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Analysis of Oil Spill Risks in the Islands of Lanzarote and Fuerteventura Due to Exploration Under Adverse Weather Phenomena

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ABSTRACT

The 23rd January 2002 BOE (n#20) published the Real Decreto 1462/2001, of 21st December, a resolution by which the Spanish Government allows the Repsol Company to search hydrocarbon, in the areas near to Lanzarote and Fuerteventura. This permission is the so-called CANARIAS 1-9. A large amount of institutions such as the councils of Lanzarote and Fuerteventura, the Canary Government, ecologist organisations, political parties and citizens have shown their opposition to this imposed measure due to the impact it would have upon these coasts.
This project aims to analyze the risk that oil prospection and extraction would suppose in the bordering ecosystems, since they would take place so close to the littoral of Lanzarote and Fuerteventura. Actually, this study concentrates on the possible consequences of oil prospection during an episode of adverse meteorological phenomenon, like the ones in December 2013. It is clear that these weather conditions are being more frequent in recent years.

The Model of Hydrocarbon Transport Simulation (Modelo de Simulación de Transporte de Hidrocarburos), or TESEO provides information about hydrocarbon deterioration and also about objects floating freely in the sea.

1. Introduction and approach

One of the main handicaps Spain faces in relation to its development is the high energetic deficit, close to 4% of the Gross Domestic Product (GDP) in 2011 (INE, 2011). It means a serious obstacle in order to adjust a common deficit. Therefore, to reduce the electricity bill is one of the main economic challenges specially taking into account the perspectives of price maintenance in energetic properties. In fact, in cases of elevated levels, the origins are related to the recent problems in Middle East, which provoke an increase in the price of Brent – referential to Europe- that has reached its highest value, up to $116 per barrel (Intercontinental Exchange, 2013).

The importance of the energetic sector in Spain goes further than its participation in the total production. It is a strategic segment from which all the economic activity depends and thus, a key factor to any kind of service or property production. For this reason, the poor energetic resources have limited the economic development of Spain (Gutiérrez Jodra, 2003). To be more precise, it is because of the lack of gas and liquid hydrocarbon and the bad quality of the existing coal. Such scarcity of resources has traditionally condemned the Spanish energetic system to a situation of deficit and dependence from others. There are few deposits in Spain and the little amount of oil extracted is directly exported to other countries. Some oil and gas deposits have been found both in land and sea. The first one occurred in 1964, in Ayoluengo, Burgos. The next ones progressively appeared along Mediterranean Sea, Valencia Gulf, Bay of Biscay, Guadalquivir Valley and Gulf of Cadiz. The interior oil production during 2011 increased to 100.000 Tm. (approximately 733.000 barrels), which meant a reduction of the 18% in respect to the previous year. This production only supposes the 0,16% of the primary consumption of oil in Spain. The current production fields are: Lora (Burgos), Casablanca-Montanazo (Casablanca), Rodaballo and Angula-Casablanca (Boquerón), which belong to the Casablanca platform in front of Tarragona in the Mediterranean Sea. (Boletín estadístico de hidrocarburos. Informe resumen, 2011).

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For more than 30 years, experts have believed on the existence of an oil reserve near the coast of the Canary Islands. Recently, they have decided to launch a project to start a formal exploration. The central government has given Repsol their authorization to look for oil in waters located in front of the eastern coasts of Lanzarote and Fuerteventura. (Alenta, 2013). The company, following the current law, has published the results of the first environmental research required before exploring for oil, which is likely to occur in 2014. Repsol (2013) estimates the Canary reserve to have about one thousand million oil barrels, which would mean between 11 to 15 per cent of Spain's annual supply (that is 38 million barrels per year). In such case, it would take a period of 25 to 30 years of exploration. This would be the biggest oil discovery in our country. If the declaration of environmental impact done by Repsol, currently under discussion, was positive, the exploration would be carried out with a dynamic positioning ship. To do so, the first step would be an exploratory perforation in an area of 6100 km² and 61 km from the coast of Fuerteventura. The depth of this perforation would take between 3000 and 3500 meters (approximately 900 meters of water sheet and 2000 meters of underground).

The Canary Islands are typified by good weather conditions during the majority of the year; however, this situation is occasionally interrupted by extraordinary meteorological phenomena which cause adverse circumstances to the whole community. The adverse meteorological phenomena (A.M.F), contained in the Plan Específico de Protección Civil y Atención de Emergencias de la Comunidad Autónoma de Canarias por Riesgos de Fenómenos Meteorológicos Adversos (PEFMA) (BOC 114, 23th January 2007), produce situations which completely modify the daily life and affect human activity like the interruption in communications, electricity cut-off, etc. Of course, this has direct consequences in economy and in people's properties.

The following are the situations of risk associated to atmospheric phenomena which represent a potential danger due to the fact of being outside the normal parameters, as (Dorta) explains:

–Rain
–Snow
–Wind
–Dust in air
–Storms
–High temperatures
–Low temperatures
–Heat waves
–Cold waves
–Tropical storm

And among coastal phenomena:
–Wind in coastal areas
–Wave height in windy weather
–Wave height in groundswell

Since Deepwater Horizon platform accident in Gulf of Mexico, the 20th April 2010, we have been intensively studying all the events occurred, including the attempts to close the cracks that were provoking oil-spill. We have also been analysing the flowing of hydrocarbon in the sea and its recuperation with absorption skimmers, as well as the elimination of some oil through burning techniques. In addition, both cleaning labour and the restoration of the environment have been studied too. This research is contained in the following publications: El siniestro de la plataforma "Deepwater Horizon" en el Golfo de México (ISBN; 978-84-694-2225-0); Modelos De Simulación Y Gestión Utilizados En El Vertido De La Plataforma "Deepwater Horizon" En El Golfo De México (ISBN: 978-84-694-3381-2); Acontecimientos Acaecidos Durante el Vertido de la Plataforma Deepwater Horizon en el Golfo de México (ISBN: 978-84-694-9690-9) ; Modelos Complementarios Utilizados en la Gestión del Vertido de la Plataforma Deepwater Horizon (ISBN: 978-84-694-9689-3). During this accident, the fight against pollution was affected and interrupted in two occasions because of adverse meteorological phenomena. The first time, it was hurricane Alex in July 2010 and later on, tropical storm Bonnie in august that same year.

2. Methodology

The application of hydrocarbon drift models aim to answer the question generated directly after an oil spill: what is the trajectory of the spill and which areas will be affected? Knowing this beforehand provides essential information about the protection of ocean resources and allows the authorities to establish a successful intervention plan.

The exact prediction of the movement and behaviour of an oil spill is a quite difficult task, due to the interaction of several physical processes which in many cases carry incomplete and random information. The TESEO* model allows us to predict the trajectory of oil spills. A graphic interface developed by the Hydrographical Institute of Cantabria manages all the

Table 1.

