

A Numerical Study on the Diurnal Variation of Precipitation Bands Observed around the West Coast of Sumatra Island

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It is known that the diurnal cycles of precipitation near the Maritime continents have different features between the land and the ocean. One example is near the west coast of Sumatra, Indonesia. After taking the precipitation maximum in the afternoon, the precipitating region keeps moving toward offshore during the nighttime. Although several mechanisms have been proposed about this phenomenon, their validities have not been evaluated sufficiently yet.

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) had conducted an intensive observation campaign around the west coast of Sumatra from December 2017 to January 2018. This campaign was operated as a part of the Year of the Maritime Continents (YMC) international campaign from July 2017 to February 2020. Prior to the YMC, JAMSTEC also operated a preliminary observation campaign called as Pre-YMC almost in the same geological region as YMC from November to December 2015. In both campaigns, the diurnal cycle of the precipitation was observed, but the observed features were different. While the system developed in most of the days in the first half of the Pre-YMC period, it developed only in some limited days in the YMC.

In this study, we examine the diurnal cycle of the precipitation during the Pre-YMC period. To investigate the mechanism of the offshore propagation of the precipitation, numerical simulations through the Pre-YMC period have been performed a cloud-resolving model, Scalable Computing for Advanced Library and Environment (SCALE). Several sensitivity experiments have also been conducted. The domain-mean fields of zonal wind and relative humidity reasonably followed the time evolution of the large-scale environment. But, in some days, the behaviors of the diurnal cycle of the precipitation system in the observation and the simulation was different.

The sensitivity experiments were conducted in terms of the cloud- radiation interaction, the difference in the cloud microphysics schemes, and the impacts of the large-scale horizontal wind. An interesting result was found when the standard 6-class 1-moment cloud microphysics scheme of SCALE was replaced with the 3-class 1-moment bulk method, which did not represent ice microphysics. Thick clouds prevailed widely in the upper troposphere, and precipitation occurred almost only over the ocean region. The precipitation propagation did not occur. When the clouds were made transparent, being combined with the same 3-class microphysics schemes to both the shortwave and longwave radiations, the precipitation propagation recovered. The result denies the importance of the cloud-radiative interaction as the mechanism of the precipitation propagation. Besides, the heating of the land surface by the shortwave radiation is thought to be essential as the trigger of the precipitation propagation. In the sensitivity experiments that enhanced background westerly winds, the precipitation propagation still occurred, but the frequency of occurrence was reduced, compared to the control experiment. This result indicates that the large-scale westerly makes it difficult for the precipitation propagation to occur. In contrast, under the easterly-enhanced condition, the frequency of the precipitation propagation was raised, showing that the easterly background is favorable for the propagating system.

We also investigate the reasons why the actual observed propagation systems were not reproduced in the simulation on some days. When ERA5 was used for the initial and boundary conditions in place of NCEP-FNL, the improvements of the reproducibility were obvious. In another experiment, the precipitation system could be reproduced well if the simulation period was less than 24 hours. These results commonly indicate that the dry bias, which developed within a day in the SCALE model, set up unfavorable conditions for the occurrence of the propagation events.

Keywords: Diurnal cycle, Precipitation system, Simulation, Pre-YMC