DIRECTIONAL MEASUREMENTS FOR REED DIFFERENTIATION

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ABSTRACT

Chris/Proba water mode data were acquired from two test sites in the Danube Delta on the 27th of September and on the 14th of October 2003. The multispectral imaging capability of the system should be used for water content analysis and macrophyte abundance mapping. In the test images aquatic macrophytes already disappeared due to the late registration date. The existing data set is used to test the synergy between the so called "multispectral approach" evaluating the spectral information, and the "anisotropy approach", which is exploring the backscatter differences between correspondent off-nadir view angles in the different spectral bands. An improvement in reed geno- and/or phenotype identification is expected, which in the field are mainly differentiated by morphological features. Preliminary results show a couple of features supporting the work hypothesis.

5 INTRODUCTION

Wetlands, being predominantly natural or semi-natural land cover types are in several cases subject of conservation or at least restrictions controlled by national or international treaties, conventions or directives like Ramsar, Natura 2000, UNESCO biosphere reserve, the water framework directive, etc. and should not change her character and/or function. Reed is a dominant species of wetlands and a sensitive indicator for disturbances of the natural balance. The problem addressed with our research may be fixed by some few words: invasion or uncontrolled expansion on the one hand side, but decline and dieback on the other hand. Both developments are associated with severe, partially irreversible disturbances of the affected ecosystems. In Northern America the haplotype M of common reed (Phragmites australis) is counted to the top ten of most invasive species. Haplotype M is on the way to substitute the native genotypes gaining substantial disturbances of wetland ecosystems in the US. In Europe reed populations of the prealpine lakes are diminishing whereas in the Masurian Lake District an ecologic balance disturbing expansion is to be observed. Additionally, predictions of climate change simulations let expect an expansion of Mediterranean reed types into Northern latitudes.

National programs in Europe try to stop the decrease of reed in the prealpine environment and to stop or at least to control the expansion in the Masurian Lake District. National programs in the US focus on identification of haplotype M populations, on concepts for the monitoring of the expansion of these populations and on the development of mitigation strategies. As most prospective strategy, the control by specialised bio-agents was identified.

All these tasks require a stable and reliable method for detection, inventory and monitoring of reed population dynamics. The areas affected but the dynamics of the observed phenomena exceed the possibilities of terrestrial surveys and direct the expectations toward RS based methods. The strategic objectives addressed by our research are:

- To develop and demonstrate a reed phenotype identification and status assessment prototype based of advanced remote sensing systems and data analysis software solutions.
- To develop an RS based monitoring prototype for invasion detection and mitigation measure success evaluation.

Recent projects on wetland monitoring by remote sensing in Upper Bavaria exploring Ikonos data sets ([1] finished end 2003) as well as HyMap/Rosis/HRSC data sets ([2] ongoing up to the end of 2005 [2]) gained promising results applying a strategy based on rule based classification routines incorporating existing information with object-oriented software [3][4]. The requirements on a reed geno- and/or phenotype identification prototype based on state of the art remote sensing data are higher then for wetland types in general and need further development. Solely by considering all the specific features of the new generation of remote sensing instruments as they are high to very high spatial, spectral but radiometric resolution, it seems to be possible to solve the problems and to realise the envisaged semi- to automatic data evaluation chain for reed identification and status assessment.

Proc. of the 2nd CHRIS/Proba Workshop, ESA/ESRIN, Frascati, Italy
28-30 April (ESA SP-578, July 2004)

2 BACKGROUND

2.1 Remote sensing technical background

Satellite remote sensing systems with ground resolutions in the 1m range are already operational. Systems equipped with multi- to hyperspectral sensors and multiangular look capabilities are scheduled to become operational in near future. The integration of more efficient scanners with better spectral resolution and almost simultaneous acquisition of on track panchromatic stereo-, multi- to hyperspectral data with different looking angles should provide the means for extrapolating essential parameters for vegetation analysis, expanding the present data evaluation options.

