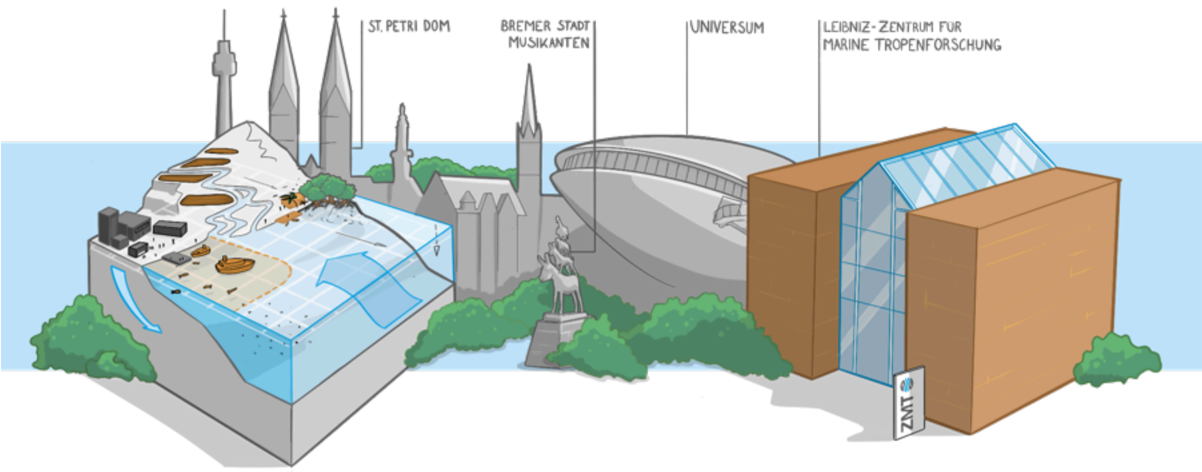
ZMT LEIBNIZ CENTRE for Tropical Marine Research

AGENDA

TropEcS Symposium

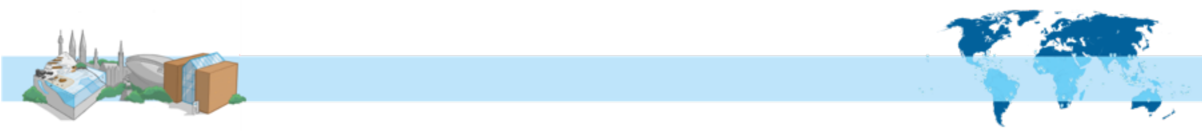
Coupling Tropical Coastal Ecosystems to Earth System Models
Bremen, Germany | 22.09.25 – 25.09.25



🧊 Monday, 22 September, 18:15 – 21:00, Registration & Icebreaker Reception at Universum® Bremen, Wiener Straße 1a

Welcome addresses by Raimund Bleischwitz (Scientific Director, ZMT) and Kathrin Moosdorf (Senator for Climate, Environment and Science of the State of Bremen).

Musical performance by [Biyotob] and science quiz with Tom & Darren.



Within session speaker order: From land and atmosphere via the coast to the open ocean. Each session is guided by a framing question to orient discussion; these are prompts rather than deliverables.

Day 1 – Strengths and Limitations of Existing Earth System Models

Tuesday, 23 September 2025 – Atlantic Hotel Universum, Wiener Straße 4

8:00–8:45 – Registration

8:45 – Opening by Raimund Bleischwitz (Scientific Director, ZMT)

09:00–09:30 – Catalyst Talk: Bjorn Stevens (MPI-M, Germany)

Opportunities for elucidating tropical climate dynamics with a new generation of km-scale climate models

Traditional climate models depend on statistical representations of processes that act on regional and smaller scales and which dominate the climate of tropical regions. These approximations are designed to limit extremes and necessarily neglect land-scape scales. While such simplifications do not seem to strongly impact the ability to inform us about global scale changes, it makes such models inadequate for the study of regional and coastal processes and extremes, as well as the tropics more generally. Thanks to advances in computing, km-scale global climate models, which are designed to explicitly represent processes on the regional scale, and explicitly simulate extremes, are coming into scientific use. In this talk I will present the status of this new modelling paradigm and the opportunities it offers for advancing understanding of the coastal systems, regional processes, extremes, and the tropics more generally.

09:30–10:00 – Catalyst Talk: Veronika Eyring (DLR & University of Bremen, Germany)

AI-empowered Next-generation Multiscale Climate Modeling for Mitigation and Adaptation

Earth System Models (ESMs) are fundamental to understanding and projecting climate change. They have continued to improve, but systematic errors and large uncertainties in their projections remain. A large contribution to this uncertainty stems from the representation of processes such as clouds and convection that occur at scales smaller than the resolved model grid. This impacts the models' ability to accurately project global and regional climate change, climate variability, and extremes. High-resolution, cloud resolving models with horizontal grid resolution of a few kilometers alleviate many biases of coarse-resolution models, but their high computational costs limit their applicability to run multiple decades and large ensembles. Yet short simulations from high-resolution models can serve as information to develop machine learning (ML)-based parametrisations that are then incorporated into hybrid (physics+ML) ESMs that promise to have significantly reduced systematic errors and enhanced projection capability compared to current ESMs. We argue that an AI-empowered multiscale approach is needed to improve climate information in the tropics and more generally on the global and regional scale, drawing on km-scale climate models and hybrid ESMs that include essential Earth system processes and feedbacks yet are still fast enough to deliver large ensembles for better quantification of internal variability and extremes. The talk presents progress in hybrid modelling work as well as key challenges and visions how to enhance climate modeling with ML (Eyring et al., 2024a,b).

References:

Eyring, V., Gentine, P., Camps-Valls, G., Lawrence, D. M., & Reichstein, M. (2024a). AI-empowered next-generation multiscale climate modelling for mitigation and adaptation. Nature Geoscience. https://doi.org/10.1038/s41561-024-01527-w

Eyring, V., Collins, W. D., Gentine, P., Barnes, E. A., Barreiro, M., Beucler, T., Bocquet, M., Bretherton, C. S., Christensen, H. M., Gagne, D. J., Hall, D., Hammerling, D., Hoyer, S., Iglesias-Suarez, F., Lopez-Gomez, I., McGraw, M. C., Meehl, G. A., Molina, M. J., Monteleoni, C., Mueller, J., Pritchard, M. S., Rolnick, D., Runge, J., Stier, P., Watt-Meyer, O., Weigel, K., Yu, R., & Zanna, L. (2024b). Pushing the frontiers in climate modelling and analysis with machine learning. Nature Climate Change. https://doi.org/10.1038/s41558-024-02095-y

Session 1: Global Coupled Earth System Models

This session analyses the current generation of global Earth System Models (ESMs), with emphasis on their capacity to represent land–ocean–atmosphere interactions and their potential for incorporating tropical coastal processes. The session explores the architectures and coupling strategies of ICON-ESM, ACCESS, Tai-ESM, POEM and IITM-ESM, examining the extent to which they support integration of physical, biogeochemical, and ecological components. It highlights how such models handle interactions across spatial and temporal scales, from large-scale circulation to regional and nearshore dynamics, and addresses the treatment of socio-ecological feedbacks and coastal boundary complexities. While some ESMs now enable limited nesting or coupling to higher-resolution modules, considerable challenges remain in resolving coastal–terrestrial exchange, biophysical feedbacks, and fine-scale bathymetric features. Guiding question: How can global coupled models capture land–atmosphere–ocean interactions, and what near-term steps would most improve their relevance for coastal dynamics without compromising large-scale skill?

Chair: Bjorn Stevens (MPI-M, Germany)

10:00–10:15 – Jan Härter (University of Potsdam, Germany)

A vision for tropical coastal modeling and observations

Tropical coasts are unique with an astounding ecological diversity at the interface between the oceanic, terrestrial and atmospheric Earth system components. The tropical coasts provide essential ecosystem services to 40% of the world's population, constitute bottlenecks for international trade and experience heavy impacts of global environmental change. Yet, key processes at this interface of disciplines remain poorly understood. Such lack in understanding may be the result of an insufficient push to holistically modelling the relevant processes - in combination with the incorporation of local expertise and observational campaigns. We present a vision of how to model tropical coastal regions to tackle the combined effects of processes at these coasts using a numerical modelling approach combined with targeted observational campaigns.

