LA-UR- 00-4794

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Submitted to: American Meteorological Society 81st Annual Mtg.
Precipitation Extremes: Prediction, Impacts and Responses
January 15-19, 2001
Albuquerque, NM

Los Alamos
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REGIONAL CLIMATE MODELING OF THE MONSOON SEASON OVER THE RIO GRANDE BASIN

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1. INTRODUCTION

Los Alamos is involved in an effort to understand the local hydrology of the upper Rio Grande basin situated in northern New Mexico. A suite of coupled environmental models (e.g., an atmospheric model, surface, river, and groundwater hydrology models) is required for successfully simulating the hydrologic cycle for this semi-arid region (e.g., Bossert et al. 1999). The atmospheric model used in this study is the parallel version (4.2) of the Regional Atmospheric Modeling System (RAMS).

Precipitation predicted by RAMS is one of the critical variables within the above coupled modeling system. On-going research to improve quantitative precipitation forecasting (QPF) at Los Alamos has led to the current study. The study particularly focuses on summer convection during the north American monsoon season. Although the onset of the monsoon can vary from year to year, most rainfall is likely to occur in the months of July, August, and September (e.g., Bowen 1990). Both explicit microphysics and cumulus parameterization schemes to represent convection in RAMS are tested in predicting preciptation over the monsoon region (see Fig. 2b) for July and August. A similar study of individual storm events using the above two schemes indicated that cumulus parameterization may be useful in predicting precipitation during the monsoon (Stalker et al. 2000). Stalker et al. (2000) also present a brief background on the limitations of the schemes in improving QPF.

2. RAMS

RAMS is a fully-compressible atmospheric model that includes a modified Kuo cumulus parameterization scheme (Kuo 1974) and an explicit microphysics scheme (Walko et al. 1995). A general description of RAMS can be found in Pielke et al. (1992). The model predicts wind, ice-liquid water potential temperature (Tripoli and Cotton 1981), the Exner function (related to atmospheric pressure), mixing ratios of all hydrometeors and number concentration of pristine ice, and total water mixing ratio. A surface-layer scheme based on a soil model developed by Tremback and Kessler (1985) is used. This scheme also includes a vegetation model based on Avissar and Pielke (1989) that has eighteen categories of vegetation. The radiation scheme of Mahrer and Pielke (1977) is used. A first-order turbulence closure scheme is used for the horizontal components while a second-order Mellor and Yamada (1974) scheme is used in the vertical diffusion direction. For further details, the reader is referred to Stalker et al. (2000).

3. OBSERVATIONS

Monthly total rainfall for July and August of 1994 were reported by the National Oceanic and Atmospheric Administration's Coop stations within the four-corner states of Utah, Arizona, New Mexico, and Colorada (see Fig. 1). From Fig. 1a, it is evident that central, southeastern Arizona, most areas in New Mexico and central (the Rockies), and eastern Colorado recorded monthly rainfall over 50 mm. In August, northern Utah (the Wasatch mountains), southern Utah, central and western (the San Juan mountains) Colorado recorded monthly total rainfall well over 70 mm. In addition, higher elevations in New Mexico (e.g., the Jemez mountains, the Sangre de Cristo mountains, and the Sacramento mountains) recorded rainfall amounts well over 100 mm (see Fig. 1b).

4. RESULTS

The objectives of the modeling were to accurately simulate the monsoon rainfall for July, August, and September (not included) and investigate mesoscale modeling issues. Simulations of July and August of 1994 using NCEP reanalsyis data were completed for three different experiments. Two nested grids were spawned in the domain of interest (see Fig. 2 a,b) in all three experiments. In all three experiments, grid 1 has a horizontal resolution of ~80 km. The horizontal resolution in grid 2 was changed from ~20 km (experiment 2) to

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~40 km (experiment 3). Experiment 1 employs a bulk microphysics scheme while experiments 2 and 3 employ a cumulus parameterization scheme.

