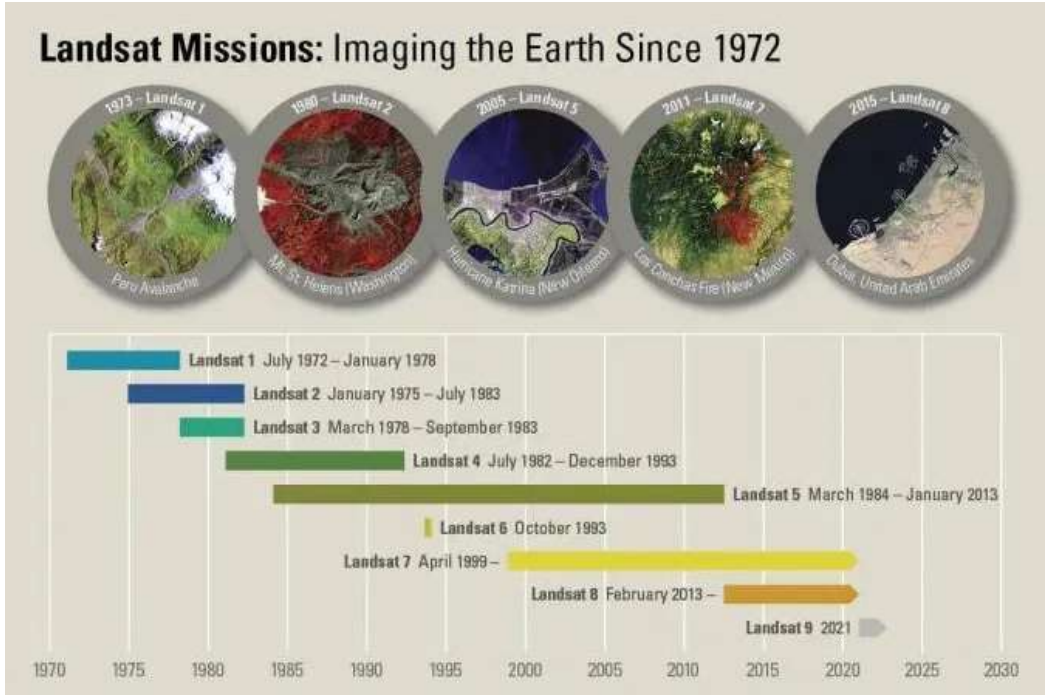
The Landsat (NASA) and Sentinel (ESA) programs

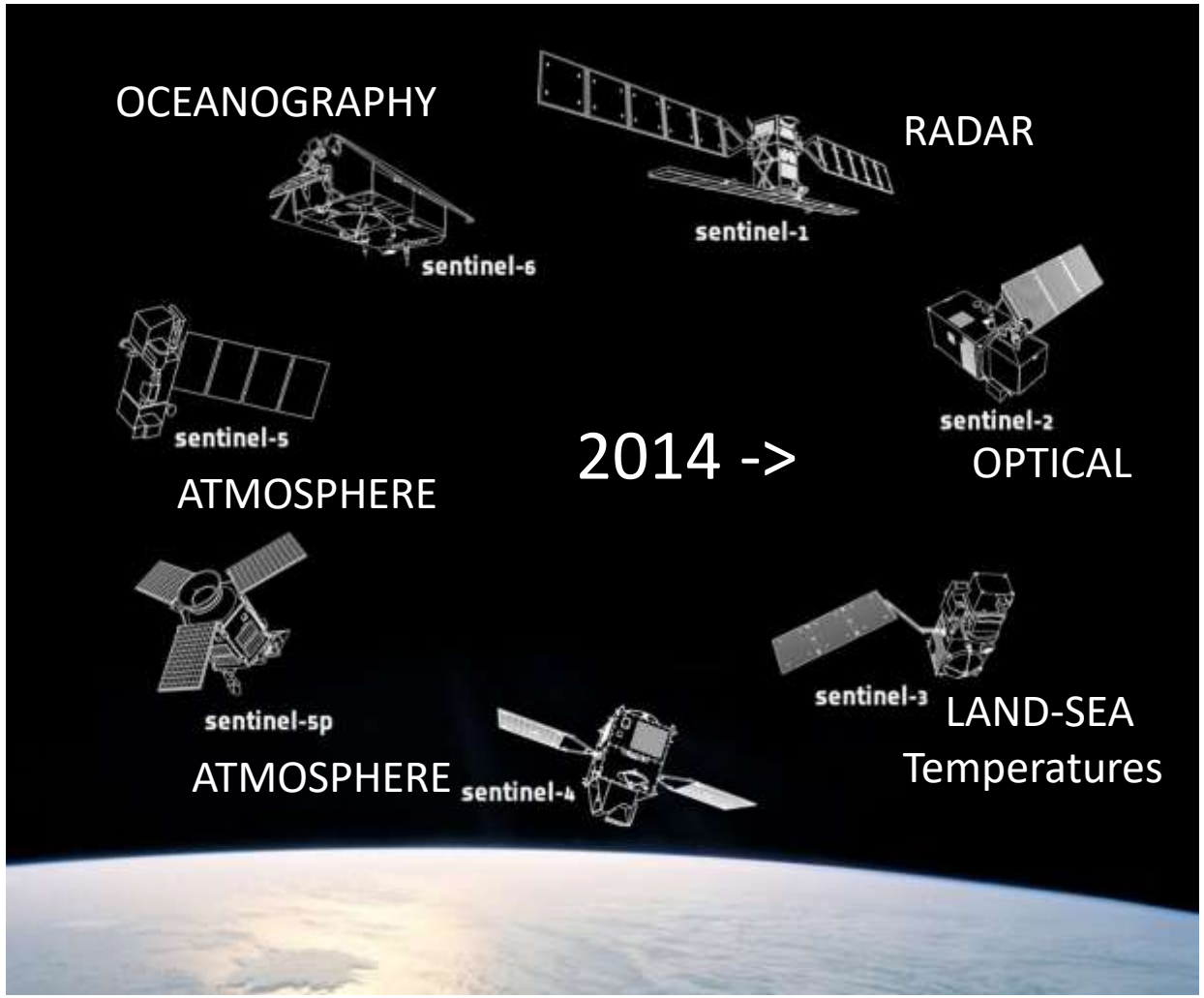
Cooperation between NASA and ESA

Landsat 8/9 and Sentinel 2A/B Orbits :
https://www.youtube.com/watch?v=yPF2jpjB3Qw

https://earthnow.usgs.gov/
EarthNow! Landsat Image Viewer



https://gisgeography.com/landsat/



https://www.esa.int/Applications/Observing_the_Earth/Copernicus/The_Sentinel_missions

