Cross-Sector Applications & Solutions

Wed. Nov 11, 2026 4:00 PM - 5:30 PM JST | Wed. Nov 11, 2026 7:00 AM - 8:30 AM UTC | Room D (Icho) (3F)

Oral D1 Cross-Sector Applications & Solutions

Chair: Takashi Enomoto, Arne Jørgen Berre

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[BSG7SMHd-01] AI/ML-Augmented Metocean Digital Twins for Predictive and Actionable Maritime Intelligence

*Ruoying He[1] (1. North Carolina State University (USA))

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[BSG7SMHd-02] From Ocean Integration to Ocean Strategy: A Principles-Driven Framework for the Long-Term Success of Regional Digital Twins

*Joaquín Tintoré[1] (1. IMEDEA (CSIC-UIB) (Spain))

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[BSG7SMHd-03] Digital Twins at the Land–Ocean Interface: A Platform for Cross-Sector Dialogue and Public Engagement

*Francisco Werner[1] (1. Smithsonian Institution, National Museum of Natural History (USA))

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[BSG7SMHd-04] Connecting the DOTs: An Exploratory Study of Global Activities and Collaboration Potential for Digital Ocean Twins

*Sigmund Kluckner[1] (1. Sigmund Kluckner (Austria))

5:00 PM - 5:15 PM JST | 8:00 AM - 8:15 AM UTC

[BSG7SMHd-05] Accelerating a Fully Coupled Earth System Forecast Model through an Efficient CPU-to-GPU Development Approach

*Yun-Chuan Shao[1] (1. National Taiwan University (Taiwan))

5:15 PM - 5:30 PM JST | 8:15 AM - 8:30 AM UTC

[BSG7SMHd-06] Impact of Coastal Upwelling on Biological Production: Numerical Modeling Investigation of the Situation on the Ghanaian Shelf

*Kwabena Danso[1] (1. Africa Centre of Excellence in Coastal Resilience, University of Cape Coast (Ghana))

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[BSG7SMHd-01] AI/ML-Augmented Metocean Digital Twins for Predictive and Actionable Maritime Intelligence

*Ruoying He[1] (1. North Carolina State University (USA))

The maritime industry increasingly requires accurate, timely, and actionable insights to manage risks, optimize operations, and support sustainability. This presentation introduces an AI/MLaugmented Digital Twin of the Ocean (DTO) that integrates hyper-local, atmosphere–ocean–wave models with advanced data assimilation, cloud computing, and machine learning. By combining real-time observations with process-based modeling and AI-enhanced analytics, this framework creates a dynamic, interactive representation of the marine environment that can anticipate evolving conditions and support decision-making.

The talk will describe examples of how this innovation delivers predictive and actionable intelligence for a wide range of maritime applications, including port operations, offshore platforms, marine life protection, and search-and-rescue missions. Beyond operations, these systems also enable scenario testing to evaluate climate impacts, guide spatial planning, strengthen ecosystem resilience, and mitigate pollution risks.

Aligned with the UN Ocean Decade program DITTO and the IEEE P3501 standardization effort, this work emphasizes the importance of interoperability, engineering frameworks, and interface standards to ensure long-term scalability across science, industry, and policy. By advancing both the scientific foundations and practical implementations of DTOs, this research demonstrates how AI/ML-driven digital twins can transform metocean forecasting into predictive, decision-ready intelligence that supports a sustainable and resilient maritime future.

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[BSG7SMHd-02] From Ocean Integration to Ocean Strategy: A Principles-Driven Framework for the Long-Term Success of Regional Digital Twins

*Joaquín Tintoré[1] (1. IMEDEA (CSIC-UIB) (Spain))

Regional Digital Twins of the Ocean (RDTOs) offer a unique opportunity to transform ocean science by delivering measurable societal impact. Realizing this potential requires recognizing RDTOs not simply as complicated technological platforms, but as complex socio-technical systems. Despite advances in observing systems, modelling, and digital infrastructures, societal impact remains constrained by fragmented disciplinary and institutional silos, persistent “sea-blindness” in governance, and limited progress in ocean literacy and connecting people with the ocean.

