J5.2 PARAMETERIZATION OF CONVECTION AT MESOSCALE RESOLUTION

James M. Done* Peter A. Clark, George C. Craig, Mike E. B. Gray and Suzanne L. Gray
University of Reading, UK

1 INTRODUCTION

Quantitative precipitation forecasting is particularly difficult in convectively unstable conditions (e.g Stensrud *et al.* (2000)). A successful forecast of convection ultimately depends on the ability of the model to capture the triggering location and timing of convection. Convective precipitation is highly sensitive to the formulation of the convection scheme (e.g. Wang and Seaman (1997)) and no single scheme is found to consistently outperform others in a wide range of meteorological situations (Gallus Jr and Segal (2001)). The explicit method used here provides an alternative to cumulus parameterization.

An ensemble technique is employed to examine specifically the sensitivity of precise triggering location of deep convection to small-scale uncertainty in a mesoscale model. The Met Office model used in this study has repeatedly failed to capture the location and timing of mid-latitude deep convection (Mike Gray, personal communication and first author's experience). We investigate whether the model can trigger deep convection in different locations within the limit of small-scale uncertainty in the buoyancy field. The work is based on two cases of deep, organised convection over the UK chosen because of their different synoptic environments and triggering locations. This allows the investigation to cover a wider range of possible events within the mesoscale domain.

2 CASE STUDIES

Case 1: Early on 5/29/99 a low-level plume of high wet-bulb potential-temperature (θ_w) air tracks north towards southern England beneath a cooler, drier mid and upper-level south-westerly flow. The front edge is elevated above a low-level easterly flow resulting in a band of CAPE and almost zero convective inhibition (CIN). Cells triggered within this band organise into an mesoscale convective system (MCS) over southern England.

Case 2: On 9/11/00 a synoptic-scale shallow wave-cyclone below 600mb tracks over the UK. Low-level northward advection of warm, moist air in the warm sector is overlain by mid-level northeast-ward advection of cooler, drier air by a 650mb jet providing CAPE and significant CIN over most of England. Cells trigger ahead of the surface cold-front where CIN is almost zero and organise into an MCS that tracks over Northeast England.

3 MODEL DESCRIPTION

The Met Office unified mesoscale model version 4.5, formulated around the hydrostatic primitive equation set, has horizontal resolution of approximately 12.5km, 38 levels and a timestep of 5 minutes. Dynamic precipitation is generated by a physically-based, mixed-phase transfer scheme representing water vapour, liquid water, rain and prognostic ice. We choose to allow all convection to occur explicitly without employing a subgrid parameterization scheme. The initialisation time is such that convection triggers after a period of model spin-up.

4 ENSEMBLE TECHNIQUE

The temperature field between 900 and 700mb, the layer of convective initiation, is modified by the addition of a randomly generated field of spatially coherent gaussian perturbations. Each modified field has equal probability of estimating truth consistent with small-scale uncertainty. The horizontal perturbation scale is chosen to be consistent with the unobserved scales spun up by the model, typically 70km. Specific humidity within the same layer is consistently modified by ensuring constant relative humidity during the modification. Six random perturbation fields are generated and inverted to initialise a twelve member ensemble in addition to an unmodified solution. This technique constrains the perturbation field ensemble mean to be zero. Theoretical results from Leith (1974) show that an ensemble size as small as 8 appreciably increases accuracy over the deterministic forecast.

Case 1: At 00Z 5/29/99 the band of high 850-750mb θ_w in the unmodified solution contains small-scale amplitudes of approximately 0.1K. Three hours later a small-scale maximum has amplified to approximately 1.0K and triggers deep convection. The appropriate ensemble technique is therefore to apply the field of perturbations of amplitude 0.1K at 00Z. Each ensemble member grows a small-scale maximum (sometimes two, depending on the perturbation field) of similar magnitude to that of the unmodified solution in different locations within the band of high θ_w.

Case 2: Much larger θ_w gradients exist due to the cold front and land-surface heating during the day within the warm sector. The appropriate ensemble technique for case 2 is to apply the field of perturbations of amplitude 1.0K at 16Z, 2 hours prior to convective initiation.

5 RESULTS

Case 1: Accumulated model precipitation for the unmodified solution, shown in Fig 1, shows the northward track

---

Corresponding author address: James Done, Dept. of Meteorology, University of Reading, Earley Gate, PO Box 243, Reading RG6 6BB, UK; e-mail: j.m.done@reading.ac.uk.

of a single persistent cell across the English Channel parallel to the mid-level environmental flow shown in 700mb geopotential height. The model captures the timing but not the location of triggering. Ensemble mean accumulated precipitation for the same period in Fig 2 shows greater spread in the east-west direction. Each member triggers convection within the band of CAPE in a location determined by the modification.

