EO Data Access, Infrastructure, Challenges, Opportunities & Applications

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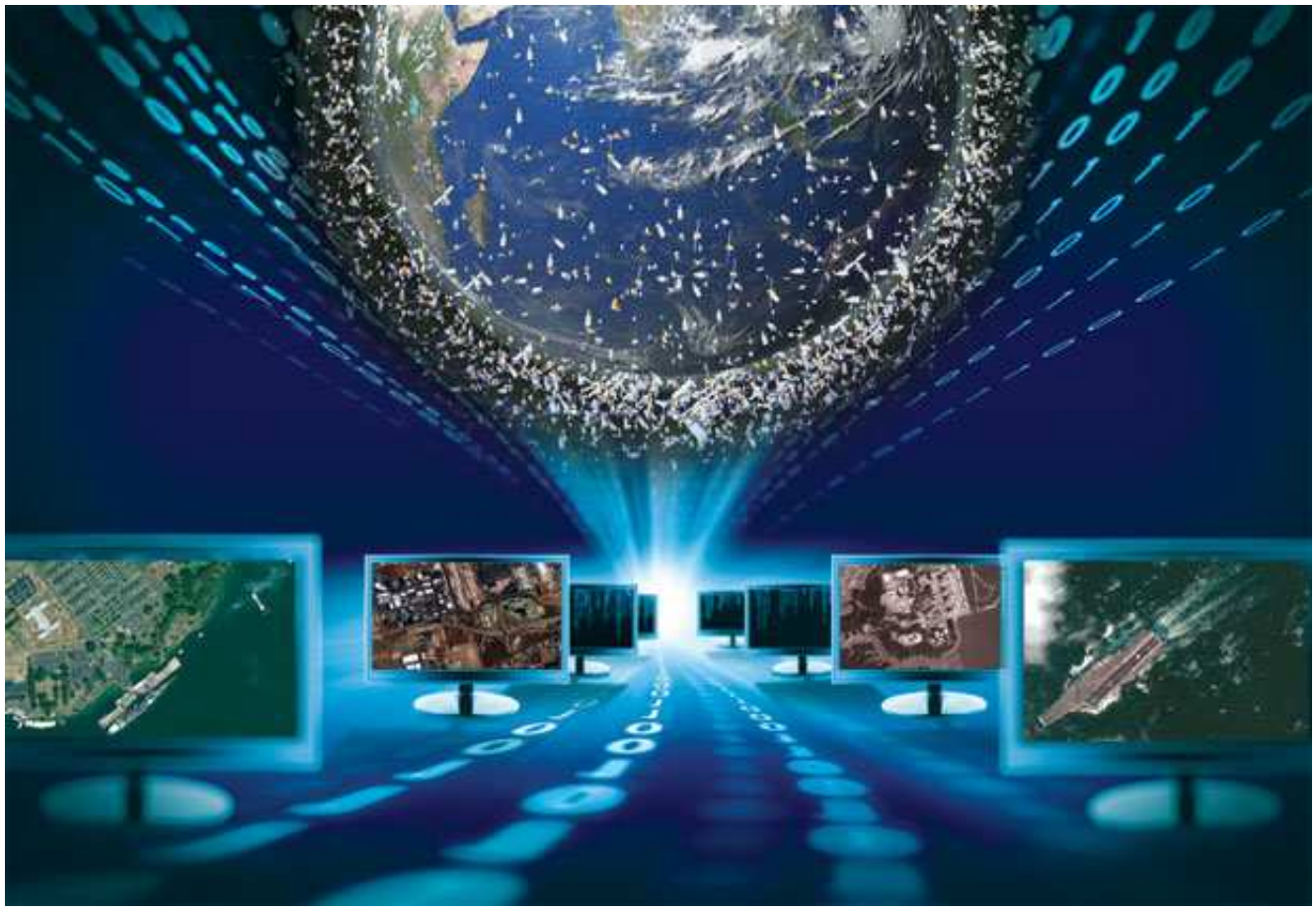
Technische Universität Wien

Earth Observation Data Centre

The Golden Era of Earth Observation

Earth Observation – A Rapidly Growing Field



GEOSPATIAL WORLD

https://www.geospatialworld.net/article/satellite-based-commercial-eo-industry-time-to-get-down-to-business/

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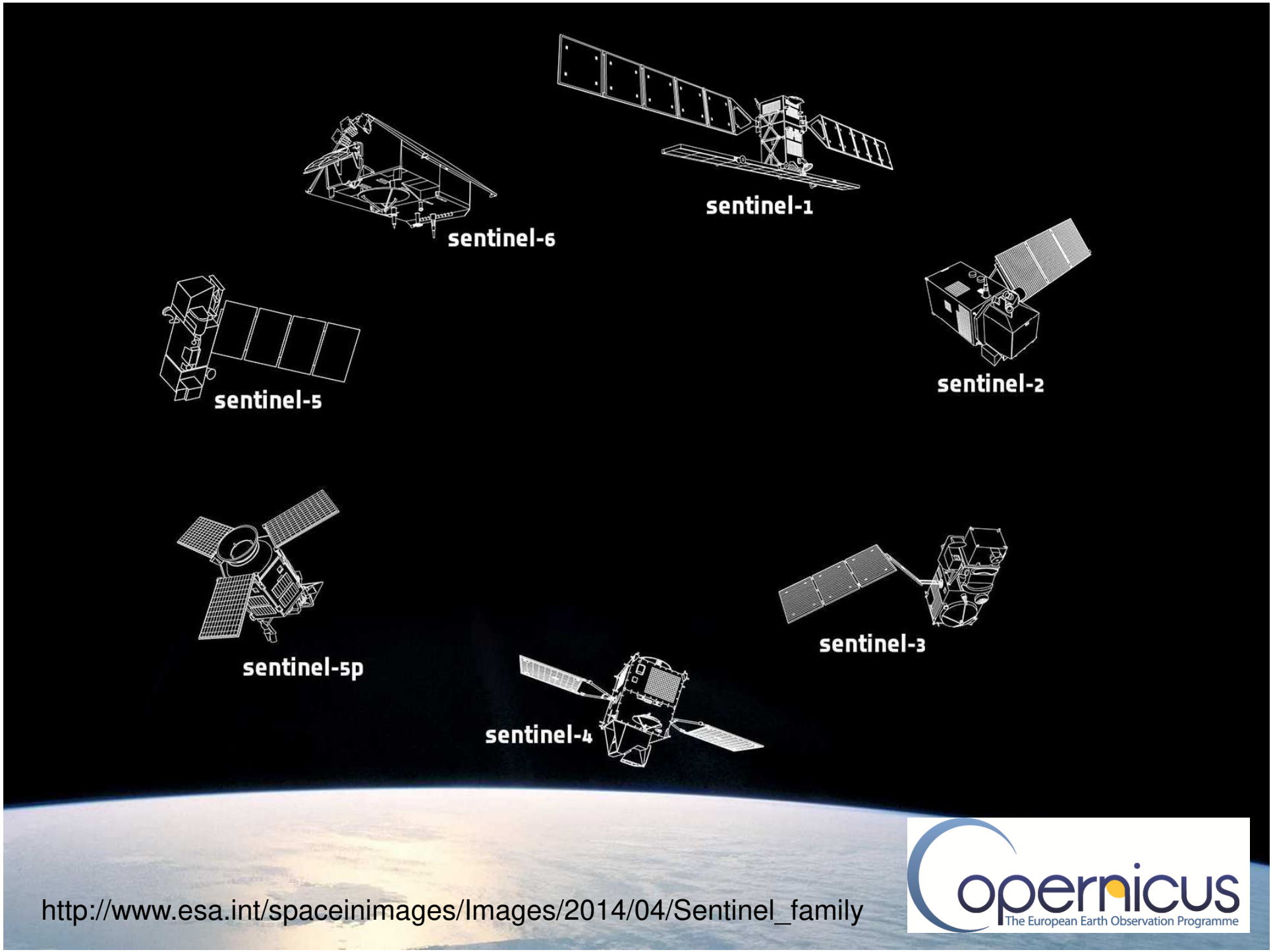
Earth Observation in Europe

