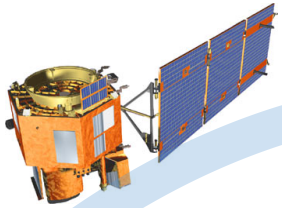
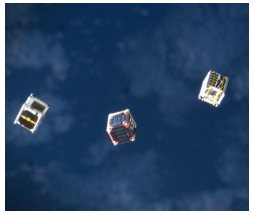
ER-2

EO-1



HyspIRI



cubesats

Twin Otter

CESNA

Drone

OnBoard Low-Latency Products Development

Pat Cappelaere

Petya Campbell, Betsy Middleton

Dan Mandl, Stu Frye

Jacqueline LeMoigne

Vuong Ly

Steve Adler Golden (SSI)

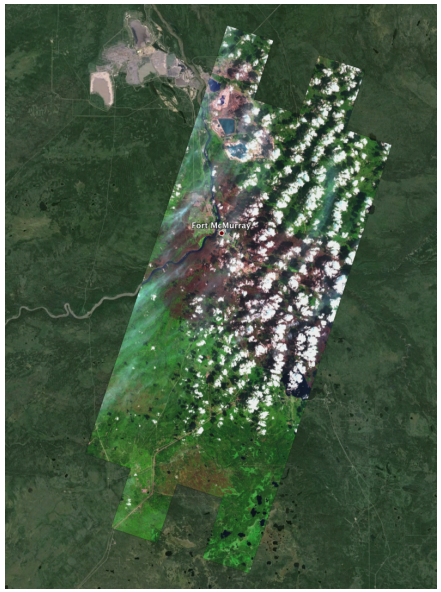
Aka Near Instant Remote Sensing

Near Instant Remote Imaging

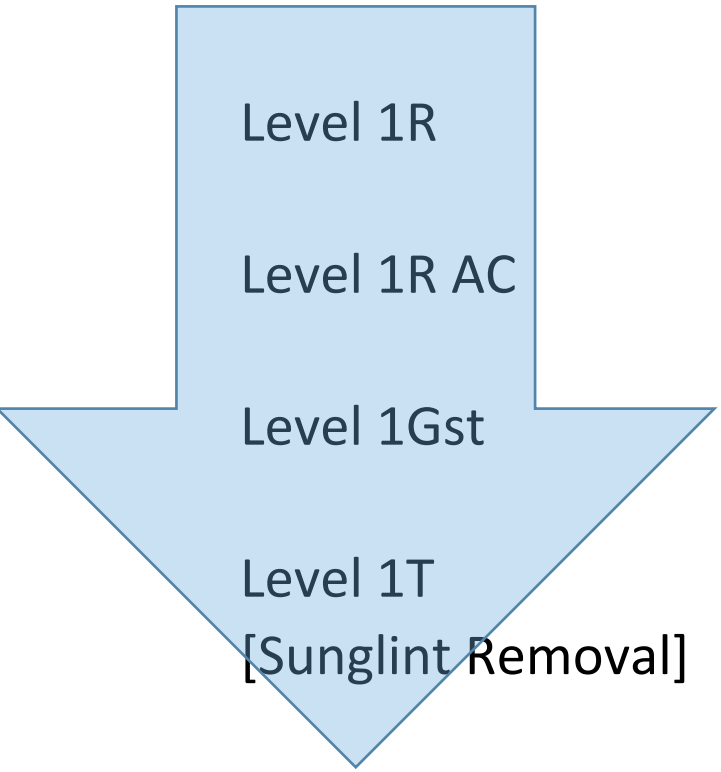
Imagine!

- User Needs Image At Some Location
- User Sends Target Information
- User Waits A Few Instants… Then Receives A Product That Can Be Viewed In Google Earth (Raster) Or Sent To Mobile Phone (Vectors)

Burnscar Product



How It Works! *Flight Workflow*



Level 0	Pixel Acquisition
Level 1R	Radiometric Corrected
Level 1R AC	Atmospherically Corrected
Level 1Gst	Geometric/Ortho Rectified
Level 1T [Sunglint Removal]	Co-registered
Level 2	Actionable Products Generation

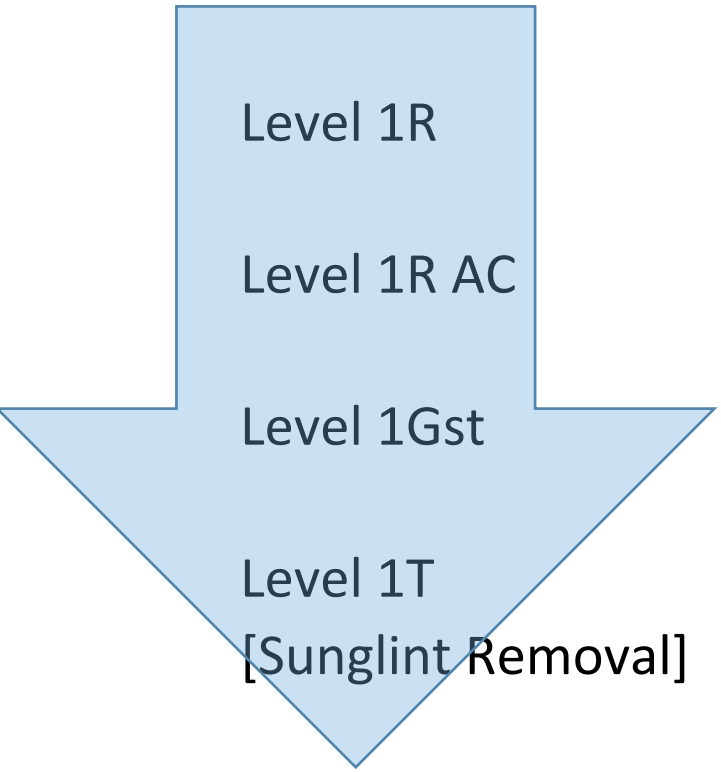
Onboard Imaging Service (2014)
Web Coverage Processing Service (WCPS)

How It Works!