Case 2: Accumulated model precipitation for the unmodified solution, shown in Fig 3 over Northern England, shows the northeastward track of two independent, persistent convective cells parallel to the mid-level environmental flow. The model captures both the timing and location of the observed cell and also triggers one unobserved cell to the north. Ensemble mean accumulated precipitation for the same period in Fig 4 shows that each ensemble member triggers convective cells in the same two locations. The triggering location is not sensitive to the initial perturbations.

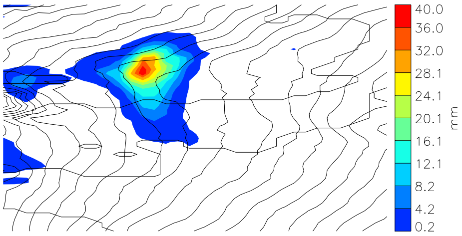

Figure 1: Case 1: Accumulated model precipitation between 03 and 13Z 29/5/99 (shaded) and 700mb geopotential height at 08Z (contoured) for the unmodifed solution.

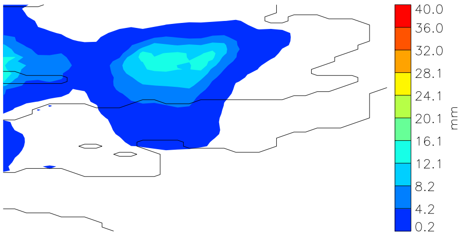

Figure 2: Case 1: Accumulated model precipitation between 03 and 13Z 29/5/99 for the ensemble mean solution.

6 CONCLUSIONS

We have presented a case of deep convection where triggering location is sensitive and a case where triggering location is not sensitive to small-scale uncertainty. Moreover, one of the insensitive triggering locations in case 2 was that observed by Meteosat. Our results suggest both CAPE and CIN together provide guidance on the region where convection is possible. A deterministic mesoscale forecast only has skill in triggering location in those cases where the triggering mechanism dominates small-scale uncertainty. Insensitive convection in case 2 is hypothesised to trigger due to convergence at the surface cold front. We have shown the ensemble provides additional useful information regarding triggering sensitivity that may be useful for quantitative precipitation forecasting.

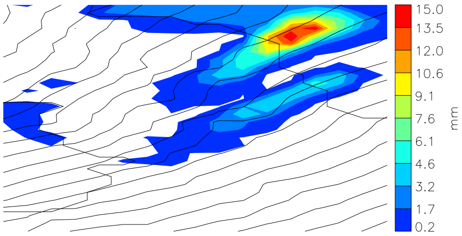

Figure 3: Case 2: Accumulated model precipitation over Northwest England between 18 and 23Z 11/9/00 (shaded) and 700mb geopotential height at 20Z (contoured) for the unmodifed solution.

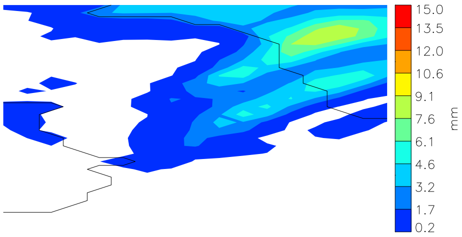

Figure 4: Case 2: Accumulated model precipitation over Northwest England between 18 and 23Z 11/9/00 for the ensemble mean solution.

ACKNOWLEDGEMENTS. We thank ECMWF and Met Office for model data. This work is supported by Met Office grant PB/b/2987 and NERC grant GT04/99/AS/229.

REFERENCES

Gallus Jr, W. and Segal, M. (2001). Impact of improved initialization of mesoscale features on convective system rainfall in 10-km Eta simulations. *Wea. Forecasting.*, **16**, 680–696.

Leith, C. (1974). Theoretical skill of monte carlo forecasts. *Mon. Wea. Rev.*, **102**, 409–418.

Stensrud, D., Bao, J.-W., and Warner, T. (2000). Using initial condition and model physics perturbations in short-range ensemble simulations of mesoscale convective systems. *Mon. Wea. Rev.*, **128**, 2077–2107.

Wang, W. and Seaman, N. (1997). A comparison study of convective parameterization schemes in a mesoscale model. *Mon. Wea. Rev.*, **125**, 252–278.