ESA Digital Twin Earth
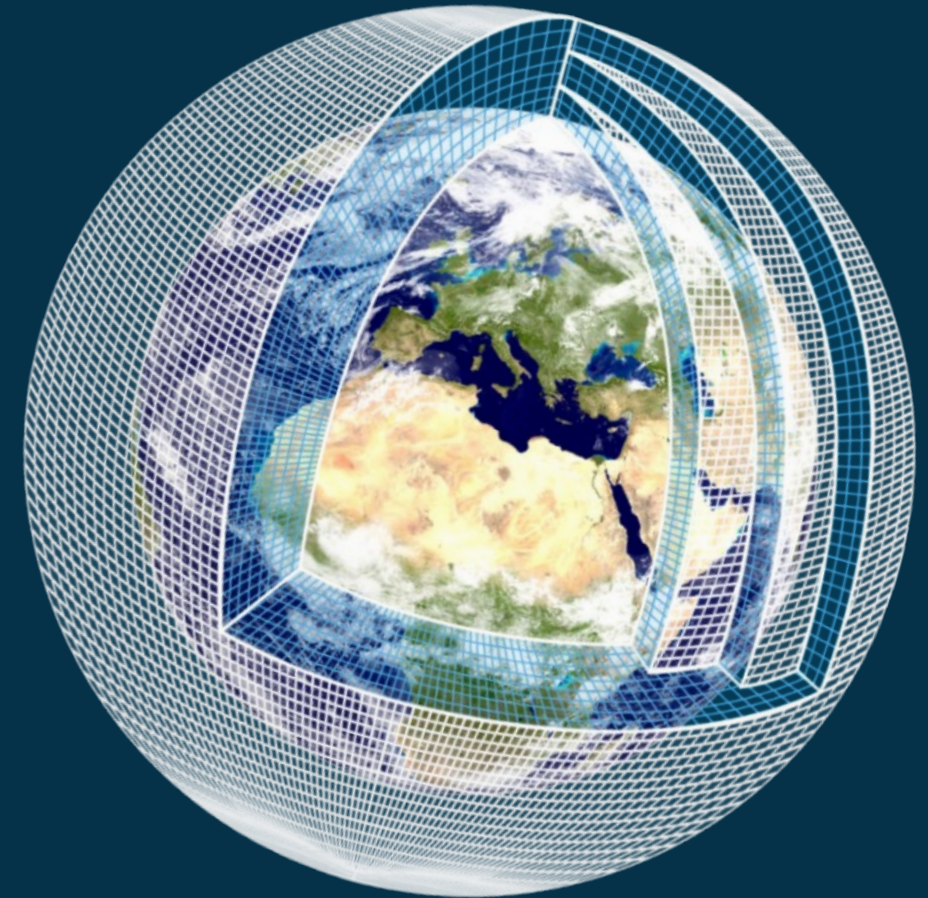
EO-based Digital Twin Components of the Earth System

Martin Wearing, Digital Twin Earth Scientist, ESA

Ed Malina, Earth Observation Atmospheric Scientist, ESA
Diego Fernandez Prieto, Head of the Science Section, ESA

→ THE EUROPEAN SPACE AGENCY

Overview

- Provide a high-level overview of ESA's activities developing Digital Twin Components (DTCs) of the Earth system based on Earth Observation (EO) data.

- These activities put EO at the heart of Digital Twin developments and are designed to explore the possibilities offered by EO data.

- NOW: Contracts are being negotiated and signed, and projects are kicking off in the next few weeks.

- Overview of driving philosophy and progress so far.

Introduction

- ESA Science cluster activities have developed novel Earth Observation (EO) datasets that characterise many components of the Earth system

DISASTER SCIENCE   AGRICULTURE SCIENCE   ATMOSPHERIC RESEARCH   CARBON CYCLE SCIENCE   OCEAN RESEARCH   POLAR SCIENCE

- These datasets form the foundation for EO-based digital replicas of the Earth system → EO-based DTCs

