9.4 THE EFFECT OF VARIOUS PRECIPITATION DOWNSCALING METHODS ON THE SIMULATION OF STREAMFLOW IN THE YAKIMA RIVER

Eric P. Salathé Jr.*
Climate Impacts Group (JISAO/SMA), University of Washington, Seattle

1. INTRODUCTION

Streamflow models are an important tool in assessing climate impacts on water resources by simulating the streamflow associated with climate change scenarios. Essential climate forcings are temperature and precipitation, which are required at high spatial resolution (0.125 degrees latitude and longitude). Climate models, however, are run at much coarser resolution (2 degrees) and do not resolve important mesoscale processes and surface features that control the regional precipitation.

In the Pacific Northwest, the surface orography creates dramatically different precipitation zones over the horizontal distance of one or two climate-model grid cells. In order to create precipitation fields appropriate to force a streamflow model, additional information must be added to the climate simulation to account for the mesoscale variations, using methods referred to as "downscaling". Various statistical methods for downscaling Pacific Northwest precipitation are proposed by Widmann, Bretherton, and Salathé (2002) to produce monthly-mean precipitation downscaled to a 50-km mesoscale grid. These empirical methods are based upon a daily 50-km gridded dataset of precipitation over Washington and Oregon (Widmann and Bretherton, 2000).

2. DOWNSCALING METHODS

Two downscaling methods from Widmann, Bretherton, and Salathé (2002) will be presented here. These are a local scaling and a dynamical scaling of the large-scale precipitation field. Each method represents monthly-mean precipitation as the product of the large-scale precipitation and a scaling factor that is resolved on the mesoscale grid. For the purposes of this study, large-scale precipitation is taken from the NCEP reanalyses. The precipitation is entirely model-generated from a observation-based depiction of the atmospheric conditions. The period 1958-1976 is used to derive fitting parameters for the period 1977-1992, while the second period is used to derive parameters for the first.

In the local scaling method, the scaling factors are fixed for each season and are simply the ratio of the climatological seasonal mean observed and model precipitation at that grid point. Figure 1 shows the monthly-mean NCEP large-scale (upper left) and observed mesoscale precipitation (upper right) fields for January 1992. The lower left panel shows the scaling factors for the December-January-February season (DJF). The lower right panel is the locally-scaled precipitation for January 1992, and is simply the product of the upper and lower left panels.

In the dynamical scaling, the effect of atmospheric circulation is taken into account and the scaling factor depends also on the monthly-mean 1000-hPa heights. On the East side of the Cascade range, the small amount of precipitation that does occur is highly dependent upon the atmospheric circulation, which modulates how much moisture can be carried past the mountains. The leading mode of variability in 1000 hPa heights, as revealed by EOF analysis, is a modulation of the mean southwesterly onshore flow between a more westerly and a more southerly phase. The first phase is associated with drier-than-average conditions east of the Cascades while the more southerly phase allows more precipitation to the rain shadow.

Figure 2 shows the correlation of the downscaled monthly-mean precipitation for the two methods with the observations during the period 1958-1992. The upper left is for the local scaling, the upper right is for the dynamical scaling. The dynamical scaling produces a significant improvement in the result over the dry region in the lee of the Cascades, indicating a strong control of the precipitation distribution due to circulation patterns.

3. STREAMFLOW SIMULATIONS

In mountainous regions, where there is considerable storage in snowpack, streamflow is determined both by temperature, which controls melting, and precipitation, which affects the total available water and also directly controls streamflow when the precipitation falls as rain. In order to isolate the effects of precipitation, streamflow simulations for the Yakima River made with observed temperature and various precipitation data for the period 1958-1993 using the Variable Infiltration Capacity (VIC) hydrology model (Liang *et al.*, 1994) implemented at 0.125-degree resolution.

