EVALUATION BREFCOR BRDF EFFECTS CORRECTION FOR HYSPEX, CASI, AND APEX IMAGING SPECTROSCOPY DATA

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ABSTRACT
The correction of BRDF effects for airborne wide FOV imaging spectroscopy data is of interest for a consistent data processing and products generation. Recently, a new BRDF effects correction method (BREFCOR) has been implemented as additional processing step after the well-known atmospheric compensation workflow. This paper shows validation results of the method for sample data sets of HYSPEX, CASI, and APEX data. It can be shown that the method is able to deal with a broad variety of sensors and surface characteristics. The spectral albedo data products are substantially increased in terms of consistency for all data sets. Future potential improvements and additions for a better operational usability and for the processing of complete spectra are finally summarized.

Index Terms— Atmospheric Correction, ATCOR, BREFCOR, BRDF, Radiometric correction, HYSPEX, CASI, APEX.

1. INTRODUCTION
Airborne optical scanners are able to provide measurements of the at-sensor radiance accurate to a level of 2-3% in absolute radiance units. These radiance values are converted to bottom of atmosphere reflectance values, mostly by inverting the radiative transfer using an atmospheric compensation package such as ATCOR-4 [1]. In a first order, this output quantity is a not-well defined reflectance quantity as it depends on the angular distribution of the illumination field, the main solar incidence angles and the observation angle. By improved treatment of the solar irradiance field for the diffuse and the direct component and the terrain influences, and by taking into account the relative solar incidence angle on a per-pixel basis, the reflectance may be modeled closer to the ideal situation of a true isotropic hemispherical irradiance field [2]. Taking these additions and assumptions into account, we may describe the output of the atmospheric correction as a hemispheric directional reflectance factor (HDRF, [3]). Note: the term "HDRF" is often used in an ambiguous way as it is also used for a description of the geometric situation regardless of the distribution of the illumination field across the hemisphere; we rely on the original physical definition where an isotropic irradiance field is a precondition of any HDRF value. The observation direction, i.e., the second direction of the bidirectional reflectance distribution function BRDF [3] is still to be corrected after this processing as the HDRF values may deviate relative to the average spectral albedo by up to 50% [4, 5].

Recently, a novel correction method has been implemented within the framework of the ATCOR-4 atmospheric correction package. We name it the BREFCOR 'BRDF effects correction’ method. The method uses the Ross-Li sparse reciprocal BRDF model which is tuned based on a preclassification of the imagery and a continuous class index. This allows to get a surface cover dependent but yet continuous correction of the HDRF to bihemispherical reflectance (BHR), i.e., to the spectral albedo. The method is of generic nature and has been successfully applied to 4-band photogrammetric imagery as well as to multispectral space borne multi-angle imagery. In this paper, we focus on the use of BREFCOR with imaging spectroscopy data. Firstly, we shortly summarize the principles of the method. Secondly, we’ll show sample results for three imaging spectroscopy data sets from three different sensors and surface characteristics by analyzing the spectra in overlap regions of adjacent image lines. Validation is done on the level of spectral albedo which is the basis for a broad variety of imaging spectroscopy applications.

2. THE BREFCOR METHOD - OVERVIEW
The BREFCOR method which is used in this paper is part of the ATCOR atmospheric correction process. It is described in detail in [6] and [7]. The idea is to apply a scaling of the volume scattering and the geometric scattering component within a well accepted BRDF model. A fuzzy classification index which we call the BRDF correction index (BCI) of the
complete image is used for this purpose. The index covers all surface types from water to asphalt and concrete, soils, sparse vegetation and dense vegetation as a unified continuous index. This parameter extends the NDVI to both, non-vegetated and densely vegetated surfaces. The Ross-Li-sparse reciprocal BRDF model is used as the basis for the correction of reflectance anisotropy [8]. The kernel weights within the BRDF model are derived in a continuous way from the BCI values after model calibration on the scenes to be processed.