- In the civil domain Europe has taken over leadership from the USA

esa

opernicus
The European Earth Observation Programme

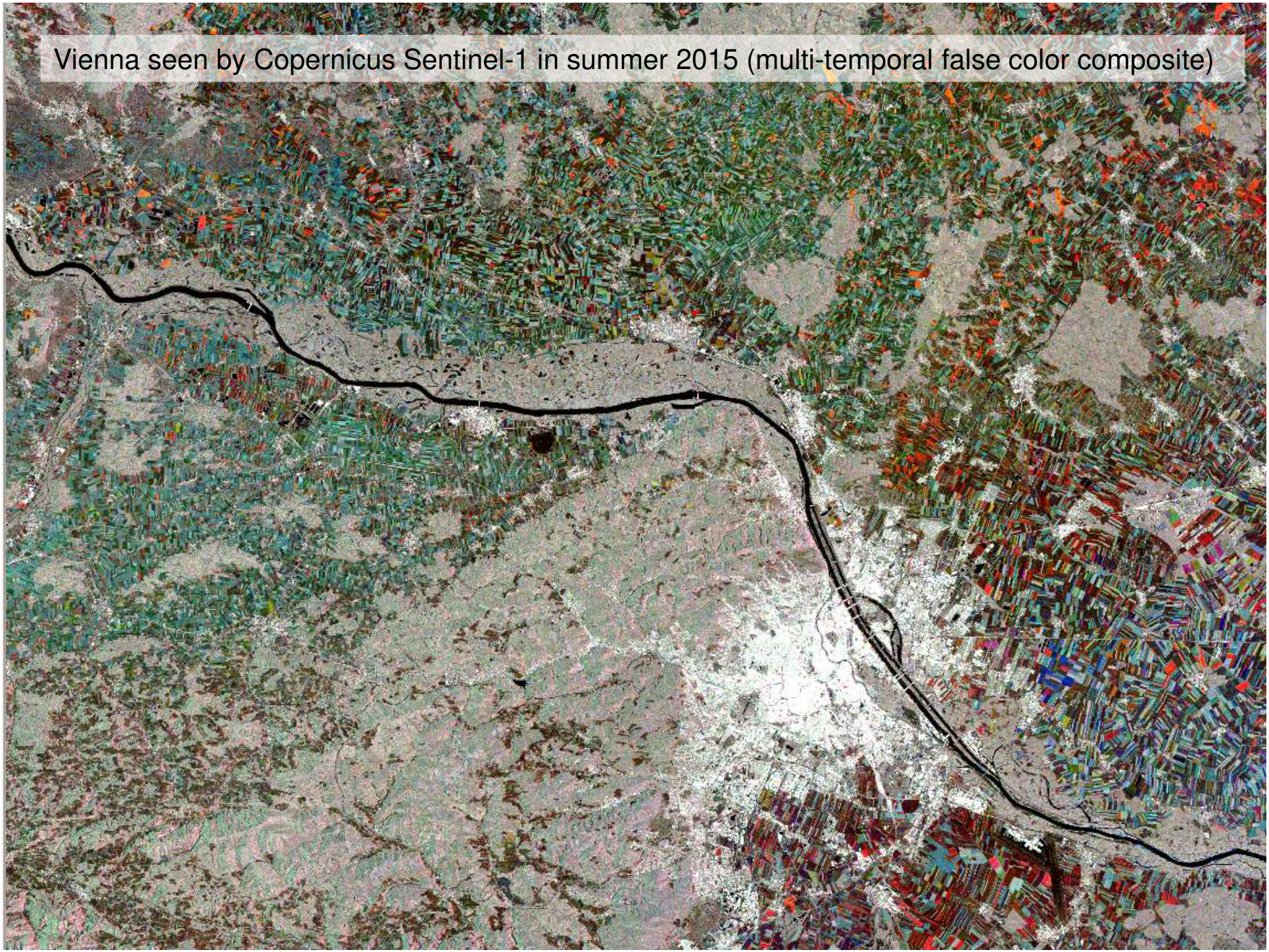
EUMETSAT



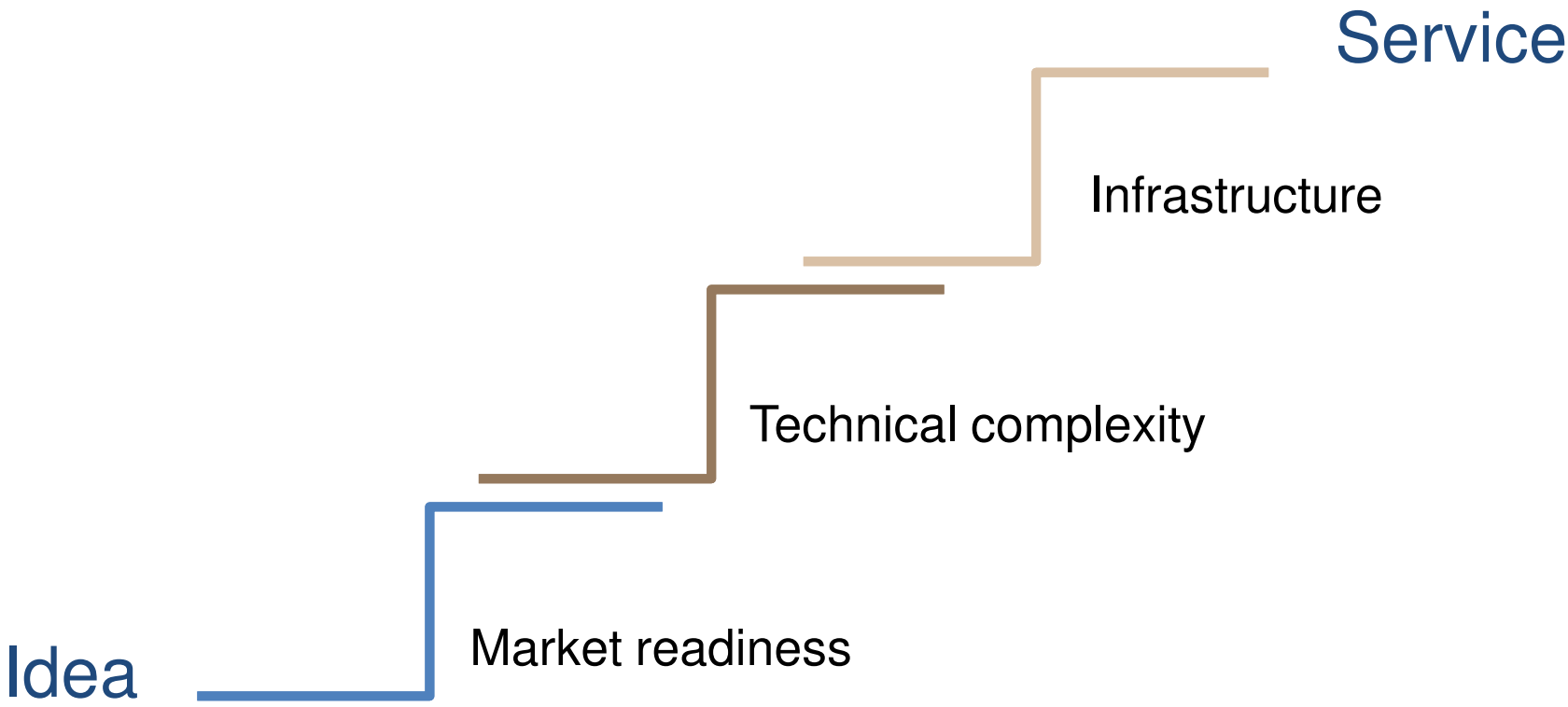
http://www.esa.int/spaceinimages/Images/2014/04/Sentinel_family

opernicus
The European Earth Observation Programme

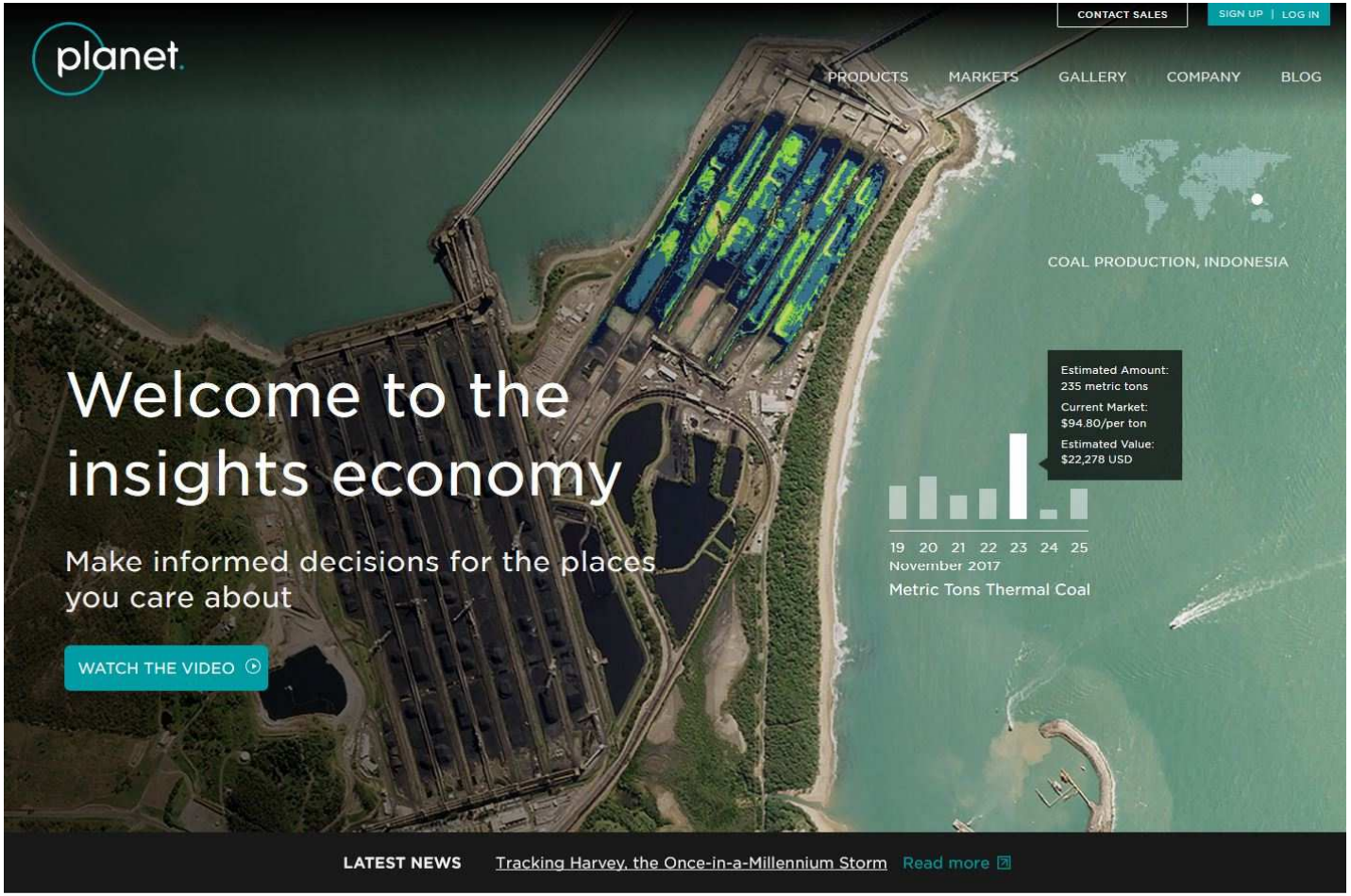

Vienna seen by Copernicus Sentinel-2 on 15 October 2017 (true-color composite)


Vienna seen by Copernicus Sentinel-1 in summer 2015 (multi-temporal false color composite)

“Make Space Part of Your Business”



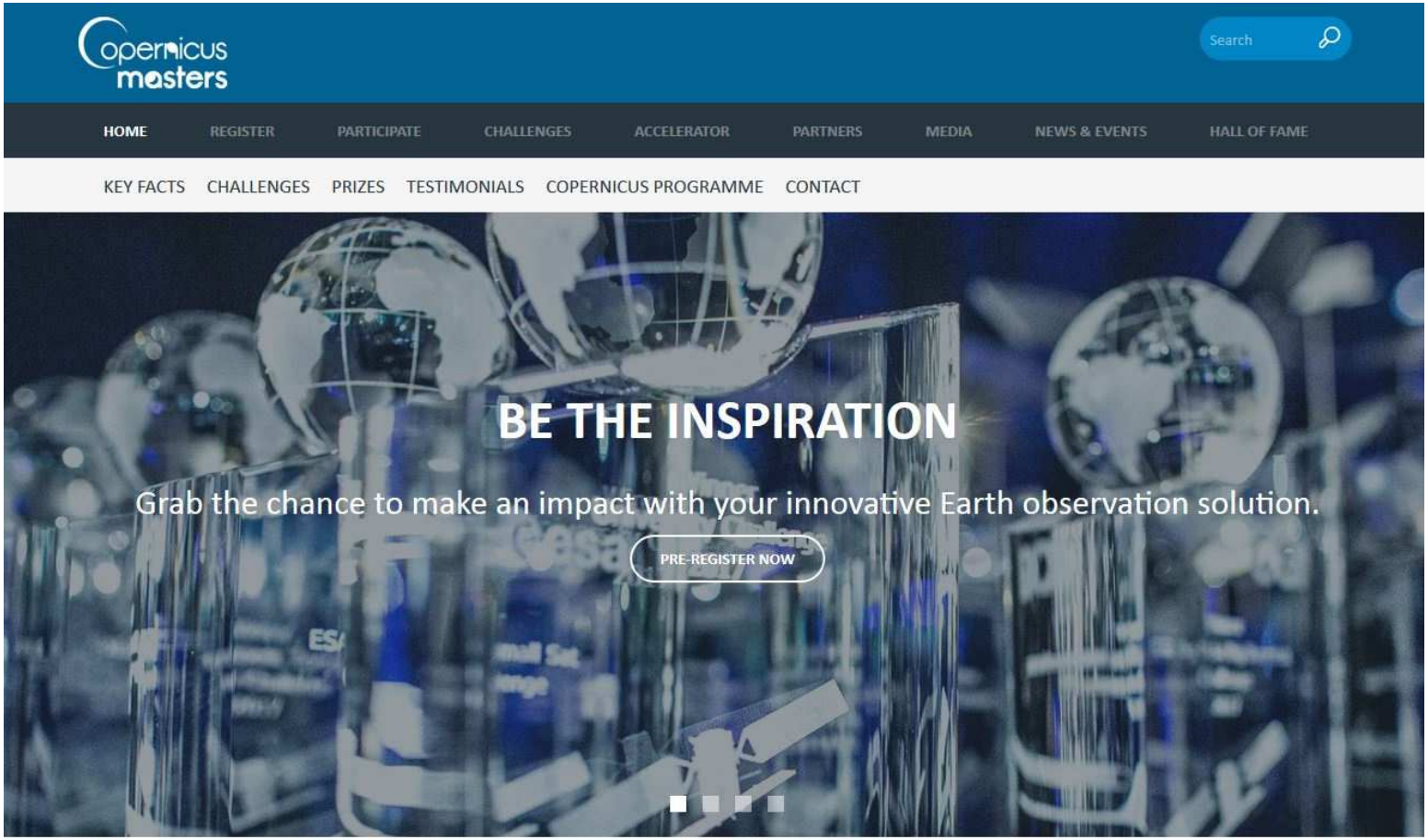
Market Readiness



Monitor Daily

Discover Trends

Deliver Insights



BOOST YOUR BUSINESS WITH BIG DATA FROM SPACE

https://www.copernicus-masters.com/

Are there costumers who

have a need for the service?

have the technical skills to exploit it?

are capable and willing to pay?

