

DESIS Applications & Processing

Extracted from Teledyne & DLR Presentations to JACIE – April 14, 2016

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Presentation Agenda

- ▶ **Imaging Spectroscopy Applications of DESIS Hyperspectral Data**
- ▶ **Image Processing**
- ▶ **Revisit Analyses**



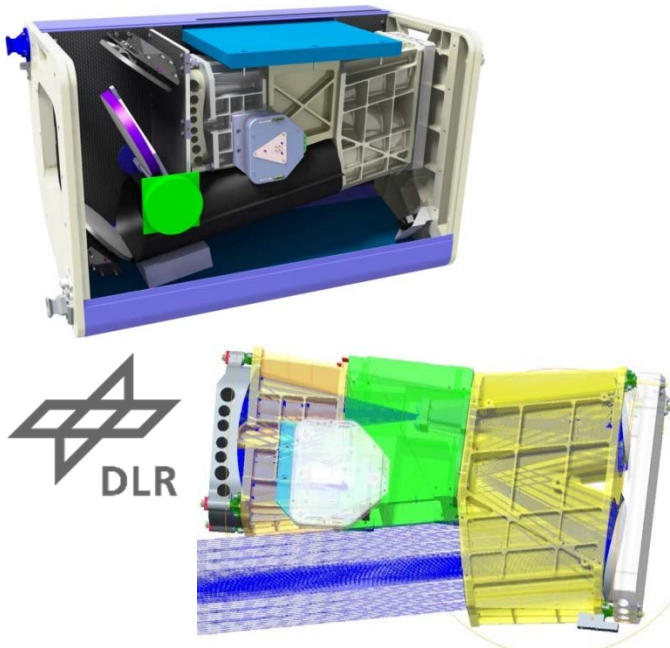
Imaging Spectroscopy Applications

- ▶ Teledyne and DLR have partnered to build and operate the DLR Earth Sensing Imaging Spectrometer (DESIS) from the Teledyne-owned MUSES Platform on the ISS
- ▶ The DESIS Instrument will be used to
 - Enable scientific RESEARCH
 - Expand HUMANITARIAN response
 - Provide COMMERCIAL value



DLR Earth Sensing Imaging Spectrometer (DEISIS-30)

- ▶ Teledyne is responsible for payload integration and operations
- ▶ Teledyne retains rights for commercial use
- ▶ DLR retains rights for scientific use
- ▶ Launch planned for Q2,

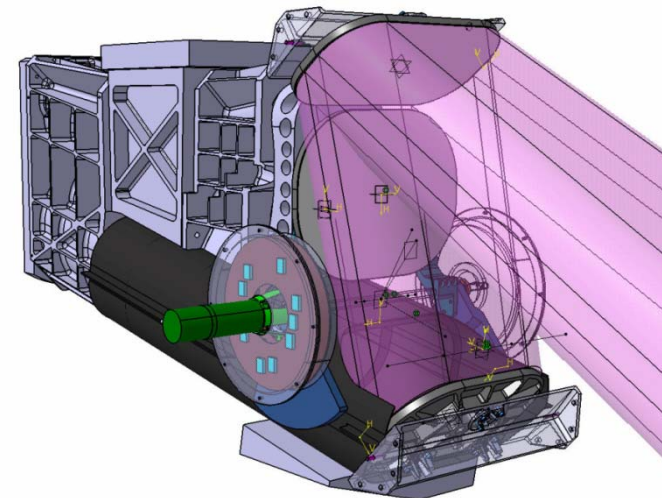
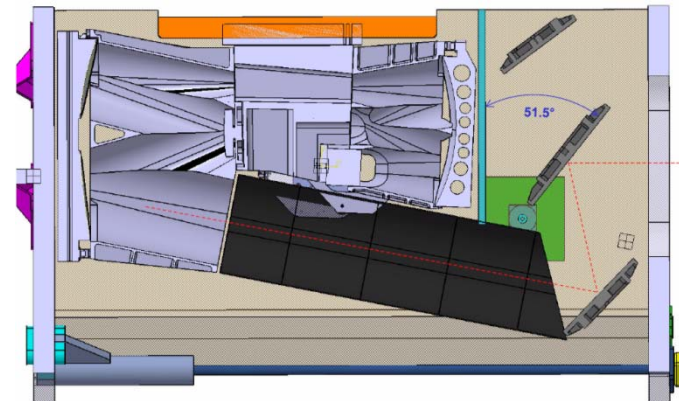


Parameter	Value
Focal length	320 mm, telecentric
F#	2.8
Field of view	4.4 °
Pixel IFOV	0.004 °
GSD @ Nadir	30 m @ 400 km
Swath @ Nadir	30 km @ 400 km
Spectral Channels	235 measured
Spatial Pixels	1024
SNR	205:1 sampled at 2.55 nm @ 550 nm 406:1 binned to 10.2 nm @ 550 nm
Radiometric Linearity	> 95% (10%-90% FWC)
MTF @ Nyquist (no smearing)	< 3 nm
Instrument Independent Pointing	± 15 ° along track
Pixel Size	24 x 24 μm
FPA Size	1056 (spatial) x 256 (spectral)
Pixel Quantization	12 bits
Design Lifetime	5 years
Operational Mode	Pushbroom
Instrument Developer	DLR Adlershof/Berlin

DESIS Pointing Unit



- ▶ Changes sight $\pm 15^\circ$ in the along-track direction
- ▶ Allows acquisition of up to 3 image tiles under different angles
- ▶ ES-Mode
 - 11 measurement positions $\pm 15^\circ$ (every 3°)
 - Repeatability / accuracy 20 arc minutes
 - Target replacement time ≤ 0.5 seconds
- ▶ FMC-Mode
 - Speed 0.6 deg/sec and 1.5 deg/sec
 - Accuracy 0.06 degrees (1/10 GSD)
 - Range of rotation $\pm 15^\circ$



DESIS Data Utilization (1)

Basic hyperspectral method developments



- ▶ Spectral unmixing techniques (linear & non-linear methods)
- ▶ De-noising techniques (especially at wavelengths close to 400 nm for water applications)
- ▶ Improvements of hyperspectral data classification methods (deep learning, compressive sensing / sparse reconstruction, synergetics)
- ▶ Derivation of geophysical parameters employing bidirectional reflectances
- ▶ Fusion of hyperspectral (DESIS) and multispectral (WV-2/3, Sentinel-2,...) for resolution enhancement keeping the spectral integrity (*not only pan-sharpening*)

see next slide (based on *Joint Sparsity Model for Multilook Hyperspectral Image Unmixing*)

- ▶ *and many more...*



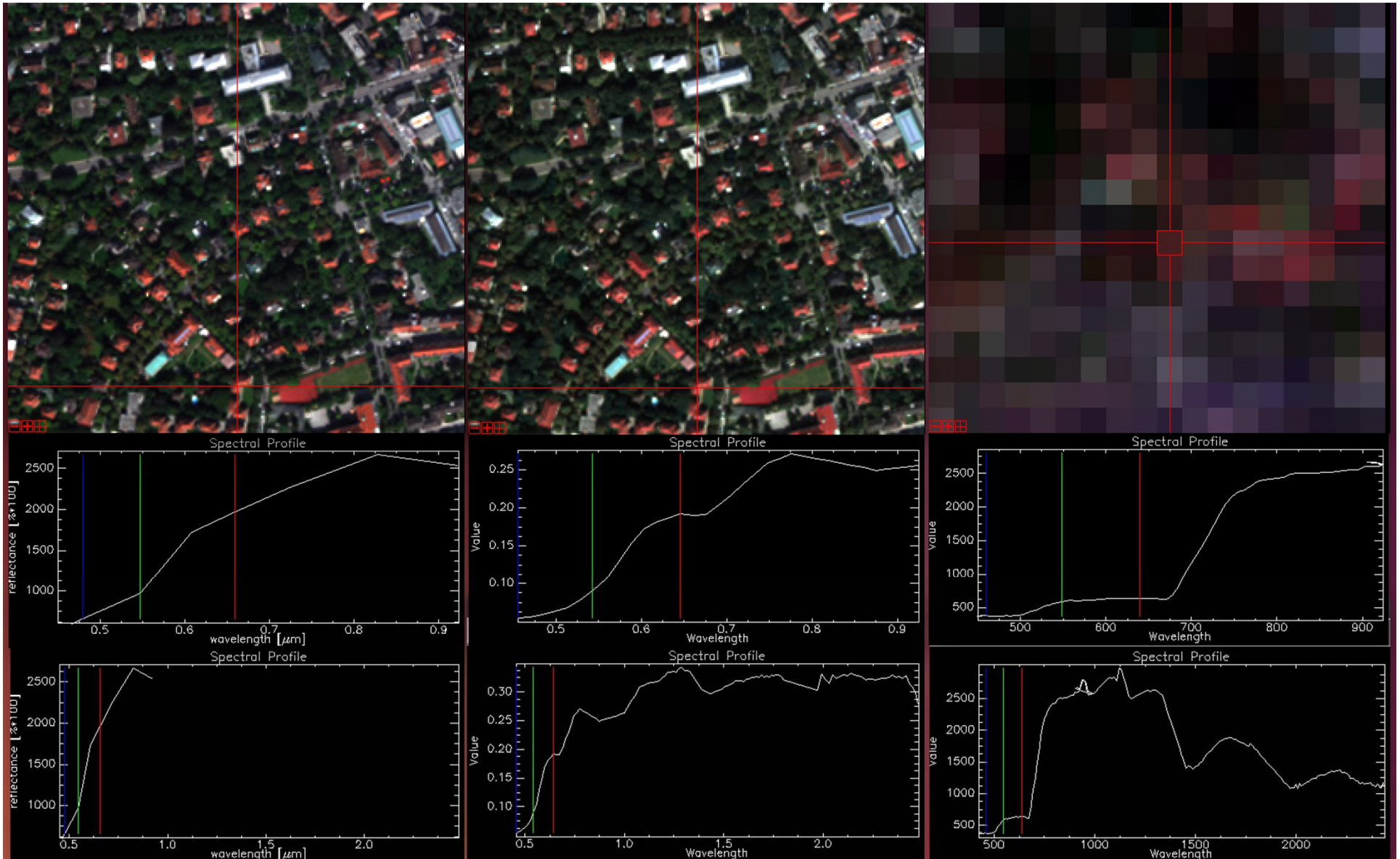
Example Fusion of Multispectral and Hyperspectral Data