*Address: Box 354235, Seattle WA 98195. salathe@atmos.washington.edu

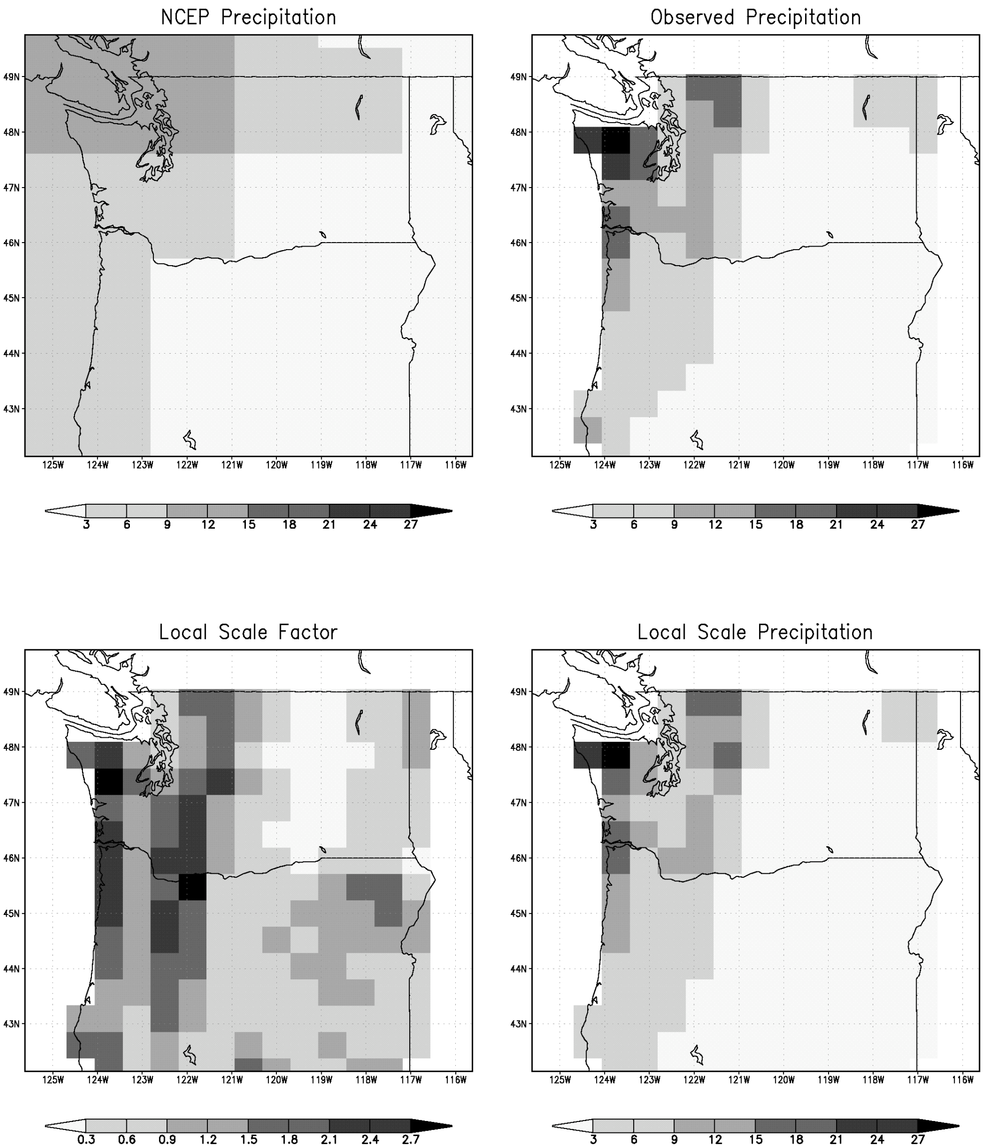

Figure 1. Upper panels: Precipitation for 1JAN1992 from NCEP reanalysis (left) and observations (right). Lower left: Local scaling factor for DJF. Lower right: Locally scaled precipitation for 1JAN1992

The Yakima Basin is on the East side of the Cascade Range. Flow in this basin has two principal seasonal maxima, one due to melting of the high-altitude snowpack during early summer and a second due to rainwater in late fall.

