Ten years of remote sensing advancement & the research outcome of the CRC-AGIP Lab

Dr. Yun Zhang

Canada Research Chair Laboratory in Advanced Geomatics Image Processing (CRC-AGIP Lab)

Department of Geodesy and Geomatics Engineering
University of New Brunswick (UNB)

YunZhang@UNB.ca

CRC-AGIP

Content:

1. Remote Sensing Advancement

2. AGIP Lab Technologies

   a. Image Fusion
   b. Adjustable SAR-MS Fusion
   c. Moving Target Detection
   d. Image Matching
   e. Image Segmentation
   f. InSAR DEM Reconstruction
   g. Online 3D
   h. Generic RPC sensor model refinement

1. Remote Sensing Advancement

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Optical earth observation satellites

Optical satellite	Spatial resolution (m) (# of bands)				Swath (km)	Year of launch
	Pan*	MS*				
		VNIR*	SWIR*	TIR*		
Landsat 7	15	30 (4)	30 (2)	60 (1)	185	1999
CBERS 1 and 2	20	20 (4)			113	1999, 2003
Ikonos 2	1	4 (4)			11	1999
Terra/ASTER		15 (3)	30 (6)	90 (5)	60	1999
KOMPSAT-1	6.6				17	1999
EROS A1	1.9				14	2000
Quickbird 2	0.61	2.44 (4)			16	2001
SPOT 5	2.5–5	10 (3)	20 (1)		60	2002
IRS-P6 / ResourceSat-1	6	6 (3), 23.5 (3)			24, 70, 140	2003
DMC-AlSat1		32 (3)			600	2002
DMC-BILSAT-1	12	28 (4)			25, 55	2003
DMC-NigeriaSat 1		32 (3)			600	2003
UK-DMC		32 (3)			600	2003
OrbView-3	1	4 (4)			8	2003
DMC-Beijing-1	4	32 (3)			24, 600	2005
TopSat	2.5	5 (3)			25	2005
KOMPSAT-2	1	4 (4)			15	2006
IRS-P5/CartoSat-1	2.5				30	2006
ALOS	2.5	10 (4)			35, 70	2006
Resurs DK-1	1	3 (3)			28.3	2006
WorldView-1	0.5				17.5	2007
RazakSat	2.5	5 (4)			20	2008
RapidEye A–E	6.5	6.5 (5)			78	2008
GeoEye-1	0.41	1.64 (4)			15	2008
EROS B – C	0.7	2.8			16	2009
WorldView-2	0.46	1.84 (8)			16	2009
Plèiades-1 and 2	0.7	2.8 (4)			20	2010, 2011
CBERS 3 and 4	5	20 (4), 40	40 (2)	80	60, 120	2009, 2011

[Zhang and Kerle, 2007; Stoney, 2008]

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Airborne digital cameras/sensors

Brand	Name	Date of update	Weight [kg]	# of lenses	# of CCD[a] chips	# of pixels across track	# of pixels along track	Spectral bands[b]
Applanix	DSS 422	2007	7kg	1	1	5,436	4,092	R,G,B or NIR,R,G
	DSS 439	2007	24kg	1	1	7,216	5,412	R,G,B or NIR,R,G
DIMAC	DiMAC 2.0	2006	100kg	2 to 4	2 to 4	10,500	7,200	R,G,B, NIR
IGI	DigiCAM-H/39	2007	1.8kg	1	1	7,216 or 5,412	5,412 or 7,216	R,G,B, or NIR
	DigiCAM-H/70	2008	3.6kg	2	2	13,500 or 10,000	10,000 or 13,500	R,G,B, or NIR
Intergraph	DMC	2003	88kg	8	8	13,824	7,680	Pan, R,G,B, NIR
Jena	JAS 150s	2007	65kg	1	9	12,000/line	Unlimited	Pan, R,G,B, NIR
Leica	ADS40	2006	61-65kg	1	8 or 12	12,000/line	Unlimited	Pan, R,G,B, NIR
RolleiMetric	AIC x1	2004	1.4kg	1	1	5,440 or 4,080	7,228 or 5,428	RGB or IR
	AIC x2	2007	12kg no lenses	2	2	10,227 or 4,080	13,588 or 5,428	RGB and IR / RGB or IR
	AIC x4	2008	38kg	4	4	10,227 or 7,670	13,588 or 10,204	RGB and IR / RGB or IR
Vexcel	UltraCam X	2006	54kg	8	13	14,430 (pan)	9,420 (pan)	Pan, R, G, B, NIR
Wehrli	3-OC-1	2006	25kg	3	3	8,002/line	Unlimited	R,G,B

[GIM International, 2008]

Radar earth observation satellites

Satellite	Sensor	Year of launch	Band	Wavelength (cm)	Polarization	Resolution range (m)	Resolution azim. (m)	Scene width (km)
ERS-1	AMI	1991	C	5.7	VV	26	28	100
JERS-1	SAR	1992	L	23.5	HH	18	18	75
ERS-2	AMI	1995	C	5.7	VV	26	28	100
Radarsat-1	SAR	1995	C	5.7	HH	10 – 100	9 – 100	45 – 500
Envisat	ASAR	2002	C	5.7	HH/VV	30 – 150	30 – 150	56 – 400
Alos	PALSAR	2006	L	23.5	All[a]	7 – 100	7 – 100	40 – 350
Radarsat-2	SAR	2007	C	5.7	All	3 – 100	3 – 100	50 – 500
TerraSAR-X	TSX-1	2007	X	3	All	1 – 16	1 – 16	5 – 100
Cosmo/SkyMed 1, 2, 3, 4	SAR-2000	2007, 2007, 2008, 2010	X	3	HH/VV	1 – 100	1 – 100	10 – 200
TerraSAR-L	SAR	2008 (plan)	L	23.5	All	5 – 50	5 – 50	20 - 200
TanDEM-X[b]	TSX-SAR	2010	X	3	HH/VV	1.7-3.5	18.5	100

[Zhang and Kerle, 2007; Düring et al., 2008]

Airborne LiDAR sensors

Brand	Name	Date of update	Weight [kg]	Wave-length [nm]	Elevation precision at 1km [cm]	Overall planimetric precision [cm]	Max. # of points/m^2
Airborne Hydro-graphy AB	Dragon Eye	2008	25kg	1,000	GPS/INS Pending	GPS/INS Pending	50 @ 150m, 300kHz, 20m/s
	Hawk Eye II	2006/ 2008	95kg	532 /1,064	Bathy<50 Topo<30	Bathy<5m Topo<1m	Bathy 1/m^2, topo 10/m^2
Leica Geo-systems	ALS60	2008	38.5kg	1,064	14 - 16	20 - 26	91 @ 150km/h, 200m, 15
Optech	ALTM Gemini	2006	23.4kg	1,064	< 10	1/11000	
	ALTM Orion	2008	27kg	1,064	< 10	1/5500	
RIEGL	RIEGL VQ-480	2008	11.5kg	1,550	< 15	< 10	50 @ 50km/h, 150m, 60
	RIEGL LMS-Q560	2008	16kg	1,550	< 15	< 10	4 @ 200km/h, 500m, 60 66 @ 50km/h, 150m, 60
	RIEGL LMS-Q680	2009	17.5kg	1,550	< 15	< 10	5 @ 200km/h, 500m, 60
TopoSys	Harrier 56/G4	2008	42kg	1,550	< 15	< 10	4 @ 200km/h, 500 m, 60 66 @ 50km/h, 150m, 60
	Harrier 68/G1	2009	N/A	1,550	< 15	< 10	5 @ 200km/h, 500m, 60
	Falcon II	2000 / 2008	41kg	1,560	< 15	< 10	12 @ 200km/h, 500m, 14.3

[GIM International, 2009]

2. AGIP Lab Technologies

2.a. Image Fusion

Popular IHS Technique for IKONOS Fusion

IKONOS 4m Multispectral

+

IKONOS 1m Panchromatic

=

IHS Fused 1m IKONOS Image

- **Significant Colour Distortion**

QuickBird 60-cm natural color image (www.DigitalGlobe.com)
Brussels, Belgium, June 2, 2002

IKONOS UNB Fusion (UNB PanSharp)

IKONOS 4m Multispectral

+

IKONOS 1m Panchromatic

=

New 1 mIKONOS Fusion Image

- **Minimized Colour Distortion**

Landsat 7 ETM+ Image Fusion (Bands 1, 2 and 3)

30m Multispectral

15m Panchromatic

15m UNB Fusion Result

Landsat 7 ETM+ Image Fusion (Bands 2, 3 and 4)

30m Multispectral

15m Panchromatic

15m UNB Fusion Result


QuickBird 2.8m MS
Courtesy Digital Globe


QuickBird 0.7m Pan
Courtesy Digital Globe


QuickBird 0.7m MS, UNB Fusion
Courtesy Digital Globe

QuickBird 0.7m MS, UNB Fusion & Color Enhancement

Courtesy Digital Globe

QuickBird 2.4m MS

Courtesy Digital Globe

QuickBird 0.6m MS, UNB Fusion

Courtesy Digital Globe


GeoEye-1, MS 1, 2 and 3, 2m


GeoEye-1, Pan, 0.5m


GeoEye-1, UNB-PanSharp, 0.5m


GeoEye-1, GeoEye-Pansharp, 0.5m


GeoEye-1, MS 1, 2 and 3, 2m


GeoEye-1, Pan, 0.5m


GeoEye-1, UNB-PanSharp, 0.5m

GeoEye-1, GeoEye-Pansharp, 0.5m


GeoEye-1, MS 1, 2 and 3, 2m


GeoEye-1, Pan, 0.5m

GeoEye-1, UNB-PanSharp, 0.5m


GeoEye-1, GeoEye-Pansharp, 0.5m

Conclusions

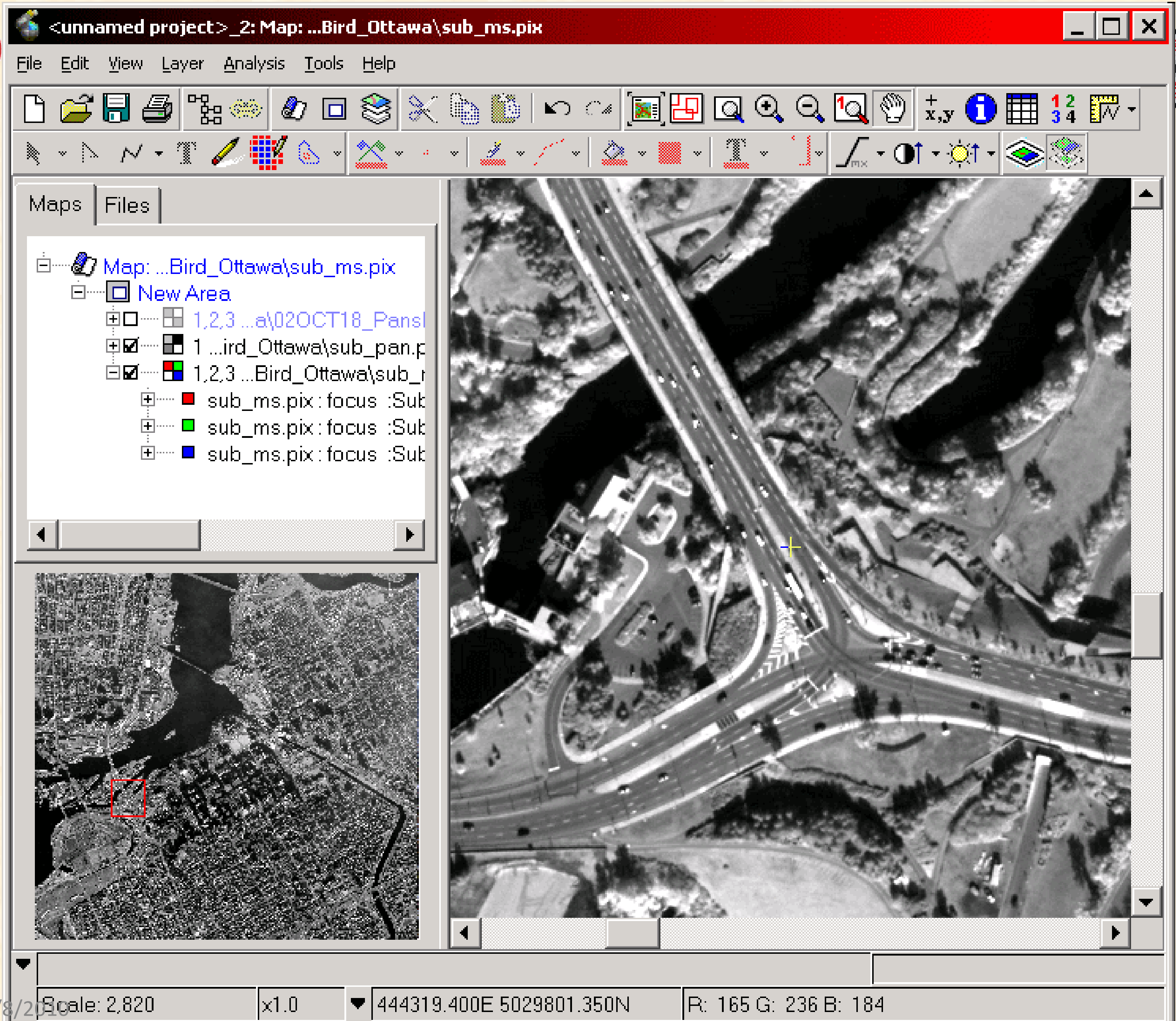
UNB Fusion

— UNB-Pansharp

(1) Fully automated, one step process.

(2) All the fusions have shown a perfect result with:

- **maximum detail increasing,**
- **minimum colour distortion, and**
- **natural colour and feature integration.**



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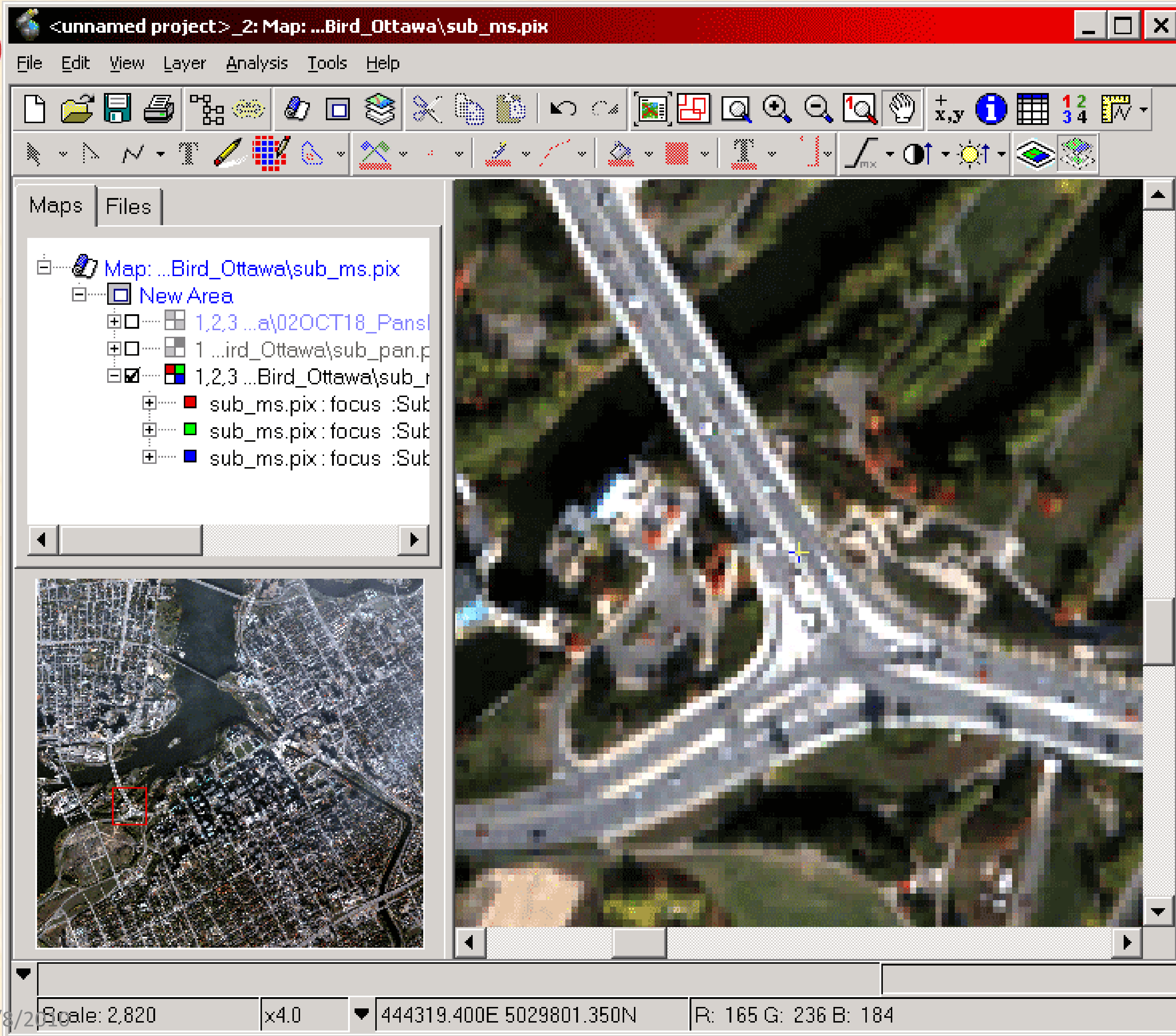
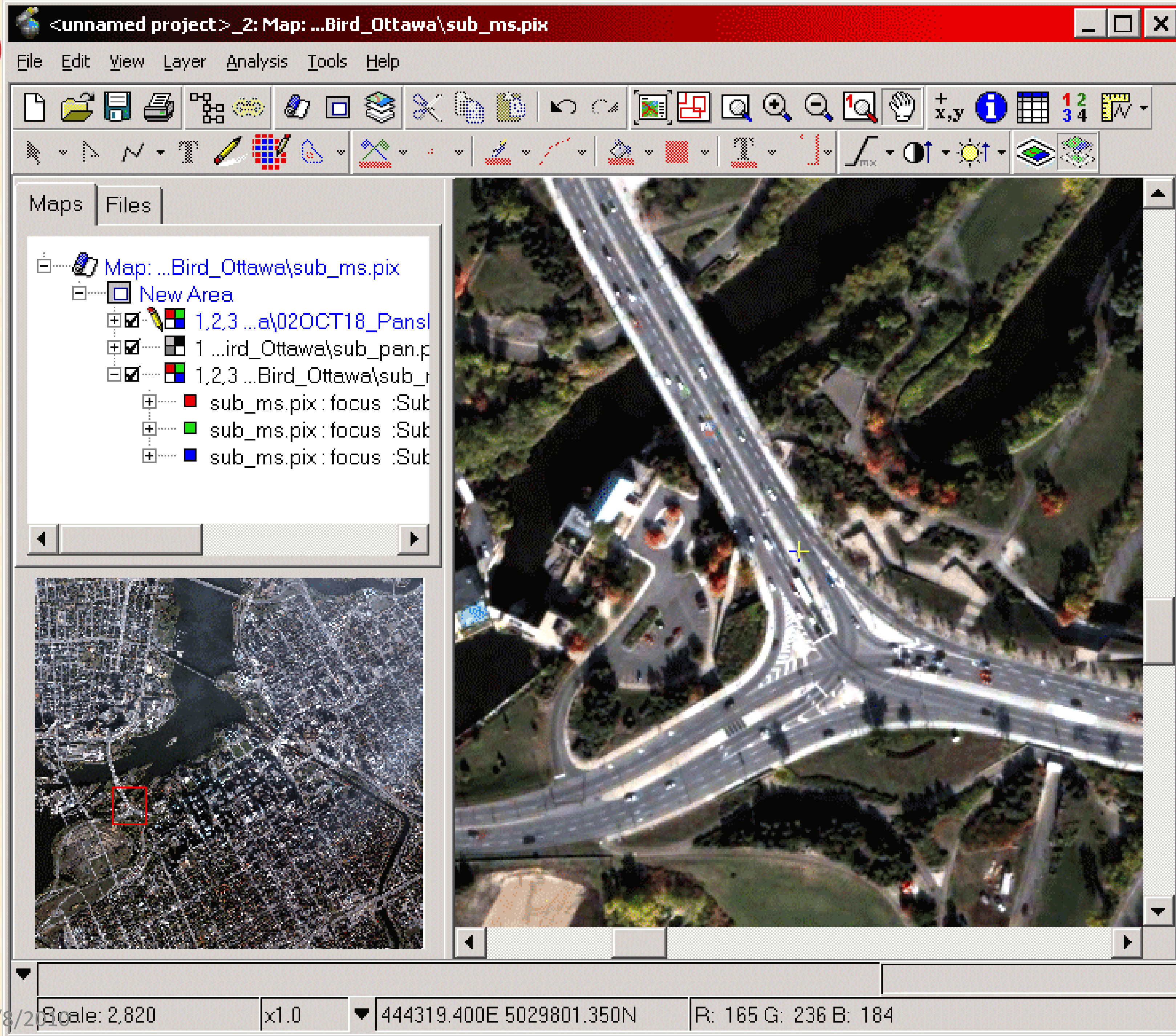
File Edit View Layer Analysis Tools Help
Maps Files
Map: ...Bird_Ottawa\sub_ms.pix
New Area
1,2,3 ...a\02OCT18_Pansl
1 ...ird_Ottawa\sub_pan.p
1,2,3 ...Bird_Ottawa\sub_
sub_ms.pix : focus :Sub
sub_ms.pix : focus :Sub
sub_ms.pix : focus :Sub
Scale: 2,820
x1.0
444319.400E 5029801.350N
R: 165 G: 236 B: 184


<unnamed project>_2: Map: ...Bird_Ottawa\sub_ms.pix
File
Edit
View
Layer
Analysis
Tools
Help
Maps
Files
Map: ...Bird_Ottawa\sub_ms.pix
New Area
1,2,3 ...a\02OCT18_Pansl
1 ...ird_Ottawa\sub_pan.p
1,2,3 ...Bird_Ottawa\sub_r
sub_ms.pix : focus :Sub
sub_ms.pix : focus :Sub
sub_ms.pix : focus :Sub
Scale: 2,820
x4.0
444319.400E 5029801.350N
R: 165 G: 236 B: 184



<unnamed project>_2: Map: ...Bird_Ottawa\sub_ms.pix
File Edit View Layer Analysis Tools Help
Maps Files
Map: ...Bird_Ottawa\sub_ms.pix
New Area
1,2,3 ...a\02OCT18_Pansl
1 ...ird_Ottawa\sub_pan.p
1,2,3 ...Bird_Ottawa\sub_
sub_ms.pix : focus :Sub
sub_ms.pix : focus :Sub
sub_ms.pix : focus :Sub
Scale: 2,820
x1.0
444319.400E 5029801.350N
R: 165 G: 236 B: 184