In experiment 1, the important regions such as central and southeasten Arizona, western New Mexico were underpredicted in July. This underprediction is expected because of the coarse horizontal resolution (20 km) used in grid 2 for this experiment (see Fig. 3a). At the same time, the highly mountainous regions of the Sacramento mountains of southern New Mexico, the San Juan mountains of southwestern Colorado, and the Jemez mountains of northern New Mexico produced large amounts of precipitation (see Fig.3a). This behavior is due to the model inadquacies in accurately simulating flow past steep barriers. This experiment further underpredicts in August over much of the monsoon region including over the elevated regions (see Fig. 3b). Our preliminary investigation indicates that the errors in upward motion over steep barriers tend to increase considerably in the presence of strong mean flow. The explicit microphysics scheme, thus, is promising to simulate precipitation accurately with sufficient resolution.

In experiment 2, good agreement between simulations and observations is shown over much of the monsoon region including the Sacramento mountains in July (see Fig.4a). However, it overpredicted over the Rockies and the Wasatch mountains. This experiment produces the best agreement between observations and simulations for much of the monsoon region in the month of August (see Fig. 4b). One exception to this close agreement is that severe underprediction of precipitation over the Sacramento mountains occurs in August (see Fig. 4b).

In experiment 3, the overpredictions of experiment 2 over the Rockies are diminished somewhat and thus indicates that cumulus parameterizations may only be suitable for precipitation forecasting with coarse horizontal resolutions (see Fig. 5a,b).

5. DISCUSSION AND FUTURE WORK

The explicit microphysics scheme available in RAMS (version 4.2) does not capture convection over southwest, especially in the peak monsoon month of August at 20-km horizontal resolution. This does not, however, mean that by merely increasing the horizontal resolution, the southwestern region of the U.S. can be simulated well during the monsoon. This is due to some severe model deficiencies that are associated with the model formulation. While cumulus schemes may alleviate some of the above problems and produce reasonable precipitation amounts for the monsoonal region at 20-km horizontal, especially during the peak month of August, underpredictions of precipitation are noted during the month of July. However, cumulus parameterizations may produce reasonable rainfall amounts for coarse resolution (e.g., 40-km). An investigation of the finest resolution required to reproduce observations for the monsoonal region is currently underway and the results of that study will be presented at the conference.

ACKNOWLEDGEMENTS

This research was supported by the Laboratory-Directed Research and Development (LDRD) resources of Los Alamos National Laboratory.

REFERENCES

Avissar, R. and R. A. Pielke, 1989: A parameterization of heterogeneous land surfaces for atmospheric numerical models and its impact on regional meteorolgy. *Mon. Wea. Rev.*, **117**, 2113-2136.

Bossert, J.E., et al., 1999: A coupled modeling system to simulate water resources in the Rio Grande basin. Preprints, *14th AMS Conference on Hydrology*, Dallas, TX, 83-86.

Bowen, B., 1990: Los Alamos climatology. Published as Los Alamos National Laboratory Report LA-11735-MS.

Kuo, H.L., 1974: Further studies of the parameterization of the influence of cumulus convection on large-scale flow. *J. Atmos. Sci.*, **31**, 1232-1240.

Mahrer, Y. and R.A. Pielke, 1977: A numerical study of the airflow over irregular terrain. *Beitrage zur Phys der Atmosphare*, **50**, 98-113.

Mellor, G.L. and T. Yamada, 1974: A hierarchy of turbulence closure models for planetary boundary layers. *J. Atmos. Sci.*, **31**, , 1791-1806.

Pielke et al. 1992: A comprehensive meteorological modeling system–RAMS. *Meteor. and Atmos. Phys.*, **49**, pp. 69-91.

Stalker, J.R., et al., 2000: User of cumulus parameterization and explicit microphysics fro climate studies over the Rio Grande basin. *15th AMS Conference on Hydrology*, Long Beach, CA, 74-79.

