Geostationary Satellite Re-Analysis

-Estimation of radiation budget-

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Abstract

In this study, we analyze Refined - Visible and Infrared Spin-Scan Radiometer (R-VISSR) data set. An accurate calibrated data propose the better accuracy for analysis of cloud and radiation budget. Therefore, in Asian Atmospheric Particle Environmental Change Studies (APEX) - E2 period, diffuse component and aerosol optical thickness showed the pattern that looked like well. Thus, analysis of 12 months of 2001 was executed that the results indicate a feature trend of the direct and the diffuse component of downward solar radiation from East Asia to North Pacific Ocean. Moreover, contrast is clear between East Asia and South side of Australia in direct and diffuse components.

Keywords : Geostationary satellite, GMS-5/VISSR, Solar radiation, Radiation budget

1. Introduction

Clouds has an important role to be cool the Earth by reflecting solar radiation and also to keep it warm by absorbing and emitting terrestrial radiation. These effect are important in the energy balance at the surface and the Top of the Atmosphere (TOA) and connected into the Earth system through the complicated climate feedback processes. Thus, understandings of the influence of the clouds on radiation budget by an accurate observations have been requested. Wetherald and Manabe discussed the cloud feedback process using a General Circulation Model (GCM) [Wetherald and Manabe, 1988][1). Tsushima and Manabe tested the cloud feedback sensitivity to global mean surface temperature based on explicit definition of feedback processes. GCM has strong sensitivity for global mean surface temperature although analysis of sensitivity based on observations are negligible [Tsushima and Manabe, 2001][2). Cloud modeling is a big uncertainty for the climate model and long term analysis for the global change would be estimated. It is important to evaluate the influence of cloud for Earth's radiation budget based on observations.

Geostationary Meteorological Satellite - 5/Visible and Infrared Spin-Scan Radiometer (GMS-5/VISSR) observes every hour on geostationary orbit. The optical characteristics of particles (aerosols and clouds) can be retrieved from the consecutive observational data of seven years. In this study, we newly analyzed Refined

- VISSR (R-VISSR) data set. The R-VISSR data set promote the better calibration quality for atmospheric analysis. An accurate calibrated data propose the better accuracy for analysis of cloud and radiation budget. In this study, we report the estimated solar fluxes and discuss the influence of cloud for solar fluxes.

2. Data set

The VISSR sensor has four channels of visible (VIS) and infrared (IR). Three IR channels are calibrated simply by equipped Blackbody. The VIS channel is calibrated by vicarious calibration using the Terra satellite equipped Moderate Resolution Imaging Spectroradiometer (Terra/MODIS) data. The vicarious calibration with sea surface, land surface and clouds provides an accurate dataset that is validated from ground observations. Therefore, Refined - VISSR (R-VISSR) data set is applied to retrieve aerosols and the clouds particles optical characteristics for analysis of radiation budget. An atmospheric profiles data are used Japanease 25-year Re Analysis (JRA-25).

3. Algorithm

We develop a high speed and accurate algorithm based on Neural Network (NN). The advantages of the NN approach are to be speed of the computations and allows to produce numerous parameters since it does not require a large data base. Figure 1 indicates a three layers network structure. Neuro-link Network solver (NN solver) is built by improved learning algorithm "Dist.-BP" that has an anti-local minimum and a survival rule of neuron depending on nerves activities [Takenaka et al., 2008]$^{3)}$.

$$\Delta W^{(s+1)} = -\eta \left.\frac{\partial E}{\partial W}\right|_{W=W^{(s)}} + \alpha \Delta W^{(s)}$$

$$\Delta V^{(s+1)} = -\zeta \left.\frac{\partial E}{\partial V}\right|_{V=V^{(s)}} + \beta \Delta V^{(s)}$$

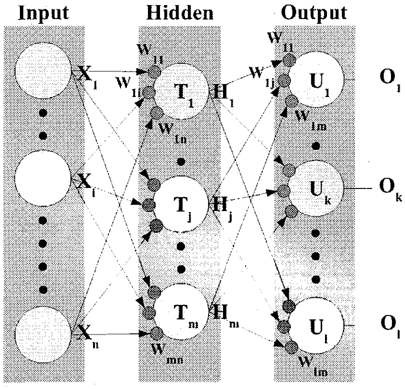


Figure 1 : Structure of three layer neural network. It has three components of layer (Input, Hidden, Output). Each layer has m,n,l number of neurons.

