



Summary report

Second Destination Earth User eXchange

November 13-14, 2023
Bonn, Germany



Funded by
the European Union

Destination Earth

implemented by



The objective of the User eXchange series is to encourage participation and dialogue between the different actors involved in DestinE and to create a space for discussion, progress and new opportunities.



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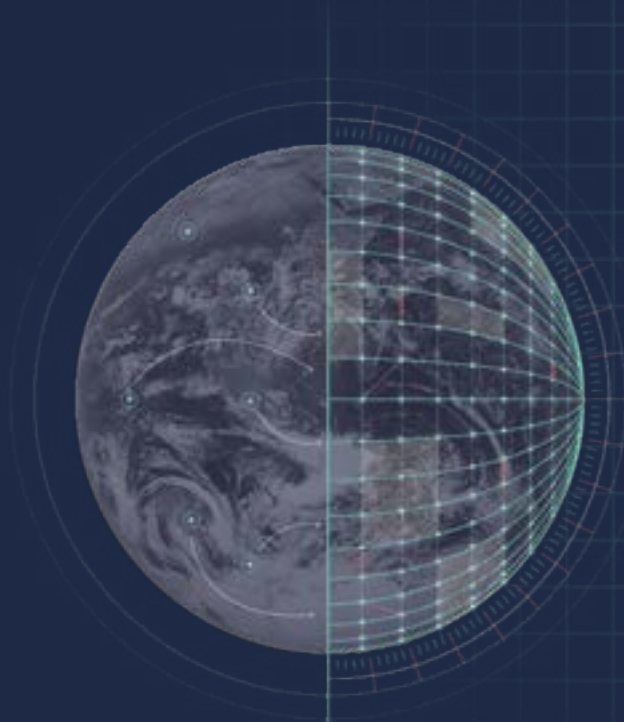
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“The 2nd DestinE User eXchange was an exciting, productive and inspiring event. DestinE aims to push the boundaries of what is possible today in this area and users are an integral part of it and central to its success.”

Charalampos Tsitlakidis, Team Leader for Destination Earth
European Commission



REPORT



“Destination Earth has the capacities to monitor, simulate and predict the interaction between natural phenomena and human activities. This initiative, your initiative, will contribute to achieving the objectives of the twin transition, green and digital, and with this, we will be better prepared to respond to major natural disasters, adapt to climate change and predict the socioeconomic impacts.”

Leena Ylä-Mononen, Executive Director
European Environment Agency

Im

Summary

The implementation of Destination Earth (DestinE) follows a co-design paradigm. Strong and continuous dialogue with relevant stakeholders is a critical element of the initiative. The second DestinE User eXchange convened the wider community involved with, and interested in, DestinE. The widespread attention given to this eXchange and the lively discussions during the event testified to the great expectations and interest in DestinE developments.

The entities entrusted with the implementation of DestinE: ECMWF, ESA, and EUMETSAT, informed on the progress made during the current development phase regarding all DestinE System Components. The teams and stakeholders engaged in several thematic use cases discussed their progress and anticipated the impact for a variety of sectors.

Several panels in different sessions involved representative users, as well as science and technology stakeholders to discuss needs and opportunities for developing DestinE further. These panels strongly confirmed the continued need for DestinE and the importance of the co-design paradigm, notably via use-case implementations, as well as recommending strong linkages to related developments in Europe and beyond.

1 Introduction

Destination Earth (DestinE) is an ambitious initiative of the European Commission to build a novel information system, a Digital Twin of the Earth system, to support policy development and decision making. The Commission has entrusted the European Centre for Medium-range Weather Forecasts (ECMWF), the European Space Agency (ESA), and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), with the implementation of DestinE.

Broad stakeholder engagement for DestinE is key to the success of the initiative. An open stakeholder dialogue aimed at the wider community ensuring engagement of all relevant players is thus implemented to support this. The DestinE User eXchange is a central building block of this dialogue.

The User eXchange contributes to building a DestinE community and provides a space for informing about progress in implementing DestinE, collecting needs and understanding plans of users, collecting feedback on usability and fitness-for-purpose, as well as presenting an opportunity to exchange on related developments in Member States, at European and international level. A first DestinE User eXchange took place on February 15, 2023 at ESA-ESRIN (Frascati).



Building a DestinE community

The second DestinE User eXchange on November 13-14, 2023 was hosted by ECMWF in Bonn, i.e. 7.5 months before the end of the DestinE's first development phase and the opening of the system to users. It convened the community of stakeholders already engaged and interested in the development activities during the first phase of DestinE. The event aimed at demonstrating progress and strengthening and engaging the forming

community. Specific targets were to:

- inform stakeholders about the progress on the DestinE System Components and use cases;
- confirm the development path;
- explore future avenues for interaction and engagement.

Registration by country

The 2nd DestinE User eXchange was organised as a 1.5 day event and attracted 200 participants on-site with 231 joining online.

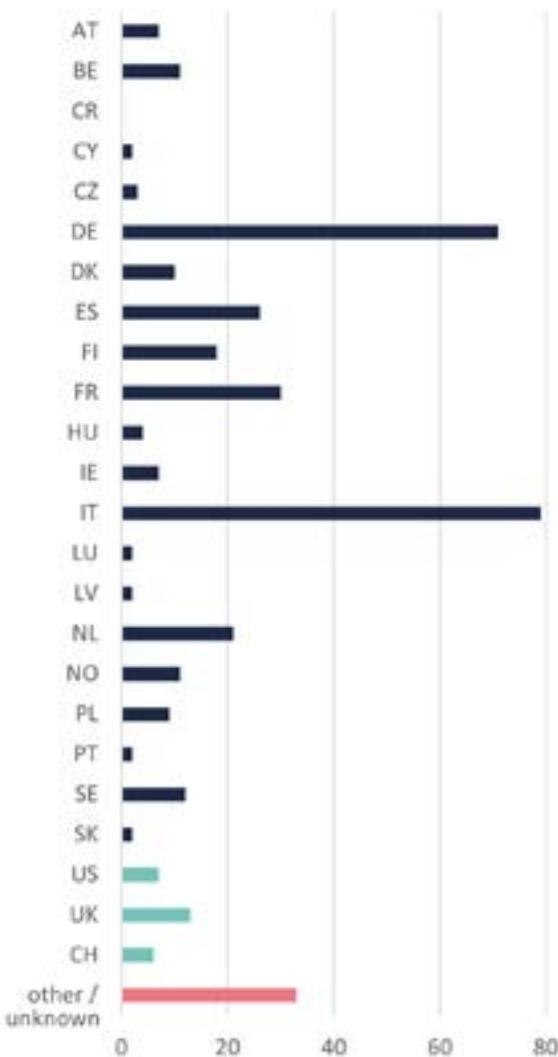


Fig. 1 Number of registrations by country (excluding ECMWF, ESA and EUMETSAT registrations)

The programme included a total of 14 topical sessions, including plenaries and a poster session on the first day, whilst the second day followed sessions held in two parallel tracks. (full programme included as Annex A).

