AN ATMOSPHERIC CORRECTION ALGORITHM FOR HYPERSPECTRAL IMAGERY OF LAKE WATER BY CHINESE SATELLITE HJ-1A

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1. PROBLEM

In remote sensing of water color, atmospheric correction of retrieving water apparent optical properties (Lw, Rrs etc.) is a decoupling procedure in water-atmosphere system. The corresponding algorithms have been developed over the past three decades. In the 1980's, Gordon and Clark [1] proposed an original CZCS algorithm of application to open ocean waters based on the single scattering assumption, and later modification accounting for the multiple scatting effects. Later, as the new generation instruments (e.g. SeaWiFS, MODIS) possessed more NIR bands as well as increased the radiometric sensitivity, it is possible to derive the aerosol model and an aerosol optical depth by assumption that water-leaving radiances are zero in the NIR spectral range [2]. More recently, because of highly correlated to the anthropic activities, coastal zone and inland waters by remote sensing is thought to be more important, and thus attracts more interest. Ruddick [3] extended the standard SeaWiFS atmospheric correction algorithm and demonstrated its performance over Belgian turbid coastal waters. Wang and Shi[4] chose alternative zero water-leaving SWIR bands (1240nm and 1640nm) instead in the Gordon's standard algorithm. Hu [5] transferred the atmospheric properties above clear water to the turbid area by "nearest neighbor" method by assuming the type of aerosol does not vary much over relatively small spatial scales.

As for China, there are few water color satellites and especially lacks the ability of remote sensing of inland waters. Yan Bai [6] developed an atmospheric correction algorithm of COCTS, which was the first Chinese ocean color sensor onboard HY-1 launched in 2002. However, there would be a more choice when, on 6th September 2008, China successfully launched the first hyper-spectral sensor onboard HJ-1A, which combined with HJ-1B constitute a micro-satellite constellation of environment disaster monitoring. The hyper-spectral imager (HSI) is an interferometric imaging spectrometer with spectrum range from 0.45um to 0.95um. It possesses 115 bands with averaged bandwidth of 5nm and its spatial resolution is 100 meters with a swath of about 50km. The instrument characteristics of high spectrum resolution and radiometer sensitivity reveal the potential of building an atmospheric correction algorithm to retrieving apparent optical properties for lake waters.

2. METHODOLOGY

Here, we consider applying the Ruddick's algorithm to the hyper-spectral imager sensed data correction over lake waters, and checking the assumptions appropriated for true situation. Lake waters are always turbid with high chlorophyll concentrations or, even more suspended matters, the water-leaving radiances in red or near-infrared channels are non-zero, so the assumption of zero water-leaving in NIR bands is not up to the practical situation. The hyper-spectral imager on HJ-1A only covers the VIS and NIR spectrum range, absent of short-wave infrared bands. So we can't derive the atmospheric properties and aerosol models from SWIR spectrums yet. Meanwhile, the Ruddick's algorithm seems to be more appropriated for application to the inland lake water.

It is based on two assumptions. First, the ratio of total multi-scattering aerosol reflectance at two NIR bands (probably 765 and 865nm) is assumed to be spatially homogeneous in each image, or at least over the subscene of interest. It is based on the fact that, although aerosol concentration can vary considerably over small space scales, the aerosol type can be expected to vary only weakly in space.

Second, the ratio of water-leaving reflectance normalized by the sun-sea (downward) atmospheric transmittance at two NIR bands(probably 765 and 865nm) is assumed to be spatially homogeneous in each image, or at least over the subscene of interest. The water-leaving reflectance ration can be set to a default value by considering an ocean color model. The two are feasible based on our validations on these two assumptions in Chinese lake waters.

HSI has 115 channels so that we can choose high SNR channels to carry out atmospheric correction. In viewing of the algorithm efficiency, we only subtract water color bands with number of N from the channel set, in which are two NIR bands of $(n-1)$ and n . Therefore, combined with the two assumptions above, available relations are as follows:

$$\begin{cases} \rho_{am}^{i} + t_{I}^{i}\rho_{w}^{i} = \rho_{c}^{i} & i = 1\cdots \text{n} \\ \varepsilon_{I,s}^{(j,n)} = \dfrac{g_{I}[\rho_{am}^{j}]}{g_{I}[\rho_{am}^{n}]} & j = 1\cdots n-1 \\ \varepsilon_{I,m}^{(n-1,n)} \equiv \dfrac{\rho_{am}^{n-1}}{\rho_{am}^{n}} & \text{aerosol model index I} \\ \alpha \equiv \dfrac{\rho_{w}^{n-1}/T_{0}^{n-1}}{\rho_{w}^{n}/T_{0}^{n}} & \end{cases}$$

Where ρ_{am}^{i} is the total multiple-scattering aerosol reflectance ($=\rho_{a}^{i}+\rho_{ar}^{i}$) for the i th band with bandwidth λ_i, ρ_{w}^{i} is the water leaving reflectance, ρ_{c}^{i} is the Rayleigh-corrected reflectance, I is the best-fit aerosol model index in lookup table, t_{I}^{i} is the viewing atmospheric transmittance corrected for two-way ozone and oxygen absorption for best-fit aerosol model, $\varepsilon_{I,s}^{(j,n)}$ is the ratio of single-scattering aerosol reflectance between band i and n th, g_I is the near-linear relationship between ρ_{am}^{j} and the single-scattering aerosol reflectance, α the ratio of water-leaving reflectance normalized by the sun-sea (downward) atmospheric transmittance at the $(n-1)$ th and n th band.

Clearly, $2n+1$ unknown quantities involved (ρ_{am}^{j}, ρ_{w}^{i}, aerosol model index I) equals to the number of equations. We can work out the ρ_{w}^{i} theoretically and then obtain the hyper-spectral sensed data atmospheric corrected.

3. RESULTS AND CONCLUSIONS

The atmospheric correction algorithm applies to the hyper-spectral imager data obtained by HJ-1A. The test region is over Taihu Lake in the southeastern China. The lake is a shallow area (1.9m average depth), where is full nutrient water with high concentrations of Chlorophyll (e.g., 10-100ug/L) and suspended sediment (e.g., 10-80mg/L), occasionally with phytoplankton bloom. The imagery we choose is in the year 2009, and we analyze the results. It is showed that the algorithm performs well when applied to the Taihu Lake which is typical case II waters. It is also demonstrated that the assumptions are reasonable. The atmospheric correction algorithm takes advantages for automation of the procedure and treatment of scenes with variable aerosol types. The preliminary result of accuracy will be discussed. Finally the conclusion will be made as well as the ongoing work in future.

4. REFERENCES

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