A Spaceborne View at Archeological Sites on Intertidal Flats on the German North Sea Coast

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Abstract – More than 375 years ago, a big storm surge in the German Bight of the North Sea destroyed farmland, farms, and villages, and killed a great number of both cattle and men. The big (second) "Mandränke" of 1634 is still one of the most famous storm surges in the area of the North Frisian Wadden Sea. We present first results of our analyses of spaceborne SAR data, which show imprints of former settlements in the area, which was destroyed by the "Mandränke". For the first time, data from the high-resolution TerraSAR-X are used to demonstrate that residuals of former agricultural areas can still be detected from space. The data are complemented by aerial photographs and in-situ data.

Keywords: SAR, Wadden Sea, fossil landscapes, storm surges, TerraSAR-X.

1. INTRODUCTION

In the Middle Ages, farmsteads and villages were built along the German North Sea coast, surrounded by farmland and also floodplain forests. The houses were mostly built on dwelling mounds, protected by small dikes, and ditches were built to take out the water of the farmlands. In the mid 14th century, a period of bad harvests due to cold summers, corresponding hunger, and the Black Death in 1350, the population in that area was reduced by about 75%. As a result, the small dykes had been in a bad condition. On January 16, 1362, after more than 24 hours of severe storm, the small dykes broke and a great number of both cattle and men died. During that storm surge, large land areas used as farmland were lost to the sea, and they haven't been diked ever since. After this biggest catastrophe of the late Middle Ages in northern Europe it took a long time until new dikes were built to protect the marsh land. The new farmland was structured by a wide-meshed system of ditches. Dykes enclosed larger polders than in the centuries before, and farmhouses on terps were connected by narrow lanes. Still there was ongoing land destruction by the extraction of salt; however, the marsh land had also become an important region for farming.

Another major storm surge occurred on October 11, 1634, again destroying farmland, farms, and whole villages, and killing cattle and men. The big (second) "Manndränke" is still the most known storm surge in history in the area of the North Frisian Wadden Sea. Major parts of the populated area were destroyed and the swampy land changed its face and became the Wadden Sea as it is known in modern times. Over the years, great parts of this former agricultural area have been buried by muddy and sandy sediments, which nowadays form the German Wadden Sea, and which fall dry once during each tidal cycle. Under the permanent action of the tidal forces, morphodynamics take place, the muddy and sandy marine sediments are partly driven away, and traces of former peat digging, farmland, and settlements appear again on the bottom of the Wadden Sea. These sedimental structures show distinct biological effects and are often marked by benthic organisms. Since those areas are difficult to reach and, thus, to observe from the ground, spaceborne sensors have proven to be advantageous for a systematic observation of the residuals of those historical places.

2. RESULTS

When today erosion moves away the muddy and sandy marine sediments on intertidal flats, banks of peat, old clay, and structures of farmland and settlements appear again on the dry-fallen surface. Fig. 1 shows an aerial photograph taken in July 2009 from dry-fallen intertidal flats north-east of the German island of Pellworm. Clearly visible are linear structures that witness the historical land use, before the great "Mandränke". Also visible is the sandy sediment, by which those structures were buried, and which was driven apart by the action of currents and waves.

Figure 1. Aerial photograph taken on July 29, 2009, at low tide and showing residuals of former settlements in the German Wadden Sea, close to a tidal creek (upper left). Image courtesy of Kai Eskildsen, LKN.

Fig. 2 shows a reconstruction of a historical lane, with ditches on either side, which can be found on the intertidal flats north of Pellworm and which caused structures like those shown in Fig. 1. Fossil farmland structures, mostly ditches, but also lanes or dykes, cannot be observed through their relief of less than 10 cm. Rather it is the sediments on the lost pastures that are different from those in the linear structures of ditches. Typical wadden sediments on the flat sand banks consist of marine fine sand, which had been the basic compound of the old marsh land and which is still a major part of the marine environment. The surface of the fossil ditches is different. In the center there are pillowy sediments while the ditch edges are often stabilized by fossil roots and other plant material connected with the sediment. This causes narrow ridges with thicknesses of only 10 cm to 20 cm, which can still be observed.

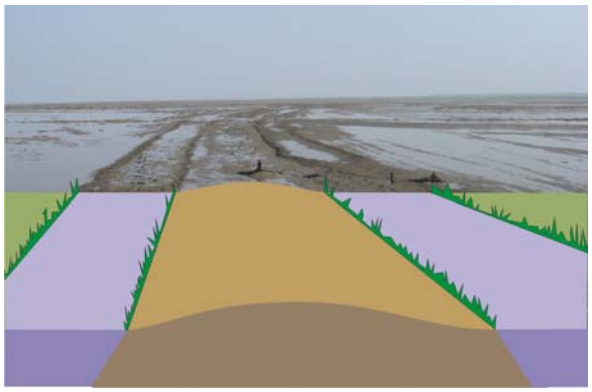

Figure 2. Reconstruction of a medieval lane (Kohlus 2008) crossed by a ditch in the background.

