FOREDUNE EVOLUTION AT A PROGRADING LOW-ENERGY SEA-BREEZE DOMINATED MICRO-TIDAL BEACH

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INTRODUCTION

Foredunes provide habitat and natural protection in coastal areas. The dune formation and development are controlled by aeolian, marine, and ecological processes (Hesp, 2002; Houser, 2009). The dune height is a key parameter for determining storm impact on barrier islands (Sallenger, 2000) and for calculating the Coastal Resilience Index (Dong et al., 2018). Therefore, the understanding of the relative role of both aeolian and marine processes on controlling dune evolution are fundamental for coastal hazards assessment on the context of climate change. A previous study (Cohn et al., 2018) conducted on a meso-tidal beach suggested that extreme water level can contribute to dune growth. The purpose of the present study is to investigate the role of aeolian and marine processes on the dune growth at a low-energy sea-breeze dominated micro-tidal beach located in northern Yucatan peninsula by means of high-resolution beach surveys.

STUDY AREA

The study area is located on a barrier island in the northern Yucatan peninsula, Mexico (Fig. 1c). A wide continental shelf dissipates wave energy and hence the wind and wave climate are mainly dominated by local sea-breezes that are more intense during the spring months (Fig. 1a,b).

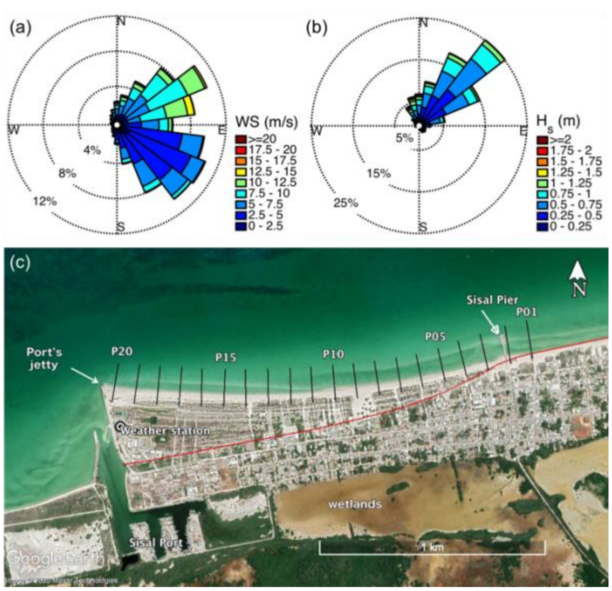

Figure 1. (a) Wind and (b) wave roses at the study area located (c) at a barrier island between the port's jetty and the Sisal pier. Survey transects are shown in black and shoreline prior to port's construction in red.

Central American Cold Surge events occur during the fall-winter and are responsible of more energetic wave conditions. On the other hand, hurricane events occur less frequently owing to the northern Yucatan coast orientation. A micro-tidal regime with tidal range <1 m characterizes this area. The study site is bounded by coastal structures (Figure 1c) that play an important role in beach morphodynamics (Medellin and Torres-Freyermuth, 2019). Significant beach accretion has occurred during the past 30 years due to the construction of the port. A subaqueous bar system is present throughout the year. The Yucatan coast presents dunes with heights between 1.5 and 4 m (Rey et al., 2020).

METHODS

Beach profiles have been conducted from May, 2015 to March, 2020 on a weekly and bi-weekly basis using an RTK GPS system (Fig. 1c). The beach surveys were carried out along 20 cross-shore transects. A fixed reference station is located in the roof of the coastal laboratory located near the port. The beach surveys were taken with a rover antenna carried out on a backpack, extending seaward to approximately -1.5 m. Therefore, shoreline, inner sand bar, and dune dynamics can be investigated with this data set. Environmental conditions were also measured for the study period. Mean sea level has been recorded using a tide gauge installed inside the port and waves at 10 m water depth (10 km offshore) have been also measured with some gaps in the records that are filled with reanalysis data. Furthermore, atmospheric conditions (wind speed and direction, temperature, precipitation, atmospheric pressure) were measured with a meteorological station installed 10 m above the ground level (Fig. 2).

