Prototype and Metrics for Data Processing Chain Components of IPM

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HyspIRI Symposium
Intelligent Payload Module Session
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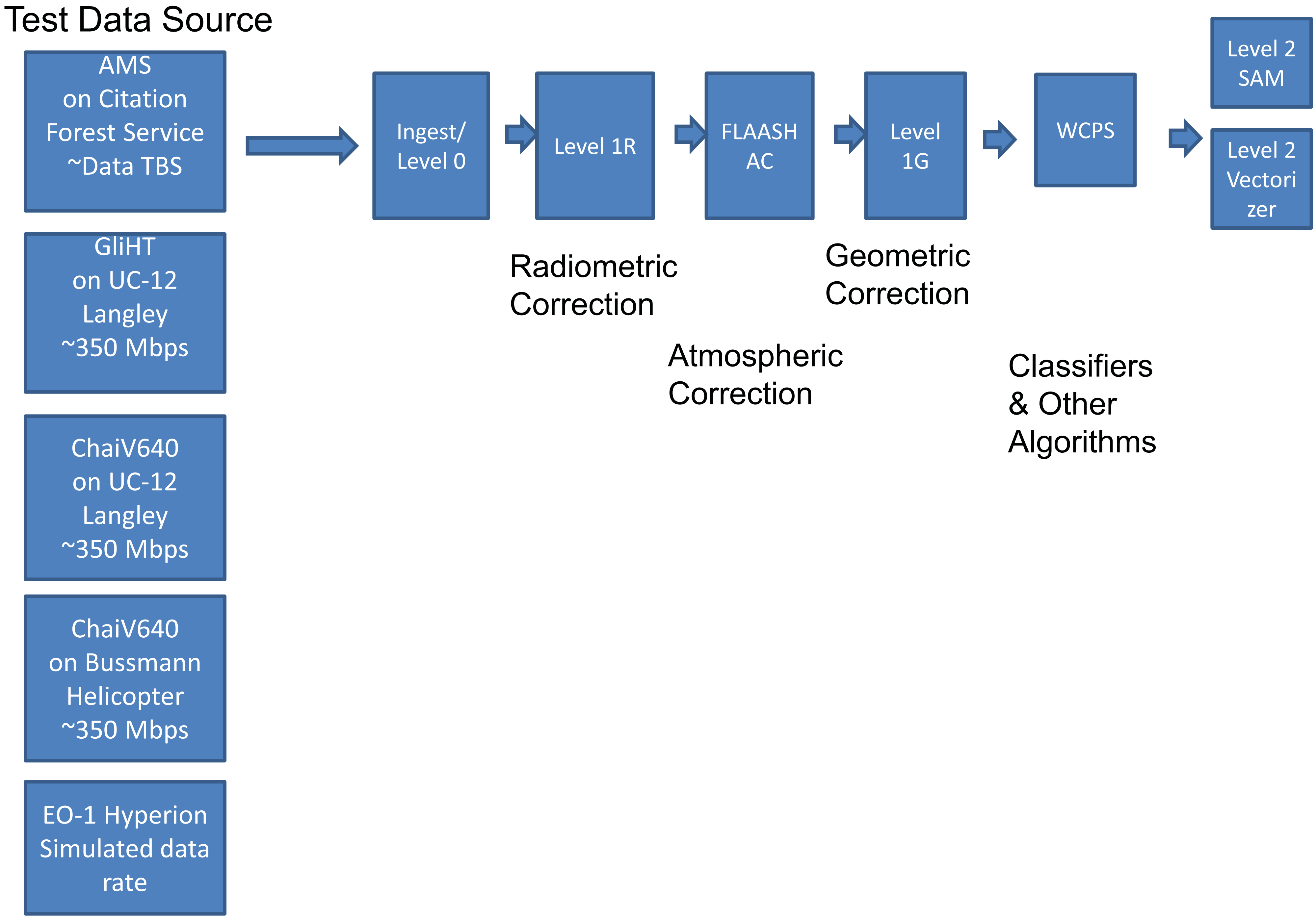
Representative IPM Data Processing Chain



Platforms and Algorithms

Platforms Ground	Level 0	Level 1R	FLAASH Atm Corr	Level 1G Geocorr	GCAP Geocorr	Coreg Geocorr	WCPS SAM	WCPS Potrace
Maestro Multicore								
Tilera 64 Multicore								
Tilera Pro Multicore								
TileGX Multicore	☺	☺	🙂		☺	🙂	🙂	🙂
SpaceCube 1.5			🙂					
Csp ARM/FPGA								

☺ Tested

🙂 In process

Platforms and Algorithms

Platforms Airborne	Level 0	Level 1R	FLAASH Atm Corr	Level 1G Geocorr	GCAP Geocorr	Coreg Geocorr	WCPS Hot Pixel	WCPS Potrace
AMS/IPM/ Citation								
Platforms Airborne	Level 0	Level 1R	FLAASH Atm Corr	Level 1G Geocorr	GCAP Geocorr	Coreg Geocorr	WCPS SAM	WCPS Potrace
GliHT/IPM Cessna								
ChaiV640/ IPM/Heli								
ChaiV640/ IPM/B200								
Platforms Airborne	Frame Grabber	Jellyfish Det	Autonom Navigation					
Camera/ MiniIPM/ UAV Heli								

