3rd ECMWF – ESA WORKSHOP on ML4ESOP

WELCOME AND INTRODUCTION

Rochelle Schneider

Destination Earth AI Applications Lead at ESA

Visiting Researcher at **ECMWF**

Honorary Assistant Professor at the London School of Hygiene & Tropical Medicine **(LSHTM)**

3rd ECMWF – ESA WORKSHOP

MACHINE LEARNING FOR EARTH OBSERVATION AND PREDICTION

14-17 November 2022 at ECMWF (Reading, UK)

esa European Space Agency

 # THEMATIC AREAS:

(1) ML for Earth Observations
(2) Hybrid Data Assimilation - ML and ML at the edge
(3) ML for Model emulation and Model discovery
(4) ML for user-oriented Earth Science applications

 # DAY 1-3

✓ Keynotes + 10 oral sessions + 2 poster sessions
✓ **43** Oral Presentations from experts across 4 TA
✓ **40** posters

AIM: hear the recent progress and research directions in ML4ESOP

 # DAY 4

✓ reverse the order and listen to the participants across TA working groups.

AIM: hear your view/opinion and discuss the advantages and limitations of ML in comparison with more traditional methods and outline future directions.

Why working groups?

Thursday, 17 November			
	Working Groups		
09:00 → 10:30	**Working Group 1 - Machine Learning for Earth Observations** Speakers: Alan Geer (ECMWF) , Rochelle Schneider (ESA Φ-lab)		1h 30m
09:00 → 10:30	**Working Group 2 - Hybrid Data Assimilation - Machine Learning** Speakers: Marcin Chrust (ECMWF) , Rossella Arcucci (Imperial College London)		1h 30m
09:00 → 10:30	**Working Group 3 - Machine Learning for Model emulation and Model discovery** Speakers: Massimo Bonavita (ECMWF) , Matthew Chantry (ECMWF)		1h 30m
09:00 → 10:30	**Working Group 4 - Machine Learning for user-oriented Earth Science application** Speakers: Bertrand Le Saux (ESA/ESRIN) , Claudia Vitolo (ESA) , Patrick Laloyaux (ECMWF)		1h 30m
10:30 → 11:00	**Coffee break**		30m
	Working Groups		
11:00 → 12:30	**Working Group 1 - Machine Learning for Earth Observations** Speakers: Alan Geer (ECMWF) , Rochelle Schneider (ESA Φ-lab)		1h 30m
11:00 → 12:30	**Working Group 2 - Hybrid Data Assimilation - Machine Learning** Speakers: Marcin Chrust (ECMWF) , Rossella Arcucci (Imperial College London)		1h 30m
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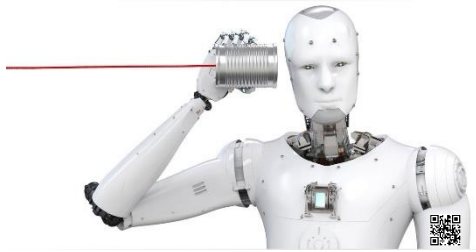
11:00 → 12:30	**Working Group 4 - Machine Learning for user-oriented Earth Science applications** Speakers: Bertrand Le Saux (ESA/ESRIN) , Claudia Vitolo (ESA) , Patrick Laloyaux (ECMWF)		1h 30m
12:30 → 14:00	**Lunch break**		1h 30m
14:00 → 15:30	**Session 5: Working Groups plenary discussion and close** Chair: Massimo Bonavita (ECMWF) , Rochelle Schneider (ESA Φ-lab)		1h 30m

Listen and report



npj | climate and atmospheric science

www.nature.com/npjclimatsci

MEETING REPORT OPEN

Check for updates

ESA-ECMWF Report on recent progress and research directions in machine learning for Earth System observation and prediction

Rochelle Schneider[1,2✉], Massimo Bonavita[2], Alan Geer[2], Rossella Arcucci[3], Peter Dueben[2], Claudia Vitolo[1], Bertrand Le Saux[1], Begüm Demir[4] and Pierre-Philippe Mathieu[1]

This paper provides a short summary of the outcomes of the workshop on Machine Learning (ML) for Earth System Observation and Prediction (ESOP / ML4ESOP) organised by the European Space Agency (ESA) and the European Centre for Medium-Range Weather Forecasts (ECMWF) between 15 and 18 November 2021. The 4-days workshop had more than 30 speakers and 30 poster-presenters, attracting over 1100 registrations from 85 countries around the world. The workshop aimed to demonstrate where and how the fusion between traditional ESOP applications and ML methods has shown limitations, outstanding opportunities, and challenges based on the participant's feedback. Future directions were also highlighted from all thematic areas that comprise the ML4ESOP domain.

npj Climate and Atmospheric Science (2022)5:51 ; https://doi.org/10.1038/s41612-022-00269-z

2021, 2nd ML4ESOP edition

ML4ESOP → AI4DTE4...

