3-4 FEBRUARY 2021

GEO-INPE WEBINARS

Learn about Brazil's monitoring system and the recent technological advances by Brazil's National Institute for Space Research (INPE)

Welcome back
by the GEO Secretariat Director, Gilberto Câmara

Moderator

Dr Thelma Krug
IPCC Vice-Chair

Thelma Krug is a former senior researcher at the National Institute for Space Research (INPE) in Brazil. She was elected Vice-Chair of the Intergovernmental Panel on Climate Change (IPCC) for the Sixth Cycle (October 2015 – October 2022), after having been co-chair of the IPCC Task Force on National GHG Inventories from 2002 until 2015.

Throughout her career, she has held high-level positions at the Ministry of Science, Technology, Innovation and Communication (MCTIC) and at the Ministry of the Environment (MMA) in Brazil.

For more than 15 years she represented Brazil in the negotiations at the United Nations Framework Convention on Climate Change (UNFCCC).

She holds a PhD on Spatial Statistics from the University of Sheffield, UK.

Housekeeping

- **Indicate your name and your affiliation** by going to the list of participants, clicking on your name and then on “rename”.

- **Post your questions in the chat box**. The moderator will pick them up and speakers will respond in the chat as well as during the Q&A session.

- **We are recording** this webinar and we will post it on the GEO website.

Structure of the GEO-INPE Webinar - Day 2

- **The TerraAmazon application for forest monitoring** - Lubia Vinhas, Daniel Silva, João Felipe Kneipp (20 min)
- Moderated Q&A and discussion (30 min)
- Short break (5 min)
- **The Brazilian Data Cube project: innovation to automatize land use and land cover data production using Big Earth Observation data and machine learning methods** - Karine Ferreira, Gilberto Queiroz (20 min)
- Moderated Q&A and discussion (30 min)
- Wrap-up (5 min)
- Final remarks and closing - Gilberto Câmara (5 min)

Dr Lubia Vinhas
Senior Researcher
INPE

Lubia Vinhas has been a researcher at the National Institute for Space Research (INPE) in Brazil since 1997, working with spatial databases, free and open-source software for GIS, remote sensing and other geographical applications.

She was head of INPE's Image Processing Division from April 2014 to March 2018 and the General Coordination of Earth Observation from March 2018 to June 2020.

She is currently collaborating with the Program for Satellite Monitoring of the Brazilian Amazon and the Brazil Data Cube Project. She is also leading the design of INPE's new Georeferenced Database Program. Lubia has a doctoral degree in Applied Computing from INPE (2006).

Dr Daniel E Silva
Technical Manager - Amazon PRODES Project
INPE

Daniel E Silva is the technical manager of Amazon PRODES Project at the National Institute For Space Research (INPE) since 2019, working on detection and quantification of annual deforestation in the Amazon Biome, based on Remote Sensing data and Geoprocessing techniques. He currently deals with different aspects of the Program like map production, methodology and research.

He has experience on Ecosystems Ecology, niche modeling and vegetation responses to environmental stress, and worked with forest inventory databases at large spatial scale and local ecological characterizations.

He holds a PhD in Biodiversity, Ecology and Forest Sciences.

João Felipe S. Kneipp, Msc
Geoprocessing Analyst - Cerrado PRODES Project
INPE

João Felipe Kneipp is part of the technical group of the INPE's forest monitoring projects (TerraClass, PRODES, DETER, and Capacity Building) since 2012. As a member of INPE-CRA staff, trained over 300 international professionals from different countries utilizing the INPE's forest monitoring methodologies and TerraAmazon software. He has a master's degree in Environmental Sciences from the Federal University of Pará.

The TerraAmazon Application for forest monitoring

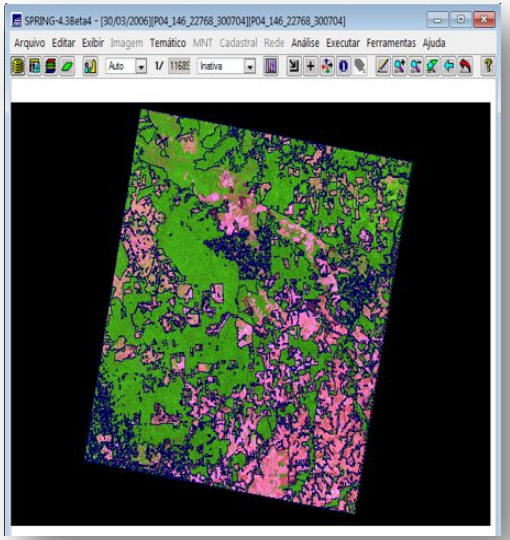
Lubia Vinhas

Daniel E Silva

João Kneipp

PRODES from 1988 to 2003

Visual analysis using paper overlay plus vector correction in a vector GIS



PRODES from 2003 to 2005

Image interpretation directly on the computer screen using a general-purpose vector and raster GIS

PRODES DETER TerraClass

TerraAmazon manages the complete flux of data, processes, and users required to produce land cover mapping data using remote sensing data through visual interpretation

TerraAmazon

Continuous data dissemination

TerraAmazon A performant, trustworthy and adapted GIS

PRODES annual volume (ex. of PRODES in 2019):

3.202.599 km^2 of forest observed (100% audited) = **229** Landsat scenes

493 satellite images (from 3 satellites) used to detect deforestation

18 contributors to map production

43.404 polygons of deforestation

10.897 km^2 of deforested area increment

Deforestation rate, maps, images and analyses online

Workflow Management

TerraAmazon capture the singularity of each project in terms of area of interest, imagery used, classes of mapping as well as data and team management

Project Manager

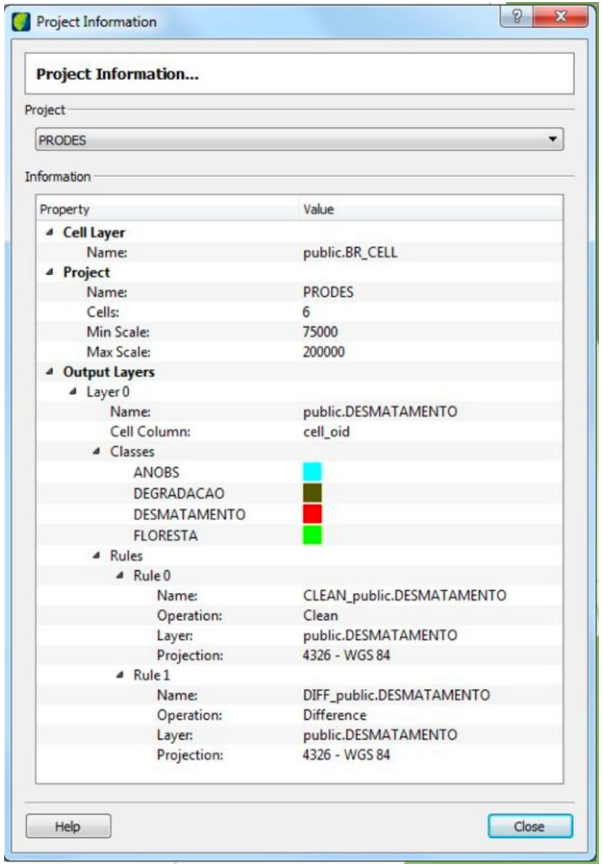
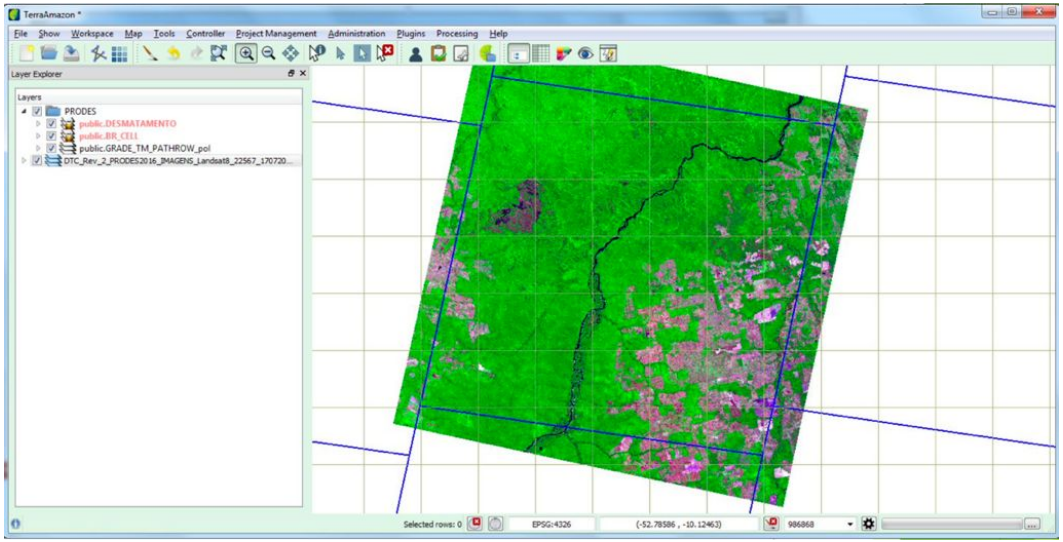


Image Access

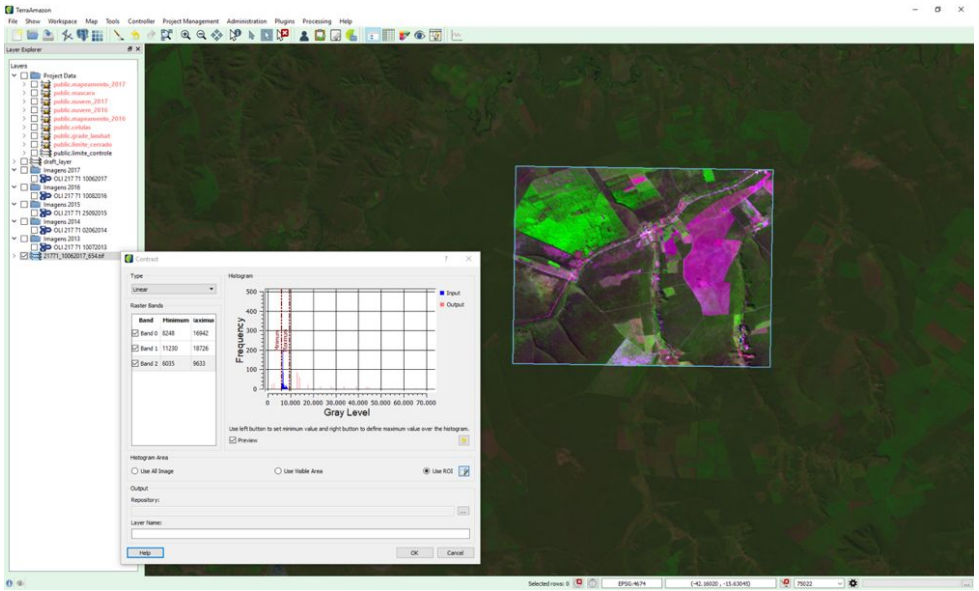
Operators
Remote sensing experts

TerraAmazon can access images from local files or web services, that will be available for the photo interpretation

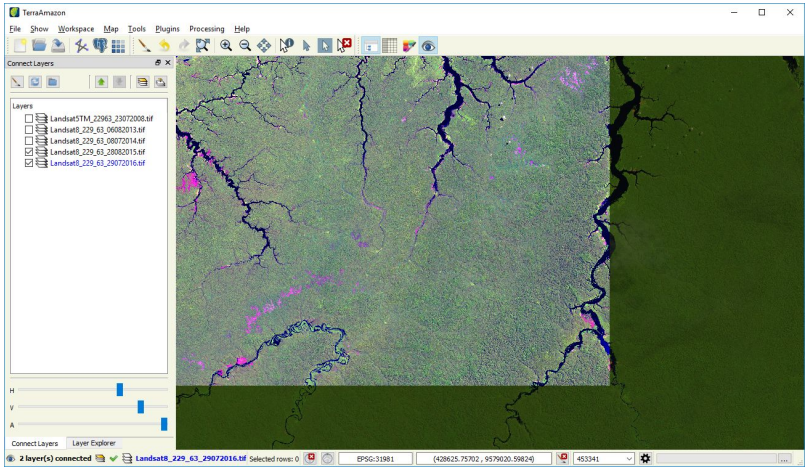


Data Analysis

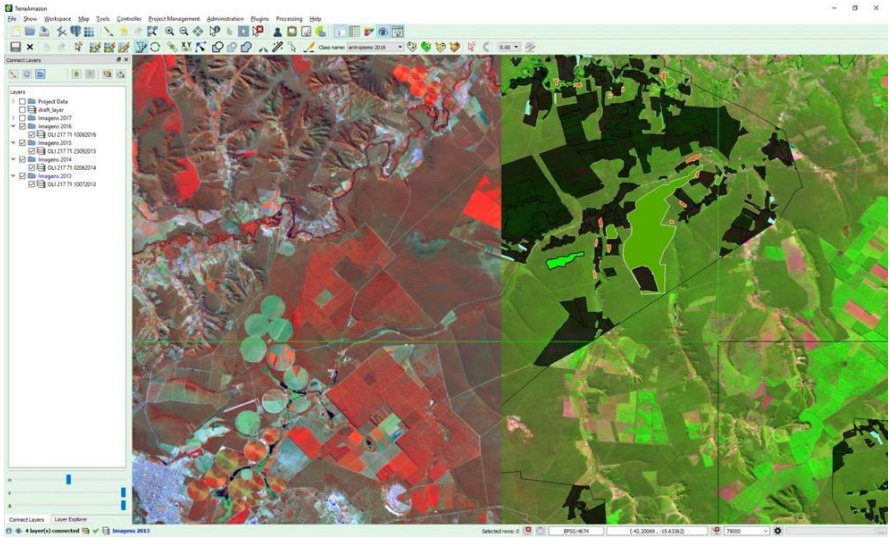
TerraAmazon provides image processing functions, band composition, contrast, LSMM, segmentation, classification, cloud detection, and others