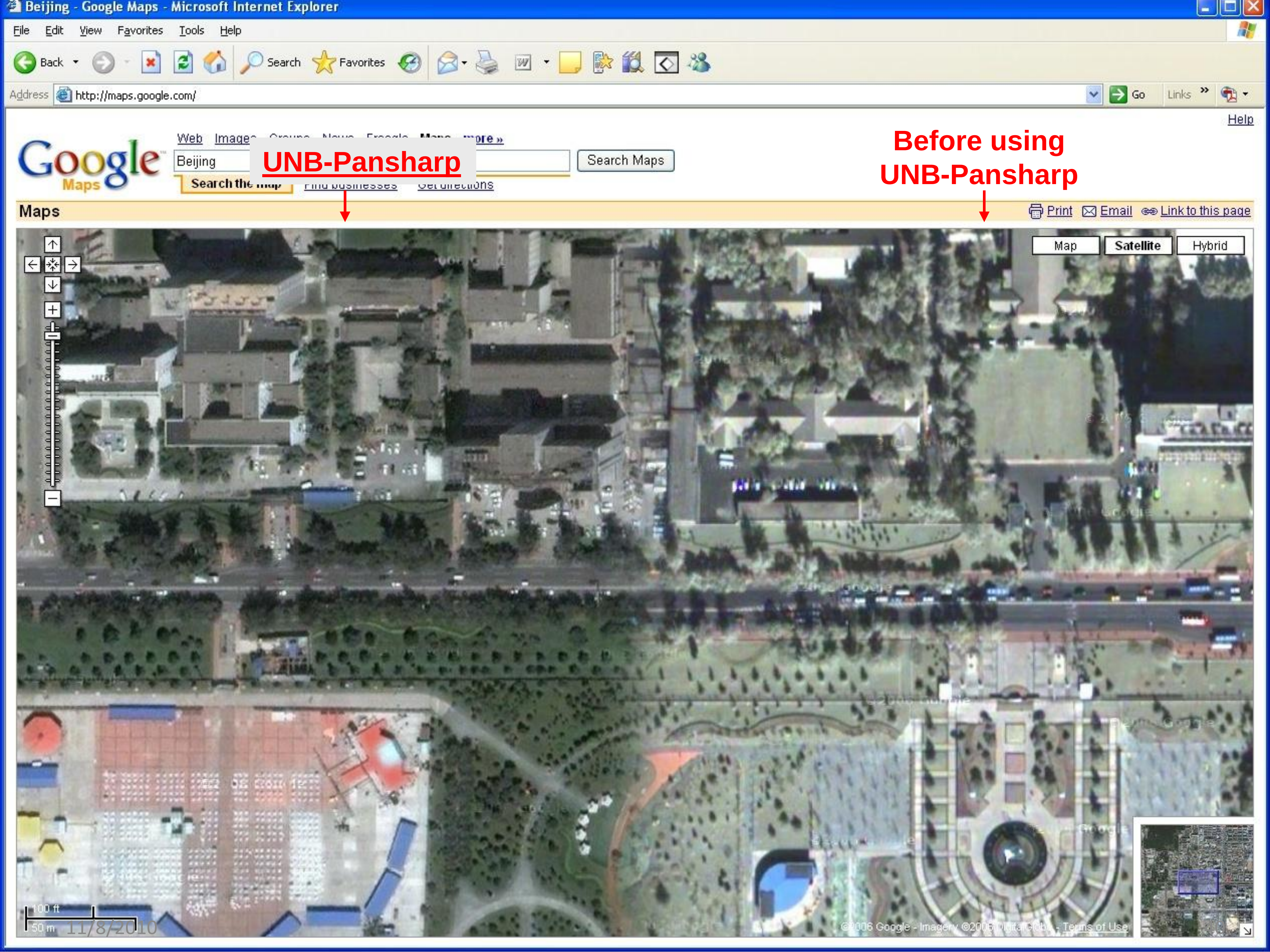
GigitalGlobe's employees waiting for QuickBird, Boulder, CO

Photography: Yun Zhang,

GigitalGlobe's employees thank QuickBird image users, Boulder, CO

Photography: QuickBird satellite, Oct 10, 2003

Dr. Y. Zhang helping DG install UNB-Pansparp



Beijing - Google Maps - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://maps.google.com/
Go Links
Help
Google Maps
Web Images
more »
Beijing
Search Maps
Search the map
Find businesses
Get directions
UNB-Pansharp
Before using UNB-Pansharp
Maps
Print Email Link to this page
Map Satellite Hybrid
100 ft
50 m
11/8/2010
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- **Being used worldwide, including NASA, Google, and US and Canadian national security.**
- **One of 9 Canadian successful research achievements for the "Technology Transfer Works: 100 Cases from Research to Realization", by the Association of University Technology Managers 2006.**
- **Other universities being selected into the 100 Cases include: MIT, Yale, Stanford, Columbia and Brown Universities.**

2.b. Adjustable SAR-MS Fusion

UNB-ASMF

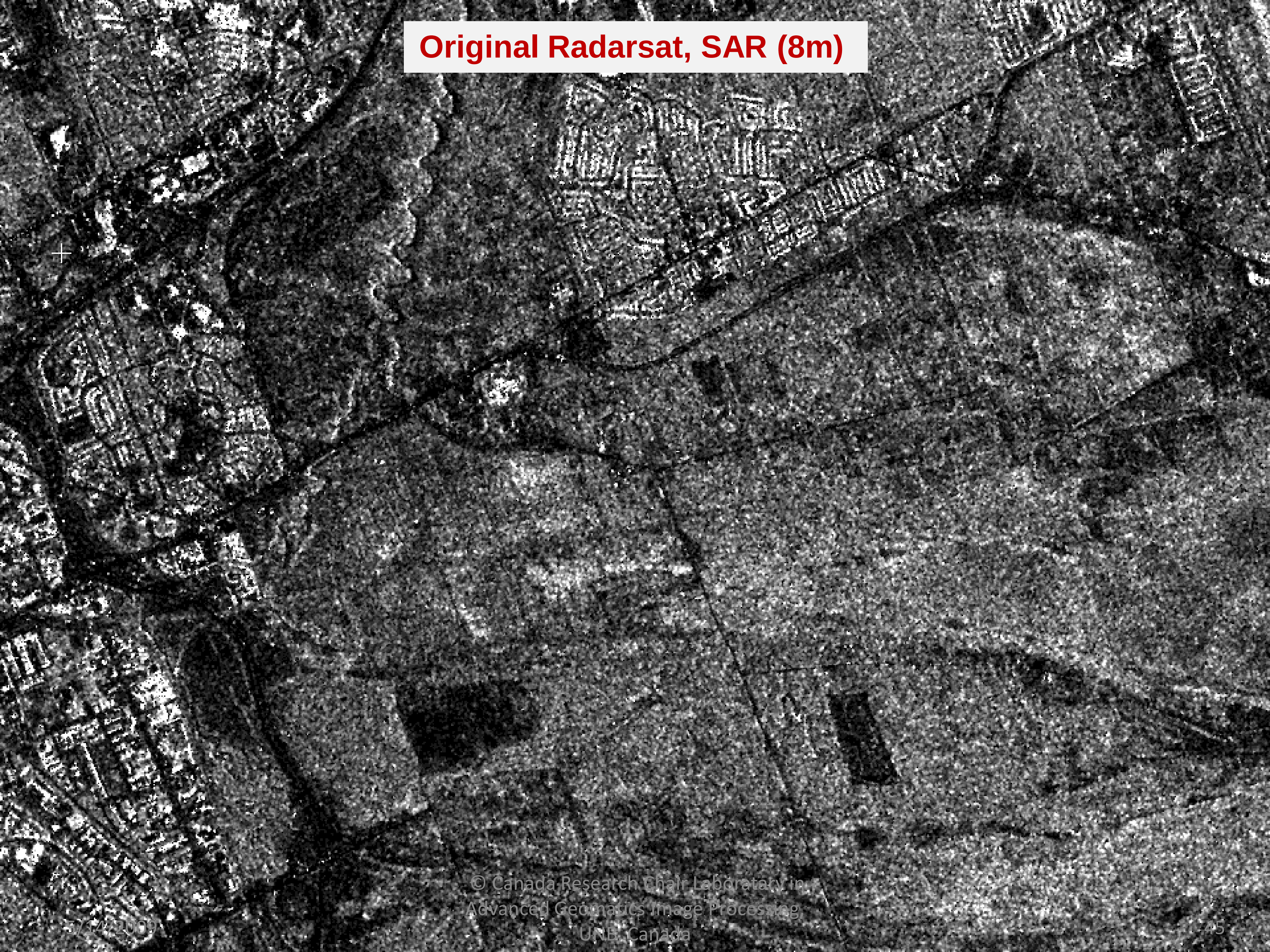
Adjustable SAR-MS Fusion

Radarsat, SAR (8m) – Landsat TM, MS (30m)

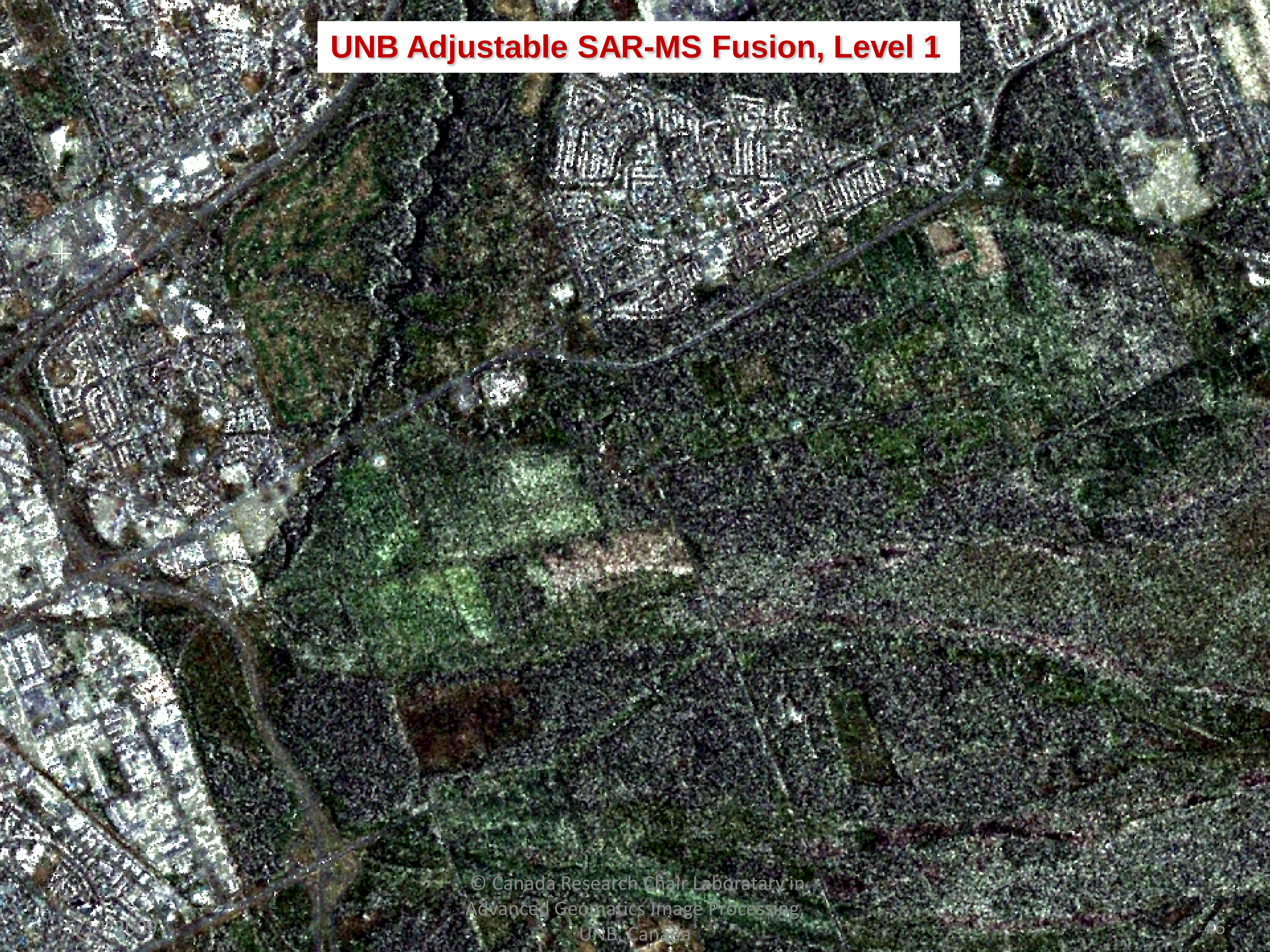
For display purpose, the same standard linear image stretching is applied to all the images.

Original Landsat, MS 123 (30m)

Original Radarsat, SAR (8m)

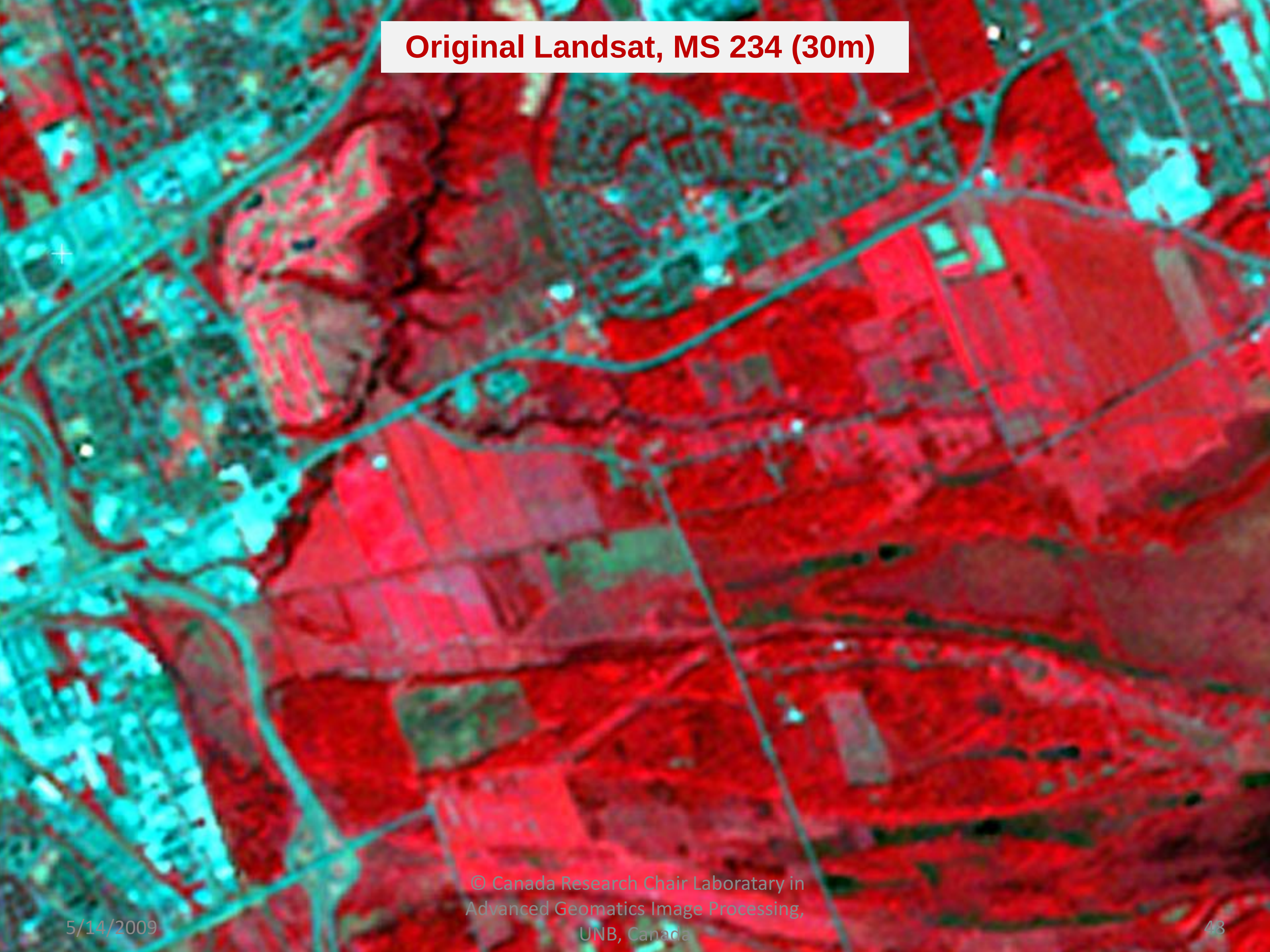


UNB Adjustable SAR-MS Fusion, Level 1

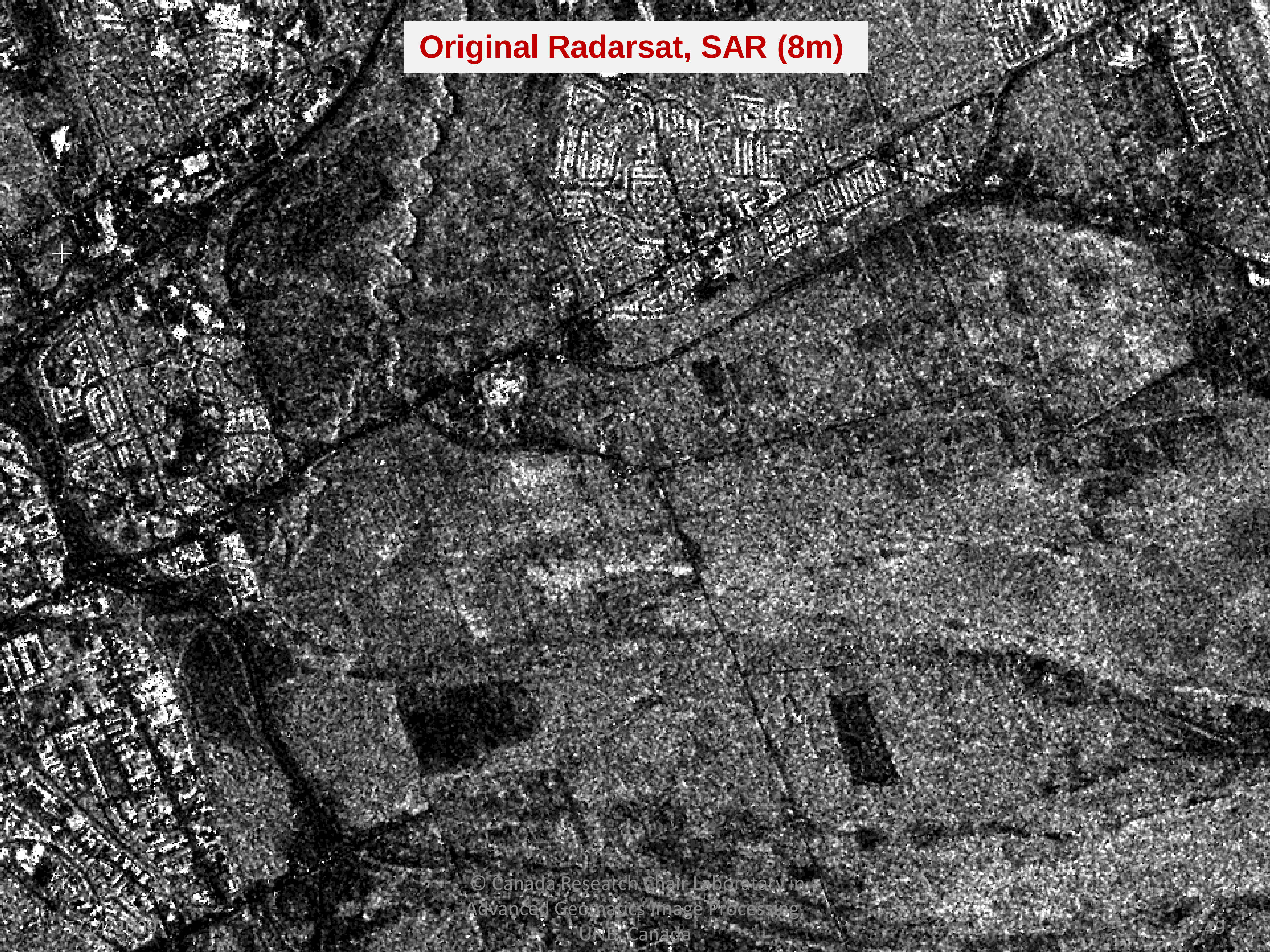


UNB Adjustable SAR-MS Fusion, Level 2

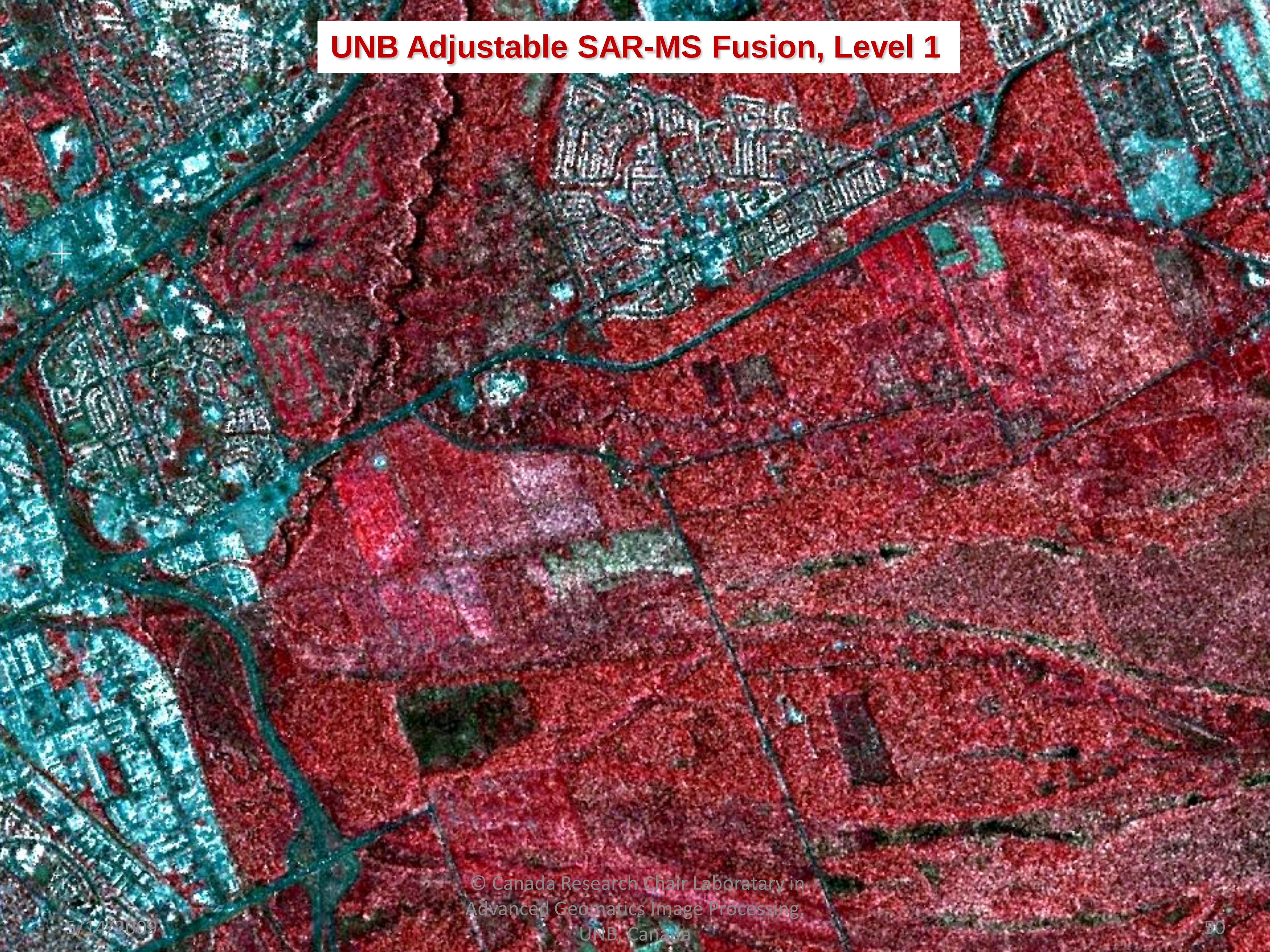
Original Landsat, MS 234 (30m)



Original Radarsat, SAR (8m)

