ITRES RESEARCH LIMITED

Airborne Hyperspectral & Thermal developments at ITRES: A summary of systems & examples of applications

GMA-V – Moscow 2014

Brief Introduction to ITRES

CASI-1500 Visible Near InfraRed (VNIR)

SASI-600/1000 Shortwave InfraRed (SWIR)

Broadband MWIR (TABI-1800)
- Conventional
- Real-Time Detection

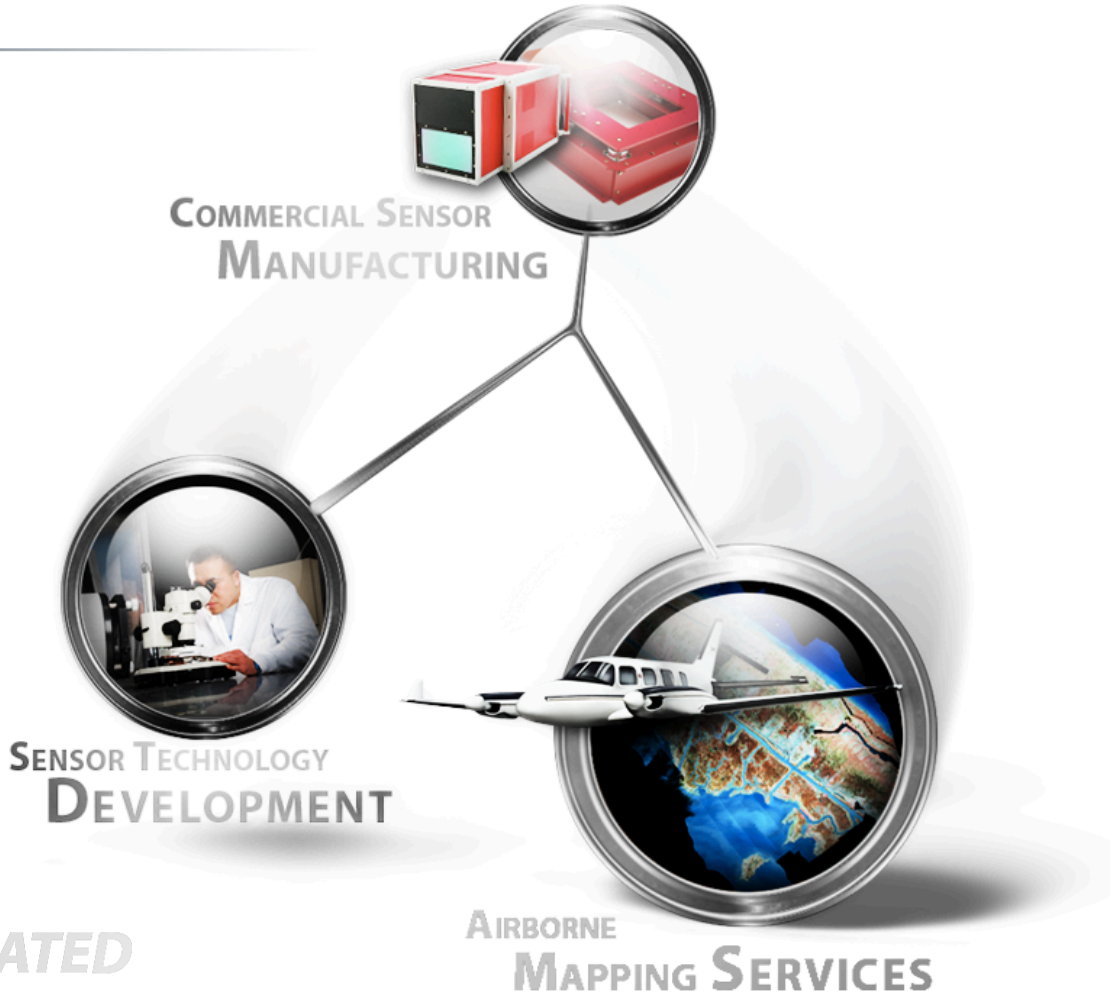
Multi sensor fusion (Lidar / ITRES Suite)

Corporate Structure

Our primary lines of business are:

- Sensor technology and algorithm development
- Commercial sensor manufacturing
- Airborne mapping services

Heritage in space physics



VERTICALLY INTEGRATED

Sensors

CASI 1500

- Hyperspectral VNIR Imager
- 1500 spatial pixels

SASI 600 / SASI 1000

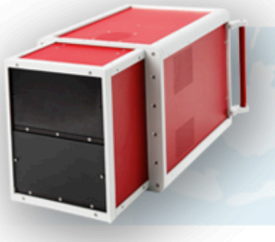
- Hyperspectral SWIR Imager
- 600 spatial pixels (current)
- 1000 spatial pixels (next generation)

MASI 600

- Hyperspectral MWIR Imager
- 600 spatial pixels

TASI 600

- Hyperspectral Thermal Imager
- 600 spatial pixels

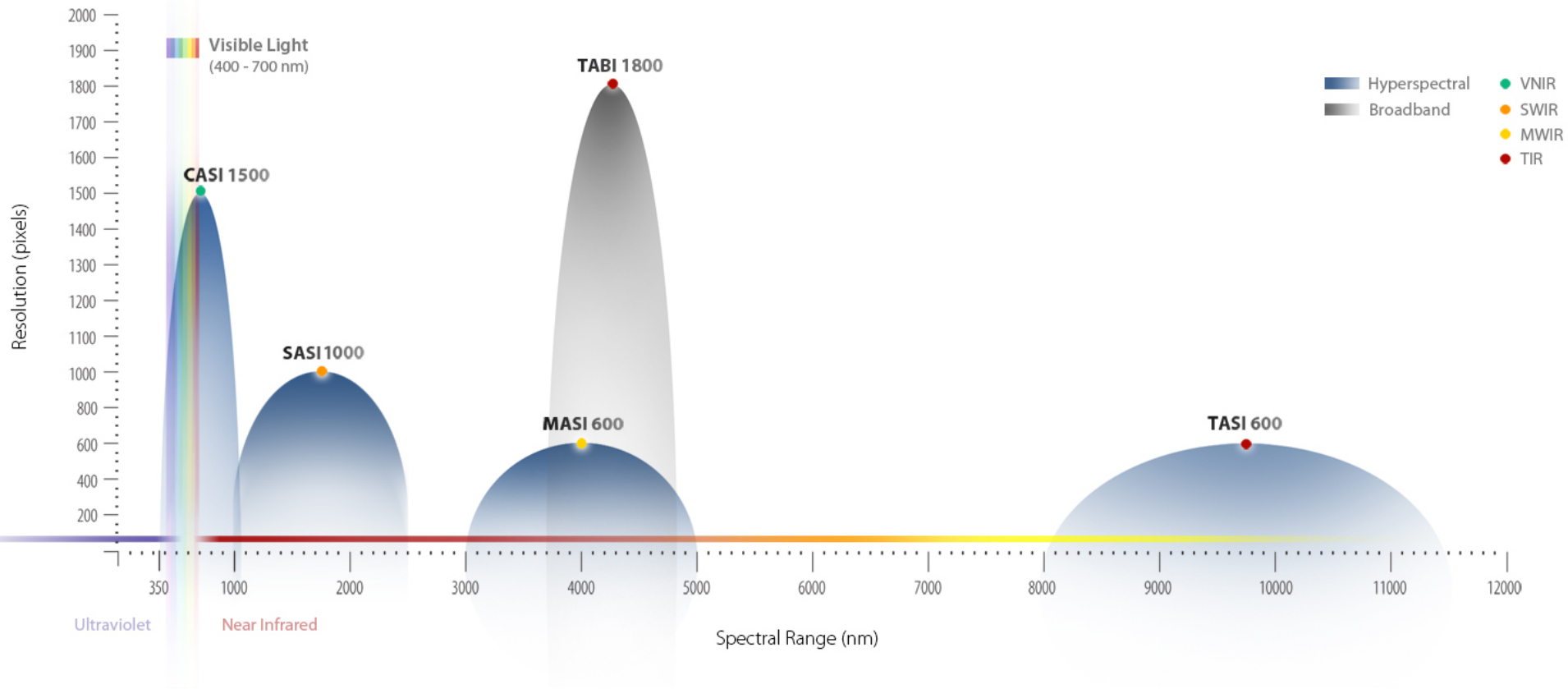


TABI 1800

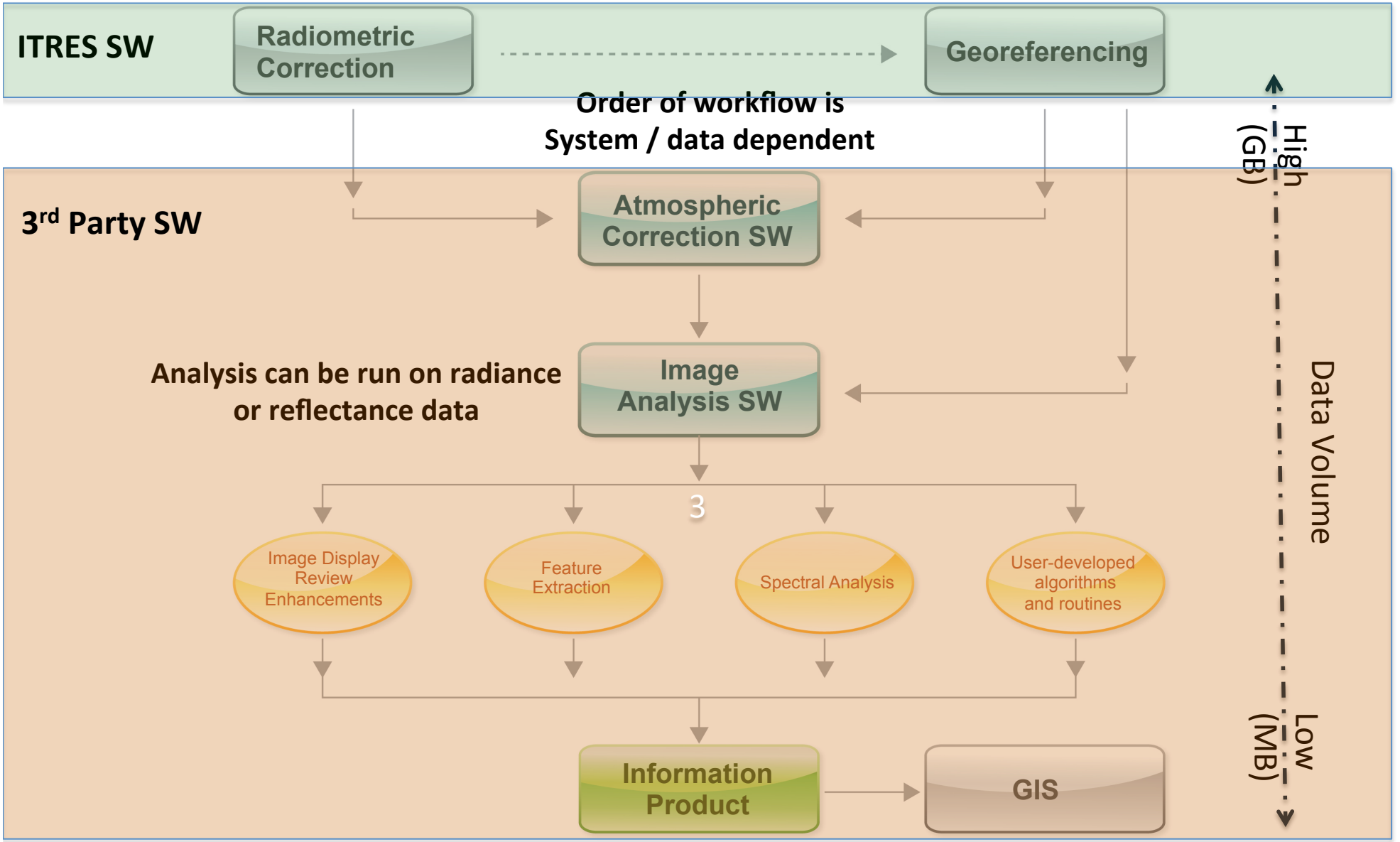
- Broadband Thermal Imager
- 1800 spatial pixels

For instrument performance specifications: please visit ***www.itres.com***

Instrument Spectral Range & Resolution



Data Processing Workflow

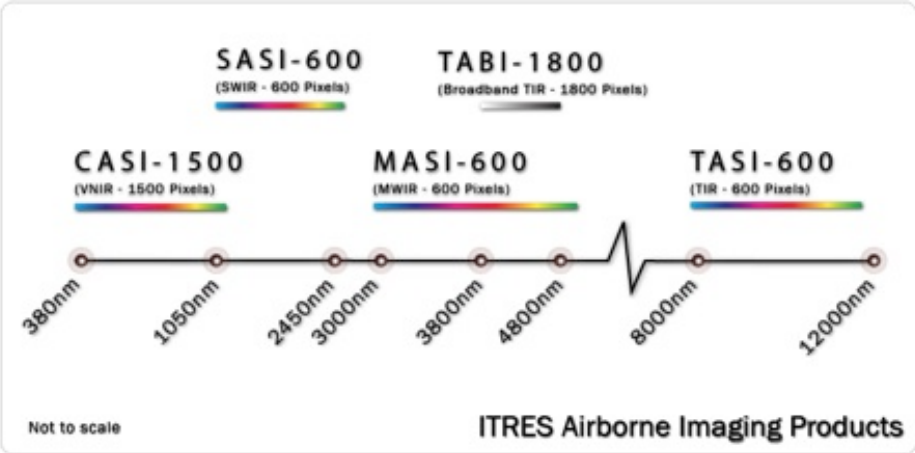


CASI-1500

CASI-1500 & MASI 600 Installation
– Piper Navajo 2009

Class-leading VNIR sensor with extremely sharp optics.

- 380 to 1050nm range
- 288 spectral bands (programmable)
- 1500 spatial pixels
- Up to 30cm spatial resolution



Georeferencing Examples : CASI-1500 (b)

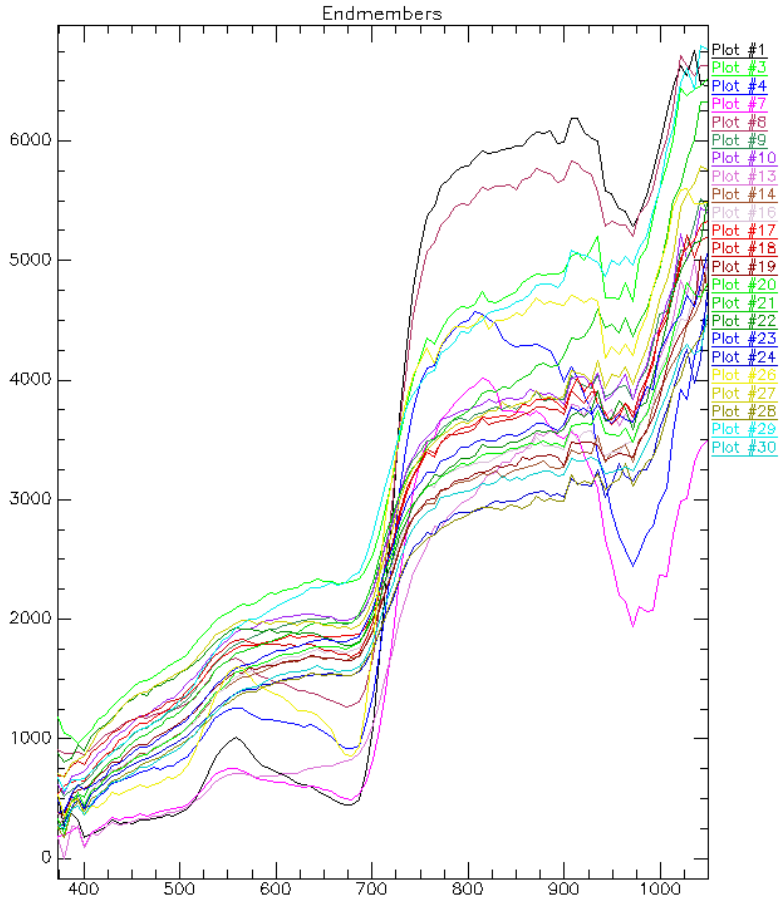
CASI-1500 mosaic (6 lines subimage) –
New Orleans, LA, USA
(1.0m GSD / 36 bands)

Imagery orthocorrected using LiDAR DEM.

Spectral Information Extraction Examples : CASI-1500 (a)

Candelaria, Chile – 2013. 4.0m GSD

Spectral Feature Fitting - CASI Chile data, Vegetation Application

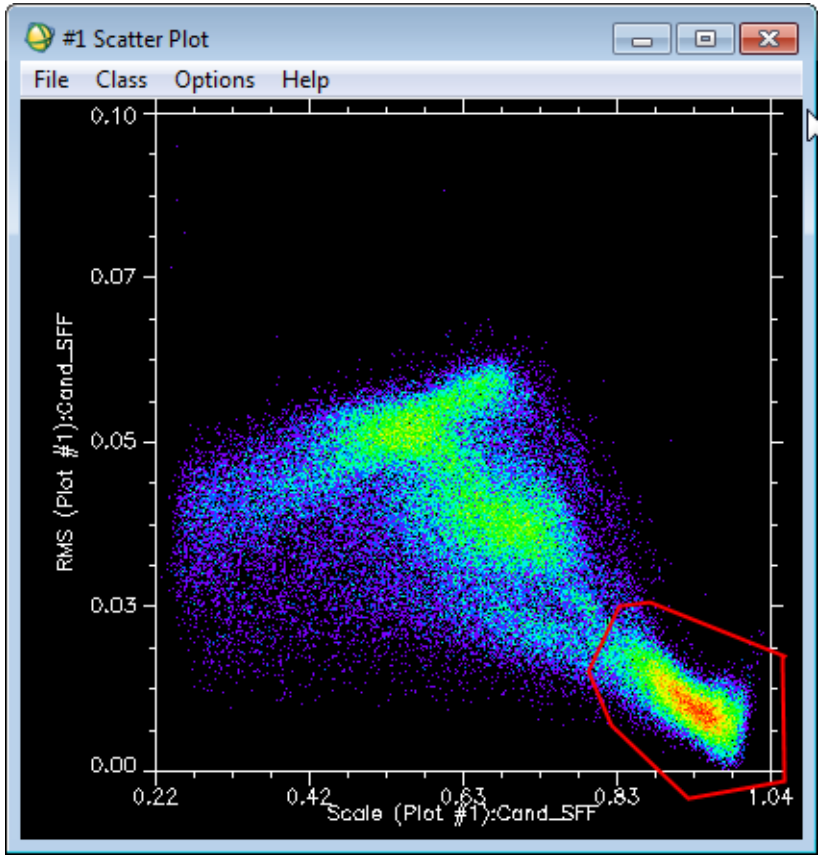


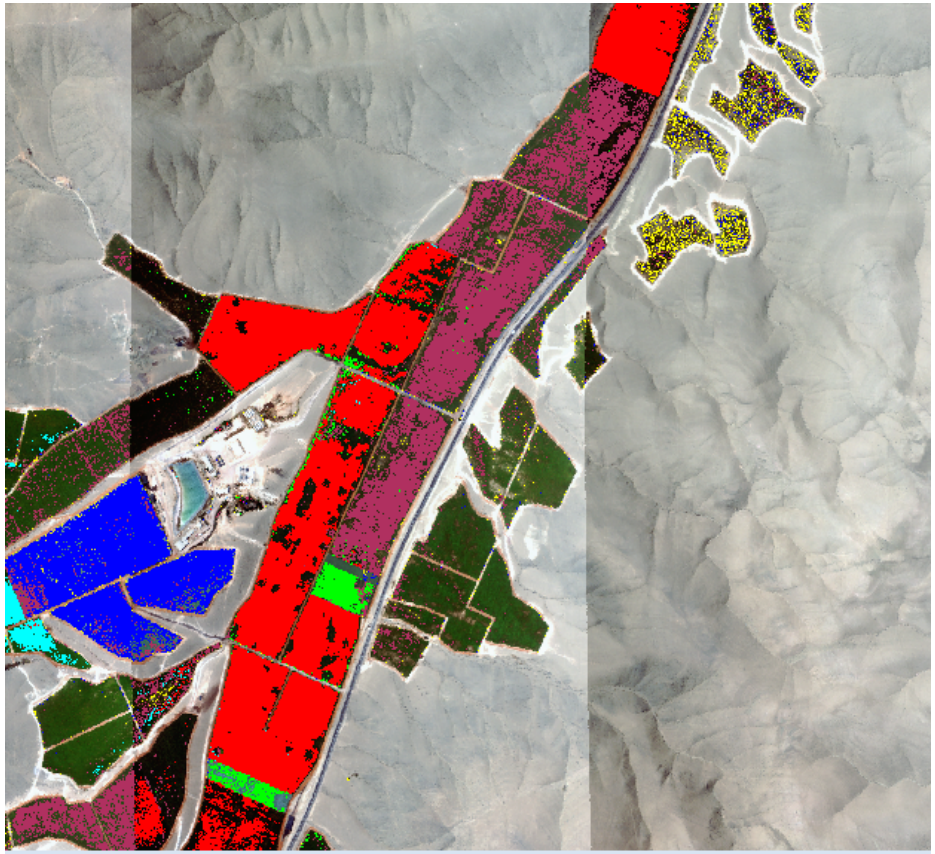
Endmembers extracted using SMACC

Courtesy: Joe Zamudio, Excelis, 2013

Spectral Feature Fitting - CASI Candelaria Chile Data, Vegetation Application

Semi-automated crop classification using extracted spectral endmembers

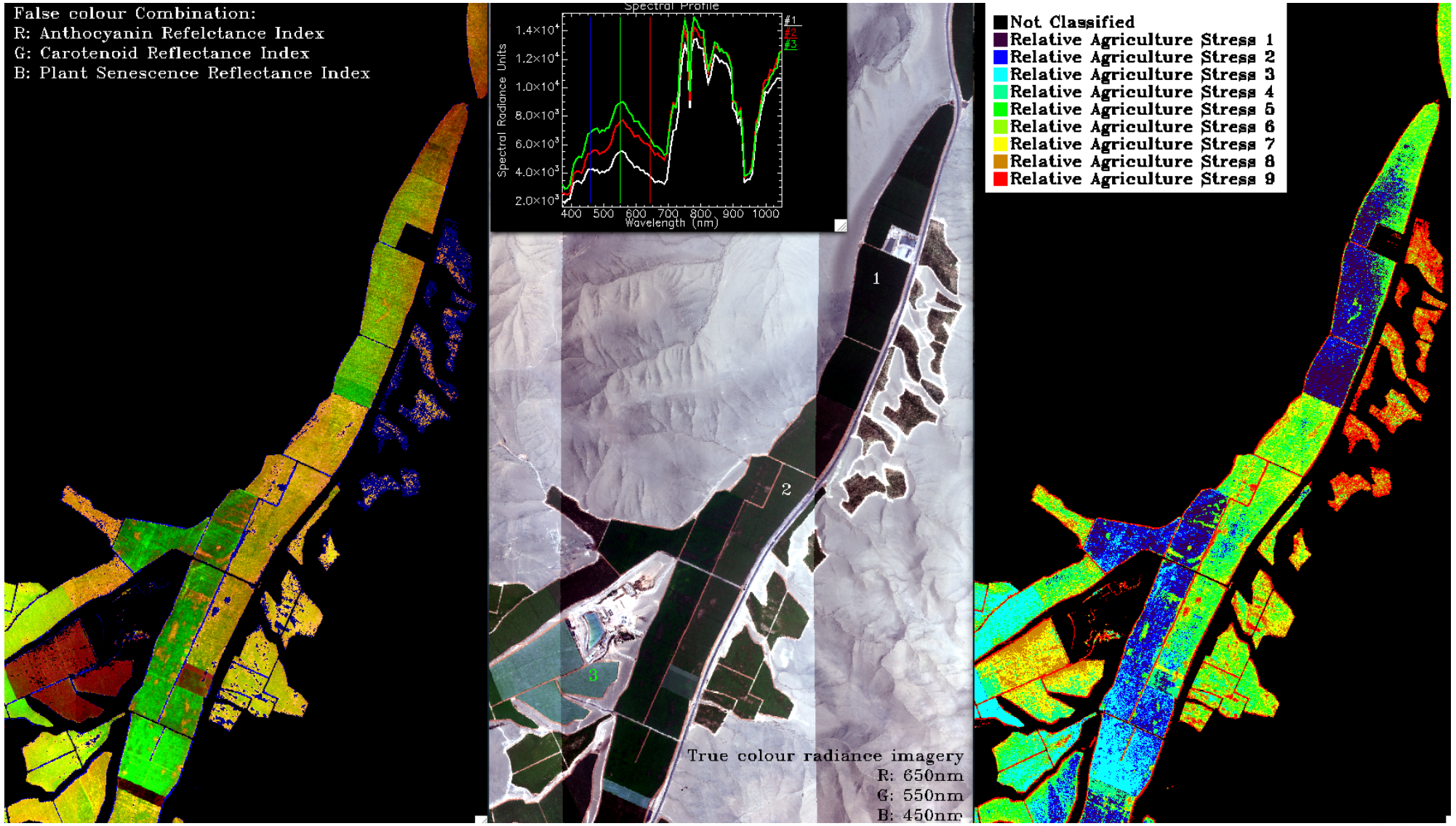




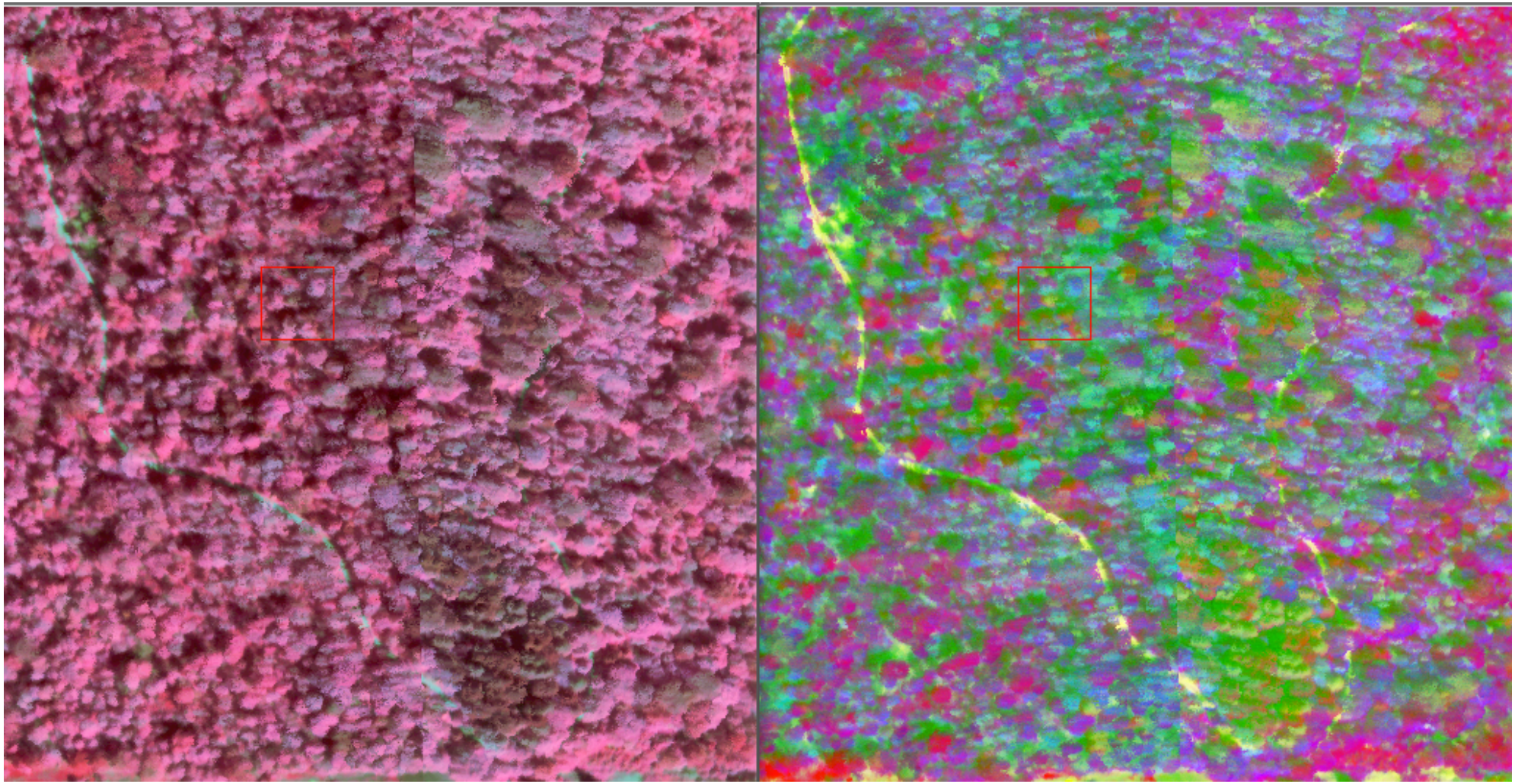
Endmembers mapped by plotting Scale versus RMS