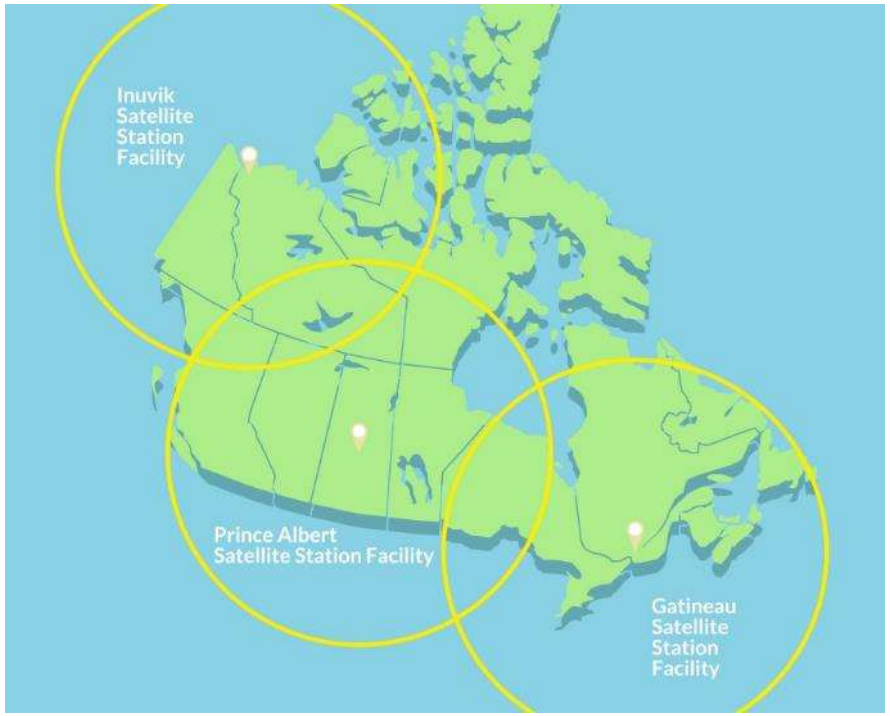
Ground receiving stations

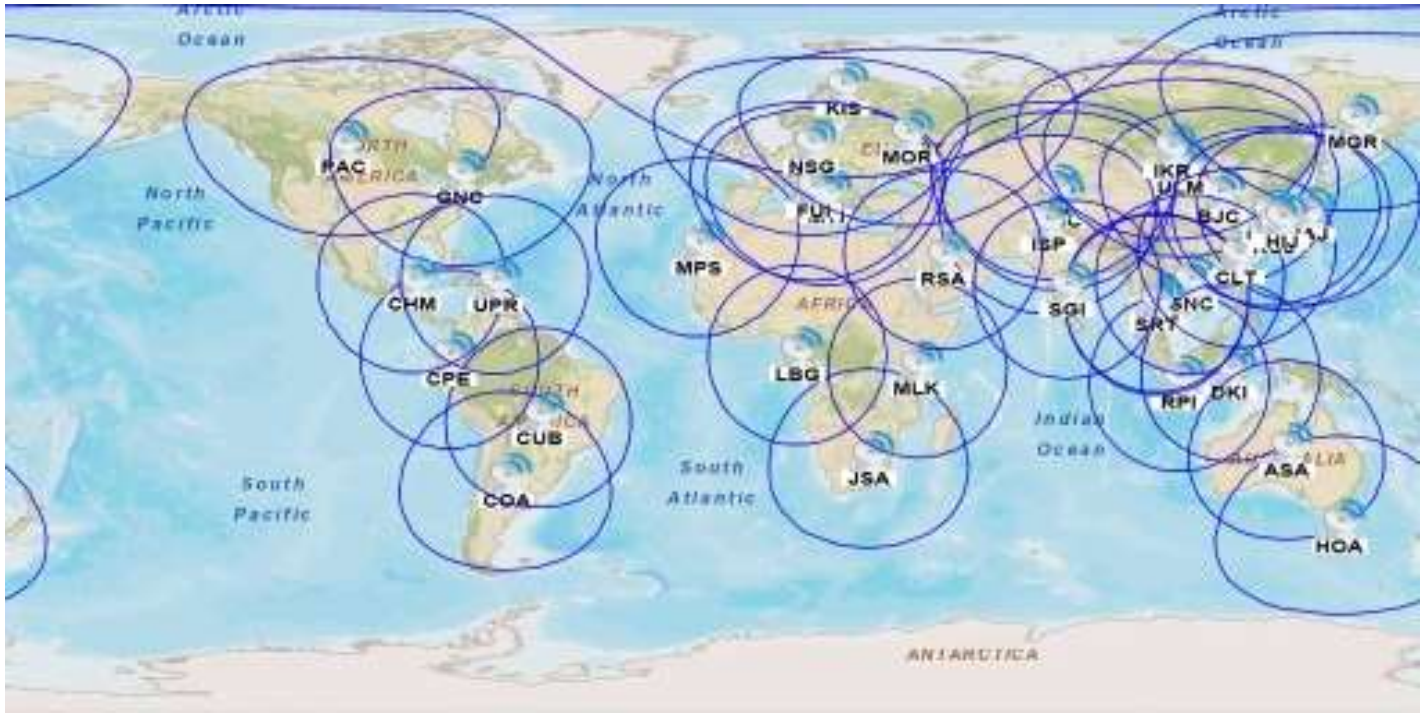
many built/designed by MacDonald-Dettwiler, BC
Landsat Ground Station: U.S. Geological Survey (USGS), Earth Resources Observation and Science (EROS) Center in Sioux Falls, SD

Svalsat, Svalbard, Norway 78N

Canada

- Prince Albert Satellite Station (1972)
- Gatineau Satellite Station (1986)
- Inuvik Satellite Station Facility (2010)