Toward

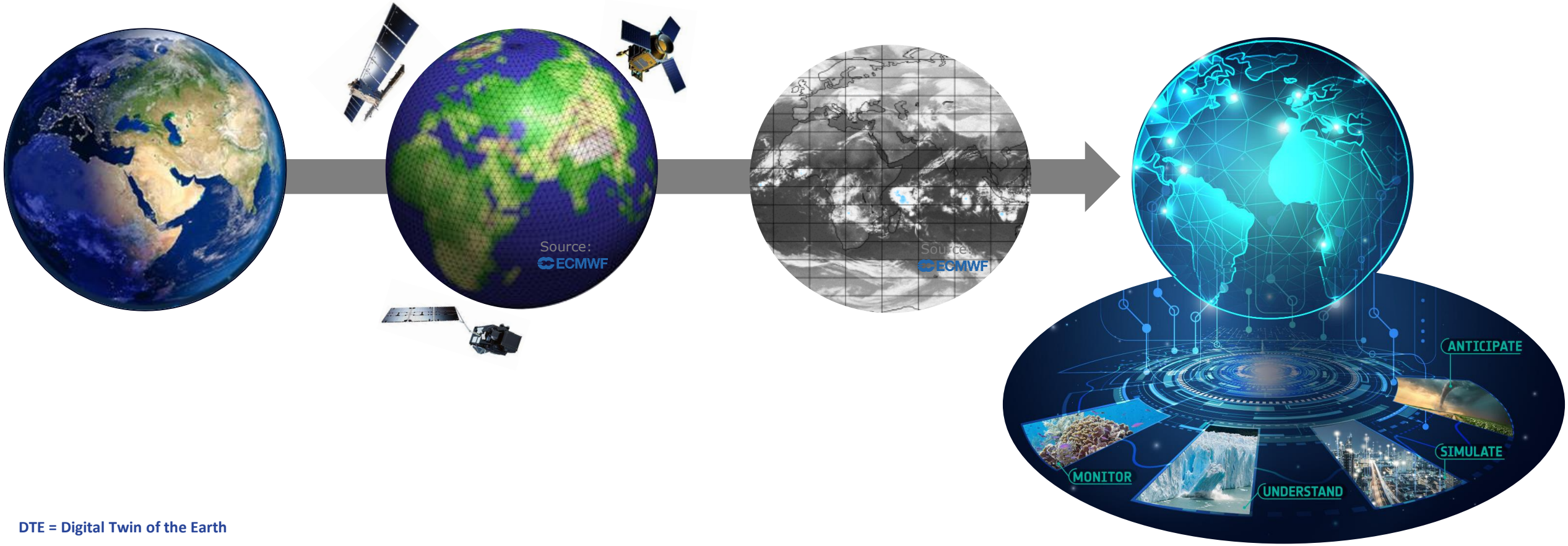
- Weather-Induced and Geophysical Extremes
- Climate Change Adaptation

DATA ACQUISITION

DATA ASSIMILATION

MODEL SIMULATION

DIGITAL TWINS



DTE = Digital Twin of the Earth

Where is AI/ML?

