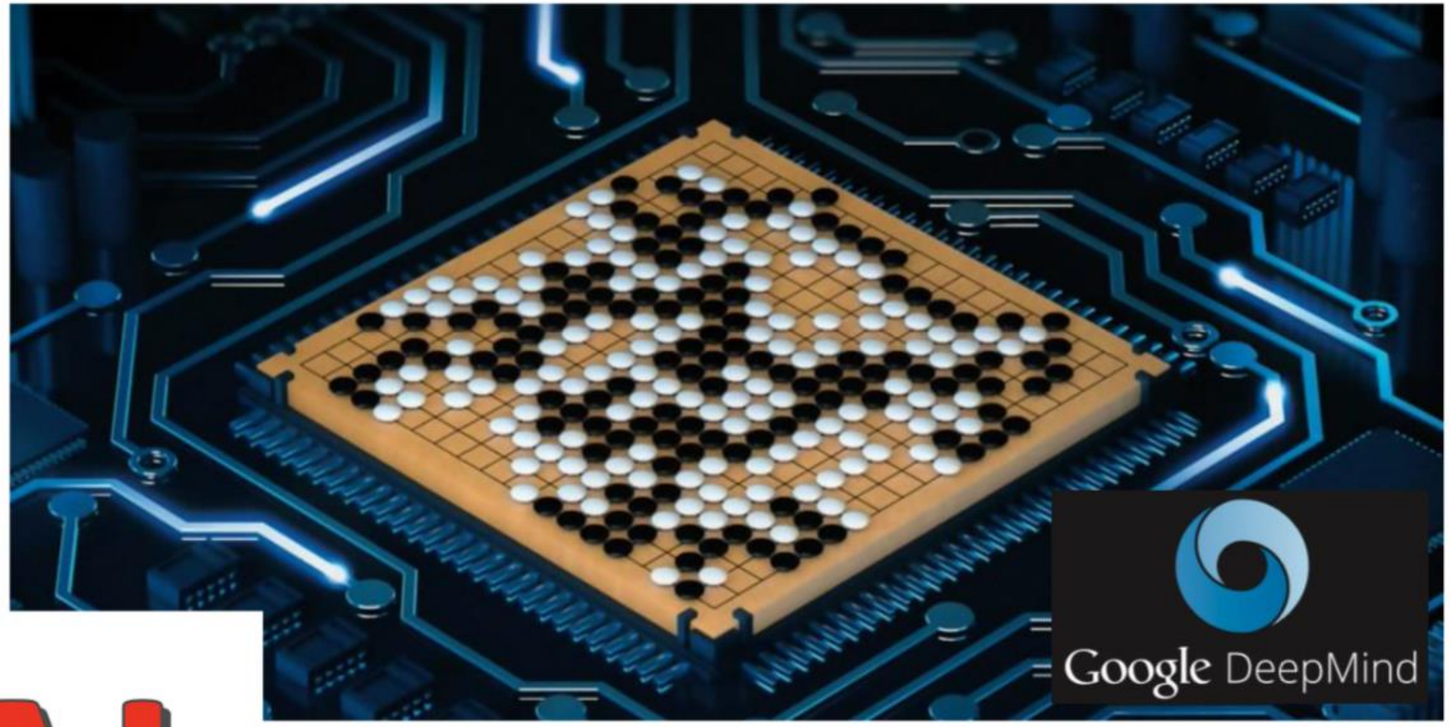
The applications of AI to Earth observation and PhiSat-1: the AI-powered satellite

Φ-lab explore office
Directorate of Earth Observation Programmes
By Nicolas LONGEPE

The AI Revolution

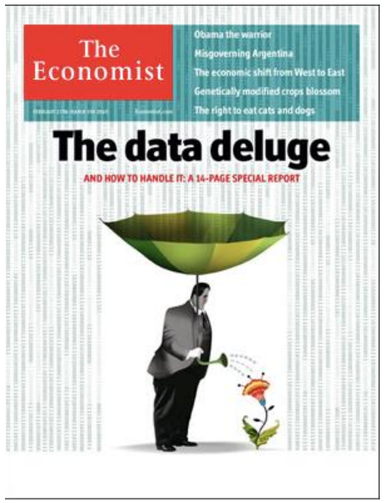


AI

The new Electricity

Why Now? Perfect Storm feeding on Big Data

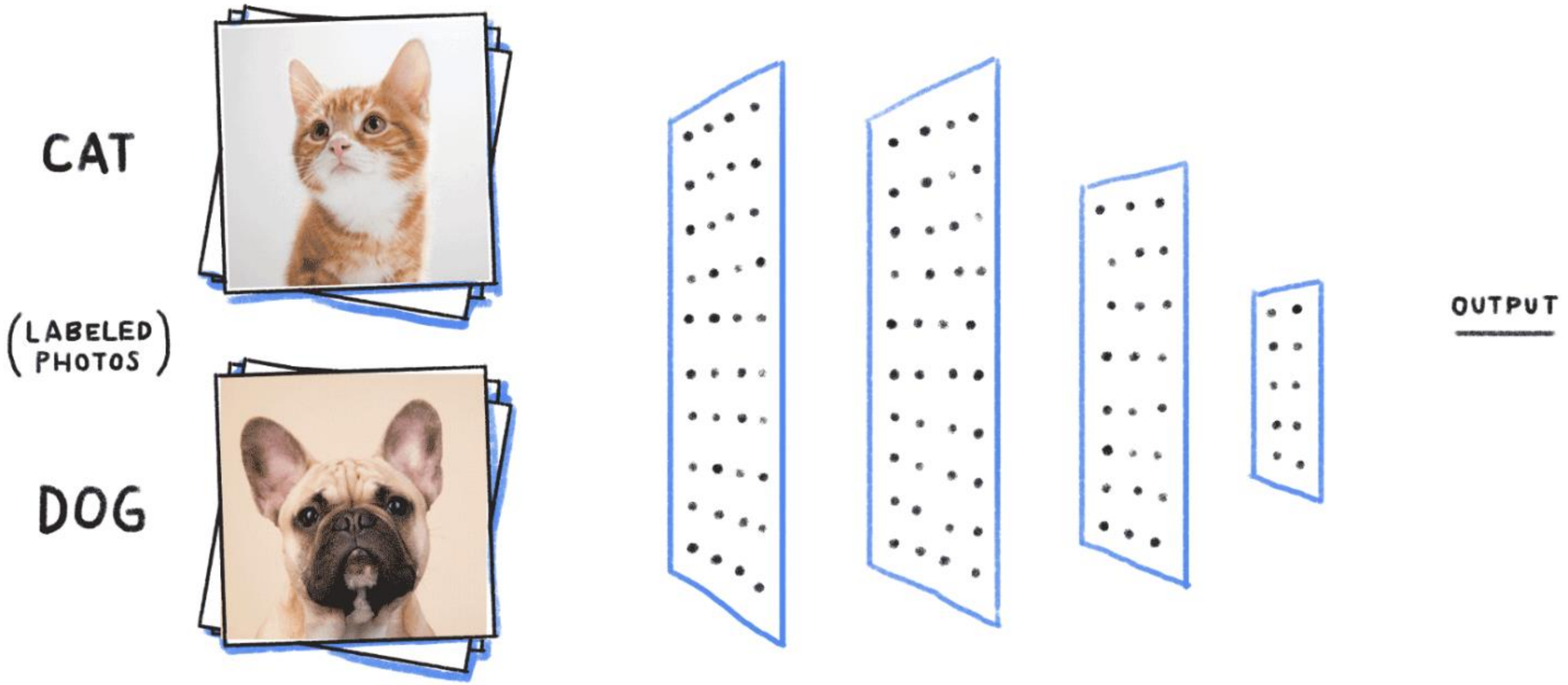
AI^{x} = **Data** x **Compute** x **Algos**



- **Driven by Moore's Law**
- Big + High Speed
- Small, Cheap, Scalable
- Parallel
- Fault Tolerant
- Low Power, Edge

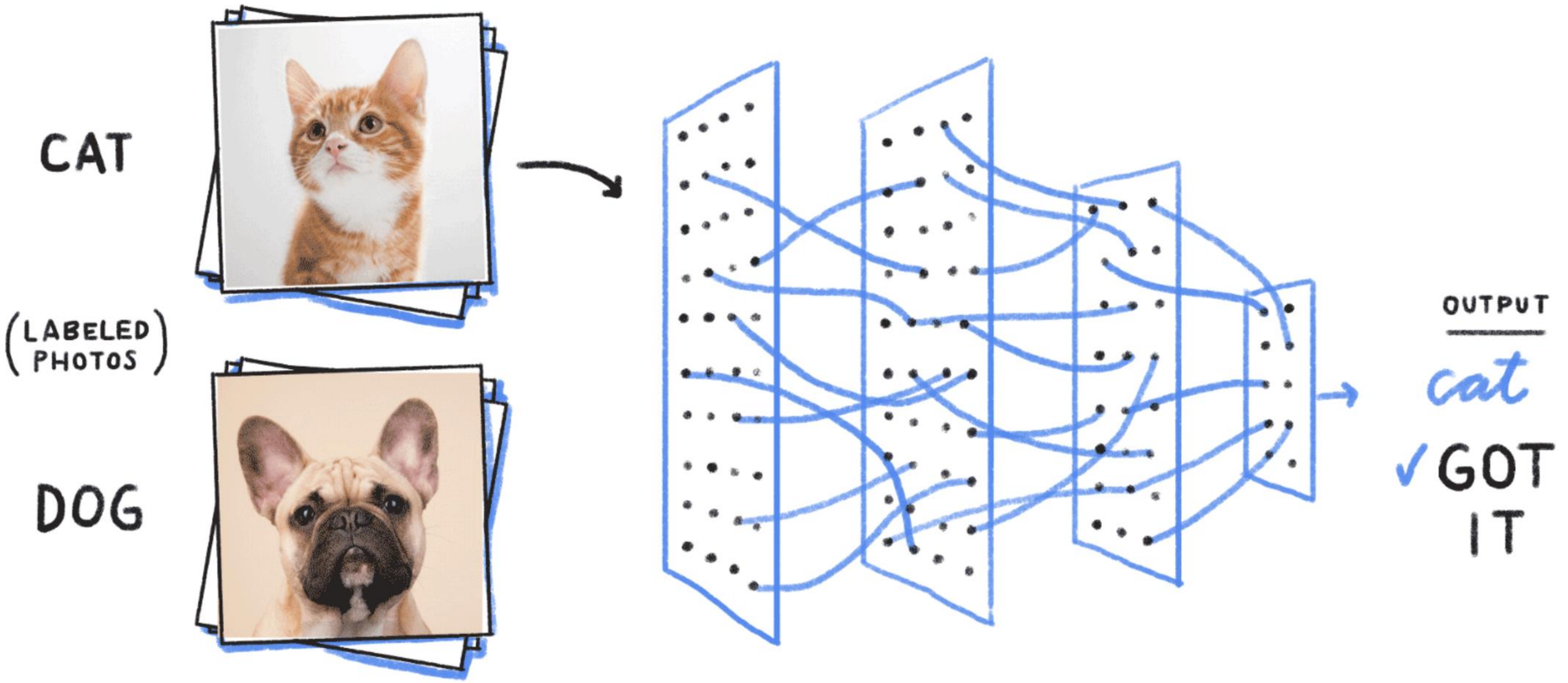
- **Open**
- Framework
- Zoo of Algos
- Pre-trained libraries
- Tutorial MOOC