10:15–10:30 – Nils Brüggemann (MPI-M, Germany), Arjun Kumar, David Nielsen, Mikael Karvinen, Fatemeh Chegini, Nuno Serra, Cathy Hohenegger, Tatian Ilyina, and Jochem Marotzke

Air-Sea Interactions of Tropical Cyclones in Kilometer-Scale Earth System Models

Tropical cyclones (TCs), with their enormous destructive potential, pose extreme risks to societies in coastal regions. Despite their severe impacts, many aspects of TC dynamics remain poorly understood. Recent advances in computational modeling now make it possible to gain new insights into TC behavior. In this study, I present results from global, non-hydrostatic, storm-resolving, and fully coupled simulations that enable a deeper understanding of the air–sea interactions and feedbacks shaping TC dynamics. In particular, I examine how small-scale and mesoscale oceanic turbulence influences TC intensity, how ocean biogeochemistry responds to TCs, and how the internal variability of TC frequency can be assessed. Finally, I discuss potential avenues for improving the representation of TCs in coupled high-resolution Earth System Models.

☕ 10:30–11:00 – Morning Coffee Break

11:00–11:15 – Georg Feulner (PIK, Germany)

Paleoclimate Modelling Perspectives on Coastal Systems

After a brief introduction into the philosophy and design of the Potsdam Earth Model (POEM) developed at the Potsdam Institute for Climate Impact Research (PIK), I will highlight examples from Earth's history for which coastal dynamics and coastal ecosystems play an important role – and for which improved modelling capabilities linking global and coastal processes would be crucial.

11:15–11:30 – Praveen V. (IITM, India), Swapna P., Sandeep N., Ayantika DC., Priya P., Umakanth U.

IITM-ESM v3: Advances in Tropical Climate Simulation and Bias Reduction

The IITM Earth System Model (IITM-ESM) is India's primary coupled climate model participating in the Coupled Model Intercomparison Project (CMIP). Recent developments enhance the representation of tropical variability and global teleconnections, critical for South Asian monsoon prediction and climate impact studies. Key upgrades include: (i) a Triangular-Cubic-Octahedral (TCO) atmospheric grid for higher tropical resolution, (ii) refined ocean resolution over the tropics, (iii) improved land surface representation with 24 vegetation types using Land Use Land Cover data from the National Remote Sensing Centre (NRSC), India, and (iv) a basin-based river discharge scheme. These improvements yield more realistic simulations of monsoon intra-seasonal oscillations (MISOs), Atlantic Meridional Overturning Circulation (AMOC), and low-pressure system (LPS) propagation. Control simulations show better agreement with observations, notably reducing long-standing biases in rainfall distribution, temperature, winds, and ocean stratification.

The upgraded IITM-ESM (v3) will contribute to CMIP7, providing a vital tropical perspective to the global modeling community.

11:30–11:45 – Yolandi Ernst (University of the Witwatersrand, South Africa) Francois Engelbrecht, Jessica Steinkopf, Gregor Feig, Nolusindiso Ndara, Amukelani Maluleki

Tailoring an Earth system model to the African context

Africa contributes significantly to uncertainties in the global greenhouse gas budget. Savanna ecosystems, covering about 40-50 % of Africa, amplify this uncertainty due to the large seasonal and interannual variability over short time periods and unique drivers of change, such as fire, bush encroachment, and land use. Additionally, Africa is observationally poor, making it challenging to parametrise and validate models. To improve land-surface process characterisations in Africa, we coupled the conformal-cubic atmospheric model (CCAM) with a dynamic land-surface model, CABLE. With its flexible downscaling capabilities, this modelling system adopts a spectral nudging methodology and can be integrated as a quasi-uniform global model or a stretched-grid, variable-resolution regional model to obtain high resolution over a region of interest. We nudged the model using ERA5 reanalysis data, ensuring simulations were consistent with historical weather patterns as captured in the reanalysis outputs. This enabled the evaluation of several land-atmosphere fluxes and attributes of the simulated model outputs against Eddy covariance flux tower observations, as well as satellite data. In general, the modelling system does remarkably well at capturing the key attributes of the seasonal and diurnal cycles of certain land-atmosphere fluxes. Good agreement between satellite-derived and modelled soil moisture further supports the model's capability. The skill of the model does vary by site, highlighting the importance of further validating the model across different biomes and climatic zones. Current efforts are directed to increasingly targeted in situ observations and variables, together with earth observation data, for improved calibration and model improvement to understand the underlying processes that drive carbon flux variations across the African region. Ultimately, the improvement of the land-atmosphere model will provide valuable input for addressing the biochemical component in an ocean model that is being developed in parallel.

11:45–12:00 – Knut Klingbeil (IOW, Germany)

Requirements for the ocean model component in a coastal ESM

The coastal ocean, ranging from the shelf break to estuaries, has a number of characteristics which discriminate it from the global ocean. Therefore, simply increasing the resolution in a global ocean model will not provide a proper coastal ocean model. Coastal ocean models need to reproduce physical processes on different scales and require specific numerical techniques. This talk highlights physical, numerical and technical aspects to be considered when coastal and estuarine dynamics should be represented in Earth System Models.

12:00–12:15 – Tilo Ziehn (CSIRO, Australia)

The Australian Earth System Model: A Southern Hemisphere perspective

The Australian Community Climate and Earth System Simulator (ACCESS) is a complex modelling system designed to support both operational weather forecasting and cutting-edge climate research. In this presentation, we introduce the Earth System Model variant, ACCESS-ESM, and highlight its recent applications in assessing future carbon budgets, exploring climate stabilisation pathways, and investigating scenarios involving temperature overshoot. Particular emphasis is placed on the critical role of the Southern Ocean in those simulations and on the broader implications of future climate change for the Southern Hemisphere.

🍽️ 12:15–13:30 – Lunch Break (lunch provided on site)

Session 2: Regional Models

This session examines the development and application of regional and nested ocean and biogeochemical models as a means to improve the representation of coastal and nearshore processes. It emphasises downscaling strategies, regional nesting of global models, and hybrid approaches that combine dynamical and statistical techniques to overcome resolution and boundary-condition constraints. The session addresses scientific and technical challenges, including data limitations, computational efficiency, and the need for realistic forcings and boundary interactions in highly dynamic coastal regions. The role of new modelling platforms (e.g. MPAS-Ocean, ICON-Coast), more established models (e.g. WRF-NEMO), and regional reanalyses is reviewed, along with emerging strategies to represent fine-scale physical and ecological features. Guiding question: How can regional models be more effectively nested within ESMs, and what benchmarks are most useful for representing tropical coastal and nearshore dynamics?

Chair: Alexandra Klemme (ZMT)

13:30–14:00 – Keynote: Yu-Heng Tseng (NTU, Taiwan)

Challenge of multi-scale Ocean-Atmosphere Coupled Modelling System

This talk addresses the challenges of building a multi-scale ocean–atmosphere coupled modeling system that connects coastal ocean models with the global Earth System Model (ESM). I will begin with early efforts in coupling coastal dynamics to basin- and global-scale circulation, then highlight applications that reveal both limitations and possible solutions. Major challenges include coupling strategies, non-hydrostatic effects of complex topography, and unresolved processes such as internal tides, internal waves, mesoscale and submesoscale eddies, and land–ocean exchanges through estuaries. A particularly critical issue is representing estuarine processes that cannot be explicitly resolved within land-ocean interaction. To address this, simplified parameterizations, such as estuary box models, are introduced within the ESM framework. These examples illustrate the broader challenge of bridging fine-scale coastal processes with large-scale climate dynamics, a key step toward improving predictions of the coupled ocean–atmosphere system.

14:00–14:15 – Bodo Ahrens (Goethe University Frankfurt, Germany)

Coupled Regional Climate Modelling Systems in MED-CORDEX: Atmospheric Perspective

The WCRP Mediterranean Coordinated Regional Downscaling Experiment (Med-CORDEX) has significantly advanced the implementation and application of fully coupled regional climate modelling systems, which integrate a regionally closed water cycle. This study highlights key atmospheric impacts stemming from model coupling, particularly in the simulation of extreme weather events such as medicanes, the dynamics of near-coastal ocean-atmosphere interactions, and the influence of grid resolution and model ensemble configurations. These examples underscore the added value provided by coupled systems in enhancing the fidelity of regional climate projections. Additionally, the presentation includes an outlook on forthcoming developments within MED-CORDEX and reflects on the broader implications for other regions and coordinated modelling initiatives.

14:15–14:30 – Dante Espinoza (IMARPE, Peru)

Physical-biogeochemical modeling in the Northern Humboldt Current Ecosystem: Present trends and future scenarios

The Northern Humboldt Current Ecosystem (NHCE) is among the most productive coastal upwelling systems worldwide, sustained by equatorward winds that bring cold, nutrient-rich waters to the surface. Its functioning is strongly modulated by El Niño and the climate change. To investigate present coastal trends and potential future responses, we employed the regional coupled physical–biogeochemical model CROCO–PISCES. Model performance depends critically on the quality of wind products and the specification of open boundary conditions. The model reproduces main NHCE features, including coastal cooling, enhanced surface productivity, and progressive deoxygenation, with remote forcing identified as the dominant driver. Under high-emission climate scenarios toward the end of the twenty-first century, most dynamically downscaled Earth System Models project surface warming, increased surface productivity, and reduced subsurface productivity, while projections for dissolved oxygen remain uncertain. Recent advances in biogeochemical modeling of coastal bays are also discussed.

