Copyright statement

Liz Buxton, External Relations & Marketing Manager, IBRU,
Department of Geography, Durham University DH1 3LE, UK
Tel: +44 191 334 1965 ◆ Fax: +44 191 334 1962 ◆ Email: e.a.buxton@durham.ac.uk

Thank you.

IBRU

Durham University

Sources of Geographical Data
Remotely Sensed Imagery

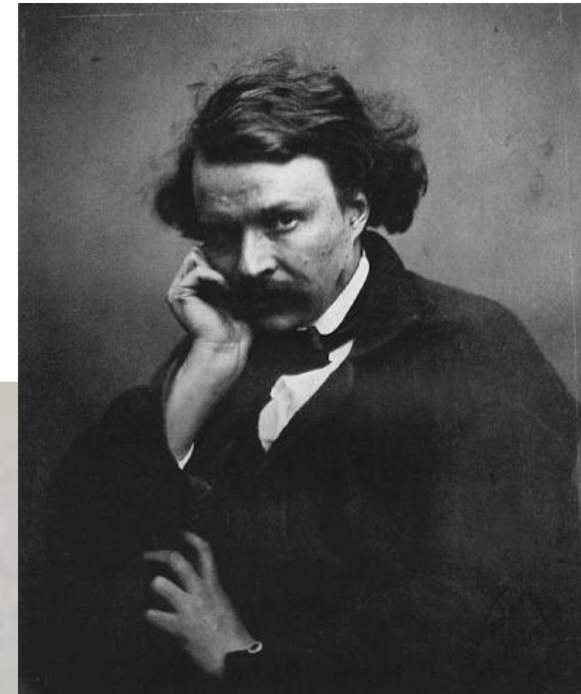
Professor Daniel Donoghue
Durham University

Outline

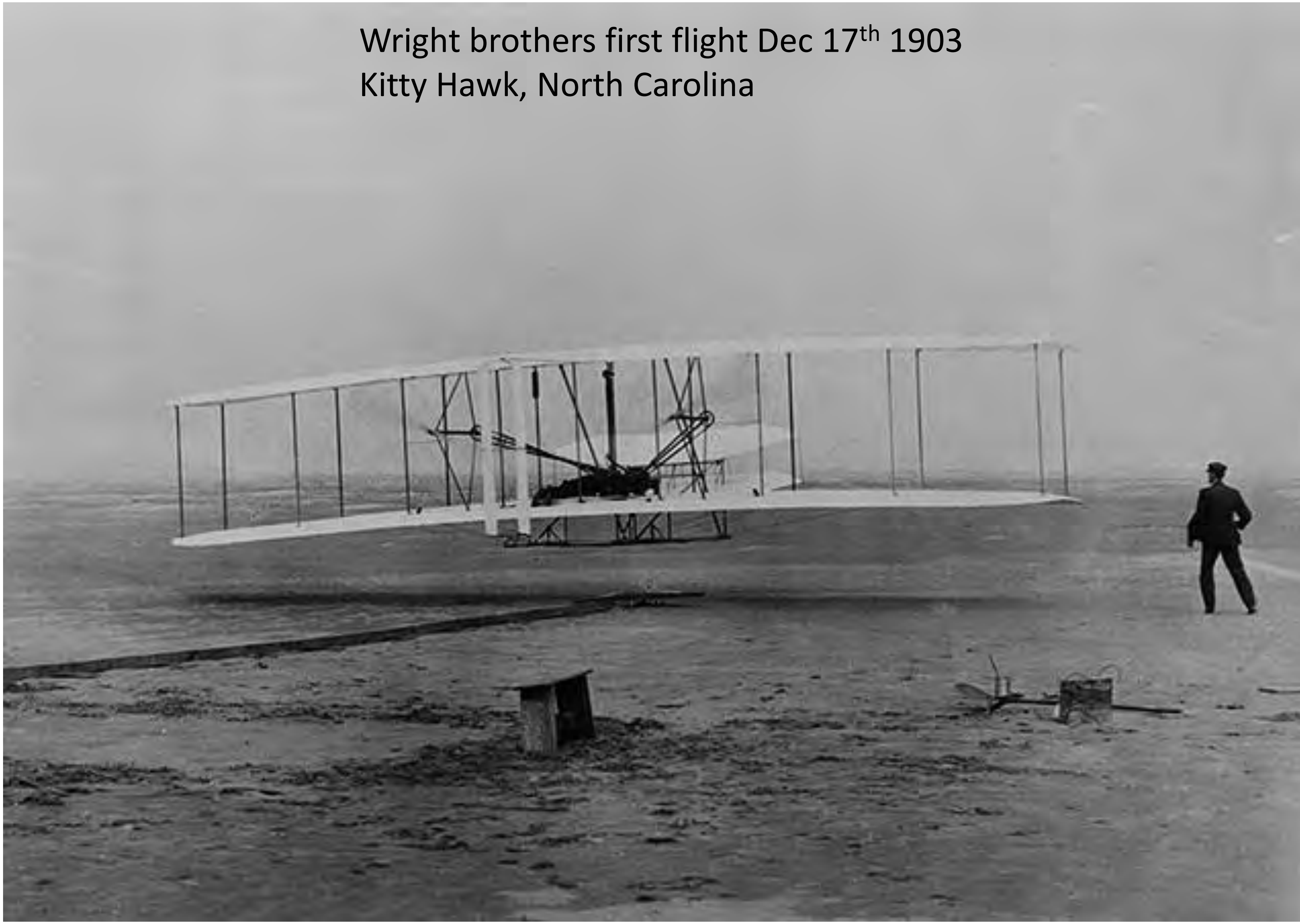
1. Background
2. Types of Imagery
   - Google
   - Aerial Photography
   - Satellite Imagery
   - RADAR Imagery
   - LiDAR data
3. Uses of Remote Sensing in Boundary Work
4. Acquiring and Interpreting Imagery

The first photographs date from circa 1826

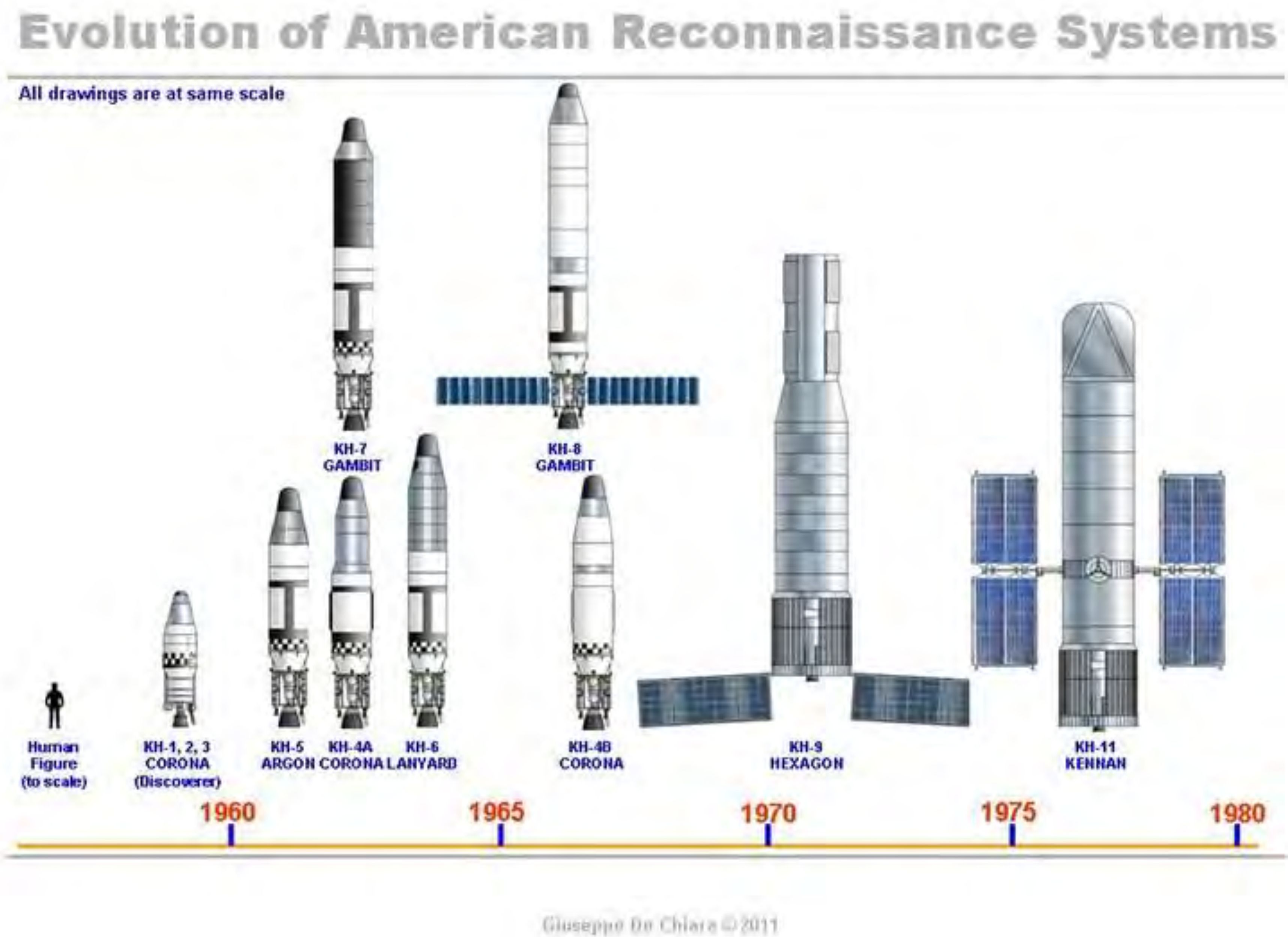
Felix Nadar 1858 – First aerial photograph from balloon using the calotype process of Henry Fox-Talbot using silver iodide



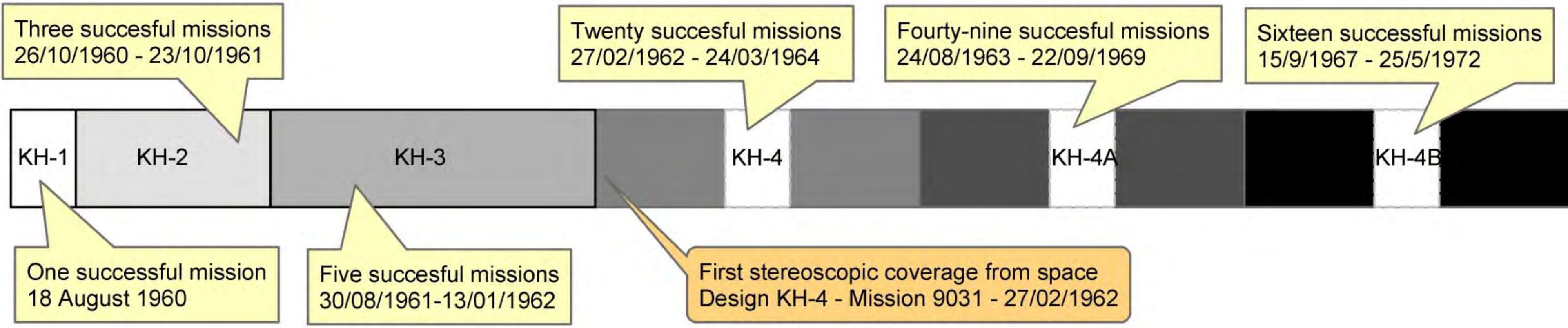
Wright brothers first flight Dec 17th 1903
Kitty Hawk, North Carolina

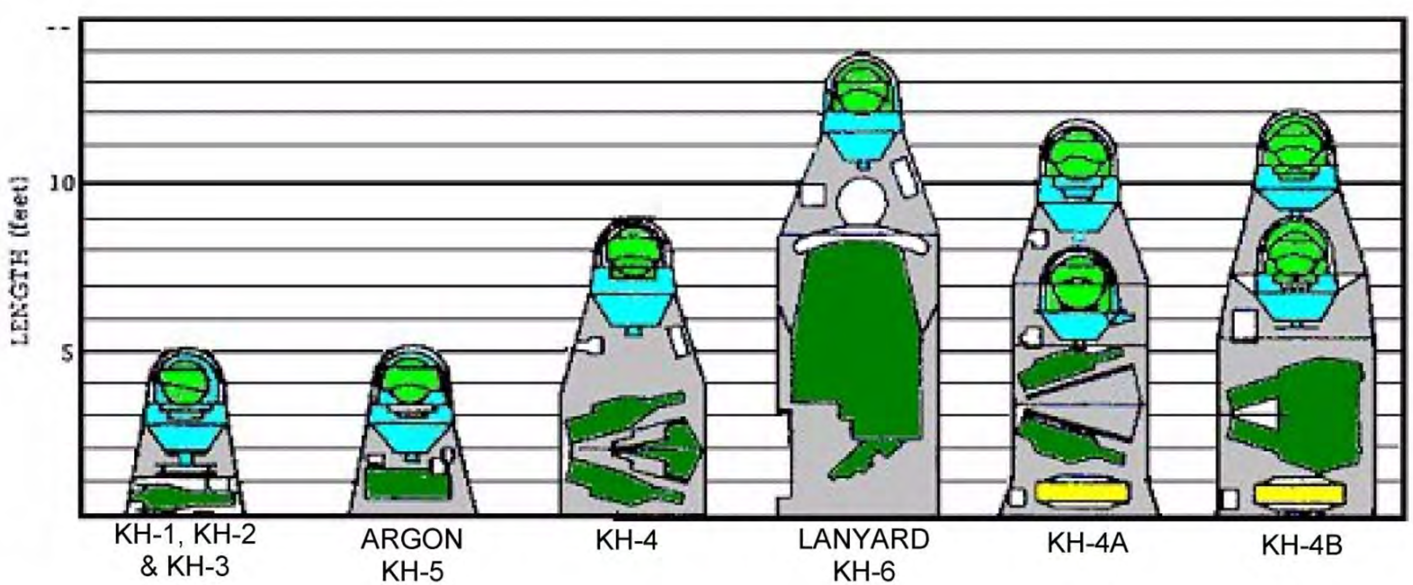


Cuba 1962 - Low level photography

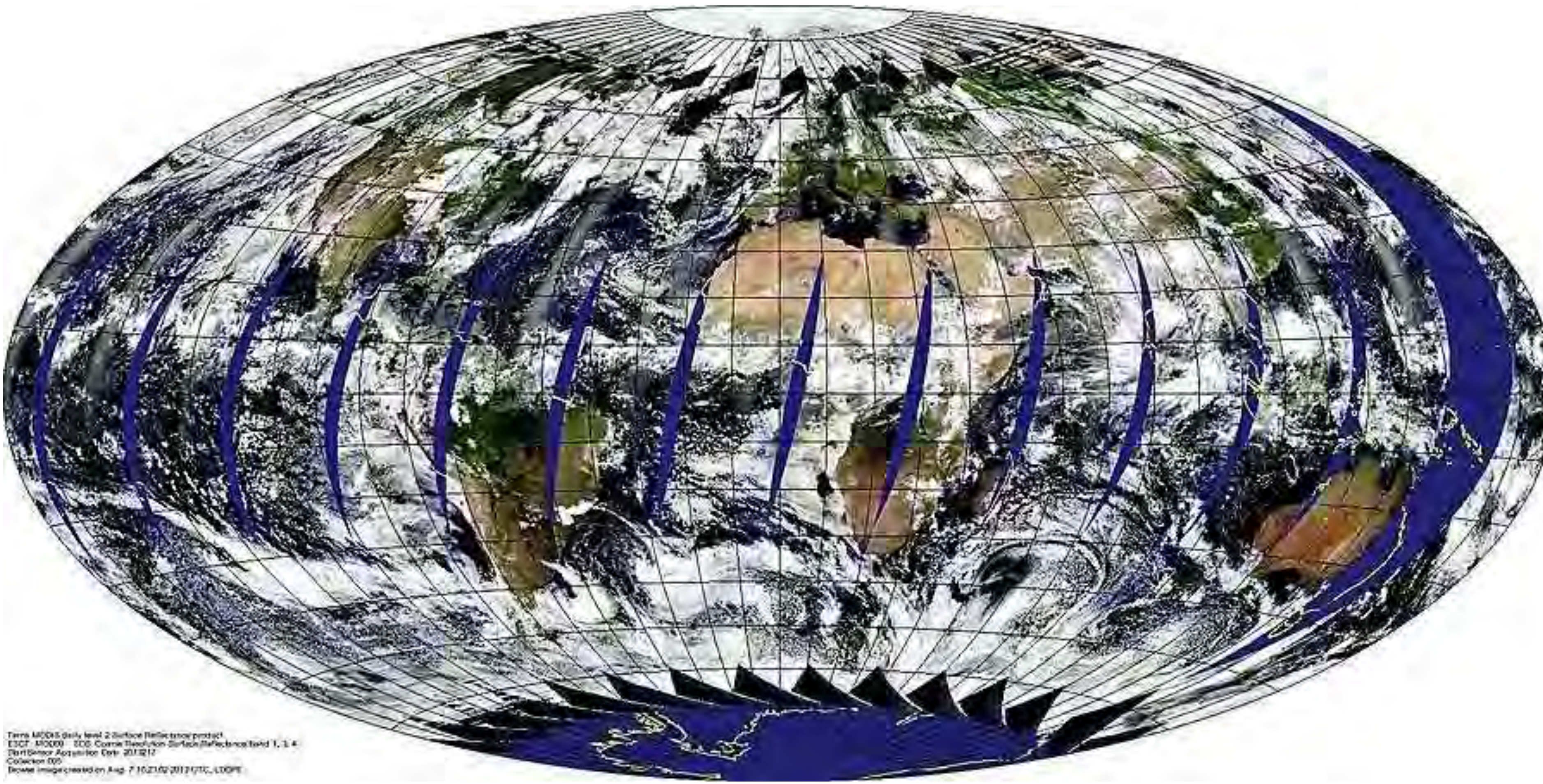

Evolution of American Reconnaissance Systems
All drawings are at same scale
KH-7
GAMBIT
KH-8
GAMBIT
Human
Figure
(to scale)
KH-1, 2, 3
CORONA
(Discoverer)
KH-5
ARGON
KH-4A
CORONA
KH-6
LANYARD
KH-4B
CORONA
KH-9
HEXAGON
KH-11
KENNAN
1960
1965
1970
1975
1980
Giuseppe De Chiara © 2011

CORONA - Six designs





Daily MODIS image for August 5, 2013



Outline

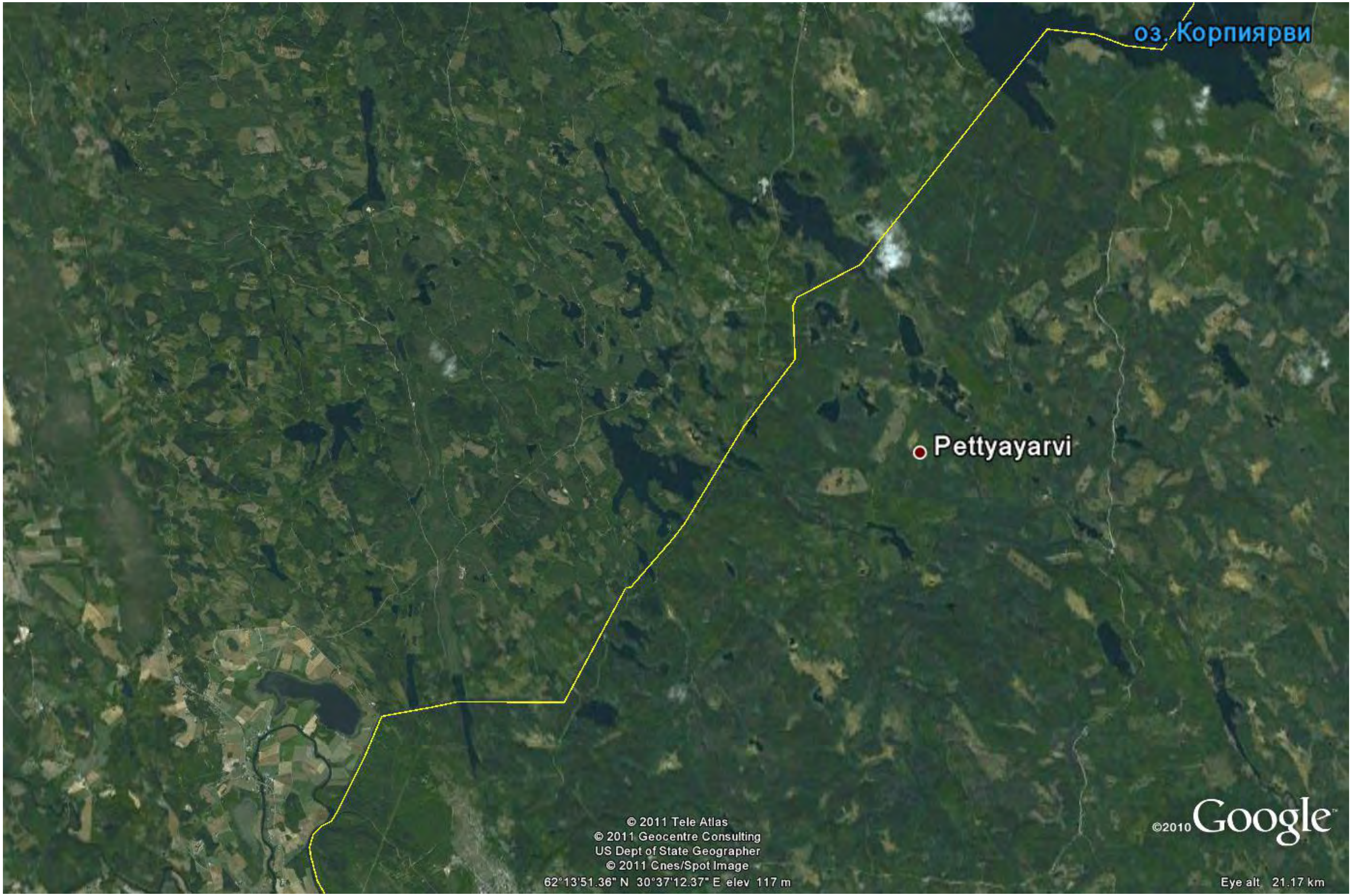
1. Background
2. Types of Imagery
   - Google
   - Aerial Photography
   - Satellite Imagery
   - RADAR Imagery
   - LiDAR data
3. Uses of Remote Sensing in Boundary Work
4. Acquiring and Interpreting Imagery

Outline

1. Background
2. Types of Imagery
   - Google
   - Aerial Photography
   - Satellite Imagery
   - RADAR Imagery
   - LiDAR data
3. Uses of Remote Sensing in Boundary Work
4. Acquiring and Interpreting Imagery

Akhziv Canyon
Golan Heights
Haifa
Irbid
Pardes Hanna-Karkur
Umm al-Fahm
Dayr al-Ghusun
Netanya
Ajloun
Jarash
Nablus
Tel Aviv-Yafo
Al Zarqa
Balqa
West Bank
palestine
Amman
© 2011 Google
US Dept of State Geographer
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2011 DigitalGlobe
32°39'09.31" N 34°33'25.88" E elev -1081 m
©2010 Google
Eye alt 179.66 km


© 2007 Europa Technologies


оз. Корпиярви
Pettyayarvi
© 2011 Tele Atlas
© 2011 Geocentre Consulting
US Dept of State Geographer
© 2011 Cnes/Spot Image
62°13'51.36" N 30°37'12.37" E elev 117 m
©2010 Google
Eye alt 21.17 km