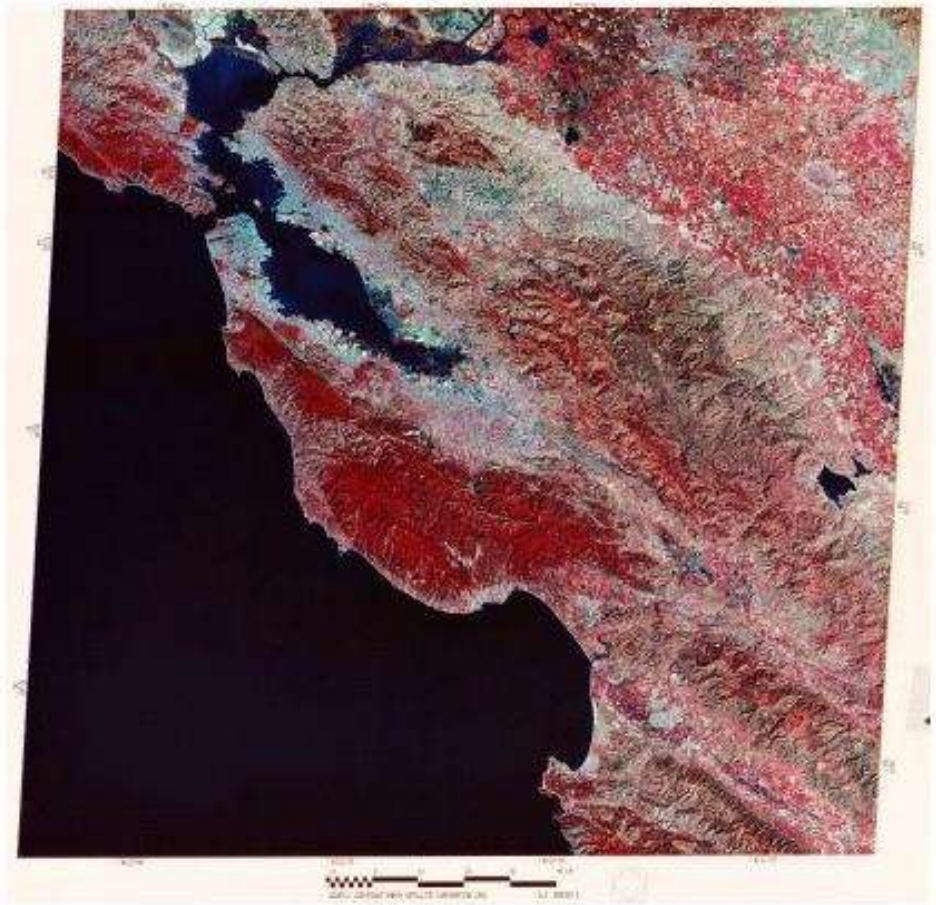




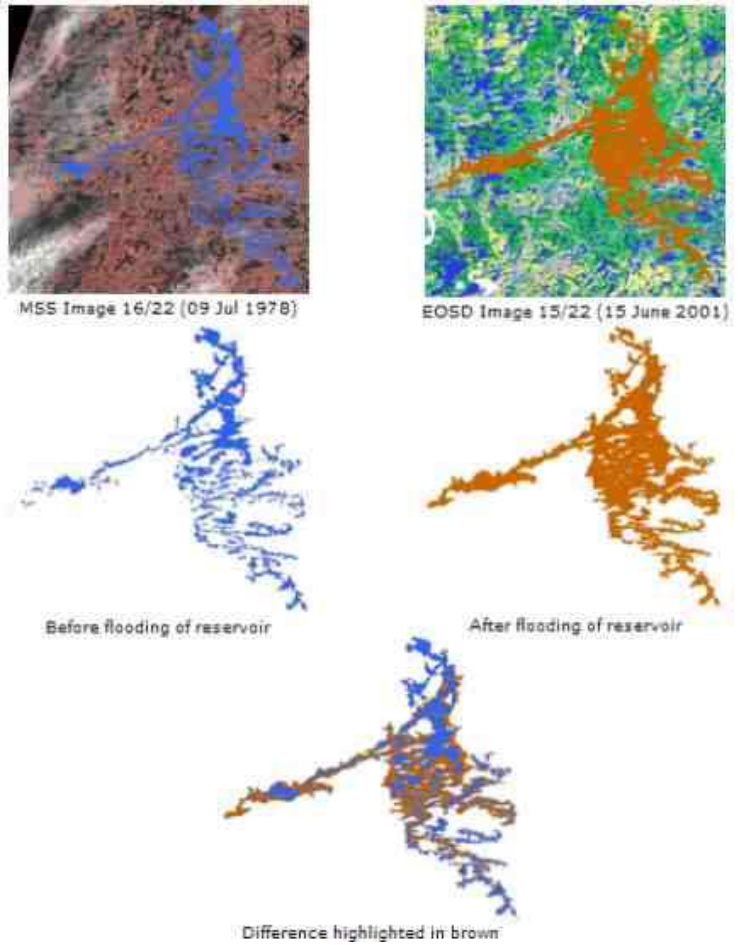
1970s Multispectral image processing: The Landsat Era -this changed everything..

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

Virginia Norwood: https://www.technologyreview.com/2021/06/29/1025732



Manual interpretation e.g. fault lines



Map updating: 1:250,000

Landsat (and other) satellites

- near polar orbit (8- 9 degrees NE-SW off polar)
- Landsat 13 orbits / day; 1 orbit every 99 minutes
- total coverage every 16 days – notwithstanding cloud cover

- Sun synchronous orbits = ~ same time of day coverage
- Satellite crosses the equator on descending orbit ~ 10am +- 30 minutes local time
- Time of day = compromise between minimum shadow and clouds
- Ascending orbit (night-time) 12 hours earlier on ‘dark side of the earth’

- Continuous swaths, providing image data (no ‘photos’ or ‘pictures’)
- Swath 185km wide with side-overlap 7-85% (40-50% in BC)

https://earthnow.usgs.gov/

Landsat 1-5 MSS

Landsat 4-5 TM

Bands

Landsat 1–5 Multispectral Scanner (MSS)

Landsat 1–3 MSS	Landsat 4–5 MSS	Wavelength (micrometers)	Resolution (meters)
Band 4 – Green	Band 1 – Green	0.5 – 0.6	60*
Band 5 – Red	Band 2 – Red	0.6 – 0.7	60*
Band 6 – Near Infrared (NIR)	Band 3 – NIR	0.7 – 0.8	60*
Band 7 – NIR	Band 4 – NIR	0.8 – 1.1	60*

* Original MSS pixel size was 79 x 57 meters; production systems now resample the data to 60 meters.

Landsat 4–5 Thematic Mapper (TM)

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 – Blue	0.45 – 0.52	30
Band 2 – Green	0.52 – 0.60	30
Band 3 – Red	0.63 – 0.69	30
Band 4 – NIR	0.76 – 0.90	30
Band 5 – Shortwave Infrared (SWIR) 1	1.55 – 1.75	30
Band 6 – Thermal	10.40 – 12.50	120* (30)
Band 7 – SWIR 2	2.08 – 2.35	30

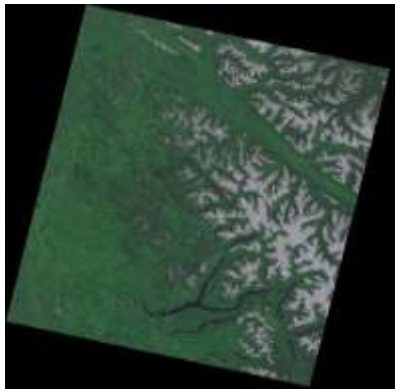
* TM Band 6 was acquired at 120-meter resolution, but products are resampled to 30-meter pixels.

