COUPLED RETRIEVAL OF AEROSOL OPTICAL THICKNESS, WATER VAPOR, AND SURFACE REFLECTANCE FROM AIRBORNE HYPERSPECTRAL SENSORS

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1.Introduction

The current work investigates the feasibility of auto retrieving AOT, CWV and surface reflectance from Compact Airborne Spectrographic Imager (CASI-1500) and SWIR Airborne Spectrographic Imager (SASI-600) and compared the retrieval results with ground-based data. The most features of the work are that: (i) building the new empirical relationships between 465.6nm, 659nm and 2105nm for CASI and SASI sensors; (ii) using minimizing the merit function to retrieve AOT at 550nm; (iii) estimating initial CWV value by CIBR, and the optimal CWV by SODA method, (iv) using Powell's method for finding optimal AOT and CWV.

2. Study area and data acquisition

The test site is a remote sensing test station in Huailai County, Zhangjiakou City, Hebei Province, China. Airborne hyperspectral CASI and SASI (reference) data were acquired on 21 Jul, 2010. The sensor height is 1.0 km with a nadir viewing which reduces solar illumination angle effects for each image. The study area consists of cropland, water reservoir, pine trees, cypress, some shrubs, meadow, and wet land within the 10 km range. In-situ surface reflectance spectra were measured with an ASD FieldSpec spectrometer (Analytical Spectral Device, Boulder, CO) under cloudless conditions at the time of the CASI and SASI over flights.

3. Methodology

The methodology comprised:

1) Radiometric and spatial cross-calibration of the CASI VNIR and SASI SWIR module data;
2) Retrieval AOT is based on the assumption that the atmospheric state is spatial homogeneous in the study area. The rural aerosol model is also set in advance according the characteristics of study area. Dense dark vegetation (DDV) was identified as a suitable reference to estimate the AOT over land surfaces. The method makes use of three channels (465.6nm, 659nm and 2105nm) to retrieve AOT@550nm.
3) Estimating pixel-based CWV initially using the CIBR[1-3] method, and then by refining the CWV using SODA[4];

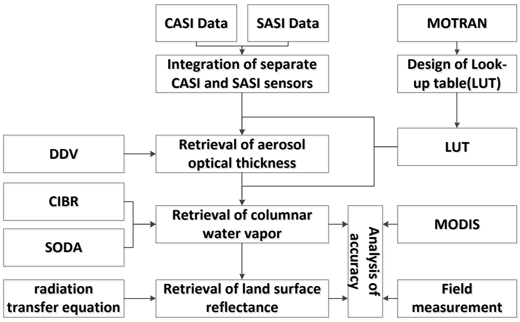


Figure 1. Flow chart for land surface reflectance retrieval

4) Once the AOT and CWV have been estimated from hyperspectral images, the atmospheric parameters { S , $L_{path,j}(\theta_s,\theta_v,\phi_s-\phi_v)$, $T_{\uparrow}$, E_{dir} , μ_s , and E_{dif} } can be calculated from the LUT for given VZA, SZA, RAA and ELEV values and the surface reflectance spectra calculated by radiative transfer equation.
5) Validating the airborne results using the available ground-based reflectance data.

4. Result and analysis

The validation of CASI and SASI atmospheric correction and surface reflectance retrievals presented herein are given in two sections: analysis of atmospheric parameters retrievals and analysis of surface reflectance accuracy.

4.1 Analysis of atmospheric parameters accuracy

The inter-comparison between the CWV from CIBR and SODA methods is resumed in Figure 2. The statistic result shows that the ranges of CWV for CIBR and SODA are 0.941-4.250gm/cm2 and 0.525-2.350 gm/cm2 respectively and the mean CWV for CIBR and SODA is 2.222±0.190gm/cm2 and 1.630±0.111gm/cm2. The CIBR method estimates CWV by linear interpolation between two adjacent continuum values and assumes that reflectance is a linear function of wavelength. In fact, it rained from the 14-Jul to 20-Jul 2010 and had clear and sunny conditions on 21-Jul when the field campaign was carried out. Therefore, the water contents of vegetation and soil are assumed to be high and hence influencing the linearity of the surface reflectance around the water vapor absorption bands (Figure 3a). Consequently, the CWV value from CIBR method overestimated. Especially, the CWV values from CIBR on the water pool (the area labeled A in Figure 2) are greater than other surrounding pixels, and that from SODA are less than other surrounding pixels.

The images of CWV from the two methods show surface feature such as the edge of cropland and road. However, the surface features in the SODA image are greatly decreased by detailed comparison. The area labeled B in Figure 2 shows that the CWV image from CIBR has more significant surface imprint than from SODA. The result is similar to that found in Rodger (2011).