Global Climate Observing System

Measurement domain	Essential Climate Variables (ECVs)
Atmospheric	Surface: air temperature, wind speed and direction, water vapour, pressure, precipitation, surface radiation budget Upper-air: temperature, wind speed and direction, water vapour, cloud properties, Earth radiation budget, lightning Composition: carbon dioxide (CO_2), methane (CH_4), other long-lived greenhouse gases, ozone, aerosol, precursors for aerosol and ozone
Oceanic	Physics: temperature: sea surface and subsurface; salinity: sea surface and subsurface; currents, surface currents, sea level, sea state, sea ice, ocean surface stress, ocean surface heat flux Biogeochemistry: inorganic carbon, oxygen, nutrients, transient tracers, nitrous oxide (N_2O), ocean colour Biology/ecosystems: plankton, marine habitat properties
Terrestrial	Hydrology: river discharge, groundwater, lakes, soil moisture Cryosphere: snow, glaciers, Ice sheets and Ice shelves, permafrost Biosphere: albedo, land cover, fraction of absorbed photosynthetically active radiation, leaf area index, above-ground biomass, soil carbon, fire, land surface temperature Human use of natural resources: water use, greenhouse gas fluxes

GCOS • GTOS • WCRP
TOPC Terrestrial Observation Panel for Climate

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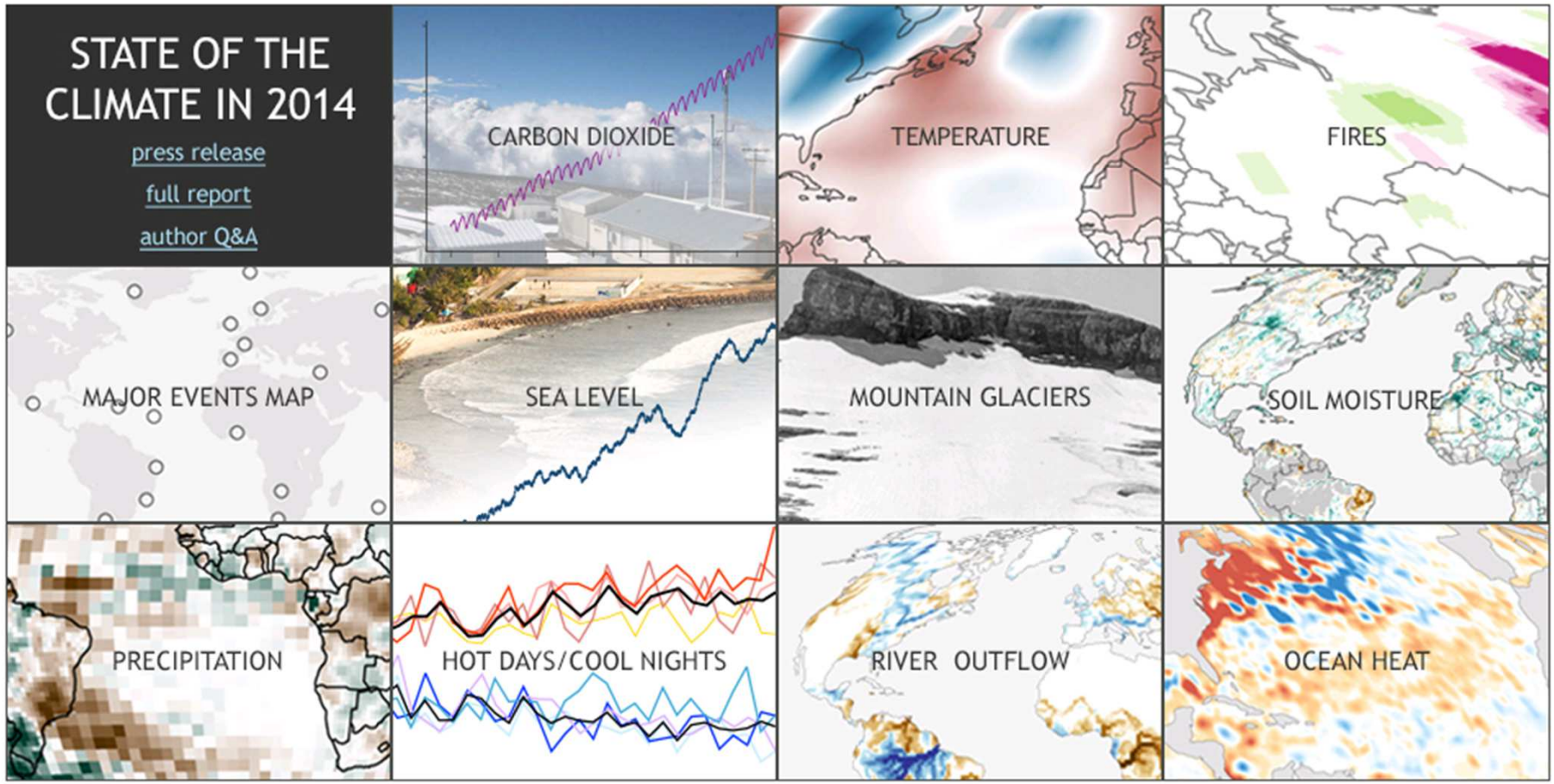
2014 State of the Climate: Highlights

Author: Adpated from State of the Climate in 2014

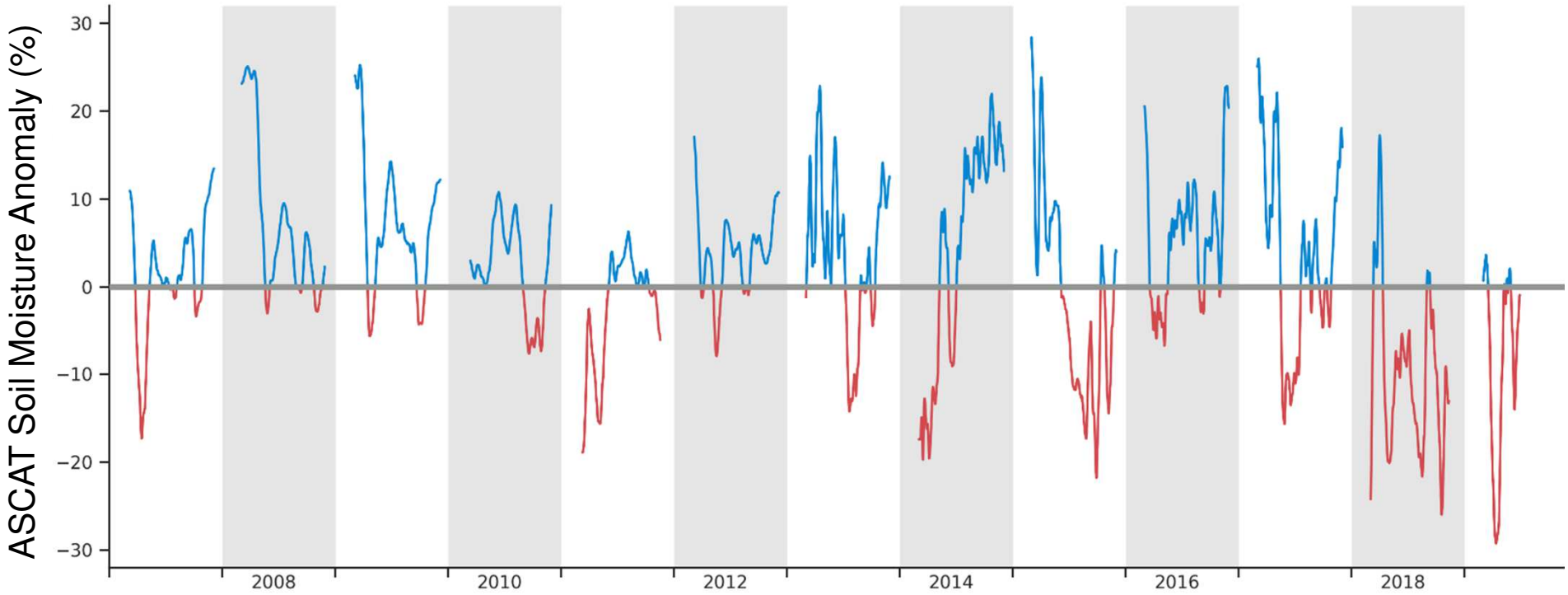
Tuesday, July 14, 2015



Upper Austria in August 2015

Upper Austria in August 2018

Drought Monitoring with Satellite Soil Moisture Data



Drought-index derived from ASCAT soil moisture data over Offenhausen, Upper Austria

