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A SUMMARY OF METEOROLOGICAL AND HYDROLOGICAL DATA FROM THE BAY OF SANTA MARTA, COLOMBIAN CARIBBEAN

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RESUMEN

Un resumen de datos meteorológicos e hidrológicos para la Bahía de Santa Marta, Caribe colombiano.

Se presentan datos de precipitación, temperatura y salinidad del agua superficial para la Bahía de Santa Marta, Caribe colombiano, para el período de noviembre 1978 a mayo 1982. Se obtienen generalizaciones de los patrones anuales incluyendo datos ya publicados (Müller, 1979). A partir de mediciones adicionales de la variación de la temperatura del agua y de la salinidad durante el día, valores preliminares de cuantos de luz, junto con datos disponibles sobre contenido y saturación de oxígeno, pH, alcalinidad, estabilidad, dirección y velocidad del viento, horas de luz, temperatura del aire y descarga del Río Manzanares, se hace una caracterización cuantitativa de las estaciones seca y húmeda que se observan en el área investigada.

ABSTRACT

Data on rainfall, water surface temperature and salinity from the Bay of Santa Marta, Colombian Caribbean, are presented for the period November 1978 to May 1982. Including data already published (Müller, 1979) generalizations of the anual patterns are obtained. Additional measurements of the variation of water temperature and salinity in the course of one day, preliminary values of light quanta, together with available data on oxygen content and saturation, pH, alcalinity, stability, wind direction and velocity, hours of sunshine, air temperature, and water discharge of the river Manzanares permitted a quantitative characterization of the dry and rainy season which can be observed in the area of investigation.

INTRODUCTION

It is common knowledge in Santa Marta and its vicinity that there are two seasons a year, the dry season ("época seca" "or" época de brisa") and

the rainy season ("época de lluvia"), the latter with an intermediate short dry season ("veranillo de San Juan"). The time intervals of these seasons can vary from year to year and different information is obtained consulting different authors (Herrmann, 1970; Schnetter, 1970). For reasons of convenience we defined the following time intervals: dry season - December to April, rainy season - May to November (including the short dry season in July/August).

Even though the seasons are well known, meteorological and hydrological data characterizing them are relatively scarce (Müller, 1979; Ramírez, 1983), or scattered in the biological literature (Schnetter, 1970; Wedler, 1975), or not published (data from the archives of the Instituto Colombiano de Hidrología, Meteorología y Adecuación de Tierras, Himat). The aim of this study, besides presenting some new data on precipitation, water temperature and salinity, was to compile available information in order to provide generalized annual patterns of some important parameters and to quantify the differences between the dry and rainy season.

On this occasion we want to thank both the HIMAT (Sevilla) and the Universidad Tecnológica del Magdalena, UTM (Santa Marta) for providing unpublished data and for their friendly and uncomplicated obligingness in recovering them from the archives. Our sincere thanks are due to Mr. R. Van Thielen for valuable discussions and critically reading the manuscript and to Miss B. González for drawing the figures. Special thanks also go to Mr. L. Cadena for taking water samples and to Mr. C. Henry for his collaboration in SCUBA diving.

MATERIAL AND METHODS

Measurements of temperature and salinity of surface waters and registration of rainfall are conducted at Punta de Betín (Fig. 1) since November 1974 and September 1975 respectively.

Data collected until November 1978 have been published earlier (Müller, 1979); this paper contains the values obtained from December 1978 to May 1982. Computing the mean values for a week, a month, or a year, however, we included the already published data. The observations were carried out at approximately 8 am almost every day, mostly with the exception of weekends, thus collecting a mean of 238 data per year each for temperature and salinity. Temperature was measured by means of a thermometer with a precision of 0.1° C, salinity using an areometer and the M. Gillbricht tables of alignment. Precipitation was registered only when exceeding 0.1 mm per day.

The variation of water temperature, salinity and light condition in the course of one day (about 6 am to 6 pm.) was determined in about monthly intervals from May 1981 to April 1982. Records were realized near and below the NW-pier in front of the Instituto de Investigaciones Marinas de Punta de Betín (INVEMAR) because they are expected to serve especially for some biological studies carried out in that area.

Temperature and salinity data were recorded in about one-hour-intervals at water surface, 1, 3, 5, and 8 m depth using an "Oceanographic Salinity and Temperature Measuring Bridge", type MC 5/2. Light could be measured only in terms of "lens aperture numbers" using a SCUBA diver held "Sekonic Marine Meter II" (fixed positions 100 ASA and 1/8 sec). Directing sensorswindow upwards parallel to the water surface, readings were made above water surface, at 1 and 8 m depth and at 8 m depth below the pier about every hour (between 2nd and 3rd row of columns, counting from the SSW-end and between 2nd and 3rd row counting from the NW -face, see Fig. 1). Especially between 10 am and 2 pm above water surface and at 1 m depth we often used an opaque plastic tap placed over the sensor window thus reducing the values by three aperture numbers.

This method to measure light by no means is "up to date" but the data obtained showed clear differences between the three sites of measurement which are supposed to hold also when light will be measured with more adequate instruments.

Only recently we have had an "Underwater Quantum Meter" (Li- 192 SB, Li-cor) at our disposal which in May 1982 served to make some additional measurements of light quanta in air *Wind* (Fig. 2).

