5.3 APPLICATION OF PRISM CLIMATOLOGIES FOR HYDROLOGIC MODELING AND FORCASTING IN THE WESTERN U.S.

John Schaake*, Art Henkel and Shuzheng Cong
Hydrology Laboratory, Office of Hydrologic Development
National Weather Service, NOAA, Silver Spring, Maryland

1. INTRODUCTION

Results of an evaluation of the technique currently used in the National Weather Service River Forecast System (NWSRFS) to analyze precipitation in mountainous areas is presented. The same technique also is used at the National Centers for Hydrologic Prediction (NCEP) for daily precipitation analysis for the Land Data Assimilation System (LDAS) and for daily precipitation analysis for the regional reanalysis. This technique, known as "Mountain Mapper" uses PRISM precipitation climatologies to assist the spatial analysis of gage precipitation amounts. In the NWSRFS this technique is applied to daily and to 6-hr precipitation amounts.

The evaluation procedure used for this study estimates daily precipitation amounts at gaged locations and compares the results to the gaged amount. This estimate is also compared to precipitation estimates made without considering orographic effects. The results show that the Mountain Mapper approach is clearly better than not using it at all. Some suggestions on how to improve the approach using forecasts from an atmospheric model and using simplified approximations to atmospheric models will be discussed.

2. MOUNTAIN MAPPER TECHNIQUE

The mountain mapper technique uses an inverse distance weighting approach to estimate precipitation at ungaged locations from values at gaged locations while taking into account the climatology of precipitation at the gaged and ungaged locations. If the precipitation climatology at the gages and at the ungaged location to be estimated are the same, then a simple inverse distance estimate can be made using:

----

* Corresponding author address: John Schaake, NWS/NOAA, Office of Hydrologic Development, OHD12, 1325 East_West Highway, Silver Spring,MD 20910; e-mail: john.schaake@noaa.gov

$$Y = \sum_{i=1}^{n} W_i X_i \,/ \sum_{i=1}^{n} W_i \qquad (1)$$

where X_i is the amount at gage i, i=1,n, and

$$W_i = 1 \,/\, d_i^m \qquad (2)$$

and d_i is the distance from the point to be estimated and gage i. The exponent, m, is equal to 2 for inverse distance squared weighting, as used in this study.

To account for the effects of variable climatology of precipitation owing to orographic or other causes, consider the variables

$$F_Y = Y \,/\, \overline{Y} \qquad (3)$$

and

$$F_X = X \,/\, \overline{X} \qquad (4)$$

that represent precipitation as a fraction of normal. The mountain mapper procedure interpolates fractions of normal using

$$F_Y = \sum_{i=1}^{n} W_i F_{X_i} \,/ \sum_{i=1}^{n} W_i \qquad (5)$$

and then estimates precipitation from the estimataed fraction of normal using

$$Y = F_Y \overline{Y} \qquad (6)$$

3. ANALYSIS STRATEGY

The main objective of this analysis is to show that it is better to use the mountain mapper procedure to account for precipitation climatology when interpolating precipitation amounts in mountainous areas than to ignore it. Moreover, if there is little or no variation in precipitation climatology, then we also want to demonstrate there is no reduction in accuracy of the analysis if it is considered anyway. Values of $\overline{X}$ can be estimated from gage observations, but values of $\overline{Y}$ are unknown and must be estimated. In this study estimates of values of both $\overline{X}$ and $\overline{Y}$ are taken from the 1961-1990 mean monthly PRISM precipitation climatology (Daley, 1994).

A number of precipitation gage locations where precipitation is affected by orography in both the east and the west were chosen for the analysis. The basic strategy is to withhold the observed gage amount and to estimate the amount using both the mountain mapper procedure (Eqs 5 and 6) as well as the original inverse distance procedure (Eqs 1 and 2). Daily values are estimated with both procedures and resulting estimation statistics are compared. A location not affected by orography also is included in the analysis.

It might be expected that the mountain mapper technique might not work very well when applied to daily data because of the intermittent nature of daily precipitation. Accordingly, one of the verification statistics considered is the proportion of wet days estimated to occur as compared to the number of wet days observed to occur.

