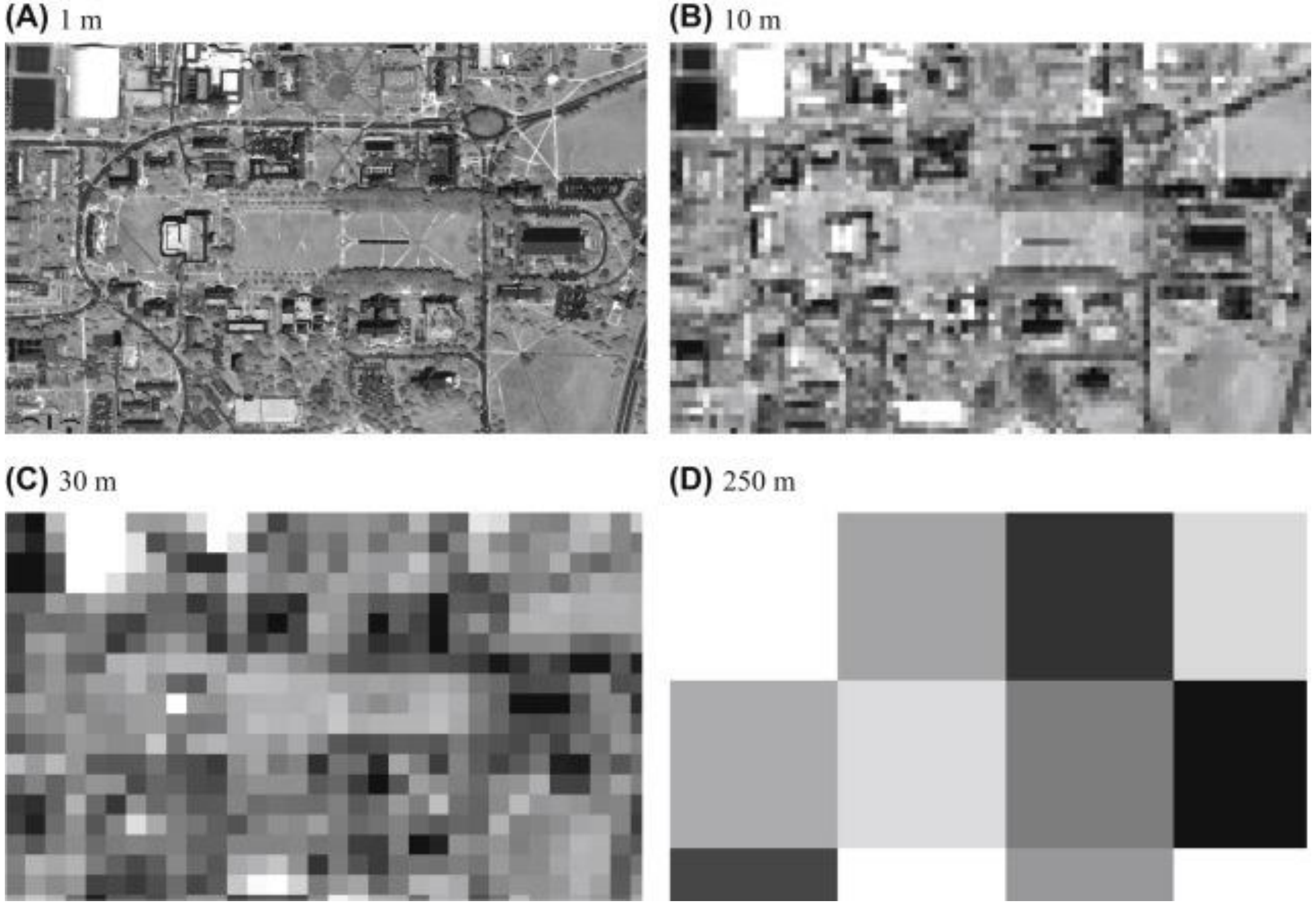
Fundamentals of Optical Remote Sensing

UNBC GEOG 457/657
Tuesday, January 9, 2024
Instructor: Alex Bevington

Spatial Resolution

- Size of the pixels on the ground
- Size of minimum target
- “Coarse” or low ~ > 200 m
- “Fine” or high ~ < 10 m



Spectral Resolution

- Pan-chromatic (1 visible), Multispectral (<~30), Hyperspectral (>~30), Thermal

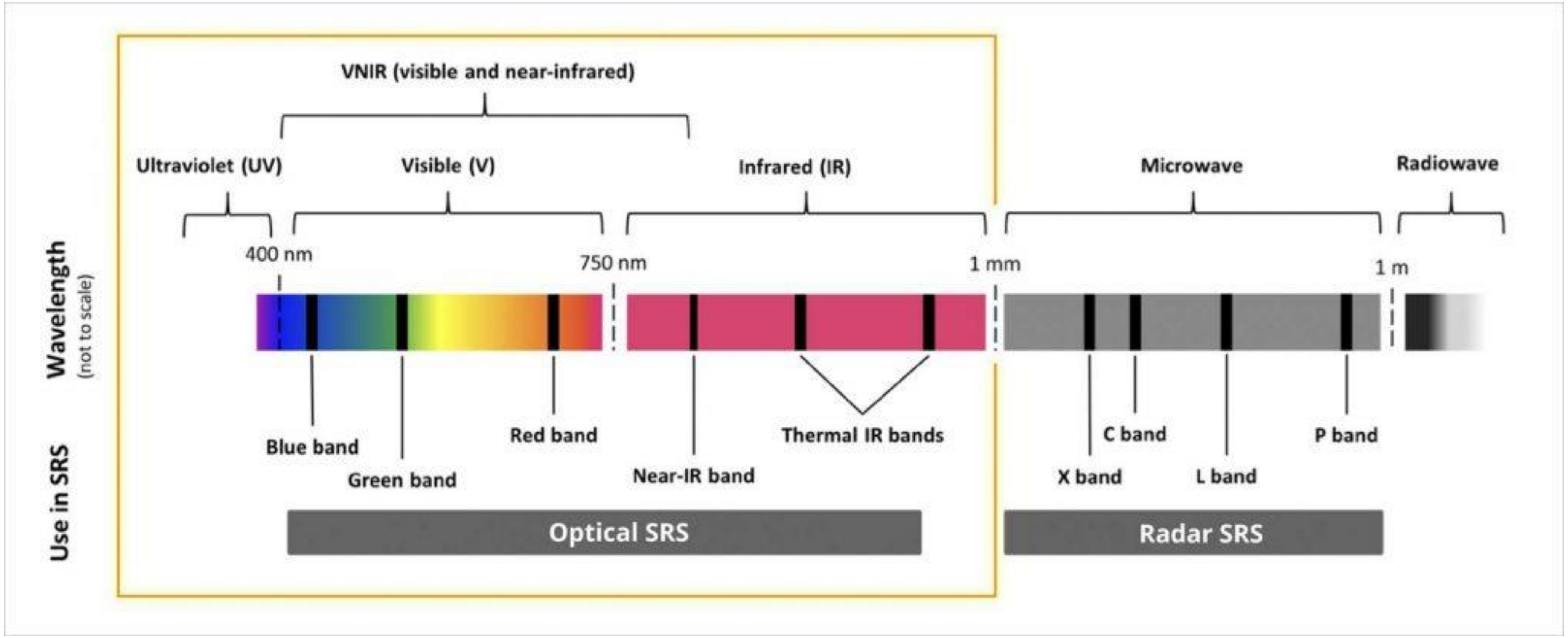


Table 1. Common multispectral band names and their interpretations

Band Name	Common Interpretations
Panchromatic	Usually samples visible light at a higher resolution
Ultra-Blue	Shallow water, suspended sediments, chlorophyll concentrations, algae blooms, and aerosols; also known as the coastal or aerosol band
Blue	Shallow water, land cover, and deciduous/coniferous, sensitive to atmospheric scatter
Green	Emphasizes the true colour of vegetation
Red	Discriminates vegetation and chlorophyll absorption for vegetation health
Red Edge	Exploits the sharp contrast between red and near infrared
NIR	Emphasizes biomass content and shorelines
SWIR1	Soil and canopy moisture and thin cloud penetration
SWIR2	Soil and canopy moisture and thin cloud penetration
Cirrus	Detection of cirrus clouds
TIR	Thermal mapping, soil moisture, cloud mapping

Note: Not all sensors have these bands, and not all bands are in this table. *Source:* Modified from USGS (2017a) and Geospatial Innovation Facilities (2008).

