Remote Sensing and Machine Learning

Project 1 ***Topic:*** *Machine Learning in Ground Subsidence and Climate Pattern mapping with Interferometric Synthetic Aperture Radar (InSAR) in Ny-Ålesund, Svalbard, Norway.*
Keyword : *Permafrost Degradation, Ground Subsidence Mapping, Machine Learning, Thermokarst and Synthetic Aperture Radar (SAR)*
Method : *Interferometric Synthetic Aperture Radar (InSAR)*
Tool : *ESA - Sentinel Application Platform (SNAP) and GAMMA InSAR Processing Software.*
Sensing Period : *to be defined*
Data : (copernicus) *ESA Copernicus Sentinel 1 (SAR) (C-band data), ALOS PALSAR (L-band data), ALOS-2 PALSAR-2 (L-band data).*
DEM : *S0 Terrengmodell Svalbard (by Norweigian Polar Institute) (for C-band data), ArcticDEM (for C-band data), ALOS World 3D (AW3D) (by Jaxa) (for L-band data) .*
Presentation : *Presentation 1, Presentation 2, Presentation 3.* (Team Lead and Presentation by Amartya)
Phases : *Phase 1 (Ground Subsidence), Phase 2 (Climatic Parameters), Phase 3 (Machine Learning).*

ABSTRACT : *Proposal Draft, Tracking Sheet*

Ny-Ålesund is host to sixteen permanent research stations run by agencies from ten countries. Representatives for the participating institutes meet in the Ny-Ålesund Science Managers Committee (NySMAC) twice per year. NySMAC's main goals are to distribute information on existing research and plan future research. National Centre for Polar and Ocean Research (NCPOR) operates the Himadri and IndARC Arctic research stations in Svalbard, Norway. India is a permanent member and focuses on atmospheric sciences, marine ecosystems and pollution.

The International Permafrost Association (IPA), founded in 1983, has as its objectives to foster the dissemination of knowledge concerning permafrost and to promote cooperation among persons and national or international organisations engaged in scientific investigation and engineering work related to permafrost and seasonally frozen ground. The International Arctic Science Committee (IASC) is a non-governmental organization which is composed of international science groups participating in arctic science research. IASC is an International Scientific Associate of ICSU, and was established in 1990. IASC's main aim is to initiate, develop, and coordinate leading edge scientific activity in the Arctic region, and on the role of the Arctic in the Earth system. The Arctic Council is a high-level intergovernmental forum that addresses issues faced by the Arctic governments and the indigenous people of the Arctic. India is an observer member of the Arctic Council. India has been extensively working on Arctic Research and Climate Change.

