The role of observations in EVE

&

Some observations about EVE from the perspective of Destination Earth

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formerly ECMWF

What information system would we want?

Abstraction level:

knowledge/insights

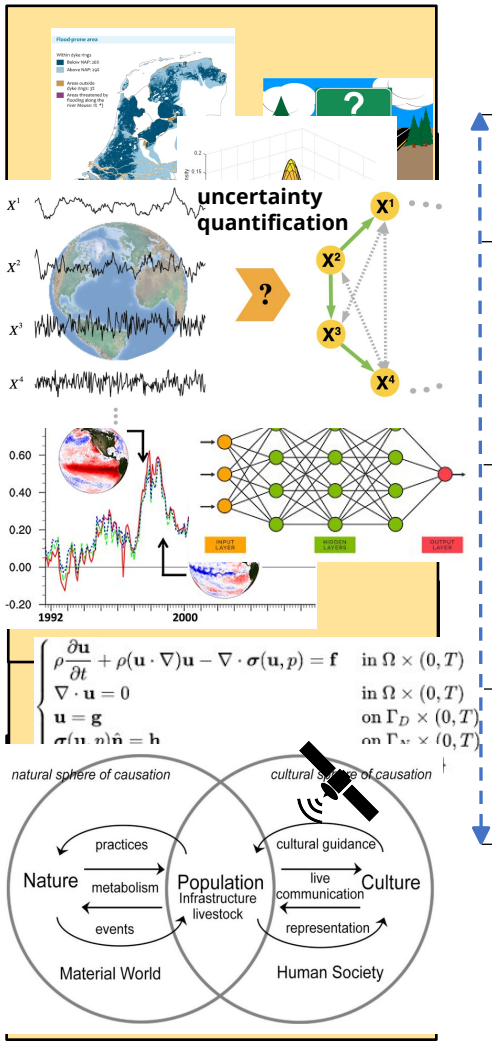
information

data

physical system (digital)

human system (digital)

fully traceable model, data & information hierarchy



Expertise level:

- decision maker
- information broker
- data scientist
- Earth system scientist
- social scientist

Interaction level:

What is the risk of coastal flooding in the Netherlands in 2030?

And what is the most cost-effective adaptation scenario?

Interact with information extraction, add own interpretation, inference

Interact with data generation, fusion of different sources, ML training

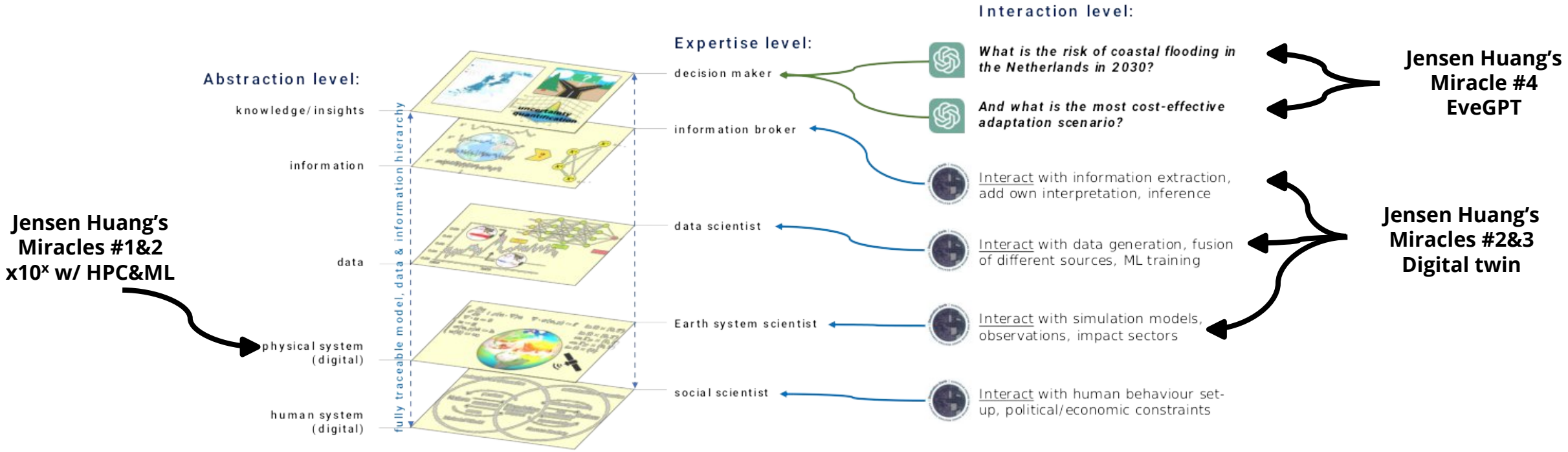
Interact with simulation models, **observations**, impact sectors

