5.1 OROGRAPHIC ENHANCEMENTS IN PRECIPITATION: AN INTERCOMPARISON OF TWO GAUGE-BASED PRECIPITATION CLIMATOLOGIES

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1. INTRODUCTION

Accurate documentation of terrestrial precipitation climatology is very important for many meteorological and hydrological applications. A number of such long-term mean data sets have been constructed through objective analysis of gauge observations (e.g. Legates and Willmott 1990, Rudolf 1993; Chen et al. 2002), and, in some cases, taking into account related topographic information (Daly et al. 1994; New et al. 1999). While most of these data sets present very similar spatial distribution patterns of precipitation over land, differences exist in smaller scale features and in magnitude, especially over mountainous areas (Chen et al. 2002).

In this study, an intercomparison is conducted between two gauge-based precipitation climatologies, the PRISM of Daly et al. (1994) and the PREC/L of Chen et al. (2002), to examine how orographic enhancements in precipitation may impact the quantitative accuracy of the interpolated precipitation fields over mountainous areas.

2. THE PRISM AND PREC/L DATA SETS

In the PRISM (Daly et al. 1994), the monthly precipitation climatology is calculated from grid point elevation via a rainfall – elevation relationship. The relationship is established empirically for each calendar month and for each hillside of a mountainous region by local comparisons. A relatively dense gauge network is therefore required to ensure stable quality and fine spatial representativeness of the analyzed precipitation fields. The PRISM climatology, available for United States and several other regions, is widely regarded as one of the best precipitation climatologies, especially within the hydrological community.

In the PREC/L (Chen et al.. 2002), monthly climatology at a grid point is defined by an inverse-distance interpolation (Shepard 1968) of gauge observations. Long-term mean monthly precipitation data at over 17,000 stations, collected from the GHCN Version 2 data set of NOAA/NCDC and the CAMS data set of NOAA/CPC, are used to define the gridded fields of monthly climatology over global land areas. No orographic considerations, however, are included in the interpolation.

3. COMPARISON RESULTS

First, the PRISM and PREC/L mean precipitation fields are compared on a 0.5^{o} lat/lon grid over the United States (fig.1). While good agreements in both quantitative magnitude and

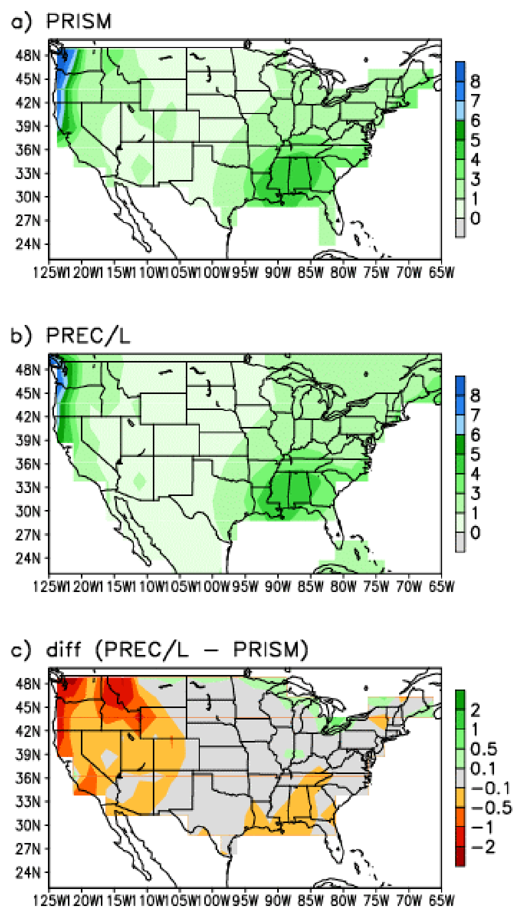

Fig. 1: Annual mean precipitation (mm/day) over the United States as defined in the PRISM (top, Daly et al. 1994), the PREC/L (middle, Chen et al. 2002), and the differences between them (bottom).

