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IMAGING SPECTROSCOPY IN ECOLOGY AND THE CARBON CYCLE: HEADING TOWARDS NEW FRONTIERS

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ABSTRACT

Recent advances in successfully coupling remote sensing derived products with requirements of ecologists have been documented and summarized widespread in the scientific literature (c.f., i). The particular role of imaging spectroscopy in that relation has been outlined repeatedly (ii), but still some major issues remain open, uncertain, or even very challenging to be solved. Following an approach to structure various imaging spectroscopy based approaches to ecology, focus shall be put on selected existing challenges. Finally some perspectives for the future are given.

This contribution is based on a keynote talk given at the conference of these proceedings. The slides that were used along with this talk are reprinted in the appendix.

IMAGING SPECTROSCOPY BASED APPROACHES TO ECOLOGY

Liang (iii) proposes to group quantiative remote sensing based methods into the following approaches:

- Continuous fields
- Quantitative, *physical* methods
- Quantitative, *statistical* methods
- Categorical variables
- Classification based approaches
- Discrete classes
- Base maps
- Orientation and visualisation

For all of the above examples are given as follows: physical based approaches are the LAI and fPAR products of MODIS (iv) and the example for a statistical approach is demonstrated using a regional correlation based approach to estimate LAI from HyMap data (v). The classification based approach is a comparison of EO-1 ALI with Hyperion using a segmented linear discriminant analysis (vi) and discrete classes are generated for icplant invasive specie map in California (vii). Finally, base maps are not frequently produced using imaging spectrometers, but the presented case from the September 11 WTC incident (viii, ix) is a good demonstrator case not only for airborne imaging spectroscopy, but also a combination of the presented methods was used in outer space research recently (x).

CHALLENGES

Even though still numerous challenges exist in linking ecological research to remote sensing, only a few shall be mentioned here. Particular focus shall be put on research areas like:

- Climate scenarios vs. vegetation scenarios (c.f.,xi;xii;xiii,xiv)
- Global Land Use/Cover Monitoring (c.f.; xv, xvi; xvii)

- Land-Biosphere Models (c.f., xviii; xix)
- Validation (xx; xxi), and
- Biochemistry (xxii; xxiii).

CONCLUSIONS/OUTLOOK

Over the past years, significant advancement has been made whilst using imaging spectroscopy for the integration of remote sensing and ecology. Eventually this has lead to a deepened understanding of the physical interaction of photons with surface properties. In particular – as the above examples demonstrate - certain links between remote sensing and ecology have been significantly advanced because of advances in imaging spectroscopy.

But it needs to be emphasized that imaging spectroscopy solely will never solve the challenges alone – integrated solutions (e.g., multiple-sensor platforms, swarms of instruments, coupled instrument platforms, etc.) will be dominating future trends.

Due to the lack of an existing long term view for data continuity provided by imaging spectrometers, the scientific community needs to demonstrate with sound applications that imaging spectroscopy has the potential to become soon a commodity and not remain a fancy technology.

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APPENDIX

Power Point presentation

REFERENCES

i Cohen, W.B. & Goward, S.N. (2004) Landsat's role in ecological applications of remote sensing. *Bioscience*, **54**, 535-545.

ii Ustin, S.L., Roberts, D.A., Gamon, J.A., Asner, G.P., & Green, R.O. (2004) Using imaging spectroscopy to study ecosystem processes and properties. *Bioscience*, **54**, 523-534

iii Liang, S. (2004) *Quantiative Remote Sensing of Land Surfaces* John Wiley & Sons, Inc., Hoboken (NJ), USA.

iv Myneni, R.B., Hoffman, S., Knyazikhin, Y., Privette, J.L., Glassy, J., Tian, Y., Wang, Y., Song, X., Zhang, Y., Smith, G.R., Lotsch, A., Friedl, M., Morisette, J.T., Votava, P., Nemani, R.R., & Running, S.W. (2002) Global products of vegetation leaf area and fraction absorbed PAR from year one of MODIS data. *Remote Sensing of Environment*, **83**, 214.

v Schlerf, M., Hill, J., & Atzberger, C. (2005) Remote sensing of forest biophysical variables using HyMap imaging spectrometer data. *Remote Sensing of Environment*, **95**, 177.

vi Xu, B. & Gong, P. (2002) Land use/cover classification with multispectral and hyperspectral EO-1 data: a comparison. *http://www.cnr.berkely.edu/~bingxu/pub/hyper_101002.pdf*.

vii Underwood, E., Ustin, S., & DiPietro, D. (2003) Mapping nonnative plants using hyperspectral imagery. *Remote Sensing of Environment*, **86**, 150.

viii Clark, R.N., Green, R.O., & et al. (2001) Environmental Studies of the World Trade Center area after the September 11, 2001 attack. *http://pubs.usgs.gov/of/2001/ofr-01-0429/index.html*.