Tremback, C.J. and R. Kessler 1985: A surface temperature and moisture parameterization for use in mesoscale n ume rical models. *Preprints, 7th Conf. on Numerical Wea. Prediction*, 17-20 June 1985, Montreal, Canada, AMS.

Tripoli, G.J. and W.R. Cotton 1981: The use of ice-liquid water potential temperature as a thermodynamic variable in deep atmospheric models. *Monthly Weather Review*, **109**, 1094-1102.

Walko, R.L., W.R. Cotton, M.P. Meyers, J.Y. Harrington, 1995: New RAMS cloud microphysics parameterization. Pa rt I: the single-moment scheme. *Atmos. Research*, **38**, 29-62.

a) b)

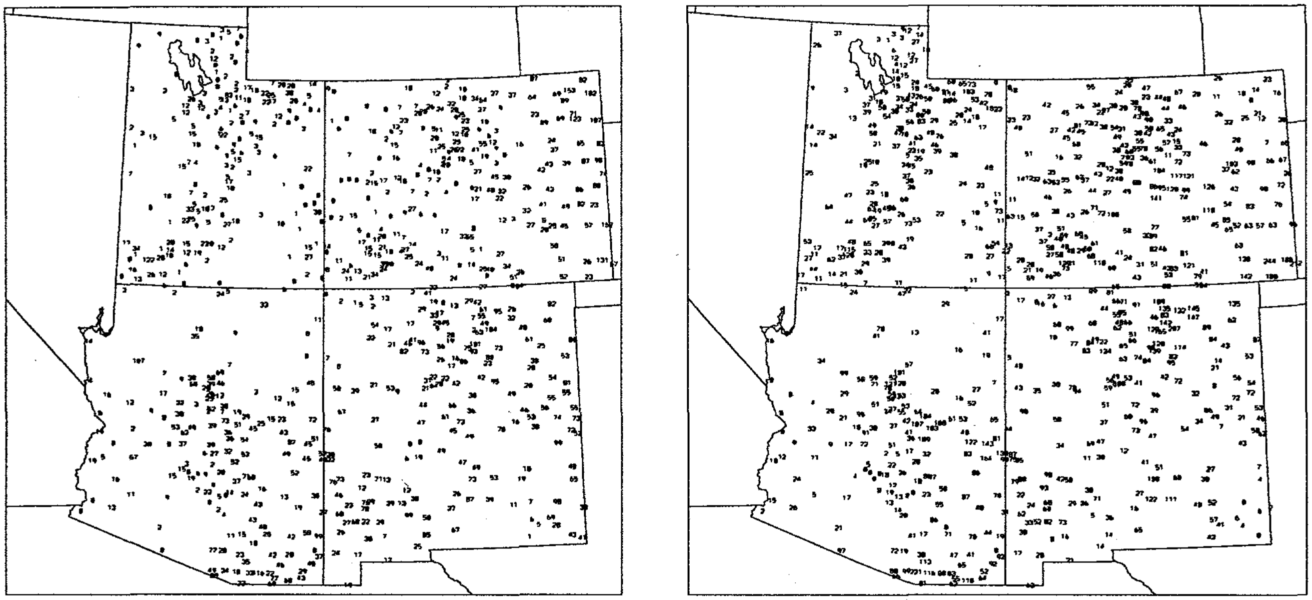

Figure 1: a) Monthly observed total precipitation (mm) for july
b) Monthly observed total precipitation (mm) for August.