RESULTS

Wind (Fig. 2)

Originating from the trade winds (Herrmann, 1970) the strong local wind, called "brisa", blows from about NE offshore with the highest velocities during the dry season from December to April (mean monthly velocities 2.1 - 5.1 m/sec, max. up to 22 m/sec during 1981/82; Herrman, 1970, registered more than 30 m/sec in 1967/68) and-with less intensity - in July/August (1.7 - 2.9 m/sec), the so called "veranillo de San Juan". During the rest of the year velocities are relatively low (0.8 - 1.8 m/sec).

If the wind does not blow from NE normally calm prevails; other wind directions are not important, even though a strong SW-wind, the "vendaval", occurs sometimes. It must be mentioned, however, that the site of registration (on land between hills) might favour the NE direction abo-

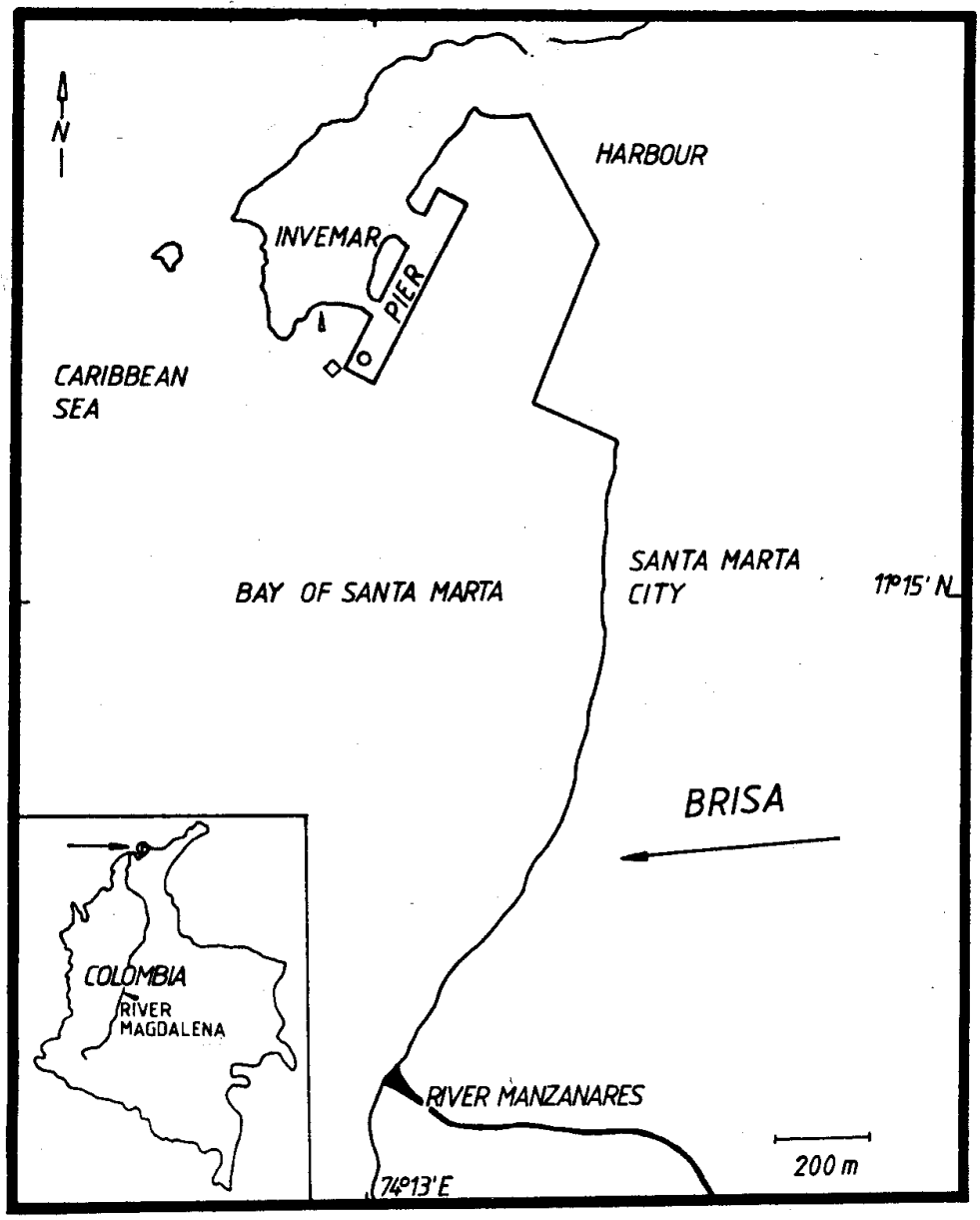

Figure 1. Bay of Santa Marta, Colombian Caribbean, indicating the Instituto de Investigaciones Marinas de Punta de Betín (INVEMAR), the sampling site of the about daily registration of surface water temperature and salinity ( ), as well as the sites of the about 12-h-measurements of temperature, salinity, and light (□), and light below the pier (O).

ve others. Nevertheless, the percentage distribution of wind direction is assumed to be also representative for the Bay of Santa Marta.

