The Evaluation of the Vertical Structures of Marine Boundary Layer Clouds over Mid-Latitudes

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1. Introduction

Mid-latitude marine low clouds are not adequately represented in the operational global model of the Japan Meteorological Agency (JMA); i.e., the GSM (Global Spectral Model). In order to understand the faults in the physical processes related to the mid-latitude marine low clouds in the models, the characteristics of such clouds in the model should be evaluated in detail from many perspectives using observational data. Here, we examine the vertical structures of such clouds using cloud mask data, which were retrieved from CloudSat and CALIPSO.

The structures of mid-latitude marine low clouds have not been investigated as intensively as have subtropical ones. One of the reasons is that evaluation for mid-latitude low clouds is more difficult than that for subtropical low clouds because high or middle clouds often prevail in the mid-latitudes. Moreover, comparison of low clouds represented in GCMs with those from observational data is complicated by the need for an overlap assumption. Therefore, the influence of upper-level clouds is minimized by considering only the low cloud top area, and the impact of the overlap assumptions on the evaluation is also examined, in this study.

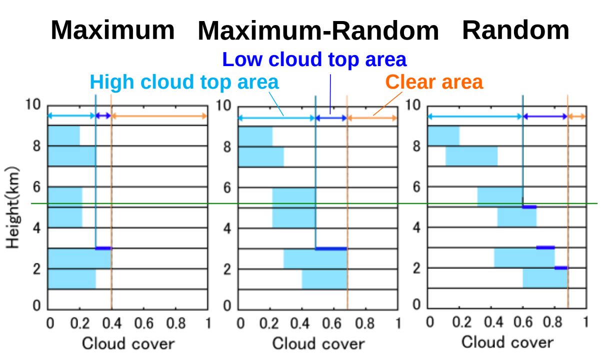

Fig. 1: Schematic diagrams showing three cloud overlap assumptions tested in this study (left: maximum overlap, middle: maximum-random overlap, right: random overlap), which are modified from Hogan and Illingworth (2000). The light blue double-headed arrows correspond to high cloud top area, blue to low cloud top area, and orange to clear area.

2. Data and the Processing

2.1. Observation data

The Kyusyu University cloud mask data (Hagihara et al. 2010), which were retrieved from CloudSat and CALIPSO and have a vertical resolution of 240 m and a horizontal resolution of 1.1 km, were used in the comparison ("CloudSat or CALIPSO mask (C4) data" were used). The data were excluded from the statistical analysis if there were clouds present above 5 km, because the target of this study is low clouds not covered by upper-level clouds (higher than 5 km), which are important for global radiation budget.

2.2. Model data

The original vertical level data (TL159L60) from the simulation using the model are used for the comparison. Three different assumptions related to cloud overlap (Fig. 1) are tested (note that the maximum-random overlap is used in the radiation process in the JMA-GSM). The occurrence frequency of cloud top height (CTH) is normalized by the low (lower than 500 hPa) cloud top area (blue arrow areas in Fig. 1). CTH data in model grids with no or little upper-level cloud cover (higher than 500 hPa) are selected and used.

3. Results

Figure 2 shows the results of the comparison. The characteristics of the CTH in the mid-latitudes from the observations are presented and discussed in detail in Kawai et al. (2014), and we briefly summarize the results of the comparison between the observations and the model in this report.

Over the North Pacific, the observed CTH is remarkably high (ca. 2 km) in winter and clearly low (ca. 500 m) in summer around 40°–55°N. The amplitude of the seasonal variation simulated by the model is smaller than that observed. In particular, the CTH in winter is much lower in the model than that observed.

Over the Southern Ocean, the observed CTH is higher in winter around 40°–55°S than in summer. Although the model represents this seasonal variation to some extent, CTH in the model is lower than that observed. The southward increase in CTH is found in summer in the observations but is not clear in the model, although the model captures low CTH around

40°–45°S. In winter, the lower CTH observed around 60°–65°S, possibly corresponding to the area of sea ice, is qualitatively represented in the model.

Figure 2 also shows that the difference in CTH distribution among different overlap assumptions is smaller than the systematic differences between the model and observations. The maximum overlap and the maximum-random overlap assumptions provide similar results. The random overlap assumption gives a wider distribution of CTH compared with the other assumptions.