Addressing these systemic barriers requires organizational transformation alongside scientific and technological innovation. Building on progress in ocean integration, the next step is a coherent Ocean Strategy. Here, strategy is understood as an integrative set of mutually reinforcing choices that aligns people, disciplines, and organizations around a shared purpose. Such a strategy must be principles-driven, since decision-making in complex systems requires enduring principles rather than fixed rules to guide short-term decisions while sustaining a clear long-term direction. If strategy defines the map, principles provide the compass for navigating uncertainty.

Drawing on Roger Martin’s Strategy Choice Cascade, we develop an Ocean Strategy to guide the design and long-term success of Regional DTOs. We illustrate its implementation through the 17-year strategic evolution of the SOCIB Research Infrastructure and discuss the leadership and organizational changes required in two-sided scientific organizations balancing scientific excellence and societal impact.

Our analysis shows that the long-term success of Regional DTOs depends on a paradigm shift: from bureaucratic inertia to principle-based agile governance, from fragmented disciplinary efforts to symbiotic innovation ecosystems, and from scientific excellence alone to scientific excellence with societal impact. By aligning people around a shared purpose, such an Ocean Strategy builds trust, sustains communities of practice, connects people with the ocean, attracts the next generation, and enables Regional DTOs to evolve beyond technological platforms into socio-technical catalysts for ocean sustainability and human well-being.

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[BSG7SMHd-03] Digital Twins at the Land–Ocean Interface: A Platform for Cross-Sector Dialogue and Public Engagement

*Francisco Werner[1] (1. Smithsonian Institution, National Museum of Natural History (USA))

Beyond their role as scientific and decision-support tools, Digital Twins (DTs) have the potential to transform how museums and public institutions diffuse knowledge. Immersive and interactive DT environments can allow users to experience complex land–ocean systems in ways that static exhibits cannot, exploring how ecosystems function, how human activities influence environmental outcomes, and how alternative futures may unfold under different decisions. By making scientific knowledge tangible, participatory, and accessible, DTs can expand the traditional role of museums from repositories and interpreters of knowledge to active platforms for exploration, learning, and informed dialogue about the future. In this way, DTs align closely with the Smithsonian Institution’s mission of the increase and diffusion of knowledge, creating new opportunities to connect research, education, resource management, and public engagement.

This presentation explores how Digital Twins can serve as a platform for addressing complex challenges at the land–ocean interface. By integrating observations, collections, historical records, socioeconomic information, predictive models, and stakeholder knowledge, DTs can enable users to explore alternative futures, evaluating potential synergies and tradeoffs to assess the consequences of management actions before they are implemented. Such capabilities support applications ranging from coastal resilience and ecosystem restoration to sustainable fisheries, biodiversity conservation, watershed management, and climate adaptation.

Drawing on emerging initiatives in coastal and ocean digital twinning, including applications spanning watershed-to-ocean systems from the Arctic to the tropics, this presentation argues that DTs can simultaneously advance science, support actionable solutions, and strengthen public engagement. By connecting discovery, decision-making, and education within a common framework, Digital Twins offer a powerful pathway for fostering more resilient and informed futures at the land–ocean interface.

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*Sigmund Kluckner[1] (1. Sigmund Kluckner (Austria))

Connecting the DOTs provides a global overview and interactive map of Digital Twins of the Ocean (DTOs), examining the current status of DTO developments, stakeholders, technologies, and opportunities for collaboration. The report reveals a rapidly expanding but highly fragmented landscape in which governments, research institutions, international organizations, and private-sector actors are developing ocean digital twins and related components, often using similar technologies, datasets, and objectives but with limited coordination.

A central finding is the strong and growing demand for international cooperation. Organizations consistently highlighted the need to share challenges, exchange experience, increase access to data and computational infrastructure, and avoid duplication through the reuse of models, workflows, and software components. International networks and standards initiatives are already creating momentum toward more connected and interoperable DTO ecosystems. The report argues that federated architectures, common standards, shared registries of models and datasets, and stronger cross-border partnerships will be essential to unlock the full value of DTOs for science, policy, and the blue economy.

At the same time, significant challenges remain. Technical barriers include limited interoperability between systems, difficulties integrating data and models, infrastructure constraints, uncertainty in model outputs, and the challenge of moving from static digital replicas to interactive digital twins. Organizational barriers include fragmented governance, inconsistent funding, data licensing restrictions, and uneven technical capacity across regions. These challenges are especially pronounced in areas with limited resources but growing demand for ocean information and decision-support tools.

