PLATFORMS & SENSORS

Platform:
the vehicle carrying the remote sensing device – e.g. ground, airborne, spaceborne

Sensor:
the remote sensing device recording wavelengths of energy e.g. camera, scanner

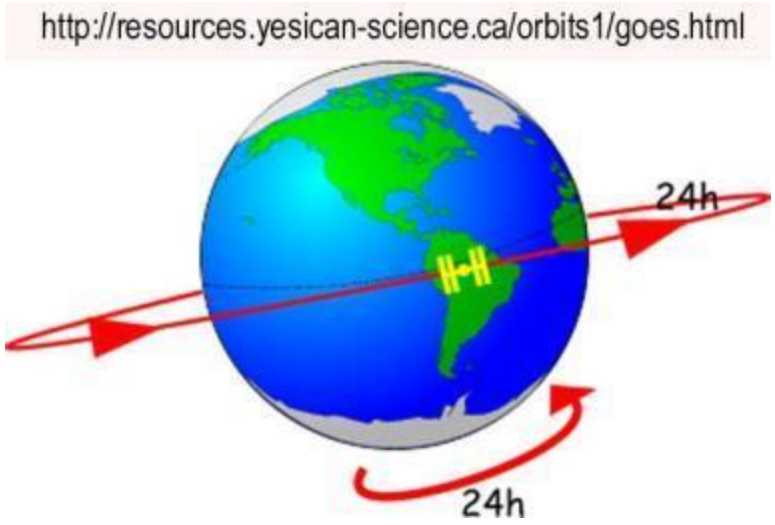
Image data might be referred to using platform or sensor

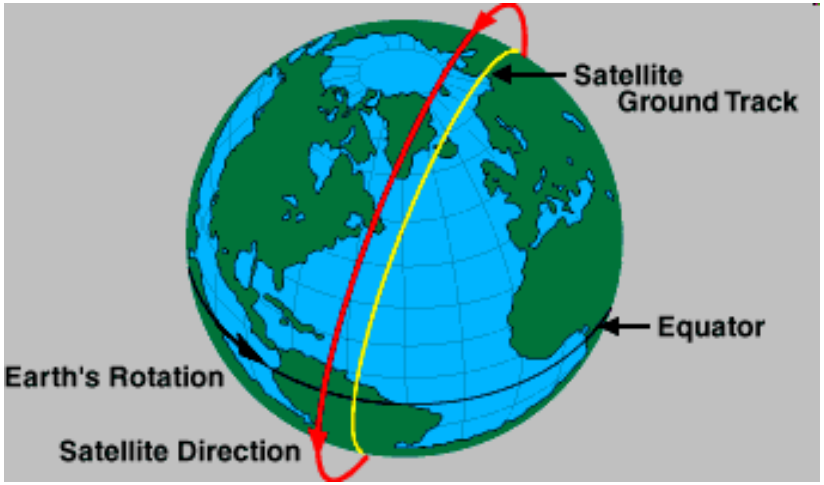
Another copy of my (old) lecture notes:
http://web.pdx.edu/~nauna/resources/15-sensors.pdf

Platform = International Space Station

Sensor = Chris Hadfield's Nikon

1. Satellite orbits



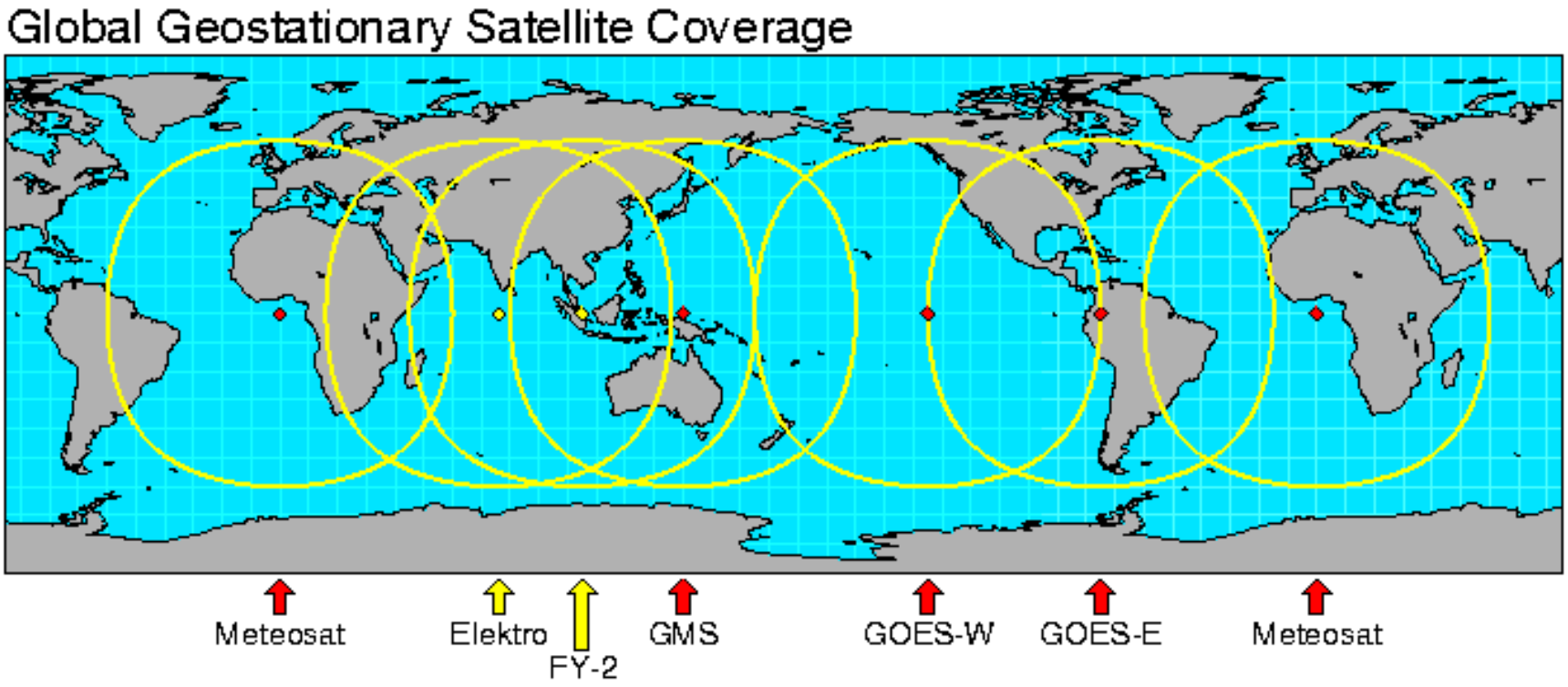


"Geostationary"
e.g. Weather satellites
TV, Internet, GPS-WAAS
~ 36,000 km altitude

"Sun-synchronous"
EO Surface monitoring
mapping / updating
~ 400-900 km altitude

Satellite orbits

Geostationary / geosynchronous : 36,000 km above the equator, stays vertically above the same spot, rotates with earth - weather images, communications, e.g. GOES (Geostat. Operational Env. Satellite)

