

**Recent environmental dynamics of the High Wave at Icacos Beach, Acapulco, Guerrero****Dinámica ambiental reciente del Alto Oleaje en la Playa Icacos, Acapulco, Guerrero**

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**Abstract**

The objective was to synthesize the effects of High Wave 2013-2018. The methodology was based on cabinet and field work. The total contribution was to detect the critical points and to propose the semaphore of danger of the High Wave. The main results were: 1) in Icacos, the continental shelf along 25 m presents a minimum inclination of one meter of depth and 2) the Icacos Beach has 48 m in front of the sea and 2 600 m in which High Wave during May-November of each year. The conclusions were a) the risk is built, not respecting the limits of the Federal Maritime Ground Zone (ZOFEMAT in Spanish); b) is one of the most important social challenges in Guerrero, being the main economic asset due to its tourist use and c) Icacos Beach is subject to various human and climatic pressures that physically condition its three basic functions, being a natural habitat for biodiversity, provide protection to the coast and meet human leisure needs.

**High Wave, Risk, Global Warming****Resumen**

El *objetivo* fue sintetizar los efectos del Alto Oleaje entre 2013-2018. La *metodología* se sustentó en trabajo de gabinete y campo. La *contribución* total fue detectar los puntos críticos y proponer el semáforo de peligro por Alto Oleaje. Los principales *resultados* fueron: 1) en Icacos, la plataforma continental a lo largo de 25 m presenta una inclinación mínima de un metro de profundidad y 2) la Playa Icacos tiene 48 m frente al mar y 2 600 m en los cuales se presenta Alto Oleaje durante mayo-noviembre de cada año. Las *conclusiones* fueron a) se construye el riesgo, al no respetar los límites de la Zona Federal Marítimo terrestre (ZOFEMAT en español); b) constituye uno de los retos sociales más importantes en Guerrero, al tratarse del principal activo económico debido a su uso turístico y c) la Playa Icacos se encuentra sometida a variadas presiones humanas y climáticas que condicionan físicamente sus tres funciones básicas, al ser hábitat natural de biodiversidad, ofrecer protección a la costa y satisfacer las necesidades de ocio humanas.

**Alto Oleaje, Riesgo, Calentamiento Global**

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## Introduction

At a planetary level, throughout the 20th century, greenhouse gases accumulated in the atmosphere due to human activity, which has resulted in global warming, which means that during the 21st century the temperature will increase by an average of 1.2 °. C in such a way that, one evidence is the increase in sea level observed in the coasts of the different continents (UN, 2016).

In South America, specifically in Peru, it has "more than 2,000 kilometers of coastline used, without control or planning, with a degradation of its increasingly large use that has led to the privatization of the littoral territory" (Cobeñas, 2017: 4). The coastal coastline that covers the countries of the Pacific Basin between the Republic of Chile, Peru and Mexico, where the population settled on the coasts is high to very high density or square meter, which brings with it high vulnerability to the effects of the floods (Villanueva, 2017).

In Mexico, global warming is evident with the changes in temperature seen in the north and south of the country (WWIS, 2016), as well as atmospheric pressure, humidity alteration, rainfall and wind intensity and all This is related to another current phenomenon, climate change, a topic that will be addressed in another manuscript. The state of Guerrero in Mexico is affected by a series of natural risks associated with its coastal location along its 505 km of extension in the Pacific (INEGI, 2005); global warming combined with the interaction of several plates entails anthropic risks, such as loss and / or modification of the strip of littoral sand, environmental pollution, decrease in the inflow of scarcely sustainable sun and beach tourism; coupled with this, poor education in disaster prevention, whatever its nature, generates a negative exponential predisposition to social vulnerability and conscious or subconscious acceptance of the risks that this implies.

At present, knowledge of risks is presented as a priority in the development of economic, environmental, social, and even technological policies. The elaboration of diagnostics, procedures and / or administrative tools, as well as operational techniques, aimed at the prevention and mitigation of disasters, in order to achieve ideal states of certainty, starts from a preconception of what is determined to be "risky", category in which the problem of disasters has been registered.

