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[fISC.z5m-14] Oceanographic Drivers of Bigeye Tuna (Thunnus obesus) Habitat Suitability in the Eastern Indian Ocean off Java

*Mega Laksmini Syamsuddin (1. Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran (Indonesia))

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*Tsubasa Kodaira (1. The University of Tokyo, Graduate School of Frontier Sciences (Japan))

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Posters 2

[fISC.z5m-01] Deep-Learning Nowcasting of HF-Radar Surface Currents in the Sunda Strait: From One-Step Prediction to Six-Hour Forecasts

*Dhava Gautama[1] (1. Badan Meteorologi Klimatologi dan Geofisika (Indonesia))

Surface currents in the Sunda Strait, which links the Java Sea and the Indian Ocean, are dominated by strong semidiurnal (M2) tides modulated by the reversing monsoon, and can exceed 200 cm/s, a hazard to the dense shipping traffic that crosses it. Indonesia's operational ocean model, Ina-CAWO, provides regional current forecasts, but does not resolve the narrow strait and its extreme tidal currents at kilometre scale, nor does it ingest the local HF radar. We test whether deep learning applied to high-frequency (HF) radar observations can provide skillful, kilometre-scale surface-current nowcasts that complement this model as a data-driven component of an ocean digital twin.

We use hourly current fields from a BMKG HF radar covering 291 sea cells on a ~1 km grid, from December 2022 to February 2026. The fields are quality-controlled with speed, temporal, and spatial outlier filters, and short gaps are filled by tidal harmonic analysis. Models are trained on December 2022–December 2024 and evaluated on an independent July 2025–February 2026 period. We first benchmark nine one-step predictors; a CNN-GRU model attains the lowest error (U/V RMSE 13.8/19.6 cm/s), improving on a moving-average baseline by 19%/12%. For six-hour nowcasting, a bidirectional ConvLSTM encoder-forecaster predicts all six lead times at once, reaching 18.8/22.6 cm/s U/V RMSE and reducing persistence error by up to 56%. Skill is highest when the input window spans a full semidiurnal cycle (12 h), indicating the network exploits the dominant tidal periodicity.

Forecast error concentrates near the strait boundaries, where current gradients are steepest, and shows a diurnal modulation likely linked to diurnal tides and wind forcing. These results show that HF-radar deep learning can provide a high-resolution, observation-driven nowcasting layer that complements Indonesia's operational ocean model in a Sunda Strait digital twin, with potential to extend to other tidally energetic, data-sparse coastal seas.

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[fISC.z5m-02] Subsurface Structure and Drivers of Marine Heatwaves in the Andaman Sea Using Bio-Argo Data

*Dr. Nibedita Behera[1] (1. Berhampur University (India))

A marine heatwave (MHW) is defined as a prolonged anomalous warming of ocean temperatures persisting for more than five consecutive days. Such events pose significant threats to regional marine ecosystems, particularly coral reefs, which are highly sensitive to thermal stress. Although widespread coral bleaching associated with MHWs has been reported, in situ observations remain limited, and the physical mechanisms governing the persistence of MHWs in specific regions are still poorly understood. This study focuses on the northern Andaman region, known for its rich coral diversity. A Bio-Argo float (ID: GL_PR_PF_2902158) is used to investigate the physical oceanographic conditions during MHW and non-MHW periods along its trajectory, with emphasis on their implications for coral bleaching. Since reef-building corals are primarily confined to shallow waters (upper ~200 m), Argo profiles were selected based on upper-ocean depth coverage and the occurrence of MHW and non-MHW events. Results show that during the MHW event (28 November–3 December 2017), the barrier layer thickness increased to 30 m, accompanied by a deeper mixed layer depth (55 m). In contrast, during the non-MHW period (4 December 2017–5 March 2018), a thinner barrier layer (20 m) and a shallower mixed layer (40 m) were observed. Additionally, the MHW period was characterized by stronger surface winds and elevated sea surface temperatures (SST), indicating enhanced surface mixing. However, the presence of a thick barrier layer inhibited vertical heat exchange, trapping heat within the upper ocean and thereby sustaining the MHW conditions. This prolonged thermal stress likely contributed to coral bleaching in the northern Andaman region.