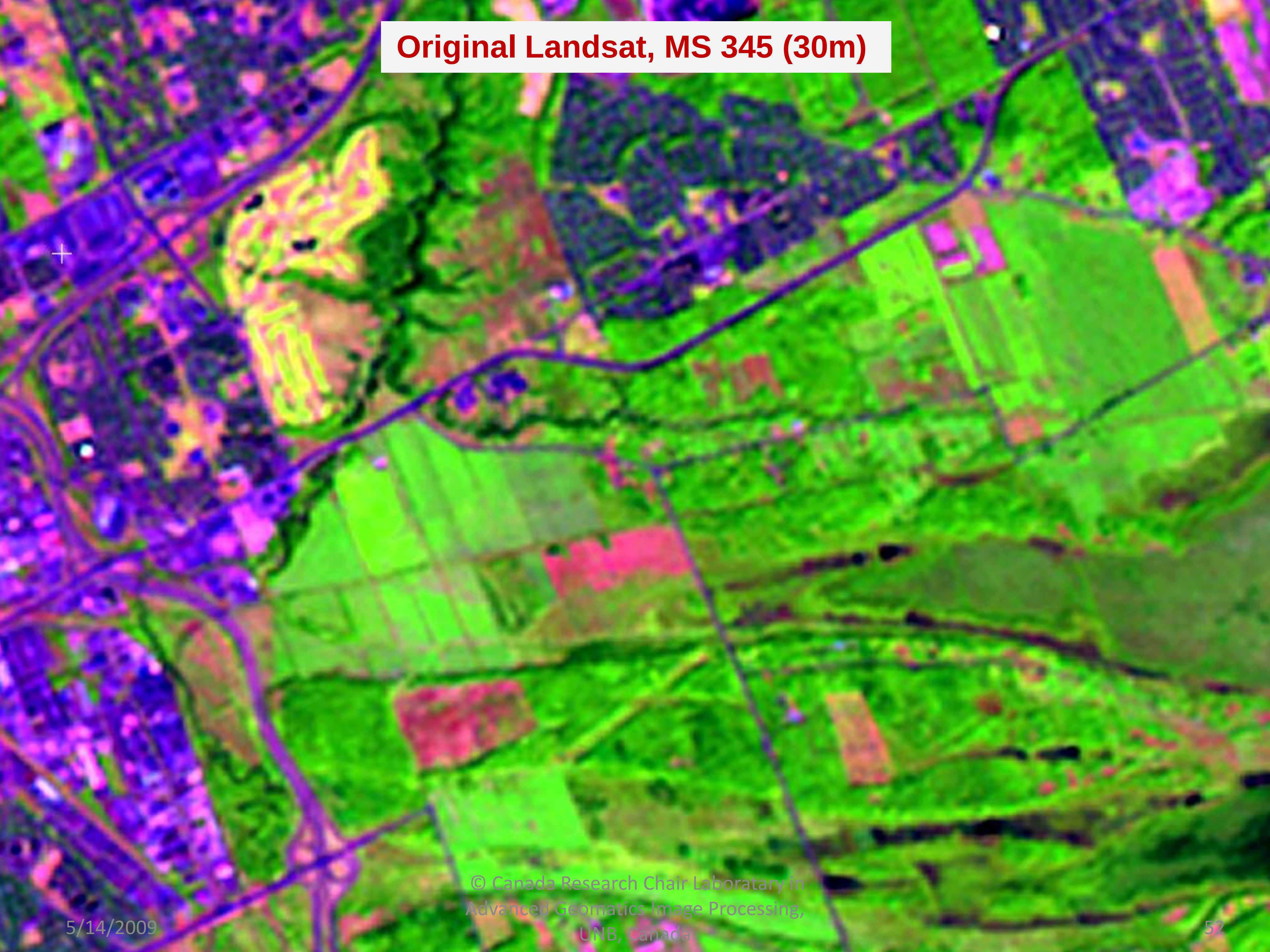


UNB Adjustable SAR-MS Fusion, Level 1

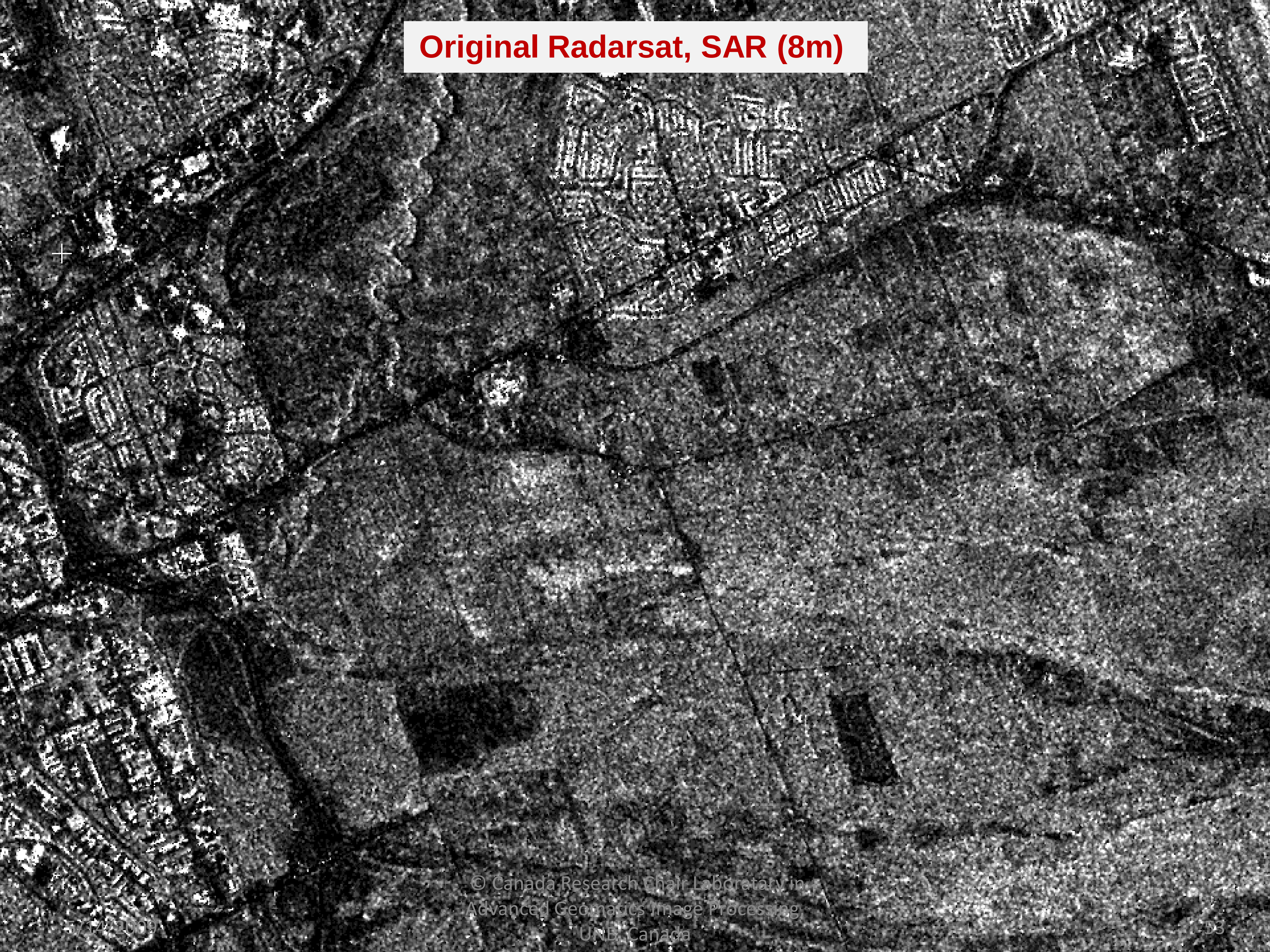


UNB Adjustable SAR-MS Fusion, Level 2

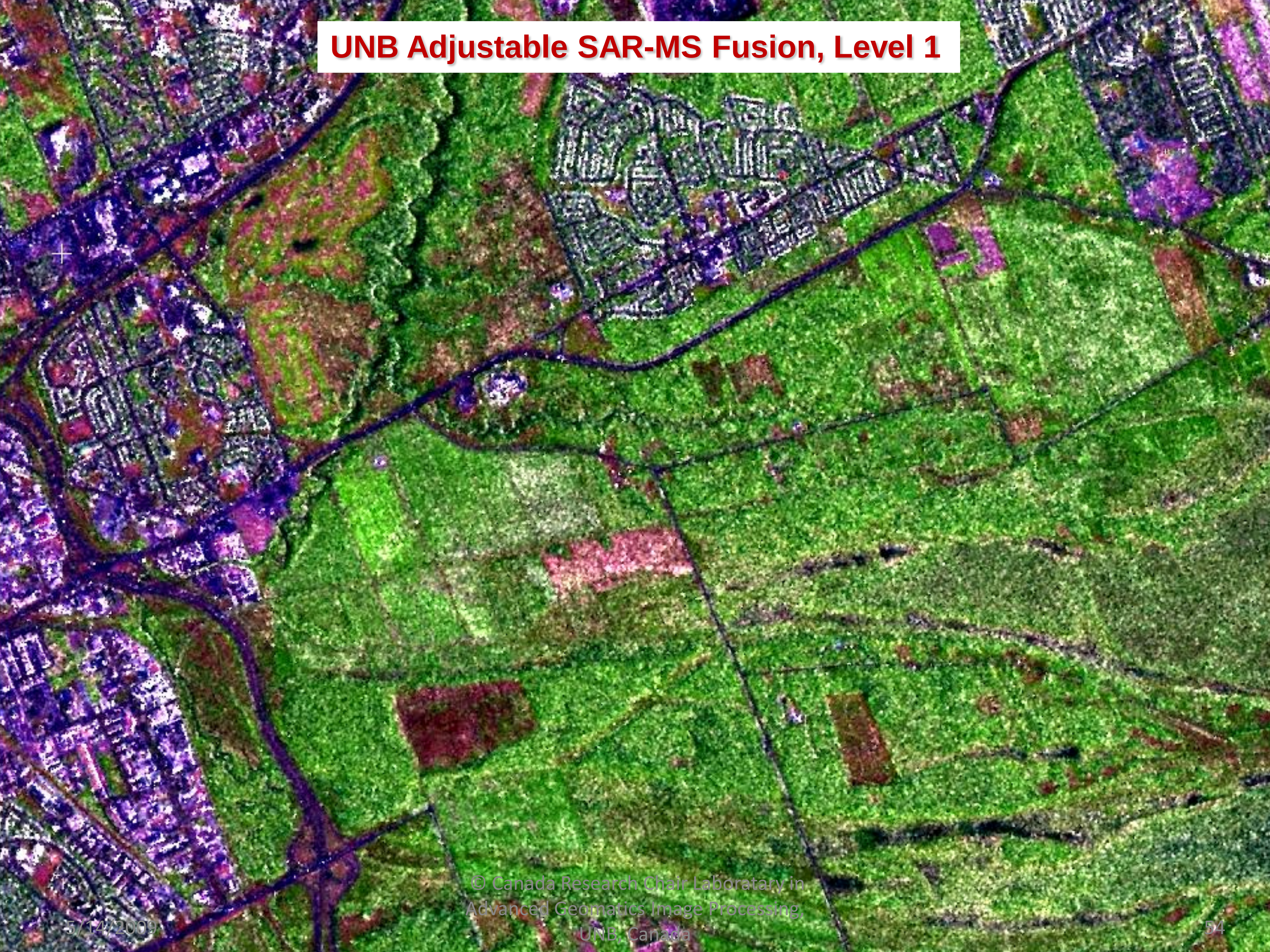
Original Landsat, MS 345 (30m)



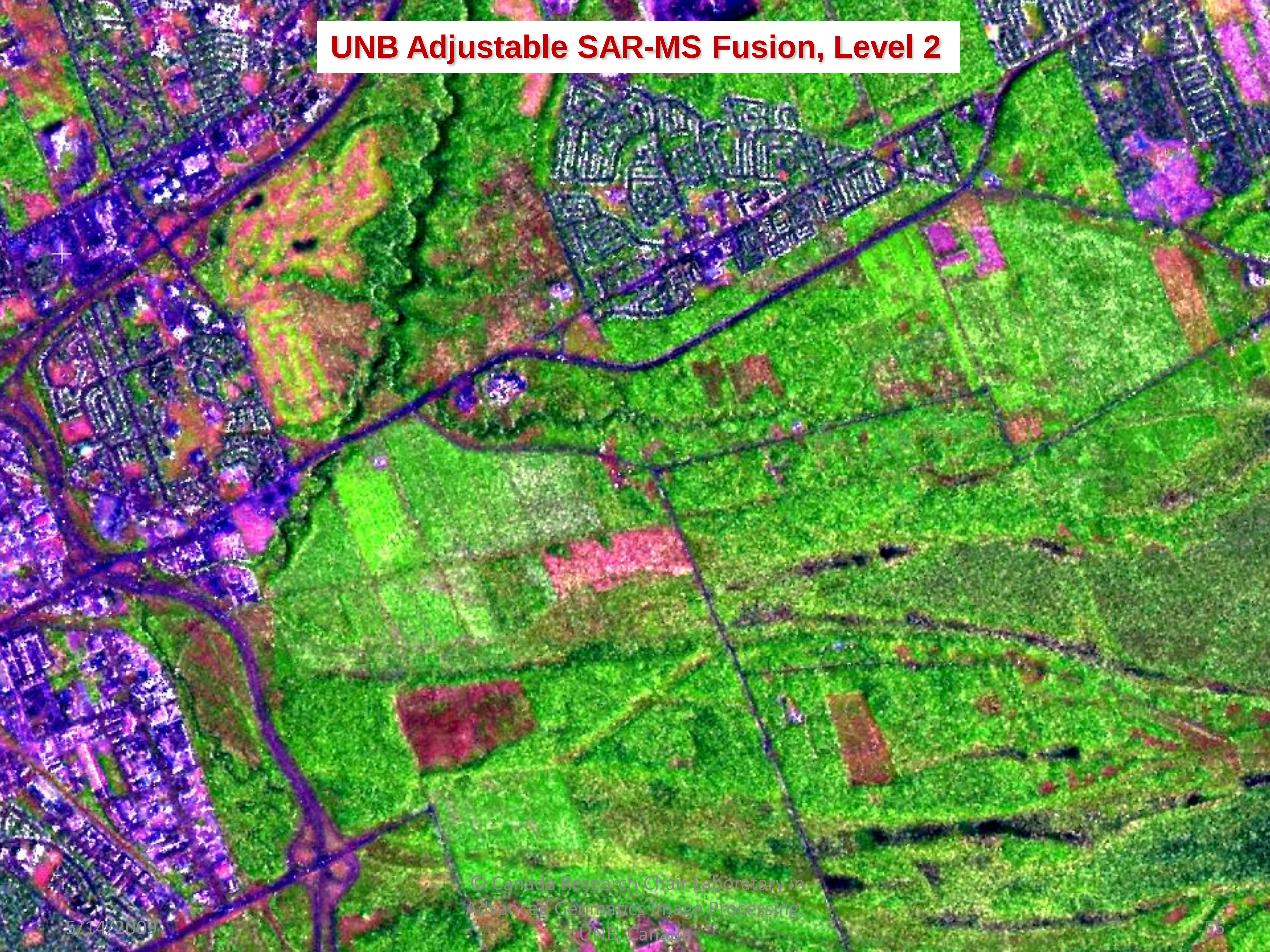
Original Radarsat, SAR (8m)



UNB Adjustable SAR-MS Fusion, Level 1



UNB Adjustable SAR-MS Fusion, Level 2



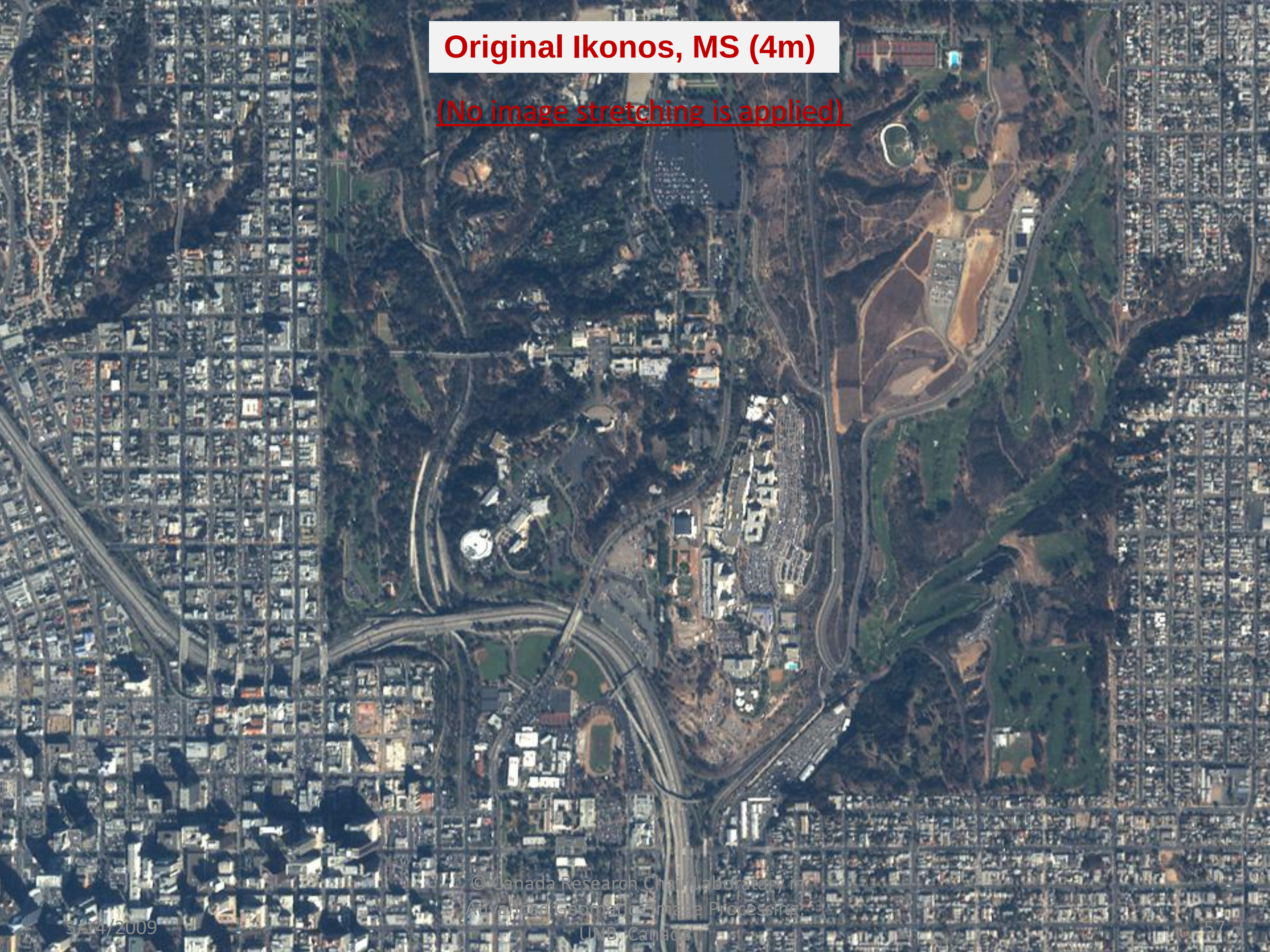
Adjustable SAR-MS Fusion

Radarsat, SAR (12.5m) – Ikonos, MS (4m)

For display purpose, the same standard linear image stretching is applied to all the images.

Original Ikonos, MS (4m)

(No image stretching is applied)



Original Radarsat, SAR (12.5m)

(No image stretching is applied)

UNB Adjustable SAR-MS Fusion, Level 1

(No image stretching is applied)

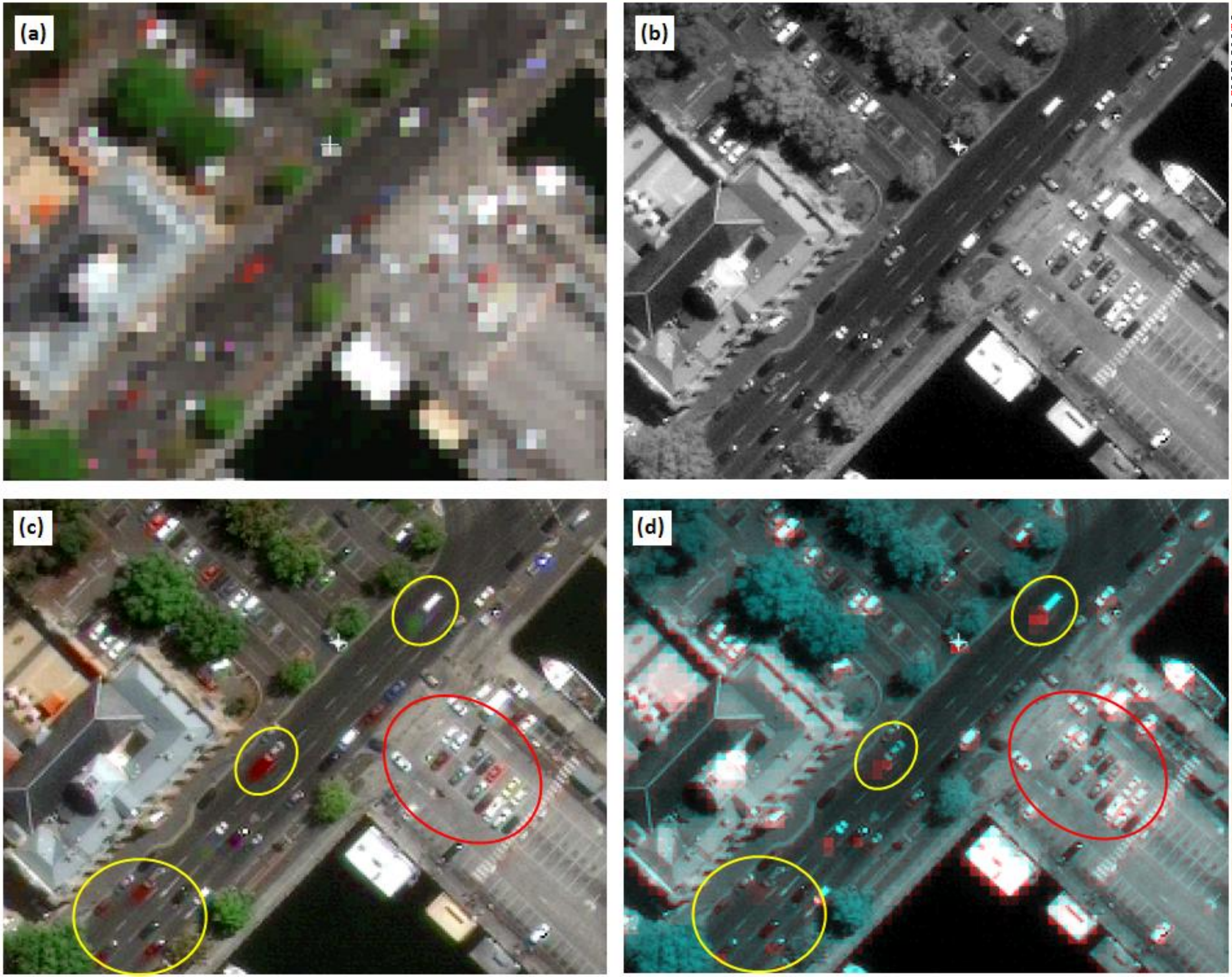
UNB Adjustable SAR-MS Fusion, Level 2

(No image stretching is applied)

2.c. Moving Target Detection

QuickBird Pan

QuickBird MS


(a)
(b)
(c)
(d)