2 Opening

Florence Rabier, Director General of ECMWF, opened the 2nd User eXchange, welcoming participants and commending DestinE as a timely initiative to address the accelerating impacts of climate change. Rabier outlined how DestinE leverages EuroHPC supercomputers, enabling detailed simulations and unprecedented interactivity.



Florence Rabier, Director General of ECMWF

Users will be able to assess the short-term impact of storms on energy production and foresee future extreme events, especially in cities and heatwaves. As such DestinE aims to enhance decision-making capabilities. DestinE she explained, builds on past achievements in weather forecasting at ECMWF and integrates machine learning, overcoming the limitations of current systems. Destination Earth is a European initiative that demonstrates the value of EuroHPC, showcases technological advancements, and has a growing user base, positioning Europe at the forefront of addressing climate change through innovative, data-driven solutions.

Overall, DestinE emerges as a comprehensive and innovative solution addressing challenges of climate change and advancing the capabilities of decision-makers across various sectors.

Gustav Kalbe, Acting Director for the Digital Excellence and Science Infrastructures at the European Commission's Directorate General Communications Networks, Content and Technology (DG CNECT)

recalled the objectives of DestinE to build a digital twin; a new type of information system to support evidence-based decision making in the green transformation. He stressed the continued importance of this investment in the face of extreme events and climate change.



Gustav Kalbe, Acting Director for the DG CNECT

Mr. Kalbe celebrated the progress made since the 1st User eXchange in Frascati, Italy, hosted by ESA in February 2023 on configuring, deploying and demonstrating the initial infrastructure, and emphasized that Phase 2 will expand the user base, data sources and service offering of DestinE. Looking to Phase 2, he also expected the use of Artificial Intelligence (AI) in DestinE to grow, increasing the efficiency and impact of DestinE, but also benefiting the European AI industry. He recognized the importance of the User eXchange in building and engaging a DestinE community and encouraged participants to make the most of the two days of exchanges.

Kicking-off the second day of the User eXchange, **Leena Ylä-Mononen, Executive Director of the European Environment Agency** placed DestinE in the context of the European Union's priority objective for 2030 of "Living well within planetary boundaries", emphasizing a climate-neutral and resource-efficient economy that recognizes the dependence of human wellbeing on healthy ecosystems. She recalled that recent years have seen humanity cross several planetary boundaries, including on climate change and biodiversity. Looking at significant economic losses and fatalities due to climate extremes over the last 40 years, Ms. Ylä-Mononen emphasised the need for strategic investments in climate mitigation and adaptation measures to build resilience of key sectors (e.g. energy, mobility, agriculture, and industry).



Leena Ylä-Mononen, Executive Director of the European Environment Agency

She called for expedited implementation of solutions to address the interconnected social, economic, and environmental crises, particularly in key sectors like food, energy, infrastructure, and transport. Effective solutions require synergies between policy objectives and the creation of conditions for transformative decision-making. Knowledge is crucial in addressing climate challenges, and

so the DestinE initiative, with its monitoring and simulation capabilities, can contribute to improved assessments and responses.

Ms Ylä-Mononen saw the importance of DestinE in facilitating green and digital transitions for societal preparedness, supporting linkages between these transitions, investment, innovation, cost-effective solutions, comprehensive legislation, improved implementation, increased preparedness, and global integration.

3 Progress



Irina Sandu, Director for Destination Earth at ECMWF

Irina Sandu, Director for Destination Earth at ECMWF introduced DestinE as a comprehensive initiative involving the creation and utilization of digital twins for Earth system modelling. DestinE aims to capture the evolution of various systems, allowing users to explore climate change and extreme events at different scales. DestinE is formed of three components: the Earth System Digital Twin Engine (DTE) with the two digital twins (DTs), the Data Lake (DEDL), and the Core System Platform (DESP). Key characteristics of the digital twins include quality, impact analysis, and interactivity.

The digital twin for Climate Change Adaptation ('Climate DT') aims to provide multi-decadal climate projections at kilometre scale, supporting adaptation planning. The digital twin for Weather-induced Extremes ('Extremes DT'), operating continuously at a 2-4km global scale, or on-demand at sub-kilometre scale, enhances resilience to disasters and supports disaster risk management. Sandu stressed that both twins were developed with a large consortia involving leading capacities in Europe.

The DTE facilitates simulations on EuroHPC systems and big-data management, incorporates machine learning, tailors information to user needs, and enhances interactivity. She summarized that by the end of the first DestinE development phase in June 2024, DestinE workflows will have been established, models adapted to EuroHPC, data handling software developed, data processing capabilities piloted, and interactive visualization capabilities deployed. By then, the Core Platform, the Data Lake, and the Digital Twin data streams will open to users.

Michael Schick, DestinE System Manager at EUMETSAT presented the implementation of the DestinE Data Lake (DEDL). The DEDL is a self-standing component with geographically distributed physical elements. It facilitates seamless access to data based on a Harmonization of Data Access (HDA). The architecture provides access to Digital Twin data, implements data federation, is built on distributed infrastructures, and implements the DTE-DEDL Reference Architecture Interface. Increment #1 of the DEDL was accepted in October 2023 and is now ready for integration with the DTE and DESP.

The DestinE Data Portfolio facilitated by DEDL includes digital twin data from the Climate DT and Extremes DT, external federated datasets from various satellite missions and other sources, as well as user-generated data.



Michael Schick, DestinE System Manager at EUMETSAT

The Data Lake supports big data processing, including distributed computing, workflows, and support for the data preparation of Artificial Intelligence / Machine Learning (AI/ML) applications.

Mr. Schick stressed the crucial importance of data governance, covering data classification, policy, stewardship, access control, lifetime and retention management, attribution, provenance, and quality.

Danaële Puechmaile of EUMETSAT then reported that EUMETSAT had organized workshops to identify use case candidates for the Data Lake. These span applications in agriculture, biodiversity, health, energy, and potentially AI/ML. She also highlighted existing applications funded by EUMETSAT in domains such as drought, flooding and hydrology, demonstrating direct usage of developed DEDL services.

Kathrin Hintze, Deputy DestinE Project Manager at ESA presented the DestinE Core Service Platform (DESP), a comprehensive and open digital ecosystem designed to exploit and make the most out of DestinE Data. She reported that the platform, currently in its alpha version, had undergone significant progress, transitioning from a complex concept to a

tangible reality within nine months. The cloud infrastructure below DESP ecosystem will be provided by OVHCloud.

DESP she explained, has adopted a service approach, efficiently managing resource allocation, scalability, and high standards of quality and performance. It operates 24/7 with a commitment of straightforward information and support. Users play a central role, being active contributors to DESP evolutions through a co-design approach. DESP is set to open in June 2024, with the code of conduct being under preparation. The platform emphasizes open and inclusive access for users with configurable restrictions at the service level.