14:30–14:45 – Mia Sophie Specht (MPI-M, Germany)

Resolving Tropical Instability Waves: Seasonal Dynamics of Shear Instabilities and Coupled Ocean-Atmosphere Responses in high-resolution simulations

Tropical Instability Waves (TIWs) are a major source of intraseasonal variability in the tropical oceans. Characterized by sharp sea surface temperature fronts, they strongly influence the exchange between the ocean surface, its interior, as well as the overlying atmosphere. Using high-resolution ICON-Ocean simulations, we find that TIW-driven shear instabilities at the wave fronts extend below the mixed layer into the thermocline and follow a pronounced seasonal cycle. They peak in boreal summer, when TIW-induced shear combines with background shear from the northern South Equatorial Current (nSEC). High-resolution coupled IFS/FESOM simulations further demonstrate that the influence of TIWs is not confined to the ocean: they alter the atmospheric boundary layer, modify its height, and affect circulation above. These results highlight that a realistic representation of TIWs in climate models is crucial, not only to resolve oceanic variability, but also to capture their broader role in shaping regional ocean-atmosphere dynamics.

14:45 - 15:00 - Patrice Brehmer (IRD / SRFC, Senegal) Elodie Martinez, Thomas Gorgues, Hervé Demarcq, Shunya Koseki, Etienne Pauthenet, Keerthi Madhavan-Girijakumari, Ndague Diogoul, Aldo Affenou, Yoba Kande, Saliou Faye, Ndague Diogoul, Abdoulaye Sarré, Noel Keenlyside.

Coupling high-resolution Earth system model outputs and data-driven methods to project ecosystem change in the Canary Current upwelling system

Projecting ecosystem change in tropical coastal upwelling systems requires approaches capable of capturing fine-scale physical–biological interactions. In this study, we integrate high-resolution simulations from the nextGEMS project with Earth observation products and empirical models to assess past and projected changes in marine productivity and fish distributions in the southern Canary Current Large Marine Ecosystem (sCCLME). We employ a deep learning approach (UNet) trained on MODIS and OC-CCI chlorophyll-a data, using physical predictors (SST, sea surface height, eddy kinetic energy, wind stress) from nextGEMS simulations to reconstruct spatially and temporally continuous Sea Surface Chlorophyll-a (SSC) fields. In parallel, Generalised Additive Models (GAMs) based on long-term sea survey data (1995–2015) are used to investigate how environmental drivers shape the distribution and biomass of micronekton and small pelagic fish schools. Results show contrasting trends in micronekton biomass and fish school density, suggesting spatial reorganisations in trophic structure under changing ocean conditions. The combination of storm-resolving model outputs with data-driven ecological reconstruction demonstrates the potential of hybrid approaches to improve representation and forecasting of tropical coastal ecosystems, especially in data-limited regions. This work contributes to broader efforts to bridge the gap between global Earth system simulations and regional ecosystem applications.

☕ 15:00–15:30 – Afternoon Coffee Break

15:30–16:15 – Wrap-up Panel Discussion | Härter, Eyring, Klemme, Tseng

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Day 2 – Coupling Components

Wednesday, 24 September 2025 – Atlantic Hotel Universum,
Wiener Straße 4

Session 1: Integrating Ecological Models with Physical and Biogeochemical Processes

This session focuses on modelling approaches for marine and coastal higher trophic levels, their use of ocean and biogeochemical model output, and advancing the integration of ecological processes into coastal models. Key themes include trophic feedbacks, habitat–species interactions and environmental driving of biological dynamics, and assessing anthropogenic impacts through fisheries and climate change. It examines the integration of ecological models with physical and biogeochemical components, with special attention to cross-scale interactions (e.g. larval dispersal to living marine resource productivity), ecological thresholds, and the calibration of models to empirical data and their projection into the future. These models provide important decision support in resource and ecosystem-based governance and societal adaptation to climate change. Guiding question: Which ecological drivers and resolutions are most critical for linking coastal ecosystems with large scale processes, and how can such coupled models best be validated against empirical data?

Chair: Kenny Rose (University of Maryland, USA)

09:00–09:30 – Keynote: Edward Gross (GEI Consultants, USA)

Estimating rate parameters in ecological models utilizing novel representations of transport processes

Ecological models and biogeochemical models use a variety of methods to represent transport processes. I will present two novel and computationally efficient approaches to infer parameters in ecological models driven by information on hydrodynamic transport in the San Francisco Estuary. First, movement information from a particle-tracking model was utilized for Bayesian inference of hatching distributions of the endangered longfin smelt *Spirinchus thaleichthys* in the estuary. This understanding informs management actions intended to minimize entrainment of larvae by water diversions. Second, rates in an offline biogeochemical model were inferred using scalar concentration and age distributions computed by a hydrodynamic model. The analysis revealed that uptake of nutrients by aquatic vegetation was a key biogeochemical process that had been overlooked by previous models. The examples demonstrate that simplified representations of transport processes are useful to infer unknown ecological rates. These rates can be used in more complex coupled hydrodynamic-ecological models.

09:30–09:45 – Alonso Del Solar Escardó (ZMT)

Co-designing Adaptation Pathways for Peru's Coastal Systems under Compound Drivers: Linking Ecological Modelling, Climate Projections, and Stakeholder Insights

Peru's rich, interconnected coastal systems face compound pressures from climate variability and human use. Combining trophic modelling (EwE) with stakeholder insights, this talk explores ecosystem drivers – from ecological responses and masked heatwave feedbacks to market forces and trade-offs – and the emerging challenges and adaptation strategies for local actors. We updated models for two bays (Sechura, Independencia) and the offshore pelagic–demersal system, grounding testable scenarios with historical time series, downscaled ocean–biogeochemical projections, and stakeholder engagement. This enables cross-ecosystem comparisons and supports co-designed scenarios under shared socio-economic pathways. In Sechura, exposure to El Niño, hypoxia, and scallop over-stocking reveals tensions between resilience and human needs. Next steps are to pinpoint the key ecological and socio-economic drivers and system responses, refine and validate scenarios using targeted indicators and broader stakeholder input, and translate results into decision-support tools at appropriate scales to co-design adaptation pathways that balance ecosystem health with livelihoods.

09:45–10:00 – Kenny Rose (University of Maryland, USA)

Some Issues Related to Coupling Physical/Biogeochemical and Upper Trophic Level Models: Fallacy of Averaged Values, Incompatible Spatial Resolutions, and Nervous Skill Assessment

I will discuss three issues related to coupling physical and biogeochemical models (lower trophic level, LTL) to upper trophic levels. These issues are: (1) transferring more than the average values from ESM to LTL to upper trophic level models should be considered, (2) matching of the spatial resolutions of the ESM, LTL and upper trophic models should start by considering the dynamics of the upper trophic levels (i.e., top down), and (3) challenges to skill assessment posed by the different scales and expectations of LTL and upper tropic level models, especially under novel conditions. These issues will be discussed in general terms and illustrated with examples, including coupled LTL-upper trophic models of sardine and anchovy population dynamics in the California Current and anchovy recruitment in the Humboldt Current off Peru. Possible solutions to these issues will be discussed.

10:00–10:15 – Ken Andersen (Technical University of Denmark)

How can size-spectrum and trait-based models advance the integration of marine ecosystem dynamics into Earth System Models? Towards a broader perspective on ecological modelling across scales

We are currently challenged to model how climate change affects higher trophic levels, such as fish. Traditional fish models are food-web models that describe all species in a region and their predator-prey interactions. These models work well for describing the impacts of fishing on the community, but struggle with climate change impacts because they do not resolve the crucial effect of species invasions and their reliance on stock-recruitment relationships. Here I present the "FEISTY" size- and trait- based fish community model that explicitly resolves the dependence of fish on pelagic and benthic energy pathways that can be provided by standard lower-trophic-level models. The model framework predicts emergent food-web structure, potential fisheries production, and carbon sequestration under climate change scenarios on a global scale. I discuss pros and cons of different strategies for coupling the lower-trophic-level models to higher trophic level models.

10:15–10:30 – ZMT's Senior Scientists

TropEcS Topics in a Nutshell: Speed Talks about Posters on Display

TropEcS brings together expertise from the natural and social sciences to improve the model representation of tropical coastal ecosystems under global change. This session features a series of speed talks that introduce the diverse research topics and model components addressed within TropEcS. The talks provide a preview of posters on display during the session breaks, where the individual contributions can be explored in greater detail and discussed directly with the researchers.