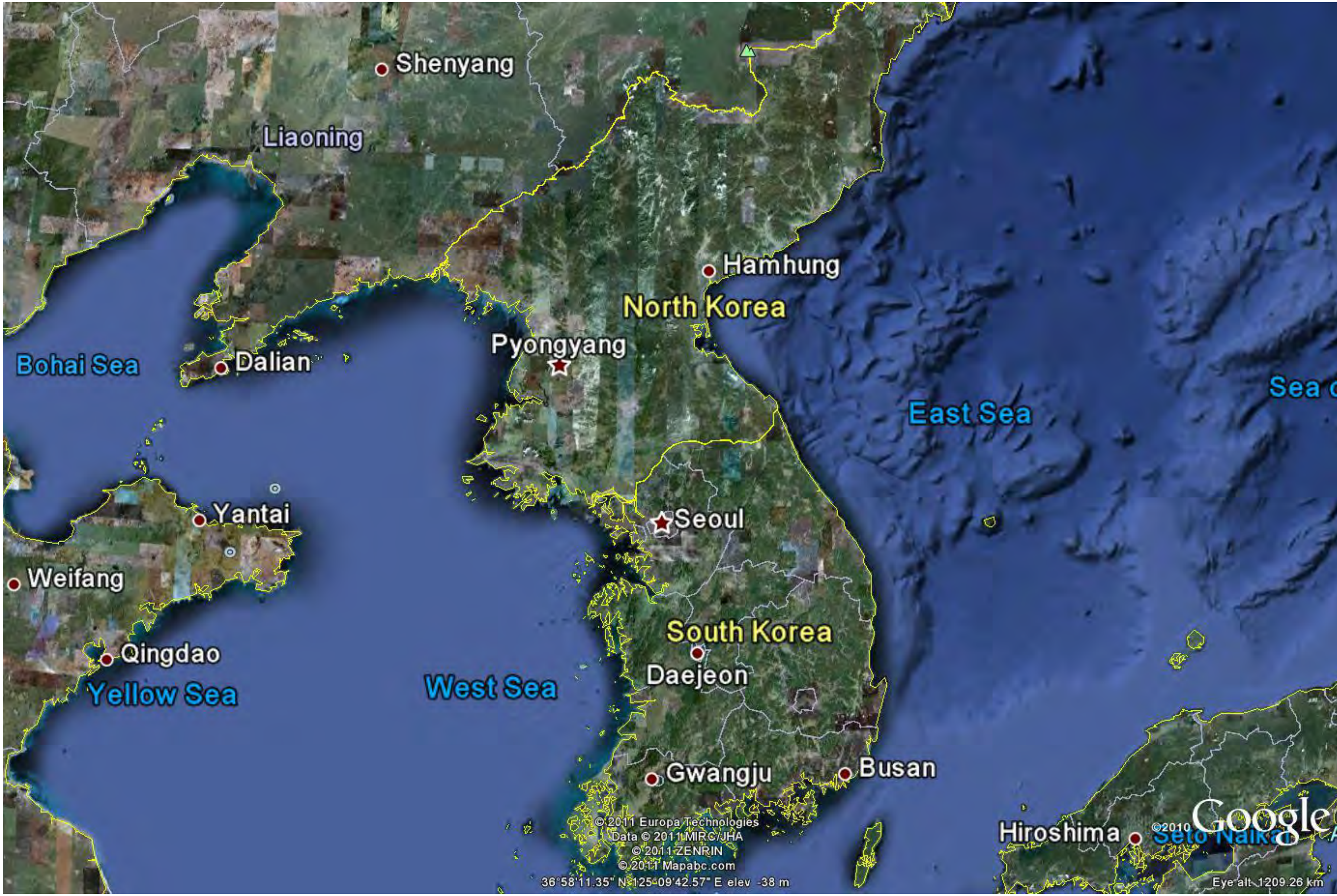

Shenyang
Liaoning
Hamhung
North Korea
Pyongyang
Bohai Sea
Dalian
East Sea
Sea o
Yantai
Seoul
Weifang
South Korea
Qingdao
Daejeon
Yellow Sea
West Sea
Gwangju
Busan
Hiroshima
Seto Naikai
© 2011 Europa Technologies
Data © 2011 MIRC/JHA
© 2011 ZENRIN
© 2011 Mapabc.com
36°58'11.35" N 125°09'42.57" E elev -38 m
©2010 Google
Eye alt 1209.26 km


Image © 2011 GeoEye
©2010


Limbe
Pepillo Salcedo
Monti Cristi
Valverde
Mao
Gonaives
Dajabón
Santiago Rodríguez
Corocito
Santiago
Hinche
Saint-Marc
L' Artibonite
Haiti
La Estrelleta
San Juan
San Juan de la Maguana
Arcahaie
Port-au-Prince Bay
Port-au-Prince
Baoruco
© 2011 Europa Technologies
US Dept of State Geographer
© 2011 Google
Image NASA
19°24'23.96" N 72°27'38.25" W elev 617 m
©2010 Google
Eye alt 191.88 km

Outline

1. Background
2. Types of Imagery
   - GPS
   - Google
   - Aerial Photography
   - Satellite Imagery
   - RADAR Imagery
   - LiDAR data
3. Uses of Remote Sensing in Boundary Work
4. Acquiring and Interpreting Imagery

NATURAL ENVIRONMENT RESEARCH COUNCIL

Airborne Research & Survey Facility

Instruments 2014/15

- Leica RCD105 39 mega pixel digital camera
- Specim Fenix
- Specim Owl (Thermal)
- Airbus X and S-band SAR
- Leica ALS50 (II) laser scanner
- Applanix POS and IPAS attitude and position

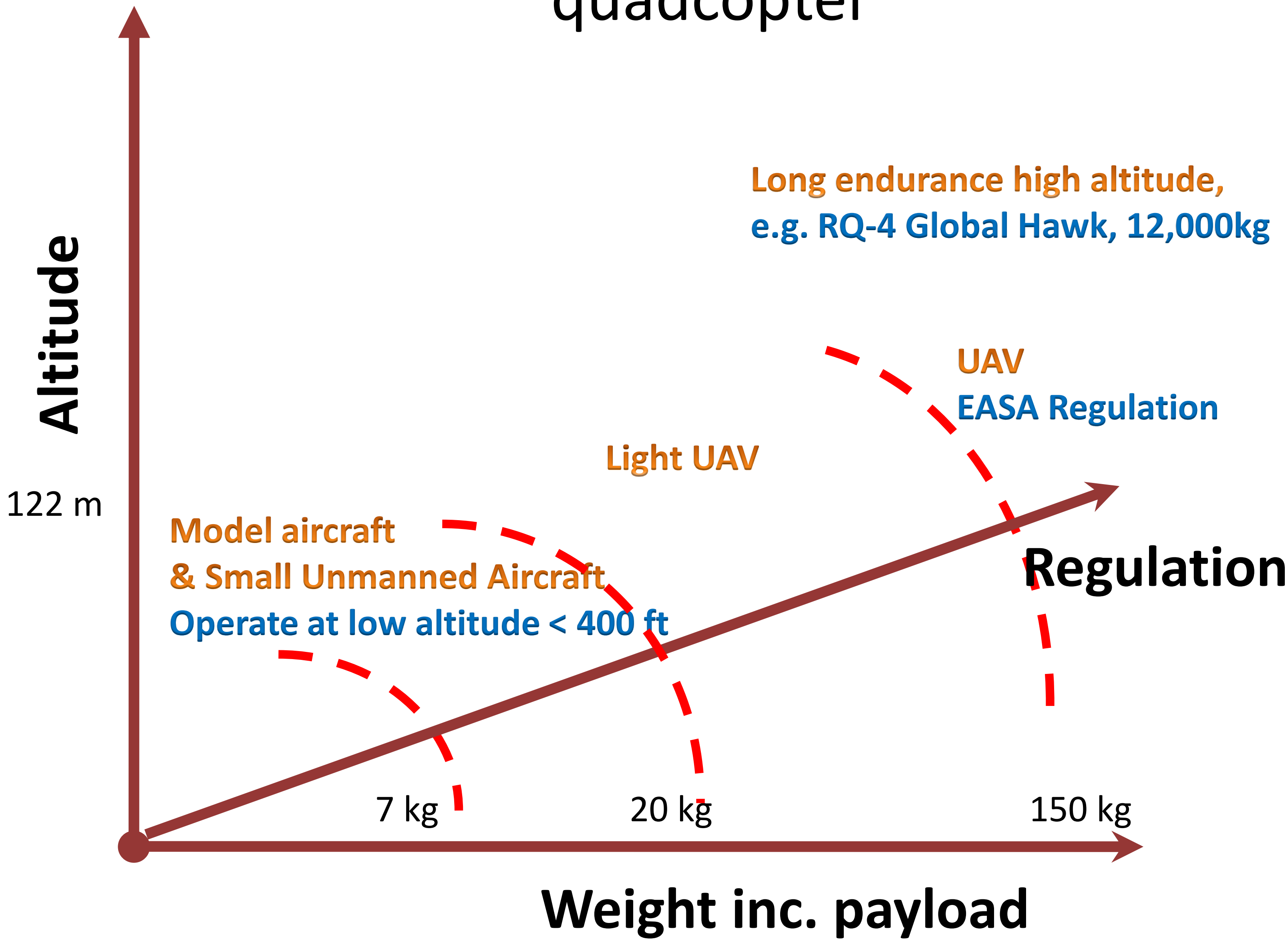
a) Response design: GeoVantage

Advantages

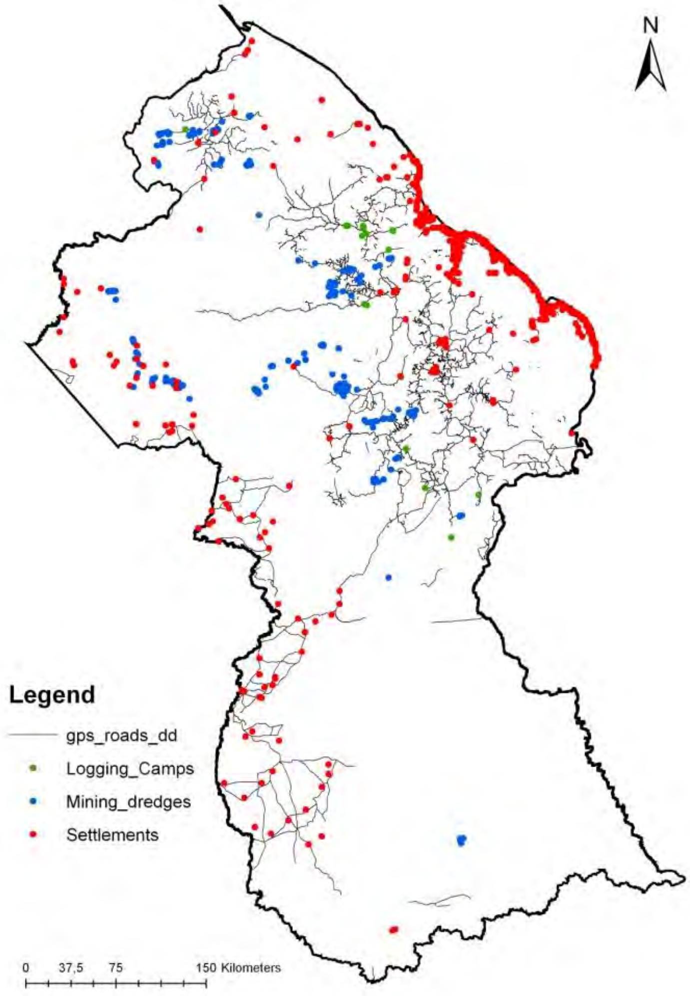
- Provides random sample that covers forest and forest change
- System adaptable to suit local conditions – i.e. cloud cover
- low cost compared to space data

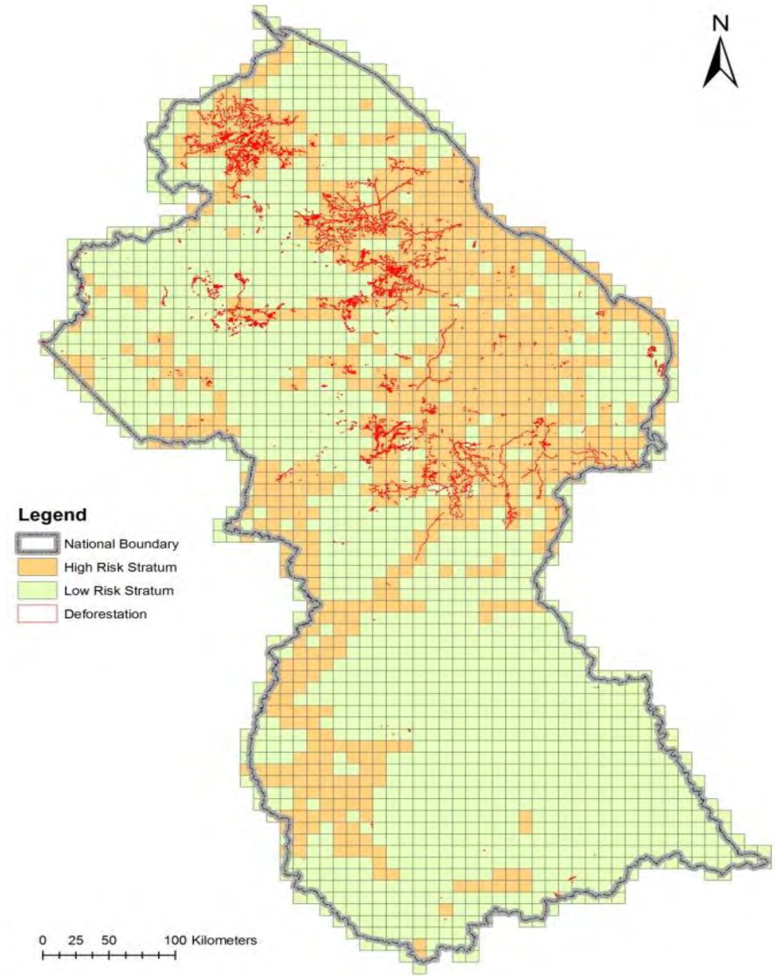

mc-12

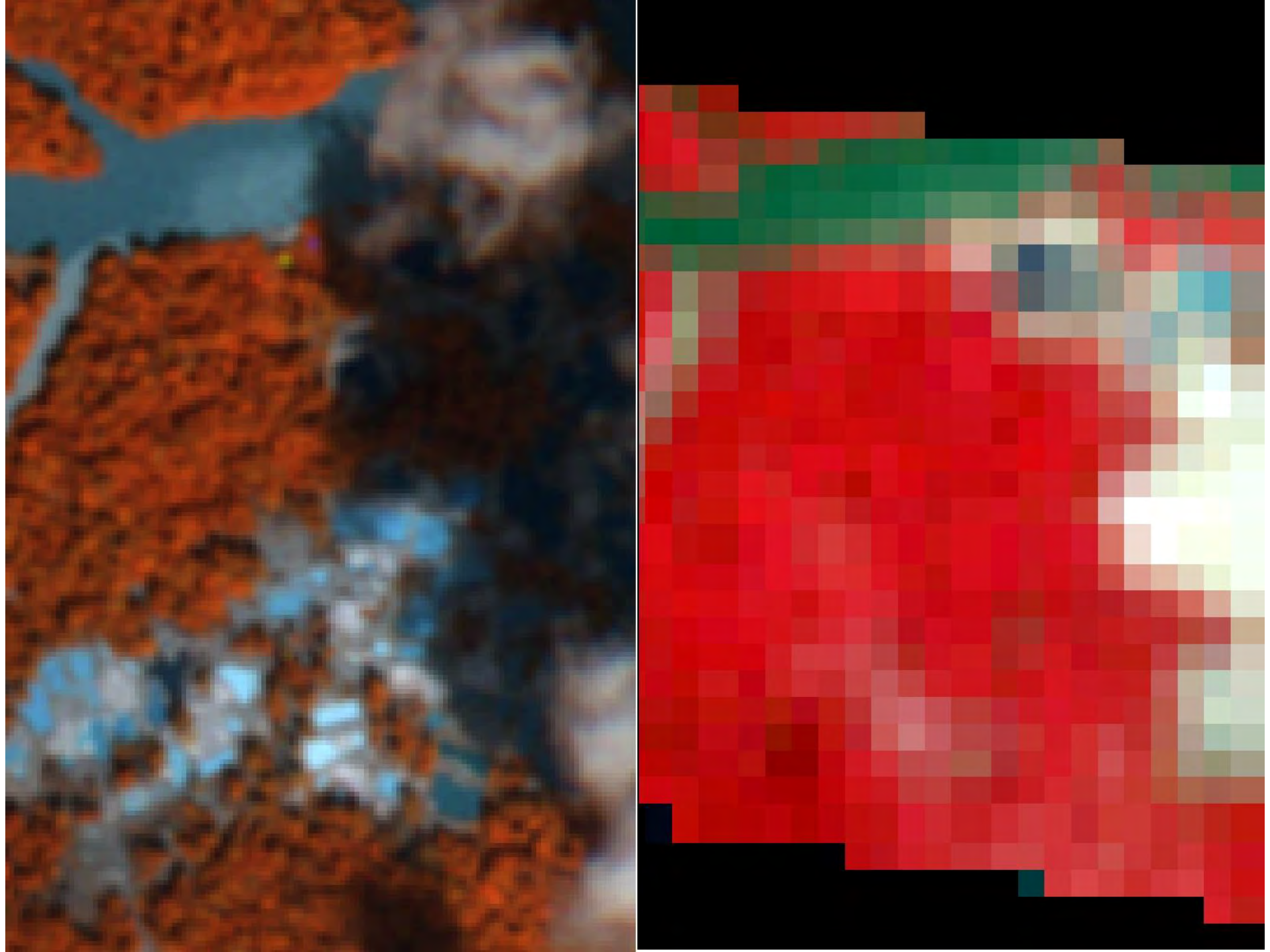
Low-altitude = smallUAV, balloon, blimp, kite, quadcopter

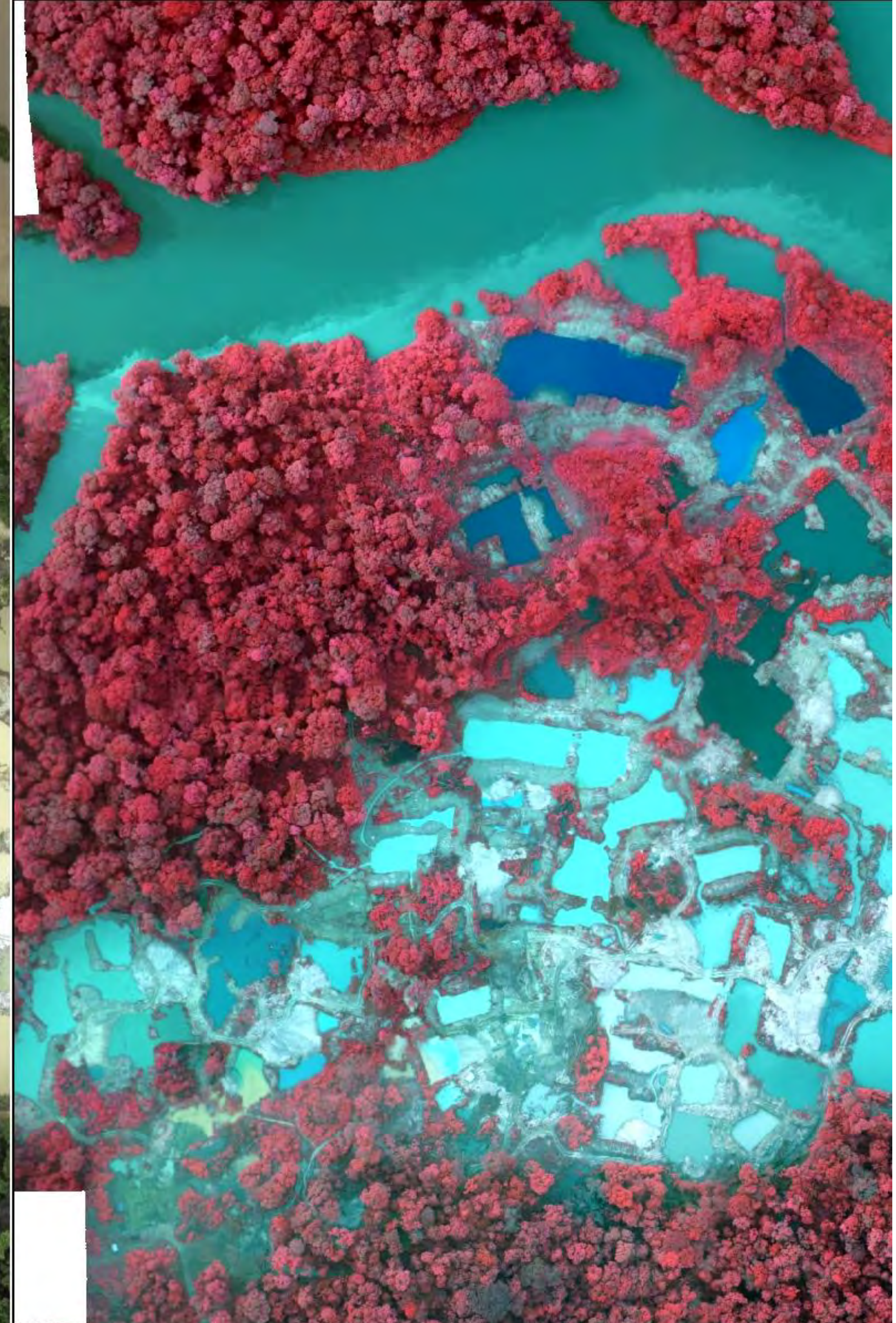


Deforestation risk







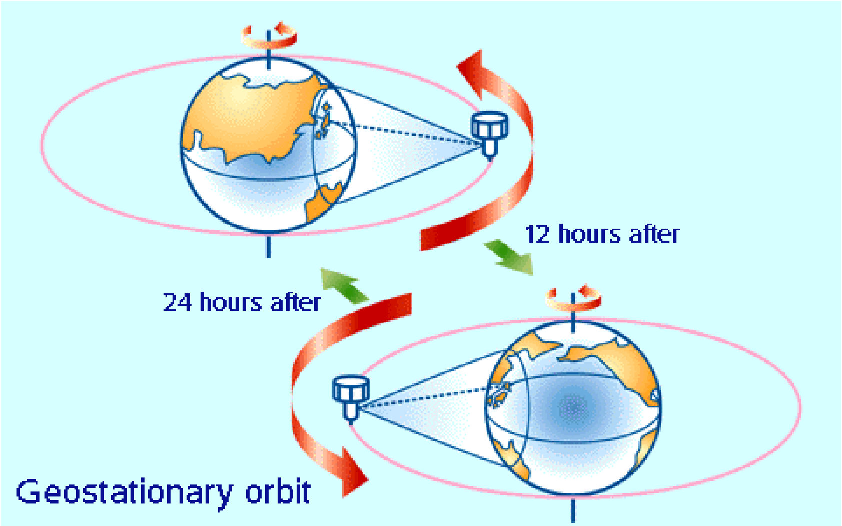


Outline

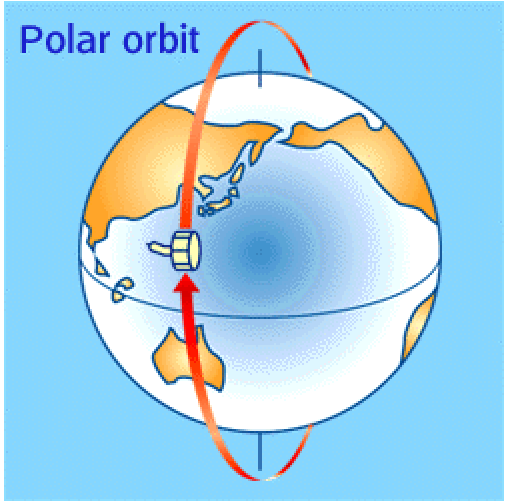
1. Background
2. Types of Imagery
   - GPS
   - Google
   - Aerial Photography
   - Satellite Imagery
   - RADAR Imagery
   - LiDAR data
3. Uses of Remote Sensing in Boundary Work
4. Acquiring and Interpreting Imagery

