UNDERSTANDING OCEAN SURGES AND POSSIBLE SIGNALS OVER THE NIGERIAN COAST: A CASE STUDY OF THE VICTORIA ISLAND BAR – BEACH LAGOS

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ABSTRACT

Eighteen different occurrence of ocean surge events over the beach of the Victoria Island in Nigeria were recorded between 1990 to 2002 and each with its devastating consequences resulting from the massive flooding and erosion. Statistical analysis and parametric wind-wave model were used to investigate the ocean atmospheric interactions in terms of their characteristics, especially before during and after every surge event from 1990 to 2002. It revealed that all ocean surges apart from the surge of March 2002 were experienced in summer months of April to October, but more frequent in August. Coastal atmospheric pressure was generally transiently low and observed to coincide with high tides. However, pressure varies from one event to another, between 1008 – 1013millibar. The lowest pressure was observed during the 30th May 1998 event and the highest was observed during the 14th September 2001 event. Also, pressure during any event was generally lower by about 0.8mb than the pressure two days before the event. Further investigations revealed that the ocean surges are influenced by moderate winds (between 15 - 18kts in strength on the average) over the fetch (Lat. 10^{o}S – 20 ^{o}S and Long. 0 ^{o}E – 10 ^{o}E**)**. These winds were observed to be generally strongest three to two days before the event. They can generate wave height of about 1.8m and with favourable cross equatorial flow, the swell may reach the coast in about 2 – 4 days and when they coincide with high tide they can inundate the beach.

INTRODUTION

The threat imposed by ocean surges and associated flood over the low-lying coast of Nigeria especially that of Victoria Island is becoming unbearable. It has caused the contamination of coastal water resources, decimation of coastal agricultural and recreational area, destruction of settlement, major roads like Ahmadu bello way, habour and navigational structures. It also dislodged oil producing and export handling facilities and environmental impact of loss of properties, income and sometimes lives. The combination of strong onshore winds, low atmospheric pressure and astronomical tides resulted in the exceptionally high water level, which is referred to as ocean surge. Ocean surges and associated coastal flooding are well known problems facing the coast of Nigeria especially the Victoria Island bar-beach in Lagos. In 2002, beach front homes, liaison offices, and almost all the streets in the area were heavily flooded. In the second event of the surge same year about four lives were reportedly lost. Presently there seems to be less than one meter of the beach width left. Ocean surges are meteorologically forced long waves. The anomalous forcing is generally sustained for several days with largest disturbances arising from storm tracks Komen 1999. Murthy 1984 defines storm surges as "oscillation of the water level in a coastal or inland water body in period range of few a minutes to a few days, resulting from forcing from weather system". Detailed analyses of catastrophic storm surge events are contained in the monograph of Murty 1984. It follows then that knowledge of the meteorological forcing (its history, pattern, and amplitude and its future development or decay), and the physics of energy transfer from the atmosphere to the ocean, is crucial for understanding ocean surges. Ocean surges involve abnormal and sustained elevations of coastal sea level, often endangering life and properties, and usually involving some non-trivial impact on coastal environment. The meteorological forcing is predominantly through the action of wind stresses at the surface of the ocean but anomalous atmospheric pressure and fast moving pressure gradient can also be a significant factor in many cases. There are, however several other factors that influence the evolution and build-up toward potentially critical surge-induced sea level. The characteristics of the continental shelf and the geometry of the coastal region can have a profound effect on the evolution and amplitude of the surge. Obviously the phasing of the astronomical tide relative to the ocean surge is critical. A peak surge coincident with low tide may be of no consequence, whereas even a modest surge occurring at high tide can have significant consequences. The most serious flooding often results when an extreme storm surge event occurs concomitantly with a tidal maximum (Lowe et al 2001). Water level during some ocean surges in Nigeria can rise up to about 5m (Awosika et al 1995). Surface waves and other coastal circulation changes can modify or amplify the impact of a surge in the coastal region. Winds are by far the most common cause of observed ocean waves . And winds over most oceans are classified into light, moderate and strong winds, which are respectively influence by trade winds, average cyclone and hurricane weather system Lyons (1994). Wind waves are formed in many sizes blowing across the ocean and transferring energy from one region to another. They are important factor in the near surface ocean, causing mixing, as well as promoting evaporation and exchange of atmospheric gases across the water surface details of the behaviour of wind stress in the Marine Atmospheric boundary layer can be seen in Yelland and Taylor (1995) and Chen et al (2000). Wind wave occur on the sea surface with wave length ranging from a few millimetres up to several hundred meters. Although larger-scale waves contain most of the energy, small-scale wavelets that make up the sea surface microstructure are known to play an important part in interfacial transfer process. These small-scale waves transfer the momentum they absorbed from the wind to larger gravity waves and surface layer currents through nonlinear wave-wave interactions and microwave breaking Chen et al (2000). Waves in the ocean affect everything from shipping, the operation of offshore structures and the breaking up of oil spills. When waves arrive at coastal areas as swells, they may cause flooding (especially during high spring tide) and coastal erosion. Knowledge of wave height of ocean waves forms an essential prerequisite for any engineering or transportation-related activity over the ocean. This information can be obtained either by gathering wind data and the using wind-wave relationships or by analysing the instrumental wave data itself Deo and Kumar (1997). The former approach i.e. the using of wind-wave relationships and which form the basis of the model, is the focus of this paper and it is important to know that the mathematical derivation of the wind-wave relationship will not be discussed. However, the reader can refer to Yeon (1988), Lyon (1994) and Whitford (2001), for details of the wind-wave mathematical derivations. While of the latter was treated in detail by Deo and Kumar (1997). A wind wave interaction over the coast of West Africa has not been well established for reason due to lack of funds to acquire necessary measuring instruments. However, observation has shown that waves at the Victoria Island beach are mainly swells caused by the prevailing westerly winds, with a long ocean fetch, having wave period between 8 – 13secs and are not regular. Also coastal winds especially over the Nigerian coast, have mean velocities between 5 – 10 knots but more consistent and strong during raining season especially when there are squall lines lying over the coast. Plunging wave at breaking tends to marginally dominate the beach Ibe (1988), and Olaniyan (2002).

