Retrieval of aerosol optical thickness from the relation between satellite imagery and ground data over farmland in the Okhotsk area

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Abstract

We present a method for retrieving aerosol optical thickness over the Okhotsk area based on ground data of a vegetation index for farmland monitoring. In the first step, we developed a camera for observation of the vegetation index. A NDVI value from the camera around the wheat canopy showed a good relation with SPAD, the chlorophyll content meter, in the same farmland. The NDVI value from ground data in west Abashiri farmland was 0.355 (June 12, 2003). In the second step, we compare the ground data of NDVI and NDVI obtained from atmospherically corrected TERRA/MODIS imagery using 6S, the radiative transfer code (Channel 1 and channel 2, on June 12, 2003). Then the aerosol optical thickness value is 0.12 with the continental aerosol model and 0.07 with the maritime model. The methods appear to be useful to validate satellite remote sensing for non-regular atmospheric observation.

1. Introduction

The Okhotsk area is an exceedingly important place for both agricultural and environmental problems. Firstly, in it resides one of the foremost granaries in Japan for crops such as wheat, beets, and potatoes. In order to estimate the yield of crops accurately, it is important to determine the actual reflectance of the leaf canopy. However, in order to observe the exact ground reflectance using satellite remote sensing, we must remove the atmospheric impact. Satellite imagery is influenced by atmospheric effects, such as radiative decline and blur due to ray absorption or scattering by a molecule and atmospheric aerosol, because its vantage point of detection lies above the atmosphere (*Ouaidrari and Vermote, 1999*). Accordingly, atmospheric correction is greatly important when focusing on an agricultural field. Second, the Okhotsk area is an important environmental observation point because Asian dust passes through it. Asian dust originates from the eastern part of China, passes through Japan extensively and reaches the North American Continent where it covers a wide range of earth radiative forcing. Thus, the retrieval of aerosol optical properties at various observation points is important. An additional observation point, recommended to World Heritage is the Siretoko peninsula, which has a unique ecological system. In the future, the Okhotsk area is likely to become an important observation point for environmental remote sensing. Unfortunately, there is currently no regular observatory for atmospheric surveying such as a lidar system, sun-photometer or sky-radiometer, or exclusive spectrum radiometer for the ground surface in the Okhotsk area.

In this paper, we conducted a trial application of a vegetation index obtained via observation of wheat on farmland in Okhotsk to validate the retrieval of aerosol optical properties from satellite imagery as ground data. First, we developed a camera sensitive to the degree of chlorophyll activation in order to observe this activity in wheat. Second, NDVI values from the camera were validated by comparison with the SPAD values from ground data on the same farmland. Third, the value of optical thickness was determined based on agreement of the NDVI value obtained from atmospherically collected TERRA/MODIS image calculated using 6S as the radiative transfer code (*Vermote, et al., 1997*) with the value from the camera over the same farmland.

2. Methodology

2.1 Development of a camera for observation chlorophyll activation in wheat

In order to retrieve the normalized vegetation index (NVDI) of farmland in the Okhotsk area for comparison with NDVI from satellite imagery in same area, a camera capable of observing the degree of chlorophyll activation in wheat was developed. The camera was altered for separation of visible and near

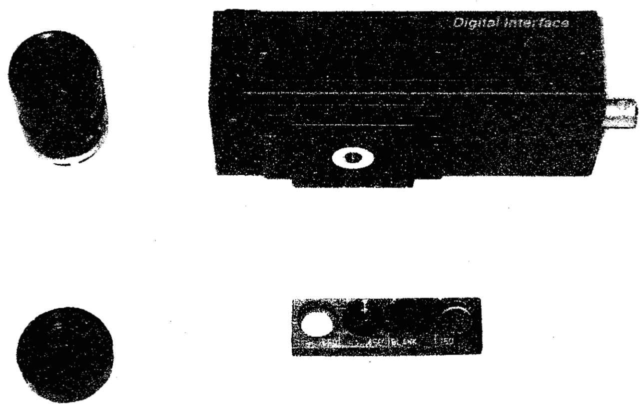

Figure 1. The exterior of XCD-X700

rays so that the NDVI could be calculated using a commercially available digital CCD camera, the XCD-X700 manufactured by SONY. The XCD-X700 has a wide band wavelength (400 nm to 1,000 nm) and high resolution (1,024 × 768 pixels). Two spectroscopic filters, representing the visible band (center wavelength 450 nm, HVHW 40nm) and near infrared band (center wavelength 970 nm, HVHW 40nm), were installed on the lens of the XCD-X700. These filters could be exchanged manually operated each other (see Fig. 1).

