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IX INTERNATIONAL SYMPOSIUM ON MARINE SCIENCES
VALENCIA. JULY 10-12

VIII MEETING OF PHYSICAL OCEANOGRAPHY

VALENCIA, JULY 10-12

Universidad Católica de Valencia San Vicente Mártir

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COASTAL OCEANOGRAPHY

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ROLE OF MIXING ON PHYTOPLANKTON BLOOM INITIATION, MAINTENANCE AND DISSIPATION IN THE GALICIAN RÍAS (REMEDIOS)

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Abstract: Upwelling bays harvest outstanding biological production, which is frequently jeopardized by harmful algae blooms (HAB). The mechanisms responsible for this high productivity and the specific role of Thin Layers of Phytoplankton (TLP) in toxicity events are not completely understood. The REMEDIOS project combined field observations, analysis of time-series monitoring data, and numerical modeling in the Galician Rías: 1) to describe the temporal variability of phytoplankton growth and its connection with turbulent mixing, and 2) to discern the role of TLP in HAB toxicity hotspots. The analysis of a twenty-four years dataset showed that seasonality was the most important component of chlorophyll-a variability (~50%), followed by a shorter-term mode (~30%) and a long-term trend (~20%). Whilst a relationship between turbulence mixing and phytoplankton at seasonal and longer time scales could not be established, our results suggest that mixing could be involved in the formation of short-lived phytoplankton blooms. The chlorophyll-a long-term trend, which mimics the temporal evolution of the winter North Atlantic Oscillation, was negatively correlated with the average duration of upwelling events. Consistently, high-temporal-resolution cruise observations showed that the rapid response of phytoplankton to synoptic wind forcing inside the Rías, three times faster than in the shelf, could explain their higher productivity. The monitoring dataset analysis showed more frequent TLP in Ría de Pontevedra, characterized by longer toxicity events caused by *Dinophysis* species. Numerical simulations and observations indicate that weaker rates of turbulent energy production in Ría de Pontevedra could foster stable conditions, leading to higher TLP and HAB persistence. TLP maintenance may be supported by nutrients flushing via night-time biological mixing due to frenetic activity of spawning fish aggregations.

These results emphasize that understanding short-term variability of physical-biological coupling is crucial for discerning the drivers of phytoplankton production and toxicity of upwelling bays, and their evolution under global change.

Key words: Coastal upwelling, Galician Rías, Thin Layers of Phytoplankton, Harmful Algae Bloom, turbulence

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TOWARDS A BETTER COMPREHENSION OF THE INTERACTION BETWEEN COASTAL BREEZES AND UPPER SYNOPTIC WINDS

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Abstract: Some sensitivity experiments performed with the Weather Research and Forecasting (WRF) model have shown how the vertical structure of the synoptic background wind is a key factor that controls the characteristics of the breezes that form in the lowest layers of coastal areas under conditions of weak to moderate synoptic forcing (Román-Cascón et al., 2022). This issue, also studied through more ideal experiments (e.g., Allouche et al., 2023), motivated the development of the LATMOS-i, the WINDABL, and the WIND4US projects*, all of them including among their objectives the study of the important interaction between coastal breezes and upper winds through different observational and modeling strategies. In this work, we present part of the observational strategy developed at the Gulf of Cádiz, which consisted of 1) the installation of meteorological and (atmospheric) turbulence stations at strategic locations for the long-term monitoring of breezes, as well as; 2) the launching of atmospheric radiosoundings during intensive observation periods characterised by breeze conditions. We also present some first results obtained from the analysis of the data of the meteorological stations and from several radio soundings launched during different breeze events. This allows us to highlight the breeze characteristics during contrasting background winds and different thermodynamic vertical structures of the atmospheric boundary layer.

Key words: coastal breezes, marine boundary layer, atmospheric radiosoundings, model evaluation

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A THEORETICAL POINT OF VIEW OF THE KORTEWEG-DE VRIES EQUATION AND ITS CONNECTION TO THE OCEANOGRAPHY

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Abstract: The Korteweg-de Vries (KdV) equation is a mathematical model when you have to describe the shallow water wave dynamics. It has been analized the Lie symmetries and the conservation laws (energy, mass, linear momentum and Galilean momentum) of the KdV equation, on the first part of this work. On the other hand, we show the connections between these properties, and the ocean dominium, where it can be found soliton waves, solutions of the KdV equation generated in certain zones in the ocean.

Key words: Korteweg- de Vries equation, Lie symmetries, soliton waves.

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DINOPHYSIS ACUTA BLOOMS ON THE NORTHWESTERN IBERIAN SHELF: A COMPARATIVE STUDY OF A ROBUST, MID AND NULL ADVECTION YEARS

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Abstract: Harmful algal blooms (HABs) caused by *Dinophysis acuta* are recurrent on the Northwestern Iberian (NW) shelf at the end of the upwelling season, from late summer to early autumn. Blooms of this dinoflagellate can cause outbreaks of diarrhetic shellfish poisoning (DSP) in humans, ensuing a necessary ban on shellfish harvesting, resulting in significant economic losses. In the Galician Rías Baixas, the presence of *D. acuta* may be due to local growth and/or to a northward advection of populations already established in Portuguese waters. Three years, 2015, 2017 and 2019, were selected for this study based on the cell count data collected by the Galician (INTECMAR) and Portuguese (IPMA) monitoring programmes along the NW Iberian coastline, from Aveiro to the Galician Rias Baixas. *D. acuta* cells were present in all sampling stations in 2015 and 2019, whilst in 2017 no *D. acuta* cells were identified at intermediate stations. To investigate whether the non-presence of *D. acuta* cells from August to November 2017 was related to the absence of a northward transport, we used a lagrangian model, ROMSPath. This incorporated some limitations associated with *D. acuta* ecology, as maximum depth limit and offshore limits, and was forced with the output of a two-way nesting hydrodynamic model, CROCO, constructed with three domains of 1.6 km, 500 m and 180 m horizontal resolution. Running the ROMSPath model in forward showed the absence of a northward advection of D. acuta from Aveiro to the Galician Rias Baixas in 2017, whilst in 2015 and 2019 there was. It confirmed the previous hypothesis based on count cell data from the monitoring programmes. Furthermore, velocity-averaged currents from the hydrodynamic model output showed the relation between the northward transport and the formation of the innershelf countercurrent, with a strong presence in 2015, medium in 2019 and none in 2017.

Key words: HAB, lagrangian, NW Iberian shelf, upwelling, currents.

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IMPACT OF COASTAL BREEZES ON SURFACE CURRENTS IN THE GULF OF CADIZ (SPAIN)

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Abstract: The surface oceanic circulation in the Gulf of Cadiz is a complex research topic due to the complex interaction between coastal breezes, river discharges, seafloor topography, and proximity to the Strait of Gibraltar. This study focuses on the impact of coastal breezes on the surface current near the northern coast of the Gulf of Cadiz. The trajectories of four lagrangian buoys launched east of Cape Santa Maria in October 2022, two at 25 m and two at 100 m depth, are analyzed. These trajectories are correlated with wind data from coastal meteorological stations and numerical simulations obtained with the Weather Research and Forecasting (WRF) model, as well as with oceanographic variables such as chlorophyll concentration and sea surface temperature. The potential relationship between sea breezes and surface circulation is confronting the wind fields with the buoys trajectories. The aim is to determine if changes in wind direction and intensity, associated with sea breezes, influence the surface current (intensity and direction) on the continental shelf of the Gulf of Cadiz. Additionally, validation of the Atlantic Iberian Biscay Irish (IBI) reanalysis product will be conducted using these lagrangian trajectories, in a first step to extend the horizontal extension of this work. This study deepens understanding of surface circulation and the interaction of atmosphere-ocean processes in the area, aiding in the interpretation of substance transport mechanisms such as plastics or larvae, among others.

Key words: surface circulation, sea breezes, WRF

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DISPERSAL MODELING OF THE INVASIVE ALGAE *RUGULOPTERYX OKAMURAE* IN THE STRAIT OF GIBRALTAR AND ADJACENT BASINS

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Abstract: Since its initial detection on the coast of the Strait of Gibraltar in 2015, the exotic brown alga *Rugulopteryx okamurae* has spread explosively over a large part of the Atlantic and Mediterranean coasts, producing severe impacts on previously established benthic communities, and causing massive accumulations along the shorelines, affecting fisheries and tourism. The impact and adaptability of the algae in the Mediterranean environment has recently been the subject of extensive research, but crucial aspects of the invasion, including its distribution and the underlying causes of its success, remain unknown. To gain insight into the spreading and establishment of the species, two nested high-resolution hydrodynamic models coupled with a lagrangian particle tracking algorithm were used, with virtual tracers representing free spores, thalli fragments or detached mats of *Rugulopteryx okamurae*. The work focuses on the Strait of Gibraltar and its adjacent basins, the Gulf of Cadiz and the Alboran Sea, which have been significantly affected by the algal invasion so far. Simulations of larval dispersal from an introduction in the Strait indicate that the algal propagules first spread eastward before spreading westward, with transport by the Atlantic jet leaving the Strait of Gibraltar being the most influential process. The potential utility of computational tools in elucidating the dispersal dynamics of introduced and expanding species, identifying high-risk areas, and formulating management strategies for this species is discussed.

Key words: Invasive species, numerical modeling, dispersal patterns.

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4D EVOLUTION OF A RIVER PLUME FROM MULTIPLATFORM OBSERVATIONS AND MODEL DATA

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Abstract: The evolution of the Adour River plume was characterized in 4D by means of *in situ* and remote multiplatform observations and model data in the southeastern Bay of Biscay. Observations were provided by satellite measurements and a glider equipped with hydrographic and biogeochemical sensors. HF radar observations were also used along with a high-resolution operational numerical model data, both belonging to the EuskOOS observatory.

In the water column, the glider captured the evolution of the plume which showed a remarkable extension westwards along 85 km in front of the Basque coast from 23 to 27 November 2023. At the beginning of the mission, well-stratified conditions were observed due to the plume with marked vertical gradients from surface to 15 m of around 3 mg m^{-3}, 2.7 °C, 3 psu and 0.26 mg l^{-1} for Chl-a, temperature, salinity and NO_3^-, respectively. At the end of the mission, after the dissipation of the plume, the glider revisited the initial area, showing increased mixing conditions.

At the surface, SST and Chl-a satellite images showed the evolution of the plume which was also simulated by the numerical model. A maximum westward surface current velocity of 74 (61) cm s^{-1} was reached, observed by the HF radar (model), in concordance with the observed westward extension. Lagrangian analyses, such as the identification of coherent structures based on surface current velocities, were used to identify the plume advection and the presence of transport barriers.

This study highlights the potential of combining multiplatform observations and model data to study coastal (sub)mesoscale variability and physical-biogeochemical coupling from an integrated perspective. Moreover, it represents a further step in the implementation of autonomous platforms for ocean observation in the area.

