



*ECOsystème Spaceborne Thermal Radiometer
Experiment on Space Station*

L1B Geolocation Review

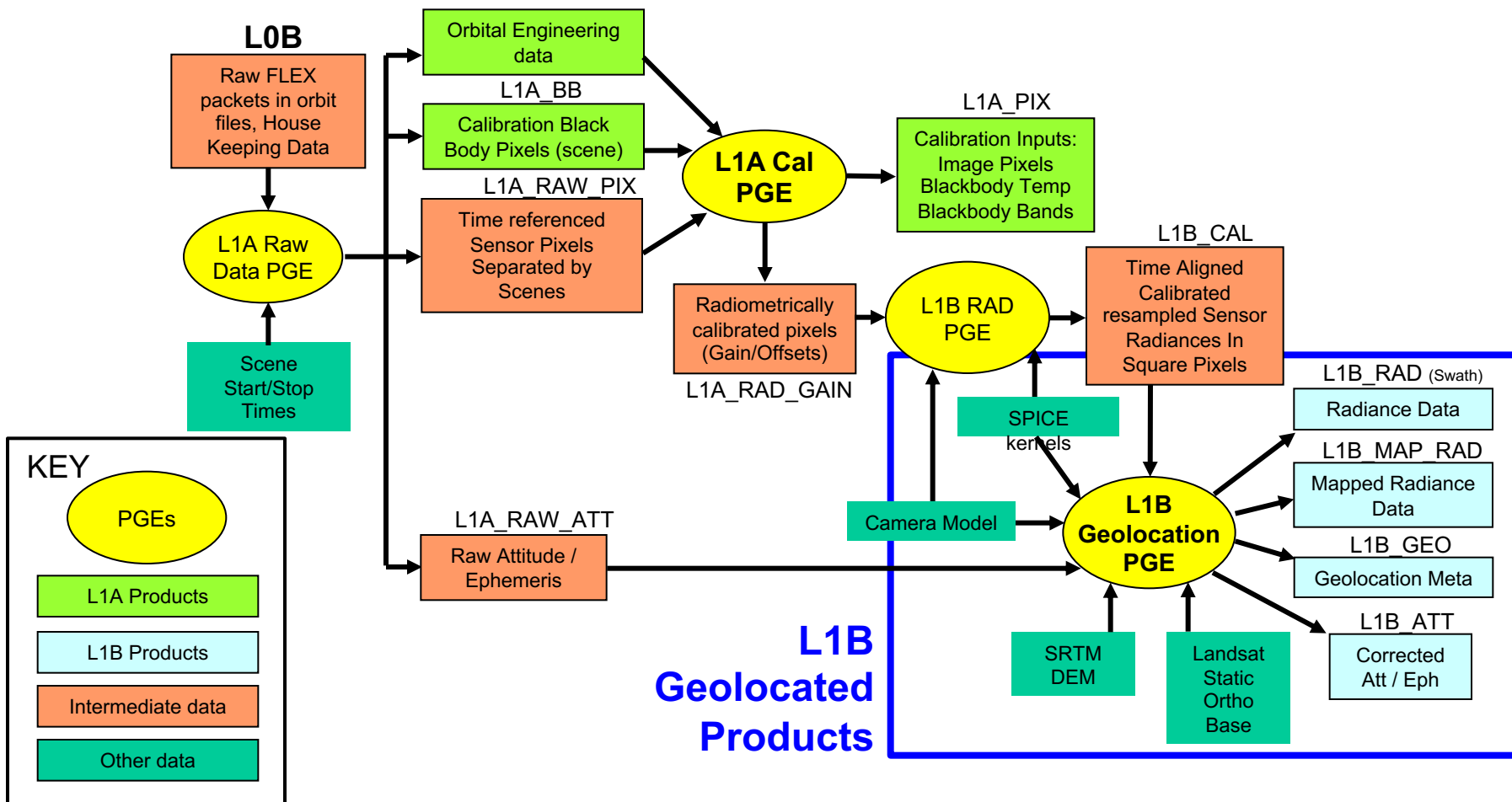
Science Team Meeting
01DEC2020

Michael M. Smyth, JPL

Thomas L. Logan, JPL (Presenter)