SONDEO EXPLORATORIO	CARACTERISTICAS		SONDEO EXPLORATORIO COORDENADAS UTM (EUROPEAN DATUM 50, ZONA 28 NORTE)		DISTANCIA MÍNIMA (Km)	
	Tipo de Sondeo	Profundidad (M)	X	Y	Lanzarote	Fuerteventura
Plátano 0	Somero/Vertical	852	685577	3175826	50.0	69.6
Sandía 1	Somero/Desviado	870	677455	3160589	56.0	62.2
Chirimoya 1	Somero/Desviado	1093	665302	3153274	55.7	50.5
Cebolla 1	Somero/Vertical	1148	717880	3206287	67.8	104.5
Zanahoria 1	Somero/Vertical	1018	671260	3157240	55.1	56.2
Naranja 1	Somero/Desviado	1420	722593	3232048	68.8	117.4

Source: RIPSA, 2013.

necessary operations for the use of a numerical model of transport and alteration of hydrocarbon. In order to operationally obtain ocean and weather data, the TESEO system is connected via ftp to AEMET (National Meteorology Agency) and to the regional system of Puertos del Estado (State Seaports).

The drift reproduction is a Lagrangian bidimensional model which estimates the oil movement, as well as any object or person floating freely in the sea. This model is based on the PICHI model, developed by the University of Cantabria during the Prestige accident. Transportation is reproduced through particles moving independently because of wind, waves and water currents. To imitate the aging progression that the oil spill suffers, they consider certain emulsion and evaporation processes. With the purpose of calibrating the model they used an evolution method and different search groups. The final measuring was achieved thanks to the algorithm SCE-UA (Shuffled Complex Evolution Method – University of Arizona) (Duan et al., 1994) adapted for oceanographic application (Abascal et al., 2009).

The center of the system is the Oil Spill Transport and Fate Unit. The model considers the influence of the aging processes in the evolution of oil spill. On the one hand, the drift processes are described through the approximation of the stain to a system full of many particles, where the position of each one is obtained from the following vector equation:

$$\frac{d\vec{x}}{dt} = \vec{u}_a(\vec{x}_i, t) + \vec{u}_d(\vec{x}_i, t) \tag{1}$$

where

$\vec{x}_i$ is the coordinate (x,y) of the particle i.

$\vec{u}_a$ and $\vec{u}_d$ are the advective and diffusion speed.

Advective speed, $\vec{u}_a$, is calculated from a line combination of current velocity, wind speed and Stoke drifting produced by waves.

$$\vec{u}_a = \vec{u}_c + C_D\vec{u}_w + C_H\vec{u}_H \tag{2}$$

where

$\vec{u}_c$: surface current speed

$\vec{u}_w$: wind speed 10 meters over sea surface

$\vec{u}_H$: Stokes trawling

C_D: coefficient of wind trawling

C_H: coefficient of waves

According to Dean y Dalrymple (1991), the Stokes trawling is taken from

$$u_H = \frac{gH}{8C} \tag{3}$$

g : gravity

H : wave height

C : speed of wave train associated to the main period (m/s)

The turbulent diffusion is obtained using a random sampling of Montecarlo in the speed rank $[-\vec{u}_d, \vec{u}_d]$, which is assumed proportional to the diffusion coefficients (Hunter et al., 1993). The fluctuation of speed in each moment is:

$$|\vec{u}_d| = \sqrt{\frac{6D}{\Delta t}} \tag{4}$$

Where D is the diffusion coefficient.

After oil is spilt on the sea surface, this is affected by different physical and chemical processes which depend mainly on the spill circumstances and the environmental conditions. The aging processes mentioned before interact in different degrees of time and their influence is explained through mass balance. The model developed identifies the amount of oil that has impacted into the coast. Quantities are deleted from the computing process.

. In the current model, evaporation is calculated according to the analytic model proposed by Stiver y MacKay (1984). In their formulation, the evaporation tax is related to steam pressure, the spill area and a mass-transfer coefficient which depends of wind speed, the surrounding temperature and the type of oil spilt.

The evaporation speed is estimated using a basic kinetic law:

$$\Delta F = \exp\left[6{,}3 - \frac{10{,}3}{T}(T_0 - T_G F)\right]\left(\frac{kA\Delta t}{V_0}\right) \tag{5}$$

where

F is th e evaporated fraction; k is the mass-transfer coefficient; A corresponds to spill area; V_0 is the volume spilt; T is the surrounding temperature; and T_0, T_G are the fixed value of distillation.

The emulsifying model is based in the calculation proposed by Mackay et.al(1980):

$$\frac{dY}{dt} = -k(W_{10}+1)^2\left(1-\frac{Y}{Y_f}\right) \tag{6}$$

Where

Y is the water content; Y_f the maximum content of water admitted by oil; W_{10} is wind speed 10 m over sea surface; k is the constant depending on the oil type.

The physical-chemical properties of oil change due to aging processes. In TESEO, the viscosity evolution and the oil density are calculated according to temperature, evaporation loss and water absorption. The formula used to calculate density variations and viscosity are described by Comerma (2004). As a consequence, density intensification is calculated taking into account the following equation:

$$\rho = Y\rho_w + (1-Y)\rho_0\big(1-C_T(T-T_0)\big)(1+C_F F) \tag{7}$$

Where: ρ is the pollutant density; ρ_w is the water density; ρ_0 is the initial oil density to T_0. T_0 is the oil reference temperature; C_(T,) C_F are regulatory parameters and Y is oil in water.

Viscosity is determined according to the emulsion content in water, the atmosphere temperature and the evaporation.

$$\upsilon_f = \upsilon_0 \exp\left(\frac{C_3 Y}{1-C_4 Y}\right) \exp[C_5(T - T_0)] \exp(C_6 F) \quad (8)$$

Where: υ_0 is the initial oil viscosity to T_(0 ,) C_(3 ,) C_4, C_5 and C_6 which are regulatory parameters.