One of the main objectives of the National Development Plan 2001-2006 that was published in the Official Gazette of the Federation (DOF, 2001), regarding disaster prevention within the framework of the Habitat Program of the Ministry of Social Development, "aims to strengthen actions that contribute to reduce the vulnerability of the population in the presence of recurrent natural hazards, with emphasis on identifying high risk sites "(SEDESOL-Mineral Resources Council, 2004: 4), which was the key to act in the preventive plan, as a foundation of strategies aimed at reducing economic and social costs, as well as human losses.

This study is referred to a natural phenomenon of local presence, but with global effects. The five-year period analyzed was 2013-2018, so the information provided in the document is basic, and enriched by the inhabitants, tourists and tourist service providers, within the coastal strip of Icacos Beach, in the Municipality of Acapulco de Juarez, from an environmental perspective.

The study area is influenced by two types of floods: the first corresponds to the upper part of the continent, where there are narrow streams that in the summer season are revaded as a result of intense rainfall (DOF, 2012); the second has to do with the irruption of marine waters that penetrate the continent caused by cyclonic waves. In the present work, emphasis will be placed on the second type of flood, where the High Surf stands out, formerly known as the "Deep Sea".

Cyclonic waves in particular, are an abnormal growth of sea level, associated with hurricanes or other maritime storms. "Which are caused by strong winds from the open sea towards the coast; by low pressure cells and ocean storms "(OAS, 1991). The level of the waters is determined by the winds, atmospheric pressure, marine currents, waves, topography of the coast, bathymetry and proximity of the storm to the coast especially in the rainy season of the year. Generally, the resulting destructions due to cyclonic waves are attributed to: 1) the direct impact of the waves against hotel structures and furniture, 2) sand deposition occurs simultaneously (Niño, 2015); 3) the indirect impacts translate into floods and 4) undermining in the lower part of the buildings (Niño, 2016). The work is a multifactorial approach due to the need to study this phenomenon that is transcendent for the inhabitants, tourists, tourism service providers and authorities of the three levels of government that are linked to this coastal area under study.

In this order of ideas, the situation becomes more complex if one takes into account that the Guerrero coast is located in an area with strong influence of cyclonic activity, tropical storms, proximity to the Pacific Ring of Fire, which also makes it susceptible to telluric activity and the threat of tsunamis, generated in the entity or in more distant places such as South America, or the South Pacific (Rodríguez, 2011: 9).

The occupation of soils potentially vulnerable to flooding due to their location and characteristics, raises a controversy; On the one hand, these are considered attractive places for various activities of social and economic interest, without taking into account the consequences that this may cause, since their location is unfavorable, during the summer period, which can cause damage to nearby properties to Icacos Beach.

To understand the effects of hydrometeorological events in situ, it is necessary to know the history of urbanization in the ejido of Icacos, which is an interesting issue because it is the only one in the country that has ejidatarios, but no longer has ejido plots, although it is Constitutionally recognized as such. "The ejido is integrated by 762 hectares that belong to 37 ejidatarios, in which the Convention Center, the Sports Club and the Pemex facilities were built, among others" (Harrison, 2016: 1).

The general objective implied, to synthesize the effects of the High Surf between 2013-2018 in the Icacos Beach of Acapulco, Guerrero. To date there is little culture of prevention to coastal phenomena, as well as minimal literature regarding the High Surf in the Santa Lucia Bay of Acapulco, hence the interest in explaining the causes, presence and effects of this phenomenon. In particular, it was decided to carry out the study at Icacos Beach, since it is the most extensive and boasts the Blue Flag distinction as a clean beach, therefore, the most visited by visitors according to the results obtained in situ.

It is important to take into account the prevention of high waves, since it is a component of the Integrated Risk Management. In addition, preventing is more economical than trying to repair the damages caused by an emergency. Guiding question How has the presence of the High Surf affected the development of in-situ economic activities?