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[fISC.z5m-03] Developing a LiDAR-Derived Digital Twin of Mangrove Ecosystems in Tobago

*Deanesh Ramsewak[1] (1. Centre for Maritime and Ocean Studies, The University of tt (Trinidad and Tobago))

Mangrove forests are important coastal ecosystems that support biodiversity, shoreline protection and blue carbon storage. Despite conservation efforts, they continue to experience degradation and fragmentation due to climate change impacts and anthropogenic pressures. Monitoring and conservation frameworks can be enhanced by capturing and incorporating more detailed information on the structural nature and spatial dynamics of mangrove ecosystems. Light Detection and Ranging (LiDAR) technology can be used to produce high-resolution, digital replicas of these forests for enhanced analysis and monitoring. In this study a handheld mobile terrestrial scanner (Simultaneous Localization and Mapping – SLAM) was used to capture LiDAR point cloud data of mangrove forest on the island of Tobago. Handheld mobile LiDAR systems offer increased portability and agility which are particularly advantageous in dense mangrove environments. The point cloud data was used to generate a detailed, spatially accurate digital twin of the mangrove forest area. Established field sampling plots were used to capture spatial extent and canopy structure of trees. The three-dimensional digital model produced was used to derive key structural parameters, including tree height and canopy complexity. This information along with other key thematic layers were integrated to provide a comprehensive depiction of the natural mangrove forest environment. This study produced an interactive digital twin of the mangrove forest from remotely sensed LiDAR data for mapping and monitoring of fine scale, gradual changes in the system. Handheld LiDAR systems have significant mobility advantages and are particularly useful in small island developing states (SIDs) where the mangrove systems are relatively small. The digital twin generated here can be used for improved monitoring and assessments to support informed planning and simulation of future environmental changes. It is also a powerful tool for strengthening blue carbon accounting and coastal resilience within the Caribbean region.

Keywords: Mangrove, LiDAR, Digital Twin, Blue Carbon, Coastal Resilience, Remote Sensing

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Posters 2

[fISC.z5m-04] SURF: A deep learning-based satellite-driven underwater reconstruction framework with fine-tuning for global three-dimensional particulate organic carbon retrieval

*Haneul CHO[1] (1. Graduate School of Carbon Neutrality, Ulsan National Institute of Science and Technology (UNIST) (Korea))

Particulate organic carbon (POC) in the ocean plays a central role in the biological pump, which transports carbon to the deep ocean for long-term storage. Accurately analyzing its spatiotemporal variability is therefore crucial for understanding the global carbon cycle. However, existing ocean-color-based POC estimation algorithms are limited by the complexity and regional specificity of bio-optical relationships, and they have the particular drawback of relying excessively on surface data, which leads to error amplification when estimating values below the surface. To properly assess ocean carbon stocks, it is necessary to go beyond simple surface estimates and understand subsurface carbon dynamics.
To overcome these limitations, this study proposes SURF (Satellite-driven underwater reconstruction and fine-tuning framework), a foundation model-based framework that integrates satellite observations with multiple environmental proxies to reconstruct global 3D POC. The proposed model transforms data into 2D and 3D tensors to process data from various sources.
Furthermore, by combining a FiLM (Feature-wise Linear Modulation) network with multi-head depth attention, it organically links surface-level environmental factors with depth-dependent features to capture complex vertical POC structures. In the training process, the model undergoes pre-training using 3D chlorophyll-a data estimated in previous studies based on profile types and parameterization, followed by fine-tuning using sparse in-situ observational data.
This model was validated using extensive global in-situ observation data. Cross-domain experiments conducted existing baseline models in terms of root mean square error (RMSE), mean absolute error (MAE), and profile correlation (R^2). Qualitatively, it also realistically reconstructs the response of the biological carbon pump to environmental changes using 3D continuous data at a resolution of 0.25 degrees.
In conclusion, the SURF framework is a highly robust and innovative model that successfully integrates satellite observation data with physical and biogeochemical dynamics, enabling high-resolution reconstruction of three-dimensional POC distributions and carbon dynamics across the entire ocean depth range.

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[fISC.z5m-05] Understanding the Earth System Oscillations through Phase Reduction

*Ayumi Ozawa[1] (1. JAMSTEC (Japan))

The Earth system exhibits a wide variety of oceanic and atmospheric oscillations arising from interactions across multiple spatial and temporal scales. Although predictions of the Earth system have become increasingly accurate, informed decision-making and the improvement of the models both require understanding the dynamical mechanisms underlying the predicted behavior. Numerical simulations under diverse conditions are valuable for investigating such mechanisms, but their computational cost limits the number of scenarios that can be explored, particularly when high spatiotemporal resolution is required.

We introduce the phase reduction method as a tool that complements large-scale numerical simulations and AI-driven analyses. It transforms an oscillatory system into a low-dimensional phase equation that describes how its oscillation responds to external perturbations. The reduction also provides a phase sensitivity function, which identifies where perturbations most effectively influence the system dynamics. However, many mathematical models in ocean and Earth science fall outside the scope of conventional phase reduction theory. We are therefore extending the phase reduction method for such models.

In this presentation, we analyze the quasi-biennial oscillation (QBO), the approximately periodic reversal of equatorial stratospheric zonal winds. The developed method identifies the altitudes at which external forcing most effectively modifies the QBO period. It also clarifies how the influence of the annual cycle depends on the drivers of QBO. Finally, we discuss the potential application of this framework to Boundary Current Synchronization, the synchronized sea surface temperature variability observed between the Kuroshio and the Gulf Stream. Thus, the phase reduction may contribute to digital twins that provide not only accurate predictions but also elucidate the underlying mechanisms.

