ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

ECOSTRESS

L1 Radiance at Sensor & Instrument Design
Science and Applications Team Meeting
11FEB2020

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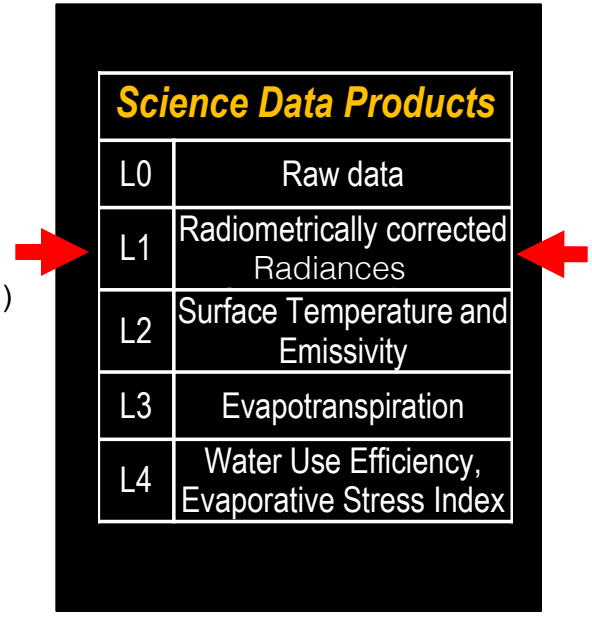
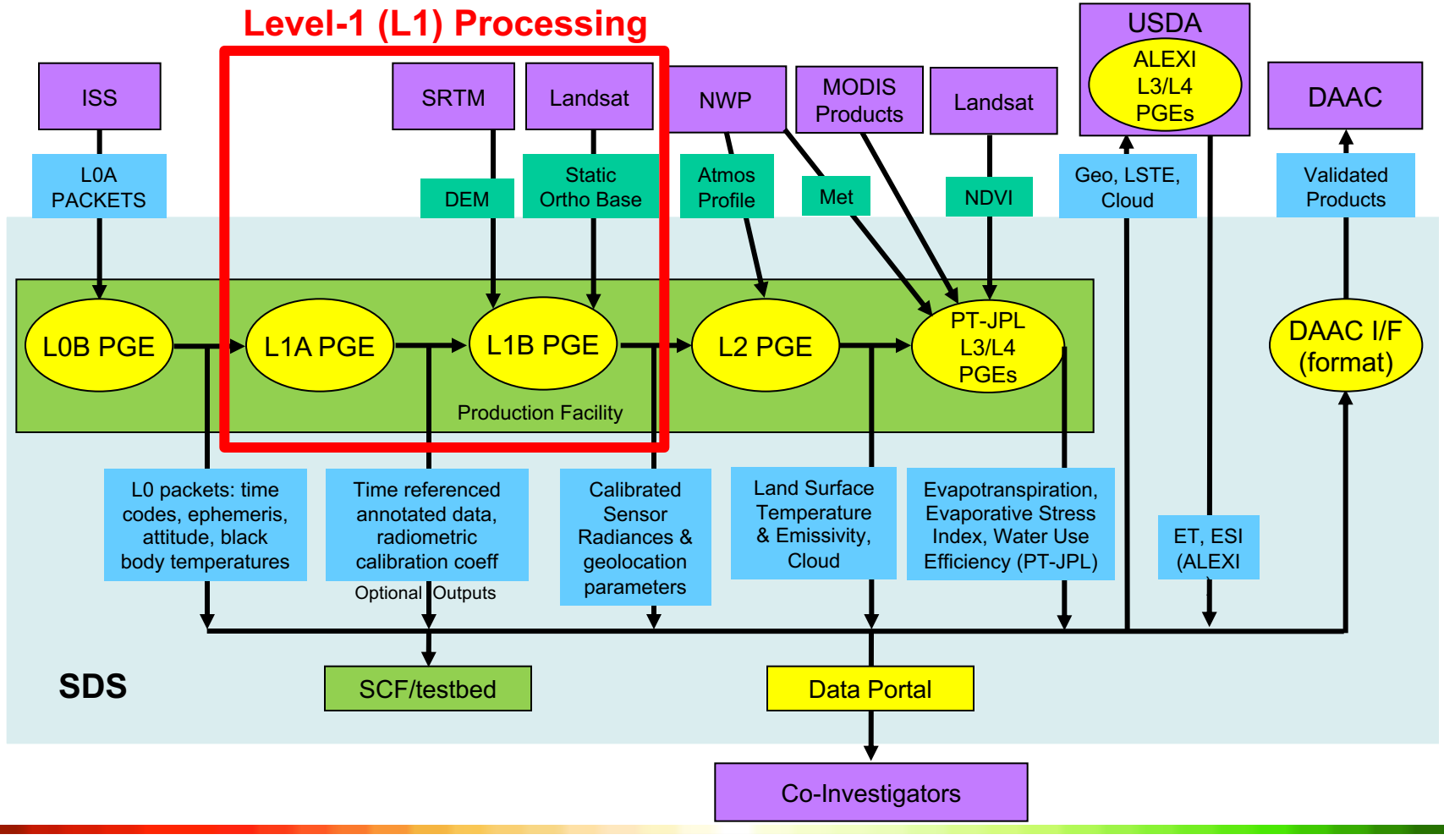
Level-1 Introduction

- Level-1 (L1) is part of the Science Data System (SDS), where the SDS:
  - Creates L0, L1, L2, L3, and L4 products, and
  - Delivers products to the Land Process DAAC (Sioux Falls, SD)
- Level-1 Inputs include:
  - L0 Data
    - Raw Image Data Packets
      - Ground Imagery and BlackBody packets
    - Spacecraft Orbital Metadata
  - Ancillary Data
    - Landsat Ortho-Rectified Image Base (geolocation)
    - Digital Terrain Models (pass-through)
      - Elevation
      - Land/Water Mask
- Level-1 Outputs include:
  - Calibrated Radiance images with
  - Geolocation (position) and
  - Associated metadata