Computer Vision - DL & Classification



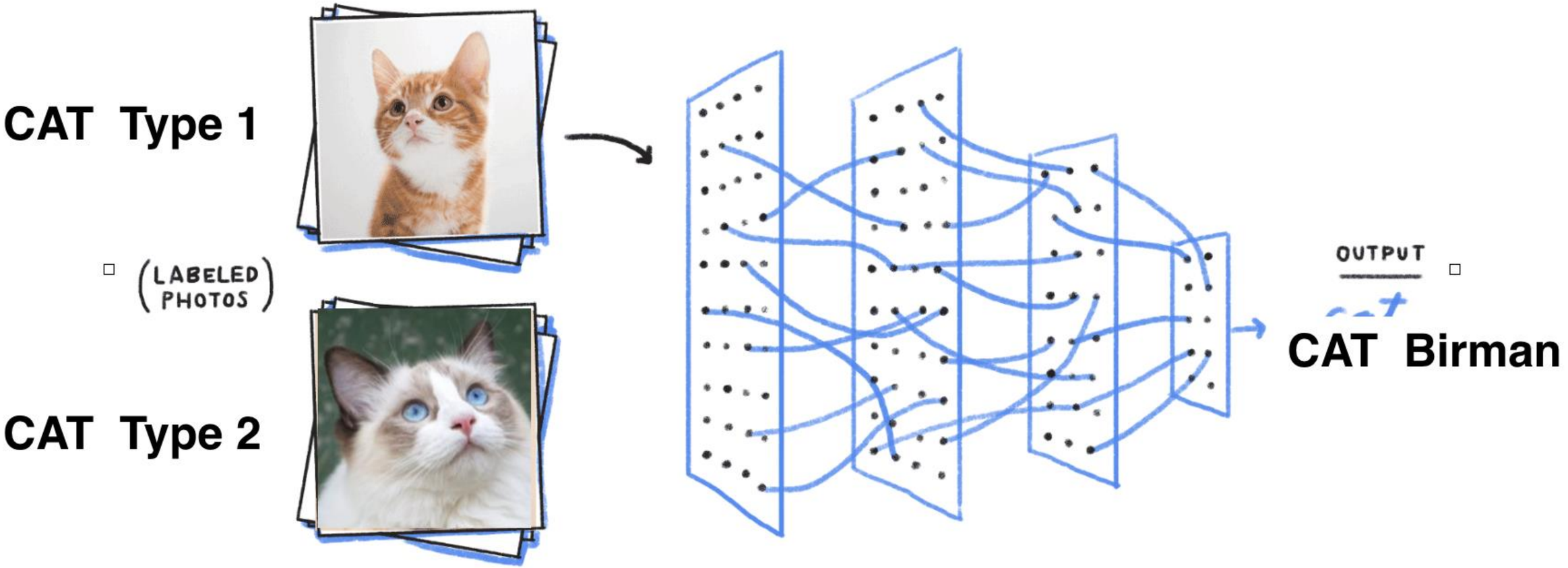
Source: https://becominghuman.ai/building-an-image-classifier-using-deep-learning-in-python-totally-from-a-beginners-perspective-be8dbaf22dd8

Computer Vision - DL & Classification



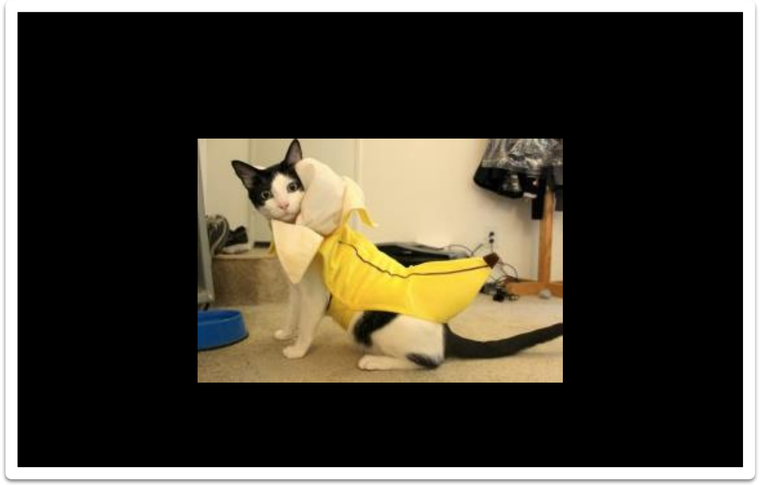
Source: https://becominghuman.ai/building-an-image-classifier-using-deep-learning-in-python-totally-from-a-beginners-perspective-be8dbaf22dd8

Deep Learning Fine Grain Classification



Source: https://forums.fast.ai/ Birman vs. Ragdoll kitten

What’s in a Black Box?



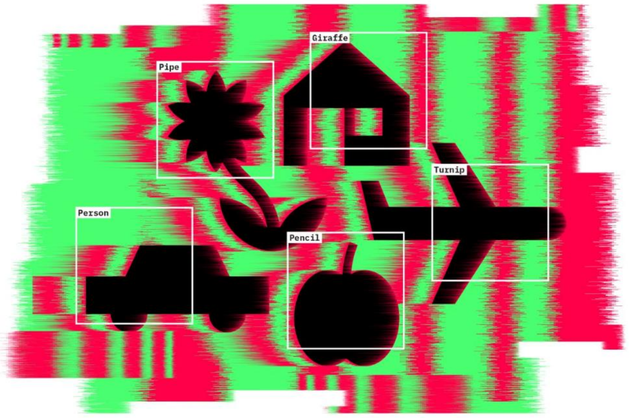


Illustration by Edgar Bąk

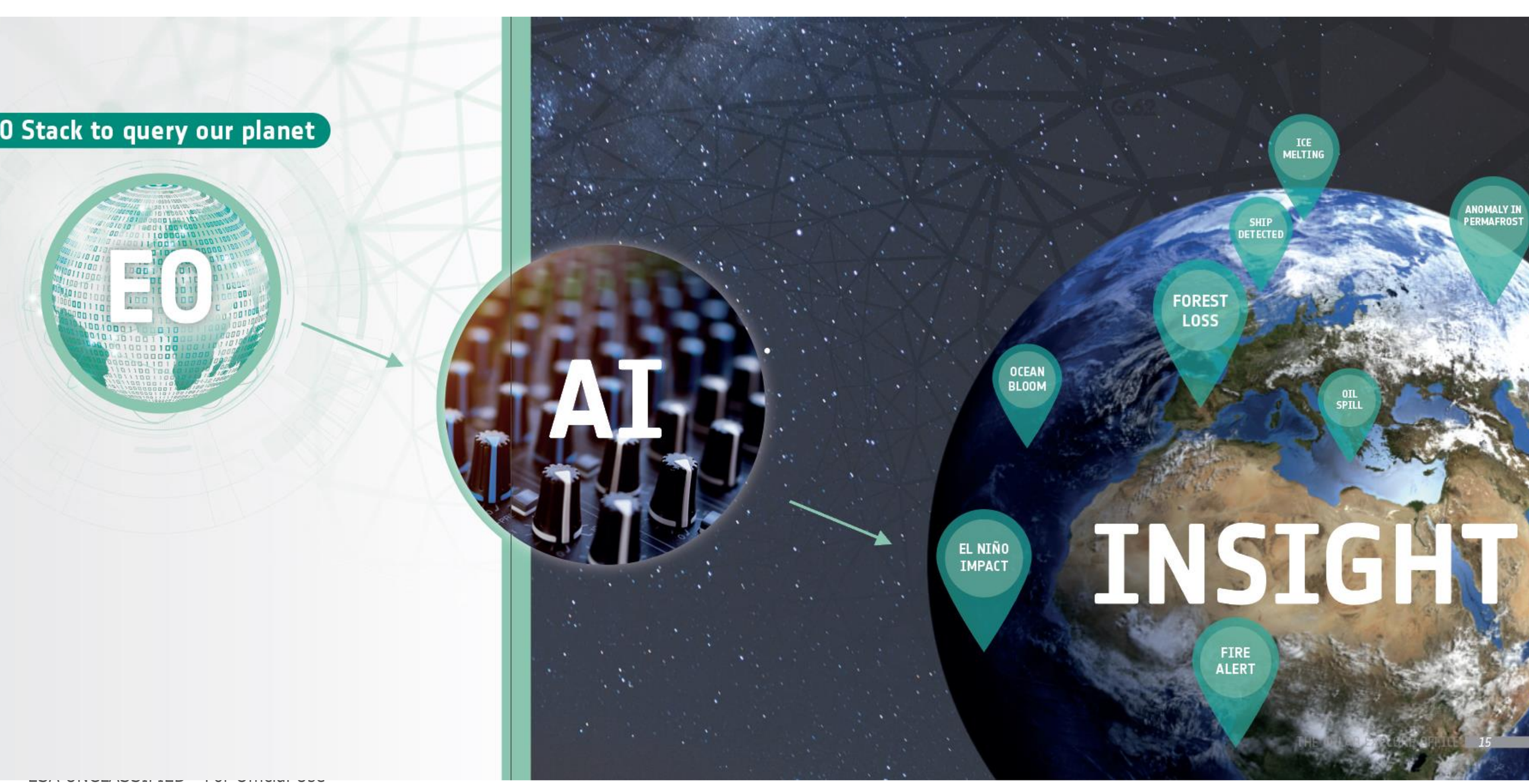
WHY … Causality ? ERROR … Accuracy?

- **Trust** issue preventing wider adoption? **Fooling** AI
- Black or Grey Box? AIx **Explainability**? **Physics-aware** AI
- Service Robustness ? **Reliability** ?
- **Bias** In Bias Out? Representativeness? Outlier?
- Difficulty of **Benchmarking**
- Still .. emergence of **self-driving** cars

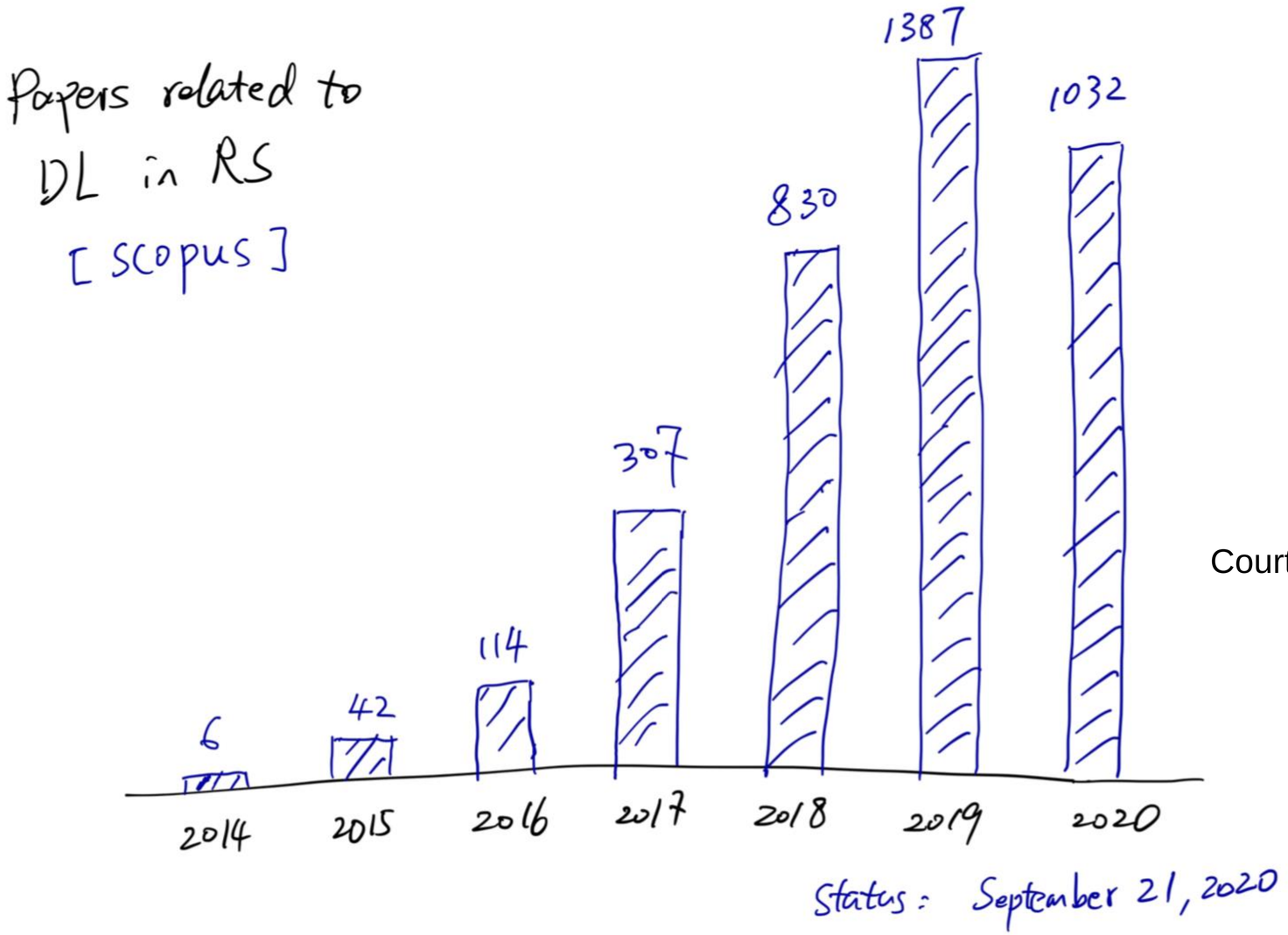
Info: Deep troubles for Deep Learning, Nature, 2019 https://go.nature.com/33kIOur

