J1.22 AN EVALUATION OF DOWNSCALING PREDICTED PRECIPITATION IN A COUPLED MODELING SYSTEM

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1. INTRODUCTION

With limited supplies and increasing demands for water resources, especially in arid and semi-arid regions, it is becoming increasingly important to understand the workings of the hydrologic cycle within river basins. A thorough understanding of the typical precipitation and runoff and the nature of the their variability is vital for planning the best use of these water resources. In the long term, all aspects of the hydrologic cycle affect the availability of water and it is therefore important to explore the entire cycle in order to understand the potential effects of increased water use and of changes in the regional climate.

To simulate water resources, we are coupling a series of existing and previously tested models that address the multitude of physical processes and temporal and spatial scales that are important (Bossert, et al., 1999). The modeling system (Figure 1) includes the Regional Atmospheric Modeling System (RAMS) (Pielke et al., 1992), which simulates regional climate and provides meteorological variables and precipitation to the Los Alamos Distributed Hydrologic System (LADHS), a land-surface hydrology model. The Finite Element Heat and Mass (FEHM) model (Zyvoloski et al., 1997) is being added to the system to include ground water in the simulations.

This modeling system is being applied to the upper Rio Grande Basin of Colorado and New Mexico. 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.

2. THE NEED TO DOWNSCALE

This paper focuses on the link between the atmospheric component of the coupled modeling system and the land-surface hydrology component by concentrating on the distribution of the RAMS precipitation fields onto the LADHS grid. This distribution is accomplished through the use of a downscaling algorithm.

The RAMS 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, some of the eastern Pacific Ocean, 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. Grid 3 (Figure 2) is located over the upper Rio Grande basin and includes the San Juan, Sangre de Cristo, and Jemez mountain ranges of southern Colorado and northern New Mexico. The third grid uses 5 km grid spacing.

The LADHS domain also covers the upper Rio Grande basin, occupying a subset of the area within the RAMS third grid. LADHS employs 100 m horizontal grid spacing, with precipitation and meteorological input data required at that resolution. Thus, one component of the coupled modeling system includes a method to downscale the RAMS predictions to the 100 m grid required by LADHS.

Keeping the technique simple, yet reflective of the influences of the complex topography in the area, downscaling is accomplished by a linear prediction model (the same model that underlies “kriging”). In the simplest case, with no elevation dependence, the variable as calculated by RAMS at the centers of the large-scale grid cells is interpolated smoothly to the centers of the small-scale grid under the control of an appropriate auto covariance model. The underlying model is a locally constant or planar surface plus a spatially auto correlated random effect (i.e., either the “ordinary” or “universal” kriging model). For variables with significant elevation dependence, elevation is treated as a second random effect, whose coefficient (the “lapse function”) satisfies a similar underlying model (Campbell, 1999). This technique allows for greater spatial variability and does not constrain total precipitation to be conserved within an area covered by a RAMS grid cell.

3. DISCUSSION

In earlier work (Costigan et al., 2000, 2001), we have presented evaluations of RAMS predicted precipitation to observations of snow water equivalent at SNOTEL

