Data, Observation & Modelling

Fri. Nov 13, 2026 2:00 PM - 3:30 PM JST | Fri. Nov 13, 2026 5:00 AM - 6:30 AM UTC | Room A (Oshidori) (2F)

Oral A5 Ocean Digital Twins, Data Architectures and AI-Enabled Approaches

Chair: Philipp S. Sommer, Tomoki Tozuka

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[7MgO-EqD-01] Second Cooperative Study of the Kuroshio and its Adjacent Region (CSK-2)

*Akira Nagano[1] (1. JAMSTEC (Japan))

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[7MgO-EqD-02] Federated Data Architectures for Environmental Evidence: Observations from Offshore Energy Programmes and the DAFNI Fellowship

*Thomas Mansfield[1] (1. Plymouth Marine Laboratory (UK))

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[7MgO-EqD-03] Understanding and Predicting Ocean–Climate Variability through Dynamical Models and Data-Driven Approaches

*Tomoki Tozuka (1. The University of Tokyo (Japan))

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[7MgO-EqD-04] OceanDataStore: Cloud-Native Ocean Data for Research, Collaboration and Scalable Science.

*Oliver Tooth[1] (1. National Oceanography Centre (UK))

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[7MgO-EqD-05] JAXA's Earth Observation Data Infrastructure for Digital Twins

*Kei Oyoshi[1] (1. Japan Aerospace Exploration Agency (JAXA) (Japan))

3:15 PM - 3:30 PM JST | 6:15 AM - 6:30 AM UTC

[7MgO-EqD-06] Developing an Observation-Constrained Ocean Digital Twin: EnOI Data Assimilation for the GEPSv3 Coupled Prediction System

*Lalu Mantigi Wana Paksi (1. Academia Sinica X National Taiwan University and BMKG (Taiwan))

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[7MgO-EqD-01] Second Cooperative Study of the Kuroshio and its Adjacent Region (CSK-2)

*Akira Nagano[1] (1. JAMSTEC (Japan))

Our knowledge of the Kuroshio is mostly based on data obtained in the international Kuroshio observation programme during 1965-1977, the Cooperative Study of the Kuroshio and Adjacent Regions (CSK). Most of ongoing long-term observations in the western North Pacific have been initiated since the CSK era. In addition, the activity of the CSK led to the establishment of WESTPAC as a branch of UNESCO/IOC. To take our current understanding of the Kuroshio to the next level such that it can benefit society, we have initiated the successor of the CSK, the CSK-2, since 2022 as a UN Decade Action project of UN Decade of Ocean Science for Sustainable Development (UNDOS). The CSK-2 contributes to UNDOS with two objectives: to elucidate the relationship between the Kuroshio Current and climate and weather, and its impact on marine ecosystems. As of now, 14 projects from 6 countries participate the CSK-2. To achieve the goals, we share information on progresses, discuss future cooperation and direction, and solicit new proposals. Stimulating research activities across the themes due to data sharing and gaining a deeper understanding of the Kuroshio and surrounding current systems due to data assimilation are future tasks and are working on them. In addition, we are eager to enhance collaborative research with numerical modeling and prediction communities. In this presentation, we introduce the present efforts of the CSK-2 for further collaboration with ocean modeling and prediction communities.

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[7MgO-EqD-02] Federated Data Architectures for Environmental Evidence: Observations from Offshore Energy Programmes and the DAFNI Fellowship

*Thomas Mansfield[1] (1. Plymouth Marine Laboratory (UK))

The increasing scale and complexity of environmental evidence generated through offshore energy programmes presents significant challenges for data interoperability, discoverability, and reuse. While FAIR (Findable, Accessible, Interoperable and Reusable) data principles are widely recognised, their implementation across distributed projects, organisations, and disciplines remains inconsistent. This fragmentation can limit the integration of environmental datasets into digital research infrastructures and reduce their value for digital twins, decision-making and policy development.

This paper presents findings from a DAFNI (Data & Analytics Facility for National Infrastructure) Fellowship investigating how federated data architectures can support improved environmental data management across UK offshore energy programmes. Drawing on experiences from the EQUIFy, VALMAS and AtlantiS projects, the research examines technical, organisational and workflow-related barriers to interoperability, with a particular focus on metadata practices, data onboarding, and cross-community collaboration.

The study adopts an iterative co-design approach involving stakeholders from academia, industry, government and environmental data centres. Evidence is collected through a series of workshops, structured observations and engagement activities embedded within existing project and community events. These insights are synthesised to identify recurring challenges and emerging good practices for enabling federated approaches that allow communities to maintain local ownership of data while supporting system-wide integration and reuse.

The work demonstrates how federated FAIR workflows can enhance the readiness of environmental datasets for integration with platforms such as DAFNI, improving reproducibility and supporting national-scale digital infrastructure initiatives. It also explores the role of digital research environments in bridging the gap between technical standards and operational practice.

These interim findings provide practical recommendations for digital twin communities seeking to improve the interoperability and long-term value of environmental evidence. More broadly, the work highlights how federated architectures can strengthen the digital foundations needed to support resilient, evidence-driven decision making in the transition to sustainable offshore energy systems.