Figure 2. Comparison of bands measured by low- and medium-resolution FOSI satellite sensors. Note: some values have been altered slightly for display purposes; wavelengths between 3,000 and 10,000 nm have been omitted.

Composites

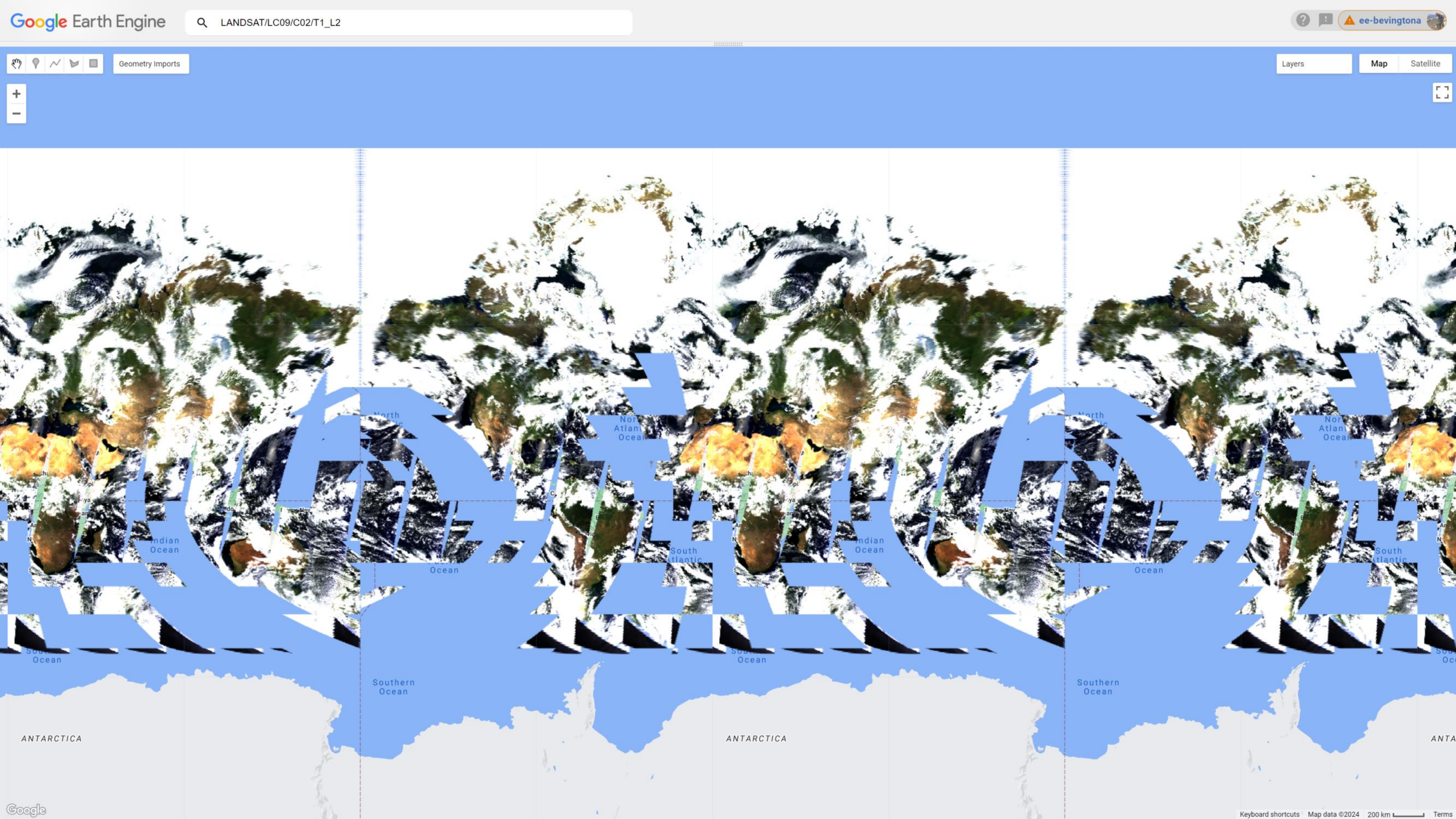
Table 2. Common band combinations for the visualization of multispectral composite imagery

RGB Band Combination	Combination Name
RED, GREEN, BLUE	True Colour
NIR, RED, GREEN	Near Infrared Vegetation
SWIR2, NIR, RED	False Colour Vegetation
SWIR1, NIR, BLUE	False Colour Agricultural
SWIR2, RED, BLUE	False Colour Geological
RED, GREEN, COASTAL	False Colour Bathymetric
SWIR2, SWIR1, RED	False Colour Urban

Note: Modified from Geospatial Innovation Facilities (2008) and Butler (2013)

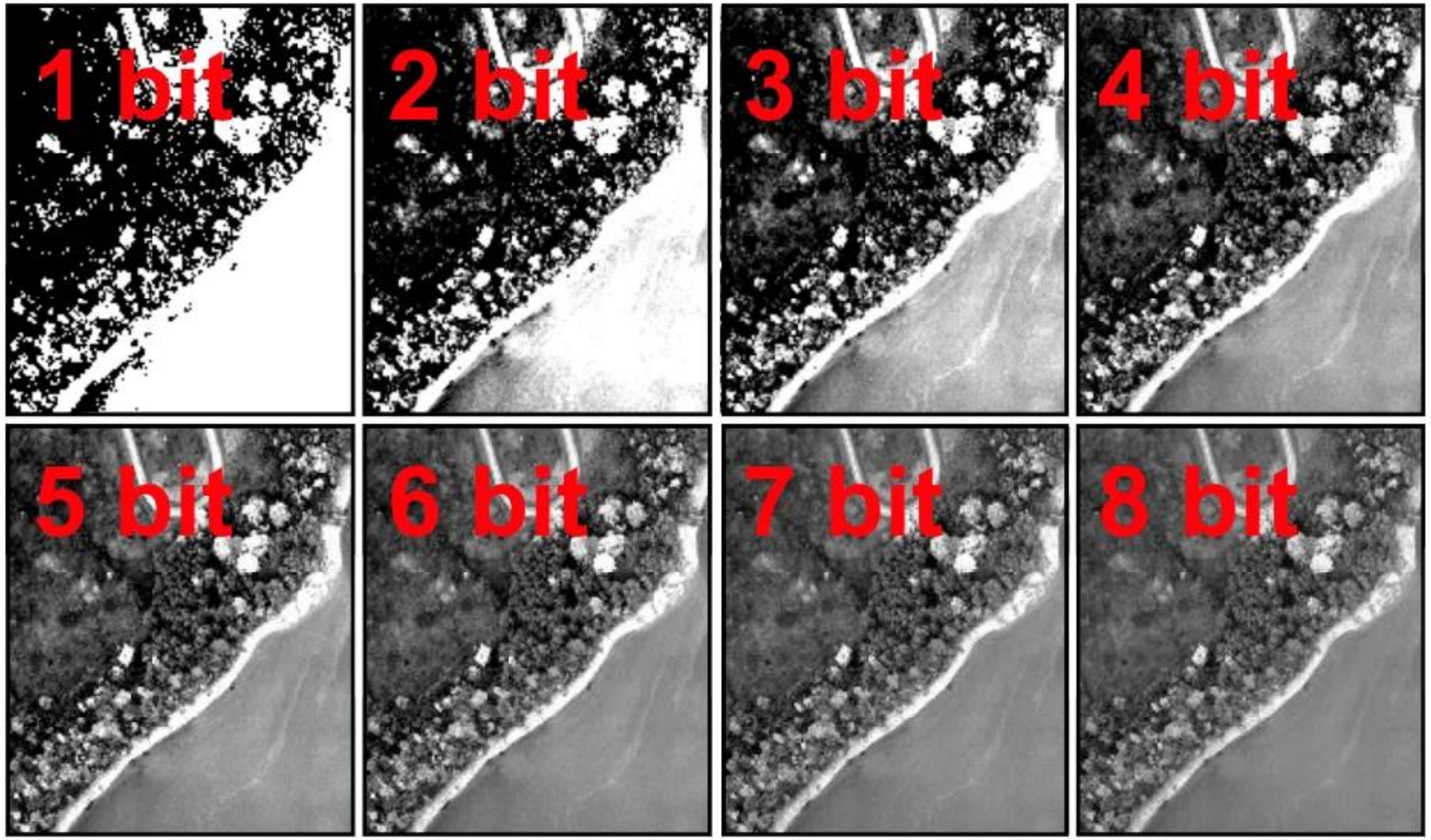
Temporal Resolution, Swath, and Look Angle