WV-2 (~2 m, MS 8 bands)

Fusion

DESIS (30 m, HSI)

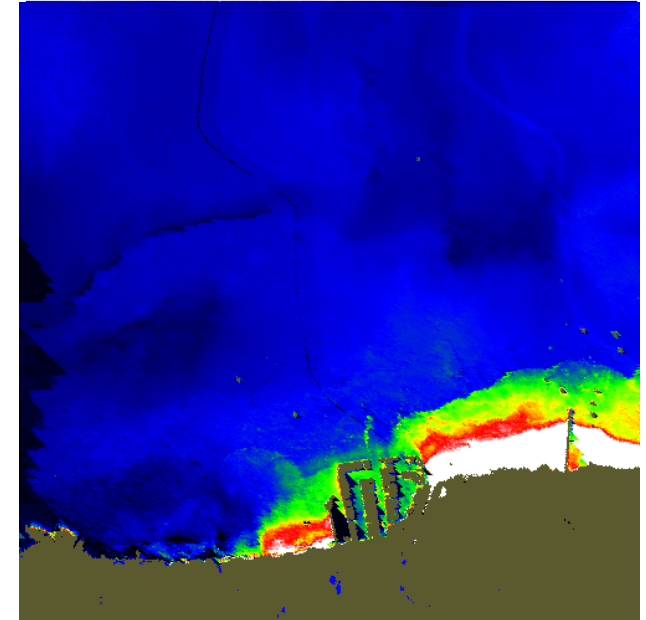
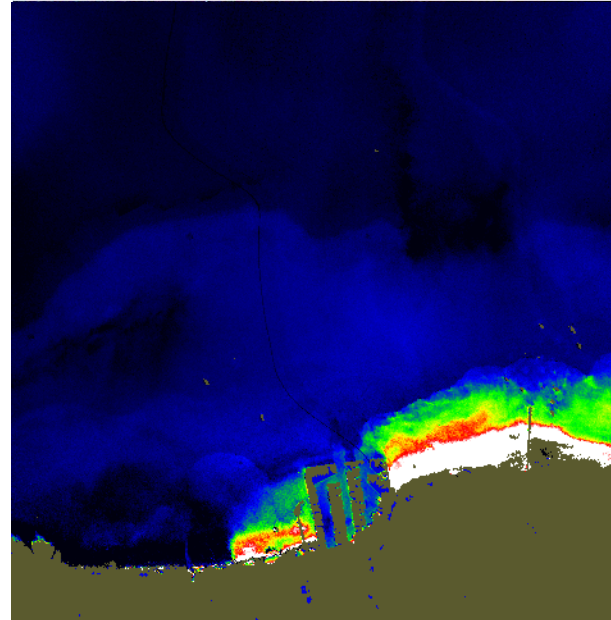


Example Denoising of Hyperspectral Data (HySpex)



Before Denoising

After Denoising



Starnberger See,
Germany

Noisy & 'clean' bands



Absorption Estimation (WASI Tool) of
Coloured Dissolved Organic Matter

(Error in model fit drops down 50% after denoising)



DESIS Data Utilization (2)

Application Oriented Applications



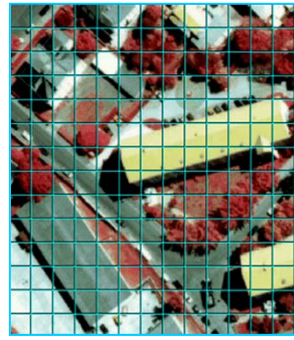
- ▶ Mid- and long-term environmental monitoring of mining resource districts (environmental acidification, monitoring, restoration assessment)
- ▶ Soil degradation (indicators, pollution, salinization)
- ▶ Vegetation monitoring (stress parameters, monitoring)
- ▶ Inland waters (chlorophyll, pollution, bathymetry, water content models)



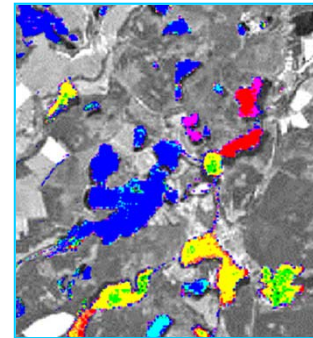
management of agricultural and forest ecosystems



hazard assessment



urban development



inland water



dryland degradation



DESIS Data Utilization (3)

Natural Disasters and Humanitarian Aid



- ▶ Analysis for the utilisation of HSI data for rapid provision, processing and analysis of satellite imagery during natural and environmental disasters, for humanitarian relief activities and civil security issues worldwide
- ▶ Development of algorithms (mapping of damages before/after e.g. floodings, natural resources, change detection, burned areas,...)
- ▶ Operational service also in the context of the International Charter 'Space and Major Disasters'



Example Natural Disasters and Humanitarian Aid

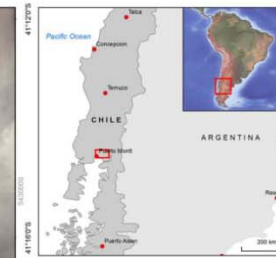
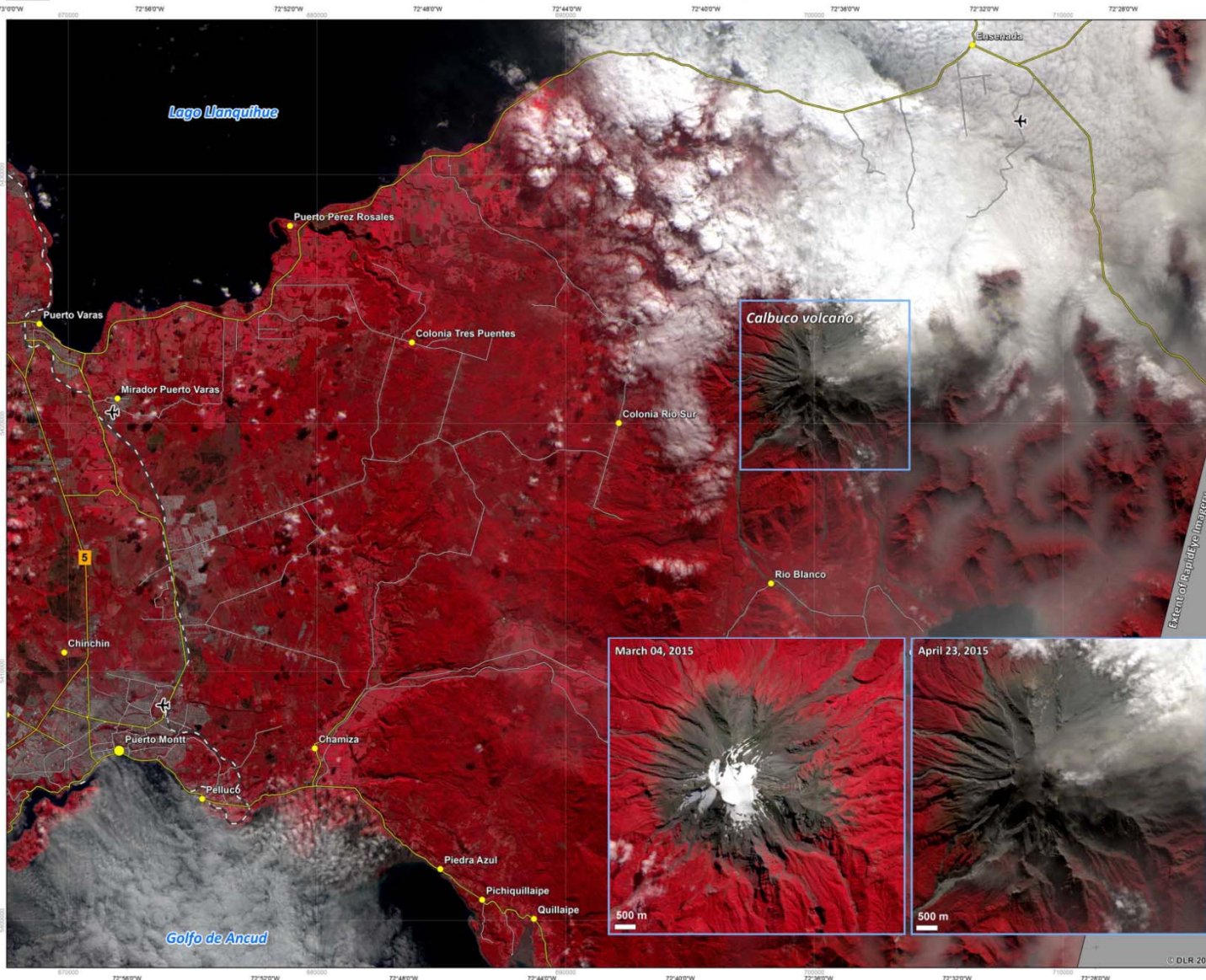


CHILE - Calbuco volcano eruption

Situation as of April 23, 2015 - Overview Map

1:70,000

Charter Call 528
Product No. 01
Version No. 01



Legend

Infrastructure

- City
- Town / Village
- ✈ Airport
- Highway
- Primary road
- Secondary road / Track
- Railway

Interpretation

The map shows the Calbuco volcano in southern Chile and its surroundings. The volcano erupted on April 22, 2015 for the first time in over 42 years sending a plume of ash up to an altitude of about 10 km into the sky. A second eruption occurred seven hours later on the following morning and early reports indicate that it was on the same scale as the first one. The event triggered a Red Alert in the Los Lagos Region of Chile. Thousands of people within a 20 km radius of the volcano have been evacuated.

