RapidAI4EO

Virtual Constellations for Continuous Monitoring

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ESA Living Planet Symposium, 25 May 2022

Earth Explorers

Multi dimensionality, multi-level nature of EO (satellites, HAPs, UAVs) presents connectivity, integration and interoperability challenges.

Credits: ESA

The RapidAI4EO Project

GOAL

- Establish the foundations for the next generation of rapid cadence land monitoring applications

STRATEGY

1. Creation of a spatio-temporal machine learning training dataset for land monitoring applications combining Sentinel-2 and Planet imagery at 500,000 patch locations in Europe
2. Development of a solution for higher frequency updates of the CORINE Land Cover inventory through detecting and classifying change from very high cadence observations via supervised and unsupervised DL classifiers

DURATION

- January 2021 – March 2023

https://rapidai4eo.eu/ https://www.linkedin.com/company/rapidai4eo/

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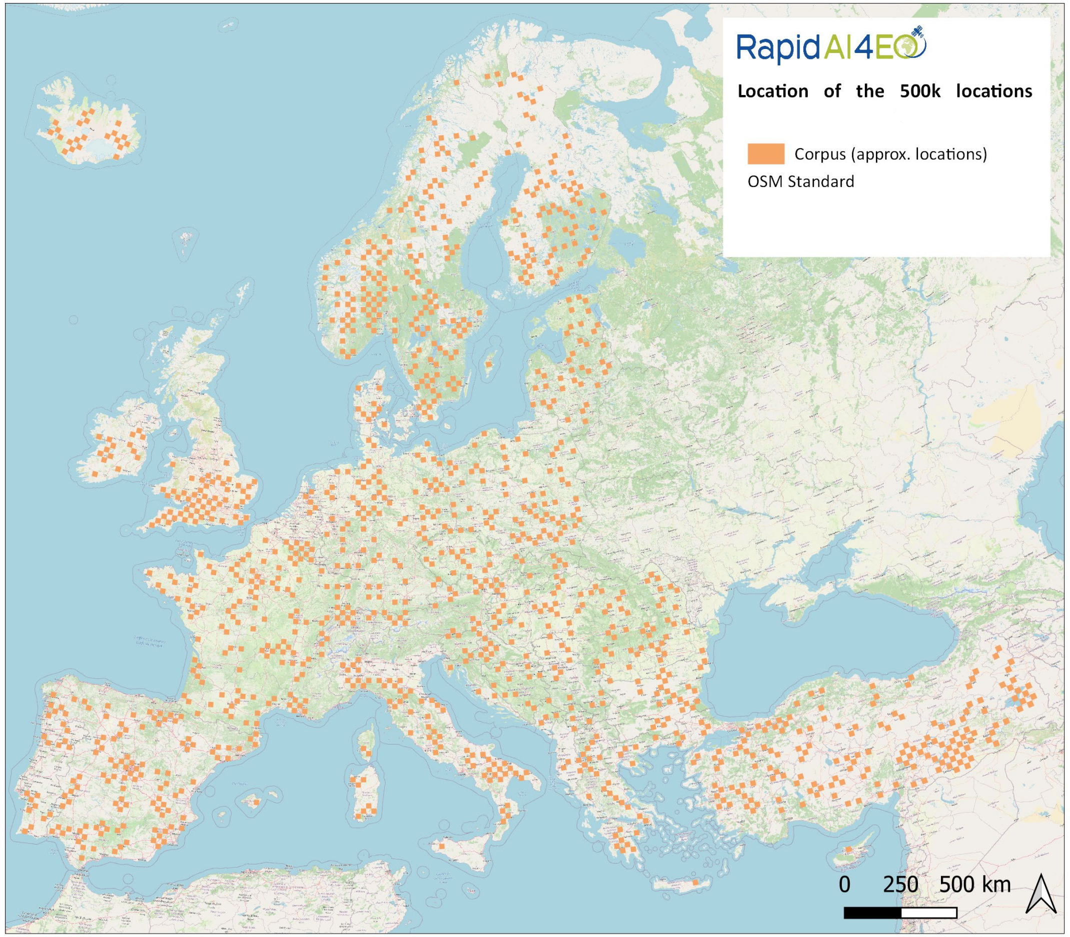
The RapidAI4EO Corpus

- The inspiration for the RapidAIO4EO corpus comes from the BigEarthNet and Eurosat datasets
- 600m x 600m patches with Sentinel-2 (1 year) and Planet Fusion (2 years)
- Sampled at 500,000 locations, accounting for
  - CLC class distribution
  - Spatial distribution
  - Country representation
- Multi-class annotations based on CLC 2018
- Designed for LULC change detection use case, but generalisable to other problems
- **Open sourcing in July 2022**



Base map and data from OpenStreetMap and OpenStreetMap Foundation (CC-BY-SA). © https//www.openstreetmap.org and contributors.

