Introduction to Modern Water Resources Management using AI

From Environmental Data to Intelligent Decision Support

SATELLITE DATA | CLOUD COMPUTING | ARTIFICIAL INTELLIGENCE

Cloud-native Environmental Data Processing

From Earth Observation Data to
Analysis-ready Water Information

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- Artificial Intelligence is changing environmental analysis.
- We need new skills to transform data into decisions.

From data collection to intelligent decision support

The Environmental Data Revolution

Landsat — 1972 — Archive

Sentinel — 2014 — Open Access

Cloud-native EO — Today — Analysis-ready Data

We are no longer limited by data availability.

We are limited by our ability to extract knowledge.

From Downloading Data to Cloud-native Analysis

Traditional workflow

Search
↓
Download
↓
Store locally
↓
Pre-process
↓
Analyse
↓
Repeat

$\Longrightarrow$

Evolution

Cloud-native workflow

Search
↓
Access
↓
Analyse in the cloud
↓
AI-ready datasets
↓
Decision support

Move computation to the data,
not data to the computation.

What will you learn?

From environmental observations to intelligent decision support

Earth Observation

↓

Cloud-native Data

↓

Analysis-ready Data

↓

Artificial Intelligence

↓

Water Resources Management

By the end of this session you will be able to:

- Discover modern Earth Observation data sources
- Access cloud-native datasets without downloading large archives
- Prepare analysis-ready environmental data
- Apply AI methods to a simple water management problem
- Understand the complete workflow from EO to decision support

Types of Environmental Sensors

Environmental observations come from many different sources.

Passive

Optical sensors
Example: Sentinel-2

Active

Radar sensors
Example: Sentinel-1

Remote

Satellite imagery

In situ

Ground measurements

Mobile

UAVs, aircraft

Fixed

Weather stations
River gauges
Ocean buoys

Different sensors observe different aspects of the Earth system.

Remote Sensing vs In Situ Measurements

Satellite observations and ground measurements provide complementary environmental information.

Remote Sensing

- Large spatial coverage
- Regular satellite revisits
- Historical image archives
- Global availability
- Affected by clouds & atmosphere

In Situ Measurements

- High local accuracy
- Continuous monitoring
- Physical measurements
- Calibration reference
- Local coverage

No single sensor tells the whole story.

Modern environmental monitoring combines remote sensing with in situ observations.

Choosing the Right Sensor

Different applications require different sensor characteristics.

Spatial Resolution

How much detail can be observed?

Temporal Resolution

How often are observations collected?

Spectral Resolution

How many wavelengths are measured?

Radiometric Resolution

How precisely is energy measured?

There is no "best" sensor.

The right sensor depends on the scientific question and the application.

How can satellite imagery help monitor water quality?

Study area

- Urumea estuary (San Sebastián, Spain)
- Sentinel-2 multispectral imagery
- 10 m spatial resolution
- Water quality indicators:
  - chlorophyll-a
  - turbidity
  - suspended sediments

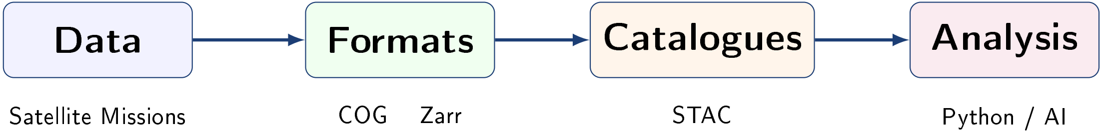
Study area: Urumea estuary (San Sebastián, Spain)

Goal

Monitor spatial variability of coastal water quality using freely available satellite data.