Poster session (Foyer Atlantic Hotel Universum)

Esteban Acevedo-Trejos (ZMT) – Earth Surface and Eco-Evolutionary Dynamics Group

Life, climate, and landforms interact to shape the patterns of biodiversity we observe on the Earth's surface. Models serve as valuable tools for testing our intuitions of how these complex systems form and function. While advances have been made in modelling these system components, the focus is typically on just one - either the landscape, climate, or eco-evolutionary part. Hence, to continue investigating how these components interact, there is a need to develop coupled numerical tools. In my contribution, I outline the research focus of the recently established Earth Surface and Eco-Evolutionary Dynamics

Group at ZMT, which aims to develop coupled numerical models to explore how geophysical processes influence functional diversity and how trait variability impacts biogeomorphic systems. The proposed modelling approach is illustrated with potential applications in two research foci. The first focus looks into long-term dynamics, such as mountain-building processes (i.e. surface uplift and erosion), and how such processes affect the morphology of volcanic islands and biodiversity. The second centres on short-term dynamics such as river delta formation, emphasising how trait variability and the unresolved role of organic sediments affect the morphology and sediment composition of deltas. Future directions involve establishing a dedicated modelling group at ZMT, where the development of coupled numerical tools to capture feedbacks between Earth system components at local/short-term and regional/long-term scales will be central. This interdisciplinary approach ultimately aims to advance knowledge of Earth system components' interactions and their influence on biodiversity, thus contributing to a deeper understanding of the dynamic relationships between life and the physical environment.

Alexandra Klemme (ZMT) – Carbon and Nitrogen Dynamics in Rivers: Modelling Oceanic Yields and Atmospheric Emissions

Tropical coastal ecosystems are shaped by complex interactions between terrestrial, aquatic, and socio-economic processes. Understanding carbon and nutrient fluxes across the land–ocean continuum is essential for assessing greenhouse gas emissions, ecosystem functioning, and the impacts of land-use change. This poster presents planned research within the TropEcS framework at ZMT, focusing on carbon and nitrogen dynamics in tropical peat-draining rivers and wetlands. I aim to improve their representation in the ORCHIDEE land surface model by integrating process understanding from field studies in Southeast Asia, which showed how peat extent and pH regulate riverine carbon dioxide and oxygen dynamics. This work will be implemented in a model version with river routing, with extensions planned to include peatland methane processes and nitrogen fluxes.

Murugan Ramasamy (ZMT) – Land–Ocean Fluxes and Transformations

Current Earth System Models treat land and ocean as largely disconnected systems, with freshwater discharge as the most explicitly represented link. Their coarse spatial resolution overlooks key coastal features such as tidal rivers, estuaries, wetlands, submarine groundwater discharge, and subterranean estuaries, and limits the representation of subsurface and biogeochemical processes at the land–sea interface. To address this, we are developing a physically based model that will couple surface and subsurface water flow with reactive transport of carbon and nutrients. The goal is to more accurately quantify material fluxes across land–ocean boundaries, incorporating both flow pathways and transformation processes. Scenario-based simulations will be used to explore how these fluxes respond to socio-economic drivers.

Subhendu Chakraborty (ZMT) – Understanding the Biogeography of the Cyanobacterial N2 fixer UCYN-A

Biological nitrogen (N_2) fixation is essential for sustaining marine productivity, yet most ocean surface waters are depleted in bioavailable nitrogen. Among marine diazotrophs, the unicellular cyanobacterium UCYN-A is one of the most widespread and ecologically important contributors to oceanic nitrogen input. UCYN-A was long considered an obligate symbiont of the haptophyte *Braarudosphaera bigelowii*, but recent work suggests that the

UCYN-A2 sublineage exhibits traits of an early-stage organelle. Despite its ecological importance, UCYN-A is difficult to culture in the laboratory, leaving its physiology and global distribution poorly understood. Here, we integrate new experimental data with a cell-based mathematical model to explore how intracellular regulation of carbon and nitrogen exchange governs N_2 fixation in the UCYN-A/haptophyte association. The model explains its persistence under low light and across a broad thermal range, supporting activity across depths and latitudes. Our simulations predict high fixation in the Atlantic and Indian Oceans, patchy distributions in the Pacific, and strong seasonal patterns at high latitudes driven by temperature, with iron emerging as the dominant control in the tropics. Together, these results provide a mechanistic framework linking UCYN-A cell physiology to its global biogeography.

Stefan Koenigstein (ZMT) – The devil's in the details when linking marine fish to ocean environments

Marine fisheries provide food and livelihoods to about one billion people globally. Earth system and ocean-biogeochemical (BGC) models can be used to drive ecological models of marine fish populations, to support sustainable fisheries governance, global food security and climate change adaptation. However, the characteristics of biological systems and some technical challenges complicate the coupling of ocean and fish models: For instance, high spatial and temporal resolution is needed to model fish habitats shaped by fine-scale ocean and coastal features such as fronts, eddies, and river plumes. Linking phyto- and zooplankton productivity and mortality in BGC models to fish consumption currently constitutes a major uncertainty. Migration and behavioral adaptation, distinct environmental preferences among life stages, food-web interactions, and evolutionary adaptation further complicate fish responses to the environment. Furthermore, especially in many tropical areas, fish observational data is typically patchy and uncertain, and fisheries landings are strongly influenced by socio-economic drivers. To overcome the challenges, coupled models need to consider biological detail and bridge among disciplines, to advance understanding of marine fish productivity, spatial distribution, and sensitivity to fisheries, and robustly project the impacts of global change.

Camilla Novaglio (ZMT) – Modelling Ocean Futures for Fisheries and Food Security

Marine ecosystems and fisheries are increasingly threatened by climate change and resource exploitation, with profound implications for food security and livelihoods, particularly in the tropics. Although these regions are highly dependent on fisheries, they remain underrepresented in modelling efforts that are essential for understanding ecosystem dynamics and anticipating ecological shifts. The Ocean Futures and Fisheries Modelling working group applies marine ecosystem models to investigate how tropical ecosystems and fisheries may respond to alternative climate and resource use scenarios. By integrating ecological and human dimensions, we assess strategies that balance environmental sustainability with socio-economic resilience. In addition, model outputs are combined with aquaculture and agriculture projections, as well as socio-economic data, to evaluate climate risks to integrated food systems, identify cross-sectoral trade-offs, and inform policy. Through collaborations with initiatives such as the Fisheries and Marine Ecosystem Model Intercomparison Project (FishMIP) and FAO the group advances modelling capacity in the Global South and provides science-based guidance for sustainable, climate-ready food systems.

Michael Kriegl, Annette Breckwoldt (ZMT) – Participatory Modelling of Social-Ecological Systems

Millions of people in tropical coastal regions depend on healthy marine ecosystems for their livelihoods. Yet the models that inform environmental management and policy rarely reflect the perspectives of coastal communities. Including local voices into modelling efforts is essential to co-produce knowledge that is not only scientifically robust but also contextually relevant. Within TropEcS, integrated participatory modelling will be advanced across Peru, Colombia and Indonesia, using three complementary approaches: 1) Co-developing interdisciplinary qualitative network models with local actors to identify drivers, feedbacks, and leverage points in social-ecological systems (fisheries, aquaculture, tourism and conservation). 2) Facilitating scenario-building through drawing workshops to elicit visual narratives of desired futures. 3) Applying Bayesian Belief Networks to integrate diverse knowledge systems and TropEcS model results into accessible decision-making tools for data-limited contexts. Embedding local perspectives throughout TropEcS seeks to ensure that its outputs have a positive impact on both communities and the ecosystems they rely on.

Posters by our partners

Heidi Retnoningtyas, Irfan Yulianto (Rekam, Indonesia) – Implementing Ecosystem-Based Fisheries Management (EBFM) in Indonesia: A case study from Saleh Bay

Ecosystem-based approaches to fishery management examine how fisheries integrate with ecological and human considerations to achieve acceptable sustainability. Implementing Ecosystem-Based Fisheries Management (EBFM) in tropical small-scale fisheries presents significant challenges, particularly in multispecies and multigear contexts such as those found throughout Asia. Indonesia's fisheries (as well as those of many other Asian countries) rely on multi-species resources, all of which interact within the ecosystem. Climate change, habitat degradation, and overfishing leave fisheries vulnerable to sudden declines or unexpected shifts in population dynamics. There is a pressing need for a more holistic management approach that examines how fishing, food webs, habitat conditions, and environmental changes influence fished species. This study documents the application of EBFM in the grouper–snapper fishery of Saleh Bay, Sumbawa Island, eastern Indonesia. The goal is to apply the recently developed Lenfest tools for EBFM to better align Indonesian fisheries with the principles of EBFM by integrating indicators of ecosystem structure and function into the management of small-scale fisheries in Saleh Bay, Indonesia. Key challenges included the diversity of demersal fish stocks (over 80 species recorded in landings and 12 indicator species for management) and fishing methods (8 fishing gears and three main ones for serranids (grouper) and lutjanids (snapper)), limited ecological and fisheries data, and difficulties in balancing complex ecosystem models. Ecopath with Ecosim (EwE) is used to develop the model, which provides tools to develop a flexible, customized, and multi-species fisheries management approach for Saleh Bay that aligns with EBFM.