Ny-Ålesund Research Station Norway

IPA

IASC

SIOS
SVALBARD INTEGRATED ARCTIC EARTH OBSERVING SYSTEM

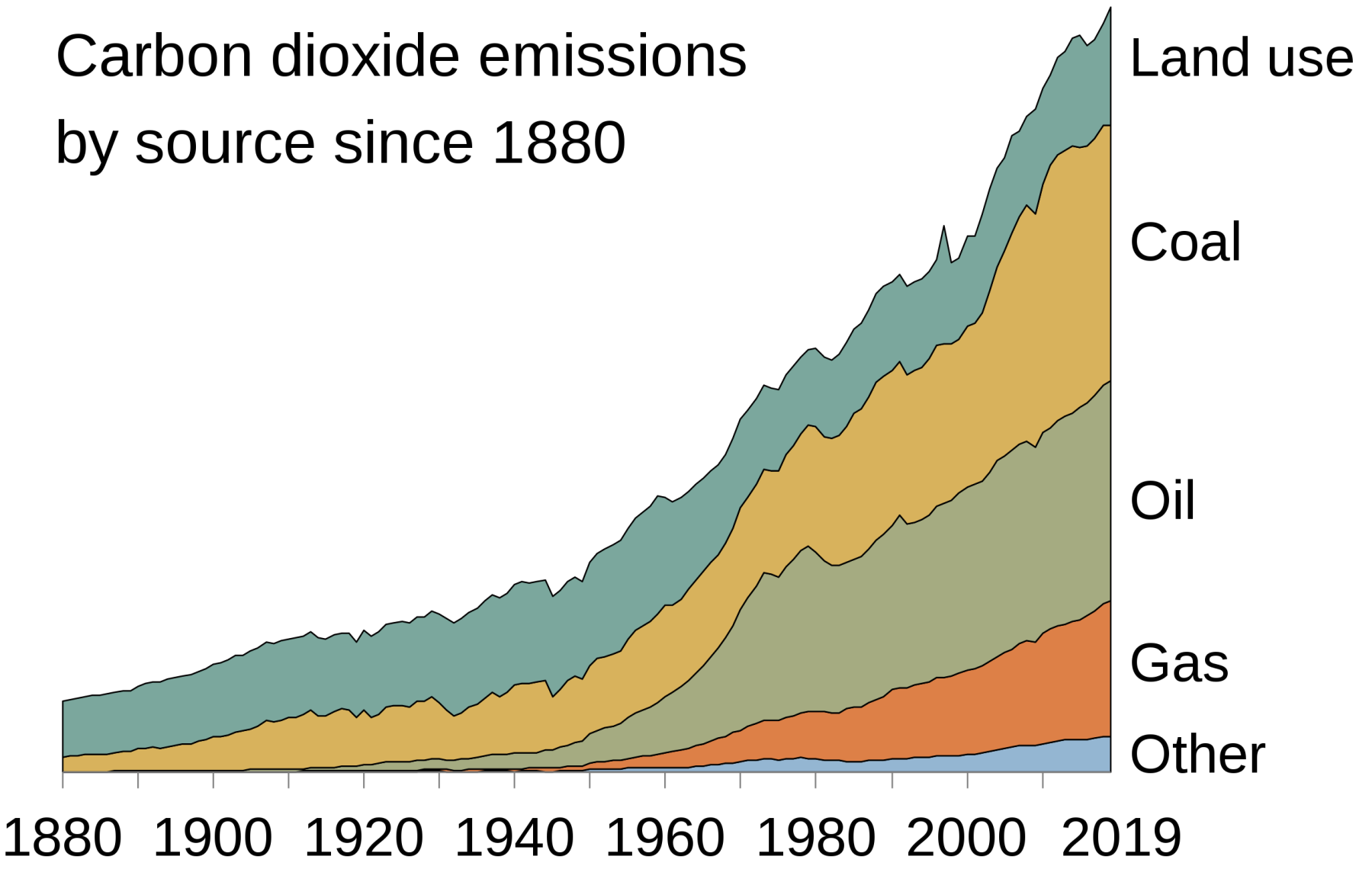
ARCTIC COUNCIL

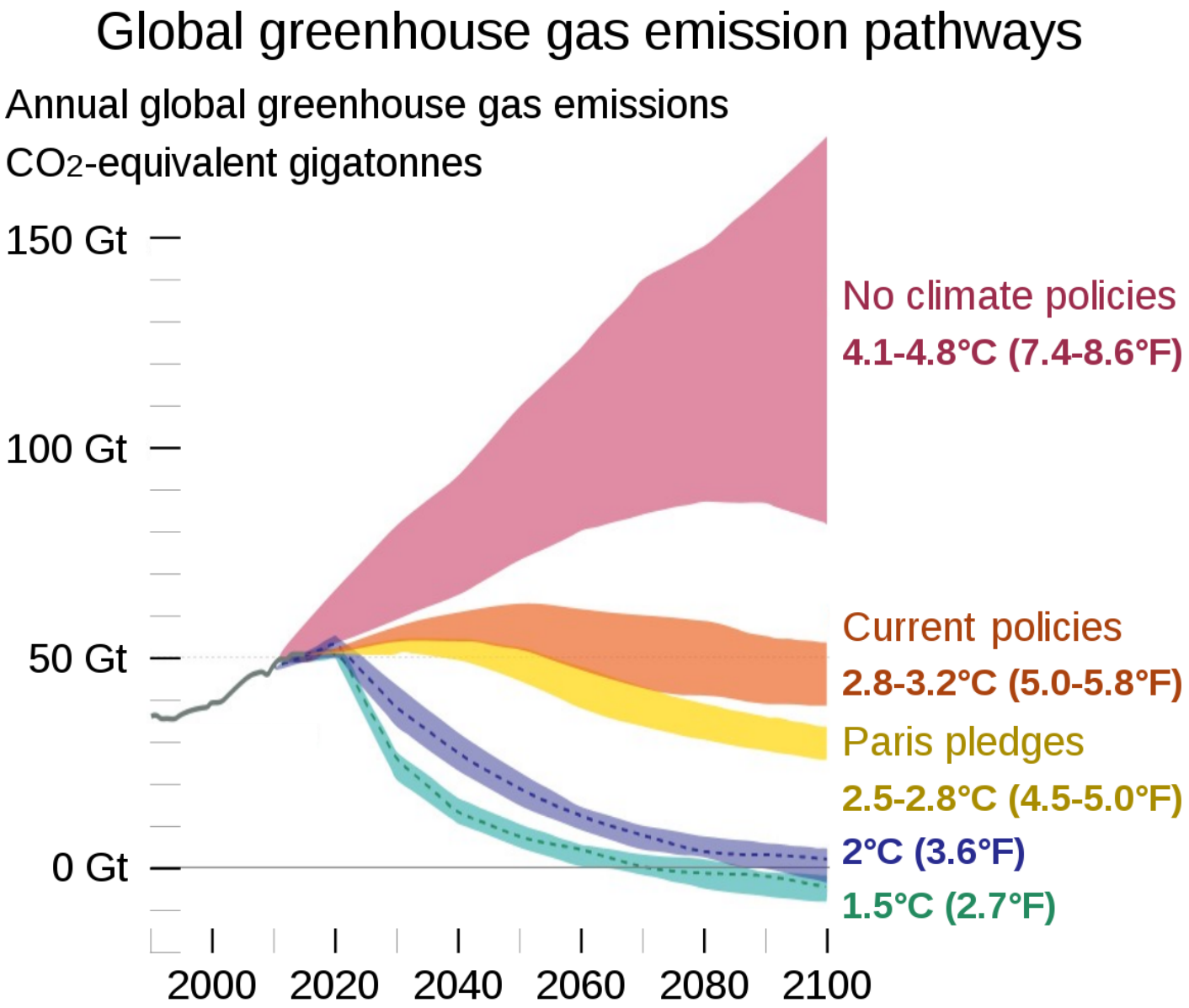
Research

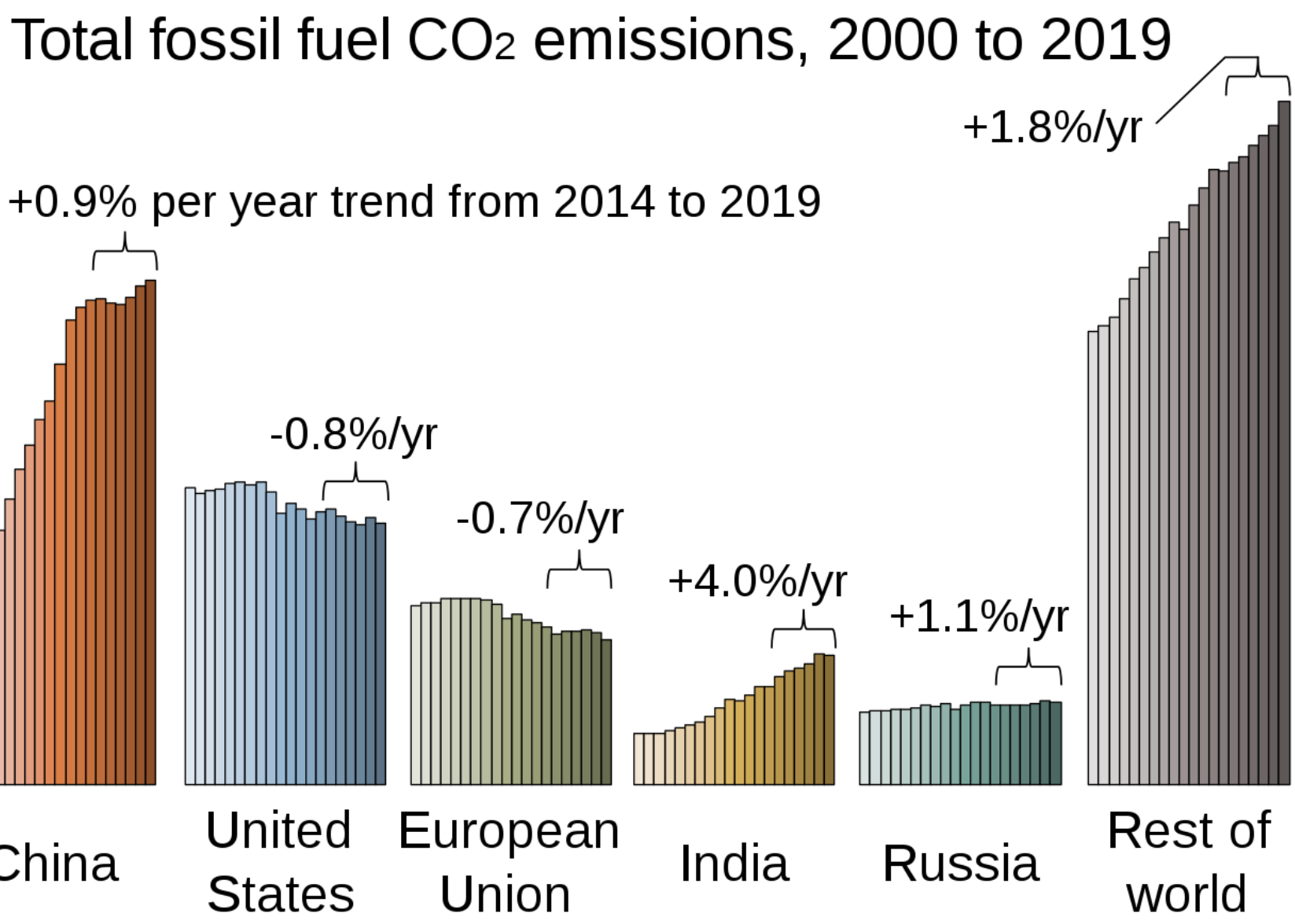
Literature Review:

Wiki Read : *Climate Change*, *National Action Plan for Climate Change*, *Permafrost*, *Remote Sensing*, *Svalbard*, *Subsidence*, *Synthetic Aperture Radar (SAR)*, *Thermokarst*, *Climate Variability and Change*, *Carbon Cycle*

Arctic temperatures have increased and are predicted to continue to increase during this century at over twice the rate of the rest of the world [A]. The land-surface sink is estimated to remove about 29% of annual global CO_2 emissions. Over the last two decades, the world's oceans have absorbed 20 to 30% of emitted CO_2. [A]. Limiting new black carbon or soot deposits in the Arctic could reduce global warming by 0.2 °C (0.36 °F) by 2050. [A]. Sea ice reflects 50% to 70% of incoming solar radiation while the dark ocean surface only reflects 6%, so melting sea ice is a self-reinforcing feedback. [A]. As more CO_2 and heat are absorbed by the ocean, it acidifies, its circulation changes and phytoplankton takes up less carbon, decreasing the rate at which the ocean absorbs atmospheric carbon. [A]. Albedo is a non-dimensional, unitless quantity that indicates how well a surface reflects solar energy. A value of 0 means the surface is a "perfect absorber" that absorbs all incoming energy. A value of 1 means the surface is a "perfect reflector" that reflects all incoming energy [A]. India is +4%/yr and really needs to have its Carbon emission under control. India is working on National Action Plan for Climate Change (NAPCC).







