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Hypothetical Blowouts of Oil and Gas from Frade and Lula Fields, Brazil

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Abstract: Simulations of hypothetical blowouts of oil and gas from oil wells located in Frade (FF) and Lula Fields (LF) were performed using a Lagrangian numerical model to determine the trajectories of the components along the water column from these different locations. The depths in FF and LF are, respectively, 1181.85 m and 2213.0 m. In both locations, the releases started on January 15, 2018 with 24 hours duration. The ocean conditions used in the simulations are from Mercator Ocean. The trajectories were influenced by the variation in the ocean current directions. In FF, the mass of oil and gas was displaced towards northwest below $z \approx -400$ m, changing for southeast above. In LF, the components were transported towards northeast throughout the entire water column. After 24 hours, most of the oil reached the surface, while the gas was completely dissolved underwater in 1.5 hours.

Key words: blowouts, oil and gas, deepwater, Frade and Lula Fields

1. Introduction

The importance of petroleum and its derivatives in modern society as a great energy source increases its consumption, resulting in a growing demand for its exploration and transport. The intensification of oil-related activities is worrying due to the risk of accidents, which cause damages to the environment and the local population [1].

In Brazil, the discovery of oil and gas reserves in the Pre-salt region increases the exploration of these natural resources. In 2018, the national maritime production was around 903.47 million of oil barrels and 32.8 billion of cubic meters of natural gas. Campos and Santos Basins were responsible for 96.8% of the total maritime production [2].

In face of a current scenario full of possible accidents, the simulation of the oil and gas behavior is an important tool to develop emergency control plans in risky situations. From predictions of blowout scenarios provided by numerical models, important information can be anticipated, such as time spent by the oil to reach the surface and its approximate location, if gas will reach the surface or not, and the quantity of components dissolved into the water [3].

This study aims to simulate hypothetical blowouts of oil and gas from oil wells located at Frade Field (Campos Basin) and Lula Field (Santos Basin), in order to determine the plume behavior under different ocean conditions.

2. Material and Methods

Hypothetical simulations of oil and gas blowouts were performed using a Lagrangian numerical model, developed to be applied in underwater releases based on the Comprehensive Deepwater Oil and Gas Blowout (CDOG) Model [3, 4] and DeepBlow Model [5, 6]. In this model, the plume trajectory and its interaction with the ambient were developed in two stages: plume dynamic and advection-diffusion.

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The plume dynamics is the first stage to be simulated. The plume transport is governed by the dynamics of the mixture of oil, gas, water, and hydrate, following the Lagrangian Control Volume Method [7]. The plume is represented by elements named as control volume (CV), whose properties vary along their trajectory. The changes in the mass and composition of a CV are related to the following processes: water entrainment [8]; loss of gas bubbles from the main structure of the plume [9]; oil dissolution [10]; gas dissolution [11]; and formation [12, 13], dissolution [14], and decomposition [15] of hydrates, a solid agglomerate composed of gas and water formed around the bubbles. The particles (gas bubbles or oil droplets) size distribution computed by the model is influenced by the effects of the initial turbulence [16] and the breakup and coalescence processes [17]. In each time step, the equations of momentum, energy, and mass conservation of the components were computed for each CV, in order to determine the evolution of its properties.

When the plume density becomes similar to the ambient density in a level called neutral buoyancy level (NBL), the movement of oil droplets and gas bubbles becomes based on the buoyant velocity and ambient conditions, starting the second stage called advection-diffusion. In this second moment, the processes of oil and gas dissolution and those related to hydrates keep changing the mass and composition of the components. The particles transport is governed by the advection and diffusion processes. To implement this stage into the model, the Lagrangian Parcels Method [18] was used, in which the components are grouped in parcels composed of thousand of bubbles or droplets. The displacement of each parcel depends on the mean velocity, the particle buoyant velocity, and the turbulence. This plume trajectory and the physico-chemical processes along the water column is illustrated in Fig. 1.

