

## REPORT ON PHYSICAL OCEANOGRAPHY WORK DONE IN MEXICO DURING THE TRIENNIUM 1964-1968

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INTRODUCTION. Although Physical Oceanography work began in Mexico in the XVIIIth. Century in various aspects, it was really after 1900 that it became systematized through the action of Federal agencies, and later on in the form of scientific programs at the National Autonomous University of Mexico. In the beginning years, hydrographic surveys were carried out in the Gulf of Mexico and the Pacific Ocean by Spanish navigators, out of which grew charts and manuals published in Madrid, and after the Independence War, in Mexico City, Veracruz and other places in this country. Soundings, sampling of waters and their analysis were done by the 1850's in various ports (Veracruz, Acapulco) and published by the Federal Government.

In 1890, the Secretaría de Comunicaciones y Obras Públicas (Ministry of Communications and Public Works) established a General Directorate of Lighthouses, where it was soon understood that construction of maritime facilities was almost impossible without the study of the physical and chemical characteristics of marine waters; surveys were made as well as studies of the dynamics of the sea through tide-gauges and other instruments. After 1900, the development of the fishing industry made necessary the creation of other Federal agencies devoted to the study of the biological characteristics of Mexican waters; in 1936 the Mexican Navy Department was established as a separate dependency of the Federal Government, charged with the data surveying, processing and mapping of adjoining seas as well as of supplementary research. At the same time a General Directorate of Fishing was created, and later on transferred to the Secretaría de Industria y Comercio (Ministry of Industry and Commerce), formerly Secretaría de Economía.

In those years the National Autonomous University of Mexico began to develop its own programs through the Institutes of Geophysics, Geology and Biology, although the physical regime of marine waters was mainly the responsibility of the first, and partially of the second. Numerous national

and foreign expeditions have surveyed Mexican waters in the last 25 years; 19 tide-gauge stations are operated by the Institute of Geophysics for public services, together with scientific research in Physical Oceanography, while marine geological studies are in charge of the Institute of Geology, and marine biological studies of the Institute of Biology. In this report, mention is only made of research conducted by agencies charged with the physical aspects of oceanographic studies by academic and official institutions.

## NATIONAL AUTONOMOUS UNIVERSITY OF MEXICO

### INSTITUTE OF GEOPHYSICS

The Department of Physical Oceanography, Institute of Geophysics of the N.A.U.M., has carried out the following activities during the years 1964 to 1966:

- I. MAREOGRAPHIC SERVICE
- II. TIDE FORECASTING
- III. HYDROGRAPHIC STUDIES
- IV. OCEANOGRAPHIC RESEARCH
- V. PUBLICATIONS.

#### I. MAREOGRAPHIC SERVICE:

The Department of Physical Oceanography has 19 tide gauges on both coasts, which give information on tides, storm surges, external surges, tsunamies and variation of sea level in the Pacific Ocean and in the Gulf of Mexico, at the following sites (Fig. 1):

<i>Name</i>	<i>Date of installation</i>
Ensenada, Baja California	May 20, 1965
Punta Peñasco, Sonora	November 24, 1964
Guaymas, Sonora	June 28, 1950
Topolobampo, Sinaloa	February 25, 1956
Puerto Ángel, Oaxaca	October 25, 1961
La Paz, Baja California	July 8, 1950
Mazatlán, Sinaloa	November 20, 1952
Manzanillo, Colima	January 22, 1953
Acapulco, Guerrero	March 23, 1949
Salina Cruz, Oaxaca	March 14, 1952
Ciudad Madero, Tamaulipas	April 4, 1962

