The Effect of Sand Grain Size in the Aeolian Transport Processes of Transgressives Dunefields of the Coast of the Santa Catarina State  Brazil

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Abstract

The aeolian transport of sediment is a result of the relationship between wind energy and local sediment properties. The aim of this work is to analyze the effect of sand grains in the aeolian transport processes of the dunefields of the Santa Catarina coast plain. Along its 538 kilometers the coast of Santa Catarina presents transgressive dunefields. An inversion in the migration direction can be verified in the central portion of the state, in an distance of approximately 50 kilometers between the cities of Florianópolis and Palhoça. In an attempt to explain this divergence in the migration directions, 39 samples from 8 dunefields, between the latitudes 26°58'37''S and 29°18'18''S along in the coastal. Grain sized analysis was conducted and used to account the threshold velocity. The results show that the mean sand grain size increases from south to north as well as the fluid threshold shear stress (u*), impact threshold wind velocity at 10 m u10m. The pattern shows that the role of grain size is an important factor in the analysis of eolian transport processes.

Additional Index Words: Transgressives dunes, grain size, drift potential, Santa Catarina.

Introduction

To know the wind regimen and the textural characteristics of the available sediments on the beach and dunes is basic to analyze the transport and depositional processes of the coastal Aeolian systems of Santa Catarina.

In the central portion of Santa Catarina coast, in an interval of approximately 50 km between the cities of Florianópolis and Palhoça, evidence an inversion in migration direction of transgressive dunes can be found. Existing dunefields south of Palhoça migrate towards SW, while the northern dunefields migrate towards NW. In an attempt to explain this divergence in the migration directions, 39 samples from 8 dunefields, between the latitudes 26°58'37''S and 29°18'18''S along in the coastal. Grain sized analysis was conducted and used to account the threshold velocity. The results show that the mean sand grain size increases from south to north as well as the fluid threshold shear stress (u*), impact threshold wind velocity at 10 m u10m. The pattern shows that the role of grain size is an important factor in the analysis of eolian transport processes.

Study Area

The study area encompasses eight (8) existing dunefields long of the State of Santa Catarina between latitudes 26°58'37''S and 29°18'18''S. Being these: Praia Grande (São Francisco do Sul), Barra do Sul (Balneário Barra do Sul), Lagoa da Conceição, Ingleses (Florianópolis), Siriú (Garopaba), Ribanceira (Imbituba), Santa Marta/Camacho (Jaguaruna/Laguna), Morro dos conventos (Araranguá) (Figure 2).

Methods

Thirty nine samples were collected at the eight transgressive dunefields throughout the coast. Laboratorial grain sized analysis was carried out for determination of statistical parameters, using the graphical moments method (FOLK and WARD, 1957). Threshold of shear stress (u*) gotten by equation 1:

\[ u_* = A \sqrt{\frac{\rho_g - \rho_a}{\rho_a}} gd \]  (1)

Where: \( \rho_g \) is air density (1.22 kg.m^-3), \( \rho_a \) is sand grain density (2650 kg.m^-3), g is gravity (9.8 m.s^-2), d is the grain diameter in mm, A is an constant equal to 0.1 (esteemed by BAGNOLD, 1940).

To calculate the tension of shear stress related to wind speed distribution of logarithmic speed was used, expressed by equation 2:

\[ u_{10m} = 5.75u_* \log \frac{Z}{Z_d} + u' \]  (2)

Where: Z is the roughness factor of the sand grain surface determined by (BELLY, 1964), Z = 10^(-d) (mm) (plain surface was assumed), Z is height standard of the wind data (10 meters), u' is the shear speed 894 * d (mm) (m.s^-1), u_{10m} is the impact threshold wind velocity, measured at a 10 meters high.

The wind regimen along the coast was analyzed from superficial winds registers from three meteorological stations.

Figure 1. Divergence observed in migration direction of dune fields in the central portion of the coast of the Santa Catarina State. A Ingleses, B Lagoa da Conceição, C Pinheira e D Siriú.
The amount of sand carried by the wind was calculated through the model considered by Fryberger and Dean, (1979) (Equation 3):

$$Q = \frac{u^2}{c} t$$

(3)

Where: $Q$ is the proportional amount of sand carried by the wind in a time, $u$ is the average speed of the wind in 10 meters (standard height of registers in meteorological stations), $c$ is the measured limiting impact threshold wind velocity at 10 meters (minimum speed to keep the sand in saltation) and $t$ is the time where the wind blew in the given direction (percentile value of the registers of frequencies of wind directions, registered in the meteorological stations).

