BIO-PHYSICAL CHARACTERIZATION OF INDICATORS OF SEDIMENT STABILITY IN MUDFLATS USING REMOTE SENSING (CISS)

Stefanie Adam[1], Annelies De Backer[2], Steven Degraer[2], Jaak Monbaliu[1], Erik Toorman[1] and Magda Vincx[2]

1. Katholieke Universiteit Leuven, Department of Civil Engineering, Hydraulics Laboratory, Heverlee, Belgium; stefanie.adam@bwk.kuleuven.be
2. Universiteit Gent, Department of Biology, Marine Biology Section, Ghent, Belgium

ABSTRACT

Within the framework of the CISS-project ('Bio-physical Characterization of Indicators of Sediment Stability in mudflats using Remote Sensing' 2005-2008), which is financed by the Research Foundation - Flanders (FWO), the Hydraulics Laboratory of the KULeuven and the Marine Biology Section of the University of Ghent are collaborating to investigate the influence of sediment properties on erodibility and on spectral properties.

The interpretation of hyperspectral remotely sensed images over mudflats is only possible if the appropriate bio-geophysical models for information extraction are available. The main objectives of the CISS-project are therefore the quantitative assessment of bio-geophysical characteristics of the surface sediments in the intertidal zone using remote sensing and the determination of the erodibility of these sediments based on their bio-geophysical characteristics. This paper will only discuss the first objective of the CISS project.

The methodology which will be followed in the CISS project will consist of (i) laboratory spectral measurements and the development of a mathematical modelling procedure to extract bio-geophysical sediment properties from a remotely sensed signal, and 2) application of the developed models on in situ spectral measurements and hyperspectral imagery.

Spectral absorption features of clay and water look promising for their quantification in sediment mixtures. In laboratory conditions, correlation coefficients (r^2) of 0.98 and of 0.95 were found between the scaled band area of absorption features and clay and water content respectively.

Future work will focus on the use of feature selection combined with linear and non-linear classification methods and on bidirectional effects of intertidal sediment.

INTRODUCTION

Mudflats are important for coastal zone ecosystems by providing wildlife habitats and by acting as natural sea defences that serve to dissipate tidal and wave energy. The erodibility of cohesive sediments on these mudflats is dependent on the interaction between the physical and biological processes of stabilization and destabilization. In spite of the scale and economic/ecological importance of the intertidal zone, the dynamics and behaviour of fine sediments and the biota living in this region are poorly understood. The general paucity of data on intertidal mudflats is primarily due to physical difficulty of working in soft mud and the vast scale of many mudflats. Remote sensing offers a means to acquire the necessary data to study these large mudflats. This was demonstrated in the TideSed and SedOptics project using remotely sensed data from a variety of sensors (I, II). However, the quantification of sediment properties from the hyperspectral signal is only possible if mathematical models which explain the influence of biological and physical properties on the hyperspectral signal are available.

The main objective of the CISS project is to develop methods to quantify biological and physical properties of intertidal sediments using a remotely sensed signal.

METHODS

Hyperspectral measurements were acquired in the laboratory with the Analytical Spectral Device (ASD), which records the reflectance in the visible, near infra-red and short wave infra-red region of the spectrum (350 till 2500nm). The spectral resolution is 3nm at 700nm and 10 nm at 1400 and 2100nm. The field of view is set to 1 degree, the height of measuring is 50cm, and the instrument is nadir looking. Calibration is performed every 30 minutes using a spectralon panel. Since the light source is constant and illumination conditions are not changing, calibration does not need to be carried out more frequently.

Sediment was collected on a Belgian intertidal zone located at the outlet of the IJzer river in the North Sea. The sediment was sieved into fractions of medium, fine and very fine sand. A clay fraction without organic matter and water were also used to make the sediment mixtures.

The sediment mixtures were made in small pots which were painted in black so that the reflectance of the pots was almost equal to zero. The depth of the sediment mixtures was 0.5cm.