☕ 10:30–11:00 – Morning Coffee Break

Session 2: Forces, Fluxes, and Exchange at the Land–Sea Interface

This session addresses the physical and biogeochemical linkages between terrestrial and marine systems in tropical coastal zones. It explores how sediment, freshwater, nutrient, and pollutant fluxes shape nearshore oceanography and coastal state and exchange, and how these dynamics are influenced by anthropogenic alterations such as land-use change, deforestation, and coastal development. It emphasises empirical approaches, including observational networks and remote sensing, and their integration into regional and coupled process modelling frameworks. A central aim is to assess the representation of coastal–terrestrial coupling in existing physical–biogeochemical models and to identify strategies for better capturing these fluxes and exchanges across scales and data regimes. Guiding question: How do land–sea and air–sea exchanges shape tropical coasts, and which improvements at these interfaces would most reduce uncertainties from coastal to basin scales?

Chair: Joke Lübbecke (University of Bremen, Germany)

11:00–11:30 – Keynote: Moninya Roughan (UNSW, Australia)

Measuring, Monitoring, and Modelling the East Australian Current System: Closing Observational Gaps and Reducing Uncertainty at the Coastal–Shelf–Bluewater Interface

Knowledge of the three-dimensional structure and variability of the (tropical) coastal – shelf seas is critical for understanding ocean hydrodynamics and circulation, ocean heat uptake and sea level rise (with climate change) as well as for quantification and detection of marine extremes; all of which have significant ecological impacts on the abundance and distribution of marine life, with far-reaching socio-economic consequences.

However, while satellite technology offers near-global coverage of some variables (e.g. sea surface temperature, salinity, ocean colour and sea surface height), and Argo and XBT programs provide sparse subsurface observations, substantial gaps remain, particularly in coastal regions where fisheries are most productive and where humans interact most heavily with the coastal ocean. Additionally, accurate submesoscale representation in ocean models remains a challenge due to rapidly evolving flow and the lack of observations at suitable scales in highly dynamic coastal oceans. Yet, ocean state estimates that represent mesoscale and submesoscale dynamics are crucial for both operational ocean forecasting and climate projections.

Here, I will demonstrate some of the recent efforts in the East Australian Current System to measure, monitor, and model the ocean across a range of time and space scales in an effort to reduce uncertainty at the coastal – shelf – bluewater interface. These initiatives include long-term, sustained, research-quality, ocean monitoring using moorings, HF radar, hydrographic sampling and ocean gliders, as well as a novel crowd-sourced citizen science initiative for real-time operational data delivery. These data are integrated into a data-assimilating ocean model, along with new inputs such as data from the high resolution SWOT satellite, to improve state estimates. We show enhanced representation of ocean processes across scales, essential for improved ocean forecasts and projections, and for reducing uncertainty. Together, these initiatives provide a comprehensive view of an oceanic region undergoing rapid environmental change and are a valuable resource for ocean managers.

11:30–11:45 – Lívia Sancho (Universidade Federal do Rio de Janeiro, Brazil)

From Global Oceans to Regional Extremes: Towards Better Earth System Models

Earth System Models (ESMs) still struggle to represent regional and coastal processes, as their coarse resolution limits the simulation of land–sea exchanges and hydrological extremes. These shortcomings hinder our ability to capture freshwater, sediment, and nutrient fluxes and contribute to large uncertainties in future projections. A range of approaches - such as artificial intelligence, downscaling, and statistical frameworks based on teleconnections - can help bridge this gap. In this talk, I present our recent work on multi-ocean teleconnections and synoptic drivers, including atmospheric blocking events and the South Atlantic Convergence Zone, and their influence on droughts, floods, and heatwaves in South America. By quantifying these links, we propose methodologies that can be integrated into ESMs to improve the representation of regional processes. This multiscale perspective offers a pathway to reduce uncertainties from regional to basin scales.

11:45–12:00 – Kirsten Thonicke, Sabine Mathesius (PIK, Germany), Georg Feulner

Modelling Land-Ocean linkages in Earth System Models, a roadmap to consider coastal ecosystems

Large rivers are a substantial source of freshwater, sediments, nutrients and carbon that influence coastal ecosystems and their biodiversity. They also contribute substantially to marine biogeochemical cycles and coastal deoxygenation. Modelling approaches exist to quantify carbon export to and biogeochemical modification in large river systems, such as the Amazon river (Langerwisch et al. ESD 2016). Embedding such approaches in the hydrological modules and river routing schemes that run inside Dynamic Global Vegetation Models such as LPJmL (Schaphoff et al. 2018) allows to quantify changes in vegetation and cycling of terrestrial carbon and nitrogen under changing environmental conditions, including climate and large-scale deforestation. Such a process-based approach becomes very important when studying land-ocean linkages inside Earth System Models. The LPJmL DGVM is coupled to the Potsdam Earth Model (POEM, Drueke et al. GMD 2021) and provides the ideal modelling platform to study the described effects and changes. However, the modulation of biogeochemical processes in coastal ecosystems is largely missing from such Earth System Models. We provide a model concept on how such analyses can be conducted in Earth System Models, based on coupling land and ocean through a coastal box model that simulates conditions for coastal ecosystems at a finer spatial resolution than captured by the ocean model component.

12:00–12:15 – Sabine Mathesius (PIK, Germany)

Land-Ocean Coupling in POEM: Exploring new ways to simulate climate impacts on coastal ecosystems in an Earth System Model

Coastal marine ecosystems play a key role in global carbon sequestration, but many are increasingly degraded by climate change and other anthropogenic stressors, reducing their capacity for carbon uptake and storage. The Earth system model POEM (Drüke et al. 2021) has been applied to simulate global impacts of rising atmospheric CO_2 (Drüke et al. 2024), but rarely to assess marine ecosystem impacts. We aim to further develop POEM to investigate climate-change effects on the marine biosphere, including coastal ecosystems such as mangroves, seagrass meadows, and kelp forests. Within the Planetary Boundaries framework (Richardson et al. 2023), coastal ecosystems are expected to gain increasing relevance as additional marine processes will likely be incorporated, possibly including biological carbon sequestration (in open-ocean and coastal systems), ocean deoxygenation, and the deterioration of the marine biosphere. Building on POEM's current marine biogeochemical module (BLINGv2, Dunne et al. 2020), we consider developing a coastal box model that could resolve coastal biological processes, carbon sequestration, and deoxygenation. This box model would account for riverine nutrient and freshwater inflow as well as exchange with open-ocean waters, and it would resolve key biogeochemical variables such as net primary production (NPP), remineralization, phosphorus and nitrogen concentrations, detritus, and burial of organic matter. Marine plant functional types could be implemented and parameterized to represent ecosystems, for example mangroves and kelp. Such an extension of POEM would enable us to better quantify the role of coastal ecosystems in the Earth system, to simulate their future under climate change, and to investigate potential marine planetary boundaries.

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🍽️ 12:15–13:30 – Lunch Break (lunch provided on site)

13:30–13:45 – Marie-Christin Wimmler (TU Dresden, Germany), Ronny Peters, Guanzhen Liu, Uta Berger

Advancing Ecological Modeling with pyMANGA: Modularity and Reusability for Robust and Reproducible Research

Individual-based vegetation models are essential for understanding and predicting ecosystem responses to environmental change. While these models rely on well-established processes—such as vegetation establishment, growth, and mortality—models of mangroves and other coastal vegetation are often developed from scratch, despite including similar processes. We present pyMANGA, an open-source, modular platform that streamlines model development and enables systematic hypothesis testing. Researchers can combine, modify, and extend concepts of plant growth, competition, and resource dynamics, supporting flexible, reproducible modelling. The platform is particularly suited to the study of ecohydrological interactions, including plant-soil feedback loops in tropical coastal ecosystems. Defined interfaces make it straightforward to compare models of varying complexity, while open access, version control, and automated benchmarking ensure transparency and collaboration. pyMANGA provides opportunities to link vegetation dynamics with observational networks, remote sensing, and coupled physical–biogeochemical models in the future, supporting improved representation of coastal–terrestrial coupling.

13:45–14:00 – Andrés Fernando Osorio Arias (UNAL, Colombia)

Multiscale numerical approaches for evaluating the protective role of coral reefs and mangrove forests

Tropical coastal ecosystems like coral reefs and mangrove forests protect shorelines by reducing flooding, erosion, and wave damage. However, human pressures and climate change threaten their survival, making it vital to quantify their protective role. Numerical modeling offers powerful tools for this purpose. At large scales, process-based models such as XBeach and Delft3D simulate nearshore hydrodynamics, sediment transport, and wave energy dissipation. For example, XBeach has shown how coral reefs reduce flooding by dissipating waves during storms, while Delft3D represents mangroves with vegetation modules that incorporate drag from roots and trunks to capture their wave attenuation capacity. At finer scales, Computational Fluid Dynamics (CFD) models like OpenFOAM analyze fluid–structure interactions. In corals, CFD reveals how colony geometry affects drag, inertia, and turbulence, while for mangroves it resolves root effects on flow and sediment stability. Together, these approaches link ecosystem structure with coastal processes, supporting conservation, management, and adaptation strategies.