CHRIS/Proba, developed as technology demonstrator, proofed to be of high interest for the scientific community dealing with data analysis aspects as well. Basically three approaches can be tested with CHRIS/Proba data sets:

(i) The increase in information reliability by hyperspectral in front of multi-spectral data sets, subdivided in land and water applications

(ii) Investigation of the so called "anisotropy approach" [5] evaluating the angular signatures as derivable from the five view angles

(iii) The calculation and thematic implementation of pixel sharp and simultaneously registered surface models into thematic evaluations

The majority of the ongoing investigations are concerned with the hyperspectral aspect of CHRIS/Proba data evaluations. At least during the 2nd CHRIS/Proba workshop the "anisotropy approach" has been addressed solely by one forest application [6] and the research proposal presented in this paper. An attempt to calculate digital elevation models from multiangular CHRIS/Proba data was missed at all.

The focus of the planned research as described in this paper is on the ***synergistic use*** of *spectral* and *angular* signatures derived from the hyperspectral and multiangular CHRIS/Proba data sets. Data acquired simultaneously from different view angles provide information about the angular signature. In case of CHRIS/Proba data there are two sets of corresponding registration angles with opposite view directions, one with +/- 36° and the second with +/-55°. First estimates on the potential of angular signature evaluations are reported from agriculture [5] and forestry [7]. The present investigations should give an estimate on the potential of the approach for reed identification and status assessment.

2.2 Thematic background

The trend in remote sensing data evaluation is oriented toward the retrieval of bio- chemo- and geo-physical parameters. Such parameters are used in modelling from the local scale, where identification and status assessment are in the focus, to matter and flux transport modelling at regional and global scales. In vegetation mapping the focus is on the derivation of parameter describing the canopy. Profiling methods for the identification and the assessment of the status of the canopy incorporated in expert systems are based on such parameter. In traditional spectral based remote sensing, canopy status is estimated by parameter like LAI, biomass, equivalent water thickness (EWT), etc., which are correlated to the spectral reflectance in different wavelength and are exploring the spectral signature. Using ratios of specific wavelength some of the radiometric effects can be eliminated. Unfortunately few of the common used indices, namely the normalised differentiated vegetation index (NDVI) and the simple ratio (SR) (both evaluating the differences between chlorophyll a, b absorption in the red and the high reflecting and the cell structure related signal in the near infrared region of the reflective spectra) are running into the saturation once canopy is closed and more than three to four leaf layers occur (LAI 3-4). Additionally, in vegetation oriented field spectroscopy it is a well known fact that a slight drought stress can lead to an accentuation of vitality indicators. This is related to leaf shrinking and connected effects like concentration of pigments and an increase of the shadow fraction, which can result in an increase in NIR reflectance and a decrease in VIS reflectance, both indicating a higher vitality and are leading to errors in status assessment, especially at the starting point of drought stress phases [8].

The deduction of bio- chemo- and geo-physical parameter from multi- to hyperspectral data is considered to be in general solved. In our overall research concept emphasis is there fore given to the description of data flow from the anisotropy information derived from angular signals to the step of structure parameter extraction on behalf of "inverted" physical models of surface backscattering (see[9]).

For vegetated surfaces the property of anisotropic backscattering is considered to be a function of plant architecture and stand structure. Both are changing with the phenologic phase and the physiologic condition. From ground observations in the agricultural domain it is well known, that already slight differences in crop development inside one plot can be detected on behalf of leaf position. For example cereals show a significant change in leaf alignment from erectophile towards planophile during the transition phase from the vegetative to the reproductive phase of plant development. Other crop types show specific reactions on water deficit. A typical reaction on drought stress for maize for example, is the rolling of leafs. Other crops react to drought with the reduction of turgor pressure and leaf shrivelling. This is a very significant reaction of sugar beet but also of rape and bean.

The backscatter characteristic as formalised in the Bidirectional Reflection Distribution Function (BRDF) proved to be very sensitive to structural changes of the canopy [10][11].

The reaction on reed reflectance on differing environmental conditions is still not investigated. The expectances on evaluating angular data following the anisotropy approach are in the derivation of structure parameters, especially of the leaf angle distribution (LAD). LAD is a very sensitive parameter describing phenologic /physiologic differences inside the plot and one of the most important parameter in physical models. LAD can not be derived from nadir looking spectral data sets.

