

Brazil Data Cube Project

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August 19, 2020



BRAZIL
DATA CUBE

FUNDO
AMAZONIA



 **FUNCATE**
Fundação de Ciência, Aplicações
e Tecnologia Espaciais

 **BNDES**

MINISTÉRIO DA
ECONOMIA

MINISTÉRIO DO
MEIO AMBIENTE

 **PÁTRIA AMADA
BRASIL**
GOVERNO FEDERAL

National Institute for Space Research (INPE), Brazil

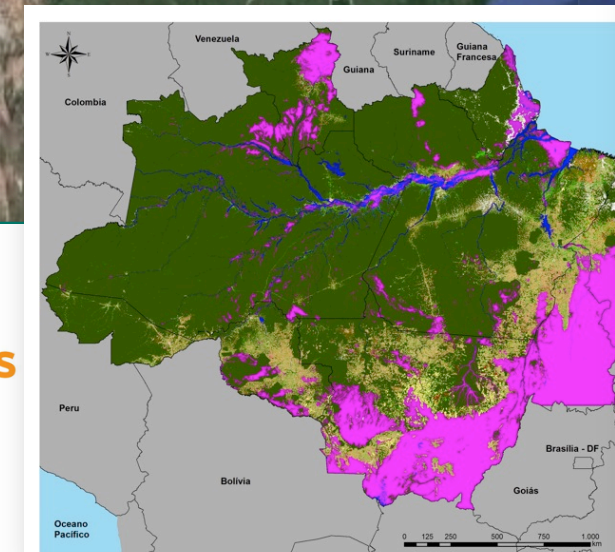
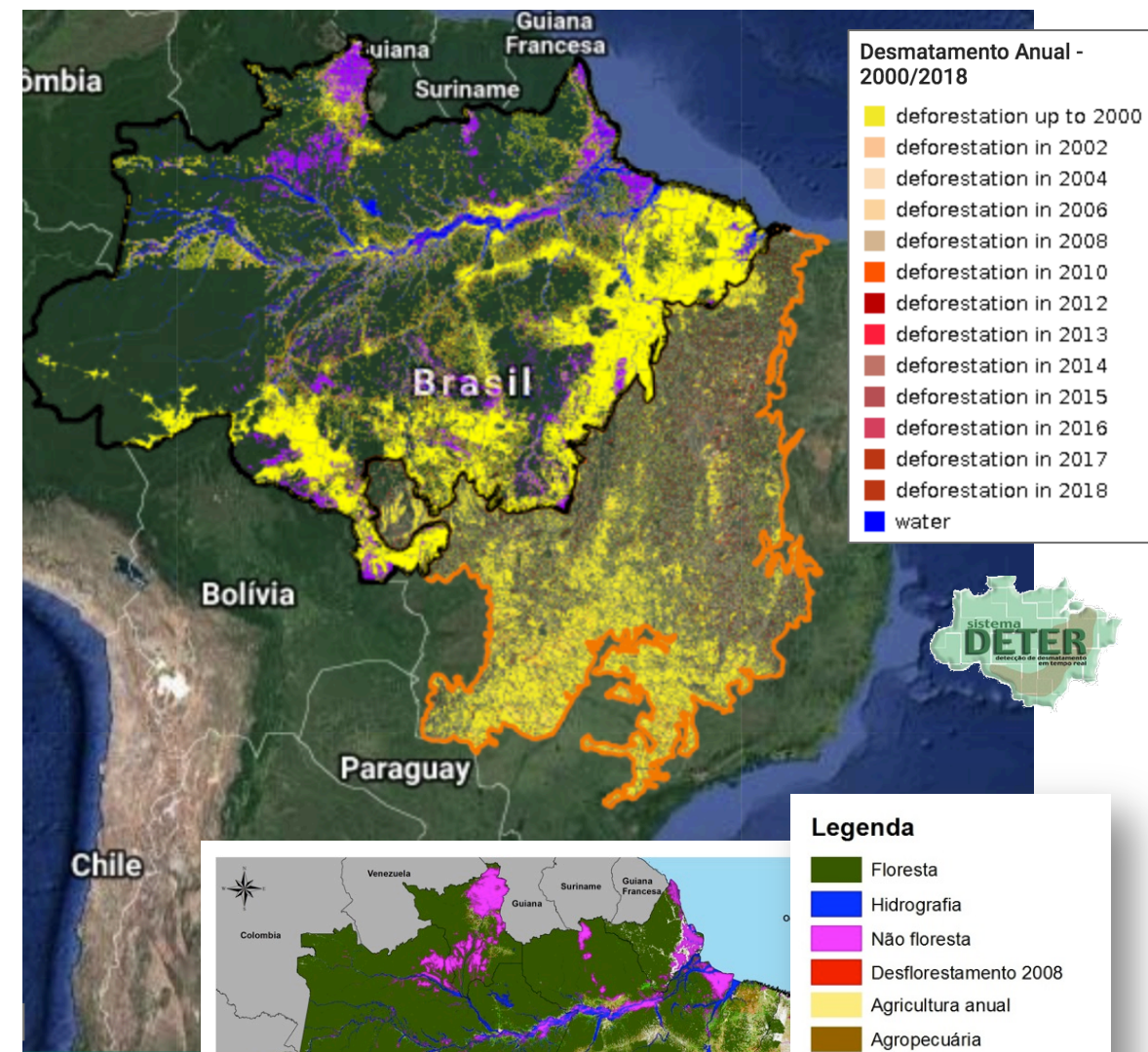
Responsible for producing official land use and cover information in Brazil

Projects:

- ✓ **PRODES**: clear cut deforestation
- ✓ **DETER**: alerts of deforestation
- ✓ **TerraClass**: identify what the deforested areas detected by PRODES have become.
- ✓ ...



MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

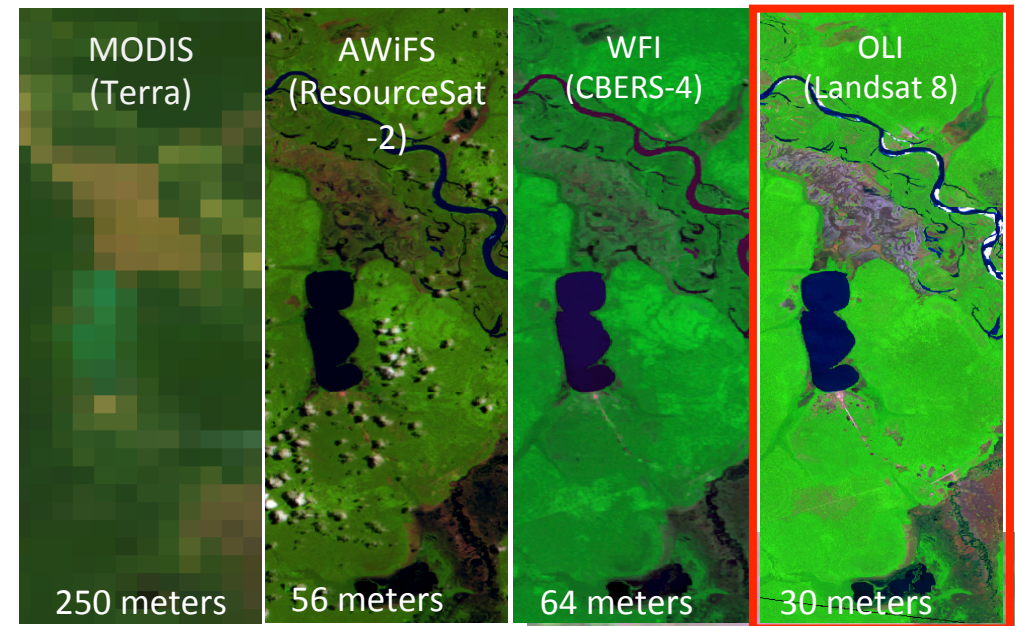


National Institute for Space Research (INPE), Brazil

Responsible for producing official land use and cover information in Brazil

Projects: **PRODES**, **DETER** and **TerraClass**

Use a methodology mainly based on visual interpretation of remote sensing images.



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Brazil Data Cube Project – Main Motivation

Responsible for producing official land use and cover information in Brazil

Projects: **PRODES**, **DETER** and **TerraClass**

Use a methodology mainly based on visual interpretation of remote sensing imagery.

Brazil Data Cube project

Produce technological innovation to **improve this methodology**.

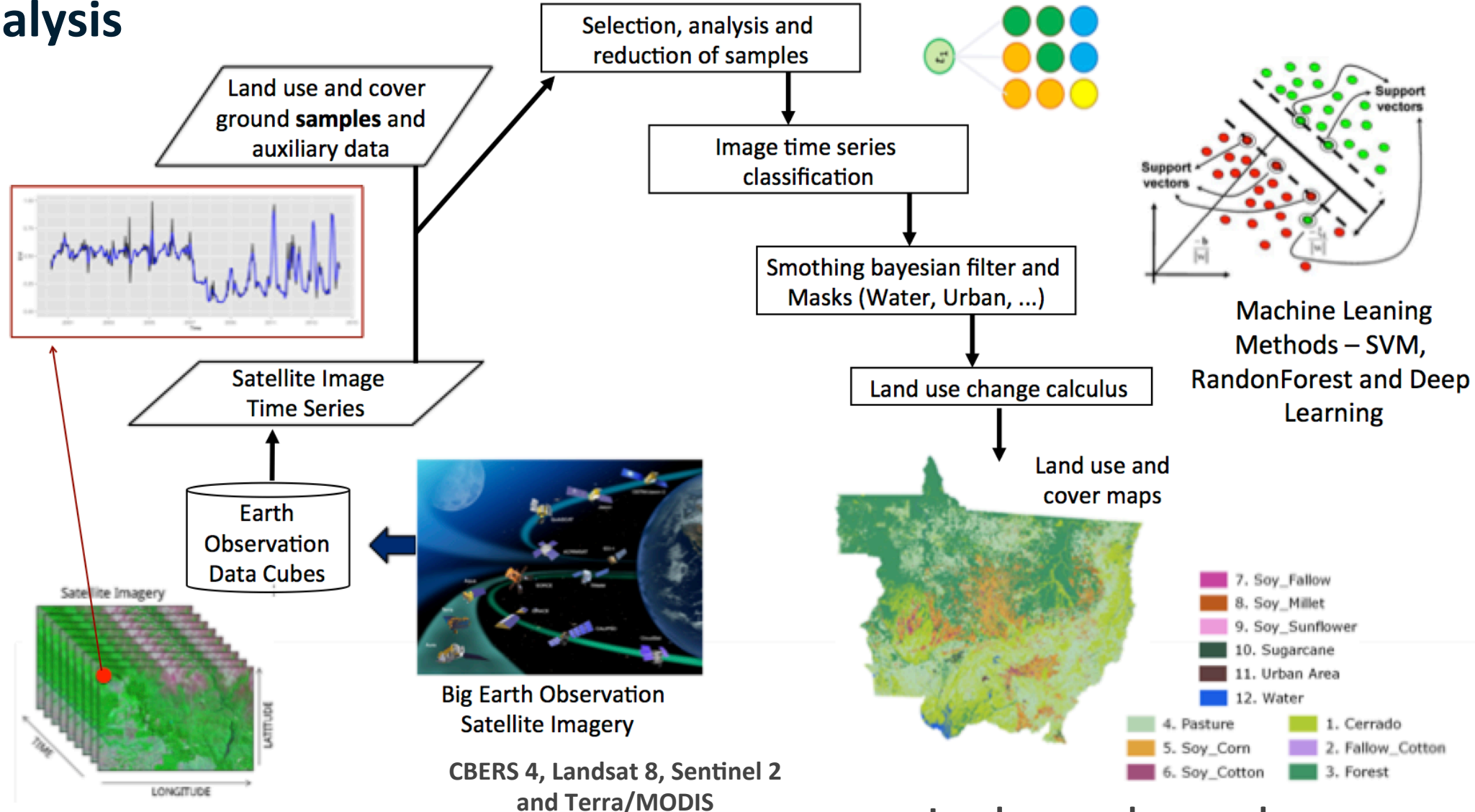
Big data technologies, **time series analysis** and machine learning methods to store, process and analyze big Earth observation data sets mainly for land use and cover change detection.



