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Faculty of Geosciences
Physical Geography

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Modelling airflow patterns in a man-made trough blowout

1. Introduction

Background

Coastal foredune systems have long been stabilized to ensure coastal safety. Nowadays high-quality safety assessments allow for a less strict management strategy in which more dune dynamics can be allowed. In this context several man-made trough blowouts have been created to promote dune dynamics and improve biodiversity. in the backdunes As there is little knowledge on how to optimize blowout layout for these purposes, the present approach is largely 'learning by doing'.

Problem definition

The behavior of wind in man-made blowouts and the associated erosion and deposition patterns are not well understood.

Aim

Creating a model set-up in which the wind patterns and associated shear stresses can be studied in order to optimize blowout layout.

2. Methodology

Model set-up

Using the open source Computational Fluid Dynamics (CFD) package OpenFOAM we modeled flow through a man-made through blowout created in the Dutch National park Zuid-Kennemerland. Blowout topography was obtained through aerial photography which was processed using a structure-from-motion algorithm into a 1x1m DEM (Ruessink et.al. ,2018). One of the in total five man-made blowouts (highlighted in red in Figure 1) was extracted from the topography. The domain was extended to the south and north of the area, where the domain was considered alongshore uniform. At the northern and southern boundaries cyclic boundaries were imposed to allow for tests with strongly oblique wind conditions. OpenFOAM was used with similar settings as in Hesp et al. (2017). At the off-shore boundary a logarithmic wind profile was assumed ($z\_0=0.0005$ m; $u(10)= 15$m/s).

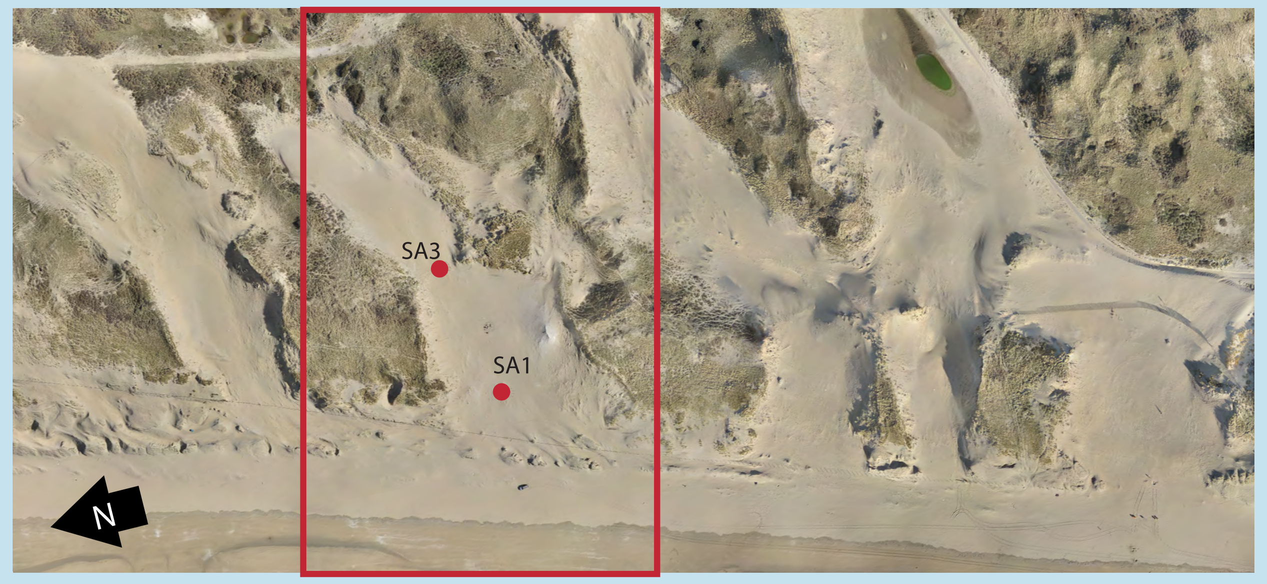


Figure 1: Orthomosiac of 5 blowouts in the Dutch National Park Zuid-Kennemerland created with photographs made on 15-3-2017. Red box highlights the blowout that was modelled. Red dots indicate the locations of sonic-anemometers stations. Station SA1 is located at the mouth of the blowout and SA3 is located in the most narrow part of the blowout. Black arrow points towards the north.