H SAF

Interreg
Danube Transnational Programme
DriDanube

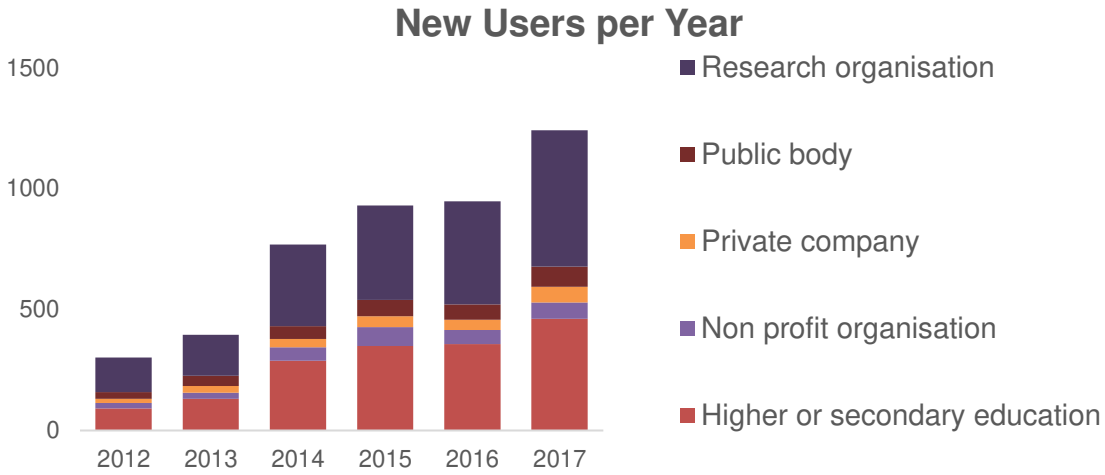
eodc

TU WIEN

GEO

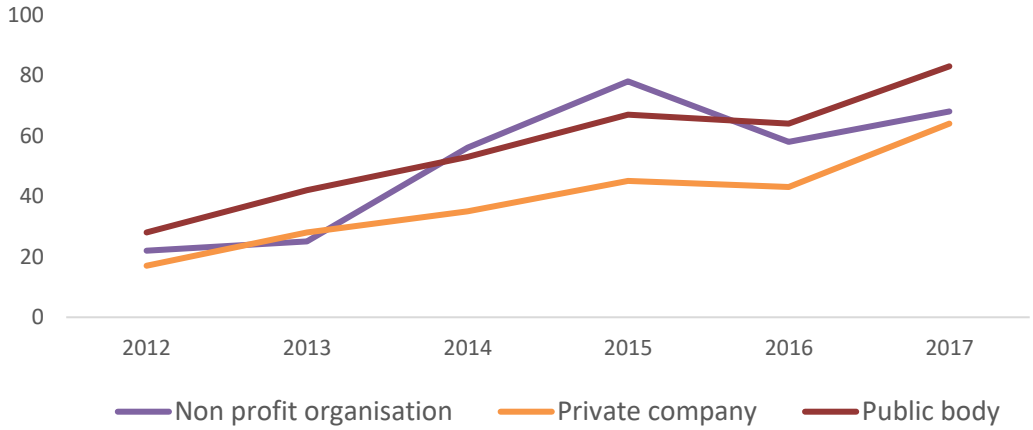
CCI Soil Moisture Users

- Registered users > 5200 and more than 5 registrations per day



soil moisture cci

User statistics prepared by GeoVille



→ Increasing uptake from NGOs, private companies and public bodies

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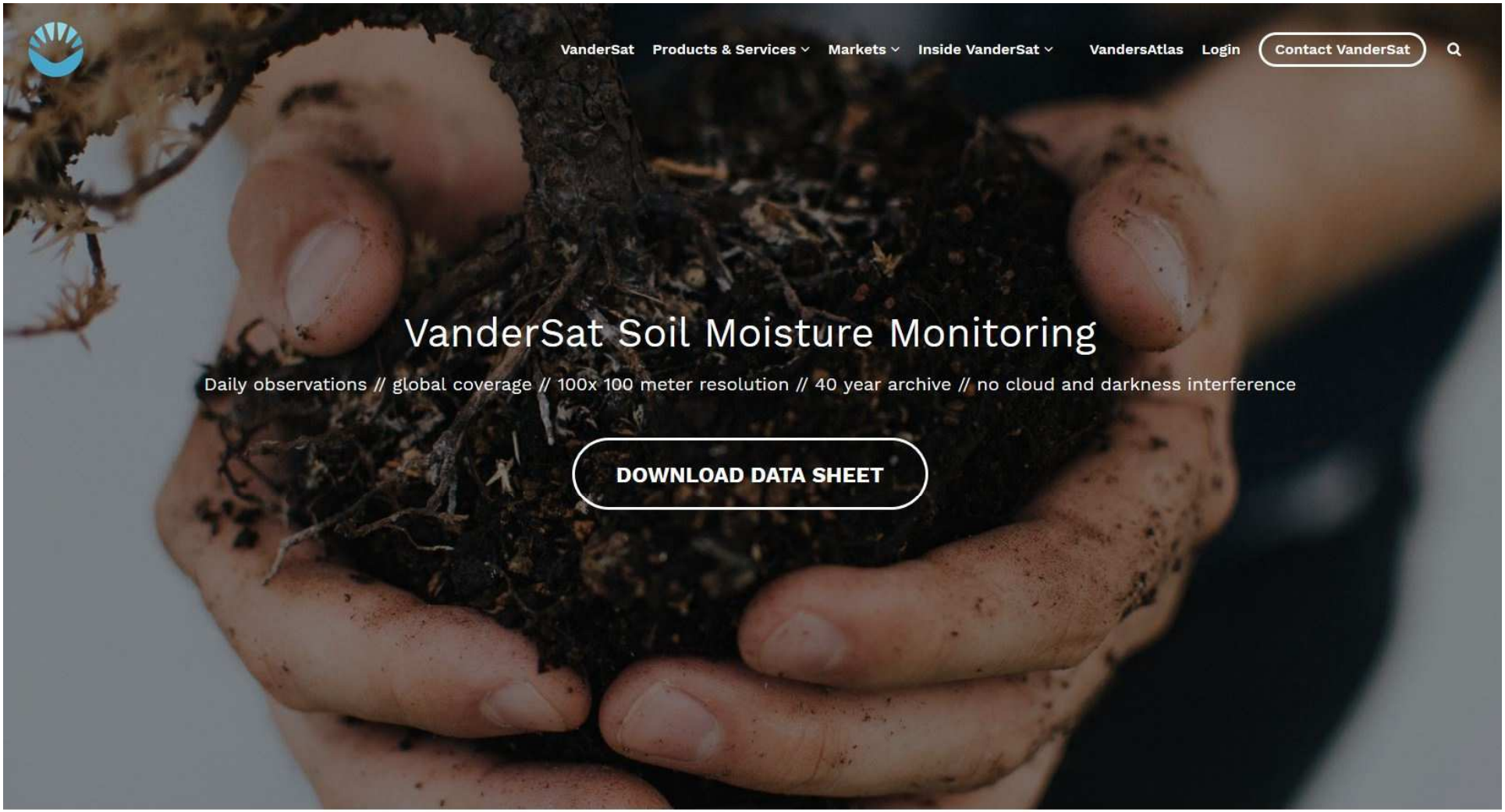

Detailed soil moisture data. Every day, everywhere on earth.

VanderSat

https://www.vandersat.com/soil-moisture-monitoring

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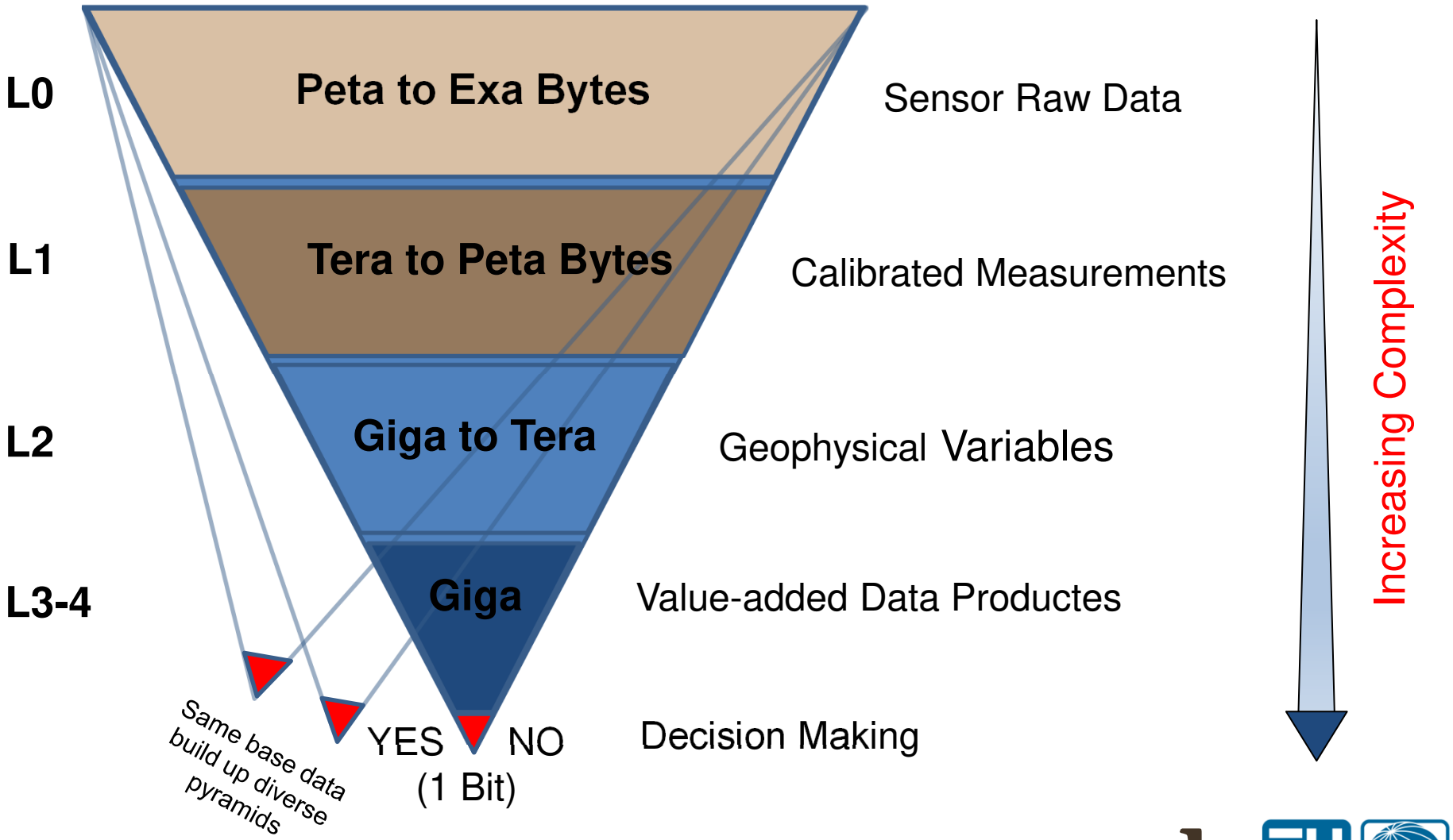
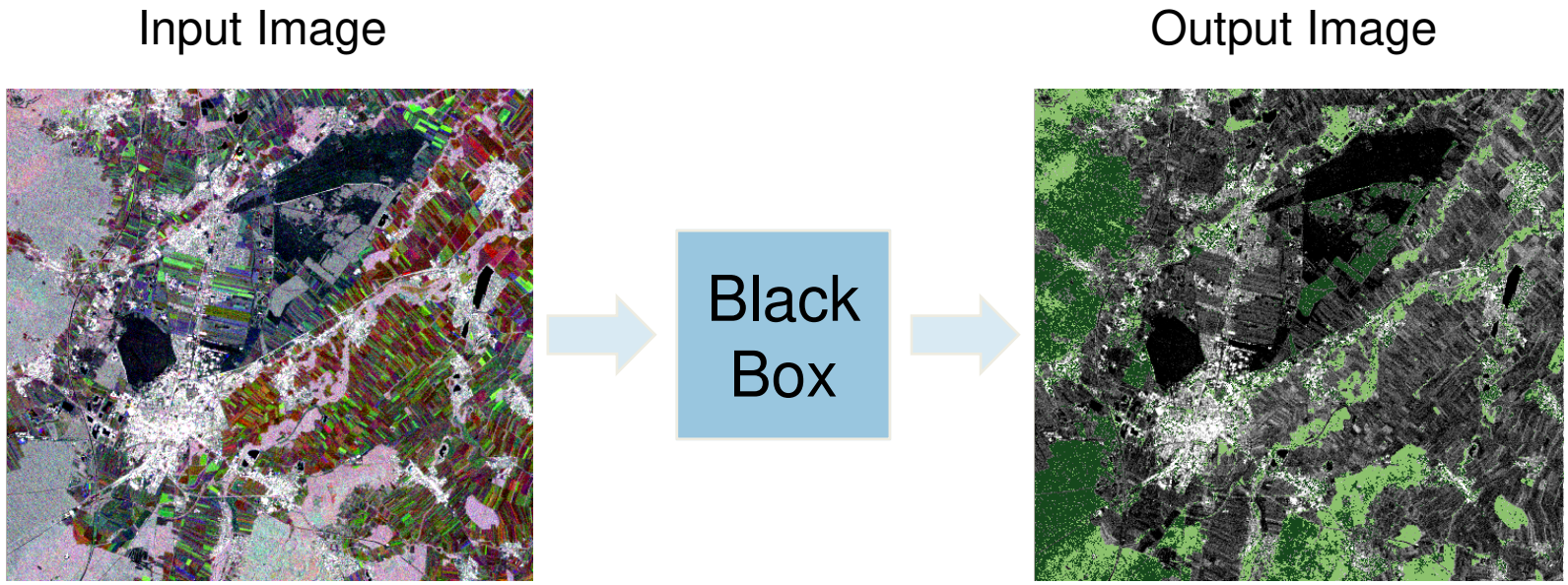
Technical Complexity

