

# Earth observation and AI

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Head of ESA  $\Phi$ -Lab

“To provide for and promote, for **exclusively peaceful purposes**, cooperation among European states in **space research** and **technology** and their **space applications**.”

Article 2 of the ESA Convention

**ESA was established in 1975**



# Our Blue Marble



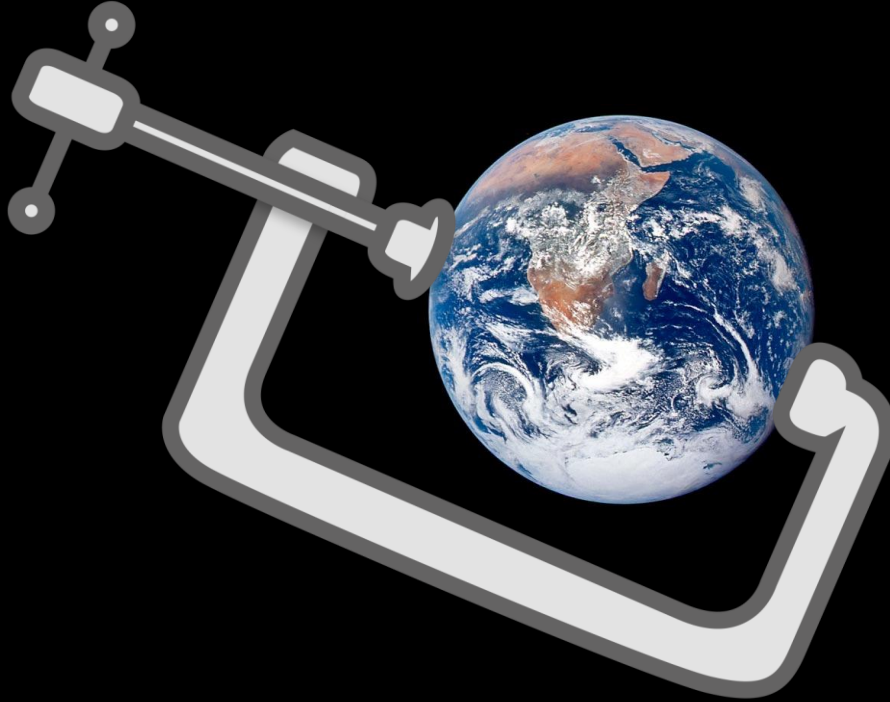
Apollo 17, 1972

