INFLUENCE OF MORPHOLOGY ON WIND FLOW AND SEDIMENT TRANSPORT PATTERNS ON TWO AQUITAINE COASTAL DUNES (SW, FRANCE)

Nicolas Robin, CEFREM, Université de Perpignan, France nicolas.robin@univ-perp.fr
Camille René, CEFREM, Université de Perpignan, France, camille.rene@univ-perp.fr
Antoine Lamy, CEFREM, Université de Perpignan, France, antoine.lamy1@univ-perp.fr
Emma David, CEFREM, Université de Perpignan, France, emma.david@etudiant.univ-perp.fr
Olivier Raynal, CEFREM, Université de Perpignan, France, olivier.raynal@univ-perp.fr
Alexandre Nicolae Lerma, BRGM, Régional Direction Nouvelle-Aquitaine, France, a.nicolaelerma@brgm.fr
Bruno Castelle, CNRS / Université de Bordeaux, France, bruno.castelle@u-bordeaux.fr
David Rosebery, Office National des Forêts, Paris, France, david.rosebery@onf.fr

INTRODUCTION

Coastal areas are one of the most attractive environments with tourism and residential resorts leading to ecosystem loss and beach-dune degradation. Coastal dunes are providing many environmental and ecosystemic services among which protection from wave attack and flooding hazard during storms. Worldwide, management plans generally seek to stabilize and maintain dunes. However, a few recent initiatives are promoting dune remobilization in order to boost ecosystemic rejuvenation or maintain their buffer role against hazards. In this context, the detailed assessment of wind-induced aeolian processes and resulting morphological change on coastal dunes has become an important research subject.

Across the coastal dunes, wind velocity and consequently sand transport is strongly controlled by the interaction between regional wind flow, vegetation cover and surface topography (topographic steering, Schwarz et al., 2020). Recently, knowledge has been improved on how winds erode, transport and deposit sand across coastal dunes, including the specific effects of vegetation and moisture as exemple (e.g Bauer et al., 2012; Hesp et al., 2015; Davidson et al., 2022). However, most of the existing studies are based on measurements collected along a single profile, thus limiting the understanding of alongshore variability and of the influence of the beach-dune profile on windblown sand pathways. The aim of this study is to address the differences on the wind flow pattern and resulting sediment transport during the same storm events at two beach-dune systems separated by only 7 km. The two field sites, which are exposed to the same ambient wind conditions, have contrasting dune profile morphologies primarily due to different human action (fixation/remobilization), allowing to discuss the impact of coastal dune management on aeolian processes.

STUDY AREA

Both field sites (FS1 and FS2, Figure.1) are located at Biscarrosse, on the Aquitaine coast (southwest France). The coast is approximately west facing, with an inclination relative to north of 14° and 6° in FS1 and FS2 respectively. The median sand grain size at both the beach and the dune is approximately 0.25 mm. It is a wave-dominated, meso-macrotidal environment (mean spring tide range of 3.7 m) with an annual mean offshore significant wave height of 1.8 m. Winter winds mainly come from the west, whereas dominant spring and summer winds come from north to northwest, driving a dominant eastwards aeolian sand transport across the two field sites.

FS1 dune crest is at 15 m/NGF, with a very steep dune front (around 36°) due to chronic marine erosion in the area. This managed dune is fixed with moderate vegetation density and is characterized by a sub-horizontal plateau. Dune shape of FS2 was modified a few years ago to promote its remobilization. The resulting current morphology shows a gently unvegetated stoss slope (around 11°) and a crest culminating at 25 m/NGF.

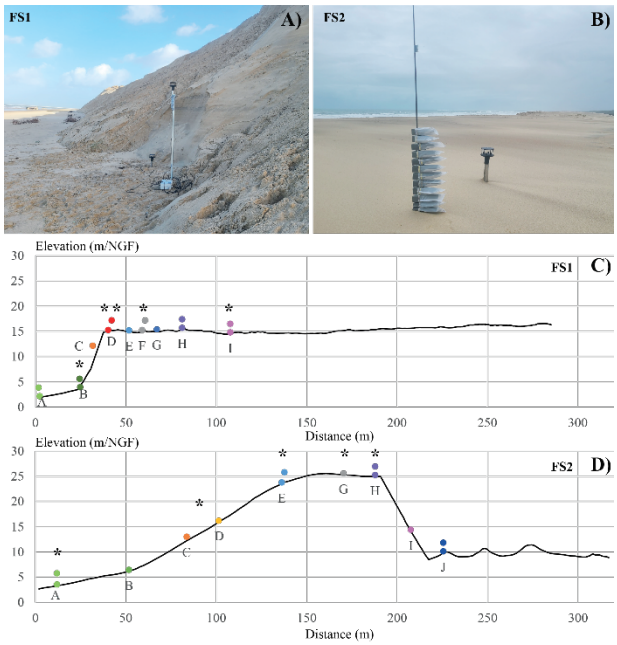

Figure.1: Photographs showing the foot dune at FS1 (A) and the ramp dune at FS2 (B). The locations of 2D anemometers utilized in the field measurements are indicated by circles on the profiles (0.3 m and 2 m above sand surface) and sediment traps by asterix points (C and D).

