A stochastic simulation methodology for preliminary evaluation of environmental susceptibility to oil spills originated in large marine areas

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INTRODUCTION

A methodology based on numerical modeling for evaluation of environmental assets susceptibility to oil spills that may occur in large marine areas is developed. The methodology was thought to meet the goals of the Sedimentary Area Environmental Assessment Study (SAEAS), a broad multidisciplinary analysis instituted by a joint effort of the ministry of the environment and the ministry of mines and energy of Brazil. The SAEAS is supposed to be accomplished before the bidding rounds for exploration and production of Oil and Gas and aims to anticipate environmental issues of the permitting processes, or even to withdraw from the bidding rounds exploratory blocks that have unacceptable environmental risks identified.

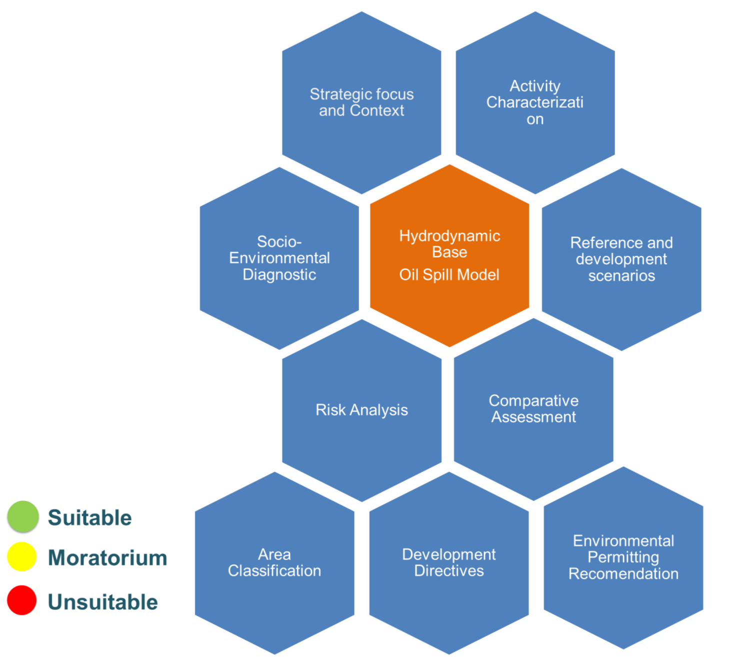


Figure 1: Term of reference structure for the Sedimentary Area Environmental Assessment Study (SAEAS). Adapted from ANP (Brazilian National Agency of Petroleum) presentation

The figure beside shows the term of reference structure the SAEAS. As can be seen the hydrodynamic base and oil spill model are central parts of the study

METHODOLOGY

The proposed methodology is based on stochastic modeling of oil slicks trajectories. Rather than using a sophisticated approach, such as the methodology required for the permitting process, we used a simplified and less computationally costly approach. The simplified approach only considered the bi-dimensional transport of the oil slick on the surface, without taking into account the oil weathering process. Parallel computing techniques were used to enable the calculation of hundreds of thousands of oil slick trajectories originated in hundreds of positions distributed along the entire sedimentary basin, considering different environmental conditions. The massive number of oil slick trajectories allows the preparation of probabilistic maps of oil presence and minimum arrival time for spills that may occur anywhere within the sedimentary basin, as well as backtrack calculations to identify the potential origins of spills that may affect valuable environmental assets.

The figure below shows probabilistic maps of oil slick presence obtained with Sintef Oscar model (left) considering a 20.000 m³ oil (API 27°) spill and with the simplified approach (right) for an oil spill in Foz do Amazonas Basin, in the equatorial Margin of Brazil. The simplified approach runs 500 faster than the OSCAR simulation.

