THE ANALYSIS OF ADEOS / POLDER DATA

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ABSTRACT

We have made the cross calibration in terms of space reflectance between POLDER and OCTS sensors on board ADEOS satellite, using the POLDER and OCTS data acquired simultaneously on April 24, 1997. The space reflectance values for the same target computed from the POLDER and OCTS data are in very good agreement, when we adopted the new calibration coefficients of OCTS suggested by the vicarious experiment by NASDA. Then, we estimated aerosol parameters for several target areas (two areas in the Sea of Japan and three in the Pacific Ocean) from ADEOS/POLDER's directional reflectance and polarization data in 760nm and 865nm bands. A single atmospheric layer model with an isotropic Gaussian type ocean surface (Cox-Munk model) was assumed in this study.

I. INTRODUCTION

CNES(Centre National d'Etudes Spatiales)'s POLDER (POLarization and Directionality of Earth Reflectance) sensor, on board NASDA(National Space Development Agency of Japan)'s ADEOS satellite, had collected the global data sets for about 8 months during the ADEOS's operational period (launched in August,1996 - ended in June, 1997). The POLDER consists of wide-field-of-view telecentric optics, a rotating wheel with spectral and polarizing filters and a two dimensional CCD detector array. In addition to the reflectance measurements of the Earth's reflectance image in 8 bands, centered at 443, 490, 565, 670, 763, 765, 865 and 910 [nm], it had a new capability of measuring the polarization in 3 bands, centered at 443, 670, and 865 [nm]. The POLDER's unique sensor design makes measurements of both reflectance and polarization possible from up to 14 different viewing directions in a single satellite pass. The directional measurements of a single scene image by POLDER cover up to 51 degrees in the cross-track direction and up to 43 degrees in the along-track direction (a single scene image consists of 274x242 pixels) and the corresponding ground size is about 2447[km]x1809[km] with a pixel resolution at nadir is about 7[km]x6[km]. Since POLDER and OCTS are on the same ADEOS satellite and they have 6 nearly identical spectral bands, centered at 443, 490, 565, 670, 765 and 865[nm], it is possible to make a cross calibration between two sensors. For more detailed information on the calibration coefficients for POLDER and OCTS after the launch, refer to the papers [1] and [2], respectively.

II. BASIC FORMULATIONS

The incident solar flux vector in Stokes vector representation is given by Eq.(1).

$$\pi\mathbf{F}=\pi[f \quad 0 \quad 0 \quad 0]^t \qquad (1),$$

where a superscript t represents the matrix transposition. In this notation we assume an incident solar flux vector $\pi\mathbf{F}$ illuminates a plane parallel atmosphere with the optical thickness of τ_{at} from the direction of (μ_0, ϕ_0), where μ_0 and ϕ_0 are the cosine of the solar zenith angle θ_0 and the solar azimuth angle ϕ_0, respectively. In the right side πf is equal to the extra-terrestrial irradiance per unit area normal to the direction of solar rays, $E_s[W/m^2]$. Then, the upwelling Stokes vector at the top of the atmosphere (TOA) in the direction of (μ, ϕ), $\mathbf{I}(\tau_{at}, \mu, \mu_0, \phi - \phi_0) = [\,I \quad Q \quad U \quad V\,]^t$ can be expressed by Eq.(2) in terms of the reflection matrix of the atmosphere-ocean system $\mathbf{R}_{at+sf}$.

$$\mathbf{I}(\tau_{at}, \mu, \mu_0, \phi - \phi_0) = \mu_0\, \mathbf{R}_{at+sf}(\tau_{at}, \mu, \mu_0, \phi - \phi_0)\, \mathbf{F} \qquad (2).$$

As for the components of Stokes vector, I is the radiance, Q is related to the linear polarization, U to the plane of polarization, and V to the circular polarization. In the Earth's atmosphere the circular polarization can be ignored. By using the adding method [3], $\mathbf{R}_{at+sf}$ can be expressed in terms of the reflection matrix, the transmission matrix, of the atmosphere and the reflection matrix of the sea surface, $\mathbf{R}_{at}$, $\mathbf{T}_{at}$, and $\mathbf{R}_{sf}$, respectively. For the basic formulations of these matrices for a single atmospheric layer with a Gaussian type ocean surface (Cox-Munk model [4]), refer to our previous paper [5].

