Quantifying the dependence of convective parameterization activity on horizontal grid spacing in WRF: Preliminary Results

WRF-DTC VISITOR PROGRAM
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Introduction

Due to the availability of increased computational power, numerical weather prediction (NWP) models can be run at horizontal scales fine enough to explicitly resolve cumulus convection. While it is generally thought that NWP models with grid spacing below around 4 km can resolve some cumulus convection, the degree to which the convective parameterization remains active at small grid spacing is not well known and likely varies with parameterization scheme and meteorological factors. As high resolution NWP models become available for operational use, a detailed knowledge of these length scales becomes critically important for determining optimal model configurations.

The goal of this project was to develop new diagnostic techniques for quantifying the activity of the convective parameterization within WRF as a function of horizontal grid spacing. As described below, the initial approach, which focused on developing code for tracking the calls to the parameterization, was not fruitful. A simpler approach, based on the ratios of convective to explicitly resolved precipitation, is much more promising. I present preliminary results from a summer and winter case that illustrate the utility of the new technique.

Tracking the calls to the convective parameterization

My first approach to this problem was to add code to the WRF cumulus driver to track the number of calls to the convective parameterization. This total was stored in a new two-dimensional field CONV_TOT. At each time step and at each grid point, if the convective heating tendency was non-zero, then the value of the CONV_TOT field at that point was increased by 1. After the entire model simulation, the CONV_TOT field contained the number of times the convective parameterization was called at each grid point.

Unfortunately, this approach proved to be a dead-end, because the convective parameterization was called as frequently, or more frequently at very high resolution (below 3 km) as at low resolution (above 12 km). Because the triggering function for the Kain-Fritsch convective parameterization is linked to vertical velocity, and because vertical velocity will tend to increase as grid spacing decreases, the convective scheme will continue to be called very frequently even at high resolution. Thus, the number of calls to the convective scheme is **not** a useful diagnostic for the scale dependence of convection in WRF.

A probabilistic approach

The more successful approach to this problem was somewhat simpler. Even though the convective parameterization may be quite active at high resolution, it may not contribute very much to the precipitation totals. We can formalize this idea in terms of a conditional probability based on two thresholds. First, we are only interested in regions of significant precipitation, so we consider only those grid points where precipitation exceeds some fixed threshold, ***P***. Second, of those grid points that received significant precipitation, we want to know how many received a significant fraction, ***C***, of that precipitation from the convective parameterization. For the cases presented here, I found that a precipitation threshold ***P*** of 20 mm and a convective precipitation fraction ***C*** of 20% were sufficient to identify scale dependence in the activity of the convective parameterization.

Results

I ran summertime and wintertime cases in the WRF-ARW version 2.1 at grid spacings of 48 km, 24 km, 12 km, and 6 km, with 30 vertical levels for all simulations. All simulations used the Lin microphysics scheme, and both sets of simulations were run with the Kain-Fritsch and Betts-Miller-Janjic schemes. The summertime case covered the central United States, beginning at 00:00:00 UTC on June 11, 2003 and running for 72 hours (Figure 1). The wintertime case covered the eastern seaboard of the United States during the February 2006 blizzard, beginning at 00:00:00 UTC on February 11, 2006 and running for 48 hours (Figure 2).

Figure 3 shows the conditional probability of convective precipitation exceeding 20% of the total precipitation at grid points where the total precipitation exceeds 20 mm for the forecast period. Figure 3a shows the results for the Kain-Fritsch parameterization, and shows a detectable but relatively weak dependence on grid spacing, ranging from 0.31 at a grid spacing of 48 km down to 0.27 at a grid spacing of 6 km. Figure 3b shows the results for the Betts-Miller-Janjic scheme, which is much less active than the Kain-Frisch scheme, with probabilities declining from .015 at a grid spacing of 48 km down to less than .009 at 12 km and 6 km.

Figure 4 shows the conditional probabilities for the wintertime case (Kain-Fristch only). There is a stronger dependence on grid spacing for the wintertime case, with probabilities declining from around 0.1 at a grid spacing of 48 km down to less than 0.04 at a grid spacing of 6 km. The Betts-Miller-Janjic scheme contributes negligible amounts of precipitation in the winter case at all grid spacings, consistent with other studies that have shown the weak activity in the BMJ scheme in ARW version 2.1 (Jimy Dudhia, pers. comm.).

