

The Rise of Artificial Intelligence (AI) for Earth Observation (EO)

BELSPO Space Talks

17 April 2023

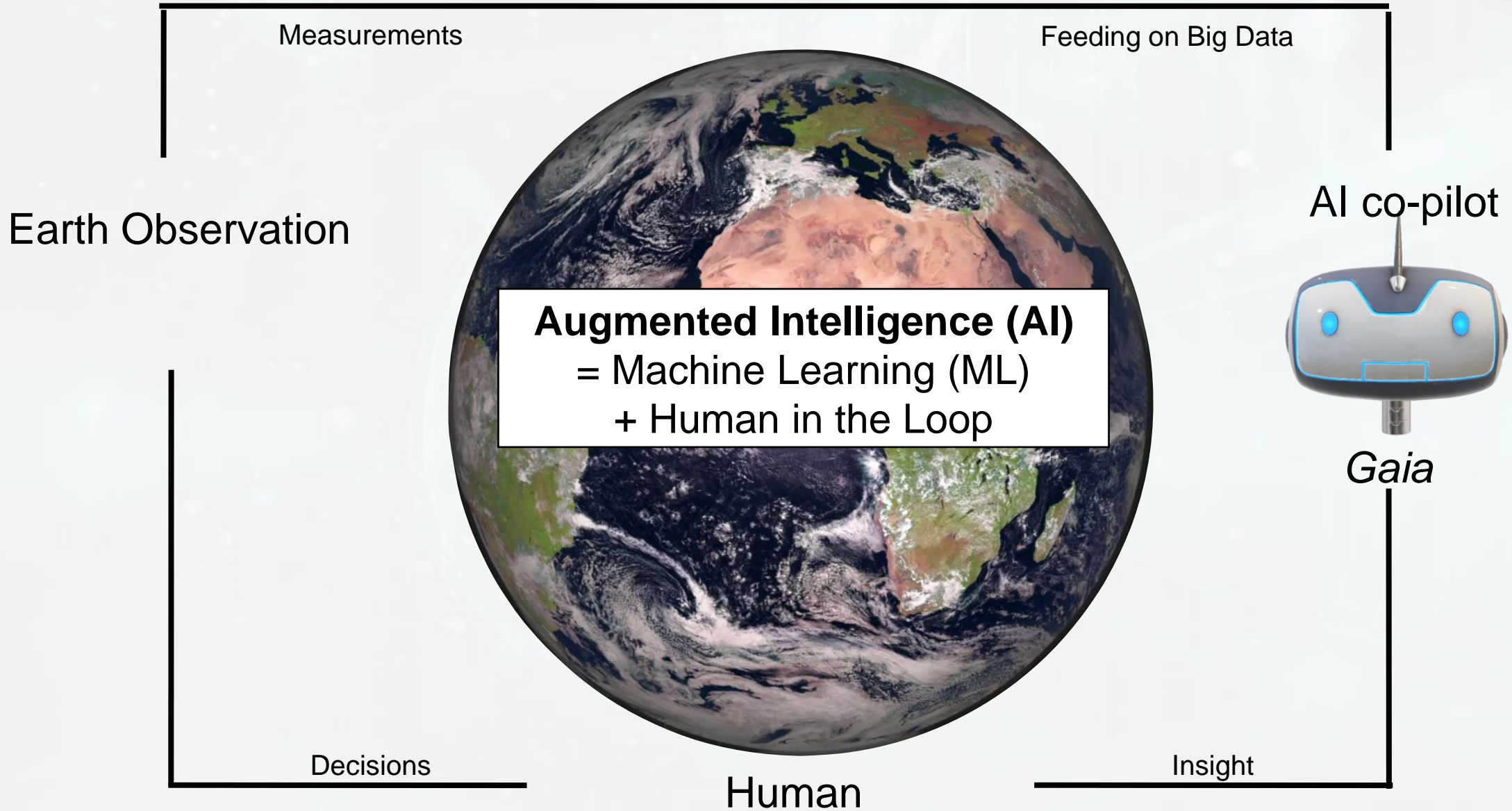
ESA Φ -lab team, pierre.philippe.mathieu@esa.int



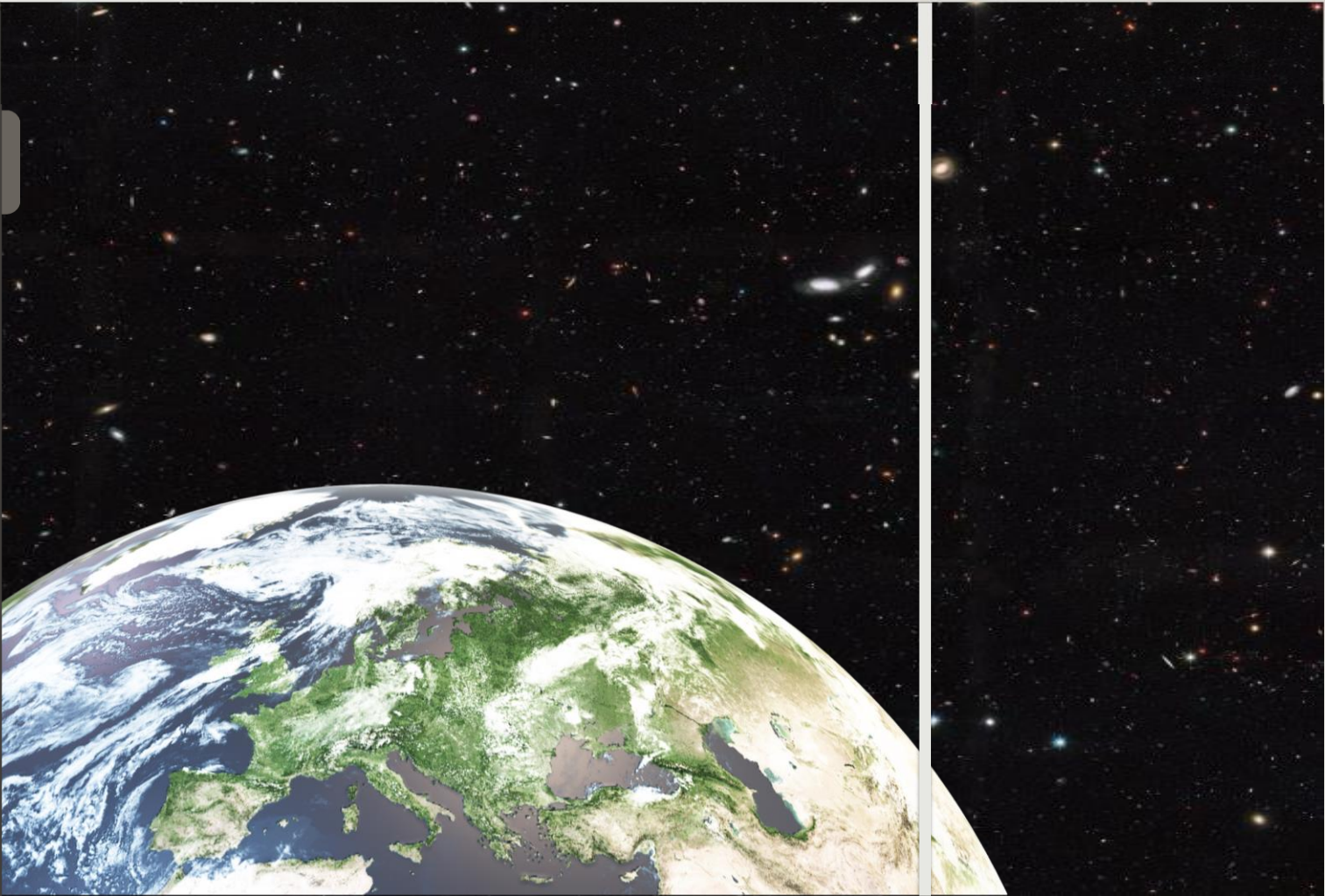
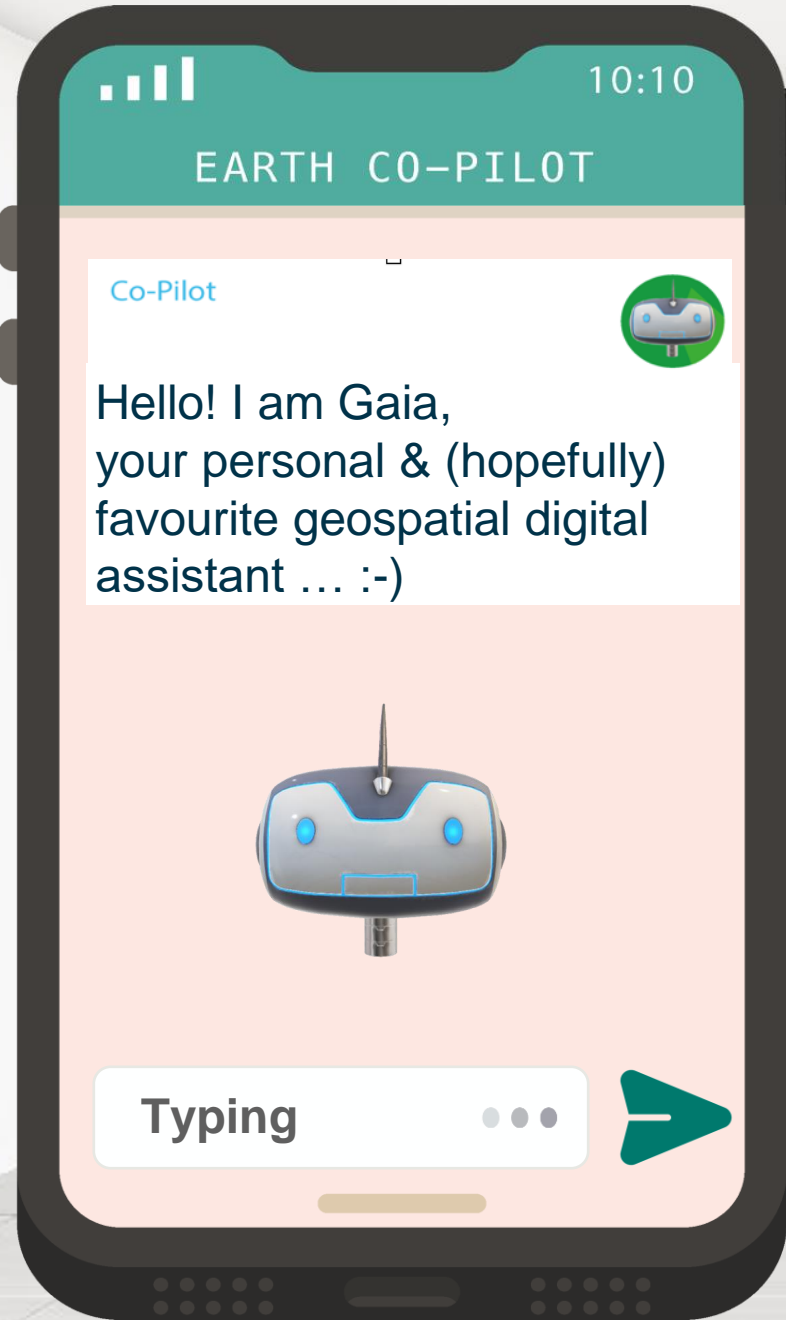
Courtesy ESA/EUMETSAT, MSG Mar 2022



AI co-pilot to guide Spaceship Earth



AI4Earth co-pilot



Courtesy Roberto del Prete
MOCKUP - not real



10:10

EARTH CO-PILOT

Co-Pilot



Bonjour, here is a suggested itinerary you cannot miss ..

Maybe you could visit the Atomium & Royal Palace, the Grand Place, & Cathedral of St. Gudula.