L1 Overview

SDS Processing Flow

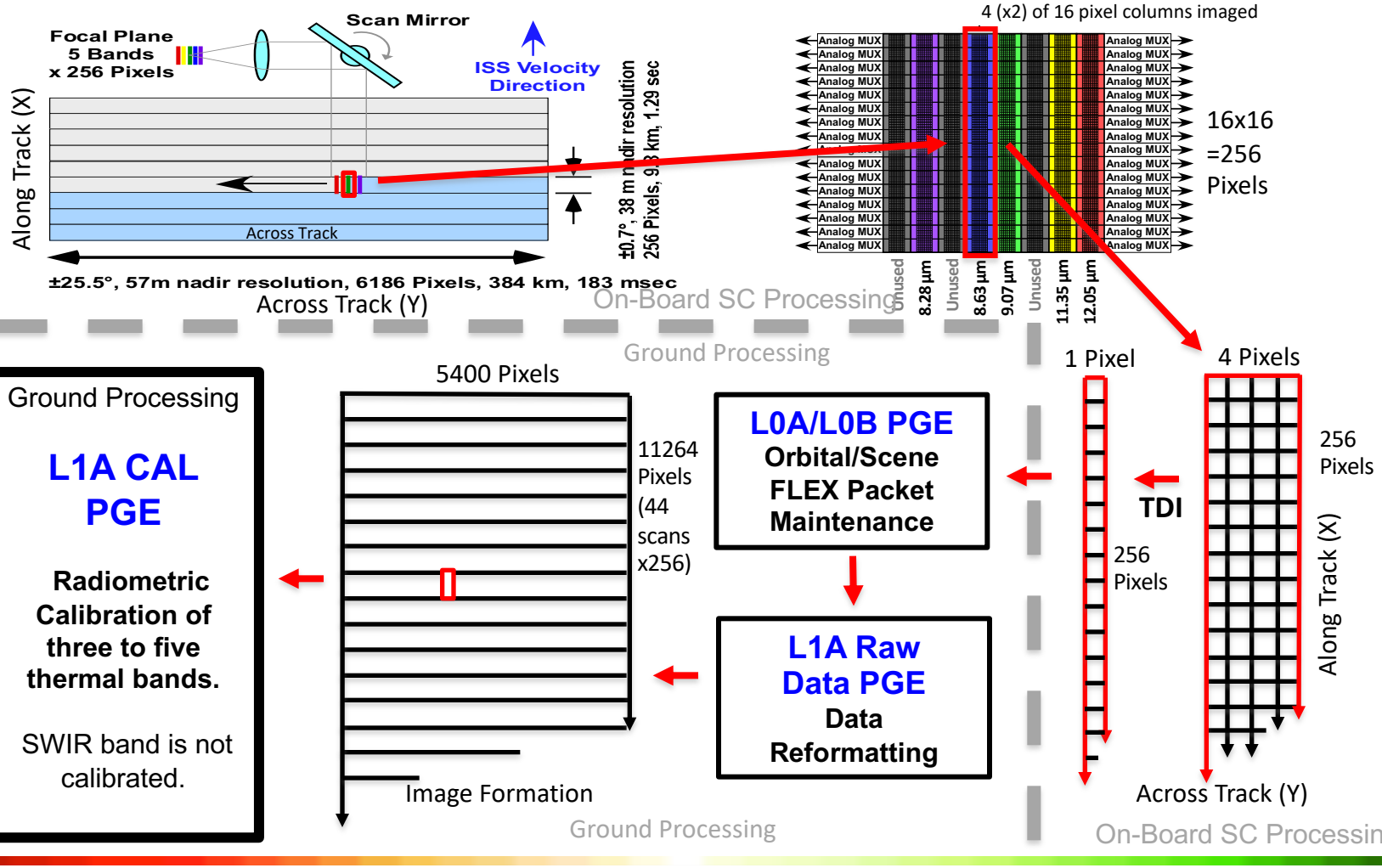


L1 Overview

- L1 Processing consists of four PGEs (Product Generation Executives)
  - L1A
    - Raw Data Processing (Chu)
      - Reformat Incoming ISS data packets, metadata, and ancillary data
        - Formulate Focal Plane (FPA) Earth images by spectral band DNs
        - Formulate on-board FPA Blackbody Calibration image DNs
    - Radiometric Calibration (Logan and Johnson)
      - Convert Image Pixel DNs to Radiance Coefficients
        - FPA Blackbody temperatures are converted to radiances using the Planck function.
        - FPA DNs are converted to radiance values using a two-point affine transformation. Conversions are stored as coefficients.
  - L1B
    - Resampling and Radiance Delivery (Smyth)
      - Merge Focal Plane overlap and average pixels (lines) to improve signal.
      - Fill Missing Data (Nguyen and Hulley)
    - Geolocation (Smyth)
      - Geolocation Matching (using Landsat orthobase) to correct for Positional Errors
      - Geolocated L1B Products

L0 Inputs to L1A Raw Data PGE

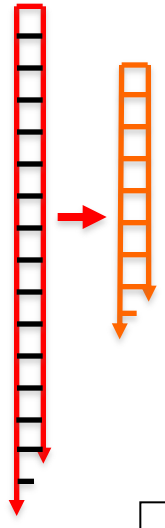
L0 to L1 Travel Path of the ECOSTRESS Pixel



L1B Resampling

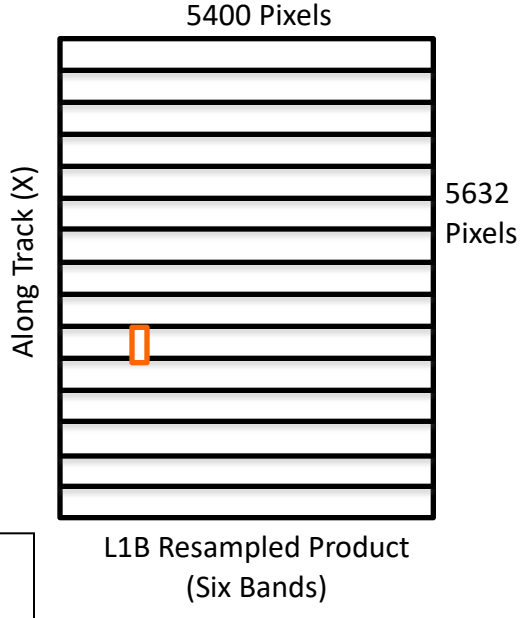
Processing

1) Average FPA 2-to-1 to improve signal



2) Composite multiple FPAs into one image
3) Fill Dropped Lines

Output



- L1B Corrections Include:
  - FPA Overlap
  - Resampling
  - Optical Distortion Removal
  - Data Fill for Dropped Lines using Machine Learning

L1A Radiometric Calibration Steps*

- Purpose: Convert Image TIR DNs to Radiance
  - Procedure for each image:
    - Read temperatures from Sensor's Cold (~295K) and Hot (~325K) Blackbodies.
    - Create synthetic FPA temperature images of Cold and Hot Blackbodies and convert them to Radiance (Watt/m2/sr/um) using the center wavelength of each TIR band and the Planck function.
    - Collect push-whisk FPA Digital Number (DN) scans of the Cold and Hot Blackbodies And Ground for all wavelengths.
    - Using the FPA Radiance values and corresponding FPA DNs, use a two-point affine transformation (creating gain/offset coefficients) to convert each Ground pixel's DN to Radiance.

- Accuracy is expected to be ~1.0 Kelvin. The Science Team can also choose between two Planck algorithms and linearly fine tune each TIR band radiance.

- TOA Radiance and Temperature images can be generated for Validation and Verification purposes as necessary.

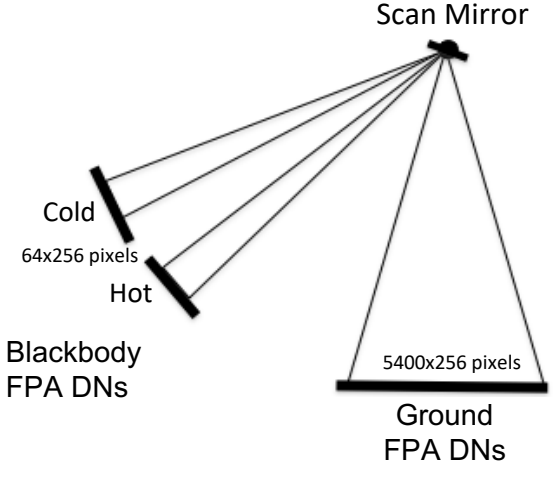
- SWIR band is not radiometrically calibrated. It was intended for Geolocation "matching," but provided unsuitable. It maybe provided as a non-science "visual" product.

