Morphodynamic Aspects and El Niño Oscillations in Ingleses Beach, Santa Catarina Island, Southern Brazil

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ABSTRACT


The Ingleses beach, characterized by dissipative to intermediate morphology, is located at the northeast part of Santa Catarina island, on the southern Brazilian coast. With a parabolic planform orientated northwest-southeast, the study area is sheltered from the south and southeast swell associated with cold fronts passage in the region and mainly exposed to east swell action, generated by the blockage of these frontal systems. Two set of beach profile data obtained in 1996/1997 and 2000/2001, characterized respectively by influence of El Niño and La Niña oscillations, showed a distinctive behaviour in relation to the beach processes, with a larger mobilization of beach sediments in the first period and a lesser beach volume variation in the second one. Observed variations between the two periods could be related to changes in atmospheric processes associated with El Niño Southern Oscillation (ENSO) cycle. During El Niño years, the subtropical jet intensity increases and results in a more frequent blockage to front systems that arrive on the Brazilian south coast, remaining motionless. Such situation is favorable to east swell formation, which originates storm waves in the region. During La Niña period, the subtropical jet loses intensity, allowing a quicker passage of cold front systems, which are normally responsible for the south and southeast swell. In this case, the Ingleses beach is less affected, due to low exposition to these wave conditions related to its planimetric shape and general orientation.

ADDITIONAL INDEX WORDS: Beach profiles, ENSO, Brazilian beaches.

INTRODUCTION

Inter annual and large scale variations in the sediment volume of the beaches have been reported in several parts of the world. One of the main hypothesis pointed out to explain the occurrence of more intense erosive processes in certain periods is associated with El Niño Southern Oscillation (ENSO). Several papers in the international literature have attributed the erosion/deposition cycles to the negative ENSO (El Niño), or to the positive ENSO (La Niña) as STORLIZZI et al. (2000), TREMBANIS (2001), ALLAN and KOMAR (2002), and ARÇINIEGA et al. (2003).

On southern and southeastern Brazilian coast an intensification of the wave energy and a major occurrence of storm waves is equally associated to El Niño events. TOZZI et al. (2001) referring to the coast of Rio Grande do Sul, the magnitude of storms to the occurrence of El Niño/La Niña events. MARTINS and MAHIQUES (2000) noticed significant variations in the sand grain size on the beach of Bertioga, coast of São Paulo State, attributing this fact to the very intense El Niño action during the winter of 1997. NOERNBERG (2000) also attributed to El Niño an important shoreline recession in the Pontal do Paraná beach from 1997 to 1999.


Although there seems to be a consensus about the influence of El Niño and La Niña events on the morpho-sedimentary processes of the beaches, little is known about this matter. It should be considered that the ENSO causes different changes in the atmospheric dynamics around the world, therefore their effects on the coastal zone cannot be generalized. Thus, a regional analysis is necessary to have a better comprehension of their impact on determined area.

The aim of this paper is to evaluate the oscillations of the morphodynamic processes of a sandy beach located on the central coast of the Santa Catarina State, on the Brazilian southern coast, and their relationship with the El Niño/La Niña events, between 1996 and 2001.

STUDY AREA

The Ingleses beach, nearly 5km long, is situated in the northeastern part of Santa Catarina island (Figure 1). This beach presents a northwest-southeast- oriented parabolic planform with a headland at the southeast sector. The study area is composed by quartzite fine sand, originated from the continental shelf and an important coastal dune system, situated at the southeast side, between Santinho and the Ingleses beaches. The dominant south winds in that region transport the eolic sand to the north, and promote the by-passing of sediments between these two beaches (ABREU de CASTILHOS et al., 1995).

The local tide is semi-diurnal and microtidal type with a mean range around 1.0m. The wave climate in the region is predominantly represented by the incidence of southeast and east swells, associated with the passage of cold fronts in the region and northeast wave incidence for sea conditions (ALVES, 1996). The study area is sheltered from the south and southeast swells, and it is mainly exposed to the east swell action, generated by the blockage of frontal systems.