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[fISC.z5m-06] Data-Driven Inference of ENSO Phase Dynamics under Annual Forcing

*Takahiro Arai[1] (1. Japan Agency for Marine-Earth Science and Technology (Japan))

The El Niño–Southern Oscillation (ENSO) is a dominant mode of interannual climate variability. Although ENSO events recur irregularly with periods of approximately 2–7 years, their evolution exhibits a pronounced seasonal preference, with El Niño events often peaking in boreal winter. This seasonality suggests that the annual cycle influences the timing and progression of ENSO events. However, how the annual cycle modulates ENSO phase dynamics remains insufficiently quantified.

In this study, we infer the phase dynamics of ENSO directly from observational sea surface temperature data. Using a data-driven Koopman analysis, we extract the fundamental oscillatory mode of ENSO. Its temporal evolution is represented by a rectified phase that behaves approximately as a harmonic oscillator. From the resulting phase time series, we infer a phase equation for ENSO. The inferred phase equation describes how periodic forcing by the annual cycle modulates the phase velocity of ENSO. The inferred dynamics reveal partial 3:1 phase synchronization between ENSO and the annual cycle. These results demonstrate that data-driven phase dynamics provide a quantitative framework for investigating the seasonal modulation of ENSO evolution.

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[fISC.z5m-07] An eDNA-based Functional Community Representation for Coastal Digital Twins: A Proof of Concept in Orido Bay

*Aya Suzuki[1] (1. Space Environment and Energy Laboratories, NTT, Inc. (Japan))

Environmental DNA (eDNA) metabarcoding has become a powerful tool for biodiversity monitoring by enabling broad, non-invasive detection of taxa from environmental samples. While recent studies have explored functional trait or guild analyses within individual taxonomic groups (e.g., fish communities), few have addressed the integration of heterogeneous biodiversity observations derived from eDNA into a unified functional representation of ecosystem structure for ecosystem-level assessment and Digital Twin applications.

In this study, we propose an eDNA-based framework for generating functional community representations through ecological functional guilds. Instead of directly interpreting species detection results, detected taxa are assigned to ecological functional guilds and integrated to generate functional community structure profiles that describe the relative composition of ecological functional guilds. This approach bridges biodiversity observations and ecosystem-level assessment by integrating heterogeneous observations across different biological groups into a common functional community representation.

As a proof of concept, the proposed framework was applied to seasonal eDNA observations collected in Orido Bay, a coastal ecosystem in Japan. The resulting functional community profiles resolved seasonal differences in functional guild composition beyond what could be inferred from species inventories alone. The proof of concept demonstrates the feasibility of translating eDNA-based biodiversity observations into a functional community representation.

Finally, we discuss the potential of the proposed functional community representation as a candidate ecological observation variable for future Digital Twin of the Ocean (DTO) applications. Beyond ecosystem monitoring, the proposed framework provides a model-compatible ecological representation that can be coupled with forecasting ecosystem models to project future changes in ecosystem balance under different environmental conditions and restoration scenarios. Such a capability could support quantitative biodiversity assessment, restoration planning, and adaptive management for nature-positive coastal ecosystems.

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[fISC.z5m-09] Beyond Conventional Sampling: Coastal Biogeochemical Insights from an Autonomous Water Quality Nowcasting System in the Southeastern Arabian Sea

*Sanjiba Kumar Baliarsingh[1] (1. Indian National Centre for Ocean Information Services, Ministry of Earth Sciences, Government of India, Hyderabad-500090 (India))

Coastal waters off Kochi, in the southeastern Arabian Sea, change biogeochemically over hours rather than weeks, yet these sub-daily signals rarely surface in routine monthly or fortnightly sampling. To examine what such sampling misses, we analysed three high-frequency observation windows from the moored buoy of the INCOIS Water Quality Nowcasting System (INCOIS-WQNS) off Kochi, representing August 2023, January 2024, and April 2024. The INCOIS-WQNS is an autonomous moored platform carrying a multiparameter suite of in-situ physical, chemical, and biological sensors; it samples the water column continuously and relays observations to shore by satellite telemetry, supporting near-real-time water-quality nowcasting. Each window spanned three continuous days at 30-minute intervals. Thirteen quality-controlled variables were examined, namely temperature, salinity, dissolved oxygen (DO), pH, water and air pCO2, chlorophyll-a, turbidity, CDOM, dissolved methane (CH4), hydrocarbons, and currents, using Kruskal–Wallis testing, diel composites, spectral analysis, principal component analysis (PCA), k-means clustering, and a Hydrographic Stability Index. Every variable except current direction differed significantly among periods. Most striking was a near-anoxic event in the pre-dawn hours of August 2023, when DO fell to 0.09 mg L-1 and stayed there for close to five hours, with several readings below the 2 mg L-1 hypoxia threshold; August also showed the strongest diel swings in oxygen and pH. April differed, marked by the highest methane concentrations (2.11 $\pm$ 0.30 µM), the broadest pCO2 range, and the weakest hydrographic stability, all pointing to a more unstable biogeochemical state. PCA explained 83.5% of the total variance, and clustering cleanly resolved the three seasonal regimes. Low-frequency sampling would therefore overlook the transient hypoxia, understate the diel range of the carbonate system and oxygen, and miss the episodic methane enrichment. Resolving these dynamics and improving monitoring in the southeastern Arabian Sea depends on sustained, autonomous high-frequency observation.