Obtaining imagery from space

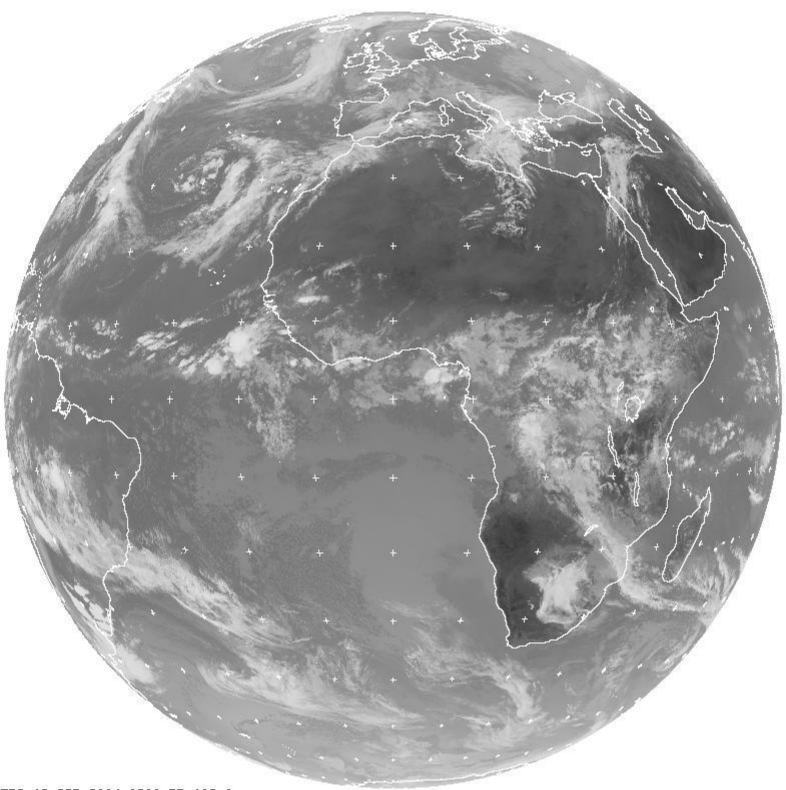
- Geosynchronous or geostationary
- Located directly above equator 36,000 km from Earth
- Orbit at the same rate as Earth rotation
- Used for meteorology



- Polar or near polar
- Approx 90 min orbital period
- Operate close to the Earth from 100 – 800 km
- Near Polar orbits can be sun synchronous; the orbit shifts by approx 1 degree per day

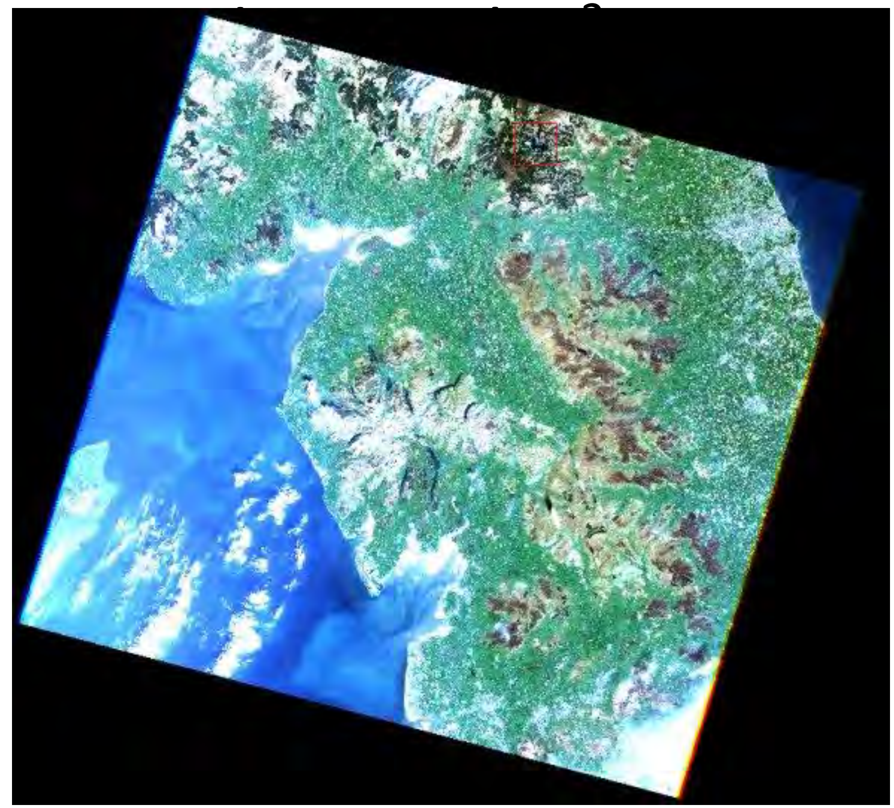


- Geostationary



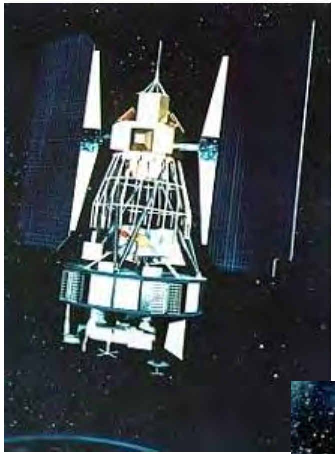
MET8 12 OCT 2004 0900 IR-108-0

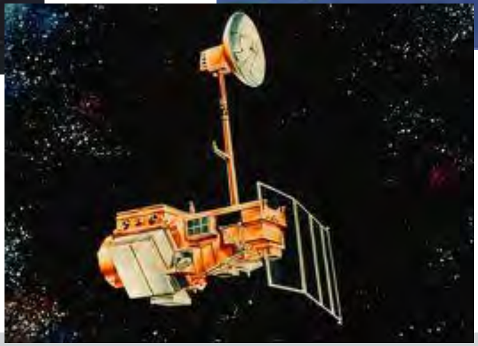
- Near-Polar



Landsat (USGS & NASA)

- Milestones
- ERTS-1 (Landsat-1 (MSS, RBV) 1972
- Landsat 4 – TM ‘82
- Landsat 7 – ETM+ ’99
- Landsat 8 – OLI, TIR, 2013
- Landsat 9 – OLI, TIR, 2021





Near-Polar Earth Observation Sensors

Medium resolution sensor		Low resolution sensor	
Landsat TM	30m	AVHRR	1000m
Landsat ETM+	**15m**	MODIS	250m
Sentinel 2 MSI	**10 m (20m)**	MERIS	500m
SPOT XS	6m (1.5m pan)	SPOT Vegetation	1k
RapidEye	6m		
SPOT Image	6m (1.5 Pan)		

Near-Polar Earth Observation Sensors

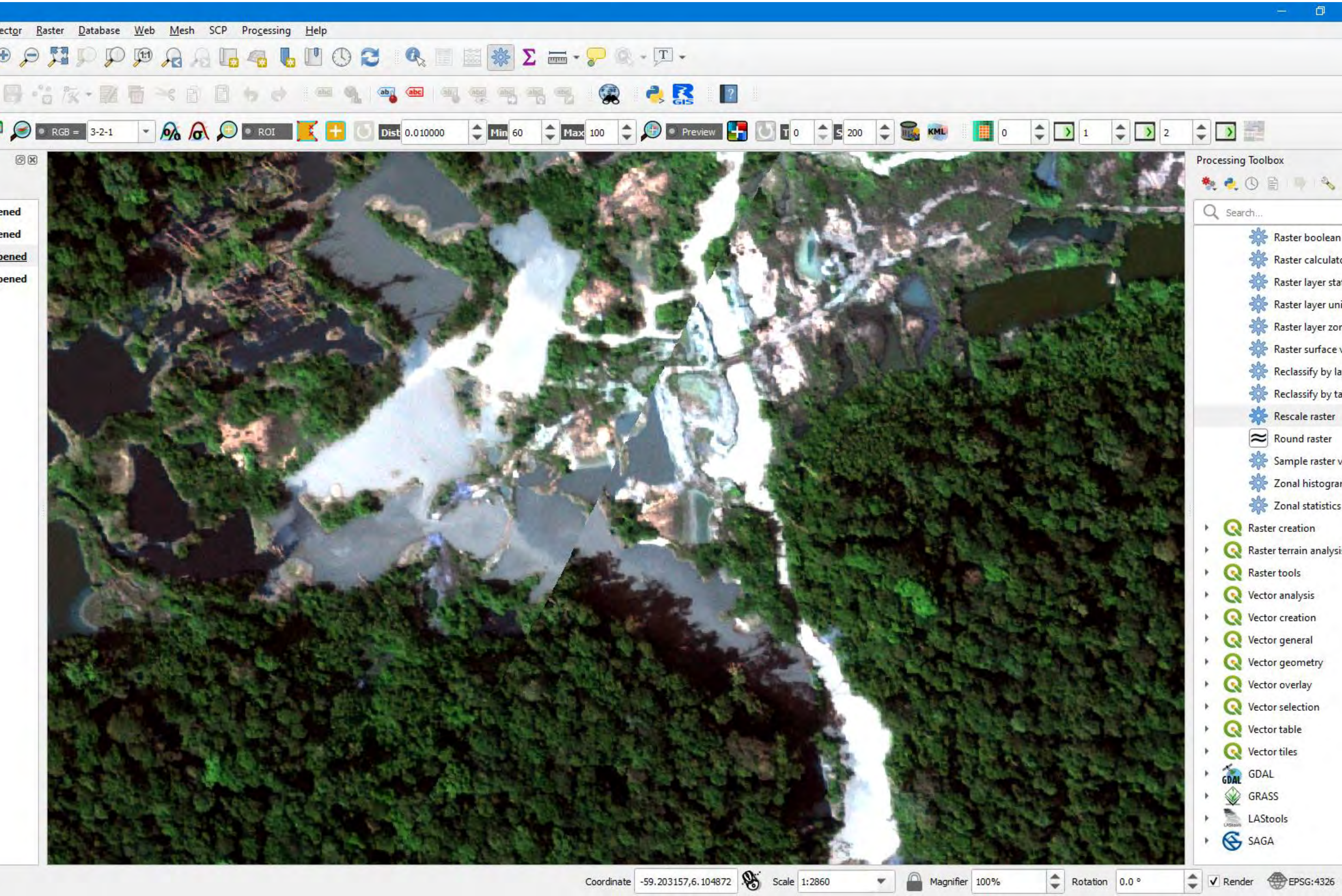
High resolution Sensors

IKONOS	(0.82m pan; 4m MS)	1999-2015
QuickBird	(0.61m pan; 2.4 m MS)	2001-2014
OrbView-3	(1 m pan; 4 m MS)	2003-2007
GeoEye	(0.46m pan; 1.65m)	2008-
WorldView-1,2	(0.46m pan; 1.84m MS)	2007,2009-
WorldView-3	**(0.31m pan;1.24 m MS)**	**2014-**
WorldView-4	(0.31m pan;1.24 m MS)	2016-2019
PlanetScope	**(3.7m MS) 200 CubeSats**	**2009-**
Pléiades 1A, 1B	**(0.5 m) Off-Nadir**	**2011,2012-**

Active Near-Polar Earth Observation Sensors

Latest High resolution Sensors

SkySat (21sats)	4 band 0.81 m	2013-
Kompsat 3A	4 band+Pan 1m	2015-
SuperView-1	4 band+Pan 1m	2016,2018-
OVS-1/2	RGB + Video	2017,2018-
BlackSky	RGB+Pan 1m	2018-
Pleiades Neo	6 band 1.2,0.3 m	2021-
(mono, stereo, tri-stereo; 6 bands plus Pan)		
SuperView Neo	4 band 0.3 m pan	2022
Pelican	0.3 m + SAR fusion	from 2023
Albedo	4 band+pan 0.1 m	from 2024

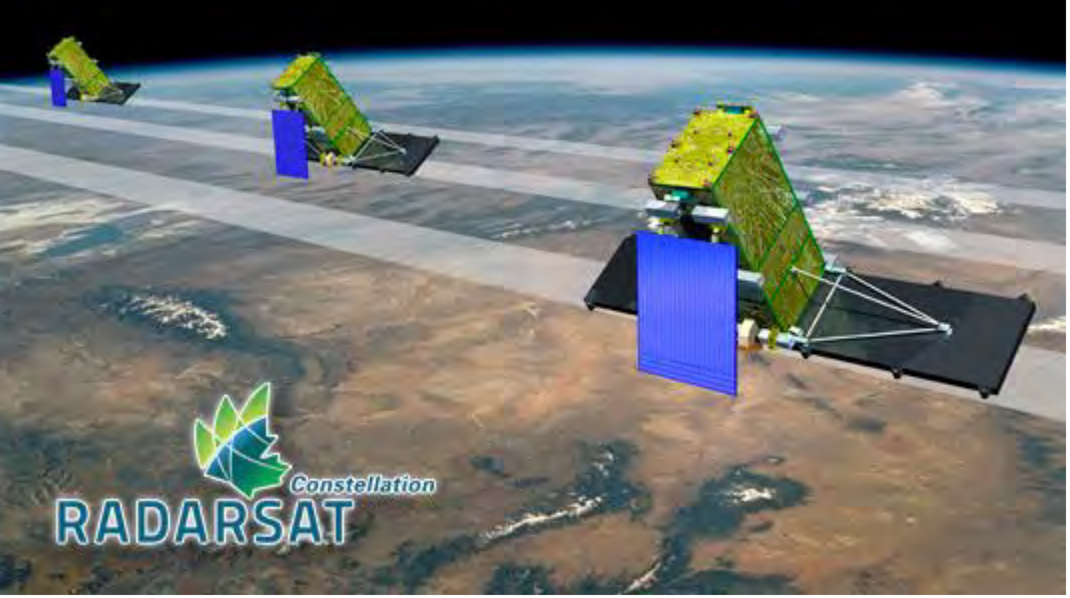

ector Raster Database Web Mesh SCP Processing Help
RGB = 3-2-1
ROI
Dist 0.010000
Min 60
Max 100
Preview
T 0
S 200
KML
0
1
2
ened
ened
pened
pened
Processing Toolbox
Search...
Raster boolean
Raster calculat
Raster layer sta
Raster layer uni
Raster layer zor
Raster surface v
Reclassify by la
Reclassify by ta
Rescale raster
Round raster
Sample raster v
Zonal histogra
Zonal statistics
Raster creation
Raster terrain analysi
Raster tools
Vector analysis
Vector creation
Vector general
Vector geometry
Vector overlay
Vector selection
Vector table
Vector tiles
GDAL
GRASS
LAStools
SAGA
Coordinate -59.203157,6.104872
Scale 1:2860
Magnifier 100%
Rotation 0.0 °
Render
EPSG:4326

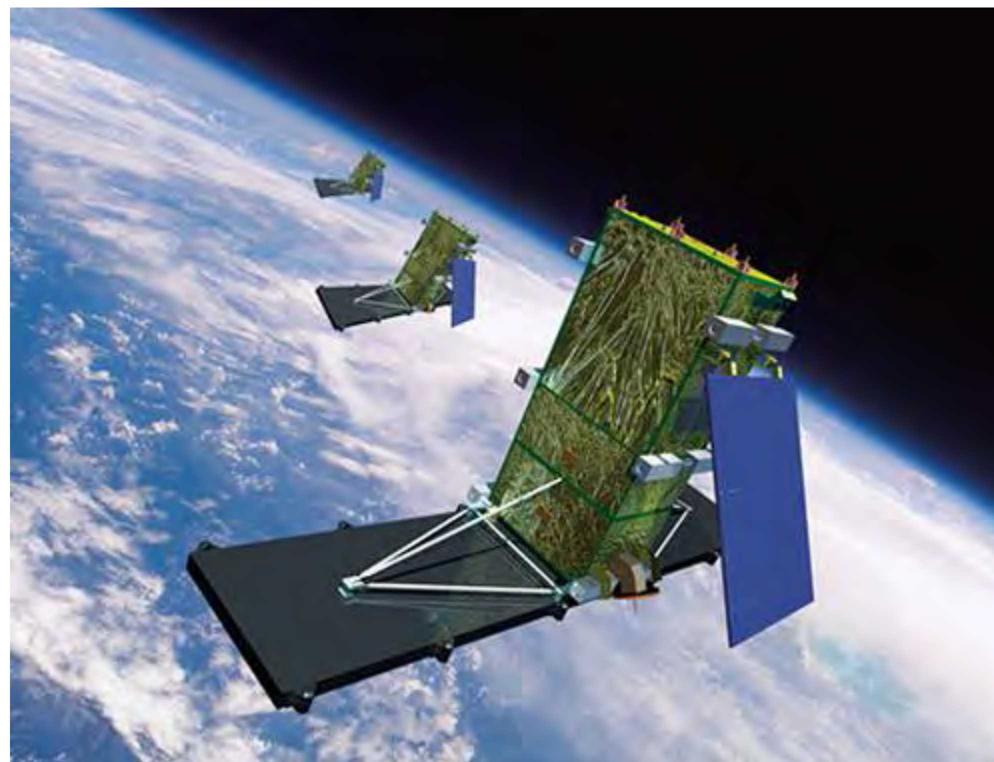
SAR Earth Observation Satellites

- TerraSAR-X and TanDEM-X, DLR & Astrium, Germany
  - Resolution: 1 m, dual-use
- Radarsat 2, Radarsat Constellation, Canada
  - Resolution: 1 m/ 3 m
- Sentinel-1   EU-Copernicus
  - Resolution: 10 m
- Capella Space
  - X-band fine resolution 0.5 – 1.2 m

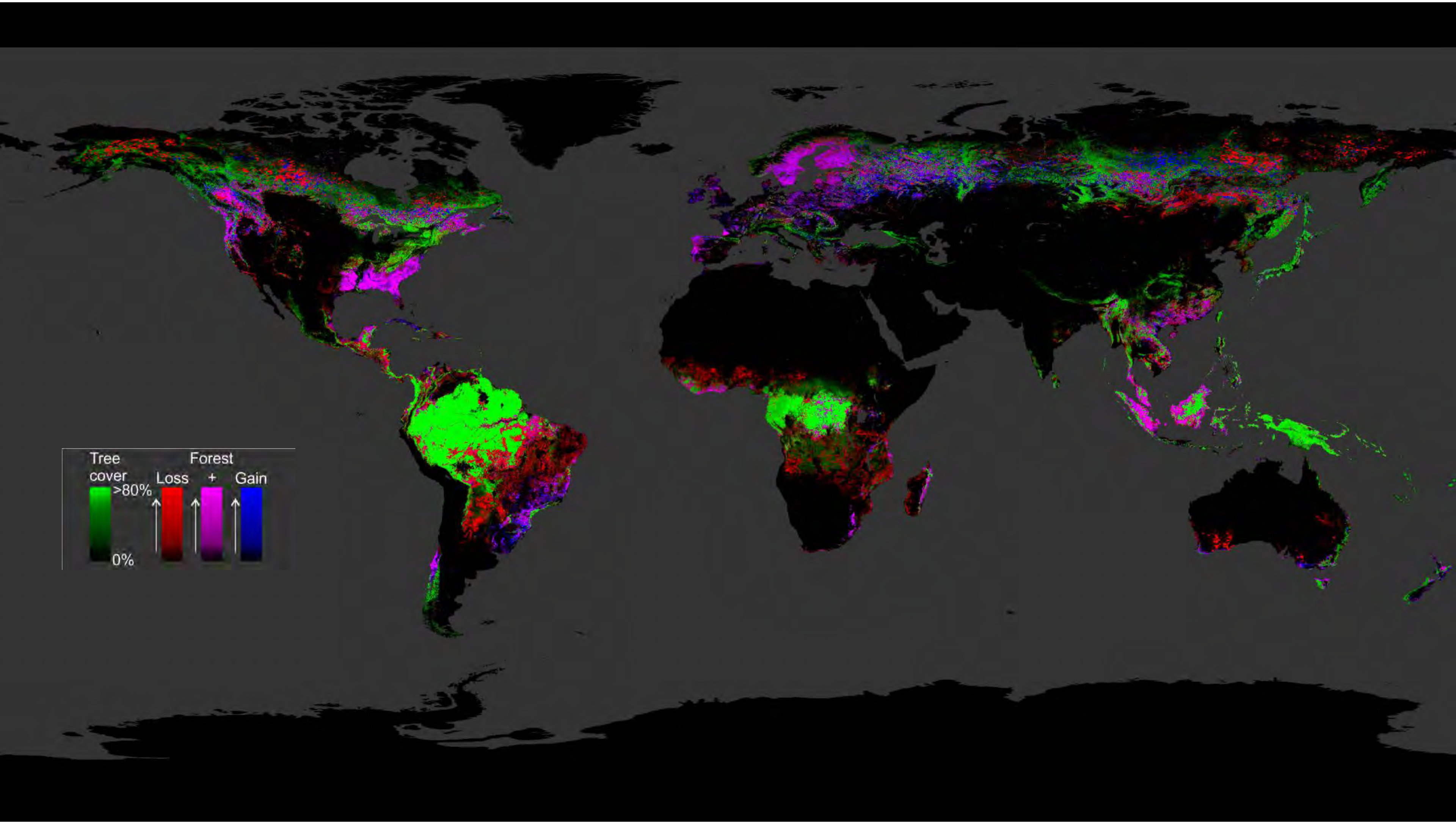
Constellations

- DMC (UK, Surrey Space Technology Ltd)
  - Six satellites; Daily revisit; Multispectral imagery; Wide swath (600km+); 32m GSD resolution; 4m PAN
- RapidEye, Germany (DLR & private)
  - Five 6.5 m multispectral EO satellites in constellation
  - Daily imagery across the globe
- Digital Globe (quasi-constellation)
  - Three satellites (all different resolutions & other characteristics)
- PlanetLabs, USA (Private) first 28 satellites, Flock 1, which were
- launched in January 2014, planned for 200+ giving 24 hour coverage
- Cosmo-SkyMed, Italy
  - Four SAR satellites at maximum 1m resolution
- Radarsat Constellation Mission


