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Nearshore circulation on a sea breeze dominated beach during intense wind events

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Abstract

A field experiment was conducted on the northern Yucatan coast from April 1 to April 12, 2014 to investigate the role of intese wind events on coastal circulation from the inner shelf to the swash zone. The study area is characterized by a micro-tidal environment, low-energy wave conditions, and a wide and shallow continental shelf. Furthermore, easterly trade winds, local breezes, and synoptic-scale events, associated with the passage of cold-fronts known as Nortes, are ubiquitous in this region. Currents were measured concurrently at different cross-shore locations during both local and synoptic-scale intense wind events to investigate the influence of different forcing mechanisms (i.e., large-scale currents, winds, tides, and waves) on the nearshore circulation. Field observations revealed that nearshore circulation across the shelf is predominantly alongshore-directed (westward) during intense winds. However, the mechanisms responsible for driving instantaneous spatial and temporal current variability depend on the weather conditions and the across-shelf location. During local strong sea breeze events ($W > 10$ m s^{-1} from the NE) occuring during spring tide, westward circulation is controlled by the tides, wind, and waves at the inner-shelf, shallow waters, and inside the surf/swash zone, respectively. The nearshore circulation is relaxed during intense land breeze events ($W \approx 9$ m s^{-1} from the SE) associated with the low atmospheric pressure system that preceded a Norte event. During the Norte event ($W_{max} \approx 15$ m s^{-1} from the NNW), westward circulation dominated outside the surf zone and was correlated to the Yucatan Current, whereas wave breaking forces eastward currents inside the surf/swash zone. The latter finding implies the existence of large alongshore velocity shear at the offshore edge of the surf zone during the Norte event, which enhances mixing between the surf zone and the inner shelf. These findings suggest that both sea breezes and Nortes play an important role in sediment and pollutant transport along/across the nearshore of the Yucatan shelf.

Keywords: sea breeze; land breeze; Norte; surf zone; swash zone; nearshore circulation; nearshore hydrodynamics.

1. Introduction

Nearshore circulation plays an important role in the transport of pollutants, phytoplankton, and sediment between the inner shelf and coastal waters (Nittrouer and Wright, 1994; Hendrickson and MacMahan, 2009; Grifoll et al., 2015). However, the relative role of the different physical processes and their coupling while driving transport across the shelf remains poorly understood in some regions due to the lack of concurrent field observations at different water depths.

The Northern Yucatan peninsula is characterized by the influence of intense winds mainly associated with local sea/land breezes and synoptic-scale events associated with cold-front passages (Figueroa-Espinoza et al., 2014). Sea breezes are a local phenomenon that occur at coastal locations owing to differential heating of the land and the ocean (Masselink and Pattiaratchi, 1998; Gille et al., 2003). Sea breezes develop when solar