The BRECOR correction procedure is following the following steps:

- calculation of scene-specific kernels,
- calculation of BCI from image and aggregation into 4-7 discrete classes,
- calibration of the BRDF-model (i.e. the kernel weights) for all classes and scenes,
- creation of a generic model by combining all image scenes of the processing,
- calculation of anisotropy map using the continuous BCI applied to the calibrated BRDF model and the observation angles for each image pixel,
- application of the anisotropy to the imagery on a per-pixel basis.

The final product is a spectral albedo image cube corrected for observation BRDF effects.

3. EVALUATION ON HYSPEX IMAGERY

The method has been applied on Hyspex imagery [9]. The sample data was acquired over the Kaufbeuren test site in Southern Germany on the 8th of July 2013; the sun was at 41° zenith and 113° azimuth angle. The Hyspex imaging spectroscopy system scans the surface with a total FOV of 34° in 160 contiguous bands for the VNIR spectral range from 410 to 990 nm. Each of the 160 spectral bands is calibrated individually using 6 classes with calibration limits for dense summer vegetation. For the calibration, one of the scenes was contained with cirrus clouds and had therefore to be excluded from the model calibration step. A sample result of this correction is shown in Figure 1. BRDF effects are well removed for both the lawns and forested areas.

A collection of spectra which illustrate the effect of the BRDF correction are given in Figure 2. The BRDF effects are strongly reduced for the vegetation cover across the full spectral range whereas the concrete is hardly affected by the correction (as it contained only small BRDF effects in the original image already).

4. EVALUATION ON CASI IMAGERY

A second evaluation was done on a CASI-1500 VNIR data [10] set acquired on January 17th 2013 in the Copiapo Mining district in Chile. The solar zenith angle was between 13° and 21° whereas the solar azimuth was at 284° to 299° for the five data strips analyzed. The FOV of the instrument is 40°, which results in more pronounced BRDF effects as seen in the previous imagery. The underlying digital elevation model stems from ASTER imagery. ATCOR correction was performed with a 60 km visibility. Due to the reduced accuracy
If comparing the spectra, a significant portion of the BRDF effects was corrected using the BREFCOR method (see Figure 4). The correction is on a 80% level for the unvegetated areas. The remaining artifacts could be attributed to the insufficient correction of terrain influences by the coarse DEM involved in this image. For vegetation, the correction is less significant as only a small portion of the image could be used for calibrating the BRDF model for vegetation.

5. EVALUATION ON APEX IMAGERY

The third evaluation uses APEX data from Lyss, Switzerland, acquired on May, 14th 2013. The APEX instrument scans the full spectral range between 400 and 2450 nm with a total FOV of 28° [11]. The scene consists of a broach variety of heterogeneous agricultural fields. The solar zenith angle was at 29°. BRDF effects are not as pronounced for these data sets due to the small FOV, but still they account for significant differences of HDRF signature. The data was processed in a setup very similar to the one used in HYSPEX. The terrain had only little influence on the data quality as the area is almost flat. The faintly visible across track variations are apparently well corrected with the BREFCOR method, as visible in Figure 5.
Fig. 6. Spectra of three surface types of APEX with ATCOR (top) and BREFCOR correction (bottom).

Samples of corrected full spectra are displayed in Figure 6. Correction is done mostly consistently for soils and sparse vegetation. However, if it comes to the spectra of densely vegetated agricultural fields, the spectral variability between various plant types leads to correction artifacts in certain cases (mostly in the spectra deviating most from average vegetation). This variation may be explained by the nature of the applied pre-classification which was made under the assumption that the vegetation density alone is a good indicator for the BRDF correction type. Also, the (interpolated) atmospheric absorption regions are corrected in a non-appropriate way. Further analysis is required to deal with this situation.

6. CONCLUSIONS AND OUTLOOK

The evaluation has shown that the BREFCOR method is applicable for various kinds of imaging spectrometer systems and surface characteristics. It could be shown that the method improves the consistency of surface reflectance products such that the output results are closer to an ideal bihemispherical reflectance than the HDRF results available after atmospheric compensation. The current implementation is operationally implemented and is ready to be used for both, imaging spectroscopy and multispectral imagery. Future improvements should be focused on the treatment of the full spectrum for highly variable vegetation types (in the same region) and to improve the spectral consistency within strong absorption features of both, the atmosphere and surface spectra.

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8. REFERENCES