Claudia Vitolo of ESA went on to describe the communication strategy surrounding DESP, focusing on raising awareness, community building, and active participation of the user community in shaping the platform's future. This also involves joint activities with ECMWF, EUMETSAT, ESA, and the European Commission, notably a joint website, User eXchange events, and outreach actions.

With the DestinE User Community ESA aims to create an inclusive ecosystem that aligns with EU policies, values diversity, fosters transparent participation, and provides tools for effective engagement with the digital twins. Actions to grow the community include integration with existing networks, topic-driven interactions, innovation challenges, regular updates, easy onboarding, and feedback utilization for platform enhancements. Ms Vitolo pointed out that joining the community offers the opportunity to innovate, shape future capabilities, share expertise, tackle challenges, and expand professional networks for collaborations.

4 Visualisation

Session organised by Gianluca Palumbo (Exprivia) and Nils Wedi (ECMWF)

The session described three different themes; immersive visualisation of digital twin data, tools for effective storytelling and communication of questions involving environmental data and climate change information, as well as lessons learned from a workshop series to access, visualise and effectively use Copernicus Earth observation data.

Gianluca Palumbo and Cuomo Massimo of Exprivia described new and emerging tools and design principles for handling digital twin data in a distributed digital (cloud-based) environment. Exprivia aims to develop an interactive AR/VR application for DestinE, focusing on visualizing extreme weather and climate change data. This work follows an iterative visual design strategy, considering global and local scales, multi-resolution assets management, and multi-layer visualization techniques. The goal is to create a comprehensive and effective data visualization system ready for June 2024, marked by development cycles and continuous feedback integration.



Gianluca Palumbo, Exprivia

Rita Lecci of the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC) then presented a use case on visualising the management and interactive use of fusing climatological weather data with related information. CMCC uses advanced data analysis and visualization techniques, emphasizing both global and regional scales. At the global scale, Earth Observation visual data is employed to study large-scale patterns like climate change, deforestation, and land use change. On the local scale, visual data is utilized to understand specific areas like cities or natural landscapes.

For extreme events, the use case is working on visualizing Medicanes—Mediterranean hurricanes using interactive and immersive visualizations.

The climate use case focuses on the impact of climate change on the energy sector, particularly in relation to solar and wind energy. CMCC is developing interactive visualizations that compare present climate conditions with future high emission scenarios, providing insights into the effects of climate change on renewable energy production, energy transmission and storage capacity to identify warning situations under different climate change scenarios.

Arturo Montieri of Alia Space Systems introduced an interactivity solution service designed for engaging with data and sharing user stories. Digital Earth Architecture (DEA) aims to make complex data understandable for policymakers and stakeholders. It offers a Story Editor for users to create narratives and visualize data, along with advanced features like http streaming.

DEA's interactive visualization service aims to allow users to:

1. Explore datasets globally or locally, presented as time series or volumetric renderings.
2. Request specific data for defined areas and time spans.
3. Integrate user-provided data into the visualizations.
4. Construct compelling user stories utilizing data, plots, images, and text.

The service will be ready for the system opening in June 2024.

Finally, Neil Fletcher of EUMETSAT presented results of the Copernicus data visualization workshop. He reported that there is a significant interest in data visualisation, and efforts are being made to develop a good practice guide, ensuring simplicity, appropriate use of colour, minimal text, and compatibility with mobile formats. He also saw the need for more practical resources like Jupyter notebooks. Finally, challenges of misinformation on social media were highlighted, pointing to the necessity for credible voices in visualizing and communicating scientific data.

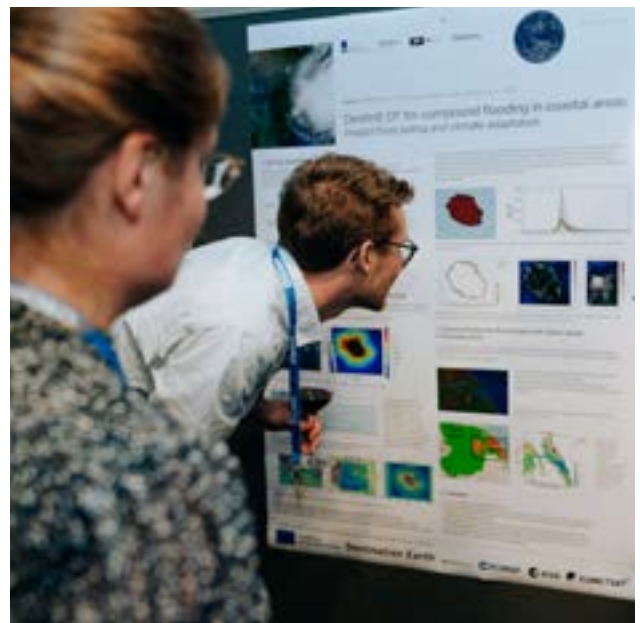
Interactive demonstrations were shown on-site.



Interactive demonstrations



Poster session



A1/2 Adapting to Climate Change

Session organised by Barbara Früh (Deutscher Wetterdienst) and Sami Niemelä, Finnish Meteorological Institute)

The sessions on Adapting to Climate Change covered progress and plans of applications and use cases in the context of the DT Climate.

The first part of the session was kicked-off by **Jenni Kontkanen, Development Manager in Digital Twin Technologies at CSC – IT Center for Science**, who introduced the Climate DT as a new type of climate information system that can be used to assess the impacts of climate change and different adaptation strategies at local and regional levels over multiple decades. It encompasses global climate simulations at an unprecedented horizontal resolution in two leading European Earth system models, IFS FESOM/NEMO and ICON, run on European pre-exascale supercomputers. ClimateDT implements a novel approach by streaming of climate model output to applications from different impact sectors. Users can expect hindcasts and projections on the same resolution while different climate projections, based on different scenarios, will inform policy.

Francesc Roura Adserias of Barcelona Supercomputing Centre focused on the novel concept of data streaming in the Climate DT. In order to adapt to a changing climate, there is a need for local information at global scale. This requires the use of cutting-edge Earth system models and infrastructure, to obtain high resolution data globally. Even though the Climate DT is using some of the most powerful HPC systems, not all of the model data can be stored in such high resolution. The solution is the streaming concept that gives the applications access to the full model state vector at runtime. This approach turns climate data into climate information in one single step, without the need to store the full volume of output data.

Léa Hayez of the Renewables Grid Initiative presented the Energy Systems use case and how it can improve climate energy modelling.

DestinE provides opportunities for enhanced energy system modelling, fresh creative ways to incorporate climate data into typical energy sector user workflows, and increased cooperation and communication amongst the energy system users of the results, planners, and modelers. The use case provides an increased knowledge about model uncertainties but also about data needs of users that are mainly energy system modelers and academics.