Interact with human behaviour set-up, political/economic constraints

ML is everywhere

(thumbnails from ChatGPT, MDPI/Deltares, U Valencia, TIBCO, Wikipedia, A. Magerl)

From yesterday



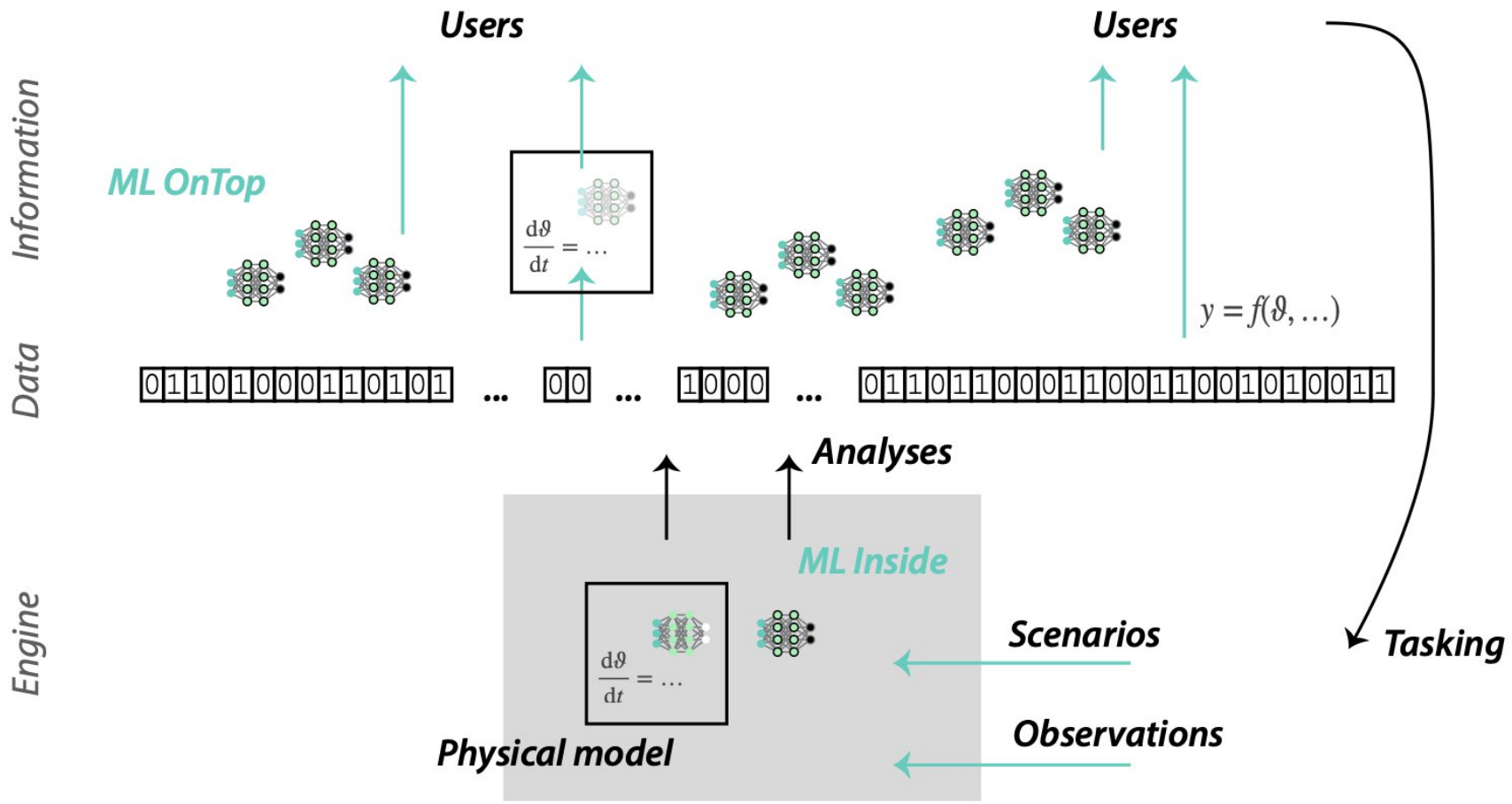
Bjorn Stevens: "…new quality of generation of data & new quality of interaction with data…"

Debra Roberts: "…information alone will not be sufficient to create **Δ** for impacts…"

Aromar Revi: "…the information needs to scale down to local impacts…"

Tim Palmer: "…the quality of present climate information is (utterly) insufficient…"

At the core of EVE there is an information system



traditional: physics-based models, **observational constraints**, ..., **ML inside**

novel: users fully interacting with workflows, federated digital infrastructure, fast update cycling, ..., **ML on top**