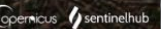


2023-02-14 00:00 - 2023-02-14 23:59, Sentinel-2 L2A, True color



500 m

Credit: European Union, contains modified Copernicus Sentinel data 2023, processed with EO Browser





10:10

EARTH CO-PILOT

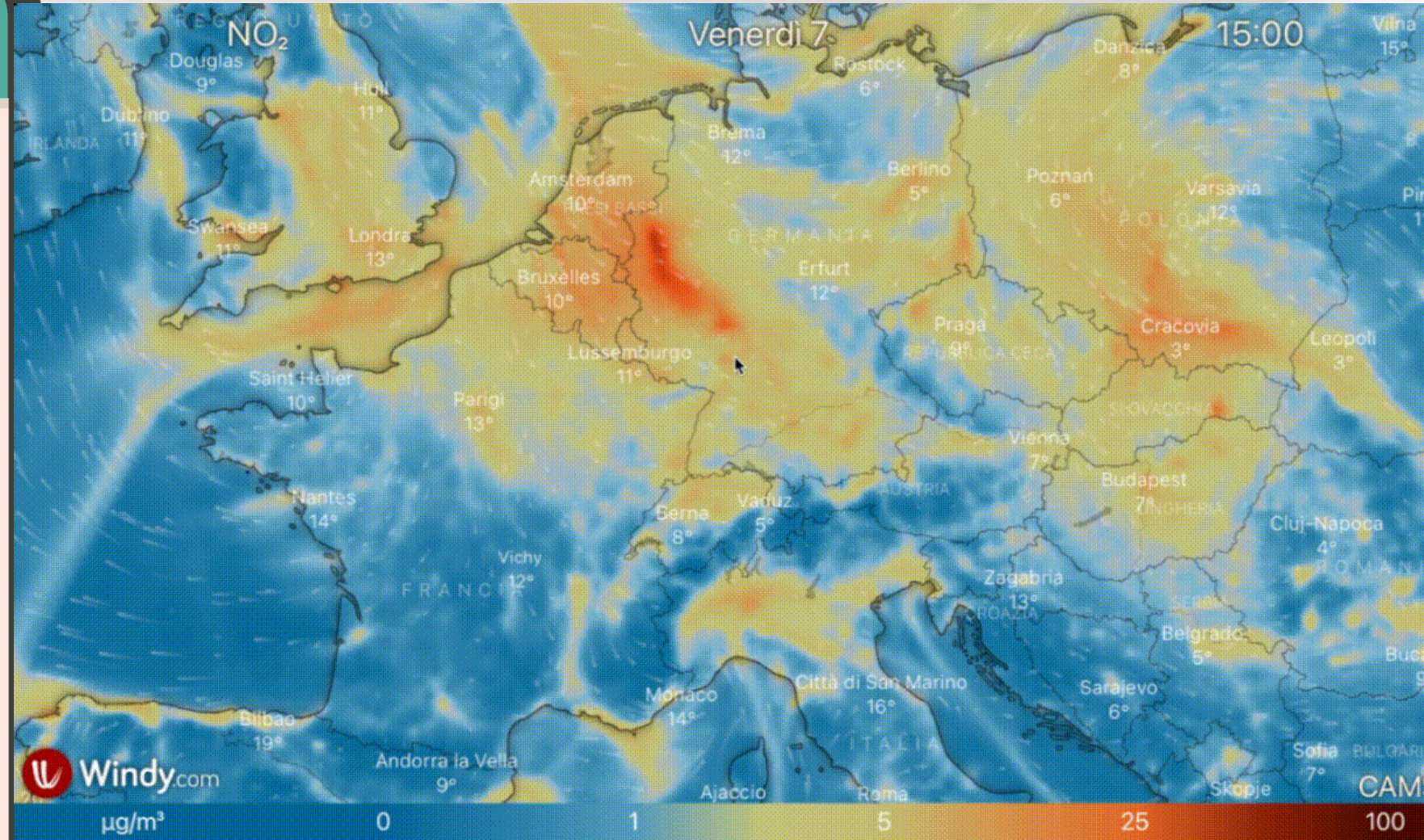
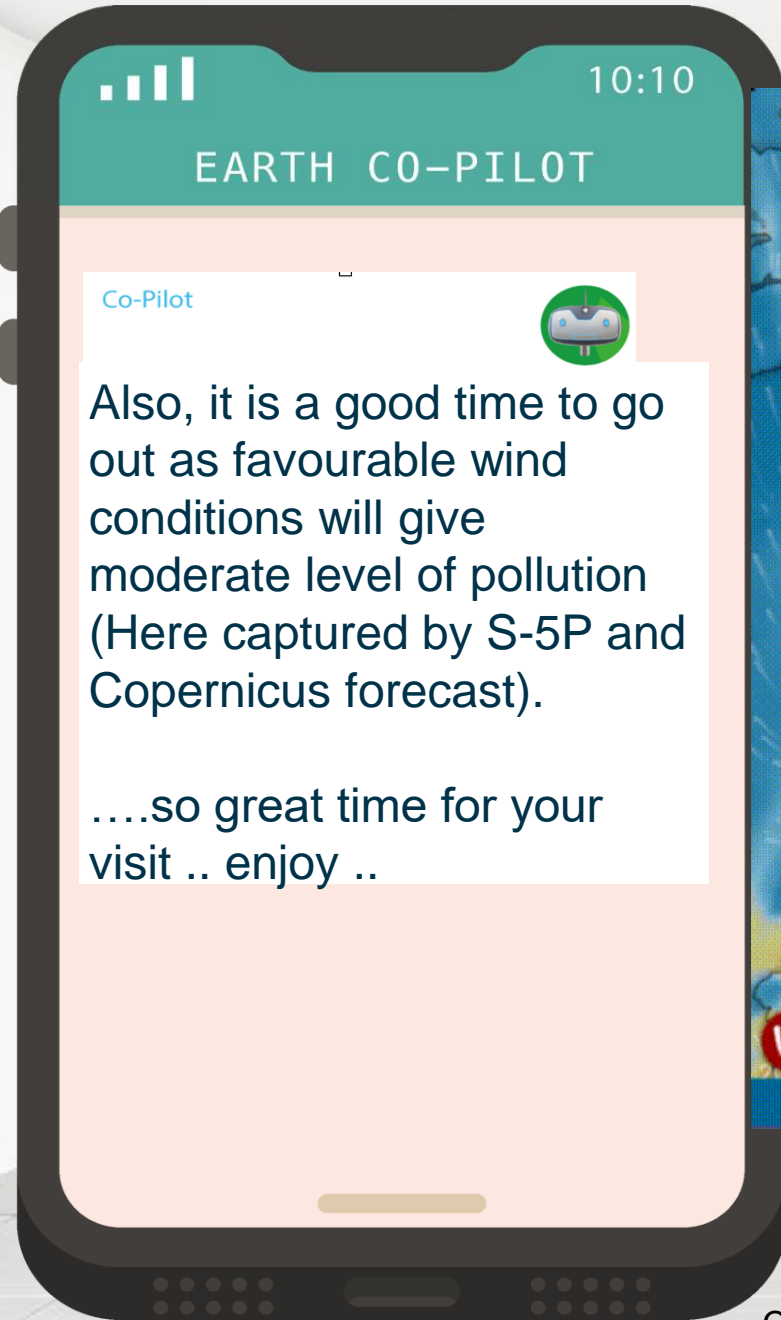
Co-Pilot



Brussels is one of the greenest European capitals, so you could relax in a variety of parks, here is a quick assessment of the current state of vegetation captured by Sentinel-2 ...

Typing





Courtesy Windy, CAMS



10:10

EARTH CO-PILOT

You



Hey Gaia! I am working on disaster management for UN ... What are the flooding risks in Nairobi now? following recent strong precipitation?

Co-Pilot



You can see here, the flood risk and impact quantified from S-2





10:10

EARTH CO-PILOT

You

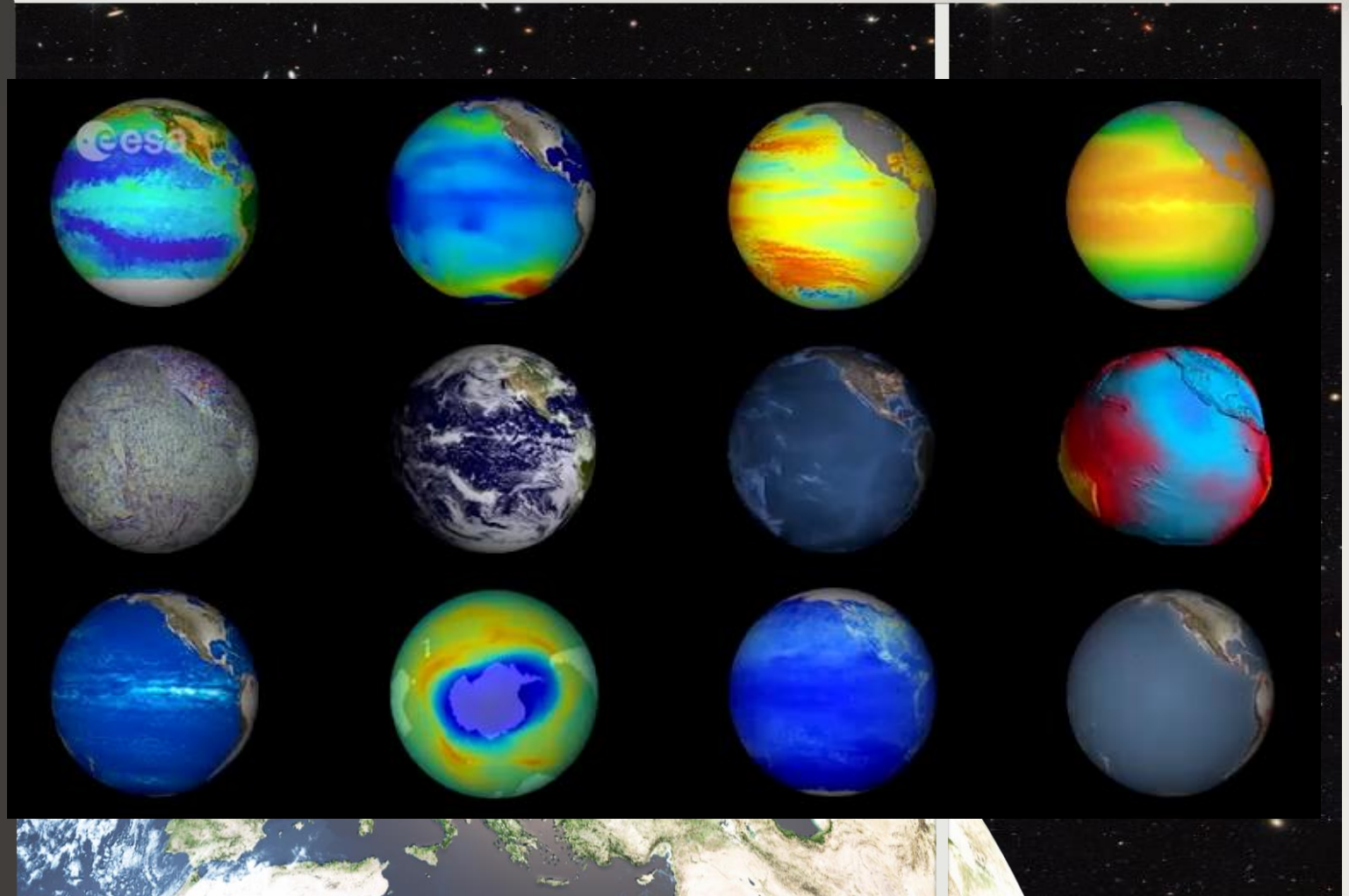


Hey Gaia! I am a climate scientist ... How can satellite help us **monitor our climate** and assess the **impact of our human activities**?

Co-Pilot



Hello, satellites are continuously monitoring the **vital signs of our home planet** as a doctor, these are called **Essential Climate Variables (ECVs)** .. here is some examples ..Sea Level, Surface Temperature, ...





10:10

EARTH CO-PILOT

Co-Pilot



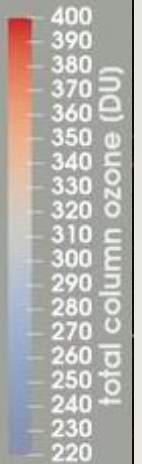
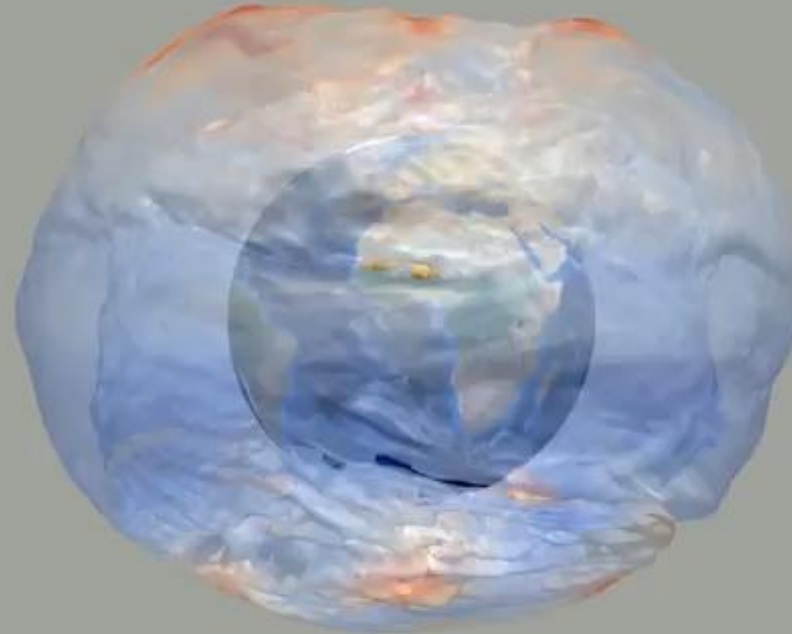
Another famous example in the Antarctic is the Ozone hole, here you can see how EO data help scientists to quantify the benefits of the Montreal protocol ...



