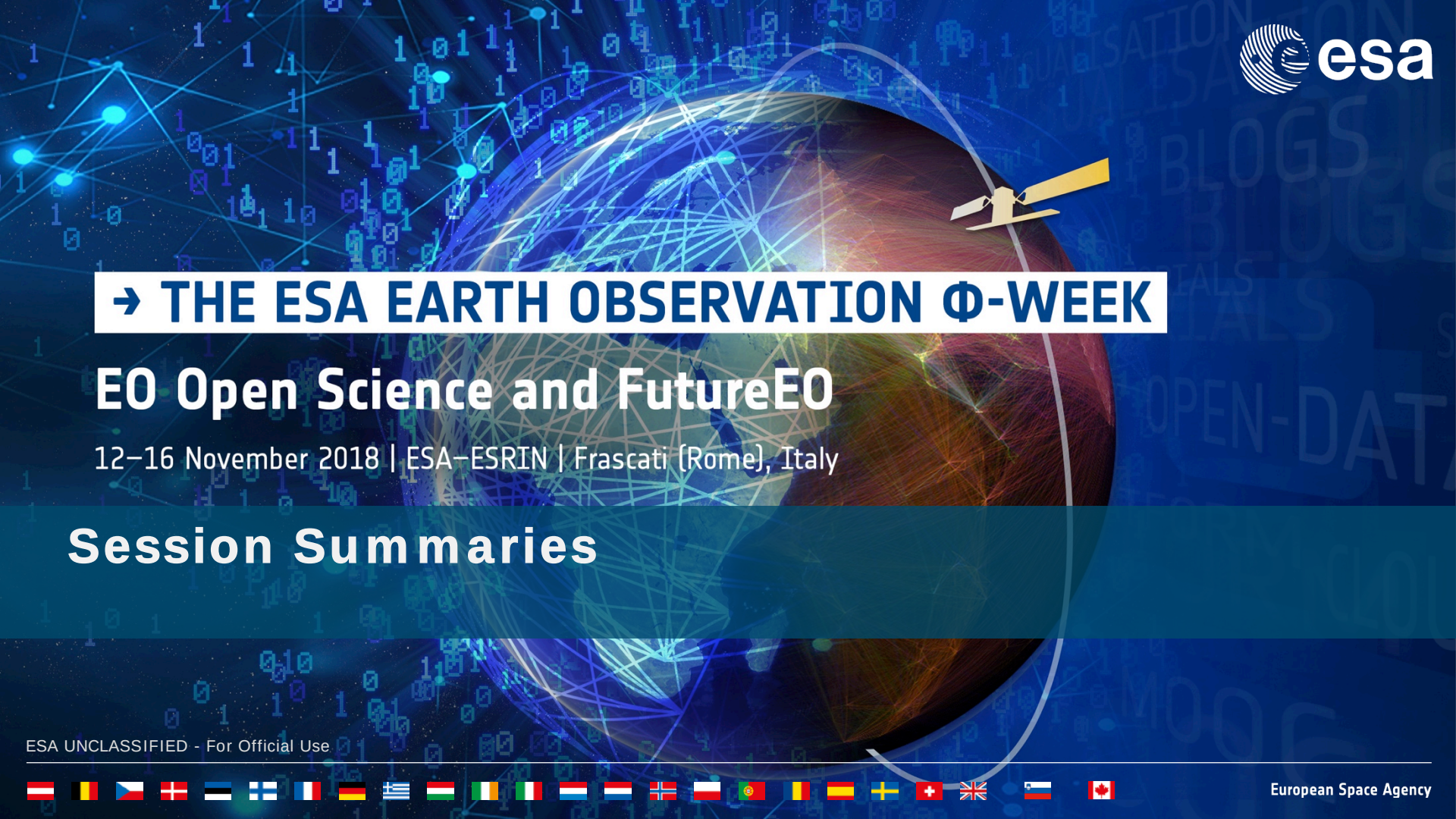
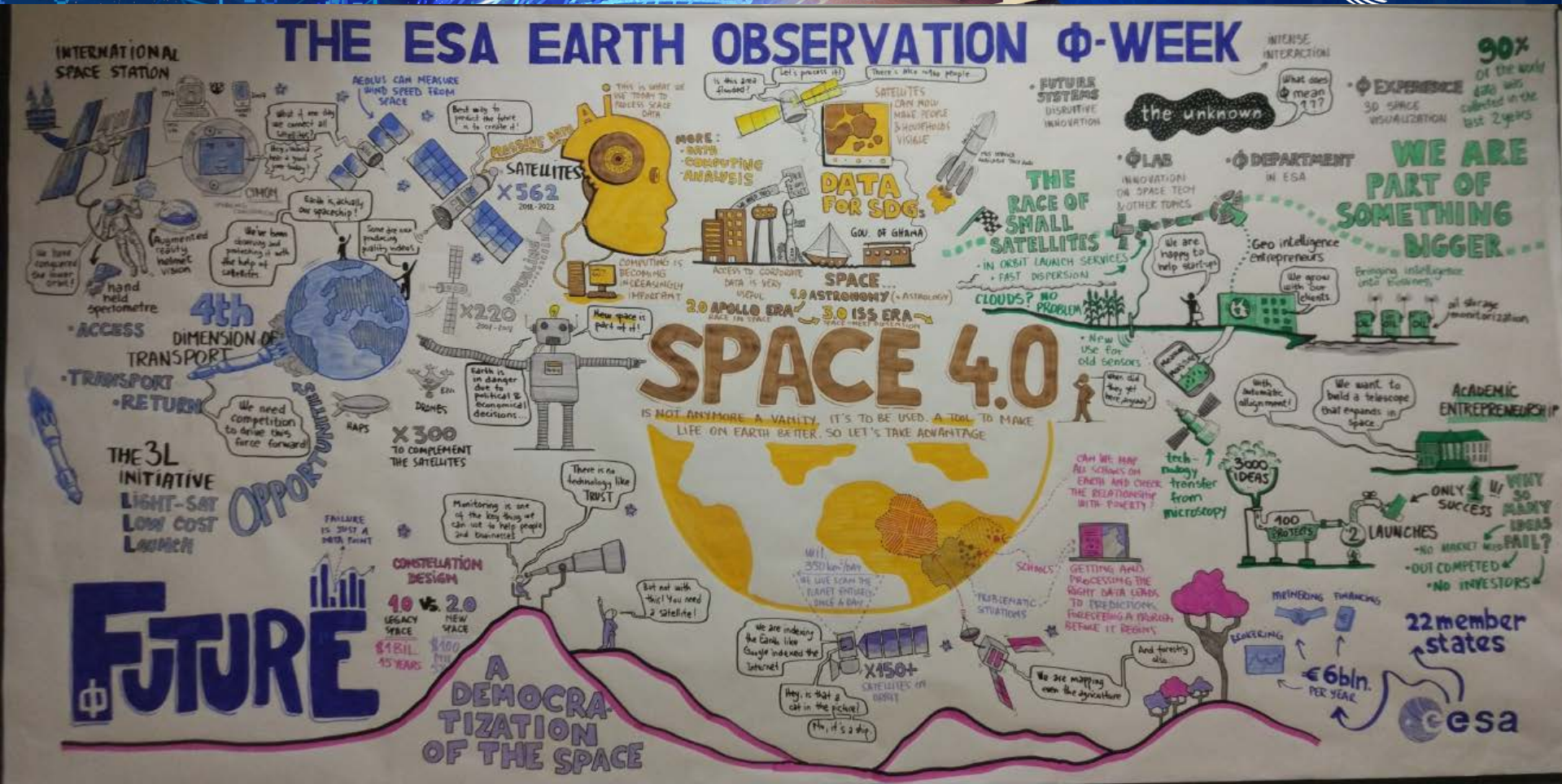


