CLASSIFICATION OF SALT MARSH HABITATS WITH MULTI-POLARIMETRIC AND MULTI-FREQUENCY AIRBORNE SAR

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ABSTRACT

Within GMES there is much interest in the ability of remote sensing technology to deliver operational solutions to many areas of life including environmental management. This paper describes research focused on the application for Earth Observation for Integrated Coastal Zone Management. The main topic of this research is to explore to which extent salt marsh habitats from can be identified from SAR remotely sensed data. Multi-frequency, multi-polarimetric SAR images from airborne (S- and X-Band quad-polarimetric from the Astrium airborne SAR Demonstrator) is used to examine salt marsh habitat classification potential in the Llanrhidian salt marshes in South Wales, UK. This is achieved by characterizing their botanical and structural composition, flooding regimes as well as fluctuations in soil moisture. Different SAR features as backscatter coefficient, band ratios and polarimetric decomposition are extracted.

INTRODUCTION

Research objectives

The coastal zone is often described as the region where land and sea meet. In that regard coastal zone studies can focus on near-shore sea phenomena, whereas others focus on maritime-influenced terrestrial zones. This study researches the area between the high and low water mark, the intertidal zone. The intertidal zone can be characterized by the presence of specific halophytic plant communities, salt marshes. Salt marshes are fringing many of the world's soft coasts exposed to relatively low-energy wave action. They are characterized by a suite of herbaceous or low woody vascular plants. The upper elevation limit of occurrence is approximately that of the highest astronomical tide (HAT) while the lower limit is rarely below mean high water neap (MHWN) tide level (1). In Europe, large salt marsh communities can be found around Britain (The Wash, North Norfolk, Severn, Essex estuaries), the Dutch-German-Danish Wadden Sea (2) and in other low-lying coastal areas. Intertidal habitats can deliver ecosystem services in the form of food supply and flood mitigation, yet two thirds of coastal habitat types and more than half of coastal species have an unfavorable conservation status (3).

Due to the specific environmental circumstances that salt marsh vegetation have to cope with, salt marsh habitats are relatively species-poor. Salt marshes show distinct vegetation zonations, highly dependent upon soil salinity, flooding frequency and topography (4). Fig. 1 is a schematic profile of a typical salt marsh vegetation succession.

Remote sensing techniques have unique properties in the sense that they can provide spatial and temporal information about areas and phenomena in a panoptic sense. A number of new and existing remote sensing sensors provide data sets that can be used to analyze and monitor coastal processes. Intertidal areas are often difficult to access, so remote sensing can provide a very useful tool for monitoring these areas. This research benefits from the increasing availability of polarimetric SAR remote sensing data sets to tests their applicability for salt marsh habitat mapping and monitoring. A SAR classification research will be carried out in Llanrhidian Marsh, which is located between the Gower Peninsula and the Welsh mainland (5).

Figure 1: Typical zonation pattern of salt marsh habitats in Northern Europe

Study area characteristics

The Llanrhidian salt marsh is one of the UK's biggest salt marsh complexes (2), in which a number of ecological and geomorphological studies have been carried out (6, 7). It is a prime example of a salt marsh that is slowly increasing in size. During an initial field survey in November 2012, a photographic assessment of the major vegetation habitats is made. Fig. 2 provides a photographic overview of the major salt marsh habitats.

