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REPORT: OCEANOGRAPHIC CONDITIONS

June 2023

GENERAL STUDY OF HYDROGRAPHIC AND OCEANOGRAPHIC CONDITIONS FOR THE DESIGN CALCULATION OF THE MOORING OR DOCKING SYSTEM OF THE DESIGN VESSEL FOR THE TERMINAL OF PUERTO QUETZAL, GUATEMALA

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Date: May 2023

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1. FIELD STUDIES

Bathymetric surveys and/or basic oceanography studies to obtain necessary parameters for the design of mooring at the facilities of Empresa Portuaria Quetzal, Puerto San José, Escuintla, Guatemala.

1.1 Calculations and evaluations:

- Characteristics of the design vessel, dock calculation, and maneuver of the design vessel within the assigned area or percentage of low-speed transverse movements of the vessel with limited depth.
- Moment of inertia of the vessel to determine its turning radius or submerged longitudinal area of the vessel subjected to the action of the current or submerged transverse area of the vessel subjected to the action of the current.
- Vessel displacement or over draft due to load distribution for design vessel or average height of the structure's surface of the vessel, over a transverse plane.
- Average height of the vessel's surface over a longitudinal plane or safety and control clearance of the vessel's maneuverability or vertical free clearance that should always remain between the hull of the vessel and the bottom.
- Safety margin or Froude number for dock, mooring maneuver, and access to the dock.
- Dimensioning of the maneuvering zone of the turning basin or dock design.
- Area of the dock and turning basin.
- Design of the access channel.
- Vessel displacement in cubic meters.
- Rudder factor calculations.
- Nominal width of the navigation route.
- Dynamic mooring calculation.
- Squat.
- Length of the access channel.
- Channel width.
- Channel buoyage.
- Transition length for vessels.
- Dock maneuverability.
- Lateral mooring.
- Dock draft.
- Total length of the mooring line.
- Width of the mooring area.
- Loading and unloading of bulk solid and liquid cargo or vessel operations.
- Hydrodynamic effects induced by vessels in transit.

2. BATHYMETRIC STUDY IN THE ASSIGNED AREA

2.1 Technical staff:

- Adalberto Alguero – Certified Hydrographer Category “B” (PE-8-373)

2.2 Technical data:

- Bathymetry configuration: single-beam with high-frequency transducer (210KHz).
- Vertical references: MLWS (mean low water spring) tied to the reference tide table of Puerto San José.
- Horizontal references: WGS84, zone 15 North.
- Data format: x,y,z text format (east, north, depth).
- Quality parameter: according to S-44 Standards (international hydrographic standards).

2.3 Equipment to be used:

- Syquest Hydrobox digital single-beam echo sounder.

- High-frequency transducer 210KHz.
- DGPS South Galaxy 3 with differential correction.
- Hydrographic software HyPack 2015 (valid license).
- Hydrographic boat (23 feet length) Name: BASH.
- Sound speed calibration plate, marks every 2 meters.

2.4 Quality standards:
Regarding quality control, we rely on international S-44 standards, governed by the International Hydrographic Organization (IHO) and the U.S. Naval Office, which describe the standard as follows:
"Order 1a: This order is intended for areas where the sea is sufficiently shallow to allow natural or artificial features on the seabed to be a concern for expected maritime traffic transiting the area, but where the keel-to-bottom separation is less critical than for Special Order. Where artificial or natural features may be of concern to navigation, a full seafloor search is required; however, the feature size to be detected is larger than for Special Order. Where keel-to-bottom separation becomes less critical as depth increases, the feature size to be detected by full seafloor search also increases from those areas where the depth is greater than 40 meters. Order 1a surveys can be limited to waters shallower than 100 meters."

IMAGE N°1. Table 1 Minimum Standard for Hydrographic Surveys

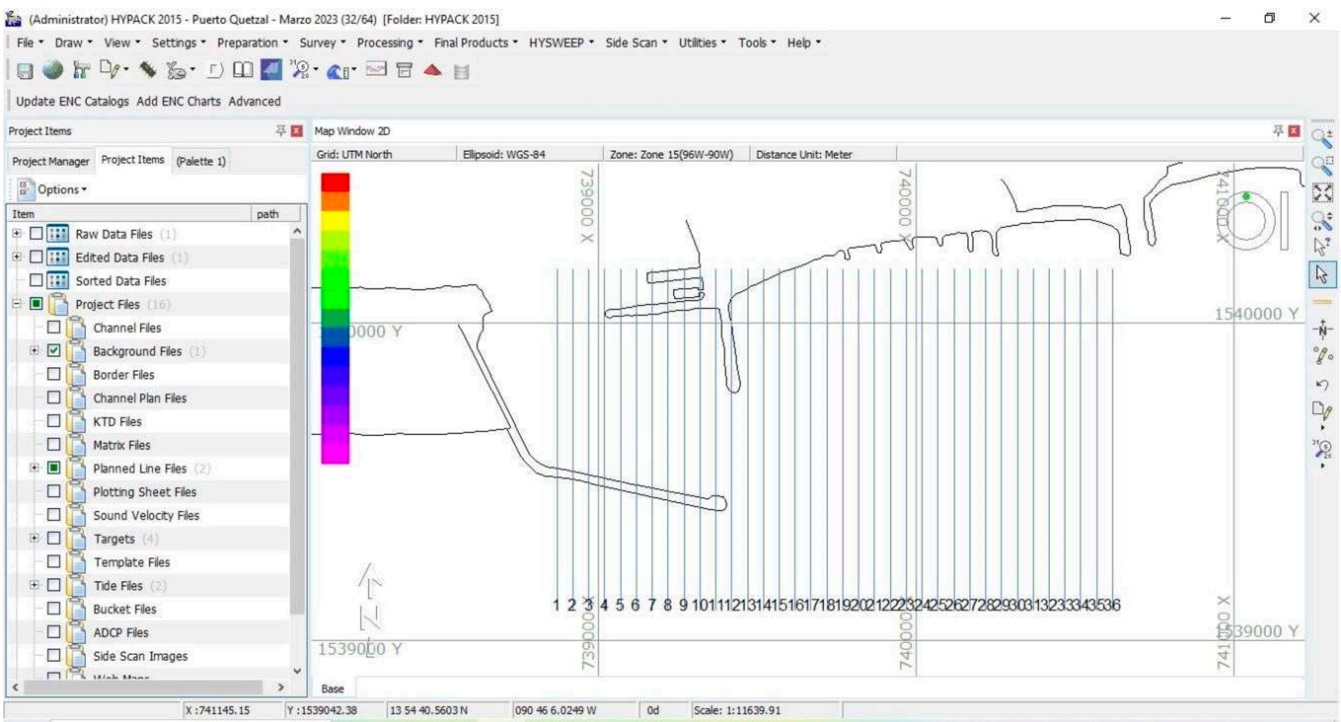
Refere	Order	Special	1a	1b	2
Survey Classification	Area Description	Areas where the separation	Areas with depths less than 100 meters where the separation between keel-bottom is	Areas with depths less than 100 meters where the separation between keel-bottom is not considered critical for	Areas generally deeper than 100 meters where a general description of
Positioning	Maximum allowable THU 95% Confidence	2 meters	5 meters + 5% of depth	5 meters + 5% of depth	20 meters + 10% of depth
Vertical Uncertainty	Maximum allowable TVU 95% Confidence	a= 0.2 meters b= 0.0075	a= 0.5 meters b= 0.013	a= 0.5 meters b= 0.013	a= 1.0 meters b= 0.023
Seabed Knowle	Complete Seabed	Required	Required	Not required	Not required
Depth Measurement	Detection of features	Cubic features > 1 meter	Cubic features > 2 meters and depth accuracy of 10% of the depth or 1 meter	Not applicable	Not applicable
Sounding Density	Maximum spacing not defined, but sufficient	Not defined, depends on required	3 x average depth or 25 meters, whichever is greater, for LIDAR with spacing < 5 x	Not defined, but sufficient for general description of seabed	4 x average depth

3. DEVELOPMENT OF THE BATHYMETRIC SURVEY

Geodetic Configuration: In the hydrographic software HyPack, the geodetic parameters for our project must be configured, and the equipment is configured in WGS-84, Zone 16.
Navigation Configuration: The survey lines are planned, and for this work, the standard indicates that because it is an area of docking and navigation, the survey will be of type Order 1-A; the spacing will be 50m for survey lines perpendicular to the coast, in addition to verification lines with 100m separation.
Therefore, we prepared the area with the base reference, survey lines, and verification lines, and below is the image from the software with the distribution of the lines:

- 35 survey lines separated by 50m in the North-South direction.
- 5 verification lines separated by 50m in the 400m long East-West direction.

IMAGE N°2. Navigation Lines Plot

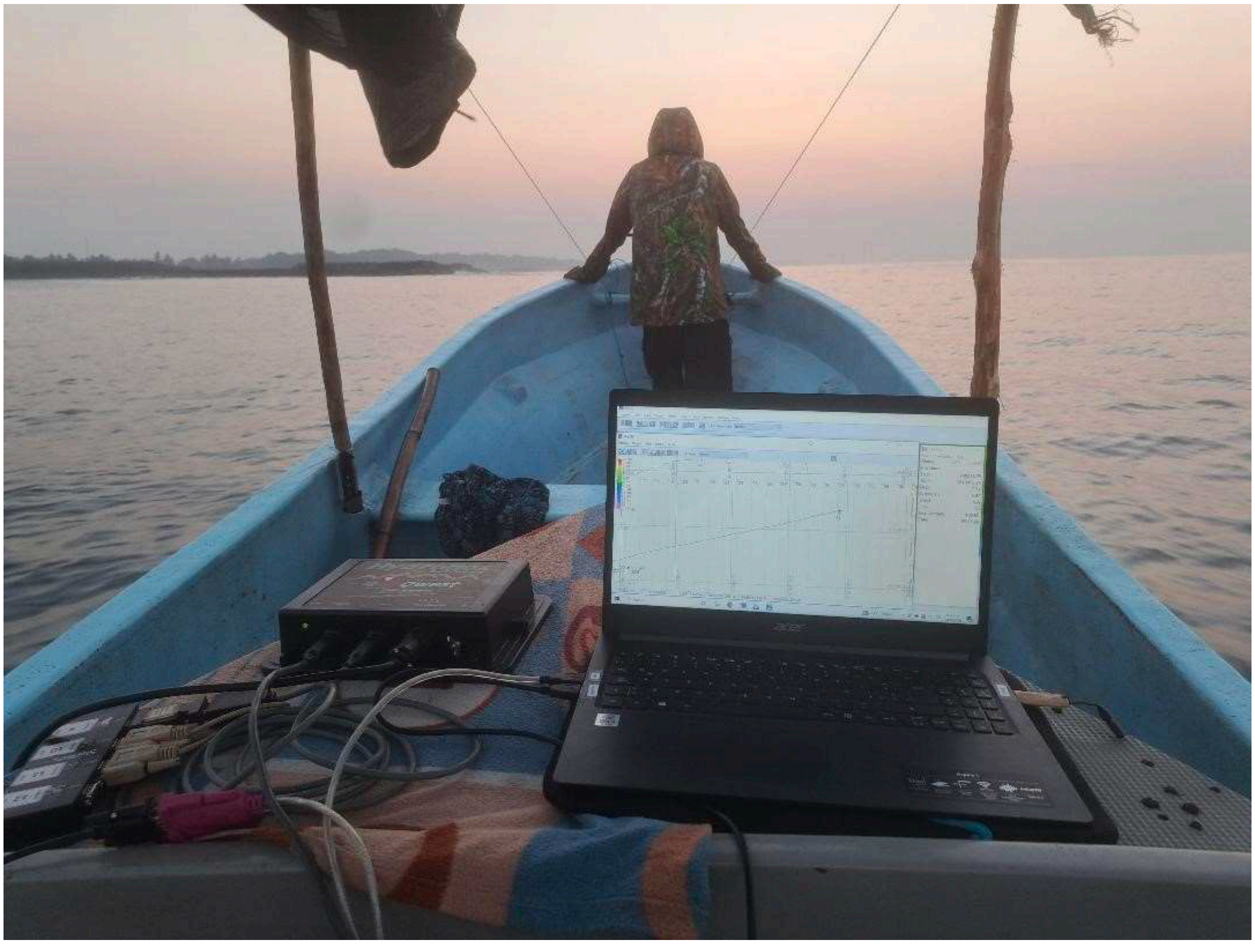


3.1 Survey and field work:

- Transfer of the hydrographic boat to the project area, an adapted fishing boat will be used for this work, departing from the channel of Puerto San José.
- Verification of GPS coordinates concerning the mooring point.

