Sensitivity of Simulated Oceanic Convection to Microphysics Parameterization

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ABSTRACT

This study investigates the kinematic and microphysics characteristics of oceanic convection initiated by a Mei-Yu front on 15 May 1998 during the South China Sea Monsoon Experiment (SCSMEX), using the Penn State/NCAR mesoscale model (MM5) on a triply nested grid. A Grell cumulus parameterization scheme and an explicit microphysics scheme were used simultaneously to simulate the evolution of the Mei-Yu front on the coarse (with a grid size of 45 km) and intermediate (with a grid size of 15 km) domains. The intense oceanic convection over the northern South China Sea is explicitly resolved over the inner domain (with a grid size of 5 km) using the Goddard microphysics scheme containing prognostic equations for cloud water, cloud ice, rainwater, snow and graupel. As verified against satellite observation, the model captures reasonably well the evolution of the Mei-Yu frontal convection. Of particular significance is that both shear-parallel and shear-perpendicular rainbands were simulated, in agreement with radar observation. The microphysics sensitivity experiment shows that different microphysics schemes do not have a significant impact on the 45-km and 15-km grids. However, on the 5-km grid, detailed microphysics parameterization schemes clearly affect the distribution and amount of simulated rainfall, the strength and depth of cold pool, and the moving speed of gust front.

1. Introduction

Oceanic convection is recognized as one of the most difficult parameters to forecast in numerical weather prediction. Difficulties of oceanic convection prediction exist in at least three areas. First, our understanding of oceanic convection is still quite limited. Second, data deficiencies in open ocean often limit the accuracy of a model's initial conditions. The third is the representation of physical processes which are responsible for oceanic convection in a numerical model.

Kuo et al. (1996) assessed the performance of various subgrid-scale cumulus schemes and resolvable-scale microphysics schemes in the simulation of an explosive oceanic cyclone, using the Penn State/NCAR mesoscale model MM5. Yang et al. (2000) performed similar precipitation parameterization comparison for a Mei-Yu front. However, a systematic evaluation of the microphysics schemes in the simulation of *oceanic convection* triggered by a Mei-Yu frontal system has been rarely in the literature. In this study, we conduct a series of numerical simulations of the oceanic convection triggered by a Mei-Yu front on 15 May 1998 during the South China Sea Monsoon Experiment (SCSMEX), using the Penn State/NCAR nonhydrostatic mesoscale model MM5 at a triply nested grid (with grid sizes of 45 km, 15 km, and 5 km, respectively). Our objective is to access the performance of various explicit-scale microphysics schemes in the simulation of oceanic convection over the northern South China Sea. We are particularly interested in understanding how different microphysics schemes affect the oceanic convection development, the precipitation organization and evolution, and the resulting mesoscale structures.

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2. Model and experiment design

The numerical model used in this study is the Penn State/NCAR non-hydrostatic model MM5 (Grell et al. 1994) Version 2.11. The MM5 is a three-dimensional, limited-area, primitive-equation, nested-grid model with a terrain following σ (non-dimensional pressure) vertical coordinate. The physical parameterization of the model includes the Blackadar planetary boundary layer scheme with surface energy flux and friction (Blackadar 1974), the short-wave and long-wave radiation scheme with the interaction between clear sky and clouds, the grid-scale microphysics scheme, and the subgrid-scale cumulus parameterization. The model configuration includes a coarse mesh of 45-km grid size, an intermediate mesh of 15-km grid size, and a fine mesh of 5-km grid size. Domain size for each mesh is 81×71 for coarse mesh, 91×91 for intermediate mesh, and 100×109 for fine mesh. There are 27 σ levels in the vertical (surface pressure level to 50 mb). MM5 model is initialized at 1200 UTC 14 May 1998 and the forecast length for each MM5 run is 36 hours (i.e., simulation ends at 0000 UTC 16 May 1998). The initial condition is provided by the analysis field of the Central Weather Bureau Global Forecast System (CWBGFS; Liu et al. 1997), and the boundary condition is provided by the CWBGFS forecast field. Surface observation and sounding data are included through objective analysis to improve the initial condition field. The sea surface temperature (SST) field is provided by CWBGFS analysis, and is held constant throughout the simulations.