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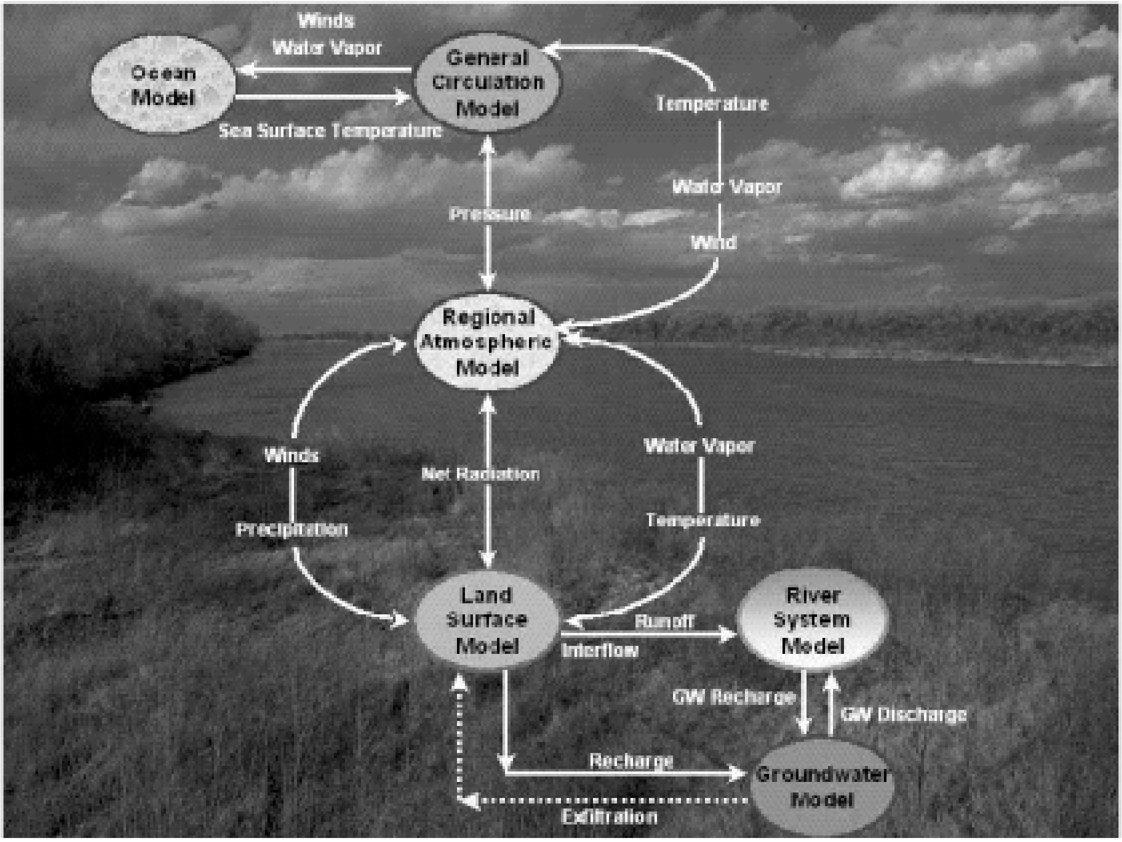

Figure 1. Data flow diagram of the coupled modeling system for simulating the regional water cycle.

and Summary of the Day Cooperative network sites, using a simple bi-linear interpolation of the predictions to the observation sites. This point comparison is rather severe for RAMS because a number of stations are affected by topography and very localized effects that the model does not resolve. It is hoped that the downscaling of the precipitation fields to the LADHS grid will improve the representation of the precipitation, because topography is a factor in the downscaling. This paper evaluates the precipitation fields, after they have been downscaled in LADHS. It compares the downscaled precipitation to the observed precipitation data and the RAMS precipitation from a simulation of the 1992-1993 water year.

Each 5 km by 5 km grid cell in the finest mesh of the RAMS simulation covers 2500 LADHS grid cells, with 100 m by 100 m horizontal dimensions. The comparisons in this paper look at RAMS total accumulated precipitation for the month of October in individual grid cells as compared to the mean precipitation, after downscaling, for the 50 by 50 LADHS grid cells that underlie the RAMS grid cell. Because the locations of most of the observing stations are only known to the nearest degree and minute of latitude and longitude, precise locations of the stations in the LADHS grid are not possible. Therefore, for the purpose of this comparison, we have identified two RAMS grid cells nearest to each of selected observation sites, and compared the RAMS predicted precipitation in those two grid cells to the observed precipitation. We also calculated the mean, standard deviation, minimum, and maximum precipitation of 278 averages over blocks of 3 by 3 grid cells, which make up the 2500 LADHS grid cells within each of the RAMS grid cells. The minimum and maximum precipitation totals in the LADHS cells, as well as the LADHS standard deviation, serve to bracket the mean value for comparison.