Methodology based on data cubes and satellite image time series analysis

SITS (Satellite Image Time Series) R package:

<https://github.com/e-sensing>



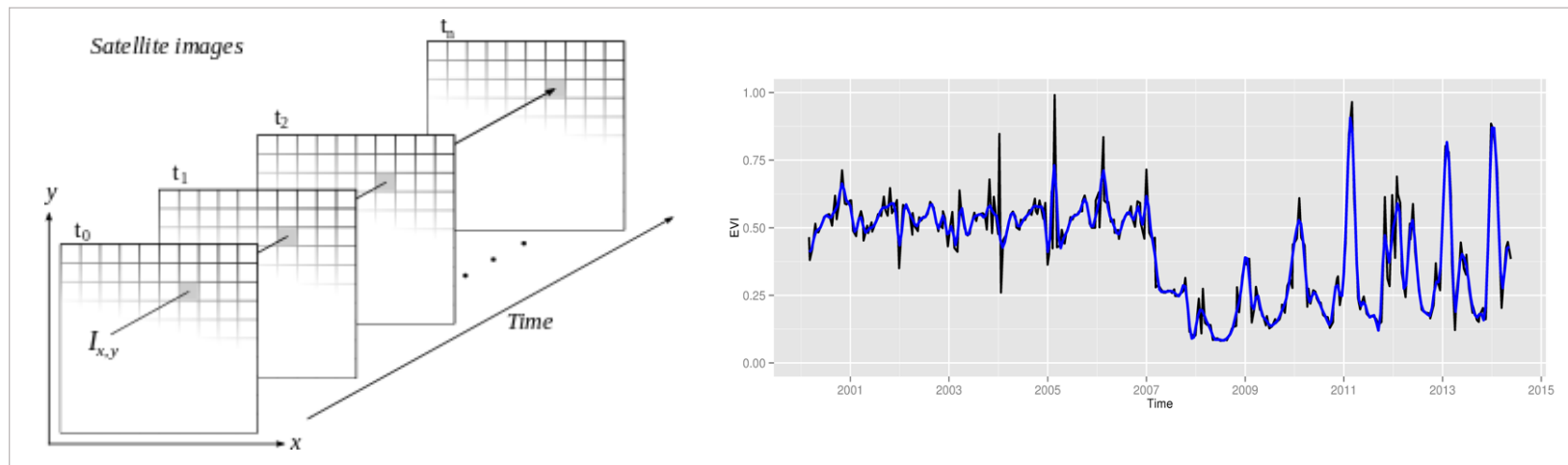
Data cubes available at:

<http://brazildatacube.dpi.inpe.br/portal/explore>

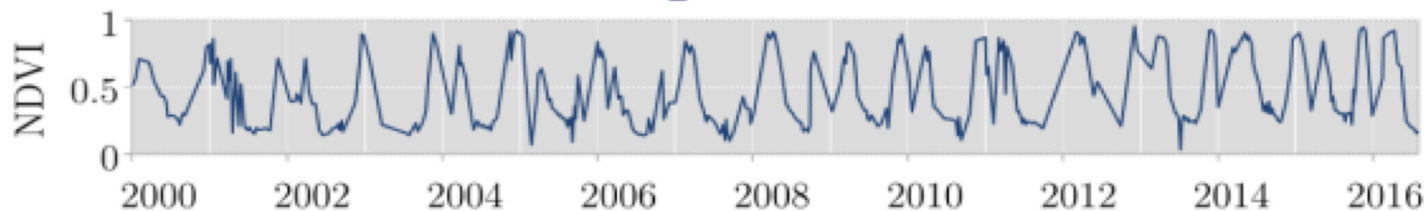
Land use and cover change maps:

<https://doi.pangaea.de/10.1594/PANGAEA.899706>

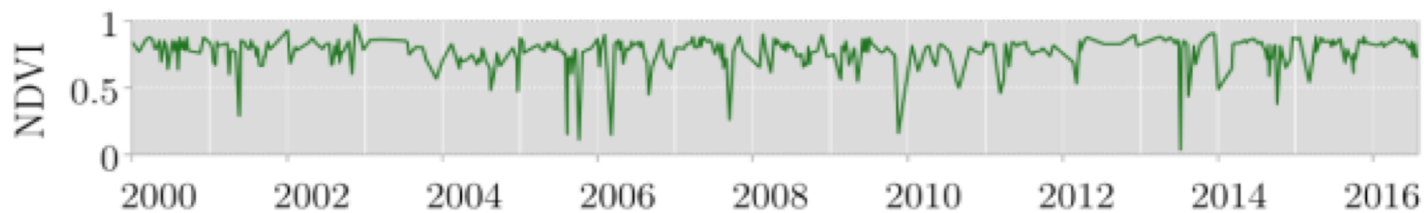
Satellite Image Time Series Analysis



Agriculture



Forest



Forest

Pasture

Agriculture



Brazil Data Cube Project

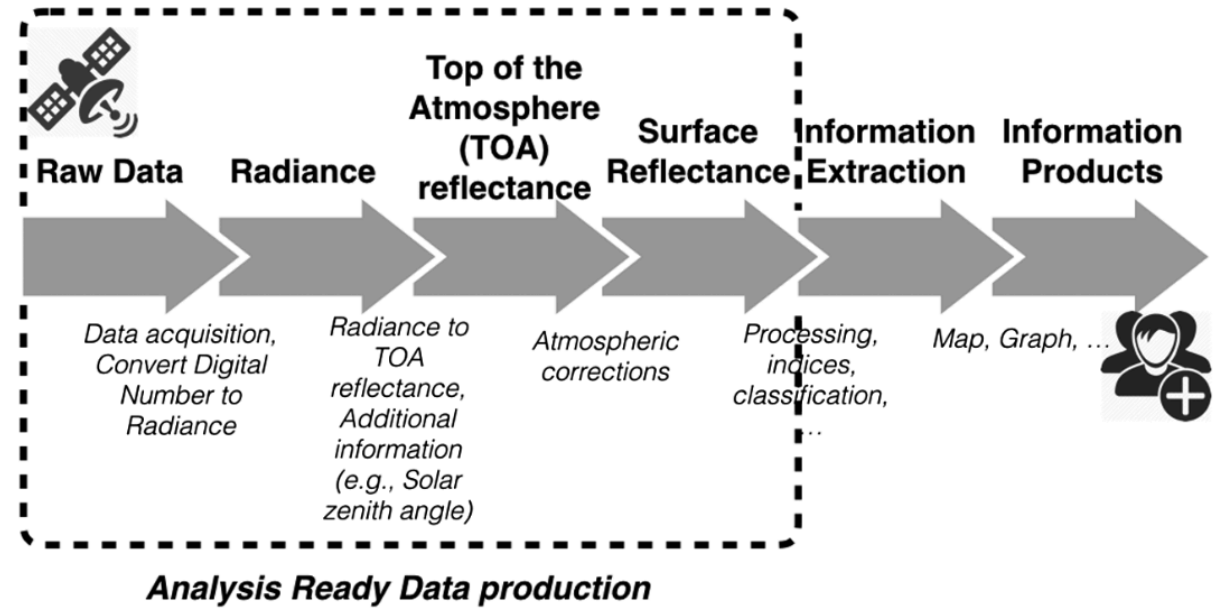
Started in 2019. Developed by INPE.

(Goal 1) *Analysis-Ready Data (ARD)* of medium-resolution satellite images (10 to 60 meters) for all Brazilian territory: CBERS-4, Landsat 8 and Sentinel 2

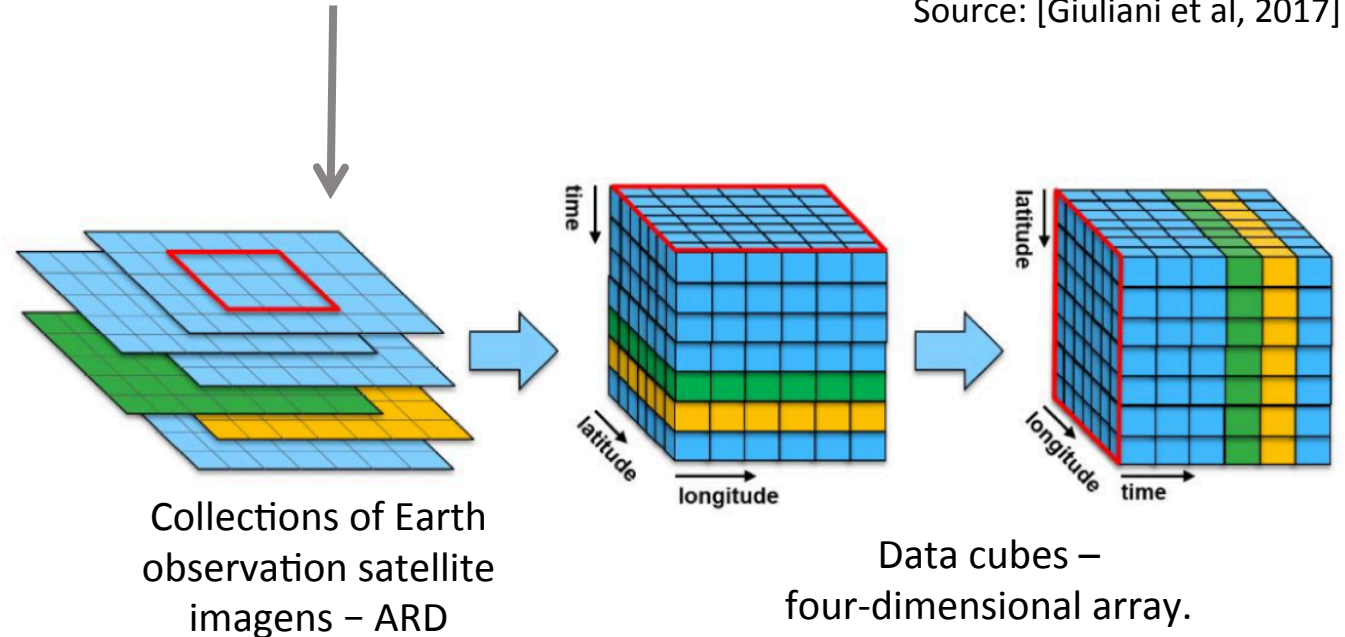
(Goal 2) Multidimensional data cubes from these ARD image collections

(Goal 3) Big data technologies, image time series analysis and machine learning methods

(Goal 4) Land use and cover information for all Brazilian territory.



Source: [Giuliani et al, 2017]



Source: [Kopp et al, 2019]



Open Data and Software Products

Software

Applications

- Web Portal
- Forest Monitor
- Interactive computing JupyterHub
- Satellite Image Time Series (SITS) R package
- Open Data Cube (ODC)

Services

- Web Data Cube Service (WDCS)
- Web Time Series Service (WTSS)
- Web Land Trajectory Service (WLTS)
- Web Land Samples Service (WLSS)
- Tile Map Service (TMS)
- STAC Service
- OGC Web Services - WFS, WMS e WCS
- Web Land Classification System Service (WLCSS)

Data and metadata

Data and metadata

- Image collections
- Data cube collections
- Metadata - collections of images and data cubes
- Land use and cover samples and metadata
- Land use and cover data sets and metadata

External providers

- Image collections

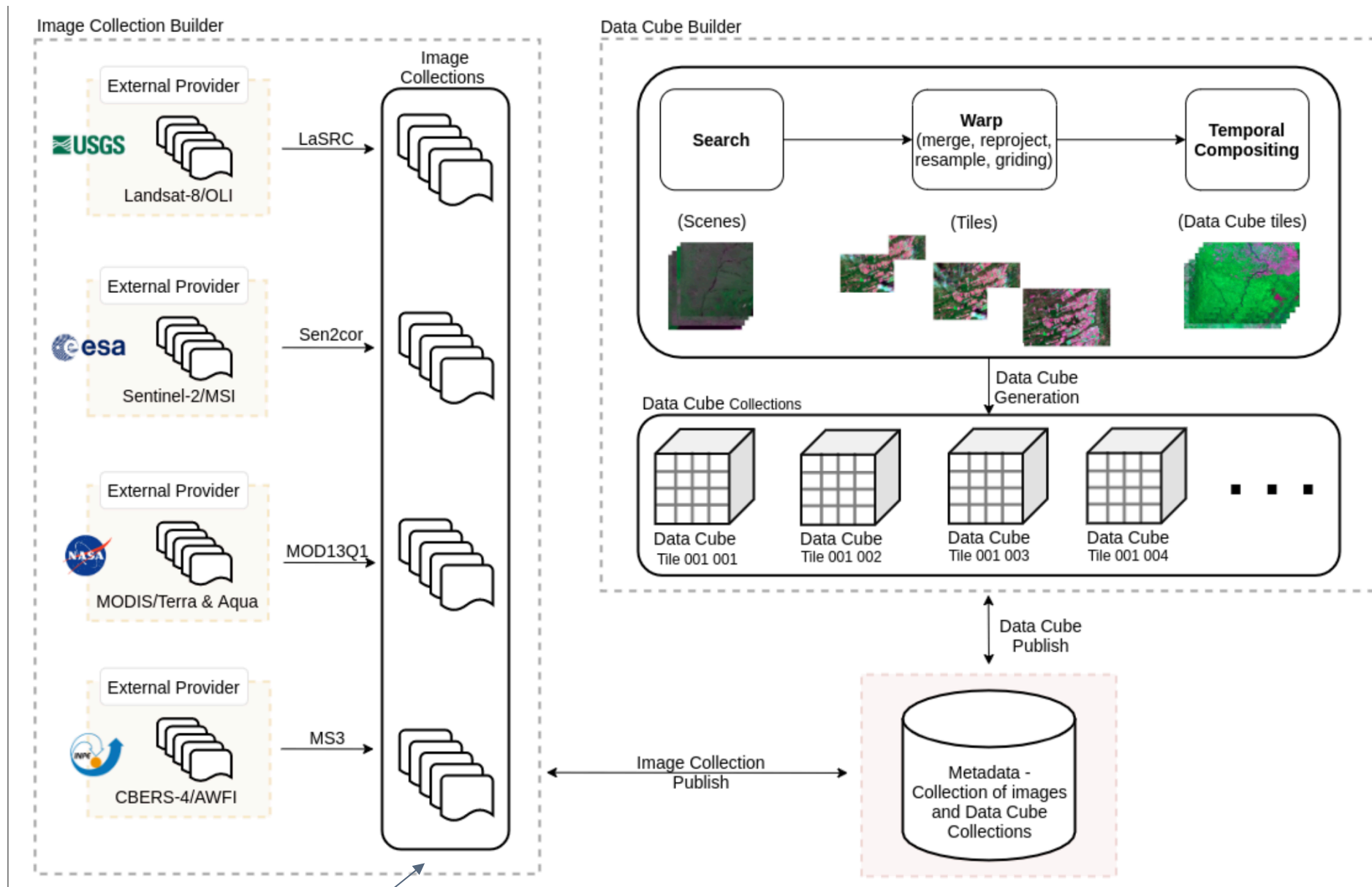
Data acquisition, processing and data cube generation