The hypothetical blowouts of oil and gas were simulated from two different locations: 7FR25HPRJS Oil Well (21.8959°S/39.8286°W), located in Frade Field (Exp. FF), and 9LL2RJS Oil Well (25.1872°S/ 42.9208°W), located in Lula Field (Exp. LF). The location of these oil fields is shown in Fig. 2 and the characteristics of both experiments are described in Table 1. The oil is composed of a mixture of pseudo-components and the gas only by methane. The ocean conditions (zonal and meridional velocity, temperature, and salinity) used in the simulations were daily average provided by the operational system of numerical prediction developed by Mercator Ocean and made available by Copernicus Marine Environment Monitoring Service [19].

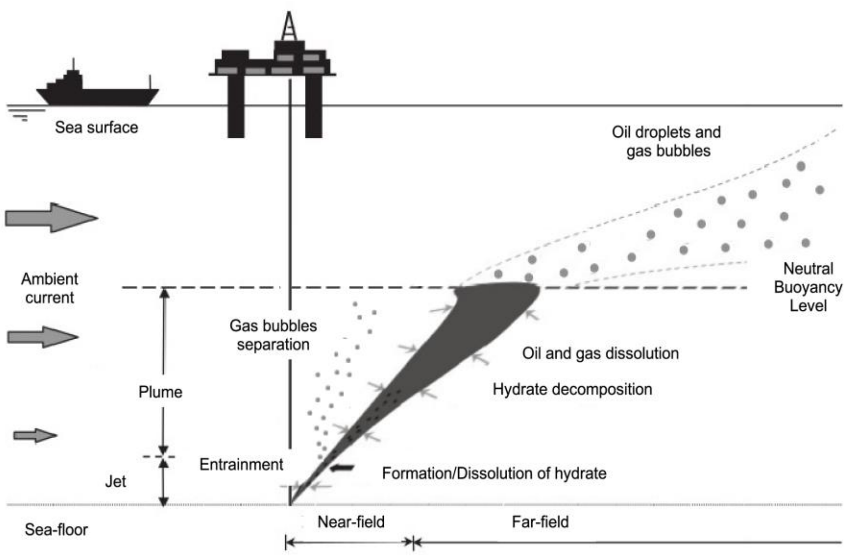

Fig. 1 Plume trajectory along the water column after an oil and gas blowout, adapted from [3].

Table 1 Characteristics of the blowout simulations.

Description	Exp. FF	Exp. LF
Basin	Campos	Santos
Oil well	7FR25HPRJS	9LL2RJS
Location (latitude/longitude)	21,8959°S/39,8286°W	25,1872°S/42,9208°W
Depth	1181.85 m	2213.0 m
Start of the discharge	January 15, 2018 at 12:00 am	
Duration	24 hours	
Period of the discharge	Each 1 hour	
Oil discharge	0.0071 m^3/s	
Gas discharge	0.48 m^3/s	
Oil density	885.7 kg/m^3	778.5 kg/m^3

