Paradigm Shift in Satellite Earth Observation Analytics; from Desktop to Cloud

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استاد وابسته

دانشکده مهندسی نقشه برداری و اطلاعات مکانی
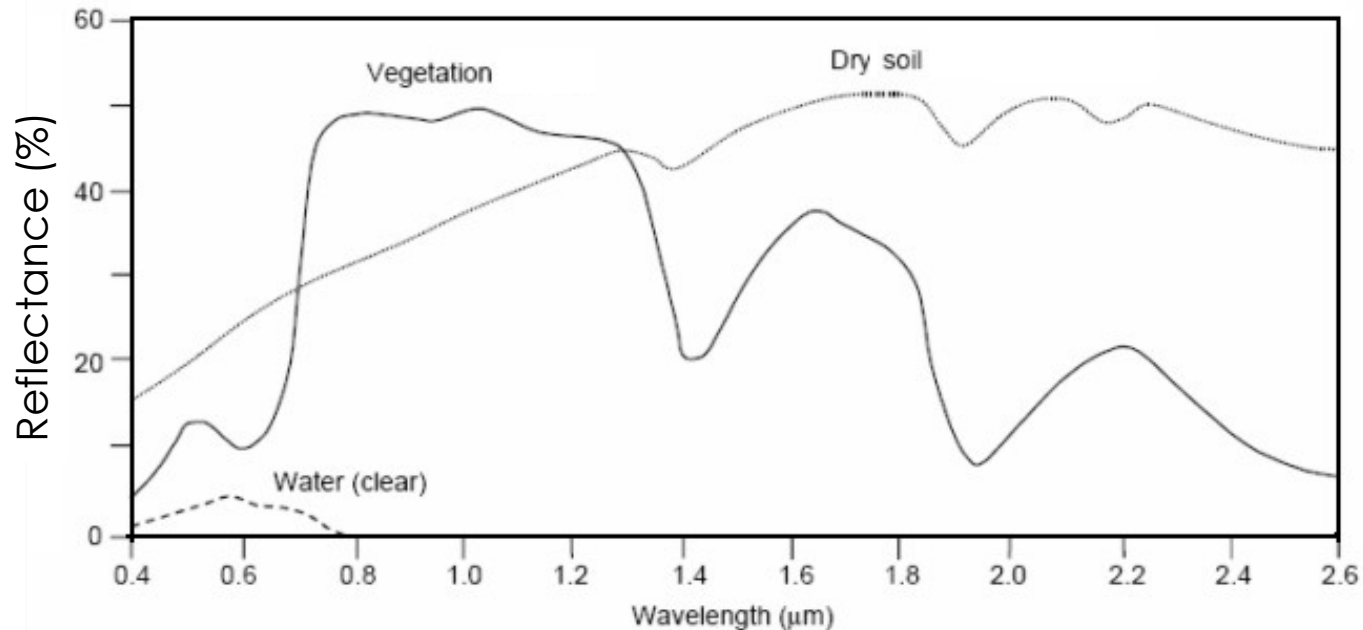
دانشگاه تهران

Outline

- Introduction to Remote Sensing
- Earth Observation Technology
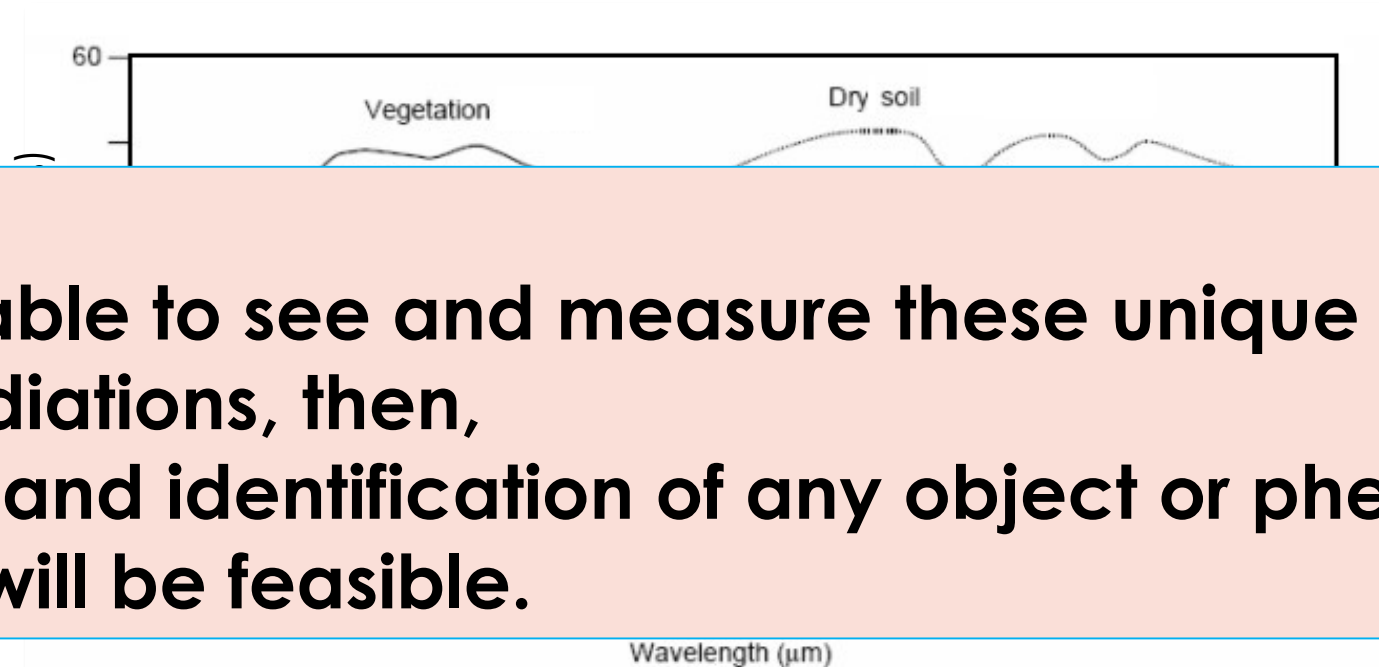- Big EO Analytics
- Google Earth Engine

Introduction

What is the main idea of Remote Sensing?

Each object based on its properties has a very specific reaction to the energy.

Introduction

Spectral Signature

60 —

Vegetation   Dry soil

Wavelength (μm)

So,
   If we are able to see and measure these unique reflections and/or radiations, then, detection and identification of any object or phenomenon remotely will be feasible.

Introduction

A general definition…

System for collecting the information about the objects without any contact
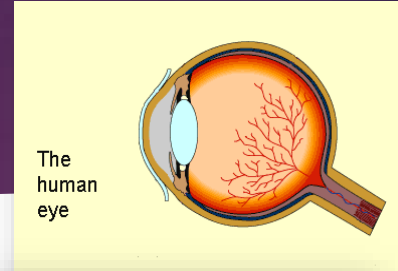
Introduction

Some Examples:

A)Alive creatures:
- Human vision sense
- Bat's and birds' path finding
- Bees, dolphins' communication

B) Man-made systems:
- Photographic camera
- Telescopes/Microscopes
- Surveying Instruments
- Military/Civil Radars
- Medical imagery systems
- Satellite/airborne imaging systems

Introduction

Definition for Geosciences:

Remote Sensing is the science and technology which uses the sensors on board of satellites or airplanes to collect the image and data from Earth's surface and atmosphere, to observe and identify different phenomena.
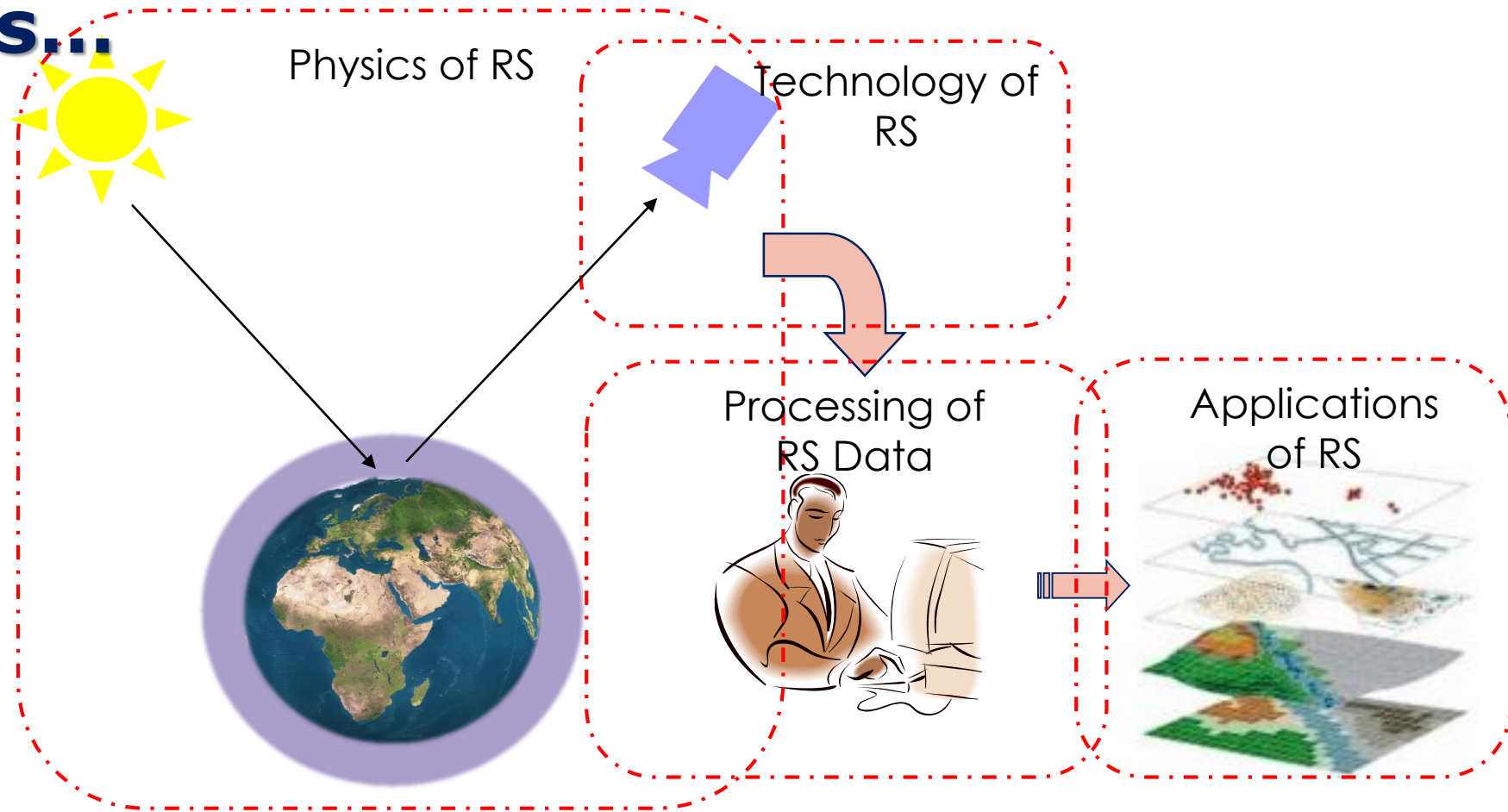
Earth Observation System