Courtesy: Joe Zamudio, Excelis, 2013

Agricultural Stress – CASI data



Feature extraction & tree discrimination, British Columbia, Canada 2013

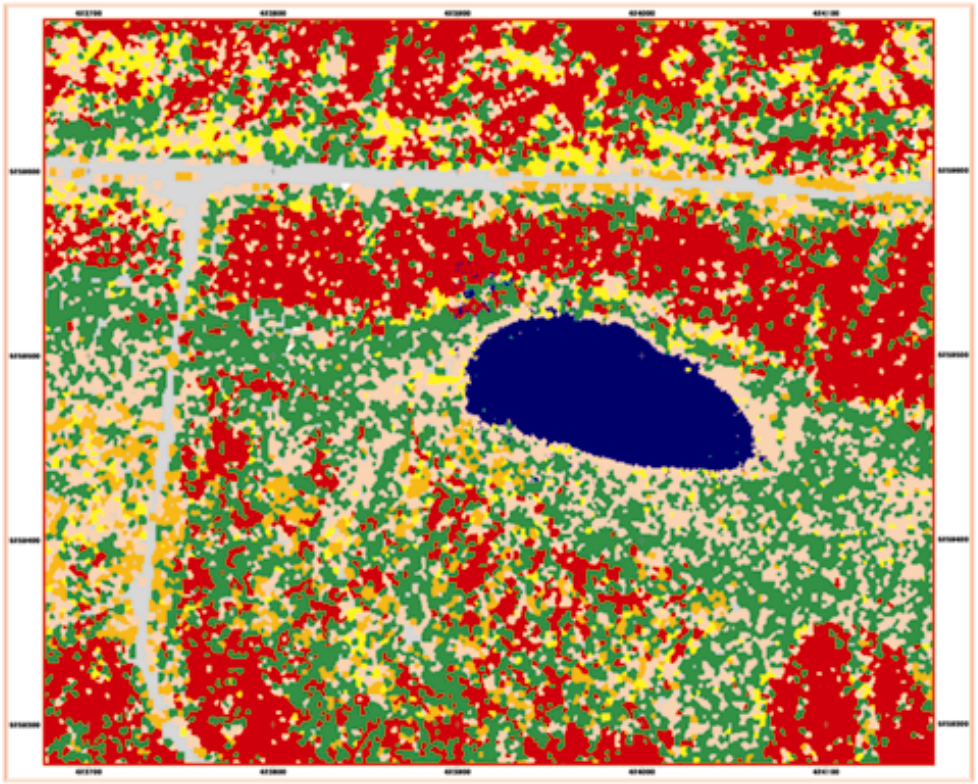


Color Infra red CASI-1500 imagery
1.0m GSD, 72 band image

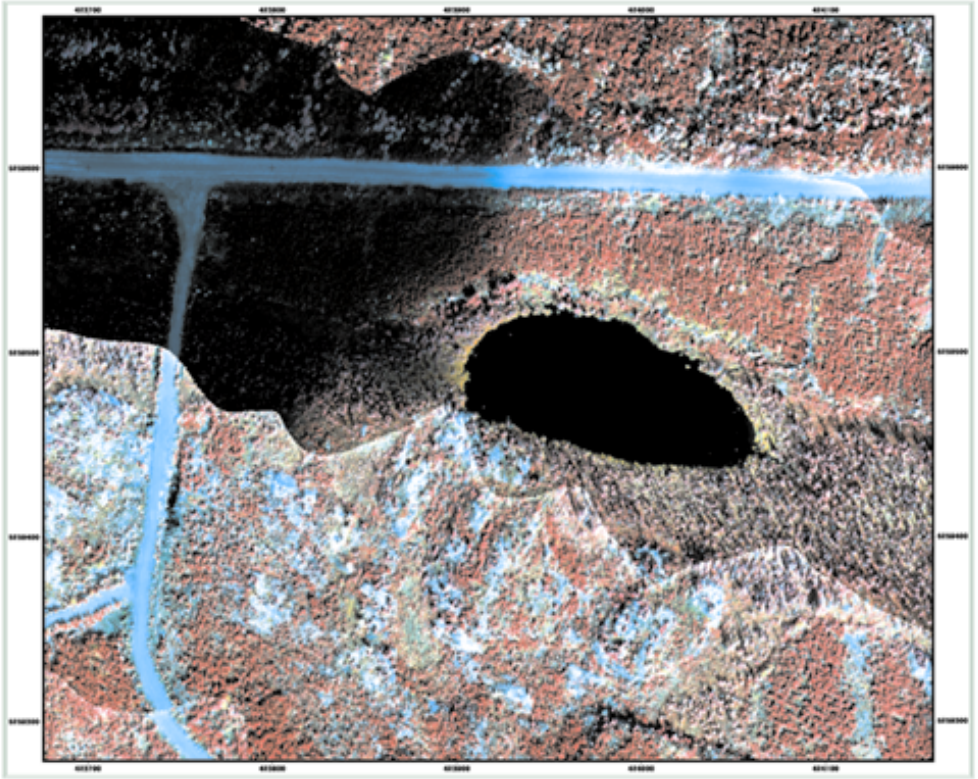
MNF bands 2,3,4

Species Separation

Casi Species Map



Casi False Color Image



Water | No Data | Non Tree | Unclassified

Deciduous Class 1 | Deciduous Class 2 | Spruce | Pine

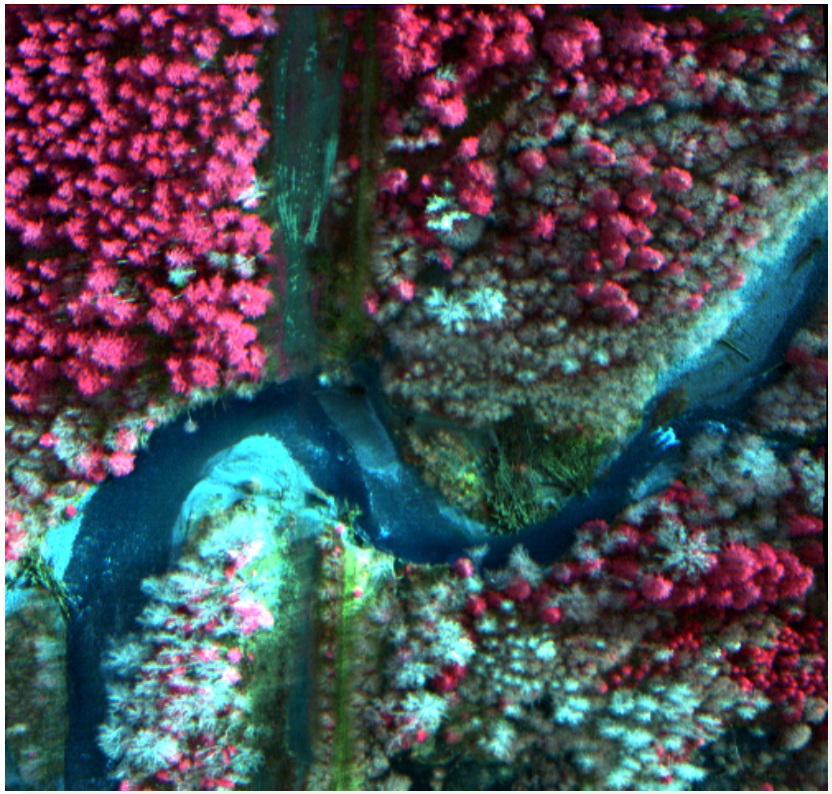
Scale =1:1,250

Spanish Forest, Ontario

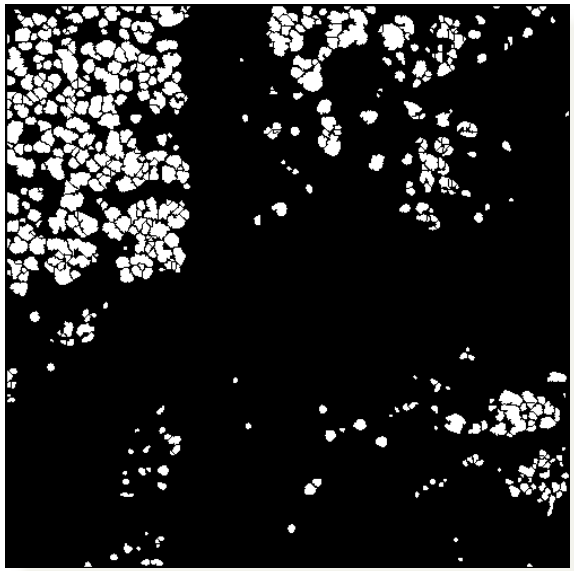
N

casi Hyperpectral Data collected October 1998 using 60 cm pixel resolution and 10 spectral bands.
Imagery was orthorecitfied and mosaicked to UTM coordiante system Zone 17, NAD 83.
Data courtesy of Itres Research Limited, Domtar Forest Management Corporation, and the National Science and Engineering Research Council

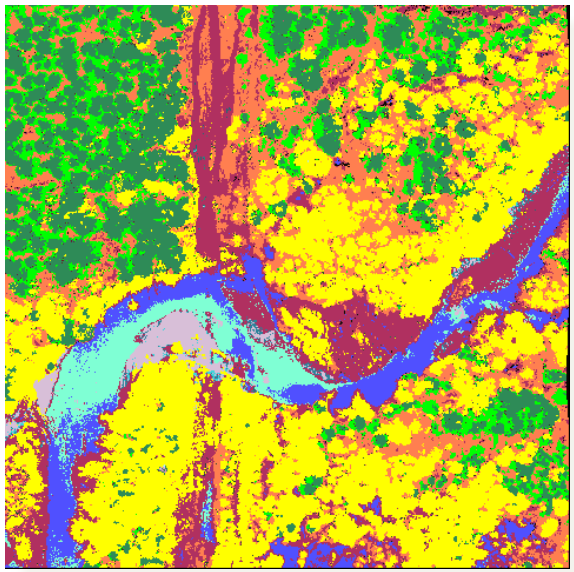
UTILIZATION OF HIGH RESOLUTION CASI IMAGERY IN FOREST STAND ASSESSMENT



Douglas Fir Forest, Haslam Creek, British Columbia, Canada

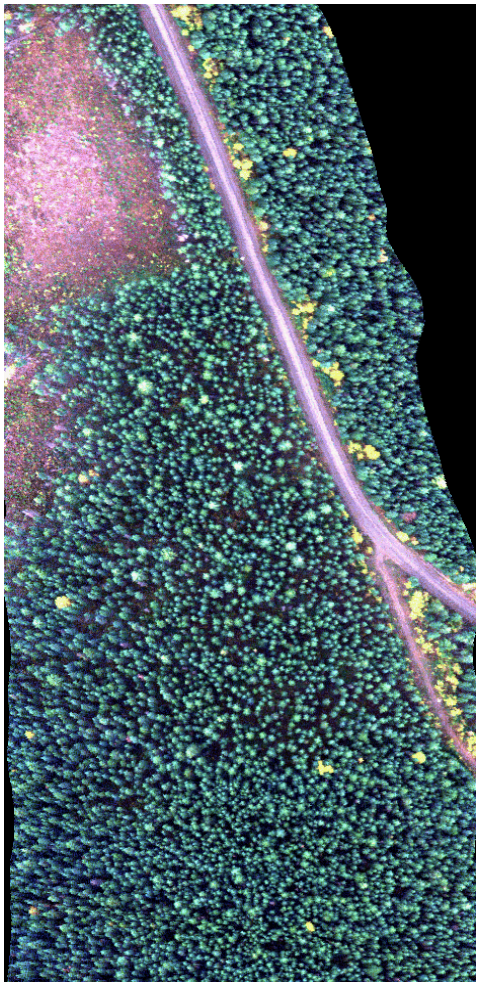


Stem crown map

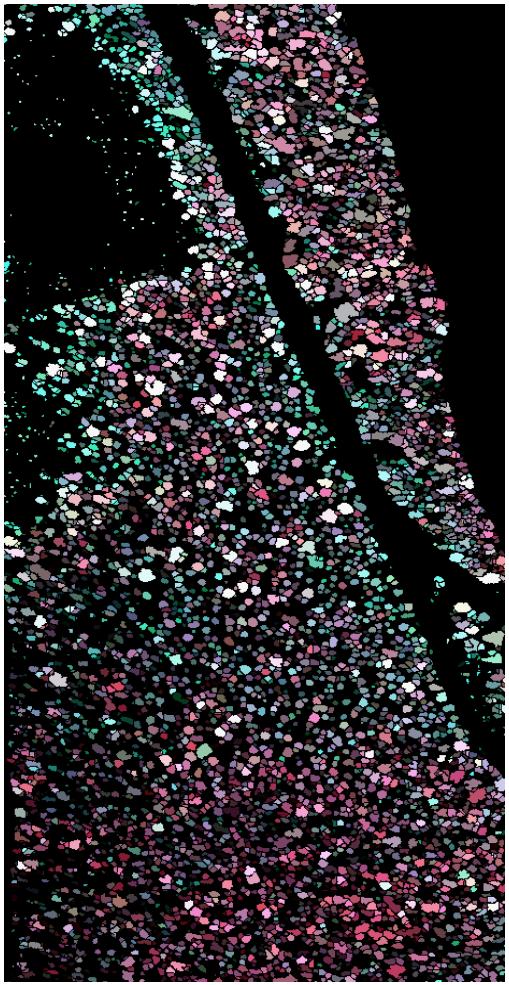


Classification

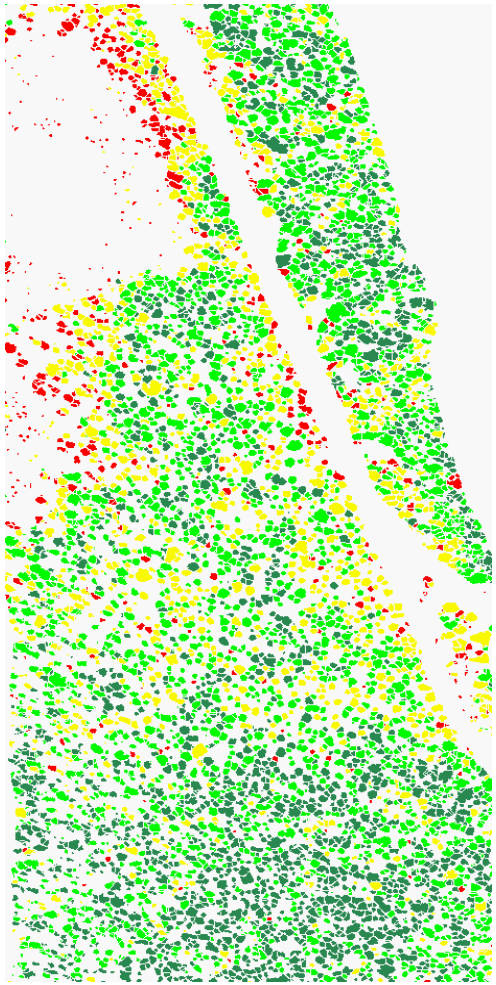
Forest Health Mapping



True color ***casi*** images of test site for tomentosus root rot

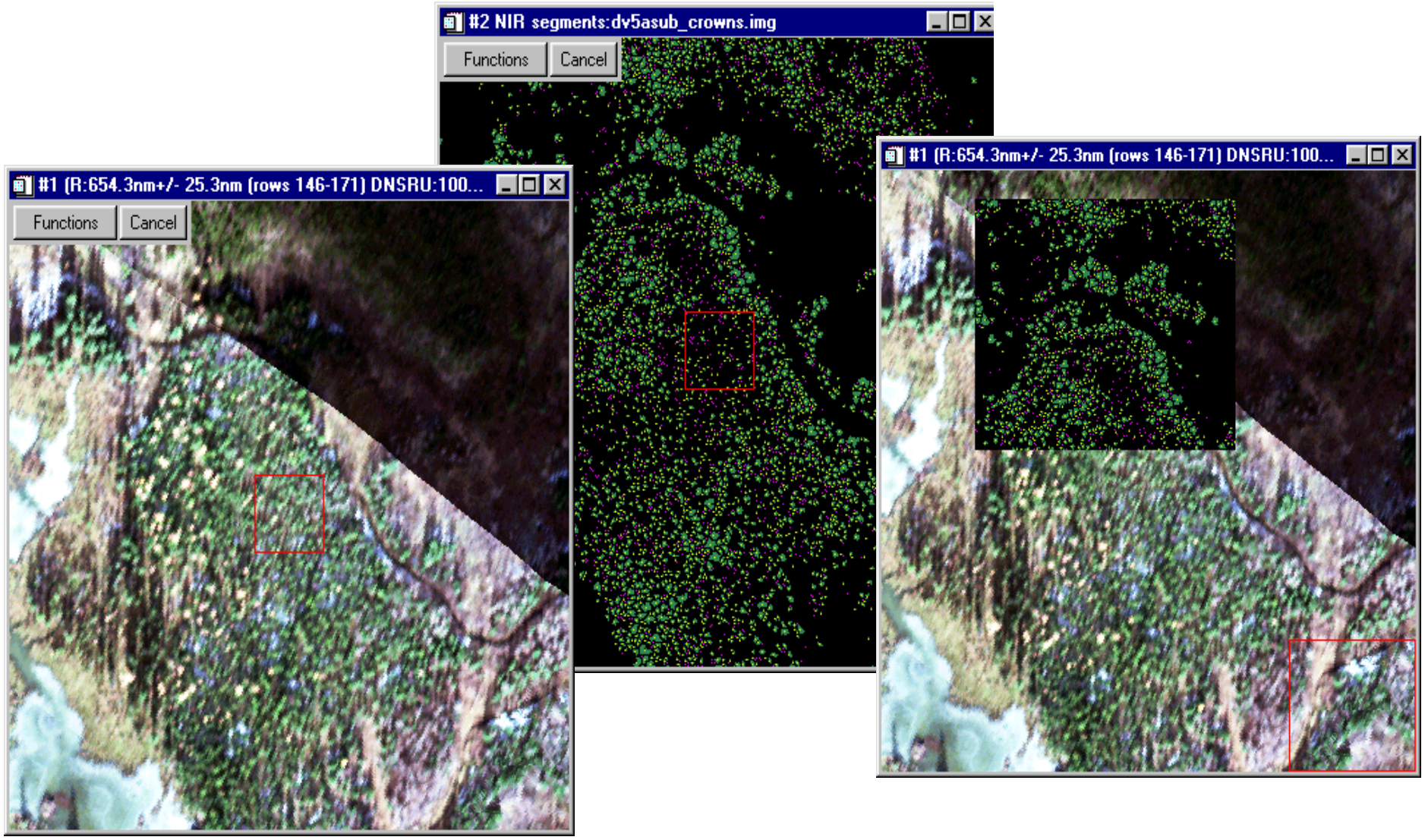


Mean spectra of isolated tree crowns

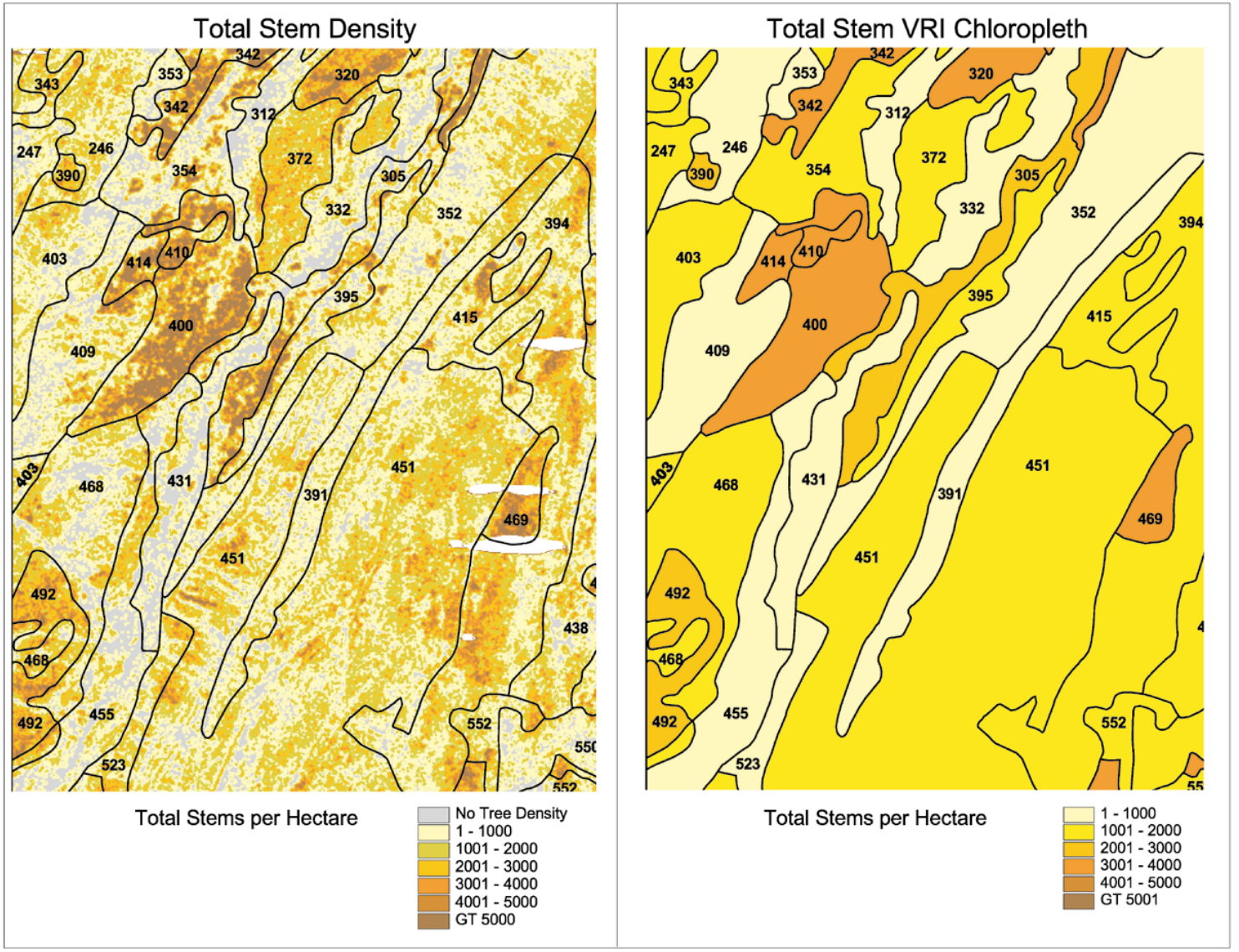


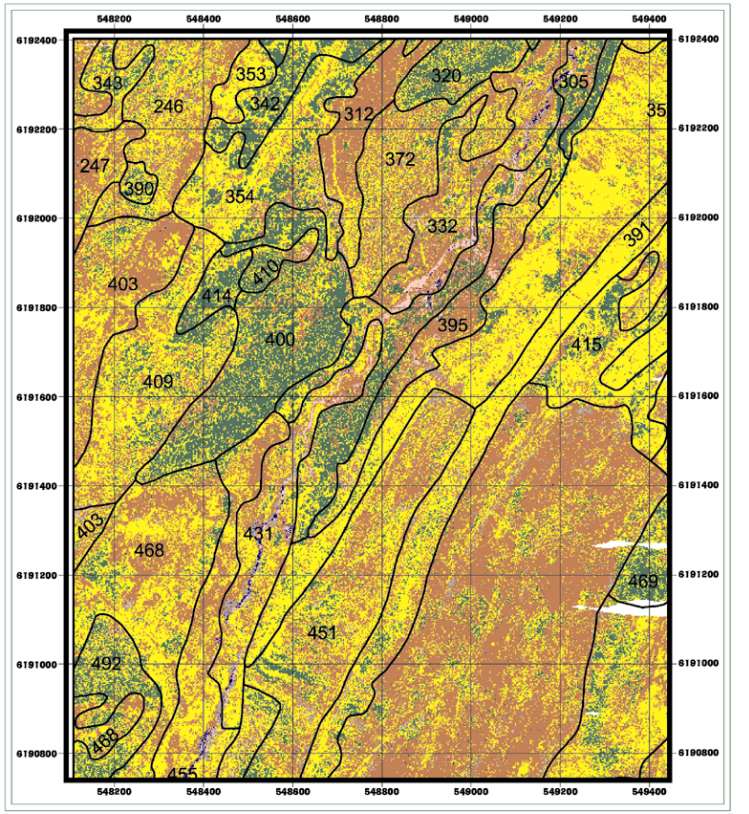
Forest health classifications: Healthy (dark green), Light (green), Moderate (yellow), Severe (red)

Stem Segmentation and Counts

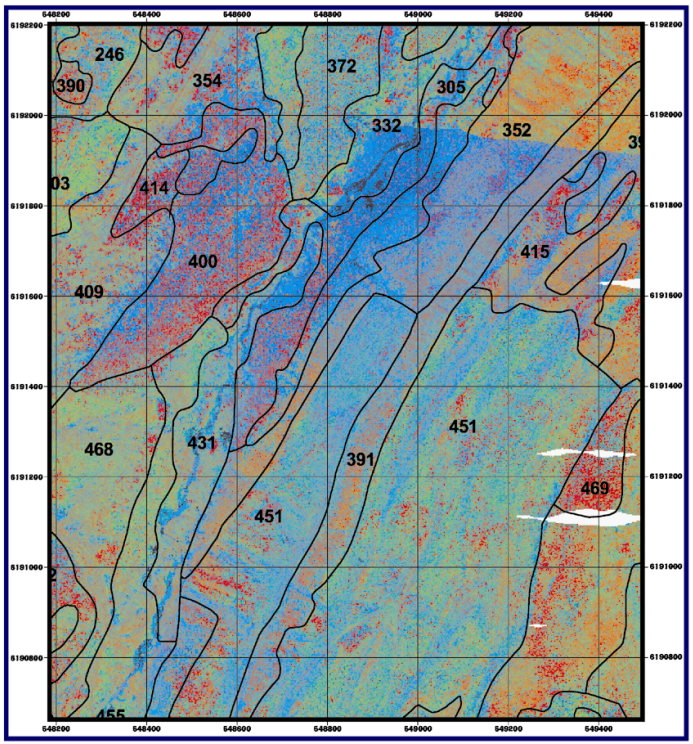


Total Conifer Stem Products





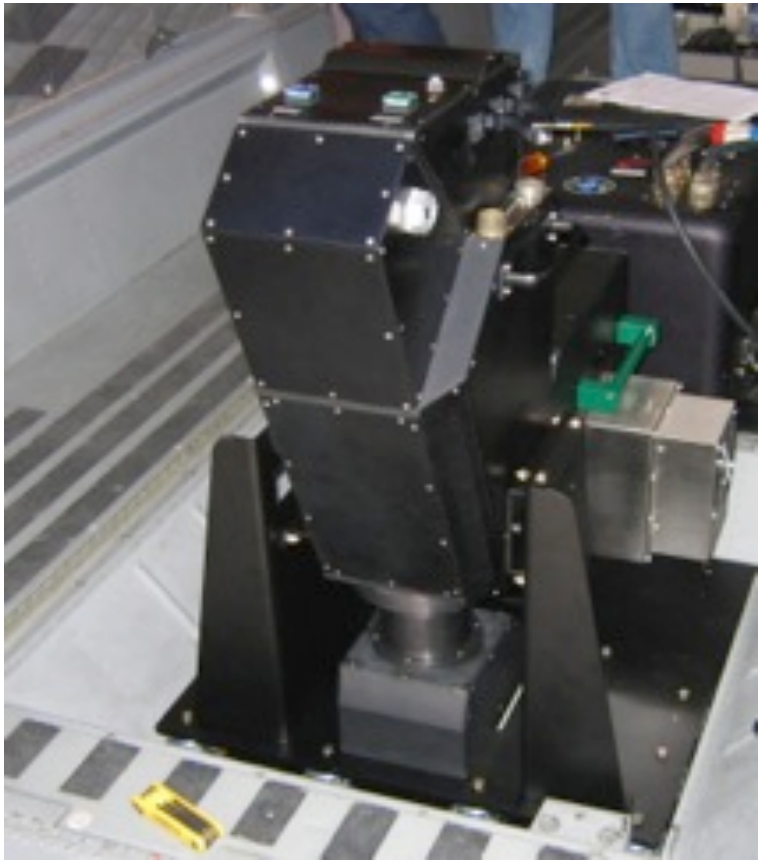
Spectral Angle Mapper Land Cover Classification



Normalized False Color

SWIR applications

Geology
Man made materials
Vegetation mapping

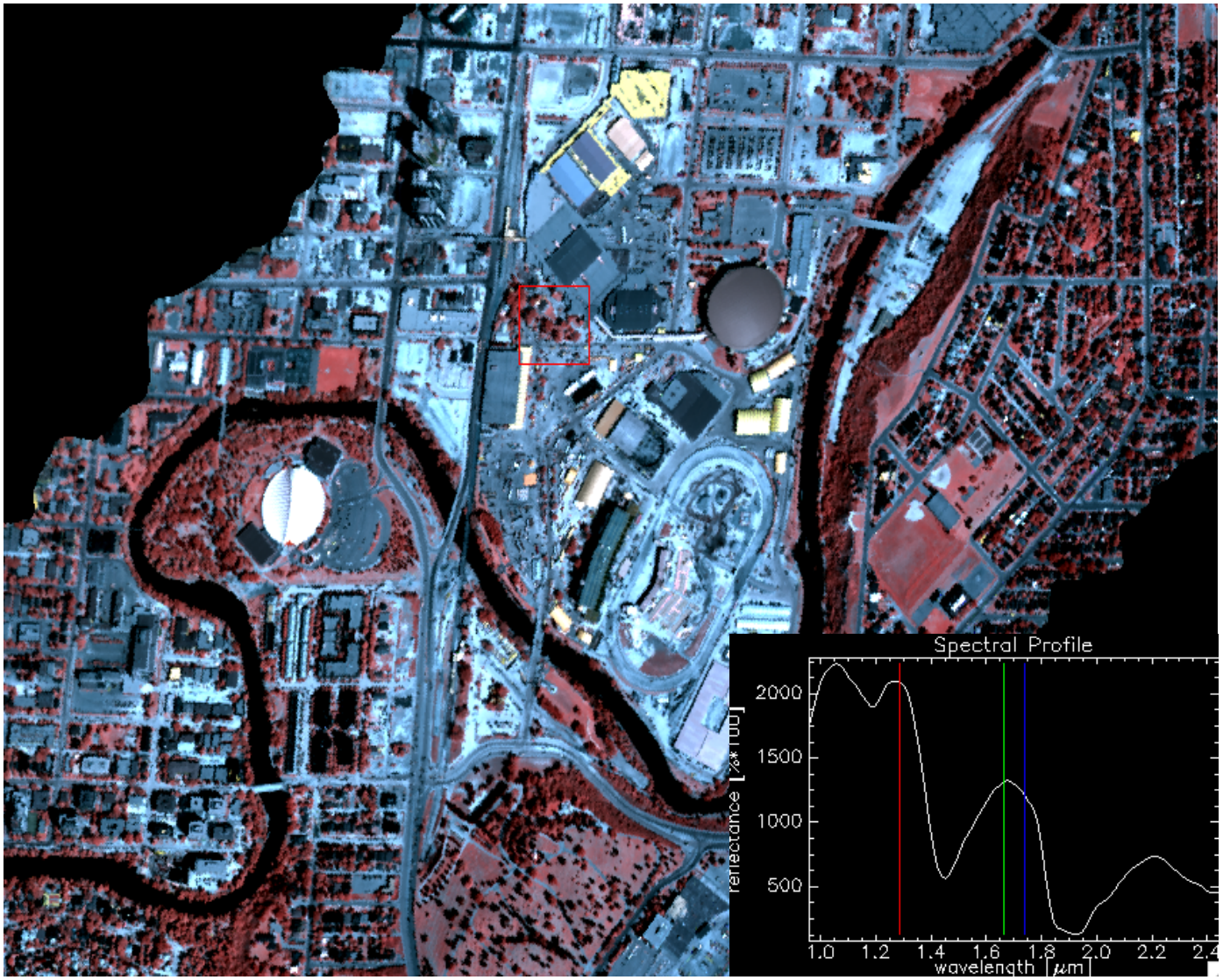


SASI600 co-mounted with CASI1500
CASA-212 – Madrid, Spain 2009

Roof material discrimination : Calgary , Canada – June 29, 2013

SASI-600 Data
2.5m GSD

Acquired 6 days after large scale flooding event in Calgary watersheds.
Acquired under sunny conditions close to noon local time



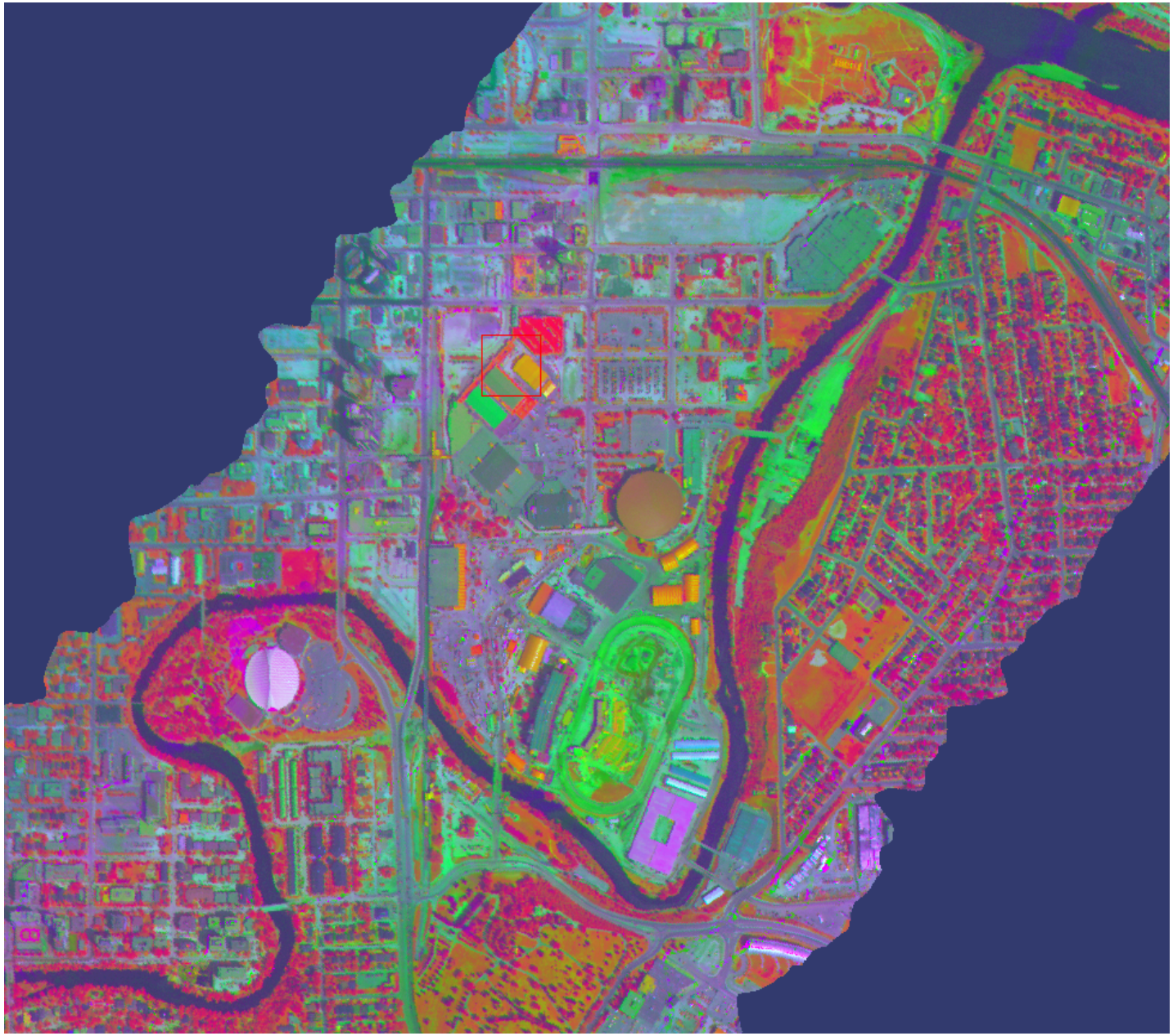
Notes:

2.5m pixel GSD

Green tinge related to flood sediment deposited on river edges, racetrack & roadways.