The report concludes that realizing the full potential of DTOs will require coordinated international action, sustained investment, and a culture of openness and collaboration. Building on momentum within DITTO and related initiatives, there is growing interest in strengthening peer exchange, convening collaborative workshops, and establishing an active global community of practice that promotes the sharing of data, models, infrastructure, and expertise to accelerate DTO development worldwide.

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*Yun-Chuan Shao[1] (1. National Taiwan University (Taiwan))

Over the past decade, limitations in GPU hardware and development technologies have made it difficult to migrate global numerical weather prediction models to GPU architectures. Although these models run efficiently on CPU-based systems, porting them to GPU typically requires substantial development effort to rewrite low-level code for specific GPU architectures. In addition, the high double-precision requirements of global numerical weather prediction models introduce challenges related to rounding errors and numerical accuracy during GPU implementation. Similar issues have been reported in GPU-based weather and climate model development, particularly when different numerical precisions and CPU–GPU implementations are compared.
To address these issues, our team developed a CPU-to-GPU migration framework that combines OpenACC with the NVIDIA Collective Communications Library (NCCL). Using this framework, we upgraded the Central Weather Administration's Global coupled Earth system Prediction System, GEPSv3, from its original CPU-based high-performance computing platform to a GPU-based architecture. The proposed approach aims to reduce the need for extensive low-level code rewriting while addressing the inter-GPU communication and numerical-accuracy requirements of a fully coupled global ocean–atmosphere forecasting system.

A performance comparison was conducted between the original configuration using 496 CPU cores on the FX1000 system and the GPU-based configuration using 16 CPU cores and eight GPUs on an A100 node. For a 45-day integration of GEPSv3, the GPU-based configuration reduced the computational time by 86%, while the node-hour consumption was reduced to approximately 1.4% of that of the original CPU-based configuration. These results demonstrate that the proposed NCCL-OpenACC framework can substantially improve computational efficiency and reduce resource consumption, while providing an effective approach for migrating a fully coupled global ocean–atmosphere forecasting system from a CPU-based to a GPU-based architecture.

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[BSG7SMHd-06] Impact of Coastal Upwelling on Biological Production: Numerical Modeling Investigation of the Situation on the Ghanaian Shelf

*Kwabena Danso[1] (1. Africa Centre of Excellence in Coastal Resilience, University of Cape Coast (Ghana))

In Ghana and other countries around the Gulf of Guinea, the strength of upwelling is mostly assessed based on changes in sea surface temperature (SST). This approach ignores surface wind conditions that drive Ekman transport and the upwelling of nutrient-rich water, which stimulate biological production. Therefore, the purpose of this study was to evaluate a new index for assessing upwelling events on the coast of Ghana. The study utilised satellites measurements (wind, nitrate, etc.) from the Copernicus Marine Service from 1995 to 2021. The occurrence of upwelling was assessed using the Coastal Upwelling Transport Index (CUTI) based on the combined effect of alongshore wind and geostrophic velocities. Nutrient input associated with upwelling was assumed to be directly related to Biologically Effective Upwelling Transport Index (BEUTI); vertical transport of nitrate by upwelling into productivity euphotic zones of the ocean. A generalised addictive model was applied to investigate relationship between the strength of upwelling and abundance of three small pelagics (Sardinella maderensis, S. aurita, and Engraulis encrasicolus). Intense upwelling was predicted to occur in July, August and September of each year, with moderate to significant relationship between average CUTI (1.94 ± 0.37 m2 s-1) and the concentration of nutrients such as silicate (R2 = 0.70, p = 0.001), phosphate (R2 = 0.54, p = 0.007) and nitrate (R2 = 0.42, p = 0.022) in surface waters of the ocean. Consequently, nutrient input was also significantly high in July, August and September with BEUTI at 7.16 ± 3.45 STD mmol m-1 s-1 and had a strong relationship between abundance of S. maderensis (R2 = 0.193, p = 0.0279) and E. encrasicolus (R2 = 0.194, p = 0.0279). These results agree with previous reports on the characteristics of coastal upwelling in Ghana.

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