Mid-latitude marine low clouds in the model capture the characteristics of CTH in nature to some extent. However, the comparison of the model with observations shows several significant differences, and the comparison result could help us to improve the parameterization and representation of clouds in the model.

Acknowledgements

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References

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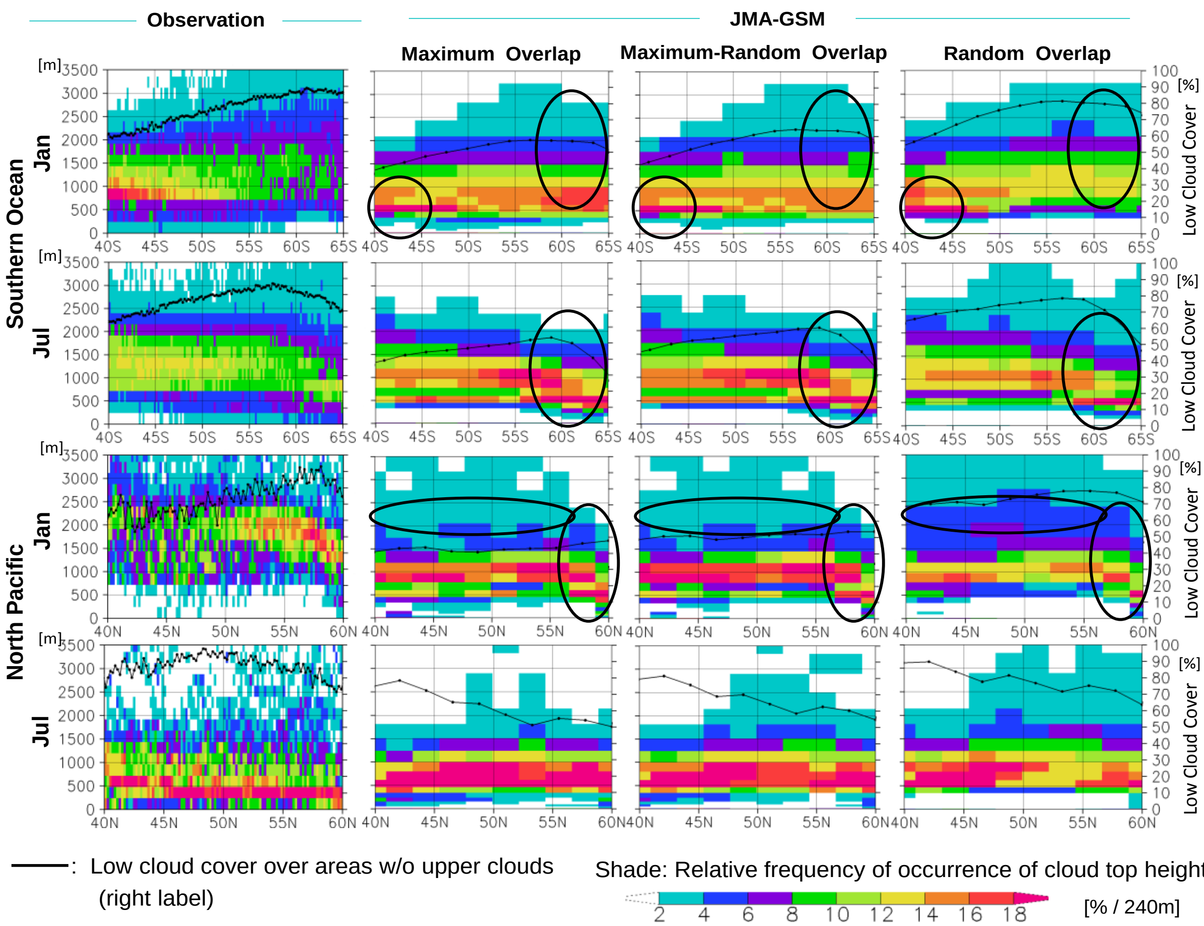

Fig. 2: Relative frequency of occurrence of cloud top height (CTH), which is normalized by the low cloud top area and the 240 m vertical bin, from observational data (left) and from simulations by the JMA-GSM (others). Three different overlap assumptions are used (second from left: maximum overlap, third from left: maximum-random overlap, fourth from left: random overlap). Black lines show low cloud cover over areas with no upper-level clouds. Three-year climatologies for January and July over the Southern Ocean (0°−360°) and over the North Pacific (165°E−165°W) are shown.