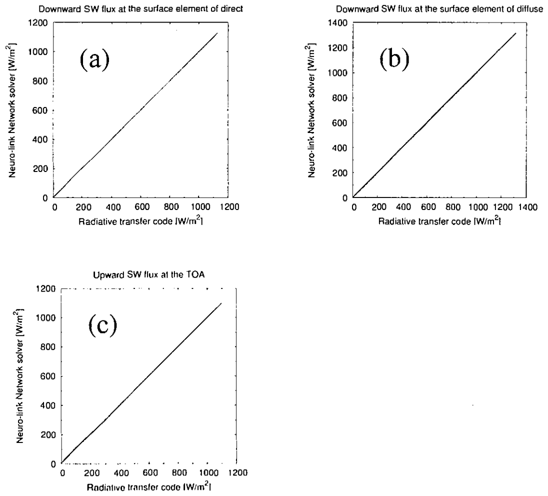


Figure 2 : Comparison of calculation results between radiative transfer code and NN solver. (a)direct component (b)diffuse component (c)upward SW flux at the TOA.

The NN solver traces radiative transfer code System for Transfer of Atmospheric Radiation (RSTAR) [Nakajima and Tanaka, 1986, 1998]$^{4,5)}$ for high speed and accurate computation (Figure 2). The Extreme speed and Approximation module Multiple drive System (EXAM SYSTEM) controls NN solvers by multi-threading. EXAM SYSTEM applies to MTSAT-1R, estimates the solar radiation at the TOA and the surface with semi-real time, and evaluated against *in situ* observations. The EXAM SYSTEM uses eight Central Processing Unit (CPU) cores, And logically sliced target area (from 60N,80E to 60S,160W) is processed with high speed. It is validated in Chiba/SKYNET site. Achieved accuracy is rms =112.23 and the correlation between the estimates and measurements is 0.92. Moreover, NN solvers are also enabled for feature bands. By-products of the algorithm include Ultraviolet rays A, B (UV-A, UV-B), and Photosynthetically Active Radiation (PAR) fluxes as well as direct and diffuse components with semi-real time. These fluxes products promotes detail information of the influence of clouds for each spectral bands.

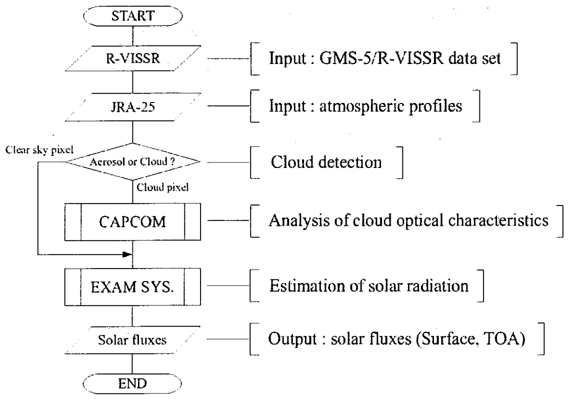


Figure 3 : Flow chart of estimation of solar radiation. It executed combination of EXAM SYSTEM and Comprehensive analysis Program for cloud Optical Measurement (CAPCOM) [Nakajima and Nakajima, 1995]6).

