# TOUCHING THE SKY: NEW SPACE AND EARTH OBSERVATION

Guillem Sadurní Fabrellas

ETSEIB - UPC, Universitat Politècnica de Catalunya - BarcelonaTech, Barcelona, Spain

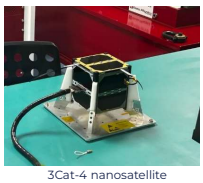
## OBJECTIVES

This research aims to demonstrate that satellite imagery and artificial intelligence can be leveraged to quantify and mitigate the effects of climate change, using resources that are accessible to all.

1. **Gain an understanding of nanosatellites** — their inner structure, components, functioning, and the process of creation, launch, and orbit insertion — while deepening my knowledge into the New Space ecosystem.

2. Create, from satellite data, **real applications in the field of Earth Observation** to quantify and monitor climate change variables.

3. Discover **the importance of Artificial Intelligence**, to process geospatial data, understand how it works, and integrate it into the satellite applications.



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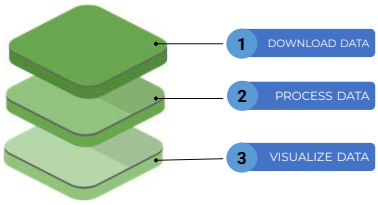
NANOSAT LAB

## THE PROCESS




**Google Earth Engine** Platform has been used for the design of the apps, as it is a powerful tool to process geospatial data and it's a free platform for students.

### 1 DOWNLOAD DATA

Thanks to ESA's and NASA's open data policies, such as the Copernicus program initiative, free data is available to everyone online and the continuity of measurements is also ensured.

**For the development of the applications, Sentinel-2 (ESA), Sentinel-5 (ESA), Landsat-8 (NASA) and Terra & Aqua (NASA) satellites have been used.**

### 2 PROCESS DATA

- Javascript
- Google Earth Engine

### 3 VISUALIZE DATA

Animations, charts and mapping layers were applied to enhance the understanding of the results. Users can interactively explore values in their areas of interest, and uncover insights about the territory conditions in a personalized way.

## THE USE OF ARTIFICIAL INTELLIGENCE

To monitor climate change variables in the applications, it is necessary to distinguish between different land cover types on maps, such as, water, vegetation and urban areas. For this purpose, it's necessary to use Machine Learning models. In this project, Random Forest has been applied.

### Machine Learning and Supervised Classification

Supervised Classification means that the algorithm learns from known training data. It is used when it is known the correct outcome of classification.

To understand how this process works, an example has been developed in Google Earth Engine.

**The Algorithm: Random Forest**

- Combines multiple decision trees for precise predictions
- High performance and accuracy for land cover classification
- Can handle multiple bands

**Data import:**

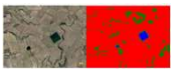
- Landsat-8 bands: B2, B3, B4, B5, B6, B7, B10, B11 (RGB, infrared and thermal images)
- Cloud cleaning

**The Workflow: (Google Earth Engine)**

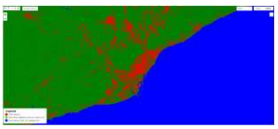
1. Training
2. Classification
3. Validation

**1 Training:**
Manual data has been introduced distinguishing between water, vegetation and urban areas. More than 200 training points have been used.

**2 Classification:**
The Random Forest algorithm associates each pixel into a classification category, based on training data.



**3 Validation:**
20 % of data is kept for validation.
Algorithm accuracy is evaluated by comparing its classification with validation data.



## WATER RESOURCES - DROUGHT ASSESSMENT

- Reservoir monitoring app to assess the water volume of rivers and reservoirs over time.
- In response to the severe water crisis that affected Catalonia, during the years 2022 and 2023.

**Case Study: Sau Reservoir, 2016-2023 (Osona, Catalonia)**

Reservoir water levels reached the lowest historical levels during the drought.

The app generates a chart with the water levels from 2016 to 2023, and creates an animation with images of the region every 2-3 months.

**Data source:**

ESA satellite Sentinel-2.

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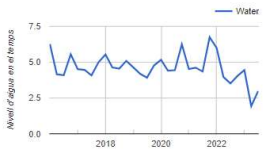
|---|---|
| SATELLITE | Sentinel-2 |
| COLLECTION | Dynamic World |
| RESOLUTION | 10 meters |




Evolution of the water levels in Sau reservoir


Image of Sau reservoir water levels on January, 2017

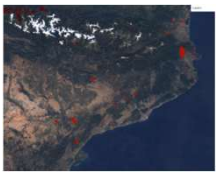
## WILDFIRE MONITORING APP

Track the evolution of hectares burned each year and visualize the areas where fires have occurred. The application detects the extension of forest fires, quantifies burned hectares and helps to understand fire damage over the years.