 Tested

 In process

Overview of Effort

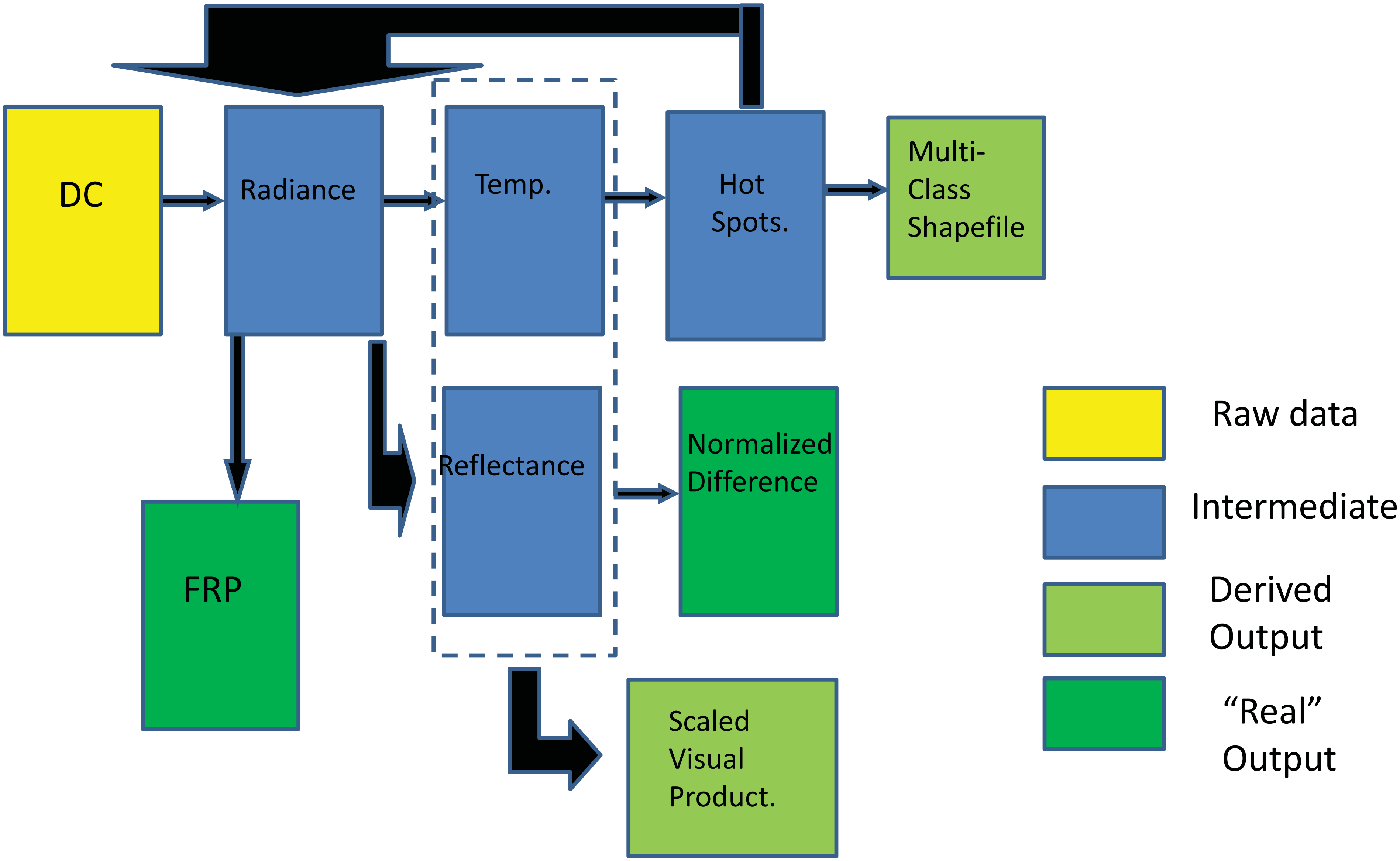
- Year 1 Build hardware, begin writing software and arrange flights
- Year 2 Run simulated science scenarios (e.g. instrument calibrations)
- Year 2 Begin Flight tests
- Year 2 Investigate software benchmarks
- Year 3 More flight tests and benchmarks based on results of year 2
- Year 3 Recommendations for future missions

Key Methods to Accelerate Onboard Computing for a Space Environment

- Intelligent onboard data reduction
- Parallel processing, multicore processors
- Use of FPGA as co-processor to accelerate portion of algorithms

Example 1 of Intelligent Onboard Data Reduction: Autonomous Modular Sensor Onboard Processing