- Image Collection Builder (Image acquisition, ARD builder and metadata publishing)
- Data Cube Builder (Warping, temporal compositing, and metadata publishing)

Source: [Ferreira et al., 2020]



Analysis-Ready Data (ARD) image collections



Surface Reflectance Images

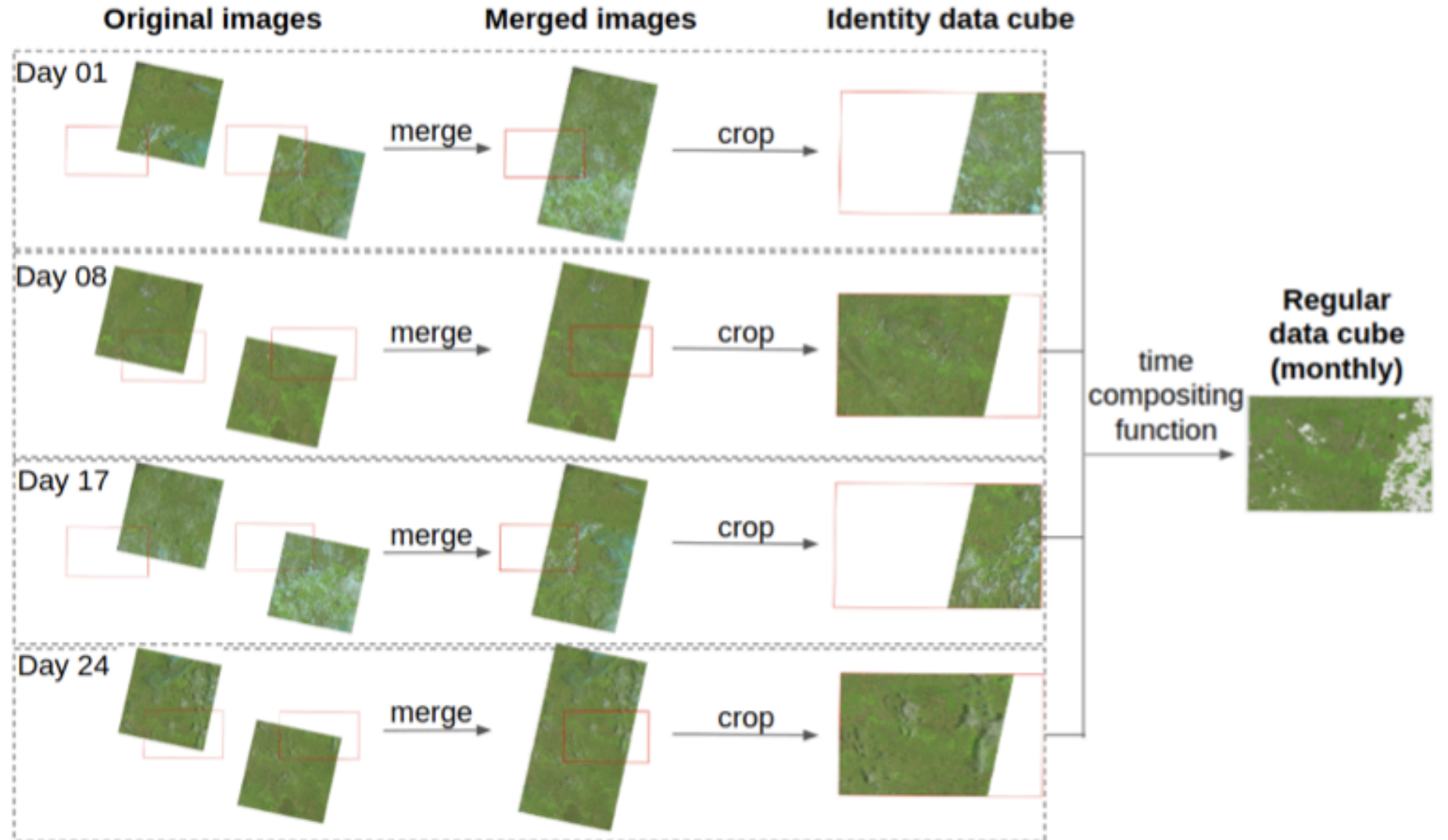
Source:
[Ferreira et al., 2020]



BRAZIL
DATA CUBE

Data Cube Builder

Example of the process to create a monthly data cube, considering one BDC grid tile (red rectangle).



Source:
[Ferreira et al., 2020]



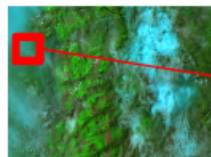
BRAZIL
DATA CUBE

Data Cube Builder

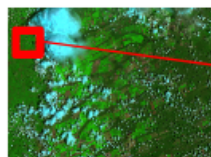
Time Composition

Available Images in 1 month

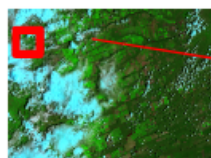
Day 03
Valid pixel
prop.: 0.5



Day 08
Valid pixel
prop.: 0.7



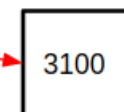
Day 13
Valid pixel
prop.: 0.6



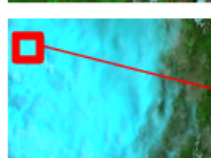
Day 18
Valid pixel
prop.: 1.0



Day 23
Valid pixel
prop.: 0.8



Day 28
Valid pixel
prop.: 0.1



input



Average

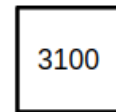
Average
Compositing
Function Result

2900, 3150, 3100

Average



input



Median

Median
Compositing
Function Result

2900, 3100, 3150

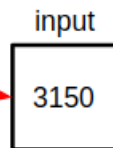
Median
(Middle Value)



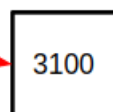
Images sorted by valid
observations quantity

Stack

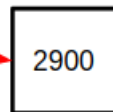
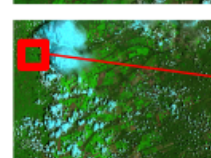
Day 18
Valid pixel
prop.: 1.0



Day 23
Valid pixel
prop.: 0.8



Day 08
Valid pixel
prop.: 0.7



3150, 3100, 2900

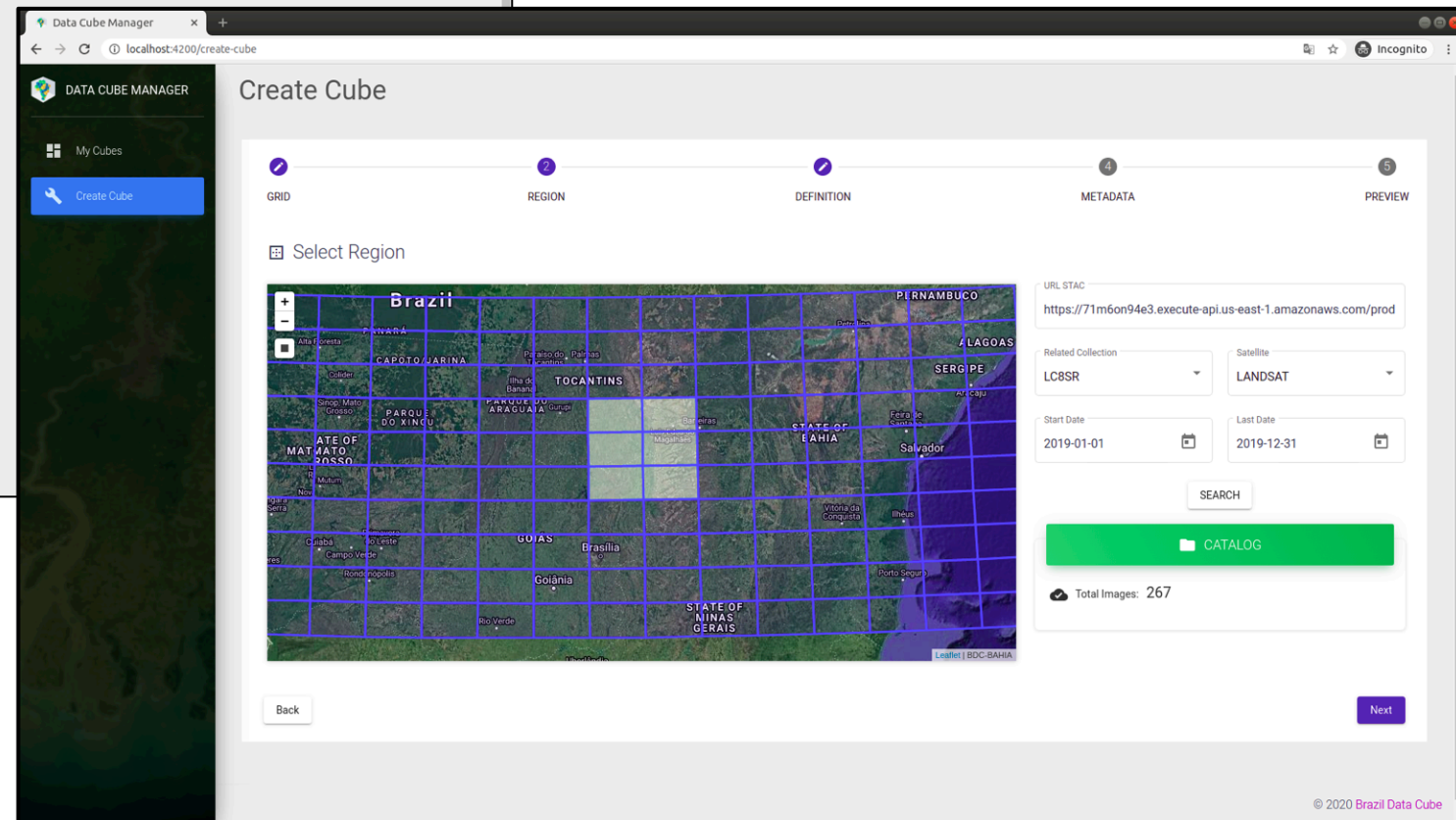
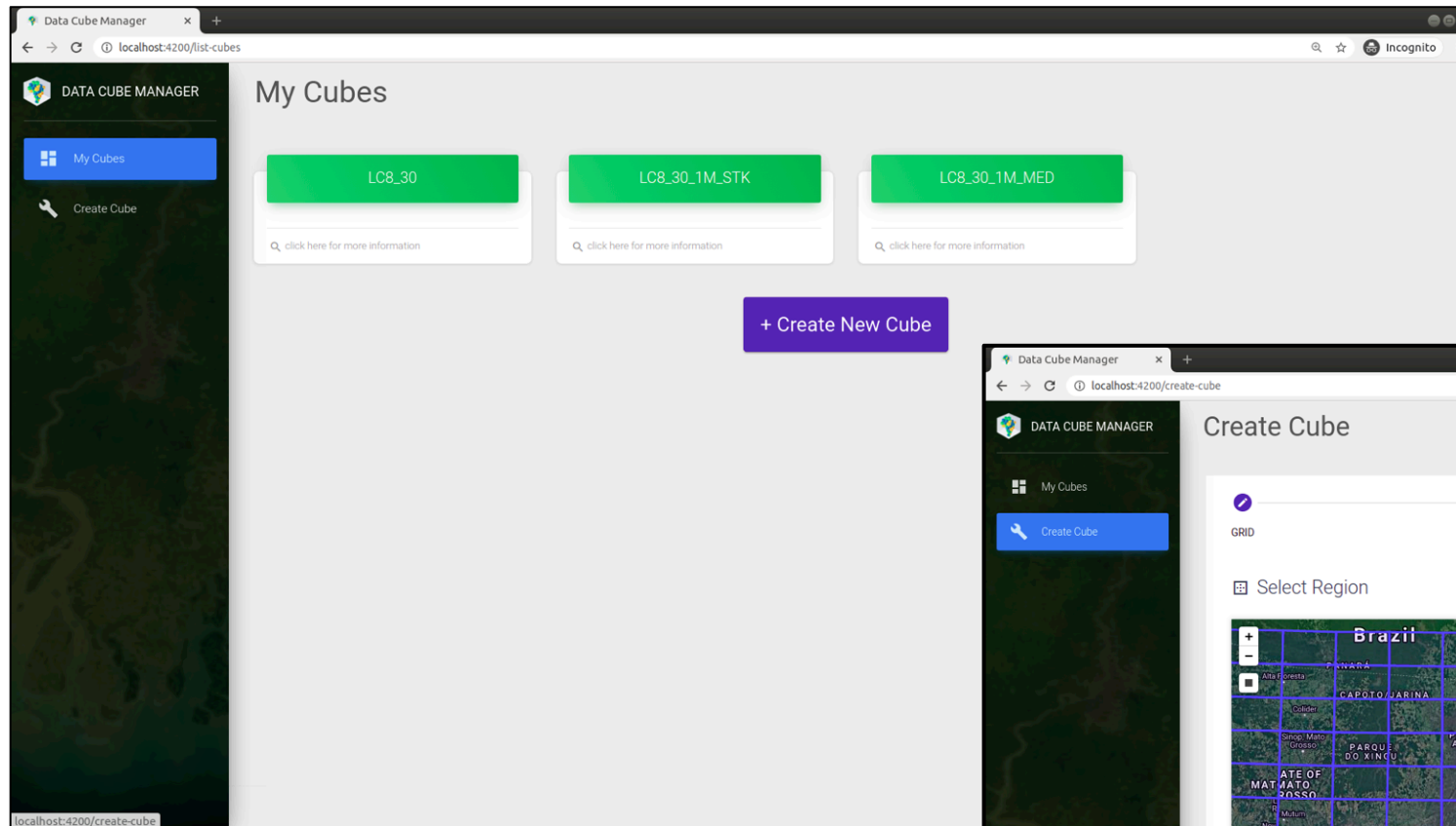
First value from sorted
input

