ASPECTS OF ATMOSPHERIC AND TOPOGRAPHIC CORRECTION OF HIGH SPATIAL RESOLUTION IMAGERY

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1. INTRODUCTION

Airborne scanners have evolved to well-calibrated radiometric measurement devices in the past years. In parallel to the improvement of the hardware, the radiative transfer based processing of the acquired data to surface reflectance products has advanced. The atmospheric correction allows for automatic and consistent compensation of the effects of the atmosphere and the topography. With the broader use of high spatial resolution instruments from space, in digital photogrammetry, and in airborne imaging spectroscopy, the correction of illumination conditions has gotten more challenging. A pure geometric calculation of the illumination using solar illumination angles and a digital elevation model (DEM) is no longer sufficient for an accurate processing.
This paper presents current challenges and solutions for an operational implementation of a radiative-transfer based radiometric correction method for high resolution instruments. It puts a special emphasize on the treatment of fully and partially shadowed areas in an image. The methods are analyzed on the basis of the ATCOR-4 technology [1]. The ATCOR-4 atmospheric correction software inverts the MODTRAN®-5 radiative transfer code [2] for atmospheric compensation of trace gas and aerosol influences as well as for topographic correction of the illumination field. The output of this processing has been optimized for automatic quantitative processing, including the correction of irradiance variations and cast shadow effects. Tests are shown on the basis of photogrammetric airborne digital scanner imagery (ADS) [3].

2. METHODS

The ATCOR-4 method is a well-established process for atmospheric compensation and topographic correction of optical and thermal imagery. It calculates the direct and the diffuse irradiance field for each image pixel using MODTRAN-based Look-Up-Tables, which allows for an accurate correction of illumination effect. However, specific additions are to be made to the standard procedure whenever high resolution instruments are to be processed. The illumination $f_{ilu,0}$ is first calculated on the basis of the terrain model using an efficient vector algebra based method [4]. Further refinements are required to account for the variability of the illumination field at high spatial resolution.

2.1. Cast Shadow Preparation

Our tests show that the correction of cast shadows and illumination on the basis of a surface model does not lead to useful results as the surface representation with respect to the radiometry is never accurate enough. Severe over- and under-correction artifacts are observed due to these inaccuracies in the resulting images.

The correction of cast shadows has been widely studied, specifically for space borne high resolution instruments [5, 6]. A new method for cast shadow detection has been implemented for the ATCOR case. It produces a continuous shadow field and relies on the fact that all areas in cast shadows are illuminated by diffuse irradiance only. The diffuse illumination is caused by scattering and thus exhibits very specific spectral characteristics if compared to the direct irradiance. Specifically, the signal in the blue spectral band is significantly higher in cast shadow areas than in directly illuminated areas. For the shadow quantification, the brightness in the NIR spectral band is first calculated using the solar illumination. Secondly, two blue indices have been defined as the band ratios green/blue and red/blue, respectively. These three measures are combined such that a value equivalent to the illumination between 0 and 1 is created (0 being a cast shadow area). The shadow fraction parameter is then defined as:

$$p_{shade} = \sqrt{(L_{red}/L_{blue})^2 + (L_{green}/L_{blue})^2 + \rho^2_{app,nir}}, \quad (1)$$

where L_{blue}, L_{green}, and L_{red} are the calibrated at-sensor radiance values int he three true color bands and $\rho_{app,nir}$ is the apparent at-sensor reflectance in the near infrared band. This parameter is then scaled to a shadow fraction number f_{shadow} between 0 (full cast shadow) and 1 (nocast shadow) using empirically found limits of 0.9 and 1.2 for the two thresholds (these limits need further evaluation, however). The output is continuous and may be used as such in the atmospheric correction directly as a side input to ATCOR-4. Our tests show that this algorithm detects the cast shadows definitely to a higher accuracy than the geometrical approach based on a DSM. In a second step the such found map is combined with the standard illumination map such that:

$$f_{ilu} = f_{shadow} < f_{ilu,0}, \tag{2}$$

The such derived illumination map is used in operational processing of high resolution imagery.