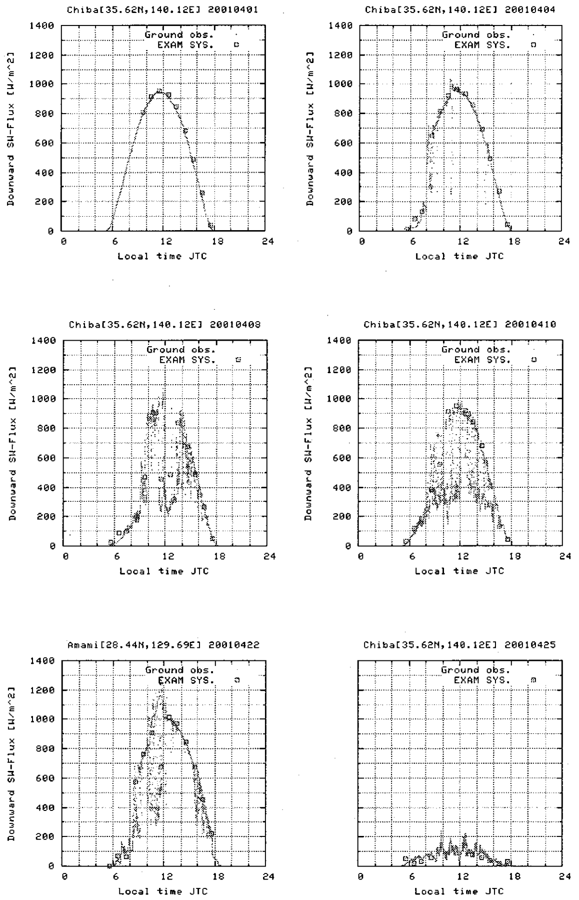
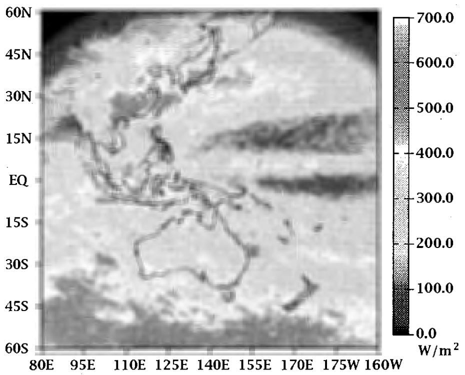


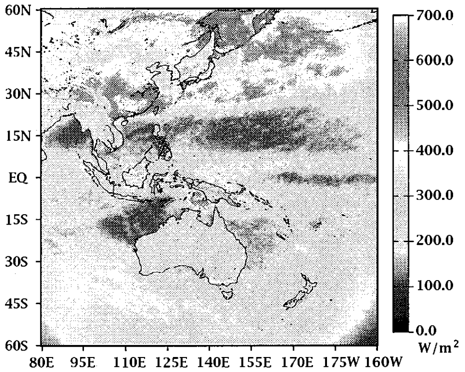
Figure 4 : Typical example of ground validation for downward SW flux at the surface, location is 35.62N, 140.12E Amami/SKYNET site in APEX-E2 period. Clear sky and cloudy condition indicate a good relation to estimation and observation. However, because very small phenomenon, broken clouds are caused problems.

4. Results and discussions

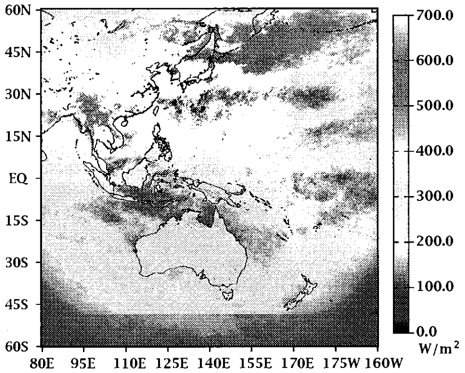
The flow chart of estimation of solar radiation is shown in Figure 3. Cloud optical characteristics are analyzed by Comprehensive analysis Program for cloud Optical Measurement (CAPCOM). Aerosols retrieval is skipped. Figure 4 shows one of the validation results of downward SW flux at the surface based on ground measurements in Asian Atmospheric Particle Environmental Change Studies (APEX) -E2 at. (35.62N and 140.12E) Amami/SKYNET site. Clear sky and cloudy condition are good relation. However, broken cloud condition has problem. Because it is very small sub-pixel phenomenon, satellite sensor can not capture yet. Figure 5 presents monthly average upward SW flux at the TOA. The observation is unstable since July at northern hemisphere (45S to 60S). In January (Fig.5a), high latitude area (45S to 60S) has strong reflecting flux. In April and July, the strong reflecting are in East Asia and North Pacific Ocean. Figure 6 indicates a monthly average downward SW flux at the surface. It has strong flux in the vicinity of Australia in January and October. A weak flux line is the influence of clouds of Intertropical Convergence Zone (ITCZ) in the equator. In April, North Pacific Ocean has strong downward flux, however, it is more higher than July. Figures 7 and 8 are direct and diffuse components of down ward SW flux at the surface. These fluxes indicate the influence of clouds for downward SW flux. In January and October, Because, it has few clouds, Australia has strong direct component. However, diffuse component increases in a wide region in the ocean of the south of Australia. In East china sea to North Pacific Ocean, it has same trend. And, July is most strong. Moreover, direct component decrease in from East china sea to North Pacific Ocean at April and July, however, south side of Australia has not decreasing of direct component. They might have closely related aerosols and cloud activity in East Asia (Fig.9). The strong diffuse components are brought by thin clouds. On the other hand, thin cloud (about tau=1to5) blocks the direct component of solar radiation. In April, from East china sea to North Pacific Ocean are kept bright by cloud scattering. And In July, blocking of direct component and strong diffuse component are predominant in North Pacific Ocean. This area has also strong reflection of upward SW flux at the TOA.