The analysis was designed to focus on point estimates for NCDC COOP and SNOTEL gages. Surrounding gages were used to estimate point precipitation at gages not used in the analysis. Analyses were made for the following mountain and non-mountain locations:

a. Beltsville, MD - Eastern non-mountain (1961-1990)
b. Canaan Valley, VA - Appalachian mountains (elevation 989m) (1961-1990)
c. Wolf Creek Pass, CO - Rocky mountains (elevation 3243m) (1987-1999)
d. Berthoud Summit, CO - Rocky mountains (elevation 3444m) (1987-1999)
e. Spud Mountain, CO - Rocky mountains (elevation 3249m) (1987-1999).

At each of these locations, estimates were made using:

a. Only NCDC COOP gages
b. Only SNOTEL gages (in west)
c. Both NCDC and SNOTEL gages (in west)

4. 4. ANALYSIS RESULTS

Annual results of the analyses at each location are given in Table 1. In these analyses only NCDC gage data were used to make the estimates.

At Beltsville there is no orographic effect and the 30-year gage climatology agrees well with the PRISM value. The analysis results agree well with the gage average as well. Including the mountain mapper procedure had no practical effect on the analysis.

At Canaan Valley, there is an orographic effect but not as strong as in the west. The annual PRISM value is 1.5 percent higher than the observed annual mean for 1961-90. Estimates from nearby gages without using PRISM were about 5 percent low. Estimates using PRISM were within about 2 percent.

At Wolf Creek Pass there are 2 precipitation gages located near each other. One is an NCDC gage. The other is a SNOTEL gage. The precipitation climatology is different at the 2 gages, but the gages are so close that the climatology of the estimates is the same. Note in Table 1 that the PRISM annual climatology is lower than both NCDC and SNOTEL annual values. Although the mountain mapper estimates using PRISM are close than the untransformed estimates that do not use the PRISM climatology, the mountain mapper results are closer to the PRISM climatology than to either the NCDC or SNOTEL climatologies.

Similar results to those for Wolf Creek Pass were found for Berthoud Summit and Spud Mountain gages. In each case the mountain mapper results were better than the untransformed estimates. But the PRISM estimates were less than the observed annual average. The mountain mapper estimates were close to the PRISM estimates than to the observed average values.

To illustrate how the accuracy of the mountain mapper estimates may vary seasonally, more detailed analyses are presented for Wolf Creek Pass. Figure 1 shows how the average bias (estimated/observed ratio) varied from month to month when only NCDC data are used in the analysis. The effect of orography is much stronger in winter than in summer. Including the PRISM climatology in the mountain mapper analysis reduced the bias in all months. Figure 2 shows the average bias when both NCDC and SNOTEL gage data are used in the analysis. When PRISM climatolgies are not used in Figure 2, the addition of SNOTEL data is shown to reduce the bias in the Wolf Creek estimates. But when PRISM data are used in the analysis the bias of Wolf Creek estimates is essentially the same as when only the NCDC data are used. This suggests that the PRISM data have successfully removed much of the bias in the estimates and that the remaining bias may be due to limitations in the PRISM climatology at the Wolf Creek gage location.

Figures 3 and 4 present the accuracy, expressed in terms of Nash-Sutcliffe Efficiency, of Wolf Creek estimates using mountain mapper for different precipitation durations from 1 to 32 days. In both figures, the accuracy improves with the duration of the estimate. But the accuracy of short duration (1-3 days) estimates are improved when SNOTEL data are used in the analysis. There is little difference in the accuracy of 32 day estimates. Two curves are shown in each figure. These correspond to different definitions of the reference variance used to compute the Nash-Sutcliffe efficiency. The lower curves, labeled (2), use the variance of the observed precipitation about the mean as the reference variance. The upper curves, labeled (1), use the total variance about the origin, including the variance associated with the mean, as the reference variance. Option (1) is included here because the mean is highly variable in mountainous regions and the estimation problem involves estimating both the mean and variations about the mean as well.