Key words: River plume, Glider, Lagrangian, Multiplatform observations, Coastal observatory

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METEOTSUNAMIS IN THE WESTERN MEDITERRANEAN: REGIONAL ANALYSIS FROM HIGH FREQUENCY SEA LEVEL OBSERVATIONS

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Abstract: The atmospherically generated tsunamis, known as meteotsunamis (Monserrat et al., 2006), have been widely studied in Ciutadella, Menorca (Balearic Islands), where they can cause hazardous sea level oscillations of several meters. Furthermore, extreme meteotsunamis have also occurred in other nearby locations, but they have never been analysed altogether. In this study we characterize the occurrence of meteotsunamis in the Western Mediterranean from a regional perspective. To do so, we use operational tide gauges from several institutions (Puertos del Estado, SOCIB and PortIB), from the VENOM ultra-dense research network (UPC, UIB and IEO-CSIC), and from Josep Pascual in l'Estartit. The data set includes 27 instruments, covering the Balearic Islands and the eastern coasts of the Iberian Peninsula, all them providing high quality 1-minute sampling time series with different temporal coverage (from 2 years to more than 17 years).

The analysis of the dataset has revealed that high-frequency sea level oscillations have larger amplitudes where topography features are prone to the amplification of open-sea long waves by harbour resonance. Thus, aside from the well-known hotspot of Ciutadella, other locations as Vilanova, Portocolom or Port de Sóller also suffer from frequent large meteotsunamis. Moreover, we have found that sea level oscillations often occur simultaneously in several locations. The reason is that meteotsunamis are triggered by atmospheric disturbances associated with synoptic-scale meteorological patterns that cover a large part or the whole sampled region, affecting several locations at the same time. Finally, we have also found that the meteotsunami amplitude depends on small-scale features of the atmospheric disturbances; this makes that trying to infer amplitude relationships among locations or developing accurate forecasting system are very challenging tasks.

Key words: Meteotsunamis, Sea level, Tide gauges, regional characterization, Mediterranean

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EVOLUTION OF A COASTAL SYSTEM STRONGLY INFLUENCED BY HUMAN PRESSURES/ACTIVITIES

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Abstract: Coastal areas are exposed to natural hazards that are expected to increase due to the growth of coastal populations and infrastructure, as well as the effects of climate change, sea level rise and increase in the frequency of extreme events. Also, human activities can deteriorate these areas, and the joint action of the above can result in reduced resilience. Sotogrande beach, located on the Guadiaro sandspit, is a clear case, an area that has transformed from being natural in 1956 to being heavily modified in 2022. Nowadays, Sotogrande is surrounded by different infrastructures, such as residential areas, jetties, and a marina, and has recurrent problems with the closure of the Guadiaro river mouth, that generates eutrophication conditions in the estuary. The aim of this work is to analyse the long- and cross-shore evolution of Sotogrande beach and their implications for coastal management. Medium-term changes have been analysed through a study of aerial photography for the period 1956-2022, and short-term changes through topographic monitoring for the period 2015-2019 consisting of profiles carried out on a biweekly to monthly basis.
Results show erosion rates above -3 m/year at some points, with a 150 m retreat of the shoreline from its original position. The erosion trend has accelerated over the last 20 years in the natural area, the only section of the sandspit with capacity to migrate backwards. This erosive trend is also observed in the short term, accentuated by storm conditions after which only partial recoveries have been observed. The strong deterioration suffered by the sand spit is associated with the human occupation of the area, which has led to different interventions on the coastline to reverse a situation that has lasted for more than five decades.

Key words: Sotogrande beach, coastal erosion, aerial photograph, topographic monitoring

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SEAGRASSES MEADOWS PROVIDE ESSENTIAL COASTAL PROTECTION UNDER CLIMATE CHANGE

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Abstract: Climate change is already modifying the marine environment, and these alterations will presumably increase in the coming decades. Some changes expected during this period include ocean warming, rise of sea level and modifications to circulation and wind wave patterns (Pörtner et al.,2019, Fox-Kemper 2021).
In this context, despite ongoing efforts to reduce greenhouse gas emissions, it is crucial to develop realistic and effective plans for adapting to climate change. Nature-based solutions (NBS), such as the increase of coastal seagrass meadows through restoration, present a particularly interesting approach. The interaction of seagrasses with water flow leads to a reduction in flow energy, thereby limiting the impact of waves reaching the coast (Koftis and Prinos, 2011; Hemavathi et al., 2020).
However, ocean warming threats seagrass meadows, as some species are vulnerable to marine heatwaves (Marbà and Duarte, 2010). Therefore, the primary goal of the SEAFRONT project is to quantify the potential benefits of seagrass meadows in protecting the coast from future marine storms under different scenarios of global warming and seagrass evolution. SEAFRONT focuses on Spanish coastal areas, which exhibit a variety of hydrodynamical situations and seagrass coverages.
Specifically, SEAFRONT aims to 1) assess the impacts of marine storms over the last decades, evaluating the role of seagrasses; and 2) generate future scenarios of physical and economic impacts.
In this presentation, we share the results of numerical simulations focused on estimating the total water level at the shore under several scenarios. These scenarios account for sea level and wave changes, coastal shapes, and seagrass coverage (Ruiz et al., 2015, Ramírez Pérez et al., 2019). Our analyses suggest that restoring seagrass meadows is a highly effective way to adapt to marine storms, countering the effects of rising sea levels on coastal impacts. However, in areas where seagrasses already exist, losing them could lead to severe consequences, increasing the impact of marine storms up to a 100%.

Key words: beaches, flooding, sea level rise, Spain, climate change.

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ENHANCING BARRIER BEACH RESILIENCE WITH EMBRIONARY DUNES

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Abstract: This study, conducted on Trabucador Beach (Ebro Delta), aimed to assess the efficacy of different soft protection strategies in mitigating breaching occurrences through the utilization of numerical modelling. Notably, the findings indicated that all three management scenarios; Embryonic Alternating dunes (AD), Continuous dunes (CD) and Classical Nourishment (CN) notably succeeded in reducing breaches during storm events, with 100% efficiency observed during Storm Isaak (a mid-tier double peak storm). Even under the more intense Storm Filomena (a typical larger storm of the region), these measures continued to effectively mitigate breaches, achieving reductions ranging from 82% to 86%. However, during Storm Gloria (the largest ever storm to hit the region), certain distinctions in effectiveness became evident, with the AD and CD designs displaying relatively lower efficiency than CN design strategy. Still, the protection measures, including beach widening via shore-face nourishment and the deployment of alternating and continuous dune designs proved to be effective for breaching reduction. Particularly, AD design, characterized by larger back-barrier dunes and smaller foredunes, exhibited promise in reducing storm impacts, especially against annual storms. Although AD produced smaller breaches, most of the beach remained intact due to the foredunes protecting the larger dunes in the back shore. By contrast, CD and CN design strategies need from frequent renourishment to recover their stability due to the effect of an active swash and surf zones that produce a loss of sediment in both approaches while AD design would be sustainable considering its effectiveness during storm impacts and relative stability during the calmer periods. Then, by considering the challenges associated with each protection measure, encompassing sediment availability, implementation costs, environmental impacts and effectiveness at long-term, AD is the best strategy to apply in the study area.

Key words: Barrier beach, dunes, nourishment, coastal protection, XBeach model

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UNVEILING THE DOMINANT PATHWAYS OF THE ANTARCTIC BOTTOM WATER CROSSING THE SOUTH SCOTIA RIDGE

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Abstract: The Weddell Sea Bottom Water (WSBW), a dense precursor of Antarctic Bottom Water (AABW), is formed in the southern Weddell Sea due to intense air-sea-ice interactions. This water masses circulates north along the western boundary of the Weddell Sea, enters the Powell Basin and ultimately crosses the South Scotia Ridge, which becomes a critical location for assessing the final transformation of WSDW into AABW. While the water characteristics exported through the South Scotia Ridge Passages are well documented, the specific sites and processes driving the WSDW/AABW cross-slope convection remain largely unknown. With the aim of identifying these key locations and later deploying an instrumented mooring in one of them, we use a versatile open-source toolbox for digital elevation model analysis (Schwanghart and Scheler, 2014). The underlying premise is that the outflow will be conditioned by an excess pressure in the Powell Basin, either arising from the high density of these basin waters or from a local increase in the sea level. Assuming that the flux will be very slow, we hypothesize that the Coriolis force is weak so that the flow will follow down-pressure-gradient, resembling hydrologic water tributaries in a drainage basin, and further propose that the pressure gradient is mirrored by the gradients in bottom topography. Our preliminary results suggest that the dense water masses passes through the three passages located in the interior part of the South Scotia Ridge, with the easternmost passage, near the South Orkney Islands, exhibiting the most dominant outflow.

Keywords: South Scotia Ridge Passages, Antarctic Bottom Water, Powell Basin, digital elevation model analysis

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MONITORING THE CANARY CURRENT UPWELLING SYSTEM THROUGH ANIMAL TELEMETRY: A PILOT STUDY

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Abstract: The Canary Current Upwelling System (CCUS) is a dynamic region with cold, nutrient-rich waters that support diverse marine life and play a key role in the ocean-atmosphere heat exchange. However, areas near and over the continental shelf of the CCUS have been traditionally undersampled, with most data from remotely sensed observations facing difficulties near land. We show the development of animal telemetry has revolutionized our ability to monitor and sample this environment through in situ observations collected by instrumented marine animals.
This work synthesizes recent research on the application of animal telemetry to the CCUS using instrumented marine animals. This technology has enhanced our understanding of upper ocean variability with unprecedented time resolutions, collecting temperature and pressure data every 10 minutes over long periods of time and large distances. Preliminary results emphasize the need for careful calibration of remotely sensed sea surface temperature observations in shallow waters near land, where biases of over 2°C have been noted by independently calibrated sensors. The instrumented animals have sampled various oceanographic features, including eddies, strong currents, open ocean temperature gradients, and upwelling fronts.
We also address ongoing challenges and propose solutions to optimize telemetry research in this and similar upwelling systems as a complementary tool to other observational platforms. While animal telemetry cannot continuously monitor large regions alone, it can enhance the performance of satellite observations near land and improve global ocean reanalysis and modeling products that currently fail to capture upper ocean variability at high temporal resolutions (hours to days). By advancing telemetry methodologies and overcoming current limitations, we aim to better monitor the upper ocean variability that governs the vital resources of the CCUS, especially important in the context of climate change.

Key words: Animal Telemetry, Satellite Observations, Canary Current Upwelling System, Sea Surface Temperature, Temperature Gradients.

ON THE GULF STREAM PATH DECADAL VARIABILITY AND FUTURE PROJECTIONS

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Abstract: The Gulf Stream (GS), as the western boundary current from the North Atlantic subtropical gyre, represents a significant climate regulating mechanism that carries warm salty water from Florida Straight toward the North Atlantic. After it separates from the US continental shelf near Cape Hatteras, it experiences latitudinal shifts. Those movements have been explored using an index created from thirty years of altimetry data, the Gulf Stream Index (GS16). This index shows significant interdecadal variations of the GS path and a northward overall shift in the last decade, reaching 160 km north from its mean position. Positive phases of the North Atlantic Oscillation (NAO) and negatives of the Atlantic Multidecadal Oscillation (AMO) lead by near 1-year lag the northward GS shifts. Significant correlations are also obtained between GS16 and the European near-surface temperature, at almost 0 years lag. On the other hand, the point where the GS path loses its stability shows a zonal shift, it went from 62.4ºW to 64.3ºW between 1993 and 2013 and returns eastward to 63.4ºW in the last decade. Future projections of the GS shifts and its link with the NAO and AMO are analyzed using 23 Sixth Generation Coupled Models of Intercomparison Project (CMIP6) and 6 high-resolution models (HighresMIP).