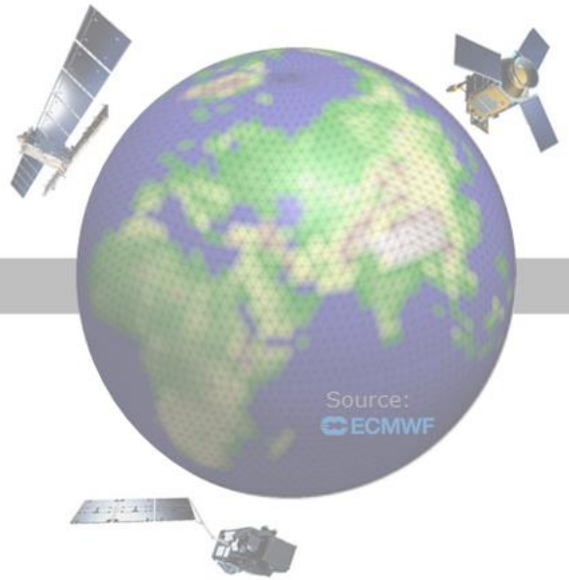
esa
European Space Agency
Φ-lab

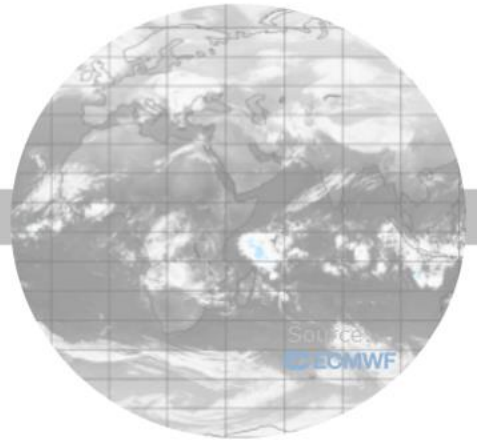
DATA ACQUISITION

DATA ASSIMILATION

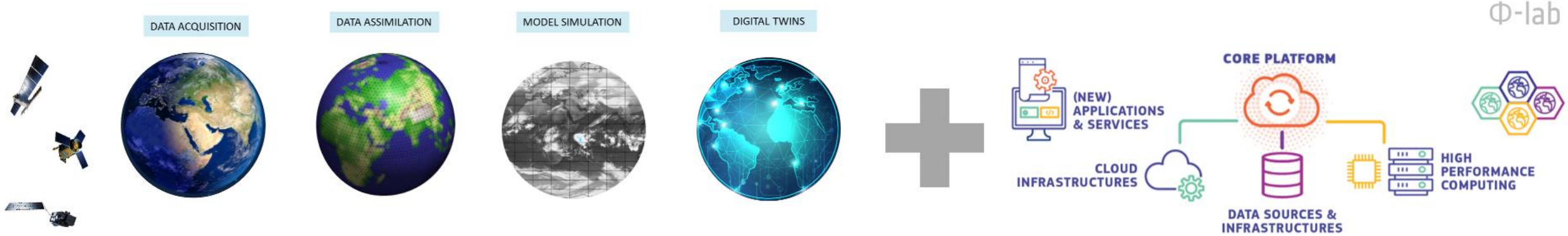
MODEL SIMULATION

DIGITAL TWINS





Where is AI/ML? *An overview*



Benchmark ML datasets/problems
Peter Dueben et al. AI4ES paper 2022

Variable emulation
missing *X* (Clouds?) or unresolved physical process in ESM

Autoencoders
Dimensionality reduction of ***X***. Preserve original variance (most)

HPC accelerators
Speed-up data processing, Performance, TPUs

Partial model emulator
Model component (shortcut)

Full model emulator
Surrogate models

Explainable AI
Earth System Models and DTE

Correcting / Quantifying model imperf
(error estimation, bias correction)

