Improvement of low-level cloud parameterization in climate model (Abstract of the Final Report)

Contact person Toshiro Inoue
Head of Forth Research Laboratory
Satellite Meteorology and Observation System Research Department
Meteorological Research Institute
Nagamine 1-1, Tsukuba, Ibaraki, 305-0052 Japan
Tel:+81-298-853-8507 Fax:+81-298-856-0644
E-mail:tinoue@mr-jma.go.jp

Total Budget for FY2004-FY2006 37,574,000Yen (**FY2006**; 11,277,000Yen)

Key Words Boundary layer cloud, Parameterization, Climate Model, Cloud Climatology, Satellite data analysis

1. Introduction

It has been recognized that cloud feedback on climate sensitivity is the largest internal source of uncertainty in climate change prediction. Current version of climate models indicates the climate sensitivity from 1.5K to 5K in a CO_2 doubling simulation. The model, which shows the larger climate sensitivity, indicates large decrease of low-level cloud cover in subtropical area. While, the model which shows lower climate sensitivity indicates the increase of low-level cloud cover in subtropical area. This suggests the improvement of low-level cloud parameterization in climate model is essential to climate change prediction. There are a variety of cloud processes that affect the large-scale behavior of climate system. However, the scale of processes is too small to represent explicitly in climate model grid. The parameterization to represent the cloud processes is one of the issues among the scientists. The GEWEX Cloud System Study (GCSS) encourages the development of the parameterization schemes of low-level boundary layer cloud, cirrus, extra tropical cloud, deep convection and Polar cloud. The priority of the improvement of low-level boundary layer cloud is still very high.

2. Research Objective and Method

In this study, we aim to improve the low-level cloud parameterization in climate model. We first analyze the cloud parameters (cloud cover, cloud height, optical thickness, effective radius of cloud particle etc) of low-level cloud from satellite observations. The cloud parameters are compared with the coincident radiosonde observations to evaluate the correlation of meteorological parameters with low-level cloud parameters. Using the appropriate parameters, we improve and develop the parameterization scheme for low-level cloud in the climate model. The performance of the new parameterization scheme is validated by the current cloud climatology.

In this study the better analysis of low-level cloud parameters is essential. We aim to improve and develop the cloud analysis method using the multi-channel data of meteorological satellite. Then we analyze the variation of cloud parameters in terms of meteorological elements which governs the formation and maintenance of low-level cloud.

Meteorological elements from radiosonde and satellite retrievals such as microwave radiometers are also used to analyze the variation of cloud parameters. Based on the improved understanding of low-level cloud behavior in terms of meteorological elements, we develop and improve the parameterization scheme to express the low-level cloud parameters using several proper meteorological elements.

3. Results

A simple scheme to represent the low level marine stratocumulus clouds off the west coast of continents is developed and implemented in the climate model. The parameterization is based on diagnostic cloud schemes where cloud fraction is diagnosed mainly as a function of inversion strength considering other parameters. The following three conditions are set for forming the low level clouds. 1) Strong inversion exists (stability is greater than0.07). 2) Stability is less than 0.01 at near surface. 3) The height of clouds is below 940 hPa.

Experiments using the parameterization show that the global distribution of marine stratocumulus clouds off the west coast of continents is improved remarkably with this new scheme. Low-level cloud amount shows reasonable agreement with the International Satellite Cloud Climatology (ISCCP) (Fig.1). With the improved cloud amount, the radiation fields are also improved in comparison with Earth Radiation Budget Experiment (ERBE). Seasonal and diurnal variations of marine stratocumulus cloud amount off the west coast of continents also show reasonable agreement with surface-based cloud amount data from Klein and Hartmann (1993) and satellite observations.

The parameterization is partly based on the radiosonde observations at Pt Reyes, California, and cloud analysis from geostationary satellite (GOES) during June – August, 2005. When the low level cloud exists at Pt. Reyes, the stability is higher stability, relative humidity is higher and the stability at near surface is rather weak or unstable. The strong inversion layer exists at the level of 940-950 hPa. Optically thicker (thinner) cloud corresponds to the stronger (weaker) stability and thicker layer of higher (lower) relative humidity.