Bands:
R: 1347.5nm
G: 1767.5nm
B: 2367.5nm

Decorrelation stretch to highlight sediment & painted roof surfaces



Notes:

2.5m pixel GSD

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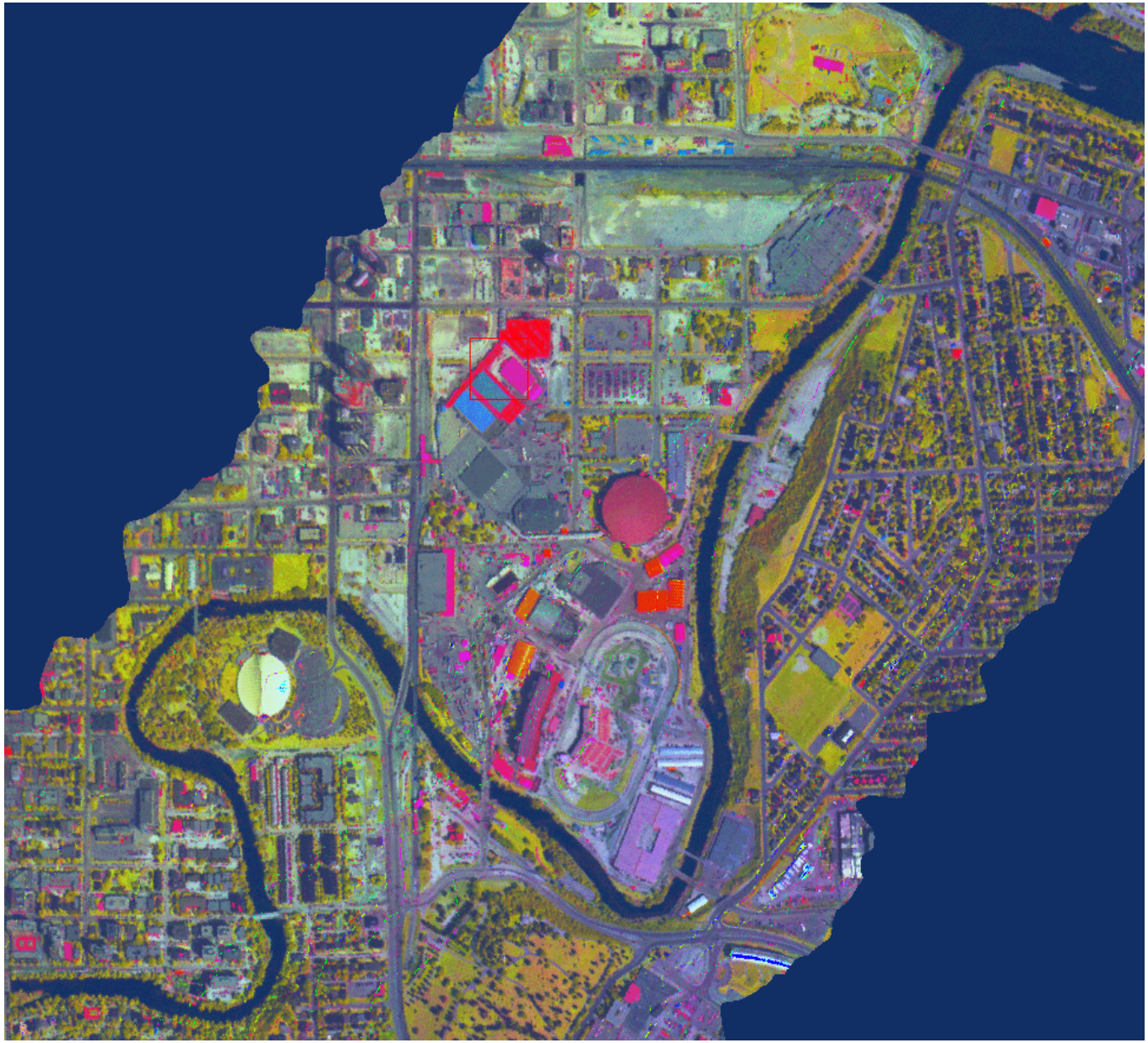
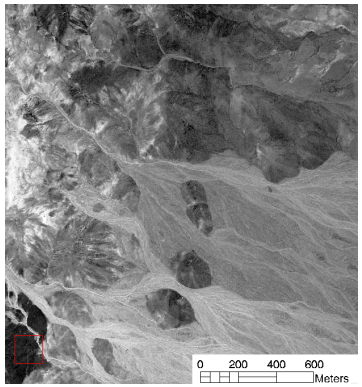
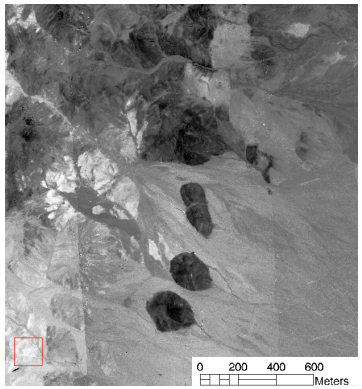
Bands:
R: 1677.5nm
G: 1707.5nm
B: 1752.5nm

Decorrelation stretch to highlight plastic & painted roof surfaces

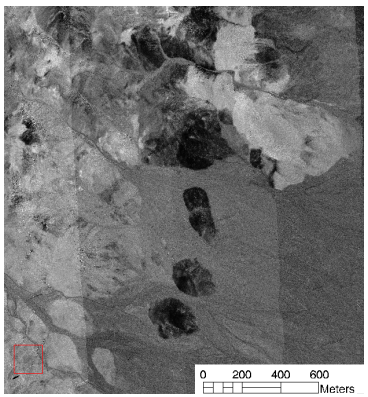




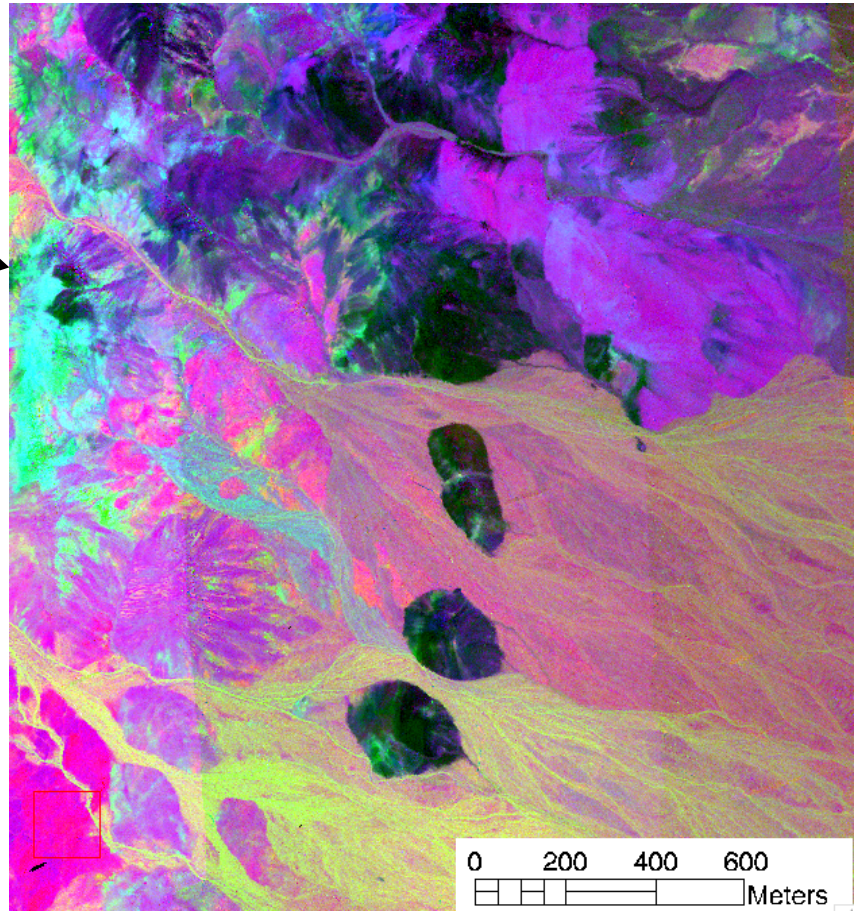
Band ratio :
2142nm / 2187.5nm



Band ratio : 2187.5nm / 2367.5nm



Band ratio :
2322.5nm / 2307.5nm



Band ratio products based on known spectral features allow for quick discrimination of scene elements. False colour composites of band ratio products create effective images for initial assesment of mineral groups.

SWIR HSI – A geological prospecting example, China, 2010

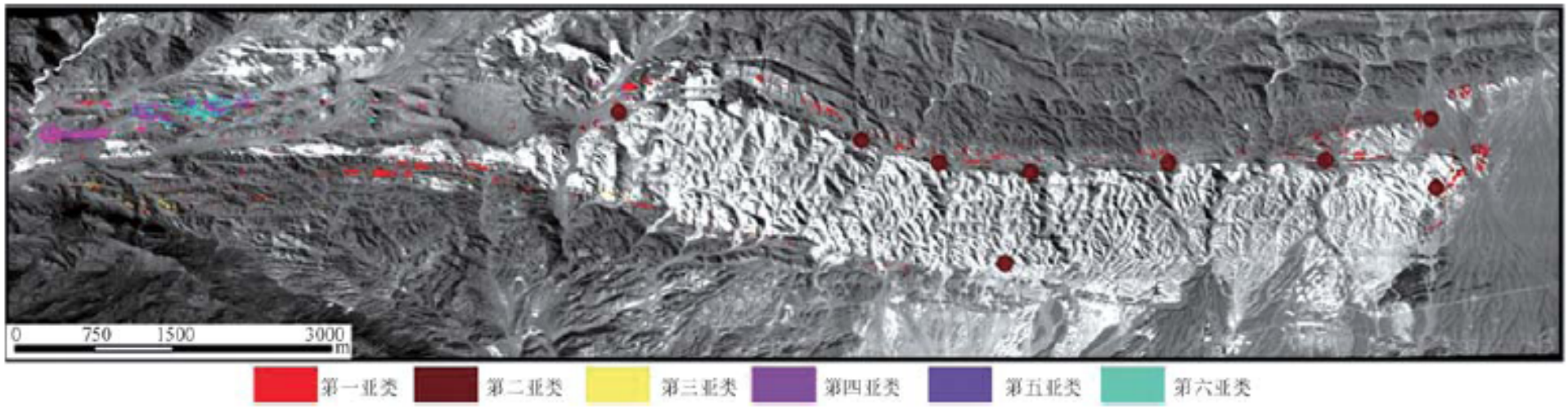
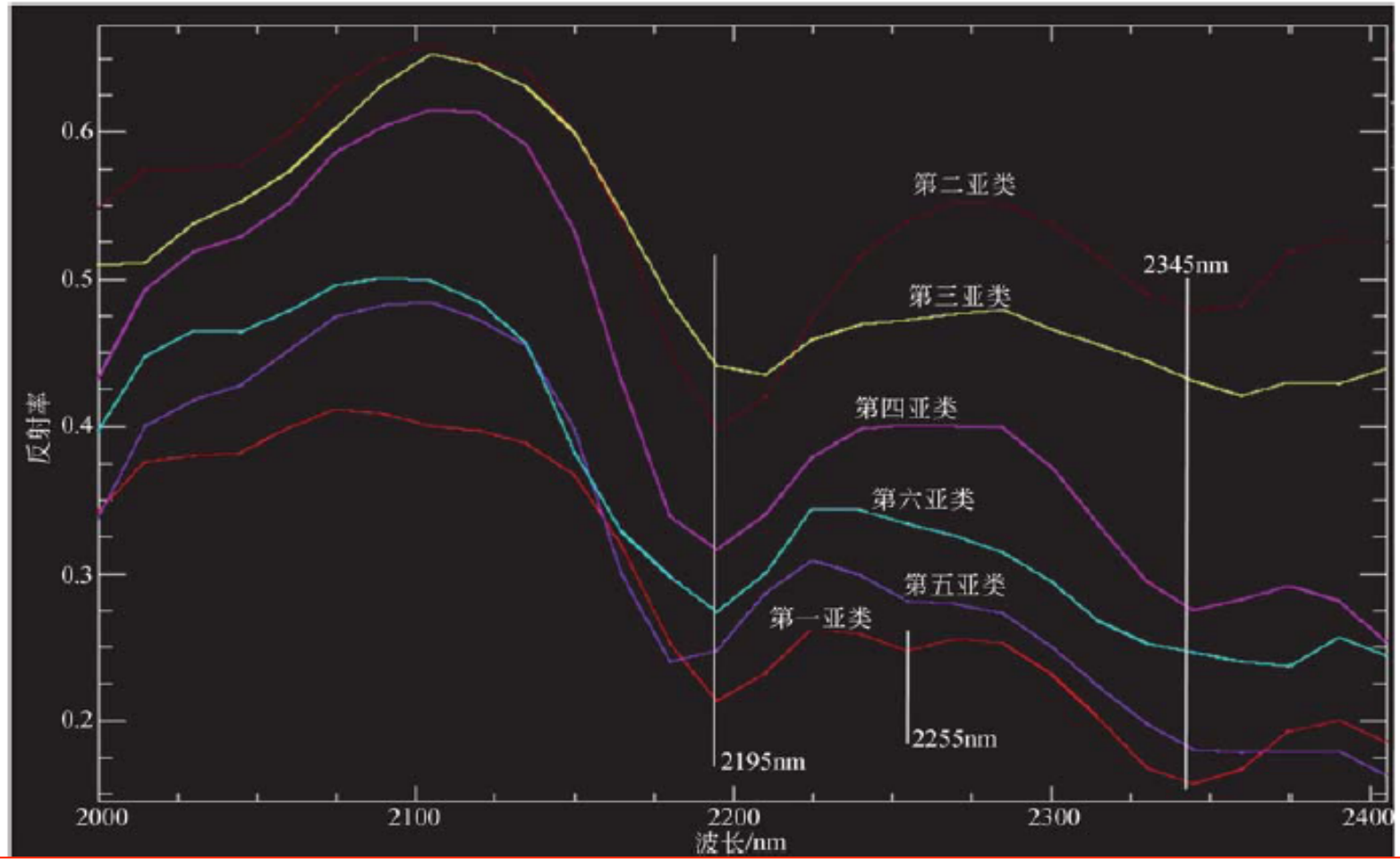


图 4　白杨河地区不同亚类高铝绢云母分布图

Sericite-indicated outcrops (red= best fit) distribution on the south edge of a sub-volcanic body middle and the northern edge (Figure 4), as well as the eastern edge.

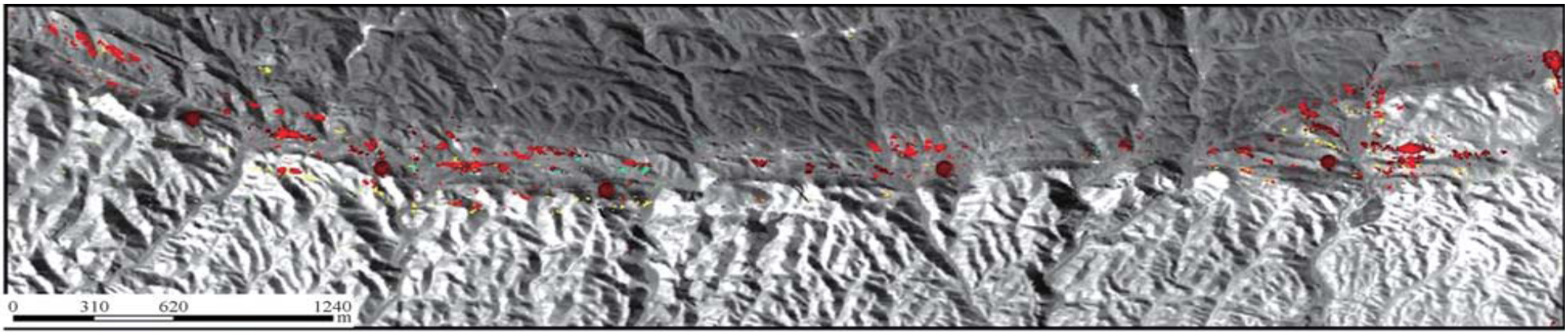
Maroon dots indicate know Uranium sites
Red > Yellow = Declining U mineralization related to outcrop of sericite
Purple – low prob. sericite (abnormal irregular flakes)
Mauve- carbonate
Blue- epidote

Data courtesy of BRIUG

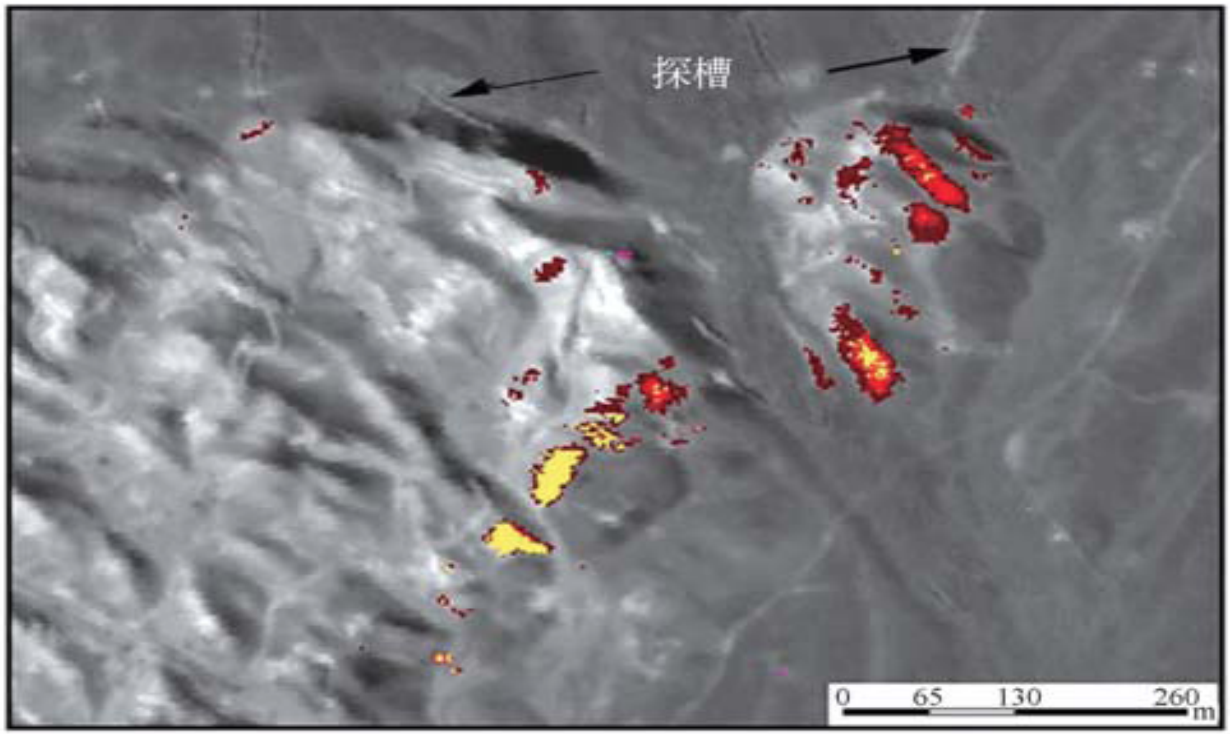


The similarities and differences of the spectral characteristics of six identified sub-classes related to sericite incidences. Uranium mineralization is most closely related to the first 1 (red) and the second (maroon – top) with sericite having 2195nm strong absorption, and the asymmetry of the absorption peak, left narrow right-width and a second significant absorption spectra at 2345nm. Data from SASI-600 system.

Data courtesy of BRIUG



Surface expression of Sericite tied to uranium mineralization (detail) – Identified using SWIR HSI (SASI600)



Data courtesy of BRIUG

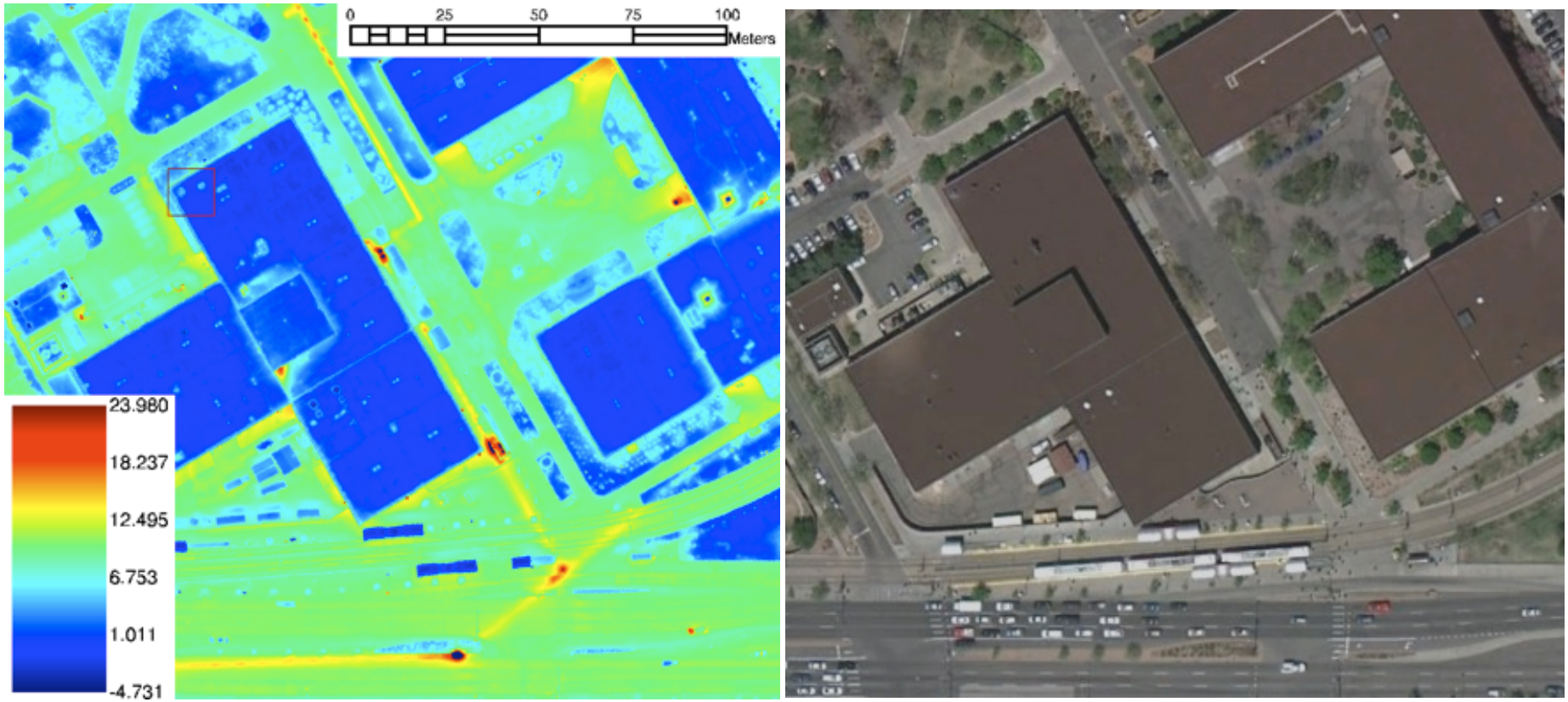
TABI-1800 : Broadband MWIR temperature mapping

TABI1800

Airborne Wide-Array Broadband Thermal Imager
40° FOV
High Thermal Resolution
Integrated Control & Recording System
Integrated IMU (optional)
Reduced acquisition costs (less flying, wider swath coverage)
Custom diffraction-limited, high-performance optics[1]

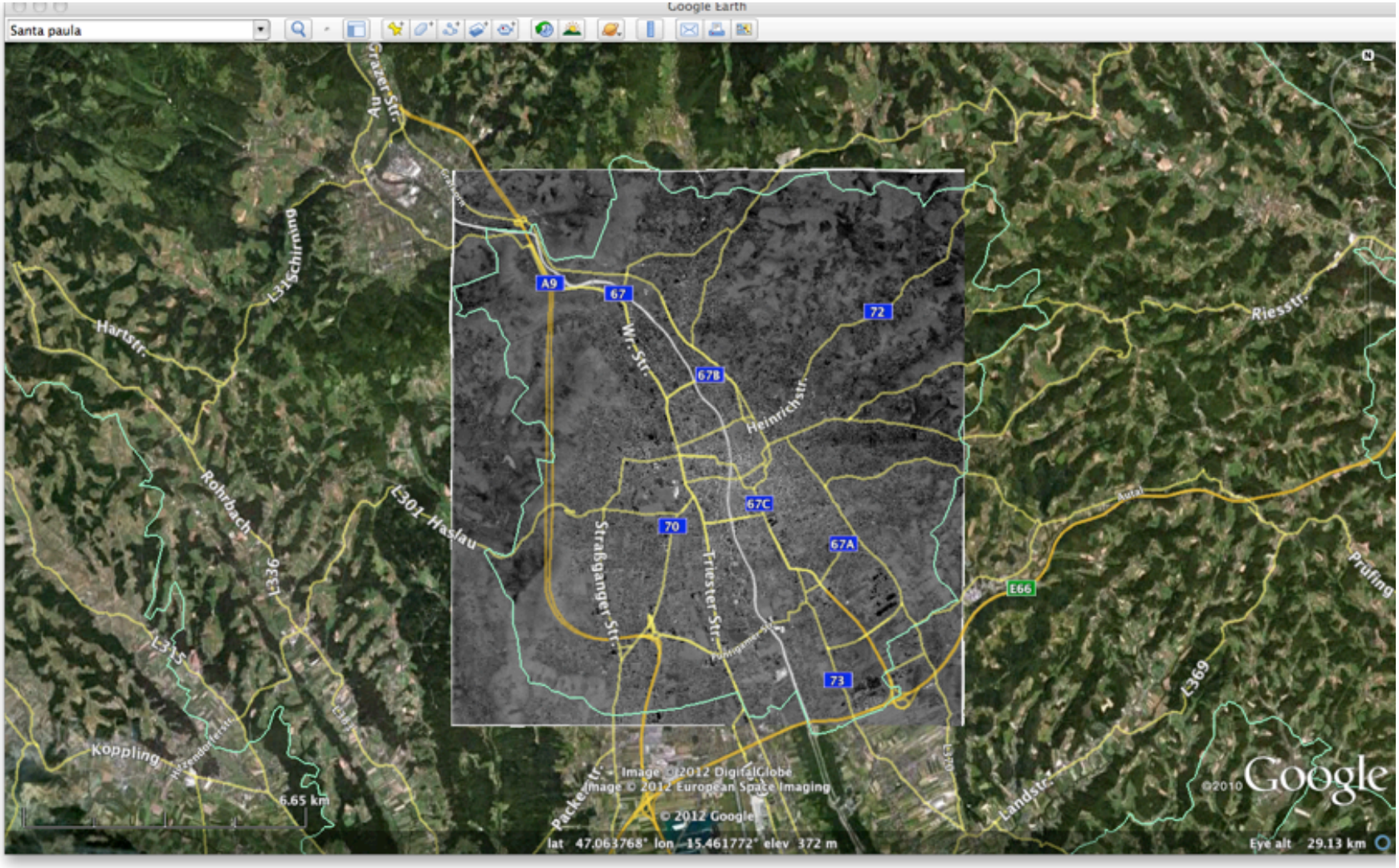
marine / geothermal / infrastructure / Fire mapping Search and Rescue (SAR)

HYPERSPECTRAL & THERMAL REMOTE SENSING

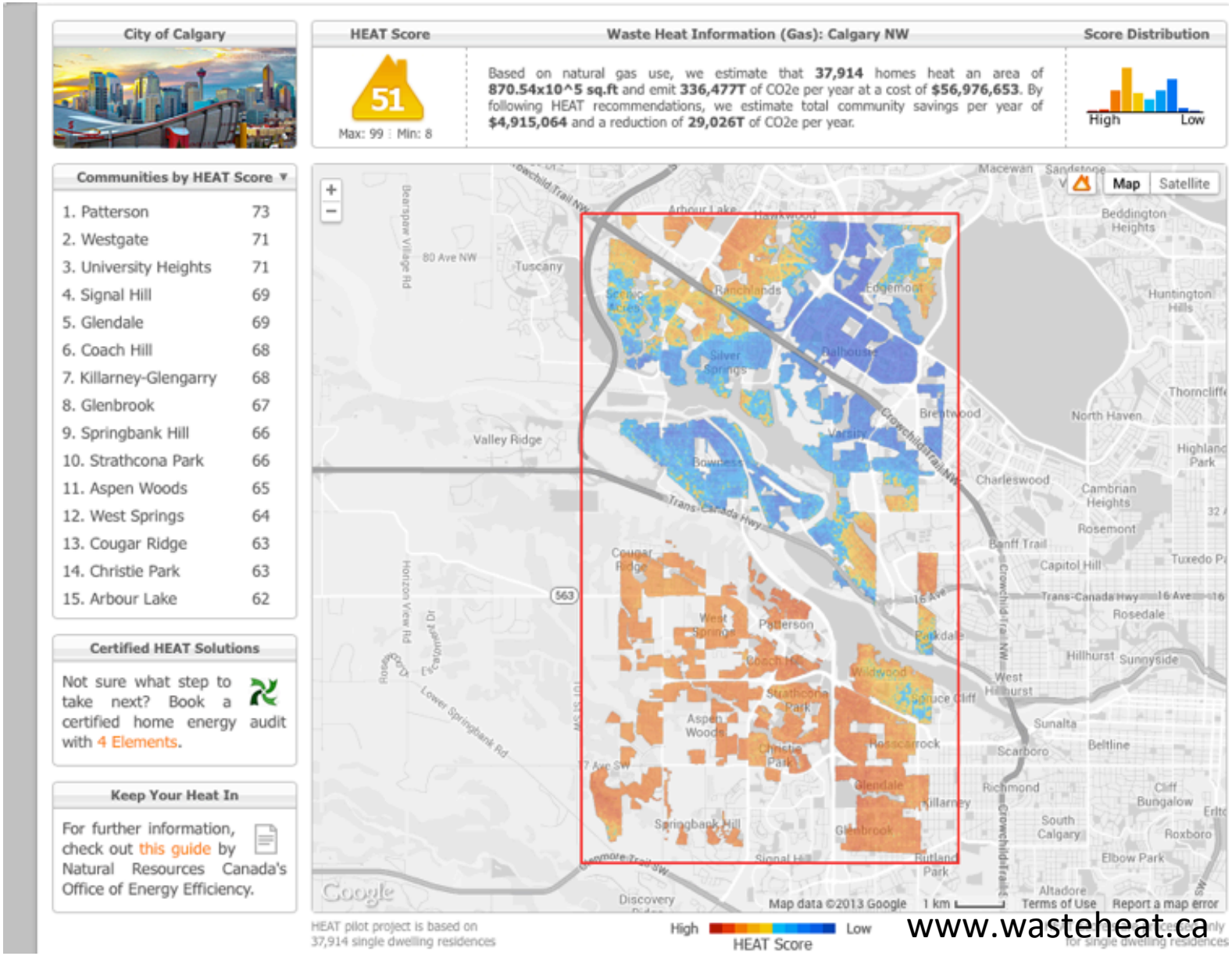


Broadband MWIR imagery highlighting subsurface heating conduits in downtown Denver, CO with accompanying Google Earth image (for reference). Imagery acquired 03-16-12, 01:00 local. (night time flight / 0.25m GSD)