Slide 3



European Space Agency

# Human Footprint



Slide 4

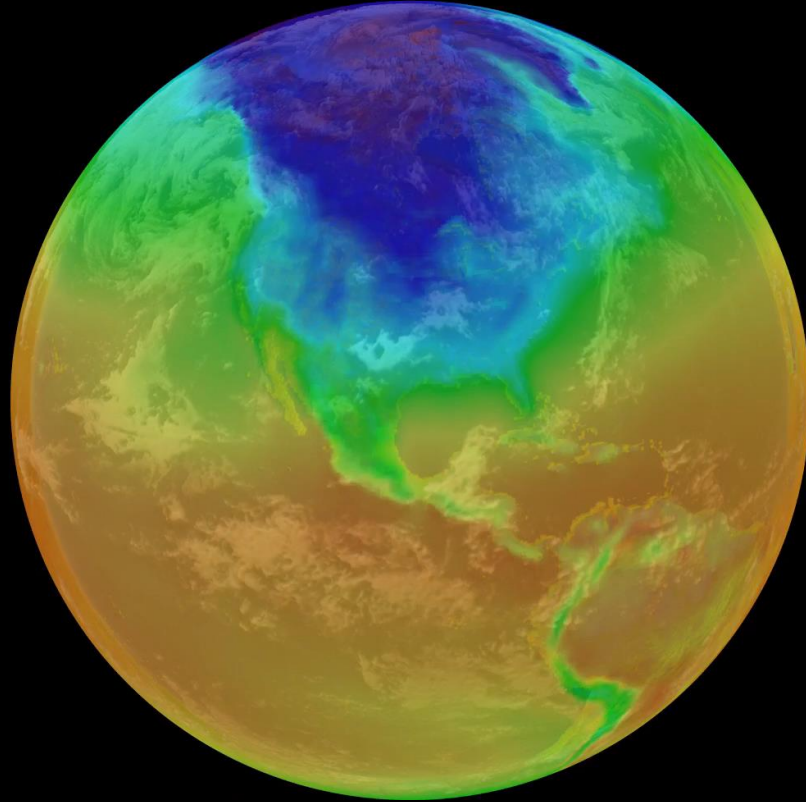


European Space Agency

# Earth Observation is our planetary microscope

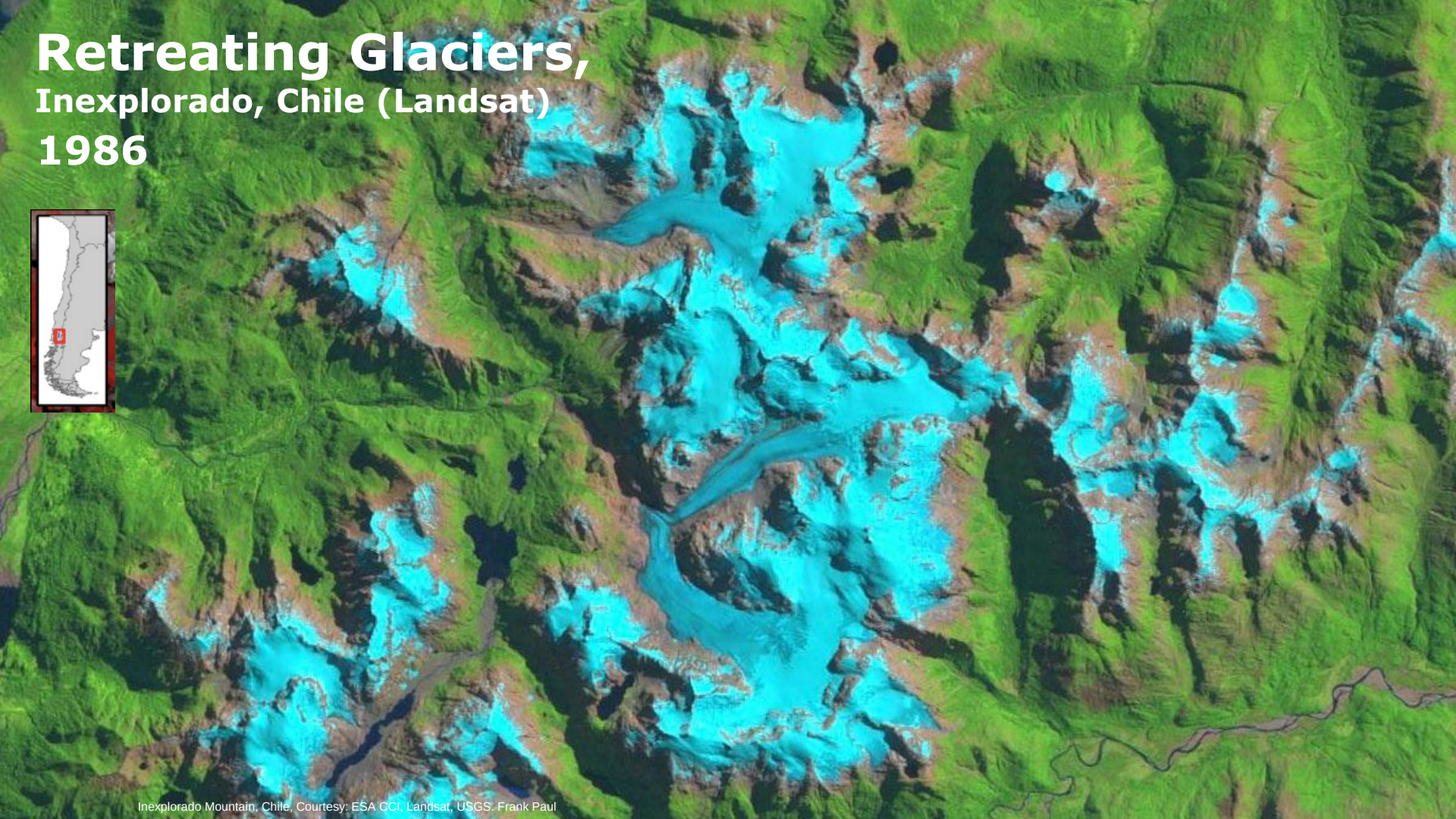