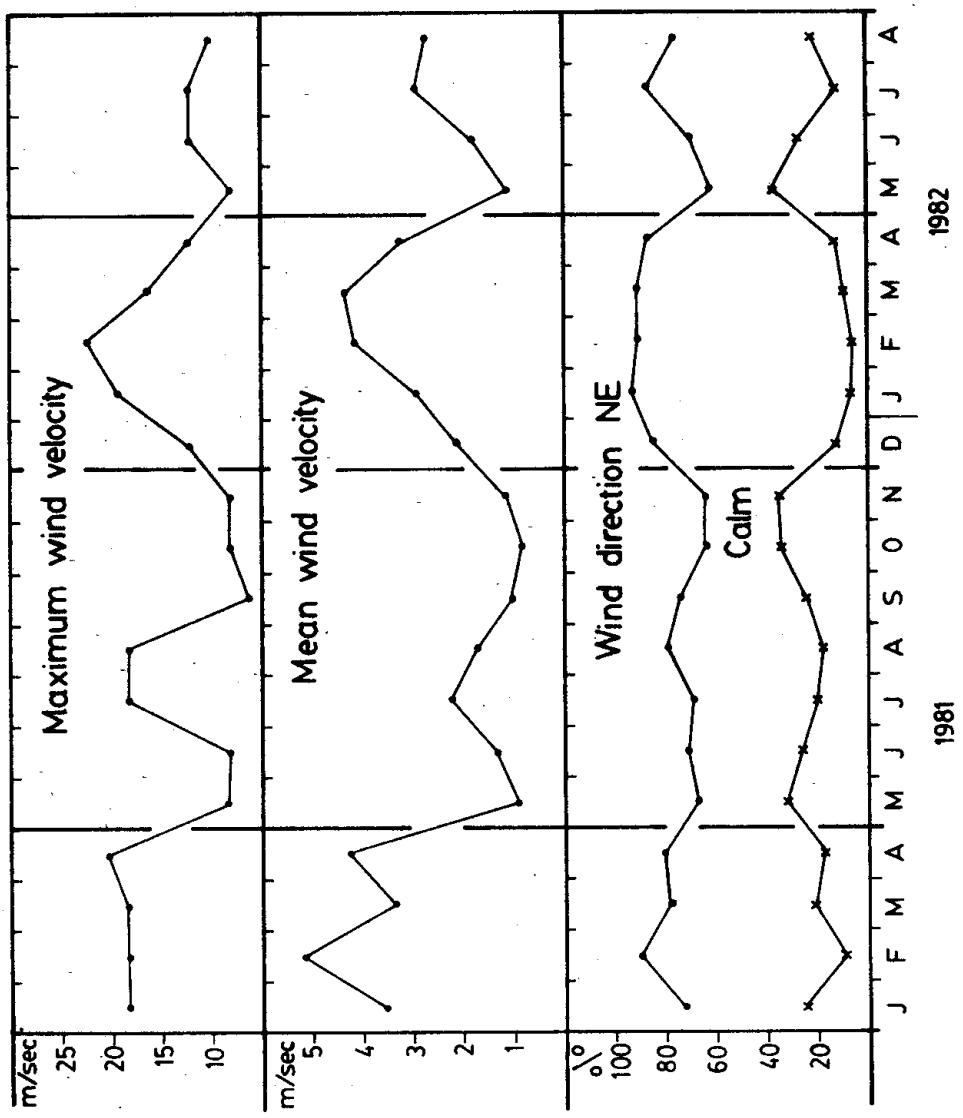

Figure 2. Wind velocities and predominating direction, as well as percentage of calm at the Universidad tecnologica del Magdalena, Santa Marta, Colombia. Data based on monthly sums of anemometer readings and observations of the wind direction (HIMAT and UTM, pers. com).

Table 1. Total annual precipitation, number of rainy days per year, and mean water surface temperature and salinity during 1975-1981 at Punta de Betin, Santa Marta, Colombia.

1) rain measurements for September-December, only
2) no rain data during August - November.

Year	Amount of rain (mm)	Number of rainy days	Temperature of water (°C)	Salinity ‰ S)
1975[1]	(282)	(32)	26.1	36.0
1976	169	15	26.7	36.4
1977	153	17	26.9	36.8
1978	351	44	27.6	36.1
1979[2]	(117)	(16)	27.2	35.6
1980	354	22	26.9	36.1
1981	676	36	27.7	35.9
Mean	347	30.5	27.0	36.1

Table 2. Mean differences between minimum and maximum values of water surface temperature and salinity in the course of one day, one week, and one month respectively. Data based on eleven about 12-h-measurements realized from May 1981 to April 1982 (daily variation), and on about daily records from November 1974 to May 1982 (means for weekly and monthly variation), at Punta de Betín, Santa Marta, Colombia.
x - without March/April 1982

Mean for	△ Temperature (°C)			△ Salinity (‰ S)		
	Rainy season	Dry season	Year	Rainy season	Dry season	Year
Day	1.6	0.7	1.1	2.9	0.8[x]	1.9[x]
Week	1.0	1.2	1.1	1.7	0.9	1.4
Month	2.4	3.0	2.6	4.0	1.7	3.1

Precipitation (Figs. 3 and 4)