Key words: Gulf Stream, NAO, AMO, CMIP6

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SEASONAL AND INTERANNUAL CIRCULATION IN THE GERLACHE STRAIT

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Abstract: We present an observational-based assessment of the seasonal and interannual variability of the circulation in the Gerlache Strait (GS). This location plays a crucial role for water mass exchanges between the relatively warmer Bellinghausen waters, transported northeastward by the Gerlache Strait Current (GSC), and the colder Weddell-sourced waters, transported southwestward by the Antarctic Coastal Current (CC) at subsurface (Wang et al., 2022).
We use a Shipboard Acoustic Doppler Current Profiler (SADCP) dataset collected from 379 cruises performed by R/V Nathaniel B. Palmer and R/V Laurence M. Gould between 1999 and 2018. Therefore, we address an ad hoc approach through which we grid the data based on boxes of about 70 km2 located along the strait and adjusted to the ship tracks from the Palmer station (south) to Bravant Island (north). Before gridding the data, the barotropic tidal signal was removed using the Circum-Antarctic Tidal Simulation (CATS2008), an update to the model described by Padman et al. (2002). From the Palmer station to the channel between the Anvers and Bravant Islands, we define one unique pathway of boxes. From Bravant Island to Liège Island, two pathways are defined, one following the islands' margin (to the northeast) and one following the Antarctic Peninsula margin (to the east).
Along the western margin, the seasonal climatologies of the along-strait velocities reveal that the GSC flows northeastward, except to the north of the northern entrance (Liège Island), where the flow is negligible in summer and autumn, and southwestward in winter and spring. We cannot attribute this flow to the CC indistinctly without hydrographic measurements as our study is based on direct velocity measurements. The GSC exhibits the strongest maximum velocities in spring (24.7 ± 4.0 cm/s), followed by winter (21.5 ± 9.0 cm/s), summer (16.9 ± 4.7 cm/s), and autumn (6.7 ± 8.0 cm/s). Interannually, we find the GSC is maximum in winter 2010 at 38.2 cm/s, and minimum in autumn 2018 at 0.6 cm/s. Along the eastern margin, we find a weaker and less defined northeastward current exhibiting different velocities through seasons and years.
These results highlight the variability of the circulation in the GS, what can potentially impact the exchange of water masses of remote origin along the strait.

Key words: Gerlache Strait, Direct Velocity Measurements, Dynamic Structure, Seasonal and Interannual variability.

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OCEANOGRAPHIC CONDITIONS IN THE COLOMBIAN PACIFIC OCEAN UNDER THE EFFECTS OF THE LA NIÑA 2022 AND EL NIÑO 2023

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Abstract: In the Colombian Pacific Basin (CPC), there is a strong coupling between the ocean, atmosphere, and continental zone; this coupling modulates various physicochemical and biological processes. Seasonal and interannual climatic variability (e.g., Panama Jet, Choco Jet, ENSO) and oceanographic dynamics (e.g., surface currents, coastal upwelling, mesoscale eddies) are among the main physical forcings that influence the region (Devis-Morales et al., 2008; Ordoñez et al., 2021). The dynamics of atmospheric variables (i.e., wind and precipitation), oceanographic variables (i.e., temperature, salinity, oxygen, and fluorescence) and circulation patterns, were analyzed during the cold (La Niña 2022) and warm (El Niño 2023) phases of the ENSO.
A greater magnitude of wind and precipitation was found during La Niña, with opposite conditions associated with the development of the El Niño phase. During August 2022, there was a greater influence of atmospheric processes, with a lower sea surface temperature (~26°C) and higher salinity (25-32 UPS). The water column was highly mixed in the first 40 meters of depth, due to mixing processes by winds and a sinking of the thermocline (40-60 meters depth), which is contrary to what is expected during La Niña (thermocline shoaling), as observed in Peru-Chile. By April 2023, the sea surface temperature increased (29°C) influenced by warm water masses from the central Pacific due to the presence of El Niño, which began developing in February of the same year. The thermocline was shallower (10-20 meters depth), with less saline surface waters due to increased rainfall and associated runoff of the Mira River during this month. Finally, temperature was the variable that showed the greatest changes between periods, registering an increase of up to 5°C at 55 meters depth between the two periods. Our results indicate that, although there is an increase in sea surface temperature, coastal processes, and the local climatology are influencing the environment to a greater extent than large-scale processes such as ENSO.

Key words: Mixing Layer, ENSO, Climate Variability.

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hydrobiological resources in the area of influence of the Cabo Manglares - Bajo Mira and Frontera Integrated Management National District (Department of Nariño, Colombian Pacific).

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THE SEASONAL CYCLE OF THE EASTERN BOUNDARY CURRENTS OF THE NORTH ATLANTIC SUBTROPICAL GYRE

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Abstract: For the first time, four dedicated hydrographic cruises – one in each season – took place in 2015 around the Canary Islands to determine the seasonality of the flows at the eastern boundary of the North Atlantic Subtropical Gyre. The Canary Current (CC) is the eastern boundary current of the North Atlantic Subtropical Gyre and links the Azores Current with the North Equatorial Current. The 2015 estimations show that the CC has a seasonal behavior in its path and strength, flowing on its easternmost position in winter (3.4±0.3 Sv), through the Canary Islands in spring (2.1±0.7 Sv) and summer (2.0±0.6 Sv) and on its westernmost position in fall (3.2±0.4 Sv). At the Lanzarote Passage (LP), the dominant flow is southward except in fall, where a northward transport is observed at the surface (1.1±0.3 Sv) and intermediate (1.3±0.2 Sv) layers. Combining all the available transport estimations a historical composite observational seasonal cycle is constructed and fits the 2015 seasonal cycle. Hence, a solid seasonal cycle is constructed supported by all the available observations in the area. The LP seasonal cycle and seasonal amplitude match the seasonal cycle of the Atlantic Meridional Overturning Circulation (AMOC) measured by the RAPID-MOCHA data array. These indicates that the seasonal cycle of the AMOC of the RAPID-MOCHA data array is driven by the dynamics of the eastern boundary currents.

Key words: AMOC, Canary Current, Lanzarote Passage, Eastern Boundary, North Atlantic Subtropical Gyre

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A LIMIT ON EASTERN BOUNDARY UPWELLING SYSTEMS ABILITY TO OFFSET CLIMATE CHANGE IMPACTS

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Abstract: Upwelling along the ocean's eastern boundaries is expected to intensify due to coastal wind strengthening driven by the increasing land-sea pressure gradient, according to Bakun'shypothesis; and therefore assessing the future impacts of Global Warming on upwelling processes remains crucial for efficient ecosystem management. In this study, we apply a novel index based on deseasonalized sea surface temperature (SST) trends to test the Bakun's hypothesis and analyze the intensification patterns within Eastern Boundary Upwelling Systems (EBUS) in the future projections according to the (The Intergovernmental Panel on Climate Change) IPCC scenarios. To assess future impacts, we evaluate twelve high-resolution models from the Couple Model Intercomparison Project, comparing their performance against the SST AVHRR/NOAA reanalysis dataset in the historical simulations. The EBUS are known to have considerable bias in SST due to misrepresentation of the upwelling process. Recognizing the variability in SST biases for each specific EBUS, we conduct a comparative analysis with historical observations to elucidate the model performance, while all models contribute to uncertainty quantification. Three socio-economic share pathways (SSP1.26, SSP2.45, and SSP5.85) representing a full range of future projections according to the IPCC scenarios are considered. Additionally, we incorporate two independent models: the MOM-JRA55, an oceanic-only model utilizing MOM5 forced with JRA55 atmosphere reanalysis (only historically data available), and a fully coupled atmospheric-oceanic model with a super high resolution of 0.1°, capable of resolving the upwelling process. The Canarian and Californian systems exhibiting better representation in the MPI-ESM1-2-HR and CESM-H models respectively, while the MOM-JRA55 model best represents the Humboldt upwelling system. Our analysis indicates an initial stage of upwelling intensification under global warming, in line with Bakun's hypothesis. However, the intensification mechanism may reach a saturation point, leading to a αUI around 0º after 2075, indicating no discernible differences between open ocean areas and upwelling-related trends. These findings are consistent with high-emissions scenarios revailing an anthropogenic forcing. These findings provide valuable insights into the intensification of EBUS and underscore the significance of considering future projections in the context of global warming for future evolution of the EBUS.

Key words: Eastern Boundary Upwelling Systems, Climate Change, sea surface temperature.

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ORAL COMMUNICATIONS

OCEAN METHODS: INSTRUMENTATION, REMOTE SENSING AND NUMERICAL METHODS

Universidad Católica de Valencia San Vicente Mártir
Universitat d'Alacant Universidad de Alicante
Universitat de Barcelona
UCA Universidad de Cádiz
ULPGC Universidad de Las Palmas de Gran Canaria
Universidad de Vigo

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CORRECTION OF NWP OCEAN SURFACE WIND BIASES WITH MACHINE LEARNING AND SCATTEROMETER DATA

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Abstract: Global Numerical Weather Prediction (NWP) model sea-surface wind output is commonly used to force ocean models due to their time and space continuity. However, the output of NWP models presents local biases, with one of the most systematic and longstanding biases in the sea surface wind direction (Sandu et al., 2020). After the assimilation of the stress-equivalent winds (U10S) measured by scatterometers, the European Center for Medium-range Weather Forecasts (ECMWF) model output still presents the mentioned biases, which need to be corrected since they mostly represent unresolved geophysical processes by NWP models.
In this work we aim to correct the mentioned biases with the use of machine learning (ML), and in particular, neural networks. To generate predictions of the biases and apply the corrections to the NWP output, the ML models use several NWP and ocean model output parameters as inputs. This way the corrections of the NWP errors do not depend on the availability of the observational data and can be applied to both its operational use and the development of valuable, long-term ocean forcing data series. The results show that such models can significantly reduce NWP local biases and therefore its overall error variance. When validating against independent scatterometer, i.e., that onboard HY-2B (HSCAT-B), the error variance is reduced globally up to 6.63% for a year not used for training, and in particular, up to 10.27% in extra-tropics. In the tropics, the ML models are less effective with a reduction of only up to 3.82%. The ML architectures that are currently used include the Extreme Gradient Boosting and fully-connected feed-forward neural networks and are trained on a grid-point basis. Future work will include the implementation of convolutional neural networks architectures for extraction of the spatial information of the NWP fields and generative adversarial networks.