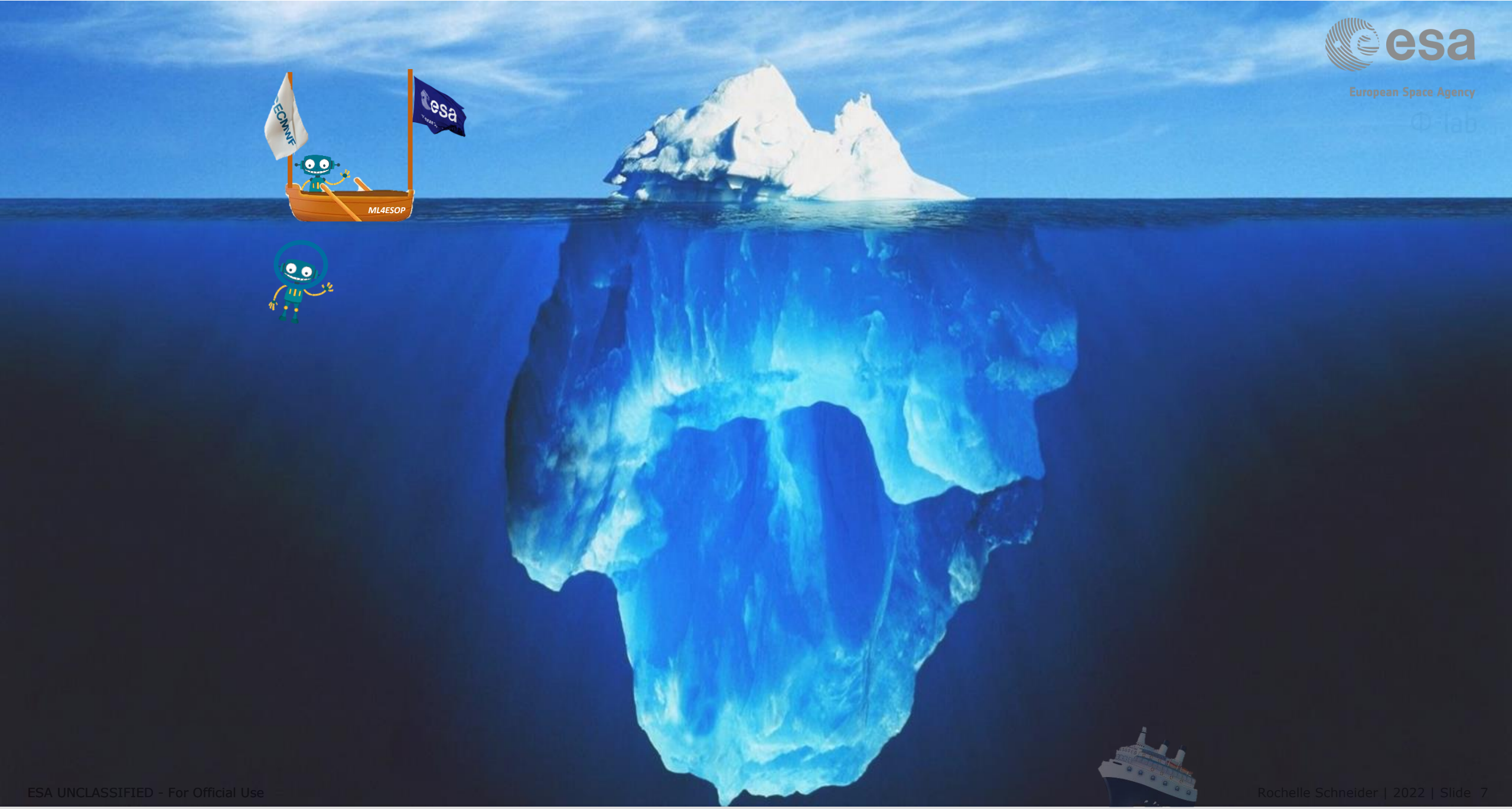
Reasoning and AI for Causality discovery

Post-processing
(event detection, downscaling/ super-resol)

Computing infrastructure
Move compress data (Low-dim filters). Web-service

AI Augmented/ Virtual reality
DTE

AI-ready Cloud-based Service platform
Address different user profiles


ECMWF
esa
ML4ESOP

AI4EO at scale – Φ-lab's Research Agenda

European Space Agency

Φ-lab

AI MULTI-DOMAINS

- Computer Vision (novelty detection)
- Time series analysis
- Natural Language Processing (NLP)
- Sensor Enhancement (Super Resolution)
- Data Science
- Network Intelligence in Orbit (NIO)
- Explainable AI (xAI)
- AI Safety
- Metaverse (w3.0 Blockchain)

COMMUNITY ENABLING

- AI-ready Data Augmentation (simulated, labelled, invariant)
- AI engineering (MLOPs)
- Challenges / Research Sprints
- Digital Companion

LEARNING PARADIGMS

- Supervised + Self-Supervised Learning
- Physics-Informed (PINNs)
- Graph Neural Network (GNN)
- Generative Learning (GANs)
- Transfer Learning (Domain Adaptation)
- Reinforcement Learning (RL)
- Federated / Edge Learning
- Adaptative Learning / AutoML