→ THE ESA EARTH OBSERVATION Φ-WEEK

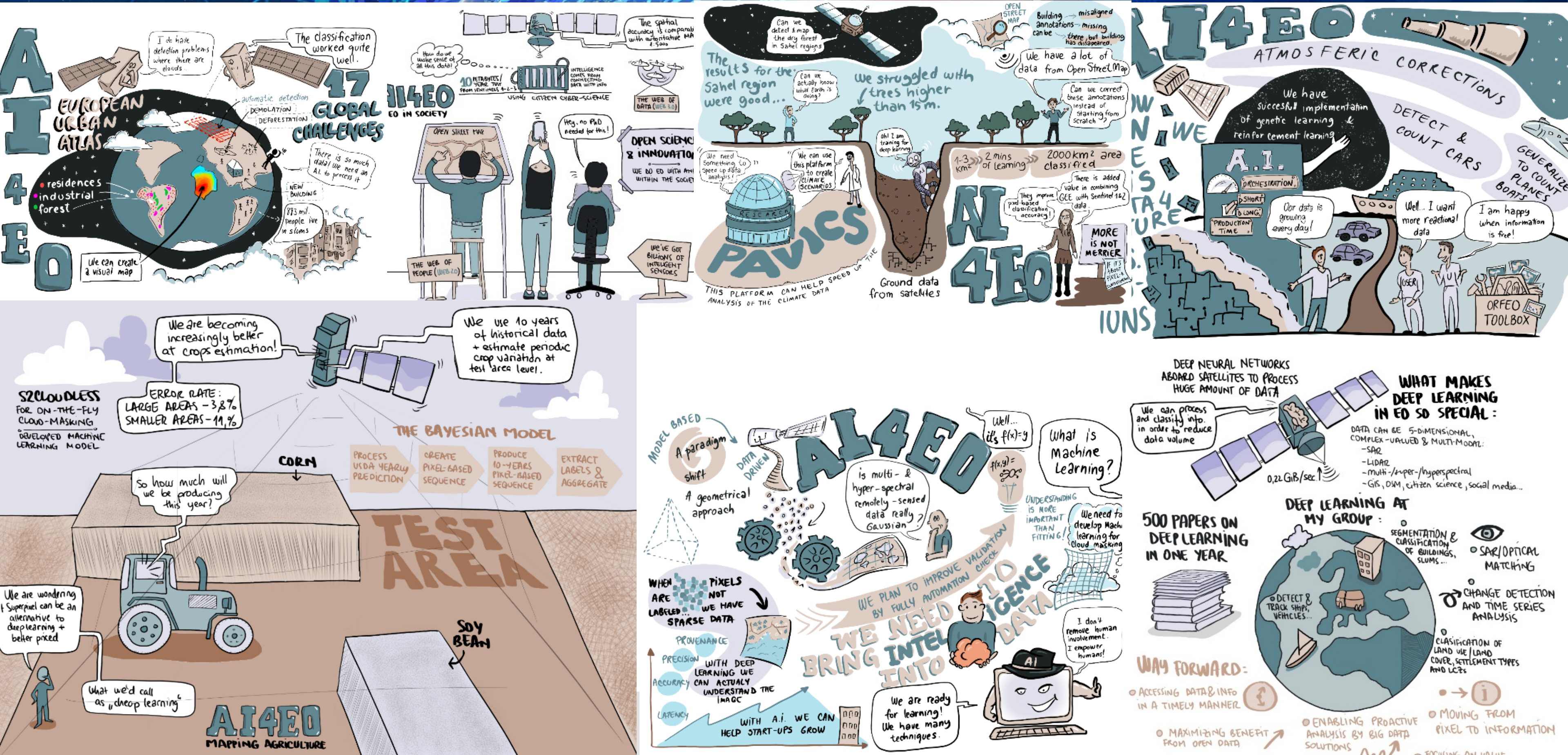
EO Open Science and FutureEO

12–16 November 2018 | ESA–ESRIN | Frascati (Rome), Italy

Session Summaries


THE ESA EARTH OBSERVATION Φ-WEEK
INTERNATIONAL SPACE STATION
AEOLUS CAN MEASURE WIND SPEED FROM SPACE
SATELLITES
X562
2018-2022
MISSING DATA
PREDICTING
X220
2018-Today
4th DIMENSION OF TRANSPORT
ACCESS
TRANSPORT
RETURN
We need competition to drive this force forward!
DRONES
RAPS
X300
TO COMPLEMENT THE SATELLITES
OPPORTUNITY
THE 3L INITIATIVE
LIGHT-SAT
LOW COST
LAUNCH
FAILURE IS JUST A DATA POINT
CONSTELLATION DESIGN
40 vs. 2.0
LEGACY SPACE
NEW SPACE
$1BIL
15 YEARS
$100 MIL
FUTURE
A DEMOCRATIZATION OF THE SPACE
Earth is in danger due to political & economical decisions...
New space is part of it!
There is no technology like TRUST
Monitoring is one of the key things we can use to help people and businesses
But not with this! You need a Satellite!
MORE: DATA COMPUTING ANALYSIS
DATA FOR SDGs
GOV. OF GHANA
SPACE...
2.0 APOLLO ERA
3.0 ISS ERA
4.0 ASTRONOMY
SPACE 4.0
IS NOT ANYMORE A VANITY. IT'S TO BE USED. A TOOL TO MAKE LIFE ON EARTH BETTER. SO LET'S TAKE ADVANTAGE
THE RACE OF SMALL SATELLITES
IN ORBIT LAUNCH SERVICES
FAST DISPERSION
CLOUDS? NO PROBLEM
We are happy to help start-ups
Geo intelligence entrepreneurs
We grow with our clients
WE ARE PART OF SOMETHING BIGGER
Bringing intelligence into business
FUTURE SYSTEMS DISRUPTIVE INNOVATION
the unknown
INTENSE INTERACTION
What does Φ mean ???
EXPERIENCE
3D SPACE VISUALIZATION
90% of the world data was collected in the last 2 years
LAB
INNOVATION ON SPACE TECH & OTHER TOPICS
DEPARTMENT IN ESA
ACADEMIC ENTREPRENEURSHIP
We want to build a telescope that expands in space
With automatic alignment!
tech-industry transfer from microscopy
New use for old sensors
3000 IDEAS
100 PROJECTS
2 LAUNCHES
ONLY 1 SUCCESS
WHY SO MANY IDEAS FAIL?
NO MARKET NEED
OUT COMPETED
NO INVESTORS
22 member states
€6bln. PER YEAR
ENGINEERING
FINANCING
BROKERING
X150+
SATELLITES IN ORBIT
We are indexing the Earth, like Google indexed the Internet
Hey, is that a cat in the picture?
Nah, it's a dog
We are mapping even the agriculture
And forestry also
SCHOOLS
PERIGEMATIC SITUATIONS
GETTING AND PROCESSING THE RIGHT DATA LEADS TO PREDICTIONS, FORECASTING A DISASTER BEFORE IT BEGINS
Will 350 km/day WE LIVE SCAN THE PLANET ENTIRELY ONCE A DAY
CAN WE MAP ALL SCHOOLS ON EARTH AND CHECK THE RELATIONSHIP WITH POVERTY
esa