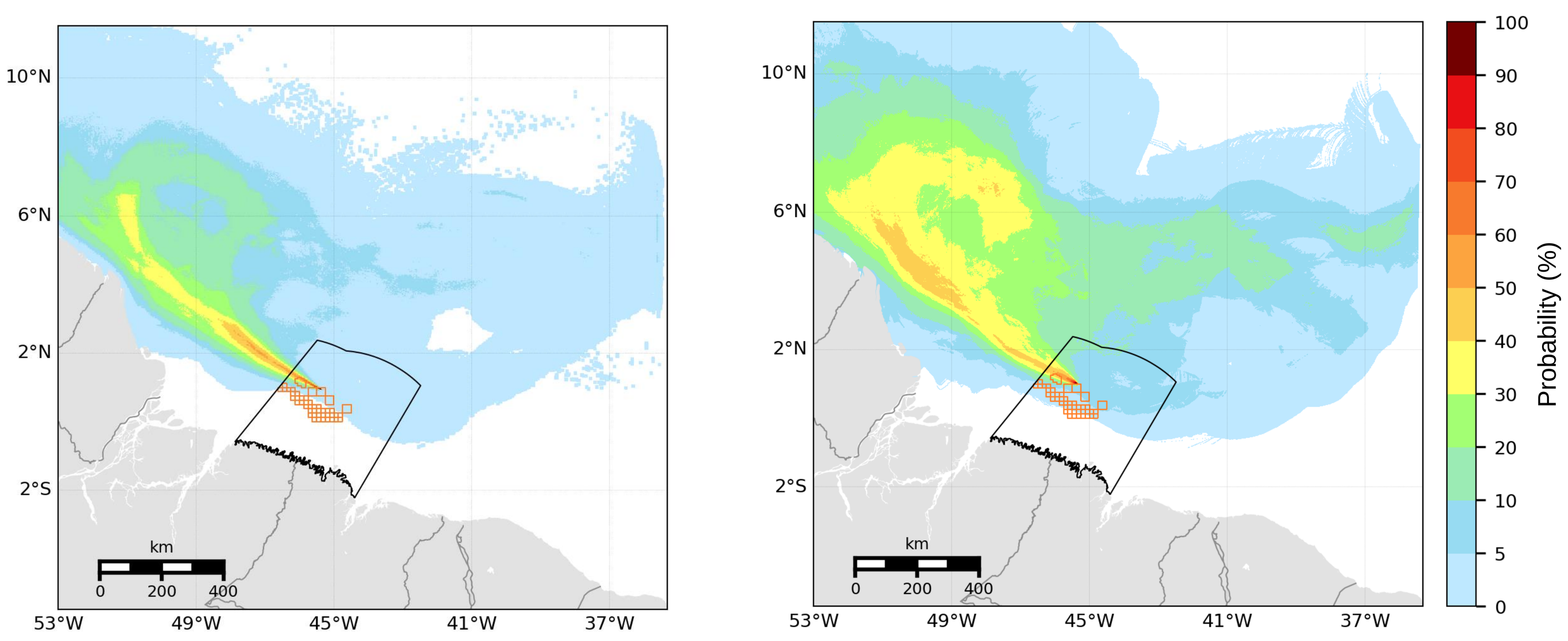
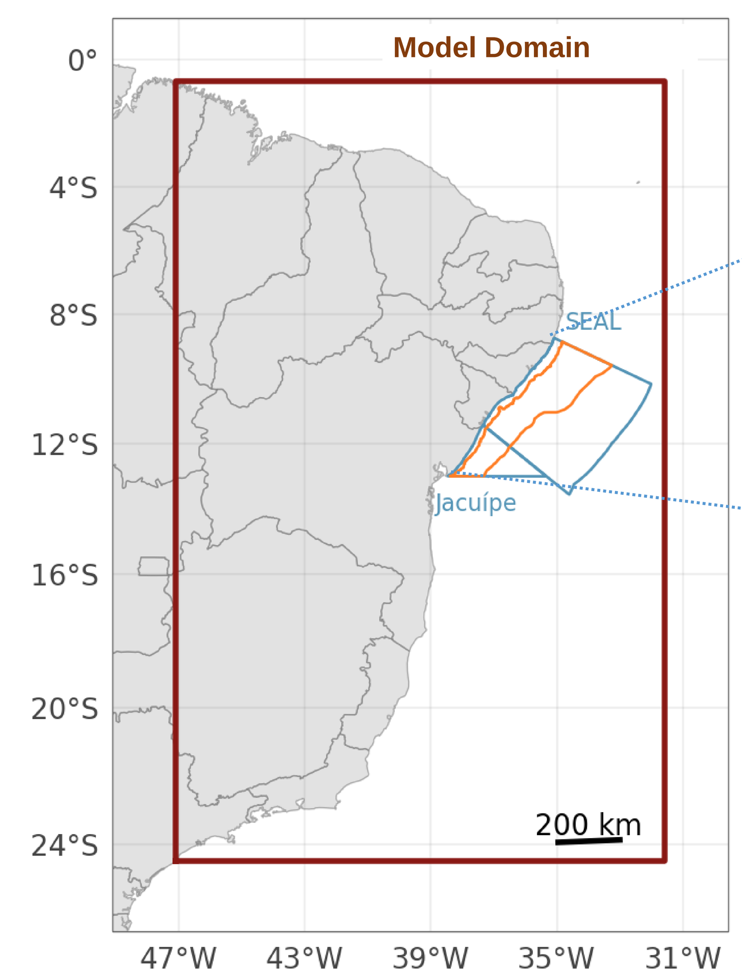