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[fISC.z5m-10] Impact of Marine Heatwaves on Ocean-Atmosphere CO2 Fluctuations

*Pierre Simiganoschi (1. Tohoku University (Japan))

Marine heatwaves (MHWs) are prolonged periods of extreme ocean warming that are increasing in frequency and intensity under global warming. They can alter the air–sea exchange of CO_2, yet their effect on the CO_2 flux (FCO_2) remains poorly constrained, particularly at sub-monthly timescales. Using a daily-resolution decomposition of FCO_2 anomalies (1982–2023, global 2° grid), we apply a first-order Taylor-series decomposition to separate the flux anomaly into wind, ΔpCO_2, thermal, and non-thermal components and composite them over MHW events. To compare events of different length, each event's duration is min–max normalized onto a common 0–1 life-cycle axis and divided into onset, mature, and decay phases. Wind speed is systematically reduced during MHWs, consistent with the atmospheric high-pressure conditions that often accompany them; weaker winds slow gas exchange and reduce CO_2 uptake in sink regions. This wind suppression dominates the flux response for short events (10–30 days), whereas for events longer than about one month the thermal component accumulates and becomes the leading driver. The wind contribution is also seasonal in the midlatitudes—strongest in spring and autumn and weakest in summer. The phase analysis shows the response is not steady: the total FCO_2 anomaly is largest at onset, where a negative wind-speed anomaly reduces uptake, and weakens toward decay, where the wind effect fades or reverses while thermal and non-thermal components grow in relative importance. MHW impacts thus behave as compound events, in which co-occurring high SST anomalies and reduced winds jointly modulate the flux. As MHWs continue to intensify and lengthen, resolving this duration- and phase-dependent behavior will be essential for accurately quantifying their contribution to ocean carbon-sink variability.

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Posters 2

[fISC.z5m-11] Interpretable Latent Dynamics of Deep-Ocean Variability from Three-Dimensional Temperature Fields Using Koopman Autoencoders

*Min Su Song (1. Chungnam National University (Korea))

Deep-ocean circulation is a key component of the climate system, governing large-scale heat transport, carbon storage, and long-term variability. Its dynamics emerge from nonlinear interactions among buoyancy forcing, stratification, and internal ocean processes, making them difficult to characterize with conventional linear frameworks alone. In particular, much of the interior ocean's memory of climate variability is embedded in three-dimensional thermal structure.

This study applies a Koopman Autoencoder framework to three-dimensional ocean temperature fields to investigate whether low-dimensional and interpretable latent dynamics can be learned from high-dimensional ocean interior variability. The approach combines nonlinear compression of temperature fields with approximately linear temporal evolution in latent space, offering a structured way to represent complex ocean dynamics while retaining dynamical interpretability.

Using long-term climate model output, we examine whether the learned latent variables capture dominant variability patterns and characteristic time scales associated with deep-ocean circulation. Their physical relevance is assessed through comparison with conventional circulation metrics, including overturning-related indices. This work explores the potential of Koopman-based representation learning as a new framework for physically interpretable analysis of nonlinear deep-ocean climate variability.

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Posters 2

[fISC.z5m-12] Storm surges associated with cut-off low-pressure systems along the South African coastline

*Ramontsheng Sakia Rapolaki (1. South African Weather Service (South Africa))

Cut-off low (COL) pressure systems are among the most devastating natural phenomena, with severe impacts on infrastructure and substantial socio-economic damage in South Africa. Beyond their known impacts, including damaging winds and flooding, they can also trigger storm surges along coastal areas when they occur under favourable ocean-atmosphere conditions, such as spring tides. Here, using three COL events that occurred between January 2014 and April 2024, the ocean-atmospheric mechanisms behind storm surges associated with these events are investigated. The 0.25° (~ 25 km) gridded Global Tide and Surge Model v3.0 data are used to identify storm surge events, and 0.25° (~25 km) gridded ERA5 data are used to assess the atmospheric circulation associated with the COLs. The preliminary results indicate that 2 out of 3 COLs (January 2014 and April 2024 events) were associated with storm surges along the South African coast. The analysis reveals that the location of the COL and its interaction with regional atmospheric circulation patterns, including the tidal cycle, are key determinants of storm surge occurrence. These findings underscore the critical need for a coupled ocean-atmosphere approach to improve disaster preparedness, as COLs increasingly intensify under climate change, leading to more costly disasters.