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[7MgO-EqD-03] Understanding and Predicting Ocean–Climate Variability through Dynamical Models and Data-Driven Approaches

*Tomoki Tozuka (1. The University of Tokyo (Japan))

Ocean–climate variability arises from complex interactions across a wide range of spatial and temporal scales, posing fundamental challenges for both physical understanding and prediction. In this presentation, I will highlight our recent efforts to address these challenges using complementary dynamical and data-driven approaches. First, long-term, high-resolution climate model simulations provide “virtual oceans” in which ocean–atmosphere interactions and rare events can be investigated beyond the limitations of the observational record. Examples include interactions between the Kuroshio Extension, the atmosphere, and the tropical Pacific, as well as the dynamics of rare Kuroshio large-meander events. Second, reduced-order data-driven models provide an efficient framework for exploring climate variability and its underlying interactions. Using a cyclostationary linear inverse model of the Indo-Pacific climate system, we examine how changes in interbasin coupling alter the characteristics of El Niño–Southern Oscillation, illustrating how data-driven models can be used not only for prediction but also for hypothesis testing through virtual experiments. Finally, neural-network-based prediction of winter temperature variability around Japan demonstrates how artificial intelligence can help identify important predictors and motivate subsequent investigation of the underlying physical mechanisms. Together, these studies illustrate the complementary strengths of dynamical models, reduced-order models, and artificial intelligence. Integrating these approaches with observations may provide a pathway toward ocean digital twins that not only reproduce and predict ocean states, but also facilitate exploration and understanding of the processes governing ocean–climate variability.

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[7MgO-EqD-04] OceanDataStore: Cloud-Native Ocean Data for Research, Collaboration and Scalable Science.

*Oliver Tooth[1] (1. National Oceanography Centre (UK))

The growth of high-resolution ocean models, sustained observing systems and machine learning applications is transforming marine science, but also bringing new challenges in how large datasets are stored, maintained and distributed. OceanDataStore is an open-source library developed to streamline writing, updating and accessing ocean model and observational datasets by leveraging cloud object storage, enabling more scalable and accessible ocean science throughout the research community.

Developed by the National Oceanography Centre (NOC), OceanDataStore has evolved into a production-ready platform serving both data producers and data consumers. For ocean modellers, the library provides command-line and scripting interfaces to transform archival datasets (e.g., netCDF) into Analysis-Ready Cloud Optimised (ARCO) formats, including version-controlled data cubes. For users of ocean data, the accompanying OceanDataCatalog enables dataset discovery and access using Spatio-Temporal Asset Catalog (STAC), allowing researchers, students and stakeholders to access public ocean datasets seamlessly across local and high-performance computing environments.

Developed through the AtlantiS National Capability programme and now integrated into NOC's global ocean modelling pipelines, OceanDataStore has transformed how we distribute ocean model outputs, including through the Earthmover Data Marketplace. This work provides a foundation for future digital services that prioritise data accessibility, accelerate multidisciplinary research, and broaden access to strategic ocean datasets across the wider NERC community.

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[7MgO-EqD-05] JAXA's Earth Observation Data Infrastructure for Digital Twins

*Kei Oyoshi[1] (1. Japan Aerospace Exploration Agency (JAXA) (Japan))

Earth observation satellite data provide a fundamental data infrastructure for digital twins by archiving the state of the Earth from the past to the present and supporting change detection, understanding current situation, and future prediction. JAXA develops and operates a wide range of Earth observation satellites and has continuously advanced the observation, calibration/validation, archiving, and distribution of satellite data.
To facilitate the development of digital twins and AI-driven applications, JAXA has been exploring scalable data management and dissemination approaches, including cloud-native architectures and API-based access services. These efforts are expected to promote wider adoption of Earth observation data, expanding the user community beyond traditional Earth science researchers to include private-sector stakeholders developing operational solutions and value-added services.
Recent advances in cloud computing enable large-scale analysis of archived satellite data in combination with numerical models and AI technologies, supporting both research and service development. Furthermore, the integration of satellite observations with measurements from ground-based sensor networks is accelerating the creation of practical decision-support services.
This presentation highlights JAXA’s recent activities, technological advancements, and emerging applications in satellite data infrastructure, generative AI, foundation models for Earth observation data analysis, and integrated Earth observation systems designed to contribute to digital twin ecosystems.

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[7MgO-EqD-06] Developing an Observation-Constrained Ocean Digital Twin: EnOI Data Assimilation for the GEPSv3 Coupled Prediction System

*Lalu Mantigi Wana Paksi (1. Academia Sinica X National Taiwan University and BMKG (Taiwan))

Accurate ocean state estimation is crucial for developing operational Digital Twins of the Ocean and coupled climate prediction. We've created an Ensemble Optimal Interpolation (EnOI) system for the Taiwan Multi-scale Community Ocean Model (TIMCOM), which is the ocean component of Taiwan's Global Ensemble Prediction System version 3 (GEPSv3). This system operates in a cycling, weakly coupled configuration and provides ocean initial conditions for subsequent coupled forecasts. It assimilates diverse observations, including Argo temperature and salinity profiles, World Ocean Database in situ profiles from moorings, XBTs, CTDs and OSDs, and NOAA OISST sea-surface temperatures. A 100-member NMC-method ensemble is used for surface assimilation, followed by a demeaned 250-member year-to-year ensemble for in situ assimilation.

We evaluated the system using an observing system experiment with four configurations: full assimilation, assimilation without Argo, SST-only assimilation, and a no-assimilation control. An independent 20% subset of Argo profiles from the SynObs ArRef dataset was withheld from all experiments for verification. Full assimilation significantly reduced the temperature RMSE by 7.8% at depths of 100–300 metres and 4.4% at 300–750 metres, with no statistically significant degradation at any depth. This improvement is particularly notable in the upper thermocline. However, below 300 metres, attributing the improvement to individual observing systems remains uncertain due to sparse independent profile coverage.

Following the SynObs Flagship protocol, TIMCOM achieved a 0.710 °C RMSE over the 0–50 metre depth range, comparable to MOVE-G3F, FOAM, GIOPS and ORAS6. These results demonstrate the effectiveness of the observation-assimilation component in a global coupled prediction system and support further development towards an operational, observation-constrained ocean digital twin.

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