Mapping from Space

Nearly 80% of our modern knowledge of the earth system is thanks to remote sensing technology.
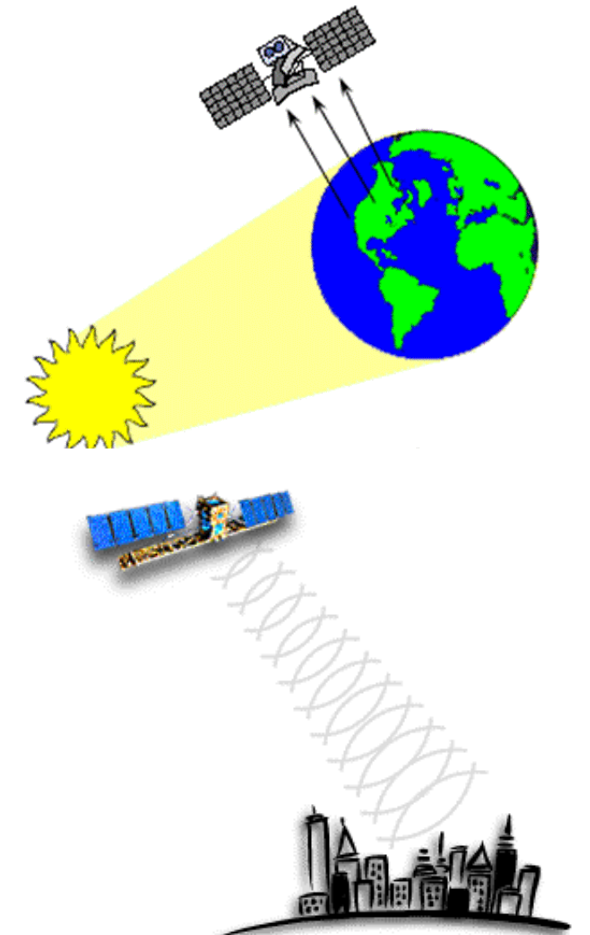
Introduction

Principles...

Physics of RS

Technology of RS

Processing of RS Data

Applications of RS

Introduction

Earth Remote Sensing Sys:

- <u>Passive:</u> Source of energy: Natural (Sunlight)

    - Optical Sys. (multi & hyper spectral)

    - Thermal or Microwave

- <u>Active:</u> Source of energy: Artificial (Antenna)

    - RADAR/SAR Sys.

    - Lidar

Introduction

Main fields of Earth Remote Sensing

- **Atmosphere**
(Troposphere, Stratosphere, …)

- **Hydrosphere**
(Oceans, Seas, Ice,…)

- **Lithosphere**
(Solid surface: Rocks, Soil, Geology..)

- **Biosphere**
(Vegetation: Crops, Forests, Grasslands, Wetlands, …)

Introduction

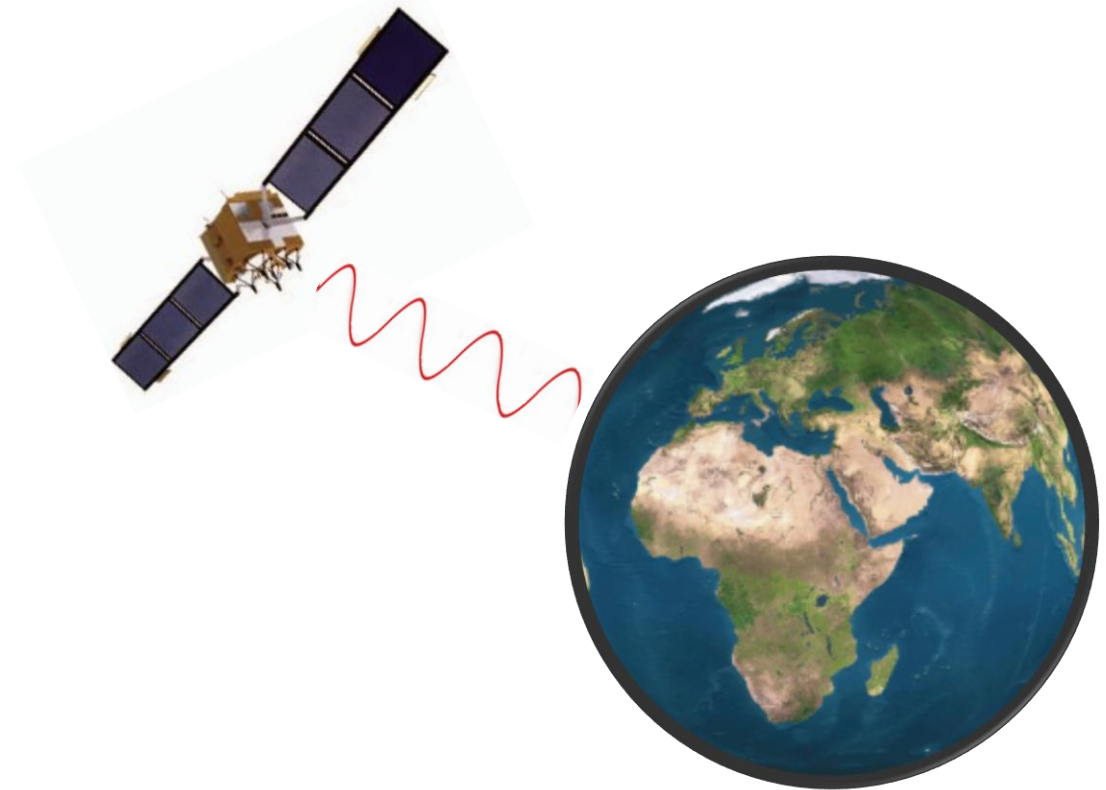**Thematic Applications**

Introduction

A very good documentary:

Big Earth Observation Data

Sensors record the received energy from earth surface.

