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Determining sand strip characteristics using Argus video monitoring

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ABSTRACT

The wind transports sand from the beach to the dunes and is therefore important for dune growth and recovery after a storm. Identifying the conditions that favour aeolian sand transport is especially important for narrow beaches, where measured long-term (seasons to years) deposition volumes on the foredune are often substantially less than the potential input from the beach. One of the most visually distinct signs of aeolian transport can be seen when relatively dry sand moves over a wet beach and organises itself to form low, slipfaceless bedforms. These features are known as sand strips. Here, we investigate the presence and characteristics of sand strips and their dependence on regional wind conditions by using a multi-year data set of video images of the Argus tower at Egmond aan Zee, The Netherlands. The dataset average wavelength and migration rate of the sand strips is 12.0 m and 1.24 m/h, respectively. Little to no relation was found between these two sand-strip characteristics and the wind velocity. The presence of these bedforms does not depend on wind velocity either, provided the wind velocity exceeds ~8 m/s. Instead, the wind direction determines if fully-developed sand strips form, as they are seen during alongshore or almost alongshore winds only. Our observations are indicative of topographic steering of the wind by the 25-m high foredune into the alongshore direction, as sand strips move alongshore even under onshore-oblique, regional winds.

1. Introduction

The intertidal beach is the primary source of the wind-blown sand needed for dune growth and/or recovery after an erosive storm event (e.g. Hoonhout and de Vries, 2017). However, knowledge of aeolian sediment transport on beaches is limited (e.g. Delgado-Fernandez, 2010), and most existing models have a tendency to overestimate sand deposition on the foredune (Miot da Silva and Hesp, 2010; Keijsers et al., 2014; Davidson-Arnott and Law, 1996). These models relate time-averaged sediment transport to wind shear velocity (Davidson-Arnott and Law, 1996; Bauer and Davidson-Arnott, 2002) and grain size (Sherman et al., 2013a). While this is realistic for a steady wind blowing over an unobstructed, horizontal surface with a uniform grain size (Gares, 1988; Sherman and Hotta, 1990; Bauer et al., 2009; Sherman and Li, 2012), transport on a natural beach is affected by, for example, the moisture content of the sand, the beach slope and the bed roughness (e.g. Delgado-Fernandez and Davidson-Arnott, 2011; Edwards and Namikas, 2009; Wiggs et al., 2004; Nield et al., 2013; Nield et al., 2014; Bauer and Davidson-Arnott, 2002; Svasek and Terwindt, 1974; Davidson-Arnott and Law, 1996; Jackson and Nordstrom, 1998; Sherman et al., 1998). Therefore, the moments with strong aeolian activity do not necessarily coincide with moments of high wind velocities (Delgado-Fernandez and Davidson-Arnott, 2011). Actual transport rates can be acquired through detailed field measurements (Sherman et al., 2017; Sherman et al., 2013b; Bauer et al., 2009; Davidson-Arnott and Bauer, 2009; Bauer and Davidson-Arnott, 2003; Udo et al., 2008; Davidson-Arnott et al., 2005; Jackson and Nordstrom, 1997; Baas and Sherman, 2006), however, most field campaigns on beaches concerning aeolian sediment transport are generally short in duration (ranging from minutes to weeks) and may therefore not contain the conditions that are most relevant to long-term (months to years) dune development (Delgado-Fernandez et al., 2009).

A suitable method for long-term measurements is video monitoring, which has already been used extensively to sample the wave-dominated part of the nearshore on timescales of years (van Enckevort et al., 2004; Ruessink et al., 2009; Pianca et al., 2015). Delgado-Fernandez et al. (2009) pioneered video monitoring to study aeolian transport. Their temporary camera system photographed the beach at Greenwich Dunes, Canada, at hourly intervals and occasionally picked up traces of aeolian sand transport during a nine-month period. Transported sand can be seen on video imagery because wind-blown sand usually is dryer and therefore lighter in colour than the moist bed, providing visual contrast. Additionally, the dry, transported sand can organise itself to form sand strips. These clearly visible, slipfaceless bedforms often form when a relatively moist bed is present (Bauer and Davidson-Arnott, 2002; Jackson et al., 2004; Davidson-Arnott et al., 2008; Bauer et al., 2009;

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Nield et al., 2011; Nield, 2011), especially when vegetation (Sherman and Hotta, 1990; Eamer and Walker, 2010), frozen material (Hesp and Arens, 1997), or other roughness elements are present as well. Sand strips can grow into ephemeral dunes, which have a slipface and a height in the range of decimetres to a metre (Guimarães et al., 2016; Kocurek et al., 1992; Elbelrhiti, 2012), but waves and tides often destroy sand strips before they can grow this far. Video monitoring has been used to study ephemeral dunes on a long-term timescale by Guimarães et al. (2016). Like the traces of aeolian transport in the work of Delgado-Fernandez et al. (2009), these features were visible on camera because of a difference in moisture content, and therefore colour, between the transported sand of the bedforms and the bed (McKenna Neuman and Langston, 2006).

The most extensive field research into sand strips has been conducted by Nield et al. (2011), who have measured sand strip patterns with terrestrial laser scanning for a period of three and a half hours after a rain event. During this field experiment, sand transport increased as the beach surface dried, with erosion taking place at wet/dry surface boundary, and deposition further downwind (Nield and Wiggs, 2011). The patterns were later described in a cellular automaton model (Nield, 2011). According to the model, sand strip development is related to bed roughness, saltation and moisture patterns. The results gave rise to a conceptual model where the feedback between the surface properties and transport processes results in the development of bedforms at different spatial scales. Despite sand strips being common features in wet aeolian systems (Bauer and Davidson-Arnott, 2002; Jackson et al., 2004; Davidson-Arnott and Bauer, 2009), their behaviour under a wide range of wind conditions is largely unknown. The aim of this paper is to quantify the presence, length and migration velocity of the sand strips found at the beach of Egmond aan Zee, the Netherlands, using long-term video imaging, and to determine how these characteristics depend on regional wind conditions.