Stack
Compositing
Function Result



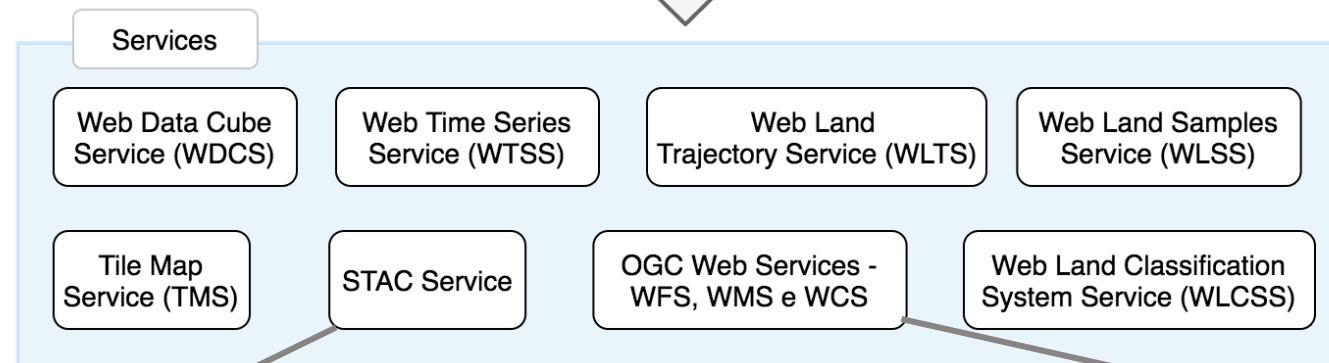
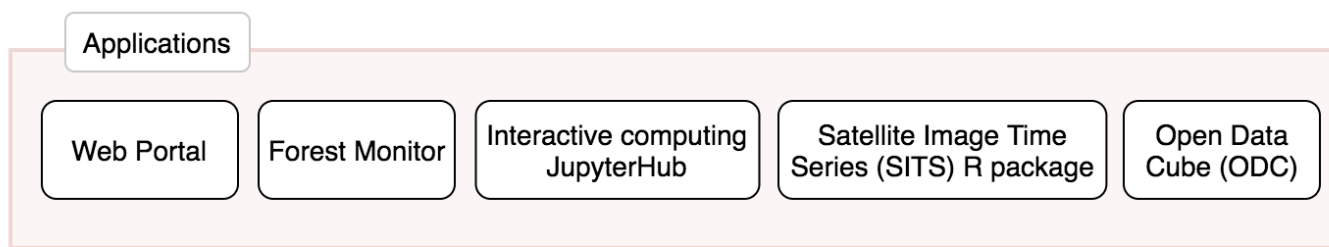
Source:
[Ferreira et al., 2020]

Data Cube Builder – Web Application with GUI

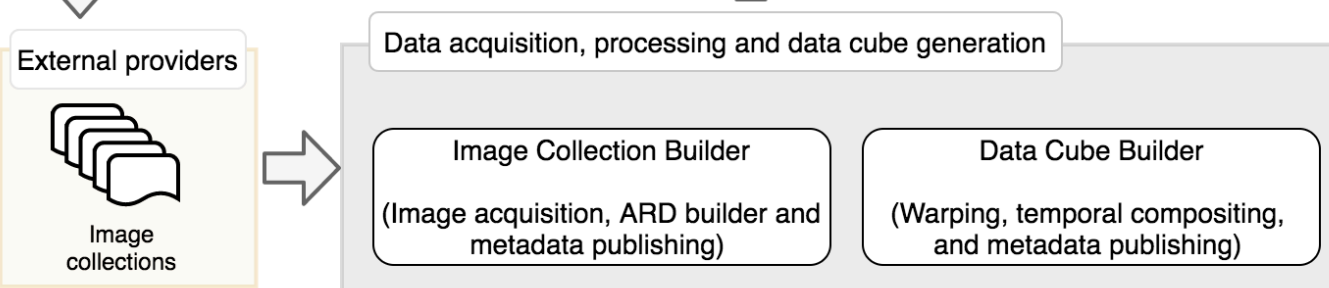
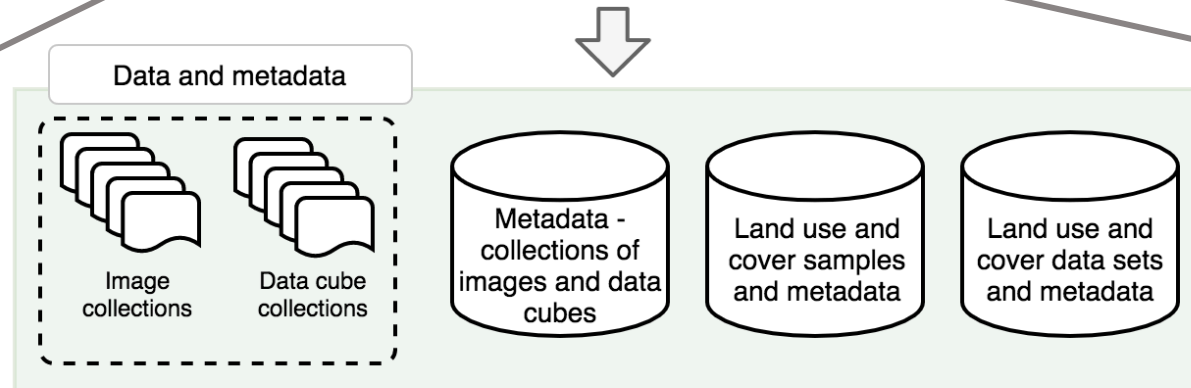




BRAZIL DATA CUBE



Web services to search, query, access and process the data sets and their metadata.



Source: [Ferreira et al., 2020]

BDC Project – Web Time Series Service (WTSS)

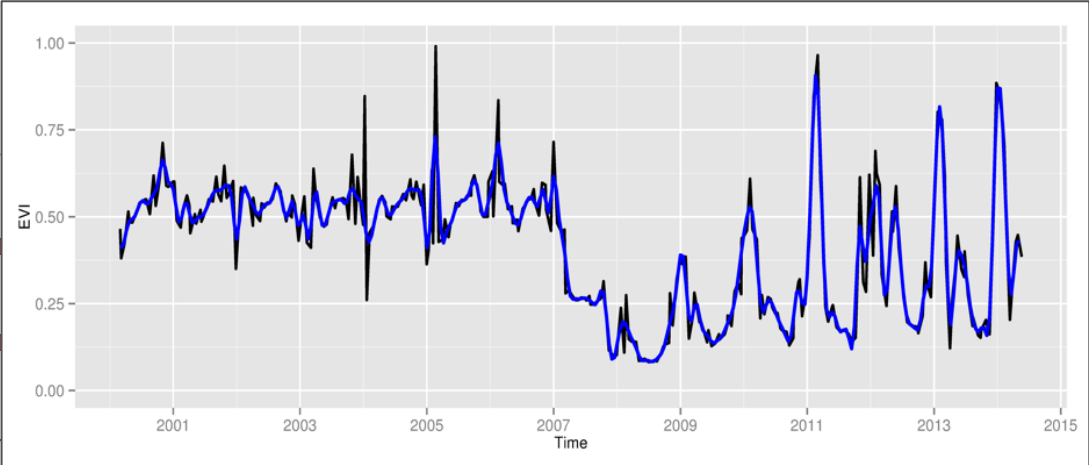


WTSS Client

```
http://www.dpi.inpe.br/wtss/time_series?
coverage=MOD09Q1,attributes=evi&
longitude=-54,latitude=-12&start=2001-02-18&end=2015-03-05
```

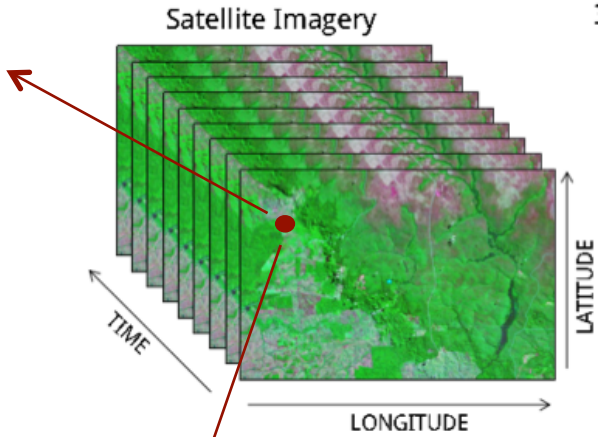


Web Time Series Service



```
{
  "result": {
    "attributes": [
      {
        "name": "red",
        "values": [ 1004, 1100 ]
      },
      {
        "name": "quality",
        "values": [ 4842, 3100 ]
      }
    ]
  },
  "timeline": [ "2000-02-18", "2000-02-18" ],
  "center_coordinates": {
    "latitude": -11.99,
    "longitude": -53.99
  }
},
{
  "query": {
    "coverage": "MOD09Q1",
    "attributes": [ "red", "quality" ],
    "latitude": -12,
    "longitude": -54,
    "start": "2000-02-18",
    "end": "2000-03-05"
  }
}
}
```

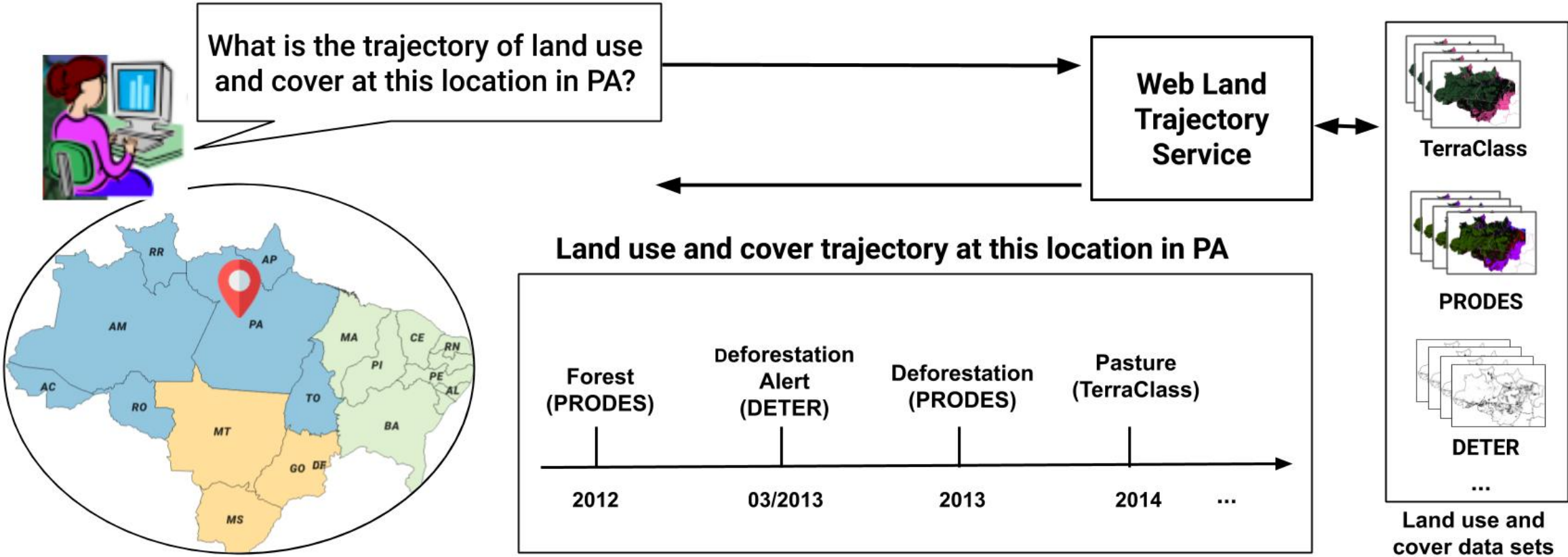
JSON Document



(longitude=-54,latitude=-12)

Source: [Vinhas et al., 2016]

BDC Project – Web Land Trajectory Service (WLTS)



Applications

Web Portal

Forest Monitor

Interactive computing
JupyterHub

Satellite Image Time
Series (SITS) R package

Open Data
Cube (ODC)

