METEOROLOGICAL AND OCEANOGRAPHIC CHARACTERIZATION FOR OFFSHORE PRODUCTION FACILITIES DESIGN. MARISCAL SUCRE PROJECT (MSP). NORTH PARIA – VENEZUELA

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ABSTRACT

In the present study, the meteorological and oceanographic conditions for production facilities design of Mariscal Sucret Project (MSP) were caracterized. In order to do this, ADCP currentmeters was used with a capacity of measuring speed, currents direction and temperature, as well as an aceanographic bouy with a capacity to measure currents, wind and wave. Monitoring stations were distributed among the Dragon, Patao, Mejillones, Río Caribe fields and locations nearthe coast. Measurements were made continuously during the periods 2006-2014. The average speed of the surface currents of Río Caribe field 0.151m/s was until 1.95times lower than those recorded in the Dragon, Patao fields and Mejillones with 0.310 , 0.295 and 0.245m/s respectively, with predominant direction O-OSO. The deeper layerof Río Caribe field registeredthe lowest current speed 0.07m/sand the highesttemperature 20,69°C with an inversed tendency proporcional to the current speed relative to the temperatura for the rest of the stations. The Dragon field station showed the maximum values of bottom currents and temperature under with 0.111 m/s and 17.82°C respectively, with a predominant direction ESE and NE rerspectively.Current speed (middleand botton layers) seems to be influenced by the depth and and temperature with a tendency to decrease insofar as they tend to the west. The area study seems not to be directly influenced by the action of atmospheric phenomena from the North Atlanctic Ocean. The records obtained are an important reference for offshore production facilities design.

Keywords: Currents, Wave, wind, production, gas.

INTRODUCTION

The maritime area which correspond to the nort front of the Paria Peninsula brings important reservoirs of non-associated gas and condensates distributed between the Dragon, Patao, Mejillones and Rio Caribe fields that integrates Mariscal Sucre Project (PMS). This maritime area is influenced by physical factors such as sea currents from the Atlantic Ocean and Gulf of Paria, temperature as well as by the action of atmospheric phenomena, which are crucial for modeling environmental patterns in the area (Fukuoka 1964, Okuda 1974 Quintero 1991).
There are reports that point as in the north-eastern shelf of Venezuela vertical transport of nutrients (areas of coastal upwelling) from sub-surface waters to the surface layer, either induced by the wind, currents divergence or topographic effects, has an influence on the physical patterns that govern the area and are intimately linked to seasonality (Aparicio-Castro, 1986 and 1993.
For this reason, it is essential to characterize the meteorological and oceanographic conditions in Mariscal Sucre project area comprehensively so as to define the physical patterns that govern the area, strengthening the available historical records and facilitate statistical modeling of various meteorological and oceanographic trends the region, high impact during design engineering phases of offshore production facilities.

PROCEDURES

Study area

The study area covered the Dragon, Patao, Mejillones and Rio Caribe Fields that integrates Mariscal Sucre project (PMS), located 40 km north of the Paria Peninsula, Sucre State and included the coastline of the Peninsula of Paria to evaluate oceanographic behavior in the areas near the coast.

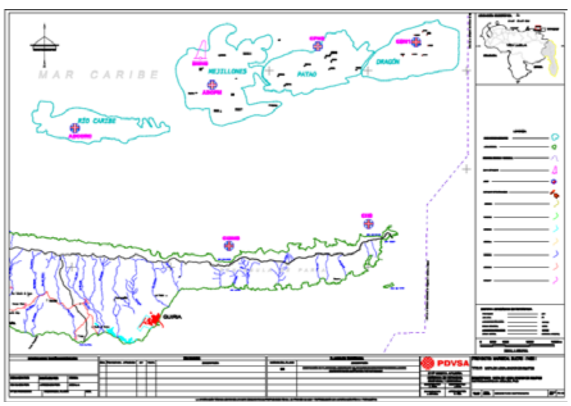


Figure 1. Relative location of measuring stations

Tabla 1. Coordinates of the measuring stations
(Coordenadas de las estaciones de medición)