During the years under study, serious flooding resulting from the perennial ocean surges has occurred on numerous occasions over the Victoria Island beach. This paper is looking at the behavioural pattern of some marine and oceanographic parameters, in order to see possible signals of these elements during the event of the surge. There has been recent concern that changes in climate, brought about by mans anthropogenic activity, will alter the frequency of storm surges because of the fact that the crest of the surge only represent the wind influence on the water body during high tide (Gonnert 1999, Lowe 2001). However, Lowe (2001) suggested that in addition to the effect of rising mean sea level, at many locations especially around the

United Kingdom coastline, future changes in local meteorology will lead to further significant changes in the return period of extreme storm surges.

STUDY AREA

The Nigerian coastline (Figure 1a) is about 850km of the Atlantic Ocean between the western and eastern borders of the country, with the Republic of Benin and Cameroon respectively. It lies generally between latitude 4º 10’ and 6º 20' N, and longitude 2º45' and 8º 35'E, adjacent to the Gulf of Guinea. A common feature of this geomorphic zone is their low-lying nature. Most areas along these zones are less than 3m in elevation. Victoria Island (Figure 1b) is located immediately east of the eastern breakwater on the down drafts side of the natural inlet into the harbour. It is delineated further to the east by Karamo water and the Igbosere creek. In reality, this is only an administrative eastern boundary because the beach continues as a narrow strip between the sea and the lagoon further inland and merges at about 5km distance with the Iludo Maroko beach. To the north, Victoria Island is bounded by the five cowries creek; to the west by the Lagos harbour and to the south by the Atlantic Ocean (Ibe, 1988). Sediment on the island are medium to coarse sand (mean gram size of 0.35mm) with an admissive of broken shells. There are no obvious major differences in sediment sizes either along or across the Island but sediments taken from the beach ridge are better sorted than those from the active beach. The active beach is on average 50m wide with rather steep slope (>5) from the 1m (average) erosion scarp off shoreward.

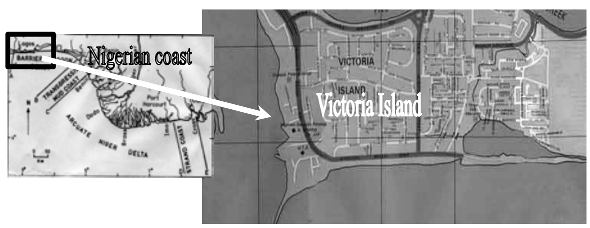

Fig. 1. (a) Geomorphology of the Nigerian coastline (Source: Ibe, 1988) and (b) Victoria Island