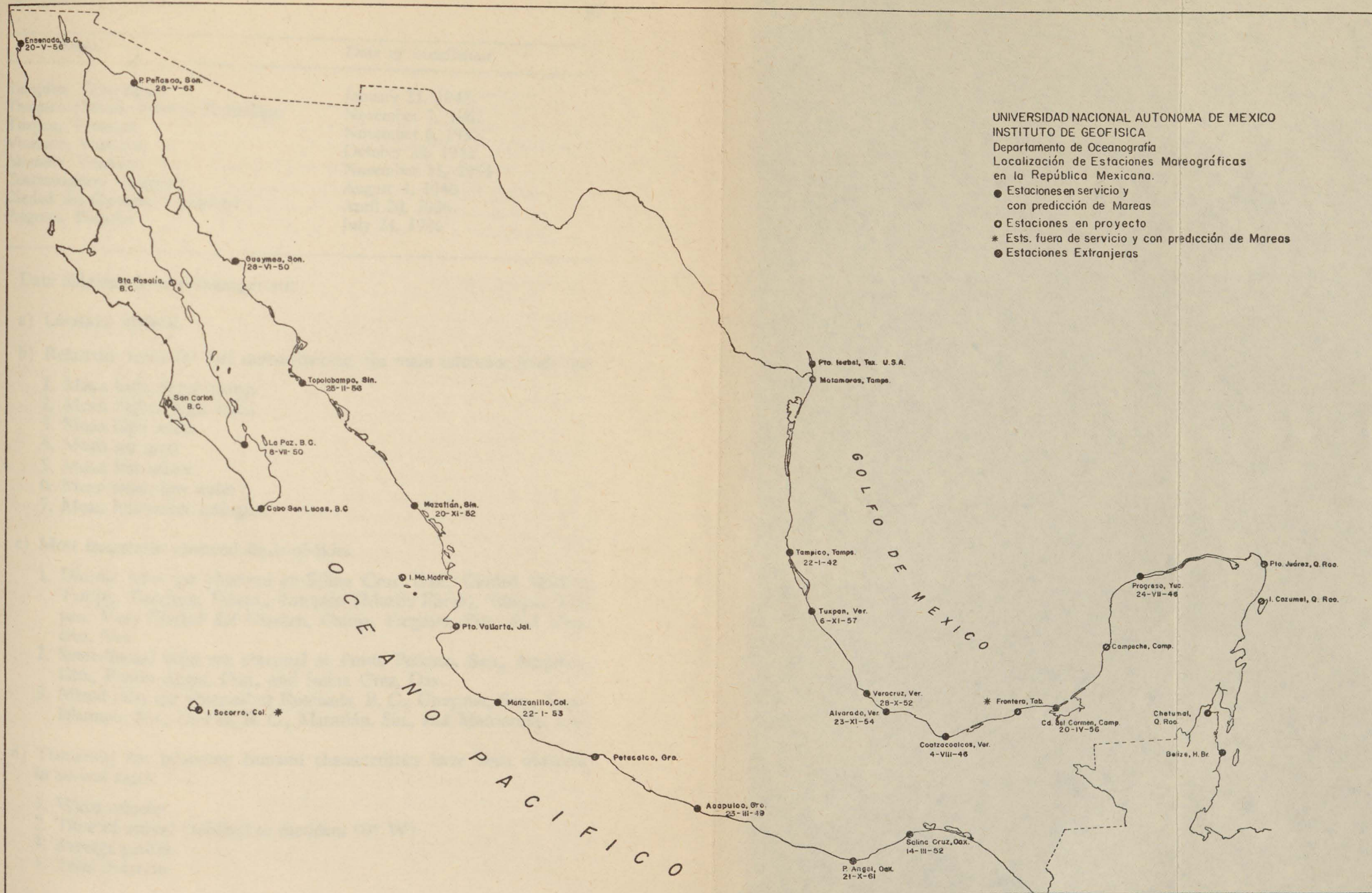


Fig. 1. Distribution of tide-gauge stations in Mexico.

<i>Name</i>	<i>Date of installation</i>
Tampico, Tamaulipas	January 21, 1942
Tampico (Muelle Fiscal), Tamaulipas	November 7, 1962
Tuxpan, Veracruz	November 6, 1957
Veracruz, Veracruz	October 28, 1952
Alvarado, Veracruz	November 23, 1954
Coatzacoalcos, Veracruz	August 4, 1946
Ciudad del Carmen, Campeche	April 20, 1956
Progreso, Yucatán	July 24, 1946

Data obtained from tide-gauges are:

- a) Lunitidal interval.
- b) Reference levels for tide measurements; the main reference levels are:
  1. Mean high water springs
  2. Mean higher high water
  3. Mean high water
  4. Mean sea level
  5. Mean low water
  6. Mean lower low water
  7. Mean low water springs.
- c) Most frequently observed kinds of tides.
  1. Diurnal tides are observed at Salina Cruz, Oax., Ciudad Madero, Tamps., Tampico, Tamps., Tampico (Muelle Fiscal), Tamps., Tuxpan, Ver., Ciudad del Carmen, Camp., Progreso, Yuc., and Veracruz, Ver.
  2. Semi-diurnal tides are observed at Punta Peñasco, Son., Acapulco, Gro., Puerto Ángel, Oax., and Salina Cruz, Oax.
  3. Mixed tides are observed at Ensenada, B. C., Guaymas, Son., Topolobampo, Sin., La Paz, B. C., Mazatlán, Sin., and Manzanillo, Col.
- d) Tsunamis; the following tsunami characteristics have been observed in several cases:
  1. Wave velocity
  2. Time of arrival (referred to meridian 90° W)
  3. Average period
  4. Total duration

5. Distante to epicenter
6. Initial wave, period, height and amplitude
7. Maximum height.

e) Inspection of tide-gauges.