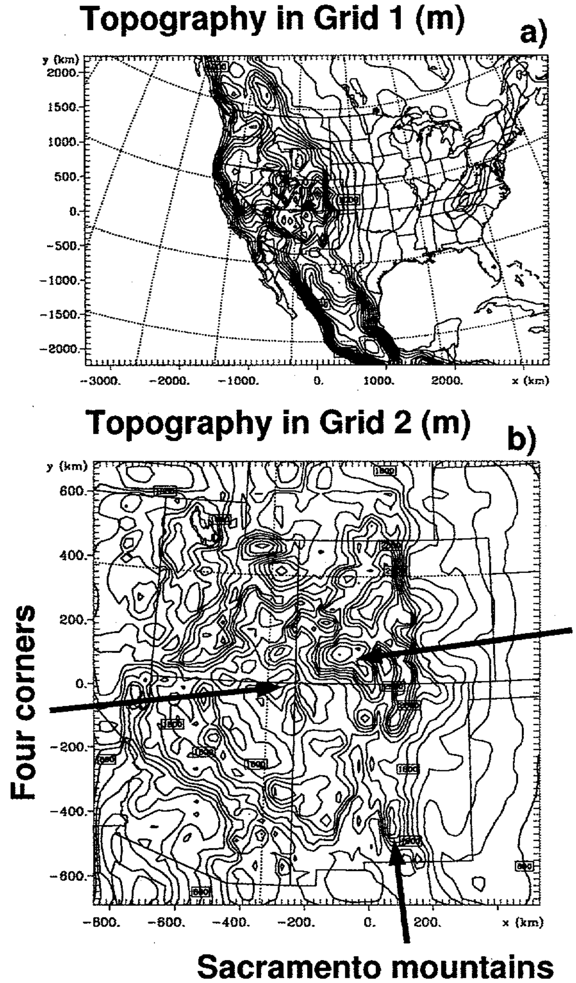

Figure 2. a) Topography in grid 1 (m). b) Topography in grid 2 (m).

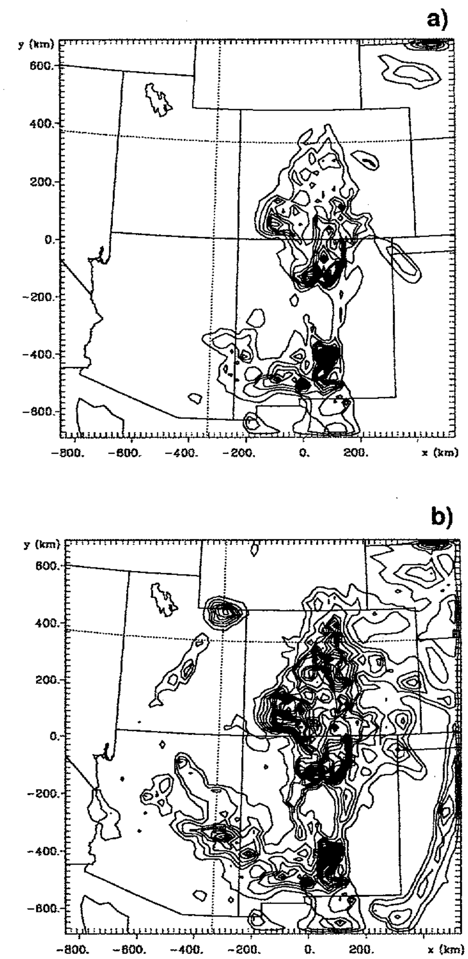

Figure 3. a) Accumulated total precipitation (mm) for July. Contours start from 10 mm with an increment of 10 mm. b) Accumulated precipitation for July and August. Contours start from 10 mm with an increment of 10 mm.