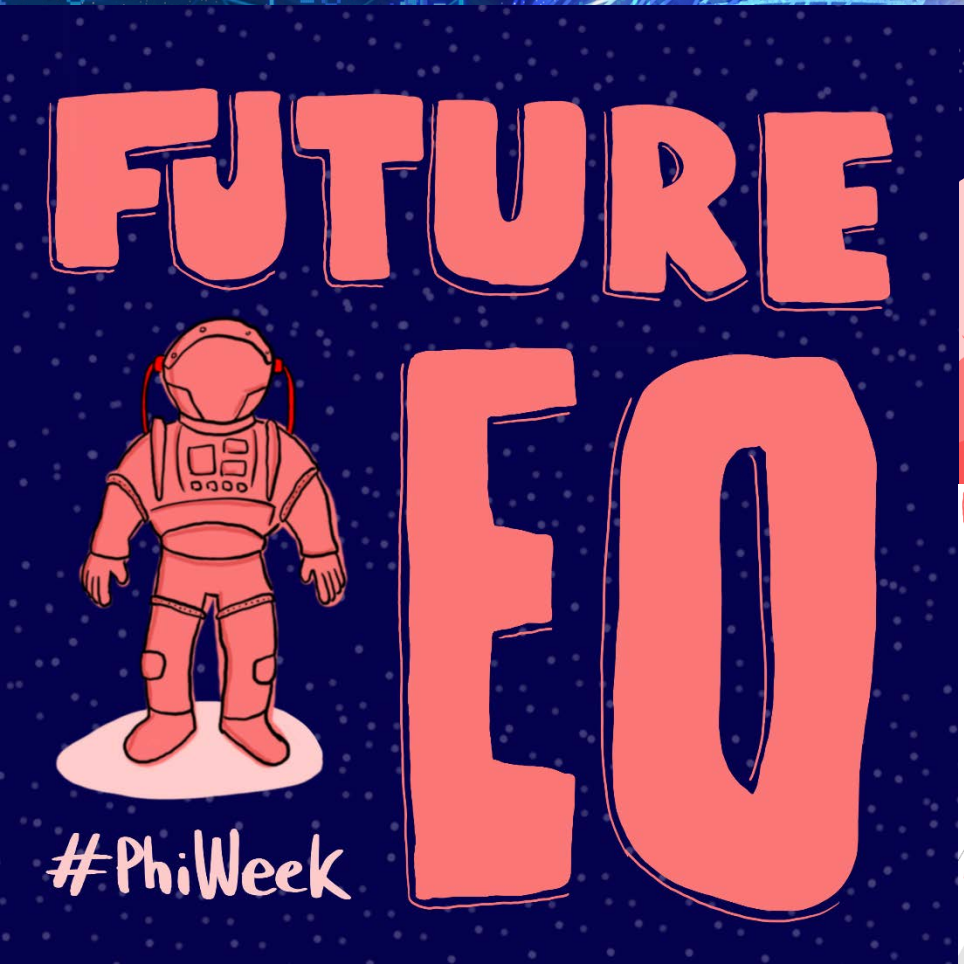
#AI4EO Day 2

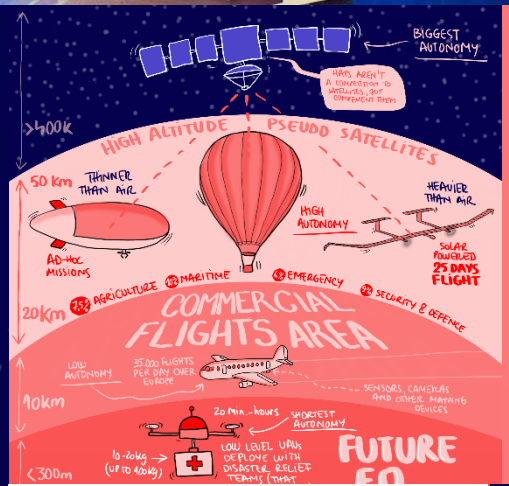


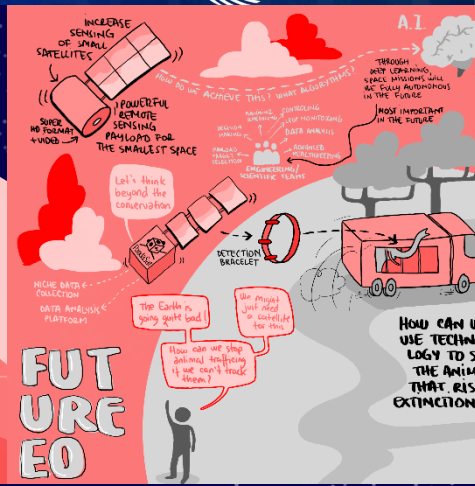
AI4EO
EUROPEAN URBAN ATLAS
residences
industrial
forest
I do have detection problems where there are clouds
The classification worked quite well.
17 GLOBAL CHALLENGES
automatic detection
DEMOLATION
DEFORESTATION
There is so much data! We need an A.I. to process it
NEW BUILDING
883 mil. people live in slums
We can create a visual map
How do we make sense of all this data!
10 PETABYTES/YEAR
USING CITIZEN CYBER-SCIENCE
THE WEB OF DATA (WEB 3.0)
The spatial accuracy is comparable with authoritative MA
AI4EO IN SOCIETY
OPEN STREET MAP
Hey, no PhD needed for this!
OPEN SCIENCE & INNOVATION
WE DO EO WITH AND WITHIN THE SOCIETY
THE WEB OF PEOPLE (WEB 2.0)
WE'VE GOT BILLIONS OF INTELLIGENT SENSORS
Can we detect & map the dry forest in Sahel regions
The results for the Sahel region were good...
We struggled with trees higher than 15m.
We need something to speed up data analysis!
We can use this platform to create CLIMATE SCENARIOS
PAVICS
THIS PLATFORM CAN HELP SPEED UP THE ANALYSIS OF THE CLIMATE DATA
Ground data from satellites
2 mins of learning
2000km² area classified
There is added value in combining GEE with Sentinel 1&2 data
MORE IS NOT MERRIER
OPEN STREET MAP
Building annotations can be misaligned, missing
We have a lot of data from Open Street Map
Can we correct these annotations instead of starting from scratch?
AI4EO
ATMOSFERIC CORRECTIONS
We have successful implementation of genetic learning & reinforcement learning
DETECT & COUNT CARS
GENERALIZE TO COUNT PLANES BOATS
A.I.
ORCHESTRATION
PRODUCTION TIME
Our data is growing every day!
Well... I want more real-time data
I am happy when information is free!
ORFEO TOOLBOX
We are becoming increasingly better at crops estimation!
We use 10 years of historical data + estimate periodic crop variation at test area level.