Observations: Climate monitoring (= investment in ML on top)

Purpose: Monitoring the past evolution of climate (global to local) to quantify change, impacts of change and anthropogenic contribution (together with numerical experiments)

Tools: Observation-only data records and reanalyses (= numerical models constrained by observations through objective methods aka *data assimilation*)

Providers: Space agencies and NWP centres ∈ climate services;
~5+ year-cycle between versions;
heavily constrained by computational resources

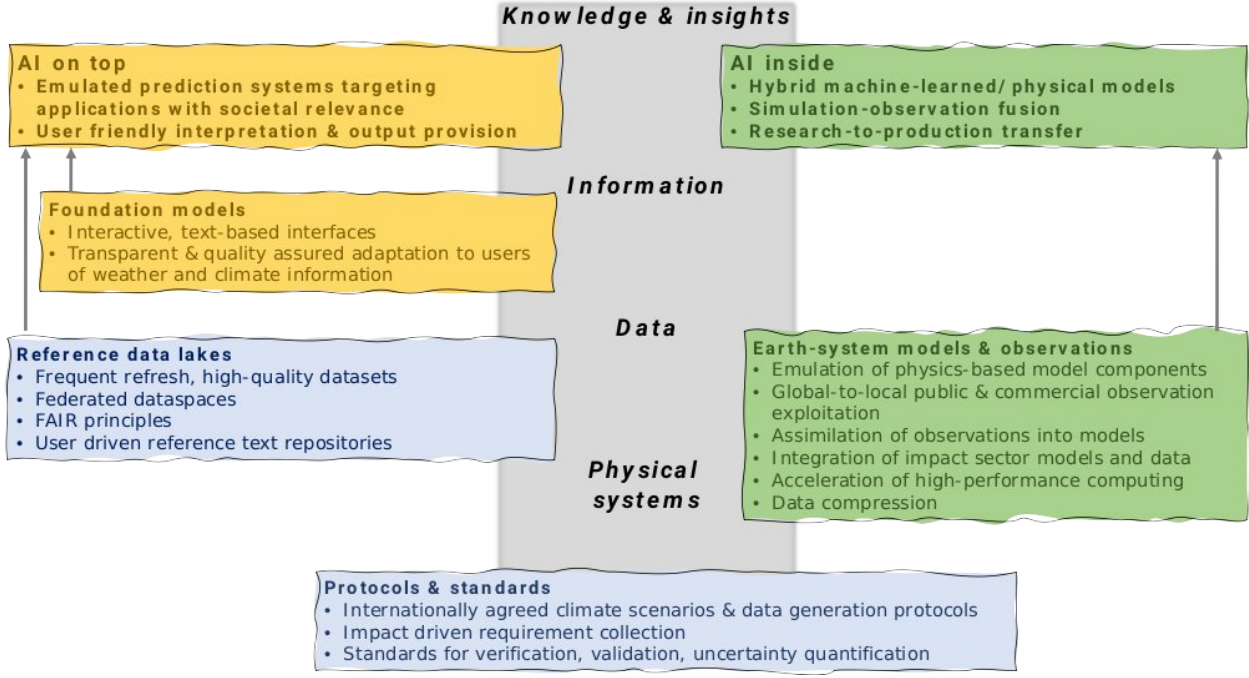
… enable these providers to use EVE as a platform

Observations: Climate monitoring (= investment in ML on top)

In EVE:

Same methodological framework, ***but***:

- applied to a wider range of scales, and with more flexibility
- extending into application sectors & their observations (e.g. cities, farms, windfarms, IoT)
- strongly empowered by ML to:
  - use more, and more diverse observations
  - better deal with observation & model errors and sampling
  - supplement/supplant traditional data assimilation methods for speed and quality (!!)
  - provide better uncertainty quantification