Equipment installation on the hydrographic vessel, taking care that cable installation is done in such a way to avoid accidents or inadvertent disconnections due to people moving within the boat and when we are in the working area.

IMAGE N°3. Example of Equipment Installation on the Boat



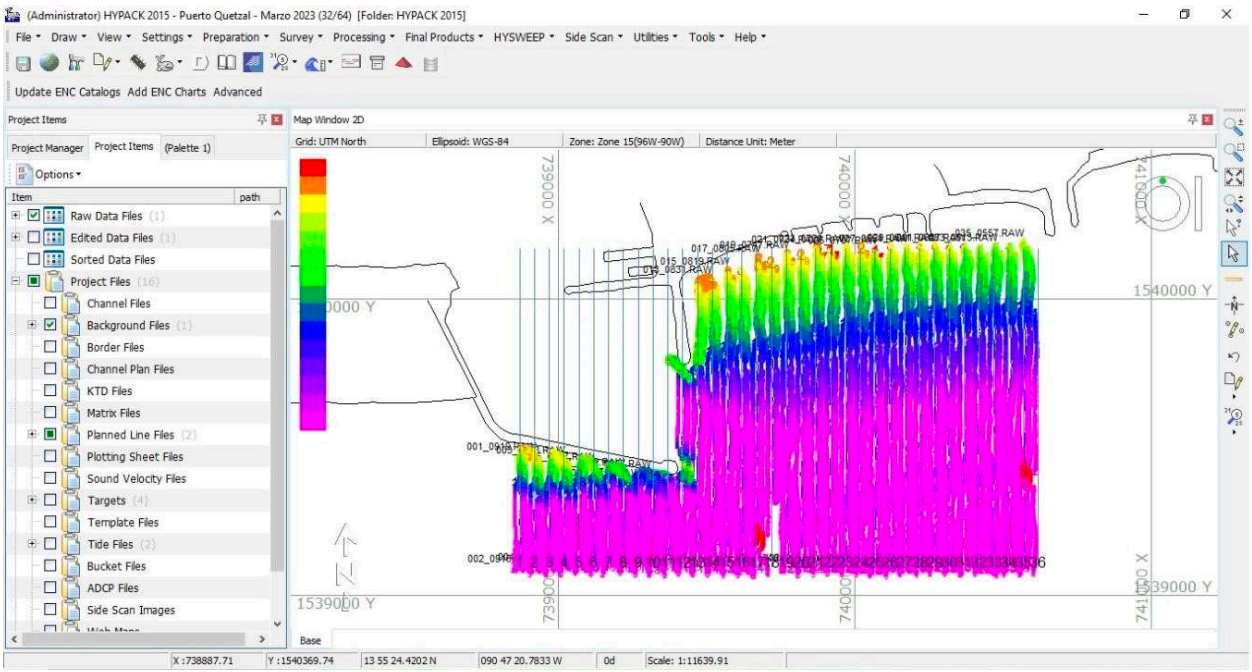
Once the equipment is installed on the hydrographic vessel, we proceed with the calibration of the equipment, using a calibration plate graduated every 2m to measure the parameters of: draft and sound speed.
This calibration plate is placed under the transducer, and the obtained readings are observed, and the sound speed is increased or decreased to get better results.
Since it is saltwater masses, calibration started with a sound speed of 1535m/sec, and from there, it varied until obtaining the value that makes the depth data correct and accurate. During the measurement, reliable data were obtained in the readings, so we worked with this sound speed of 1535m/sec.

3.2 Raw data collection

In the data collection process, the survey lines are followed, starting with the lines transverse to the coast, to obtain better slope resolution since in a simple inspection, we noticed drastic changes in slopes and depths.

This is a sample of how the raw data appeared on the HyPack survey screen after data collection in the internal area (shallow area).

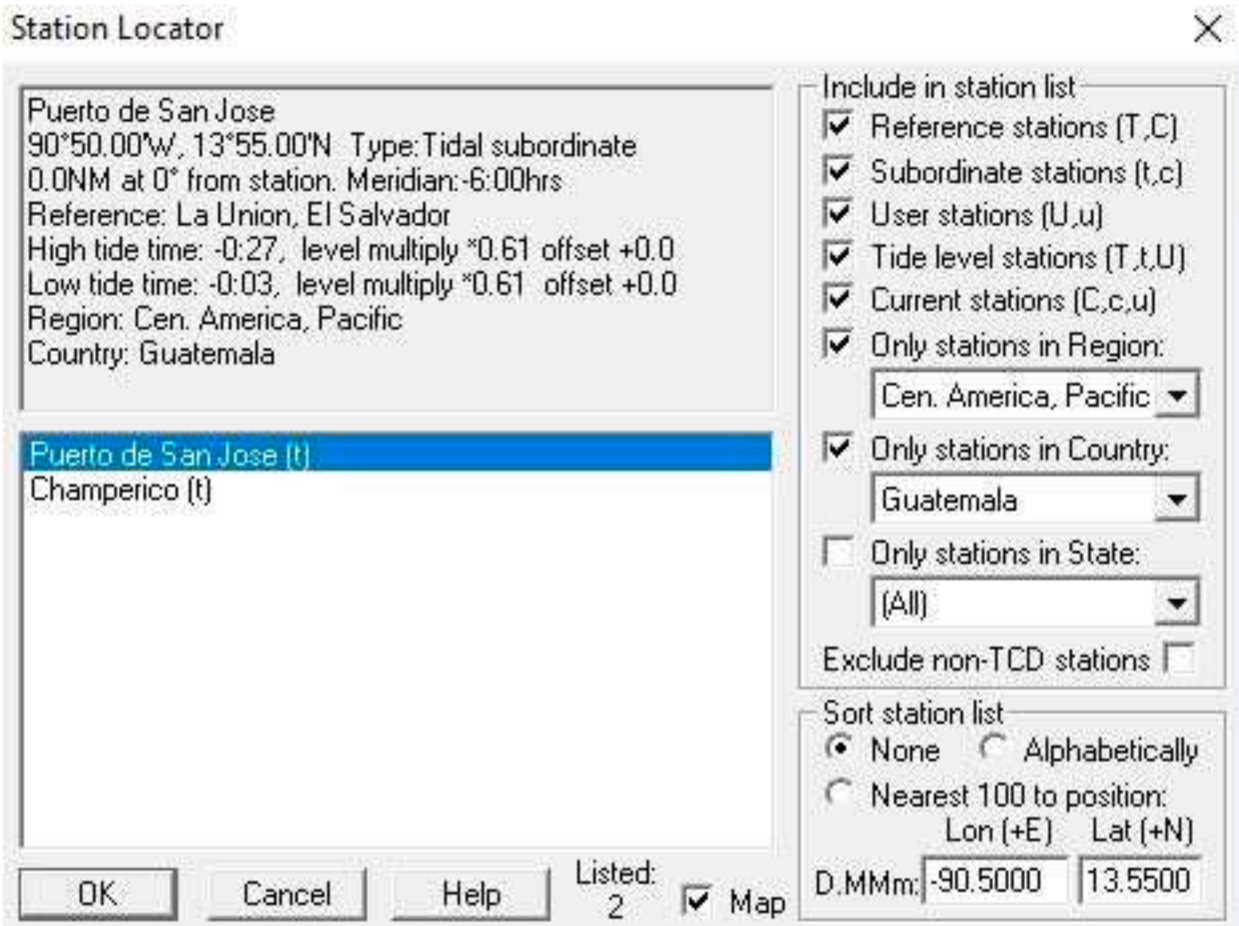
IMAGE N°.4 from the Software with the Raw Lines Collected

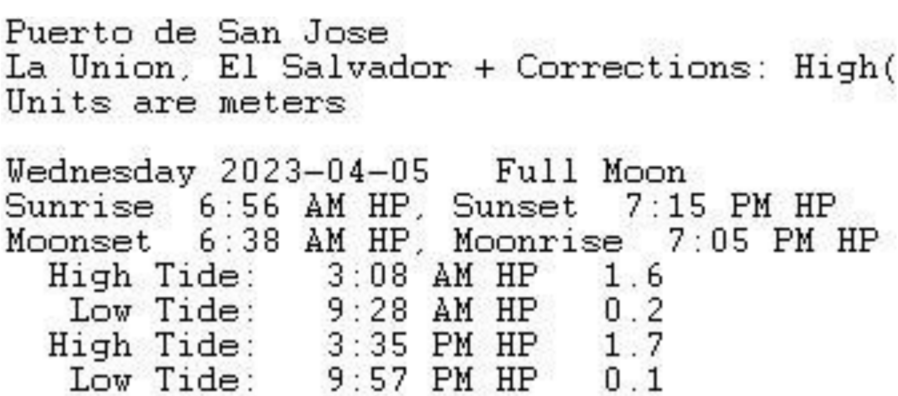


Once all the planned lines have been collected, the equipment is uninstalled and stored:
For processing the collected data, the following steps are carried out:

- Post-processing of the collected data, selecting raw files collected. Inclusion of tidal data for correction; these surface water level data were obtained post-survey from the WxTide32 source, referenced to a tide gauge located in Puerto San José.