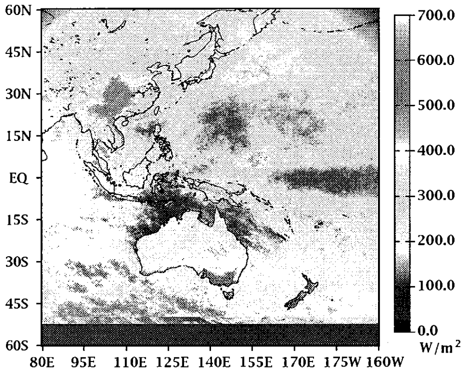
(a) January, 2001



(b) April, 2001

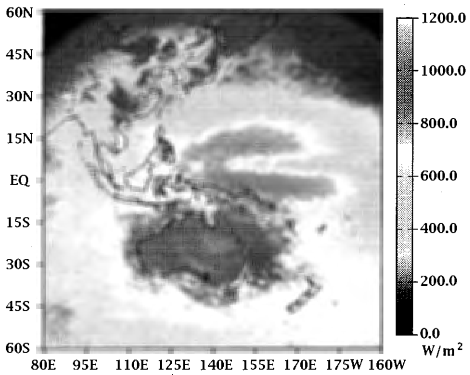


(c) July, 2001

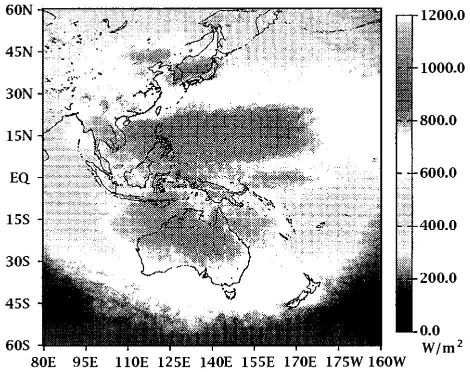


(d) October, 2001

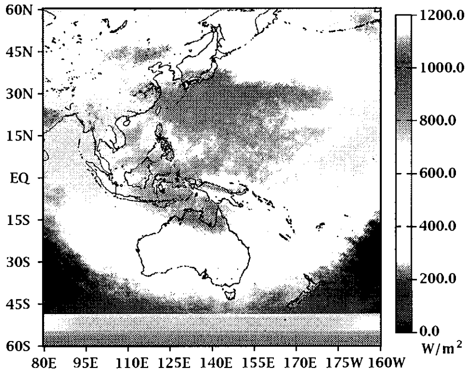
Figure 5 : Monthly average upward SW flux at the TOA at 03UTC. (a)January (b)April (c)July (d)October in 2001.



(a) January, 2001



(b) April, 2001



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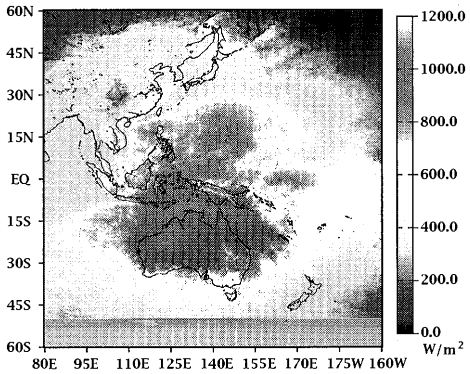