Such linear structures have been observed during field campaigns north off Pellworm. Fig. 3 shows an aerial photograph of the island's north coast, with the locations of residuals of historical land use superimposed.

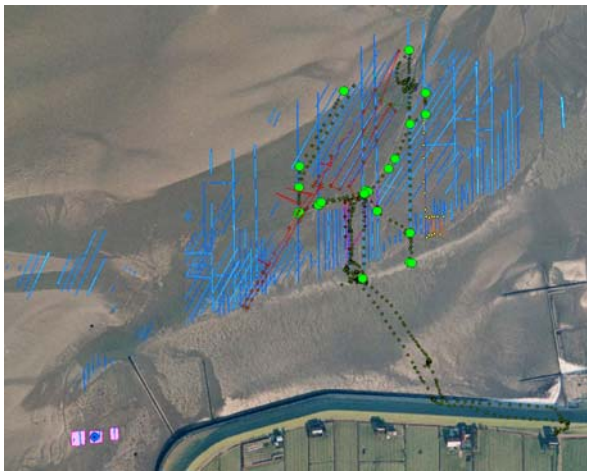

Figure 3. Aerial photograph of dry-fallen intertidal flats north off Pellworm. Superimposed are locations of ditches and lanes (green and brown) and of fossil terps and field structures provided by the State Archeological Department of Schleswig-Holstein (purple and blue).

The high-resolution X-Band synthetic aperture radar (SAR) aboard the German TerraSAR-X allows for mapping the Wadden Sea surface from space, and SAR images with a pixel spacing of less than 1 m can be used to detect small-scale surface structures if they are linked with a variation of the surface roughness of the Wadden Sea sediments. As an example, Fig. 4 shows a small (1900 m × 2000 m) section of a TerraSAR-X image acquired on August 3, 2009, over the same area as shown in Fig. 3. The residuals of the historical structures can clearly be delineated as linear bright and dark signatures. For the first time, thus, residuals of historical land use in the North Frisian Wadden Sea are detected by a spaceborne SAR sensor. Moreover, a direct comparison of the SAR image and the available data from aerial survey and field campaigns (Fig. 4 and Fig. 3, respectively) demonstrates that formerly unknown structures have been identified by TerraSAR-X (cf. the upper image center in both figures).

Results from our field campaigns prove that it is the former system of ditches that causes the distinct signatures on the SAR imagery. The change in surface roughness, together with the high-resolution capability of TerraSAR-X

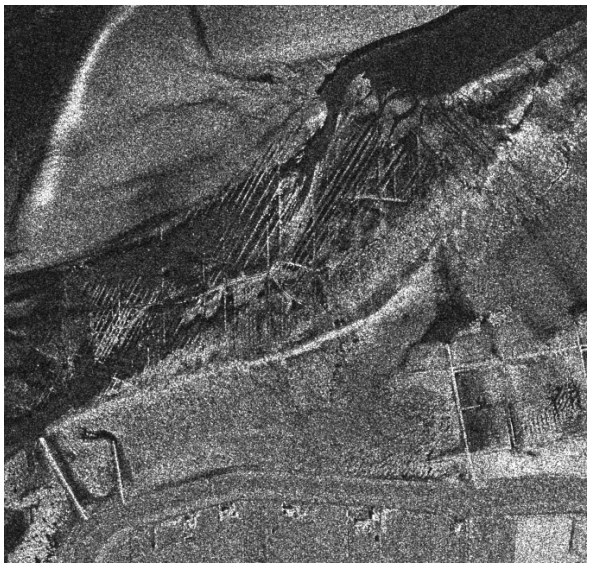

Figure 4. Section (1900 m × 2000 m) of a TerraSAR-X image of dry-fallen intertidal flats north off Pellworm. Residuals of historical land use can be delineated through linear bright and dark structures. © DLR 2009.

3. CONCLUSIONS

High-resolution TerraSAR-X images can be used to complement archeological surveys on intertidal flats on the German North Sea coast. The radar images the former systems of ditches, dating back to the 14th century and to the 16th/17th century. The observed signatures are due to different sediment types, which in turn are due to the very ditch morphology. Moreover, different sediments cause different biological effects and are also often marked by benthic organisms. Thus, the ditch structures containing more biogenic material may be a preferred habitat of certain mussels while sand worms (*Arenicola marina*) are usually found on sandy sediments. Those benthic organisms may cause different surface roughness patterns that can be sensed by the high-resolution X-Band SAR.

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