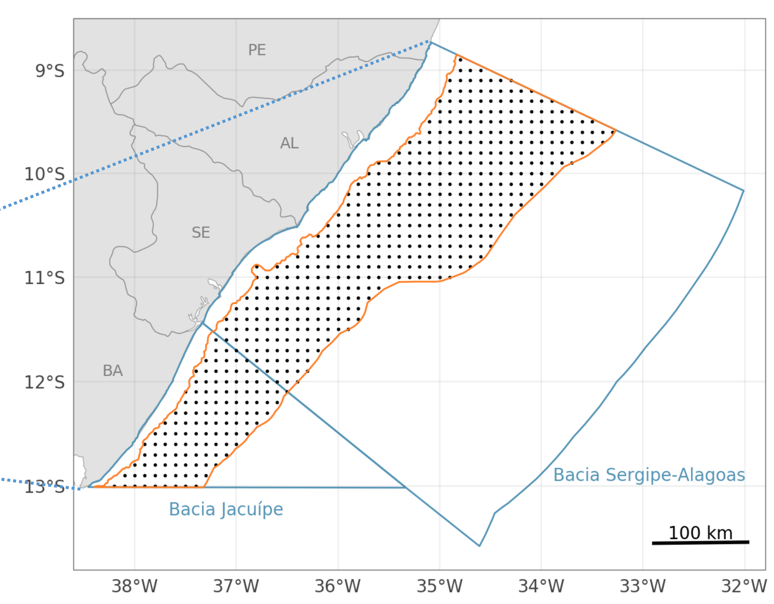


