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SIMULATIONS OF PRECIPITATION VARIABILITY OVER THE UPPER RIO GRANDE BASIN

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1. INTRODUCTION

The headwaters of the Rio Grande are located in the San Juan Mountains of Southwestern Colorado. It flows through semi-arid and arid lands in the states of Colorado and New Mexico and along the Texas/Mexican border on its journey to the Gulf of Mexico. Along the way, the Rio Grande provides an essential water supply for flora, fauna, and human populace in these areas. The city of Albuquerque also depends upon the Rio Grande for its sustainability. Although the city does not directly tap the Rio Grande for its water supply, the river is an important source of recharge to a shallow aquifer that does provide its water and the river is a possible resource for the future water needs of the city. The upper portions of the river are primarily fed by snowmelt from winter storms. In contrast, the lower portions of the river accumulate runoff from thunderstorms of the summer monsoon season. Thus, the waters of the Rio Grande are impacted by regional climate and could be vulnerable to climate change.

In this research, we study Albuquerque's water and how it may be affected by changes in the regional climate, as manifested by variations in Rio Grande water levels. To do this, we rely on the use of coupled atmospheric, runoff, and ground water models. Preliminary work on the project has focused on uncoupled simulations of the aquifer beneath Albuquerque and winter precipitation simulations of the upper Rio Grande Basin. The latter is discussed in this paper. In particular, we are simulating the spatial variability of precipitation in this region. We focus on the effects of the model horizontal resolution over the Rio Grande headwaters on the spatial variability of the predicted snowpack within complex terrain. The simulation results are compared to observations of daily precipitation obtained from cooperative network sites and SNOTEL data in the region. To examine the temporal variability, we are carrying out model simulations for the months of January 1996, which represents a dry extreme for the upper Rio Grande region and January 1993, representing a recent wet extreme.

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2. MODEL DESCRIPTION AND SETUP

The numerical model used to carry out the simulations of the atmospheric circulations is the Regional Atmospheric Modeling System (RAMS). RAMS was created from the merger of a non-hydrostatic cloud model (Tripoli and Cotton, 1980) and a hydrostatic mesoscale model (Mahrer and Pielke, 1977). A description of RAMS can be found in Pielke et al. (1992). For the simulations in this study, the model was run as non-hydrostatic and included a terrain following vertical coordinate system. The top boundary is a wall with a Rayleigh friction layer that damps vertically propagating gravity waves and reduces wave reflection. The lateral boundary conditions on the largest grid assume the Klemp-Wilhelmson condition. Solar and terrestrial radiative processes are parameterized as well as vegetation and soil processes and their influence on surface fluxes, temperature, and moisture. Precipitation processes are parameterized using a partial two moment microphysics scheme which includes eight water species (see Stalker and Bossert, 1998 for a description).

The simulations require the use of two-way interactive, nested grids. The largest grid is necessary to simulate the synoptic-scale flow features in the region. Grid 1 covers most of the western United States and parts of Canada and Mexico (Figure 1). Horizontal grid spacing on grid 1 is 80 km. Grid 2 contains the states of Utah, Arizona, Colorado, and New Mexico and has horizontal grid spacing of 20 km (Figure 2). Grids 1 and 2 both use a modified Kuo-type cumulus parameterization. In the simulation which employs higher horizontal resolution, 5 km grid spacing is used on a third grid. Grid 3 is located over the upper Rio Grande and includes San Juan, Sangre de Cristo, and Jemez mountain ranges of Southern Colorado and Northern New Mexico (Figure 3).

The RAMS simulations were initialized with gridded data derived form the National Centers for Environmental Prediction (NCEP) 2.5 degree gridded analysis. In addition, time-dependent fields were derived from the NCEP data for 4-dimensional data assimilation, where the model solution is nudged toward the observed fields.

3. DISCUSSION

Figure 4 gives the predicted total precipitation on grid 2 for the time period from 0000 UTC on 1 January 1996 through 1200 UTC on 31 January 1996. This month long simulation represents a month in the winter of

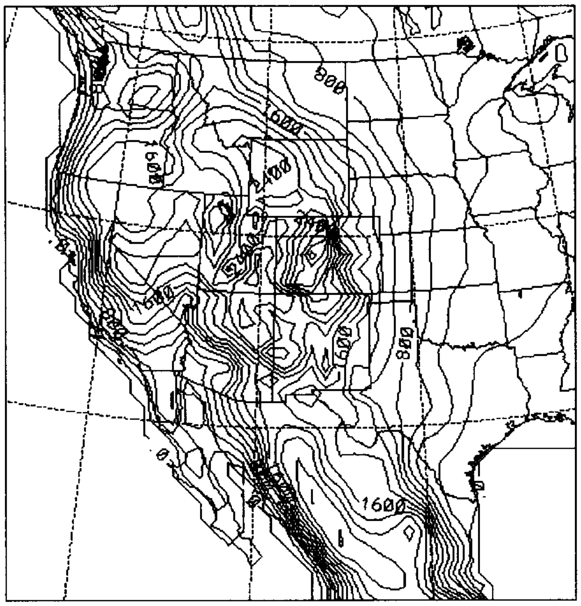

Figure 1. Topography on grid 1. Contour interval is 200 m.