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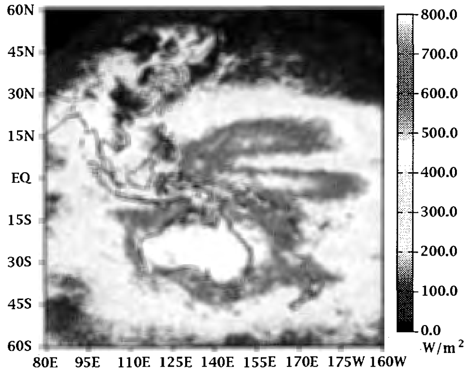
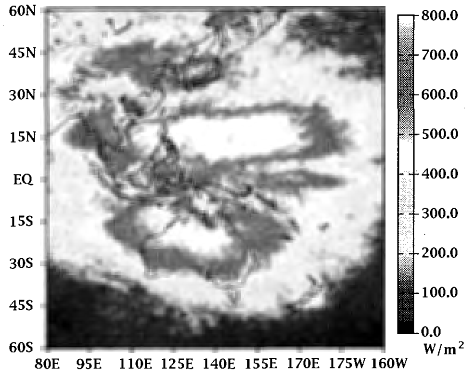
Figure 6 : Monthly average downward SW flux at the surface at 03UTC. (a)January (b)April (c)July (d)October in 2001.



(a) January, 2001



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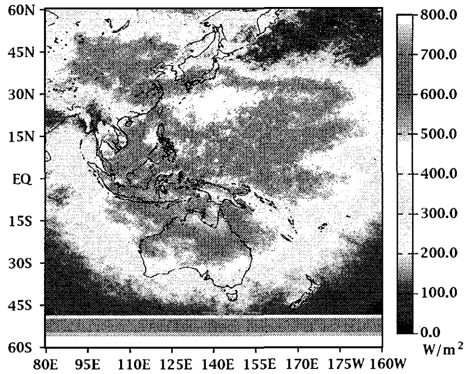

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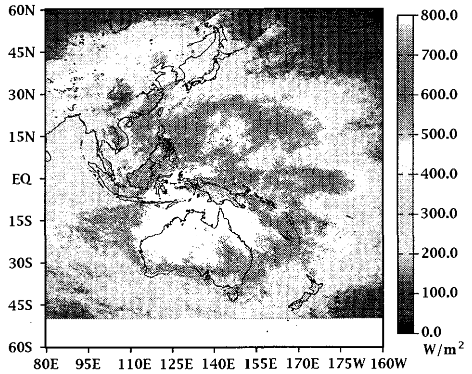
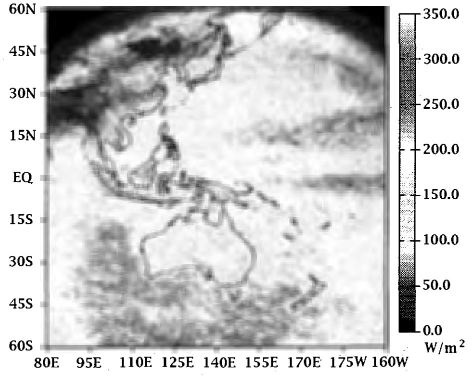
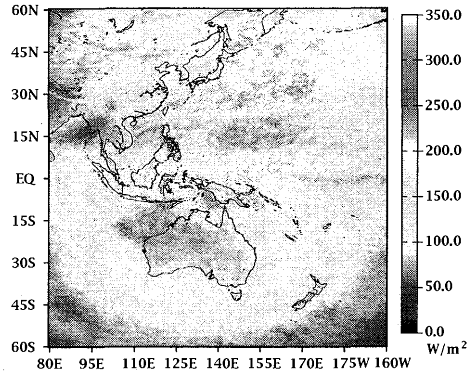


(d) October, 2001

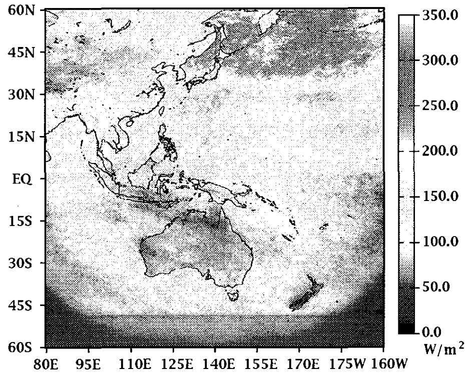
Figure 7 : Same as Figure 6, but for direct component. (a)January (b)April (c)July (d)October in 2001.