To evaluate the down-scaling methods, comparisons are made among simulations using observed precipitation, downscaled precipitation using the two methods described above, interpolated NCEP precipitation, and cyclic observed climatological mean precipitation. To generate daily precipitation from the downscaled monthly-means, the daily NCEP precipitation is interpolated to each grid point, normalized by its monthly mean, and multiplied by the downscaled monthly-mean. Thus, the daily variability comes from the NCEP analyses while the mean is taken from the downscaling.

Figure 3 shows the total water-year flow during the simulation period. After the first few years where the hydrology model is spinning up, the downscaled precipitation datasets yield interannual variability that captures the main observed features. The interpolated

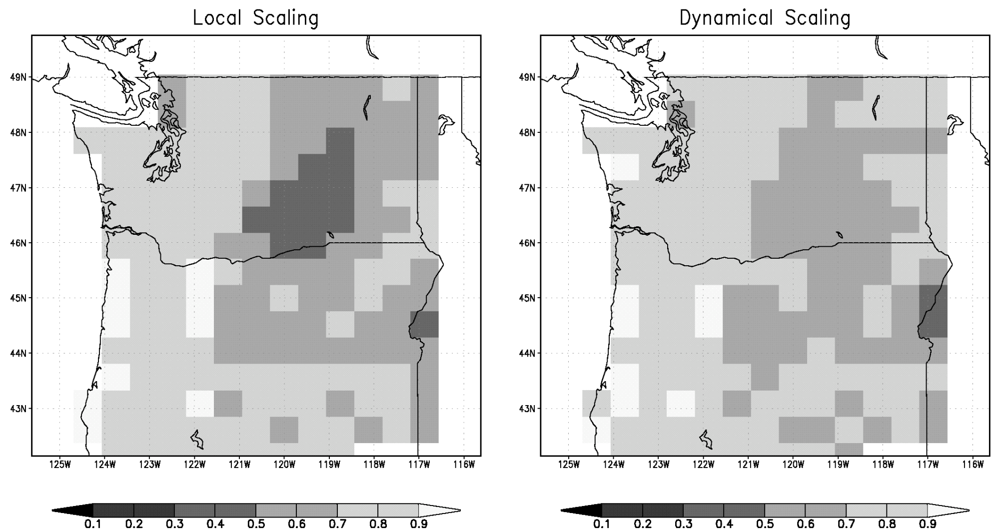

Figure 2. Correlation of downscaled precipitation time series at each grid point to observations for local scaling (left) and dynamical scaling (right) methods.

NCEP precipitation, in addition to yielding too little flow, does not capture much of the observed interannual variability missing, for example, the increased flows during 1966-68. Thus, downscaling is essential even in order to capture flow variability at interannual time scales. The two downscaling methods give indistinguishable results for annual flow.

By examining the flow on a monthly scale, the details of the interannual variability are revealed. Figure 4 shows the period 1974-1978 where there is strong interannual variability. Variability in the simulation with climatological precipitation is due to interannual variations only in temperature, thus changes relative to the dotted line are due to differences in the precipitation datasets. During this period, the downscaling methods both capture the monthly variability quite well. The NCEP precipitation, in addition to a consistent dry bias, does not capture some of the significant seasonal features. For example, there is significant rain-driven flow in the fall of 1975 and of 1977, as compared the previous year. The NCEP precipitation does not capture this feature, which is well represented by simulations using precipitation from either downscaling method.

4. CONCLUSIONS

These simulations illustrate how local scaling, a very simple and efficient statistical downscaling method, is able to capture all the essential precipitation features required for accurate simulation of flow in the Yakima River. The Yakima is in the dry rainshadow of the Cascades, and is subject to precipitation variability that is connected to the large-scale winds, as indicated by the results of Figure 2. Nevertheless, the quality of information needed to perform hydrologic simulations does not evidently require such detail.