RESULTS AND DISCUSSION

The values obtained from equations (1) and (2) proposed by Bagnold (1941) and the grain sizes found at the analyzed dune fields can be visualized in Table 1.

Table 1. Limit shear stress and impact threshold wind velocity determined in accordance to mean grain size for each dune field.

<table>
<thead>
<tr>
<th>Dunefield</th>
<th>Mean Grain Size (mm)</th>
<th>$u^2$ (m$^2$.s$^{-2}$)</th>
<th>$c$ (m.s$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. Grande</td>
<td>0.352</td>
<td>0.274</td>
<td>8.59</td>
</tr>
<tr>
<td>Barra do Sul</td>
<td>0.206</td>
<td>0.210</td>
<td>6.29</td>
</tr>
<tr>
<td>Ingleses</td>
<td>0.227</td>
<td>0.220</td>
<td>6.63</td>
</tr>
<tr>
<td>Joaquina</td>
<td>0.200</td>
<td>0.207</td>
<td>6.18</td>
</tr>
<tr>
<td>Sirie</td>
<td>0.188</td>
<td>0.200</td>
<td>5.96</td>
</tr>
<tr>
<td>Ribanceira</td>
<td>0.198</td>
<td>0.205</td>
<td>6.14</td>
</tr>
<tr>
<td>Farol</td>
<td>0.181</td>
<td>0.196</td>
<td>5.83</td>
</tr>
<tr>
<td>M. Conventos</td>
<td>0.167</td>
<td>0.189</td>
<td>5.59</td>
</tr>
</tbody>
</table>

For the meteorological station of the Biological Reserve of the Arvoredo Island situated one to the south, in the Cabo de Santa Marta Lighthouse, another one in geographic center of the coast, situated at the Biological Reserve of the Arvoredo Island and another one to the north, at the PXIV oil platform in the Latitude 26°46'22"S and Longitude 046°47'02"W (~ 180 km of the coast) (see Figure 2). Data was analyzed for speed (m/s) and direction, directional 16 proveniences of sectors of superficial winds. The meteorological data was given by BNDO Brazilian Navy from the stations of Arvoredo Island (period 1963-1997) and of the Santa Marta Lighthouse (period 1964-1997) with six hour interval sampling. The data from Platform PXIV, had an one second during 10 minutes every hour (period 1995-1999).

The wind regimen found at the Platform PXIV during the period of 1995 to 1999, highlights the predominance of northeast (NE) winds with frequency of 24%, and average speed of up to 8.22 m/s (Figure 4). The east winds (E-NE) follow in frequency, with an average speed of 7.40 m/s. The SSE-S-SSW winds, together add 17% of occurrence, with speeds of up to 10m/s.

For the meteorological station of the Biological Reserve of the Arvoredo Island in the center-north of the coast, the predominant regimen of winds occurred from the south quadrant (s) with 18.47% and average speed of 6.52 m/s, the winds of the north quadrant (N) and northeast (NE) correspond 12.35% and 15.88% respectively, of the occurrences, with average speeds of 5 m/s.

For the south region of the coast wind analyzes obtained from the meteorological station of the Santa Marta Lighthouse, presented winds proceeding from northeast sector (NE) with a percentage of 21.69% of occurrence, and average speed of 7.63 m/s is the predominant one. The second highest occurrence of wind is from the south quadrant (S) with 10.62% of average occurrence speed of 6.11 m/s (Figure 4).

The wind regimen along the coast of Santa Catarina presented a difference between the stations. This difference can be attributed to the data registers of acquired superficial winds, for still presenting differences in of stations anemographic towers heights and for the difference of data collection methods, in relation to sampling interval. However, in a general way, it was possible to verify that the predominant wind is northeastward, represented by the platform PVIX and Santa Marta stations.

Where a similarity in wind regimen patterns between these two stations was evidenced, due to the absence of obstacles surrounding these, as the of platform PVIX station is located 100 miles offshore and the Santa Marta Lighthouse station in a coastal plain with low relief.