- **Temporal resolution**: Time to complete an orbit and return to the same location
- **Swath width:** Width on the ground of the acquired images
- **Look Angle:** Nadir (down looking), Back looking, Side-looking
- **Revisit time:** Time between seeing the same object on the ground
    - Look angle impacts revisit time – think high res!


Google Earth Engine
LANDSAT/LC09/C02/T1_L2
ee-bevingtona
Geometry Imports
Layers
Map
Satellite
Indian Ocean
North Atlantic Ocean
South Atlantic
Ocean
Southern Ocean
ANTARCTICA
Google
Keyboard shortcuts
Map data ©2024
200 km
Terms

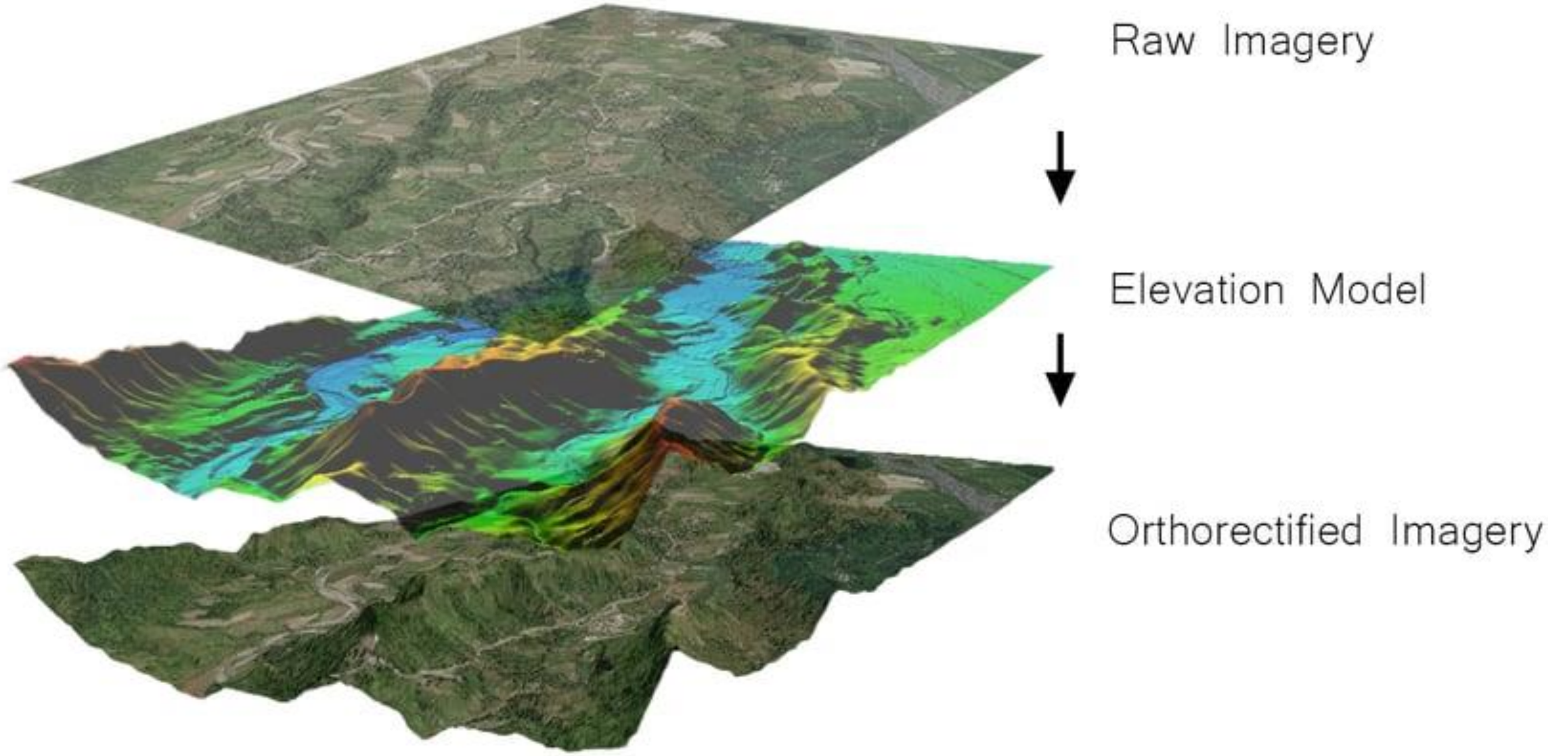
Radiometric Resolution

- Think ‘colour by numbers`…
- Pixel values can be:
  - 1 bit = 2^1 = 1:2
  - 2 bit = 2^2 = 1:4
  - 4 bit = 2^4 = 1:16
  - 8 bit = 2^8 = 1:256
  - 10 bit = 2^{10} = 1:1024
  - 12 bit = 2^{12} = 1:4096
  - 16 bit = 2^{16} = 1:65536
- Implications for data sizes and what you can do with the data