Summary and conclusions

The goal of this study was to develop techniques for identifying the scale-dependence of convective parameterizations in WRF. The initial idea of tracking the number of calls to the convective scheme proved to be a dead-end because of the way that convective schemes are triggered. The more fruitful approach involved simply comparing the amount of precipitation generated by the convective scheme to the amount that was explicitly generated within the model. This approach shows that there are indeed ‘natural’ scales of activity for the convective parameterization within WRF. The presence of such scales, however, does not necessarily imply that they can be used to determine the grid-spacing at which the convective scheme can be turned off. At grid-spacings below around 12 km, the required scale separation between resolved and parameterized convection is not present, and even though the convective scheme may contribute significant precipitation below these scales, it is not theoretically justified to leave the schemes on below around 10-12 km. Nevertheless, the diagnostic tools presented here can provide a useful characterization of the activity of the convective schemes in WRF and may point toward the development of better parameterizations for relatively small grid spacings.

Acknowledgements

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Figure Captions

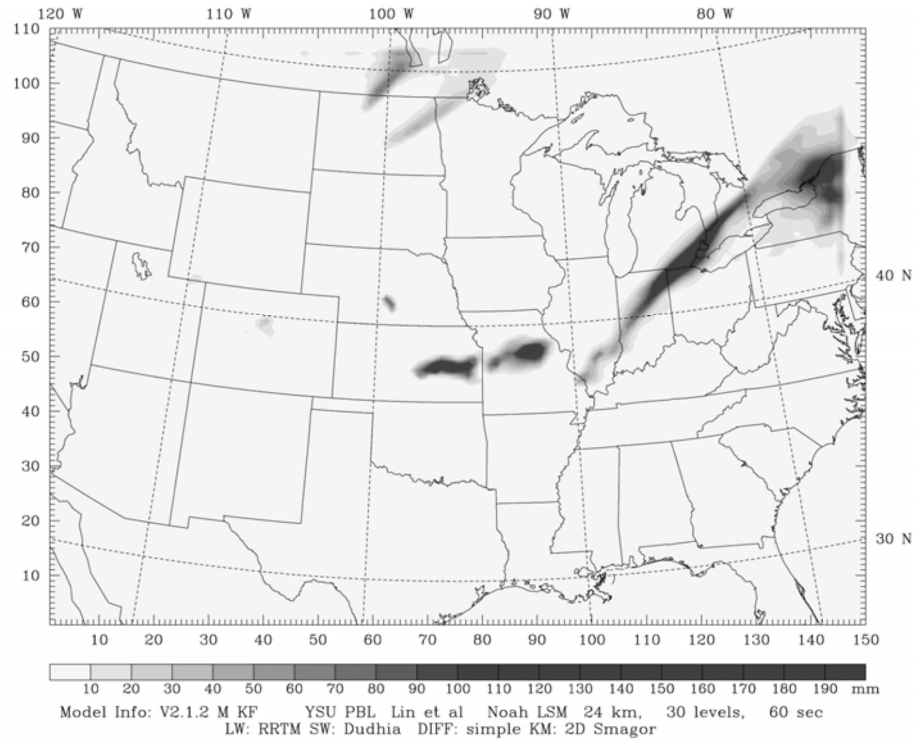
Figure 1: (a) 48 hour accumulated explicit precipitation for the summertime case (June 14 2003) from the simulation with 24 km grid spacing; (b) as in (a) except for precipitation produced from the convective scheme.

Figure 2: As in Figure 1, except for the wintertime case (13 February 2006) from the 12 km simulation.

Figure 3: Probability of convective precipitation exceeding 20% of the total precipitation at a grid point, where the total precipitation exceeds 20 mm for the forecast period in the summertime case. Top panel is for the Kain-Fritsch parameterization; bottom panel is for the Betts-Miller-Janjic scheme.