Key words: stress-equivalent winds, NWP model biases, scatterometer, neural networks

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HYBRIDIZABLE DISCONTINUOUS GALERKIN METHOD APPLIED TO A TWO-LAYER SHALLOW WATER MODEL

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Abstract: We are interested in simulating certain physical oceanographic phenomena such as upwellings or baroclinic instabilities using numerical methods. We model these phenomena using multilayer shallow water equations. For discretization, we employ a finite element-based method, specifically Hybridizable Discontinuous Galerkin (HDG), previously used in single-layer models (Betteridge et al., 2021). Finally, we validate its effectiveness and accuracy with some academic problems.

Key words: Multilayer shallow water equations, Hybridizable Discontinuous Galerkin (HDG).

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ANALYSIS OF THE CONSERVATION PROPERTIES OF DIFFERENT NUMERICAL DISCRETIZATIONS OF THE SHALLOW WATER EQUATIONS

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Abstract: Several methods numerically solve the Shallow Water Equations (SWE). Among them, the classical Finite Difference is likely the most popular in the oceanographic community and also the Hybridizable Discontinuous Galerkin (HDG). The latter method, derived from Finite Elements, stands out for its preservation fundamental properties (Bui-Thanh, 2016). Here, we specifically compare these two numerical methods in solving the SWE, focusing on the conservation of mass and momentum, as well as the computational efficiency of each method. The evaluation is carried out by numerical simulation of examples taken from Kämpf (2009), analyzing the performance of each method in representative scenarios of ocean dynamics.

Key words: Shallow Water Equations, Finite Difference, Hybridizable Discontinuous Galerkin, energy conservation.

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VERY HIGH-RESOLUTION HYDRODYNAMIC MODELLING FOR IMPROVED FORECASTING AND MANAGEMENT OF THE COASTAL ZONE

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Abstract: This study represents a significant advance in coastal zone management through the development of a sophisticated three-dimensional hydrodynamic modelling tool tailored to the coastal and nearshore waters of Barcelona. The tool employs the Coupled Ocean-Atmosphere-Wave-Sediment Transport (COAWST) Modelling System [1], which uses the Model Coupling Toolkit to integrate the Regional Ocean Modelling System (ROMS) with the Simulating Waves Nearshore (SWAN) model. This integration enables the exchange of prognostic variables in a comprehensive manner, thereby enhancing the capacity to simulate and understand complex wave-current interactions [2], which are of critical importance for the management of coastal environments affected by both natural and anthropogenic influences.

The model employs a three-level nested grid system, offering detailed spatial resolution from a broad 350m coastal domain down to 70m port domain to a local 14m domain. This downscaling setup enables high-resolution hydrodynamic simulations, which are essential for capturing the complex dynamics of coastal flows, influenced by variations in wave heights, periods, and directions. The model's accuracy and reliability in simulating wave-driven processes and nearshore dynamics is significantly improved by combining EMODnet bathymetric data [3] with high-resolution datasets from field campaigns, and using Copernicus data [4] to force the system. With this approach, the model becomes effective in addressing coastal challenges such as erosion, flooding, and the tacking of marine debris.

Extensive validation through field campaign data, highlighted by observations during the significant Celia storm that impacted Barcelona in March 2022, has substantiated the model's high capacities. This validation not only emphasises the model's practical utility but also equips managers and policymakers with precise, forecast-driven data to enhance sustainable coastal development and informed decision-making.

Future improvements, including the incorporation of more accurate ocean data and high quality forcing, will significantly enhance the potential of this modelling tool, particularly with regard to the accuracy of ocean forecasts. These developments contribute significantly to advancements in coastal science and environmental management, providing essential insights to policymakers and industry stakeholders, and promoting a sustainable integration of human activities with marine ecosystems.

Key words: 3D hydrodynamic modelling, wave-current interaction, nearshore dynamics,

forecasting capabilities, coastal management.

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VIII Encuentro Oceanografía Física

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IX INTERNATIONAL SYMPOSIUM ON MARINE SCIENCES

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MONITORING OCEAN WARMING: FROM CLIMATE RESEARCH TO OPERATIONAL COASTAL SERVICES

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Abstract: Monitoring and forecasting essential ocean variables using both observational and model data have allowed scientists to detect and understand ocean warming and climate change impacts for the last decades. The extensive research, from global to regional scales, summarized in the annual EU Copernicus Marine Service Ocean State Report has revealed significant rising trends in temperature and heat content, particularly in some European seas such as the Mediterranean, Black Sea and North Atlantic up to 50º N. Additionally, there has been an increase in the frequency, intensity and extension of marine heat waves (MHWs) in recent years. In this work, an overview of MHW events occurred in the period 1982-2022 in the Iberian-Biscay-Ireland (IBI) Atlantic region, including a surface and sub-surface analysis focused on 2022, is provided. The applied methodology combines uses of both satellite and *in situ* data (from Argo floats) together with model products provided by the Copernicus Marine IBI Monitoring and Forecasting Center (MFC). This investigation confirms observed trends in the area, pointing also to the need of redefining MHWs in a way that considers the evolution of sub-surface temperature anomalies. This MHWs 3D characterization can contribute to get better assessments in zones where impacts on marine ecosystems can be more severe (i.e., coastal zones, benthonic environments). To move towards this new approach, achievement of accurate coastal ocean models is a key element. Indeed, development of operational coastal services, continuously delivering 3-D high-resolution model products, can contribute to provide a more complete characterization of MHWs. As example in the Iberian region, e3HOPE and EUSCOMvu, both coastal pilot services fostered by the Copernicus Marine User Engagement Programme, provide a more

accurate forecasting for Ebro Delta and Basque coastal zones, respectively, helping their stakeholders to monitor local marine conditions and warn them of extreme events.

Key words: EOVs monitoring, forecasting, marine heat waves, coastal modelling, operational services

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The work carried out by AZTI and Nologin Teams on EUSCOMvu was funded as part of the Copernicus Marine Service EUSCOMvu project (User Engagement Programme 2022–2028; Copernicus Marine Service is implemented by Mercator Ocean in the framework of a delegation agreement with the EU).
The work carried out by Nologin, LIM and IRTA Teams on e3HOPE was funded as part of the Copernicus Marine Service e3HOPE project (User Engagement Programme 2022–2028; Copernicus Marine Service is implemented by Mercator Ocean in the framework of a delegation agreement with the EU).

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IMPACT OF CLIMATE CHANGE ON UNDERWATER CULTURAL HERITAGE PRESERVATION: CHANGES IN WAVE-INDUCED HAZARDS

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Abstract: Global climate change is causing alterations in maritime climate, especially in coastal areas where a large amount of underwater cultural heritage (UCH) is found. Waves play a significant role in preserving this heritage in shallow waters, but there is still a need to evaluate how waves affect the long-term risk of UCH. This is crucial due to changes in maritime climate caused by climate change (CC). This study has developed a methodology capable of assessing the risk associated with wave impact in the historical period and analyzing future changes due to changes in hazards imposed by CC. This methodology has been applied in the Bay of Cadiz, which is known for having one of the highest concentrations of shipwrecks in the world.

For this study, wave projections forced by five global models belonging to CMIP5 are used. After correcting these data to reduce biases inherent in using data from a global model for a local study area, wave climate is transferred from deep waters to shallow waters using hybrid downscaling. Afterward, the three main hazards affecting UCH preservation in the long term are evaluated: decontextualization, scouring, and erosive wear. The risk index is calculated as the square root of each hazard multiplied by the vulnerability scores. Finally, changes in maritime climate and UCH risk for mid and late century are analyzed using RCP 4.5 and RCP 8.5 scenarios compared to the historical period. The results indicate an increase in wave energy flux, particularly pronounced in the 10 and 5-meter isobaths, by 60% and 80%, respectively. A shift in incident wave conditions towards the south was observed in the bay. These changes have implications for key UCH hazards, including decontextualization, with a notable increase in shallow regions.

Key words: Underwater cultural heritage, Climate change, Hybrid downscaling

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MECHANISMS OF MEDITERRANEAN SEA LEVEL INTERANNUAL VARIABILITY

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Abstract: The different contributors to the Mediterranean sea level variability at interannual scales are analysed based on a combination of observational and numerical datasets. The relative role of the mass content change and the thermosteric change will be analysed. Namely, changes in the mass content of the Mediterranean sea are characterized using several satellite gravimetric products from the GRACE mission. The results are compared with previous estimates also based on GRACE measurements and with indirect estimates obtained from a combination of hydrographic observations, satellite altimetry and numerical modelling. Our results show that some of the gravimetry products provide a good representation of the Mediterranean mass variability (correlation with indirect estimates up to 0.85), significantly improving other standard gravimetric products (correlation lower than 0.3). Also it is shown that most of the Mediterranean mass variations at interannual scales are due to mass redistribution due to wind forcing around the Strait of Gibraltar. Sea level changes in the nearby Atlantic are a secondary source of mass variability in the Mediterranean. Also, we estimate the role of salt changes in the variability of gravimetric derived mass estimates. Although changes in the salt content have little effect on the seasonal to interannual time scales they are non-negligible in what concerns multidecadal and long term trends.

Key words: Mediterranean, Sea Level, Gravimetry, Altimetry, Hydrography

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DEGLACIAL CHANGES IN MEDITERRANEAN THERMOHALINE CIRCULATION

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Abstract: Mediterranean thermohaline circulation is a very sensitive system to changes in regional climate conditions. The current warming conditions have already been transferred into the deep water properties, and future projections indicate an overall weakening of this circulation system. In this context, it becomes extremely relevant understanding the natural range of variability of this system and the interplay between the different basins and sub-basins controlling deep and intermediate convection in the Mediterranean Sea. Here we use the past record as a natural laboratory to learn on the impact that different climate forcings had in this circulation system, and also evaluating its consequences in the Mediterranean Outflow Water (MOW) and thus in the Atlantic oceanography. These are the main results of the ERC-Consolidator grant TIMED, devoted to understanding of past changes in Mediterranean thermohaline circulation. This new data set is based in a variety of proxies that are sensitive to ocean circulation changes such as U/Mn ratios measured in the foraminifera diagenetic coatings, Nd isotopes, absolute dating on deep sea corals, among other geochemical and sedimentological tools applied in sediment cores from both E- and W-Med. The obtained results indicate the deglacial development of an intense minimum oxygen zone in the W-Med associated to the LIW which extended down to at least 950m. These evidences support by the first time, that the formation of the deglacial Organic Rich Layer was also connected to a weakening of E-Med convection, this would indicate a long pre-conditioning prior to the last Sapropel (S1) that would start with last Heinrich event in the North Atlantic and fully develop with the onset of the African humid period. We identify that an intense aridification and cooling of the E-Med driven by the AMOC weakening of the Younger Dryas was responsible of a strong reactivation of E-Med convection that

resulted in a stronger MOW, and also triggered enhanced deep intermediate convection in the W-Med. This circulation change pushed out an old water mass previously accumulated in the Med for several centuries with major consequences in deep ecosystems sustained by deep sea corals. The onset of the last S1 in the E-Med led to major changes in deep convection in both E and W-Med, but with opposite sign in their response. These results highlight the tide connection between the AMOC and E-Med convection and rise questions on the potential role that the associate changes in the MOW could have on the AMOC, particularly during weak stages.