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[fISC.z5m-13] Ocean State Estimation for Climate Research: Overview and Recent Progress of ESTOC at JAMSTEC

*Satoshi Osafune (1. JAMSTEC (Japan))

Recent progress in the ocean observing network enables us to obtain an unprecedented amount of observational data. However, because observations contain variability across a wide range of temporal and spatial scales, it remains challenging to quantitatively assess the global budgets of heat and freshwater on climate timescales solely from observations. Therefore, much effort has been devoted to ocean state estimation, a synthesis of observations through a data assimilation approach that brings an ocean general circulation model (OGCM) into consistency with the diverse observations. At JAMSTEC, we have been developing and operating an ocean state estimation system which we call “Estimate of global ocean for climate research (ESTOC)”. In this presentation, we provide an overview of our system, highlight recent technical developments, and discuss its application to climate research.

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[fISC.z5m-14] Oceanographic Drivers of Bigeye Tuna (Thunnus obesus) Habitat Suitability in the Eastern Indian Ocean off Java

*Mega Laksmini Syamsuddin (1. Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran (Indonesia))

The eastern Indian Ocean off Java (EIO) is recognized as one of the primary tuna fishing grounds, with bigeye tuna (Thunnus obesus) being a prominent target species of economic significance. This study utilized bigeye tuna occurrence records and satellite-derived oceanographic data from 2017 to 2024, applying the Maximum Entropy (MaxEnt) model to predict habitat suitability based on six oceanographic variables: sea surface temperature (SST), chlorophyll-a, sea surface height (SSH), salinity, wind speed, and current speed. An empirical orthogonal function (EOF) analysis was carried out to gain a better understanding of the region's spatio-temporal ocean variability. The results showed that the first EOF modes for SST, SSH, wind speed, chlorophyll-a, salinity, and current speed each accounted for 68.53%, 60.42%, 58.27%, 51.41%, 51.16%, and 18.09% of the total variation, corresponding to the interannual signal. The model demonstrated strong predictive capability, achieving an area under the curve (AUC) of 0.837. SST was found to have the highest contribution (24.7%), followed by wind (23.5%) and current (20.1%), highlighting temperature as the primary environmental factor influencing bigeye tuna distribution, while chlorophyll-a contributed the least at 5%. Bigeye tuna thrives in optimal environmental conditions with SST between 27 and 28 °C, chlorophyll-a levels of 0.05 to 0.10 mg m^{-3}, salinity ranging from 33 to 34.5 psu, SSH between 0.65 and 0.70 m, wind speeds of 4 to 10 m s^{-1}, and current speeds of 0.01 to 0.2 m s^{-1}, according to response curve analysis. The southern waters off Java (8°-11° S, 105°-115° E) consistently had the greatest habitat suitability index (HSI) values, with September to November being the most favorable months. The MaxEnt model accurately described bigeye tuna environmental conditions, however it is a correlation model that is dependent on the environmental variables included in the research.

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Posters 2

[fISC.z5m-15] Supporting Essential Ocean Variables integration for Digital Twins with machine readable specification sheets

*Adam M. Leadbetter (1. Seascape Belgium and Intergovernmental Oceanographic Commission of UNESCO (Belgium))

The value chain of ocean observing to data to application and services (including forecasting) has been well established at the heart of the digital ecosystem development for the UN Ocean Decade.

Working closely with the Global Ocean Observing System and taking on board feedback from Member States of the Intergovernmental Oceanographic Commission of UNESCO, the Essential Ocean Variable (EOV) framework has been identified as a key strategic driver for data interoperability and data exchange in the UN Ocean Decade's data discovery and access service.

An analysis of the potential for EOV identification in regional and global data systems was undertaken in November 2025 by the Decade Coordination Office for Ocean Data Sharing, the European Marine Observation and Data Network technical coordinator, and experts from the British Oceanographic Data Centre and Ireland’s Marine Institute. A key finding of was that machine readable EOV specification sheets would be a vital next step in establishing EOV data exchange, which can underpin EOV product generation on Digital Twins.

In summer 2026, work was commenced on a JSON Schema to formally describe the structure of an EOV specification sheet. This work revealed that the current PDF documents are not well harmonised in structure and that a JSON Schema allows consistency, cross-checking and validation of the original documents. Experiments have also been conducted using Large Language Models to populate JSON documents with content from the EOV PDF specification sheets conforming to the JSON Schema, giving the first fully machine readable EOV specification sheets.