Figure 4: As in Figure 3, except for the wintertime case, Kain-Fritsch scheme only.

a.) 48 hour accumulated explicit precipitation, valid 0000 UTC 14 Jun 03, 24 km grid spacing



b.) 48 hour accumulated cumulus precipitation, valid 0000 UTC 13 Feb 06, 24 km grid spacing

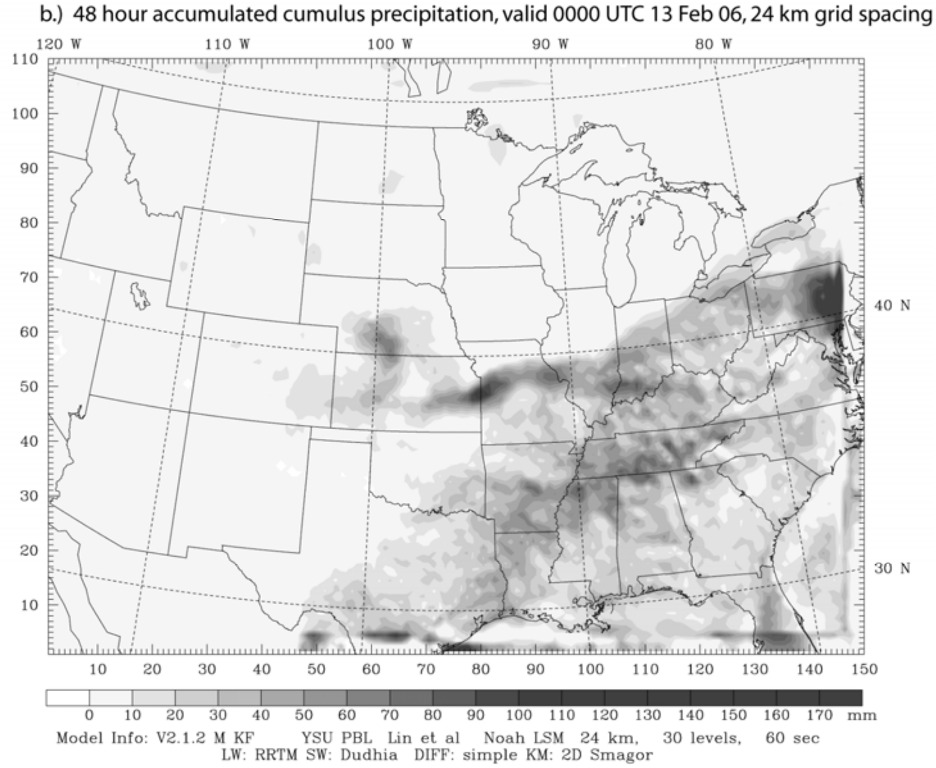
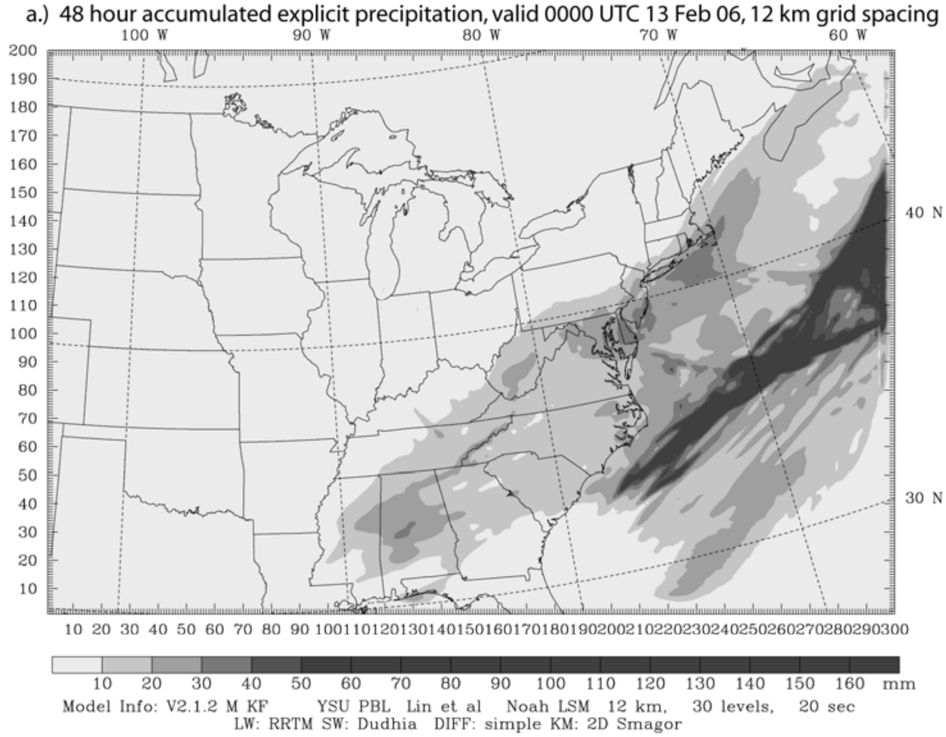