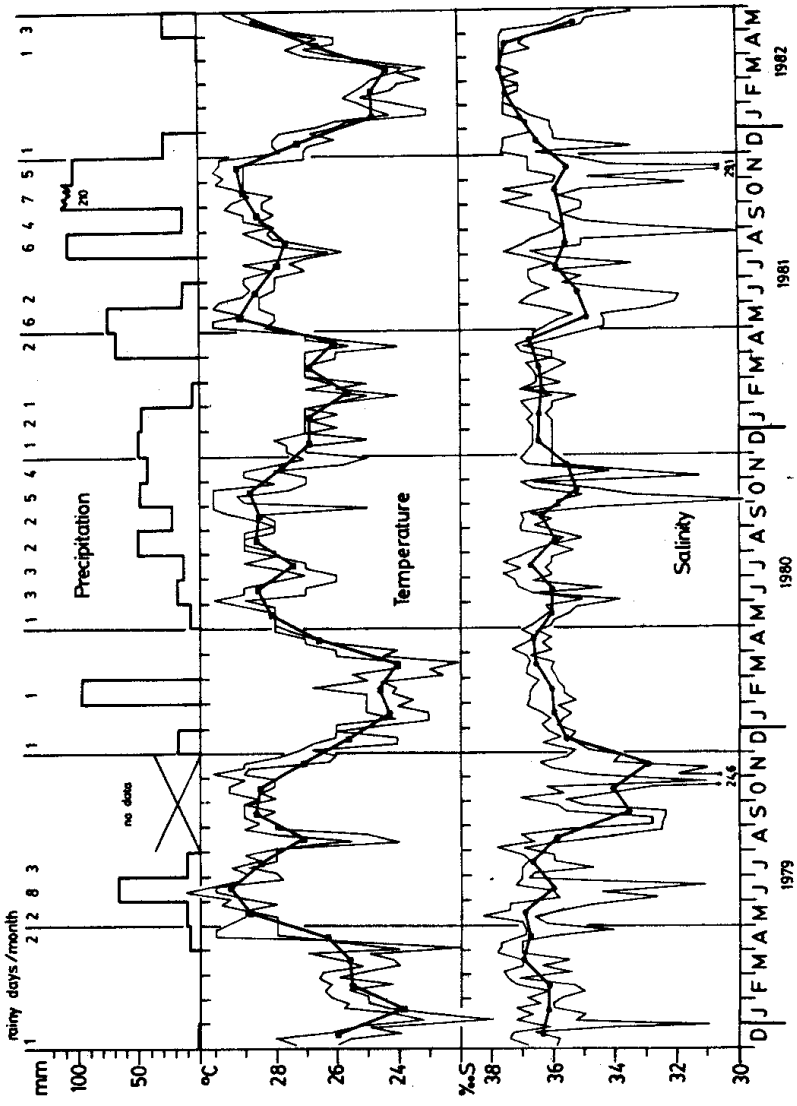

Figure 3. Precipitation, water surface, temperature and salinity at Punta de Betín, Santa Marta, colombian Caribbean.
The graphs represent monthly sums (precipitation) or means (temperature salinity) with their respective weekly minimum and maximum values for the latter two. Dry season (December-April) and rainy season (May-November) are separated be vertical lines.

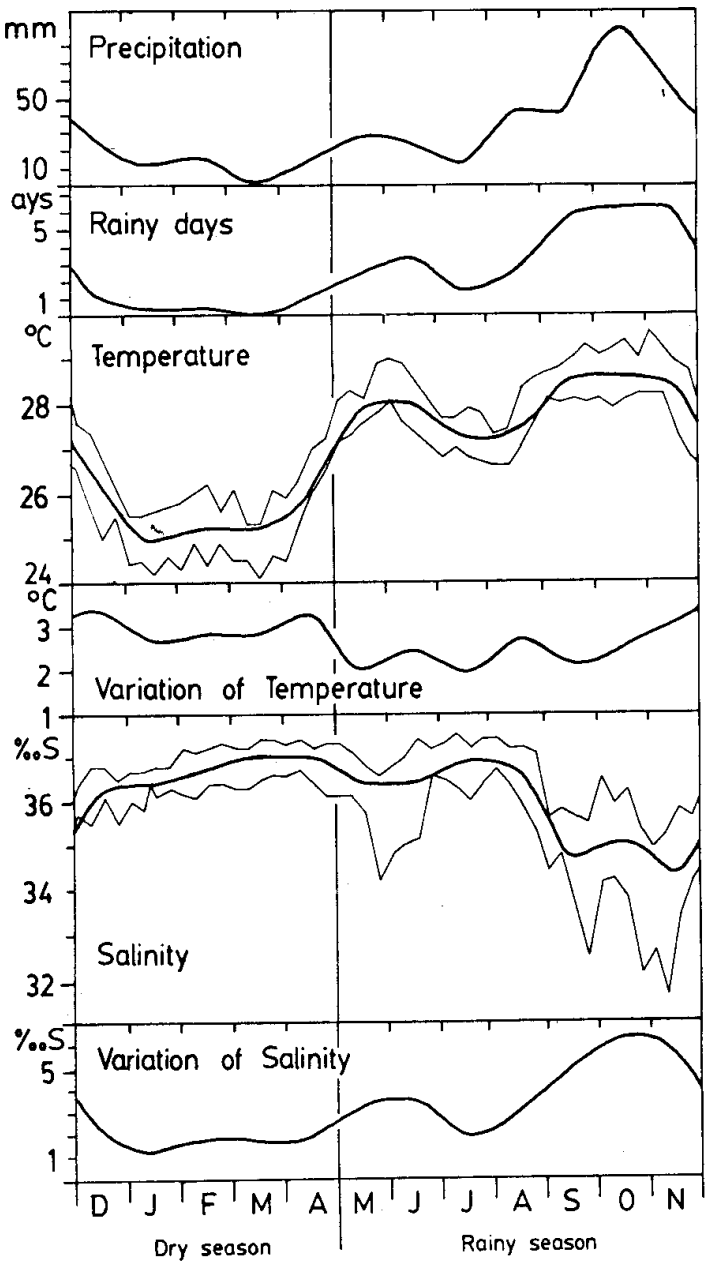

Figure 4. Generalized annual patterns of precipitation, water surface temperature and salinity and the weekly mean minimum and maximum values of the latter two as well as the mean variation of temperature and salinity during one month. Based on about daily registrations of rainfall from September 1975 to May 1982 (excluding Aug.-Nov. 1979) and of temperature and salinity from November to May 1982 at Punta de Betín, Santa Marta.