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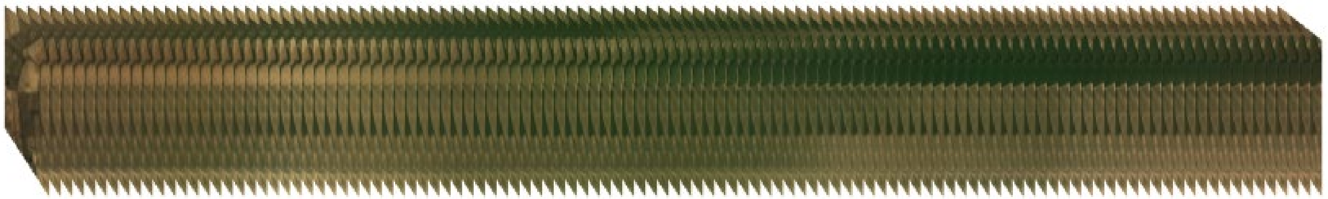
Development of Datasets

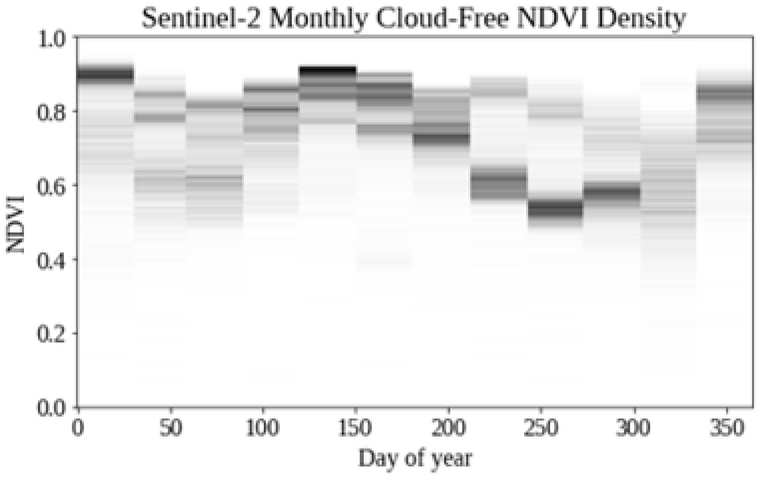
Multiformat Data

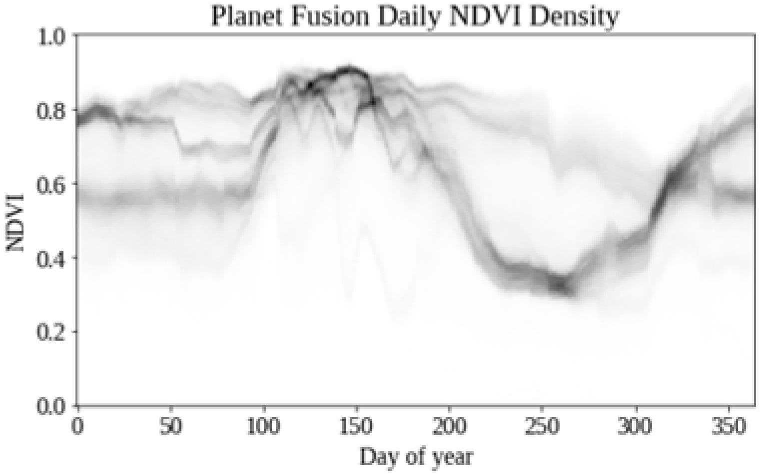
Source	Spatial resolution	Temporal resolution	Spectral resolution
Sentinel-2	10-60m	1 cloud-free image/month 2018	12 bands
Planet Fusion	3m	1 gap-filled image/every 5 days 2018-2019	4 bands

