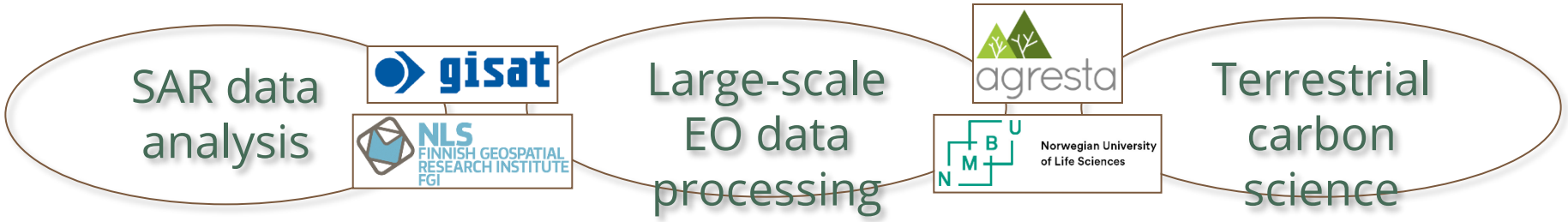
Sentinel-1 for Science Amazonas

Project Presentation

Sentinel-1 for Science Amazonas

Using a data cube to monitor forest loss in the Amazon

Consortium: Key Expertise



- **Continuous monitoring** of change dynamics using Sentinel-1 SAR time-series
- Long-term seasonal **trend analysis** and short-term break detections
- Knowledge of robust **statistical methods**, accuracy assessments and reporting

- **Automated procedures** to process SAR imagery, including polSAR and InSAR
- Experiences with **large scale cloud-based EO production** (DIAS, AWS, GEE,eodc)
- Experiences with state-of-art approaches in geospatial data **presentation and dissemination** through user stories and websites

- Active field experience, experience in working with a variety of **NFIs and local teams** in Amazonia
- **Mapping forest changes** and associated spatial dynamics
- Expertise in **statistically rigorous estimation and inference of essential LUC parameters** (area, carbon stock) using EO data

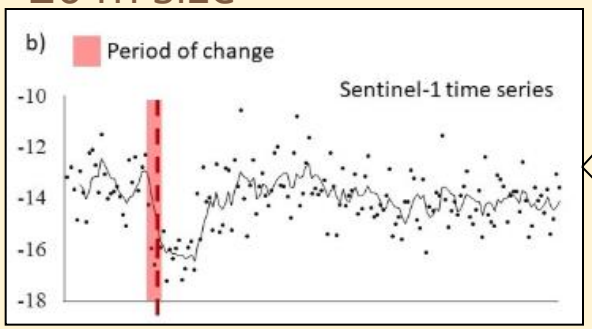
Project Objectives and Main Challenges

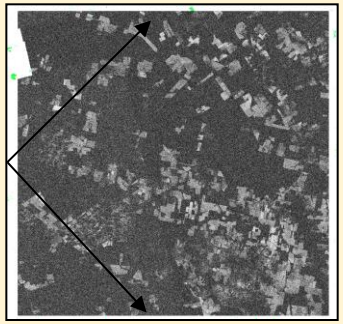
Develop, test and validate an operational-level Multi-temporal forest Change Detection (MCD) algorithm using Sentinel-1 SLC IW time series.

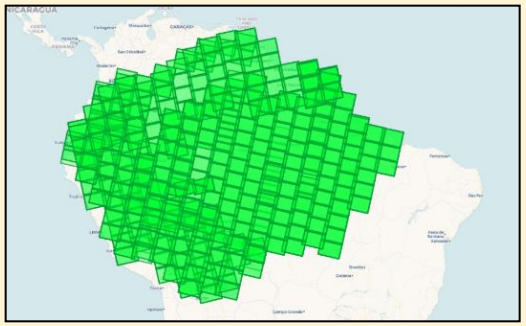
Estimate Carbon loss from forest cover loss areas in the Amazonas based on the MCD outputs

Perform a contextual scientific analysis, accounting for the impact of seasonal stressors such as severe precipitation, droughts or fires on the MCD.

Create algorithms that are able run to on an area of >16 billion pixels of 20 m x 20 m size







Cloud Services (e.g. CREODIAS) for:

- S1 IW SLC pre-processing
- Extraction of statistical information for each pixel for each date
- Generation of maps of changes in forest cover

Project Objectives and Main Challenges

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Perform a contextual scientific analysis, accounting for the impact of seasonal stressors such as severe precipitation, droughts or fires on the MCD.

- Estimate Carbon loss at time of occurrence of changes
  - Analysis of existing forest biomass maps and use of latest field and ALS data
  - A new estimate of forest biomass obtained post-change
- Accommodate for a diverse number of land uses and land use patterns and dynamics

Project Objectives and Main Challenges

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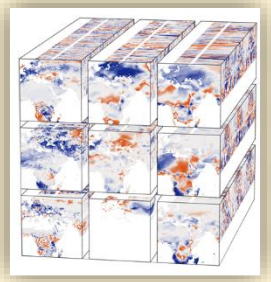
Estimate Carbon loss from forest cover loss areas in the Amazonas based on the MCD outputs

Perform a contextual scientific analysis, accounting for the impact of seasonal stressors such as severe precipitation, droughts or fires on the MCD.

- Provide an output that can be easily put into the context of existing research

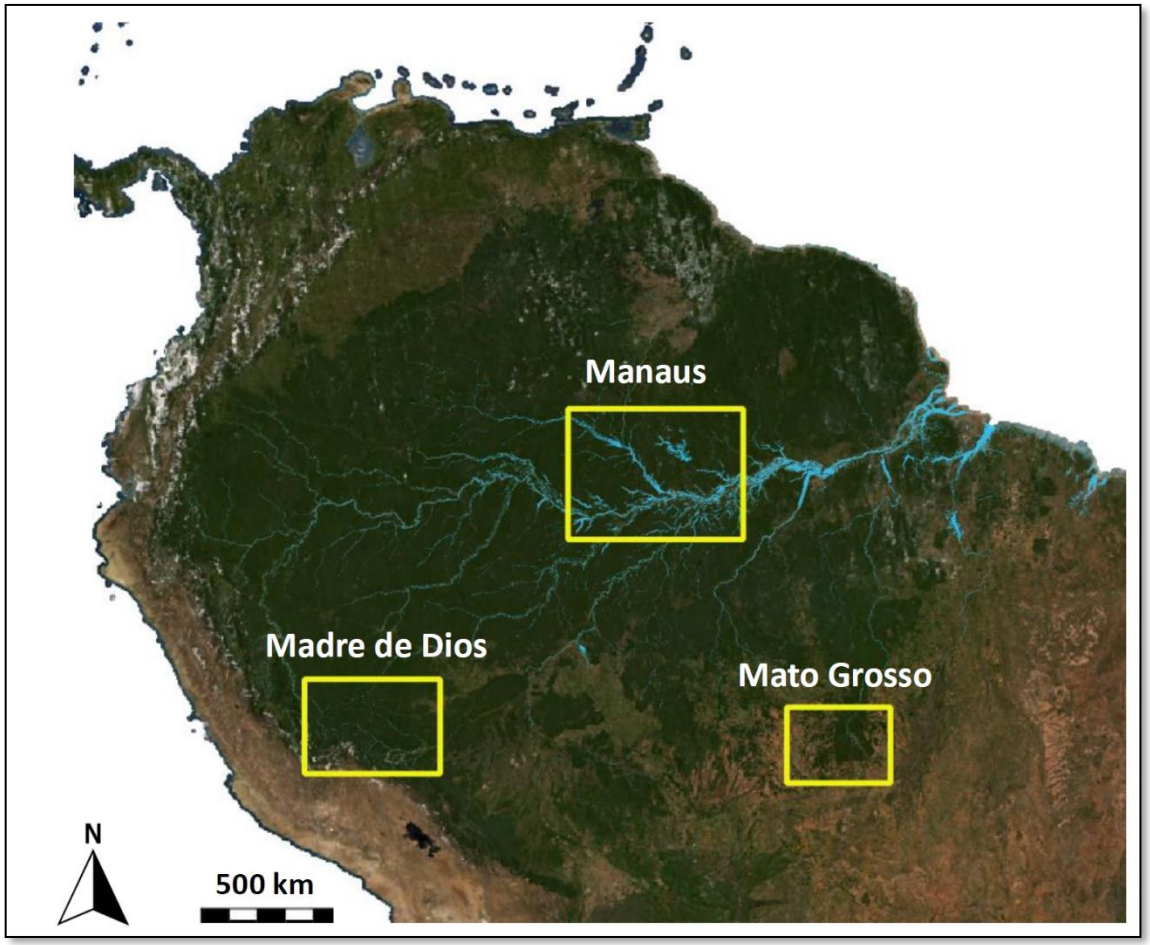
esa climate change initiative
biomass cci
land cover cci
fire cci
soil moisture cci