Constellation
RADARSAT



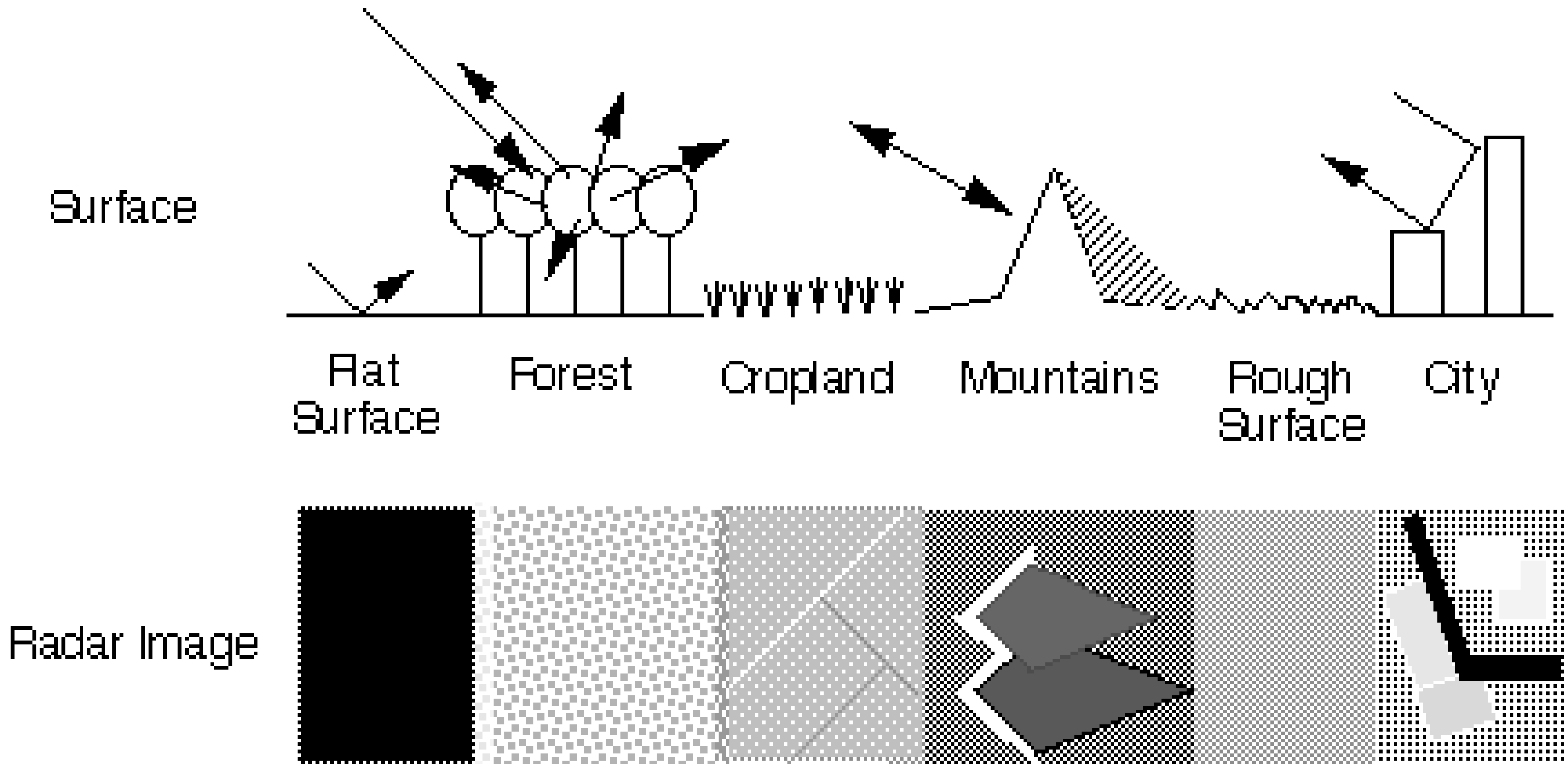
Banda Aceh: Northern Shore

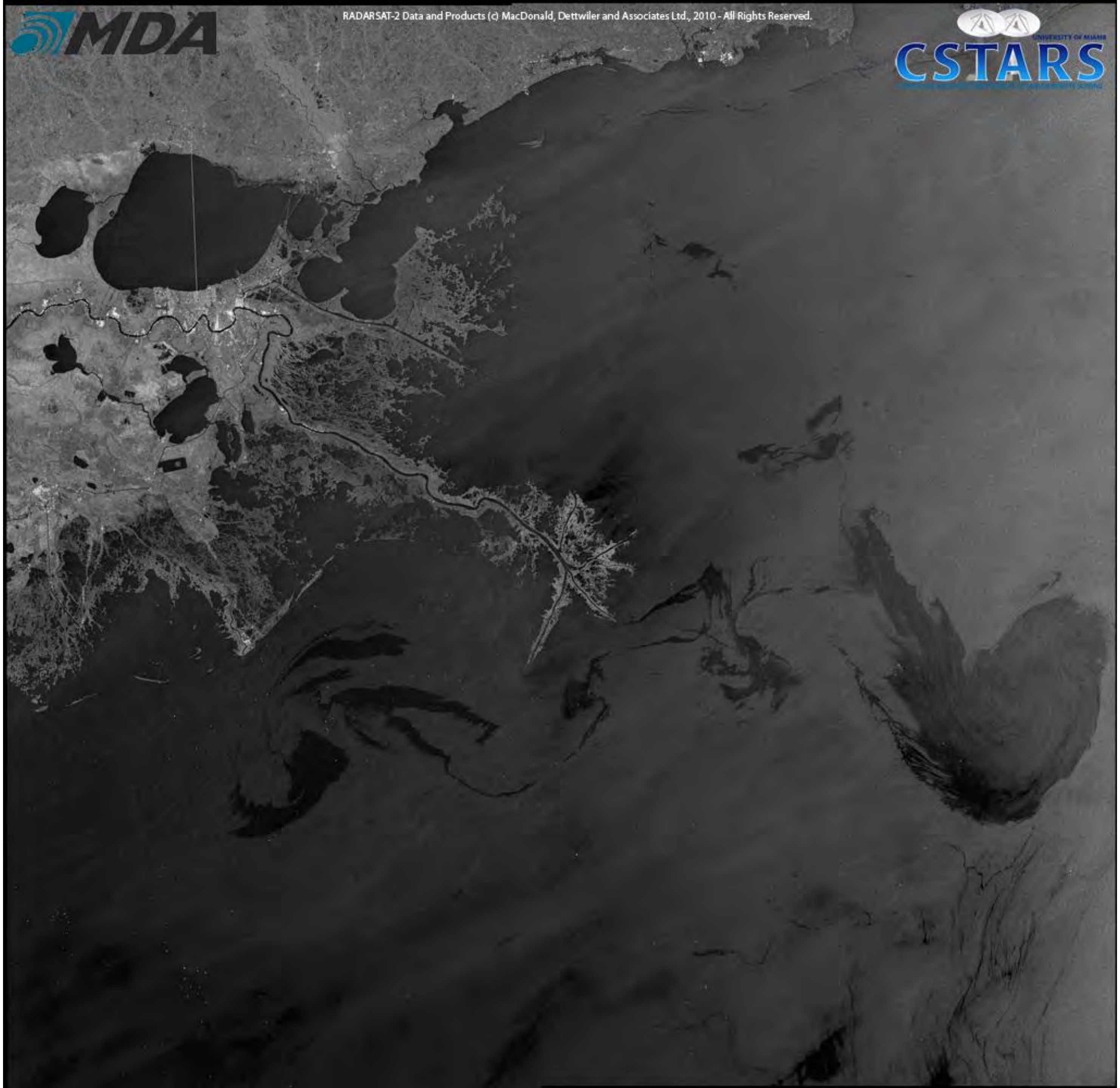


Global Forest Change 2000-2012, Matt Hanson, University of Maryland

Outline

1. Background
2. Types of Imagery
   - GPS
   - Google
   - Aerial Photography
   - Satellite Imagery
   - RADAR Imagery
   - LiDAR data
3. Uses of Remote Sensing in Boundary Work
4. Acquiring and Interpreting Imagery

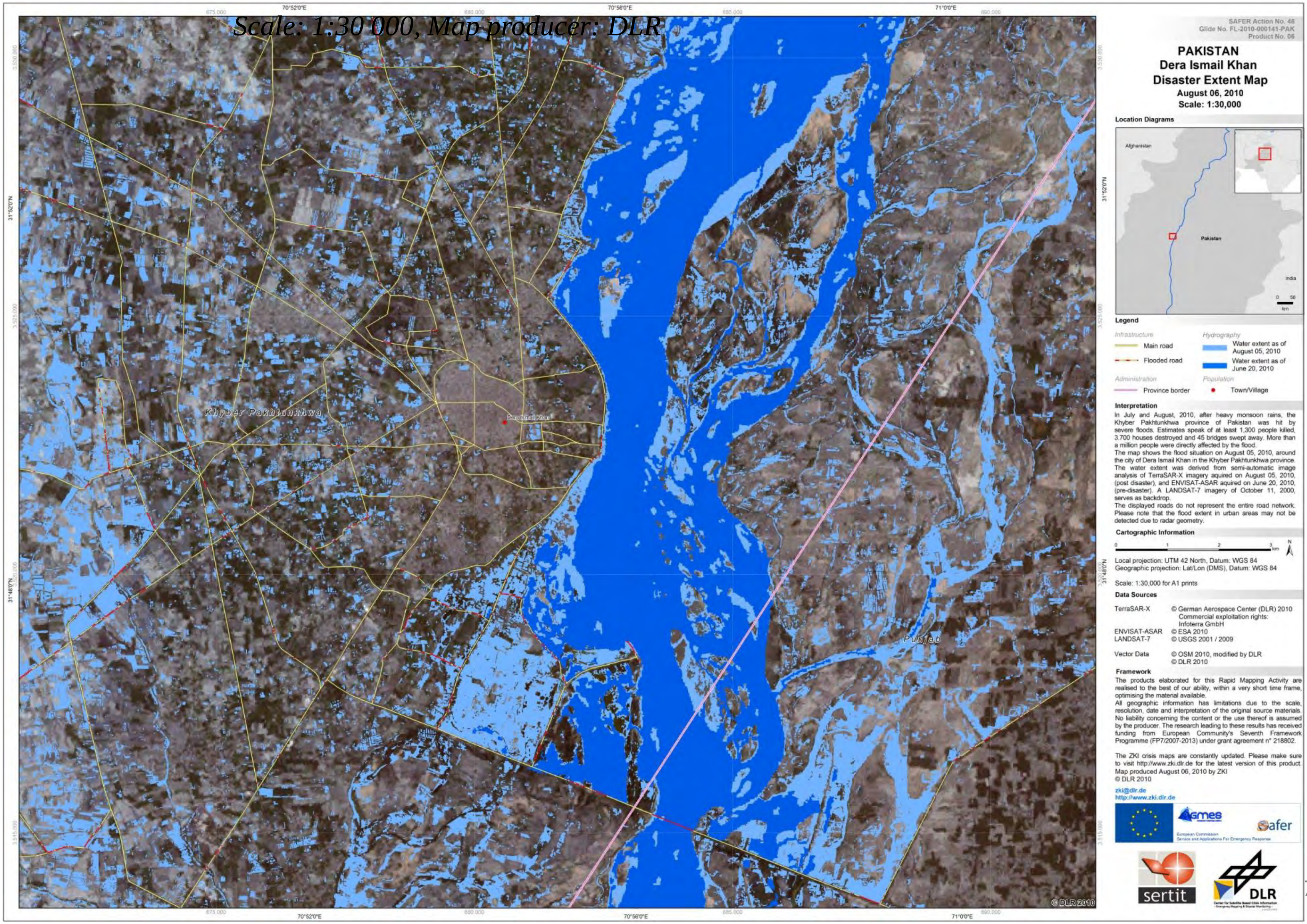

Surface
Flat Surface
Forest
Cropland
Mountains
Rough Surface
City
Radar Image


MDA
RADARSAT-2 Data and Products (c) MacDonald, Dettwiler and Associates Ltd., 2010 - All Rights Reserved.
CSTARS

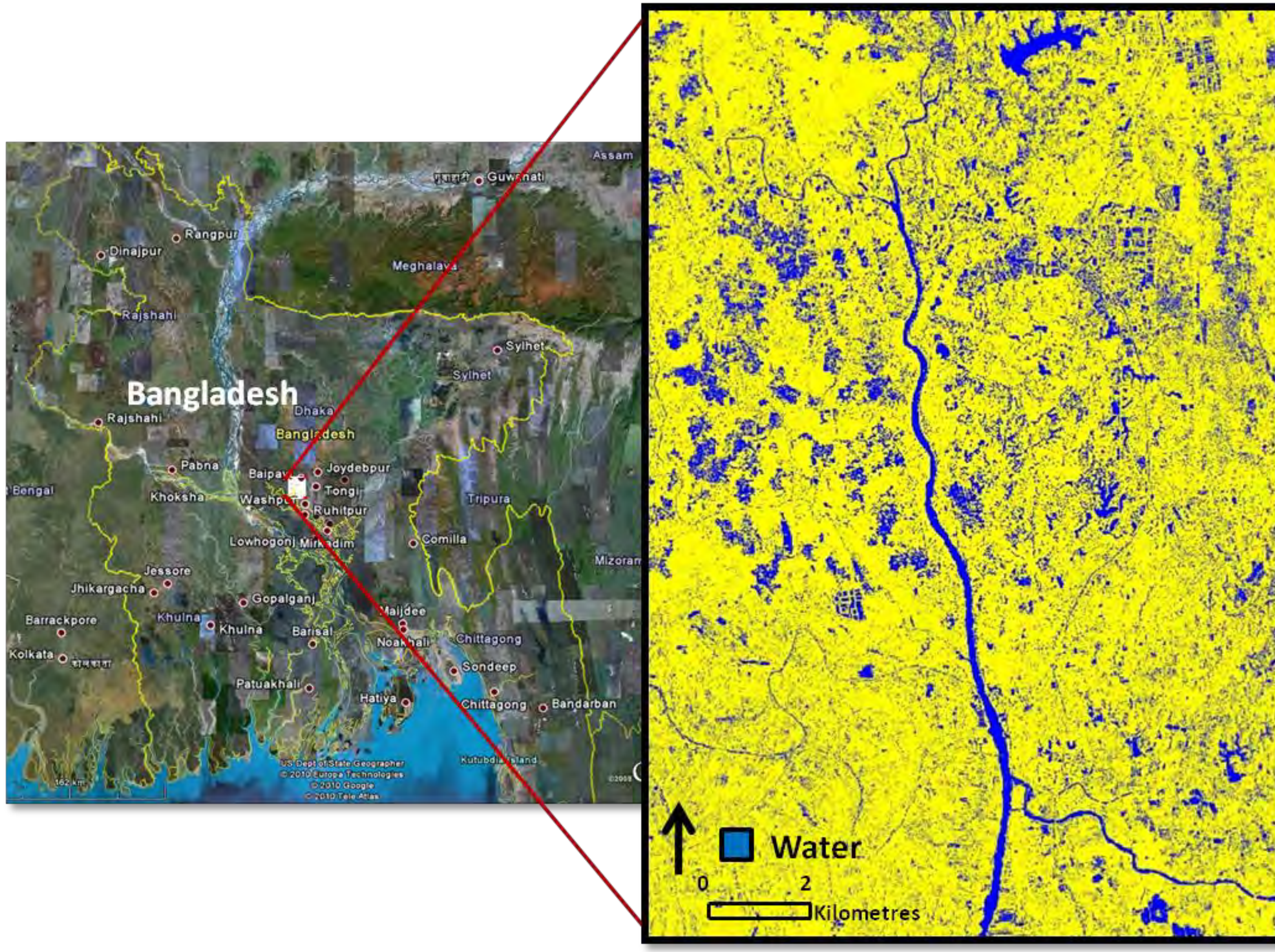
The 2010 Pakistan flood disaster

Water extent (light blue)-TerraSAR-X imagery as of August 05, 2010

Scale: 1:30 000, Map producer: DLR

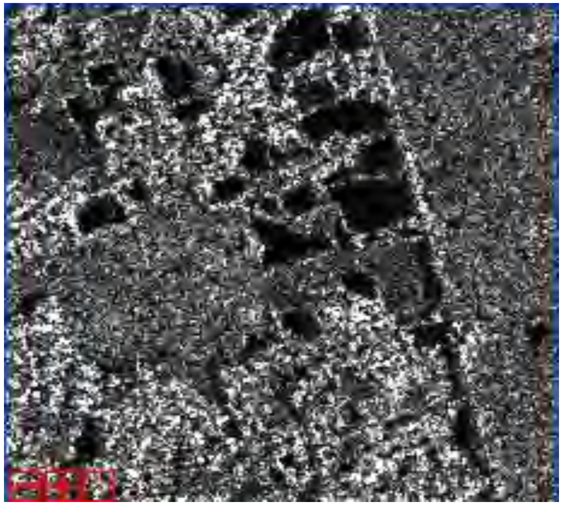


Study Area



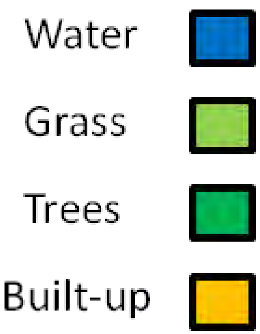
Study area extracted from RADARSAT-2 HH Image Density Sliced-Water class (Bangladesh map extracted from Google Earth 2010); 2004 flood impacted 1.7 M homeless, 800 deaths

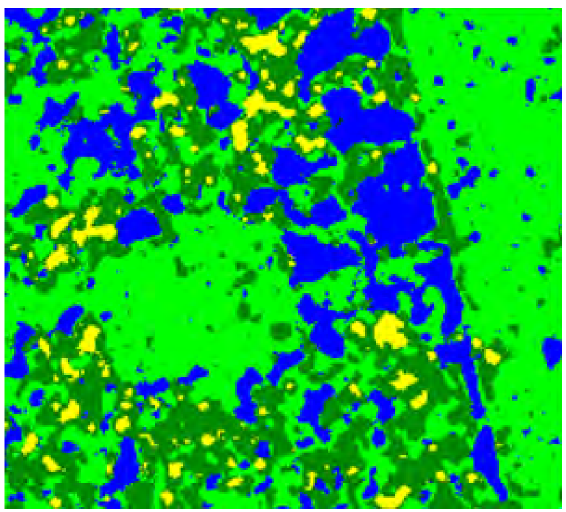
Image Classification



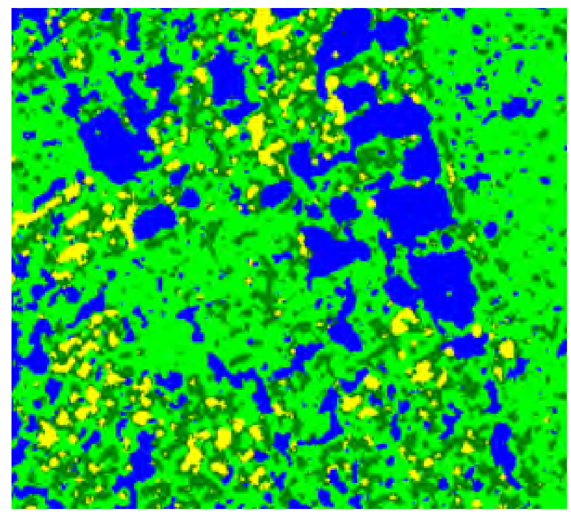
Original Image

Google Earth



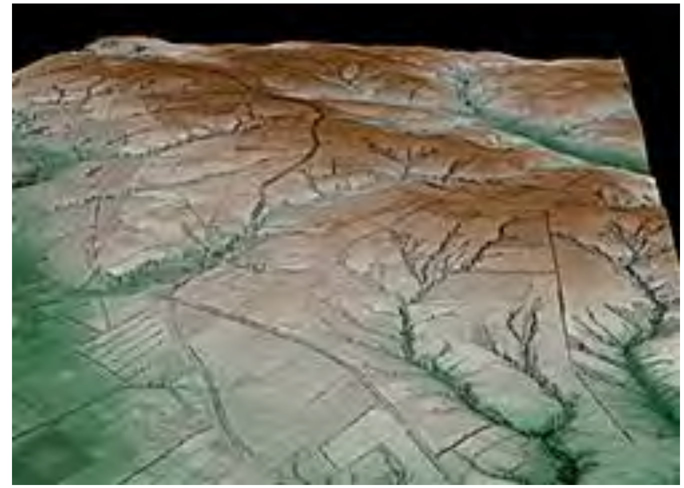


Unsupervised Classification-RSAT2_HH1

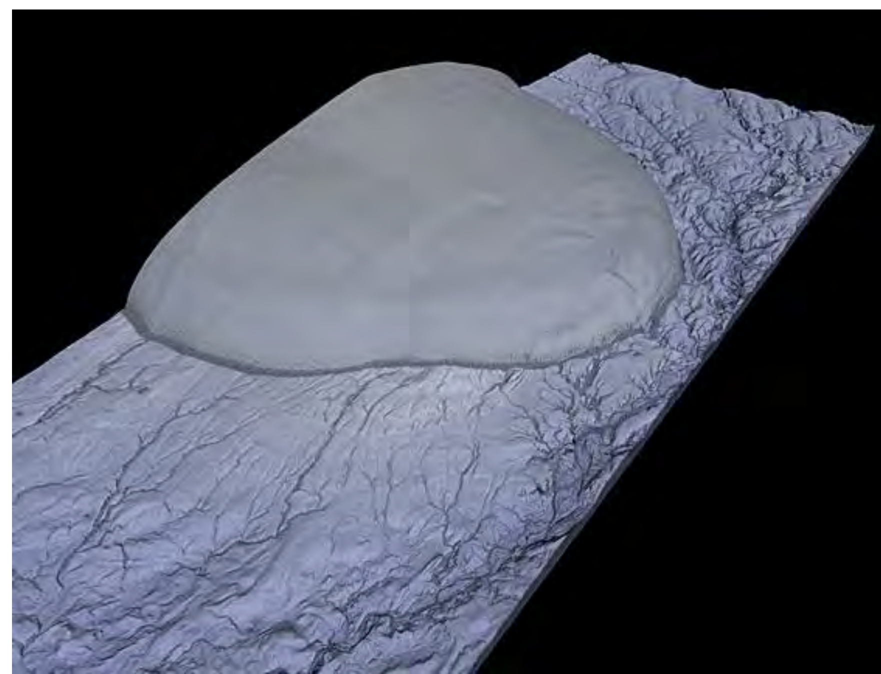


Supervised Classification-RSAT2_HH1

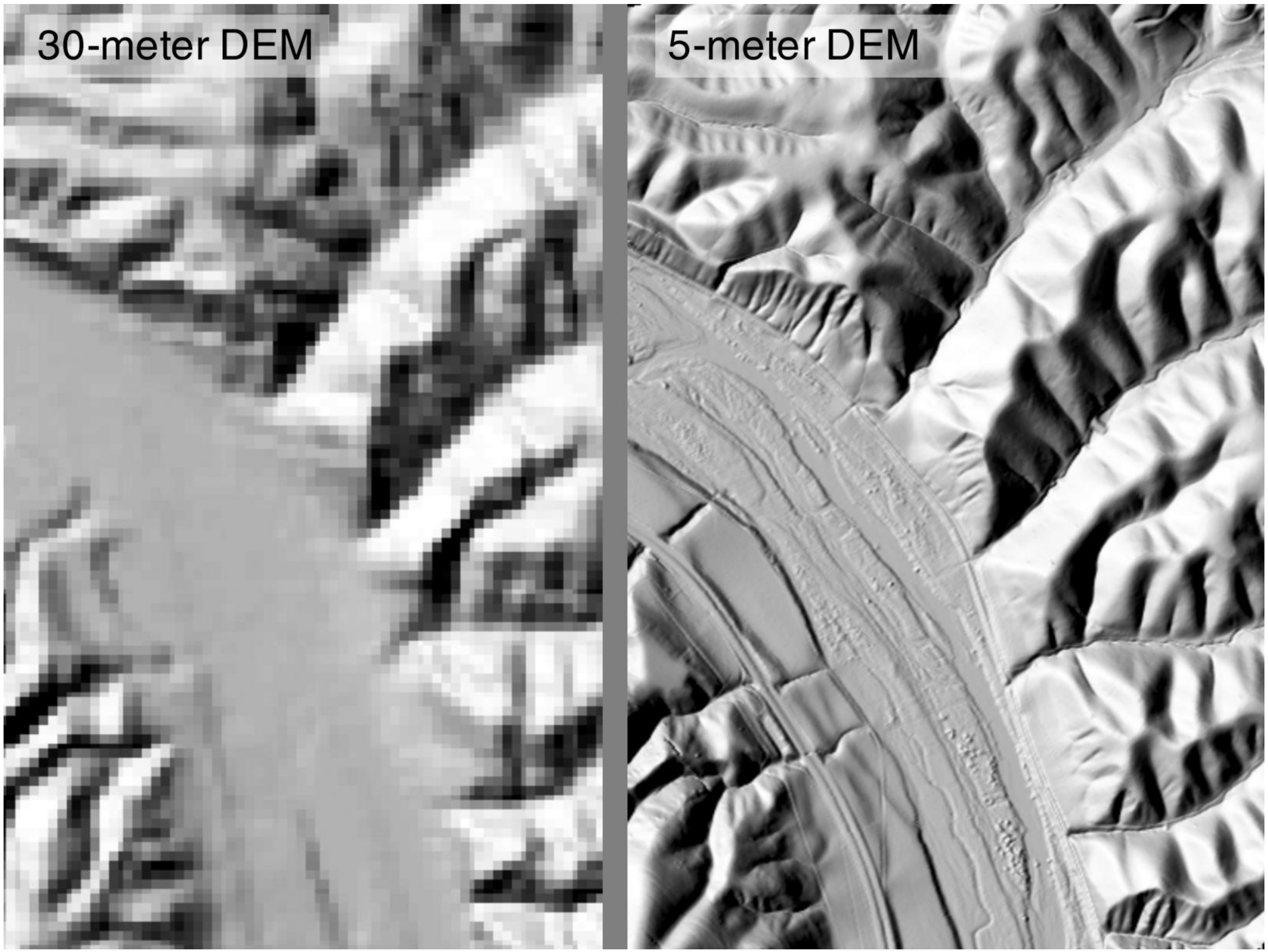
TanDEM-X mission Global Terrain data



1. Joint DLR/InfoTerra mission
2. Constellation of two X-band radar satellites TerraSAR-X and TanDEM-X
3. 12m and 6m posting DEMs produced using Bistatic Interferometry



