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Physical Geography

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Long-term observations of airflow patterns in a man-made coastal trough blowout

1. Introduction

Background
Foredune stabilization for improved coastal safety has negatively affected geomorphological dynamics and biodiversity in coastal dune systems. As a remedy, foredunes are nowadays increasingly reactivated by digging trough-shaped depressions (Fig. 1a), resembling natural trough blowouts, to stimulate aeolian dynamics and improve biodiversity.

Problem definition
Learning-by-doing: Aeolian processes that steer the development of (man-made) trough blowouts are not well understood.

Aim
To analyze long-term (> seasons) observations of wind speed, direction and turbulence in a man-made trough blowout.

2. Methodology

Field site
The study site is a man-made trough blowout in Dutch National Park Zuid-Kennemerland excavated in winter 2012 (Fig. 1b; Ruessink et al., in press). The blowout is ≈100 m long, up to 11 m deep, and has a trapezoidal plan view that narrows from 100 to 20 m in the landward direction. Its main axis is aligned with the dominant southwesterly wind direction (250 °N).

(a)

(b)

(c)

Figure 1 (a) Man-made gaps through the 20-m high foredune at Dutch National Park Zuid-Kennemerland viewed from the sea. (b) Panorama view through one of the gaps, also showing the four measurement locations (SA1-SA4). (c) Close-up of SA2. The 3D ultrasonic anemometer is a Young 81000 RE.

Field data

- Four ultrasonic 3D anemometers, sampling at 10 Hz at 0.9 m above the bed, were installed in winter/spring 2017 from the mouth of the blowout (SA1), across its floor (SA2 and SA3), on to the depositional lobe (SA4) and have been operational since (Figs. 1b and c). The time series have been processed into 10-minute values of:
  1. Mean wind speed w_s [m/s]
  2. Wind direction w_d [°N]
  3. Turbulent kinetic energy, *TKE* [m²/s²], and relative wind gustiness, $\sqrt{TKE}/w_s$ [-]
- Wind recordings (w_s and w_d) of a nearby, offshore weather station serve as the seaward reference. The wind speed was transformed to a height of 0.9 m above beach level assuming a logarithmic velocity profile and a roughness length of 0.1 mm.