Atmosphere
Monitoring Service
atmosphere.copernicus.eu

Ozone hole development 2022

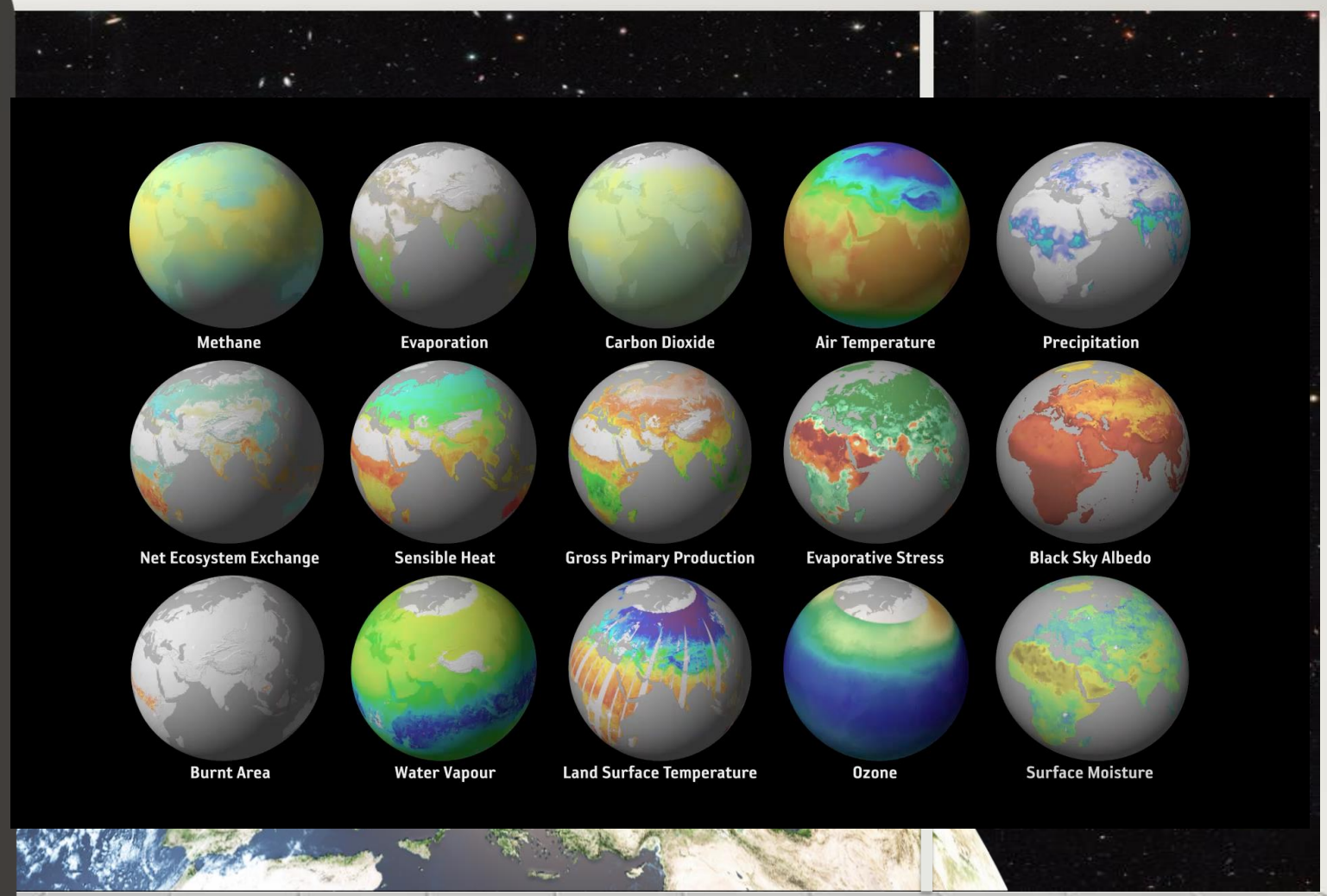
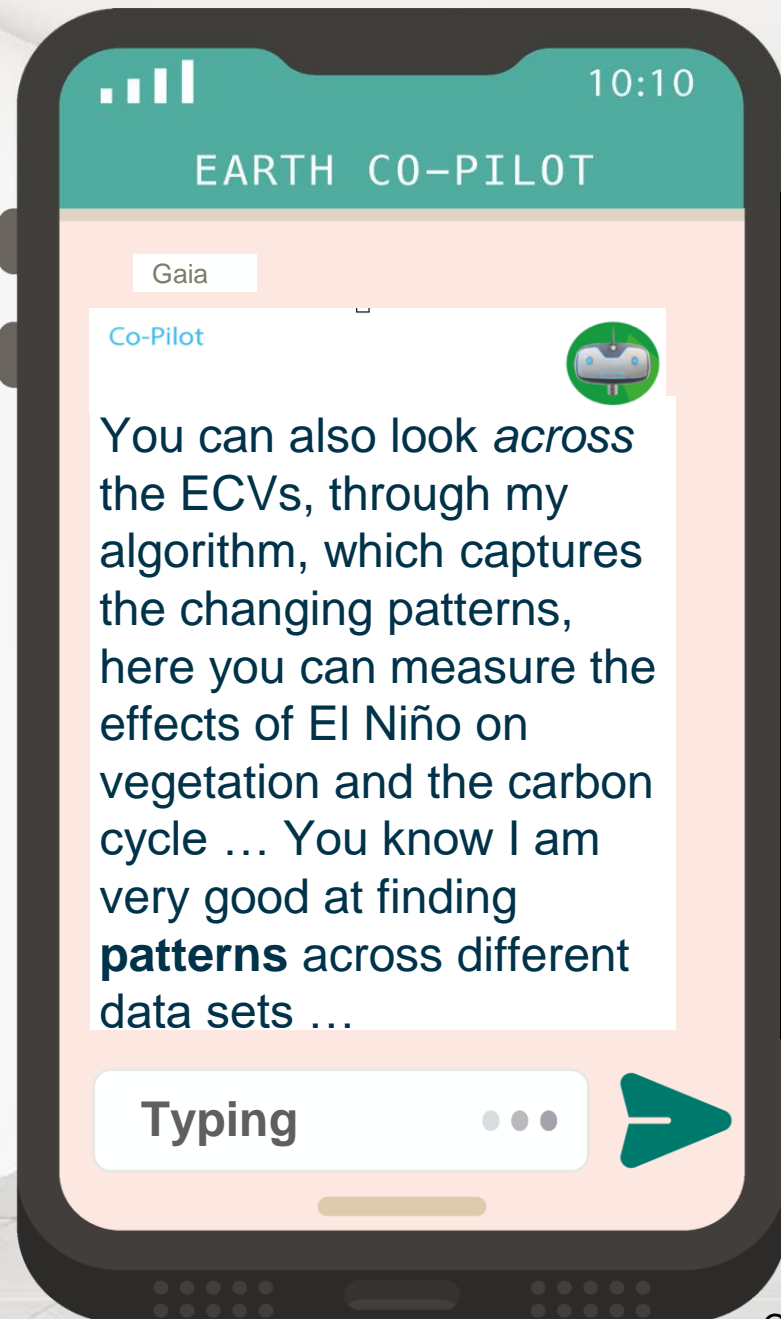
12 mPa ozone partial pressure isosurface coloured by total column ozone



PROGRAMME OF THE
EUROPEAN UNION



01 Jul 2022 00 UTC



Why AI matters?