3. Development (application and results)

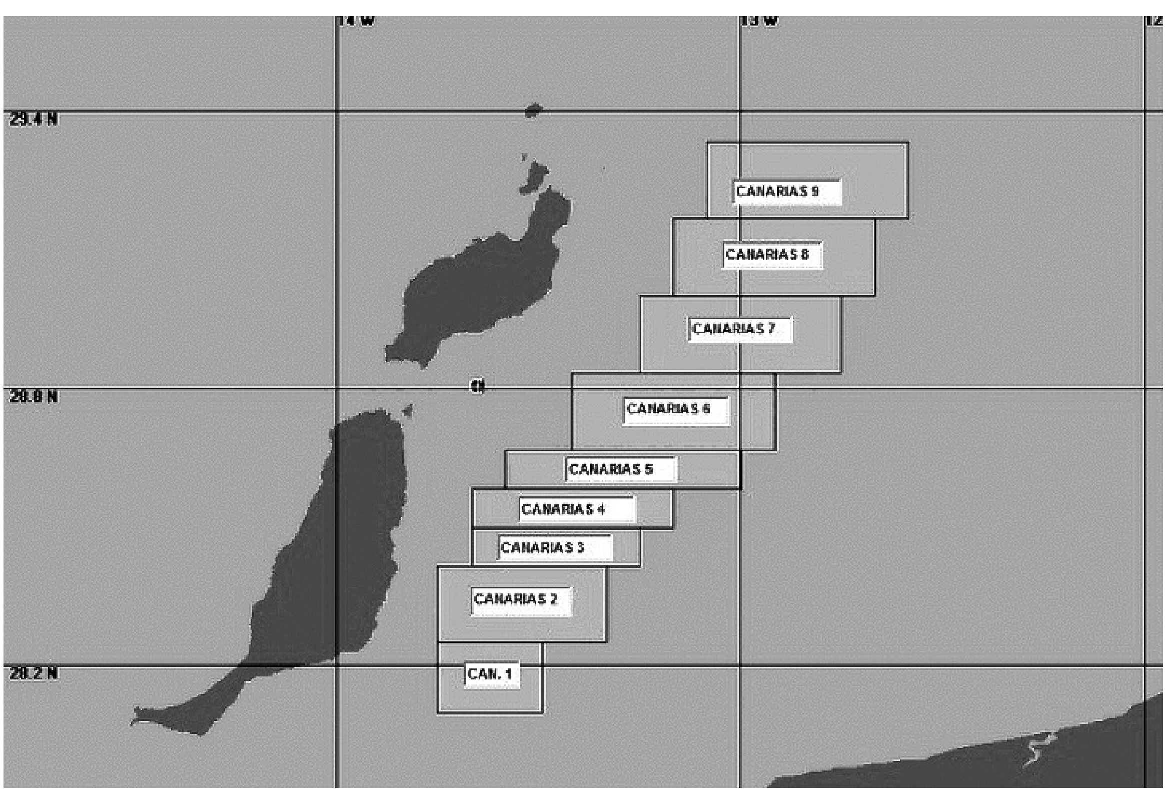
This project has been carried out taking into account the data collected from the episodes of weather alerts ordered by the Canary authorities in December 2013. Moreover, we have considered the case of oil spill produced by oil exploration in the areas established by Repsol and the trajectory of the supposed spill during an episode of Adverse Meteorological Phenomena like the ones occurred in the last decades. Furthermore, we point out the possibility of oil spill in one of the most interesting locations in what has to do with oil research for Morocco, the coast of Cape JubBy.

SIMULATIONS CARRIED OUT WITH TESEO MODEL
DATA: WINDS, WATER FLOWS, WAVES (AEMET - ESTATE PORTS)
EXPLORATION AREAS: SANDÍA 1, CHIRIMOYA 1, CEBOLLA 1, CAPE JUBBY (MOROCCO)

Oil spill characteristics:

— Name: Arabian Light
— Type: Crude
— Spill volume: 960 m^3
— Density: 869 kg/m^3 (20ºC)
— Viscosity: 12 cSt (38ºC)
— Maximum evaporation: 35%
— Minimum evaporation: 0%
— Maximum emulsion: 85%
— Simulation length: 10 days

Figure 1. Prospection Areas.



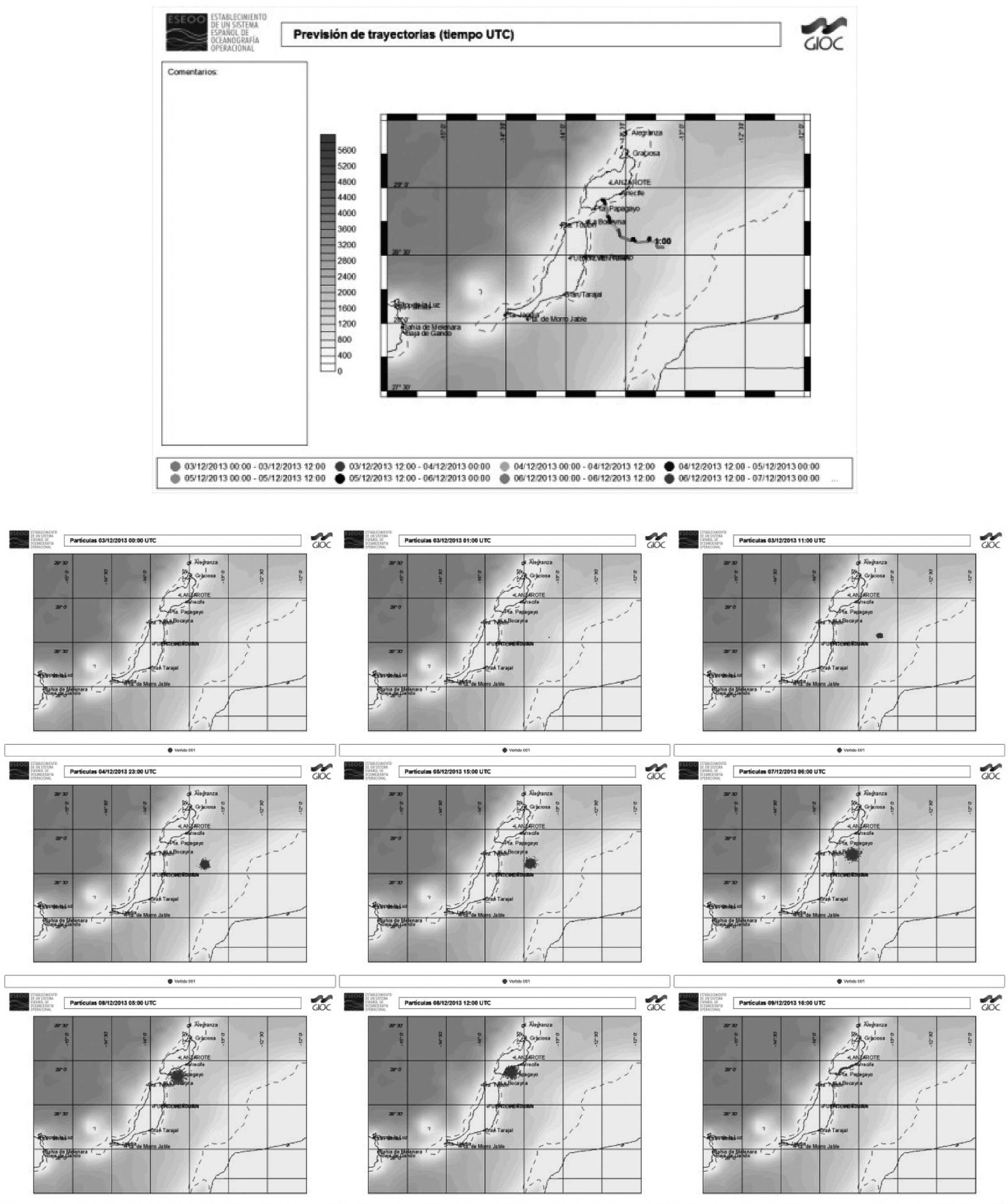
Source: Consemar, 2014

Table 2

SONDEO EXPLORATORIO	CARACTERISTICAS		COORDENADAS		DISTANCIA MÍNIMA (Km)	
	Tipo de Sondeo	Profundidad (M)	LAT	LONG	Lanzarote	Fuerteventura
SANDÍA 1	Somero/Desviado	870	28.560060°	13.185873°	56.0	62.2

