Dynamics of storm surge characteristics and its devastating flooding of Nigerian coast: A case study of Lagos beach

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Abstract

The occurrence of storm surge over Nigerian coastal cities is always accompanied by catastrophic hazard which have frequently resulted in environmental degradation of the coastal areas and loss of lives and property. This study investigates the meteorological phenomena that influence the occurrence of storm surge, on the August 17-18, 2012, over Lagos beach. Results show that mean sea level pressures (MSLP) over North and South Atlantic Ocean, wind direction and speed, wave height and sea surface temperature anomalies (SSTA) play crucial roles during the pre-, during and post-storm surges over Lagos beach. The characteristics of ocean-atmospheric exchanges reveal the sensitivity of storm surges, over Lagos beach, to anomalous atmospheric warming. There exist see-saw relationships between the MSLP over both hemispheric parts of the Atlantic Ocean. Further investigations show that wave height, ranging from moderate to rough-sea (about 2–3m), coupled with relatively strong wind (>> 5knots) must have been generated 2 to 3 days before the event over the fetch area. The study further discusses the destructive characteristics of storms surge event and also demonstrates the need for precautionary measures.

1.0 Introduction

On August 17-18, 2012 a catastrophic surge of the sea water towards the coast occurred over one of the Nigerian coastal cities, Lagos Beach. Though, this is not the first of its kind over this area but the hazard and the accompanying environmental degradation witness by this popular beach, during this incident, cannot be quantified economically. For instance, it is reported that the surge wreaks havoc on the beach community. These havocs include loss of sixteen lives, missing of several people that are not accounted for and the leveling of the entire beach community[1] (Figure 1; Ezeobi, 2012). Properties worth millions of Naira were also destroyed[2] (Ezeamalu, 2012). Unconfirmed information, from an eye witness and victim, says that the instantaneous flood depth may be as deep as 20m.

As the populations of coastal cities, in developing countries, are increasing (Dasgupta *et al*, 2009) it is pertinent to investigate the meteorological phenomena that normally influence the occurrence of ocean surges, particularly, over the beaches. Identifying these phenomena will aid in the forecasting of the ocean surge thereby preventing lives and properties. In particular, identification of these phenomena will trigger the early warning systems; improve liaison and collaborations between the agencies that are responsible for natural disaster management; it will also improve the technicalities of providing clear and safe evacuation routes during a wave-related emergency.

A case study here is the Lagos beach (Figure 2). The low lying sandy beach with maximum elevation of 3m is located immediately east of the natural inlet into the harbour. The beach is bounded in the north and west by creeks, while it is bounded in the south by the Atlantic Ocean. It then stretches eastward by a distance of over 75km around 6°.25’00"N parallel. It forms the easternmost fringe of a chain of barrier-lagoon complexes in Nigeria.

The data utilized for the achievement of the objective of this study include: the mean sea level pressure (MSLP) over the Atlantic Ocean (North and South) obtained from the National Oceanographic and Atmospheric Administration (NOAA) web portal[3]; the sea surface temperature anomalies over the Gulf of Guinea (GOG: between longitudes 10 °W

[1] https://en.wikipedia.org/wiki/Eko_Atlantic

[2] http://www.old.thegreentimes.co.za/stories/vulnerable-people/item/1493-lagos-ocean-surge-levels-kuramo-beach

[3] *http://www.nodc.noaa.gov/General/sealevel.html*

and 8°E and latitudes 5 °N and 5°S) obtained from the International Research Institute for Climate Prediction at 2° × 2° spatial resolution (Toure, 2000); surface wind speed and direction, including the weather, for the related periods were obtained from the archives of the Nigerian Meteorological Agency (NIMET); and, the wind–wave model charts were obtained from the passageweather.com[4]. These data were subjected to series of statistical analyses in order to determine the pre-, during and post- characteristics of the ocean surge.

