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Measuring sediment deposition and accretion on anthropogenic marshland – Part I: Methodical evaluation and development

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ABSTRACT

The North Frisian Halligen (Northern Germany) are inhabited and highly anthropogenic modified coastal marshlands. Today a lack of knowledge about sedimentological parameters prevent for a predicated discussion on their adaptation capacity to recent and future sea-level changes. A combined field and laboratory method to calculate marshland accretion rates based on short-term (2010–2013) measurements of sediment depositions was developed. All studies were carried out at the marshlands of the Halligen Hooge, Langeness and Nordstrandischmoor. One litre LDPE bottles and small synthetic turf mats were used as simple but coast, time and quantity efficient sediment trap devices. Up to a deposition rate, of ≈ 2.0 kg/m^2, both devices gained comparable results. Above this threshold the retention efficiency of the turf mats is decreasing compared to the LDPD bottles. The combined use of bottles and mats, especially when deposition rates are not exceeding the threshold, allows to (1) checking internal consistency of the data, (2) detecting outliers with respect to cattle- or man-made damage, and (3) estimating possible effects of post-storm sediment remobilization. To transfer sediment depositions into rates of vertical accretion, the bulk dry density as well as the organic matter concentration of the correspondent marsh soil was considered using data from shallow percussion cores. These parameters are different among all Halligen. Higher inundation frequencies cause lower soil organic matter concentrations, resulting in higher bulk dry densities (BDD) of the soil (Hooge 0.64 g/cm^3, Langeness 0.67 g/cm^3, Nordstrandischmoor 0.83 g/cm^3). Autochthonous organic material (by source of the marshland vegetation) contributes by 9.0 ± 1.4 % (Hooge) to 21.4 ± 6.6 % (Nordstrandischmoor) to marshland accretion, for a correspondent time scale of 1915–2011. Average accretion rates (2010–2013) were calculated with 1.2 ± 0.8 mm/a for Langeness, 1.5 ± 0.9 mm/a for Hooge and 2.6 ± 0.9 mm/a for Nordstrandischmoor.

1. Introduction

The adaptation of tidal environments, especially of salt marshes due to a changing hydrographical environment has been recently discussed by various studies (Craft et al., 1993; Allen, 2000; D'Alpaos et al., 2007; Kirwan and Guntenspergen, 2010; Andersen et al., 2011; Schuerch et al., 2012; Spencer et al., 2012; Suchrow et al., 2012). Just as much data exists about salt marsh accretion in relation to recent and future sea level changes (van Wijnen and Bakker, 2001; Morris et al., 2002; French and Burningham, 2003; Bartholdy et al., 2004; Kolker et al., 2009; Kirwan et al., 2010; D'Alpaos et al., 2011; Schuerch et al., 2013). Nevertheless, most of these studies were examining natural or semi natural tidal marshlands, which have to be distinguished from the marshlands of the North Frisian Halligen. At the beginning of the 20th century, massive coastline protection constructions like revetments and shallow dykes turned the Halligen into an "anthropogenic" marshland. The consequence of these measures was a decrease of the inundation frequency and changes in the sediment availability and distribution.

The present study, presents the first part of two coupled papers about short- to long-term sediment deposition and marshland accretion on the Halligen, dealing with the development and evaluation of field methods to measure the annual sediment deposition and vertical accretion on those anthropogenic marshlands. In detail two reasons forced us to conduct additional methodological research on this topic. (1) The infrastructural conditions of the Hallig marshland as well as the temporal limitation of a three year lasting research project revealed the need for a transportable and easy to handle sediment trap, which could be used in high

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quantity. Long-term measurement devices for a direct measurement of accretion rates like sedimentation-erosion tables (SET) or bars (SEB) (Cahoon et al., 2000, 2002a, 2002b; van Wijnen and Bakker, 2001) as well as sedimentation plates (French and Burningham, 2003), which provide reliably results only after decades could not be used during the present study. (2) Previous studies have shown that the organic content of flood related sediment depositions on coastal marshlands is highly variable (Craft et al., 1993; Neubauer, 2008) as well as the content of soil organic material with regard to increasing soil depth and time (Bartholdy et al., 2010). Hence, it is essential for the calculation of long-term vertical accretion rates based on annual, short-term sediment depositions (see chapter 2, definition of terms), to know the proportion of organic to clastic sediment contents both of flood sediments and the correspondent soil. For the calculation of vertical accretion from deposition rates we developed a new approach which has not discusses so far.

With regard to those presettings, the main objective of the current study is to (1) test if one litre LDPE bottles in combination with synthetic turf mats could be used as simple but suitable sediment traps to measure short-term sediment deposition rates and (2) to evaluate if the deposition data could be used to calculate long-term accretion rates instead of using direct methods like SEBs/SETs and plates.