The Rise of AI4EO

0 Stack to query our planet

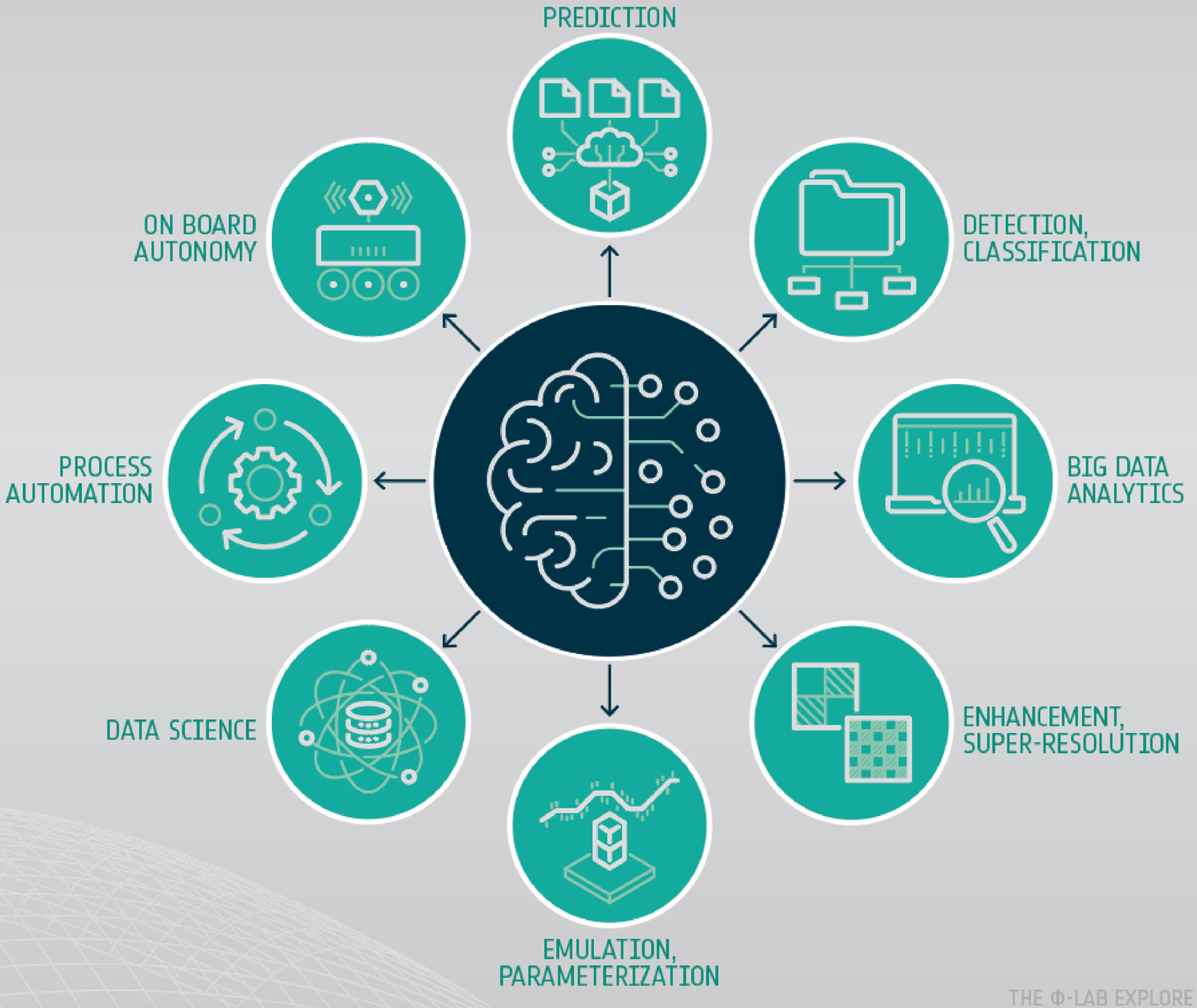


AI = New Paradigm for Computing



Courtesy: Xiaoxiang Zhu @ TUM/DLR

AI TURBO-CHARGING EO

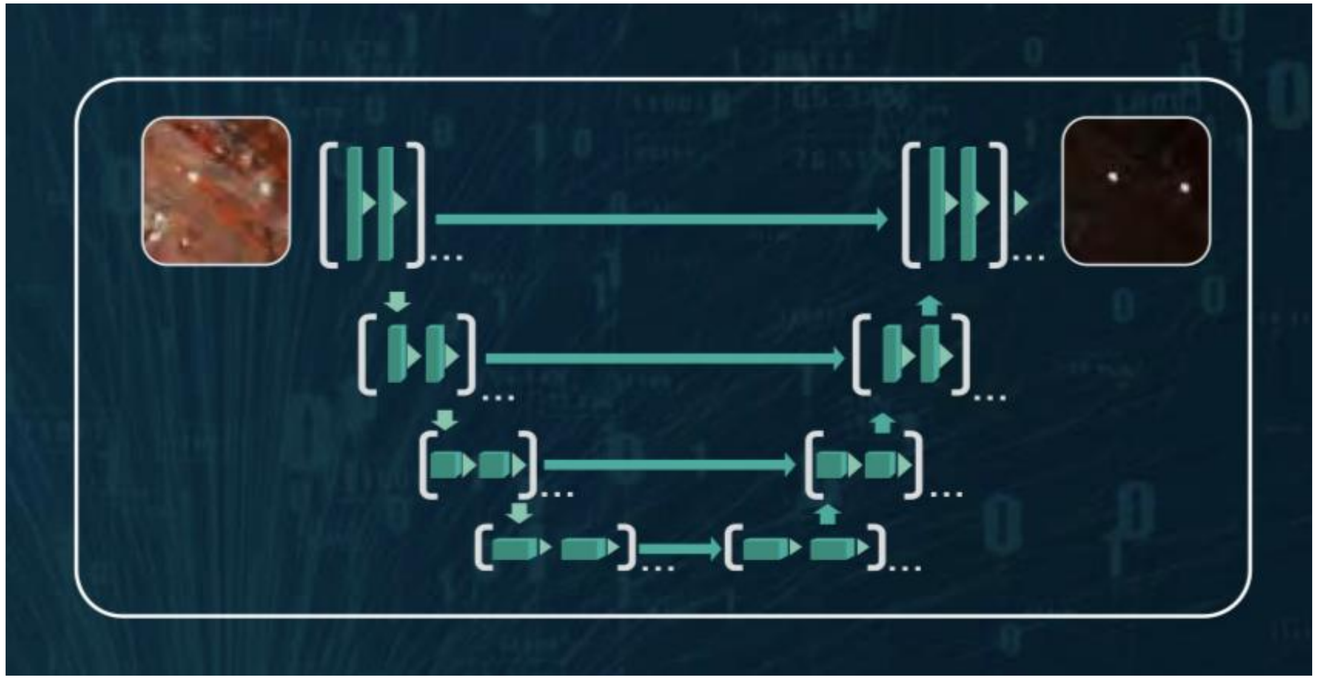


AI **accelerates Time to Insight** for EO

AI can help **learning** the underlying **Structure** of data

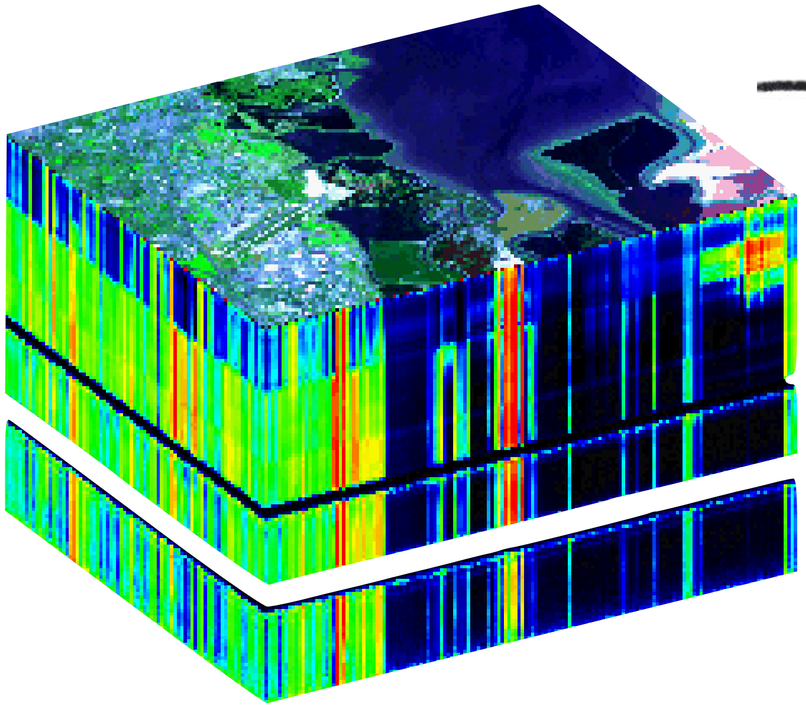
Observing System

Learning from Data

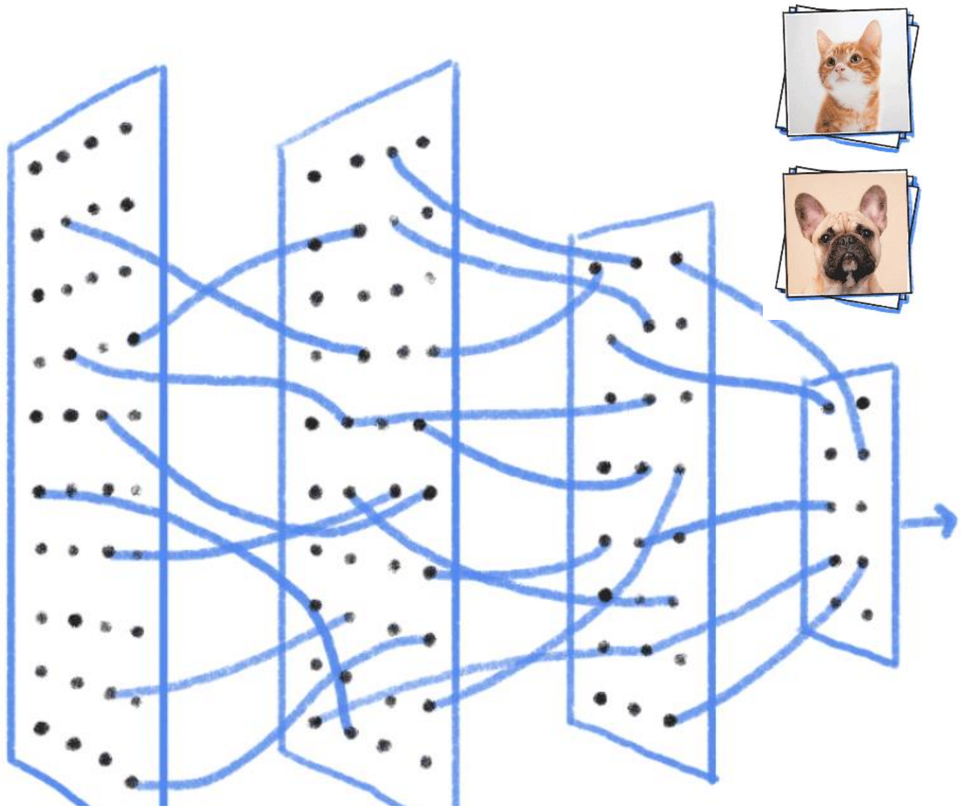


A **tensor** view of the data

Deep Learning for EO image segmentation



Data Cube



Feature Detection
Classification

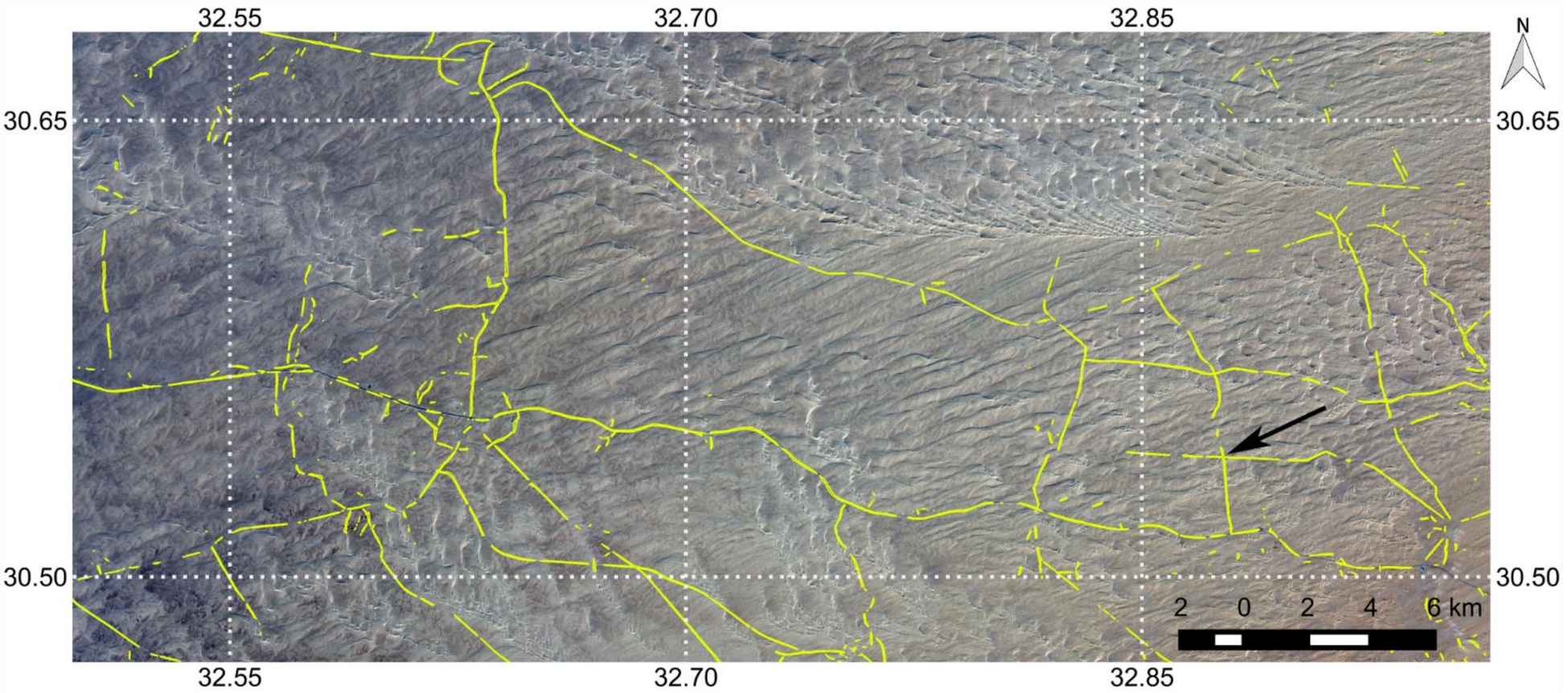
- Crops
- Oil Palm
- Ships
- …

A suite of algos/architectures to mine ALL available information —-> Space * Time * Spectral

Infrastructure Monitoring in Desert Regions (Collaboration ESA / EU SatCen)

Challenge: Mapping & monitoring of infrastructure in desert areas

- Deserts = extensive areas of inhospitable terrain