Landsat 7 Enhanced Thematic Mapper Plus (ETM+)

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 – Blue	0.45 – 0.52	30
Band 2 – Green	0.52 – 0.60	30
Band 3 – Red	0.63 – 0.69	30
Band 4 – NIR	0.77 – 0.90	30
Band 5 – SWIR 1	1.55 – 1.75	30
Band 6 – Thermal	10.40 – 12.50	60* (30)
Band 7 – SWIR 2	2.09 – 2.35	30
Band 8 – Panchromatic	0.52 – 0.90	15

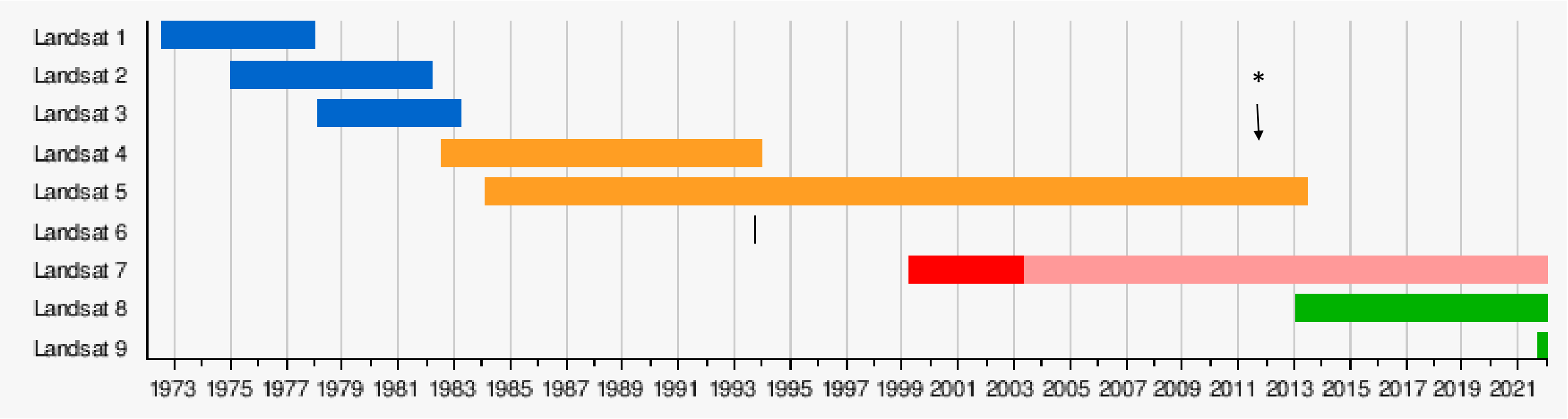
Scan Line Calibrator failed in May 2003, disabling capacity to compensate for forward movement.
Data still being transmitted, but striped (missing scan lines) except for 25km central portion.
Landsat 7 ETM+ image data were used to build Google Maps and Google Earth
Stacked Landsat 7 image dates were used to generate the 2012 ‘missing year’ mosaic in the Timelapse

The end of Landsat 5



Landsat 5 has been the longest-operating Earth observation satellite 1984-2011 / 2013
The basis for Google Earth TimeLapse 1984-2011: https://earthengine.google.com/timelapse/
November 2011 – end of transmission of TM data- 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. Jan 2012-13

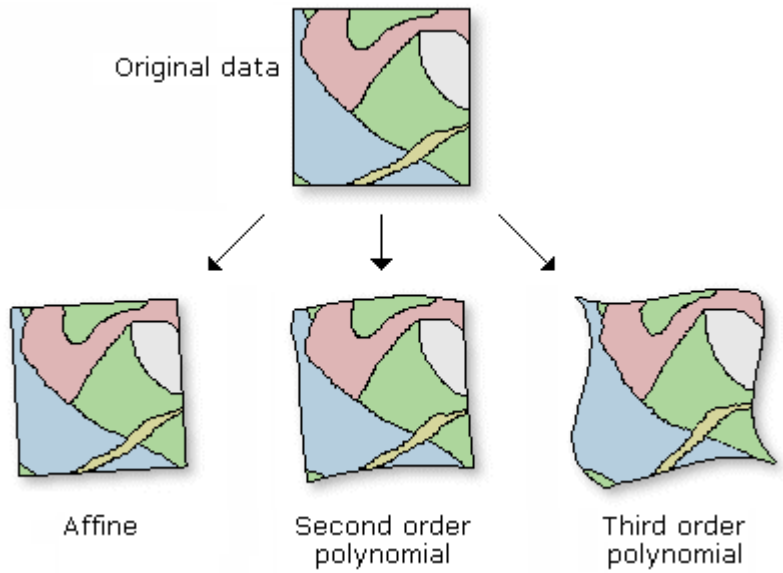


* Landsat 5 TM transmission ceases November 2011

Data and geocorrection / Resampling methods

Landsat data in raw format, scan lines 9 ° off N-S (pixels/lines) NOT aligned to (UTM) coordinates

- need to 'rectify' and resample e.g. to 25m pixels

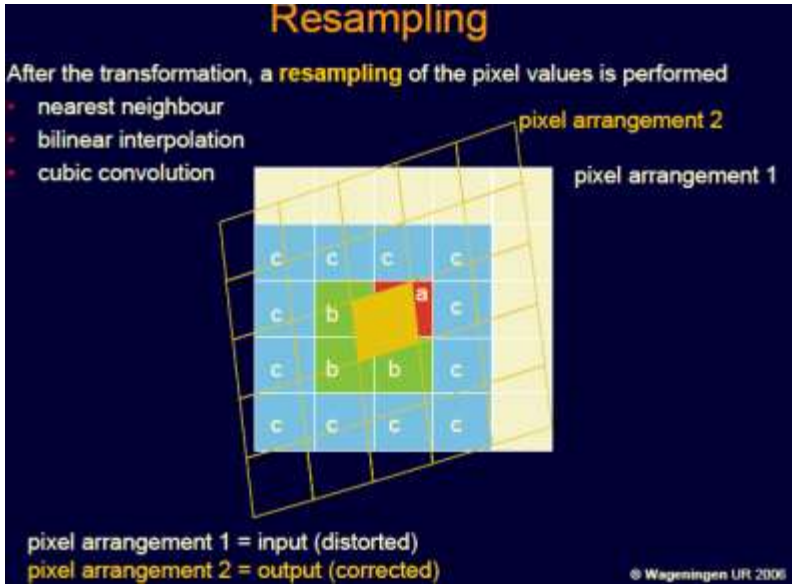


New DN values are assigned in 3 ways:

a. Nearest Neighbour Pixel in new grid gets the value of closest pixel from old grid – retains original DNs

b. Bilinear Interpolation
New pixel gets a value from the weighted average of 4 (2 x 2) nearest pixels; smoother but is 'synthetic'

***c. Cubic Convolution* (smoothest)**
New pixel DNs are computed from weighting 16 (4 x 4) pixels



Georectification and data distribution milestones

Pre 2000: Landsat image scenes 'uncorrected' $5000 (pixels/lines)
corrected (within 100-200m) $7000

- Not good enough for overlay work and detailed mapping
- First labs in RS courses or projects was picking ground control points and rectifying

In Prince George, users bought PCI software for photo/image **Ortho**-rectification
= using DEM for 'correction' of projected vs surface areas

With Landsat 7 data, 2000: NASA / USA removed copyright, enabling copy / distribution

2000-2008 UMBC (U. Maryland, Baltimore County) free download, corrected to within 100m