EURO DATA CUBE



EARTH SYSTEM DATA LAB

Pilot Study Sites



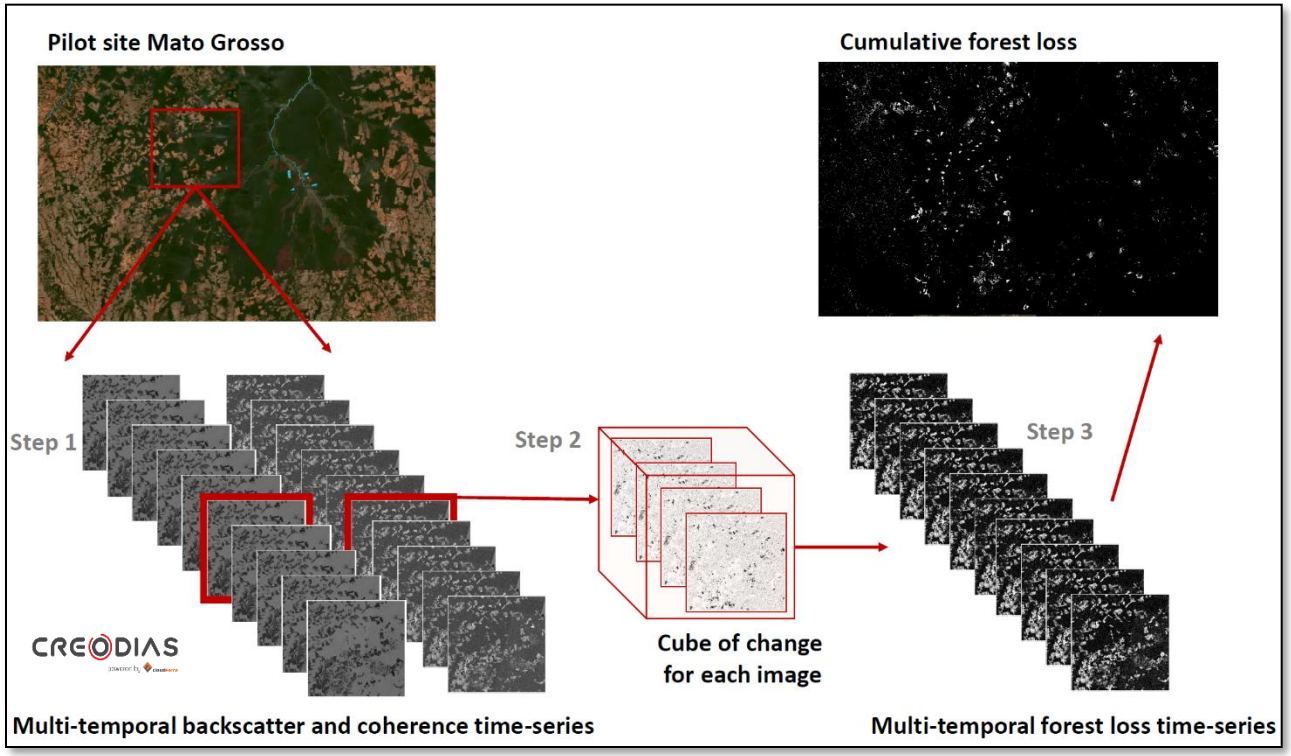
Develop, test and validate an operational-level Multi-temporal forest Change Detection (MCD) algorithm using Sentinel-1 SLC IW time series.

- Manuas (34.5 million ha)
- Mato Grosso (14 million ha)
- Madre de Dios (27 million ha)

Tested decision tree & thresholds,
random forests,
deep-learning

MCD : Decision-Tree & Thresholds

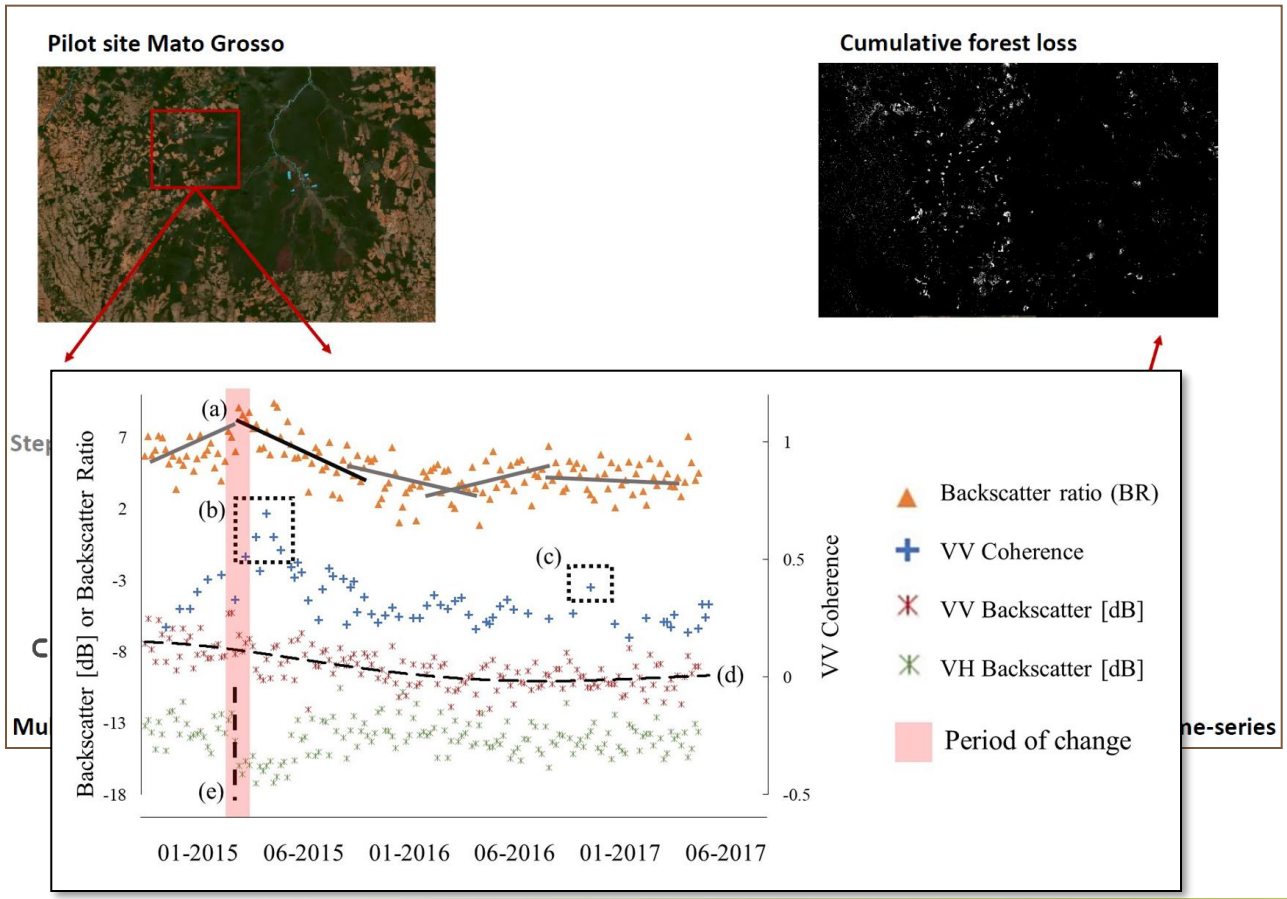
Space-time data cube design : statistical information relevant to identify deforestation is extracted at each point in the backscatter and coherence time-series



- 20 m pixel size
- 12-day frequency
- ASC and DSC analyzed separately
- Window-size in cube flexible
- Study site can be split into user-defined tiles

