Comparison of MM5 simulated precipitation to gage precipitation within the Lake Tahoe Basin

prepared by:

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in Cooperation with:

the Lake Tahoe Basin Storm Water Quality Improvement Committee

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Executive Summary

- The purpose of this study is to add to the previous analysis performed by the Corps of Engineers (2004) to evaluate MM5 (NCAR, 2006) simulated precipitation for the Lake Tahoe Basin. In the previous study, frequency curves estimated from MM5 simulated precipitation were compared to that obtained from NOAA14 (NWS, 2004).
- This analysis was prompted by the finding of a Tetra Tech study (2005) finding that MM5 under predicts annual total precipitation measured by precipitation gages within the study area. This finding is interesting in that in the Corps study, it was found that MM5 over predicted annual maximum daily precipitation for relatively rare events (events less frequent than 1/10 years).
- Consistency between MM5, gage information and NOAA14 is important to promote consistency in the design of facilities intended to address drainage and best management practice problems. Consequently, the comparisons being done in this report, the Tetra Tech (2005) study and Corps (2004) study is important in evaluating if potential inconsistencies may occur because of the differences in the source of precipitation information.
- The analyses performed in this report found that:

    - As found in the Tetra Tech (2005) study, MM5 under predicts annual total precipitation.
    - The under prediction in precipitation is generally due to seasonal prediction differences. For example, January maximum annual daily precipitation is significantly under predicted, as opposed to February maximum annual daily precipitation, which is over predicted.

- Taken together with the Corps (2004) report, MM5 overestimates rare – extreme events but under predicts precipitation on the average.
- Recommend the following:

    - A peer review be conducted to understand the reason for MM5 modeling bias. The Nation Center for Atmospheric Research MM5 users group probably would be a good contact to begin the peer review process
    - Depending on recommendations from the peer review, MM5 calibration needs to be revisited to improve model performance.

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1. Introduction

In a previous report (Corps of Engineers, 2004), a comparison was made between depth-duration frequency estimates for Lake Tahoe Basin obtained from the MM5 atmospheric model simulations (NCAR, 2006) and those published by the National Weather Service in NOAA14 (NWS, 2004, and Bonin,2004 personal communication). The purpose of this report is to provide an additional analysis comparing MM5 simulated precipitation with period of record Lake Tahoe Basin gage precipitation measurements.

The additional analysis was prompted by work done by Tetra Tech (2005) to develop watershed models for simulating continuously precipitation runoff processes within the Lake Tahoe Basin for water quality investigations. As part of this investigation, MM5 was found to under predict annual total precipitation in comparison to gage measurements. In the previous study performed by the Corps, , MM5 was found to over predict the annual maximum daily precipitation for relatively small exceedance probabilities (smaller than 1/10 years).

The comparison of depth-duration-frequency (ddf) curves and annual precipitation series resulting from the MM5 model simulations to both the annual series from gage observations and published in NOAA14 have important implications for traditional drainage design and best management practice with the Lake Tahoe Basin. The MM5 simulated precipitation is being used by the State of California – Lahontan Regional Water Quality Control Board to estimate permissible total maximum daily loads (TMDLs) for the Lake Tahoe Basin receiving waters. TMDLs, in turn, provide the basis for establishing best management practice to control pollutant runoff.. NOAA14 ddf curves will potentially be used in drainage design analysis to establish the capacity requirements for flow conveyance (e.g., culverts and channels) and retention/detention structures. Given the need to integrate drainage design and best management practice approaches, reasonable agreement between all precipitation measures is important.

Section 2, describes the data used to perform additional test on the MM5 data sets. An analysis of the data on annual time scale is described in section 3. Section 4 examines the data on a seasonal times scale. Conclusions are provided in section 5.

2. Gages and MM5 Grids

MM5 results were provided (personal communication, Kavvas, 2004) as grid cell average amounts for Lake Tahoe basin (see figure 2.1). Comparisons of measured precipitation at both Tahoe City (NOAA cooperative, NCDS, 2006) and Hagan's Meadow (SNOTEL, NRCS 2006) gages with corresponding grid cells are shown in Table 2.1. The Tahoe City gage was chosen because it is the longest record gage and Hagan's Meadow because it represents a drier – higher elevation gage within the basin. The grid cells chosen correspond both to the location of the gages and provide some perspective on spatial variation in simulated precipitation. In particular, grid cell 99 was chosen because it is located in the wettest sub-basin within the basin, Ward Creek.