Existing Autonomous Modular Sensor (AMS) Pre-processing/Product Relationships

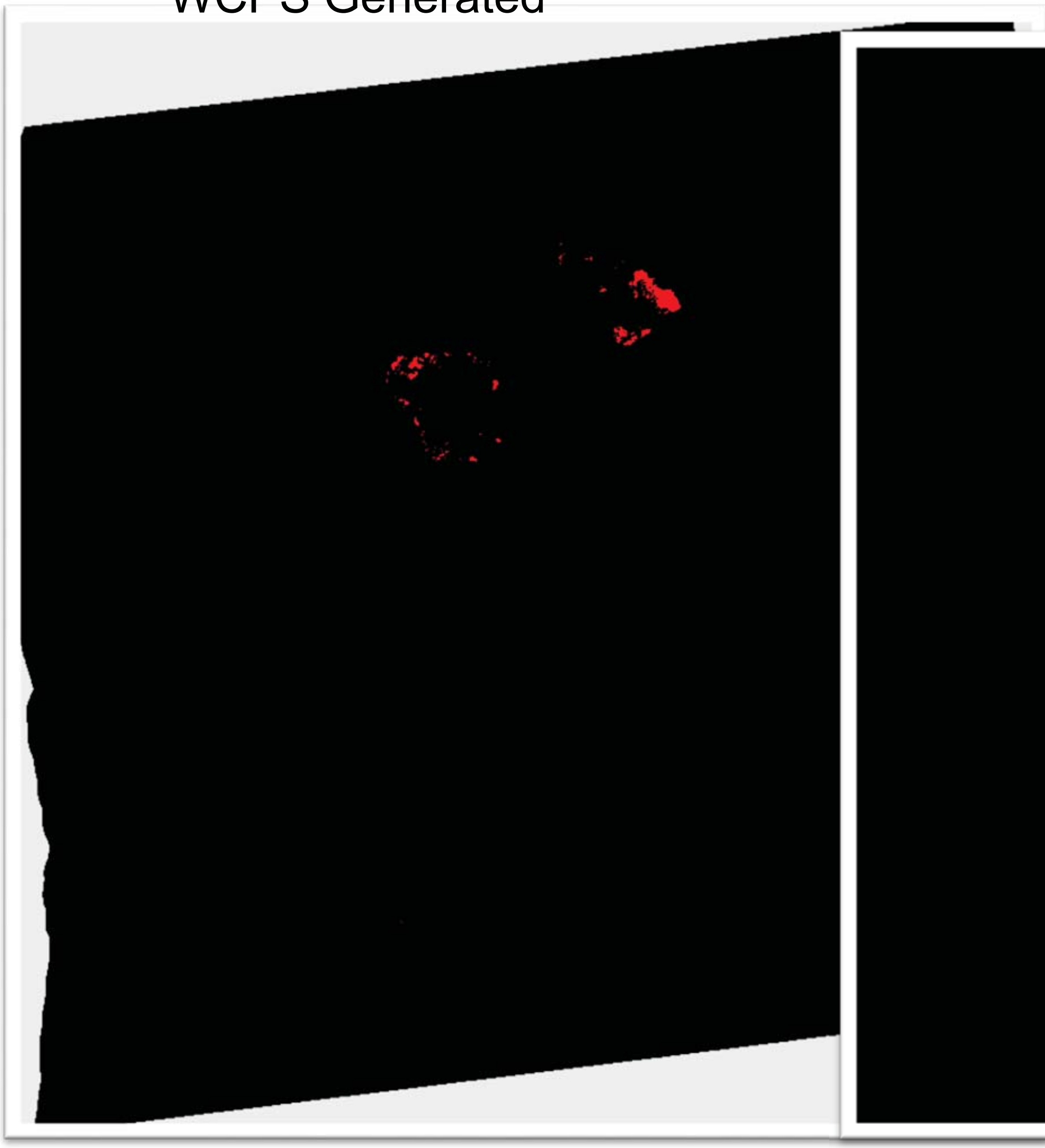


Burn Area Emergency Rehabilitation Imagery

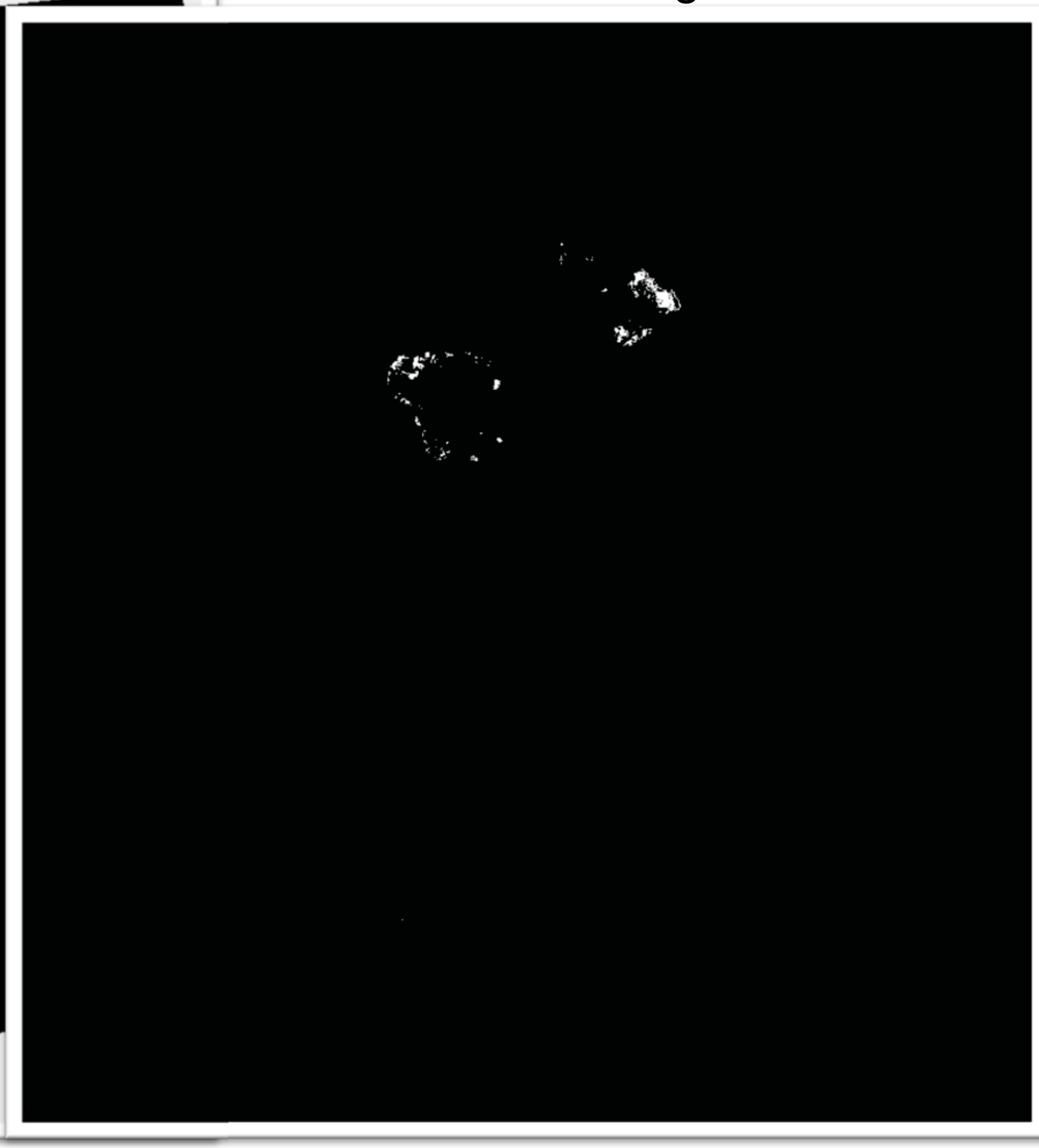
BAER Bands:
10 – 7 - 9
Linear Stretched 2%

CCRS (Hot Pixels Algorithm)