Permafrost extends to a base depth where geothermal heat from the Earth and the mean annual temperature at the surface achieve an equilibrium temperature of 0°C [A]. I was amazed by this image of a Massive blue ground ice exposure on the north shore of Herschel Island, Yukon, Canada. The amount of carbon sequestered in permafrost is four times the carbon that has been released to the atmosphere due to human activities in modern time [A]. [Svalbard Global Seed Vault].

Subsided house, called The Crooked House, the result of 19th-century mining subsidence in Staffordshire, England [image]. Factors resulting in subsidence include various karst phenomena, thawing of permafrost, consolidation, oxidation of organic soils, slow crustal warping (isostatic adjustment), normal faulting, caldera subsidence, or withdrawal of fluid lava from beneath a solid crust.

Remote Sensing may be split into "active" remote sensing (when a signal is emitted by a satellite or aircraft to the object and its reflection detected by the sensor) and "passive" remote sensing (when the reflection of sunlight is detected by the sensor). The quality of remote sensing data consists of its spatial, spectral,

radiometric and temporal resolutions. **Spatial resolution:** The size of a pixel that is recorded in a raster image – typically pixels may correspond to square areas ranging in side length from 1 to 1,000 metres (3.3 to 3,280.8 ft). **Spectral resolution** The wavelength of the different frequency bands recorded – usually, this is related to the number of frequency bands recorded by the platform. Current Landsat collection is that of seven bands, including several in the infrared spectrum, ranging from a spectral resolution of 0.7 to 2.1 µm. The Hyperion sensor on Earth Observing-1 resolves 220 bands from 0.4 to 2.5 µm, with a spectral resolution of 0.10 to 0.11 µm per band. **Radiometric resolution** The number of different intensities of radiation the sensor is able to distinguish. Typically, this ranges from 8 to 14 bits, corresponding to 256 levels of the gray scale and up to 16,384 intensities or "shades" of colour, in each band. It also depends on the instrument noise. **Temporal resolution** The frequency of flyovers by the satellite or plane, and is only relevant in time-series studies or those requiring an averaged or mosaic image as in deforesting monitoring. This was first used by the intelligence community where repeated coverage revealed changes in infrastructure, the deployment of units or the modification/introduction of equipment. Cloud cover over a given area or object makes it necessary to repeat the collection of said location.

Here's some video supporting the above topics : Basic of Remote Sensing by Dr. Manu Mehta, IIRS, Remote Sensing [Hindi], How Does LiDAR Remote Sensing Work? Light Detection and Ranging, Mapping the Invisible: Introduction to Spectral Remote Sensing, Introduction to Hyperspectral Remote Sensing: A Presentation, Why scientists are so worried about this glacier, What is Climate Change? | Start Here, What if The Polar Ice Caps Of The Earth Melt?, Permafrost - what is it?, NASA Explorers: Permafrost, Russian Oil spill disaster due to ground subsidence by permafrost degradation - news, Climate change in Russia: Can Siberia's permafrost be saved? | Focus on Europe, Why parched California land is collapsing at rapid rate, Our Dynamic Earth: Rebound and Subsidence, Ground Subsidence due to overpumping water from deep underground - California Community Slowly Sinking Into Ground, In the News - This Virginia Island Is Literally Sinking Into The Sea, Parts of California sinking because of water use, Thermokarst: Thawing Permafrost at Wolverine Lake, CARBON CYCLE (Biology Animation), The Carbon Cycle Process, Satellites Use 'This Weird Trick' To See More Than They Should - Synthetic Aperture Radar Explained., NASA ARSET: Basics of Synthetic Aperture Radar (SAR) : slide, Geo for Good 2019: Learn about Synthetic Aperture Radar (Sentinel-1), A technique to track Earth's subtle movements with orbiting radars is heating up, Synthetic Aperture Radar: Of Bats and Flying Pianos .

Literature Review of Papers: [InSAR], [D-InSAR]

➔ *(2020) Surface displacement revealed by L-band **InSAR** analysis in the Mayya area, Central Yakutia, underlain by continuous permafrost.*

➔ *(2019) Seasonal dynamics of a permafrost landscape, Adventdalen, Svalbard, investigated by **InSAR**.*

➔ *(2019) Time-Series MT-**InSAR** Monitoring of Permafrost Freeze-Thaw Seasonal Displacement over Qinghai–Tibetan Plateau Using Sentinel-1 Data*

➔ *(2021) Seasonal Surface Subsidence and Frost Heave Detected by C-Band **DInSAR** in a High Arctic Environment, Cape Bounty, Melville Island, Canada*

➔ *(2018) Thaw Subsidence of a Yedoma Landscape in Northern Siberia, Measured In Situ and Estimated from TerraSAR-X Interferometry **(DInSAR)**.*

➔ *(2014) RADARSAT-2 **D-InSAR** for ground displacement in permafrost terrain, validation from Iqaluit Airport, Baffin Island, Canada.*

Machine Learning :

➔ *(2021) Spatiotemporal modeling of land subsidence using a geographically weighted deep learning method based on PS-InSAR*

➔ *(2020) Land Subsidence Susceptibility Mapping in Jakarta Using Functional and Meta-Ensemble Machine Learning Algorithm Based on Time-Series InSAR Data*

➔ *(2020) A Deep Learning Based Method for Local Subsidence Detection and InSAR Phase Unwrapping: Application to Mining Deformation Monitoring*

➔ *(2020) Urban subsidence monitoring by SBAS-InSAR technique with multi-platform SAR images: a case study of Beijing Plain, China.*

➔ *(2020) Predicting land deformation by integrating InSAR data and cone penetration testing through machine learning techniques*

➔ *(2019) The Application of Convolutional Neural Networks to Detect Slow, Sustained Deformation in InSAR Time Series*

➔ *(2019) Seasonal Deformation of Permafrost in Wudaoliang Basin in Qinghai-Tibet Plateau Revealed by **StaMPS-InSAR***

Article : *UN SDGS, Mummies From a Mysterious Arctic Civilization Found In The Permafrost, There's a Long-Lost 'Paleo-River' Beneath the Sahara Desert Nobody Knew Existed, Dynamic Time Warping, Mapped ice wedge polygon patterns from GeoEye-1, WorldView-1*

Research Paper :

➔ *Zimov, S. A., Schuur, E. A., & Chapin III, F. S. (2006). Permafrost and the global carbon budget. Science(Washington), 312(5780), 1612-1613.*

➔ *Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote sensing of Environment, 202, 18-27.*

Weekend Reading: [Remote Sensing], [Research Notes]

➔ *TerraClimate, a high-resolution global dataset of monthly climate and climatic water balance from 1958–2015.*

➔ *Estimating 1992–2000 average active layer thickness on the Alaskan North Slope from remotely sensed surface subsidence.*

➔ *Sentinel-1 SAR Interferometry for Surface Deformation Monitoring in Low-Land Permafrost Areas.*

➔ *[P2] Using the satellite-derived NDVI to assess ecological responses to environmental change.*

➔ *[P2] Evaluating vegetation phenological patterns in Inner Mongolia using NDVI time-series analysis.*

➔ *NASA-ISRO SAR (NISAR) Mission Science Users' Handbook.*

➔ *Seasonal dynamics of a permafrost landscape, Adventdalen, Svalbard, investigated by InSAR.*

➔ *A Machine Learning-Based Approach for Surface Soil MoistureEstimations with Google Earth Engine.*

➔ *Surface subsidence and uplift above a headrace tunnel in metamorphic basementrocks of the Swiss Alps as detected by satellite SAR interferometry*

➔ *46-Year (1973–2019) Permafrost Landscape Changes in the Hola Basin, Northeast China Using Machine Learning and Object-Oriented Classification*

➔ *Study of permafrost distribution in Sikkim Himalayas using Sentinel-2 satellite images and logistic regression modelling*

➔ *Automatic Mapping of Thermokarst Landforms from Remote Sensing Images Using Deep Learning: A Case Study in the Northeastern Tibetan Plateau*

➔ *Using deep learning to map retrogressive thaw slumps in the Beiluhe region (Tibetan Plateau) from CubeSat images*

➔ *Mapping Abrupt Permafrost Thaw from Space Using Machine Learning*

➔ *Machine learning-based thermokarst landslide susceptibility modeling across the permafrost region on the Qinghai-Tibet Plateau*

➔ *Bundle Adjustment Using Space-Based Triangulation Method for Improving the Landsat Global Ground Reference*

➔ *ArcticNet: A Deep Learning Solution to Classify Arctic Wetlands*.

