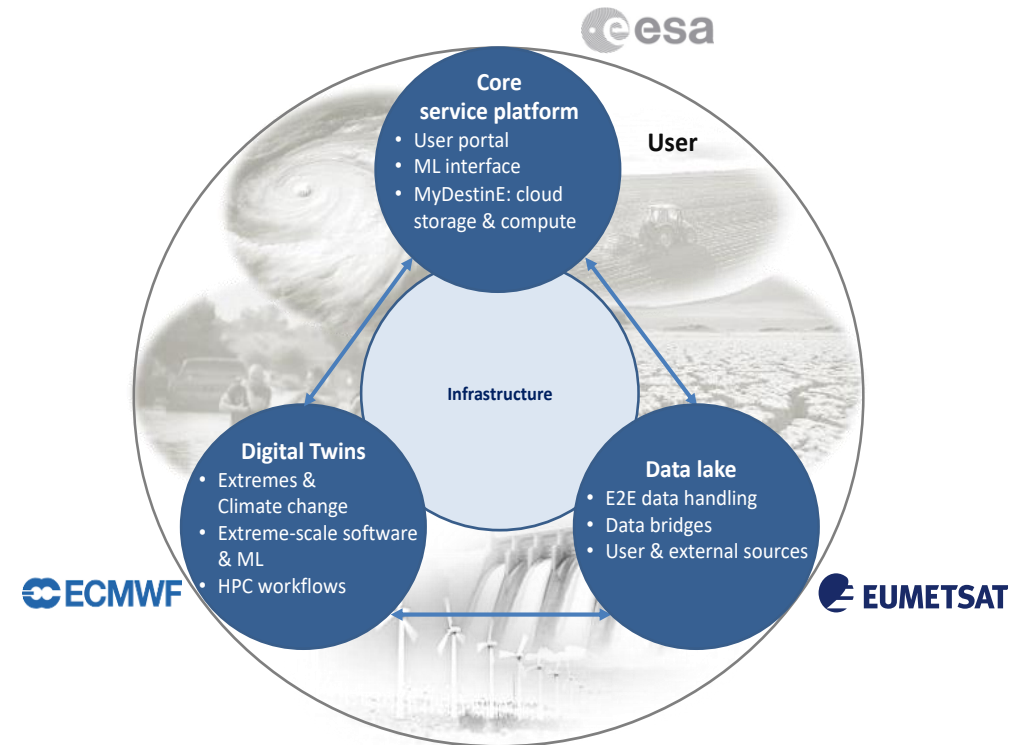


European's Commission Destination Earth (DestinE) programme



Irina Sandu & Peter Bauer, ECMWF

@irinasandu_ec

DestinE formal announcement

Aim and goals

Key initiative, announced in:

A European Green Deal (2019)

A European strategy for data (2020)

Shaping Europe's digital future (2020)



Develop a **very high precision digital model of the Earth (Digital Twin)** of the Earth to monitor and simulate natural and human activity and to develop and test scenarios for

- more sustainable development and achievement of the EU green deal objectives
- saving lives
- avoiding large economic downturns
- **support EU policy-making and implementation**
- reinforce Europe's industrial and technological capabilities in advanced computing, simulation, modelling, predictive data analytics and Artificial intelligence (AI)

DestinE candidate implementation



- **Lead and business owner: European Commission (DG CONNECT)**
- **Strategic partnership** with ESA-ECMWF-EUMETSAT
- Responsibilities:
 - **ESA : key role of system integrator and implementer of the core platform**
 - ECMWF: Digital Twin implementer
 - EUMETSAT: responsible for the big data lakes and data integration
- Formal organization: **“contribution agreements”** by summer 2021

2021-2023

- Operational cloud-based platform
- First two digital twins

2023-2025

Platform integrates the next operational digital twins and offers services to public sector users