- Drift sand = often buries infrastructure
- Expensive & time consuming using ground based techniques = need for EO



SAR average coherence and extracted vectors overlain on Sentinel-2. Area: North Sinai Desert.

Workflow: Deep Learning with Sentinel-1 on Cloud

Environment:

- Sentinel-1 on Creodias,
- Virtual Machine with GPUs (ESA Advanced Concepts Team)

Pre-processing of Sentinel-1:

- σ^0, coherence,
- terrain correction,
- multiteporal speckle filtering.

Training data:

- Open Street Map

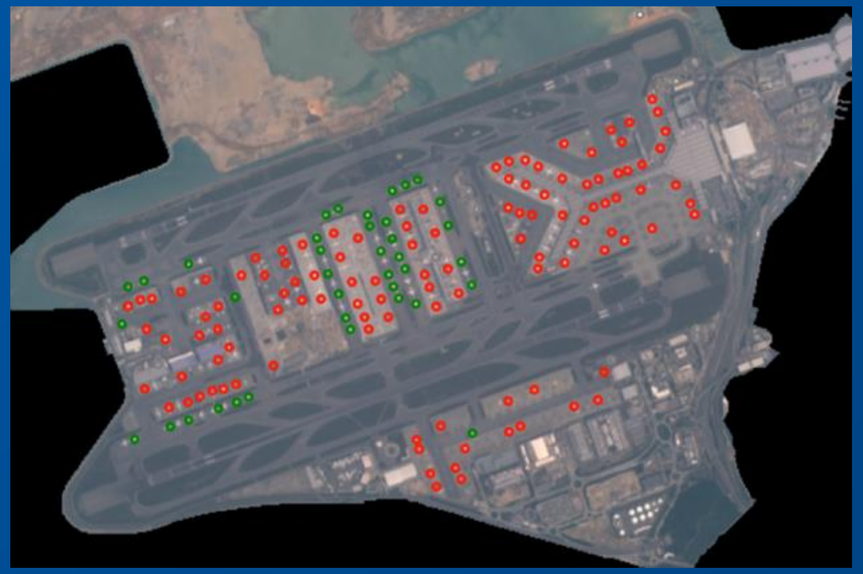
Deep Learning:

- U-Net

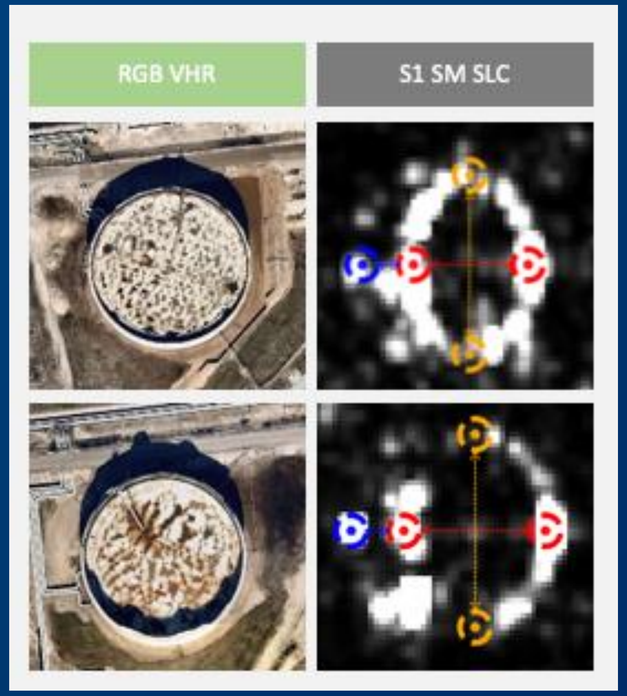
Results:

- updated vectors to improve OSM
- update SatCen database

Big Data Analytics: AI + EO (Sentinels) + Knowledge ---> Indicators



 # grounded planes
(lock down Hong Kong Airport)
- Parking (Conventional) +25%
- Parking (Un-conventional) +300%



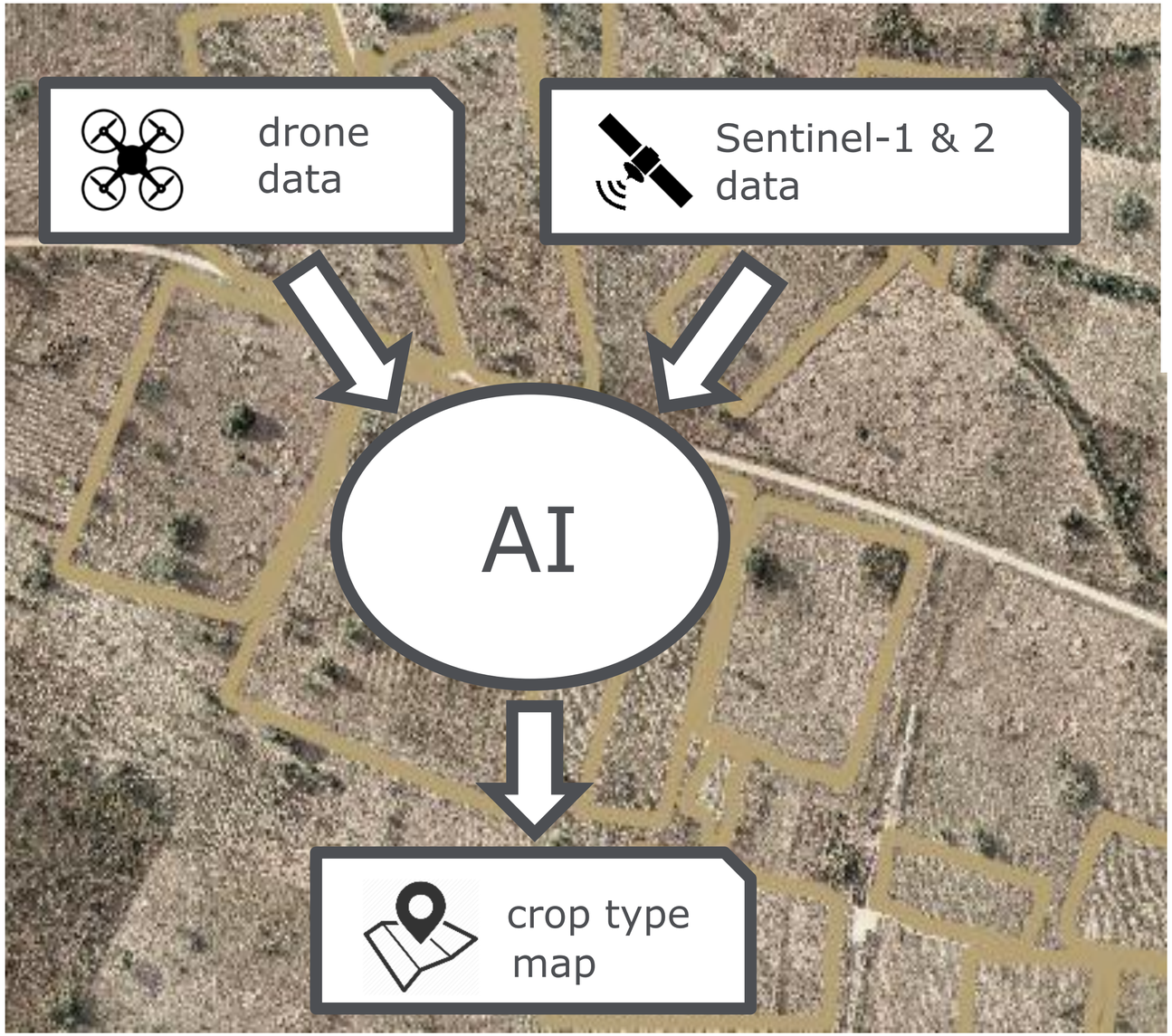
AI identified relevant changes (health structure)