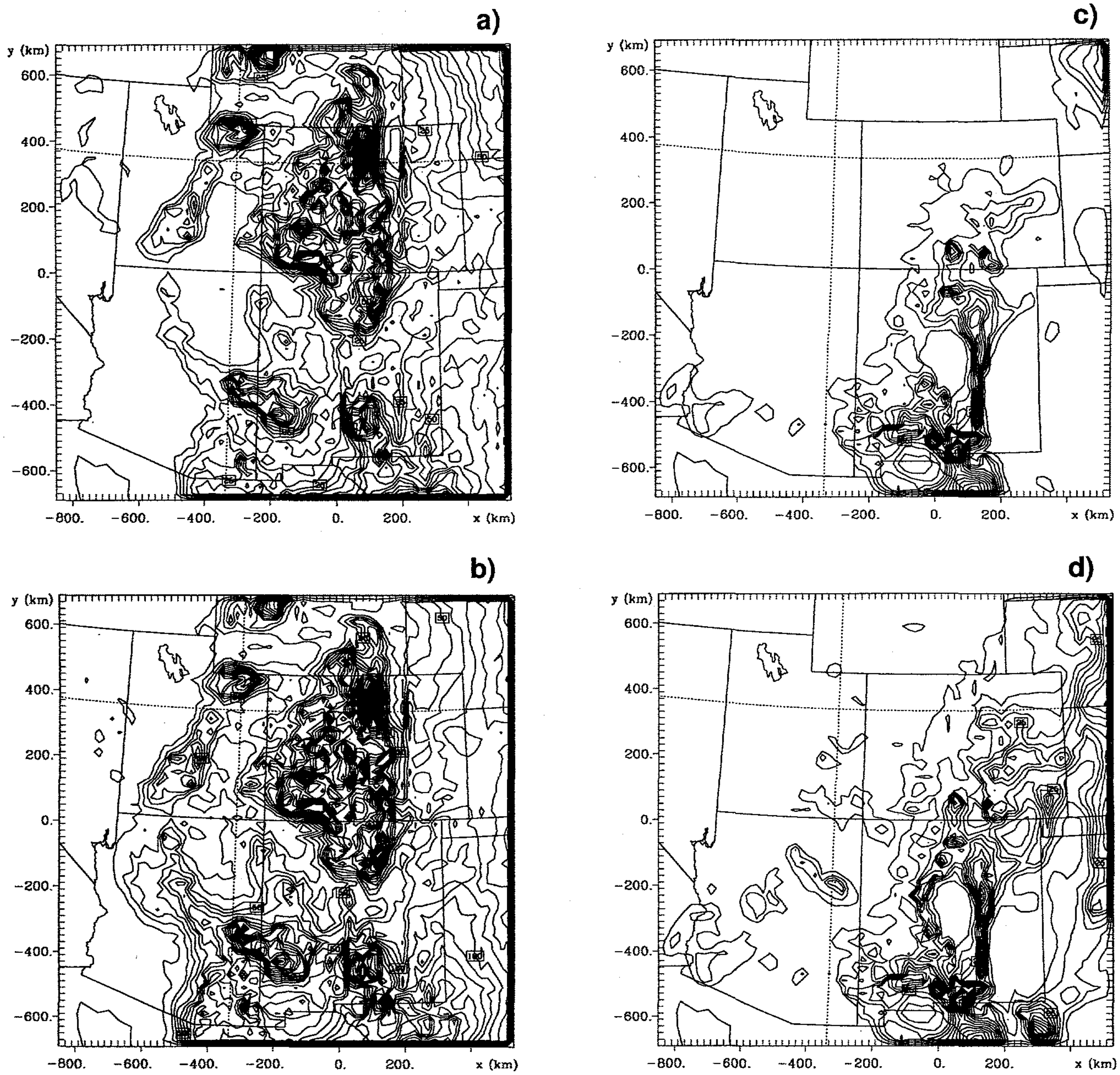

Figure 4. a) Accumulated convective precipitation (mm) for July in experiment 2. Contours start from 5 mm with an increment of 5 mm. b) Accumulated convective precipitation (mm) for July and August. Contours start from 10 mm with an increment of 10 mm. c) Accumulated non-convective precipitation (mm) for July. Contours start from 5mm with an increment of 5 mm. d) Accumulated non-convective precipitation for July and August. Contours start from 5 mm with an increment of 5 mm.