Automation of Computer Programming

Rules

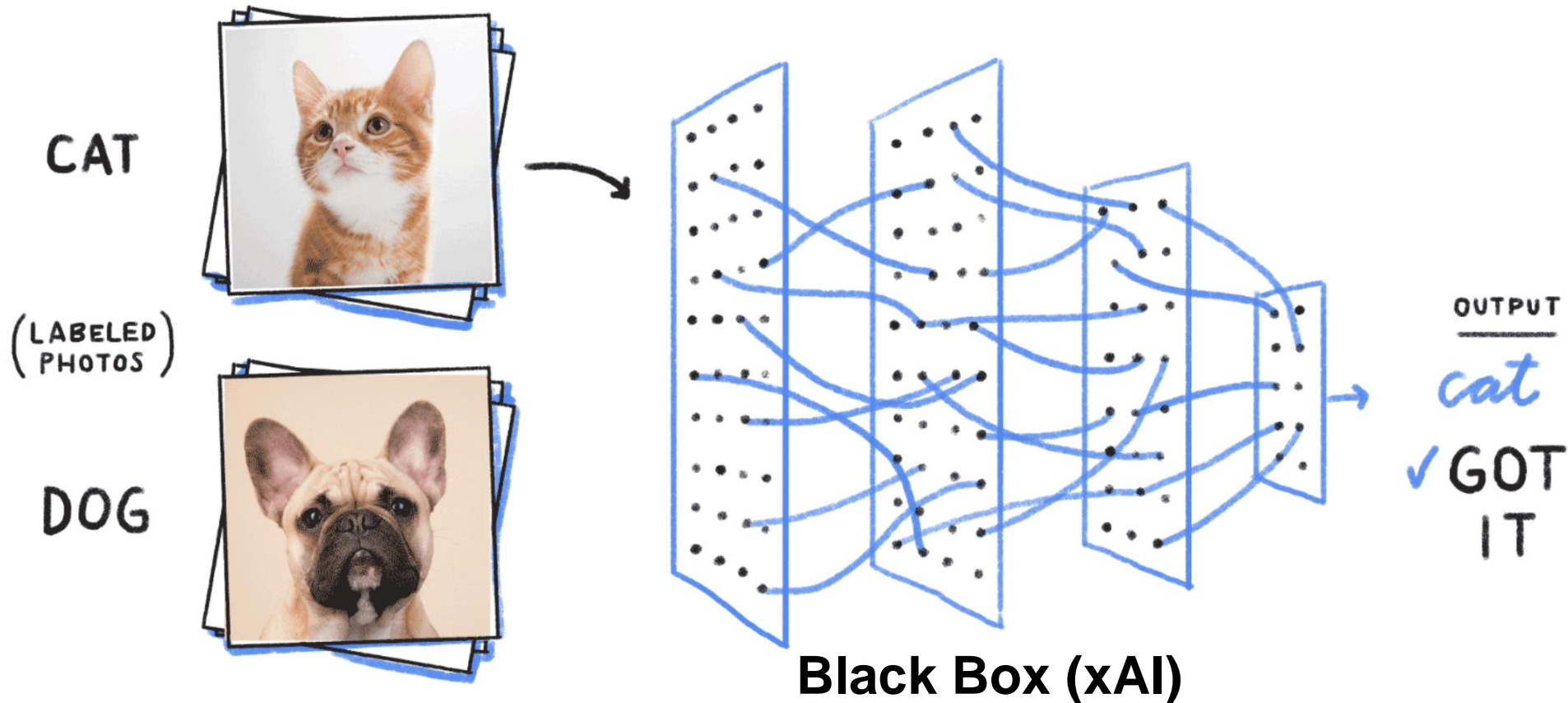
Output = **Data**



Learning

Output = **Software**

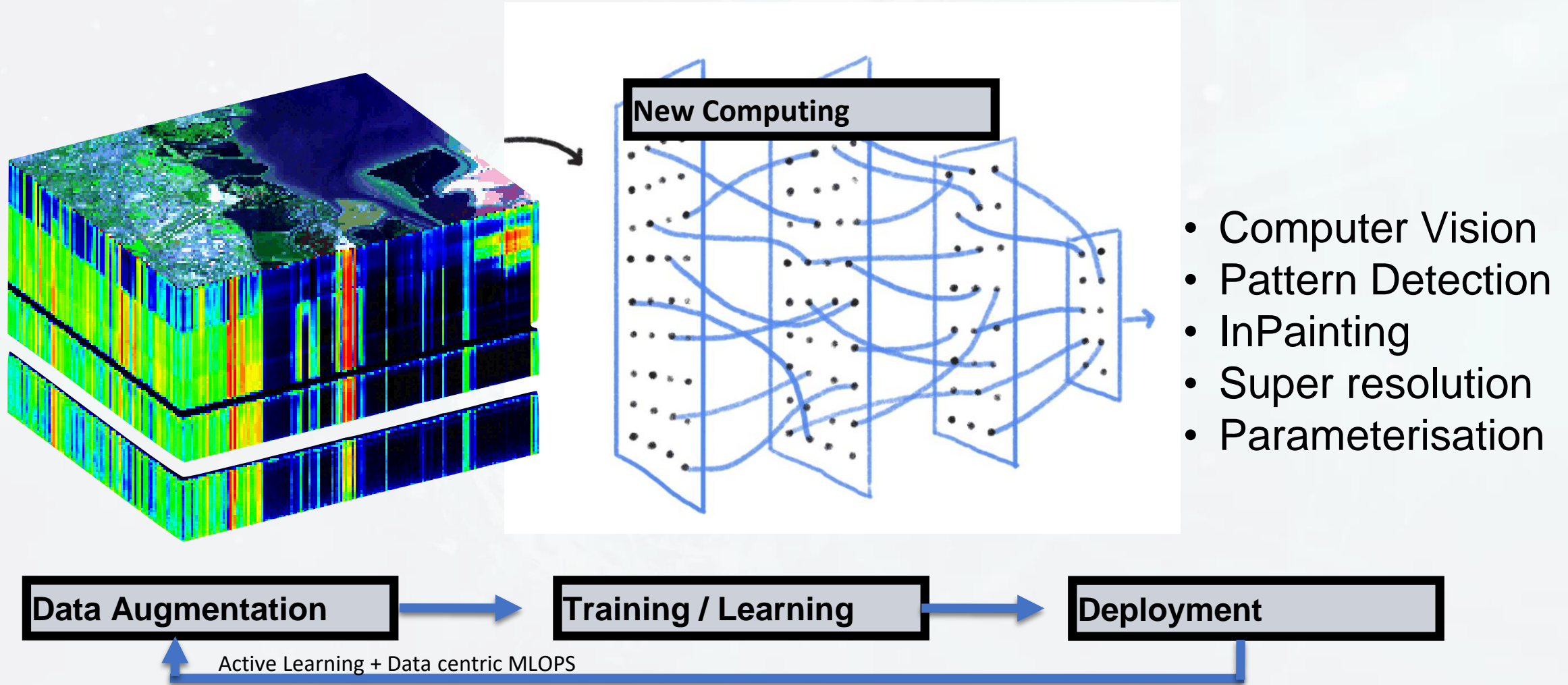
Pre-trained model = Software



Data-driven

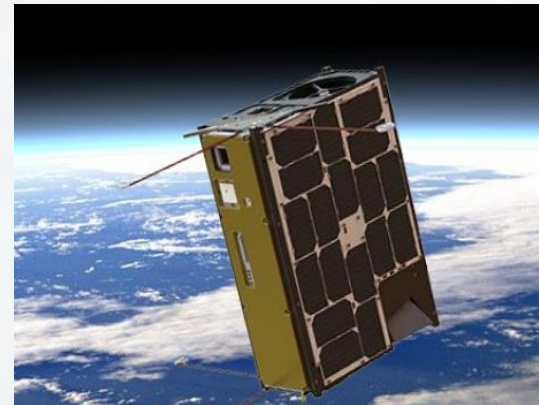
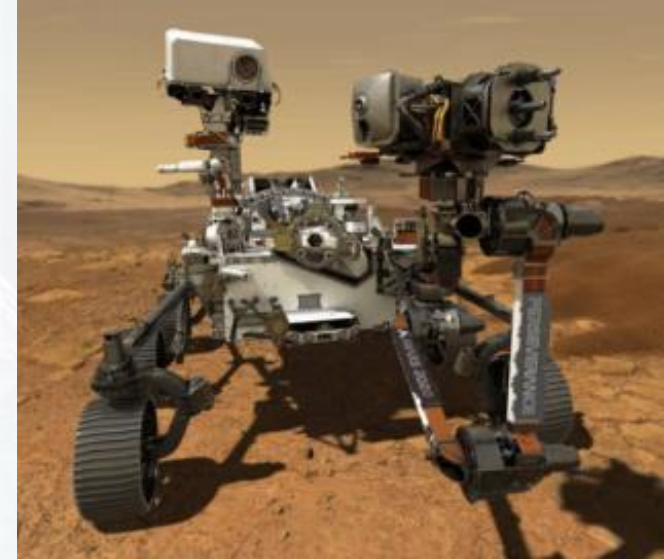
Lack of Understanding

Courtesy <https://becominghuman.ai/building-an-image-classifier-using-deep-learning-in-python-totally-from-a-beginners-perspective-be8dbaf22dd8>



A photograph of popcorn and kernels on a white surface. The popcorn is in the center, surrounded by many un-popped kernels. The background is a dark blue and green abstract graphic with a globe and lines.

Why timely?



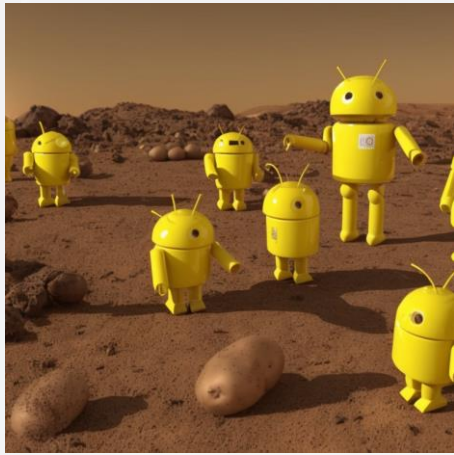
CIMON, ISS

The Great AI Acceleration

"... the **computational** ability to achieve **goals**." John McCarthy

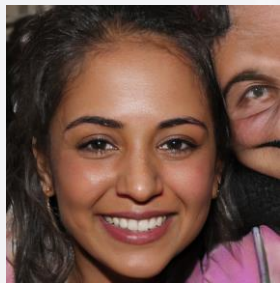


Diffusion Models



Prompt: a group of cute yellow robots farming potatoes on post apocalyptic mars

Synthetic Data
ITT out



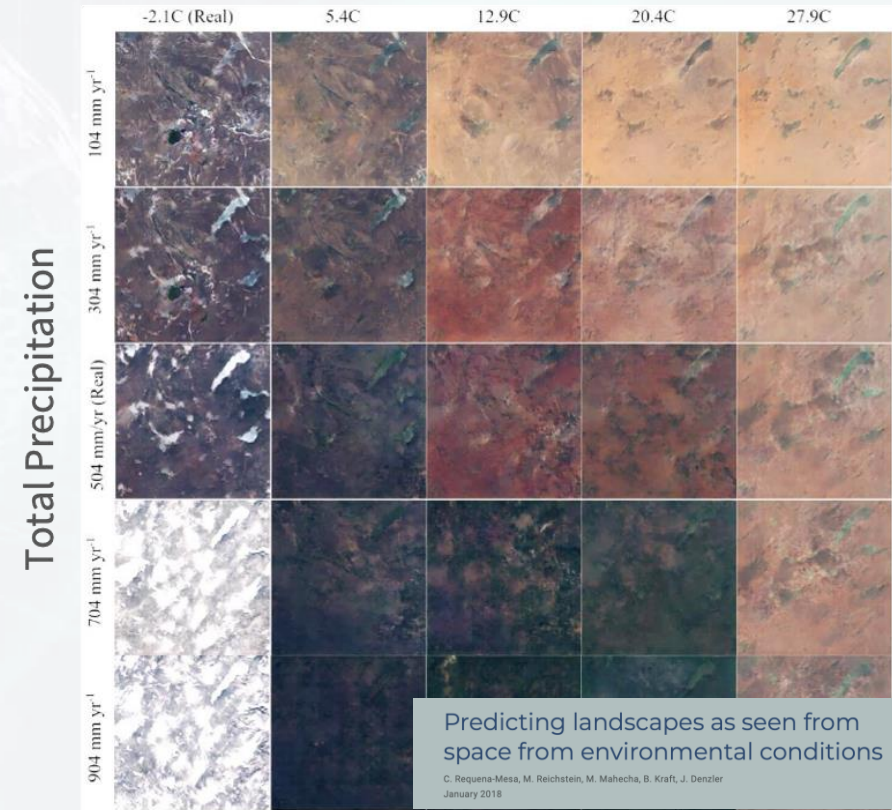
this **person** does not exist



this **city** does not exist

BELSPO DeepV. DeepFaking ecosystem response to climate extremes. DeepV. Prof Stef Lhermitte & Ben Sommers, Ku Leuven

Mean Temperature

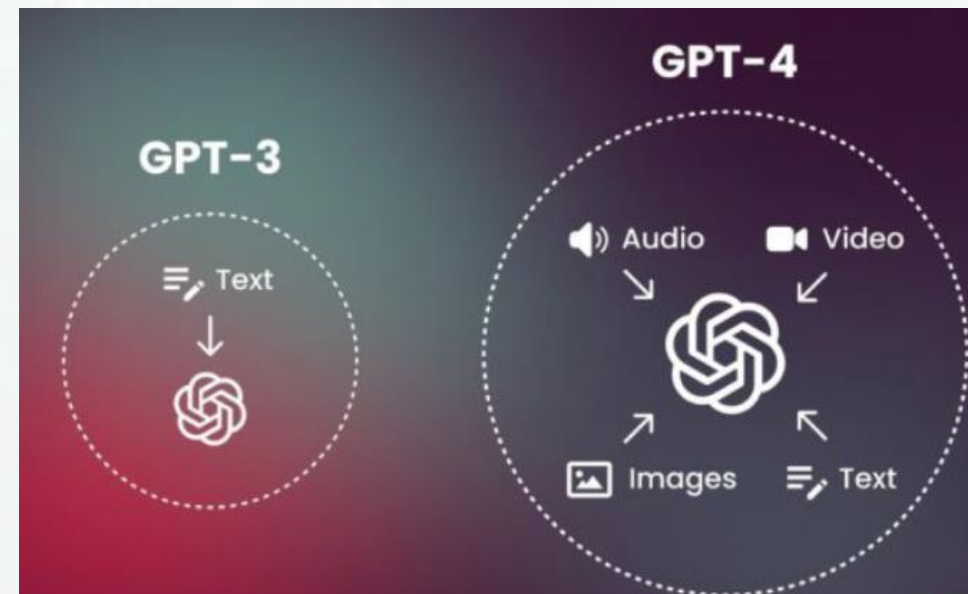
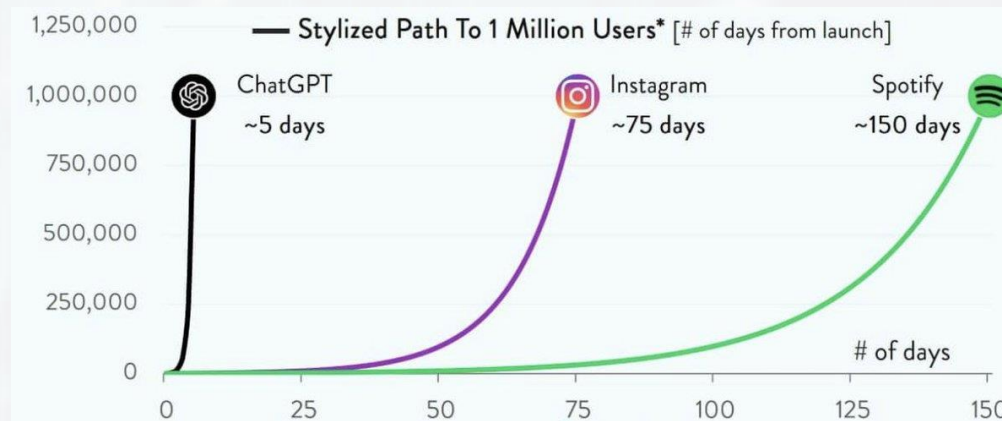


this **landscape** does not exist

Large Language Models



Large Language Model for EO
ITT out



175 B parameters

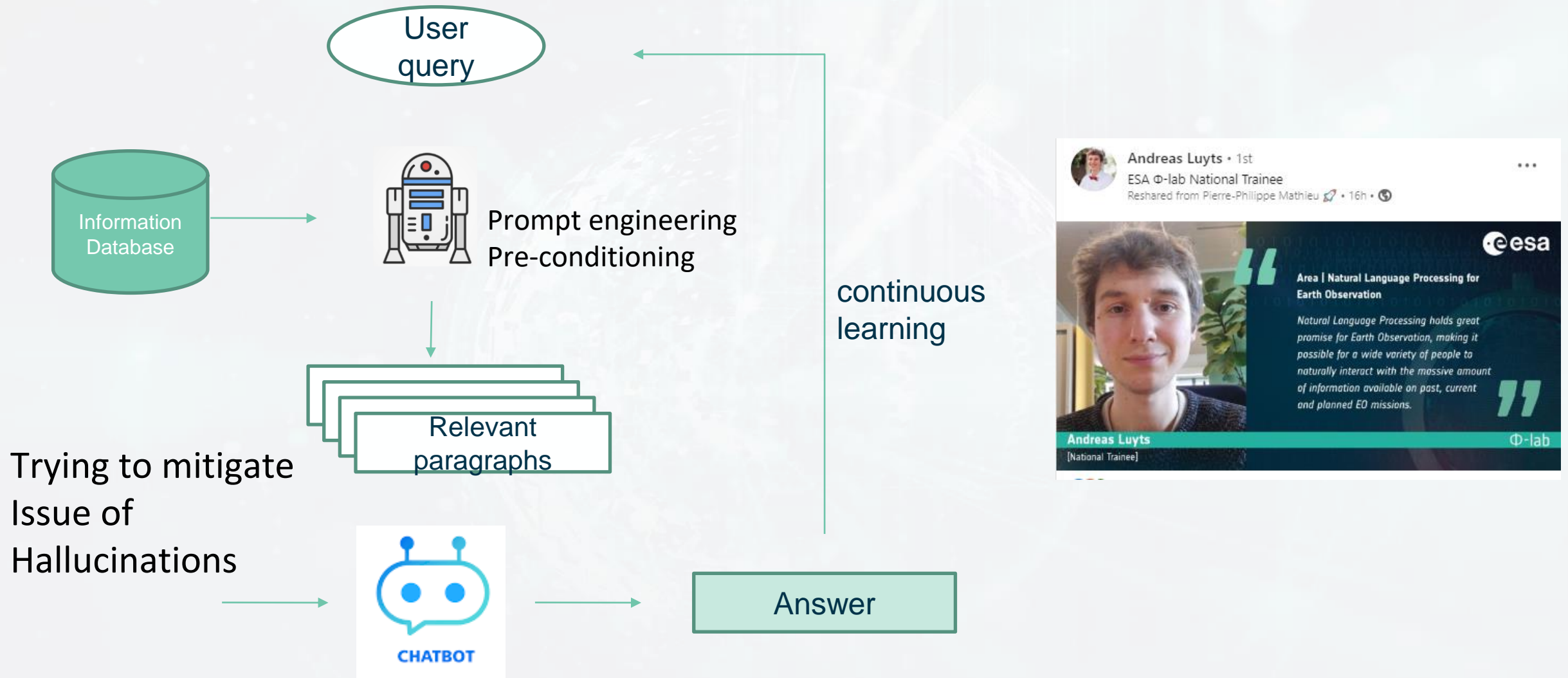
1000+ B parameters?