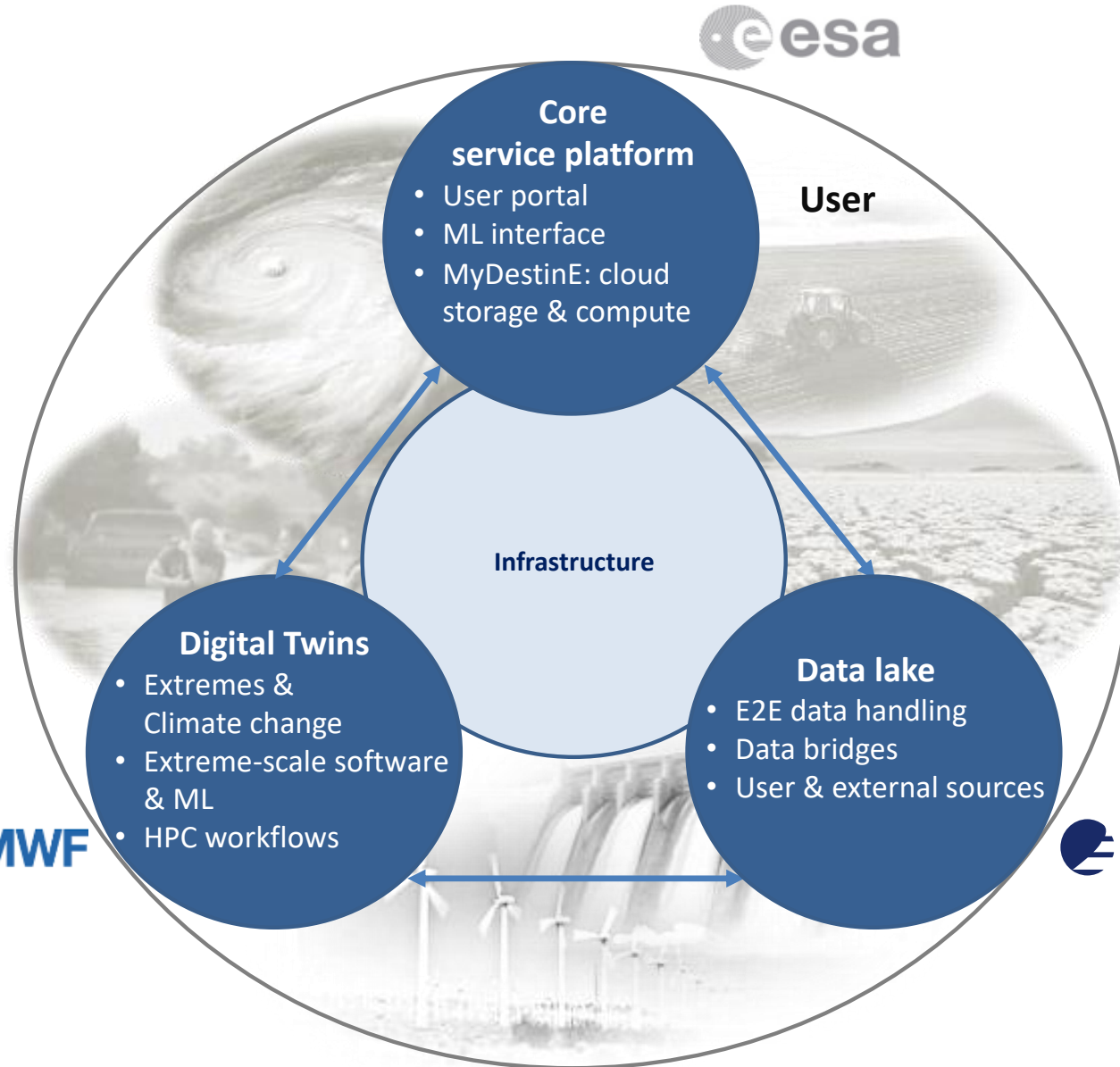
2025-2027+

Towards a full “digital twin of the Earth” through a convergence of multiple digital twins on the platform

DestinE partnership



Governance incl. external advice



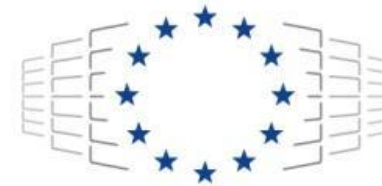
DestinE partnership

DestinE will engage in continuous partnerships to co-evolve its components and deliverables → complementarity!