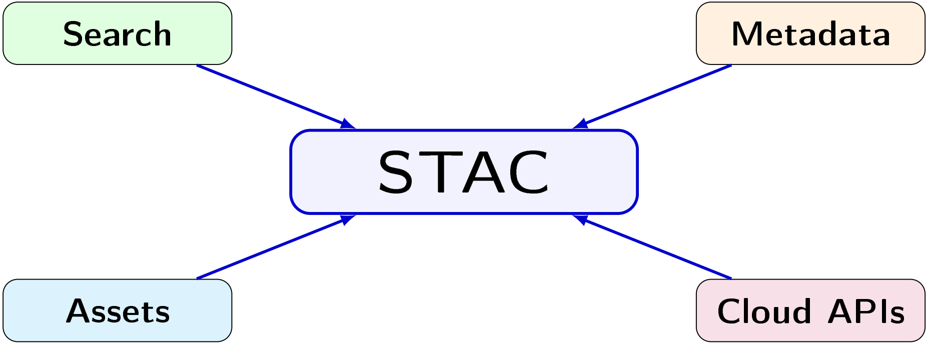
Why Open Standards Matter

An ecosystem is stronger when everything works together.



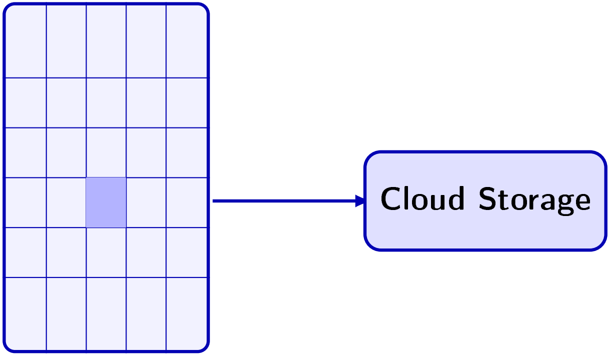
Open standards make Earth Observation data interoperable, reproducible and ready for modern scientific workflows.

SpatioTemporal Asset Catalog (STAC)



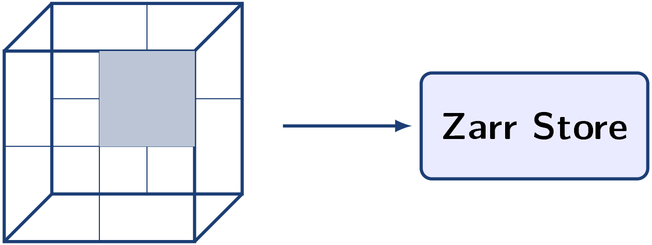
STAC provides a common language for discovering Earth Observation data.

Read only what you need.



Only the requested tiles are transferred, making access to large raster datasets much faster and more efficient.

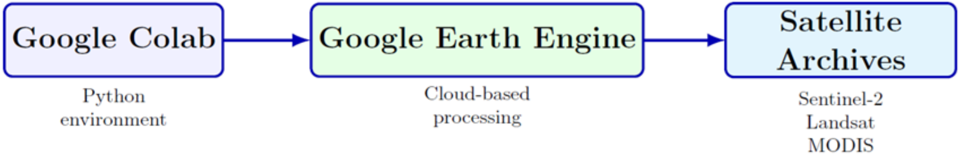
Built for scalable analysis rather than visualization.



Independent chunks enable efficient parallel processing directly in the cloud.

Hands-on with Google Earth Engine

From theory to practice



Google Earth Engine provides direct access to petabytes of satellite data without downloading complete archives.

Connecting to Google Earth Engine

The first step is authenticating your Google Earth Engine account.

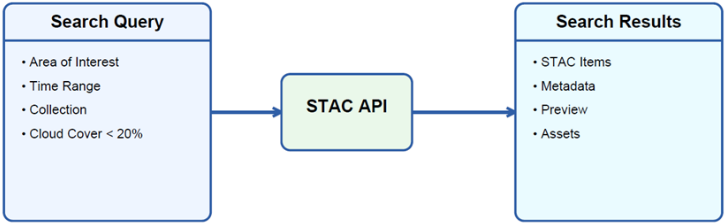
Google Colab → **Authentication** → **Google Earth Engine**

Notebook 1

Authenticate to Google Earth Engine from Google Colab and verify the connection.