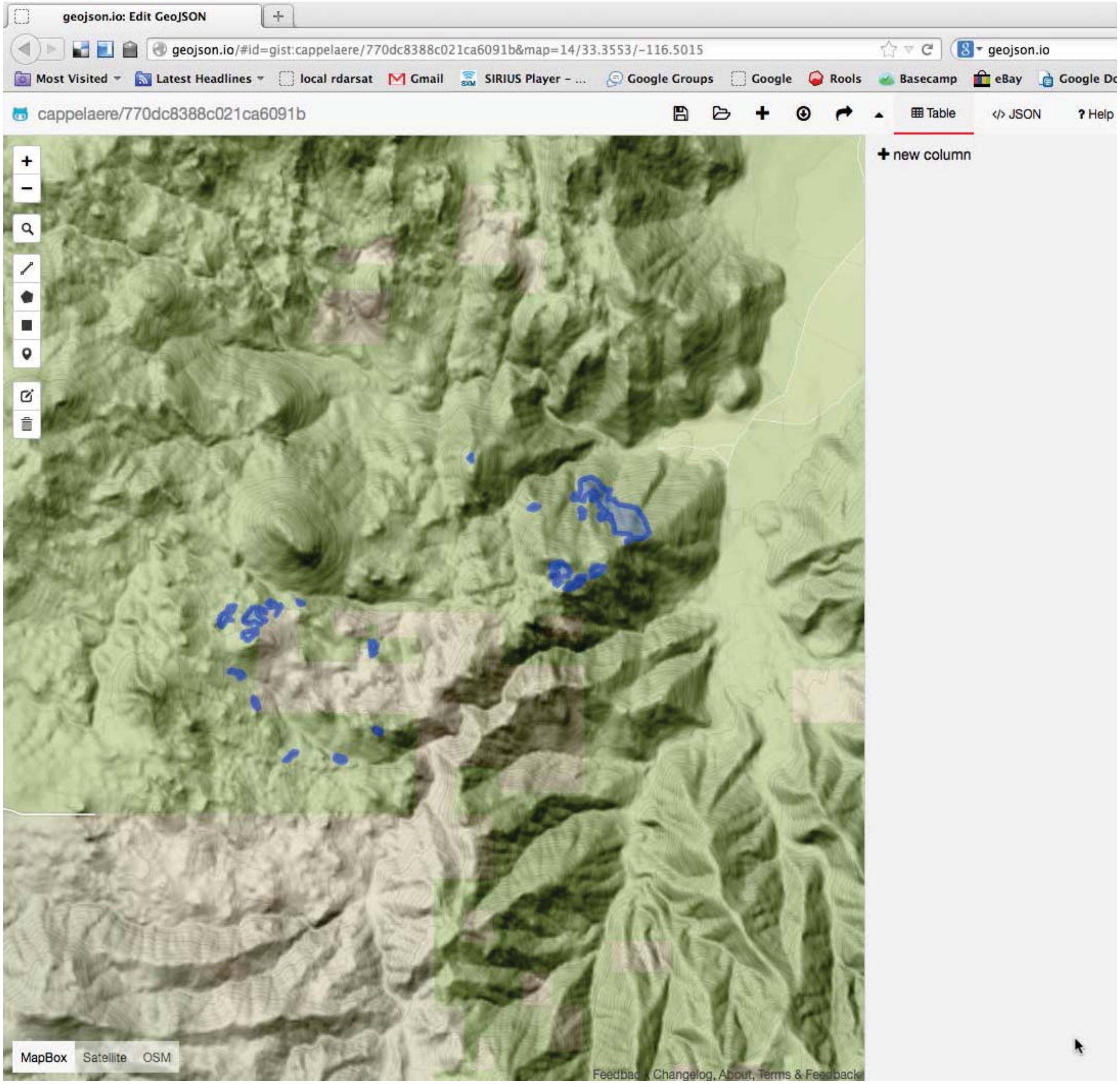
WCPS Generated



Provided Original



Hot Pixels as Topojson on Github



Vectorized Hot Pixs to Topojson format (50% simplification)
File Size: 6KB (2KB .tgz)

Topojson converted to C++ from javascript

Potrace integrated into WCPS

Displayed on MapBox TopoMap

Can be shared on Facebook/Twitter…
All Open Source

http://geojson.io/#id=gist:cappelaere/770dc8388c021ca6091b&map=14/33.3553/-116.5015

Metrics

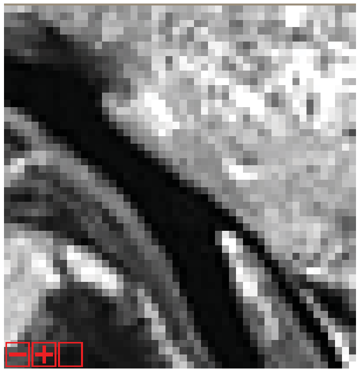
- Original AMS files size 3.1 Mbytes
- Potrace – converts to raster to vector with the output being GeoJSON
  - Geographic Javascript Object Notation (GeoJSON) file size is 31 kbytes
- Topographic Javascript Object Notation (TopoJSON) converts GeoJSON to TopoJSON format
  - file size is 6 kbytes (choose 50% simplification of vectors)
  - User selectable to about 90%
- Compress TopoJSON using ZIP
  - Compressed size is 2 kbyte
- Compression of 1000:1
- Download 2 kbyte GitHub then can visualize on built in map visualized (Mapbox)
  - OpenStreetMap compatible
  - Viewable in browser
  - Shareable on Facebook and other social media
  - Github is used for versioning on maps and thus will store user annotation to map

Example 2 for Intelligent Onboard Data Reduction: Running Coregistration with Chips

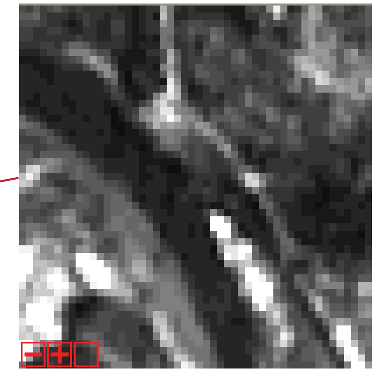
Global Land Survey Maps

- A collection of Landsat-type satellite images from USGS
  - Near complete global coverage
  - Orthorectified
  - Each image has cloud cover of less than 10%
  - Four versions: 1970, 1990, 2000, and 2005
- Ground truth for the registration programs was drawn from the GLS 2000 and can be updated when the GLS 2010 is completed
- http://landsat.usgs.gov/science_GLS.php