The tide-gauges are checked at least twice a year with the aim of verifying the work of the instrument as well as to mark the differential movents of the tide-gauge with respect to well known reference elevations.

## II. TIDE FORECASTING:

Tide forecastings are prepared by means of a Fourier sum; this kind of work requires computation, which is carried out by means of an electronic computer and previous selection of observed data.

The solution gives the tide height at a port at any given time, for which purpose phases and amplitudes of the different tide constituents (components) are needed. These phases and amplitudes are called harmonic constants, and are characteristic for each port.

The numerical work is done by substituting, in the Fourier sum, the observed values; the system of equations is then solved by the method of the least squares, and the values of the harmonic constants obtained. After that, the computation is carried out backwards and the tidal values computed from the computed harmonic constants. In other words, if the harmonic constants are known for a given port, tide forecasting can be made.

The computations have been made with an IBM 709 electronic computer belonging to the National Polytechnic Institute; a new program is presently being written for the G-20 CDC-Bendix in possession of the N.A.U.M.

## III. HYDROGRAPHIC STUDIES.

At each port where the Department of Physical Oceanography has a tide-gauge, measurements of temperature, density and salinity are also made as follows:

- a) Surface temperature of sea water is taken together with environmental temperature; both in Farenheit degrees.
- b) Density is measured by means of a pycrometer, and reduced to 15°C.
- c) Salinity is obtained from temperature and density values, and reduced to 15°C.

## IV. OCEANOGRAPHIC RESEARCH.

Tide propagation in the Gulfs of Mexico and California is studied by means of numerical hydrodynamic models. The method of building these models consists in transforming differential equations which govern the motion of the sea into finite difference equations and solve them numerically. With these models the following studies were made:

1. Currents in the Gulf of Mexico
2. The  $M_2$ -tide in the Gulf of Mexico
3. A hurricane storm-surge in the Gulf of Mexico
4. The influence of a polar front in the Gulf of Mexico
5. The  $M_2$ -tide in the Gulf of California
6. The influence of atmospheric elements in the Gulf of California.

Some papers on these subjects have been presented in congresses and symposia and others have been written, for example:

- N. GRIJALVA (1967). Anwendung eines Numerisches Verfahren zur errechnung der Vorgänge im Golf von Mexico, *Geofísica Internacional*. Vol. 7, N<sup>o</sup> 4 (in press).
- N. GRIJALVA and F. COCHO GIL (1966). The Influence of a Polar Front in the Gulf of Mexico. *Proceedings of the I.A.P.O. Symp.* (Moscow) (to be published by Institut für Meeresforschung, Hamburg).

## V. PUBLICATIONS.

The Department of Physical Oceanography is charged with the preparation and publication of the annual tide-forecast tables in which the following data are given:

- a) Mean sea level
- b) Level of mean tide
- c) Maximum high water, time and height
- d) Minimum low water, time and height
- e) Maximum amplitude, in a day and in a month.

Data are published for each of the 19 tide-gauges established along the coasts of the Gulf of Mexico and the Pacific Ocean.

## INSTITUTE OF GEOLOGY

Marine geological and geophysical work in coastal lagoons began in 1959; one project of study was the sedimentology of the three large coastal

lagoons bordering the Gulf of Mexico, namely, Laguna Madre, in the State of Tamaulipas, Laguna de Tamiahua, in the State of Veracruz, and Laguna de Términos, in the State of Campeche. Their comprehensive study included bathymetry, temperature, salinity, dissolved oxygen, and turbidity, in the physical aspects as well as others of diverse nature.

Seasonal measurements of the above mentioned physico-chemical factors have been made in Laguna de Términos, Camp., during three years in an attempt to understand corresponding variations in the environment. Currents have not yet been measured in neither of the three lagoons, but they will be in subsequent stages of the investigation, whose results have partially appeared in the publications of the Institute of Geology, mainly for Laguna de Términos, Camp., and only of some aspects for Laguna Madre, Tamps.

Another project of marine geological and geophysical studies was carried out in the Bay of Topolobampo, in the State of Sinaloa, on the Gulf of California, now in its latest stages of completion and which will be published this year (1967). It had three objectives specially aimed to understand: a) the dynamics of the lagoons, governing the sedimentary processes; b) the distribution of sediments, and c) the evaluation of suspended sediments. Several physical aspects were included in seasonal measurements, such as bathymetry, tides, currents, suspended sediments, temperature, and salinity as well as a summary of meteorological informations of the area.