Instrument Payload Module (IPM) & Field Programmable Gate Arrays (FPGA)

Level 0	Pixel Acquisition
Level 1R	Radiometric Corrected
Level 1R AC	Atmospherically Corrected
Level 1Gst	Geometric/Ortho Rectified
Level 1T [Sunglint Removal]	Co-registered
Level 2	Actionable Products Generation

How It Works! *Onboard…*



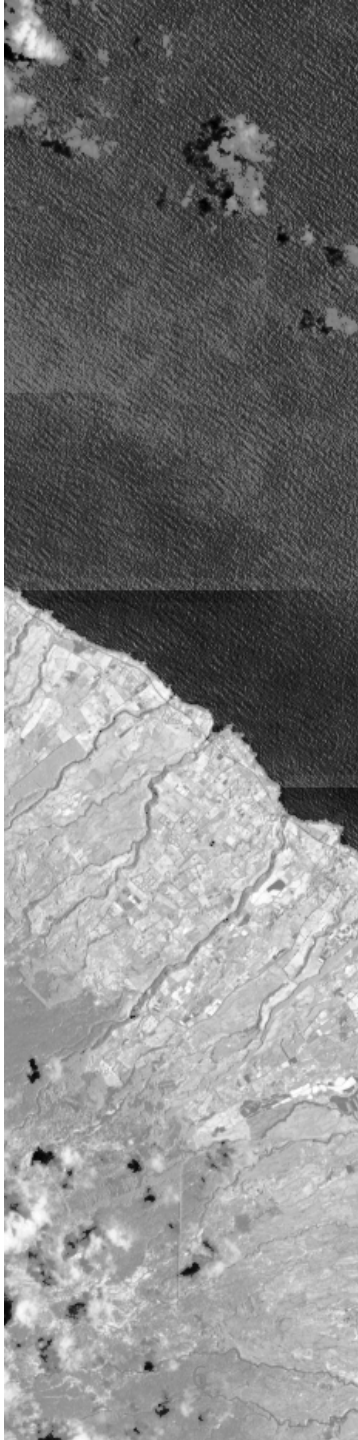
Level 0	Pixel Acquisition	
Level 1R	Radiometric Corrected	
Level 1R AC	Atmospherically Corrected	FLAASH-C
Level 1Gst	Geometric/Ortho Rectified	
Level 1T [Sunglint Removal]	Co-registered	
Level 2	Actionable Products Generation	

Onboard Atmospheric Correction

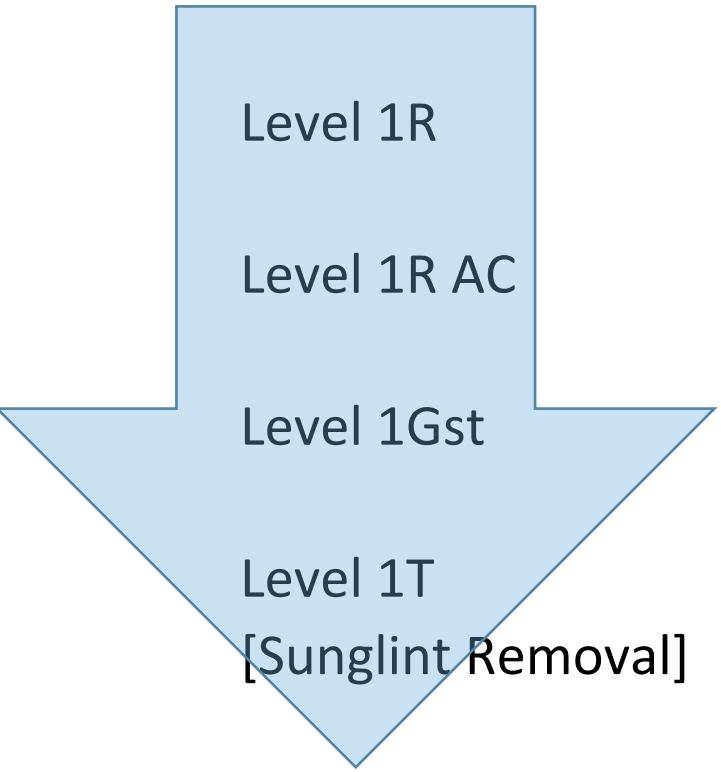
L1R → L1R_AC

- FLAASH C Version with Lookup Table
- Fixed adjacency correction problem in the original code, which created artifacts in high-contrast scenes
- We don‘t want to turn off Adjacency Correction

FIXED ✓



How It Works!



Level 0	Pixel Acquisition	✓
Level 1R	Radiometric Corrected	
Level 1R AC	Atmospherically Corrected	✓
Level 1Gst	Geometric/Ortho Rectified	
Level 1T [Sunglint Removal]	Co-Registration	
Level 2	Actionable Products Generation	✓

After 16 years, EO-1 is still a Technology Pathfinder Paving the Way for New NASA Missions

EO-1
"Adapt and Overcome"
Co-Registration Story

We Could Use Really This In Near Future…

Recent Status (Two Weeks Ago)

- GPS “Failure” (Not Uncommon for Many Missions)
- On-board Clock Drift
- Image Location Way Off (up to 12km off along track)
- USGS Cannot Co-register the Imagery

Ft McMurray Fires (Alberta Canada – May 2016

- The fire spanned more than 241,000 hectares
- An estimated 2,432 homes and other structures have been destroyed,
- Last Tuesday afternoon, the wildfires are cutting the main road through Fort McMurray and sending its 80,000 inhabitants fleeing north and south.

The Fire Rescue Center Tasks the Satellite to Get Current Fire Extent…

Actual Problem!!!

Fort McMurray Fires (Alberta, CA)
EO1A0420202016132110KF
2016-05-11

Band 10 overlay on Google Earth
~10-12km offset

Note: Image is very cloudy.