City-scale thermal mapping – Graz, Austria (2011) 0.6m GSD

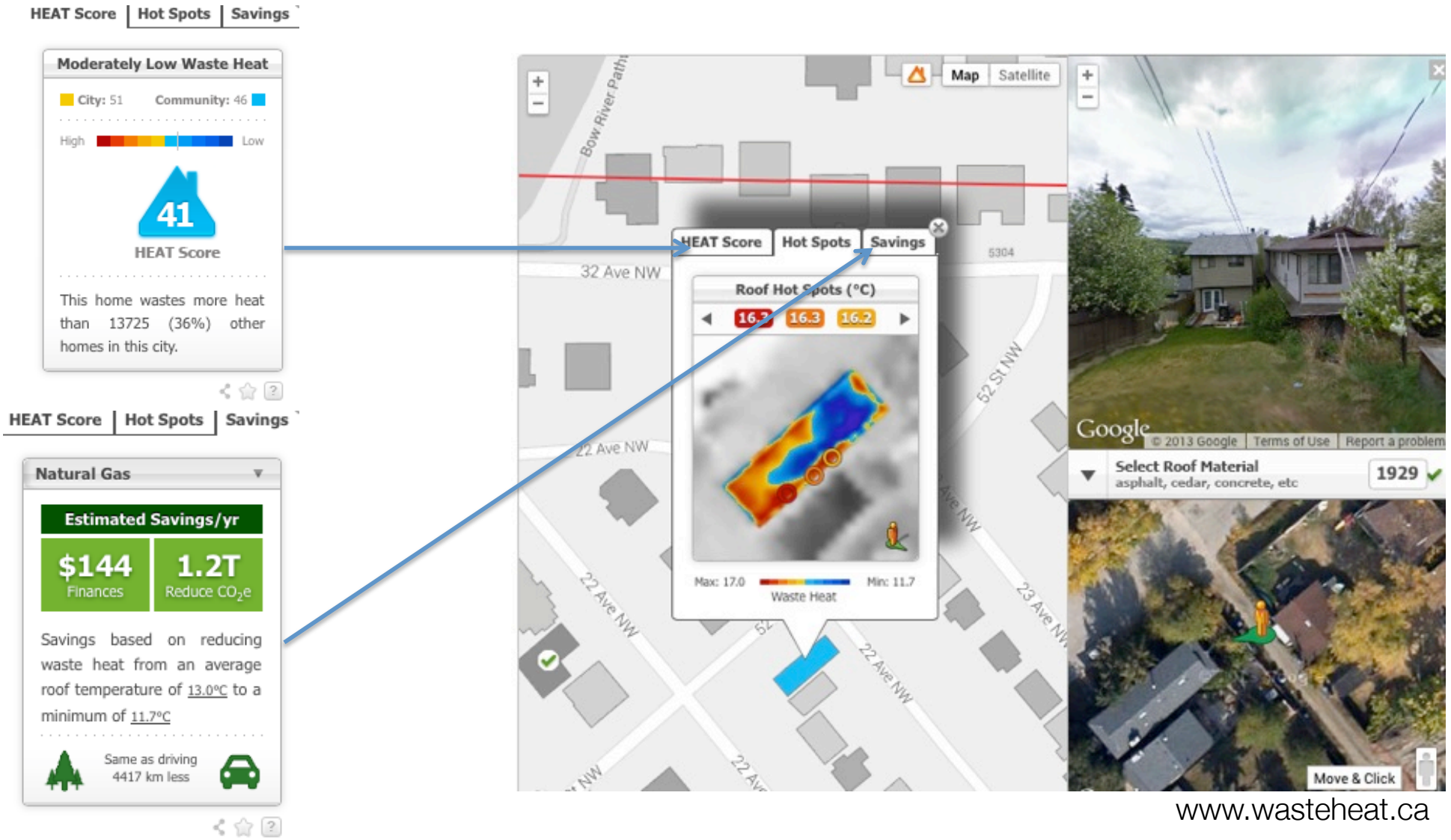


City-scale waste heat monitoring & reporting application

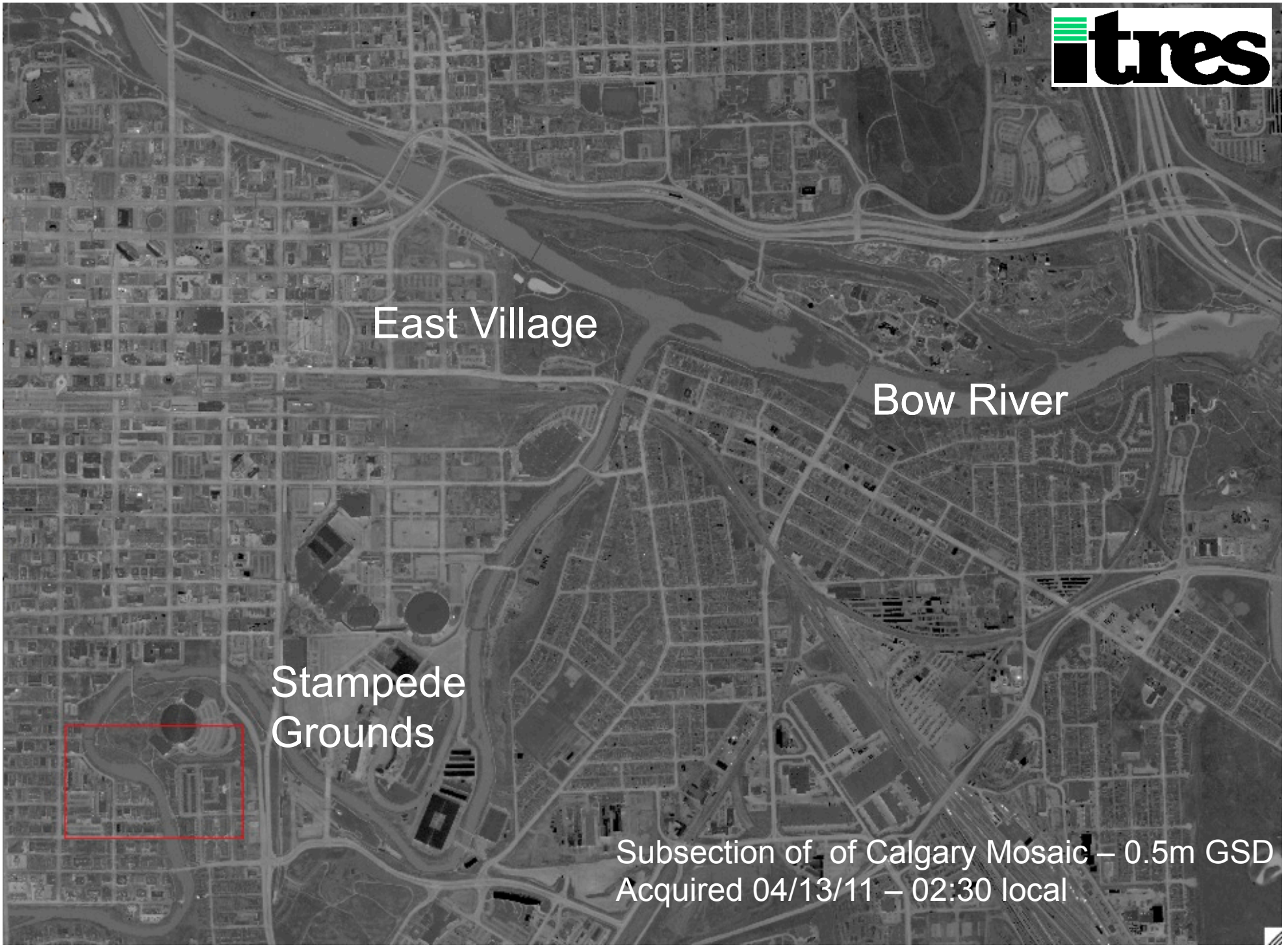


www.wasteheat.ca

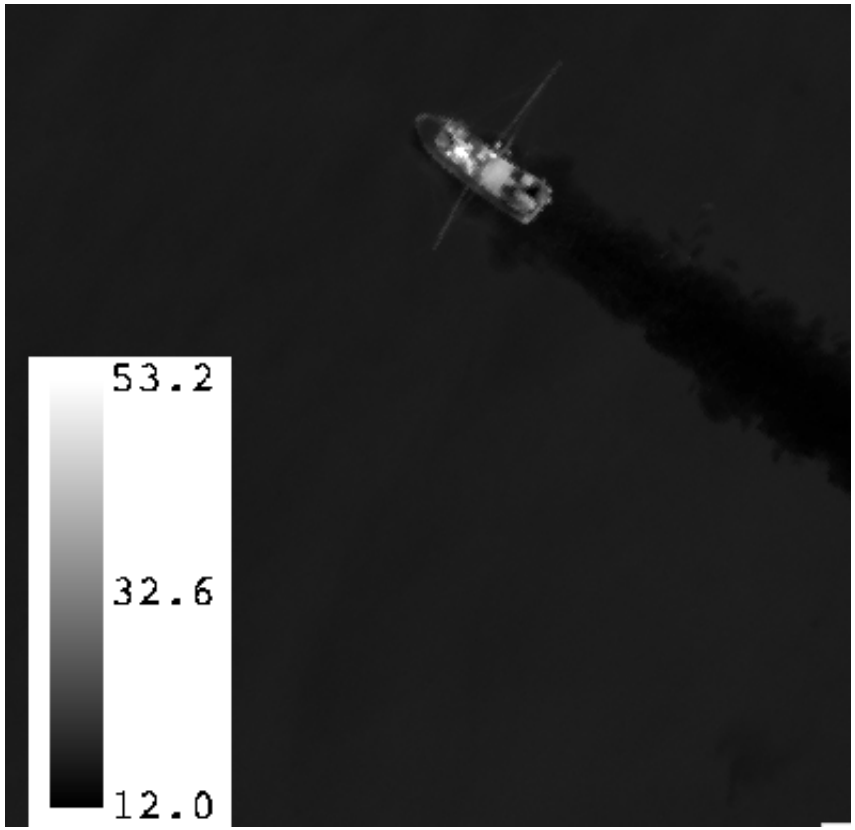
TABI-1800 derived heat loss information compared against roofing material information & publicly available gas record for each property.

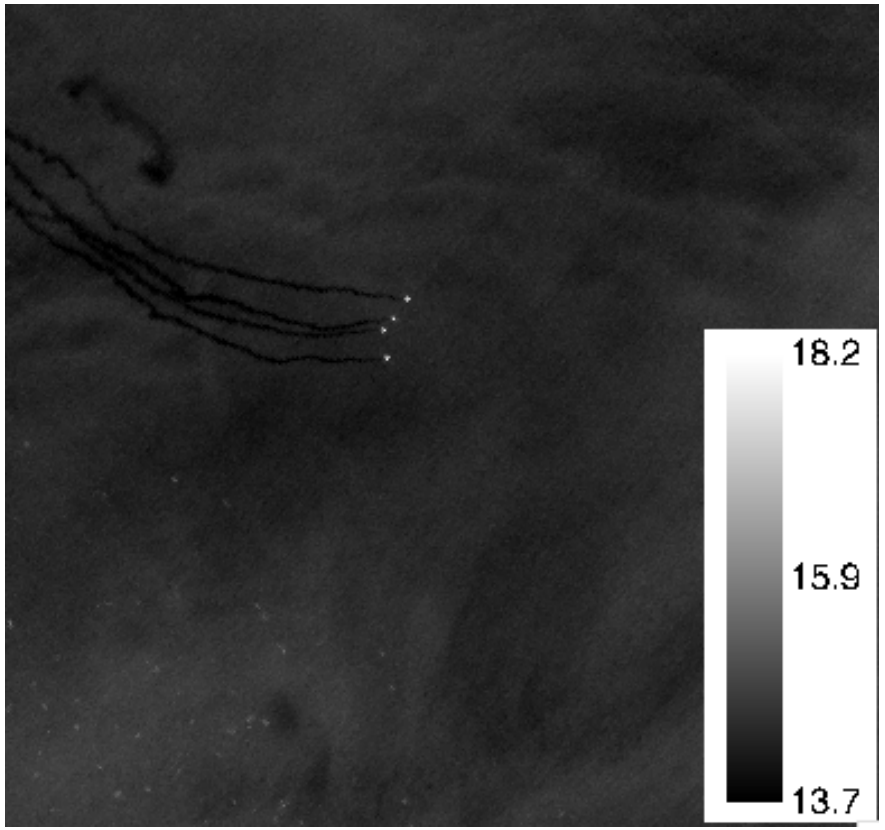


www.wasteheat.ca


East Village
Bow River
Stampede
Grounds
Subsection of of Calgary Mosaic – 0.5m GSD
Acquired 04/13/11 – 02:30 local

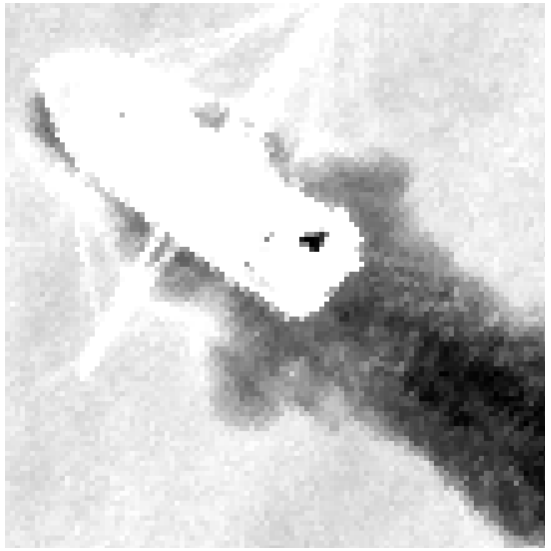
Maritime Daytime test flight 05-12-13, Vancouver Island, Canada





Linear

2% Linear



equalization

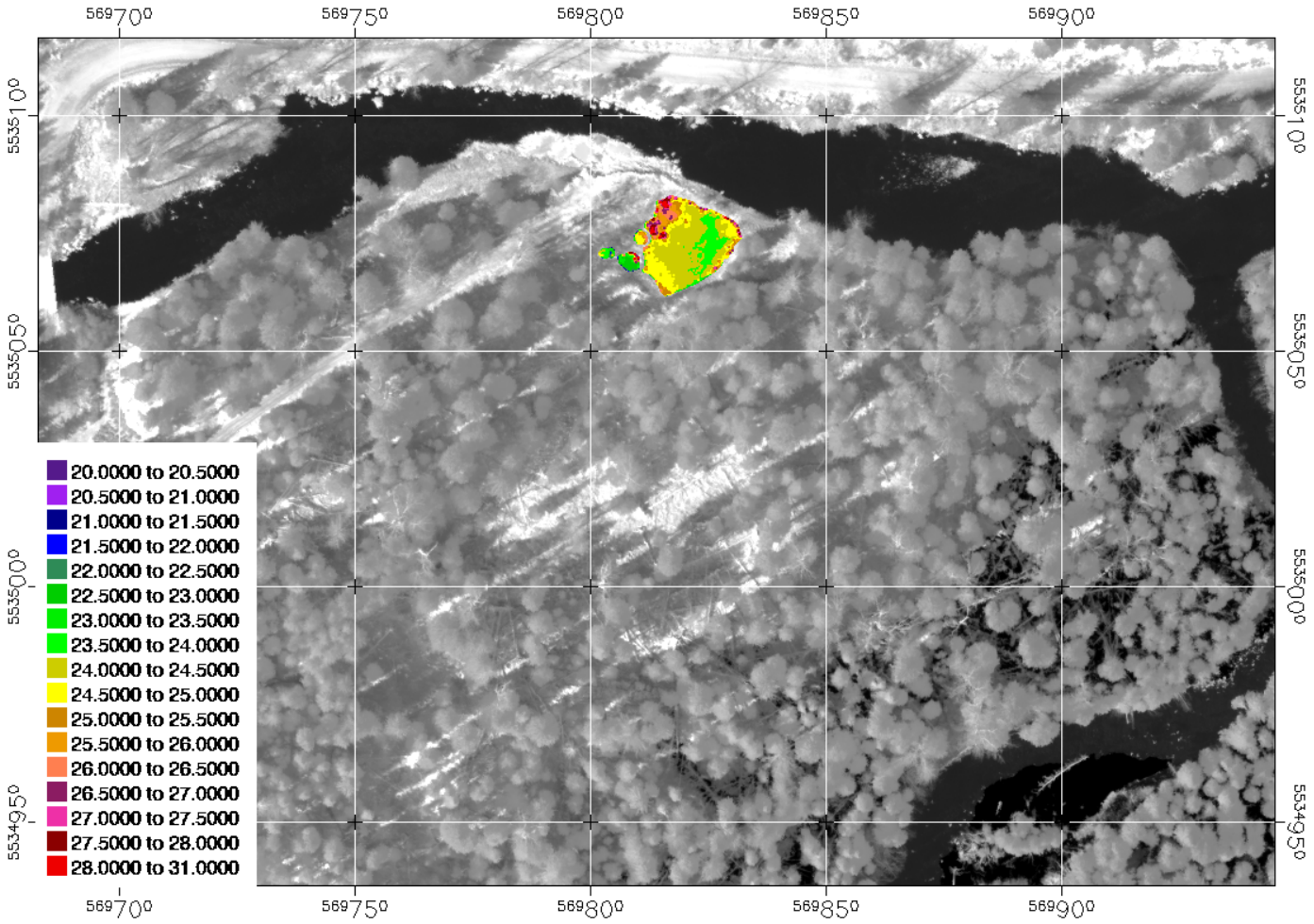
TSR1800 sensitivity range – depending on image display enhancement (scaling), various scene aspects can be derived from real-time corrected images.

A high spatial resolution example of swimming bodies & their thermal traces
(Daytime, 0.20m GSD).

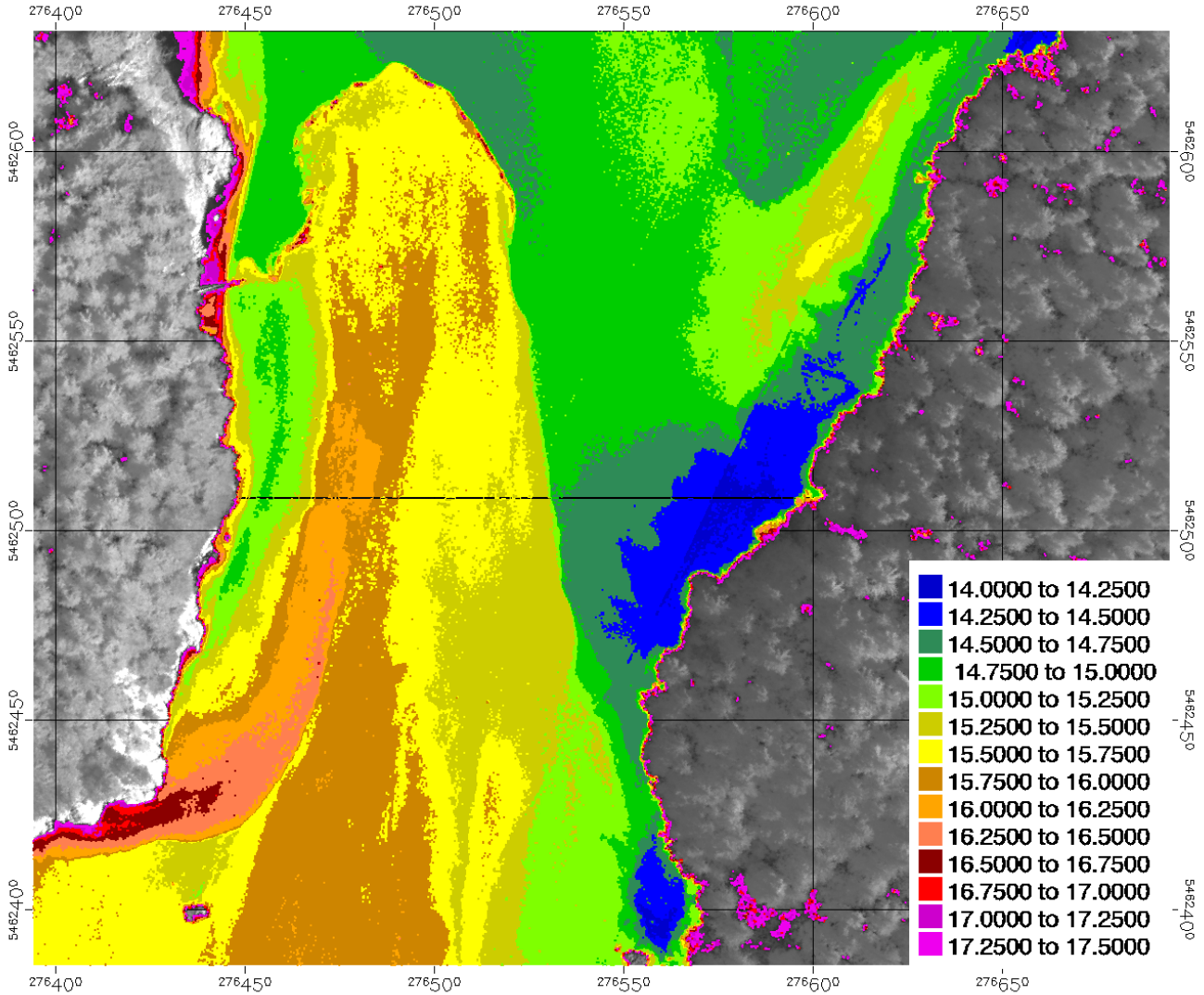
A 2nd high spatial resolution example of swimming bodies & their thermal traces
(Daytime, 0.20m GSD). Marine life surveys
Dolphin trail – Sea water thermal mixing

Note the direction of travel (right to left) by dilution of 'punches'

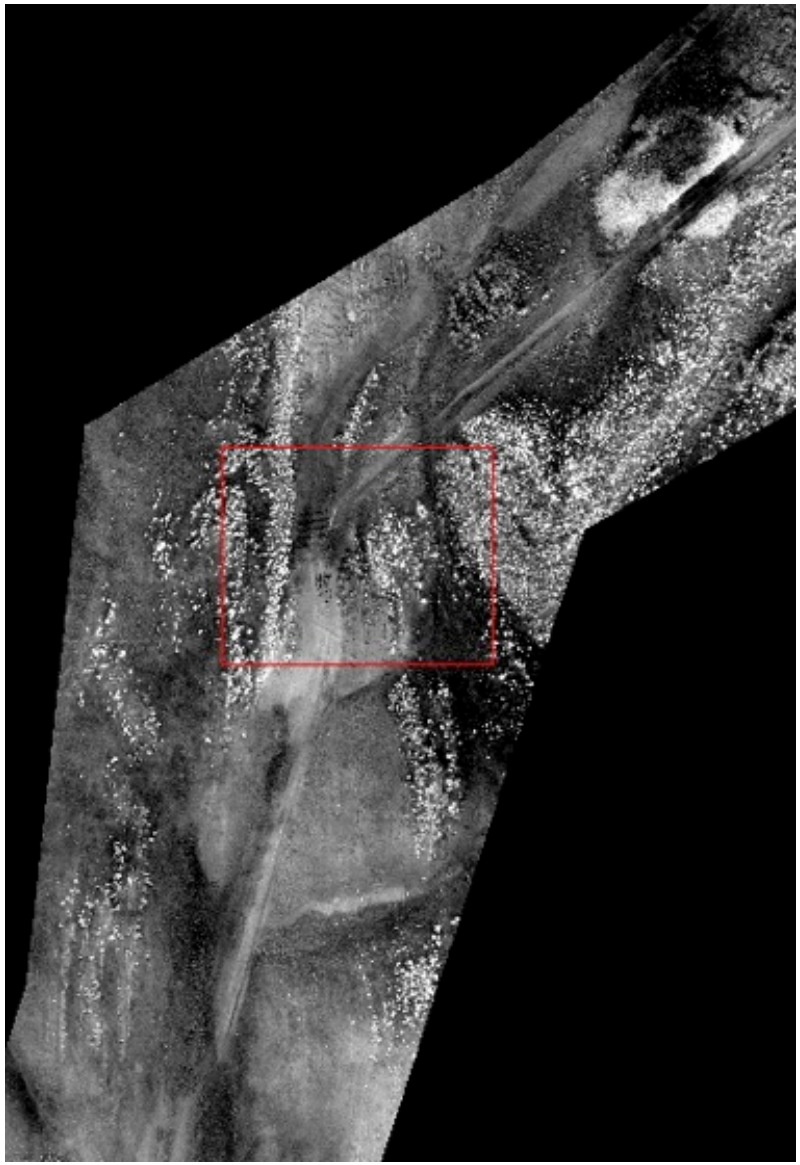
Buhl Creek, BC – Daytime TABI1800 onshore geothermal feature



Ahousat, BC – Daytime TABI1800 marine geothermal feature



Pipeline monitoring Alberta – October 22, 2013



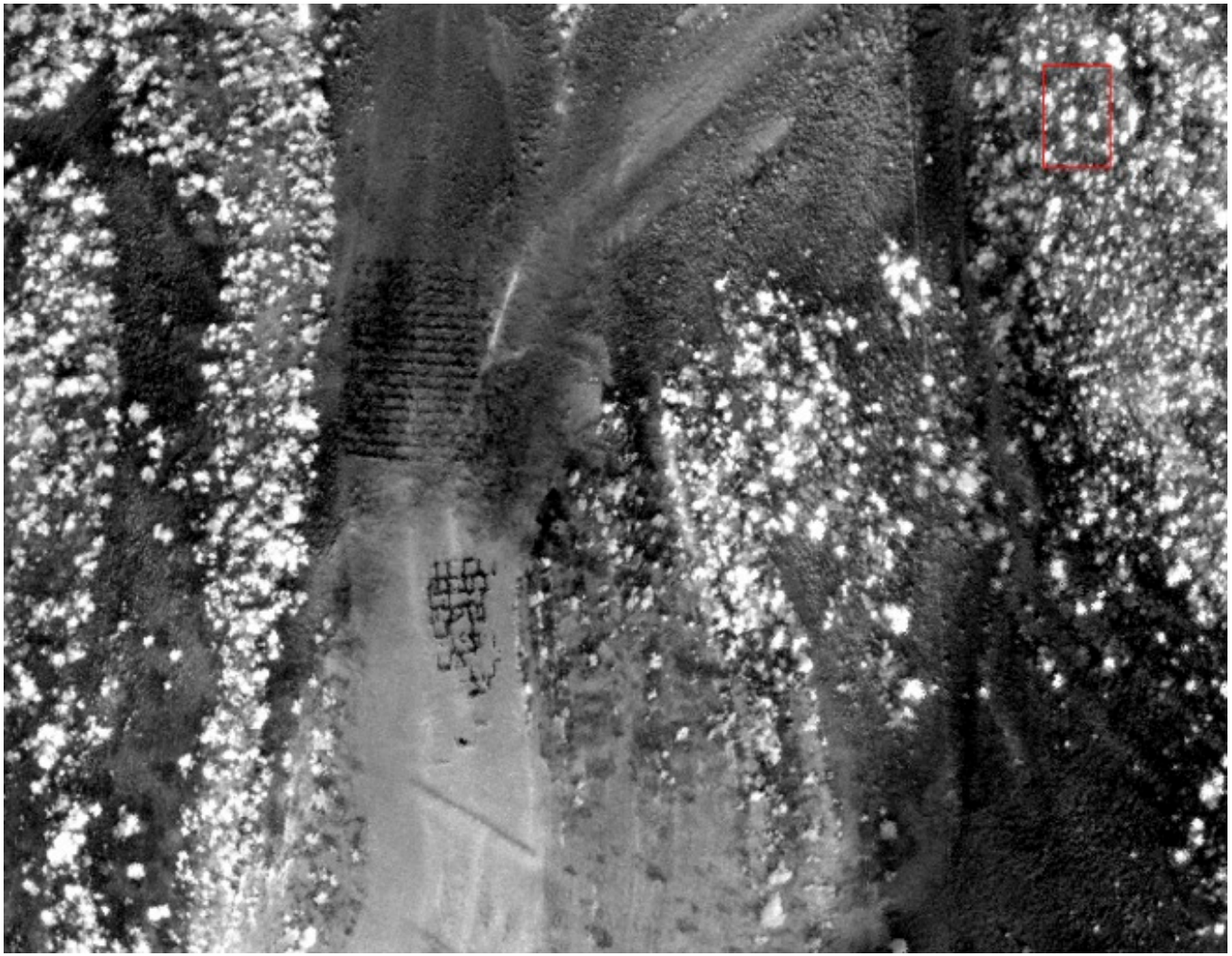
80 km of Natural Gas mainline acquired in Southern Alberta.