→ THE EUROPEAN SPACE AGENCY

Introduction

- ESA Science cluster activities have developed novel Earth Observation (EO) datasets that characterise many components of the Earth system
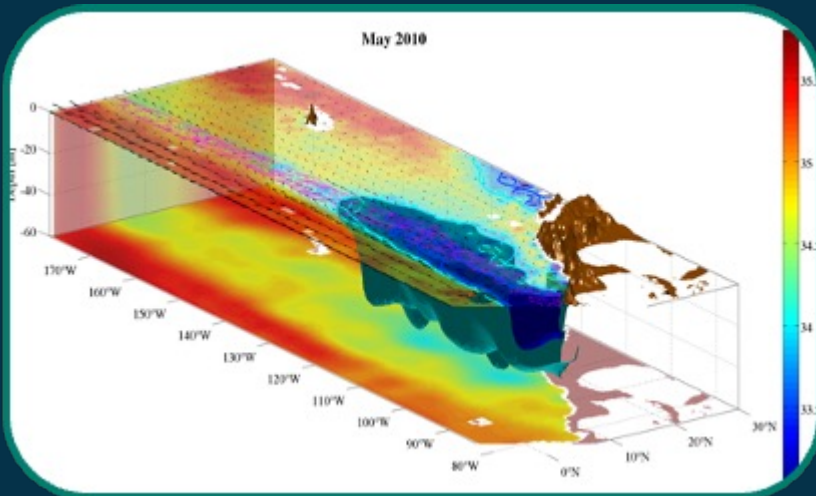
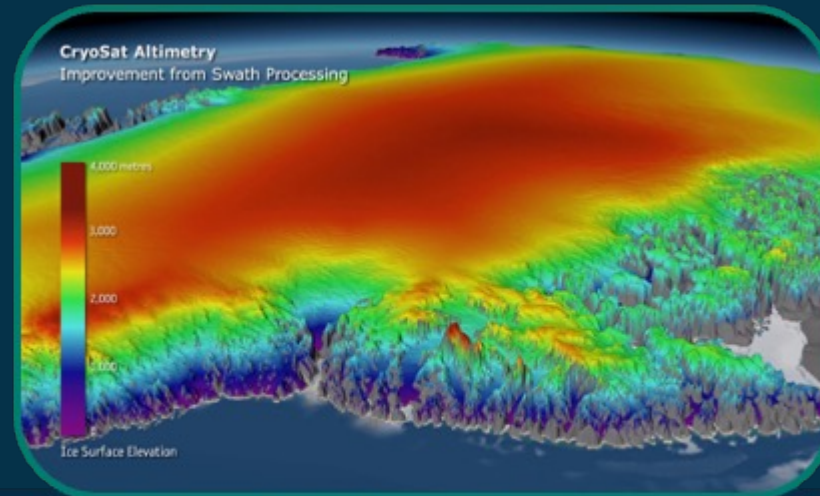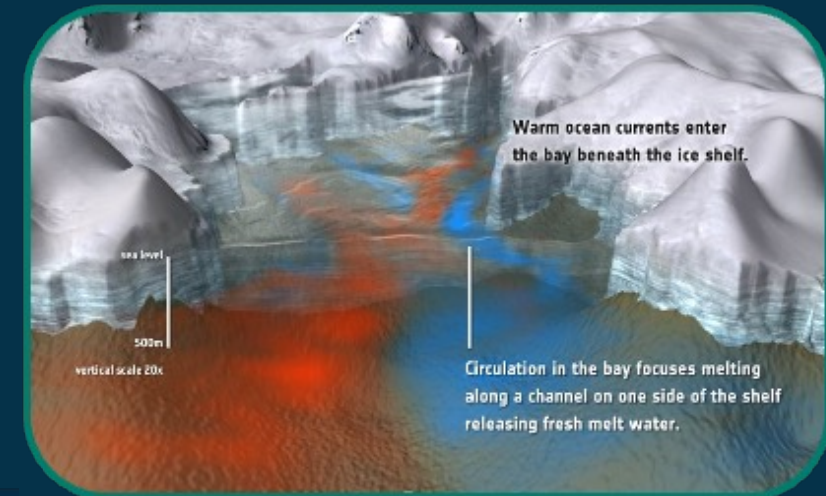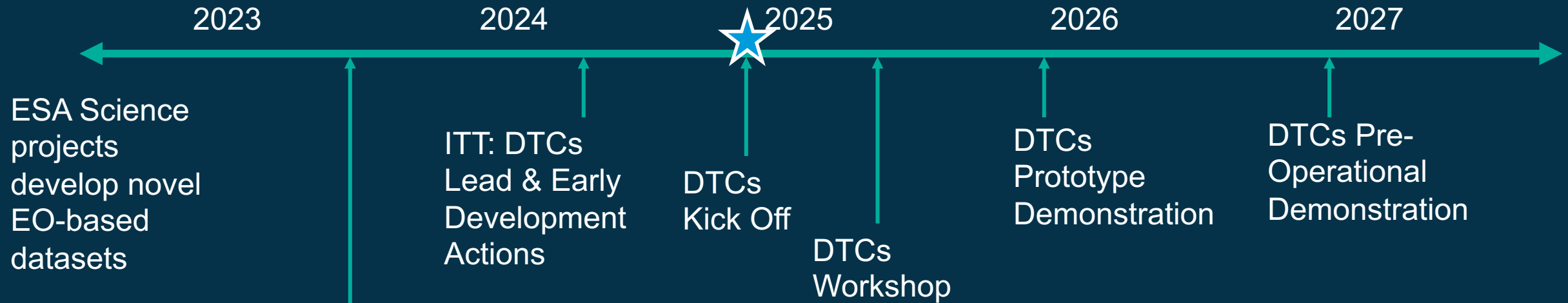4D Ocean data driven reconstruction