The definition of space reflectance R_{sp} at TOA is given by Eq.(3),

$$R_{sp} = \pi I / \mu_0 E_s = \pi I / \mu_0 (\pi f) = I / \mu_0 \qquad (3).$$

The degree of linear polarization in the reflected radiation is also defined by Eq.(4).

$$P = \mathrm{sqrt}\,(Q^2+U^2) / I \qquad (4).$$

For simplicity, we shall call it the polarization in this paper.

III. CROSS CALIBRATION BETWEEN TWO SENSORS

We have made the cross calibration between POLDER and OCTS sensors on board ADEOS, using the reflected radiance data acquired simultaneously on April 24, 1997. Fig.1 is a geometrically corrected subimage of POLDER scene, showing a target site in the Pacific Ocean near Sanriku coast of Japanese main island by a square. The mean space reflectance values for the same target area were computed in 6 bands, using the pre-flight calibration coefficients and measured reflected radiances by POLDER and OCTS. We found that the agreement in the space reflectance between POLDER and OCTS is good in 550[nm] and 670[nm] with relative difference of about 5 – 7 %, whereas it is rather poor in shorter wavelength bands (443[nm], 490[nm]) and near infrared bands(765[nm], 865[nm]) with relative difference of about 11 – 25 %. However, we are able to obtain a very good agreement in space reflectance between two sensors when we adopt the new OCTS calibration coefficients deduced from NASDA's OCTS vicarious experiment conducted off California coast on Nov. 1, 1996[2]. In this case the agreement is excellent in the visible and near infrared, whereas it is not so good in the short wavelength bands. Our results indicates that POLDER's in-flight calibration coefficients in 443[nm] and 490[nm] should be smaller and larger by about 10 % and 7 %, respectively. The results on the cross calibration between two sensors are tabulated in Table 1.

IV. DIRECTIONAL POLDER DATA ANALYSIS

We have analyzed the directional reflectance and polarization data acquired by POLDER on board ADEOS satellite. The ADEOS/POLDER's directional reflectance and polarization data at 760 [nm] and 865[nm] over the Sea of Japan and the Pacific Ocean near Japan, taken on April 26, 1997(Path No.55; Level-1), were used to estimate appropriate aerosol models for 6 selected areas with their size of 3x3 pixels (about 20kmx20km). The locations of 6 study areas are marked by A, B, C, D, E and F in Fig.2 and their latitudes and longitudes are given in Table 2. As for aerosol size distribution models, we examined Junge type power law models [6] with the index of ν = 2.5, 3.0, 3.5, 4.0 and 4.5. The specific refractive indices, m=1.35, 1.40, 1.45, 1.5, 1.55 and 1.60 are examined. In this analysis we assumed a ocean wind speed of V=5.0 [m/s] , because European Center for Medium-Range Weather Forecasts(ECMWF) data base indicates the wind speeds for the study areas at near ADEOS observation time are in the range of 4.5[m/s] < V < 5.7[m/s]. We have made the look up tables (LUT) for different aerosol optical thickness values of τ , namely, τ = 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.0 for each set of ν and m. We have retrieved an appropriate aerosol model for each study area by using the LUT and the retrieved results are shown in Table 3. In the retrieval scheme, the aerosol optical thickness and Junge's power law index are determined so as to minimize the mean difference between the observed and theoretical space reflectance values for different directional angles and the refractive index of aerosol particles is determined so as to minimize the mean difference between the observed and theoretical linear polarization values.

