Utrecht University

Netherlands Organisation for Scientific Research

Faculty of Geosciences
Department of Physical Geography

EP23C-2345
FALL MEETING

Predicting Potential Aeolian Sand Supply to a High and Steep Foredune

Gerben Ruessink,
Christian Schwarz, Pam Hage, Yvonne Smit, Winnie de Winter and Jasper Donker
Department of Physical Geography
Faculty of Geosciences, Utrecht University
Utrecht, the Netherlands
(b.g.ruessink@uu.nl)

1. Introduction

Background

Foredune growth results predominantly from sand that is blown landward from the beach and backshore. Predictions of multi-annual potential aeolian sand supply that are based on wind data from a regional meteorological station, however, often grossly overpredict measured deposition volumes on the dune.

Problem

High and steep foredunes modify the regional wind field but this is not considered in predictions of aeolian sand supply.

Aims

- To relate local (i.e., on the beach) to regional wind data using field measurements at a high and steep foredune and
- to quantify the effect of using local versus regional wind in predicting multi-year potential aeolian sand supply.

2. Modelling potential sand supply

We use Hsu (1971) to predict the onshore potential transport rate q_{on} [kg m^{-1} s^{-1}]. In default form, it reads

$$q_{on} = 0.1K\left(\frac{\alpha U}{\sqrt{gD_{cm}}}\right)^3 \cos(\theta_{SN}) \qquad (1)$$

Here, K is a grainsize dependent aeolian sand transport coefficient [g cm^{-1} s^{-1}], g is 981 cm s^{-2}, D_{cm} is the grain diameter [cm], U and θ_{SN} are the regional (at 10-m height) wind speed [m/s] and direction [deg with respect to shore normal], respectively, and α relates U to the friction velocity U_* in cm s^{-1}. With D_{cm} = 0.025 cm and α = 4 [Hsu, 1974], this results in the commonly quoted $q_{on} = 1.16 \times 10^{-5} \times U^3 \cos(\theta_{SN})$.

Here, we modify Equation (1) into

$$q_{on} = 0.1K\left(\frac{\alpha f_1(\theta_{SN})U}{\sqrt{gD_{cm}}}\right)^3 \cos(\theta_{SN} + f_2(\theta_{SN})) \qquad (2)$$

The θ_{SN} dependent function f_1 modifies the regional wind speed at a specific height z to the local wind speed at the same z. We *a priori* expect f_1 to equal 1 for alongshore wind ($\theta_{SN} = \pm 90°$) and to be between 0 and 1 otherwise, with a minimum for onshore wind ($\theta_{SN} = 0°$). The second function reflects the steering of the wind at the beach-dune interface. We expect it to be 0° for alongshore and onshore winds, and to be maximum for shore-oblique winds ($\theta_{SN} = \pm 45°$).

3. Regional versus local wind

Methodology

Wind speed and direction measurements in October 2017 using (1) 4 Ultrasonic Anemometers in a cross-shore array from the beach-dune interface to the waterline and (2) a mast of 5 cup-anemometers at Egmond beach (Netherlands, Figure 1). The latter data resulted in z_0 = 0.1 mm and α = 3.56. Regional data are available from the IJmuiden meteorological station, 15 km to the south of Egmond.

Figure 1 The beach at Egmond is bordered by a 20-m high, 1:2 sloping foredune.

Wind speed

(Figure 2a) Local wind speed is lower than regional wind speed, with the largest speed reduction (to about 70% of the regional value) for shore-normal wind.

Wind direction

(Figure 2b) The wind at the beach-dune interface is steered alongshore. The steering is maximum (about 15°) for shore-oblique winds, and minimum for onshore and almost alongshore winds.