S2CLOUDLESS
FOR ON-THE-FLY CLOUD-MASKING
DEVELOPED MACHINE LEARNING MODEL
ERROR RATE:
LARGE AREAS - 3,8%
SMALLER AREAS - 11,%
THE BAYESIAN MODEL
PROCESS USDA YEARLY PREDICTION
CREATE PIXEL-BASED SEQUENCE
PRODUCE 10-YEARS PIXEL-BASED SEQUENCE
EXTRACT LABELS & AGGREGATE
CORN
So how much will we be producing this year?
TEST AREA
SOY BEAN
We are wondering if Superpixel can be an alternative to deep learning + better pixel
What we'd call as "cheap learning"
AI4EO
MAPPING AGRICULTURE
MODEL BASED
A paradigm shift
DATA DRIVEN
A geometrical approach
AI4EO
Well... it's f(x)=y
What is Machine Learning?
is multi- & hyper-spectral remotely-sensed data really Gaussian?
UNDERSTANDING IS MORE IMPORTANT THAN FITTING!
We need to develop Machine learning for cloud masking
WHEN PIXELS ARE NOT LABELED... WE HAVE SPARSE DATA
PROVENANCE
PRECISION
ACCURACY
LATENCY
WITH DEEP LEARNING WE CAN ACTUALLY UNDERSTAND THE IMAGE
WE PLAN TO IMPROVE VALIDATION BY FULLY AUTOMATION CHECK
WE NEED TO BRING INTELLIGENCE INTO DATA
WITH A.I. WE CAN HELP START-UPS GROW
We are ready for learning! We have many techniques.
I don't remove human involvement. I empower humans!
AI
DEEP NEURAL NETWORKS ABOARD SATELLITES TO PROCESS HUGE AMOUNT OF DATA
We can process and classify info. in order to reduce data volume
0,22 GiB/sec
WHAT MAKES DEEP LEARNING IN EO SO SPECIAL:
DATA CAN BE 5-DIMENSIONAL, COMPLEX-VALUED & MULTI-MODAL:
-SAR
-LIDAR
-multi-/super-/hyperspectral
-GIS, OSM, citizen science, social media...
500 PAPERS ON DEEP LEARNING IN ONE YEAR
DEEP LEARNING AT MY GROUP:
SEGMENTATION & CLASSIFICATION OF BUILDINGS, SLUMS...
SAR/OPTICAL MATCHING
DETECT & TRACK SHIPS, VEHICLES...
CHANGE DETECTION AND TIME SERIES ANALYSIS
CLASSIFICATION OF LAND USE/LAND COVER, SETTLEMENT TYPES AND LCZs
WAY FORWARD:
ACCESSING DATA & INFO IN A TIMELY MANNER
MAXIMIZING BENEFIT FROM OPEN DATA
ENABLING PROACTIVE ANALYSIS BY BIG DATA SOLUTIONS
MOVING FROM PIXEL TO INFORMATION