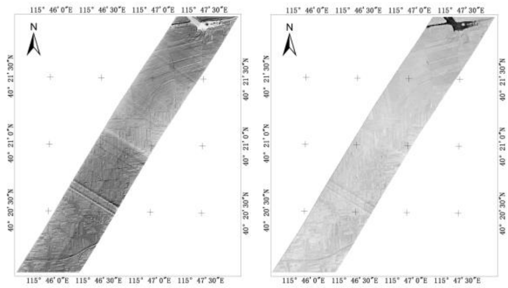


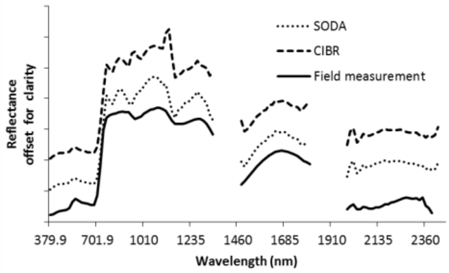
Figure 2. The estimated CWV by CIBR (left) and SODA (right) methods. The ranges of CWV for CIBR and SODA is 0.941~4.250 gm/cm2 and 0.525~2.350 gm/cm2 respectively. The mean CWV for CIBR and SODA is 2.222±0.190 gm/cm2

and 1.630±0.111 gm/cm2.

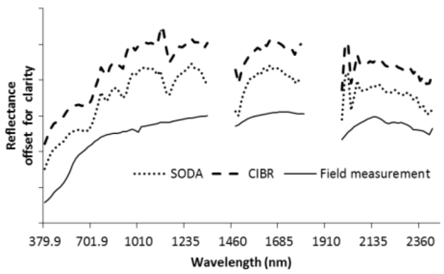
4.2 Analysis of surface reflectance accuracy

Figure 3 a and b show the direct comparison of magnitudes, which apply offset for clarity. Firstly, Surface reflectance values retrieved by CIBR and SODA method were compared for quantitative analysis. From Figure 3, out of water vapor absorption band surface reflectance are mostly same, while the main difference are found at 916nm~980nm and 1110nm~1160nm absorptions region. The spectrum smoothness indices of soil retrieved by CIBR and SODA are 0.0470 and 0.0351 respectively. The spectrum smoothness indices of vegetation retrieved by CIBR and SODA are 0.0552 and 0.0494 respectively.

Secondly, Surface reflectance values retrieved by SODA methods were compared with the measurements in field campaign. From Figure 3a, the retrieved vegetation reflectance show good agreement in shape of curve across most of 400-2500nm with ground-based with R^2 being 0.942 and RMSE being 0.0387. SODA underestimate the vegetation reflectance in the 379.9nm~1340nm and 1475nm~1790nm, while SODA overestimate the vegetation reflectance in the 1985nm~2420nm. One possible explanation to this trend in VIR region may be DDV overestimates the AOT, and in NIR-SWIR region may be the uncertainty of CWV retrieval. In case of soil reflectance, R^2 is 0.786, with RMSE being 0.041. One possible cause to this difference may be high roughness, non-lambertian and directional effects of soil surface. These factors can affect both the at-sensor and ground-based data. Therefore, both the spectral shape and RMSE indicate the method proposed in this paper may be reliable enough for auto (in-scene) atmospheric correction and surface reflectance retrieval from hyperspectral remote sensing data.



(a)



(b)

Figure 3. Comparison of the retrieved surface reflectance from airborne images and at-ground reflectance. Panels a and b are vegetation and soil reflectance respectively.

5. Summary and Conclusion

Hyperspectral sensors collect spectral radiance throughout the solar reflective region (400 - 2500nm) in which there are numerous atmospheric absorption features. This characteristic makes it possible to retrieve atmospheric correction factors from data themselves for each pixel. Therefore, a comprehensive approach has been presented to retrieve atmospheric parameters and surface reflectance based on radiative transform function and hyperspectral data in this paper. Although this method has been only tested by CASI&SASI data, it is sufficiently mature and can be used for routine processing of other hyperspectral imaging data.

The result show that CIBR method

overestimate the CWV because the water contents of vegetation and soil was high. The result of SODA may be reasonable on the assumption that surface reflectance curves are smooth. From the comparison, it may be possible to retrieve the water content of vegetation and soil by CIBR and SODA methods.

The final purpose is to inverse the surface reflectance from hyperspectral data. Therefore, we analyze the surface reflectance accuracy comparing with ground-based reflectance by ASD. The reflectance curves estimated via SODA are smoother than via CIBR, and the former are higher than the later with the water vapor absorption band while out of water vapor absorption band surface reflectance are mostly same. In summary, both the spectral shape and RMSE indicate the SODA method proposed in this paper may be reliable enough for auto (in-scene) atmospheric correction and surface reflectance retrieval from hyperspectral remote sensing data.

It must be point out that the DDV method will be limited to the vegetated areas and dark soils (excluding ice/snow cover and desert). So, the new method for AOT from hyperspectal data should be developed over some bright reflecting source region in the future. Secondly, the effect of elevation, adjacency and directional in the surface are not considered in this paper, and the main reason is that the study region can be regard as large flat homogeneous areas, where those effects are minimized. Certainly, these effects will be considered according to the characteristic of study region in the future work.

Acknowledgements

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