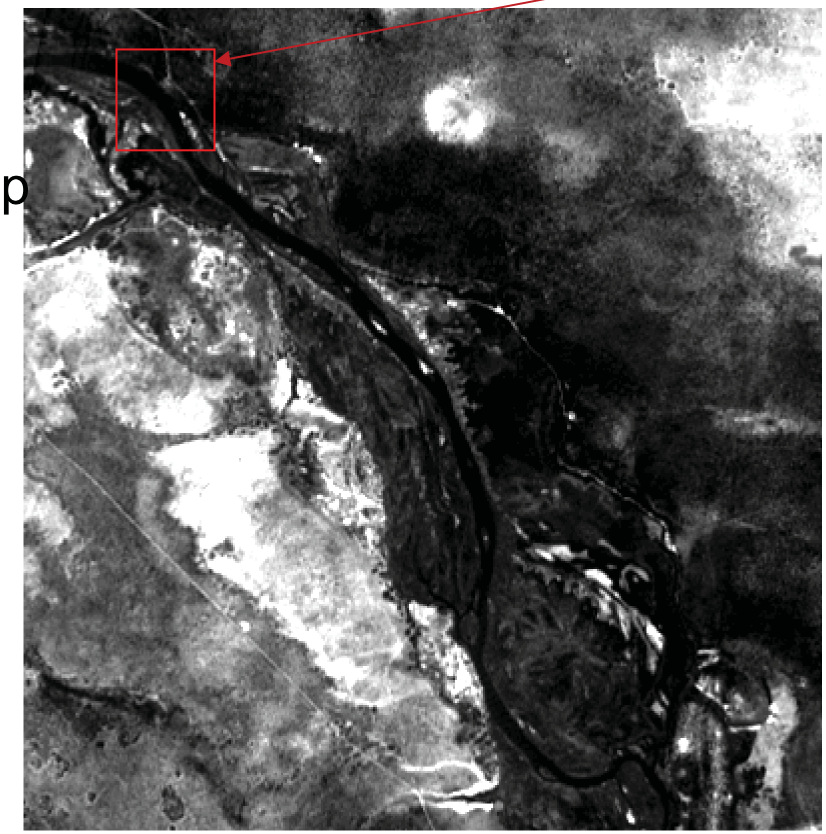
Chip Registration



Overlapping chip from database



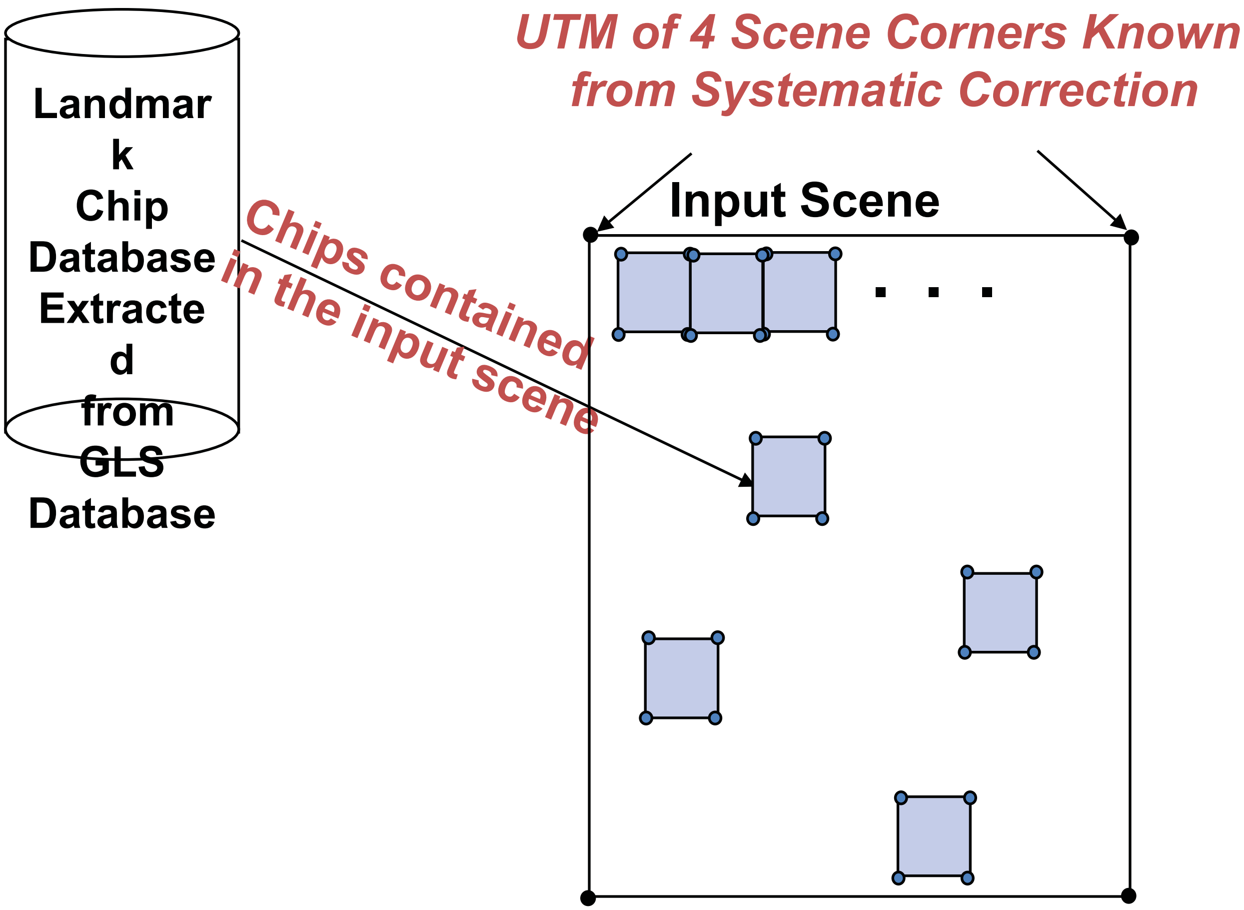
Chip extracted from EO1 scene



Area in EO1 scene where chip was extracted

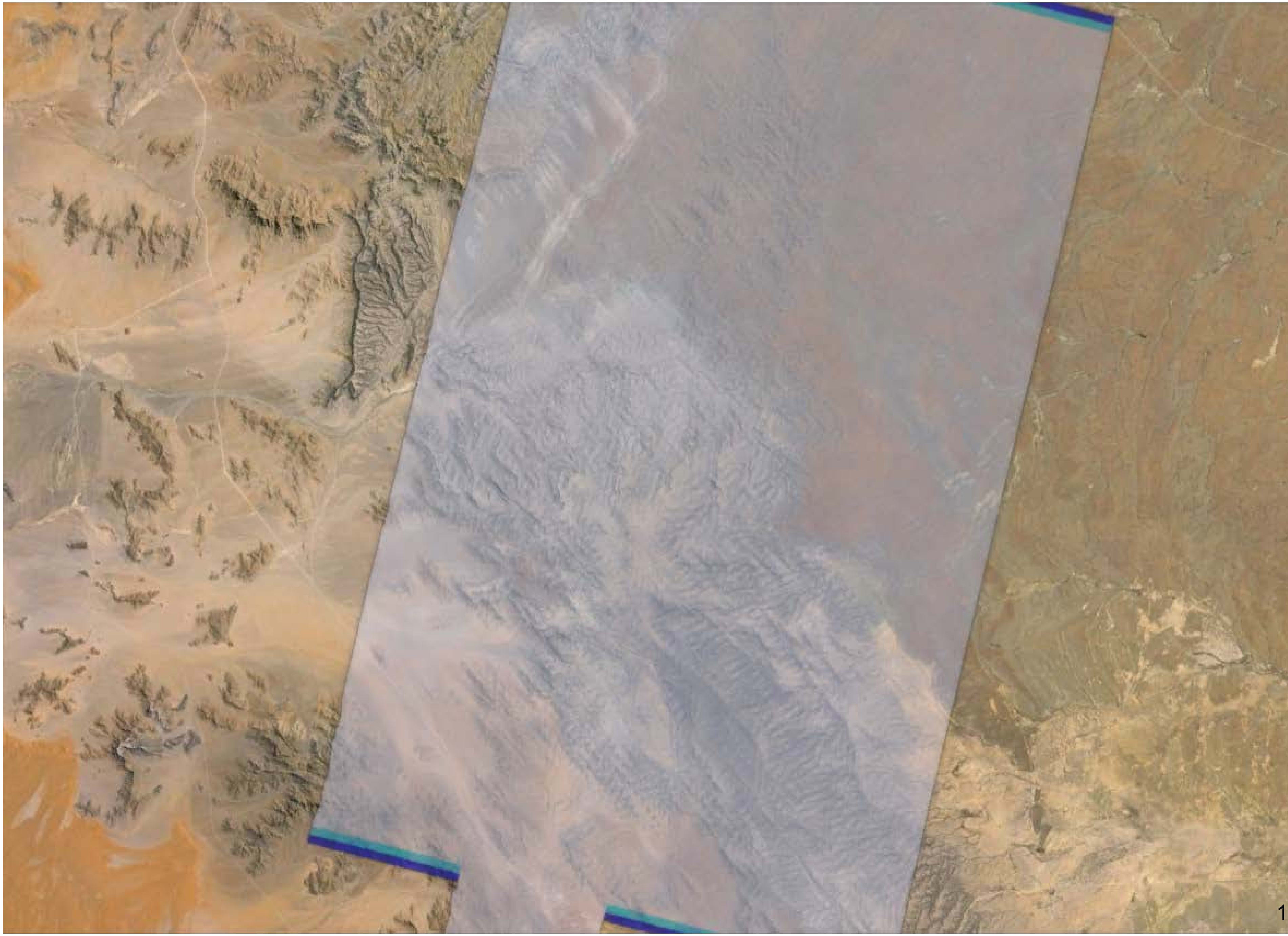
Currently "chip database" created (in a brute-force fashion) by extracting successive 256x256 sub-images of all GLS scenes and storing them according to path and row

Automatic Registration of EO1 Scenes Using Global Land Survey (GLS) Database

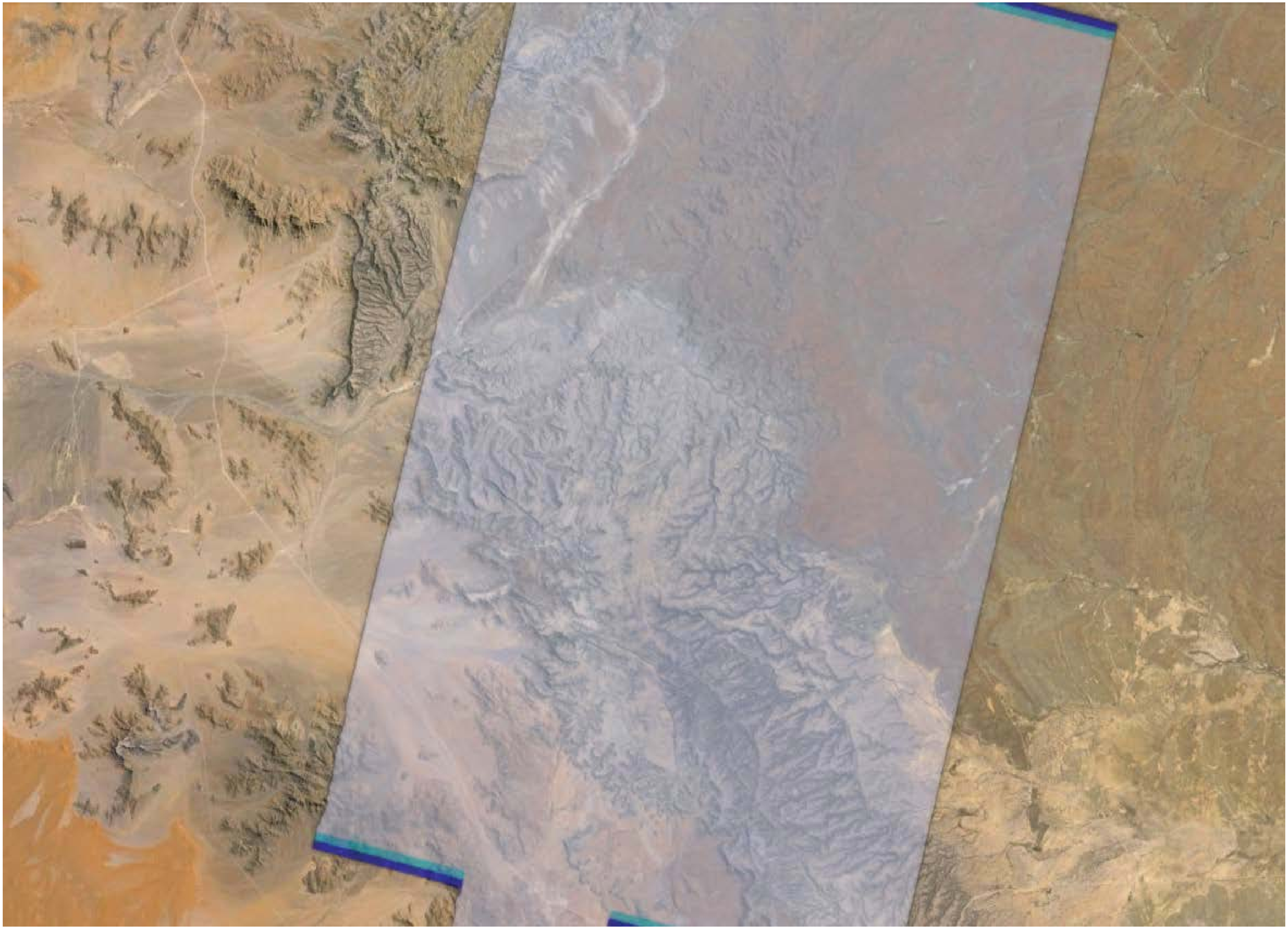


1. ***Find Chips that correspond*** **to the Incoming Scene**
2. ***For Each Chip, Extract Window*** **from input scene using UTM coordinates**
3. ***Eliminate Windows*** **with insufficient information**
4. ***Smooth and Normalize*** **gray values of both Chip and Window using a Median Filter**
5. ***Register each (Chip,Window) Pair*** **using a wavelet-based automatic registration: get a local rigid transformation for each pair**
6. ***Eliminate Outliers***
7. ***Compute Global Rigid Transformation*** **as the median transformation of all local ones**
8. ***Compute Correct UTM*** **of 4 Scene Corners of input scene**
9. ***If desired, Resample*** **the input scene according to the global transformation**

