

Report on Sea Level Drop Observed at the Manatí Coast

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1 Introduction

The Puerto Rico Seismic Network (PRSN) received news about dramatic receding of the coastline of up to 30 meters in horizontal extent at the beaches of Hacienda La Esperanza in Manatí, Puerto Rico. Dr. Maritza Barreto, from the University of Puerto Rico - Rio Piedras has been conducting both quantitative and qualitative documentation of the phenomenon. Her preliminary results led her to contact PRSN and seek advise on whether her observations were related to a unique but astronomically scheduled sea level drop or to tectonic uplift associated to the heightened seismicity offshore north of the same area that began on November 2008.

2 Study Area

The area of study is located at latitude $18.48^{\circ}N$, longitude $-66.52^{\circ}E$ (Figure 1). This area is within the jurisdiction of Hacienda La Esperanza, an antique sugarcane processing factory, now converted as a museum and administered and maintained by the Conservation Trust of Puerto Rico. Dr. Barreto began her qualitatively observations on November 2008 and

quantitative measurements on February 2009. She has documented times and dates of her visits to try and constrain as much as possible her observations in relation with tide levels.

3 Background

3.1 New Moon and Perigee Effects

As a matter of background information, during the month of May, several phone calls were received at PRSN reporting an unusually low sea level at several locations along the southern coast of the island, namely in Ponce, Humacao, Salinas, and Yabucoa. The citizens of these areas were worried because they believed a tsunami was coming. Given that no seismic activity have occurred and after carefully examining PRSN tide gauge data, it was confirmed that the phenomenon was of astronomical origin; a summed effect of lunar perigee and new moon. It was estimated that the same magnitude of extreme low and high tides were to happen on June 23, July 21 and August 19. Whether the observations along the northern coast of Manat are due to the same effect is highly probable, however, the fact that they have been documenting the unusually low sea levels there since February, may be indicative of additional tectonic activity, and thus led to additional careful examination.

3.2 Seismicity

On October 2008 an unusual heightened seismicity began occurring offshore north of Puerto Rico roughly north of Manatí. Approximately, 835 events of $M > 2$ have occurred on a peculiar North-South orientation along the southern slope of the Puerto Rico trench. Two events, $M5.5$ and $M4.8$ occurred on November 2 and 23, 2008, respectively, with similar fault mechanism and depths ($\sim 10km$). The nature of this seismicity is baffling even to seismologist, but speculations are placed on existing upper crustal faults or interplate inter-