1995-1996, a dry season in the area. Due to the length of this simulation, only two nested grids were incorporated in this run. The finest horizontal grid spacing in this run was 20 km and precipitation was calculated by the cumulus parameterization scheme. In general, higher precipitation amounts are predicted over higher topography, namely over the San Juan and Sangre de Cristo mountain ranges. Comparisons to the observed accumulated precipitation indicate that the model is doing a pretty good job of predicting the high precipitation areas in the central San Juan mountains and the Sangre de Cristo mountains near the Colorado and New Mexico border. However, it is not resolving some of

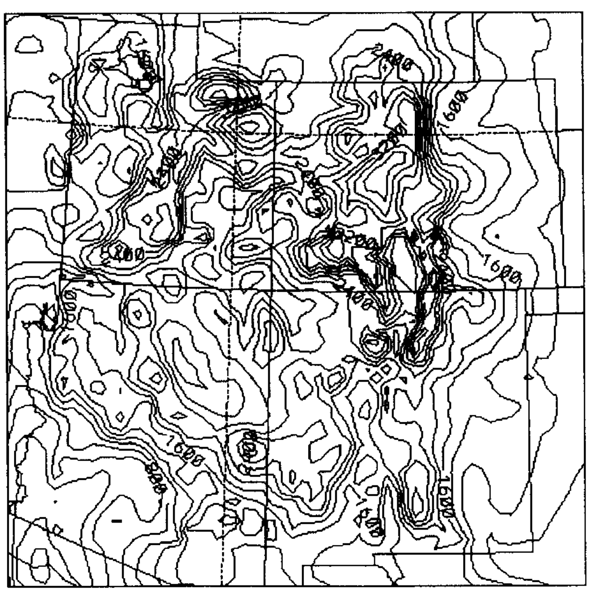

Figure 2. Topography on grid 2. Contour interval is 200 m.

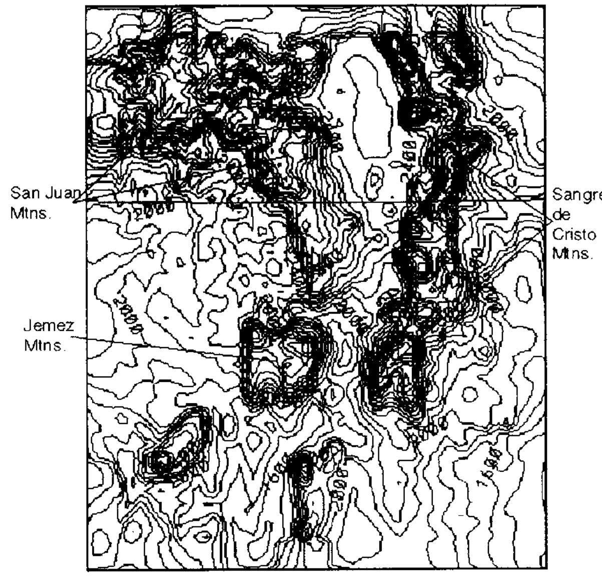

Figure 3. Topography on grid 3. Contour interval is 200 m.

the finer details of the observed precipitation field. In particular, the model underestimates precipitation in the southern Sangre de Cristo Mountains and in the Jemez Mountains.

Another model simulation was then run on a single, three-day precipitation event during this January case. The simulation actually began at 0000 UTC on 31 December 1995 because daily observations indicated that precipitation in the area began sometime on 31 December. A third grid was added to investigate the effects of model resolution on the predicted precipitation field. Figure 5 gives the accumulated total precipitation

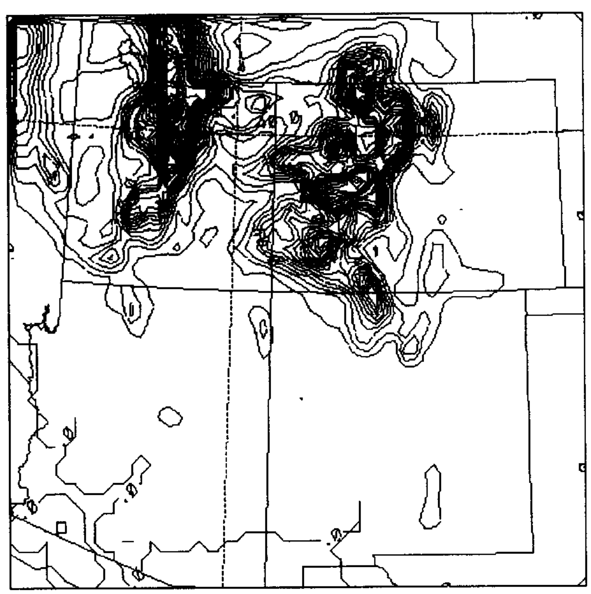

Figure 4. Total accumulated precipitation for January 1996 on grid 2. Contour intervals are approximately 10 mm.