## Methodology

Cabinet work, the research was based on data and official sources of printed or electronic information disclosed by different government agencies at the federal, state and municipal levels. This work investigated the negative effects in the sectors of the population involved of the Icacos Beach due to the presence of the High Surf, and even, it was resorted to the revision of the topographic letter E14C57 Acapulco, at scale 1:50 000 (INEGI, 1994 and 2005).

Field work, this work included 12 exploratory and on-site verification tours during the period from June 2013 to July 2018 in different periods, but with emphasis on Easter, winter holidays and summer. These included recognition of facilities and tourist infrastructure, which supports the formal and informal commerce of Icacos Beach. The above was enriched by six meetings with key informants belonging to government agencies and civil society, in addition, 775 questionnaires were carried out, applied to tourists (national and foreign), tourism service providers (PST) (tenants, waiters and informal vendors), as well as local residents.

In order to synthesize the level of information about the High Surf that the members of the sectors involved have and their perception, from this, obtain a broad perspective to conclude opportunities, strengths and even weaknesses in the dissemination and distribution this. The number of interviewees was determined by the formula of the American Psychological Association (APA), which states that the sample is a numerical part that represents an entire population, and since this study is based on the quantitative and qualitative approach, As it has been reflected in the methodological framework, it was important to apply the questionnaire in order to determine the number of tourists, residents and PST, living in the Icacos Beach, so that the results obtained can be representative of the total population that transits the holidays of the year.

## Results

The areas susceptible to risk according to the field work are located in bathymetric ranges that go from zero to five meters below the mean sea level, where the risk is medium for people who move on the beach to be hit by the High Surf, whereas, between five to ten meters below mean sea level, the risk is high for people who dive and swim away from the shoreline.

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Icacos has a natural flood potential, because it is a plain, as can be seen in the topographic map Acapulco E14C57, scale 1: 50,000 (INEGI, 1988a and 1988b). The almost flat topography at Icacos Beach (CICESE, 2016) allowed the identification of vulnerable zones by High Surf, that is, a close relationship between topography, bathymetry and precipitation was observed, in such a way that the risk increases during the rainy season (May -November), and decreases in the dry season in each year.

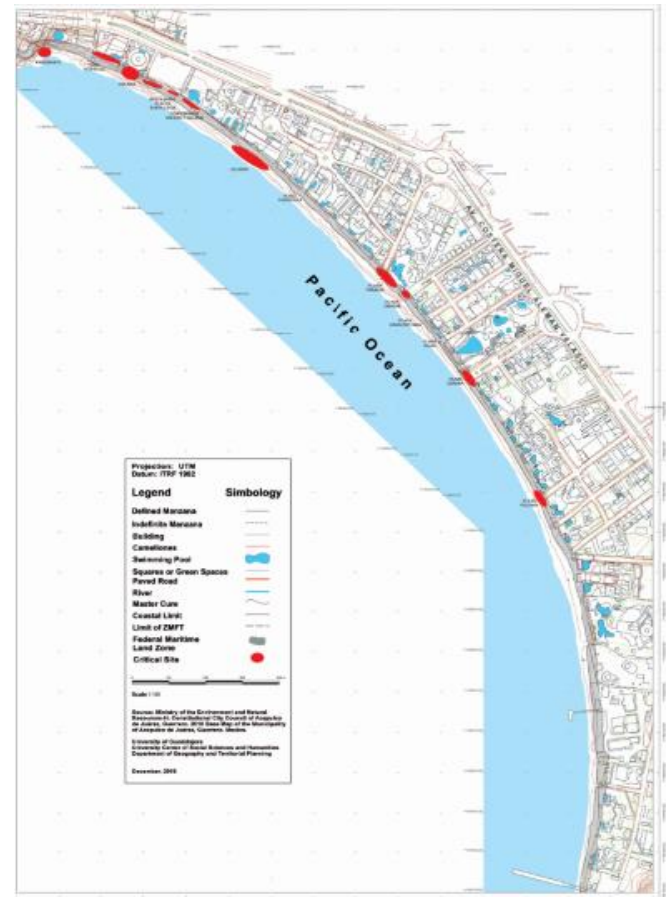
The width of the beach is on average 48 m, except where there are walls of hotels or restaurants that reduce the amplitude, so the risk of deteriorating the infrastructure is high accentuated by sand accumulations with a height of five meters. The seabed of this site is of sandy type with scarce rock formations, and a slope of  $10^\circ$ , the place is suitable for beginners and advanced divers, since its depth goes from four to 18 m; the months of November to February are the most recommended to dive in depth because of the high visibility (SEMAR, 2016).

