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Long-term and high-resolution measurements of bed level changes in a temperate, microtidal coastal lagoon

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Abstract

This study presents the results of a long-term monitoring program of bed level changes measured during 8 yr at an intertidal mudflat in a microtidal, temperate coastal lagoon. Additionally, bed level measurements obtained at a 10-min temporal resolution at the same tidal flat and at the bed of a nearby tidal channel are presented. Short-term changes in bed level are one or two orders of magnitude larger than the annual net-deposition rate, which shows that the environment is highly dynamic with respect to erosion, transport and deposition of fine-grained sediment. Some seasonality in the bed level changes was observed and there is a tendency for mudflat deposition in spring, summer and early autumn and erosion during the rest of the year, but interannual variations are large and different parts of the mudflat show different seasonal signals. A close coupling between sub- and intertidal deposition and erosion was observed. The time-series showed that some of the material eroded from the mudflat was not exported to the open sea, but instead temporarily deposited in a nearby shallow tidal channel and later returned to the mudflat during calmer weather conditions. These findings support previously published hypothesis and results of modelling studies. Based on the observed abundance of fine-grained sediment at the study sites and the high accretion rates generally found on fine-grained tidal flats in the Danish Wadden Sea area, it is argued that these fine-grained tidal flats are not seriously threatened by the expected sea level rise in the 21st century.

Keywords: mudflat; sediment transport; erosion; deposition; bed level; sea level rise

1. Introduction

Mudflats are abundant on many coasts worldwide and are often found in estuaries and coastal lagoons but may also be situated at exposed coasts if the supply of fine-grained sediment is large. Intertidal mudflats are generally accretionary and a large part of the fine-grained material found in estuaries and coastal lagoons will eventually end up in the associated mudflats. They are often important habitats for various macrozoobenthic species and provide feeding grounds for both fish and birds. They may also act as natural shoreline protection and this ability is one of the reasons for the increased interest in intertidal mudflats. The location in the intertidal zone and the inherent sensitivity to sea level changes also calls for attention due to the possible future sea level rise caused by global warming. Recent interdisciplinary European research programmes (e.g., LISP UK, Black and Paterson, 1998; INTERMUD, Dyer et al.,

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2000) have shed increased light on the complex sedimentological processes and the generally strong interaction between biota and sediments. The sediment dynamics on an intertidal mudflat was addressed in an early review by Anderson (1981), but quantification of a number of key processes only took place recently, partly due to lack of appropriate measuring equipment. The mediation of the erodibility of fine-grained sediments by both microzoobenthos and macrozoobenthos has for example now been described for several species and field sites (e.g., Nowell et al., 1981; Paterson, 1989; Yallop et al., 1994; Widdows and Brinsley, 2002). In spite of these studies, little is still known about the net-effect of biotic processes with respect to mudflat sedimentation and budgets of fine-grained sediments although a few modelling studies have indicated that this effect may potentially be large (Wood and Widdows, 2002; Widdows et al., 2004; Lumborg et al., in press).

Although mostly situated at sheltered sites, mudflats may show substantial sediment reworking induced by waves and currents (Christie et al., 1999; Kirby, 2000) and some studies of the hydrodynamics and sediment transport on tidal flats have been carried out in the past (e.g., Pejrup, 1986; Christie et al., 1999; Bassoullet et al., 2000; Andersen and Pejrup, 2001). These studies have given valuable insight into the sediment dynamics at mudflats and for example highlighted the importance of waves. However, one of the major challenges for such studies is that the net-deposition which takes place is normally orders of magnitude smaller than the gross-deposition and it has generally not been possible to determine the net-deposition from measurements of the hydrodynamics at the study sites. A possible solution to this problem is to undertake measurements of the actual accumulation/erosion, which takes place by repeated measurements of bed level.

Bed level changes on tidal flats occur on a wide range of timescales spanning from tidal cycles to decades or longer. Recordings of bed level changes in intertidal environments have generally been few and the periods between measurements have mostly been days when tidal cycles were investigated and months when longer periods like years were addressed (e.g., Kirby et al., 1992; Allen and Duffy, 1998; O'Brien et al., 2000; Andersen and Pejrup, 2001). Such measurements give valuable information on the amount of sediment cycling and redistribution and may also record seasonal and yearly changes in sediment deposition. Measurements at high temporal resolution provide detailed information on the sediment dynamics but only few studies have been undertaken and they were generally restricted in time to days or weeks (e.g., Bassoullet et al., 2000; O'Brien et al., 2000; Gouleau et al., 2000; Lund-Hansen et al., 2004).

The purpose of the present study has been to examine the short- to medium-term sediment dynamics at a temperate microtidal mudflat and in a nearby tidal channel by use of manual and automated acoustic bed level measurements for longer periods. The results of these measurements are then discussed in terms of possible seasonal signals and the possible biological contribution to such seasonalities. The implications for the dynamics of fine-grained sediments in the entire coastal lagoon are also addressed.

2. Study site

The main investigation site is the Kongsmark mudflat situated in the microtidal Rømø Bight (Fig. 1), which is part of the Lister Dyb tidal basin. Additional bed level measurements were carried out in a tidal channel situated 3.6 km south of the mudflat station. The tidal range in the basin is about 1.8 m (Pejrup et al., 1997) and the water column is well-mixed due to low freshwater inflow and frequent mixing by wind waves. The sediments in the tidal basin are generally sandy but muddy sediments are found in the sheltered parts of the basin. A causeway connecting the barrier island Rømø with the mainland was finished in 1948 and fine-grained sediments have accumulated in large parts of Rømø Bight since then. The net accumulation at the mudflat (inferred form ^{210}Pb and ^{137}Cs dating) is about 15 mm yr^{-1} (Andersen and Pejrup, unpublished data). The average local sea level rise has been 1.3 mm yr^{-1} during the last century, but has increased recently to about 4 mm yr^{-1} for the last 25 yr (Nielsen and Nielsen, 2002).

Maximum current velocities measured 0.5 m above the bed are only about 30 cm s^{-1} at the mudflat and about 50 cm s^{-1} in the tidal channel. However, wind-generated waves often cause erosion of the bed at the mudflat as shown by numerous time-series records of the suspended sediment transport (Andersen and Pejrup, 2001). The mudflat site is very fine-grained with a sand content mostly below 2% and the bed is hosting a large macrozoobenthic population including the bivalves *Cardium edule*, *Macoma balthica* and *Mytilus edulis*, the polychaete *Nereis diversicolor* and the prosobranch *Hydrobia ulvae*. The channel site is mainly composed of sandy and mixed sediments and the macrozoobenthic community is very sparse with