- Science
- Technology
- Services
- Infrastructures



EUMETSAT



EuroHPC
Joint Undertaking



WORLD
METEOROLOGICAL
ORGANIZATION



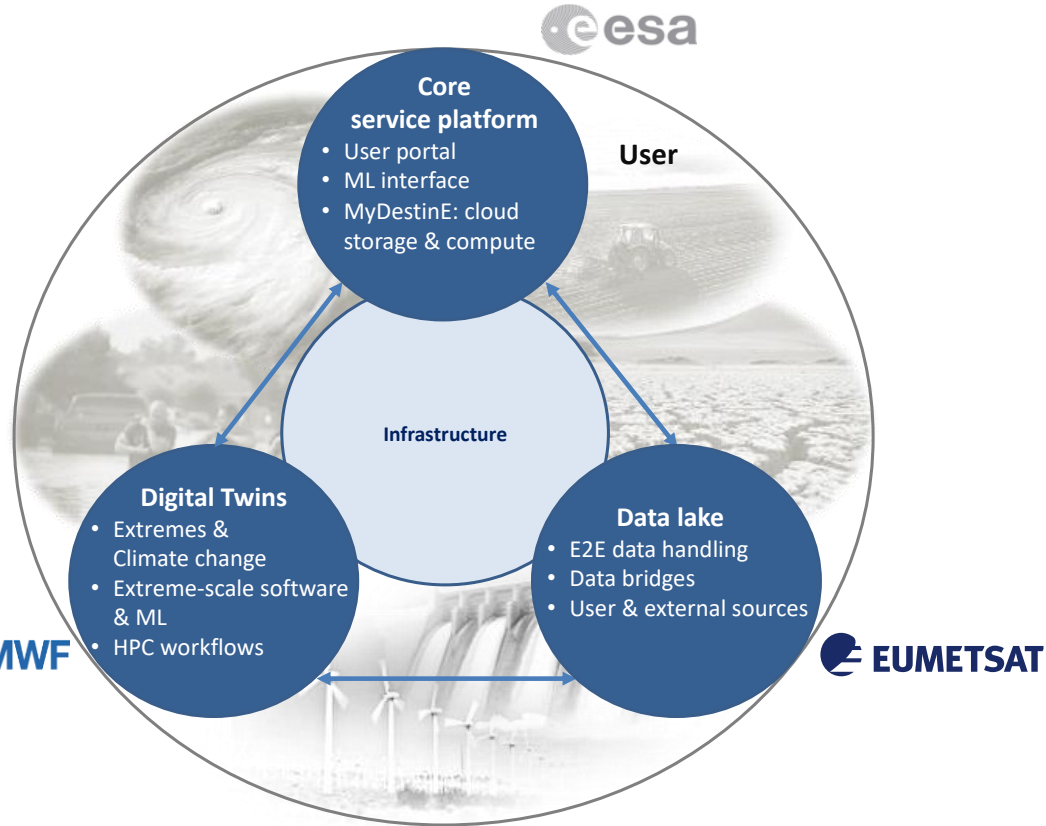
TCI
TransContinuum Initiative



European
Commission

ECMWF Member States

High-priority Digital Twins in DestinE



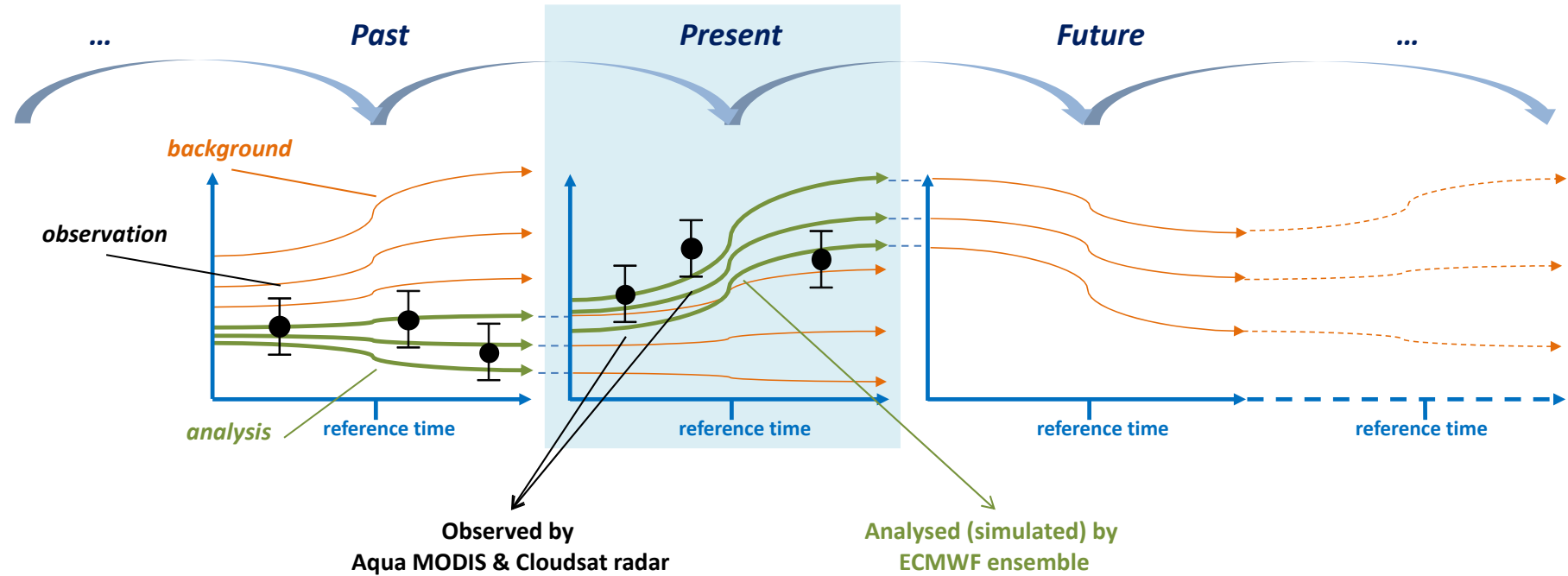
Weather-induced and Geophysical Extremes:

Environmental extremes at very high spatial resolution and close to real-time decision-making support at continental, country, coastline, catchment and city scales in response to meteorological, hydrological and air quality extremes

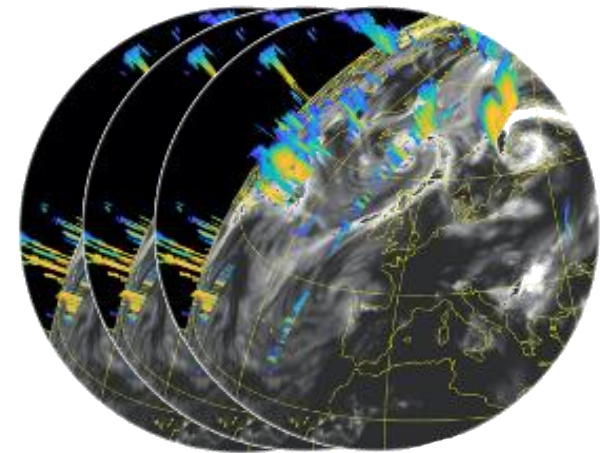
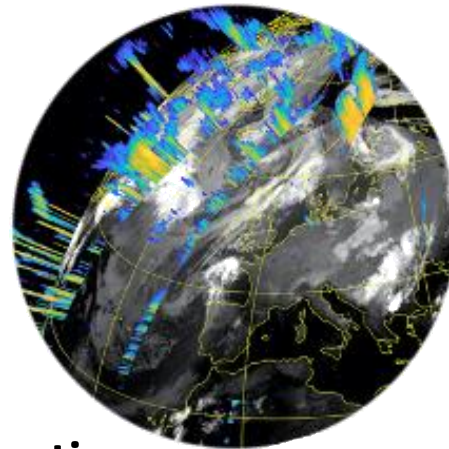
Climate Change Adaptation:

Climate change adaptation policies and mitigation scenario testing at multi-decadal timescales aiming at a real breakthrough at the level of reliability at regional and national levels, for understanding the causes and explaining the feedback mechanisms of change, and predicting possible evolution trajectories

Digital Twin Engine builds on advances in NWP science



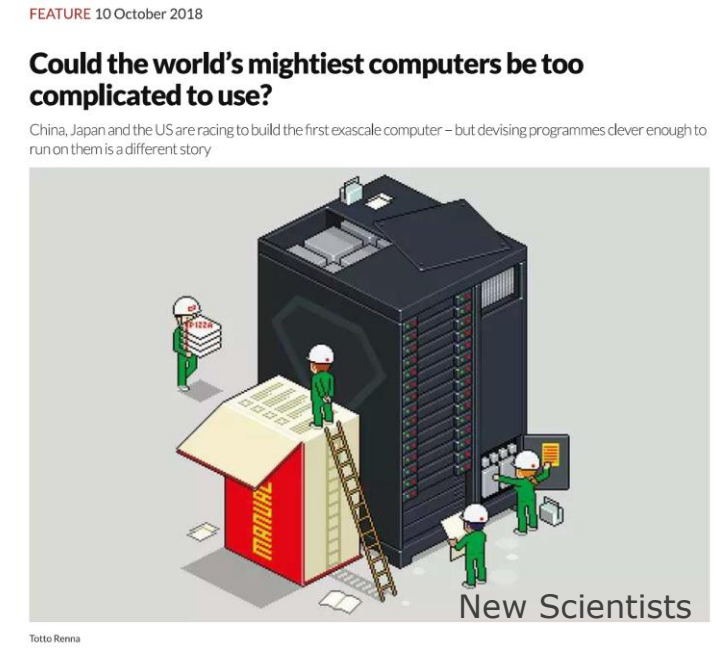
- continuous **simulation & observation**
- **performance** monitoring & prediction
- **science user interaction**
- scientific theory and adaptation **scenario testing**