2. Results and Discussion

The average MSLP values, in August 2012, over the southern Atlantic and GOG exhibit opposing characteristics. For instance, Figures 3, 4 and 5 show that the MSLP over the southern Atlantic is greater (1030hPa) than that over the GOG (1006hPa) thereby setting up considerably large horizontal pressure gradient. This implies influx of strong wind towards the GOG and it is climatologically consistent with the boreal summer monsoon wind patterns (Wang et al. 2009). The daily values of the MSLP at the center of St Helena high pressure system over the southern Atlantic and the GOG in August 2012 also reveal a see-saw relationship. Figure 6 and 7 shows that intensification of the St Helena high pressure system is, mostly always, concomitant with a deepening of the MSLP over the GOG. The correlation coefficient between these MSLP values is about -0.63. The figures show that MSLP deepens over the GOG two to three days prior to the surge event. The pressure gradients produced enable the flow of fluids from regions of high pressure to region of low pressure Shinoda (1990). Meanwhile Øyvind (2005) has concluded that 1hPa drop in pressure correspond to 1cm rise in sea level and that rising seas could dramatically increase the chances of damaging floods from the ocean storm surges.

Anomalously warmer than normal sea surface temperature may likely have contributed to the lethality of the ocean surge observed over the Lagos beach on August 17-18, 2012.

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[4] http://www.passageweather.com/

Figure 8(a, b) shows that the average sea surface temperature anomalies (SSTA), in August, is about $0.4^{O}C$ warmer than normal, especially during the surge event. For instance, the Figure 8b shows that SSTA increases from 16^{th} reaching its maximum value on the 19^{th} before recession to negative SSTA on the 20^{th} of August. Positive trend is also observed in the temperature anomalies, implying the sensitivity of storm surges to anomalous atmospheric warming. A warmer than normal Ocean will experience thermal expansion which may likely lead to sea level rise of about 17-28cm (IPCC, 2007). This will likely induce ocean surge thereby creating more damaging flood conditions in coastal zones and adjoining low-lying areas as in the case of Lagos beach.

The wave direction and height are very influential in the formations, as well as the lethality of the ocean surge. Figure 9 shows that the wave direction is perpendicular to the coast of GOG thereby giving it the maximum force needed to impact the coast. The figure also shows that the wave height, which ranges from moderate to rough-sea (about 2–3m; Figure 9), coupled with relatively strong wind (>> 5knots; Figure 10) must have been generated 2 to 3 days before the event over the fetch area. Combinations of all these phenomena enable the approaching high waves to inundate the low lying coastal barriers of Lagos beach resulting in loss of life and properties.

3. Conclusion and Recommendation

Investigations carried out in this study have shown that ocean surges over Lagos beach are influenced by ocean-atmospheric dynamics. The role played by the MSLP of the ocean-atmospheric dynamics is crucial to the formation and sustenance of the ocean surge. Deepening over the GOG, followed immediately by a very sharp intensification in MSLP over the center of St Helena high pressure system always precede an ocean surge along the Nigerian coast. This induces perpendicular wind waves of about 2-3m which can take up to two days to reach the coast. The kinetic impact of the surge may have also been influenced by the impacts of positive anomalies of the ocean temperature. Investigations further show that surges begin to recede after a reversal of the two pressure systems i.e. when St Helena high pressure system starts to weaken while the MSLP over the GOG begins to fill up normally. This is an indication that the coupled behaviors of these atmospheric phenomena can be adopted as a useful forecasting tool for storm surges over Nigerian coasts.

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Figure1. Pictures of the scenes after the ocean surge on August 17-18, 2012 in Lagos.

Figure 2. Map of Lagos showing the Study area (source: google map)

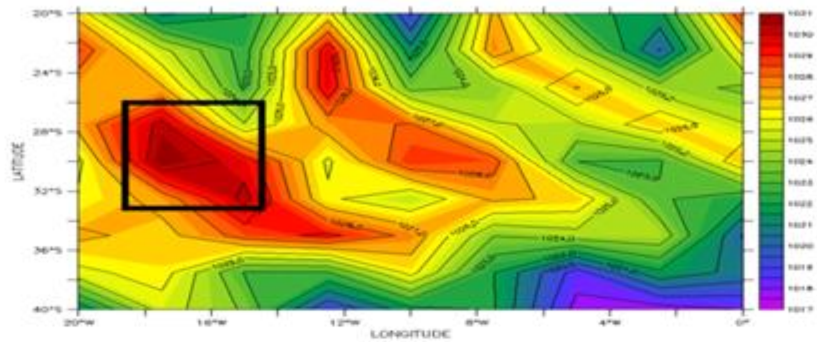

Figure 3. Spatial distributions of the average mean sea level pressure (MSLP) over the western flanks of the southern Atlantic Ocean in August 2012. Black box indicates the center of St Helena high pressure system.