Experimentation

➔

Result

➔

Takeaway

Assignment :

➔ Self Assignment: *https://code.earthengine.google.com/81d81735ee45ebcc5824bfb11538d398 (Kaziranga Flood Mapping)*

Resources :

➔ Google Earth Engine : Machine Learning in Earth Engine, RUS Webinar: Land Subsidence mapping with Sentinel-1 - HAZA03, NASA ARSET - Introduction to Synthetic Aperture Radar, ESA SNAP, **NASA-ISRO SAR Mission (NISAR)**, indiaai.gov.in, Sankey Diagram Python

➔ Videos: Spatial Thoughts, Google Earth Engine 1 - 2, ISRO Google Earth Engine, Nasa Google Earth Engine, Google Earth, Earth Engine Classification and Regression, ML with Earth Engine, Stanford Google Earth Engine, GEE, TensorFlow in GEE, TensorFlow Models, Analyzing a Landsat 8 image in Google Earth Engine, QiushengWu, Learn how to get started in Earth Engine with an overview of the Code Editor and Colab, Time Series Analysis in Earth Engine, RUS Demo: Land Subsidence mapping using Sentinel-1, planet.com.

➔ Completed Courses : Google Earth Engine for Machine Learning & Change Detection , QGIS & Google Earth Engine for Environmental Applications, Google Earth Engine for Remote Sensing Analysis Masterclass and Get started with GIS & Remote Sensing in QGIS #Beginners.