Terrain Corrections

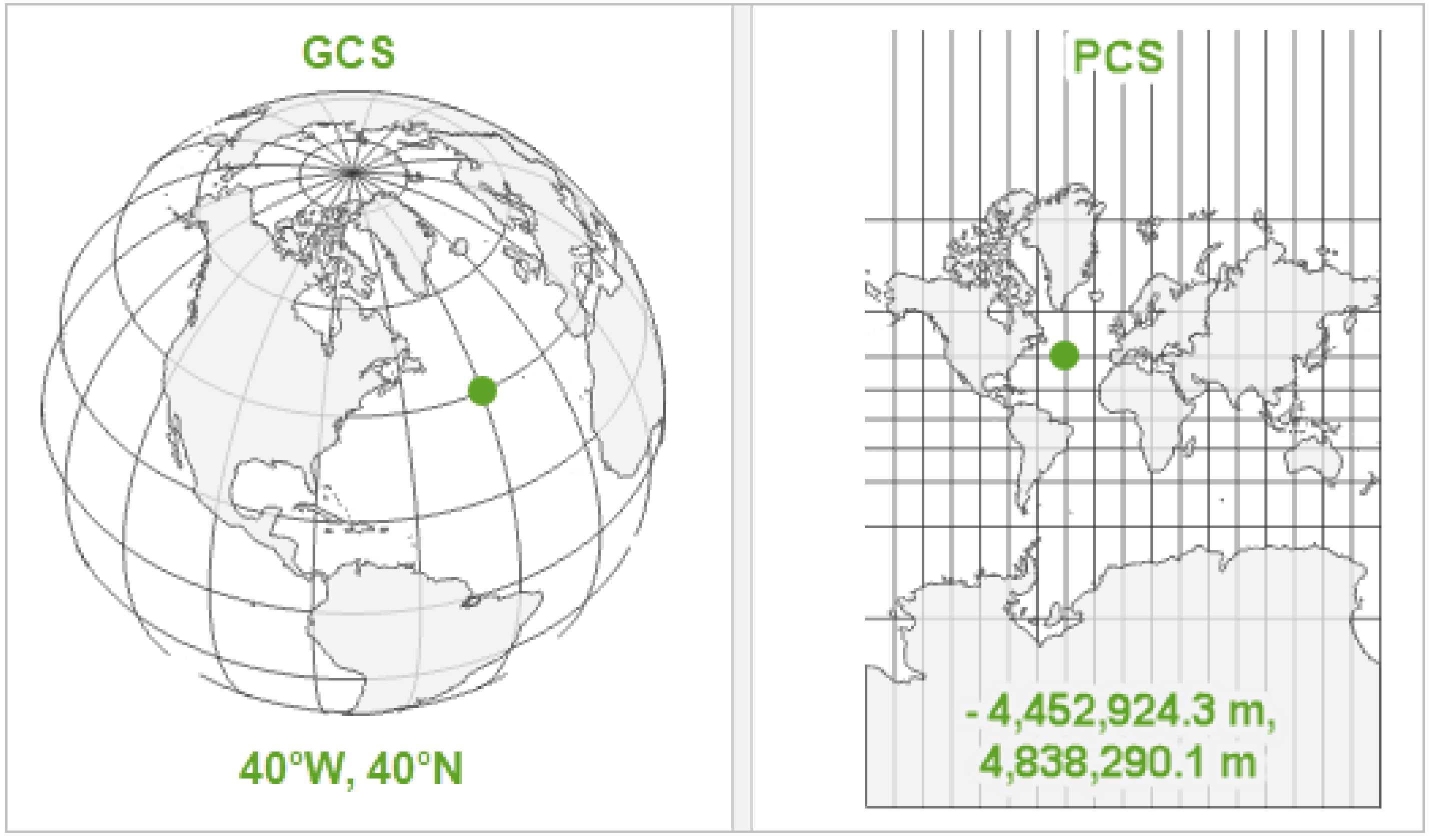
- Geo-referencing:
  - Anchor the raw image to a known coordinate reference system.
- Ortho-rectification:
  - Corrects perspective distortions, topographic variation and the curvature of the Earth using a digital elevation model



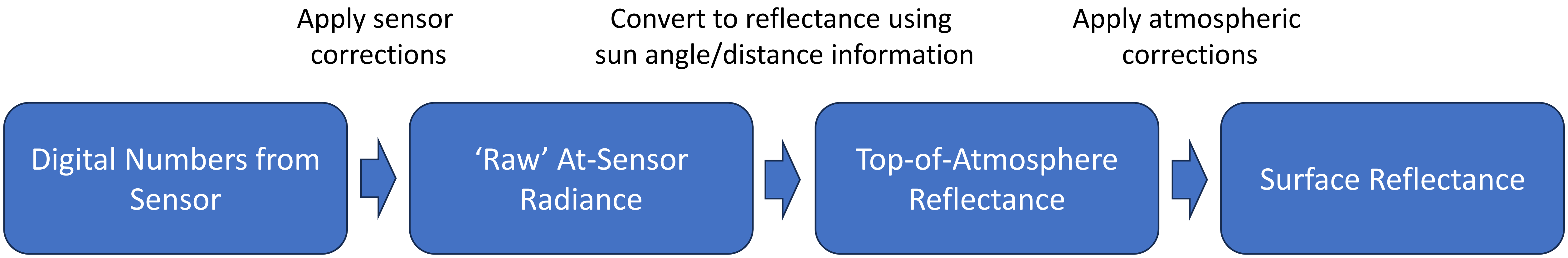
https://www.intermap.com/blog/orthorectification-in-a-nutshell

Coordinate Reference Systems

- Geographic vs Projected
- GCS = where on the earth
- PCS = how to draw on a map
- Common in BC:
  - EPSG:4326 = WGS 84
  - EPSG:3005 = BC Albers
  - EPSG:32610 = WGS 84 / UTM zone 10N
  - EPSG:26910 = NAD83 / UTM zone 10N
  - …



Data Levels

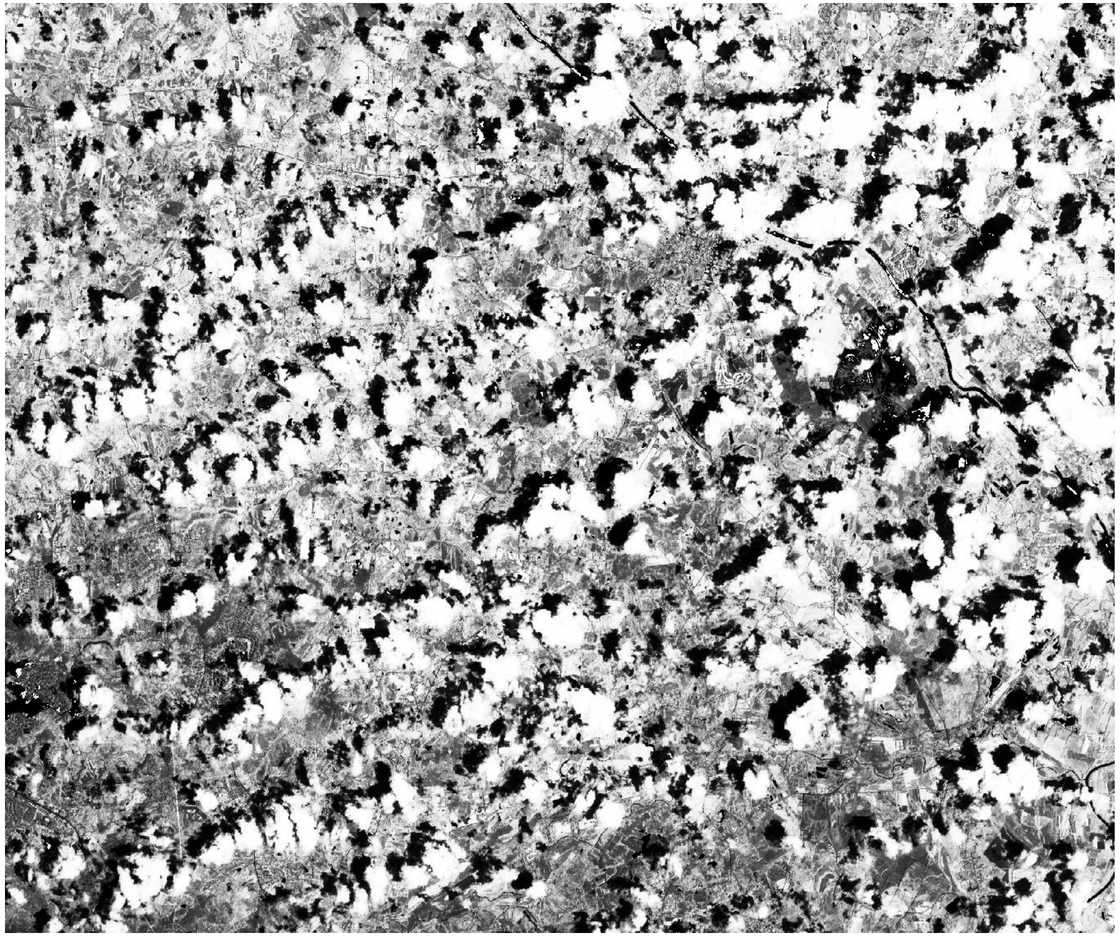

Apply sensor corrections
Convert to reflectance using sun angle/distance information
Apply atmospheric corrections
Digital Numbers from Sensor
‘Raw’ At-Sensor Radiance
Top-of-Atmosphere Reflectance
Surface Reflectance

