Comparison of NDVI of ground measurement, atmospheric corrected ASTER L1B data and ASTER surface reflectance product (AST07) data

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Abstract—In this study, we compared NDVI of ground measurement, atmospheric corrected ASTER L1B data and ASTER surface reflectance product (AST07) data to evaluate the accuracy of the ATCOR software atmospheric correction of Terra/ASTER data (Jun 30, 2002), using ground radiometric measurement data (ASD’s FieldSpec® Pro). Our research selected the study area Sarobetsu Marsh located in coastal area of Hokkaido, Japan. We found that 5% of scattering radiation is contained in the ASTER Green band and 47% of radiation was absorbed in the ASTER NIR band and 17% of radiation was absorbed in the ASTER SWIR bands. And it was found that the ASD’s measurement values and the ATCOR software output values are no big difference in the ASTER reflection bands and absorption bands of chlorophyll (i.e. NIR-band and Red-band); However, the difference were seen in the ASTER scattering bands (i.e. visible Green band) and soil reflection bands (i.e. ASTER SWIR bands). Compared with the data of ASD’s measurement, the AST07 (©NASA/EOSDIS ASTER surface reflectance product data (L2B)) values are too low in a NIR band.

Keywords: NDVI, ASTER L1B & AST07, ASD’s FieldSpec®, surface reflectance, ground measurement.

I. INTRODUCTION

Radiation from the Earth’s surface undergoes significant interaction with the atmosphere before it reaches the satellite sensor. Regardless of the type of analysis that is performed on the remotely sensed data, it is important to understand the effect the atmosphere has made to the radiance responses [1]. In order to acquire an exact radiation of target, we must correct the atmosphere effect of satellite imagery. Correction of image data for the effects of atmospheric propagation can be carried out in essentially three ways [2]. It is respectively, based on atmospheric scattering and absorption characteristics physically model; Based on pre-calibration, on-board calibration against targets of known reflectance method and Based on dark-pixel subtraction method. The physically based methods attempt to model are (for example, Look-up table (LUT) approach and top-of atmosphere (TOA) radiance) is the most rigorous approach, and also the most difficult to apply [3]. The atmospheric scattering and absorption characteristics are calculated by a computer model (the best-known being LOWTRAN-7 [4], MODTRAN [5] [6] and 6S [7] which requires as input data meteorological, seasonal and geographical variables. In practice, these variables may not all be available with sufficient spatial or temporal resolution, and, in particular, estimation of the contribution of atmospheric aerosols is difficult [3] [8]. In the calibration based atmospheric correction of VNIR, SWIR imagery method, these targets can be artificially constructed or naturally occurring, but they need to satisfy a number of criteria: (1) their reflectances must be known sufficiently accurately, in the same spectral bands as are used by the imager; (2) the range of reflectances represented by the calibrators must span the range of interest in the sensor; (3) each calibrator should cover an area of at least several resolution cells; (4) the calibrators should be well distribution over the entire scene, so that possible variation of atmospheric conditions from place to place can be assessed and if necessary, allowed for [3] [9]. Dark pixel subtraction is a technique which determines the pixel in the image with the lowest brightness value. This pixel is assumed to have a zero ground reflectance such that its radiometric value represents the additive effect of the atmosphere [10]. This method is quite crude: it assumes that the minimum reflectance in each band is zero, that the atmospheric correction can be modeled adequately as an additive effect, and that the correction does not vary from place to place within the scene. To some extent, visual inspection of an image can determine whether these assumptions are likely to be valid. Zero-reflectance pixels can be provided by shadows and, in the near-infrared region, by water bodies [3] [11] [12].

In this study, we evaluate the accuracy of the atmospheric correction with ATCOR software algorithm based on ground radiometric measurement data, and compared also with the radiative transfer code (RTC) based atmospheric corrected ASTER L2B standard products surface reflectance (AST07) data simultaneously.