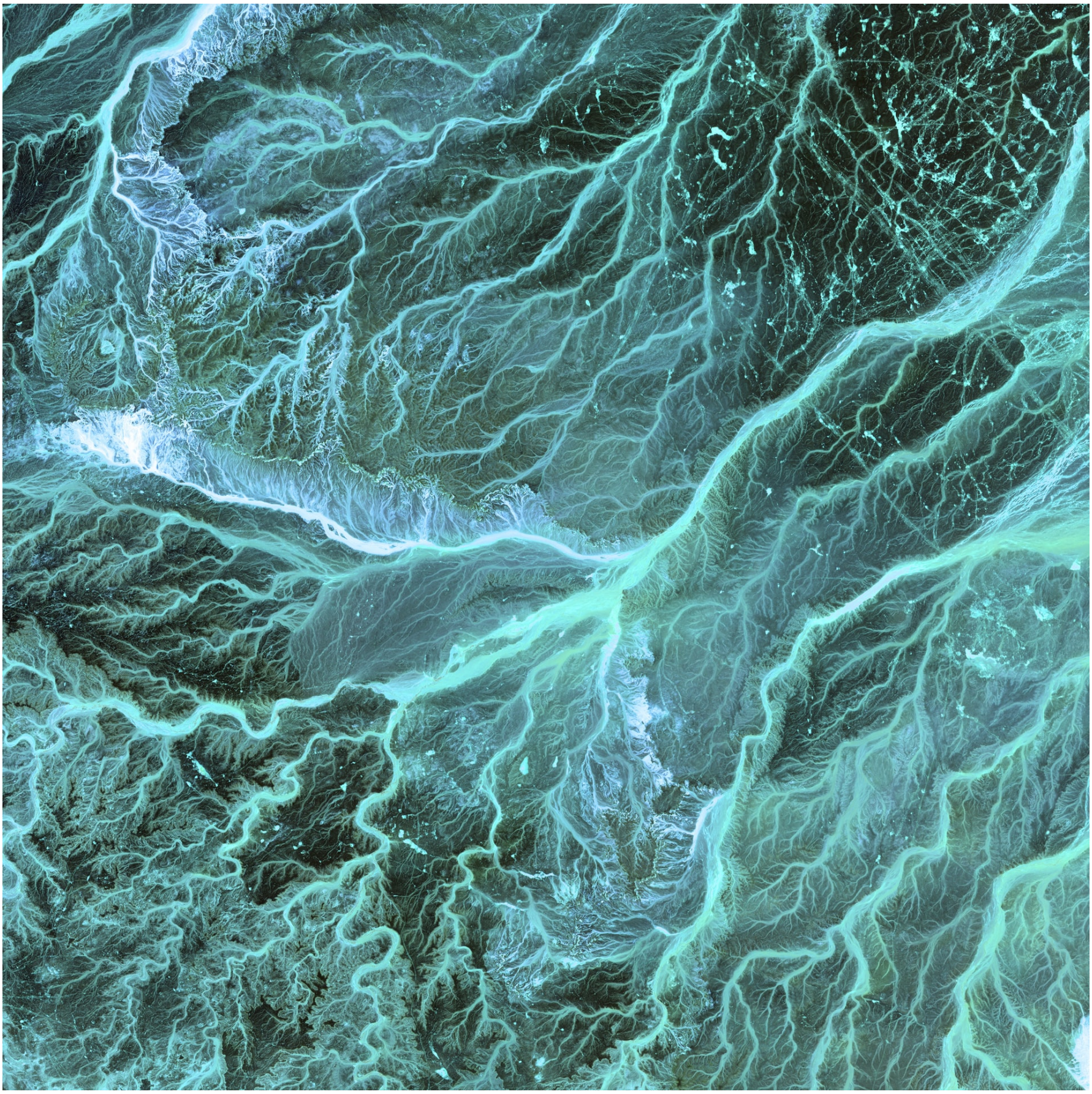
Notes

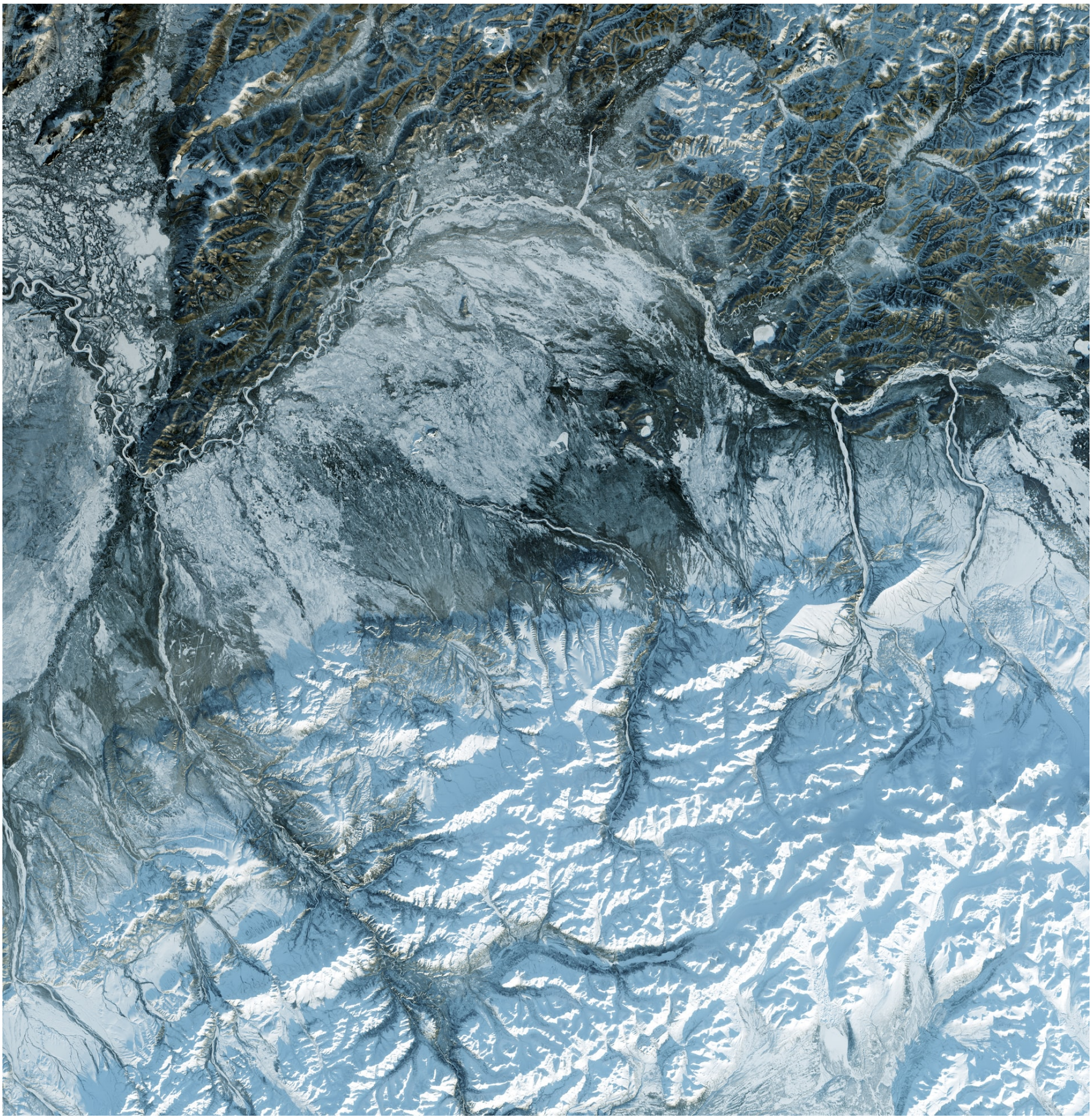
Google Earth Engine for Machine Learning & Change Detection | Spatial Analysis and Remote Sensing

Google Earth Engine

Keyword : Unsupervised Learning, Supervised Learning, Image Preprocessing, Change Detection, Spectral Indices

We will be working on Google Earth Engine which holds data, dating back 40 years for global scale data mining. Google Earth Engine API is available in JavaScript and Python. We will be using mostly GEE Code Environment, where code can be shared online with other developers like colab. GEE holds a variety of datasets.





JavaScript :

// and /* */ are comments in JS.

variable is declared with 'var' ; var my_var = 10;

print(my_var); print(my_var,my_var2);

var str_my = 'hey this is Amartya'; var str_my2 = "good evening"; //string objects

print('google earth engine is amazing'); //function calling directly with strings

var my_list = ['nrsc', 'nesac', 'iirs']; //list with first index 0 ; print(my_list[0]);

var my_dict = {'nrsc':'hyd', 'nesac':'umium', 'iirs':1}; //key-value pair; print(my_dict['nesac']); or print(my_dict.nesac)

To define a function:

```
var my_function = function(string){
    return 'Hello' + string + '!';
};
print(my_function('saikia'));
```

Lab Mapping and Reducing Collection : LandSat Example

All datasets in Google Earth Engine are arranged in collections. Lansat Bands.

Code: https://code.earthengine.google.com/afe38ad416b80d646cb7f902a4cba79b

```
var landsat = ee.ImageCollection("LANDSAT/LC8_L1T")
    .filterDate('2016-01-01', '2017-01-01')
    .filterBounds(geometry)

var composite = ee.Algorithms.Landsat.simpleComposite({
collection: landsat,
asFloat: true
```

```
}) // dict as function parameter

Map.addLayer(composite, {bands: ["B4", "B3", "B2"], min:0, max: 0.3}, "RGB")
Map.centerObject(geometry, 11)
```

Lab Raster Operations : Calculate NDVI

Code: https://code.earthengine.google.com/55ecac6efd6124c4b132af3d0ad8e984

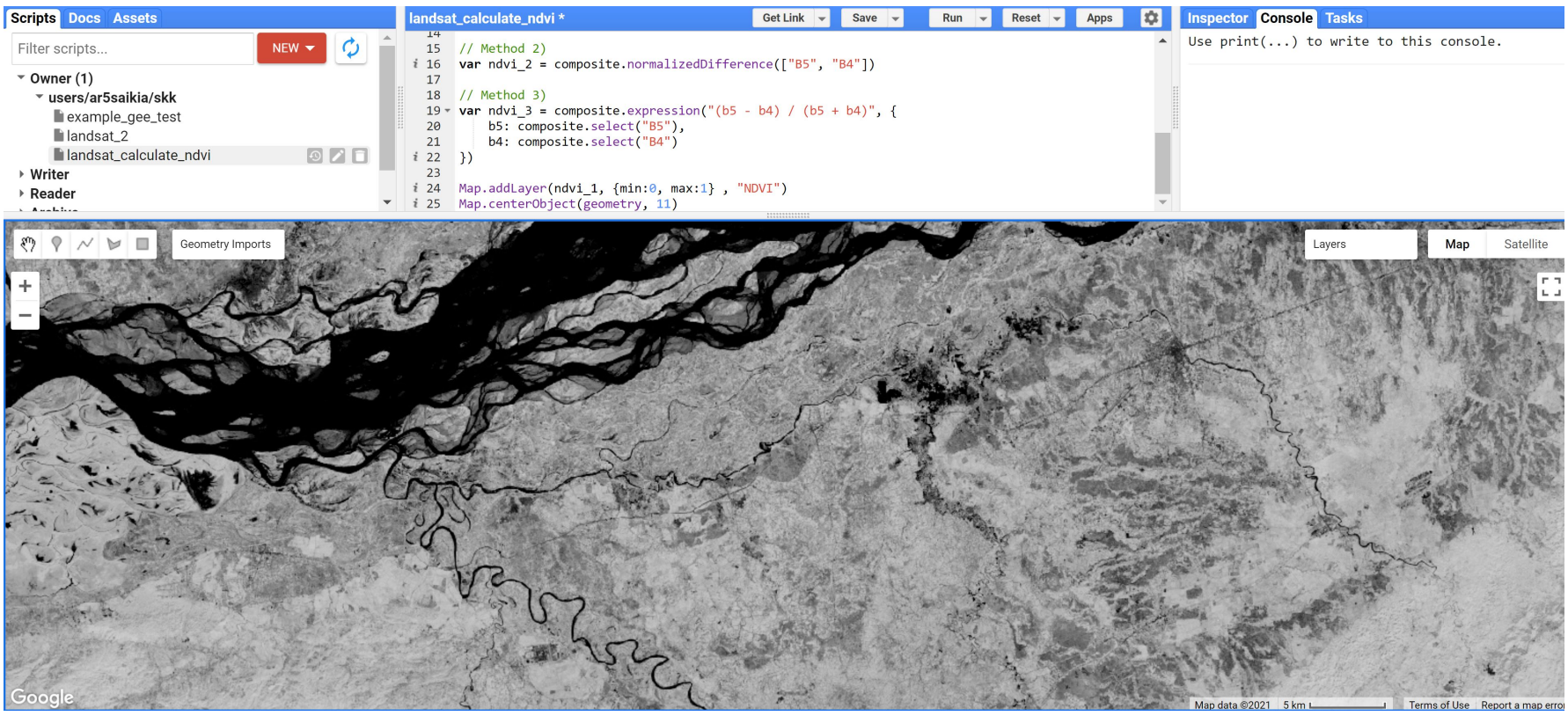
Code: (Max NDVI) https://code.earthengine.google.com/7c9f841a06173a19c244039591259f22

```
// Method 1)
var b5 = composite.select("B5")
var b4 = composite.select("B4")
var ndvi_1 = b5.subtract(b4).divide(b5.add(b4))

// Method 2)
var ndvi_2 = composite.normalizedDifference(["B5", "B4"])

// Method 3)
var ndvi_3 = composite.expression("(b5 - b4) / (b5 + b4)", {
    b5: composite.select("B5"),
    b4: composite.select("B4")
})

Map.addLayer(ndvi_1, {min:0, max:1} , "NDVI")
Map.centerObject(geometry, 11)
```