Wind data

The model outcomes were compared with data gathered with 2 sonic-anemometers (Figures 1 & 2) one placed at the mouth (SA1) of the blowout and one located at the narrowest part of the blowout (SA3). The timeseries were procssed into a 10minute mean windspeed, see abstract EGU2018-2088 by Ruessink et al.

Figure 2: Sonic anemometer station (SA3) during a storm (13 september 2017).

3. Main findings

Figures 3 and 4 show model results for runs with oblique winds approaching under an angle of 60° (214°N) with respect to the shore normal.

Wind speed Approaching the foredune the wind velocity increases as the height of the foredune increases (Figure 4b). Through the blowout wind accelerates up to 40-50% towards the most narrow part after which it decelerates again. On the upwind slope of the blowout the largest wind velocities inside the blowout are observed.

Wind direction On the straight parts of the foredune winds approaching the dune rotates toward a more alongshore direction (Figure 4c). At the blowout wind rotates toward the blowout axis. This continues through the center of the blowout after which it rotates back to the gereral wind direction At the edgesof the blowout wind rotates towards an along edge direction.

Model data comparison The model is able to simulate the observed flow acceleration between the mouth and the narrow part of the blowout. (Figure 5) However, the whole behavior appears to have shifted by approximately 30°.

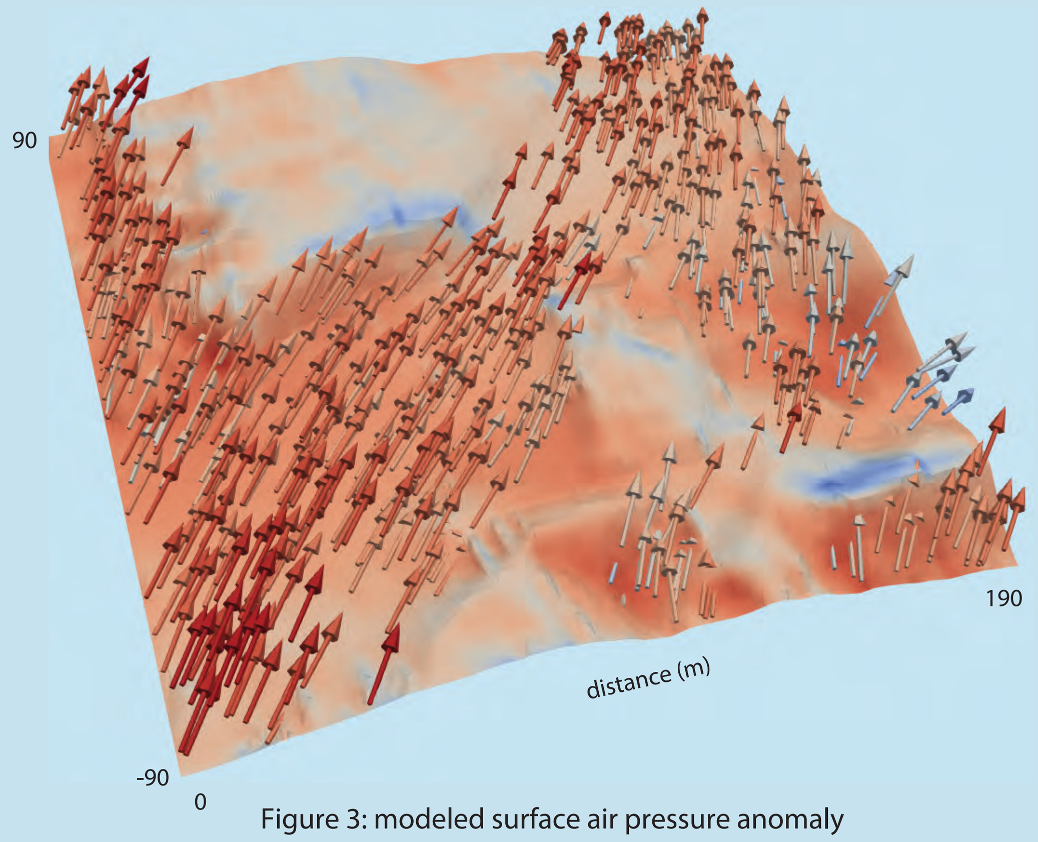


Figure 3: modeled surface air pressure anomaly ranging from -150 bar (blue) and 75 bar (red). Vectors indicate flow direction colors indicate wind speed ranging from 0 m/s (blue) to 16 m/s (red).