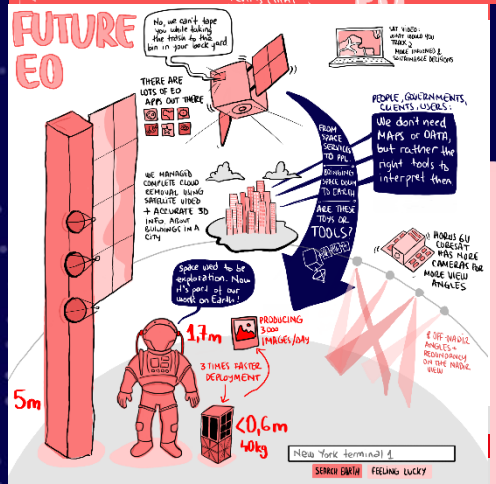
#FutureEO Day

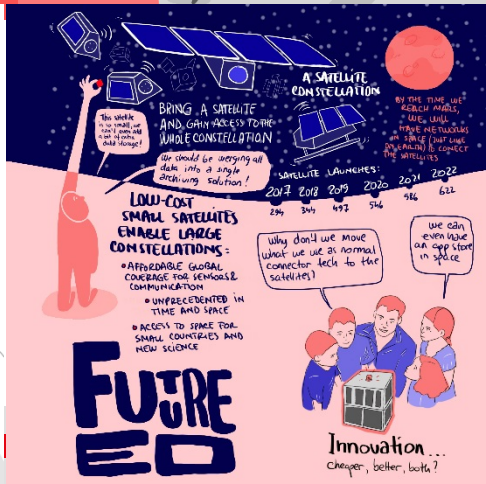
esa





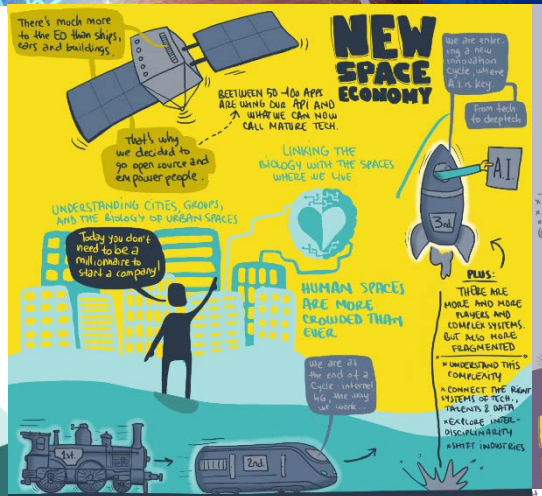


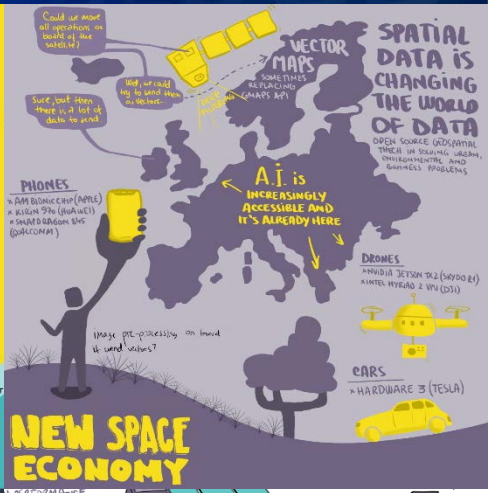


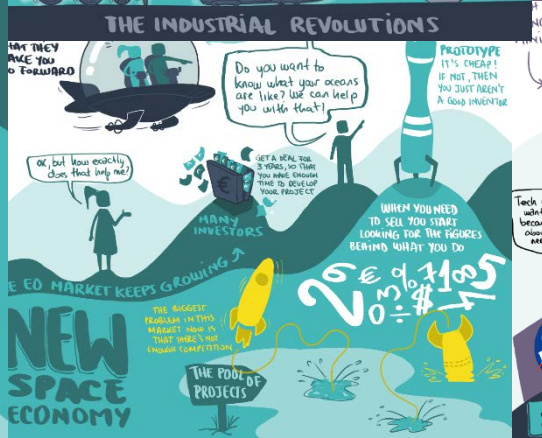


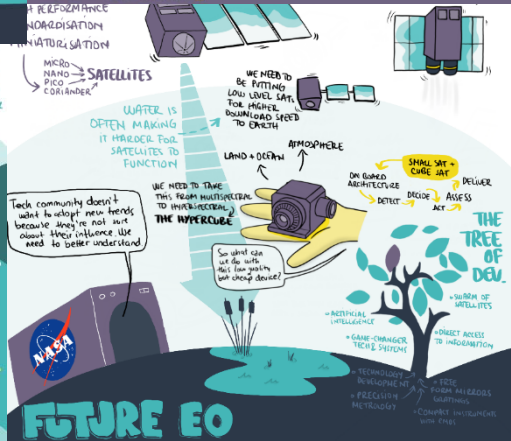
#FutureEO Day

esa



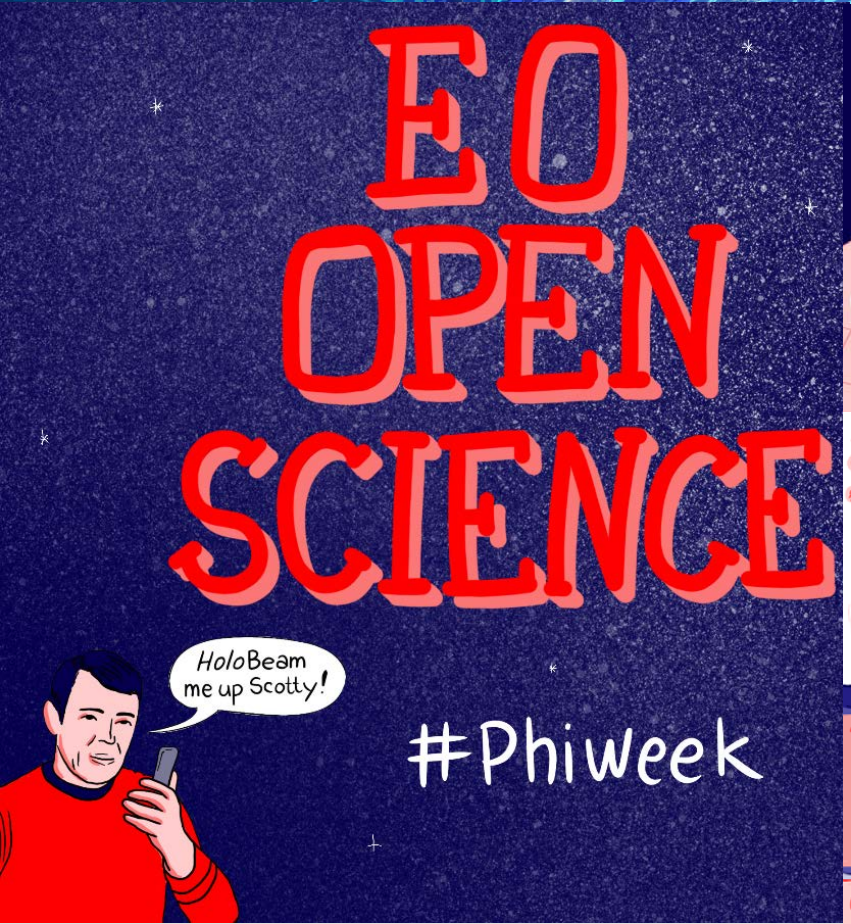


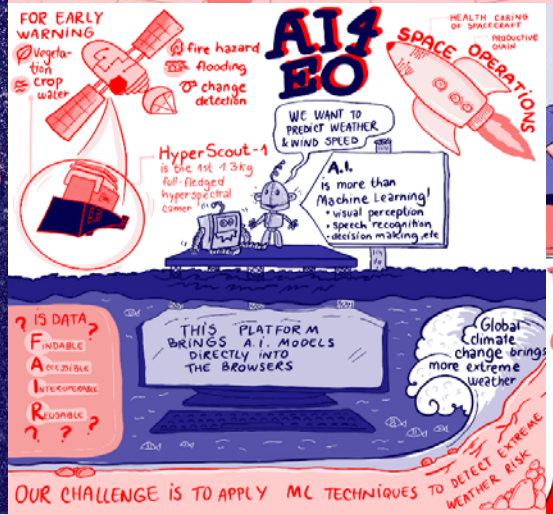




#OpenScience Day

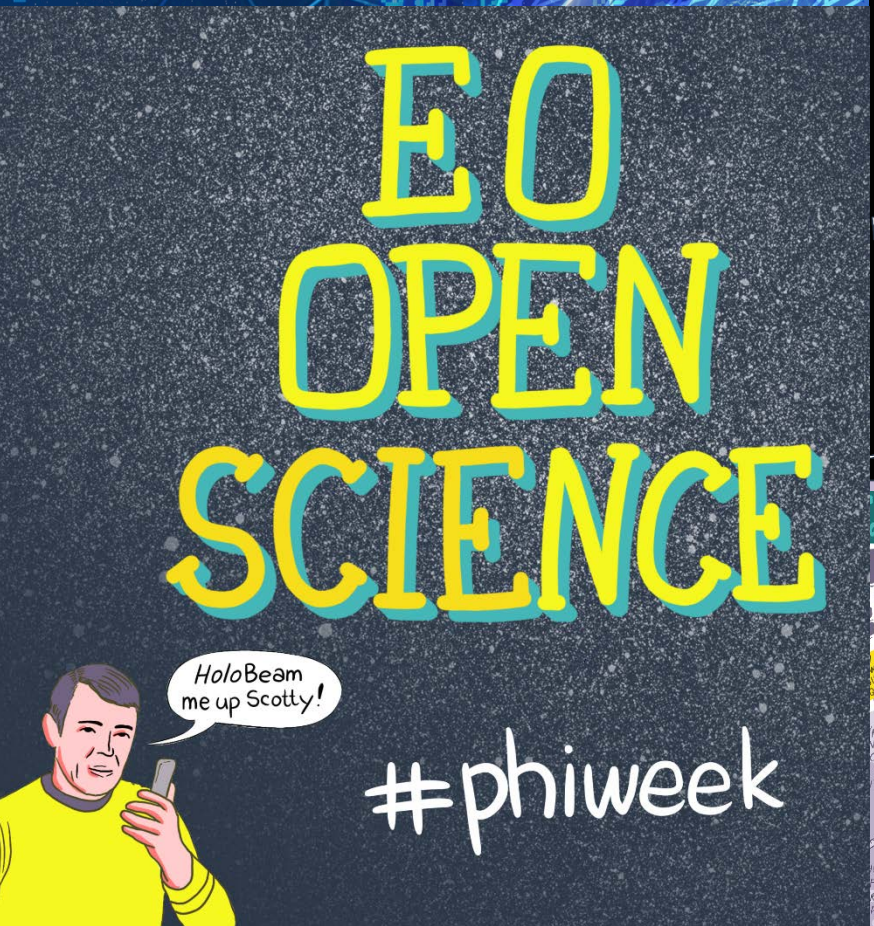
esa

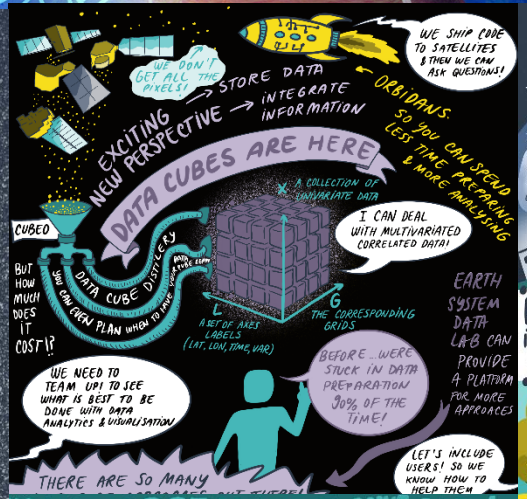




#OpenScience Day

esa





Sessions Overview

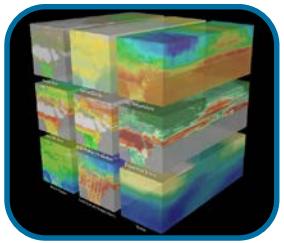
New Education

Toolboxes & Virtual Labs

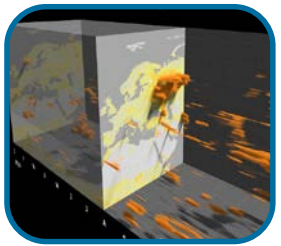
Research Infrastructures

AI4EO

Citizen Science



Data Cube



Science Visualisation

New Education

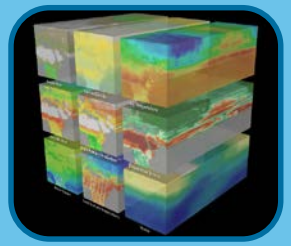
New Education

Toolboxes & Virtual Labs

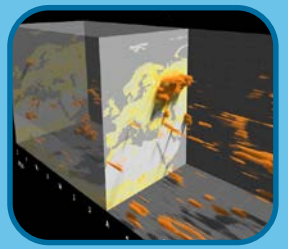
Research Infrastructures

AI4EO

Citizen Science



Data Cubes



Science Visualisation

New Education

- **Novel education methods (e.g. gamification)**, together with novel IT capabilities **(collaborative and adaptive systems) are still underexploited in EO**. A dedicated effort to incorporate these new techniques into ESA portfolio of training activities is recommended.