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

L1A Radiometric Two-Point Calibration*

Approach

- Read BB 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)*

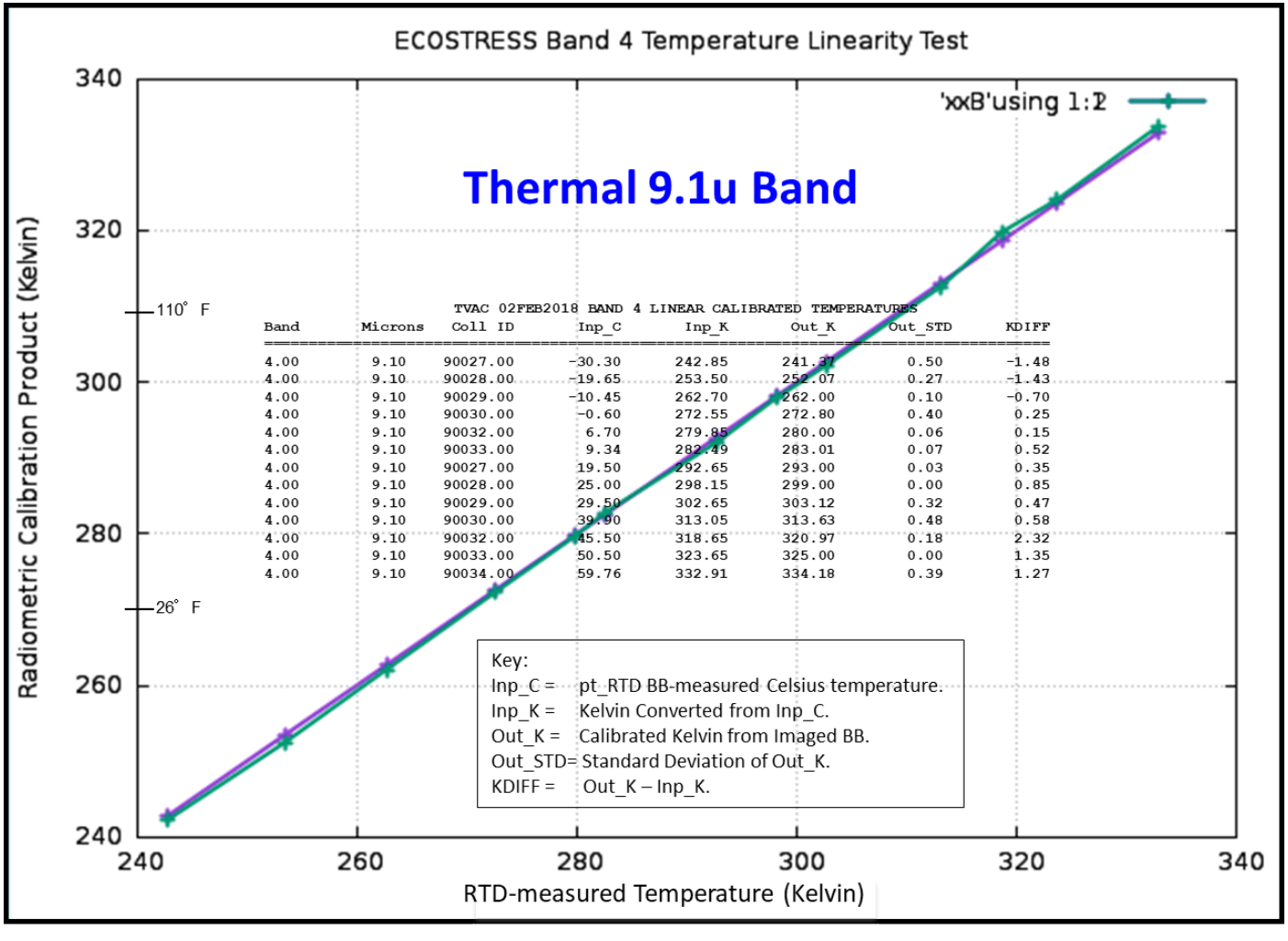
R_h = *Radiance of the Hot Blackbody (Section 3.3.2)*

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.

Pre-Launch Performance (20180202)

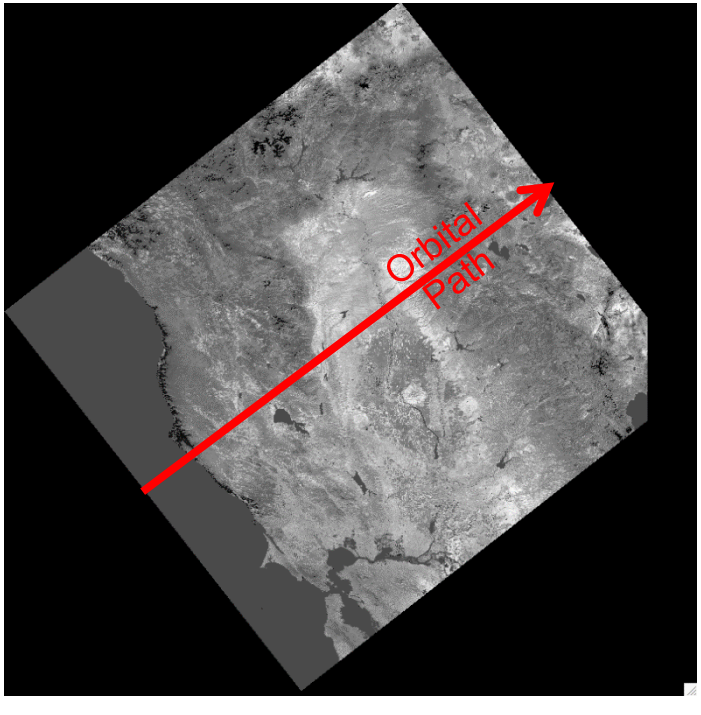


L1B Geolocation*

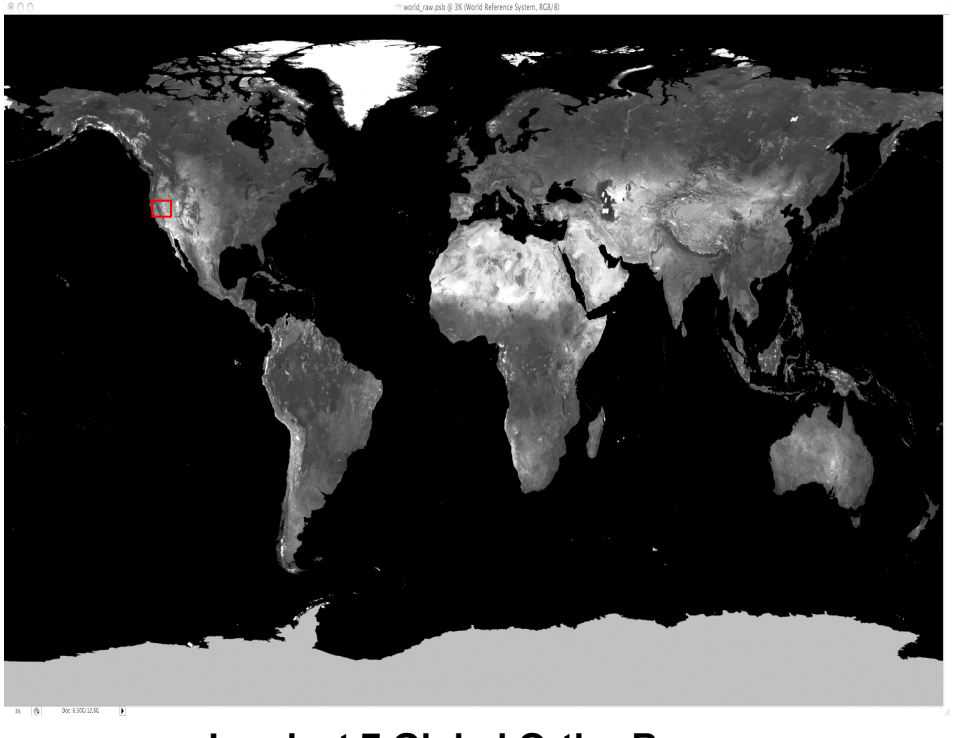
- Purpose: Calculate the Latitude and Longitude of each image pixel.
  - Corrections for Small Errors (less than 2 pixels):
    - Focal Plane Scan-Line Offsets.
    - ISS altitude, pitch, yaw, and roll.
    - Orbital position uncertainties and camera jitter.
  - Corrections for Large Errors (2.5km to 7.5km):
    - Attitude drift can be large (position must be extrapolated from the ISS. No Star Tracker).
      - Attitude correction is performed by co-registration/matching an ECOSTRESS TIR image with a similar ortho-rectified Landsat wavelength.
      - Testbed results suggest ECOSTRESS images with positional offset errors up to 12.5km can be geolocated to about 0.1pixel RMS.
- Geolocation accuracy meets the 50m positional requirement.
- Latitude and Longitude coordinates are extracted and supplied for each input 75x68m ECOSTRESS pixel. Note that pixel size will vary with ISS Altitude.

