TEMPORAL ANALYSIS OF OPTICAL AND SAR REMOTE SENSING FOR MONITORING OF INTERTIDAL SALT MARSHES

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ABSTRACT

This study proposes a methodology in support of Integrated Coastal Zone Management, through analysis of the seasonal variations in intertidal habitats, as recorded in satellite remote sensing. Knowledge of seasonal and phenological cycles associated with different intertidal coastal habitats is critical for their identification and monitoring as part of an integrated remote analysis. This research seeks to improve understanding of the impact of external fluxes such as erosion, habitat loss and sea level rise. To achieve these aims, this research uses a multi-annual time series of both SAR data and medium/high resolution optical imagery (Landsat, ASTER) to develop vegetation products such as NDVI or FAPAR. The SAR data (airborne SAR, ASAR, ERS1/2) allows fluctuations in vegetation structure, standing biomass and flooding regimes to be examined. The combination of a multi-sensor and multi-temporal approach, with knowledge of habitat phenological cycles gives greater insight into the long-term dynamics of intertidal land cover and ecosystem functions and service associated with intertidal habitats. The temporal analysis of medium-resolution optical and SAR data can also be regarded as a precursor study for the upcoming Sentinel-1 and -2 missions, which will provide an unprecedented influx of satellite imagery.

INTRODUCTION

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 characterised 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 unfavourable 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). Salt marsh habitats show seasonal variations in primary productivity and these cycles can be used as a proxy for ecological status of the habitats.

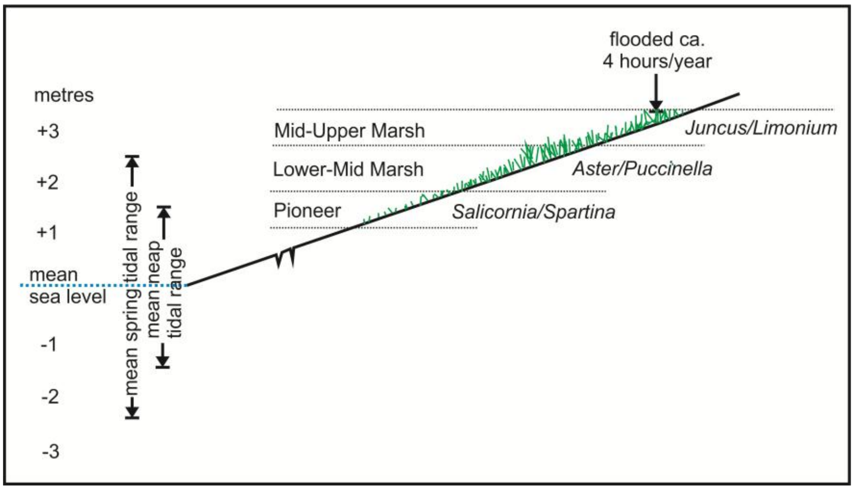

Figure 1: Typical zonation pattern of a salt marsh in Northern Europe.

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 analyse 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 affordable remote sensing data sets tests their applicability for coastal zone management. The use of existing data archives are used to research intertidal zone habitat dynamics through the development of time-series. Furthermore novel RS technologies (SAR, VHR satellite data, satellite constellations) are tested for classification and monitoring of intertidal habitats and dynamics. The study area is the salt marsh complex of North Norfolk, between Hunstanton and Sheringham.This salt marsh area has been studied intensely over the last decades and is one of the best examples of an ecological well functioning back-barrier salt marsh area in the United Kingdom(5).

Figure 2: The location of the study area.