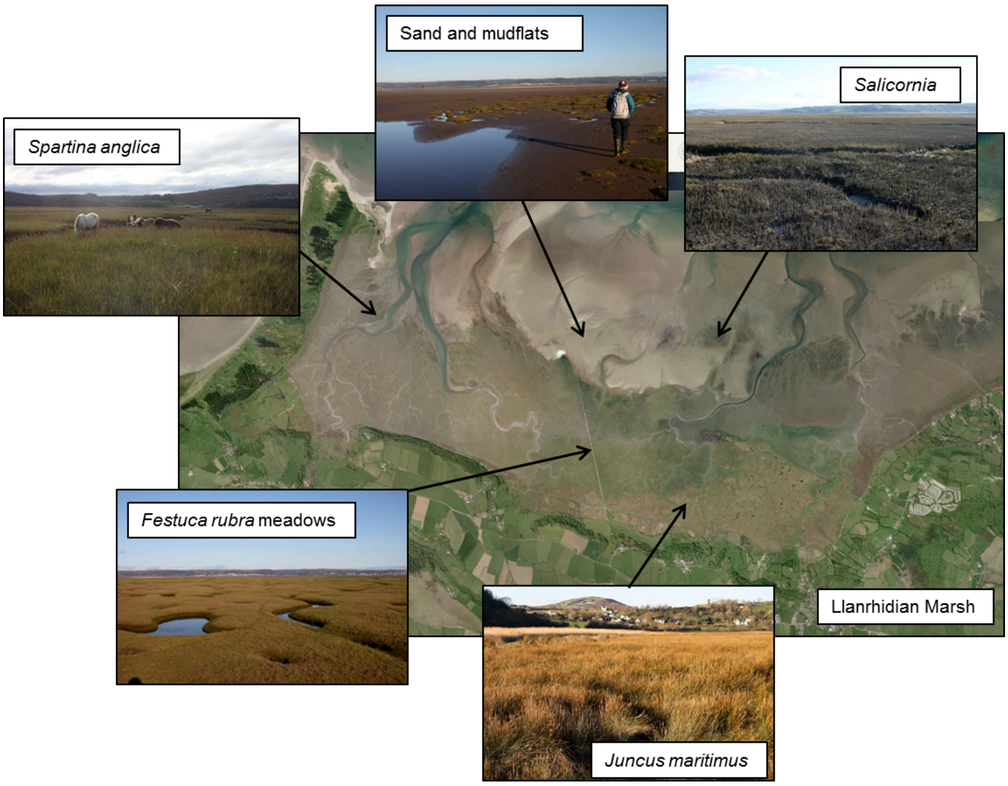

Figure 2: Overview of the research area and the different vegetation habitats

METHODOLOGY

Fully polarimetric airborne S- and X-Band SAR is used for habitat mapping of salt marsh areas, following common habitat classification schemes as National Vegetation Classification (NVC) and Habitat Directive Annex 1. This is done on the basis of a data set which is acquired over the Llanrhidian salt marsh in Wales on 25 July 2010 with the Astrium Airborne Demonstrator. This system operates in X-Band (9.65 MHz) and S-Band (3.2 MHz). SAR acquisition in X-Band is well established in both the airborne and space domains (E-SAR, F-SAR, TerraSAR-X and TanDEM-X), but S-Band SAR acquisition is only carried out with the short-lived Russian Almaz satellite, and is the proposed frequency band for the NovaSAR-S satellite. The initial test flights with the system and the calibration routines are described by (8). The data is acquired with a single look slant range resolution of 0.69 m in both range and azimuth direction. Even though the system is capable of acquired quad polarimetric data (HH, HV, VV and VH), due to technical problems during the survey campaign the analyzed data set is acquired in HH, VV and HV polarisations only. This data set provides an excellent opportunity to research the potential of high resolution fully polarimetric SAR for classification of salt marsh habitats, by characterising botanical and structural composition of specific salt marsh vegetation zones.

Processing of the SAR data is performed with PolSARpro, the polarimetric SAR processing tool maintained by ESA (9). The airborne SAR data is imported as a generic SAR format into PolSARpro. Consequently, the data is multilooked using a 3x3 window, converted from slant range into ground range with a resampling pixel size of 2x2 meters and a correction for the antenna pattern is performed. Speckle filtering is done with the Enhanced Lee method with kernel size 3x3. The result can be seen in Fig. 3.

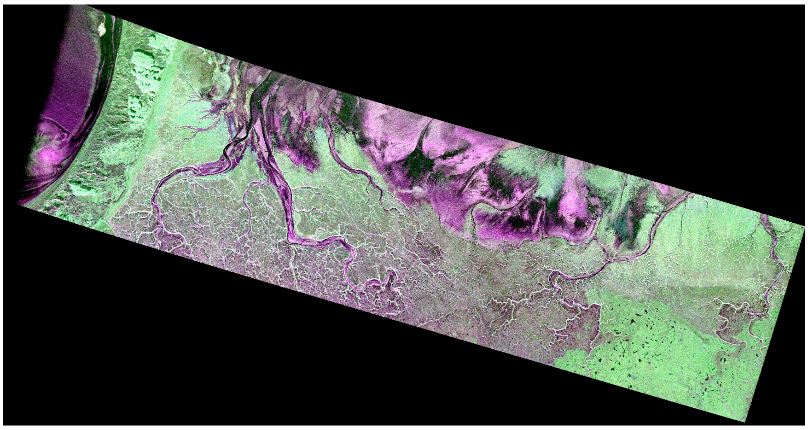

Figure 3: Airborne S-Band SAR image in Pauli basis (R=|HH+VV|, G=2|HV|, B=|HH-VV|).*

Consequently, polarimetric decomposition parameters and products are extracted. A number of polarimetric decomposition methods exist, and new ones are developed, but in this study it is chosen to focus on the most often used ones, as the Cloude-Pottier (10) and Freeman-Durden (11) decompositions. Fig. 4 displays the Freeman-Durden decomposition of the S-Band image.