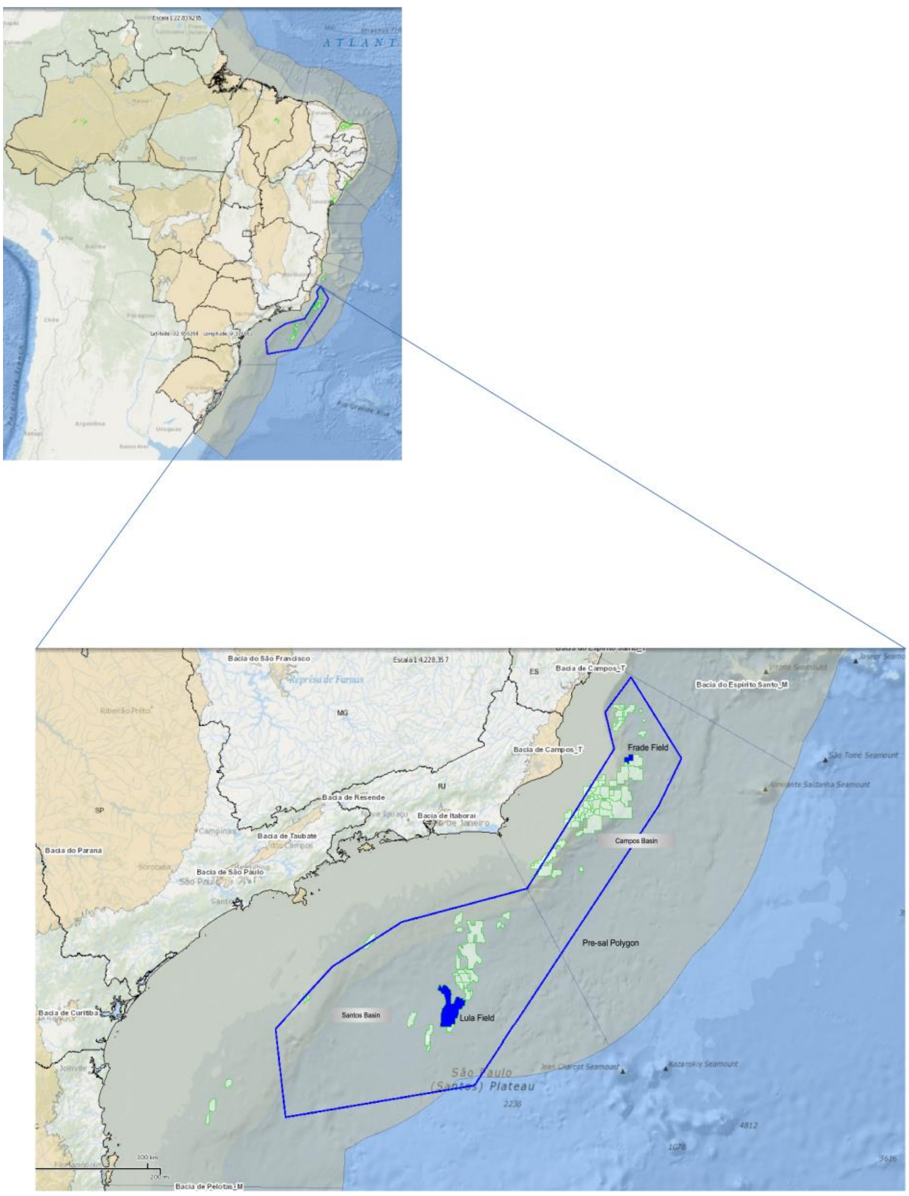

Fig. 2 Location of Frade and Lula oil fields.

3. Results and Discussion

In both simulations, the results showed no separation of bubbles from the main structure of the plume. The hydrates were formed around the bubbles immediately after the release. In Figs. 3 and 4, the oil and gas locations in x-z and y-z directions are illustrated 1 hour after the start of the release for Exp. FF and Exp. LF, respectively. The positive-negative x axis represents the east-west direction, while the positive-negative y axis represents the north-south direction. In Exp. FF (Fig. 3), the plume rose 298 m following to northwest up to the NBL, while the plume in Exp. LF (Fig. 4) went up 432 m bending slightly to northeast.

Above the NBL, oil droplets and gas bubbles continued their trajectories as independent particles towards the surface. Oil droplets reached the surface after 2.2 hours in Exp. FF and 3.6 hours in Exp. LF. The gas-hydrate bubbles did not reach surface in both experiments due to the complete dissolution of the gas in 1.5 hours. The moment when the first oil reached the surface is shown in Figs. 5 and 6, respectively, for Exp. FF and Exp. LF.