- **Spatial Sampling**

- **Spectral Sampling**
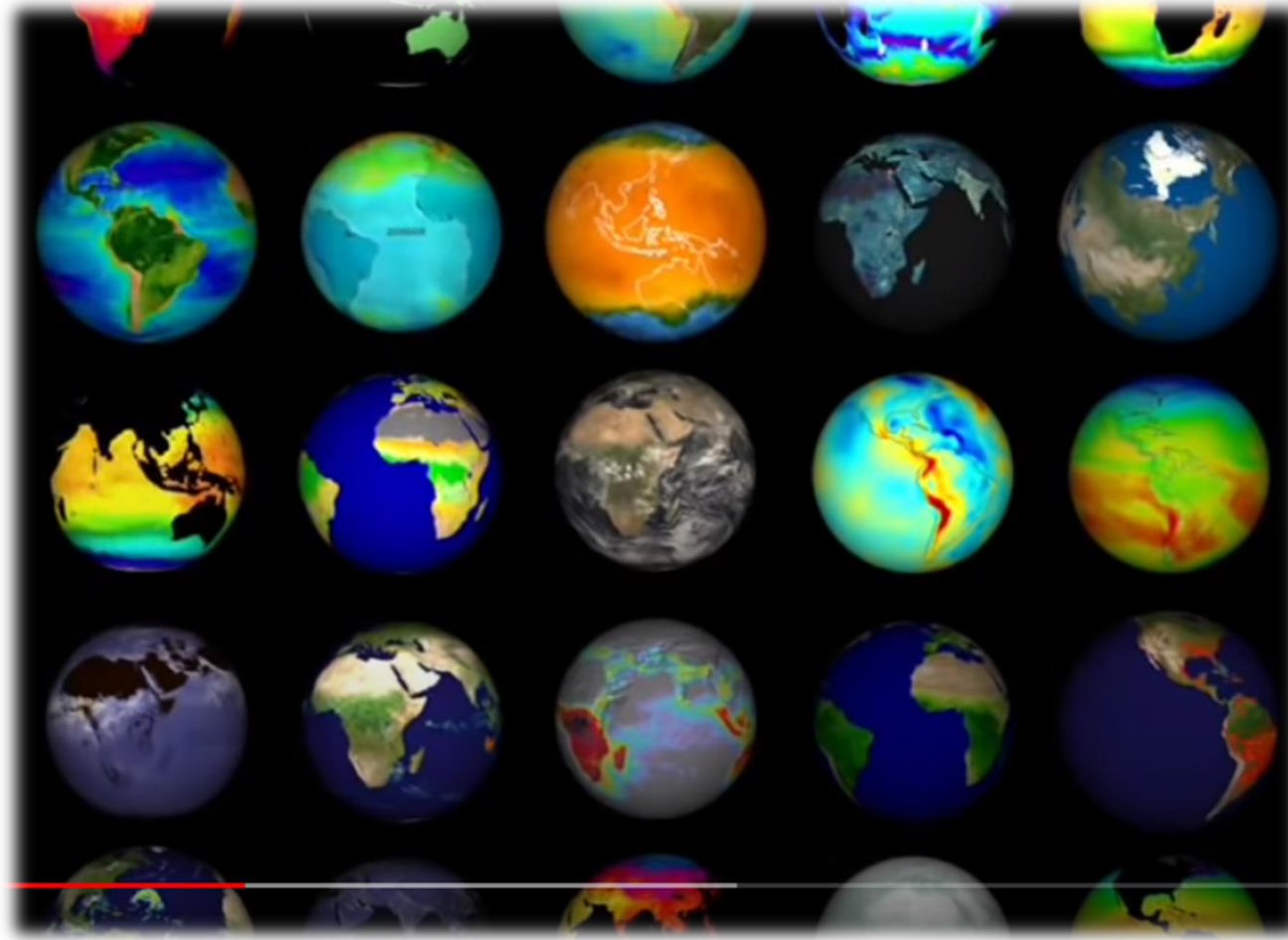
- **Radiometric Sampling**
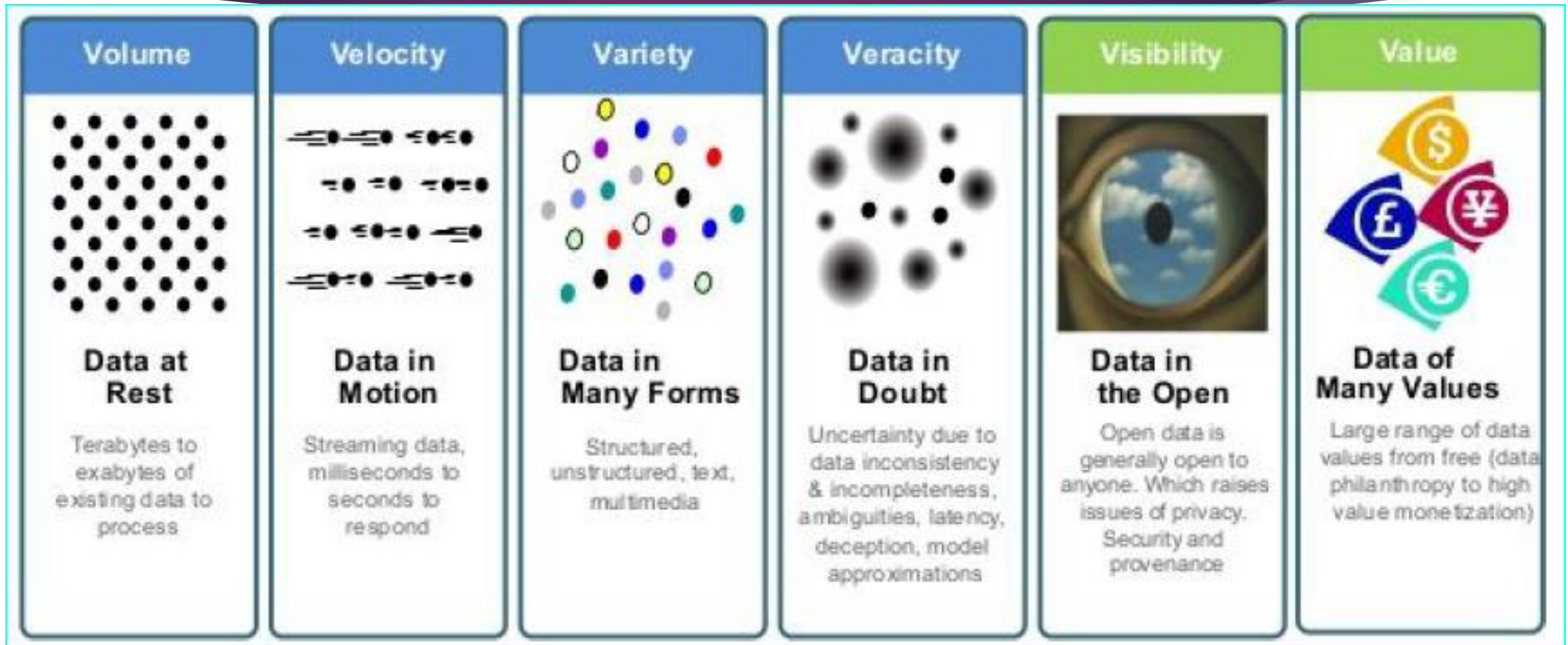
- **Temporal Sampling**

Big Earth Observation Data

- **Spatial Sampling**

- **Spectral Sampling**

- **Radiometric Sampling**

- **Temporal Sampling**

- **Spatial Resolution**

- **Spectral Resolution**

- **Radiometric Resolution**

- **Temporal Resolution**

They are very important for all geosciences applications.
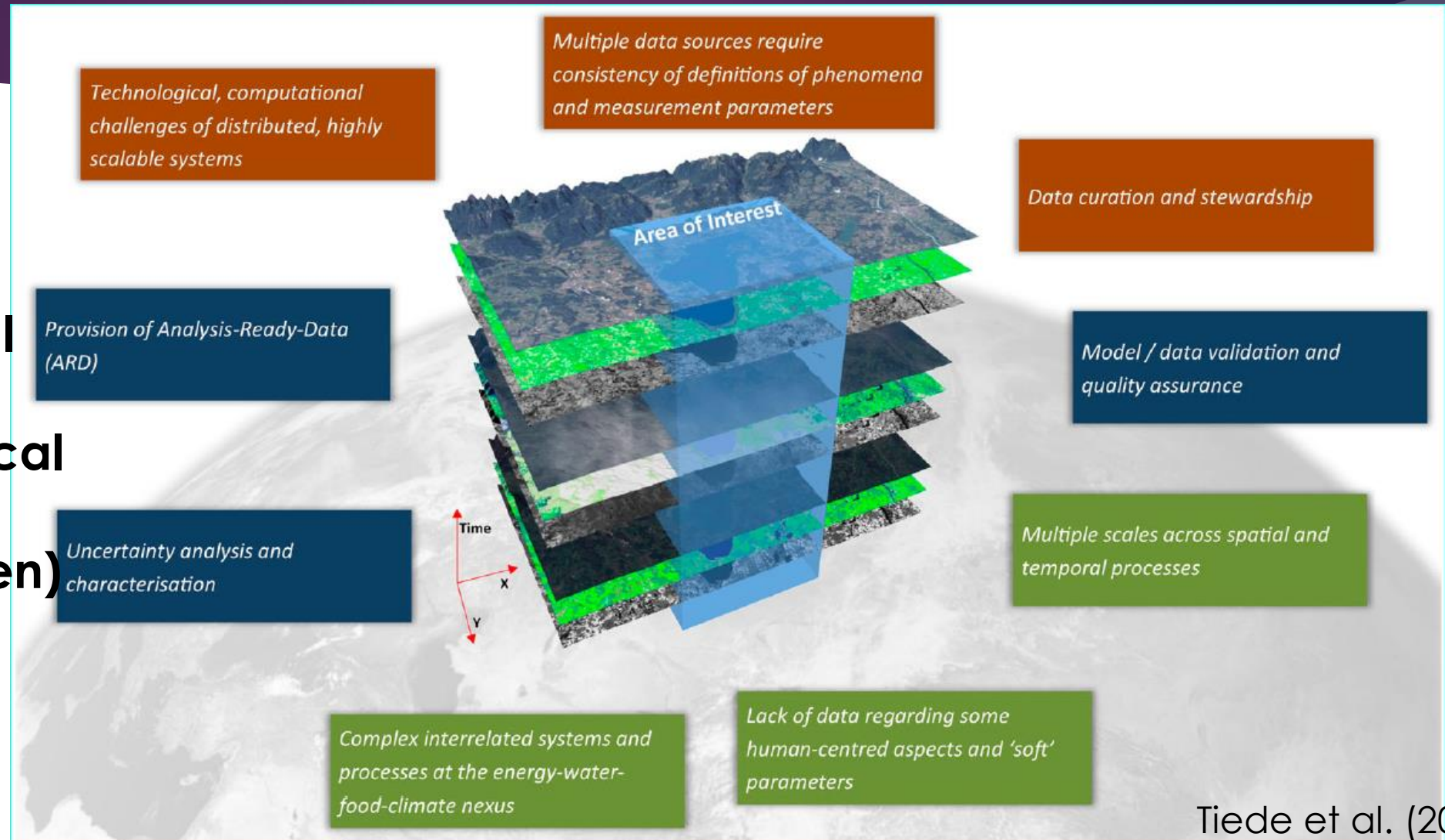
Big Earth Observation Data

Big Earth Observation Data

| Volume	Velocity	Variety	Veracity	Visibility	Value
Data at Rest	**Data in Motion**	**Data in Many Forms**	**Data in Doubt**	**Data in the Open**	**Data of Many Values**
Terabytes to exabytes of existing data to process	Streaming data, milliseconds to seconds to respond	Structured, unstructured, text, multimedia	Uncertainty due to data inconsistency & incompleteness, ambiguities, latency, deception, model approximations	Open data is generally open to anyone. Which raises issues of privacy. Security and provenance	Large range of data values from free (data philanthropy to high value monetization)

Big Earth Observation Data

Some key challenges attached to
1) **technological (orange),**
2) **methodological (blue), and**
3) **societal (green) aspects.**

Multiple data sources require consistency of definitions of phenomena and measurement parameters

Technological, computational challenges of distributed, highly scalable systems

Data curation and stewardship

Area of Interest

Provision of Analysis-Ready-Data (ARD)

Model / data validation and quality assurance

Uncertainty analysis and characterisation

Time

X

Y

Multiple scales across spatial and temporal processes

Complex interrelated systems and processes at the energy-water-food-climate nexus

Lack of data regarding some human-centred aspects and 'soft' parameters

Tiede et al. (2017)