The parameterization is improved using the vertically 60 levels layer model. The relative humidity greater than 80% is added for low level cloud formation conditions. Another condition is that the vertical diffusion coefficient is not smoothed when the strong inversion exists below 910 hPa. Using this parameterization, the gradual increase of low level cloud top is simulated along the west coast of California to near Hawaii (Fig. 2)

Our parameterization is implemented in the forecast model for the re-analysis. The performance of representation of low-level cloud is compared with the re-analysis of ECMWF (ERA40) and US Forecast Center (NCEP). The representation of low-level cloud by JRA25 is better than other re-analysis for off the west coast of continents (Table 1). We studied the low-level cloud amount in the CO_2 doubling climate situation. The difference between current climate and CO_2 doubled climate is not so large. However, the low-level cloud amount increases off the west coast of continents except California and near Hawaii and Indian Ocean (Fig. 3).

We develop the method to retrieve both optical thickness and effective particle radius from the split window data for low-level water cloud which is classified by the 11 μm and 8.7 μm data. The method utilizes the differential absorption by water between the split window. Brightness temperature and brightness temperature difference between the split window for various optical thickness and effective radius of water cloud (Fig.4). Comparison between the new method and solar reflection method shows reasonable agreement. The method can be used for both day and night in equal quality, although current solar reflection method can be used only for daytime analysis.

Reference

Klein, S. A. and D. L. Hartmann, 1993: The seasonal cycle of low clouds., J. Climate, 6, 1587-1606.

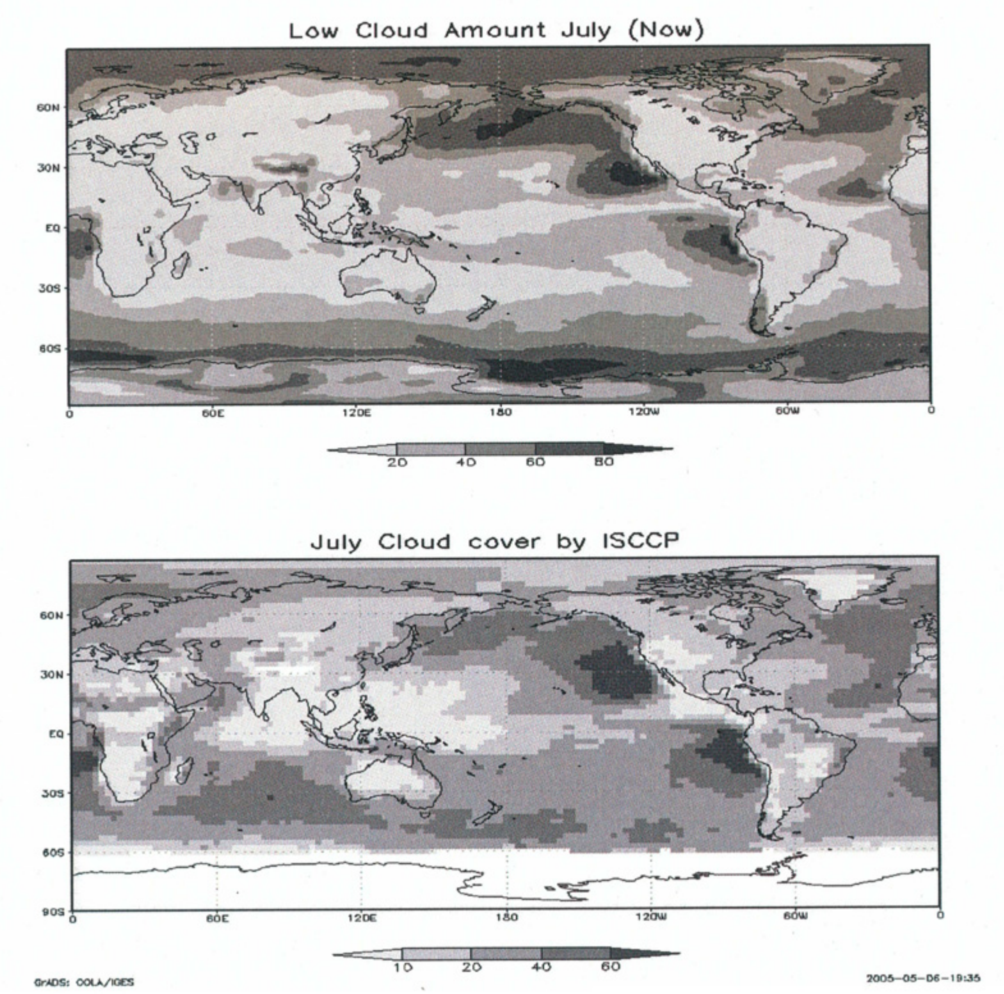

Figure 1 Low-level cloud amount of July represented by our parameterization (top) and low-level cloud amount constructed from satellite data in International Satellite Cloud Climatology Project (bottom).