Once authenticated, all Earth Engine datasets become available directly from the cloud.

Finding the right observations



Notebook 2

Search Sentinel-2 imagery using an Area of Interest (AOI), temporal and cloud-cover filters.

Only observations matching the search criteria are retrieved from the cloud.

Opening analysis-ready data without downloading complete archives

Notebook 3

Open Sentinel-2 imagery as an xarray Dataset using stackstac.

The data remain in the cloud until computations are requested.

Visualising analysis-ready satellite data

xarray Dataset — RGB Composite — Earth Observation Image

Notebook 4

Visualise Sentinel-2 imagery using RGB composites and explore individual spectral bands.

Cloud-native datasets can be explored interactively without downloading the original imagery.

Removing clouds from Sentinel-2 imagery

Sentinel-2
Image Collection

Cloud Filtering
SCL • QA • Metadata

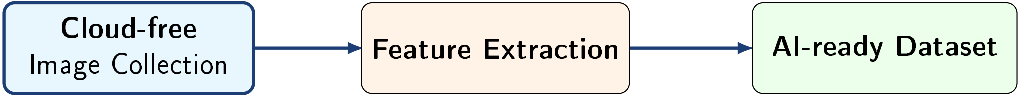
Cloud-free
Image Collection

Notebook 5

Filter Sentinel-2 Image Collections using cloud masks and metadata to create cloud-free analysis-ready datasets.

Reliable environmental analyses require cloud-free observations.

Preparing Earth Observation data for AI models



Notebook 6

Prepare Earth Observation features for AI models applied to water resources.

Reliable AI models begin with high-quality Earth Observation data.

Today's Challenge

Integrating the complete cloud-native workflow

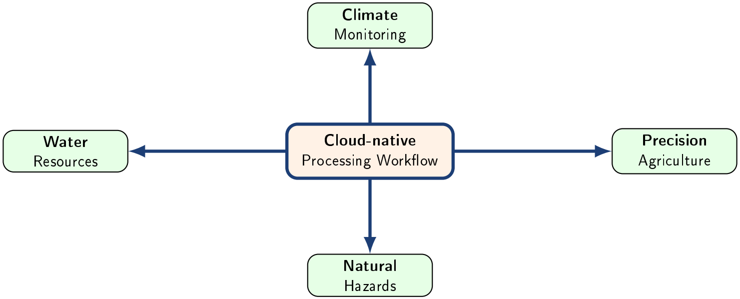
Earth Observation Data → Cloud-native Processing → AI-ready Dataset

Notebook 7

Integrate the complete cloud-native workflow to prepare an AI-ready Earth Observation dataset for environmental analysis.

Today's challenge integrates all previous notebooks into a single end-to-end cloud-native workflow.

The same cloud-native workflow supports many environmental applications



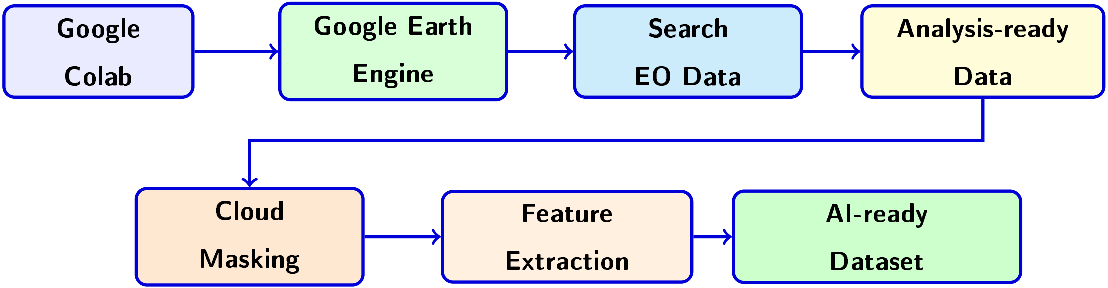
Beyond today's hands-on exercise

The workflow developed in these notebooks can be directly applied to multiple Earth Observation applications.