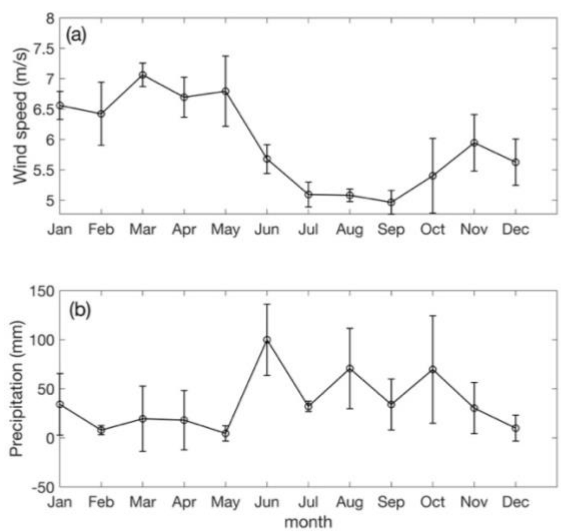

Figure 2 -(a) Monthly mean wind speed and (b) monthly total precipitation for the 2017-2020 period in Sisal, Yucatán. Error bars show the standard deviation.

FIELD OBSERVATIONS

Beach profiles are analyzed to investigate the spatial and temporal evolution of the beach width, subaerial beach volume, sandbar migration, and dune crest elevation. Figure 3 shows the temporal evolution at one transect located 300 m west of the Sisal pier (P05 in Fig. 1c). The foredune was not present at the beginning of the study period (Fig. 3b). Thus, dune formation and development can be investigated.

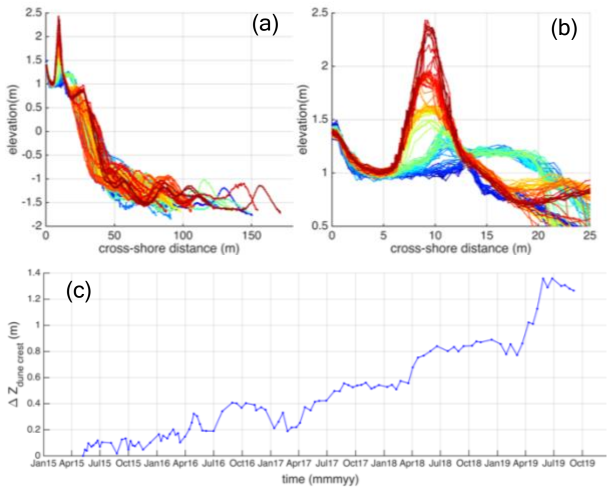

Figure 3 – (a) Beach profile measurements at P05 from foredune to submerged sand bars from May 2015 to September 2019 (timescale from cool to warm colors), showing (b) zoom at foredune area, and (c) time series of foredune crest elevation relative change.

Both marine and aeolian processes contribute to the formation and growth of the dune at this location. Seasonal variation of wave energy and mean sea level contribute to the increase of both subaerial sand volume and the available wind fetch, respectively. Winter storms play an important role on the subaerial sand volume increase via bar welding and beach berm formation. Moreover, the intense winds and low precipitation conditions during the spring months (Fig. 2) allow dune growth during that season. The temporal evolution of the dune elevation (Fig. 3c) shows higher growth rates during periods of intense sea breezes (March-June). At the early stages of dune formation, the dune elevation varies along the year without a clear trend. However, when the dune elevation is higher, the growth period is followed by a period of small changes during the rest of the year. Dune elevation shows small drops associated to energetic winter storms. Analysis of beach profiles at other alongshore locations show different foredune dynamics that can be ascribed to differences on the beach prograding rate, the presence/absence of vegetation, and anthropogenic effects.

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