Table 1 Mean and rms error in parencis of low-level cloud amount represented by JRA25, ERA40 and NCEP over off California, off Peru and off Namibia.

	ISCCP	JRA25	ERA40	NCEP40
Off California	72.3%	82.6%(13.6%)	62.0%(12.4%)	67.6%(9.2%)
Off Peru	70.1%	62.6%(15.4%)	56.3%(17.3%)	45.2%(28.4%)
Off Namibia	69.8%	56.0%(15.5%)	45.5%(25.2%)	40.6%(30.5%)

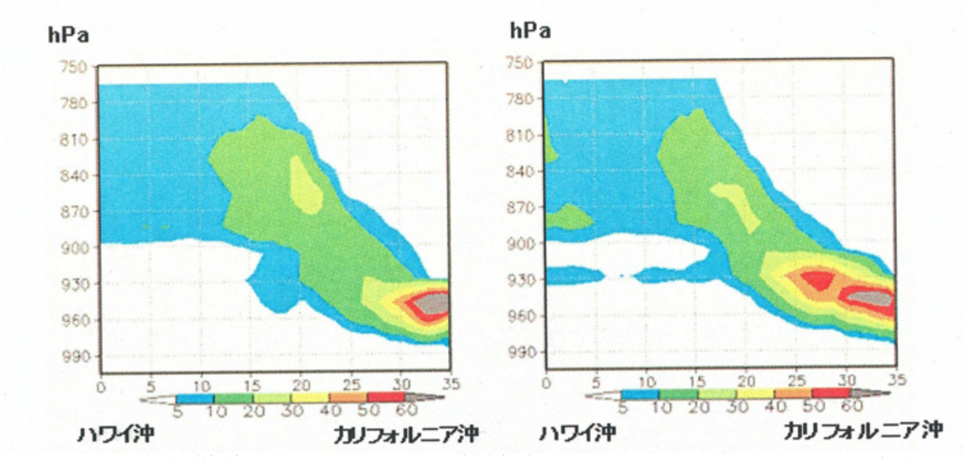

Figure 2 Vertical cross section of cloud over from California and Hawaii represented by version-1 parameterization (left) and version-2 parameterization(right).

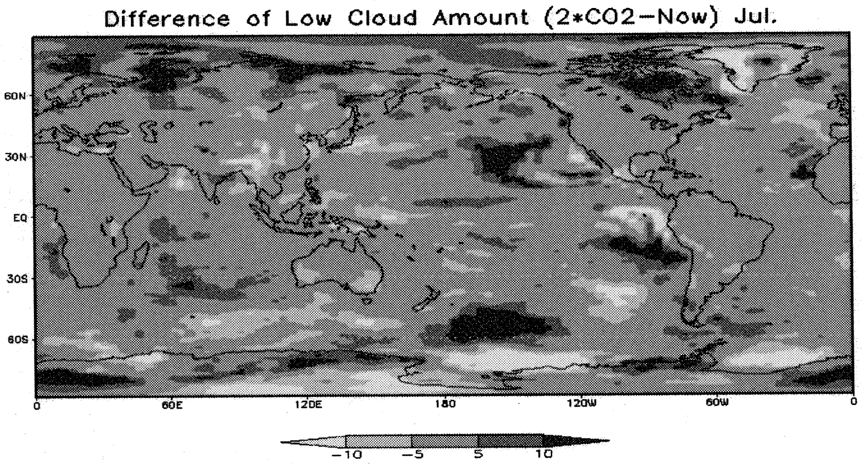

Figure 3 Difference of low-level cloud amount simulated by our parameterization between current climate and CO_2 doubled climate.

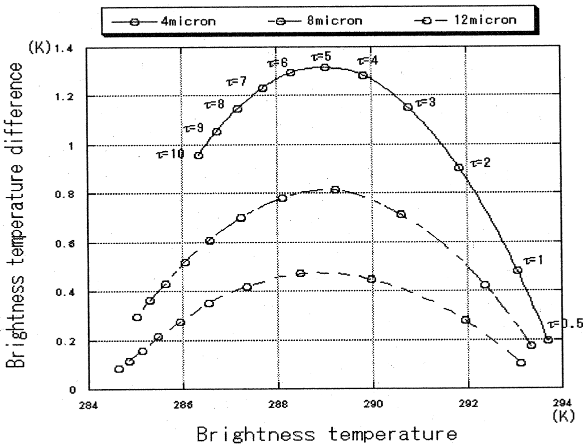

Figure 4 Relationship between brightness temperature and brightness temperature difference between the split window for various optical thickness and effective radius of water cloud.