THE USES, ABUSES AND OPPORTUNITIES FOR HYPERSPECTRAL TECHNOLOGIES AND DERIVED GEOSCIENCE INFORMATION

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INTRODUCTION

The emergence of hyperspectral sensing technologies from drill core logging to imaging satellites provides new opportunities and challenges for the resources community. The value of some of the currently available hyperspectral derived geoscience products is compromised by their quality, which is highly dependent on robust instrument, radiative transfer and cross-calibration corrections. Furthermore the processing of the hyperspectral data into valuable information products is non-trivial and ultimately requires standardized procedures. The current lack of standard procedures, including traceable validation and error assessment, prevents the resources community from recognizing the full potential of hyperspectral technologies. The Western Australian Centre of Excellence for 3D Mineral Mapping (C3DMM), which is part of the Minerals Down Under Flagship program of CSIRO Earth Science and Resource Engineering, is working on a processing strategy of hyperspectral proximal (e.g. HyLogger™, ASD Terraspec™) and remote sensing data (e.g. HyMap) for the development of traceable geoscience and higher level products to overcome the abuse of hyperspectral data.

PROCESSING STEPS

The processing strategy for generating geoscience and higher level products (Figure 1) is based on the Queensland Next Generation Mineral Mapping Project (Cudahy et al., 2008) and builds on the quality control of the acquired data. In the case of image processing of hyperspectral remote sensing data well calibrated radiance-at-sensor or surface reflectance data are required. Leveling and statistics-based methods should be avoided as these introduce undesirable scene-dependencies with the result that image products from different areas are not comparable. Physics-based reduction models are preferred. Complicating effects should be removed in their order of development (e.g. first instrument, then atmospheric, followed by surface effects) through either offsets or normalization.

When data are derived from proximal sensing techniques (e.g. HyLoggingTM suite, ASD TerraspecTM) standard calibration procedures have to be applied, including a regular re-calibration of the instrument with appropriate standards (e.g. spectralon panel). The calibration can be monitored by using a suite of natural and synthetic standards to observe possible changes in the quality or the setup of the calibration panels.

The integration of hyperspectral data acquired from various proximal and/or remote sensing sources requires a well designed cross-calibration procedure, to avoid for example shifts in band positions of the respective spectrometer, which can have a major influence in all successive data sets and higher level products.

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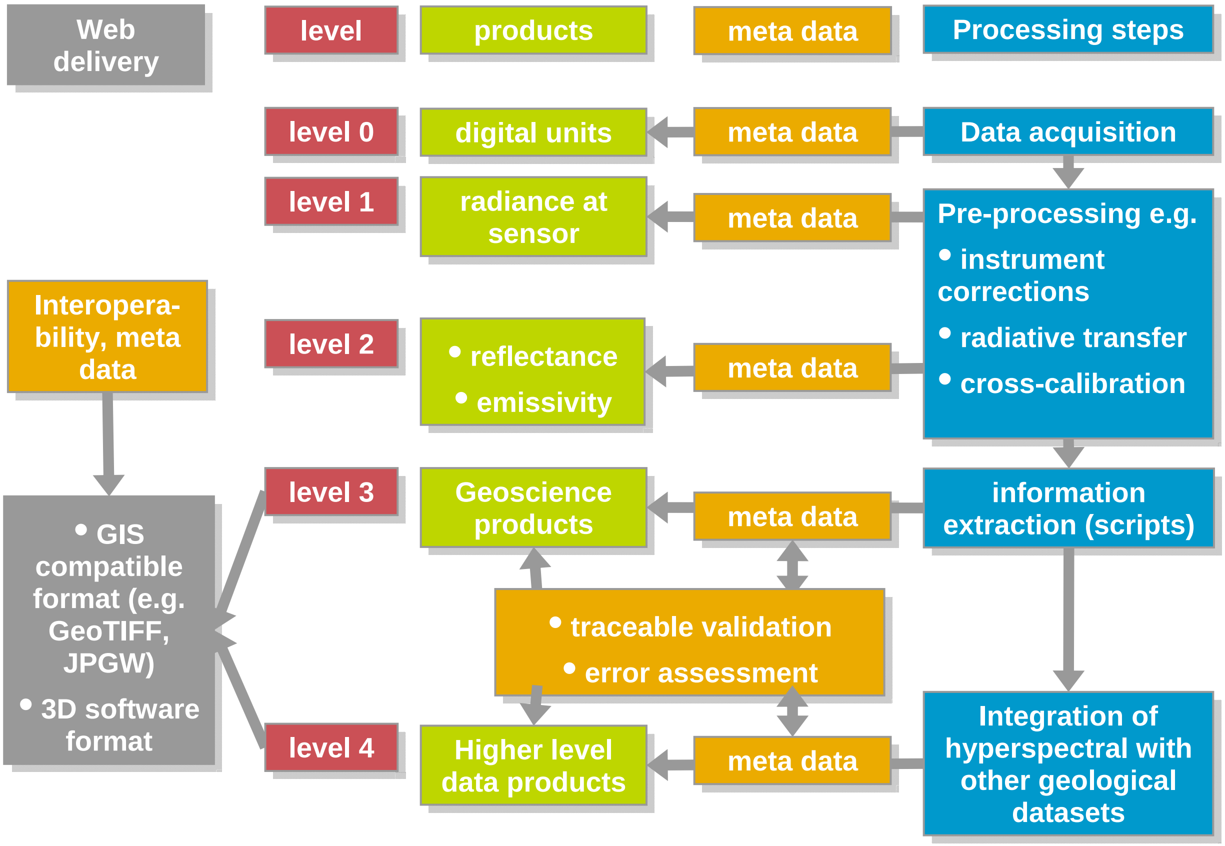