METHODOLOGY

A time series of medium and high resolution optical data is developed from exisiting data archives. The imagery is orthometric corrected to achieve sub-pixel accuracy, and atmospheric correction is performed with the use of the MODTRAN atmospheric correction model. After correction, reflectance values in selected test areas are validated for all the images in the time-series. The test sites consist of surfaces that are assumed to be unchanging, for example airport runways or building roofs. The corrected and validated imagery is used to calculate the Normalise Differential

Vegetation Index (NDVI) and Fraction of Absorbed Photosynthetical Active Radiation (FAPAR) vegetation indices to model the primary productivity of salt marsh habitats. NDVI is a popular and robust vegetation index, which is often used for the monitoring of salt marshes (4, 6), whereas FAPAR analysis produces more distinct seasonal variability. Multi-frequency and multi-temporal SAR imagery is used to model the vegetation structure and biomass fluctuations of the salt marsh habitats over the course of several years. The potential of airborne S-Band SAR data for the modelling of temporal variations in a salt marsh is analysed and compared to spaceborne L-, C- and/or X-Band SAR. It has been shown that combination of optical and SAR data for monitoring temporal variations has proved to complementary (7). However, there is a need to implement tidal recordings and topography into the model to account for the fluctuation in soil moisture.

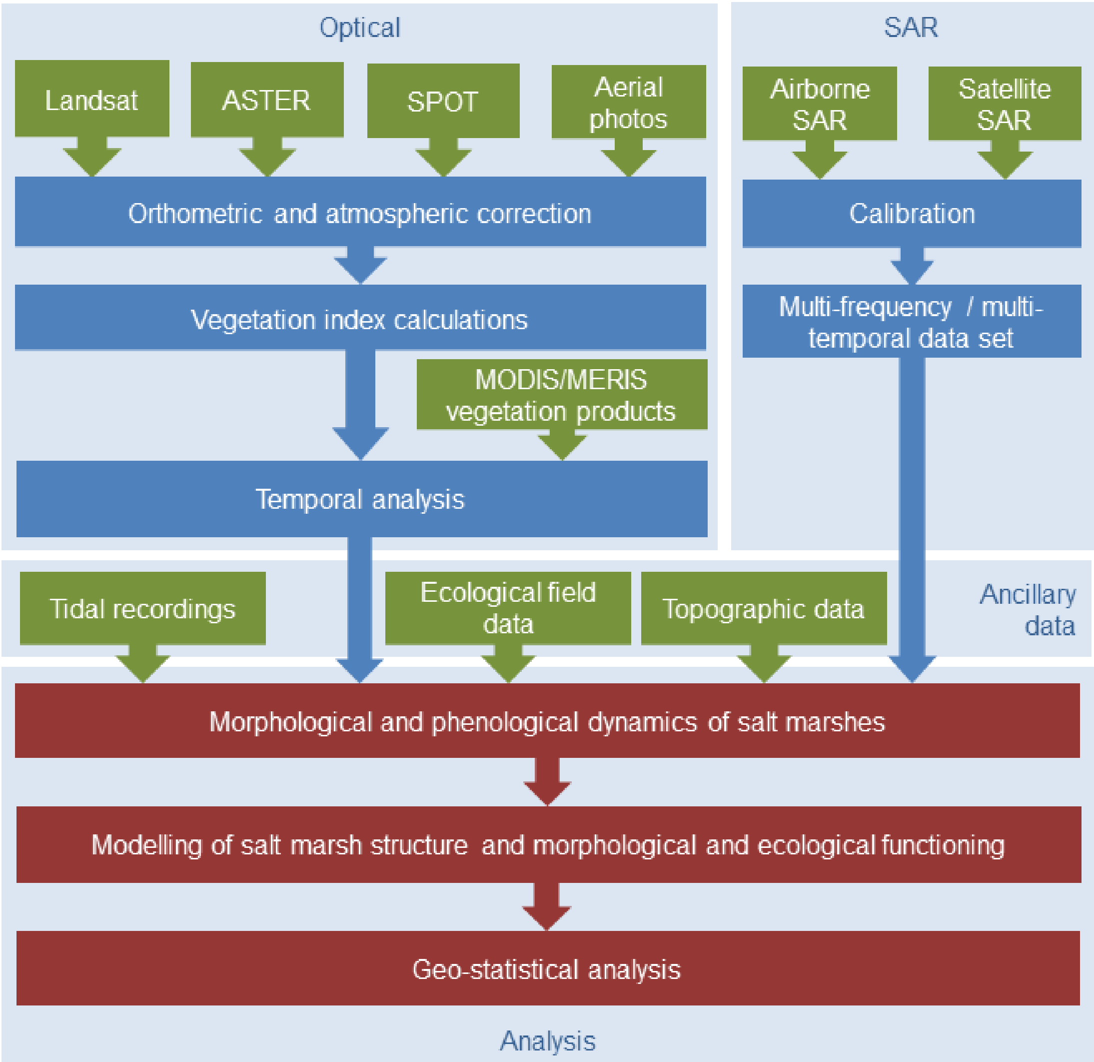

Figure 3: Methodology overview of this research. Green boxes indicate data input, blue boxes processing steps and red boxes analysis steps.

RESULTS

A time series biophysical parameters derived from Landsat-5 and Landsat-7 imagery for the year 2011 shows that different salt marsh habitats can be distinguished by analysing the primary production variation throughout the year. The results from the NDVI and FAPAR indices show a clear increase in spring and a maximum in early summer for the lower-mid and mid-upper salt marsh habitats. On the other hand, the pioneer marsh habitat does not show an increase in seasonal FAPAR and only a small seasonal change in NDVI.

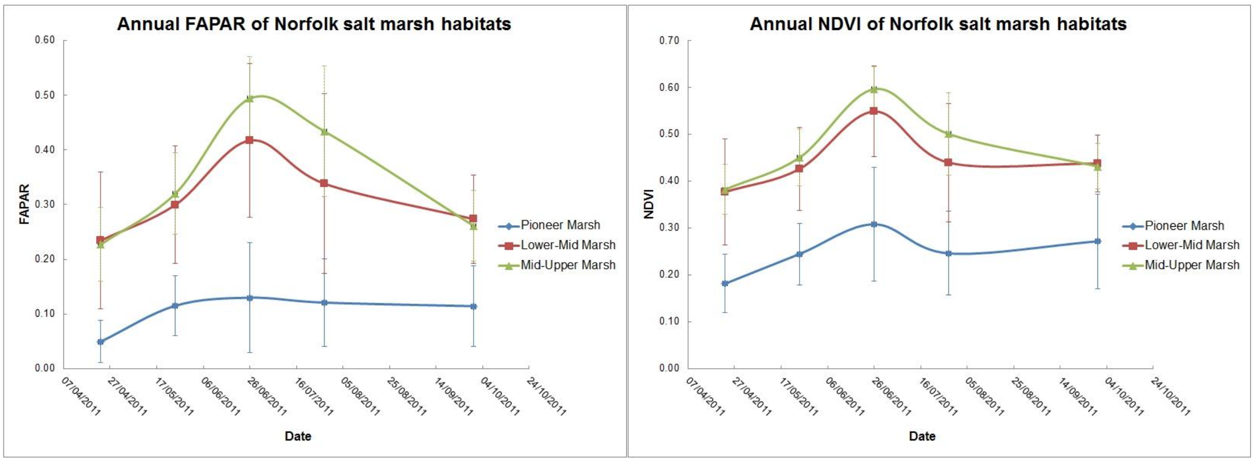

Figure 4: Biophysical parameters from Landsat imagery of selected salt marsh habitats. The seasonal fluctuation of FAPAR (left) and in NDVI (right).

Multi-polarimetric airborne SAR imagery of the salt marshes north of the Gower Peninsula in Wales shows a clear distinction between the main salt marsh habitats. The image is recorded with the Astrium UK airborne SAR demonstrator and is calibrated by using a trihedral corner reflector according to (8), multilooked and orthometrically rectified. The S-Band displays the different habitats clearly and provides better imagery than the simultaneiously recorded X-Band SAR data.