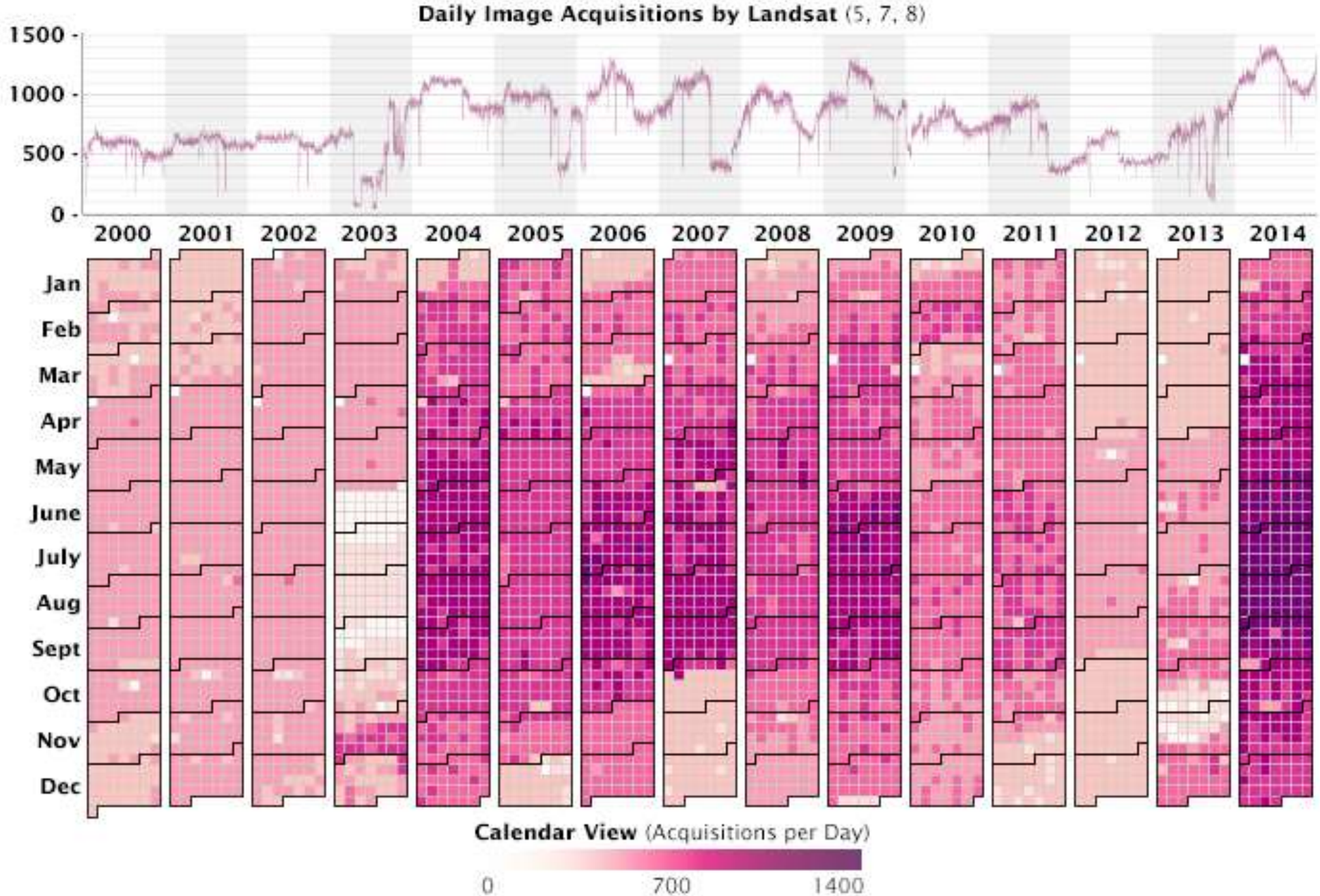
2009-> USGS free download, auto corrected using available DEMs

2010-> Airborne data auto-corrected using GPS and DEM data

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)

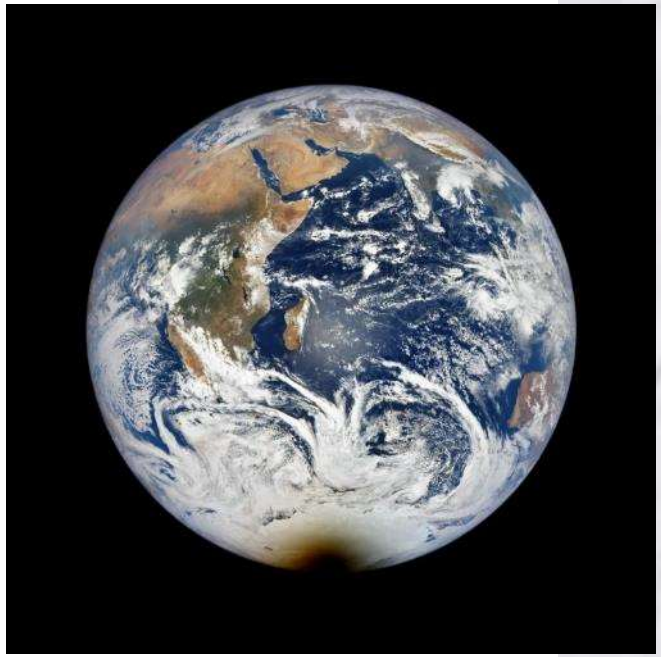
* TIRS bands are acquired at 100 meter resolution, but are resampled to 30 meter in delivered