- There is an urgent need for **closer cooperation and information exchange in the field of EO education**. The recommendation is for a better coordination between ESA and other European initiatives such as Copernicus Academy, Copernicus relays, EO4GEO, and others.

- **Permanent availability of ESA MOOCs** (and provision of learning kits), was identified as an enabler for the **establishment of educational curricula,** and incorporation of **flipped classroom concepts also in professional ESA training** (e.g. prerequisite of MOOC completion for admission to ESA Summer School)

Toolboxes and Virtual Labs

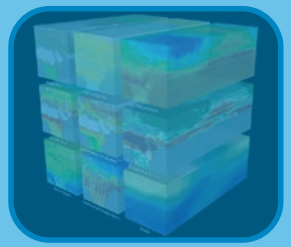
New Education

Toolboxes & Virtual Labs

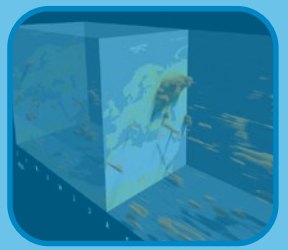
Research Infrastructures

AI4EO

Citizen Science



Data Cube



Science Visualisation

Toolboxes and Virtual Labs

- Need to **engage the community more** in the development of tools with Open Source. There is a **gap between the volume of tools and available developers**, which can only support one or few tools on a systematic basis.

- It is suggested to **increase the commitment of the community of developers through reward mechanisms**, such as public acknowledgments of contribution, financial incentives, or value-in-kind such as certificates, computing power, server access, or other resources.