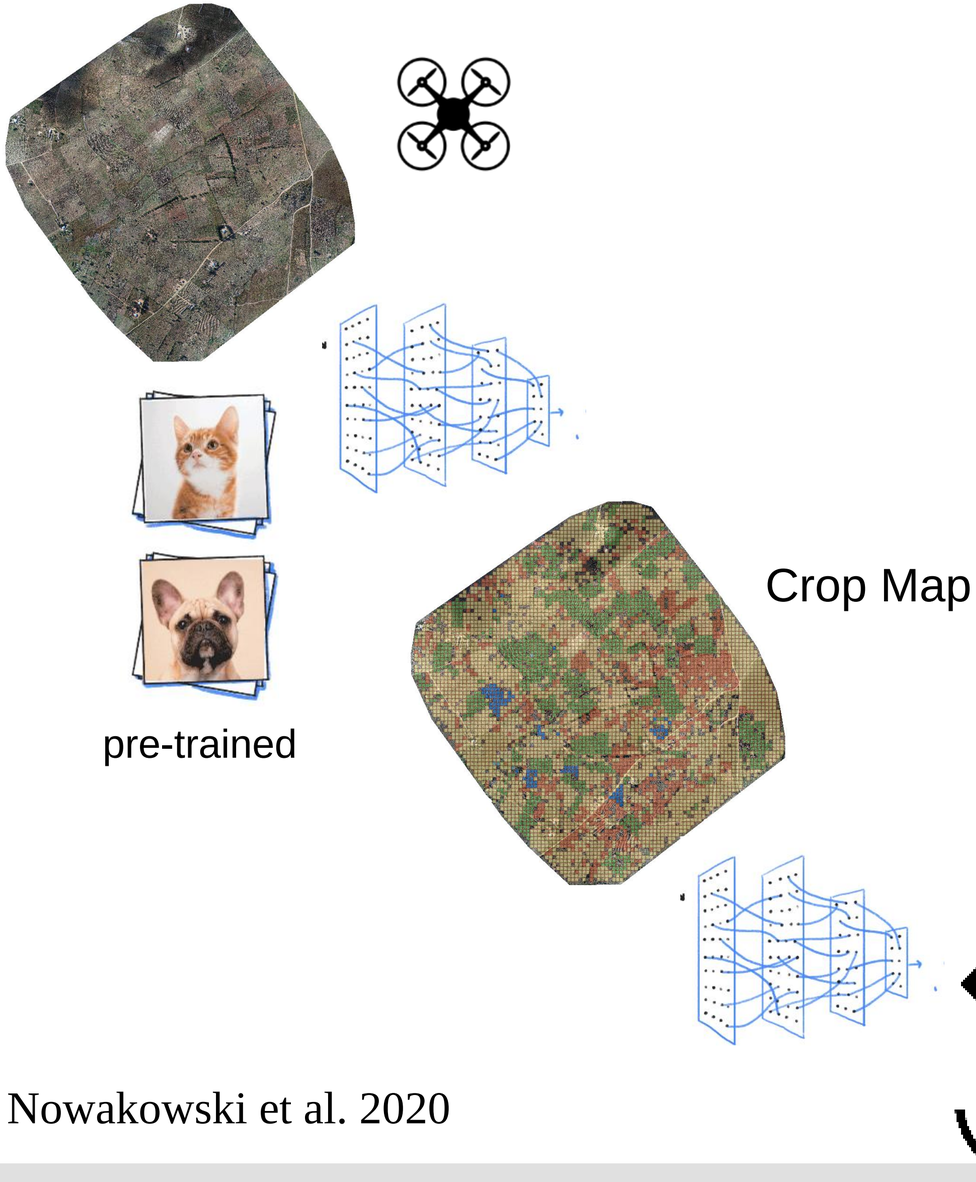
 # land use change
- 4+ ha Vegetation -> Buildings (Wuhan, Mar-Apr 2020)

% of oil storage
Experimental product on tank filling % based on physical model of S-1 backscatter

aerospacelab

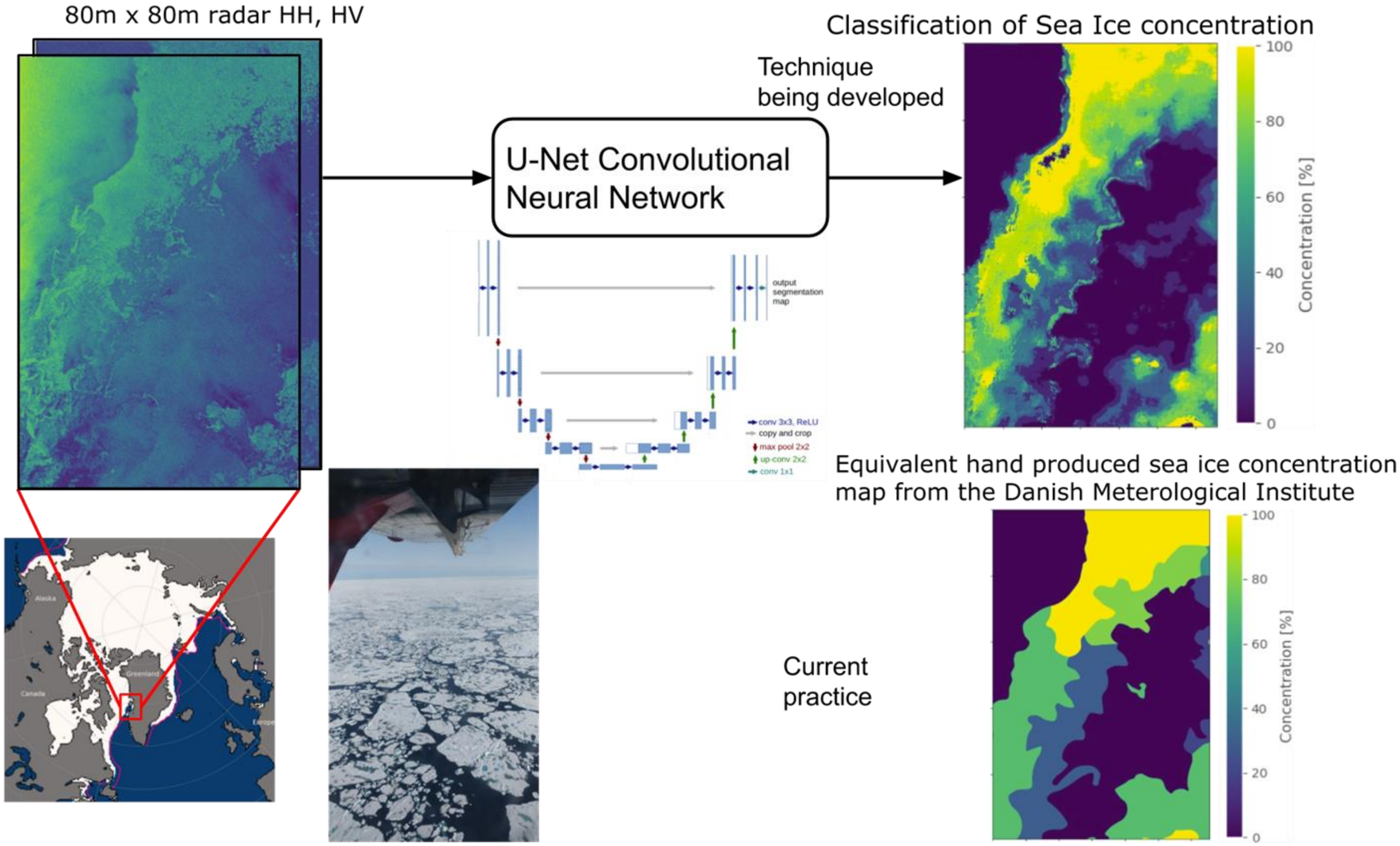
Transfer Learning:
Identifying crop type mapping in Malawi





