JUNE 27 – 30, 2023

Hamburg, Germany

ABSTRACT BOOKLET

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Information about the 13^{th} IWMO

The IWMO was first held in 2009 with the goal that modelers and observationalists interested in ocean processes and coupling with its surrounding can exchange their latest research and wide-ranging ideas in an intellectually rewarding and relaxing environment. The IWMO focuses on all aspects of ocean and coupled air-wave-sea, ice and current-sediment modeling: processes, analysis and prediction. The earth system is inter-connected on a broad range of temporal and spatial scales, and we welcome coastal, regional and basin-scale studies and interdisciplinary topics. As in past workshops, we particularly encourage participation from young scientists – graduate students and postdocs – and will host the Outstanding Young Scientist Awards (OYSA) competition again. IWMO participants are welcome to submit a manuscript to a special issue in Ocean Dynamics dedicated to the workshop.

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KEYNOTE SPEAKERS

Fei Chai

Digital Twin Ocean for China Coastal Seas

THU.
June 29
14:00

Chai, Fei*
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With over 2 billion people relying on the marine resources, the East Asian seas have nourished rapid economic growth over the past decades. But this comes at the expense of ocean health. Coastal-SOS - "Coastal Zones Under Intensifying Human Activities and Changing Climate: A Regional Programme Integrating Science, Management and Society to Support Ocean Sustainability", a UN Ocean Decade endorsed project aims to provide solutions for the sustainable development of coastal ocean through effective integration of science, governance, and society. Numerical modelling is a key programmatic effort, serving synthesis analysis, mechanistic studies, and most importantly, predictions, which will contribute to construct the next generation of product: the data-model fully integrated Digital Twin Ocean. One of the expected outcomes of this project is a decision-making support system and toolbox aided by numerical modelling and the Digital Twin Ocean initiative that will result in integrated coastal management and development of marine spatial planning and ecosystem conservation practices. I will review the existing observational data and modelling work in Xiamen Bay and Changjiang Estuary which are two pilot sites and discuss plan of constructing a Digital Twin Ocean in these regions.

Agustin Sánchez-Arcilla

Coastal restoration through modelling. A tool to enhance resilience

WED. June 28 14:00

Sánchez-Arcilla, Agustín*
**Universitat Politècnica de Catalunya-Barcelona Tech (UPC), Spain; email: agustin.arcilla@upc.edu*

Coastal systems, steadily squeezed by sea level rise, experience an increasing degradation due to a powerful combination of human pressures and rigid infrastructures. To stave off this degradation it is necessary to undertake large-scale restoration projects that enhance the sustainability of present coasts linked to a sustained delivery of ecosystem services, which decrease the negative impacts of conventional coastal protection and result in biodiversity gains. Within the REST-COAST project, modelling tools are applied to assess risk reduction and to support restoration upscaling based on: a) Connectivity along the coast b) Connectivity along the river c) Room for coastal dynamics This talk will illustrate how coastal restoration projects in 9 Pilot cases can be supported by monitoring and modelling to steer maintenance and to adapt the design to evolving climatic and human pressures. After presenting the hands-on restoration at the 9 Pilots, we shall discuss how modelling, combined with observations, can help to overcome current restoration barriers and provide enablers for a decarbonized coastal adaptation. The approach will be illustrated for the Ebro delta (Spanish Mediterranean coast, one of the 9 Pilots where significant reduction of the river solid discharge has led to accelerated erosion and subsidence. Both factors increase current risks for the important natural and socioeconomic assets in the delta, where the metocean negative impacts are expected to aggravate under future climate scenarios. The projected coastal risks can be reduced by a combination of NBS blocks, which together suppose a systemic restoration for the Ebro delta coast, a well-recognised climatic vulnerability hotspot in the Mediterranean. REST-COAST prepares a combination of early warning and climatic warning systems, supported by coupled hydro-morpho-eco models suitably validated under present conditions. The simulation of future scenarios, combining climatic pressures with river and coastal management alternatives, will serve to steer restoration design and maintenance, achieving a progressive decarbonisation of coastal protection. The talk will end with some considerations on the work ahead, particularly in the frame of the REST-COAST project.

Nadia Pinardi

Coastpredict: the power of science in support of global coastal communities

Pinardi, Nadia*; Kourafalou, Villy; Tintore, Joaquin; Heslop, Emma
**Decade Collaborative Center for Coastal Resilience, University of Bologna, Italy; email: nadia.pinardi@unibo.it*

WED.
June 28
09:00

The Global Coastal Ocean concept, at the center of CoastPredict https://www.coastpredict.org/, considers all coastal ocean regions as an interface area. The present definition is that the global coastal ocean is that region extending inshore from the estuarine mouths to river and urban settlements and offshore from the surf zone to the continental shelf and slope where waters of continental origins meet open ocean currents. The key science paradigm to be developed is the development of the quality and effectiveness of predictions for the global coastal ocean. This new science requires an integrated approach of observing and modelling that will allow to improve our understanding, test theories and hypothesis, reduce uncertainties from events to the climate time scales. CoastPredict is part of the Global Ocean Observing System (GOOS) strategy to design and implement a permanent global system for observations, modelling, and analysis systems for marine and ocean variables in support of operational coastal services worldwide. GOOS and CoastPredict will provide: 1) accurate descriptions of the present state of the coastal oceans; 2) continuous forecasts of the future coastal ocean conditions as far ahead as possible; 3) the basis for predictions of climate change impacts on the coasts.

Joseph Zhang

Mesh generation for coastal compound flooding studies

Zhang, Y.J.*; Ye, F.; Cui, L.; Yu, H.C.; Yang, Z.; Seroka, G.; Moghimi, S.; Mani, S.; Myers, E.P.
**Virginia Institute of Marine Science,USA; email:yjzhang@vims.edu*

FRI.
June 30
9:00

Coupled inland-coastal (compound) flooding has increasingly been recognized as a major hazard for coastal communities located in the 'coastal transition zone', where flood risk from multiple factors (storm surge, river flow and heavy precipitation) converges. Forecasting compound flooding for this zone entails tighter coupling between hydrologic and hydrodynamic regimes and incorporation of multi-scale nonlinear processes from watershed to coastal ocean in the model. The accuracy is also critically dependent on resolving channels that serve as the major conduit for flows.The latter is very challenging particularly for large areas, due to the complexity and sheer number of the channels present.We developed an efficient and robust python-based tool to aid unstructured mesh generation with focus on automatic detection and resolution of channels directly from raw DEMs. The tool is parallelized for continental-scale applications (e.g. U.S. East Coast and Gulf of Mexico coast). A 'direct' meshing approach is used for channels, with explicit specification of along- and cross-channel resolutions in the form of river arcs and vertices. This direct approach (which is quasi-1D in essence), unlike the size function-based approach, leads to considerable savings in the mesh size and makes the mesh suitable for 3D applications. A creek-to-ocean 3D model (SCHISM) using the generated mesh is demonstrated to have significantly improved the flow connectivity between watershed and ocean, and thus accuracy for the predicted total water levels. Furthermore, a geoid-based approach in conjunction with satellite altimetry further improves the non-tidal elevations. The tool developed here is widely applicable for compound flooding studies in any other regions, subject to the quality of DEMs.

TOPIC 1:

Modeling Waves, Currents, Ice and Their Interactions in Coastal and Shelf Seas

Sea state contributions to steric sea-level

TUE. June 27 11:40

Bonaduce, Antonio*; Pham, Nam; Staneva, Joanna; Grayek, Sebastian; Raj, Roshin; Breivik, Øyvind
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The effect of wave-induced processing on steric sea-level is investigated through ocean-wave coupled simulations. The experiments are performed with a high-resolution configuration of the Geestacht COAstal model SysTem (GCOAST), implemented in the Northeast Atlantic, the North Sea and the Baltic Sea which are considered as connected basins. The GCOAST system accounts for wave-ocean interactions and the ocean circulation relies on the NEMO (Nucleus for European Modelling of the Ocean) ocean model, while ocean-wave simulations are performed using the spectral wind wave model WAM. The objective is to quantify the sea-state contribution to steric sea-level variability and trend over a 26-year period (1992-2017). The ability of wave-ocean coupled simulations to disclose the sea-state contributions to sea-level variability and surge is demonstrated. The contribution of the wave-induced processes (WIPs) to the sea surface dynamics (e.g. temperature and salinity), ocean mixing (mixed layer thickness), and on the modulation of air-sea fluxes (e.g. heat flux) clearly appear both during winter (10-20 %) and summer (10 %), which in turn affect the steric sea-level variability. Investigating the components of steric sea-level signal, significant contributions to the thermosteric sea-level variability (40 %) due to wave-induced processes are observed in the North Atlantic (in summer) and along the Norwegian Trench (in winter). WIPs influence the thermosteric sea-level trends in the North Atlantic up to the order of 1 mm yr-1, both during winter and summer, in the open ocean and at the shelf break, while smaller contributions are observed over the shelf areas of the North Sea.

The inherence of seabed gullies on the erosion of the seashore in the segment of the South Baltic nearshore zone

POSTER

Szmytkiewicz, Piotr; Dudkowska, Aleksandra*; Uścinowicz, Grzegorz
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Specific geomorphological structures occur in the eastern part of the dissipative, multibar coastal zone of the south Baltic Sea. Such structures were first identified in the coastal zone in the vicinity of the Hel Peninsula in the 1990s. In recent years, a few of them have also been discovered on a section about 40 km long from Łeba to Karwieńskie Błota. These formations resemble underwater gullies situated at an angle to the shore. On their extension, coastal erosion processes are observed. The aim of this work is to explain the mechanism of influence of such seabed forms on shore erosion. Taking into account the local hydrodynamic characteristics, it is assumed that in the presence of these subsea gullies, gravity waves break closer to the shore, thus more destructive energy reaches the shore. Therefore, erosion is more intense near the end of these gullies. The methodology of the work includes (1) a geomorphological and geological description of the analysed section of the shore and identified gullies, (2) a description of the hydrodynamic characteristics of this sea area, (3) a description of the mathematical models used to calculate the transformations (e.g. breaking) of waves over the irregular seabed, and (4) carrying out these calculations showing quantitatively and qualitatively the impact of the presence of these gullies on the erosion of the seashore.

Research Capacity Building for healthy, productive and resilient Seas (SeaReCap)

Gramcianinov, Carolina B.*; Macovei, Vlad-Alexandru; Husmann, Eva; Staneva, Joanna; Voynova, Yoana; Neumann, Andreas; Stefanova, Kremena; Slabakova, Violeta
**Helmholtz-Zentrum Hereon, Germany; email: carolina.gramcianinov@hereon.de*

POSTER

The increasing concern about marine ecosystems and coastal structure states has recently contributed to implementing policies toward mitigation and adaptation plans to human- and climate-induced changes. The challenging tasks that arise from this demand rely on pure research, transfer-of-knowledge activities, and capacity building. In this way, the SeaReCap project primarily aims to build research capacity through the exchange and collaboration between the Helmholtz-Zentrum Hereon and the Bulgarian Institute of Oceanology. The geographical focuses of the SeaReCap are the Western Black Sea and German Bight, which are strategic regions for the project partners. Both regions have experienced various human impacts, including eutrophication, hypoxia, pollution, and overfishing. These processes are intensified by climate change. In SeaReCap, we work towards the achievement of (i) the integration of observations and modeling, including the improvement of forecasting capability in the regions, (ii) the development of what-if scenarios to assess the impacts of extreme events, warming, deoxygenation, and acidification into the coastal structures and ecosystems, (iii) the strengthening of the capability and collaboration between the two partners, focusing on the young scientist generation.

An attempt to parameterize surface-wave breaking for a wave-resolving simulation

Imamura, Haruka*; Yoshikawa, Yutaka
Graduate School of Science, Kyoto University, Japan; email: imamurahrk@kugi.kyoto-u.ac.jp

TUE.
June 27
10:30

OYSA

Recently, wave-resolving models, such as NHWAVE (Ma et al., 2012), SWASH (Zijlema et al., 2011), and CROCO (Marchesiello et al., 2020), are used to simulate currents and sea surface elevations in the coastal waters. Wave-resolving models solve the nonhydrostatic momentum equation with free sea surface condition at the top, and hence can simulate surface waves which play important roles in the coastal waters. These models however hardly reproduce surface wave breaking and need to parameterize the wave breaking to reproduce wave-induced set-up and set-down. As the parameterization of the wave-breaking, these three models commonly adopt the upwind difference method in advection terms of the momentum equation and the conservation equation of the water volume and handle discontinuities in velocity and elevation due to the wave breaking. These three models were tested against horizontal variations of mean sea level and mean wave height induced by waves but the sudden energy dissipation by the wave breaking, another important physical quantity of the wave breaking, has not been examined. Therefore, the wave energy dissipation and associated momentum transfer between waves and currents through the wave braking, which might have potential impacts on coastal currents such as rip currents, need to be more quantitatively examined. We developed an original wave-resolving model in which a sigma-coordinate nonhydrostatic model similar to Tsai and Hung (2007) is used. This model can explicitly simulate surface waves but can not represent the surface overturns as previous models, thus some parameterizations are required to represent the wave breaking effects in our model. While the previous three models adopt FVM or FDM, our model adopts the pseudo-spectral method based on the Fourier series which enables us to represent wave motions more precisely with coarser grids. However, little is known about the wave breaking parameterization for such a wave-resolving model. The aim of this study is to develop a parameterization scheme of the wave breaking for the wave-resolving model using the pseudo-spectral method, and to validate the parametrization scheme from the standpoint of wave energy dissipation. In analogous to the upwind method, we added diffusion terms (corresponding to the upwind advection term) and correction terms (which ensure the volume and momentum conservation) to the horizontal advection terms in our model. To validate our parameterization scheme from viewpoint of the wave energy dissipation due to the wave breaking, we performed two-dimensional numerical experiments as a counterpart of those of Deike et al. (2015), in which the wave energy temporal changes were examined by direct numerical simulations for a two-phase air-water flow which can reproduce overturning of the air-sea interface. We considered third-order stokes waves freely propagating on the surface of the water. Following the numerical experiments of Deike et al.(2015), we performed simulations with different conditions of wave steepness and surface tension with keeping its Reynolds number to be constant. Simulation with the parameterization showed that the simulated waves dissipated their energy while keeping wave characteristics such as the wave orbital motion. The dissipation rates were overall similar to those of Deike et al.(2015), though some mismatch was observed in cases when wave breaking should not occur. Thus, though some parameter tunings are required, we believe that our parameterization scheme does good work in presenting the wave breaking effects in our wave-resolving simulation. The wave-induced set-up and set-down in our model will also be tested as in the previous three models in near future.

Longshore sediment transport analysis for the Gulf of Riga based on high-resolution wave model results

TUE.
June 27
12:00

Jankowski, Mikolaj*; Parnell, Kevin; Soomere, Tarmo; Eelsalu, Maris
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OYSA

We analyse the average modelled rates of potential bulk and net sediment transport rates along the shorelines of the Gulf of Riga between the Suur Strait on the western shore of the Gulf and Kolka Cape. The calculations used data generated from triple-nested SWAN model simulations, with varied resolution up to 260 meters. The potential bulk and net sediment transport is calculated based on the well-known CERC formula. The properties of potential wave-driven alongshore transport and both convergence and divergence sedimentary zones in the area of interest are identified. The high-resolution findings are compared to previous estimates based on lower resolution models. In areas covered by both models there is reasonable agreement.