Equipos De medición	Estación	Ubicación	Coordenadas (U.T.M) Datum WGS 84		Prof. estimada (m)
			Este (m)	Norte (m)	
Correntímetros ADCP sumergidos	CDN1	Campo Dragón	629.804	1.225.919	135
	CPN2	Campo Patao	609.879	1.225.020	123
	ADCPM	Campo Mejillones	588.450	1.217.190	98
	ADCORC	Campo Rio Caribe	560.605	1.208.406	85
	CEM8	Ensenada de Mejillones	591.882	1.184.368	83
	CII9	Istmo de Obispos	620.186	1.188.848	82
Boya Meteorológica	BMN6	Mejillones norte	586.064	1.222.613	98

In the study were selected a total of seven (7) monitoring stations distributed at the site of the project, ensuring the highest possible coverage and areas close to the coast (Figure 1 y Table 1).

Data acquisition

Data acquisition was made continuously by installing current acoustic profilers ADCP line, in underwater oceanographic arrays and buoy and each selected sites (Table 1). Equipment with a capacity of speed measure and currents direction, temperature and wave bottom as well as ability to measure meteorological parameters such as wind direction and speed**.**

Measurements were made during the periods 2006 - 2008 in case of the stations located in the Dragon, Patao fields and stations near the coast during the period 2012 - 2014 for the case of stations located in Mejillones, Rio Caribe fields .

Equipment

Current Profilers

To monitor current and temperature of background acoustic profilers were used (current meters) CONTINENTAL NORTEK brand provided with current sensors, temperature and pressure individually arranged (Dragon, Patao fields station and close to the coast) and underwater arrangements (Mejillones and Rio Caribe stations).

The current meters were installed next to a dead ballast or concrete to fix to the seabed and ensure measurements in the vertical profile of the speed and current direction in the whole water column. Also were connected to an acoustic release, to facilitate recovery team maneuvers during periodic review, download data and maintenance, and were provided with a protective dome or antirastra base.

Maintenance, data download and reinstallation of profilers from the planning program is a bimonthly throughout the study. The current meters sensors was made as follows:

Intervalo entre perfil(es)	900 seg (15 minutos)
Numero de celda(s)	14
Longitud de las celda(s)	1.000 cm (10 metros)
Intervalo de muestreo(s)	120 seg. (2 minutos)
Blanking distance	2,00 metros

Oceanographic buoy

For continuous monitoring of speed and direction of surface currents, waves and wind an oceanographic buoy AXYS brand was used, naval aluminum-hulled naval 3 m in diameter.
Buoy maintenance was made at a rate not exceeding four (4) months throughout the study, ensuring optimal performance of the sensors during the data acquisition. The buoy oceanographic sensors were configured as follows:

Oleaje	
Frecuencia de muestreo	4 Hz
Intervalo de muestreo:	20 minutos (1.200 segundos)
Intervalo entre muestras	60 minutos (3.600 segundos).
Vientos:	
Intervalo de muestreo:	10 minutos (600 segundos)
Intervalo entre muestras:	10 minutos (600 segundos)
Ráfaga de viento	Valor máximo durante 3 segundos
Correntímetro Doppler:	
Intervalo entre perfiles:	5 minutos (300 segundos).
Intervalo de muestreo	1 minuto (60 segundos).
Blanking distance	4,55 m.
Número de celdas:	20 -25
Longitud de celdas	5 m.

Processing and data interpretation

From recovered data the teams proceeded to perform the pre-processing, processing and the respective analysis. The handling of the data was made by AWAC software(file.dat). The verification of data quality was made by AWAC application, the software indicates "Error Codes" in the output files of data.

From processed and validated data time series and comparative statistics of current records, temperature, wind and waves for each of the selected monitoring stations were calculated. Also calculated were the percentage (%) of exceedance and return periods. The wave and Wind records were compared with models developed from historical data gathered OceanWeather.