GSD : 0.5m

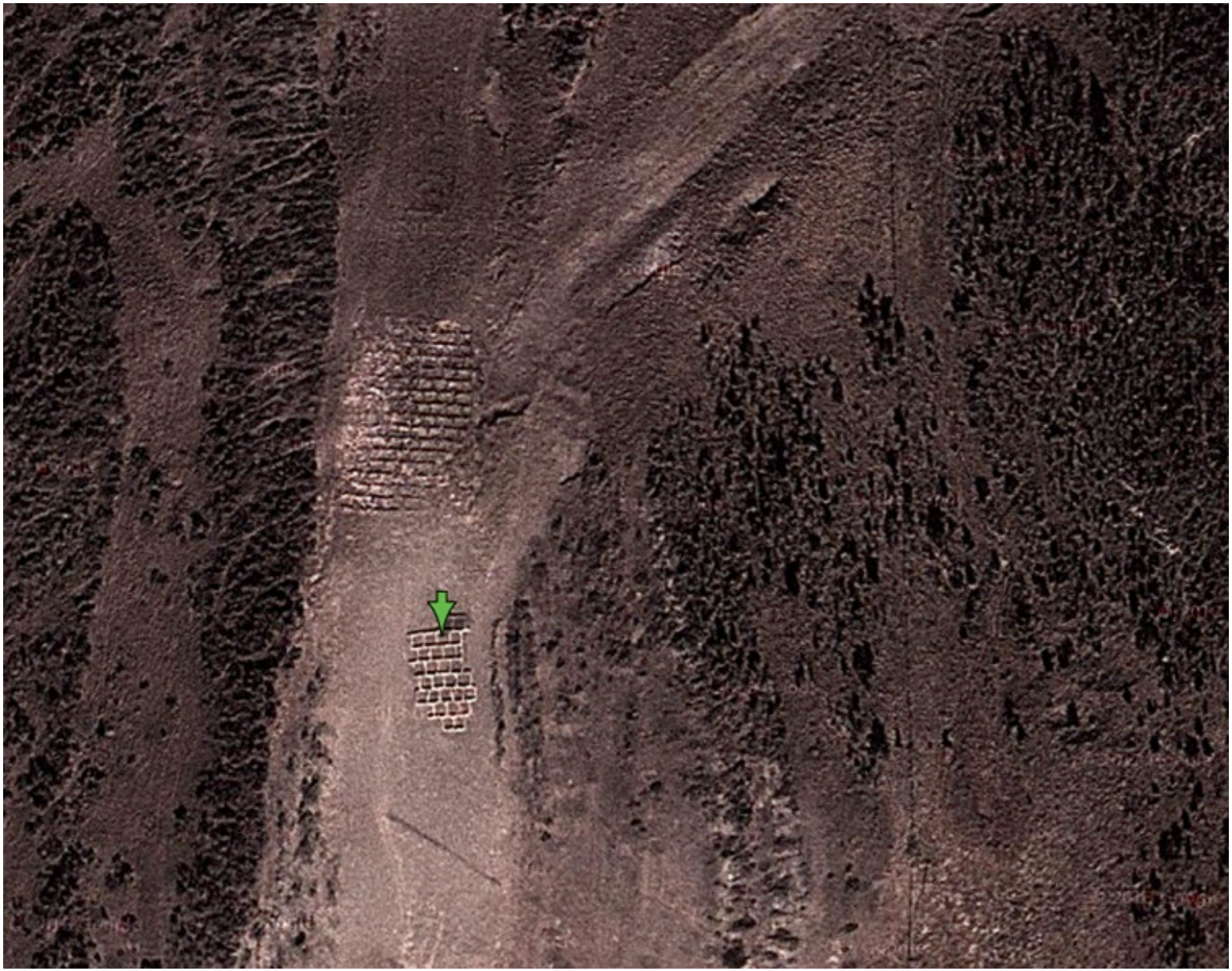
Time of acquisition: ~ 02:00 local

Example A: Slope stabilization & loss of overburden

TABI-1800 Imagery ~2:00 AM – Oct 22, 2013 – 0.5m GSD



Google Earth imagery over area of previous slide

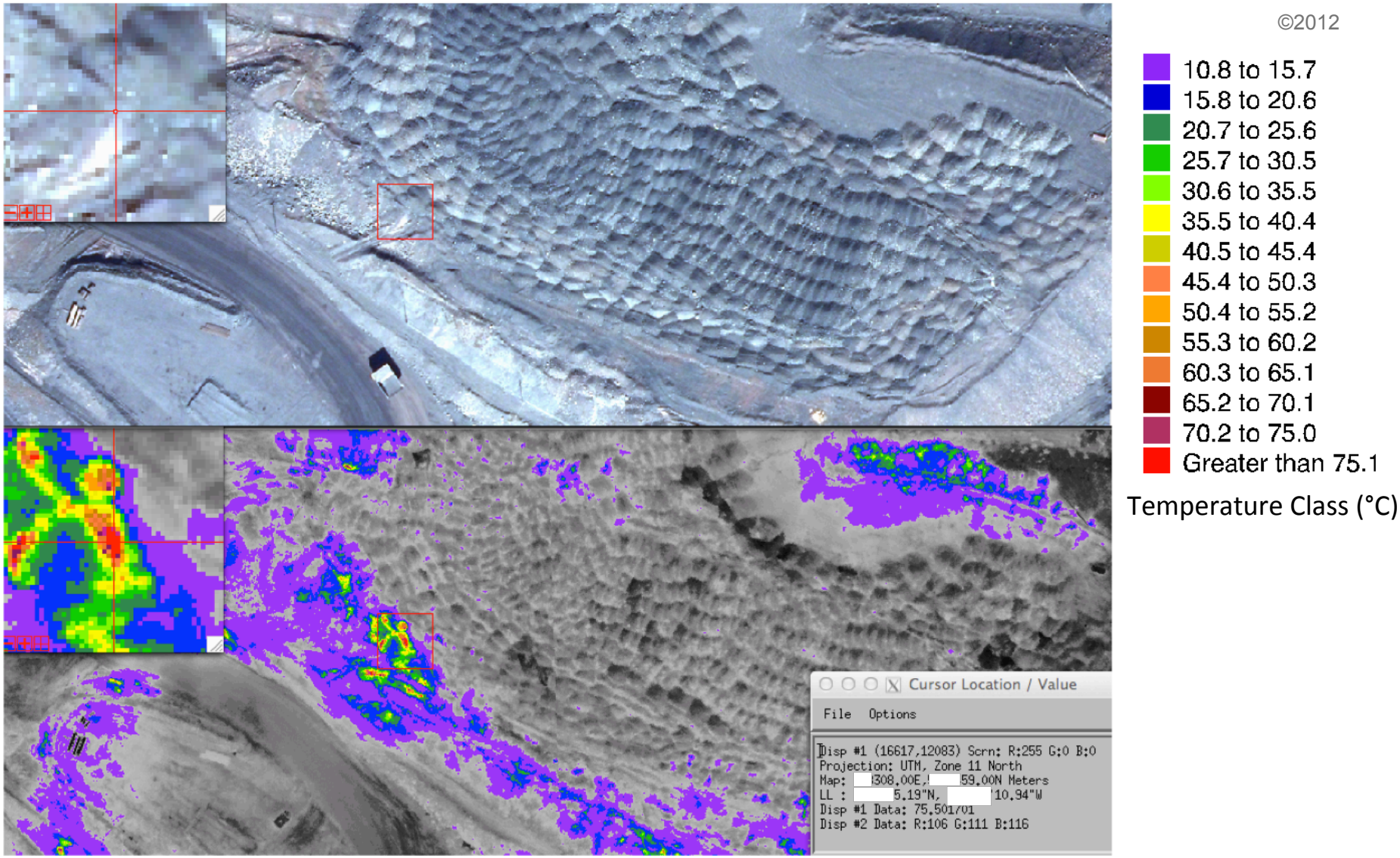


Example B – River crossing

TABI-1800 Imagery ~2:15 AM – Oct 22, 2013 – 0.5m GSD

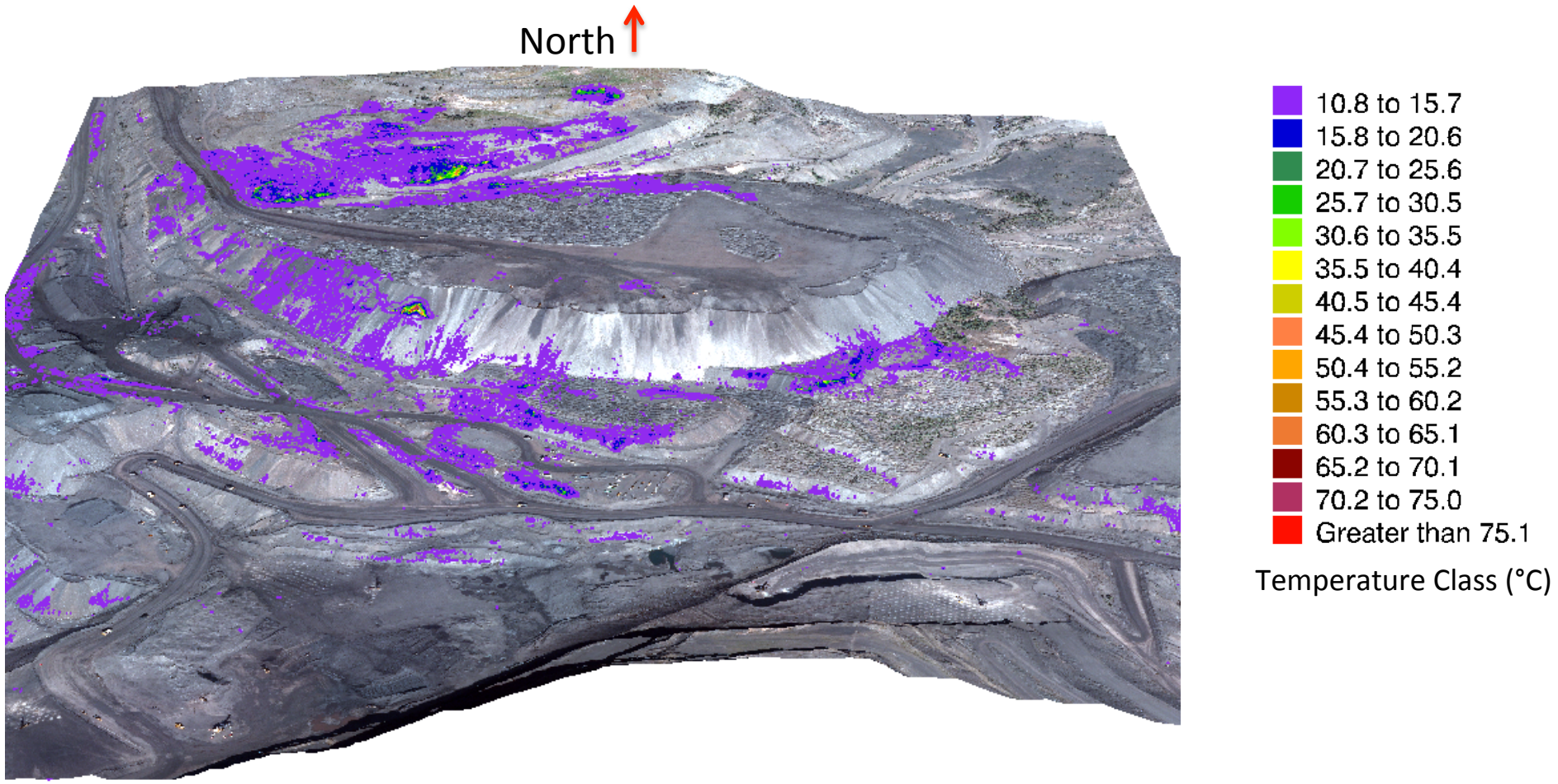
Google earth Imagery of Old Man River crossing

Preliminary Image Analysis – Sample
Underground Coal Fires – Canada, 2012



Example of Near co-incident RGB imagery vs. temperature-classified TABI-1800 imagery

Preliminary Image Analysis – Sample
Underground Coal Fires – Canada, 2012



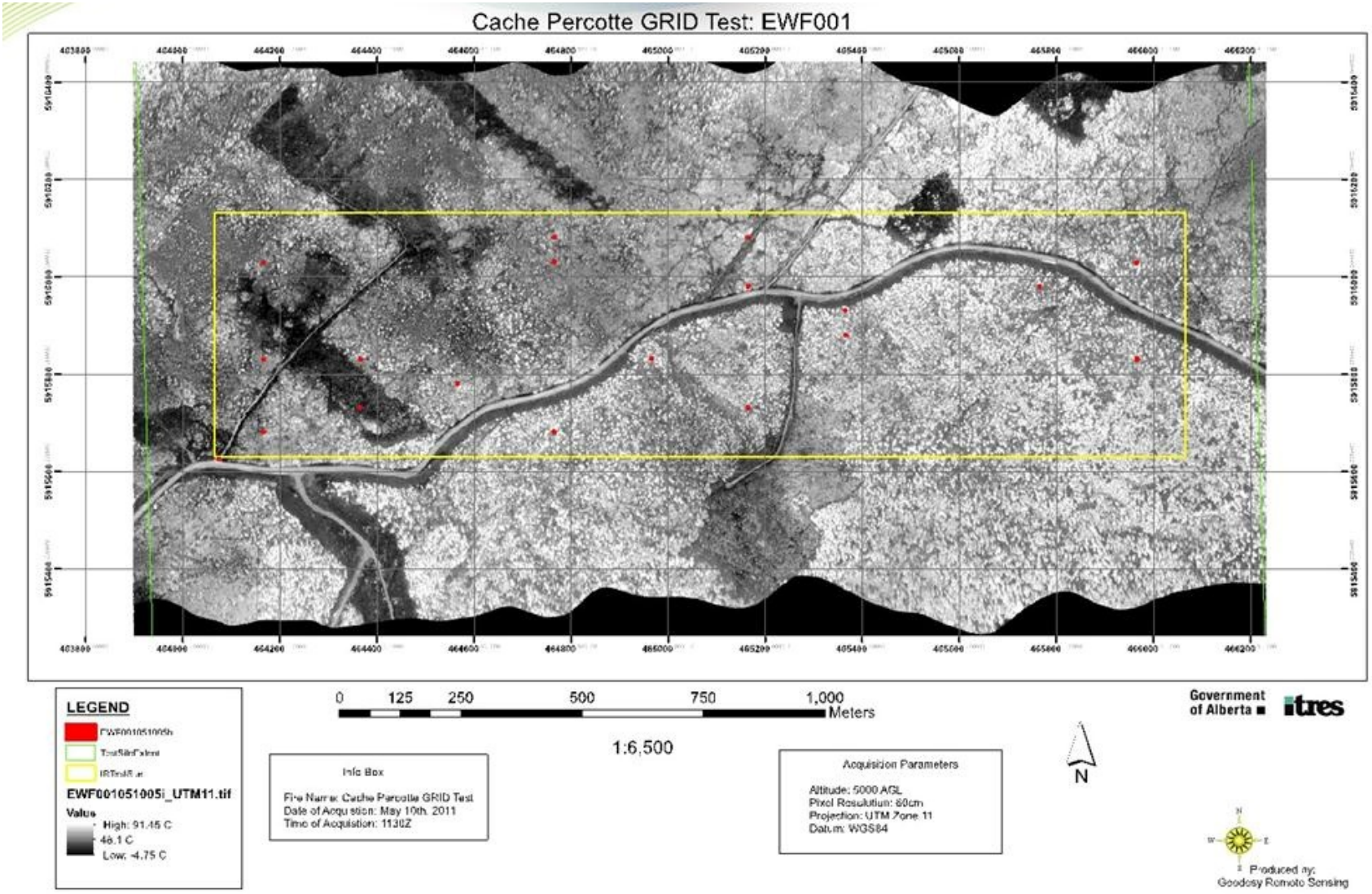
Client-provided Orthophoto draped over bare-Earth LiDAR DEM (detail), with thermal anomaly vectors from TABI-1800 overlain.

Rapid response & near real-time image processing

TABI & Alberta SRD.

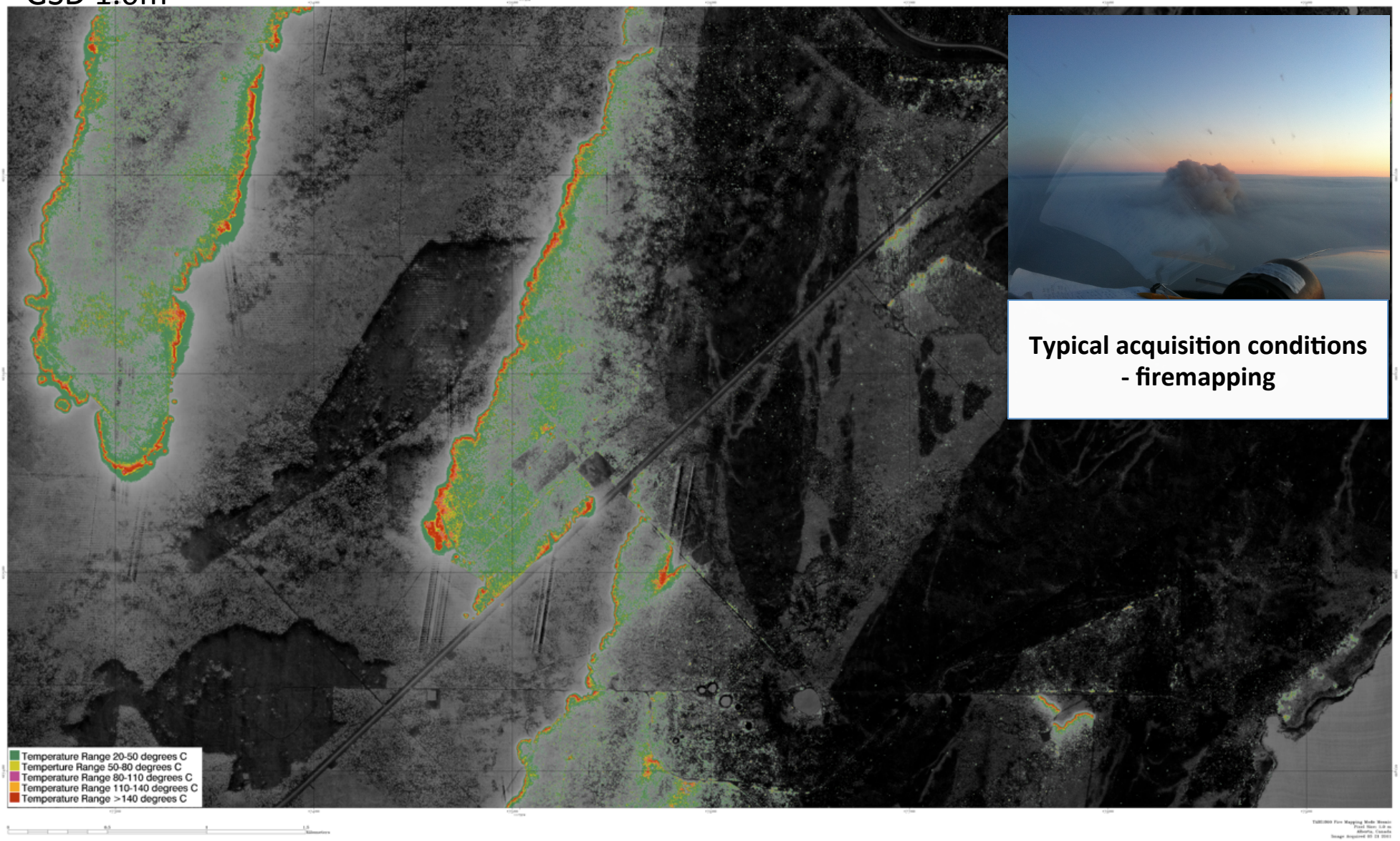
May 2011: TABI-1800 demonstrated 90% hotspot detection rate (Cache Percotte GRID Assessment).

Targets detected under variety of cover (open, obscured) conditions. Grid size 0.5 x 2 km.



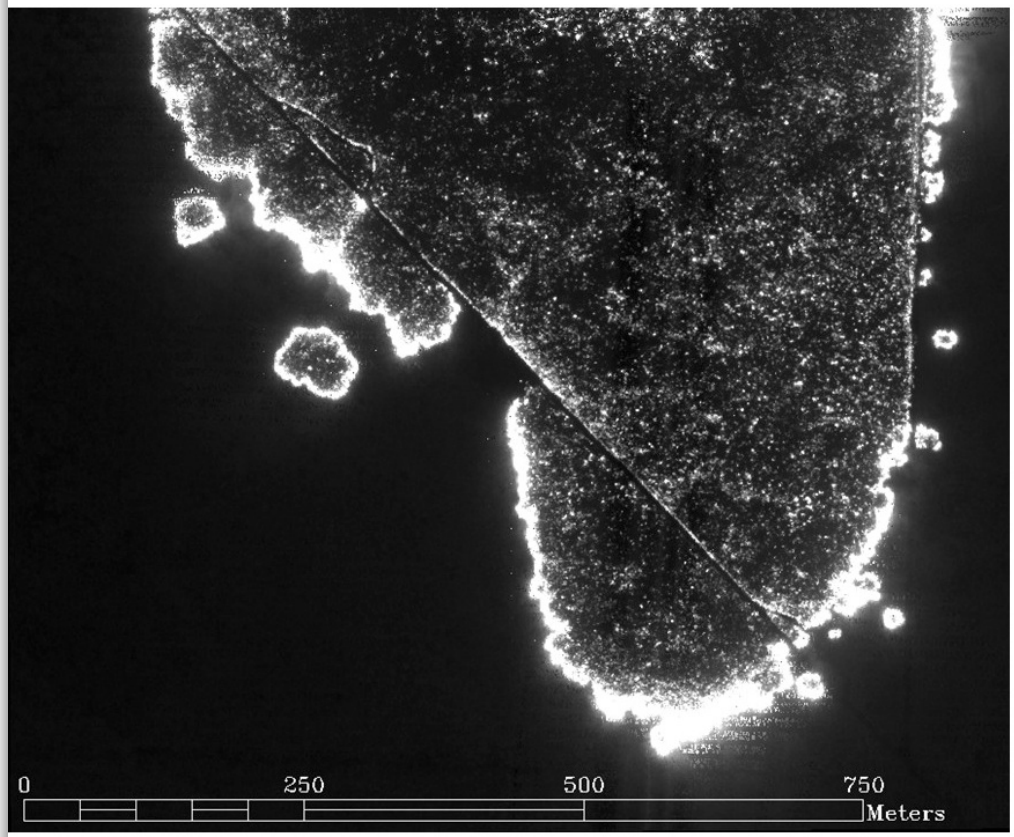
Georeferencing Examples : TABI-1800(a)

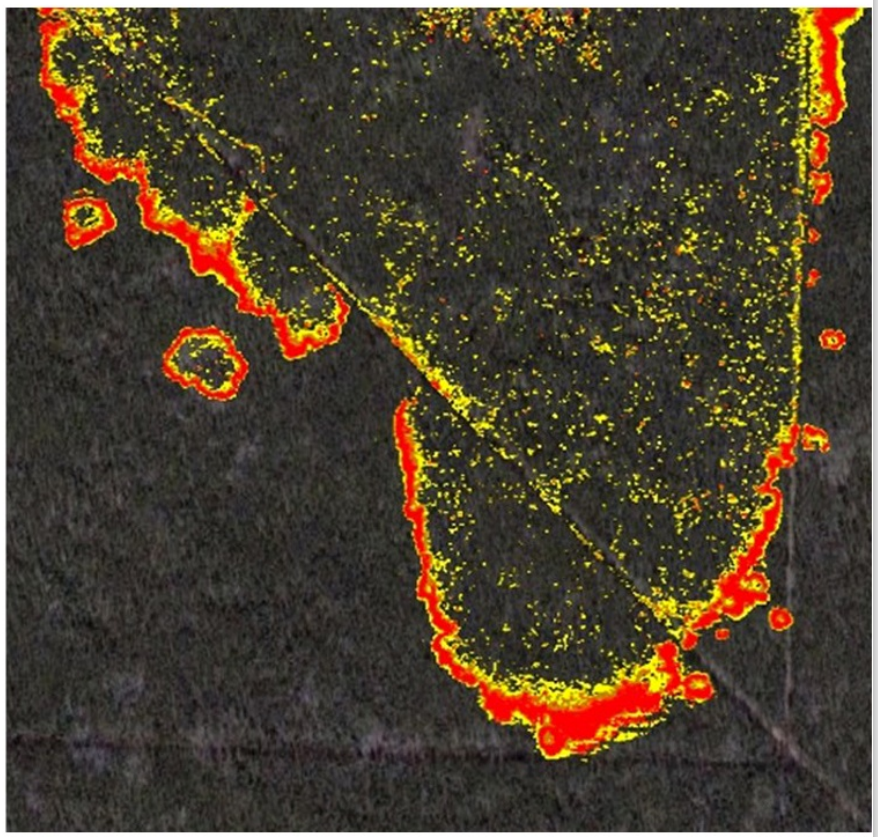
TABI-1800 mosaic with vectorized hotspots (night image, through smoke) Alberta, 2012 – GSD 1.0m



TABI Fire Perimeter Mapping.

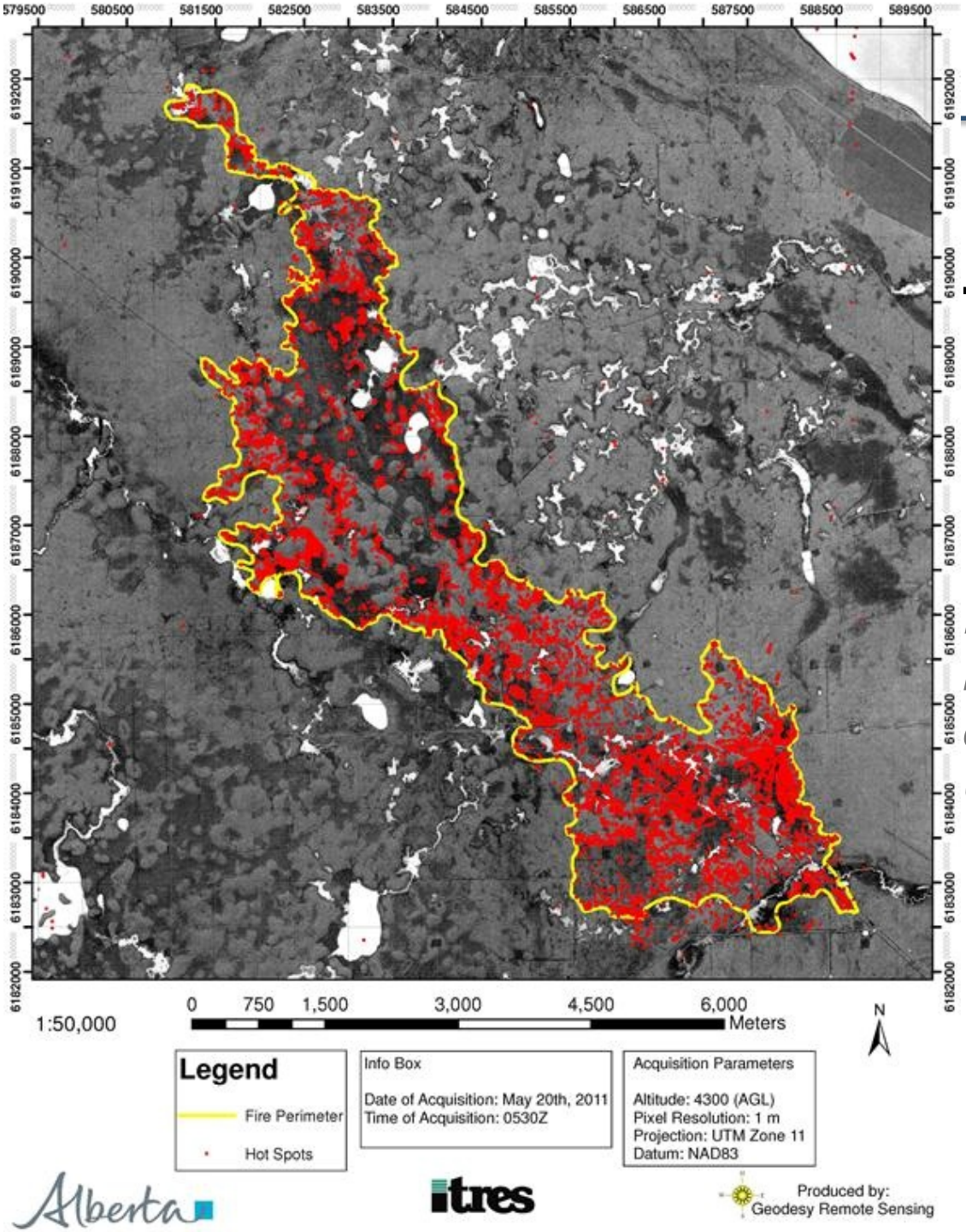
TABI-1800 Wildfire Mapping Imagery, Northern Alberta
(L) Calibrated and geolocated thermal imagery
(R) Same image after simple threshold operation, overlain on Google Earth





All images courtesy Alberta Sustainable Resource Development

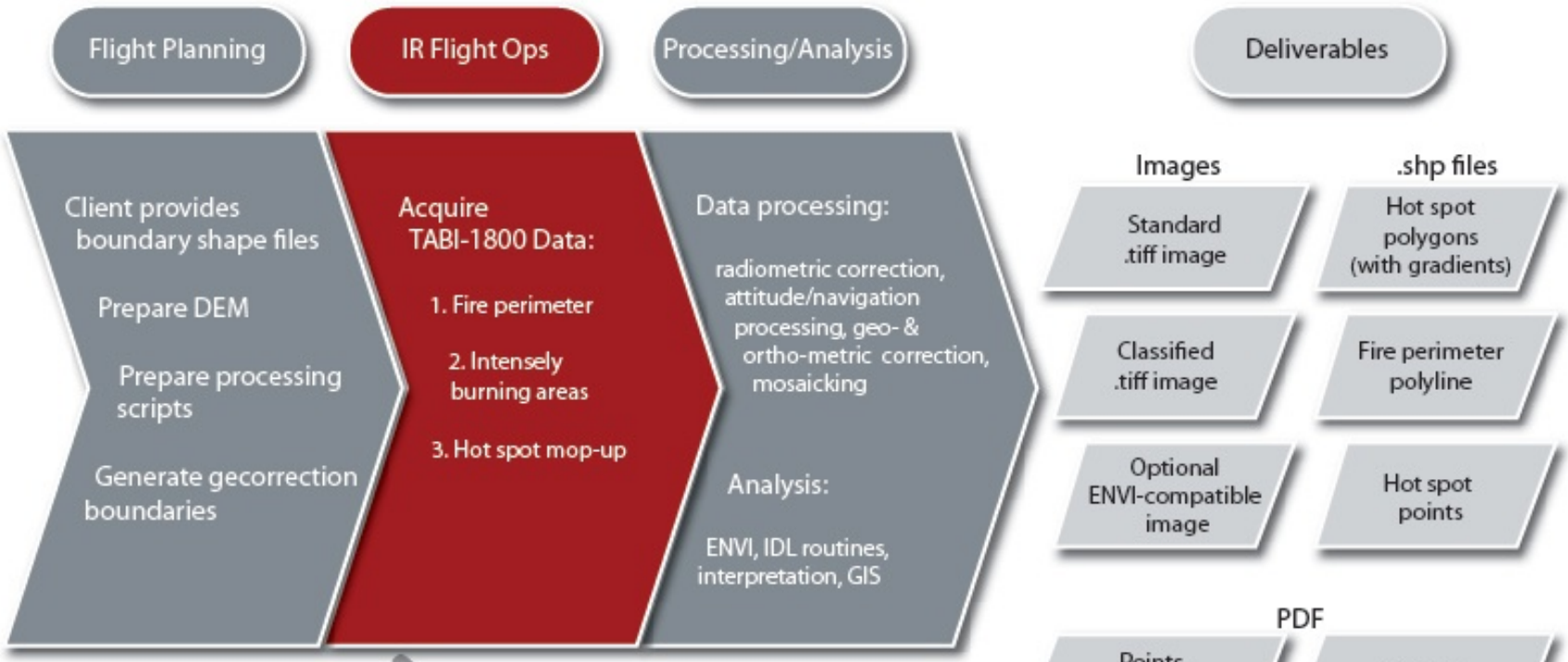
Fire Perimeter Map Derived From 1m TABI Data



Fire perimeter (yellow polygon) and intense burning areas (red areas) overlain on greyscale TABI image. Courtesy Alberta SRD.