Novel HR elevation changes

Sub-glacial and ice shelves environment

- These datasets form the foundation for EO-based digital replicas of the Earth system → EO-based DTCs

→ THE EUROPEAN SPACE AGENCY

Timeline

2023   2024   2025   2026   2027

ESA Science projects develop novel EO-based datasets

Digital Twin Precursor Activities

ITT: DTCs Lead & Early Development Actions

DTCs Kick Off

DTCs Workshop

DTCs Prototype Demonstration

DTCs Pre-Operational Demonstration

- Antarctica
- Food systems
- Hydrology
- Climate Impacts
- Forest
- Ocean

Each DTC shall be focused on a particular component of the Earth system

DTC Themes

Following a public consultation on the scientific priorities of the European community, 8 Earth system components or Themes were selected for **Lead Development Actions**: Development of end-to-end pre-operational system, maximum price of 1.5MEuro each and 24 months duration.

- Terrestrial biosphere & carbon cycle
- Agriculture
- Forests
- Hydrology & hydro-hazards
- Ice Sheets & regional global impact
- Coastal processes & extremes
- Data-driven Ocean
- Land Biodiversity

Further themes were selected for **Early Development Actions** to consolidation and advance the themes in terms of community building, concept definition or science/technical aspects. Up to 6 parallel projects: maximum price of 0.5MEuro each and 12 months duration.

- Wildfires
- Transport & infrastructure
- Geo-Hazards
- Mountain glaciers
- Arctic: land & ocean
- Solid Earth
- Air quality & health
- Urban areas & smart cities
- Energy Sector

→ THE EUROPEAN SPACE AGENCY

EO DTCs Basic Principles

We have developed a set of Basic Principles and Fundamental Elements that an EO-based DTC must address.

EO DTCs shall:

✓ Valorise the capacity and maximize the use of EO data.

✓ Provide a comprehensive description and scientifically sound representation of the Earth system component including its connections with human activities.

✓ Follow high scientific and technical standards, ensuring the use of state-of-the-art data, AI, models, and data-driven processing based on scientifically sound validation and uncertainty characterisation processes.

✓ Maximise the use of open science and FAIR principles, ensuring datasets and workflows could be further developed and expanded in time by the community.

DTC Basic Principles

→ THE EUROPEAN SPACE AGENCY

EO DTCs Basic Principles

✓ Provide advanced scientific support and science-based decision support capabilities, including enhanced simulations and what-if scenarios.

✓ Be based on a strong community support and developed in view of serving a wide variety of stakeholders including:

- The scientific community
- Policymakers, international and national public institutions.
- Value-added companies/industry
- Citizens

✓ Allow interrogation of the DTC system with high levels of interactivity (e.g., through notebooks, interactive dashboards, immersive visualisation) with different levels of access and interoperability to different categories of user.

DTC Basic Principles

EO DTCs Basic Principles

✓ DTCs shall ensure complementarity with ongoing initiatives and programmes, including other Digital Twin activities related to DestinE and other European (e.g., Digital Twin of the Ocean) or national activities.

