OnBoard Low-Latency Products Development

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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)
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**: Co-registered
  - [Sunglint Removal]
- **Level 2**: Actionable Products Generation
  - Onboard Imaging Service (2014)
  - Web Coverage Processing Service (WCPS)
How It Works!

Level 0

Level 1R

Level 1R AC

Level 1Gst

Level 1T

[Sunlight Removal]

Level 1T

Pixel Acquisition

Radiometric Corrected

Atmospherically Corrected

Geometric/Ortho Rectified

Co-registered

Actionable Products Generation

Instrument Payload Module (IPM) & Field Programmable Gate Arrays (FPGA)
How It Works!

Onboard...

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 1T

Level 2
- Actionable Products Generation

FLAASH-C
Onboard Atmospheric Correction

- 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
How It Works!

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- Co-Registration

[Sunglint Removal]

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](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 Offsets: tx= 188, ty= -320
Before
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!

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Level 1T
  [Sunlight Removal]

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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...
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

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

• Reference

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 \textbf{K-Nearest Neighbors} and CIE Lab)

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

But We Still Need To Identify the Water Classes/Regions
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

Before

After

Top Scene

Before

After
Next Steps...

• More Coastal Scenes
• Validate Approach With Low Bathymetry
• Validate Spectral Output (Petya)
How It Works!

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Level 1R AC

Level 1Gst

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[Sunglint Removal]

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