RESULTS AND ANALYSIS

Currents and temperature

The average speed of the surface current Río Caribe field 0.151 m / s was only 1.95 times lower than those recorded in the Dragon, Patao and Mejillones fields 0.310, 0.295 and 0.245 m / s respectively, while for stations located closer to the coast superficial velocities less than 0.1 m / s were recorded, remaining homogeneous direction of the same with O OSO predominant component (Figure 2 and Table 2).

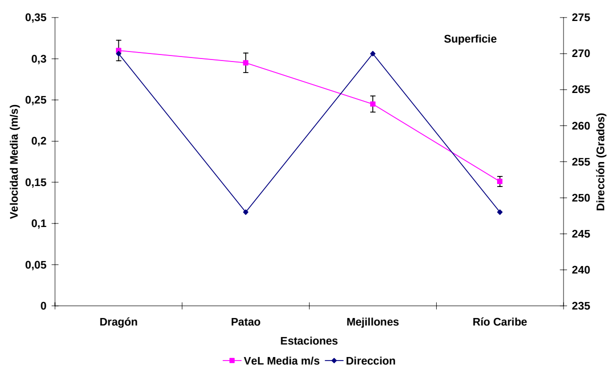


Figure 2. Average speed (m / s) and direction (degrees) of the surface currents between the Dragon, Patao, Mejillones and Rio Caribe fields

Table 2. Average speed (m / s) and address prevailing of surface currents between the Dragon, Patao, Mejillones and Rio Caribe fields

	VeL. Media (m/s)	Dirección
Dragón	0,31	O
Patao	0,295	OSO
Mejillones	0,245	O
Río Caribe	0,151	OSO

This behavior can be attributed to the influence of the action of the North-equatorial surface currents, north of Brazil and Guayana on stations in the Dragon, Patao and Mejillones fields, which travel from the east and south, converging close Trinidad Island (Müller-Karger y col., 1989; Pelegri – Padrón, 1986; Van Andel – Postma, 1954).

However in lower layers (middle and bottom) average and maximum speed currents seem to be influenced by the depth and temperature. In the deepest layer (84 m) of the lower Rio Caribe field current speed and the highest temperature was recorded with 0.07M / s and 20.69 ° C respectively, maintaining an inverse porportional tendency of current against temperature in the other stations (Figure 3).

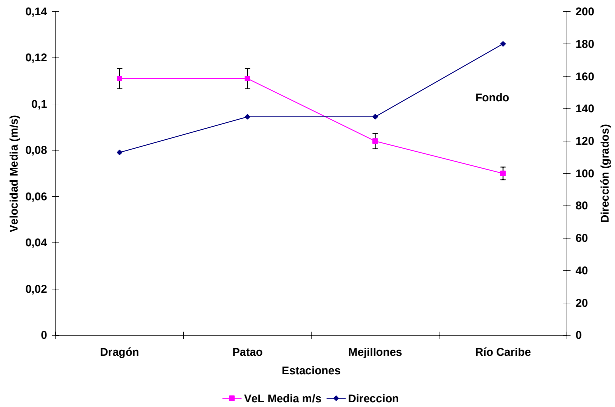


Figure 3. Average speed (m / s) and direction (degrees) of bottom currents between the Dragon, Patao, Mejillones and Rio Caribe fields

Table 3. Average speed (m / s) and direction (degrees) of bottom currents between the Dragon, Patao, Mejillones and Rio Caribe fields

	VeL. Media (m/s)	Dirección
Dragón	0,111	ESE
Patao	0,111	SE
Mejillones	0,084	SE
Río Caribe	0,07	S

Table 4. Comparison of bottom temperature (° C) between the Dragon, Patao, Mejillones and Rio Caribe fields

	Profundidad (m)	Temp mín. (°C)	Temp máx (°C)	Temp media (°C)
Dragón	135	14,95	21,98	17,32
Patao	123	15,48	25,05	18,79
Mejillones	97	17,03	23,61	19,67
Río Caribe	85	17,89	25,3	20,69

The Dragon field (122 m) station exhibited the maximum values of bottom currents and lower temperature with 0.111 m / s and 17.32 ° C respectively, with a dominant ESE.