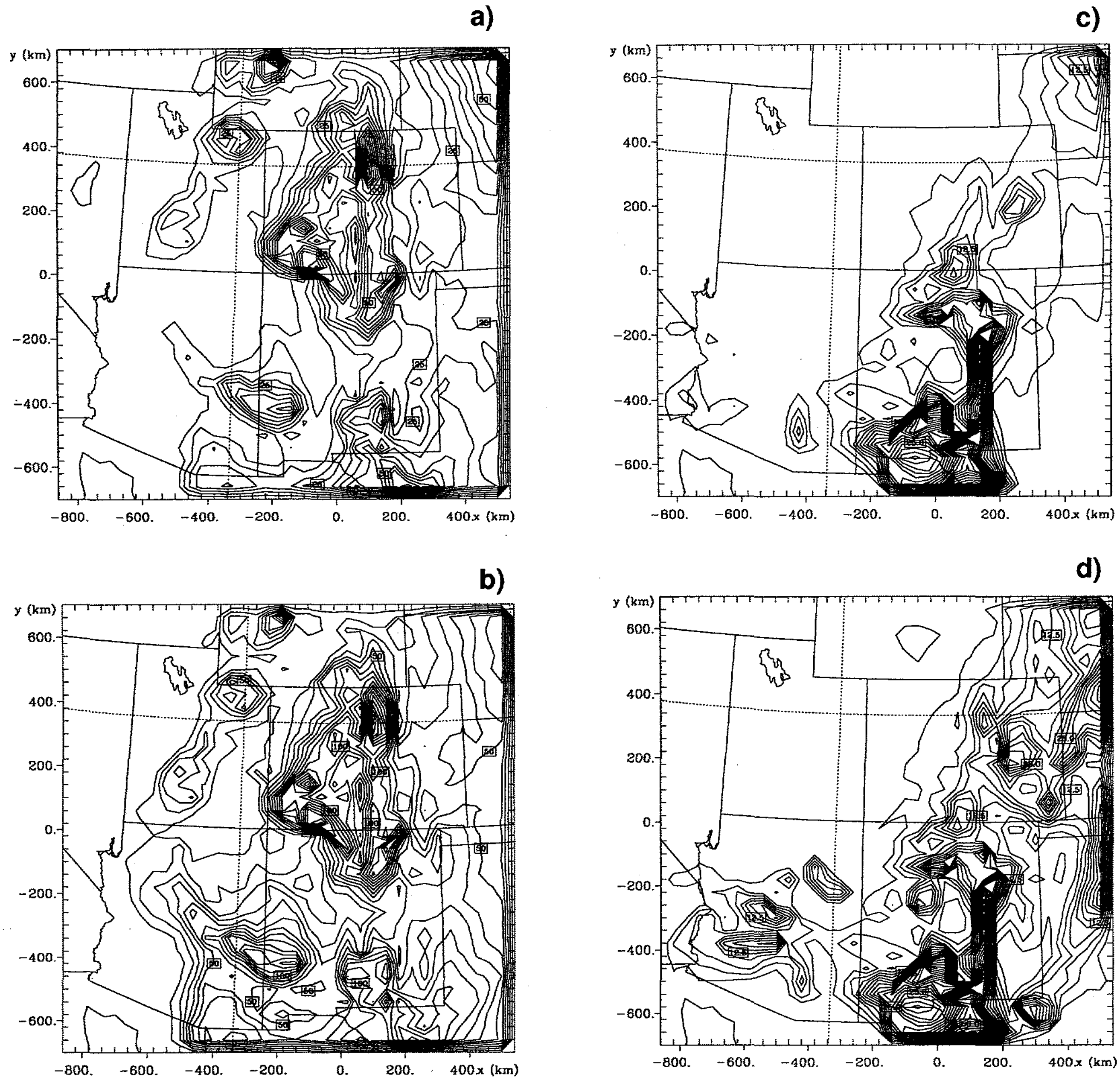

Figure 5: a) Accumulated convective precipitation (mm) for July in experiment 3. Contours start from 5 mm with an increment of 5 mm. b) Accumulated convective precipitation (mm) for July and August. Contours start from 10 mm with an increment of 10 mm. c) Accumulated non-convective precipitation (mm) for July. Contours start from 2.5 mm with an increment of 2.5 mm. d) Accumulated non-convective precipitation for July and August. Contours start from 2.5 mm with an increment of 2.5 mm.