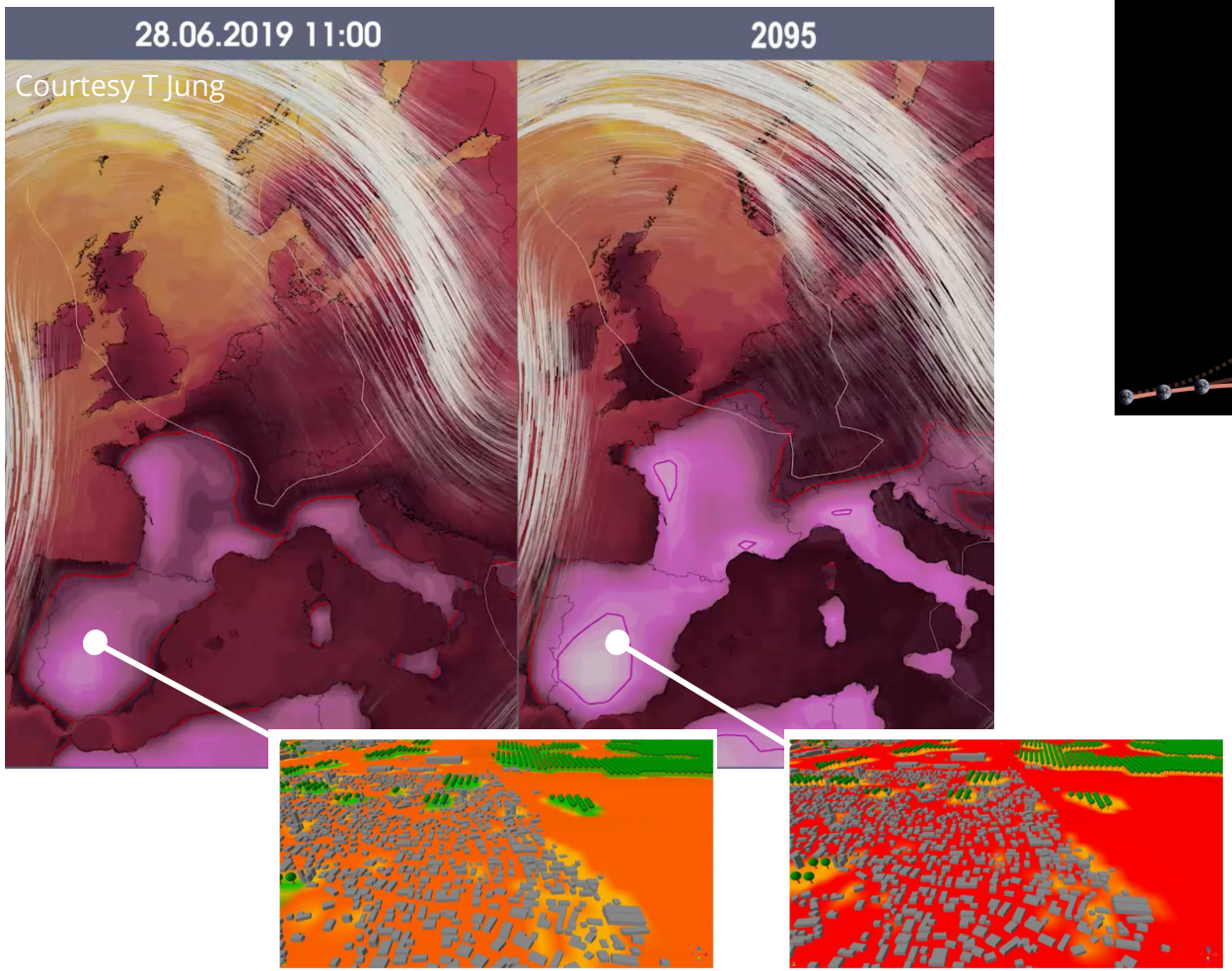
Must haves*:

- data assimilation type methods to create best possible reference training datasets for ML (of everything)
- interoperability of data and software
- agreement on observational data sharing incl. metadata (public & commercial)
- agreement on protocols and reference datasets, verification and uncertainty quantification