EO Data Pyramid



EO Processing Models

- A simple “image-to-image” processing model dominates the current engineering practices in EO



- This processing model is scalable and can be easily implemented in cloud environments, but fails to account for the reality that many EO data processing workflows have become much more complex

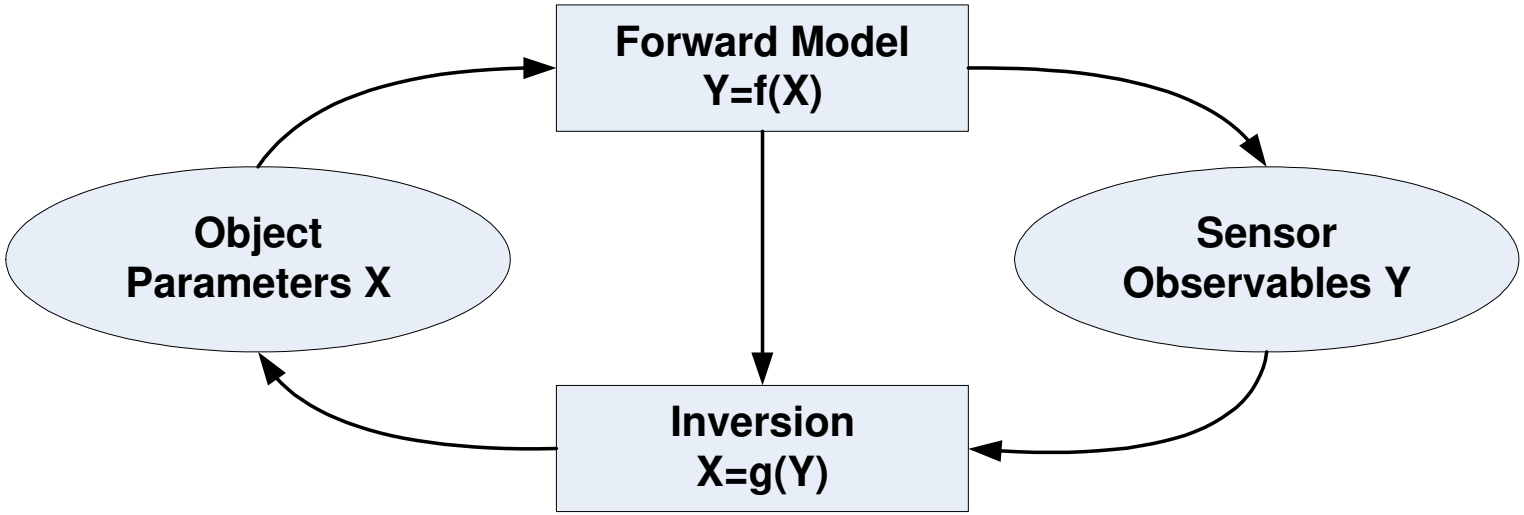
Soil Moisture Retrieval Algorithms

Backscatter depends on
- Soil moisture
- Surface roughness
- Vegetation structure
- Vegetation density

Empirical models

Semi-empirical models

Theoretical models



Lookup tables and machine learning

Least-square matching

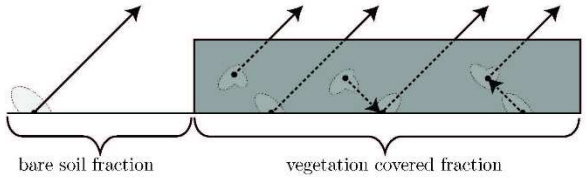
Direct inversion

Radiative Transfer Models

Model formulation

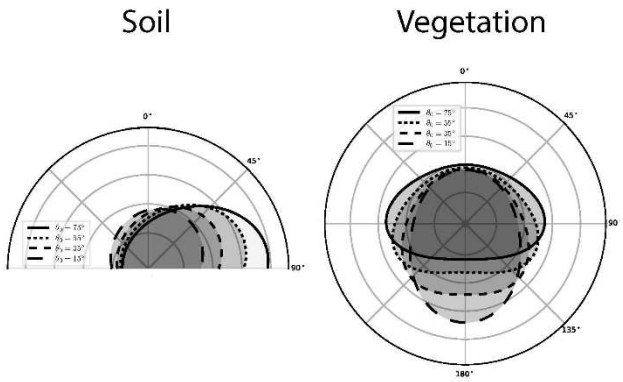
First order Radiative Transfer Model

$$\sigma_0 = f_{bs} \cdot \sigma_0^s + (1 - f_{bs}) \cdot \left(\sigma_0^v + \gamma^2 \sigma_0^s + \overbrace{\sigma_0^{vs} + \sigma_0^{sv}}^{\sigma_0^{int}} \right)$$



+

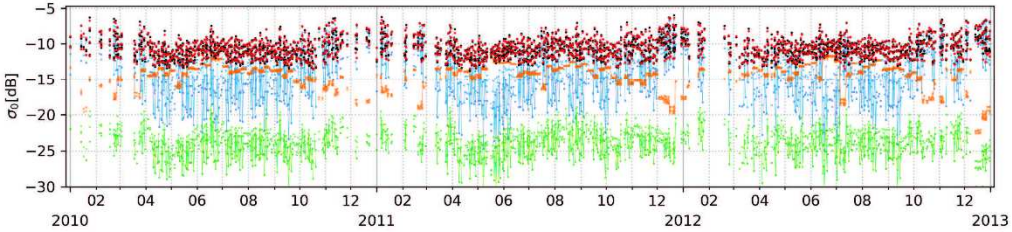
Parametric scattering distributions



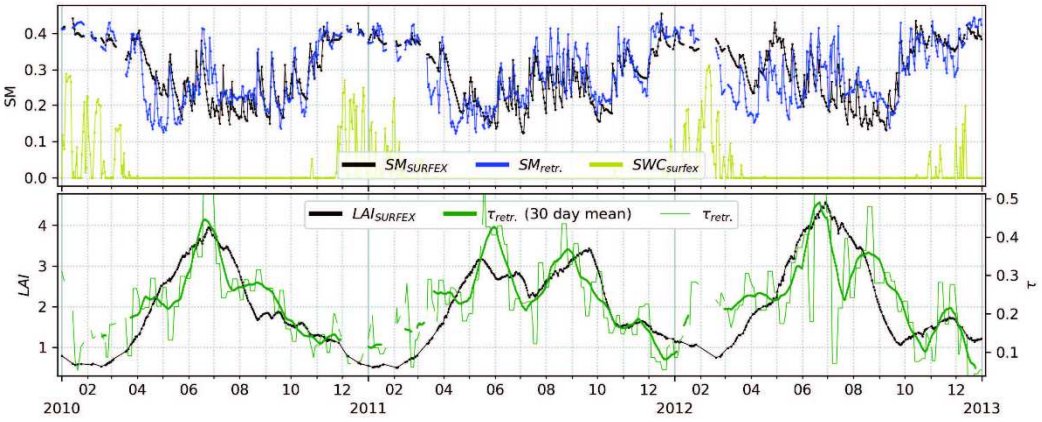
Application of model to 157 test-sites in France

Calibration with SURFEX soil-moisture (SM) and LAI

decomposition of ASCAT backscatter timeseries



Soil- and vegetation-parameter timeseries



Quast et al. (2019) A generic first-order Radiative Transfer modelling approach for the inversion of soil- and vegetation parameters from scatterometer observations, Remote Sensing, 11, 285, 24p.

“Give me six variables and I can model you a …”

SPACENEWS

NEWS | OPINION | VIDEO | LAUNCH | BUSINESS | MISSIONS | POLICY & POLITICS

From selling data to selling answers, EO market faces transformation

by Tereza Pultarova — September 15, 2017

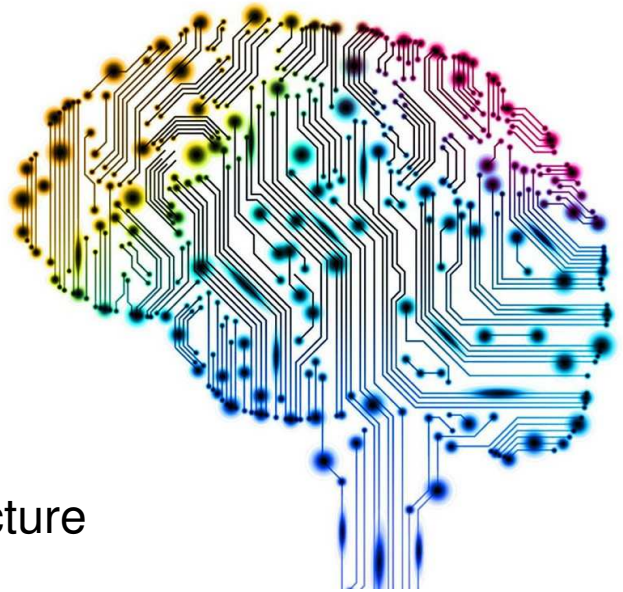
http://spacenews.com/from-selling-data-to-selling-answers-eo-market-faces-transformation/

Hera Systems is developing commercial remote-sensing satellites to gather "images of the Earth, enabling commercial and government organizations to monitor change and make smart decisions about our planet's constantly changing features and emerging situations across the globe, in near-real time," according to the company. Credit: Hera Systems

PARIS — Earth-observation startups are investing in data analytics and machine learning to transform raw satellite data into marketable insights they say have the potential to be every bit as indispensable to investors and business leaders as the up-to-the-second analytics they get from the likes of a $20,000-a-year Bloomberg terminal subscription.