Figure 1

a.) 48 hour accumulated explicit precipitation, valid 0000 UTC 13 Feb 06, 12 km grid spacing



b.) 48 hour accumulated cumulus precipitation, valid 0000 UTC 13 Feb 06, 12 km grid spacing

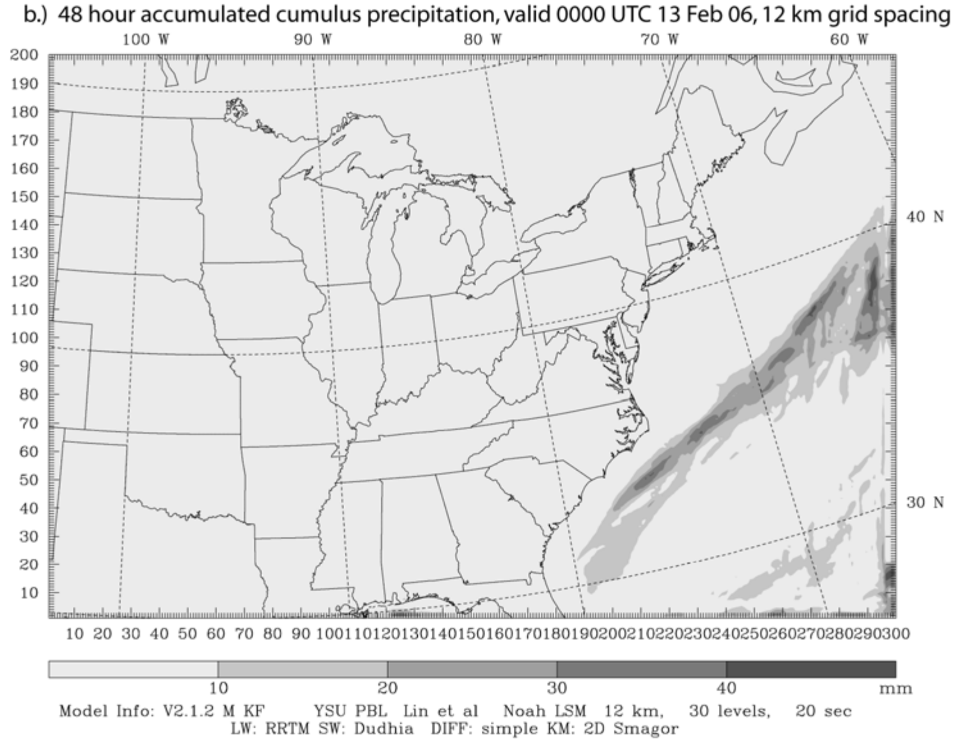


Figure 2

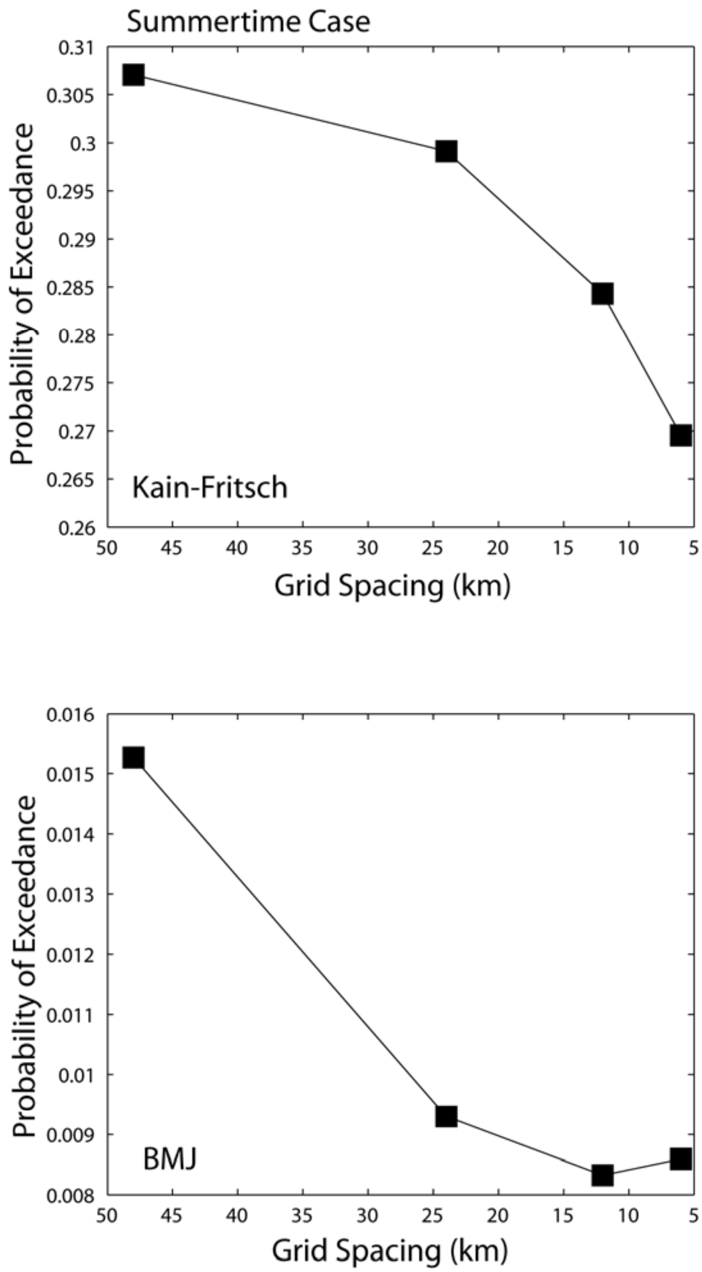
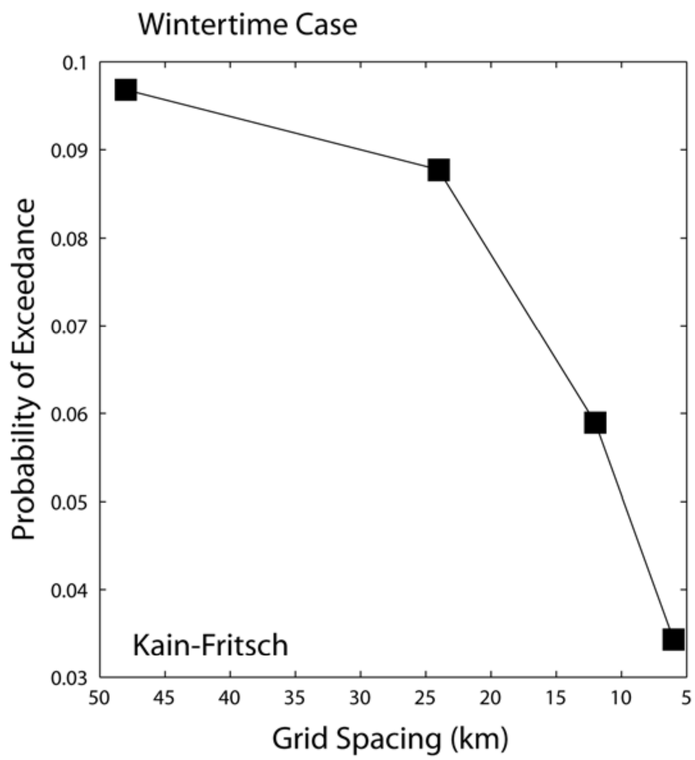

Summertime Case
Probability of Exceedance
0.31
0.305
0.3
0.295
0.29
0.285
0.28
0.275
0.27
0.265
0.26
Kain-Fritsch
50
45
40
35
30
25
20
15
10
5
Grid Spacing (km)
Probability of Exceedance
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
BMJ
50
45
40
35
30
25
20
15
10
5
Grid Spacing (km)

Figure 3



Wintertime Case
Probability of Exceedance
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
50
45
40
35
30
25
20
15
10
5
Kain-Fritsch
Grid Spacing (km)

Figure 4