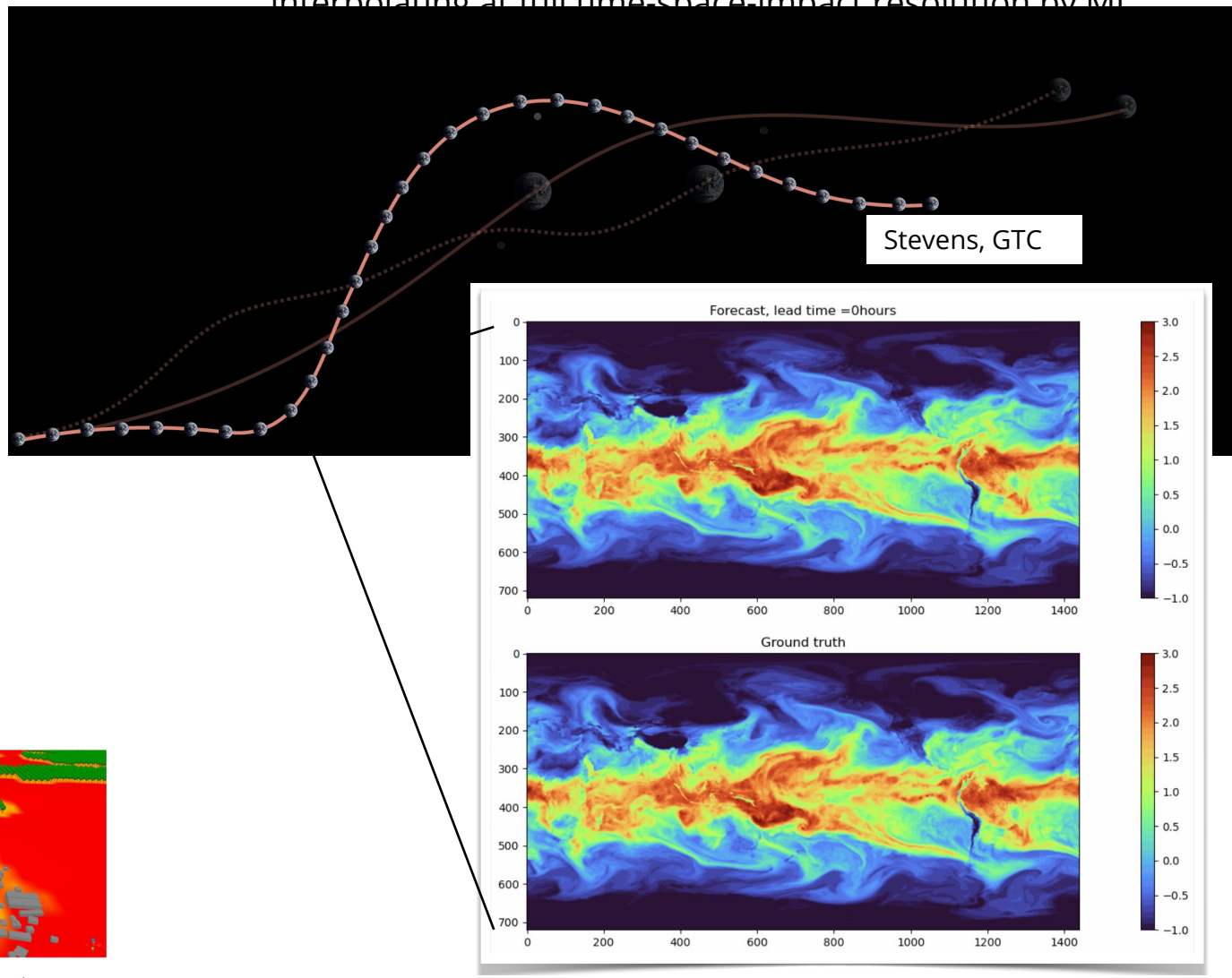
* lots of this exists already, but primarily in public context (… but think EveGPT)

Observations: Climate projection (→ *return on investment from ML on top*)

Storylines:
… projecting past events into the future
(informed by past records: dynamics, scales, impacts)



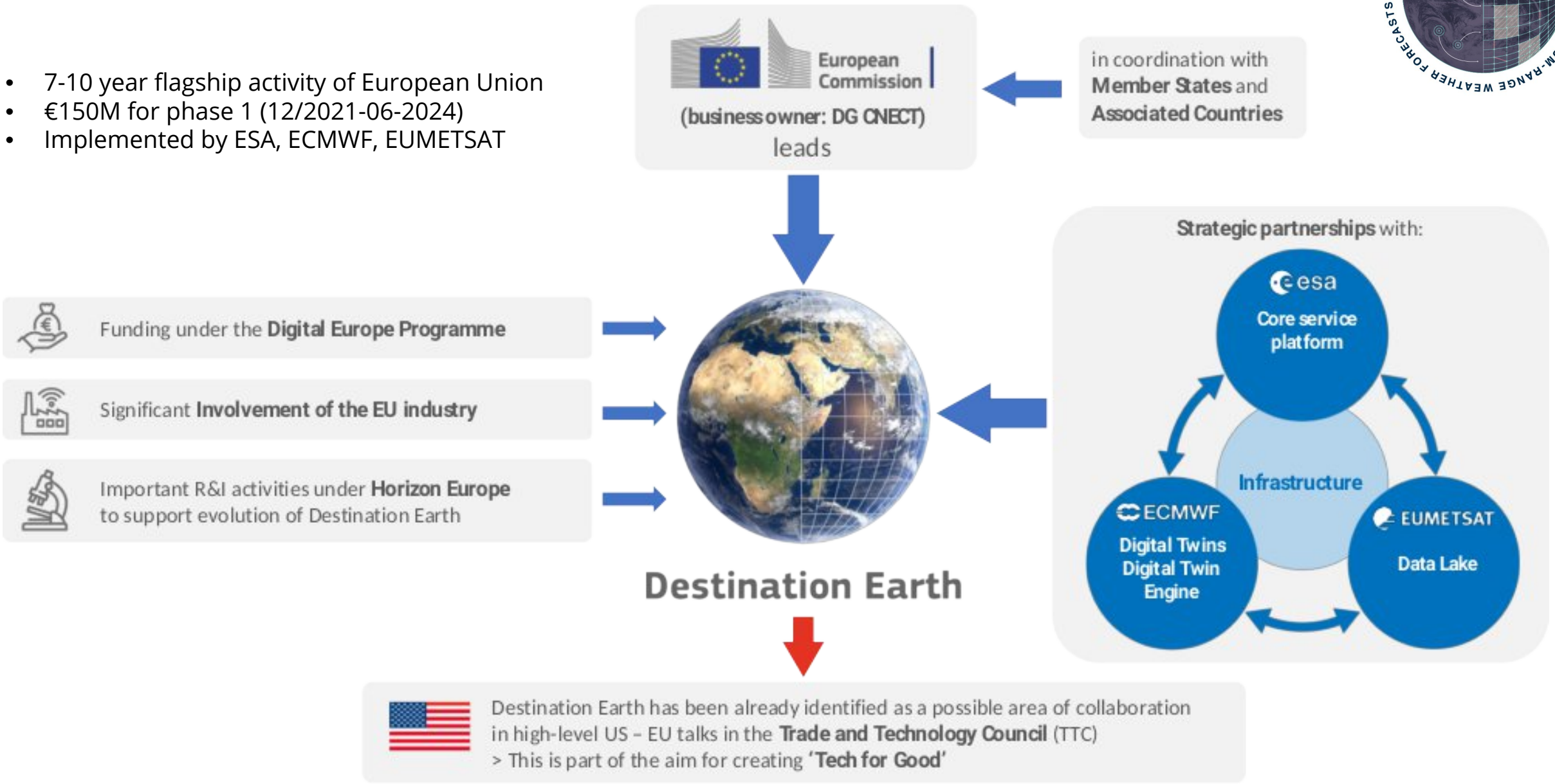
Climate trajectories:
interpolating at full time-space-impact resolution by ML