USGS cannot georeference it with current L1T ground capabilities

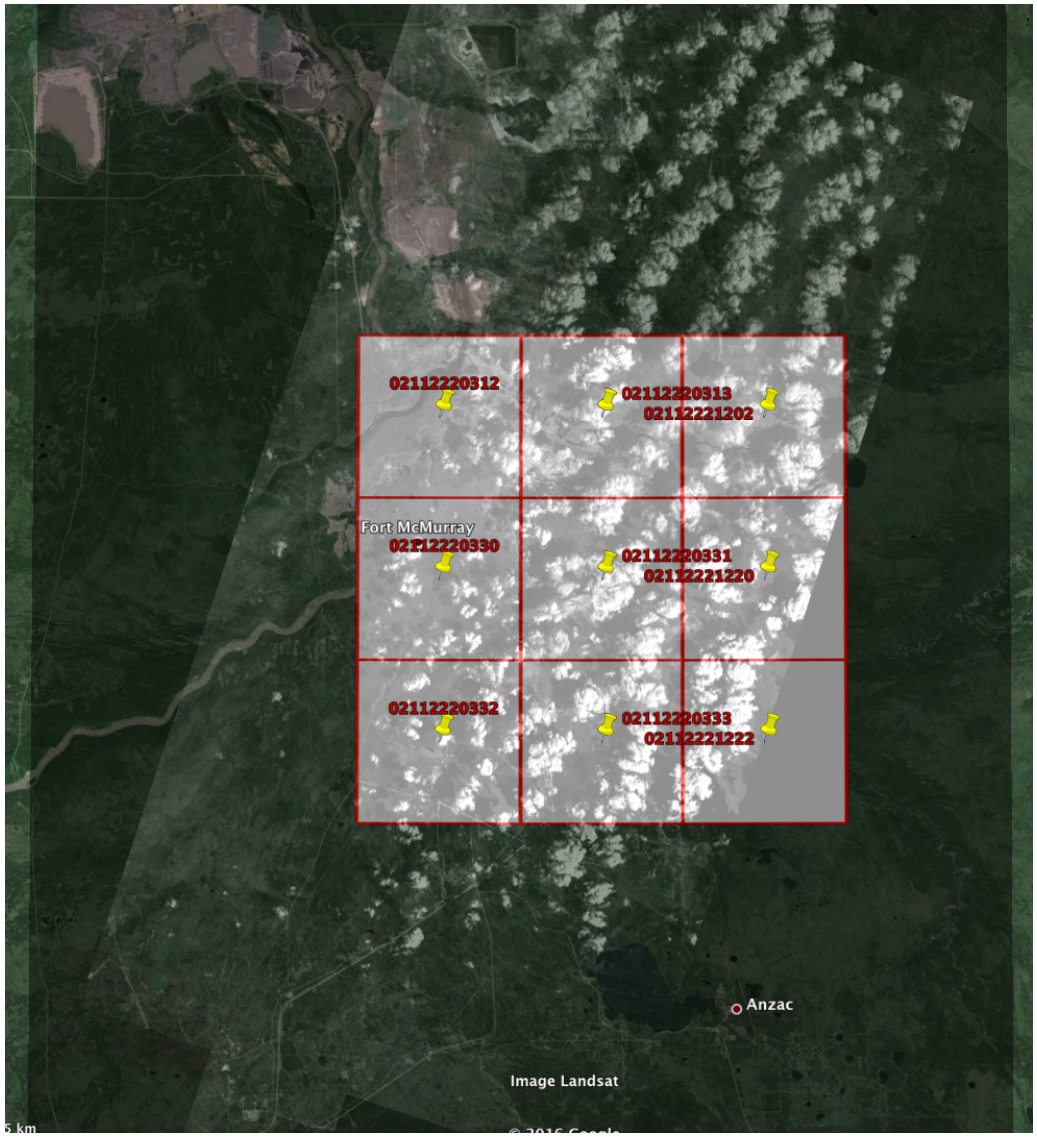
Imagine…

- Despite Major Onboard Clock Drift, End-User Still Gets a Co-Registered Product that Can be Overlaid on Google Earth (or Other)
- Proposed Solution:
  - Along with Target "Location", A [Dynamically-sized] Referenced Landsat-8 Tile is Uploaded
  - We Co-Register L1Gst to It

How It Works…

- USGS
  - Landsat 8 (L8) Surface Reflectance NDVI product ordering
    - https://espa.cr.usgs.gov
- Onboard Surface Reflectance + NDVI (because we can)
- Dynamically Sized GeoReferenced L8 Quad-Tiles
  - Tile size is picked based on expected/past deviation
    - ~210x210
    - ~521x521
    - ~1042x1042
    - Note: Tiles are re-squared to factor projection issue at higher latitudes
  - Tile is picked based on best features (entropy)

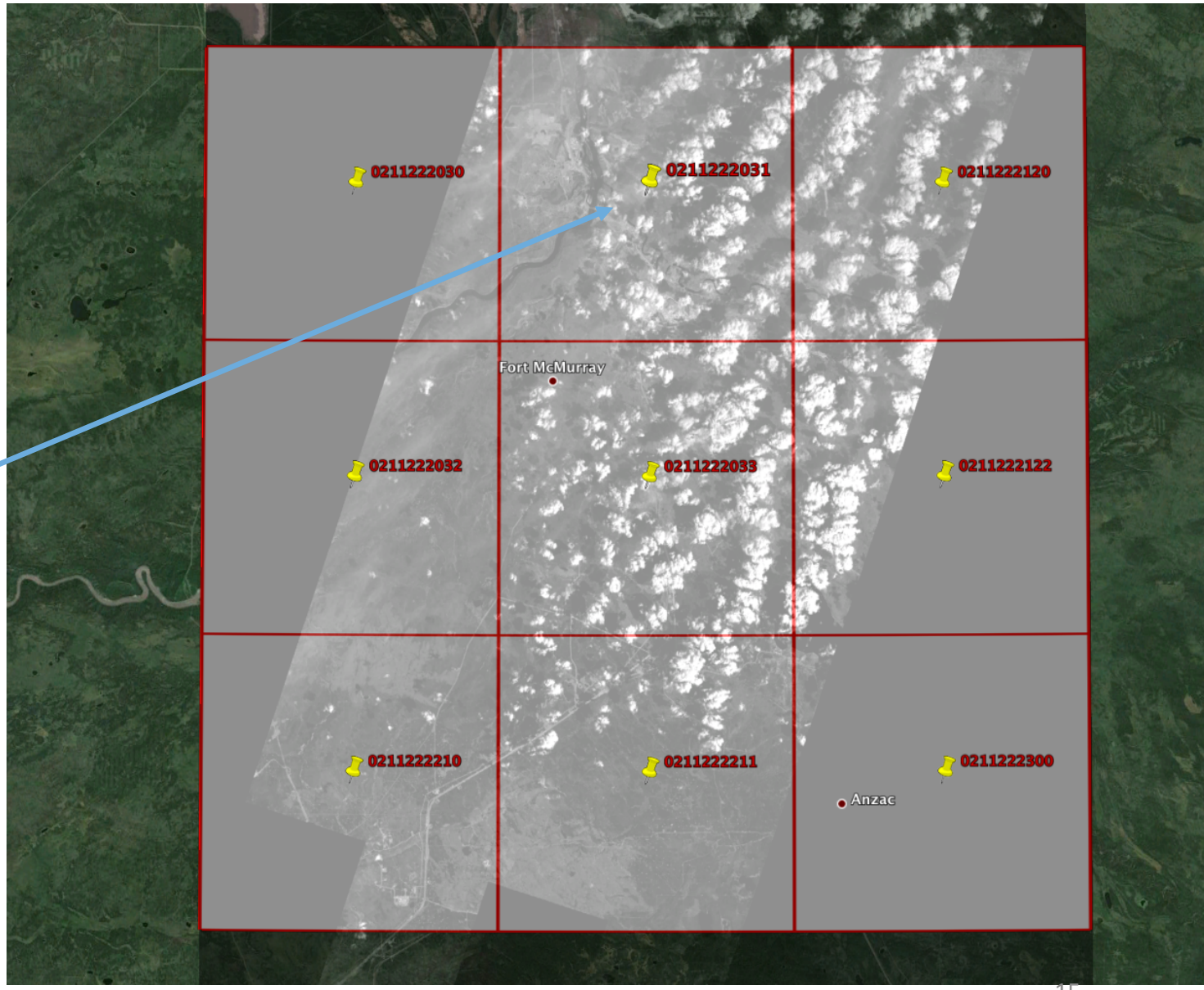
Example:
Zoom Level 11
These are 9 adjacent quadtiles
From target.