As for the validation of the aerosol parameters retrieval, the simultaneous sky observation experiments were made by the aureolemeter (POM-01: PREDE) at Uchinada Agricultural Experiment Center, very close to the study area F. The retrieved aerosol parameters agree in general with the measured ones, as seen in Table 4. Although the retrieved aerosol optical thickness is slightly larger than the measured one at 500[nm], it is understandable because of our LUT's incompleteness. In our LUT the absorbing aerosol cases are not included yet at this time. If slightly absorbing aerosol case is considered, then we are able to obtain similar aerosol optical thickness value.

V. CONCLUSIONS

We have made cross calibration between POLDER and OCTS sensors on board ADEOS satellite, using the POLDER and OCTS data acquired simultaneously on April 24, 1997. We found the agreement between two sensors is excellent in visible and near infrared bands, when OCTS's in-flight calibration coefficients are adopted. Then, we retrieved the local aerosol's optical parameters at several target areas from ADEOS/POLDER's directional reflectance and polarization data in 760[nm] and 865[nm] bands. The retrieved parameters were examined by the simultaneous sky measurement data. A single atmospheric layer model with an isotropic Gaussian type ocean surface (Cox-Munk model) was assumed in this study.

ACKNOWLEDGEMENT

This study is supported by NASDA Research Contract, NASDA-PSPC-20172. The results were obtained from CNES's POLDER and NASDA's OCTS on board NASDA's ADEOS.

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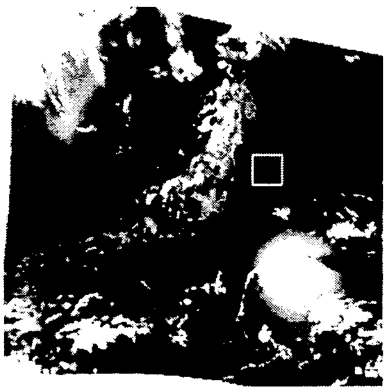

Fig. 1. Location of the target site for cross calibration in POLDER image.

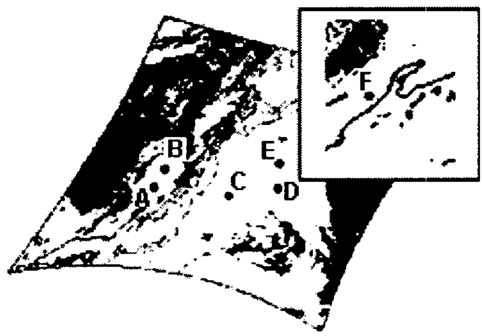

Fig.2 Locations of study sites in POLDER scene

Table 1. Cross Calibration results between POLDER and OCTS.

Rel. Diff* -- based on pre-flight OCTS calibration coefficients.

Rel. Diff --- based on new OCTS calibration coefficients[2]

Wavelength[nm]	POLDER	OCTS	Rel. Diff.[%]*	Rel. Diff.[%]
443	0.1476	0.13175	11.4775	10.738
490	0.0900	0.09677	13.8463	7.522
565	0.0557	0.05351	7.2856	3.932
670	0.0303	0.02942	4.4874	2.904
765	0.0189	0.01910	11.6676	1.058
865	0.0149	0.01431	25.6988	3.960

Table 2. Specification of the study sites, A- F.

Target Area	Sea of Japan		Pacific Ocean			Truth site
	A	B	C	D	E	F
Latitude[deg.]	N38.8	N39.9	N38.2	N38.8	N40.2	N36.7
Longitude[deg.]	E137.4	E137.7	E143.7	E147.6	E147.0	E136.7

Table 3. The retrieved aerosol optical parameters for study sites, A – F.

ref -> pol	τ[500nm]	ν	m
A	0.4	3.5	1.4
B	0.3	4	1.4
C	0.1	2.5	1.45
D	0.2	3	1.4
E	0.1	2.5	1.4
F	0.3	3.5	1.4

Table 4. The comparison of the retrieved aerosol optical parameters with the measured ones at the study site F

*--Retrieved α is converted from $\alpha = \nu - 2$

	Retrieved*	Measured
λ / α	1.50	1.54
500nm	0.30	0.2635
670nm	0.1934	0.1680
865nm	0.1318	0.1135