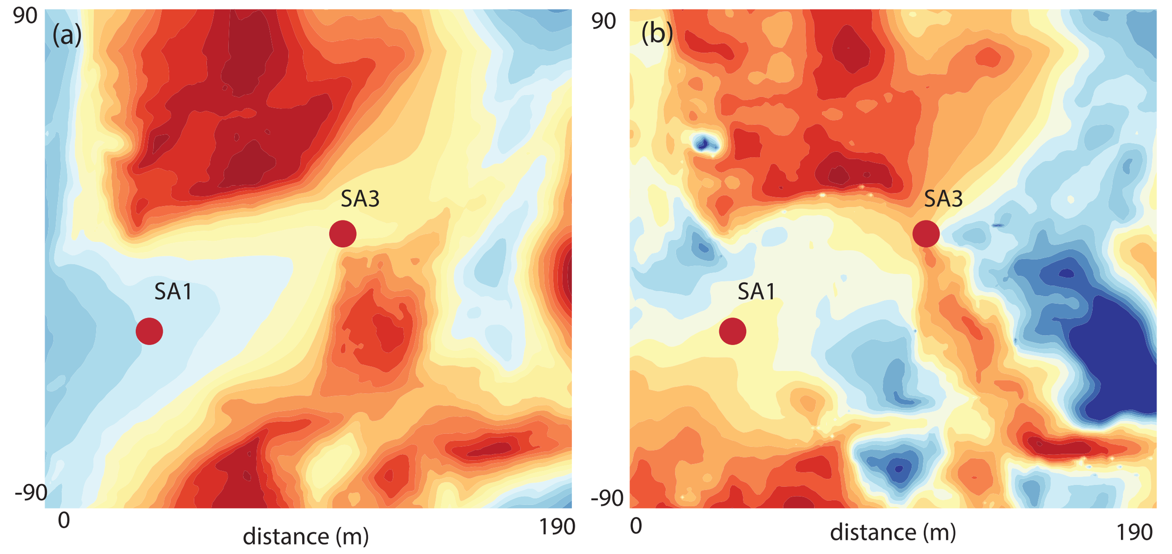
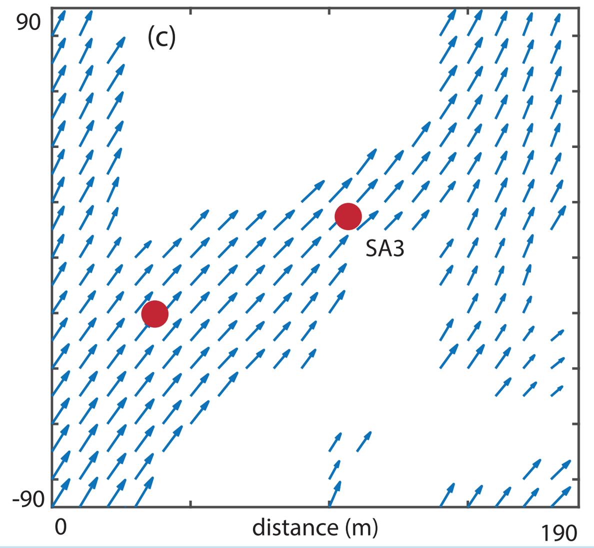


Figure 4: (a) topography of the blow-out area of the model domain, colour ranges between mean sea level (MSL) and MSL+22m in dark red. (b) wind velocity, colours range from 8 m/s (dark blue) to 17 m/s (dark red). (c) quiver plot of horizontal wind vector inside the blowout (parts higher than 14 m were cut for clearity).