MCD : Decision-Tree & Thresholds

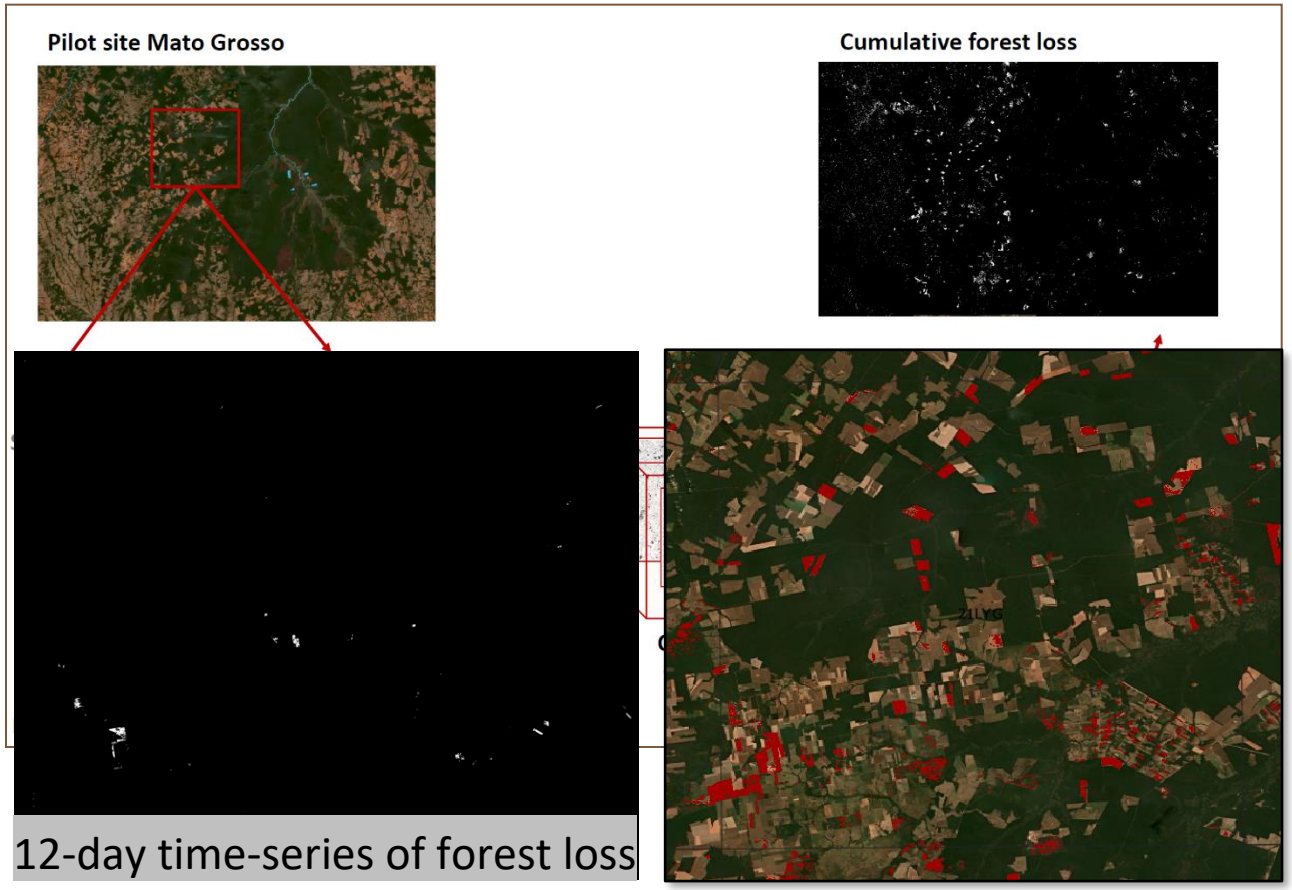
Space-time data cube design : statistical information relevant to identify deforestation is extracted at each point in the backscatter and coherence time-series



- Difference in VH/VV Coherence between each date and average of previous 5 images
- Difference in VH/VV Backscatter between average of future and previous 5 images
- Standard dev. of VH/VV Backscatter in future and previous 5 images
- T-statistic and P-value of VH/VV Backscatter between future and previous 5 images
- Difference in VV-VH ratio between average of future and previous 5 images
- R-squared value of linear trend fit on VV-VH ratio data in future and previous 5 images
- Slope of the above linear trend fit
- Standard dev. of VV-VH ratio in future 5 images and previous 5 images
- T-statistic and P-value of VV-VH ratio between future and previous images

MCD : Decision-Tree & Thresholds

Space-time data cube design : statistical information relevant to identify deforestation is extracted at each point in the backscatter and coherence time-series



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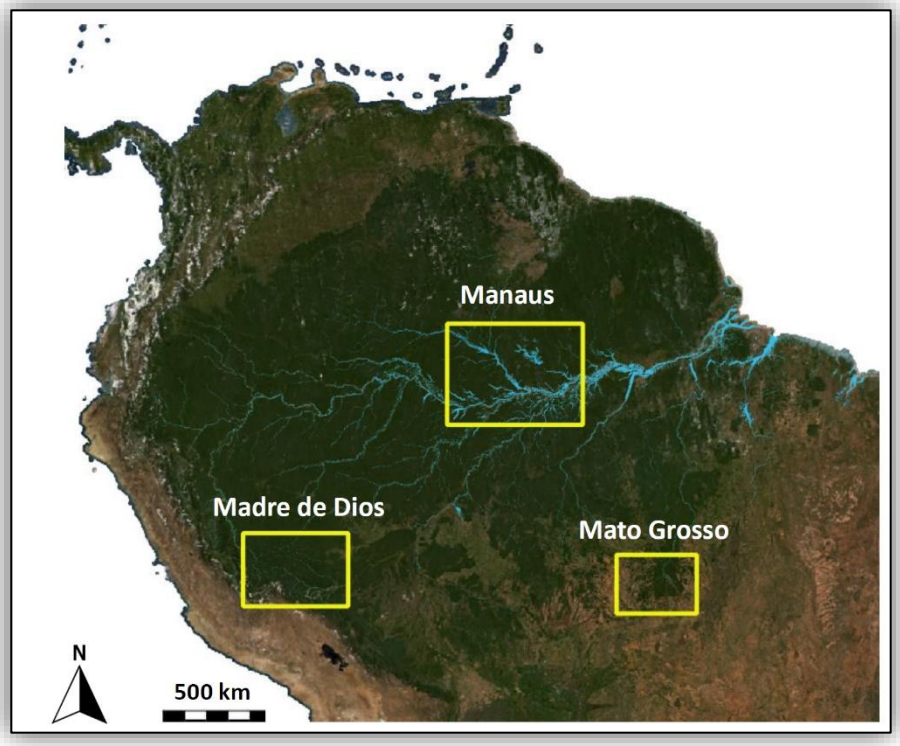
Pilot Study Sites

Develop, test and validate an operational-level Multi-temporal forest Change Detection (MCD) algorithm using Sentinel-1 SLC IW time series.



- Manuas (34.5 million ha)
- Mato Grosso (14 million ha)
- Madre de Dios (27 million ha)

Tested decision tree & thresholds,
random forests,
deep-learning

Output of the MCD:

Forest cover loss of
0.4% (Manuas) (GFW = 0.4%)
1.8% (Mato Grosso) (GFW = 3.5%)
0.9% (Madre de Dios) (GFW = 0.8%)

of their total area.