- There is also a need to **promote more interaction between different communities in order to boost development**, e.g. between the QGIS developer community and the scientific community under Anaconda.

- **Documentation is key for uptake,** but is still lacking, insufficient and/or outdated. The process of maintaining comprehensive and updated documentation is too cumbersome for SW developers. There is a need to facilitate and encourage documentation.

Toolboxes and Virtual Labs

- **The offer of tools is overwhelming for the average user**, more so due to a large number of tools coming from other domains to Earth Observation. It is difficult to identify the most suitable tool for a particular use.

- There is a need for **a tool inventory and showcase mechanism** providing an overview of the different tools and their applicability and use, preferably **streamlined per community of users**. A one-stop-solution such as a dedicated website could be an option. However, it would require considerable effort and resources to make and keep updated an overview of all tools. **AI could play a role, assisting in identifying and suggesting the most suitable tool for the job.**

- It is required to **bring the tools to the data** to increase uptake**, in particular on DIAS and TEPs.** This is **already the case for SNAP**, where having tools available with the data has generated significant demand and use.

Toolboxes and Virtual Labs

- There is **progress still to be made with interoperability and standardization** in terms of data formats, with many **tools locking users into proprietary formats**.
- More standardization is recommended also for the ESA Sentinel data formats.
- **Making validation information, and even the ground-truth data used for validation, available** in a standardized way in order to facilitate the evaluation and comparison of the tools, would make it easier to assess the fit for use and thereby increase the uptake.
- There is a growing demand from the user community for **Standardized Analysis Ready Data,** possibly at higher levels (i.e. Level 2 and above). ESA should remain at Level 2 for the systematic production of ARD data in order to be useful for wide communities and also in order to ensure continuity. Higher level products should be produced via dedicated tools.

Research Infrastructures & Platforms

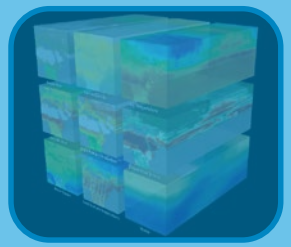
New Education

Toolboxes & Virtual Labs

Research Infrastructures

AI4EO

Citizen Science



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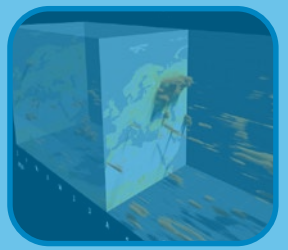


Science Visualisation

Research Infrastructures & Platforms

- **Long-term sustainability of collaborative networks, infrastructures and platforms** is a key issue, and it is essential to find further strategies to attract sponsors.
- **Standardisation & interoperability** create the premises for sustainability and are key to increase the collaboration between existing platforms, ensuring cooperation towards an **integrated offering rather than duplications**.
- The links between **the European Research Infrastructure environments** (in particular EOSC, ENVRI, GEO/GEOSS) **and the EO community** should be strengthened by identifying a common language and by making use of common standards.
- **Collaboration with existing research projects** (e.g. H2020, Interreg, National, etc.) helps platforms to raise visibility and achieve application readiness maturity.

Research Infrastructures & Platforms

- **Open Data** should be the baseline for **collaborative networks, infrastructures and platforms.**

- **Free and open access** to high temporal and high spatial resolution such as Copernicus data is becoming a major **game-changer in the EO sector**, **but it creates huge challenges** to handle enormous data volumes. On-line platforms are key to enable **data access, processing and analytics to all**.

- There is a **critical need for Analysis Ready Data (ARD)**. The availability of ARD data can remove the pre-processing burden, one of the most time-consuming tasks in EO data analytics.

- Provision of **in-situ data should receive more support**, in particular for enabling data availability on multiple platforms.

Research Infrastructures & Platforms

- Platform business models are reshaping the EO Space sector, with a proliferation of offerings both for R&D/science users and businesses, but the offering is still not consolidated. **ESA should work to develop strategies with EU** and Member States to facilitate a consolidation of the European offerings.

- **European and National public support** to interdisciplinary research infrastructures, and networking is essential, and financial support for **early development of collaborative platforms** is required **for achieving critical mass**.

- Further efforts are required to **close the communication gap between the EO Space and the geospatial community**.

- A solid maintenance policy is required to support the **growing development of Open Source tools and platforms** and to ensure full benefit is gained from the large community of software developers.

Artificial Intelligence in EO

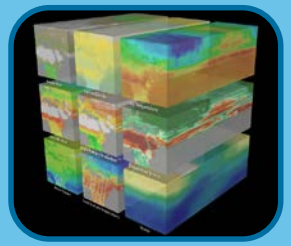
New Education

Toolboxes & Virtual Labs

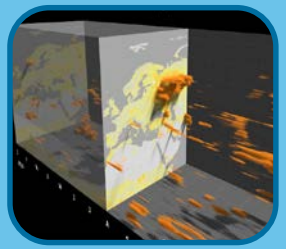
Research Infrastructures

AI4EO

Citizen Science



Data Cube



Science Visualisation

Artificial Intelligence in EO

- **Combining AI techniques with EO and new IT capabilities** has a great potential. However, while there is significant uptake of AI for applications and services (e.g. massive research reported on classification and detection), the **potential for science is still to be fully explored** (e.g. **retrieval of geophysical variables, process understanding,..**).

- Hybrid methods combining models and AI open an interesting perspective for exploiting **AI to substitute poorly resolved processes** in models or simple parameterizations.

- The capabilities of **AI to identify anomalies in large stocks of multivariate data** and characterise their temporal behaviour needs to be explored as a new way to identify and **characterize complex interactions in the Earth system**.

- **AI capability to characterise spatial patterns through direct image analysis**, without the need to extract features, opens a new panorama to better identify dynamic processes in the Earth system.

Artificial Intelligence in EO

- One of the main drawbacks remains the time required for data preparation. Means to enable **systematic provision of Analysis Ready Data** should be further developed and made available to the scientific community.

- There is an exponential growth of research papers on **Deep Learning,** but the **lack of annotated training data continues to be a major challenge** for AI applications.

- Large annotated databases (e.g. **BigEarthNet archive**) are key enablers of research. However, more data does not always guarantee better results. Efforts on ensuring **data quality** should be supported.

- The potential of data fusion for improving results on classification should be further explored, in synergy with Machine Learning techniques and leveraging cloud computing. Good results were reported with **Google Earth Engine**. However, the ML algorithms need to be manually tuned, so further advances in this field are required.