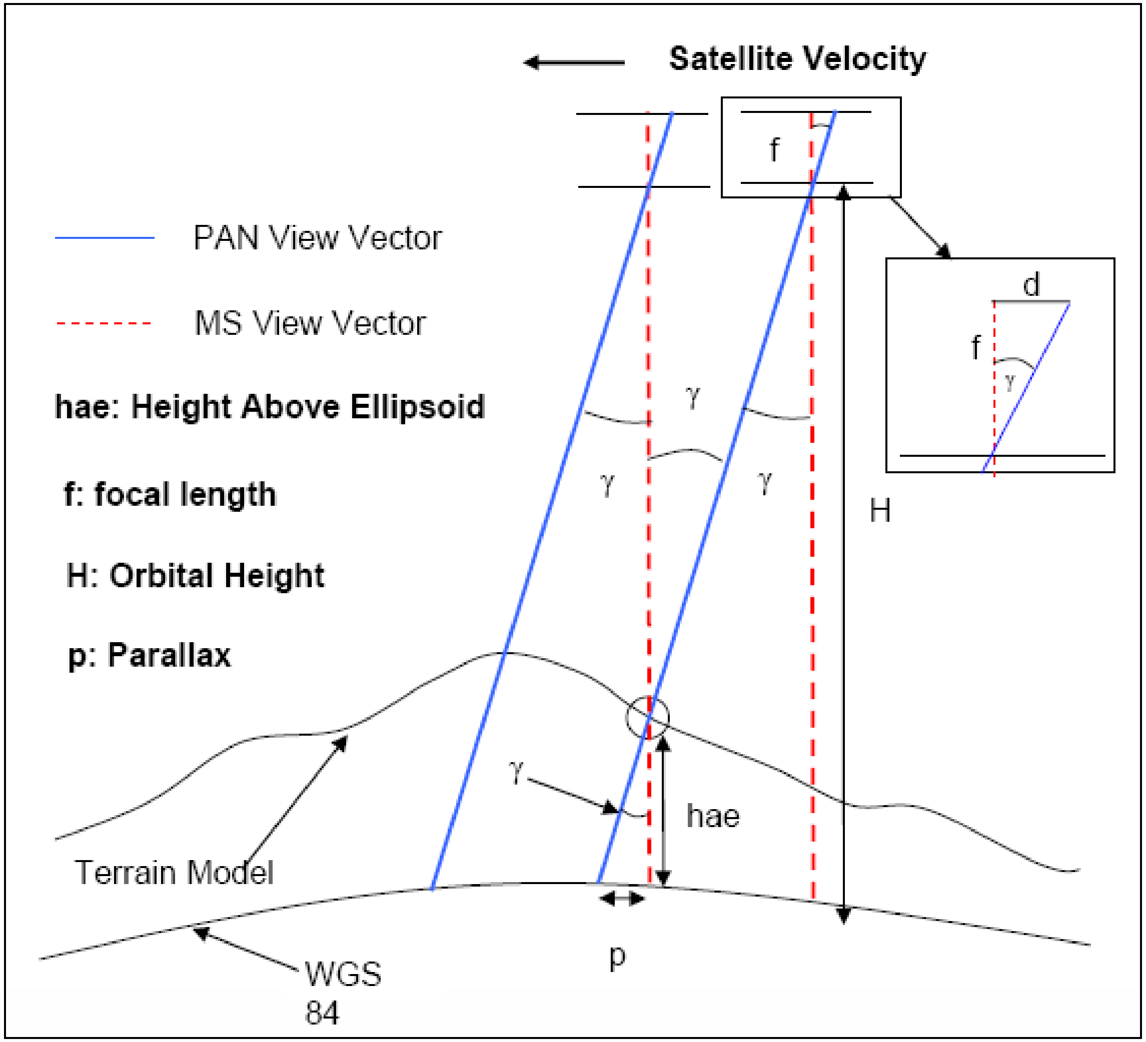
Parallax

QuickBird Pan-MS arrays alignment

DIGITALGLOBE

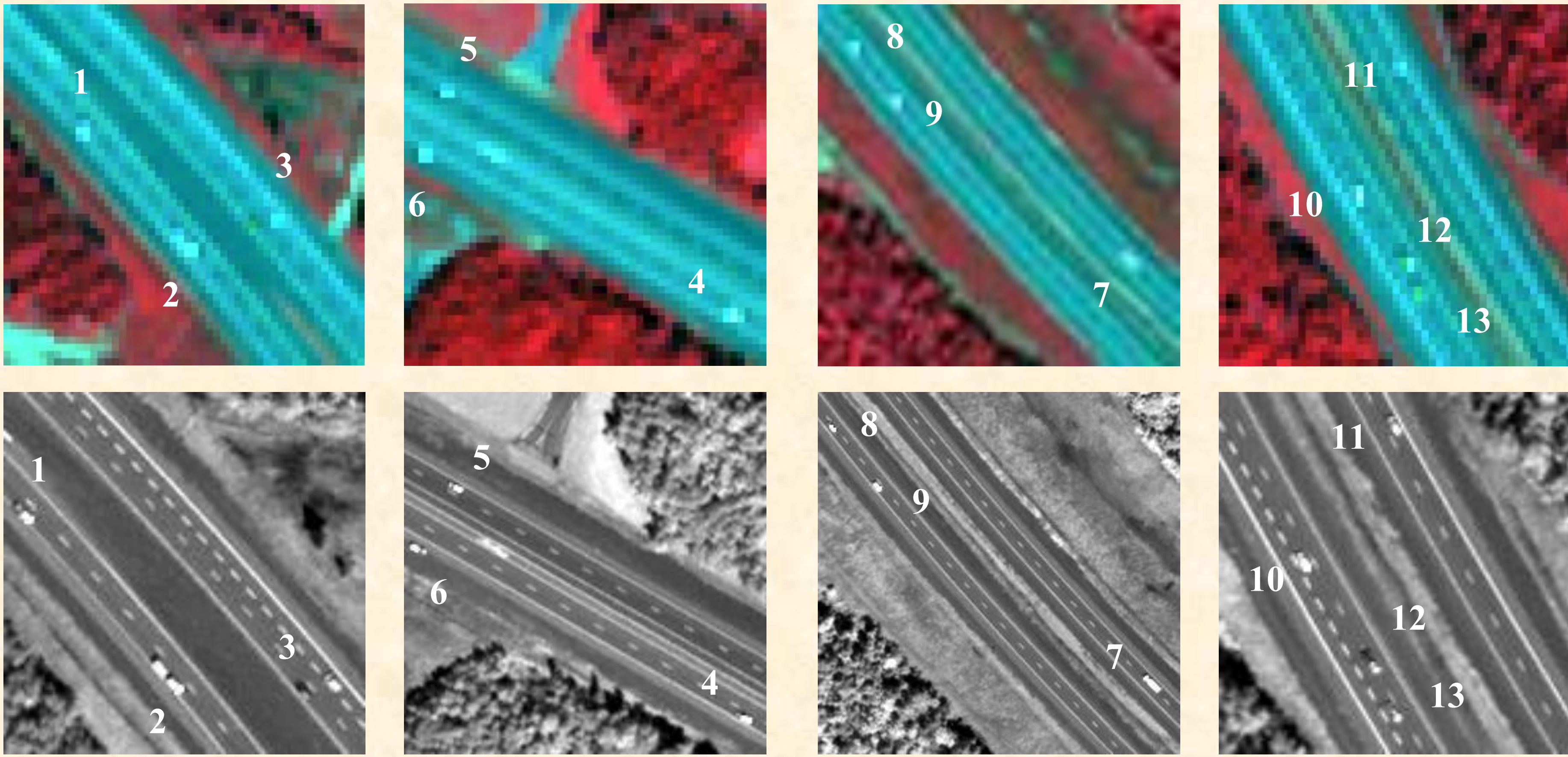
$$p = hae\frac{d}{f} \times \frac{1}{\cos\theta}$$

P -> parallax
Hae -> ellipsoidal height
D -> focal plane distance
F -> focal length
θ -> off nadir angle



Reference:
Padwick, C., 2004. Pan Sharpening of High Resolution Satellite Imagery, ASPRS Annual Conference, June 8, 2004

Moving targets



Moving targets

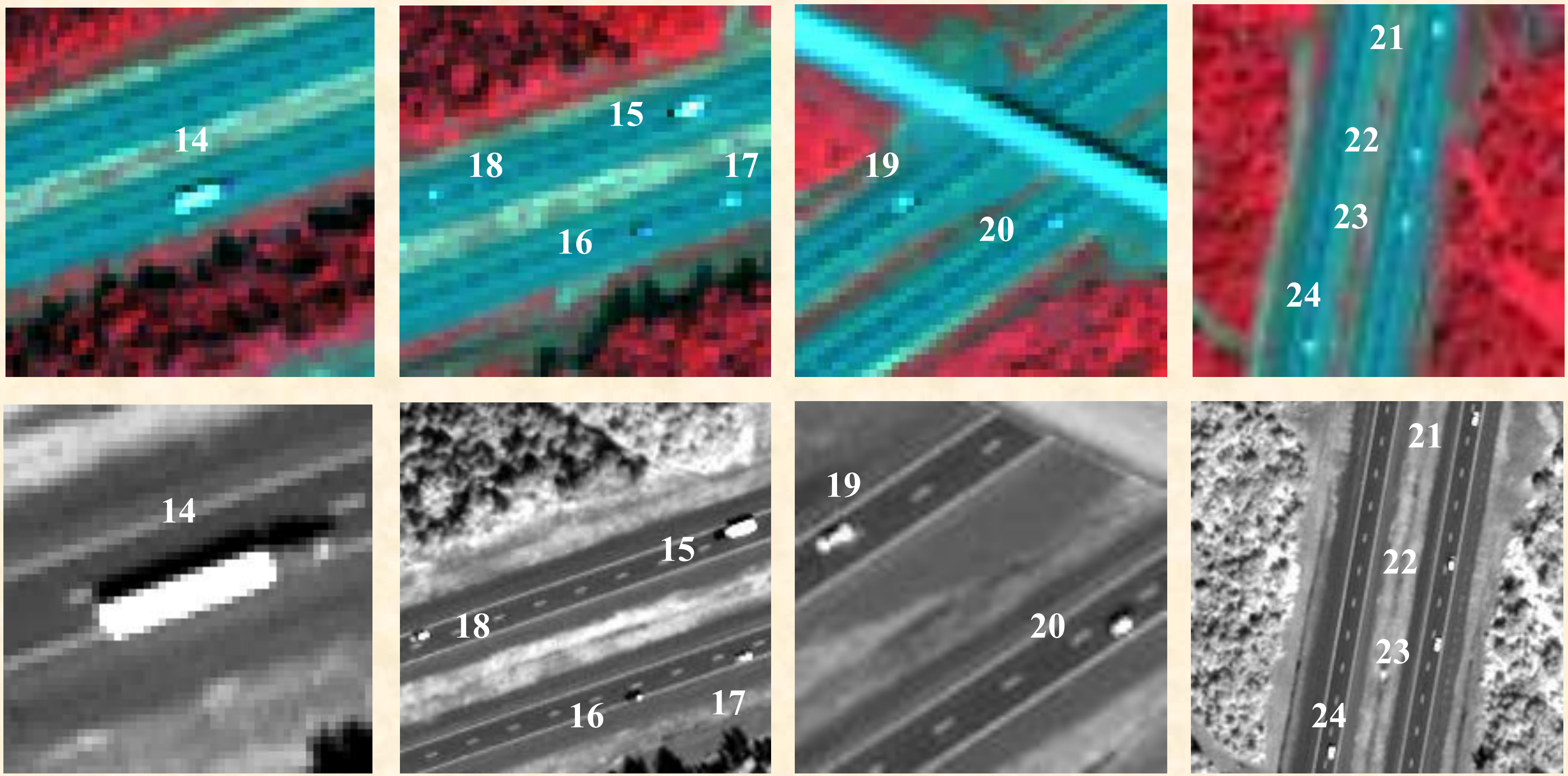


Table 5: Coordinates, speed, and azimuth angle of moving targets

No	X(m)	Pan Y(m)	H(m)	Speed(km/h)	Azimuth(degree)
1	694447.8621	5079066.252	29.539007	118.522133	133.830994
2	694485.7676	5079025.978	30.392731	109.926338	150.191025
3	694524.2158	5079028.594	30.532267	68.152657	323.130402
4	694021.1658	5079358.151	18.099633	133.697861	126.339523
5	693929.825	5079424.877	15.421739	93.154297	306.870209
6	693917.1496	5079406.324	15.740675	23.862312	74.054672
7	695493.5569	5077424.519	30.564808	135.721359	317.726593
8	695349.1159	5077532.095	30.622373	113.871544	152.488144
9	695370.0456	5077506.848	30.630486	149.73671	134.356384
10	695185.9368	5077759.267	30.330296	107.45369	150.191025
11	695206.4002	5077792.369	30.298069	145.642273	337.50769
12	695203.0379	5077735.757	30.372644	145.450485	146.192184
13	695209.0495	5077724.515	30.388153	83.820351	164.745041
14	698168.0609	5077339.579	37.840326	71.232735	52.957577
15	698551.6409	5077532.603	43.529508	120.406052	254.578079
16	698525.3102	5077484.445	43.616787	162.604324	74.188698
17	698553.9627	5077496.88	44.048217	127.154083	75.379196
18	698465.6076	5077497.859	42.224455	150.211761	249.145782
19	699557.0058	5078000.132	42.423995	144.731583	243.904816
20	699597.5814	5077989.308	42.318242	143.545547	68.198654
21	700452.3905	5079682.306	27.973226	96.366844	4.39871
22	700445.0516	5079628.63	28.158358	138.395966	11.228902
23	700441.445	5079599.551	28.268832	100.277542	10.35333
24	700404.1849	5079558.529	28.569551	77.596268	183.252106

On slow lane (3)

On road side (6)

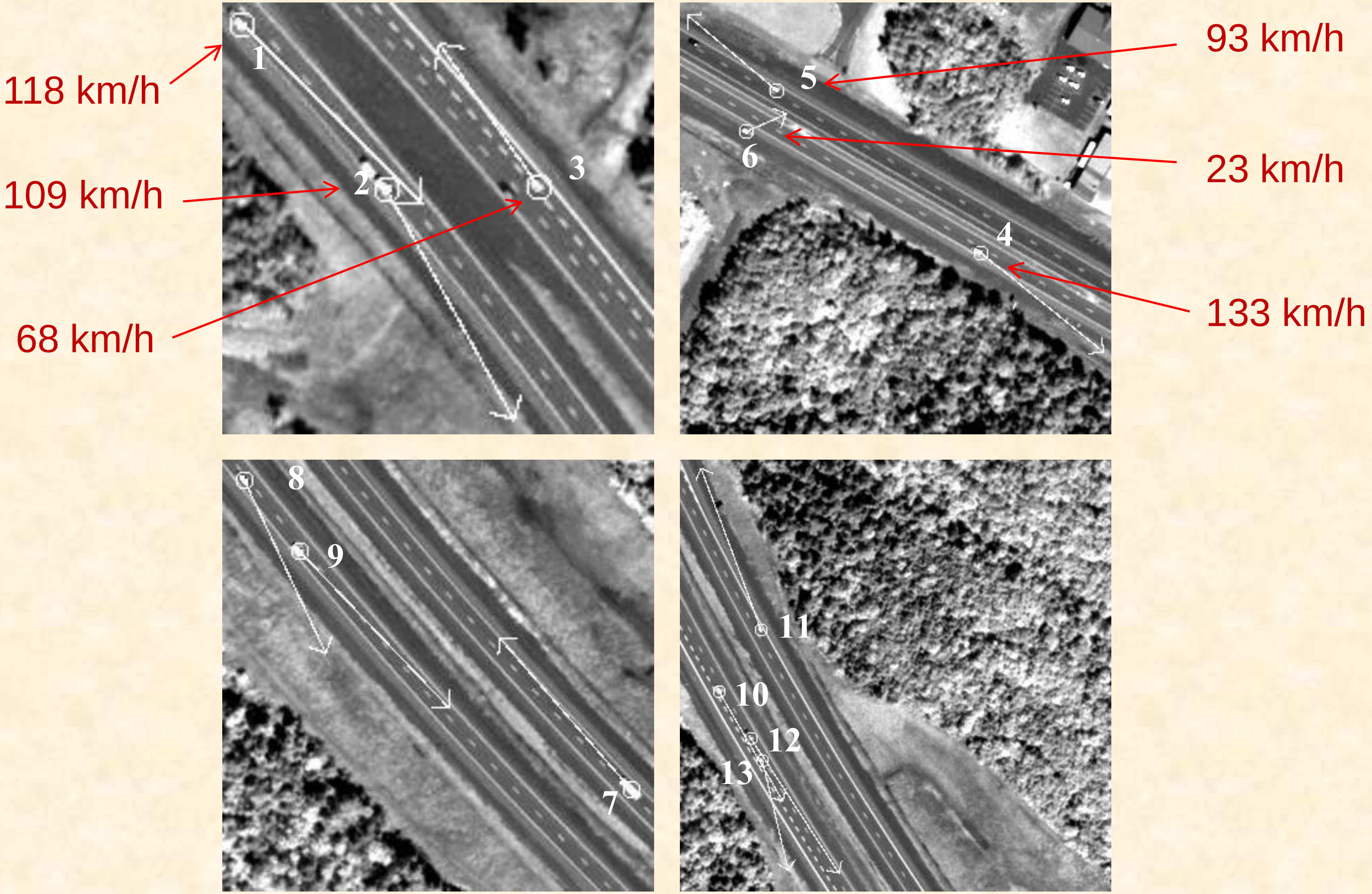
On high speed lane, will pass over 13 (12)

Big truck (14)

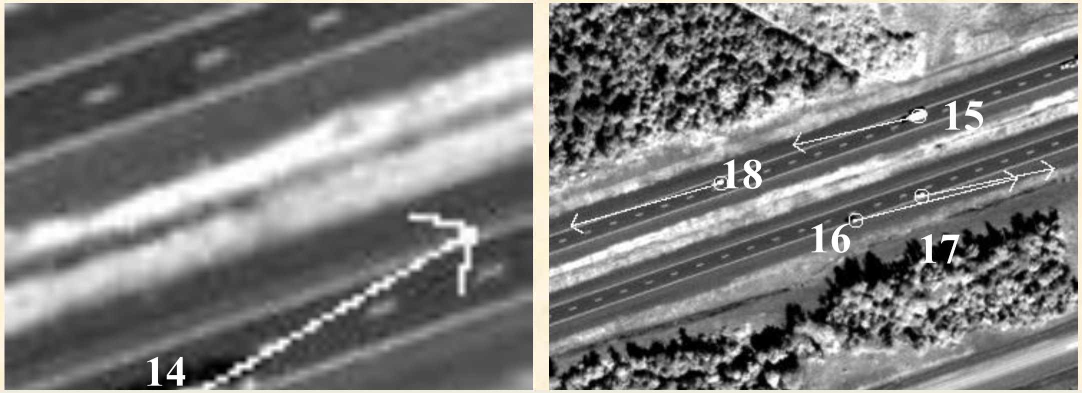
Will pass over 17 (16)

Just passed over 15 (18)

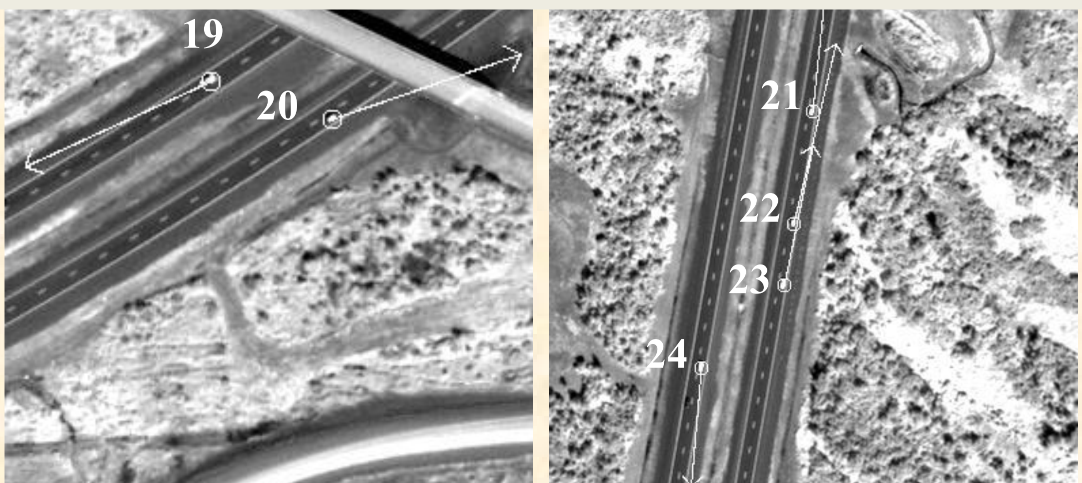
Speed and direction of moving target:



Speed and direction of moving target:



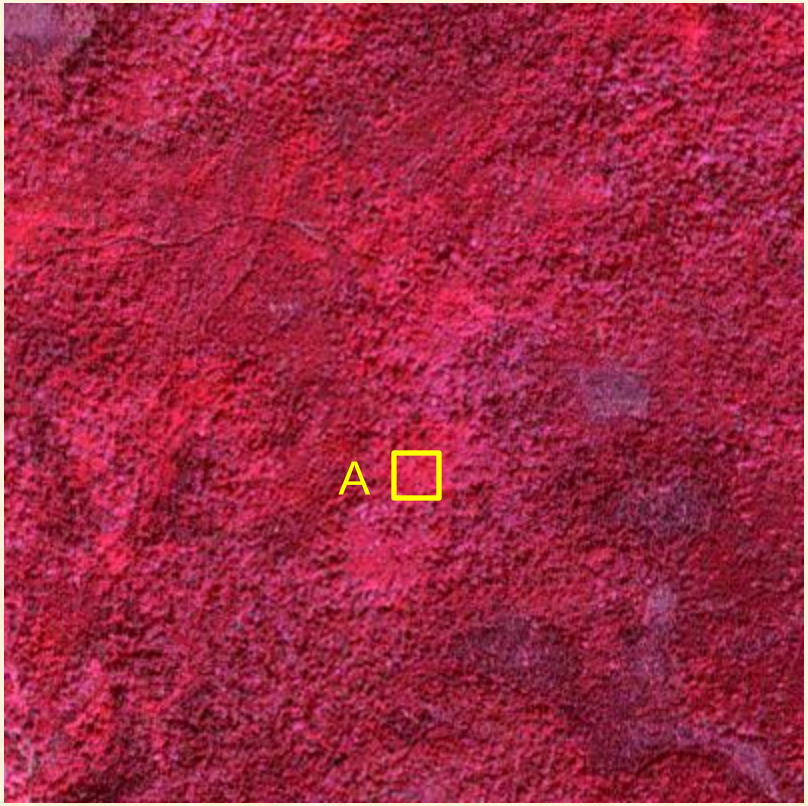
- ASPRS John I. Davidson President's Award for Practical Paper, 2009, with my PhD student Z. Xiong

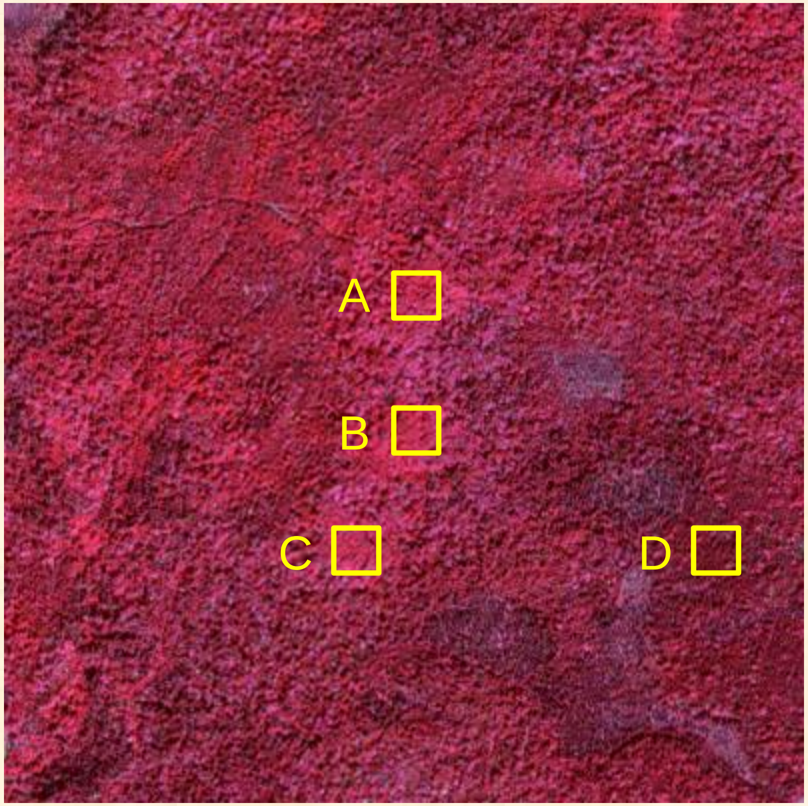


2.d. Image Matching

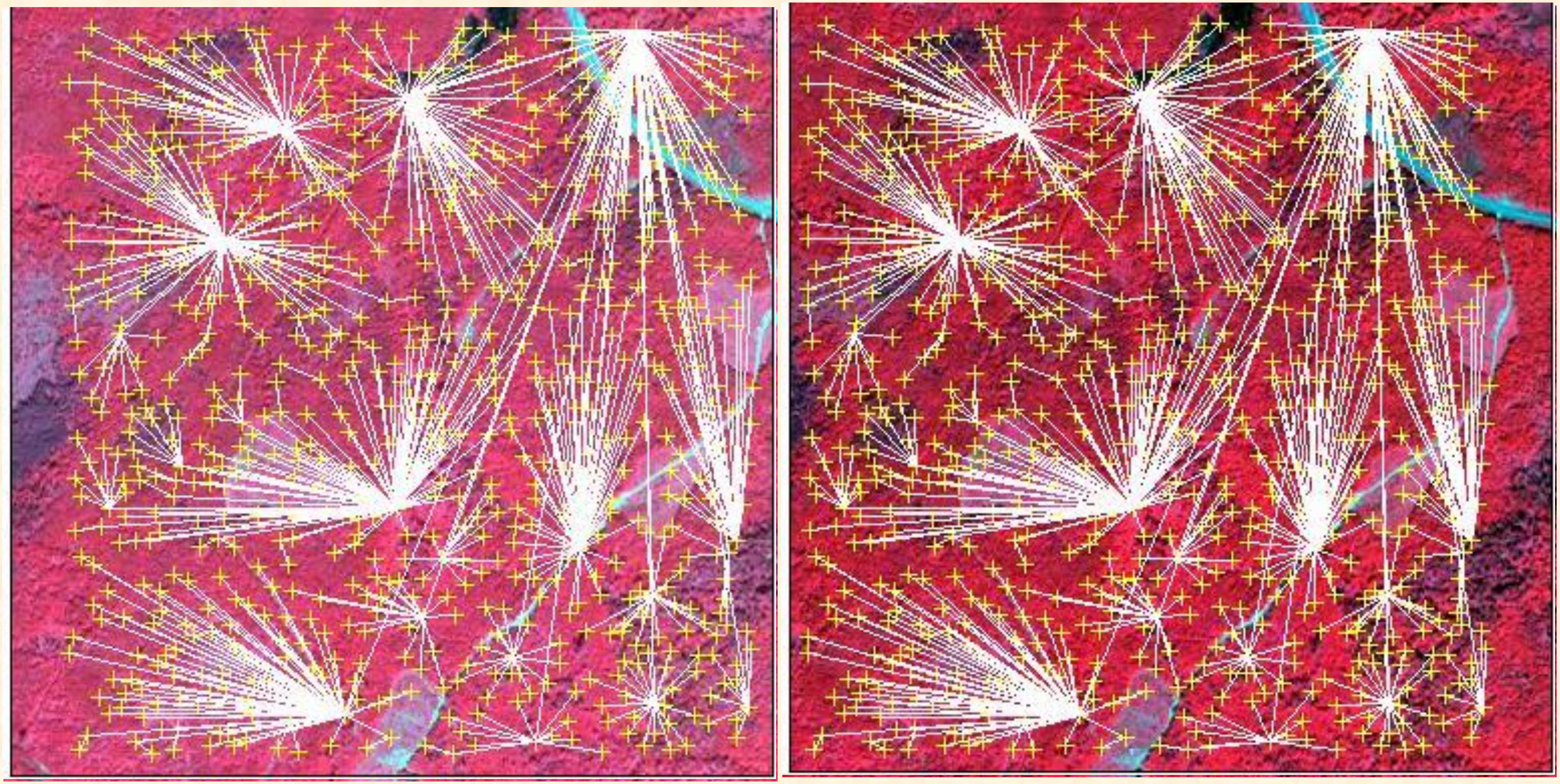
Problems with the Existing Solutions

Ambiguity in smooth (low texture) areas, such as forest, grass, water, highway surfaces, building roofs, etc.