Deep Learning

Modified from https://startuplab.io/

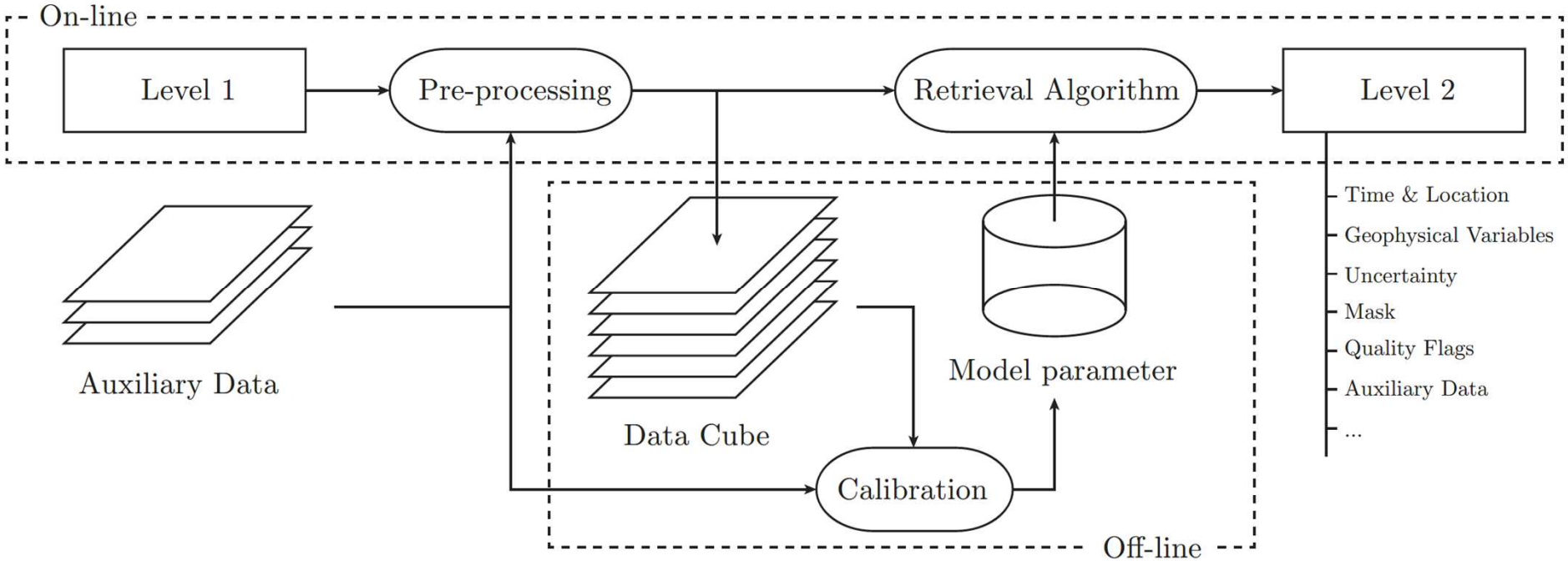


- Like our brain machine learning methods need guidance
- Deep learning thus far
  - is data hungry
  - is shallow and has limited capacity for transfer
  - has no natural way to deal with hierarchical structure
  - has struggled with open-ended inference
  - is not sufficiently transparent
  - has not been well integrated with prior knowledge
  - cannot inherently distinguish causation from correlation
  - presumes a largely stable world, in ways that may be problematic
  - works well as an approximation, but its answers often cannot be fully trusted
  - is difficult to engineer with

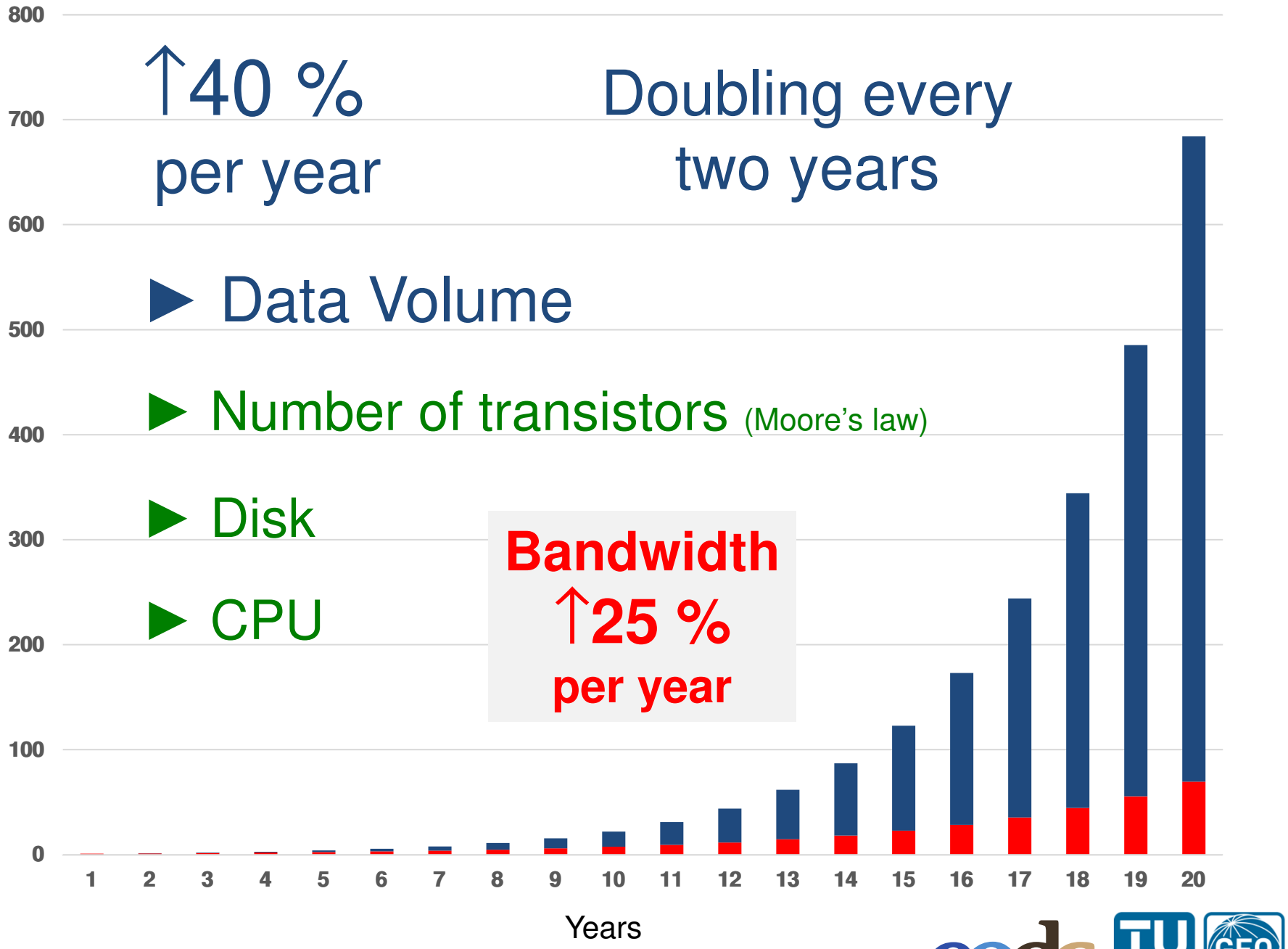
Gary Marcus (2018) Deep Learning: A Critical Appraisal, arXiv:1801.00631

Level 2+: Need to Calibrate EO Algorithms

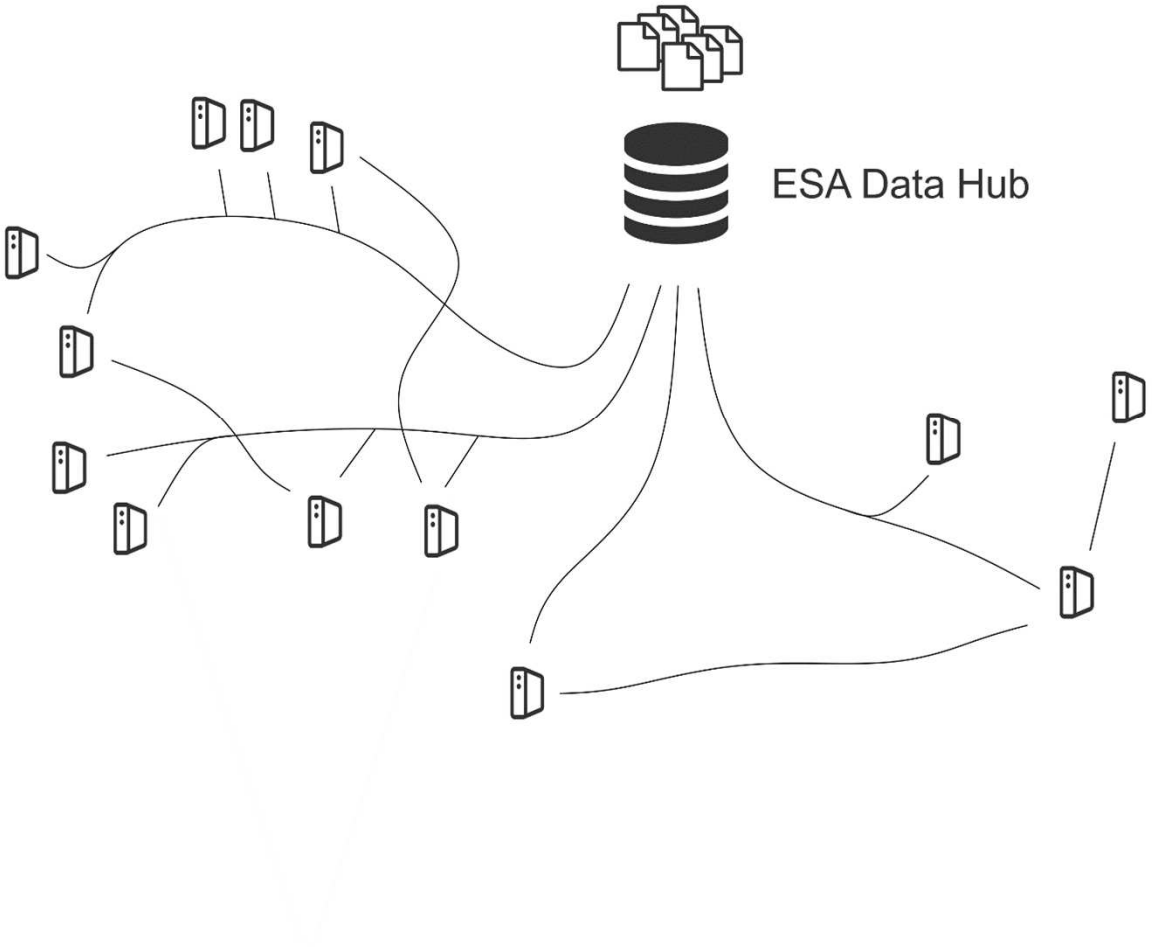
- No EO data model used for retrieving higher-level data from Level 1 data is perfect
  - Physical, semi-empirical, empirical/statistical models
- Calibration is needed
  - Model calibration is a difficult process requiring historic EO data, ancillary data and procedures for model parameter selection