Sentinel-2

Planet Fusion







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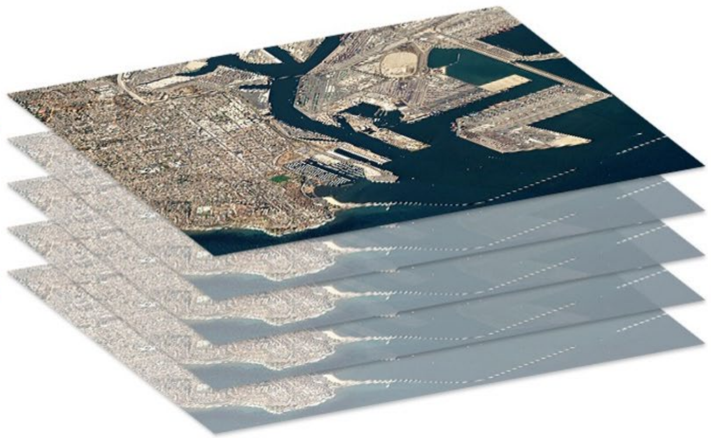
Development of Datasets

Planet Fusion

- Harmonised output from many sensors
- Cloud masking & gap filling
- High resolution multispectral imagery with unprecedented cadence and completeness

PlanetScope
LANDSAT-8
Sentinel-2
MODIS



CubeSat-Enabled Spatio-Temporal Enhancement Method (CESTEM, Houborg and McCabe, 2018) https://doi.org/10.1016/j.rse.2018.02.067

INPUTS

PS - TOAR

HLS (L8 and S2)

OUTPUT

CESTEM - SR (gap-filled)

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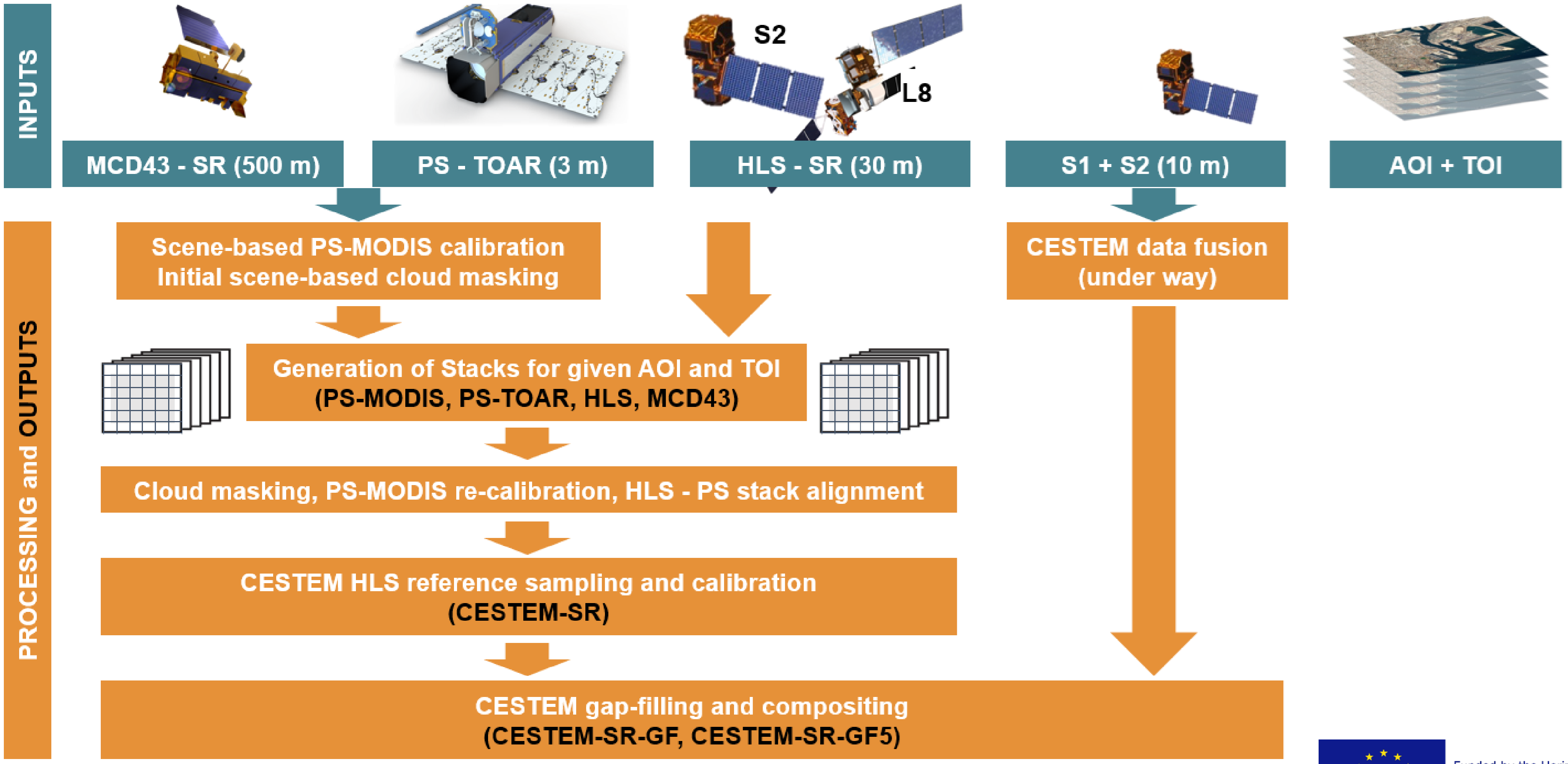
Next Generation Monitoring via Sensor Fusion