Key words: Mediterranean circulation, Last deglaciation, Last Sapropel, Oxygen content.

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ROLE OF THE OCEAN MEAN STATE IN THE DEVELOPMENT AND CONFIGURATION OF THE ATLANTIC NIÑO

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Abstract: The Atlantic Niño, characterized by sea surface warming in the equatorial Atlantic, dominates interannual variability in the tropical Atlantic during the boreal summer and impacts both tropical and extratropical regions. However, its spatial pattern and variability, as well as its global teleconnections, differ across decades. In this study, we evaluate changes in the Atlantic Niño configuration under different atmospheric and ocean mean state conditions. For such purpose, we examine three perturbed experiments where incident radiation is abruptly reduced across three latitude bands, located at the northern and southern extratropics and southern subtropics. The data we use involve five coupled models from the Extratropical-Tropical Interaction Model Intercomparison Project (ETIN-MIP).
Our results suggest that the Atlantic Niño pattern with warm anomalies extending more to the west, is associated with weaker dynamical coupling. Furthermore, we find that the strength of vertical dynamics largely depends on the tilt of the thermocline in the Atlantic, the ocean stratification and wind patterns. In particular, we find that when the second and third components of the Bjerknes Feedback are weaker, the wave propagation is reduced and the Atlantic Niño is less confined to the east.

Key words: Atlantic Niño configuration, Bjerknes Feedback, Mean state conditions

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THE CRUCIAL ROLE OF REALISTIC WINDS IN CONNECTING NORTH TROPICAL AND EQUATORIAL SST VARIABILITY

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Abstract: A correct representation of tropical Atlantic variability (TAV) still remains a challenge. TAV is governed, at interannual time scales, by two air-sea coupled modes, the Atlantic Meridional Mode (AMM) and Atlantic Zonal Mode (AZM) peaking in boreal spring and summer respectively. AZM is characterized by an equatorial warm (cold) tongue associated with a reduction (intensification) of the trade winds (Zebiak et al. 1993). On the other hand, AMM displays an interhemispheric Sea Surface Temperature (SST) gradient accompanied by anomalous surface winds blowing to the warmer core (Nobre and Shukla 1996).

Recent findings suggest an AMM-AZM connection through the triggering of a north-equatorial Rossby wave that is boundary reflected into an equatorial Kelvin wave, impacting on SST anomalies during boreal summer (Foltz and McPhaden 2010; Martín-Rey et al. 2019; 2023). Here, this linkage and the driving role of realistic surface winds are investigated through a set of three initialized climate predictions with the global coupled version of the EC-Earth3.3 model (Döescher et al 2021) for the 2017 event. The experiments only differ from the wind stress fields prescribed, which come from the model, ERA-interim reanalysis, and the new ERA* product.

Our results demonstrate an amelioration of the SST simulation over the equator and the eastern tropical Atlantic basin, particularly along the Senegalese-Mauritanian and Angola-Benguela coasts when the observed wind is imposed. This improvement seems to be associated with highly sensitivity of ocean wave activity to realistic wind stress during the whole evolution of the event. Moreover, the wind forcing, notably that of ERA*, appears as a key factor to correctly reproduce the Rossby-wave reflected mechanism connecting the

north tropical Atlantic and equatorial SSTs. This information is quite valuable to enhance the prediction of tropical Atlantic variability, currently compromised by errors in surface winds, between others.

Key words: Tropical Atlantic variability, ocean waves, surface winds, Atlantic Zonal Mode, Atlantic Meridional Mode

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GLOBAL RESPONSE OF OCEAN STRATIFICATION TO CLIMATIC FORCING

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Abstract: The global ocean plays a pivotal role in climate by taking up, storing and redistributing vast amounts of heat, carbon and other tracers (Fox-Kemper et al., 2021). A fundamental factor shaping this role is the ocean's stratification, which accounts for the resistance of a water column to be mixed vertically. As such, stratification modulates the transfer of climatically important properties (e.g., heat, carbon, oxygen and nutrients) between deeper oceanic layers and near-surface waters, which are in frequent contact with the atmosphere and may thus interact with the rest of the climate system.

It has traditionally been assumed that beyond the deepest extent of surface mixing in winter, ocean stratification remains approximately constant or evolves very slowly on the interannual and longer time scales of pertinence to contemporary climate variability – comprising both internal and anthropogenic changes imprinted on the historical record. As a result, most research efforts to document or understand ocean stratification and its climatic function have, to date, primarily focused on near-surface waters (Somavilla et al. 2017; Yamaguchi and Suga, 2019; Salleé et al. 2021; Fox-Kemper et al., 2021). Deeper in the water column, little is known about the extent to (or time scales over) which the stratification of the main pycnocline, extending to depths in excess of 1000 m, is influenced by climate variability.

Here, we test this view by performing the first global-scale, systematic investigation of the spatio-temporal variability of ocean stratification from the surface to the main pycnocline, using 20 years (2003-2022) of data from the Argo float array. We demonstrate that, contrary to previous assumptions, deep-ocean stratification varies significantly with well-defined spatio-temporal patterns. Both near-surface and main pycnocline stratifications are found to exhibit spatially-structured, vertically-coherent, global-scale variations on seasonal-to-decadal time scales, unveiling a new view of ocean stratification from surface to depth as a rapidly-evolving, readily-interactive element of the climate system. Variability in stratification is organized into well-defined patterns that replicate the spatial footprints and time scales of major climate modes, pointing to these modes of internal variability as important drivers of stratification changes. Our diagnosed patterns and forcings of stratification variability provide an important benchmark for advancing the climate models used to understand and predict the ongoing climate change.

This work is under review in AGU Advances and can be found at https://essopenarchive.org/.

Key words: ocean stratification, main pycnocline, seasonal and decadal variability, spatial footprints, climate modes (ENSO), atmospheric forcing

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CHARACTERIZING THE 2023 ATLANTIC OCEAN MARINE HEAT WAVE: WIND-TEMPERATURE ANOMALIES AND DEPTH PROFILES ACROSS LATITUDES

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Abstract: In the latest reviews published regarding marine heatwaves, there is no mention of significant events of this type in the Northeast Atlantic. However, in mid-May 2023, high Sea Surface Temperature (SST) values were reported throughout this region.
In order to identify the cause of this increase in SST and determine the extent of the event, data from ERA5 wind speed and sensible heat flux as well as Copernicus SST (products METOFFICE-GLO-SST-L4-REP-OBS-SST and METOFFICE-GLO-SST-L4-NRT-OBS-SST-V2) have been employed. Data from 1982 to 2023 have been used to create a climatology. To characterize this event in depth, Argo float data (Argo WMO ID: 6903080 / 4903713) and the World Ocean Atlas 2023 climatology have been used to create a temperature anomaly. These analyses have been conducted in two regions at different latitudes (Canary Basin and off the northwestern margin of the Iberian Peninsula coast).
A drop of approximately 10 m/s in less than two weeks in mid-May was observed, followed immediately by an increase in SST (reaching 2.83ºC / 3.15ºC). This decrease in wind could result in lower mixing efficiency followed by stratification in the water column. It appears that in the Canary Basin, despite a resumption in winds, the ocean did not seem to release all the stored heat, keeping the SST above the climatology until the end of the year. In higher latitudes, on the other hand, after a strong wind event in October, the SST returned to normal values. This event reached the first and second categories for MHW as diagnosed according to the methodology proposed by Hobday et al. (2018) in the study regions. The highest anomalies are reached near the MLD (3.1ºC / 3.9ºC) and deepen over time. In some occasions, the anomaly even extends beyond the MLD reaching 120 m depth.
The characterization and monitoring of these types of events in depth are of key importance as in shallow waters, a MHWs of this intensity could cause damage to marine ecosystems. Further investigation on a third location might be done.

Key words: Marine Heatwaves, Northeast Atlantic, SST, Wind speed, Argo float

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EUSKADI COASTAL OPERATIONAL MODEL VALIDATION & USER-ENGAGEMENT (EUSCOMVU)

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Abstract: Coastal hydrodynamic modelling aims to understand and predict water circulation generated by wind, tides, differences in density of water masses and freshwater discharges. Accurate coastal modelling is essential to correctly assess and predict the risks of adverse events to human life, activities and infrastructure. The EUSCOMvu project aims to: (1) generate a highly optimized oceanic and coastal operational forecast in the waters of the Basque Country (southeastern Bay of Biscay); (2) develop and implement an online validation capability to assess the performance of forecasts and compare it with that obtained using Copernicus Marine Service products; and (3) promote close cooperation for the operational exchange of data on ocean currents with the Spanish Maritime Safety and Rescue Society (SASEMAR) and the definition of new hydrological indicators with the Basque Water Agency (URA). These objectives will help lay the foundation for a seamless coastal hydrodynamic forecasting service in the southeastern Bay of Biscay and consolidate the use of Copernicus Marine Service products.

Key words: Bay of Biscay, Copernicus Marine Service, EUSCOMvu, Hydrodynamic modelling

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CHARACTERIZATION OF EXTREME EVENTS OVER THE SPANISH MEDITERRANEAN COAST AND EVALUATION OF PREDICTION MODELS

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Abstract: Since the second industrial revolution, the increase in greenhouse gases gave rise to the concept we now know as Global Warming, a fact that is causing discernible changes in global temperature patterns, affecting atmospheric dynamics, and influencing the ocean-atmosphere interface. This has resulted in rises in mean sea level and variations in current patterns as well as wave action, having direct impacts on continental climates. These changes are significant as, coupled with the growth of coastal populations centers, they are increasing the exposure of coastal areas to natural disasters, highlighting the potential for extreme weathers events. An example has been the episodes of isolated high-level atmospheric depressions (DANAs) that occurred during 2019 and early 2020 on the Mediterranean coast of south-eastern Iberian Peninsula. Therefore, a greater understanding of the physical processes governing these atmospheric systems and their maritime impact is required, along with improvements in prediction and modelling systems, in order to develop adaptative responses capable of mitigating potential future damages. Under these premises, the present study aims to validate different wave models offered by the Copernicus Marine Environment Monitoring Service and analyze the mentioned events from an oceanographic perspective, focusing primarily on wave patterns generated by these atmospheric situations in the western Mediterranean basin.