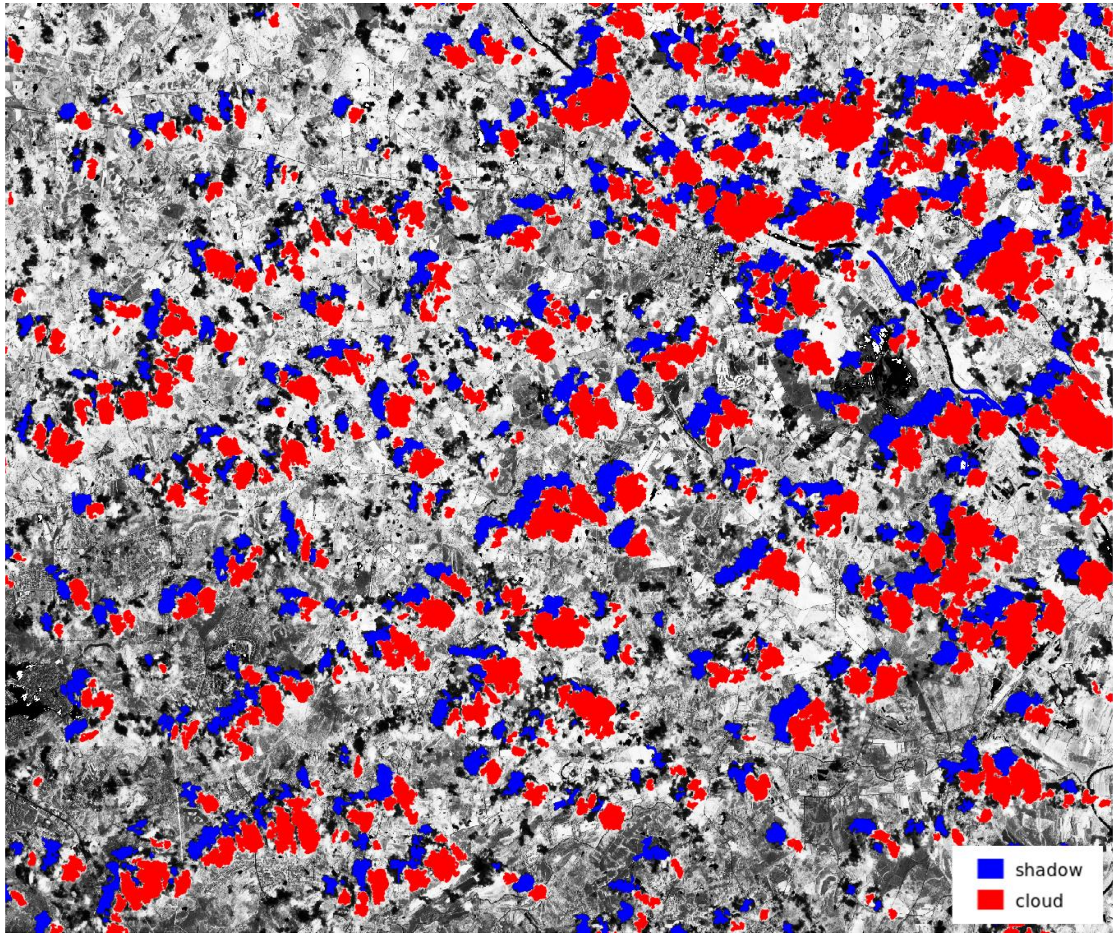
Coregistration

- Two orthorectified images may not be well aligned. Why do you think this could happen?
- Coregistration is the process of georeferencing an image to another one
- This can be done automatically … wait for the terrain lecture!

https://medium.com/sentinel-hub/how-to-co-register-temporal-stacks-of-satellite-images-5167713b3e0b

