Applicability of large-scale convection and condensation parameterization to meso-γ scales.

Sami Niemelä[1] and Carl Fortelius
Finnish Meteorological Institute

Introduction

The representation of convective phenomena is very difficult in meso-γ-scale models. The rapid development of computing power has enabled limited area NWP models to use a grid spacing of about 10 km. Weisman et al. (1997) proposed that organized convective structures could be resolved explicitly with a smaller grid spacing than 4 km. The grid spacing range of 5–20 km is especially difficult for convection schemes to handle.

Jung and Arakawa (2004) showed that convection parameterization is highly dependent on the model resolution (in both time and space) in the range of meso-γ scales. Traditionally, convection parameterizations are "tuned" for a fixed grid spacing. Therefore, the behaviour of non-resolution-dependent convection schemes may be undesirable, when these schemes are applied for different scales. Jung and Arakawa (2004) also argued that the formulations of future physical parameterizations should include resolution dependencies.

The objective of this study is to evaluate the applicability of the existing convection and condensation scheme of the HIgh resolution Limited Area Model (HIRLAM) in meso-γ-scale convective conditions. Here, we concentrate on the issue of the grid-size-dependent convection scheme. The performance of the different model configurations is mainly validated using radar reflectivity data from the Finnish radar network. Modelled radar reflectivites are produced by using the Radar Simulation Model (RSM) of Haase and Crewell (2000).

Description of the model

HIRLAM is a complete NWP system including an anelastic nonhydrostatic model with an extensive set of physical parameterizations and data assimilation (Undén et al., 2002). STRACO scheme (Soft TRansition COndensation; Sass, 2002) parameterizes both convective and stratiform condensation, clouds and precipitation. It also allows a gradual transition between both regimes. The convection scheme is a modified Kuo scheme that includes cloud water as a prognostic variable. The diagnostic precipitation release depends on the amount of cloud water.

STRACO was originally developed for use on meso-β scales. However, improved applicability for meso-γ scales is sought by introducing simple grid-size-dependent entrainment function in the triggering mechanism for convection scheme,

$$\epsilon_e = \left(1.3 \cdot 10^{-4}\ \mathrm{m}^{-1} + \frac{7.5 \cdot 10^{-4}\ \mathrm{m}^{-1}}{\mathrm{Ri}_*}\right)\left(\frac{z}{500\ \mathrm{m} + z}\right)\left(\frac{10\ \mathrm{km}}{D}\right). \quad (1)$$

In Eq. (1), z is height [m], D is the grid spacing [km] and Ri_* is a Richardson number. Eq. (1) gradually switches the convection parameterization off as the grid spacing decreases.

Results

6 different model simulations of a single cold air outbreak event with small scale convective precipitation are carried out. The event occurred over Southern Finland on 25 May 2001. Two types of experiments are made; with (NH-2) and without (NH-1, third term in Eq. 1 equals 1) grid-size-dependent convection scheme. Both types utilize three different horizontal grid spacings: 11, 5.6 and 2.8 km.

Fig. 1 shows the radar reflectivity fields from the experiments with the highest model resolution after 12 hours of simulation. It can be seen from the observed field (Fig. 1c) that almost the whole of Southern Finland was covered by small-scale convection. Both models are able to form cellular structures similar to the observed ones. However, NH-2 produces the precipitation area that most resembles the observed field.

The radar reflectivity distributions of NH-1 and NH-2 experiments are compared in Fig. 2. The grid-size-dependent triggering mechanism for convection is clearly beneficial for the models operating with a dense grid. NH-1 increasingly overestimates the amount of moderate reflectivities as the grid spacing reduces. Evidently, without any dependency on model resolution the convection scheme is too active. However, the grid-size-dependent triggering mechanism does not have an effect on strong reflectivities. Both NH-1 and NH-2 overestimate the areas

[1]Corresponding author: Finnish Meteorological Institute, P.O.Box 503, FI-00101 Helsinki, Finland. E-mail: sami.niemela@fmi.fi

of strong echoes. The triggering mechanism employed in the present study becomes really effective with grid spacings smaller than 3 km.