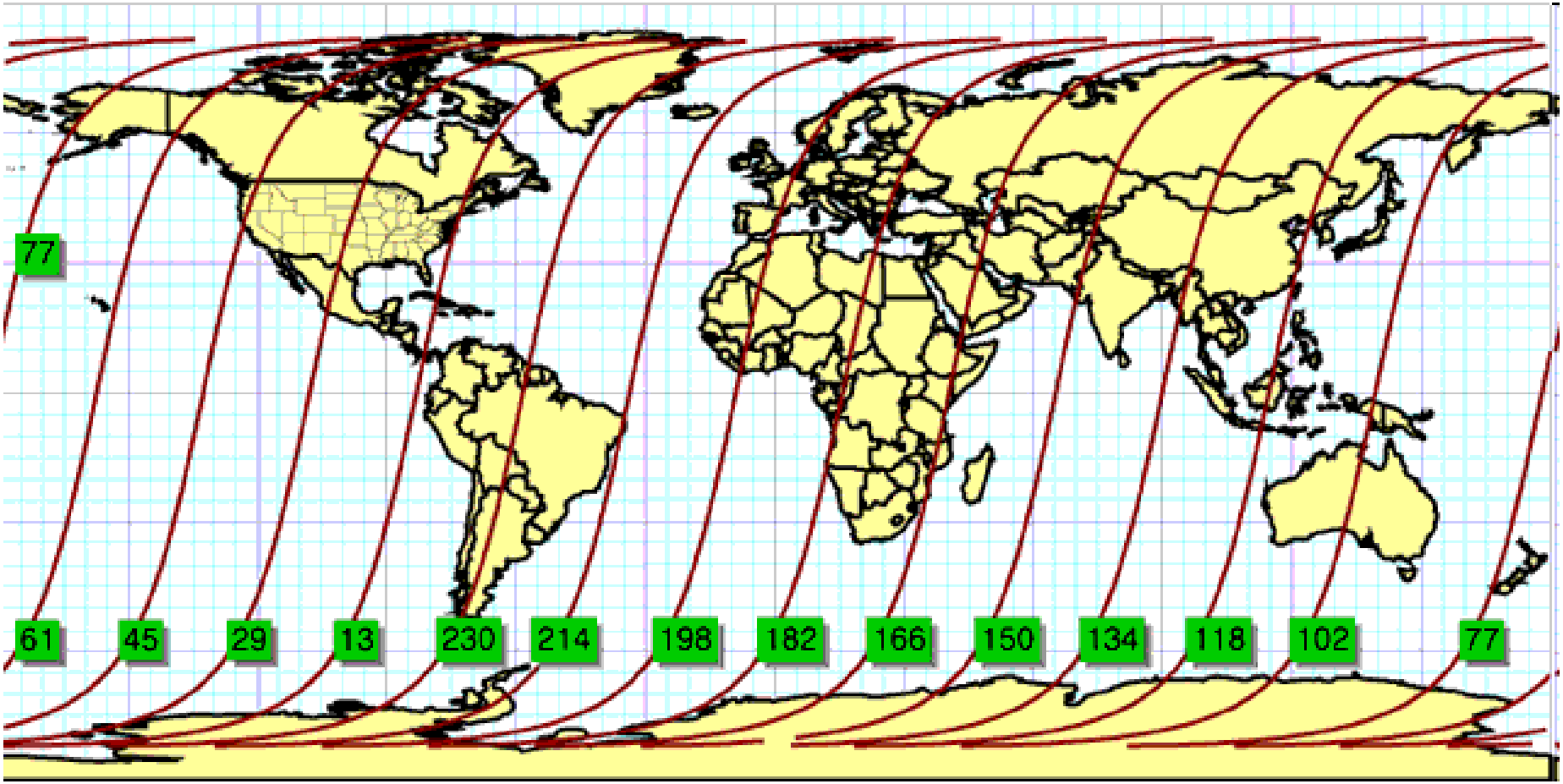


Geostationary satellites capture a (~rectangular) scene,

Sun-synchronous satellites: 400-900km altitude, rotate at ~81-82 degree angle to equator: imagery ~ the same local time each day (~10.30am)

Time of day = compromise between minimum shadow and clouds (9.30-11.00am)

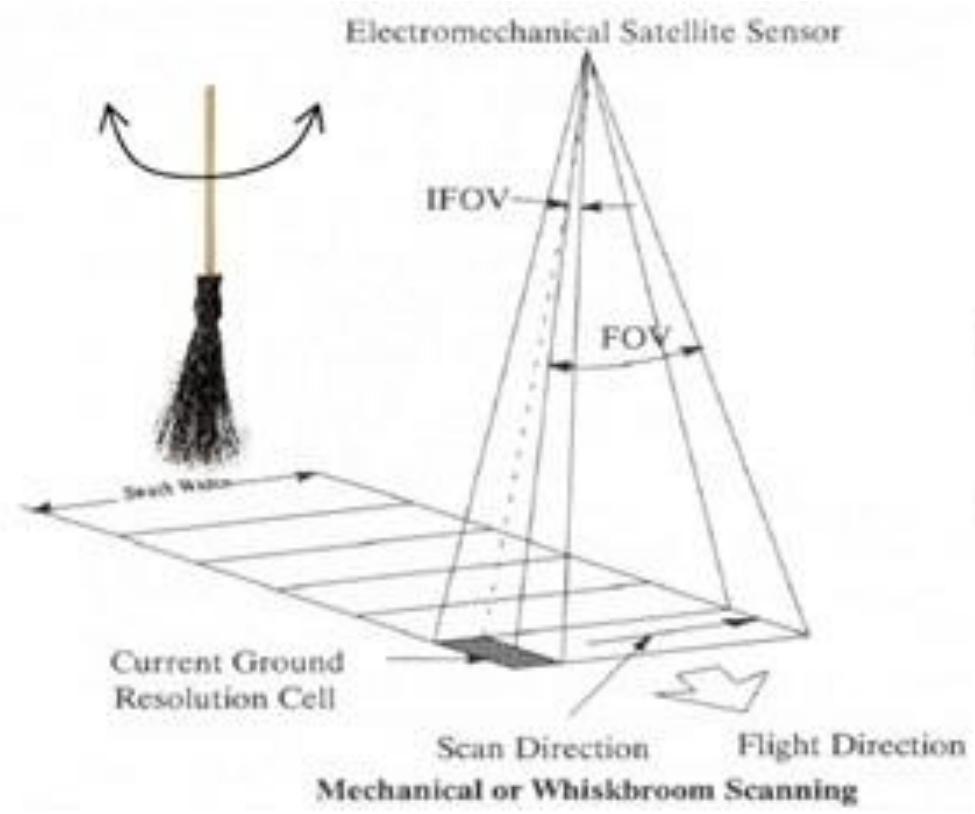
ISS orbit is at 408 km altitude

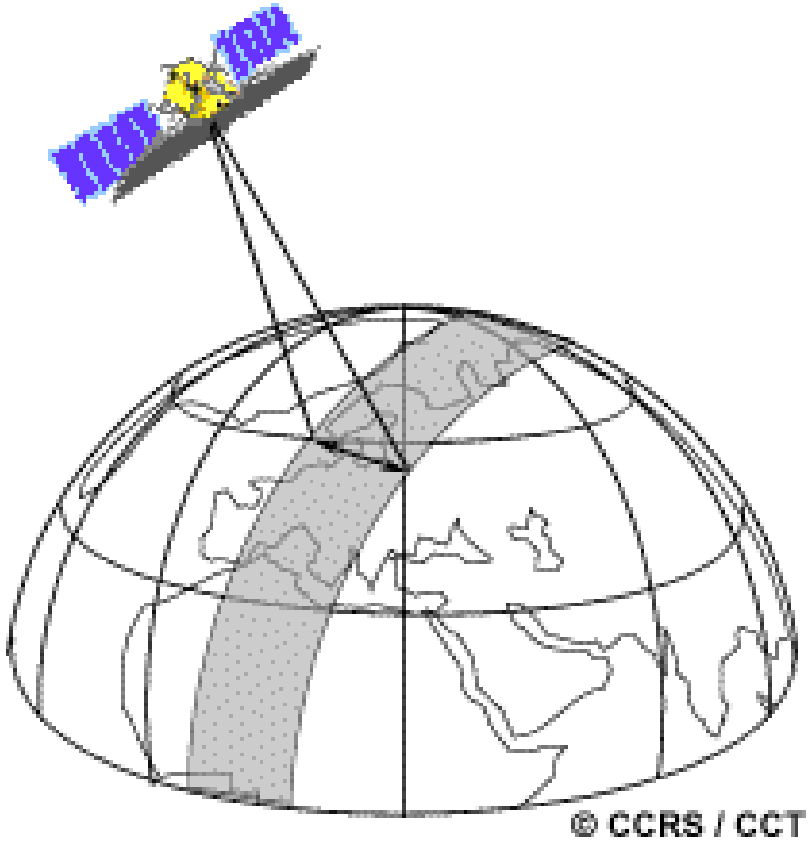


Landsat path: earthnow

2. Scanner types

a. Whiskbroom (mirror/ cross-track):
a small number of sensitive diodes for each band sweep perpendicular to the path or swath, centred directly under the platform, i.e. at nadir
e.g. LANDSAT MSS /TM/ETM