Figure 2: Probabilistic maps of oil slick presence obtained with Sintef Oscar model (left) considering a 20.0003 oil (API 27°) spill and with the simplified approach (right). The position of the spill is located in Foz do Amazonas Basin in the equatorial Margin of Brazil.

The methodology was applied for the Sergipe-Alagoas basin, an area of 31,750 Km2 with high environmental sensitivity, many important estuarine regions and important conservation units. This basin is the study area of the pilot experience of SAEAS. Input data are a 4-year hindcast simulation of currents with a resolution of 1/36° and winds from NCEP reanalysis



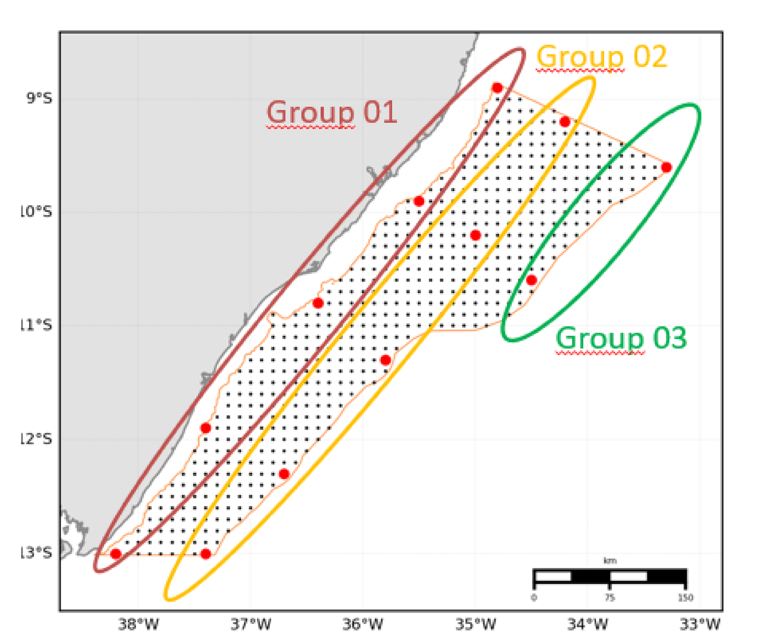


Parameter	Value
Period of simulation	4 years
Duration of each simulation	30 days
Duration of the spill	24 h
Number of spill positions	569
Number of simulation per spill position	715
Total Number of simulation	406.835

Figure 3. Model Domain (left), oil spill origins (upper right) and simulation parameters (lower right).

RESULTS AND DISCUSSION

The results of the simulation were used to choose 12 spill origins which probabilistic results could better represent the probabilistic maps obtained considering 569 spill origins equally distributed within the limits of Sergipe-Alagoas sedimentary basin. The Figure below shows the best combination of 12 spill origins. 5 positions were chosen in shallow water areas (~50 m), 5 spills origins were positioned along the continental slope and 2 spills were positioned in deeper areas (> 4.000m). In the context of the Sergipe-Alagoas SAEAS, the 12 chosen positions were considered in modeling simulations with Sintef OSCAR model with different volumes and oil types



Group	position	Distance do the Coast	Depth
1	1	36 km	50 m
	2	36 km	50 m
	3	30 km	50 m
	4	18 km	50 m
	5	15 km	50 m
2	6	110 km	3.930 m
	7	97 km	3.600 m
	8	116 km	3.640 m
	9	112 km	3.520 m
	10	88 km	3.510 m
3	11	220 km	4.735 m
	12	177 km	4.400 m

Figure 4. Positions choose 12 spill positions which probabilistic results could better represent the probabilistic maps obtained considering 569 spill origins equally distributed within the limits of Sergipe-Alagoas sedimentary basin.