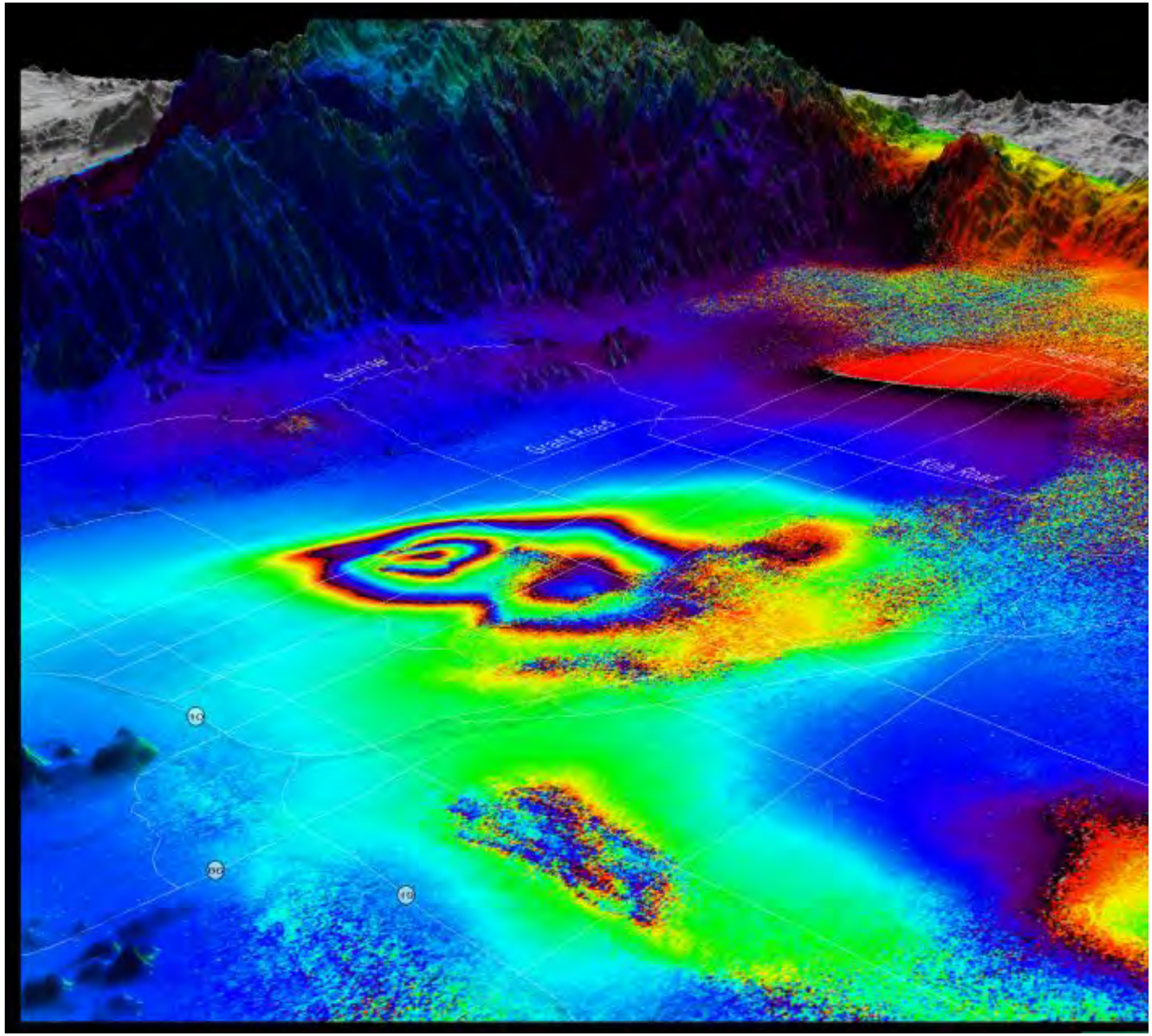
PLANNED SPACE LIDAR MISSION: California's Salinas River and surrounding hillslopes. The left-hand image shows the finest resolution (30 m) that is currently available over much of Earth's surface. The right-hand image shows the same scene at the resolution achievable with lidar mapping from space (5 m). Mapping landslideand flood hazards in this landscape is achievable with 5-m topographic data, but impossible with 30-m data. SOURCE: Courtesy of J. Taylor Perron, University of California, Berkeley.



Ground-Water Withdrawals

90 mm of subsidence in Tucson, Arizona

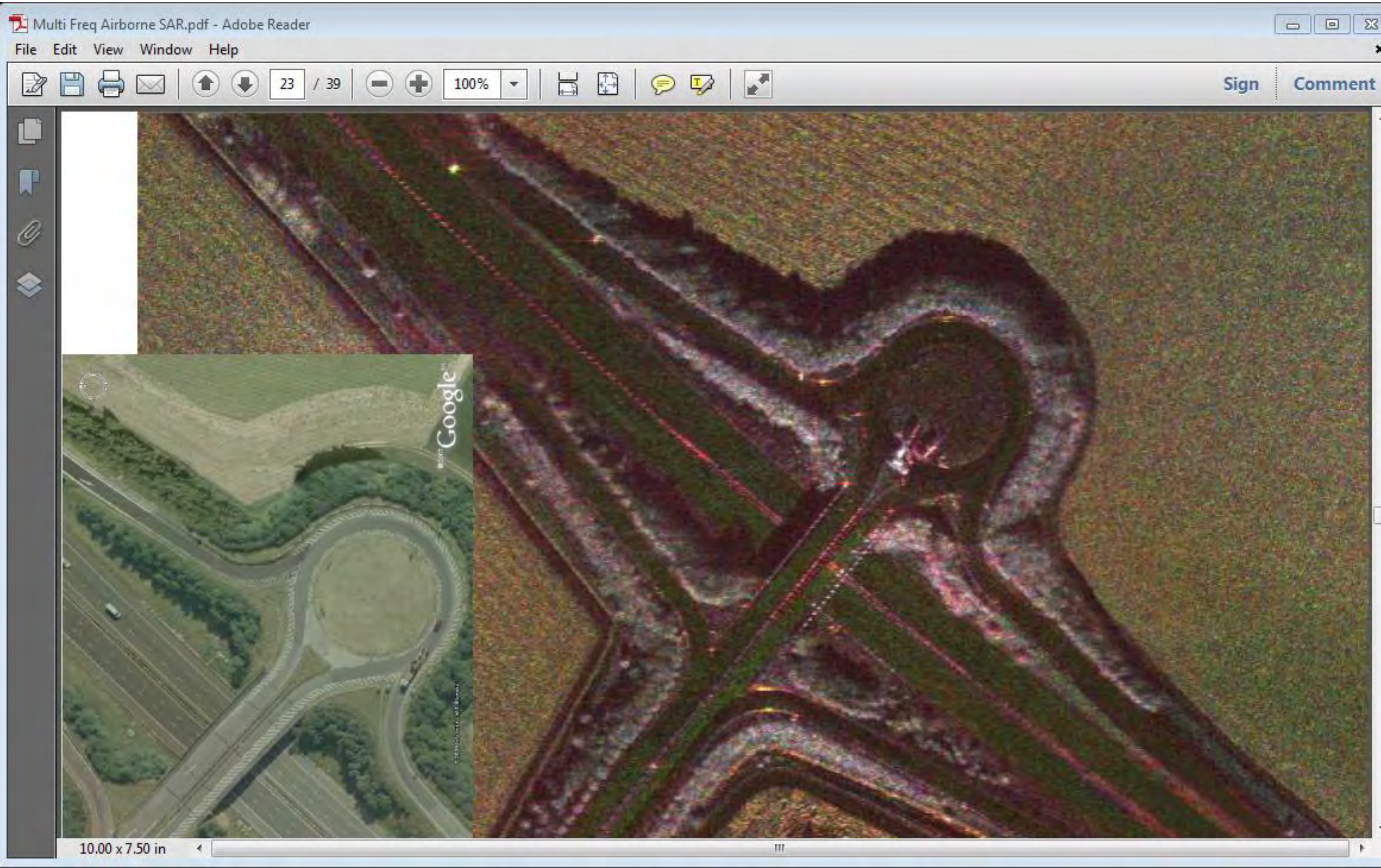
November 1992 to January 1997



InSAR data from Envisat

X-Band Quad Polar SAR Imagery
7" / 18cm Resolution
Acquired 19th Dec 2008 near Goole, UK

Airborne X-band SAR



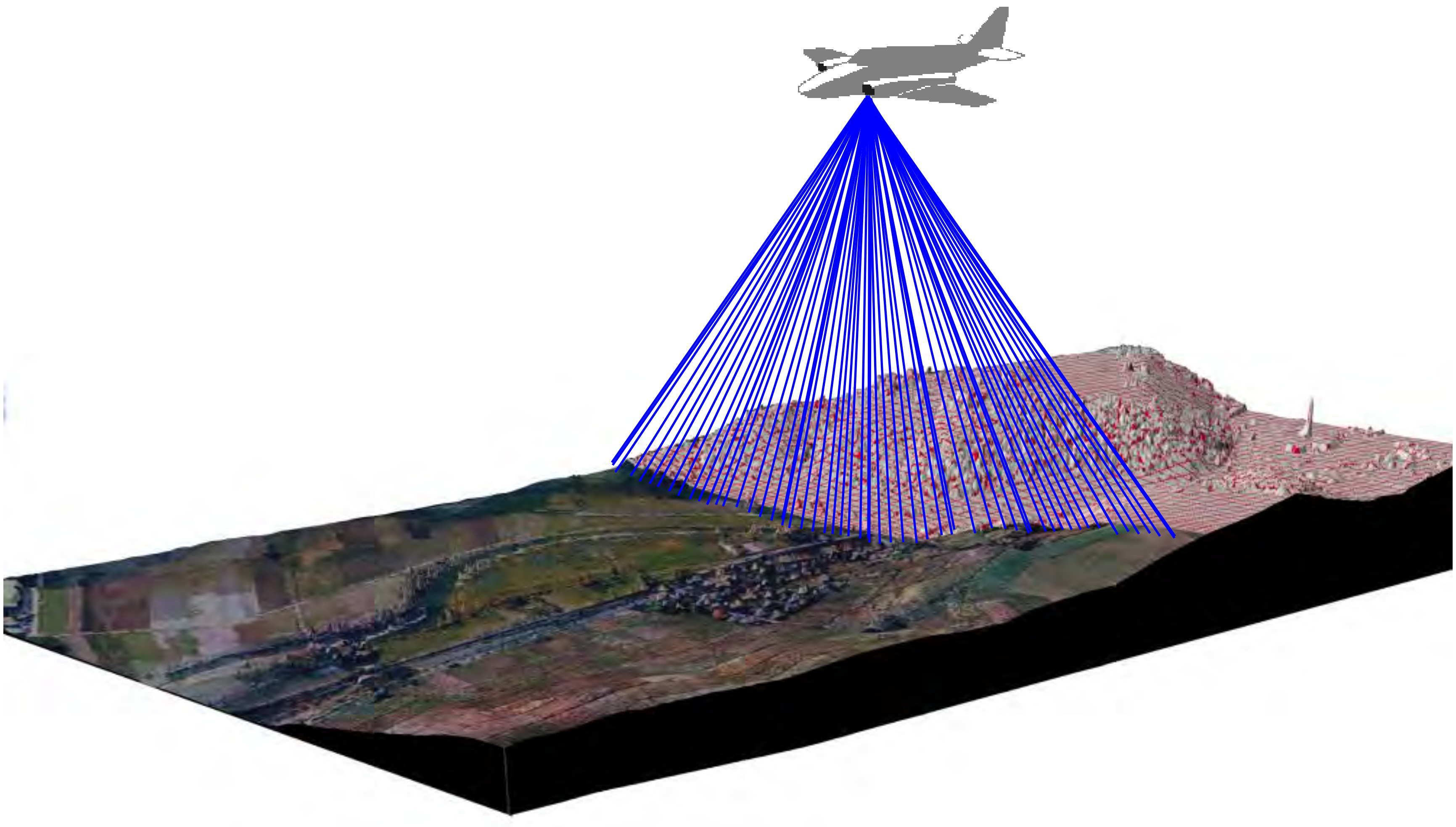
Outline

1. Background
2. Types of Imagery
   - GPS
   - Google
   - Aerial Photography
   - Satellite Imagery
   - RADAR Imagery
   - LiDAR data
3. Uses of Remote Sensing in Boundary Work
4. Acquiring and Interpreting Imagery

LIDAR

- Light Detection and Ranging
  - Laser generates optical pulse
  - Scanning mirror directs pulses
  - Pulse reflected off object and returns to receiver
  - Time of flight from start pulse to the return pulse is measured
  - Time measurement converted to a distance
  - Distance = (Speed of Light x Time of Flight)/2

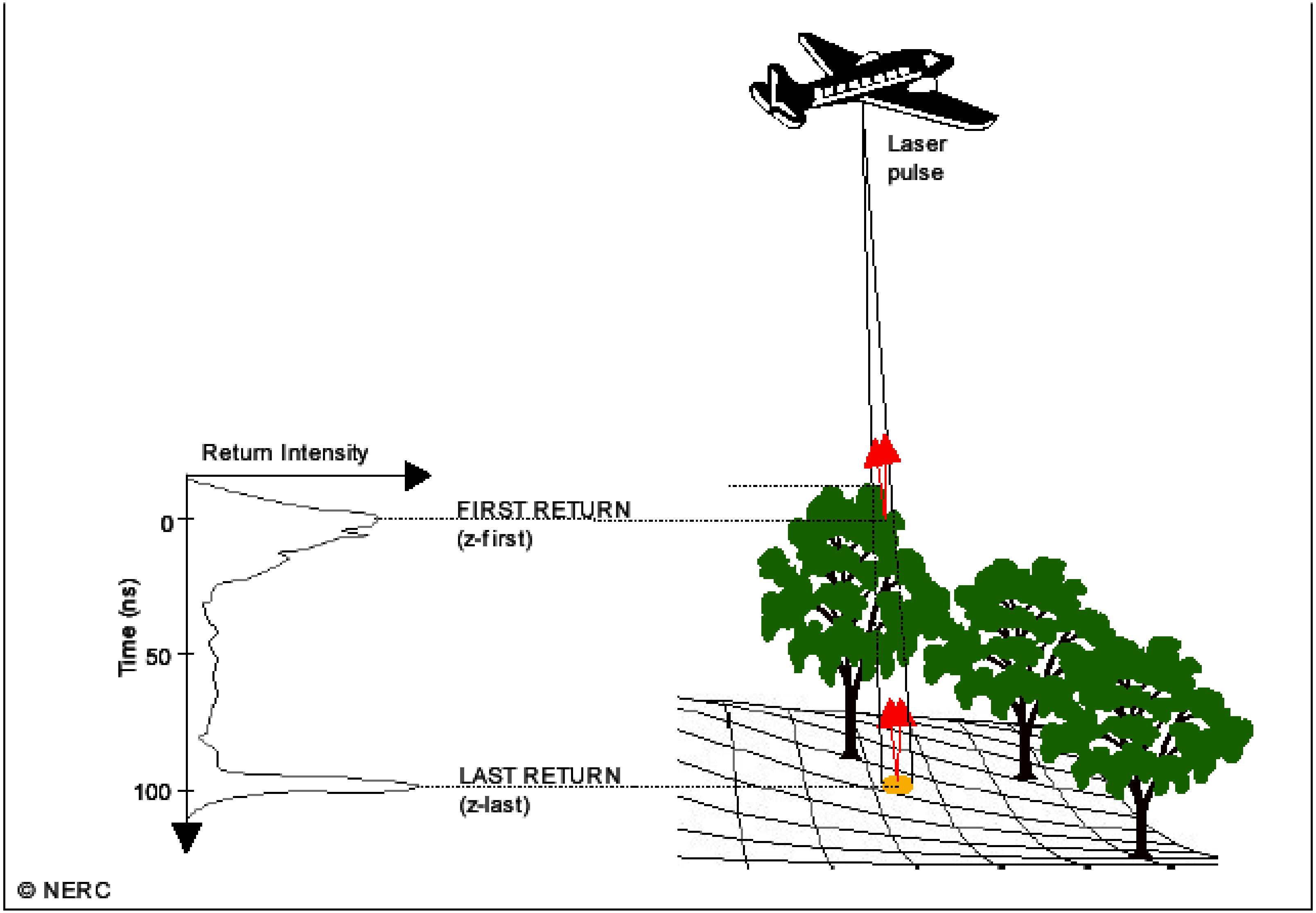
Airborne Laser Scanning

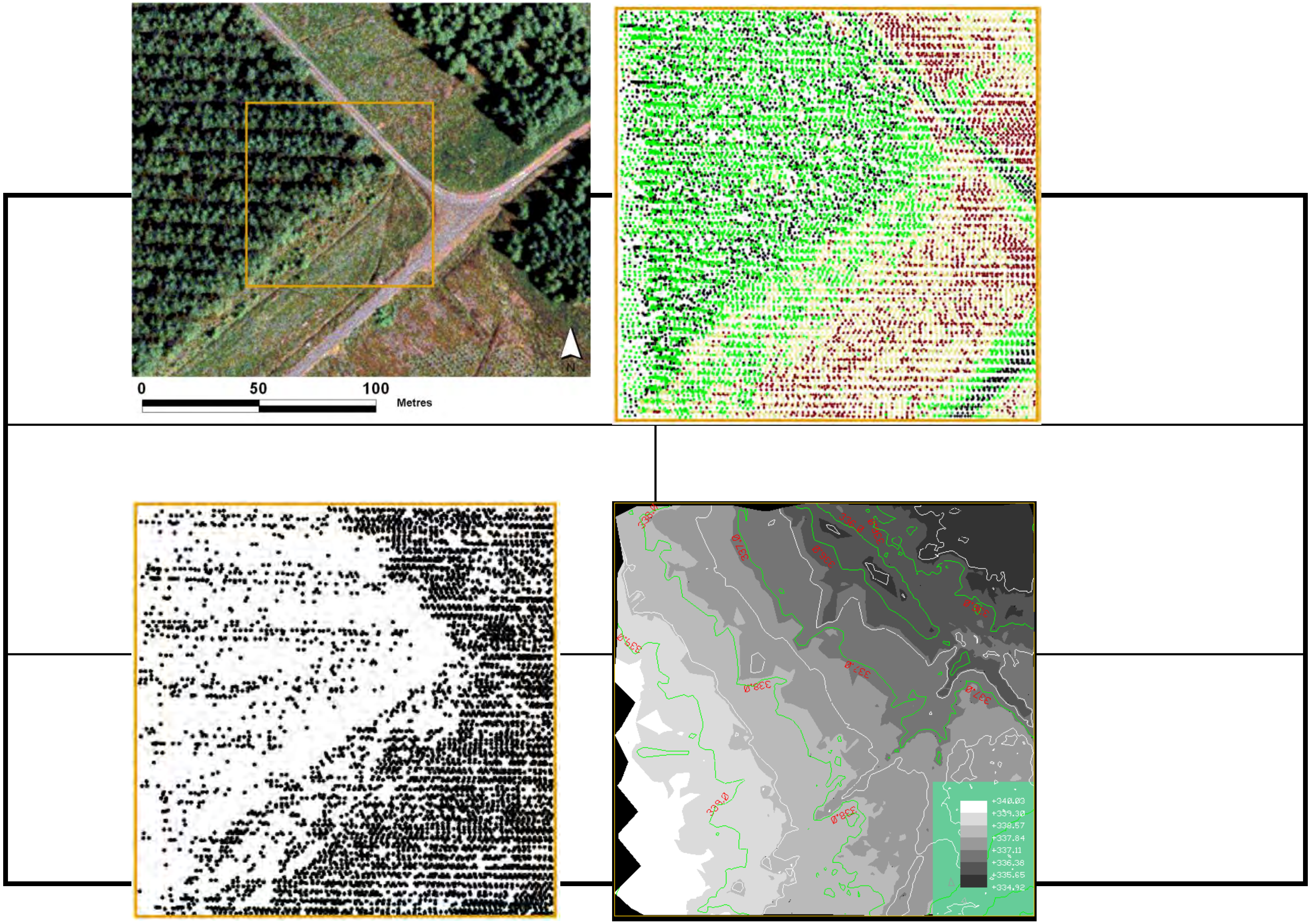


Typical Specifications

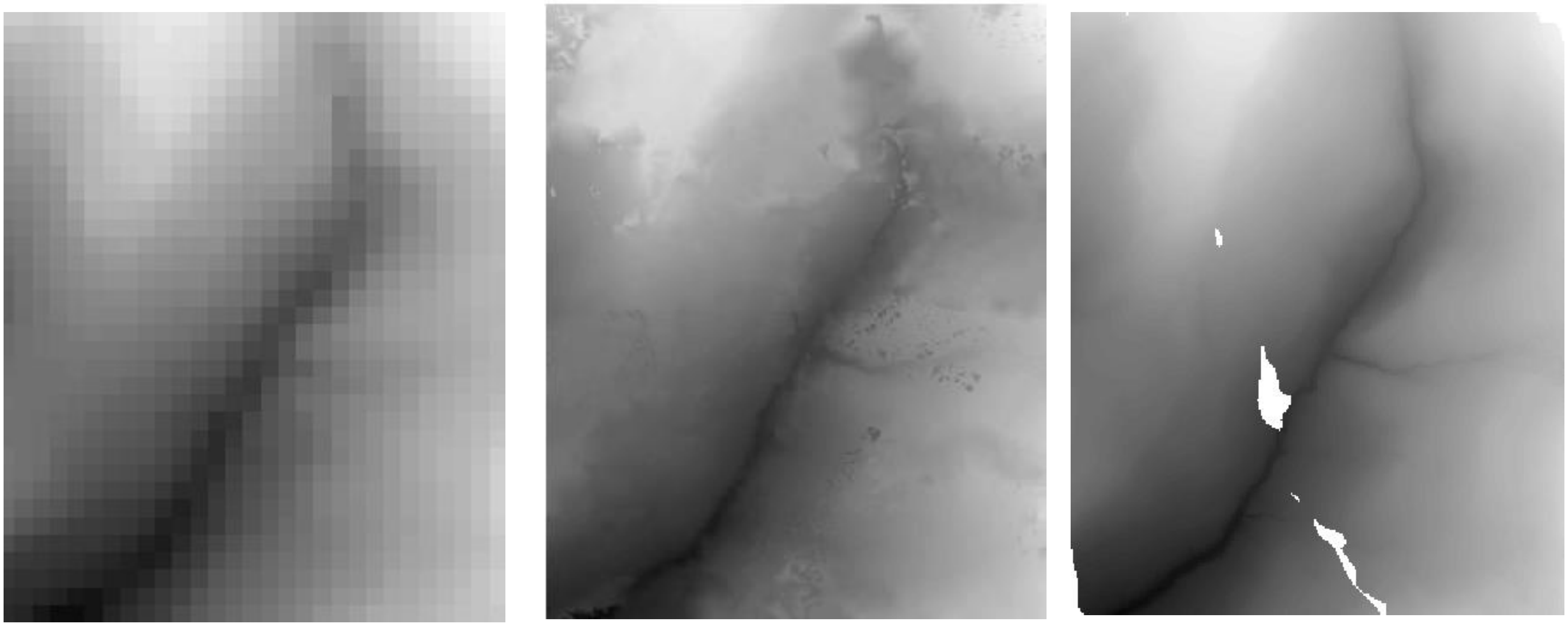
- 33000-100000 measurements per sec
- Altitude 300-2000 m
- Speed: average 60 m/s
- Accuracy
  - Vertical: ± 15 cm
  - Horizontal:
    - DGPS: ±3m
    - KGPS: ±1m
- Variable density 10cm – 10 m
- 0-60m bathymetry (dual frequency system)
- Surveys up to 35 km^2 per hour