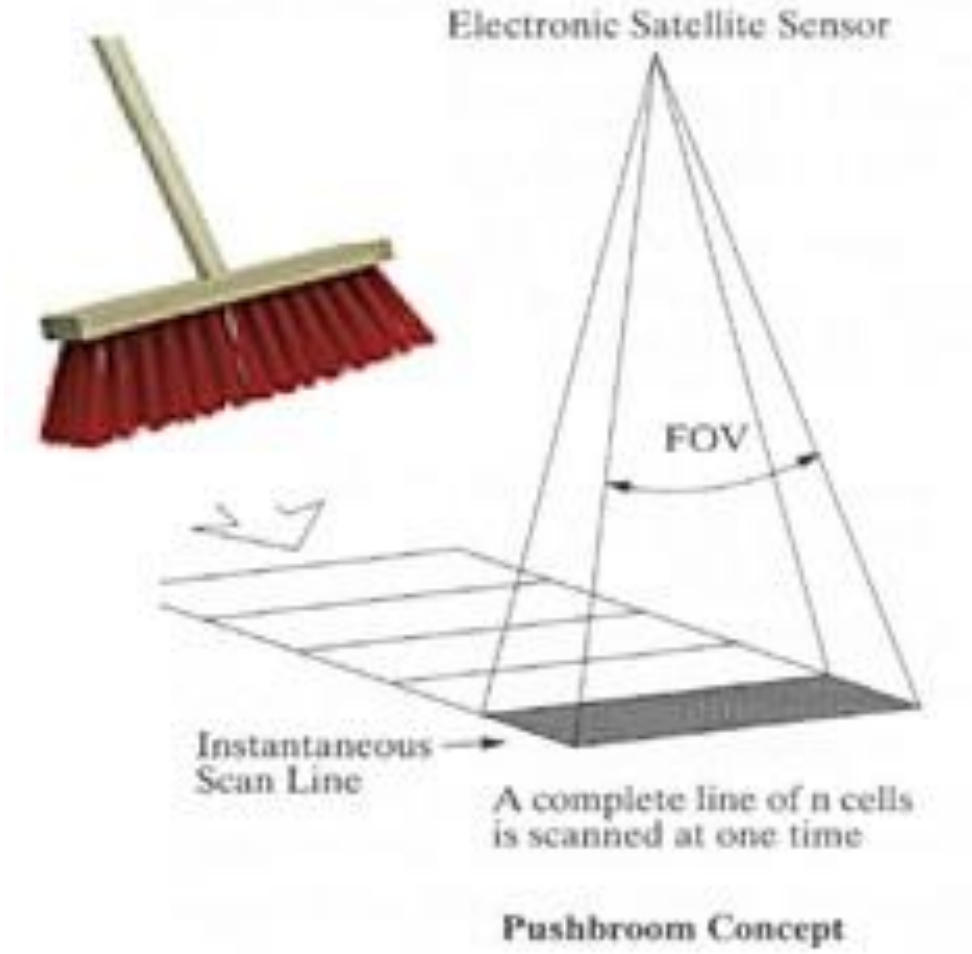


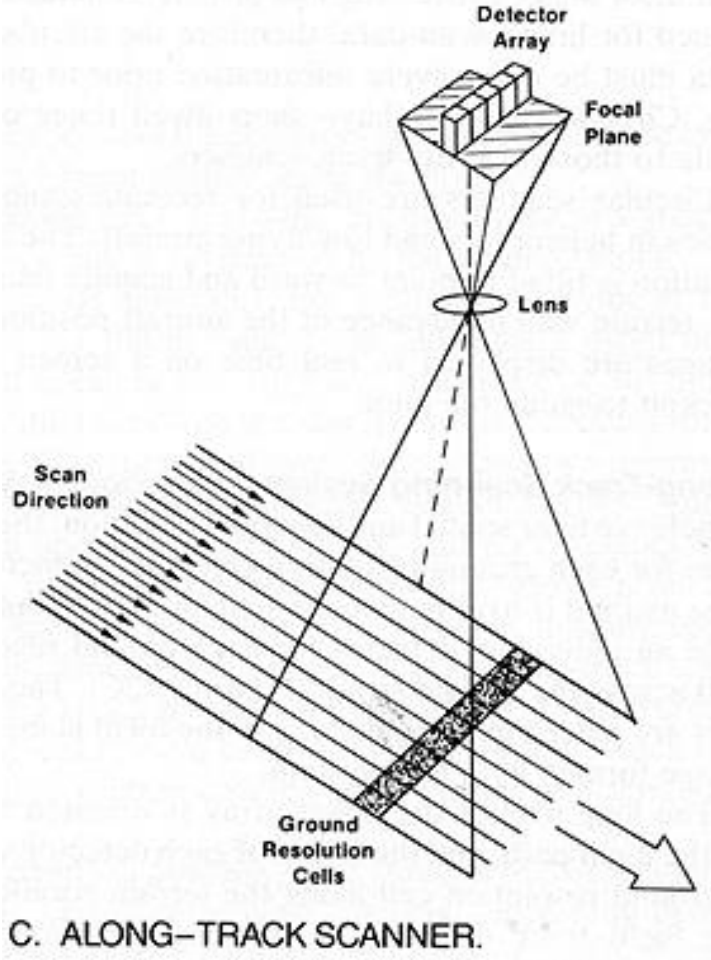


b. Pushbroom (along-track):

an array of diodes (one for each column of pixels) can be 'pointed' in a selected direction, **nadir or off-nadir**, on request, usually 0-30 degrees (max.), e.g. SPOT HRV, Landsat 8 OLI* - almost all now ..

* Landsat 8 is not redirectionned; swath = 185km = ~ 6000 pixels





3. Sensor groups

Multi-spectral sensors record bands in multiple **wavelengths**:
… but tend to focus on one of these groups

- Visible, Near IR, SWIR - Reflective
- Thermal - emissive
- Microwave – emissive or RADAR

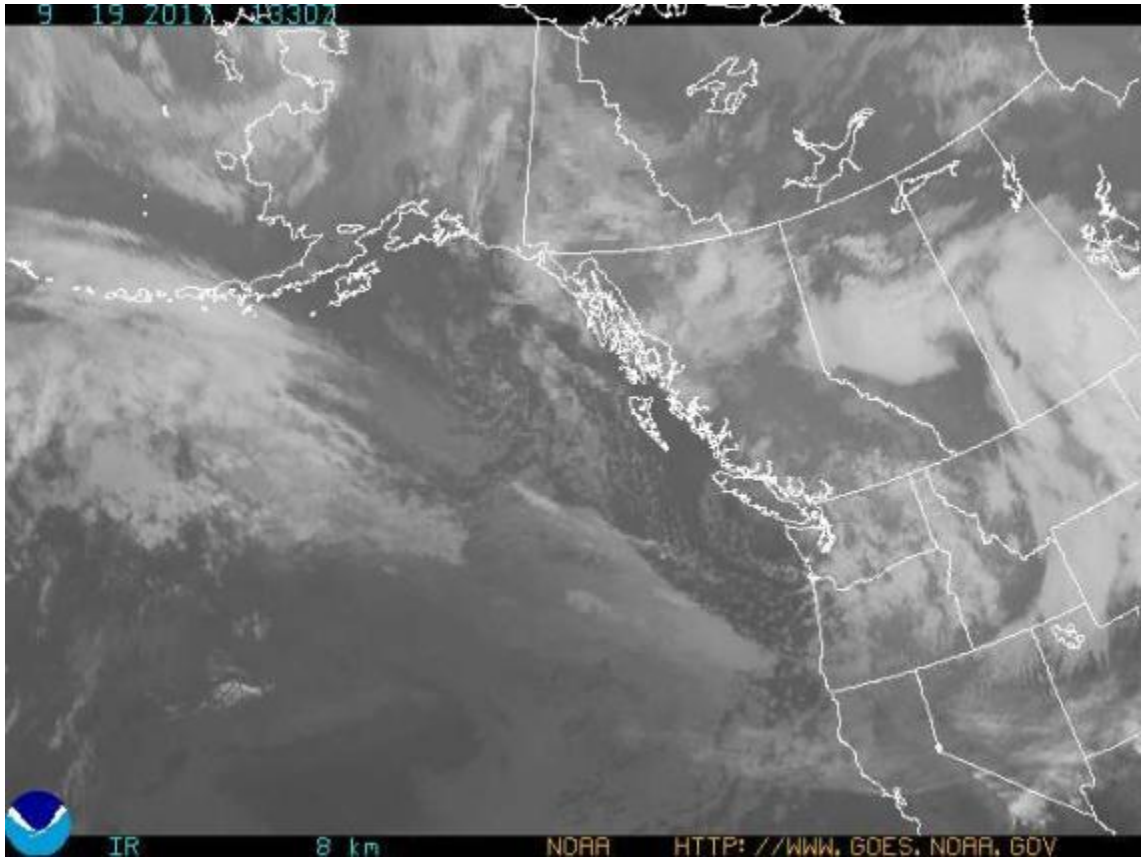
And at different **spatial resolutions** (pixel size e.g…):

- Low 1km
- Medium 500m
- High 30m
- Very high 1m

Most satellites now carry multiple sensors with varying resolutions

4. Low Resolution

Weather: GOES (24 HOURS per day)
GOES 8: 75W longitude, GOES 9: 135W longitude
Visible: 1km, Thermal: 4km, 10-bit data (DN = 0- 1023)
GOES 17: 16 bands, VNIR (5)/ TIR (11)
http://www.goes.noaa.gov

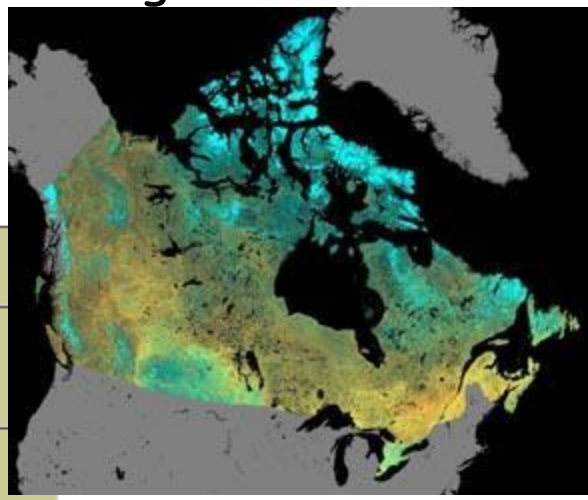


Low Resolution

NOAA AVHRR (Advanced 'Very High' Resolution Radiometer)

1.1km Red / NIR / TIR (5 bands)

1978-present (19 satellites) - global vegetation monitoring: data are freely downloadable. 18, 19 operational



2500 x 2500 pixels, 10 bit data

AVHRR/3 Channel Characteristics			
Channel Number	Resolution at Nadir	Wavelength (um)	Typical Use
1	1.09 km	0.58 - 0.68	Daytime cloud and surface mapping
2	1.09 km	0.725 - 1.00	Land-water boundaries
3A	1.09 km	1.58 - 1.64	Snow and ice detection
3B	1.09 km	3.55 - 3.93	Night cloud mapping, sea surface temperature
4	1.09 km	10.30 - 11.30	Night cloud mapping, sea surface temperature
5	1.09 km	11.50 - 12.50	Sea surface temperature

5. Medium RESOLUTION

LANDSAT (NASA) initially known as ERTS (Earth Resource Technology Satellite) ; **Multi-Spectral** Scanner (MSS: 80m)

