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Environmental variability and hazards in the coastal and continental shelf regions of South America and the Caribbean

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This special collection of articles aimed to improve our understanding of the physical, biological, chemical, geological and biogeochemical processes of the coastal and continental shelf regions of South America and the Caribbean. We were particularly interested in broadening our knowledge on the patterns of natural variability of the ocean-atmosphere-continent system in our study region and on the description of natural and human-induced hazards or accidents and their effects on the environment and biota. The South Atlantic and Western Tropical Atlantic oceans are known to play important roles in seasonal and larger-scale climate variability in South and Central America. At the same time, the effects of growing anthropogenic influence on the coastal seas and transitional environments via marine pollution and urban expansion have been little studied, although they deeply impact coastal populations. Recent episodes of human-generated disasters in coastal and transitional environments, including major oil spill events off the coast of northeastern Brazil and in the Gulf of Mexico, reinforce the need for a better understanding of these environments and the ongoing natural and anthropogenic threats to marine life in these places. Climate variability and change also directly affect coastal regions. In the tropics, for instance, the combined and inter-basin connections between the Atlantic and the Pacific oceans during the positive (El Niño) and negative (La Niña) phases of the El Niño – Southern Oscillation (ENSO) phenomenon forced remote positive or negative precipitation anomalies far beyond coastal regions in the Americas and worldwide.

In the subtropical South Atlantic, sea surface temperature anomalies (SSTA) that occur on the continental shelf have a direct impact on fish recruitment and, consequently, on subsequent catches of pelagic fish, impacting the economy of fishing communities and the fishing industry. In association with SSTA and other oceanic phenomena on different temporal and spatial scales, ocean-atmosphere coupling processes are the major forcing mechanisms for modulating surface wind, precipitation, air-sea fluxes and other ocean-atmosphere interaction variables that can impact the coastal regions of South and Central America. Heat waves, atmospheric blocking, the generation and movement of extra-tropical and tropical cyclones, hurricanes and storm surges are some of the known natural hazards that affect coastal regions and originate at sea. Over short or long periods of time, most

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of these phenomena also affect the coastal environment via coastal erosion. On longer time scales, the known impacts of climate change affect the World Ocean via rising sea levels and ocean acidification, imposing new threats to coral reefs and transitional environments such as estuaries, salt marshes, mangroves and others. Overall, we still do not have an appropriate understanding of how all these processes occurring in the Southern and Western Tropical Atlantic oceans on different spatial and temporal scales affect the coastal and continental shelf regions.

This special article collection from Ocean and Coastal Research contains seven original research articles and two brief communications produced by 56 different authors from 20 different institutions in Brazil and another 6 institutions from Argentina, Spain, Germany, the Czech Republic and the United States. These contributions are the result of state-of-the-art research and focus on a range of subjects related to the physics of the ocean and the ocean-atmosphere coupled system; the biogeochemistry of the ocean; the characterization of the biomass or abundance of coral reefs, picoplankton and cyanobacteria and their related environmental variability, and the effects of polycyclic aromatic hydrocarbons and oil spills on specific species or marine protected areas in Brazil.

In this special issue of Ocean and Coastal Research, readers will find an interesting new study by Soares et al. (2023a) investigating how precipitation over the Brazilian state of Maranhão responds to ENSO-forced zonal teleconnection and its impacts on sea surface temperature patterns in the Western Equatorial Atlantic Ocean. Affe et al (2023), on the other hand, computed air-sea fluxes of carbon dioxide (CO_2) in five different marine ecoregions of the Brazilian continental margin from 4 °S to 34 °S. These authors used surface water data from the Surface Ocean CO_2 Atlas (SOCAT v2020) from 1991 to 2018 and noticed that air-sea CO_2 fluxes depend on the biogeographic characteristics of the study area, which, in turn, depends on the effects of local upwelling, freshwater outflow from rivers, water mass and the variability of currents in the different ecoregions. The authors also observed a positive trend in the partial pressure of CO_2 in water and air during the study period and emphasized the meridional gradient in the direction of air-sea fluxes, in which the northern areas off the coast of Brazil tend to be sources of CO_2, while the southern regions tend to be sink areas for atmospheric CO_2.

Santos and Garcia (2023) used new data collected by a meteoceanographic buoy belonging to the Brazilian Coastal Monitoring System (SiMCosta) to study coastal currents and salinity variability on the inner shelf of southern Brazil at 32 °S. The authors described a high correlation between currents and the winds, emphasizing the predominance of correlated energy peaks in the period from day 3 to day 10, referring to the passage of atmospheric frontal systems in the study area. They also reported a negative correlation between surface salinity and the discharge of Patos Lagoon, especially during the winter period. Patos Lagoon, in southern Brazil, was also studied by Canever et al. (2023), who investigated the relationships between cyanobacterial blooms in the estuarine region of the lagoon with atmospheric variables on scales ranging from weather to climate. The authors also used satellite-derived data (including chlorophyll concentration) and water level data to describe the influence of physical parameters in promoting the growth and accumulation of cyanobacteria inside Patos Lagoon.