IMAGE N°5. Reference of the Tide Tables





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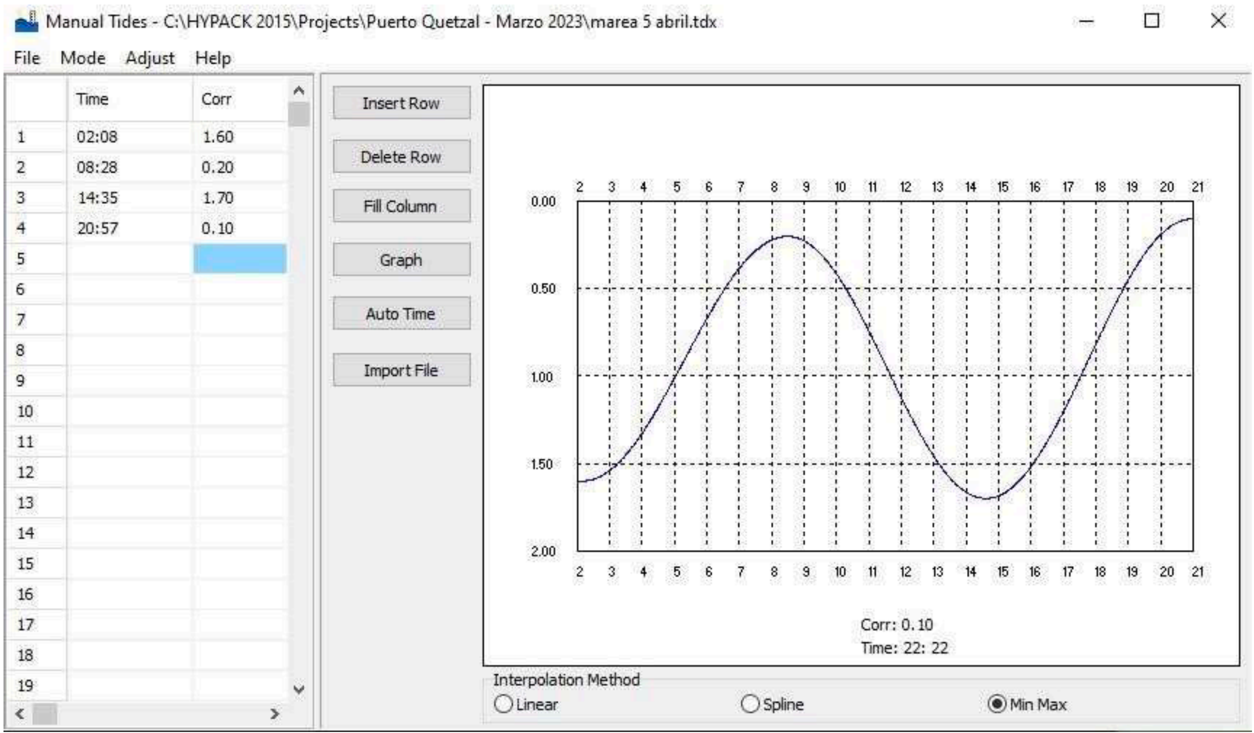
Puerto de San Jose
La Union, El Salvador + Corrections: High(
Units are meters