Léa Hayez (Renewables Grid Initiative)

compared to the opportunities the Climate DT provides. Aleksander Lacima, focused on urban areas like Barcelona, arguing for the utility of high-resolution streaming data and Python libraries for heat stress indicators. Ana Olivera, highlighted the needs and aims to bridge the gap between models and local scales in urban planning, while Enno Nilson championed fast, stakeholder-relevant climate adaptation information through hydrological models.

The discussion explored the DestinE use case, stressing the need to accelerate the

current 10+ year process for the generation of climate projection data. Mr. Nilson presented a GANTT chart illustrating DestinE's potential to speed up information dissemination. He emphasized, however, that it is important to understand the structure and timing of reporting cycles in federal administrations that inform policy makers to provide the right and consolidated information at the right time. Mr. Laksima underscored DestinE's role in enabling faster adaptation by providing improved understanding, eliminating the need for downscaling. Ms Olivera aimed to scale her Machine Learning model to Barcelona in Phase 1, with recommendations for clarity in connecting to initiatives like CMIP and CORDEX.



Christian Steger (Deutscher Wetterdienst) and Ana Oliveira (+ATLANTIC)

The key users highlighted DestinE as a tool for quicker access to high resolution results. They also emphasised the importance of involving young scientists. Bringing new generations into this profession is key to its success and once the added value of the Climate DT is known, this tool can be used on a daily basis to understand climate information. Furthermore, the panellists recommended that in subsequent phase(s) DestinE should develop further the interactive aspects of the system to make sure DestinE will not become just another data source/portal.

The second part of the session was opened with a presentation by **Carlo Buontempo, Director of the Copernicus Climate Change Service at ECMWF**. Implemented by ECMWF with extensive collaboration, he outlined how the Copernicus Climate Change Service (C3S) offers reliable, open, and free access to state-of-the-art climate data. Mr. Buontempo emphasized the importance of quality, transparency, and user engagement, discussing the challenges of the complex interface between climate information and decision-making (feedback loop). In his presentation he highlighted C3S's investment in quality assessment, focusing on datasets like ERA5 with high spatial and temporal resolution, suitable for climate monitoring, impact assessment studies, and retrospective weather analysis. However, limitations include potential artificial trends due to changes in assimilated data and insufficient spatial resolution for some regional applications. Overall, the talk emphasized the commitment to providing trustworthy, actionable climate information to support informed decision-making.

Johannes Klumpers of DG CLIMA (European Commission) talked about the EU adaptation strategy and the EU Mission on Adaptation to Climate Change's objectives, emphasizing the collaboration opportunities with DestinE. Mr. Klumpers highlighted the importance of a smarter and more systematic adaptation and the need for faster adaptation in all areas where DestinE can contribute. The talk also addressed guidelines on adaptation strategy and plans, climate proofing with storylines, and the potential role of DestinE in helping countries with political decision-making.



World Café session

World Café

During the remainder of the session participants engaged in a World Café to discuss various topics in smaller groups. The groups discussed four pre-defined questions:

- “How do you want to use Climate DT data?” This should highlight the complexity of the DestinE system providing information for adaptation to climate change and give the developers insights on what is needed from the user’s perspective.
- “How do you want to interact with Climate DT data?” This group discussed opportunities on how to interact with the Climate DT system.
- “What do you need Climate DT data for?” Attendees were asked about preferences for the future development of use cases.
- “When do you want to use Climate DT data?” The participants gave insights on when to retrieve data.

These discussions yielded insights on using climate data provided from the DT, with a focus on uncertainty information, and also clarified general questions the participants had. Key

applications include energy system modelling, urban heat scenarios, forestry planning, crisis management, and ecosystem restoration, with a call for improved accessibility for African countries. Participants expressed the importance of ‘what-if scenarios,’ emphasizing the desire for robust and reliable information for decision-making. Specific applications included forest management, hydrological modelling, urban heat mapping, and using the Climate DT output as an input for their own impact models.

The discussion on interacting with Climate DT data emphasized the importance of user-friendly, standardized services with traceability and uncertainty information. The dialogue highlighted the demand for expert guidance in using the data, suggesting a collaborative approach to interpretation, and stressed the significance of integrating the data provided by the Climate DT seamlessly into existing frameworks like CMIP and CORDEX to enhance accessibility and comprehension.

The discussion on when to use Climate DT data centred on triggers such as new forcing or initialization with varying preferences for update frequency. While some users favour real-time access for ongoing services, others

lean towards more conservative update schedules, emphasizing the importance of new elements like scenarios. The need for quality-assured, traceable data is paramount with considerations for influencing update frequency based on user-defined criteria.

B1 Extremes Digital Twin co-development – for renewable energy

Session organised by Kristian Pagh Nielsen (Danish Meteorological Institute) and Roger Randriamampianina (Norwegian Meteorological Institute)

The session offered different perspectives that should be understood by those involved in renewable energy applications to facilitate successful co-development.

The owners and operators of renewable energy sources can benefit from focussed exchange of the Digital Twin Engine (DTE) weather model output. Also, the DTE can benefit from near real time data from the renewable energy systems. Thus, digital twin co-development is a win-win opportunity.

Tiago Quintino, Head of Development in the Forecast Department at ECMWF presented the ECMWF software tools for facilitating co-development between the two Extremes Global and On-Demand DT teams and the end-users. The Aviso extreme event notification tool is essential in this context. Also, many users will benefit from the Polytope tool to get a tailor-made selection of the DT model output time and space data hypercube.

Nikola Karadža, Lead Engineer at Professio Energia presented the challenges of extreme weather for renewable/wind production from the point of view of a company that develops and manages large scale renewable energy projects. He focused particularly on Croatia and wind energy production and discussed

examples of wind turbine blade damage due to lightning strikes and dust storm erosion.

Geert Smet, Senior Scientist at the Royal Meteorological Institute of Belgium

presented test results for sub-km scale modelling of wind energy production from the Destination Earth On-Demand Extremes DT team. Knowledge about the thrust effect of wind turbines as a function of wind speed is important for modelling the atmospheric wind and for modelling the wind power production correctly. A wind farm parametrization has been implemented in the Extremes DT for this purpose. Mr. Smet demonstrated that this improves the wind power forecast for the test case.

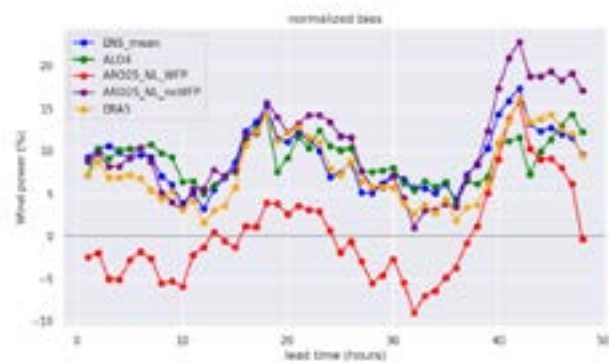


Fig. 2 Comparison of normalised biases from several model configurations for wind power production (shown by Geert Smet)

Kristian Pagh Nielsen, Technical Coordinator for the On-Demand Extremes DT at the Danish Meteorological Institute showed results for a solar photovoltaic test case, in which the original weather forecast had overestimated the solar irradiance by up to more than 50% for the Danish grid regions during a weather situation with convective potential and inhibition. A test run with the On-Demand Extremes DT at 750 m resolution improved these results, though now with an underestimation of the solar irradiance of up to 20%.