Key words: Extreme events, Wave models, Mediterranean basin, DANAs

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OPERATIONAL OBSERVATIONS OF COASTAL CURRENT CONVERGENCE STRUCTURES DRIVING FLOATING MARINE LITTER AGGREGATIONS IN THE SOUTHEASTERN BAY OF BISCAY

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Abstract: The southeastern Bay of Biscay has been described as a "dead end" for Floating Marine Litter (FML), often accumulating along small-scale linear streaks. Coastal Current Convergence Structures (CCS), often associated with vertical motions at river plume edges, estuarine fronts, or other physical processes, can be at the origin of the accumulation. Understanding the formation of CCS and their role in the transport of marine litter is essential to better quantify and to help mitigate marine litter pollution. The Lagrangian framework, used to estimate the Finite-Size Lyapunov exponents (FSLE) and the Finite-Domain Lagrangian Divergence (FDLD), has proved very effective for identifying CCS in the current velocity field. However, the quality of CCS identification depends strongly on the Eulerian fields used for the computations. In this work, different surface current velocity data sets were used: remotely sensed velocities from the EuskOOS High-Frequency Radar (HFR) network and velocities from three-dimensional model outputs. Two gap-filling and an optimization method, involving the fusion of drifting buoys and HFR velocities, are tested to obtain the best reconstruction of the fine-scale structure of the current velocity field, reducing the mean Lagrangian error by 50%. Moreover, since a fraction of FML is buoyant and its motion can be driven also by windage, computations are also conducted considering the additional drag force of wind on FML trajectories and Lagrangian quantities. Our results suggest that the wind has a significant influence on the FML distribution and accumulation paths in the study area. Different locations of barriers to transport were obtained, depending on the wind regime and windage coefficients considered. Above 3% of windage, FML is not accumulated in CCS but tend to escape the domain or beach.

Key words: Current convergence structures, High-Frequency Radar, Surface drifters, Lagrangian metrics, Wind drift factor.

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SMALL, SUBMESOSCALE AND MESOSCALE PROCESSES

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SUBMESOSCALE SYMMETRIC INSTABILTIES AND MIXING PROCESSES IN FRONTAL SYSTEMS

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Abstract: Submesoscale symmetric instability (SI) in the ocean interior may contribute to water mass modification and mesoscale energy. The density front with geostrophic shear initiates SI, leading to onset of secondary shear instability, dissipation of geostrophic energy, and turbulent mixing. We explore the impact of parameterizing shear-driven mixing on the representation of diapycnal mixing in different density frontal systems. The parameterization is based on identifying unstable regions through a balanced Richardson number criterion.
We assume that the potential energy extracted from the large-scale flow is equivalent to the kinetic energy associated with symmetric instability, which dissipates through shear mixing. As ocean models advance to resolve mesoscale eddies and fronts but not the submesoscale phenomena they host, it becomes crucial to parameterize submesoscale instabilities by integrating isopycnal slumping with diapycnal mixing.

Key words: Submesoscale Symmetric Instability, Shear Mixing, Mesoscale Eddies, Frontal Systems

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GLOBAL TRENDS IN EDDY KINETIC ENERGY FROM ALTIMETRY: ARE THE OCEANS BECOMING MORE ENERGETIC?

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Abstract: Ocean mesoscale variability, a key component of the climate system, influences ocean circulation and heat, gas, carbon and nutrient distribution. Trends on Eddy Kinetic Energy (EKE), a metric measuring its intensity, are investigated using two products constructed from 30 years of altimetric observations. Statistically significant positive trends in globally-averaged EKE reveal a strengthening of 1-3% per decade. Regions of intense mesoscale activity become more energetic than other areas. Robust positive EKE trends are observed in the Kuroshio Extension and the Gulf Stream, with remarkable EKE increases of ~50% and ~20%, respectively, over the last decade. Our study opens a new question into how the observed Gulf Stream strengthening impacts the AMOC, and challenges existing climate models emphasizing the necessity for improved small-scale ocean process representation.

Key words: Physical Oceanography, Mesoscale, Altimetry

EVALUATING UPPER-OCEAN STRATIFICATION IN CMIP6 MODELS

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Abstract: In the context of global warming, the impact of increasing ocean surface temperatures on ocean stratification and mixing is crucial. Recent studies have introduced a new paradigm in our understanding of this relationship, revealing that surface warming is not definitively linked with a more stratified ocean (Somavilla et al., 2017; Sallée et al., 2021). This points to a critical gap in our knowledge of the ocean's interior response to climate forcing, which, up to date, has never been examined in modern coupled climate models. Such absence may contribute to their poor performance in accurately represent ocean surface temperature evolution, particularly critical in tropical regions. Here, we address this necessity by implementing a comprehensive evaluation of upper-ocean stratification in historical simulations from a representative number of CMIP6 models. The ocean's water column is characterized by fitting vertical density profiles based on an analytical one-dimensional model through the sharp homogenization/diffusive retreat (SHDR) algorithm (Gonzalez-Pola et al., 2007). This analysis offers an integrated solution that incorporates various measures of stratification, better representing the ocean's vertical structure. The resulting fields of different stratification parameters, such as pycnocline slope and maximum stratification depth, are compared with observations derived from Argo profiles on a global scale. Additionally, the results serve to examine the spatiotemporal variability of upper-ocean stratification specifically associated with major modes of tropical climate variability such as ENSO and Atlantic Niño.

Key words: Ocean stratification, Climate variability, Ocean-atmosphere interaction, CMIP6

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EXPLORING INTERNAL SOLITON SIGNALS AND THEIR EASTWARD TRAVEL IN THE ALBORAN SEA. THE IMPACT OF SUBINERTIAL FORCING AND FORTNIGHTLY VARIABILITY

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Abstract: Internal waves, ubiquitous in highly stratified water bodies, profoundly influence the hydrodynamics of oceans and lakes. This study focuses on unraveling the complex dynamics of internal solitons within the intricate setting of the Strait of Gibraltar (e.g., Vázquez et al., 2008; Bolado-Penagos et al., 2023) and the adjacent Alboran Sea (Dessert et al., 2022). Specifically, we investigate the eastward propagation of internal soliton signals originating from the Camarinal Sill, extending to the continental slope of the northwestern Alboran Sea. This analysis encompasses an exploration of how subinertial forcing influences the release of solitons into the marine environment, previously identified by Vázquez et al. (2008). Internal soliton activity is evaluated through a combination of in-situ data, including current and temperature measurements, High-Frequency Radar observations, as well as numerical modeling and analytical methods. Through this integrated analysis, we uncover compelling fortnightly variability in both the occurrence and amplitude of solitons over the continental slope of the northwestern Alboran Sea, particularly evident during spring tides in contrast to neap tides. Remarkably, observed arrival times of solitons demonstrate fluctuations ranging from 14 hours during spring tides to 20 hours during neap tides. However, to understand the dynamics of these fluctuations in travel times, it is essential to consider role of subinertial variability induced by atmospheric forcing. Moreover, atmospheric influences, characterized by complex interactions, significantly impact the flow dynamics within the Strait of Gibraltar and the mesoscale patterns within the Alboran Sea.

Key words: internal waves, Strait of Gibraltar, atmospheric forcing, Alborán Sea

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VARIABILIDAD DEL NIVEL MEDIO DEL MAR EN EL GOLFO DE CÁDIZ

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Abstract: El estudio de la variabilidad del nivel medio del mar debe ser visto como un factor ambiental clave, ya que su impacto en las áreas costeras actúa como un indicador del cambio climático, permitiendo así la evaluación de la vulnerabilidad de dichas zonas y la anticipación de los riesgos asociados con el aumento del nivel del mar, especialmente en las zonas costeras del Golfo de Cádiz. El propósito de esta investigación es analizar la variabilidad y la tendencia del nivel medio del mar en el Golfo de Cádiz desde el 1 de enero de 1993 hasta el 31 de diciembre de 2020. Para llevar a cabo este estudio, se analizará el nivel del mar registrado por mareógrafos en los puertos de Bonanza y Huelva, pertenecientes a la Red de Mareógrafos de Puertos del Estado (REDMAR), así como datos de altimetría por satélite disponibles en la base de datos del "Copernicus Marine Environment Monitoring Service" (CMEMS). Los datos altimétricos tienen una resolución espacial de 0,25° x 0,25°. Con base en estos conjuntos de datos, se trabajará con promedios mensuales y anuales. Este análisis permitirá estimar la tendencia y la variabilidad espacio-temporal del nivel medio del mar en el Golfo de Cádiz.

Key words: Presión atmosférica, nivel medio del mar, respuesta isostática, LIB, tendencia.

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SPATIO-TEMPORAL PATTERNS OF CONNECTIVITY AND DISPERSAL IN THE ADRIATIC SEA

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Abstract: Hydrodynamic features largely control the dispersal and connectivity of marine populations, especially in highly energetic areas determined by currents, river flows, and meteorological variability. Understanding how species interact with these physical processes is critical for effective management of threatened populations and identification of areas in need of conservation efforts. This study focuses on the hydrodynamics regulating connectivity in the Adriatic Sea, a shallow and semi-enclosed basin widely recognized as one of the most important areas for conservation in the Mediterranean Sea. A high-resolution hydrodynamic model coupled with a lagrangian tracking module serves as the numerical tool. Lagrangian particles in this network, representing eggs and larvae with typical biological characteristics of generic marine organisms inhabiting the region, are released throughout the basin at different times during a test year to identify the most likely pathways of individual dispersal. Presented through a traditional connectivity matrix and a novel retention clock matrix, seasonal connectivity emerges as the most influential factor, with increased variability and reduced efficiency in winter compared to summer. The duration of the pelagic larval stage is a critical factor in dispersal, as revealed by a numerical sensitivity test. The potential implications of the results for better assessment and management of highly valued marine species in the basin are highlighted.

Key words: numerical modeling, hydrodynamic connectivity, Retention Clock Matrix

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VARIABILITY OF THE PHYTOPLANKTON COMMUNITY IN RESPONSE TO THE OCEANOGRAPHIC CONDITIONS IN THE RÍA DE MUROS-NOIA (NW SPAIN)

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Abstract: The ría de Muros- Noia, located in the northwest Iberian coastal upwelling system, is characterized by particular conditions that differentiate it from the rest of the Rías Baixas. Among this, the higher oceanic influence from the lack of an island on its entrance and the low anthropogenic pressure due to a lower population density and industrial activities, makes it a perfect system to compare with the more industrialized Rías.
In order to characterize the biogeochemistry of the ría de Muros-Noia, a campaign was carried out during february 2024, where the physical and chemical conditions of the water column were analyzed, as well as the planktonic community < 200µm. Vertical profiles were made for the hydrographic variables, and samples for fractionated chlorophyll, photosynthetic pigments (by HPLC) and for the planktonic community (microplankton and nanoplankton by microscopy and picoplankton by flow cytometry) were taken at discrete depths.
During the sampling period, two distinct phases in the hydrographic conditions were observed. First, there was a period favorable to downwelling, corresponding to lower salinity levels of continental origin at the surface. Subsequently, there was a favorable upwelling period with higher salinity values of oceanic origin.
These changes in hydrography have generated quick responses from the biological community. During the study days, a decrease in chlorophyll levels was observed over time. In the first days, corresponding to the downwelling phase, organisms larger than 2 µm predominated, corresponding mainly to diatoms larger than 20 µm and small dinoflagellates. However, a change occurred later, with overall decrease in abundance with predominance of small size fractions (picoautotrophs and small diatoms).
This study shows a clear structure and a rapid response of the phytoplankton community to the hydrographic conditions even during the winter period.

Key words: phytoplankton, upwelling system, ría de Muros-Noia.