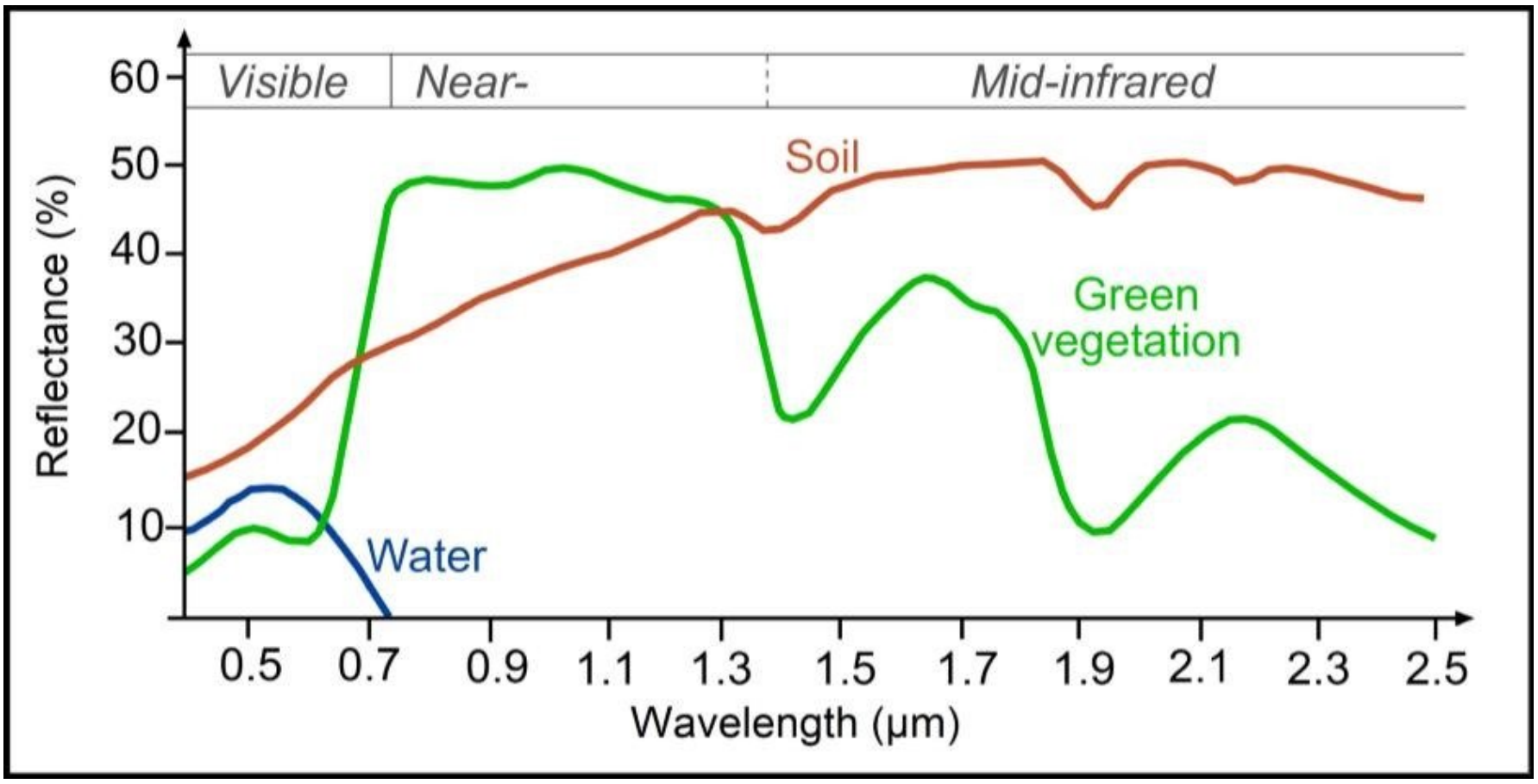


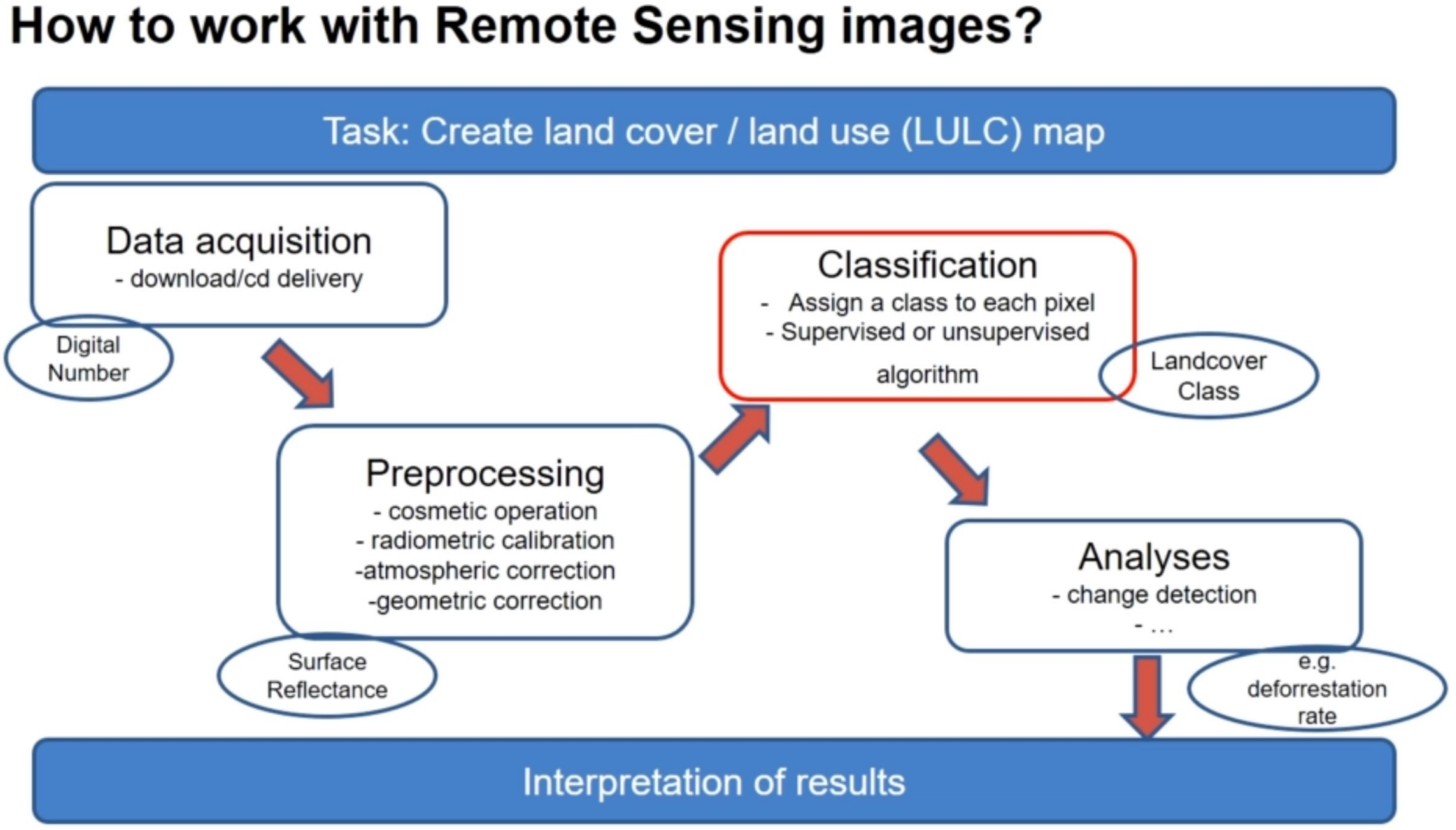
To Export Image: Run > Go to Task > Save, it gets stored in Google Drive.

