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Coarsening of tidal flat sediments - long-term mud depletion in a tidal bay in the northern Wadden Sea (SE North Sea)

Tobias Dolch

Alfred Wegener Institute for Polar and Marine Research, Wadden Sea Station Sylt, Germany

Abstract

The Wadden Sea is a highly dynamic system characterised by unconsolidated sediments and continuous changes which are mainly driven by hydrodynamics. The grain size composition of the tidal flats reflects information on the prevailing hydrodynamic conditions. The long-term development of the grain size composition of tidal flat surface sediments was surveyed in a shallow semi-enclosed bay in the northern Wadden Sea in order to gain information on changing hydrodynamic forces. Surface sediments were sampled during low tide from November 2004 to December 2006. The outcome was a general spatial distribution pattern of sediment types which was compared to earlier surveys conducted in 1932 - 1933, 1981 and 1989. A significant general coarsening of the surface sediments can be observed over the last 70 years. It is suggested that changing hydrodynamic conditions, that accompany ongoing climate change, are primarily responsible for the mud depletion. The coarsening of sediments is furthermore supported by rigid coastal protection measures, which increase energy levels in the bay, and a reduced areal extent of intertidal seagrass and mussel beds which means a reduction of sheltered areas.

1 Introduction

The shallow sedimentary coastal zone of the south-eastern North Sea is called the Wadden Sea. It is a highly dynamic system characterised by unconsolidated sediments and continuous changes which are driven by waves, currents, tides (hydrodynamics) and wind. The Wadden Sea's most remarkable features are the tidal flats which are exposed during low tide. The grain size composition of tidal flat sediments reflects information on the prevailing hydrodynamics. The aim of this study is to gain information on long-term changes in the grain size composition of these sediments in order to reveal possible relation to a shift in the hydrodynamic regime that might accompany ongoing climate change.

2 Study area and methods

The study area is Königshafen (55° 02' N, 8° 25' E), a sheltered tidal bay at the island of Sylt located in the northern Wadden Sea (figure 1). The tides are semidiurnal with a mean tidal range of 1.8 -2 m. The current velocities vary from 0.6 m s-1 in a tidal channel near the opening of the bay to 0.1 m s-1 in the inner Königshafen (Backhaus et al. 1989). The tidal flats are primarily sandy but muddy and mixed sediments occur in sheltered locations (figure 2, 2004 - 2006).

Surface sediment samples of 129 equally distributed stations in the Königshafen were collected during low tide in 15 sampling campaigns at regular intervals from November 2004 to December 2006. The averaged sediment data were georeferenced with a Geographic Information System (GIS) and area-wide maps calculated. The outcome was a general spatial distribution pattern of sediment types. This pattern was compared to earlier surveys conducted in 1932 - 1933, 1981 and 1989.

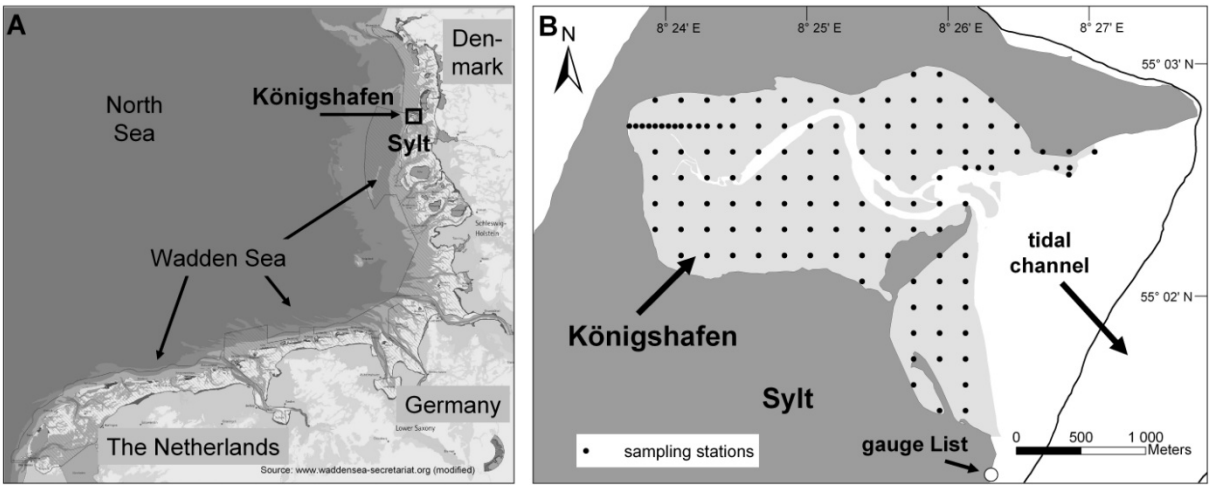

Figure 1: The sampling stations on the tidal flats of the study area Königshafen (B) at the northern top of the island of Sylt, located in the Wadden Sea (A)

3 Results

The current sediment distribution pattern reveals that finest sediments occur in the inner part while coarser sediments occur in the eastern half of Königshafen (figure 2, 2004 - 2006).