Figure 1. Strategy for processing of hyperspectral data

EXTRACTING MINERALOGY

A key step in the development of geoscience products is the extraction of mineralogical information from the calibrated infrared reflectance spectra. In hyperspectral technologies usually the visible-near (VNIR: ca. 350 - 1350nm), short-wave (SWIR: ca. 1350 - 2500nm) and thermal (TIR: ca. 8000 - 12500nm) infrared part of the electromagnetic spectrum are used to infer abundance and composition of various geological materials. The mineralogical information is captured in the reflectance spectra in absorptions features, which are based on the physicochemical characteristics of the various minerals. C3DMM is using feature extraction methods (Figure 2) to determine the mineralogy of a sample material regardless if the reflectance spectra are acquired with remote or proximal sensing methods. The advantage of the multiple feature extraction method (MFEM) is that the associated scripts are not biased on a training dataset or library spectra. This allows the same scripts to be applied to remote sensing and proximal hyperspectral data, which enables a straightforward integration of for example subsurface (e.g. HyLogging™) and surface data (e.g. HyMap) in 3D modelling software packages. Complications, such as spectrally overlapping materials, are removed by the application of thresholds. Interferences of mineralogical information with other surface materials such as vegetation can be evaluated by using a multiple linear regression model for unmixing vegetation from hyperspectral remote sensing data (Rodger & Cudahy, 2009). However, new feature extraction methods such as Gaussian Deconvolution are currently under development, which might need a smaller number of thresholds and enable more progress in mapping mixtures of minerals or even geological and other materials.

To process mineral maps from multi-scene HyMap apparent reflectance data CSIRO developed the IDLTM based software module C-HyperMAP, which can be imported into ENVITM (Cudahy et al., 2008). C-HyperMAP is designed to rapidly generate accurate seamless mineral maps from large volume, multi-run, hyperspectral surveys and is based on a programmable feature extraction-processing pipeline. The hyperspectral data are processed with the multiple feature extraction method on a per-flight-line basis, followed by mosaicing of the single flight lines and the generation of georeferenced mineral maps in standard GIS formats.