RapidEye satellite imagery (false colour composite NIR/Red/Green, red colour indicating vegetation) acquired on April 23, 2015 (15:47 UTC) is used as backdrop.

Note: The transport network is not complete. The map shows predominantly major roads.

Cartographic Information

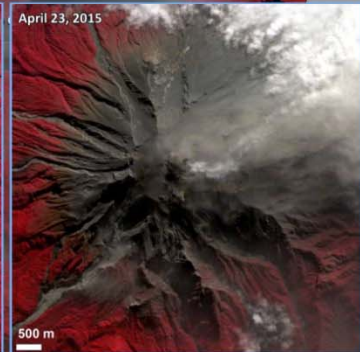
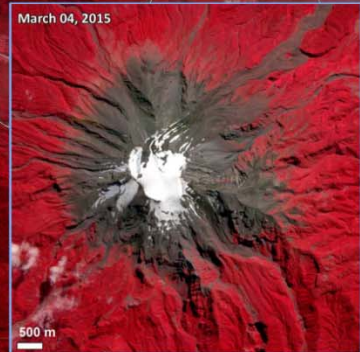
0 1 2 3 4 5 km
Local projection: UTM Zone 18S, Datum: WGS 1984
Geographic projection: Lat/Lon (DMS), Datum: WGS 84
Scale: 1:70,000 for A1 prints.

Data Sources

RapidEye (5 m) © 2015 BlackBridge AG. All rights reserved.
Vector data © OpenStreetMap contributors 2015 © DLR 2015

Framework

The products elaborated for the Rapid Mapping Activity are created to the best of our ability, within a very short time frame, optimising the material available. All geographic information has limitations due to the scale, resolution, date and interpretation of the original source materials. No liability concerning the content or the use thereof is assumed by the producer. The ZKI crisis maps are constantly updated. Please make sure to visit <http://www.zki.dlr.de> for the latest version of this product. Map produced April 24, 2015 by ZKI © DLR 2015 zki@dlr.de <http://www.zki.dlr.de>



Humanitarian Response

- ▶ **Environmental impact assessments of refugee camps**
- ▶ **Wetland monitoring for water shortages**
- ▶ **Change detection under near-real time conditions**
- ▶ **Vegetation mapping for habitat characterization**
- ▶ **Flood area mapping and characterization**
- ▶ **World Heritage Site monitoring**
- ▶ **Aid developing countries manage climate risks and land use**
- ▶ **International Disaster Charter support**

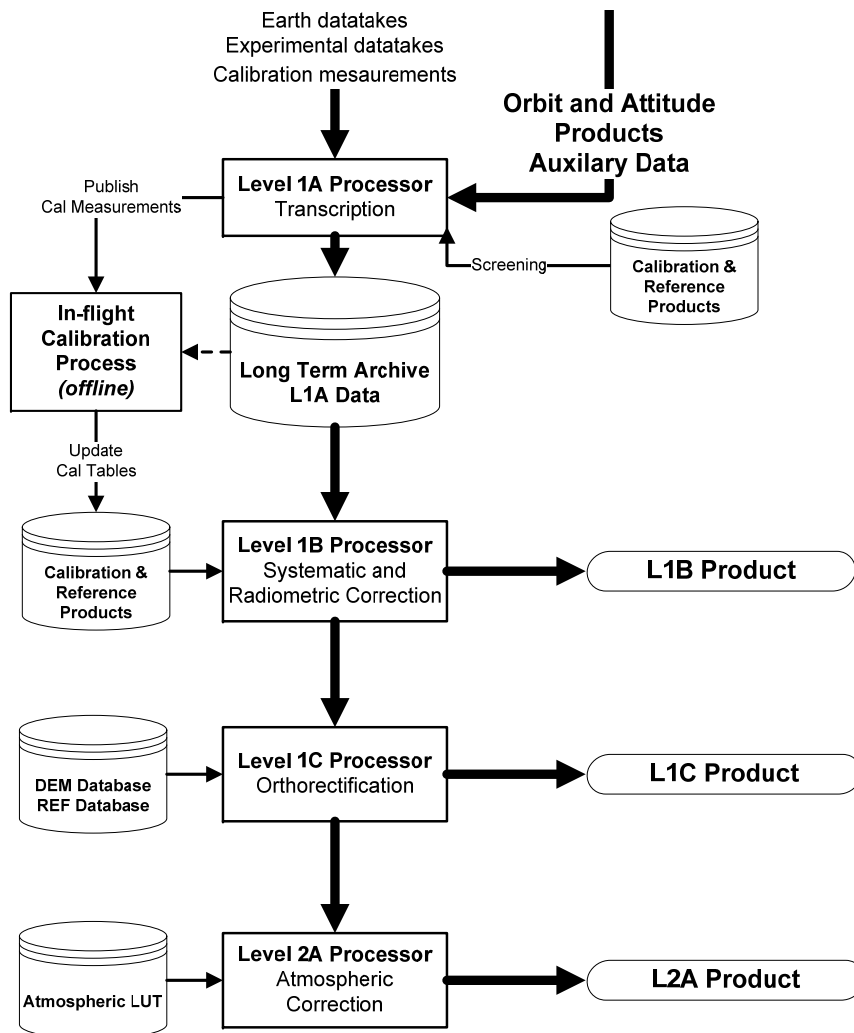


Commercial Value

- ▶ **Provide a commercial source of near-global, production quality, moderate spatial, high spectral resolution data**
 - On-demand tasking services
 - Hyperspectral data archive
 - Utilize both direct sales and distributor / value added reseller market access
- ▶ **Orthorectified, atmospherically corrected hyperspectral data**
 - Registered and cross-calibrated to Landsat 8
- ▶ **Hyperspectral Analytic Products for**
 - Vegetation classification
 - Crop and forest health assessments and stress indications
 - Ocean, estuary, and inland water monitoring
- ▶ **Multi-sensor Fusion Products**
 - Spatial Enhancement with Panchromatic and/or Multi-spectral data
 - Radar/Lidar Fusion
- ▶ **Migrate validated research applications into production applications**



Image Processing



L1A

- Data from different data streams: Image data, calibration data, AOCS, prepared for long term data storage.
- Not delivered to the user.

L1B

- L1A data + applied systematic and radiometric corrections (housekeeping and AOCS data appended).
- TOA radiance.