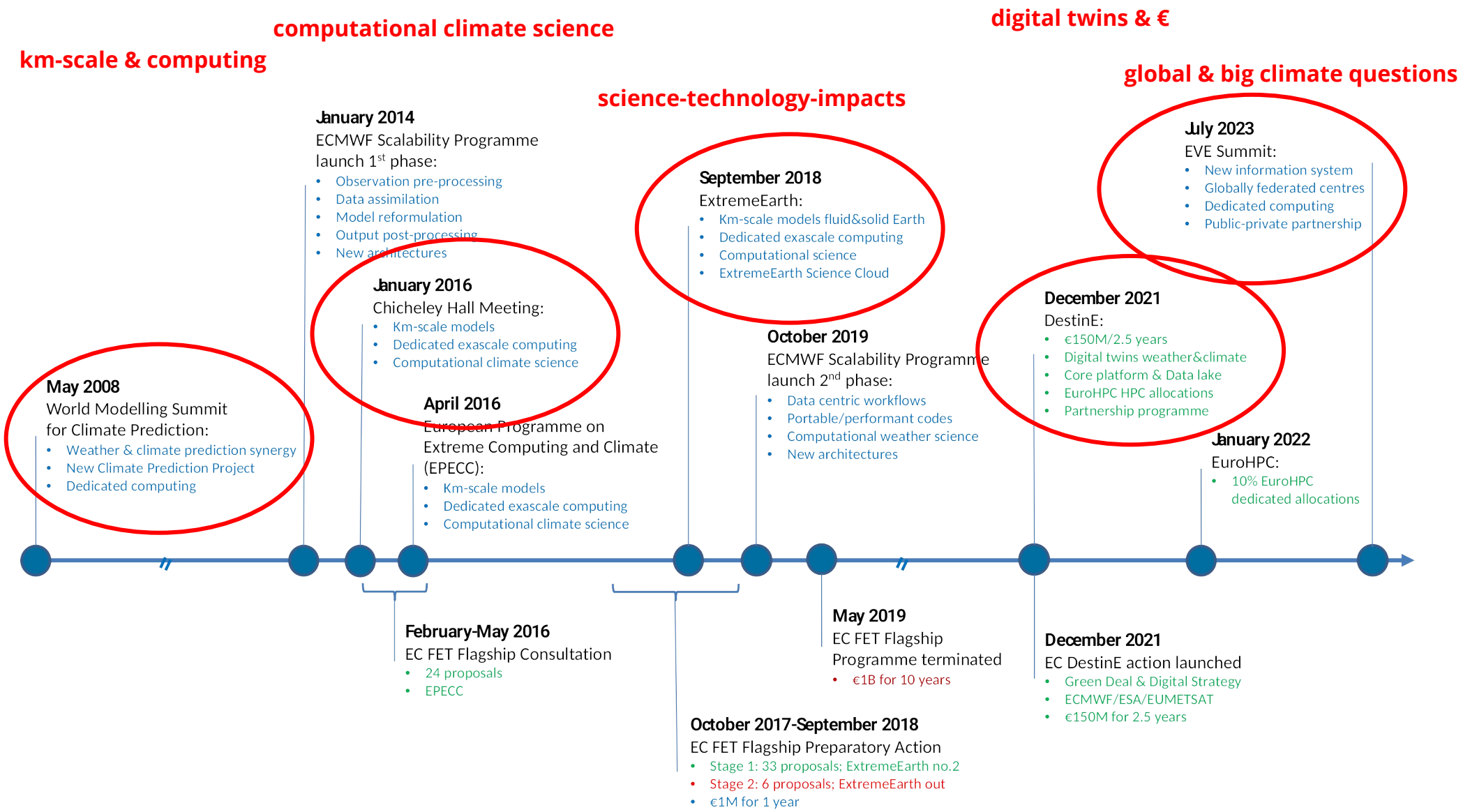
What would the June 2019 heatwave look like in a +4° climate, and what would be the impact on heat stress at city level?