3 TEST SITE

The Danube Delta in Romania is one of the largest reed covered areas in the world with differing reed type populations from land-, aquatic and floating reed. In the Danube Delta our partner from National Danube Delta Institute (INDD) in Tulcea, Romania is involved in different national and international long term studies. Ground reference data on water quality, macrophytes, fisheries, reed stands as well as on restored polder areas are regularly collected with funds from the World Bank and the WWF.

The centre co-ordinates of the "red" lake test site are 45,0833 N, 29,5833 E. The location is near the seaside, in the "brackish" zone of the delta (Fig. 1). The evaluated data is from 27th of September 2003, registered with the so called "water-mode" with 18 bands.

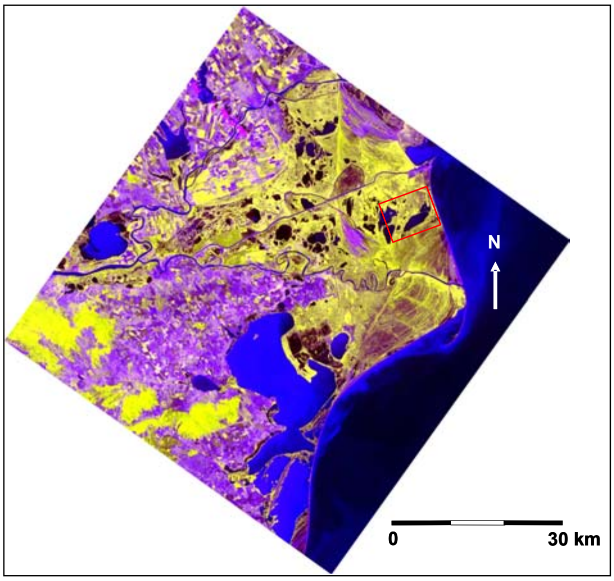

Fig. 1: MOMS-2P mode D image showing the location of the CHRIS/Proba test site Danube Delta "Red Lake" (red frame) imaged on 27th of September 2003

4 INVESTIGATION CONCEPT

The special goal for CHRIS/Preoba data analysis is oriented toward the evaluation synergies between the so called "multispectral–" and the "anisotropy- approach" as described by [5].

„Multispectral approach": The multispectral imaging capability of the system should be used for water content analysis and macrophyte abundance mapping. From the approach we expect information on pigments, cell structure, water contents (chlorophyll, yellow matter, suspended matter, etc.)

„Anisotropy approach": multidirectional imaging capability should be used for deriving structural parameter from land vegetation. The general evaluation concept is shown in Fig. 2.

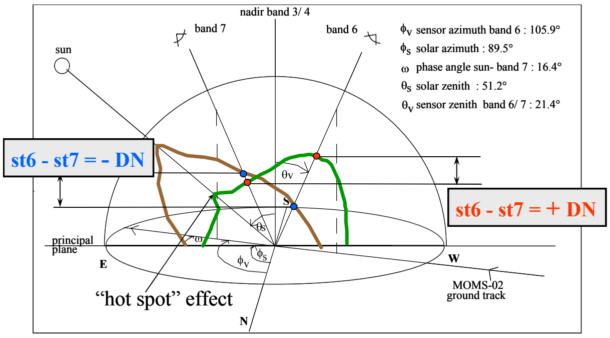

Fig. 2: Principle of information extraction from nadir symmetric angular image pairs shown for the MOMS-02 stereo data registration geometry and the assumed backscatter function of a forward (green) and a backward (brown) scattering surface.

The work hypothesis of our ongoing research is that angular signatures as retrieved by the multiangular imaging capability of the CHIS/Proba system, deliver information which may be related to morphological differences of reed stands. The differentiation of reed from other wetland types should be possible by spectral and textural analysis [12][13]. The differentiation of reed geno- and/or phenotypes solely by these signature types often fails due to the effect of spectral confusion and similar texture. For this case angular signatures may be a solution. In the field the differentiation of reed geno- and/or phenotypes is mainly based on morphological features. Angular signatures are controlled by plant architecture and canopy structure. Combining spectral and angular signatures we expect a better differentiation of reed geno- or at least phenotypes.

