Multi-Sensor Remote Sensing of the Wadden Sea Ecosystem on the German North Sea Coast

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Abstract – High-resolution multispectral remote sensing data from satellite-borne optical sensors have already been used for the classification of sediments, macrophytes, and mussels in the German Wadden Sea. Since the use of those sensors in northern latitudes is strongly limited by clouds and haze, we included synthetic aperture radar (SAR) data, allowing earth observation that is independent of cloud coverage and daytime. The data acquired at different radar bands (L, C, and X band, from ALOS PALSAR, ERS SAR and ENVISAT ASAR, and TerraSAR-X , respectively) have been used to analyse their potential for crude sediment classification on dry-fallen intertidal flats and for detecting benthic fauna such as blue mussel or oyster beds. The information gained from optical and SAR sensors, together with in-situ observations, will yield an improved classification of different sediment types, together with mussel beds and sea grass.

Keywords: multi-sensor, Wadden Sea, sediment classification, benthic fauna.

1. INTRODUCTION

The increasing requirements of coastal monitoring, to some extend, can be met deploying remote sensing techniques that allow for relatively cheap surveillance of large coastal areas. Optical sensors are already being used for sediment classification on intertidal flats, and promising results have been achieved through the classification of different sediment types, vegetation, and mussel beds (see Fig. 1). However, because of the strong dependence on daylight and cloud conditions, useful optical data (acquired at low tide) from the German North Sea coast are rare. A classification system based on spaceborne remote sensing data would therefore strongly benefit from the utilization of synthetic aperture radar (SAR) data.

Gade *et al.* (2008) suggested to use multi-frequency SAR data for a sediment classification on exposed intertidal flats. However, current spaceborne SAR sensors operate at single frequencies, and as a consequence, SAR data from different satellites have to be used for multi-frequency SAR classification purposes. Because they are usually acquired with a considerable time lag in between, a profound knowledge of the radar backscatter properties of the sediment types, and their dependence on weather conditions, tidal cycle, and imaging geometry is needed, which can only be gained from a joint analysis of multi-satellite SAR data and optical remote sensing data, together with a-priori knowledge gained during in-situ campaigns. The sub-project 4 of the German national project DeMarine-Environment (DMU) is particularly devoted to this synergistic approach.

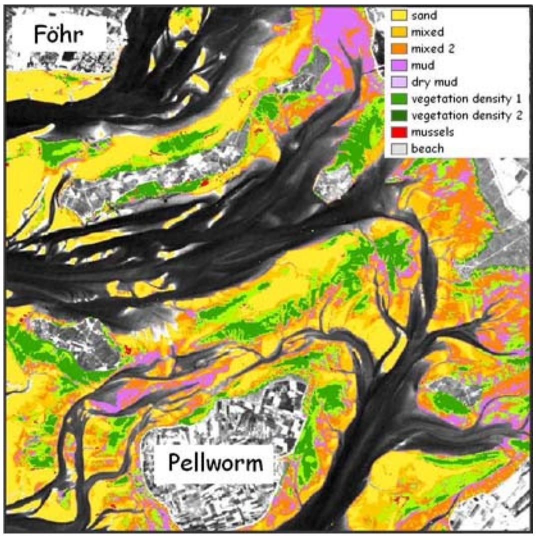

Figure 1. Sediment classification for the North Frisian DMU testsite "Halligenwatt", as generated from Landsat TM data from July 2, 2007 (original data © eurimage 2007)

2. RESULTS

The method used for the classification of optical remote sensing data is based on a linear spectral unmixing and feature extraction from the spectral reflectances (Brockmann and Stelzer 2008). All extracted information from the optical data is combined in a decision tree, which is used to relate each pixel to a class representing different surface types, i.e., five sediment types, two vegetation density classes, one mussel class and a dry and bright sands class. The water coverage, having a strong influence on the spectral reflectance and on the radar backscattering, is considered within the endmember selection for the linear spectral unmixing. Fig. 1 shows the result of a classification applied to a Landsat-5 TM scene from July 2, 2007.

The spatial variations of different sediment types, along with the occurrence of mussel beds, see grass, and macro algae, is typical for the test site "Halligenwatt" in Schleswig-Holstein. Fig. 2 shows two SAR images of the test site that were acquired from different satellites on the same day, during, or shortly after, low tide. The ENVISAT ASAR image in the upper panel was acquired on October 18, 2007, at 09:55 UTC (at low tide), and the ALOS PALSAR image in the lower panel was acquired on the same day, at 10:23 UTC (28 minutes after low tide). Note the different radar contrast of the exposed intertidal flats, which cannot be attributed to the different acquisition time (water level). In general, the radar backscattering from the exposed tidal flats is much lower than that from the surrounding wind-roughened sea surface, because of a strong north-westerly wind (12-13 m/s).