This presentation will highlight the findings of the EOV data identification analysis, the need for machine readable EOV specification sheets and the progress made in delivering this vital piece of the ocean data interoperability puzzle.

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Posters 2

[fISC.z5m-16] Improving Temporal Homogeneity of Long-Term Sea Ice Concentration Records Through Spatial Distribution Transformation Using Flow Matching

*Suwon Choi (1. Department of Earth, Environmental and Space Sciences, Chungnam National University (Korea))

Sea ice concentration (SIC) is a key variable for understanding polar climate variability, ocean–atmosphere interactions, and long-term climate change. Long-term climate analysis requires not only an extended observational record but also consistency across changes in satellite sensors, retrieval algorithms, and production systems. Although passive microwave SIC products provide multi-decadal coverage, systematic differences in their spatial structure can introduce artificial discontinuities, particularly across product-transition periods.

This study addresses this issue by treating SIC homogenization as a spatial field transformation problem between historical and recent satellite products. We reconstruct a temporally more consistent Antarctic SIC record by learning a transformation from historical Bootstrap SIC fields to AMSR2-like SIC fields. Daily Bootstrap SIC is used as model input, while daily AMSR2 SIC serves as the target reference product during the overlap period after spatial grid harmonization and preprocessing. AMSR2 is not treated as absolute ground truth, but as the target observational product space for harmonization.

We employ a Flow Matching model with a U-Net-based vector-field estimator. Unlike direct one-step regression, the model learns a continuous transformation path from the Bootstrap SIC state to the AMSR2 SIC state through a time-dependent vector field. During inference, this vector field is numerically integrated to generate AMSR2-like SIC fields from Bootstrap inputs. Rather than smoothing the time series directly, the method improves temporal consistency by consistently applying a learned spatial transformation between product spaces.

A mask-aware learning strategy is applied to exclude land, ice shelves, and missing-value regions. Results show lower root mean square error, higher coefficient of determination, and reduced coastal artifacts relative to the original Bootstrap fields. The learned transformation reduces product-dependent structural differences, improving continuity while preserving physically meaningful nonstationarity in Antarctic sea ice variability.

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Posters 2

[fISC.z5m-17] From Basin to Coast: Assessing the Added Value of High-Resolution Nested Wave Modeling for Future Coastal Hazards along the Alexandria Coast

*Amani Ali[1] (1. egyptian meteorological Authority (Egypt))

Future climate change is expected to influence coastal wave regimes through modifications in atmospheric circulation, storm characteristics, and air–sea interactions. Translating these large-scale climate signals into actionable information for coastal adaptation remains a major challenge, particularly in vulnerable urban regions of the Global South. Alexandria, Egypt, located along the southeastern Mediterranean coast, is highly exposed to coastal flooding, erosion, and wave-induced hazards, making it an ideal testbed for investigating the benefits of high-resolution coastal modeling.

This study employs a multiscale nested modeling framework based on the Simulating WAves Nearshore (SWAN) model to examine future wave conditions along the Alexandria coastline. The modeling system consists of a regional Eastern Mediterranean domain at 5 km resolution and a nested coastal domain at 500 m resolution designed to resolve local shoreline geometry and nearshore bathymetric controls. Future simulations are conducted using climate-driven atmospheric forcing under the SSP1-2.6 and SSP5-8.5 scenarios through the end of the twenty-first century.

The framework is designed to evaluate how increasing horizontal resolution affects the representation of coastal wave processes and extreme-event characteristics. Particular emphasis is placed on the ability of sub-kilometer simulations to capture wave transformation, refraction, shoaling, and localized wave-energy concentrations that may not be adequately represented in coarser regional configurations. The analysis further investigates whether future climate forcing may alter the frequency, intensity, or spatial distribution of extreme wave conditions along the Alexandria coast and how these changes vary across scales.

By directly comparing basin-scale and coastal-scale simulations, this study addresses a central question in next-generation Earth system modeling: what scientific value is gained through increasing model resolution? The results will contribute to ongoing efforts to bridge climate projections and coastal impact assessments while providing a framework for evaluating future coastal hazards and adaptation needs across the Mediterranean region.

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Posters 2

[fISC.z5m-18] Five-year molecular monitoring indicates range expansion of harmful benthic dinoflagellates in Korean coastal waters

*Eun Young Yoon[1] (1. Climate Change Research Laboratory, Advanced Institute of Convergence Technology (Korea))

Long-term standardized biological observations are fundamental for developing Digital Twins capable of representing dynamic coastal ecosystems and supporting ecosystem-based management. However, quantitative molecular observations of harmful benthic dinoflagellates remain scarce despite their increasing ecological and public health importance. Once considered restricted to tropical and subtropical reefs, several harmful benthic dinoflagellate taxa are now reported from temperate coasts undergoing rapid warming. Here we present results from a five-year (2021–2025) nationwide monitoring program designed to establish a long-term biological observation dataset for Korean coastal waters.