Sediment dynamics in a macro-tidal turbid estuary during typhoons: an observational and numerical study in Hangzhou Bay

TUE.
June 27
9:50

Li, Li*; Yihan Ren; Xiao Hua, Wang; Yuezhang, Xia
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The hydrodynamics and sediment characteristics of tidal flats during typhoons are of great significance for coastal geomorphology and ecosystems. Field records of waves, currents, and suspended sediment concentration (SSC) in the southern tidal flat (Andong) in the macro-tidal turbid Hangzhou Bay, China, were collected during Typhoon Mitag. The field data showed that there was little variance in the magnitude of the tidal currents during the typhoon. The directions were disordered with the peak ebbing currents changing from the southeast to the east, presumably due to the winds and northerly currents from the tidal creeks during the precipitation period. The significant wave heights (Hs) and turbulence kinetic energy (TKE) significantly increased during Typhoon Mitag. During normal weather conditions, the bed shear stresses induced by currents (τ_c) were mostly larger than those induced by waves (τ_w), while the τ_w exceeded the τ_c during the storm. The instantaneous bed shear stresses induced by currents and waves were mostly lower than the critical shear stress. Extracting turbulence from waves effectively diminishes the overestimation of turbulence. In calm conditions, the small-scale features ($>$ 0.5 Hz) of the scalograms exhibited some degree of disorder owing to the random nature of turbulence. Small-scale characteristics were embedded in relatively large-scale motions during extreme conditions, and a small quantity of plume-like streaks appeared between the frequency bands of 1/16 and 1 Hz. The temporal distributions of the high wavelet power regions of UW and cW coincided with each other, indicating the critical role of intermittent turbulence in sediment dynamics. The sediment characteristics and the effects of wave-current interactions on sediment dynamics during typhoons were numerically studied. The calibrated model considers tides-wave-sediment interactions and the reconstructed typhoon wind field. Numerical model results show that the winds and pressure fields dominated the storm surge, while the tide-surge nonlinear interaction modulated the surge. The waves and winds dominated the sediment resuspension. The combined interactions of currents and waves led to high SSC during the typhoon. The combined bottom stress was the primary wave-current interaction changing the sediment resuspension and increasing SSC, especially in shallow waters or during storms. The advection term, which played an essential role in reducing the SSC in HZB, mainly affected the SSC by enlarging the velocity. The wave dissipation term enhanced the vertical mixing, which involved the vertical exchange of suspended sediment and the currents. In the shallow waters of the southern bay, the wave dissipation term mostly led to the decrease of bottom stresses, the increase of currents, and the decrease of SSC, while the rise of SSC in the deep waters. The effects of the form drag, wave radiation stress, and refraction terms on suspended sediment dynamics were relatively small. The results of this study shed light on the study of coastal morphology and marine disasters.

The impact of extreme river discharge on the coastal ocean in the German Bight

POSTER

Nguyen, Thao T.*; Staneva, Joanna; Grayek, Sebastian; Bonaduce, Antonio; Hagemann, Stefan; Pham, Nam; Kumar, Rohini; Rakovec, Oldrich
**Helmholtz-Zentrum Hereon, Germany; email: thi.nguyen@hereon.de*

OYSA

The impact of river discharge forcing on the forecasting skills of a model was investigated for the German Bight. The experimental setup is based on the high-resolution Geesthacht Coupled cOAstal model SysTem (GCOAST), which couples wave and ocean models to account for wave-induced processes at the air-sea interface (ocean model NEMO and waves model WAM). The river discharge is imposed on the ocean model grid, resulting in unrealistic freshwater gradients in the coastal and shelf regions, known as Regions of Freshwater Influence (ROFI). The non-linear interactions between wind-waves, river run-off, and tides in these regions pose challenges in assessing their impact. Sensitivity experiments were performed using different river runoff datasets with both the stand-alone ocean model NEMO and the fully coupled hydrodynamic-wind wave model (NEMO-WAM). Statistical analysis of sea surface salinity indicates that the mesoscale hydrologic model (mHM) provides the most appropriate discharge data for the ocean model, enabling the simulation of the impact of freshwater discharge on the coastal zones, particularly in extreme flooding events such as the one that occurred in June 2013. Another set of experiments focused on coupling estuarine and coastal models. The regional model NEMO was laterally forced by outputs from a higher-resolution unstructured grid estuarine and coastal model called SCHISM. The performance of the models was assessed against in-situ observations (e.g., FerryBox, station data, tide gauges) and satellite observations. The proposed approach in this study offers a more realistic estimate of river runoff inflow into the ocean, leading to an improvement in the coastal ocean operational system. Overall, the results presented in this study provide new insights into the importance of high-frequency river freshwater buoyancy as drivers of salinity variations during extreme flooding events in the German Bight.

Regional impacts of offshore wind farms on ocean waves

TUE.
June 27
9:30

Schulz-Stellenfleth, Johannes*; Akhtar, Naveed; Staneva, Joanna
**Helmholtz-Zentrum Hereon, Germany; email: johannes.schulz-stellenfleth@hereon.de*

Offshore wind farms can cause atmospheric wakes with length up to 100 km and wind speed reductions of the order of 10-20. The presented study is concerned with the impact of these wakes on ocean waves with a focus on the regional scale. Offshore wind farms were included into the atmospheric model COSMO using the well-established Fitch parameterization. A one-year run was conducted for the North Sea considering all installations, which were either existing or planned in 2015. The ocean wave model WAM was then driven by the resulting near surface wind fields and a comparison was performed with a reference run without offshore windfarms. Statistics are presented for standard wave parameters, like significant wave height Hs, peak and mean periods as well as wind sea and swell energies. The study shows, that the impact of windparks on waves can be significant with relative wave height reductions of the order of 10. The strongest effects are found in fetch-limited conditions, where the wind is blowing from land towards the sea. These conditions are found very frequently, in particular, along the English east coast. Furthermore, it is shown that the wake impacts on waves can have larger spatial scales than the wakes themselves, because wave energy reductions are advected by swell over large distances. The evolution of two-dimensional wave spectra in fetch limited conditions with and without wind farms is discussed for some cases studies. A comparison is shown with measurements presented in an earlier study. The practical relevance of the observed impacts, e.g. in the context of wind park maintenance operations, is discussed. An attempt is made to generalize scaling laws known for growing wind seas to situations where wind farms are located inside the fetch region. Dimensionless length scales are obtained by scaling with the friction velocity and are used for both fetch length and geometric wind farm parameters. A simple parametric model is derived to replicate the wind farm impact using the scaled quantities.

Effects of observation-based physics on validation and wave climate in the wind-wave model WAM

TUE.
June 27
10:10

Ricker, Marcel*; Kousal, Joshua; Günther, Heinz; Behrens, Arno; Staneva, Joanna
**Helmholtz-Zentrum Hereon, Germany; email: marcel.ricker@hereon.det*

OYSA

For decades, third-generation spectral wave models have been based on semi-empirical physics often referred to as ST3 and ST4. They have proven their reliability and accuracy in a wide range of applications. However, they depend on thorough calibrations for the specific region of interest. For this purpose, observation-based physics have been developed (ST6 or BYDBR), which do not require tuning (up to a certain wind scaling). Subsequently, the ST6 physics were implemented into various wave models. Despite being one of the most widely used wave models, the ST6 physics have not been implemented into WAM (WAve Model). Recently, the ST6 implementation into the ecWAM branch was presented, and then the physics were transferred to the official development branch of WAM.This work analyses the implementation of ST6 physics into WAM and their performance in comparison to ST3 and ST4. The domain used is the Black Sea, which presents some challenges for spectral wave models, such as low wave heights and a semi-enclosed coastline. Good and comparable skills for both total and extreme event statistics are shown by comparing the validations for the three physical approaches ST3, ST4 and ST6. However, depending on the variable considered, each physical approach has its strengths and weaknesses with respect to satellite and buoy measurements. Furthermore, analyses of the wave climate reveal differences due to the different physics. This assessment focuses on spatially inhomogeneous differences in wave parameters and their statistics, such as different percentiles.The conclusion is that none of the physics performs significantly better than another, which is in line with the existing literature. Rather, the results demonstrate that model tuning and high-quality wind forcing of greater importance than the choice of source term physics. Furthermore, the study provides decision support for selecting the best physics for specific applications, such as wave forecasts and hindcasts, wave power assessments, or safety at sea.

Modeling two-way ice-wave interactions in the Great Lakes using FVCOM_ice + wave model

TUE.
June 27
14:40

Wang, Jia*; Cannon, David; Fujisaki-Manome, Ayumi; Beletsky, Dmitry; Constant, Steve; Ruberg, Steve; Orendorf, Sophie
**NOAA Great Lakes Environmental Research Laboratory, Michigan, USA; email: jia.wang@noaa.gov*

A two-way fully coupled wave-ice model is being developed with the ability to resolve ice-induced attenuation of waves and ice breaking by waves. Wave and ice interative dynamics in the Laurentian Great Lakes were simulated using the Finite-Volume Community Ocean Model (FVCOM) framework. Seven simple, flexible, and efficient parameterization schemes originating from the WAVEWATCH III IC4 were used to quantify the wave energy loss during wave propagation under ice. Ice-induced reductions of wind energy input and wave energy dissipation via whitecapping and breaking were also implemented (i.e., blocking effect). The model showed satisfactory performance in both wave and ice modeling, as validated using buoy-observed significant wave height during the ice-free season and satellite-retrieved ice concentration, respectively. Simulations were run over the basin-scale, and the five-lake computational grid provided spatial distribution of ice-induced wave attenuation in the heavy-ice year 2014. Results suggest that, with the exception of Lake Ontario and central Lake Michigan, lake ice almost completely inhibited waves in the Great Lakes under heavy-ice conditions. A practical application of the model in February 2011 revealed that simulations could accurately reproduce the ice-attenuated waves when validated by wave observations from bottom-moored AWAC. However, the AWAC wave data showed quick responses between waves and ice, while the model with one-way coupling was unable to simulate the quick response of ice melting. We are further developing a module in which wave-induced ice breakage reduces the floe size, thus increasing the lateral ice area and leading to enhanced lateral melting. This module is being applied to the five-lake model to complete the two-way coupling between ice and waves. Further validation using in-situ measurements is being conducted.

The "two-step" yielding process of the natural mud under steady and oscillatory shear stress

TUE.
June 27
12:20

Wang, Shaohua; He, Zhiguo; Gu, Hengye; Xia, Yuezhang*
**Ocean College, Zhejiang University, China; e-mail: yzxia@zju.edu.cn*

OYSA

The rheological properties of natural mud are closely related to nautical depth estimation, wave propagation, and morphology evolution of muddy coast. In this study, the rheological properties of the natural mud collected from Luxi Island and Zhoushan Island in China were investigated. Shear stresses in steady state or oscillatory state were imposed on mud samples directly to obtain the yielding process under tidal currents or waves. The results showed that both apparent viscosity and complex viscosity experienced two sharp declines with increasing shear stress, indicating a two-step yielding nature of natural mud. Two yield stresses, namely, static yield stress and fluidic yield stress correspond to the yielding processes of elasticity and viscosity breakdown, respectively. The static yield stress in the oscillatory shear stress tests was lower than that in the steady shear stress tests, and the fluidic yield stress of natural mud in oscillatory shear stress tests was higher than that in the steady shear stress tests. The above phenomenon was explained by the viscoelastic-oscillation theory. Furthermore, the experimental results indicated that the initial storage modulus had a closer connection to both yield stresses in comparison with mud density. This study not only provided a guideline for having a better understanding of the two-step yielding process of natural mud, but will also provide scientific support for the assessment of fluid-mud formation, sediment transport and morphology evolution, the interaction between waves or tidal currents and muddy seabed, and protection of seafloor infrastructures.

TOPIC 2:

Circulation and Dynamics Modeling

Effects of a surface layer cross-flow and slope steepness on the pathways of dense water flows along a slope

TUE.
June 27
14:20

Berntsen, Jarle*; Hansen, Bogi; Østerhus, Svein; Larsen, Karin; Margretha Husgard; Hatun, Hjalmar
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There is a strong flow of dense and cold water through the ridge between Iceland and Scotland. The main route of this water is through the Faroe-Shetland channel and further through the Faroe Bank Channel. After leaving the Faroe Bank Channel, the dense water continues along the slope along the Iceland-Faroe Ridge. Across this ridge there is also a strong flow of Atlantic water that may affect the pathway and mixing in the dense plume. The pathways and mixing in dense water overflows have been addressed in a range of numerical studies based on the DOME (Dynamics of Overflow Mixing and Entrainment) setup. In these studies, that are motivated by overflows such as the flows over the ridge between Iceland and Scotland, there is no active background flow in the ambient water masses above the dense plume. With the situation along the Iceland-Faroe Ridge in mind, the setup from the DOME experiment is adjusted to study the effects of i) the slope profile ii) flows crossing the slope on top of the along slope flow of dense water, and iii) the topography near the dense water inlet. It is found that the rate of descent is depending on slope steepness, and for a curved slope goingfrom flat on top of a ridge to much steeper away from the ridge, dense water parcels near the ridge will sinkdown more than the faster flowing dense water further down along the slope.A cross flow across the ridge mimicking the situation with a flow of Atlantic waterover the Iceland-Faroe Ridge will force stronger mixing between the dense water and the ambient water above anddense water mixed up into the surface water can be allowed to flow out across the ridge. Furthermore, the dynamical situation will along the slope will change and fluid parcels deep down along the slope can experience a faster rate of descent. By adjusting the topography to allow a pathway from the inlet of dense water to the ridge, without a barrier between, the starting point of the center of mass of the descending dense water will be higher up on the slope.

Variability of the bottom boundary layer induced by dynamics of cross-isobath transport over a variable shelf

TUE.
June 27
16:30

Cheng, Weicong*; Gan, Jianping
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OYSA

The dynamics of the bottom boundary layer (BBL) play a critical role in regulating energy and momentum balances in shallow shelf areas. In this process-oriented modeling study, we investigated the spatially variable BBL mixing dynamics in response to flow-topography interactions over the shelf of the Northern South China Sea. Driven by southwesterly upwelling-favorable winds, the northeastward depth-mean along-shelf current generated frictional upslope Ekman transport within the BBL. However, along-isobath pressure gradient over meandering shelf modulated the total bottom cross-isobath transport geostrophically. The downwave along-isobath PGF enhanced upslope transport over the shelf to the east of the Pearl River Estuary (PRE), while the upwave along-isobath PGF offset the frictional shoreward transport over the shelf to the west of the PRE. As a result, the intensified upslope-dense water transport induced stratification, weakened the effect of bottom stress-induced mixing, and thus limited the development of the BBL over the eastern shelf. Without the upslope-dense water invasion, the BBL over the western shelf was further developed, albeit under smaller bottom stress. River discharge and tidal currents modulated the wind-driven shelf circulation, changed the intensity of cross-isobath transport and bottom stress, and regulated the BBL development. Trajectory of seabed particles responded following the BBL dynamic regimes, with high (low) concentration, small (large) suspending time, and strong (weak) shoreward transport found over the eastern (western) shelf, respectively. The study demonstrated the dynamics connection between the wind-driven shelf circulation and BBL, and indicated the potential impacts of the dynamics on the transport of sediment and biogeochemical processes in the BBL.