Jet Propulsion Laboratory, California Institute of Technology

L1 Data Flow Diagram





L1B Geolocation

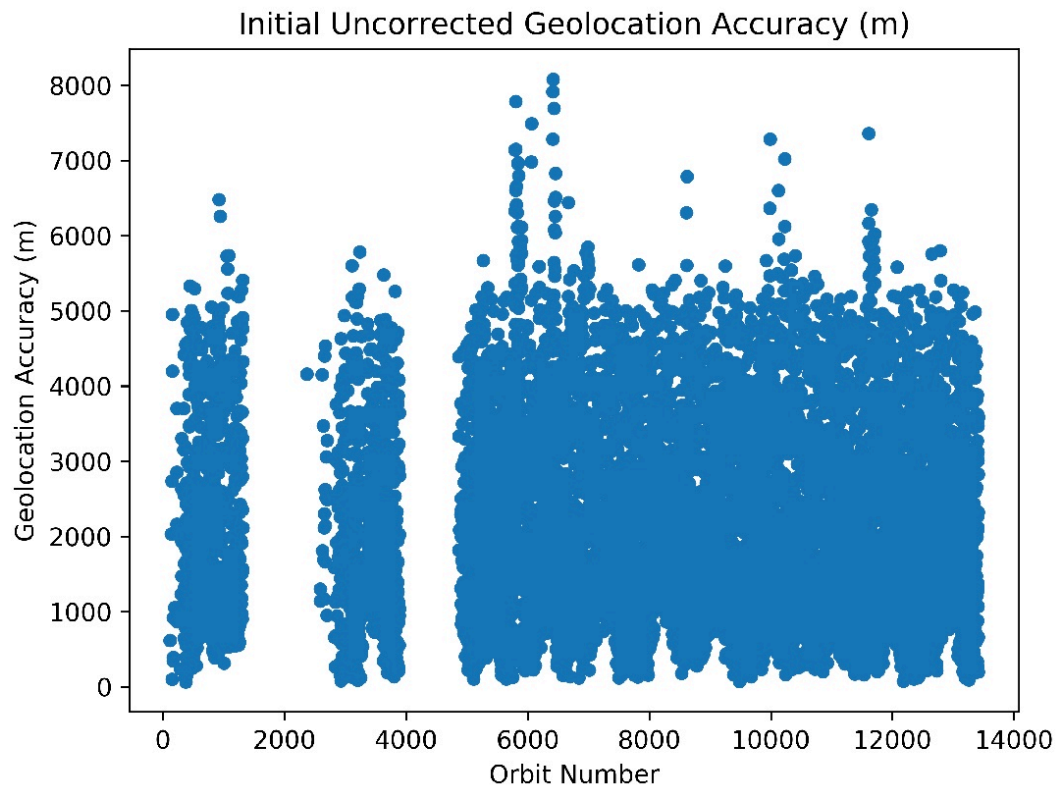
- Geolocation calculates the Latitude and Longitude of each image pixel.
- Geolocation is calculated from Spacecraft Attitude or Attitude corrected by an Orthobase.
 - ECOSTRESS does **not** have a Star Tracker for attitude/orientation correction.
 - ECOSTRESS extrapolates ephemeris/pointing/timing (BAD*) information from the ISS to the camera system on the JEM module and 1553 HK/Telemetry Data.
 - Errors include ISS altitude, pitch, yaw, roll, time, drift, and camera jitter.
 - Composited 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 mosaic.
 - The ortho-mosaic is based on Landsat7 imagery circa 2000.
 - The estimated positional accuracy of the mosaic is 0.5-0.6 pixel (Pan).
- Pixel Latitude and Longitude coordinates are passed to L2 processing.
- A gridded Orthomap of L1B Radiance is also produced.

* BAD: ISS Broadcast Ancillary Data

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

Typical (Uncorrected) Orbital Error

- Initial orbital error
 - Plot of Individual Scene Errors (from 8522 corrected orbits)



