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Hydrodynamics simulation of a hypothetical oil spill in the Cumuruxatiba Basin (BA) with the MEDSLIK-II model

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ABSTRACT
Oil spills are one of most impactful sources of marine pollution. The damage caused requires knowing the behavior of oil in the marine environment, through studies of prevention, control and mitigation of oil spills. In this study, two climatological simulations were carried out for the Cumuruxatiba Basin, for summer and winter periods, using the MEDSLIK-II oil spill dispersion model. The region was chosen due to its closeness to the Abrolhos National Park and the high environmental risk associated with the oil industry in this region. The main objective was to analyze the impact of ocean circulation on possible oil spills near the Exclusive Economic Zone (EEZ) of Brazil. For this, simulations were performed using the outputs of the ROMS ocean model and atmospheric data from the ERA5 reanalysis, used to force the MEDSLIK, through a Lagrangean oils spill representation. The results show that in winter the ZCIT displacement occurs and the southern expansion of South Atlantic Subtropical High (SASH) causes, in the region, an intensification of the southeast trade winds. The increase in longitudinal oil transport is evidenced at the lower speeds of the Brazil Current (BC), in the winter months, increase the likelihood of spills reaching the northeastern Brazilian coast. For summer, the simulations showed that the trade winds and the greater BC transport act as a physical barrier preventing the oil from moving to the coast. Based on the results obtained, we believed that the methodology used may be essential for future studies of oil spills in coastal areas of the Brazilian coast.
Keywords: Dispersion Modeling, Ocean Circulation, Oil Spill

Simulação hidrodinâmica de um derramamento de óleo hipotético na Bacia de Cumuruxatiba (BA) com o modelo MEDSLIK-II

RESUMO
Os derramamentos de óleo correspondem a uma das mais impactantes fontes de poluição marinha. Devido aos danos causados, conhecer o comportamento do óleo no ambiente marinho através de estudos de prevenção, controle e mitigação de derramamentos de óleo, é necessário. Neste estudo realizou-se duas simulações climatológicas para a região da Bacia de Cumuruxatiba, durante os períodos de verão e inverno, através do modelo de dispersão de óleo MEDSLICK-II. A região foi selecionada devido à sua proximidade com o Parque Nacional do Abrolhos e ao alto risco ambiental associado à indústria do petróleo na região. O objetivo foi analisar o impacto

da circulação oceânica em possíveis derramamentos de óleo próximo à Zona Econômica Exclusiva do Brasil. Para isso foram realizadas simulações a partir das saídas do modelo oceânico ROMS e dos dados atmosféricos do modelo ERA-5, utilizados para forçar o MEDSLIK através de simulações lagrangeana da mancha. Os resultados mostram que nos períodos de inverno, o deslocamento da ZCIT e a expansão meridional da Alta Subtropical do Atlântico Sul (SASH) geram uma intensificação dos ventos alísios de sudeste aumentando o transporte zonal de óleo. Com menores velocidades da Corrente do Brasil (BC) no inverno, aumenta a probabilidade de derramamentos atingirem a costa Nordeste brasileira. Nos meses de verão, os ventos predominantes de nordeste e o maior transporte da BC atuam como uma barreira física impedindo o deslocamento do óleo para a costa. Assim, acredita-se que a metodologia usada possa ser de fundamental importância para aplicação em futuros estudos de derramamentos de óleo nas áreas costeiras do litoral brasileiro.
Palavras-chave: Circulação Oceânica, Derramamento de óleo, Modelagem de dispersão.

Introduction

Incidents related to the oil and gas industry are responsible for insertion of hydrocarbons in marine environments (Peterson, 2003; Beyer, 2016; De Oliveira Soares, 2020), where it is estimated that 48% of ocean oil pollution is combustible and 29% are crude oil (Fingas, 2001). The oil is a complex mixture composed predominantly of hydrocarbons that changes according to the geological formation where it is found (Barker, 1985; Fingas, 2016). It is possible to find a composition Polycyclic Aromatic Hydrocarbons (PAH's) which are hydrophobic chemical compounds, which limits its solubility in seawater, favoring its association with solid particles (Celino & Queiroz, 2006) described in the literature as aggregates of oil-Sediment Aggregates (OSA's) [Moreira, 2015]. This can cause significant environmental impacts, often irreversible (Mignucci-Giannoni, 1999; Peterson, 2001; Zhang, 2020).

The oil exploration processes in Bahia began from the 1950's and involve several activities associated with exploration, processing and transportation (Moraes, 2013). Currently there are nine sedimentary exploration basins in the Bahia state, being 4 continental (Recôncavo, Tucano, São Francisco e Irecê) and 5 oceanic (Jacuípe, Camamu/Almada, Jequitinhonha, Cumuruxatiba e Mucri) (Mohriak, 2003). In addition to the exploration industry, the presence of exudations is responsible for most contamination in coastal waters (Timmerman *et al*., 2003). Oil exploration and refining areas often surround regions of high ecological importance, either due to the presence of rare and/or endemic species, breeding sites or fishing activity. In this context, the Cumuruxatiba basin consists of an important region of reserves and oil exploration in the Bahia state. According to the Exploration and Production Database (EPDB) of the Brazilian National Petroleum Agency there are 52 exploratory wells drilled (05 land and 47 at sea), and 43 wells are pioneers, 08 extension and 01 stratigraphic, according to the (Castilho, 2005).

