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Title: Evaluation of Precipitation Predictions
in a Regional Climate Simulation

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1. INTRODUCTION

The headwaters of the Rio Grande are located in the San Juan Mountains of southwestern Colorado and the upper portions of the river are fed primarily 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 strongly influenced by regional climate and could be vulnerable to climate change. Given that precipitation and runoff in arid regions, including the Rio Grande basin, are low and exhibit significant variability, water resources in these areas are tenuous. Therefore, improved knowledge of the climate and hydrology and their variability is essential for optimum planning and management of water resources in the Rio Grande basin and other arid regions of the world. It is important to understand the entire hydrologic cycle, including the natural variability within the system, and to be able to explore the potential effects of increased use and of changes in the global and regional climate.

The research reported here is part of a larger project that is coupling a suite of environmental models to simulate the hydrologic cycle within river basins (Bossert et al., 1999). These models include the Regional Atmospheric Modeling System (RAMS), which provides meteorological variables and precipitation to the Simulator for Processes of Landscapes, Surface/Subsurface Hydrology (SPLASH). SPLASH partitions precipitation into evaporation, transpiration, soil water storage, surface runoff, and subsurface recharge. The runoff is collected within a simple river channel model and the Finite Element Heat and Mass (FEHM) subsurface model is linked to the land surface and river flow model components to simulate saturated and unsaturated flow and changes in aquifer levels. Our goal is to produce a fully interactive system of atmospheric, surface hydrology, river and groundwater models to allow water and energy feedbacks throughout the system.

This paper focuses on the evaluation of the precipitation fields predicted by the RAMS model at different times during the 1992-1993 water year. The evaluation includes comparing the model predictions to the observed precipitation as reported by Cooperative Summary of the Day and SNOTEL reporting stations.

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2. MODEL DESCRIPTION AND SETUP

The numerical model used to carry out the atmospheric simulations 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 nonhydrostatic and included a terrain following vertical coordinate system. 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. 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. Grids 1 and 2 both use a modified Kuo-type cumulus parameterization. A third grid uses 5 km grid spacing. Grid 3 is located over the upper Rio Grande and includes the San Juan, Sangre de Cristo, and Jemez mountain ranges of southern Colorado and northern New Mexico.

The RAMS simulations are initialized with gridded data derived from the National Center 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 weakly nudged toward the observed fields in the center of the domain. Stronger nudging is applied at the boundaries of the domain to specify the influence of synoptic conditions outside the model domain.

3. DISCUSSION

During the relatively wet month of January 1993 in the Rio Grande basin, the storm tracks tended to cross the southern tier of states. This is reflected in the observed total liquid equivalent precipitation plotted in Figure 1. While northern California received heavy pre-

January 1993

Observed total precipitation

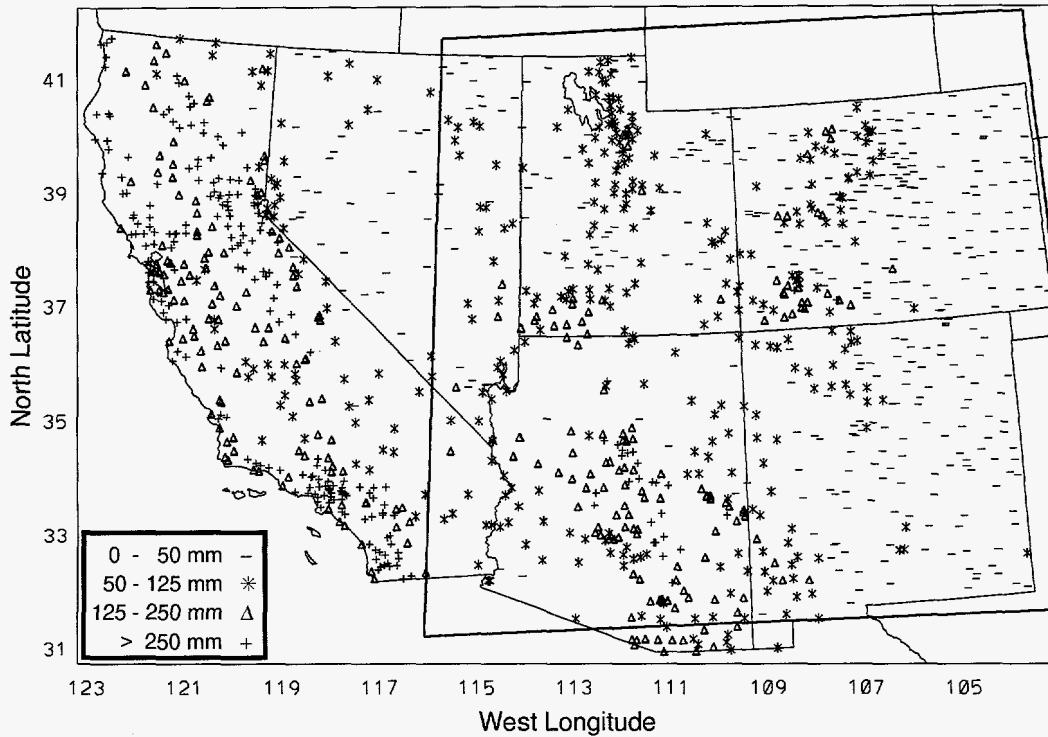


Figure 1. Observed total accumulated liquid equivalent precipitation during January 1993. Units are in mm.