Data Statistics Compiled
17NOV2020

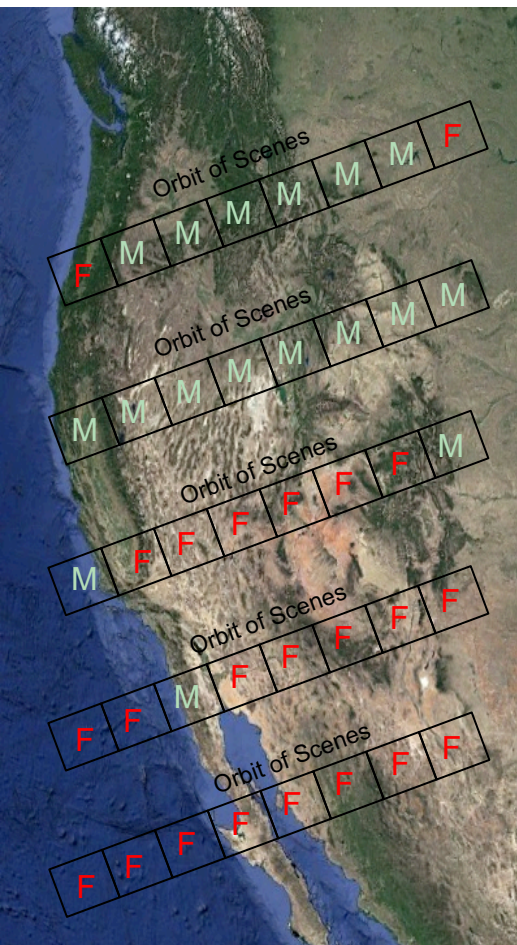


Geolocation From Co-Registration

- Geolocation correction is only possible for scenes where image matching 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; Poor Lighting; Non-Descript Terrain
- Images without Geolocation Matching use the available ISS positioning information which can be 2.5km to 7.5km from true geographic location.

L1B Geolocation PGE

Orbital Geolocation from Scene Matching



Orbital Attitude Geolocation extrapolated from **M**atched Scenes

Every Scene **M**atched and contributes to orbital Attitude

Geolocation for **F**ailed Scenes interpolated from Between **M**atched Scenes

Orbital Attitude extrapolated from Single **M**atched Scene

Geolocation Failed; Using ISS Attitude information

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



Geolocation Statistical Summary From First to Latest Orbit (Individual Scenes From 8522 Corrected Orbits*)

Parameter	Initial Uncorrected (m)	Final corrected (m)
Mean Error	2199.4	47.7
Standard Deviation	1357.4	56.4
Minimum Error	65.96	11.2
0-25% Range Mean	1090.3	34.4
25-50% Range Mean	1922.6	42.6
50-75% Range Mean	3171.1	53.7
Maximum Error (75-100% Range)	8078.8	2282.7

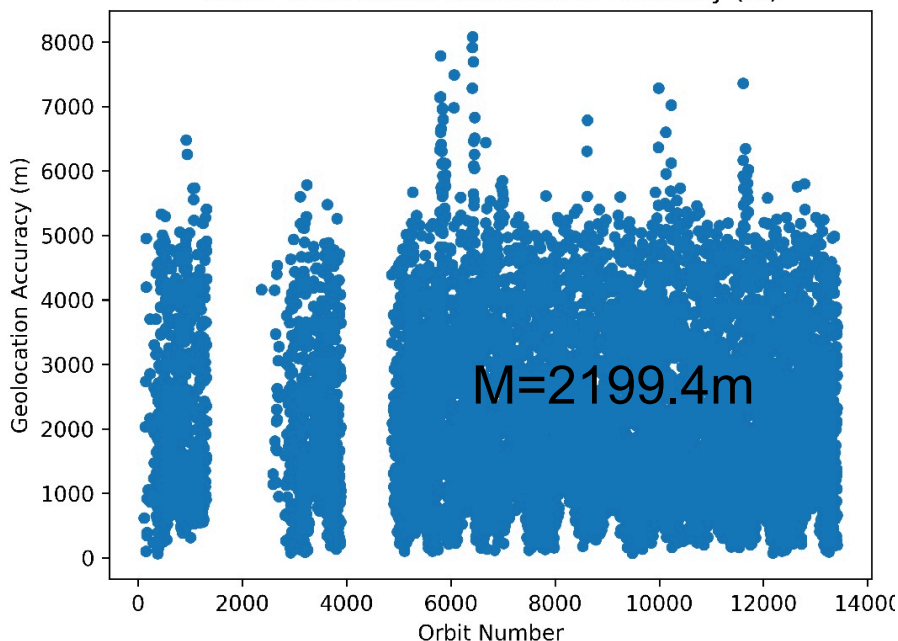
*Data Collected 17NOV2020 from 13416 Total Orbits