QuadTiles Tile Set
At Zoom Level 10
1042x1042

9 tiles considered

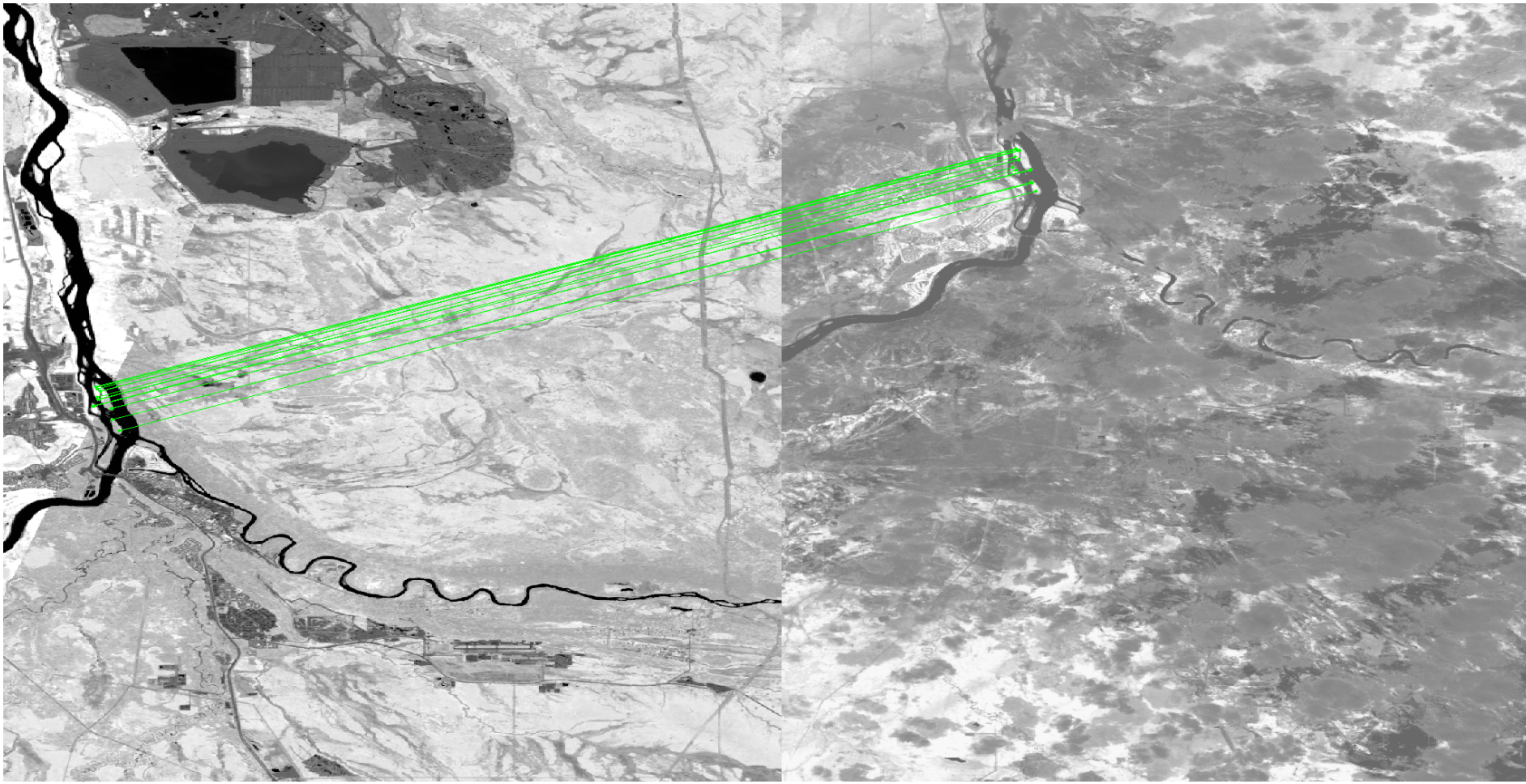
We will pick



Brute-Force Matching with ORB Descriptors

L8 Reference Tile

EO-1 ALI Tile



Showing top 10 matches – Average Pixel Offets: tx= 188, ty= -320

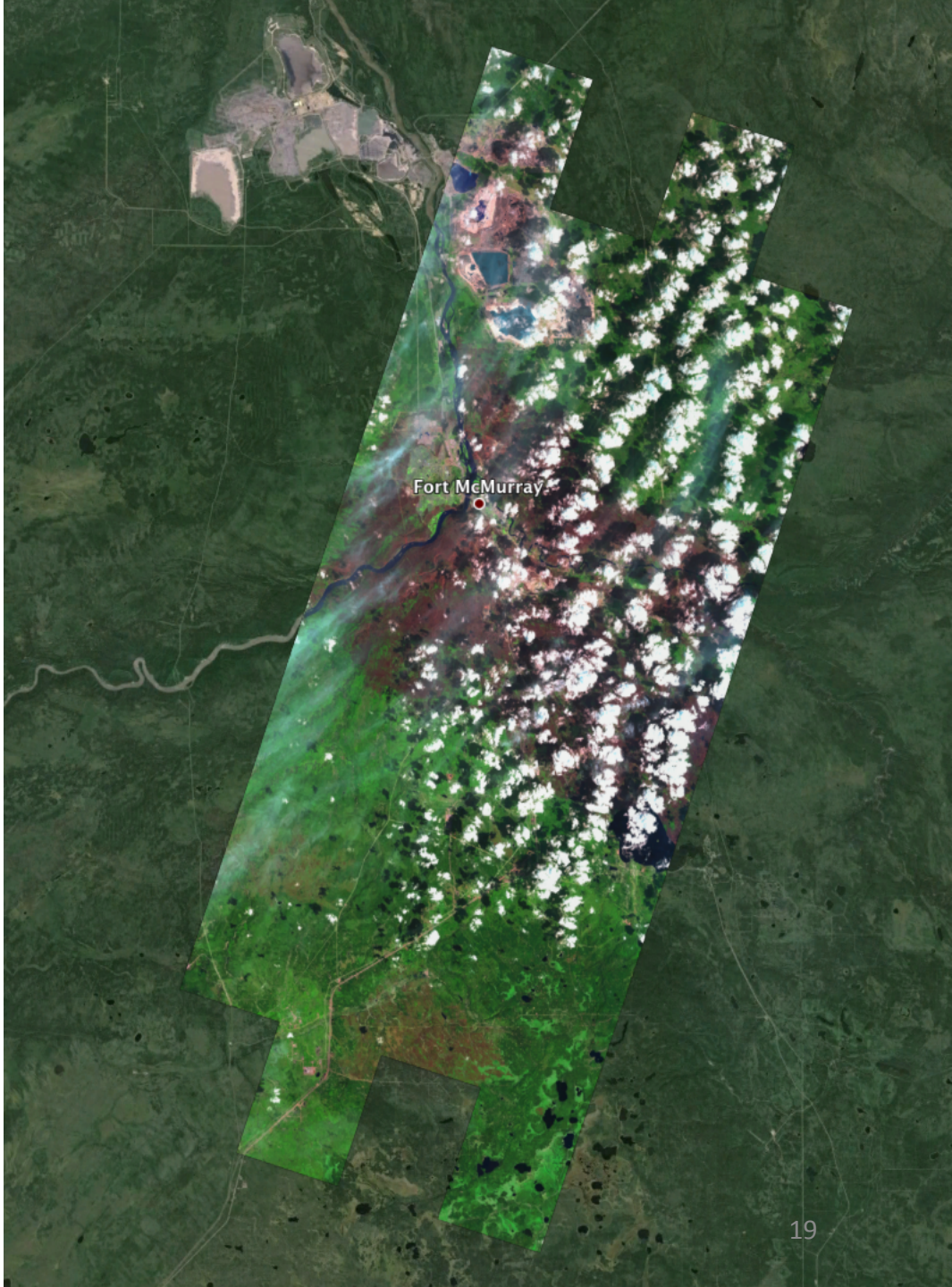
Before

After

Good Alignment

Fort McMurray Fires
EO1A0420202016132110KF
2016-05-11

Recovered False Color RGB
Purple: Fire Extent
Co-Registered and Displayed
on Google Earth



Next Goals…

- Autocorrect remaining 30 recent EO-1 scenes
- Evaluate Wavelet/Shearlet Approach (Jacqueline LeMoigne)

How It Works!