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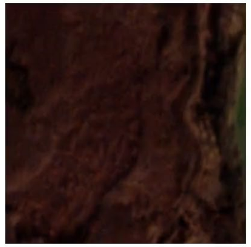
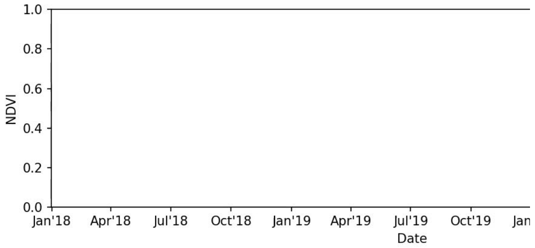
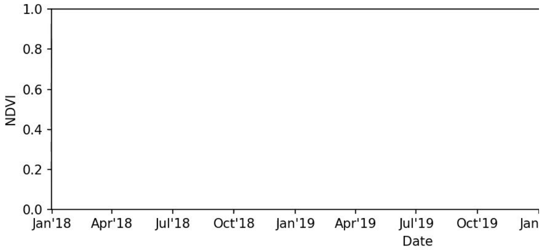
Examples of Stable Land Cover Behavior



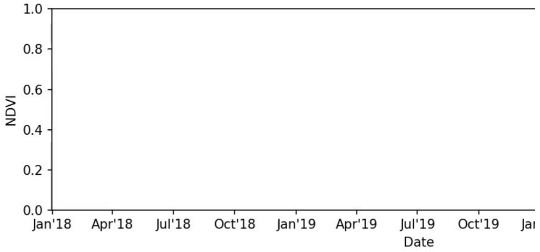


January 2018

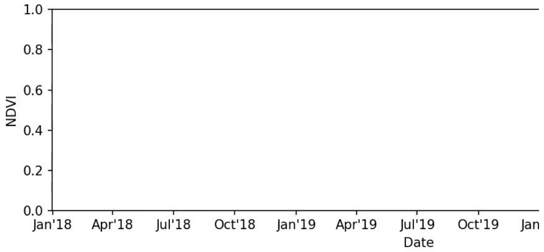


January 2018

Examples of Change



January 2018



January 2018

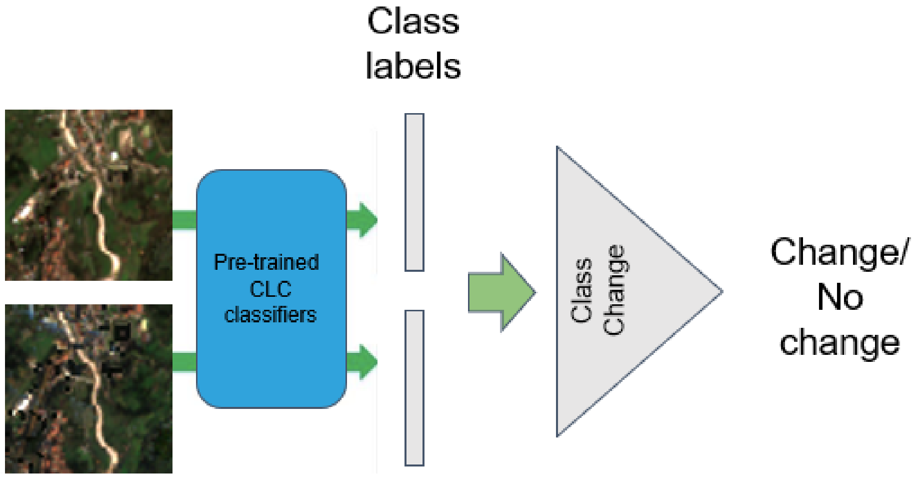
← **2 years** →

← **2 years** →

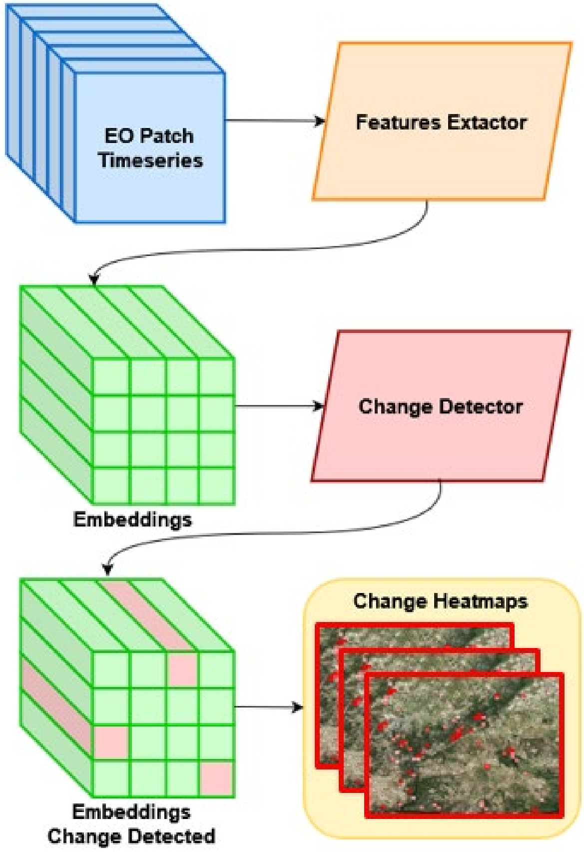
Change Detection Model Development

Deep Learning for detecting changes

- Supervised (CNN, LSTM, ConvLSTM) and unsupervised (auto-encoder, triplet-loss)
- Derive heat maps of change to prioritize areas for map updates



Change Detection approach with class labels