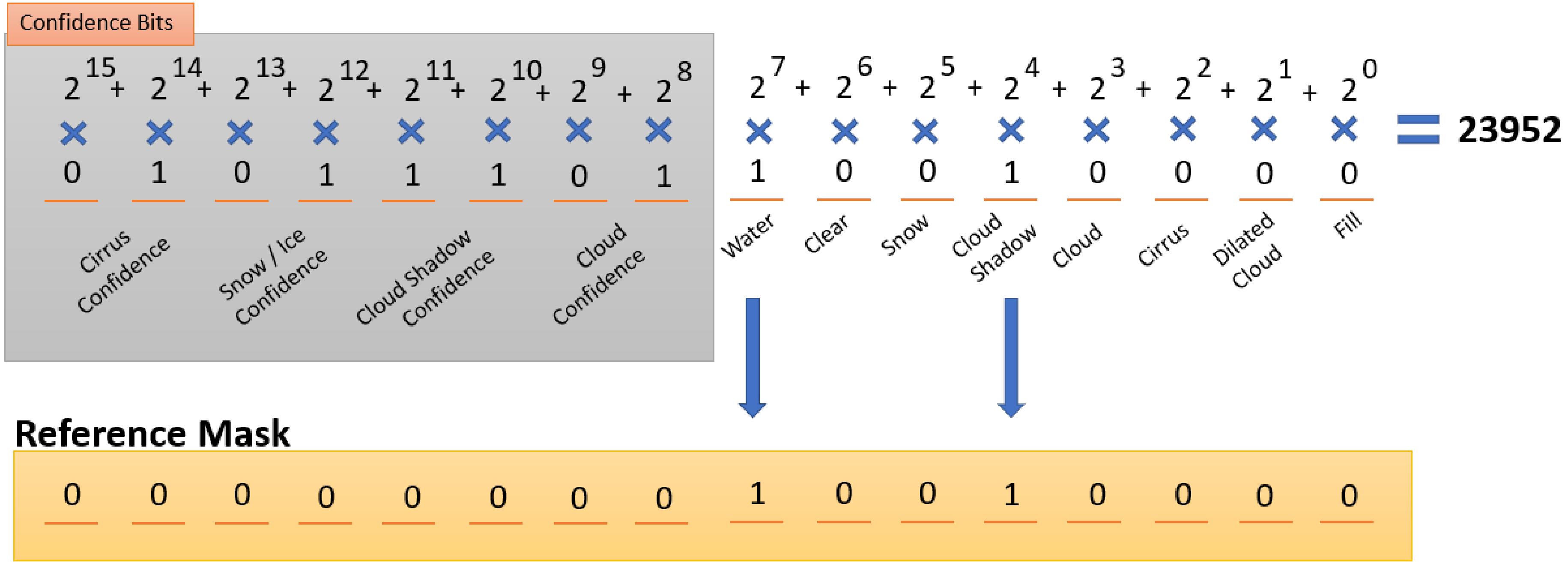
Cloud Masks





Bit Masks

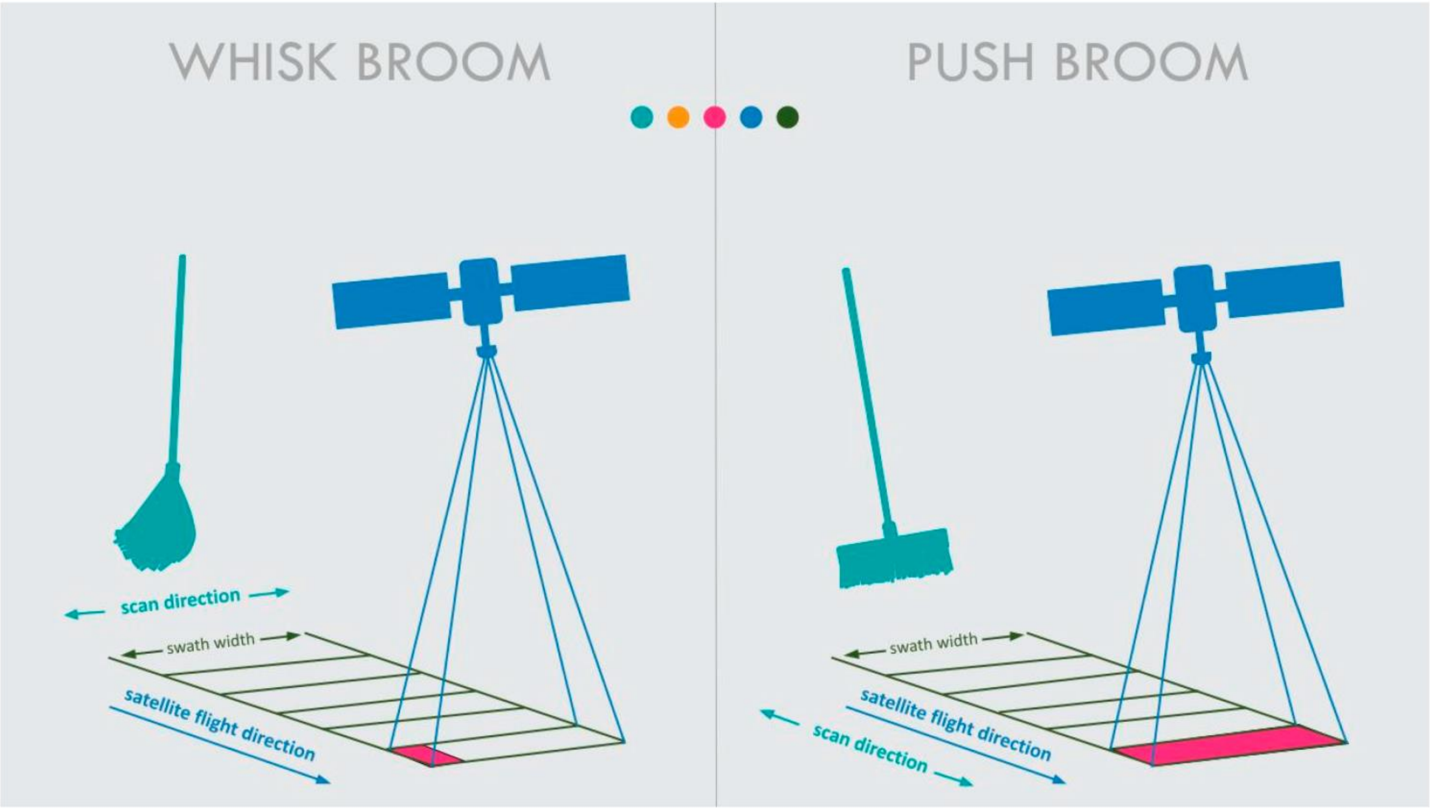
- How to store many different masks in a single band?
- Use a bit mask!
- Here is a Landsat-8 example:



https://medium.com/analytics-vidhya/python-for-geosciences-raster-bit-masks-explained-step-by-step-8620ed27141e

Optical Sensor Types

- Along-track (push broom)
  - Array of detectors
  - **Good**: No moving parts, fast
  - **Bad**: Many detectors to calibrate
- Cross-track (whisk broom)
  - One detector with mirror
  - **Good**: Only one sensor to calibrate
  - **Bad**: Moving parts and slow
  - Think Landsat 7 Scan Line Corrector Failure…



https://www.mdpi.com/2077-1312/11/3/595

Near-polar, sun synchronous, low earth orbit

https://www.youtube.com/watch?v=0oKijt2EAq0&ab_channel=AlfonsoGonzalez-Astrodynamics%26SEPodcast

Downlink Stations

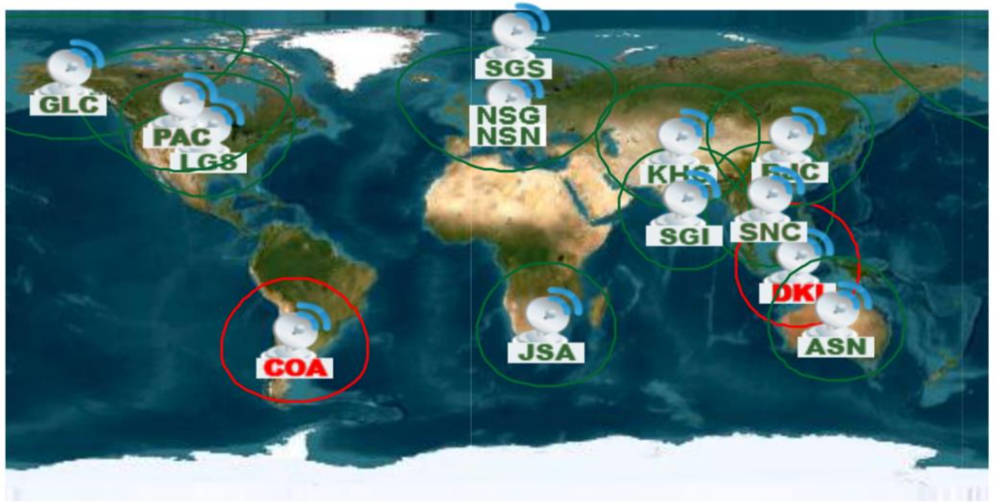
International Ground Station (IGS) Network

The map shows the locations of all active ground stations operated by our US and International Cooperator (IC) ground station network for the direct downlink and distribution of Landsat 8 and Landsat 9 data. The circles show the approximate area over which each station has the capability for direct reception of Landsat data.

In addition to the ground stations displayed on this page, many stations have received Landsat data in the past. The Historical International Ground Stations page displays these ground stations, and lists the approximate date ranges of the Landsat data collected.