HYBRID COMPUTING

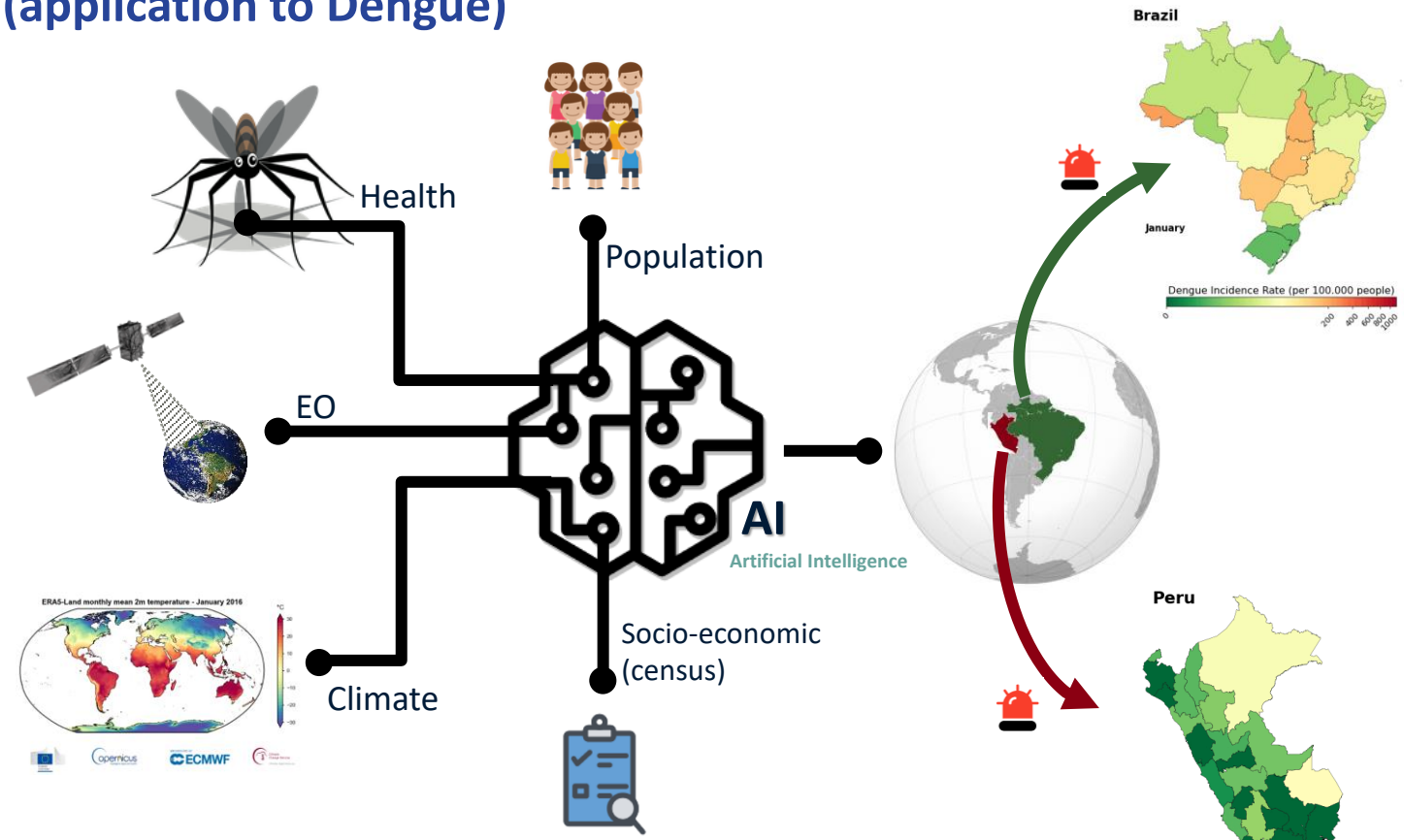
- Edge Computing (TinyML)
- Neuromorphic Computing (Spiking NNs)
- Quantum Computing (QML)
- Large-scale High Performance Computing (Scalable AI4HPC)

EO MULTI-DOMAINS

- Digital Twins (DTE)
- Sustainable Development (SDGs)
- ...
- Atmosphere (Air Quality)
- Ocean (Floating Objects)
- Cryosphere (sea-ice charting)
- Land (Urban, Agriculture)
- Solid Earth

Quantifying health-risk with EO data and AI

(application to Dengue)



*"**This project** is a **perfect example** of **collaboration** between a humanitarian organisation and a research entity to support the UN SDGs."*

Dohyung Kim - Data Scientist at the UNICEF Office of Global Innovation.

unicef INNOVATION

esa Φ-lab

Multi-Award Winning Project

1 – UNESCO – IRCAI

United Nations Educational, Scientific and Cultural Organization

International Research Centre of Artificial Intelligence under the auspices of UNESCO

GLOBAL TOP 100 AI solutions for SDGs

2 - Best of UNICEF Research

showcase the most rigorous, innovative and impactful research produced by UNICEF offices worldwide