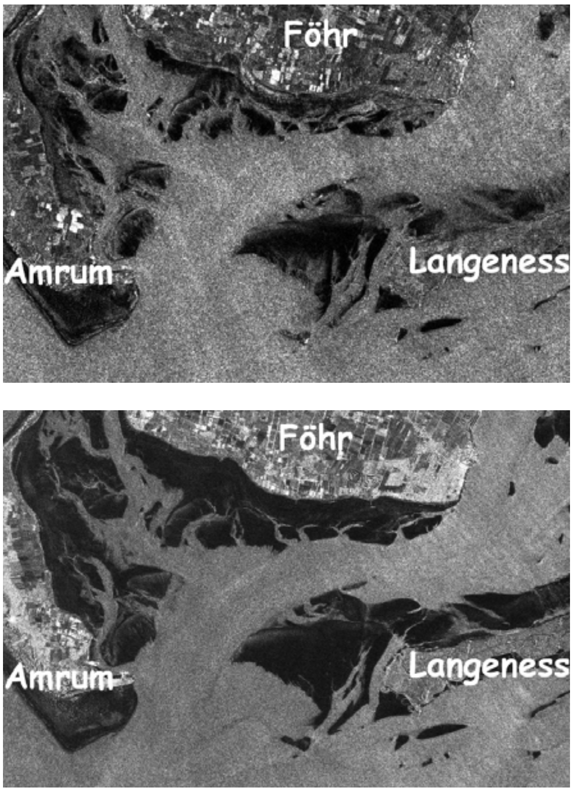

Figure 2. Two SAR images (37.5 km × 25.0 km) of the test site “Halligenwatt”, acquired at, or shortly after, low tide. Top: ENVISAT ASAR image (© ESA 2007); bottom: ALOS PALSAR image (© JAXA 2007).

The southern test site “Lütetsburger Plate” in Lower Saxony is dominated by a strong spatial variation of different sediment types, along with a high coverage by mussels. During summer season, some regions are covered by sea grass and green algae. Thus, a simple classification method that assumes bare sediments cannot be applied in this area. Fig. 3 demonstrates how the test site is imaged by SAR sensors working at different radar bands: the upper panel shows an ALOS PALSAR (L-band) image acquired on April 12, 2008, at 21:43 UTC, 23 minutes after low tide, and the lower panel shows a TerraSAR-X (X-band) image acquired on August 30, 2008, at 17:10 UTC, 34 minutes after low tide. The location of the tidal creeks can be identified through enhanced radar backscattering from the sediment on their edges. This local enhancement of the radar backscatter was already found by Gade *et al.* (2008) who attributed it to an enhanced current-induced surface roughness of the sediments (i.e. sand ripple height). However, some irregular bright patches in the left part of both SAR images are not due to sand ripples, but due to mussel beds. That is, for the first time, benthic fauna on exposed intertidal flats has been imaged by multi-frequency (L, C, and X band) SAR sensors.

3. CONCLUSIONS

Within subproject 4 of the national German project DeMarine-Environment (DMU) data from optical sensors and multi-satellite SAR images of exposed intertidal flats are analyzed to improve existing classification systems by including SAR data. For the first time, extensive mussel beds (composed of a mixture of Pacific oysters and blue mussels) have been observed in multi-frequency SAR imagery. However, the strength of their signatures, and thus the capability of SAR sensors to detect and to classify them, may depend on the seasonal change in coverage by brown algae.

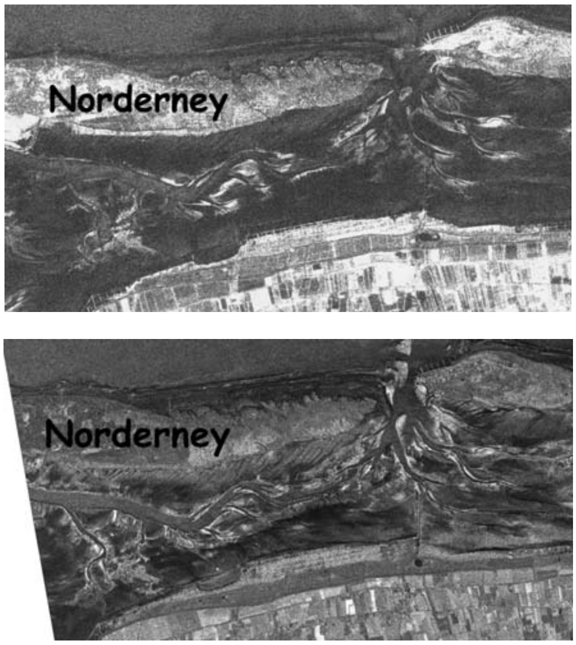

Figure 3. Two SAR images (25.7 km × 13.4 km) of the test site “Lütetsburger Plate”, acquired shortly after low tide. Top: ALOS PALSAR image (© JAXA 2008); bottom: TerraSAR-X image (© DLR 2008).

During later stages of the project, results from in-situ campaigns will be included, along with further classification results derived using optical remote sensing data. Of particular interest will be to investigate how the observed SAR signatures depend not only on radar frequency and polarization, but also on the season, on weather conditions, and on the tidal phase. A profound knowledge of all main factors contributing to the observed SAR signatures is essential for any improvement of existing classification systems, and our preliminary results show evidence that multi-satellite SAR data can be used for an improved sediment classification on exposed intertidal flats.

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