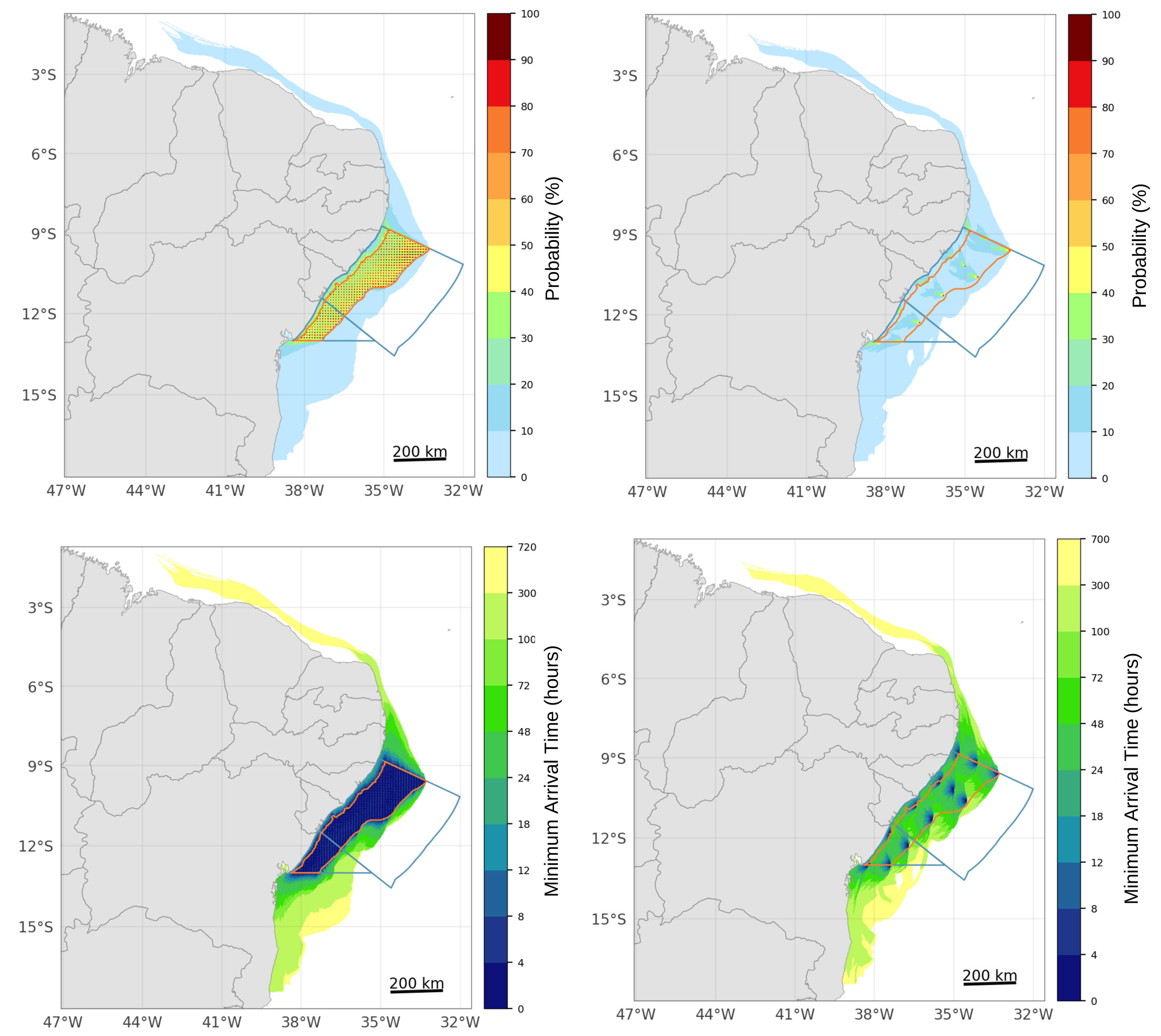


Figure 5. Map of probabilistic results obtained with 559 spill origins (left) and with 12 origins (right)

The evaluation of environmental assets susceptibility is usually oriented to the risk assessment of accidental scenarios originated from specific potentially polluting sources. Nevertheless, the results obtained with the multi-source simulation, allows the identification of potential origins of spills that may affect specific areas - defined after the model run, granting flexibility exploring the results - with their probabilities and minimum arrival times. Rather than knowing where the oil goes, the interest now is in where the oil may come from.

Below, we present some examples of probabilistic maps that may be obtained by post processing 569 probabilistic maps. Two examples of environmental assets were chosen to illustrate the methodology: The mouth of São Francisco River, located in the border of the states of Sergipe and Alagoas and Abrolhos Archipelago, a group of 5 small islands with coral reefs off the southern coast of Bahia state in the northeast of Brazil.