LiDAR pulse return

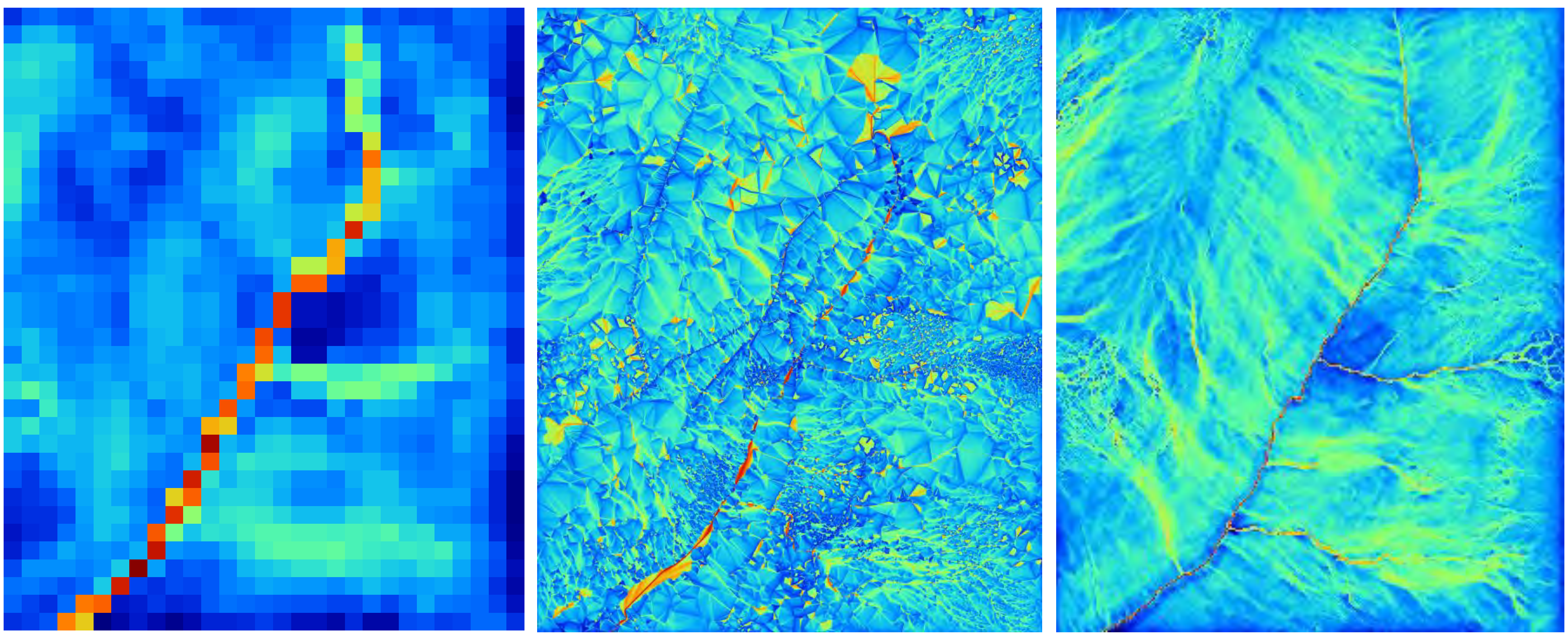



0
50
100
Metres
N
+340.03
+339.30
+338.57
+337.84
+337.11
+336.38
+335.65
+334.92

DEM comparison

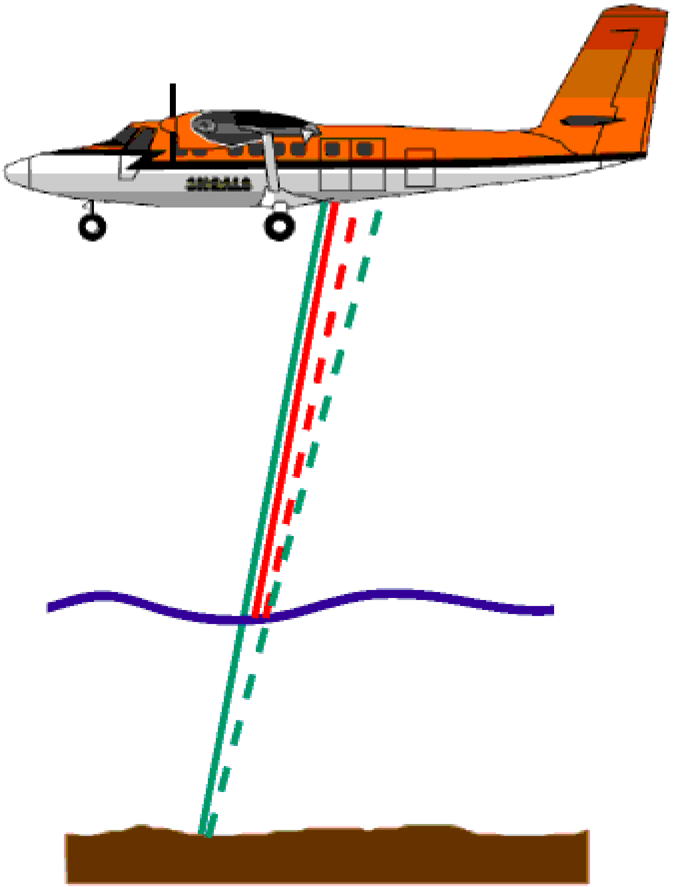


Surface models TWI

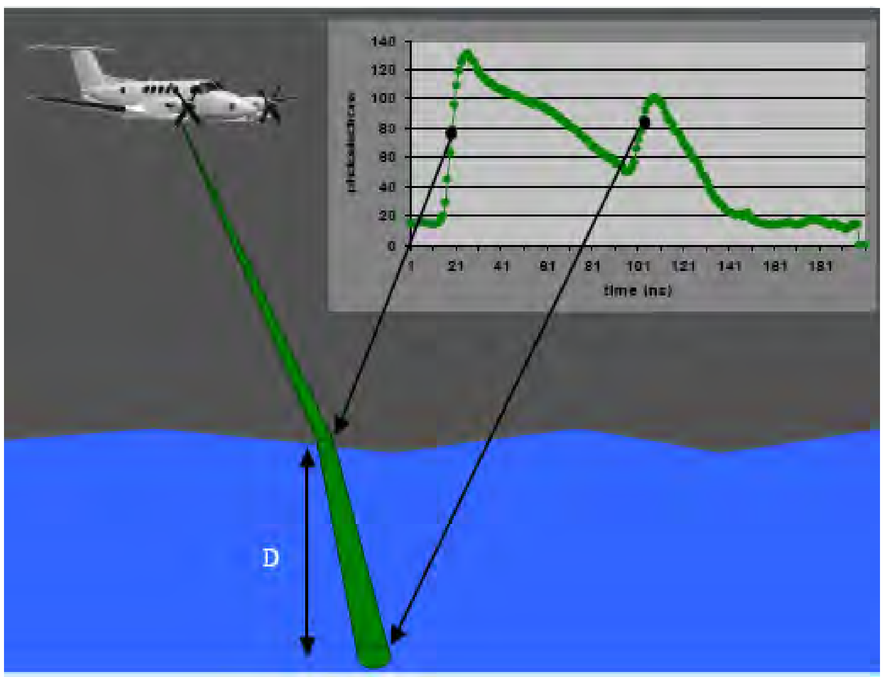


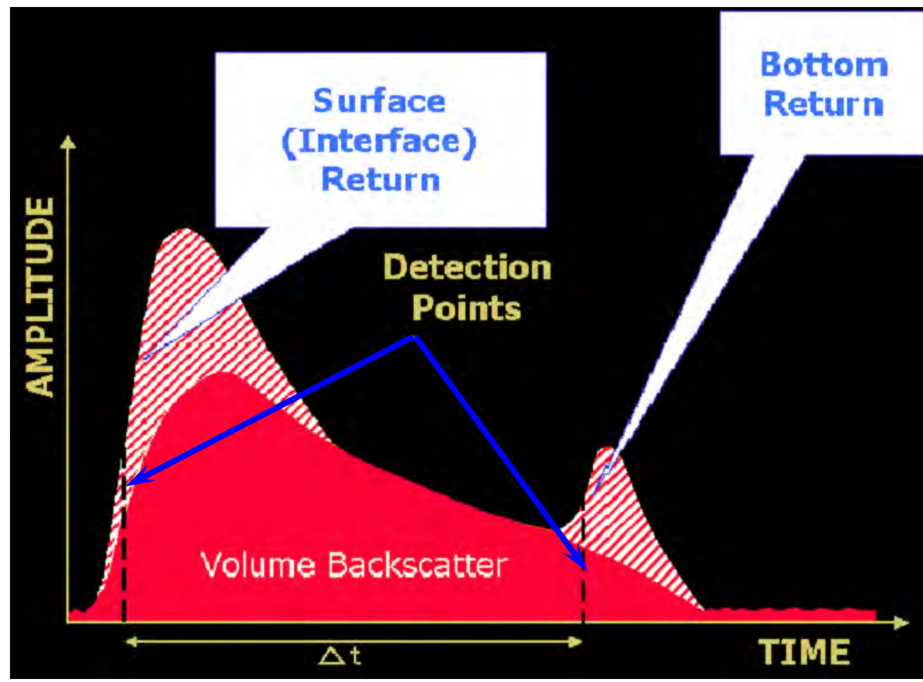
LiDAR Bathymetry

- Optech SHOALS
- Red laser 1064 nm
- Green lasers 532 nm

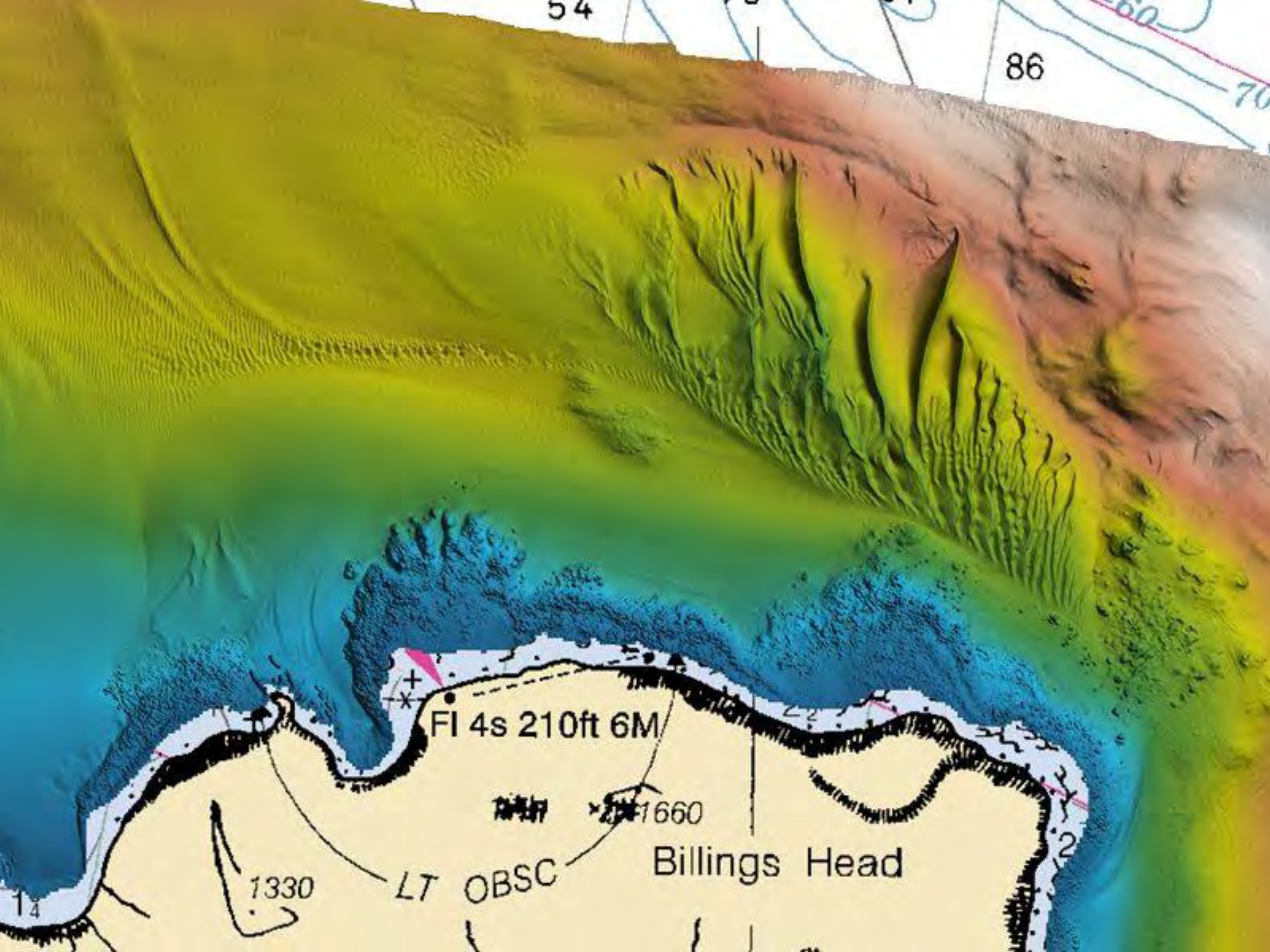


Surface and Bottom Detection

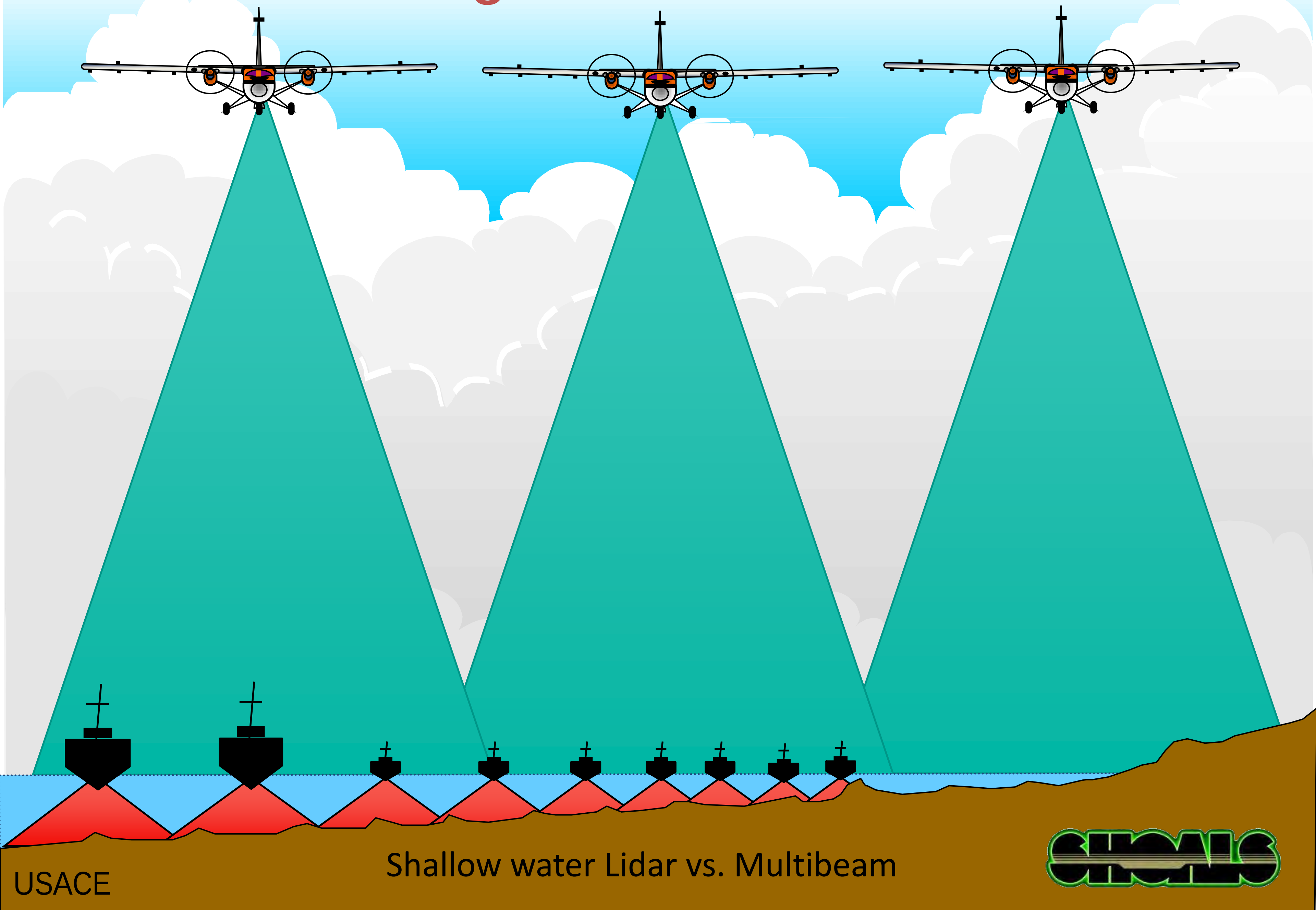




USACE


54
86
Fl 4s 210ft 6M
1660
Billings Head
LT OBSC
1330

Advantages of Airborne Lidar



Active LiDAR summary

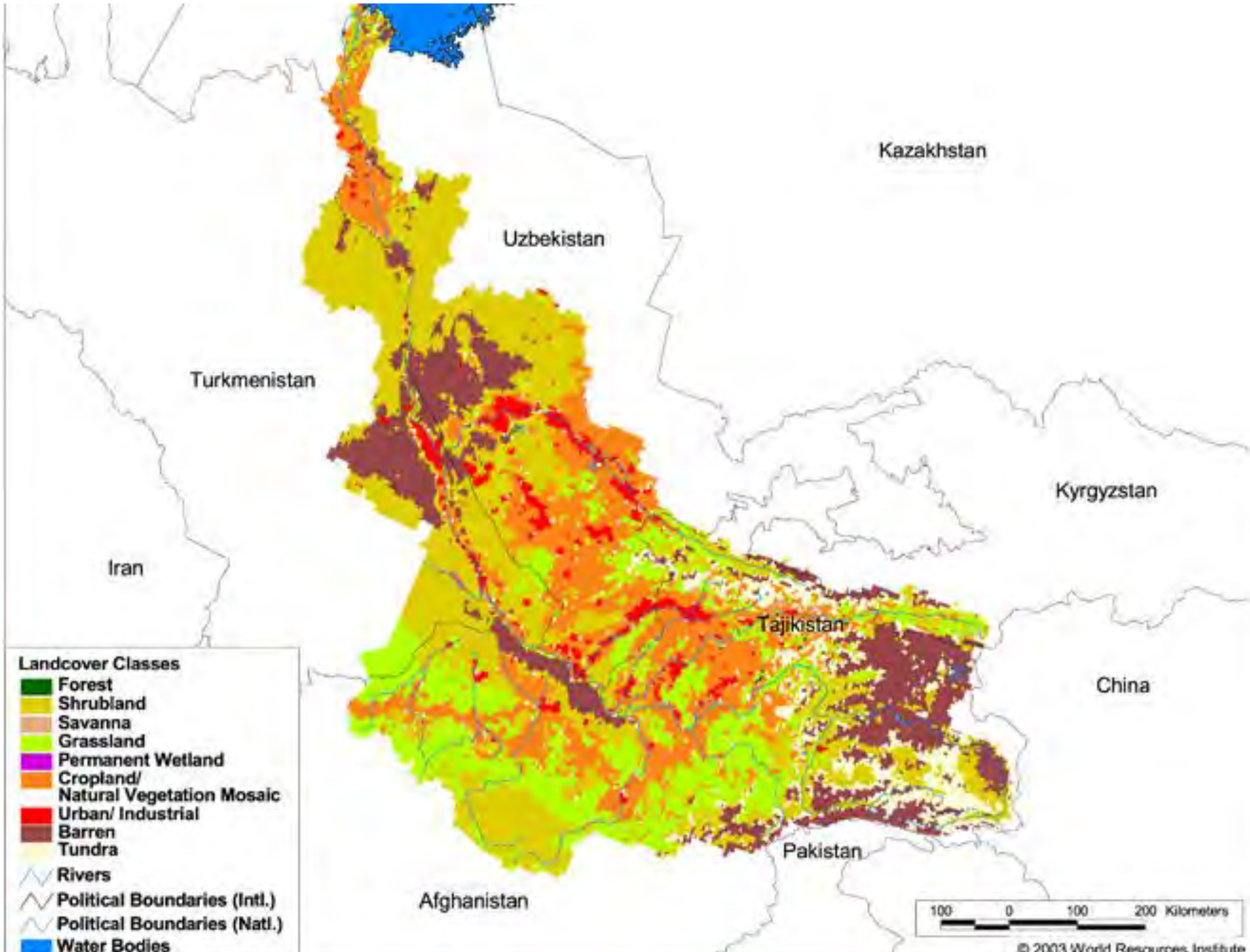
- Provide own source of energy / radiation
- Day & night capability
- High spatial and vertical accuracy
- Contains intensity information
- Little atmospheric interference
- Makes physical measurements
- Can “look” through forest cover
- Can “see” through shallow (<70 m) water depth