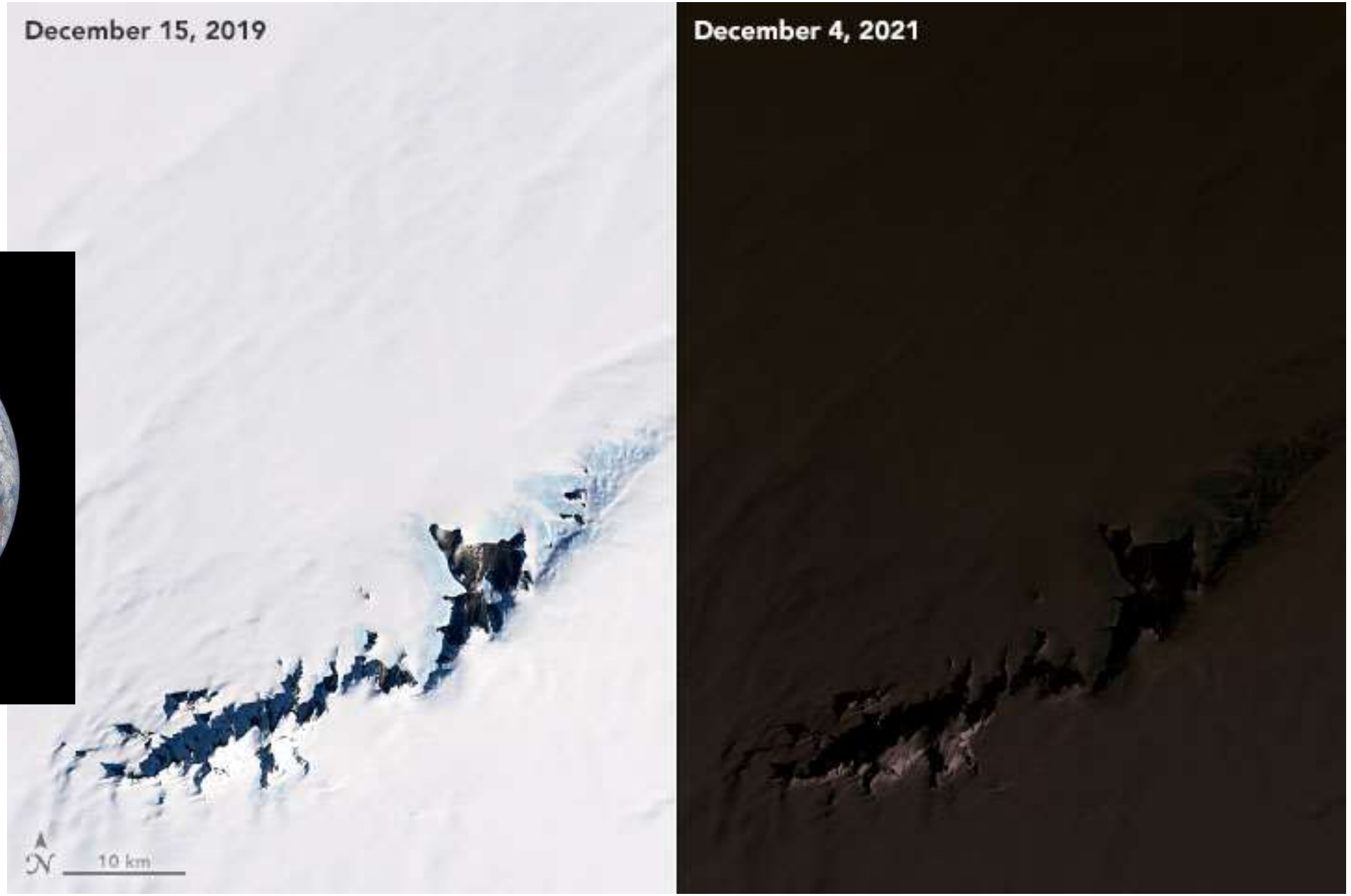


https://earthobservatory.nasa.gov/images/85703/a-lot-of-data-a-lot-of-possibilities

Solar eclipse
Dec 4, 2021

DSCOVR and Landsat 8





Landsat 9 launched 27 September 2021

Data from Landsat 9 will be publicly available from USGS in early 2022
Landsat 9, joins Landsat 8 in orbit; the satellite orbits will be 8 days out of phase. Landsat 9 will replace Landsat 7 (launched in 1999), taking its place in orbit.

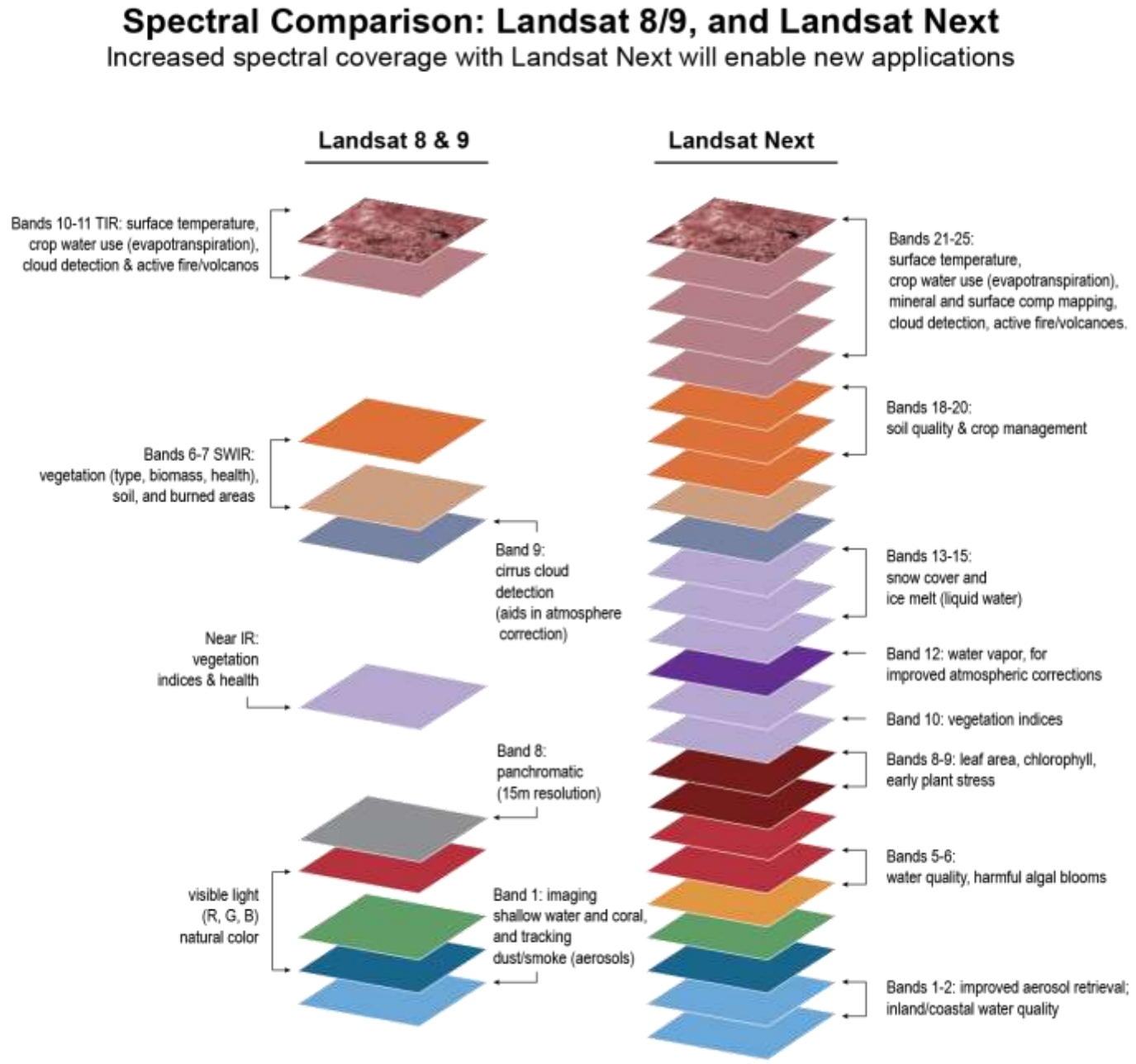
OLI: 12 bit (4096 values) OLI-2: 14-bit (16,384 values) – both stored in 16-bit (65,536 DNs)
14 v 12 bit data = more discrimination of glaciers in shadows, and details in accumulation areas?