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DETERMINATION OF BENTHIC OXYGEN FLUXES IN A COASTAL UPWELLING SYSTEM USING THE AQUATIC EDDY COVARIANCE TECHNIQUE (RÍA DE MUROS-NOIA)

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Abstract: The Ría Muros-Noia, located in the northwest Iberian coastal margin, belongs to the Rías Baixas. It is characterised by low anthropogenic pressure and great oceanic influence due to the absence of island at the entrance. Therefore, it meets unique conditions compared to the rest of the Rías.
NEMUNO project aims to quantify the pelagic and benthic domain metabolism along the coast-ocean gradient in the Ría Muros-Noia. In this framework, the main objective of the present study is to determine benthic metabolism based on benthic oxygen fluxes in a muddy sediment in the Ría Muros-Noia during winter season.
Intensive sampling of water column was performed using CTD casts. Meanwhile, benthic fluxes were measured using an Aquatic Eddy Covariance (AEC) deployment in a relatively shallow position, approximately 15 m deep. The AEC technique allows a much higher frequency of benthic fluxes compared with traditional techniques as benthic chambers.
Winter sampling was carried out during February 2024. The hydrographic conditions responded to the existing wind conditions, hence two different phases were observed. During the first phase, low salinities and susceptibility to coastal downwelling were recorded. On the other hand, during the second phase, the water column experiences a decrease in temperature and an increase in salinity from the influx of ocean water, since an upwelling was taking place.
Taking these conditions into account, a comparison has been done between the data obtained through the AEC and the benthic chamber. Preliminary results show that at all times oxygen fluxes were towards the sediment, indicating dominance of respiration in the benthic metabolic balance.

Key words: Benthic fluxes, Aquatic eddy covariance, Benthic chamber, Dissolved oxygen, Muddy sediments.

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M. López-Haslett would like to thank the IIM – CSIC for granting her the JAE Intro Fellowship (Programa Junta para la Ampliación de Estudios – JAEINT_23_00015).

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ASSIMILATION OF OBSERVATIONS AND SHORT-TERM FORECASTS OF RIVER RUNOFF IN THE EUSCOMVU COASTAL MODEL

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Abstract: The large variability of the 3D mesoscale oceanic circulation patterns observed in the Bay of Biscay is driven by the interaction between Atlantic and Mediterranean origin waters, global scale teleconnections such as the NAO index, atmospheric processes and continental freshwater discharges from Spanish and French rivers. The predictive capability of coastal models, such as the EUSCOMvu model for the southeastern Bay of Biscay, can be improved by assimilating high temporal and spatial resolution observations. Most of the rivers flowing into the southeastern Bay of Biscay are small, short and torrential, with a fluvial regime and an average discharge ranging between 1.5 and 22.5 $m^3 s^{-1}$. In addition, the Adour River on the neighbouring French coast, which follows a nivo-pluvial regime, is the river with the highest discharge values (~1,500 $m^3 s^{-1}$). River plumes play a key role in the biological, geochemical and physical functioning of the coastal zone, as well as being the main transport mechanism for nutrients, sediments, and land-based chemical and microbiological pollutants. Therefore, near real-time observations and short-term empirical forecasts of river runoff are collected/generated daily and assimilated into the EUSCOMvu model to reflect the evolution of river plumes in the forecast. Here we show the operational steps to assimilate this data into the EUSCOMvu model and the improvement of the simulation results obtained. The increased confidence gained will allow the coastal model to be used for applications such as bathing area management, litter monitoring and water quality assessment.

Key words: EUSCOMvu, Bay of Biscay, Coastal model, River plume, River runoff

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IX INTERNATIONAL SYMPOSIUM ON MARINE SCIENCES

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~

LARGE SCALE CIRCULATION

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TRANSPORT VARIABILITY OF THE NORTH ATLANTIC DEEP WATER IN THE SOUTH ATLANTIC

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Abstract: The aim of the SAGA (South Atlantic GAteway) project is to quantify and monitor the return limb of the Atlantic Meridional Overturning Circulation (AMOC). As part of this project, three moorings have been deployed along the 10ºW in the South Atlantic from 21º to 31ºS. This area has been recently identified as the Atlantic Gateway, serving as an observatory for both the starting and returning branches of the AMOC. Each mooring includes two MicroCat Conductivity-Temperature (CT), two Nortek Aquadop, four Anderaa SeaGuard, an Anderaa RCM 11 and one RDI Acoustic Doppler Current Profilers (ADCP). Data were collected for 2 years and one month in the approximate depth range from 1950 to 4000 m, thus characterizing the North Atlantic Deep Water (NADW) along the Mid-Atlantic Ridge (MAR). This study focuses on the transport variability through the MAR in deep layers, as well as the technical analysis, placing emphasis on the methodology used to process the raw data, ensuring coherence within and among datasets, thereby guaranteeing data quality.

Key words: SAGA, AMOC, NADW, Transport, South Atlantic.

Acknowledgments: This study was supported by the SAGA (RTI2018-100844-B-C31, RTI2018-100844-B-C32 and RTI2018-100844-B-C33) and SACO (PID2022-139403NB-C21 and PID2022-139403NB-C22) projects funded by the Ministerio de Ciencia, Innovación y Universidades of the Spanish Government, and Feder. This study was conducted by A. Alcalá-Verdugo as part of his work at IOCAG, in the final degree project in Marine Sciences, at the University of Las Palmas de Gran Canaria.

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TEMPORAL VARIABILITY OF THE CANARY CURRENT FROM PIES DATA

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Abstract: Five Pressure Inverted Echo Sounders (PIES) have deployed north of the Canary Islands spanning from the African slope to La Palma Island. A Gravest Empirical Mode (GEM) has been applied to the acoustic travel time from the PIES to infer the time variability of temperature and salinity in the water column and, therefore, the baroclinic component of the flow thorough the thermal wind equation. The barotropic component has been estimated from the bottom pressure and reference velocities from a numerical model. The main result is that the time variability of the Canary Current is well represented through PIES data.

Key words: Canary Current, Gravest Empirical Mode, PIES

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A SYNOPTIC VIEW OF THE LARGE-SCALE CIRCULATION AT DENMARK STRAIT DURING THE FARDWO-DS1 CRUISE

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Abstract: The Nordic Seas are key to the formation of the dense, deep water that drives the thermohaline circulation. Strong air-sea heat loss drive the formation of deep water by triggering convection. This dense water is then stored in the deep areas of the Nordic Seas. The Iceland-Scotland Ridge topographically prevents this flow of moving southward. At the western side of the ridge, Denmark Strait (DS) is a narrow path between Iceland and Greenland where this dense water overflows the ridge, forming the Denmark Strait Overflow Water (DSOW). This deep flow forms the lower limb of the Atlantic Meridional Overturning Circulation (AMOC) and thus it plays a determining role in the planet's climate. The FAR-DWO project is an interdisciplinary project that aims to understand the formation, propagation, and seafloor impact of dense water overflows in the DS and also in the Cap de Creus submarine canyon in the Mediterranean Sea, where cascading of dense waters also occur. In summer 2023, a high-resolution hydrographic cruise took place between 64.5ºN and 67.5ºN. This study describes the large-scale circulation from the DS to roughly 200km downstream and shows exchanges between the Greenland continental shelf and the deep Irminger Basin.

Key words: Denmark Strait, Denmark Strait Overflow water, Atlantic Water, Kangerlussuaq Glacier

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CONNECTIVITY OF THE WEDDELL SEA BOTTOM WATER PLUME

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Abstract: We investigate the along-stream connectivity of the bottom water plume from its source regions in the southern Weddell Sea (Filchner Trough) to its most important gateway across the South Scotia Ridge (the Orkney Passage), where a fraction of it escapes into the Atlantic abyss in the form of Antarctic Bottom Water (AABW). We first selected key instruments from 4 mooring arrays which were deployed at different locations of the Weddell Sea: 1) on the continental slope just outside of the Filchner Trough, 2) off the tip of the Antarctic Peninsula, 3) south of the Orkney Plateau and 4) across the Orkney Passage. We then constructed long time series of conservative temperature, absolute salinity, neutral density and along-slope current velocity, and applied a lagged cross-correlation analysis between the different time series. From this analysis, we obtained the specific time lags that maximized the cross-correlations of the oceanographic properties measured at the different mooring arrays. We assume that these time lags inform on the representative timescales of the flow of the bottom water plume between the different mooring arrays. Our results indicate the existence of a fast (~270 days) and a slow (~400 days) connection between the source and export regions of the bottom water plume, depending on the depth range at which the plume flows. We also found that the bottom water plume gains buoyancy along its pathway and that its flow speed decreases by ~40% between the tip of the Antarctic Peninsula and the Orkney Passage. This analysis will be complemented with an on-going Lagrangian analysis of the connectivity using a high-resolution (~2km at the continental slope) regional configuration of the Finite volume Sea ice Ocean Model (FESOM2).

Key words: Bottom water plume, AABW, Weddell Sea, Antarctica, AMOC.

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IX INTERNATIONAL SYMPOSIUM ON MARINE SCIENCES

POSTER COMMUNICATIONS ~ OCEAN METHODS: INSTRUMENTATION, REMOTE SENSING AND NUMERICAL METHODS

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WAVE REGIME IN LANGOSTEIRA: OBSERVATIONS AND WAVE MODEL

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Abstract: A wave regime constitutes the statistical evaluation of all the conditions (wave height, period, direction…) of the wave field in a specific place or region during a specific period of time with the objective of defining those sea states (combinations of wave parameters) most likely to be found in those places at those times (Pde, 2022).
To carry out this type of analysis, the data of the variables that define the sea states are adjusted to a theoretical distribution (MeteoGalicia, 2014). This theoretical distribution allows obtaining statistical parameters such as the mean, standard deviation, percentiles or the probability that a certain value of that variable is not exceeded in the average year for the study area, this being useful for decision making in the design of marine and coastal infrastructure, risk management and security.
To perform the study of the wave regime in Punta Langosteira (NW Galicia, Spain), between 2013 and 2021, two datasets were used: observational data provided by the buoy Langosteira II, which belongs to REDCOST from Puertos del Estado (PdE, 2024), and simulations from the SWAN Model ran under the STRAUSS project by Meteogalicia with some specific and new configurations of the model (Barreiro, 2023).
These two datasets were adjusted to the normal, lognormal, Weibull and Gumbel distributions, choosing the best adjustment to obtain the statistical parameters of interest. Some comparisons between the observations, modelled data and adjusted data were carried out to assess the performance of the wave numerical model at Punta Langosteira. A wave model that validates well with in situ observations will allow us to extend both the spatial and temporal coverage of the sea regime near Punta Langosteira.

Key words: wave regime, wave model validation, wave buoy observations.