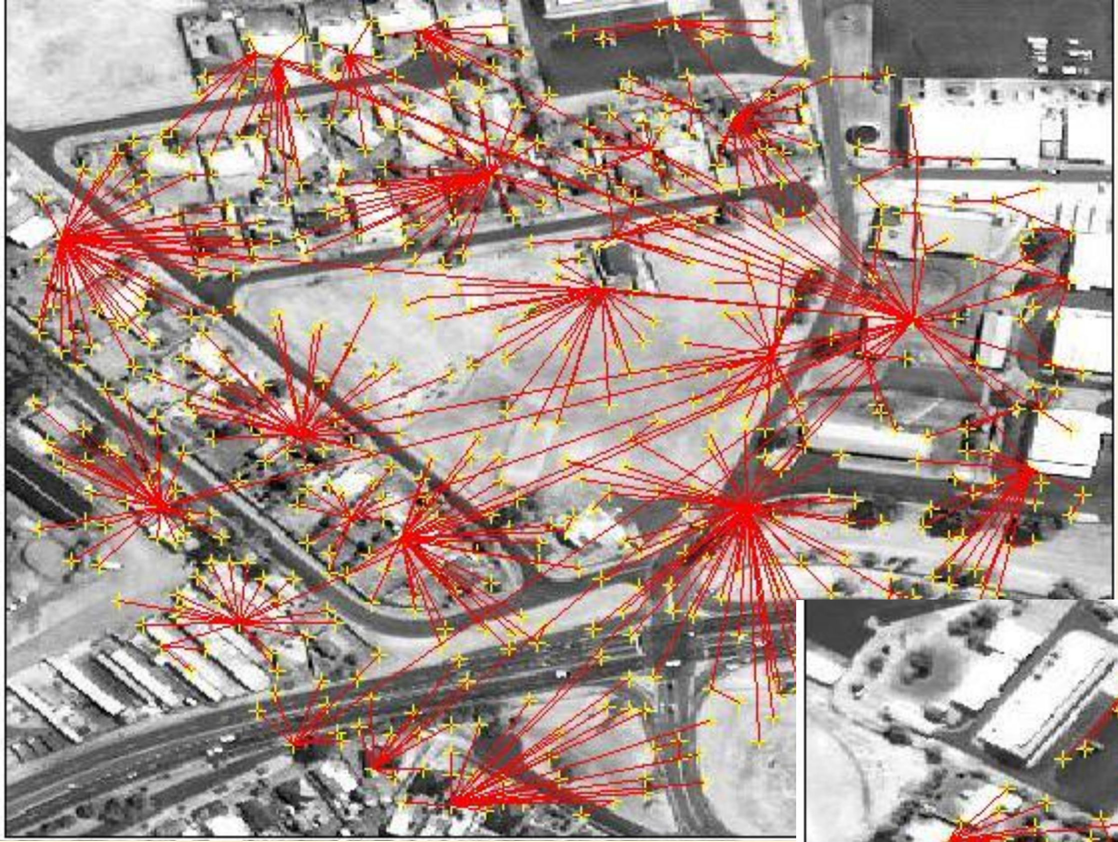




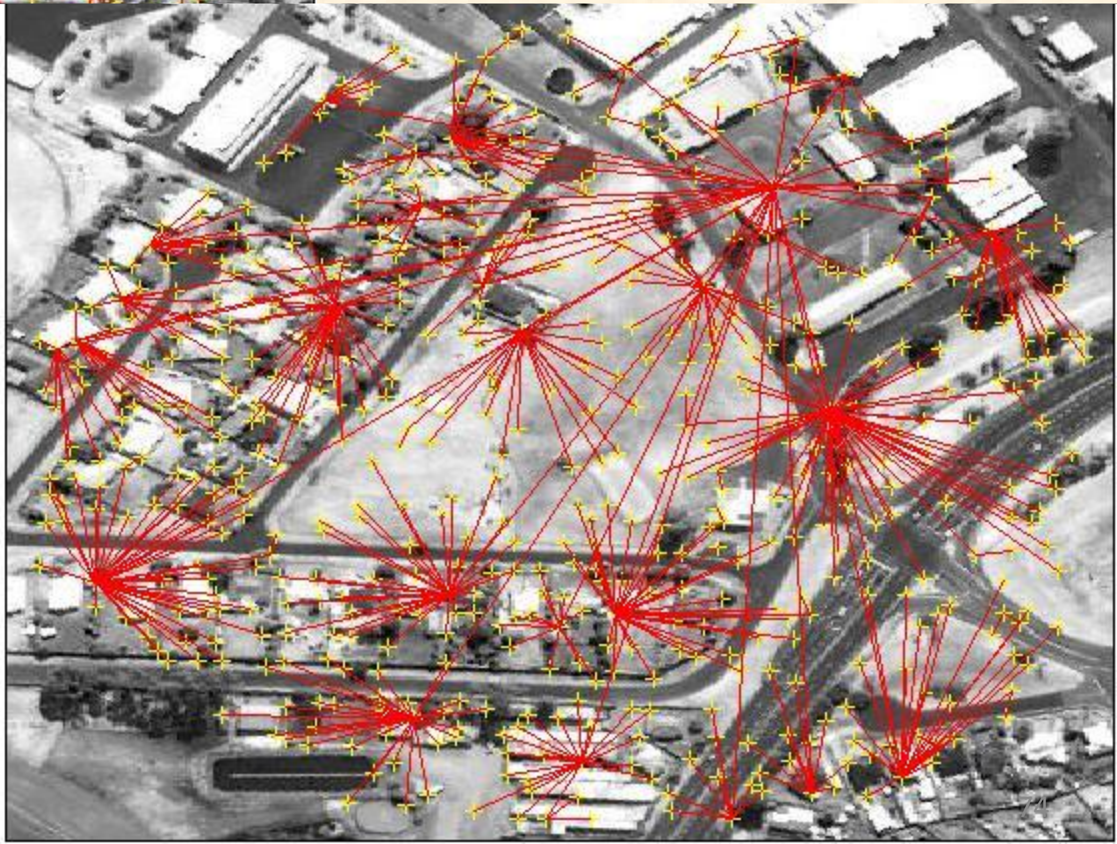
UNB Image Matching



UNB Image Matching



Right image rotates 315

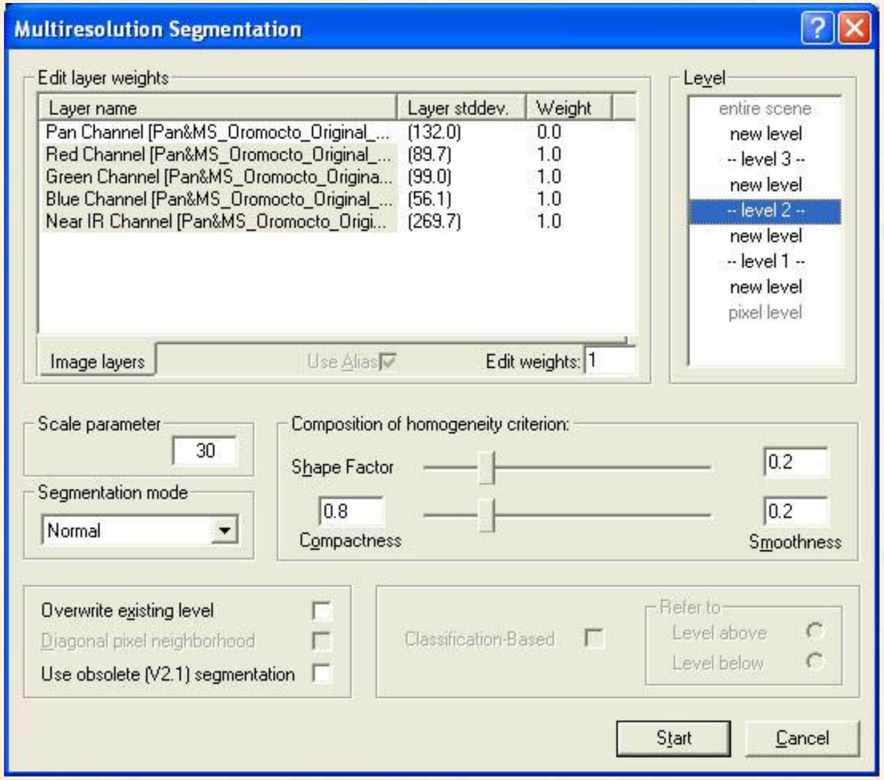


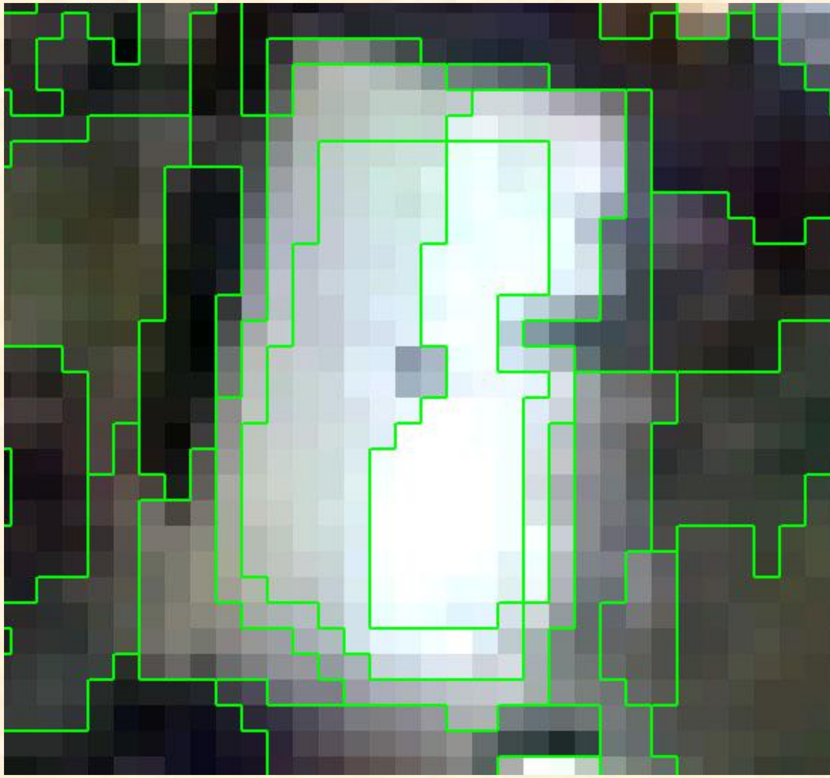
UNB Image Matching

2.e. Image Segmentation

Problem in object-oriented classification

- Segmentation in eCognition™





The operator must use his/her experience and a trial-and-error method to find the appropriate segmentation parameters:

- Scale = ?
- Shape weight (factor) = ?
- Smoothness = ?

Existing object-oriented classification (eCognition)

Step 1:

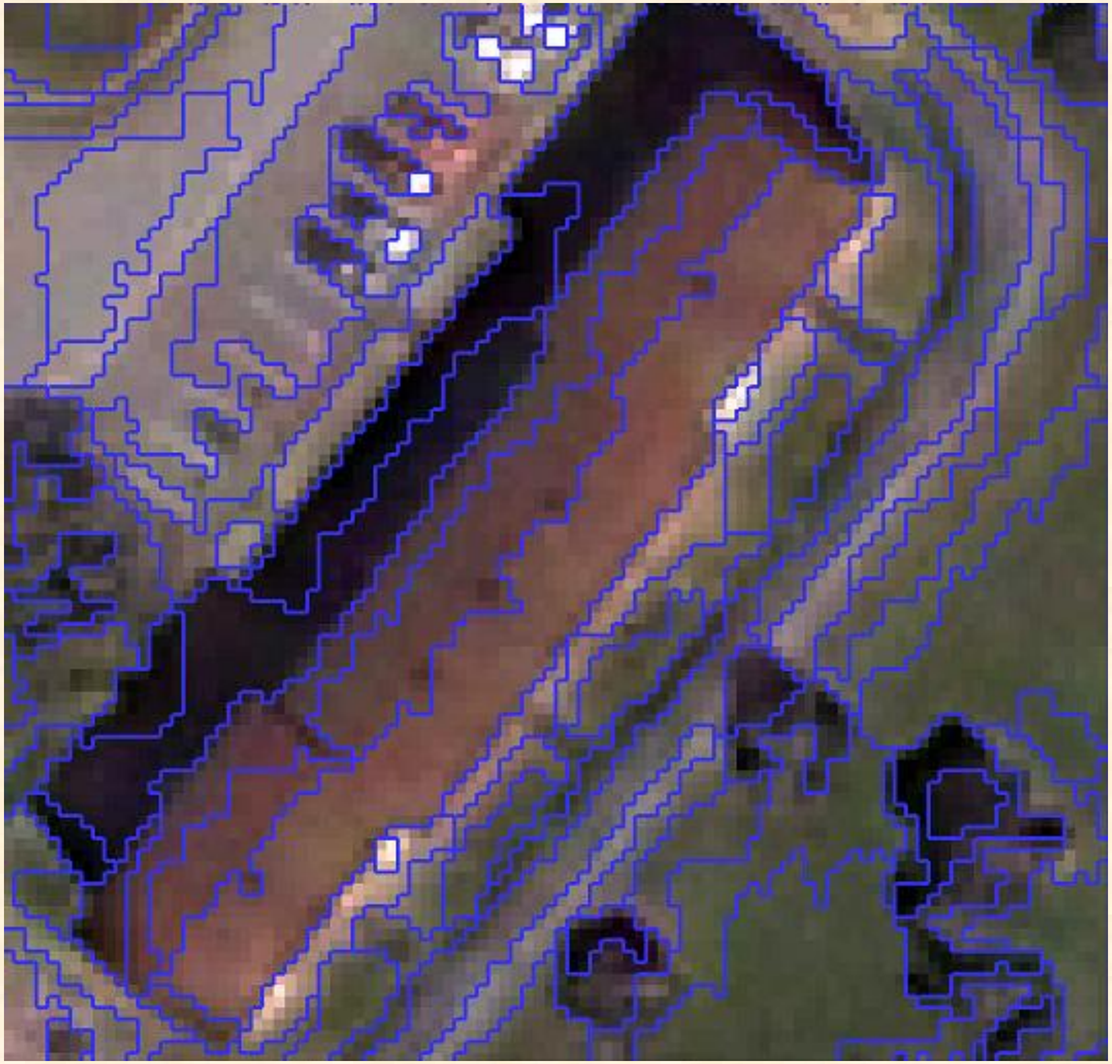
Segmentation at various scales

Step 2:

Classification of image objects

UNB Supervised Segmentation

(1) Initial Segmentation



- Perform Preliminary Segmentation

- Parameters used:

Scale = 25

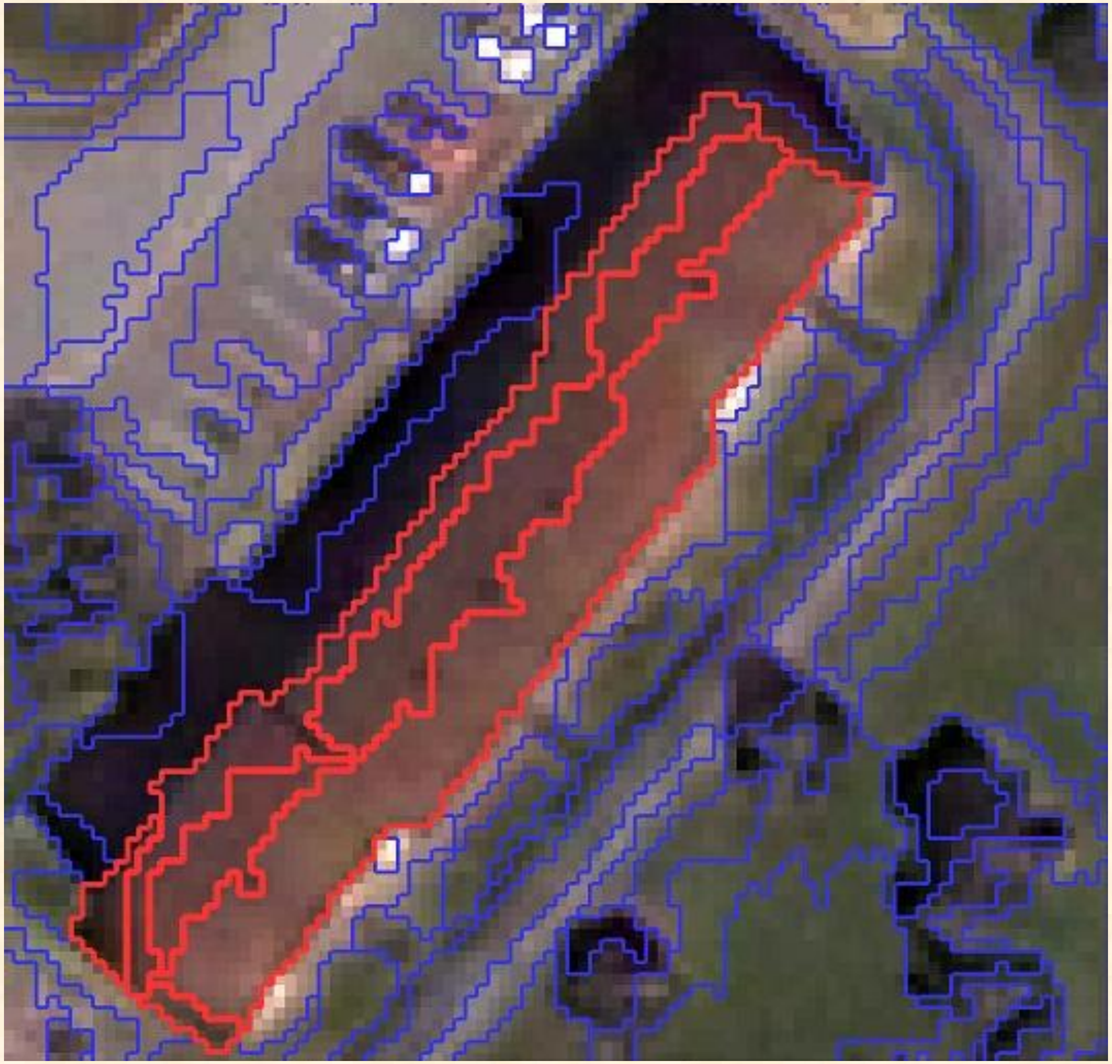
Shape weight = 0.1

Smoothness = 0.1 weight

UNB Supervised Segmentation

(2) Segmentation Training

- **Train the system by selecting appropriate sub-objects that comprise the object of interest**
- **Start iterative process to determine appropriate segmentation parameters**



UNB Supervised Segmentation

(3) Automatically finding optimal segmentation parameters

- Convergence in 4 iterations
- Solution parameters:

  Scale = 120

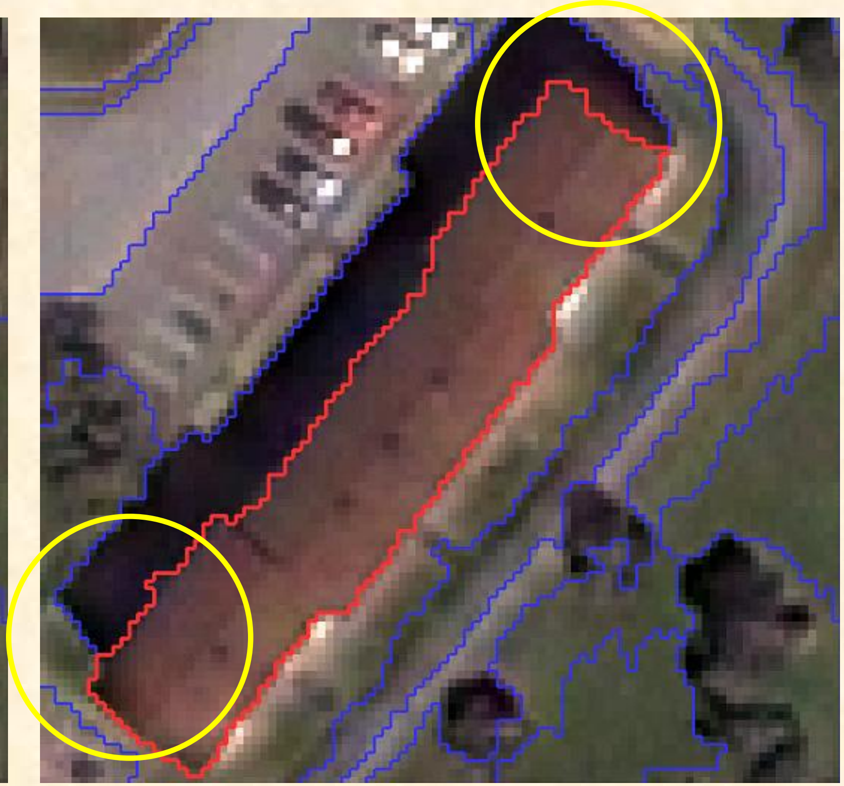
  Shape weight = 0.410

  Smoothness = 0.868 weight

Re-segmentation Results and Comparison

Trial and error approach

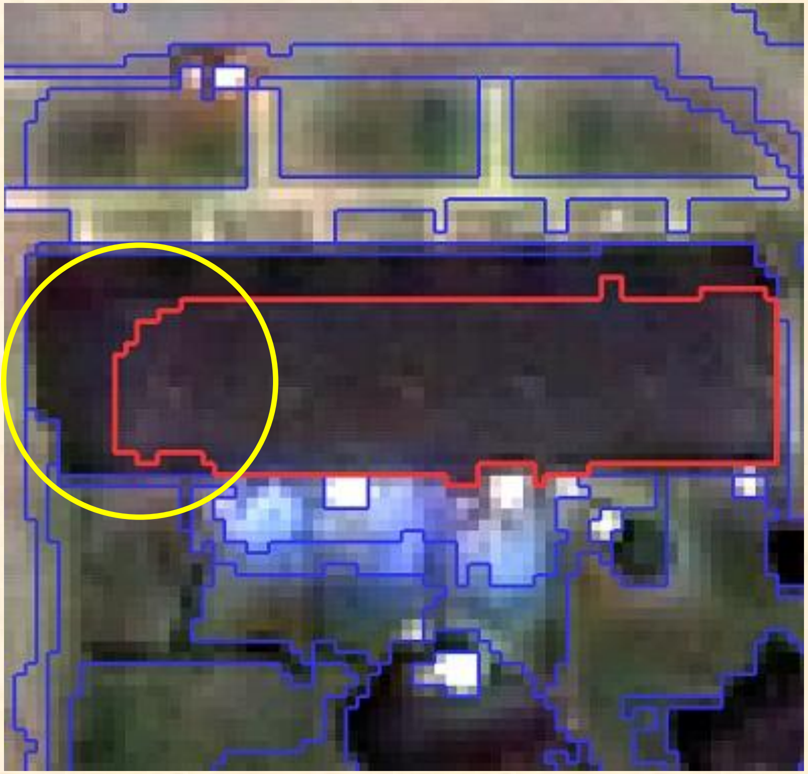
(State-of-the-art)