Icacos Beach is exposed to a series of geological (earthquakes) and hydrometeorological threats (tsunamis, tropical storms, hurricanes, floods, etc.); despite this, the general lack of awareness among the local population of the potential risk in which they live, has caused the city to grow in a disorganized manner, and now the phenomenon known as Alto Oleaje is added to it.

The High Surf indicates that the wave travels and the energy that displaces it, but does not move with it the volume of water as in the case of a tsunami, according to the head of the Mareographic Service of the Center for Atmospheric Sciences of the National University of Mexico (UNAM), Jorge Zavala Hidalgo (Environmental Forum, 2015: 2).

The energy stays until breaking on the beach. In Icacos the transition from high to low energy becomes more noticeable from the beach in front of the Plaza España, and the Naval Base, where the energy conditions are low, thanks to the Las Brisas peninsula, which protects this portion of Strong surf terrain from the open sea. The High Surf affects the Icacos Beach between the months of May to November, where there are waves with an average height of three meters, but in some cases they have reached seven meters (Rosey, 2016a: 5A and 2016b, 2A).

In the field, it was possible to appreciate the accumulation of material in the form of sand escarpments of 1.5 meters high. This is why there are eleven critical sites that are located and identified with the red color in Figure 1.



**Figure 1** Critical sites affected by High Surf.  
Source: Own Elaboration

From the geomorphological point of view, Icacos Beach is located in the alluvial plain of the coastal plain of the Pacific Ocean (Lugo, 2011), with slopes ranging from  $0$  to  $10^\circ$ , and in a minimal extension it is undulated, as a consequence of the tides. Specifically in the study area, the maximum slope is  $10^\circ$ , and has a runoff coefficient of between 20 and 30%, which maximizes the vulnerability to the phenomenon studied.

The Icacos Beach has the character of river water receiver and the accumulation of material transported from the upper part. Therefore, there is laminar water erosion, presence of sedimentary rocks that originate beaches of medium and fine texture, beige. This is attractive for the development of hikes made by national and foreign tourists. The climate is warm subhumid with rain in summer (Aw1), and has influence of the trade winds, most of the year.

Cyclones occur between the months of May to November of each year, and the dry season occurs between December and April; with an average annual temperature of approximately 26.5 ° C. The average number of cloudy days per year is 72. The thermal oscillation is 0.6 ° C. "The presence of the sea plays an important role as a local thermal regulator" (Vidal, 2005: 173).

The average temperature and average precipitation registered in Acapulco in the last 30 years, allow us to appreciate that the coldest month is January with a temperature of 23.3 ° C, and the warmest month corresponds to July with 32.3 ° C; while, the minimum total rainfall corresponded to March with 1.2 mm, and the heaviest rainfall occurred in September with 298.8 mm (SMN-CONAGUA, 2015). The Automatic Meteorological Station (EMA) of the CONAGUA in the port of Acapulco is limited to the one found in the National Park "El Veladero", managed by the National Meteorological System Network (SMN), said station is located at an altitude of 302.9 msnm, latitude north 16 ° 53'03 ", longitude west with respect to Greenwich 99 ° 54'25", which reports that the data are punctual, therefore, they are not accumulated and the graphs that can be consulted, They are 24 hours a week and 90 days (SEMAR, 2015).

In the area under study, the burst direction in 24 h from March 7 to 8, 2016 from 6:00 AM to 2:00 PM was 250-350 degrees; from 3:00 pm to 8:00 pm, there was a calm as the burst direction decreased upon reaching a 70-110 degree offset, and shortly after 20:00 the burst direction went up again until 2:00 : 30 AM, when achieving displacements from 240-320 degrees (SMN-CONAGUA, 2016a).