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

Position Correction
ECOSTRESS TIR Band Registered to Landsat TIR Ortho-Base



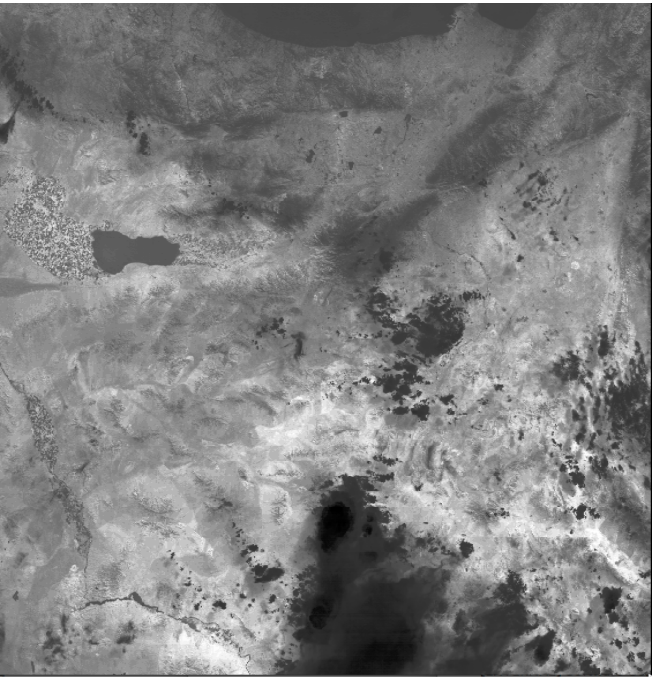
ECOSTRESS TIR Band
Simulated from ASTER Band14 (11u)
With Rotation for Geolocation Matching



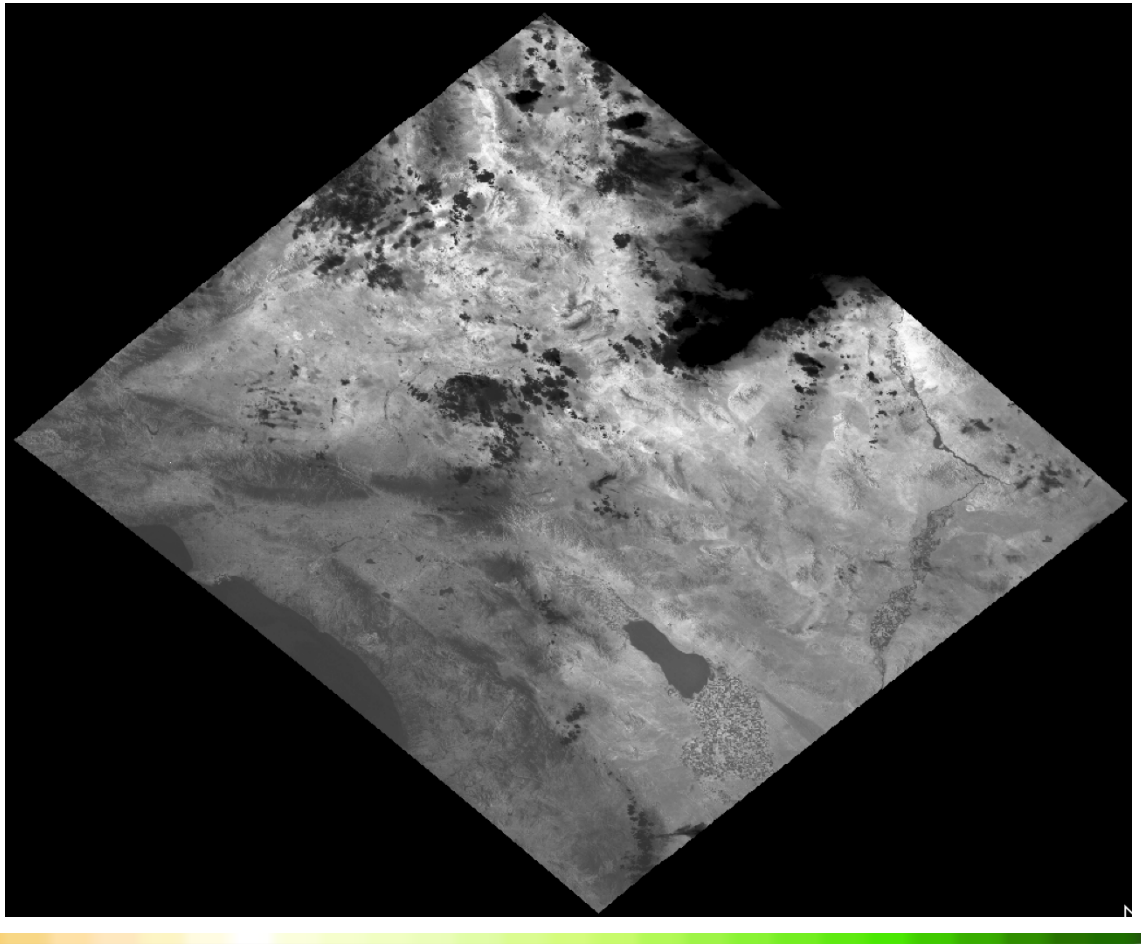
Landsat 7 Global Ortho-Base
Band6 (TIR) Band (10.4-12.5u)
Co-Registration provides precise Geolocation

L1B Geolocation PGE

TOA Radiance Swath



Mapped TOA Radiance*



*With rotation to North/South

L1 Product

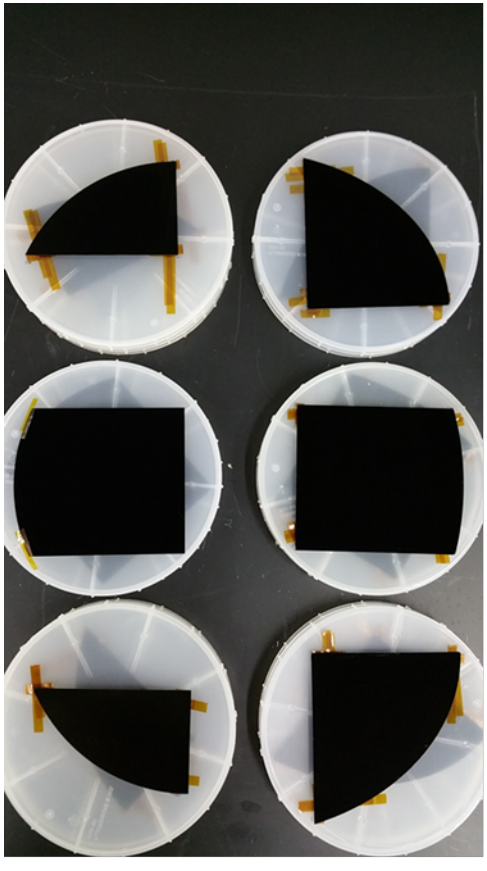
Has anything changed recently? What are the current topics?