# Europe leads the World in this

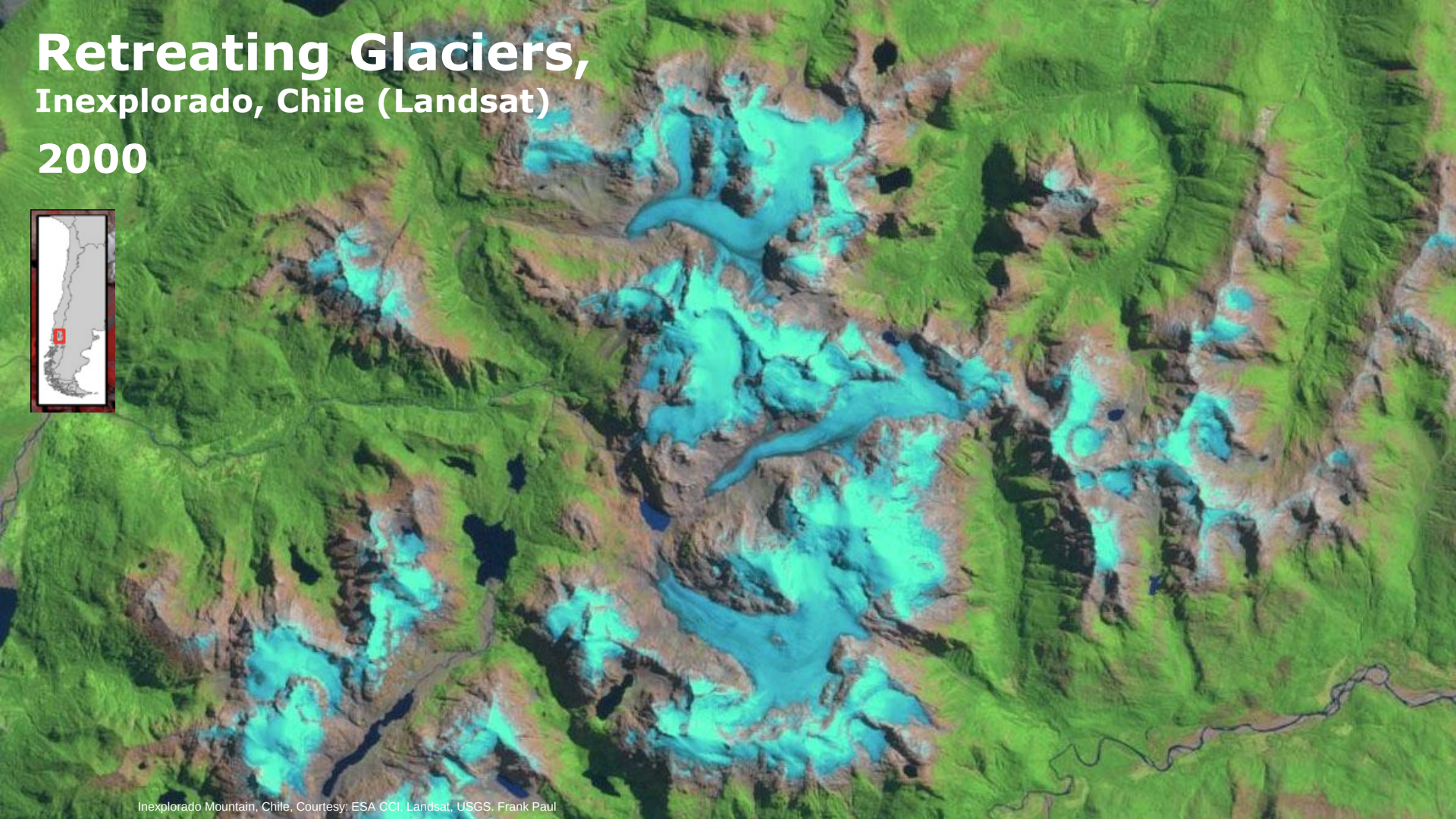


European Space Agency

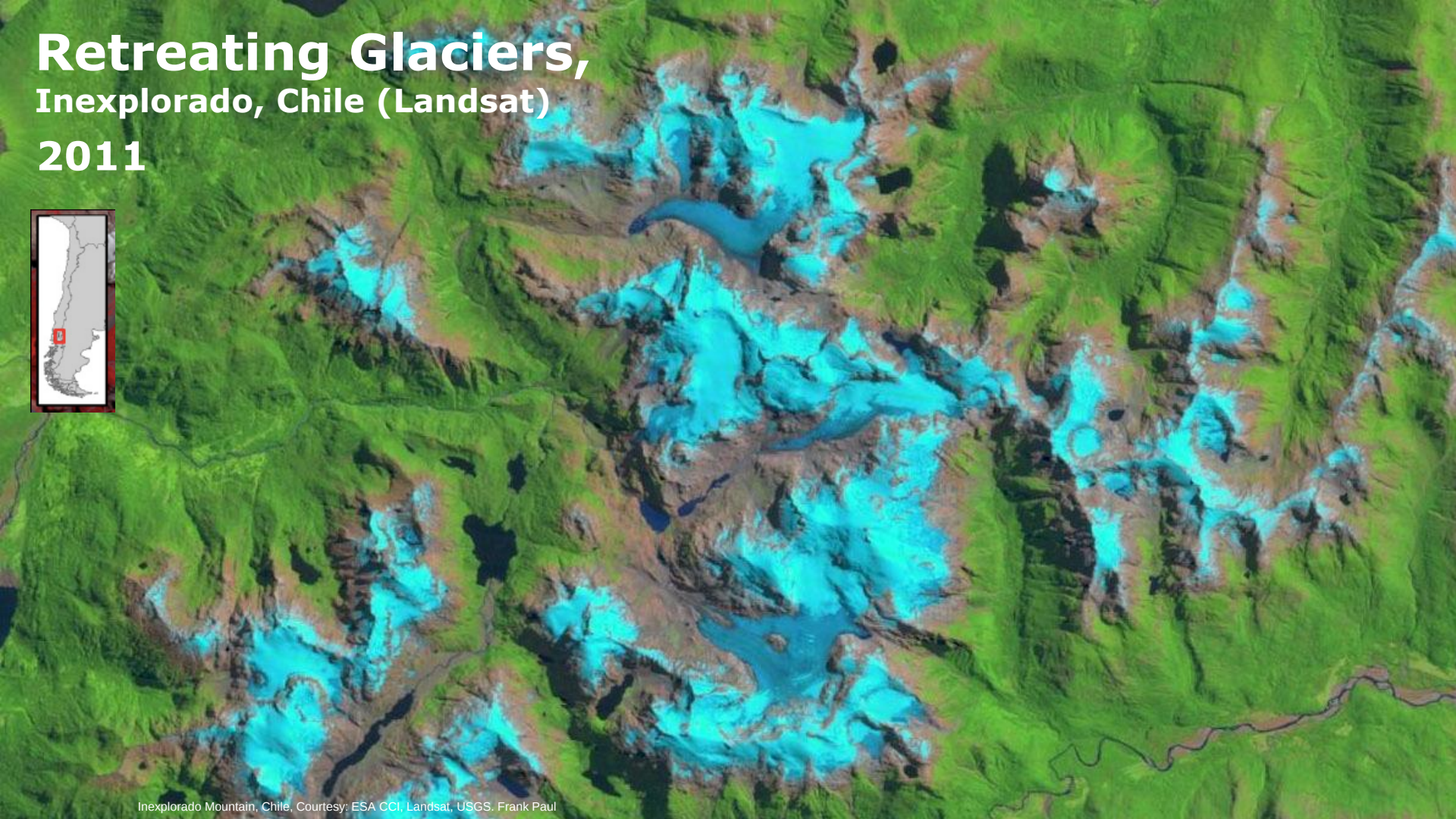
# Retreating Glaciers, Inexplorado, Chile (Landsat) 1986