The wind direction marked by the EMA in "El Veladero", for a period of seven days between March 1 and March 8, 2016, between 10: 00-11: 59 PM, was predominantly from southwest to northeast, whose speed was maintained between 250-290 degrees; between 12: 20-12: 40 AM, although the direction of the winds kept the speed, it decreased from 90-50 degrees. This dynamic happened alternately throughout the mentioned week. The relative humidity in the month between February 8 to March 8, 2016, was a minimum of 59.5%, and a maximum of 97.5%, between February 8-10.

Between the 2-4 of March it had a notorious decrease, registering only 18% while, the precipitation between February 25 to March 8, 2015, a minimum sheet of 0.90 mm was observed; During April to June of the same year, there was a drought, but from July 2 to November 20, copious rains occurred with maximum sheet of 2.25 mm in 24 h (SMN-CONAGUA, 2016b).

Some phenomena associated with precipitation from January 2002 to December 2015, was the minimum Bajamar record with a value of 62 cm below the mean sea level; the mean Bajamar level was 28.8 cm; however, the mean Pleamar level reached was 49.7 cm and Pleamar maximum recorded 90.0 cm. The height of the tides complements the aforementioned phenomena. In the study area it was observed that the average height of the tides is 2.20 m, according to the SEMAR tide station located in the Eighth Naval Region of Acapulco, which is part of the Icacos Beach, close to the mainland, and is not relevant for the analysis of the High Surf, because the data are scarcely significant because at the height of the peninsula Punta Brujas the impact of the waves is slowed down, which is why it reaches the Icacos beach without force (SEMAR, 2015).

The solar radiation during 24 hours that comprised the day September 10, 2016, showed that between 2:00 AM and 1:00 PM, the temperature gradually made between 0-100 Watt / m<sup>2</sup>; after 14: 00-16: 00 PM the highest radiation was reached on average 900 W / m<sup>2</sup>; which is directly linked to high rates of ultraviolet rays (6-7 high), so it is recommended that the public wear sunscreen, light-colored clothing and shirts, preferably long sleeves in order to avoid sunburn during the day, skin blemishes over the course of the year and long-term skin cancer.

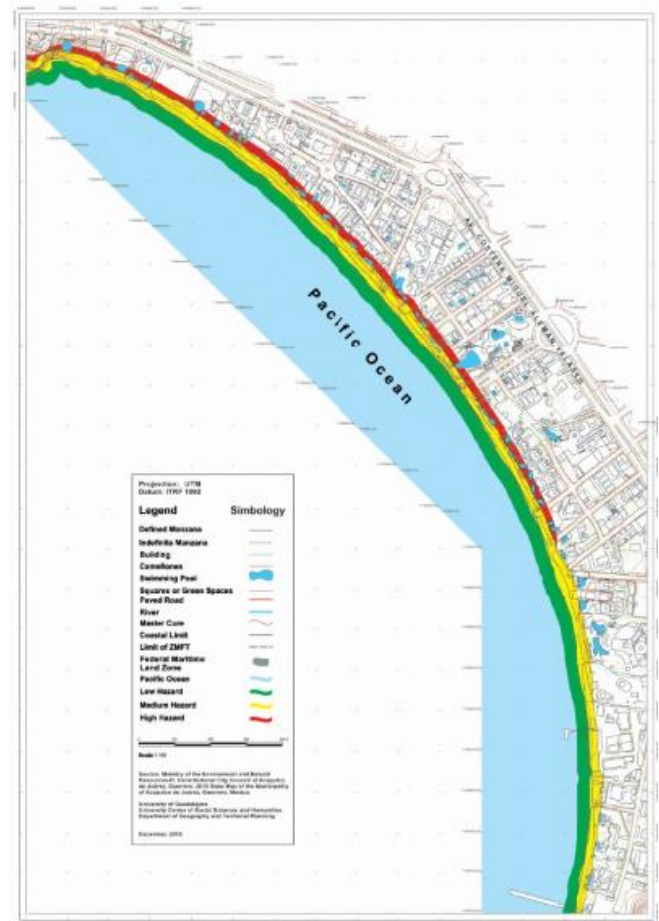
Burst speed is directly related to the presence of solar radiation, that is, between 3:00 AM and 12:30 PM it is minimal, but between 15:00 and 17:00 PM when the insolation is high, the Burst speed increases at an average speed of 21.5 km / h. While the wind speed and the air temperature show similar dynamics to the aforementioned, where at higher temperature faster wind and higher air temperature.