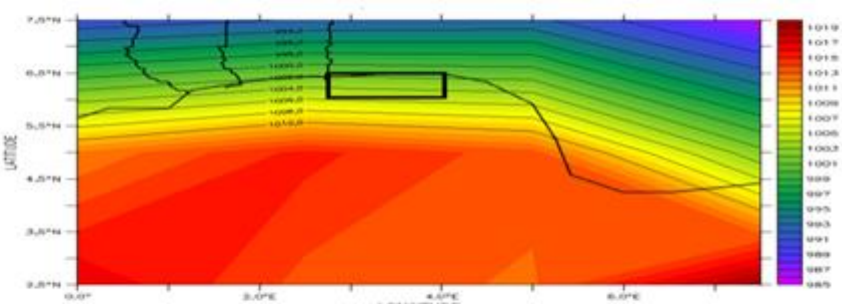

Figure 4. Spatial distributions of the average mean sea level pressure (MSLP) over the Gulf of Guinea (GOG) in August 2012. Black box indicates the GOG.

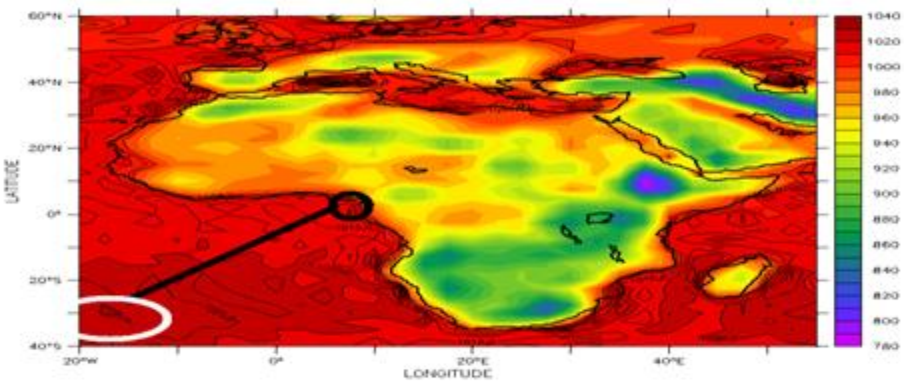

Figure 5. Spatial distributions of the average mean sea level pressure (MSLP) over the Atlantic Ocean in August 2012. Black and white circles indicate respectively the GOG and the center of St Helena high pressure system.

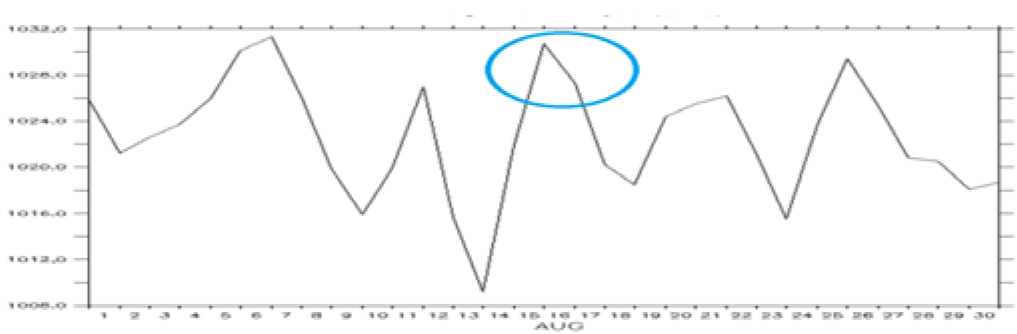

Figure 6. Daily evolutions of the average mean sea level pressure (MSLP) over the center of St Helena high pressure system in August 2012. Blue circle indicates the surge event periods.

