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Numerical Simulations of Clouds and Storms Using the Cloud-Resolving Model

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High-impact weather systems are most significant phenomena in the atmosphere and sometimes cause huge disasters to the human society. Understanding their mechanisms and structures is necessary for prediction and prevention/reduction of disasters. Most high-impact weather systems that cause heavy rainfalls and/or violent winds consist of cumulonimbus clouds and their organized systems. They are usually embedded within a larger weather system and occasionally have a multi-scale structure. It ranges from the cloud-scale to the synoptic-scale.

In order to perform simulations and numerical experiments of high-impact weather systems, we have been developing a cloud-resolving numerical model named ``the Cloud Resolving Storm Simulator" (CReSS). Since the multi-scale structure of the weather systems has wide range in horizontal scale, a large computational domain and a very high-resolution grid to resolve individual classes of the multi-scale structure are necessary to simulate evolution of the weather systems. In particular, an explicit calculation of cumulonimbus clouds is essentially important for a quantitative simulation of precipitation associated with the high-impact weather. It is also required to formulate accurately cloud physical processes as well as the fluid dynamic and thermodynamic processes. For this type of computation, large parallel computing with a huge memory is necessary.

The CReSS model has been optimized for the Earth Simulator and its performance was evaluated as sufficiently high. Using CReSS on the Earth Simulator, we performed high-resolution simulations of high-impact weather systems: the localized heavy rainfalls in Kyushu in 2003 and in Niigata area in 2004, typhoons of T0418 and T0423, and snowstorms in cold polar air streams. These results show that both detailed structures of individual convective clouds and overall structures of storm systems are successfully simulated using CReSS on the Earth Simulator. These experiments will contribute for accurate and quantitative prediction of high-impact weather systems and disaster prevention/reduction.

In the present paper, we will describe the basic formulation and characteristics of CReSS and summarize some results of the simulation experiments of high-impact weather systems such as localized heavy rainfalls associated with the Baiu front, typhoons, and snowstorms.

Keywords: Clouds, Storms, Cloud-Resolving Model, Heavy rainfall, High-impact weather