14:00–14:15 – Sinikka Lennartz (University of Oldenburg, Germany)

Bridging Scales in Coastal Biogeochemistry from Microbes to Climate

Coastal areas are dynamic hotspots for biogeochemical processes but face increasing anthropogenic pressures from nutrient inputs, pollution, and intensive fishing. Numerical models are essential tools for projecting ecosystem responses, yet they often struggle to bridge critical scales, i.e. from microbial and molecular processes that underpin carbon storage and food web dynamics, to regional impacts of human activities and global climate feedbacks. In this talk, I will present two topical examples that demonstrate approaches to address this issue of scale transitioning in numerical, spatially resolved models. The first example examines the production and emission of climate-relevant trace gases, in particular photochemically produced compounds like carbonyl sulfide. I will highlight how parameterizations based on high-resolution field data can enhance our understanding, with a focus on tropical regions. The second example provides a system-level view of the marine carbon cycle, emphasizing dissolved organic carbon (DOC), a key carbon pool historically overlooked in management strategies. Here, I apply the concept of emergent properties, that is, features of the system that arise only at larger scales. Based on this principle, microbial-scale processes can be scaled up to basin-level patterns using an integrated approach that combines theory, network science, and biogeochemistry. Together, these examples underline key research directions relevant to the TropECs project, particularly the connections between coastal biogeochemistry and the climate system. They also showcase generalizable strategies for advancing coastal ecosystem modeling, in particular scale-aware parameterizations and leveraging emergent properties.

14:15–14:30 – Siny Ndoye (Université Amadou Mahtar Mbow, Senegal)

Physical Modelling of Southern Canary Upwelling System: results, applications, perspectives and needs in terms of in situ data and future perspectives

The dynamics and circulation in the Southern Canary Upwelling System (SCUS) have been investigated for over 10 years with regional CROCO simulations using a grid nest focusing on the Senegal coastal ocean ($\Delta x \approx 2$ km). Hydrographic measurements during UPSEN2-ECOAO survey (4-week intensive field campaign), satellite images datasets (SST and SSH), data from SOLAB low-cost field surveys and Melax observatory buoy are used to evaluate the model skills. Our studies have shed light on the climatological functioning of the senegalese upwelling, offered new perspectives on the connections between the SSUS physics and its ecosystems, and provided insight into the future consequences of climate change on the senegalese coastal ocean. Further model improvements including the operational delivery of short-term forecast would require enhanced in situ data collection. Low-cost field surveys and mooring deployment strategies based on partnerships with artisanal fishermen can potentially help remedy data scarcity for the benefit of model developments and more generally monitoring of the Senegalese marine environment.

14:30–14:45 – Joke Lübbecke (University of Bremen, Germany)

Importance of Large-Scale Climate Modes for Eastern Tropical Atlantic Coastal Conditions

Ocean mean state and variability in tropical-subtropical coastal regions are governed by both local conditions but are also connected to large scale climate modes. This presentation will focus on the role of remote drivers for sea surface temperature (SST) variations in the Mauritanian upwelling and the Angola-Benguela region. SST variations in the Northeastern Tropical Atlantic Upwelling region are related to local wind stress variability that is partly affected by teleconnections from the El Niño – Southern Oscillation in the Pacific. Recent findings also point to a role of thermocline depth variations driven from the equatorial Atlantic. As for the Angola Benguela area, the link to the Atlantic Niño via the propagation of equatorial and coastal trapped waves is well established. A newly discovered link also exists to the Indian Ocean Dipole via the impact on precipitation over the Congo basin and subsequent river runoff.

☕ 14:45–15:15 – Afternoon Coffee Break

15:15 –16:00 – Wrap-up Panel Discussion | Rose, Gross, Lübbecke, Roughan

Day 3 – Spatio-Temporal Scales and Socio-Economic Perspectives

Thursday, 25 September 2025 – Leibniz Centre for Tropical Marine Research (ZMT), F 6, Fahrenheitstraße 6

Session 1: Cross-Scale Modelling of Physical–Ecological Interactions in Tropical Coastal Systems

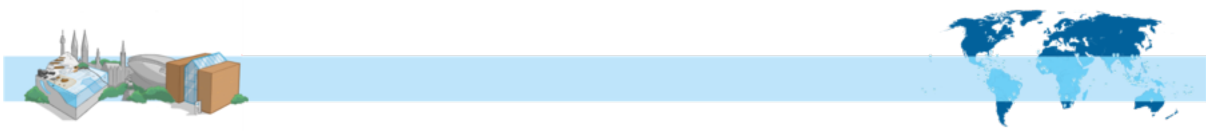
This session examines how physical and ecological processes interact across scales at the tropical land–sea interface. It highlights modelling approaches that integrate extreme weather, hydrodynamics, biogeochemistry and ecological response, spanning groundwater and nutrient fluxes, sediment and salinity dynamics, and vegetation–climate feedbacks under anthropogenic and climatic pressures. Emphasis is placed on modular, cross-scale integration frameworks that enable realistic, process-based predictions of ecosystem states and indicators. The session links empirical observations (including remote sensing) to model development in under-represented tropical regions and defines transferable validation metrics and decision-relevant benchmarks. Guiding question: How can we connect large-scale atmospheric and terrestrial forcing to coastal and ecological outcomes, and what approaches are most transferable across regions?

Chair: Nils Moosdorf (ZMT)

09:00–09:30 – Keynote: Erma Yulihastin (BRIN, Indonesia) Ibnu Fathrio, Albertus Sulaiman, Mochamad Furqon Azis Ismail, Dwiyoga Nugroho, Rahaden Bagas Hatmaja, and Ginaldi Ari Nugroho

Assessment of Extreme Weather Events in the Changing Climate over the Indonesia Maritime Continent

Global warming contributed to severe weather events by increasing and intensifying worldwide occurrences. Recent studies revealed that 71% of extreme weather events are related to human-caused climate change. Hence, 56% of heavy rainfall or flooding events studied concluded that human activity influenced the severity of the events. Since the Indonesian Maritime Continent (IMC) comprises thousands of islands with complex topography surrounded by seas and has the 3rd longest coastline, this region experienced island-based, highly concentrated precipitation. The IMC also affects global climate through multiscale interaction from diurnal to interannual timescale due to ocean-atmosphere interaction. The variability of sea surface temperature in sub-daily timescale was proven to generate excessive rainfall, thus triggering several extreme weather events from micro-to-large scales with devastating impacts over several islands during transition-to-dry season periods, i.e., high wind in Cimenyan-Java (2021), flash flood in Luwu-Sulawesi (2021), storm surges in Java-Bali (2020), tropical cyclone in Flores-east Nusa Tenggara (2021). Our recent studies investigated the mechanisms of several extreme weather events mentioned previously. We suggested the role of moderate to extreme warming local seas in developing favorable conditions for extreme weather events. Due to the highly warming



ocean under the global warming condition that tends to increase significantly in intensity and frequency, extreme weather events could reoccur with varying severity and become worse. Considering the preparation for climate change adaptation, we need more detailed monitoring data, correct analysis, and accurate short-range numerical weather prediction to anticipate and mitigate the risk of weather-related hydrometeorological disasters.

09:30–09:45 – Maxime Colin (ZMT), Vishal Dixit, Jan O. Haerter

Running regional models as if they were global? Atmospheric simulations over an aquapatch to understand the role of convection, land, and ocean in the "hysteresis" of the tropical rain band migration

The tropical rain band is the most prominent feature of convective precipitation on Earth. It includes the monsoons over land, and the ITCZ over the ocean. The dominant theories are based on large-scale energetics and on a circulation regime shift, but they do not take into account the life cycle of convection. To estimate the role of convection on the tropical rain band migration, we run idealised simulations of the seasonal cycle over an aquapatch, with just an atmosphere. We show that (1) there are several monsoon non-linearities, including the rapid and delayed monsoon onset, (2) there is a hysteresis in the seasonal migration of the tropical rain band, even when no oceanic processes are taken into account, demonstrating the importance of atmospheric memory. By comparing simulations over ocean and over a pseudo-land, we also suggest that the monsoon retreat behaves differently, but the monsoon onset properties are fairly robust.