In the long term the identification of reed stands should be possible within automatic procedures evaluating multi- to hyperspectral multiangular data by combining ancillary data, growth- and backscatter models in a joint model environment as described in [14] for precision agriculture applications. The presented work is part of that general investigation concept for bio-geo-chemo-physical parameter extraction and status assessment, dealing with the satellite data, while the work presented in [9] is addressing the ground segment "laboratory loop".

5 PRELIMINARY RESULTS

The present level of data evaluation is a first “quick and dirty” estimate of the potential. No state of the art georectification and radiometric correction for sensor and atmospheric attenuations have been performed. The results show solely relative differences.

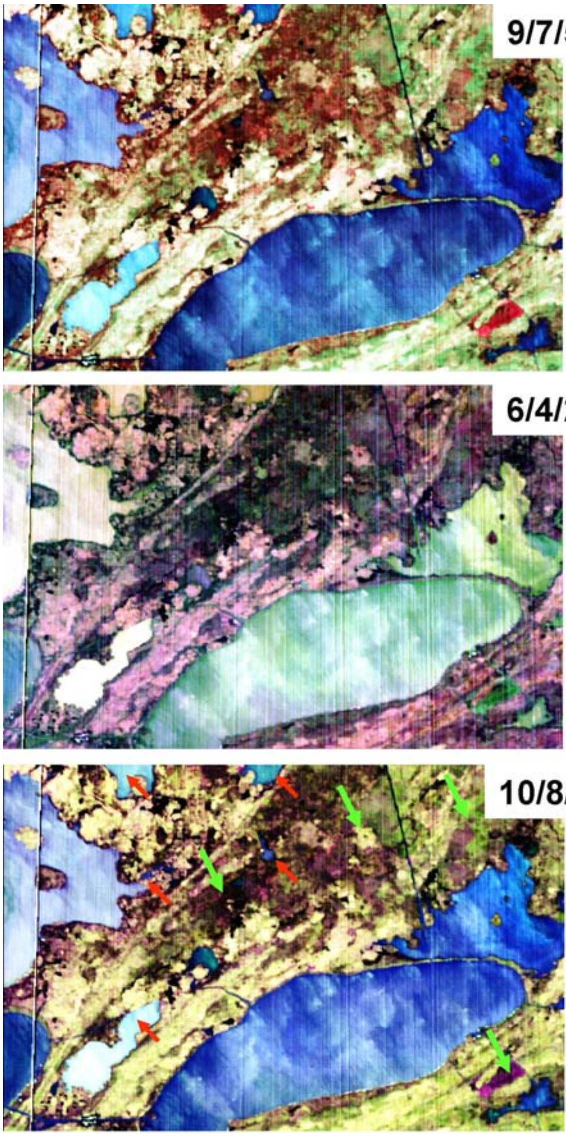

Fig. 3: Three different RGB composites giving an impression on the potential of spectral data evaluations in the domain of water content and vegetation analysis. No radiometric correction was applied,

Fig. 3 displays three different RGB composites giving an impression on the potential of spectral data evaluations in the domain of water content and vegetation analysis. As the striping proves no radiometric correction was applied, the only image enhancement step was a standard data stretch. At the present stage no water content analysis has been performed. It is envisaged to apply methods of water content analysis developed at the DLR [15][16] on the data sets of the 2004 vegetation period.

For a first “quantitative” comparison of surface types we processed the data with the object oriented image analysis system eCognition. The first step in an eCognition analysis is the segmentation of the data, which is resulting in homogeneous regions. A detailed description of the process is given in [17]. For each segment a data base is created with a couple of features describing spectral, textural, form parameter and neighbourhood relations. Evaluating the mean value of each segment we take the assumption that the segmentation is working like a filter process which is eliminating the striping effects in the data (Fig. 4). Based on this assumption we restricted the comparison on the mean values of the segments.