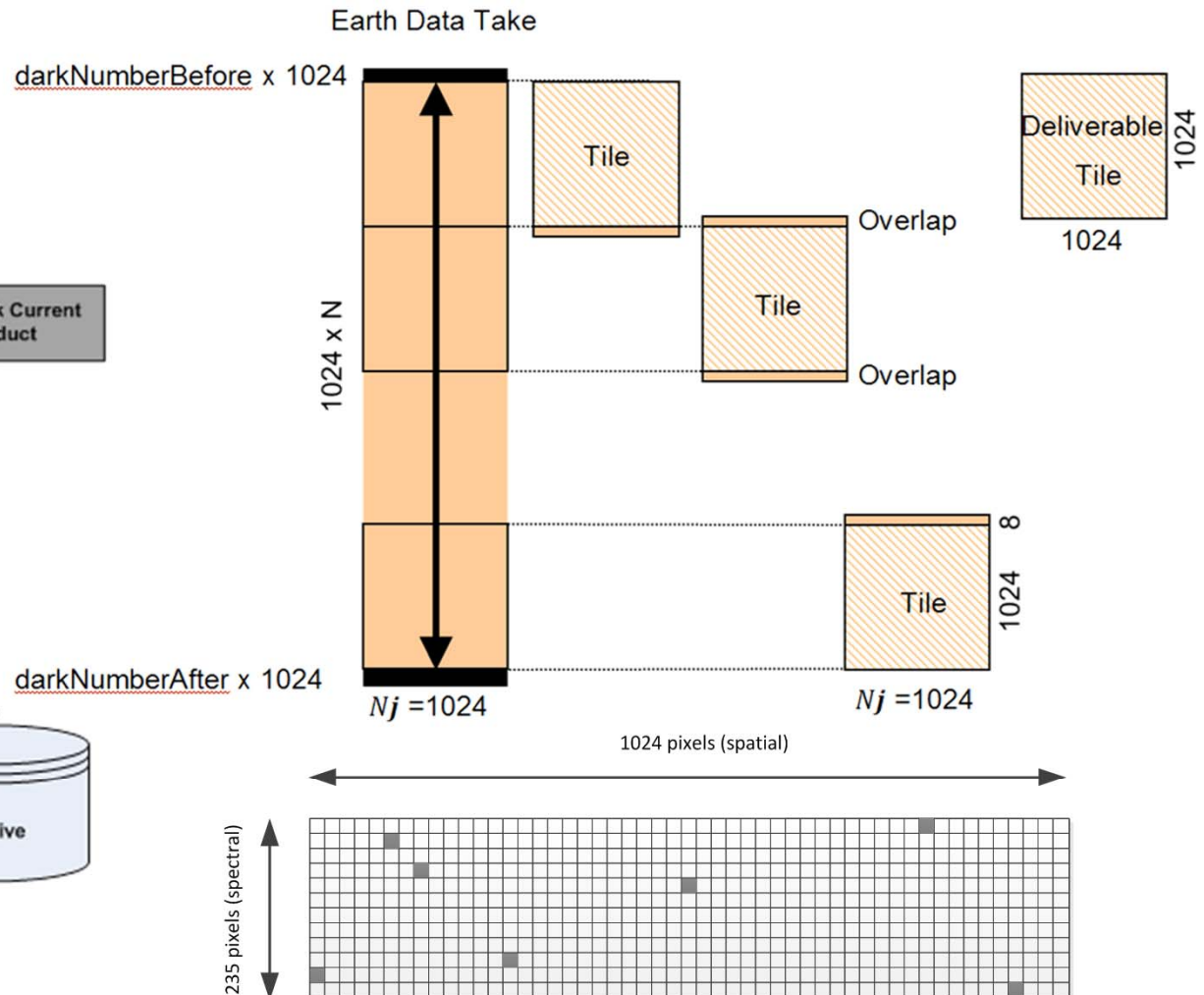
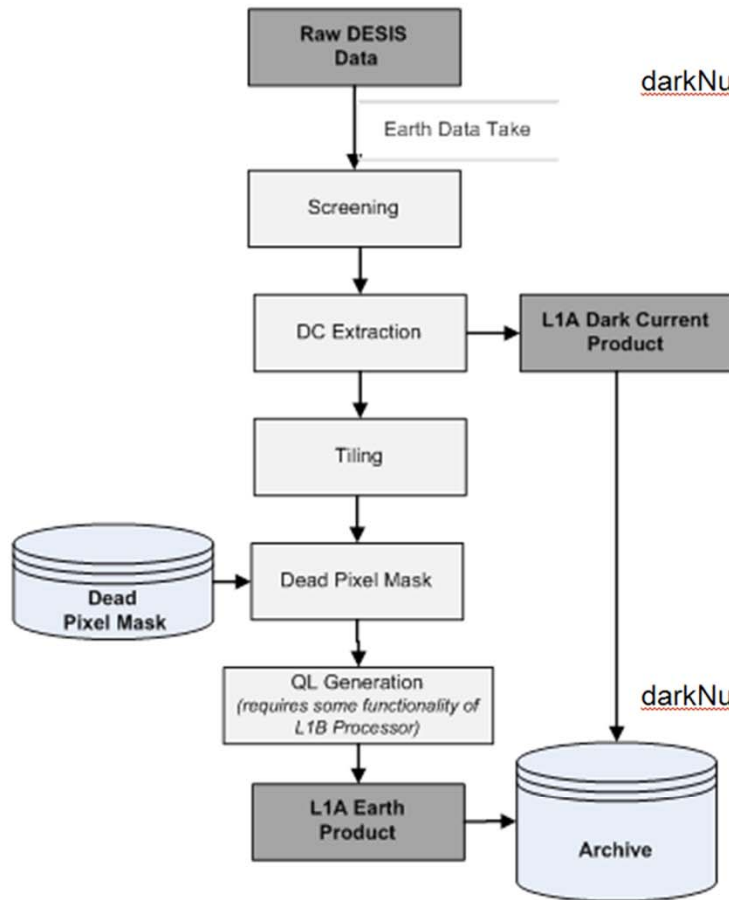
L1C

- Orthorectified and resampled L1B data
- Direct georeferencing, GCP registration, DEM.

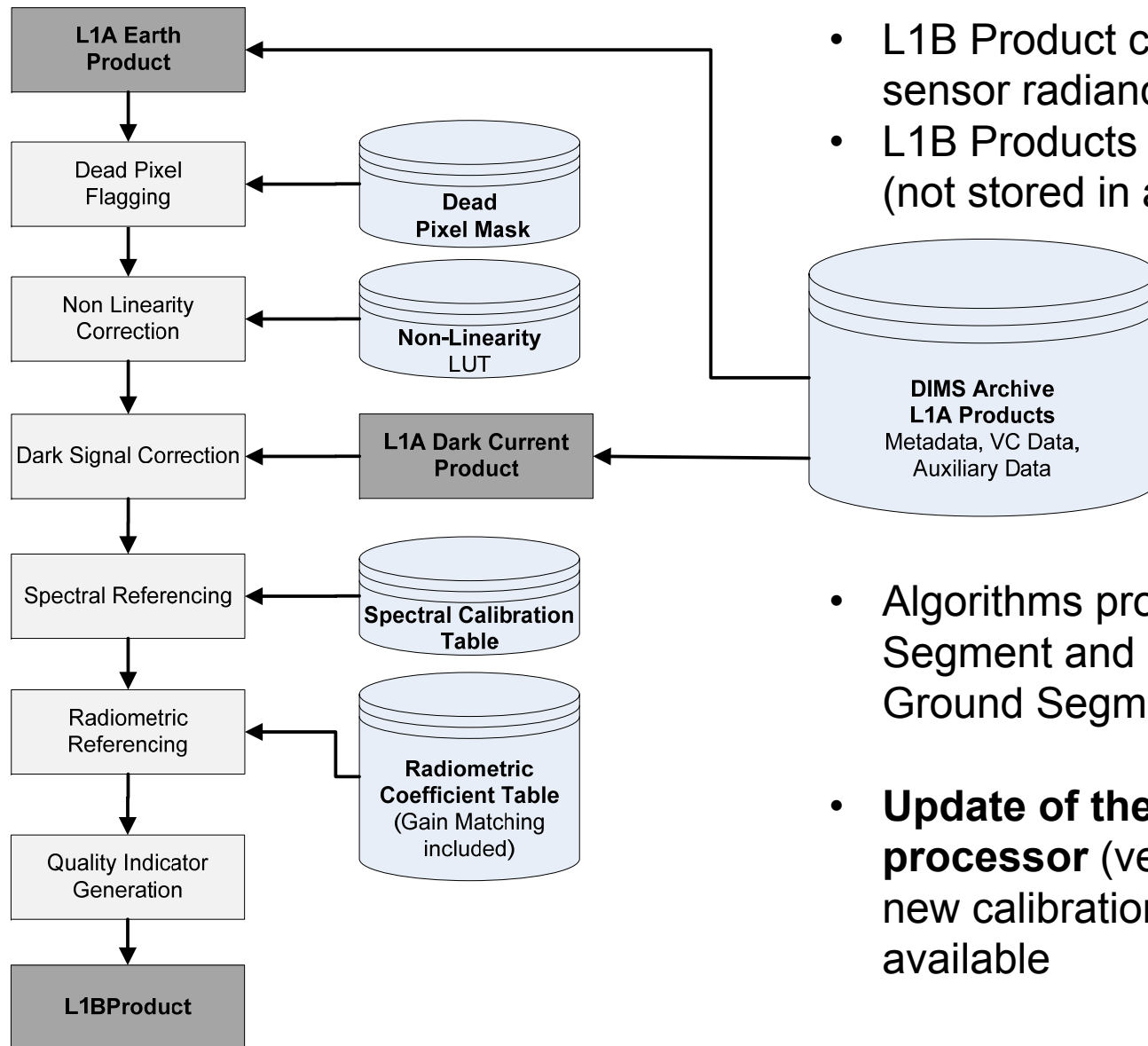
L2A

- Atmospheric corrections

Transcription Processor Level 1A



Systematic and Radiometric Correction Processor Level 1B



- L1B Product converts DN to at-sensor radiance
- L1B Products delivered to the user (not stored in archive)

- Algorithms provided by Space Segment and implemented by Ground Segment
- **Update of the development processor** (versioning), every time a new calibration/ reference table is available

Geometric Correction Processor

Level 1C

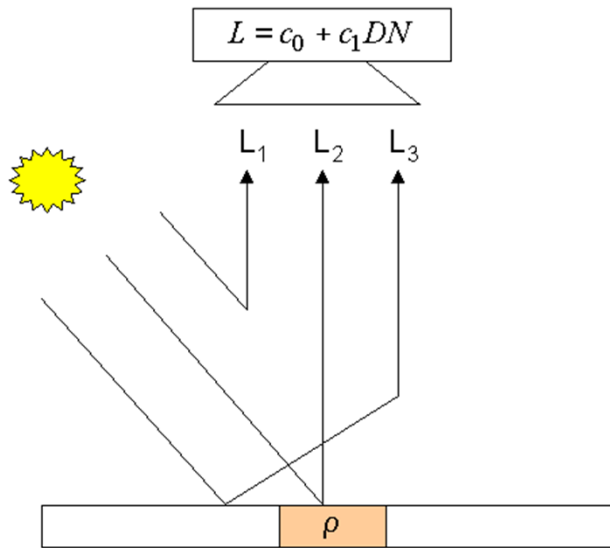
Geometric Correction of L1B Product for sensor, satellite motion and terrain related geometric distortions:

- ▶ **Sensor Model (including laboratory calibration & in-flight boresight angles)**
- ▶ **Sensor Model refinement by automatic GCP extraction from references**
 - Different image matching methods
 - Several outlier detection and removal mechanisms
- ▶ **Resampling by accounting for the rolling shutter**
- ▶ **Geometric performance targets**
 - 0.5 pixel (15 m) w.r.t. Landsat-8 orthos (linear RMSE)
 - 95% achievement

L2A Processor

ATCOR – atmospheric correction accounting for elevation model

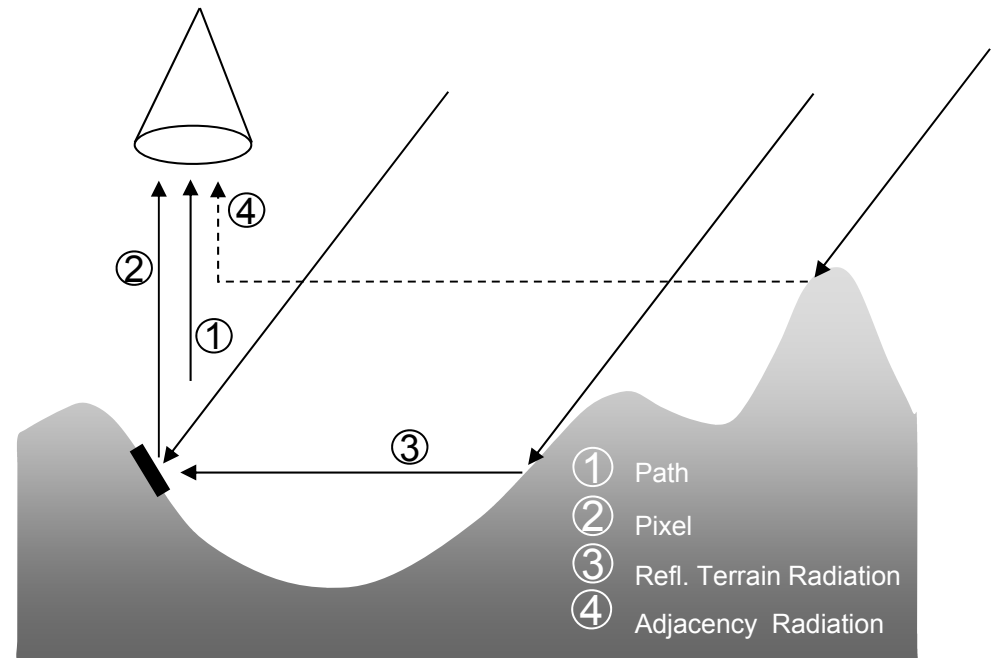
Radiation components flat terrain



Surface reflectance

$$\rho = \frac{\pi (L - L_1)}{\tau (E_{dir} \cos \theta_s + E_{dif})}$$

Radiation components rugged terrain

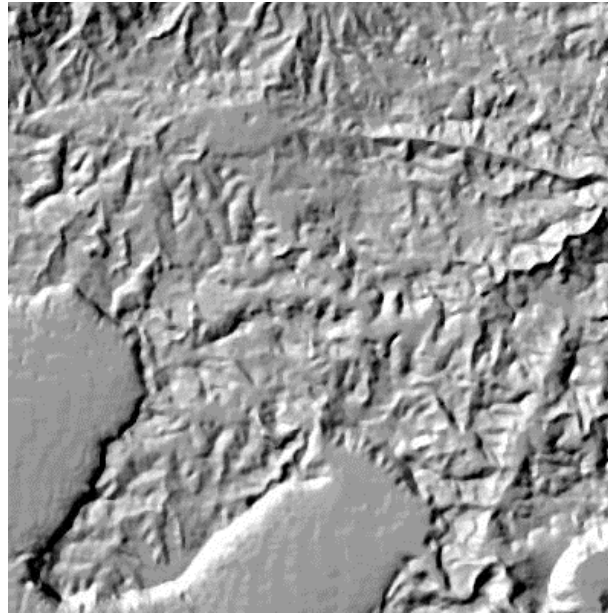


L2A Processor

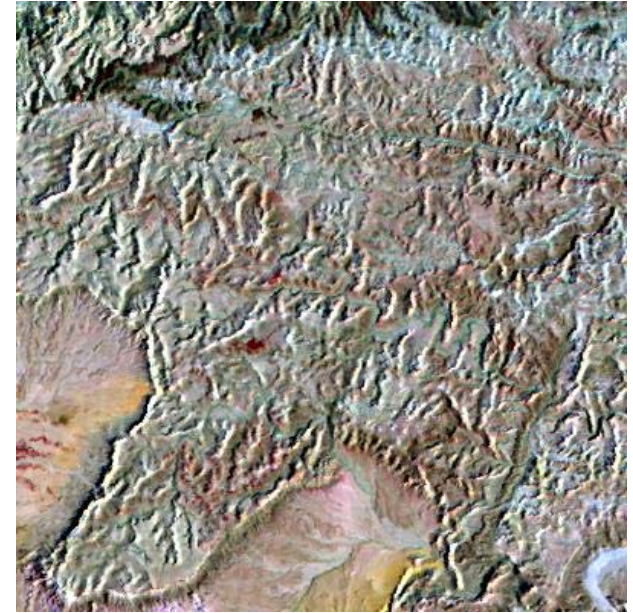
- ▶ ATCOR – atmospheric correction accounting for elevation model
- ▶ High geometric accuracy needed for topographic correction



- Atm + Topo corrected
- Geom. Acc. < 1 pixel



- Illumination map
- $\cos(\text{local SZA})$

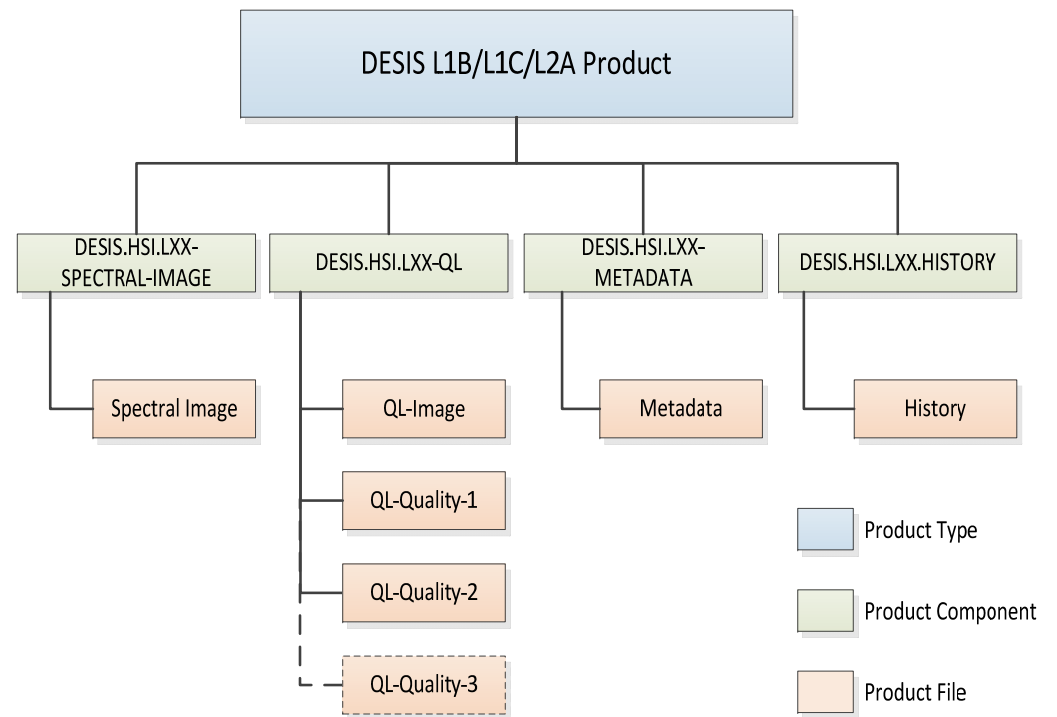


- atm + topo corrected
- 3 pixel shift →



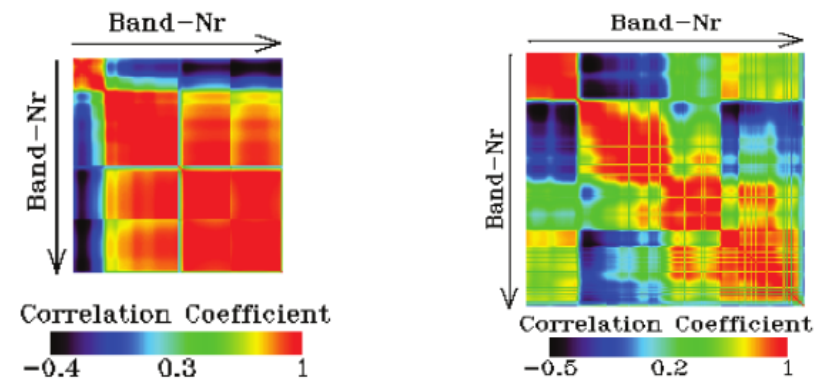
Products

- Data Products:
 - L1A Earth
 - L1A Calibration
 - L1A Dark Current (DC)
 - **L1B, L1C, L2A Products**
- Calibration:
 - Pre-launch and onboard measurements
 - Geometric
- Reference Products:
 - Dark current
 - Dead pixels
 - Etc.