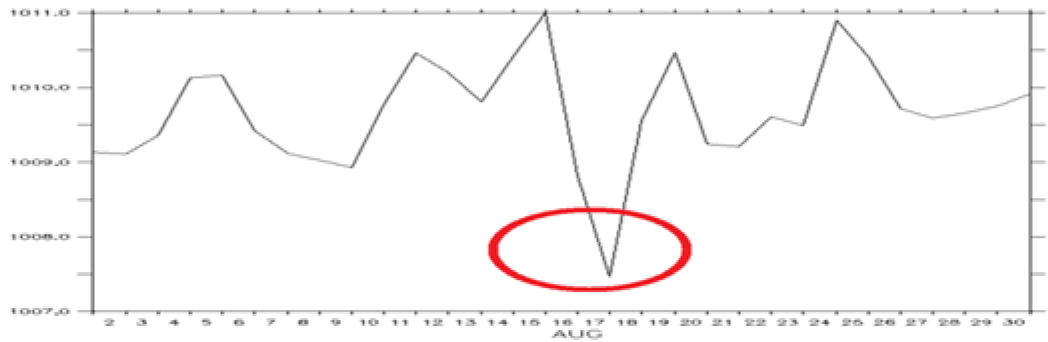

Figure 7. Daily evolutions of the average mean sea level pressure (MSLP) over GOG in August 2012. Red circle indicates the surge event periods.

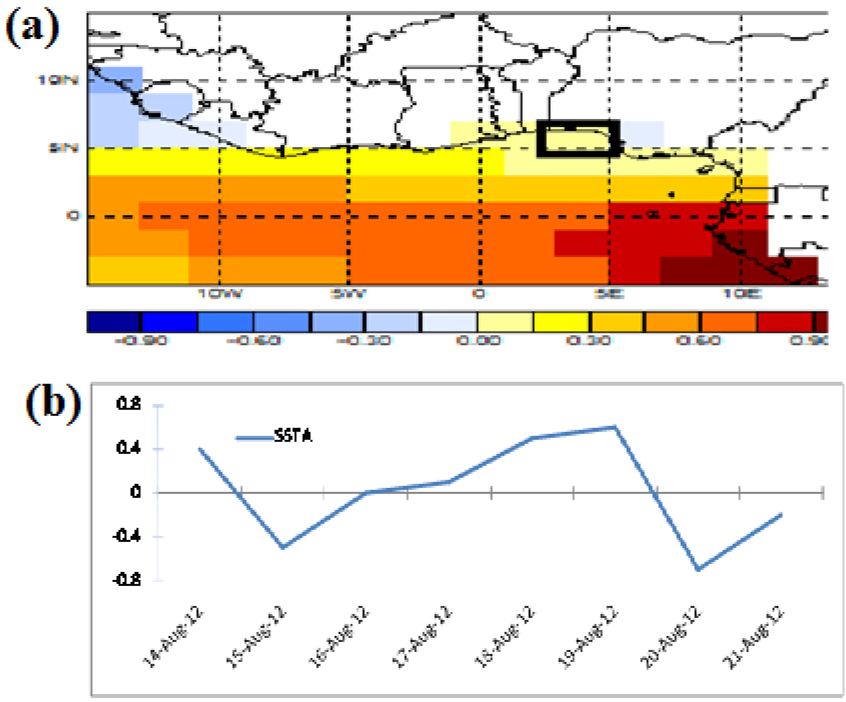

Figure 8. Sea surface temperature anomalies (SSTA) over the GOG for **(a)** the spatial distributions over the Atlantic Ocean in August 2012 and **(b)** the daily evolutions over GOG during the surge event in August 2012.