precipitation during this month, precipitation totals in southern California are also high. Numerous stations in the California coastal ranges and in the Sierra Nevada mountains reported greater than 250 mm of precipitation for the month. The Wasatch Mountains and the Rocky Mountains of northern Colorado received less precipitation, with only a few stations reporting more than 125 mm and no stations reporting more than 250 mm. In contrast, the stations in Arizona, western New Mexico (especially in the Gila Mountains), and extreme southwestern Utah reported higher than normal precipitation. Many stations in Arizona accumulated more than 125 mm of precipitation and some stations, along the Mogollon Rim, reported more than 250 mm.

In the San Juan mountains of southwestern Colorado, a number of stations reported between 125 mm and 250 mm of precipitation, and one station reported greater than 250 mm. Several stations posted precipitation amounts between 50 and 125 mm in the San Juan Mountains (including the section that extends into north-central New Mexico). Elsewhere in north-central and northeastern New Mexico precipitation was lighter, generally less than 50 mm.

The results of preliminary RAMS simulations, with just the two largest grids, also reflect the influence of a southerly storm track during January 1993. Interpolating the RAMS precipitation fields to the observation sites (Figure 2), the RAMS totals are found to be similar to the

observations over a large part of the domain. The model predicts the relatively high precipitation found in northern California, but does not predict the greater than 250 mm amounts that were observed at a number of stations. The model also picks up the precipitation maximums in the southern mountains of Arizona and New Mexico. Only moderate amounts of precipitation were estimated in northern Colorado. Just as in the observations, light precipitation is indicated over the Great Plains. This is also evident in Figure 3, which presents the ratio of RAMS predicted total precipitation to the observed. Overall, the model compared well to the observations in much of the domain. Probably because the model resolution on grid 1 is coarse, the model underpredicts the heavy precipitation in southern California and some stations east of the Sierra Nevada and in mountainous areas are over-predicted. A few predictions that exceeded the observations by more than 50 percent are indicated in Colorado and Utah, where the model predictions are compared to stations located in narrow valleys that the model does not resolve.

4. CONCLUSIONS AND FUTURE WORK

In this study, the RAMS model has been successfully applied to produce regional climate simulations over the upper Rio Grande basin for January 1993. Although the model reproduces the gross features of the precipitation in the region, the runs with 20 km grid spacing do not