Data visualization



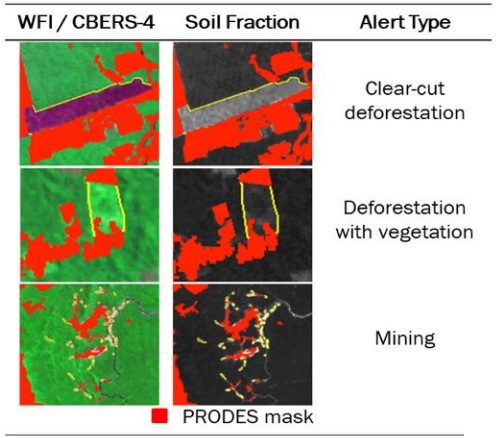
Images from consecutive years



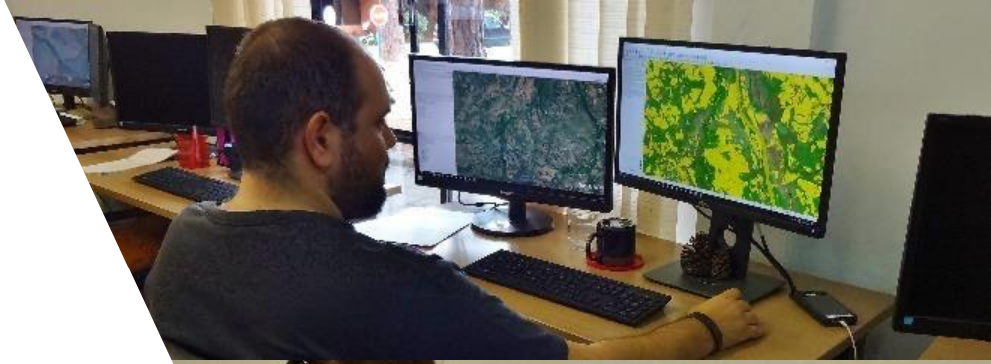
PRODES deforestation mask

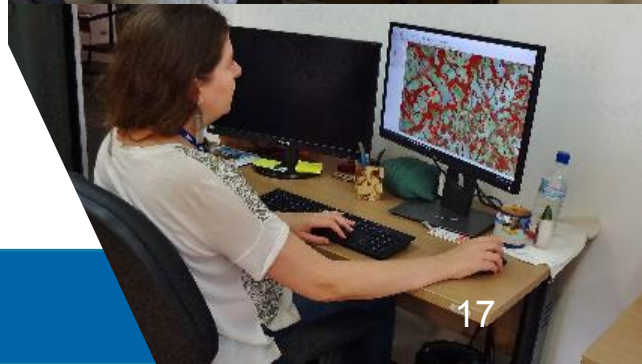
Data visualization

DETER alerts



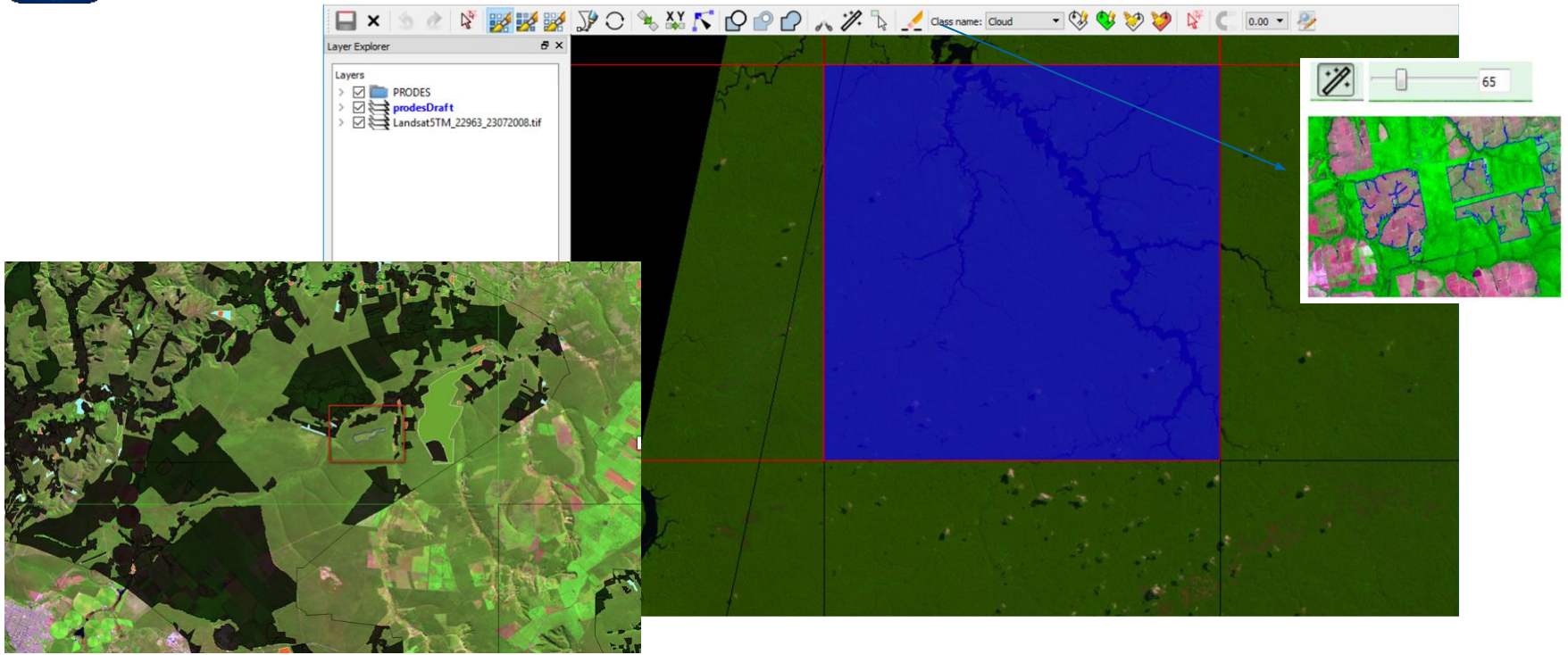
PRODES clear cut: Magenta / reddish or very light green (faded). Regular shape, smooth texture, well-defined boundaries between the polygon with exposed soil and the forest



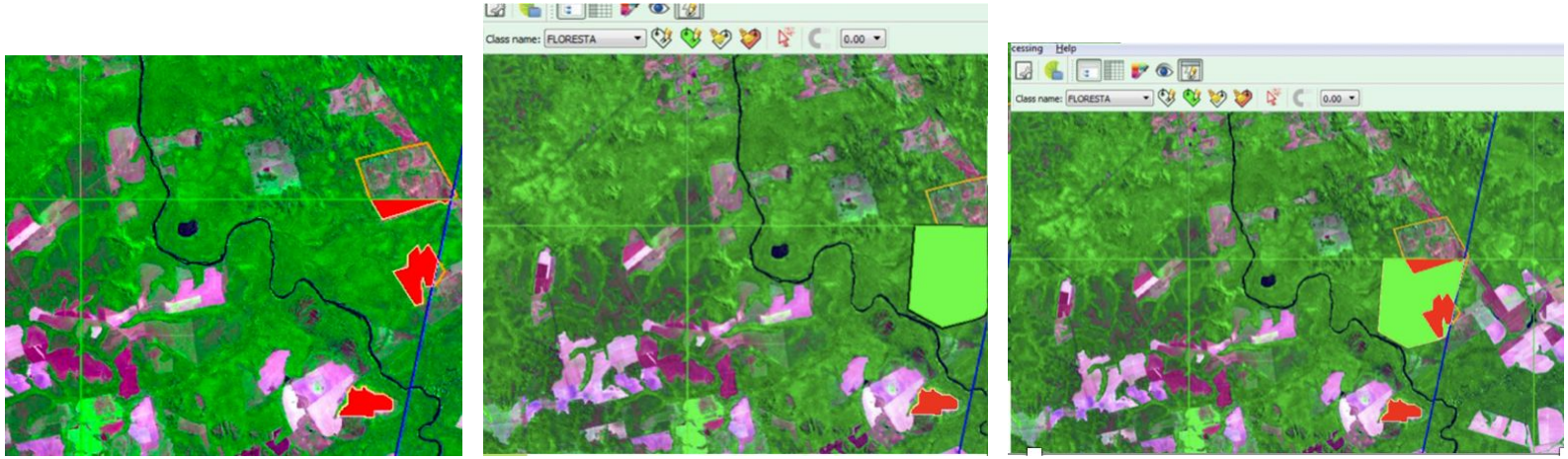


Vector Edition

snap / split / magic wand / topological correction



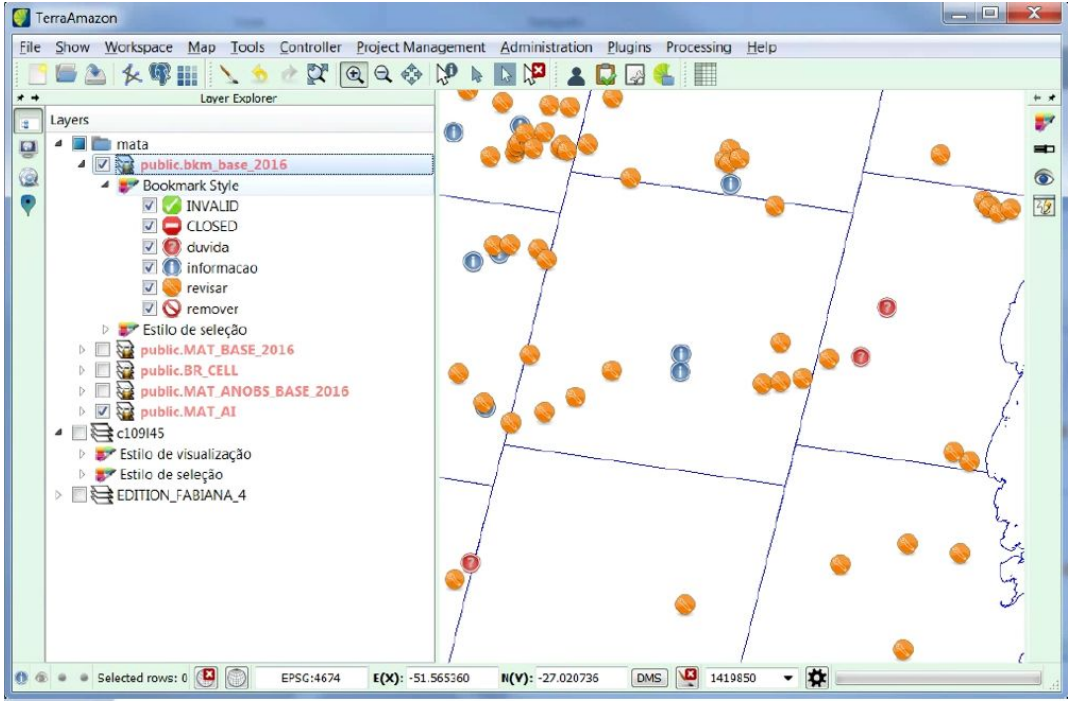
Vector Edition



Instantaneous and automatic maintenance of the topology consistency and the compliance with the rules for the project

Auditing

Change geometries or annotate them with text, photos, image clips to identify mapping errors or difficulties

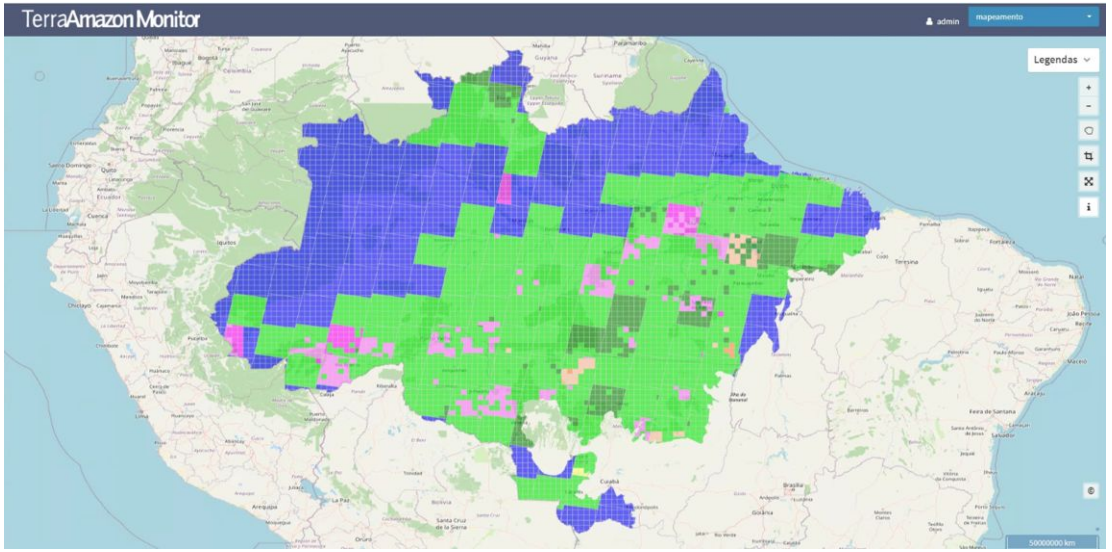


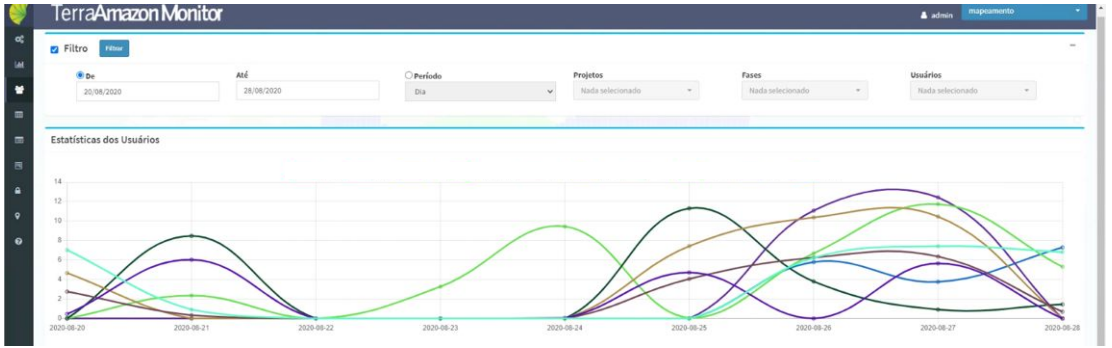
TerraAmazon Monitor

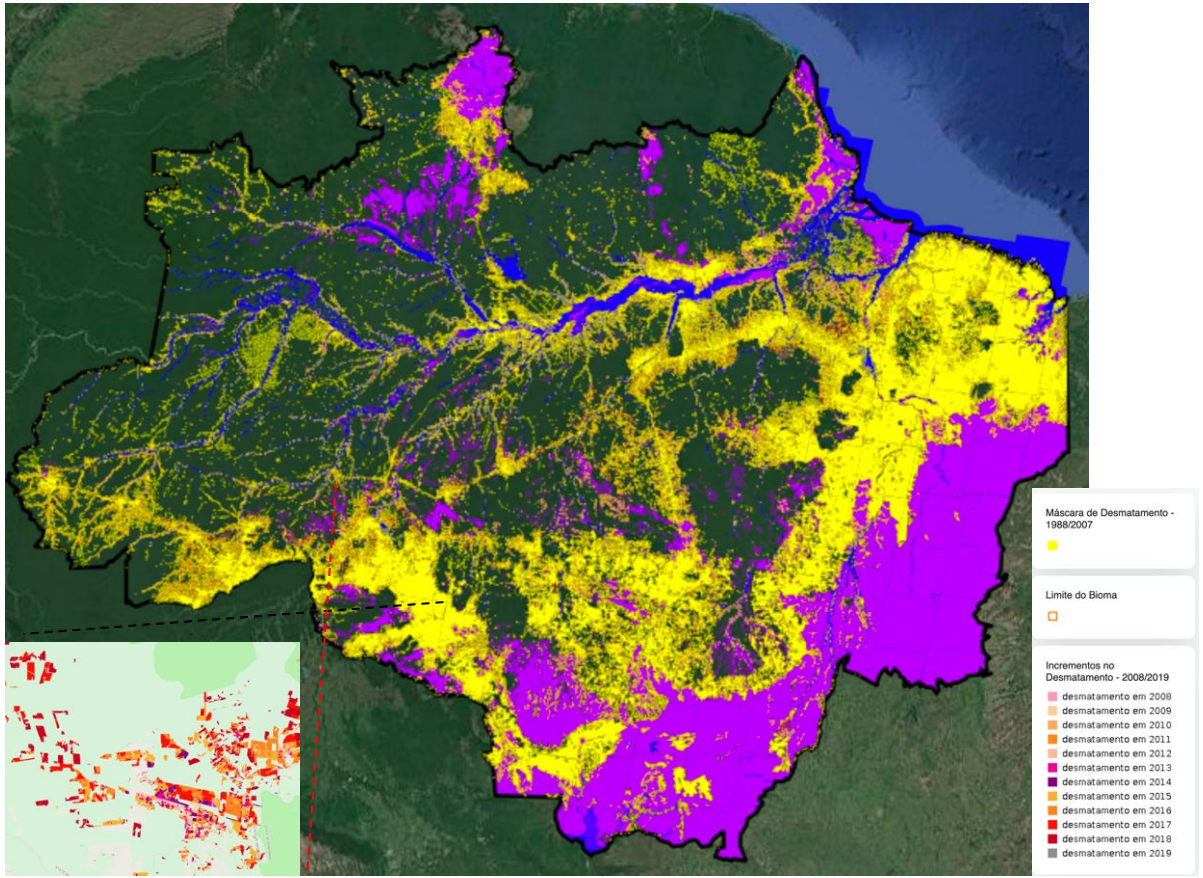
Web application to a monitor progress and production at user and team level

TerraAmazon Offline

Part of the database extracted to a local computer, limiting the internet connection only necessary at the download/upload steps