Subtidal secondary circulation induced by eddy viscosity-velocity shear covariance in a predominantly well-mixed tidal inlet

TUE.
June 27
17:10

Chen, Wei*; Jacob, Benjamin; Valle-Levinson, A.; Stanev, Emil; Staneva, Joanna; Badewien, T.H
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OYSA

The secondary circulation in a predominantly well-mixed estuarine tidal inlet is examined with three-dimensional numerical simulations of the currents and density field in the German Bight. Simulations analyze two complete neap and spring tidal cycles, inspired by cross-section measurements in the tidal inlet, with a focus on subtidal time scales. The study scrutinizes the lateral momentum balance and quantifies the individual forces that drive the residual flow on the cross-section. Forces (per unit mass) from the covariance between eddy viscosity and tidal vertical shear (ESCO) play a role in the lateral momentum budget. During neap tide, the ESCO-driven flow is weak. Accelerations driven by advection dominate the subtidal secondarycirculation, which shows an anti-clockwise rotation. During spring tide, the ESCO acceleration, together with the baroclinicity and centrifugal acceleration, drives a clockwise circulation (looking seaward). This structure counteracts the advection-induced flow, leading to the reversal of the secondary circulation. The decomposition of the lateral ESCO term contributors reveals that thedifference in ESCO between neap and spring tides is attributed to the change in the vertical structure of lateral tidal currents, which are maximum near the bottom in spring tide. The findings highlight the role of the tidally varying vertical shears in the ESCO mechanism.

Regional impacts of offshore wind farms on the North Sea hydrodynamics

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TUE.
June 27
15:20

OYSA

Offshore wind is a vital source for renewable energy generation, which is essential for reducing greenhouse gas emissions and decarbonizing the energy sector. However, the development of offshore wind infrastructure in coastal seas such as the North Sea introduces novel structures to the marine environment that have implications for the physics of the atmosphere and ocean. This study aims to investigate the effects of offshore wind energy production on the North Sea hydrodynamics, with a focus on induced wind speed reductions and structure-induced mixing. We present first-order parameterizations of surface wind speed anomalies and underwater structure drag, and use unstructured grid modeling to illustrate the consequences for regional ocean dynamics. The model simulations consider recent European offshore wind development and cover the seasonal cycle of summer stratification in the southern North Sea. The modeling results demonstrate that offshore wind farm wake effects influence regional ocean dynamics by causing large-scale structural changes in the hydrodynamic conditions. The wake effects lead to spatial adjustments in current speed and affect the development of regional-scale seasonal stratification. Although the magnitudes of induced alterations are within the range of natural variability, the offshore wind farm effects create an anthropogenic bias in regional hydrodynamics and suggest potential consequences for marine biogeochemical processes. Overall, this study proves new insights into coastal ocean adaptation to offshore wind energy production and raises awareness of potential changes in the future North Sea.

Towards high resolution climate projections for the German coasts with NEMOv4.2

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TUE.
June 27
15:00

OYSA

The German Federal Maritime and Hydrographic Agency (BSH) provides ocean monitoring and regional climate projection data in support of climate change adaption within the framework of the "German Strategy for Adaption to Climate Change" (DAS). BSHs main target areas for climate products include the German Bight with its large tidal flats. Current climate products as well as the operational forecasting at BSH are realized with nested high-resolution HIROMB-BOOS-Model setups including wetting-and-drying schemes to represent the complex dynamics of the German Bight. In this work, the development of a 2nm NEMOv4.2 setup towards higher resolution to provide coastal climate projection data is presented. An adjusted bathymetry based on up-to-date measurements of the sea floor from the EMODNET network is introduced and studied with regard to its tidal behaviour especially in the German Bight. The wetting-and-drying scheme implemented in NEMOv4.2 is explored in experiments with varying resolutions and bathymetries. An outlook on a methodological inter-model comparison between NEMOv4.2 and HIROMB-BOOS will be given.

Towards A Global Coastal Ocean Model Based On Unstructured Grids

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POSTER

OYSA

We present the first results obtained from a global-ocean extension of the model SHYFEM-MPI (Micaletto et al., 2022). The latter is the MPI-based parallelization of the three-dimensional finite-element circulation model SHYFEM (System of HydrodYnamic Finite Element Modules), able to run on unstructured meshes based on triangular elements. SHYFEM has already been implemented in large-scale case studies, but still in limited domains (Umgiesser et al., 2004, Federico et al., 2017). The new global mesh has a variable resolution that goes from 25 km at the equator to 6 km at the poles. The main advantage of the mesh is the realistic representation of the coastline, while having an eddy-resolving configuration until the mid-latitudes and an eddy-permitting configuration poleward. A simulation is run for one year with ERA5 atmospheric forcings and initial conditions taken from WOA18 climatological values. The atmospheric fluxes are computed through the ECMWF bulk formulae. A first qualitative analysis reveals a satisfactory representation of the large-scale ocean circulation and sea surface temperature. The global model is then preliminarily compared with the structured-grid model NEMO, run on the ORCA025 grid with a comparable experimental setting. This study is a first validation test for the global model, but further configurations with higher resolution in coastal regions are planned. The scope is to assess storm surges induced by hurricane events, with the aim of understanding the compound role of local (coastal) and remote (open-ocean) forcings. This model configuration could represent a step towards a new generation of models capable of integrating the coastal with the global scale.

The Role of Tides on Salinity Distribution in the Persian Gulf

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POSTER

OYSA

The relative role of tidal forcing on Persian Gulf salinity is investigated using a 3D hydrodynamical model. We perform three simulations for the years 1993-2001: one excluding wind forcing, one excluding tidal forcing and one including both forcings. The analysis shows that the sheared salt transport driven by horizontal density gradients is always seaward in the Persian Gulf, as in other inverse estuaries. Conversely, the tidal advective salt flux mainly becomes landward due to the relevant landward netflux (net inflow rate). It diminishes toward the head of the Persian Gulf due to the decrease in mean tidal height. The landward salt transport by tidal advection is generally stronger than the seaward sheared salt flux throughout the gulf at annual time scales. This results in a landward net salt flux. Therefore, tides tend to increase the salinity of the Persian Gulf. In the Strait of Hormuz, tides enhance the horizontal salinity gradient strengthening the sheared salt flux. Tides also reduce the vertical salinity gradient weakening the stratification.

An implementation of ROMS for the Indian Ocean with riverine freshwater fluxes: model setup and validation

POSTER

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OYSA

The Indian Ocean experiences a strong semiannual reversal of monsoon winds, which determines the weather and climate of Asia, including freshwater fluxes between the atmosphere, land and ocean. Recent work has shown that the Indian Monsoon system is becoming more extreme and erratic due to climate change, with unknown consequences for the regional Indian Ocean circulation, and inter-basin fluxes of salt between the Arabian Sea and the Bay of Bengal. To better understand how monsoon variability affects the Indian Ocean circulation patterns, we have developed a Regional Ocean Modeling System (ROMS) simulation of the Indian Ocean, including riverine freshwater fluxes. To improve the model simulation of salinity, river discharge data of the Ganges, Brahmaputra, Irrawaddy, Godavari, Krishna, and Cauvery are used and implemented in the model as point sources. This study will focus on the set up of the model, including a discussion of the atmospheric and riverine forcing fields used. We will also discuss model validation techniques applied using a range of satellite products including Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Along-Track Scanning Radiometer (AATSR) for sea surface temperature, Aquarius for sea surface salinity, AVISO satellite altimetry data for sea surface height anomalies and Ocean Surface Current Analysis Real-time (OSCAR) for surface ocean currents. The simulated fields are compared to the observed fields and the fidelity of the model is assessed by examining statistical relationships including correlation, Root Mean Square Error (RMSE) and mean bias between the modeled and observed fields.

Evaluation of seagrass as a nature based solution for coastal protection in the German Wadden Sea

**TUE.
June 27
16:10**

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OYSA

Global climate change increases the overall risks for coastal flooding and erosion.Meanwhile nature based solutions (NbS) are increasingly becoming a focus of coastal protection measures to improve the climate adaptability. In this study, the present and potential future role of seagrass in coastal risk reduction strategies is explored for the highly energetic Wadden Sea area of the German Bight. The methodology in this study combines seagrass coverage data (Zostera marina and Zostera noltei) obtained by field surveys and what-if scenario simulations using the SCHISM unstructured grid model framework, coupling hydrodynamics, waves,sediments, and a seagrass module. The results suggest that the introduction of seagrass meadows locally can reduce both current velocities and significant wave heights in the order of up to 30 in the deeper areas and above 90 in the shallow areas. Reduction in bottom shear stress of a similar relative magnitude significantly reduced sediment mobilisation on the order of 2 g/L in the 95th quantile of bottom layer sediment concentrations. Effectively altering hydromorphodynamic conditions favouring sediment accumulation, seagrass expansion could help tidal flats height growths to keep up with SLR, thus further maintaining the bathymetry induced tidal dampening and lowering flooding and erosion risks as well the amount of energy at dike infrastructure. The accumulated effect of seagrass under calm weather conditions is considered more important than the increased attenuation in absolute values it provides during extreme conditions. The overall conclusion is that seagrass expansion could be a useful addition to engineered coastal protection measures.

Estuarine turbidity maximum in the Pearl River estuary – formation mechanisms and dynamics in response to climate and human drivers

TUE.
June 27
16:50

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OYSA

Suspended particulate matter (SPM) plays an important role in both physical and biogeochemical processes in the estuarine system, and the variation of SPM concentrations have multiple environmental and societal implications. Previous research has shown that gravitational circulation, tidal trapping, sediment resuspension and deposition, and runoff of rivers are the primary controlling factors for the formation of the estuarine turbidity maximum (ETM) in the Pearl River estuary (PRE). However, the mechanistic connection between surface riverine sediment plumes and the ETM, and the spatial and temporal variation of the ETM caused by human-induced morphological change and climate- and land subsidence-induced sea level change remain largely unknown. In our study, Landsat data from the 1970s to 2010s were analyzed to identify the variation of the surface sediment concentration. A 3-Dimensional hydrodynamics-sediment transport model (SCHISM) were used to investigate the impacts of decadal-changes (1970s-2010s) of morphology, riverine sediment discharge and sea level on the spatial and temporal variation of ETM. Based on a model validation which satisfactorily reproduced the three major observed ETM zones, sediment trapping mechanisms were investigated for their influence on the variation of the ETM to clarify the nonlinear relationships between various sediment trapping processes and the ETM in the PRE. A better understanding of the formation mechanisms of ETM in the PRE and its spatio-temporal development in response to climate and human drivers is gained.

Assessment of wave-current interactions on the Mediterranean Sea dynamics through numerical experiments

TUE.
June 27
11:20

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Ocean-atmosphere interface is governing both the ocean and the atmosphere dynamics by means of a large number of complex processes such as the fluxes of momentum, energy and heat. An accurate representation of ocean surface waves and wave-current dynamical processes has long been recognized as essential for hydrodynamical ocean forecasting systems and operational oceanography. Waves impact the ocean dynamics in three major ways: the momentum transfer, the turbulent energy injection and the generation of mass transport. All these feedback mechanisms can be modelled by coupling hydrodynamic and wave numerical models which have usually been developed separately.Here we present a coupled hydrodynamic-wave modelling system implemented in the Mediterranean Sea using NEMO v4.2 coupled to the third generation wave spectrum model WaveWatchIII v6.07 through the OASIS coupler. The aim of this study is to assess the impact of the wave-current interactions, especially the effect of the wave-induced mixing, on the Mediterranean sea dynamics.The configuration is based on the operational Copernicus Marine Service Mediterranean forecasting physical system. Numerical experiments are carried out in both uncoupled and two-way coupled mode. In order to validate the system, numerical results are compared with in-situ and satellite data. This study is focused on the impact of the coupling on upper-ocean properties such as temperature, salinity, sea surface height and surface currents at mesoscale. The coupled numerical simulations show a global increase of the temperature and salinity skill in the Mediterranean Sea in comparison to uncoupled experiments. For the current, in coupled mode, the Stokes drift compensates for the reduced shear of the mean current due to wave-induced mixing. The modifications of the Turbulent Kinetic Energy vertical closure scheme and the inclusion of the Langmuir turbulence lead to an increase in the mixing in specific areas, thus helping to deepen the Mixed Layer Depth.

Determining Main processes Affecting Circulation and Variability in Bras d'Or Lakes using a Coupled Circulation-Ice Modelling System

FRI.
June 30
09:30

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Bras d'Or Lake Biosphere Reserve over the central Cape Breton Island of Nova Scotia is a UNESCO Biosphere Reserve established in 2011. One of main features of this Biosphere Reserve is the Bras d'Or Lakes (BDL), which is the saltwater tidal body connected to the Atlantic Ocean through two narrow channels. Influenced by the net heat flux at the lake surface and variability of freshwater discharges circulation and hydrography in the Lakes have large temporal and spatial variability. A coupling circulation-ice modelling system for BDL (CMS-BDL) is used to examine the three-dimensional (3D) circulation and hydrography in the Lakes. The CMS-BDL is based on the Regional Ocean Modeling System (ROMS) and the Los Alamos Sea Ice Model (CICE), with the three-level nested-grid setup. The ERA5 hourly reanalysis data are used in driving the modelling system. The tidal forcing with 15 tidal constituents from the TPXO9 dataset is specified along the open boundaries of the outmost component of the CMS-BDL. Time series of hourly freshwater discharges from 11 rivers around the Lakes are constructed from the hourly rainfall observations at weather stations in Cape Breton Island. The performance of the CMS-BDL is assessed using various types of observations. The monthly mean circulation in the Lakes produced by the CMS-BDL is characterized as a two-layer circulation with seaward flow in the upper layer and lake-ward flow in the lower layer. Consistent with observations, the simulated ice in the Lakes starts to form in early January and disappears in late April, with the maximum coverage occurring in mid-March. The large effect of tides occurs mainly in the Great Bras d'Or Channel, with the maximum tidal velocity up to $\sim$1.0 m/s. Process studies using the CMS-BDL show that winds affect significantly the circulation and hydrography in the whole Lakes during the ice-free period. Model results are also used in quantifying the important roles of winds and tides in driving southward intrusion of sub-surface salty waters through Barra Strait of the BDL.