1-4244-1211-0/07/$25.00 ©2007 IEEE 1806
A. ATCOR software atmospheric correction method

The ATCOR software can be correct the path radiance, adjacency radiation and terrain radiation reflected to the pixel in order to calculate the reflected radiation from the viewed pixel. ATCOR2 software atmospheric correction algorithm is for a flat terrain working with an atmospheric database, and ATCOR3 software can be correct terrain radiation reflected to the pixel (from opposite hills, according to the terrain view factor) [9]. The database contains the atmospheric correction functions stored in LUT. ATCOR does the atmospheric correction by inverting the results obtained from MODTRAN, which are stored in a look-up table. If anything, the ATCOR software method is kind of applied to the above-mentioned method of 1-the physically based methods attempt to model [13].

B. The ASTER surface reflectance product (AST07) algorithm

This validated version of the VNIR/SWIR surface leaving radiance and reflectance products (product name: (c)NASA/EOsdS) AST07) provide an estimate of the total radiance leaving the surface including both the reflected solar and sky components for ASTER bands 1-9. The atmospheric correction for the VNIR and SWIR is based upon LUT approach using results from a Gaussian-Seidel iteration radiative transfer code [14]. The method has its basis in the reflectance-based, vicarious-calibration approach of the Remote Sensing Group at the University of Arizona [15]. We are applying the knowledge learned from our calibration methods to the atmospheric correction of the VNIR and SWIR bands for ASTER. Specifically, the RTC we have used for the past 10 years is used as a basis for LUT approach to atmospheric correction. The method currently assumes atmospheric scattering optical depths and aerosol parameters are known from outside sources. Using these parameters, a set of piecewise-linear fits are determined from the LUT that relate the measured satellite radiances to surface radiance and surface reflectance (Buehe).

II. THE DATA ANALYZED IN THIS STUDY

A. Resampling the original ASTER data

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) onboard NASA’s satellite Terra is a high-resolution multispectral radiometer with 14 bands, covers the visible and near-infrared (VNIR), short wave infrared (SWIR) and thermal infrared (TIR), and is effective in studying the Earth’s surface land cover, vegetation and mineral resources, etc. Data used Terra/ASTER original level 1B VNIR/SWIR/TIR data (time of day (UTC): 1:30, June 30, 2003, path-108/row-835, and 1:30, July 12, 2004, path-109/row-837, the subset coordinate of the UL Geo N45° 08’, E141° 36’). The database contains the atmospheric correction functions stored in LUT, which are stored in a look-up table. If anything, the ATCOR software method is kind of applied to the above-mentioned method of 1-the physically based methods attempt to model [13]. In order to carry out calculation between bands, we resampling (layer stacking) this 3 layers different spatial resolution ASTER VNIR (15 m), SWIR (30 m) and TIR (90 m) data to one layer same spatial resolution (15 m) dataset, and used this dataset input to ATCOR software.

<table>
<thead>
<tr>
<th>Band No.</th>
<th>c0</th>
<th>c1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.1</td>
<td>0.0676</td>
</tr>
<tr>
<td>2</td>
<td>-0.1</td>
<td>0.0708</td>
</tr>
<tr>
<td>3</td>
<td>-0.1</td>
<td>0.0862</td>
</tr>
<tr>
<td>4</td>
<td>-0.1</td>
<td>0.02174</td>
</tr>
<tr>
<td>5</td>
<td>-0.1</td>
<td>0.00696</td>
</tr>
<tr>
<td>6</td>
<td>-0.1</td>
<td>0.00625</td>
</tr>
<tr>
<td>7</td>
<td>-0.1</td>
<td>0.00597</td>
</tr>
<tr>
<td>8</td>
<td>-0.1</td>
<td>0.00417</td>
</tr>
<tr>
<td>9</td>
<td>-0.1</td>
<td>0.00318</td>
</tr>
</tbody>
</table>