WINDS AND OCEAN CURRENTS AT THE COAST

Two air streams affect the weather over the coast of Victoria Island Bar-beach. These are the southwest monsoons, which represents a large scale cross-equatorial flow of air from South Atlantic Ocean, in summer, and the cool, dry and dusty northeast trade from the Sahara anticyclone, in winter. In both northern summer and winter, the dominant air stream is the southwest monsoon. The winds associated with southwest monsoon are the southwesterly winds, which are long-shore currents. However, the type of air stream that affect Victoria Island coast depends on the position of the Inter-Tropical Discontinuity (ITD) over the country on regional scale, and globally by the effect of the Walker circulation. The southerly to westerly winds from the Atlantic Ocean can penetrate inland to as far as 22ºN during the summer month of August. Apart from the prevailing southwesterly winds which characterize the long-shore currents, the coastal areas are also influenced by the Guinea current, and the fluvial current among others.

MODEL DESCRIPTION

The parametric wave model used in this study, is derived from the empirical wave growth relationship for wave height and wave period, which best fit observations, from measurements of thousands of wind speed, fetch lengths, and wind duration by oceanographers in the ocean wave environment. The model was first developed at the National Hurricane Centre, Miami, Florida. It has been undergoing modification to meet the regional conditions. The computer program provides quicker computations, and the forecaster is able modify the model to suit local conditions in an effort to converge upon an idealistically "perfect" wave forecast. The parametric wave equation does not integrate the wave equation through time, and does not supply the wave energy spectrum. Rather, the model is based on large numbers of wave measurements for various wind speed, fetch length and wind duration, and from these measurements wave growth lines are identified. The wave model can be thought of as computerised look-up tables of wave statistical behaviour. It is presently used at the marine and oceanography laboratory of the Nigerian Meteorological Agency to forecast and warn offshore prospecting industries and ship handling facilities.

METHOD OF DATA ANALYSIS

Marine meteorological data such as coastal atmospheric pressure 2 – 3 days before and after major surge event was extracted between the 1990 event to 2002 event from the department of the Nigeria meteorological agency. Monthly mean water level for 1993 and 1994 were also extracted from the Nigerian Institute for Oceanography and marine research (NIOMR). To determine the characteristics of the surge especially during the event, data were subjected to statistical analysis. Analysis of the coastal pressure for 1990 – 1993 and 1996 were not included due to lack of data. However, days of occurrence of the surge were considered. Daily marine winds, at 10m level, over the Atlantic Ocean, between lat.10°S - 20°S and long 10°E - 20°W were extracted from general circulation model (GCM) of METEO-FRANCE during 1998 – 2002 surge events. These winds were statistically downloaded to critically determine the nature and characteristics of fetch during the surge events. Also the extracted winds served as input data for a parametric wind-wave model. This model has been adapted to suit local conditions. The output variables (wave height, swells etc) were then subjected to statistical analysis.

RESULT AND DISCUSSION

From the above discussion the study has revealed that most ocean surges apart from the surge of March 2002 were experienced in summer months of April to October (fig.2), but more frequent in August when the prevailing southwesterly winds are consistent and can penetrate up to about 22°N.

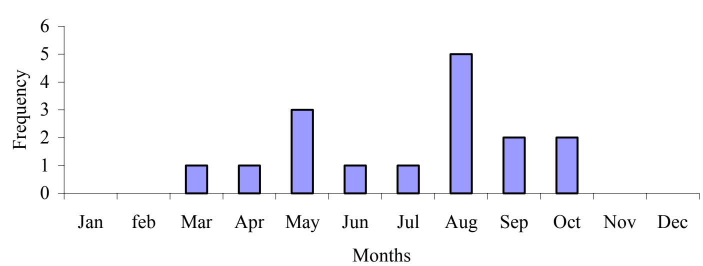

Fig 2. Frequency of ocean surge events since 1990

As presented by figures 3, 4 and 5, low pressure always coincides with high water. Closer look into yearly events revealed that coastal atmospheric pressure varies from one event to another, between 1008 – 1013millibar. The lowest pressure value was observed during the 30th May 1998 event and the highest value during the 14th September 2001 event. However, coastal atmospheric pressure was generally transiently low. Also, pressure during any event was generally lower than the pressure two days previous to the event.