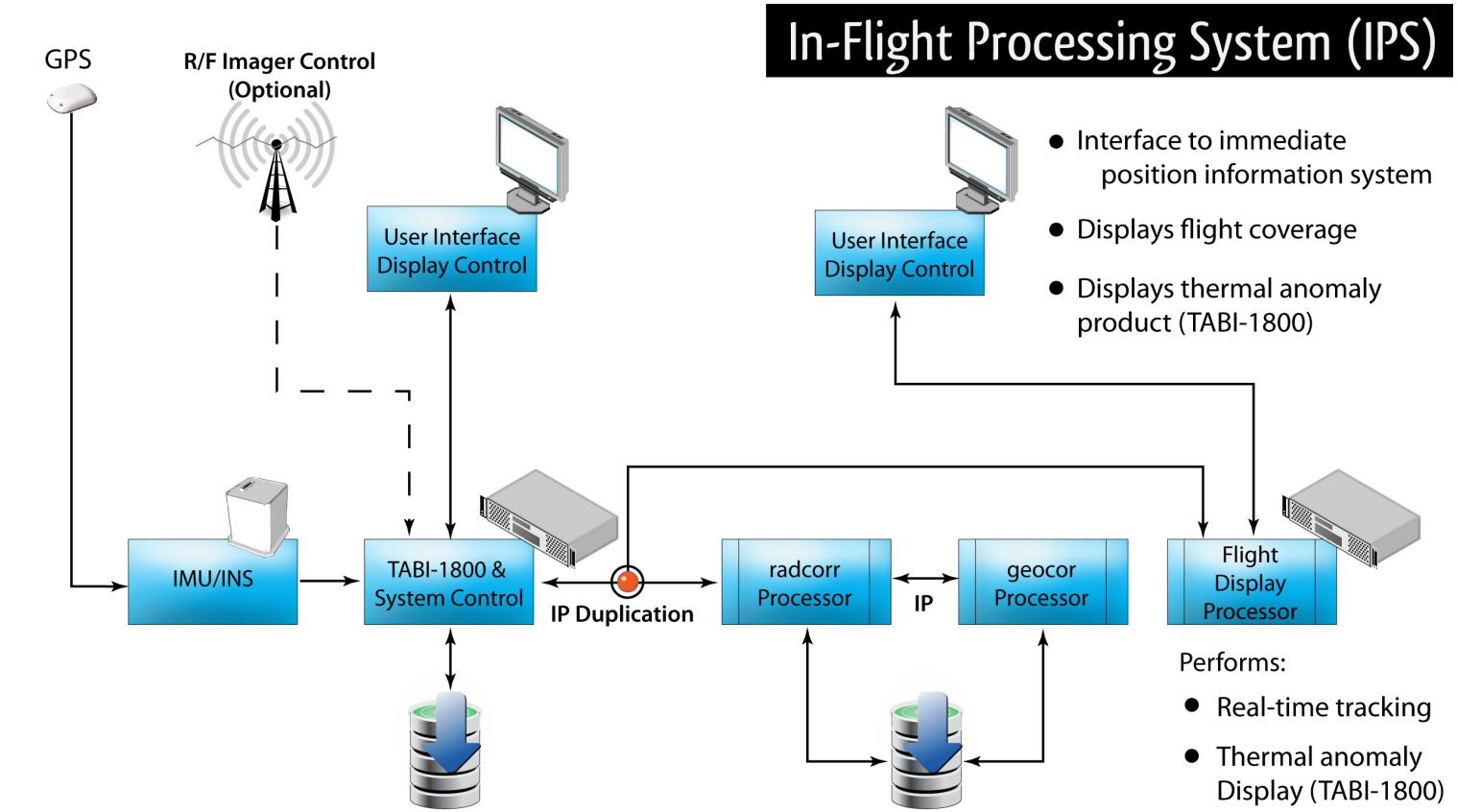
TABI-1800 Fire Mapping Operations

Thermal Airborne Broadband Imager - MWIR - 3.7 - 4.8 microns - 1800 across-track imaging pixels



*Typical. Depends on area to be imaged, ceilings, perimeter complexity, and specific tasking

Inflight Processing System (IPS)



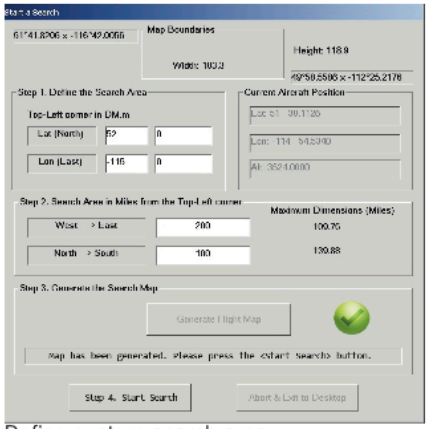
Outputs:

Raw Image Data
Raw Attitude & Position Data

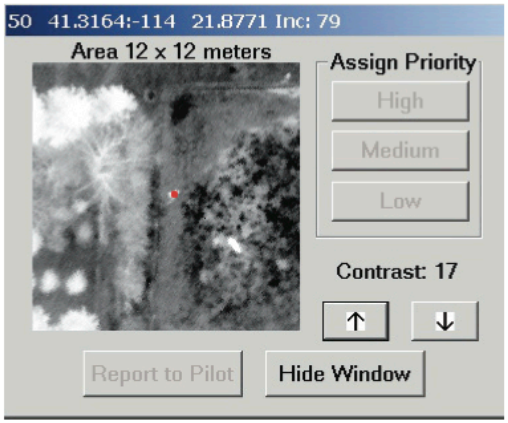
Radiometrically Corrected Image Data
Geocorrected Image Data
Geocorrected Mosaics
Thermal Anomaly Product

Alaskan Trials of TSR-1800 Conducted

Coastal, ocean, and tundra SAR detection flights illustrate system's automated detection capabilities



Define custom search area



High resolution thermal thumbnails (brighter pixels=warmer temperatures, darker=cooler)

Real-Time Thermal Anomaly Detection

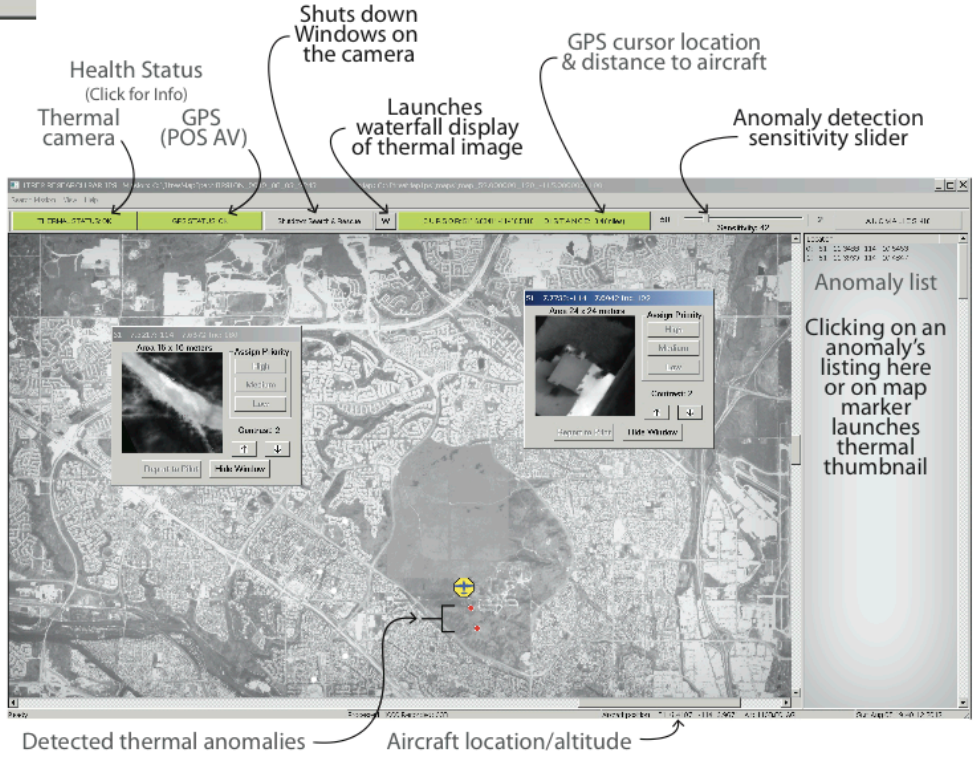
High Resolution Thermal Image

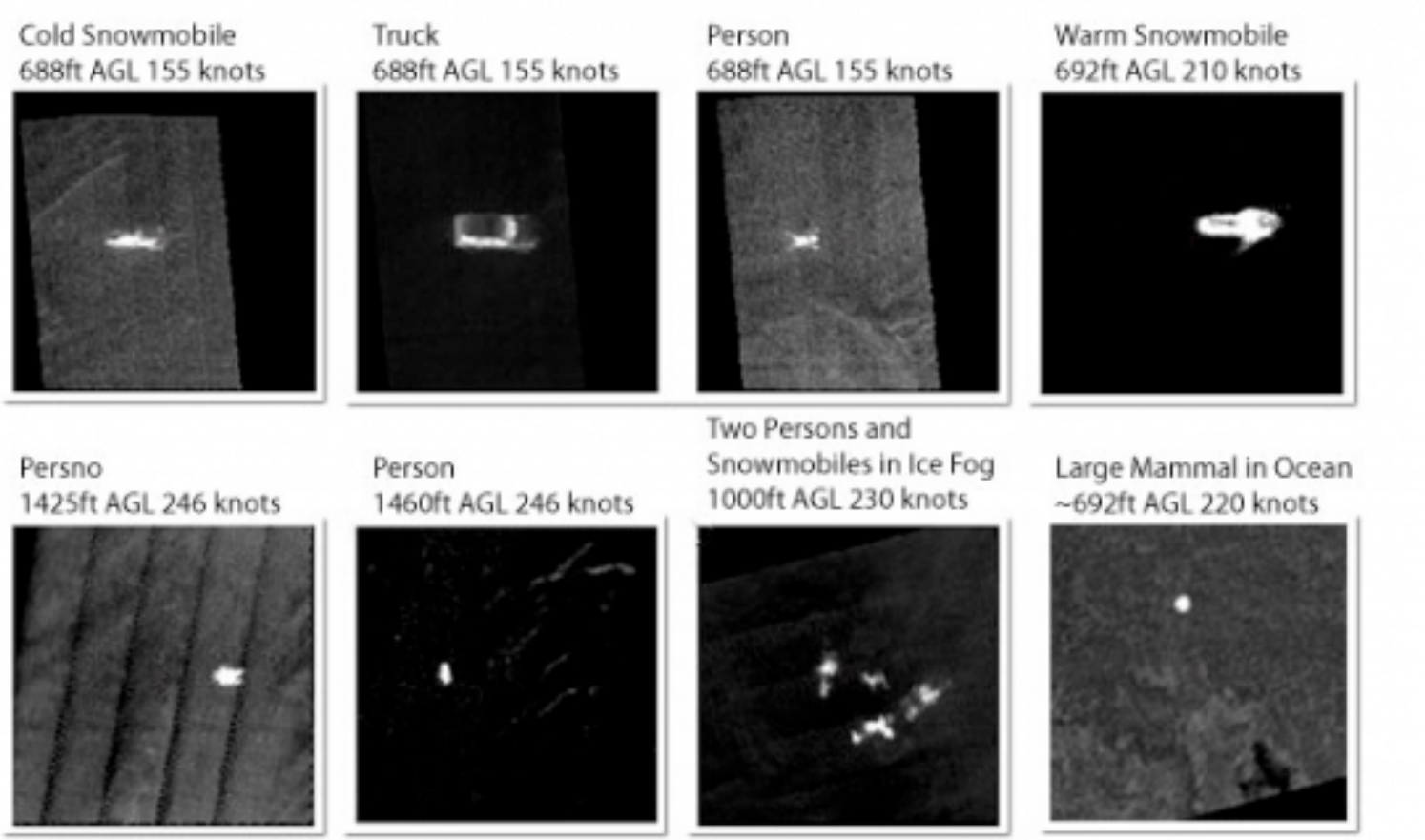
Real-Time Position

SEARCH AND RESCUE

TARGET DETECTION

RAPID RESPONSE





Thermal thumbnails of automatically detected people, vehicles, and large mammal (February 2013, Barrow Alaska).

System co-mounting & synchronization

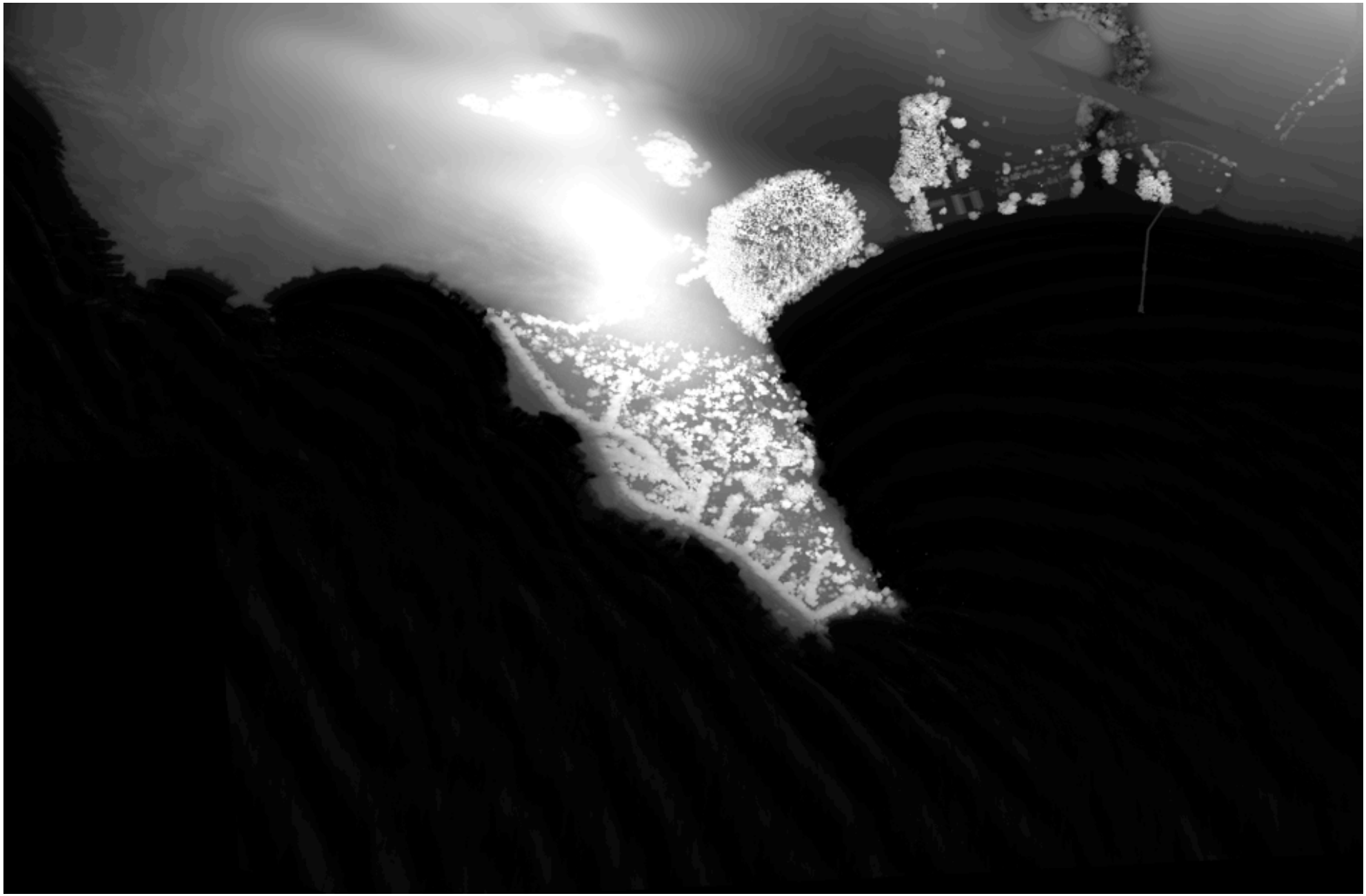
- Multiple ITRES Systems
- LiDAR

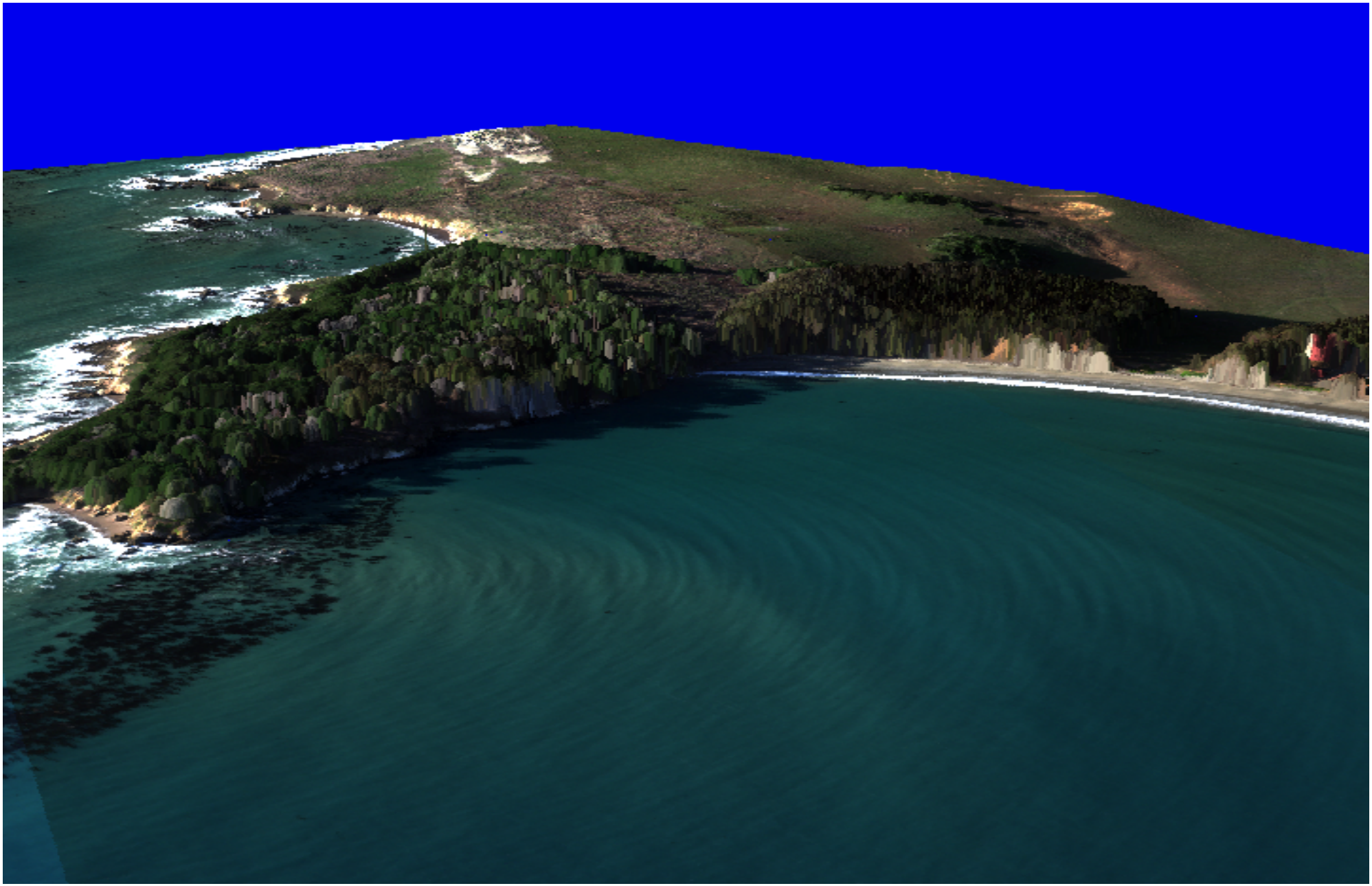
Sensor Fusion -LiDAR

CASI1500 &ALTM3100EA co-mounted in Navajo C-FFRY, 2007

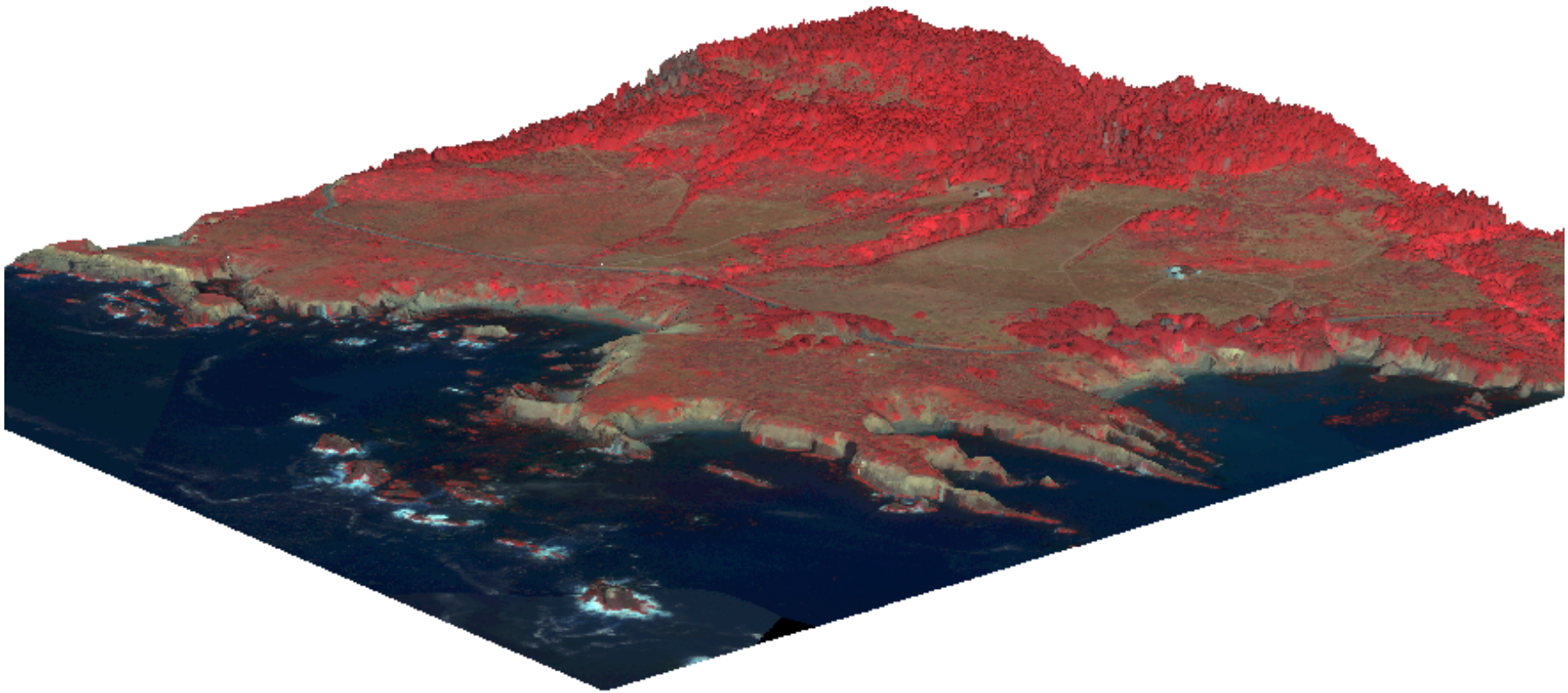
Sensor Fusion -LiDAR

LEICA ALS AND CASI-1500

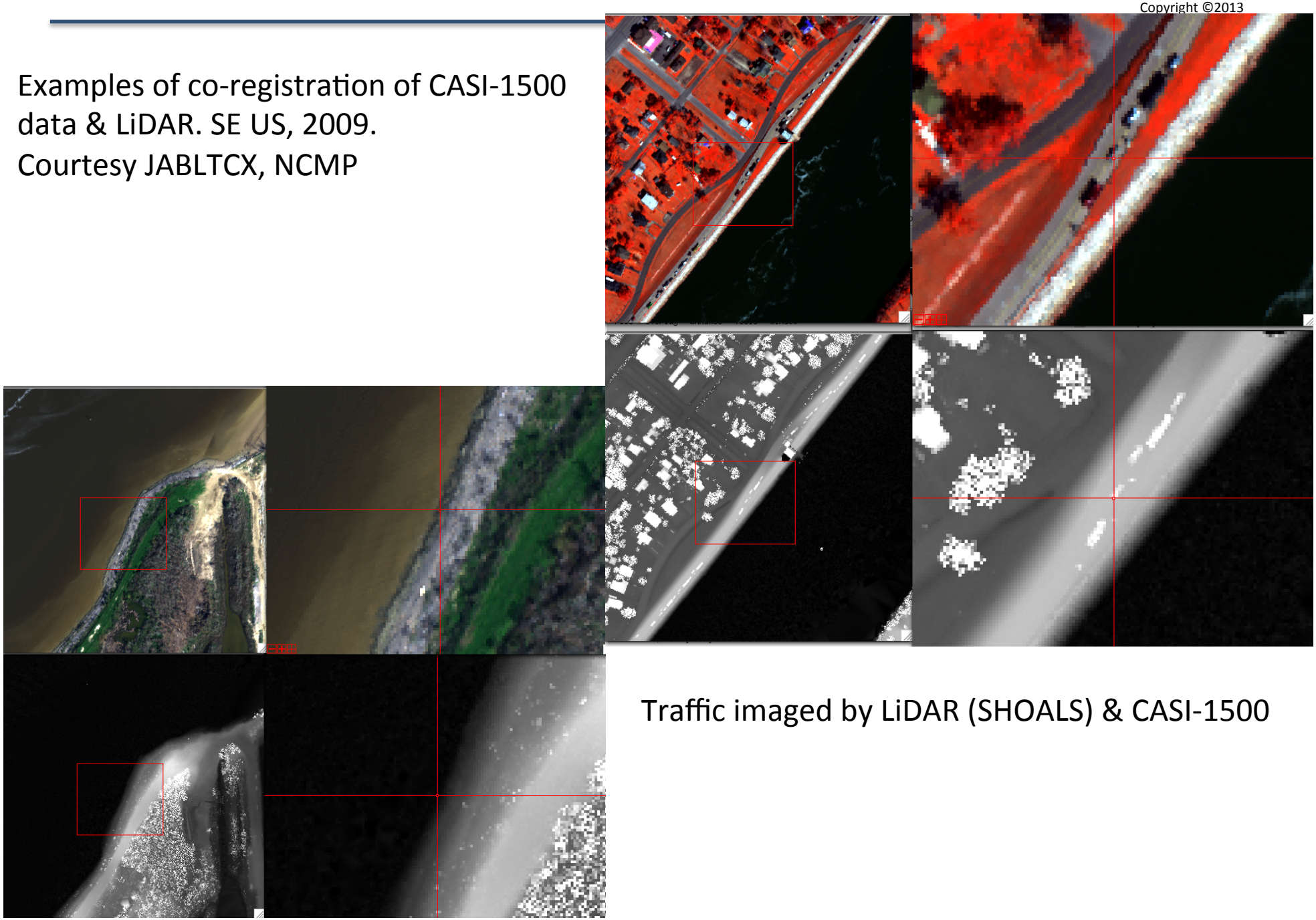




Fused CASI-1500 / LiDAR : Data imaged simultaneously
CASI-1500 orthocorrections performed with LiDAR data
California, 2010 (JALBTCX, NCMP).

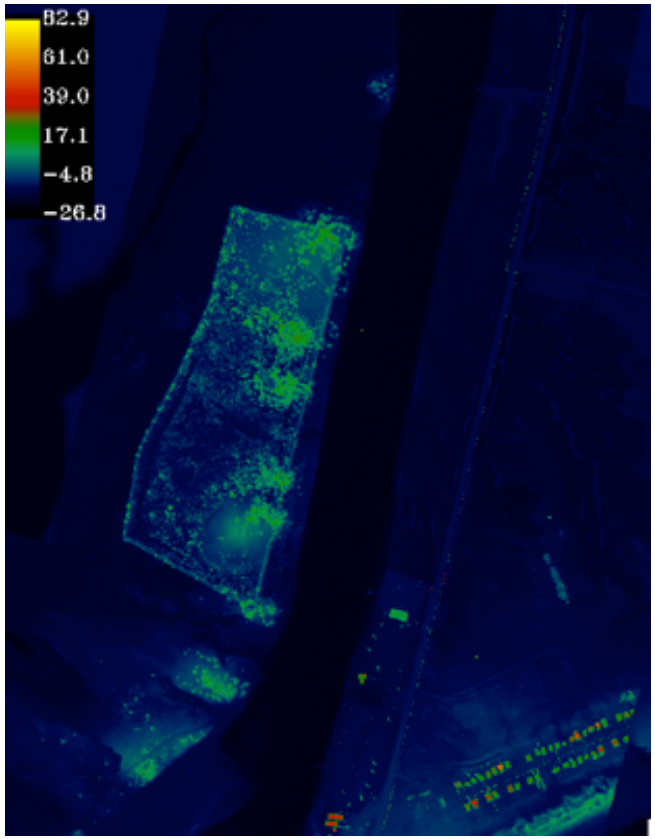


Examples of co-registration of CASI-1500 data & LiDAR. SE US, 2009.
Courtesy JABLTCX, NCMP

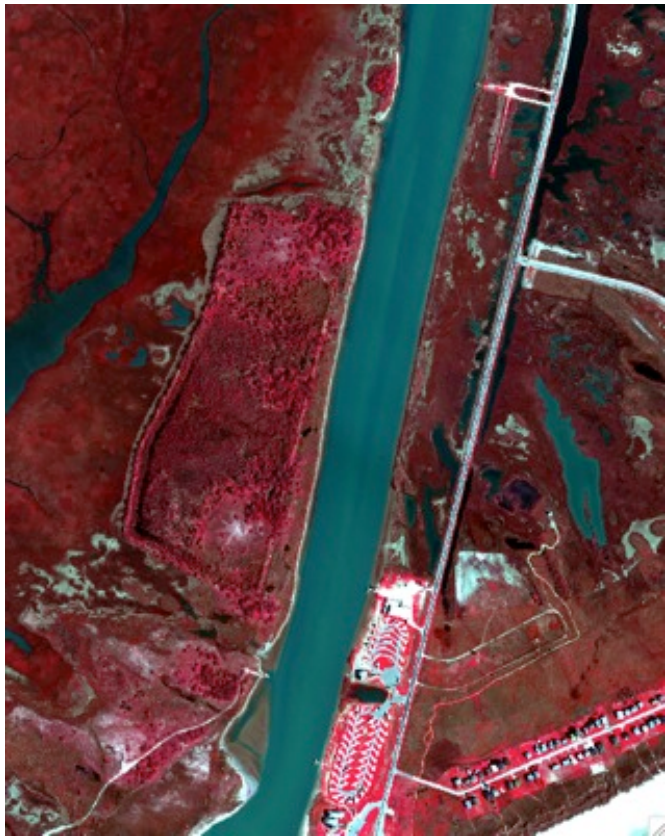


Traffic imaged by LiDAR (SHOALS) & CASI-1500

LiDAR & Spectral combined to separate domains
Example of CASI-1500 & Terrestrial LiDAR

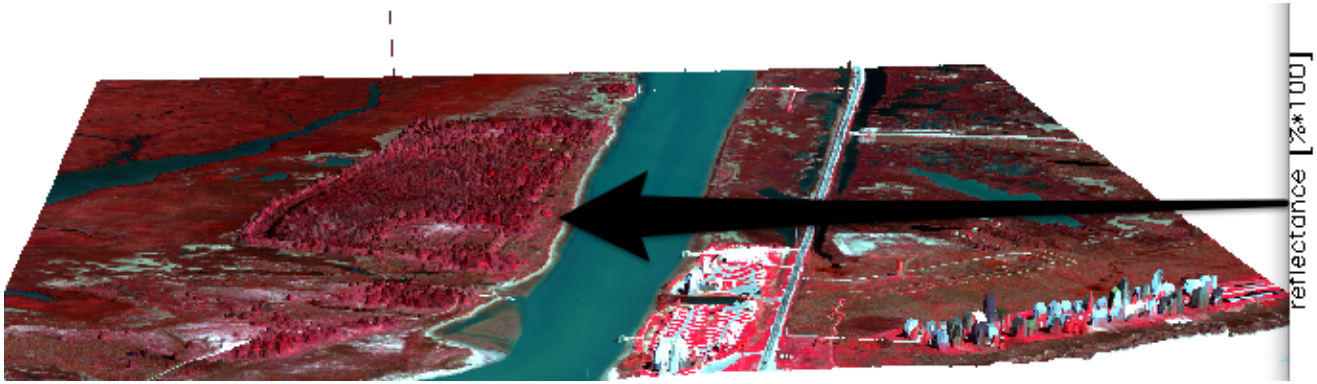


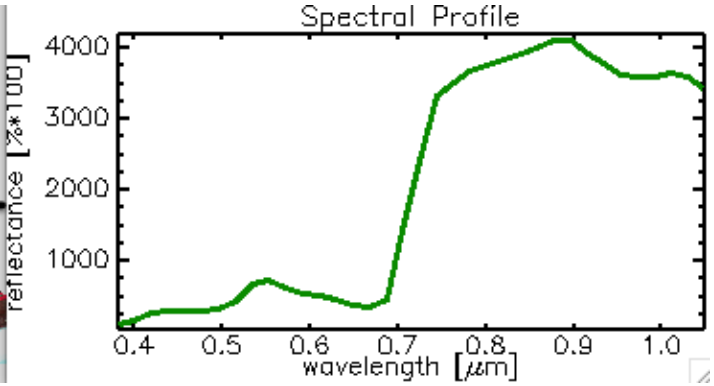
LiDAR DSM
1.0m GSD
Ellipsoidal Height



CASI-1500
1.0m GSD
36 spectral bands

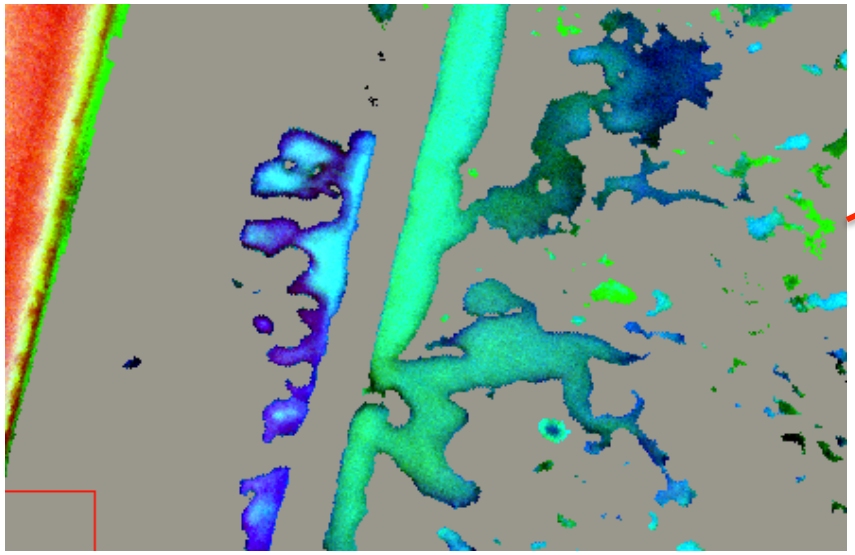
Imagery courtesy of JABLTCX, 2010





LiDAR & Spectral combined to separate domains
Example of CASI-1500 & Terrestrial LiDAR

Removal of ground above water via threshold values in LiDAR & Spectral ratios to allow for better discrimination in the H2O domain of the image.