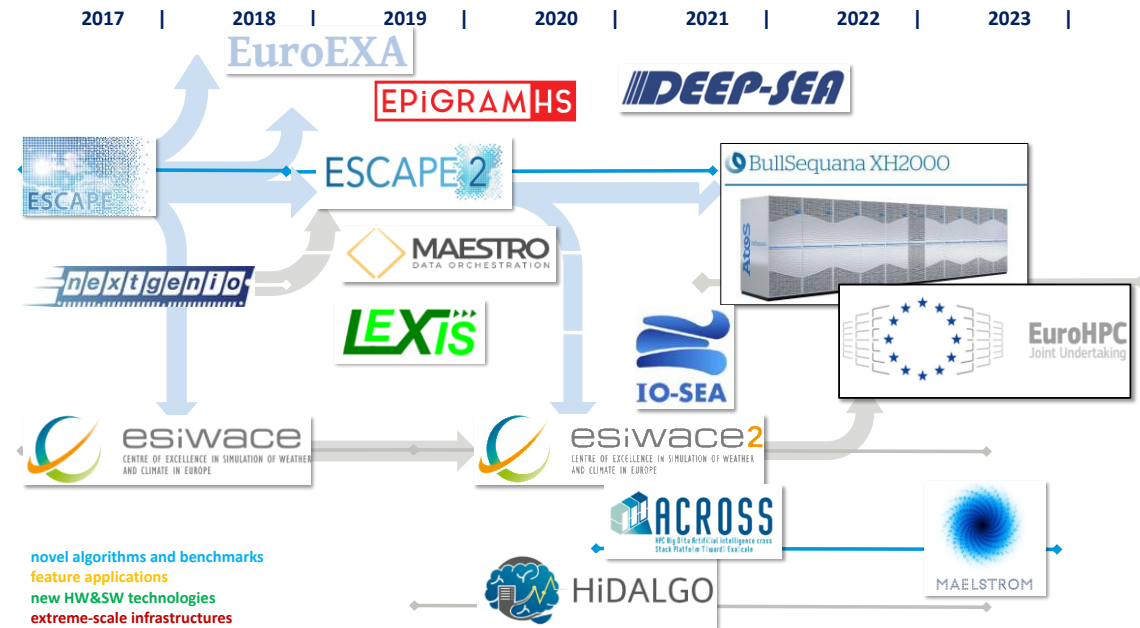
*Bauer et al. Nature Comp. Sci., 2021
Courtesy Mark Fielding and Marta Janiskova*

Digital Twin Engine builds on advances in technology and scalability

Input data = $\sim 10^8$ observations/day + IoT; Output data = PBs/day; Compute = ~ 100 PFLOP/s:



Projects with ECMWF lead/partner roles supported by DG CNECT's FET-HPC & EuroHPC programmes:



→ Programming

→ Algorithms

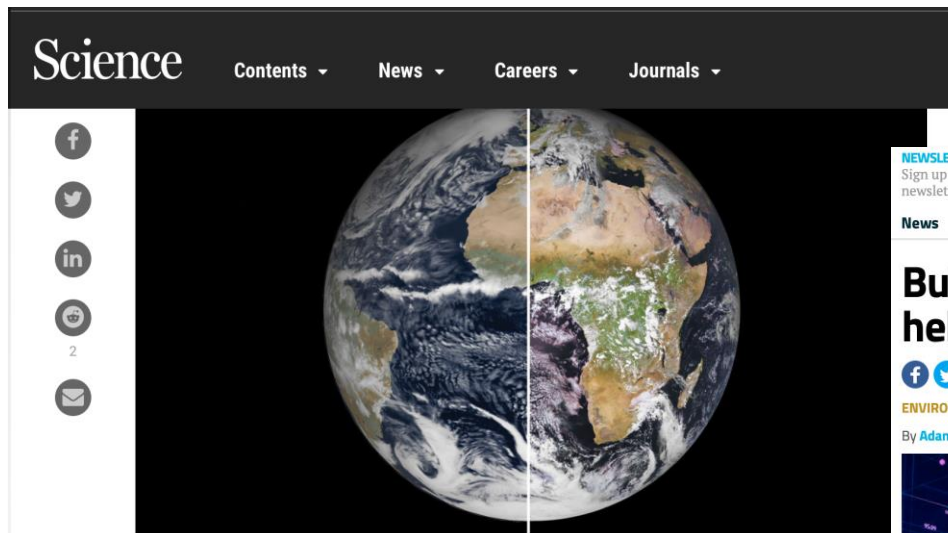
→ Architecture

→ Data handling

→ Centres of Excellence

DestinE break-throughs

- 1. Extreme-scale computing and data handling**
= much more realistic models + better combination of simulations + observations
- 2. Full integration of policy sectors in workflow**
= Earth-system + energy + food + water + finance
- 3. Open and interactive access to data, software and workflows**
= non-expert access and intervention



At 1-kilometer resolution, a European climate model (left) is nearly indistinguishable from reality (right). (LEFT RIGHT) ECMWF; © EUMETSAT