L1B Geolocation PGE

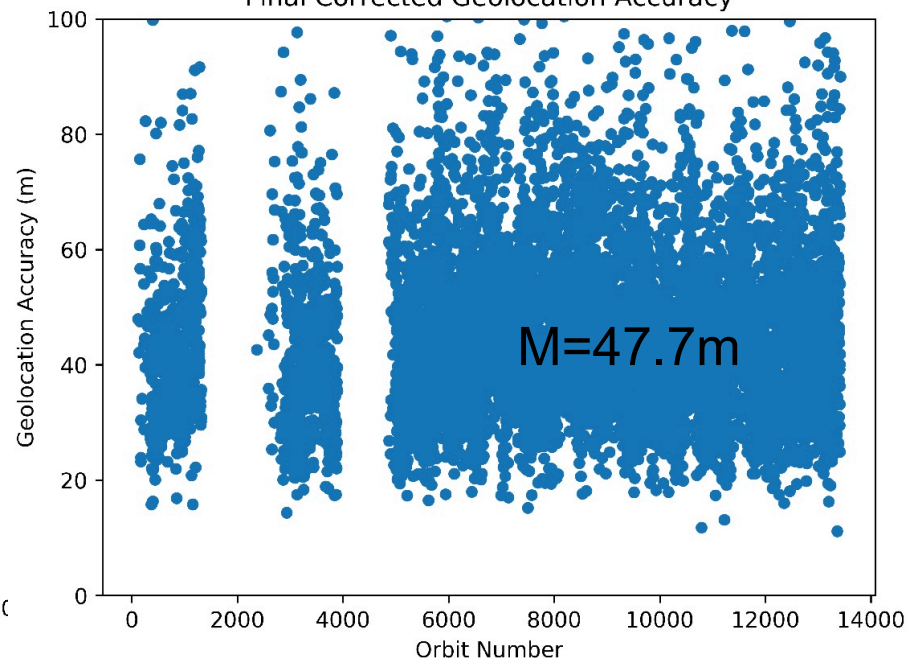
Typical Orbital Error Correction

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

Initial Uncorrected Geolocation Accuracy (m)



Final Corrected Geolocation Accuracy

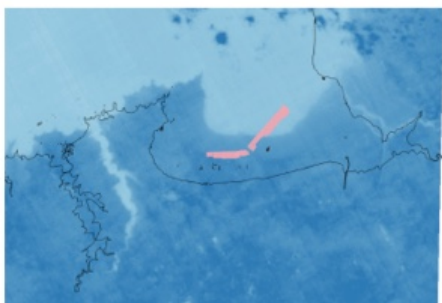


Data Statistics Compiled
17NOV2020

User-Identified Geolocation Issues

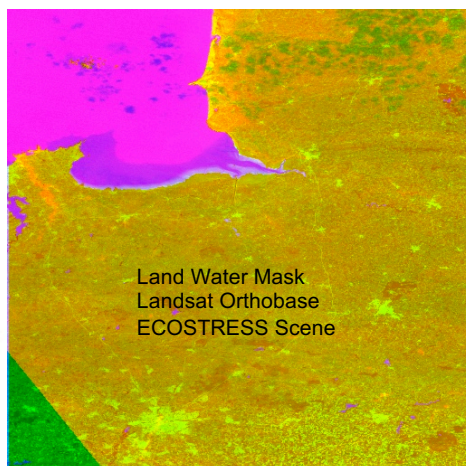
User Test Case 1

	Ex	Date / Orbit	Clouds?	Metadata	Distance Off	Pixel Shift	Build ID
User1	1	3798_001	None observed	Orbit Correction True Quality Flag PASS	8.8 km	125-126	0503

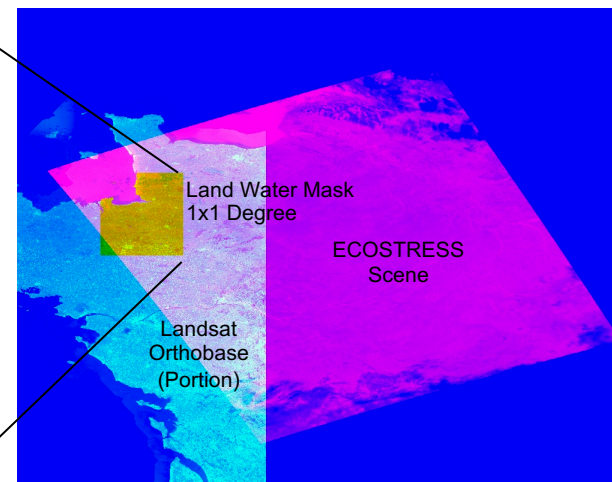


3798_001 No clouds **8.8 km error**
Build ID 0503
Orbit Correction TRUE

User-Supplied Pix



Error Confirmed.
Landsat & LWM Align, but
ECOSTRESS is Offset.