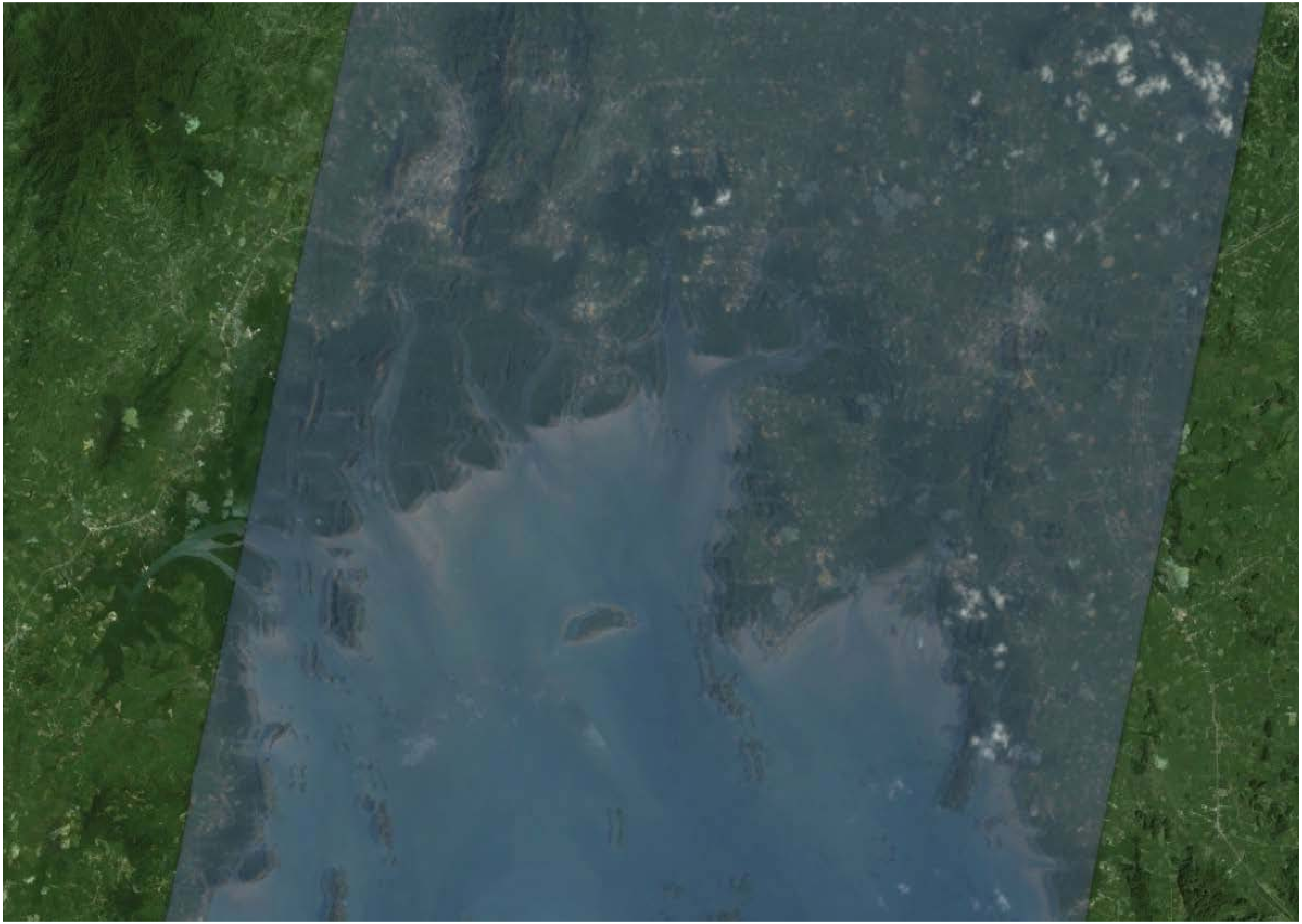
Scene 1 Before Automatic Registration Superimposed onto Goggle Earth



Scene 1 After Automatic Registration Superimposed onto Goggle Earth



Scene 2 Before Automatic Registration Superimposed onto Goggle Earth



Scene 2 After Automatic Registration Superimposed onto Goggle Earth

Conclusions and Future Work

- Results visually acceptable
- Computations very fast and real-time
- RMS still too high (Translation errors between 0.4 and 2.5 pixels) because:
    1. Chips and windows need to be pre-selected based on the information content (e.g., using an entropy measure)
        - ⇒ Registration would be more accurate because transformation would only be computed on pairs that have a significant amount of features
        - ⇒ Registration would be faster because less local registrations
        - ⇒ Chip database would be smaller to be stored onboard
    2. Global transformation should be computed by taking the list of original corners coordinates of each window and their corresponding corrected coordinates, and treat them as a list of ground control points and their corresponding points => after outlier elimination, global transformation can be computed using a rigid, an affine or a polynomial transformation.
    3. Masks for clouds and water should be included, so registration would not use cloud or water features that are often unreliable
- Onboard, computations can be performed on SpaceCube or hybrid processor

Representative IPM Data Processing Chain & Metrics Building to Helicopter Experiment

Hyperspectral Image Processing

	Radiometric Correction (CHAI data)	*Atmospheric Correction (FLAASH) (EO1 Hyperion data)	Geometric Correction (GCAP) (GLiHT data)	*WCPS (vis_composite) (EO1 Hyperion data)
864 MHz TILEPro64 (1 core)	121.95	2477.74	183.42	72.39
864 MHz TILEPro64 (49 cores)	23.83	1744.13	4.59	21.63
1.0 GHz TILE-Gx36 (1 core)	57.22	897.71	28.51	19.93
1.0GHz TILE-Gx36 (36 cores)	9.21	588.71	1.41	8.72
2.2GHz Intel Core I7	2.09	58.29	0.169	2.26
Virtex 5 FPGA	TBD	TBD	TBD	TBD