Europe is building a 'digital twin' of Earth to revolutionize climate forecasts

By Paul Voosen | Oct. 1, 2020, 10:40 AM



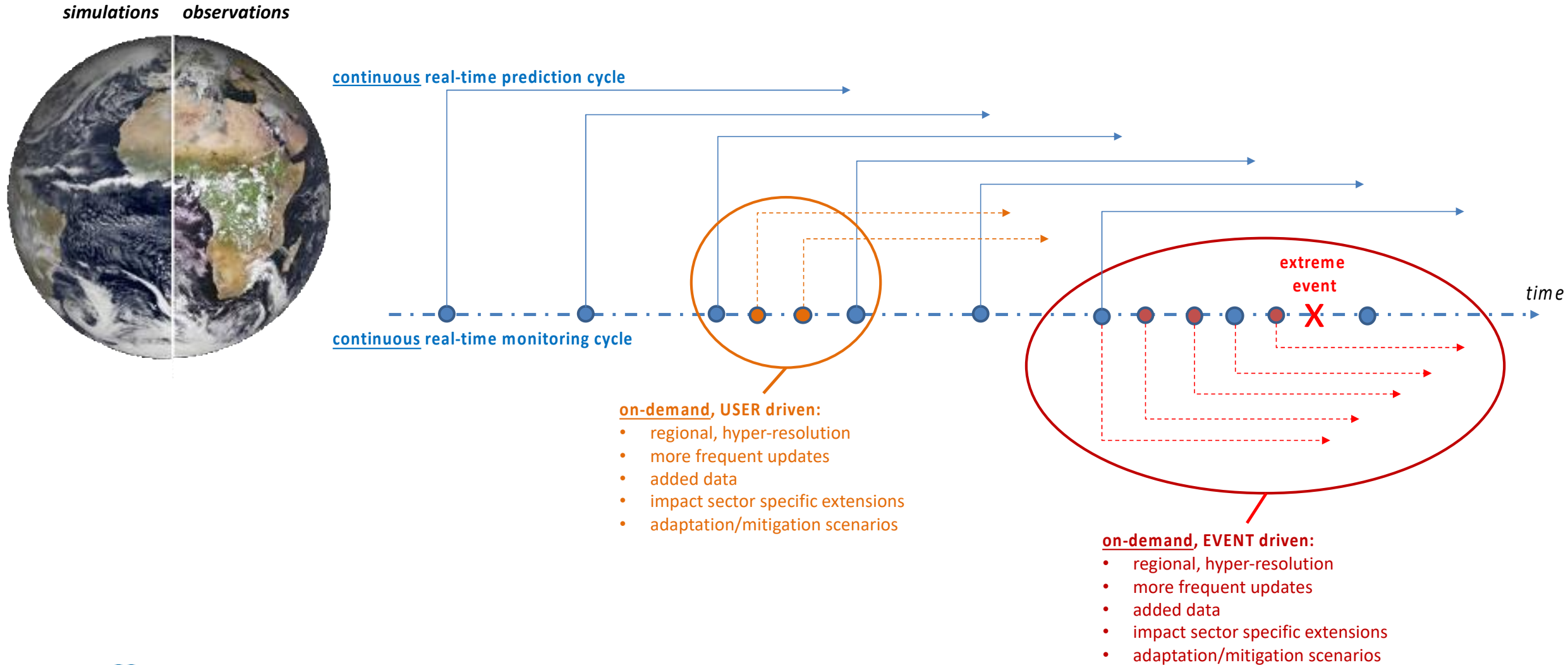
HPCwire

Since 1987 - Covering the Fastest Computers in the World and the People Who Run Them



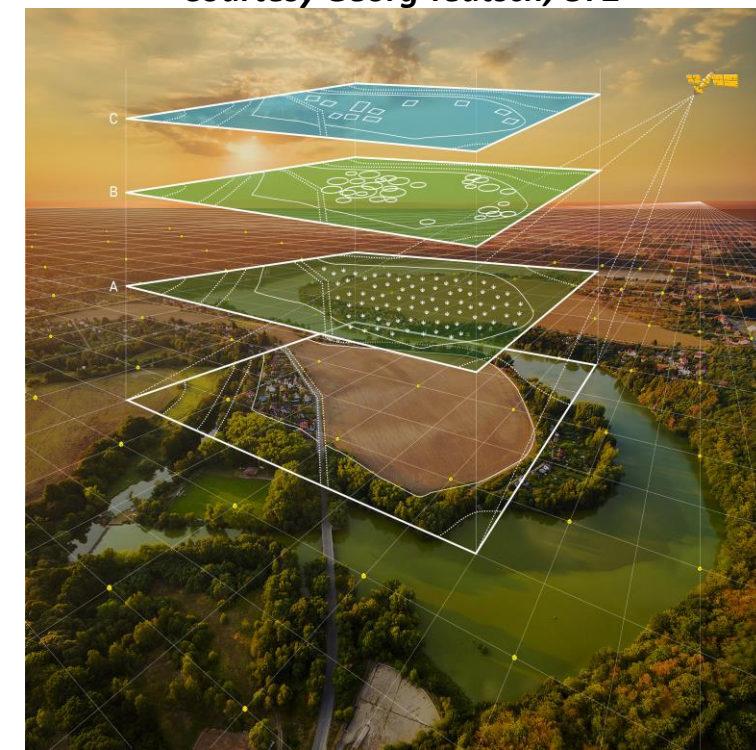
October 10, 2020

Digital Twin production modes

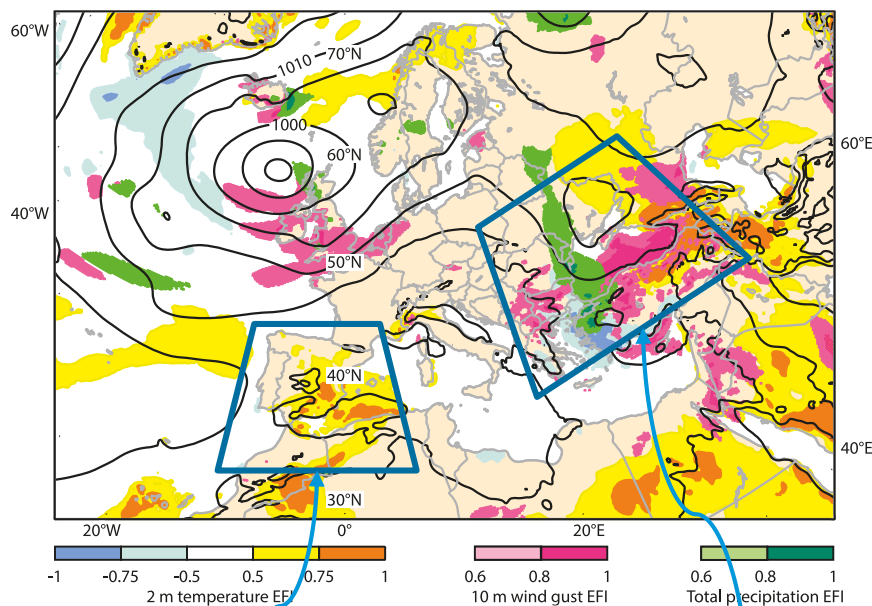


New levels of flexibility: on-demand downscaling & configuration

Courtesy Georg Teutsch, UFZ



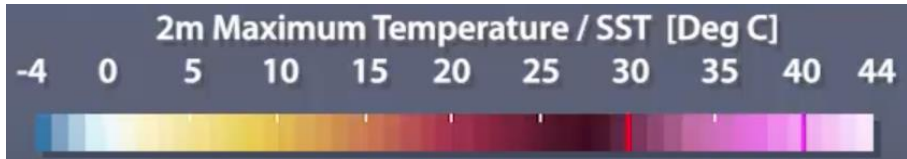
- simulation – observation fusion
- hyper-resolution limited-area nesting
- extreme-type added components
- more value-chain components
- adaptation & mitigation planning