2.2 Calculate NDVI from the camera and validation data

Figure 2 shows a range of images from the camera used to calculate the average NDVI value. The range area was extracted from the images in the camera and averaged out per pixel. This operation was performed for each respective farmland image. In this camera system, NDVI is expressed as:

$$NDVI = (r_{NIR} - r_{VIS})/(r_{NIR} + r_{VIS}),$$

where r_{NIR} and r_{VIS} are the ratio of each pixel value of observational farm land from the camera to the correction value from simultaneously photographed white board to which coats of barium sulfate had been applied. The average value of NDVI for each image of farmland was compared with the average SPAD value to obtain the difference between visible and NIR emission of a leaf, obtained using a MINORUTA SPAD-502 on the same farmland.

Figure 3 shows the variation in NDVI between the average of the camera-obtained images and average SPAD in the west Abashiri area of northern farmland on June 12, 2003. It appears that the NDVI values obtained from the images in the camera, which show the average vegetation index of the canopy of wheat, have only a slight correspondence with the average SPAD value for the flag leaf and second leaf from top. The average

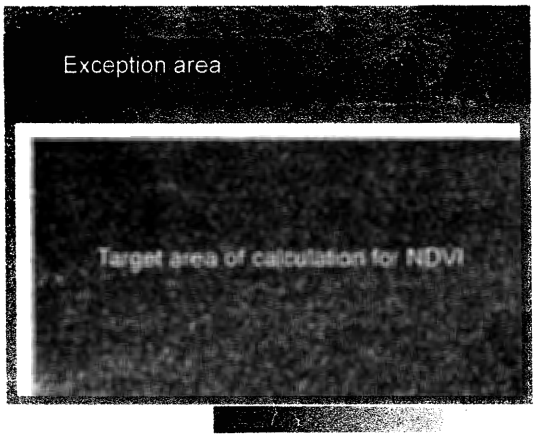

Figure 2. Range on the image from the camera for calculation of average NDVI

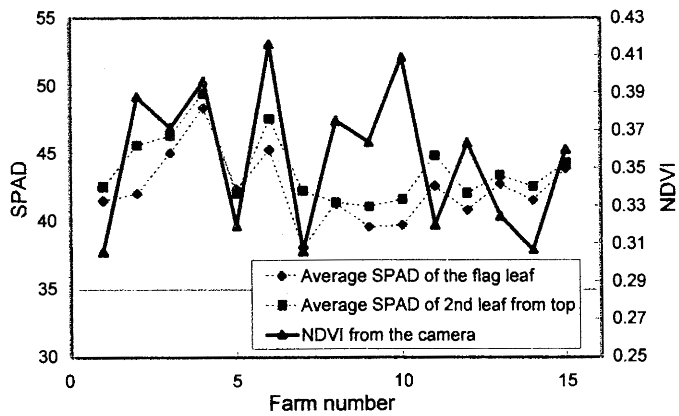

Figure 3. Variation of NDVI from the camera image and average SPAD on farmland of wheat (June 12, 2003)