Unsupervised change detection workflow

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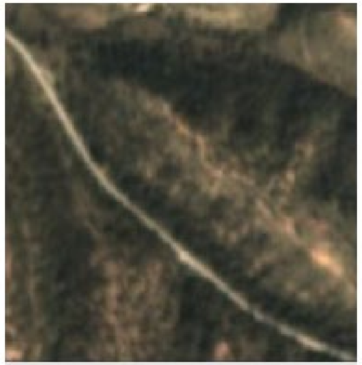
ML Models Learn to Recognize Land Cover Mixes

Class	Class Name	F1-Score (Micro)
1	Artificial Surfaces	80.89
2	Agriculture	92.82
3	Forests	88.85
4	Shrubs	61.94
5	Bare Areas	72.87
6	Wetlands	69.01
7	Water bodies	83.68

Artificial surfaces: 0.36
Agricultural areas: 0.56
Forest: 0.06
Shrubs: 0.00
Bare Areas: 0.00
Wetlands: 0.00
Waterbodies: 0.00

Artificial surfaces: 0.00
Agricultural areas: 0.09
Forest: 0.37
Shrubs: 0.50
Bare Areas: 0.01
Wetlands: 0.00
Waterbodies: 0.00

Artificial surfaces: 0.32
Agricultural areas: 0.64
Forest: 0.02
Shrubs: 0.00
Bare Areas: 0.00
Wetlands: 0.00
Waterbodies: 0.00