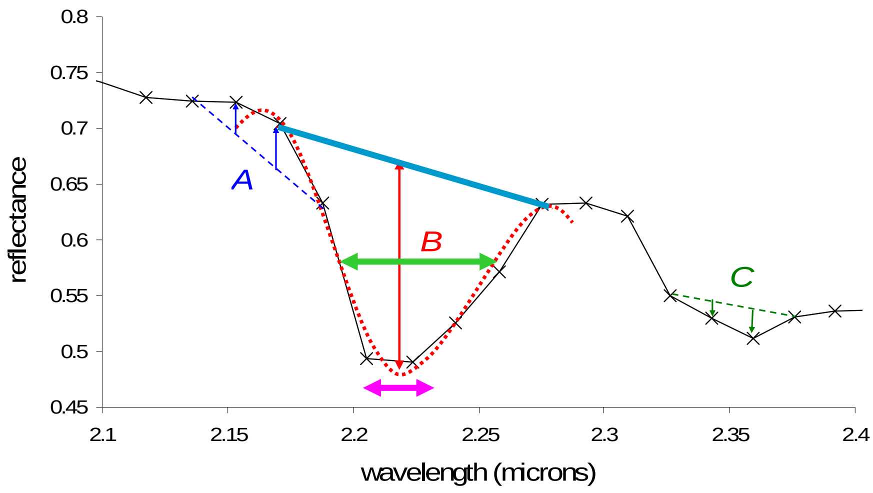

Figure 2. Multiple feature extraction method for identification of mineral abundance and composition: The absorption depth (B), relative to the background continuum, is assumed to be proportional to the mineral content. If the characteristic absorption feature for a given mineral is absent then this mineral is not present. The wavelength position of the absorption feature provides information about the composition of the mineral, the geometry of the absorption feature (full width half max and asymmetry) about the disorder. Multiple absorption features are used for each mineral to resolve ambiguities regarding mixtures with other minerals or materials (e.g. B-A+C = presence of mineral x)

PRODUCT LEVELS AND META DATA

Information products derived from hyperspectral remote sensing and proximal data can be distinguished in various levels. C3DMM would like an internationally recognized description of the various product levels (Figure 1), to make the Australian hyperspectral products more accessible to global users while maintaining high standard products. As a guideline the processing levels of ASTER products provided by ERSDAC are used, where Level 1 products are the radiance at sensor data and Level 2 products are for example reflectance and emissivity data. Level 3 comprises geoscience products, such as mineral group and mineral abundance and composition products. Level 4 includes higher level products, such as regolith or alteration models, where hyperspectral data were integrated with other geoscience datasets. All of the listed product levels ought to be accompanied by meta data, which comprise for example a detailed description of the source, spectrometer details, acquisition conditions, sampling geometry, quality, processing steps, applied scripts and error assessment to enable a traceable validation.

OPPORTUNITIES FOR HYPERSPECTRAL TECHNOLOGIES

Geoscience and higher level products of high quality derived from airborne hyperspectral data (e.g. abundance and compositional maps of kaolin, white mica and Al-smectite), were made available by the Queensland Geological Survey in 2008 (http://c3dmm.csiro.au). The high download rate of these data shows the high demand of precompetitive geoscience products. The successful application of mineral maps derived from hyperspectral airborne data for mapping geology was shown by several studies (e.g. Cudahy et al., 2005; Laukamp et al., in press). However, the full potential of mineral maps derived from hyperspectral remote sensing is narrowed when converting geoscience products into currently GIS-compatible formats like GeoTIFF and JPGW.

The integration of hyperspectral surface and subsurface data with other geoscience datasets (e.g. radiometrics, magnetics, drill hole geochemistry) provides further challenges. These challenges can include but are not limited to diversified data types (e.g. vector, raster) and spatial incoherency of the various datasets. The full quantitative (forward and inverse) modelling of all critical input measured data (no residuals) based on geological, regolith and alteration models will lead to a better understanding of mineral systems and a review of existing geological models. New methods and software modules are being developed by C3DMM to make the mineralogical information accessible in geological modelling software packages, which will inevitably result in an increase of the data volumes (terabytes to petabytes). Furthermore the interoperability and metadata structure has to be made easily accessible with the web delivery of the geoscience products. C3DMM is working on various case studies, ranging from Channel Iron Deposits to Iron oxide Cu-Au and Achaean Au deposits in Australia, to develop standard procedures, including traceable validation and error assessment, and to showcase the uses and opportunities for hyperspectral sensing technologies and derived geoscience information in geoscience, exploration and mining.

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