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spatial distribution patterns are observed between the two climatologies over areas with flat terrain, significant underestimates are reported in the PREC/L compared to the PRISM over the mountainous areas in the western United States.

The differences shown in fig.1 are then examined quantitatively and related to the topography over the western United States. Fig.2 shows the scatter plots between the precipitation differences and the elevation over 0.5^o lat/lon grid boxes over a selected area in the northwestern United States. The differences between the PRISM and the PREC/L are relatively stable when the grid box elevation is under 800m but they tend to increase as the elevation goes up. This implies that the differences between the two climatologies are related to the differences in the manner in which orographic effects are handled.

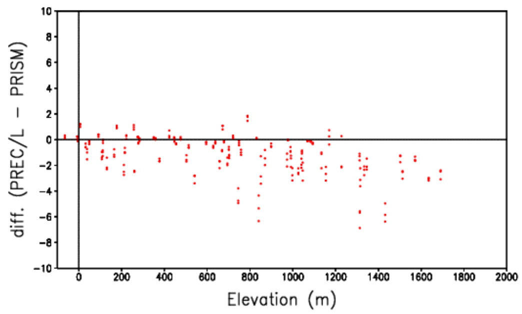

Fig. 2: Scatter plots between the PREC/L ~ PRISM differences (mm/day) and the grid box elevation (mm) over the northwestern United States [45^{o}N-49^{o}N; 129^{o}W – 120^{o}W].

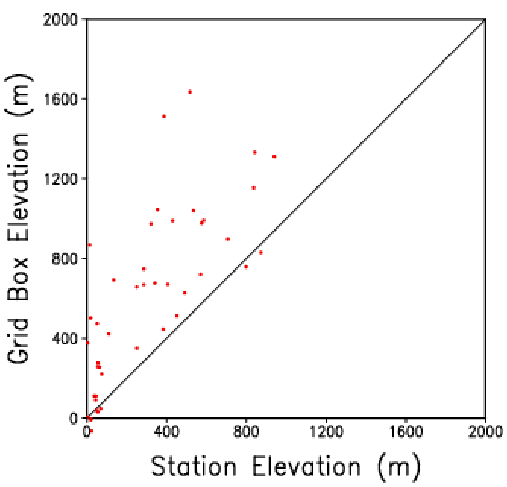

Fig. 3: Scatter plots between the mean elevation over a 0.5^o lat/lon grid box and that for the gauge stations used in the definition of the PREC/L.

Presented in fig.3 are scatter plots between the mean elevation over a 0.5^o lat/lon grid box and that over gauge stations for which the monthly gauge observations are used to define the PREC/L climatology. The stations used in the definition of our PREC/L tend to be located in lower elevations in a grid box, indicating that bias may exist in our PREC/L if there is systematic relationship between the precipitation and elevation.

4. RAINFALL – ELEVATION RELATIONSHIP

To understand if and how precipitation is influenced by topography, the relationship between the monthly station precipitation climatology and station elevation is examined statistically using the GHCN Version 2 data set. Shown in fig.4 are scatter plots between the station climatology of monthly precipitation and station elevation over the selected mountainous area in the northwestern United States for the 12 calendar months.

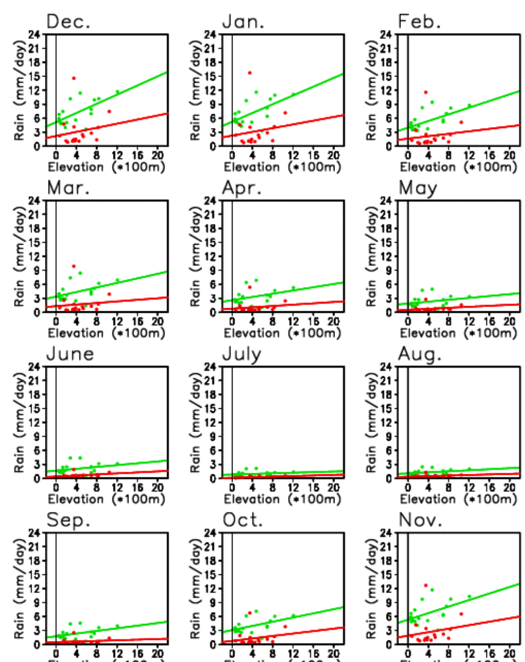

Fig. 4: Scatter plots between the monthly climatology of station precipitation (mm/day) and station elevation over a mountainous area in the northwestern United States [45^{o}N-49^{o}N; 129^{o}W-120^{o}W]. Solid lines represent best linear fittings between the two variables. Results for stations over the west and east sides of a mountain are plotted in green and red, respectively.