Artificial surfaces: 0.00
Agricultural areas: 0.00
Forest: 0.99
Shrubs: 0.00
Bare Areas: 0.00
Wetlands: 0.00
Waterbodies: 0.00

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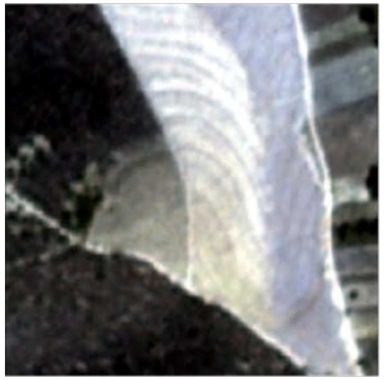
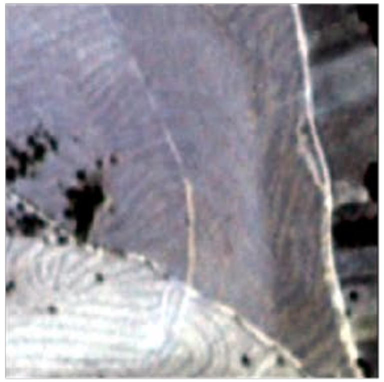
Convolutional Neural Network Activation Map

TILE-ID: 29N-26E-183N/33_17



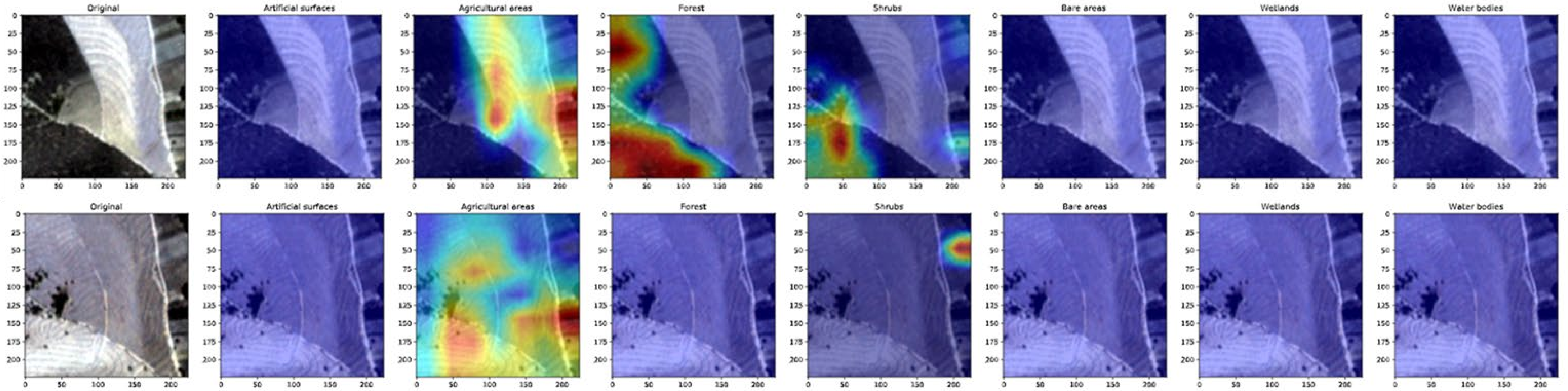
July, 2018

Artificial surfaces: 0.00
Agricultural areas: 0.45
Forest: 0.27
Shrubs: 0.25
Bare Areas: 0.00
Wetlands: 0.00
Waterbodies: 0.00

