2.2 IMPACT OF ADJUSTMENTS IN THE KAIN-FRITSCH CONVECTIVE SCHEME ON QPF OF ELEVATED CONVECTION

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1. INTRODUCTION

Elevated convection may form into one of a wide spectrum of storm types that ranges from widely spaced, isolated storms to storms that are embedded within a mesoscale convective system (Rochette and Moore 1998; MCS). This wide range of spatial scale is a characteristic of convection in general that limits accuracy of QPF from mesoscale weather prediction models, because the scale of individual storms is smaller than typical grid point spacing in mesoscale models, requiring parameterization rather than explicit simulation of convective processes. Simulations of elevated convection may further suffer from a lack of scientific understanding about mechanisms that give rise to elevated convection, leading to parameterizations that might be based upon incorrect physical assumptions.

It is probable, yet still unknown, that mechanisms releasing elevated and near-surface potential convective instability differ (Rochette and Moore 1998). Yet, convective parameterizations are developed from assumptions that heavily rely on evidence gathered from studies of convection that initiated near the surface. Herein we report on sensitivity of QPF for elevated convection to values of parameters in the Kain-Fritsch convective parameterization scheme as well as modifications of the scheme itself as implemented in the workstation non-hydrostatic ETA model with 32-km grid spacing.

2. MODIFICATIONS OF THE KAIN-FRITSCH CONVECTIVE PARAMETERIZATION

The cloud model in the KF scheme has three basic components: trigger function, one-dimensional entraining-detraining plume model, and downdraft model. Grid-resolved vertical velocity influences the trigger function through a proportionality constant, *c*, that converts grid-resolved vertical velocity to a potential temperature perturbation. In the standard version of the KF scheme implemented in the workstation Eta, *c* is set to 4.64 K $m^{-1/3}$ $s^{1/3.}$ Similarly, in the Eta model, a temperature perturbation is added if grid point relative humidity is greater than 75% at the lifted condensation level (LCL). This is designed to offset the effects of grid-scale condensation beginning at 75% relative humidity in this model. Updraft parcels are released at the LCL in the KF scheme if the temperature perturbation added to the updraft temperature is warmer than the grid point temperature at the LCL. If parcel theory calculations suggest that these parcels can maintain upward motion due to buoyancy to a depth of ~ 4km, parameterized deep convection in invoked.

This trigger function is based on the idea that boundary-layer thermals have greater vertical velocity within regions of convergence (Kain and Fritsch 1992). It is unclear whether this mechanism is important to convective initiation aloft, since an elevated mixed layer is not usually heated from below. Once invoked, the KF scheme uses a one-dimensional entraining plume model with a downdraft to redistribute mass until 95 % of the initial CAPE is eliminated. The adjustment occurs over a time scale, *t*, that is computed by the ratio of the mean wind to the grid point spacing, i.e., an advective time scale. Kain and Fritsch (1992) and Stensrud and Fritsch (1994) demonstrate sensitivity of QPF in simulations of MCS to both *c* and *t*. We have examined the sensitivity of QPF for elevated convection to *c* and *t* by generating simulations in which these parameters are varied independently and jointly (Arritt et al. 2001). The proportionality constant *c* was set to 0, 5, and 10 K $m^{-1/3}$ $s^{1/3}$, and the convective time scale *t* was set to 1800, 3600, and 5400 s.

In addition to sensitivity of QPF to parameter values in the KF scheme, QPF is known to be sensitive to convective downdraft formulation. For example, Spencer and Stensrud (1998) found sensitivity of QPF to downdraft formulation for flash flood events, some of which were likely elevated. Based on this sensitivity, we have tested three modifications of the KF scheme: reformulated downdraft model, variable updraft radius, and updraft temperature perturbation for certain grid point temperature profiles.

The original downdraft formulation begins the downdraft about 150 mb above the LCL and entrains mass as a linear function of pressure-depth. We have tested a modification in which the downdraft mass flux is related to the mean relative humidity within the downdraft layer, such that more downdraft mass is generated when the mean relative humidity in the downdraft layer decreases.