A Lagrangian estimate of the Mediterranean outflows origin

POSTER

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OYSA

The Mediterranean Sea is characterized by an anti-estuarine circulation with Atlantic Water entering the Strait of Gibraltar at the surface and denser waters formed within the basin exiting at depth as Mediterranean Outflow. The bulk of the outflow is constituted by Levantine Water, formed in the Levantine Basin, and Western Mediterranean Deep Water, originating in the Gulf of Lions. Recent studies have demonstrated the additional contribution of Tyrrhenian Deep Water and Western Intermediate Water, both formed in the Western Mediterranean Sea (Millot, 2014; Naranjo et al., 2015).In this study, the origin of the Mediterranean Outflow is investigated by deploying six millions virtual Lagrangian parcels from 2005 to 2012 at the Strait of Gibraltar, and tracing them backward in time using velocity estimates from an eddy-permitting reanalysis. The Lagrangian parcels are followed until they intercept one of three sections, in maximum 78 years. The hypothesis is that each section is associated with distinct water masses: the Gulf of Lions, related to Western Mediterranean Deep Water and Western Intermediate Water, carries 86 of the Outflow's transport; the Northern Tyrrhenian, related to Tyrrhenian Deep and Intermediate Waters, carries 1 of the transport; the Strait of Sicily, related to Levantine Intermediate Waters, carries 13 of the transport. Volume transport pathways indicates that these dense waters recirculate in the Algerian Basin and in the deep Tyrrhenian basin, before exiting the Strait of Gibraltar. The median transit times from the sections to the Strait of Gibraltar range from 5 years (Gulf of Lions) to 8 years (Strait of Sicily).

Living Lab Wadden Sea: Learning from Transboundary Pilots on Nature Restoration and Nature Based Solutions

POSTER

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OYSA

The Wadden Sea, known for its unique tidal mudflat ecosystem, is protected by international agreements for nature conservation. Initially, management focused on preserving existing nature, landscape values, and habitats. However, recent efforts aim to expand targeted nature habitats, promote natural processes, and enhance salt marsh structures for wading birds. The implementation of the EU Water Directive introduced goals to improve estuarine water quality. These evolving management strategies reflect a comprehensive approach to preserve the Wadden Sea, integrating ecological considerations for its long-term sustainability and ecological health. Since the 2010s concern about the impact of climate change also generated interest in the role of the Wadden Sea in flood risk management. The shallow Wadden Sea with its row of barrier islands and tidal flats, banks, and salt marshes performs a key role in protecting the mainland coast. This new interest resulted in a series of pilot projects to explore innovative ways to integrate flood protection and nature development. An example is the project REST-COAST (Large scale RESToration of COASTal ecosystems through rivers to sea connectivity) funded by the European Union Green Deal program. The Wadden Sea, as the only transboundary pilot site in the project is being considered jointly by German and Dutch partners. REST-COAST is a collaborative project that aims to foster cooperation among scientists and policymakers to ensure the long-term preservation of coastal areas. One of the project's unique contributions lies in risk reduction through Ecosystem Services (ESS) parameters and the consideration of restoration scale using hydro-morpho-eco coupled models. The coupled models simulate impacts under present conditions and future scenarios, providing a consistent evaluation across different scales. The risk assessment outcomes support decision-making processes related to short- and long-term investments and management, facilitating broader adoption of risk products in coastal adaptation efforts. Additionally, the project's findings contribute to the definition of tipping points and influence policy evolution toward the internalization of risk reduction.

Characterizing the Variability of the Circulation in the Indonesian Seas

TUE.
June 27
14:00

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A regional ocean model simulation for the period from 2000 through 2019 is used to study variability of the circulation in the Indonesian seas. The modeled sea surface height anomalies compare favorably with satellite and in situ observations. The model simulation also suggests the dominance of annual cycle and intra-seasonal variability in the Indonesian Seas in contrast to the relative dominance of interannual variability in the Philippine Sea and along the south Java coast. Lag correlation analysis suggests that the interannual sea level anomaly and opposite responses of the velocity above and below the thermocline in the western (the Sulawesi Sea and the Makassar Strait) and eastern (the Halmahera Sea) pathways of ITF are associated with the ENSO forcing from the equatorial Pacific rather than the local wind forcing. On the other hand, annual variations are monsoon driven, which are limited in the upper layer, while the intra-seasonal variability is mostly eddy induced with significant responses below the thermocline.

TOPIC 3:

Data Assimilation and Ocean Forecast Systems

Ocean climate predictability study in the Mediterranean Sea

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WED. June 28 9:30

OYSA

Two types of variability are discernible in the ocean: a response to the external forcing, here defined as signal, and the internal ocean variability, here called noise. The latter is associated to mesoscale variability characterized by intermittency and relatively small spatial scales. Producing an ensemble of five ocean multi-year simulations of the Mediterranean Sea in 2021 initialized with different initial conditions but forced by the same atmospheric forcing, noise and signal are analyzed to understand the relative importance of the former compared to the latter. It is found that the noise is stronger in summer in the surface layers for temperature and in winter for the current velocity amplitude. Moreover, the noise dominates at all depths in both seasons, except for the first 100 m for temperature and for the shallowest areas in the basin, such as the Adriatic Sea and the Gulf of Gabès, for current velocity. Finally, the temperature noise in summer concentrate in the upper thermocline and the depth of its maximum coincides with the maximum of the vertical temperature gradient, whereas the noise relative to current velocity is greater where the current velocity itself is stronger, thus hinting to the presence of active instability processes. In conclusion, this study allows to quantify the intrinsic uncertainty of ocean simulations in the Mediterranean Sea and to begin to shed light over the main drivers of internal ocean variability, such as vertical mixing processes and mesoscale eddies.

Combining variational Data Assimilation and Artificial Intelligence to improve short-term wave forecasts for Offshore Wind Farms operational decisions

WED.
June 28
9:50

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Accurate sea state predictions are crucial for various applications in the offshore sector. As a practical example, the timing of construction and maintenance of Offshore Wind Farms (OWF) strongly depends on short-term Significant Wave Height (Hs) forecasts, because service vehicles are only allowed to access if Hs is under a safe limit (SL). If the ship is mobilized, but then Hs is above the limit, typically around 1.5m, ship fuel and personal costs are wasted (Decision error of Type A). On the contrary, if the vessel is not mobilized but Hs doesn't exceed the limit, the chance to operate is lost (Decision error of Type B). This results in a huge waste of money and time, which motivates a further optimization of short-term wave forecasts [1]. This is especially true for inner basins and coastal areas, where wave models forecast skill still has some weakness even when used together with several classical Data Assimilation (DA) methods [2,3]. With the aim of improving the Hs short-term forecast skill of the WAM wave model [5], the power of artificial intelligence (AI) is exploited in this work and a new hybrid DA scheme is introduced. Particularly, the proposed method consists of a Neural Network (NN) component used in combination with the classical 3DVAR DA scheme [4]. For the training of the NN buoy observation data and model simulations results are used. The method is applied to the North Sea to forecast Hs up to 12 hours lead time and it is tested for 4 months in 2018.For the statistical evaluation of the performance of the method, the Root Mean Squared Error (RMSE) has been computed at every buoy location and results show an overall improvement. A closer analysis was performed of the assimilation impact on decisions, which are based on forecasts exceedance of the SL. It is shown that the analysis in fact reduces decision errors of type A and type B, which are related to vessel operations around offshore windfarms. Furthermore, some general statistical results about the time/space structure of model errors are presented, in particular the respective correlation times and lengths. A short discussion will be given about possible origins of the errors in the driving wind fields.

OYSA

References: [1] J. W. Taylor and J. Jeon. "Probabilistic forecasting of wave height for offshore wind turbine maintenance", European Journal of Operational Research 267 (2018). [2] L. Cavaleri and L. Bertotti. "Accuracy of the modelled wind and wave fields in enclosed seas", Tellus A 56 (2004)[3] G. Emmanouil et al. "Assimilation of radar altimeter data in numerical wave models: an impact study in two different wave climate regions", Annales Geophysicae 25.3 (2007). [4] A. C. Lorenc. "Development of an Operational Variational Assimilation Scheme", Journal of the Meteorological Society of Japan. Ser. II 75.1B (1997). [5] The WAMDI Group. "The WAM model – a third generation ocean wave prediction model", Journal of Physical Oceanography (1988)

Assimilation of sea ice in the Baltic Sea with BSH operational circulation model

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POSTER

The operational service at the BSH bases on its 3D baroclinic circulation model HBM (HIROMB-BOOS Model), which provides reliable forecast data of water level, current, temperature, salinity and sea ice for the North and Baltic Sea, focusing on German coastal waters. The HBM model is coupled to the parallel data assimilation framework (PDAF, https://pdaf.awi.de). The HBM-PDAF system uses the Local Error Subspace Kalman Transform Filter (LESKTF) algorithm. Since 2021 satellite sea surface temperature (SST) are assimilated every 12 hours operationally in the model system. Two different SST satellite products can be assimilated: 1) Advanced Very High Resolution Radiometer (AVHRR), which is processed, interpolated onto the model grids and quality controlled every 12 hours by the BSH satellite data service. 2) CMEMS SST L3 product, which is a daily ensemble product from multi-sensor with horizontal resolution of 0.02deg x 0.02deg. The selection of the dataset is generally based on the availability of satellite data. Recently, the data assimilation component has been further developed and has modules to assimilate sea ice concentration and thickness charts from the BAL MFC of CMEMS at the same or different time instants. Using different coupling regimes (weakly or strongly) and different satellite data sets lead to different results. Here we will compare the influences of the SST and sea ice assimilation in the HBM model system and will discuss the results from different assimilation experiments.

On the role of temporal irregularities and spatial dependencies in the development of time-series models for predicting biotoxin contamination in shellfish

WED. June 28 10:10

Krippahl, Ludwig; Tavares, Sérgio*; Lopes, Marta B.
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OYSA

Shellfish production is an important economic activity in Portugal, which makes shellfish contamination with biotoxins both a public health problem and a significant economic risk. The development of technologies for predicting shellfish contamination is an attractive solution since it can help improve production management and public health protection.This work uses biotoxin contamination data collected by the Portuguese Institute of Sea And Atmosphere (IPMA) from shellfish species since 2015 at 14 locations across the southern coast of Portugal with the aim of predicting contamination events. A contamination event occurs when the toxin concentration in shellfish exceeds the safety limits after previously being below such limits.One important aspect of shellfish contamination data is that samples are obtained approximately every week at each sampling point, but the exact day varies significantly, and sometimes there are more or fewer samples in the same time period. To deal with these irregular time series without resampling or interpolation, we extract features to be used in subsequent regression models by fitting polynomial curves to the sampled concentrations, using the curve parameters as features. Furthermore, we compute lagged correlations between series of samples using a Gaussian kernel method that can be applied to irregular time series. This avoids depending on an arbitrary choice of points for interpolation, which is a problem when converting irregular time series to regular time series.Another aspect of these data is that concentrations are not always independent between different locations. Here we find where these dependencies occur by computing time-lagged correlations between series of different locations, and we show that these correlations can be used to improve the prediction of the time to the next contamination event at one location by using concentration data sampled both at that location and at a relevant neighbor.In conclusion, this work proposes a novel methodology that accounts for temporal sampling irregularities and spatial dependencies in the generation of regression models for predicting the time to shellfish contamination events. The usefulness of the proposed methodology is illustrated by the resulting improved predictive ability of models across relevant shellfish production areas of the southern Portuguese coast.

TOPIC 4:

Multi-Scale Ocean and Atmospheric Processes

Island-induced eddy generation mechanism analysis with Lagrangian and Eulerian approaches

THU. June 29 10:10

Ko, Changhoon*; Sung Yong, Kim
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OYSA

Submesoscale island-induced eddies are persistently generated behind Tsushima Island, located on the Korea Strait. Observational data can be used to understand the eddy generation mechanism with Lagrangian approaches in the vicinity of Korea Strait. Chlorophyll concentration fields are observed through satellite, and the generation and propagation of submesoscale eddies can be analyzed from Geostationary Ocean Color Image (GOCI) data. Submesoscale eddies are induced at the north and south tips of Tsushima island within 2-5 days, and they tend to propagate northeastward along surface current at a speed of 0.1m/s. Furthermore, submesoscale processes can be observed with Lagrangian drift data from Global Drifter Program. Several drifters are affected by submesoscale eddies, which have O[1-10km] diameter and 0.1 to 0.5 normalized vorticity magnitude, located behind Tsushima Island.The eddy generation mechanism of observed island-induced eddies can be explained with Eulerian approaches, such as Eddy Kinetic Energy (EKE) analysis and EKE budget, with the high-resolution numerical model (MITgcm llc4320npm). Island-induced eddies are associated with barotropic instability, and EKE is dominant behind the island due to energy transport from mean kinetic energy to eddy kinetic energy. The intensity of EKE varies with spring-neap frequency.

Seasonal Variability of Circulation and Freshwater Transport over the Continental Shelf off Eastern Canada

POSTER

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Seasonal variability of three-dimensional hydrodynamics, sea ice and freshwater transport over the eastern Canadian shelf (ECS) is examined using a coupled circulation-ice model for the northwest Atlantic (CCIM-NWA) based on the ROMS and CICE. This coupled model is forced by hourly ERA5 atmospheric reanalysis fields produced by ECMWF and boundary forcing based on the daily GLORYS ocean reanalysis. The tidal forcing with 15 tidal constituents from the TPXO9 dataset is also specified along the model open boundaries. In comparison with in-situ and remote-sensing data and previous numerical results, the CCIM-NWA has reasonable skill in simulating the large-scale circulation, hydrography and associated seasonal variability over the ECS. The seasonal variation of freshwater content and freshwater transport pathways are examined based on the model results. It is found that the freshwater content is transported equatorward over the ECS from the northern Labrador Shelf. On the eastern and southern Newfoundland Shelf and adjacent waters, the freshwater transport is divided into two branches. One branch follows the pathway of the Labrador Current between the Flemish Cap and Grand Banks. Another branch follows the coast into the northwestern Grand Banks. On the Scotian Shelf, the freshwater content is influenced by not only the freshwater discharge from the St. Lawrence River, but also by the freshwater content from the Labrador Shelf. The interannual variability of the freshwater flux over the ECS is mainly affected by the large-scale atmospheric forcing over the NWA.

TOPIC 5:

Modeling and Prediction of Extreme Marine Events

Wave energy associated with extreme events along the southern coast of Brazil

POSTER

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The wave energy flux is commonly used by ocean engineering to estimate the amount of electrical energy that can be generated from waves. On the other hand, many studies that consider all variables to describe the wave pattern (height, period, and wavelength) could include wave energy for quantifying the magnitude of storms, mainly those that hit the coast. Therefore, this study aims to evaluate the wave energy flux associated with extreme events on the South and Southeast Brazilian coast. To accomplish this, a climatological analysis of wave energy flux was conducted using Global Ocean Waves Reanalysis (Waverys) data spanning the period from 1993 to 2021. Monitoring points were positioned on the 100-meter isobath and distributed throughout the study region. Cases above the 95th percentile were isolated and verified with a database containing information on the occurrence and damage caused by storms. The wave energy flux was decomposed into orthogonal components to obtain the energy perpendicular to the coast, which is the most damaging. The energy thresholds for each state of the S/SE region and the trend over the years were determined statistically. These results are important to reinforce knowledge about previous events and could help to help improve forecast systems in order to minimize the damage caused by storms.