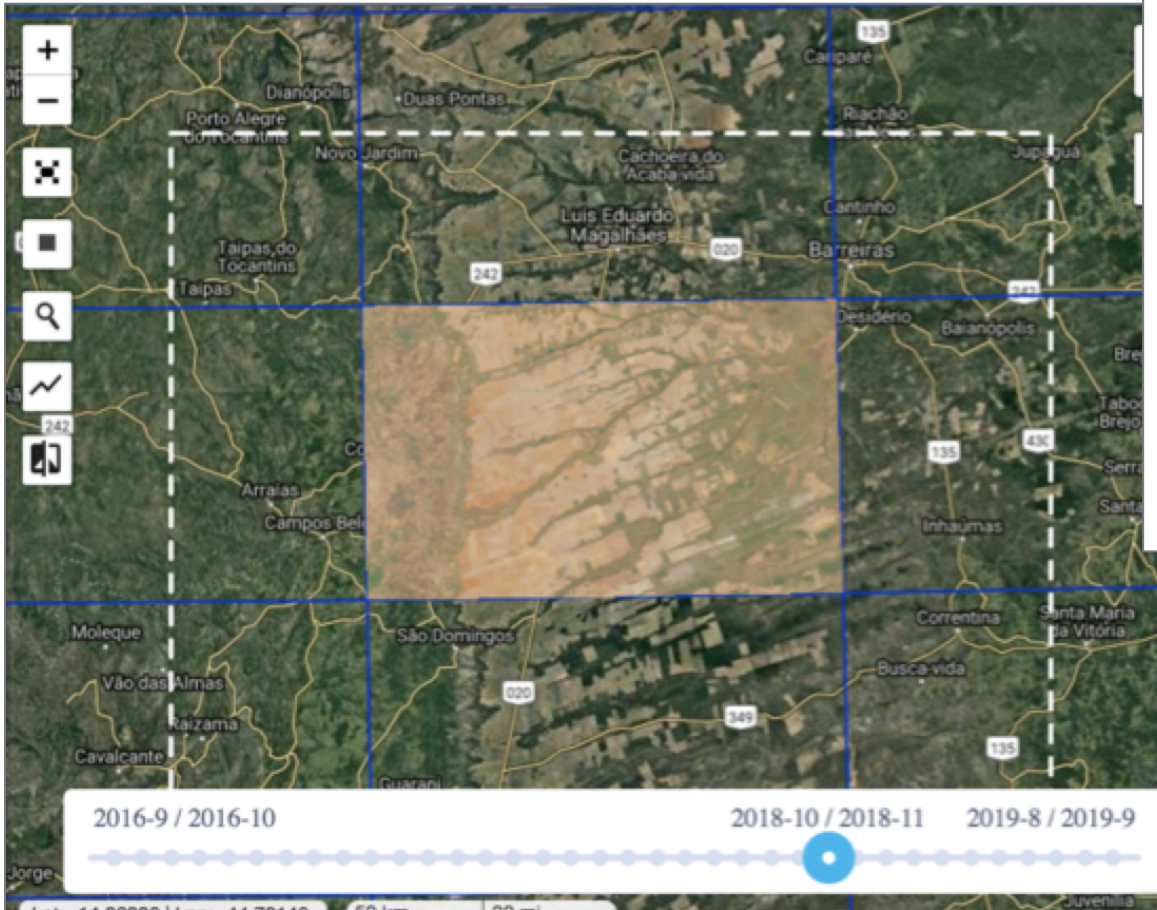
<http://brazildatacube.dpi.inpe.br/portal/explore>



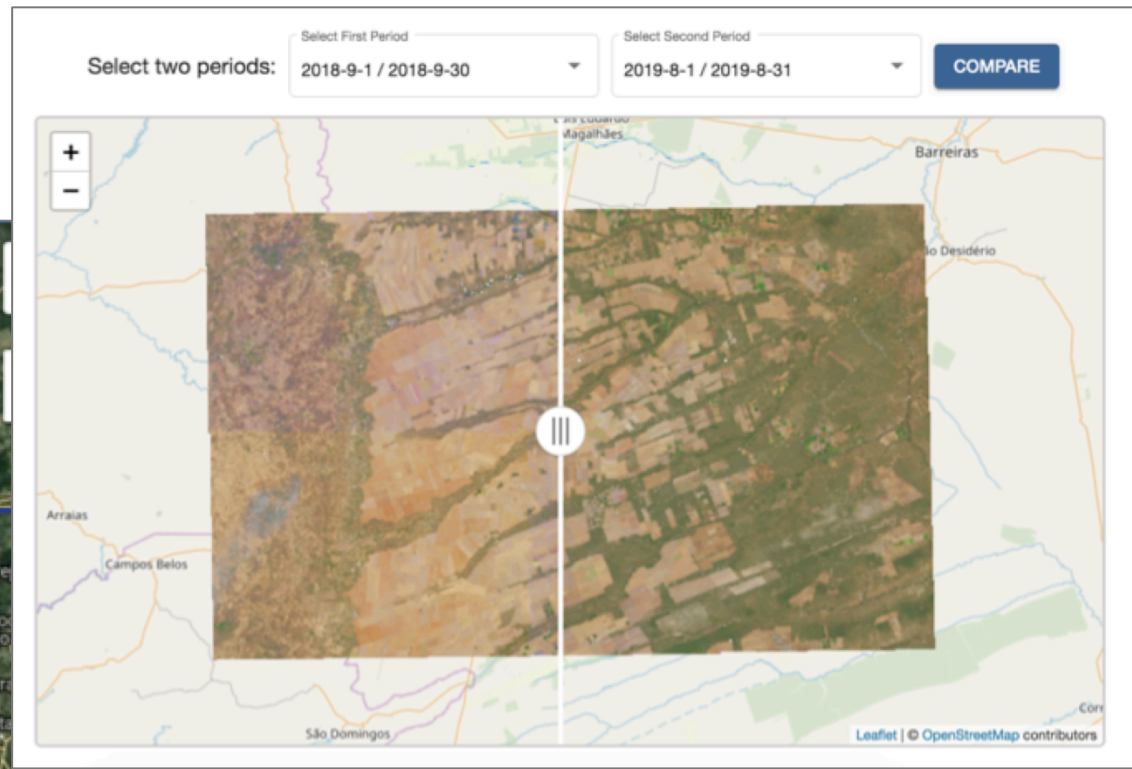
SITS (Satellite Image
Time Series) R package:

<https://github.com/e-sensing>

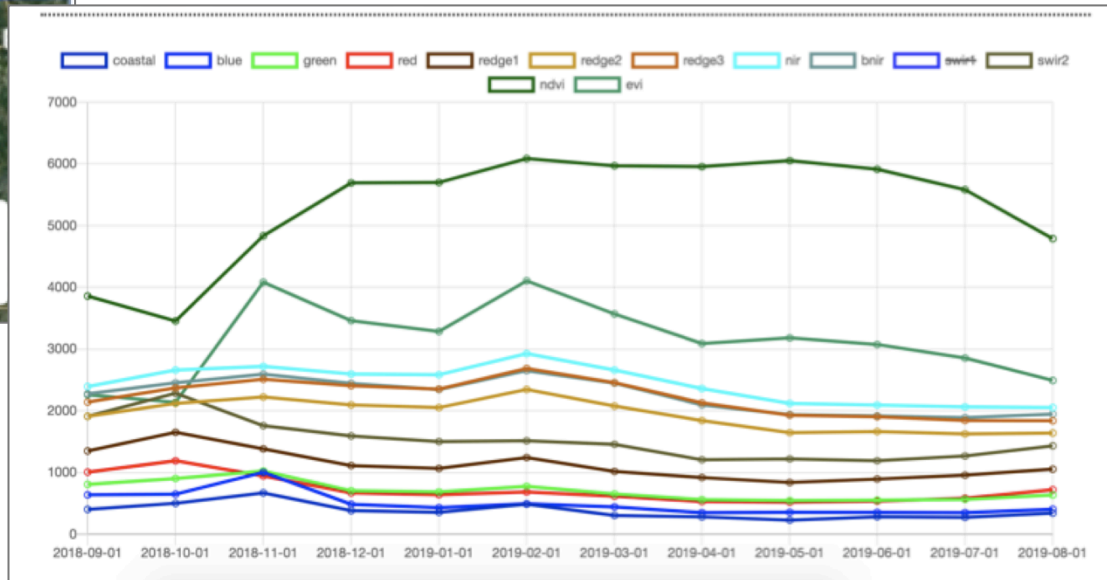
Select data cubes by tiles



Visualize data cubes by time using a slider
Download data cube files

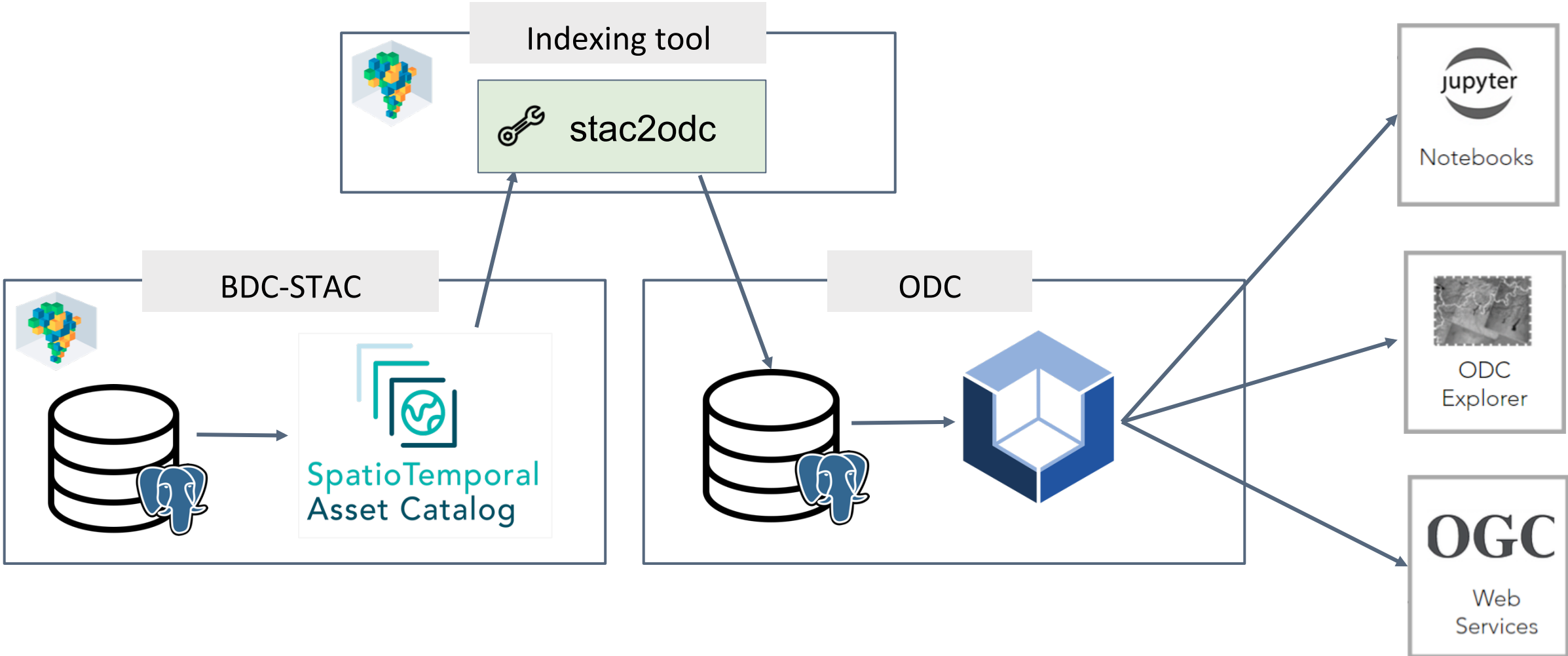


Visualize the difference between two time periods of data cubes



Access time series associated to specific locations of data cubes

Open Data Cube (ODC) + Brazil Data Cube (BDC)





ODC + BDC

Jupyterhub

jupyter Home Token Admin

Spawner Options

Select an image:

- ODC:1.8
- ODC:1.8**
- R-SITS
- Anaconda:3.0



KMeans Clustering - CB4_64_16D_STK_v1

This document presents an example of spectral clustering in the CBERS4 collection (CB4_64_16D_STK_v1) of

This simple example aims to present how to clustering the data from the BDC stored inside the ODC. To [BDC-STAC](#).

```
In [1]: import datacube
import numpy as np
import matplotlib.pyplot as plt
dc = datacube.Datacube(app='datacube')
```

```
In [2]: PRODUCT_NAME = "CB4_64_16D_STK_v1"
```

Load CB4_64_16D_STK_v1 product

Initially, an entire scene will be loaded, in a range of specific dates

```
In [3]: cb4_64_16d_ftile = dc.load(PRODUCT_NAME, measurements = ['red', 'green', 'blue', 'nir'],
                                time = ("2019-12-19", "2019-12-31"), resolution = (64, -64))
cb4_64_16d_ftile
```

Tile Viewer

This document presents a utility that makes it possible to view the BDC tiles that are registered in the ODC.

To see all the available products, see the [BDC-Portal](#) and [BDC-STAC](#).