Wednesday 2023-04-05   Full Moon
Sunrise   6:56 AM HP, Sunset   7:15 PM HP
Moonset   6:38 AM HP, Moonrise  7:05 PM HP
  High Tide:   3:08 AM HP   1.6
   Low Tide:   9:28 AM HP   0.2
  High Tide:   3:35 PM HP   1.7
   Low Tide:   9:57 PM HP   0.1
```

IMAGE N°6. Tide Level File for Correction Applied in the Software



- Application of corrections: surface water levels (tides) and draft.

IMAGE N°7. Inclusion of the Tide Level Values

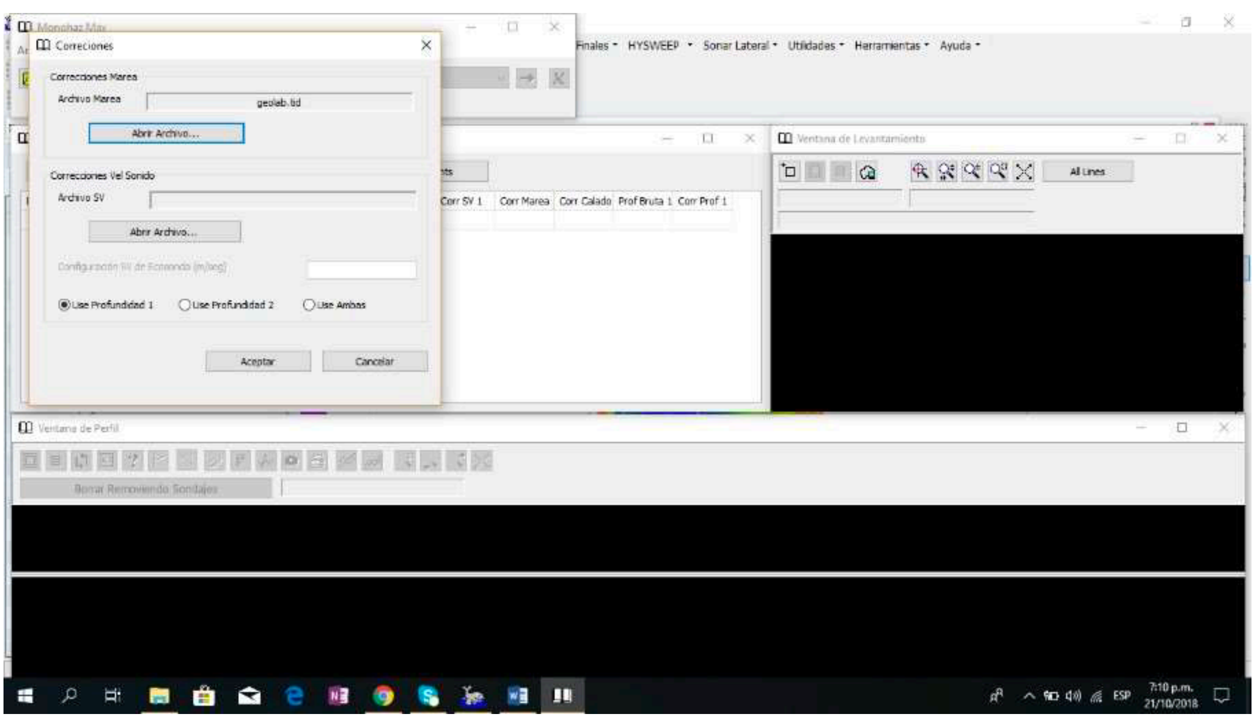
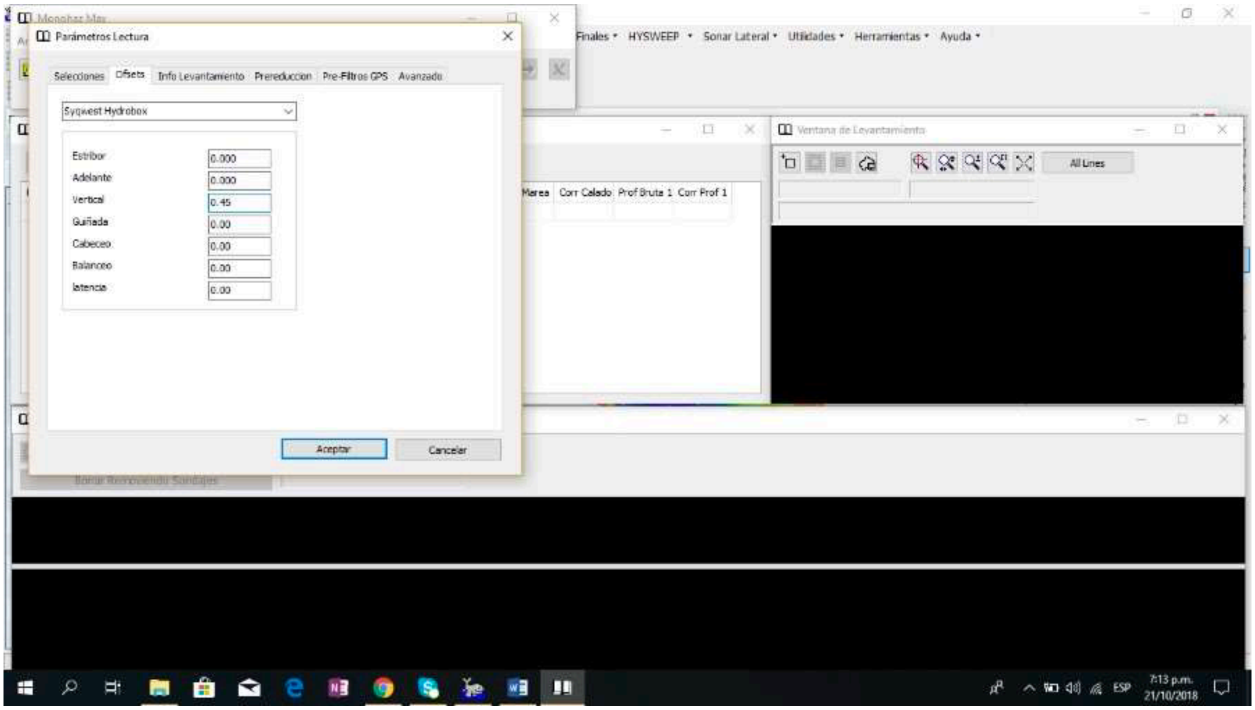
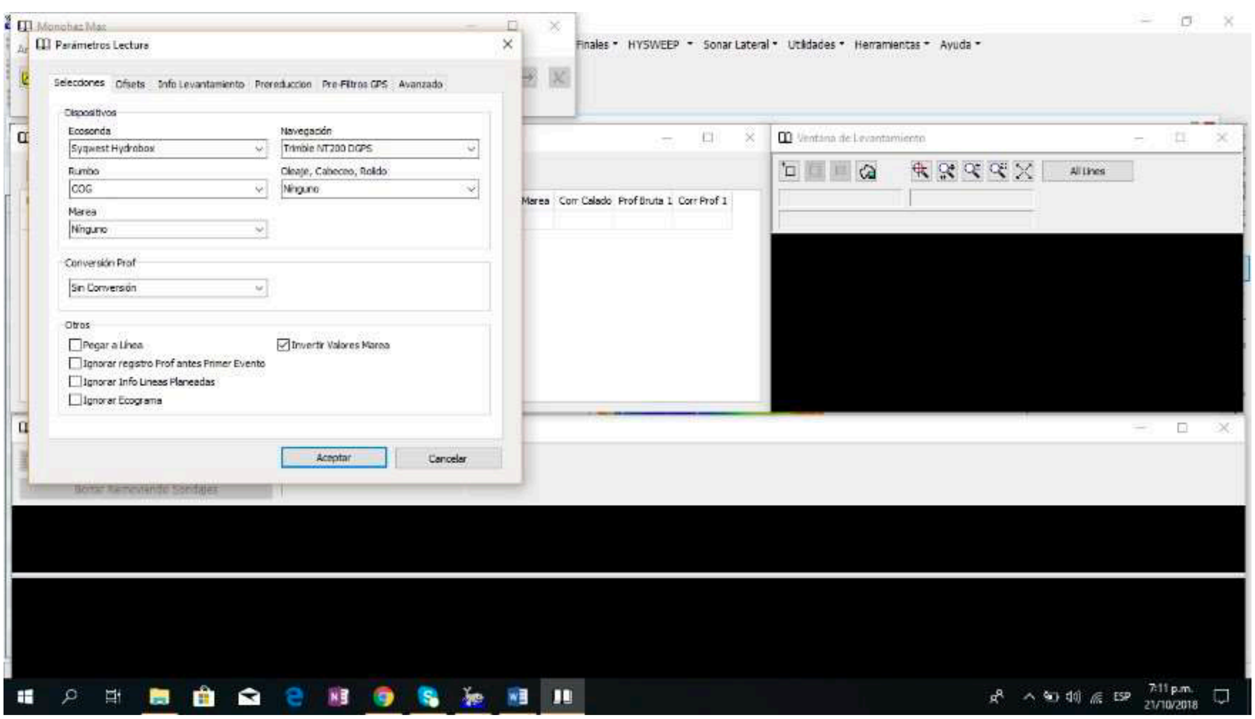


IMAGE N°8. Application of the Draft Value



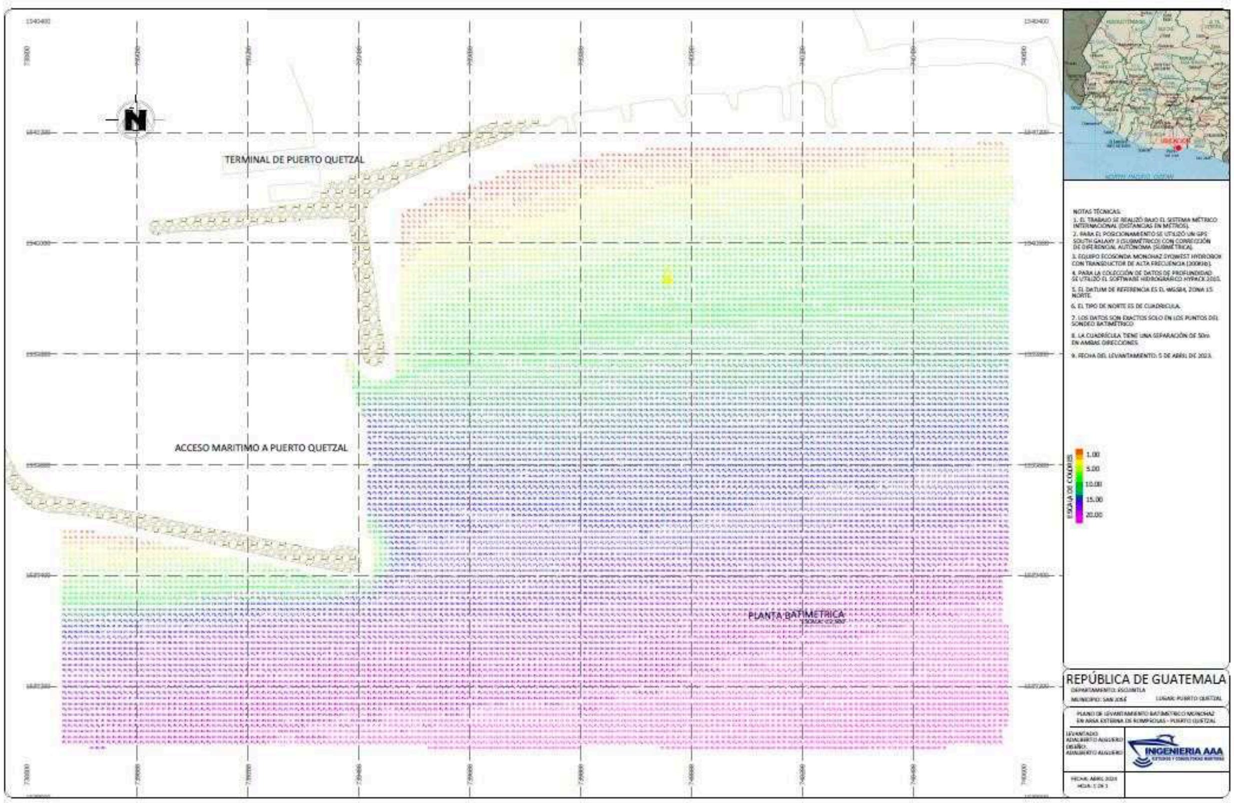
- Reading and applying corrections to raw data for processing.
-

IMAGE N°9. Verification of Datum, Systems, and Others



- Line by line, the collected data is verified, and false data and detected echoes are eliminated, generating a data selection with 1m separation.
- Selection of a data selection matrix for the software to classify critical survey data that will be part of the final data matrix.
- Selection of final data, each case requires a different survey separation, varying the scale and selection of the survey matrix so that the printed plan will have a survey every 1.5cm, complying with the S-44 standard on hydrographic data processing and graphic representations.

IMAGE N°10. Final Processed Data Matrix of 10m x 10m



- A yellow buoy was placed within the survey area with coordinates N1539937, E 739958, used as a verification method for data validation.

IMAGE N°11. Yellow Buoy

4. RESULTS AND FINAL BATHYMETRY DATA

All final processed information will be delivered in digital form (CD) in AutoCAD and PDF formats, x,y,z file with the collected data; in addition to printed plans at appropriate scales with Datum WGS84 in the UTM (Universal Transversal Mercator) system.
The entire project will be delivered in digital form (USB) and printed format, sealed and signed by the responsible professional, delivering the following files:

- Bathymetric plan in AutoCAD format.
- Bathymetric plan in PDF format.
- Work report in PDF format.
- Processed bathymetric data in a 2x2 matrix.

5. HISTORICAL OCEANOGRAPHIC DATA EVALUATION STUDY FOR THE DESIGN PROJECT OF THE DOCK, MOORING AND DOCKING, PUERTO QUETZAL, GUATEMALA

Puerto Quetzal is a port located in the municipality of San José, Escuintla, Guatemala, on the Pacific coast (Latitude 13º 55' N; Longitude 90º 47' W); 98 km from the country's capital. The port is state-run, managed by Empresa Portuaria Quetzal, and since its inception in 1983, it uses a mixed system by authorizing private individuals to provide certain ship and cargo services with tariffs set by the Company and approved by Government Agreement.

- The main dock is a marginal type, and the ships it serves include: bulk solid, container, tanker, gas carrier, barge, refrigerated, general cargo, roll on-roll off, cruise ships, and other cargo vessels.

Access to maritime routes is through an access channel 210 meters wide between the ends of the west and east breakwaters. At the entrance of the maneuvering basin, in the area of the west breakwater elbow, it has a width of 340 meters. This channel also has a curvature of 1,000 meters to allow access without swinging. Its orientation is southeast to face appreciable wave forces with an azimuth of 150°.

- Climatological conditions: The climate is called tropical warm, where different periods of rainfall can be devastating, to the point of completely flooding San José, as happened in November 2022. Temperatures can reach up to 29.4°C. According to Holdridge, the life zone is a warm subtropical humid forest. Geographically, Guatemala is in a privileged zone due to its climate, which affects the species dependent on it. In the sea, there are usually large quantities of organisms. Even in the dock area, influenced by industrial activities, diverse marine life is present despite the muddy bottom and the usual movement caused by vessel engines. There is a convergence zone of the trade winds from both hemispheres (north and south) affecting the climate of areas under its influence, particularly important for our country: the Intertropical Convergence Zone (ITCZ), which moves following the apparent movement of the sun throughout the year. This north-south migration of the ITCZ produces the two (dry and rainy) seasons characteristic of most of our territory.

Officially, according to the Hydrometeorology Department of INSIVUMEH, the periods for different seasons in our country are:

- Dry season starts December 16 to April 15.
- Rainy season starts April 15 to December 16.

6. METHODOLOGY

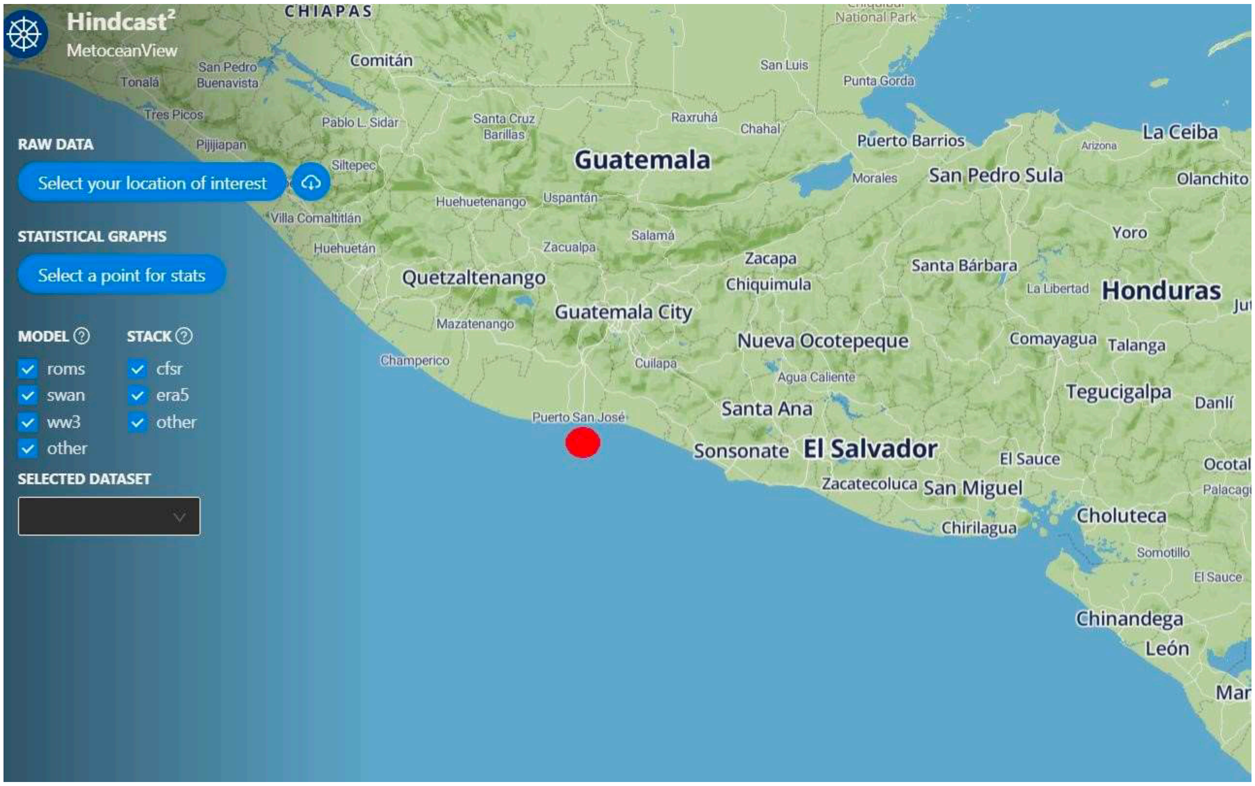
The method we will use to evaluate the preferences and trends of the five basic oceanographic parameters will help us know all the design values when calculating and designing a construction project, through tables, graphs, and values of the most important oceanographic data with historical data collected by oceanographic buoys.