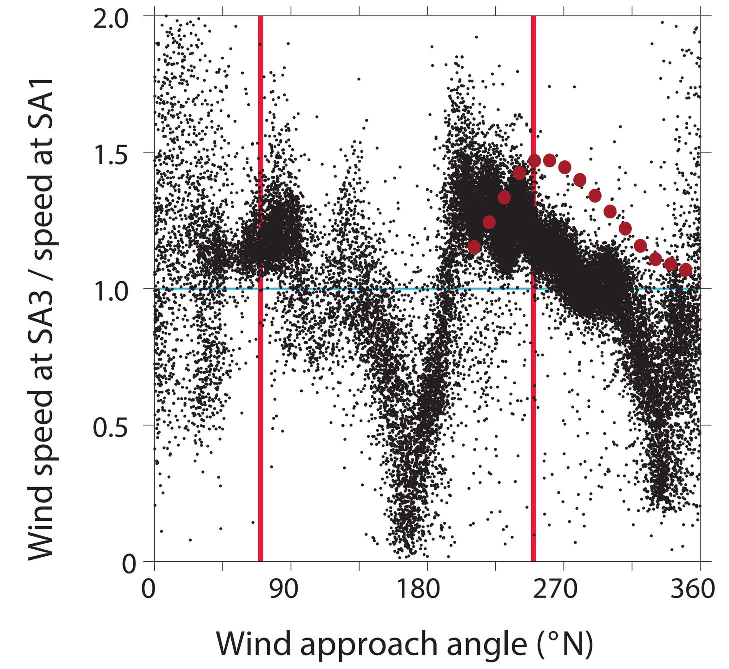


Figure 5: Modelled (red) and measured (black dots) flow acceleration from the mouth of the blowout towards the most narrow part of the blowout. Red lines indicate central axis of the blowout

4. Conclusions

- When wind flows through a blowout it first rotates from the main wind direction towards the direction of the main axis and then rotates back to the main wind direction.
- Highest wind velocities are found on the upwind blowout slope.
- Modelled wind behavior mimics that of observations but further improvement is required to improve resemblance.

5. Outlook

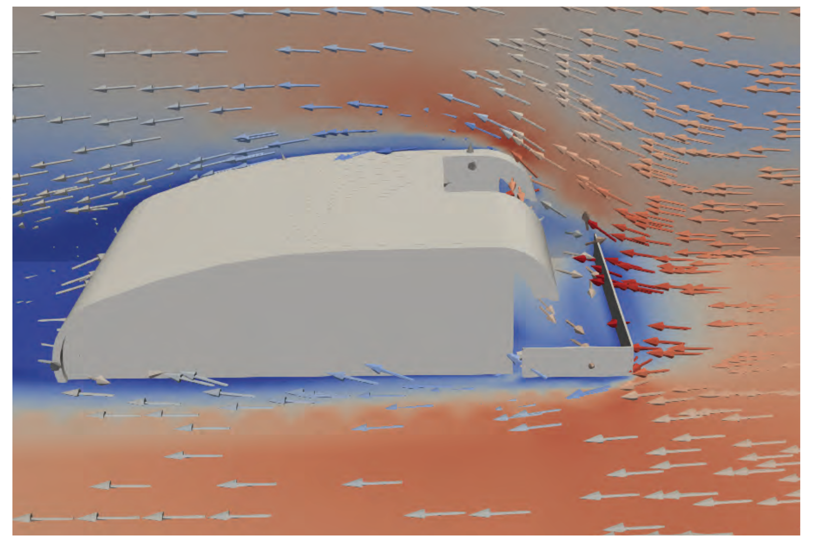
We aim to further improve the model by

- Increasing the grid density in the inner regions of the blowout.
- Adding Ekman rotation with height to boundary conditions.
- Studying the effects of different turbulence parametrisations (k-ε vs k-ω).

In future work we aim to use CFD to study:

- The effect of the orientation of man-made trough blowouts in relation to local wind climate.
- Shear stresses patterns in the through blowouts to determine where to expect erosion and deposition (and compare with observations).
- Wind flow around beach houses and restaurants (see Figure 6 for an example).

Figure 6: Modelled wind flow around a beach restaurant designed to be aerodynamicly smooth to limit the effects of wind whistling.



Acknowledgements

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References

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