Evaluation of a mass-flux convection scheme for mesoscale atmospheric models

Edgar Herrera* and René Laprise

Département des sciences de la Terre et de l'Atmosphère, Université du Québec à Montréal.
*e-mail : herrera@sca.uqam.ca

Introduction

Mesoscale atmospheric models have been used for a wide variety of applications in the environmental sciences during the last two decades. Since greater computing power has become available and the quality of the model simulations has improved as a result of our better understanding of physical processes, the use of Mesoscale atmospheric models has become much more widespread. One of the major physical processes that affects the dynamics and energy of atmospheric circulation systems is the cumulus convection. Hence, it becomes necessary to represent the net effect of an ensemble of convective clouds upon the atmosphere in terms of the grid-scale parameters.

This paper is devoted to the new bulk mass flux convection parameterization for deep and shallow convection developed by Bechtold (Bechtold et al., 2001), hereinafter referred to as Bechtold scheme, employed in a Regional Climate Model (RCM).

Experimental framework

We have chosen the region of Mexico since it includes a tropical climate, a steep topography and, during the fall, heavy precipitations are frequently observed. This constitutes a combination of conditions rarely present in a RCM simulation. The simulation was carried out with the Canadian RCM (Caya and Laprise, 1999) for fall 1989 with a 15 min. timestep. The computational domain is centered over central Mexico, with 130 by 100 grid points in the horizontal with nominal grid spacing of 45 km, and 20 Gal-Chen scaled-height layers in the vertical.

In order to validate the convection scheme, we have compared its performance with that of the Kain-Fritsch (KF) scheme (Kain and Fristsch, 1990) and the dataset of monthly terrestrial surface climate from CRU (New et al., 2000). Both convective schemes, Bechtold and Kain-Fritsch, have a closure assumption based on the removal of the Convective Available Potential Energy (CAPE). Their cumulus cloud model formulation uses a one-dimensional entraining/detraining plume. The stratiform component of the precipitation is obtained from the large-scale condensation part of the second-generation general circulation model (GCMii, McFarlane et al., 1992). The RCM was driven by the NCEP (National Centers for Environmental Prediction) reanalysis at the lateral boundary.

Results

Figure 1 shows the distribution of the fall-mean precipitation, as simulated by the CRCM with the KF and the Bechtold schemes. This pattern shows a correspondence between the simulations and actual observations of the relative maxima, although there is a clear over-estimation over the region of Central America. There is also a strong modulation of precipitation due to the topography. The CRU data of the southern coast of USA show a precipitation maximum of up to 15 mm/day, while KF shows 10 mm/day and Bechtold 6 mm/day. This is a region where the high density of meteorological stations provides a strong support to the CRU dataset. The CRU data of southwestern USA, northern and central Mexico, show a precipitation minimum of 2 to 3 mm/day, which is reproduced by the CRCM with (slightly lower) values of 0 to 1 mm/day. The maximum value over the region of Guatemala is clearly localized and attains values over 4 mm/day with KF and 7 mm/day with Bechtold, which are very close to the actual observations. The average values of the models over the desertic region of Southwestern USA, North and Central Mexico, are 1 to 2 mm/day which differ from the actual observations by only ±1 mm/day. In the region of Cuba, it is only possible to compare the values of the models over a small fraction of the island given the resolution of the ground-cover of the CRU data which has values of up to 5 mm/day, KF presents values of up to 6 mm/day and Bechtold of up to 10 mm/day. By comparing both schemes we see that KF is noisier that Bechtold, which can be clearly observed over Southeastern USA, Northern and Central Mexico. Hence, the convection parameterization of Bechtold gives an efficient and reasonable numerical description of atmospheric convection.

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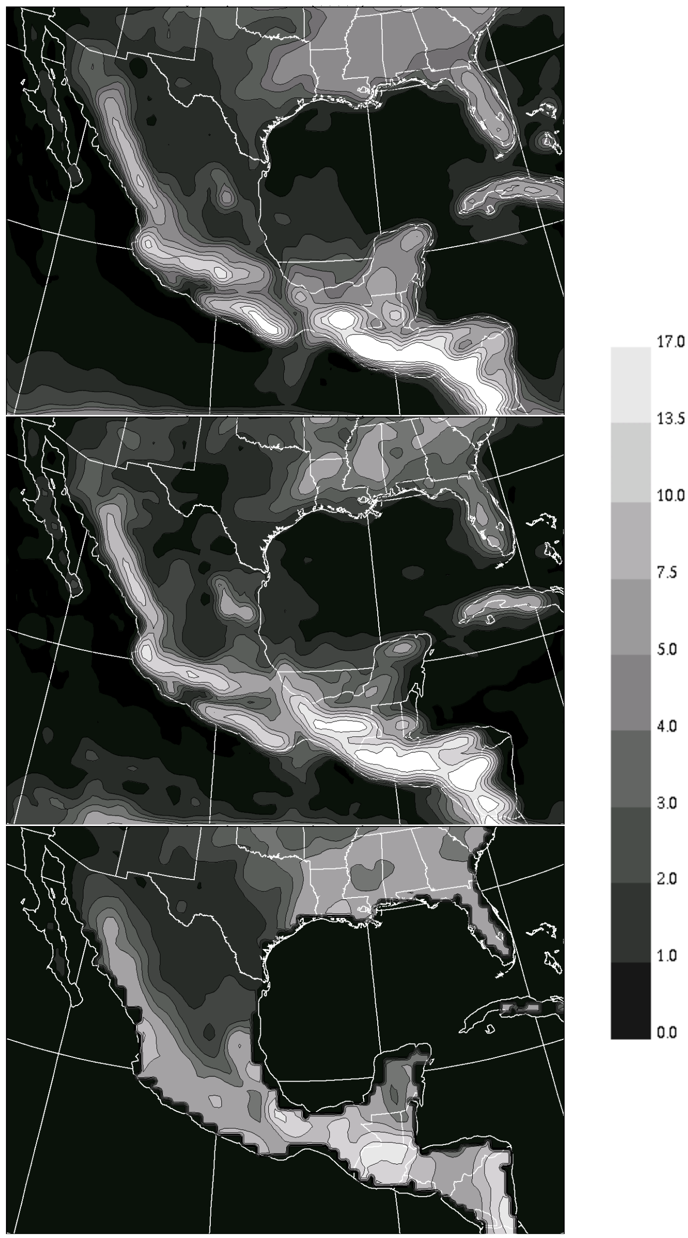

Figure 1. Fall-mean precipitation simulated by the CRCM using the scheme of Bechtold (top), of Kain-Fritsch (middle), and observed climatology from CRU (bottom). Units are in mm/day, contoured at values of 1, 2, 3, 4, 5, 7.5, 10, 13.5 and 17 mm/day.