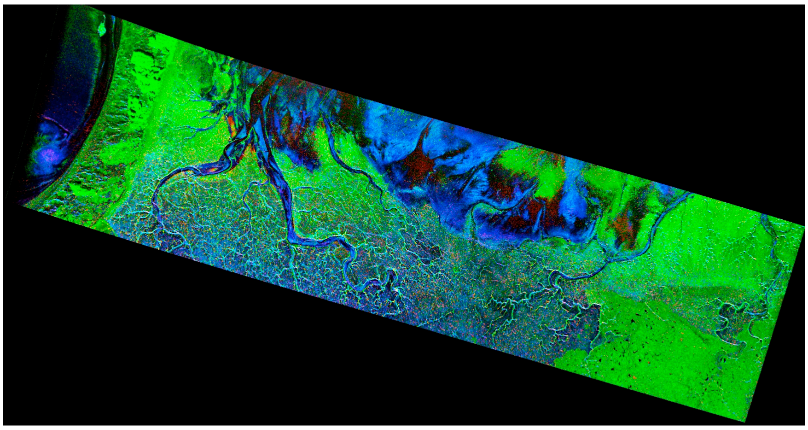

Figure 4: Freeman-Durden decomposition image of airborne S-Band SAR image (R=double bounce, G=volume scattering, B=odd bounce)

PolSARpro provides a number of classification routines based on the Cloude-Pottier decomposition parameters, entropy (H), anisotropy (A) and alpha angle (α). Entropy is a measure of the predominance of a single scatter mechanism. In case of low entropy, a single scatter mechanism is dominant. The alpha angle is a measure of the scatter mechanism. If the alpha angle approaches 0, the dominant scatter mechanism is odd bounce or surface scattering, when it approaches 90 the dominant scatter mechanism is primarily double bounce.

These classification methods are applied to the data sets in both S- and X-Band. The decomposition layers are exported to be used as input layers for further object- based and pixel-based classification analyses in Envi, IDRISI and eCognition.

RESULTS

Unsupervised classification

The existing routines in PolSARpro for unsupervised classification are utilised for an initial classification of different habitats. A scatterplot of the image pixels on the H/α plane can be found in Fig. 5. From this scatterplot it is clear that there is very limited backscatter behaviour in the low entropy/high alpha domain, which corresponds in general to predominant double bounce scatter behaviour. This is not surprising, as this occurs mainly in built-up areas, which are not present in the image. In the SAR image Bragg surface scattering (low entropy and alpha) and medium entropy vegetation scattering are predominant (10).

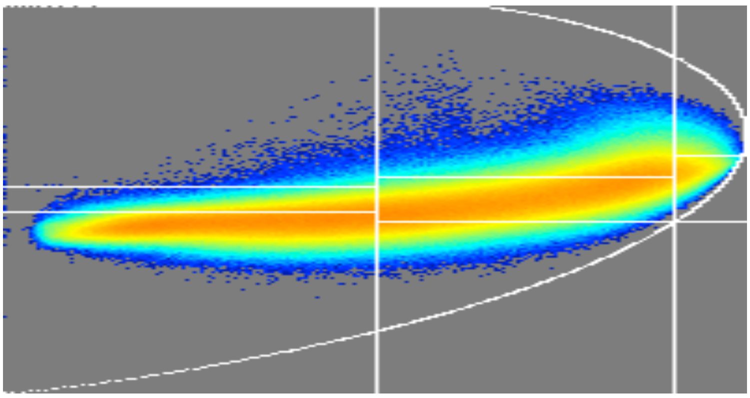

Figure 5: PolSARpro scatterplot of entropy (X-axis, scale from 0 to 1) and alpha angle (Y-axis, scale from 0 to 90 degrees) of the S-Band image.

PolSARpro uses the H/A/α-information to perform classification based on Wishart distribution, as described by (12). In each of the eight zones of the H/α-plane clusters are identified and after a number of iterations based on the complex Wishart distribution of the pixels, a classification is assigned.