Inside this region, the Abrolhos Bank is located on the southern Bahia continental shelf (Teixeira, 2006). Abrolhos is a region with the greatest marine biodiversity in the South Atlantic, housing the largest coral bank and some of the main nursery areas (Dutra *et al*., 2011). Thus, the nearest of Abrolhos National Park to the exploration areas offers great hazard to this environment, either by oil leaks in the region or by exudation processes (Leão, 1999).

Study area and research objective

The surface layer of this region is composed of the southward Brazil Current (BC), which is formed near16°S, from the bifurcation of the southern branch of South Equatorial Current (sSEC) (Schott *et al.*, 2002; Schott *et al.* 2005; Silva *et al.*, 2009), along the South American continental shelf to the Brazil-Malvinas Confluence (BMC), in approximately 38°S (Olson *et al*., 1988). The BC is a shallow, warm and saline current, which transports Tropical Water (TW) at surface layers (Stramma & England, 1999; Soutelino, 2008). At 20°S, BC receives a contribution from the South Atlantic Central Water (SACW), becoming deeper and with an increase in its transport towards the south (Silveira *et al*., 2000). The water mass below the SACW is the Antarctic Intermediate Water (AIW), moving equatorward north of 25°S, flowing south below 28°S (Muller *et al*., 1998; Stramma & England, 1999). And below the AIW, the North Atlantic Deep Water (NADW) flows south. Thus, south of 28°S then, TW, SACW, AIW and NADW flow in the same direction (Stramma & England, 1999; Soutelino, 2008).

The main hydrodynamic processes on the Bahia continental shelf stand out waves, tidal currents, currents generated by wind and geostrophic currents (Dominguez *et al*., 2012). The currents generated by wind are the main circulation mechanisms in the region, in which, quickly, these currents respond to wind changes and orient themselves zonally to the platform (Lessa & Cirano, 2006; Amorim *et al*., 2011). The prevailing winds in Bahia coast their seasonal variations associated with synoptic and mesoscale mechanisms. In the south of Bahia predominates anticyclonic South Atlantic Subtropical High (SASH) and crossing of frontal systems, in the north prevails the action in constant regime of the SE trade winds. The convergence of these mechanisms results in prevailing winds of northeast (NE), southeast (SE) and east (L). The submesoscale mechanisms, the sea breeze and land breeze regimes prevail (Uvo *et al*, 1989; Santos *et al*, 2013; Cavalcanti, 2016). In the austral summer (following quotes about seasons refer to the austral season), the increased warming of South Hemisphere, the South American and African continents generate negative pressure anomalies on the continents due to the contrasting thermal capabilities with the South Atlantic Ocean (SAO) causing a weakening of SASH. The opposite happens in winter, with continental cooling and southern expansion of SASH, moving close to South America as shown in Figure 1b (Machel *et al*., 1998; Lemos, 2009).

Figure 1 shows variations in SASH position in summer and winter. In summer (Figure 1A) the position of SASH generates winds from quadrant NE over the study region. In winter (Figure 1B), the advance of high pressure towards the South America continent generates east winds and southeast over the Cumuruxatiba basin. This period is characterized by the crossing of frontal systems over the south/southeast region of Brazil, intensifying the south and southwest winds over the study area (Lemos & Calbete, 1995). In autumn and winter, the winds are associated with low temperatures, high humidity and intense rainfall regimes, mostly in April and July (Bittencourt *et al*., 2000; Lessa & Cirano, 2006).

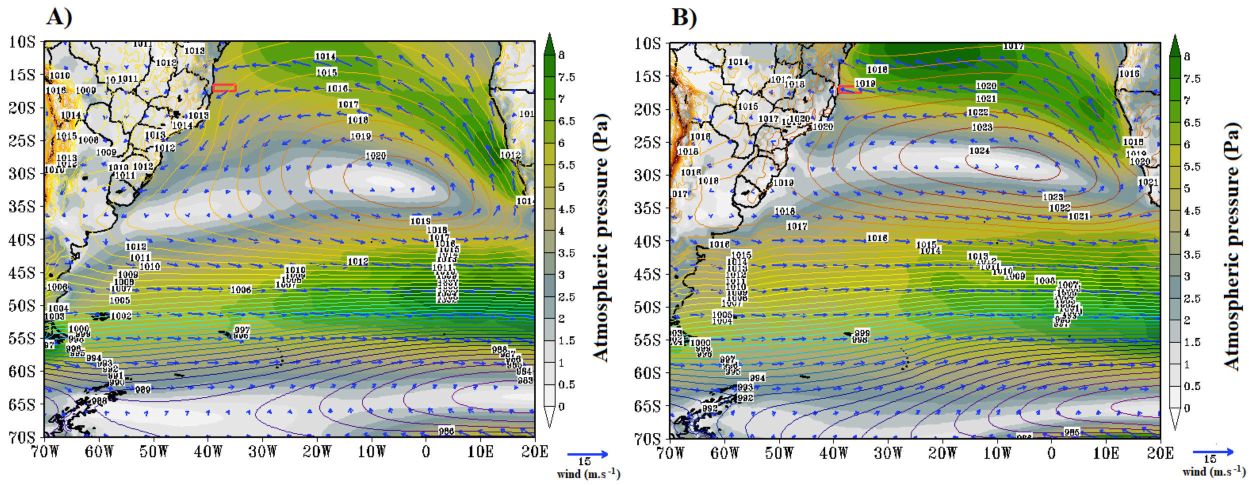

Figure 1 - Seasonal average of Medium Sea Pressure (MSP) and wind at 10m [m/s], for the period 1990-2020, from data d REANALYSIS ERA5. (A) summer (B) winter. The red box shows the Cumuruxatiba Basin location.