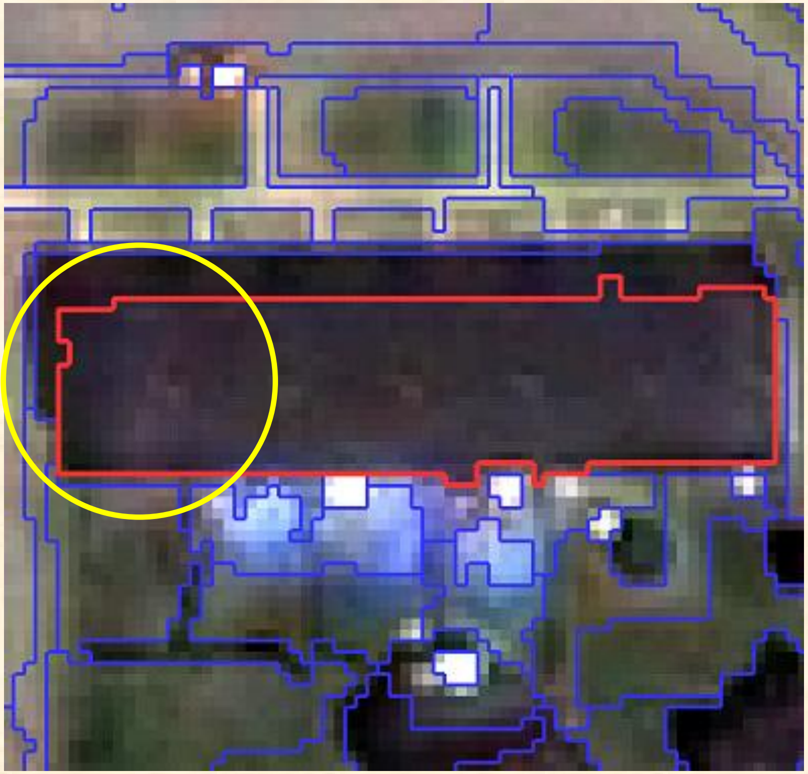
UNB approach

(UNB solution)

Re-segmentation Results and Comparison



Trial and error approach

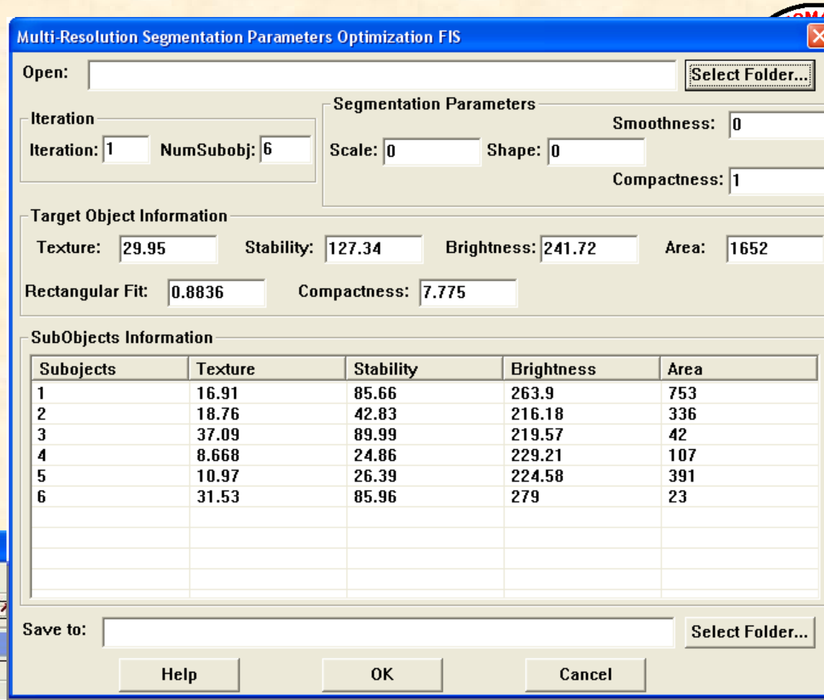


UNB approach

Re-segmentation Results

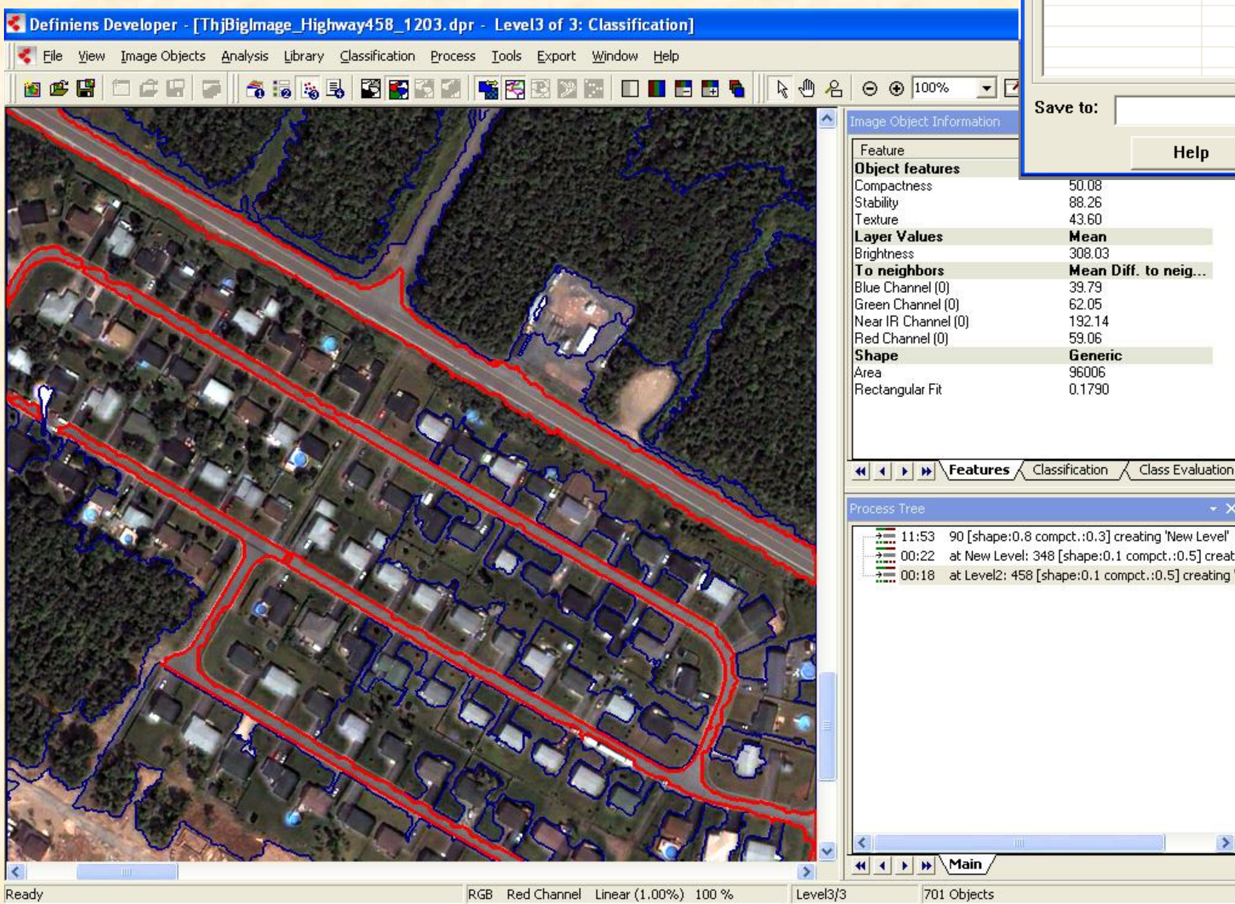
(UNB result)

UNB Supervised Segmentation

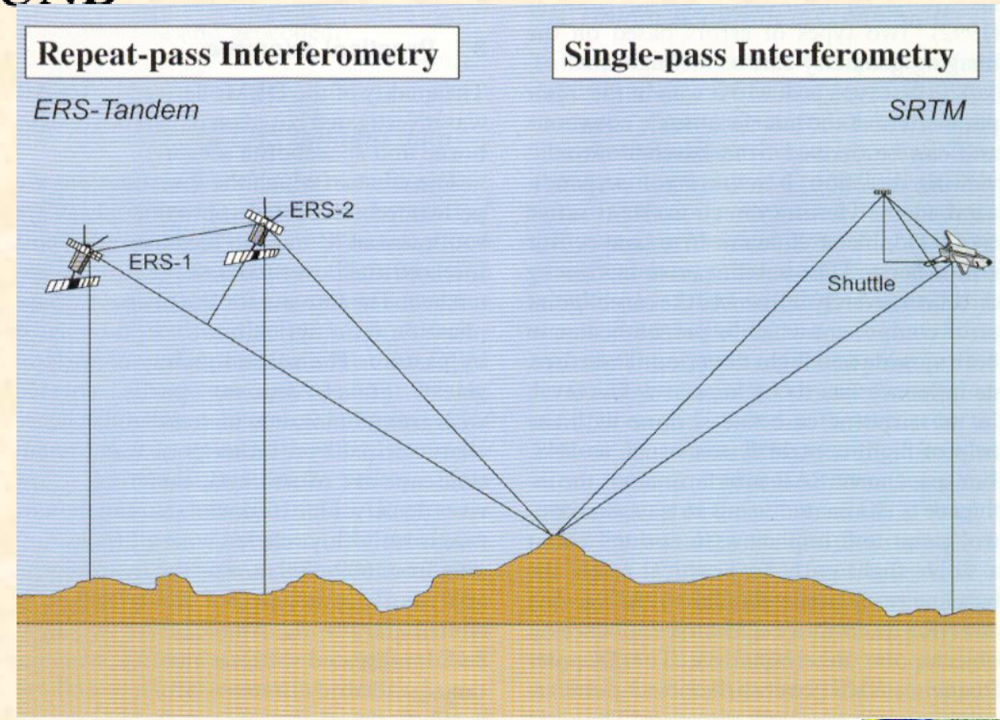


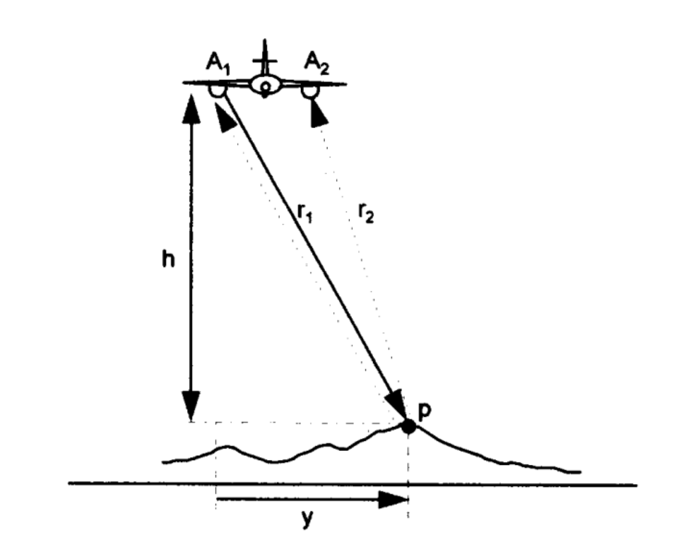
UNB SP Optimizer

eCogintion



2.f. InSAR DEM Reconstruction





Interferometric SAR (InSAR)
for DEM generation

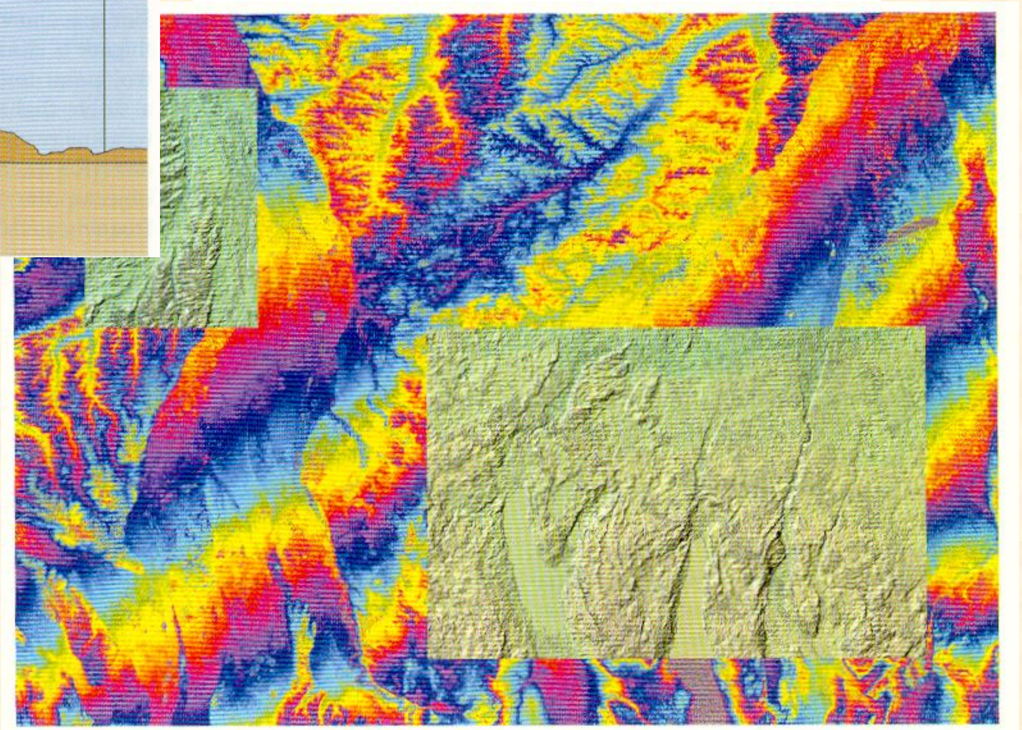
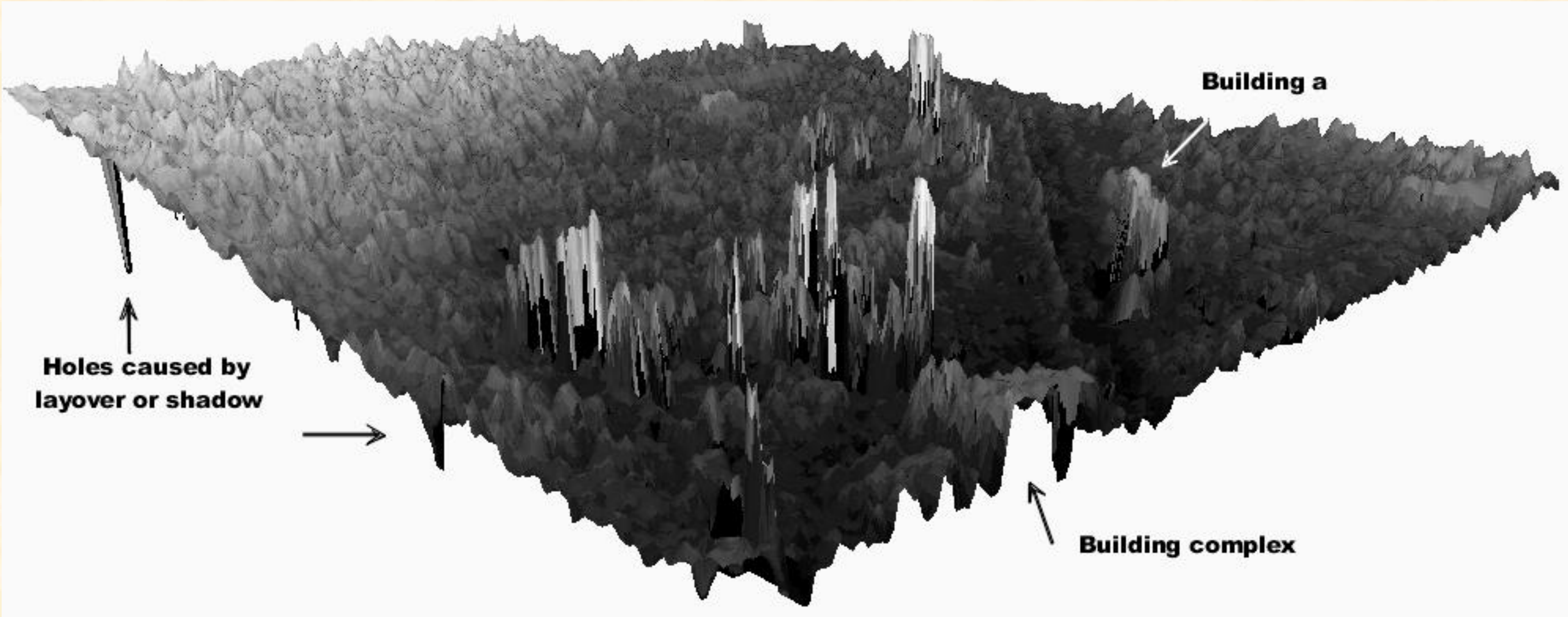
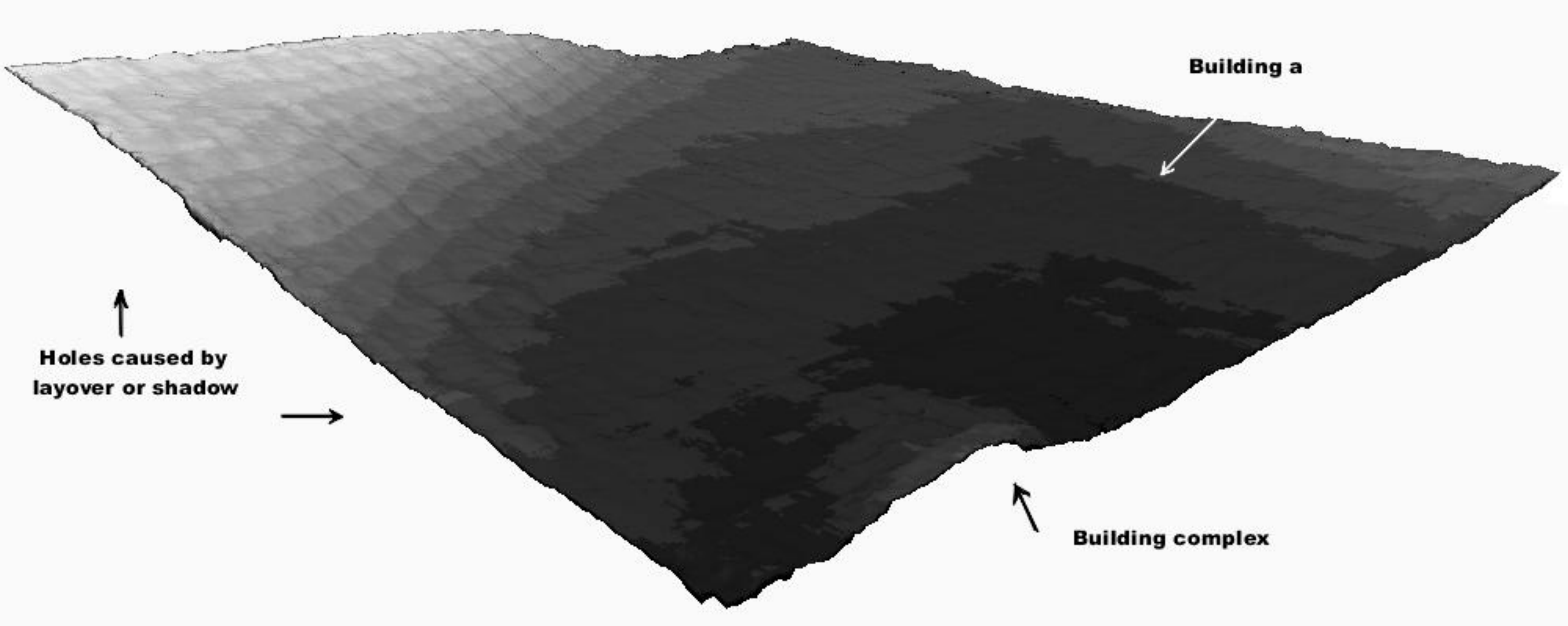
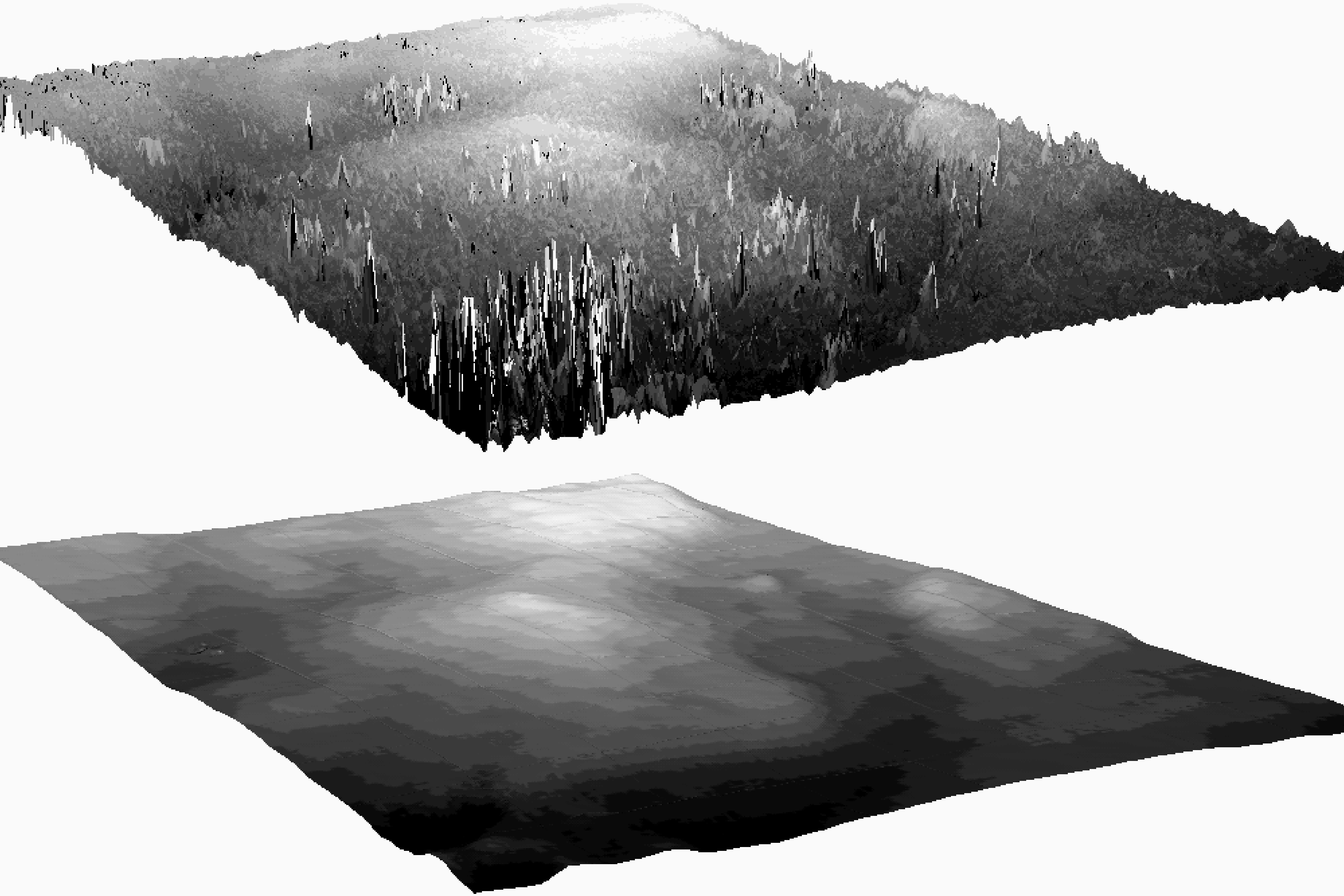
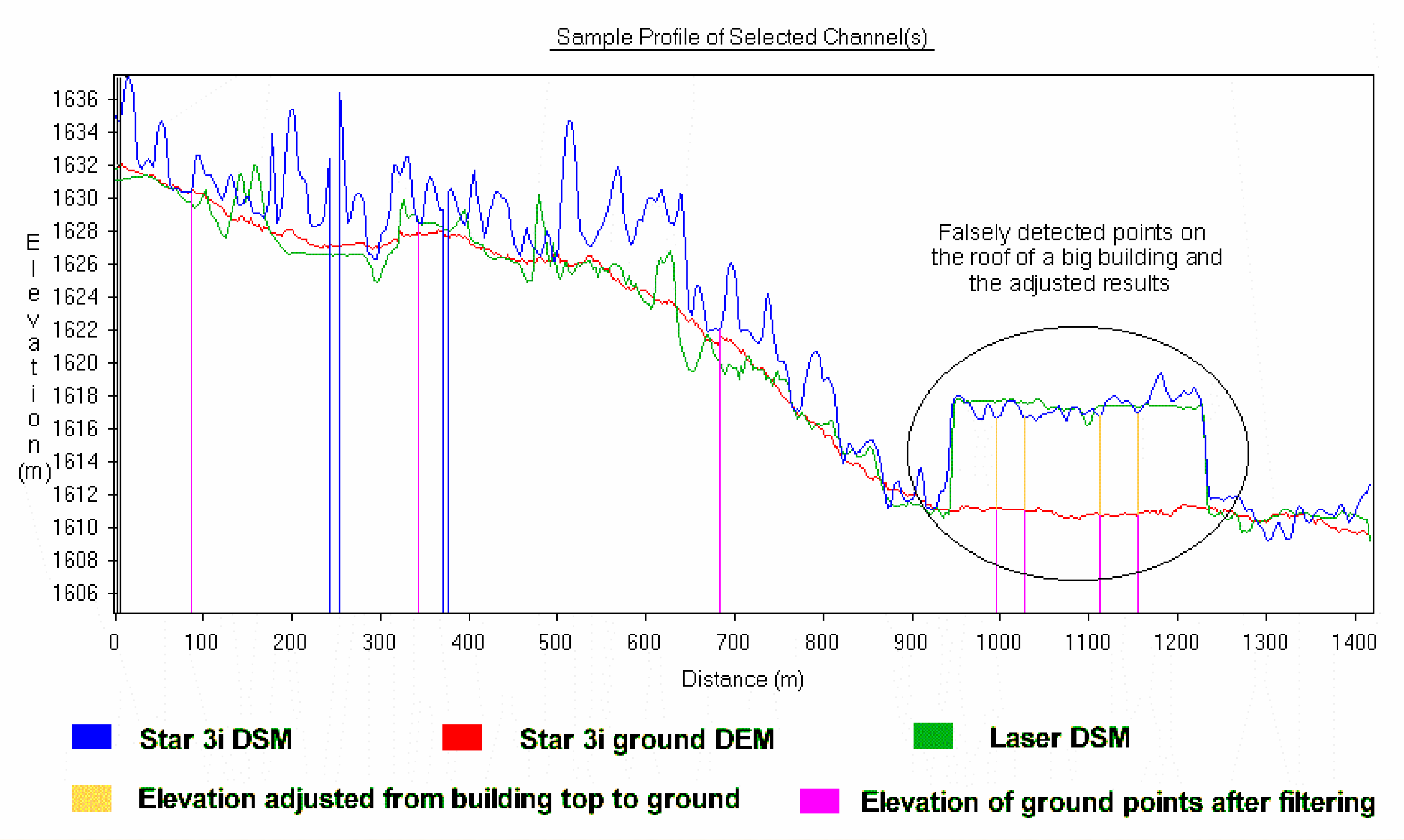


Fig. 1: Interferogram and sections of corresponding DEM of Upper Bavaria.