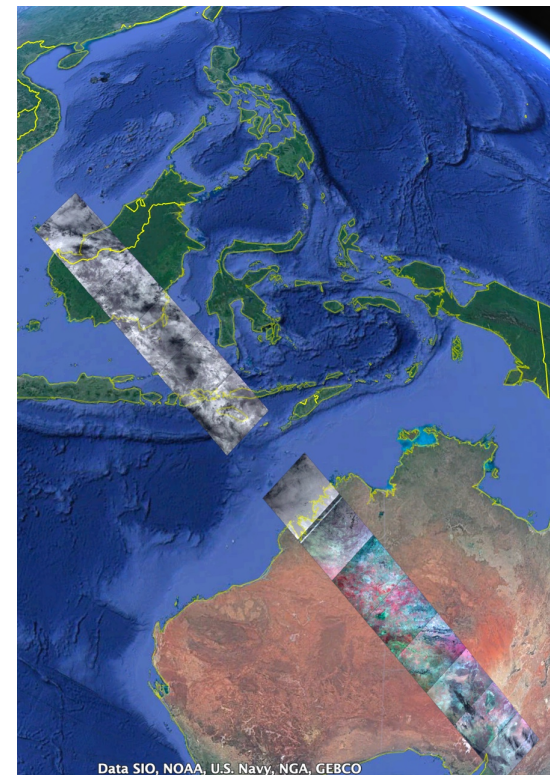
Overview

User-Identified Geolocation Issues

User1 Test Case L1B Geolocation Processing Statistics

Orbit Band	Initial Accuracy	Final Accuracy	Solar Zenith Angle	Land Fraction	Day or Night	Number of Tiepoints
03798_001	-9999	-9999	126.913	93.8097	Night	0
03798_002	-9999	-9999	123.746	99.6639	Night	1
03798_004	-9999	-9999	28.642	6.2461	Day	0
03798_005	-9999	-9999	25.923	95.9038	Day	5
03798_006	-9999	-9999	23.363	92.3781	Day	3
03798_007	-9999	-9999	21.021	18.7758	Day	1
03798_008	-9999	-9999	18.976	8.1861	Day	0
03798_009	-9999	-9999	17.336	15.9980	Day	1
03798_011	4088	39.1	15.7454	17.1619	Day	53
03798_012	4144	18.6	15.9790	99.715	Day	216
03798_013	4180	27.5	16.8767	99.886	Day	120
03798_014	4169	29.2	18.3409	99.700	Day	208
03798_015	4146	22.3	20.2484	99.412	Day	215
03798_016	4127	26.4	22.4856	99.784	Day	237
03798_017	4122	31.6	24.9630	90.509	Day	199
03798_018	4131	28.1	27.6151	97.611	Day	154