Four sets of experiments were carried out:

1) With varying grain size distribution of sand mixtures. Measurements on the medium, fine and very fine sand fractions, and on mixtures of varying contents of these three sand fractions were carried out.

2) With varying clay content. The clay fraction was gradually increased in fine sand and in medium sand. The weight percentage clay and the reflectance of each mixture were measured.

3) With varying water content. Fine sand, medium sand and mixtures of fine sand and clay were saturated with water. The moist samples were then heated on a warm plate to ensure homogeneous drying. The drying procedure was checked regularly and appeared to happen very gradually. The samples were regularly weighted and reflectance was measured.

4) Sediment with and without bioturbation by *Corophium volutator*. *Corophium volutator* is a macrobenthic species, mainly occurring at high tidal flats with high mud content, low current velocity and the presence of diatoms. Its influence on sediment stability is related to diatom grazing and bioturbation, thereby changing the physical sediment properties. Two reservoirs were filled with a sediment mixture of 50% clay and 50% sand. The sediment was saturated with water. *Corophium volutator* was added to one of the reservoirs where it was allowed to bioturbate the sediment for 12 hours. Afterwards, the water was drained. Spectral measurements of the sediment in the two reservoirs were taken every 30 minutes during the drying of the sediment. At each interval, sediment samples were taken to analyse the moisture content.

The absorption features of clay and water can be quantified in three different measures and then related to clay and moisture content (Figure 1):
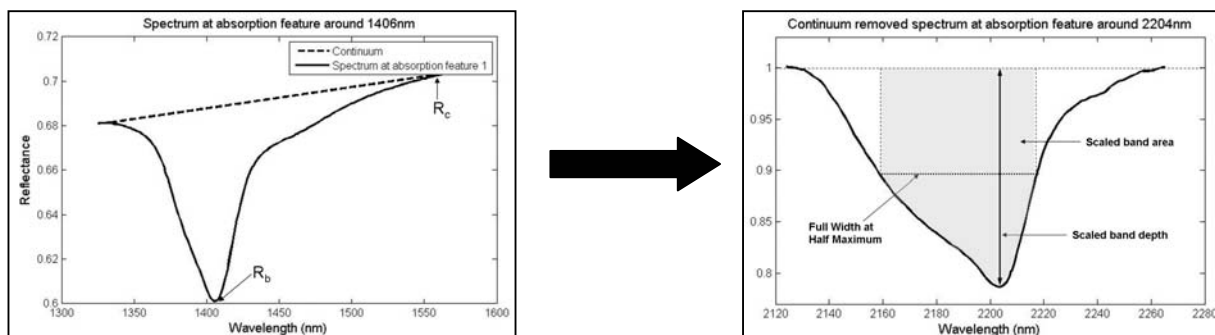

Figure 1: Measures that quantify absorption features

1. Ratio: R_b/R_c (R_b =reflectance at maximum absorption, R_c =reflectance out of absorption feature)
2. Depth of absorption feature of continuum removed spectrum: $(R_c - R_b)/R_c$
3. Scaled band area: $\int (R_c - R_b)/R_c \, d\lambda$. The integral is taken over Full Width at Half Maximum (FWHM)

The wavelength of maximum absorption, the start position of the absorption feature and the FWHM are calculated for each spectrum, since these parameters might be dependent on instrument, grain size and moisture content.