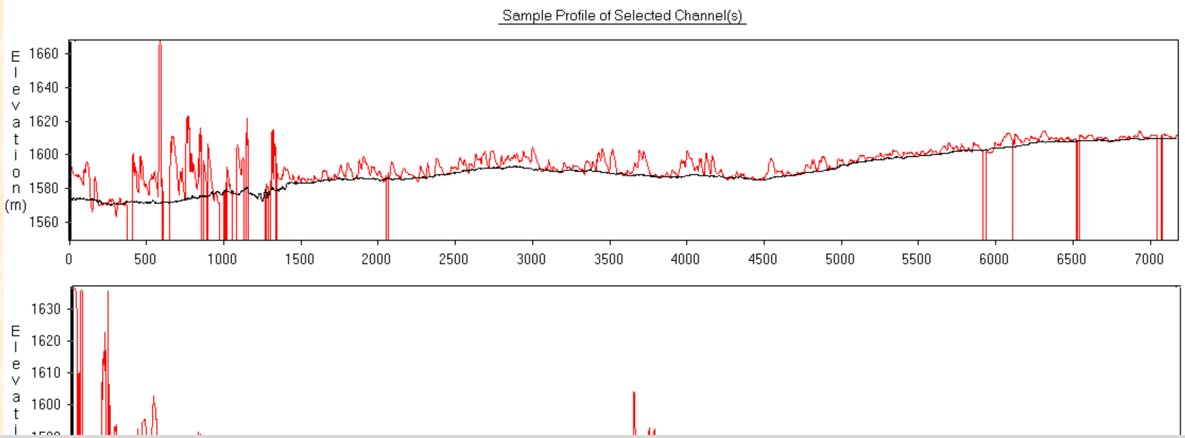

Building a
Holes caused by
layover or shadow
Building complex


Building a
Holes caused by
layover or shadow
Building complex



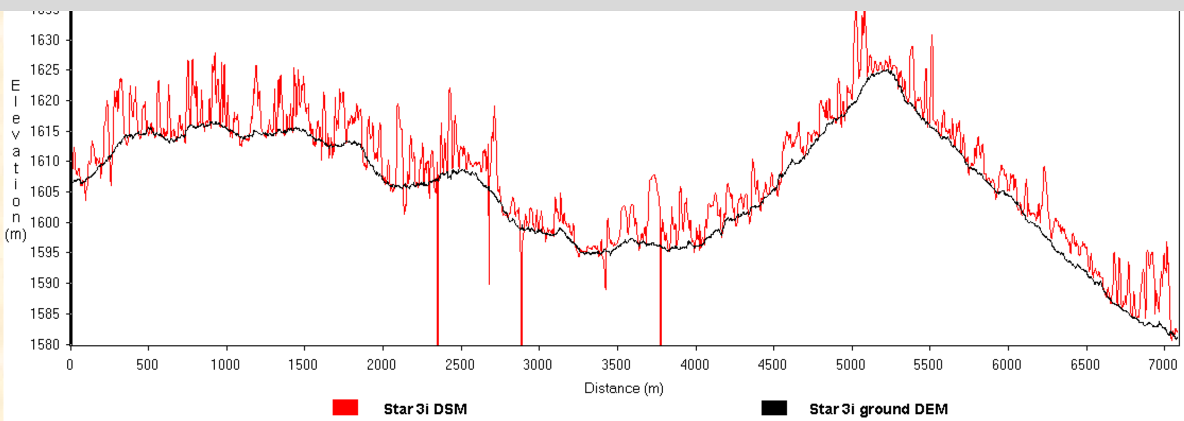


Sample Profile of Selected Channel(s)
Elevation (m)
1636
1634
1632
1630
1628
1626
1624
1622
1620
1618
1616
1614
1612
1610
1608
1606
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
Distance (m)
Falsely detected points on the roof of a big building and the adjusted results
Star 3i DSM
Star 3i ground DEM
Laser DSM
Elevation adjusted from building top to ground
Elevation of ground points after filtering



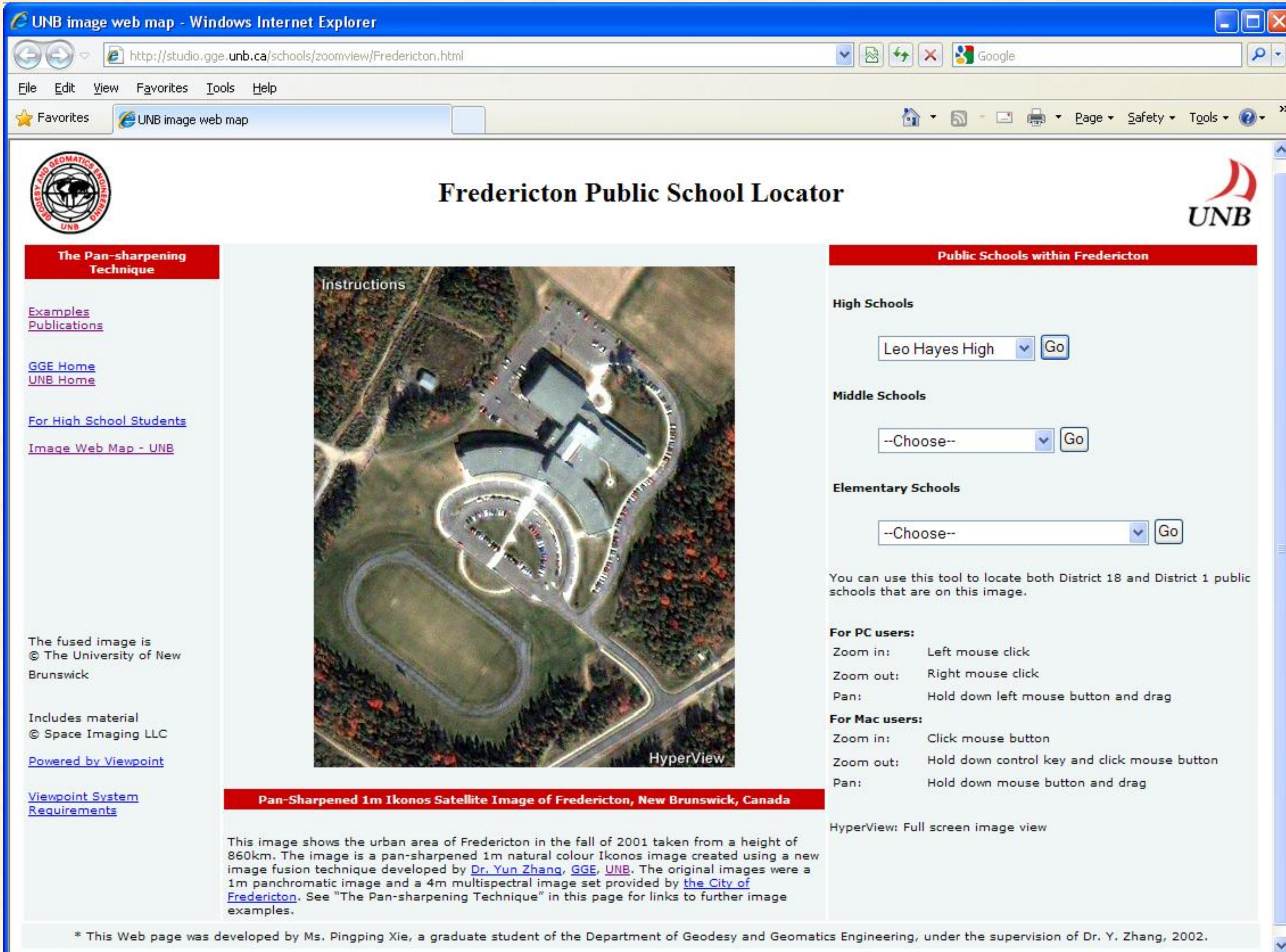
- **ASPRS Talbert Abrams Grand Award**

- **Used by Intermap Technologies Inc.**

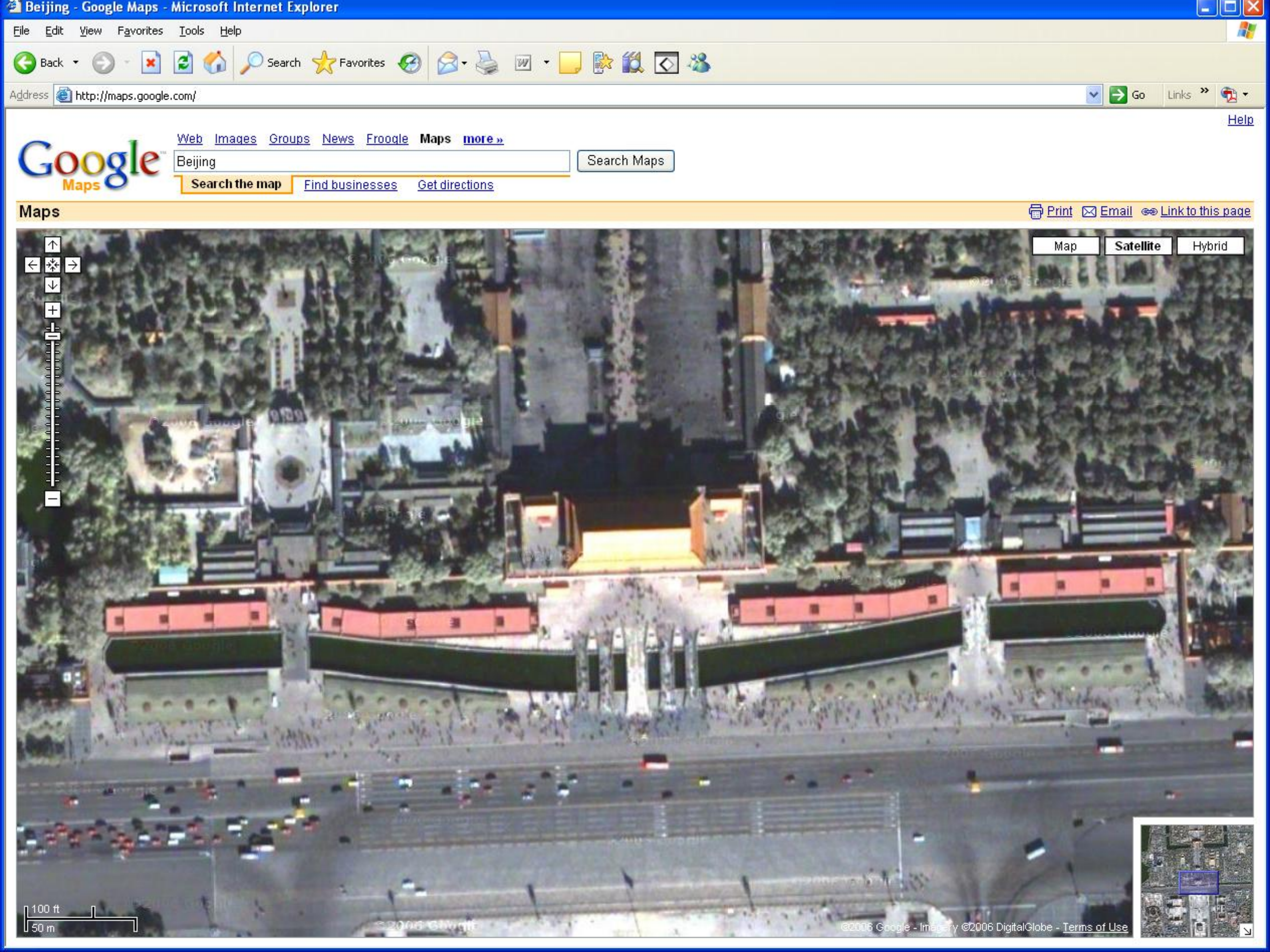


2.g. Online 3D

UNB



Developed in 2002


Beijing - Google Maps - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back
Search
Favorites
Address
http://maps.google.com/
Go
Links
Help
Google Maps
Web Images Groups News Froogle Maps more »
Beijing
Search Maps
Search the map
Find businesses
Get directions
Maps
Print
Email
Link to this page
Map
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Hybrid
100 ft
50 m
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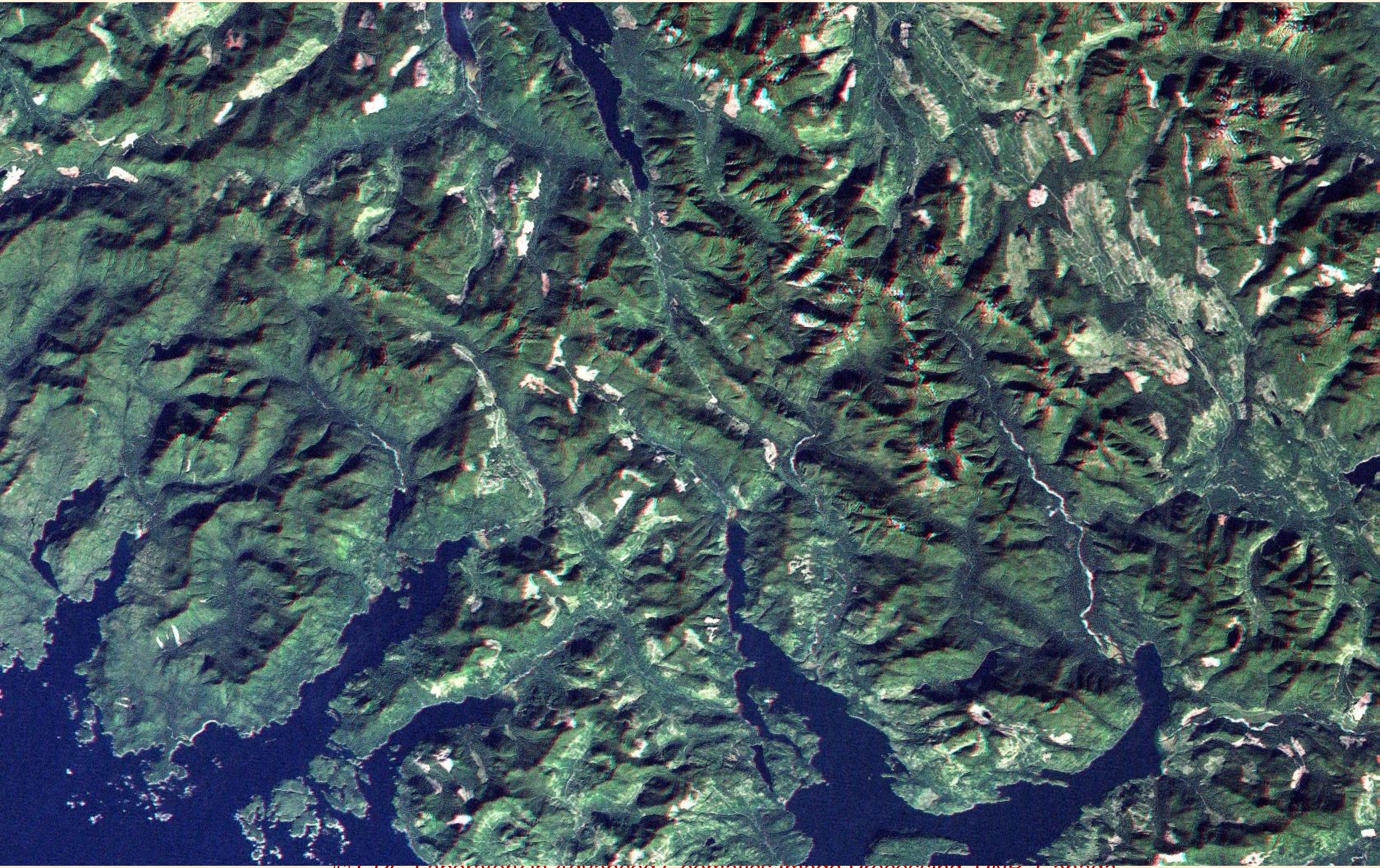
Glasses-free 2D and 3D monitors