- Modifying the firmware to optionally choose between the current 3 bands with more collects versus 5 bands with fewer collects
- GeoTIFF generation in addition to the hdf5 products: For L1B, only the map-rad will have an added GeoTIFF. Most of the new GeoTIFFs will be for L2, L3-4

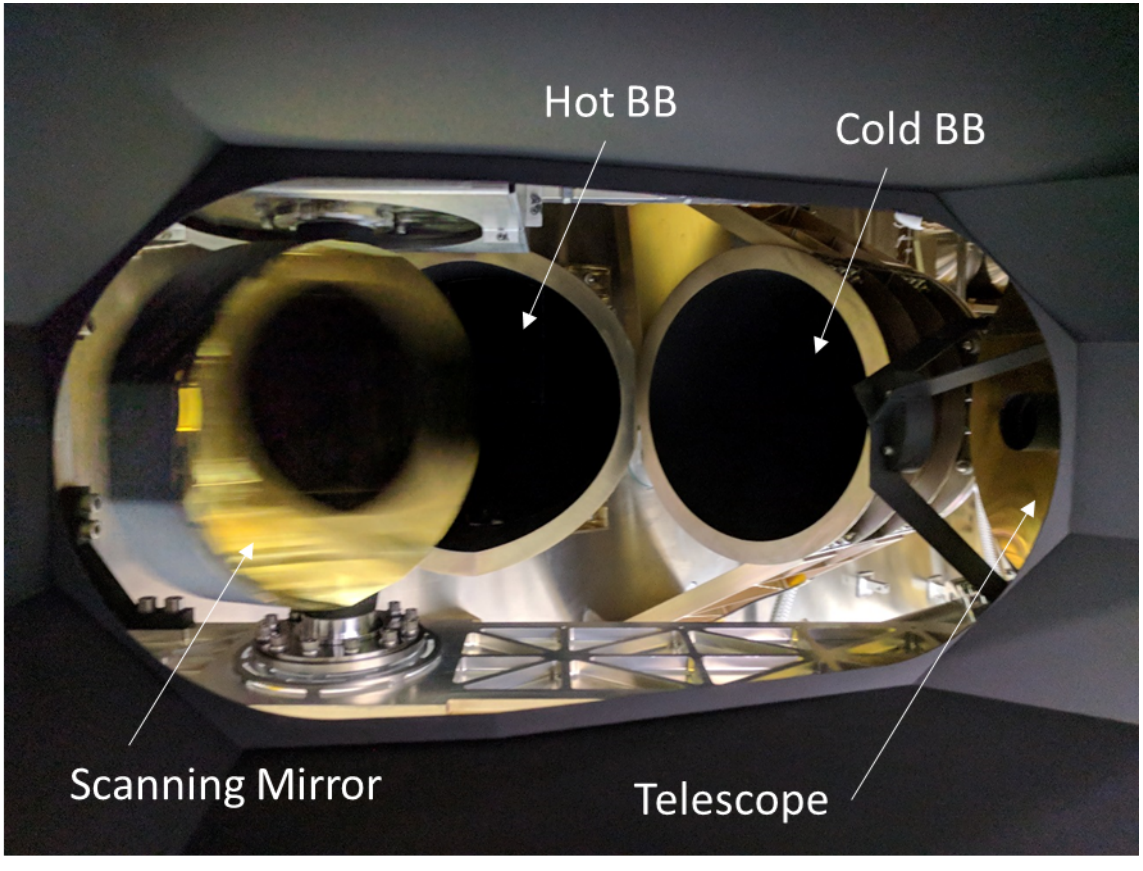
Calibration System

Has the ECOSTRESS calibration system changed since launch?