Source: Authors

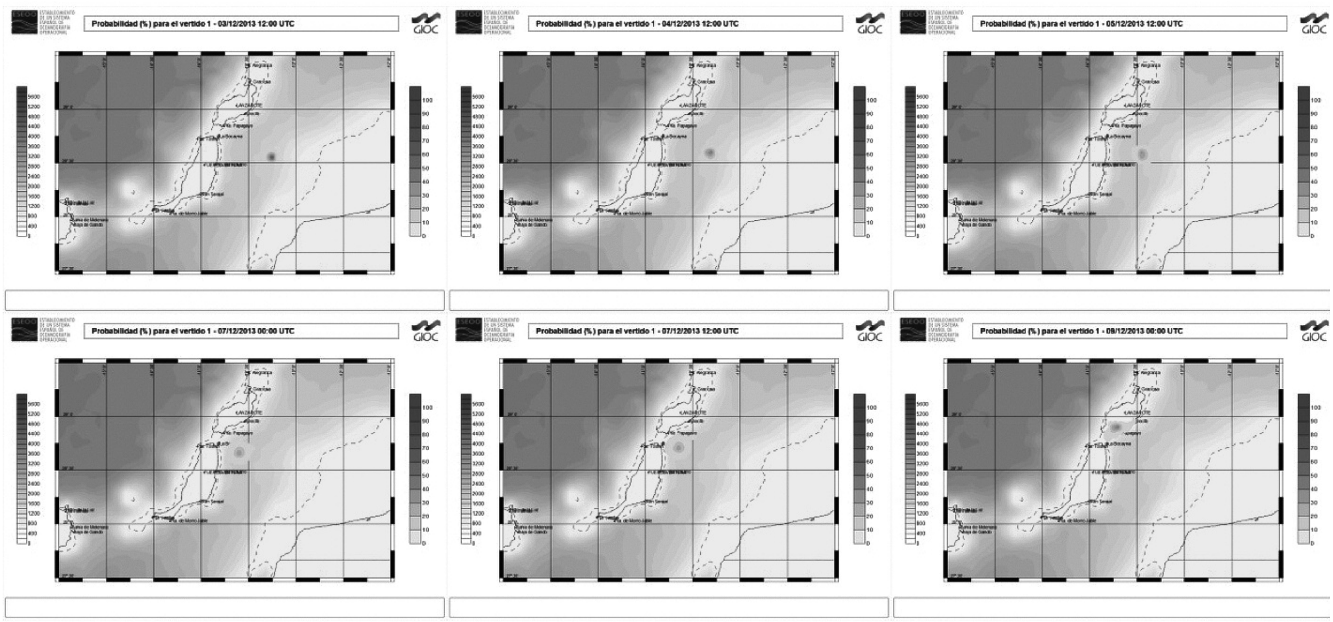
Figure 2



Source: Authors

According to the evolution sequence, from the research area Sandia 1, the oil spill reaches the south coast of Lanzarote in approximately 96 hours.

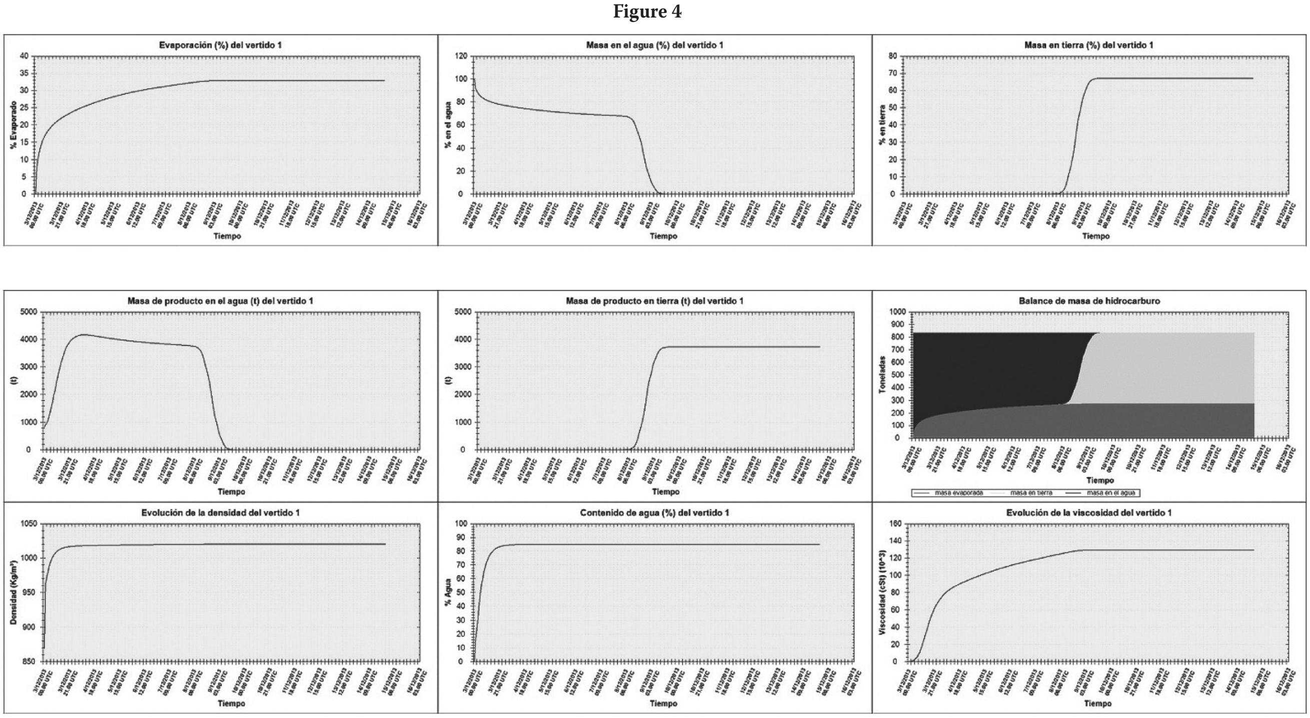
Figure 3



Source: Authors

In the previous sequence we can see the places where the drift particles will reach the coast.

