Retrieval of aerosol optical properties over Chiba land area from Landsat/TM imagery

- Part II: Determination of aerosol size distribution -

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Abstract:

We present a case study in which aerosol optical properties over Chiba land area are derived from Landsat/TM visible channel data. First, the surface albedo value is obtained for each pixel from the atmospherically corrected TM image (January 14, 1999) with relatively small aerosol optical thickness (AOT). After the correction using the 6S code, this ‘clean’ image provides the “ρ map” that can be used as a reference. Second, a test image (December 13, 1998) with relatively large AOT is compared with the clean image to study the aerosol optical properties. By changing the aerosol particle radius, this test image is also subjected to the atmospheric correction, and the resulting surface albedo is compared with the ρ map. The parameter optimization is carried out on the basis of the standard WMO-WCP55 continental aerosol model, with the contribution from WMO-WCP112 water-soluble particles. The aerosol particle radius over Chiba area on December 13, 1998 is found to be 4.0×10^{-3} μm, slightly smaller than the radius of the standard water-soluble particles.

1. INTRODUCTION

Atmospheric correction is indispensable to retrieve accurate surface albedo from satellite images in the visible and near infrared bands. The essential parameter for the correction is the accurate value of aerosol optical thickness (AOT) [1-3]. The wavelength dependence of AOT is also important, and in general, this is automatically given by the aerosol model (such as the continental, maritime or urban aerosol model) [2,3]. The actual aerosol property at the time of the satellite overpass, however, is unknown for most cases. On the other hand, simulation studies indicate that the relationship between the ground albedo and the AOT can vary significantly in accordance with the aerosol properties such as the size distribution and the refractive index. Thus, even if the value of AOT is given from the ground observation (e.g. by means of a sun photometer), different assumption about the aerosol model can lead to a different value of the surface albedo as a result of the atmospheric correction [3].

In this paper we present an algorithm of deriving the aerosol size distribution from Landsat/TM images. The algorithm is demonstrated on the image observed over the Chiba land area. By means of the radiative transfer calculation, the aerosol size distribution is determined from the condition that the apparent albedo at the top of the atmosphere agrees with the "reference" surface albedo. This reference albedo is obtained from the atmospheric correction of the 'clear' image (see Part I: Determination of spatial distribution of aerosol optical thickness). On the other hand, the apparent albedo is obtained from the TM image with 'turbid' atmospheric condition. As for the AOT values, we make use of the values measured by a sun photometer operated on the campus of Chiba University.

2. METHODOLOGY

We employ the 6S radiative transfer code [4] for determination of the aerosol size distribution. The code gives the apparent albedo once the surface albedo, AOT and the aerosol model are specified. In addition to the seven standard models such as the continental, maritime, and urban models, the 6S code allows the user to specify detailed aerosol parameters in a form of the multi-modal log normal distribution, the modified gamma distribution, or the Junge power-law distribution. In the standard aerosol model equipped in the 6S code, the user can also modify the volumetric percentage of four basic components (dust-like, water-soluble, oceanic and soot aerosols). Table 1 shows the default percentage of these components [5], given as the WMO-WPC55 standard aerosol models. While the continental and maritime models have large influence of the water-soluble component, the urban aerosol model is remarkably contributed by soot aerosols with large absorption.

As explained in Part I, the analysis of TM data over Chiba land area indicates that reasonable values of the AOT can be retrieved when continental or maritime aerosol models are employed, but not with the urban model. In view of this effect, here we rely on the continental model, and the surface albedo is simulated for various values of the particle radius R_M of the water-soluble component. Table 2 shows the specification of four basic components given in WMO-WCP112, where the mean particle radius of the water-soluble component is 0.005 μm. Here we change the value of this parameter in a range of 0.001 to 1.0 μm. In order to focus on the effect of this size distribution, other parameters including the reflective index are fixed in the present simulation.

Table 1. Volumetric percentage for WMO-WPC55 standard aerosol models.

	Dust Like	Water Soluble	Oceanic	Soot
Continental	2.265×10^{-6}	0.9383	---	0.0617
Maritime	---	0.9996	4.208×10^{-4}	---
Urban	1.651×10^{-7}	0.5925	---	0.4075

Table 2. Specifications of the four basic components in WMO-WCP112: R_M is the mean radius, the standard deviation, V the volume concentration, N the particle number concentration, and n_r-in_i the refractive index.