Courtesy tinykiwi

Issue of Hallucinations



Pre-conditioning prompt for ChatGPT



Courtesy Andreas Luyts, Luke Camelleri, phi-lab

AI Foundation Models for EO



Solve big problems with small solutions



Gaia

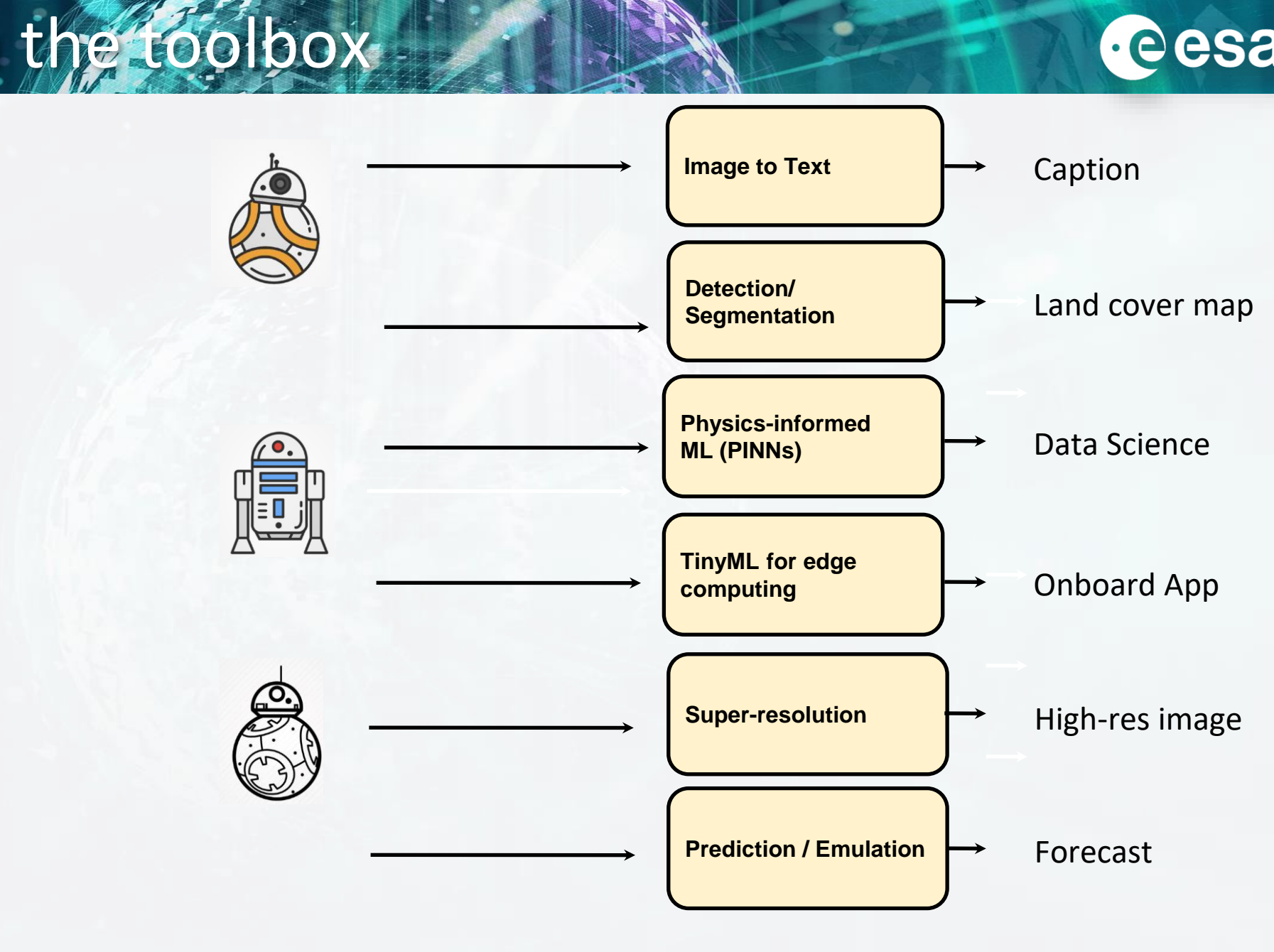


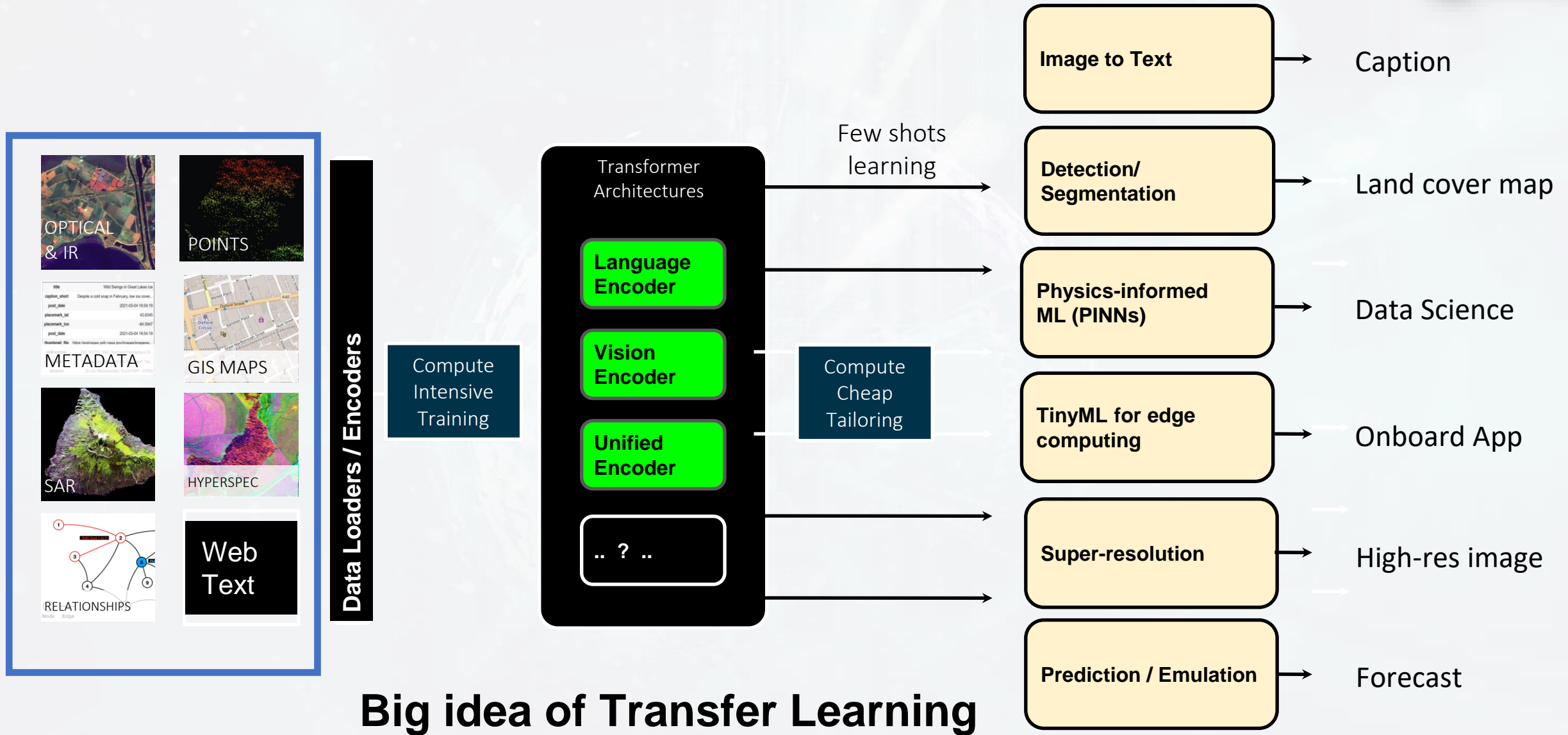
AI Future = Federated Learning



Who will be the biggest user of EO in 10 years?

A Bot?

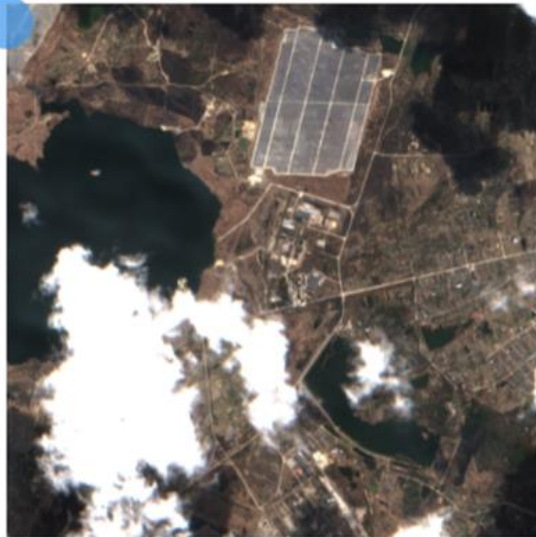




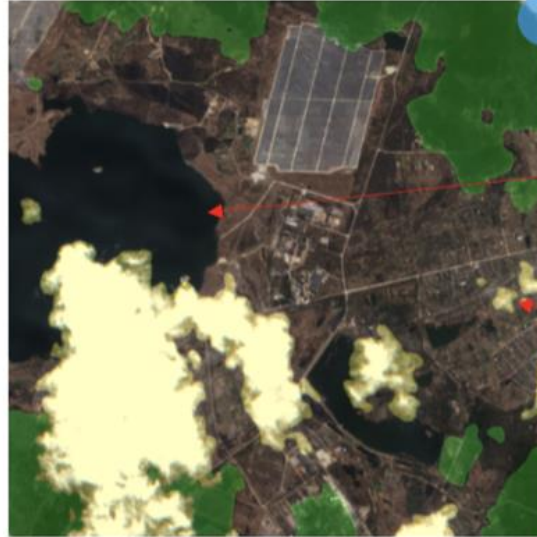
Big idea of Transfer Learning

Courtesy: FDL

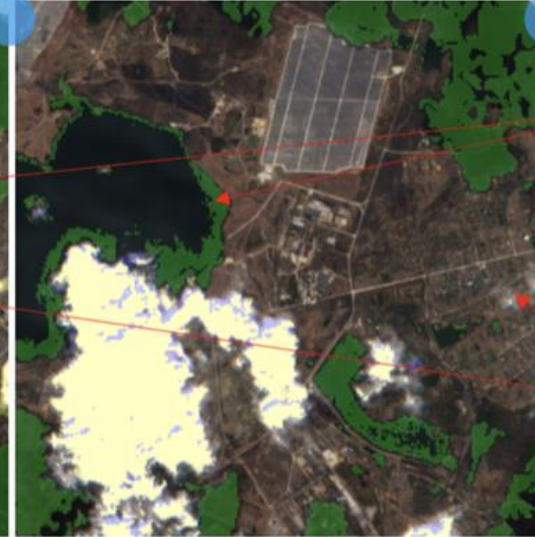
Sentinel-2 image



KappaMask (AI)



Sen2cor (rule based)