Quality Quicklooks

Quality Layer (Geotiff)	L1B	L1C	L2A
Dead pixels	X	X	X
Abnormal pixels	X	X	X
Too high radiance level	X	X	X
Too low radiance level	X	X	X
Shadow			X
Land			X
Water			X
Haze over land			X
Haze over water			X
Cloud over land			X
Cloud over water			X
Aerosol optical thickness			X
Perceptible water vapour			X
Band cross-correlation	X	X	X
Bad columns	X		
Bad lines	X		



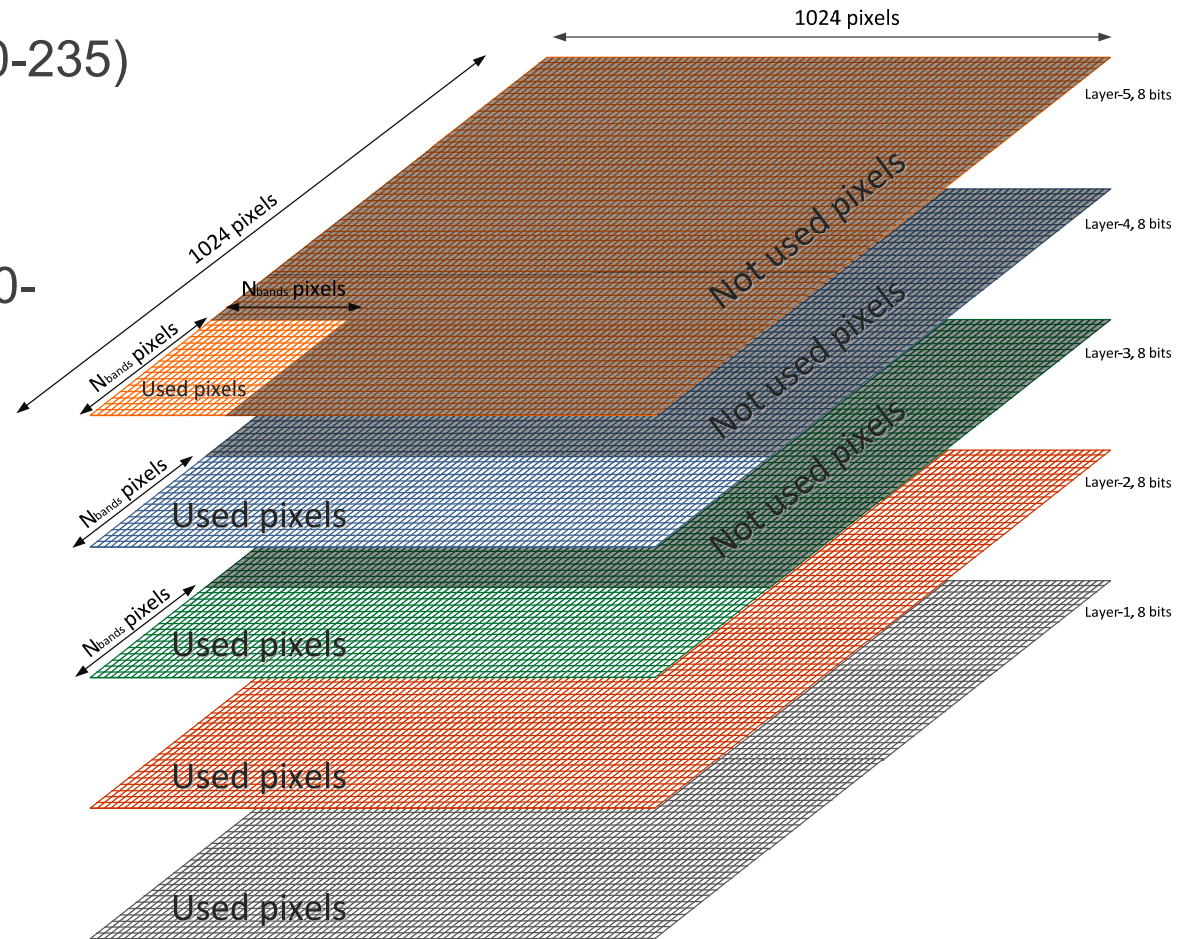
Band-cross-correlation matrix

Processor L1B: Quality Quicklook

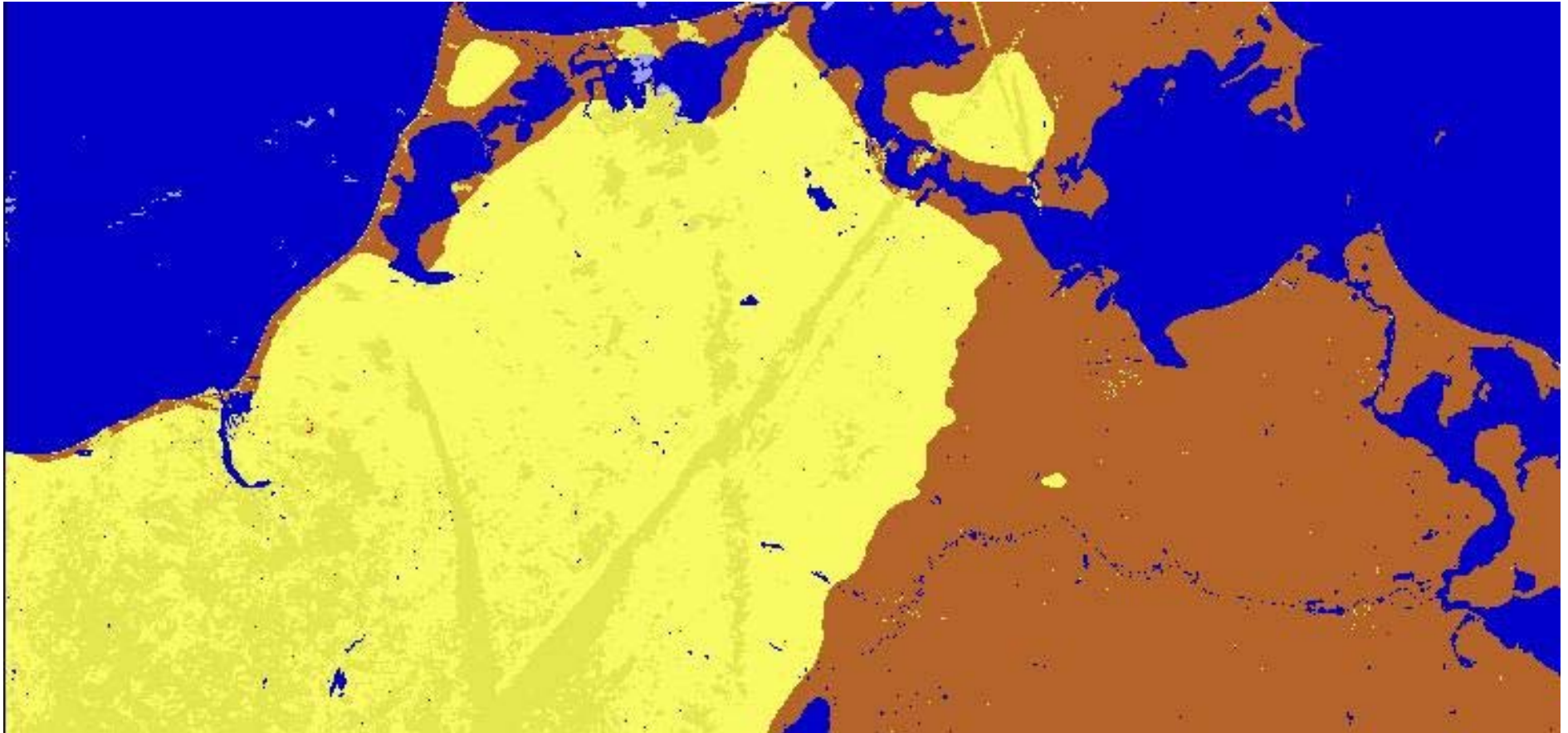
8-bit Geotiff

- Suspicious pixel mask (0-235)
- Bad pixel mask (0-235)
- Bad line mask (0/1)
- Bad column mask (0/1)
- Band cross-correlation (0-255)