The results of the DDR (Direction of Resultant Drift) obtained by the sand roses agree with the general migration direction of the dune fields (Figure 5).

The Praia Grande dunefield presented a concordant DDR with the real direction of migration of dunes. The drift potential (DP) found was of 201.91 uv, that according with the wind energy classification proposed by Fryberger (1979), is a low wind energy Aeolian environment. A high directional variability, with a RDP/DP rate of 0.076, represents a complex regimen of wind. At Barra do Sul dunefield, a value of DP of 324 uv shows a intermediate energy wind regime with a high directional variability, and a RDP/DP rate of 0.12, presenting the complexity in the wind regimen that acts in this field. However the DP magnitude was considerably higher, since the average sand grain size of this field is smaller and the wind makes the sand grain transport more effective.

For superficial wind data corresponding to platform PVIX, DP values were obtained at the Ingleses and Lagoa da Conceição dunefields were 330 and 304 uv respectively. The DDR from sand rose does not accurately represent the direction of migration evidenced in the field. At Lagoa da Conceição (Joaquina) dunefield, analyzed with registers of superficial winds of the meteorological station of the Biological Reserve of the Arvoredo Island, DDR corresponds to migration route of the northwest (NW) fields, presenting a DP of 85 uv. seasonally this field has the most effective transport during winter and spring, however, the directional variability is intermediate throughout
all the stations, what represents contrary winds to migration direction of this field, thus characterizing, what BIGARELLA (1972) and BIGARELLA (2000) call reverse dunes. The same author does not associate the migration of these dunefields to the NE winds, as these would be hindered to act in the transport due to high topographical granites that borders the system.

The Siriú dunefield analyzed from the data of PXIV platform shows a DDR disagreeing with the real migration direction of the dunefield. This probably occurs because the south winds of this station are intense as north-east ones, with average speed of circa 8 m/s. Since the necessary speed to place the grain in movement is of 5.96 m/s what occurs is a balance of the resultant forces of these wind directions generating a resultant vector (DDR) that it does not accurately correspond to the reality observed in field.

In the same way, the results found here agree-with those obtained by BIGARELLA et al. (1972) that, on basis of the analysis of the sedimentary structures, showed that the direction of migration of the dunefields is southwest (SW) at the south of the State.

The Ribanceira dunefield presented a DP of 103 uv, being considered a regimen of low energy according to classification of FRYBERGER (1979). Winter and spring are the most effective in transport due to the northeast (NE) winds that are the predominant ones for this region; the same was evidenced by MARTINHO (2003), for this dunefield.

The Santa Marta Lighthouse/Camacho dunefield presented a DP of 285 uv, considered an intermediate energy wind, but very next to the limit of high energy winds according to classification proposed by FRYBERGER (1979). The directional variability, with a 0.37 rate, can be classified as intermediate to low. The seasonal and annual sand roses has a DDR that fully reflects the route of migration of this field. Seasonally observed pattern is similar to the ones of the Ribanceira dunefield. The obtained results were similar to the found ones by GIANNINI (1993) that pointed a similar drift pattern in this region.

The Santa Marta Lighthouse station was consistent with the sand rose and the DP found for the Siriú dunefield, with a DP of 279 uv, being classified as of intermedite energy the high one. The variability, with a 0.37 rate was classified as intermediate to low. This field also possesses annual as seasonal sand roses, concordant with the route of observable migration over the terrain. Seasonally the results obtained in drift potential calculations confirmed the pattern found by GIANNINI (1993), where the winter and spring winds are most effective in the transport.

CONCLUSION

Some factors must be taken in consideration when analyzing the processes of Aeolian transport, as: quality of superficial winds data; the choice of the meteorological stations for the verifications in relation to the dunefields to be analyzed and mainly the average sand grain size, when significant differences between the dunefields.

The pattern found reveals that the effect of average sand grain size to be considered in the analyses of Aeolian transport
processes and not only the winds directional variability, but also
the intensity of the superficial winds must be always analyzed
in relation to the average grain size when considered
variability between dunefields.

Thus, it was verified that the migration direction of the
dunefields agrees with the predominant wind (highest
occurrence) when the average speeds surpass the limiting
velocity of impact of the sand grain. However when this speed is
lower the average sand grain size of starts to determine the
migration direction of the dunefield in agreement with the
prevailing winds (highest intensity).

LITERATURE CITED

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