KMZ



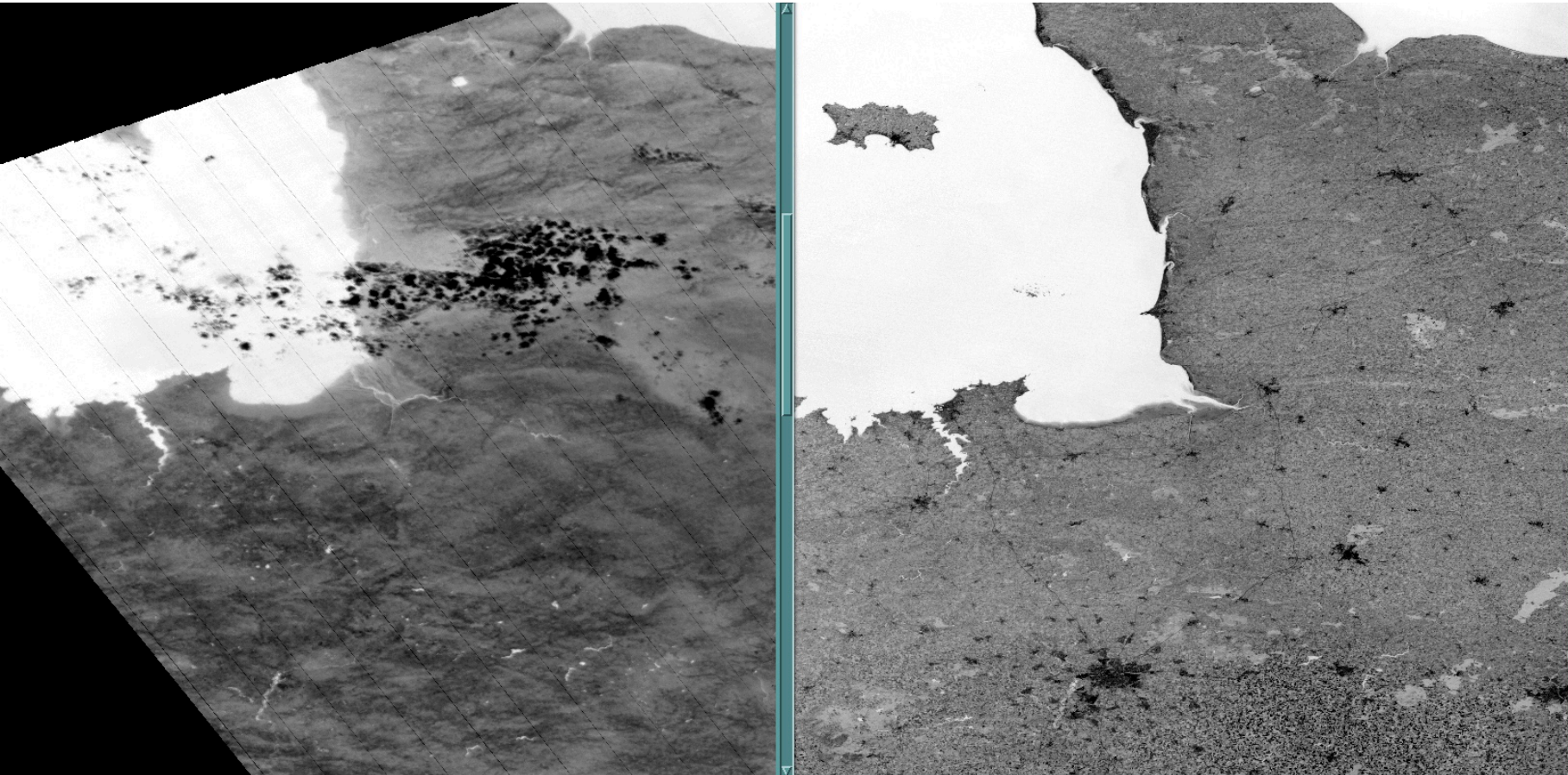
/L1GEOMetadata/OrbitCorrectionPerformed="TRUE"

Matching ECOSTRESS Band 4 to Landsat Band 62

Build = 6.01

User-Identified Geolocation Issues

User1 Test Case Image Comparison



ECOSTRESS 03798_001 B4 Scene Detail

Landsat7 TIR Orthobase Detail (inverted)

Mostly dis-similar terrain.



User-Identified Geolocation Issues



Test Case Analyses

	Case	Scene	Error	Analysis
1.	User1 Case 1	03798_001	"8.8km"	Matching failed; SZ=127; LFrac=94%; Night; TP=0; Attitude alignment from 8 images on other end of Orbit.
2.	User1 Case 2	08592_001	"2km"	Matching failed; SZ=156; LFrac=52%; Night; TP=0; Attitude alignment from 2 images.
3.	User1 Case 3	06761_001	"500m"	Matching failed; SZ=130; LFrac=72%; Night; TP=0; Attitude alignment from 7 images.
4.	User2 Case 1	03005_001	"100-840m"	Match accuracy=111.8m; SZ=129; LFrac=51%; Night; TP=23; Only match in orbit.
5.	User2 Case 2	05883_008	"100-840m"	No scene matches in orbit; SZ=109; LFrac=45%; Night; TP=0; OrbitCorrectionPerformed=FALSE
6.	User2 Case 3	06473_006	"100-840m"	Matching failed; SZ=114; LFrac=06%; Night; TP=0; Attitude alignment from 8 images.
7.	User3 Case	10620_013	"5-8km"	Matching failed; SZ=113; LFrac=17%; Night; TP=0; Attitude alignment from 4 images.
8.	User4 Case	05149_006	"3km"	No scene matches in orbit; SZ=099; LFrac=69%; Night; TP=0; OrbitCorrectionPerformed=FALSE



Proposed Geolocation Improvements

- Improve Geolocation QA Metadata:
 - Current Geolocation QA is binary: Match / No Match in Orbit
 - /L1GEOMetadata/OrbitCorrectionPerformed=“**TRUE**”
 - A single metadata value represents 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.
 - Propose to provide a per scene 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.
 - **Poor** – No matches in the orbit. Expect largest geolocation errors.
 - Propose to provide an estimated geolocation accuracy statistic for each scene that was matched (ACCCK); “**Best**” matches only.
- Propose to review/adjust Image Scene Matching parameters.