The Dragon field (122 m) station exhibited the maximum values of bottom currents and lower temperature with 0.111 m / s and 17.32 ° C respectively, with a dominant ESE.
The movement of much of the flow to the ESE, along water column in most seasons, as opposed to westward flow (O) recorded in the surface layer of the stations further north, can obey the joint action of several factors: the action of surface currents, strongly affects the dynamics of the current regime, as well as differences in density of the fluid, caused by these temperature gradients (thermal effects) and salinity (haline effects), and the effects of this upwelling throughout the study area and allow greater mixing of the water column (Karger and Aparicio 1994; Müller-Karger y Varela, 1990; Monente, 1990; Kjerfve, 1981; Michaelov and col., 1969).

On the other hand, the values of currents associated to different return periods have been extracted from the exceedance currents graphs for whose development the Weibull probability distribution, commonly used for the analysis of current records was used. Extending records current, which in the best case does not reach 14 months, is a limiting factor if you want to extrapolate data accurately and find current magnitudes for longer periods of return to those listed in Table 5:

Table 5. Return period of current speed (m / s) for Dragon, Patao stations, and near coast

Estación	Velocidad de corrientes (m/s)											
	Periodo de Retorno (Años) Capa Fondo				Periodo de Retorno (Años) Capa media				Periodo de Retorno (Años) Capa superficial			
	1 mes	1	2	5	1 mes	1	2	5	1 mes	1	2	5
Campo Dragón CDN1	0,37	0,57	0,62	0,69	0,59	0,82	0,88	0,93	0,99	1,08	1,11	1,13
Campo Patao CPN2	0,34	0,46	0,48	0,51	0,47	0,53	0,55	0,57	1,02	1,12	1,15	1,18
CEM8	0,40	0,43	0,44	0,44	0,56	0,66	0,68	0,70	0,50	0,55	0,56	0,58
CII9	0,50	0,54	0,55	0,57	0,83	0,87	0,89	0,90	0,85	0,90	0,91	0,93
BMN6	-	-	-	-	3,05	3,40	3,48	3,62	2,60	3,15	3,25	3,40

Therefore, values for return periods up to 5 years, being able to estimate the effects of data for higher return periods, extrapolating the curves presented are reported, taking into account that any data that comes from a deemed year records , so it should be carefully evaluated when used in the design of structures.

Wave

Given the short length of the records, which although are valuable and useful for estimating short-term (1 or up to 2 years return period), are insufficient for accurate estimation and study of extreme waves generated by the effect of hurricanes or tropical storms that annually could be impacting the study area. That is why the values measured by the wave oceanographic buoy (2007-2008) were analyzed and compared using information provided by OceanWeather (1986-2005).

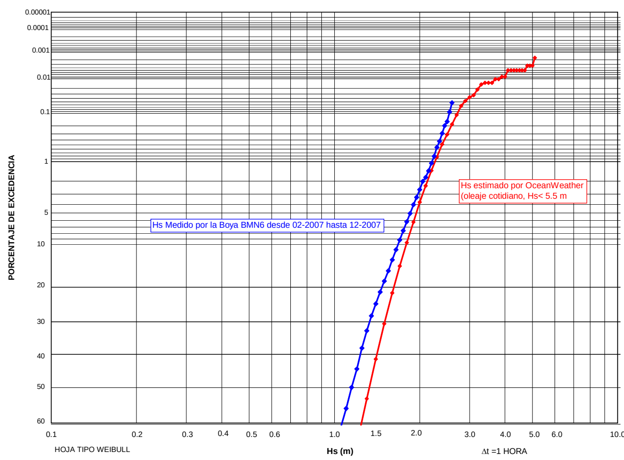


Figure 4. Comparison of the percentages of exceedance estimated by OceanWeather Hs (1986-2005) and the oceanographic buoy (2007-2008).

Table 6. Distribution of Hs with respect to provanence direction.