Water misclassified as cloud shadow

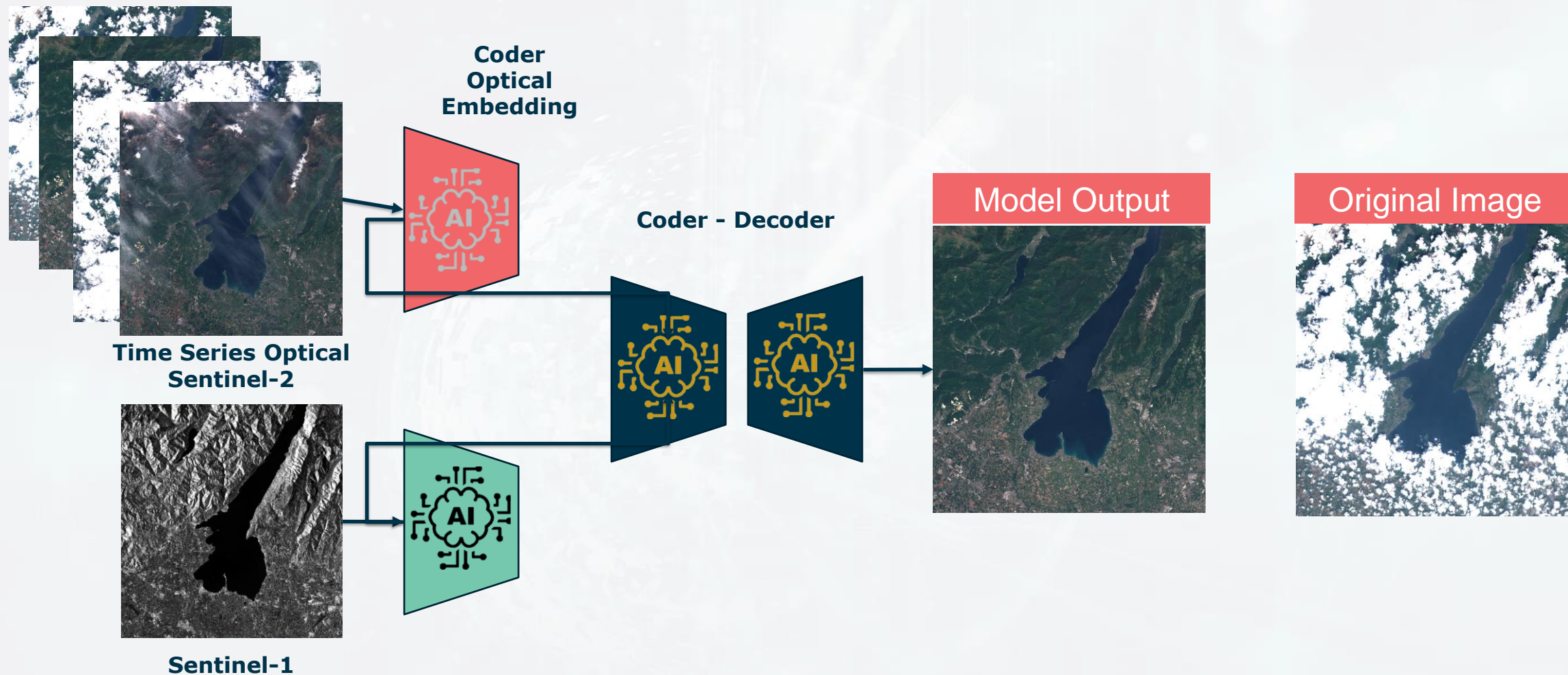
Small fragmented clouds undetected

- See more at: <https://kappazeta.ee/cloudcomparison>

Legend:
Yellow – cloud
Green – cloud shadow

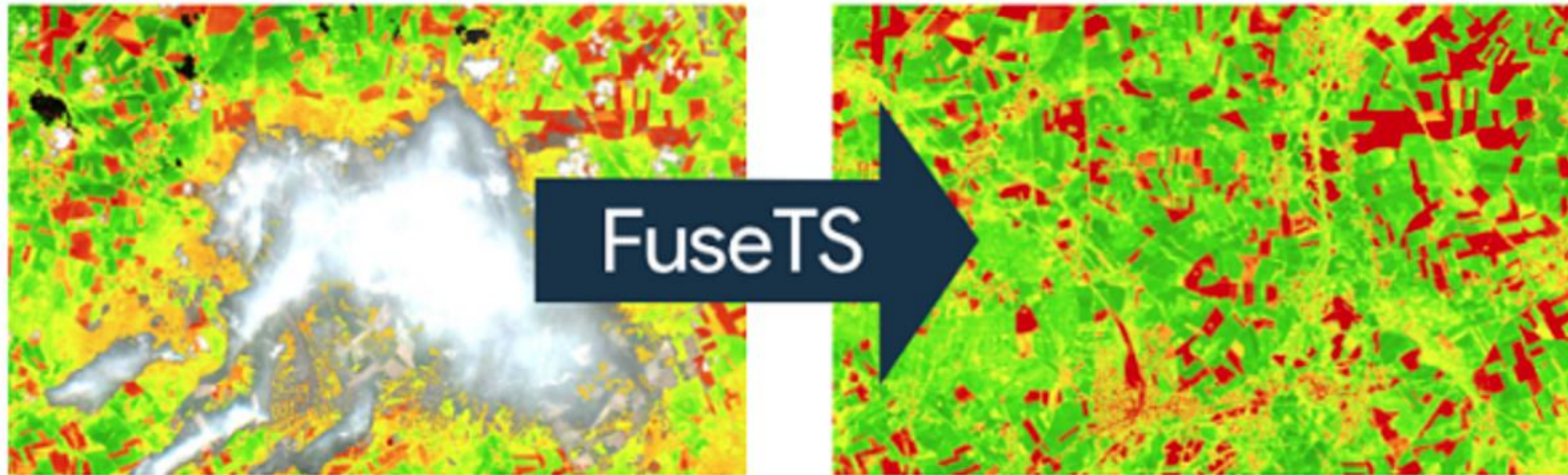
6

Challenge —> Capturing the Long Tail! Generalisation is in extreme case



Courtesy: Sebastianelli, A., et al. (2022). PLFM: Pixel-level merging of intermediate feature maps by disentangling and fusing spatial and temporal data for cloud removal. *IEEE Transactions on Geoscience and Remote Sensing*, 60, 1-16.

Moving from **Static** to **Dynamic** land cover maps
Enabling the open source community



Radar S-1 + optical S-2



Courtesy ESA AI4Food project, VITO, Uni Valencia, Sinergise

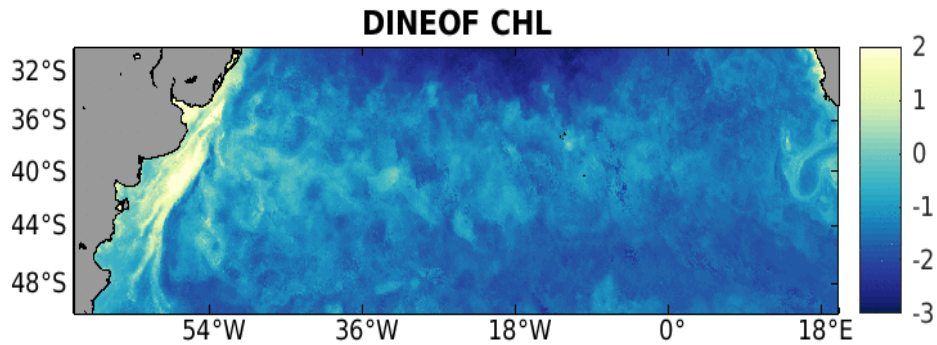
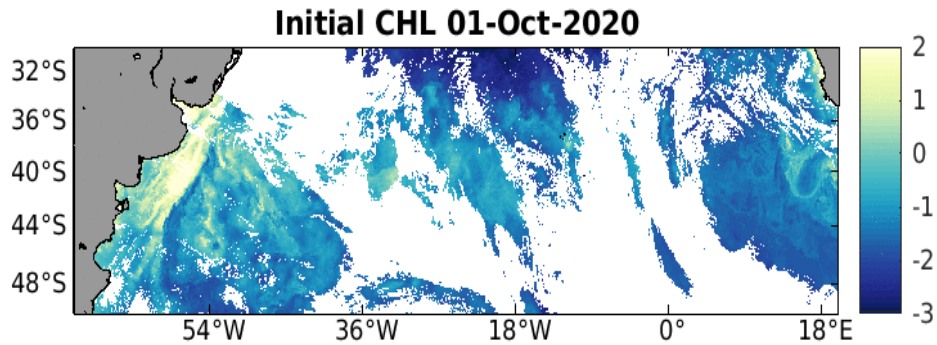
<https://open-eo.github.io/FuseTS/>



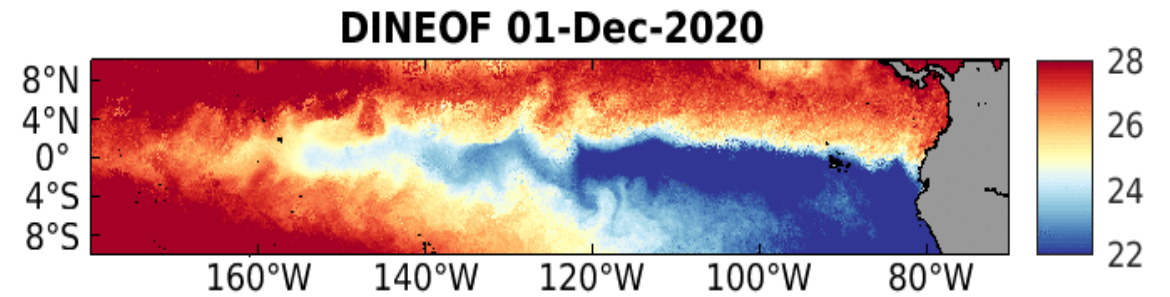
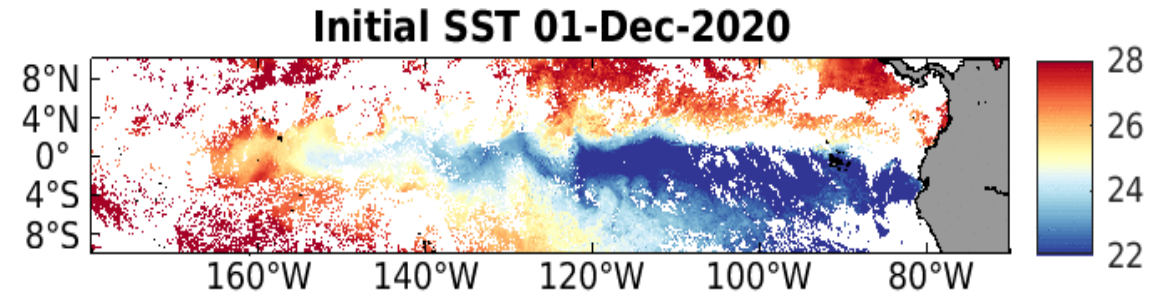
InPainting - Filling Gap with Statistics



ECV: Ocean Colour - Chlorophyll
(South Atlantic Ocean)



ECV: Sea Surface Temperature (SST)
Equatorial Pacific



Courtesy GHER, Uni Liege, Aida, DINEOF (Data Interpolating Empirical Orthogonal Functions):