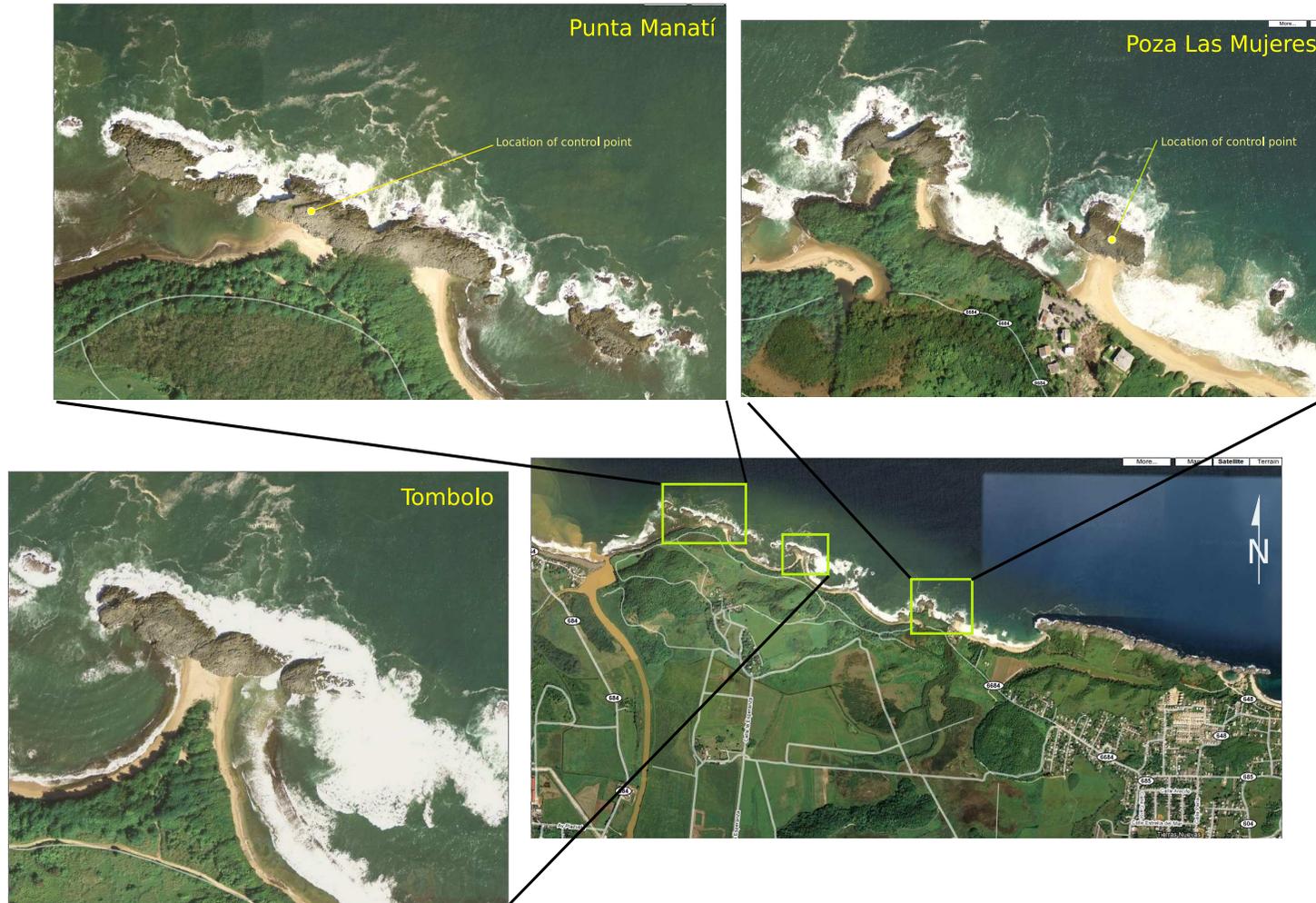


Figure 1: Aerial image of the study area. The two upper figures show the location where the GPS control points were installed; Punta Manatí (left), and Poza Las Mujeres (right). Both locations are accessed through the Hacienda La Esperanza from the Conservation Trust of Puerto Rico. Images courtesy of Google Maps.

actions. Further studies are necessary to understand its tectonic implications and estimate whether the drop in sea level are related to the seismic activity.