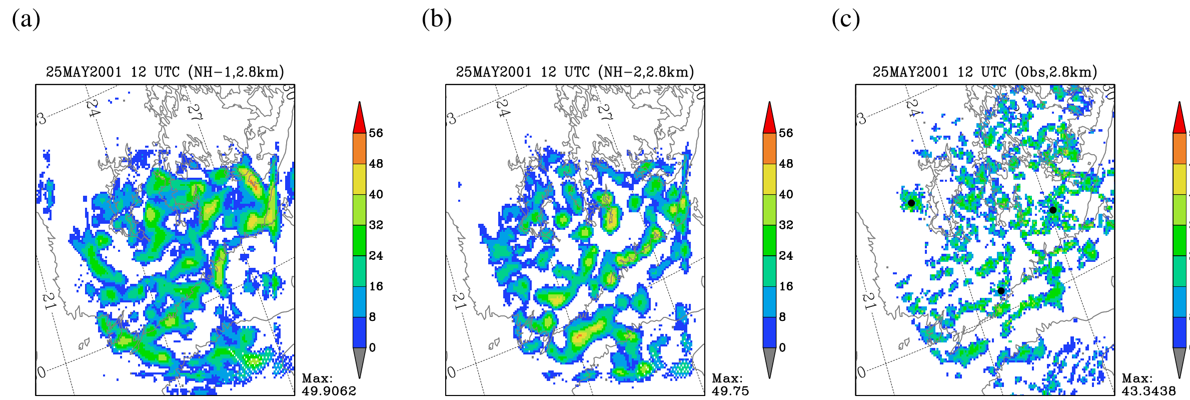

Figure 1: Composite radar reflectivity [dBZ] fields after a 12 hour simulation valid at 12 UTC 25 May 2001. (a) NH-1, (b) NH-2 and (c) radar observation. The horizontal grid spacing of each field is 2.8 km. The locations of the radars are marked with dots in figure (c).

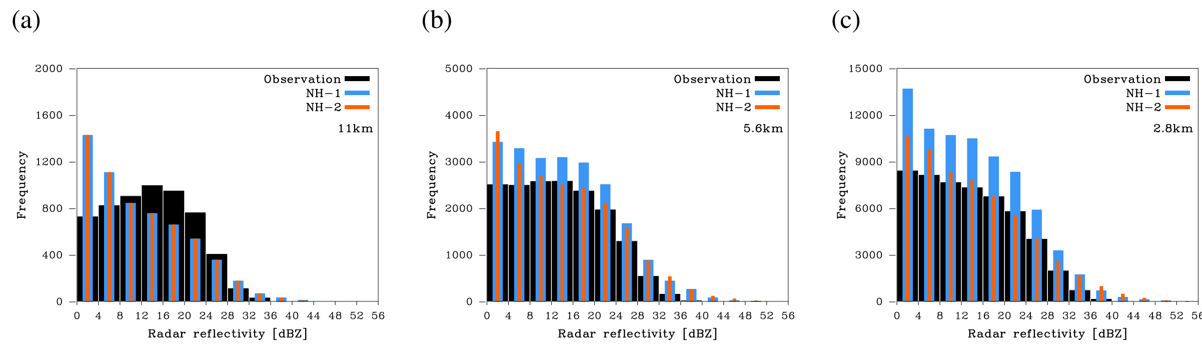

Figure 2: Frequency distributions of radar reflectivity [dBZ] produced by 21 hour simulations (NH-1 and NH-2) starting from 00 UTC 25 May 2001. Horizontal grid spacings are (a) 11, (b) 5.6 and (c) 2.8 km. Black bars represent dBZ-observations. The radar antenna elevation is 0.4°.

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