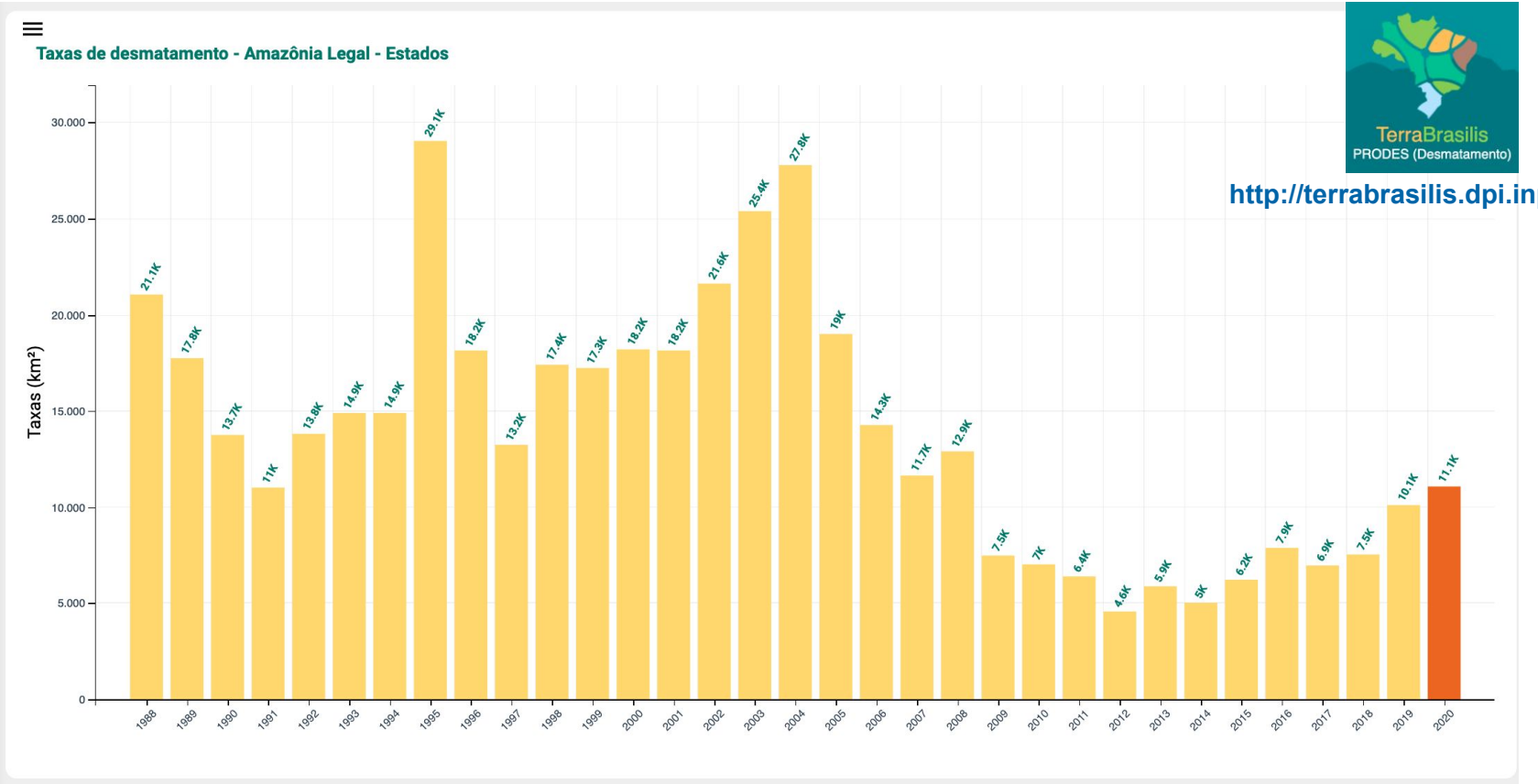


TerraBrasilis
PRODES (Desmatamento)

http://terrabrasilis.dpi.inpe.br

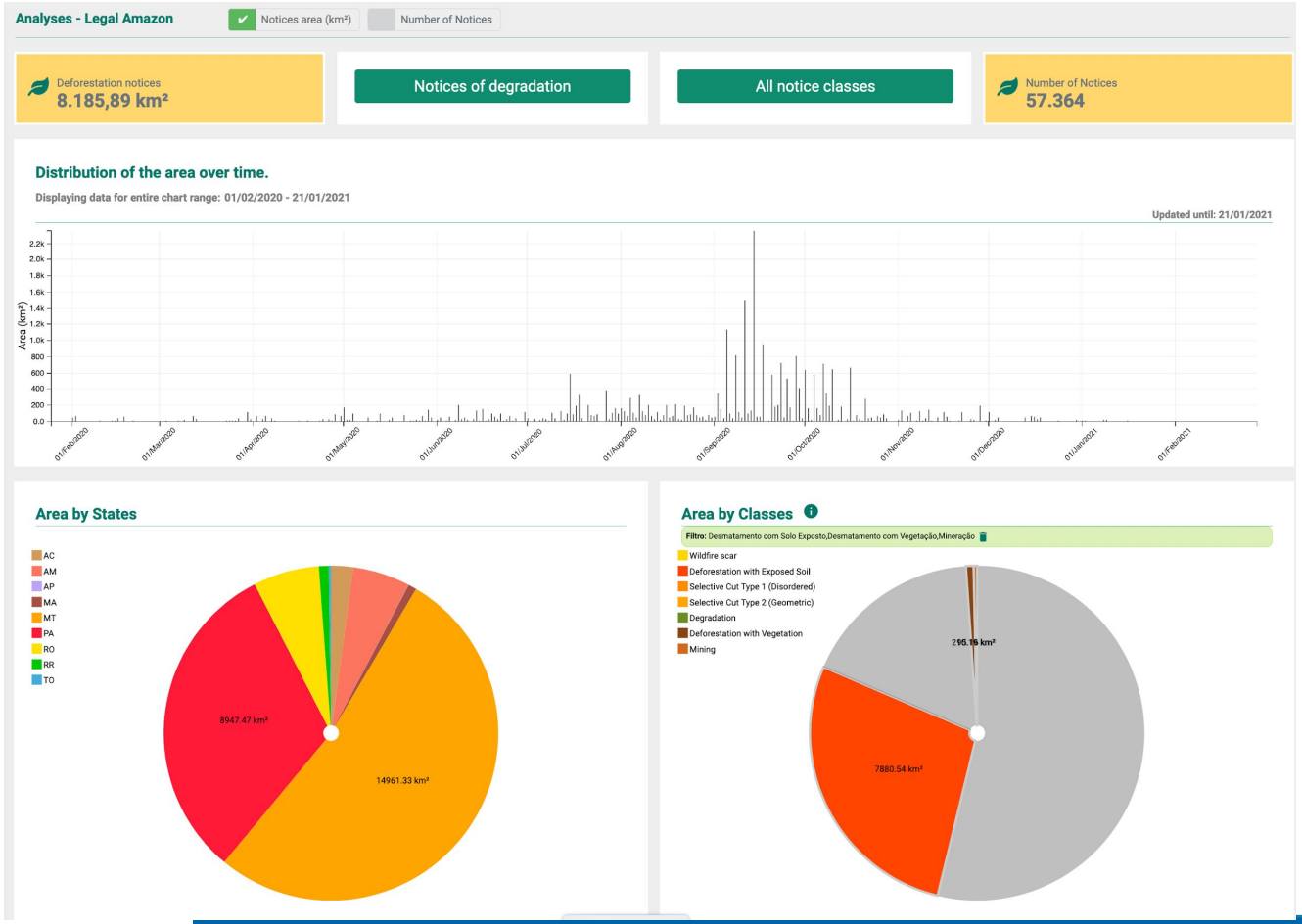
The data from PRODES and DETER, generated using TerraAmazon, are published online through the TerraBrasilis portal.

Users can see the data, download it or consume it through using web services clients.



TerraBrasilis
PRODES (Desmatamento)

http://terrabrasilis.dpi.inpe.br



TerraBrasilis
PRODES (Desmatamento)

http://terrabrasilis.dpi.inpe.br

DETER dashboard showing alerts per day

An open software "ecosystem"

Mapping data

Imagery

…

Internet/Intranet

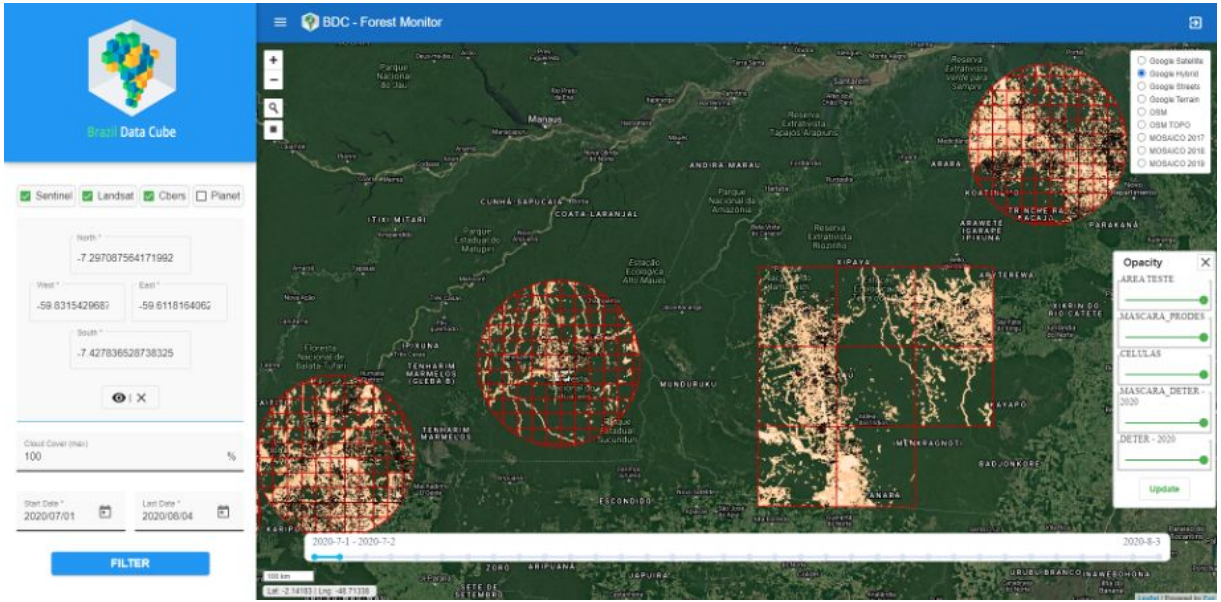
…

…

Forest Monitor + DETER Intenso

Web application based on the Amazon Web Services, to use data from AWS buckets directly on a web browser.

Prototype running in 7 priority areas of the Amazon, using CBERS, Landsat and Sentinel buckets



FUNCATE
Fundação de Ciência, Aplicações e Tecnologia Espaciais

http://www.terraamazon.dpi.inpe.br

lubia.vinhas@inpe.br (@VinhasLubia)

daniel.silva@inpe.br

jfkneipp@gmail.com

Q&A and discussion

30 minutes

Short break

5 minutes

Dr Karine R. Ferreira
Associate Professor
INPE

Karine Reis Ferreira works at the Brazilian National Institute for Space Research – INPE, with research in Geoinformatics and coordinating technological innovation projects, such as TerraLib, TerraBrasilis and Brazil Data Cube (http://brazildatacube.org/).

She holds a PhD in Applied Computing and she is an Associate Professor of Geoinformatics in the Applied Computing Graduate Course at INPE. Her main research topic is: representation, processing and analysis of spatiotemporal and big Earth observation data.

Dr Gilberto R. Queiroz
Associate Professor
INPE

Gilberto is a senior technologist at the National Institute for Space Research (INPE). He works in research and development projects related to the geotechnologies that supports the activities of the program of Monitoring Amazon and Other Brazilian Biomes.

Since 2016 he is an Associate Professor of Geoinformatics and Geospatial Data Science at INPE. Currently, he is one of the Brazil Data Cube project leaders and his research interests include remote sensing applied to LULC mapping and geospatial big data platforms.

Brazil Data Cube

Technological innovation to improve environmental monitoring

Karine R. Ferreira

Gilberto R. Queiroz

National Institute for Space Research, Brazil – INPE

Brazil Data Cube (BDC)

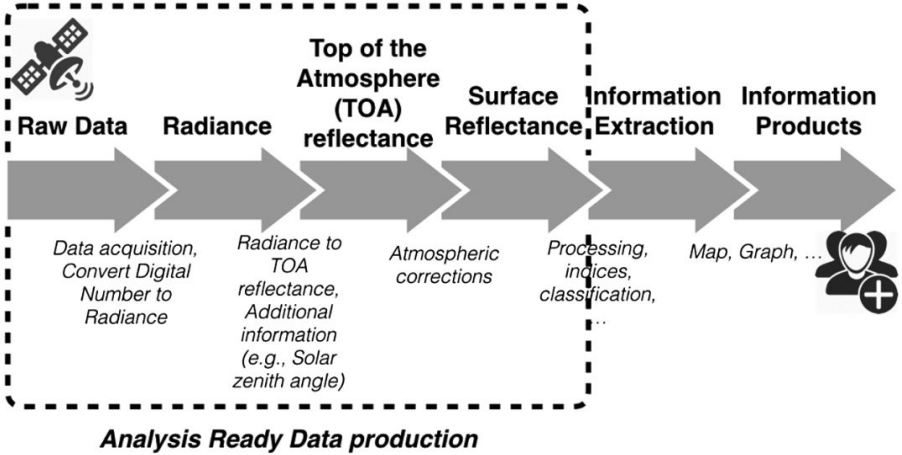
Started in 2019.

(Goal 1) *Analysis-Ready Data* (ARD) of Landsat-8, Sentinel-2 and CBERS-4 for Brazil

(Goal 2) Multidimensional data cubes from ARD collections

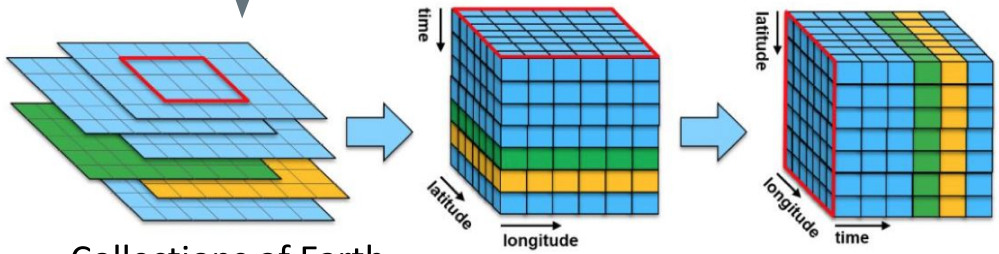
(Goal 3) Big Earth observation data management and analysis

(Goal 4) Land use and cover information for Brazil



Analysis Ready Data production

Source: [Giuliani et al, 2017]



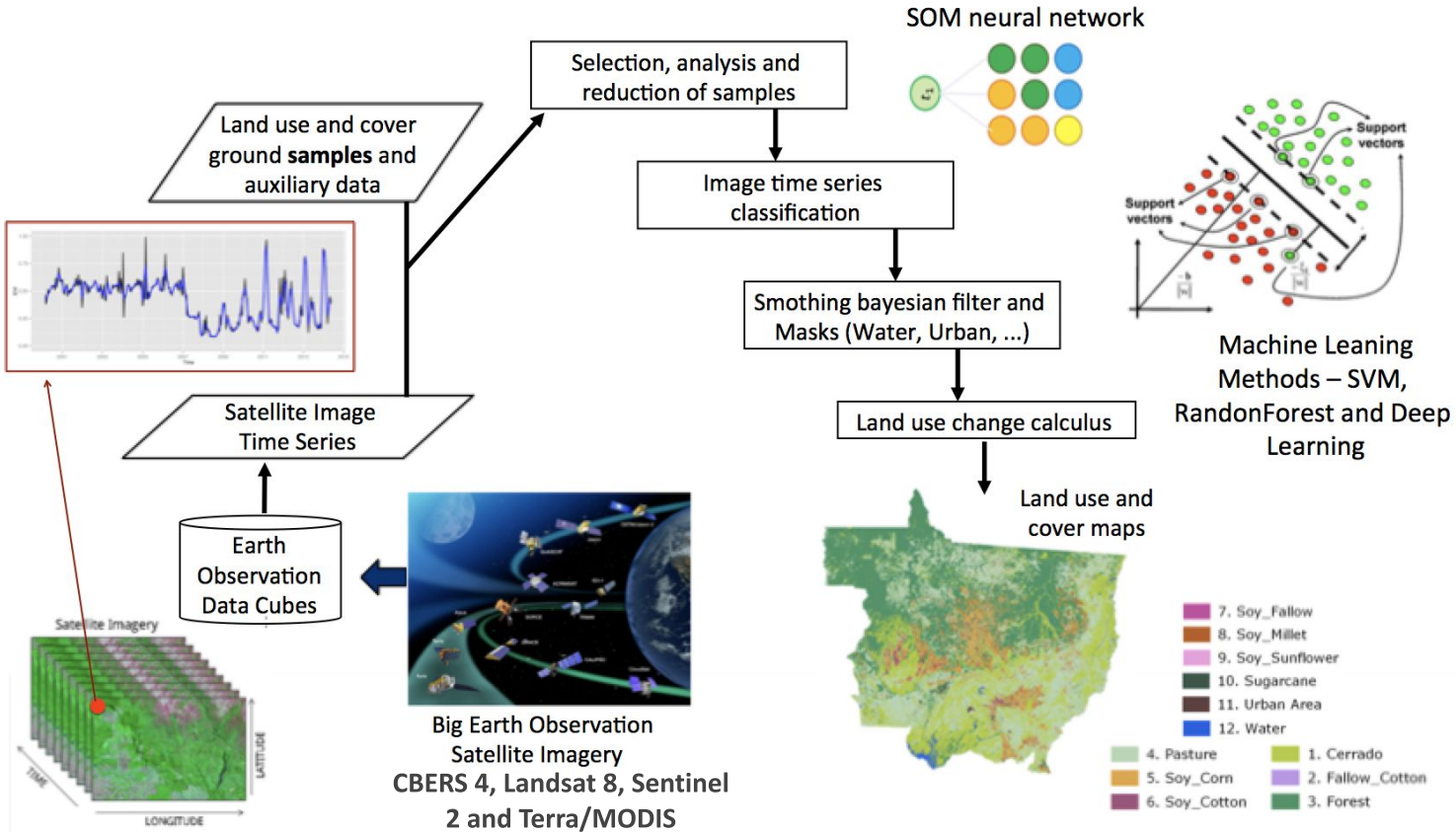
Collections of Earth observation satellite imagens – ARD

Data cubes – four-dimensional array.