2.2. Skyview Factor Preparation

The skyview factor describes the relative amount of the unobstructed sky hemisphere. This factor is highly variable on small scales, e.g., in vicinity of forest borders, and thus needs to be evaluated carefully. Due to the lack of an appropriate radiometric description of the terrain at high resolution, the skyview factor is to be adapted based on the shadow fraction. It is assumed that the cast shadow fraction is directly related to the skyview factor. As such the skyview factor is reduced whenever the cast shadow fraction is higher than the skvyiew factor calculated from the digital terrain model. This allows to correct the irradiance field within cast shadow areas at a higher accuracy, which is specifically relevant for the diffuse irradiance.

2.3. Operational Constraints

High spatial resolution imaging is directly related to large data volumes for the data processing. Specific batch scripts need to be created for the processing of the data which include the preprocessing of the illumination data as described above. Also, images are to be tiled for efficient use of the memory. Both, batch processing capabilities and image tiling modes of the ATCOR processing have been improved in order to accept large scale data occurring in photogrammetric imaging. Specifically, the treatment of background values and the enforcement of parameter continuity and code stability for large data sets has been improved during this development. The code is tested on a selected number of large scale data sets and proven to lead to consistent results. The processing speed is at a rate of approximately 4 Minutes per Gigabyte of raw image data on standard computing systems, which includes all preprocessing of digital elevation data.

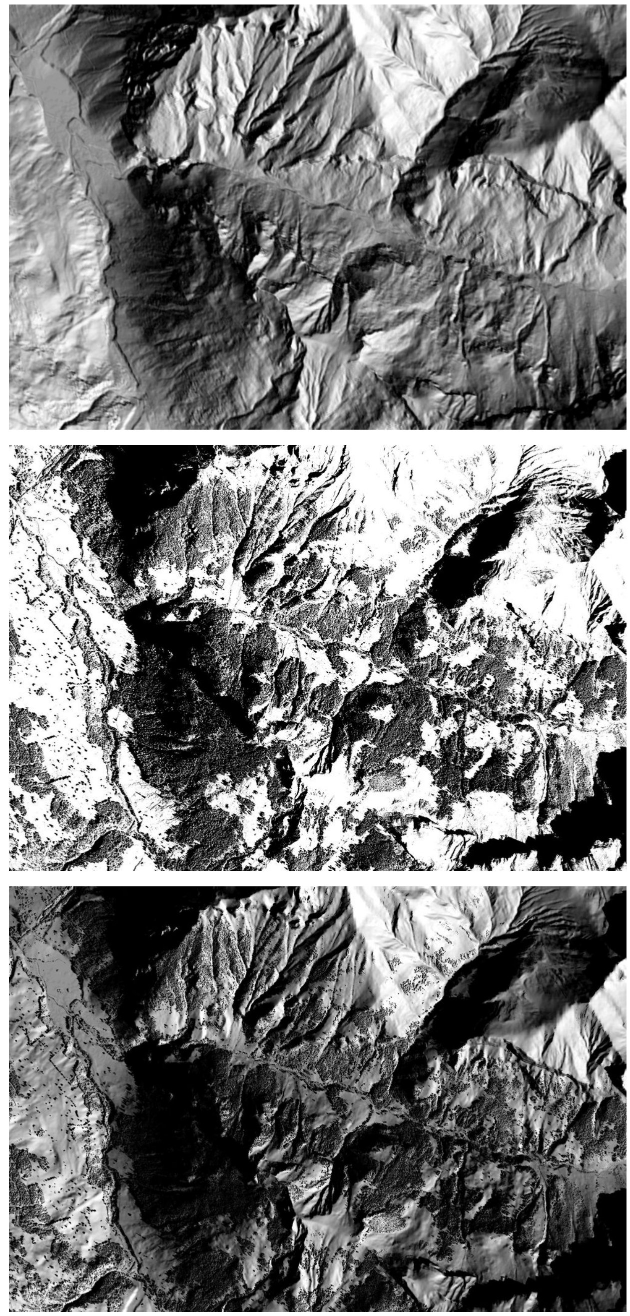

Fig. 1. Combination of illumination map (top) with cast shadow fraction (middle) into continuous illumination field (bottom).

