# Response of squall-line to tracer advection scheme

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## 1. Introduction

The influence of advection schemes on the atmospheric dynamics has been pointed out in several past studies, e.g., Peng et al. (2005), Schroeder et al. (2006). These studies noted that results of simulated flow fields are improved using appropriate advection schemes. It is considered that same improvement is expected for deep convection involving cloud microphysics. In the present study, response of deep convection to tracer advection scheme is focused on using two- and three-dimensional (2D and 3D) squall-line experiments, and the appropriate schemes for the cloud-resolving model (CRM) will be proposed.

## 2. Model descriptions and experimental setup

Dynamical core of MSSG (Multi-Scale Simulator for the Geo-environment) model which has been developed in the Earth Simulator Center (Baba et al. (2010)) is used. Simple three-class cloud microphysical scheme (Grabowski (1998)) is applied. Employed tracer advection schemes are finite difference (FDM), semi-Lagrange (CIP, Yabe et al. (2001)), upwind (WS3, WS5, Wicker and Skamarock (2002)) and TVD schemes (WAF, Toro (1989), ENO2, ENO3, Shu and Oshert (1989)). Both 2D and 3D squall-line experiments (Redelsperger et al. (2000)) are performed.

## 3. Results and discussions

General features of our model are first validated by comparing the results with the original experiments. Time variations of vertical wind speed of both 2D and 3D cases are reasonably well simulated. Statistics of the 2D cases show that finite difference and $5^{th}$-order upwind scheme tend to overestimate rainfall compared to other schemes. This effect is caused by the overshoot appearing in the computing vertical advection. On the other hand, TVD schemes are found to suppress the overestimation.

Effect of lateral advection is examined on the 3D cases. In the 3D cases, TVD schemes cannot reproduce the squall-line. The cause of failure in simulating squall-line is investigated by analyzing both lateral and vertical structures, and it is found that the TVD scheme diminishes small front structure of the squall-line, whereas $3^{rd}$-order high-order upwind scheme can reproduce it. The result means that lateral TVD scheme should not be applied to CRM.

In conclusion, TVD scheme is found to be useful for suppressing overshoot in vertical direction, on the other hand, 3rd-order upwind scheme acts well to capture lateral small structure. The combination scheme consisting of vertical TVD, lateral upwind scheme is the best scheme for simulating deep convection with organized structure which is observed in squall-line.

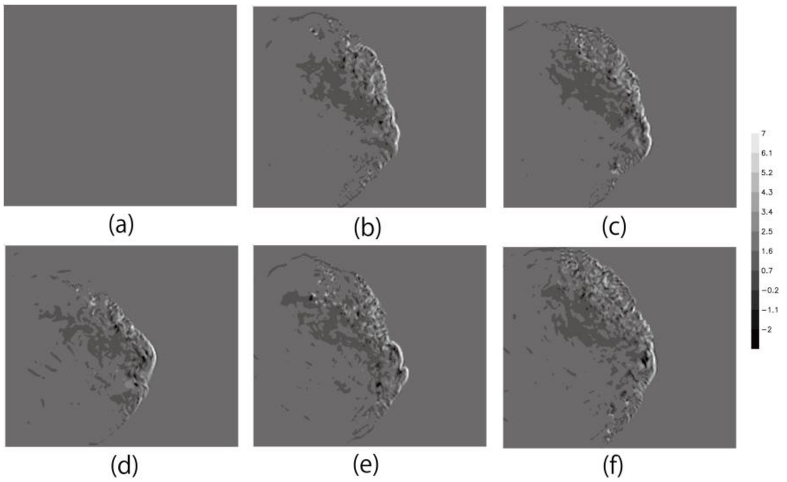


Figure 1: Instantaneous horizontal distributions of vertical wind speed of squall-lines at 7 hours and 700 m height. (a) ENO3-ENO3, (b) WS3-ENO2, (c) WS3-ENO3, (d) WS3-WAF2, (e) WS3-WS3, (f) WS5-WS3.

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