Currently, several studies use computational routines to show how an important, low-cost tool can assist in risk management associated with oil spills (Cheng, 2011; French-Mccay, 2004; Korotenko, 2018). Stringari *et al*. (2013) used an oil spill model to analyses the influence of physical ocean forces in a hypothetical spill on the southern brazilian shelf, in order to assist in emergency decision-making and the assessment of the magnitude of the risks involved. As the Cumuruxatiba Basin (BA) is an important oil exploration area and due to its proximity to the Abrolhos National Park, it is important to have a rapid and effective system to identify and prevent against environmental damage. In this manuscript, we present a study case of oil spill, on the 1st of August and February 2019, in oceanic water of the Cumuruxatiba Basin. We used the Lagrangian model MEDSLIK II (De Dominicis *et al*., 2013a, b) to define possible hydrodynamic patterns of oil spill dispersion in the Abrolhos Bank in winter and summer months.

Material and methods

Located on the east bank of the Brazilian coast, between 16,5-17,5ºS/35-39ºW (Figure 2), the Cumuruxatiba basin is limited to east by the bathymetric of 2500 m and covers the coastal plain between the Porto Seguro to Alcobaça cities, with a total area of 20.200 km^2. The underwater part surrounds the volcanic banks of Royal Charlotte in (North), Abrolhos (South) and Sulphur Minerva (East). The Abrolhos bank is formed by the enlargement of continental shelf and has a great marine biodiversity. This ecosystem has approximately 1.300 species, 45 of which are considered threatened, according to *the International Union for Conservation of Nature and* the Brazilian Institute of Environment.

The results show the stochastic simulations of a hypothetical oil spill, exposed to climatic conditions for summer and winter periods, at approximately 200 Nautical Miles from the coast, limit of Exclusive Economic Zone (EEZ). Because it is a hypothetical simulation, our scientific objective is to identify, according to local hydrodynamic conditions, the possibility of an oil spill, inside EEZ, to arrive the Abrolhos National Park. This region is about BC dynamic, which according to Stramma *et al*. (1990), has at 16°6' a reference depth between 490-580 m, transport of 5.6.10^6 m^3/s and mean annual speed of 2.7 m/s.

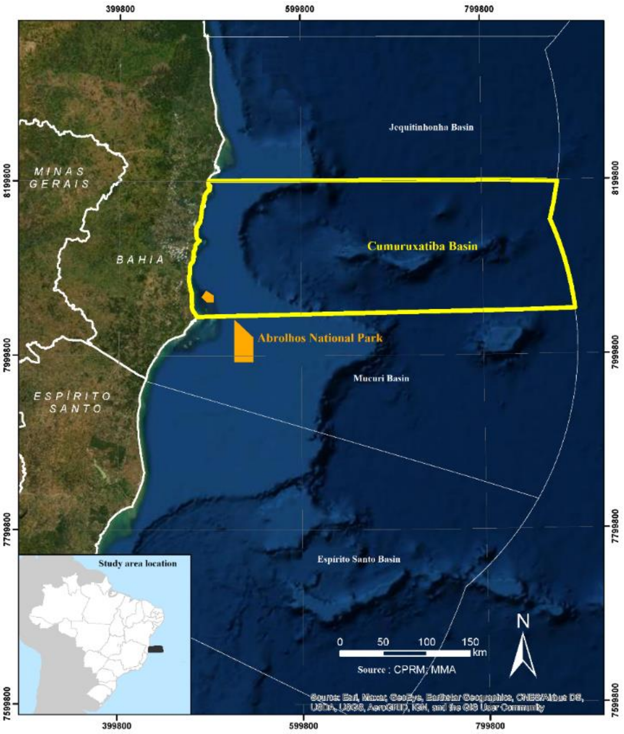

Figura 2. Location of Cumuruxatiba Basin (BA) at Brazilian Economic Exclusive Zone (EEZ).

Ocean Regional Model

Oil dispersion modeling was forced with hydrodynamic output data from the Regional Ocean Modeling System - ROMS (Haidvogel *et al*., 2000, Shchepetkin e McWilliams, 2005, 2009) and parameterized on the model code MEDSLIK-II (De Dominicis *et al*., 2013a, b). The ROMS is a free surface three-dimensional ocean model that uses sigma vertical coordinates, which accompany bathymetry, as described in Shchepetkin e McWilliams (2005). The horizontal model discretization uses an alternate grid, of Arakawa type C, described by Arakawa e Lamb (1977). The model solves the Navier-Stokes equations through the Reynolds mean, with Boussinesq approximation and balancing of the hydrostatic vertical moment. The coupling allows integrating the results of ROMS, compatible with low latitude dynamics and a Lagrangean oil model such as MEDSLIK-II, which considers the transport processes and weathering (evaporation, dispersion, emulsification and coastal adherence) that operate on the spill (De Dominicis *et al*., 2013a, b).