3. RESULTS

The updated processing is evaluated with respect to visual appearance and reliability in comparison to ground reference measurements. Figure 2.3 shows the combination of the illumination map with the cast shadow correction. The updated illumination map is more appropriate representation of the illumination field with respect to the image data.

The effect of application of this illumination correction is shown in Figure 3. Not only the atmospheric path scattering is reduced, but also shadows are enhanced and the terrain influence is corrected. Remaining brightness differences can be accounted for slight offsets in the radiometric calibration of the data. But also the calculation of the diffuse irradiance may need to be updated to get to improve the results.

The analysis shows the applicability of the enhanced methods for both, photogrammetric applications and high resolution imaging spectroscopy. Significant progress is achieved for the correction of the illumination effects. It is shown that the radiometric correction of high spatial resolution imagery requires major changes to current atmospheric compensation routines which have been inherited from coarse resolution satellite image processing.

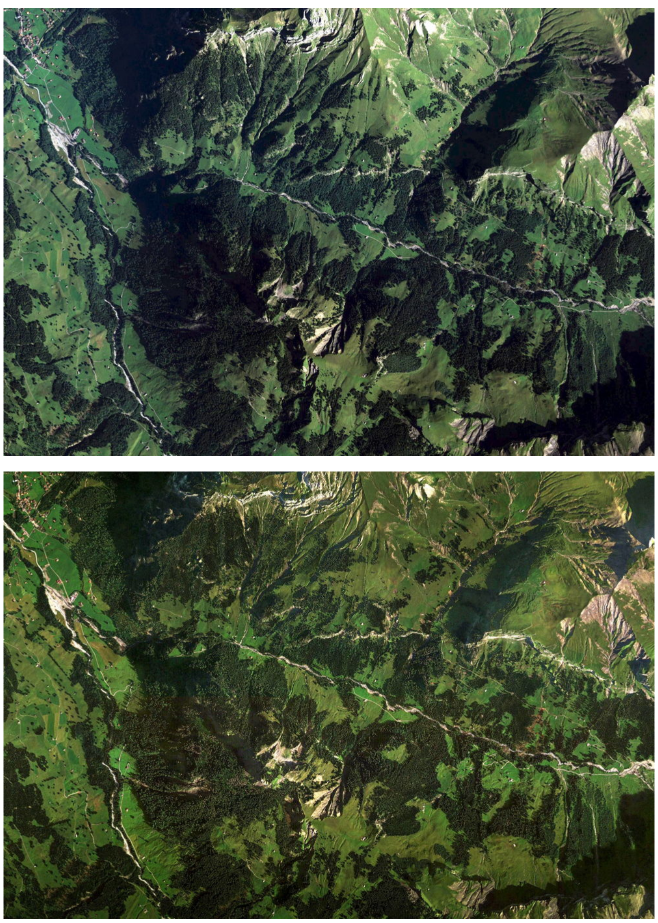

Fig. 2. Effect of combined topographic / cast shadow correction: top: original image; bottom: corrected image.

4. CONCLUSIONS

The new method for cast shadow detection has shown to significantly improve the topographic image correction. This method will be used for operational processing of remote sensing products based on the ADS systems operated by the Swiss Federal Office of Topography (swisstopo) and will be available in future releases of the ATCOR software packages.

Further developments and analyses from this state are required to consolidate this work. Specifically, an accurate masking of water surfaces is required to avoid false classifications of water bodies as land shadows. For the reduction of remaining artifacts at the shadow borders it is to be checked, if the effect of the strong circumsolar forward scattering can be corrected within the cast shadow zone. Furthermore, the influence of the local skyview factor and the needs further in-depth analysis. First checks in comparison to ground reference reflectance values have shown the reliability of the processing routines. A broad cross-validation campaign is still to be performed with respect to remote sensing standard products, and expected ground reflectance values.
Finally, a surface-cover dependent BRDF correction is envisaged which accounts for the geometric variability of airborne scanners. A specific challenge of such a correction is the incorporation of the varying illumination field to the BRDF properties. A generic solution of the BRDF problem is challenging as the variation of the illumination is only one of the problems which is to be faced when high spatial resolution imagery is to be improved radiometrically in a physical way.

5. REFERENCES

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