Source: [Kopp et al,

BDC - Overview

SITS (Satellite Image Time Series) R package:
https://github.com/e-sensing



ARD and 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

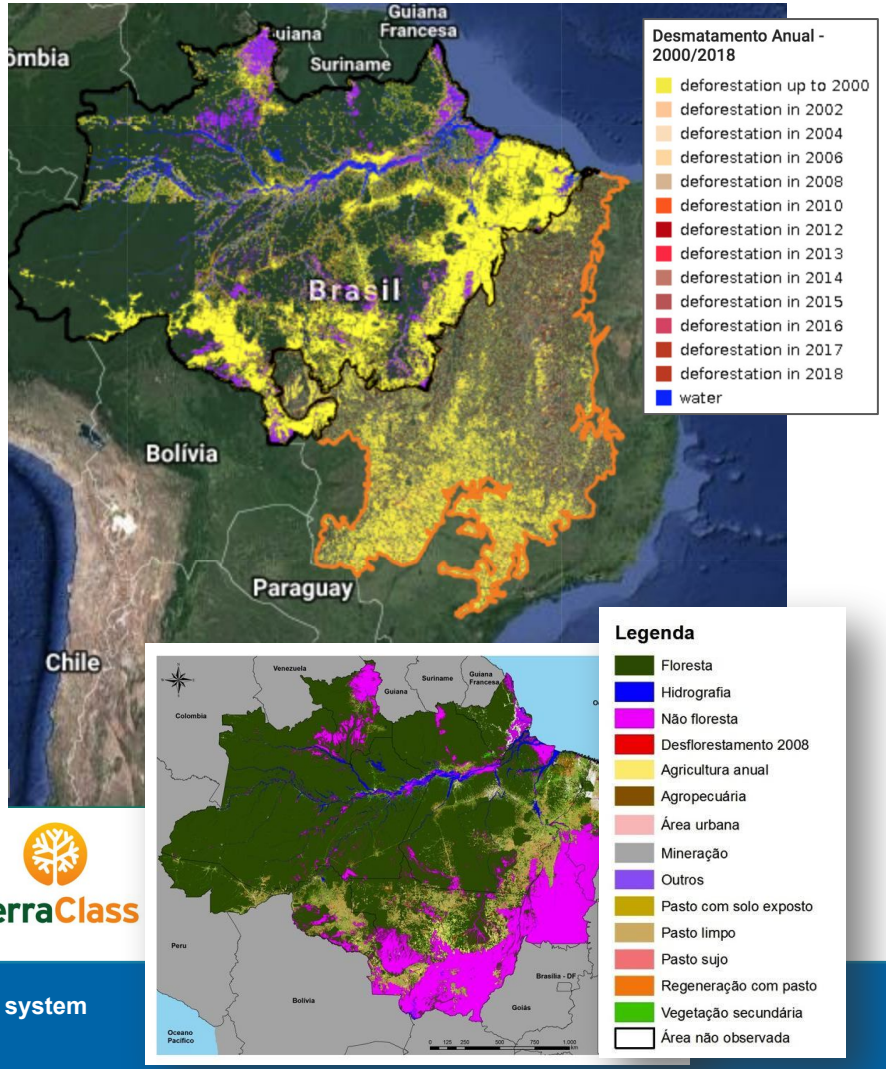
BDC – Motivation

Technological innovation to improve environmental monitoring projects developed by INPE

PRODES: clear cut deforestation

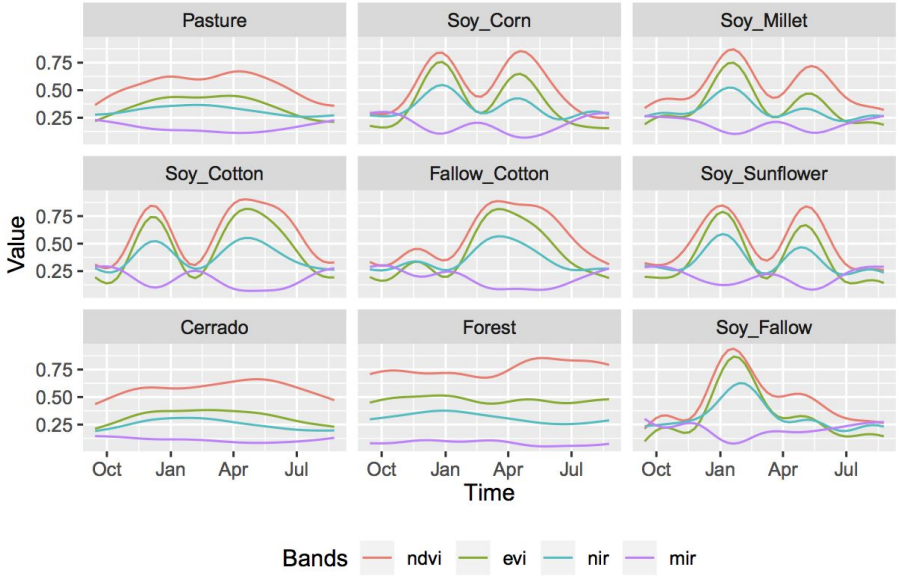
DETER: alerts of deforestation

TerraClass: identify what the deforested areas detected by PRODES have become.



BDC – Motivation

Image time series analysis for continuous land use and cover monitoring



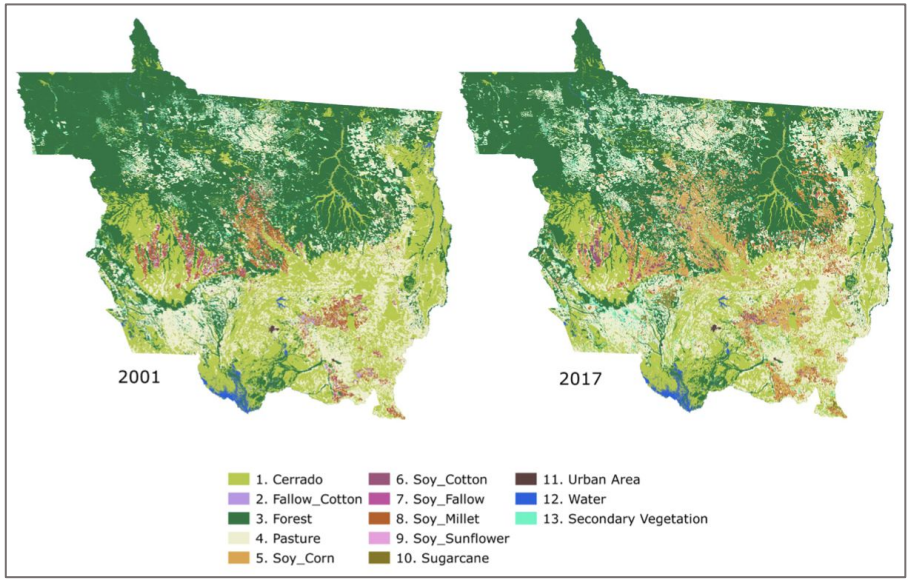


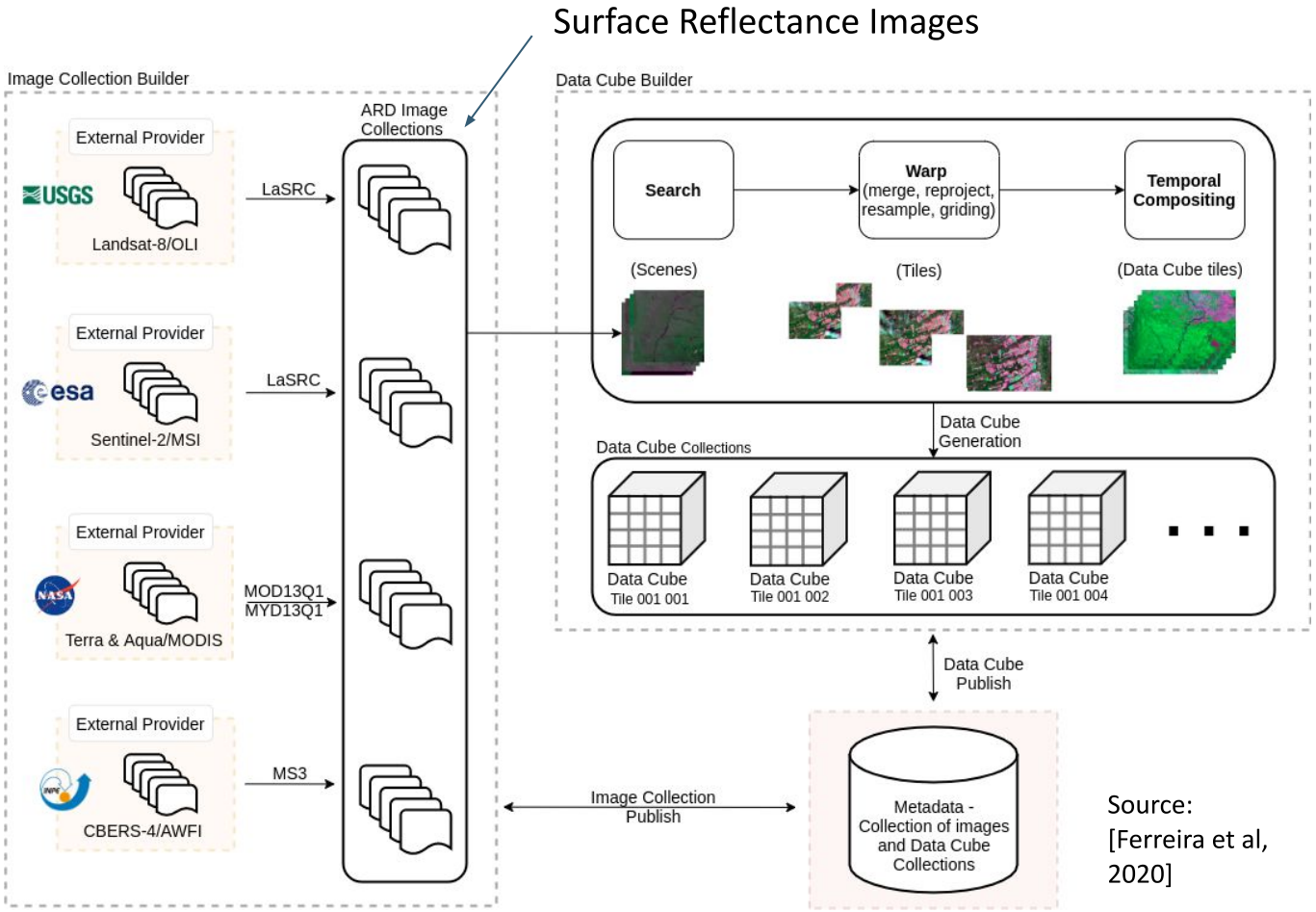
Image time series NDVI, EVI, NIR, MIR - agriculture year
MODIS – MOD13Q1 Product
Method – SVM (Support Vector Machine)

Land use and cover maps for Mato Grosso State in Brazil from 2001 to 2017, Scientific Data, 2020 (Simoes et al., 2020)

Building data cubes

Step 01:

Create Analysis-Ready Data (ARD) image collections

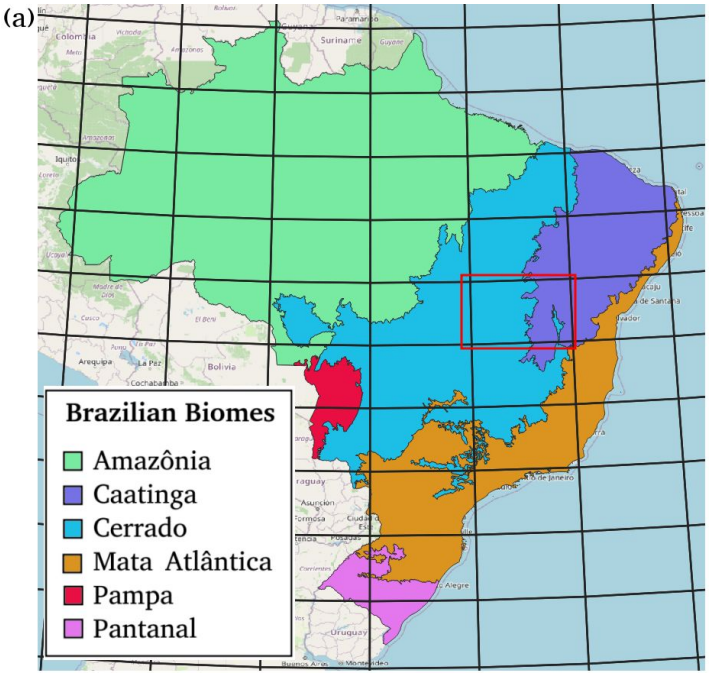


Source: [Ferreira et al, 2020]

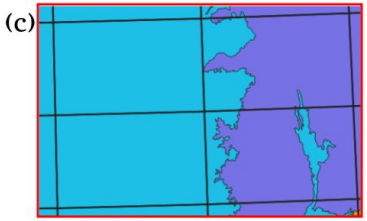
Building data cubes

Hierarchical tiling system

Three grids that are used to create the data cubes



Grid: BDC – Large
Each tile: 6 x 4 degrees



Grid: BDC – Medium
Each tile: 3 x 2 degrees

Grid: BDC – Small
Each tile: 1.5 x 1 degree

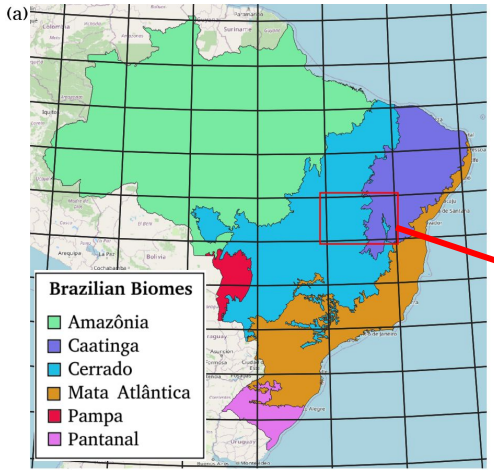
Projection: Albers equal area and Datum: SIRGAS 2000

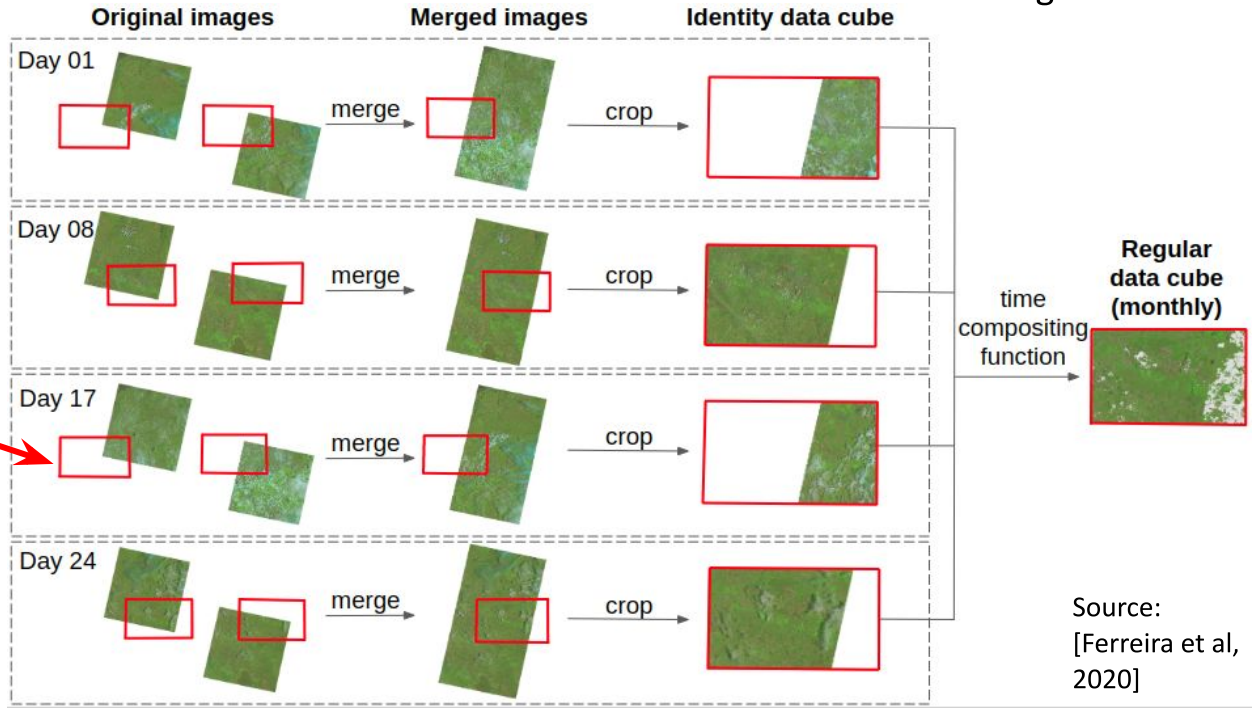
Source: [Ferreira et al, 2020]