The observations from the last years (Fig. 3) will not be discussed in detail because their annual patterns are similar to those of the foregoing years (Schnetter, 1970, 1975; Wedler, 1975; Müller, 1979) and because the data are included in the generalized pattern, given in figure 4. Comparing this pattern with the annual wind pattern (Fig. 2), it can be seen that wind and rain are parameters with alternating high values, a fact that finds its expression in the names of the respective seasons.

The mean total precipitation during one year is 347 mm, the mean number of rainy days amounts to 30.5 days per year (Tab. 1). In the rainy season from May to November, which includes the relatively dry month of July (veranillo de San Juan) 81% of the total or 283 mm rain comes down a mean of 27.5 days (90% of total rainy days). The months September - November might be called the proper rainy season. In these months 181 mm rain (52%) are registered during 18 days (59% o.t.r.d.) on an average. October is the month with the highest average rainfall: 87 mm (25%) during 6.2 days (20% o.t.r.d.). On the contrary, during the month of March only once in seven years rainfall was observed.

The amount of rain per rainy day makes to about 11 mm on an average. It is worthwhile mentioning that the mean amount of rain per rainy day is twice as high during the dry season (21.5 mm) as in the rainy season (10.3 mm). Also the heaviest rainfall was registered in the dry season: 97.5 mm on the 5th of February 1980. Schnetter (1970), analysing the data registered during 1965 - 1969 at Punta de Betín, reported an even higher value (122.2 mm) for a day in July 1967, a relatively dry month, too.

Comparing the total annual rainfall for the years 1975 - 1981 it can be stated that 1976 and 1979 were extremely dry years whereas 1981 was a year of heavy rainfalls (Tab. 1). In comparison with 1965 - 1967 when 420, 750, and 376 mm rain were observed (Schenetter, 1970) all the years since 1975 were rather dry except 1981. IGAC (1973) provides precipitation data (means for 1932 - 1959) for Santa Marta (UTM) and the valley "Las Nubes", the drainage area of the river Manzanares, which on its turn is influencing the water regime of the Bay of Santa Marta (see below). The patterns of rainfall for both areas are very similar to that observed at Punta de Betín. The mean annual total precipitation with 547 mm in Santa Marta is somewhat higher than that measured at Punta de Betín, which very probably is due to the special site of the latter, situated on a small peninsula.

Water discharge (Fig. 5)

The variation of water discharge of the river Manzanares in the course of the year reflects the annual pattern of rainfall, regardless whether the data originate from Punta de Betín, Santa Marta (UTM), or Las Nubes, the drainage area of the river (see above). That the maximum water discharge is recorded in November (1979) instead of October, the month of highest rainfall (on an average) most certainly is an artifact originating in the comparison of mean values with data of a certain interval of time.

It is open to further investigation to which degree the turbid waters of the river Magdalena, wich clearly can be distinguished when passing by the Bay of Santa Marta, are influencing the water regime of the Bay. Wedler (1975), however, attributed the regular variation of temperature and salinity in the course of one day during the rainy season to the influence of this river without considering the possibly stronger influence of the nearby river Manzanares.

Air temperature

Data on air temperature for 1966 are provided by Schnetter (1970). The variation in the course of the year is small and so is the difference between the two seasons (Tab. 4), even though a significant difference in the number of hours of sunshine per day can be observed (see below).

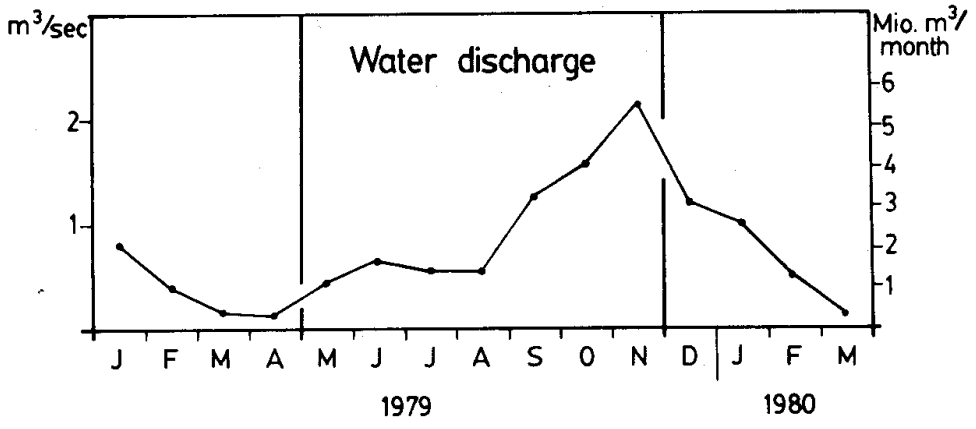

Figure 5. Water discharge of the river Manzanares from January 1979 to March 1980 based on monthly sums (HIMAT, pers. com.).