In this study, the grid domain was defined between 14°-19°S and 34º-40ºW, with horizontal resolution of 1/32 representing ~3,5 km and 32 sigma vertical levels. Grid dimensions allow avoiding instabilities generated by spurious (nonlinear) growth of high-frequency components of the model. The initial conditions of the ocean model are from the Comprehensive Ocean-Atmosphere Data Set (COADS) (Slutz *et al*., 1985), the boundary data and atmospheric forces are from the *Climate Forecast System* Version 2 (CFSv2) - *National Center for Environmental Prediction* (NCEP) (Saha *et al*., 2014), provided every 6 hours. CFSv2 has a 0,5° horizontal resolution for ocean and 0,25° for atmospheric. The simulation was running with open boundaries, except on the western grid edge, with 10-year spin-up, forced with the conditions of the year 2019 (January 1 to December 31). We use a climatological nudging for Temperature and Salinity, until the solution reached a state of near equilibrium and was able to simulate deep water processes, as suggested by Kantha & Clayson (2000). The spin-up outputs were used as the initial condition to rotate the experiences coupled with the MEDSLIK-II. The MKE and EKE values were estimated according to Oliveira *et al*. (2009), considering the annual average of zonal and southern components of current velocities.

Oil spill model

The MEDSLIK-II is a Lagrangean oil spill model, described by De Dominicis *et al*. (2013; 2013a), used wind data, sea surface temperatures (SST) and external model currents. This model produces aggregate oil concentration, distributions in 150 m horizontal boxes and oil mass balance at 30-minute intervals. Simulations use JONSWAP wave spectrum as a function of wind speed and fetch (Hasselmann *et al*., 1973). The model simulates oil advection-diffusion and weathering processes, discreetly, including spreading, evaporation, natural dispersion and emulsification. The use of MEDSLIK-II for coastal studies such as Abrolhos area is appropriate, because the model simulates interactions with the coastline and represents the absorption of oil plots in the environment (Liubasterva *et al*., 2020).

ROMS coupling with MEDSLIK-II is performed by Python routines. These new routines are necessary to recognize the ROMS output files (in netCDF format), as input of the forces of sea surface temperature, currents and winds, as described by Queiroz *et al.* (2019). The MEDSLIK-II parameterization is done through source code files and secondary codes (medslik_II.sh, Extract_II.for e medslik_II.for). Therefore, the model is performed for 25 days to simulate each of seasons (winter and summer), which represent the main seasonal patterns of wind and currents on the east coast of Brazil.

Numerical simulations

Two simulations were run in MEDSLIK-II, for winter and summer, considering, for each simulation, an oil spill from the exudation point and/or hypothetical spillage, located -16,5°S/-36,5°W, August 1 (00h UTC) February 1 (00h UTC). Each spill represented a continuous 598h oil point release (about 25 days). Initially it was estimated a width of 150 m, with a 2831 m³ of volume, which results in a mass of 1000 tons. The main simulation parametrization of MEDSLIK-II is described in Table 1. The model was running with the basic parameters, predefined and described in De Dominicis *et al*. (2013a).

Table 1 - MEDSLIK-II model boot parameters.

Parameters	Information
Simulation period	August 1, February 1
Duration	576h
Latitude	-16.5°
Longitude	-36.5°
Volume	1000 toneladas/L
Area	150 m
Oil	208 - Tiajuana Light from Venezuela
Oil density (g/cm³)	0.865
Oil API	32.10
Temperature to determine viscosity	38
Oil viscosity (50°C)	10.4
Residual oil density	0.913
Residual oil percentage	60.05
Oil steam pressure (bar)	0.357

Results and discussion

Marine environments are dynamic and disasters on the ocean surface can be virtually uncontrollable, reaching dimensions of hundreds of kilometers. Accidents such as the *British Petroleum Deepwater Horizon*, in the Mexico Gulf, in which bottom pipes were ruptured and released an estimated total amount of between 3 and 4 million barrels. Values below those simulated in this manuscript, approximately 0.1 tons/km^2. The average surface velocity values, during the 25 simulation days, for the winter (A) and summer (B) are shown in Figure 3. It is possible to observe, in addition to the thermal gradient, the increase in BC speed from summer period, following the northeast winds and the north displacement of Bifurcation of the Southern Equatorial Current (Silva *et al*., 2009). Although BC is a subtropical west contour current with a weak and shallow (Cirano *et al*., 2006), its structure acts like as a physical barrier against zonal transport from the ocean to the coast. According to Silveira *et al*. (2000) BC begins its meander and longitudinal oscillation from 22°S. Due to the coastline orientation and the increase in potential vorticity.

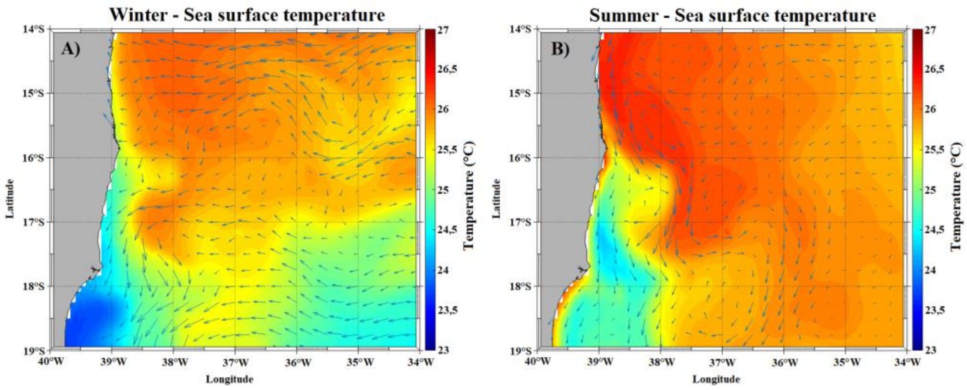

Figure 3 - Seasonal climatological SST values (°C) and surface velocity for the winter (A) and summer (B) periods.