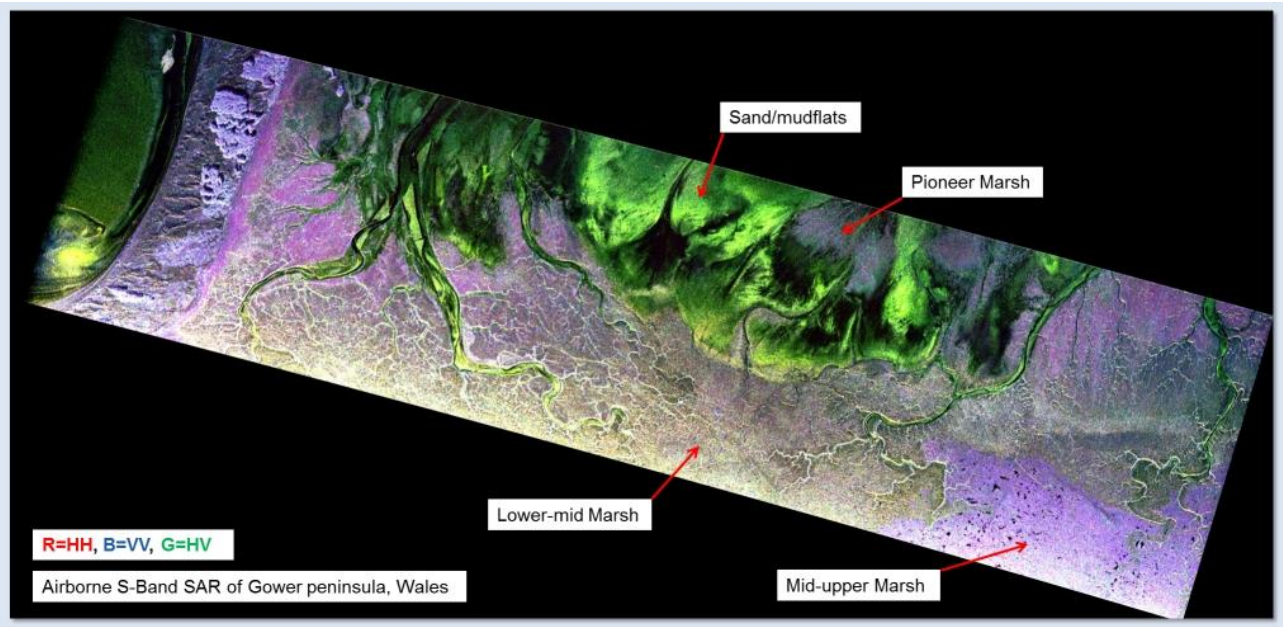

Figure 5: Astrium UK SAR Demonstator image of salt marsh near the Gower Peninsula with visual interpretation of the main salt marsh habitats.

CONCLUSIONS

Temporal analysis of vegetation indices from optical sensors of salt marsh habitats allows inferences about the phenological functioning of these habitats. The phenological dynamics of salt marsh habitats can be monitored with medium-resolution Landsat satellite imagery. The time-series will be expanded with medium and high resolution data (SPOT, ASTER, aerial photography) to create a multi-annual time-series which will allow analysis of long term dynamics.

Multi-polarimetric and multi-frequency SAR data provides data about salt marsh vegetation structure and biomass. Airborne S-Band SAR imagery can be used to classify different salt marsh habitats. An additional airborne SAR survey campaign will take place in the summer of 2012, it is planned that survey data will be recorded over the study area in North Norfolk. The airborne SAR data set is not analyzed alongside more common SAR data as ASAR, TerraSAR-X and ALOS PALSAR. This will be investigated in the next stage of this research.

The combination of these two sources of remotely sensed information will allow an Integrated approach to coastal zone management when combined with ecological knowledge of the habitats under consideration.

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