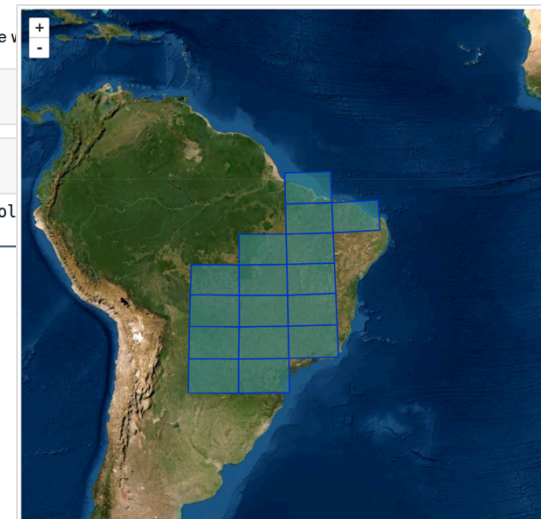
BDC CBERS Tiles

This section presents the CBERS tiles that were registered at the time this example v

```
In [ ]: dc = datacube.Datacube(app='datacube')
datasets = dc.find_datasets(product = "CB4_64_16D_STK_v1")
```

```
In [5]: from bdc_utils import bdc_plot_datasets
bdc_plot_datasets(datasets, zoom = 4)

Map(center=[-10.967901383824895, -51.143812965446976], control
```



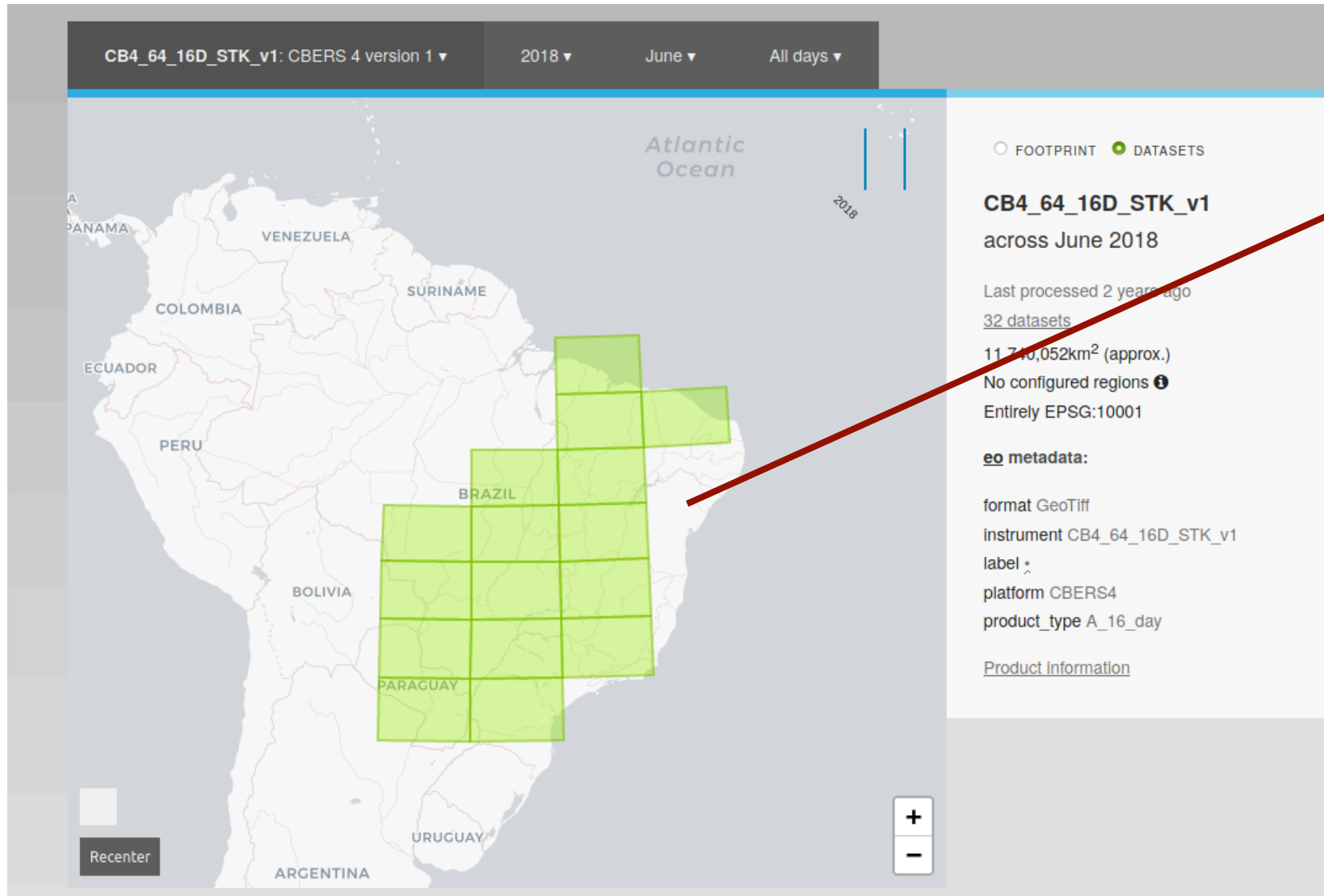


ODC + BDC

Open Data Cube Explorer



ODC Explorer



CBERS 4 data cubes for the Cerrado biome in Brazil



ODC + BDC

Brazil Data Cube - OGC Web Services (datacube-ows)

Brazil Data Cube OGC Web Services

This URL is an end-point and is not intended for direct viewing. For more information:



OPEN DATA CUBE

Open Web Services (datacube-ows) Repository

OGC

Web
Services

OGC Services

The screenshot shows a GIS application window with the following components:

- Menu Bar:** Projeto, Editar, Exibir, Camada, Configurações, Complementos, Vetor, Raster, Banco de dados, Web, Malha, Processar, Ajuda.
- Toolbar:** A row of icons for navigation, editing, and data management.
- Navegador (Navigator):** A tree view on the left showing a project structure:
 - SpatiaLite
 - PostGIS
 - MSSQL
 - DB2
 - WMS/WMTS
 - BDC
 - BDC - Debug
 - Brazil Data Cube - OGC Web Services
 - CBERS-4
 - CBERS-4 16 days (selected)
 - Landsat-8
 - BDC - Local
 - BDC GRID
 - XYZ Tiles
 - OpenStreetMap
 - WCS
 - BDC WCS - Debug
 - BDC WCS - Local
- Camadas (Layers):** A panel at the bottom left showing:
 - BDC GRID (checked)
 - CBERS-4 16 days (checked)
- Map:** A central map area displaying a satellite image of a landscape with a blue grid overlay.
- Status Bar:** At the bottom, showing coordinates (-71.86,-1.49), scale (1:36015888), zoom (Lupa 230%), rotation (Rotação 0,0°), and projection (EPSG:4326).



Main Challenge: Big Earth Observation Data Sets

Data volume estimation: ~ 750 Terabytes (TB)

CBERS-4 (AWFI)

Region: Brazil
Period: [2015, 2019]
Volume: ~ 34 TB

Landsat-8 (OLI)

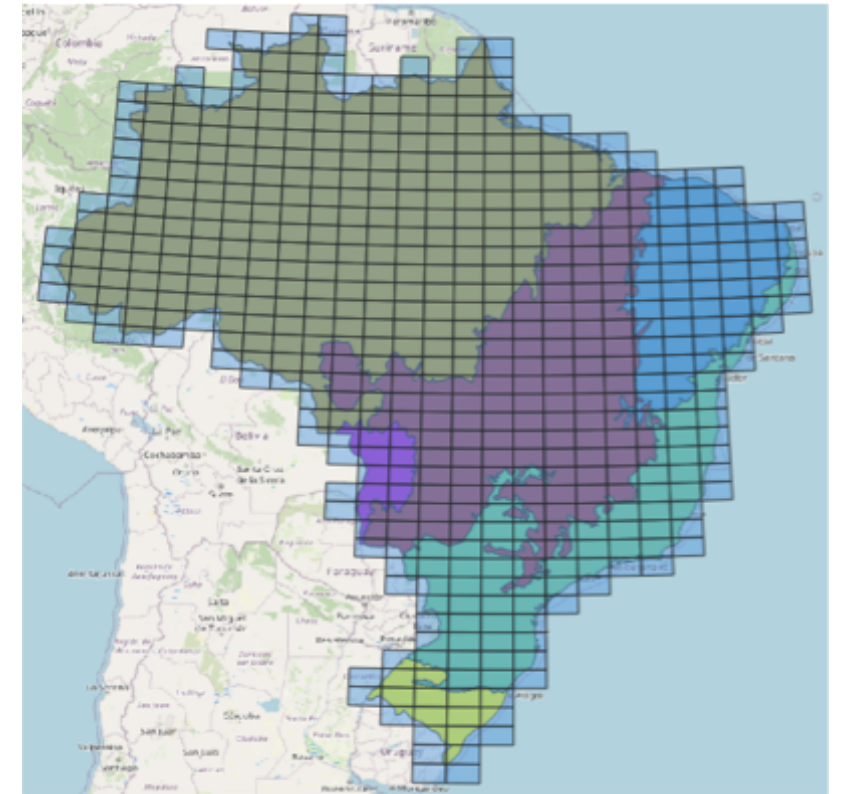
Region: Brazil
Period: [2017, 2020]
Volume: ~ 45 TB

Sentinel-2 (MSI)

Region: Brazil
Period: [2015, 2020]
Volume: ~642 TB (L1C)

Terra & Aqua (MODIS)

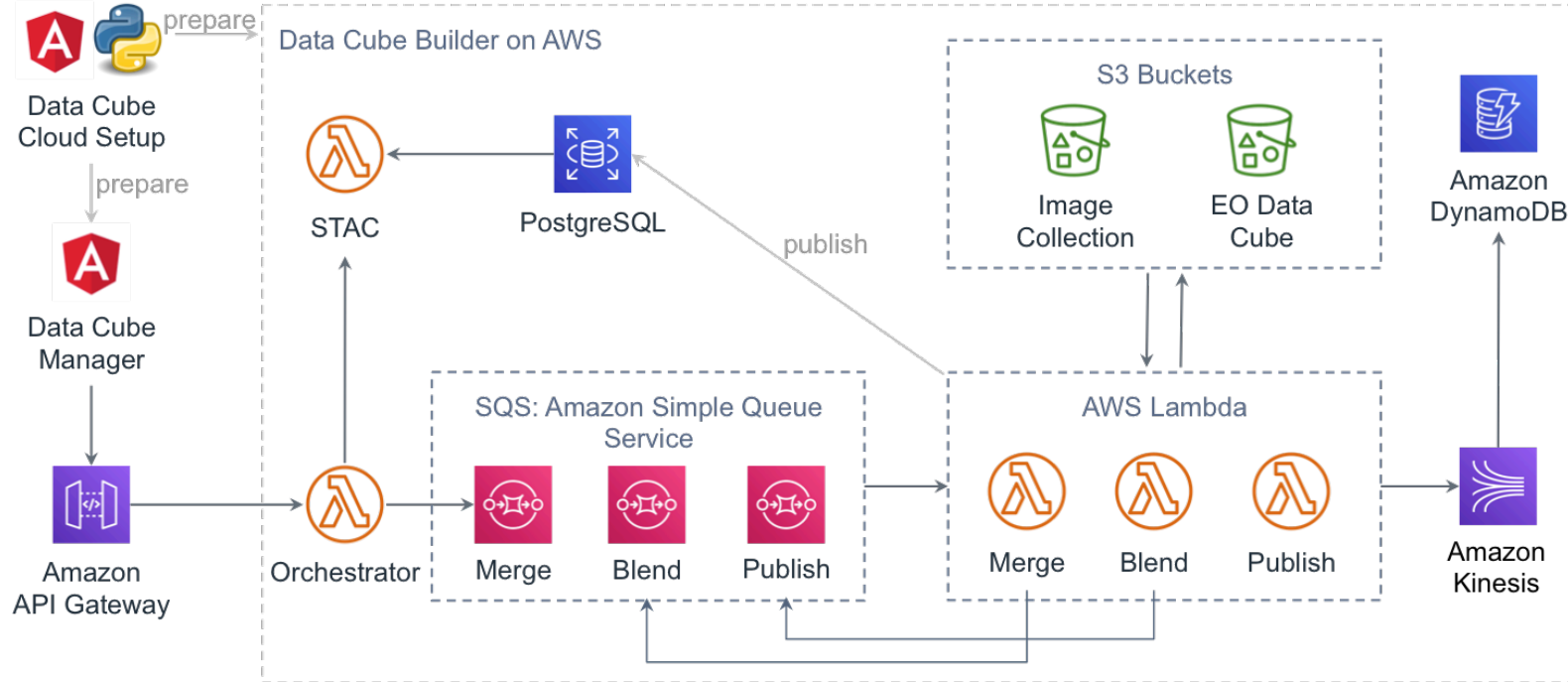
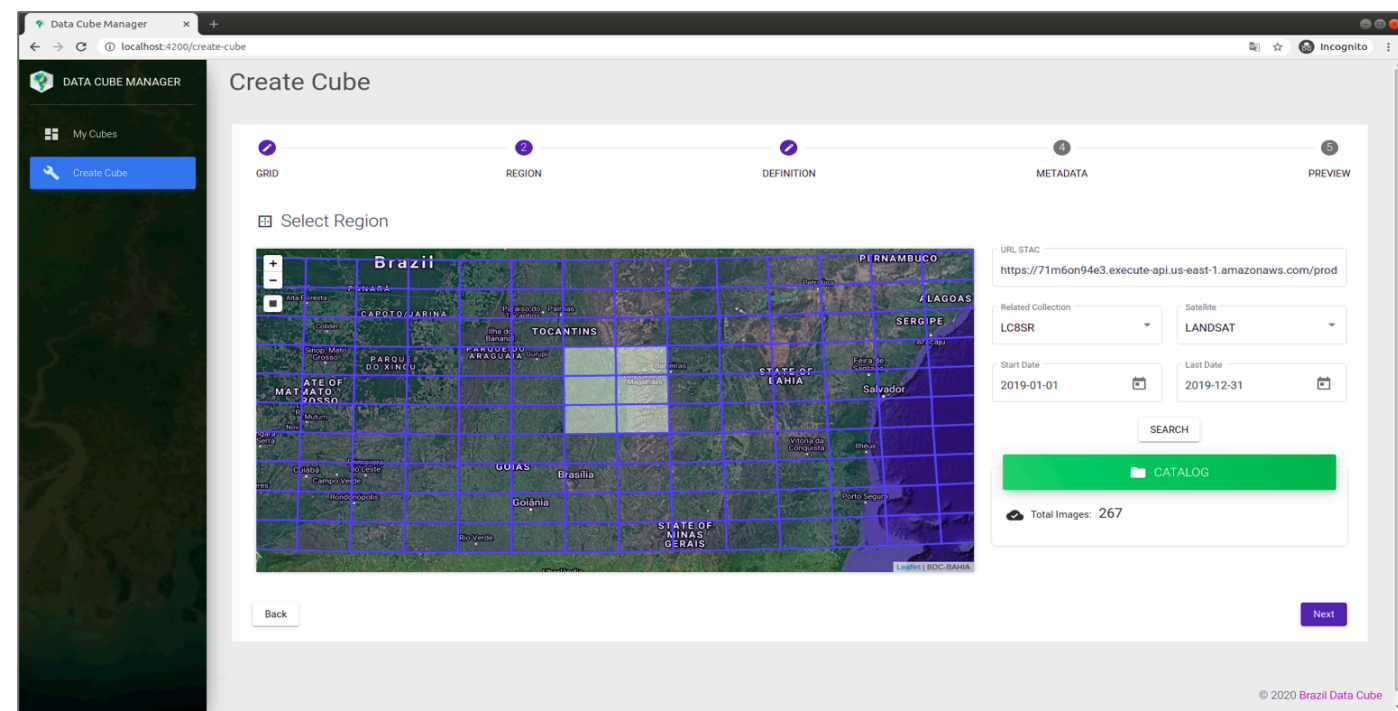
Region: Cerrado Biome
Period: [2016, 2020]
Volume: ~4 TB



The Brazil Data Cube tiling system: 560 tiles,
1 x 1.5 degree each tile.