DIRECCION (º) — Hs medido por la Boya BMN6

Hs (m)		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSO	SO	OSO	O	ONO	NO	NNO	
0	0.5	-	0.07	1.29	0.36	0.01	-	-	-	-	-	-	-	-	-	-	-	1.73
0.5	1	-	1.10	20.25	9.80	0.37	0.01	-	-	-	-	-	-	-	-	-	-	31.54
1	1.5	0.44	2.16	34.01	11.61	0.11	-	-	-	-	-	-	-	-	-	-	0.01	48.33
1.5	2	0.11	0.20	12.23	3.25	-	-	-	-	-	-	-	-	-	-	-	-	15.79
2	2.5	-	-	1.77	0.69	-	-	-	-	-	-	-	-	-	-	-	-	2.46
2.5	3	-	-	0.07	0.09	-	-	-	-	-	-	-	-	-	-	-	-	0.16
3	3.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
3.5	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
4	4.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
4.5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
5	5.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
5.5	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
6	6.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
		0.54	**3.53**	**69.61**	**25.80**	**0.49**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	100.00

DIRECCION (º) — Hs estimado por OceanWeather

Hs (m)		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSO	SO	OSO	O	ONO	NO	NNO	
0	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
0.5	1	0.01	0.09	5.94	8.10	0.04	-	-	-	-	-	-	-	-	-	-	-	14.18
1	1.5	0.05	0.65	22.69	31.23	0.50	0.01	0.00	0.01	-	0.00	0.00	-	0.00	0.01	0.01	0.04	55.19
1.5	2	0.04	0.36	14.95	11.39	0.07	0.00	0.00	0.00	-	-	-	0.00	0.00	0.00	0.01	0.03	26.86
2	2.5	0.00	0.09	2.48	0.88	0.01	-	-	-	0.00	-	-	-	-	-	-	-	3.46
2.5	3	0.00	0.03	0.22	0.02	0.00	-	-	-	-	-	-	-	-	-	-	-	0.27
3	3.5	-	0.01	0.01	0.00	0.00	-	-	-	-	-	-	-	-	-	-	-	0.02
3.5	4	-	0.00	-	0.00	0.00	-	-	-	-	-	-	-	-	-	-	-	0.01
4	4.5	0.00	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
4.5	5	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
5	5.5	0.00	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
5.5	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
6	6.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
		0.11	**1.23**	**46.30**	**51.62**	**0.62**	**0.01**	**0.01**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.01**	**0.02**	**0.06**	100.00

The results very similar behavior is observed in the magnitude of Hs, and the direction provenance waves, waves coinciding in both cases that come mainly from the NE and ENE (Figure 4 and Table 6).

Although never recorded buoy heights greater than 3 m wave, it must be remembered that in the present study were available only records one (1) year for the buoy while estimates of OceanWeather 20 years (Figure 4).

Exceedance curves as shown in the corresponding period between December and May, outside the hurricane season, where the most influence on the wave regime has its origin in the action of winds Alisios blowing westward must be significant wave heights above 1.5 m may occur 30% of the time, compared with 5% in the hurricane season, whereas if taken together all measurements, such percentage rises to 20.

Table 7. Hs Vs Tp distribution

PERIODOS (s)

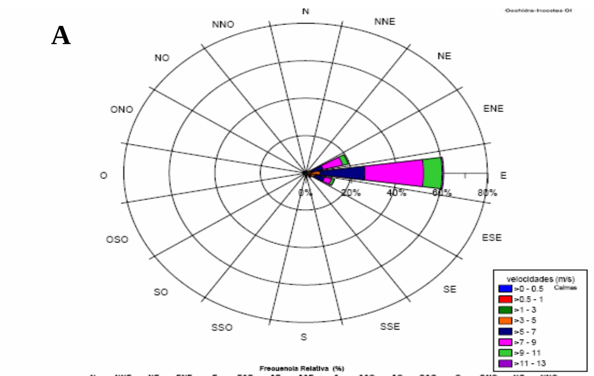
Hs (m)		0--2	2--4	4--6	6--8	8--10	10--12	12--14	14--16	16--18	18--20	20--22	
0	**0.5**												0.00
0.5	**1**		0.010	1.832	8.188	3.294	0.772	0.061	0.022			0.003	14.18
1	**1.5**			20.808	15.637	12.165	4.811	1.247	0.465	0.054	0.003	0.002	55.19
1.5	**2**			7.831	11.182	3.741	2.943	0.828	0.301	0.020	0.012		26.86
2	**2.5**			0.022	2.573	0.355	0.306	0.127	0.061	0.014			3.46
2.5	**3**				0.176	0.027	0.022	0.017	0.024	0.007			0.27
3	**3.5**				0.010	0.007	0.002		0.005				0.02
3.5	**4**					0.003	0.002						0.01
4	**4.5**						0.003						0.00
4.5	**5**						0.002						0.00
5	**5.5**					0.002		0.002					0.00
5.5	**6**												0.00
6	**6.5**												0.00
		0.000	**0.010**	**30.494**	**37.765**	**19.594**	**8.862**	**2.282**	**0.877**	**0.095**	**0.015**	**0.005**	100.00