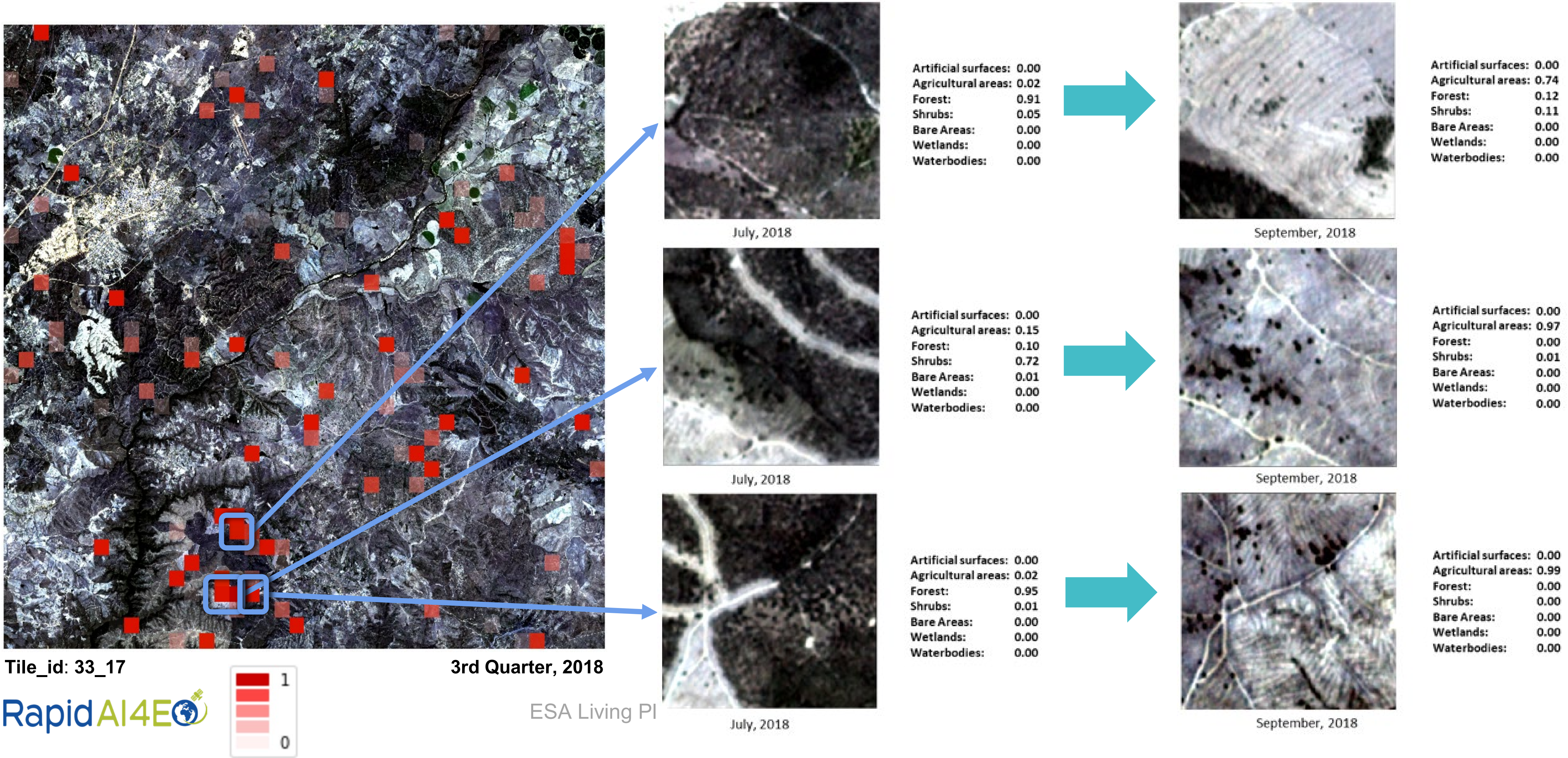


September, 2018

Artificial surfaces: 0.00
Agricultural areas: 0.97
Forest: 0.00
Shrubs: 0.01
Bare Areas: 0.00
Wetlands: 0.00
Waterbodies: 0.00



Detected Change (26E-183N)



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Key Takeaways

- The RapidAI4EO corpus is inspired by the BigEarthNet and EuroSat datasets. The main innovation is the addition of **high cadence time series** at all locations.

- High cadence time series improve our understanding of land use. They open the door to a new family of high fidelity ML models that can **disentangle phenology from structural change and learn the dynamism of land covers.**

- Results from the supervised ML models already show the advantage of including high cadence temporal information in change classification models.

Experiments with 15 classes (L2)

Method	Sensor	Months	F1-Score
ResNet-50	Sentinel-2*	All	74.24
ResNet-50	Planet Fusion**	All	77.30
LSTM	Planet Fusion**	All	80.10

* Monthly
** Daily

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