2. Study area

The study site is located between the beach towns of Egmond aan Zee and Castricum, the Netherlands (Fig. 1). The beach has a width varying between 30 and 100 m (depending on the tide) and is moderately sloping (1:30). The coastline is straight, with an orientation of 7° east of north. The sand has a median grain size of 240 µm. The intertidal beach typically contains one or two slipface bars (Masselink et al., 2006; Aagaard et al., 2005; Quartel and Grasmeijer, 2007). The foredune forms a uniform row parallel to the beach, with a height of 20–25 m. Its seaward front is steep (40–50°), due to occasional erosion events (de Winter et al., 2015). Most of the foredune is densely covered by European marram grass (*Ammophila arenaria*), especially at heights of 10 m and more above beach level.

The site experiences a semidiurnal tide with a range of 1.4 and 1.8 m during neap and spring tide, respectively, and is exposed to waves with directions between southwest and north. The annual significant offshore wave height and period along the Dutch coast are 1.2 m and 5 s, respectively, and show small alongshore differences (Wijnberg and Terwindt, 1995). During storms the offshore wave height can be over 5 m. Especially storms from the northwest are associated with surges in excess of 1 m, which can flood the intertidal beach for several days (Quartel et al., 2007). The dominant wind direction at this beach is south-southwest (210–230° with respect to north, Fig. 2), meaning the wind has a strong onshore-oblique character.

The beach of Egmond is monitored by an Argus video system (Enckevort and Ruessink, 2001), an optical remote sensing system pioneered by Holman and Sallenger (1986) to sample the nearshore environment. An Argus system consists of a suite of cameras mounted on a high structure, which provides an unhindered view on the beach. A timing module ensures synchronous camera collections (Holman and Stanley, 2007). The Argus system at Egmond aan Zee has five RGB-colour cameras, mounted on a 45-m high tower standing on the upper beach. The cameras provide an 180° alongshore view, from south-southwest to north-northeast. The Argus system was installed in April 1998. The image resolution was 640 × 480 pixels from 1998 to February 2004, 1024 × 768 pixels from 2004 to August 2005 and 1392 × 1040 pixels since then. Three different, oblique images are produced by each camera every thirty minutes: a snapshot, a time-exposure (timex) and a variance image. Only the first two types are used here. The timex images are created by averaging snapshots that are taken with a frequency of 2 Hz over a 10-min period. This blurs out movement that took place within those 10 min, such as individual waves breaking on the subtidal bars, people walking on the beach, and aeolian streamers.

The theoretical accuracy of the images is given by the footprint dimensions of individual pixels. The footprint, i.e. the projection of a

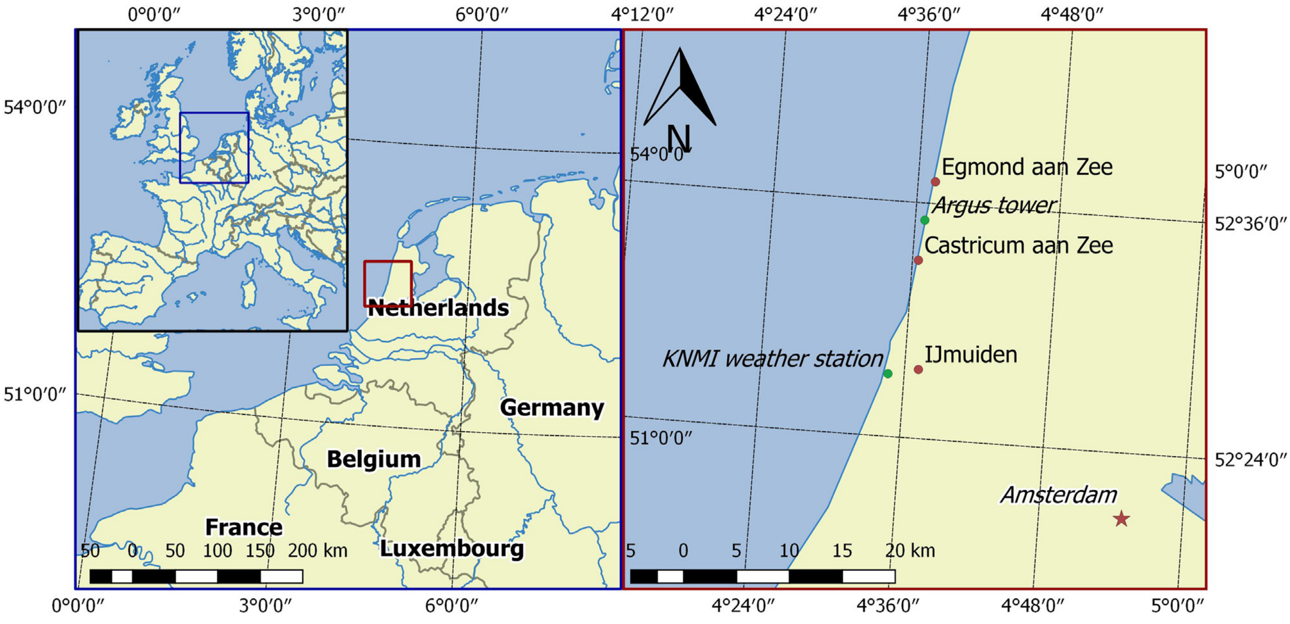

Fig. 1. Location of the field site and weather station.