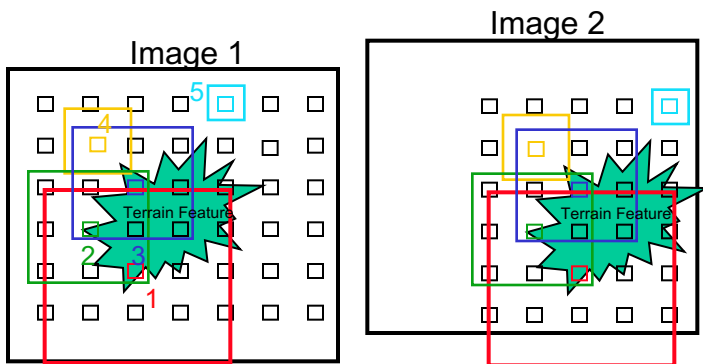
Backup



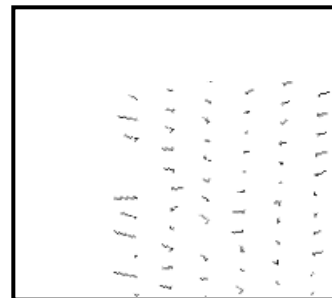
FFT Co-Registration Approach

- 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.

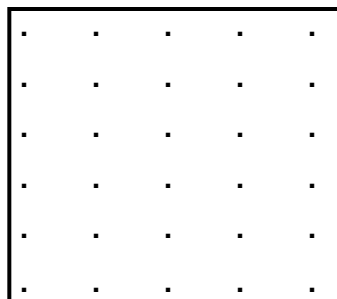
*C.D. Kuglin and D.C. Hines, "The Phase Correlation Image Alignment Method," Proc. Int. Conference on Cybernetics & Society, pp. 163-165., 1975.



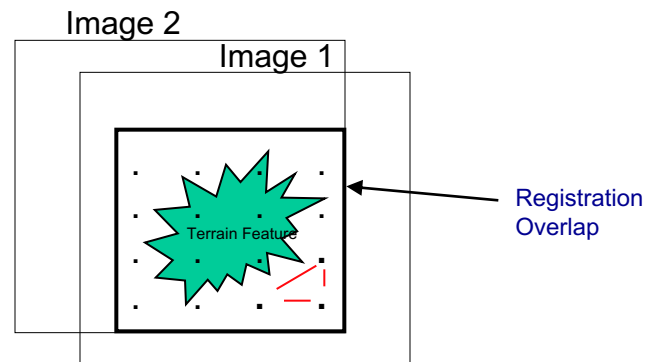
A grid of FFT tiepoints is used to match two images. FFT size starts large then decreases as matching becomes reliable. Tie point matching location order is randomly controlled by a “seed” value.