The selected observing stations were chosen to represent different regions of the upper Rio Grande basin. Unfortunately, very few SNOTEL sites were operational in 1992 so that most of the stations are located in valleys. The Lake City and Hermit stations are located in the San Juan Mountains. Lake City is just outside of the Rio Grande basin, but near the headwaters, and the Hermit station is in the Rio Grande Valley, close to the river. The town of San Luis is in the broad, relatively dry San Luis valley that is east of the San Juan Mountains. The Bateman station is in the southeastern extension of the San Juan Mountains that reaches into New Mexico. The town of Chama is on the Chama River, which is a major tributary that flows into the Rio Grande north of the Jemez Mountains. The towns of Jemez Springs and Los Alamos are in the Jemez mountains, with Los Ala-

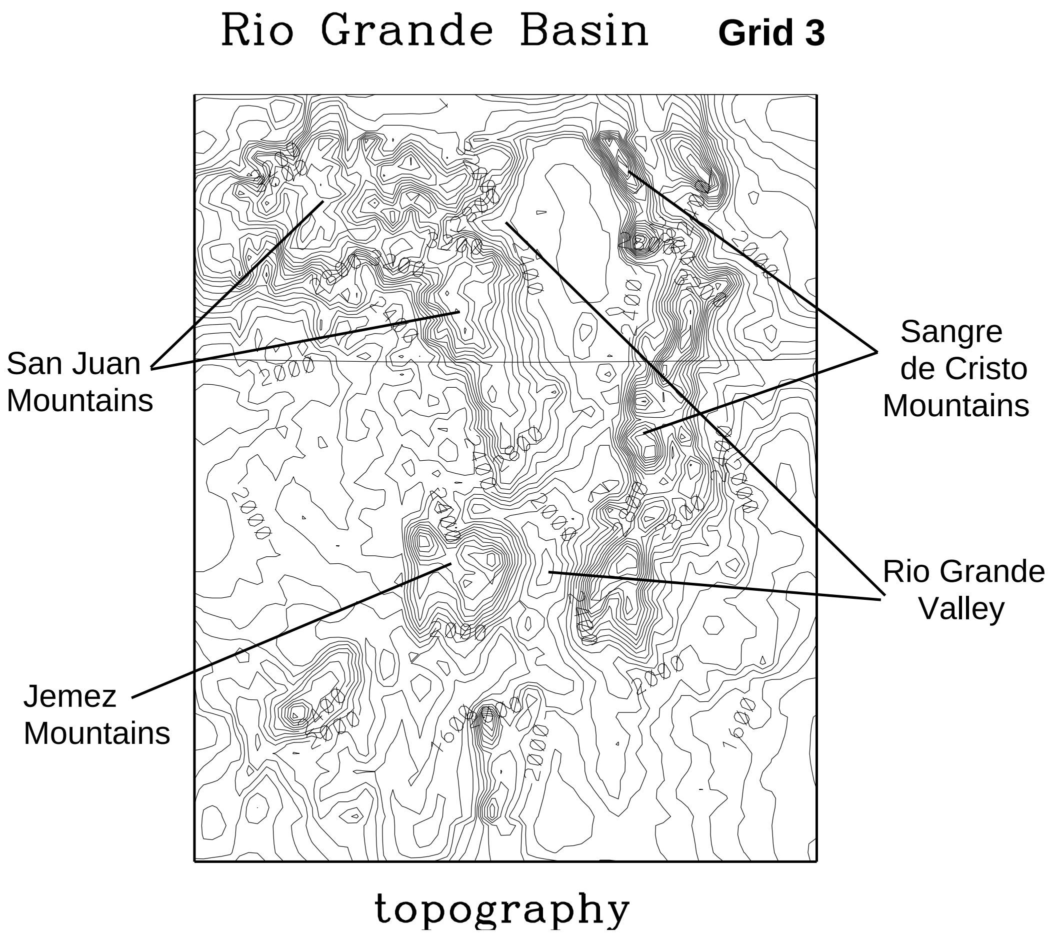

Figure 2. Topography on grid 3 of the RAMS simulation. Contour intervals are 100 m.