Figure 5 shows that estimates of daily precipitation at Wolf Creek include too many wet days (POP) as compared to what actually occurs. The problem is greater in summer than in winter but most of the precipitation occurs in winter. It was expected that the POP bias would be greater in winter than was found to occur. But the total precipitation is underestimated which could tend to explain the result.

Figure 6 shows that estimates of daily precipitation at Beltsville also have an over-estimate of the POP. This is because any interpolation technique that combines weighted fractions of surrounding gage amounts from more than one gage will tend to smooth the precipitation field and create too many small amounts and not enough large amounts. It is interesting to see that the over estimates of POP in Figures 5 and 6 are comparable.

5. SUGGESTIONS FOR IMPROVEMENTS IN FUTURE OROGRAPHIC PRECIPITATION ANALYSES

One of the limitations is that the current mountain mapper approach does not consider the synoptic scale atmospheric conditions that may produce precipitation patterns with relative spatial variability that are not consistent with the climatological patterns. For example, precipitation from storms with rapidly moving wet air masses tend to have stronger orographic enhancement that precipitation from large scale storms with closed cold low pressure centers. Also, storms approaching from different directions have different spatial precipitation patterns. Therefore additional analysis steps that would consider storm direction and synoptic conditions may help to provide better estimates from the available data. This could include analysis steps using high resolution atmospheric models such as Eta or MM5 as well as simplified high resolution approximations to such models. The high resolution approximations may be much easier to use for long period retrospective analyses.

6. REFERENCES

Daly, C., R.P. Neilson, and D.L. Phillips, 1994: A Statistical-Topographic Model for Mapping Climatological Precipitation over Mountanious Terrain. J. Appl. Meteor., 33, 140-158.

Table 1 - Average Annual Precipitation Estimates (mm) Using NCDC (only) Gage Observations in the Analysis

	Beltsville NCDC	Canaan Valley NCDC	Wolf Creek NCDC	Wolf Creek SNOTEL	Berthoud Summit SNOTEL	Spud Mountain SNOTEL
Period	1961-90	1961-90	1987-99	1987-99	1987-99	1987-99
Gage Average (mm)	1065	1318	1217	1313	1014	1204
PRISM Average (mm)	1076	1338	1003	1003	826	937
Untransformed Analysis (mm)	1088	1254	450	450	621	618
Mountain Mapper (mm)	1083	1345	1023	1023	870	869