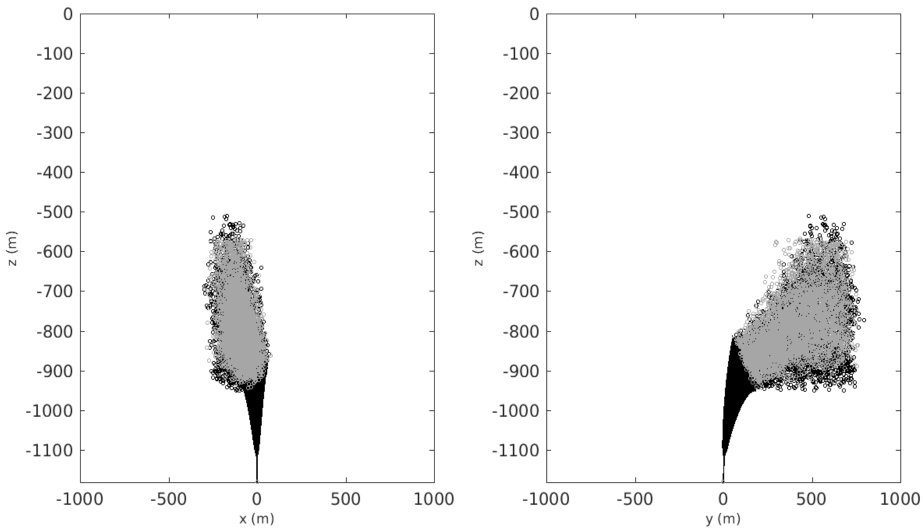

Fig. 3 Oil and gas location for Exp. FF after 1 hour of the blowout in x-z (left) and y-z (right) directions. The plume is represented by the black cone, oil droplets by black circles, and gas bubbles by gray circles.

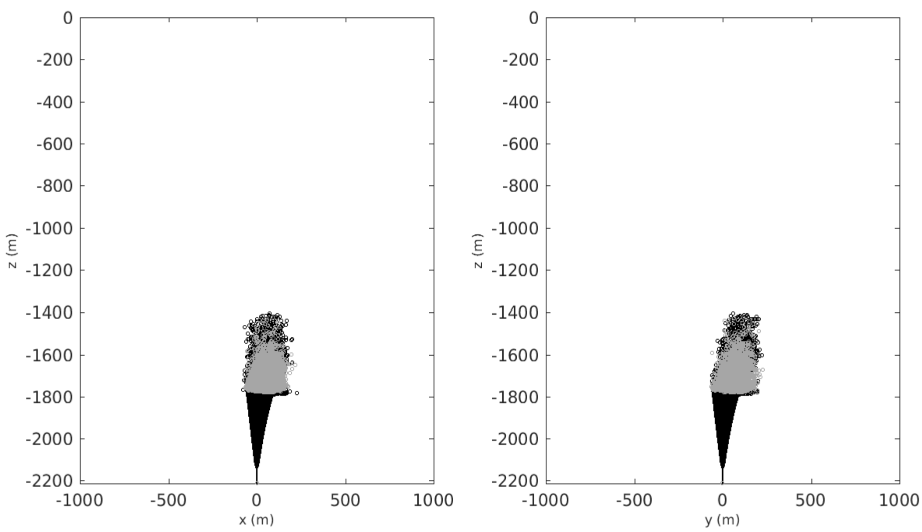

Fig. 4 Oil and gas location for Exp. LF after 1 hour of the blowout in x-z (left) and y-z (right) directions. The plume is represented by the black cone, oil droplets by black circles, and gas bubbles by gray circles.