Launch rocket de-orbit burn, seen from Yorkshire
(Slightly further north than Prince George)

Landsat Next: Launch in 2029

25 bands: ‘superspectral’

new applications for water quality, plant stress, snow cover, soil health



https://landsat.gsfc.nasa.gov/satellites/landsat-next

ESA Copernicus Program - Sentinel 2, 2A:2015/ 2B: 2017

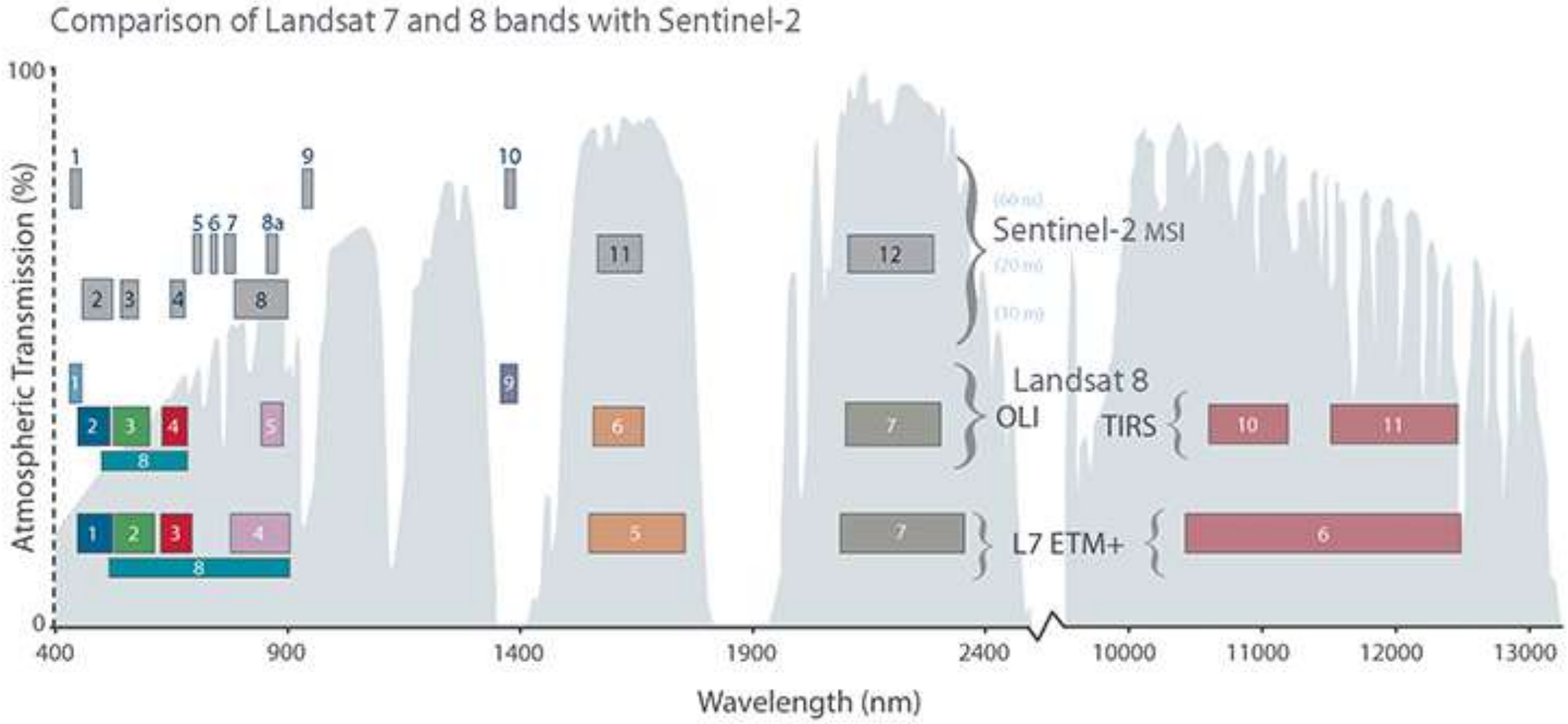
free download; multi-spectral instrument (MSI); 'Landsat 8 plus'

Main differences vs LANDSAT 8/9 : 10m resolution and Red Edge bands

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

Sentinel-2 higher in spatial / spectral resolution and # bands
but not radiometric – 12 bit data



Sentinel program

The Copernicus Sentinel-2 mission has two polar-orbiting (2015, 2017) satellites placed in the s**ame sun-synchronous orbit, phased at 180° to each other. It aims at monitoring variability in land surface conditions, and its wide swath width (290 km) and high revisit time (10** days at the equator with one satellite, and 5 days with 2 satellites under cloud-free conditions results in 2-3 days at mid-latitudes) to support monitoring of Earth's surface changes.

The orbit is at 786 km (488 mi) altitude, 14.3 revolutions per day, with a 10:30 a.m. descending node.

290 km swath, broken into 100 x 100km tiles

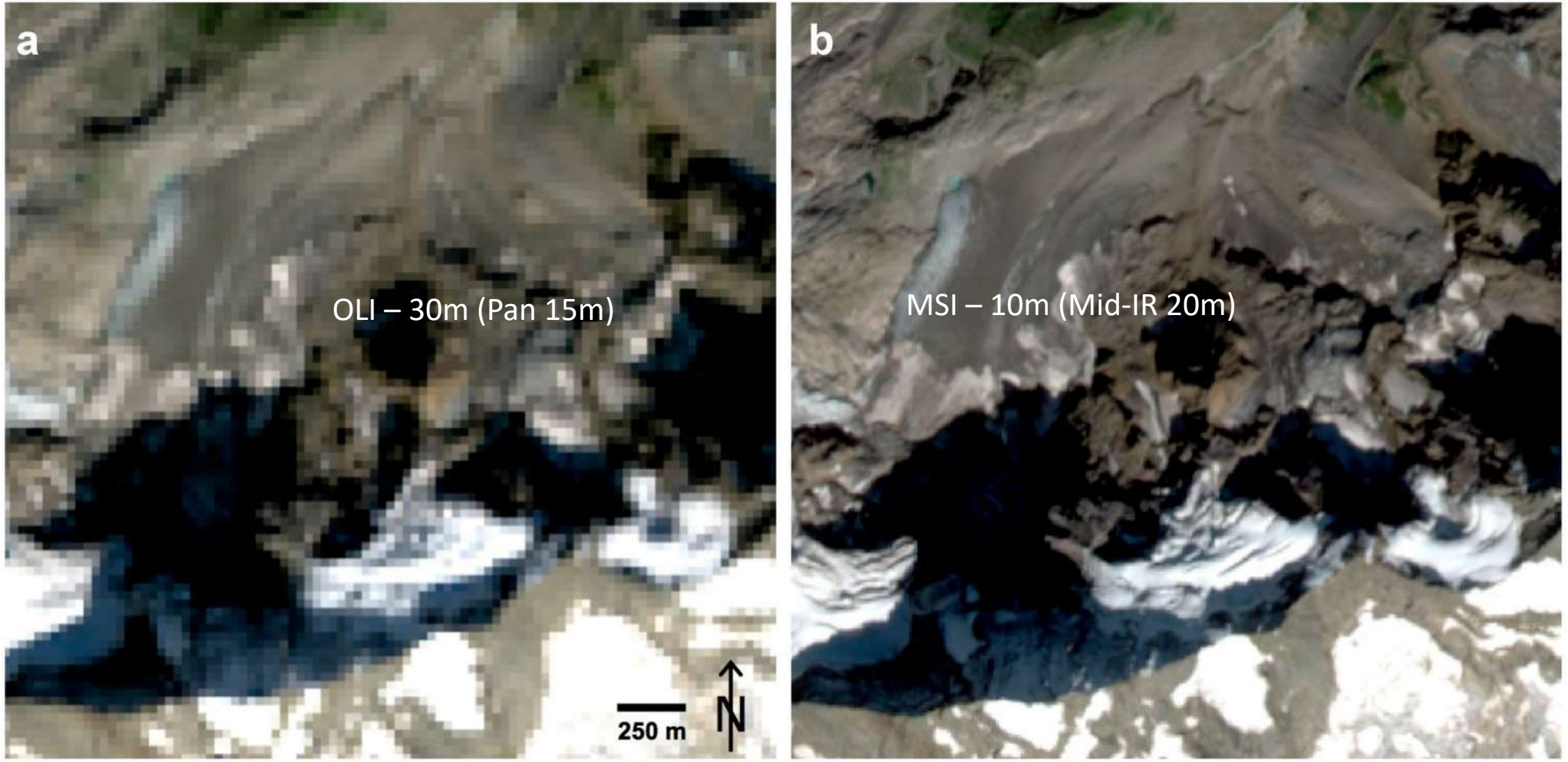
Future: Sentinel 2-C 2024 (on track) , 2-D 2025