by

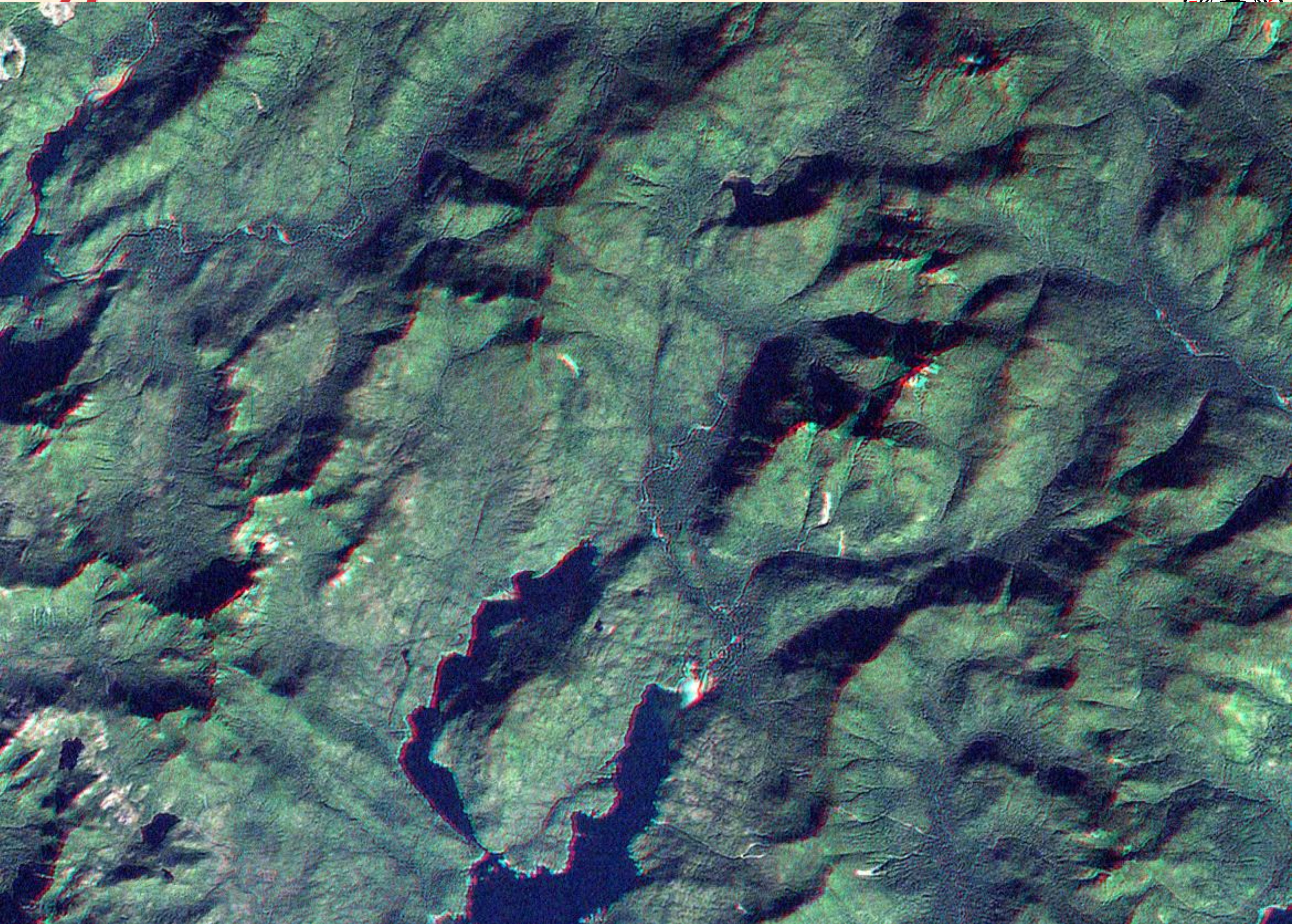
Sharp, Philips, Toshiba

3D display in Kunming airport, China

Web-I-3D, 3D satellite image



Web-I-3D, 3D satellite image

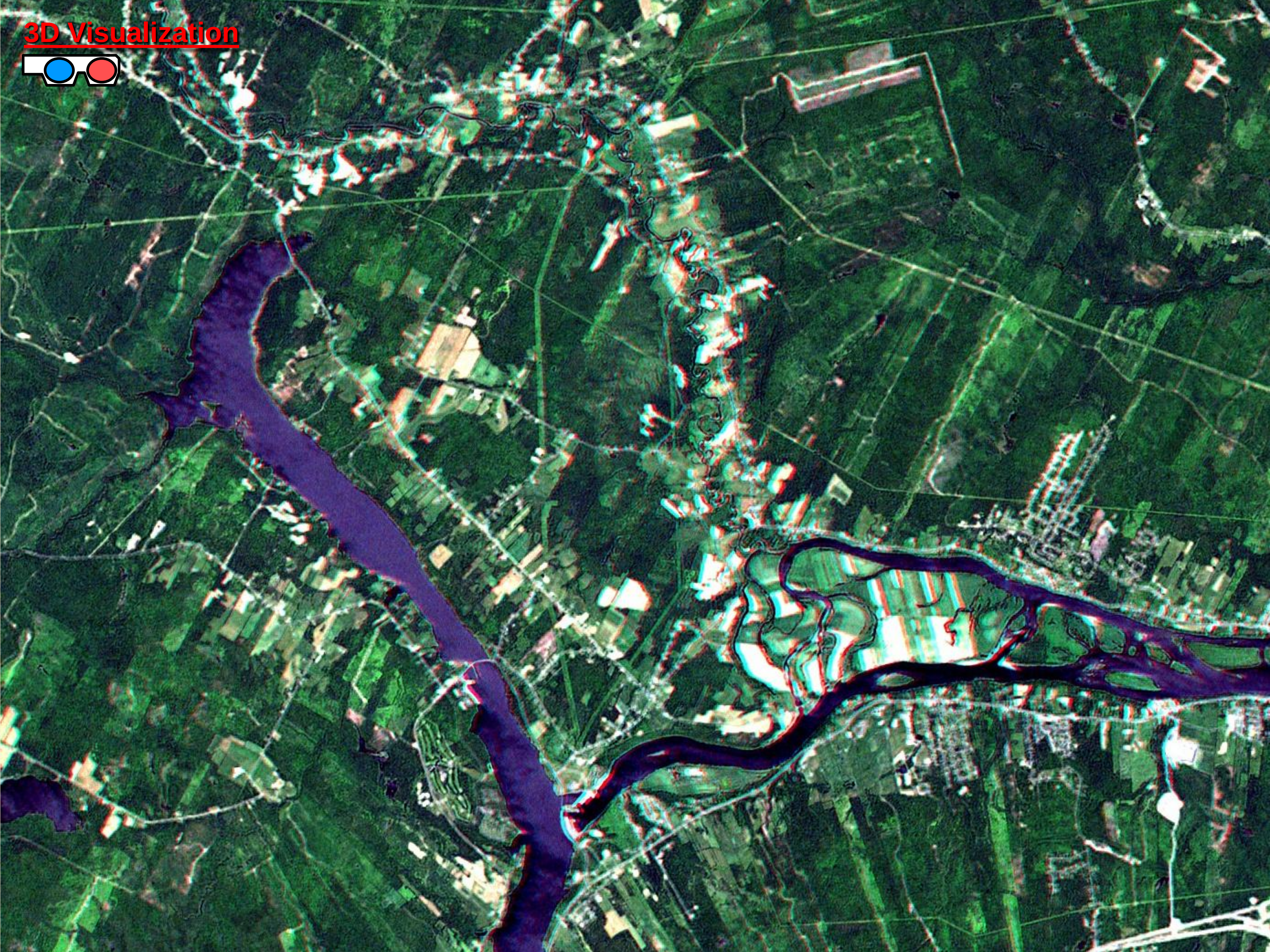


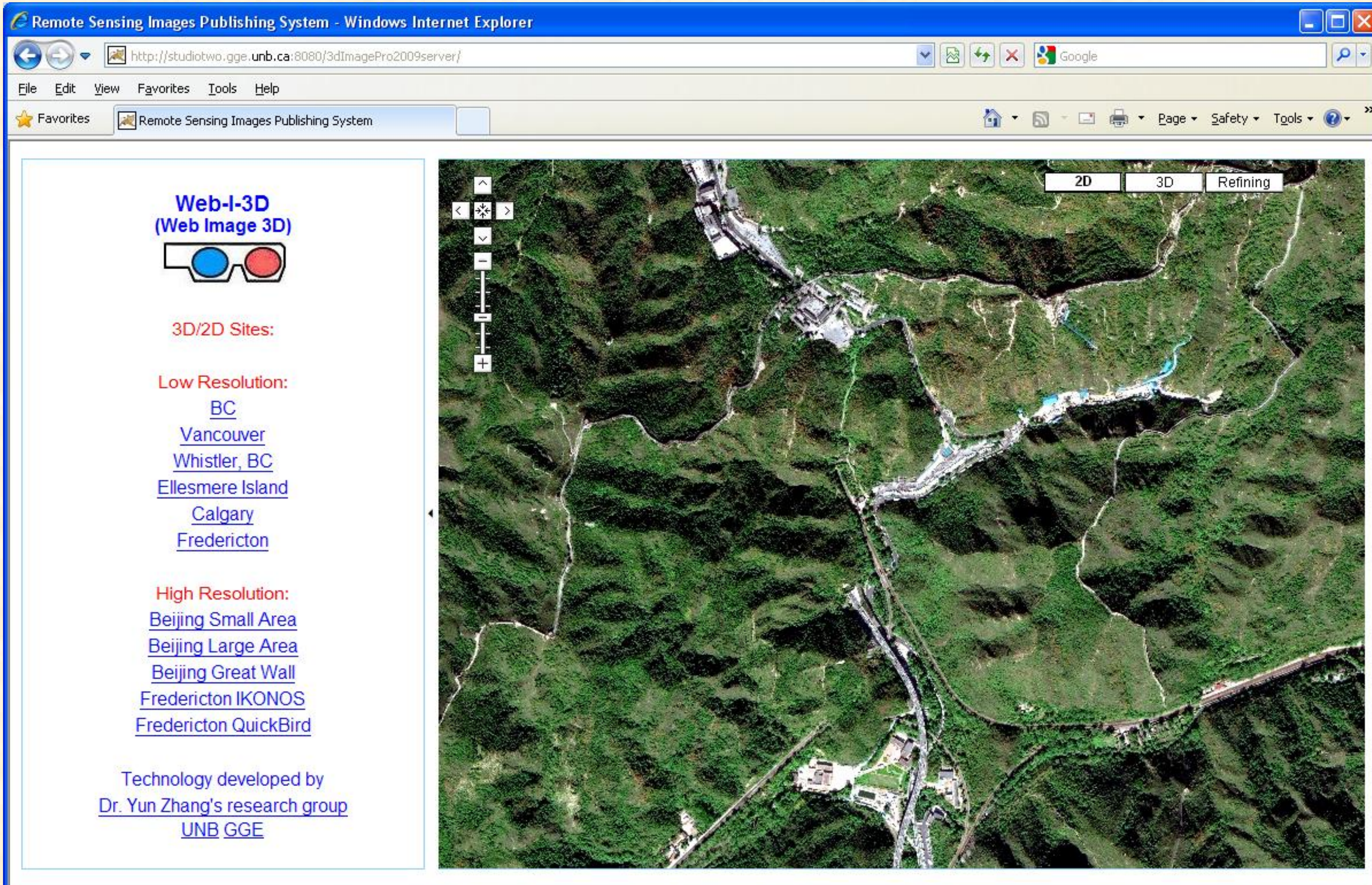
Web-I-3D, 3D satellite image

Fredericton, Canada


3D Visualization

2D Visualization


3D Visualization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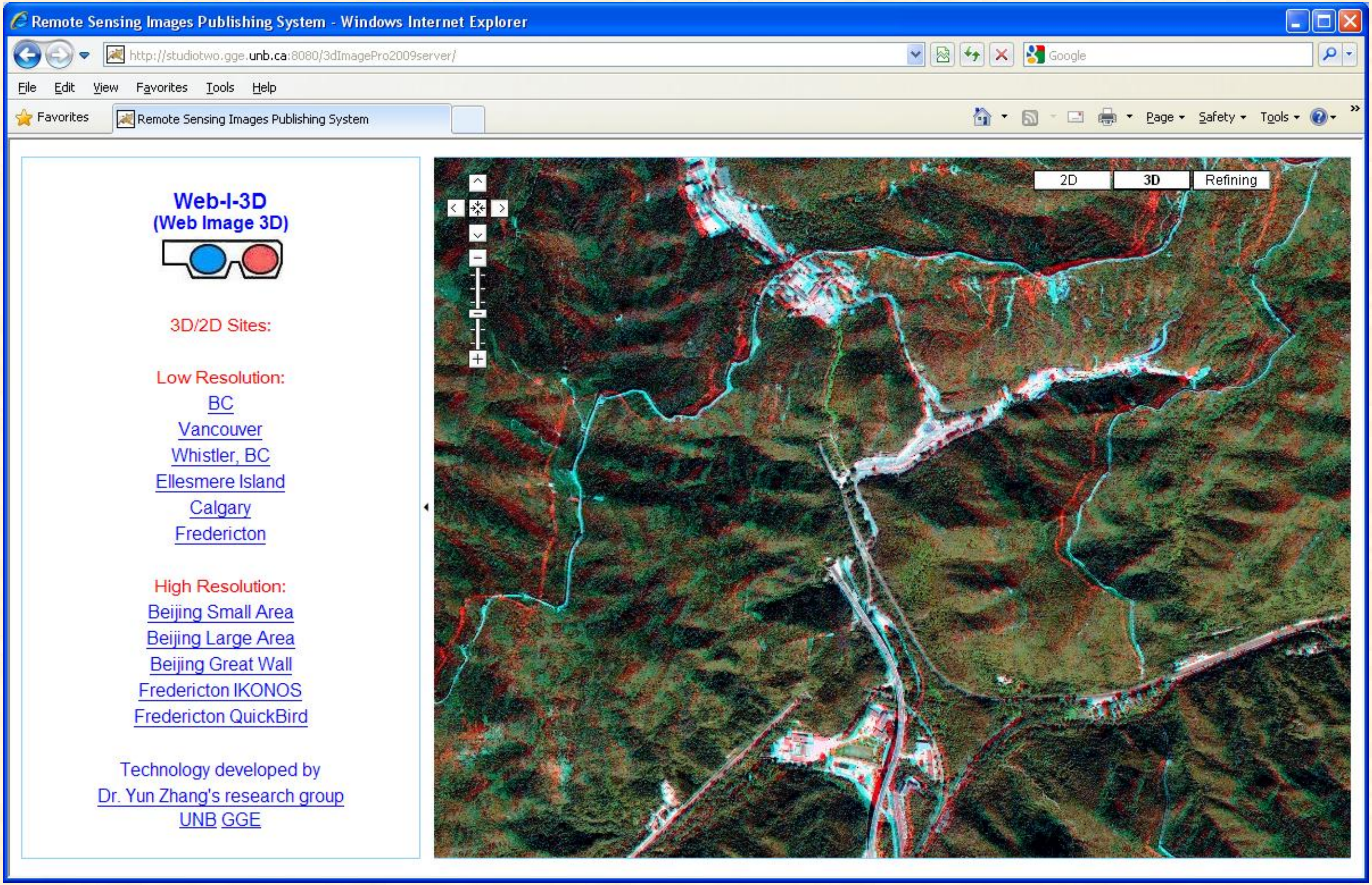
Google
File Edit View Favorites Tools Help
Favorites
Remote Sensing Images Publishing System
Page Safety Tools
Web-I-3D
(Web Image 3D)
3D/2D Sites:
Low Resolution:
BC
Vancouver
Whistler, BC
Ellesmere Island
Calgary
Fredericton
High Resolution:
Beijing Small Area
Beijing Large Area
Beijing Great Wall
Fredericton IKONOS
Fredericton QuickBird
Technology developed by
Dr. Yun Zhang's research group
UNB GGE
2D
3D
Refining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File Edit View Favorites Tools Help
Favorites
Remote Sensing Images Publishing System
Page Safety Tools
Web-I-3D
(Web Image 3D)
3D/2D Sites:
Low Resolution:
BC
Vancouver
Whistler, BC
Ellesmere Island
Calgary
Fredericton
High Resolution:
Beijing Small Area
Beijing Large Area
Beijing Great Wall
Fredericton IKONOS
Fredericton QuickBird
Technology developed by
Dr. Yun Zhang's research group
UNB GGE
2D
3D
Refining

2.h. Generic RPC sensor model refinement

Accuracy comparison between the Bias method and Generic RPC Refinement Method

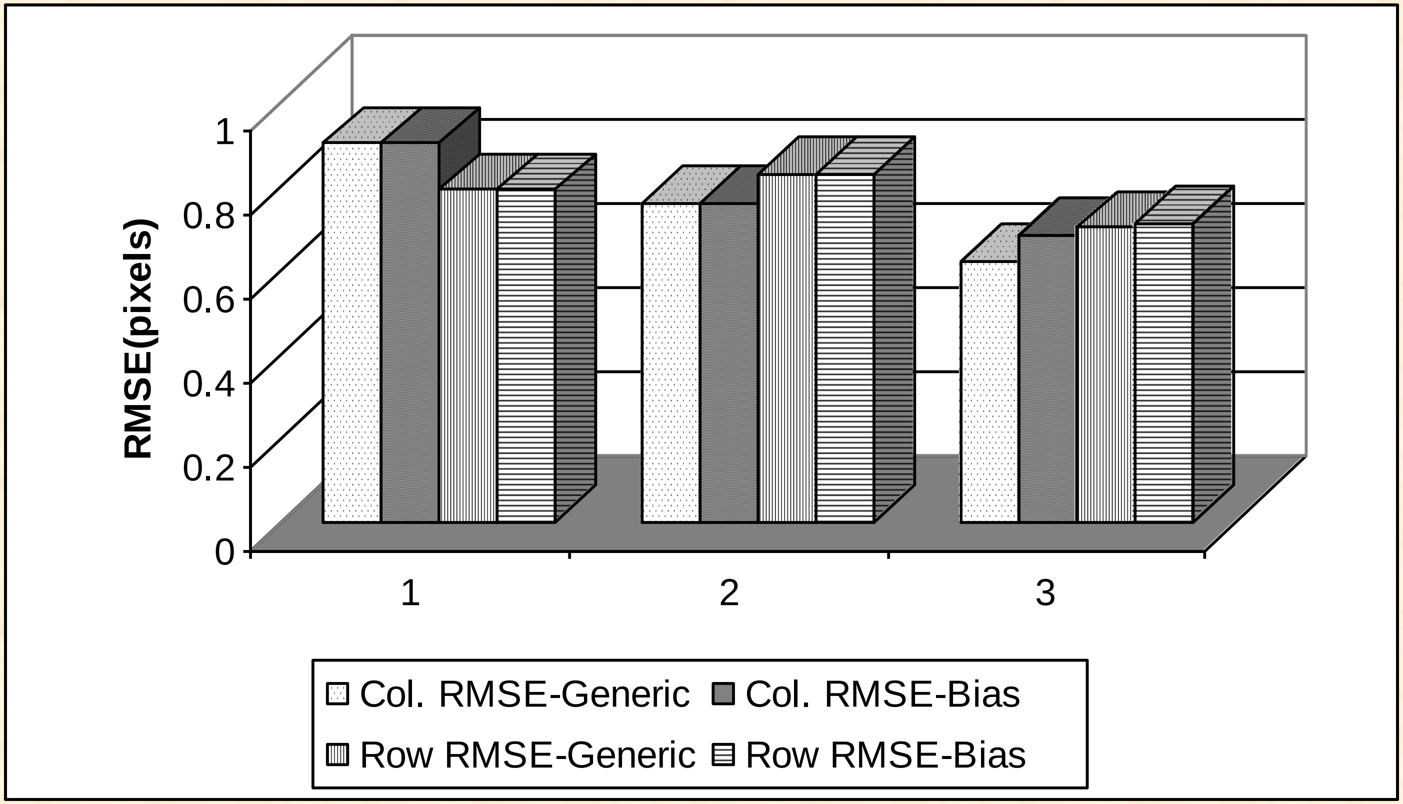


Figure 7: Accuracy comparison between the Bias Compensation method and the Generic RPC Refinement Method developed in CRC-AGIP using Ikonos images (narrow field of view) in 3 cases (all with small sensor position and attitude errors) (Note: RMSE = Root Mean Square Error; Row = Row direction of image; Col. = Column direction of image; Generic = Generic RPC Refinement Method; Bias = Bias Compensation method).

Accuracy comparison between the Bias method and Generic RPC Refinement Method

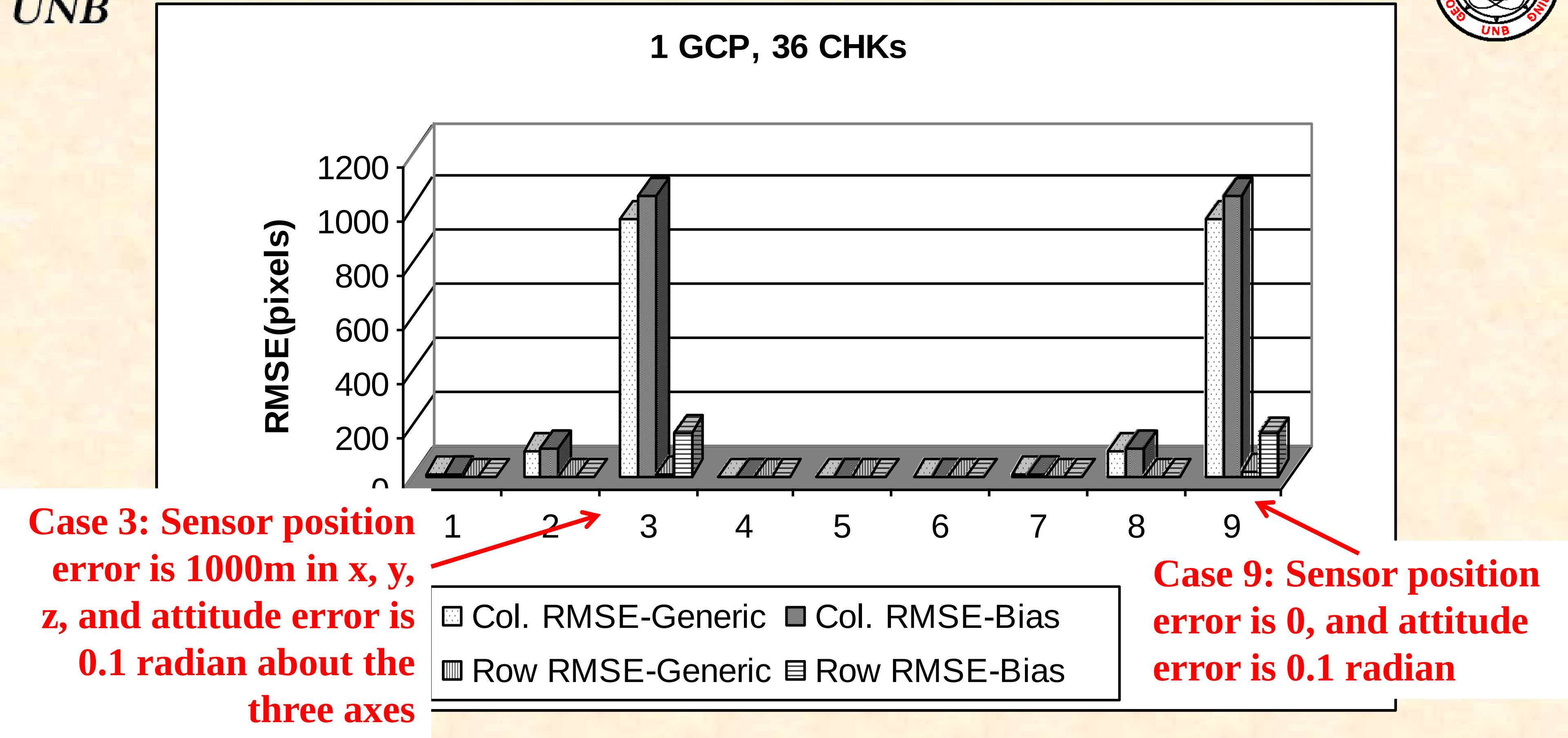
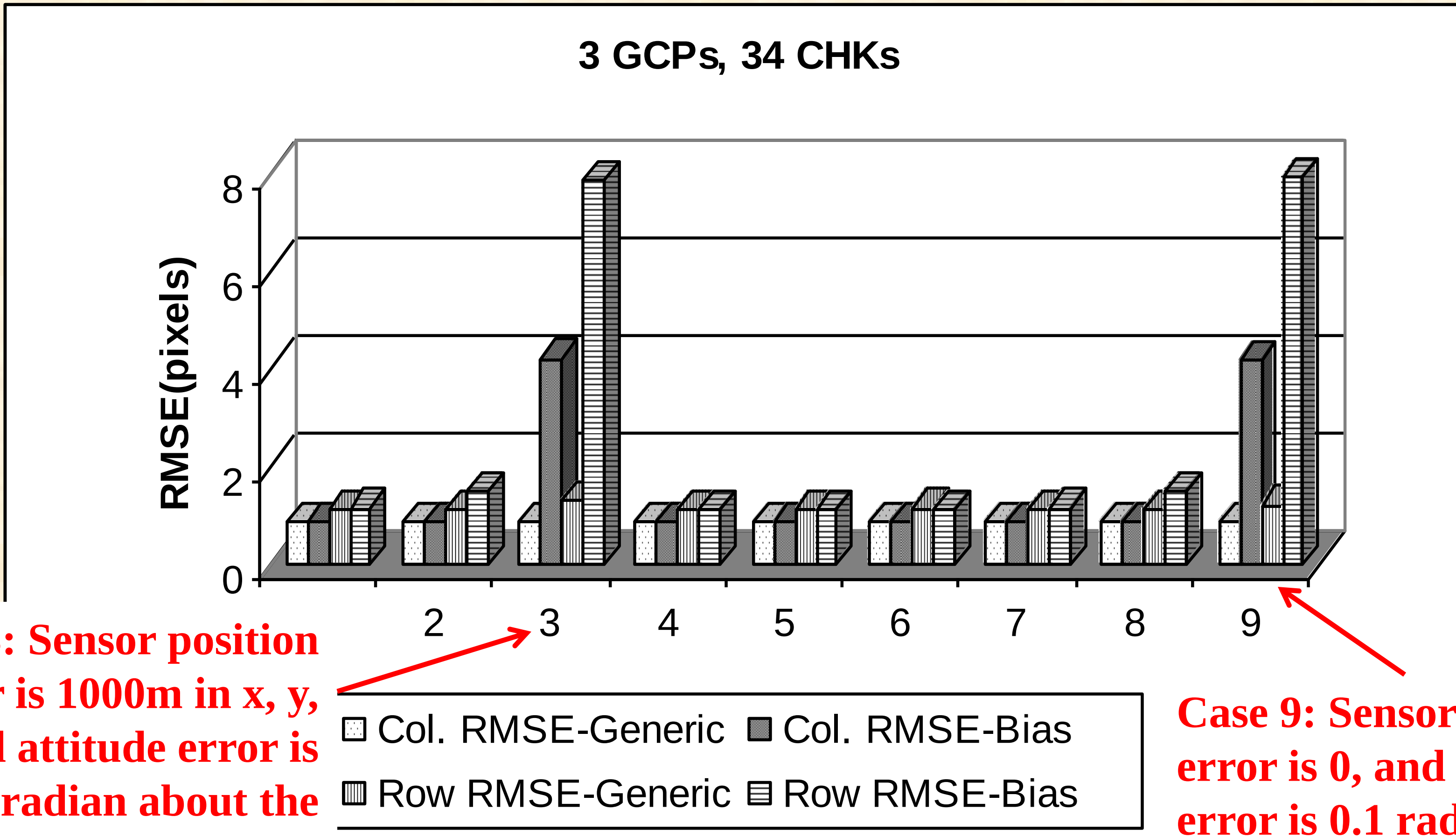


Figure 8: Accuracy comparison between the Bias Compensation method and Generic RPC Refinement Method using simulated SPOT-5 data with 9 different magnitudes of errors and using 1 GCP as ground control and 36 check points for accuracy assessment. (Case 2: the sensor position error is 100m in x, y and z directions, and the sensor attitude error is 0.01 radian about the three axes; Case 3: position error is 1000m in x, y, z, and attitude error is 0.1 radian about the three axes; Case 8: position error is 0, and attitude error is 0.01 radian; Case 9: position error is 0, and attitude error is 0.1 radian; and Cases 1, 4, 5, 6, and 7: the sensor position error varies from 10m to 1000m in x, y, z, and attitude error varies from 0.0 to 0.001 radian.)

Accuracy comparison between the Bias method and Generic RPC Refinement Method



Case 3: Sensor position error is 1000m in x, y, z, and attitude error is 0.1 radian about the three axes

Case 9: Sensor position error is 0, and attitude error is 0.1 radian

Figure 9: Accuracy comparison between the Bias Compensation method and Generic RPC Refinement Method using simulated SPOT-5 data with 9 different magnitudes of errors and using 3 GCP as ground control and 34 check points for accuracy assessment. (The magnitudes of errors of the 9 cases are the same as in Figure 8.)

•**Technology transfer and commercialization:**

1)Image fusion (UNB-PanSharp), to PCI Geomatics (2002), resulting in the best image fusion software and industry standard, used by end users globally, developer: Y. Zhang.

2)Image fusion technology, to DigitalGlobe (2003), for producing all pan-sharpened QuickBird imagery and now WorldView-2 imagery for worldwide distribution, developer: Y. Zhang.

3)Radar image colourization technology, to Intermap Technology (2005), for value added production of SAR images, developers: G. Hong (my PhD student) and Y. Zhang.

4)Colour enhancement technique, to PCI Geomatics (2006), developer: Y. Zhang.

5)Adjustable SAR image colourization, to PCI Geomatics (2008), developer: Y. Zhang.

6)Image fusion technology, to a US company, for security and intelligence (2008), Y. Zhang.

• **Patents:**

(1) US Patent (7,379,590): Method for Generating Natural Colour Satellite Images, 2008, Zhang.

(2) US Patent (7,340,099): System and method for image fusion, 2008, Zhang.

(3) Canadian Patent (2,491,794):Method for Generating Natural Colour Satellite Images, 2009. Zhang.

(4) US Patent Application (11/656,950): Method of Image Segmentation, 2007, with student Maxwell.

(5) US Patent Application (12/775,240): Method of Interest Point Matching for Images, 2010, with student Xiong.

(6) Canadian Patent Application (61/175,934): Method of Interest Point Matching for Images, 2010, with student Xiong.

(7) US Patent Application (12/775,259): Method for RPC Refinement Using Ground Control Information, 2010, with student Xiong.

(8) Canadian Patent Application (61/175,944): Method for RPC Refinement Using Ground Control Information, 2010, with student Xiong.

(9) US Patent Application: Dual Video Camera System and Method, 2010, Zhang.

CRC-AGIP ≠ Agip

(CRC-Laboratory in
Advanced Geomatics Image Processing)

(Azienda Generale Italiana Petroli)
established in 1926.

Thank you!