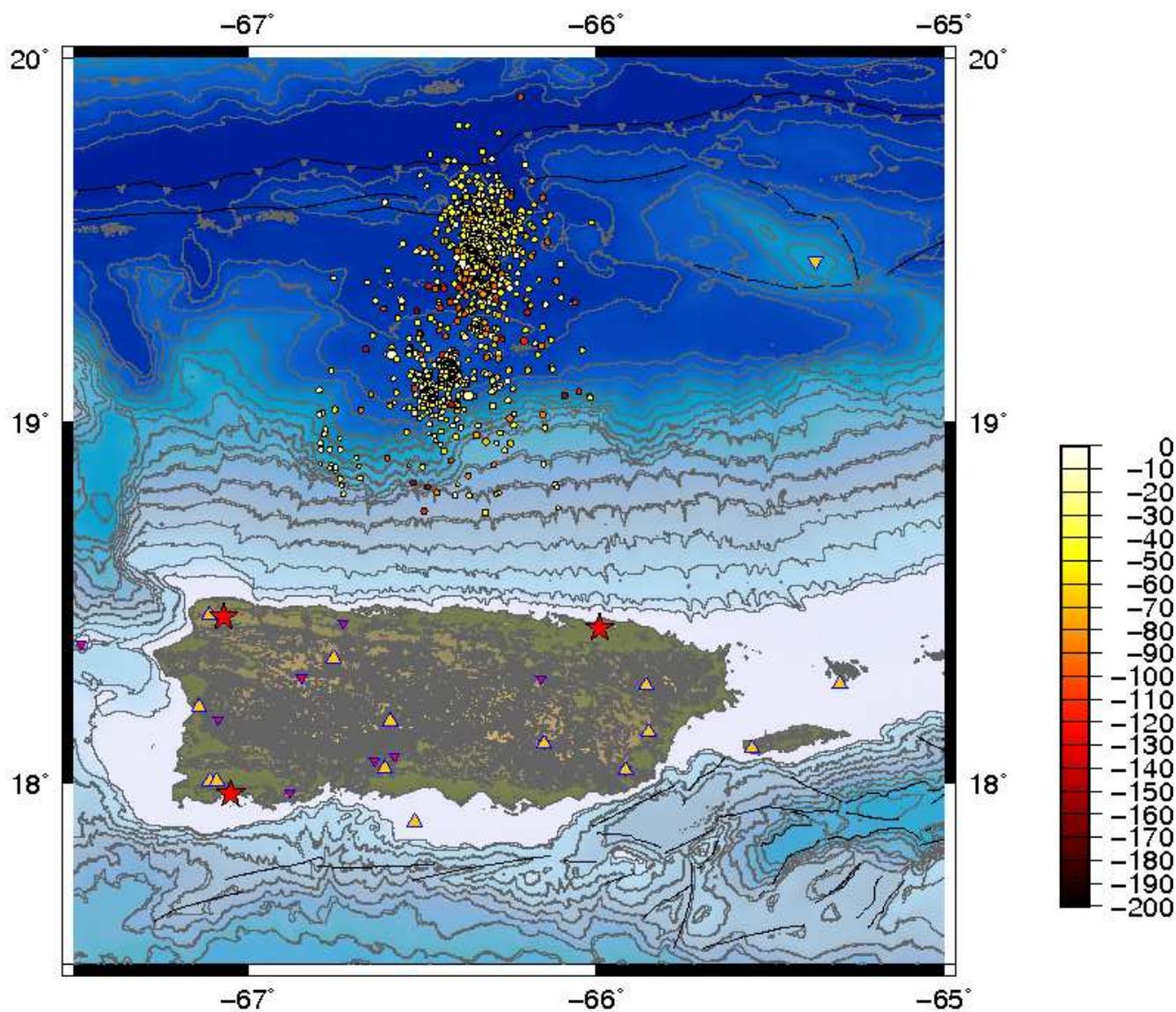


Figure 2: Map showing heightened seismicity north of Puerto Rico for the period October 2008 - June 2009. It is still uncertain whether this peculiar North-South orientation of events is related to prominent sea level changes in the Manatí coastal areas.

4 PRSN Involvement

PRSN personnel was mobilized to the area to inspect and confirm the magnitude of the event. Pictures were taken at two instances; 1) At or near high tide on Saturday, June 20, 2009 and 2) Near low tide on Monday, June 22, 2009. Figure 3 shows the approximate time of visits according to the tides predicted at the nearest tide gauge location on Aguadilla. Pictures from the same or close locations were taken to document the changes in coastline at both high and low tides. Also, personnel of Vernix Engineering., a consulting engineering and surveying firm, installed two Global Positioning System (GPS) control points on top of the eolian sandstone promontories present at the coast. Differencing the GPS measurements at these two locations with the Continuous GPS site at Arecibo may help discern whether a tectonic uplift in the area is currently underway. Three beach profiles to estimate both horizontal and vertical extent of the sea level changes in the area have also been performed by Dr. Barrento and her assistants.