09:45–10:00 – Ming Li (University of Maryland, USA)

Impacts of Tropical Cyclones on Harmful Algal Blooms in Coastal Oceans

Tropical cyclones have been linked to harmful algal blooms (HABs) in coastal oceans, but the underlying mechanisms are not well understood. Moreover, the plankton response varied, with large blooms developing after some storms but minimal or negative growth during other storms. To understand how tropical storms affect HABs, we need to couple atmospheric, hydrodynamic, biogeochemical and HAB models. We developed such an integrated modeling system to investigate a large *Karenia brevis* bloom that developed on the West Florida Shelf after the passage of Hurricane Ian in 2022. We showed that Hurricane Ian drove the bloom in two ways: (1) the northerly winds generated onshore bottom currents and transported subsurface *K. brevis* cells toward the coast; (2) the large pulse of riverine nutrient loading fueled the growth of *K. brevis* cells for several months. This mechanistic approach also enabled us to discern the individual effects of different components of storm forcing.

10:00–10:15 – Ronny Peters (TU Dresden, Germany)

Is there a way from the process scale to the ecosystem model?

Coastal ecosystems are defined by their ability to thrive in saltwater environments. Plant water uptake, excluding salt in the root zone, is a process of permanent salinisation of the soil. Tide-induced dilution processes counteract this process. Therefore, they are a decisive factor in the plants' growing conditions. The efficiency of these processes depends on local soil conditions, such as hydraulic conductivity and the presence of macropores – in mangroves, these are primarily crab burrows. Understanding and modelling these processes, as well as exploring the conditions, which can vary significantly over short distances, requires a focus on scales ranging from a few square metres to plot size. Simultaneously, the physical description of water fluxes and diffusion processes relies on a small temporal scale of minutes. This conflicts with the requirements of forest modelling, which deals with scales of hectares and tree lifetimes. The presentation will focus on how to solve this problem.

☕ 10:15–11:00 – Morning Coffee Break

11:00–11:30 – Keynote: Julia Moriarty (University of Colorado, USA)

Using high-resolution hydrodynamic-sediment–biogeochemistry models to understand data-sparse coastal systems

Coastal systems are impacted by an array of hydrodynamic, sediment transport and biogeochemical processes that operate on temporal and spatial scales ranging from sub-millimeter to kilometers, and from hours to decades or longer. This talk will focus on lessons learned from using high-resolution models to better understand and quantify coupled sediment transport - biogeochemical processes such as organic matter transport and fate in data-rich temperate systems, and how high- and low-resolution models may be applied to data poor systems such as the Arctic or tropics. In particular, recent research with high-resolution models has underscored the importance of accounting for resuspension and other sediment transport processes when modeling biogeochemical processes such as organic matter transport and fate. Ongoing work suggests that lower-resolution models, which are more easily applied to data-poor systems, may capture certain aspects of these dynamics in a robust way.

11:30–11:45 – Yuley M. Cardona Orozco (CEMarin, Colombia)

Salinity and Mixing Dynamics in the Magdalena River Estuary and Plume: Insights from a High-Resolution Delft3D Model ensemble

Estuaries reflect the intricate interplay between land and ocean processes, where temporal and spatial scales of processes add to the complexity of understanding these systems. Here, we present the hydrodynamic and salinity structure of the estuary and plume of a large, tropical, strongly stratified, and human-intervened river, the Magdalena, through a high-resolution Delft3D model ensemble and in situ data. The model simulations (21 runs) capture seasonal and diurnal variability under low, mid, and high discharge scenarios. Results show that stratification and mixing are strongly discharge-dependent: low flows promote saline intrusion and weak bottom-generated turbulence, while high flows drive a lift-off plume and intense pycnocline mixing. The transition to lift-off occurs near the 30th discharge percentile (~5200 m^3/s). Hydraulic jumps in the plume mid-field contribute minor additional mixing. Salinity intrusion scales nonlinearly with discharge, and micro-tides enhance diurnal salinity variability. Findings highlight the model's ability to resolve fine-scale mixing and plume behavior, offering insight into land-sea exchange dynamics in human-impacted tropical estuaries.

11:45–12:00 – Florian Schütte (GEOMAR, Germany)

Linking physical processes to biological responses: Interdisciplinary observational insights into the enhanced biological productivity of the Cape Verde Archipelago

The Cape Verde Archipelago (CVA) exemplifies how topographic forcing (in the atmosphere and ocean) connects to local ecological outcomes in tropical coastal systems. Drawing on two decades of interdisciplinary observations, we identify three dominant mechanisms shaping ecosystem structure. First, wind–island interactions generate atmospheric wakes and productive eddy fields downstream of steep topography. Second, mesoscale eddies originating off West Africa deliver nitrate-rich waters that, when interacting with island bathymetry and local wind curl, amplify submesoscale mixing and internal wave activity. Third, tidal flows and internal wave breaking at specific hotspots cause vertical mixing up to 1000 times stronger than in open-ocean reference sites. Collectively, these processes enhance upward nitrate flux and chlorophyll concentrations, supporting diverse pelagic food webs. Importantly, the different forcings drive distinct ecological assemblages, underpinning the exceptional biodiversity of the CVA. The CVA thus demonstrates how cross-scale physical–ecological interactions translate physical forcing into regionally transferable ecosystem outcomes.

🍽️ 12:00–13:00 – Lunch Break (lunch provided on site)

Session 2: Human Dimensions in Tropical Coastal Processes

This session interprets the physical–ecological cascade in socio-economic terms, assessing how tropical countries and their coastal ecosystems may be impacted by climate change and other environmental pressures and what this implies for macroeconomic indicators, sectoral impacts, and socio-political stability. It reviews how macro- and meso-scale models can anticipate these changes, alongside strategies to mitigate greenhouse gases and adapt to evolving risks where an ocean–climate nexus is central. Guiding question: Which socio-economic indicators and case studies are most useful for linking coastal and ocean dynamics with economic impacts and resilience planning?

Chair: Michael Obersteiner (University of Oxford, UK)

13:00–13:30 – Keynote: Rob Dellink (OECD, France)

Socioeconomic trends, drivers of environmental pressures and projecting economy-environment interactions

Environmental changes are driven by a wide range of drivers, including socio-economic trends, such as demographic changes and income growth, and sectoral drivers including structural change and technological developments. The regional and sectoral composition of economic activity shifts over time, thereby influencing environmental pressures. This presentation will provide an overview of some of the expected trends for the coming decades, including the recently updated Shared Socioeconomic Pathways and detailed projections of economic activity and environmental pressure using the OECD in-house modelling, highlighting the crucial differences in circumstances for different regions. The presentation will also cover how biophysical impacts of environmental change in turn can affect the economy, and the critical role of adaptation in limiting impacts. Specific attention will be given to how such projections can inform scientific analysis, including for tropical coastal ecosystems management.

13:30–13:45 – Fredrick Kayusi (Pwani University, Kenya)

Harnessing climate information systems and artificial intelligence (AI) innovations in enhancing resilience to climate change in Africa

The ocean-climate relationship determines a unique tropical architecture, which produces increased seasonal and temporal variation of wind, waves, currents and thermal stratification. The objective is to identify how Climate Information Systems (CIS) and emerging artificial intelligence (AI) technologies can benefit Africa's climate change resilience, with a focus on Kenya's exposed coastal economies. The study employed a mixed-methods approach on the selected population; stratified random sampling was used to select 225 individuals who were administered structured questionnaires, interviews and Focused Group Discussion. Quantitative and qualitative methods were both used to study data such as Statistical packages and regression analysis. The results were that CIS has a high level of awareness of 40.9% "Very Aware," and 41.8% of the respondents use AI occasionally. Regression analysis reveals a high positive relationship (R = 0.789) of CIS and AI with resilience explaining 61.9% of variance, highlighting indicators such as CIS awareness (coefficient = 0.441) and use of AI (coefficient = 0.358) as excellent predictors, whereas bottlenecks such as lack of infrastructure (36.0%) and awareness (28.4%) hinder effective implementation. The study recommends the mounting of gas analyzer sensors on smartphones to convert physical changes into electrical signals that can be interpreted by AI algorithm systems and automatically send collected data to various stations. The stakeholders should raise awareness and education on CIS and AI, invest in necessary infrastructure, and leverage partnership among the government, academia, and the private sector to mitigate challenges and develop resilience to climate change in Kenya's coastal economies.

13:45–14:00 – Alvaro Calzadilla (UCL, UK)

The Economic Dynamics of Climate Change Impacts on Global Agriculture

Climate change is already reshaping global agricultural systems, with most regions experiencing declines in crop yields. However, the severity and nature of these impacts vary widely. This trend is expected to intensify, posing complex challenges for food security, trade, and economic stability. A global economic modelling approach is used to quantify the future economic impacts of climate change across sectors and across countries, considering local conditions in agricultural production and adjustment processes in both domestic and international markets. The analysis highlights the dynamic feedback between the direct impact of climate change on agricultural yields and the indirect effects of climate-induced changes in competitiveness and trade. It underscores the need for coordinated responses across disciplines to address the multifaceted consequences of climate change on agriculture and the global economy.