The wind stress on the ocean surface is an important transport mechanism with influence on the mixing layer and assisting in oil solubilization. The wind stress analysis is shown in figure 4, where we observed that the zonal wind component (A) has a greater influence on west-southwest transport over the continental shelf. While the southern wind component (B) tracks the movement of SASH to north under the influence of Alisios winds and to the south by the northeast winds. Lessa & Cirano (2006) showed that, during the winter months, the Bahia coast receives winds from SE, S and SO (storms), usually after the crossing of frontal systems through the south and southeast of Brazil. From the wind stress results (Figures 4A and 4B) we observed that depth reduction creates a physical barrier, increasing bottom friction and slowing the transport. These results agree with Bittencourt *et al*. (2000), which show that the presence of Abrolhos coral reefs and Ponta Corumbaú act as a protection against the wave action. This is important because in spill case coral reefs will be the first oil deposit and its derivatives.

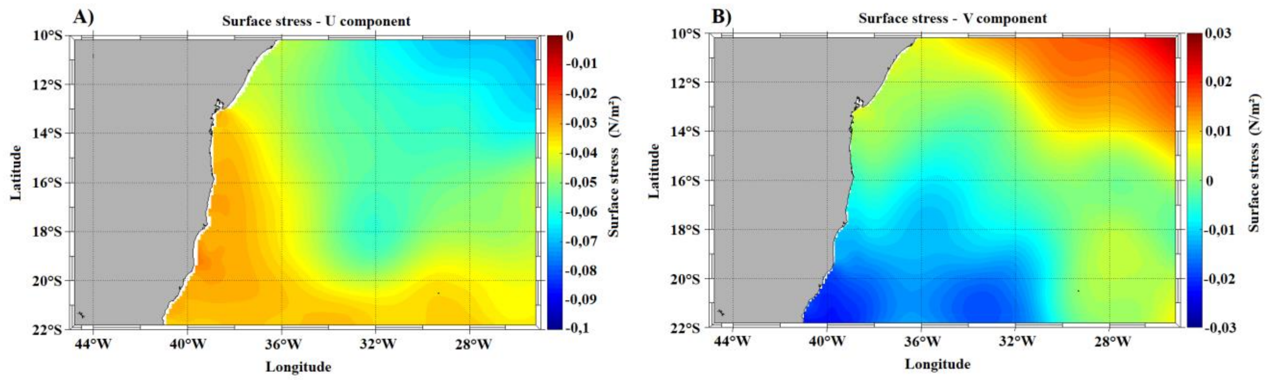

Figure 4 – Wind stress for zonal U (A) and meridional V (B) components.

The first simulation is a hypothetical scenario for winter, in which a single oil spill with 1500 ton/L was started on August 1, 2019 (Local Time 00:00) at location 16.5°S/36.5°W. Initially, the output model showed a general consistency in the oil movement in the south direction, following the core of the BC. During the simulated oil spill, the oil volume remained close to the core for the first five days simulation (Figure 5B), but with high solubility associated with weathering at the spot boundary (<0,3 ton/km²). After 10 simulation days, the spill enters the continental shelf and reaches the Abrolhos Bank, with an enlargement of the oil spill plume with strong zonal displacement. We believe this is due to the prevailing east winds this time of year, as described by Degola (2013). From the 15th day of the spill, the oil is close to the coast and suffers the influence of gravity waves, increasing the mixing rate, accelerating emulsification and water content in the internal structures of the stain (Paladino, 2000). Figure (5F) shows oil stranding with values below 0.1 (ton/km²), between 16-20 simulation days, indicating a high degradation and a reduction in zonal transport due to average current and wind conditions on the continental shelf in winter.