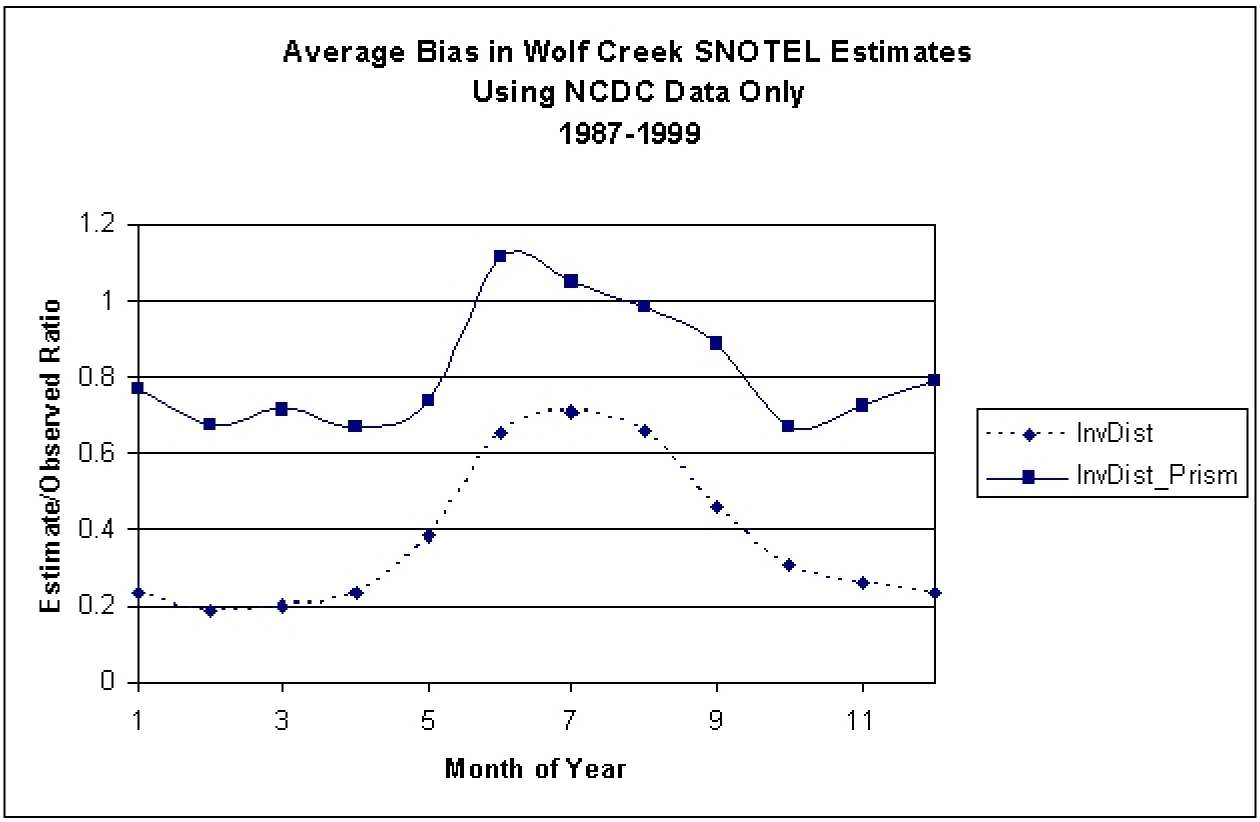

Figure 1 - Average Bias in Wolf Creek SNOTEL Data Using NCDC Data Only

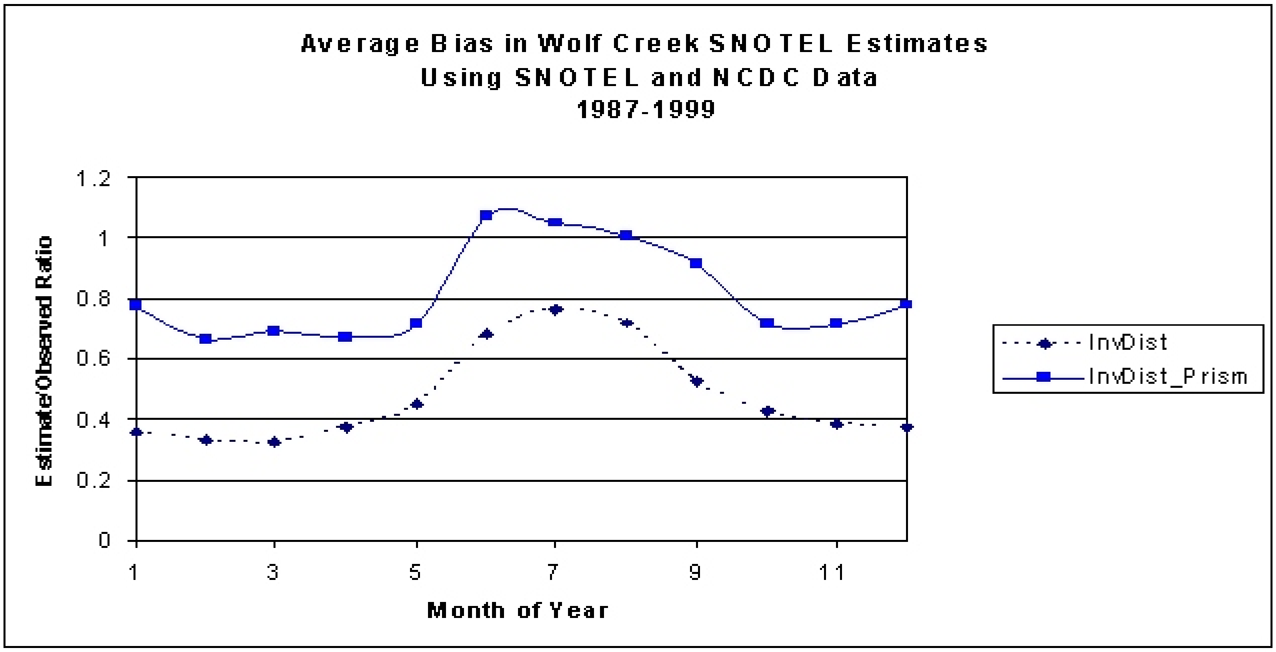

Figure 2 - Average Bias in Wolf