Nowakowski et al. 2020

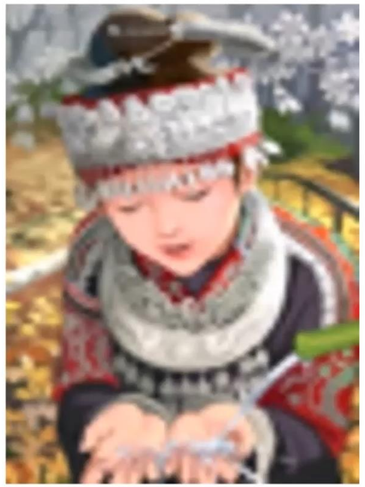
Arctic Sea Ice Charting



A. Stokholm

Enhancing Spatial Resolution

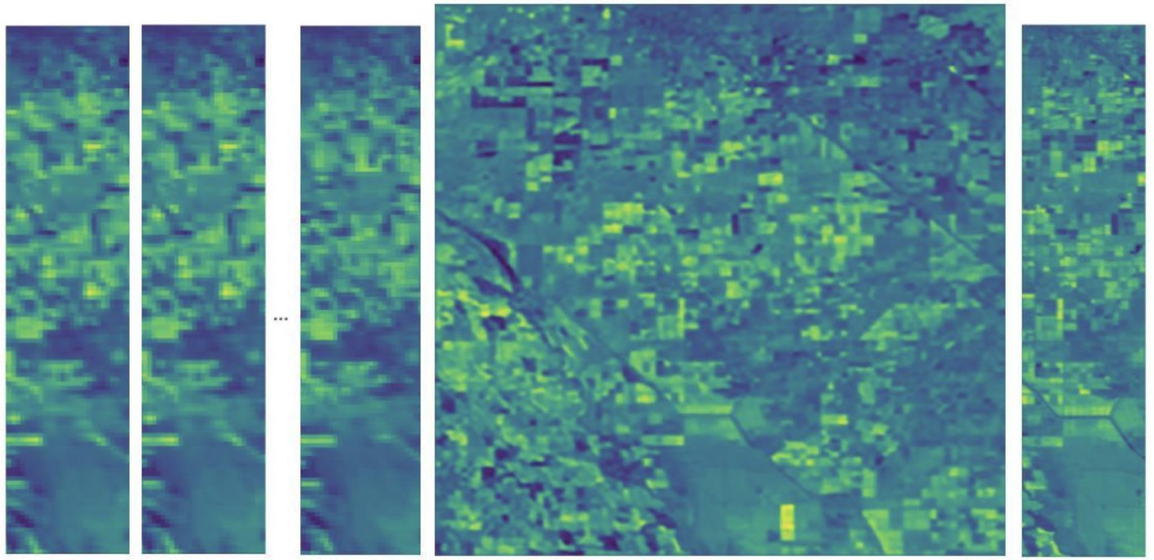
SRGAN, Ledig et al, arXiv:1609.04802



bi-cubic

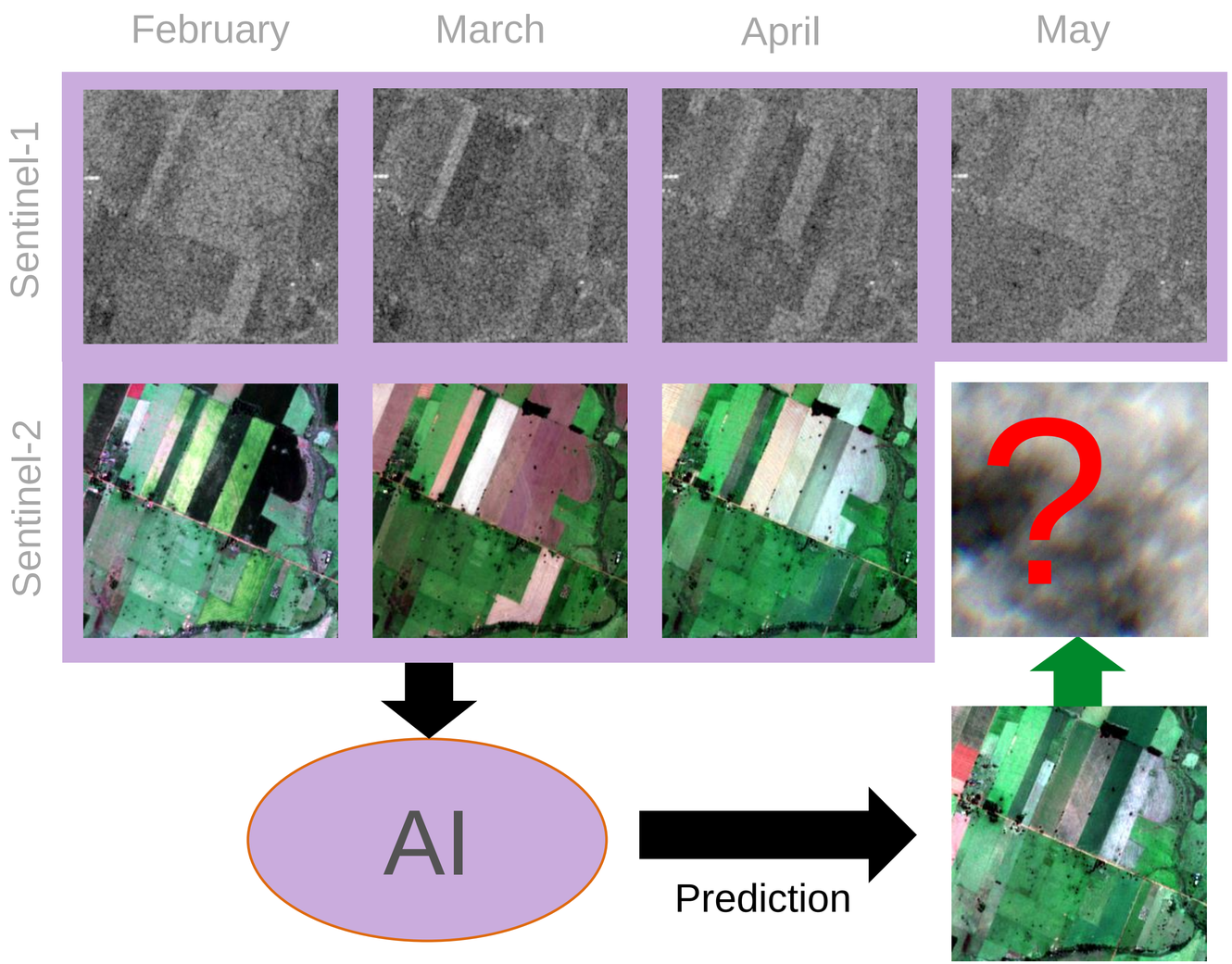
SR-GAN

Original



AI4EO Challenge Kelvin platform, DeepSUM, Super-res: https://bit.ly/2kNR8Sr

“Seeing through the clouds” challenge



Run a challenge on reconstruction of Sentinel-2 images behind clouds based on time series of Sentinel-1
and Sentinel-2 images

A.Nowakowski, A. Sebastianelli, E. Puglisi, J. Mifdal

AI for Emulation: Sentinel 5-P TROPOMI

Collaborator: Edward Malina (EOP-SMA)

Project aim: Replace costly RTMs within the current S5-P Methane retrieval scheme with an AI-based emulator

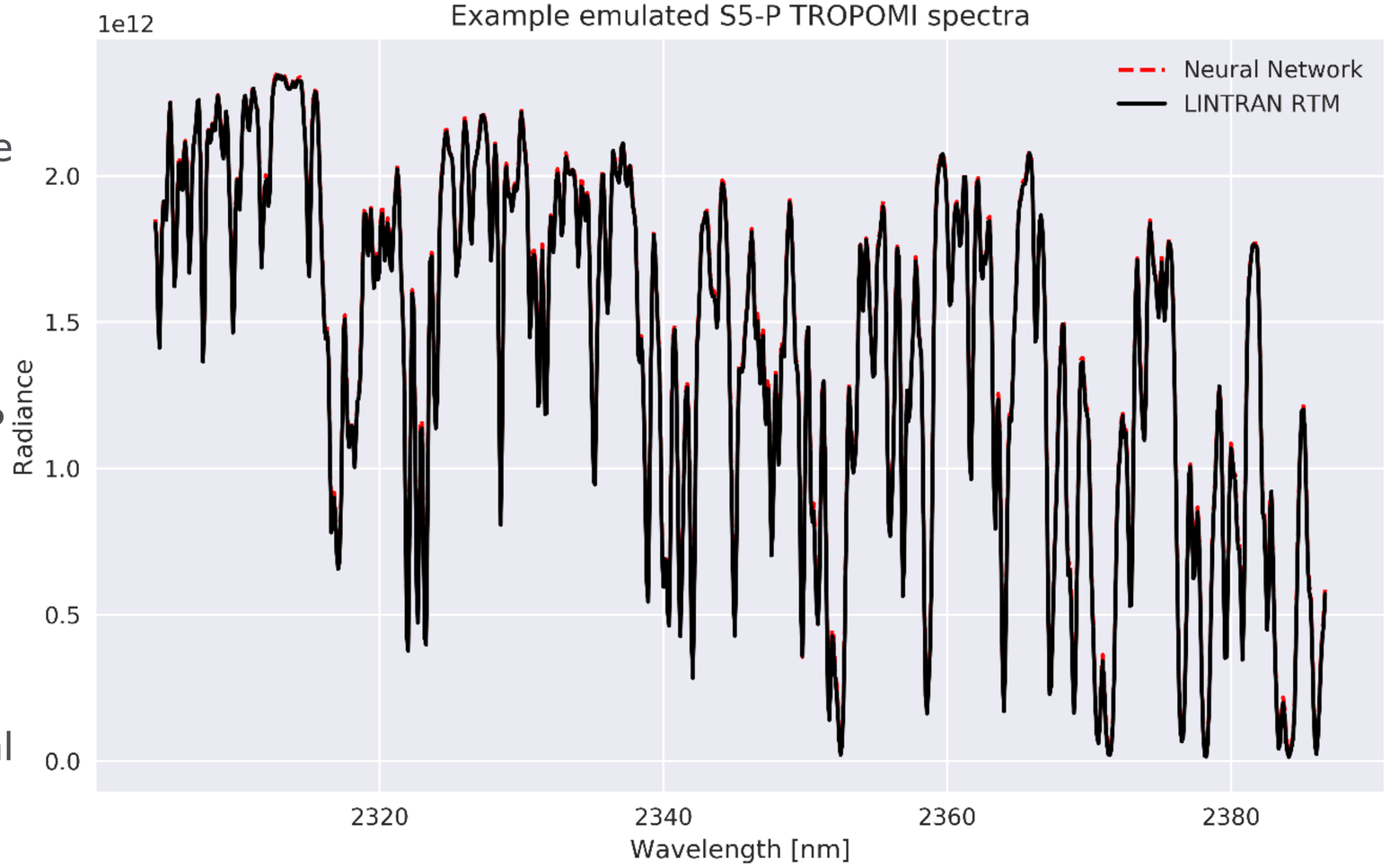


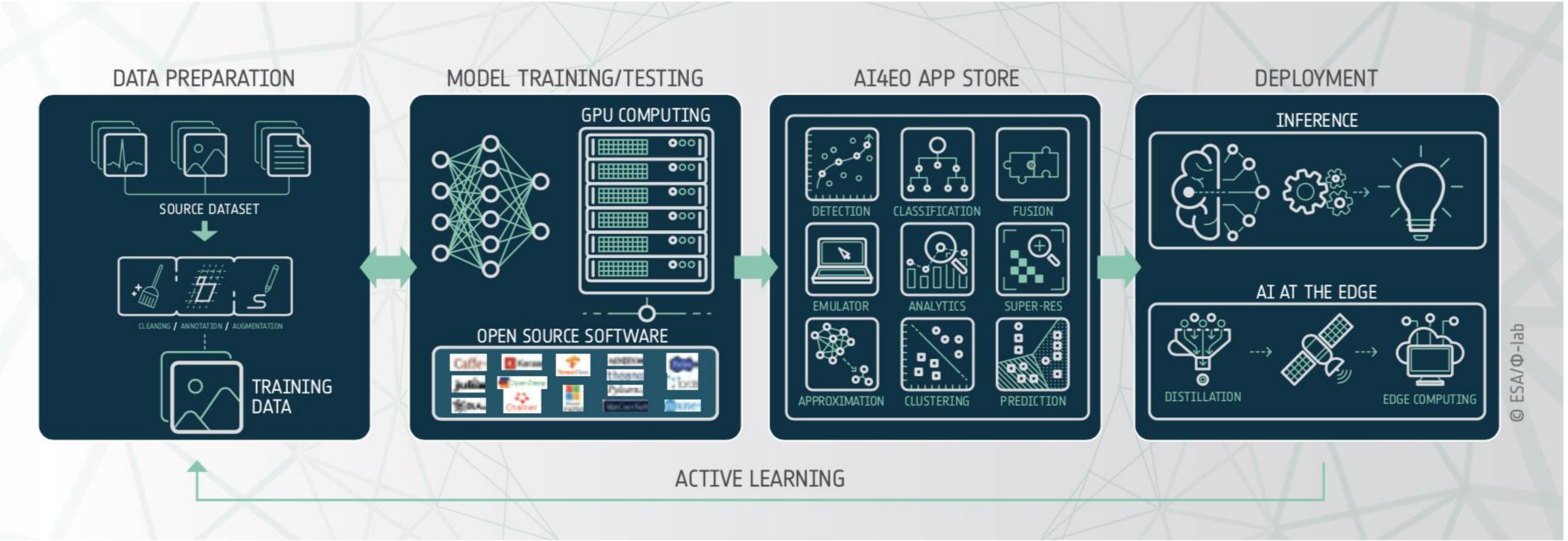
Figure: Example of emulated Sentinel 5-P TROPOMI Top-of-Atmosphere (TOA) Radiance spectra in the SWIR bands.

Black line: Original LINTRAN Radiative Transfer Model (RTM)

Red line: Emulated spectra using a Neural Network

Infrastructures, tools, AI-ready data sets & New Business Models

DTE App Store



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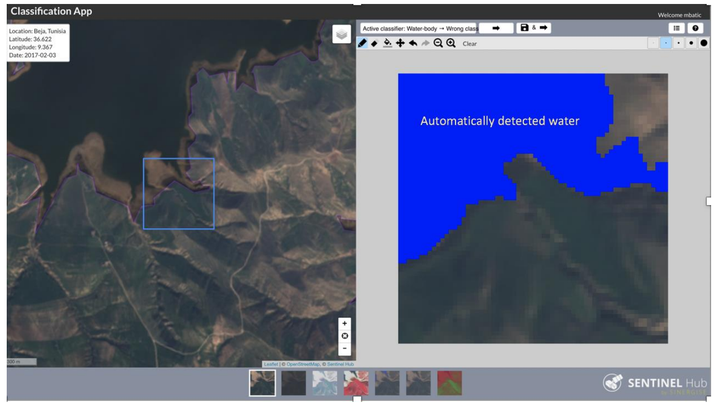
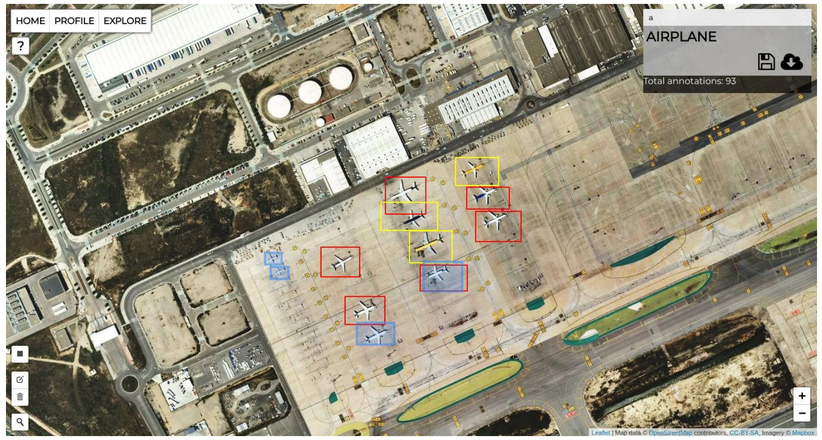
EO annotated data sets

