Cloud properties analysis based on EarthCARE observation for climate variability prediction

Seiko Takagi [1], Makiko Hashimoto [2]

1. Tokai University, Research and Information Center, 4-1-1 Kitakaname, Hiratsuka, Kanagawa 259-1292, Japan

2. JAXA, 2-1-1 Sengen, Tsukuba, Ibaraki 305-8505, Japan

Abstract

EarthCARE (Earth Clouds, Aerosols and Radiation Explorer) is one of the future earth observation mission of ESA and JAXA. The satellite will carry four instruments for observation of clouds and aerosols; Atmospheric Lidar (ATLID), Cloud Profiling Rader (CPR), Multi-Spectral Imager (MSI), and Broad-Band Radiometer (BBR). This mission aims at understanding of the role that clouds and aerosols play in reflecting incident solar radiation back into space and trapping infrared radiation emitted from Earth's surface. These observations are needed to improve the precision of climate variability prediction.

MSI provides across-track information on cloud with channels in the visible, near infrared, shortwave and thermal infrared. Water cloud optical properties are derived in using EarthCARE/MSI standard product based on CLAUDIA [Ishida and Nakajima, 2009] and CAPCOM [Nakajima and Nakajima, 1995; Kawamoto et al., 2001]. Research product based on MWP method [M. Hashimoto, 2015. PhD Thesis] is advanced to obtain the ice cloud optical properties. In this presentation, development of the cloud analysis algorithms and the results will be introduced.

Introduction

Cirrus clouds play an important role in the energy budget of the Earth-atmosphere system by their effects on the transfer of radiative energy through the atmosphere. Low clouds have a cooling effect on solar radiation by scattering. On the other hand, the high thin cirrus clouds scatter a small amount of solar radiation and absorb a large quantity of outgoing long-wave radiation from the Earth and its atmosphere. The overall effect of the high thin cirrus clouds is heating on the Earth-atmosphere system.

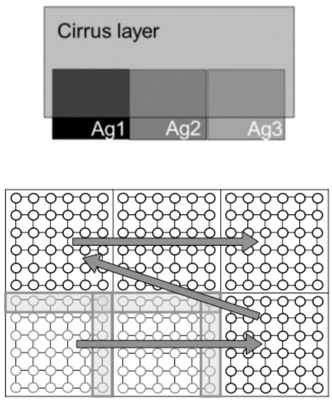
Cirrus clouds are prominent and yet uncertain components in weather and climate studies because of high location and composed of almost exclusively nonspherical ice crystal of various shapes, such as bullet rosetts, plates, and columns. Progress in numerical model of climate change prediction require improved representations of cloud processes and decreased uncertainties in parameterizations of cloud radiation interactions. Cloud parameterizations in numerical climate models need to define the temporal and spatial distributions of high cloud optical properties.

EarthCARE (Earth Clouds, Aerosols and Radiation Explorer) is one of the future Earth observation joint mission of Japanese (JAXA) - European (ESA). EarthCARE satellite aims at understanding of the role that clouds and aerosols play in reflecting incident solar radiation back into space and trapping infrared radiation emitted from the surface in order to improve the numerical climate prediction models. The satellite payload is composed of four instruments; an Atmospheric backscatter Lidar (ATLID), a Cloud Profiling Rader (CPR), a Multi-Spectral Imager (MSI), and a Broad-Band Radiometer (BBR). The EarthCARE orbit is sun-synchronous with an altitude of around 393 km and 14:00 mean local time of the descending node. The MSI will provide Earth images over a swarth width of 150 km with a spatial resolution of 500×500 m in 7 spectral bands; one visible (0.67 um), one near infrared (0.865 um) and two shortwave infrared (1.65, 2.21 um) channels capturing reflected solar right on the day-side of the orbit, and three thermal infrared (8.80 10.80, 12.00 um) channels measuring the emitted thermal radiation from the Earth.

We develop an algorithm to derive cirrus clouds optical properties from MSI Level 2 radiance data as a research product of EarthCARE project. In this study, we modified MWP (Multi-wavelength and multi-pixel) method [M. Hashimoto et al., in revision] to derive cirrus clouds optical properties and operation tests of modified algorithm were performed in using MODIS/Aqua radiance data for the first time.

Algorithm

In this section, we overview the MWP (Multi-wavelength and multi-pixel) method. The method has been described in detail in M. Hashimoto et al. (in revision). Figs.1 and Fig.2 show the concept of the algorithm and the analysis flow. Supposing Cirrus Optical Thickness (COT) and other cirrus properties do not change in horizontal direction, we can find an optimal set of cirrus parameters, such as COT and SSA (Single scattering albedo), and ground albedo Ag, by solving a set of Radiative Transfer Equations (RTEs) for pixels composing the target area with various ground albedo.