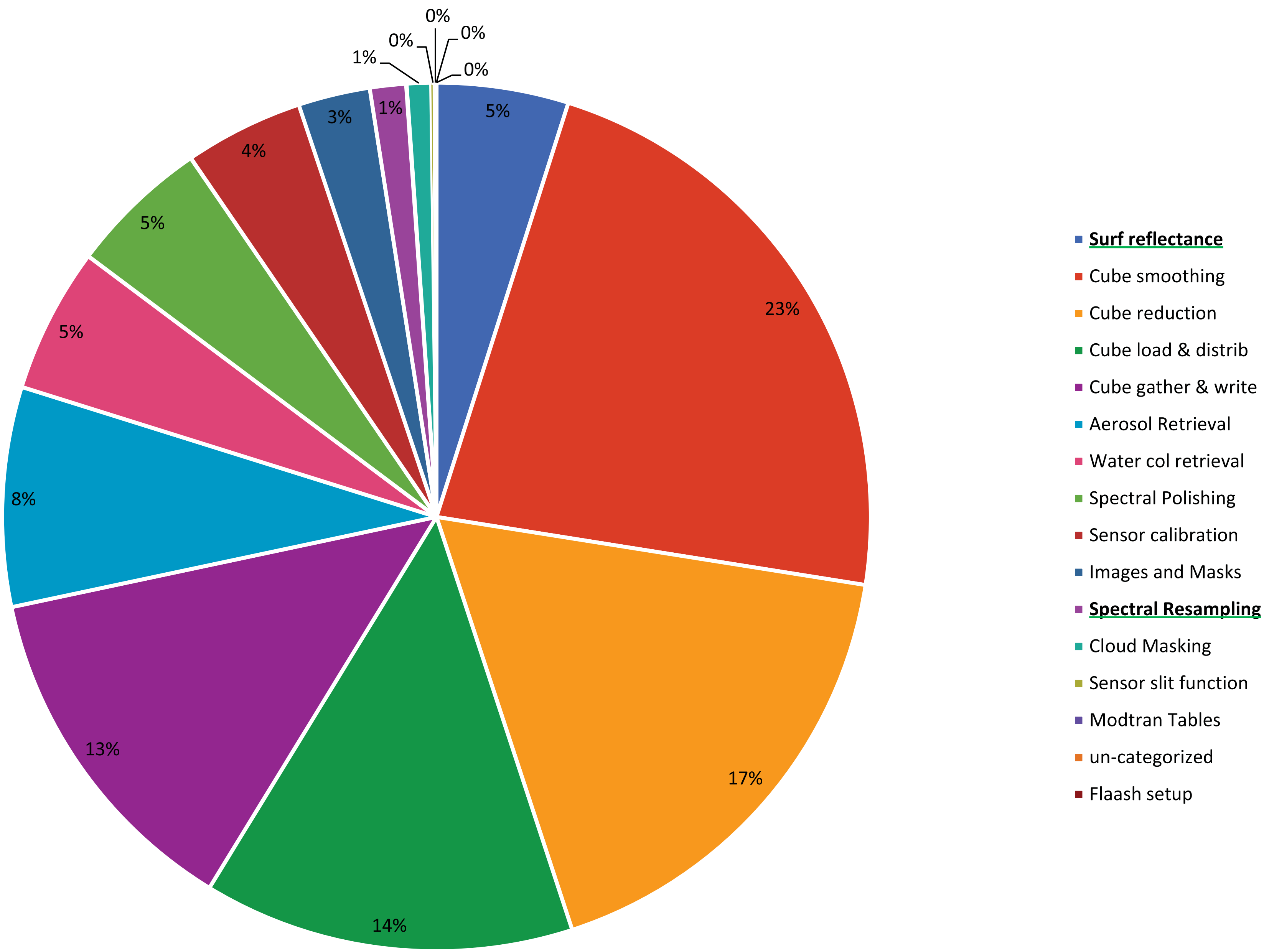
Image data:
GLiHT 1004 x 1028 x 402 (829,818,048 bytes)
Hyperion (EO1H1740732001151111K3)
256 x 6702 x 242 (830,404,608 bytes)
Chai640 696 x 2103 x 283 (828,447,408 bytes)

Notes: Unit is in seconds
TILEPro64 – No floating point support
TILEGx36 – Partial floating point support
* Indicates time includes file I/O

FLAASH Parallelization Effort

	wall	system	user	notes	Parallelized?	Original Walltime	Parallel Speedup
Surf reflectance	32.7952	5.1398	27.6554	Reflect:: RadtoRef	YES	197.317	6.016642679
Cube smoothing	145.741	18.1373	127.6037	mini_cube->Smooth; FFT			
Cube reduction	112.363	13.9834	98.3796	mini_cube->Condense			
Cube load & distrib	89.0128	11.0775	77.9353				
Cube gather & write	83.2988	10.3664	72.9324				
Aerosol Retrieval	52.6236	6.54892	46.07468				
Water col retrieval	34.7984	4.3306	30.4678				
Spectral Polishing	33.5795	4.17891	29.40059				
Sensor calibration	28.5097	3.54799	24.96171				
Images and Masks	17.1781	2.13779	15.04031				
Spectral Resampling	8.72743	1.08611	7.64132	Smile_Resampler::Cube_Copy	YES	241.669	27.69074057
Cloud Masking	5.93287	0.738336	5.194534				
Sensor slit function	0.764612	0.0951547	0.6694573				
Modtran Tables	0.416416	0.0518223	0.3645937				
un-categorized	0.0397966	0.00495262	0.03484398				
Flaash setup	0.000163794	2.04E-05	1.43E-04				
total time	645.7813884	81.425006	564.3563824				1.641422344
total time (h:m:s)	0:10:46	0:01:21	0:09:24				
Original Wall time:	1060						
	0:17:40						

Time spent in FLAASH components



Conclusion

- Examining a variety of methods to speed up onboard processing chain to meet needs of low latency users
- Dovetailing efforts and metrics with High Performance Space Computing (HPSC) effort sponsored by NASA Office Chief Technologist
- IPM data processing effort applied to multiple future mission needs