This method provides a quick unsupervised classification, utilising the unique properties of fully polarimetric SAR. The result of the unsupervised Wishart classification with additional 7x7 kernel size filtering is shown in Fig. 6. From this classification it can be seen that wet and dry bare mudflats as well as unvegetated channel edges are distinguishable from vegetated areas. In the vegetated areas the grassy *Festuca Rubra* meadows are detected, with a gradual transition towards areas where *Spartina Anglica* is dominant. This plant species consists of 1-1.5 meter tall grasses, but not very densely covering the soil. On the higher part of the salt marsh *Juncus maritimus* species (1.5 meter tall grasses, very densely covering) are well discernible. On the lower part of the salt marsh the pioneer *Salicornia spp.* beds (0.1-0.3 m tall plants, sparsely packed) are detected.

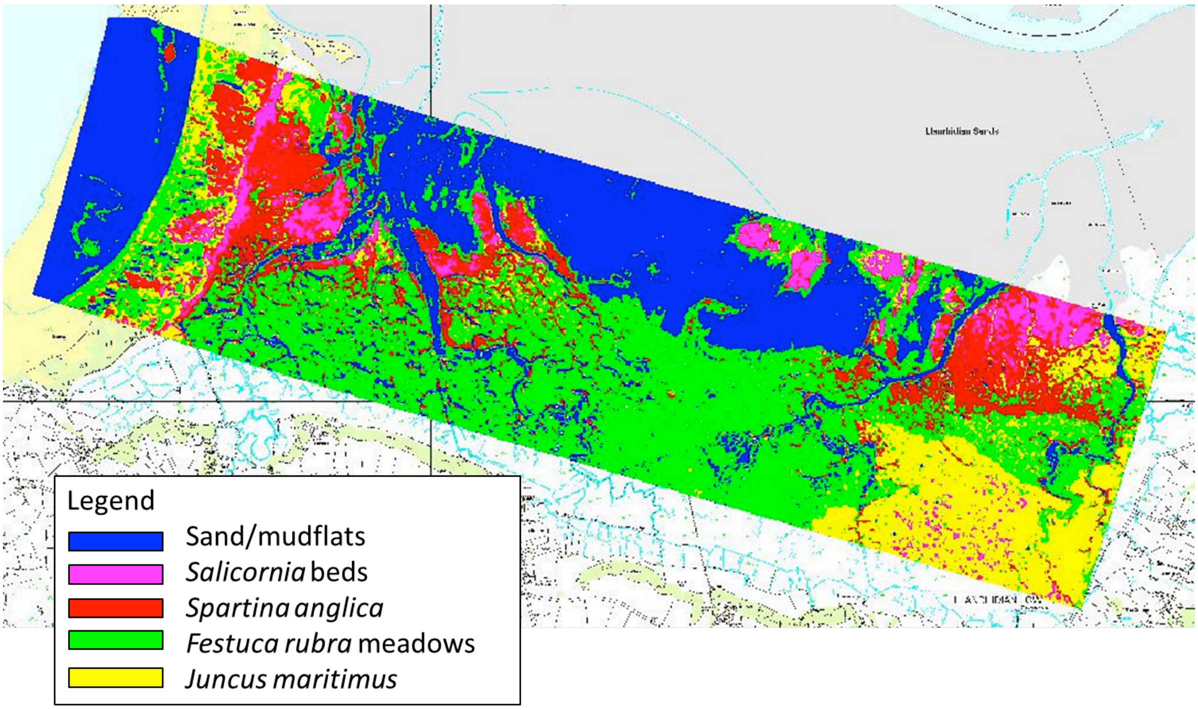

Figure 6: Classification map, based on unsupervised H/A/α Wishart classification using S-band data.

Supervised classification

Besides the unsupervised Wishart classification, a number of supervised classifications have been performed, using the polarimetric decomposition H, A and α-layers of both S- and X-band frequencies as attributes for supervised pixel-based Maximum Likelihood and Support Vector Machine, as well as object-based rule-set classification. As reference data survey data from the NVC survey of 1998 and 2012, as well as photographic information from a field visit in November 2012 were used.