The beach profile can show dissipative to intermediate morphology, according to the methodology proposed by KLEIN (1997). The beach width increases from southeast to northwest, ...
Following the predominant direction of littoral drift, while the beach slope decreases in the same direction.

**METHODS**

In order to evaluate the morphodynamic processes in the Ingleses beach, four beach profiles were monitored from October/1996 to September/1997 (FARACO, 1998) and from September/2000 to October/2001. The survey occurred respectively under the influence of El Niño and La Niña events. Data related to the passage of frontal systems in the region as well as to the oceanographic conditions during the two periods of beach monitoring were collected. The analysis of beach profile changes, including sediment volume variations and morphometrical parameters, allowed us to evaluate the behaviour of the sedimentary stock and the beach morphology in response to the dynamic agents, to each set of collected data.

**RESULTS/DISCUSSION**

Comparative analysis of the volume variations occurred in the beach profile of the Ingleses beach showed distinct behaviour between the first and the second monitored periods (Figure 2). In 1996/97, a greater variability of the beach sedimentary stock was observed, with significant alternating processes of erosion and accretion along the survey, indicating a great mobility of the beach profiles during this first period. In 2000/01, however, the beach presented a long phase of accretion, with only two important erosive episodes in August and October of 2001. Figure 3 shows this beach volume accretion, with only two important erosive episodes in August and October of 2001. Figure 3 shows this beach volume accretion, with significant alternating episodes of erosion and accretion, alternating with the erosion ones, were related to southeast swells coinciding with neap tide.

During the second monitoring (2000/01), the predominance of southeast waves and less significant wave height between September/2000 and June/2001 resulted in a long phase of beach deposition. As from July, erosive behaviour of beach profile is observed in response to the incidence of east swell and more expressive wave heights, with a generalized beach erosion in just two episodes, in August and October/2001.

Another condition observed during the survey, which although sporadic resulted in beach profile variation, is related to the occurrence of local north winds. Acting for several days, these winds push the water mass towards the Ingleses bay, rising the level of wave attack over the beach profile, with the possibility of reaching the backshore. This condition was noticed in the period of June/1997 under southeast waves of low amplitude.

In the two periods of monitoring, an increasing of mobilized volume from southeast to northwest was observed (Table 1).

<table>
<thead>
<tr>
<th>Morphometric parameters and mobility beach volume</th>
<th>Profile 1</th>
<th>Profile 2</th>
<th>Profile 3</th>
<th>Profile 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>beach slope ($\phi$)[°]</td>
<td>2.63</td>
<td>3.57</td>
<td>3.23</td>
<td>3.69</td>
</tr>
<tr>
<td>beach width (L)[m]</td>
<td>50.31</td>
<td>50.87</td>
<td>30.11</td>
<td>41.05</td>
</tr>
<tr>
<td>backshore mobility coefficient (Cv)[%]</td>
<td>19.06</td>
<td>10.51</td>
<td>34.83</td>
<td>21.65</td>
</tr>
<tr>
<td>total beach volume mobility (V)[m³/m]</td>
<td>111.49</td>
<td>52.91</td>
<td>77.23</td>
<td>59.95</td>
</tr>
</tbody>
</table>
The variation in the sedimentary stock in the two periods reflected equally in the morphometric parameters of the beach. The greater sediment mobility in the first period results in smaller mean width and mean swash zone slope to the beach profile in comparison to the second period, as can be seen in Table 1. The values obtained indicate a beach profile predominantly erosive in the first period, and a depositional trend in the second one. This morphodynamic behaviour of the beach in the two conducted surveys is shown by the backshore mobility index values (CV%) (Table 1), which were higher in the 1996/97 period, causing frontal dune recession, specially in the northwest sector of the beach, where it reached 4m.