# Retreating Glaciers, Inexplorado, Chile (Landsat) 2000



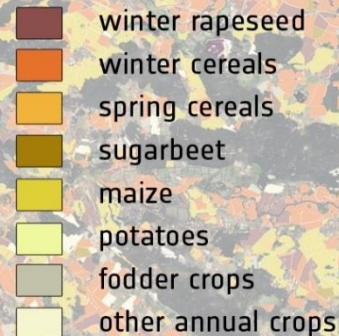
# Retreating Glaciers, Inexplorado, Chile (Landsat) 2011



# Commercial data services

*“Copernicus will significantly **reduce** the number of field inspections ... reducing the costs of controls & checks.”*

Phil Hogan  
European Commissioner for Agriculture and Rural Development  
25 May 2018



# Copernicus – Europe's permanent EO infrastructure

**> 200 000**

registered users  
= tip of the iceberg

**6 operational services**



Land



Atmosphere



Ocean



Climate



Disaster



Security



**>150 TB** satellite data  
distributed per day

**7 satellites flying**

S1



S2



S3



S4



S5P



S5



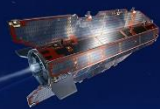
S6



**full, free & open**  
data policy

**preparing Copernicus 2.0**

# Earth Explorers



goce



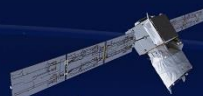
smos



cryosat



swarm



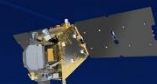
aeolus



earthcare

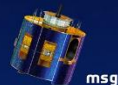


biomass



flex

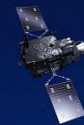
## Meteo Sat.



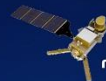
msg



metop



mtg-i

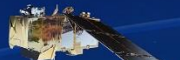


metop-sg-b

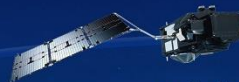
## Sentinels



sentinel-1



sentinel-2



sentinel-3



mtg-s  
sentinel-4



metop-sg-a  
sentinel-5

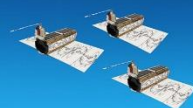
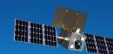