These five basic oceanographic parameters are:

- Significant wave height (m).
- Significant wave period (s).
- Current direction produced by waves (oceanographic degrees).
- Wind direction (oceanographic degrees).
- Wind magnitude (m/s).

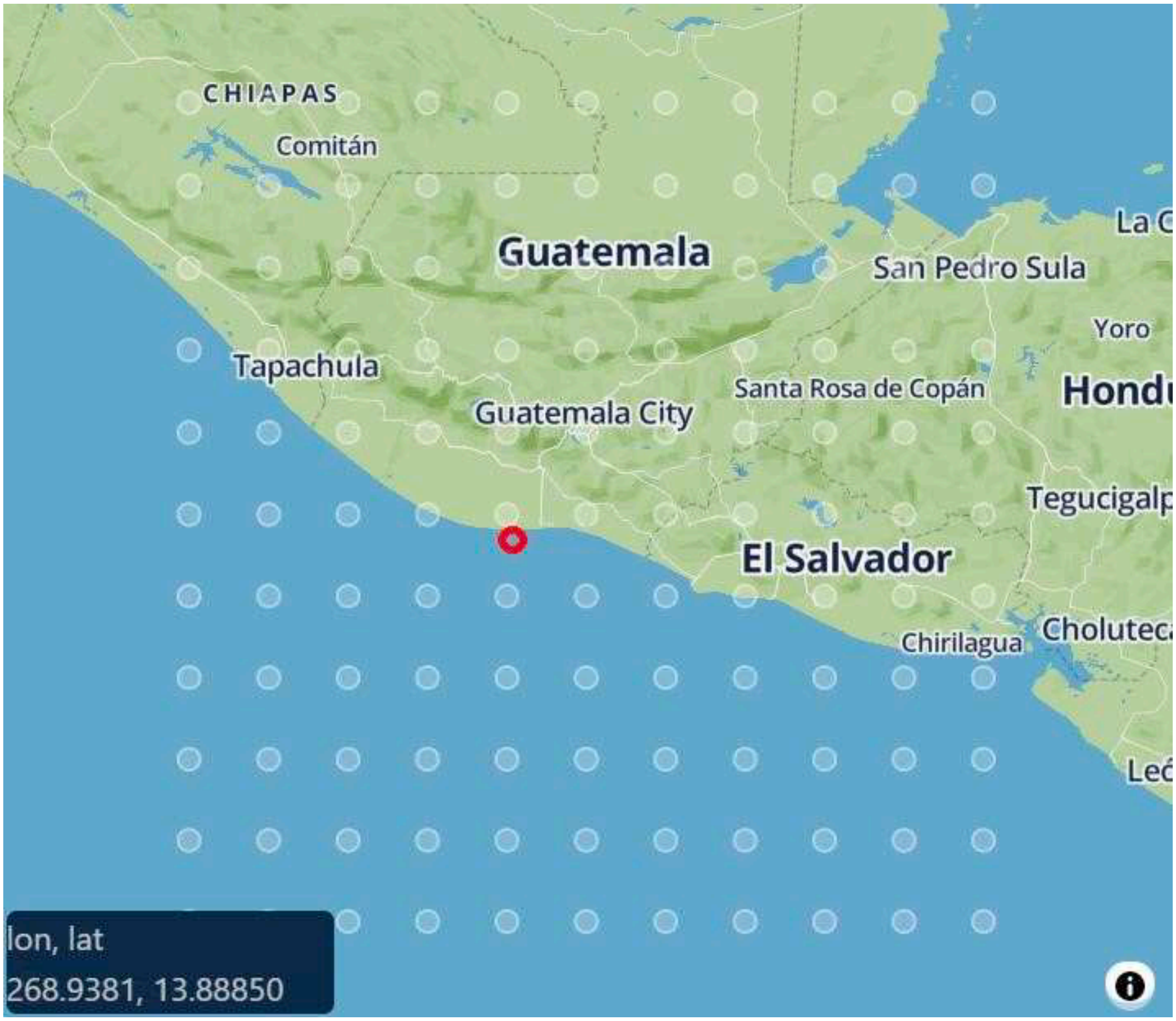
First, an online Oceanographic Retrospective program is used, aimed at purchasing historical data from a point close to our project, evaluated for all possible existing situations that may arise in our study area; for our case, the coordinates are: E739912, N1538959.

IMAGE N°12. Study Area Location



Immediately, the software creates a grid where oceanographic data from the WW3 Global ST4 model is maintained, selecting the closest point to our study area; for our case, the closest data coordinates were: Latitude 13.888850° and Longitude 268.9381°.

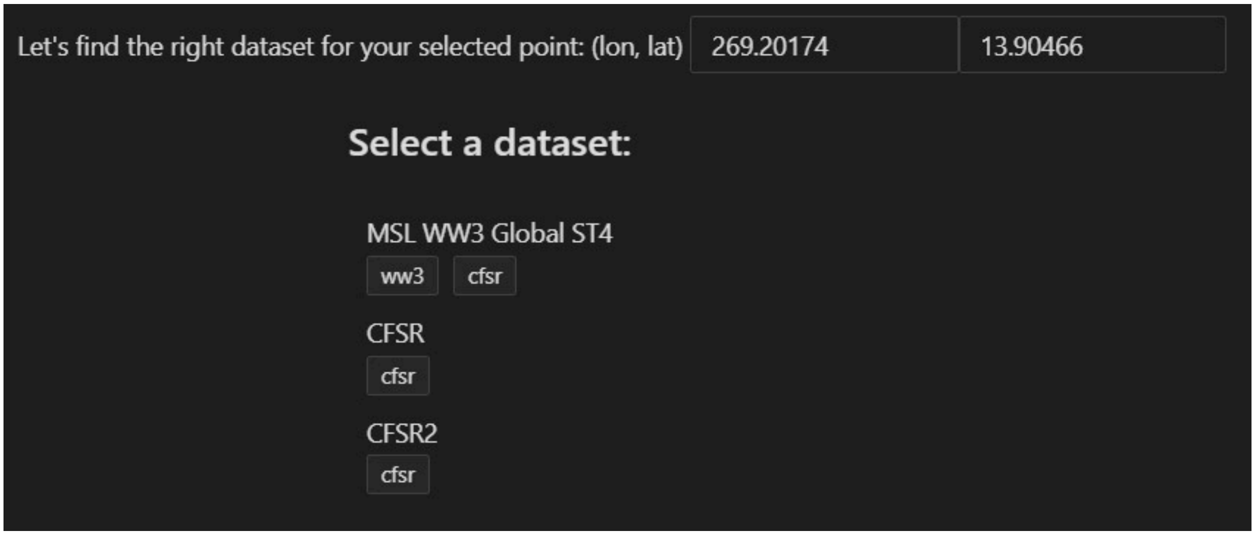
IMAGE N°13. Available Data Grid



Regarding the models and their characteristics, it should be noted that when a numerical model is used to generate WW3 (Weather Watch 3) data, it is generally used to create wave data on a global level or in large regions. SWAN (Simulating Waves Nearshore) is a spectral wave propagation model that simulates the energy contained in waves as they propagate from ocean surfaces to coastal areas and is generally used to produce high-resolution wave data in small coastal areas.

For our evaluation, we will use the WW3 model, the most basic model, which automatically generates all the required graphs for the general evaluation.

IMAGE N°14. Model Selection



For our study coordinates, we were able to obtain statistics for the dataset: MSL WW3 Global ST4 from December 1978 to December 2020.

We must consider that due to our geographical position, we are governed by the tropical dry and humid climate, characterized by having two very marked seasons, one very rainy (from June to December) and another very dry (from January to May). The rainy season occurs when the sun is in the same hemisphere, high on the horizon (in summer), while the dry season occurs when the sun is low on the horizon (in winter).

Rainfall depends on the position of the Intertropical Convergence Zone (ITCZ) and the trade winds, so when there is an orthographic obstacle, wind speeds increase.

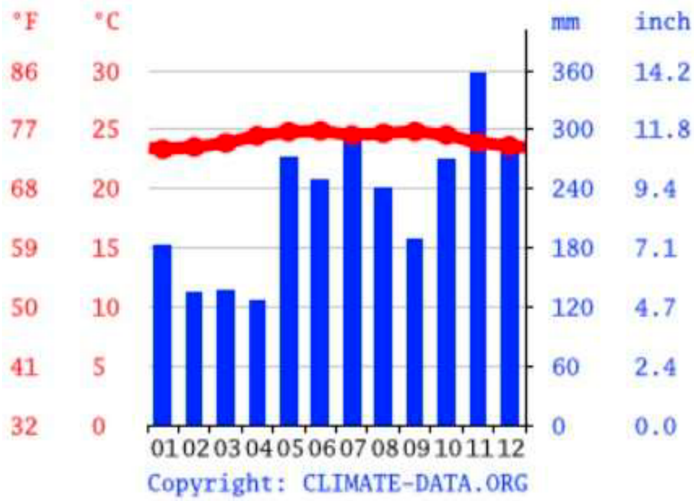
Puerto San José has a tropical climate. There is precipitation throughout the year in this area. The climate here is classified as Af by the Köppen-Geiger system. The annual average temperature in Puerto San José is 24.3 °C, with an average precipitation of 2735 mm.

The month with the most rainfall is July, with an average of 236 millimeters of rain. The month with the least rainfall is March, with an average of 23 millimeters of rain.
In this climate, the dry season should not last more than four to five months. High temperatures cause significant evapotranspiration during the dry season, depleting the water reserve, and if it is prolonged, it leads to deep aridity, with May being the driest month of the year.

For this reason, we have separated our study into two main groups:

- Dry season from January to May.
- Rainy season from June to December.

GRAPH No. 1. Monthly Average Temperature and Precipitation Tabulation



7. RESULTING DATABASE, TABLES, AND GRAPHS
For periods from January to May (dry season). – Matrices generated from the data.

TABLE No.1. Wave Height vs Average Wave Direction

significant height of wind and swell	wave mean direction							
	N	NE	E	SE	S	SW	W	NW
0 - 0.5	0%	0%	0%	0%	0%	0%	0%	0%
0.5 - 1	0%	0%	0%	0.1%	5.9%	2.4%	<0.1%	0%
1 - 1.5	<0.1%	<0.1%	0.2%	1.1%	37.6%	22.2%	0.5%	<0.1%
1.5 - 2	<0.1%	<0.1%	0.1%	0.2%	13%	12.5%	0.3%	<0.1%
2 - 2.5	0%	<0.1%	<0.1%	<0.1%	1.3%	1.9%	<0.1%	<0.1%
2.5 - 3	0%	0%	0%	<0.1%	0.2%	0.2%	0%	0%
3 - 3.5	0%	0%	0%	<0.1%	<0.1%	<0.1%	0%	0%
3.5 - 4	0%	0%	0%	0%	<0.1%	0%	0%	0%

TABLE No.2. Wave Height vs Wave Period

significant height of wind and swell	wave peak period s																			
	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 18	18 - 19	19 - 20
0 - 0.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
0.5 - 1	0%	0%	0%	0%	0%	0%	<0.1%	<0.1%	<0.1%	<0.1%	0.1%	1.1%	2.5%	2.2%	1%	0.5%	0.6%	<0.1%	0.2%	0.1%
1 - 1.5	0%	0%	0%	0%	<0.1%	<0.1%	<0.1%	0.3%	0.1%	0.2%	0.1%	0.9%	7.5%	17.9%	14.6%	7%	8.1%	1.5%	2.4%	0.9%
1.5 - 2	0%	0%	0%	0%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	0.3%	2%	6.2%	5.4%	7.5%	2%	2%	0.7%
2 - 2.5	0%	0%	0%	0%	0%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	0%	<0.1%	<0.1%	<0.1%	0.2%	0.5%	1.2%	0.6%	0.4%	0.2%
2.5 - 3	0%	0%	0%	0%	0%	0%	0%	<0.1%	<0.1%	<0.1%	0%	0%	0%	0%	0%	<0.1%	0.1%	0.1%	<0.1%	<0.1%
3 - 3.5	0%	0%	0%	0%	0%	0%	0%	<0.1%	0%	<0.1%	0%	0%	0%	0%	0%	0%	0%	<0.1%	<0.1%	<0.1%