The surface hydrography is included in the RH19 Hydrological Region of the Conagua (INEGI, 1988a), and it is reduced to the presence of two hydrographic basins: the western one known as Costa Azul, whose surface area is 764.7 hectares, dominated by the Los Lavaderos stream ; and the Oriental with an area of 373.9 hectares, which is Icos made up of two Costa Grande and National Army streams; all of them reach the sea because the study area is a low area that facilitates the berthing of Navy ships and oil tankers (Villegas, 2006: 172).

The Acapulco pedological chart reports that in the coastal plain of Icos the soils are: Alluvial (Al), and Regosol eútrico (Re), which share the characteristics of being porous, and even permeable; and at the sea-land interface the Solonchack (S) soil is located, that is to say, saline by the contact of the sandstones with the seawater (SPP, 1981: 1). This establishes the natural vocation of the land for the use of housing (residential and hotel), due to the lack of organic matter and therefore no agricultural capacity.

With the sum of these environmental indicators, the preparation of a map of hazards by High Surf for the Icos Beach was obtained, which can be seen in Figure 2. Where the green color indicates low danger, the yellow refers to the average danger in both that, the red color implies high danger to the presence of High Waves. This phenomenon is evidence of climate change that currently affects the coastal areas of the world and where geotechnologies applied correctly in vulnerable areas save countless lives.



**Figure 2** Hazard traffic light due to high waves.  
Source: Own Elaboration

Residents, tourists and PST consider it important to operate contingency plans in the face of high waves, hurricanes and earthquakes due to the high level of danger in the local sea-land phase.

## Conclusions

Before the guiding question of this investigation: How has the presence of the High Surf in the Icos Beach impacted? The answer is complex because, on the one hand, there are physical and geographical impacts such as: accumulation of waste materials from the open sea displaced by the High Surf to the beach, thereby conforming land reclaimed from the sea in the form of domes and beach escarpments, between two and three meters high. On the other hand, there is partial or total destruction of tourism infrastructure and furniture, whose economic consequences amount to just over 1.5 million pesos, as was confirmed in 2016 by the state government and the SCT.

Vulnerability, considers that the level of this is directly proportional to the exposure of the tourist real estate and hotel infrastructure to the threat by High Surf and inversely proportional to the resistance that shows such infrastructure and equipment, that is, those who only settle on the beach in the Pleamar area; whereas, the well-founded buildings have a greater possibility of resisting the swells of the waves, although with the passage of time their bases are undermined.

From the point of view of the Environmental Sciences the last three years (2015-2018), the behavior of the average temperature tends to rise, since in 2016 it reached the historical record of 32.3 ° C, and the average total precipitation goes Increased in such a way that in the month of September of the same year there was rainfall of 298.8 mm, causing floods throughout the Bay and the presence of 19 events of the High Surf never presented before, with the danger added to the risk, can occur a disaster at any time during the next triennium. All this is related to global warming whose effects are already felt in this local space.

In summary, the biogeophysical effects in the study area were: 1) High Waves through the supply of sediments brought by the tides allowed land to be reclaimed from the sea via sand deposition, 2) beach erosion, 3) intrusion of saline water to the continent which are related to local climate changes that involve changes in the coastal coastal morphology; and 4) surface runoff allowed the dragging of terrigenous materials from the upper part of the lower Icacos area. Because tourism activity is of vital importance for residents, PSTs and tourists, the need to emphasize the warning system on the part of the authorities in order to achieve greater resilience *in situ* is concluded in this area. Economic and even ecological activities are necessary to guarantee resilience in Icacos Beach, and its social value within a regional process of erosion and economic development.

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