1024x1024 pixels



Quality Quicklooks

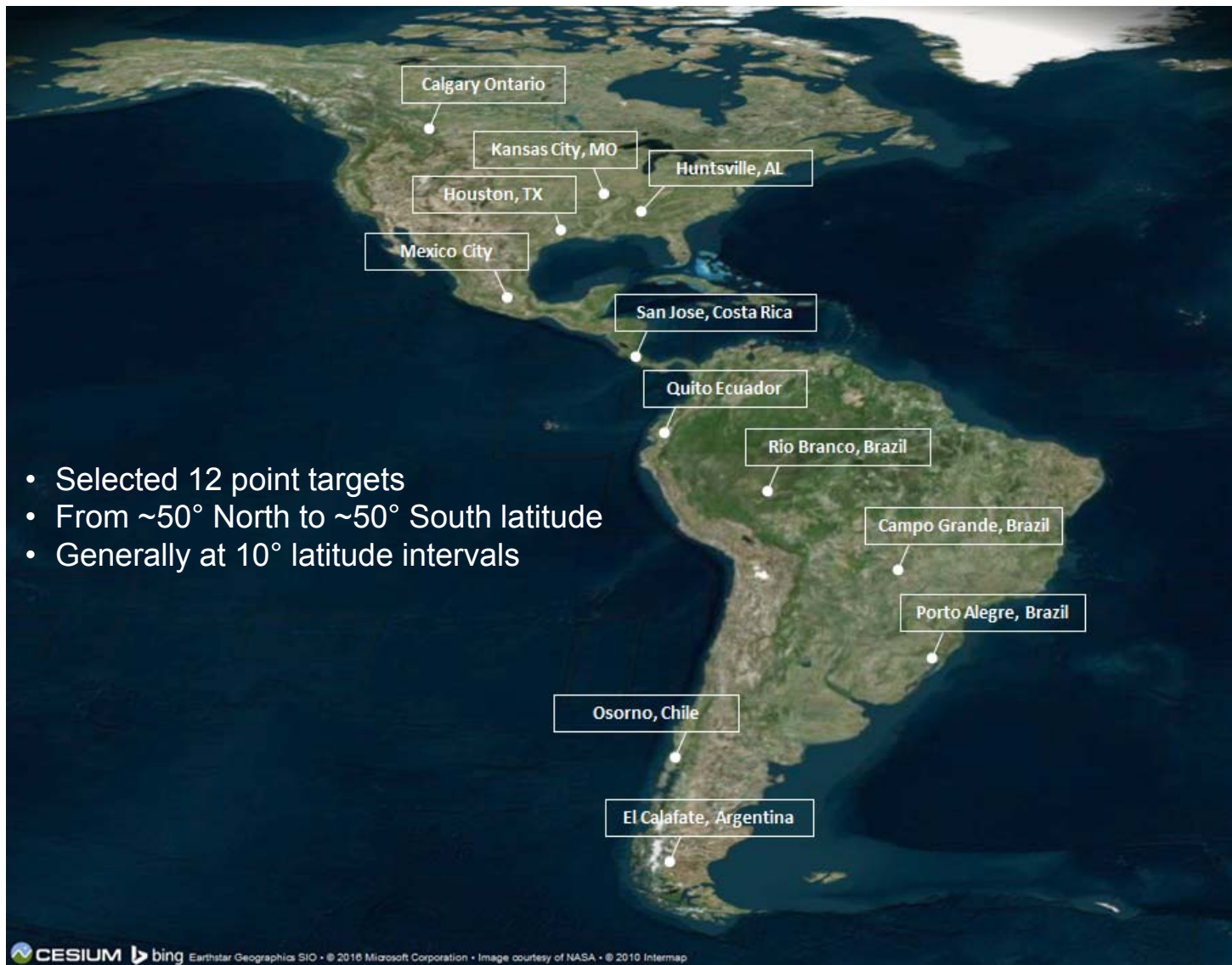


Haze / Cloud / Water / Land

Image Processing Summary

- ▶ **Processors support**
 - L1B, L1C, L2A product generation
 - Product with 4 different band binnings (1x, 2x, 3x, 4x)
 - Earth data mode, and experimental modes: BRDF, continuous
 - On demand processing
- ▶ **Same processors at TBE and DLR → Same product delivered to the users**
- ▶ **Close cooperation on outcomes of calibration and validation activities**

MUSES Imaging Revisit Analysis

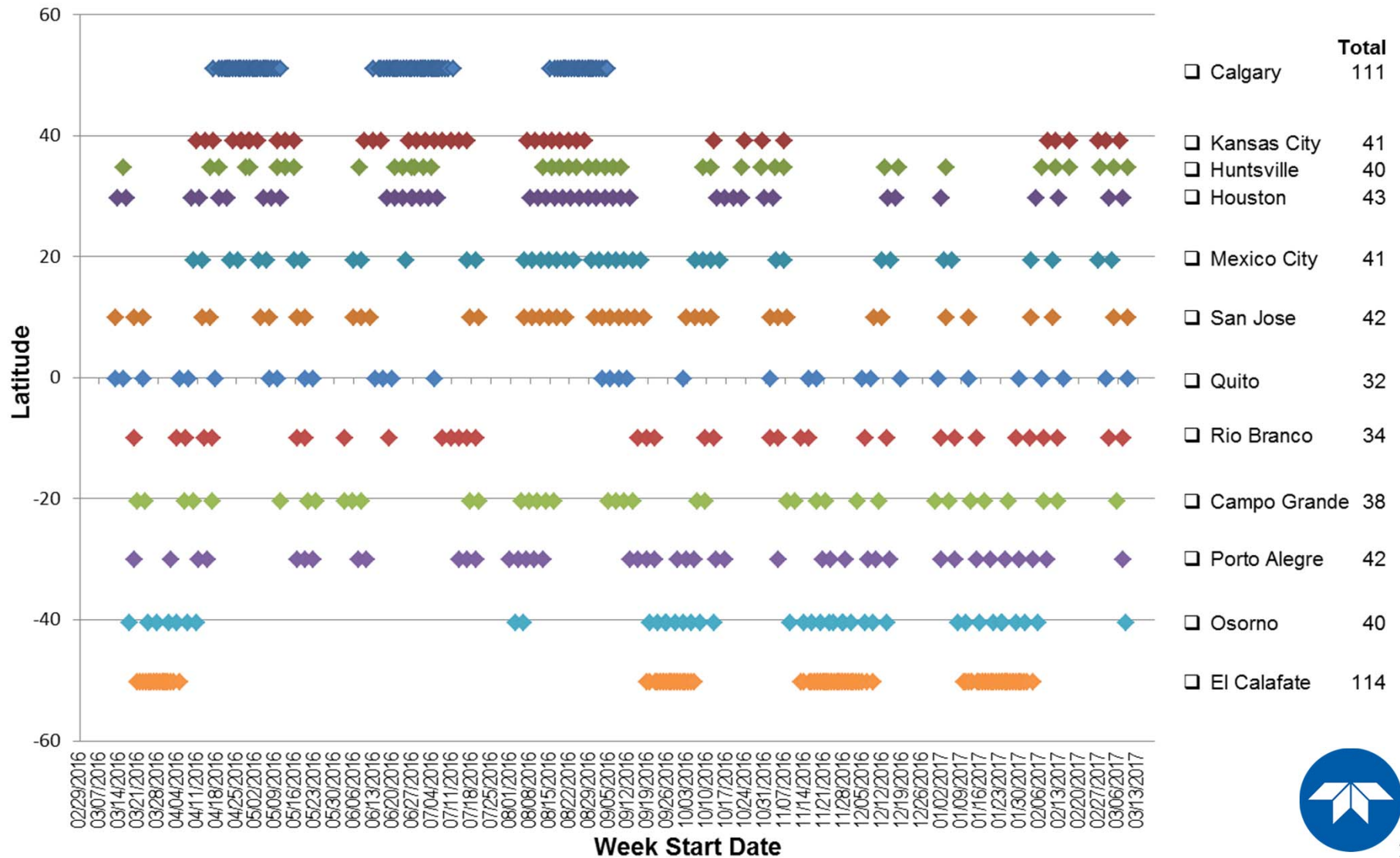


- Selected 12 point targets
- From $\sim 50^\circ$ North to $\sim 50^\circ$ South latitude
- Generally at 10° latitude intervals



MUSES Imaging Opportunities: $\geq 30^\circ$ Solar Elevation

Annual MUSES Imaging Opportunities
 Solar Elevation $\geq 30^\circ$, Off Nadir $\leq 25^\circ$