Code - https://code.earthengine.google.com/e7fa0e058c3d0da02fefc6f9b0da6290

Machine Learning for LULC (Land Use Land Coverage)

Classification in Geospatial Analysis: Input is Raster Image (Multispectral and other GIS data)). We use overall accuracy, kappa index etc from confusion matrix. If map has 85%+ accruracy then it is acceptable. Remote Sensing is the use of electromagnetic radiation sensors to record images of the environment, which can be interpreted to yield useful information. Remote Sensing sensors record electo magnetic radiations and electromagnetic waves. Each object has a unique spectral property (reflection, absorption and transmission) which produce a unique spectral signature. In the spectral signature, Soil(red) has high reflectance in the Visible region. Vegetation Spectral Index ~ NDVI is common. The behavioural spectral index of soil is different in all the em spectrum regions. Green vegetation absorbs red wavelength.



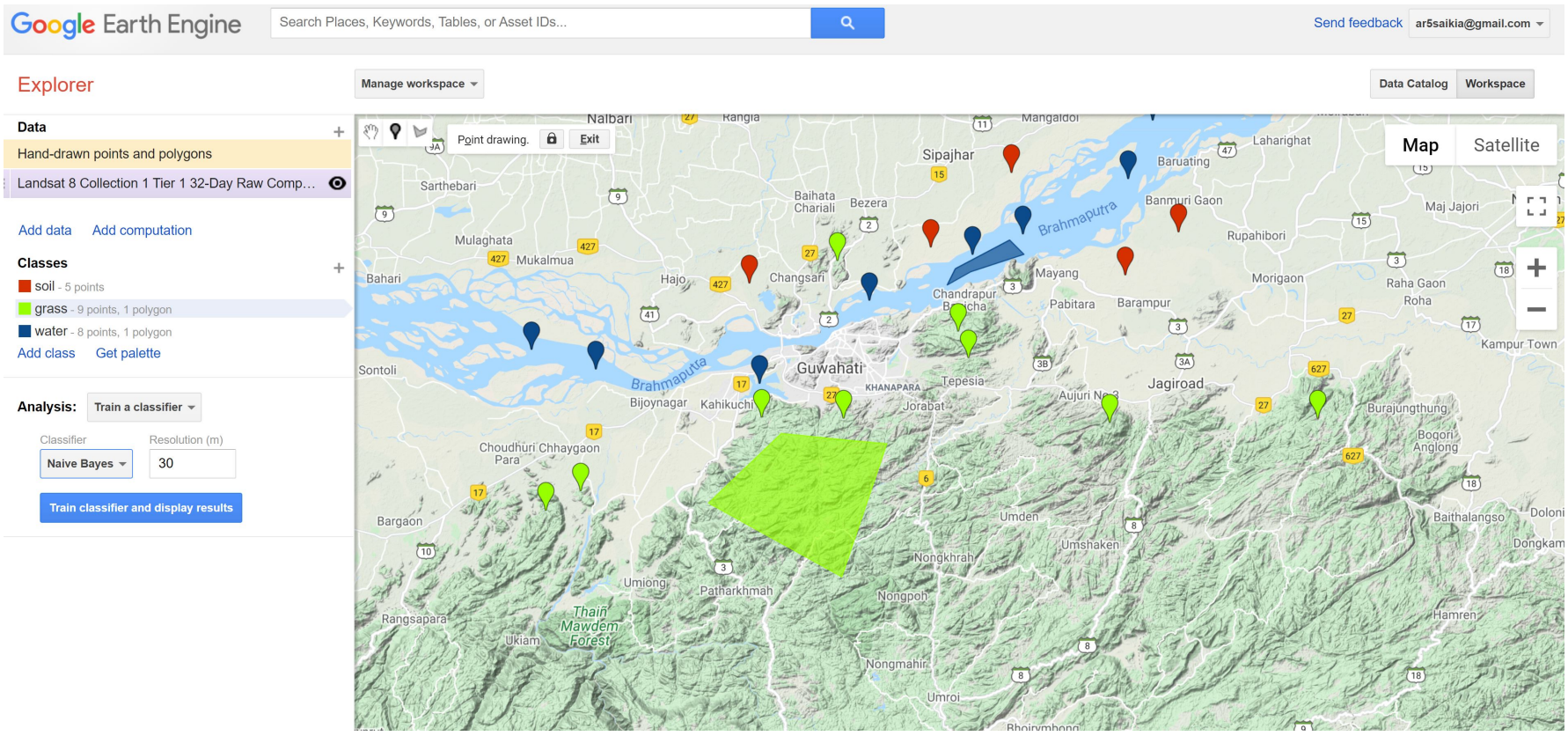


How to work with Remote Sensing Images ?

Each pixel is a data point which falls into a certain LULC category or class. In a way we form clusters of pixel.

Supervised vs Unsupervised : Multispectral Images has a lot of band in them. We use Google Earth Engine Explorer

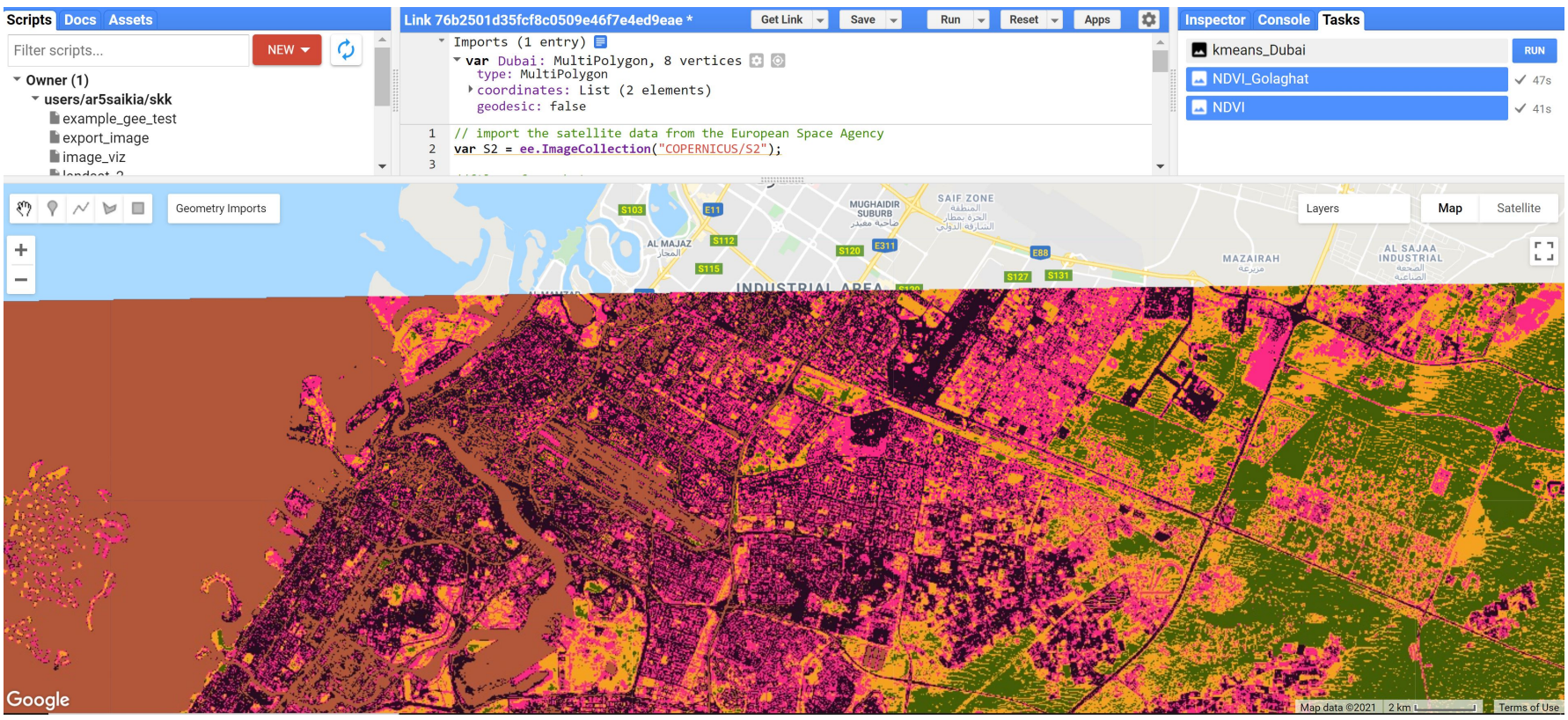
Supervised Learning : Go to Google Earth Engine Explorer and add datad , e.g - Landsat 8 data. Then add data and in Search Bar add hand drawn data and polygon. Add classes and add points in the map to collect as much varied data possible for training.