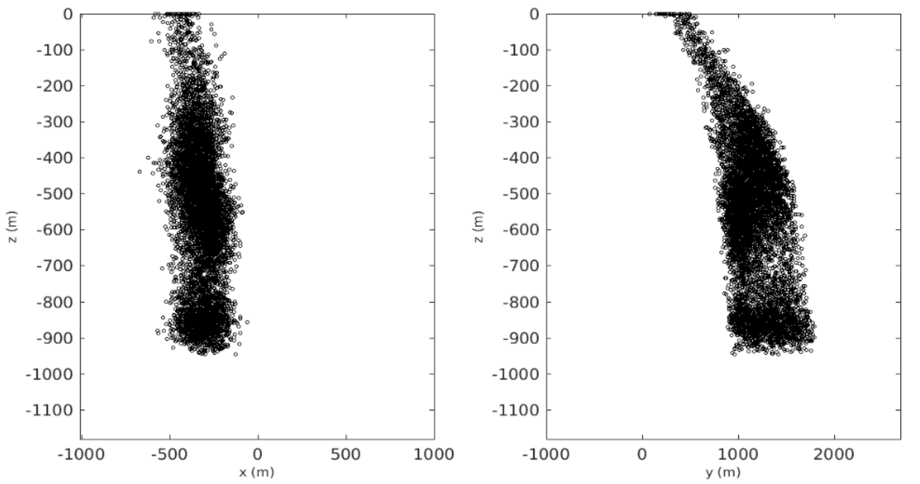

Fig. 5 Oil location for Exp. FF when the first droplets reached the surface in x-z (left) and y-z (right) directions. Oil droplets are represented by black circles.

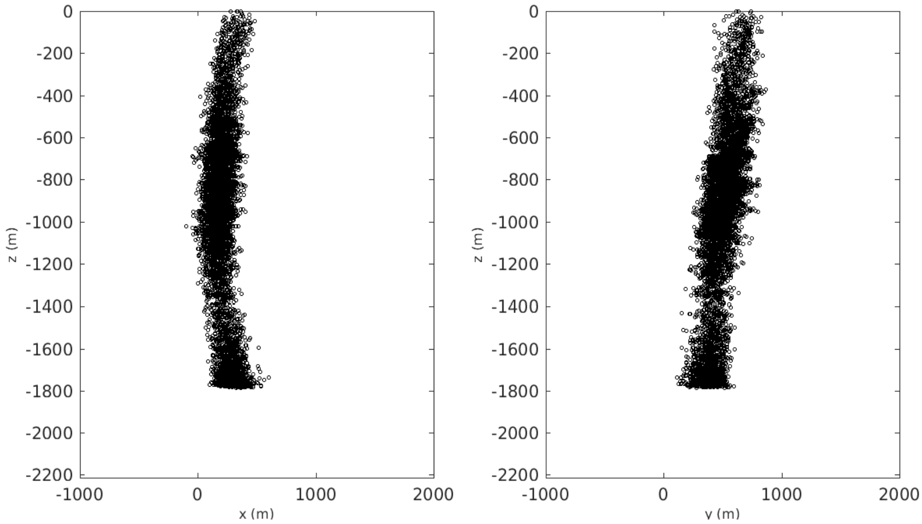

Fig. 6 Oil location for Exp. LF when the first droplets reached the surface in x-z (left) and y-z (right) directions. Oil droplets are represented by black circles.

Figs. 7 and 8 plot the position of the oil in x-z and y-z directions for Exp. FF and Exp. LF, respectively, 24 hours after the blowout started. One can note the oil has undergone changes during its upward motion influenced by variations in the ocean current directions. In Exp. FF (Fig. 7), the droplets that remained inside the water column moved approximately 5 km towards west and 15 km towards north, reversing the direction of their displacement at z ≈ -400 m. The oil trajectory in Exp. LF (Fig. 8) followed towards northeast throughout the entire water column, reaching x ≈ 2 km and y ≈ 5 km.

In Fig. 8, a fragmentation on the oil transport is observed in Exp. LF, different from that in Exp. FF (Fig. 7). This is due to the magnitude of the ocean currents because the currents are weaker in Lula Field than in Frade Field. For this reason, the movement of the droplets is governed by their buoyancy velocity, which is vertical and with magnitude proportional to the droplet diameter. As the blowout produces droplets with different sizes, a discontinuous trajectory is established as a result of their different buoyancy velocities.