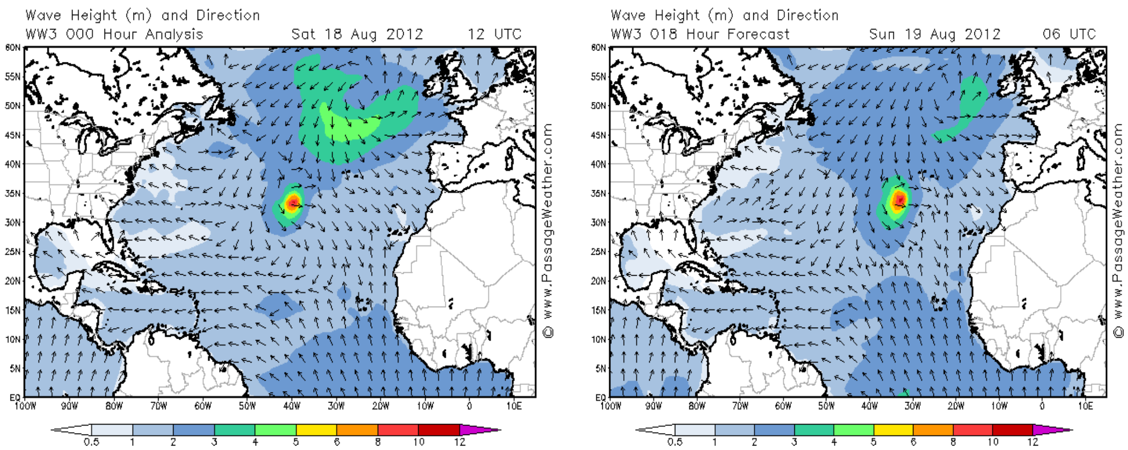

Figure 9. Wave height (m) and direction over the northern Atlantic Ocean for **(left)** August 18 and **(right)** August 19, 2012. Source: http://www.passageweather.com/

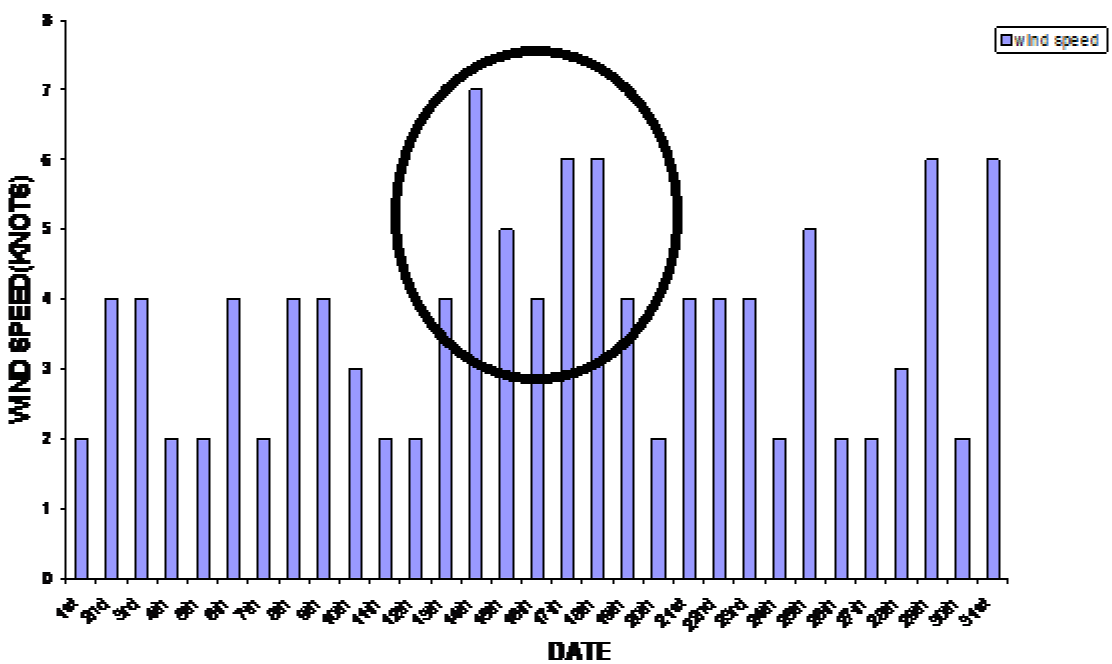

Figure 10. Wind speed for the month of August over Lagos beach. Black circle indicates period of the surge.