January 1993

RAMS total precipitation

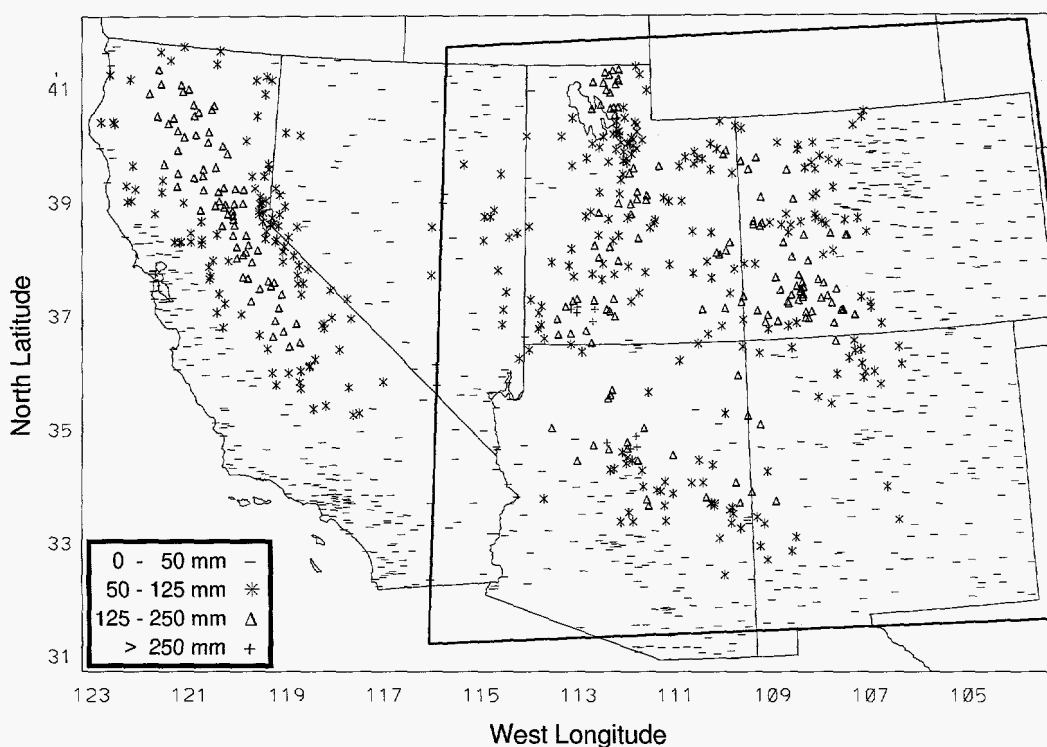


Figure 2. RAMS simulated total accumulated liquid water equivalent precipitation for January 1993. Units are in mm.

produce some of the finer spatial variations in the observed precipitation fields. However, this is not unexpected given the rigorous method used to compare point observations to the model predicted precipitation that is interpolated to the measurement sites. The comparison indicates that the month-long model simulations do not have sufficient resolution to resolve all of the horizontal variability found in the observations. In particular, precipitation at some valley locations tends to be overpredicted.

When results of a model simulation with 20 km grid spacing are compared to results of a simulation that includes a third grid with 5 km horizontal grid spacing, for a single, three-day precipitation event (not shown), increased resolution does appear to give better predictions. The improvements are modest over the Rio Grande basin as a whole. In general, in the San Juan Mountains, the RAMS predicted precipitation at valley stations decreases in the three-grid run to better reflect the observations. Therefore, we are currently using the three grid configuration of RAMS to carry out simulations through the 1992-1993 water year. The oral presentation will focus on the results with 5 km grid spacing.

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 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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January 1993

Ratio of RAMS to observed precipitation

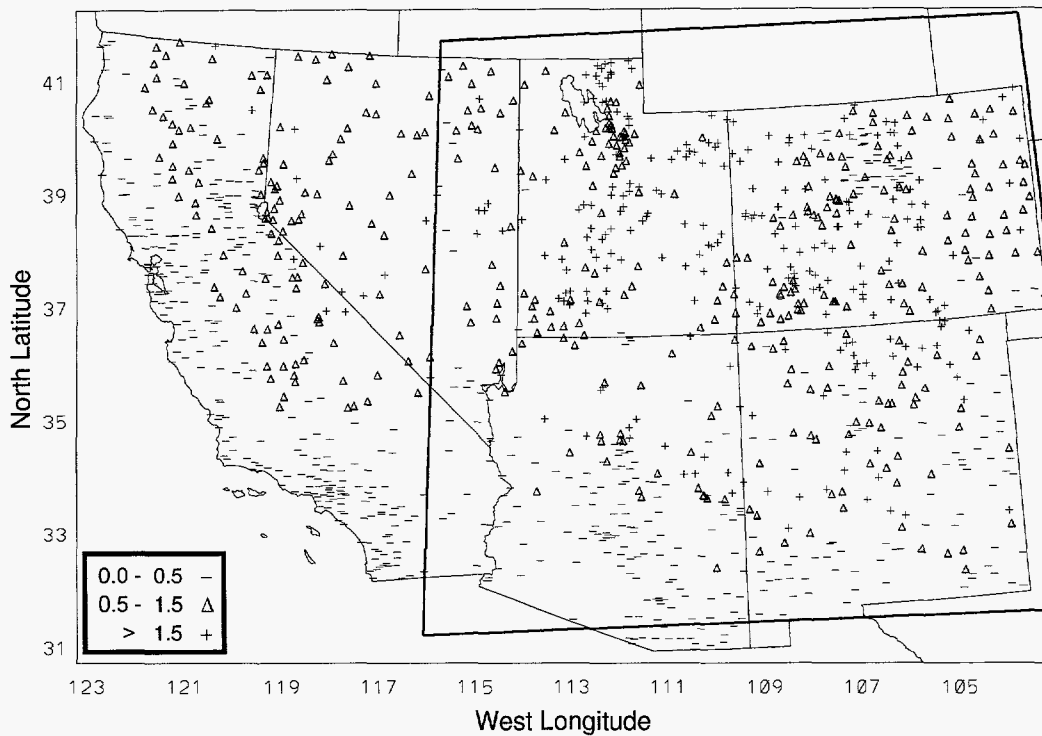


Figure 3. Ratio of RAMS predicted to observed total accumulated liquid water equivalent precipitation for January 1993.

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