The relationship between Hs and peak period (Tp), evidence that waves with higher energy level is associated with wave periods of about 10 sec. which means that are generated in the vicinity, that is, are not products from North Atlantic storm (Table 7).

The similarity in the behavior of the curve of Hs measured by the oceanographic buoy and the estimated OceanWeather and matching direction provenance, offers a glimpse of the behavior described by the oceanographic buoy during the measurement period defined in roughly the everyday normal pattern or wave climate. On average, the records of the significant wave height was 1.21 m, with a maximum recorded value of 2.65 m. As for the maximum wave heights, the highest recorded value was 4.84 m, while the average peak period is 8.5 sec.

Wind

The maximum wind speed time recorded by the buoy and corrected at the 10 m was 13.0 m / s, whereas the 3 sec burst higher. was recorded was 18.0 m / s.

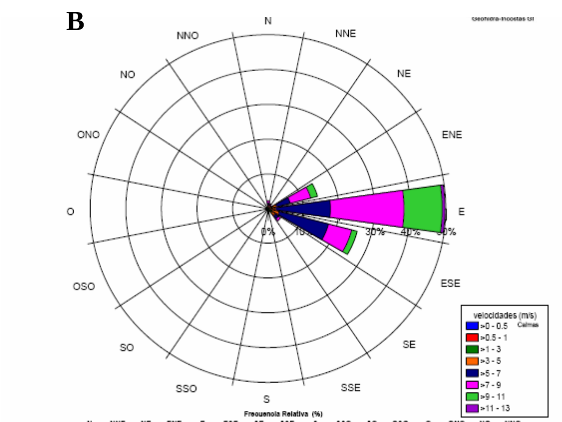


Frecuencia Relativa (%)

Velocidades Horarias (m/seg)		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSO	SO	OSO	O	ONO	NO	NNO	
0.00	0.50																	0.00
0.50	1.00		0.13		0.13	0.13	0.13			0.13								0.67
1.00	3.00		0.13		0.27	0.81	0.81	0.67	0.27	0.13	0.13			0.13				3.36
3.00	5.00			0.40	2.02	5.24	3.09	0.94	0.13	0.13			0.13					12.10
5.00	7.00		0.27	0.54	5.38	19.76	4.44	0.81	0.27	0.27	0.13							31.85
7.00	9.00			0.13	9.01	25.81	3.23	0.40	0.13									38.71
9.00	11.00				2.42	8.20	1.21	0.13		0.13	0.27							12.37
11.00	13.00				0.13	0.67	0.13											0.94
13.00	15.00																	0.00
		0.00	0.54	1.08	19.35	60.62	13.04	2.96	0.81	0.81	0.54	0.00	0.13	0.13	0.00	0.00	0.00	100

Frecuencia Relativa (%)