The Balsas river delta, in the State of Guerrero, on the Pacific Ocean, is also under investigation with the purpose of understanding its physical history, the distribution and transportation of sediments, and the role of a submarine canyon prolonging the river mouth in the sedimentary processes. Currents, tides, salinity, temperature, dissolved oxygen, turbidity and other physico-chemical factors are under investigation to prepare profiles and graphs illustrating the dynamics of the marine water mass in connection with river discharge and building phenomena in the river delta or in its vicinity.

During the summer of 1967, an oceanographic study (mostly for marine geological purposes) will begin on the continental shelf and upper continental slope of the southwestern Gulf of Mexico, between Río Grande and E of Laguna de Términos. This study will cover gravimetry, magnetometry and continuous seismic profiles by "Sparker" as well as bottom sampling and physical properties of water masses, in collaboration with the Department of Geology of Rice University, at Houston, Texas.

These programs were initiated in 1959 and pursued since then by Dr. A. Ayala-Castañares, Head of the Department of Marine Sciences of the Institute of Geology of the N.A.U.M. Recently, Dr. Ayala-Castañares was also appointed Director of the Institute of Biology of the N.A.U.M. and is trying to integrate a comprehensive program in Marine Sciences, with the collaboration of other divisions of the N.A.U.M.

## SECRETARÍA DE MARINA

As expressed in the Introduction, the Mexican Navy Department is concerned with the study of Hydrography and Physical Oceanography from a practical (or applied) standpoint through two of its divisions, although both have also contributed in a more theoretical manner to problems of importance to geophysical disciplines.

## GENERAL DIRECTORATE OF LIGHTHOUSES AND HYDROGRAPHY

Intensive work has been recently executed in the Gulf of California for the production of navigation charts as well as for a better delineation of coastal areas and islands. For such purpose, new soundings were taken and old data revised and improved, including special measurements like continuous bathymetric profiles, which gave as a result three new hydrographic charts for the Gulf of California (H-601, and H-602) and for the western coast of the Peninsula of Baja California (H-600) bordering the Pacific Ocean. Additional work in these areas has consisted in beginning soundings and bottom sampling at the entrance of Bahía Magdalena, on the western coast of the same peninsula, where a new port will soon be constructed (San Carlos).

In the Gulf of Mexico, Operation "Neptuno" was carried out along the coast of the State of Veracruz for a combined program of hydrographic and oceanographic scope in 1963. Results of this operation were published in a special volume under the responsibility of Cap. Lorenzo del Peon, who then headed the General Directorate of Lighthouses and Hydrography. This was the first time that such work was done in that area by a Federal agency, and it is hoped that similar operations be carried out in various areas of the country. Other activities of this agency are mentioned in various reports of this volume (Meteorology and Physics of the Atmosphere, Scientific Hydrology, etc.).

## GENERAL DIRECTORATE OF MARITIME WORKS

There is a Department of Studies and Laboratories charged with the investigation of physical phenomena related to the planning and execution of engineering projects in Mexican ports. Since 1963, various studies have been conducted at Ciénega de Progreso, Yuc., mainly focusing the tide-wave entry as well as viscous effects; area of Paredón, Chis., with a preliminary study for the construction of a port, including topographic triangulation and polygons, sectioning, current measurement, water sampling, soundings, temperature measurements and other data; lower Balsas River, Gro., where physical studies were initiated in 1962 also for the construction of a port in view of

regional needs; port of Matamoros, Tamps., with detailed geodetic and bathymetric studies conducted in the same year for other projects.

More recently, port models have been used duplicating natural conditions to facilitate the study of environmental phenomena, as in the cases of the ports of Matamoros, Tamps., and Puerto Vallarta, Jal. Essentially oriented towards engineering projects, these studies are very important for Physical Oceanography and data obtained adjust to mathematical and experimental principles allowing a better appraisal of wave mechanics and associated phenomena.

In 1965 the *Boletín Técnico del Departamento de Estudios y Laboratorios* of the General Directorate of Maritime Works began to be published with interesting contributions by members of its staff, mainly referring to problems of engineering projects, but with geophysical interest. Among others, studies by Dr. Ing. C. H. Castro Sepúlveda on modern methods of tide forecasting and by Ing. A. Corichi Flores on a new devise to measure currents may be mentioned.

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\* Only two of the many pamphlets printed by this agency are mentioned here.