Irene Schicker, Senior Scientist at GeoSphere Austria described how post-processing can improve wind energy production forecasts. Metadata for wind power production is essential. A Kalman Filter is used to improve extreme forecasts and web scraping is applied to find as much metadata information as possible, but this remains challenging. There is an urgent need for wind energy metadata to be generally available across Europe for optimal modelling.

The session concluded with a call for making wind and solar energy production data available across Europe. This was considered essential for making the Extremes DT work optimally for renewable electricity forecasting. Decisions are needed at the political/policy level to enable this. Metadata such as capacity and other data describing the wind and solar energy plants are also important, as are data on curtailment.



Live surveys

B2 Extremes Digital Twin co-development – for hydrology, air quality and other impact studies

Session organised by Kristian Pagh Nielsen (Danish Meteorological Institute) and Roger Randriamampianina (Norwegian Meteorological Institute)

The session presented and informed stakeholders about possible applications of the On-Demand Extremes DT and engaged a dialogue about tailor-made output from the DTs and the relevant input that can improve this.

Marcus Hirtl, GeoSphere Austria shared results from the Extremes DT initial test runs for two air quality cases. These were a winter case covering the Carpathian region in Central Europe and a summer case covering the Benelux region. For both cases Mr. Hirtl presented results from the 750 m resolution ensemble.

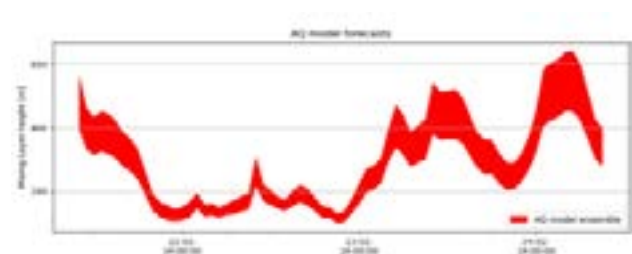


Fig. 3 Mixing layer height variation during an episode of poor air quality in the Alps presented by Marcus Hirtl

Guus Velders, Professor at the National Institute for Public Health and the Environment in the Netherlands (RIVM) presented work on air quality modelling for the public and the environment. He discussed cases in which sub-km modelling of the air quality could provide added value.

Peter Berg, Head of unit for hydrological research at the Swedish Meteorological and Hydrological Institute (SMHI) presented work with hydrological modelling test runs at sub-km scale for nine different countries around Europe. Particularly modelling cases with strong convection is challenging and thorough uncertainty quantification is essential. Particularly, the uncertainty of the initial state of soil saturation was shown to be important. In his presentation, **Niclas Hjerdt, Head of hydrological forecasting at SMHI** emphasized the challenges of forecasting hydrological events as they happen. He also stressed that

including end-users actively in the forecasting has important advantages, rather than having a cascade of models from the atmospheric model forecasting precipitation to the hydrological and hydraulic models. Mr. Hjerdt expected the On-Demand Extremes sub-km hydrological forecasting to be particularly useful for urban cases and in cases when the soil is saturated.

Chiara Marsigli of Deutscher Wetterdienst presented test results from running the “GLORI” DT. “GLORI” stands for global to regional ICON model, where ICON is the primary weather model of the COSMO weather model consortium of Germany, Switzerland, Italy and other countries. While not developed as part of Destination Earth, GLORI developments are coordinated with the activities on the Extremes DT. The GLORI test runs are focused on the Alpine region. Ms. Marsigli also presented results for the Emilia-Romagna floods in Italy in May 2023.

Kristian Horvath, Head of Meteorological Research and Development at the Croatian meteorology and hydrology service agency presented further applications of the On-Demand Extremes DT, i.e. applications beyond wind and solar energy, hydrology and air

quality. These applications include storm surge modelling for smaller basins, for instance the Adriatic Sea, spring time frost that can be damaging to agriculture, fire weather risk, and extreme heat waves.

The session demonstrated how DT On-Demand Extremes can be particularly useful for urban hydrology and air quality cases. The importance of long-term hydrological initialisation as a pre-requisite for a good hydrological forecast was stressed. To this end, it was recommended to develop a Europe-wide product with quality-controlled rain gauge calibrated radar precipitation dataset.

A3 Using the Service Platform

Session organised by Inés Sanz Morere (ESA) and Barbara Borgia (Serco)

The session aimed at presenting the Destination Earth Service Platform (DESP) implementation plan, associated long-term business strategy, and the multiple ways of taking part in the DestinE ecosystem. Commencing with a presentation by **Alexis Longuet (Serco)** on the role of the Service Platform in achieving the vision of the DestinE



Lively exchange between the sessions

Initiative, it also showed the importance of the activity for Serco's future business activity, and highlighted the objective of becoming one of the reference platforms, globally, to support the European's Green Deal and Digital Strategy.

Barbara Borgia (Serco) then presented the architecture of DestinE's Service Platform, as well as the first available services, and detailed the implementation plan. Her presentation included a first snapshot of the future DestinE's Platform web portal, and the early sections for user support, information sharing, and services registry. The operational ecosystem is expected to be ready by the end of DestinE Phase 1 in June 2024.

Daniele Pensa (Serco) stressed the process to integrate new services as one of the key points of DestinE's Platform implementation. He explained that it was a pre-requisite for a dynamic ecosystem of services that is flexible and easily adapted to the user community. Mr. Pensa presented this procedure, including the available tools to support this integration, and the expectations from external services.

In their presentation, **Alessandro Amici (BOpen)** and **Christophe Demange (GAEL Systems)** presented ESA Forerunner activities, which aim at developing early functionalities to be ready in the platform at the start of operations of DestinE System.

Mr. Amici presented a service for improving the performance of retrieving data (including DestinE data available from the Digital Twin Engine) for time series assessments. Mr. Demange discussed a user modelling framework, providing an environment for the development and running of Digital Twin elements, aiming at easing the collaboration between users.

Rochelle Schneider of ESA gave an overview over the advanced DESP services procured by ESA, to be implemented on top of the Core Services ensured by Serco. A dynamic

procurement process is planned to support the evolution of user needs in DestinE's Platform.

Finally, **Antonio Romeo (Rhea)** presented the five DESP use cases, kicked-off in the month of November, ready to be integrated in DestinE's Platform and support the verification and validation of the early services available in the platform. A second round of DESP use cases will be procured in early 2024.

Overall, DESP was presented as an open and flexible ecosystem of services to extract information from Digital Twin data, supporting users and acting as the mid-point between users and service providers to ensure good communication, service performance and quality.