sentinel-6



sentinel-6

## Small Sat Constellations



IoT

IoT

HAPS

Drones

HAPS

Drones

IoT



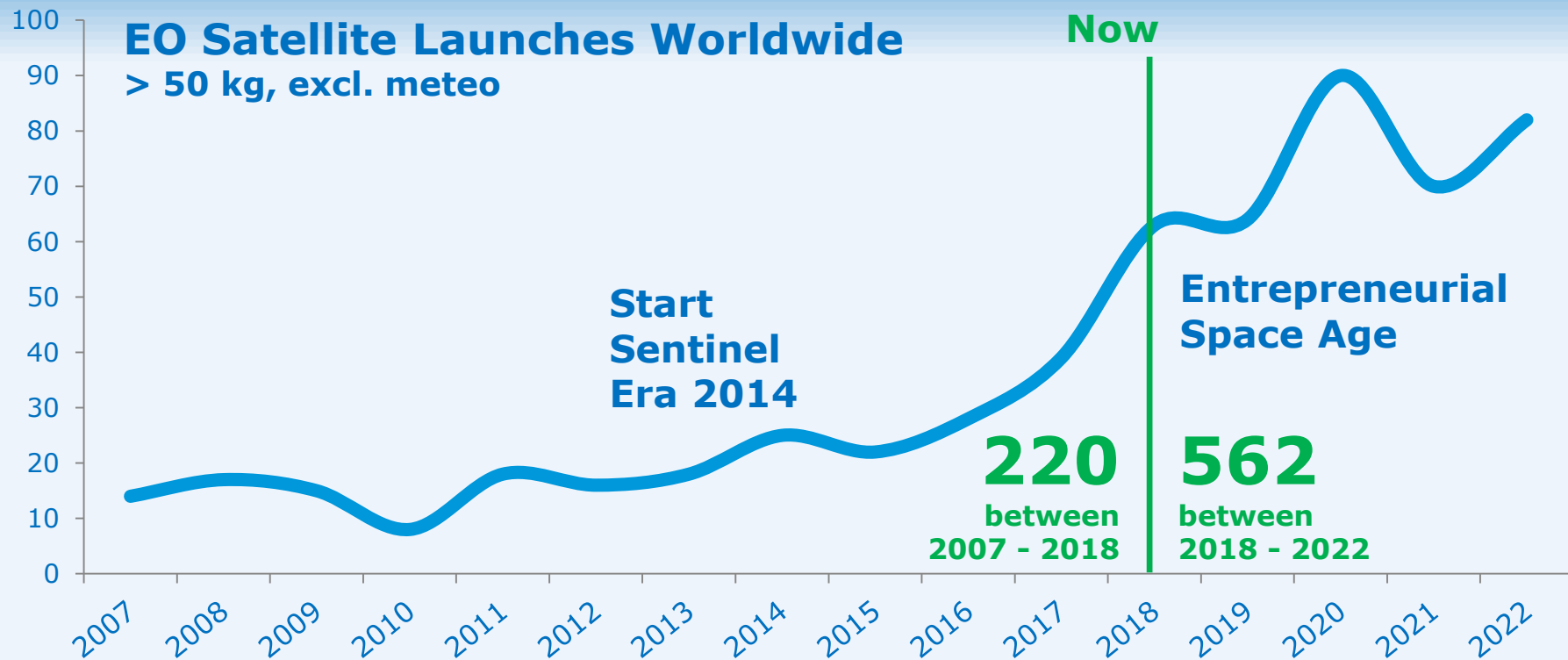
# Jeff & Space



*"I am using my resources to put in place **heavy-lifting infrastructure** so the next generation of people can have a **dynamic, entrepreneurial explosion into space.**"*

*Jeff BEZOS, CEO Amazon*

# More Eyes in the Sky



Source: Euroconsult Database, 2017



# **$\Phi$ -lab Mission**

**Accelerate use of AI  
and commercial  
development to  
extend Europe's  
leadership in Earth  
observation.**

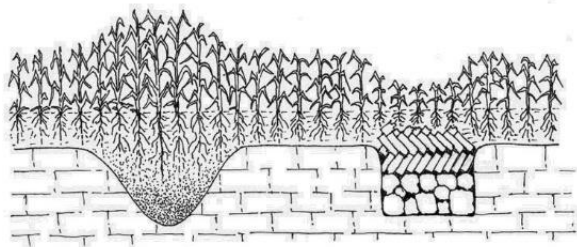


- **x1000 faster modelling** for SCOPE Photosynthesis and Energy fluxes model with  $< 2\%$  RMSE [Verrelst et al 2019]
- **x10,000 times faster** version of the PROSAIL canopy model, with RMSE  $< 0.01\%$  [Gomez-Dans et al 2016]
- **x30,000 times faster** coupled canopy and atmospheric RT models (PROSAIL + 6S) [Gomez-Dans et al 2016]; 45 seconds for full model per run can be simulated in 1.5 milliseconds for AI emulator, with bias  $< 0.01$ .