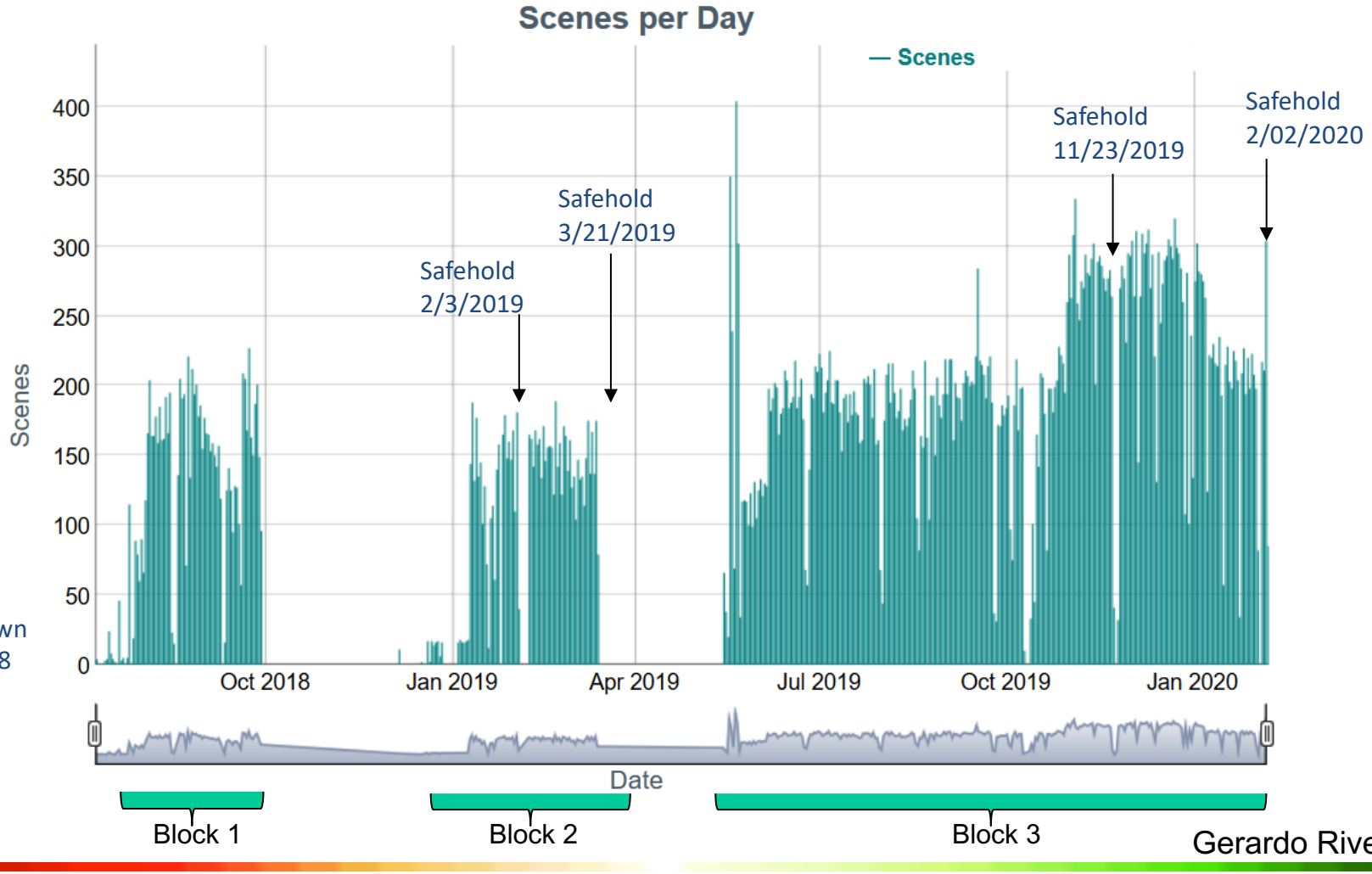
Calibration System



Black silicon wafer pieces used for mosaic



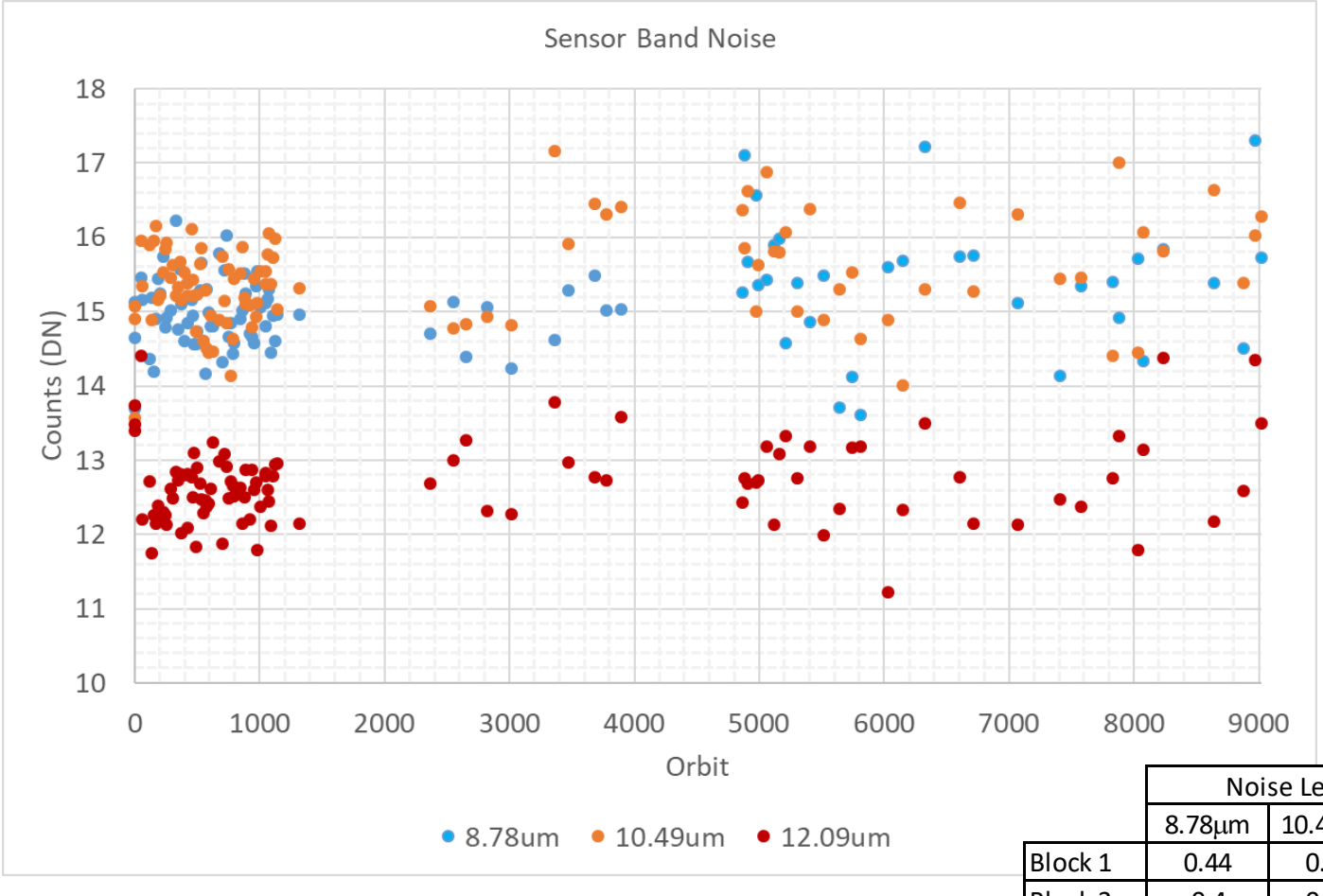
ECOSTRESS Acquired Scenes



First Cooldown 7/2018

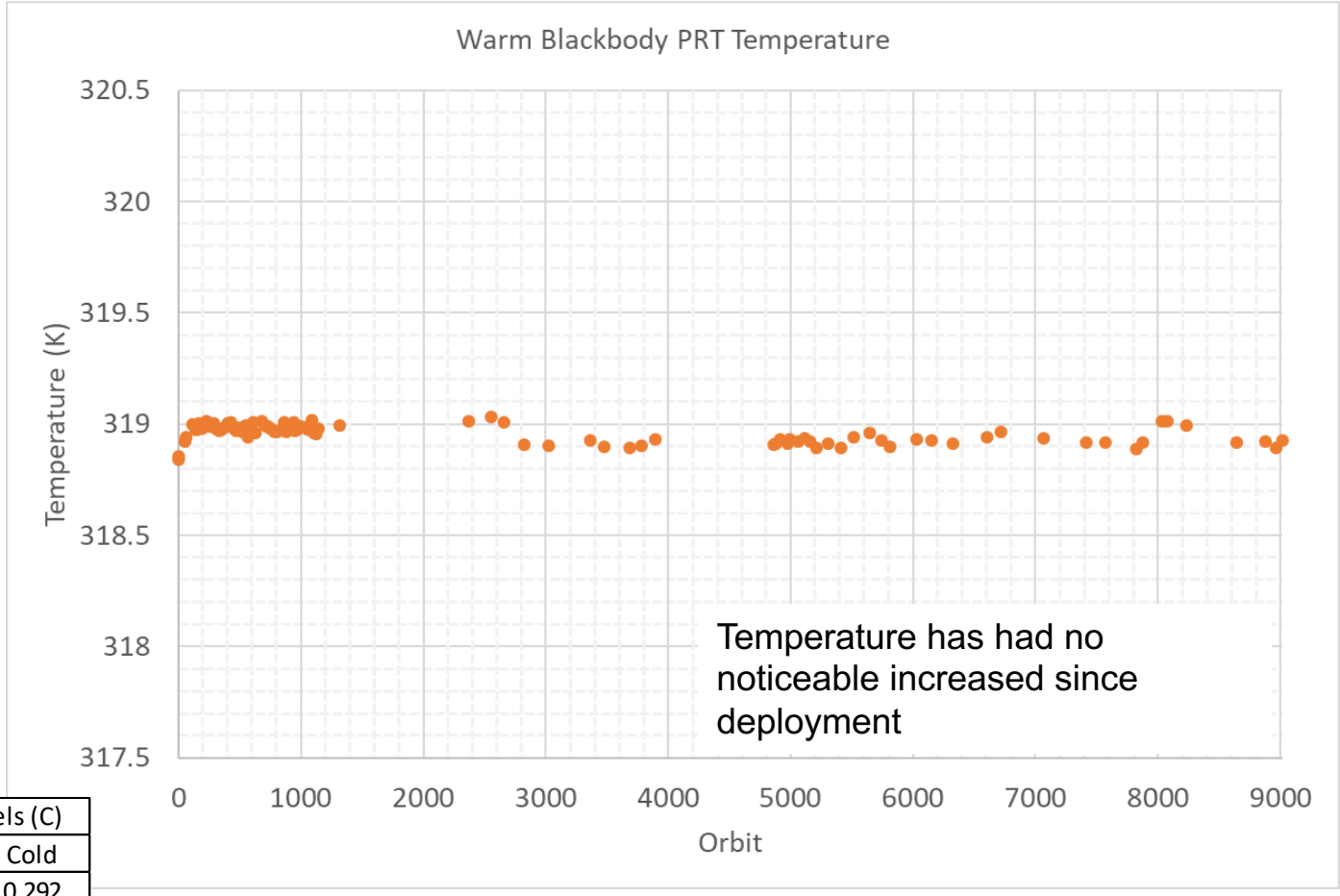
Gerardo Rivera

Calibration System



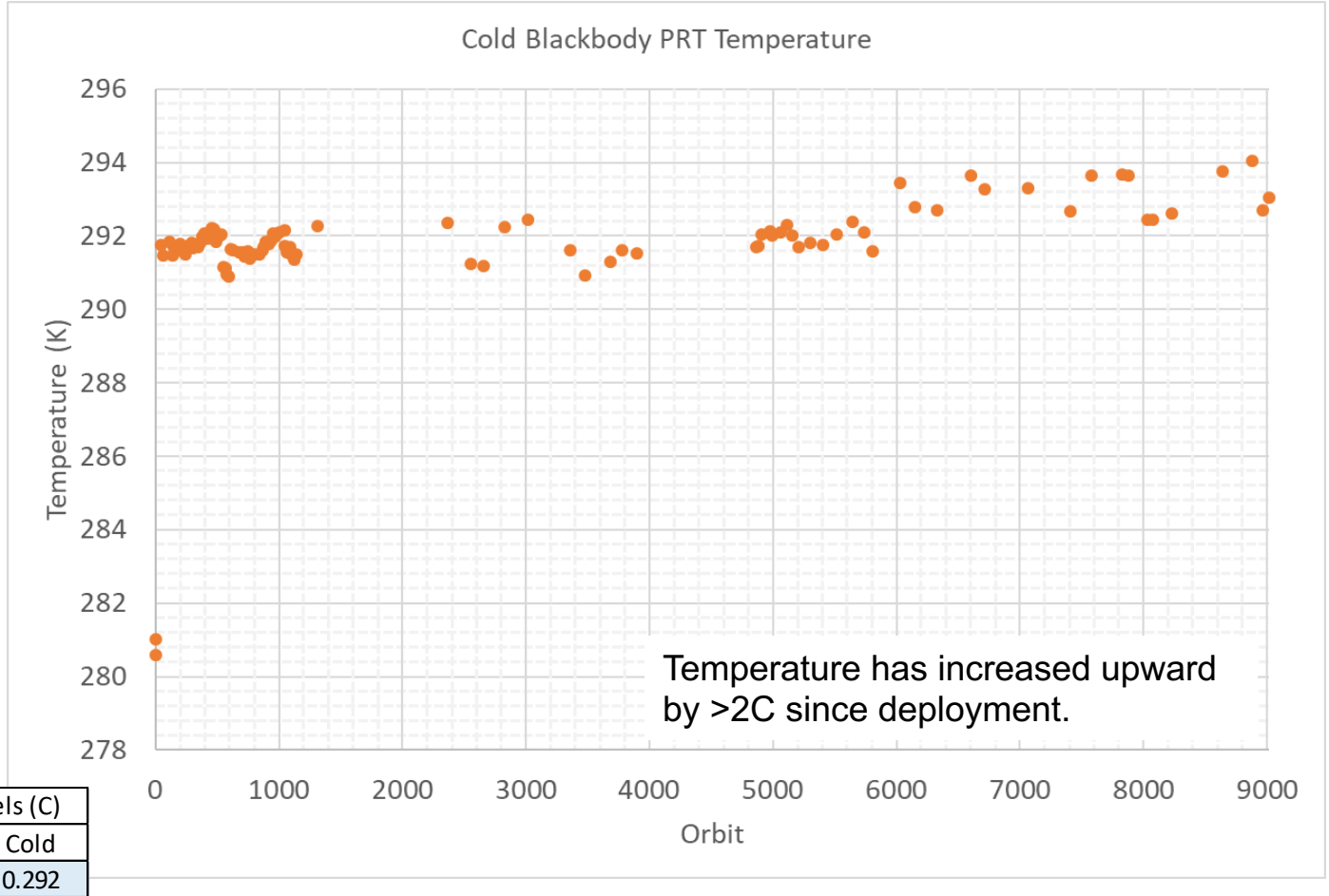
	Noise Levels (DN)		
	8.78µm	10.49µm	12.09mm
Block 1	0.44	0.46	0.52
Block 2	0.4	0.88	0.49