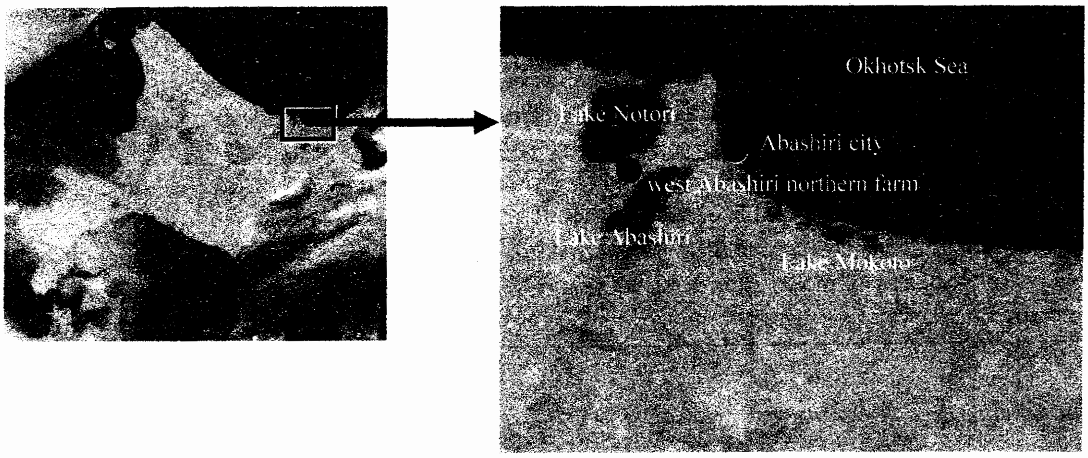

Plate 1. TERRA/MODIS imagery on June 12, 2003. The left image is the whole area of Hokkaido and the right is enlarged image of neighboring the Abashiri northern farm.

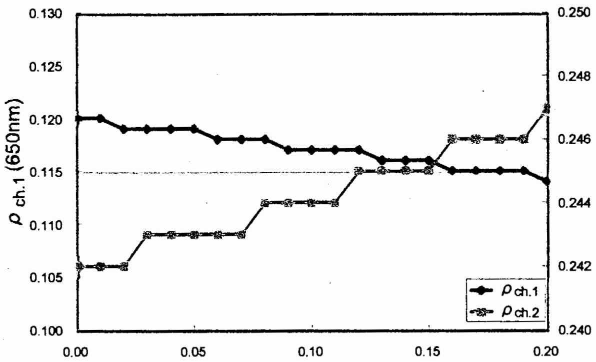

Figure 4. Relationship between atmospherically corrected reflectance and optical thickness with continental aerosol model (June12, 2003)

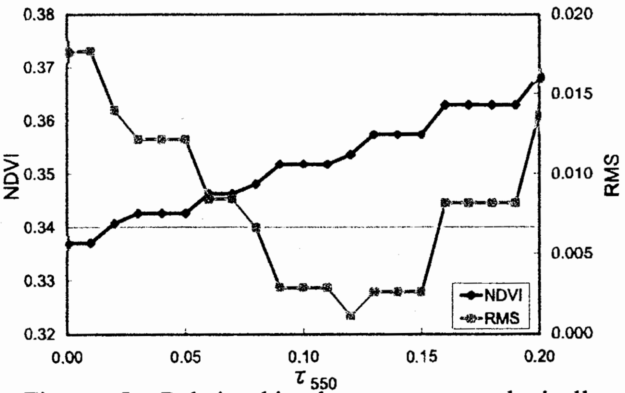

Figure 5. Relationship between atmospherically corrected NDVI and optical thickness with continental aerosol model (June 12, 2003)

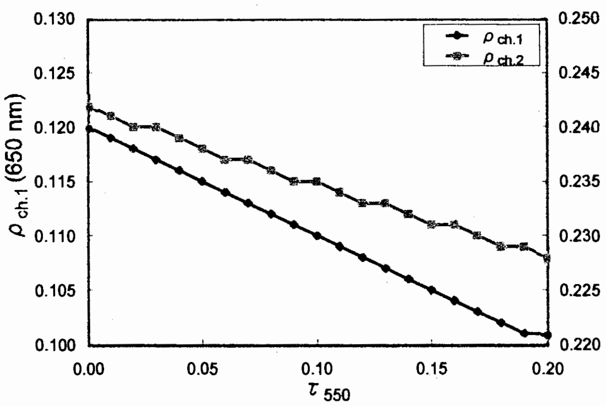

Figure 6. Relationship between atmospherically corrected reflectance and optical thickness with maritime aerosol model (June 12, 2003)

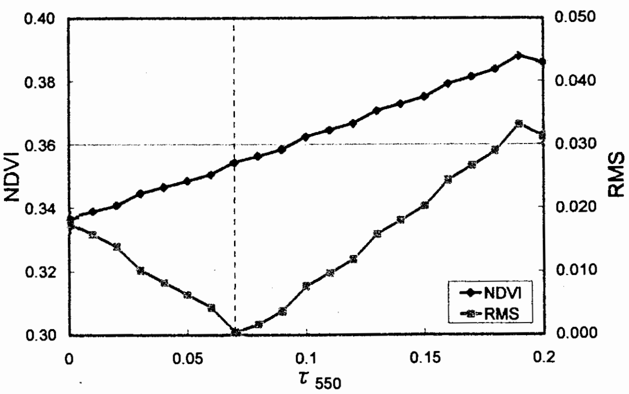

Figure 7. Relationship between atmospherically corrected NDVI and optical thickness with maritime aerosol model (June 12, 2003)