# Object Detection

## Objective: Systematic Archaeological Prospection

cropmarks...



in EO data...



through a combination of:

### 1. Crowdsourcing



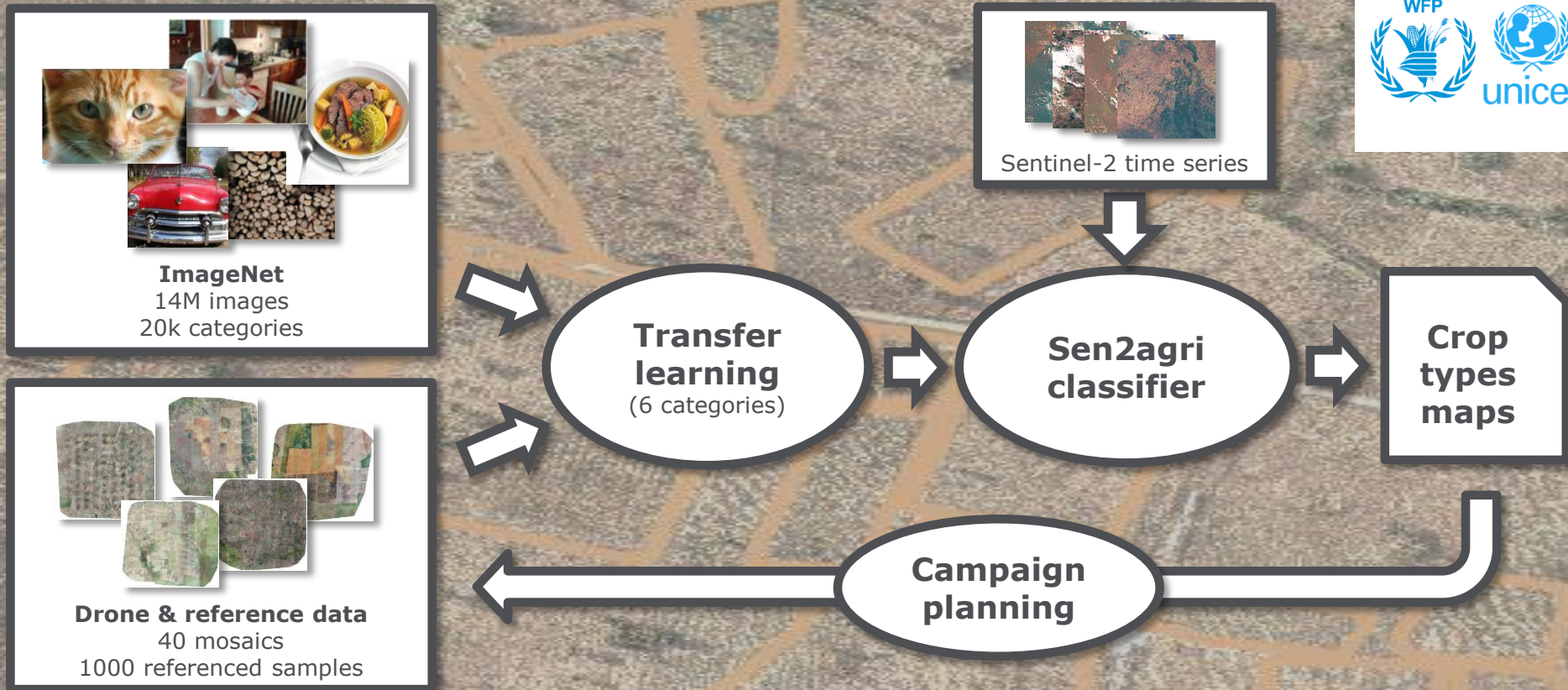
### 2. Machine Learning

Supervised transfer learning - deep CNNs, trained with output from 1, enriched with data augmentation.