Energetic patterns of intense extratropical cyclones in the Southwestern Atlantic

POSTER

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The Southwestern Atlantic is a hotspot for extratropical cyclogenesis. These systems are associated with severe weather events in coastal communities in this region, such as strong winds, heavy precipitation, storm surges and high waves. Furthermore, extreme events often cause impacts that heavily affect the coastal infrastructure, navigation, port and offshore activities. In this study, we investigated the energetic patterns associated with the most intense cyclones in the Southwestern Atlantic basin, identified by the relative vorticity at 850 hPa.We calculated the Lorenz Energy Cycle (LEC) using the atmospheric fields derived from the the Fifth generation of the European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (ERA5).We then performed cluster and principal component (PC) analyses to group cyclones into distinct energetic patterns. The principal components related to those patterns were plotted in a diagram representing the temporal evolution of the atmospheric dynamics associated with the development of disturbances in the atmosphere, named Lorenz Phase Space (LPS). Our analysis revealed that the LEC of the analyzed systems is dominated by barotropic conversions for the first PC, while the second PC shows a transition from moist barotropic to baroclinic. These findings provide insights into the energy dynamics of extratropical cyclones in the Southwestern Atlantic, which can aid in improving their prediction and risk assessment.

Investigating the TC Idai over the Mozambique Channel: effects of SST field on cyclone track and intensity

THU. June 29 09:50

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Tropical cyclones are among the most destructive natural phenomena on earth. In socioeconomically disadvantaged regions such as the Southwest Indian Ocean (SWIO) bordering nations, they are still responsible for huge losses of lives and properties. This study assesses the ability of a high-resolution ocean-atmosphere regional coupled modeling system (COAWST) to predict the evolution of the intense tropical cyclone Idai (TC Idai, March 2019) and its impacts on the ocean environment within the Mozambique Channel. Different sensitivity experiments were conducted varying the surface boundary conditions given by sea surface temperature (SST) and the impact on both the evolution of the system (track and intensity) and ocean subsurface response were analyzed. The results suggest that regionalization with COAWST was able to reproduce a system with trajectory and intensity comparable to observation for a 7-day lead time hindcast. While a first analysis may suggest that the intensity evolution of Idai was modulated by ocean mesoscale eddies present in the region when TC Idai swept the channel, the imposition of different SST conditions on the surface shows a similar evolution pattern but with slightly lower intensity. This indicates that the intensity evolution pattern for TC Idai was less sensitive to SST but was mainly constrained by large-scale atmospheric fields. At the same time, the degree of intensification is dependent on ocean stratification.

Statistical models versus climate models and the prediction of extreme coastal sea level events and flooding

THU. June 29 09:30

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Global sea level rise puts many low laying cities around the world at a high risk of flooding, including, for example, the most populated area of the US along its Atlantic coast. The severity and potential damage of extreme storm surge events may depend on many factors such as tides, waves, decadal sea level variations, impact of ocean currents, and the unpredictable frequency of major events like hurricanes and tropical storms. However, global climate models that predict mean sea level rise under different scenarios cannot account for all these factors and thus these models are not very useful to assess flood risk at a particular location and provide guidance for planning mitigation and adaptation options. Therefore, a simple statistical prediction model based on random sampling of past data was tested near the vulnerable Chesapeake Bay area. The method accounts for the combined impact of many unpredictable factors affecting sea level variability, and provides a tool to predict the probability of future flooding. The results show for example that a storm surge that observed in the past only once in ∼100 years may become a frequent event by 2100. There are also significant differences in sea level variability and rise within the same bay that climate model projections based on physical equations cannot capture, but statistical models based on local data can.
References:
Ezer, T. (2022), A demonstration of a simple methodology of flood prediction for a coastal city under threat of sea level rise: the case of Norfolk, VA, USA, Earths Future, 10(9), doi:10.1029/2022EF002786
Ezer, T. (2023), Sea level acceleration and variability in the Chesapeake Bay: past trends, future projections, and spatial variations within the Bay, Ocean Dynamics, 73(1), 23-34, doi:10.1007/s10236-022-01536-6

Reassessment of heat budget in the Mediterranean Sea and an investigation of probability distributions of heat fluxes using Extreme Value Theory

THU.
June 29
11:30

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OYSA

In a semi-enclosed sea basin, like in the Mediterranean, determining the heat flux components of the heat budget is crucial for a better understanding of the water budget and the regional climate. Due to its relatively small sea basin and the existence of many islands, it's always complex and uncertain to settle with an accurate net heat balance. The variation in the net heat budget is referred to as a heat budget "closure" problem, which has been referred by many authors for the Mediterranean Sea. The value of net heat flux under this closure hypothesis should be negative, but there is a considerable range of variation for net heat budget in published literature. In that context, we have computed the heat fluxes in the Mediterranean Sea using a higher resolution atmospheric model analysis dataset (ECMWF) along with heat fluxes using a lower resolution dataset (ERA5) to compare. The computation of heat fluxes using a high-resolution ECMWF analysis dataset is a newer one for the Mediterranean Sea. The long-term climatology of heat flux components (between ECMWF & ERA5) has shown a close agreement except a variation is observed in the Long Wave (LW) flux which matches a similar finding from Marullo et al. (2020). In addition to the net heat budget, this study has analysed the probability distributions of air-sea heat fluxes aiming for a newer statistical aspect relating to uncertainty in ocean forecast. We have investigated the probability distributions of air-sea fluxes using the Extreme Value Analysis theory, while we have observed asymmetrical differences and long tails under the qualitative validation approach for moments of model data and theoretical PDF. The statistical analysis of air-sea fluxes is not a usual one for the Mediterranean Sea but an important one to obtain the statistical inference of air-sea flux distributions concerning the probable uncertainty that arises in the ocean forecasts.

Venezia Acqua Alta Events

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THU. June 29 11:50

OYSA

The North Adriatic coast is known to be exposed to acqua alta events, namely events of exceptional high of sea water level. In particular, during two extreme events occurred in November 2019 and November 2022, sea level peaks reaching more than 150 centimeters outside the Venice Lagoon were measured. These kinds of events have a high damaging potential in terms of severe economical and social consequences, as well as impacts, for example, on the cultural heritage. Therefore, the prediction of such events is of paramount importance, especially in a changing climate characterized by sea level rise and by the increase in frequency and severity of extreme events, such as storm surges. The ability of forecasting acqua alta events in advance relies on the accuracy of the numerical model used, but it also requires accurate boundary conditions that contain the signals that are involved in the evolution of these phenomena. In particular, the pressure pattern over the Tyrrhenian Sea, in addition to the local pressure and wind conditions over the Adriatic Sea, are shown to cover a key role in Adriatic acqua alta events. Therefore, a high resolution modeling system that covers the whole Mediterranean Sea is particularly suited for the analysis and forecasts of these events. The Mediterranean Analysis and Forecasting Physical System (MedFS), operational in the framework of the Copernicus Marine Service, has shown good skills in predicting the event occurred in November 2022 since three days in advance while, the event of November 2019, was correctly predicted but the maximum high of the peak appears underestimated. The aim of this work is to assess, by means of MedFS numerical experiments, the contribution of single processes playing a role in acqua alta events in order to better understand the underlying mechanisms, and thus to improve the predictability of such events. Despite its relevance, a comprehensive analysis of these extreme events that takes into account barotropic and baroclinic mechanisms, as well as the interaction of the sea with the atmosphere is, in our knowledge, still missing in literature. The acqua alta event is in fact due to the combination of a storm surge, due to a specific pattern of low pressures at basin level, high local wind speed and to an abrupt change of wind direction to Scirocco, with a high tide. Seiches, namely specific modes of the Adriatic Sea, can contribute to the sea level peak. Furthermore, local resonance and trapped waves are good candidates to be analyzed as contributors, as well as internal tides and other baroclinic processes. The starting point of this work is the evaluation of the forecast skills of the operational system for what concerns both the acqua alta events. Then, several analysis and forecasting experiments characterized by different model settings and atmospheric forcing, are inter-compared and validated with respect to observed values. In particular, half of the experiments is carried out including the tidal potential in the dynamic equations to explicitly account for the tides as well as tides entering from the open boundary in the Atlantic Ocean, while in the rest of the experiments the sea level tidal signal is added from the TPXO9 global barotropic model. The comparison among these two classes of experiments allows to identify the tidal contribution to the whole phenomena and to identify the relevance of the non-linear effects of tides. A filter was developed to extract the seiches contribution in the area and assess their impact on the sea level increase. Atmospheric forcing fields with different spatial and temporal resolutions are used with the intent of evaluating their contribution in the evolution of these extreme events. The validation of the modeling results is carried out in terms of sea level field compared to tide gauge observations.

Subsurface dispersion of radioactive materials from Fukushima Dai-ichi Nuclear Power Plant by Mode Water

THU.
June 29
12:10

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OYSA

The Fukushima Daiichi Nuclear Power Plant (FDNPP) accident on March 11, 2011 resulted in the release of immense amounts of radioactive materials into the ocean. Due to the spatiotemporal limitations of observations, the dispersion of radioactive materials in the subsurface has not yet been clarified. Thus, herein, a tracer experiment was implemented using a three-dimensional numerical model to estimate the dispersion path of 137Cs released directly from the FDNPP and its travel time in the subsurface of the North Pacific Ocean from 2011 to 2020. The results show that the subsurface 137Cs spreads by two mode waters, namely, Sub-Tropical Mode Water (STMW) and Central Mode Water (CMW). Subsurface 137Cs primarily spreads clockwise in the sub-tropical region, while a portion driven by STMW is dispersed southward. The clockwise dispersion path of 137Cs released into the ocean by STMW is relatively shallower and more inward than that by CMW. The model described in this study can be used for estimating the water path and travel time of tritium water planned to be discharged from Fukushima.

The support of the CMEMS' Downstream operational services for the water quality monitoring-modeling-management in western Black Sea coastal areas

POSTER

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The iSWIM system was funded by the Copernicus Marine Environment Monitoring Service to promote third-party services related to the development and maintenance of an operational system already functional in March 2016 within the National Institute for Marine Research and Development (NIMRD) for the Romanian marine and coastal areas. More than the purpose of the iSWIM project, the modeling system was developed toward modeling and prediction of extreme marine events at regional level, the encompassed activities being grounded on the capabilities of an working operational system, but also on the synergic integration of several products afferent to the BS region, including EO data and BS MFC services. Several modeling-based results of the iSWIM system, to which additional features have been added, were implemented to support several specific coastal protections and maritime ports extension projects, thus contributing to the increase of the data and information fund necessary for the assessment and modeling of the marine hazards' impacts on the western Black Sea coast.

Atlantic Oceanic currents influence Sargassum movement in the Caribbean: a review of early warning systems for detection and forecasting

POSTER

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The proliferation of Sargassum seaweed in the Caribbean has emerged as a significant environmental and economic challenge for more than a decade. Pelagic Sargassum is a brown macroalgae that floats, sometimes in very large patches that never become anchored to the seafloor. Most of the Sargassum in the Atlantic region originates in the Sargasso Sea located in the northern Atlantic. In recent years both natural and anthropogenic factors including; nutrient runoff and climate change have contributed to the production of massive blooms of Sargassum. Currents in the Atlantic Ocean help to transport this ocean flora to the coastal regions and communities within the Caribbean region. These blooms can have severe consequences, including coral reef degradation, loss of biodiversity, impacts on tourism, disruption of fishing and negative impacts on other marine and coastal life. The movement of Sargassum is greatly influenced by the Atlantic Ocean currents, particularly the North Equatorial Current and the Gulf Stream. These currents transport the seaweed into the Caribbean region leading to the accumulation of large quantities along the coastlines. Remote sensing technology involving the use of satellite imaging systems has been an integral tool for detection, monitoring and forecasting sargassum. Several early warning mechanisms have been developed to assist with detection and forecasting of Sargassum movements in order to plan for and mitigate its buildup and impacts. As satellite remote sensing technologies advance so to does the availability and quality of image data for use in early warning mechanisms. A brief review and discussion of some of these mechanisms is presented.

An extreme warm event of the Yellow Sea Cold Water Mass in the summer of 2007 and its causes

THU.
June 29
09:00

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A high-resolution numerical model based on the Regional Ocean Modeling System (ROMS) was used to simulate the Yellow Sea Cold Water Mass (YSCWM) and revealed an extreme warm event of the YSCWM in the summer of 2007. This event was also captured by in situ observations. In August 2007, the average temperature of the YSCWM was above 1°C higher than its climatological mean. The unusually-high temperature anomaly of the YSCWM could trace back to the winter 2006-07. Heat budget of the Yellow Sea deep water (YSDW) below 50 m depth, indicated that vertical mixing, rather than advection, in the winter 2006-07 played a crucial role in the generation of the warm event. With the seasonal thermocline disappearing in the winter 2006-07, a weak vertical mixing effect due to weak wind speeds and high heat content in the Yellow Sea upper water (YSUW) above the YSDW, together with strong advection effect, caused the YSDW to become quite warmer than its climatological mean. After that, the seasonal thermocline above the YSDW formed again and the warm YSDW persisted until the summer of 2007, resulting in the extreme warm event of the YSCWM.

TOPIC 6:

Coupled Physical-Biogeochemical Ocean Models

New model framework NEMO-ECOSMO-E2E and its application for holistic assessment of ecosystem dynamic of the North and Baltic Seas

WED. June 28 17:20

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OYSA

With the increasing anthropogenic pressures on marine systems in the North and Baltic Seas, as well as ongoing climate change, it is essential to develop effective management measures based on a holistic assessment of these systems. To this end, the CoastalFutures project (Scenarios to promote sustainable futures of contested marine areas) aims to develop novel integrated modeling approaches to support the assessment of climate change impacts, as well as usage and protection measures. In this work, we present the recent development and implementation of a novel cross-scale end-to-end model system (NEMO-ECOSMO-E2E) for the North Sea and the Baltic Sea. This aims to evaluate the impacts of climate change and anthropogenic uses (such as offshore wind farms and fisheries) on coastal marine ecosystems, as well as test different management measures. The results focus on seasonal and interannual validation against observational data for primary and secondary production, as well as nutrient concentrations. The coming multiple scenarios in the CoastalFutures project will also be discussed. The presented end-to-end modeling framework can simulate and predict changes in the state of the marine ecosystem in response to different drivers and management scenarios, with the overall aim of supporting the decision-making process.

A numerical study on Natural and Anthropogenic effects on Primary Production in Gwanyang Bay, Korea

POSTER

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OYSA

The environment of Gwanyang Bay in Korea has been affected by natural and anthropogenic influences that impact primary production. However, identifying the leading cause of environmental changes is challenging due to the complexity of these effects. The bays environment is greatly affected by natural variations in river discharge. Anthropogenic factors such as industrial development, dam construction, and sewage treatment plant construction have significantly altered the bays environment over the past few decades. Long-term observations show a marked reduction in chlorophyll concentration in February and August since 2016. Previous studies have demonstrated that changes in light, temperature, nutrients, and dominant species can all affect the biomass of phytoplankton, which is vital for the bays primary production. Turbidity and water temperature changes may also impact phytoplankton photosynthesis. This study aims to improve our understanding of the long-term effects of natural and anthropogenic factors on primary production in Gwanyang Bay. Using the ROMS-Fennel model, the study intends to assess the impacts of these factors on primary production and quantify the contributions of natural variability and human-induced environmental changes.