B. ATCOR input parameters

With the ASTER data (Path-108/Row-835) data, ATCOR input parameters include: Solar zenith (degrees): 24.8; Solar azimuth (degrees): 147.7; Scene Visibility (km) = 30m; Model for solar region: fall/spring/rural; various aerosol types: rural; Model for thermal region: fall. Input satellite data: subset ASTER VNIR-SWIR-TIR, 10-bands one layer data. The calibration of ASTER data The Level 1B data are in terms of scaled radiance. To convert from DN to radiance at the sensor, the unit conversion coefficients (defined as radiance per 1 DN) are shown in Table 1. Radiance (spectral radiance) is expressed in units of W/(m²*sr*um). The true radiance at sensor can be obtained from the DN values as follows:

\[ L = c_0 + c_1 \times DN \]  

Where, \( L \) is radiance, \( c_0 \) (offset) and \( c_1 \) (gain) are conversion coefficients; DN is digital number.

III. THE STUDY AREA

The study area Sarobetsu Marsh is the largest registered wetland with an area of 7000 ha located in coastal of northwestern Hokkaido, Japan (Figure 1) and nominated by the Ramsar Convention on Wetlands in 2005. Test areas are mostly swamp with Sphagnum, Molinitopsis japonica while the western coastal zone area is dominated by isolated small hills covered with broad-leaf trees. The terrain of the study area is very flat and the elevation distribution between 5 m to 15 m. We selected this study area since the natural environments are well preserved by national and municipal governments and recently, follow on drying of a swamp; here often happens that a non-moor plant (bamboo grass) invades in a swamp. In the feature, we will classified this wetland into a high moor, low...
moor and non moor types, clarify the invasion front of bamboo grass, prevents that a non-moor plant (bamboo grass) re-invades in a swamp.

Fig. 1. Location of study area and test sites

IV. RESULT

Comparison of the ASTER data before and after ATCOR software atmospheric correction, we can summarize the following result:

(a) Shows the Table 2, the mean values of ASTER band 1 and band 2 are decrease in after atmospheric correction. This means that the visible green and red band has included not only the radiance from a target, radiance other than an atmospheric scattering also included.

(b) Comparison of mean values of NIR and SWIR bands before/after atmospheric correction, we found, the radiance values became large after atmospheric correction. It means the radiation from the target absorbed by atmosphere before it reaches the satellite sensor.

Atmospheric scattering primarily affects the direction of short wave radiation. There are four types of atmospheric scattering: Rayleigh, Mie, Raman and non selective. The most significant of these types of scattering is Rayleigh scatter, which affects the short visible wavelengths and results in haze. For ASTER data the scattering is four times as great in Green band of the electromagnetic spectrum as in the NIR band.

Table 2. Comparison of DN of before and after of ATCOR atmospheric correction of ASTER data ((Path-108/Row-835, UTC: 1:30, June 30, 2002)

<table>
<thead>
<tr>
<th>Band No.</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Stdev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Green)</td>
<td>0</td>
<td>255</td>
<td>50.93</td>
<td>34.97</td>
</tr>
<tr>
<td>2 (Red)</td>
<td>0</td>
<td>210</td>
<td>30.83</td>
<td>23.15</td>
</tr>
<tr>
<td>3 (NIR)</td>
<td>0</td>
<td>179</td>
<td>69.82</td>
<td>49.02</td>
</tr>
<tr>
<td>4 (SWIR)</td>
<td>0</td>
<td>111</td>
<td>45.21</td>
<td>32.59</td>
</tr>
<tr>
<td>5 (SWIR)</td>
<td>0</td>
<td>105</td>
<td>27.82</td>
<td>20.52</td>
</tr>
<tr>
<td>6 (SWIR)</td>
<td>0</td>
<td>144</td>
<td>29.90</td>
<td>22.66</td>
</tr>
<tr>
<td>7 (SWIR)</td>
<td>0</td>
<td>155</td>
<td>27.49</td>
<td>20.41</td>
</tr>
<tr>
<td>8 (SWIR)</td>
<td>0</td>
<td>191</td>
<td>23.83</td>
<td>18.10</td>
</tr>
<tr>
<td>9 (SWIR)</td>
<td>0</td>
<td>133</td>
<td>21.01</td>
<td>15.20</td>
</tr>
</tbody>
</table>