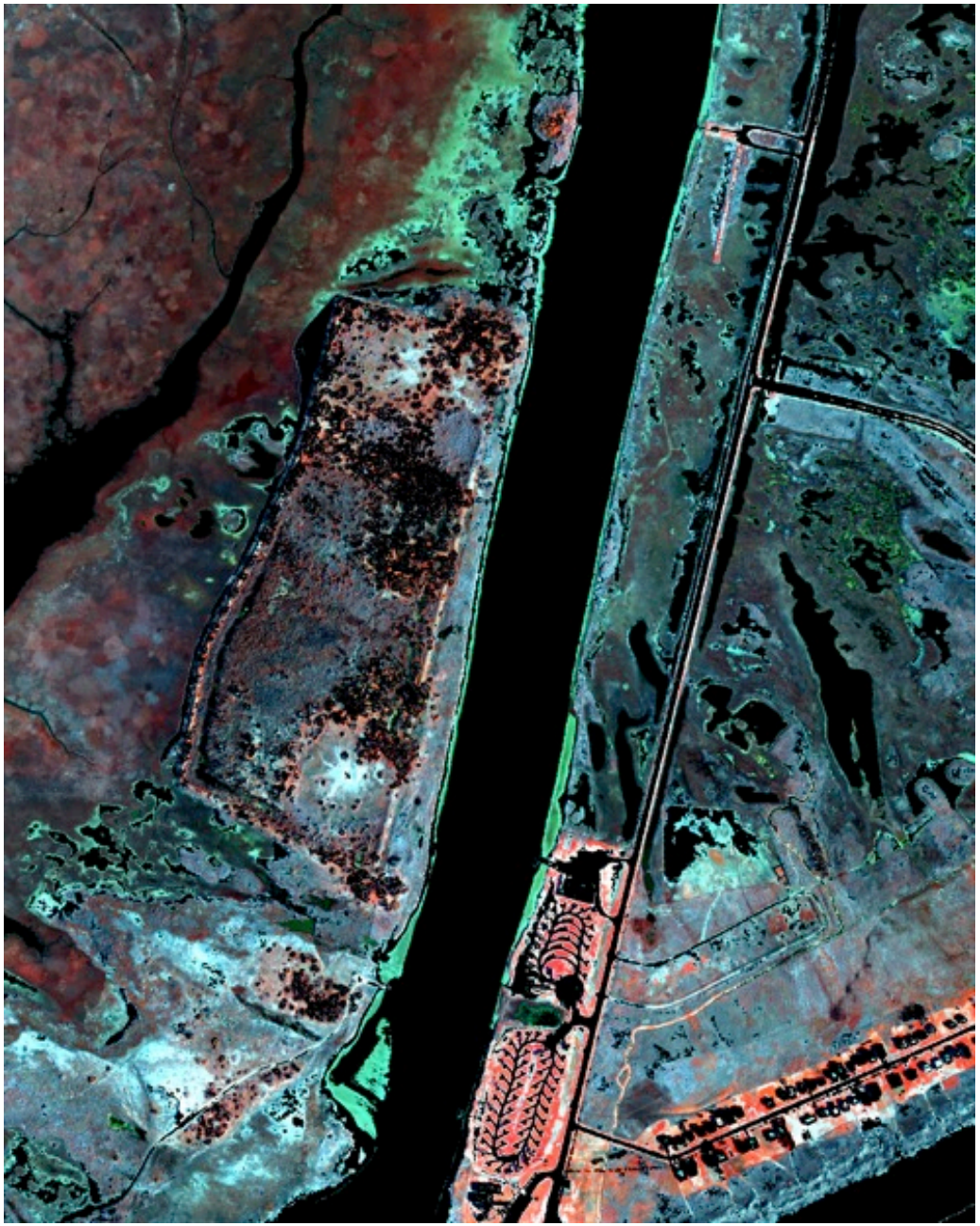


MNF bands 1, 2, 3 highlighting differences in water bodies in image

Imagery courtesy of JABLTCX, 2010

LiDAR & Spectral combined to separate domains
Example of CASI-1500 & Terrestrial LiDAR

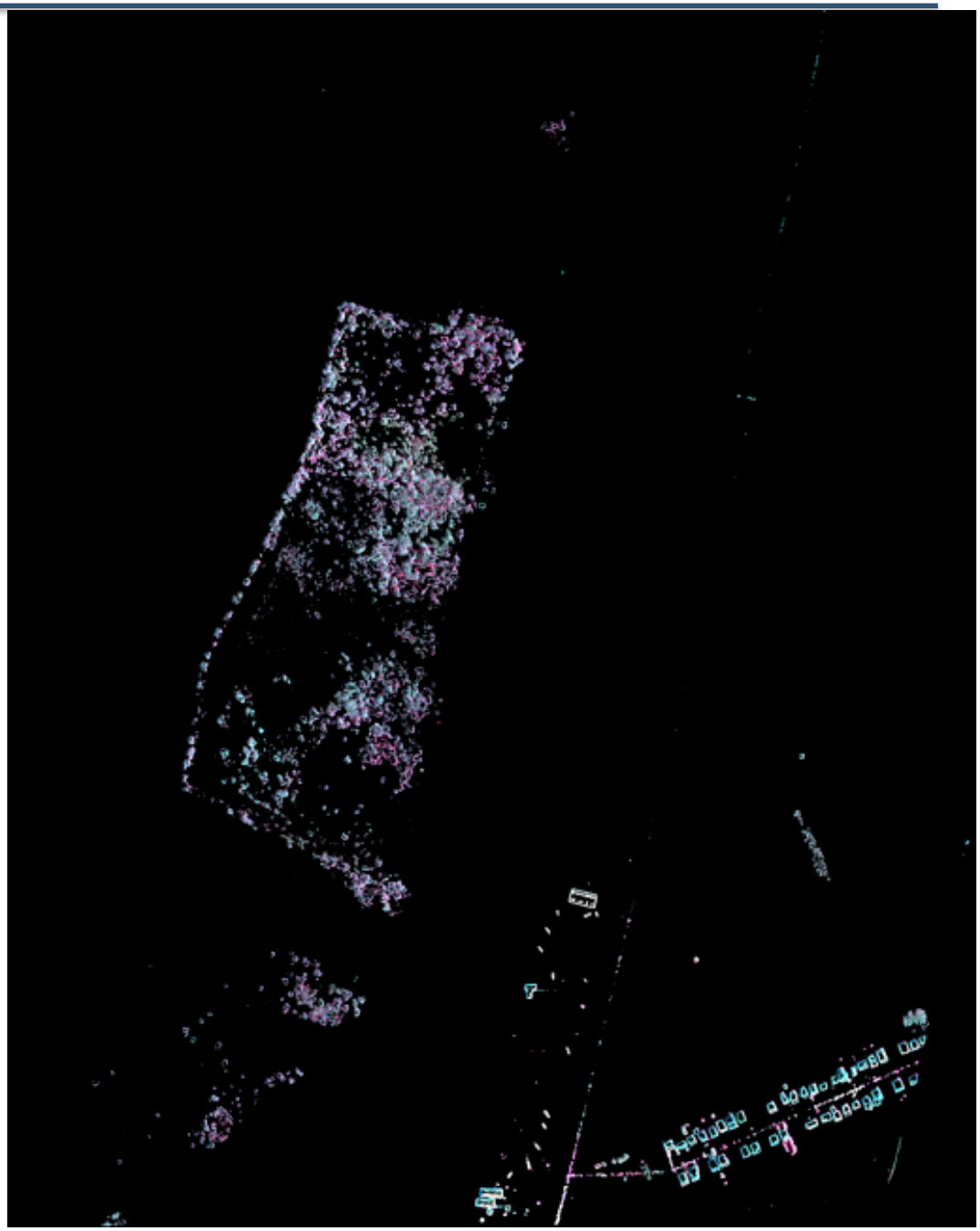
Removal of water & taller objects (trees &buildings) via threshold values in LiDAR & Spectral ratios to allow for better image depth of the vegetation domain for analysis.



Imagery courtesy of JABLTCX, 2010

LiDAR & Spectral combined to separate domains
Example of CASI-1500 & Terrestrial LiDAR

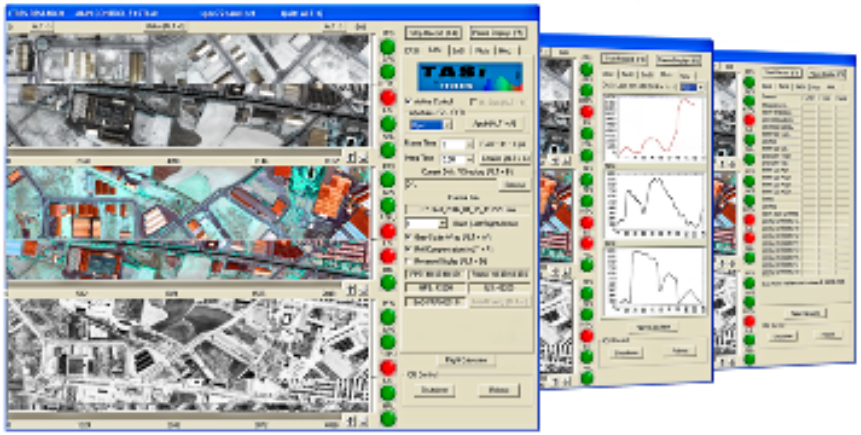
Separation of trees & taller structures allows for reduction of class confusion between spectrally similar features such as lawn grass & some types of deciduous tree.



Imagery courtesy of JABLTCX, 2010

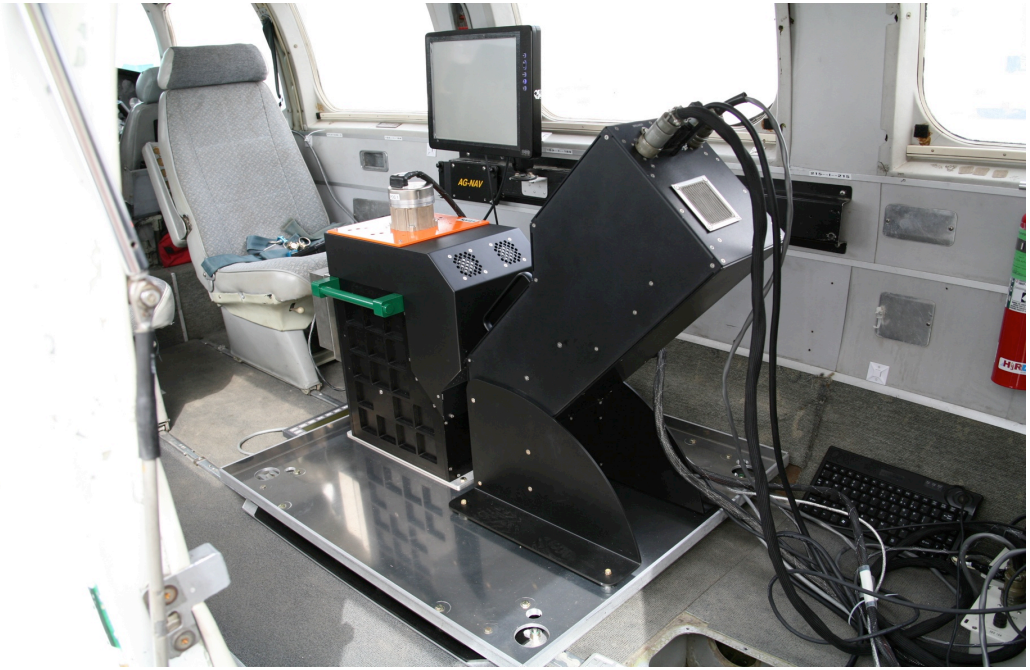
MuSIC SYSTEM

Real-Time Image Displays (left) and Signal Plots:
(TOP TO BOTTOM) CASI, TASI, SASI.

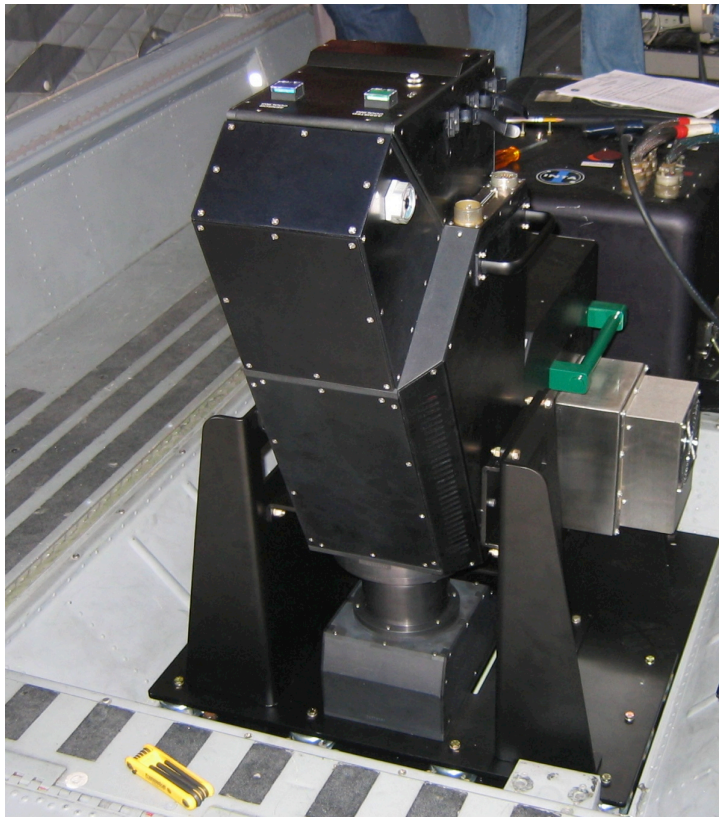


ITRES MuSIC System Showing Four Imager Simultaneous Operation & Control
Dataset simulation on single display monitor

Multiple Instrument Deployments- example installs 2/2

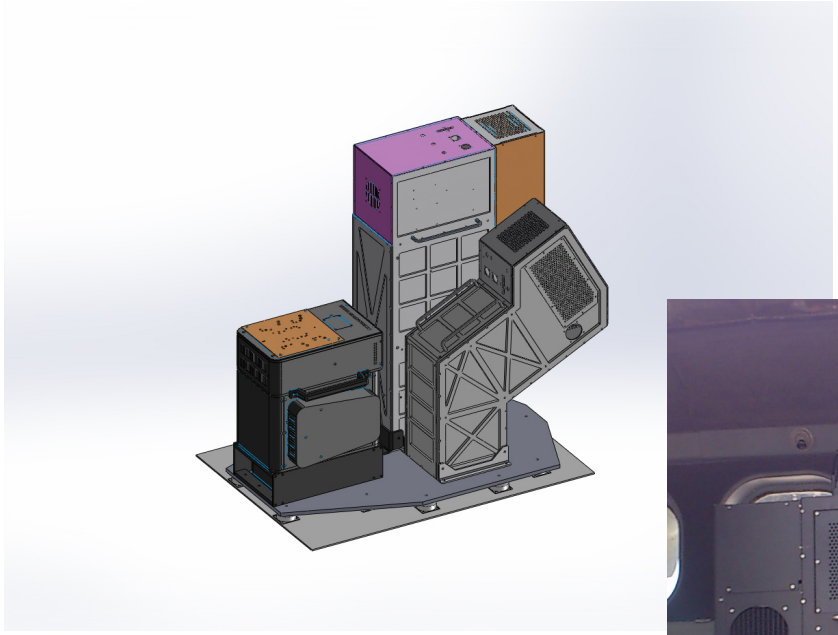


CASI-1500 & MASI 600 Installation – Piper Navajo 2009



SASI600 co-mounted with CASI1500
CASA-212 – Madrid, Spain 2009

Triple System Installation – Chile 2013
CASI1500H, SASI-600, TASI-600



Pre-deployment outlay using inputs from platform provider – ensures optimal configuration of instruments using 3D software (solidworks)

Mounted triple system on client Twin Otter

Monitor configuration (1 per system) – note this installation did not use MuSIC software

The systems were shipped to Chile for installation on a service provider's Twin Otter.

Field installation lasted 1 day, with a calibration flight the following day for post-shipping tests & bundle adjustment.

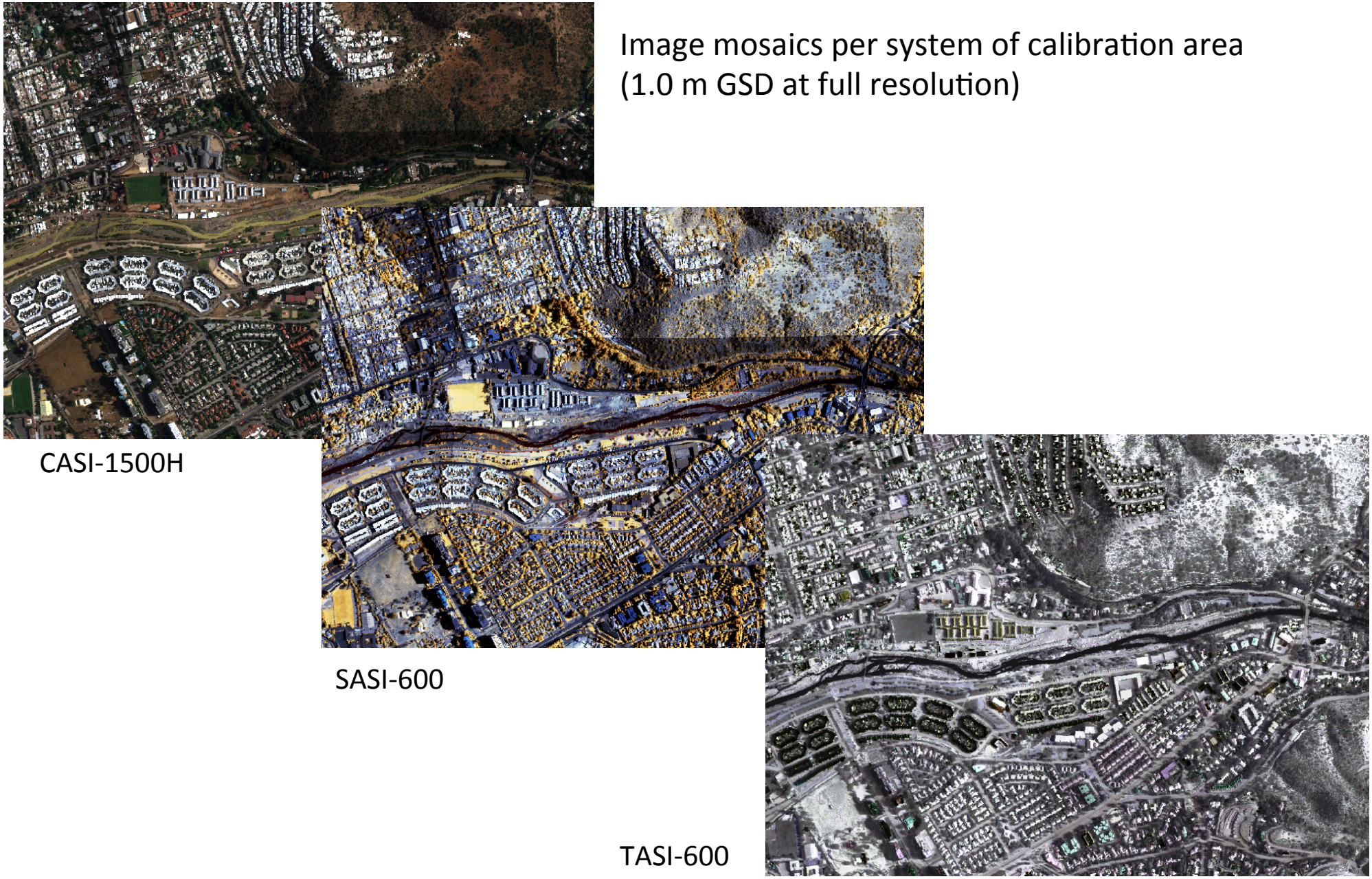
Instrument co-registration after bundle adjustment within +/-1 pixel between independent systems using a common INS source.

Project data acquired at 4m pixel GSD.

Bundle Adjustment acquired at 1.0m GSD

Flight plan of Calibration Site

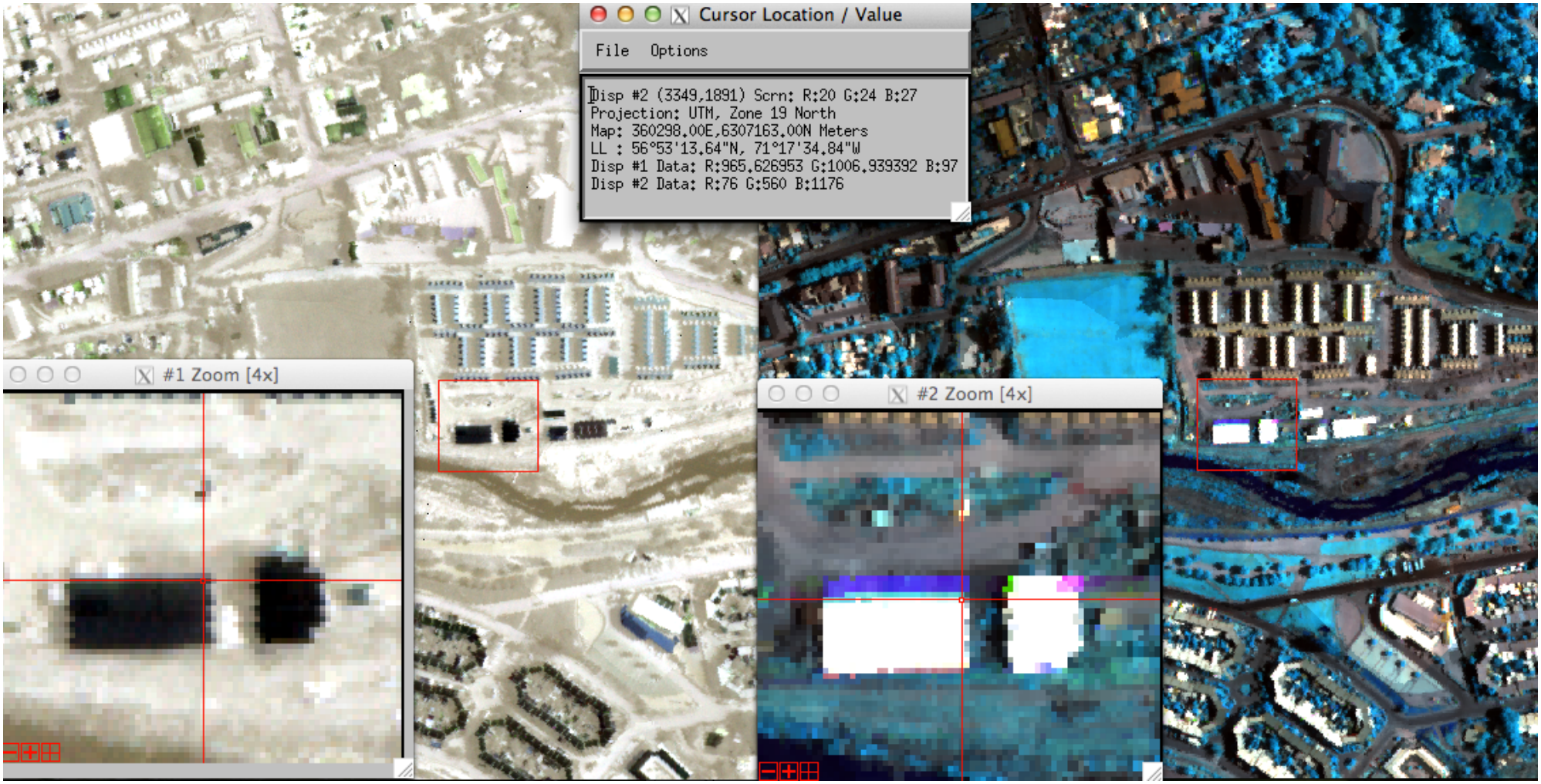
Image mosaics per system of calibration area
(1.0 m GSD at full resolution)



CASI-1500H

SASI-600

TASI-600

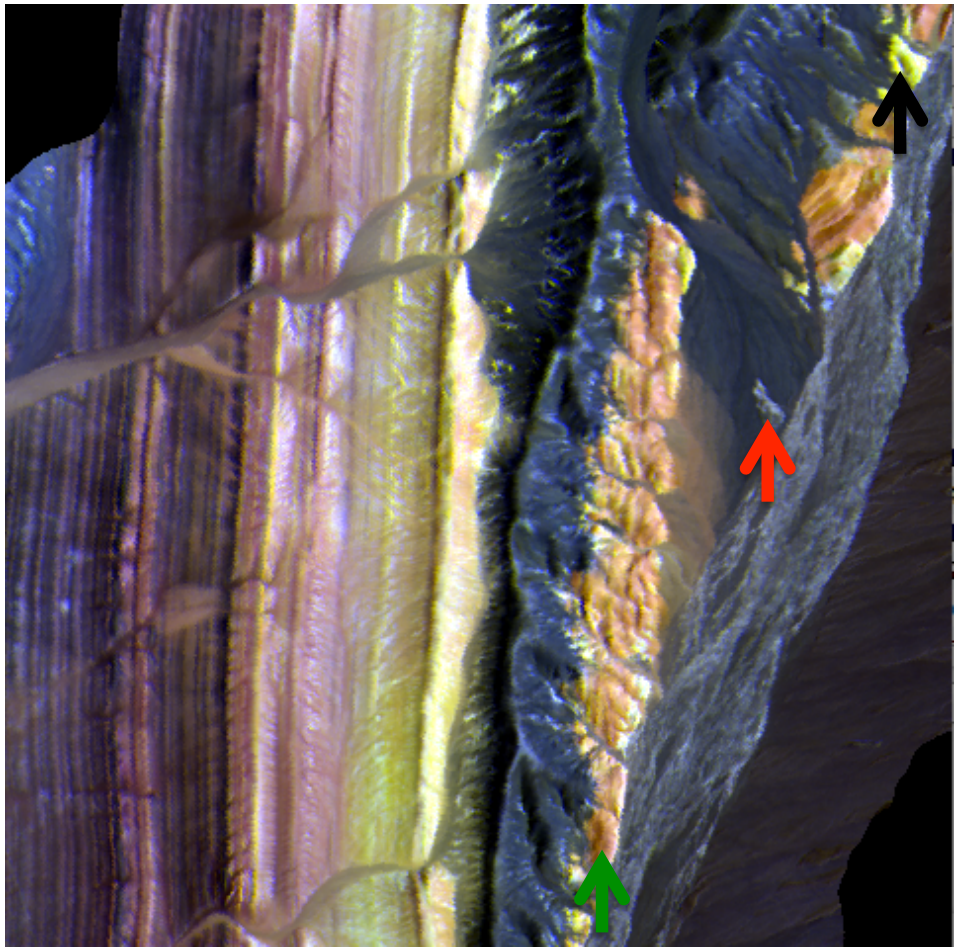


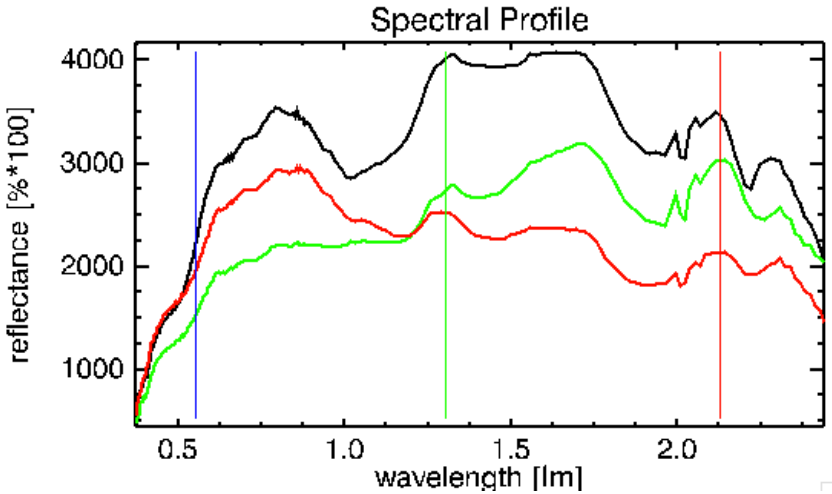
TASI-600

SASI-600

Example of coregistered Data (1.0m GSD) – Lo Barenecha, Chile

Examples of coregistered Data (4.0m GSD) – Chile 2013
CASI-1500H & SASI-600 data are fused into 1 file (0.370 – 2.450 microns)