RESULTS

A weak discrimination between very fine sand, fine sand and medium sand can be made in the visible region of the spectrum (Figure 2). The smaller the grain size, the higher the reflectance, due to the fact that more surface can scatter light when the grain size is smaller. In the NIR and the SWIR, no distinction could be made.
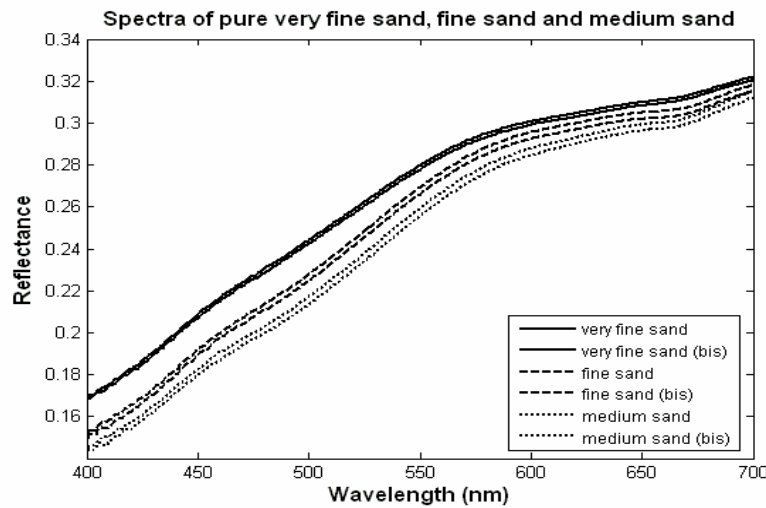

Figure 2: Spectra of very fine, fine and medium sand in the visible light

The main absorption features of clay are situated at 1406nm and at 2204nm. Good correlations between scaled band area of absorption features at 1406nm and 2204nm are observed (r2 = 0.92-0.98), but the relations are dependent on the grain size of the sand fraction (Figure 3).
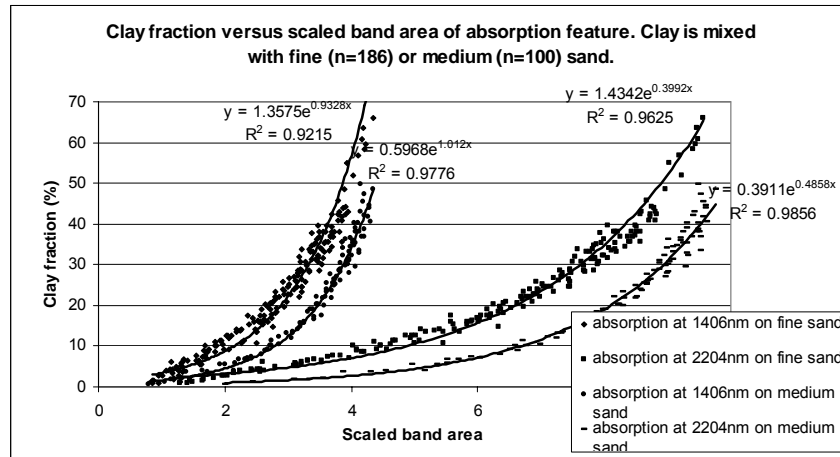

Figure 3: Clay fraction versus scaled band area of absorption features at 1406nm and 2204nm

The same observation is valid for moisture content. The best correlations are obtained between relative moisture content in fine sand and scaled band area of the absorption feature at 1450nm

(r2=0.95) (Figure 4). Correlations are the highest if one sand fraction is mixed with water. Lower correlations are obtained if samples with other sand fractions or samples with mixtures of sand and clay are used (Figure 5).
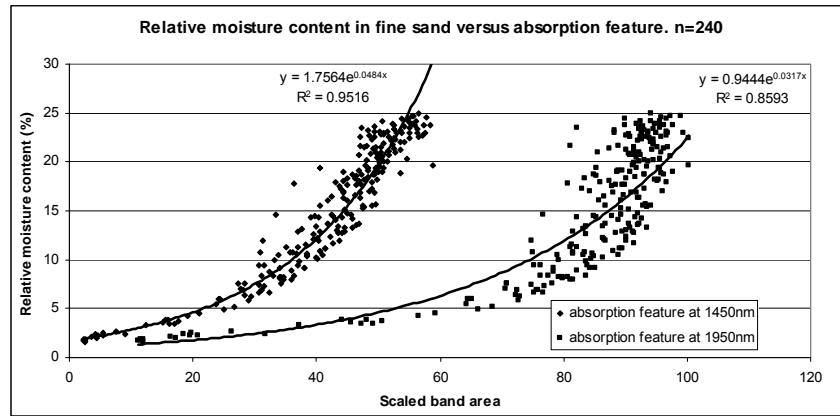