Outline

1. Background
2. Types of Imagery
   - GPS
   - Google
   - Aerial Photography
   - Satellite Imagery
   - RADAR Imagery
   - LiDAR data
3. Uses of Remote Sensing in Boundary Work
4. Acquiring and Interpreting Imagery

Amu Darya (Oxus)

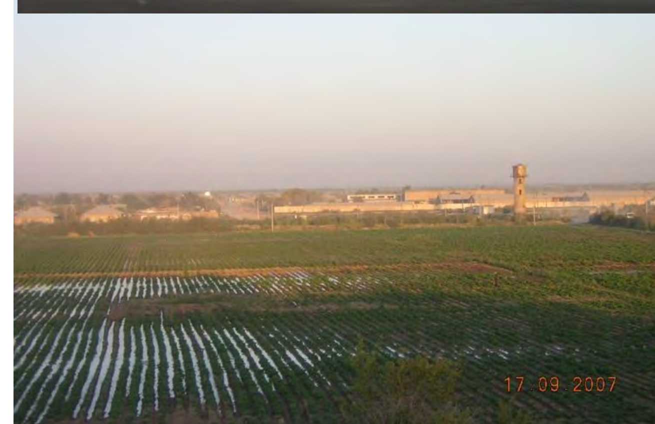
535,000 square km basin



Karakum canal

1,400 km from Amu Darya to Caspian Sea (1967-1980) in Turkmenistan

Used to irrigate the large collective cotton farms of the Murghab



Height data

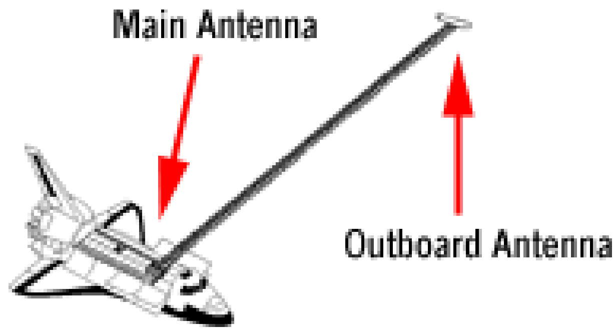
Satellite imagery

- CORONA
- SPOT
- SRTM (shuttle radar topography mission)
- ASTER
- IceSAT

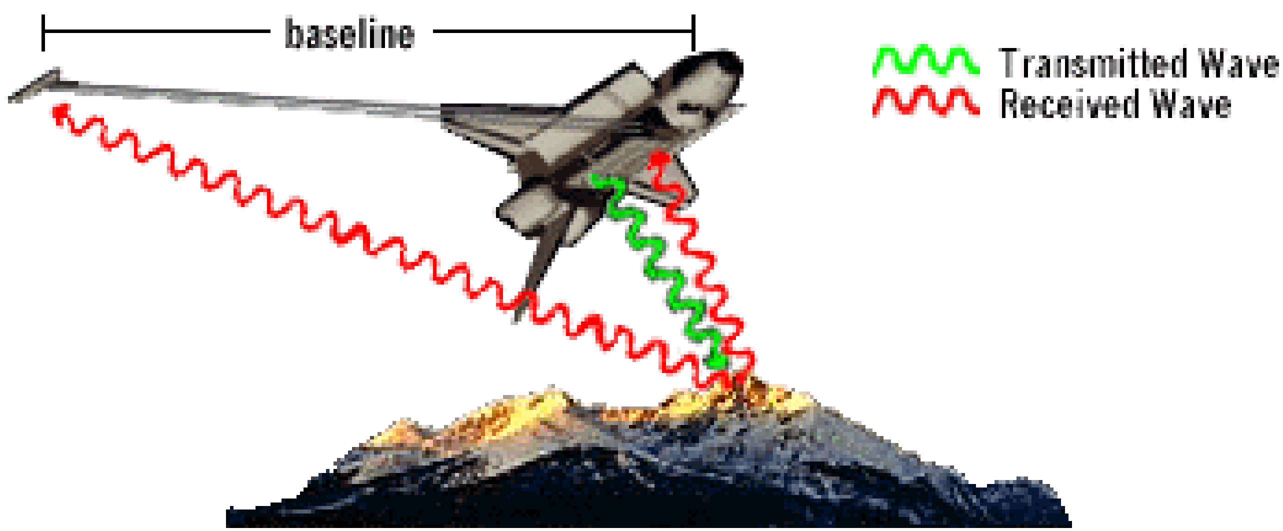
Airborne imagery

- Photogrammetry
- Laser scanning

SRTM Mission STS-99 using RADAR Interferometry

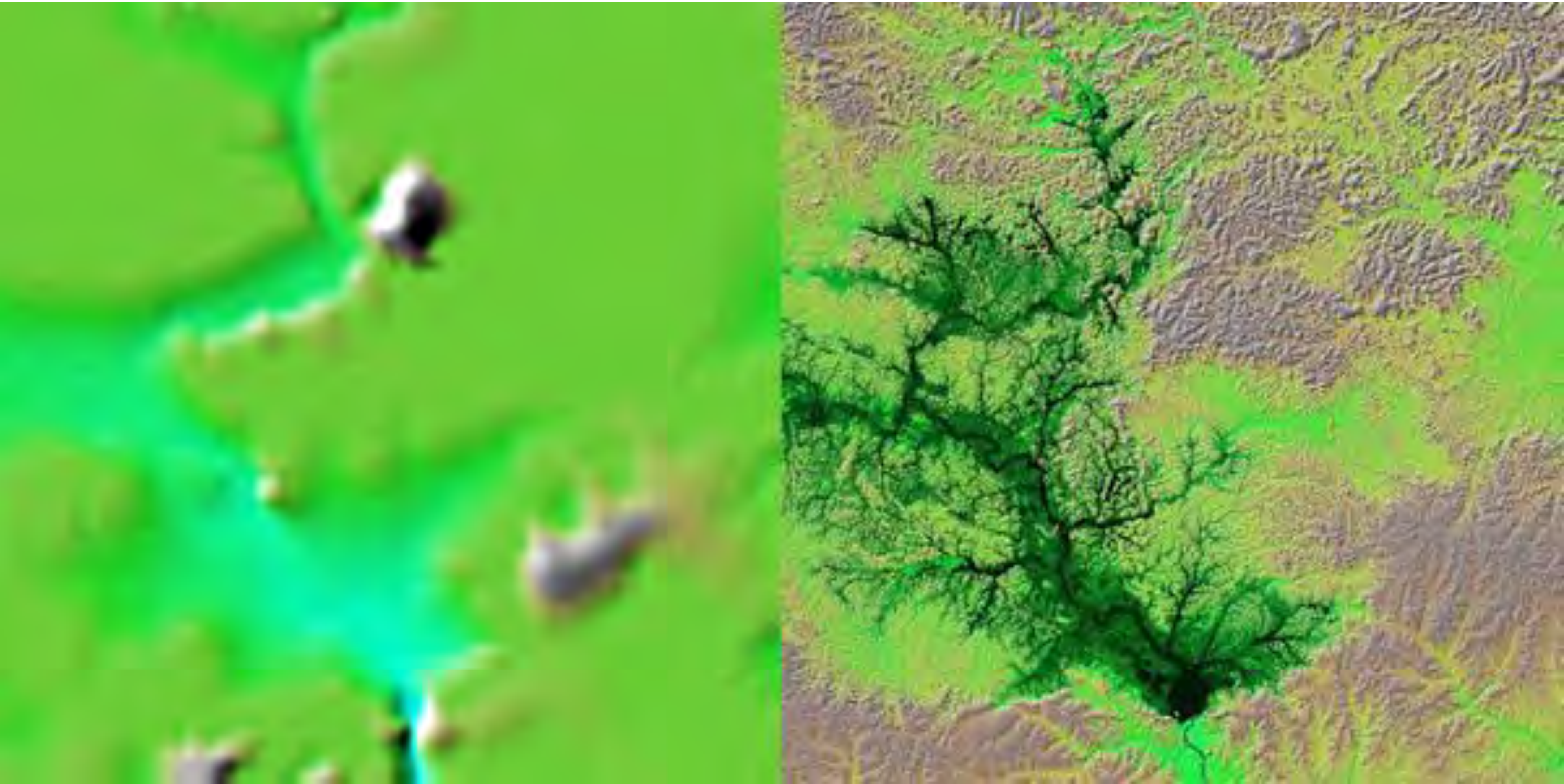


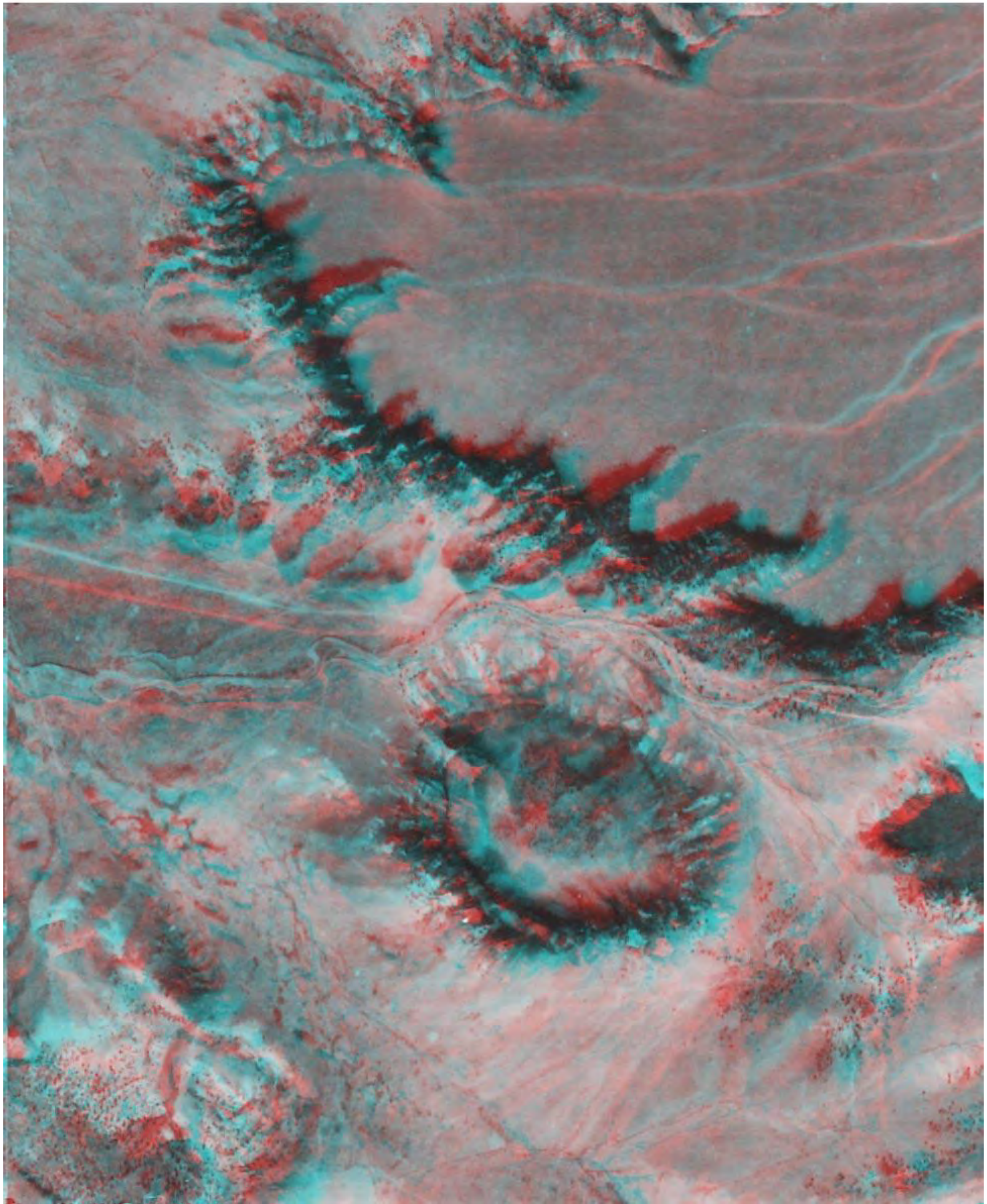
Reflected radar signals collected at two antennas, providing two sets of radar signals separated by a distance.

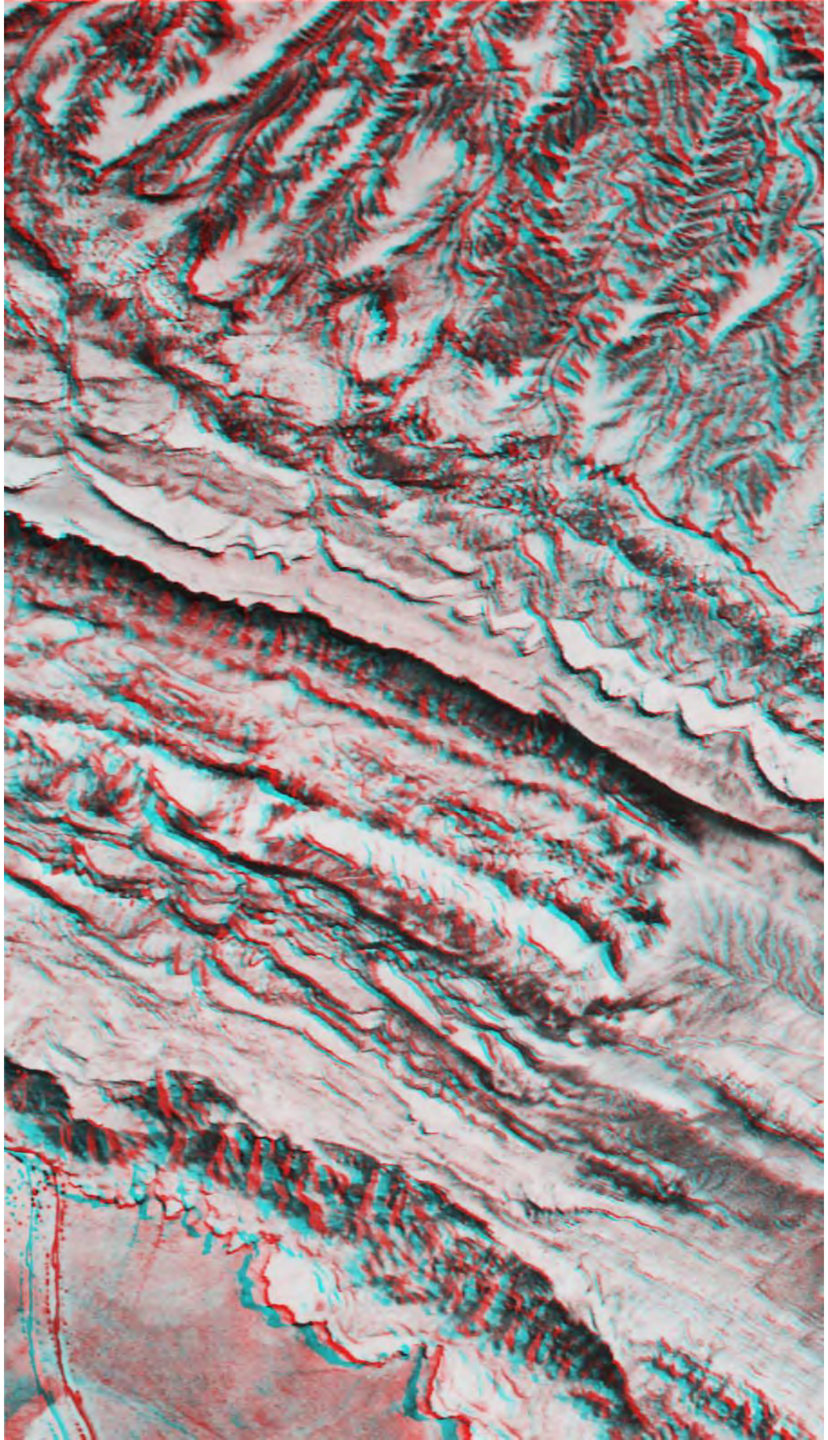


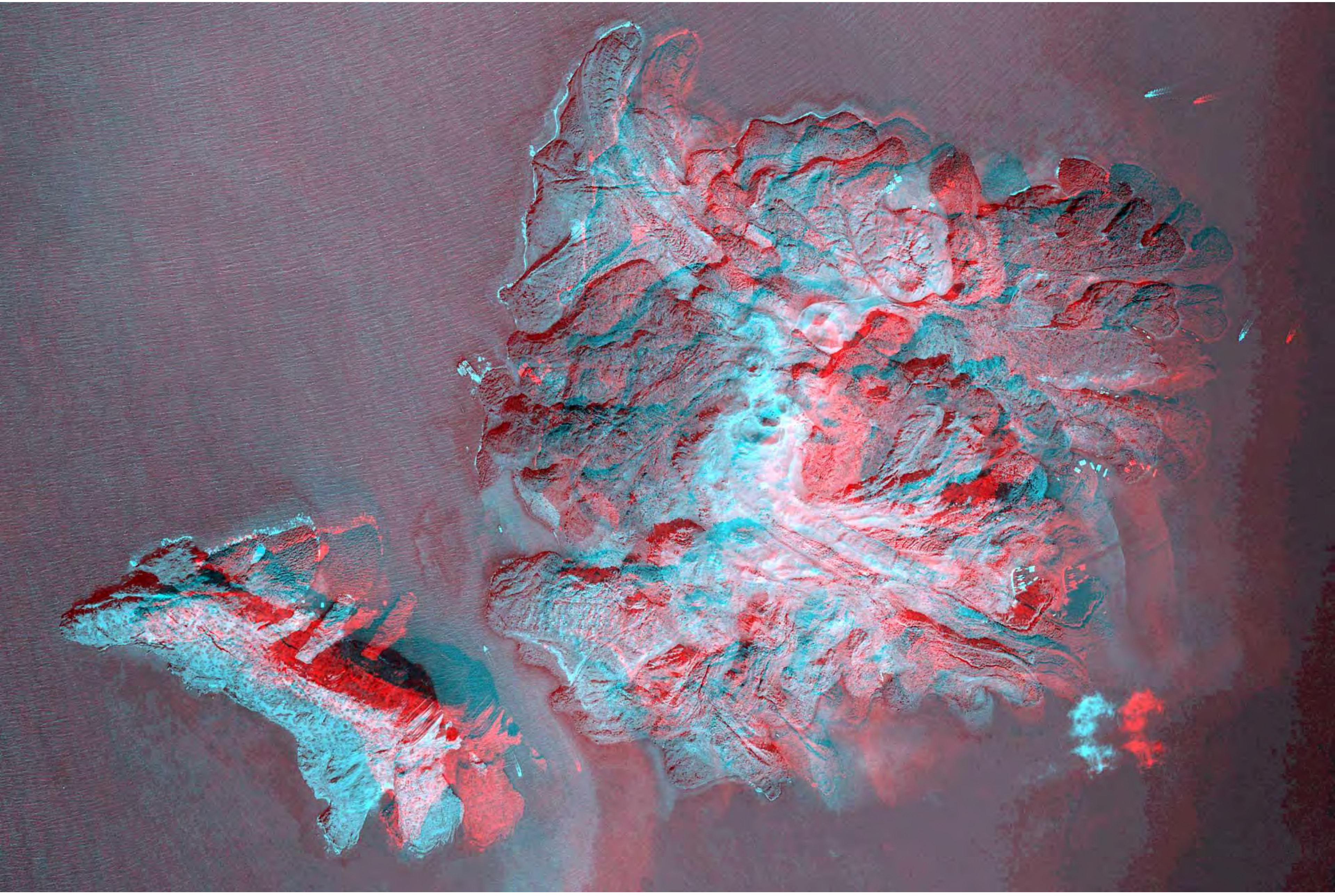
Radar signals being transmitted and recieved in the SRTM mission (image not to scale).