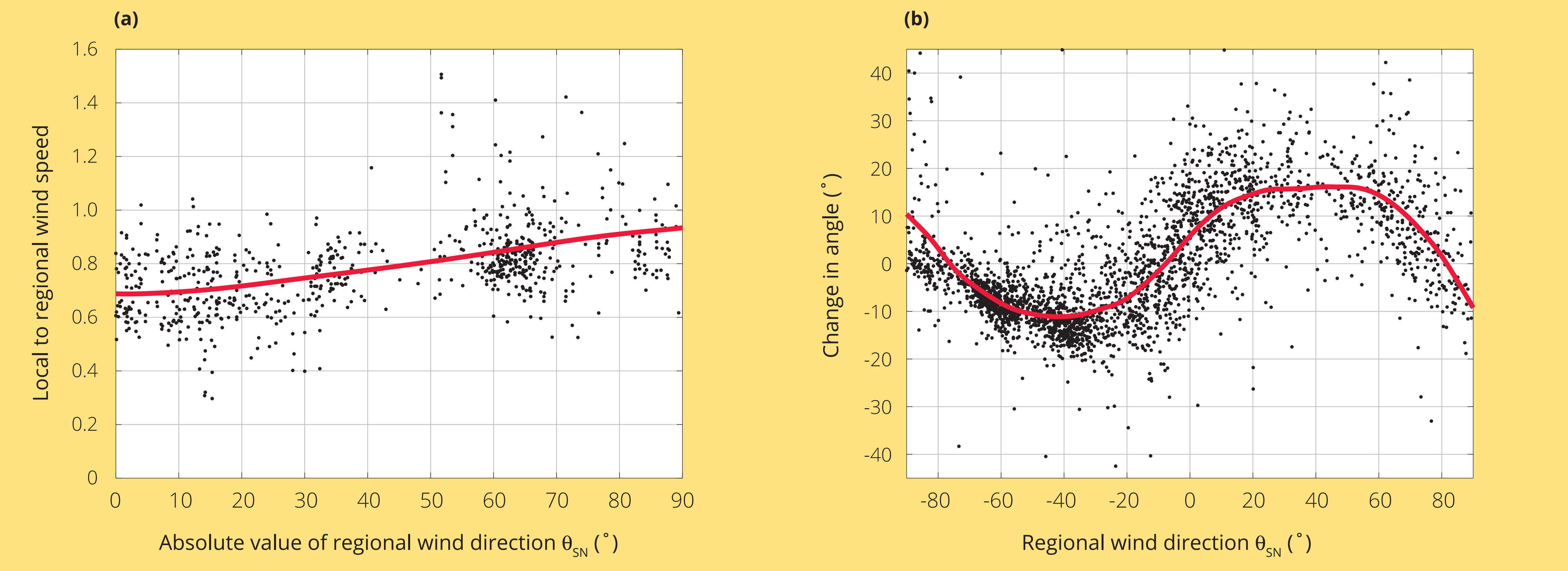

Figure 2 The regional wind direction θ_{SN} determines (a) the ratio of local to regional wind speed and (b) the degree of wind steering at the beach-dune interface. The red line in (a) and (b) represent f_1 and f_2 in Equation (2), respectively.

4. Predictions

Input

Ten years of regional wind data (2007-2016), converted to local data using correction functions of Figure 2, with D_{cm} = 0.025 cm, to predict potential annual supply Q_{on} [m^3 m^{-1} year^{-1}]. Measured deposition on the foredune is about 15 m^3 m^{-1} year^{-1} (Donker et al., 2018).

Output

(Table 1) The default scenario with regional wind data and α = 4 results in Q_{on} = 86.4 m^3 m^{-1} year^{-1}. With local wind data and α = 3.56, this reduces substantially, to 24.0 m^3 m^{-1} year^{-1}. Other scenarios illustrate that the reduction in wind speed affects Q_{on} more (60.9 to 28.2 m^3 m^{-1} year^{-1}) than the alongshore steering at the beach-dune interface (60.9 to 52.5 m^3 m^{-1} year^{-1}).

Table 1 Model predictions

Wind speed	Wind direction	α	Annual supply Q_{on} (m^3 m^{-1} year^{-1})
Regional	Regional	4.00	86.4
Regional	Regional	3.56	60.9
Regional	Local	3.56	52.5
Local	Regional	3.56	28.2
Local	Local	3.56	24.0

5. Conclusions and outlook

- The ratio of local to regional wind speed as well as the directional steering at the beach-dune interface depend on the regional wind approach angle. The largest reduction in speed (to 70%) is observed for onshore winds, and the largest steering (about 15°) for shore-oblique winds.
- The use of local wind data diminishes the overprediction of aeolian sand supply from the beach substantially (here, from a factor of 5.8 to 1.6).
- Future work will focus on (1) deriving regional to local conversion functions for arbitrary foredune shapes using Computational Fluid Dynamics and (2) exploring to what extent the remaining overprediction is due to supply-limiting factors, such as surface moisture.

Acknowledgements
We thank all MSc students and FGLab technicians involved in the 2017 Aeolex II campaign at Egmond.
Funded by the Netherlands Organisation for Scientific Research NWO under Vici-contract 13709.

References

- Hsu, S.A., 1971. Wind stress criteria in eolian sand transport. *Journal of Geophysical Research*, 76, 8684-8686.
- Hsu, S.A., 1974. Computing eolian sand transport from routine weather data. *Proc. ICCE*, paper 94, 1619-1626.
- Donker, J.J.A., M.C.G. van Maarseveen and G. Ruessink, 2018. Spatio-temporal variations in foredune dynamics determined with mobile laser scanning. *Journal of Marine Science and Engineering*, 6, 126; doi:10.3390/jmse6040126.

UU Geo C&M 9523