The different behaviour of the sedimentary stock in the Ingleses beach in the two periods of monitoring can be related to the occurrence of inter-annual cycles of erosion/accretion, influenced by El Niño/La Niña oscillations. The first survey was conducted during the El Niño event of 1997/98 (Oct/96 to Sep/97), characterized by strong intensity. In the second monitoring period (Sep/2000 to Oct/2001) the La Niña event, considered a moderate one, was predominant. It had been happening since 1998, just after the previous El Niño (CPTEC/INPE).

In years of El Niño, an intensification of cold fronts and south and southeast swells could occur, with a greater occurrence of storm waves on the south and southeast Brazilian coast. In years of La Niña, a decrease in the frontogenetic dynamics added to the rapid passage of frontal systems in the south of Brazil, may result in a decreasing of wave energy, favoring the sediment deposition on the beach profile.

Considering the degree of exposure of the Ingleses beach, a hypothesis to explain the greater variability and beach erosion in the study area during the El Niño event would be related to changes in the dynamic of atmospheric circulation in South Atlantic during these events. According to Cavalcanti, in El Niño years the strong warming in the Equatorial Pacific region creates an increase in the temperature gradient, intensifying the jet subtropical current, located between 20S and 35S. The intensification of the jet determines blockages in the atmosphere, and makes the cold fronts stationary in the Brazilian extreme south (Berlato and Fontana). As seen before, this meteorological configuration favors the formation of east swells in the region, which have more impact on the morphodynamic behaviour and variability of the Ingleses beach profile. Such oceanographic conditions tend to be more frequent in El Niño years due to a greater possibility of frontal systems blockage that migrate through the south of Brazil. Consequently, it is more likely that volume profile variation and beach erosion occurs in the study area, as observed in the 1996/97 monitoring period.

During La Niña episodes the decrease of frontal system blockages could increase the number of cold fronts that arrive in the south of Brazil. Actually, according to the data in (CLIMANALISE, 2003) journal for the monitored periods, under La Niña event the monthly average of cold fronts passage in the region was 4.57 against 1.91 for El Niño period.

In La Niña years, the quick passage of frontal systems of lower intensity through the region, associated with the
predominance of south and southeast swells do not directly affect the Ingleses beach. This would result in less mobility of the beach profile, favoring accretion processes, as can be seen between September/2000 and July/2001.

CONCLUSIONS

As shown in this work, the degree of mobility of the beach profiles varied along the Ingleses beach. This difference in beach change is related to local factors of geological, structural, and hydrodynamic order. The beach shape, the coastline orientation, and the presence of a promontory at the southeast side, make the study area totally protected against the incidence of south swells, whereas the southeast swells reach mainly the northwest sector. On the other hand, all the beach is more exposed to the east wave incidence, being the northwest sector more susceptible to beach profile changes.

The comparison between the two periods of monitoring showed a distinct behaviour in relation to the morphodynamic processes in the Ingleses beach. To the first period (1996/97) there was a greater variability of the beach profile as a consequence of a great number of erosive episodes. The second one (2000/01) was characterized by less mobility of the beach profile, as shown by the long accretional phase observed in this survey. This distinct behaviour of the beach in these two periods was associated with predominant oceanographic conditions related to the El Niño and La Niña events.

Considering that the beach is more exposed to east swells, the favoring of these oceanographic conditions in the region under the 1997/98 El Niño event, associated with the intensification of the subtropical jet, resulted in greater variability of the beach sedimentary stock. The erosive impact of this oceanographic condition on the beach profile can be even greater during spring tides, due to the low slope of beach face.

On the other hand, still taking into account the degree of beach exposure, in the second period under La Niña influence, the occurrence of northeast swells of lower intensity had less impact on the Ingleses’ beach sedimentary stock, which presented an accretional trend.

The results obtained showed different impact of ENSO events on the beach morphodynamic in the study area. Considering the strong erosion processes occurred last two decades in the Ingleses beach, as well as its economical importance to the tourism in the region, a more extended monitoring in this coastline is suitable. It would provide a large scale beach behaviour understanding, and its relationships with the El Niño and La Niña oscillations. The impact of these events on the beach processes can vary according to their intensity, and can even not occur under normal conditions, due to the fact that these events not always alternate.

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