Building data cubes

Step 02:
Build data cubes for each grid tile from ARD image collections

process to create a monthly data cube, considering one BDC grid tile

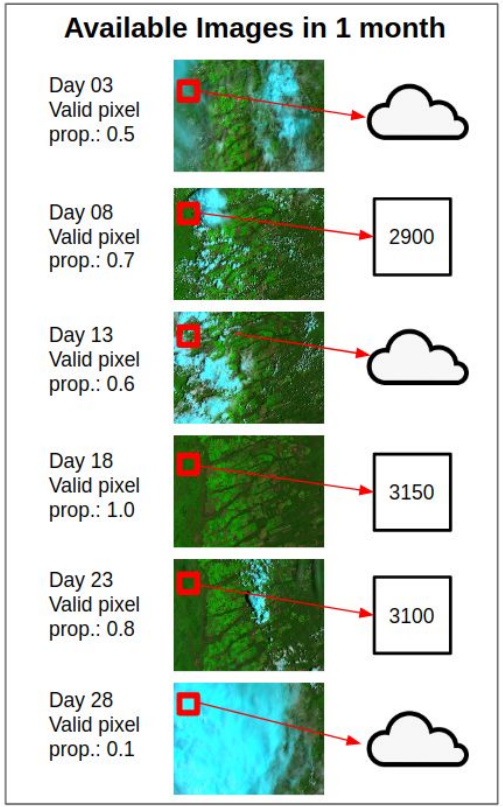


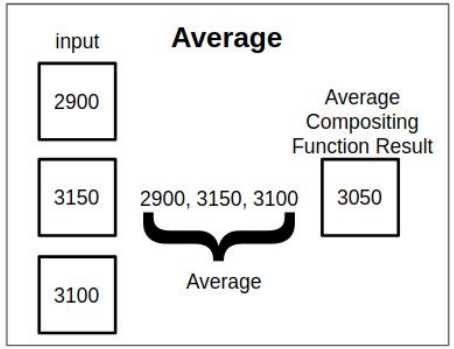


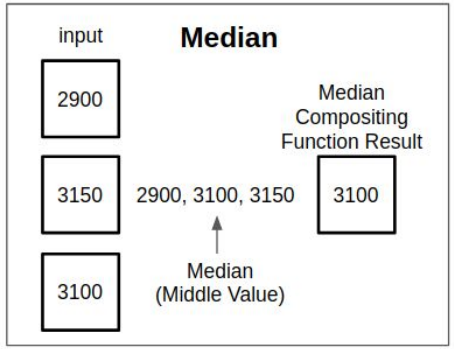
Source: [Ferreira et al, 2020]

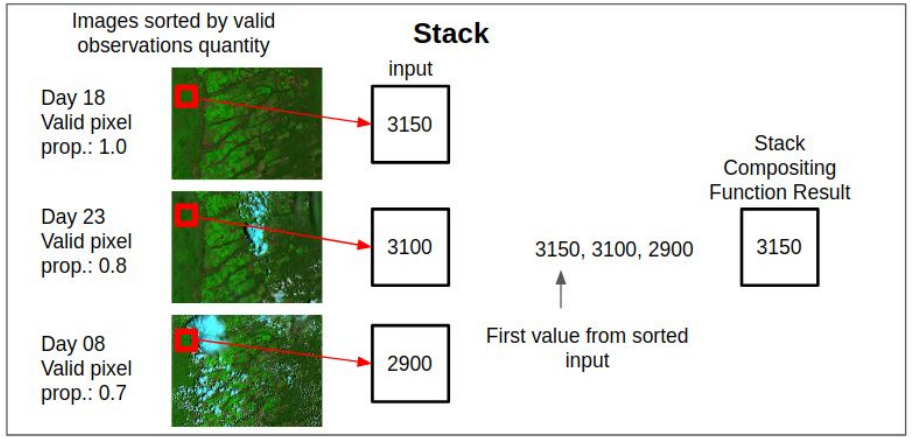
Building data cubes

Time Compositing





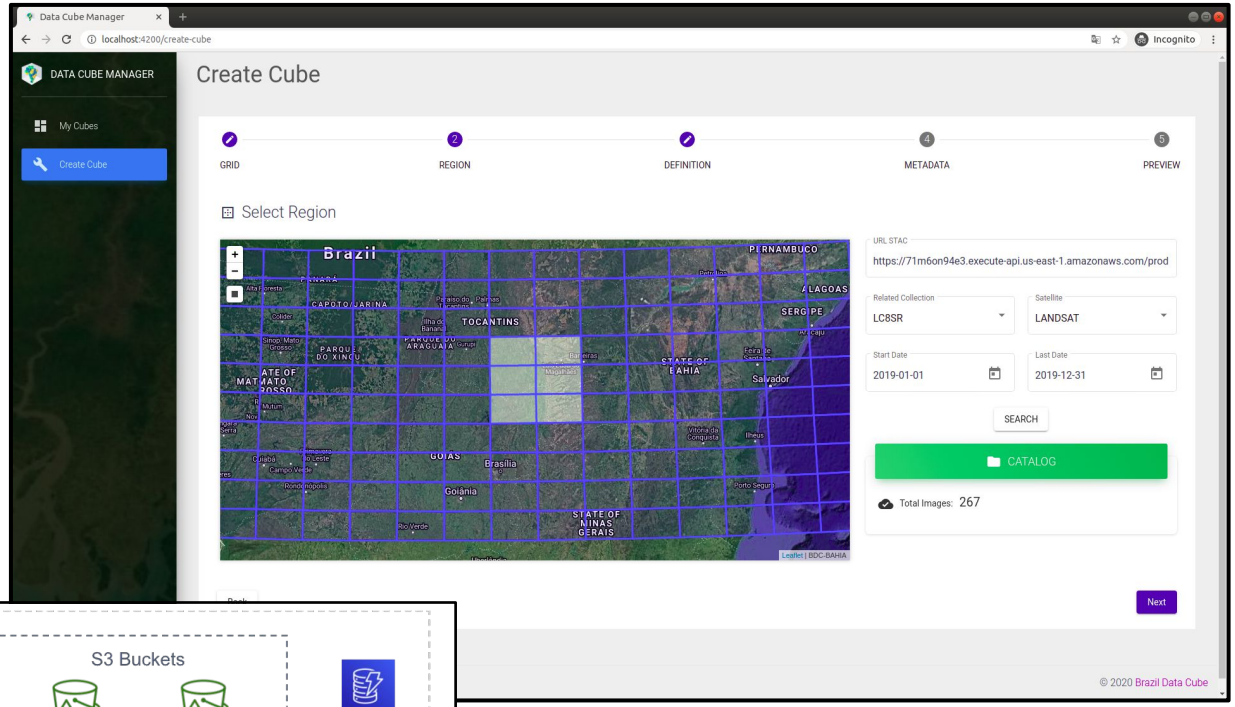


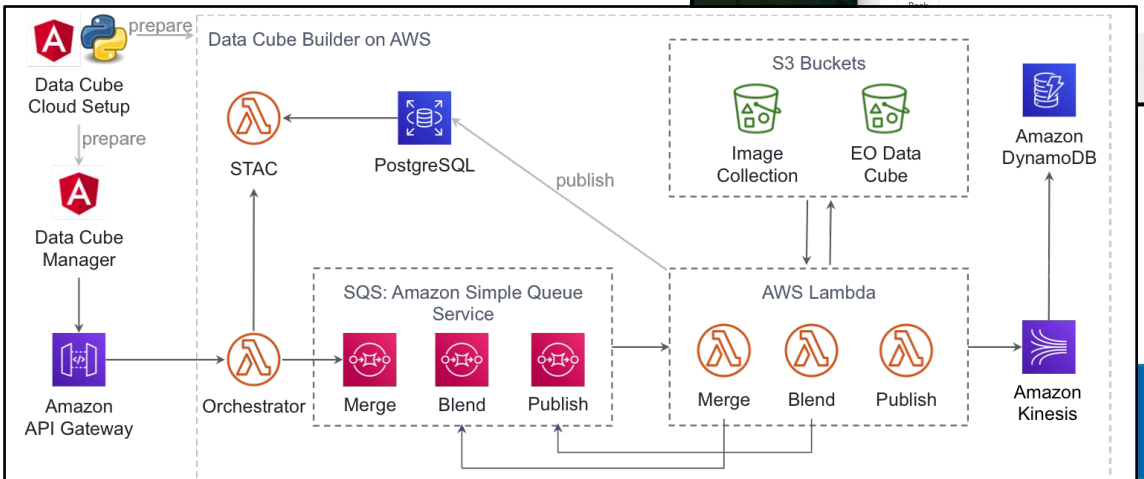


Source: [Ferreira et al, 2020]

Building data cubes

Open source
python scripts and
a web application with GUI



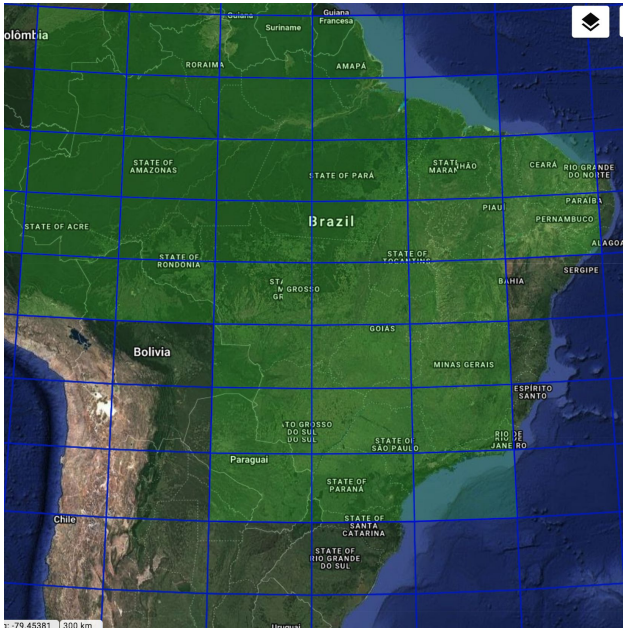


Two versions:

1. on-premises hardware
2. AWS using lambda services.

BDC Tiling Grids

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



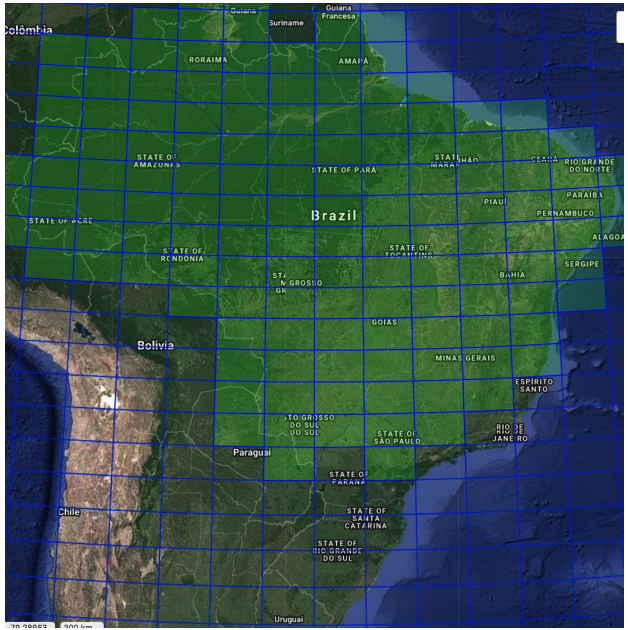
BDC – Large

Each tile: 6 x 4 degrees

CBERS-4/WFI – 64 meters

Each file (band/tile): 170 MB

Each tile: ~ 1 GB



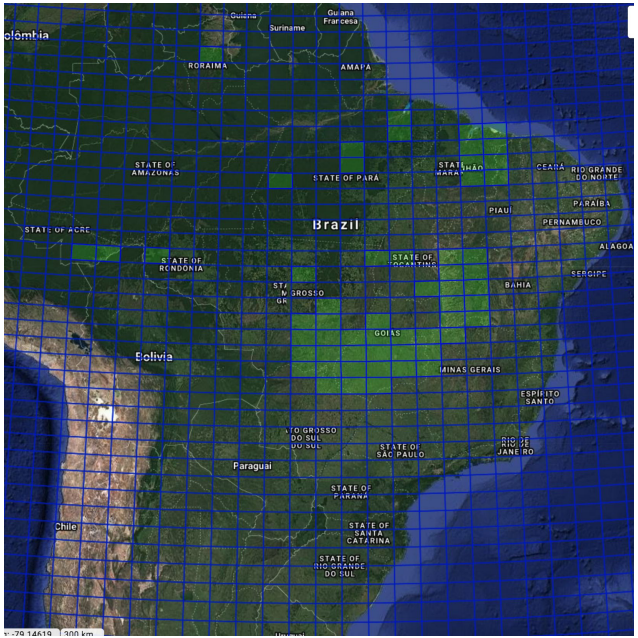
BDC – Medium

Each tile: 3 x 2 degrees

Landsat-8/OLI – 30 meters

Each file (band/tile): 200 MB

Each tile: ~ 2 GB



BDC – Small

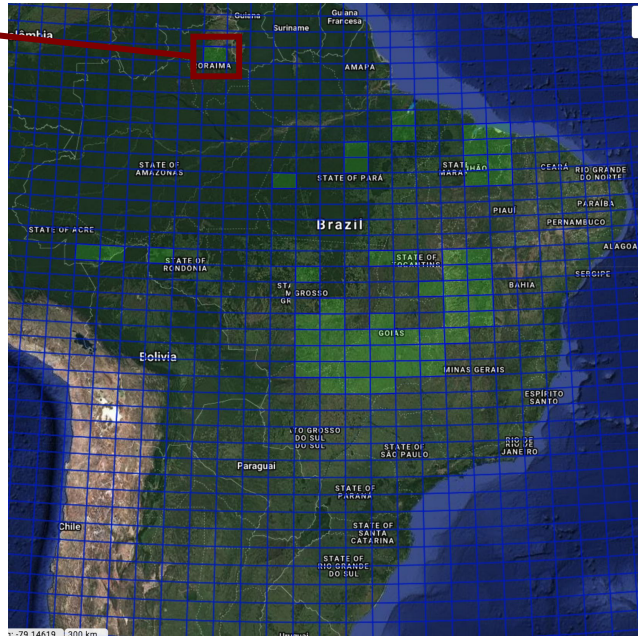
Each tile: 1.5 x 1 degree

Sentinel-2/MSI – 10 meters

Each file (band/tile): 400 MB

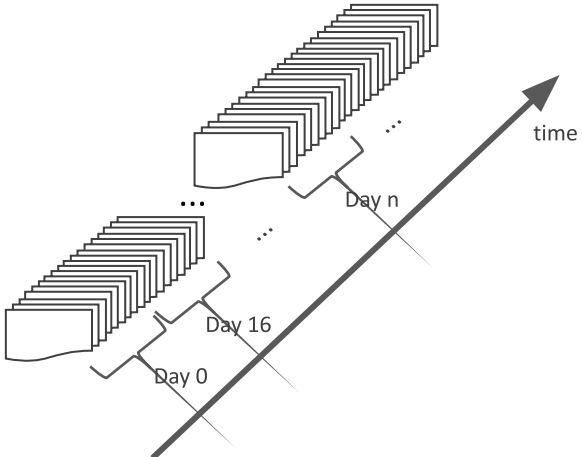
Each tile: ~ 5.4 GB

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



BDC – Small
Each tile: 1.5 x 1 degree

Sentinel-2/MSI – 10 meters
Each file (band/tile): 400 MB
Each tile: ~ 5.4 GB

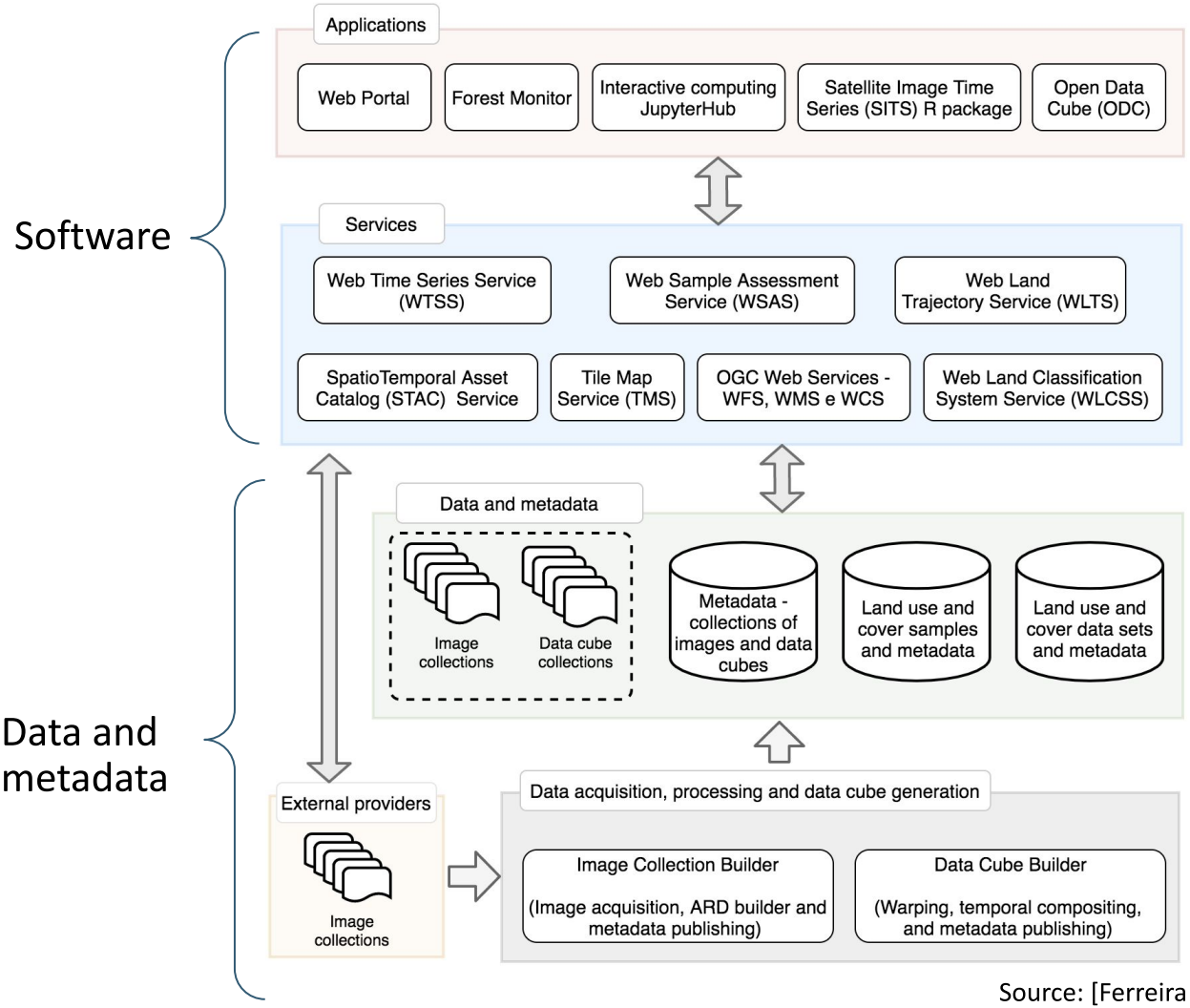


For each *tile* and *time step*, there are a set of COG (Clould Optimized GeoTIFF) files:

(1) Spectral bands from original images; (2) Spectral indices (EVI and NDVI); (3) Cloud mask; (4) valid observations (excluding cloud, cloud shadow..); (5) data provenace; ...