Table 1 lists the numerical experiments conducted in this study. The sensitivity experiment includes microphysics schemes of Warm Rain (Hsie et al. 1984), Simple Ice (Dudhia 1989), Mixed Phase (Reisner et al. 1993), and Goddard Graupel (Tao and Simpson 1993). In this sensitivity experiments, Grell (1993) cumulus scheme is used for cumulus parameterization on both 45-km and 15-km grids, and no cumulus scheme is used on the 5-km grid.

3. Results and discussion

Comparing the 6-h accumulated rainfall on the 45-km grid with satellite imaginary (not shown), it is clear that the MM5 model can simulate the development of Mei-Yu front reasonably well. The predicted Mei-Yu frontal rainfall *distribution* and *amount* by each microphysics experiment is very similar on the 45-km and 15-km grids, in agreement with Yang et al. (2000).

Figure 1 shows the simulated near-surface (40-m above sea level) radar reflectivity of the SI (Simple Ice) experiment at 20-h forecast time (valid at 0800 UTC 15 May 1998), and Figure 2 is the corresponding observed low-level (elevation angle of 0.5 degree) radar reflectivity of the BMRC/C-Pol. radar at 0759 UTC 15 May 1998. Comparing Fig. 1 and Fig. 2, it is evident that the oceanic convection triggered by the synoptic-scale Mei-Yu front is simulated quite well, although the simulated Mei-Yu front moves slightly faster than the observed front. The broad precipitation behind the frontal boundary is well simulated by the model. On the other hand, the radar observation indicates less precipitation produced by the convergence line between the cold air outflow and southwesterly than the model did.

Both observation (Fig. 2) and simulation (Fig. 1) show the shear-parallel (in northeast-southwest direction) and shear-perpendicular (in northwest-southeast direction) raindbands along the convergence line, similar to those discussed by LeMone et al. (1998). Work is in progress to investigate and understand the mechanism for the development of shear-parallel and shear-perpendicular convection.

Figure 3 shows the simulated near-surface (40-m above sea level) radar reflectivity field on the 5-km grid for each microphysics experiment at 18-h forecast time (valid at 06 UTC 15 May 1998). It is clear from Fig. 3 that on the inner 5-km grid, the microphysics scheme used in the model clearly affect the distribution and intensity of simulated precipitation (in terms of radar reflectivity) and the resulting convection organization.

A vertical cross section across the convergence line (not shown) illustrates that the microphysics parameterization employed in the model significantly affect the strength and depth of simulated cold pool. In particular, the GG (Goddard Graupel) experiment has the deepest and strongest cold pool, and the WR (Warm Rain) experiment has the most shallow and weakest cold pool. Therefore (also confirmed by the model animation), the GG experiment has the fastest-moving gust front associated with the convergence line, and the gust front of the WR experiment has the slowest moving speed.

More work is in progress to verify the simulation result with observation. In addition, sensitivity of simulation results to the boundary layer parameterization is undertaken to understand the impact of oceanic fluxes on the convection and precipitation structures.

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Table 1: Summary of numerical experiments.

Name	Cumulus parameterization	Microphysics parameterization
WR	Grell	Warm Rain
SI	Grell	Simple Ice
MP	Grell	Mixed Phase
GG	Grell	Goddarrd Graupel