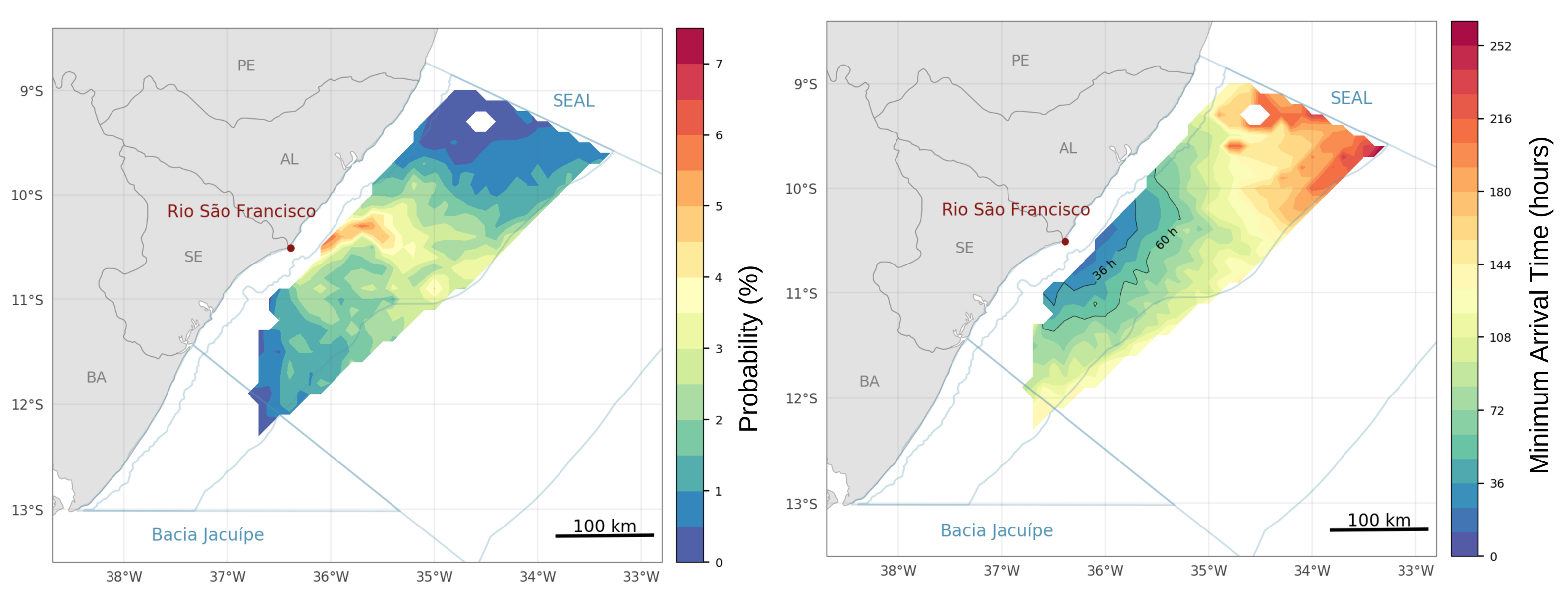


Figure 6. Probability (left) and minimum arrival time (right) at the mouth of São Francisco River associated with possible origins of an oil spill within the limits of Sergipe e Alagoas Basin