Big EO Analytics

Data Cube Processing & Analysis

Big Earth Observation Analytics are those forms of geospatial analytics that cannot be efficiently or realistically conducted on a high performance workstation.
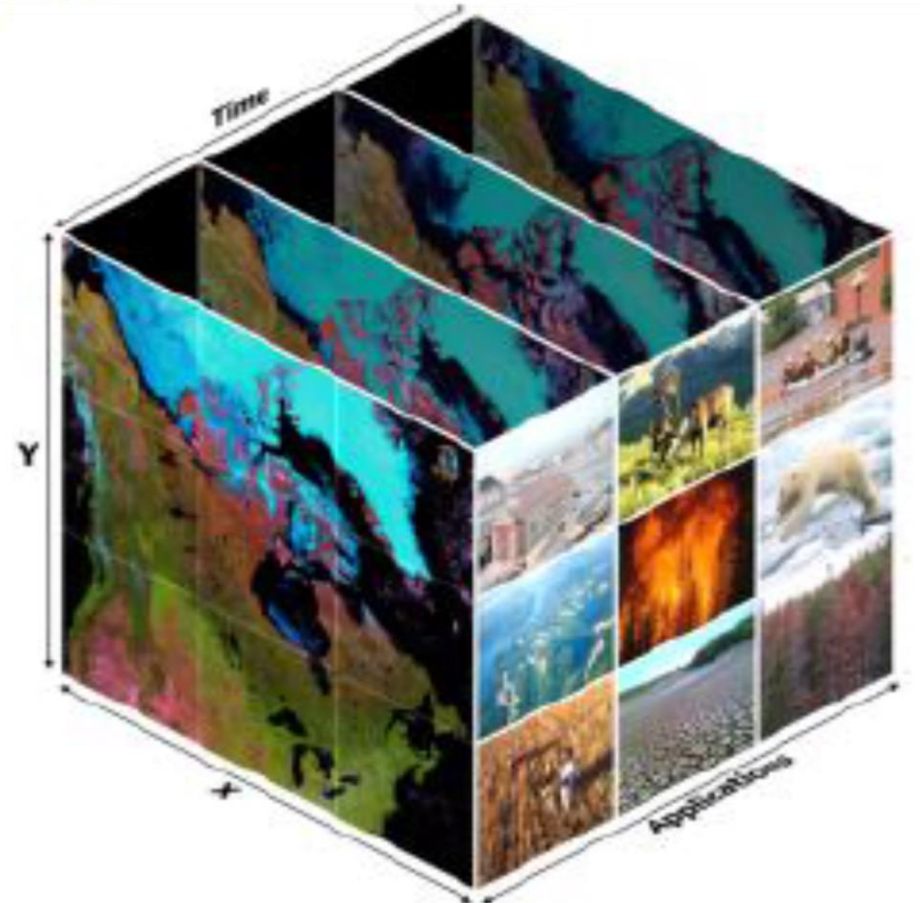
Big EO Analytics

Real World Analytical Modeling

Geometric Information   Non-Geometric Information

X,Y,Z_1 $Z_2,Z_3,...$

A GIS Concept
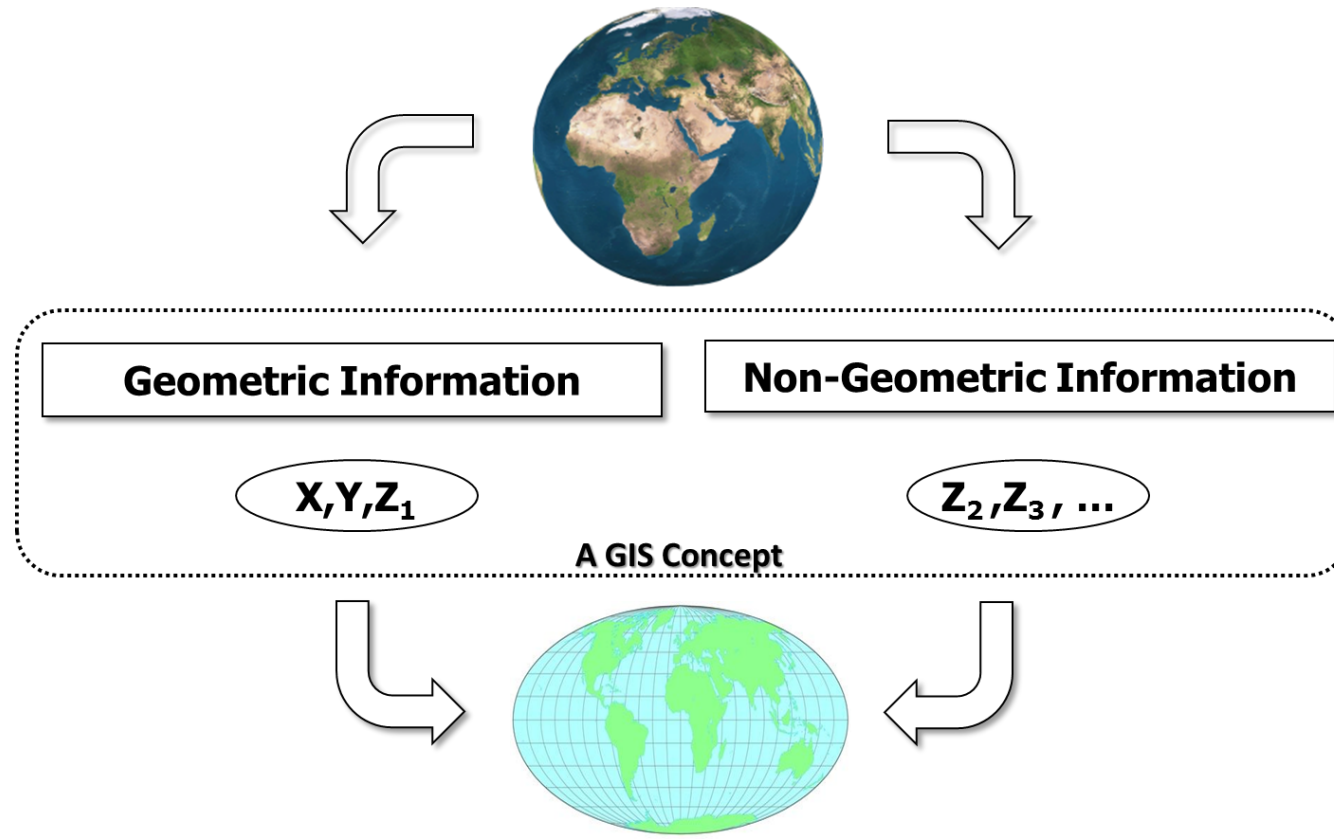
Big EO Analytics

Chain Approach Data Processing:
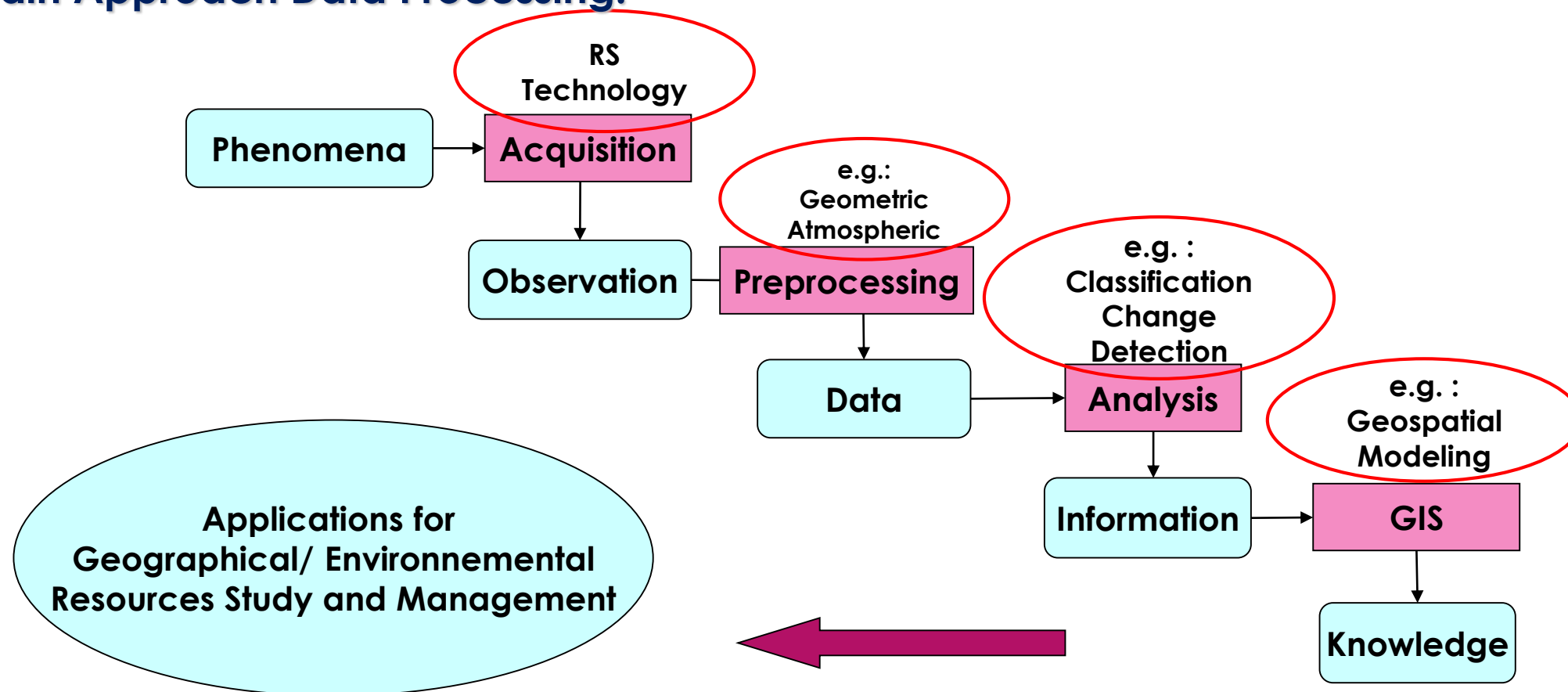
Big EO Analytics

Traditional Remote Sensing Approach

Courtesy of CSIRO & Geoscience Australia

- 80% or more of scientists/analysts time is in data preparation
- Challenges of data preparation, and available data storage and computing power lead users to typically use less than 1% of available satellite imagery