Creek SNOTEL Data Using NCDC and SNOTEL Data

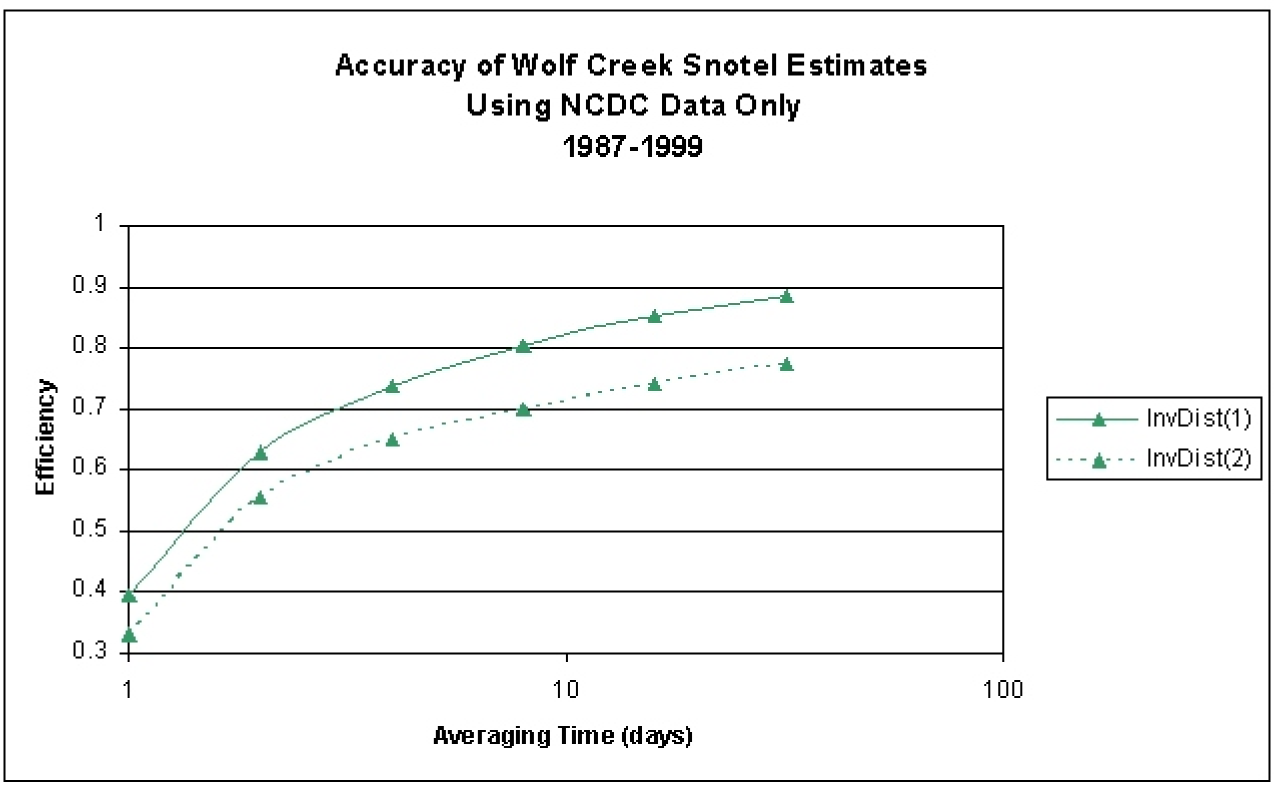

Figure 3 - Accuracy of Wolf Creek SNOTEL Estimates for Averaging Times of 1-30 Days Using NCDC Data Only