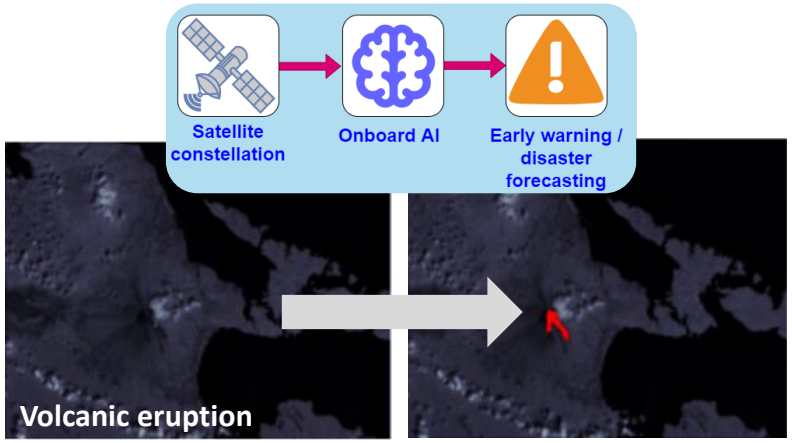
3 – Wellcome Trust support

Wellcome trust is an independent charitable foundation

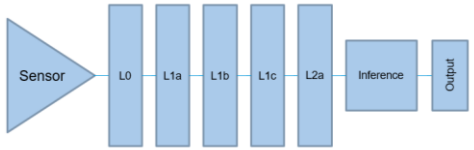
Satellite onboard AI

Φ-lab: Gabriele Meoni

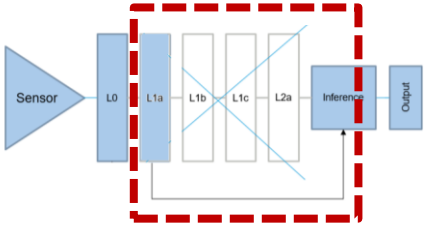
- Avoid some pre-processing parts and infer directly on L1 image (saving time and energy consumption)
- For example: detection of warm events (volcanic/fire) on raw data with DNN.
- Fast, safe and scalable solution