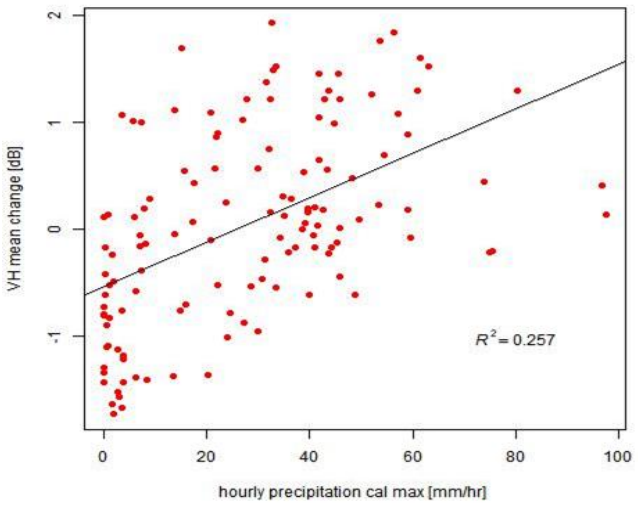
MCD : Decision-Tree & Thresholds

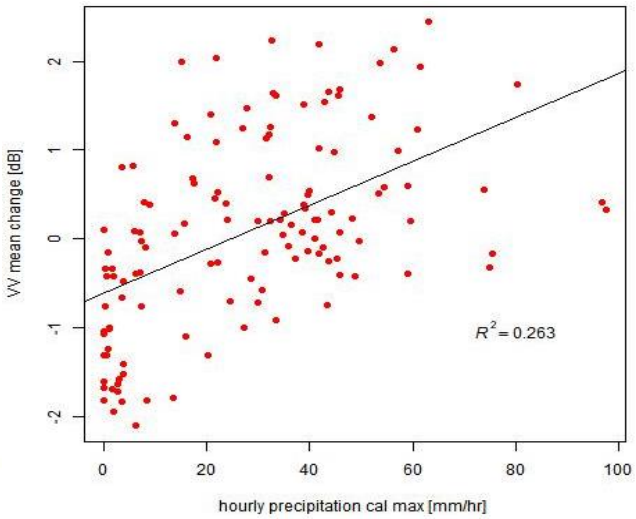
```
// S1 collection
var S1GRD = ee.ImageCollection("COPERNICUS/S1_GRD");

// import products
var modisLST = ee.ImageCollection('MODIS/MOD11A2');
var ecmwf = ee.ImageCollection("ECMWF/ERA5/DAILY");
var modisFire = ee.ImageCollection("MODIS/006/MOD14A1");
var modisBurnt = ee.ImageCollection("MODIS/006/MCD64A1");
var FIRMS = ee.ImageCollection("FIRMS");
var NASAprecip = ee.ImageCollection("NASA/GPM_L3/IMERG_V06");
var JAXAprecip = ee.ImageCollection("JAXA/GPM_L3/GSMaP/v6/operational");
```

Google Earth Engine

Perform a contextual scientific analysis, accounting for the impact of seasonal stressors such as severe precipitation, droughts or fires on the MCD.

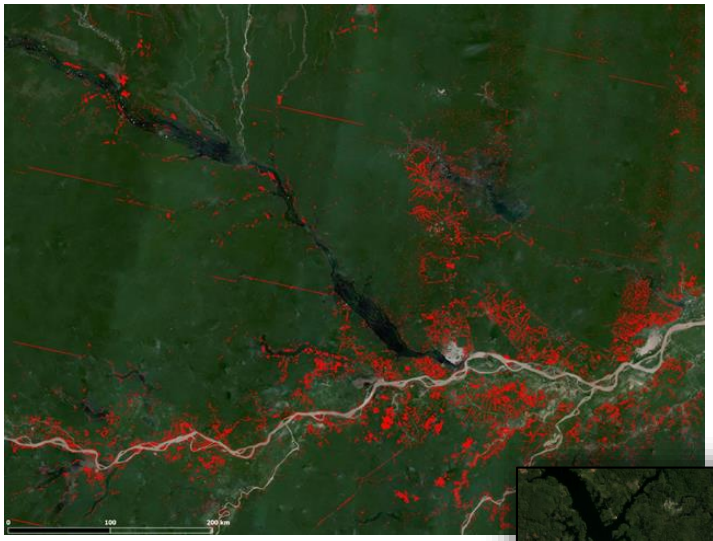
Climatic Stress	Dataset or climate variable
Drought	Land surface temperature anomalies from MOD11A2 8-day composite
Fires	MODIS Active Fire and Burnt Area products
Rainfall	Global Precipitation Measurement (GPM)



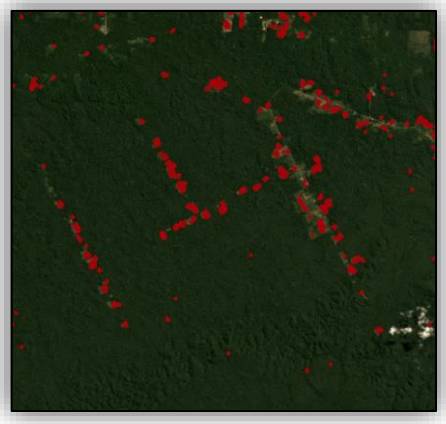


MCD : Decision-Tree & Thresholds

Manuas (34.5 million ha)

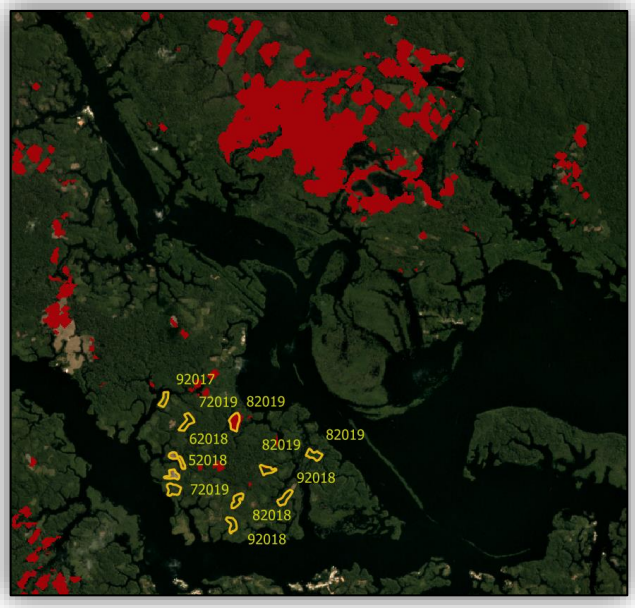


Example: Roads



12 km

Example: Floodplains

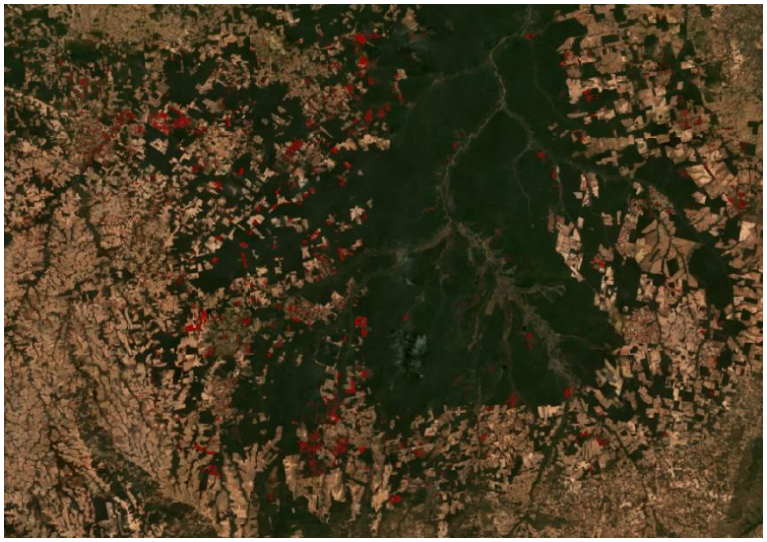


9 km

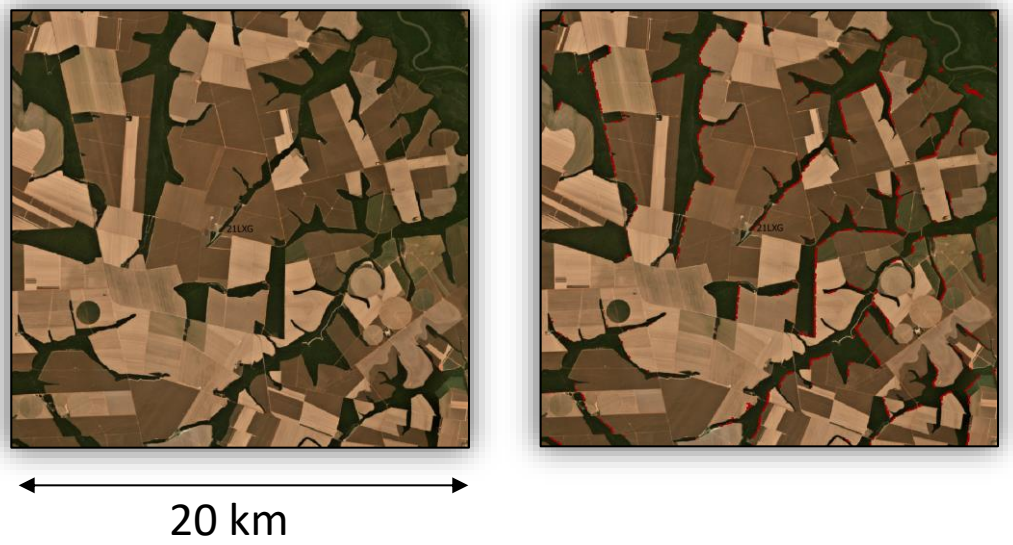
MCD : Decision-Tree & Thresholds

Example: Roads

Mato Grosso (14 million ha)