Table 2.1: Precipitation gage and MM5 grid cell latitude, longitude and elevation

Location	latitude	longitude	elevation
Tahoe City (NOAA)	39.1670	-120.1330	6305
Grid 99	39.1387	-120.1790	6755
Grid 105	39.1664	-120.1791	6787
Grid 106	[1]39.1665	-120.1433	6419
Hagan's Meadow	38.8519	-119.9374	7776
Grid 27	38.8612	-119.9644	7597
Grid 28	38.8612	-119.9287	8670
Grid 36	[1]38.8890	-119.9287	8116
Grid 37	[1]38.8889	-119.8930	8617

[1]Corresponds to gage location

									142	
									140	**141**
					131	**132**	**133**	**134**	**135**	**136**
		0	**123**	**124**	**125**	**126**	**127**	**128**	**129**	**130**
		115	**116**	**117**	**118**	**119**	**120**		**121**	**122**
		109	**110**	**111**	**112**				**113**	**114**
	104	**105**	**106**						**107**	**108**
97	**98**	**99**	**100**					**101**	**102**	**103**
90	**91**	**92**	**93**					**94**	**95**	**96**
83	**84**	**85**	**86**					**87**	**88**	**89**
	76	**77**	**78**	**79**				**80**	**81**	**82**
	69	**70**	**71**	**72**				**73**	**74**	**75**
	62	**63**	**64**	**65**				**66**	**67**	**68**
		55	**56**	**57**	**58**			**59**	**60**	**61**
		0	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**
		38	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**
			30	**31**	**32**	**33**	**34**	**35**	**36**	**37**
			22	**23**	**24**	**25**	**26**	**27**	**28**	**29**
				15	**16**	**17**	**18**	**19**	**20**	**21**
						11	**12**	**13**	**14**	
						7	**8**	**9**	**10**	
						4	**5**	**6**		
						2	**3**			
							1			

Figure 2.1: Relative location of 3kmx3km MM5 grid cells for Lake Tahoe Basin

Note: Top of figure is northern side of Lake Tahoe

3. Annual comparisons

Comparison of annual total precipitation at the Tahoe City gage and grid 106 in Table 3.1 demonstrates the MM5 under prediction of total annual precipitation as was found in the Tetra Tech study. This under predictions is particularly puzzling given that MM5 does a fairly reasonable job in capturing the variation of annual maximum daily precipitation as was found in the Corps (2004) study and as can be seen in figures 3.1 and 3.2. The ability to capture this annual variation results in a reasonable representation of the annual maximum daily frequency curve for relatively frequent events, but an over prediction of infrequent events as can be seen in figures 3.3 for the Tahoe City gage. Figure 3.4 shows an instance where MM5 simulated frequency curve resulted in a reasonable representation of the Hagan's Meadow annual maximum daily frequency curve. In general, the difference shown in figure 3.3, an over prediction, is more typical of the difference between MM5 simulated frequency curves and those obtained either from gage data or NOAA14 (see Corps of Engineers, 2004).

This over prediction of annual maximums becomes even more apparent when comparing the top five ranked annual maximum daily gage precipitation amounts with the MM5 predictions for the same day. As can be seen from Tables 3.2 and 3.3, the difference between observed and predicted precipitation can be very significant. Furthermore, the difference cannot be explained by a small daily lag in the predictions as can be seen from the reported simulated precipitation either a day preceding or following the date of observed maximum precipitation.

To provide additional perspective on storm differences, a comparison is made in Table 3.4 between the precipitation observed at the SNOTEL Ward Creek #3 gage and the corresponding MM5 grid 99 simulated values for the 01 January 1997 event. The under prediction shown is very noteworthy both because the Ward Creek basin is the wettest tributary draining to Lake Tahoe and the 1997 precipitation caused the flood event of record within the watershed.

In conclusion, the MM5 simulated precipitation captures the variability exhibited in the precipitation record, at least with regard to annual maximum daily precipitation characteristics, although a degree of over prediction occurs for large infrequent events. This may have been explained by the potential for gage under catch during windy – snow dominated precipitation events. However, the inability of MM5 to predict annual volumes or individual significant storm events calls into question its value in the application to runoff simulation using watershed models simulations.