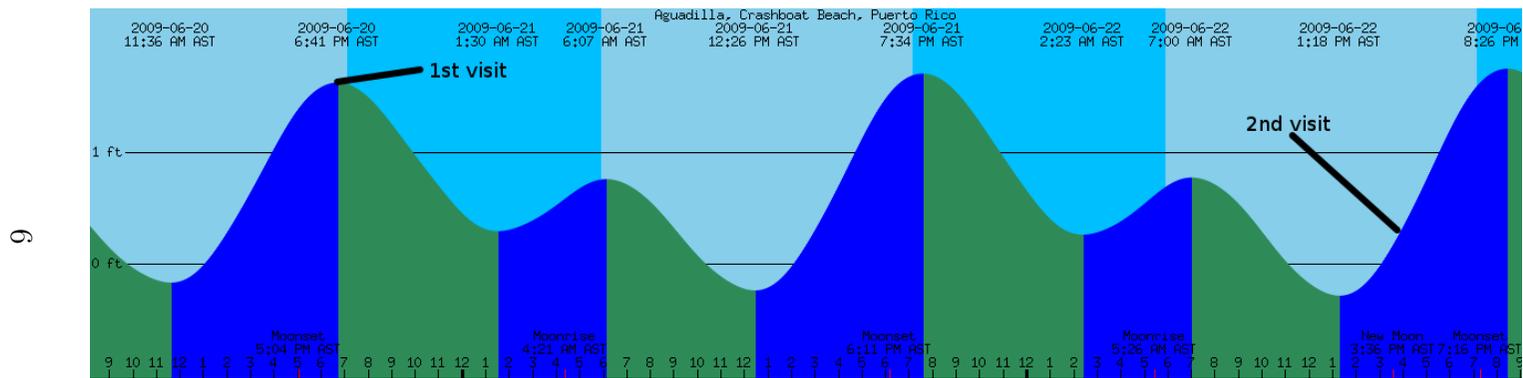


Figure 3: Tide predictions at Agudilla, ~ 50 km west of Manatí, indicating approximate time of visits.

4.1 Photographic evidence

This section is subdivided into two sections; Section 4.1.1 shows photographic documentation from similar locations at both high and low tide levels and Section 4.1.2 documents significant features observed at high and low tides. Figure 1 show the three coastal locations where the photos were taken. These are from west to east; Punta Manatí, Tómbolo, and Poza Las Mujeres.

Time details as well as larger version of these photos can be found at the following website <http://prsn.uprm.edu/~alberto/Manati/> .

4.1.1 High-Low tide changes

The following photographs show differences in the coastline between high tide observed on Saturday, June 20, 2009 from 17:00 AST to 19:30 AST and low tide on Monday, June 22, 2009 between 13:00 AST and 17:00 AST. Predicted high tide was obtained using the XTide server for the Crashboat Beach tide gauge in Aguadilla, PR, the nearest station to Manatí (Figure 3).



Figure 4: Looking west from Tómbolo. Rock is exposed at both high and low tides. According to locals, beach rock was not exposed in November.



Figure 5: Same location at/near low tide.



Figure 6: Looking east from Tómbolo. This is the location where the maximum horizontal extent of sea withdrawal has been observed.



Figure 7:



Figure 8: Also looking east from Tómbolo. Continuation to the left from Figures 6 and 7.



Figure 9:



Figure 10: Photo taken from Tómbolo toward the Southeast. Wave breaking show the location of the the beach rock.



Figure 11: At low tide waves break at the beach rock but do not go over it.



Figure 12: Northern part of Tómbolo where wave-cut platforms are exposed.



Figure 13: Platform exposed $\sim 80\%$ of the time at low tide.



Figure 14: Immediately west of Tómbolo. Notice the partially submerged wave-cut platform at the center of the photo. Western terminus of Tómbolo is seen on the right of the photo.



Figure 15: The same platform is completely exposed at low tide.

4.1.2 Selected images

As it can be seen from the photographs, at high tide, the beach rock can be seen exposed but no corals or microatolls. Coral heads, bleaching branching corals, and sea fans can be seen exposed only at low tide (See Figure 32) west of Tómbolo, the only location where they were visible. Observations made from shore do not allow to conclude whether the corals are alive or dead. Zooming in on the photos show that some of the exposed corals may still be alive, however, snorkeling or diving is required to confirm this.

Figures 16 and 17 were taken on the first visit whereas the rest were taken during the second visit at or near low tide.

4.2 Global Positioning System

In case the drop in sea level is the result of a tectonic uplift, two vertical Global Positioning System (GPS) control points were installed by Vernix Engineering at two locations: Punta Manatí, and Poza Las Mujeres (See Figure 1). Control points were measured for the first time on Saturday, June 20, 2009, and will be measured twice per month using a differencing technique employing a Continuous GPS site in Arecibo (AOPR) in order to provide precise positions that will hopefully help discern whether there is a tectonic signature.



Figure 16: High tide at Poza Las Mujeres. Sea level changes can be observed at center of photo by change in color of the rock.



Figure 17: Looking east from beach rock promontory at same location.



Figure 18: Low tide at Tómbolo looking east at the wave-cut platforms north of the beach rock promontories.



Figure 19: Looking west of Tómbolo at exposed beach rock.