3. Main findings

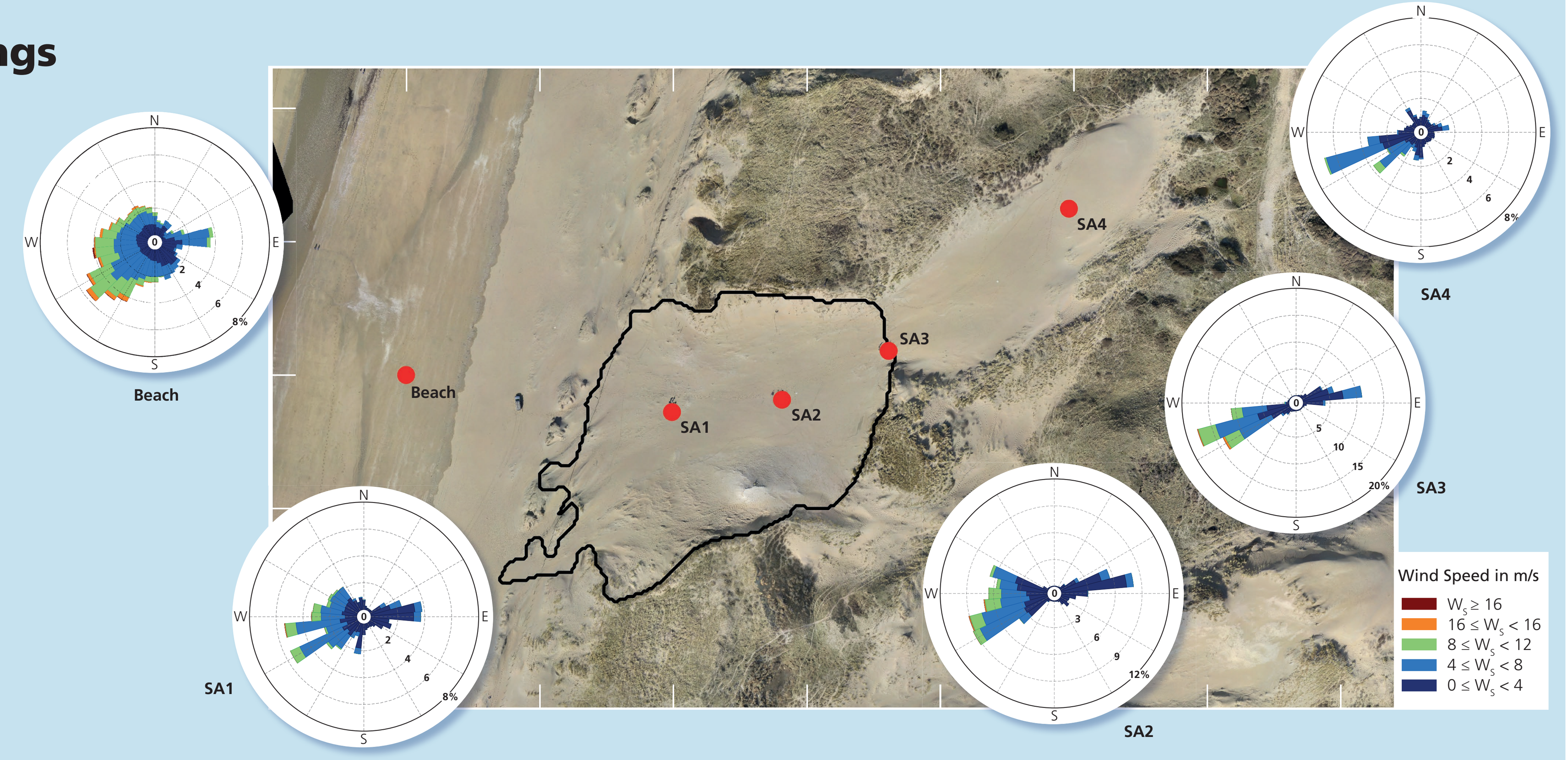

Figure 2 Wind roses based on all available 2017 data from the beach (offshore reference), through the blowout (SA1, SA2, SA3), on to the depositional lobe (SA4). Note that the frequency of occurrence at the outer circle is not constant: it varies from 8% (beach) to 20% (SA3). The black line outlines the blowout. Distance between tick marks is 50 m.

Wind direction The wind is topographically steered into the blowout (Fig. 2), to become approximately aligned with the blowout axis (250°N) at the landward blowout end (SA3). This steering happens for all winds that approach within 70° from the blowout axis (Fig. 3a).

Wind speed The wind in the blowout is generally strongest when it blows straight into the blowout (Figs. 2 and 3b). Shore-parallel winds essentially bypass the blowout (Fig. 3b). Wind speed-up is a function of offshore approach angle and is generally strongest (140%) when the wind is aligned with the blowout axis up to approximately 30° to the south of this axis (Fig. 3c).

Wind gustiness Wind gustiness in the blowout is a function of the offshore wind approach angle (Fig. 3d). The data indicate jet flow for approach angles near 250°N ($\sqrt{TKE}/w_s \approx 0.1$), changing into extremely turbulent flow ($\sqrt{TKE}/w_s > 1$) for winds approaching strongly obliquely.

Our observations confirm earlier observations of wind-patterns in natural blowouts, as presented in Hesp and Hyde (1996), Pease and Gares (2013) and Smyth et al. (2013), and extend these to a wider range of wind conditions. Also, our analyses include wind gustiness, which is potentially a relevant parameter for aeolian sand transport in blowouts (e.g., Hesp and Hyde, 1996).