Fishing effects on the biomass distribution in the North Sea and Baltic Sea ecosystem

WED. June 28 16:20

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Fisheries is, and has been for a long time, an integrated part of the North Sea and Baltic Sea ecosystem. In coupled physical-biogeochemical marine models however, the effect of fisheries on the ecosystem is hardly ever considered. One of the reasons is that most models are truncated at the zooplankton level, which would only be indirectly affected by the fishing pressure. Here, the extended marine ecosystem model ECOSMO-E2E, which includes fish as a functional group, is utilized to explore the effects of fishing pressure on the model's representation of higher trophic level production and the biomass distribution among the represented food web components. Therefore, we employ the model in a 2km-resolution setup for a 30 years simulation period for i) a reference simulation without fishing and ii) a set of sensitivity experiments to explore the effects of fishing. Excess mortality caused by fishing pressure is implemented as an additional external forcing, which is compiled from spatiotemporally varying vessel activity (GlobalFishingWatch) as well as data on historical landings and fishing efficiency (ICES).

The spatial range of mercury concentration in a river plume – modelling approach

POSTER

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Mercury is considered to be one of the most dangerous pollutants due to its specific physical and chemical properties combined with high toxicity and marine environments are particularly sensitive to contamination with this element. In the case of Baltic Sea and especially its coastal zone river run-off is the main source of mercury in the sea, for example in 2006 according to the HELCOM commission report 76 of the total mercury load came from rivers and direct waterborne discharges. Therefore models which allow for calculating the spread of mercury introduced by the rivers would be a valuable tool in assessing the magnitude of contamination and its environmental impact. At present numerous approaches to such modelling exist, some are quite simple while others being more sophisticated. It is important to notice that when mercury is considered, many processes should be included, e.g. sorption/desorption on suspended particulate matter, particle settling/sediment resuspension, volatilization, methylation and others, which makes modelling quite a difficult and challenging task.The aim of the numerical experiments presented in this paper is to determine the benchmark plumes of mercury flowing into the Gulf of Gdańsk through river mouths. In-situ data on mercury concentration in rivers are used as input for modelling.The results will be used in further work on the model of mercury flow in the Gulf of Gdańsk to a comprehensive model performance evaluation.

Deriving pre-eutrophic conditions from an ensemble model approach for the North-West European Seas

WED.
June 28
16:40

Van Leeuwen, Sonja M.; Lenhart, Hermann*; Prins, Theo C.; Blauw, Anouk; Desmit, Xavier ; Fernand, Liam; Friedland, Rene; Kerimoglu, Onur; Lacroix, Genevieve; van der Linden, Annelotte ; Lefebvre, Alain; van der Molen, Johan; Plus, Martin; Ruvalcaba Baroni, Itzel; Silva, Tiago; Stegert, Christoph; Troost, Tineke A.;Vilmin, Lauriane
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The pre-eutrophic state of marine waters is hard to estimate as historic observational evidence is scarce and untouched conditions virtually non-existing nowadays. Here, we use marine ecosystem models in an weighted ensemble approach to derive pre-eutrophic conditions for Northeast Atlantic marine waters, which can serve as a benchmark for policy purposes. Eight modelling centers from around Europe participated in the ensemble, using the same inputs and boundary conditions as much as possible to ensure compatibility. The pre-eutrophic state was defined as around 1900, thus after the start of the industrial revolution but before the invention and wide spread use of artificial fertilizer. Participants simulated the years 2009-2014 with both current and historic nutrient inputs, to ensure differences were solely due to the changes in nutrient inputs between the scenarios. Mean values were reported for eutrophication indicators like winter dissolved inorganic nutrients, (nitrogen, phosphorus), the nitrogen to phosphorus ratio, growing season chlorophyll, near-bed oxygen minimum and net primary production on the level of the OSPAR eutrophication assessment areas. Results show distinctly lower nutrient concentrations and N:P ratio's in coastal areas under pre-eutrophic conditions compared to current conditions, with differences up to 40% (dissolve inorganic phosphorous, chlorophyll) or even 60% (dissolved inorganic nitrogen) in some areas. The weighted average approach reduced model disparities, and delivered pre-eutrophic concentrations in each assessment area. Our results open the possibility to establish reference values for indicators of eutrophication across marine regions.

Alkalinity Enhancement in the North Sea: potential and risks assessed by a regional coupled physical-biogeochemical model

WED.
June 28
17:40

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OYSA

Ocean alkalinity enhancement (OAE), an approach involving adding alkaline substances to seawater to accelerate the ocean's natural carbon sink, has a large potential to reduce the concentration of CO_2 in the atmosphere. However, due to the high complexity of physical and biological processes in coastal areas, it is still not clear the AE potential and possible risks on the ecosystems when implemented on regional scales, e.g. in the North Sea. To address those questions, we set up a regional three-dimensional coupled physical-biological model SCHISM-ECOSMO, encompassing a carbonate chemistry module, to present the local physical-biogeochemical processes as well as the exchange processes across scales and compartments. The model system allows scenario studies to disentangle the efficiency of various forms of coastal AE measures as well as their side effects on the Northwest European Shelf (NWES) system. In three parallel scenarios, the same quota of alkalinity is added into three designated areas, the European coast, the German Exclusive Economic Zone in the coast of the North Sea, and the middle North Sea along with the ship tracks, respectively. In addition, we further investigate the sensitivity of the AE efficiency to the amount of alkalinity by doubling the material added in the European coast. In all the scenarios, the alkalinity is distributed continuously and evenly into the selected areas. Our results indicate that the CO_2 uptake is more sensitive to the amount of added alkalinity than to the deployment sites. The potential effect on the ecosystems due to the change of environmental conditions (e.g. pH) is strongly localized near the deployment sites and is not growing in the long-run but rather shows strong seasonal and interannual variability. This quantitative modelling assessment provides an important yet unprecedented case study for a regional to local Carbon Dioxide Removal (CDR) deployment in the proximal coastal ocean of a temperate shelf sea and thereby will serve as a guide for coastal management to reconcile the application of CDR techniques with the maintenance of a good environmental status.

Physical/biogeochemical modelling of the global coast with ICON-coast – the impact of continental runoff

POSTER

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ICON-coast is the coastal version of the newly developed global ocean model ICON-O, which is itself part of the ICON (Icosahedral Non-hydrostatic) earth system modelling framework, developed by the Deutscher Wetterdienst and the Max-Planck-Institute for Meteorology. ICON-coast uses an unstructured, triangular computational mesh with a regular bisection-type mesh refinement technique to increase the horizontal resolution along the global coast. The global tides are included and crucial shelf-specific processes are added to the pre-installed biogeochemical sub-model (HAMMOC). Furthermore, an interface to the FABM 1.0 framework was implemented, which enables a coupling with the biogeochemical model ECOSMO. We present first ICON-coast/ECOSMO experiments in order to investigate the impact of the continental runoff and its related eutrophication on the global coastal ecosystem.

Comparison of the Performance of a Simple Fetch-Based Wave Model with SWAVE in FVCOM in the Wadden Sea of the North Sea for the Use in Long-Term Biogeochemical Integrations

POSTER

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OYSA

In order to accurately model biogeochemical processes, especially primary production, the prevailing light condition within the water column is very important. In coastal waters, suspended particles can have a large impact on the light field, which itself can be influenced by wave dynamics. Therefore, using a proper wave model is essential to simulate these processes in the ocean and coastal waters.Using a simple wave model, such as a simple fetch-based parameterization, could be very efficient in long-term simulations and climate-relevant time periods to capture a proper light field and particle resuspension that are necessary to predict phytoplankton dynamics. However, they are limited in their ability to model all wave phenomena, such as wave refraction and non-linear wave-wave interactions (e.g. quadruplet and triad interaction), which could be important, especially in shallow coastal waters. Therefore, it is crucial to evaluate the performance of simple wave models against more sophisticated models, such as third-generation surface-gravity wave models, and measurements in coastal waters.To achieve this goal, a simple fetch-based wave model is implemented into the Finite Volume Community Ocean Model (FVCOM) on an unstructured grid to simulate the North Sea region with a special focus on the Wadden Sea. A comparison of the waves hydrodynamic characteristics obtained from the simple wave model against those obtained from FVCOM-SWAVE, which is an incorporated version of the third-generation wave model Simulating Waves Nearshore (SWAN) in the FVCOM model, will be presented.

Modelling the impact of Seagrass on coastal Morphology in a tidal basin

POSTER

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OYSA

In this study we are looking at the long term (decadal) feedback between seagrass growth and sediment dynamics in a coastal embayment representative for the Wadden Sea. The aim of the study is to quantify the changes that seagrass has on the morphology and vice versa. Seagrass influences the currents, which modify the sediment transport, which in turn impacts the light attenuation and therefore the seagrass growth. We are simulating the dynamic feedback using a 3D modelling system (SCHISM) to analyze the impact different factors such as the temperature or seagrass parameters can have on the system.

Parameterisation toolbox for physical-biogeochemical model in FABM

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WED. June 28 15:00

OYSA

Mathematical models are widely used to understand marine ecosystems. The performance of these models depends heavily on the accuracy of their parameters. However, there are often insufficient measurements to define the values of the parameters. Traditionally, a Trial-and-Error approach has been used to vary model parameter values to find those that reproduce observations well. However, this approach is time-consuming and therefore not applicable to ecosystem models of increasing complexity. To address this issue, this talk presents a parameterisation toolbox based on a Particle Swarm Optimizer, that can thoroughly explore parameter spaces to find all possible parameter values that equally reproduce observations well. The toolbox was implemented on a 1D physical-biogeochemical model (GOTM-ECOSMO) and resulted in parameter sets, albeit contrasting, that remarkably capture the nutrient cycle of the Sylt and Helgoland Roads. The potential application of the toolbox to 3D physical-biogeochemical models will also be discussed.

Improvement of a 3d ecosystem model in the Wadden Sea via a satellite driven light climate

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WED. June 28 14:50

OYSA

The complex interaction of hydrodynamics and biogeochemical processes in the Wadden Sea make this region extremely challenging for ecosystem models. The representation of the light climate is one of the key problems to tackle, as it is directly linked, through photosynthesis, to primary production, planktonic biomass and chlorophyll concentration. Because the Wadden Sea is typically richer in nutrients and more turbid than the outer North Sea, light limitation plays a more important role there. By applying satellite-derived sediment-specific attenuation, which was corrected for near-shore biases, we present a major improvement to a three-dimensional ecosystem model. This provides a more realistic light representation that is both seasonal and horizontally variant. A model with this configuration was compared to a base model with uniform attenuation, representative of a Jerlov-type III. Both dissolved inorganic nitrogen (DIN) and phosphorus (DIP) saw increases of more than 100 over the base run throughout much of the Wadden Sea. Around the island of Sylt, DIN increased by over 400, which was caused entirely by the increased light limitation. At the same time, the winter nutrient increases are not linearly linked to decreases in chlorophyll. While chlorophyll saw decreases in the very turbid, but nutrient rich estuaries, levels remained the same almost anywhere else, or even increased in the North Frisian Wadden Sea, showing that the implication of linearity between nutrient and chlorophyll levels is a false one. Such changes in nutrient and chlorophyll levels may have an impact on water quality assessment in the context of eutrophication studies and management – a field of research in which the model is applied.

Bottom-up effects of bottom trawling on the North Sea ecosystem

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WED. June 28 15:30

OYSA

Bottom trawling has a direct impact on biogeochemical cycling and benthic-pelagic coupling. Despite extensive trawling activities in many shelf seas, the effects on benthic-pelagic exchanges is often not considered in marine ecosystem simulations. In this study, in order to gauge the effects of bottom trawling on North Sea ecosystem productivity, two model simulations were carried out for the period 2000-2005 using the 3D, fully coupled ecosystem model SCHISM-ECOSMO, which allows for coupled simulation of the benthic and pelagic ecosystem. The first simulation includes only natural resuspension while the second experiment also considers a parametrization for bottom trawling induced resuspension. Daily forcing for bottom trawling resuspension rates was generated based on available data of fishing activity including the position, size and engine power of individual vessels, in combination with estimated resuspension rates of various fishing gears in different types of sediment. The results of these simulations were then analyzed with regard to the importance of bottom trawling for the pelagic primary production of the North Sea ecosystem. In addition, we analyzed trawling-induced changes in bottom water oxygen and sedimentary carbon, phosphorus and nitrogen pools.

Transport and cycling of DOC in the river-estuary-ocean continuum: a modeling perspective

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WED. June 28 17:00

OYSA

Dissolved organic carbon (DOC) plays an important role in costal marine ecosystem. Transport and cycling of DOC are most active in estuaries, which are affected by a variety of physical and biogeochemical processes including photo-oxidation, phytoplankton photosynthesis, salinity-induced flocculation, and microbial decomposition. However, most of existing modeling studies do not explicitly represent the transformation processes of DOC and its driving factors throughout the river-estuary-ocean continuum.Taking the Changjiang Estuary and adjacent shelf sea as a case study area, this study combines field observation and physics-biogeochemistry model in order to derive a more complete picture of the DOC transport and cycling dynamics along the river-estuary-ocean continuum. The unstructured grid, Finite-Volume Coastal Ocean Model (FVCOM), coupled with the European regional seas ecosystem model (ERSEM), is applied to simulate the DOC cycling in the study area. DOC is divided into two components, namely terrigenous DOC and marine DOC. Dynamics of terrigenous DOC is mainly affected by photo-oxidation, flocculation and microbial decomposition consumption, whilst cycling of marine DOC is mainly controlled by the processes of microbial decomposition, and biological cycling of zooplankton and phytoplankton;According to observation data over the years, elevated concentrations of DOC exist in the inner and proximal regions of the river mouth. Based on a satisfactory validation of the model results that show consistency with observation, the study area is divided into four sub-regions, namely the river channel, the estuary, the river plume and the open shelf regions, to explore the transport and cycling of DOC in detail. Results indicate that the DOC in the offshore area shows significant seasonal variations, with maximum concentration around August and minimum concentration in February. Analysis of the fluxes and budget of terrestrial and marine components in the sub-regions shows that a decrease of the terrestrial DOC budget from the river channel to the open shelf is mainly due to a depletion caused by biogeochemical processes. DOC exported to the open ocean mainly originates from marine DOC. Overall, terrigenous DOC is the main source inside the river mouth, while marine DOC is the main source outside the river mouth.

Effects of the upper ocean turbulence on particles sinking in the ocean

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WED.
June 28
14:30

Sinking particles in the ocean play a key role in transporting carbon into the deep ocean (biological pump). The particles sink due to its own gravity, but fluid motions can accelerate and/or decelerate their sinking speed. Some previous studies (e.g., Maxey 1987) show that isotropic turbulence does not have net effects on the averaged sinking velocity of inertia-less particles. But some other studies suggest that the upper ocean turbulence helps trapping the inertia-less particles in the mixed layer in the ocean. Here we performed numerical experiments of upper ocean turbulence and inertial-less particle motions in the turbulence to investigate the net effects of turbulence on the averaged sinking speed of the particles. Our simulations show that the turbulence reduces the averaged sinking velocity if the particles sinking speed in the rest fluid is close to the turbulent velocity scale and if the particles start to sink within the mixing layer (not from the ocean surface).