Table 2 shows the Figure 2(1) and 2(2), we found, the ASD's measurement values and the ATCOR output values are no big difference in the ASTER reflection bands and absorption bands of chlorophyll (i.e. NIR-band and Red-band); the difference has come out in scattering band (i.e. ASTER Green band) and soil reflection bands (i.e. ASTER SWIR bands). However, in the EOSDIS AST07 (ASTER surface reflectance products), the values are considerably different in ASTER NIR band. The problem is atmospheric corrected values of NIR is too small. In this research, the result of ATCOR software correction was better than AST07 products. Figure 2(1) and 2(2) shows the comparison of ATCOR software atmospheric correction result and ASTER surface reflectance products (AST07) data, with in non moor plant and high moor plant samples. In a swamp (high moor plant), the background soil and the open water area will be incorrect-recognized as moving haze of ATCOR software method. The ASTER all SWIR bands values after ATCOR correction are becomes larger than an original ASTER all SWIR bands values, followed on becoming the background of vegetation from moist changes to dryness.
ATCOR have rectified more correctly scattering with short wavelength visible (i.e., Green band) and absorption with NIR band. Shows the Fig. 3(1) and 3(2), it is clear that 5% of scattering radiation is contained with the green band and 47% of radiation was absorbed in the NIR band and 17% of radiation was absorbed in the SWIR6 band.

The input (x: DN of original ASTER L1B data) and output (y: DN of after ATCOR software atmospheric corrected ASTER L1B data) expression of the ASTER data using ATCOR are as follows:

- **Green band (band 1):** \[ y = 0.95x - 28.56 \] (2)
- **NIR band (band 3):** \[ y = 1.473x - 21.12 \] (3)
- **SWIR band (band 6):** \[ y = 1.171x - 1.23 \] (4)

**Comparison of NDVI of ground ASD’s measurement:** atmospheric corrected ASTER data and not atmospheric corrected original ASTER L1B data, we found that the ground NDVI and atmospheric corrected NDVI was not difference. However, the value of NDVI of ASTER L1B is smaller than the value of grand NDVI. Where, the formula of the correlation of a NDVI-Corrected value and an original ASTER L1B NDVI value is as follows:

\[ NDVI_{corrected} = 1.27 \times NDVI_{L1B} + 0.04 \] (5)
V. CONCLUSION

This formula showed that the NDVI value after atmospheric correction became larger than atmospheric correction before.

\[
\text{NDVI-Corrected} = \text{NDVI-LIB} + 0.04.
\]

The rate of change is larger than atmospheric correction to 27.5 and 131.4 respectively. The value of NDVI after atmospheric correction before, and this rate of change is (NDVI-Corrected) = 1.27

Fig. 3(3) Comparison of NDVI of around measurement.

Many techniques have been developed which determine the contribution atmospheric scattering has on the radiation detected by the satellite sensor. The radiance received from a target against a background surface by the satellite sensor comes from a combination of three sources; first, the intrinsic radiance reflected by the target and then directly transmitted by the atmosphere; secondly, the radiant energy scattered diffusely by the atmosphere which then further interacts with the target background and thirdly the radiant energy scattered diffusely by the atmosphere. The radiant energy reflected by the target carries the direct energy from the target. The other two sources produce a combined effect.

Comparison of accuracy of the ATCOR software atmosphere correction of non-moor plant and high moor plant area ASTER imagery showed that the background soil and leaf area affected the accuracy of ATCOR. In the case of a moor plant, the error in ASTER Green band is large.

ACKNOWLEDGMENT

This study was supported in part by the Scientific Research Project from the Department of Advancement of Science and Technology in the Hokkaido Government; and the Scientific Research Project No. 103-01-03 103-0210171. The authors' deep appreciation is expressed to Dr. Mark J. Chopping, from the Montclair State University, USA for the valuable comments on the manuscript.

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