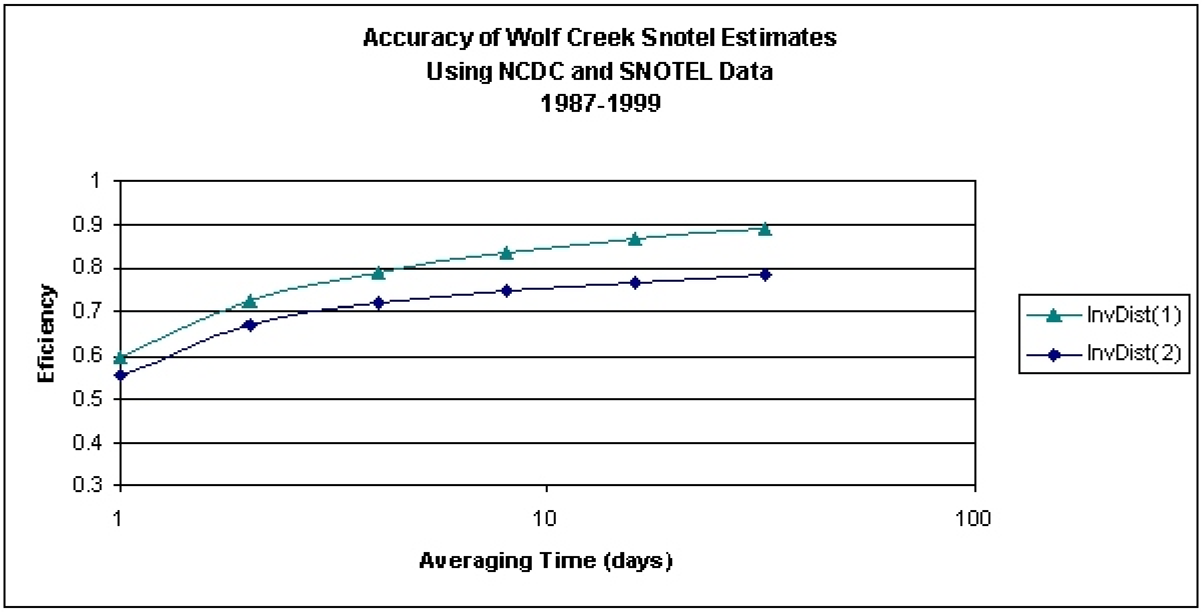

Figure 4 - Accuracy of Wolf Creek SNOTEL Estimates for Averaging Times of 1-30 Days Using NCDC and SNOTEL Data