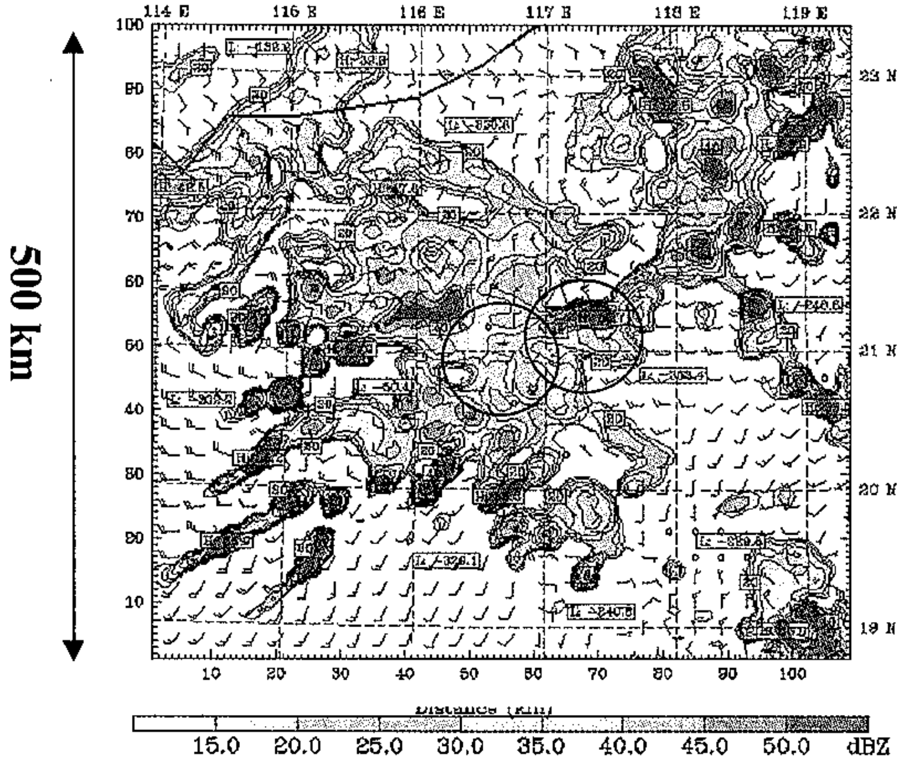

Figure 1: Simulated near-surface (40-m above sea level) radar reflectivity (in dBZ) of the SI (Simple Ice) experiment on 5-km grid at 20-h forecast time (valid at 0800 UTC 15 May 1998). Radar range of BMRC/C-Pol. radar and NASA TOGA radar are also indicated.

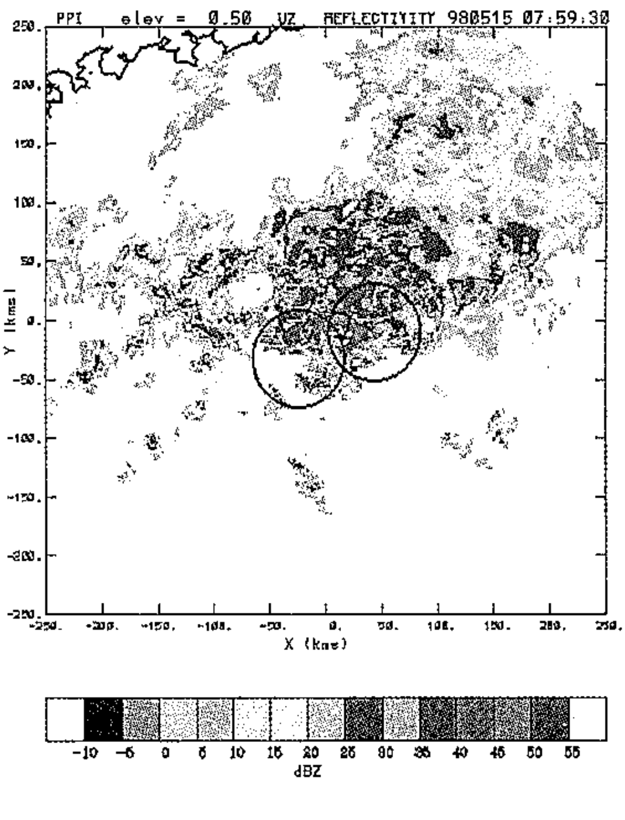

Figure 2: Observed low-level (elevation angle of 0.5 degree) radar reflectivity (in units of dBZ) by the BMRC/C-Pol. radar at 0759 UTC 15 May 1998.