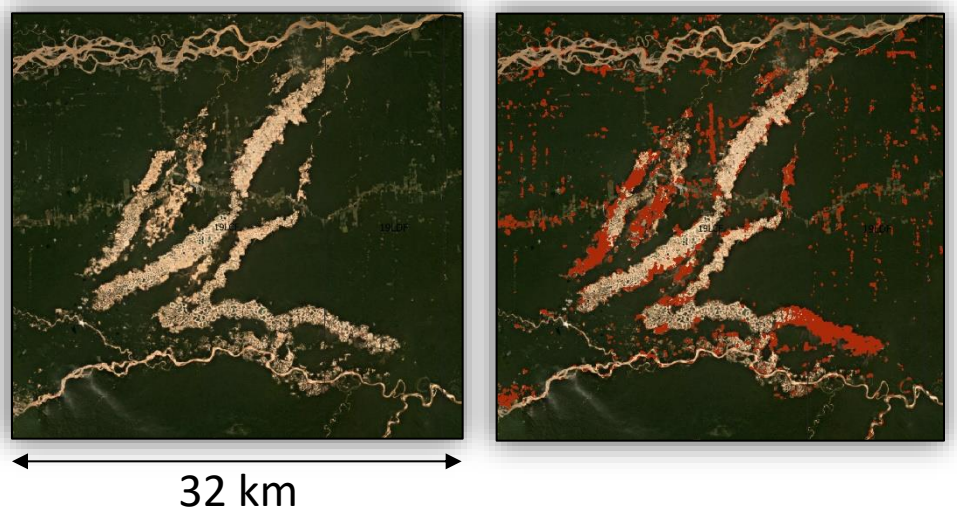


Example: SAR side-looking

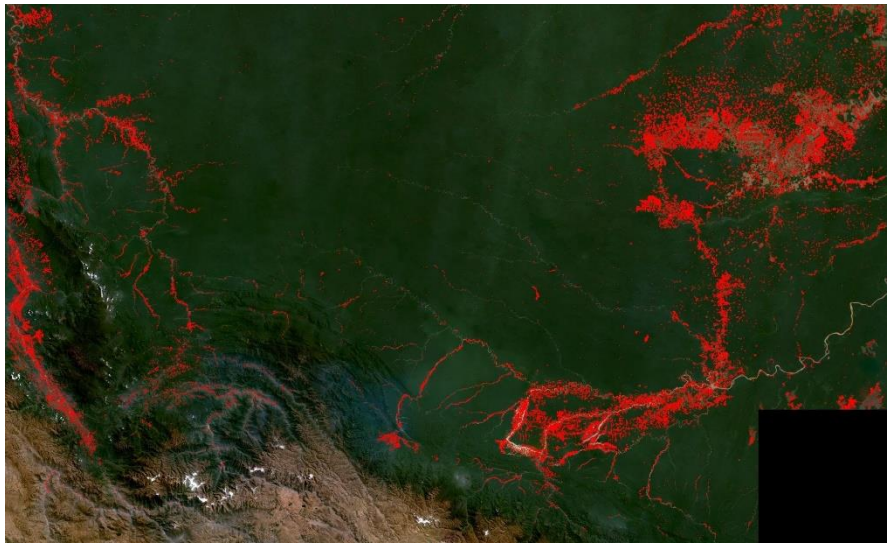


MCD : Decision-Tree & Thresholds

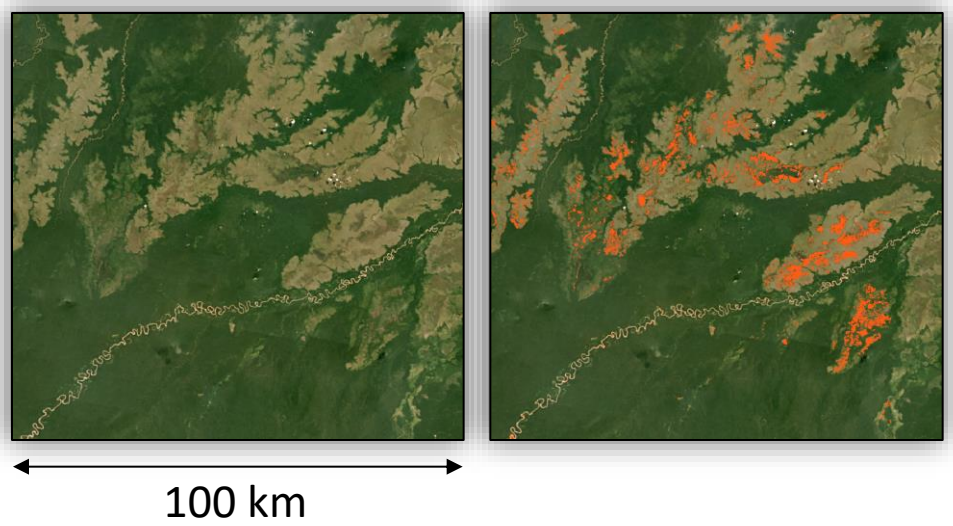
Example: Gold mining



Madre de Dios (27 million ha)



Example: Problematic land cover



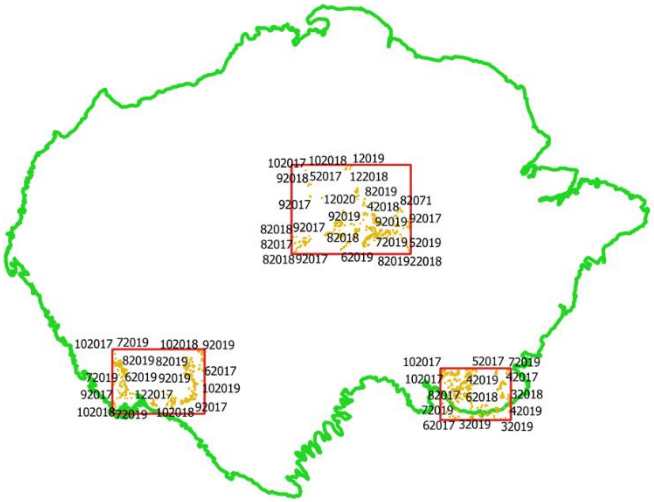
Validation of the MCD algortihm Metrics

Validation polygons based on Planet optical satellite data digitized manually

- Detection rate (%): at least one pixel of the validation polygon was detected
- Average area (%) of the validation polygon covered with MCD detections
- Temporal accuracy (months): months between the first / the most extensive (most pixels detected) MCD detection and the validation polygon month
- The detection rates for validation polygons grouped by size
- False positives (%): MCD change detected within the false positives mask (pixel level) as FP.