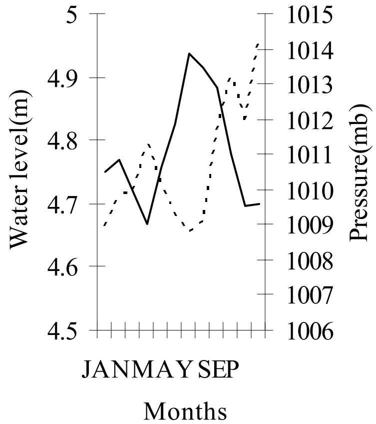

Fig.3a Mean monthly water level with coastal surface pressure for 1993 dashed line is the water level

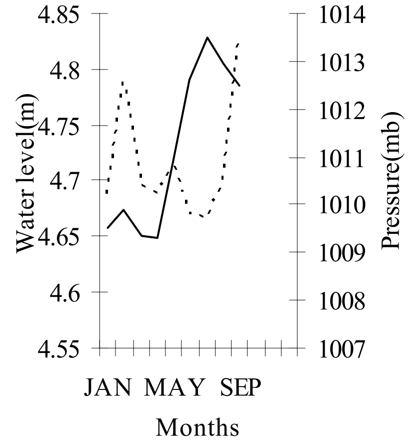

Fig.3b Mean monthly water level with coastal surface pressure for 1994 dashed line is the water level