3.5 - 4	0%	0%	0%	0%	0%	0%	0%	0%	0%	<0.1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

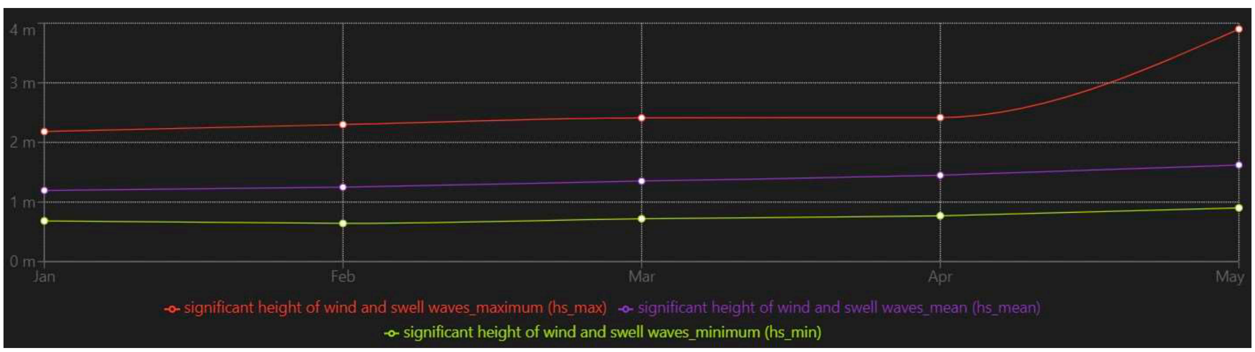
TABLE No. 3. Average Wave Direction vs Wave Period

wave peak period s	wave mean direction							
	N	NE	E	SE	S	SW	W	NW
0 - 1	0%	0%	0%	0%	0%	0%	0%	0%
1 - 2	0%	0%	0%	0%	0%	0%	0%	0%
2 - 3	0%	0%	0%	0%	0%	0%	0%	0%
3 - 4	0%	0%	0%	0%	0%	0%	0%	0%
4 - 5	0%	<0.1%	<0.1%	0%	0%	0%	0%	0%
5 - 6	0%	<0.1%	<0.1%	0%	0%	0%	0%	0%
6 - 7	0%	<0.1%	<0.1%	<0.1%	<0.1%	0%	<0.1%	0%
7 - 8	0%	<0.1%	<0.1%	0.3%	<0.1%	<0.1%	<0.1%	0%
8 - 9	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
9 - 10	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	0.1%	<0.1%
10 - 11	<0.1%	<0.1%	<0.1%	<0.1%	0.1%	<0.1%	<0.1%	<0.1%
11 - 12	<0.1%	<0.1%	<0.1%	0.1%	1.4%	0.3%	<0.1%	<0.1%
12 - 13	<0.1%	<0.1%	<0.1%	0.3%	7.1%	2.7%	0.2%	<0.1%
13 - 14	<0.1%	<0.1%	<0.1%	0.3%	14.3%	7.3%	0.2%	<0.1%
14 - 15	<0.1%	<0.1%	<0.1%	0.2%	13.1%	8.6%	<0.1%	<0.1%
15 - 16	<0.1%	<0.1%	<0.1%	<0.1%	7.1%	6.1%	<0.1%	<0.1%
16 - 17	<0.1%	<0.1%	<0.1%	<0.1%	8.8%	8.5%	<0.1%	<0.1%
17 - 18	<0.1%	<0.1%	0%	<0.1%	2%	2.2%	<0.1%	0%

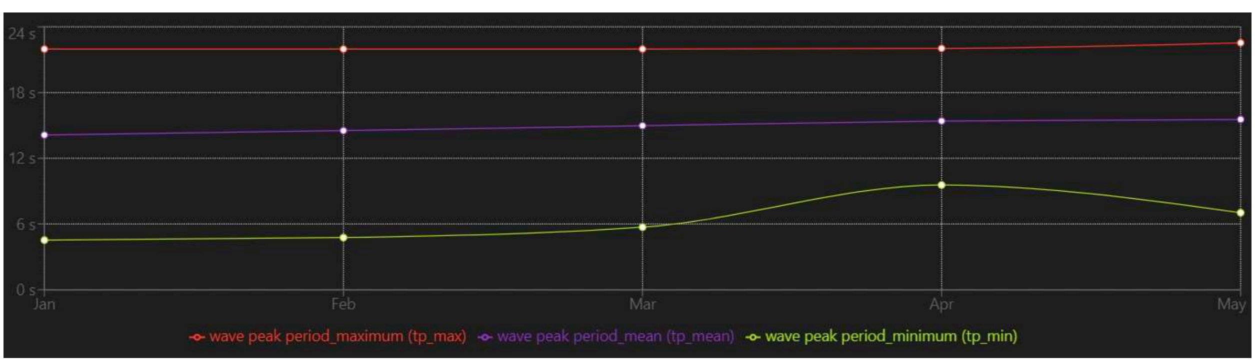
TABLE No. 4. Wind Speed vs Wind Direction

wind_speed m/s	wind_direction							
	N	NE	E	SE	S	SW	W	NW
0 - 5	10.2%	11.2%	8.1%	5.7%	8.2%	7.9%	8.1%	11.1%
5 - 10	0.6%	8.4%	2.9%	2.8%	6.7%	4.3%	2.5%	1.1%
10 - 15	<0.1%	0.1%	<0.1%	<0.1%	<0.1%	0%	<0.1%	<0.1%

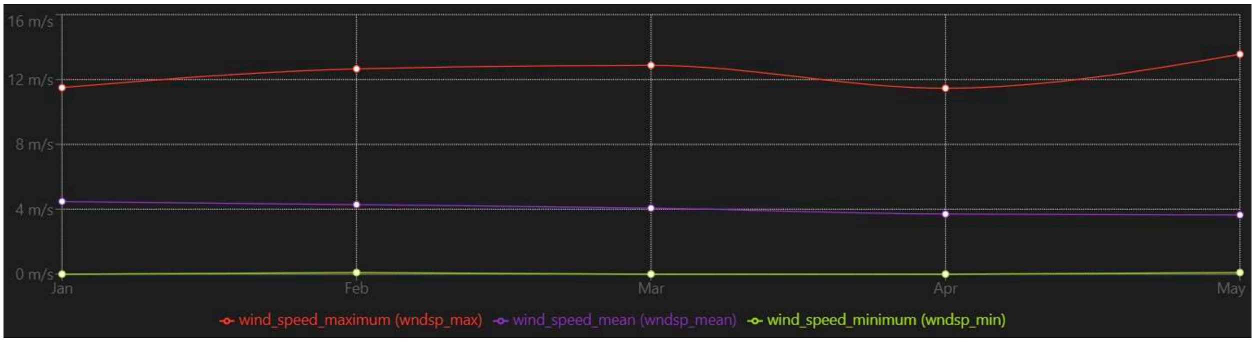
GRAPH No. 1. Monthly Wave Height (dry period)



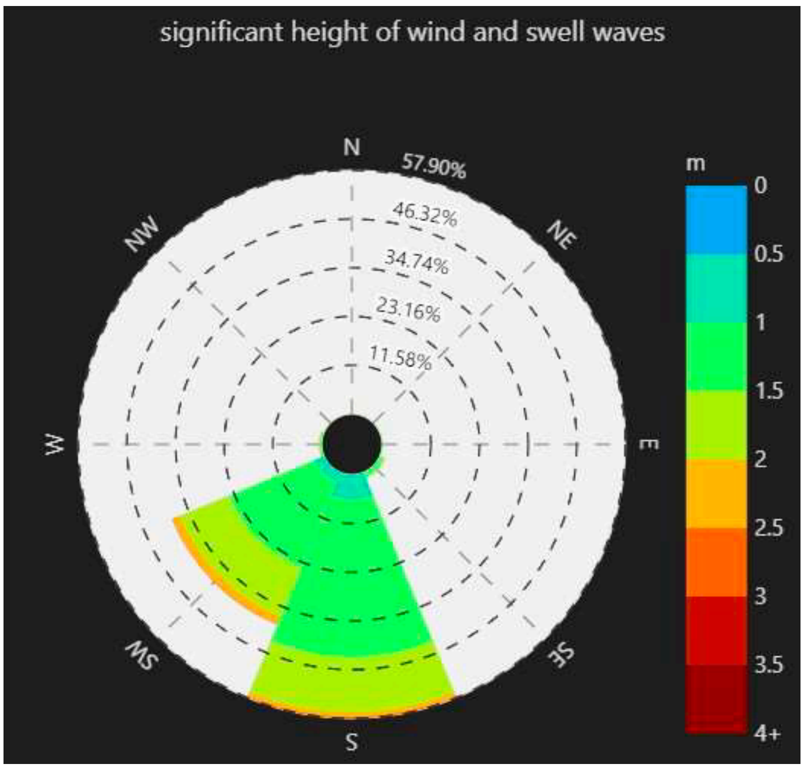
GRAPH No. 2. Monthly Wave Periods (dry period)



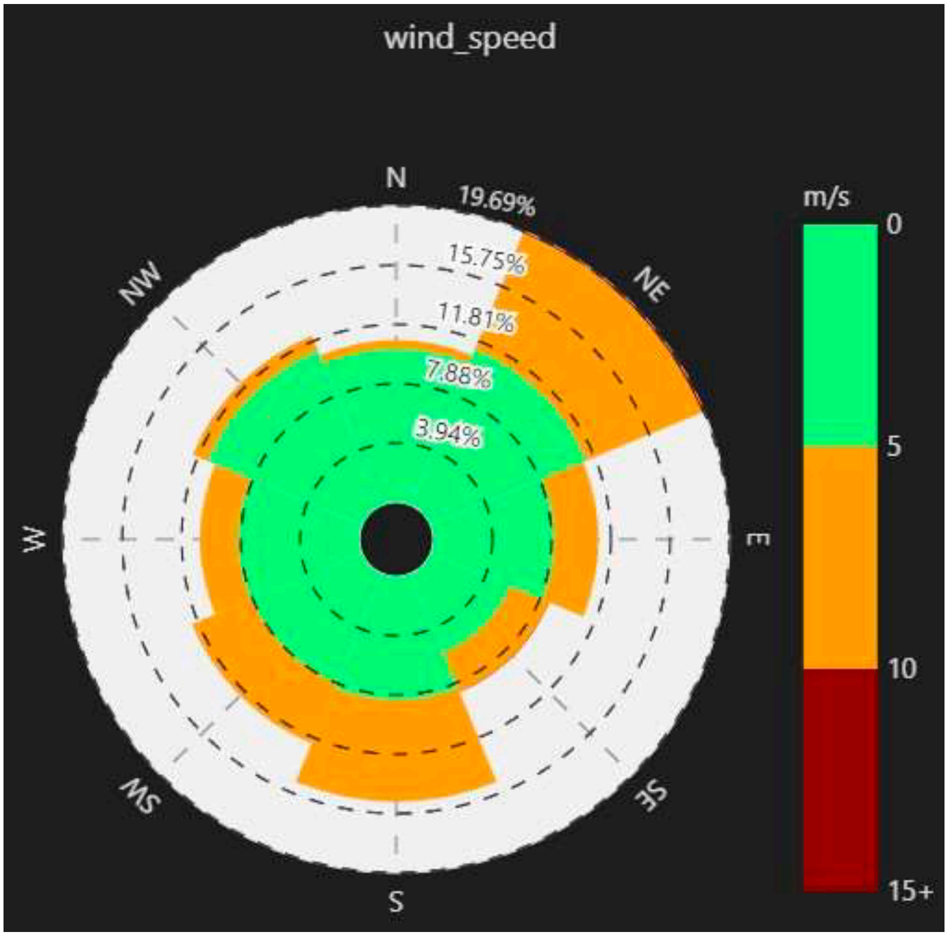
GRAPH No. 3. Monthly Wind Speed (dry period)



GRAPH No. 4. Wave Height and Swell Rose (dry period)



GRAPH No. 5. Wind Speed Rose (dry period)



For periods between June to December (rainy season). – Matrices generated from the data.

TABLE No. 5. Wave Height vs Average Wave Direction

significant height of wind and swell waves m	wave mean direction							
	N	NE	E	SE	S	SW	W	NW
0 - 0.5	0%	0%	0%	0%	0%	0%	0%	0%
0.5 - 1	0%	0%	<0.1%	<0.1%	2.6%	1.2%	<0.1%	0%
1 - 1.5	<0.1%	<0.1%	<0.1%	0.3%	27.9%	18.8%	0.2%	<0.1%
1.5 - 2	<0.1%	<0.1%	<0.1%	<0.1%	18.2%	20.4%	<0.1%	<0.1%
2 - 2.5	0%	0%	0%	<0.1%	3.2%	5.6%	<0.1%	0%
2.5 - 3	0%	0%	0%	<0.1%	0.4%	0.6%	0%	0%
3 - 3.5	0%	0%	0%	<0.1%	<0.1%	<0.1%	0%	0%
3.5 - 4	0%	0%	0%	<0.1%	<0.1%	<0.1%	0%	0%
4 - 4.5	0%	0%	0%	<0.1%	<0.1%	<0.1%	0%	0%
4.5 - 5	0%	0%	0%	0%	0%	<0.1%	0%	0%
5 - 5.5	0%	0%	0%	0%	0%	<0.1%	0%	0%

TABLE No 6. Wave Height vs Wave Period

significant height of wind and swell waves m \ wave peak period s	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 18	18 - 19	19 - 20
0 - 0.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
0.5 - 1	0%	0%	0%	0%	0%	0%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	0.5%	1.2%	1%	0.5%	0.2%	0.2%	<0.1%	<0.1%	<0.1%
1 - 1.5	0%	0%	0%	0%	<0.1%	<0.1%	<0.1%	0.2%	0.2%	0.3%	0.5%	1.5%	6.5%	13.9%	10.3%	4.7%	5.7%	1.2%	1.7%	0.7%
1.5 - 2	0%	0%	0%	0%	0%	<0.1%	<0.1%	0.1%	0.3%	0.2%	0.1%	0.2%	1%	5.2%	9.6%	7.3%	8.8%	2.3%	2.3%	1.2%
2 - 2.5	0%	0%	0%	0%	0%	<0.1%	<0.1%	0.1%	0.2%	0.1%	<0.1%	0%	<0.1%	0.3%	0.8%	1.4%	3%	1.2%	0.9%	0.5%
2.5 - 3	0%	0%	0%	0%	0%	0%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	0%	0%	<0.1%	<0.1%	<0.1%	0.2%	0.2%	0.2%	<0.1%
3 - 3.5	0%	0%	0%	0%	0%	0%	0%	<0.1%	<0.1%	<0.1%	0%	0%	0%	0%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%
3.5 - 4	0%	0%	0%	0%	0%	0%	0%	0%	<0.1%	<0.1%	0%	0%	0%	0%	0%	<0.1%	0%	<0.1%	<0.1%	0%
4 - 4.5	0%	0%	0%	0%	0%	0%	0%	<0.1%	<0.1%	<0.1%	<0.1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4.5 - 5	0%	0%	0%	0%	0%	0%	0%	0%	0%	<0.1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
5 - 5.5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	<0.1%	0%	0%	0%	0%	0%	0%	0%	0%	0%

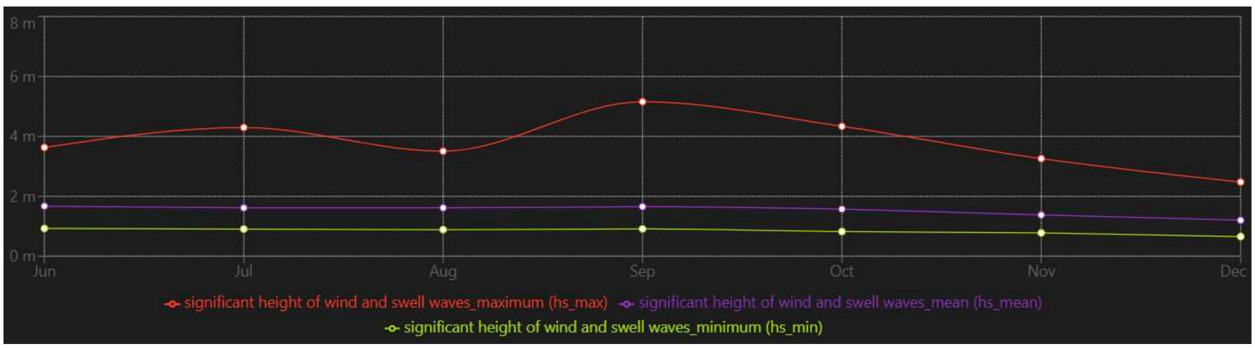
TABLE No. 7. Average Wave Direction vs Wave Period

wave peak period s \ wave mean direction	N	NE	E	SE	S	SW	W	NW
0 - 1	0%	0%	0%	0%	0%	0%	0%	0%
1 - 2	0%	0%	0%	0%	0%	0%	0%	0%
2 - 3	0%	0%	0%	0%	0%	0%	0%	0%
3 - 4	0%	0%	0%	0%	0%	0%	0%	0%
4 - 5	0%	0%	<0.1%	0%	0%	0%	0%	0%
5 - 6	0%	<0.1%	<0.1%	<0.1%	<0.1%	0%	0%	0%
6 - 7	0%	0%	<0.1%	<0.1%	<0.1%	<0.1%	0%	0%
7 - 8	0%	0%	<0.1%	0.1%	0.2%	0.2%	0%	0%
8 - 9	<0.1%	0%	<0.1%	<0.1%	0.4%	0.5%	<0.1%	0%
9 - 10	<0.1%	<0.1%	0%	<0.1%	0.3%	0.3%	<0.1%	<0.1%
10 - 11	0%	0%	<0.1%	<0.1%	0.5%	0.2%	<0.1%	<0.1%
11 - 12	0%	<0.1%	<0.1%	<0.1%	1.5%	0.6%	<0.1%	0%
12 - 13	<0.1%	<0.1%	<0.1%	0.1%	5.5%	3.1%	<0.1%	<0.1%
13 - 14	<0.1%	<0.1%	<0.1%	0.1%	12%	8.3%	<0.1%	<0.1%
14 - 15	<0.1%	<0.1%	<0.1%	<0.1%	11.4%	9.8%	<0.1%	<0.1%
15 - 16	0%	<0.1%	<0.1%	<0.1%	6.6%	7%	<0.1%	<0.1%
16 - 17	0%	<0.1%	<0.1%	<0.1%	7.9%	10%	<0.1%	<0.1%
17 - 18	0%	0%	0%	<0.1%	2.2%	2.7%	0%	0%

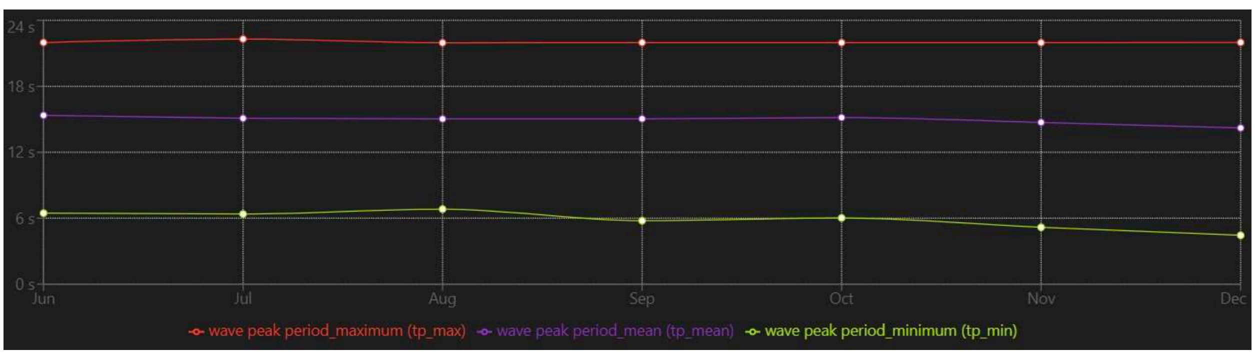
TABLE No. 8. Wind Speed vs Wind Direction

wind_speed m/s	N	NE	E	SE	S	SW	W	NW
0 - 5	9.2%	14.6%	10%	7.4%	8.4%	7.9%	8.1%	8%
5 - 10	0.6%	6.4%	3.7%	3.6%	3.6%	4.1%	3%	1%