Figure 4



Source: Authors

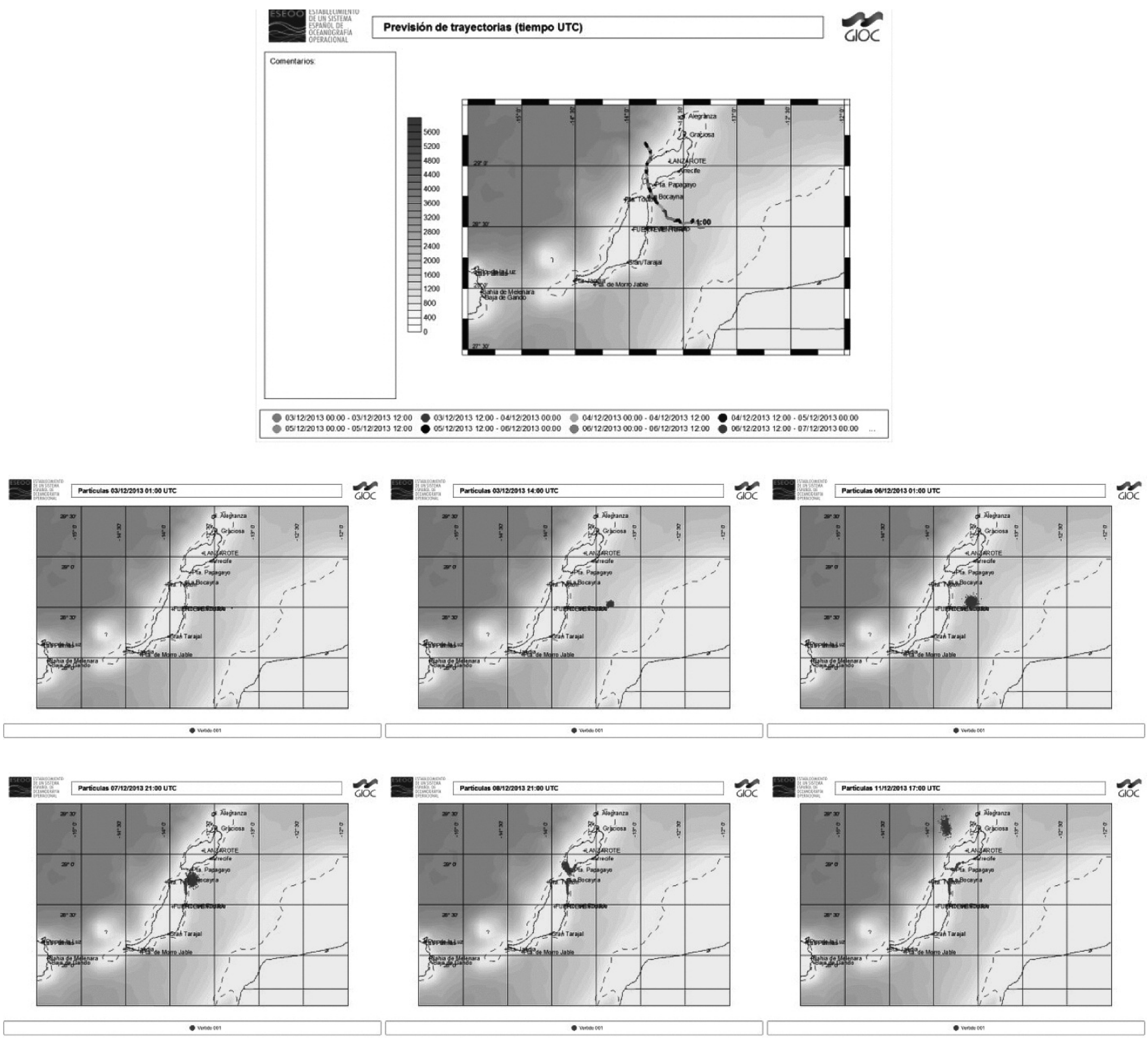
The maximum evaporation of this hydrocarbon is of about 30%, which is produced in the first 48 hours. However, oil density plus its content in water, increase very quickly. This indicates that the emulsion process occurs rapidly too. Therefore, we expect the same in the rest of oil spills like the ones we see in the following prospection areas. As we can see, the volume multiplies allowing extension to increase as well.

Table 3.

SONDEO EXPLORATORIO	CARACTERISTICAS		COORDENADAS		DISTANCIA MÍNIMA (Km)	
	Tipo de Sondeo	Profundidad (M)	LAT	LONG	Lanzarote	Fuerteventura
CHIRIMOYA 1	Somero/Desviado	1093	28.495663°	−13.311121°	55.7	50.5

Source: Authors

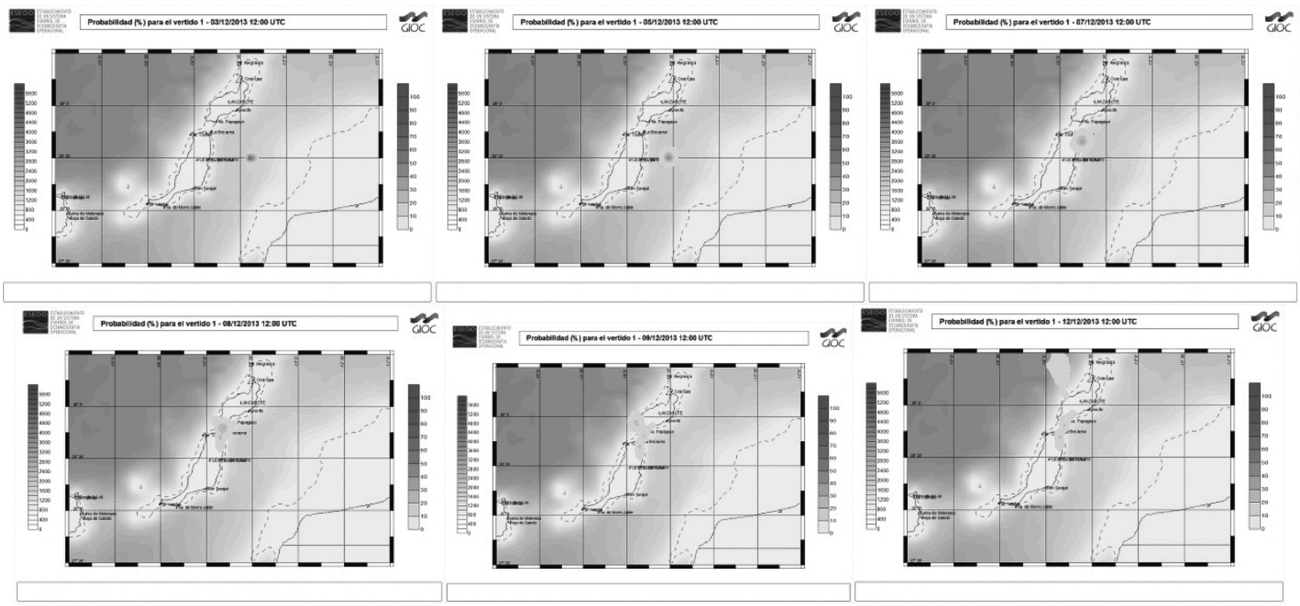
Figure 5.