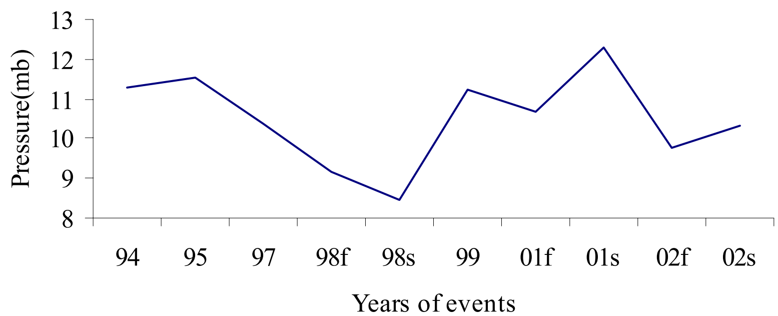

Fig4. Surface atmospheric pressure during ocean surge events

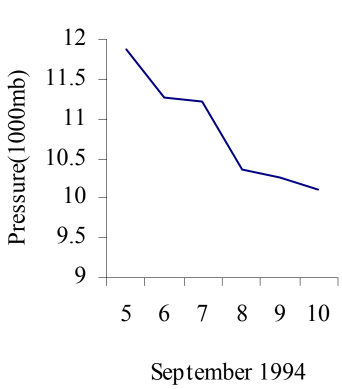

Fig 5a. Coastal atmospheric pressure of the 4th september 1994 ocean surge

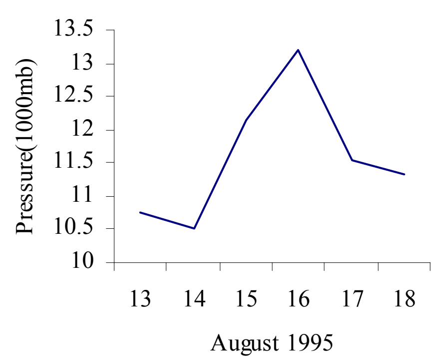

Fig.5b. Coastal atmospheric pressure of the 17th august 1995 ocean surge

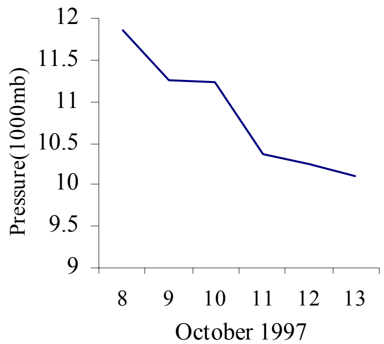

Fig 5c. Coastal atmospheric pressure of the 11th october 1997 ocean surge

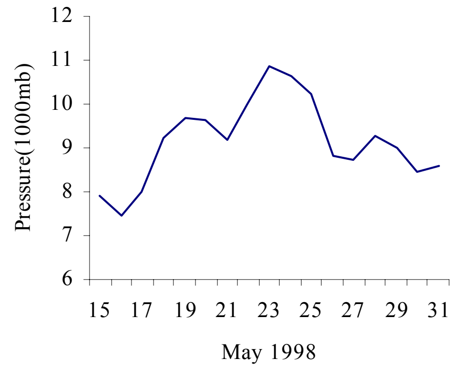

Fig.5d. Coastal atmospheric pressure of the 21 and 30th may 1998 ocean surge

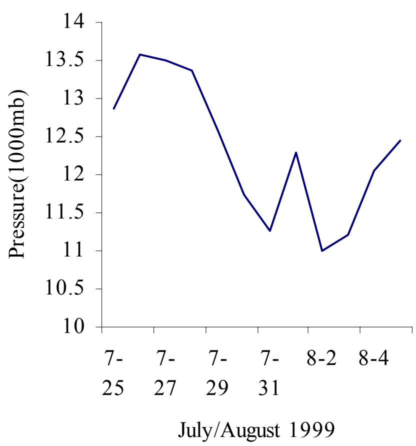

Fig.5e. Coastal atmospheric pressure of the 3rd August 1999

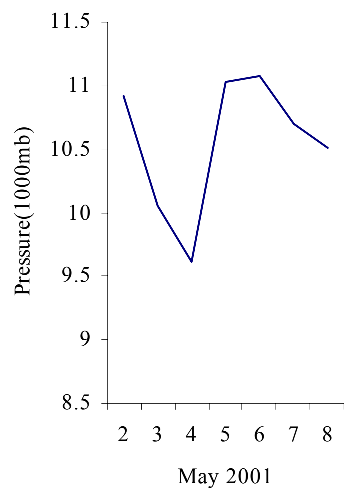

Fig 5f. Coastal atmospheric pressure of the 7 th May 2001 ocean surge

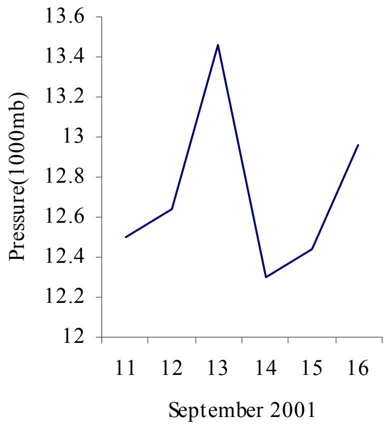

Fig 5g. Coastal atmospheric pressure of the 14th September 2001 ocean surge

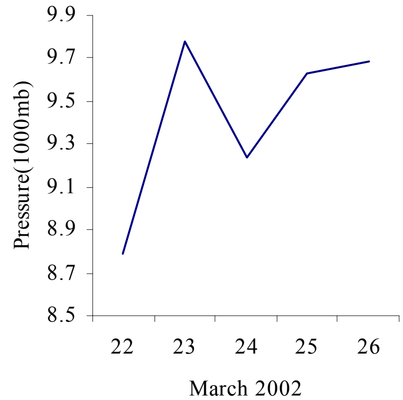

Fig 5h. Coastal atmospheric Pressure of the 24th march 2002 surge

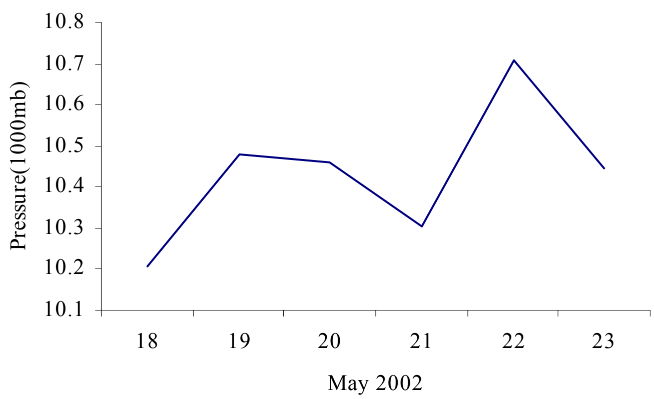

Fig 5i. Coastal atmospheric pressure of the 21st May 2002 ocean surge

Furthermore result revealed that the ocean surges are influenced by moderate winds (between 15 - 18kts in strength on the average) over the fetch (Lat. 10^{o}S – 20 ^{o}S and Long. 0 ^{o}E – 10 ^{o}E). These winds were observed to be generally strongest three to two days before the event. They can generate wave height of about 1.8m and with favourable cross equatorial flow, the swell may reach the coast in about 2 – 3 days see fig.6a-f.