Orthorectification

Calibration

Time series

Canberra
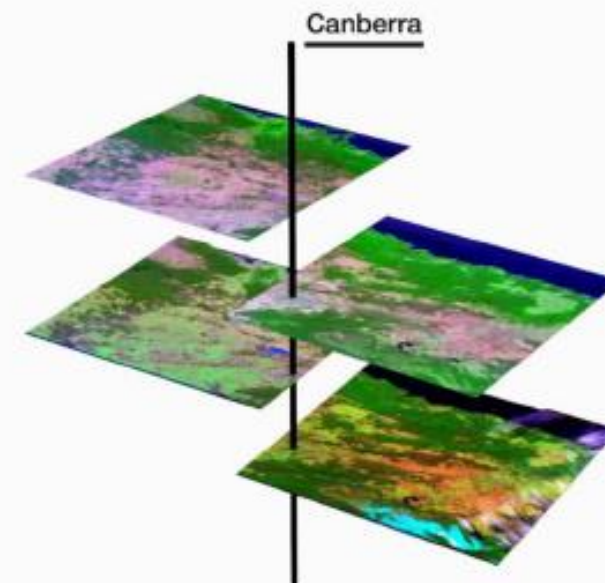
Paradigm Shift in Big EO Analytics

**State-of-the-art
or
Four revolutions in Remote Sensing**

Paradigm Shift in Big EO Analytics

Sudmanns et al. 2019
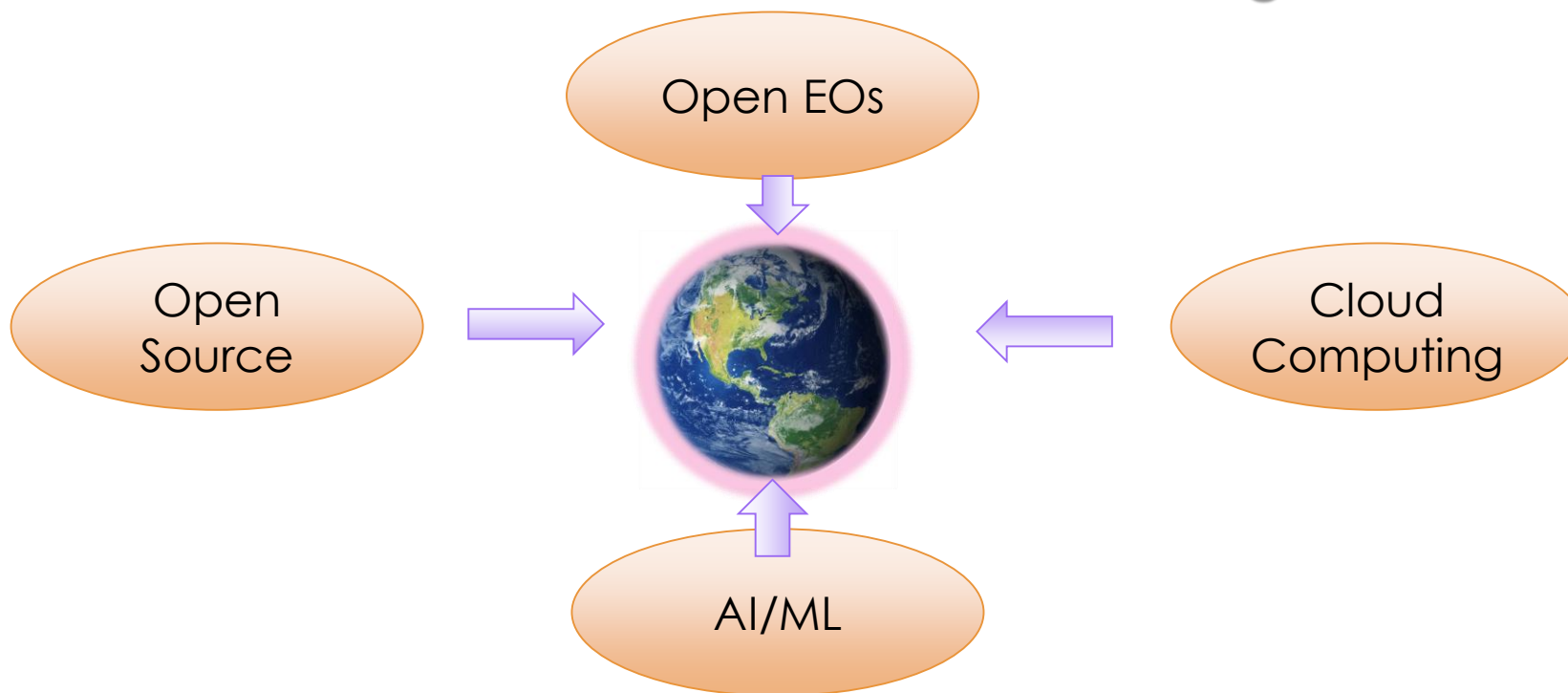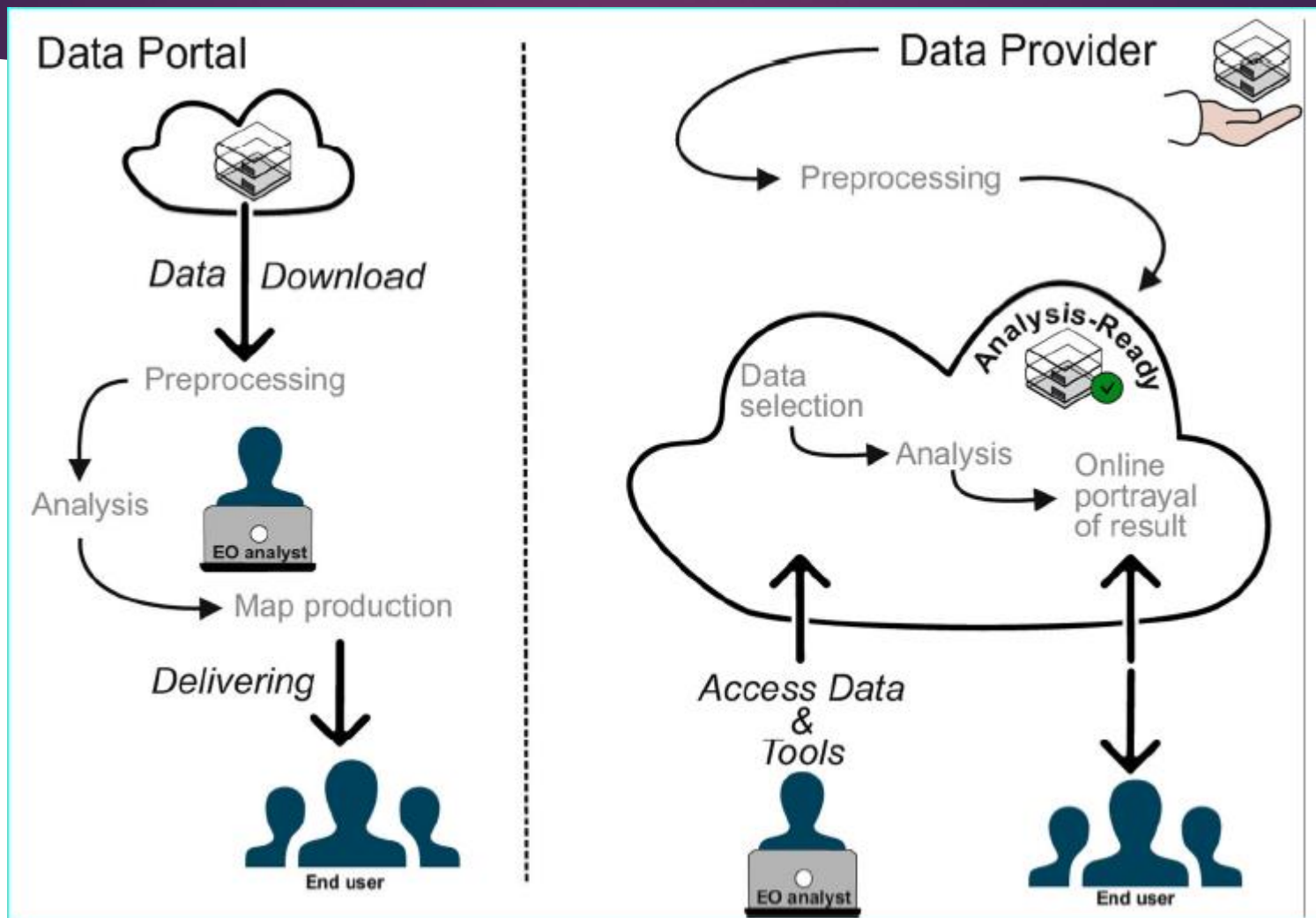
Paradigm Shift in Big EO Analytics

Analysis Ready Data

- Radiometric Calibration
- Atmospheric Correction
- Ortho-rectification
- Mosaicking
- Value-Added Products (VIs, etc.)
- Time Series
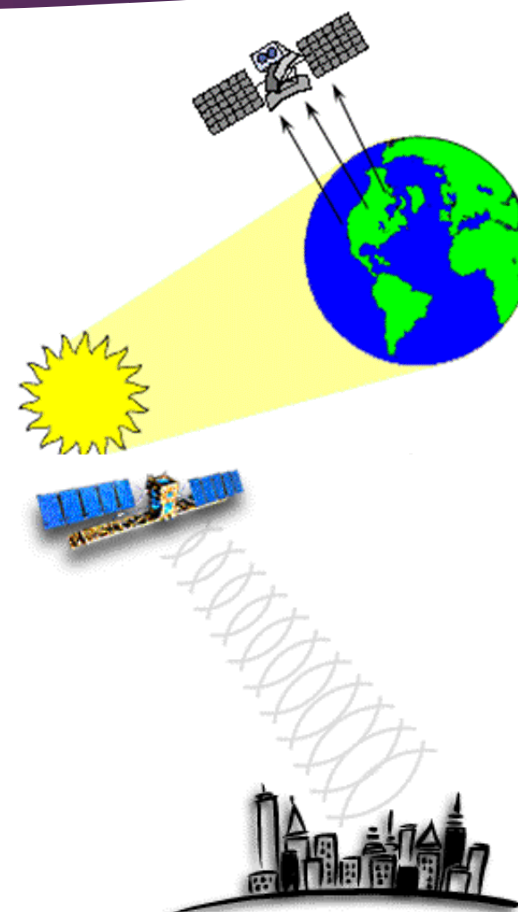
Technology Solutions

Cloud-Based EO Analytics platforms

▶ Google Earth Engine

▶ Amazon Web Service

▶ Microsoft Azure

▶ Copernicus's Sentinel Hub

▶ Digital Globe's Earth Watch

▶ PlantLab's Cloud Platform

▶ …

Google Earth Engine

Google Earth Engine

- Cloud Computing platform

- Data stored and process on Google servers

- Petabytes of data

- All Landsat (back to 1990) constellations and Sentinel 1, 2, 3 & 5, MODIS, ALOS PalSAR, etc, DEMS (ASTER/SRTM)) available.