Seasonal sampling was conducted at coastal monitoring stations throughout Korean coastal waters, including the West, South, and East Seas, between 2021 and 2025. Quantitative real-time PCR (qPCR) assays targeting species-specific rDNA regions were used to estimate the abundance of four major harmful benthic dinoflagellates: Amphidinium massartii, Ostreopsis cf. ovata, Gambierdiscus jejuensis, and Coolia malayensis. Concurrent environmental observations, including in situ water quality parameters measured using a YSI multiparameter sonde and chlorophyll-a concentrations, were collected to examine relationships between harmful benthic dinoflagellate occurrence and environmental conditions.

Results from five years of monitoring demonstrate substantial spatial and seasonal variability in the occurrence and abundance of harmful benthic dinoflagellates throughout Korean coastal waters. Species-specific distribution patterns varied among coastal regions and survey periods, reflecting the influence of water temperature and hydrographic conditions. Warm current transport along the southern and eastern coasts may be one contributing factor. The long-term observations further reveal an increasing frequency of occurrence and an expanding geographic range for several species consistent with warming-driven range expansion along the Korean coast. This monitoring program establishes a valuable biological observation resource for Digital Twin development. Integrating quantitative molecular observations with environmental monitoring provides a robust foundation for model calibration and forecasting of harmful benthic dinoflagellate dynamics in Korean coastal ecosystems.

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[fISC.z5m-19] Advancing Shallow Coral Reef Monitoring for Ocean Digital Twins: A Physics-Based Nonlinear Spectral Unmixing Approach for Simultaneous Benthic Cover, Water Quality, and Bathymetry Retrieval

*Palika Wannawilai (1. Institute of Science Tokyo (Japan))

Coastal ecosystems can change rapidly in response to sediment plumes, freshwater discharge, and thermal stress. Coral reefs are particularly sensitive to these changes; however, conventional field surveys provide observations at only a limited number of locations and time points. Ocean digital twins can help address this limitation by integrating observations, data assimilation, and numerical or AI-based models to represent the current state of a coastal ecosystem and predict its future condition.

For coral reef applications, ocean digital twins require frequent spatial information on both the seafloor and water column. Benthic cover, water quality, and bathymetry are important variables because they influence reef condition, light availability, and ecosystem responses to environmental change. Satellite remote sensing can provide repeated observations over large reef areas; however, these variables are often estimated separately or using site-specific empirical models.

This study develops a physics-based nonlinear spectral unmixing method to simultaneously estimate benthic cover, water quality, and bathymetry from seven-band PlanetScope imagery. The method combines nonlinear spectral unmixing with radiative transfer theory to retrieve the fractional cover of seven bottom-cover classes: sand, coral, seagrass, brown algae, green algae, reef rock, and red soil. It also estimates total suspended solids (TSS), turbidity, chlorophyll-a, and water depth from a single satellite observation providing spatially consistent estimates of reef condition. The method was applied to a reef area near the Todoroki River mouth, Ishigaki Island, Japan, and evaluated using in-situ measurements collected in September 2024. Further parameter refinement is ongoing to improve retrieval accuracy. These multi-variable datasets can provide regularly updated inputs for ocean digital twins, supporting coral reef monitoring and management.

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Posters 2

[fISC.z5m-20] Reconstructing food-web networks invisible in the real ocean by using the Superposition Method in the virtual ocean

*Naoto F. Ishikawa (1. Biogeochemistry Research Center, JAMSTEC (Japan))

Food webs are the fundamental engine of planet Earth, transferring energy and nutrients from one life to another. Since perfectly mapping the food-web networks is extremely difficult, stable isotope analysis has advanced in recent decades to estimate "trophic positions" (TPs) of organisms. For instance, a TP of 3.0 in a predator means that the predator primarily eats prey with TP = 2.0; however, a single TP value does not indicate which specific prey was eaten by the predator. No methods are currently available to reconstruct a plausible network in nature where a predator has too many potential prey options. To overcome this problem and reconstruct food-web networks using TP data, we developed the "Superposition Method", which assumes that predators generally prefer to eat prey being positioned approximately one TP below them. Using Bayesian statistics, the method breaks the food web down into potential prey pairs, assigns high probabilities to prey that perfectly meets the assumption, and penalize unlikely predator-prey links (such as a top predator with TP = 5.0 eating microalgae with TP = 1.0). We validated this method by hiding the original predator-prey links in 158 fully documented food webs from the EcoBase database and reconstructing the original network using only the TPs. The reconstrcuted food-web network consistently achieved over 80% accuracy and produced estimation errors <5%. Furthermore, the method proved highly stable even when noisy or imperfect data was introduced. The Superposition Method provides a new approach to study large-scale ecosystems, with applications to the conservation of keystone species, fisheries resources management, and better understanding of energy transfer through living organisms. We plan to establish a platform where anyone can reconstruct food-web networks invisible in the real ocean by using the Superposition Method in the virtual ocean.