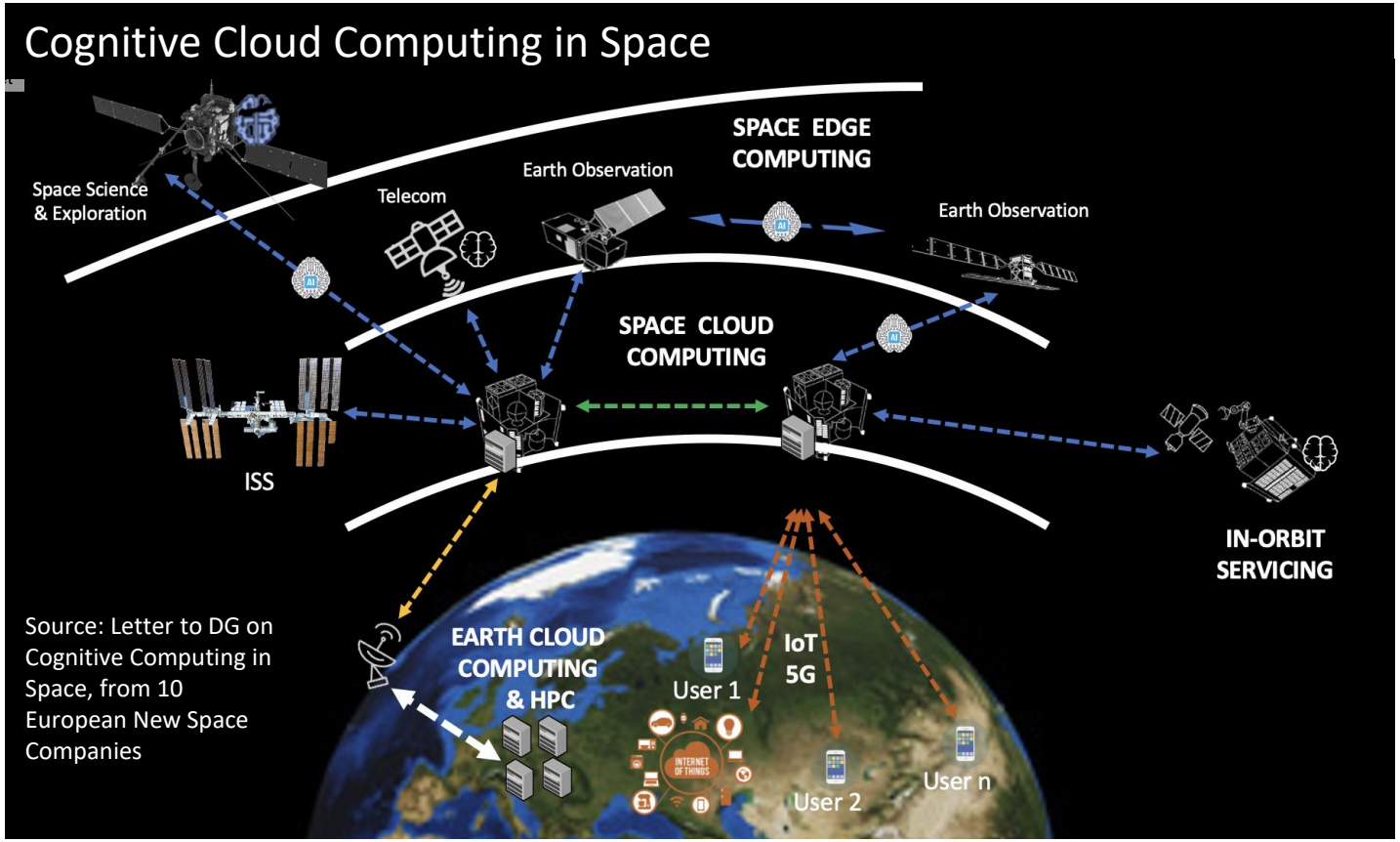


Basic processing model



Onboard END2END processing





EGU General Assembly
#EGU23
23 - 28 April 2023

DEADLINE: 10th JANUARY 2023

ESSI1.5 AI applications for Digital Twins in Earth Science

Convener: Rochelle Schneider (ESA)
Co-conveners: Bertrand Le Saux (ESA), Matthew Chantry (ECMWF), Mariana Clare (ECMWF)

A digital twin of the Earth (DTE) is an interactive, dynamic digital replica of our planet which combines observations with simulations from physical models. It aims to replicate the Earth's complex ecosystem, allowing us to estimate our planet's response to changes under both the current climate state and future climate projections. These digital simulations create a system capable of performing what-if scenarios before they occur, which is crucial for natural hazard mitigation and adaptation plans (e.g., floods, heatwaves, wildfires, droughts, etc).
The benefits of AI applications are seen across all DTE domains, including but not limited to: (i) accelerating High-Performance Computing (HPC), (ii) acting as full or partial surrogates to Earth System models, (iii) optimising data streams (i.e., quality control, compression, AI-ready dataset creation), (iv) emulating missing variables and unresolved physical processes, and (v) correcting or quantifying model imperfections (i.e., error estimation and bias correction).

This session aims to provide a venue to demonstrate where and how AI tools have been a key aspect for the success within the DTE workflow including, but not restricted to:

- **HPC acceleration** for DTE architectures;
- **Computer infrastructure** to move virtual data from DTE repositories to service platforms;
- **Surrogate models** for missing observations and unresolved physical processes;
- **Hybrid AI** / physics based modelling;
- **Extreme** value predictions;
- **Explainable AI** for DTE;
- **Uncertainty** quantification and representation;
- **Reasoning** and AI for **Causality** discovery;
- **Post-processing** (event detection and downscaling/super-resolution).

EGU General Assembly #EGU23 23 - 28 April 2023

DEADLINE: 10th JANUARY 2023

ESSI2.10 First steps towards Destination Earth

Convener: Claudia Vitolo (ESA)
Co-conveners: Joern Hoffmann (ECMWF), Danaele Puechmaille (EUMETSAT)

esa European Space Agency
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Destination Earth (DestinE) is an ambitious initiative of the European Union aiming to develop – on a global scale - a highly accurate digital model of the Earth that will help understand and simulate the evolution in the state of our planet, better predict impact on human system processes, ecosystem processes and their interaction.

DestinE will exploit state-of-the-art technologies, including high-performance computing, high-resolution Earth system models and novel approaches in analytics, including artificial intelligence, and offer unprecedented interactivity with the system for users.

A number of tangible outcomes are expected from these developments: Earth system simulations will become more skillful, the intensity and magnitude of natural disasters will be predicted more reliably, decision makers will have tools to tackle more efficiently the effect of climate change and much more.

Work is currently ongoing by the three implementing agencies (ESA, EUMETSAT, ECMWF) to develop the three components of the DestinE system: the Core Service Platform, the Data Lake and the Digital Twin Engine. This session aims at presenting progress towards the implementation of the DestinE system. It will also highlight opportunities to contribute to this challenging and ambitious endeavor and co-evolve the system together.