Barroso et al. (2023) studied the variability and correlations between phytoplankton biomass and the concentration of inorganic nutrients (phosphate, nitrogen, silicon) in seawater. These authors investigated an area off the Brazilian Semi-Arid Coast (BSC), between 2 °S to 5 °S in the Equatorial Southwestern Atlantic. They used data obtained in situ in July 2019 and remote sensing data from 2003 to 2019. They reported that the spatial variability of nutrient and chlorophyll distributions is unexpectedly heterogeneous and probably influenced by the presence of extensive reefs and sponge gardens at depths of 18 to 30 m, as well as the proximity of the study area to the coast.

Soares et al. (2023b) characterized the marine animal forests (MAFs) located in a turbid-zone reef ecosystem located in the city of Fortaleza, northeastern Brazil, a well-known urban coast in the

Equatorial Southwestern Atlantic Ocean. Although the construction of the port of Fortaleza has affected the marine geomorphology and sediment dynamics of this study region since the mid-19th century, rocky platforms with associated MAFs are still abundant and represent important features of the seabed in the area. Soares et al. (2023b) used scientific diving techniques in June and October 2018 to study the MAFs off the shore of Fortaleza, recording 31 taxa, which were identified down to the lowest taxonomic level (i.e., species, genus, family or order). The most diverse group found among the ecosystem engineers contributing to the complexity of the substrate was that of sponges. This finding coincided with descriptions of coral reefs found in deeper waters near the city of Fortaleza.

Menezes et al. (2023) studied the temporal patterns of picoplankton abundance and metabolism on the west coast of the Equatorial Atlantic Ocean. These authors described that picoplankton are a central element of the global carbon cycle and often dominate oceanic plankton communities, especially at low latitudes. They studied, for the first time, the temporal variation in the abundance and carbon flux of the picoplankton community as well as its environmental drivers, at a coastal station located at 5° 59' 20.7"S, 35° 05' 14.6"W in the Equatorial Atlantic. Monthly samplings were collected in the water from February 2013 to August 2016. The authors reported relative temporal stability in picoplankton dynamics in the study area, despite considerable inter-annual variation, including the influence of the 2015 ENSO event. They also found that picoplankton abundance had a weak relationship with environmental variables, suggesting that other factors, such as biological interactions, may lead to temporal variability in abundance. Heterotrophic bacteria dominated the picoplankton community throughout the study period and among other photosynthetic counterparts, *Synechococcus* showed greater relative importance than picoeukaryotes.

Patire et al. (2023) measured biliary metabolites in various fish species, establishing a baseline for future monitoring programs aimed at evaluating the bioavailability of Polycyclic Aromatic Hydrocarbons (PAHs). These authors presented a study carried out in Santos Bay (SB) and the adjacent Santos Continental Shelf (SCS), Brazil. Bile samples from different fish species were collected in SB monthly from July to December 2005 and on the SCS in August 2005 and February 2006. Liquid chromatography was used to determine the concentrations of the metabolites naphthalene, phenanthrene and benzo[a]pyrene. Despite their high concentrations, the levels of the naphthalene metabolite were in regions of low contamination, while those of the benzo[a]pyrene metabolite were in the same range as those reported in moderately contaminated areas, which may indicate pyrolytic contamination by PAHs. The metabolite data presented by Patire et al. (2023) are important baseline information for the study region, which is highly urbanized and home to several sources of contaminants.

Nunes et al (2023) studied the spread of the largest oil spill accident that happened off the Brazilian coast from August 2019 to March 2020. These authors identified the Marine Protected Areas (MPAs) affected by the oil spill, reporting that the accident direct or indirectly affected 81 MPAs, generating chemical, biological and socioenvironmental impacts in approximately 3% of the 2,659 protected areas currently established in Brazil. The authors presented a map of the MPAs affected by the oil spill and simple statistics of the distribution (%) of records of oil residue in different categories of MPAs, including no-take and multiple-use ones. Multiple-use protected areas (IUCN categories IV–VI) had 422 records, distributed over 29 MPAs. When considering their buffer zones, this number rose to 670 records in a total of 46 MPAs. Among these areas, nine MPAs were hit simultaneously by 20 or more episodes from August 2019 to March 2020. The authors reported that, although estimates suggest that the volume of oil spilled was moderate, the incident affected wide coastal strips, probably producing more damage to MPAs than other cases around the world. The negative impacts generated by this major oil spill negatively affected the environmental protection system in Brazil.

The studies mentioned in this special article collection have significantly improved our understanding of the complex interplay between physical, biological, chemical and biogeochemical

processes in the coastal marine ecosystems of South America, especially those in Brazil. The findings not only advance our scientific knowledge, but also underscore the urgency of comprehending and addressing the continuous threats posed by natural and anthropogenic stressors to coastal environments. We expect this compilation to serve as a valuable resource, inspiring further exploration and research initiatives in marine science and environmental management. We hope that the insights gained from this collection will contribute to informed decision-making and sustainable practices to protect these critical regions for future generations.

Author Contributions

R.B.S.: Conceptualization, Writing – Original Draft

R.M.L.: Writing – Original Draft

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