Table 3.1: Comparison of Tahoe City and MM5 Grid 106 water year precipitation (inches)

Water Year	Tahoe City	Grid 106
1960	25.6	25.6
1961	25.6	14.6
1962	29.2	29.2
1963	47.5	29.2
1964	25.6	7.3
1965	51.1	21.9
1966	25.6	14.6
1967	43.8	14.6
1968	25.6	14.6
1969	51.1	21.9
1970	36.5	14.6
1971	32.9	14.6
1973	29.2	18.3
1974	32.9	21.9
1975	25.6	29.2
1976	14.6	14.6
1979	18.3	21.9
1980	47.5	29.2
1981	21.9	11.0
1982	69.4	40.2
1983	47.5	43.8
1984	32.9	21.9
1985	25.6	14.6
1986	54.8	69.4
1987	14.6	11.0
1988	18.3	11.0
1989	36.5	18.3
1990	25.6	14.6
1991	21.9	14.6
1992	18.3	21.9
1993	40.2	21.9
1995	62.1	25.6
1996	47.5	25.6
1997	51.1	18.3
1998	47.5	36.5
1999	40.2	29.2
average	35.1	22.4

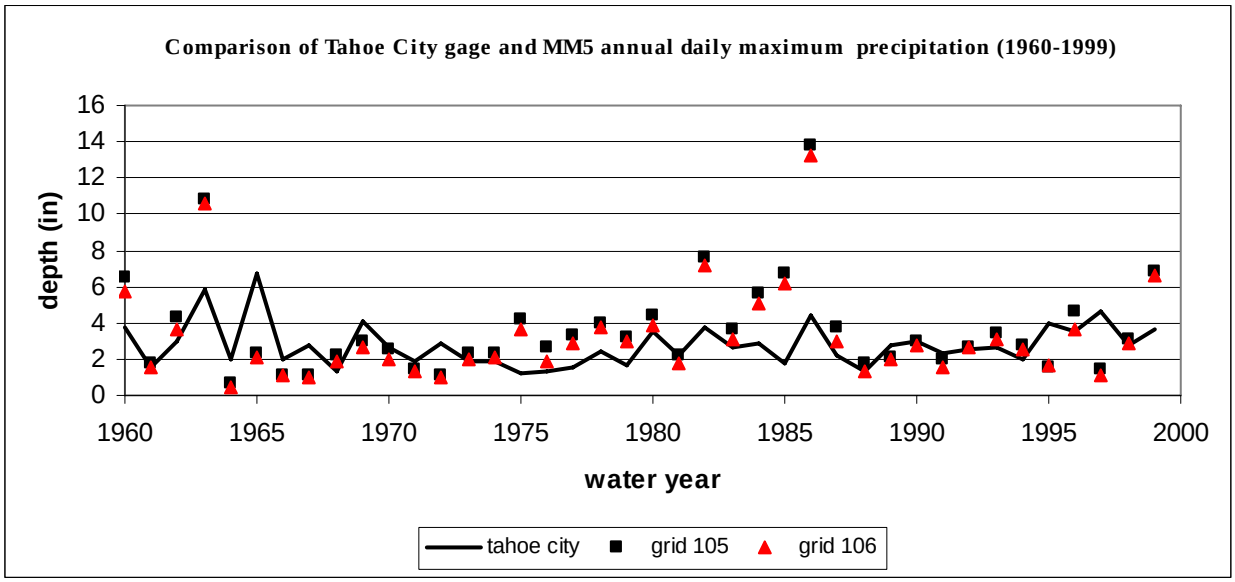

Figure: 3.1: Comparison of Tahoe City NOAA and MM5 annual daily maximum precipitation