Level 0	Pixel Acquisition
Level 1R	Radiometric Corrected
Level 1R AC	Atmospherically Corrected
Level 1Gst	Geometric/Ortho Rectified
Level 1T	Co-registered
[Sunglint Removal]	
Level 2	Actionable Products Generation

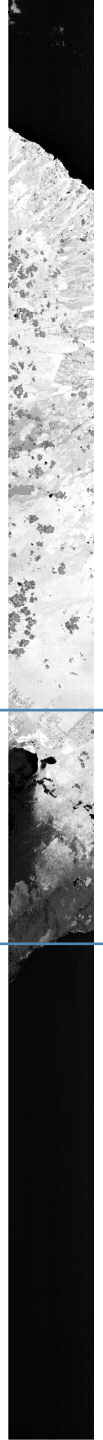
Sunglint Correction For Coastal Scenes

- Sunglint Happens Over Water!
- User May Want It Removed
- So… First, We Need Detect Coastal Waters and Create Land/Water Mask
  - Traditional Methods
    - NDVI (NIR-RED)/(NIR+RED)
      - Rouse 1973, Bo-Cai Gao 2010-2015
    - NDWI (GREEN-NIR)/(GREEN+NIR)
      - Stuart McFeeters 1995
    - MNDWI (GREEN-SWIR)/(GREEN+SWIR)
      - Xu 2006