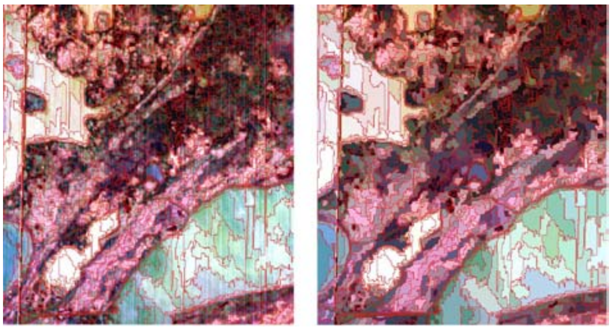

Fig. 4: Filter effect of the eCognition segmentation assumed to balance the disturbance of the mean object value by striping due to detector sensitivity differences. The left image shows the “original”, the right image the mean value per segment, both overlaid by segment polygons

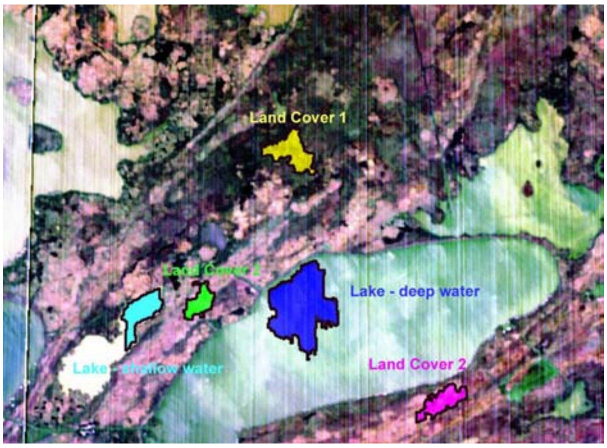

Fig. 5: Composite of CHRIS bands 6/4/2 (RGB) of the “water” mode overlaid with the objects chosen for comparison

Fig. 5 is displaying a RGB composite of a subset with the location of the visually selected and labelled objects chosen for comparison: “deep” and “shallow” water and three reed stand objects called land cover 1 to 3, all of them in the central part of the nadir scene. The objects used are the result of a second processing step which is merging segments according predefined criteria and that fore different in shape from the segments in Fig 4.