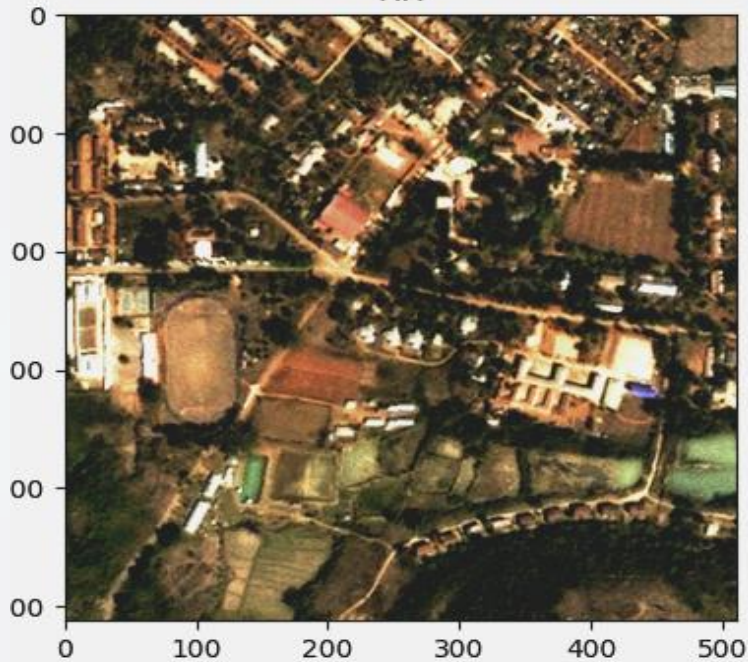


Enhancing S-2 resolution



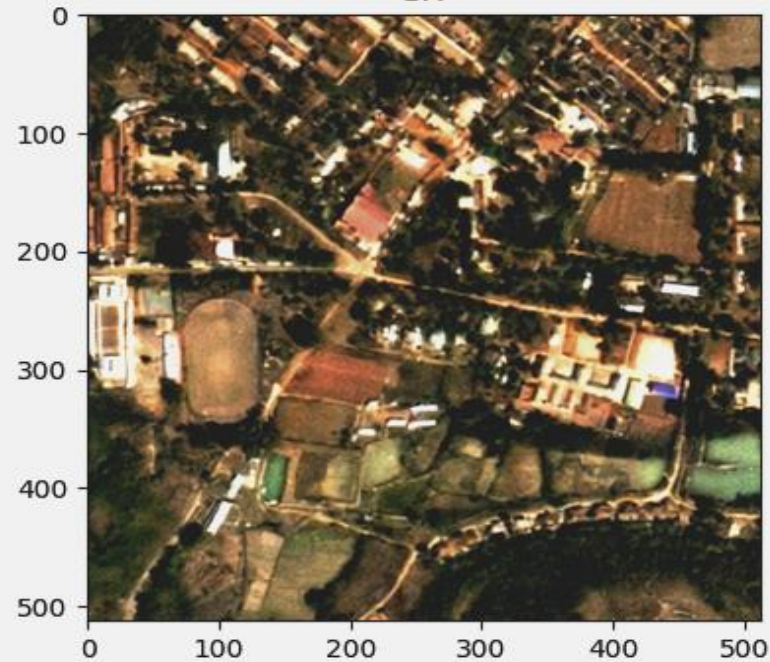
High-res (?m) ground truth

HR



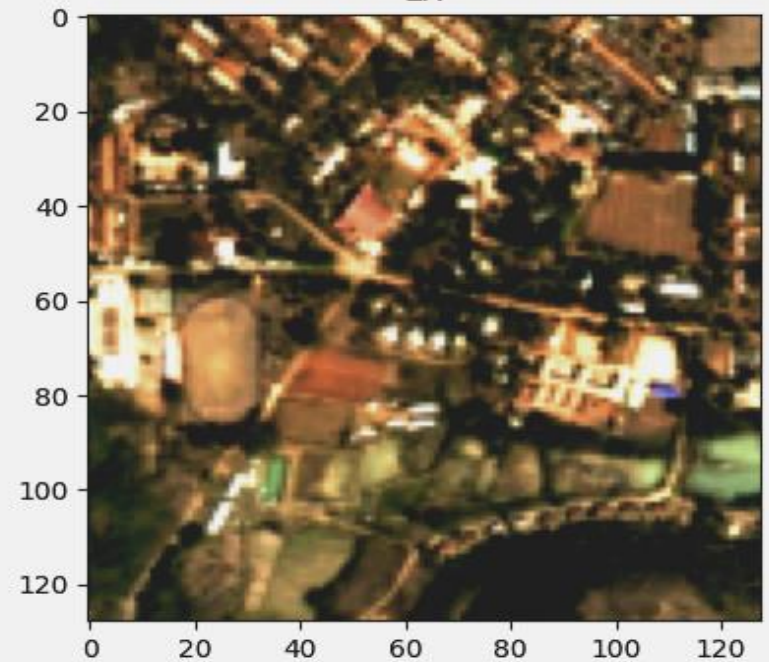
Super-res (2.5m)

SR



S-2 (10m)

LR

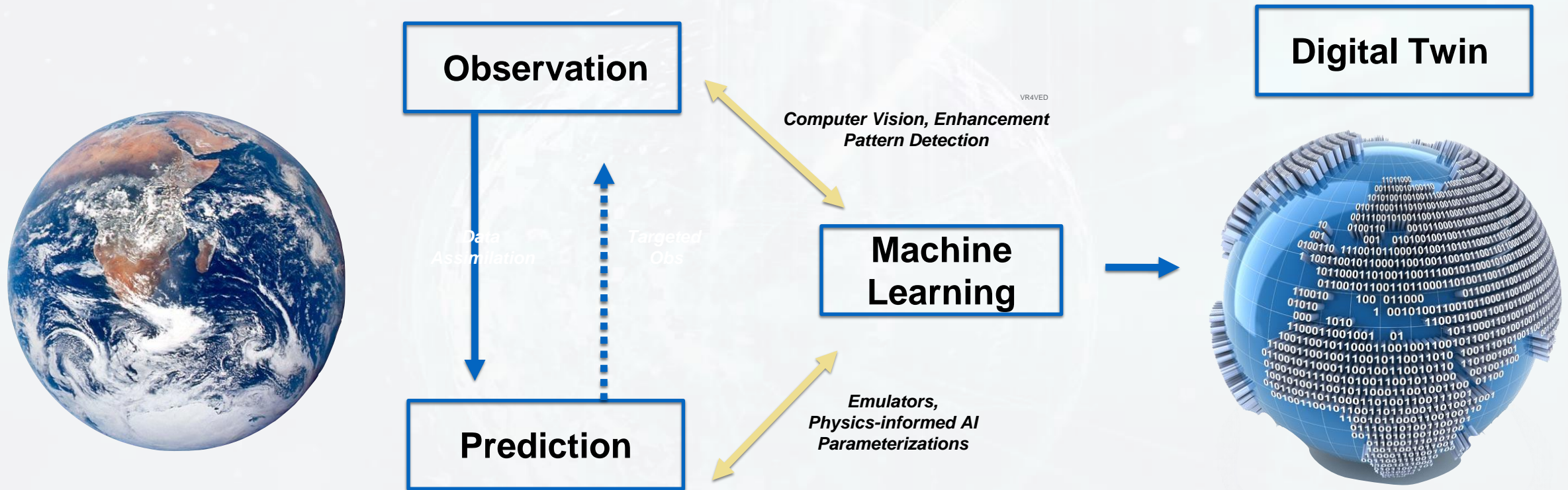


Need for:

- Uncertainty estimation
- Robustness vs hallucinations

Courtesy AI project Open SR, Uni Oxford, Uni Valencia, Brockman Consult

<https://www.ml4esop.esa.int>

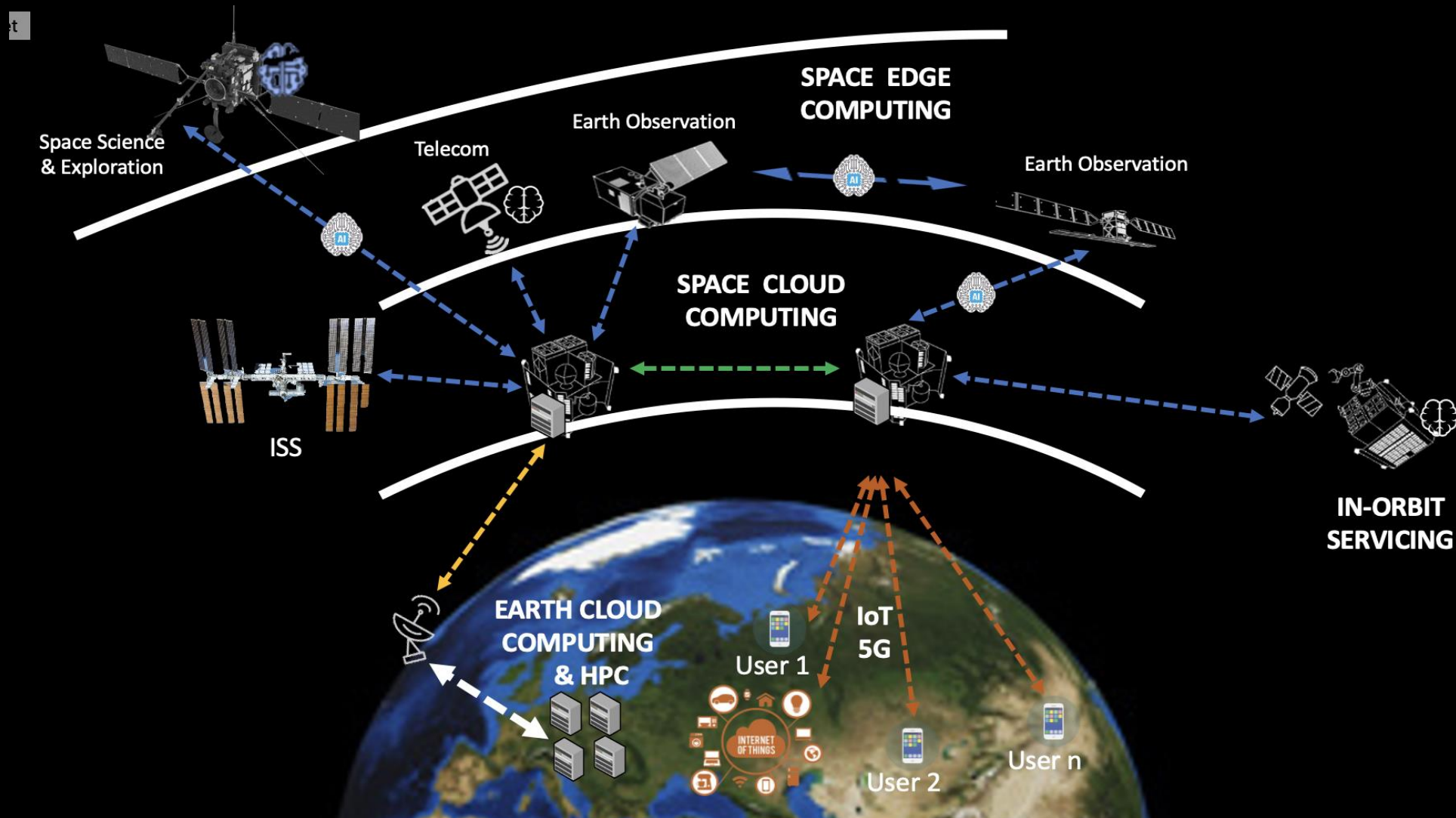


ECMWF–ESA Workshop on Machine Learning for Earth Observation and Prediction, 2024 Frascati

AI computing in Space

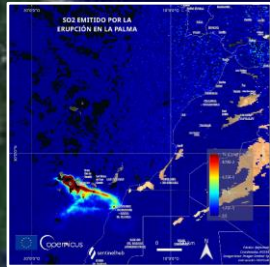
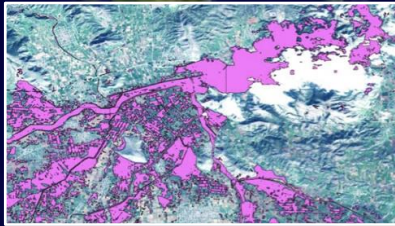
Network Intelligence in Orbit (NIO)

Cognitive Cloud Computing in Space (C3S)



Courtesy: Letter to DG on Cognitive Computing in Space, from 10 European New Space Companies

One Satellite - Many Apps - ML agility

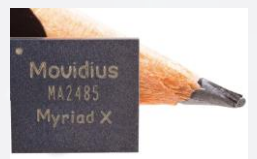


AI onboard - Programmable Brain in Orbit

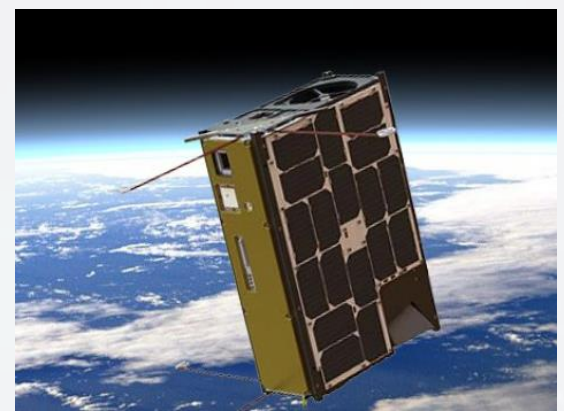
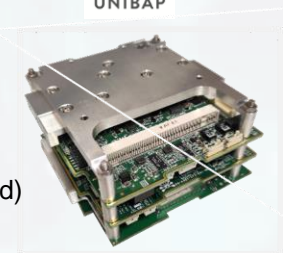
ML
On-Board
Unibap Accelerated
Compute Platform



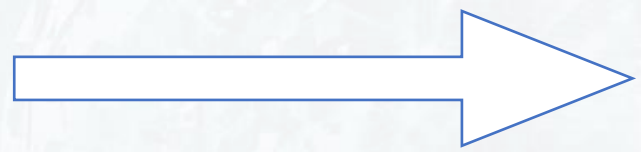
Intel Myriad
Vision AI chip



Nebula payload
On-orbit Cloud
Computing Node
(UNIBAP SpaceCloud)