One workflow. Multiple environmental applications.

Cloud-native Processing Workflow

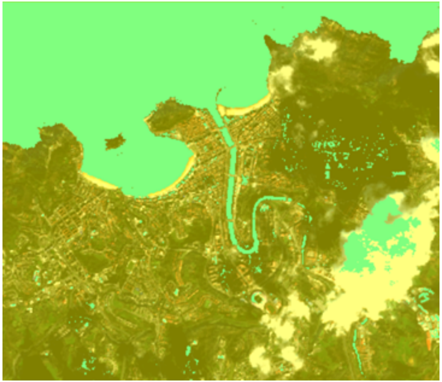
Building an AI-ready environmental dataset step by step



The complete workflow transforms Earth Observation data into AI-ready environmental datasets.

Expected Output

Products generated by the complete cloud-native workflow



Cloud-free NDWI visualization

Final Products

- Cloud-free Sentinel-2 composite
- NDWI visualization
- Water statistics
- AI-ready environmental dataset

Cloud-native workflow → Analysis-ready products → AI-ready datasets

Scaling from a single exercise to operational environmental monitoring

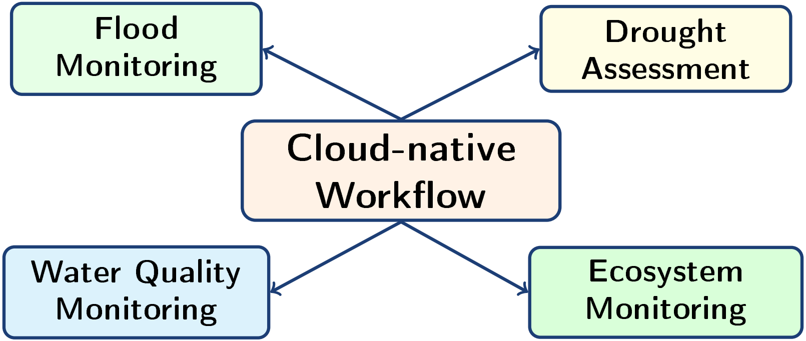
Cloud-native Workflow — Cloud-native Batch Processing — Time Series — Operational Monitoring

Looking Ahead

The workflow presented in this workshop is not limited to a single satellite scene. Using cloud-native processing, the same approach can be applied automatically to complete image archives, enabling continuous environmental monitoring at regional and global scales.

The same workflow scales from one image to continuous environmental monitoring.

One cloud-native workflow supports many environmental applications



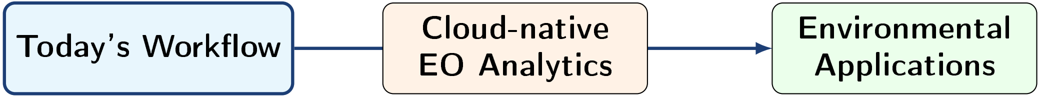
The same cloud-native workflow can be adapted to a wide range of Earth Observation applications.

Five ideas to remember from today's session

Main messages

- Earth Observation data are becoming increasingly accessible.
- Google Earth Engine provides direct access to global geospatial datasets.
- Cloud-native workflows reduce unnecessary data transfer and improve scalability.
- Open-source Python libraries make cloud-based analysis reproducible and transparent.
- Choosing the right platform depends on the research question and workflow.

The workflow presented today can be extended to many environmental applications.



Possible next steps

- Explore longer satellite time series.
- Combine multiple Earth Observation datasets.
- Integrate climate and environmental information.
- Apply Machine Learning techniques.
- Develop operational environmental monitoring workflows.

Thank You

Questions & Discussion

Cloud-native Environmental Data Processing