heat/drought case

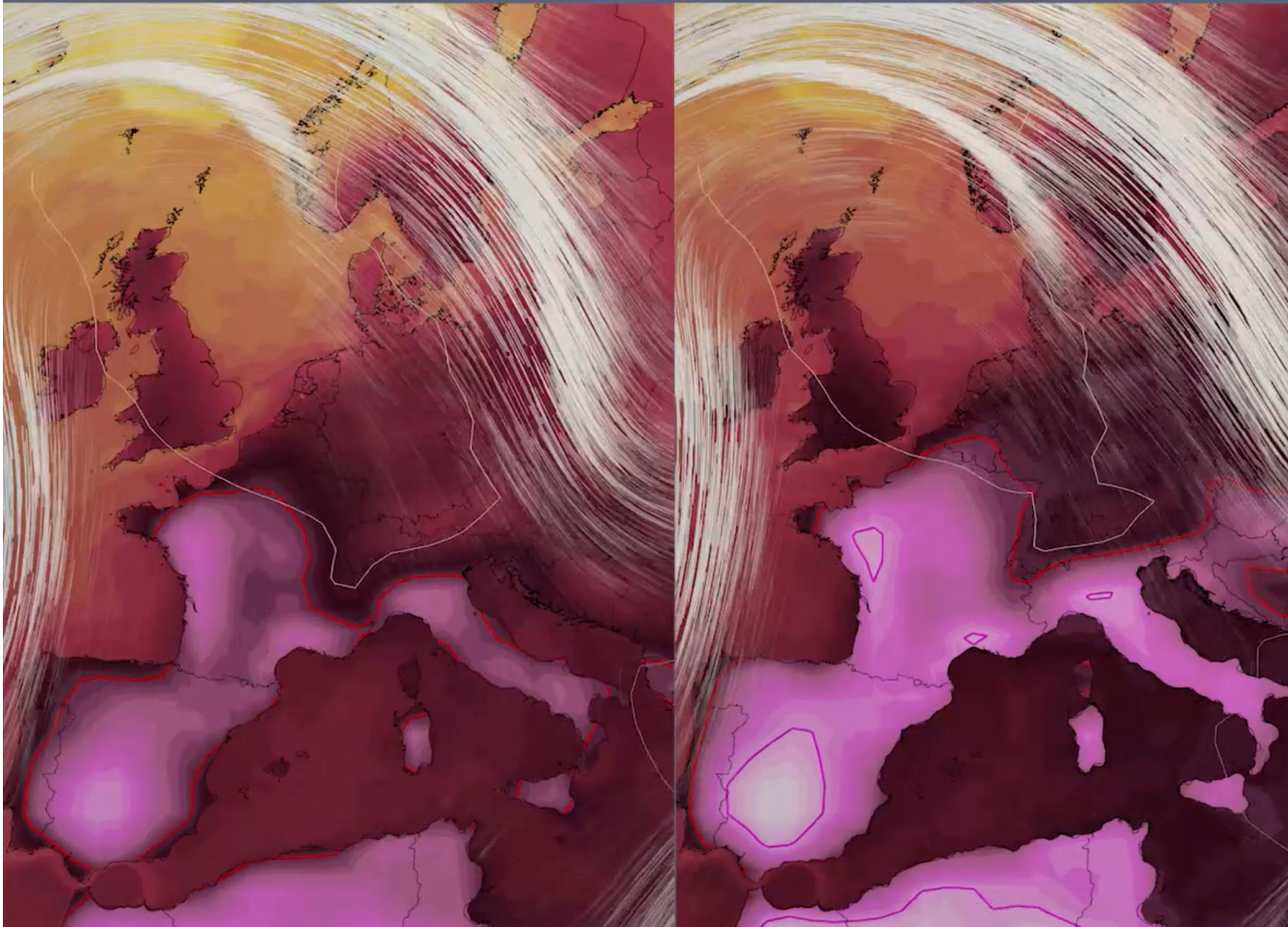
wind-storm/flooding case

Future weather under climate change



28.06.2019 11:00

2095



What would the June 2019 heatwave look like in a +4° climate?