- Continuously updated

- Other datasets

  - Global Surface Water Dataset …

Google Earth Engine

Google Earth Engine
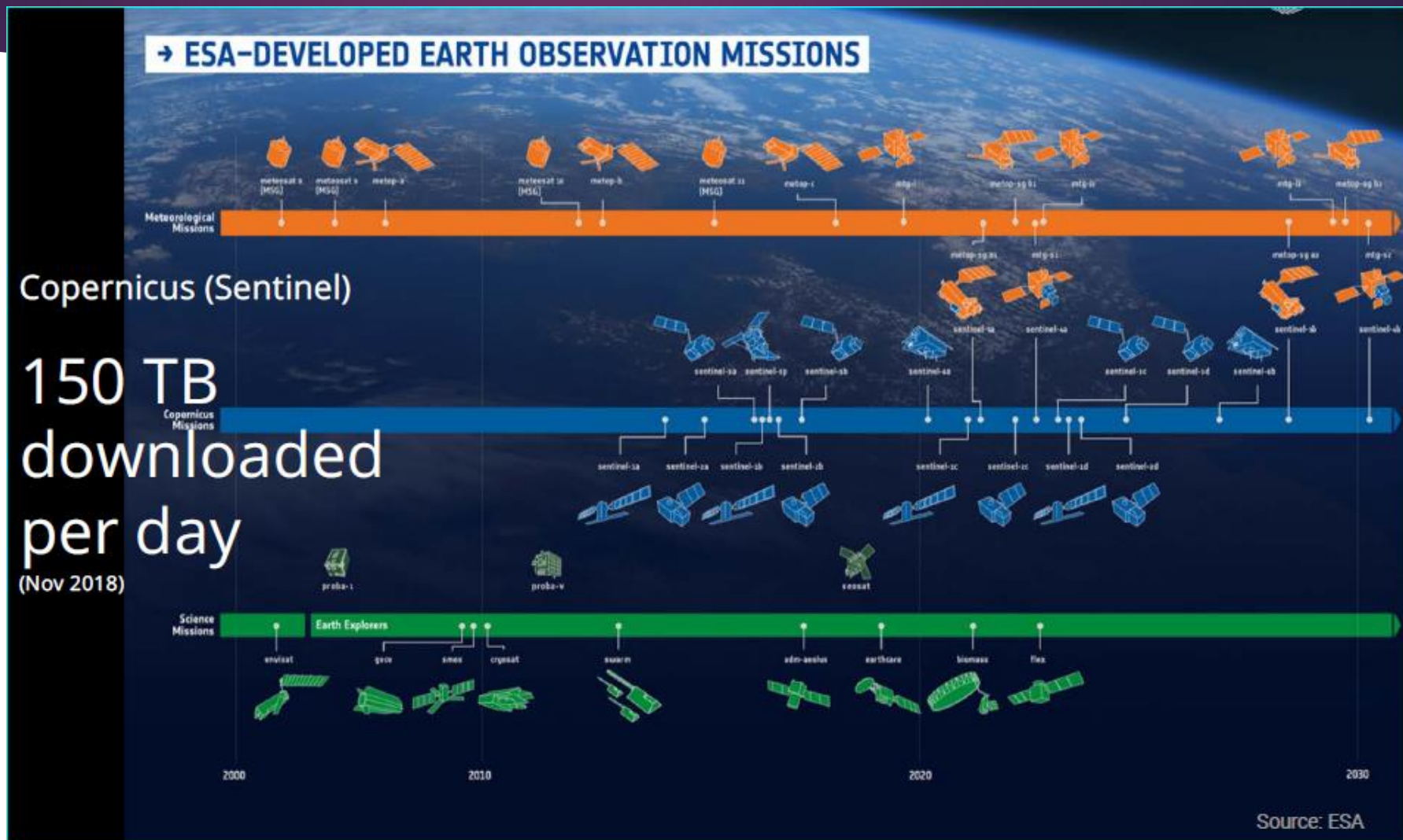
Google Earth Engine

The Earth Engine Public Data Catalog
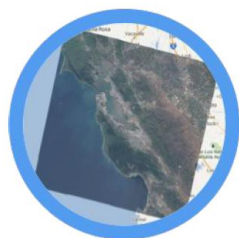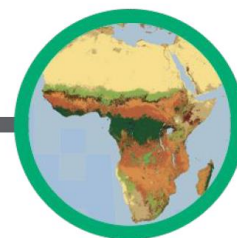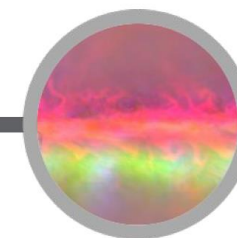
| **Landsat 4, 5, 7, 8** | **MODIS** | **Terrain** | **Land Cover** | **Atmospheric** |
| Raw, TOA, SR, ... | Daily, NBAR, LST, ... | SRTM, GTOPO, NED, ... | GlobCover, NLCD, ... | NOAA NCEP, OMI, ... |

... and many more, updating daily!

> 200 public datasets   **> 4000 new images every day**

> 5 million images   **> 5 petabytes of data**

Google Earth Engine

Google Earth Engine

Google computational infrastructure

Google mission is to organize the world's information and make it universally accessible and useful. That's why Search makes it easy to discover a broad range of information from a wide variety of sources.

Source: Google Earth Engine
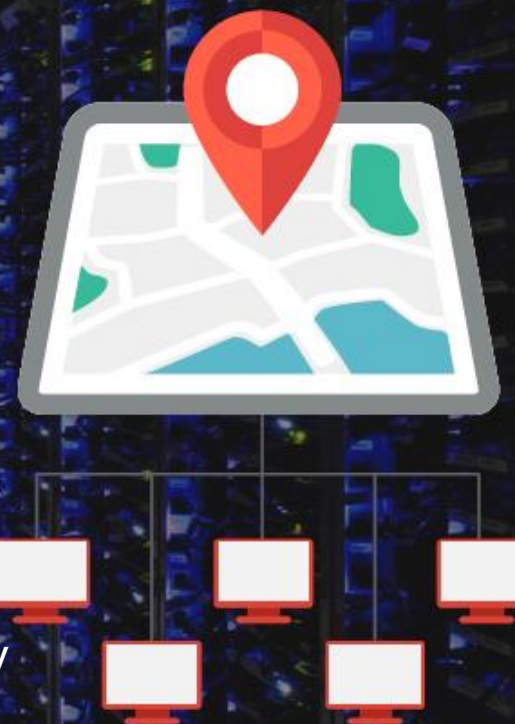
Google Earth Engine

The Earth Engine Service Architecture

Google Web Apps
(EE website and "Playground")

Specialized Web Apps
(Typically third-party sites)

Scripting Libraries
(JavaScript / Python)

Web APIs
(REST-ish)

On-the-Fly Computation

Batch Computation

Data Storage
(Raster & Vector)
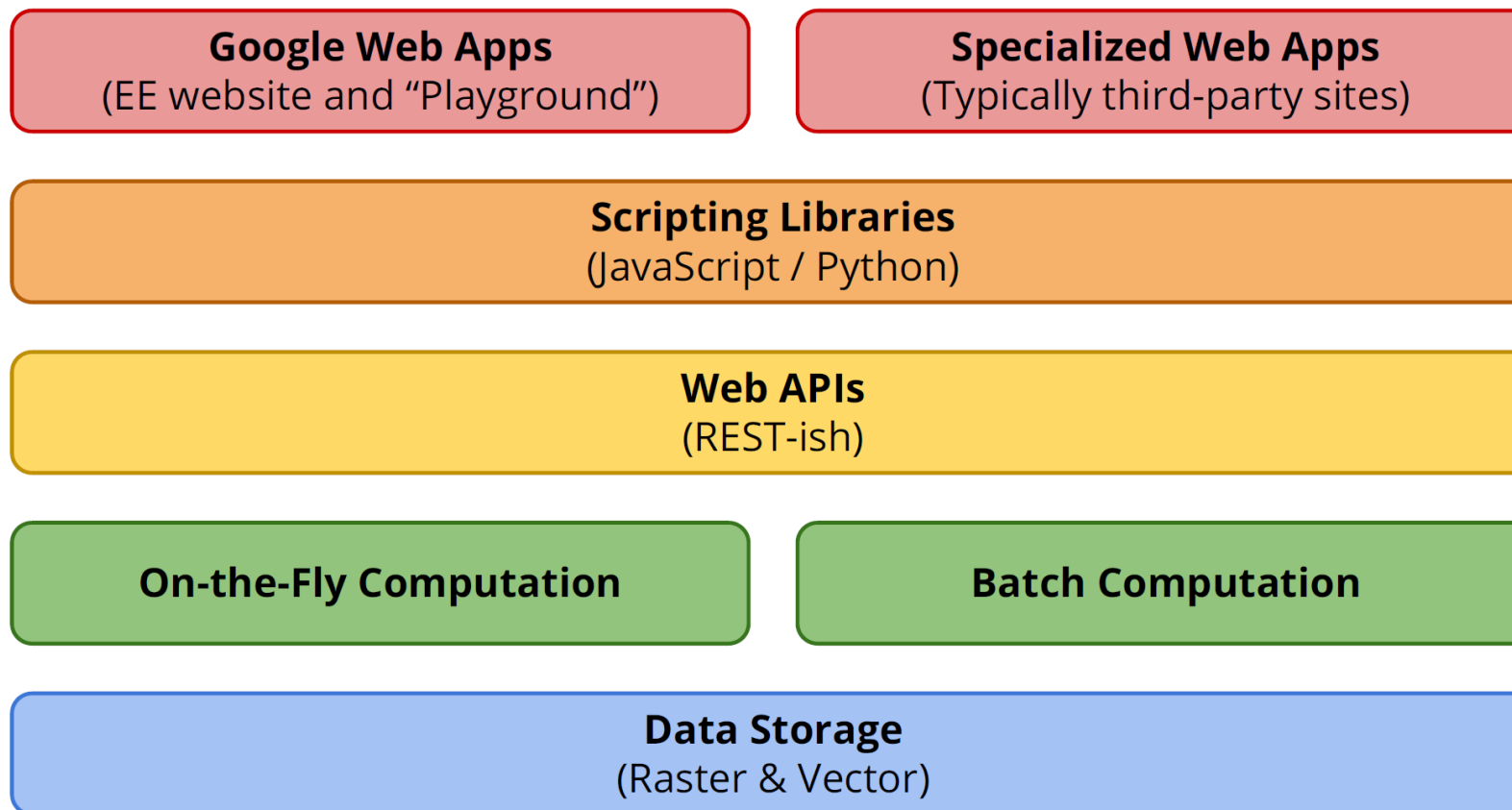
Google Earth Engine