Artificial Intelligence in EO

- Several ideas were put forward to improve the performances of specialised processors, optimizing data transmission rates, as well as information retrieval and analytics.
- **Readily-available surface reflectance data** was indicated as a useful resource, among others, to improve the performance of cloud shadow removal algorithms.
- **FPGA technology on-board satellites** (e.g. nVidia Deep Learning Accelerator) can be used for processing/compression to reduce the size of data to be downlinked.
- **Supervised or unsupervised LSH as hash functions** can be used to improve large archive image retrieval.
- **Datacubes can open opportunities for AI** and can be treated as mathematical objects to be analysed statistically.
- **Collaborative Ground Segments** were identified as relevant actors for **NRT provision**.

Artificial Intelligence in EO

- A case study to be used as **a benchmark is needed** to evaluate the performances of the proposed methods. Such a case study could be proposed by ESA (i.e. Phi-lab), providing the data to be used and the criteria of evaluation. The employed methods, software and the achieved results could be made available as free and open tools and data.

- There is still an AI skill shortage at European level, reported by industry. Further **support from ESA in growing the capabilities for AI in Europe and especially in AI for EO and AI for Science** is recommended.

- One possible way forward is through a closer cooperation with the international AI community and through **synergies with other sciences and disciplines where AI is more mature.**

Citizen Science

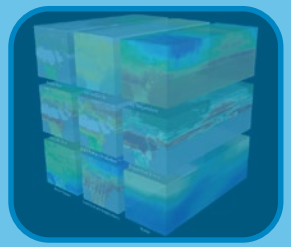
New Education

Toolboxes & Virtual Labs

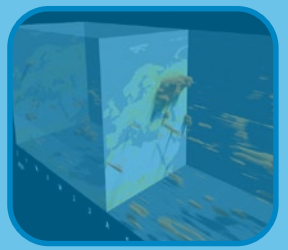
Research Infrastructures

AI4EO

Citizen Science



Data Cube



Science Visualisation

Citizen Science

- The field of Citizen Science continues to **grow in strength and expand its areas of application,** with a growing **body of knowledge** about Citizen Science approaches, and **professional organisations** being formed around the globe to promote and strengthen the field further through **shared tools, data, and know-how.**

- Citizen Science projects have been remarkably successful in **advancing scientific knowledge**, and a number of scientific publications have measured both **policy impact and economic value.**

- With more than half of the globe now having access to the Internet, and two-thirds of the population owning a mobile phone, **Citizen Science can empower individuals to actively enrich EO data** by contributing data and observations in situ that might otherwise be missing, incomplete, or inaccurate. Citizen Science also empowers local communities to **analyse, process, and act on EO data on the ground**, to the benefit of local environmental management.

Citizen Science

- Citizen Observatories engage local communities in monitoring activities across a wide range of domains, and **ensure good quality data through the use of well designed tools and protocols**.

- For the role of Citizen Observatories within EO to reach full maturity and gain traction, they must be **more closely integrated with traditional monitoring initiatives**, and better understood as a **credible and valuable source of in-situ data**.

- ESA and the Phi-Lab can play a valuable role in expanding and supporting a **sustainable ecosystem of Citizen Observatories and related activities**, to the benefit of the wider field of EO and environmental monitoring.

- Beyond science, **citizen observations are creating the premises for digital social innovation** (including digital services for governments and businesses) **and data driven societies**, where novel (Real-time) information services enable citizens to access data and be directly involved in the innovation process in the digital economy.

Data Cubes

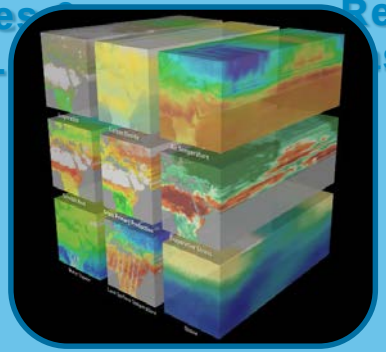
New Education

Toolboxes
Virtual L

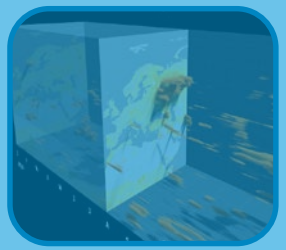
Research
structures

AI4EO

Citizen Science



Data Cubes



Science Visualisation

Data Cubes

- **Datacubes are gaining the interest of scientists** for enabling the manipulation of high-dimensional datasets across Space, Time and Variables, and could be drivers of the development of next generation services for the delivery of value-added information both to scientific and to commercial sectors.

- The **differentiating power of Datacubes comes from** going beyond data extraction and **integrating "the cube" into a scientific workflow**, i.e. allowing the execution of complex analytics on it.

- There is an **increasing number of Datacube implementations**, **which require more** efforts on ensuring **standardization and interoperability**. Presently, standardisation is mostly at interface level (i.e. OGC/WCS, WCPS…), but lacks in terms of internal implementations. The OGC Datacube Standards suite should become the common denominator to achieve interoperability and to avoid vendor lock-in.

Data Cubes

- It is still **difficult for scientists to grasp basic uses** (e.g. how to get their data into the cube).
- Datacube Tools are very much data centre oriented, e.g. **emphasizing Python programming interface**, which is not attracting a critical mass of non-EO users.
- Increasing the participation and **adoption of Datacubes by non-EO communities requires further development of APIs** powering decision support system analytical functions.
- The demand for provision of **Analysis Ready Data** was stressed as an urgent need to ensure user uptake. This would require analysis-supporting tools on both frontend and backend side.
- **European industry has an opportunity to take leadership on this domain.**

Science Visualisation

New Education

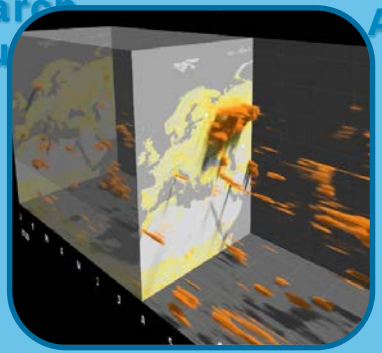
Toolboxes & Virtual Labs

Research Infrastru

AI4EO

Citizen Science

Data Cube



Science Visualisation

Science Visualisation

- **Novel visualisation techniques (e.g. AR, VR) are still underexploited in EO**.
- Today, current visualisation capacity offers new possibilities to explore large multivariate datasets in real time (e.g. by Virtual Reality) offering new prospects for exploring and processing EO data.
- The **combination of existing Virtual Labs with Virtual Reality** and new visualisation methods needs to be explored.
- Especially **Augmented Reality** offers great ways to visualize EO data products (e.g., environmental information) overlaying the real-world at the 1:1 scale with virtual EO data.
- A stronger cooperation between the EO community and the expert community in the field of digital media (e.g. **gaming industry, computer graphics) and HPC could contribute to speed the rate of adoption of new visualisation techniques for science and EO**