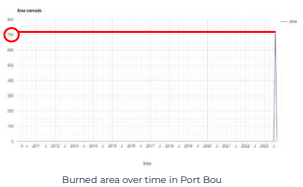
**Case Study: Port Bou Fire, August 2023 (Alt Empordà, Catalonia)**

- The program successfully identifies the burned area
- The resulting chart after selecting the area indicates a burned surface of slightly over 700 hectares, similar to official estimates.

The tool works correctly despite the 500 meter resolution of the dataset, which introduces some margin of error.



Wildfires in Catalonia between 2010 and 2023



Burned area over time in Port Bou

Port Bou burned area from satellite images, selected on the application

**Data source:**

MCD64A1, near real-time NASA dataset. It relies on the MODIS MOD14/MYD14 sensor onboard the Terra and Aqua satellites, which can identify thermal anomalies. This MODIS imagery is combined with Landsat-8 data, which provide higher resolution images, to produce a clearer view.

| | |
|---|---|
| SATELLITE | Terra and Aqua |
| COLLECTION | MCD64A1 |
| RESOLUTION | 500 meters |

## FOREST CHANGE DETECTION

This application allows users to measure forest cover change over time, quantify forest loss and visualize changes interactively. It also calculates a Soil Vegetation Index (SVI) to assess drought conditions.

**Data source:**

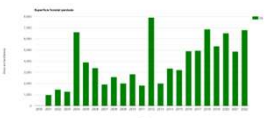
- The program defines a forest area as having more than 0.5 hectares and a tree canopy cover above 10 %.

| | |
|---|---|
| SATELLITE | Landsat-8 |
| COLLECTION | Global Forest Change |
| RESOLUTION | 30.92 meters |

- Annual forest cover data is provided by Global Forest Change dataset (Landsat-8 satellite).
- Forest loss is calculated by comparing subsequent images to the reference year, applying canopy cover and area filters.

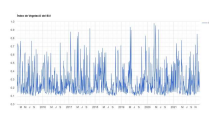
**Case Study: Catalonia**

Catalonia has one of the highest forest covers in Europe, with around 65% of its territory forested. Results show a forest loss of approximately 75000 hectares between 2000 and 2022. The app includes multiple layers to visualize forest loss and gain and an annual graph of forest loss.



Forest area (hectometres) lost in Catalonia (2000-2022)

Forest area in Catalonia



Soil Vegetation Index (SVI)

## AIR QUALITY MONITORING APP

Track air quality and gas emitted into the atmosphere, to raise awareness about air pollution.

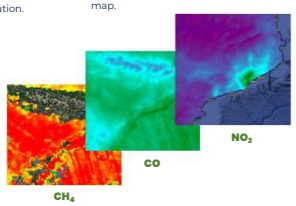
Three harmful gases to health and nature have been studied: nitrogen dioxide, methane and carbon monoxide to assess air pollution.

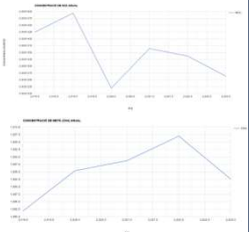
**Data source:**

**Nitrogen dioxide:** the maximum level allowed for the EU is 20 $\mu g/m^3$ ($0.435 \cdot 10^{-3}$ $mol/m^2$).
**Methane ($CH_4$)** is an intense gas that contributes to global warming.
**Carbon monoxide (CO):** His limit is set to 10 $mg/m^3$ (0.357 $mol/m^2$).

**Visualization:**

The application allows the user to select any region and generates annual and monthly charts for each gas. Users can also explore gas concentration layers on the map.



$NO_2$ and $CH_4$ annual results on Barcelona

| | |
|---|---|
| SATELLITE | Sentinel-5 |
| COLLECTION | $NO_2$, CO, $CH_4$ |
| RESOLUTION | 1000 meters |

## CONCLUSIONS

- **Earth Observation satellites are essential for studying climate change**, as they provide global data with high temporary frequency.
- The project demonstrated the value of open-access satellite data and powerful cloud-computing platforms like Google Earth Engine, which allow **complex analyses without the need of high-performance computers**.
- Thanks to ESA and NASA policy of making data openly available, this research has developed four applications **using resources accessible to everyone**: ESA and NASA satellites images and Google Earth Engine Platform
- **Satellite data and AI are powerful and essential tools for monitoring climate impacts**, but high-quality data and critical validation are essential to ensure reliability and scientific rigor.

**The use of AI:**

The integration of Artificial Intelligence proved being **really useful for processing geospatial data** and extracting climate insights.

In order to avoid misleading results, this research highlighted the importance of:

- Selecting the right predictors
- Using large datasets for training
- Applying robust validation methods
- Being critical with the obtained results to prevent false conclusions

## WEB PLATFORM

A web platform has been created to make this tools accessible to anyone, enabling customized analysis for any region worldwide.

Scan the QR Code to access the website

**Contact**

guillem.sadurni@estudiantat.upc.edu

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