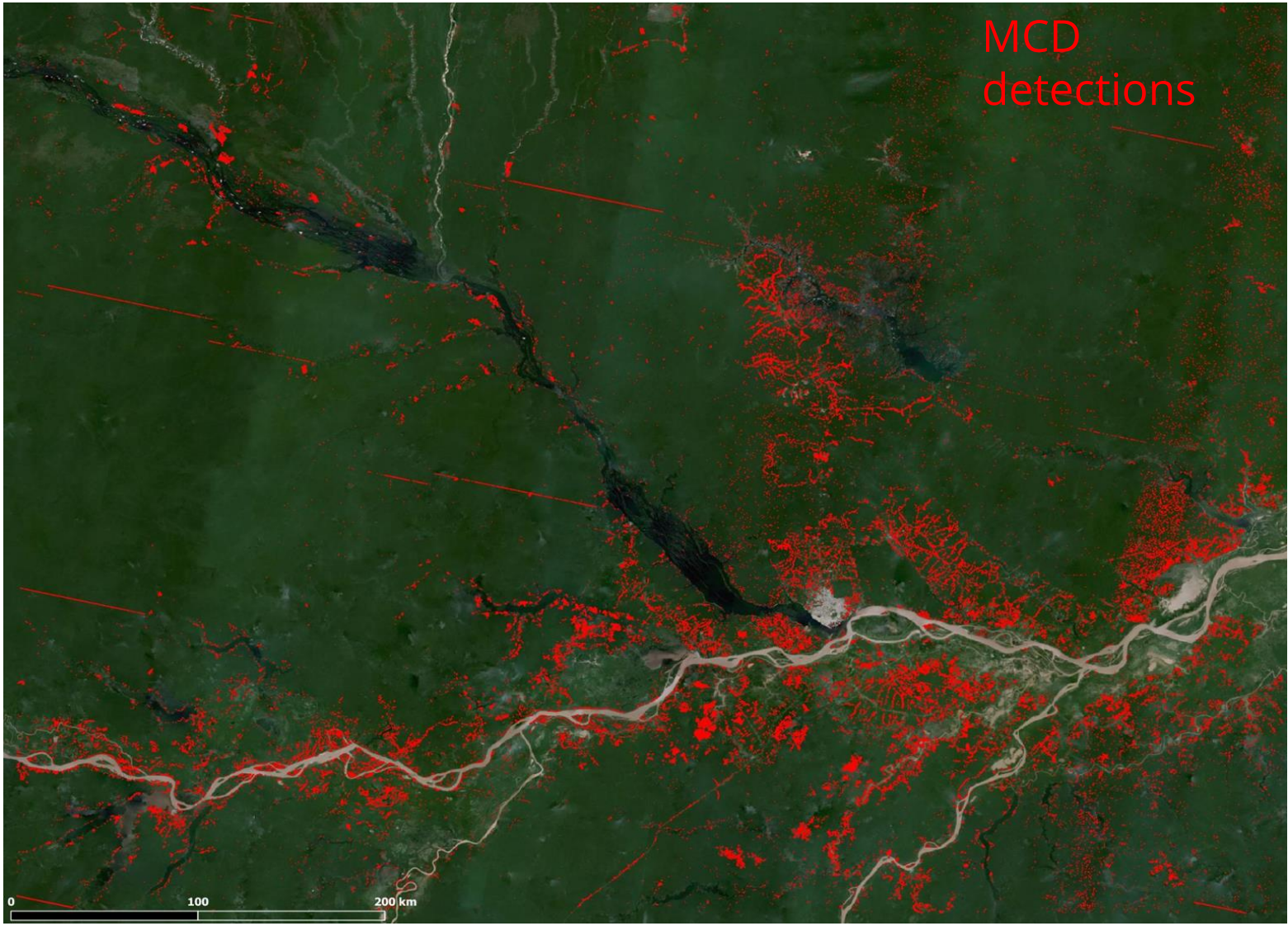
  FP rate = FP/(FP+TN)

+ Object-based comparison to GFW (Hansen)



Study site 1: Manaus

- 1398 planet polygons
- 35 Sentinel tiles



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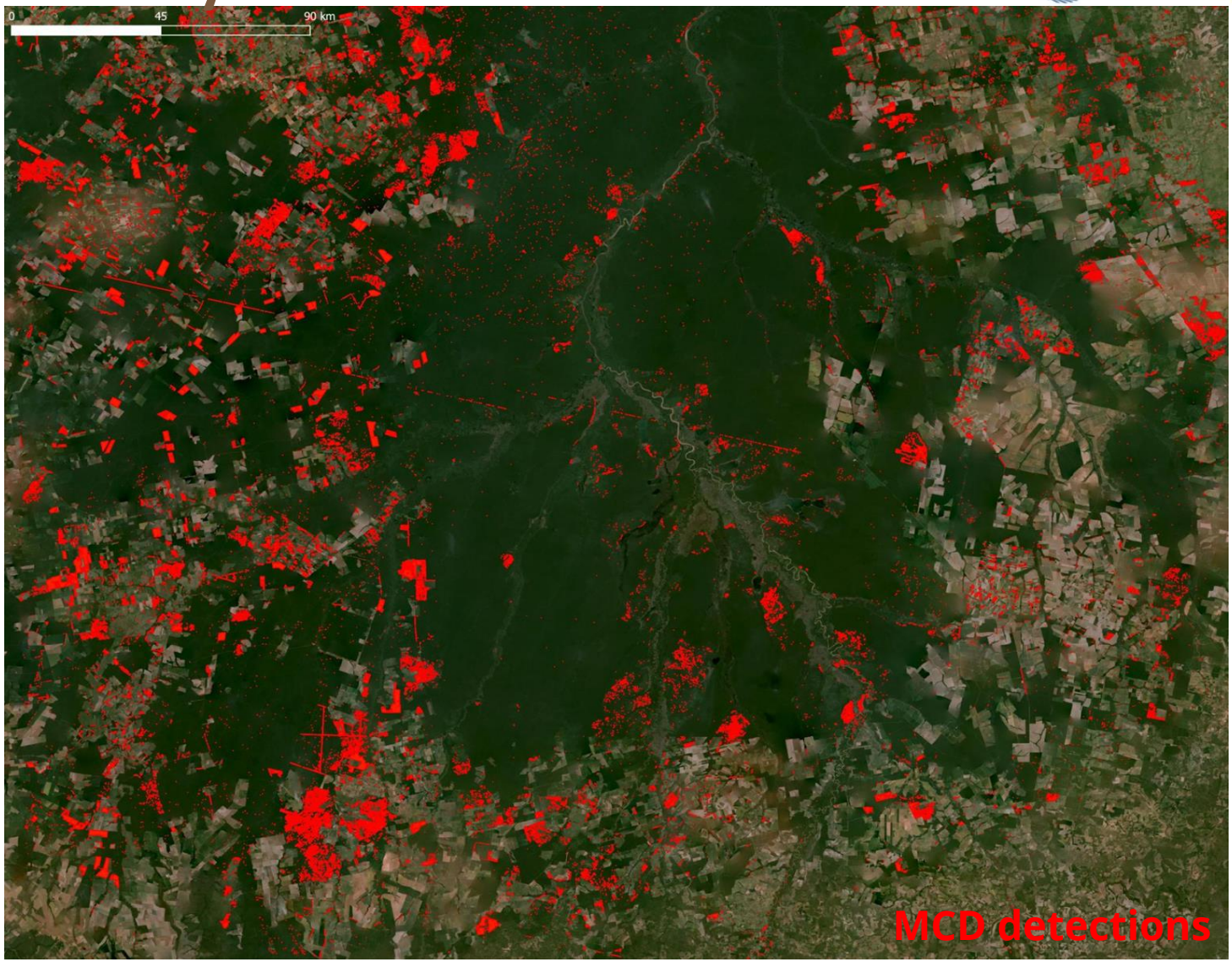
Study site 2: Mato Grosso