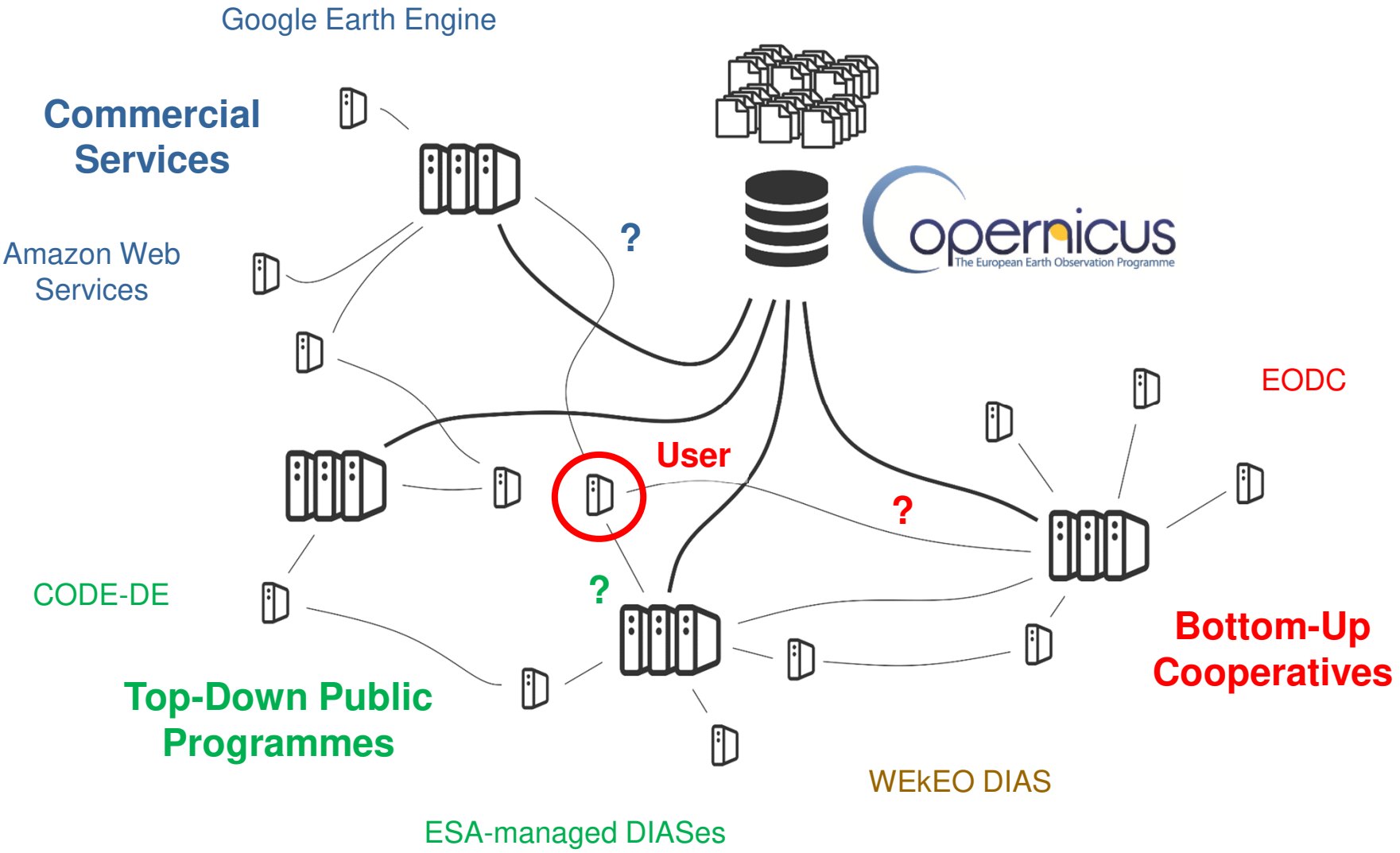
Infrastructure


↑40 %
per year
Doubling every
two years
► Data Volume
► Number of transistors (Moore's law)
► Disk
► CPU
Bandwidth
↑25 %
per year
800
700
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Years

EO Ground Segment – The Past



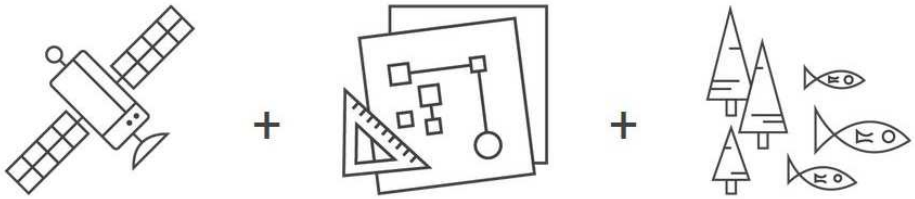
Today's Zoo of Earth Observation Platforms



Google Earth Engine https://earthengine.google.com/

Meet Earth Engine

Google Earth Engine combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities and makes it available for scientists, researchers, and developers to detect changes, map trends, and quantify differences on the Earth's surface.



Gorelick et al. (2017) Google Earth Engine: Planetary-scale geospatial analysis for everyone, Remote Sensing of Environment 202, 18-27

Global Surface Water Explorer

https://global-surface-water.appspot.com/

Pekel et al. (2016) High-resolution mapping of global surface water and its long-term changes. Nature

Data Access and Information Services (DIAS)

- Copernicus is managed by the EC's Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (DG Growth)

CREODIAS

led by Creotech Instruments S.A.

mundi WEB SERVICES

led by Atos

implemented by esa

ONDA

led by Serco Italia S.p.A.

sobloo

led by Airbus

WEkEO by COPERNICUS

implemented by EUMETSAT, ECMWF and Mercator-Ocean

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WEkEO: The Federated “Institutional” DIAS

https://www.wekeo.eu/dec_2018_update: … WEkEO collaboration with EODC (Earth Observation Data Centre for Water Resources Monitoring) based in Austria. EODC benefits from the WEkEO federated offer and is sharing with WEkEO its improved Sentinel-1 and -2 data archive for the benefits of all WEkEO’s users. ...

Earth Observation Data Centre

Collaboration for Earth Observation

Petabyte Storage
Supercomputing
Cloud Platform

- Public-private partnership
- Building a federated multi-owner IT infrastructure for
  - Scientists
  - Public services
  - Innovators
- Users are partners who participate in decision making
- Development of collaborative services
  - From data to model predictions

https://www.eodc.eu/

Which Cloud Service to Rely Upon?

- Performance?
  - Response times/bandwidth
  - Availability, quality & documentation of data
  - Data access and processing speed
  - Software & utilities
- Legal certainty?
  - Protection of property: Data, software, know-how
  - Place of jurisdiction
  - Faire exit conditions
- Participation in decision making?
  - Influence choices on data, hardware, software, etc.

Sovereignty?

- Costs?
  - In-house solutions for private storage and -compute always cheaper when needs and growth well known
  - Hidden costs

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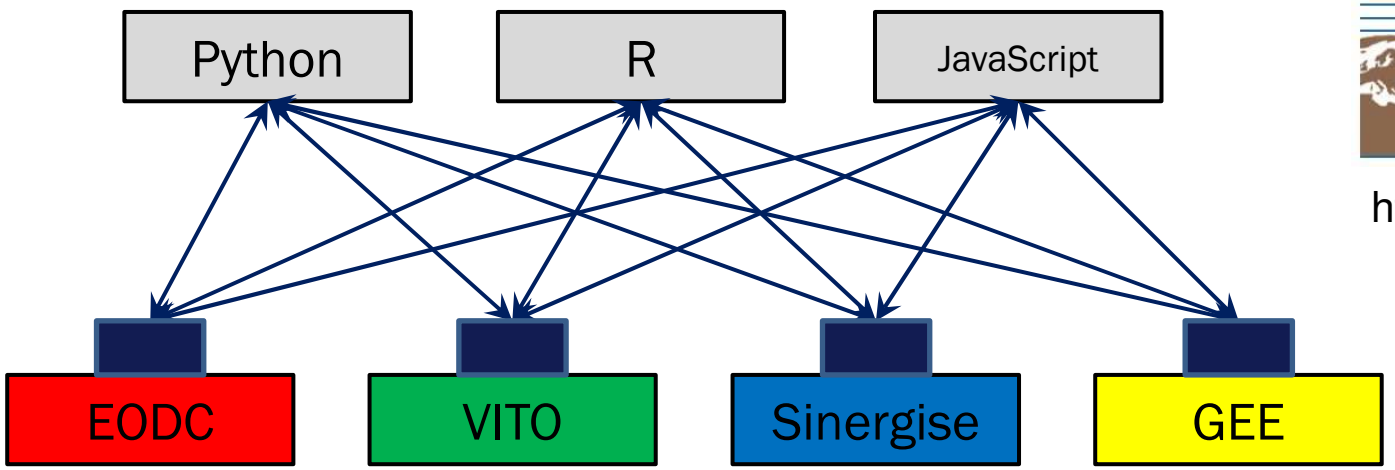
Tools for Making Platforms Interoperable

- openEO develops an open API to connect R, python, javascript and other clients to big Earth observation cloud back-ends