TOPIC 7:

Simulation of Internal Waves, Tides, Turbulence and Mixing

Anthropogenic turbulence from offshore wind turbine model suggests increase in North Sea primary productivity

WED. June 28 12:00

Boatwright, Victoria*; Carpenter, Jeff; Suzuki, Nobuhiro; van Beusekom, Justus; Lemmen, Carsten; Wirtz, Kai; Sanders, Tina; Daehnke, Kirstin; Daewel, Ute; Floeter, Jens
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OYSA

The rapid increase in offshore wind farm (OWF) structures in the North Sea has precipitated a need for estimates of local ecosystem impacts and to identify the mechanisms of such impacts. The turbulent wakes generated by tidal currents through OWF foundation structures have been shown to reduce stratification and enhance mixing. As seasonal patterns of primary productivity in the North Sea are strongly influenced by summer stratification, the effects of the OWF-structure-induced mixing may have a significant impact on regional biogeochemistry. Using a high-resolution, turbulence-resolving model and in-situ nutrient measurements, we provide estimates of OWF-structure-induced nutrient fluxes and local changes in primary production via an idealized 1-dimensional analysis in the water column. Based on the turbulent diffusivity obtained from Large Eddy Simulations (LES) of OWF-structure-induced turbulence, we compute the flux of nutrients across the pycnocline base from the nutrient-rich, bottom mixed layer into the light-rich, upper layer for various ambient stratification conditions and observed nutrient distributions along the water column. Primary productivity estimates are derived from the additional input of nutrients to more light-abundant layers, using realistic parameters for nutrient and light affinity in the North Sea ecosystem. We perform sensitivity analyses, comparing the relative impact of the ambient degree of stratification, nutrient distribution, and light conditions, and we identify a conservative upper bound for the primary productivity contribution due to the turbulent wakes of a typical OWF foundation structure. Our results suggest significant contributions to seasonal primary productivity from the anthropogenic turbulence injected across the water column, particularly into the pycnocline.

Biglobal instability analysis for the current-undercurrent system in the Western North Pacific

WED. June 28 11:00

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OYSA

In this work, baroclinic instability in a current-undercurrent system is analyzed using the biglobal instability analysis (BIA). Idealized analytical flows are considered first, and the flow parameters are estimated from the Western North Pacific circulation. BIA can deal with the basic flow of continuously nonuniform vertical shear and strong horizontal variation within the framework of the Boussinesq equation to account for non-geostrophic effects. Different types of unstable modes are identified, and their connections to ageostrophic motions are revealed. Afterward, flows extracted from high-resolution regional oceanic modeling systems are adopted for BIA. Special focus is paid to the baroclinic modes affecting the Kuroshio and Luzon Undercurrent (LUC) system. This work advances our understanding of the instability and vertical mixing process in current-undercurrent systems, and thus helps explain the dynamics and formation of LUC.

Influence of Langmuir Turbulence on the Surface Mixed Layer Depth under Surface Heating

WED.
June 28
11:40

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OYSA

Ocean and coupled general circulation models $(O/CGCMs)$ have shallow bias in the simulated mixed layer depth (MLD) in the Southern Ocean (e.g., Belcher et al. 2012). This bias is especially large in summer when the sea surface is heated. Several previous studies suggest that turbulence due to Langmuir circulation (referred to as Langmuir turbulence), whose effects on the simulated MLD were not represented by the $O/CGCMs$ at that time, intensifies the surface mixing to the make the actual MLD greater in the Southern Ocean. Based on this suggestion, efforts have been made to develop the mixing parameterization schemes for the Langmuir turbulence (LT) effects, and OGCMs with these schemes reproduce greater MLD in the Southern Ocean than MLD without the schemes (e.g., Li et al. 2016). Some previous studies (e.g., Yoshikawa 2015, Noh and Choi 2018), on the other hand, reported that the observed or simulated MLD under the surface heating is fairly well scaled with $D_w = aU_*/f(b + B/fU_*^2)$, where U_* is the friction velocity, B is the surface buoyancy flux, f is the Coriolis parameter, and a and b are empirical constants. This implies that the LT, whose magnitude is scaled with the Stokes velocity U_S, has less impact on the MLD under the surface heating. Thus, previous studies differ as to whether the LT mixing makes the MLD greater under the surface heating. Contributions of the LT to the mixing layer (ML) deepening in the heating season needs to be quantified. To quantify the LT contribution to the MLD in the heating season, we performed large-eddy-simulations (LESs) of the LT under several sets of U_*, B, f, and U_S. Ratios of the simulated MLD to D_w (the MLD without the LT effects) was evaluated as a measure of the LT contribution, and plotted as a function of the Langmuir number $(La = (U_*/U_S)^{(1/2)})$ and B/fU_*^2 (nondimensionalized buoyancy flux). LESs results show that the LT does contribute to the ML deepening under the surface heating, but its effect is limited to regions of weak heating such as the Southern Ocean. We further made global mapping of the ratio (MLD/D_w) using the U_*, B, f, and U_S of ERA5 reanalysis data. Results show that the LT certainly deepens the ML in the Southern Ocean in spring, but unlike the suggestion from the previous studies, the LT has less impact on the MLD at around 30 degree latitude and North Indian Ocean.

Internal tides in the Mediterranean Sea

WED. June 28 11:20

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OYSA

Internal tides are generated when barotropic tides interact with rough topography. The generated internal tides can propagate away from the generation sites, or be trapped and dissipate near the generation sites. In the Mediterranean Sea, few studies have been carried out on this phenomenon, since it was previously assumed that internal tides in this region mostly dissipate at or close to the generation site, except for in the Gibraltar Strait and Sicily Strait, where internal tides have been detected through moorings and regional numerical studies. However, the propagation of internal tides generated at the straits over long distances remained unclear since past studies focus on regional domains close to the generation sites. Therefore, a comprehensive high-resolution numerical study was carried out in order to understand whether internal tides are more widespread in the Mediterranean Sea than previously thought, and where they are generated, propagated, and dissipated within the basin. Two high-resolution ocean circulation models were used for this work: NEMO (Nucleus for European Modelling of the Ocean) version 3.6, corresponding to the Copernicus Monitoring Environment Marine Service (CMEMS) system, a baroclinic forecasting model for the Mediterranean Sea, and ICON-O, a hydrostatic global ocean model based on primitive equations with Boussinesq approximation, which is used as the ocean component of ICON-ESM. It was found that semidiurnal internal tides are widespread in the Mediterranean Sea, and can propagate for hundreds of kilometres away from their generation sites in both the eastern and western halves of the basin. The first mode, with a wavelength of around 100km, of the M2 internal tide can be resolved in both NEMO and ICON. Energy fluxes were also mapped to determine the propagation of internal tides.

From observations to 1D-models: how can we improve the parametrizations of mixed-layer turbulence?

POSTER

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OYSA

The oceans upper layer is constantly forced by momentum and buoyancy fluxes and their interplay operates to mix and/or stratify the first meters of the water column, suppressing or enhancing the dissipation of turbulent kinetic energy (TKE). Within this mixed layer, turbulence is generated by convection, wind-driven shear, and breaking surface waves, and is greatly influenced by the diurnal cycle of solar heating. At the air-sea interface, incoming solar short-wave radiation (sensible heat flux) acts to stabilize (destabilize) the upper layer. Wind, on the other hand, acts to vertically stir the water column through mechanical mixing, i.e. by transferring momentum from the atmosphere to the ocean. If the wind is not strong enough to trigger mixing, the surface waters immediately stratify and create a very thin, diurnal warm layer (DWL). Above the bottom boundary of the DWL, shear production can be enhanced leading to large dissipation rates; below, a well-mixed region isolated from wind-shear is formed and dissipation decays due to the stabilizing effects of buoyancy forcing. Based on observational data, within the mixed layer turbulence is highly variable and mainly one dimensional, dominated by the diurnal cycle in the absence of strong forcing. Up to now, scalings based on the law of the wall (e.g. similarity scaling) are widely used in ocean models to determine the dissipation of TKE. However, most studies lack the comparison with observations and underestimate dissipation values during daytime, making the reproduction of turbulent measurements an ongoing challenge. We use glider-based observational data from two oceanographic campaigns (spring 2022 and 2023) in the South Atlantic and the one-dimensional General Ocean Turbulence Model (GOTM) to try to improve existing turbulence parametrizations associated with diurnal warm layers.

Longitudinal scour-bar pattern in large convergent estuaries on low-lying coastal plains

WED.
June 28
12:20

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OYSA

A seaward decrease-increase-decrease trend in the longitudinal bed level, defined as scour-bar pattern, is observed in several large estuaries on low-lying coastal plains such as the Amazon, Yangtze and Fly. Why this pattern forms has not yet been well explained. The mechanism for the formation of this pattern is explored using a one-dimensional morphodynamic model, with varied geometry, fluvial water discharge, sediment flux and tide. Results show that for those estuaries with bed slopes in the order of 10^{-5} and sediment concentration in the order of 0.1 $kg\ m^3$, bars are likely to occur for channels with relatively weak convergence and wide mouth, while scours are nearly ubiquitous. Scours are classified as fluvial and tidal based on the relative strength of river and tide, which can be distinguished by bed slope and water depth. A balance between river and tide can lead to no scours or bars. Sediment reduction and sea level rise enhances the relative strength of tide, and transition of a fluvial scour to a tidal scour may occur.

TOPIC 8:

Numerical Techniques and Approaches in Ocean Modeling

Quick Forecast of Coastal Hazards using Reciprocal Green's Functions

THU. June 29 16:30

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Pre-calculated reciprocal Green's functions are accurate and efficient. They have been applied in forecasting various coastal hazards from the sea such as seismic tsunamis, submarine landslide tsunamis and storm surges. In the present study, the application of reciprocal Green's functions is integrated in a systematic way and a generalized formulation is derived for all these three coastal hazards. Because the efficiency of reciprocal Green's functions, various forcing scenarios can be considered instantaneously and an ensemble forecast is feasible. Innovative approaches to hasten the simulation of the detailed inundation induced by these hazards are also suggested.

Comparison of the computational efficiency of z, sigma, and isopycnal vertical coordinates to simulate nonlinear and nonhydrostatic internal gravity wave

THU. June 29 16:50

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Nonlinear internal gravity waves (NLIW) evolve primarily from internal tides generated at ocean ridges or shelf breaks and are important for transport and mixing in shallow coastal waters. Numerical modeling of such NLIW is challenging because of the need to compute the computationally costly nonhydrostatic pressure which can incur an order of magnitude increase in the computational cost. Additionally, to ensure that the numerical dispersion arising from errors in discretizing the hydrostatic pressure gradient is smaller than the physical dispersion arising from the nonhydrostatic pressure gradient, the horizontal grid spacing must be smaller than the depth of the upper mixed layer. In shallow coastal waters, this implies a grid resolution of 10s to 100s of meters and makes simulation of NLIW nearly intractable in domains spanning 100s of km. To help alleviate this computational cost, in this presentation I compare the accuracy and efficiency of simulating NLIWs with z, sigma, and isopycnal vertical coordinate systems. The accuracy of each vertical coordinate system is quantified by deriving the equivalent discrete normal modes equation which can then be used to compute the discrete first-mode eigenfunction and associated internal wave speed. These can then be used to estimate the accuracy with which the coordinate system represents the leading-order internal solitary wave dynamics. Because they can simulate such dynamics with one order of magnitude fewer vertical layers than z or sigma coordinates, isopycnal coordinates are the natural choice to simulate multiscale NLIW problems. I will demonstrate this result by showing that just 10 isopycnal layers produce simulations of NLIW shoaling in the South China Sea with the same level of accuracy as simulations with 100 z or sigma coordinate levels.

Spurious numerical overturning circulation in ocean models

THU. June 29 17:10

Klingbeil, Knut*; Henell, Erika; Gräwe, Ulf; Burchard, Hans
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I will present a technique for separating the overturning circulation in ocean models into physical and spurious numerical contributions. As a prerequisite I will derive an analytical relation between mixing and local dia-surface volume transports. The theory is based on a local Water Mass Transformation framework. Mixing is defined by the destruction term of squared tracer, which is equivalent to the decay of tracer variance. For demonstration purposes I will show maps of the simulated diahaline mixing and the associated diahaline exchange velocity in the Baltic Sea. In addition, our numerical model offers to separately diagnose the physical mixing due to turbulence parameterizations and the spurious mixing due to discrete transport schemes. This enables us to also quantify the amount of spuriously induced overturning circulation. The planned application to diapycnal exchange and the global overturing circulation will be outlined.

On several theoretical issues guiding modeling the oceans

POSTER

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Several issues on modeling the oceans are discussed and clarified using differencing schemes. They include energy conservation in time-space discretization scheme; numerical/computational viscosity derived from truncation error in 3-time stepping (leapfrog) scheme vs truncation error in 2-time stepping scheme; and truncation error in terms of accuracy vs amplification error in terms of stability. 1) A pure advection equation is used to examine the stability with no friction/viscosity with 4 combinations of time-space discretized schemes: first-order in both time and space, first-order in time and 2nd-order (leapfrog) in space, 2nd-order in both time and space, and 2nd-order in time and 1st-order in space. Results show that 2nd-order (leapfrog/centered) scheme in time is the key to conserve energy. 2) It is shown that the 1st-order truncation error in the 1st-order, Euler forward scheme is associated with computational bi-harmonic viscosity, which is physically meaningful; thus, simply discarding the truncation error leads to no energy conservation. However, 2nd-order truncation error in the leapfrog scheme has no physical meaning and thus is safely discarded. 3) Truncation error measures the accuracy of a discretized scheme, while amplification error gauges whether the discretized scheme converges to the true solution, i.e., neutral stability or diverges from the true solution (neutral stability, i.e. The amplification factor or eigenvalue of the discretized scheme equals to one). For example, although 2nd-stage Euler forward predictor-corrector (2-time stepping) schemes have 2nd-order amplification error (stable), the truncation error is still of 1st-order accuracy.

TOPIC 9:

Artificial Intelligence approaches applied to Ocean Data Analysis and Modelling

Machine learning approach applied to short-term forecasting of waves in the offshore zone of the marginal sea

THU. June 29 14:50

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The application of machine learning algorithms for predicting marine environment parameters faces challenges in building large training datasets and selecting optimal methods and topologies. Many studies utilize data from traditional physics-based hydrodynamics models to train machine learning models. However, these forecasts often have similar inaccuracies as physical models, due to their underlying assumptions. To capture emergent features of the marine environment, resulting from its complexity and not described by hydrodynamic models, in-situ measurement data can be used for training data-based models (e.g. ANNs). The challenge in applying the data driven approach in operational setting lies in the limited amount of available measurement data.This study aims to assess the applicability of a relatively small set of measurement data for short-term point wave prediction in the offshore marginal Baltic Sea. Datasets consist of measurements from a waverider buoy (e.g., significant wave height, maximum wave height, wave spectrum peak direction, wave spectrum peak period, maximum wave period, and surface water temperature) and an anemometer (wind speed, gust speed, and wind direction). Autoregressive models (ARIMA and naïve) and multivariable models (RNN and LSTM) are applied in order to predict significant wave height at point of measurements with varying horizons.The results suggest that artificial neural networks (ANNs), particularly recurrent neural networks (RNNs) and long short-term memory networks (LSTMs), are viable methods for operational forecasting. These networks can effectively predict significant wave height (SWH) with a horizon of up to 12 hours. The paper shows that described methods are efficient for operational forecasting of wave height at a given point with a horizon of up to 12 hours.