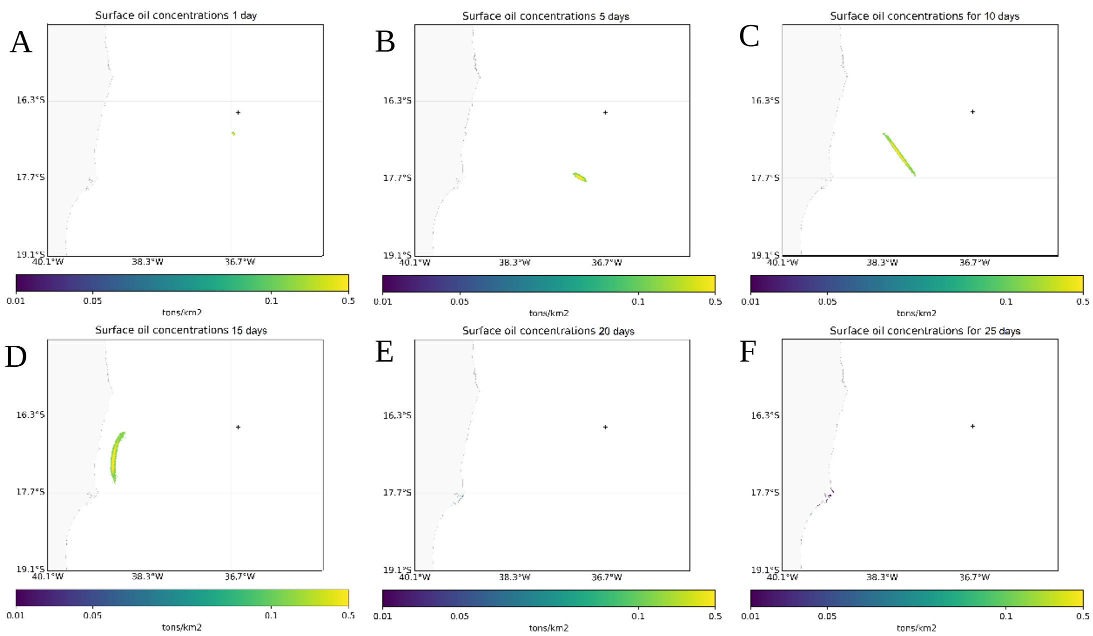

Figure 5 – Hypothetical oil spill simulation from Cumuruxatiba Basin (16,5°S/36,5°W), during the winter period. The figures represented by the letters (A) to (F) indicate the simulation time after the spill was started on August 1, 2019.

Based on the zonal and meridional current speed components U and V (Figure 6A, B) vertically integrated into the first 200m water column, we can observe the action of wind surface drag and the main currents in the study area. In this region, the main hydrodynamic effect on the continental shelf is the Ekman transport, induced by local wind (Resgalla *et al*., 2001). On the Southern of Bahia, in the winter months, if there is no crossing of frontal systems, the prevailing east and northeast winds induce Ekman transport, generating the withdrawal of shelf waters towards offshore, from the Royal Charlotte bank to Abrolhos. Positive speed values on the Abrolhos bank (Figure 6A) from ~0.04 m/s, despite breaking the spill, did not prevent the oil arrival or deposition on the coast (Figures 5E, F).

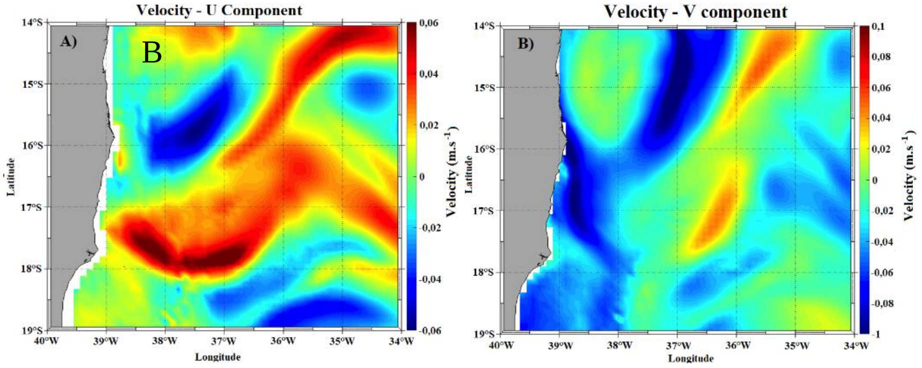

Figure 6 – Winter values from zonal U (A) and meridional V (B) components of integrated current speed, below the surface until 200 m.

Figure 7 shows that spills inside the EEZ are expected to suffer a southward deflection due to BC transport, impacting spills at latitudes lower than 15°S, as occurred in 2019. We note that when crossing the BC zonally, spills drift on the continental shelf by wind drag influence. The closer to the coast, the greater the influence of gravity waves (Daniel *et al*., 2003). Continuous wind speeds (5-6 m/s), summer, assist in the turbulence process of vertical mixing layer and speed up the oil weathering. In figure 7, from the fifth day of outpouring, the oil shows an intense weathering, reducing the spill edges to values below 0,1 tones.km^{-2}. After 15 days, the oil reaches the Abrolhos National Park with still significant values, more than 0,05 tons.km^{-2} and coverage area greater than 100km.

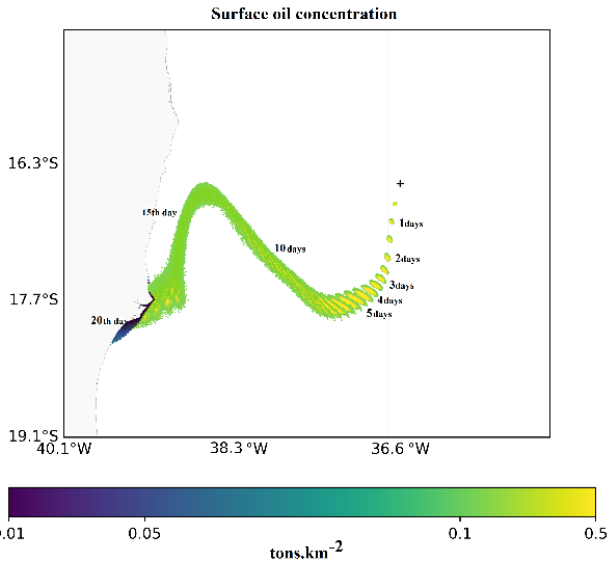

Figure 7 – Concatenated figures of Cumuruxatiba Basin oil spill (16.5°S/36.5°W) simulated during the 20 days of winter.

In summer, the ITCZ moves to south, remaining, predominantly over the Southern Hemisphere. The convergence of trade winds, influenced by SASH, generates winds from the northeast on Bahia coast (Santos *et al*., 2013). In the southern summer, the origin of BC is further south and has higher speed along the brazilian coast (Rodrigues *et al*., 2007, Goes *et al*., 2019).