1972 Landsat 1 until 1978 (ERTS 1)

1975 Landsat 2 until 1982

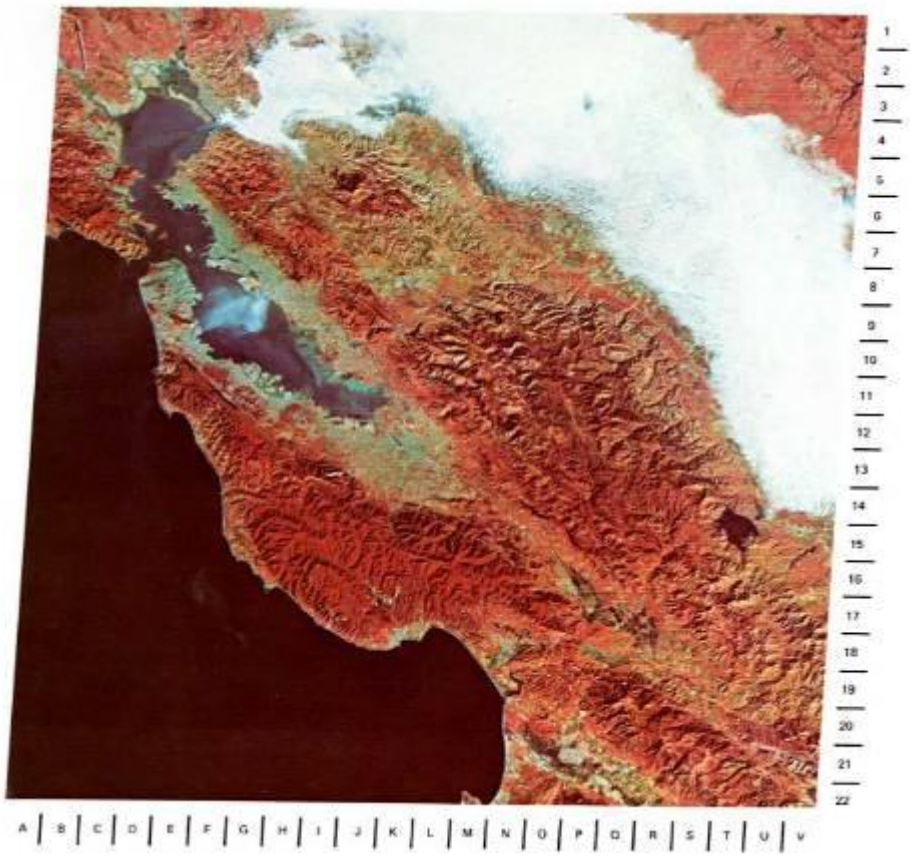
1978 Landsat 3 until 1983

Band	Spectral band	Resolution
4	0,5 - 0,6 µm	79 m x 82 m
5	0,6 - 0,7 µm	79 m x 82 m
6	0,7 - 0,8 µm	79 m x 82 m
7	0,8 - 1,1 µm	79 m x 82 m

(No mid-IR bands)

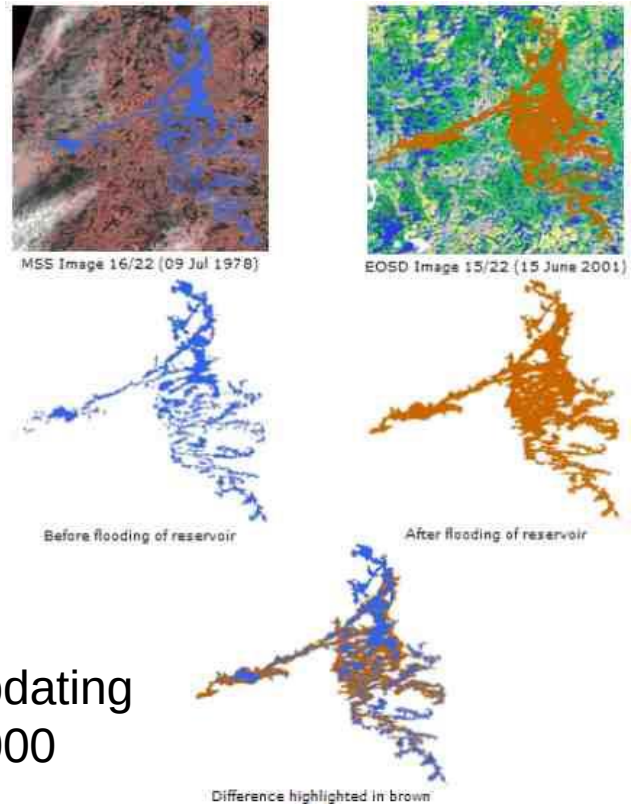
Bands 1,2,3 were on the 'Return Beam Vidicon' *(RBV)*

Manual interpretation e.g. fault lines



1972 Launch of Landsat (ERTS) 1 satellite and the 80m MultiSpectral Sensor (MSS)

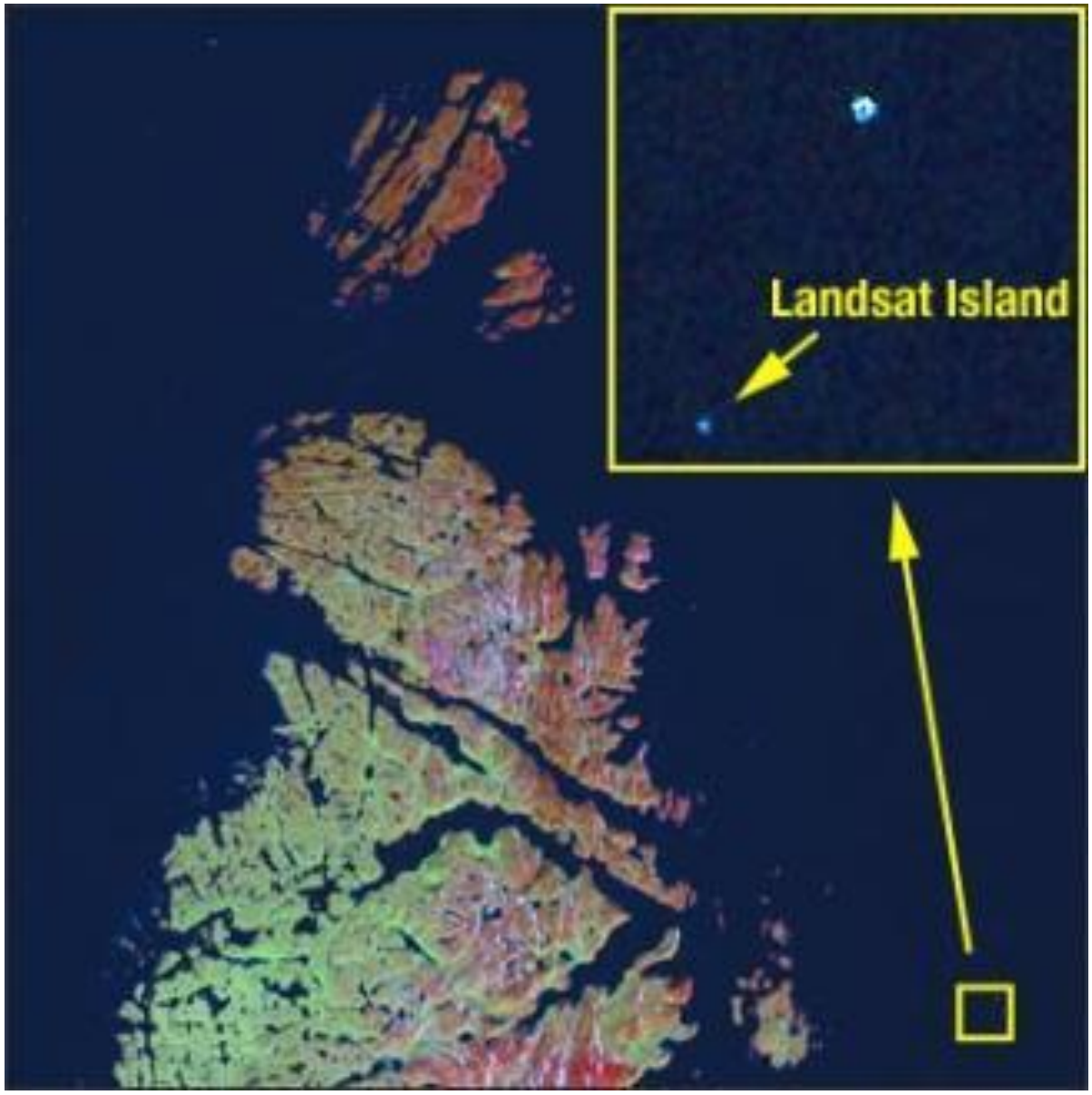
Virginia Norwood (born 1927): "The Mother of Landsat“ designed the MSS
https://www.technologyreview.com/2021/06/29/1025732



Map updating
1:250,000

Landsat image data

Discovered in 1976, Labrador
25m x 45m (Landsat 1)



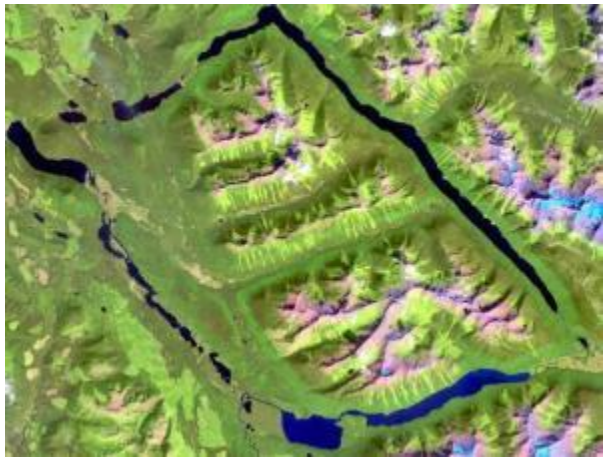
[**Landsat Island** is a small, uninhabited island located 20 kilometres (12 mi) the northeast coast of Labrador

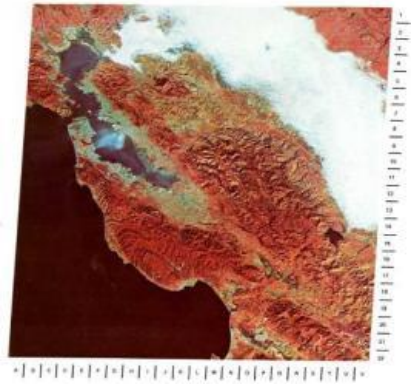
Verified by Dr. Frank Hall (Canadian Hydrographic Service). He was strapped into a harness and lowered from a helicopter down to the island. As he was lowered out of the helicopter, a polar bear took a swat at him.