Prediction of the western boundary current variability in the Northwestern Atlantic using a high resolution ocean reanalysis and a data-driven deep learning architecture

THU. June 29 14:30

He, Ruoying*
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Many meteorological and oceanographic processes throughout the northwestern Atlantic such as storm tracks and shelf water transport are dominated by the positions and dynamics of the western boundary current (WBC, namely the Loop Current-Gulf Stream system). Due to the high nonlinearity associated with this WBC current system, predicting the meanders and frontal positions of the WBC has been a long-standing scientific challenge. Based on high resolution ocean modeling and ensemble data assimilation, we have developed a 30-year ocean reanalysis (1993-2022) for the Northwest Atlantic ocean. This new daily, 4-km resolution dataset allows us to subsequently develop a highly efficient deep-learning approach that can generate long-term predictions of the eddy shedding and meanders of the WBC over several months timescales. Model constructions, validations and case studies of the meso-scale WBC dynamics and prediction will be discussed in this presentation.

Underlying models for the European Digital Twin Ocean (EDITO Model Lab)

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THU.
June 29
15:10

EDITO-Model Lab will prepare the next generation of ocean models, complementary to the Copernicus Marine Service to be integrated into the EU public infrastructure of the European Digital Twin Ocean (EDITO) that will ensure access to required input and validation data (from EMODnet, EuroGOOS, ECMWF, Copernicus Services and Sentinels satellite observations) and to high-performance and distributed computing facilities (from EuroHPC for HPC and other cloud computing resources) and that will be consolidated under developments of Destination Earth (DestinE). The objective is to make ocean knowledge available to citizens, entrepreneurs, policymakers, decision-makers and scientific experts alike, thus enabling them to become partners in knowledge generation, explore desirable futures and develop ocean management scenarios (and assemble their own twins), with the overarching goal of ensuring a safe, healthy and productive ocean. As an interactive and user driven initiative, EDITO-Model Lab will deliver a Virtual Ocean Model Lab (VOML) including (1) a core model suite including global high-resolution models and coastal configurations, (2) downstream user toolkits and (3) a developer's toolkit for a sustainable ocean. The VOML will be an interactive and co-development environment to operate models. EDITO core model suite will be based on modelling and simulation software, artificial intelligence (AI) algorithms and specialised tools to form a new service capacity for accessing, manipulating, analysing and understanding marine information. Intermediate and downstream stakeholders will find digital tools, data and information for 'focus applications' (FA) that refer to the Mission Ocean Lighthouses (MOLs) and the sustainable Blue economy, including 'what-if scenarios' to find solutions to natural and man-induced hazards. EDITO-Model Lab will be delivered in 36 months by a consortium of 14 authoritative partners, covering ocean knowledge, modelling and technological expertise. By bringing ocean knowledge, modeling and technological expertise, Hereon will contribute to the development of the Virtual Ocean Model Lab by providing modeling and simulation software and artificial intelligence (AI) algorithms. Hereon is leading the "what-if scenario" work package. Hereon is involved in all work packages and will co-develop ocean models in regional and coastal scales, combining classical numerical approaches with artificial intelligence to develop hybrid modeling tools that will be integrated into the EDITO core model suite. This Digital Twin of Ocean will combine next generation ocean modelling, Artificial Intelligence and High Performance Computing, developing interactivity and transforming the knowledge-sharing paradigm.

Dynamics of the euphotic zone in the Black Sea: The synergy of data from profiling floats, machine learning and numerical modeling

POSTER

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Data from profiling floats in the Black Sea revealed complex temporal and spatial relationships between physical variables and oxygen, chlorophyll and the backscattering coefficient at 700 nm, as well as some limits in understanding the details of biogeochemistry dynamics. To account for different interdependences between physical and biogeochemical properties, a feedforward backpropagation neural network (NN) was used. This NN learns from data recorded by profiling floats and predicts biogeochemical states using physical measurements only. The performance was very high, particularly for oxygen, but it decreased when the NN was applied to older data because the interrelationships between the physical and biogeochemical properties have changed recently. The biogeochemical states reconstructed by the NN using physical data produced by a coupled physical–biogeochemical operational model were better than the biogeochemical outputs of the same coupled model. Therefore, the use of data from profiling floats, physical properties from numerical models and NNs appears to be a powerful approach for reconstructing the 4D dynamics of the euphotic zone. Basin-wide patterns and temporal variabilities in oxygen, backscattering coefficient and chlorophyll were also analyzed. Of particular interest is the reconstruction of short-lived biogeochemical features, particularly in coastal anticyclone areas, which are difficult to observe with available floats at the basin scale.Dynamics of the euphotic zone in the Black Sea: The synergy of data from profiling floats, machine learning and numerical modeling.

TOPIC 10:

Regional systems and Land-Ocean-Continuum (LOC): modelling, coupling, and synergy with observations and applications

Mitigation of oxygen decline in fjords by freshwater injection

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POSTER

The exchange of water masses between deep fjords and the open ocean is commonly constrained by a topo¬graphical barrier called the sill. While fjord water above the sill depth communicates relatively freely with the open ocean, water below the sill depth is caught inside the fjord basin. This basin water may remain stagnant in deep fjords for many successive years. During these periods, the biological consumption of dissolved oxygen is larger than the supply of new oxygen, and the fjord basin might experience hypoxia and even anoxia. Such deoxygenation is natural but can be amplified by warming and human activities involving supplies of organic matter and other nutrients. Here, we use a general circulation model to explore how deoxygenation can be mitigated by injecting fresh water into the fjord basin. The freshwater injection causes density reduction of the basin water with subsequent water exchange and oxygenation. Our results suggest that the basin water of Masfjorden, a 480 m deep fjord with a basin volume of 4 x 10^9 m^3 , can avoid deoxygenation with a continuous freshwater injection of 0.05 m^3/s. We conclude that freshwater injection might be an efficient tool to mitigate the deoxygenation of fjord basins.

On-demand ocean modelling for user defined seamless open ocean to estuary scale applications

POSTER

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As available computational resources are expanding, ocean modeling is increasingly focusing on higher resolutions to better resolve coastal features. However, it still remains challenging to create dedicated operational model configurations to resolve all coastal-estuarial areas of interest. Therefore, it eventually requires that a user has a capability to create setup at his interested coastal area with required resolution. This involves three issues: i) to have an open source bathymetry and coastline data with sufficient resolution for coastal applications, ii) to ensure proper integrity of narrow water channels and dam-like land features in the model bathymetry; iii) to match grid depth of highly resolved domain grid with the corresponding coarse grid of the nested domain. This study focuses on the possibility and quality of automatized generation of oceanographic modelling setups, such as land-sea mask, river inflow points, and water depth grid file for user defined geographic areas and resolutions. This is required for building up on-demand modelling tool in Digital Twin Ocean project EDITO MODEL LAB. Focus area in this study is North Sea – Baltic Sea, where there is high demand of high resolution modelling both for properly resolved flows through the straits, and requirement of highly resolved coastal areas such as ports. The used oceanographic circulation model HIROMB BOOS Model (HBM) is one of the coastal models for the Digital Twin Ocean, that enables two way nesting suitable for very high coastal resolutions and seamless transition to the open seas. The baseline data for river locations, coastline and bathymetry used are derived from OpenStreetMap and EmodNet Bathymetry, respectively. Both are open source data. Gridded baseline datasets for river mouth location, land-sea mask and water depth has a resolution of about 37 m or 1/50 of nautical miles with area of North Sea – Baltic Sea. User can select resolutions which are factor of the base resolution. Possibility to add additional high resolution bathymetries of coastal areas, such as ports, is incorporated in model configuration. Proper connection of narrow straits is ensured by a special vector layer of waterways (strait, fjord, large river, estuary, channel, etc.). Lower resolution bathymetries could generate false connections over water bodies separated by a narrow land line (dam, narrow-long island or peninsula, road, narrow land form that separates lagoon, etc.). Therefore, a special vector layer of dams is made to cancel transport between the cells divided by a dam line. In addition, the river inflow points have to move towards the open sea as the resolution decreases that is solved by using the vector layer of waterways. The results of obtained automised sample oceanographic setups are compared with existing non-automized and specially tuned setup versions to improve the quality of automisation scripts.Keywords: on-demand modelling, HBM, seamless modelling

Drivers of increasing coastal CO_2 uptake identified by a global model with seamless integration of coastal marine carbon dynamics

FRI. June 30 09:50

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I will present the first global ocean-biogeochemistry model with a seamless integration of coastal carbon dynamics, ICON-Coast, and provide insights from recent simulations on the drivers of the increasing CO_2 uptake of the coastal ocean. Based on the unstructured triangular grid of the model, we globally apply a mesh refinement in the coastal ocean to better resolve complex circulation features as well as ocean-shelf exchange. Moreover, we incorporate tidal currents including bottom drag effects, and extended the models biogeochemistry component to account for key shelf-specific carbon transformation processes. In this way the model encompasses all coastal areas around the globe within a single, consistent ocean-biogeochemistry model, thus naturally accounting for two-way coupling of ocean-shelf feedback mechanisms at the global scale. Hindcast simulations over the 20th century indicate that the increasing CO_2 uptake of the coastal ocean is 40 driven by the rising pCO_2 in the atmosphere, another 40 by climate-induced changes in the circulation, and 20 by increasing historical nutrient loads from rivers. While river inputs caused a significant boost in organic carbon sequestration by enhanced biological productivity, this mainly induced an adjustment in the resource utilization, from dissolved inorganic carbon delivered by the open ocean towards absorbed CO_2 from the atmosphere. Thus the comparatively weak riverine impact on the CO_2 uptake at the sea surface is mediated by an enhanced advective export of organic carbon, this way further intensifying the carbon enrichment of the open ocean.

Estimation of residence time and identification of hotspots of eutrophication in the Odra estuary

FRI. June 30 10:10

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The Odra lagoon is an extensive shallow water zone at the mouth of the Oder River into the Baltic Sea representing the central geomorphological element of the so-called Odra estuary. The Odra is one of the most important tributaries to the western Baltic Sea and contributes significantly to its nutrient budget. These mass transports depend on the nutrient turnover in the shallow Odra lagoon, which modifies the nutrient concentrations of the river water through its intensive biological production. This modelling study focuses on the physical-biogeochemical dynamics of the Oder Lagoon and the nearby Pomeranian Bay. Particular attention is paid to the residence time in the shallow water areas and the hot spots of primary production and eutrophication. The numerical calculations were performed using the Schism model with a coupled ecological model and particle drifting experiments. Model simulations reproduce the annual cycle of primary production and nutrient update with depletion of inorganic nitrogen during the productive period. The aim of the work is to gain an in-depth understanding of the turnover processes in the Odra estuary that control eutrophication and consequences of eutrophication in the Baltic Sea. State, dynamics and fluxes are investigated both under current conditions and under simple assumptions of projected climate change.

Demonstrating Open Ocean Multi-use – OLAMUR (Offshore Low-trophic Aquaculture in Multi-Use Scenario Realisation)

POSTER

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There is ample evidence that low-trophic aquatic foods could reduce food and nutrition insecurity and malnutrition, while having minimal impact on climate and environment, delivering essential ecosystem services and enabling achieving UN SDGs. For example, mussels, which feed on microalgae, and seaweeds such as kelp can utilise excess nutrients in eutrophic waters and thereby have the potential to reduce negative impact of eutrophication in waters such as the Baltic and North Sea, while producing biomass for food, feed and materials. However, low-trophic aquaculture could put pressure on the limited space available along the coastal waters of the Baltic and North Sea. Similar spatial pressure is also experienced in other sectors, for example shipping, wind farming, and fish farming, but also for nature conservation. To tackle this issue, the OLAMUR project (Offshore Low-trophic Aquaculture in Multi-Use scenario Realisation) proposes the concept of multi-use of marine areas, predominantly in the EEZ. These areas can serve multiple purposes, including energy production, food, and other goods and services. Through a transdisciplinary and holistic approach, OLAMUR will demonstrate and document the possibilities for low-impact co-use of the marine space. A data-based service system will be developed to assist policymakers in making knowledge-based decisions. Additionally, innovative governance and policy arrangements will be devised to achieve a holistic, effective, and sustainable solution for multiple uses. The science-policy-industry-community interface plays a vital role in OLAMUR, facilitating advancements in developing optimal and carbon-neutral use. These topics are embedded in three case study sites in Germany, Denmark and Estonia, where innovative multiple-use concepts are to be set up and operated semi-commercially, and also serve as the basis for data collection for the overall project. This approach enables a significant leap towards long-term sustainable, healthy, and prosperous European marine spaces. Hereon co-leads Work package 4 on Environmental monitoring, forecasting and on physical and environmental impact assessment. It is involved in developing a forecast systems resolving farm impacts, forecast demonstration and validation and involved in activities of the German Bight Pilot. Hereon also contributes to (i) multi-use pilot farms organisation, implementation and operation, for the German Bight Pilot, in development of joint-use scenarios, synergies and safe operating procedures , (ii) service development; and (ii) communication, dissemination and exploitation of the outcome of OLAMUR. This project is funded within the Horizon Europe Mission Restore our Ocean and Waters by 2030.

Scrubber Discharges from Shipping: A Close Link between Observation and Modelling for the Development of Marine Environmental Protection Measures

POSTER

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The use of scrubbers on seagoing ships has become widespread since the introduction of international regulations (MARPOL Annex VI) to reduce sulphur oxide (SOx) emissions in the maritime industry. There are environmental concerns regarding the release of scrubber discharge water as not only SOx but also other pollutants from the exhaust gas such as heavy metals, oil residues and polycyclic aromatic hydrocarbons (PAH) are discharged into the marine environment. To estimate the environmental impacts from scrubber discharges, it is needed a) to determine the chemical composition and ecotoxicity of this effluent, and b) to model the fate of contaminants as well as consider their interaction with the ecosystem.In a first step, a sampling and measurement campaign was conducted on board four ships. The chemical characterisation evidenced that pollutants are found in elevated concentrations in the discharge water. The effluent toxicity ranged from practically non-toxic to extremely toxic and contained persistent and bioaccumulative pollutants that may cause short- and long-term detrimental effects. Further, information about typical discharge's volume rates and behaviour was gained.As a second step, these results are implemented into a three-dimensional model system to estimate the total discharges in the North Sea and Baltic Sea followed by a prediction of the contaminant physical dispersion and biogeochemical effects in the water phase and sea floor. This model system consist of an information chain ranging from data on ship movement to a model of scrubber discharge water and a coupled hydrodynamic-biogeochemical model that enables having a much-needed overview on vulnerable areas and supports the development of protective measures based on different scenarios. These scientific-based results support the implementation of the EU MSFD (descriptor 8 "contaminants").

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