Table 3. Mean temperature decrease and salinity increase with depth, taking the surface values as references. Based on eleven about 12-h-measurements during May 1981 to April 1982 at Punta de Betín, Santa Marta, Colombia.

Depth (m)	△ Temperature (°C)	△ salinity (% S)		
	annual mean	annual mean	October	rest of the year
1	0.10	0.10	0.35	0.01
3	—	—	0.91	—
5	0.14	0.43	1.44	0.09
8	0.31	0.70	2.32	0.16

Table 4. Summary of meteorological and hidrological conditions during the dry ("brisa") season and the rainy season in the Bay of Santa Marta, Colombia.
The mean values and their respective ranges given for each season are calculated from monthly means or sums (5). Light quanta (4) are approximated assuming for the dry season 137 sunny, 10 cloudy, and 3 rainy days, and for the rainy season 102 sunny, 80 cloudy, and 28 rainy days, using for the calculation 10, 40, and 55 Einstein m^{-2} day^{-1} for a rainy, cloudy, and sunny day respectively.
Site of measurement usualy was the INVEMAR, Santa Marta, or the shallow water nearby, if not mentioned otherwise. Times of observation and sources are: (1) 1966 (Schnetter, 1970), (2) UTM, Santa Marta, Jan. 1981 -Aug. 1982 (UTM and Himat, pers. com.), (3) 1969-1972 (Himat, pers. com.), (4) 19/22/25 of May 1982 (this study), (5) Sep. 1975 - May 1982 (without Aug. - Nov. 1979) (Müller, 1979, and this study), (6) Jan. 1979 - March 1980 (Himat, pers. com.) (7,8) November 1974 - May 1982 (Müller, 1979, and this study), (9-12) Bay of Santa Marta, Aug. 1980 - july 1981 (Ramírez, 1983).

Parameter	Dry Season (December - April)		Rainy Season (May - November)	
	Mean	Range	Mean	Range
(1) Air temperature (°C)	27.9	27.6-28.1	27.7	26.7-28.5
(2) Wind direction NE (%)	85	72-93	70	62-87
calm (2)	14	6-25	27	12-37
Mean wind velocity (m/sec)	3.5	2.1-5.1	1.5	0.8-2.9
Max. wind velocity (m/sec)	16.7	12-22	9.9	6-18
(3) Sunshine (h/day)	8.8	7.1-9.7	7.6	5.8-8.8
(4) Light quanta (E m day) 53	53		43	
(5) Precipitation (mm rain)	64	9-174	283	121-523
Number of rainy days	3.0	1-6	27.5	16-40
(6) Water discharge of the river Manzanares (m¾sec)	0.6	0.2-1.2	1.0	0.5-2.1
(7) Water temperature (°C)	25.5	24.8-26.4	28.0	27.4-28.6
(8) Salinity (% o S)	36.7	36.1-37.4	35.7	25.1-36.4
(9) Oxigen content ml/l)	4.5	4.4-4.6	4.6	4.4-4.8
Oxygen saturacion (%)	97	94-101	103	99-109
(10) pH	8.20	8.15-8.26	8.25	8.18-8.33
(11) Specific alcalinity	0.177	.155-.120	0.125	.118-.131
(12) Stability (x 10)	-1.6	-7.3-+3.8	4.5	-0.2-+7.0

Sunshine (Fig. 6)

Sunshine (h/day) formerly was registered at Punta de Betín by means of a heliometer. Monthly sums for the year 1969-72 (with a total of 8 months missing) could be recovered from the archives of the HIMAT, part of them already published by Wedler (1975). The variation in the course of the year is in good accordance with the annual patterns for wind and rainfall, showing highest values in the dry season and lowest in the rainy season. The total number of sunshine hours per year can be estimated to about 2900 on an average for the period of registration.

Light quanta

Some occasional measurements of light quanta carried out at Punta de Betín revealed the following values from which rough estimates for the two seasons were made (see tab. 4):

a) sunny day, little clouding in the afternoon (May 19, 1982), one day integration $\simeq$ 50 Einstein m^{-2} day^{-1} (Rp% between 10-14 hours), maximum 1950 μE m^{-2} sec^{-1}
b) rainy day (May 22, 1982; measurement until 12 m., one days integration value extrapolated), $\simeq$ E m^{-2} day^{-1}, maximum 1000 μ E m^{-2} sec^{-1}
c) cloudy day (May 25. 1982), $\simeq$ 38 E m^{-2} day^{-1}, maximum 2375 μ E m^{-2} sec^{-1}.