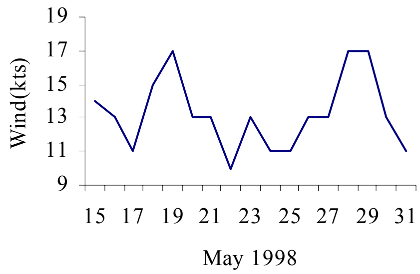

Fig 6a. Wind strength over the fetch during 21 and 30 May 1998 surge

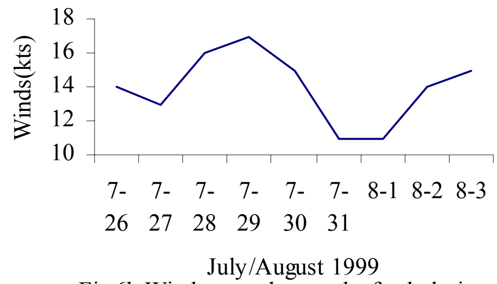

Fig 6b.Wind strength over the fetch during 3rd August 1999 surge

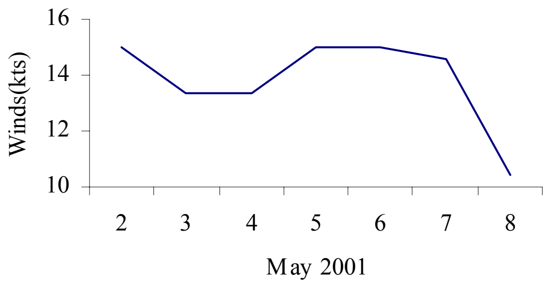

Fig 6c. Wind strength over the fetch before during the 7th May 2001 surge

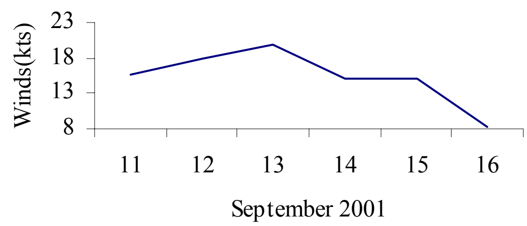

Fig 6d. Wind strength over the fetch during the 14th September 2001 surge

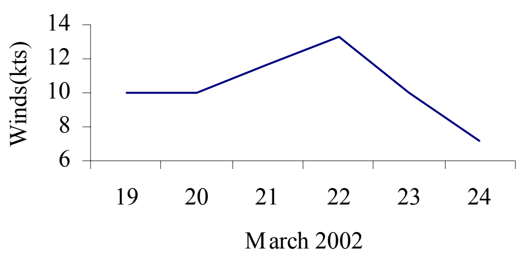

Fig 6e. Wind strength over the fetch during the 24th March 2002 surge

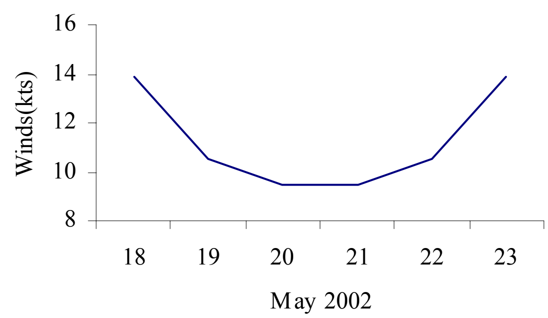

Fig 6f. Wind strength over the fetch during the 21st May 2002 surge

CONCLUSION

This investigation has revealed that the ocean surge over the Victoria Island beach are influenced by ocean-atmospheric dynamics especially wind stress at the fetch (Lat. 10^{o}S – 20 ^{o}S and Long. 0 ^{o}E – 10 ^{o}E). These winds are of moderate type and when they reach about 18 – 20 knots in strength, they can generate wind waves of about 2m in height. With cross equatorial flow, it can take up to three days to reach the coast as swell and if coincide with high water, can inundate the coast. Such inundation (apart from the march 2002 event) occur between April and October but more frequent in August. It has also showed that these winds were generally observed to be strongest three to two days before the event.

The role played by the atmospheric pressure in ocean-atmospheric dynamics as it concerns ocean surges is crucial. The result showed that pressure varies from one event to another, between 1008 – 1013millibar. However atmospheric pressure during any event was generally transiently low and observed to coincide with High tides. Finally, pressure during any event was generally lower by about 0.8mb than the pressure two days previous to the event.

Ocean surge to the people of Nigeria is a big threat to the economic growth and it has been ignored for too long. Today, there is virtually no beach left this implies that if no concrete and very urgent solution is taking we might be heading to a very great devastating consequence. Authorities continue a wait-and-see approach for so many years instead of finding a cost-effective solution to the problem. Ocean surges and their impact must be understood and solution proffered based on the scientific knowledge of meteorology and oceanographic conditions.

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