- 644 validation polygons
- 12 Sentinel tiles
- Large events



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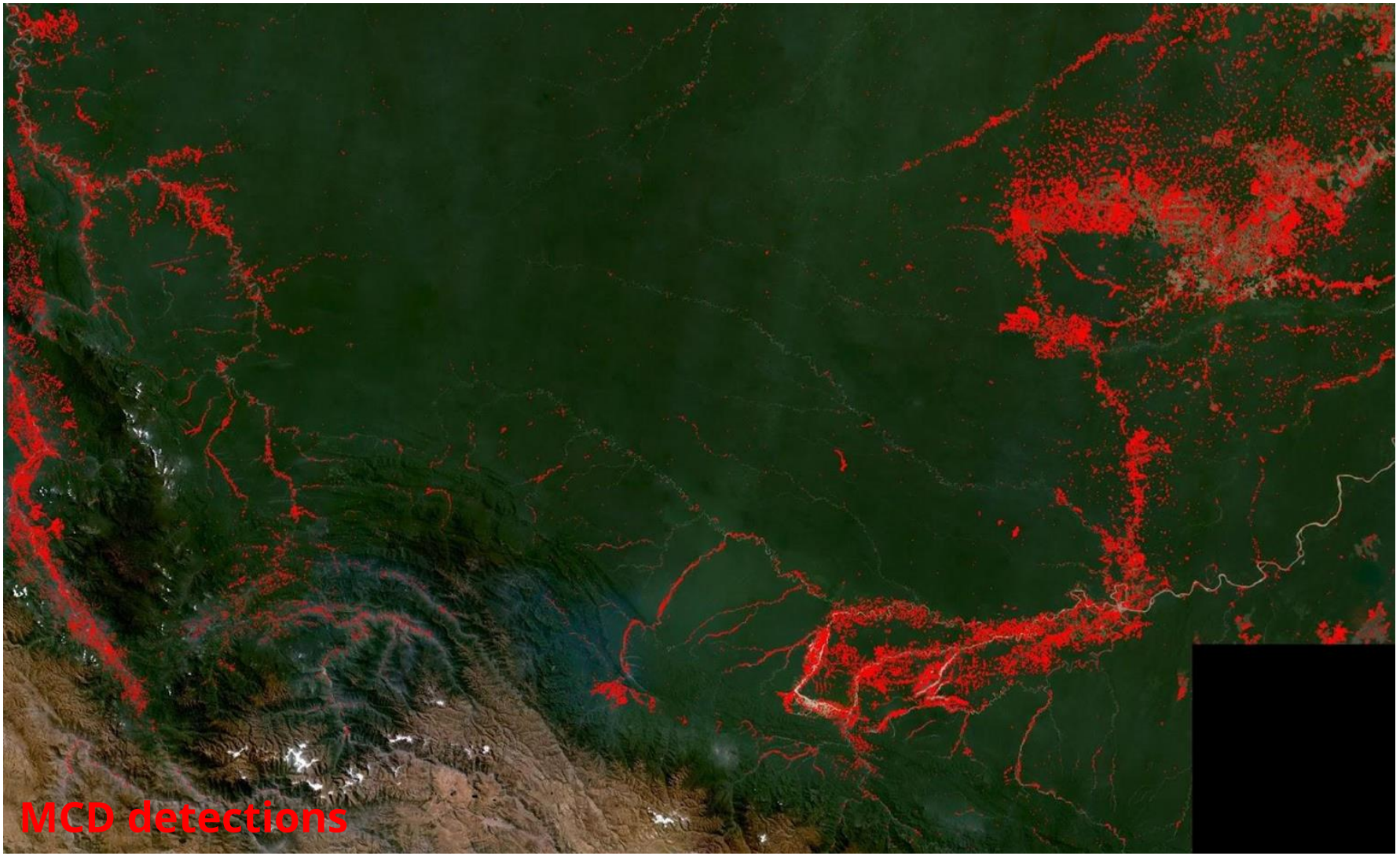
Study site 3: Madre de Dios

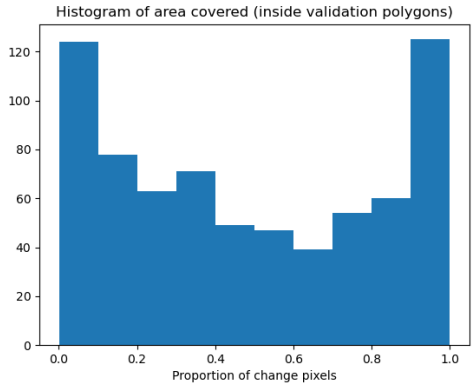


- 1089 planet polygons & 27 Sentinel tiles

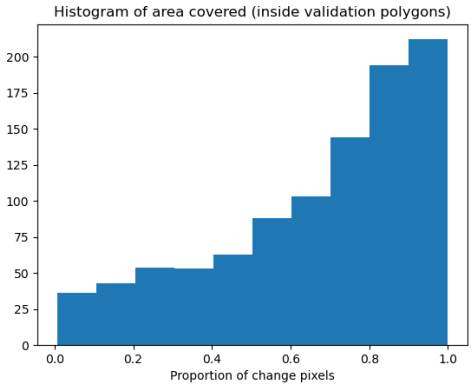
Summary results

Study Site	Detection Rate	False Alarm Rate	Area covered with detections	Temp. Acc. first (median) months	Temp. Acc. biggest (median) months	Temp. Acc. first (average) months	Temp. acc. biggest (average) months
Mato Grosso	89.3 %	0.21 %	48.3 %	-2	4	-4	7
Madre de Dios	91.6 %	0.26 %	66.9 %	-1	0	-4	1.5
Manaus	90.0 %	0.15 %	58.6 %	-1	0	-5	1

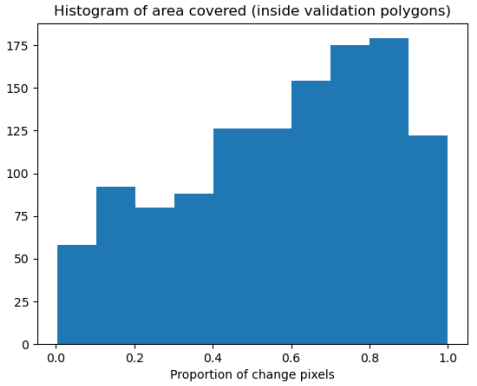
Mato Grosso



Madre de Dios

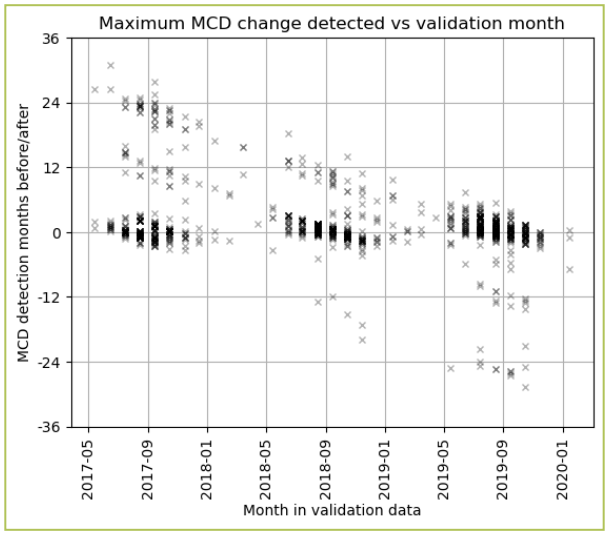


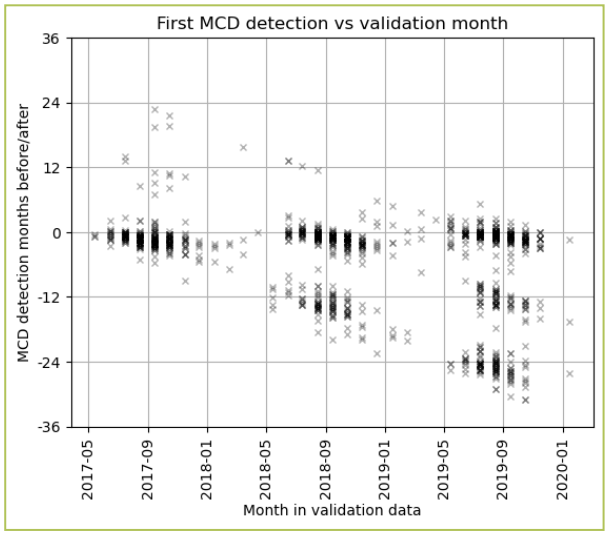
Manaus



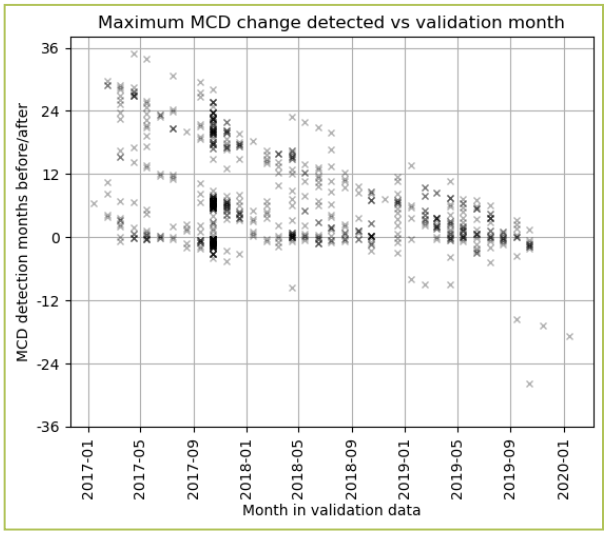
Temporal accuracy (max. and first detection)