Below 17.5°S, the continental shelf grows on the Abrolhos Bank and BC leaves the 500m isobata towards offshore, flowing south to the limit of 36.5°W. At latitudes below 17°S, the BC is more intense, with approximate velocities of 0.25 $m.s^{-1}$ (Soutelino *et al*. 2011). In Figure 8 we can observe the displacement to offshore of BC, with a slight speed reduction <1.5$m.s^{-1}$ and transport over the Abrolhos Bank to south, influenced by the seasonal wind pattern. Figure 8 is a volumetric box, north of the Abrolhos Bank, from 1°x1° from surface to 200m. This region was chosen to calculate the transport, because it concentrates more than 50% of BC main flow (Silveira *et al*., 2000). In this region it is observed that transport following the BC meandering, to the corner of Abrolhos Bank, with values close to observed by Signore *et al* (1989).

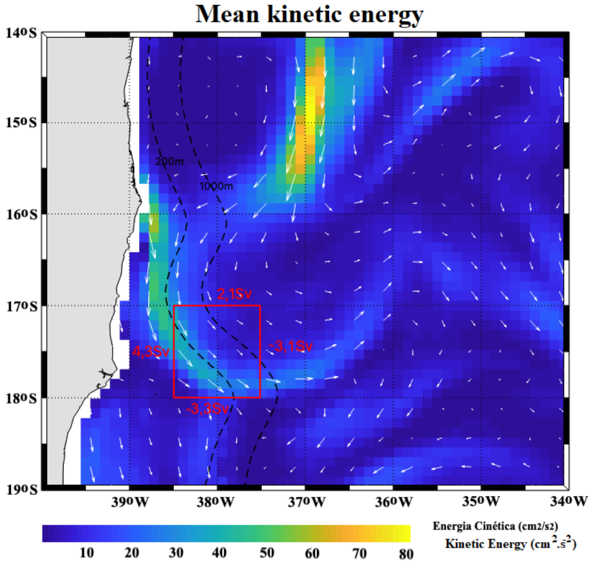

Figure 8 – Mean Kinetic Energy above 200 m, in the summer. The red square is the control area for BC transport estimation, north of the Abrolhos National Park.

The analysis of U and V components (Figuras 9 A, B) show that, in summer, the oceanic zonal component has velocity, towards the coast, higher than 0.04 $m.s^{-1}$. Furthermore, the BC southern transport is more intense, with speeds of 1 order of magnitude above. The kinectic energy values show that depth reduction and potential vorticity induce BC towards offshore. With transport values, in southwest direction, greater than 3 Sv (Sverdrup, where 1 Sv=10^6 $m^3.s^{-1}$). According to Sobey & Barker (1997), for speeds up to 0.1 $m.s^{-1}$, the surface drift can reach 600 $m.hour^{-1}$. In other words, the southern component of BC, north of the Abrolhos Bank, can transport significant oil volumes to south in the summer. In this way, we conclude that, at this time year, BC acts as a physical barrier against zonal transport of possible contaminants released east of 200 m isobath.

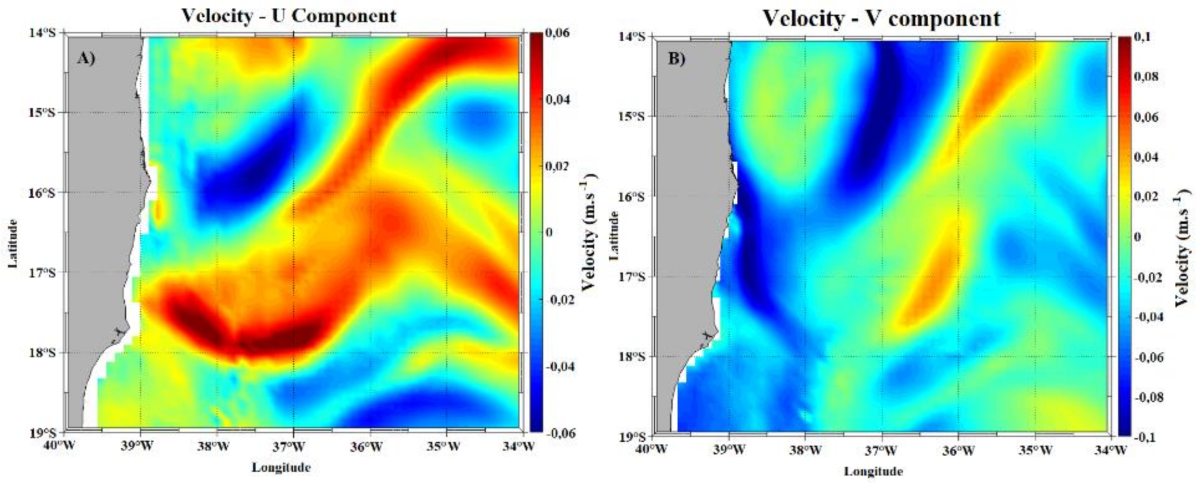

Figure 9 – Velocity component Zonal U (A) and meridional V (B) of integrated speed above 200 m, during the summer period.

Figure 10 shows three hypothetical scenarios of oil spills for the summer period. The first simulation (Figure 10A) was performed in the same position as the winter simulation (16.5°S/36.5°W). In it we can observe a fast oil degradation rate in the first days of spillage. However, because it is outside to the BC core influence, the oil spreading accompanied the ocean zonal transport (~0.05 $m.s^{-1}$) and wind drag (~4 $m.s^{-1}$). This phenomenon created a longitudinal displacement of ~1°, during the simulated twenty days. The same was observed in the second simulation (Figure 10B) that created a starting point of spillage to 14.5°S/36.5°W and generated a purely zonal displacement, also under the influence of ocean transport and wind drag.