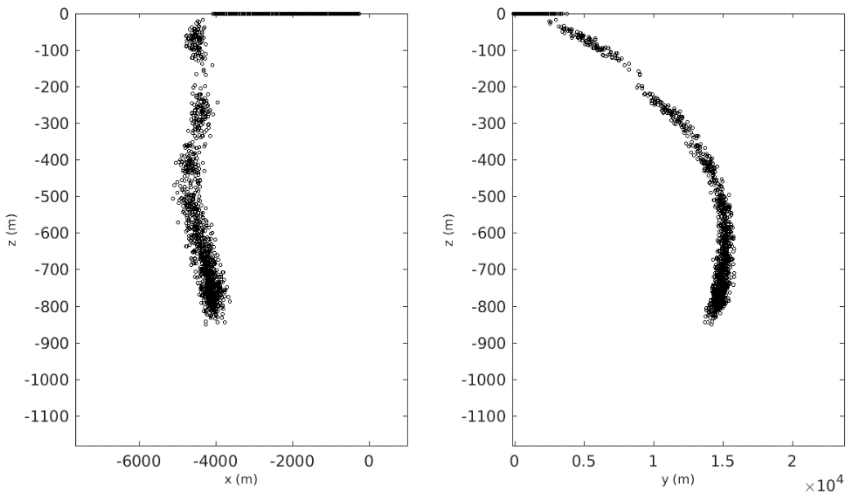

Fig. 7 Oil location for Exp. FF 24 hours after the blowout in x-z (left) and y-z (right) directions. Oil droplets are represented by black circles.

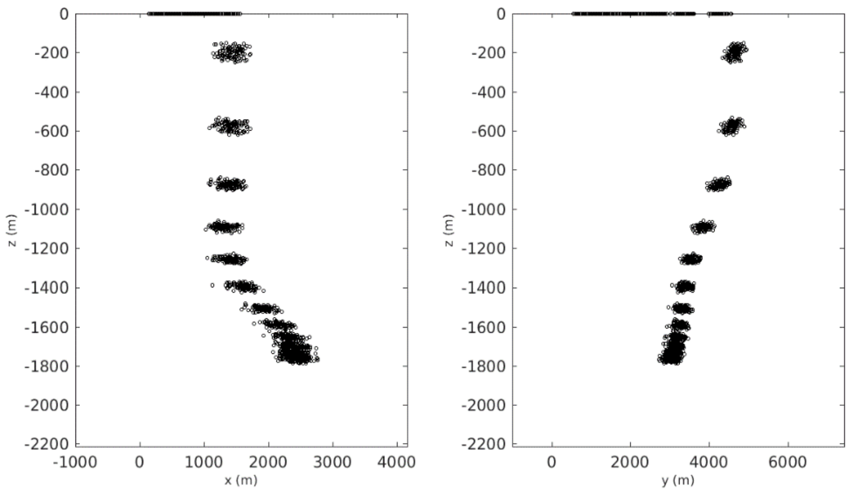

Fig. 8 Oil location for Exp. LF 24 hours after the blowout in x-z (left) and y-z (right) directions. Oil droplets are represented by black circles.

4. Conclusion

Hypothetical blowouts of oil and gas from deepwater were simulated using a Lagrangian numerical model. The experiments considered two different locations in order to verify the effects of ocean currents on the plume behavior.

The results showed different trajectories of oil and gas influenced by variations in the ocean currents directions. It was showed that oil droplets can travel long horizontal distances and reach the surface in places far from the release point. The formation of hydrates around the gas bubbles was verified, but they never reached the surface because the gas was completely dissolved.

Simulations of oil and gas discharges provide results that can help the understanding of the plume behavior during a blowout. Therefore, better planning of emergency controls can be elaborated in cases of real accidents.

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