EO DTCs Functional Elements
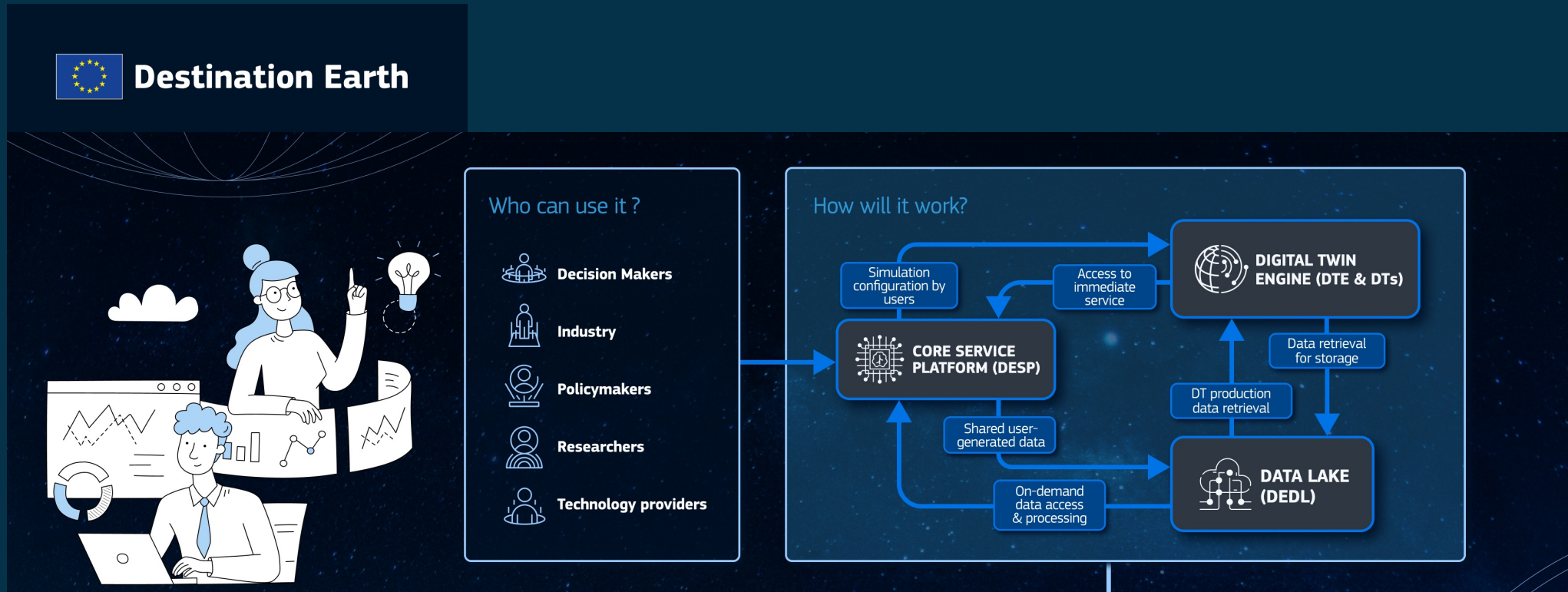
Advanced Data and Digital Services:

- enhanced digital analysis and simulation of the Earth system, representing breakthrough in terms of accuracy, holistic understanding, access-to-information, and interactivity.

Multivariate data-driven reconstruction (by advanced Earth Observation data):

- valorise and maximize the use of EO-based data to produce a **4D (space-time) reference multivariate dataset** of high-level products offering an advanced, holistic, and dynamic reconstruction of the target Earth system component.

→ THE EUROPEAN SPACE AGENCY

EO DTCs Functional Elements

Scientifically sound processing blocks, simulations & workflows:

- connecting data with state-of-the-art models, geophysical functions, AI and hybrid methods allowing digital simulations and the creation of what-if scenarios.
- Enhanced representation of the Earth system and its processes at **higher spatial and temporal resolution** compatible with the demands for policy making and resources and/or risk management.
- Improved the representation of poorly known processes.

User-driven interactive capabilities, data analytics and visualisation layer

Timeline

2023   **2024**   **2025**   **2026**   **2027**

ESA Science projects develop novel EO-based datasets

Digital Twin Precursor Activities

Call for expressions of interest

ITT: DTCs Lead & Early Development Actions

DTCs Kick Off

DTCs Workshop

DTCs Prototype Demonstration

DTCs Pre-Operational Demonstration

ESA DTCs Community Workshop

ESA will be hosting a workshop for their DTC activities, also open to the wider community.

Details are still to be finalised, but likely:
- 3rd -5th February 2025, ESA, ESRIN, Frascati, Italy