Source: Authors

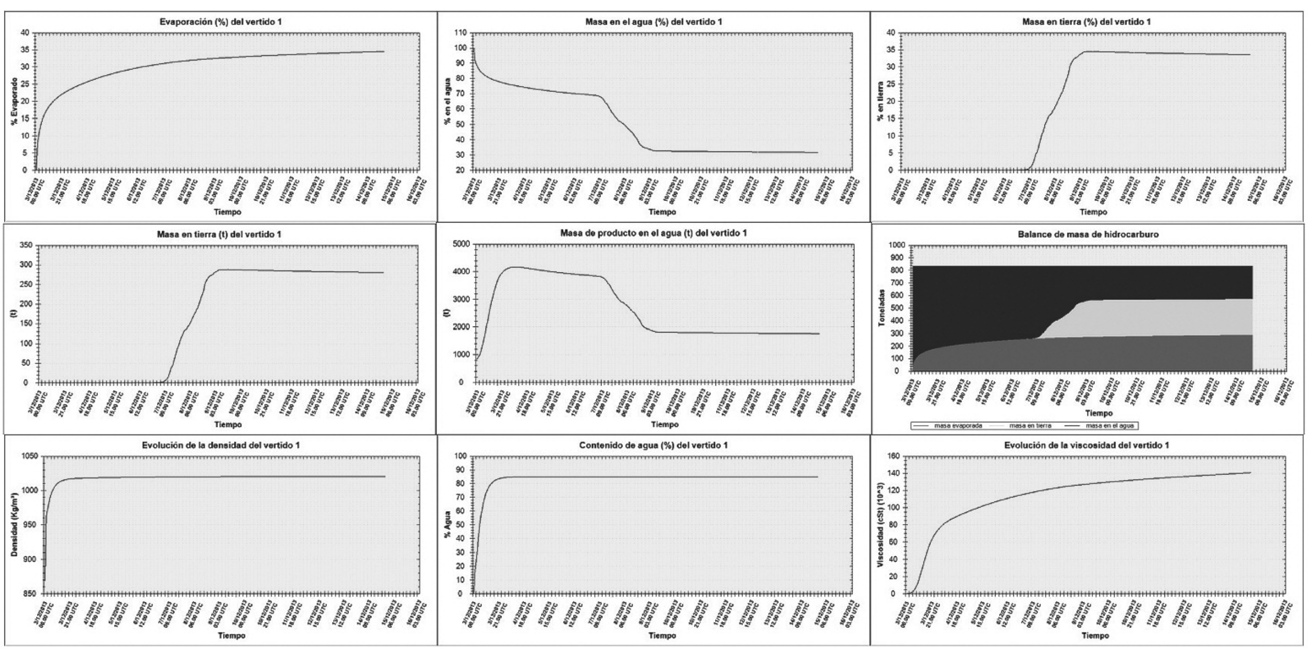
Southern Lanzarote, concretely Playa Blanca, is directly affected in this oil spill. Also Corralejo and Lobos in Fuerteventura are affected since this spill does not stop and reaches the western side of both islands, crossing the so called strait of La Bocaina, which separates them.

Figure 6.



Source: Authors

Figure 7.



Source: Authors

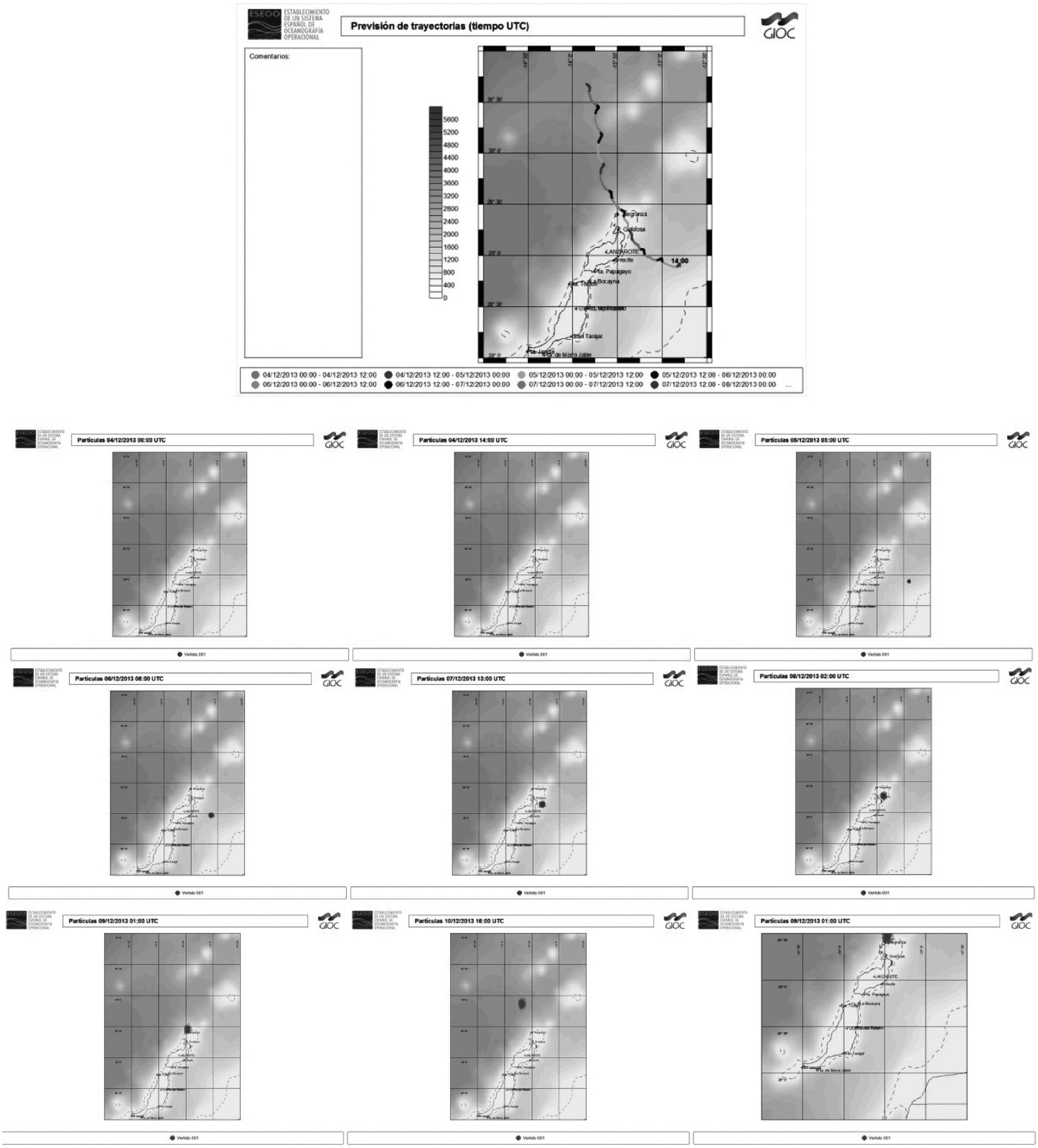
The election of an Arabian Light for simulations is due to the fact of being a reference crude, provided by Repsol Company in the study on environmental impact "Sondeos exploratorios marinos en Canarias" (Exploratory Research in Canary Waters). As we prove in all cases, it is a crude oil which transforms in certain meteorological conditions very quickly. It also increases remarkably the amount of product present in water and thus, the volume that will reach the coast.

