Keynote

Wed. Nov 11, 2026 2:00 PM - 3:30 PM JST | Wed. Nov 11, 2026 5:00 AM - 6:30 AM UTC | Room A (Oshidori) (2F)

Keynotes A1

Chair: Marina Tonani, Fei Chai

2:50 PM - 3:05 PM JST | 5:50 AM - 6:05 AM UTC

[_yrsOa95-04] From Ocean Forecasting to Predictive Digital Twins: Closing the Loop from Observations to Decisions

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Ocean forecasting has advanced considerably over the past two decades, driven by improvements in numerical models, observing systems, satellite remote sensing, data assimilation, ensemble methods, artificial intelligence, and high-performance computing. Ocean digital twins provide an opportunity to bring these elements together within an integrated framework that combines models and observations to represent and predict the evolving ocean state and ultimately support informed decision-making. Developing predictive digital twins requires the seamless integration of numerical models with in situ observations and satellite imagery, while quantifying and propagating uncertainties and enabling optimization and decision-making in real time.

In this talk, I will discuss our experience developing integrated ocean prediction systems, with particular emphasis on the Red Sea. Ensemble data assimilation provides a framework for integrating heterogeneous observations with numerical models, quantifying uncertainties in the ocean state, and propagating them into forecasts. I will illustrate these developments through two applications. The first focuses on oil-spill monitoring and prediction, using satellite imagery for detection and atmospheric and oceanic forecasts to predict spill evolution and associated uncertainties. The second explores how environmental predictions and their uncertainties can be combined with optimization methods to design shipping routes that reduce environmental impacts, including emissions and underwater noise.

Building on these applications, I will discuss how ocean prediction systems can evolve toward operational digital twins that connect observations, prediction, and uncertainty quantification with optimization and decision-making under uncertainty. Closing this loop in real time presents significant computational and methodological challenges, and this is where AI can play an important role. AI can extract actionable information from satellite imagery, accelerate computationally demanding models, and enhance data assimilation, ensemble prediction, optimization, and decision support. I will conclude by highlighting the key challenges toward operational ocean digital twins capable of transforming observations and predictions into actionable information for real-time decision-making.

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