Observations from Destination Earth (DestinE)

- 7-10 year flagship activity of European Union
- €150M for phase 1 (12/2021-06-2024)
- Implemented by ESA, ECMWF, EUMETSAT



History


km-scale & computing
computational climate science
science-technology-impacts
digital twins & €
global & big climate questions
May 2008
World Modelling Summit for Climate Prediction:
• Weather & climate prediction synergy
• New Climate Prediction Project
• Dedicated computing
January 2014
ECMWF Scalability Programme launch 1st phase:
• Observation pre-processing
• Data assimilation
• Model reformulation
• Output post-processing
• New architectures
January 2016
Chicheley Hall Meeting:
• Km-scale models
• Dedicated exascale computing
• Computational climate science
April 2016
European Programme on Extreme Computing and Climate (EPECC):
• Km-scale models
• Dedicated exascale computing
• Computational climate science
February-May 2016
EC FET Flagship Consultation
• 24 proposals
• EPECC
September 2018
ExtremeEarth:
• Km-scale models fluid&solid Earth
• Dedicated exascale computing
• Computational science
• ExtremeEarth Science Cloud
October 2019
ECMWF Scalability Programme launch 2nd phase:
• Data centric workflows
• Portable/performant codes
• Computational weather science
• New architectures
October 2017-September 2018
EC FET Flagship Preparatory Action
• Stage 1: 33 proposals; ExtremeEarth no.2
• Stage 2: 6 proposals; ExtremeEarth out
• €1M for 1 year
May 2019
EC FET Flagship Programme terminated
• €1B for 10 years
December 2021
DestinE:
• €150M/2.5 years
• Digital twins weather&climate
• Core platform & Data lake
• EuroHPC HPC allocations
• Partnership programme
December 2021
EC DestinE action launched
• Green Deal & Digital Strategy
• ECMWF/ESA/EUMETSAT
• €150M for 2.5 years
January 2022
EuroHPC:
• 10% EuroHPC dedicated allocations
July 2023
EVE Summit:
• New information system
• Globally federated centres
• Dedicated computing
• Public-private partnership

DestinE core principles

DestinE is based on **Digital Twins** at the core of a **new information system**

… supported by advanced, **physics-based models** and observations

… and **generic software infrastructures** for creating the most effective and convenient way to interact with data & models

… with a **user-centric** and societal impact focus

… using **distributed (public-private) hardware** infrastructures

… in an **international collaboration** framework

Déja vu

Statements and questions:

- EVE is just another climate model tied to a big super-computer …
- EVE will draw away funding (& computing) from existing climate research activities and services …
- EVE endangers existing climate service responsibilities …

… and many more

Déja vu

In the end, (a lot) is about governance:
(and DestinE challenges are also EVE challenges)

- How to create sustainable funding (coordination) at int'l level and €100sM/year/hub?
  (DestinE has budgets tied to annual work programmes)

- How to create an open access/membership model (that is truly democratic for knowledge, data, software)?
  (DestinE requires EU membership or association with Digital Europe Programme)

- How to access & sustain necessary HPC & data infrastructures, and how to federate those?
  (from EuroHPC for DestinE, regulated by JU and individual HPC centre policies)

- How to best engage with commercial companies?
  (not yet addressed by DestinE; focus on European technology providers)

- How to define EVE service element and complement existing services?
  (being defined between DestinE and Copernicus)

- How to create and sustain a continuous draught from science & technology R&D into production?
  (for DestinE from Horizon Europe Programme, and national programmes)

Recommendations

There is an opportunity here as DestinE is an existing, funded*, international programme based on the same *science-technology-impact* philosophy as EVE

This philosophy evolved (scaled) over time, but can the organisational form be scaled up?