Unsupervised Learning : Import images and their visualization in Google Earth Engine.
code : https://code.earthengine.google.com/a6f49e992043ce05b51b2792469af247.
Image Visualization - Thermal, RGB, False Color: https://code.earthengine.google.com/d5c58be0e234a09d99f51712f8fa0e94
K Means Clustering : code - https://code.earthengine.google.com/76b2501d35fcf8c0509e46f7e4ed9eae .

```
// Create training dataset.
var training = image.sample({
    region: Dubai,
    scale: 20,
    numPixels: 5000
});

// Start unsupervised clusterering algorithm and train it with 5 classes.
var kmeans = ee.Clusterer.wekaKMeans(5).train(training);
// Cluster the input using the trained clusterer.
var result = image.cluster(kmeans);
// Display the clusters with random colors.
Map.addLayer(result.randomVisualizer(), {}, 'Unsupervised K-means Classification');
```



Common Algorithms used in Classification
Unsupervised : K-means Clustering, ISODATA, Association Rules, ML Clustering in GEE.
Supervised : Nearest Neighbour, Logistic Regression, Decision Trees, Linear Regression, Support Vector Machines, Artificial Neural Network, Random Forests, ML Classification in GEE.
Random Forest code : https://code.earthengine.google.com/50a349a862786afbef11238ee1eef8f5.

For labelling, In the map, Geometry Imports > New Layer > Settings > Import as (Feature Collection) not 'geometry' > Add properties ('land_type':'rocks').
Decision Tree (CART) : code - https://code.earthengine.google.com/c54b845a384f3b909e635ad3c0b1ad4c
Accuracy Assessment in GEE : code - https://code.earthengine.google.com/9e1350bd315bf08a9580b6ba2de4323f

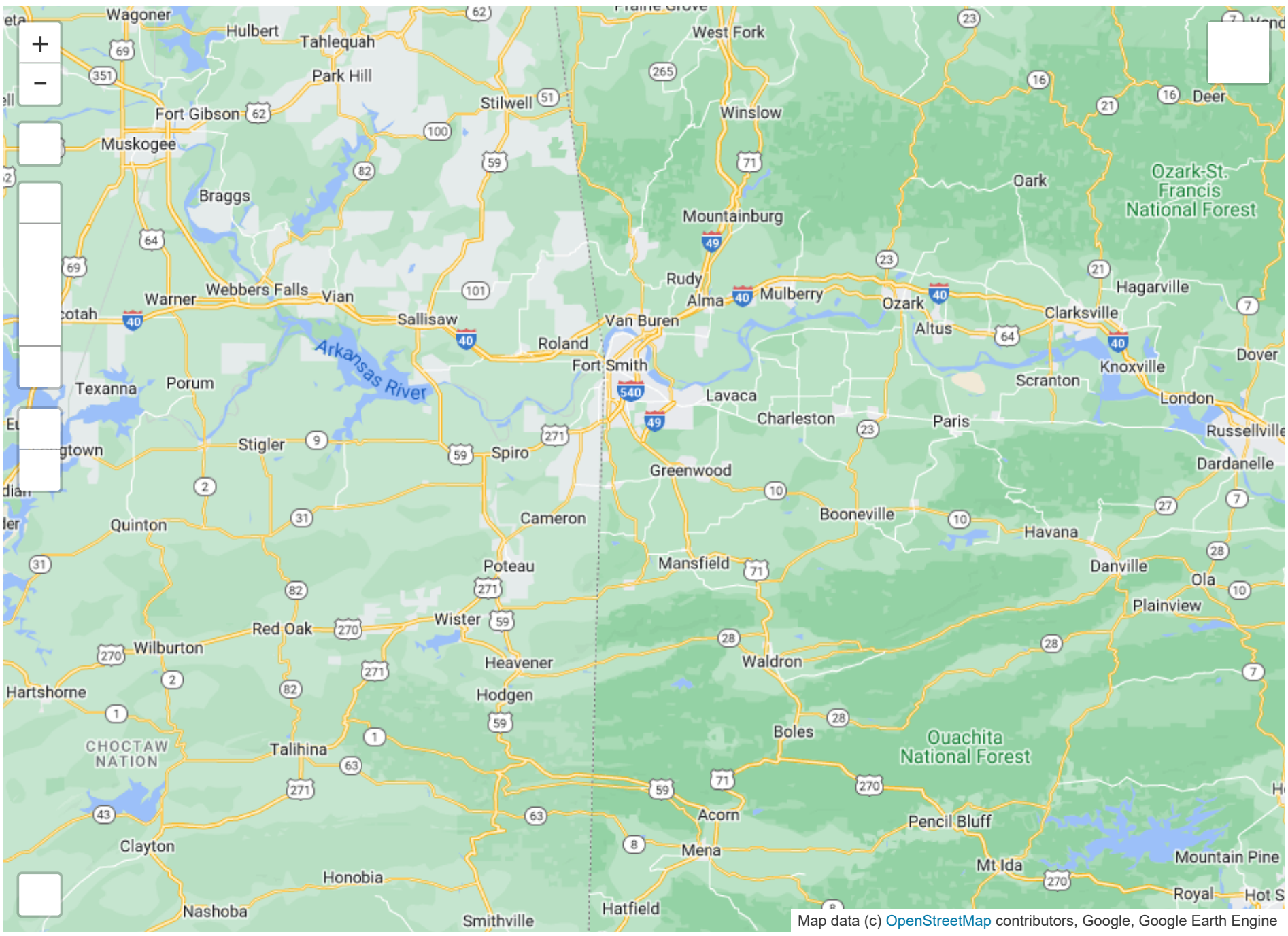
Change Detection
Change Detection = Calculating the spatio temporal variation that exist between the two datasets. ways to do change detection - 1) Image Differencing : Subtraction of 2 images 2) Post Classification : Subtraction after Classifiction 3) Trend Analysis of Image time series - NDVI averaged over area - time series of NDVI values.
Burn severity is based on NBR (Normalised Burn Ratio) dNBR = ΔNBR = Prefire NBR - Postfire NBR.

ΔNBR	Burn Severity
< -0.25	High post fire regrowth
-0.25 to -0.1	Low post fire regrowth
-0.1 to +0.1	Unburned
0.1 to 0.27	Low severity burn
0.27 to 0.44	Moderte low-severity burn
0.44 to 0.66	Moderate high-severity burn
> 0.66	High severity burn

Article : How to generate wildfire boundary maps with Earth Engine

QGIS & Google Earth Engine for Environmental Applications | Remote Sensing & GIS

Google Earth Engine, Qiusheng Wu, Spatial Thoughts, ISRO, NASA, Stanford and Conference | YouTube / Article



Indian Space Research Oraanization

" Space technology in the Service of mankind "