Velocidades de Rafagas (m/s)		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSO	SO	OSO	O	ONO	NO	NNO	
0.00	0.50																	0.00
0.50	1.00																	0.00
1.00	2.00		0.13		0.13	0.27	0.13			0.13								0.81
2.00	5.00		0.13		0.54	1.61	1.88	0.94	0.40	0.13	0.13			0.13				5.91
5.00	8.00		0.27	0.81	5.78	17.34	6.05	1.48	0.27	0.13			0.13					32.26
8.00	11.00			0.27	9.95	32.26	3.09	0.40	0.13	0.27	0.13							46.51
11.00	14.00				2.82	8.47	1.75	0.13		0.13	0.27							13.58
14.00	17.00				0.13	0.67	0.13											0.94
17.00	20.00																	0.00
		0.00	0.54	1.08	19.35	60.62	13.04	2.96	0.81	0.81	0.54	0.00	0.13	0.13	0.00	0.00	0.00	100



Frecuencia Relativa (%)

Velocidades Horarias (m/seg)		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSO	SO	OSO	O	ONO	NO	NNO	
0.00	0.50																	0.00
0.50	1.00																	0.00
1.00	3.00							1.20	0.40								0.40	1.99
3.00	5.00	0.80	0.80	0.80	2.39	1.99	3.19	1.20										11.16
5.00	7.00	0.40	0.40		3.98	15.54	14.34	1.20										35.86
7.00	9.00	0.80	0.40	0.40	5.98	20.72	6.77	0.80										35.86
9.00	11.00				1.99	10.76	1.59											14.34
11.00	13.00					0.80												0.80
13.00	15.00																	0.00
		1.99	1.59	1.20	14.34	49.80	25.90	4.38	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	100

Frecuencia Relativa (%)

Velocidades de Rafagas (m/s)		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSO	SO	OSO	O	ONO	NO	NNO	
0.00	0.50																	0.00
0.50	1.00																	0.00
1.00	2.00																	0.00
2.00	5.00				0.40	0.80	0.80	1.99	0.40								0.40	4.78
5.00	8.00	0.80	1.20	0.80	5.58	13.15	13.94	1.20										36.65
8.00	11.00	1.20	0.40	0.40	6.37	23.90	9.56	1.20										43.03
11.00	14.00				1.99	11.16	1.59											14.74
14.00	17.00					0.80												0.80
17.00	20.00																	0.00
		1.99	1.59	1.20	14.34	49.80	25.90	4.38	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	100

Figure 5. Wind Rose and percentage distribution (%) for the periods from May to November (hurricane season) and dciembre-April

The dominant source of directional wind range is made up of the E-ESE directions from where on average over all measurements, 80.3% came from the records of wind (Figure 6).

If the provenance separately for May to November and December to April periods is analyzed, it must be during hurricane season wind from the origin of the E-ESE directional range amounts to 77.7% of the records, while in the period between December to April this percentage is 81.9% (Figure 6).

The short duration of the records suggests that the vast majority of registered values corresponded to winds generated by the action of the trade winds, and very few, if any, are because of the local storms and tropical cyclones action. However, there are reports that indicate the seasonal fluctuation of the Inter Tropical Convergence Zone (ITCZ) of the trade winds is a phenomenon of global reach that strongly impacts the physical environment of the region (Aparicio, 1993).

Correspondingly, during an annual period, the temporal variation of wind intensity presents a composite signal for two seasons, governing the wind pattern throughout the year.

CONCLUSIONS

The currents speed (middle and bottom layers) seems to be influenced by the depth and bottom temperature, with a tendency to decrease (m / s) to the extent that they tend to west.

The significant wave values (Hs) and maximum recorded and the average peak period (Tp) of the waves on the order of 8.5 sec highlights the low influence of storms from the tropical North Atlantic or extreme phenomena on the study area.

The behavior similarity of wave height Hs and Hmax measures oceanographic buoy and OceanWeather estimated by the model, calibrated and validated records obtained during the study defining the pattern of normal or daily wave climate.

The wind regime seems not to be directly influenced by the action of atmospheric phenomena from the North Atlantic, being very marked influence of the Alicios winds during the study.

The meteorological and oceanographic records obtained during the study are an important reference for offshore production facilities design. However, it is essential to continue making continuous measurements of each of the meteorological and oceanographic parameters for a complete characterization of the temporal and spatial variations of the area and generate more reliable statistical models

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