Table4

SONDEO EXPLORATORIO	CARACTERISTICAS		COORDENADAS		DISTANCIA MÍNIMA (Km)	
	Tipo de Sondeo	Profundidad (M)	LAT	LONG	Lanzarote	Fuerteventura
CEBOLL A 1	Somero/Vertical	1148	28.966079°	–12.764071°	67.8	104.5

Source: Authors

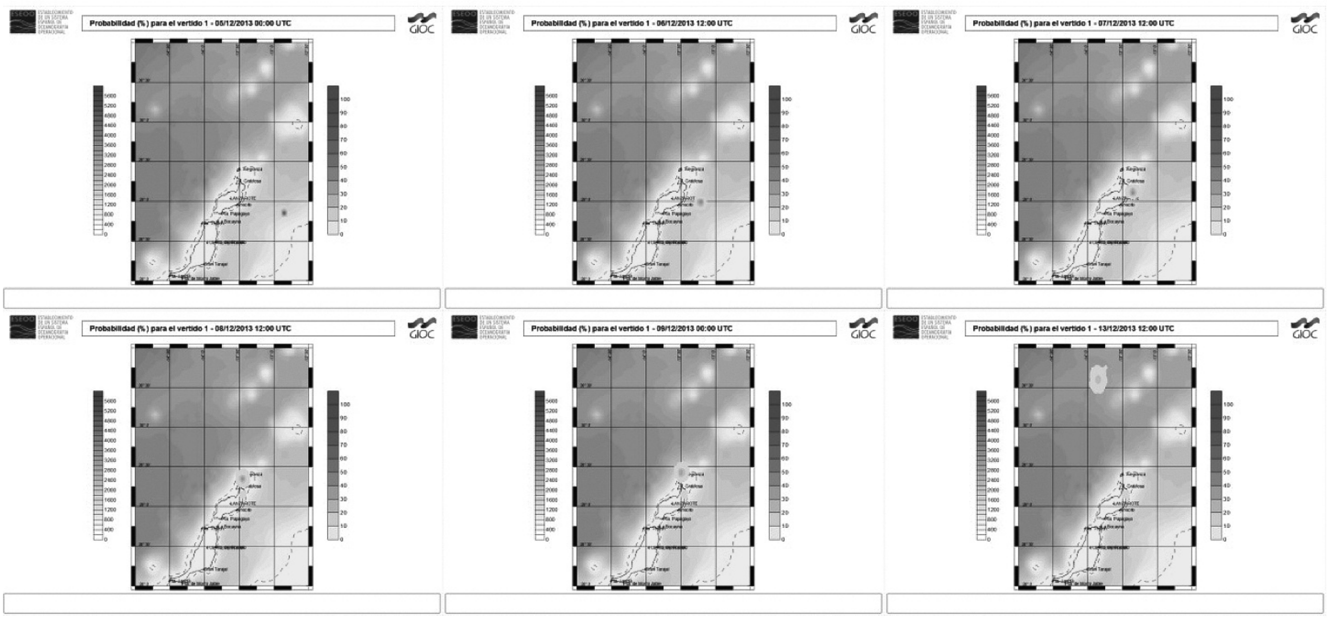
Figure 8.



Source: Authors

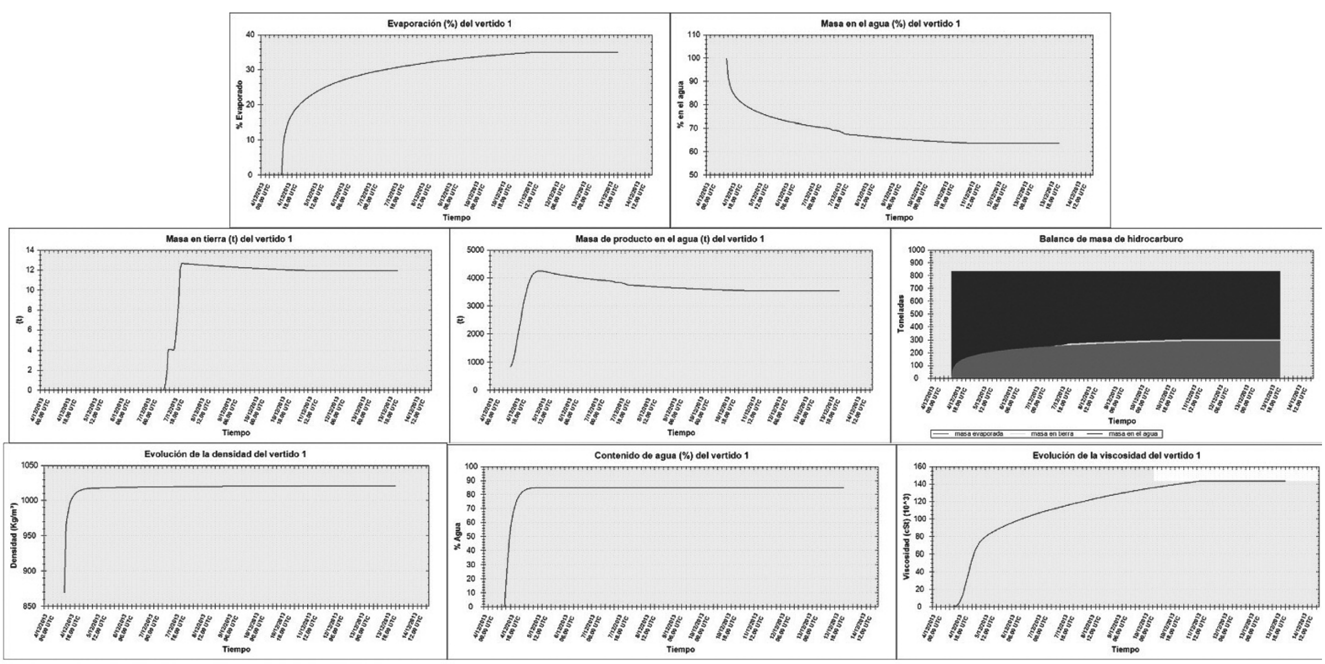
This will obviously influence the cleaning and recuperation of the coastal area in a quite negative way. We can confirm that, with the weather conditions present during the days this study was carried out, the island mostly affected is Lanzarote. The reason for this is spill direction changing to SW-SSW, something observed in seasonal simulations to NW in this decisive case.

Figure 9.



Source: Authors

Figure 10.

