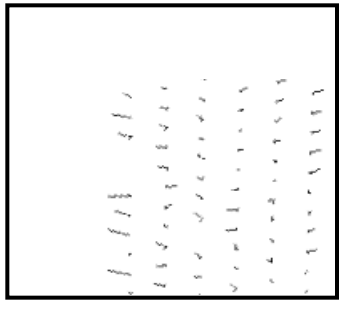
- AFIDS FFT Approach
  - Uses a grid of 2-D Fast Fourier Transforms (FFTs*) to produce tie points between images.
  - The FFT's Size initially starts out big (to cover large geographic areas) in order to catch the offset between two images, then reduces in size as the ability to predict the next tie point location improves.
  - A list of tie point matches with correlation and offset values is produced and processed to remove outliers.
  - The remaining best correlation points are used to create a polynomial fit between the two images and generate an ultra fine resolution correction grid.
  - A triangular interpolation between points in the correction grid is used to war/register the two images together.

*C.D. Kuglin and D.C. Hines, "The Phase Correlation Image Alignment Method," Proc. Int. Conference on Cybernetics & Society, pp. 163-165., 1975.

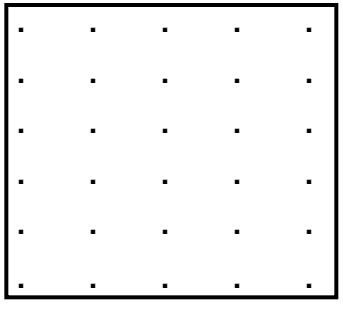
AFIDS FFT Tiepoint Interpolation Approach



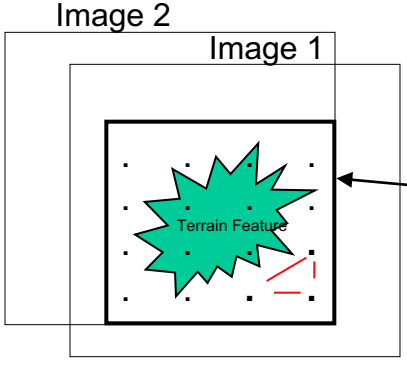
A grid of FFT tiepoints is used to match two images. FFT size starts large then decreases as matching becomes reliable. Tie point matching location order is randomly controlled by a "seed" value.



A subset of tiepoints are selected based on correlation score and offsets. Outliers are discarded. The maximum number of FFTs is 4096.



A polynomial fit is applied to the tiepoints to create an Ultra Fine grid of registration correction points. Fit options include Quad, Cubic, Linear, Keystone, and Thiessen.



A triangular interpolation is performed between points in the correction grid to produced the final registered image.