DESP is the access point to DestinE System services (including those from the DestinE Data Lake and DestinE Digital Twin Engine), integrated transparently and acting as a single picture for users.

A4 Data Lake and Data Spaces

Session organised by Danaële Puechmaille (EUMETSAT)

The session provided insights into services of the DestinE Data Lake and how the Data Lake relates to Data Spaces, and to European Data Spaces in particular.

Michael Schick of EUMETSAT explained the initial version of the DestinE Data Governance, which is complemented by the DestinE Access Governance. The DestinE Governance is managed in a Joint Change Control Board composed of ECMWF, ESA, and EUMETSAT and chaired by the EC. Mr. Schick stressed that this setup is expected to evolve over time based on feedback received, including from the DestinE Coordination Group and Strategic Advisory Board.

In his presentation **Sebastien Denvil of ECMWF**, outlined the scope of the "GREAT" Project (Green Deal Data Space). Explaining that a roadmap has just been delivered, to support the objective of the green deal with the data space. Work is presently performed to assess and look at binding targets and identify reasonable indicators to measure if they have met.

Christoph Reimer of the Earth Observation Data Centre (EODC) spoke about multi-cloud processing with DASK. Near data processing in federated cloud environments was demonstrated based on the usage of Pangeo tool chain and in particular demonstrated using DASK. This approach can be used in and outside of DestinE.

Aubin Lambare of CS-France explained the approach to harmonized data access within the DestinE Data Lake. The solution presented is open source and can also be used by others. It is based on STAC and supports the concept that data can come from multiple providers. Ms Lambare stressed that transferring big data into mega platforms has flaws, making it preferable to leave the data at the federated data provider, which takes care of the provenance and ensures data is always up to date.

These presentations were followed by a panel discussion addressing a number of questions raised. During the panel discussion, it was clarified that training for users on services will be provided continuously and as part of opening of DEDL. STAC compliance for federated providers will be done as part of provider integration and Portfolio evolutions will be discussed in the context of the data governance, data can also be accessed via the internet. DESP and DEDL services are complementary and can be chosen based on what is best for the use case (e.g. location of data).

The session confirmed the strong interest in Green Deal Data Spaces and how they relate to the DestinE data space. The presentations

and discussions helped to clarify participants' questions.

B3 Connecting to other Digital Twins

Session organised by Thomas Geenen (ECMWF)

This session gave an overview of the digital Twin Engine (DTE) components, their interfaces and how users are intended to interact with these components. The session aimed to gather feedback from users on how they intend to use the DestinE components and map any potential use cases in this landscape after providing a pre-determined example of this mapping as an example.

Thomas Geenen of ECMWF, presented the DTE components and their functionality in the introduction. He then walked through an example use case for coastal flooding mapped in the DestinE landscape with a representative from Deltares.

During an interactive exchange attendees were encouraged to develop use cases that they wish to run on the DestinE platform and then map what components could be used to achieve the goals of their use cases.

Many different use cases were proposed including the estimation of renewable energy generation based on outputs of the Climate DT and Extremes DT, or health outcomes based on publicly available health data and climate data. For each of these cases, which steps they currently require was developed and what components could be used to replicate these use cases in Destination Earth. They also pointed out areas where the DTE does not provide solutions for their problems. Based on the interactive session there are many use cases that DestinE users are interested in running. This session showed the

need to document and engage with users to make them more aware of what is currently available from DestinE, but also pointed out some missing functionality that users would be interested in, helping to better tailor components for users.

B4 Science and Technology needs

Session organised by Francisco Doblas-Reyes (Barcelona Supercomputing Center)



Developing use cases

The session discussed the developments and needs for the evolution of DestinE, in which emergent research and technological innovations can play a role. It included several presentations detailing recent results from DestinE contracts, the main suggestions from the DestinE Strategic Advisory Board, results from Horizon Europe projects, and operational activities.

Some highlights of the presentations follow:

Martin Schultz, Member of the DestinE Strategic Advisory Board, Forschungszentrum Jülich presented the draft DestinE science plan. The science plan

is expected to reflect the different information needs of the users (through the involvement of social scientists and stakeholders), such as the possibility to zoom in and out from global to local scales, the establishment of strong links with the rich research scene in Europe, and the need to develop solutions that take into account a changing world oriented towards increasing resilience. He explained that the science plan is also considering the complex funding landscape of Horizon Europe and the link to the EU mission on climate adaptation.

Francisco Doblas-Reyes of BSC then spoke about scientific and technical challenges and opportunities relevant to DestinE, followed by **Peter Düben (ECMWF)** on the digital revolution of Earth system modelling. **Mierk Schwabe of DLR's Institute of Atmospheric Physics** then spoke about Machine Learning to improve Earth System Models. Artificial intelligence is emerging as a key element in the design of new solutions for both weather and climate prediction, although for now these solutions need to be seen as a complementary tool to the more traditional process-based models.

DestinE is benefiting from existing European and international initiatives (both in the research and operational domains) that provide experience in data sources and sharing techniques, benchmarking of process-based models, and bridging the gap with the user ecosystem. It was stressed that user requirements need to be a driving force of the technological solutions, leading to the establishment of multidisciplinary approaches. **Alessandro di Felice of OVH** stressed that target-oriented and safe cloud-based infrastructures located in Europe are needed to ensure the provision of an adequate service based on the DestinE developments and tools. The presentations were followed by a lively panel discussion with panel members from different academic domains (environmental modelling and data analysis, and social

sciences) and programme managers. The panel addressed the following questions:

- What are further scientific and technical needs for the future DestinE development?
- Where can obvious synergies be built? What should be the priorities for collaboration?
- Which emerging scientific and technical developments, both in Europe and overseas, should be paid attention to?

The main conclusions of the session are:

- The role of artificial intelligence is increasing to improve and accelerate environmental models, facilitate data solutions, create an operational environment. Interfaces with the digital world are unavoidable and increased coordination is recommended.
- DestinE cannot succeed in isolation; it has to be linked to a complex scene consisting of research programmes (e.g., Horizon Europe, but in particular the Mission on Climate Adaptation), operational activities (e.g., meteorological and hydrological services or Copernicus), international collaborations (e.g., CMIP), and the identification of a myriad of user needs that need scalable solutions.
- In spite of the large amount and variety of the existing environmental data sources, there is a clear need to improve them, especially those provided by environmental models, to address some long-standing challenges in the provision of environmental information along the lines of what the initial digital twins aim at.
- Both natural and social sciences (and humanities) must be considered. This a requirement for technologically-based initiatives to efficiently reach the user arena

and respond to the increasing requirements of action-oriented environmental information.

- Access to – and use of – data for non-environmental drivers will provide the context for the environmental information generated.
- DestinE will face an important number of challenges, such as the interactivity with the service, the trustworthiness of the information provided, the consideration of the values of all those involved, the timely and efficient delivery of the information, the possibility of branching user modules, and the creation of attractive career paths for multidisciplinary scientists and practitioners.