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

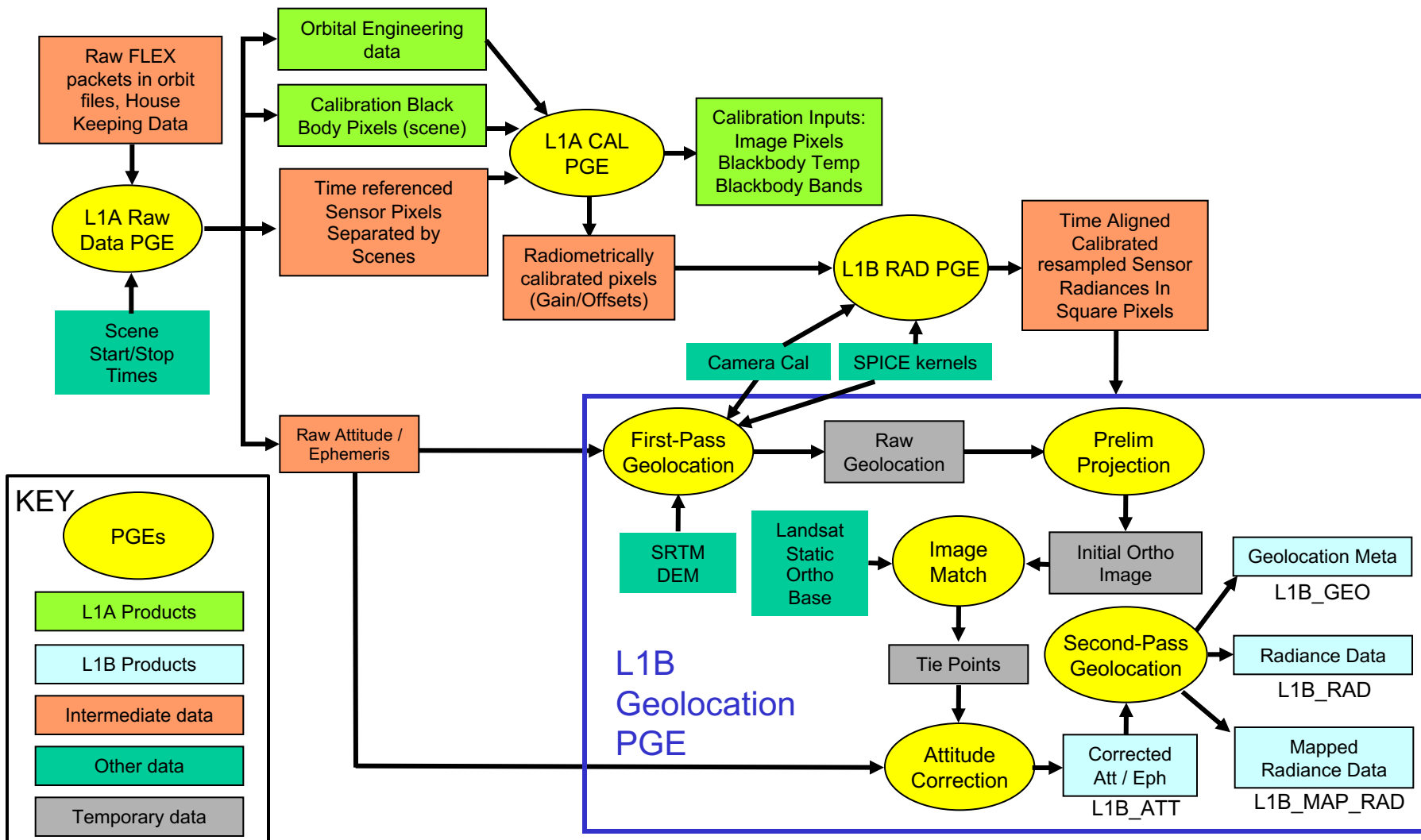


A polynomial fit is applied to the tiepoints to create an Ultra Fine grid of registration correction points. Fit options include Quad, Cubic, Linear, Keystone, and Thiessen.



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

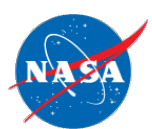
L1 Data Flow Diagram





Proposed Geolocation Improvements

- Geolocation Code/Parameter Improvements
 - Proposal to adjust Image Scene Matching parameters
 - Increase the number of FFTs per image scene.
 - To obtain more Tiepoints.
 - Adjust the geographic coverage size of the FFTs.
 - To increase matching feature detail.
 - On fail, adjust specific parameters and try again.
 - Change the initial matching location.
 - Review Orbital Interpolation/extrapolation design for improvements.
 - Design Goal is to Fail rather than permit Gross Blunders.



L1B Standard Metadata (Selected Items)

Name	Type	Size	Example
Group	StandardMetadata		
AncillaryInputPointer	String	variable	Group name of ancillary file list
AutomaticQualityFlag	String	variable	PASS/FAIL (of product data)
BuildId	String	variable	

HDF5 Format



L1B_GEO and RAD: Geolocation Metadata

Name	Type	Size	Example
Group	L1GEOMetadata		
AverageSolarZenith	Float64	Degrees	Average solar zenith angle for scene
OrbitCorrectionPerformed	String	None	One of "True or "False"
OverallLandFraction	Float64	Percentage	Overall land fraction for scene

HDF5 Format



L1B Product Metadata



L1B_MAP_RAD Product Metadata

Name	Type	Size	Example
Group	L1GEOMetadata		
BandSpecification	Float32	μm	Wavelengths available in the L1 product for bands 1-6: 1.6, 8.2, 8.7, 9.0, 10.5, 12.0; 0=fill data
OrbitCorrectionPerformed	String	None	One of "True" or "False"
QAPercentMissingData	Float32	Percentage	Percentage of data missing from L0B

HDF5 Format