The bear was on the highest point on the island and it was hard for him to see because it was white.

6. High resolution
Landsat 4/5 Thematic Mapper (TM)
1982/84: 'the next generation'

Band No.	Wavelength Interval (μm)	Spectral Response	Resolution (m)
1	0.45 - 0.52	Blue-Green	30
2	0.52 - 0.60	Green	30
3	0.63 - 0.69	Red	30
4	0.76 - 0.90	Near IR	30
5	1.55 - 1.75	Mid-IR	30
6	10.40 - 12.50	Thermal IR	120
7	2.08 - 2.35	Mid-IR	30





- Improved resolution (80 -> **30 m**)
- Addition of **mid-IR** (and thermal)
- Included MSS (till 1999) for continuity

Summary table: Landsat TM versus SPOT HRV (France)

	LANDSAT TM	**SPOT HRV**
Launch	1982 / 1984	1986
Altitude	705 km	832 km
Attitude (polar)	8.2 degrees	8.7 degrees
Equatorial time	9.45 am	10.30 am
Swath width	**185km**	60km
Repeat coverage	16 days	26 days
Sensor	Thematic Mapper (TM)	High Resolution Visible (HRV)
Number of detectors	100	6000/3000
Advantages	**#bands, swath size**	**higher resolution, # 'looks'**
Bands	7	3 + 1 (**no MIR bands**)
Scanner type	Mirror (Whisk broom)	Pushbroom

High resolution SPOT (France)

High Resolution Visible (HRV) bands 1986 ->

SPOT 1-3: 1986, 1990, 1993

Mode	Band	Spectral band	Resolution
XS-multispectral	XS1	0,50 - 0,59 µm	20m x 20m
	XS2	0,61 - 0,68 µm	20m x 20m
	XS3	0,79 - 0,89 µm	20m x 20m
P-panchromatique	PAN	0,51 - 0,73 µm	10m x 10m

SPOT 4- 5: 1998, 2002

Mode	Band	Spectral band	Resolution
Multispectral	B1	0,50 - 0,59 µm	20m x 20m
	B2	0,61 - 0,68 µm	20m x 20m
	B3	0,79 - 0,89 µm	20m x 20m
	MIR	1,58 - 1,75 µm	20m x 20m
M - monospectral	PAN	0,61 - 0,68 µm	10m x 10m

SPOT (ESA / France)

http://www.spot.com

1 - 3: 1986 – 1993 (-> 2003)
programmable, pushbroom - 60km wide
20m Red/Green/near-IR 10m PAN

4 'next generation' included
Mid-IR 1998 20m (PAN 10m)

SPOT 5 (2002): Similar to 4, but
also high-res PAN option (2.5 / 5m)

World Trade Center, Sep 11, 2001

SPOT receiving station built at U. Lethbridge (2005)

SPOT 4/5 imagery for Canada (2005-2010)
10/20m images downloadable at geobase.ca

Otherwise - **Not Free** !

[SPOT 6 and 7: 2012 / 2014 very high res. 1.5m]

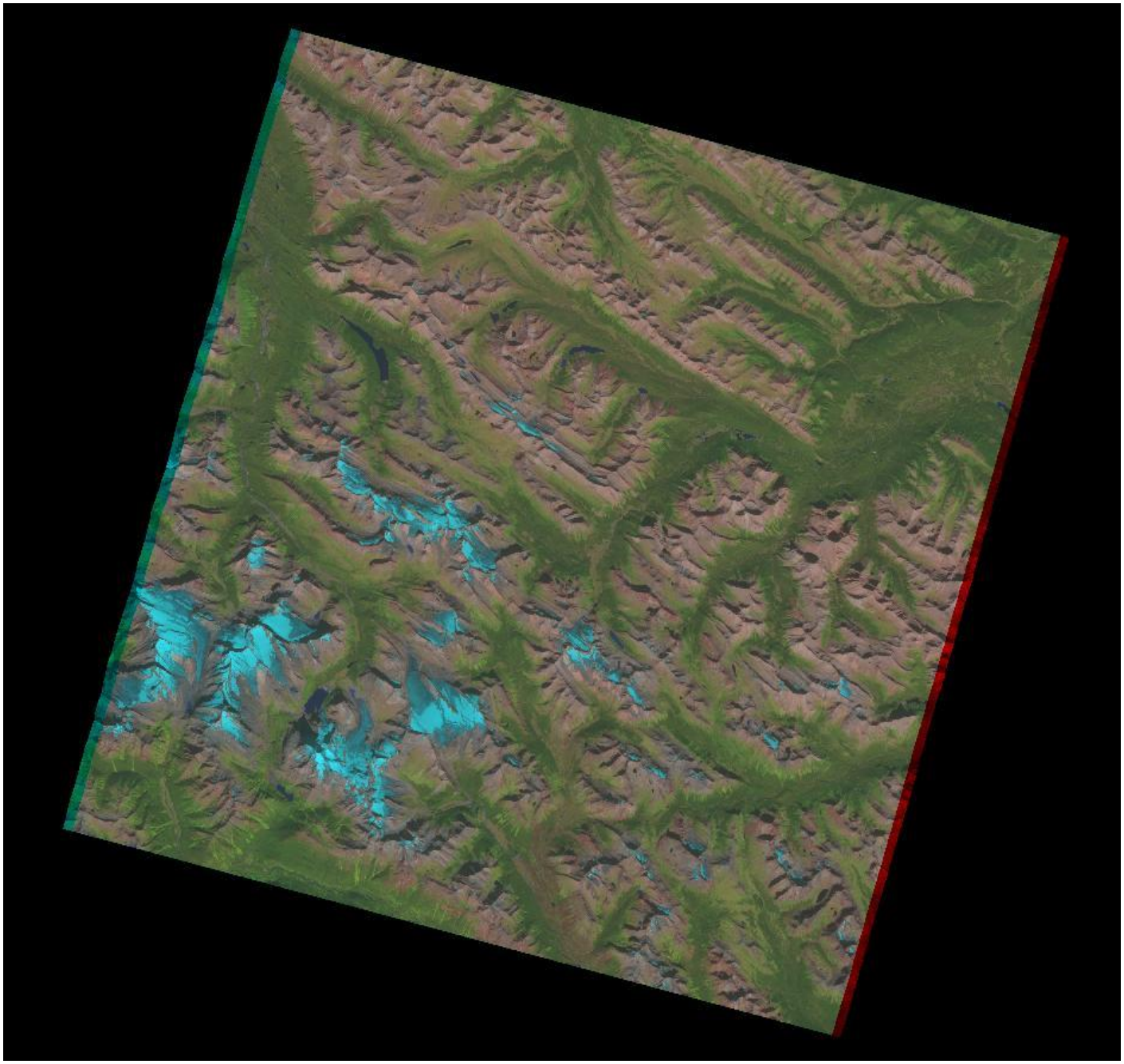
ASTER sensor launched December 1999 (NASA/ Japan) – data from 2000

2000 https://asterweb.jpl.nasa.gov/gallery.asp

ASTER bands

Band	Wavelength (microns)	Spatial Resolution (m)
	Visible to Near-Infrared Bands	
1	0.52 – 0.60	15
2	0.63 – 0.69	15
3	0.76 – 0.86	15
	Shortwave Infrared Bands	
4	1.60 – 1.70	30
5	2.145 – 2.185	30
6	2.185 – 2.225	30
7	2.235 – 2.285	30
8	2.295 – 2.365	30
9	2.360 – 2.430	30
	Mid-infrared (Thermal) Bands	
10	8.125 – 8.475	90
11	8.475 – 8.825	90
12	8.925 – 9.275	90
13	10.25 – 10.95	90
14	10.95 – 11.65	90

SWIR sensors Failed 2008



ASTER, 2000
NASA / Japan

“Landsat-like”