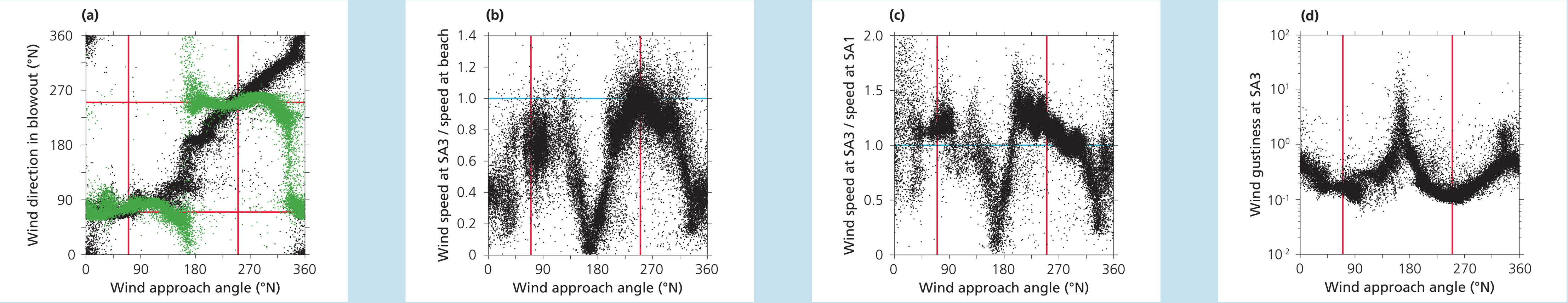

Figure 3 The offshore wind approach angle determines the wind (a) direction, (b) speed, (c) speed-up and (d) gustiness in the blowout. In (a), black and green dots are SA1 and SA3, respectively. The red lines in all panels indicate the blowout axis. The blue lines in (b) and (c) are a ratio of 1.

4. Conclusions

- Blowout geometry and offshore wind approach angle determine wind patterns in a man-made trough blowout.
- The wind is strongest, is accelerated most and is least turbulent when the wind blows straight into the blowout. Potentially, these wind conditions are most relevant to long-term throughput of aeolian beach sand toward the backdunes.

5. Outlook

Future work will include:

- Field measurements to obtain better spatial horizontal and vertical coverage of the wind patterns and to determine aeolian sand transport pathways.
- Computational Fluid Dynamics modelling (Fig. 4) to aid in the design of dune measures that optimize aeolian transport of beach sand into the backdunes. For first results, see abstract EGU2018-8627 by Donker et al.
- Vegetation studies to explore effect of increased aeolian dynamics on biodiversity.

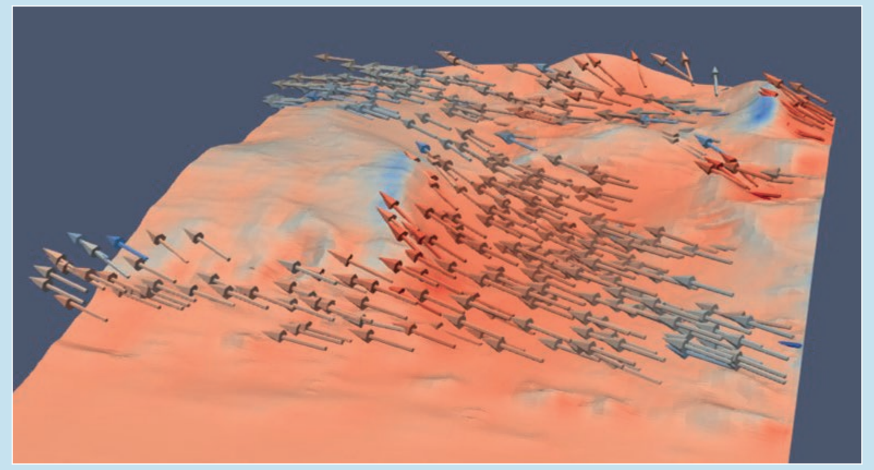

Figure 4 Example of a CFD model simulation under oblique wind approach.

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