Conclusion

Charalampos Tsitlakidis, Team Leader for DestinE at DG CNECT (European Commission) praised the second DestinE Users Exchange meeting as a success. He noted the large interest, demonstrated by the over 400 participants, the lively exchange, innovative ideas and engaging, thought-provoking discussions.

The meeting provided valuable insights into the synergy of DestinE components, exploring new ways to interact with and visualize data. Co-development for visualization and interactivity was emphasized, along with the identification of current needs and anticipation of their evolution. The discussions reinforced the ambitious goals of DestinE, pushing the boundaries in addressing climate change challenges. Mr. Tsitlakidis re-iterated that the active participation of users is crucial for DestinE's success.

He concluded that the User eXchange was a significant step forward in building an active DestinE community, deepening understanding, and stimulating progress toward the public launch scheduled in June 2024.

In his final remarks **Michael Schick (EUMETSAT)** observed the complementarity of different services and stressed the importance of benchmarking components based on use cases.

Kathrin Hinze (ESA) highlighted the key role of collaboration in ensuring DestinE's success and anticipated that DestinE operational services can be presented at the next user exchange meeting.

Jörn Hoffmann (ECMWF) closed the event, expressing his gratitude not only to participants, but highlighting the essential role of the individuals organizing individual sessions.



Jörn Hoffmann ECMWF

“It’s only the second User eXchange but we are very happy with how the community is coming together and growing. With our partners at ESA and EUMETSAT we conceive these meetings as a town square where the stakeholders in DestinE connect. In the end, the initiative must create real benefit to users.”

It will be crucial to understand users' views and requirements and how DestinE can help address these. In that sense I think the meeting in Bonn was a success.”

Jörn Hoffmann, DestinE Partnership Lead at ECMWF

200

people onsite



24

countries were represented



231

online





ANNEX

Second Destination Earth User eXchange
November 13-14, 2023, Bonn

Annex A: Programme

13.11.2023 - Monday

Opening event | 14:00 – 14:25

Setting the scene for the 2nd Destination Earth User eXchange. High-level speakers of ECMWF and the European Commission will provide their perspectives on Destination Earth.

- Welcome by ECMWF (Florence Rabier, Director General of the ECMWF)
- Welcome from DG Connect (Gustav Kalbe, Acting Director Digital Excellence and Science Infrastructures, DG CNECT, European Commission)

Progress | 14:25 – 15:45

The three Entrusted Entities – ESA, ECMWF, EUMETSAT will give an update on key developments in the implementation of DestinE during 2023.

- Introducing DestinE, its high-priority Digital Twins, and the Digital Twin Engine (Irina Sandu, Director for Destination Earth, ECMWF)
- Implementing the DestinE Data Lake (Michael Schick, DestinE System Manager, and Danaële Puechmaille, EUMETSAT)
- The user's side of DestinE: the Service Platform, Communication Plan and Community Strategy (Kathrin Hintze, Deputy DestinE Project Manager, ESA)

Coffee break | 15:45 – 16:15

Visualization and Immersive Technologies for DestinE | 16:15 – 16:45

The session will describe visualisation efforts in DestinE, including an illustration on an immersive visualisation concept leveraging modern visualization and interaction technologies, similar to those employed in the gaming industry. It will explore innovative methods for visualizing and interacting with climate and weather data, as well as other relevant societal ancillary information. Short presentations will introduce the high-level architecture and illustrate the exploitation of scenarios with examples. *Moderated by: Nils Wedi, ECMWF*

- Immersive visualisation for DestinE (Gianluca Palumbo and Cuomo Massimo, Exprivia)
- Visualisation examples from DestinE Use Cases (Rita Lecci, Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC),
- Digital Earth Architecture Service (Arturo Montieri, Alia Space Systems)
- Visualising Copernicus Earth Observation Data (Neil Fletcher, EUMETSAT)

Poster Session | 16:45 – 19:00

14.11.2023 - Tuesday

Connecting DestinE to climate adaptation policy needs | 09:00 – 09:10

The European Environment Agency (EEA) are engaged in DestinE to help develop the initiative to support critical European policy needs. As an introduction to day two, EEA's Executive Director will give a perspective of why we need DestinE and what expectations and plans the Agency has for it.

- Leena Ylä-Mononen, Executive Director, European Environment Agency

Session A1: Adapting to Climate Change (1) | 09:15-10:45

This session will present the progress and plans of applications and use cases in the context of the Digital Twin on Adaptation to Climate Change ("Climate DT"). A panel discussion with key users will discuss the future of use cases from the perspective of users and developers. Participants' views will be collected on the role of DestinE for adapting to climate change and possible questions clarified in a World Café.

Moderated by: Sami Niemelä (Finnish Meteorological Institute)

- Climate Adaptation Digital Twin transforming climate data to actionable information (Jenni Kontkanen, Development Manager in Digital Twin Technologies, CSC – IT Center for Science)
- Data streaming in the Climate Digital Twin (Francesc Roura Adserias, Barcelona Supercomputing Centre)
- Climate adaptation of the European energy system: a Destination Earth use case (Léa Hayez, Renewables Grid Initiative)
- Thematic background of the use cases to be discussed in the panel discussion (Sami Niemelä, Finnish Meteorological Institute)

Panel discussion

- Enno Nilson (Federal Institute of Hydrology, Germany)
- Christian Steger (Deutscher Wetterdienst)
- Ana Oliveira (+ATLANTIC)
- Aleksander Lacima (Barcelona Supercomputing Center)

Session B1: Extremes Digital Twin co-development – for renewable energy | 09:15-10:45

A key aspect of the Digital Twin concept is continuous updates from the modelled systems. Here renewable energy sources is a focus. How can a framework for optimally using these, together with the Destination Earth On-Demand Extremes Digital Twin run at sub km and sub hourly resolution, be made? The DT provides tailor-made output. This will be presented for further discussion and iterations with the relevant stakeholders. This session will include several presentations highlighting how the Extremes DT will add value to the domain of renewable energy.

Moderated by: Natalie Theeuwes (Royal Netherlands Meteorological Institute, KNMI)

- Technical possibilities of the Extremes DT (Tiago Quintino, Head of Development, Forecast Department, ECMWF)
- The challenge of extreme weather for renewable/wind energy production in Croatia (Nikola Karadža, Lead Engineer, Professio Energia)

- The On-Demand Extremes DT and wind energy (Geert Smet, Senior Scientist, Royal Meteorological Institute of Belgium)
- Discussion on wind energy data usage in the Digital Twin Engines
- The On-Demand Extremes DT and solar energy (Kristian Pagh Nielsen, Technical Coordinator, DE_330, Danish Meteorological Institute)
- Extremes in wind speed and power: post-processing approaches in the on-demand Extremes DT for known and unknown wind farm configurations (Irene Schicker, Senior Scientist, GeoSphere Austria)

Coffee Break | 10:45 – 11:15

Session A2: Adapting to Climate Change (2) | 11:15 –12:45

Continuation of the A1 session.