Mt. Robson

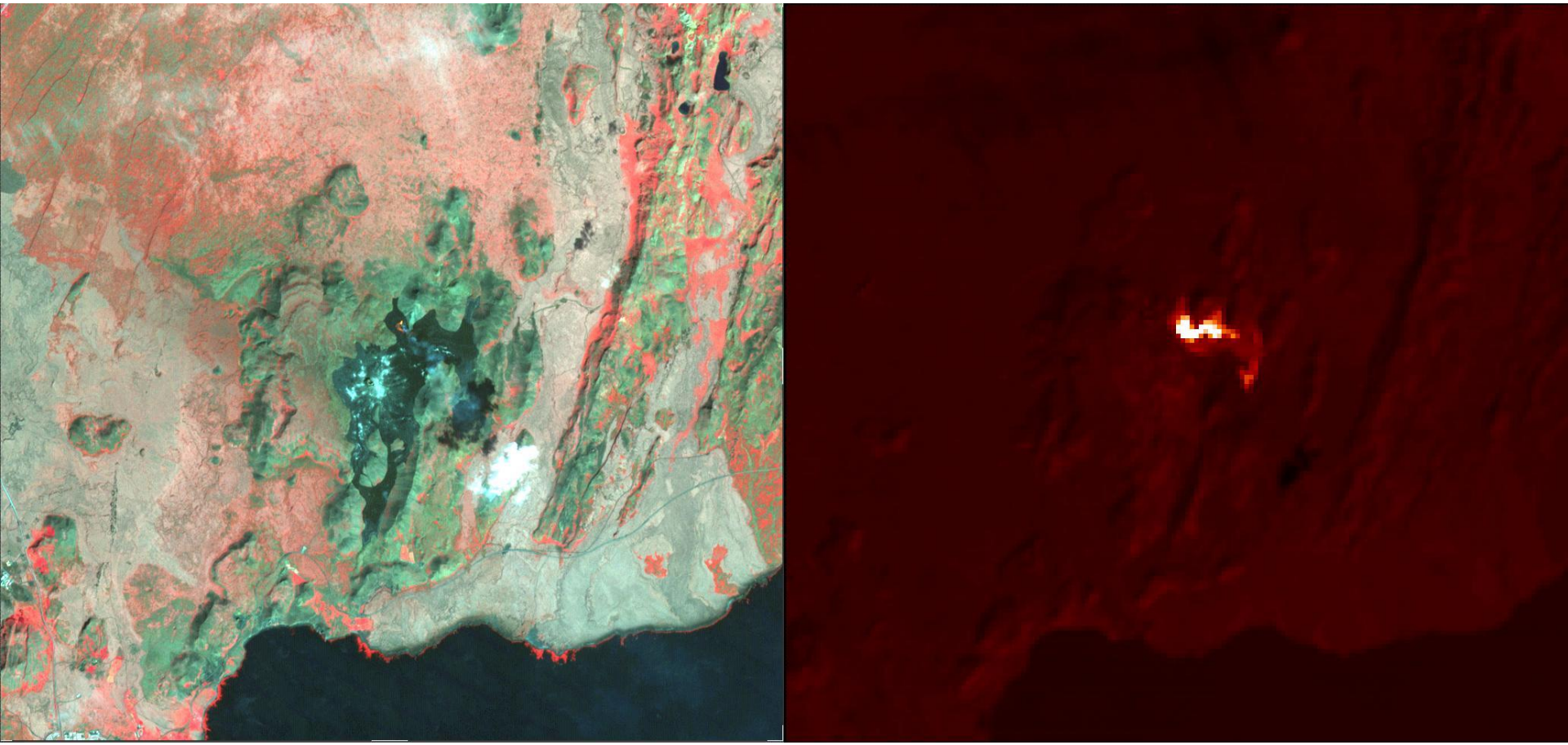
15/30m

Sept 2007

SWIR bands failed, 2008

ASTER: VNIR and Thermal images, August 2022

"end of mission" slated for Sep. 2023



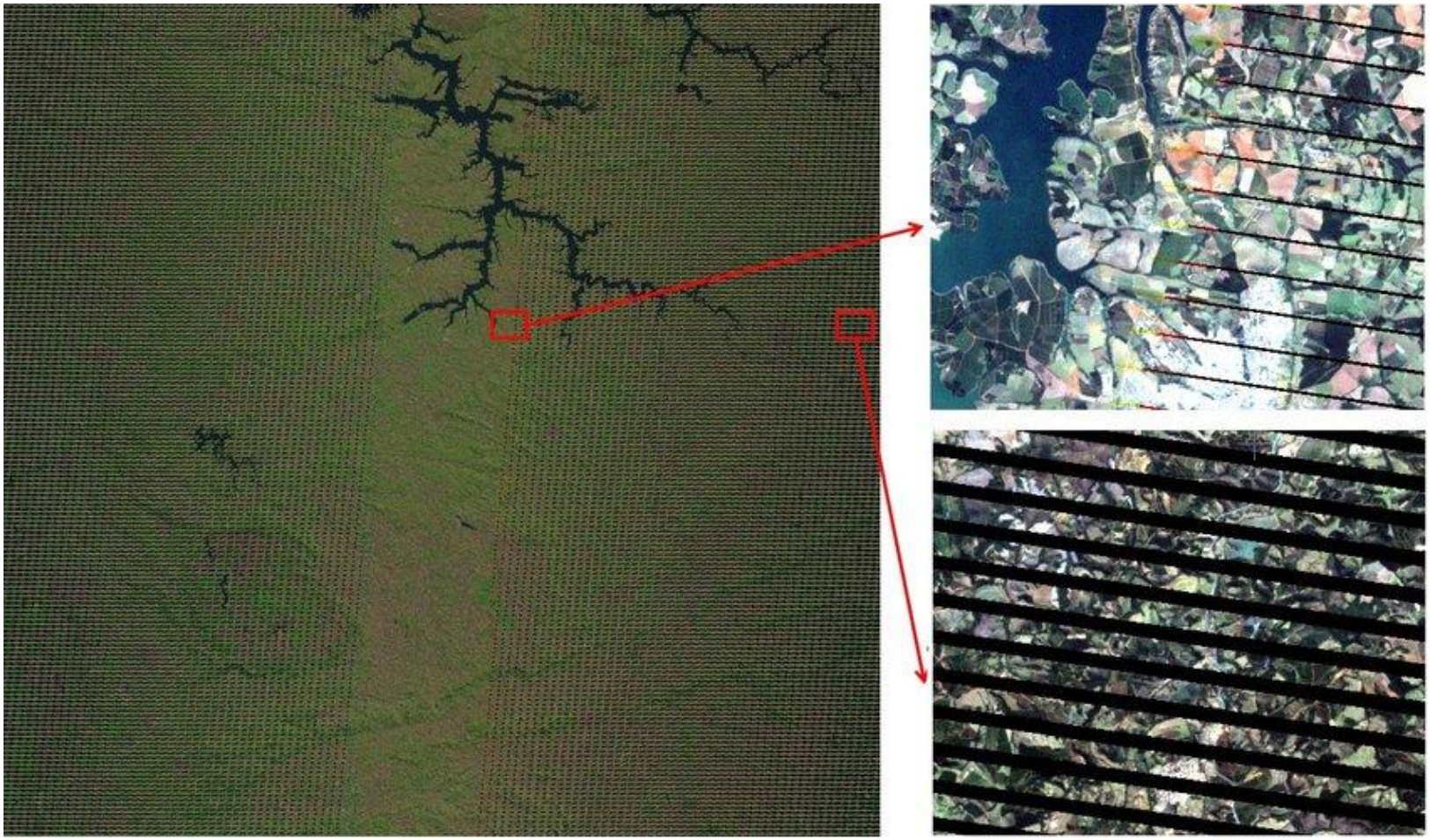
The eruption of the Fagradalsfjall volcano in southwest Iceland, August 15, 2022
Bands 321 (NIR-Red-Green) and Thermal

Enhanced Thematic Mapper Plus (ETM+) (Landsat 7):

New bands versus Landsat 5 TM: PAN 0.52-0.9 (Green->IR) band 15m

Sensor malfunctionned, April 2003
'Scan Line Calibrator' failed

Missing data lines thin towards the centre leaving a usable 20km strip; data are still transmitting



Landsat 4-7 summary

1982 Landsat 4 Thematic Mapper (TM) until 1987

1984 Landsat 5 TM ... operational till Nov 2011

1993 Landsat 6 Enhanced TM: (ETM+) failed after launch

1999 Landsat 7 ETM+ ... sensor malfunctionned April 2003

Landsat imagery (ETM+ ~2000) Google Earth mosaic in 2005

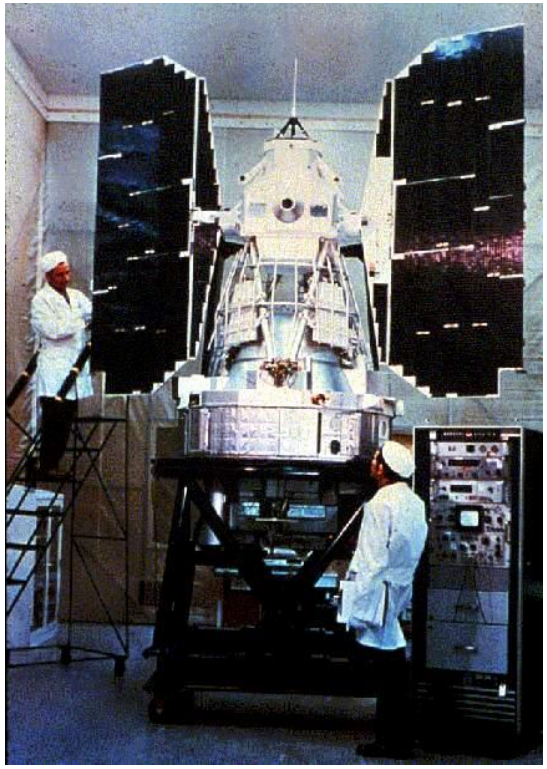
Overlap for (Landsat) scenes is 14% at equator, 45% at 50 degrees

Landsat image data

Not the only land image data but ..