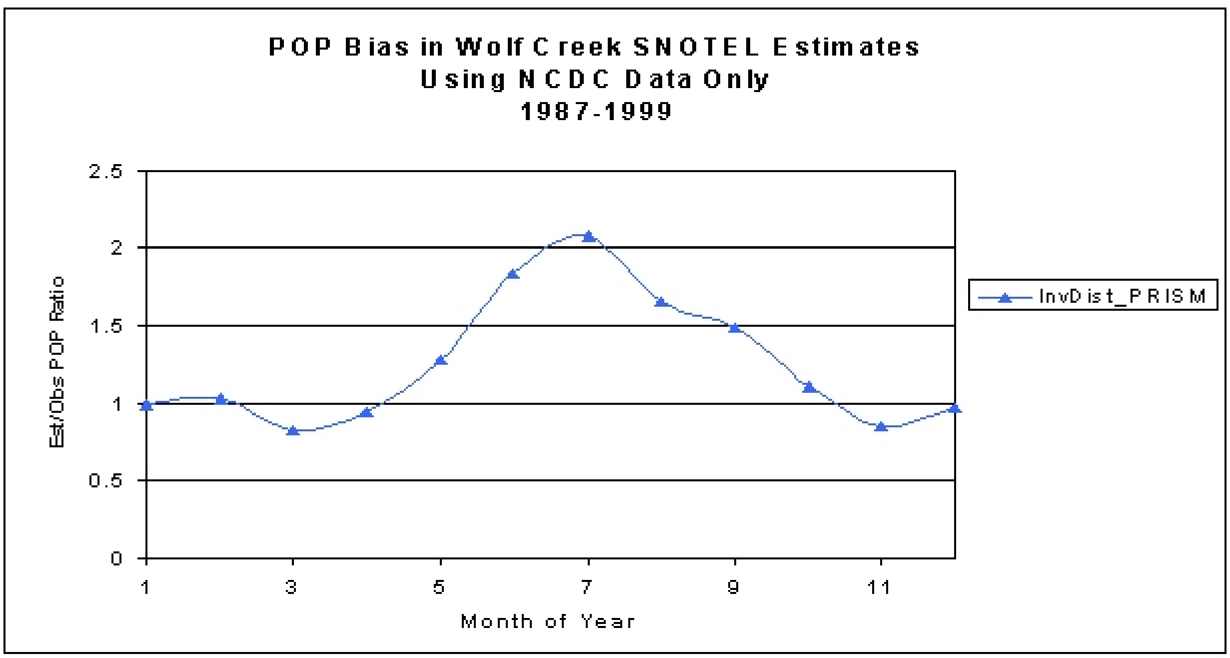

Figure 5 - Bias in Probability of Precipitation (POP) in Wolf Creek SNOTEL Estimates Using NCDC Data

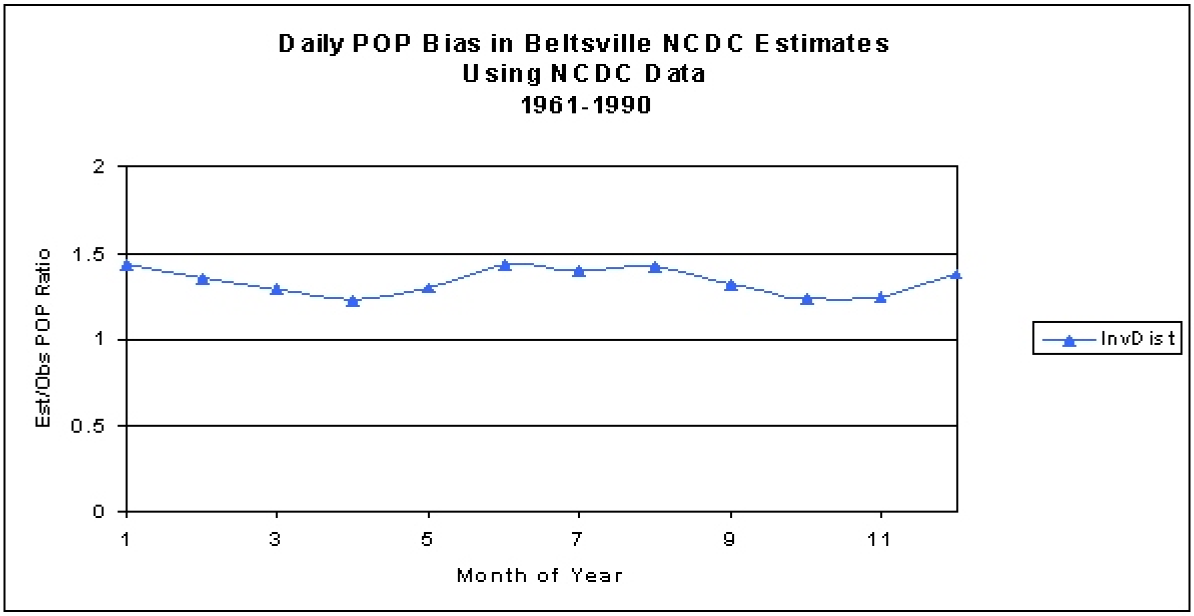

Figure 6 - Bias in Probability of Precipitation (POP) in Beltsville NCDC Estimates Using NCDC Data