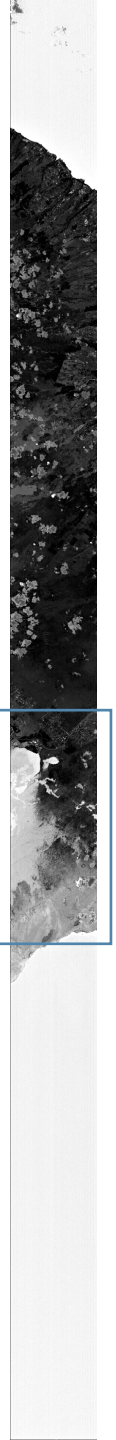
NONE PERFECT…

L1R
Composite
RED
GREEN
BLUE

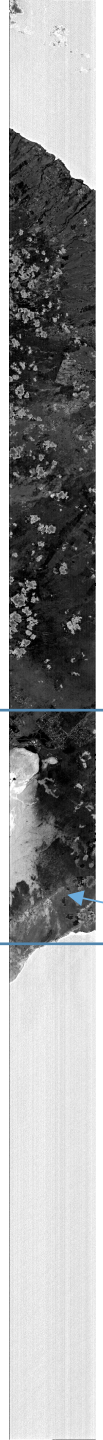
L1R
NDVI



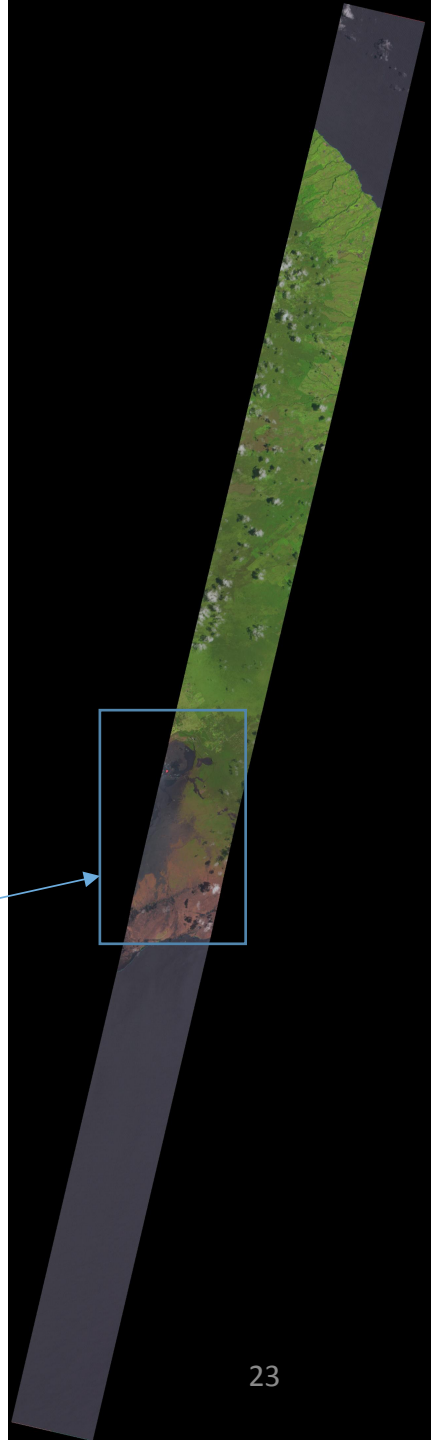
L1R
NDWI



L1R
MNDWI



USGS
L1T
Composite

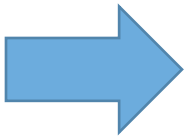


Problem
Area

Water
Confusion
????

Approach

- Detect Coastal Waters and Create Water Mask
  - Traditional Methods
    - NDVI (NIR-RED)/(NIR+RED)
      - (Rouse 1973, Bo-Cai Gao 2010-2015)
    - NDWI (GREEN-NIR)/(GREEN+NIR)
      - (Stuart McFeeters 1995, http://www.tandfonline.com/doi/abs/10.1080/01431169608948714)
    - MNDWI (GREEN-SWIR)/(GREEN+SWIR)
      - Xu 2006

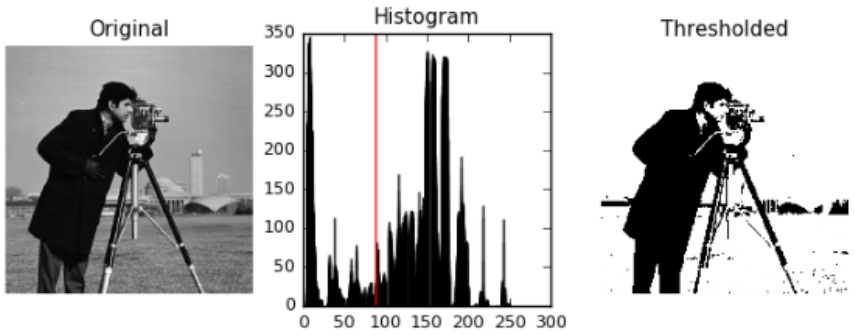


Current Choice

Land/Water Mask Thresholding Issue

- Options:
  - Manual, Scene By Scene [upload??? Not Really Feasible]
  - Hard-Coded
  - Automated OTSU thresholding (Nobuyuki Otsu, 1979)
    - Aka Histogram-based Thresholding

[1] http://en.wikipedia.org/wiki/Otsu's_method

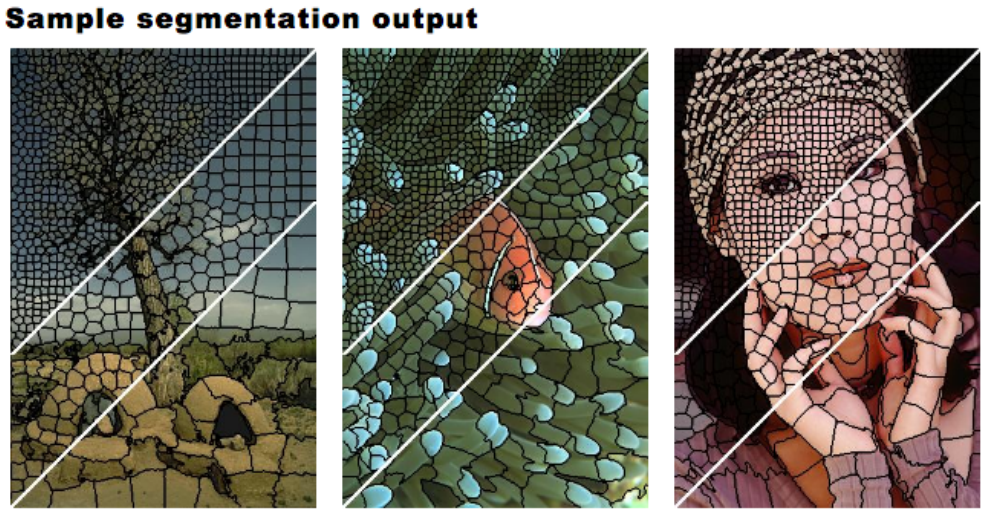


http://ivrl.epfl.ch/research/superpixels

Land/Water Mask
A Novel Approach Using SLIC SuperPixels and MNDWI

- **Reference**
  - Radhakrishna Achanta, Appu Shaji, Kevin Smith, Aurelien Lucchi, Pascal Fua, and Sabine Süsstrunk, SLIC Superpixels Compared to State-of-the-art Superpixel Methods, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 34, num. 11, p. 2274 - 2282, May 2012.
  - Radhakrishna Achanta, Appu Shaji, Kevin Smith, Aurelien Lucchi, Pascal Fua, and Sabine Süsstrunk, SLIC Superpixels, EPFL Technical Report no. 149300, June 2010

Very Low Computational Overhead
Respect Local Boundaries



SLIC (Simple Linear Iterative Clustering)

We Go From
~1Mega Pixels

(RGB
Composite)

To 55
SuperPixels
using
SLIC algorithm
(local K-nearest
neighbors and
CIE Lab)