1km and SRTM 30 m data

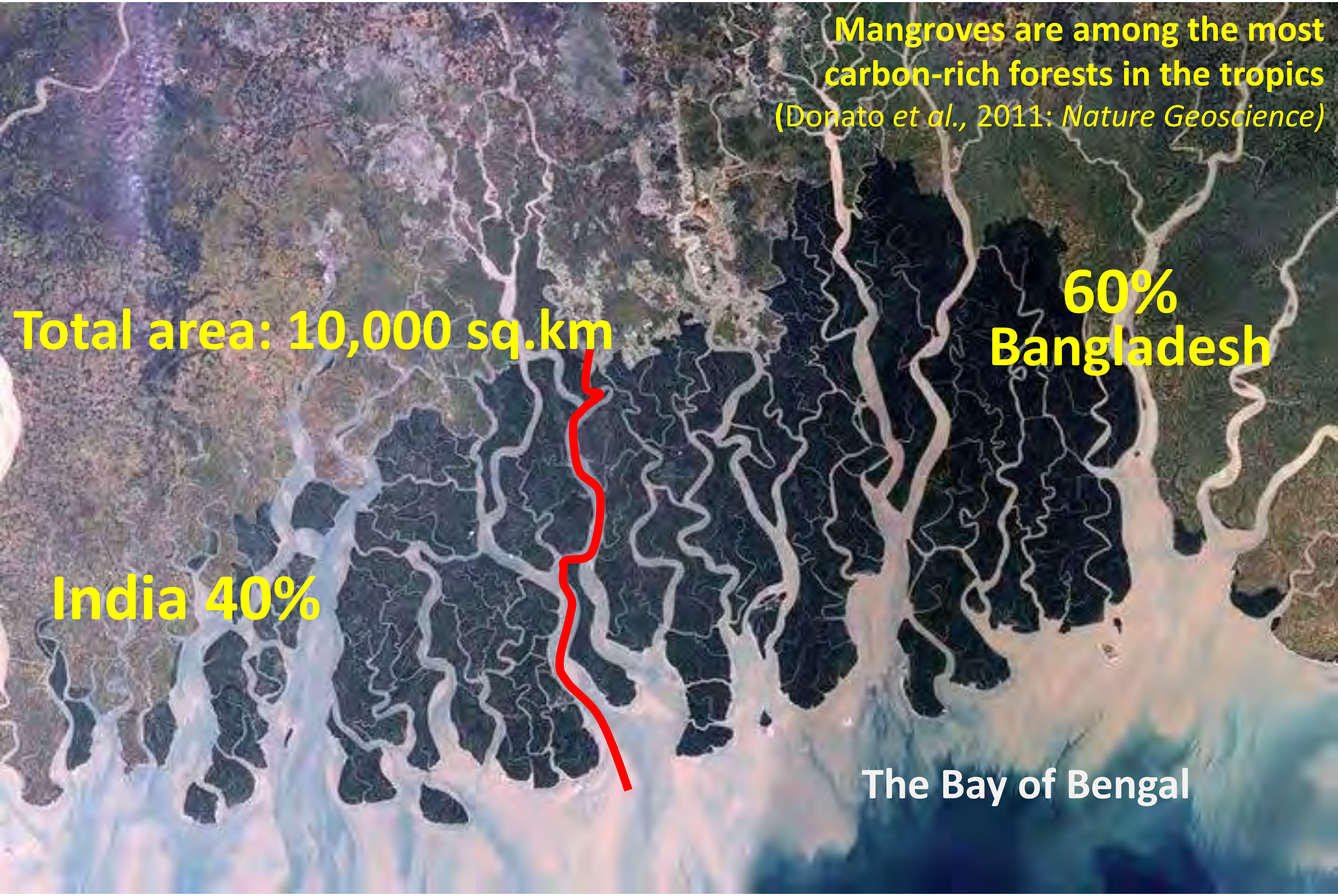


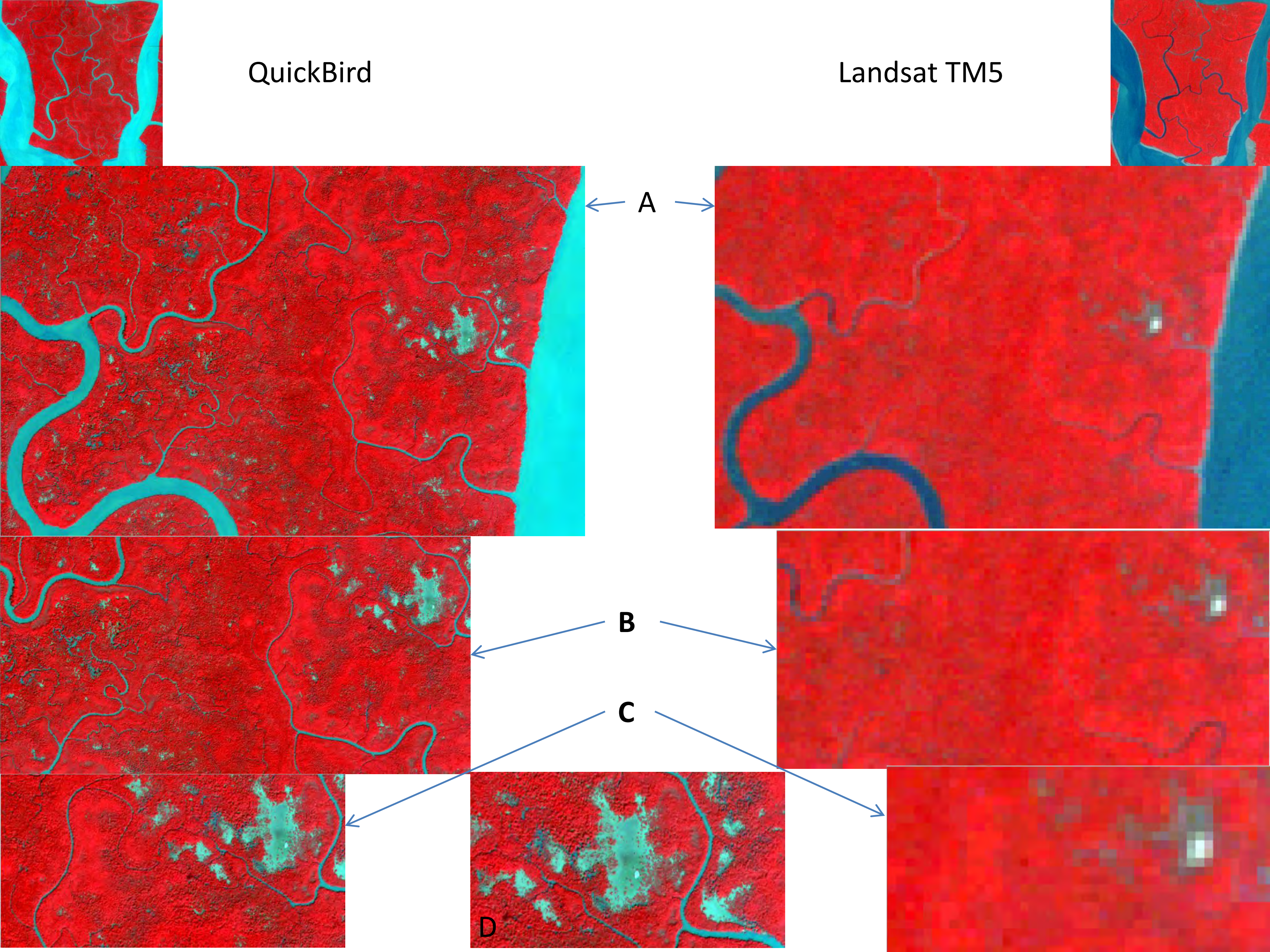






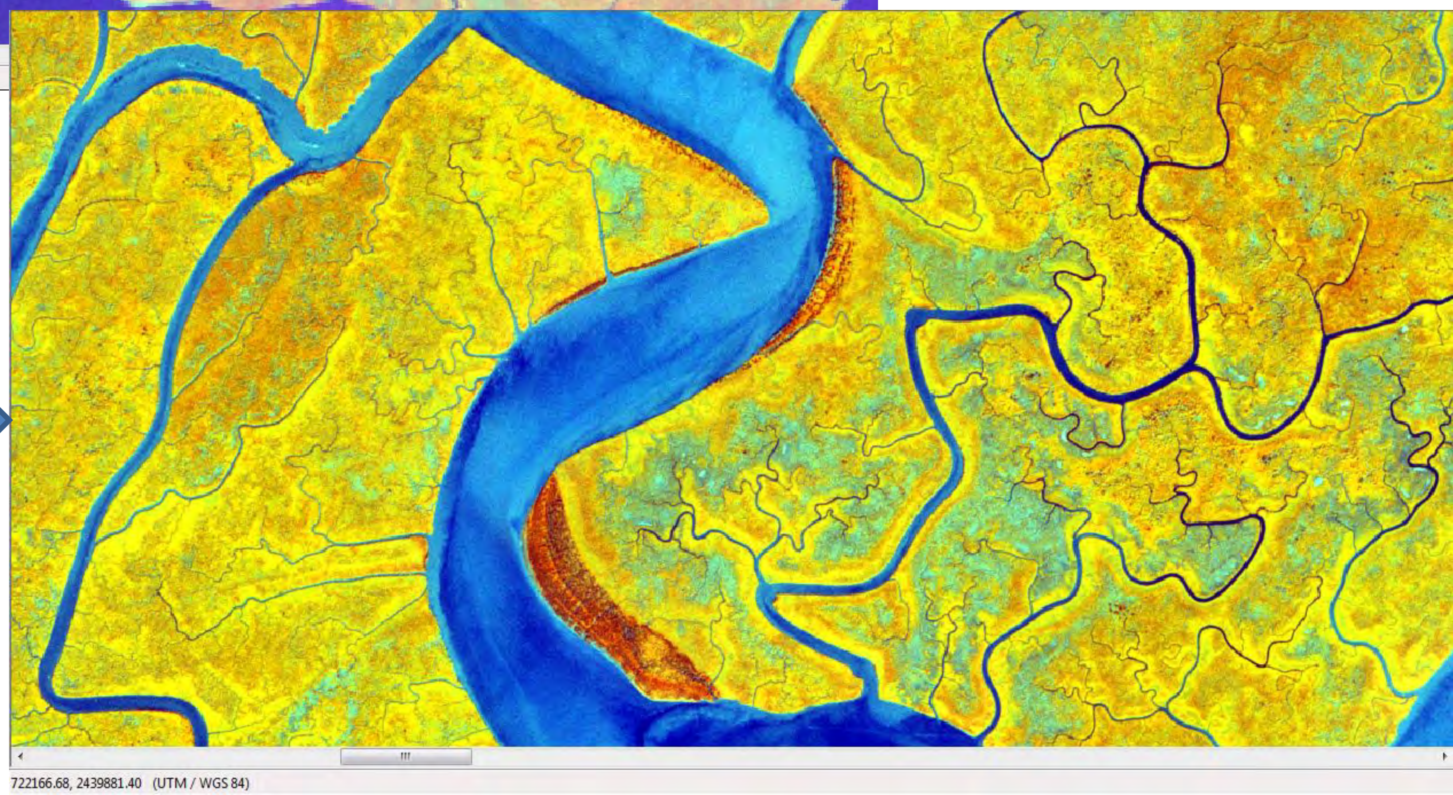
Sunderbans: The World's Largest Contiguous Mangrove

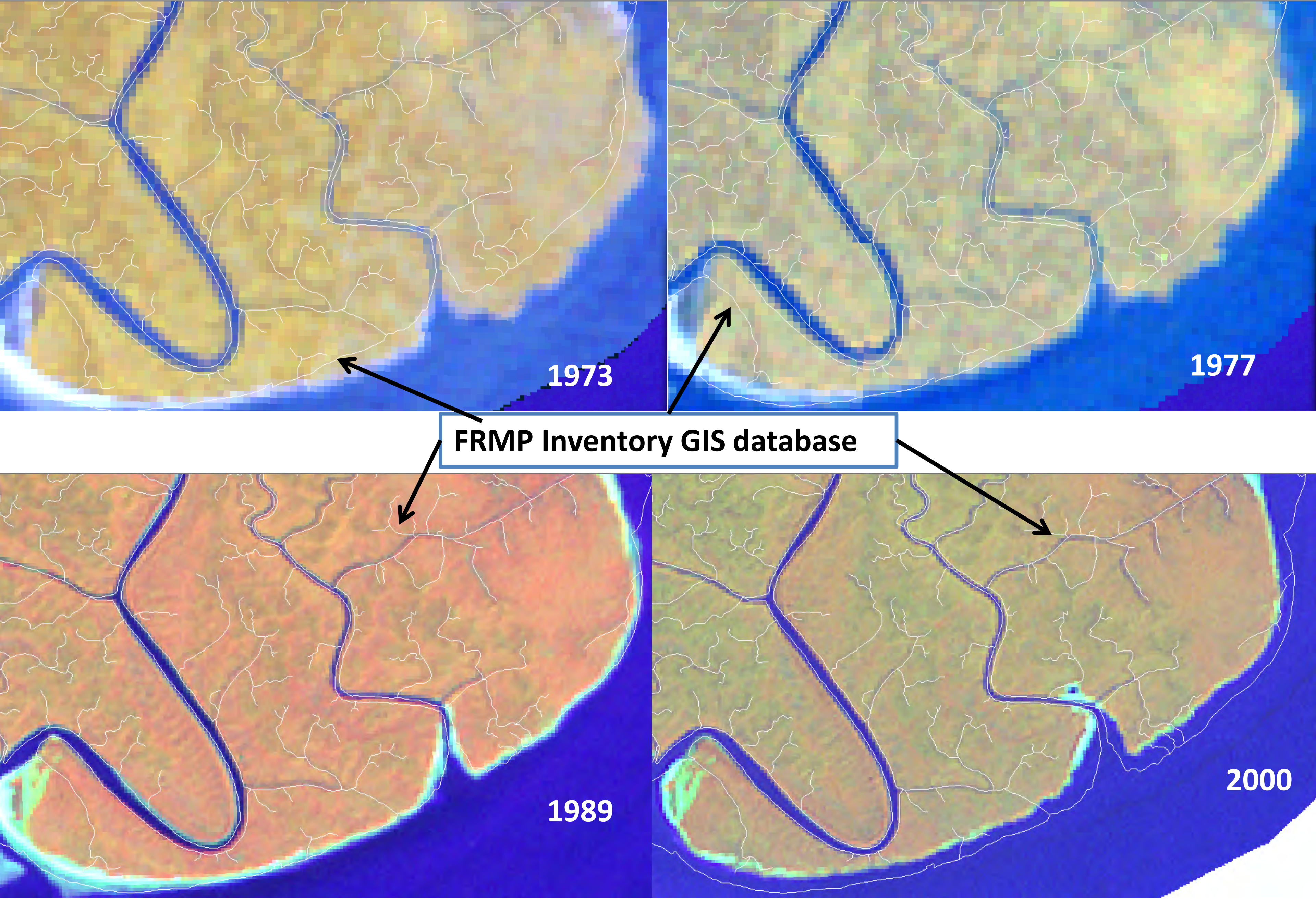


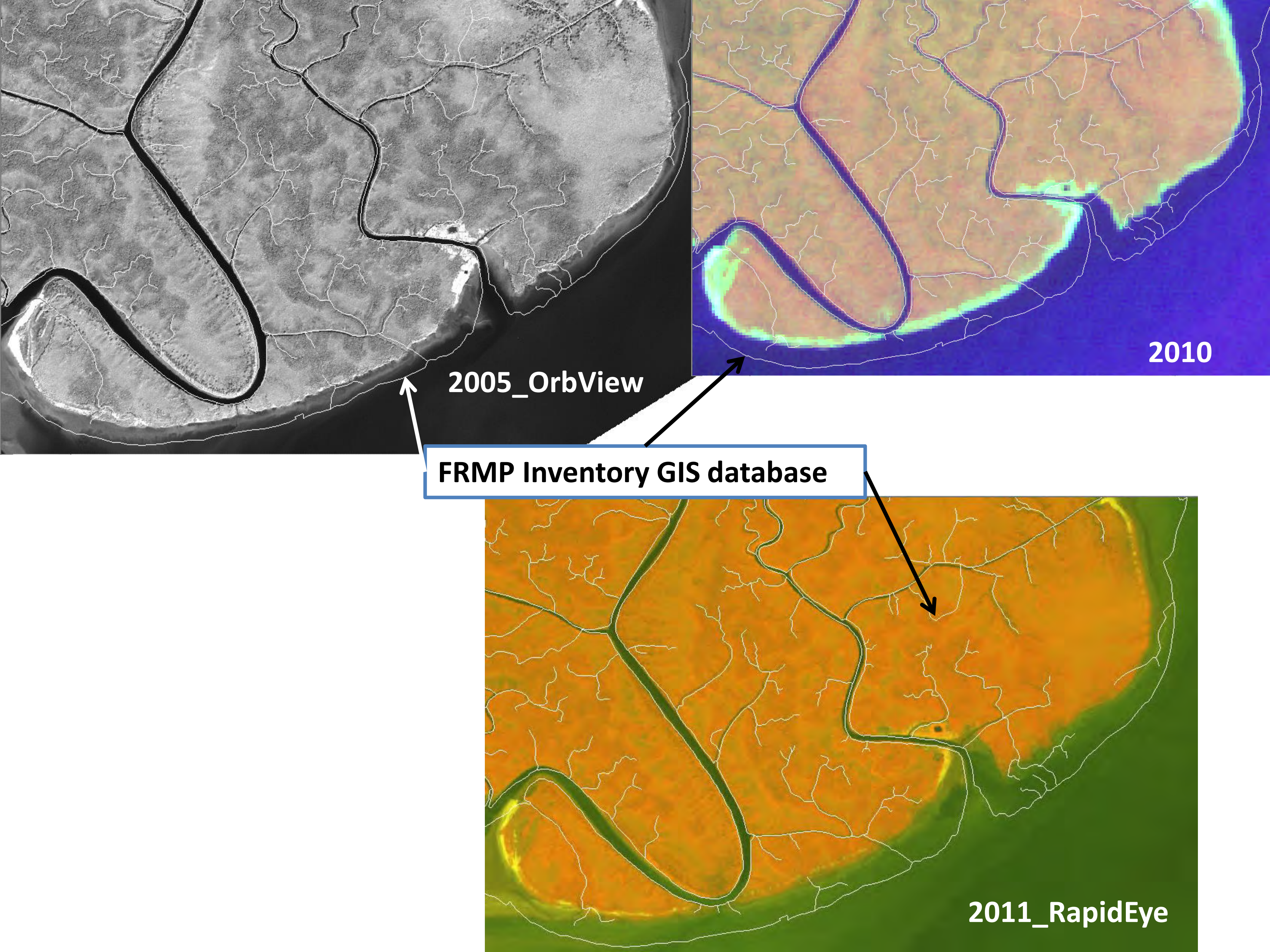

QuickBird
Landsat TM5
A
B
C
D

Landsat TM5
06 February 2010

RapidEye
08 February 2011




1973
1977
FRMP Inventory GIS database
1989
2000


2005_OrbView
2010
FRMP Inventory GIS database
2011_RapidEye

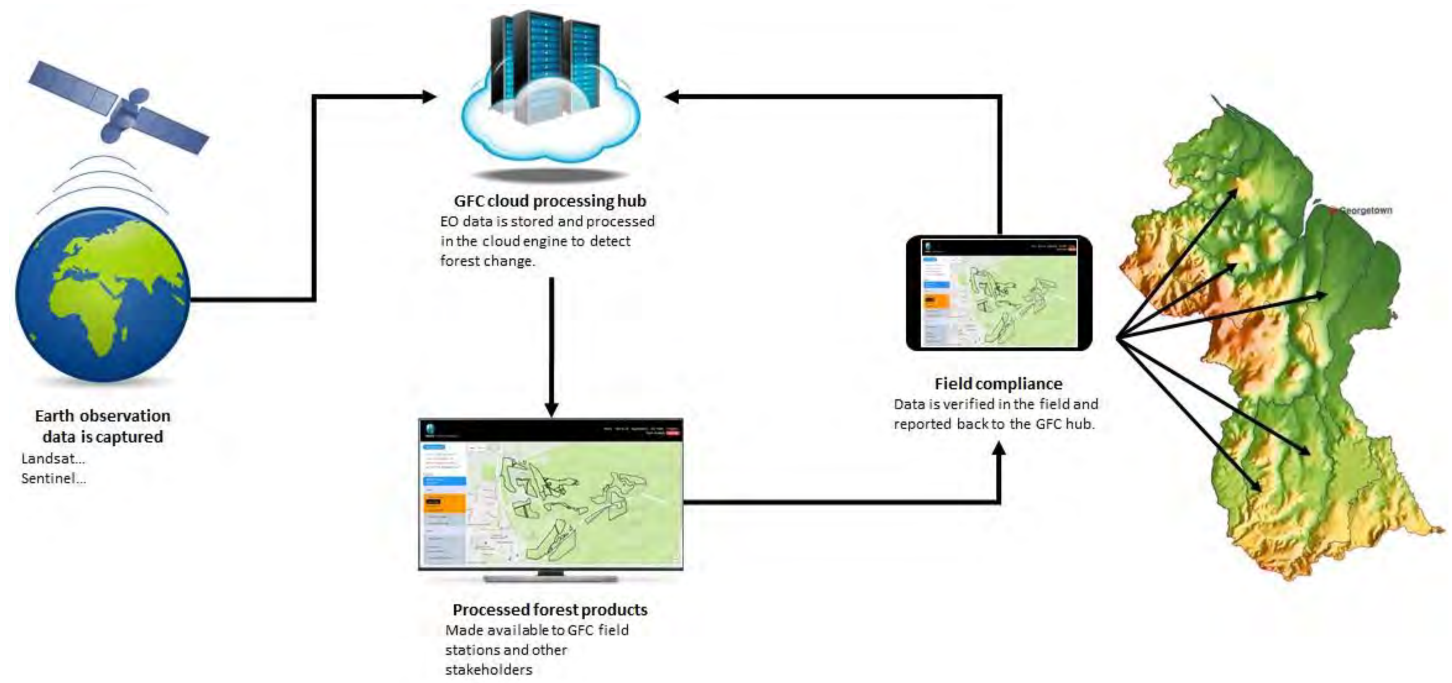
Outline

1. Background
2. Types of Imagery
   – GPS
   – Google
   – Aerial Photography
   – Satellite Imagery
   – RADAR Imagery
   – LiDAR data
3. Uses of Remote Sensing in Boundary Work
4. Acquiring and Using Imagery

Acquiring Data

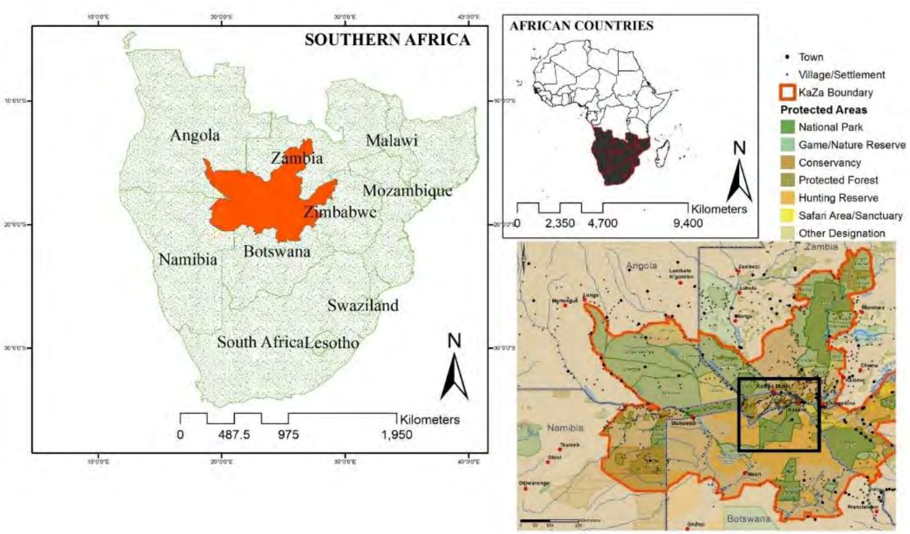
- Commercial Imagery
- On-Line sources
- National data sets
- International data sets

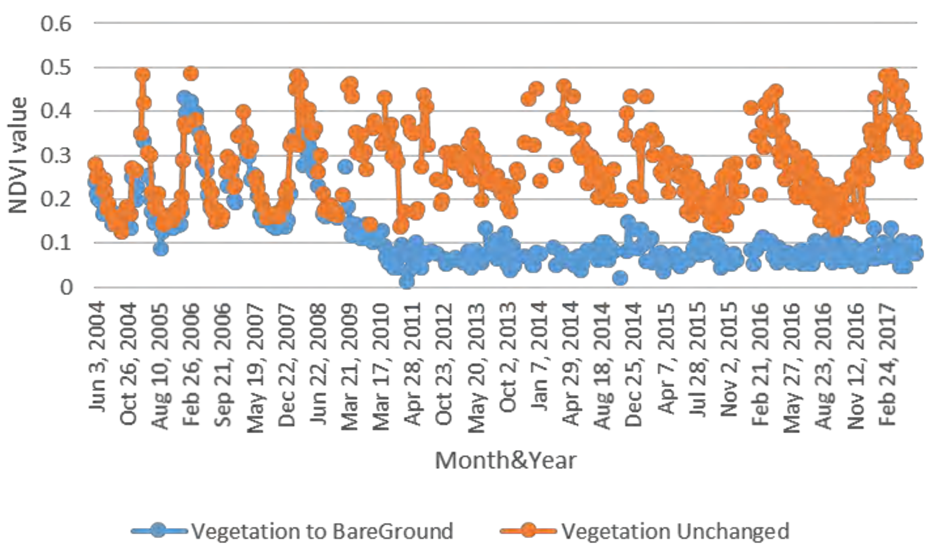
Estimating Deforestation rates in Guyana, South America – linking field and satellite data



[Guyana Web Demo (earthengine.app)]()

Monitoring forest loss in southern Africa with Landsat time series with Cloud computing





[Beech Forest Drought Monitor v3 (earthengine.app)]

Remote Sensing

- Remote sensing provides essential spatial data both qualitative and quantitative
- Provides options in terms synoptic coverage (Spatial, Spectral, Radiometric and temporal resolutions)
- Technology that allows passive and active sensing (day or night, all weather if necessary)
- Rapidly evolving and APIs provide direct GIS link

Conclusions

- Cloud computing means that spatial data are becoming more readily available and processing is relatively simple e.g.

- RS and GIS technologies open up new opportunities for monitoring and modelling

- New business models being tried to make data more accessible and reusable e.g. Satellite Imagery: Buy and Sell High Resolution Earth Data & Processing Algorithms · UP42

IBRU

International Boundaries Research Unit

Durham University

danny.donoghue@durham.ac.uk

شكرا غاىئكم

Thank you for listening