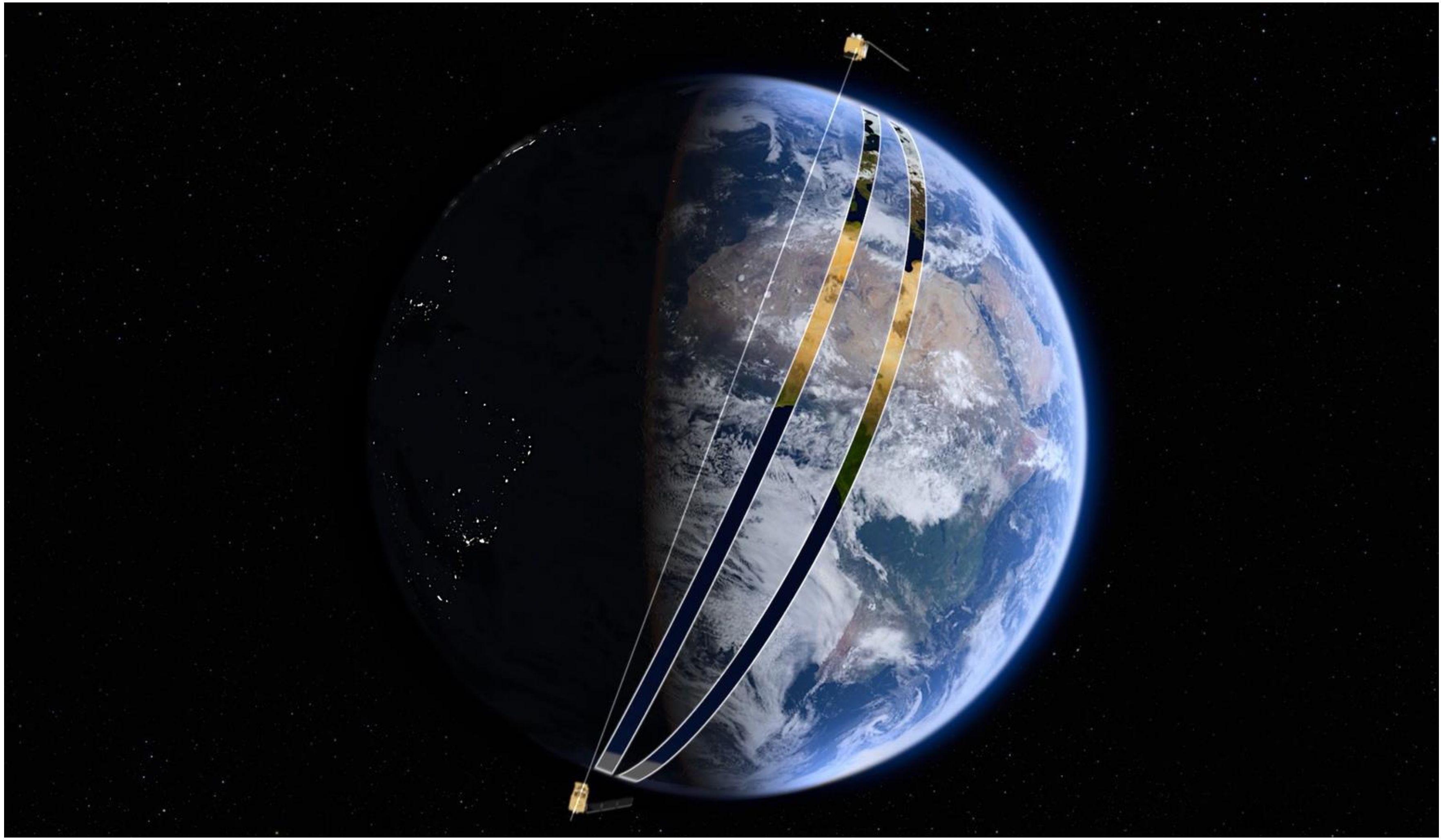
Organizations interested in pursuing direct access to Landsat 8 and/or Landsat 9 via data downlink should visit the Benefits of Becoming an IC page for more information.

Key: L8 Stations L8 & L9 Stations (5 degree station masks)



Constellations

- Similar satellites that work together to achieve higher revisit times
  - Landsat 8&9
  - Sentinel-2 A&B
  - PlanetScope Doves
  - …



Indices, Ratios, and Transformations

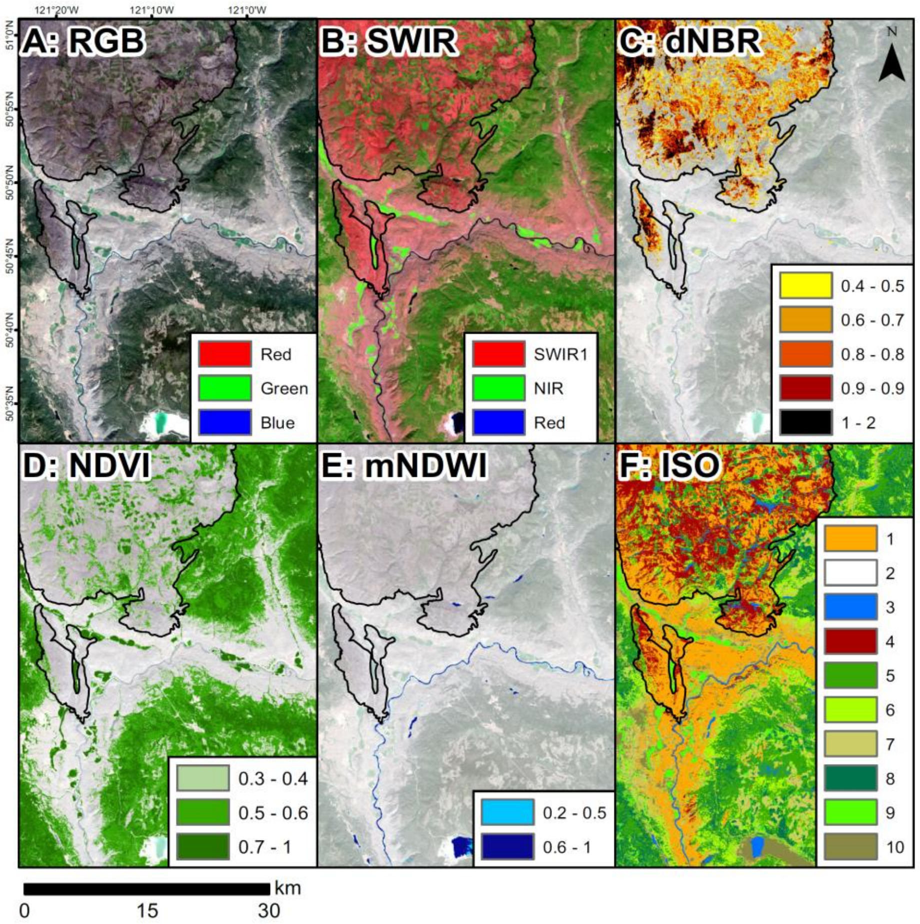


Figure 5. Landsat 8 OLI imagery near Cache Creek, British Columbia, acquired September 12, 2017. The upper left of the image is the Elephant Hill wildfire (black outline) and the main river is the Thompson River. A) True colour (R, G, B) composite. B) False colour (SWIR1, NIR, R) composite. C) Differenced normalized burn ratio (dNBR), where higher values indicate greater burn intensities. D) Normalized difference vegetation index (NDVI), where values greater than 0.4 are highly productive vegetation. E) Modified normalized difference water index (mNDWI) to extract water outlines. F) ISO unsupervised classification into 10 classes.