BRAZIL
DATA CUBE

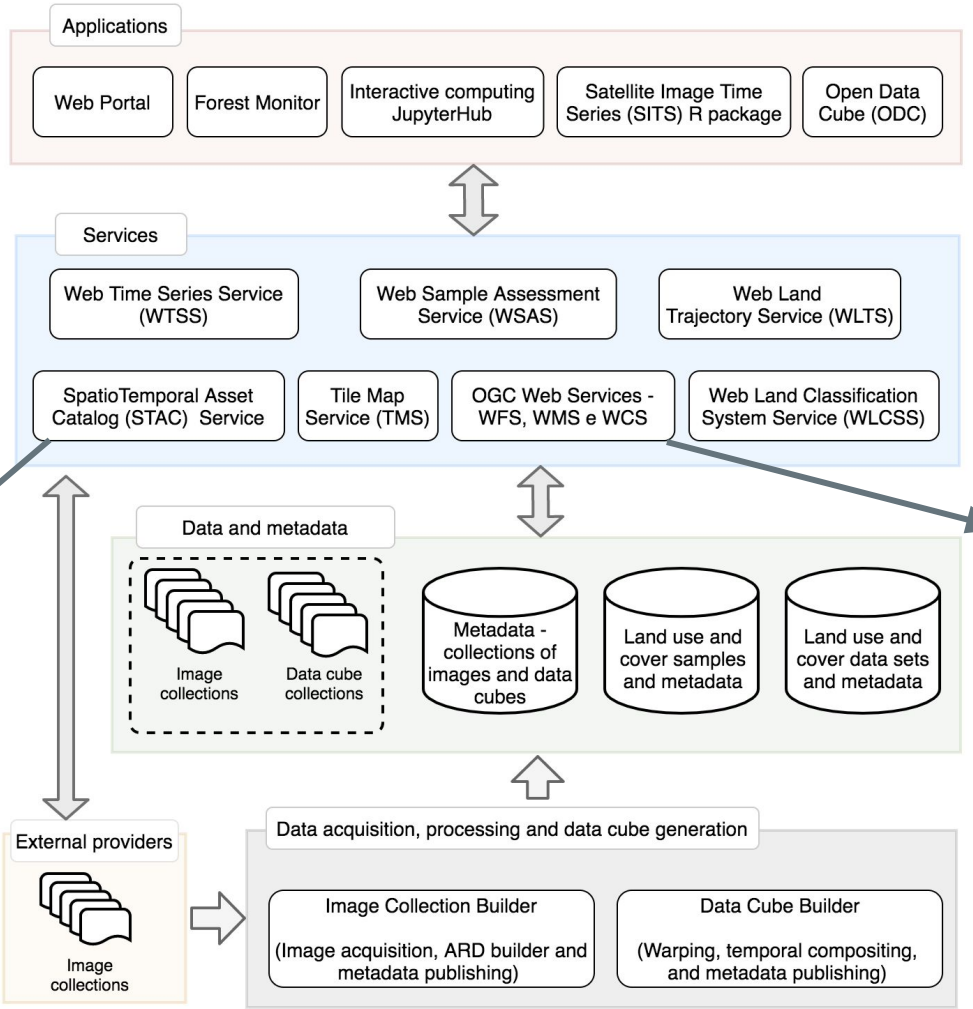
Open Data and Software Products



Source: [Ferreira et al, 2020]

BRAZIL
DATA CUBE

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



OGC™
Open Geospatial Consortium, Inc.

Source: [Ferreira et al, 2020]

Source: [Vinhas et al., 2016]

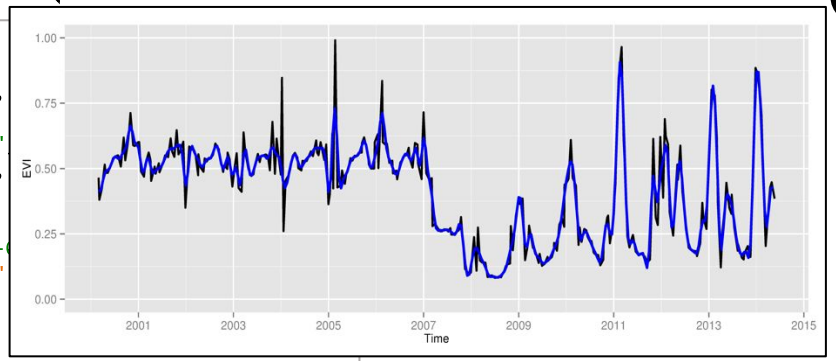
Web Time Series Service (WTSS)

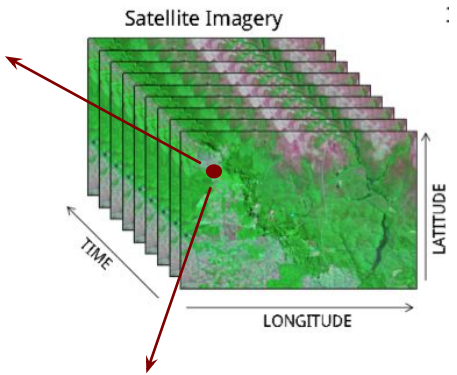
WTSS Client

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

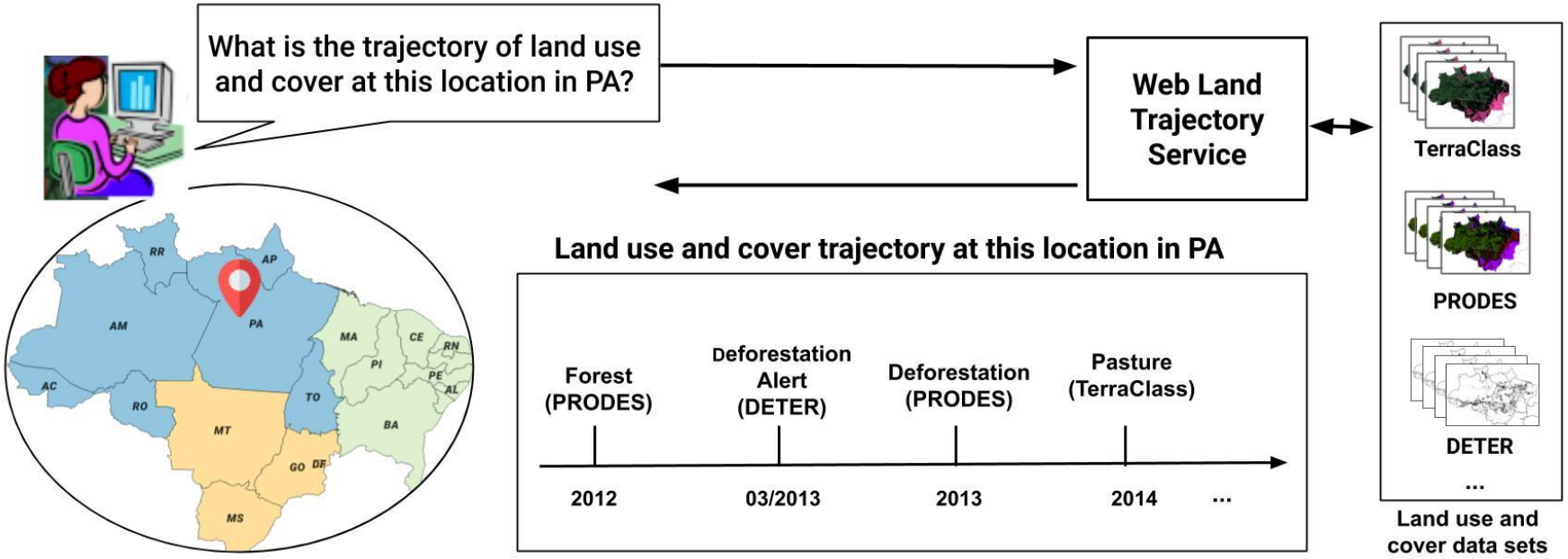



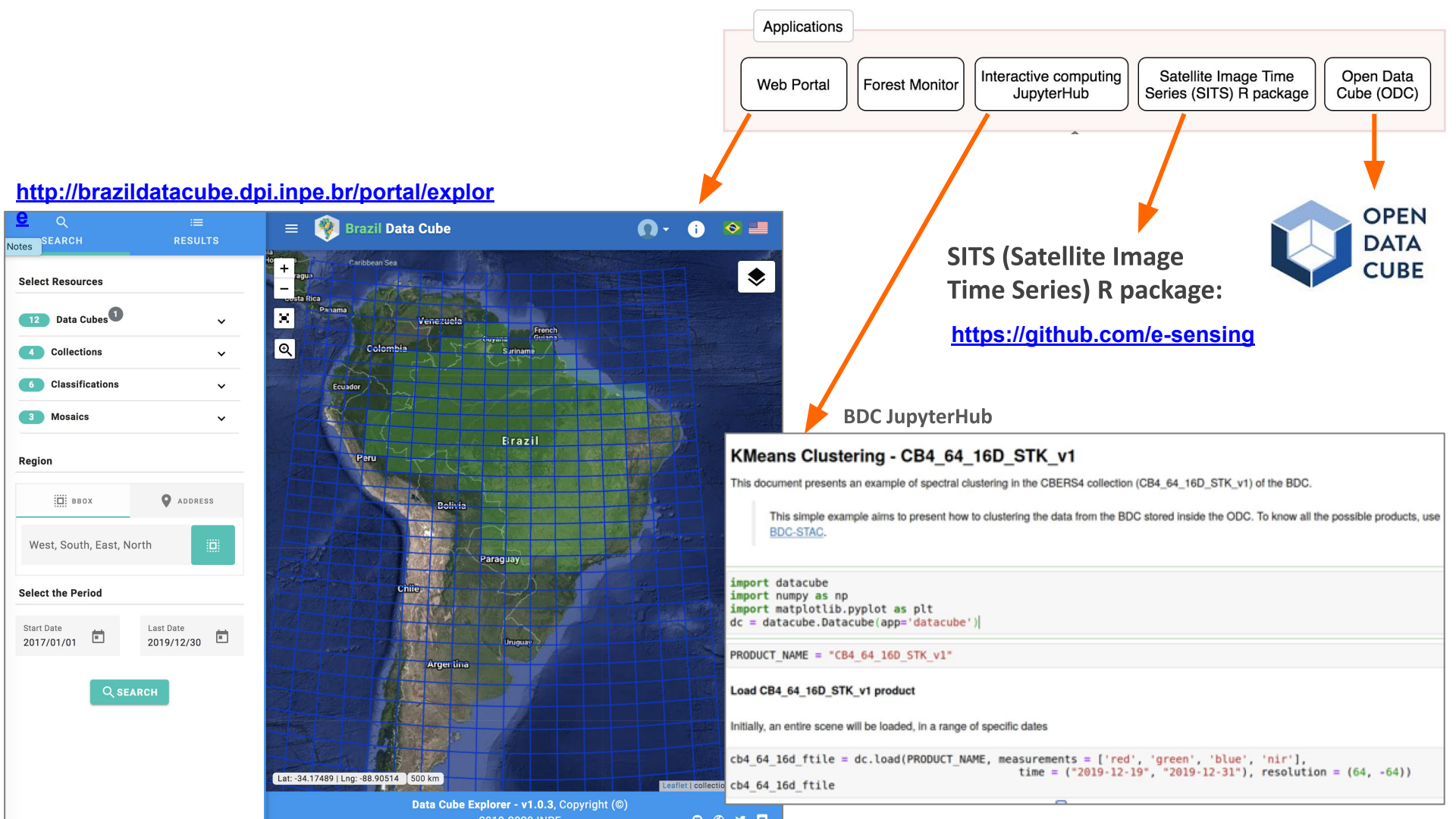


(longitude=-54,latitude=-12)

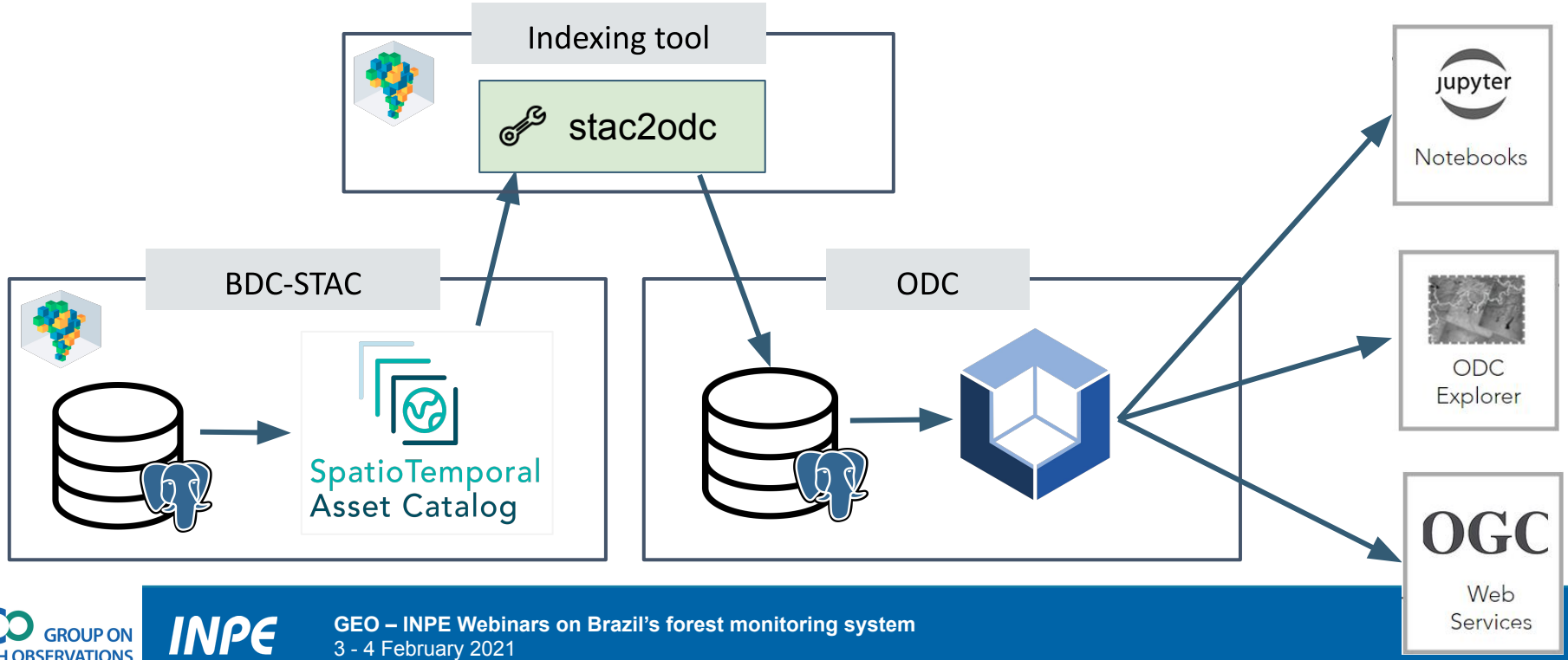
Web Land Trajectory Service (WLTS)