From 1932 - 1933 to 2004 - 2006, the intertidal mud cover decreased from 21 % to 2 % while sand cover increased from 68 % to 90 % (figure 2). The increasing sand dominance results from a loss of mud flats. The decrease of mud flats occurred primarily in the more exposed eastern half of Königshafen near the opening which is bordered by a major tidal channel (figure 1).

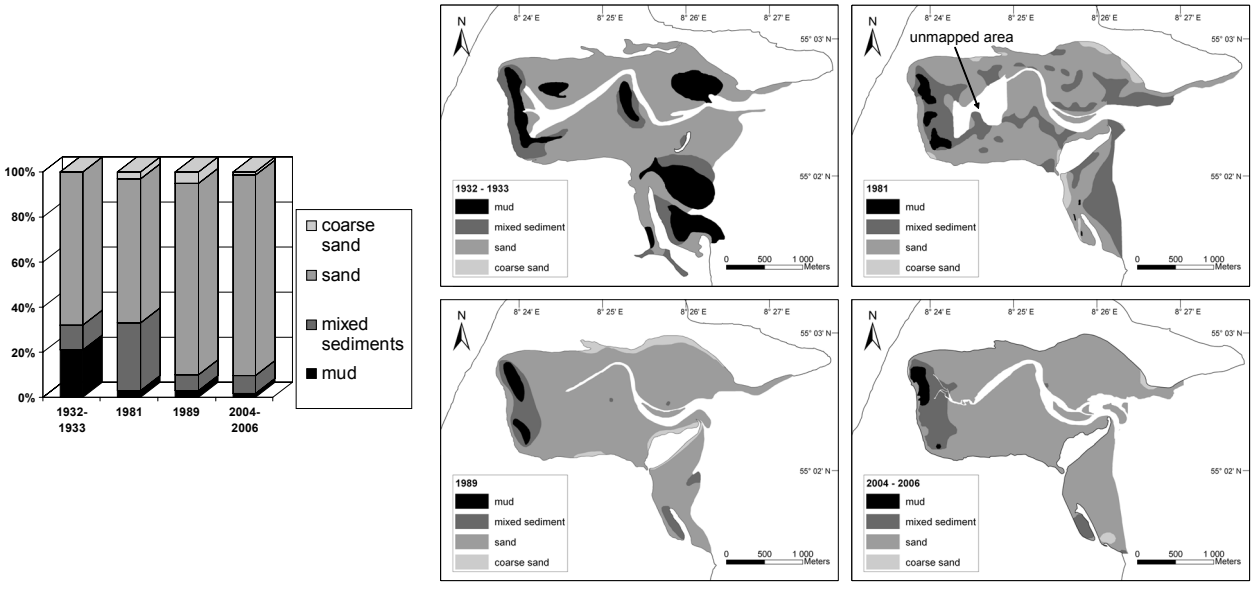

Figure 2: Sediment distribution in Königshafen in 1932 – 1933 (Wohlenberg 1937), 1981 (by Felix), 1989 (by Austen) and 2004 - 2006 (own data)

4 Discussion and conclusions

It is suggested that changing hydrodynamic conditions that accompany ongoing climate change are primarily responsible for the mud depletion. Long-term records from the gauge List show that the mean low tide level remained relatively stable at 402.9 cm (1936 – 2005), while the mean high tide level rose from 567.81 cm (1936 – 1945) to 585.23 cm (1996 – 2005). This results not only in an increased high tide level but also in an increased tidal range. Both phenomena are associated with stronger currents. The increased hydrodynamic conditions cause selective removal of fine-grained sediments and hamper mud deposition. As the opening of Königshafen is located in vicinity to a major tidal channel, the eastern half is more exposed and a decline of mud flats is predominant here.

Increased hydrodynamics are also caused by a reduction of the tidal catchment area which leads to higher energy levels within a bay (Flemming & Nyandwi 1994). Considerable embankment took place in Königshafen and the associated List tidal basin over the past 500 years, resulting in a loss of 1/3 of the tidal flat area (Reise 1998).

Mud depletion is furthermore supported by a severe decline in seagrass bed and mussel bed area (with algae cover): from 31 % (1936) to 9 % (2005) referring to the tidal flat area of Königshafen (own data). Both structures provide shelter from stronger currents and the decline of seagrass and mussel beds means fewer areas where mud flats can establish or remain.

However, coarsening of sediments is not just a local phenomenon but is reported from the entire Wadden Sea, e.g. the Dutch Wadden Sea, the East Frisian Islands and from the Hörnum tidal basin south of the island of Sylt (Flemming & Bartholomä 1997, Mai & Bartholomä 2000, Zwarts 2003, Van Bernem, pers. comm.). The change in sediment composition does not only reveal changed hydrodynamic conditions but surely has also an impact on the benthic fauna.

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Address

Tobias Dolch
Alfred Wegener Institute for Polar and Marine Research - Wadden Sea Station Sylt
Hafenstr. 43
25992 List, Germany

Tobias.Dolch@awi.de