14:00–14:15 – Jun Rentschler (World Bank, Belgium)

From Villages to Megacities: Urban expansion patterns and escalating flood risks

Disaster losses are increasing and climate change is driving up the probability of extreme natural shocks. Yet it has also proved politically expedient to invoke climate change as an exogenous force that supposedly places disasters beyond the influence of local authorities. However, locally determined patterns of urbanization and spatial development are key factors to the exposure and vulnerability of people to climatic shocks. High-resolution spatial data show us that, since 1985, human settlements around the world—from villages to megacities—have expanded continuously and rapidly into present-day flood zones, especially in coastal areas. There is systematic evidence of a divergence in the exposure of countries to flood hazards. Instead of adapting their exposure, many countries continue to actively amplify their exposure to increasingly frequent climatic shocks. The implications are wide-ranging, affecting communities and economies — often stretching well beyond the flood zones.

14:15–14:30 – Bruno Meirelles de Oliveira (AZTI, Spain)

Resilience in Tropical Coastal Social-Ecological Systems: Patterns of Behavior Across Diverse Worldviews

The decline in global biodiversity and increasing risks from climate change disruptions, combined with the escalating demand from society for the ecosystem services provided by coastal social-ecological systems (SES), especially in tropical areas, instigate the research and governance communities' interest in understanding and leveraging the resilience of these systems. Therefore, modelling the intertwined complexities of the environment and society, from where resilience emerges, is crucial. Our research presents a prototype of an integrated model that embraces coastal areas as SES in a coupled, complex, and intertwined approach. It builds on the ecosystem services coastal areas provide and integrates them with the resilience principles from the mainstream literature to reveal how resilience unfolds over time. Our results present the insights of this study with particular focus on the influence of society's worldviews in the process. An additional study embodied these worldviews in the simulations, finally revealing resilience behavior differently depending on worldviews.

☕ 14:30–15:00 – Afternoon Coffee Break

15:00–15:15 – Alistair Smith (Cambridge Econometrics, UK)

Integrating economic and physical-ecological modelling: an E3ME case study

What are the economic costs of inaction on global emissions? What are the economic opportunities of investing in mitigation and resilience? The linkages between the economy and physical world are varied and complex. The identification of these linkages and incorporation in modelling scenarios allows us to explore these key questions. Economic models can provide insights to help motivate and inform decision making. A case study for Pakistan's CCDR (Climate Country and Development Report) used E3ME, a global E3 (economy-energy-environment) model, to assess the macroeconomic impact of climate damages. Climate damages included flood damage to capital stock and infrastructure across climate scenarios. The results find real GDP losses up to 10% by 2050, with agriculture and manufacturing affected more deeply than services. This research helps to frame the case for action to minimise damages.

15:15–15:30 – Michael Obersteiner (University of Oxford, UK)

Managing Time-Lagged Climate Risks for Coastal Societies: Lasting Benefits of Temperature Peak-Shaving

Tropical coastal regions face escalating risks from time-lagged climate processes, particularly sea-level rise driven by ice-sheet loss and ocean heat uptake. These impacts unfold over centuries, exceed conventional planning horizons, and threaten the viability of small island states and low-lying coasts. Using a simplified Earth system emulator with impact dynamics, we show that temperature "peak-shaving" – temporary reduction of global warming via accelerated carbon removal or solar radiation management (SRM) – can lower the eventual stabilization level of sea-level rise. By moderating both the magnitude and duration of temperature overshoot, peak-shaving reduces long-term adaptation costs and the likelihood of crossing hard resilience limits. Our results highlight that socio-economic outcomes in vulnerable coastal regions depend not only on end-of-century temperature goals but also on the shape of mitigation pathways. This insight strengthens the case for incorporating overshoot risks and peak management into adaptation and macroeconomic resilience planning.

15:30–15:45 – Marie Fujitani (ZMT)

From Models to Meaning: Socio-Economic Indicators, Physical-Ecological Processes, and Coastal Resilience

"Modeling socio-economic dimensions across Tropical Coastal Ecosystems and the Earth System" (TropEcS) integrates decentralized socioeconomic processes with ecological and physical systems in earth systems modelling. The proposal emphasized its unique contribution to understanding the "feedbacks between social and ecological systems and the Earth system." As a bridge to the panel discussion, this presentation reflects on the proposal and the process of selecting critical inputs, indicators, and feedbacks, following the guiding question for this panel: "What are the most useful socio-economic indicators for linking coastal and ocean dynamics with economic impacts and resilience planning?" This presentation will also highlight one of the central ambitions of TropEcS: to create a permanent, participatory knowledge hub for model and observation data, to be collected and analyzed collaboratively. This hub will facilitate essential dialogue between science and policy, necessary for effective and equitable resilience strategies. The ZMT sits at a unique crossroads of expertise and vision, with an unprecedented opportunity to become a world leader in knowledge integration to guide adaptation and planning for the world's most vulnerable coasts.

16:00–16:15 – Intermission

16:15–17:00 – Wrap-up Panel Discussion (Foyer) | Moosdorf, Obersteiner, Yulihastin, Moriarty

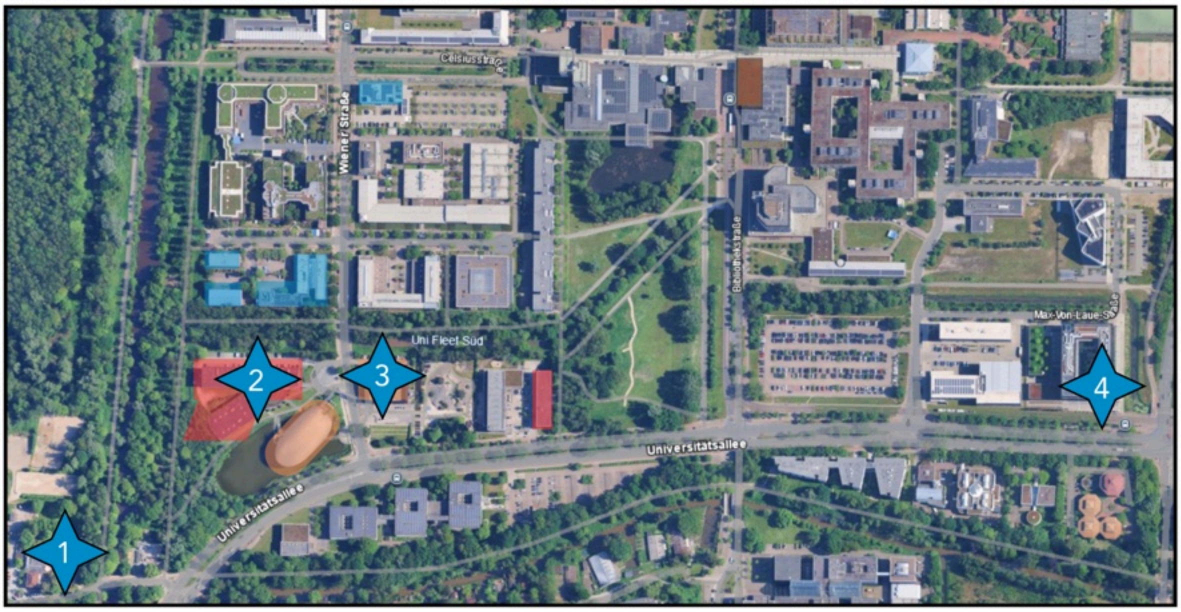
17:15 – Closing remarks by Raimund Bleischwitz (Scientific Director, ZMT)

Map of Campus

Map Legend:

- Universum Bremen:
  Wiener Straße 1a, 28359 Bremen
- Atlantic Hotel Universum Bremen:
  Wiener Straße 4, 28359 Bremen
- 7 Things Hotel:
  Universitätsallee 4, 28359 Bremen
- ZMT F6 Main Bulding - Reception & Seminar Room:
  Fahrenheitstraße 6, 28359 Bremen
- ZMT F8 & F10 - Administration:
  Fahrenheitstraße 8 & 10, 28359 Bremen
- ZMT W 7 - Management:
  Wiener Straße 7, 28359 Bremen

Restaurants close to Campus



1

Haus am Walde
Kuhgrabenweg 2, 28359 Bremen

Hours: Mon - Sun 09:00 - 23:00

2

Atlantic Hotel Universum
Wiener Straße 4, 28359 Bremen

Hours: Mon - Fri 12:00 - 22:30
Sat 17:00 - 22:30
Bar:
Mon - Sat until 00:00

3

Kubus
Wiener Straße 3, 28359 Bremen

Hours: Mon - Sun 10:00 - 17:00

4

Bellini im Tresor
Universitätsallee 14, 28359 Bremen

Hours: Mon - Sun 09:00 - 00:00