METHODOLOGY

A topographic survey was carried using a kinematic differential global positioning system (Trimble R8s) during the campaign. Wind flow and sediment transport across the dune were measured simultaneously at both FS during 48 h in November 2022. Variation in wind speed and direction were measured on the beach and across the

dune along a single transect, using ten (FS1) and eleven (FS2) 2D Windsonic (WS) anemometers (Figure.1). Data from all instruments was logged at 1 Hz and then averaged at 1 min. Colored smoke cakes and concurrent field videos were also used to qualitatively describe the 3D wind flow at different locations. Aeolian sand fluxes were measured during three experiments of 15 minutes at each FS using self-orienting, vertical-array sand traps. For each Aeolian sand transport measurements, five stations composed of twelve traps were deployed across the dune during runs of 15 min. The flux trap by trap is calculated, then integrated to get the total vertical sand flux.

RESULTS

During the campaign, mean wind velocities reached 20 m/s and wind directions from SW to NW were recorded at the reference station. During these stormy conditions, offshore significant wave height reached 6 m and the level of the high tide reached 4.3 m/NGF. The topographic evolution of FS1 shows an erosion of the beach of 0.25 m and a strong dune front retreat by 4 m driven by marine processes. On the sub-horizontal plateau, the absence of substantial/notable morphological evolution was observed. In contrast, the beach of the FS2 shows a weaker erosion by 0.18 m due to marine processes and a berm building. However, the dune foot location was unchanged. The dune ramp was an erosion around 0.17 m by aeolien processes but its top rose 0.2 to 0.8 m.

Compared to regional wind flow, near-surface wind speed on the beach at FS1 decelerated, reaching the minimum value at the toe of the dune front (Figure.2a). On the scarp, an acceleration of the wind is observed presumably due to the adverse pressure gradient. At the crest, a very localized roller vortex occurred with high wind speed at 2 m (landward direction) than 0.3 m (seaward direction, low speed). Orientation of the vortex changed in relation to the initial obliquity of the wind. Then, on the sub-horizontal plateau, wind speed increased. At FS2, a weaker deceleration is observed on the beach then an acceleration on the ramp of the dune (Figure.2b). A flow separation with large roller vortex is also observed, localized at the crest with the lee slope. At the back dune, the attenuation is higher when initial wind direction is perpendicular. Except on flow separation areas, we did not find any important differences in flow deflation at elevations of 2 and 0.3 m.

Sediment transport showed contrasting patterns between the two sites. In FS1, sediment flux on the beach is very low (0 to 0.1 Kg/m^2/h) due to the limited fetch on the narrow beach. The scarper dune face did not allow a transfer of sediment from the beach to the top and back of the dune. On the vegetated plateau, sediment flux is moderate from 14 to 50 Kg/m^2/h due to a lateral deflation area. In contrast, sand movement are substantial at FS2. Sediment flux increased between the beach (29 to 32 Kg/m^2/h) until the top of the stoss slope ramp (195 to 240 Kg/m^2/h). The flux decreased on the top of the dune (67 to 71 Kg/m^2/h) up to the limit with the crest of the lee slope.

CONCLUSIONS

This study illustrates very different wind flow patterns at two sites exposed to the same storm wind conditions but characterized by contrasting dune morphologies inherited from different management strategies. Thus, the sediment transport pattern is also drastically different as the response of the dune to hydrodynamic and wind processes during stormy conditions. At FS1 (a fixed dune by vegetation presenting a scarp induced by marine erosion), the top of the dune is very weakly supplied by sediment coming from the beach while on FS2 (presenting a gentle beach/dune slope and without vegetation (remobilization management)), beach and dune front are a source of sediment for the top and the back dune allowing its potential landward migration. These results should be put into perspective with management strategies in order to give lighting on condition able to produce dune remobilization depending on morphological state, evolutions at storm event or larger time scale and sediment availability.

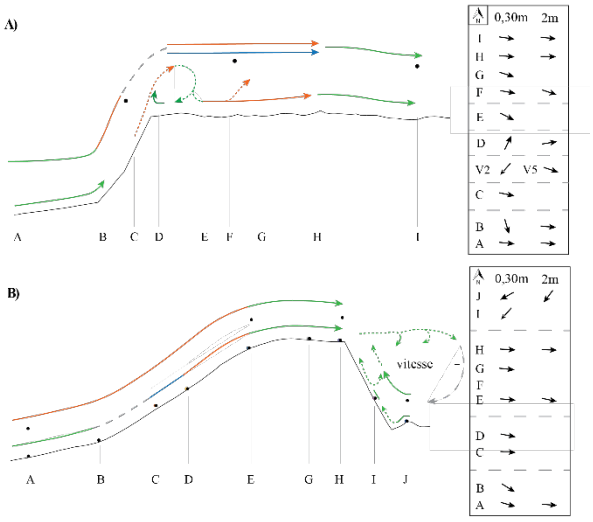

Figure.2: General model of the flow dynamics over the two FS during west (perpendicular) wind direction. Colors represent acceleration (red), stability (blue) or diminution (green) of the wind intensity. Wind directions on each part of the dunes are indicated on the right.

REFERENCES

Bauer, Davidson-Arnott, Walker, Hesp, Ollerhead (2012): Wind direction and complex sediment transport response across a beach-dune system, Earth Surface Processes and Landforms, WILEY, DOI: 10.1002/esp.3306.

Davidson, Hesp, DaSilva, Miot Da Silva (2022): Flow dynamics over a high, steep, erosional coastal dune slope, Geomorphology, ELSEVIER, vol. 402, 108111.

Hesp, Smyth, Nielsen, Walker, Bauer, Davidson-Arnott (2015): Flow deflection over a foredune, Geomorphology, ELSEVIER, vol. 230, 64-74.

Schwarz, Van Starrenburg, Donker, Ruessink (2020): Wind and sand transport across a vegetated foredune slope, Journal of Geophysical Research-Earth Surface? WILEY, vol. 125, 10.1029/2020JF005732.