Moderated by: Barbara Früh

- User interaction in the development of climate services: the lessons learnt from Copernicus Climate Change Service (C3S) (Carlo Buontempo, Director of the Copernicus Climate Change Service, ECMWF)
 - Potential links between EU Mission on Adaptation to Climate Change and Destination Earth (Johannes Klumpers, Senior Expert, DG CLIMA, European Commission)
- World Café with participants to discuss a number of questions.

Session B2: Extremes Digital Twin co-development – for hydrology, air quality and other impact studies | 11:15 –12:45

A key aspect of the Digital Twin concept is continuous updates from the modelled systems. Here the focus is on extreme hydrology, air quality events, and other extreme events. Which impact studies will work best with our Destination Earth On-Demand Extremes Digital Twin Engine run at sub km and sub hourly resolution? How can we collaborate on these? Dedicated output for extreme events such as inland and coastal flooding, unhealthy air quality, and other events such as forest fires, springtime cold spells will be presented and discussed.

Moderated by: Kristian Pagh Nielsen (Danish Meteorological Institute DMI)

- On-Demand Extremes simulations of air quality (Marcus Hirtl, DE330 air quality lead, GeoSphere Austria)
- Air quality from a user perspective (Professor Guus Velders, Dutch National Institute for Public Health and the Environment)
- Assessing the use of on-demand digital twins in national hydrological models (Peter Berg, Swedish Meteorological and Hydrological Institute)
- Hydrology from a user perspective (Niclas Hjerdt, Head of hydrological forecasting, Swedish Meteorological and Hydrological Institute)
- Advancing the application of high resolution DTs by engaging with user groups (Chiara Marsigli, Deutscher Wetterdienst)
- Towards other extreme weather impacts (Kristian Horvath, Head of Meteorological Research and Development, Croatia meteorology and hydrology service agency)

Lunch break | 12:45-13:45

Session A3: Using the Service Platform | 13:45 – 15:15

DestinE's Core Service Platform represents the entry point for users to DestinE ecosystem. This platform provides access to a wide variety of services and data addressing DestinE objectives, including to all capabilities provided by the two other components (DEDL and DTE). This session aims at clarifying to the attendants the functionalities available in DestinE's platform and the opportunities for stakeholders to take part and contribute to the ecosystem.

Moderated by: Inés Sanz Morere (ESA)

- Platform vision and objectives (Alexis Longuet, Serco)
- Platform Framework Solution (Barbara Borgia, Serco)
- Onboarding in the Service Platform (Daniele Pensa, Serco)
- ESA Forerunners (Alessandro Amici, BOpen; Christophe Demange, GAEL Systems)
- Advanced Services and Use Cases Overview (Rochelle Schneider, ESA; Antonio Romeo, Rhea)

Session B3: Connecting to other Digital Twins | 13:45 – 15:15

Digital twins in general, and Destination Earth is no exception, rely on a rich services landscape that supports interacting with the system and its components. Designing a solution path in this landscape for a particular application/use-case/digital twin (i.e., how to integrate specific applications in DestinE) is not always a trivial exercise and requires a good understanding of the Destination Earth system, its components, and interfaces. This session will briefly touch on the different system components and their interfaces. With an example it will show how a solution path can be designed for a particular solution. Common design patterns will be identified and input for the different system components evolution be formulated. Moderated by: Thomas Geenen (ECMWF) Carving out a solution path in the DestinE architecture, an example from the Deltares coastal hazard use-case in the InterTwin project (Thomas Geenen, DestinE Technology Partnership Lead, ECMWF; Björn Backeberg, Deltares)

Interactive workshop with participants to develop the connection to DestinE.

Coffee break | 15:15 – 15:45

Session A4: Data Lake and Data Spaces | 15:45 – 17:15

This session, highlights the Destination Earth Data Lake role through the description of the Data Portfolio. It will also present Data Lake use case(s) under development and explore the link to the Green Deal Data Space.

Moderated by: Danaële Puechmaille (EUMETSAT)

- From a defined towards a user-driven data portfolio (Michael Schick, EUMETSAT)
- GREAT Project: Green Deal Data Space (Sebastien Denvil, ECMWF)
- Multi-cloud processing with DASK: demonstrating the capabilities of the DestinE Data Lake (Christoph Reimer, EODC Earth Observation Data Centre)
- Usage of DestinE Data Lake Harmonized Data Access (Aubin Lambare, CS Group)
- Plenary discussion

Session B4: Science and Technology needs | 15:45 – 17:15

The objective of the session is to provide the space for a discussion on developments and needs for DestinE related to emergent research and technological solutions. The session will include a description of recent results from Horizon Europe projects, a status of the scientific and technological challenges addressed by the initial digital twins, and the identification of the requirements for the extension of their capabilities.

Moderated by: Francisco Doblas-Reyes (Barcelona Supercomputing Center)

- Science for action – the (draft) science plan of the DestinE advisory board (Martin Schultz, Member of the DestinE Strategic Advisory Board, Forschungszentrum Jülich)
- Scientific and technical challenges and opportunities relevant to the Climate DT (Francisco Doblas-Reyes, Barcelona Supercomputing Center)
- The digital revolution of Earth system modelling (Peter Düben, ECMWF)
- Machine Learning to improve Earth System Models (Dr. Mierk Schwabe, Institute of Atmospheric Physics, German Aerospace Center, DLR)
- “Unified access to Space data”: Identity and Access Management enabling cloud-to-edge federations in DestinE platforms (Alessandro Di Felice, OVH)
- Panel discussion
- Eulàlia Baulenas, Barcelona Supercomputing Center
- Wilco Hazeleger, Member of the DestinE Strategic Advisory Board, Utrecht University
- Helene Hewitt, UK Met Office
- Philippe Tulkens (DG RTD Directorate-General Research and Innovation of the European Commission)

Closure & End of User eXchange

Annex B: Programme Committee

Barbara Früh, Deutscher Wetterdienst (DWD)

Thomas Geenen, European Centre for Medium-Range Weather (ECMWF)

Jörn Hoffmann, European Centre for Medium-Range Weather (ECMWF)

Eleni Karachaliou, University of Thessaloniki

Kristian Pagh Nielsen, Danish Meteorological Institute (DMI)

Sami Niemelä, Finnish Meteorological Institute (FMI)

Gianluca Palumbo, Exprivia

Danaële Puechmaille, European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)

Roger Randriamampianina, Norwegian Meteorological Institute (MET Norway)

Najla Said, Serco

Inés Sanz Morere, European Space Agency (ESA)

Stratos Stylianidis, University of Thessaloniki

Claudia Vitolo, European Space Agency (ESA)

Nils Wedi, European Centre for Medium-Range Weather, (ECMWF)

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