Tools developed by ESA for Sentinel data

http://step.esa.int/main/toolboxes/snap/ **Sentinel Application Platform** (SNAP)

https://sentinels.copernicus.eu/web/sentinel/toolboxes/sentinel-1

Landsat 8 (2013) versus Sentinel 2 (2015, 2017)



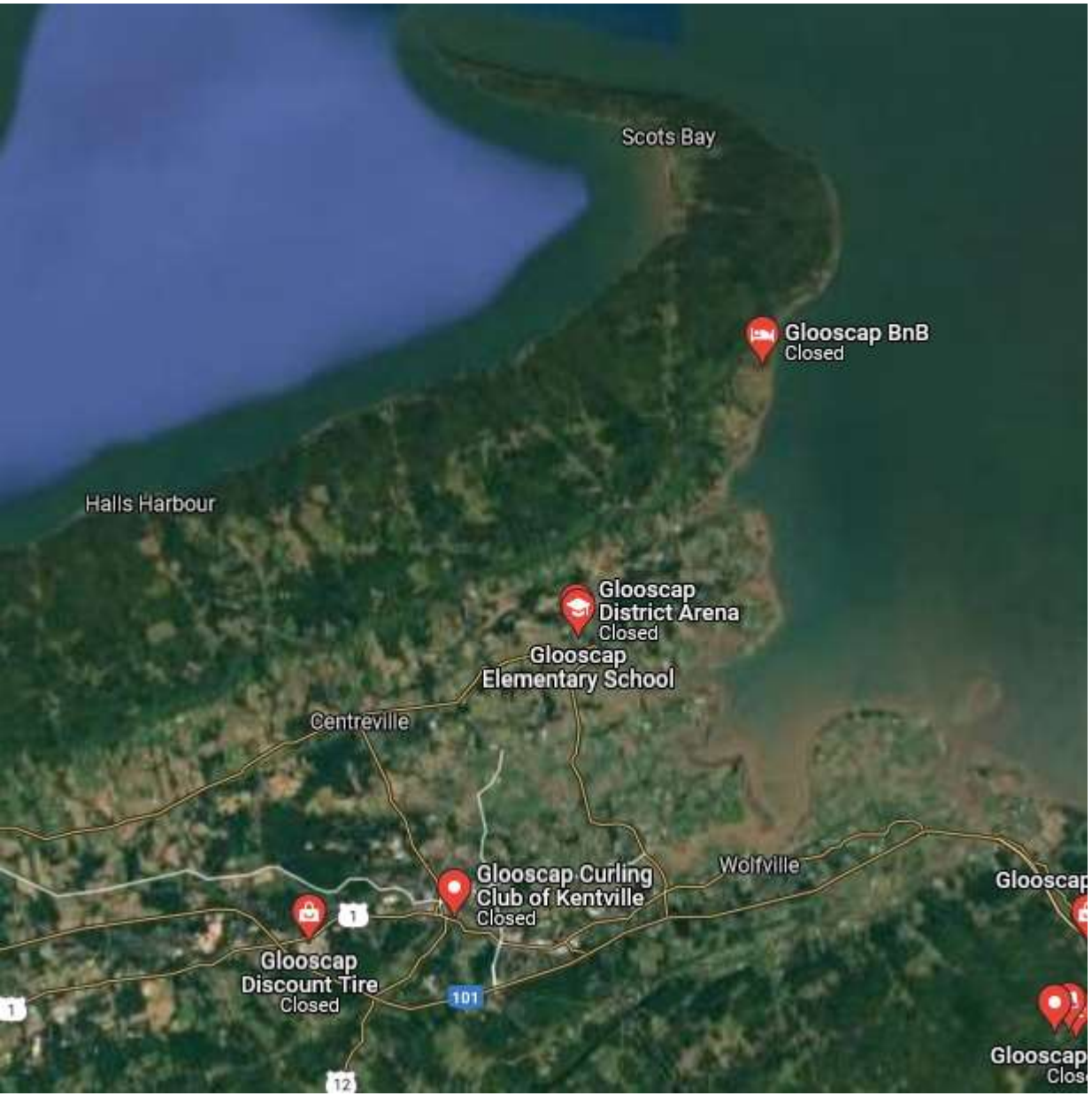
Paul et al. 2016

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

Antarctica, Sentinel 2

Vancouver and the Fraser delta before the recent floods (Landsat 8, right) and Nov 17-2021 (Sentinel-2 left)

Glooscap, NS and Blomidon Provincial Park
Landsat (Google Maps) and Sentinel 2/LiDAR
Marcel Morin, Lost Art Cartography



https://www.esa.int/ESA_Multimedia/Missions/Sentinel-2/(result_type)/images

Global Sentinel classification, Esri

https://www.bbc.com/news/science-environment-57615408

https://www.arcgis.com/home/item.html?id=d6642f8a4f6d4685a24ae2dc0c73d4ac Global viewer

https://caitlin-kontgis.medium.com/mapping-the-world-in-unprecedented-detail-7c0513205b90