Source: [Ferreira et al, 2020]



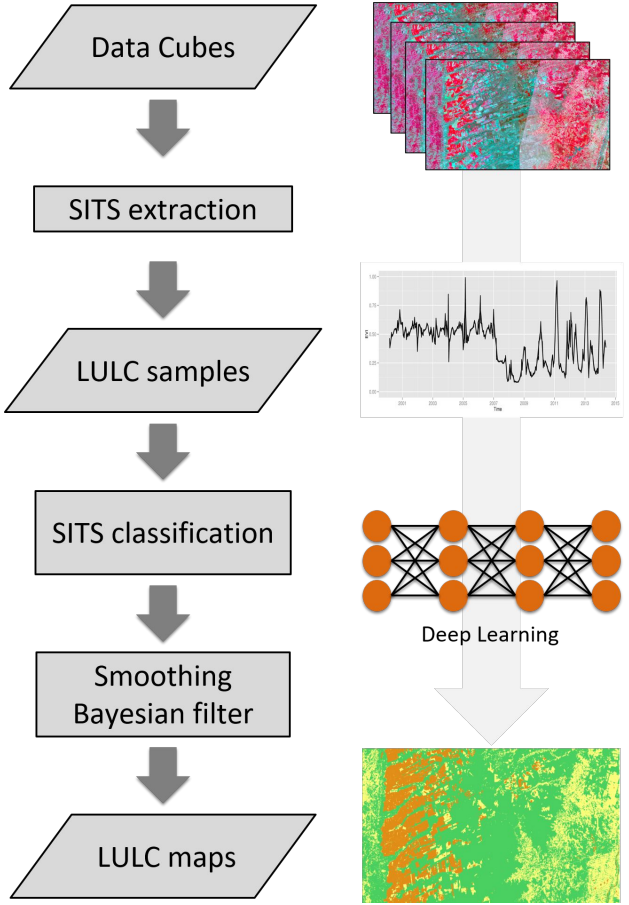

Applications
Web Portal
Forest Monitor
Interactive computing JupyterHub
Satellite Image Time Series (SITS) R package
Open Data Cube (ODC)
http://brazildatacube.dpi.inpe.br/portal/explor
e
Notes
SEARCH
RESULTS
Select Resources
12 Data Cubes
4 Collections
6 Classifications
3 Mosaics
Region
BBOX
ADDRESS
West, South, East, North
Select the Period
Start Date
2017/01/01
Last Date
2019/12/30
SEARCH
Brazil Data Cube
Caribbean Sea
Costa Rica
Panama
Venezuela
Colombia
Guyana
French Guiana
Suriname
Ecuador
Brazil
Peru
Bolivia
Paraguay
Chile
Uruguay
Argentina
Lat: -34.17489 | Lng: -88.90514
500 km
Leaflet | collectio
Data Cube Explorer - v1.0.3, Copyright (©)
SITS (Satellite Image Time Series) R package:
https://github.com/e-sensing
OPEN DATA CUBE
BDC JupyterHub
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 the BDC.
This simple example aims to present how to clustering the data from the BDC stored inside the ODC. To know all the possible products, use BDC-STAC.
import datacube
import numpy as np
import matplotlib.pyplot as plt
dc = datacube.Datacube(app='datacube')
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
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

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



Land use and cover information from BDC data cubes using machine learning and time series analysis

Process to create land use and cover maps from EO data cubes using Satellite Image Time Series (SITS) analysis and machine learning methods



Data cubes: Sentinel-2, CBERS-4 and Landsat-8

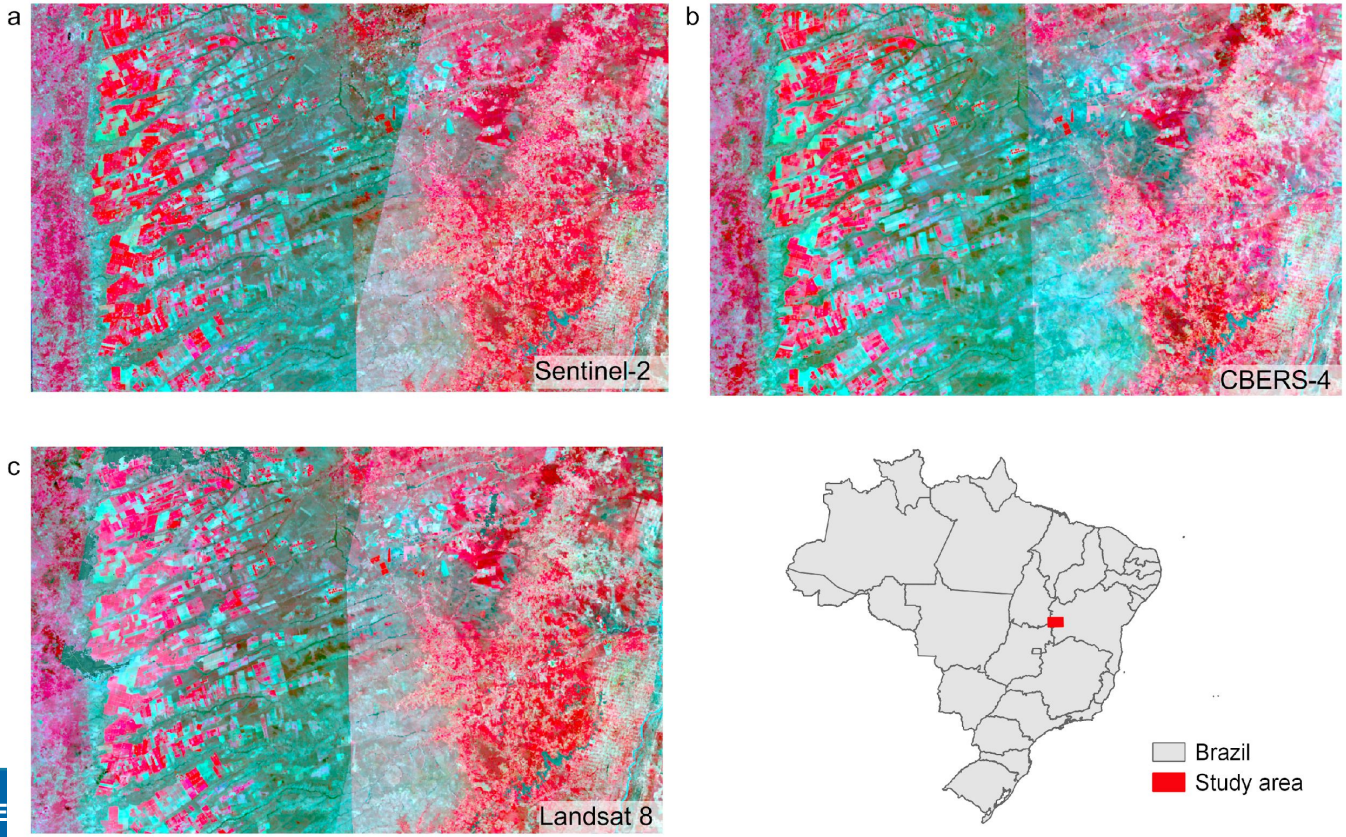
Examples of three **MONTHLY** data cubes -**STACK** from images of:

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

Period: Aug-2018 to July-2019

Agricultural calendar year

January, 2019

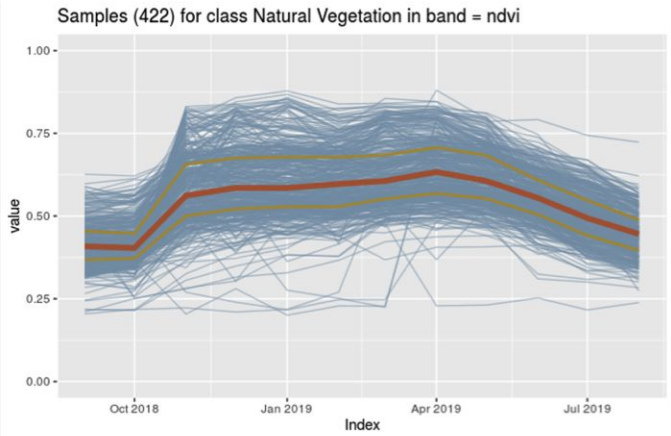


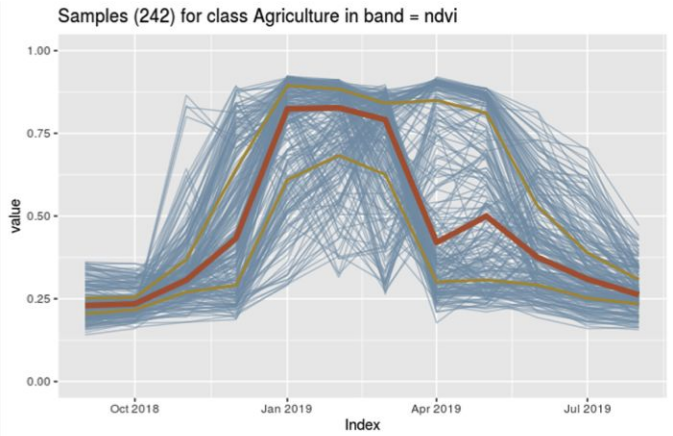
Samples

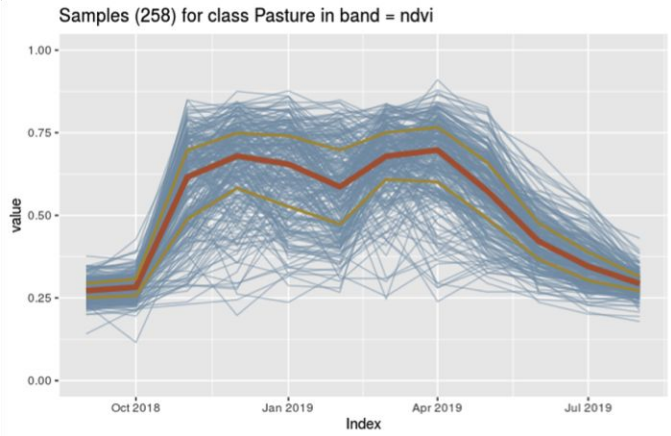
Examples of NDVI time series extracted from the CBERS-4 data:
(1) Natural Vegetation
(2) Agriculture
(3) Pasture

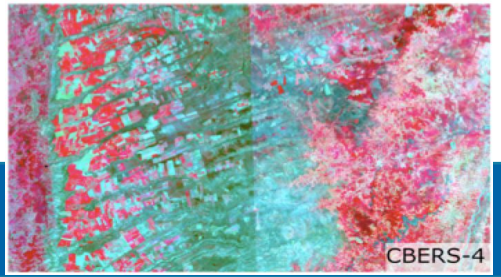
NDVI time series from Aug-2018 to July-2019

Agricultural calendar year









Results

Land use and cover classification results

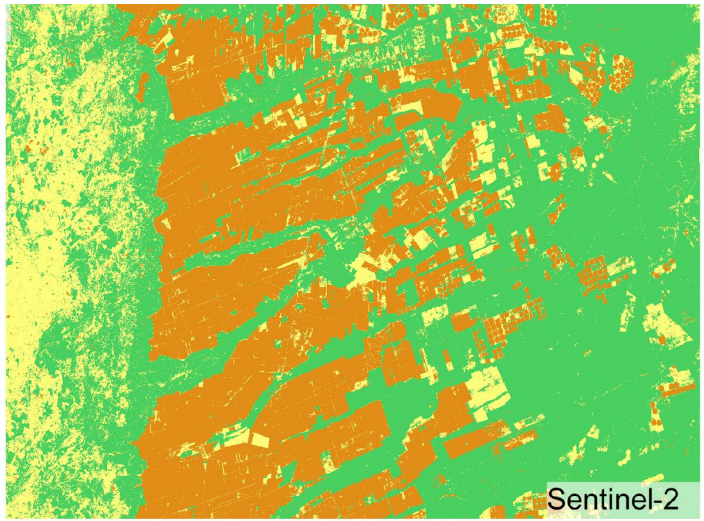
Ago-2018 to July-2019

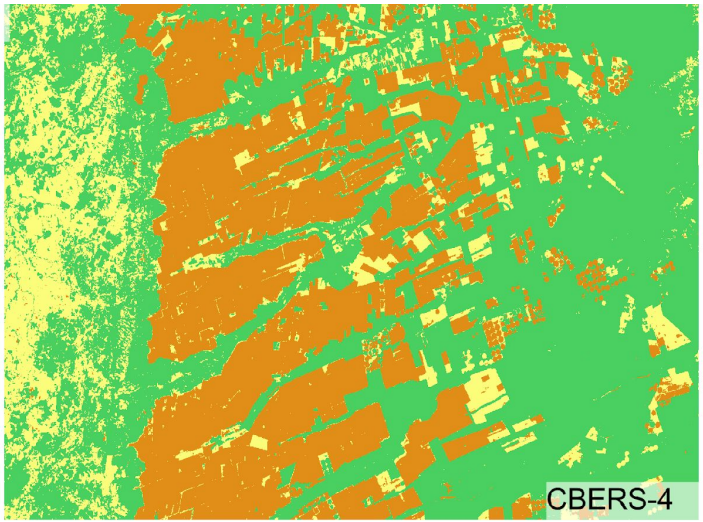
Vegetation indices and bands: NDVI, EVI, blue, green, red, near-infrared (nir).

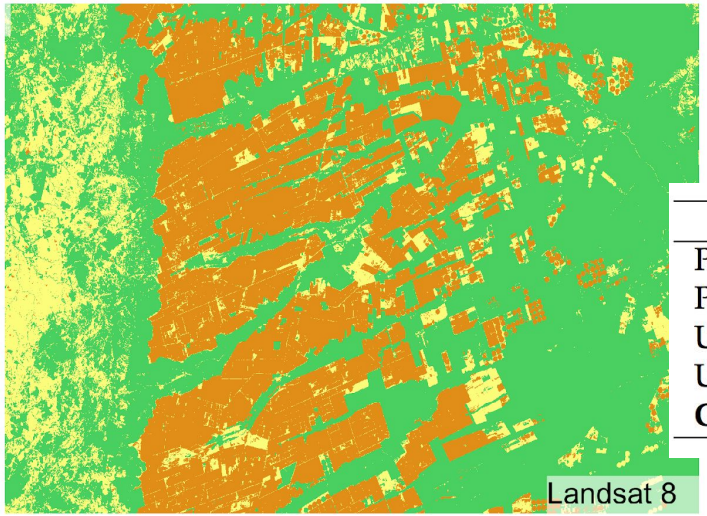
Deep learning classifier – Multi-layer perceptron – 5 layers and 512 neurons.