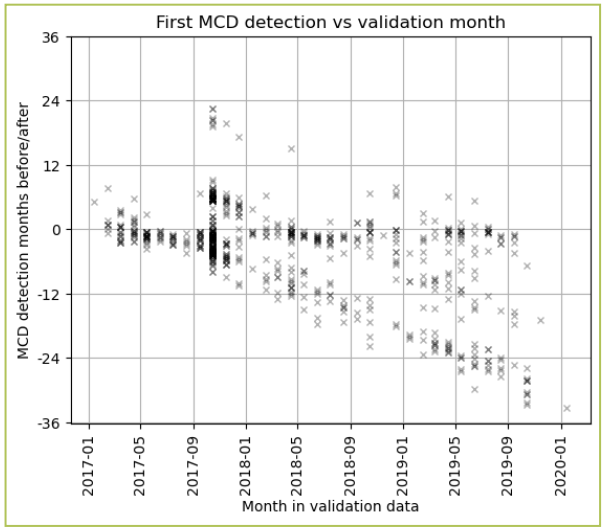
Manaus



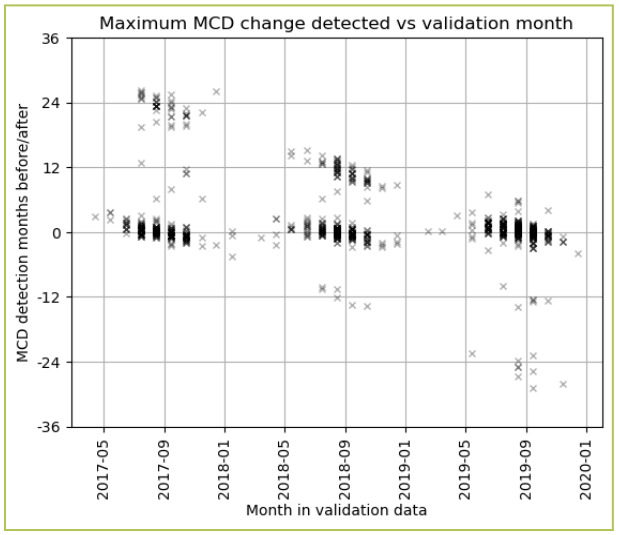


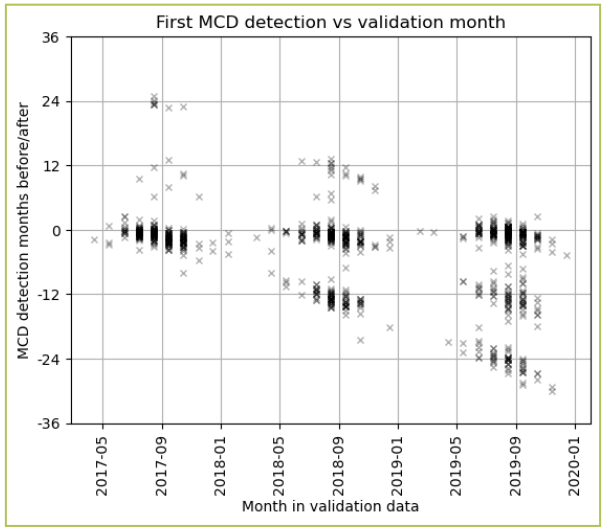
Mato Grosso





Madre de Dios





Other remarks

- Temporal differences in forest loss area border outlining
- Size of the events:
  - Small events (< 4 ha) had lower detection rates
  - Narrow (<120 m) events were difficult
- Comparison to GFW
  - GFW has many very small events (< 1ha), MCD focuses on bigger events
  - 70 % (Madre de Dios), 45% (Mato Grosso), 33% (Manaus) of MCD events have forest loss in GFW.
- Missed detections/False positives:
  - Shift due to the side looking geometry
  - Flood areas

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S14Science Amazonas

esa

Sentinel-1 for Science Amazonas

Technical Note on ICT Requirements

gisat

Norwegian University of Life Sciences

NLS FINNISH GEOSPATIAL RESEARCH INSTITUTE FGI

agresta

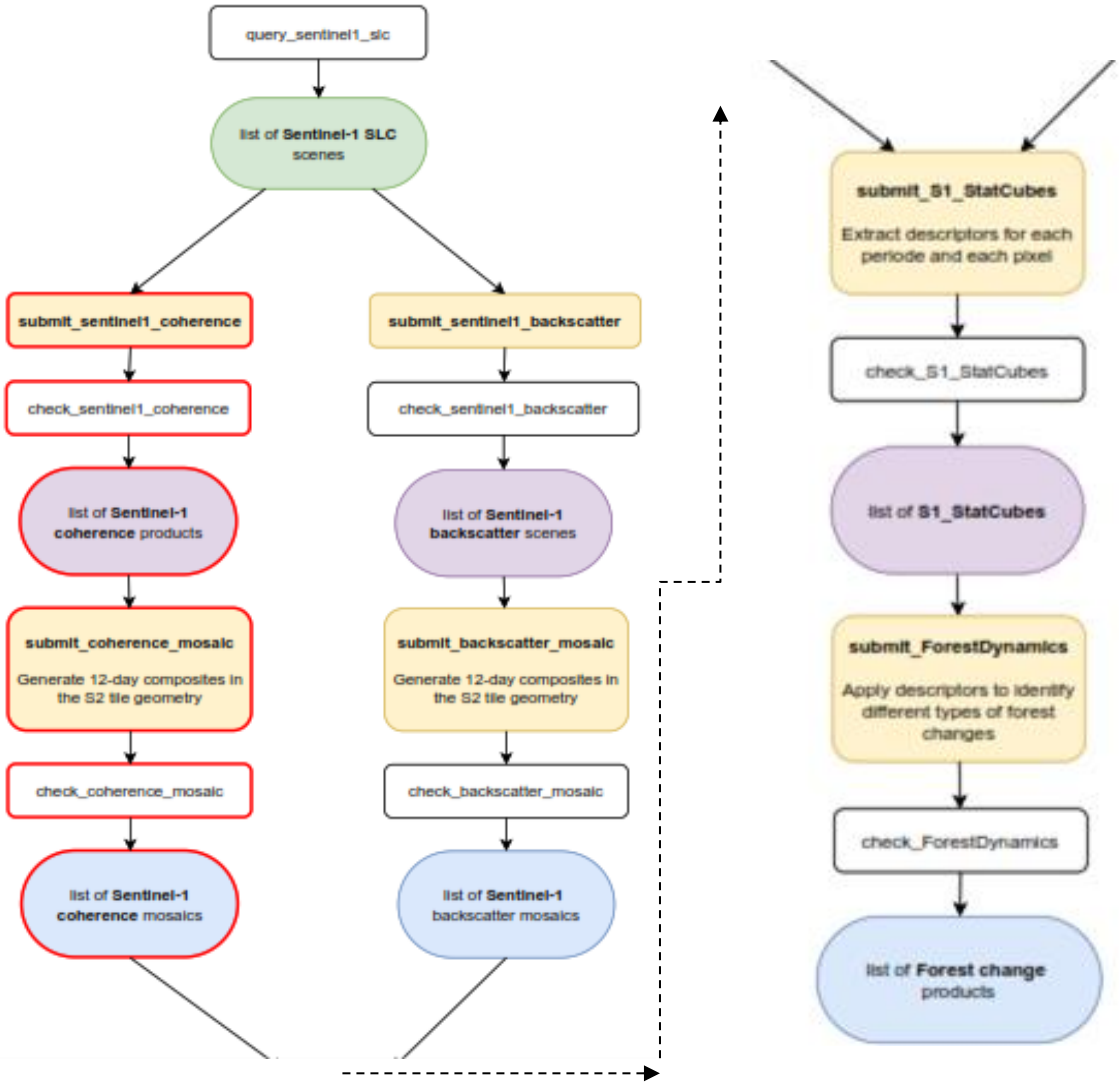
MCD Production system

- **CreoDIAS** has been selected as the cloud computing platform for the project

- Internal production system implemented (parallelization, logging & progress monitoring, scheduling, scaling, simple GUI to operate the system)

    - Selection and pre-processing of relevant S1 products
    - Generating multi-temporal mosaics for each 12-day period
    - Extracting statistical descriptors for each 12-day period
    - Generating forest dynamics products based on the thresholding & decision-tree approach

MCD Production system



- The system can be used for both scenarios
  - coherence & backscatter
  - only backscatter *(components outlined in red excluded)*
- S1 pre-processing chain to be updated to support S1 GRD data processing