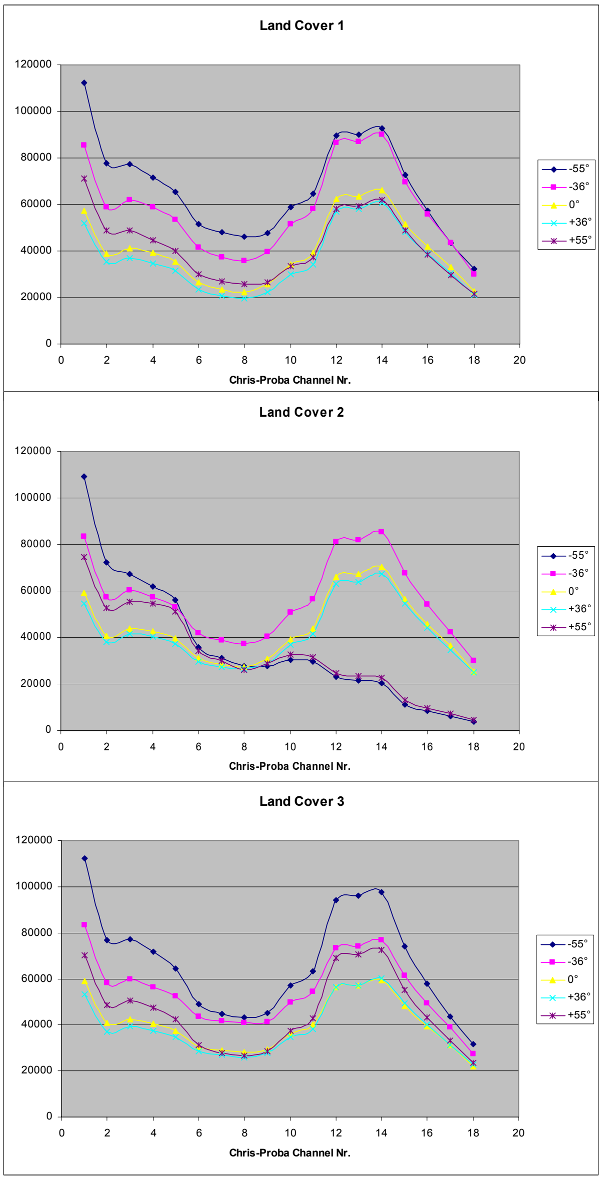

Fig. 6: Spectral signatures of the three reed stand land cover types displayed for the five view directions of the analysed CHRIS/Proba water mode data set.

The diagrams in Fig. 6 show the mean value of the three land cover objects, Fig. 7 of the two water objects for the five view directions and eighteen spectral bands of the CHRIS/Proba water mode data set analysed.

Already on the first glimpse the different behaviour of land cover type 2 is to be observed. Especially the NIR

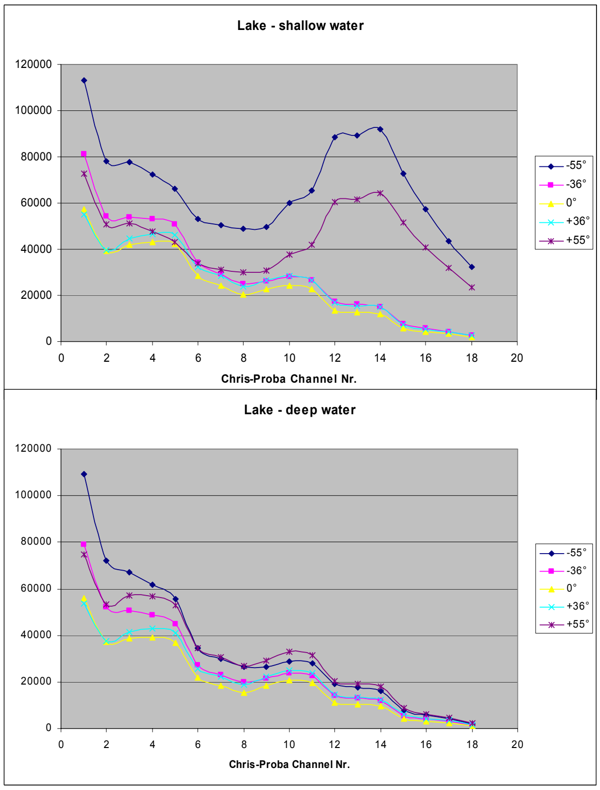

Fig. 7: Spectral signatures of the two water objects “lake deep” and “lake shallow” displayed for the five view directions of the analysed CHRIS/Proba water mode data set.

response of the 55° fore and backward looking positions is different from the backscatter intensity as well as from the shape of the signature curves. Remarkably as well is the relatively high backscatter intensity of land cover type 3 in the NIR range of the forward looking 55° position.

In case of the two water objects “lake deep” as well as “lake shallow” for the nadir and 36° view directions shows the expected backscatter behaviour with higher values in the visible and continuously decreasing values toward longer wavelength in the NIR. Unexpected high are the NIR values for the 55° view angles of the shallow water object.

A more profound analysis of the spectral signatures in relation two view angels has not been performed.

The next step was to compare the anisotropy ratio [5] also called anisotropy quotient [11] for the five objects. The “anisotropy ratio” is calculated by dividing the signals of the corresponding view angles (-36°/+36°; -55°/+ 55°) and is considered to be a measure of the anisotropic behaviour. The “anisotropy ratio” was chosen instead of the difference index shown in Fig. 2 for the MOMS-02 geometries, as while no radiometric corrections have been done and the difference index is influenced by absolute signal heights