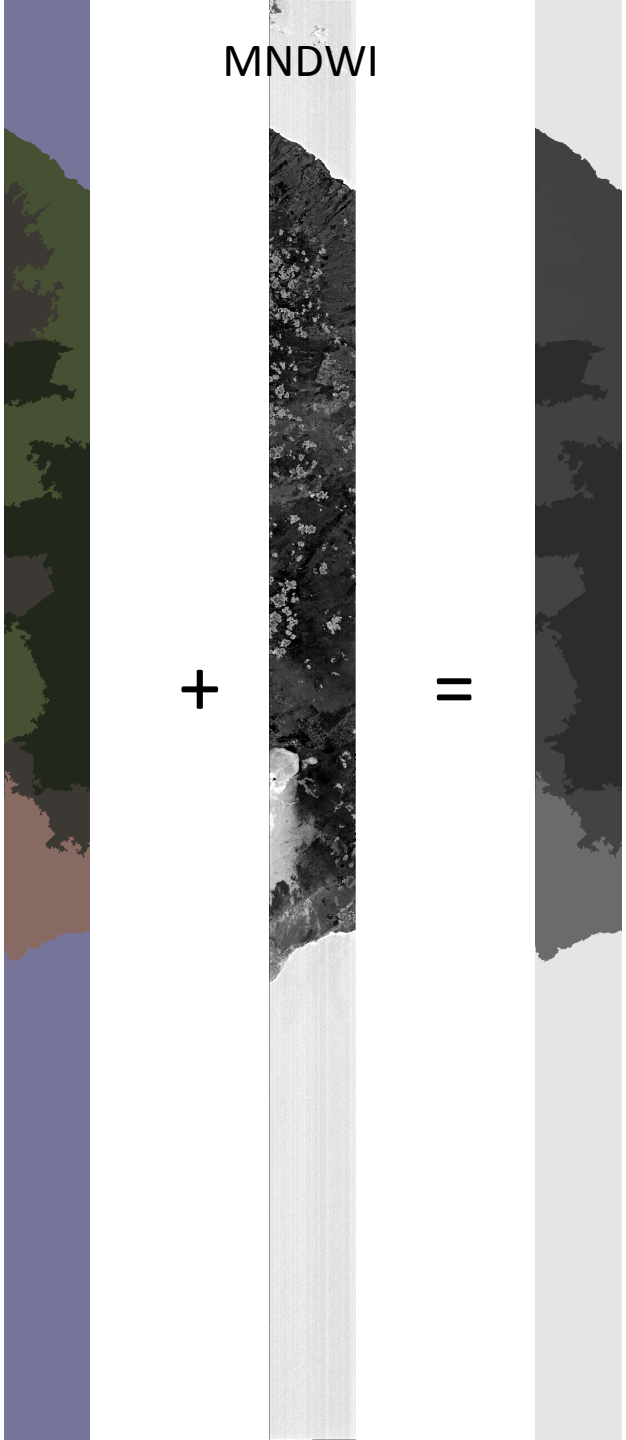
But Now You Need a Way To Merge/
Identify
Similar SuperPixels

[Notice how it took care of the
clouds…]

55 SuperPixels using
SLIC algorithm
(local **K-Nearest Neighbors** and CIE Lab)

SuperPixels are merged into 5 Classes (Regions)
Shown here with Average Image Color using
K-Means
In CIE Lab space

But We Still Need To Identify the Water Classes/ Regions



Coastal Land/Water Mask

Using Merged SuperPixels and MNDWI Information,
We Can Compute Average MNDWI per Regions.
Then Apply OTSU Thresholding.
Result is our Land/Water Mask

Sunglint Removal Starting Point

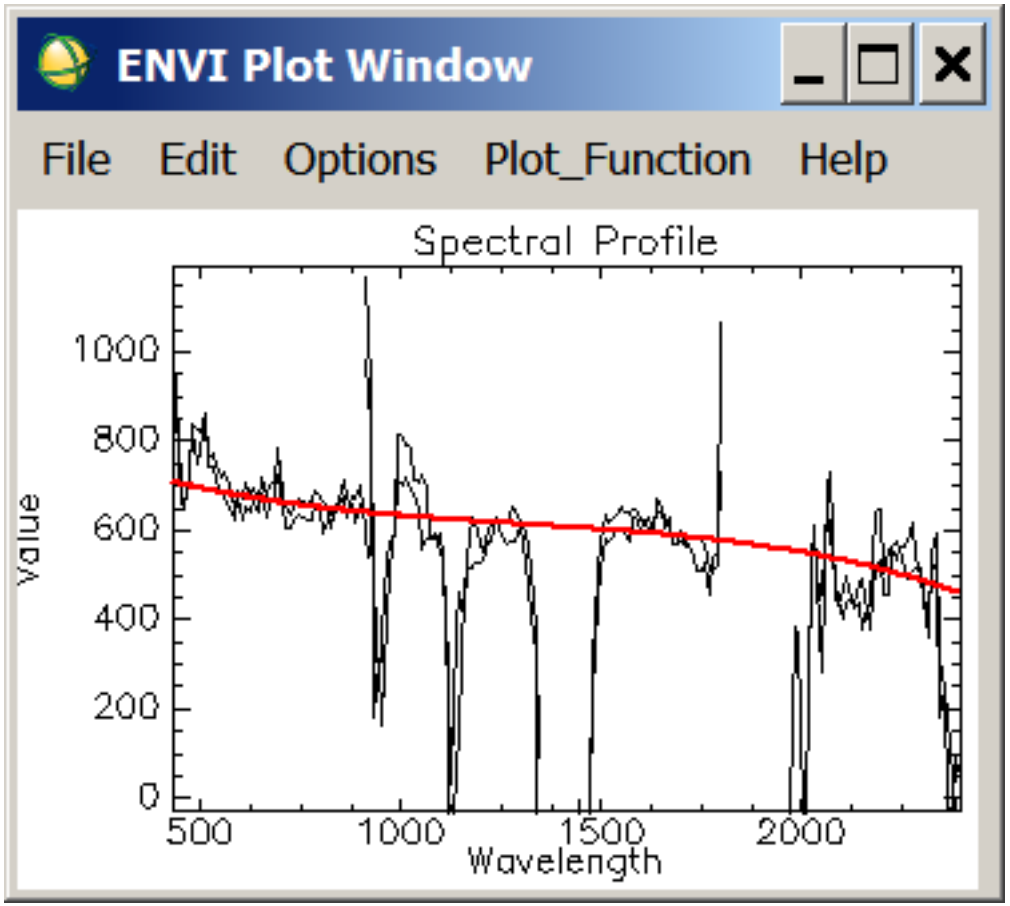
- "It is seen again that sunglint contributes a nearly constant reflectance value of ~ 8% above 0.8 μm"