Input EO data: **VHR Optical (Bing maps, BirdsEye)**

Output: vector points of archaeological **site locations**, provided to **local authorities**

# Transfer learning from drone data to Sentinel 2



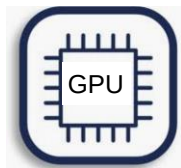
# ML in Space on FSSCat – $\Phi$ -sat 1

## Hyperspectral Sensor



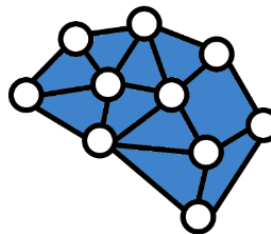
re-configurable  
VNIR, TIR  
Swath 300km  
GSD 75m/240m

## Hybrid Computing



Movidius  
Myriad-2 (1W)  
Visual Processing Unit (VPU)

## Inference at the edge



Pre-trained Machine  
Learning algorithms for  
inference  
Cloud Detection  
+ More ...

## Federated System



6U Tandem mission  
GNSS Reflectometer  
L-band radiometer  
Multi-spectral (Optical,IR)  
Radio/Optical link  
—> **Soil Moisture**  
—> **Ice extent/thickness**

# Hyperspectral

We achieve the state-of-the-art performance with our  
deep neural network architecture

- Spectral deep neural network
- Spatial-spectral neural network

KP-Labs project we funded

- Spectral deep neural networks
- Spatial-spectral neural networks (we proposed the first „real” 3D CNN in the literature - d)

Diagram illustrating the proposed CNN architecture. The input is a  $1 \times 1 \times b$  heatmap. The architecture consists of the following layers and parameters:

- Convolution:**  $f = 200$ ,  $s = 1 \times 5$
- Batch norm.**
- Max pooling:**  $s = 2 \times 2$
- Fully connected:**  $l_1 = 512$ ,  $l_0 = 128$
- Softmax:** Output layer for classification.

# Spectral-spatial convolutional network

The diagram illustrates the architecture of a Spectral-spatial convolutional network. It begins with an **Input cube** (Spectral & Spatial). This is processed by a **Spatial 2D conv** layer to produce a **Spatially reduced cube**. This is followed by a **Spectral 1D conv** layer, which is part of a **Spectral-spatial conv** block. The output of this block is then processed by a **Spectral 1D conv** layer, which is part of another **Spectral-spatial conv** block. The final output is a **1D vector**.

“With AI becoming a transformative technology and European EO capability delivering a unique and comprehensive dataset on the planet that could be analysed by AI, we are at a cross roads.

**Addressing some of these challenges ... would help accelerate our AI industries and realise the full potential of EO.**

Not doing so would miss huge opportunities. Making the most of this window of opportunity is an urgent challenge.”



Slide 22

# → CLAIRE – ESA THEME DEVELOPMENT WORKSHOP ON ARTIFICIAL INTELLIGENCE AND EARTH OBSERVATION

28 February 2019 | ESA-ESRIN | Frascati (Rome), Italy

- **The World's first AI Special Interest Group on Space** established by ESA with CLAIR.
- **10 AI visiting professors** for Earth observation.
- This Autumn, **6 workshops on AI and climate change.**
- Next year **50 visiting scholarships on Earth observation and 20 to the technology directorate.**

## → WORKING WITH $\Phi$ -LAB

Help us accelerate the future  
of observing planet Earth

# Thank you

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[www.esa.int](http://www.esa.int)