- The most accessible/downloadable – free after 2008

- Longest continuous record: 1972 (1984)



Landsat 1

- Suitable resolution (30m) for northern environments

- Suitable scale for landscape analysis

- These factors enabled it for the Google Earth mosaic

Landsat 8 successfully launched February 2013

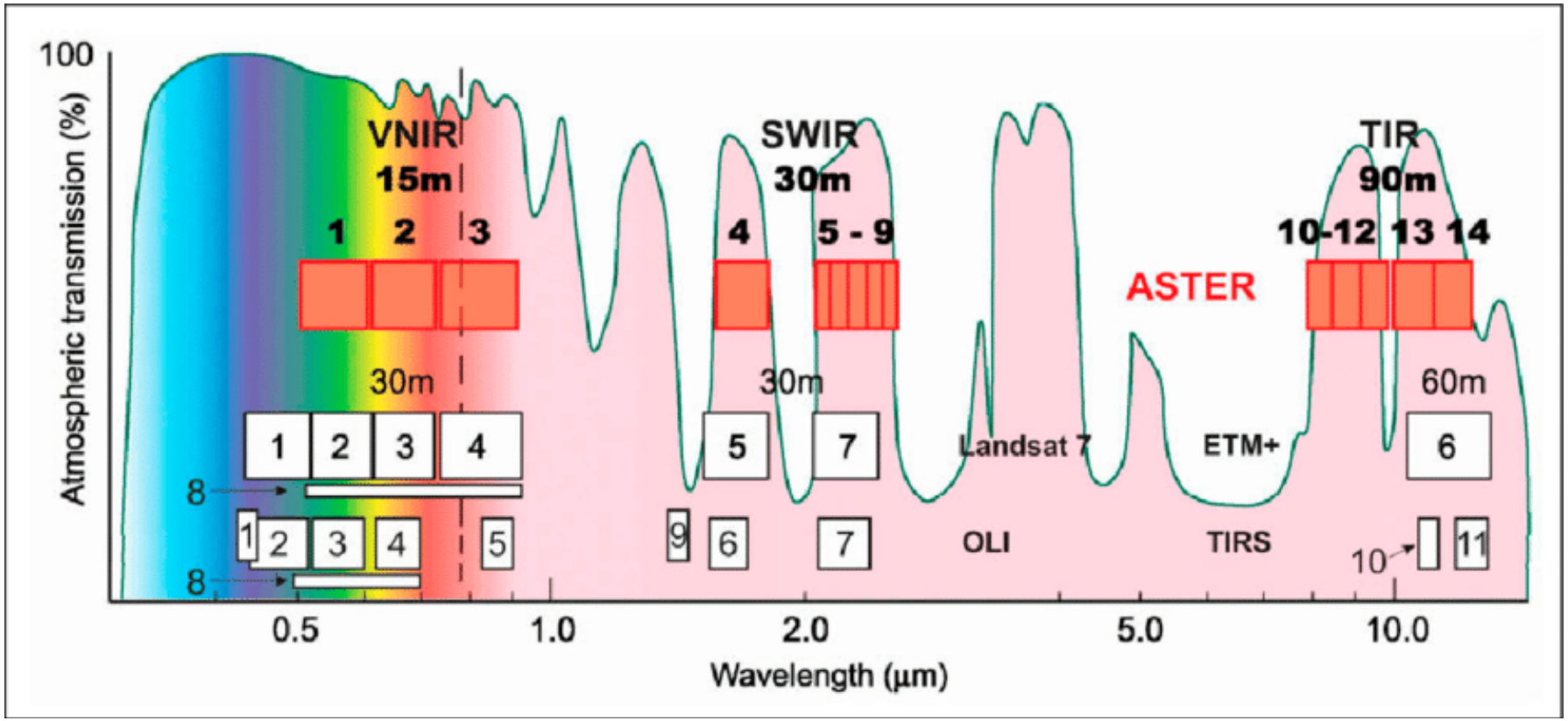
Operational Land Imager (OLI): 16-bit data (versus 8-bit for previous sensors)

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)[20]

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 - Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
Band 2 - Blue	0.452 - 0.512	30
Band 3 - Green	0.533 - 0.590	30
Band 4 – Red	0.636 – 0.673	30
Band 5 – NIR	0.851 – 0.879	30
Band 6 – SWIR 1	1.566 – 1.651	30
Band 7 – SWIR 2	2.107 – 2.294	30
Band 8 – Panchromatic	0.503 – 0.676	15
Band 9 – Cirrus	1.363 – 1.384	30
Band 10 – Thermal 1	10.60 – 11.19	100* (30)
Band 11 – Thermal 2	11.50 – 12.51	100* (30)

* TIRS bands are acquired at 100 meter resolution, but are resampled to 30 meter in delivered

Bands: ASTER v TM (Landsat 5) and ETM + (Landsat 7)



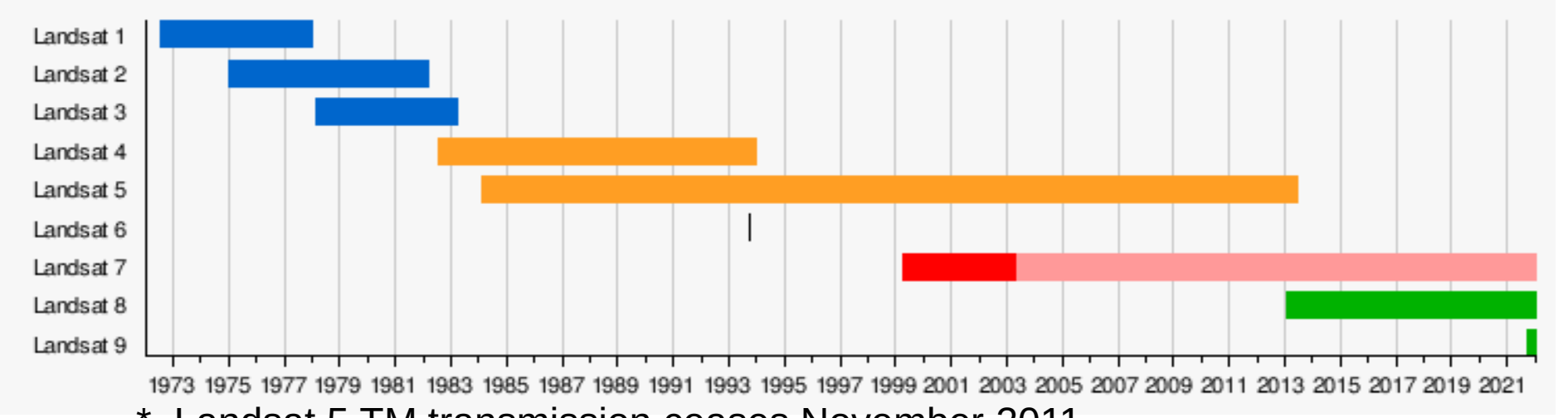
ASTER has more spectral resolution in SWIR/TIR; higher spatial resolution in VNIR
OLI has more bands than ETM+ and higher radiometric and spectral resolution

The end of Landsat 5

the longest-operating Earth observation satellite 1984-2011 / 2013
The basis for Google Earth TimeLapse https://earthengine.google.com/timelapse/

- Landsat 5 TM transmission ceased November 2011 fully decommissioned May 2012
The secondary instrument, the Multispectral Scanner (MSS) had been turned off in 1995. Mission operations engineers realized that the communication links used by MSS were still good, and the mission could continue if the MSS still worked.

Seventeen years after turning the instrument off, engineers powered it back on, and amazingly, it worked. This allowed Landsat 5 to acquire one more year of data until Landsat 8 was ready to take its place in early 2013. i.e. Jan 2012-13



* Landsat 5 TM transmission ceases November 2011

Landsat 9 launched September 2021: OLI-2 / TIRS-2

Bands near identical to Landsat 8 …….8 days apart from Landsat 8
Landsat 9 will replace Landsat 7 (launched in 1999), taking its place in orbit.
OLI: 12 bit (4096) OLI-2: 14-bit (16,384) – both stored in 16-bit (65,536 DNs)
14 v 12 bit data = more discrimination in shadows, details in sow covered areas

Radiometric resolution

Powers of 2	*Digital Value*
2^0	1
2^1	2
2^2	4
2^3	8
2^4	16
2^5	32
2^6	64
2^7	128
2^8	256
2^9	512
2^{10}	1024
2^{12}	4096
2^{14}	16,384
2^{16}	65,536

Bitmap layer = 0,1

Landsat 1-3 : 0-63

Landsat 4-7: 0-255

Landsat 8 data capture

Landsat 9 date capture

L 8/9 data stored 0-65,535

European
Space Agency
(ESA)