Overall, more precipitation is observed over the windward (west) hillside than over the leeward (east) hillside. The amount of mean precipitation tends to increase with the elevation linearly on both sides of the mountains. The slope of the linear regression between the precipitation and the elevation, or the rate of precipitation enhancements with per unit change in elevation, however, differs for different hillsides and for different calendar months.

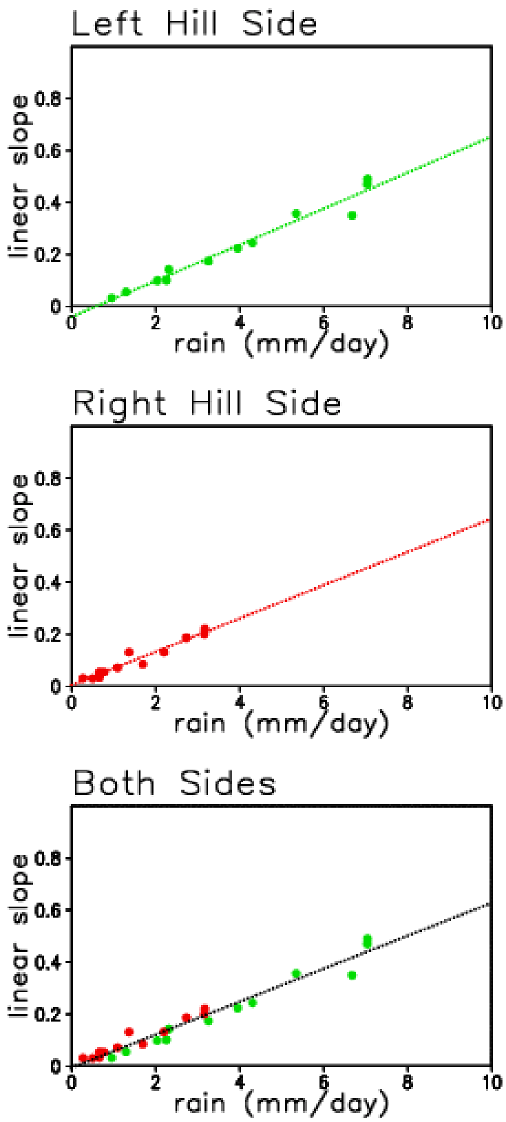

Fig. 5: Scatter plots between the slopes in linear regression in fig.4 and the mean station precipitation for the windward (top), leeward (middle), and both (bottom) of the hillsides. Each dot here presents a pair of slope and mean station precipitation over one side of the hill for a calendar month.

The rate of orographic enhancements in precipitation (the slope in fig.4), however, can be expressed very well as a linear function of the mean precipitation over the region regardless of season and location relative to the mountain ridge (fig.5).

The existence of this linear relationship is confirmed for all other mountainous regions for which the precipitation – relationship is examined in this study. The coefficients (slopes and cutoffs in fig.5), however, differ regionally.

4. SUMMARY AND FUTURE WORK

The preliminary results of this study indicate that the underestimates of the precipitation in the PREC/L climatology are caused primarily by the lack of a procedure to account for orographic enhancements in precipitation and that improvements are possible by making use of the quantitative relationship between the precipitation and elevation.

Further work is underway to investigate how the linear relationship between precipitation enhancement and elevation changes over various regions and if or not it is possible to approximate the changes as a function of large-scale parameters so that a PRISM-like technique can be applied easily to improve the quality of the gauge-based precipitation analyses over various parts of the global land areas.

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