Figure 4: Relative moisture content versus scaled band area of absorption features at 1450nm and 1950nm for mixtures of water with fine sand
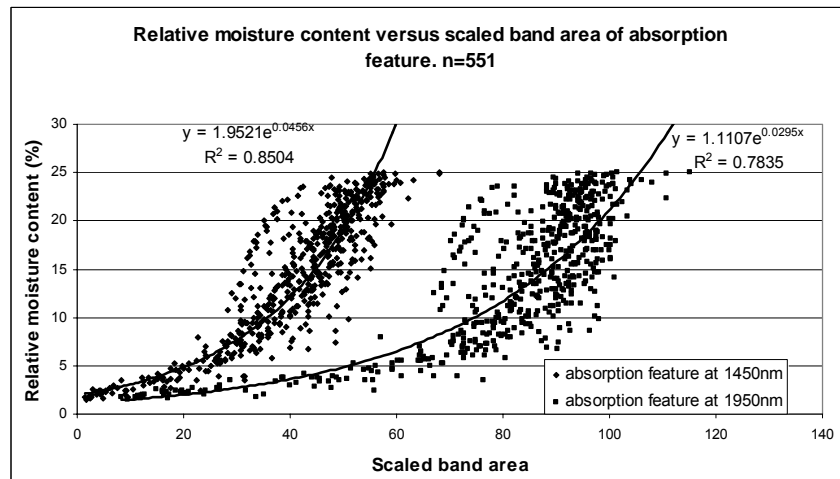

Figure 5: Relative moisture content versus scaled band area of absorption features at 1450nm and 1950nm for mixtures of water with fine and medium sand and clay

As for the experiment with *Corophium volutator*, two observations were made. Firstly, the sediment surface of the reservoir with bioturbation remained moist for a longer period after draining the water, which was also noticed in the measurements of the moisture content of the sediment. Secondly, spectra show deeper water absorption features at 1450nm and higher reflectance in the VIS and NIR in the reservoir with bioturbation.

CONCLUSIONS

The hyperspectral signal in the visible (VIS), near infra-red (NIR) and short wave infra-red (SWIR) acquired with the Analytical Spectral Device (ASD) in laboratory conditions can be used as predictor for clay and moisture content in the surface layer of sediment mixtures.

Quantitative measures of absorption features are highly correlated with clay and moisture content in sediment samples. For clay, the best correlations are obtained for the scaled band area of the absorption feature at around 2204nm (r2=0.98). The scaled band area of the water absorption feature at around 1450nm is highly correlated with moisture content (r2=0.95). A shift in the minimum reflectance of the absorption feature, probably due to grain size distribution or quantity of clay or water present, was observed and taken into account in the calculations.

Lower correlations between absorption features and clay content are obtained if the sediment samples consist of different sand fractions. For moisture content, the correlation decreases if the sediment samples consist of mixtures of different sand fractions and clay.

Bioturbation caused by *Corophium volutator* changes the sediment properties. The presence of *Corophium* might be detected using remote sensing techniques, because of the changed physical sediment properties.

Future research will include the bidirectional effects on the reflectance of sediment and mud samples. A spectrogoniometer is available.

More investigation on the use of absorption features with varying moisture content and clay content will be carried out. Other classification methodologies such as feature selection combined with linear and non-linear classification methods will be applied on the data.

Additionally, the developed methods will be applied on in situ measurements with simultaneous sediment sampling and analysis. Such measurements were collected in the framework of the Tide-Sed and SedOptics project and will also be collected for the ALGASED project (2007-2009). It is expected that the accuracy will decrease due to environmental factors such as microphytobenthos, macro algae, micro relief, macro faunal species,…

ACKNOWLEDGEMENTS

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