Bo-Cai Gao & Rong-Rong Li, NRL, DC

September 2009

Actually, Sunglint Spectrum Is Not Quite Flat…

Comparison of scaled glint expression with data:

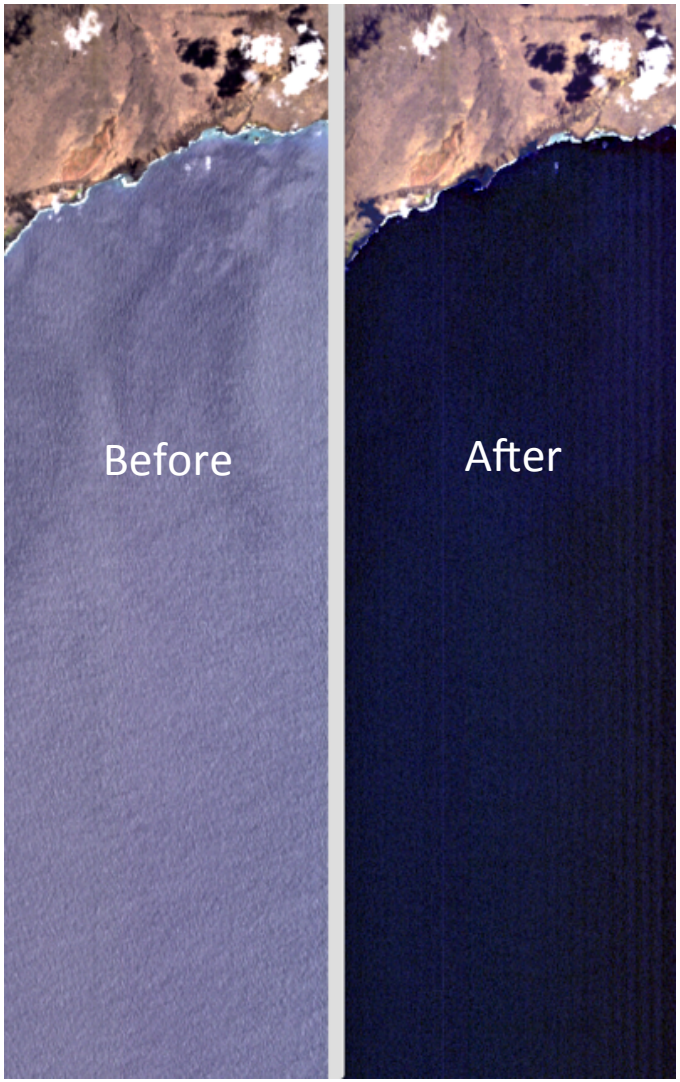


Scaled near-normal water reflectance (cubic fit to Fresnel equation)

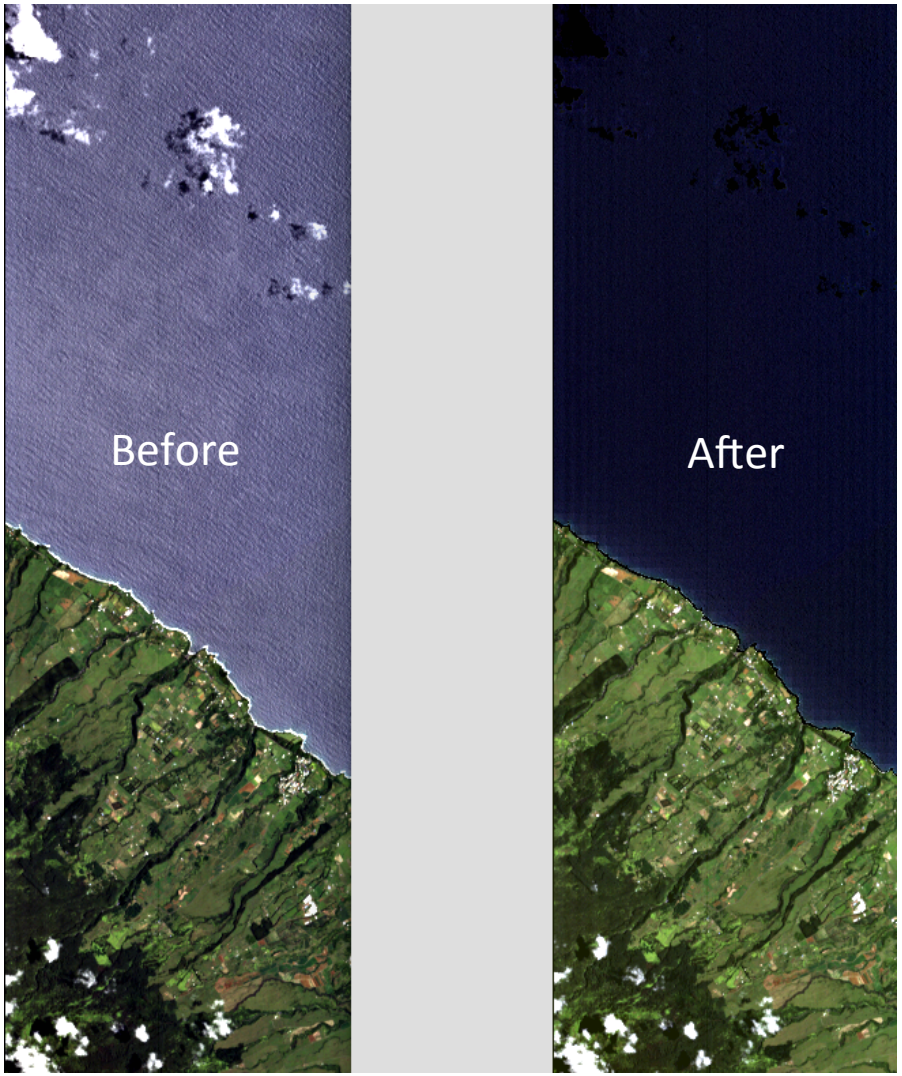
Dr. Steve Adler-Golden, SSI

Results after sunglint removal

Bottom Scene



Top Scene



Next Steps…

- More Coastal Scenes
- Validate Approach With Low Bathymetry
- Validate Spectral Output (Petya)

How It Works!

Level 0 — Pixel Acquisition

Level 1R — Radiometric Corrected

Level 1R AC — Atmospherically Corrected

Level 1Gst — Geometric/Ortho Rectification

Level 1T [Sunglint Removal]

Level 2