What can you do?

1 Pre-processing
- Filtering
- Masking (clouds, water etc.)
- Mosaic creation

2 Analysis
- Raster operations
- Vector operations
- Time-series analysis
- Image classification
- Object-based segmentation
- Machine-learning (e.g. Tensorflow)
- ...

3 Visualization
- Data visualization
- Maps
- Charts
- Web apps
- Integration with Google Cloud Platform

Google Earth Engine

Data Models

Geometry

Feature

Image

Stack of Georeferenced bands

Each band has its own:

Mask, Projection, Resolution

A list of properties, including:

Date, Bounding-box
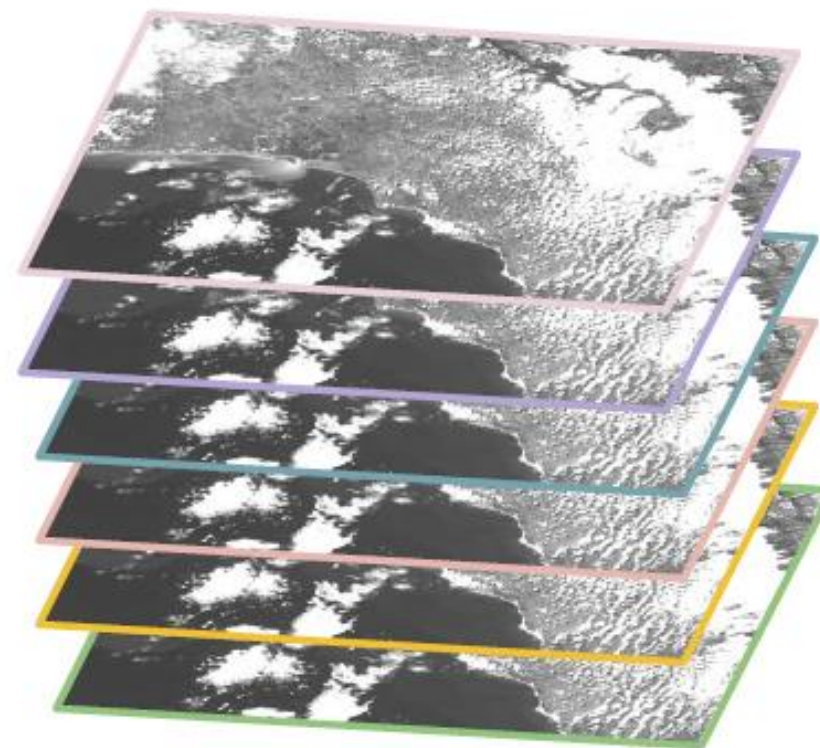
Google Earth Engine

Data Types and Geospatial Processing Functions

- **Image** - band math, clip, convolution, neighborhood, selection ...
- **Image Collection** - map, aggregate, filter, mosaic, sort ...
- **Feature** - buffer, centroid, intersection, union, transform ...
- **Feature Collection** - aggregate, filter, flatten, merge, sort ...
- **Filter** - by bounds, within distance, date, day-of-year, metadata ...
- **Reducer** - mean, linearRegression, percentile, histogram ....
- **Join** - simple, inner, outer, inverted ...
- **Kernel** - square, circle, gaussian, sobel, kirsch ...
- **Machine Learning** - CART, random forests, bayes, SVM, kmeans, cobweb ...
- **Projection** - transform, translate, scale ...

over 1000 data types and operators, and growing!

Google Earth Engine

Computation Platform

On-the-Fly Computation

Interactively visualize data, serve queries, and preview analysis results.

Batch Computation

Large-scale parallel computation at the click of a button.

Google Earth Engine

Google Resources:
- Google Cloud Storage – raster data storage
- Google Earth Engine – data processing
- Google Maps – base map, geocoding
- Google Fusion Tables– vector data storage
- Google App Engine - web hosting

Non-Google Resources:
- GitHub- code development
- Python
- Twitter Bootstrap - web framework
- Highcharts, d3- SVG

Google Earth Engine

Google Earth Engine

Google Earth Engine

Google Earth Engine

Google Earth Engine

نوشته شده توسط امیرحسین احراری

Google Earth Engine

Advantages

- **High speed**
- **Powerful/Scalable**
- **Free data coverage**
- **Format dependency**
- **Easy and convenient coding**
- **Time series processing**
- **Open source**
- **Reliable**
- **User support community**
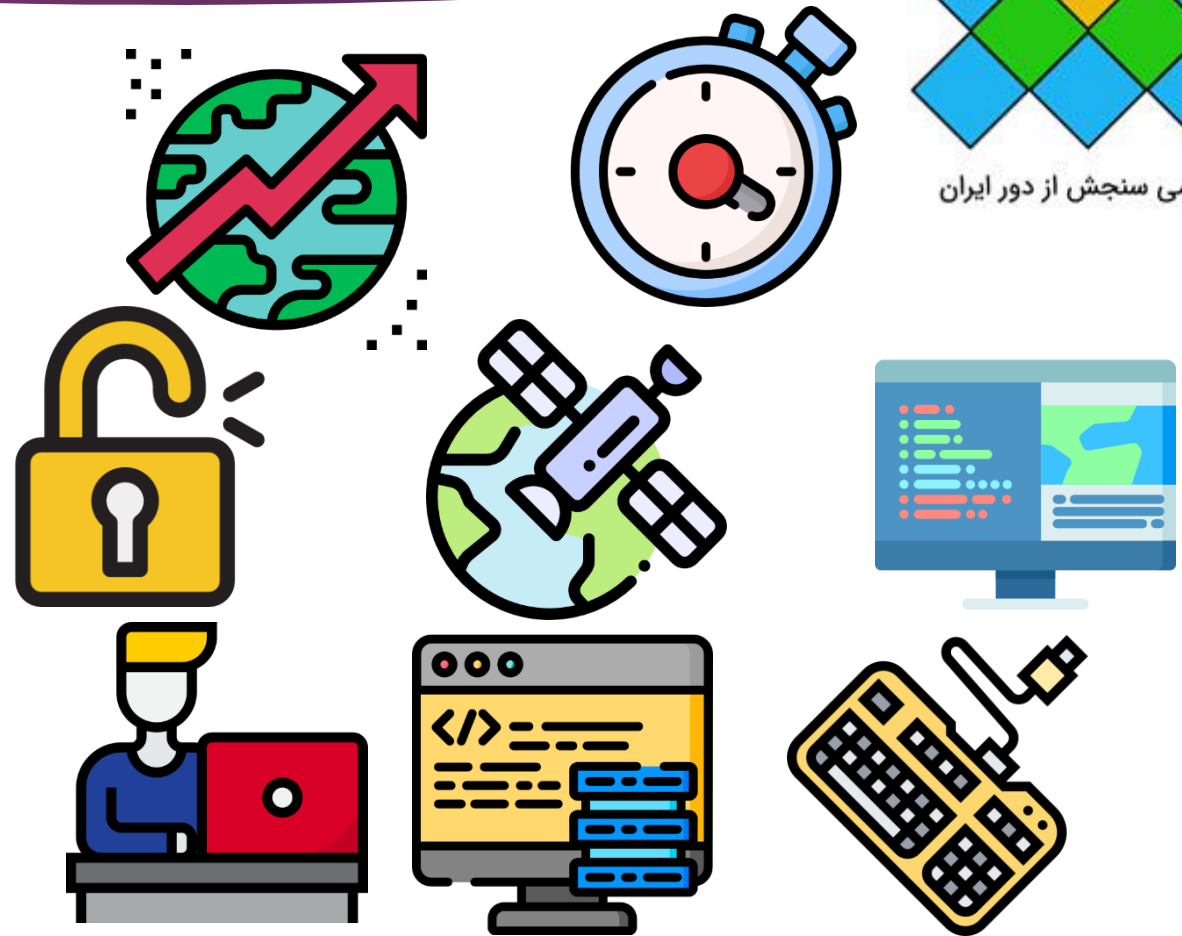
آکادمی سنجش از دور ایران