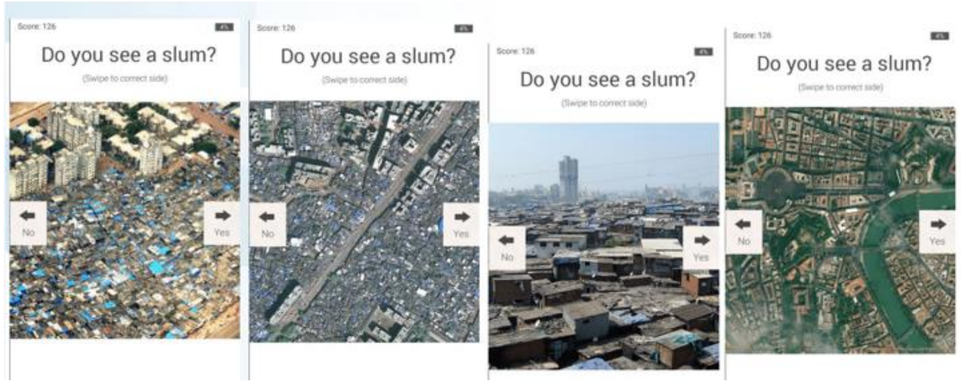
S-2 Annotation - Query Planet



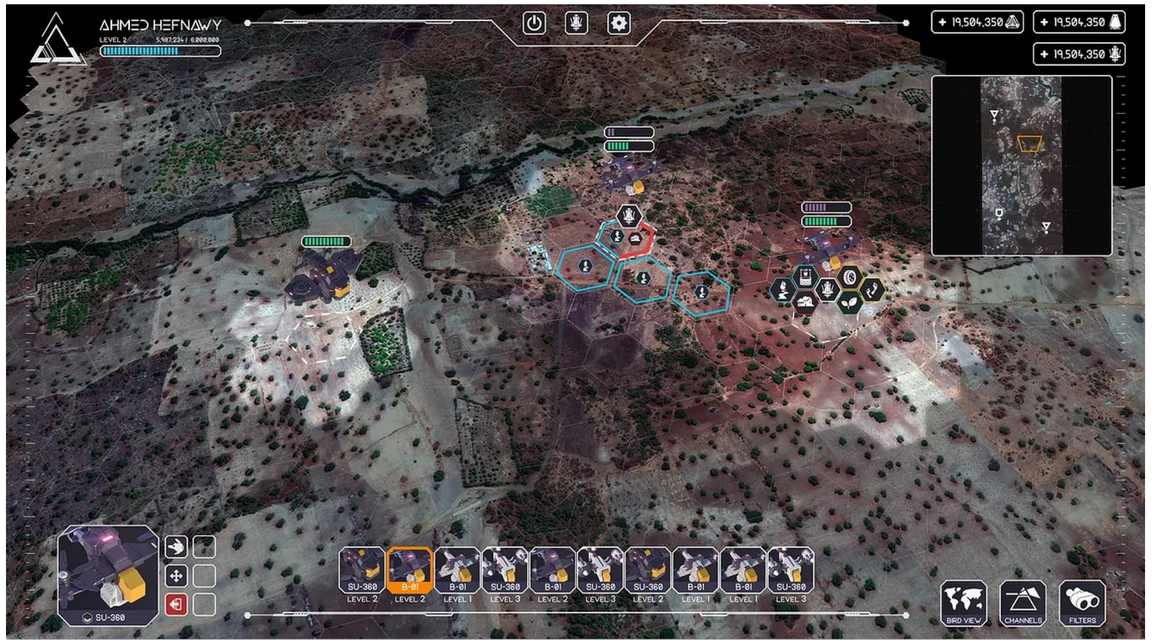
VHR Annotation - PointEO



Urban Annotation - Game.EO

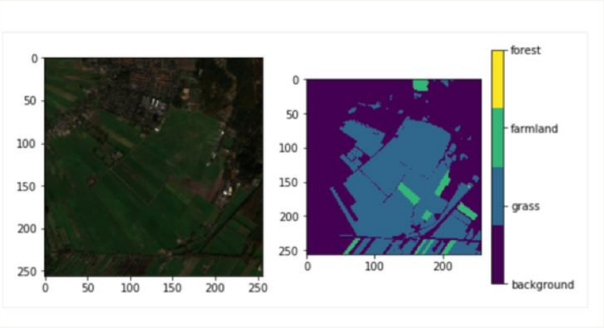


Gamification – Crowd&Machine with Blackshore



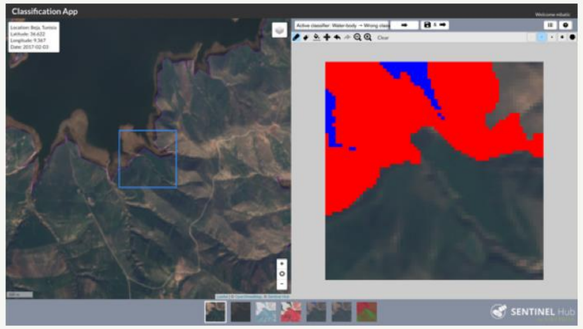
Open AI tools

Label Maker
devseed.com/label-maker

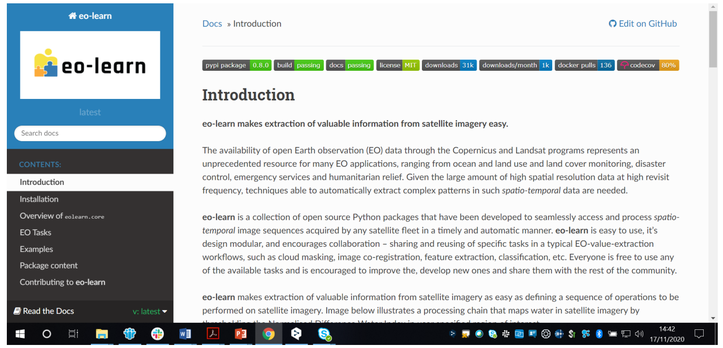


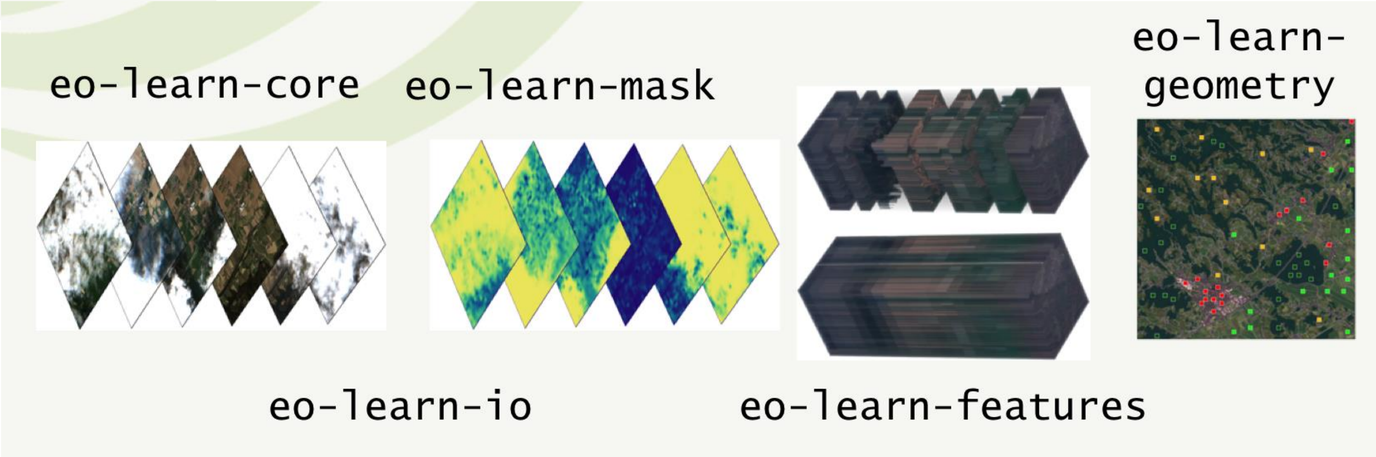
Conversion tool for OpenStreetMap and other vector data to ML labels

Classification app
apps.sentinel-hub.com/classificationApp



Crowd-sourced label collection



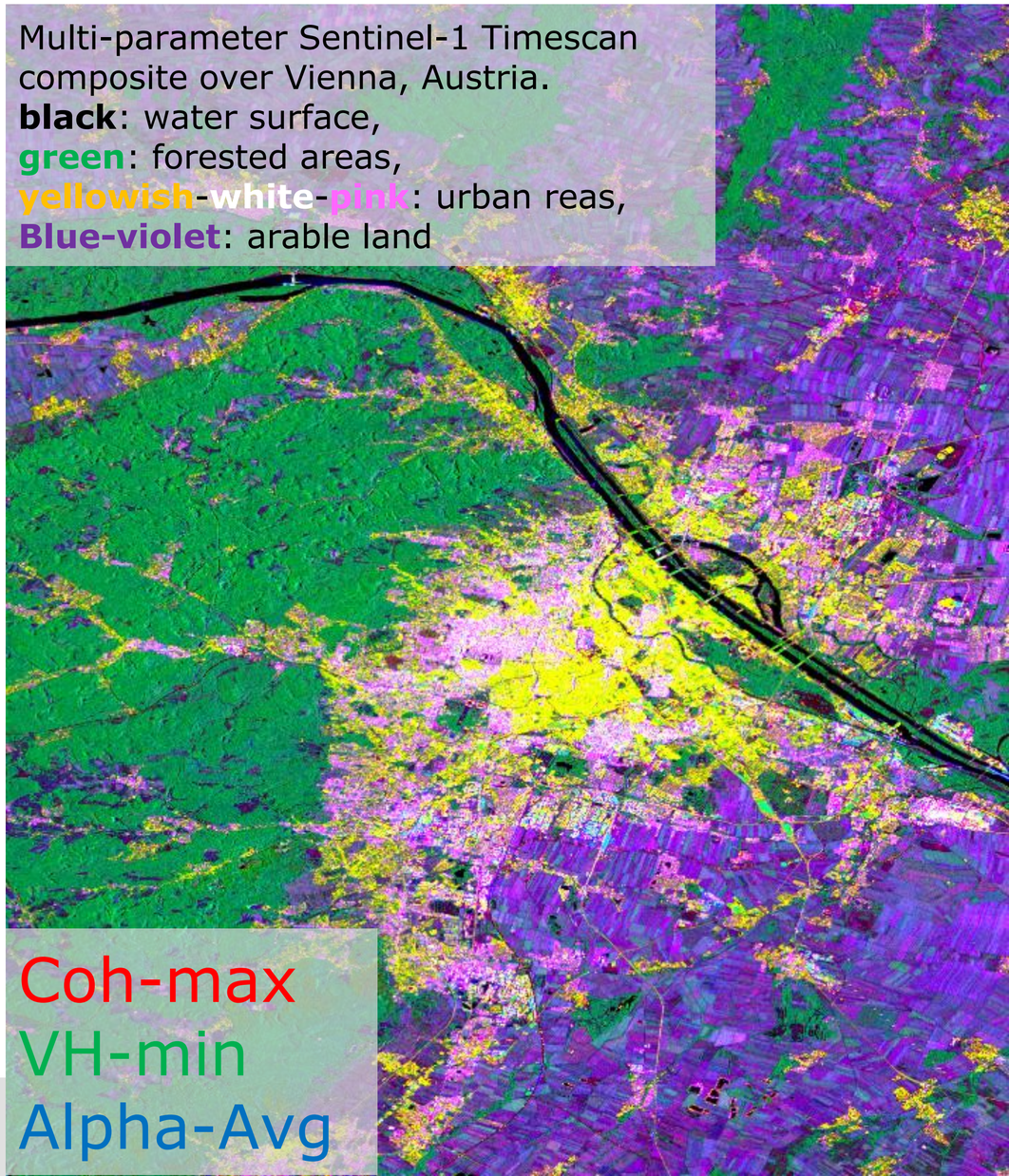


Open SAR toolkit & ARD

Open SAR Toolkit

- Aims to help non-SAR experts make most out of SAR data (e.g. AI community)
- prototype activity on advanced ***Analysis-Ready-Data formats*** for Sentinel-1
- Basic ARDs:
  - Radiometrically normalised ***backscatter***
  - Interferometric ***Coherence***
  - ***Timescans*** (i.e. Multi-temporal metrics)
  - Large-scale ***mosaics***