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COMPARISON AND VALIDATION OF DIFFERENT SWAN MODEL CONFIGURATIONS WITH INSTRUMENTAL DATA IN THE RÍA DE VIGO

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Abstract: Waves are a major factor in the movement of the ocean, in the transport and distribution of mechanical energy over long distances and sediment dynamics in coastal areas. Broadly speaking, the wind-generated gravitational waves can be divided into two types based on their frequency: the local wind sea and the swell. The local wind sea consists of high-frequency, low-energy waves formed locally, while the swell consists of low-frequency, high-energy waves formed over large distances. In the Ría de Vigo, these two types of waves can be seen, with one of them being predominant depending on the conditions. As waves are such an important element in the dynamics of coastal areas, it is essential to be able to predict and measure their characteristics. Therefore, the aim of this study is the validation of three configurations (two from Meteogalicia and one from Puertos del Estado) of the SWAN numerical wave propagation model applied to the Ría de Vigo. The validation has been done for the total wave, without differentiating between sea and swell, and by measuring it with three different types of instruments (pressure sensors, ADCP and Miros Radar from IIM-CSIC and Puertos del Estado, respectively) at two points in the ria. Once the modelled and observed records were obtained from the corresponding institutions, they were processed or purged of anomalous data and, using MATLAB software, were represented by scatter plots and Taylor plots for comparison and validation. The time range of the series allowed us to describe the seasonal variability of the waves with important differences between the winter and summer seasons. In addition, a good performance was observed in the improved configuration of SWAN by Meteogalicia, with respect to its original configuration, becoming comparable to the configuration implemented by Puertos del Estado.

Key words: Wave regime, Wave models, Model validation, Instrumental observations

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MONITORING FRINGING SALT MARSH SHORELINES: INSIGHTS FROM SATELLITE REMOTE SENSING

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Abstract: Salt marshes are critical wetland ecosystems whose widespread degradation and loss is being caused by natural and human-induced pressures (Lopes et al., 2020, 2021). Continuously monitoring their extent is crucial for protecting and restoring these ecosystems (Blount et al., 2022). Though moderate-resolution satellite data can accurately detect most of the salt marsh shorelines (Blount et al., 2022; Lopes et al., 2019, 2020, 2021), detecting edges of fringing salt marshes remains challenging. This study aims to assess shoreline changes of three fringing salt marshes in the Aveiro lagoon (Portugal) by processing and analysing satellite imagery, and to explore how the detected changes have affected the ecosystem. Remote sensed data from Landsat-5 (TM), Landsat-7 (ETM+), and Sentinel-2 (MSI) satellites were used to assess salt marsh shoreline changes between 1984 and 2022, and after analysing changes a set of recommendations aimed at protecting and ensuring the sustainability of the salt marshes against future threats were formulated. Results show that moderate-resolution satellite data can effectively determine the extent of fringing marshes. The salt marshes of the Ílhavo and S. Jacinto Channels evolved similarly, presenting shoreline stability before 2000 followed by retreats. Across four decades of study, average retreats of 66.23 ± 1.03 m and 46.62 ± 0.83 m were observed, respectively. In contrast, the salt marsh of the Mira Channel exhibited retreats before 2000, followed by progressions after this year, resulting in an average 2.33 ± 1.18 m advance until 2022. The decrease in salt marsh areas has led to the loss of important ecosystem services like coastal protection, habitat loss, and reduced carbon sequestration. Moreover, this study highlights that urgent action is needed to protect the erosion of the salt marsh front and promote its growth within the lagoon, as salt marsh inland migration is impeded by physical barriers.

Key words: Landsat and Sentinel-2 archives, DSAS, salt marsh dynamics, shoreline erosion, vegetation indices.

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MARINE HEATWAVES IN THE BALEARIC SEA

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Abstract: Marine heatwaves (MHWs) are defined as local, discrete periods of anomalous ocean warming. These phenomena have been increasing in frequency and intensity due to global warming, leading eventually to a saturation point. This is why there have been efforts to develop new ways of defining what a marine heatwave is. The motivation behind this change is to be able to differentiate between long-term temperature trends and extreme events. The Mediterranean Sea serves as a good backdrop for comparing different MHW detection methods due to its rapid response to climate change, with higher warming trends than the global ocean. This study focuses on the Balearic Sea, a subregion of the western Mediterranean that surrounds the Balearic Islands. In the classic determination method (Hobday et al., 2016), a MHW event occurs when temperature exceeds the 90th percentile of the distribution at each point of a fixed climatology (1982-2002). In this work, we compare the classic determination method with two novel methodologies. The first method consists in changing the fixed baseline for a moving climatology (Rosselló et al., 2023), only considering the 20 years before the year under study. The second method consists in detrending the temperature data before the detection of MHWs (Martínez et al., 2023). The analysis of MHWs using different detection methods reveals distinct results. All three methods detect major MHW events in 2022 and 2023. However, the fixed baseline method shows a significant increase in MHW frequency and duration over time not detected by the other methods. This study highlights the need to select the method aligned with intended impact assessments, which will depend on certain species or communities' adaptation abilities. Species that possess higher adaptability will benefit from studies performed with a moving baseline, while a fixed baseline will be a better option for those who do not.

Key words: Marine heatwaves, climate change, Balearic Sea, sea surface temperature, extreme event

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SEAS5 SKILL OF ENSO IMPACT ON BENGUELA COASTAL UPWELLING SYSTEMS

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Abstract: Using seasonal predictions from the ECMWF SEAS-5 System, we analyze the relationship between ENSO and upwelling indices in the regions of Benguela.
We find that reanalysis show correlations between El Niño and the Southern Oscillation phenomenon (ENSO) and upwelling indices in February-March-April. The system performs a very accurate prediction in the Tropics of the Sea Surface Temperature (SST) and wind stress variables leading to a good simulation of El Niño, but to a less realistic simulation of Benguela upwelling phenomenon due to problems in the reproduction of the global atmospheric teleconnection pattern related to ENSO.
The simulation of the connection between ENSO and Benguela depends on the latitude studied: While Northern Benguela Eastern Boundary Upwelling System (EBUS) is related with ENSO, Southern Benguela EBUS appears to be related to winter Atlantic Niño.

Key words: Seasonal Foercast, Teleconnections, ENSO

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OceanUCA: ADAPTATION AND CONSOLIDATION OF AN OPERATIONAL SYSTEM TO IMPROVE THE OBSERVATION AND FORECASTING OF OCEANOGRAPHIC AND ATMOSPHERIC PROCESSES IN THE COAST OF ANDALUSIA

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Abstract: The OceanUCA project focuses on the development of an operational platform to integrate and update already existing operational tools (such as the OceanMap UCA system developed by the group in the framework of previous projects), including now new observational systems and higher-resolution numerical model products.
The methodology of the project aims to improve and adapt the computational resources to respond to the current societal needs and to the higher computational time demand of the new models. This is mainly motivated by the growing spatiotemporal resolution of the models used to effectively respond to specific environmental coastal problems (e.g., oil splits, wrecks, marine and atmospheric heat waves, extreme events tracking, etc.). OceanUCA will be based on tools generated from observational data and numerical model outputs (both atmospheric and hydrodynamic), specifically designed, and configured to reach their maximum resolution in the coast of Andalusia (Southern Spain). Besides, the new operational platform OceanUCA will be coordinated with other Spanish and European operational oceanographic services already existent.
The aim of the project will serve to detect specific effects associated with climate change, to enhance the environmental protection of the area, to facilitate the conservation of natural resources, to develop early-warning products, to improve the short, medium, and long-term forecasts, and to help using adequately the set of ecosystem services that the coastal environment offers. Besides, we hope the new platform will help the decision-making from institutions and third parties through the real-time (and forecast) monitorization of marine and atmospheric processes in the coast of Andalusia.
In this work, we will show details about the platform, including overviews of the hydrodynamic and atmospheric models that will be used and the associated observations, that will be also extended in the frame of related projects currently developed.

Key words: operational system, oceanography, meteorology, models, observations

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THE ONSET OF AN UPWELLING FRONT IN THE SW IBERIAN UPWELLING SYSTEM UNVEILED WITH A LIGHT AUTONOMOUS UNDERWATER VEHICLE (AUV): A STUDY CASE

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Abstract: Oceanographic fronts, sharp boundaries between waters with distinct environmental properties, play a crucial role in biogeochemical processes and primary production, serving as hotspots for marine ecosystem services. In September 2022, within the framework of the EUROFLEETS+ project "*Climate change impact on ocean fronts ecosystems: the case of the Iberian Upwelling System (SINES)"*, a Light Autonomous Underwater Vehicle (LAUV) was deployed to investigate the onset of an upwelling front in the Southwest Iberian Peninsula.

LAUV deployment and operations took place between September 17th and 18th from the port of Arrifana, Aljezur. The LAUV Explore-4 conducted over 100 high-resolution immersion profiles between the surface and 100 meters depth. The AUV transect followed the same track as the research vessel R/V Sarmiento de Gamboa, which went from the coast to the open ocean. During its nearly 36 hours of autonomy, the LAUV successfully executed its mission, gathering valuable data on temperature and salinity for understanding the dynamics of the onset of an upwelling event. The web application Ripples was used to supervise and raise awareness of the LAUV concerning marine traffic and other layers of information. Real-time data visualization and continuous interaction between on-board oceanographers and remote operators facilitated efficient interaction with LAUV operations, enabling a 40-kilometer transect to be completed back and forth.

The collected data are available online in NetCDF format, accompanied by comprehensive metadata (Fontela et al., 2022). This study showcases the utility of autonomous underwater vehicles in characterizing oceanographic fronts. It highlights the importance of real-time data acquisition and collaboration in advancing our understanding of complex upwelling front ecosystems.

Keywords: ocean observations, coastal ocean, autonomous underwater vehicle, upwelling front

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REMOTE EFFECTS OF INTERNAL WAVES GENERATED IN THE STRAIT OF GIBRALTAR ON POPULATIONS OF DENDROPHYLLIA RAMEA IN PUNTA LA MONA, TROPICAL COAST

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Abstract: Internal waves are a recurrent phenomenon in the Strait of Gibraltar: the convergence of Atlantic and Mediterranean waters, with their different salinity and temperature characteristics, along with the presence of the Camarinal sill, allows for the formation of a hydraulic jump that displaces the two layers of different density water as a submerged wave traveling towards the Mediterranean waters. The presence of these internal waves can be demonstrated in various ways, and in our work, we investigated their arrival at the coast of Granada through three strategies. Firstly, we used synthetic aperture radar satellite images to visually confirm the arrival of these waves at the coast. The images we obtained confirm, along with the data collected at the mooring points, that this phenomenon is indeed occurring. Finally, we used an empirical model for predicting the generation of internal waves developed at the University of Cádiz. With this, we aimed to confirm that the signals recorded at the mooring points of these internal waves match the expected arrival times of waves generated at the Camarinal sill. The arrival and existence of these waves are important for maintaining populations of Dendrophyllia ramea, the candelabra coral. These waves are associated with vertical transport and suspension of particulate material, which is one of the main sources of food for these corals, which otherwise could not survive in this area or at the depth they are found. Understanding the mechanisms behind the generation and propagation of internal waves is not only a matter of basic research but is also relevant for understanding community dynamics on coral reefs.

Key words: Candelabra coral, Internal waves, tropical coast.

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