The updraft radius is used in calculations of updraft entrainment rate. The default cloud radius is 1500 m. The KF scheme was modified to allow the cloud radius to vary between 100 and 3000 m depending on the average grid-resolved vertical velocity in the 300 mb layer above cloud base, with larger cloud radius associated with greater vertical velocity.

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It is known that QPF is underestimated by the KF scheme for some cases of elevated convection in which a nearly moist adiabatic layer overlays a surface-based inversion. The KF scheme was modified such that a temperature perturbation was added to the updraft temperature under such conditions.

3. CASE STUDY: JUNE 4, 2001

An elevated convective system formed overnight on June 4, 2001 over northeast Kansas and northern Missouri. A nearly saturated inversion is evident in the 00 UTC sounding from Topeka, KS. A surface front extended along the Kansas/Oklahoma border eastward into S Missouri. Overnight a very strong LLJ developed, with 1-km wind speed reported in excess of 22 m s^{-1} at the Neodesha, KS profiler. Convection developed east and northeast of Topeka by 02 UTC as discrete cells. By 07 UTC the cells had filled in and a large region of nearly uniform, moderate echo had developed north of the cells, giving the radar image the appearance of a weak squall line. The radar echo moved eastward and dissipated by mid-morning of June 5 over Illinois and Missouri. Soundings at 12 UTC for Lincoln, IL and Springfield, MO (prior to rainfall) contained a deep surface based inversion topped by a nearly saturated moist adiabatic layer. Combined radar and gauge estimates of accumulated precipitation suggested 3-5 cm of rain fell over the eastern third of Kansas and northern half of Missouri.

Maximum rainfall produced by all variations of the KF scheme was located across east central Kansas into central Missouri. A control simulation run without any parameter adjustments or modifications to the KF scheme produced maximum precipitation >7.5 cm in central Missouri with >1.25 cm covering east central KS through central Missouri. Thus, the precipitation pattern had less areal extent and exhibited a more isolated maximum than observed. Areal coverage of precipitation was expanded only when *c* was set to 0. In all other simulations the pattern and location of precipitation was nearly unchanged, with maximum precipitation ranging from 2 to 10 cm.

4. CASE STUDY: MAY 13, 2001

On May 13, 2001 a cluster of discrete elevated storms formed at 08 UTC in southeast South Dakota and moved southeastward beyond Iowa by 15 UTC. A surface front was positioned over eastern Nebraska, northeast Kansas, and northern Arkansas. The 12 UTC sounding from Omaha, NE showed a surface based inversion through the lowest 100 mb, and a LLJ of 20 m s^{-1}. Estimated precipitation totals were generally 0.25 cm over all of Iowa, eastern Nebraska, and southeast SD. Rainfall amounts between 1.25 and 2.5 cm occurred in southeast NE and southwest IA, where large hail was also reported.

The control simulation contained a very small area of 0.1 cm in central IA. The areal coverage of 0.25 cm precipitation increased in simulations with modified updraft temperature, t=1800 s, and c=0, whereas only the variable radius simulation increased the areal coverage of 0.1 cm.

5. DISCUSSION

The role of convective parameterization is to reduce grid point convective instability. By decreasing *t* the convective scheme may be invoked more frequently and may more efficiently reduce grid point convective instability, reducing grid-resolved precipitation (Kain and Fritsch 1992). In contrast, smaller values of *c* may allow instability to increase, so that precipitation from convective parameterization may increase. Thus, both adjustments tend to emphasize sub-grid precipitation.

These case studies suggest that QPF for elevated convection might be improved by reducing the dependence of the KF scheme on grid-resolved vertical velocity, because areal coverage of precipitation increased when *t* and *c* were set to their minimum values. This might suggest a smaller spatial scale for physical processes associated with elevated convection. We are examining observations to determine whether elevated convection formed in turbulent environments with reduced mesoscale ascent.

6. ACKNOWLEDGEMENTS

This research was supported by COMET Partner's Project S0232808 and NSF grant ATM-9911417.

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