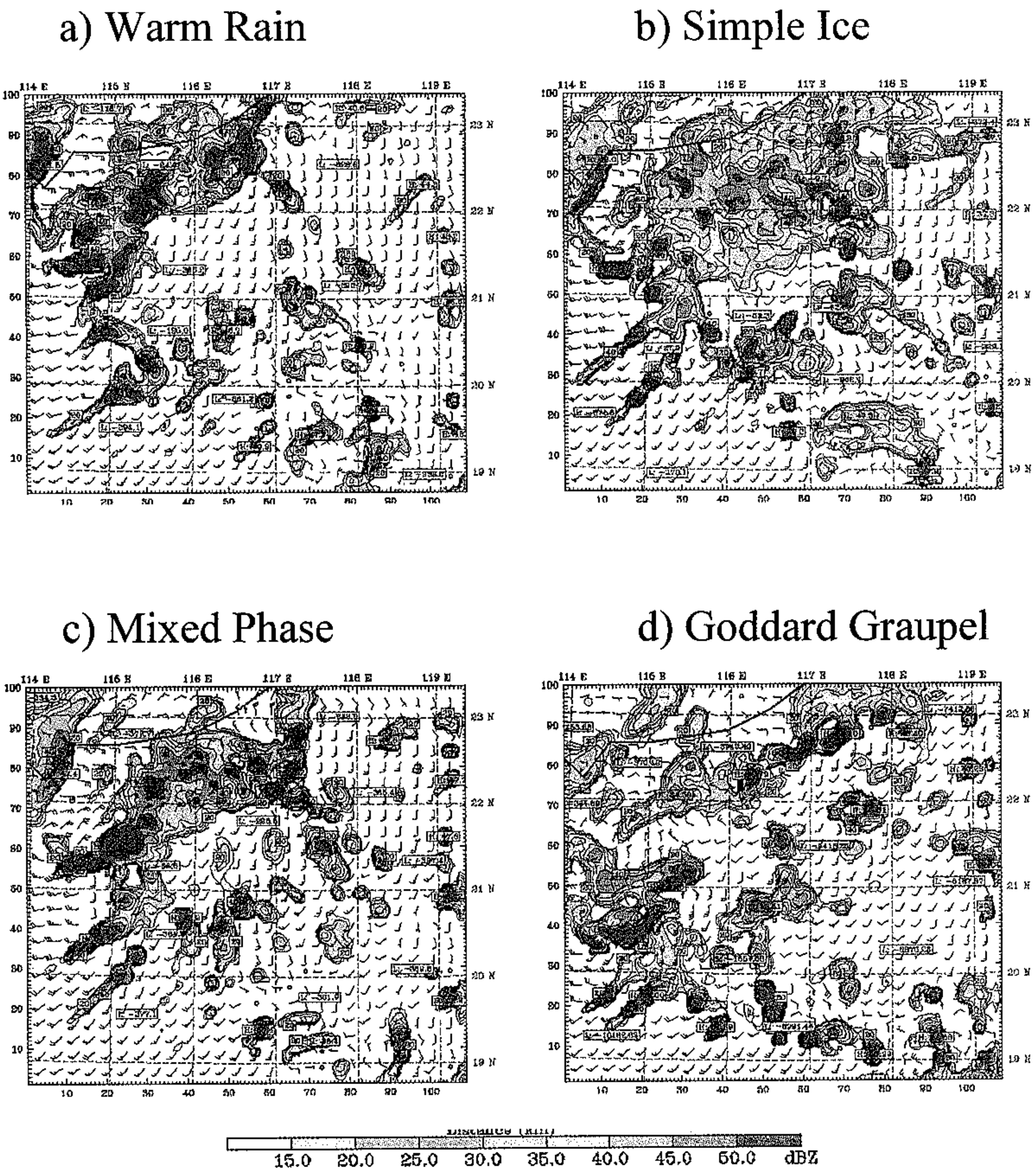

Figure 3: Simulated near-surface (40-m above sea level) radar reflectivity (in dBZ) by different microphysics experiments on the 5-km grid at 18-h forecast time (valid at 0600 UTC 15 May 1998): (a) Warm Rain, (b)Simple Ice,, (c) Mixed Phase, and (d) Goddard Graupel experiment. Near-surface wind is also plotted (full barb = 5 m s⁻¹).