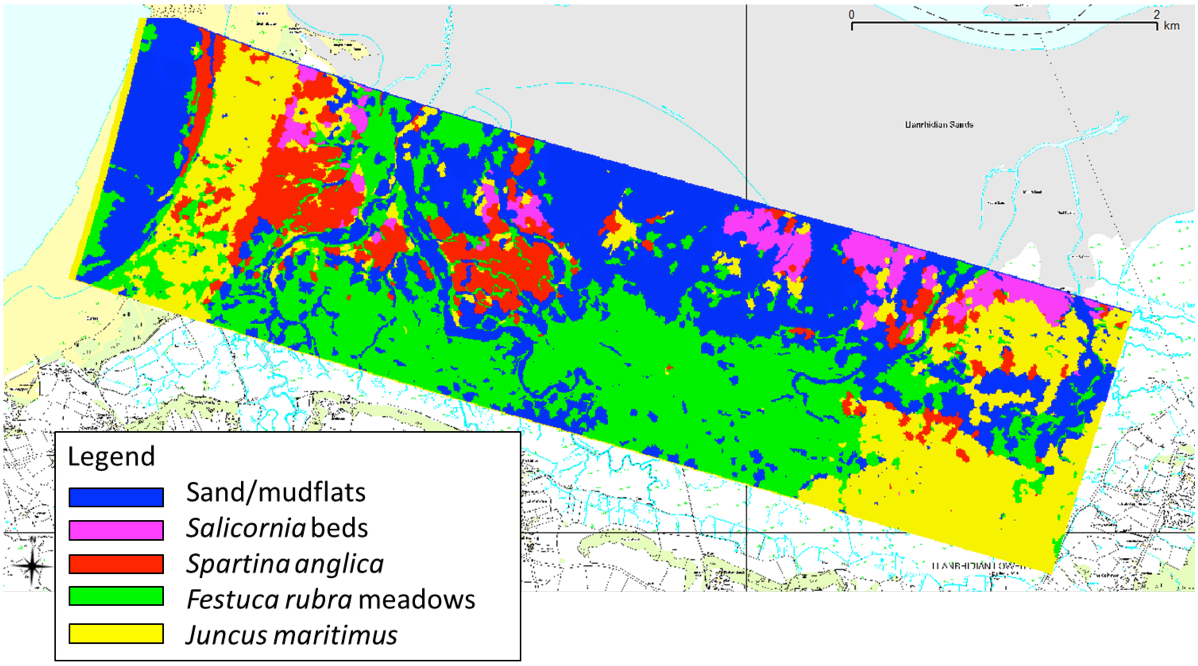

Figure 7: Classification map, based on supervised object-based classification using H/A/α layers from both S- and X-band data.

Accuracy assessment

Accuracy assessments have been performed for all five performed classifications. Ecological field survey data from the NVC surveys of 1998 and 2012 is used as reference data. Table 1 displays the accuracy assessment results of all tested classification routines.

Table 1: Accuracy assessments of different habitat classification efforts.

Classifier	Supervision	Object-or pixel-based	Bands used	Overall accuracy (%)
Wishart H/A/α	Unsupervised	pixel	S-Band	66.55
Wishart H/A/α		pixel	X- Band	59.84
Maximum Likelihood H/A/α	Supervised	pixel	S- and X-Band	53.80
Support Vector Machine H/A/α		pixel	S- and X-Band	48.68
Rule base H/A/α		object	S- and X-Band	75.67

DISCUSSION AND FURTHER WORK

The results as described in this paper are a first step towards the utilization of fully polarimetric S- and X-Band SAR to provide an additional tool for the mapping and monitoring of natural salt marsh habitats. Polarimetric decomposition routines provide a better insight into SAR backscatter processes taking place and is therefore preferable over the use of polarimetric channels alone. Even though only a few general classification routines, it seems that SAR data is capable of distinguishing the different major vegetation units.

A next step of the research will be carry out a dedicated field survey. Plant species, as well as plant density and heght will be recorded during this campaing. It is planned in July 2013, coinciding with the same season as the acquisition of the SAR imagery in 2010. A correlation between habitat, vegetation height and density and backscatter amplitudes and polarimetric decomposition layers will be made. Besides crisp classification attention will be given to fuzzy classification as well. This is proposed because natural habitats show gradients, or ecotones from one to the other. Fuzzy classification can define the degree of membership of a certain location, thereby providing more realisitc information about actual land cover.

The use of satellite SAR data for mapping salt marsh habitats will be inestigated in a later stage. A temporal image stack of ALOS PALSAR L-Band imagery will be used to investigate temporal dynamics of salt marsh habitats, as well as impact of tidal forces on backscatter signatures.

ACKNOWLEDGEMENTS

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