mos on the east side, where the plateau drains toward the Rio Grande, and Jemez Springs is nearer the center of the mountain range, on the Jemez River, another tributary. The city of Espanola and Cochiti Dam are located on the Rio Grande River, with Espanola just east of the Jemez mountains and Cochiti Dam farther to the south. Both the towns of Cerro and Red River and Gallegos Peak are in the Sangre de Cristo Mountains. Cerro and Red River are in northern New Mexico and Gallegos Peak is near the southern end of the Sangre de Cristo Range.

Table 1 gives the total accumulated precipitation for October 1992 observed at these stations, the RAMS predictions for two grid cells near the station, and the statistics of the downscaled precipitation within the RAMS grid cells. At some stations, the downscaled precipitation improved upon the RAMS predictions, but at a number of other stations, the downscaling produced dramatically different and worse results. For example, the observed precipitation at Chama, Cerro, and Gallegos Peak was within the range of values for the downscaled precipitation within one of the RAMS grid cells near those stations. However, the downscaling converted reasonable or underpredicted RAMS totals to zero at Los Alamos, Jemez Springs, Espanola, and Cochiti. At Bateman and San Luis, the downscaling greatly exaggerated the RAMS precipitation. Similar results are also found when storm event totals are examined, instead of monthly totals. However, early October was generally dry, leaving only a few events that were examined in this study. These events consisted primarily of a mixture of rain and snow.

An analysis of spatial variability of three regions within the basin, the San Luis Valley and the northern and southern Sangre de Cristo mountains, indicates that the spatial variability is increased after downscaling. Standard deviations of the precipitation on the LADHS grid are two to four times greater than the standard deviations on the RAMS grid.

We plan to investigate whether the results are similar for different types of precipitation events, such as winter storms or summer convection. The results of this study have led us to examine the downscaling technique more closely. In particular, we are investigating the how downscaled precipitation in a valley is affected by precipitation in higher topography near the valley and by grid boundaries.

Table 1: October 1992 Total Accumulated Liquid Equivalent Precipitation

Station	Observed (mm)	RAMS Grid Cell (mm)	LADHS Mean (mm)	LADHS Minimum (mm)	LADHS Maximum (mm)	LADHS standard deviation
Lake City	10.9	13.5	5.09	4.31	6.27	0.46
		14.9	3.16	1.93	5.13	0.74
Hermit	6.35	13.9	21.9	18.4	29.9	2.6
		14.2	19.9	15.3	29.1	3.44
San Luis	5.08	2.41	94.5	57.4	121	11.2
		1.21	33.2	15.6	54.7	8.92
Bateman	12.7	30.7	235	118	336	29.9
		22.8	77.4	36.8	174	30.7
Chama	10.4	10.9	18.8	9.27	41.2	5.68
		8.73	21.1	11.2	39.7	5.64
Los Alamos	15.0	7.63	0.00	0.00	0.00	0.00
		9.67	0.00	0.00	0.00	0.00
Jemez Springs	36.57	7.28	0.00	0.00	0.00	0.00
		4.89	0.00	0.00	0.00	0.00
Espanola	6.86	5.15	0.0	0.00	0.00	0.00
		4.24	1.10	0.19	11.1	1.9
Cochiti Dam	7.61	7.19	0.00	0.00	0.00	0.00
		7.73	0.00	0.00	0.00	0.00
Cerro	9.4	1.27	10.4	6.88	13.74	1.82
		1.74	4.78	4.54	6.44	0.46
Red River	15.2	4.54	28.1	22.5	33.8	2.65
		2.89	36.4	20.6	41.4	3.97
Gallegos Peak	25.3	3.57	18.6	1.62	49.9	14.2
		3.67	4.47	2.10	9.3	1.27

4. ACKNOWLEDGMENTS

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