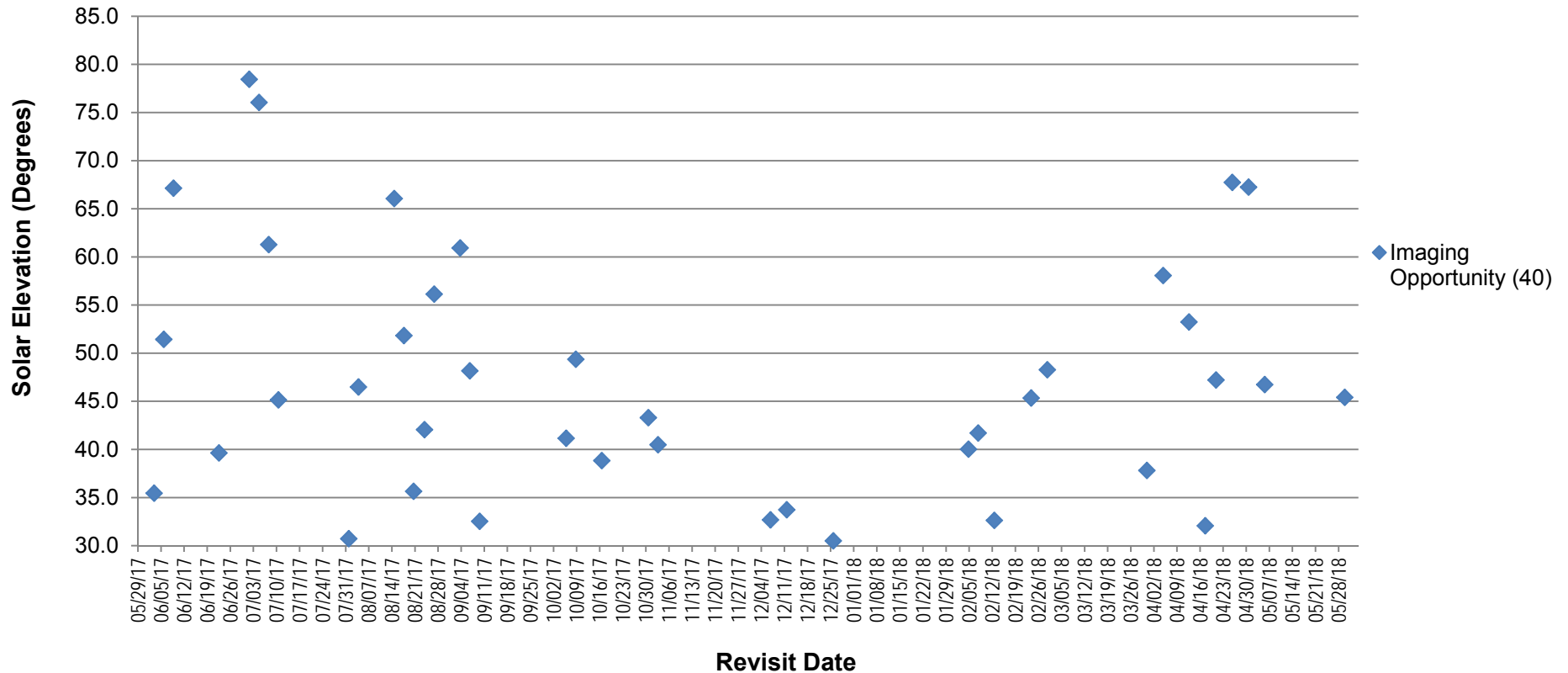


EV Smith Regional Experiment Station



EV Smith RES Revisit Analysis (Solar Elevation)

EV Smith RES Revisit Analysis
Solar Elevation $\geq 30^\circ$, Off-Nadir $\leq 25^\circ$
6-1-2017 to 5-31-2018



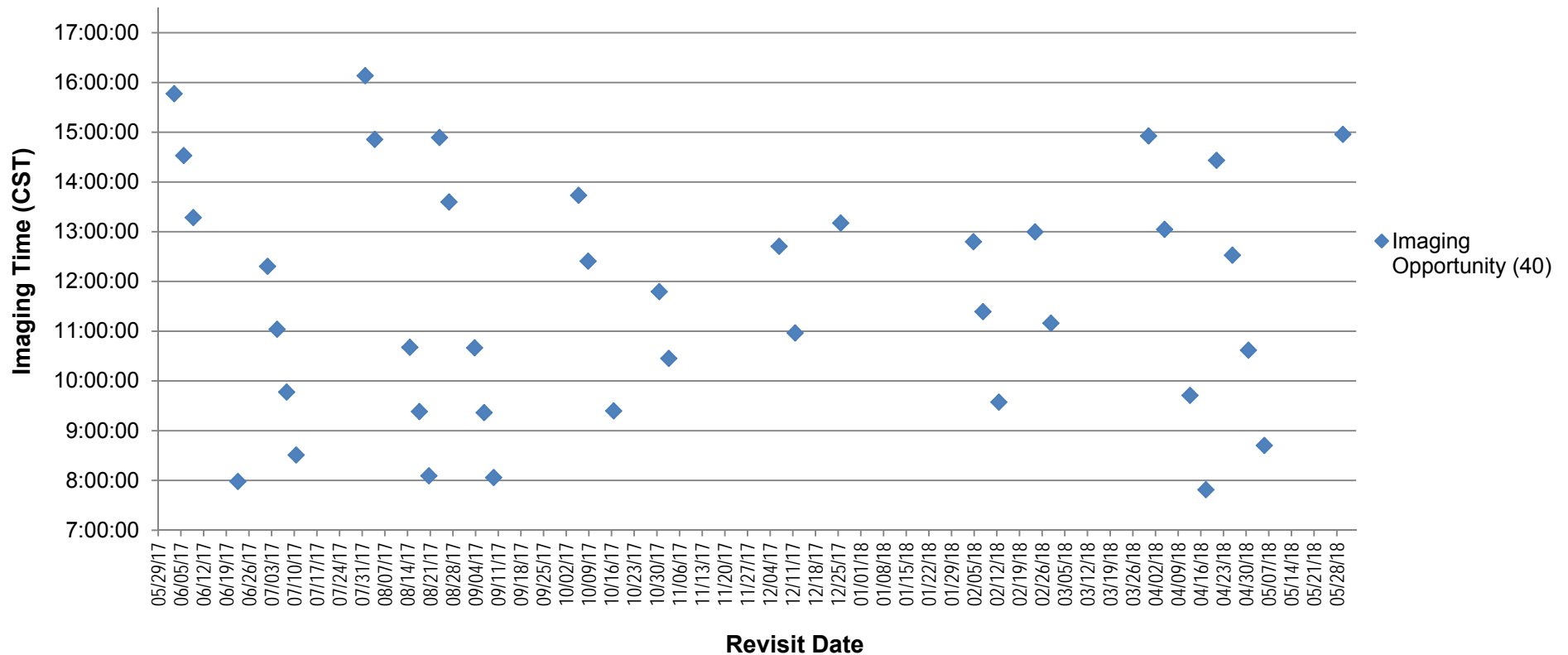
Notes:

- ▶ **Forward projection of ISS orbit ephemeris. Details of actual dates & times will change based on ISS orbit changes.**
- ▶ **Bounding Polygon:**
 - 32.43461999514509,-85.9227056415338; 32.436475480569,-85.9131174915893;
 - 32.4393161021987,-85.9138920489174; 32.4376025868357,-85.9235433146083



EV Smith RES Revisit Analysis (Time of Day)

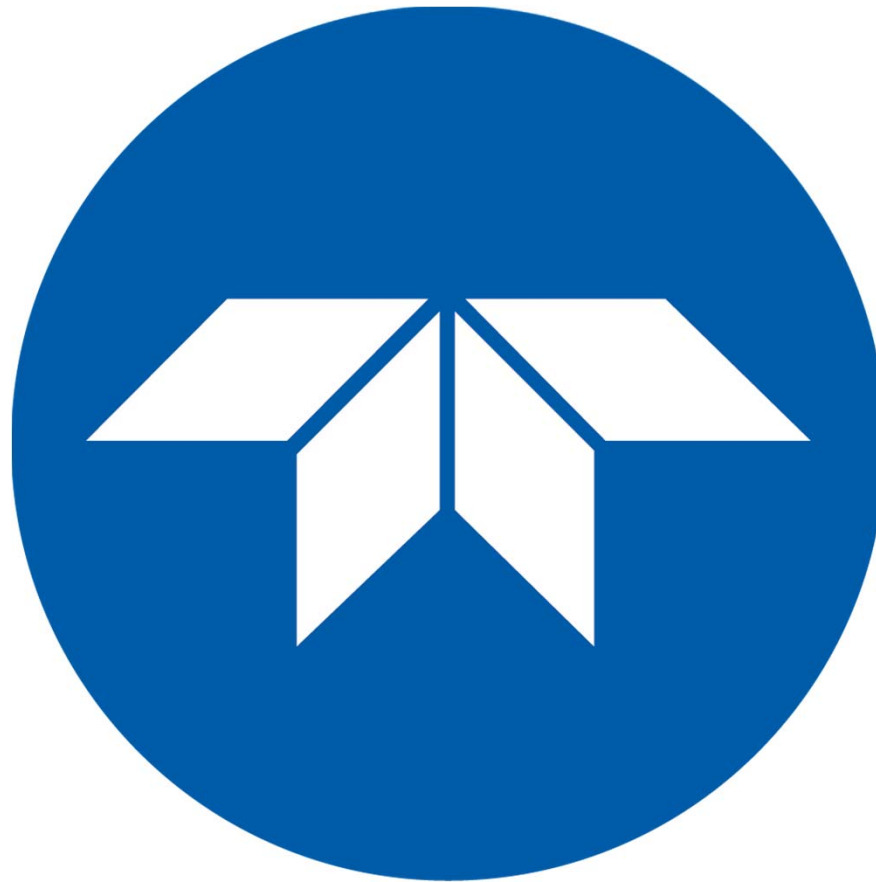
EV Smith RES Revisit Analysis Solar Elevation $\geq 30^\circ$, Off-Nadir $\leq 25^\circ$ 6-1-2017 to 5-31-2018



Notes:

- ▶ Forward projection of ISS orbit ephemeris. Details of actual dates & times will change based on ISS orbit changes.
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 - 32.43461999514509,-85.9227056415338; 32.436475480569,-85.9131174915893;
 - 32.4393161021987,-85.9138920489174; 32.4376025868357,-85.9235433146083





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