10 - 15	0%	<0.1%	0.2%	0.2%	<0.1%	<0.1%	<0.1%	0%
15 - 20	0%	0%	<0.1%	<0.1%	<0.1%	<0.1%	<0.1%	0%

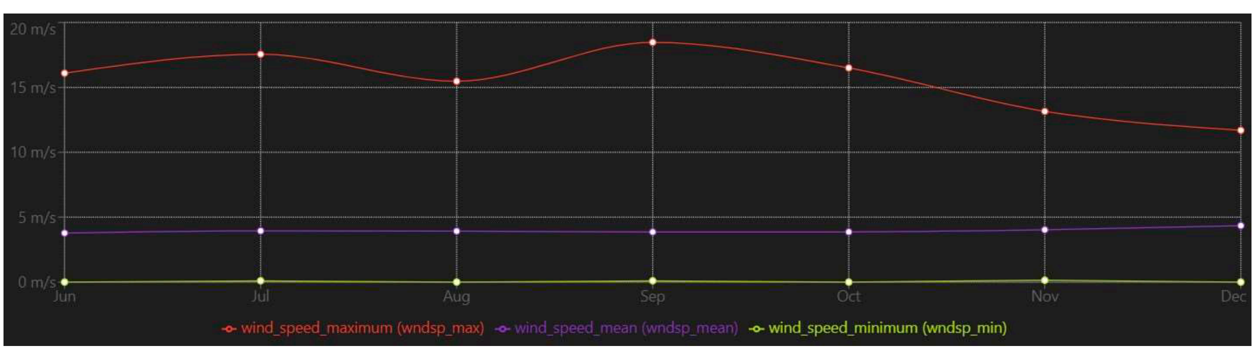
GRAPH No. 6. Monthly Wave Height (rainy period)



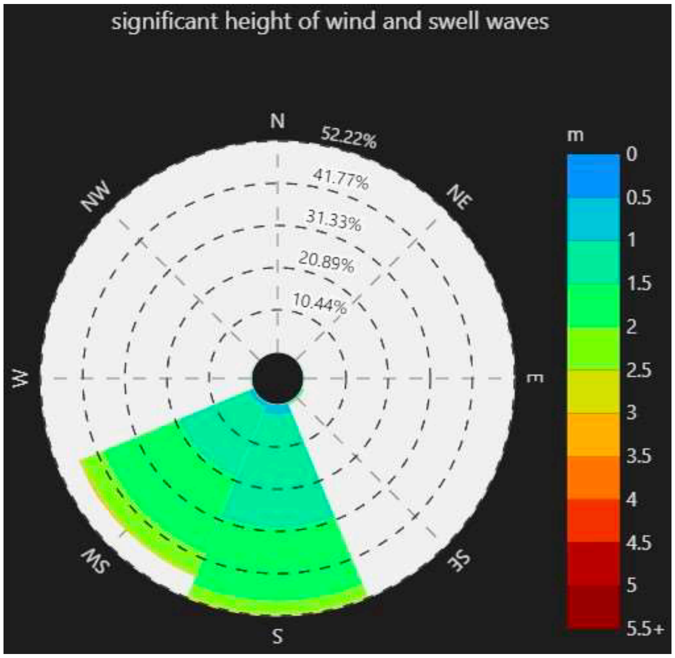
GRAPH No. 7. Monthly Wave Periods (rainy period)

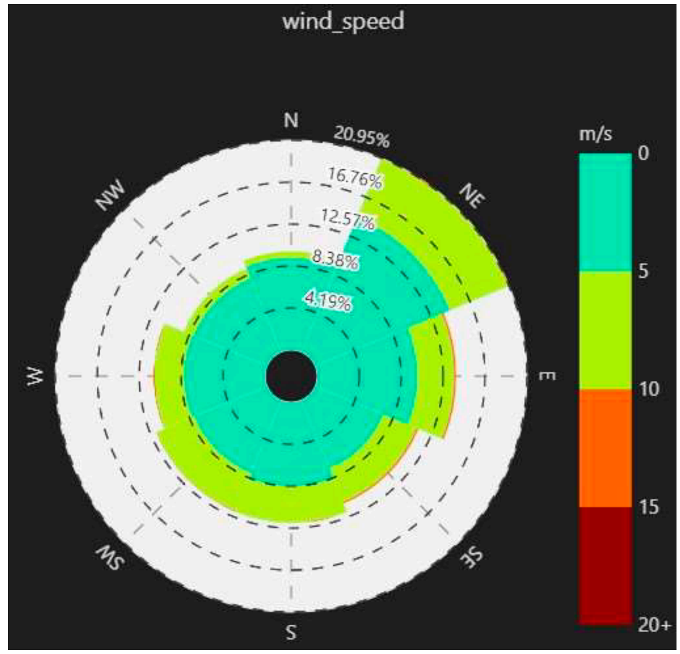


GRAPH No. 8. Monthly Wind Speed (rainy period)



GRAPH No. 9. Wave Height and Swell Rose (rainy period)





GRAPH No. 10. Wind Speed Rose (rainy period)

Seasonal Extremes Measured in: January

Return Period [years]	**1**	**5**	**10**	**50**	**100**	**1000**	**10,000**
Significant wave height							
of wind and waves (meters)	3.3	3.7	3.8	4.1	4.3	4.7	5.2
Wind speed (m/s)	12.7	13.5	13.9	14.6	14.9	15.9	16.8

Seasonal Extremes Measured in: February

Return Period [years]	**1**	**5**	**10**	**50**	**100**	**1000**	**10,000**
Significant wave height							
of wind and waves (meters)	3.2	3.6	3.7	4.0	4.2	4.6	5.1
Wind speed (m/s)	13.0	14.2	14.7	15.8	16.3	17.8	19.3

Seasonal Extremes Measured in: March

Return Period [years]	1	5	10	50	100	1000	10,000
Significant wave height							
of wind and waves (meters)	3.3	3.7	3.9	4.3	4.5	5.0	5.6
Wind speed (m/s)	14.0	15.9	16.7	18.7	19.6	22.4	25.3

Seasonal Extremes Measured in: April

Return Period [years]	1	5	10	50	100	1000	10,000
Significant wave height							
of wind and waves (meters)	2.7	3.0	3.1	3.4	3.6	4.0	4.5
Wind speed (m/s)	12.7	14.9	15.9	18.2	19.1	22.5	25.9

Seasonal Extremes Measured in: May

Return Period [years]	1	5	10	50	100	1000	10,000
Significant wave height							
of wind and waves (meters)	2.1	2.3	2.4	2.6	2.7	3.0	3.3
Wind speed (m/s)	10.7	12.0	12.6	13.8	14.4	16.1	17.8

Seasonal Extremes Measured in: June

Return Period [years]	1	5	10	50	100	1000	10,000
Significant wave height							
of wind and waves (meters)	2.4	2.6	2.7	2.9	3.0	3.3	3.6
Wind speed (m/s)	10.6	12.2	12.9	14.5	15.2	17.4	19.6

Seasonal Extremes Measured in: July

Return Period [years]	1	5	10	50	100	1000	10,000
Significant wave height							
of wind and waves (meters)	2.5	2.7	2.8	3.0	3.1	3.4	3.7
Wind speed (m/s)	10.6	11.9	12.4	13.6	14.2	15.9	17.5

Seasonal Extremes Measured in: August

Return Period [years]	1	5	10	50	100	1000	10,000
Significant wave height							
of wind and waves (meters)	2.3	2.5	2.6	2.8	2.8	3.1	3.4
Wind speed (m/s)	10.5	12.0	12.6	14.2	14.8	17.1	19.3

Seasonal Extremes Measured in: August

Return Period [years]	1	5	10	50	100	1000	10,000
Significant wave height							
of wind and waves (meters)	2.3	2.5	2.6	2.8	2.8	3.1	3.4
Wind speed (m/s)	10.5	12.0	12.6	14.2	14.8	17.1	19.3

Seasonal Extremes Measured in: October

Return Period [years]	1	5	10	50	100	1000	10,000
Significant wave height							
of wind and waves (meters)	1.9	2.2	2.3	2.6	2.7	3.0	3.4
Wind speed (m/s)	12.2	14.5	15.5	17.9	18.9		

Seasonal Extremes Measured in: November

Return Period [years]	1	5	10	50	100	1000	10,000
Significant wave height							
of wind and waves (meters)	2.7	3.1	3.3	3.6	3.8	4.3	4.9
Wind speed (m/s)	14.1	17.2	18.5	21.6	22.9	27.5	32.1

Seasonal Extremes Measured in: December

Return Period [years]	1	5	10	50	100	1000	10,000
Significant wave height							
of wind and waves (meters)	3.1	3.4	3.5	3.8	3.9	4.4	4.8
Wind speed (m/s)	13.4	15.6	16.5	18.8	19.7	23.0	26.2

Finally, we proceeded to tabulate the seasonal extreme values for different return periods, obtaining the following tables:

Its objective is to provide a general idea of extreme conditions, but they are not suitable as final oceanographic design statistics. It is possible that the values do not capture the maximum magnitude of the extremes of tropical cyclones, which are very frequent in this area.

8. CONCLUSIONS

Data resulting during the months from January to May (dry season).
For the case of wave heights generated by winds and swell, most of them (59.8%) are less than 1.5m high, and another 25.5% are between 1.5m and 2.0m, with the majority of waves coming from the South direction. See Table No.1.

Regarding wave periods, the highest percentage of them (17.9%) have periods within the range of 13s to 14s; what we observed is that they remain within a range of 12s to 17s and heights between 0.5m and 2.0m, which shows that wind-produced waves are smaller (not significant) as they are low to medium waves and mostly swell-produced waves; these swell waves have heights up to 2.0m. See Table No.2.

In terms of average wave directions graphed with high wave periods (between 12s to 17s), we can conclude that 50.4% of the waves come from the South, and another 30.5% with the same periods come from the Southwest. See Table 3.

Regarding the topic of winds, we found two large groups which should be especially taken into consideration when designing the height and location of protective works (see Table 4):

- 70.5% of the winds are almost evenly distributed in all directions; however, they are of low magnitude 0 and 5 m/s.