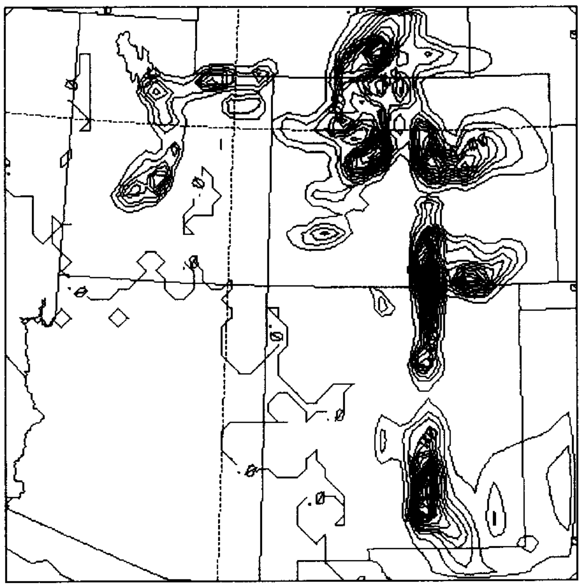

Figure 5. Total accumulated precipitation for 1-2 January 1996 on grid two of two-grid run. Contour interval is ~ 1 mm.

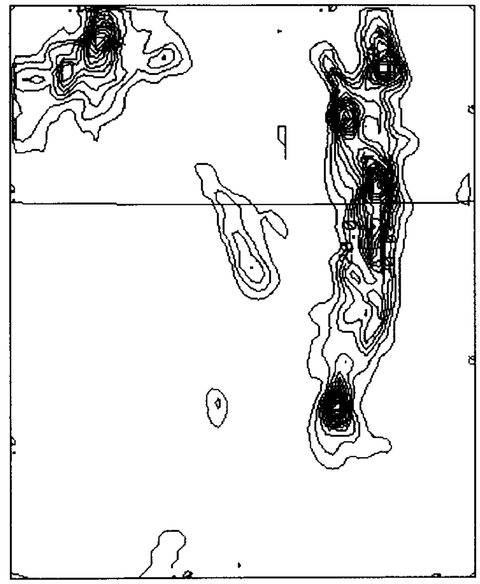

Figure 6. Total accumulated precipitation for 31 Dec 95 - 2 Jan 96 on grid three of three-grid run. Contour interval is ~ 5 mm.

on grid 2 after 48 hours in the previous simulation (the two-grid run). This can be compared to Figure 6, which gives the accumulated total precipitation on grid 3 after 72 hours for the simulation with three grids. Both plots are at 0000 UTC on 3 January 1996. The most obvious difference between the runs is the much larger precipitation amounts predicted by the three grid run (note the different contour intervals used in Figures 5 and 6). Even after taking into account the precipitation predicted by the three grid run for 31 December, the total precipitation is greater, especially in the Sangre de Cristo Mountains. For example, for the time period of 1-2 January, the three-grid simulation predicted a peak of approximately 72 mm in the northern Sangre de Cristo Mountains while the two-grid run predicted a peak of 20 mm. Peak observations were 38 mm. In the southern Sangre de Cristo Mountains, the three grid simulation produced a peak of 76 mm, while the two-grid run produced a peak of 7 mm. Observations were as high as 28 mm. Thus, the two-grid run appears to under predict precipitation totals in these areas while the three-grid run over predicts, but it should be pointed out that the observational data is sparse at the higher elevations.

Spatial variations in the precipitation totals also indicate differences between the runs. In general, finer structure can be seen in the higher horizontal resolution run. Both show relatively light precipitation from this storm in the area between the western and the southeastern San Juan Mountains, and the observations also show lighter accumulations there. A greater relative maximum in the precipitation field in northern New Mexico, south of the southeastern portion of the San Juan Mountains and a small maximum in the Jemez Mountains are predicted by the three-grid simulation. The two-grid simulation has a smaller maximum in northern New Mexico and does not indicate significant snowfall in the Jemez Mountains. The results of the three-grid run are supported by observations of 15 mm at a station in northern New Mexico and 15 to 17 mm in the Jemez mountains.

4. FUTURE WORK

To examine the temporal variability of the precipitation, this study is continuing with an additional simulation, at 20 km resolution, for the month of January 1993, which represents a recent wet extreme.

Future plans include the coupling of RAMS with runoff and ground water models. The coupled modeling system will run on the multi-processor computers available through the Accelerated Strategic Computing Initiative at Los Alamos. Running the modeling system on these machines will facilitate the use of greater than two interactive nested grids and better horizontal resolution.

Acknowledgments

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