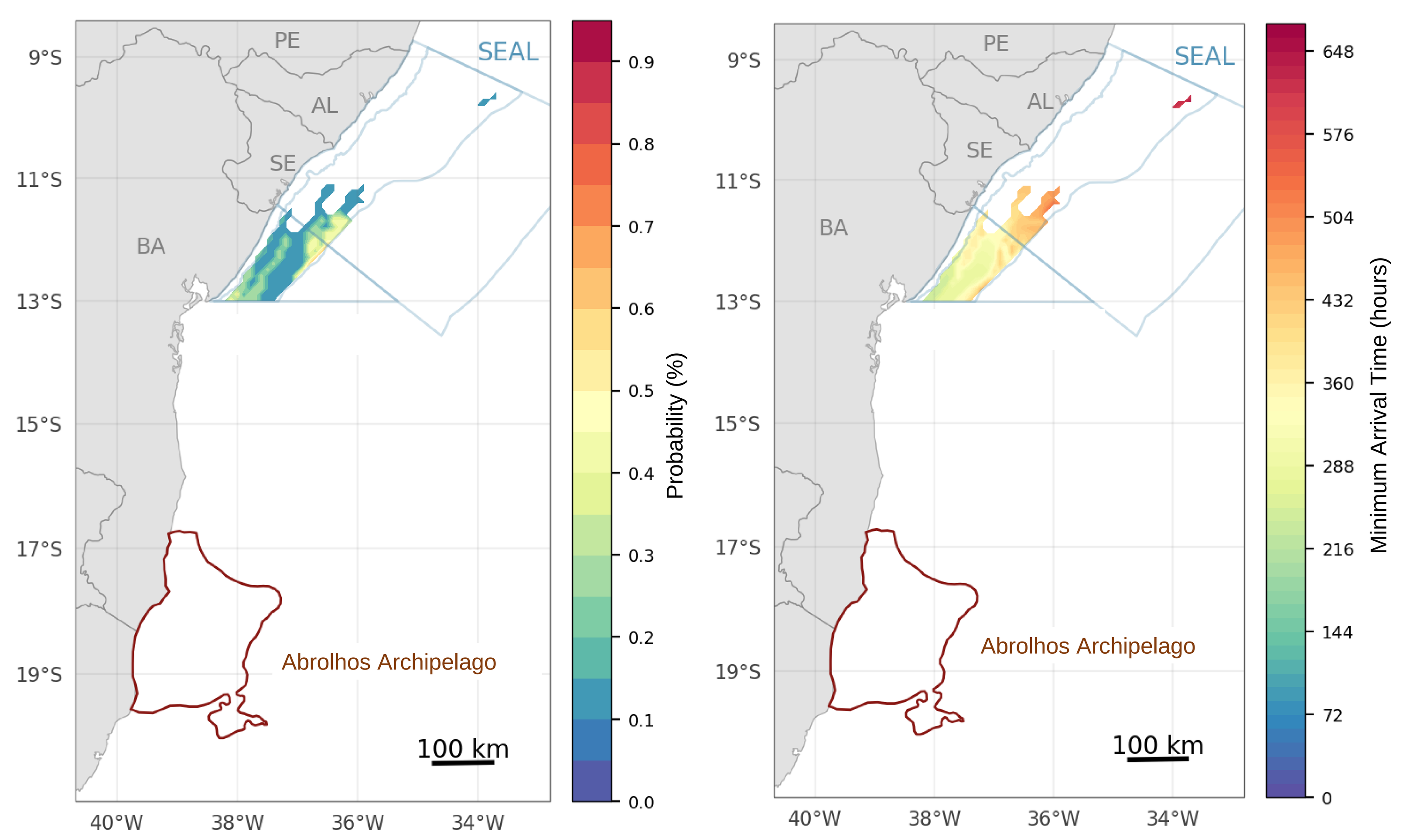


Figure 7. Probability (left) and minimum arrival time (right) at Abrolhos Archipelago associated with possible origins of an oil spill within the limits of Sergipe e Alagoas Basin

CONCLUSION

The idea of simplifying the algorithms of oil spill dispersion and fate modeling, in a trade-off between complexity and computational cost, seems to be very promising since it enables stochastic outcomes that are unfeasible to be obtained with sophisticated oil spill modeling systems, such as the Sintef OSCAR model.

The methodology is suitable for comprehensive analysis of large marine areas with potential exploitation of oil. The results may assist environmental policy managers in the identification of critical areas of oil exploitation regarding environmental risks

Comparisons between the probabilistic maps obtained with the simplified algorithm against probabilistic maps obtained with Sintef OSCAR model showed some differences in the values depending on the type of oil, oil spill volume, and environmental conditions. Although the potential impacted areas are very similar using both methods, investigations still need to be conducted in order to establish the exact level of complexity that must be taken into account in the simplified approach.

Once the presented methodology uses a bidimensional approach, the next step is the implementation of an algorithm to include the effect of vertical mixing on the horizontal drift of the oil slicks, following the findings of RÖHS et Al (2018)[1]

[1] Röhrs, J., Dagestad, K.F., Asbjørnsen, H., Nordam, T. , Skancke, J., Jones, C. E. and Brekke, C., 2018. *The effect of vertical mixing on the horizontal drift of oil spills. Ocean Sci., 14, 1581–1601, 2018 https://doi.org/10.5194/os-14-1581-2018*