- 28.2% of the winds are almost evenly distributed in all directions; however, they are of medium magnitude 5 and 10 m/s.

Wave heights are of lesser impact during the dry season due to the winds; however, for the first four months of the year, they are very similar in behavior (maximums of 3.60m), taking into account that the average or medium waves (1.442m) are 31.09% the height of the maximum waves. However, for May, the wave height increases up to 4m. Therefore, designs should be based on maximum values. See Graph 1.

Wave periods during the dry season remain quite constant, with average periods of 13 seconds considered as swell-produced waves. See Graph 2.

Similar to wave heights, wind speeds increase in May (14.615m/s), to be considered in the design. The other months simulate maintaining constant minimum and average speeds. See Graph 3.

After creating wave height graphs (wind rose type), we confirmed that most winds come from the South and Southwest with a high percentage (93.99%), but most of these waves are of medium heights (1.0 to 2.0m). See Graph 4.

Similarly, for wind speeds, we could confirm their high percentage of waves of 5 to 10 m/s coming from the Northeast; at this point, special attention should also be given to winds coming from the South as they are the most intense. See Graph 5.

Data resulting during the months from June to December (rainy season). For this season, wave, wind, and period values are very similar to the dry season.
For the case of wave heights generated by winds and swell, most of them (85.3%) are less than 2.0m high, with the majority of waves between 1m and 1.5m coming from the South and Southwest directions. See Table 5.

Regarding wave periods, the highest percentage of them (41.1%) have periods within the range of 12s to 17s, for wave heights between 1.0m and 1.5m; we also found a high wave period range (30.9%) for periods of 13s to 17s with heights between 1.5m and 2.0m; similar to the dry season, the high and medium percentages remain within a range of 6s to 10s and heights between 0.5m and 2.0m, showing that most are swell-produced waves due to low to medium waves and fewer wind-produced waves. See Table 6.

Like the average wave direction graphs with wave periods, we can conclude that 84.1% of the waves with periods between 6 to 10 seconds come from the South and Southwest. This should be taken into account when designing the structure. See Table 7.

Regarding the topic of winds, we found two large groups which should be especially taken into consideration when designing the height and location of protective works (see Table 8):

- 73.6% of the winds are almost evenly distributed in all directions; however, they are of low magnitude 0 and 5 m/s.
- 25% of the winds are almost evenly distributed in all directions; however, they are of medium magnitude 5 and 10 m/s.

Wave heights are constant during the months from June to September, showing a significant increase of 45.82% in height in November. See Graph 6.

Wave periods maintain their maximum period during July, reaching 16.74 seconds, a high value, decreasing constantly until reaching their lowest value in December with 11.34 seconds. See Graph 7.

The wind speed graph shows two marked trends:

- Minimum and average wind speeds are constant throughout the rainy season, with a marked value increase for August's maximum speeds, returning to regular values for the following months. See Graph 8.

- Regarding wave height, there is a similarity in behavior in both seasons; confirming that most winds come from the Northeast with a high percentage (90.59%), but most of these waves are of medium heights (0.5 to 2.5m). See Graph 9.

- Similarly, for wind speeds, we could confirm their high percentage of waves of 0 to 5 m/s coming from the West and Northwest; winds from the North and Northeast are much less intense and numerous with winds of 0 to 5m/s. See Graph 10.

- Finally, although not part of the oceanographic study, meteorological topics and seasonal rainfall should be considered, statistically averaging 450mm annually in the dry season, but increasing to 2600mm annually in the rainy season, with a significant precipitation increase on the northern coast of the country.

9. OCEANOGRAPHIC DATA SOURCE

All historical data of the five oceanographic parameters was obtained from the METOCEANVIEW.com Database, an online high-resolution meteorological tool for managing maritime operations.

A robust platform for accessing, monitoring, and managing meteorological information in a high-resolution domain for operations.

State-of-the-art oceanographic and atmospheric forecast models designed by MetOcean Solutions provide detailed and reliable information for any location. Innovative tools to assist port operators, pilots, tugboat captains, and maritime company managers in making informed decisions at sea or port.