NDVI value was 0.355 on June 12, 2003. Further, the west Abashiri area is located on the south end of Lake Notori and each plot of farmland planted with wheat covers an area of approximately several hectares (see Plate 1). Accordingly, the average NDVI value observed in these areas is fit to be compared with satellite imagery, which represents each area with one pixe.

2.3 Application of TERRA/MODIS to retrieve aerosol optical thickness

In order to derive accurate surface reflectance, which we refer to as the atmospherically corrected image, it is necessary to determine τ_{550}, the atmospheric optical thickness at a 550 nm wavelength, using 6S code. A relationship between the surface reflectance $\rho_{ch.1}$, which is MODIS channel 1 (at the 650 nm center wavelength), $\rho_{ch.2}$ (850 nm) and τ_{550} were calculated by 6s code with τ_{550} variation from 0.0 to 0.2 using the continental and maritime aerosol models, respectively. The relation between NDVI and τ_{550} was obtained from this result of the visible reflectance $\rho_{ch.1}$ and the near infrared reflectance $\rho_{ch.2}$. Thus, we could determine the best fit τ_{550} value with each aerosol model from the condition of the NDVI value from the relation equal to 0.355 obtained from the camera.

3. Result and conclusion

On June12, 2003, the visible channel reflectance value from above the atmosphere observed from TERRA/MODIS over the west Abashiri farmland was 0.125 and the near infrared reflectance value was 0.243. Figure 4 shows the relationship between atmospherically corrected reflectance and optical thickness with the continental aerosol model. As seen in this figure, $\rho_{ch.1}$, the visible reflectance, appears to decrease with increasing τ_{550} value; that is, inversely, $\rho_{ch.2}$, the near infrared reflectance, is increased when the continental model is used. In Fig.5, the best fit τ_{550} value of 0.12 is found with the minimum value of the route mean square (RMS). Figure 6 shows the relationship between atmospherically corrected reflectance and optical thickness with the maritime aerosol model. In contrast to findings with the continental model, both $\rho_{ch.1}$ and $\rho_{ch.2}$ have a tendency to decrease with increasing τ_{550} value. The best fit τ_{550} value found with the maritime aerosol model was 0.07. In a comparison of the two aerosol models, the continental model appears to be more reliable, based on the fact that in same season of the year 2002, the τ_{550} value observed on Memanbetsu airport ranged from 0.14 to 0.17 (*Asakuma, 2002*).

In the future, we would like to compare the optical thickness value using MODTRAN, the radiative transfer code, and retrieve more detailed aerosol optical properties such as a radius, density, and refractive index.

References

Asakuma, K., S. Otsutsumi, T. Kubota, M. Yabuki, H. Kuze and N. Takeuchi: Retrieval of aerosol optical thickness from NOAA/AVHRR data and its application to the derivation over land area in Chiba, Proceedings of SPIE 4150, Optical Remote Sensing of the Atmosphere and Clouds II, 290 – 298, 1999

Asakuma, K.: Study for atmospheric correction from TERRA/MODIS imagery over Okhotsk area, Proceedings of the 3rd workshop of the sub-project studies on natural environment and culturein ASIA, 71 –80, 2002

Asakuma, K., M. Minomura, S. Otsutsumi, H. Kuze and N. Takeuchi: Estimation of aerosol optical thickness over land in Chiba area from AVHRR data, Advanced Space Research, Elsevier Science, Vol. 29, No. 11, 1747-1752, 2002

Ouaidrari, H. and E. F. Vermote: Operational atmospheric correction of Landsat TM Data, Remote Sens. Env., Vol. 70, 4-15, 1999

Vermote, E. F., D. Tanre, J. Deuze, M. Herman and J. Morcrette: Second simulation of the satellite signal in the solar spectrum, 6S ; An overview, IEEE Trans. on Geosc. and Remote Sens., Vol. 35, 675-686, 1997