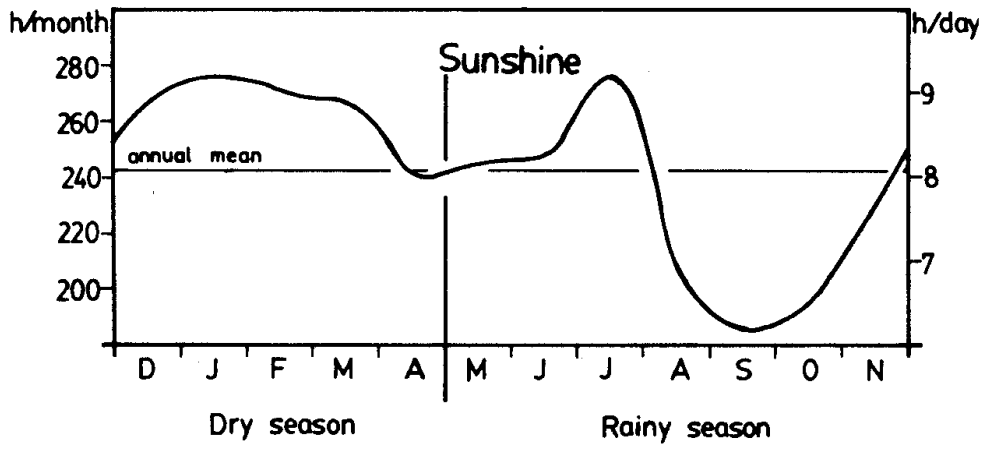

Figure 6. Sunschine at Punta de Betín, Santa Marta, Colombia. Based on registration with a heliometer during 1969-1972 (without a total of 8 months), calculating monthly mean sums (Himat, pers. com.).

Light penetration

The eleven about 12-h-measurements of light accomplished from May 1981 to April 1982 in different water depths resulted to be insufficient to show clear differences of light penetration into the water in the course of the year wich were expected because of the obviosuly higher turbidity during the rainy season (see Wedler, 1975 and Caycedo, 1977, Tab. 1 the corresponding figure 3 obviously contains errors). This might be due to an inadequate method but also to the relatively small number of observations. Regarding annual mean values (diurnal changes neglected) and taking the value measured above water as 100%, the following light penetration values were obtained: 60% in 1 m depth, 12% in 8 m depth, and 0.3% in 8 m depth below the pier (see Fig. 1 for recording site).

Stability

Recently published measurements of the stability of the water column (density diference, measured between water surface and 30 m depth) at one station in the Bay of Santa Marta for the first time directly proved the existence of an upwelling phenomenon during the dry season (Ramírez, 1983). High negative values of the stability index, characterizing instable water masses (i.e. superficial waters are denser than deeper waters), predominated from December to April, whereas water masses during the rainy season were stable, revealing positive values (Tab. 4).

This seasonal phenomenon of upwelling clearly can be attributed to the strong offshore wind which blows during the dry season (see paragraph "wind" and Fig. 2). The existence of the upwelling and its relation with the NE-wind already was supposed by various authors and the upwelling indirectly proved by Bula (1977) and Caycedo (1977), the former, based on Perlroth (1968), described the whole northern coast of Colombia east from the estuary of the river Magdalena as an upwelling area.

Water temperature and salinity (Figs. 3 and 4)

The generalized patterns of the variation of the surface water temperature and salinity in the course of a year are given in figure 4. They are reflecting the wind induced season of the year, with:

-Low temperatures (mean 25.5°C) - in spite of the higher number of sunshine hours per day during this time— and high salinities (37.7%) due to the wind induced upwelling (see above) during the dry or brisa season from December to April,

-high temperatures (28.8°C) and low salinities (35.7°/oo) due to the water discharge of the river Manzanares (and perhaps of the river

Magdalena; see above) and due to lower wind velocities during the rainy season from May to November.
During July/August (veranillo de San Juan), when less rainfall and high-wind velocities occur, a relatively small but marked decrease of tempeture and increase of salinity can be observed.

Annual mean values are 27.0°C and 36.1‰ S, their variation in the last seven years having been small (Tab. 1). Absolute minimum and maximum values registered in the period from November 1974 to May 1982 are temperatures of 21.0°C (Jan. 1979) and 31.5°C (Oct. 1978) and salinities of 24.6°/oo (Oct. 1979) and 39.8°/oo o (Feb. 1977).

The generalized annual patterns of water surface temperature and salinity are in good accordance with the values registered during the last years by these authors (Fig. 3), and also with the data provided by other authors for the Bay of Santa Marta or parts of it (Wedler, 1975; Müller, 1981; Ramírez, 1983). As our values (from one site in the Bay of Santa Marta) are very similar to those of Ramírez (1983) it can be assumed that they are representative for the whole bay, because Ramírez (1983) took samples at nine stations and pooled his results with the argument of similarity between them.

Moreover our data are very similar to those for the bays north of Santa Marta (Caycedo, 1977 and A. Acero and J. Garzón, pers. com.) and therefore might be regarded to be valid in their general tendencies for the whole area influenced by the offshore wind.

Temperature and salinity variation in the course of a week or a month ("long time variation", mean values for the period 1975-82) as well as in the course of a day ("Short time variation", mean values for the period May 1981 - April 1982) are presented in Tab. 2 and Fig. 3. From these it can be seen that the long time variation of temperature is about equal all over the year. Short-time variation, however, is significantly greater in the rainy season than in the dry season (Tab. 2). This is due to the effluent waters of the river Manzanares which - most probably due to their greater content of particulate matter - are heated up more than the surrounding waters and therefore cause significant but short time temperature increases of the upper water layers. This clearly can be seen also by an example for this period, given in figure 7.