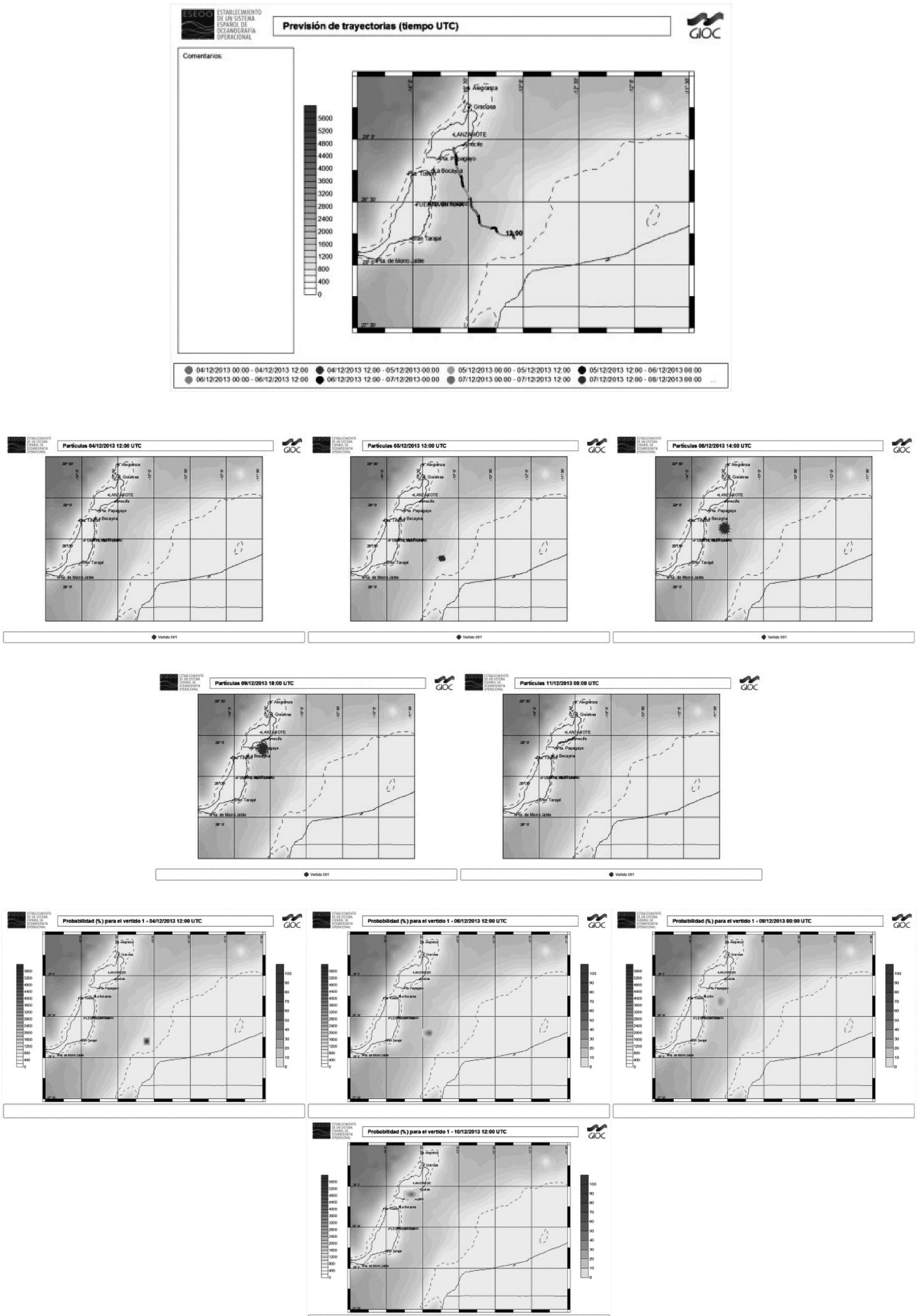


Source: Authors

Table 5.

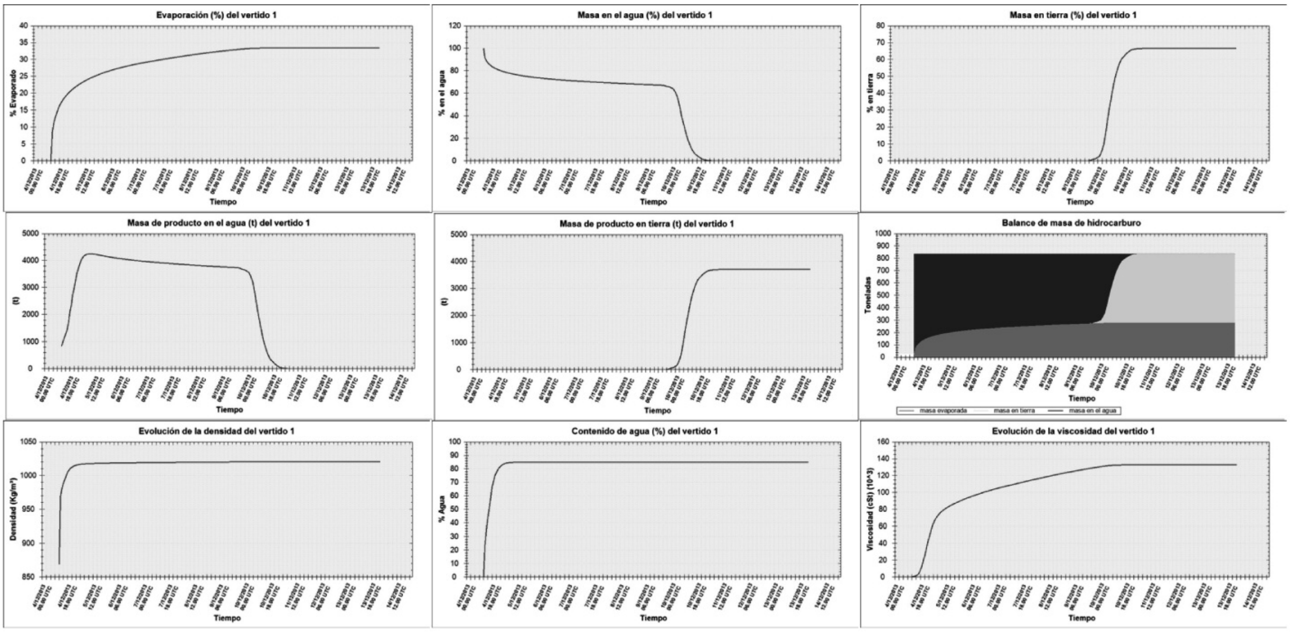
SONDEO EXPLORATORIO	CARACTERISTICAS		COORDENADAS		DISTANCIA MÍNIMA (Km)	
	Tipo de Sondeo	Profundidad (M)	LAT	LONG	Lanzarote	Fuerteventura
CAPE JUBY (Marruecos)	-----	-----	28.213678°	13.082930°	-----	-----

Figure 11.



Source: Authors

Figure 12.



Source: Authors

4. Conclusions

Along the progress of this study we present the results of crucial simulations for a possible Adverse Meteorological Phenomenon during exploratory researches of Repsol and Morocco (CAIRN ENERGY).

The potential spill trajectories have been analyzed using TESEO model to evaluate the final consequences. Real data from National Meteorological Agency and *Puertos del Estado* (State Ports) was used to accomplish the description of wind, water flows and waves in the area. From the viewpoint of impact and drift length probability:

– The eastern coast of Lanzarote has got the highest probability to receive the impact of oil spill, because of explorations SANDIA-1, CHIRIMOYA-1 and CAPE JUBBY.

– Concerning spills produced in areas located in northern latitudes like CEBOLLA-1, even though it seems they do not seriously influence the coast, they directly affect the sea reserve of northern Lanzarote, La Graciosa and the small islands of Chinijo archipelago (Montaña Clara, Roque Oeste, Roque Este and Alegranza).

– In what has to do with minimum times, the spill may reach the coastal areas in approximately 72 hours; although in that period of time the emergency supplies could not stop contamination because of the dominant adverse weather phenomenon.

– Presumably, in Fuerteventura the most affected area could be the North-East (Corralejo and Lobos island), whose land would be infected in the first 96 hours in the case of CHIRIMOYA-1.

From the results of these cases, it can be concluded that a large amount of oil spill stays in the water column. This implies evaporation, as a remarkable process of natural degradation, which reaches values up to 30%. Nevertheless, emulsion occurs very quickly, something that increases notably the spill volume and its viscosity. As a consequence, the coast cleaning and restoration labour becomes more difficult. Eventually, exploratory research in Morocco waters does not exempt the eastern Canary Islands of being affected by oil spill in view of the fact that time to reach the coast multiplies.

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