The second paper "Measuring sediment deposition and accretion on anthropogenic marshland – part II: The adaptation capacity of the North Frisian Halligen to sea level rise" deepens a discussion about marshland accretion, its spatial distribution patterns and the adaptation capacity of the Halligen Hooge, Langeness and Nordstrandischmoor to recent sea-level change based on the dataset conducted by methods introduced in the first paper. The measurement of annual short term sediment deposition (2010–2013) is complemented by a ^{210}Pb and ^{237}Cs dating campaign on 12 percussion cores of these Halligen.

2. Definition of terms

Commonly the term "sedimentation" is widely used when referring to different processes leading to surface adjustment in tidal environments. In this study we adapted the terminology of Cahoon et al. (1995) and van Wijnen and Bakker (2001), which lately was supplemented by Nolte et al. (2013). Terms are (1) suspended sediment concentration (SSC) in mg/l, (2) sediment deposition in g/m^2 or kg/m^2, (3) vertical accretion and (4) surface

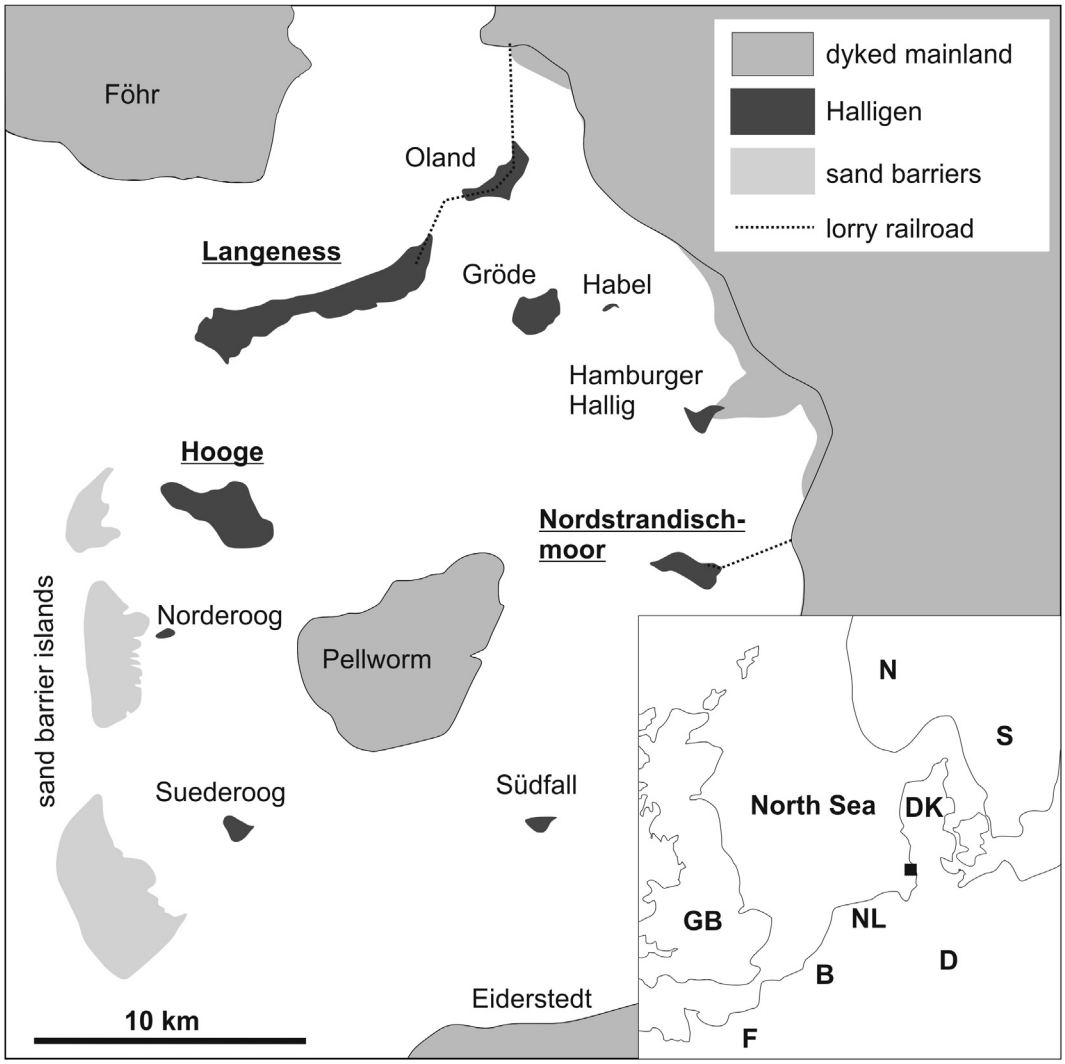

Fig. 1. Location map showing the most northern region of the German Wadden Sea between the islands of Eiderstedt (south) and Föhr (north). The three Hallig marshlands, correspondent to this paper are labeled in bold. Outline map of the North Sea Region: N=Norway, S=Sweden, DK = Denmark, NL= Netherlands, D = Germany, B=Belgium, F=France, GB = Great Britain, black rectangle = study area.