Block 3	0.9	0.75	0.67

Calibration System



	Noise Levels (C)	
	Warm	Cold
Block 1	0.018	0.292
Block 2	0.054	0.524
Block 3	0.031	0.734

Calibration System



	Noise Levels (C)	
	Warm	Cold
Block 1	0.018	0.292
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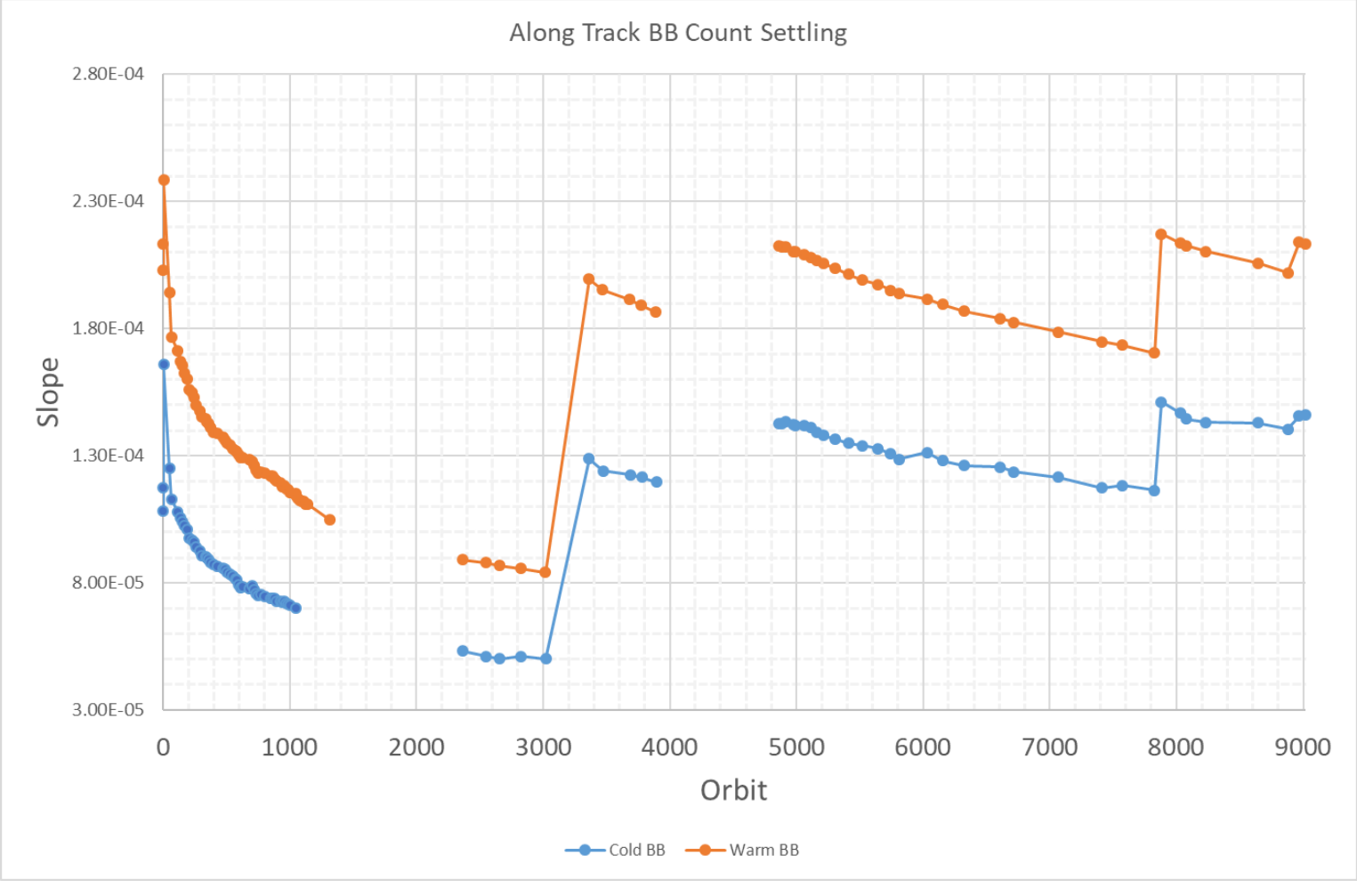
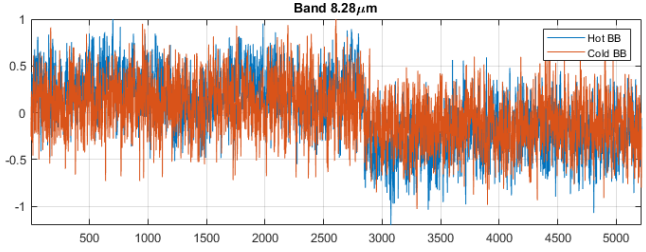
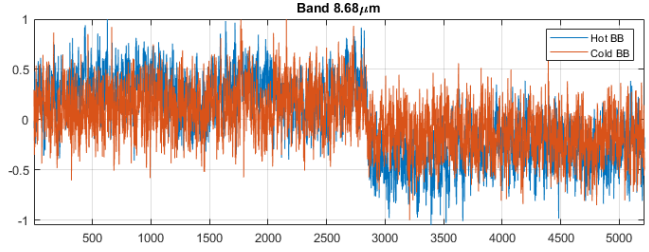
Block 3	0.031	0.734