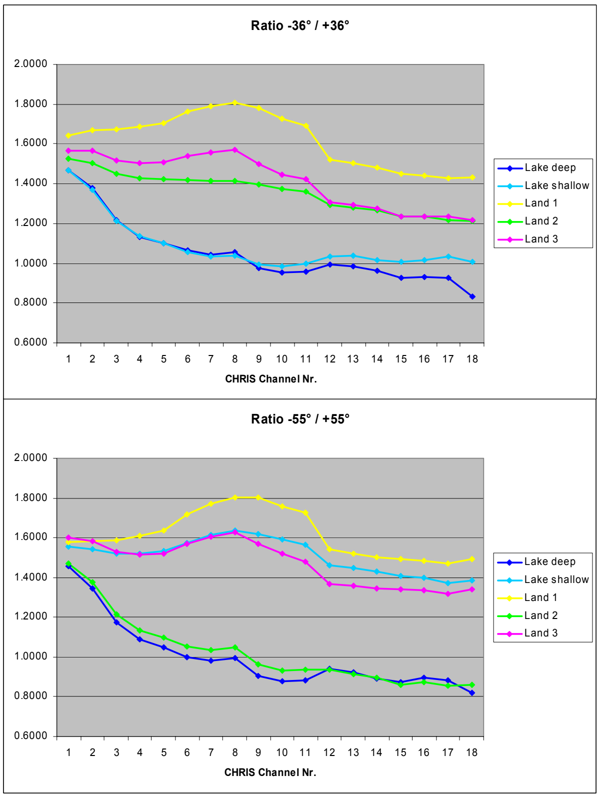

Fig. 8: Spectral behaviour of the "anisotropy ratio" of the corresponding view angles (-36°/+36°; -55°/+ 55°) for the five objects under investigation displayed for the eighteen bands of the evaluated CHRIS/Proba data set

Fig. 8 is displaying the values of these ratios for the eighteen bands of the data set and the 36° and 55° ratio.

The graph of the 36° ratio in the upper part of Fig.7 shows a clear differentiation of land and water objects. The 36° ratio of land objects is for all spectral bands higher then for water objects. Land cover 1 and 2 objects show a trend to increase from the VIS to the NIR and to decrease in the NIR with longer wavelength. The land cover 3 36° ratio is decreasing continuously similar to both water object 36° ratios, but at significantly higher ratio values.

The graph of the 55° ratio in the lower part of Fig.7 show a similar trend for land cover 1 and 3 as well as for "lake deep". "Land cover 2" and "lake shallow" practically changed their behaviour: "lake shallow" signs similar to the "land cover" objects and "land cover 2" like "lake deep".

6 CONCLUDING REMARKS

Due to the preliminary character of the research a discussion of the results seems not to be appropriate at this stage. Nevertheless we got some insight in data handling of CHRIS/Proba data and found some very interesting aspects worth to be investigated more in detail:

- The work hypothesis, that an improvement of reed geno- or at least phenotypes which differ from morphology is possible by combining spectral and angular signatures, was supported by the preliminary results.
- The use of angular signature for quantitative information is much more difficult than for spectral signatures and needs a further development of physical backscatter models for reed.
- The radiometric calibration for sensor but atmospheric and topographic effects needs to be adapted for off nadir view angles.
- The very sophisticated imaging geometry of CHRIS/Proba needs special georectification approaches. The simple image to image rectification does not work accurate enough.

All over it should be stated that the experimental CHRIS/Proba system offers a couple of very interesting research aspects which can not be investigated by operational space sensors. For a follow on experimental system we suggest an orbit which allows registering data at differing daytimes. This will broaden the experimental aspects on changes over the day and will definitively bring advantages in mountainous terrain where shading effects of a sun synchronous orbit may be reduced.

As recommendations for an operational follow on system we would suggest the following changes in system design, which we assume to increase the value of the data and facilitate the evaluation:

- The same pixel sizes for all view directions should be envisaged to allow a direct matching of nadir looking and off nadir looking bands and derived information at the highest possible spatial resolution.
- The different view angle due to the, admittedly, very sophisticated method to increase integration time, is introducing an error source very hardly to be considered during processing.

7 ACKNOWLEDGEMENTS

We wish to thanks ESA and the CHRIS/Proba technical and scientific team for providing us with data of the system and offering a forum for discussing the results.

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