→ *integrate DestinE's science-technology-impact nexus as a first step, learn lessons and adapt to new ambitions & constraints*

Lesson no. 1:
→ *we have underestimated the power of ML: ML may well be the saviour of Digital Twins*

Lesson no. 2:
→ *we have underestimated the power of industry: Big Tech companies may well be the saviours of the big tech tasks: HPC and ML for everything* *(subject to public-private win-win governance solutions)*

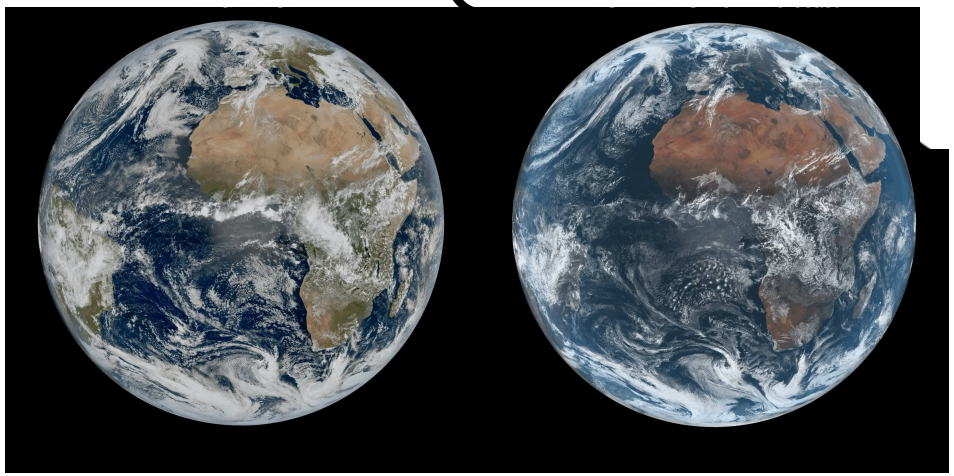
*** the European Commission is investing >€60M/year in this high-risk – high-gain project!**

Informing future observing systems

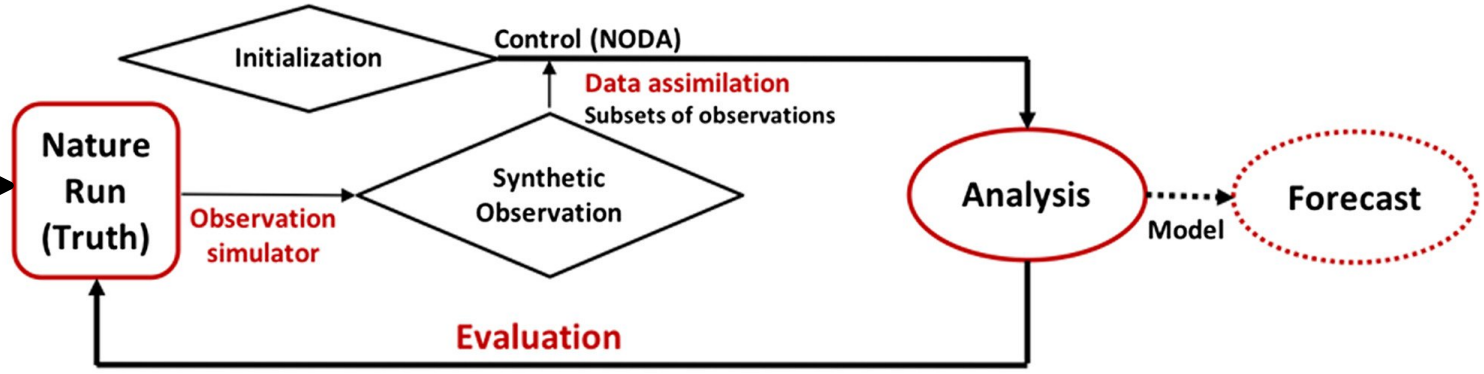
Terminology for tools used to assess value of observations (for NWP):

- Built-in quantification of degrees of freedom of observation (**DFS**) and Forecast Sensitivity to Observation Impact (**FSOI**): calculate change in metrics based on information theory as part of objective methods
- Observing System Experiments (**OSE**): run experiments adding/withdrawing observations and check skill
- Observing System Simulation Experiments (**OSSE**): assimilate simulated/novel observations in reference trajectory and check skill

Reference simulations



P. Lopez, B. Vanière for Destination Earth



A flowchart of Observing System Simulation Experiment (OSSE) Li et al. 2019

What can we contribute to future ground & space-based system design?