http://openeo.org/

H2020

GitHub https://github.com/open-eo/

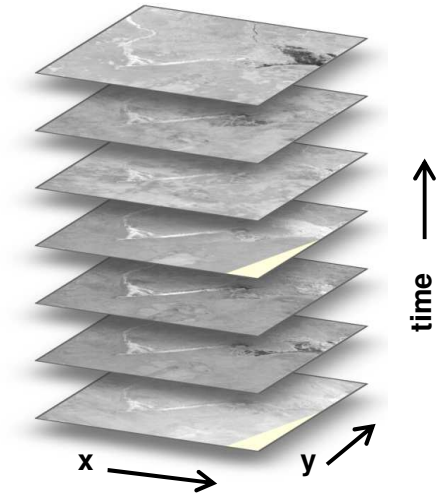
Sentinel-1 Services

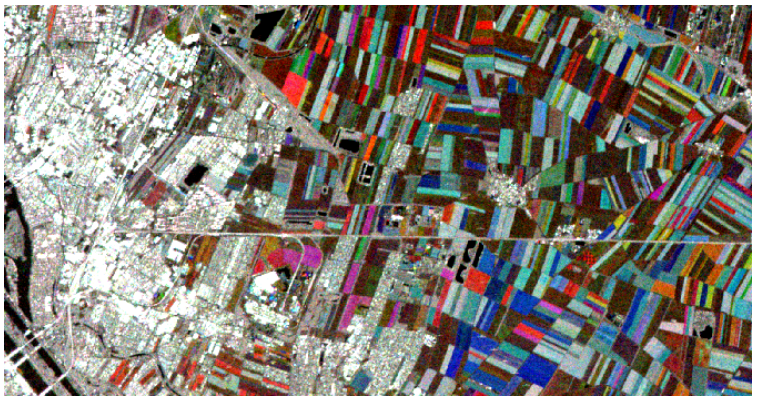
Earth Observation Data Centre

Sentinel Data Cubes

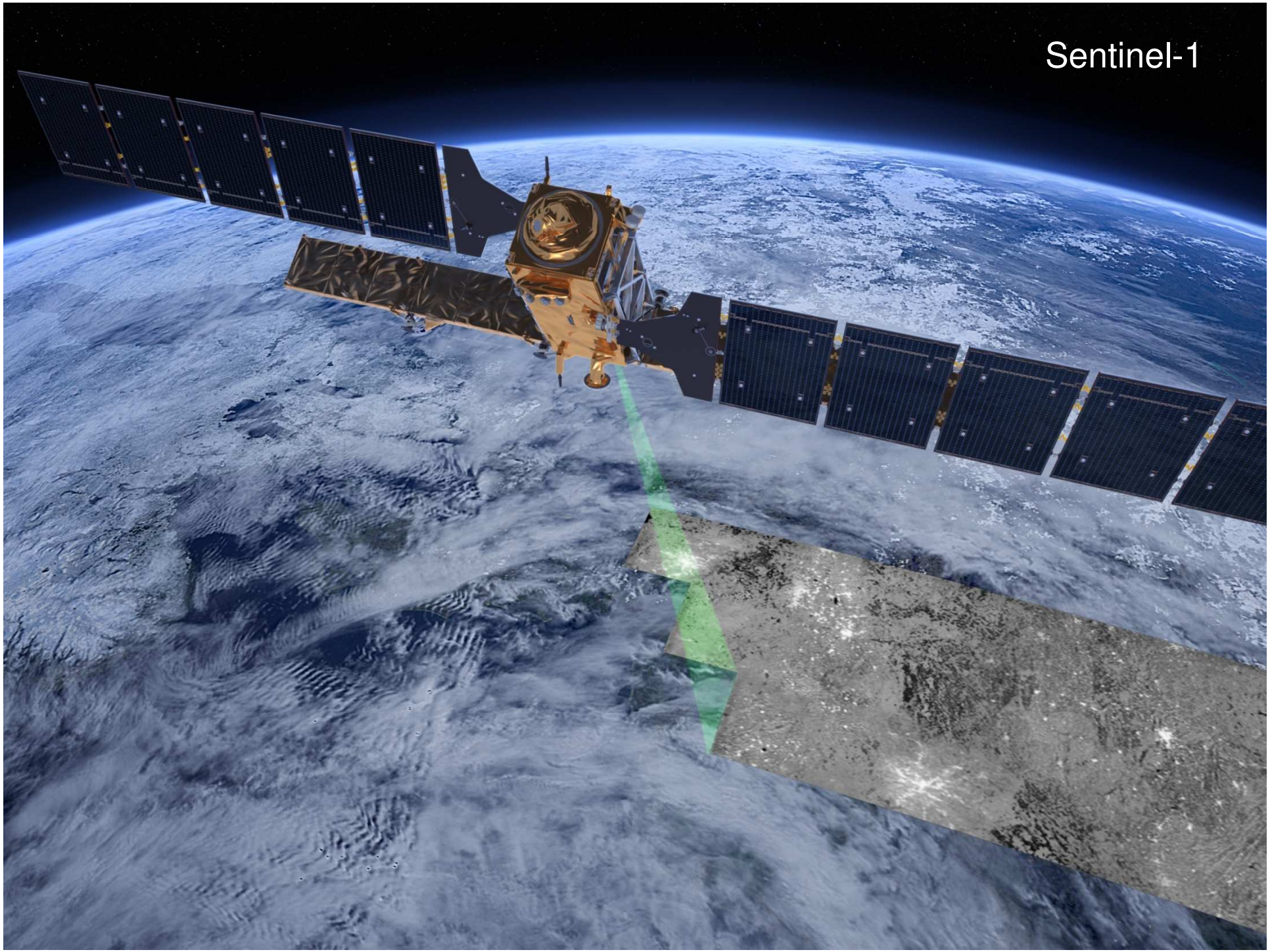
- Up-to-date worldwide Sentinel data
- Ready-to-use data cubes

- Sentinel-1
  - Image mosaics
  - Water bodies
  - Soil moisture
  - Wetlands
  - Land cover



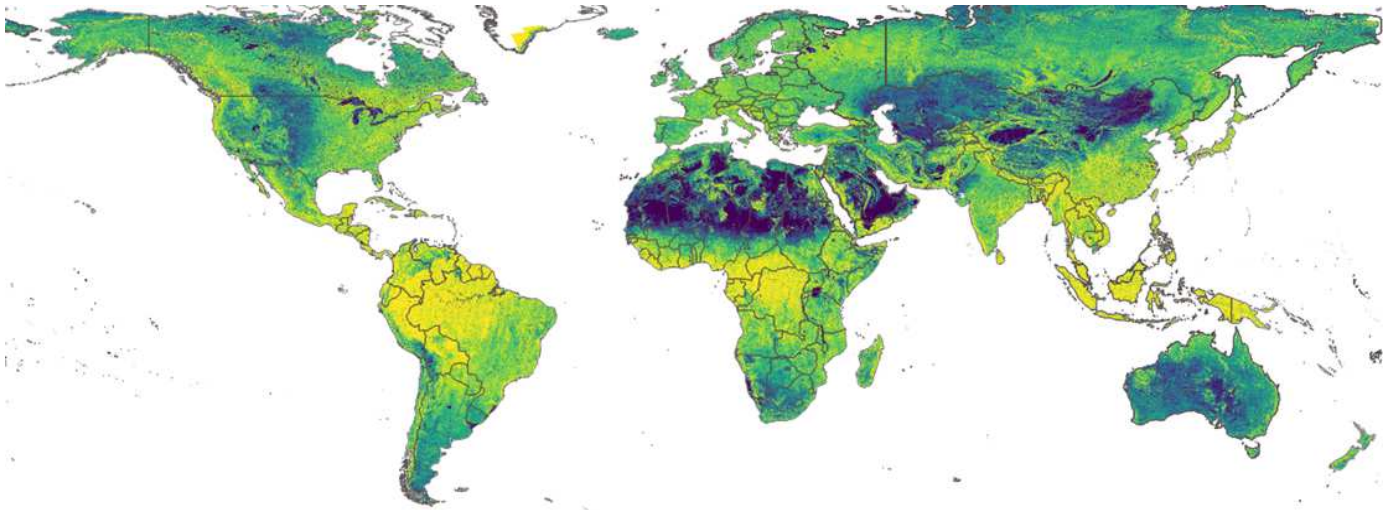


Agricultural area near Vienna as depicted by Sentinel-1

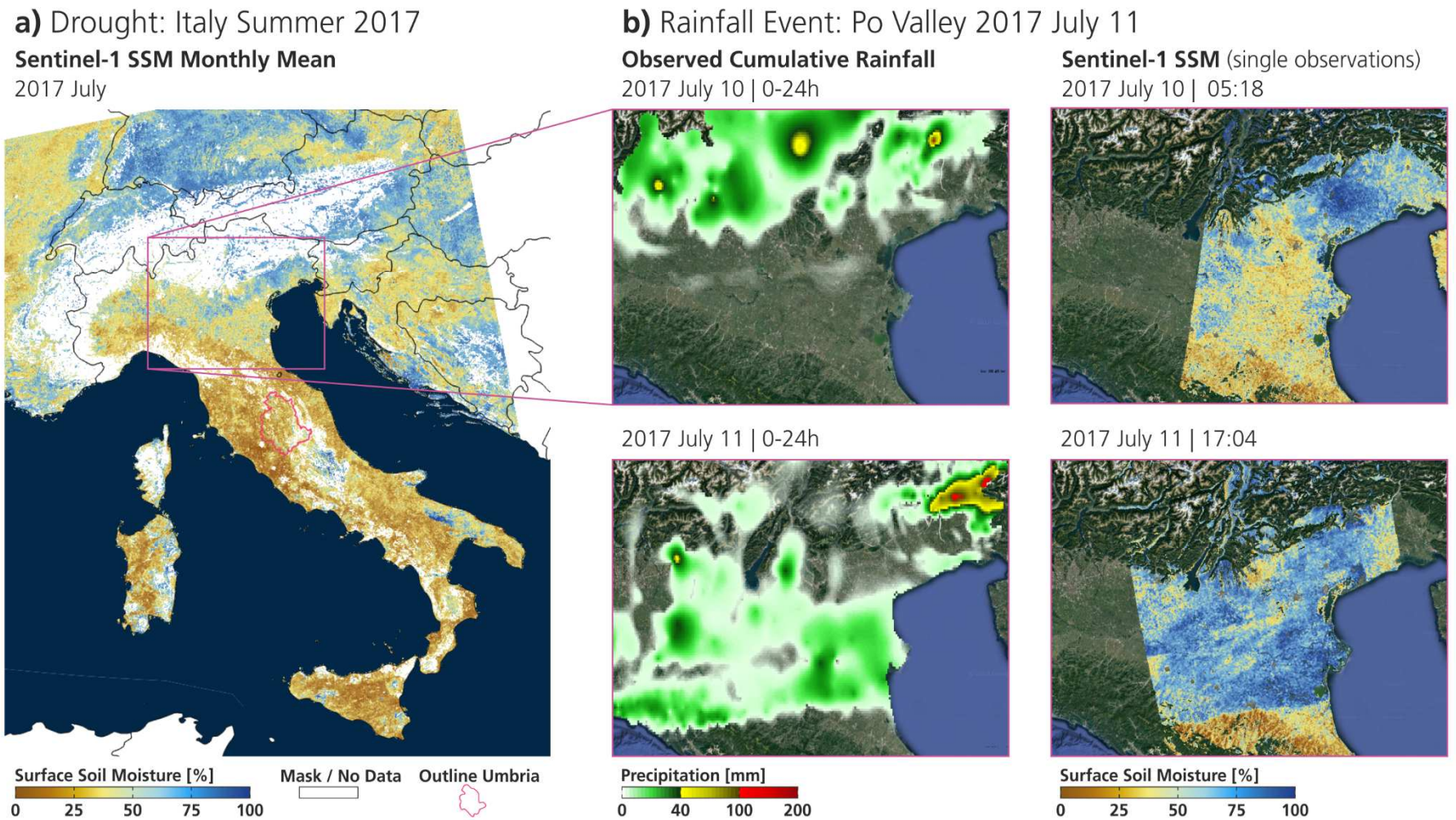

Sentinel-1

Sentinel-1 Global Backscatter Model

- Global land C-band backscatter maps based upon Sentinel-1A/B dual polarization backscatter measurements from the years 2016 and 2017
- Processing effort
  - ~3 million core hours have been consumed on VSC-3 and VSC-3+
  - 400TB of input data
  - 700TB of pre-processed data
  - ~75TB of final Global Backscatter Model database



1 km Soil Moisture Derived from Sentinel-1



Bauer-Marschallinger et al. (2019) Towards global soil moisture monitoring with Sentinel-1: Harnessing assets and overcoming obstacles, IEEE Transactions on Geoscience and Remote Sensing, 57(1), 520-539.

Final Thoughts

- European technical and scientific capacities are very strong
- Development of markets take time - not all EO products are marketable
- Good cooperation between public and private sectors is key to establish sustainable markets in „low-cash“ applications
- Watch out with whom you team up

Acknowledgements
ESA: „Sentinel-1 Global Backscatter Model“ & „Climate Change Initiative Soil Moisture“
European Commission: openEO (H2020) & DriDanube (Interreg)
Austrian Space Application Programme: BMon & ACube
BMWFW: GEOCLIM Data Infrastructure Austria
Vienna Business Agency: ID-Nr. 1430171 “Sentinel Big Data Science Cluster”