Secondly, it is clear that statistical downscaling can accomplish more that remove a uniform bias in a large-scale model simulation. The redistribution of water, implied by the scaling, can profoundly effect the hydrograph. Without downscaling, such significant a feature as rain-driven fall flows cannot be simulated with the NCEP precipitation. The large-scale precipitation, however, does provide the interannual and interseasonal information needed to capture these features once it is scaled at high spatial resolution.

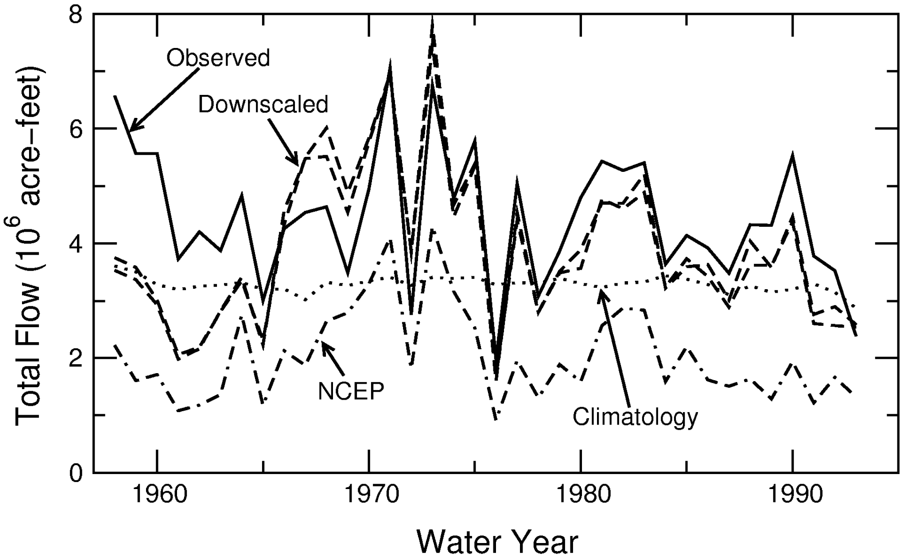

Figure 3. Total water-year flow simulated for the Yakima River. Various precipitation datasets and observed temperature are used for the simulation.

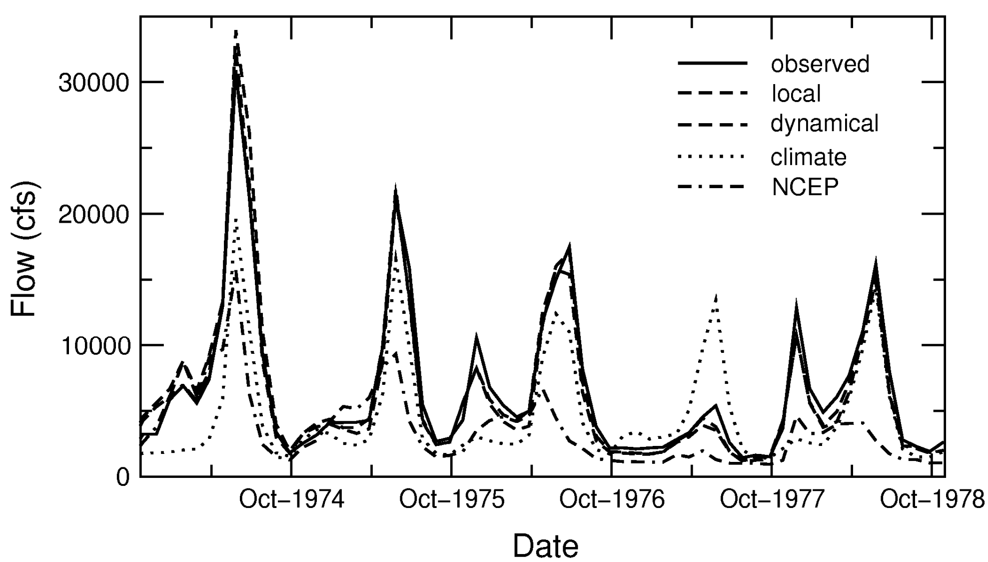

Figure 4. Monthly-mean flow simulated for the yakima river as for figure 3.

5. REFERENCES

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