BDC Project – Amazon Web Service (AWS)

(1) Sentinel 2 images – ARD (surface reflectance) and data cubes builder on AWS

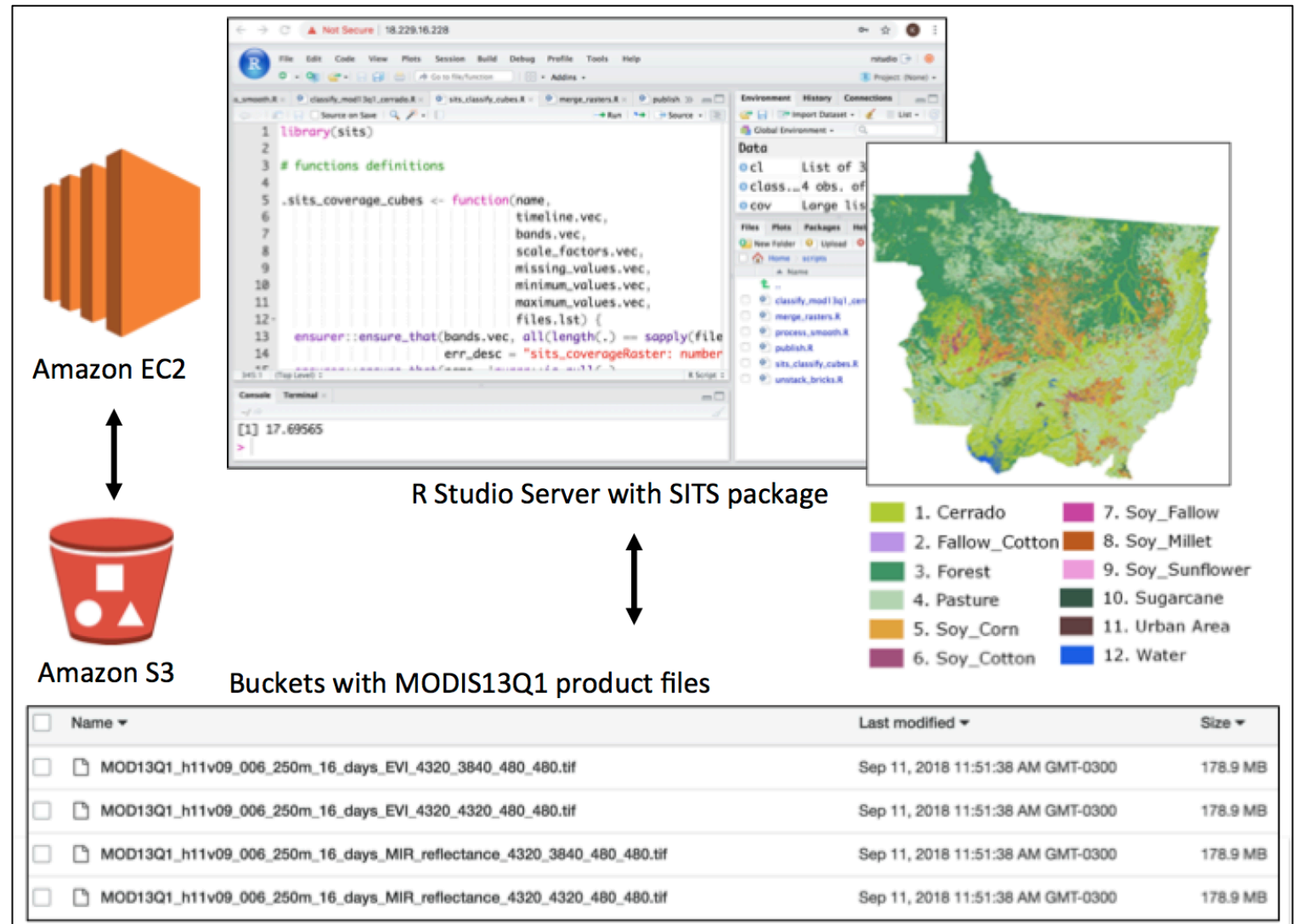


GEO AWS
Cloud Credit
Program

BDC Project – Amazon Web Service (AWS)

(2) Create Land Use and Cover Maps from the BDC data cubes

GEO AWS
Cloud Credit
Program





BRAZIL DATA CUBE

Brazil Data Cube is a project that is being developed by the Brazil's National Institute for Space Research (INPE), since January 2019, that aims to create multidimensional data cubes of analysis-ready from medium-resolution Earth observation images....

[READ MORE](#)



Portal de Brazil Data Cube

Access the Interactive Map at Brazil
Data Cube Portal



Github

Brazil Data Cube portal source
code repository



News

Be updated on the news of Brazil
Data Cube Project



Data Cubes and Land Use and Cover Classification

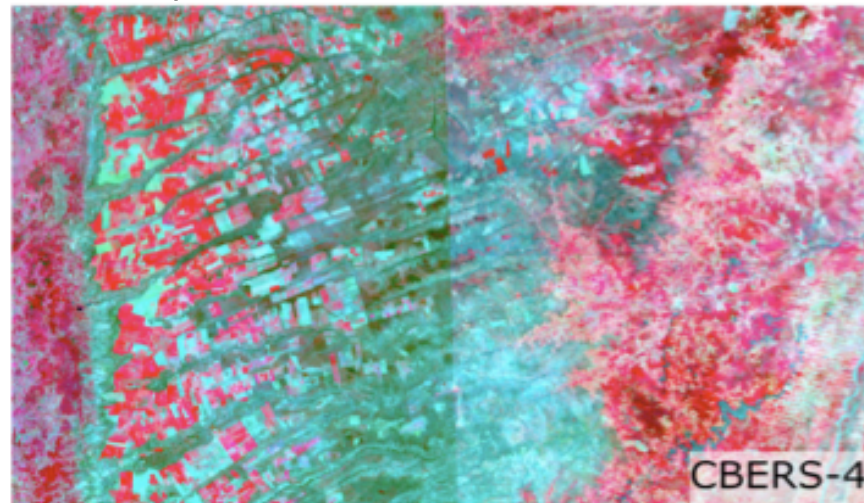
Examples of three **MONTHLY** data cubes created using the time composition function **STACK** from images of:

- (1) CBERS-4
- (2) Sentinel-2
- (3) Landsat 8

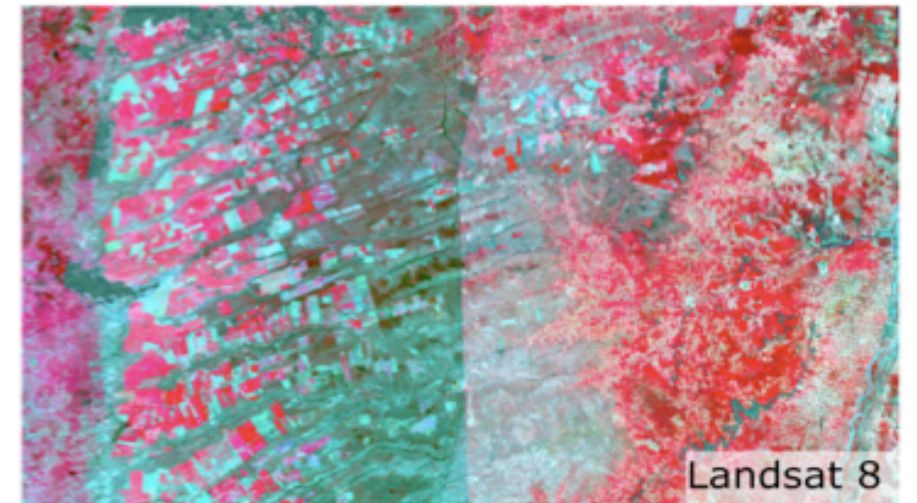
Data cube period: 08-2016 to 07-2019



January, 2019



January, 2019

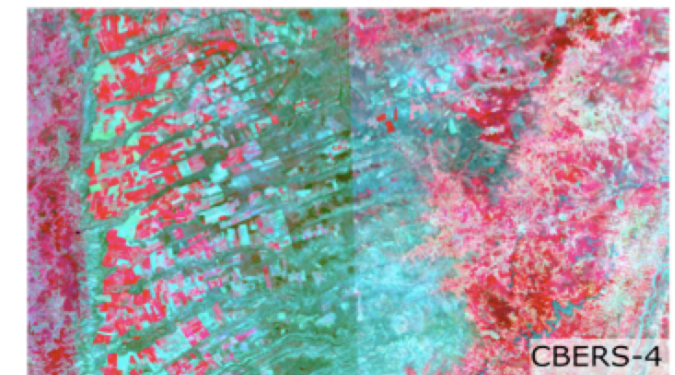
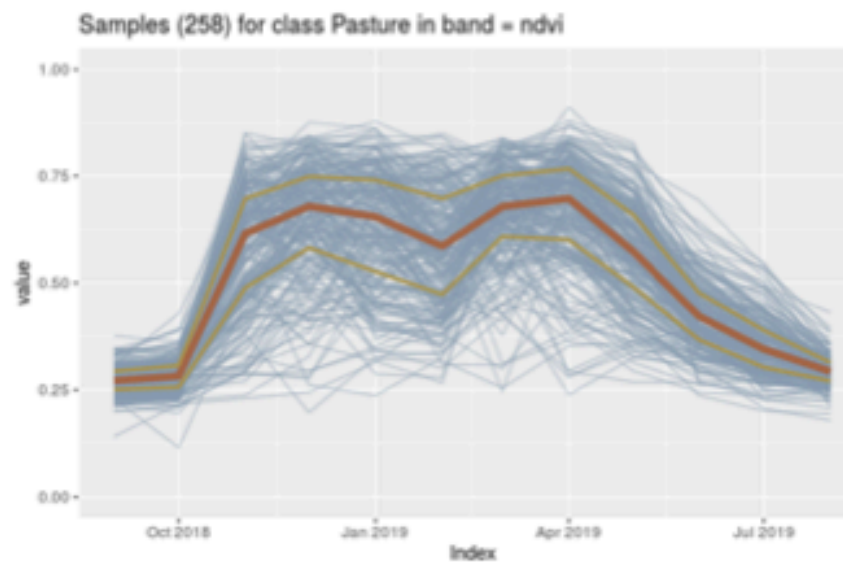
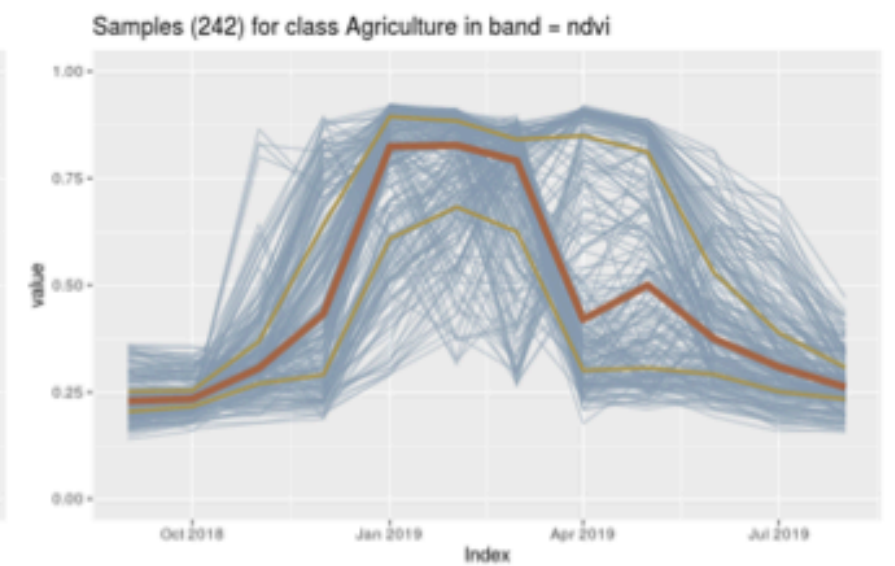
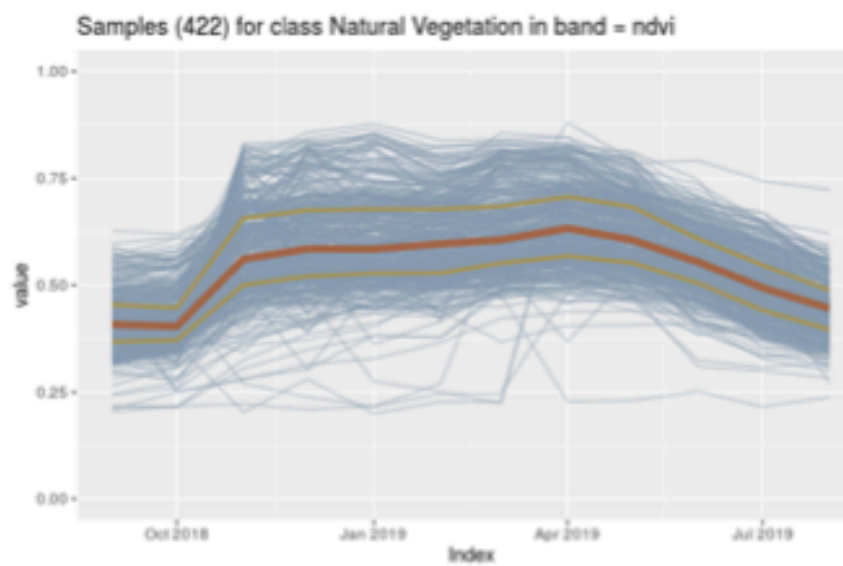