HELMHOLTZ
CLIMATE INITIATIVE
Courtesy Thomas Jung, AWI

'Hanging' glacier broke off to trigger India flood



Soutik Biswas
India correspondent

22 hours ago | Comments



Climate change



DestinE: Full integration of Earth-system & impact-sector modelling

Earth-system &
impact-sector modelling

Earth system
modelling



Impact sector
modelling



Integrated Earth-system &
impact-sector modelling

Earth system
modelling

Impact sector
modelling

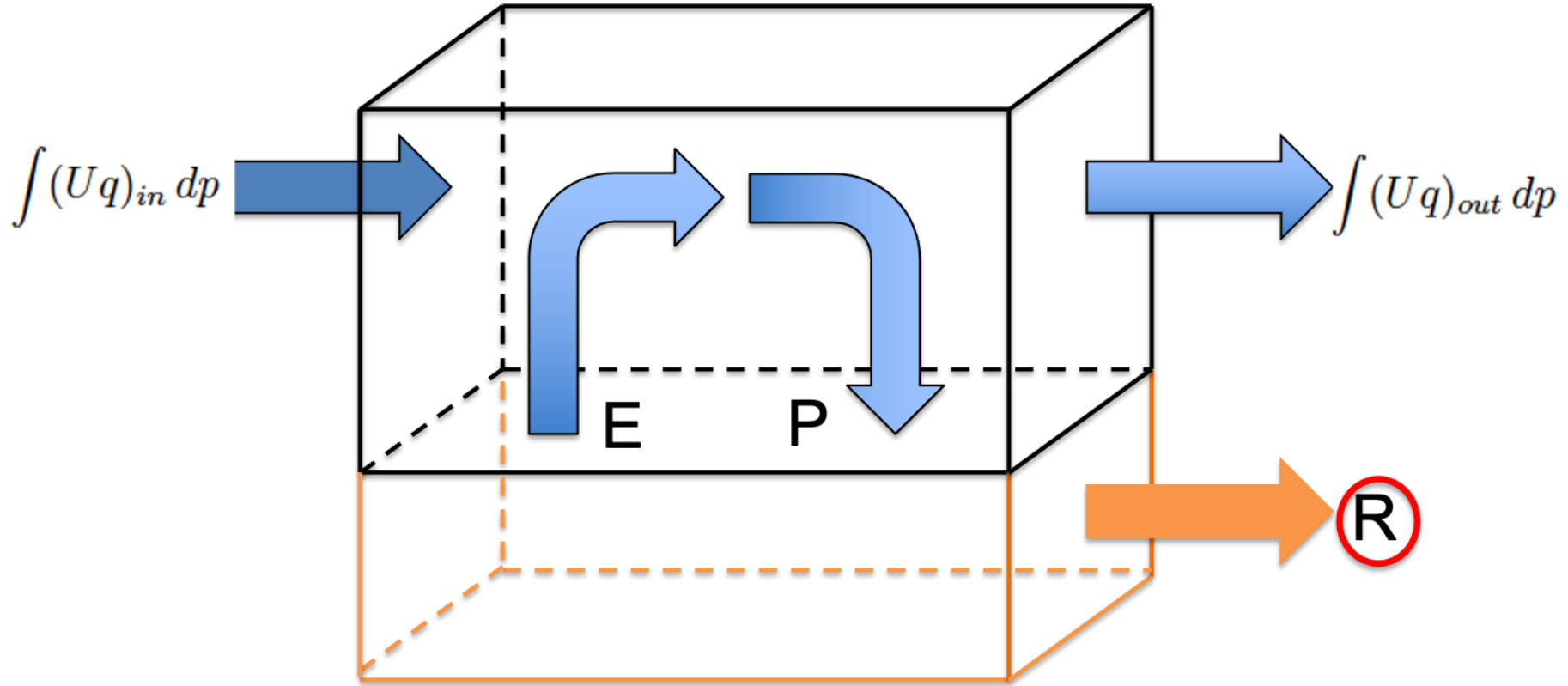


Codesign with users



Atmosphere: $\frac{\partial}{\partial t} \int q dp + \frac{\partial}{\partial x} \int Uq dp + \frac{\partial}{\partial y} \int Vq dp = \underbrace{E}_{\text{Evap.}} - \underbrace{P}_{\text{Precip}}$

Change of total column water vapour (negligible for monthly time scale) Moisture divergence

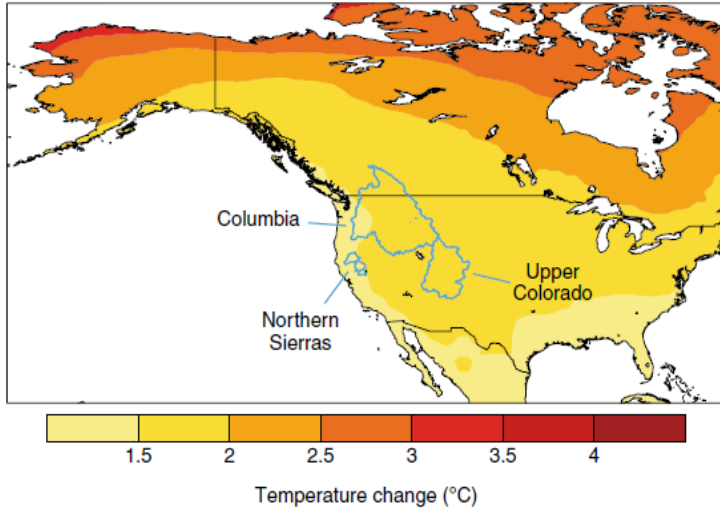


Soil: $\frac{\partial}{\partial t} \int \theta dz = \underbrace{P}_{\text{Precip}} - \underbrace{E}_{\text{Evap}} - \underbrace{R}_{\text{Runoff}}$

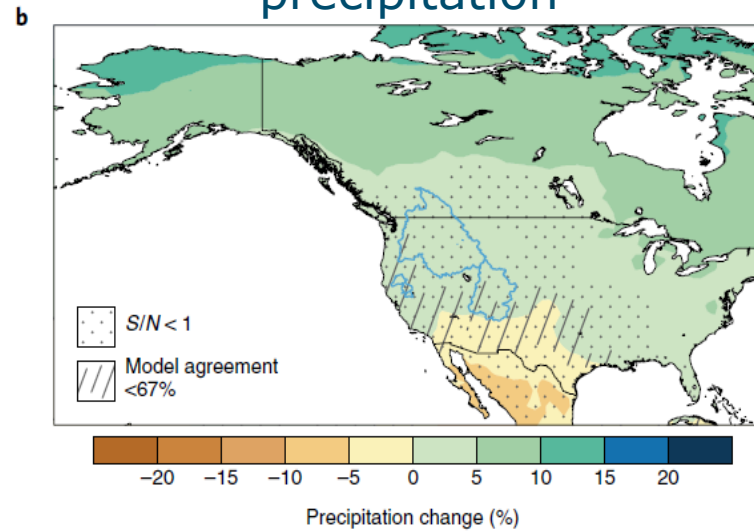
Change of soil moisture Precip Evap Runoff

Projected changes in CMIP5 (2000-2058 - 1950-2008) :