Φ-lab *is hiring!*

European Space Agency

Φ-lab

Φ-lab also have visiting schemes, hosting PhD students, postdocs, and industry-fellows from a period of weeks to months.

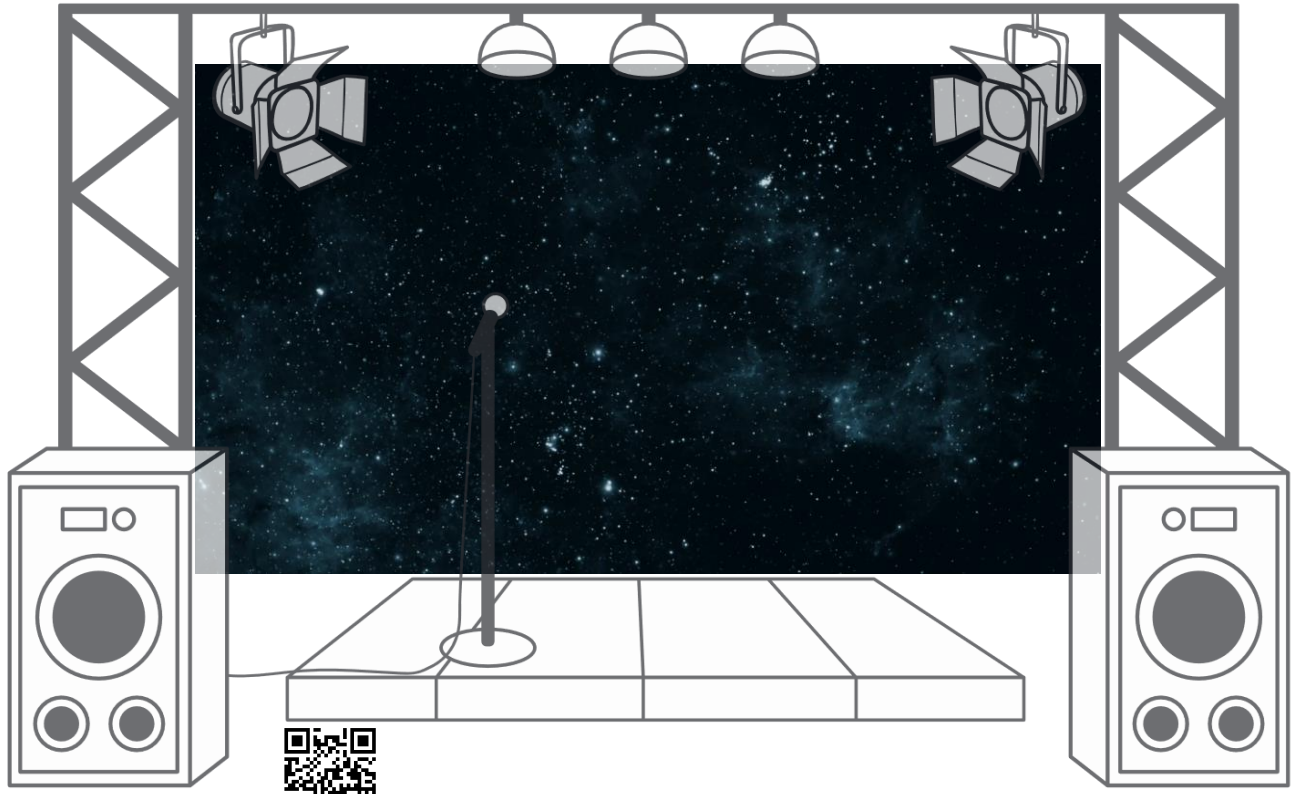
Internal Research Fellow (PostDoc) in Earth Observation (EO) and Computer Science for Climate

Job Req ID: 17067
Closing Date: 7 December 2022 23:59 CET/CEST
Publication: External Only
Vacancy Type: Internal Research Fellow
Date Posted: 9 November 2022

Internal Research Fellow (Post-Doctoral) in AI and the use of Earth Observations for Climate

Job Req ID: 16263
Closing Date: 9 November 2022 23:59 CET/CEST
Publication: External Only
Vacancy Type: Internal Research Fellow
Date Posted: 12 October 2022

Closed.



Full video about Φ-lab


00 : 06
LET'S GE
STARTE