	Dust Like	Water Soluble	Oceanic	Soot
R_M [m]	0.500	0.005	0.300	1.180×10^{-2}
σ	2.99	2.99	2.51	2.00
V [m^3/cm^3]	1.140×10^{2}	1.140×10^{-4}	5.114	5.978×10^{-5}
N [cm^{-3}]	5.473	1.869×10^{6}	2.761×10^{2}	1.806×10^{6}
n_r at 488 nm	1.530	1.530	1.377	1.750
n_i at 488 nm	8.00×10^{-3}	5.00×10^{-3}	1.38×10^{-8}	4.50×10^{-1}

The best value of the particle radius R_M is sought under the condition that ground albedo values in the clear-day image agree with the values from the turbid-day image after the atmospheric correction. The target pixel is the one that corresponds to the location of the Chiba University. From the data on January 14, 1999 (clear day), we obtain $\rho^{(C)}_{485} = 0.14$ and $\rho^{(C)}_{560} = 0.16$ for TM channel 1 and 2, respectively. The turbid image is observed on December 13, 1998 with AOT values (observed at Chiba University) of $\tau_{485} = 0.294$ at 485 nm and $\tau_{560} = 0.241$ at 560 nm.

3. RESULTS AND CONCLUSION

Figure 1 shows the relationship between the aerosol particle radius R_M and the ground albedo $\rho^{(T)}_{485}$ at 485 nm (TM channel 1) obtained from the turbid image. This value has been obtained through the radiative transfer calculation by assuming that the calculated AOT at 485 nm (τ'_{485}) is equal to the value from the sun photometer (τ_{485}). In the calculation, the AOT value at 550 nm (τ_{550}) was changed from 0.0 to 0.4. The digital number (DN) of the target pixel is 75 for channel 1. The ground albedo $\rho^{(T)}_{560}$ at 560 nm (TM channel 2) is also obtained from the same calculation with the corresponding pixel DN value of 31. In Fig. 1, the calculated albedo $\rho^{(T)}_{485}$ for channel 1 agrees with the reference albedo $\rho^{(C)}_{485} = 0.14$ at $R_M = 4.0\times10^{-3}$ and $R_M = 4.7\times10^{-2}$ μm. Similarly, we obtain $\rho^{(T)}_{560} = \rho^{(C)}_{560} = 0.16$ for channel 2 for the particle radius of $R_M = 4.0\times10^{-3}$ and $R_M = 6.5\times10^{-2}$ μm. Consequently it is likely that the aerosol model over Chiba area

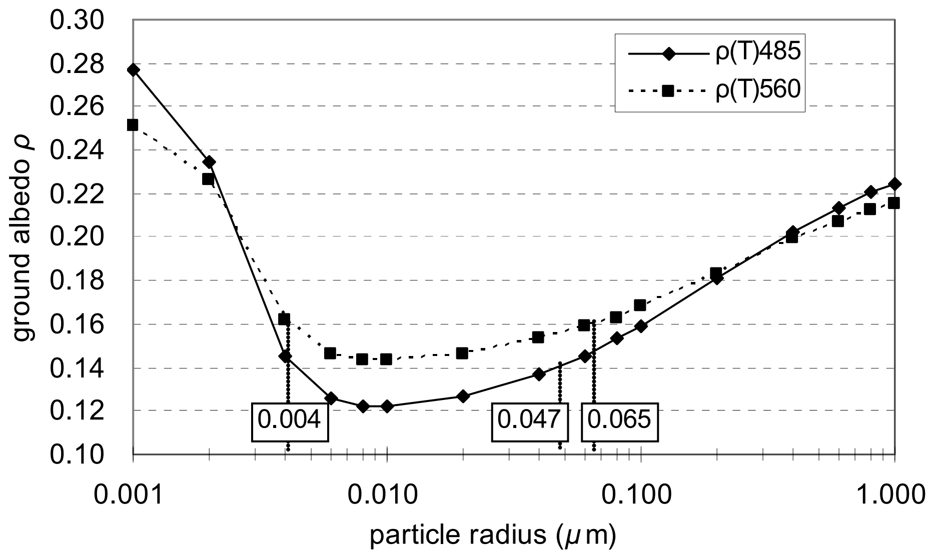

Figure 1: Relationship between the aerosol particle radius λ_m and atmospherically corrected ground albedo. The solid line shows the result at 485 nm (TM channel 1) and dotted line is at 560 nm (channel 2).

on December 13, 1998 can be described as the continental aerosol model with the particle radius of 4.0×10^{-3} μm. This value is only slightly smaller than the standard water-soluble particle which is the main component of the continental model.

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