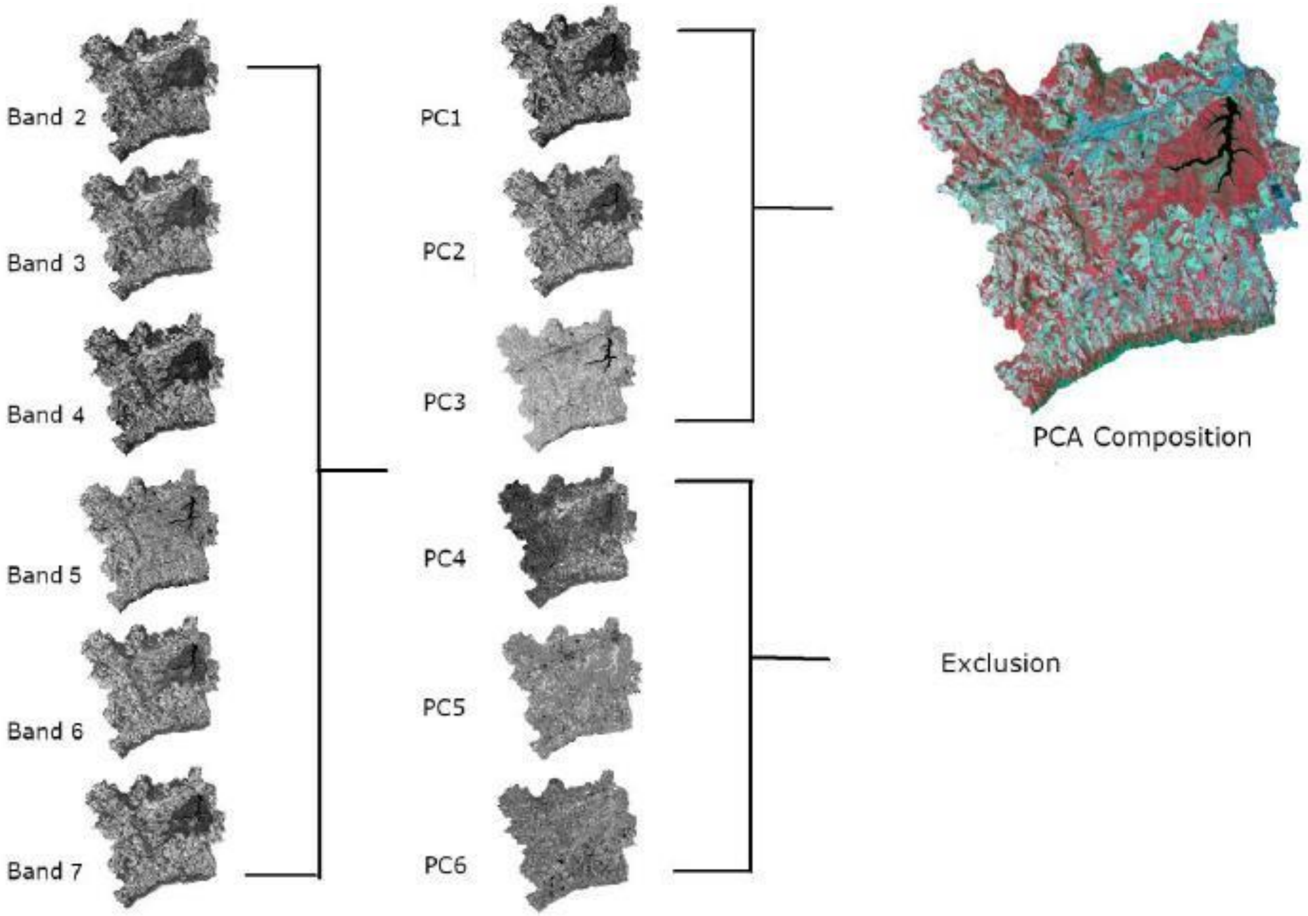
Table 3. Selected spectral indices and ratios with formulas

Index or Ratio	Formula	Description and Original Reference
Normalized Difference Vegetation Index	$NDVI = \frac{N - R}{N + R}$	Vegetation and biomass index (Rouse et al., 1973)
Normalized Difference Water Index	$NDWI = \frac{G - N}{G + N}$	Water body index (McFeeters, 1996)
Modified Normalized Difference Water Index	$mNDWI = \frac{G - S1}{G + S1}$	Improved water body index (Xu, 2006)
Automated Water Extraction Index	$AWEI_{nsh} = 4 \cdot (G - S1) - 0.25 \cdot N + 2.75 \cdot S2$	Improved water body index (Feyisa et al., 2014)
Normalized Difference Moisture Index	$NDMI = \frac{N - S1}{N + S1}$	Canopy and soil moisture index (Gao, 1996)
Normalized Burn Ratio	$NBR = \frac{N - S2}{N + S2}$	Burn severity index (Key & Benson, 1999)
Differenced Normalized Burned Ratio	$dNBR = NBR_{PRE} - NBR_{POST}$	NBR relative to pre-fire conditions (Key & Benson, 2006)
Normalized Difference Snow Index	$NDSI = \frac{G - S1}{G + S1}$	Snow index (Hall et al., 1995)
Enhanced Vegetation Index	$EVI = 2.5\left(\frac{N - R}{1 + N + 6 \cdot R - 7.5 \cdot B}\right)$	Enhanced vegetation index (Huete et al., 1997)
Tasseled Cap Wetness	$TCW = B \cdot B_c + G \cdot G_c + R \cdot R_c + N \cdot N_c + S1 \cdot S1_c - S2 \cdot S2_c$	Pixel wetness (Crist & Cicone, 1984)
Tasseled Cap Greenness	$TCG = B \cdot B_c - G \cdot G_c - R \cdot R_c - N \cdot N_c + S1 \cdot S1_c - S2 \cdot S2_c$	Pixel greenness (Crist & Cicone, 1984)
Tasseled Cap Brightness	$TCB = B \cdot B_c + G \cdot G_c + R \cdot R_c + N \cdot N_c + S1 \cdot S1_c - S2 \cdot S2_c$	Pixel brightness (Crist & Cicone, 1984)
Disturbance Index	$DI = TCB_R - (TCG_R + TCW_R)$	Forest disturbance mapping (Healey et al., 2005)
Red Green Index	$RGI = R/G$	Detection of red attack trees (Coops et al., 2006)
Red Band Ratio	$RR = N/R$	Forest, water, and cropland (Jordan, 1969)
Glacier Band Ratio	$GR = N/S1$	Glacier area delineation (Hall et al., 1987)

Note: B = BLUE, G = GREEN, R = RED, RE = RED EDGE, N = NIR, S1 = SWIR1, S2 = SWIR2, $_C$ = Sensor specific band coefficient, $_R$ = Standard deviation of a pixel relative to the mean of the image

Principal components

- **Dimensionality Reduction:**
  - PCA simplifies remote sensing data by transforming it into a smaller set of uncorrelated variables, known as principal components, reducing complexity.
- **Variance Emphasis:**
  - It maximizes important information by highlighting the most critical spectral details in remote sensing data.
- **Key Features:**
  - PCA extracts key features, aiding tasks like land cover classification and improving the efficiency of complex imagery analysis.
- Think hyperspectral!



https://www.redalyc.org/journal/3213/321364988043/html/

Demo

- Tasselled Cap Transformation:
  - https://code.earthengine.google.com/a9b3020c9e6a9a1d8ab9745db8ba06ff

UNBC GIS Lab

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GEOG 457/657 – Lab 1 (2024)

Introduction

- **Layout** Scripts, Docs, Assets, Code editor, Inspector, Console, Tasks, Search, Map
- **Declaring variables** `var`
- **Line endings** `;`
- **Commenting** `CTRL+/` or `CTRL+SHIFT+/`
- **Run** `CTRL+ENTER`

Data types

There are many data types in earth engine. Numbers, lists, strings, images, image collections, features, feature collections, geometries, etc. Here we'll start by looking at the `ee.Image()` data type.

ee.Image

If you know the path to a single image, you can insert it into `ee.Image()`. From there, print the image metadata, and add it to the map.

JavaScript

```javascript
/* ADD IMAGE */
var imgS2 = ee.Image("COPERNICUS/S2_SR_HARMONIZED/20230910T191949_20230910T191944_T10UEE");
print("Image details: ", imgS2);
Map.addLayer(imgS2);
```

ee.ImageCollection