SITS (Satellite Image Time Series) R package on AWS

Validation using PRODES Cerrado







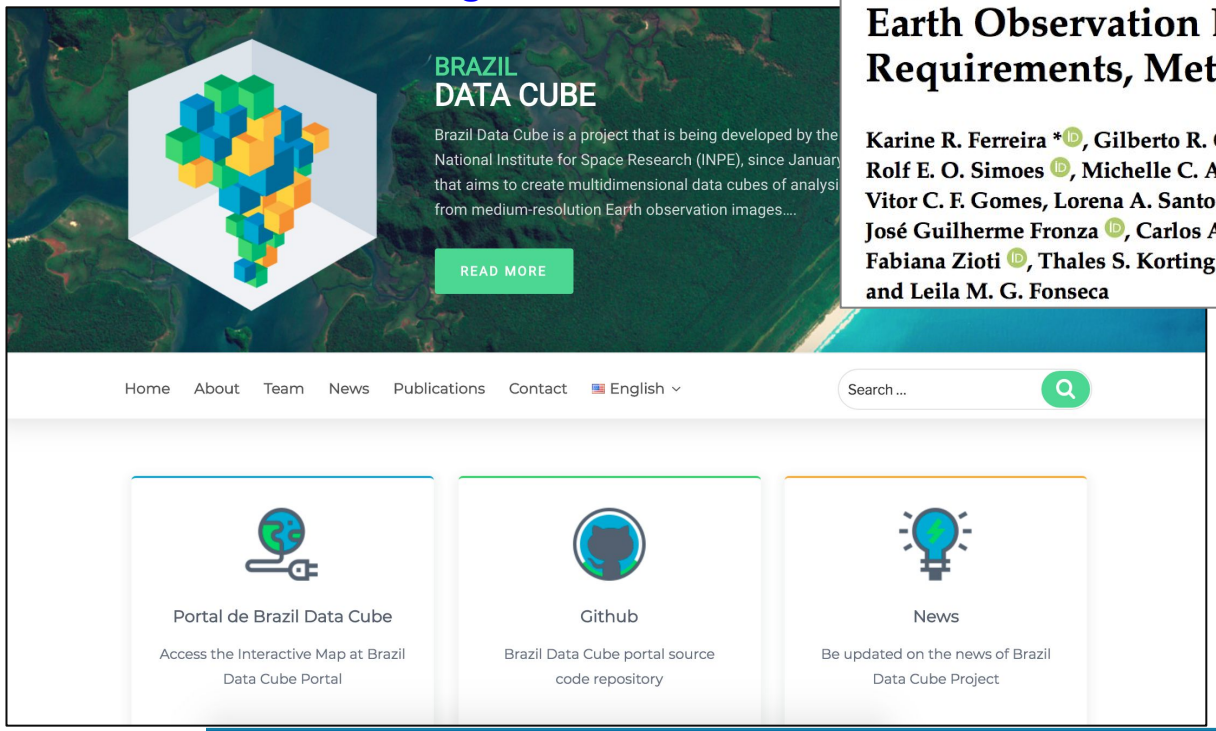
Agriculture
Natural Vegetation
Pasture

	CBERS-4	Sentinel-2	Landsat 8
PA Anthropic	0.81	0.90	0.94
PA Nat. Veg.	0.67	0.84	0.85
UA Anthropic	0.71	0.85	0.86
UA Nat. Veg.	0.78	0.90	0.94
OA	**0.74**	**0.87**	**0.90**

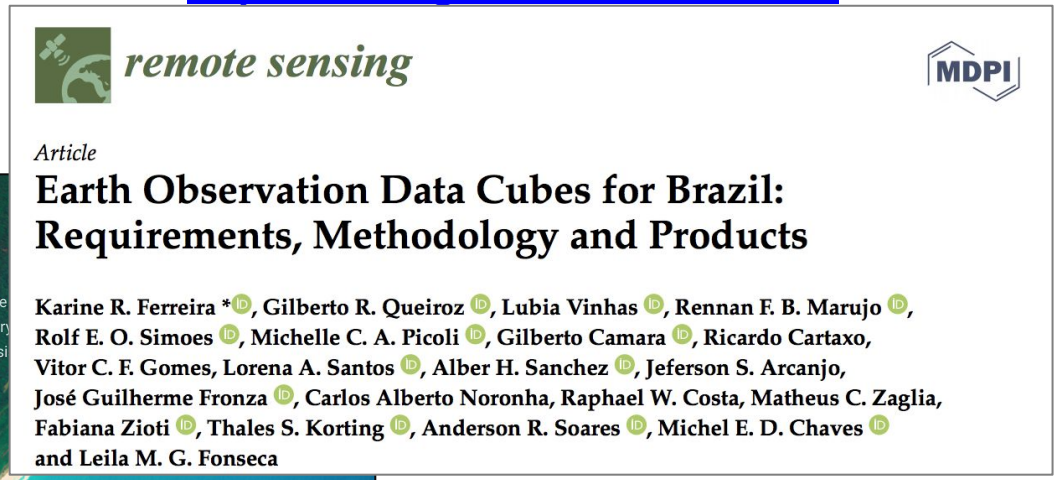
Producer's Accuracy (PA), User's Accuracy (UA), and Overall Accuracy (OA)

More information about BDC

www.brazildatacube.org



https://doi.org/10.3390/rs12244033



Published: December, 2020

Main Challenge – Big volume of satellite images

Data volume estimation: ~ 750 Terabytes (TB)

CBERS-4
(AWFI)

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

Landsat-8
(OLI)

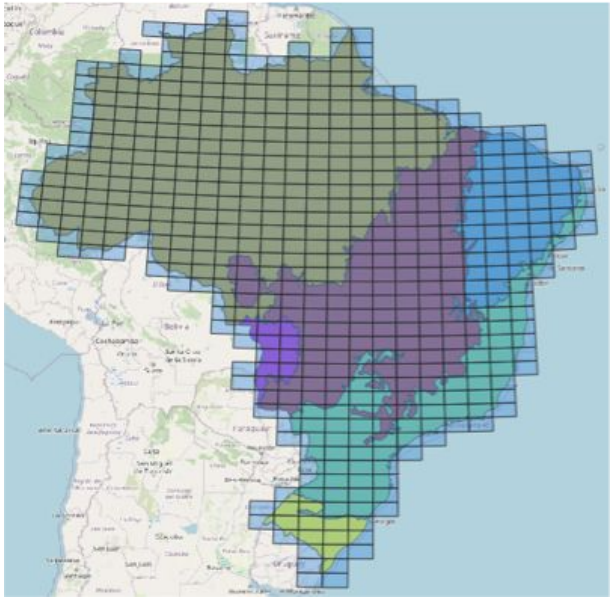
Region: Brazil
Period: [2017, 2020]
Volume: ~ 45 TB

Sentinel-2
(MSI)

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

Terra & Aqua
(MODIS)

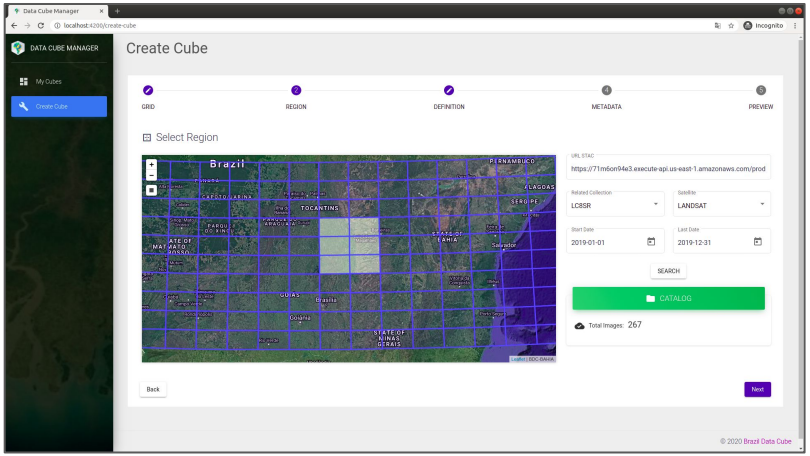
Region: Cerrado Biome
Period: [2016, 2020]
Volume: ~4 TB



Amazon Web Services (AWS)

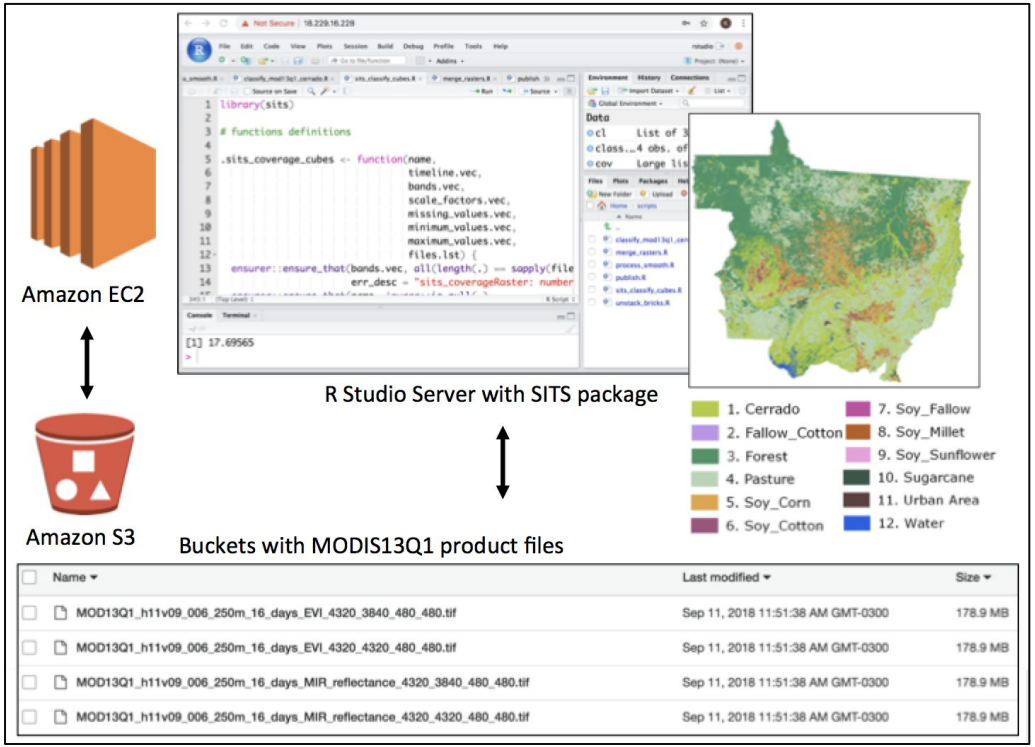
GEO AWS Cloud Credit Program
U$ 60,000

(1) Create Sentinel 2 data cubes on AWS from the Sinergize S3 bucket



(2) Create land use and cover maps from the BDC data cubes

Source: [Ferreira et al., LAGIRS Conference, 2020]



Amazon Web Services (AWS)

Source: [Ferreira et al., LAGIRS Conference, 2020]

GEO AWS Cloud Credit Program
U$ 60,000

Data Cube Sen10m16d = a data cube of Sentinel 2 images with spatial resolution of 10 meters and temporal resolution of 16 days.

Data Cube name	Temporal extent	Spatial extent	Premise hardware (1 machine with 32 CPUs / 128 GB Ram)	AWS using ~ 260 Lambdas	AWS cost using ~ 260 Lambdas
Sen10m16d	1 year	1 tile of the Brazil data cube grid	1242 minutes = ~ 20 hours	5 minutes	US$ 3,00 (without S3 cost)
Sen10m16d	1 year	All Brazilian territory (560 tiles of the Brazil data cube grid)	11592 hours = 483 days	2800 minutes = ~ 46 hours *	US$ 840,00 (without S3 cost)

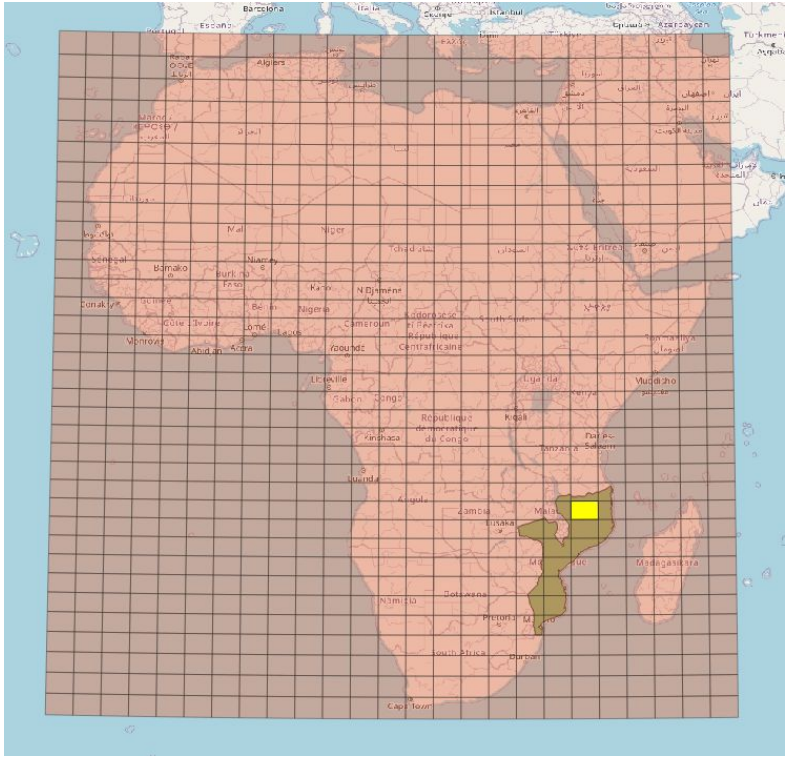
* we can use more than 260 lambdas

Final remarks and Future

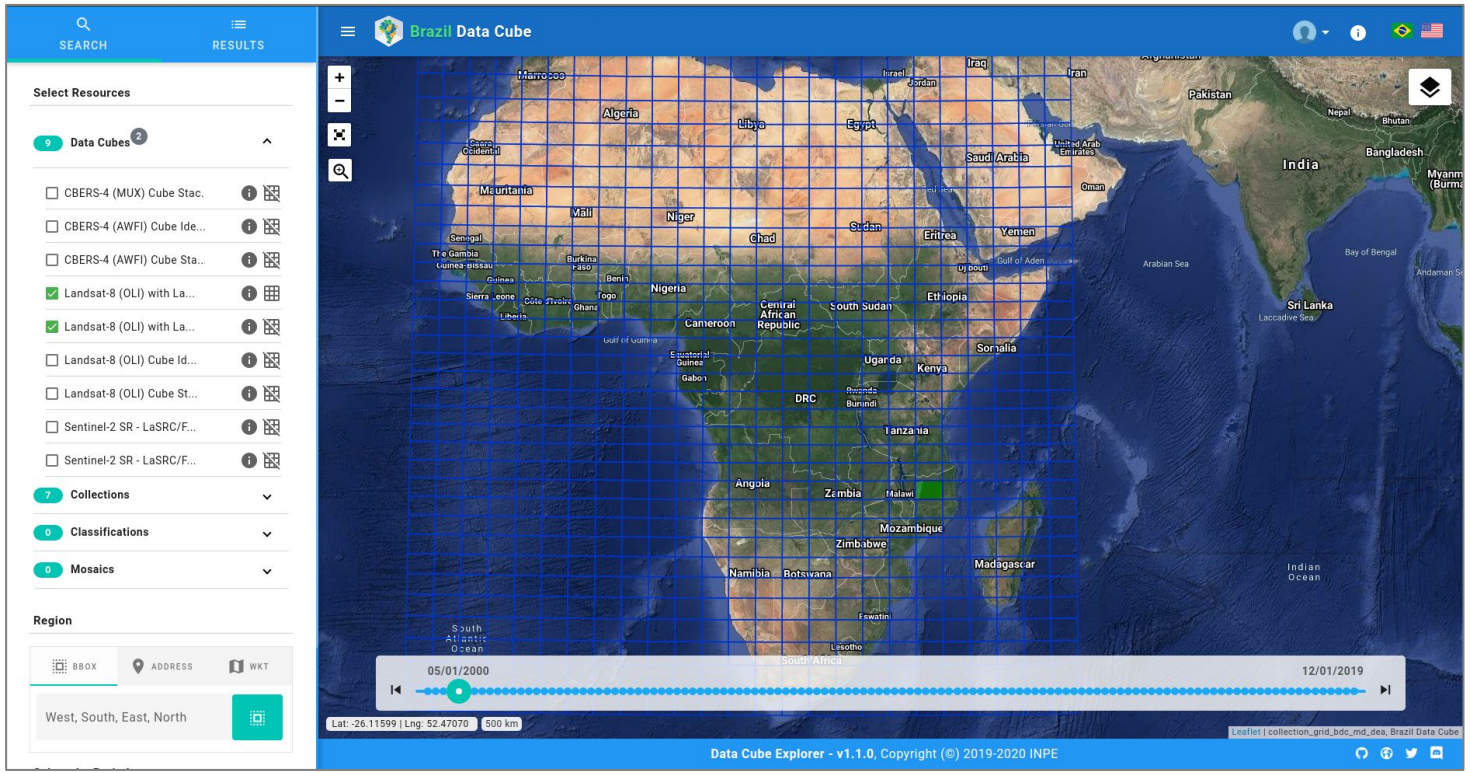
- ✔ Submit the BDC data cubes to be CEOS Analysis Ready Data for Land (CARD4L) compliance
- ✔ Create ARD and data cubes of Sentinel 1 images
- ✔ Create data cubes harmonizing/mixing Sentinel 2 and Landsat 8 satellite images
- ✔ Promote the use of data cubes and time series analysis to extract different kinds of information from Earth observation satellite images in Brazil – workshops, tutorials, ...
- ✔ Apply the BDC methodology and technologies to other countries, ex. Mozambique

Pilot Project in Mozambique

- ✔ Cooperative Initiative between the Coalition for Rainforest Nations (CfRN) and the Group on Earth Observations (GEO) Secretariat
- ✔ Main idea: BDC methodology and technologies to create Landsat data cubes and produce land use and land cover classifications for Mozambique
- ✔ Period: 1990 to 2019 (Landsat 5, 7 and 8)
- ✔ IPCC classes: "forest land", "cropland", "grassland", "wetlands", "settlements", and "other land”
- ✔ Samples: provided by CfRN



Pilot Project in Mozambique



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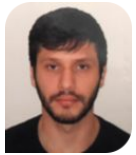

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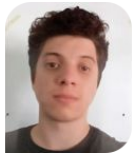

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BRAZIL
DATA CUBE

FUNCATE
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INPE

FUNDO AMAZÔNIA

BNDES

MINISTÉRIO DA ECONOMIA

MINISTÉRIO DO MEIO AMBIENTE

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GOVERNO FEDERAL

Obrigada

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Q&A and discussion

30 minutes

Wrap-up!

5 minutes

Final remarks
by the GEO Secretariat Director, Gilberto Câmara