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[fISC.z5m-21] JAMSTEC contributions for GOOS: Enhancing Observation Value through Data Integration

*Shinya Kouketsu (1. JAMSTEC-RIGC-GOORC/WPI-AIMEC (Japan))

JAMSTEC GOORC contributes sustained, high-quality observations to global networks such as GO-SHIP, Argo, and TPOS, and supports the Global Ocean Observing System (GOOS) by prioritizing rigorous sensor calibration, quality assurance, and rapid public release to international repositories. Beyond delivering primary measurements, GOORC actively shares technical development for water-sample analysis, sensor testing, intercalibration, and data processing to promote reproducible and trustworthy datasets across the observing community. We regard the downstream production of scientific outputs and the creation and publication of secondary statistical datasets from these primary observations as core activities within the DITTO framework.
To increase the scientific and operational value of observations, GOORC operates an integrated data assimilation system that fuses numerical models with multi-platform measurements from satellites, buoys, and shipborne sensors. The system provides gap filling and consistent gridded analyses that complement sparse in-situ coverage and enhance the usability of observations. Representative applications demonstrate improvements in spatial coverage and reduced analysis error enabling higher-value products. Based on the dataset, we present quantitative evaluations of ocean and climate variability, including metrics for coverage enhancement that have supported deeper scientific understanding.

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[fISC.z5m-22] A Trial of Underwater Acoustic Inverse Analysis Using Surrogate Models and Diffusion Models

*Masami Abe (1. IDEA Consultants, Inc. (Japan))

The advent of diffusion models has spurred a growing body of applied research on inverse analysis techniques that infer subsurface conditions consistent with observed data under physical constraints — a paradigm exemplified by Full Waveform Inversion (FWI) and broadly framed within the context of Physics-Informed Diffusion Models (PIDMs). Applying analogous techniques to underwater acoustic analysis, however, presents a distinct challenge: because acoustic waves propagate in a cylindrically spreading manner underwater, measurements recorded at greater distances from the source inherently reflect contributions from a wide spatial extent, incorporating complex multi-path scattering and reverberation. This physical reality makes it difficult to describe the forward problem in terms of a single, exact governing equation, thereby complicating the direct application of physics-informed frameworks.

To address this challenge, we introduce a surrogate model that approximates the forward acoustic propagation process and employ it as guidance within a diffusion model-based inversion framework. Rather than relying on an explicit physical equation, the surrogate model is trained to capture the statistical input-output relationship of the acoustic system, enabling the diffusion model to be steered toward physically plausible solutions during the reverse diffusion process.

We present results evaluating the effectiveness of the proposed approach using synthetic wavefields generated by numerical wave propagation simulations designed to emulate underwater acoustic environments. Our findings suggest that surrogate-guided diffusion models offer a promising direction for underwater acoustic inverse analysis in scenarios where exact physical formulations are unavailable.

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[fISC.z5m-23] Bridging Ocean Modeling and Ocean Engineering: Relocatable Regional Ocean Modeling for Offshore Floating Wind Turbines.

*Tsubasa Kodaira (1. The University of Tokyo, Graduate School of Frontier Sciences (Japan))

Ocean models have traditionally been developed primarily for understanding and predicting ocean circulation and variability. However, rapidly growing offshore activities, including floating offshore wind energy, increasingly require detailed and site-specific information on ocean currents and their variability for engineering design, operation, and risk assessment. This presentation discusses how regional ocean modeling can bridge physical oceanography and marine engineering, with particular emphasis on its potential applications to floating offshore wind turbines (FOWTs).

As an example, I introduce RGEM, a relocatable regional modeling framework based on MITgcm, using the global ocean reanalysis GLORYS, atmospheric forcing from ERA5, and tidal information from TPXO8 as boundary and forcing data. The framework is designed to enable regional ocean simulations to be deployed relatively easily in different areas of engineering interest.

Compared with wind and wave conditions, information on ocean currents remains relatively limited in many offshore regions. Nevertheless, current-induced loads can be important for FOWTs because of their submerged structures, mooring lines, and power cables. Reliable characterization of current magnitude, direction, vertical structure, and variability is therefore relevant to both design and operation. While operational wind and wave forecasting systems are already widely used in offshore engineering, accurate reproduction and prediction of ocean currents remain challenging.

On the other hand, at the same time, the expansion of offshore engineering may create new opportunities for ocean science. I will therefore discuss the potential for a two-way interaction: ocean science and modeling supporting marine engineering, while offshore engineering activities in turn provide new opportunities to advance ocean observation and modeling.

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