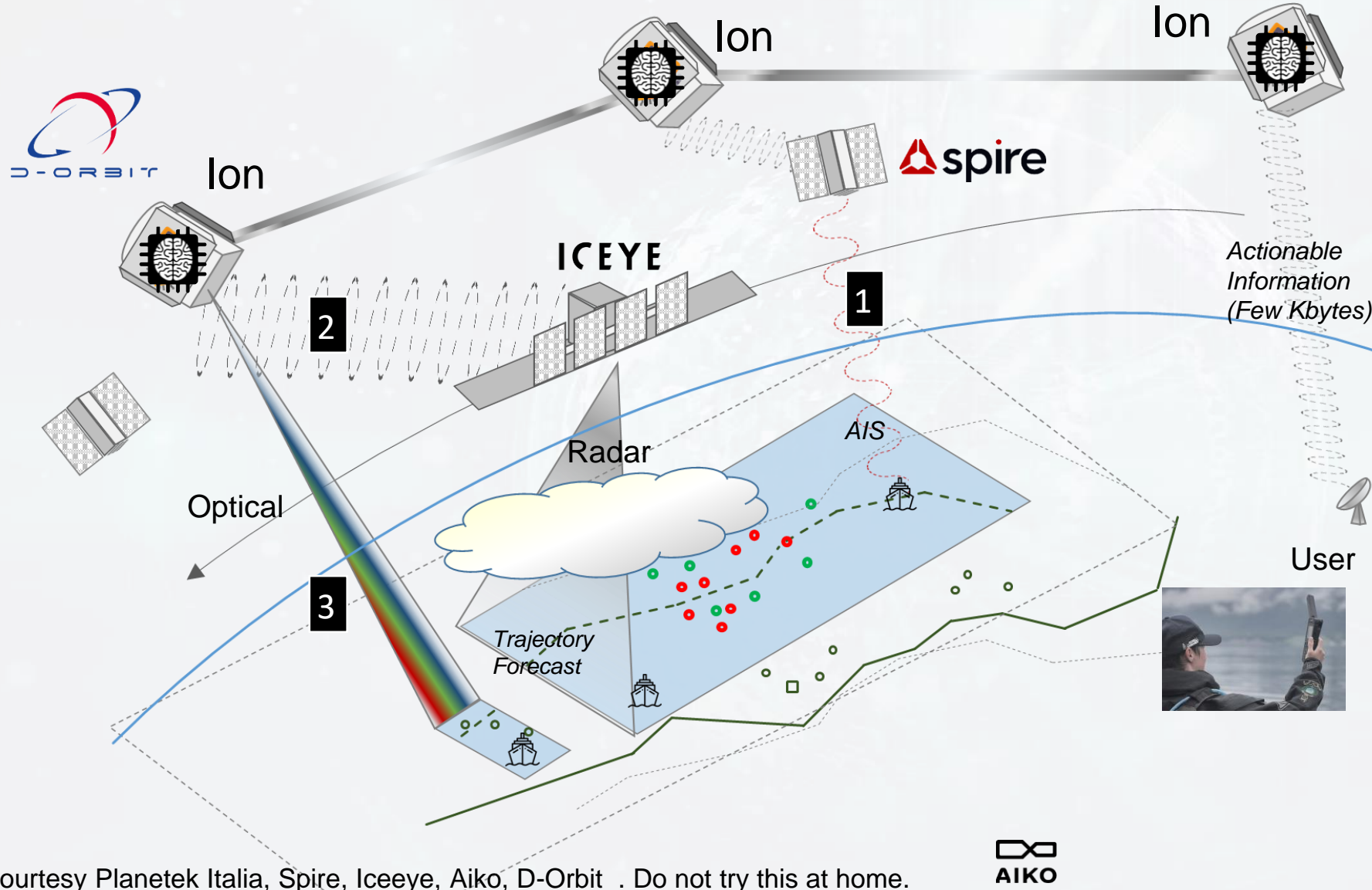


phisat-1
Sep 2020



ION WildRide
June 2021





AI Federated Learning

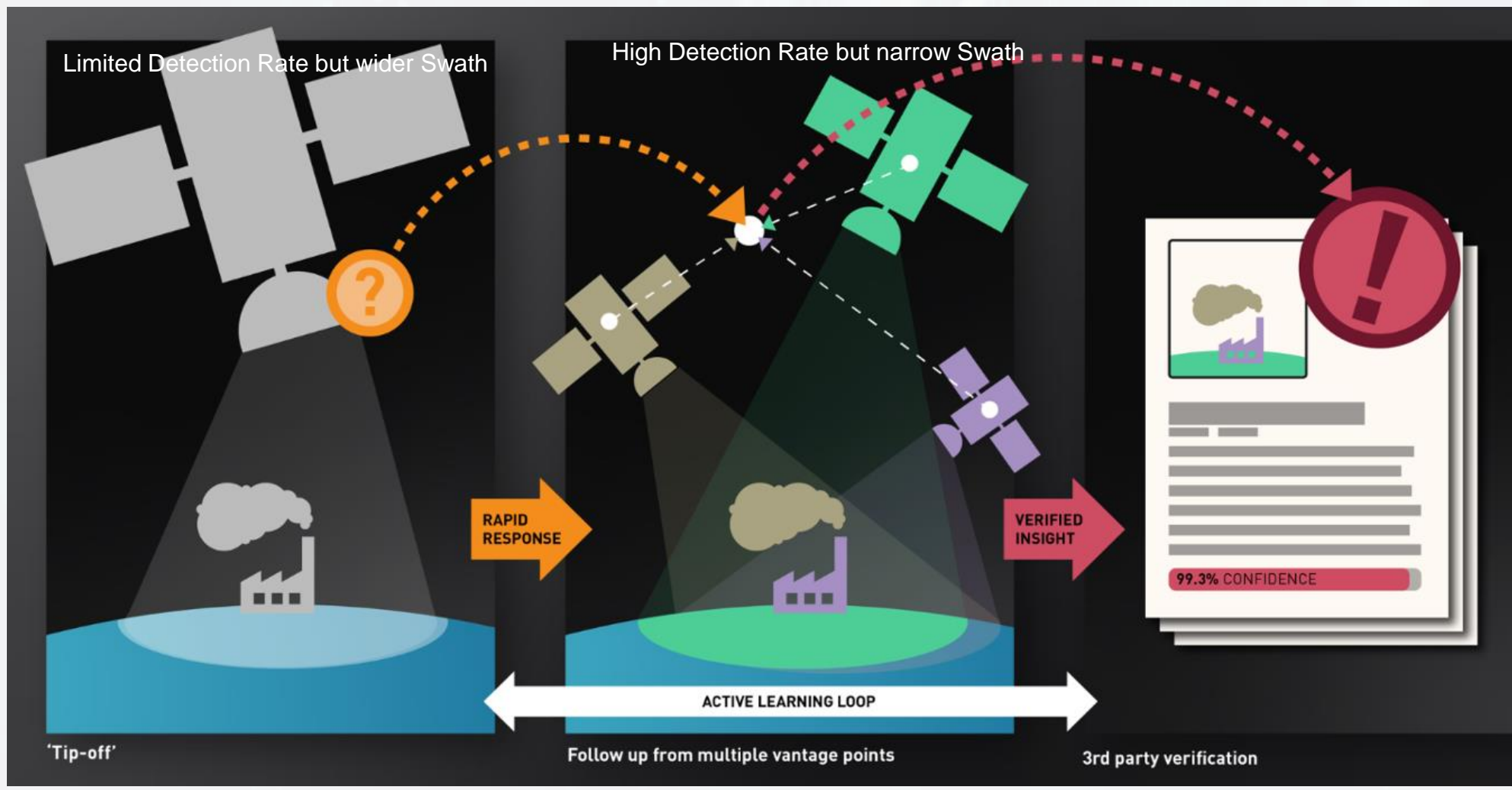
Information ultra-low latency to users

reduced from HOURS to MINs

Other use cases e.g. Methane, Land Covert

Courtesy Planetek Italia, Spire, Iceeye, Aiko, D-Orbit . Do not try this at home.





Near 100% detection rate, but narrow swath

Courtesy FDL, Trillium Tech



Ongoing open AI@edge challenge

AI4EO Challenges

EMBARK YOUR AI APP ON THE ISS

Join the OrbitalAI Challenge and get the chance to be part of a space mission! Showcase your innovative solution for in-orbit data processing with IMAGIN-e track (ISS Mounted Accessible Constellation Imaging Tool-e).

#OrbitalAI

AI4EO Challenges

EMBARK YOUR AI APP ON Φsat-2

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#OrbitalAI

ai4eo.eu

AI4EO Challenges by Φ-lab

Home Challenge portfolio Host a challenge Contact

AI4EO Challenges by Φ-lab

PARTICIPATE IN THE CHALLENGE

HOST A CHALLENGE

<h3>AutoICE</h3> <p>Create the next state-of-the-art for automated sea ice mapping from Sentinel-1 SAR data.</p> <p>€3,000 cash + 13,500 points</p>	<h3>Seeing Beyond the Visible</h3> <p>#HYPERVIEW</p> <p>Permanently Opened Challenge</p> <p>0 points</p>	<h3>Enhanced Sentinel 2 Agriculture</h3> <p>Permanently Opened Challenge</p> <p>0 points</p>
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AI on the satellite, it is the way to go!
Real-time decisions, faster than you know!
Save on bandwidth and response so quick!
With AI, we're gonna make it click!

Rap song by ChatGPT

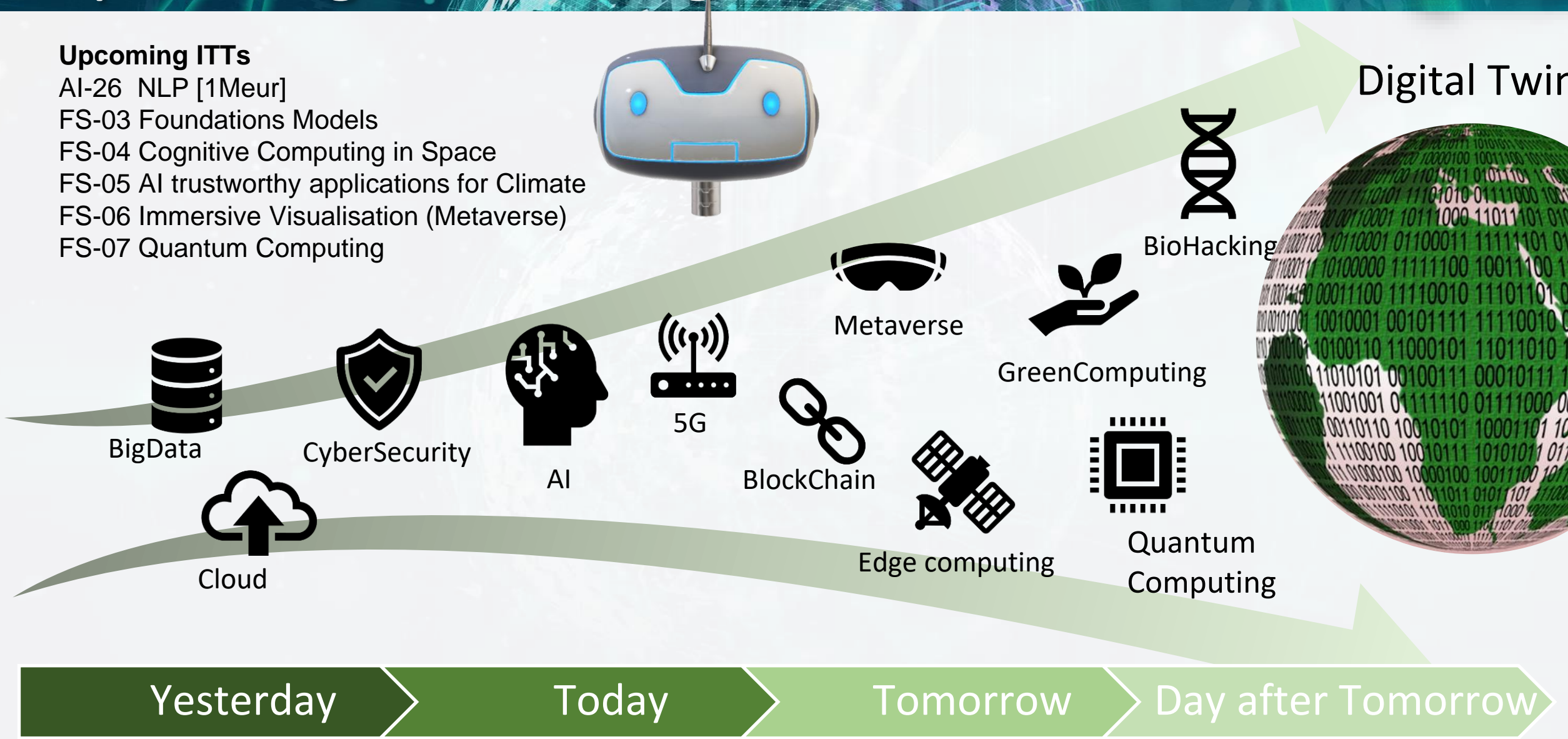
Courtesy: spacetech ai4eo.eu

Concluding Remarks

Capitalising on Convergence of Techs

Upcoming ITTs

- AI-26 NLP [1Meur]
- FS-03 Foundations Models
- FS-04 Cognitive Computing in Space
- FS-05 AI trustworthy applications for Climate
- FS-06 Immersive Visualisation (Metaverse)
- FS-07 Quantum Computing



Yesterday

Today

Tomorrow

Day after Tomorrow

Courtesy: Andreas Luyts with inspiration from Cap Gemini roadmap





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