ix Clark, R.N., Swayze, G.A., Livo, K.E., Kokaly, R.F., Sutley, S.J., Dalton, J.B., McDougal, R.R., & Gent, C.A. (2003) Imaging spectroscopy: Earth and planetary remote sensing with the USGS Tetracorder and expert systems. *Journal of Geophysical Research-Planets*, **108**, -.

x Clark, R.N., Brown, R.H., Jaumann, R., Cruikshank, D.P., Nelson, R.M., Buratti, B.J., McCord, T.B., Lunine, J., Baines, K.H., Bellucci, G., Bibring, J.-P., Capaccioni, F., Cerroni, P., Coradini, A., Formisano, V., Langevin, Y., Matson, D.L., Mennella, V., Nicholson, P.D., Sicardy, B., Sotin, C., Hoefen, T.M., Curchin, J.M., Hansen, G., Hibbits, K., & Matz, K.-D. (2005) Compositional maps of Saturn's moon Phoebe from imaging spectroscopy. *Nature*, **435**, 66-69.

xi Rast, M., Baret, F., van de Hurk, B., Knorr, W., Mauser, W., Menenti, M., Miller, J., Moreno, J., Schaepman, M.E., & Verstraete, M. (2004). SPECTRA - Surface Processes and Ecosystem Changes Through Response Analysis. ESA Publications Division, ESA SP-1279(2), Noordwijk.

xii Kooistra, L., Clevers, J., Schaepman, M., van Dobben, H., Sykora, K., Holtland, J., Batelaan, O., Debruyn, W., Bogaert, J., Schmidt, A., Clement, J., Bloemmen, M., Mucher, C.A., van den Hoof, C., de Bruin, S., Stuiver, J., Zurita, R., Malenovsky, Z., Wenting, P., Mengesha, T., van Oort, P.A.J., Liras Laita, E., Wamelink, W., Schaepman-Strub, G., Hung, L.Q., Verbeiren, B., Bertels, L., & Sterckx, S. (2005) Linking Biochemical and Biophysical Variables Derived from Imaging Spectrometers to Ecological Models - The HyEco'04 Group Shoot. In Abstracts - 4th Workshop on Imaging Spectroscopy (eds B. Zagajewski, M. Sobczak) Vol. 1, p. 61, EARSeL, Warsaw (and this volume)

xiii Schmidt, A., Kooistra, L., van Dobben, H., & Schaepman, M. (2005) Usefulness of Multispectral and Hyperspectral Remote Sensing Data to Detect Ecologically Relevant Biochemical and Biophysical Variables - A Demonstration Project. In Abstracts - 4th Workshop on Imaging Spectroscopy (eds B. Zagajewski, M. Sobczak) Vol. 1, p. 55, EARSeL, Warsaw (and this volume)

xiv Mengesha, T., Schaepman, M., De Bruin, S., Zurita Milla, R., & Kooistra, L. (2005) Ground Validation of Biophysical Products Using Imaging Spectroscopy in Softwood Forests. In VALERI Workshop (eds F. Baret & M. Weiss), VALERI website, INRA, Avignon (F).

xv MA Board (2005). Millennium Ecosystem Assessment Synthesis Report, *http://www.maweb.org*.

xvi Mucher, C.A. & Schaepman, M. (2005). Inventory of Regional, National, and Global Land Cover Maps (unpublished). WUR, Wageningen.

xvii Gerard, F. (2005) Biopress - Linking Pan-European Landcover Change to Pressures on Biodiversity. http://www.creaf.uab.es/biopress/.

xviii Dangel, S., Brazile, J., Kneubuehler, M., Schaepman, M., & Itten, K.I. (2005) The Design and Prototyping of the SPECTRA Simulator Architecture. In Abstracts - 4th Workshop on Imaging Spectroscopy (eds B. Zagajewski, M. Sobczak) Vol. 1, p. 30, EARSeL, Warsaw (and this volume)

xix Nemani, R.R. (2005) Ecological Forecasting - Monitoring, Modeling, and Forecasting the Impacts of Climate Variability and Change on Ecosystems. http://geo.arc.nasa.gov/sge/ecocast/index.html.

xx Baret, F. et al. (2005) Evaluation of the representativeness of networks of sites for the validation and inter-comparison of global land biophysical products. Proposition of the CEOS-BELMANIP. *IEEE Trans. Geosci. Remote Sens.*, **accepted**.

xxi Morisette, J.T. et al. (2005) Validation of global moderate resolution LAI Products: a framework proposed within the CEOS Land Product Validation subgroup. *IEEE Trans. Geosci. Remote Sens.*, **accepted**.

xxii Schaepman, M. (2005) *Spectrodirectional Remote Sensing – From Pixels to Processes.* Inaugural address, WUR, Wageningen, in print.

xxiii Kneubühler, M., Schaepman, M.E., Thome, K.J., & Schläpfer, D. (2004) MERIS/ENVISAT vicarious calibration over land. In Proceedings of SPIE X: Sensors, Systems, and Next-Generation Satellites VII (ed R. Meynart), Vol. 5234, pp. 614-623.