Finally, with a more detailed analysis of the impact of BC on longitudinal dispersion, in summer, we ran a new simulation with the same initial latitude 16.5°S, but at 37.5°W, west of the longitude of the other simulations. This region is more to be influenced of BC. Simulation showed a rotational oil spill process, during the first 10 days, until its entry into BC central flow brought the oil south, along the shelf break. The containment of zonal transport process generated by BC can be observed in Figure 10C, when we simulate an oil spill in west position (16.5ºS-37.5ºW), near the BC core.

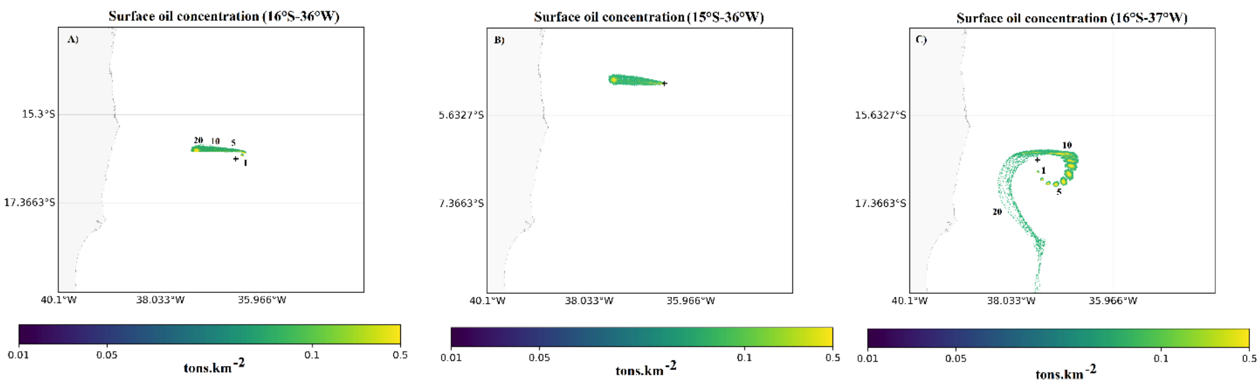

Figure 10 – Hypothetical simulation of oil spill in Cumuruxatiba basin, during the summer. The figures represent positions A (16.5°S/36.5°W), B (14.5°S/36.5°W) and C (16.5°S/37.5°W) tested to estimate possible oil-to-coast arrival situations.

This highly energetic and turbulent process caused a rapid emulsification in the oil structure, accelerating its degradation (<0.1 ton/km²), with a high surface scattering (Figure 10C). According to Ribotti *et al*. (2019), the oil routes computed by models tend to accumulate errors in longer distances and times, due to simplifications of mathematical models. However, these simulations help for decision-making in case of accidents on the northeast coast of Brazil, as happened in 2019 (Câmara *et al*., 2020, Lessa *et al*., 2021). In this case, the oil presence in Abrolhos region occurred, just over, 1 month after the first cases on the Sergipe state (Magris & Giarrizzo, 2020).

A possible accident in this area could generate environmental impacts associated with the chemical element's contamination, ranging from organic compounds (Ke *et al*., 2002; Celino *et al*., 2012) to changes in the chemical characteristics of habitats (Zhang *et al*., 2020; Al-Saleh & Al-Harshan 2008; Abo-Elmagd *et al*., 2010). In addition, an accident with oil spreading can affect the biota severely since the concentrations of oil activity are naturally high (Al-Saleh & Al-Harshan 2008; Attallah *et al*. 2012; Abo-Elmagd *et al*. 2010). According to Protásio *et al*. (2021) the dose rate due to radiation exposure of reference marine biotas such as sole, crab and seaweed can reach 0.5; 0.7; 0.3 $\mu Gy.d^{-1}$, respectively. In practice this means that the absence of immediate attitudes can expose the biota to situations ranging from reduced fertility to mortality of adult species (ICRP, 2007; 2018), depending on the waiting time for an action takeover.

Conclusions

The application of numerical modeling methodologies, focused on the knowledge of seasonal climatological patterns presents the most modern in the process of oil spill environmental spatial analysis. Our results show that there are two important points on the study area: the first indicates that the BC presents in summer acceleration that can act as a physical barrier, against the zonal transport of oil; the second important conclusion is that the western boundary currents has a transport which functions as a spreader mechanism of oil elements associated, along the Brazilian coast, since the thermohaline properties, of these tropical waters, tend to be conservative and can function as an oil transport pipeline along the coast. Our results show that, in the winter months, the meridional BC transport are lower, enabling the spills that occurred to west of the EEZ, are transported by wind and ocean zonal component to the coast, with speeds greater than 0,5 $m.s^{-1}$. According to Queiroz *et al*. (2019), the weathering of oil in the ocean tends to reduce the risk in the tropical region, but the high speed of oil transport reduces the time window for possible mitigation actions.

This study is strategic to elaborate action plans in a possible accident with oil spill in this region. The Abrolhos National Park has a great importance in the oceanic brazilian ecosystem since it harbors great marine biodiversity in the South Atlantic Ocean. The scenarios simulated by MEDSLIK-II highlight the need for a risk reassessment for the region. We add that the results obtained here could be as a basis for further studies to be developed in the region and that controlled management of vulnerable regions depends on the implementation of systems capable of see oil spills on the Brazilian coast.

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