On the contrary, not only the short time variation but also the long time variation of salinity is significantly greater during the rainy season than during the dry season (Tab. 2). This means that salinity variation is influenced not only for short times by the river Manzanares effluents but also over weeks and months, which must be attributed to relatively great amounts of freshwater causing great salinity decreases (see figs. 5 and 7)

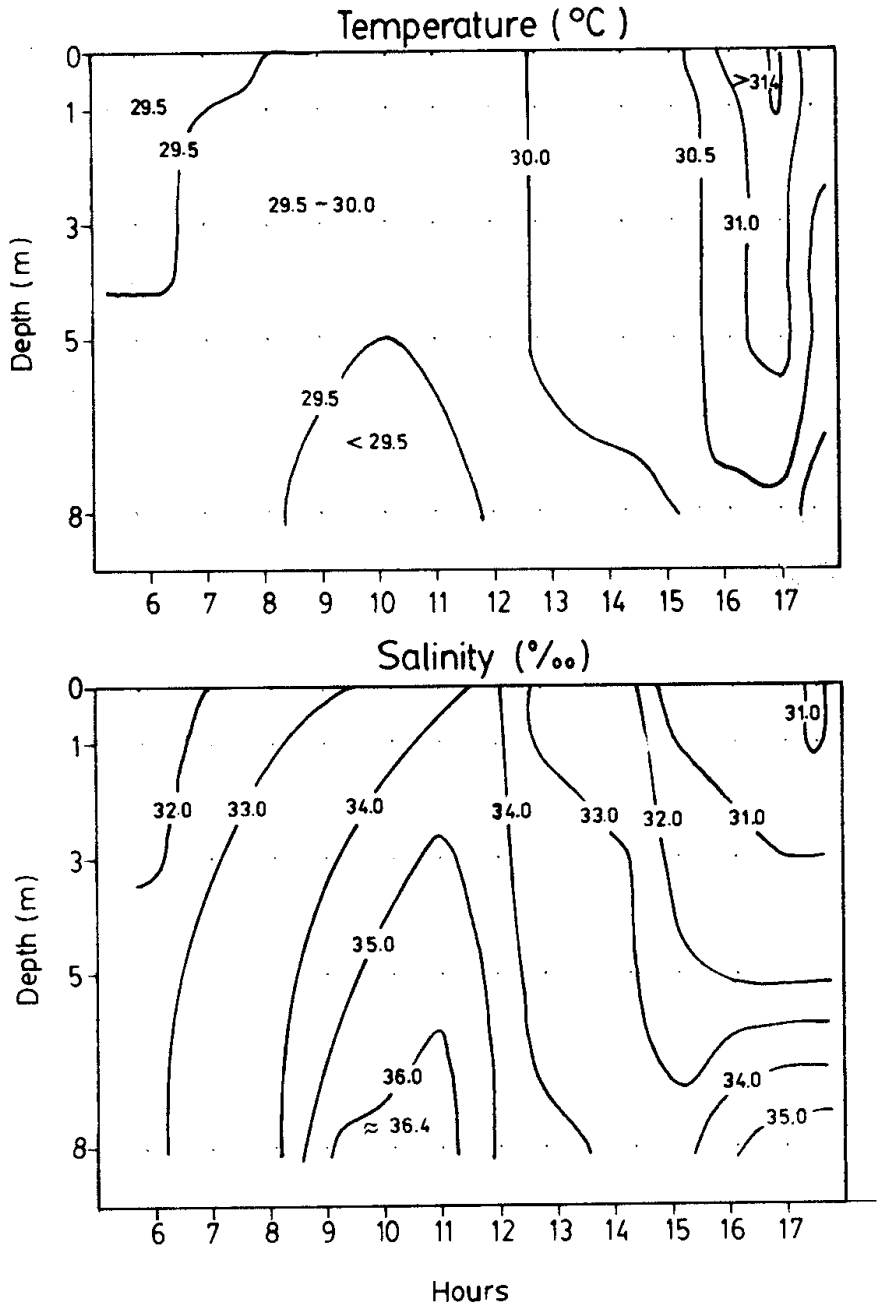

Figure 7. Variation of water temperature and salinity during one day in the rainy season (October 29, 1981) in different depths at Punta de Betín, Santa Marta, Colombia.

Regarding the temperature decrease with depth, no tendencies in the course of the year could be detected and down to 8 m depth rather small mean differences were observed (Tab. 3). The salinity increase with depth is also rather small all over the year except the month of October, when salinity in 8 m depth was 2.3°/oo S higher than at the surface as an average value for two days; short lasting differences up to 5°/oo S were observed in this month. These differences clearly must be attributed to the freshwater influence which was highest in this month for the period of investigation.

Oxygen, pH, alcalinity

Data on the oxygen content, oxygen saturation, pH, and the specific alcalinity of the surface waters of the Bay of Santa Marta are provided by Ramírez (1983). Their mean values and ranges for the dry and rainy are summarized in table 4.

The oxygen content and the oxygen saturation show slighthy lower values in the dry season than the rainy season. Whether this can be attributed to a lower oxygen content of the upwelling waters during the dry season and to a high phytoplankton activity during the rainy season must be shown by further investigations.

The pH and the specific alcalinity show relatively small differences, as Ramírez (1983) observed.

CONCLUSIONS

Available meteorological and hydrological data characterizing the dry and rainy season are summarized in table 4. Using these values it should be kept in mind that only those for precipitation, water surface temperature and salinity are based on long-time registrations and therefore are rather reliable mean values. Most of the information is based on one year of investigation and thus might reflect special conditions of that year. Light quanta estimations are based on three determinations only and further studies must supply more reliable values.

Although the region of Santa Marta and specially the different bays north of the town are characterized by a kind of microclimate (often rainfall can be observed in one bight and sunshine in the next one) common validity for the assembled information might be expected to a certain extent for the region as far as it is influenced by the trade winds, the dominating climate factor for this area.

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