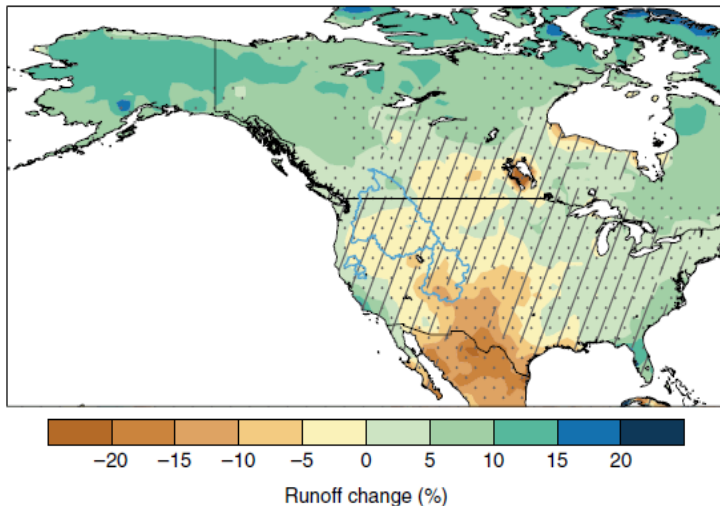
temperature



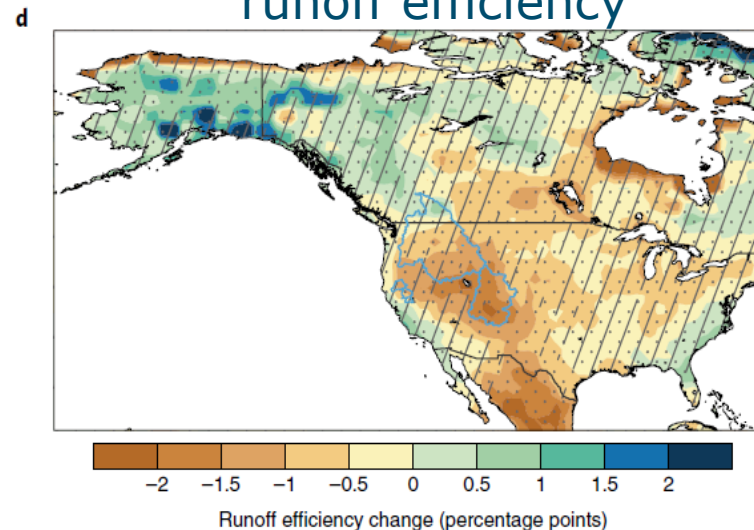
precipitation



runoff



runoff efficiency



The potential to reduce uncertainty in regional runoff projections from climate models

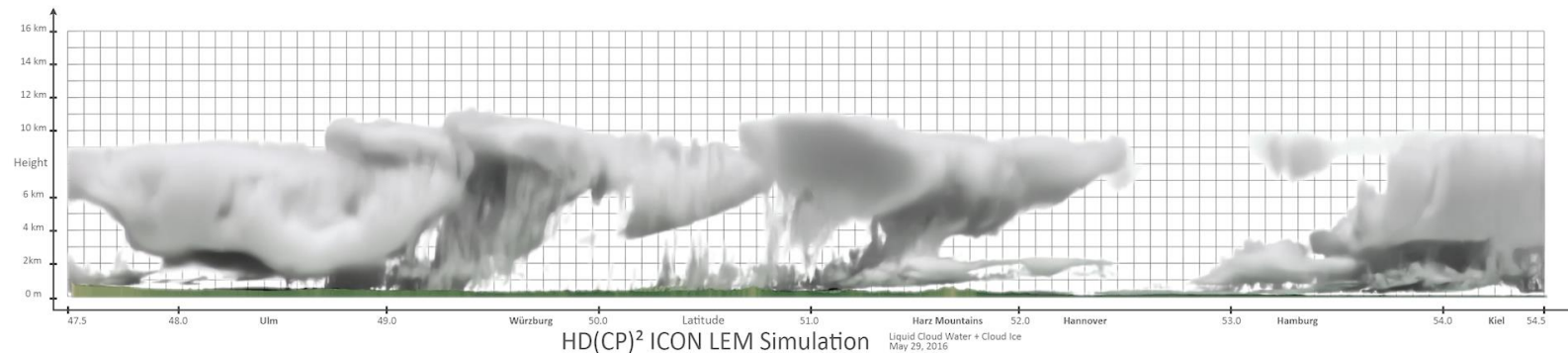
Flavio Lehner^{1,2,3*}, Andrew W. Wood², Julie A. Vano^{2,4}, David M. Lawrence¹, Martyn P. Clark⁵ and Justin S. Mankin^{6,7,8}

Coordinated model development efforts between the atmosphere/land and hydrology communities are strongly encouraged

DestinE will allow to make rapid progress in this direction and towards a fully integrated Earth-system - impact sector modelling framework

In summary – DestinE:

1. addresses (one of) the most critical challenges of our time
2. builds on decades of European excellence in Earth system science & digital technology
3. promises unprecedented impacts on society, science & technology
4. presents opportunities to demonstrate power of EuroHPC



*Simulations courtesy MPI-M Hamburg
Produced on Mistral @ DKRZ*

More info on DestinE

European Commission

- <https://ec.europa.eu/digital-single-market/en/destination-earth-destine>
- https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/shaping-europe-digital-future_en
- https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

Science and Nature

- <https://www.sciencemag.org/news/2020/10/europe-building-digital-twin-earth-revolutionize-climate-forecasts>
- https://www.nature.com/articles/s41558-021-00986-y?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+nclimate%2Frss%2Fcurrent+%28Nature+Climate+Change+-+Issue%29
- <https://www.nature.com/articles/s43588-021-00023-0>

Other

- <https://www.newscientist.com/article/2256715-building-digital-twins-of-earth-could-help-europe-cut-carbon-emissions/>
- <https://www.hpcwire.com/2020/10/10/eu-to-create-digital-twins-of-earth-run-on-eurohpc-supercomputers/>
- <https://geographical.co.uk/nature/climate/item/3940-the-eu-announces-plans-to-build-destination-earth-a-digital-twin-of-our-planet>

... thanks to many people having worked on this for months