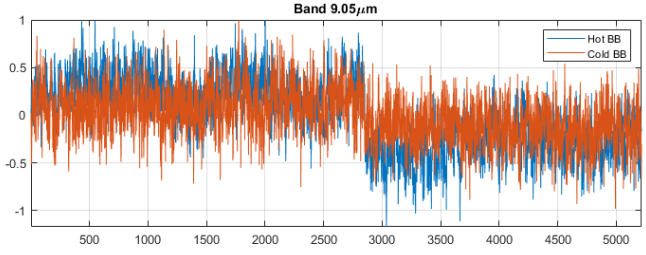
Along Track Stability

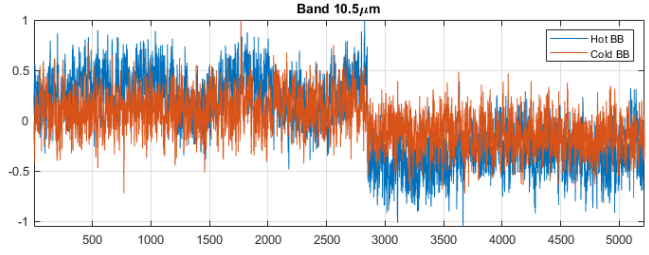


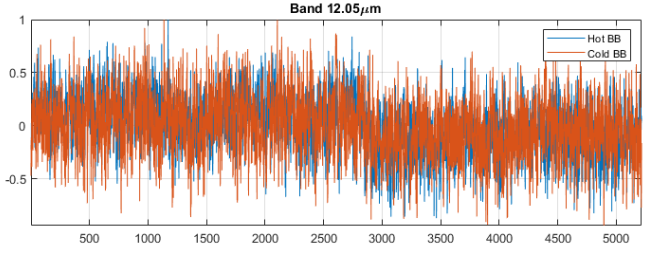
Day vs. Night BB Observations

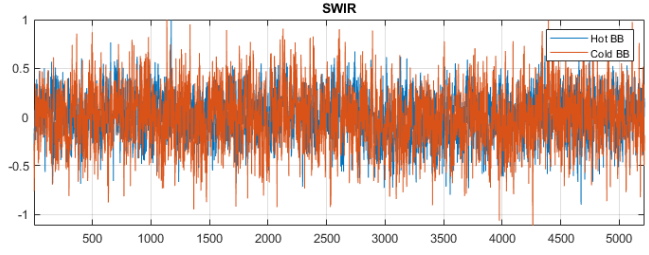






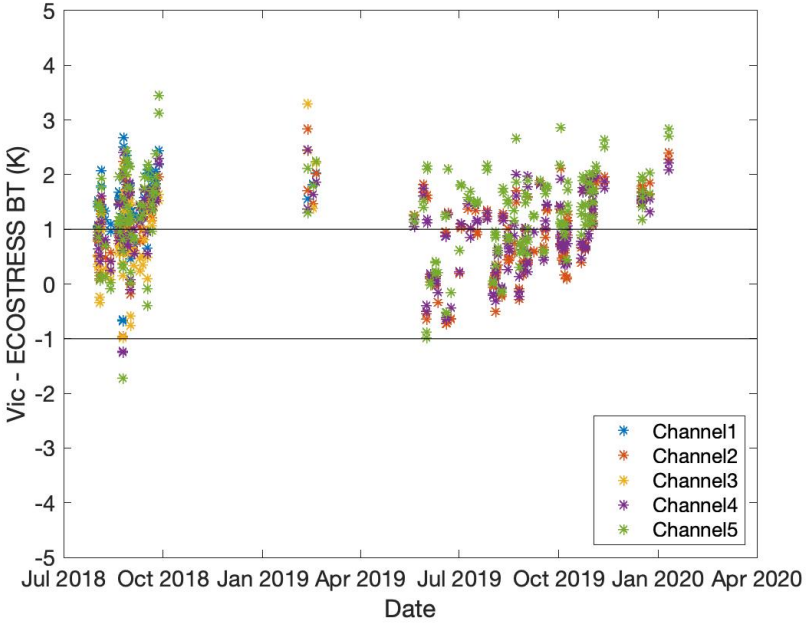


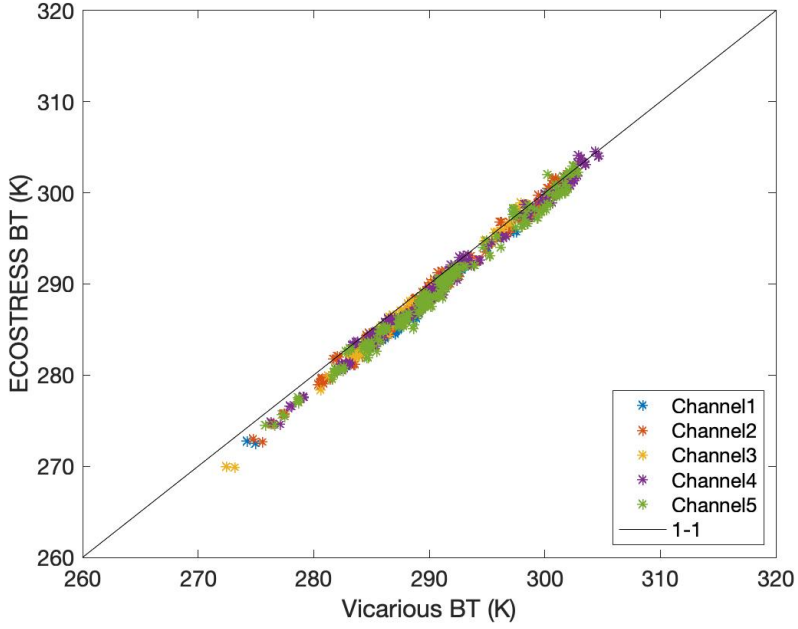




On-Orbit Vicarious Performance

Tahoe and Salton Sea Cal/Val Sites





Kerry Cawse-Nicholson & Robert Radocinski

L1 Process Summary & Products