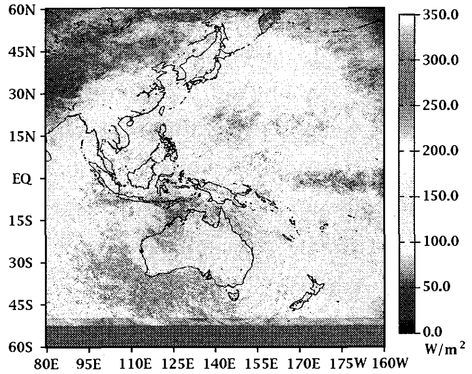
(a) January, 2001



(b) April, 2001

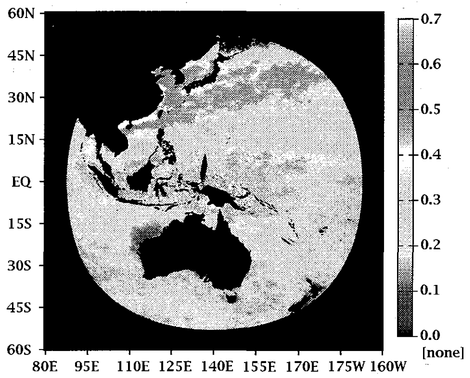


(c) July, 2001

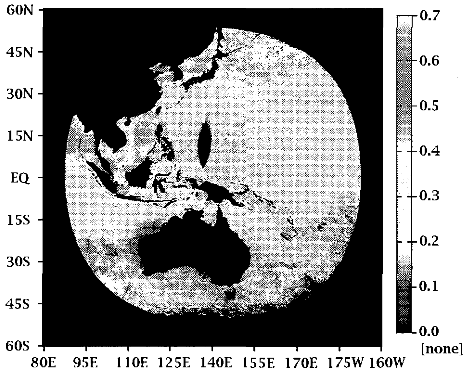


(d) October, 2001

Figure 8 : Same as Figure 6, but for diffuse component. (a)January (b)April (c)July (d)October in 2001.



(a) April, 2001



(b) July, 2001

Figure 9 : Monthly average aerosol optical thickness at the ocean surface (01UTC to 06UTC). Analyzed by Retrieval of Aerosol Optical Properties (REAP) [Higurashi and Nakajima, 1999, 2002; Fukuda et al., 2008][7,8,9)]

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References

1) Wetherald, R. T. and S. Manabe (1988), Cloud feedback processes in a general circulation model , J. Atmos. Sci., 45(8), 1397-1415.
2) Tsushima, Y. and S. Manabe (2001), Influence of cloud feedback on annual variation of global mean surface temperature , J. Geophys. Res., 106(D19), 22,635-22,646.
3) Takenaka, H., T. Y. Nakajima, A. Higurashi, A. Higuchi, T. Takamura, R. T. Pinker, Estimation of Solar radiation by Neural Network, J. Geophys. Res. (submitted).
4) Nakajima, T., and M. Tanaka (1986), Matrix formulations for the transfer of solar radiation in a plane-parallel scattering atmosphere, J. Quant. Spectrosc. Radiat. Transfer,35, 13-21.
5) Nakajima, T., and M. Tanaka (1988), Algorithms for radiative intensity calculations in moderately thick atmospheres using a truncation approximation, J. Quant. Spectrosc. Radiat. Transfer, 40, 51-69.
6) Nakajima, T. Y., and T. Nakajima (1995), Wide-area determination of cloud microphysical properties from NOAA AVHRR measurements for FIRE and ASTEX regions, J. Atmos. Sci., 52, 4043-4059.
7) Higurashi, A., and T. Nakajima (1999), Development of a two channel aerosol retrieval algorithm on global scale using NOAA / AVHRR, J. Atmos. Sci., 56, 924-941.
8) Higurashi, A., and T. Nakajima (2002), Detection of aerosol types over the East China Sea near Japan from four-channel satellite data., Geophys. Res. Lett., 29(17), 1836, doi:10.1029/2002GL015357.
3) Fukuda, S., T. Nakajimal, A. Higurashi, N. Kikuchi, and T. Y. Nakajima (2008), Aerosol retrieval from GLI over land and its comparison with ground observation, CEReS symposium 2008.