source: https://github.com/ESA-PhiLab/OpenSarToolkit



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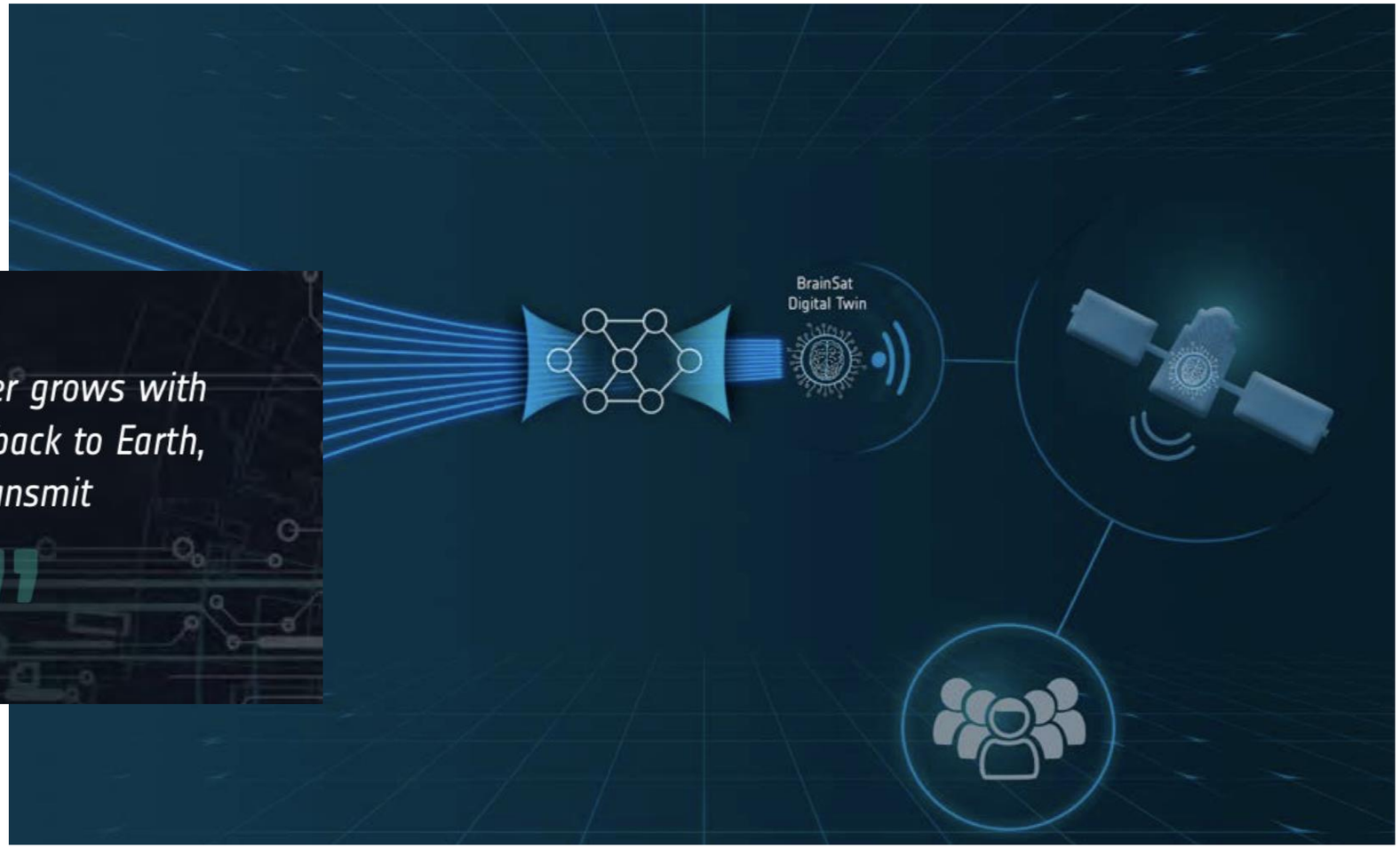
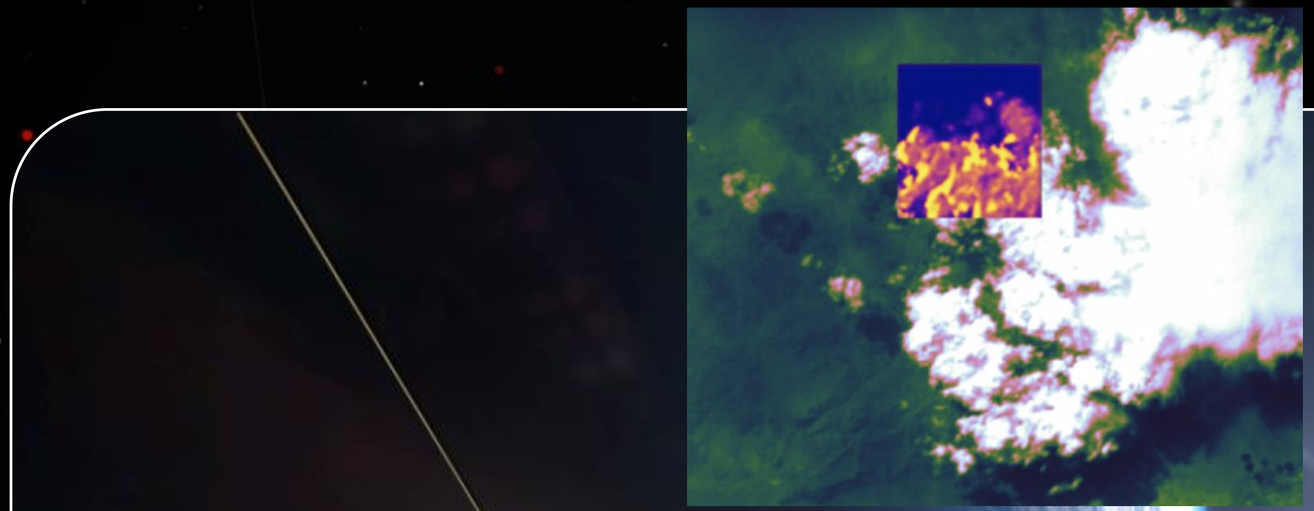
AI @ edge

> *The value of satellite-based EO no longer grows with the ability to collect and transmit data back to Earth, it increasingly lies with the ability to transmit customer-relevant insight in real-time.*
>
> **Peter Platzer,**
> *Spire, Φ-week 2019*



Φ-sat-1

Training on Ground
(S-2 mimicking)
Cloud detection



Inference in Space

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Hardware

This project is **technology driven:**

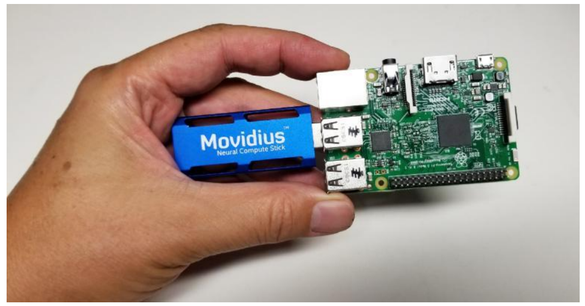
Visual Processing Unit (VPU)
Myriad-2

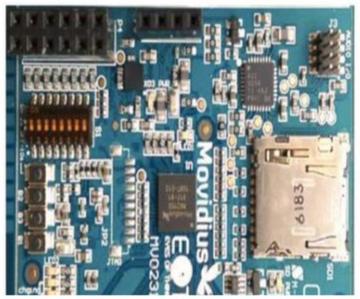
Hardware accelerator for Convolution Neural Networks (CNNs)

Fast: 1 TOPS

Low power: O(1 Watt)

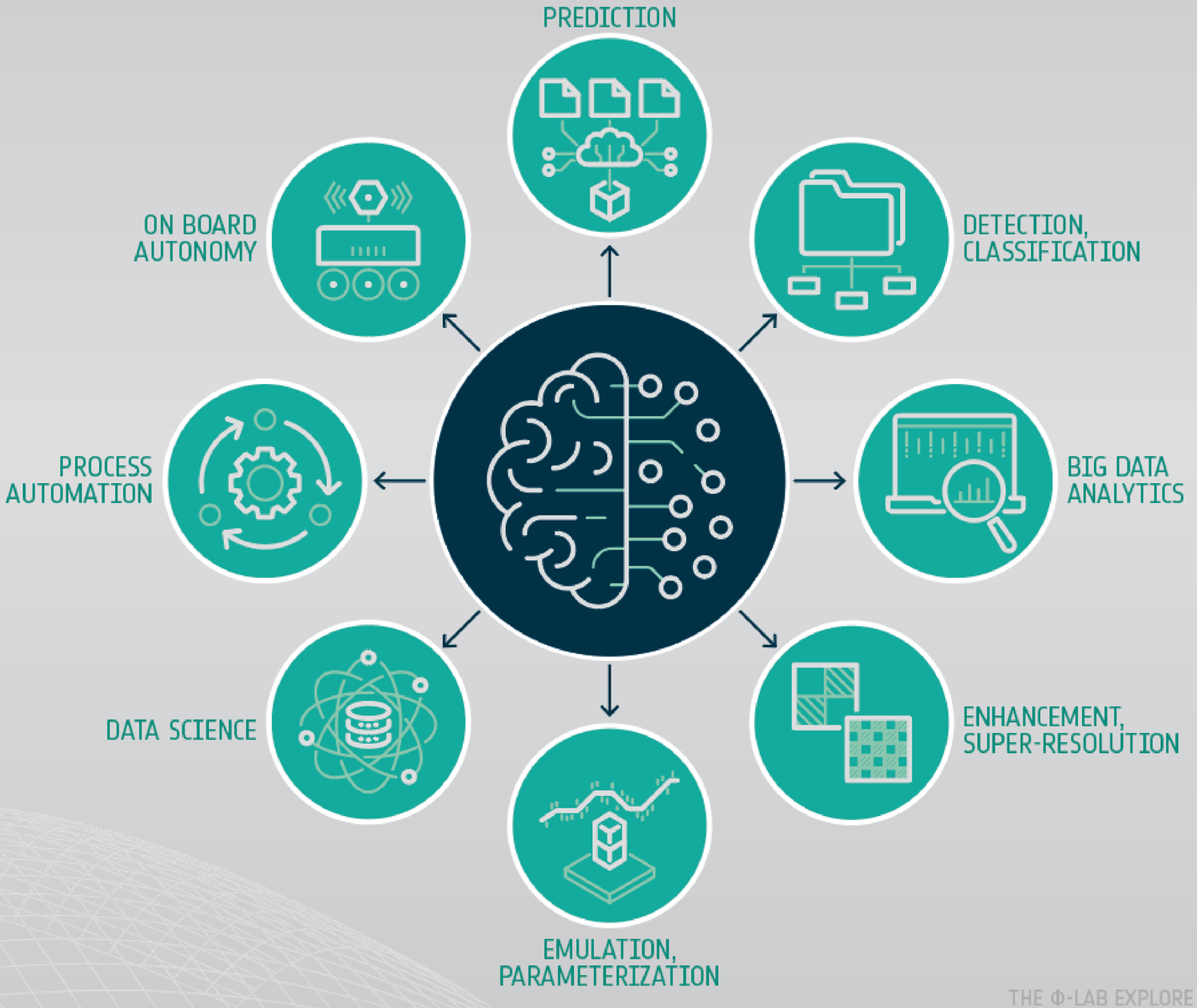
Tiny





Concluding Remarks

AI TURBO-CHARGING EO



AI **accelerates** **Time to Insight** for Copernicus

AI can help **learning** the underlying **Structure** of data

"**Technology**… is only a **magnifier** of **human intent** and capacity. It is not a **substitute**."

Kentaro Toyama
Geek Heresy: Rescuing Social Change from the Cult of Technology

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