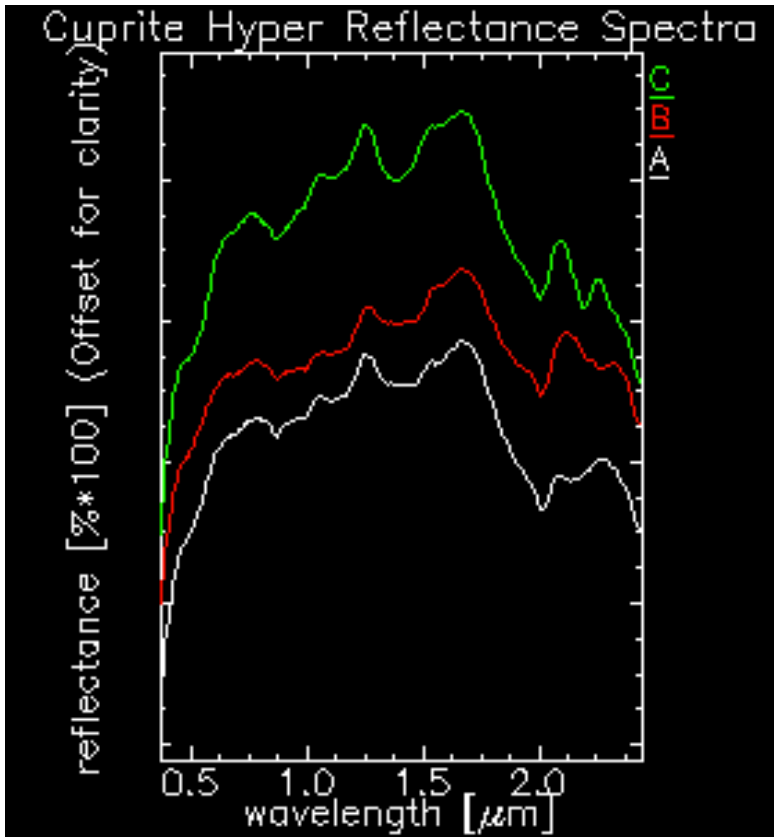


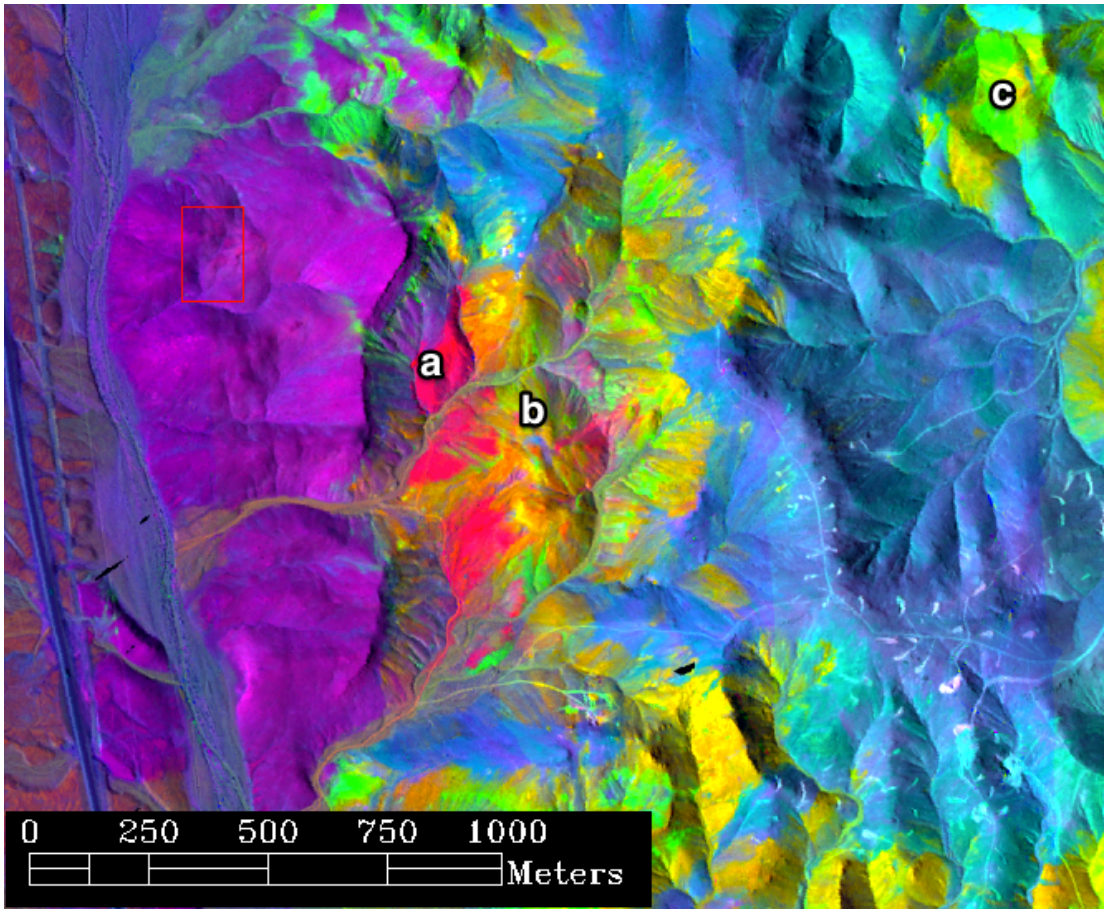


Fused CASI1500H/SASI-600 imagery – Chile 2013
(R: 2.1275 µ , G: 1.3025 µ, B: 0.5473 µ)

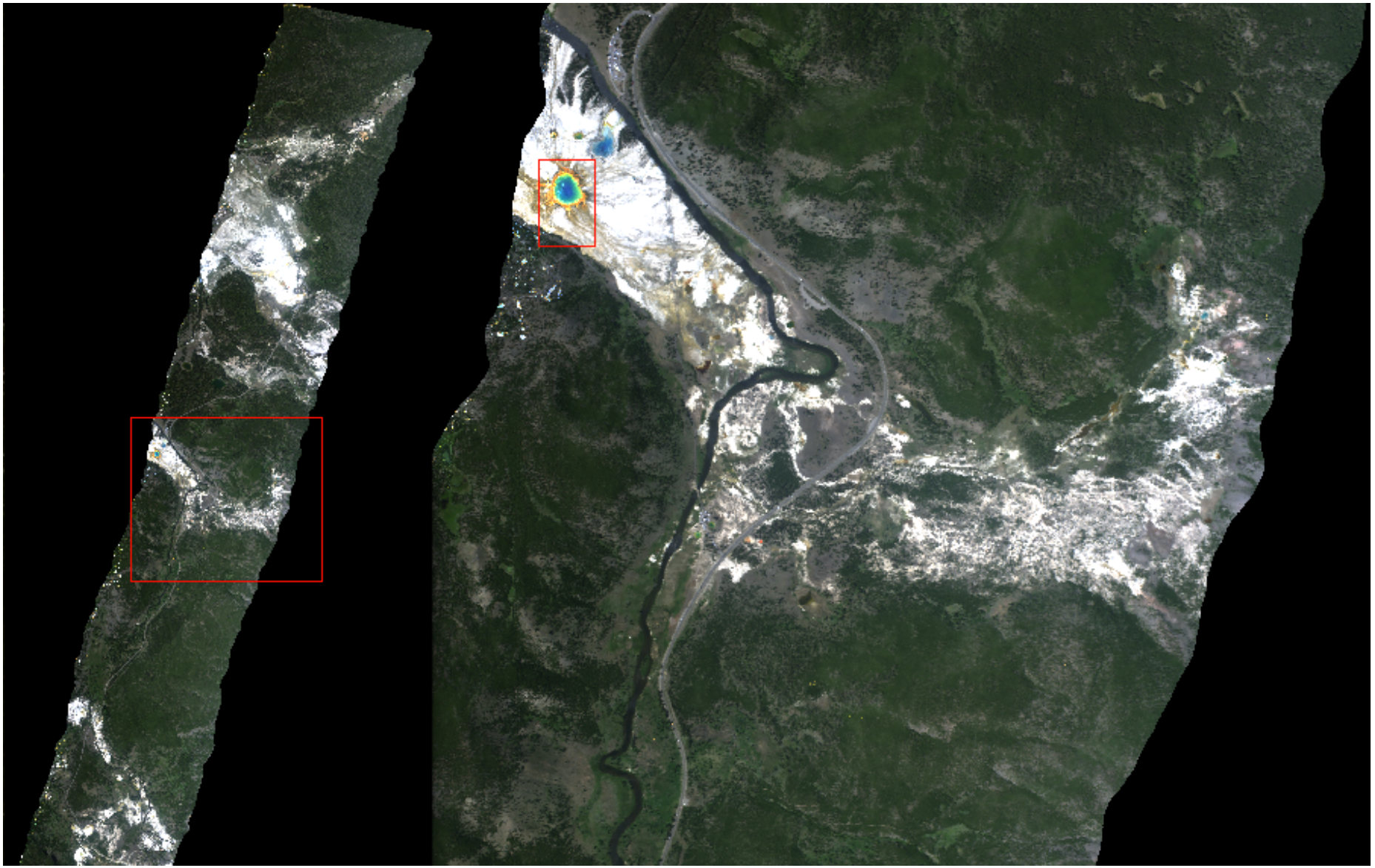
Cuprite, NV (revisit) – June 16, 2013
CASI1500 / SASI600 – 3.0m GSD

Decorrelation stretch (R: 2.295, G:2.0975, B: 2.1725)

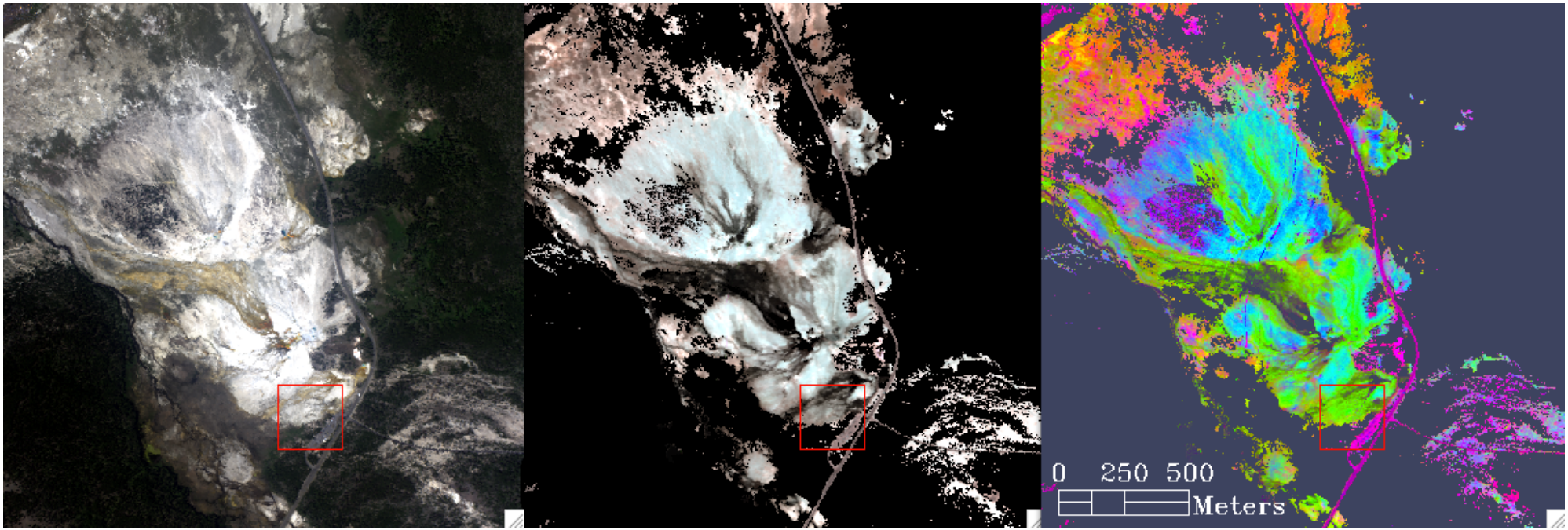




Yellowstone Geysers – VNIR/SWIR (CASI1500/SASI600)
5m GSD – June 28, 2013 – Target of convenience (en route)



Yellowstone Geysers – VNIR/SWIR (CASI1500/SASI600)
5m GSD – June 28, 2013



RGB (dark vegetation)

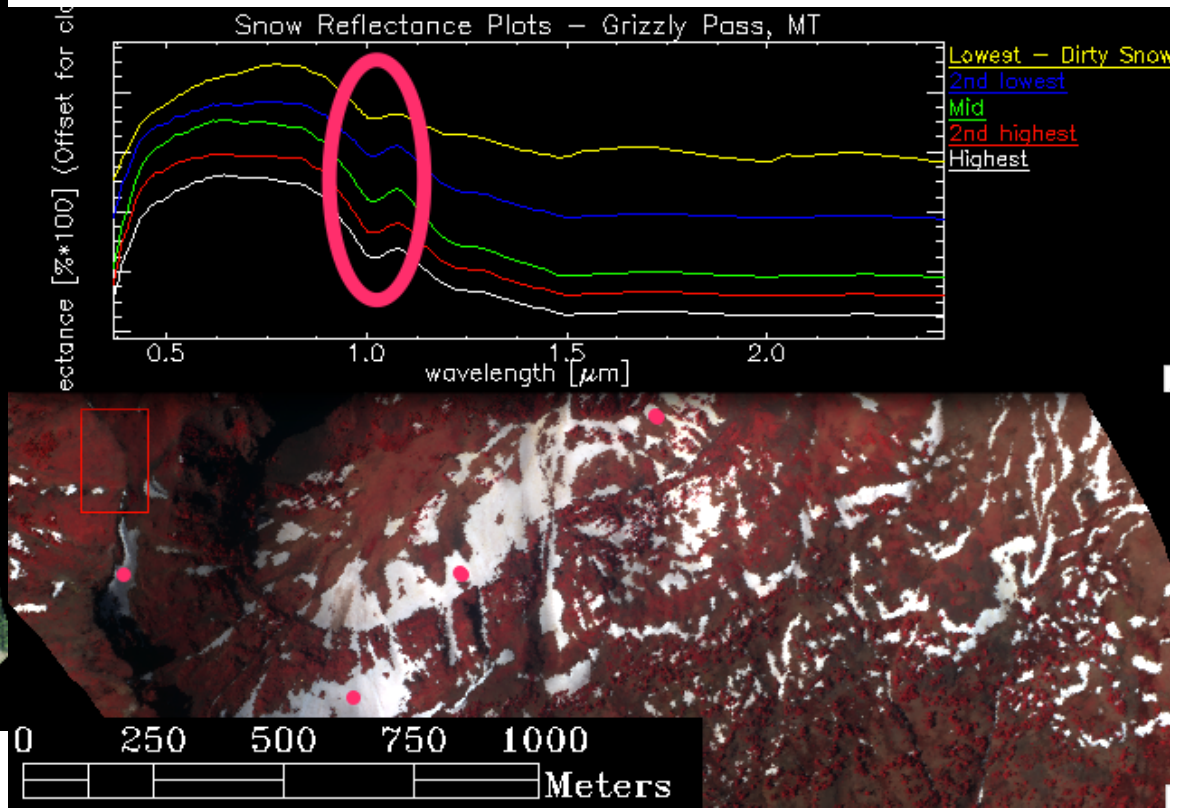
Vegetation masked out
R: 2.2475
G: 2.1425
B: 2.1125

Decorrelation Stretch

Grizzly Pass – MT : Snow sample
June 28, 2013 – late day

Feature @ ~1030nm related to snow conditions
Cold / new vs warmer , melting.

JPL Airborne Snow Observatory uses CASI1500 for Albedo & snow status for H2O budgets in Sierras, CA



Snow Measuring Mission Reaps Big Benefits for California

Monday, 9 December

10:30 a.m.

In 2013, a prototype airborne system that maps the snowpack of major mountain watersheds performed unprecedented mapping of the Tuolumne River Basin and its Hetch Hetchy reservoir in the Sierra Nevada, the primary water supply for 2.6 million San Francisco Bay Area residents. NASA's Airborne Snow Observatory also mapped the Uncompahgre watershed, part of the Upper Colorado River Basin that supplies water to much of the western United States. In this briefing, scientists will discuss how the City of San Francisco's Hetch Hetchy operation used the data to optimize reservoir filling and hydroelectric generation at its O'Shaughnessy Dam this year during California's severe drought. Scientists will also discuss how the technology is improving understanding of snow and its melt, and how it can be applied worldwide.

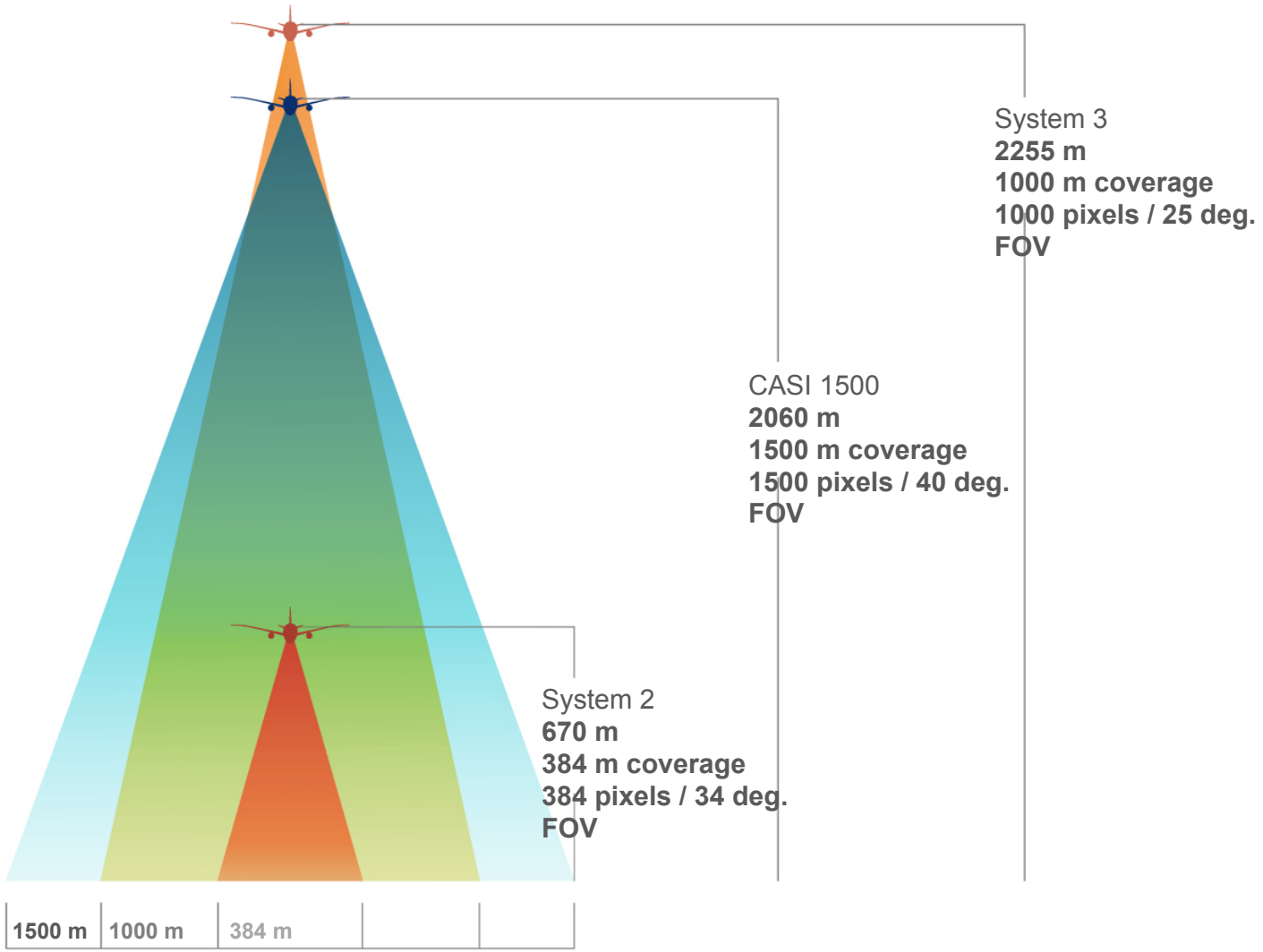
Operational Advantages of ITRES Systems

COVERAGE & FLIGHT EFFICIENCIES

- Larger image swath =
  - Fewer flight lines, lower operating costs
  - Less data to process
  - Less impacted by flight line-to flight line variations, smaller swath = more flight lines, may also have an impact on the quantity of data acquired for time sensitive missions.
  - Systems are designed for tracking any drift / stability for correction to allow for no lost flight lines, so long as flight is conducted under proper environmental constraints

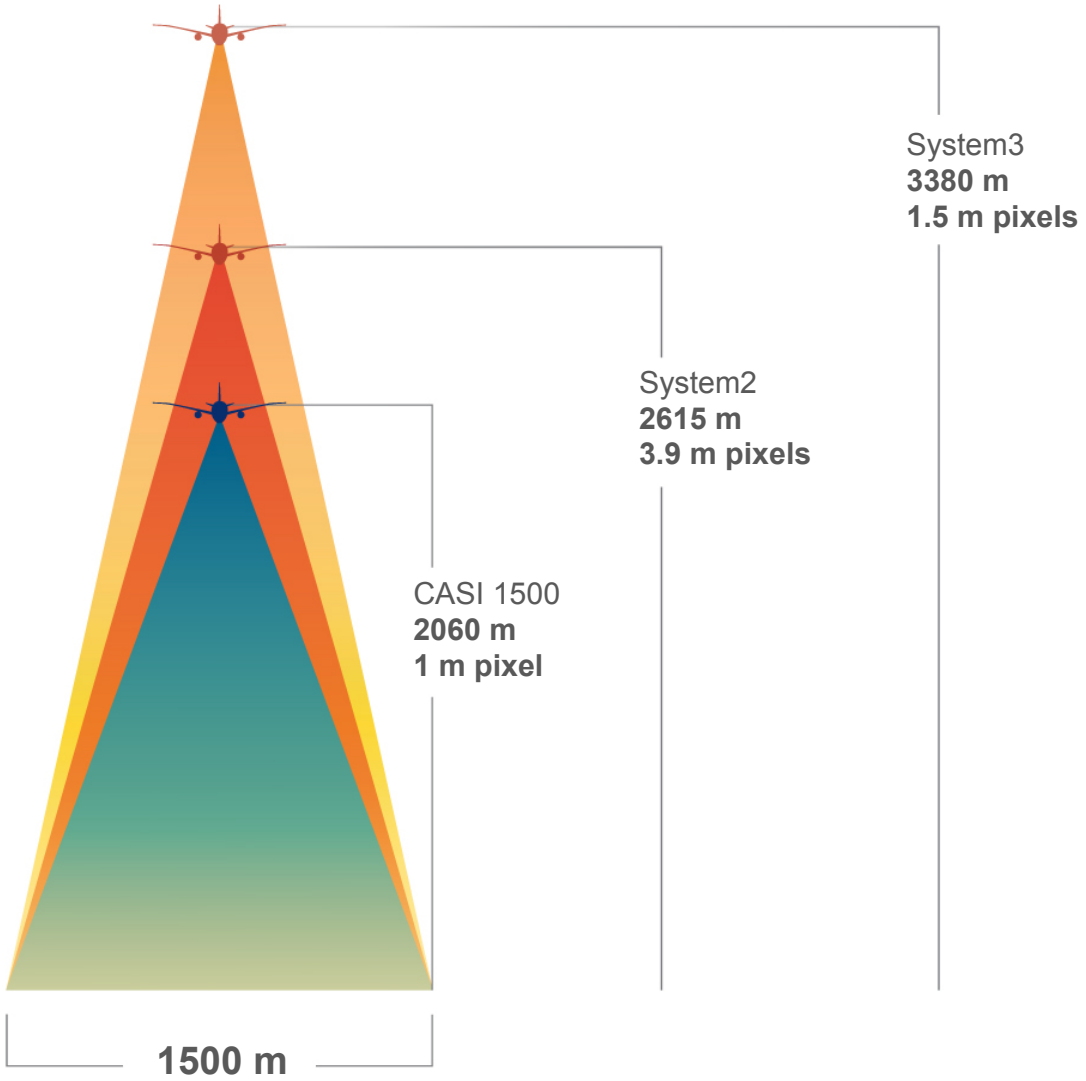
OPERATIONAL CONSIDERATIONS

VNIR Constant Pixel Size (1 m)



OPERATIONAL CONSIDERATIONS

VNIR Constant Coverage (1500 m swath)



Sample Mission Costs

Flight profiles

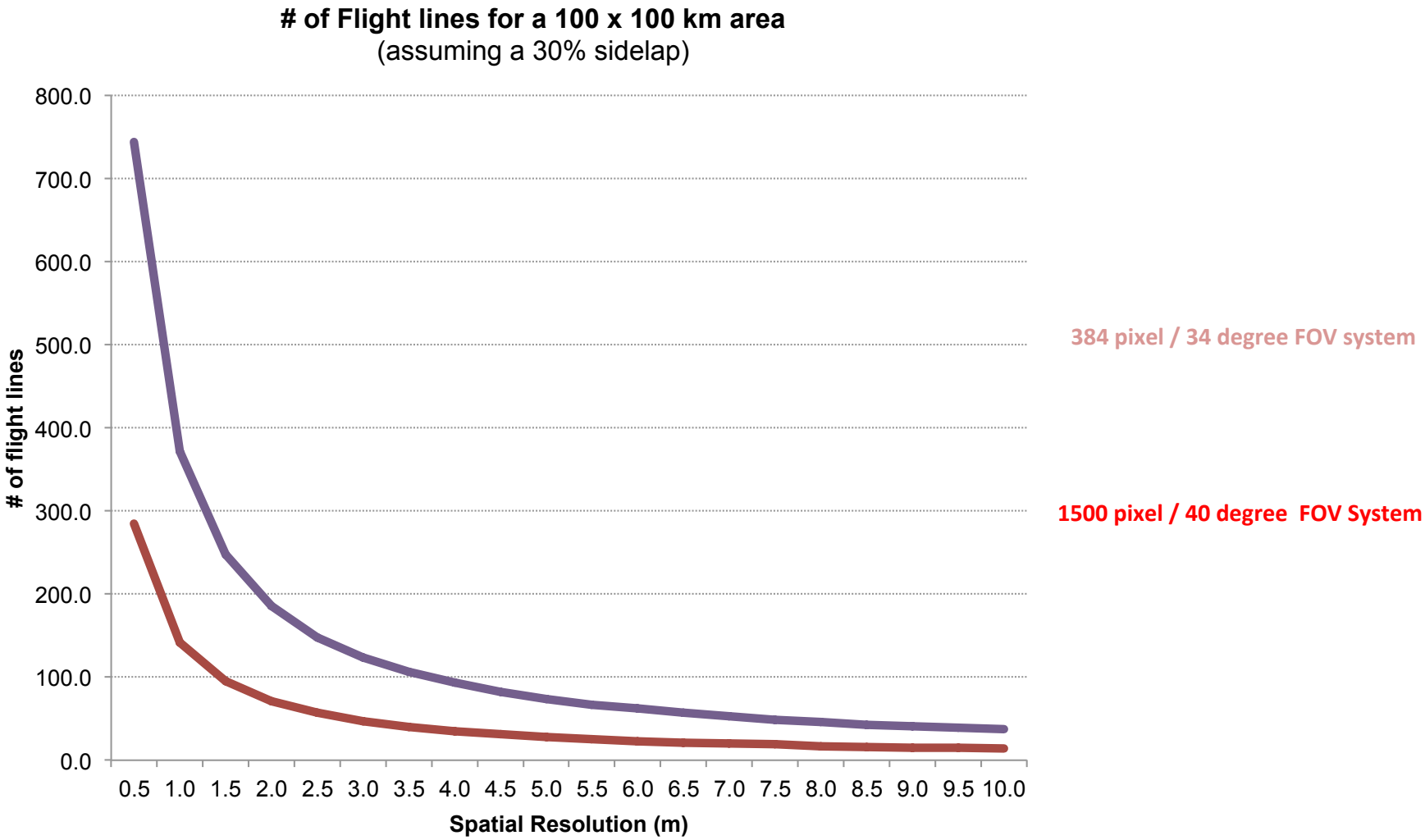
Spatial resolution	1	m
Flight block size	31	km
	33	km
Size of the area	1023	km2
Aircraft speed	150	knots
Turn times	3	mins
Sidelap	30%	
Wx	100%	
Aircraft hrly	1400	$/hr

Aircraft operating costs for the smaller system are over three (3) times higher than with the CASI-1500. Daily operating costs are not included in this comparison.

	swath @ 1 m	FOV	# flight lines	Flight hours	Flight costs	cost factor
CASI1500	**1500**	**40**	**32**	**6**	**$8,400**	**1.0**
System 1	**1000**	**25**	**48**	**9**	**$12,600**	**1.5**
System 2	**384**	**34**	**125**	**22**	**$30,800**	**3.7**

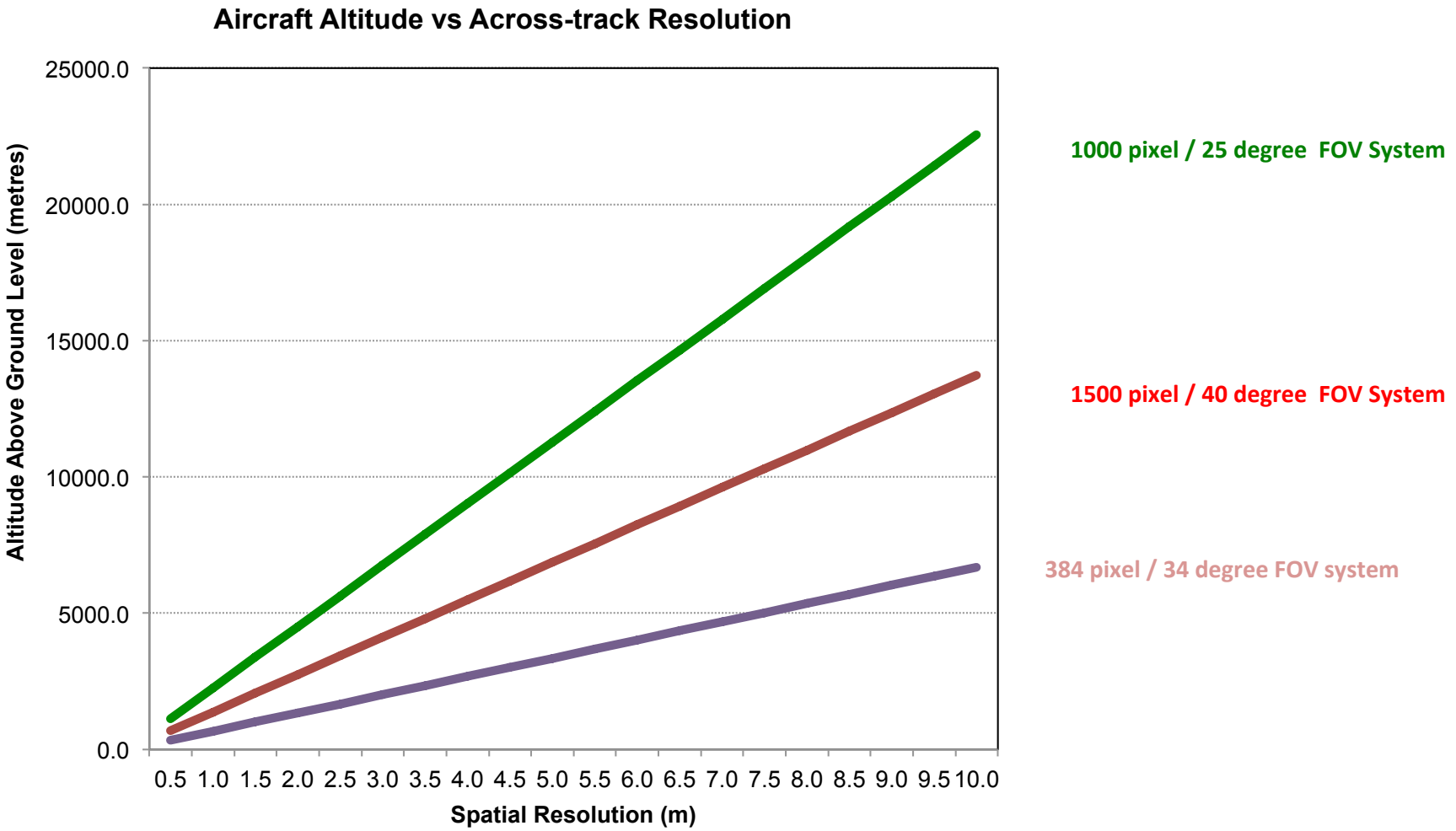
Costs are relative – not meant to represent actual values

OPERATIONAL CONSIDERATIONS



System 2 requires more flight lines to cover the same area.
More flight lines also means more data to process!

OPERATIONAL CONSIDERATIONS



System 3, with its narrow FOV (25 degrees), will need to fly higher to achieve the same spatial resolution | problematic in high relief environments

TECHNICAL PERFORMANCE | FEATURES

	MULTISENSOR CONTROL	PRECISION IMU/GPS	INFLIGHT PROCESSING CAPABILITY	SENSOR CALIBRATION SYSTEM (optional)	LIDAR DATA INTEGRATION & FUSION	SOFTWARE & WORKFLOW
ITRES	YES Multiple systems have already been delivered worldwide	YES ITRES systems have been operated with a variety of INS / IMU Packages	YES The ability to perform system health monitoring, radiometric corrections and geometric corrections in-the-air	YES Complete high precision calibration system for VNIR & broadband imagers NIST traceable standards (integrating sphere, black body sources) and sensor calibration software will be provided.	YES Employs a high precision IMU/GPS system, which is essential for fusion of lidar data. Software incorporates surface or elevation models to produce an orthocorrected image product. Numerous CASI-1500 are currently integrated with terrestrial and bathymetric lidar systems.	YES Robust photogrammetric bundle adjustment solution and efficient workflow

Thanks for your attention / Спасибо за внимание

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