Figure 20: Close-up of the exposed limit of the beach rock. Algae can be seen growing on the rock.



Figure 21: Eastern terminus of Punta Manatí. This zone is where corals and sea fans are partially exposed.



Figure 22: Exposed sea fans.

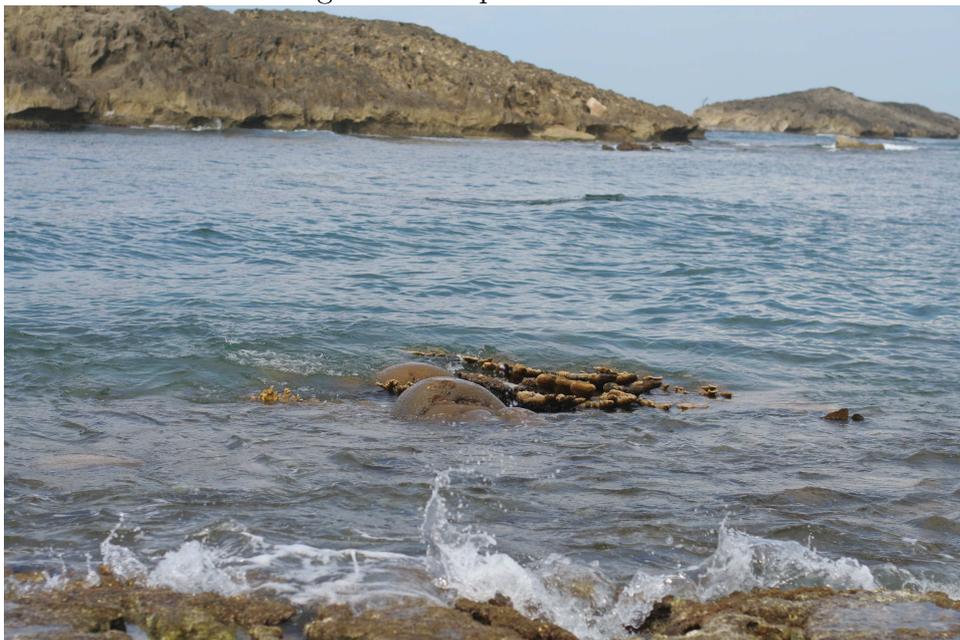


Figure 23: Partially exposed corals (*Acropora palmata* and *Diploria labyrinthiformis*). Close-up of this photo shows probability of corals being alive. Closer observations is required.



Figure 24: Exposed upper section of Fire coral (*Millepora complanata*).



Figure 25: Exposed corals at low tide near the eastern terminus of Punta Manatí.



Figure 26: Exposed wave-cut platforms on northern part of beach rock promontory at Punta Manatí.



Figure 27: Closer to the wave-cut platform. Notice the change in level where the waves used to break.



Figure 28: Looking west of Punta Manatí. Beach rock exposed and the location where Figures 21 - 24 were taken.



Figure 29: West of Punta Manatí, toward the mouth of Río Grande de Manatí.



Figure 30: Panoramic photo looking east of Tómbolo at low tide.



Figure 31: Employees of Vernix Engineering installing and measuring Punta Manatí benchmark.



Figure 32: Benchmark pin close-up.

5 Recommendations

- **Coral studies:** If the corals exposed at low tide are alive, then it may warrant closer inspection by experts in this field to confirm a tectonic signature.
- **GPS:** The PRSN will engage on bi-monthly GPS measurements of the two control points, and will install a Continuous GPS equipment on the premises of the Hacienda La Esperanza for long-term monitoring of this area. The Continuous GPS equipment will be on loan from UNAVCO for a ten-month period, when a decision will be made to purchase a replacement for this site if further measurements are required.
- **Tides:** Long-term sea-level average calculations will be computed for periods longer than 10 years for available NOAA stations, and for all of the data available for newly installed tide gauges from PRSN.
- **Shoreline changes:** Lyzaida Rodríguez, from the Conservation Trust of Puerto Rico working at the Hacienda La Esperanza, and collaborator of Dr. Barreto is conducting a Geographic Information System study to constrain shoreline changes over a period of seven decades. This study is essential to shed light on the changes this shoreline has endured over the sampled time.

6 Acknowledgement

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