Copernicus
Program
Sentinel 2A/B
2015 / 17

free download

Multi-Spectral
Instrument
(MSI)
10 / 20m

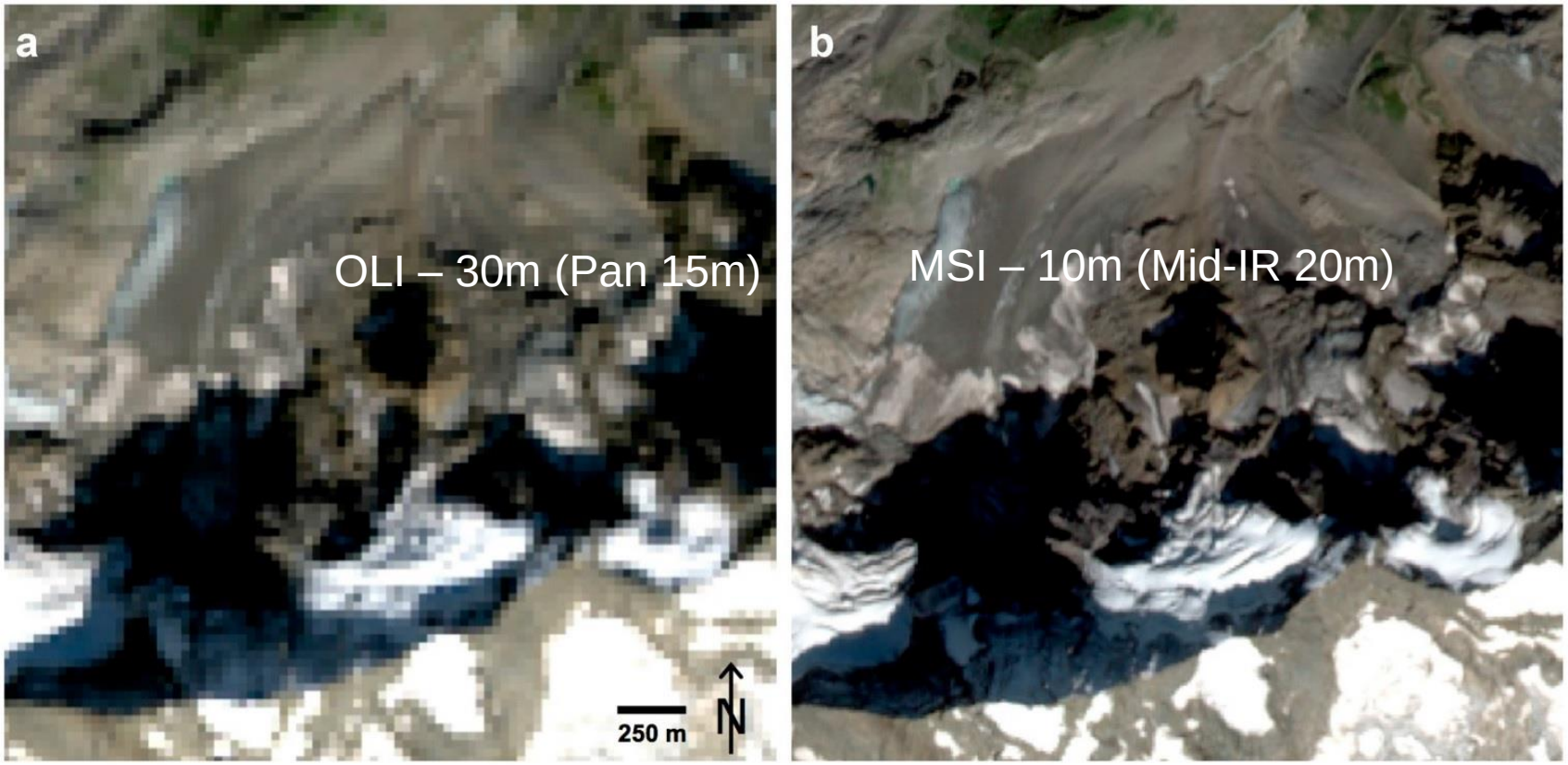
ESA Copernicus Program - Sentinel 2, 2015/2017 - free download; multi-spectral instrument (MSI) – 12 bit

Sentinel-2 Bands	Central Wavelength (µm)	Resolution (m)
Band 1 – Coastal aerosol	0.443	60
Band 2 – Blue	0.490	10
Band 3 – Green	0.560	10
Band 4 – Red	0.665	10
Band 5 – Vegetation Red Edge	0.705	20
Band 6 – Vegetation Red Edge	0.740	20
Band 7 – Vegetation Red Edge	0.783	20
Band 8 – NIR	0.842	10
Band 8A – Narrow NIR	0.865	20
Band 9 – Water vapour	0.945	60
Band 10 – SWIR – Cirrus	1.375	60
Band 11 – SWIR	1.610	20
Band 12 – SWIR	2.190	20

https://en.wikipedia.org/wiki/Sentinel-2#Instruments

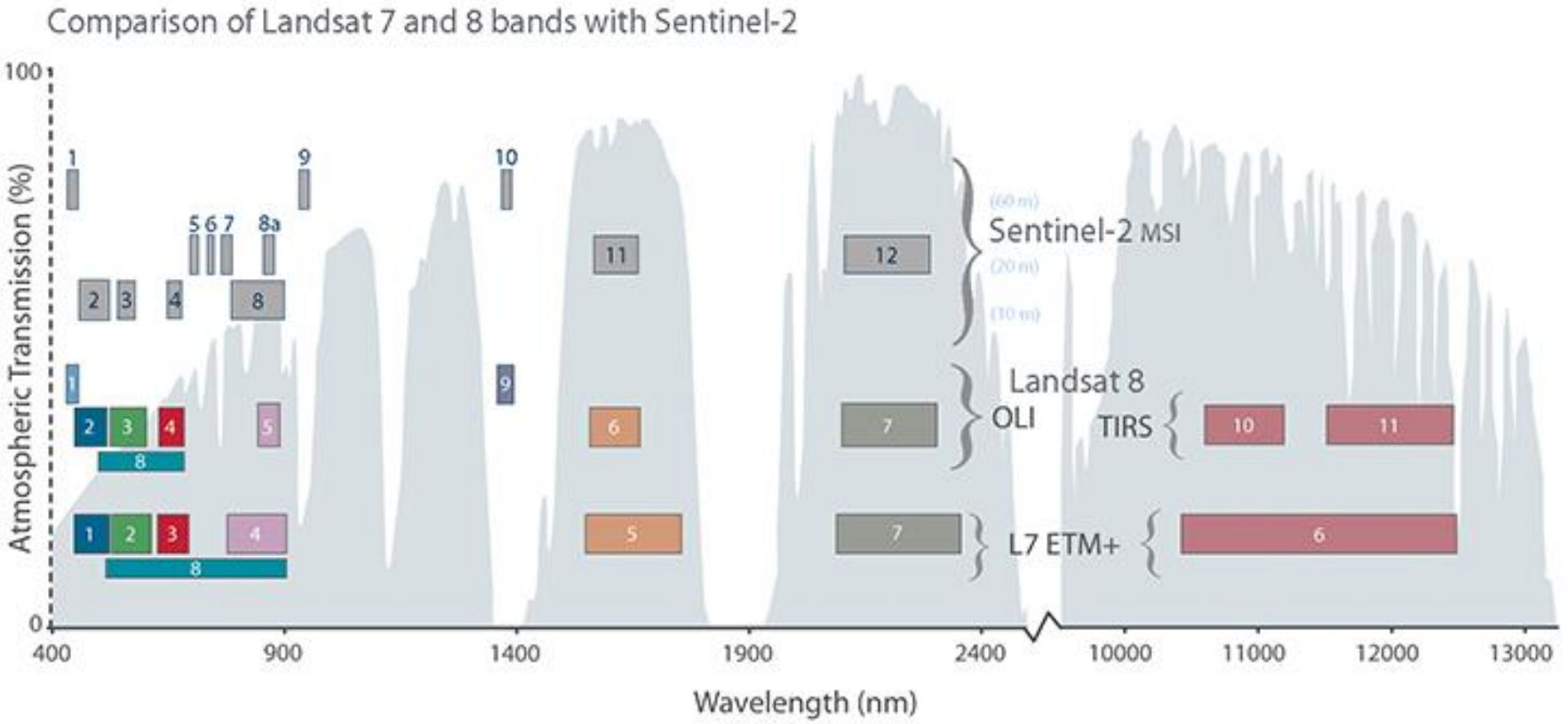
Landsat 8,9 (2013, 2021) vs Sentinel 2A,B (2015, 2017)

Orbit 8 days apart from Landsat 8 and 9 (Sentinel 2A and 2B are 5 days apart)



Paul et al. 2016: Glacier Remote Sensing Using Sentinel-2. Part II: Mapping Glacier Extents and Surface Facies, and Comparison to Landsat 8

Sentinel 2 vs Landsat 8(9) OLI vs Landsat 7 ETM+ bands:



S2 has finest '**spectral**' resolution = narrowest bands

L9 has highest radiometric resolution (14 bit)

Optical Sensors Summary so far:

NASA

- ❑ Landsat MSS 1-3 1972-82 — Free (since 2008)
- ❑ Landsat TM 4-9 1982-> — Free
- ❑ ASTER 2000-> — Free

- ❑ SPOT (France) 1-7 1986- > — NOT Free
  Satellite Pour l'Observation de la Terre (x Canada 2005-2010)

- ❑ Sentinel-2 (ESA) 2015-> — Free

- ❑ Many others –including very high resolution (see later lectures)

https://en.wikipedia.org/wiki/List_of_Earth_observation_satellites

https://www.eoportal.org/satellite-missions

https://www.itc.nl/Pub/sensordb/AllSensors.aspx

https://gisgeography.com/satellite-list/