January, 2019



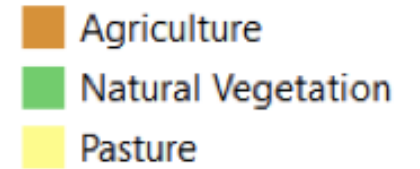
Examples of NDVI time series extracted from the CBERS-4 data cube associated to three different types of land use and cover classes:
(1) Natural Vegetation
(2) Agriculture
(3) Pasture

NDVI time series from Aug-2018 to July-2019.





Land Use and Cover Classification



Land use and cover classification results of the data cubes:

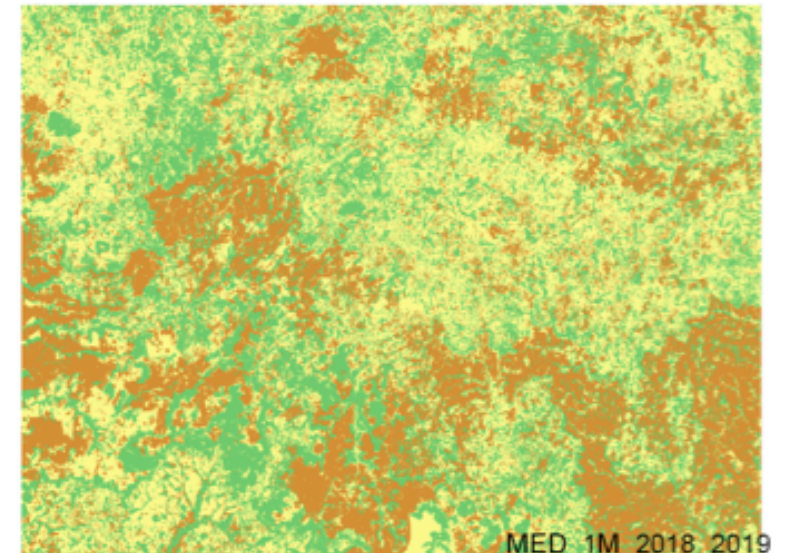
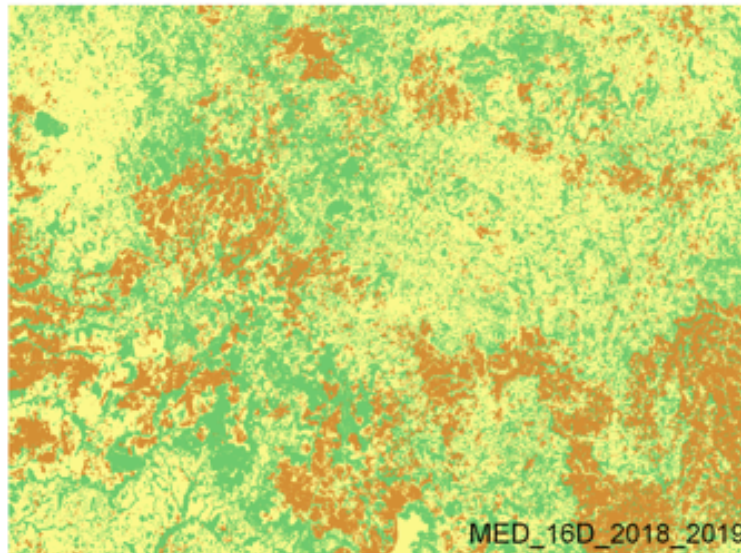
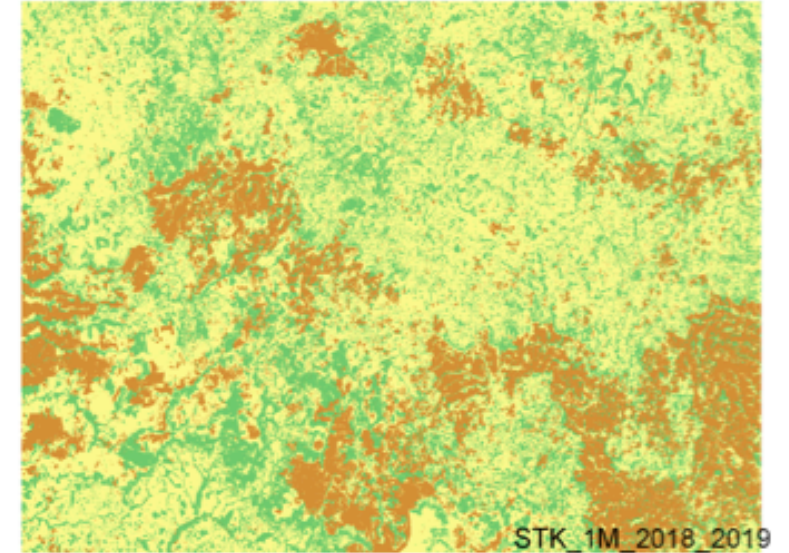
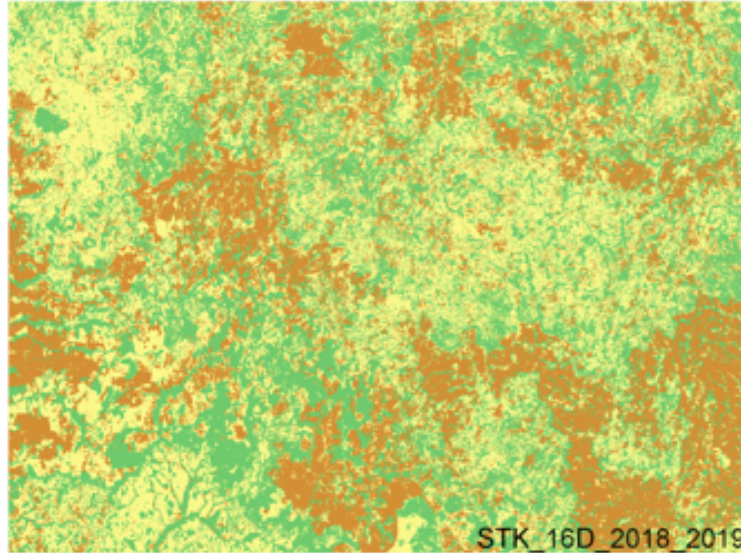
- (1) CBERS4 STACK 16Days
- (2) CBERS4 STACK Monthly
- (3) CBERS4 MEDIAN 16Days
- (4) CBERS4 MEDIAN Monthly

Period: Ago-2018 to July-2019

Vegetation indices and bands:
NDVI, EVI, blue, green, red, nir.

Deep learning classifier with 5 layers and 512 neurons.

SITS (Satellite Image Time Series) R package



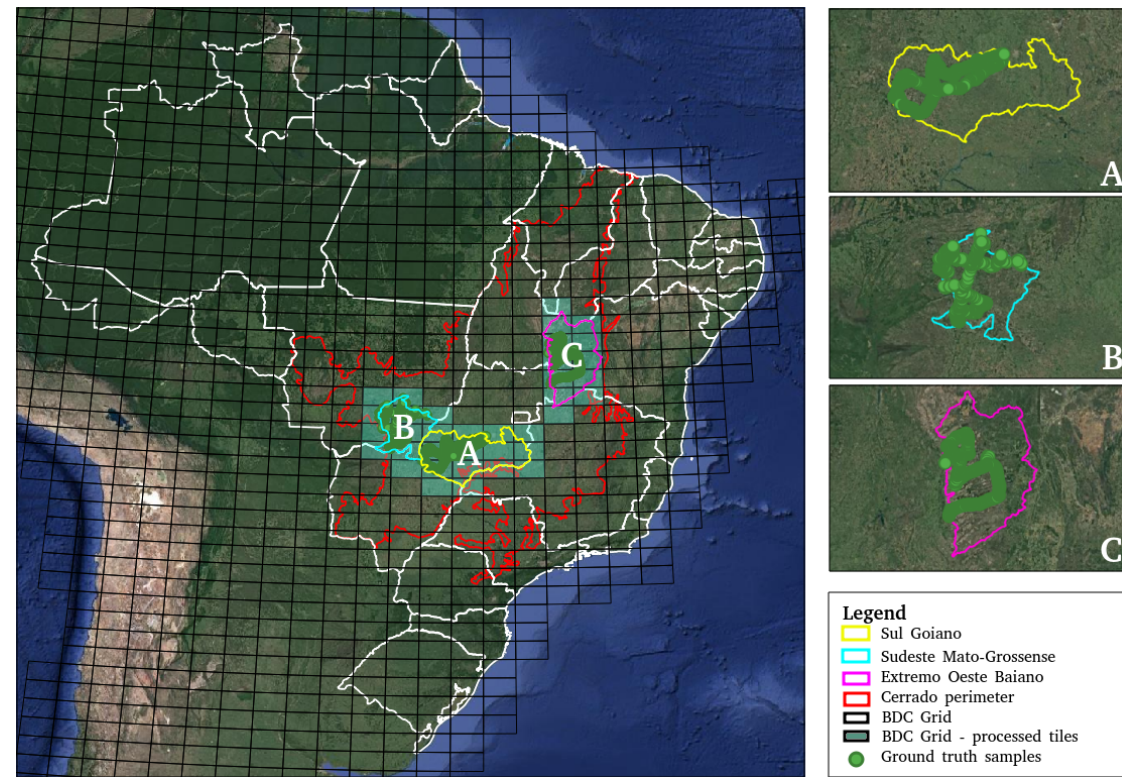
BDC Project – Status and Future

Status:

- ✓ CBERS 4, Sentinel 2 and Landsat 8 - ARD images and data cubes from 2016 to 2020 and land use and cover maps:
 - ✓ Today: three areas in Brazil (A, B and C).
 - ✓ December 2020: Cerrado biome.

Future:

- ✓ Create data cubes harmonazing/mixing Sentinel 2 and Landsat 8 satellite images
- ✓ Create data cubes using Sentinel 1 images
- ✓ Promote the use of data cubes and time series analysis to extract different kinds of information from Earth observation satellite images in Brazil
- ✓



Digital Earth America – Some Ideas

- ✓ Each country (a local institute) can be responsible for the creation and maintenance of its ARD images and data cubes; and the Digital Earth America can provide mechanisms **to integrate** these data sets from different countries.
- ✓ We can create a group/community to **share experiences and software products**. Example: the Data Cube Builder Application on AWS developed by the Brazil Data Cube project can be used to create ARD images and data cubes for other countries.
- ✓ The main challenge: the big volume of satellite images. We can join efforts to **get funds to pay cloud computing environments** (such as AWS) to store and process these big amount of data sets.

Project team

Coordinators



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Raphael Costa



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Rennan Marujo

Project team

Project Management

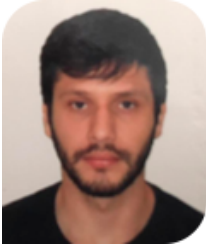


Luciana Mamede

PhD Students



Alber Sanchez



Leonardo Vieira



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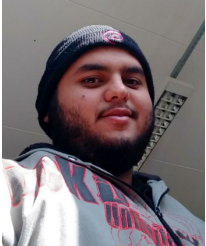


Rolf Simões



Vitor Gomes

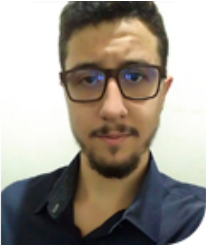
Master Students



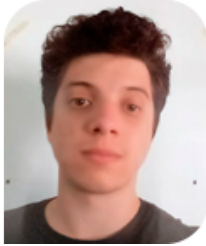
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BRAZIL
DATA CUBE



MINISTÉRIO DA
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MINISTÉRIO DO
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