Figs.1 Schematic illustration of the multi-wavelength and multi-pixel method. (Top) Satellite-received radiances for smoothly distributed cirrus layer above earth's surfaces of various albedos. (Bottom) Illustration of retrieval sequence. The total region is divided into sub-domains for simultaneous inversion consisting of multiple pixels, i.e. 5×5 pixels in the present study. Small circles show observation pixels; grey circles indicate pixels under analysis. The shaded area represents the boundary with neighboring sub-domains. The arrow represents the order of analysis.

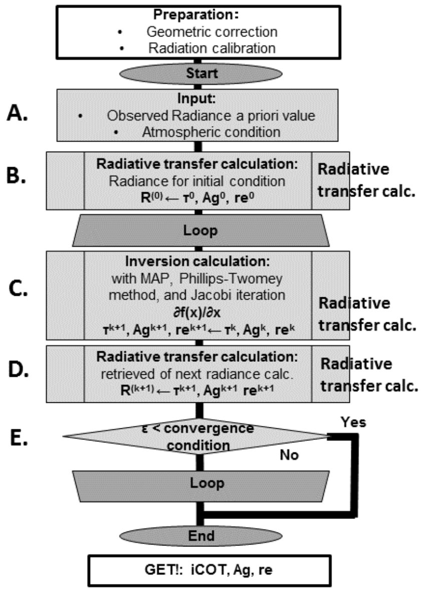


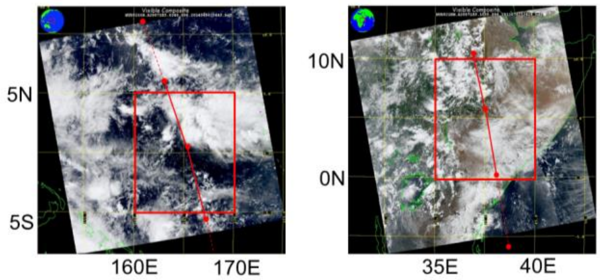
Fig.2 Flow chart of the analysis procedure of the MWP method.

Application of the MWP method

MWP method has been originally developed to derive aerosol optical properties and described in detail in M. Hashimoto et al. (in revision). In this study, we applied MWP method to MODIS/Aqua radiance data for retrieving cirrus clouds optical properties over ocean and surface regions for the first time.

MODIS (MODerate resolution Imaging Spectroradiometer) is the instrument on NASA's Earth Observing System (EOS) Terra and Aqua spacecraft. Aqua spacecraft was launched on May 4, 2002. MODIS has a viewing swarth of 2330 km and provides almost complete global coverage within one to two days. MODIS has 36 channels in the spectral region between 0.415 and 14.235 um with spatial resolution of 250 m (2 bands), 500 m (5 bands), and 1000 m (29 bands). The 250 m bands are centered at 0.65 and 0.86 um. The 500 m bands are centered at 0.47, 0.56, 1.24, 1.63, and 2.13 um.

We selected 2 cirrus regions as shown in Figs.3. The left panel of Fig.3 is MODIS/Aqua RGB image acquired over East coast of Papua New Guinea (-5-5N, 160-170E) at 2:40 UTC on July 2, 2007. The right panel of Fig.3 is RGB image acquired over Ethiopia (0-10N, 35-45E) at 10:55 UTC on July 2, 2007.



Figs.3 (Left, Area1) MODIS/Aqua RGB image acquired over East coast of Papua New Guinea (-5-5N, 160-170E) at 2:40 UTC on June 2, 2007. (Right, Area2) RGB image acquired over Ethiopia (0-10N, 35-45E) at 10:55 UTC on July 2, 2007. The red outlines indicate the regions of optical thickness retrieval with MWP method in this study.

We applied MWP method [M. Hashimoto et al., in revision] to MODIS/Aqua radiance data for retrieving cirrus clouds optical properties in several ocean regions. The red outlines indicate the regions of optical thickness retrieval with MWP method in this study (Area1 and 2).

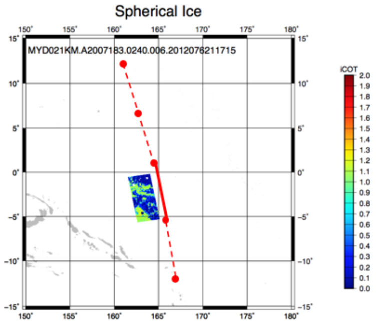


Fig4. Horizontal distribution of retrieved COT in Area1.

Fig.4 show the example of horizontal distributions of retrieved COT in Area 1. As shown in Fig4, the distributions of COT in Area1 are spatially smooth over the ocean regions. Averaged COT are about 0.7.