Google Earth Engine

Iran Land Cover Map v1 13-class (2017)
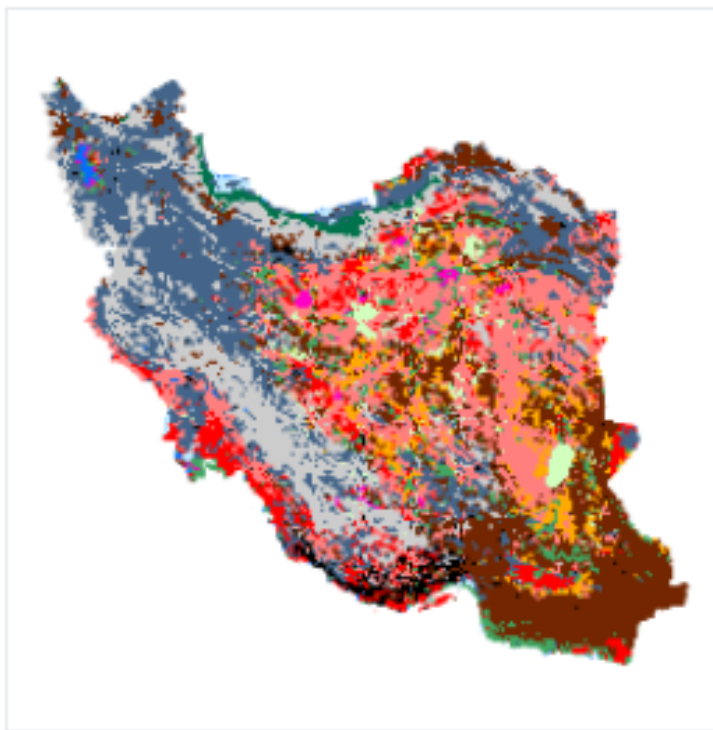
Dataset Availability

2017-01-01T00:00:00 - 2018-01-01T00:00:00

Dataset Provider

K. N. Toosi University of Technology LiDAR Lab

Earth Engine Snippet

```
ee.Image("KNTU/LiDARLab/IranLandCover/V1")
```

Google Earth Engine

Urban Heat Islands of Quebec City:
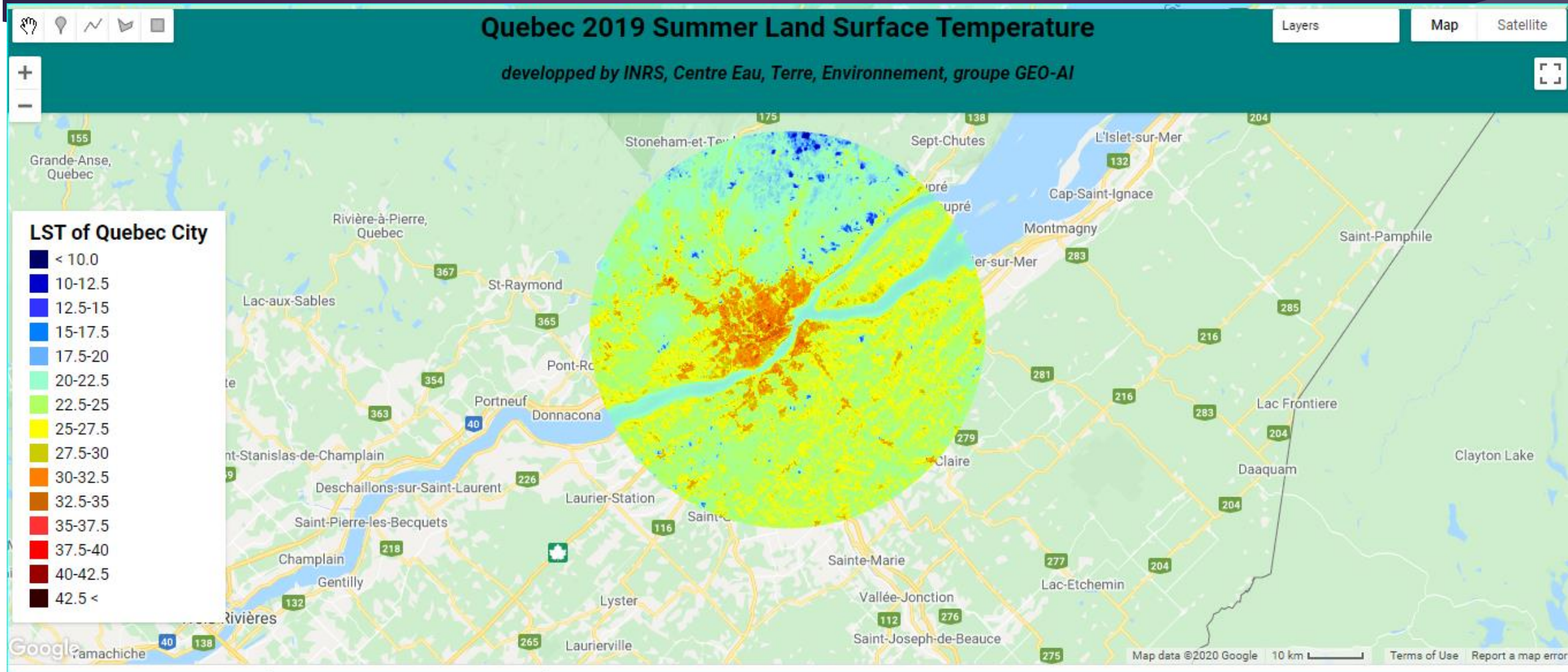
Google Earth Engine
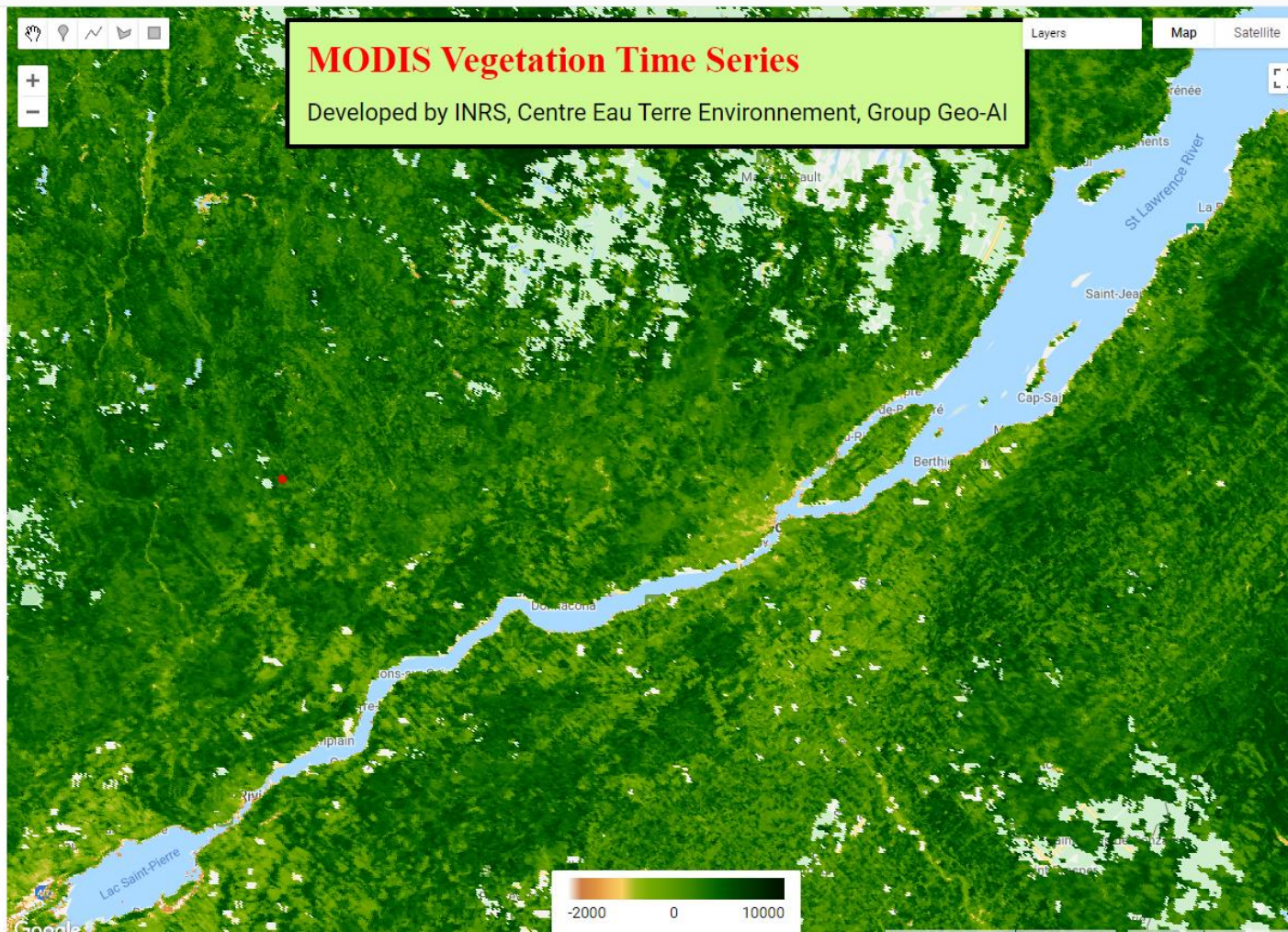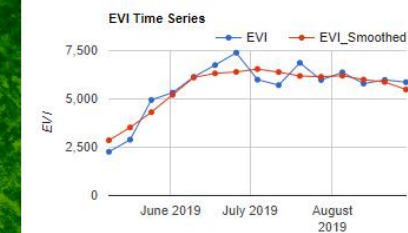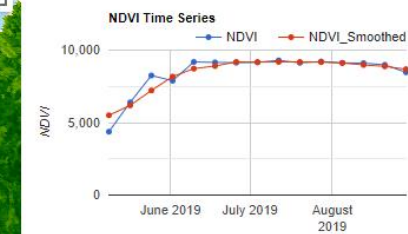
Questions…?

Some resources:

https://docs.google.com/presentation/d/1hT9q6kWigM1MM3p7IEcvNQlpPvkedW-IgCCrIqbNeis/edit