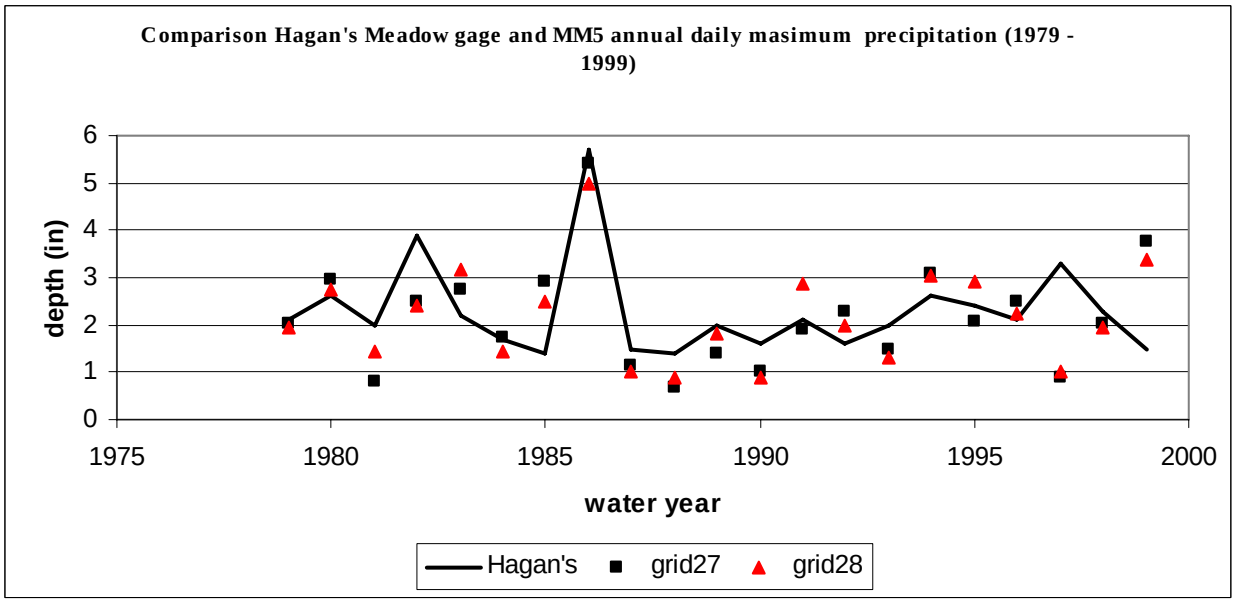

Figure 3.2: Comparison of Hagan's Meadow NOAA and MM5 annual daily maximum precipitation

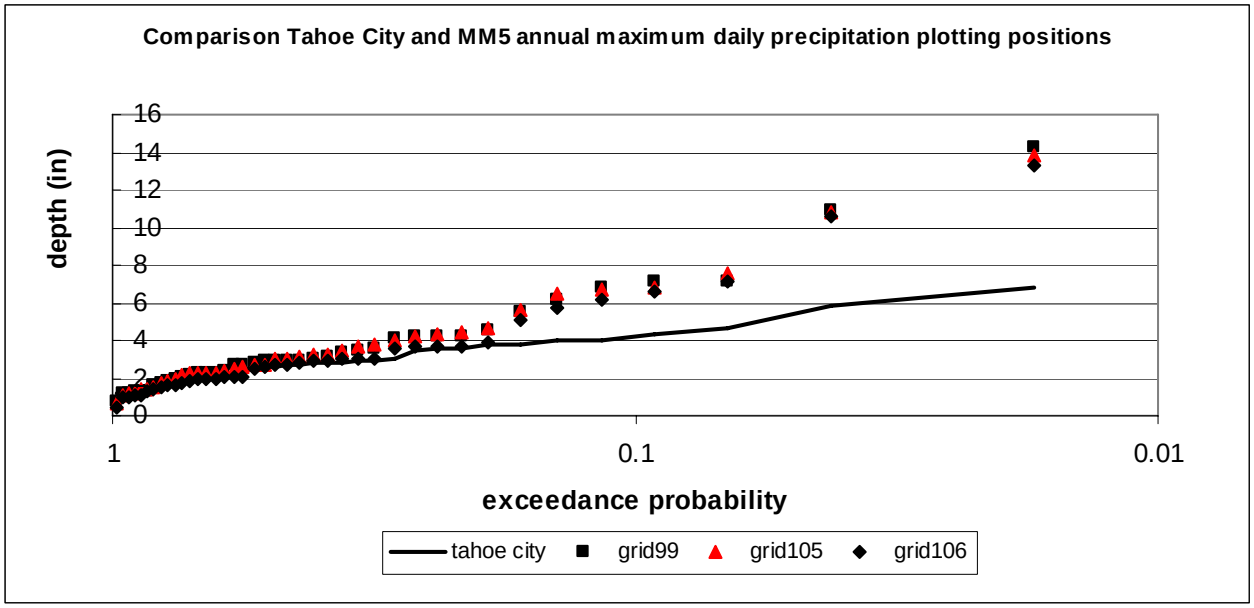

Figure 3.3: Comparison of Tahoe City NOAA and MM5 annual daily maximum precipitation plotting positions

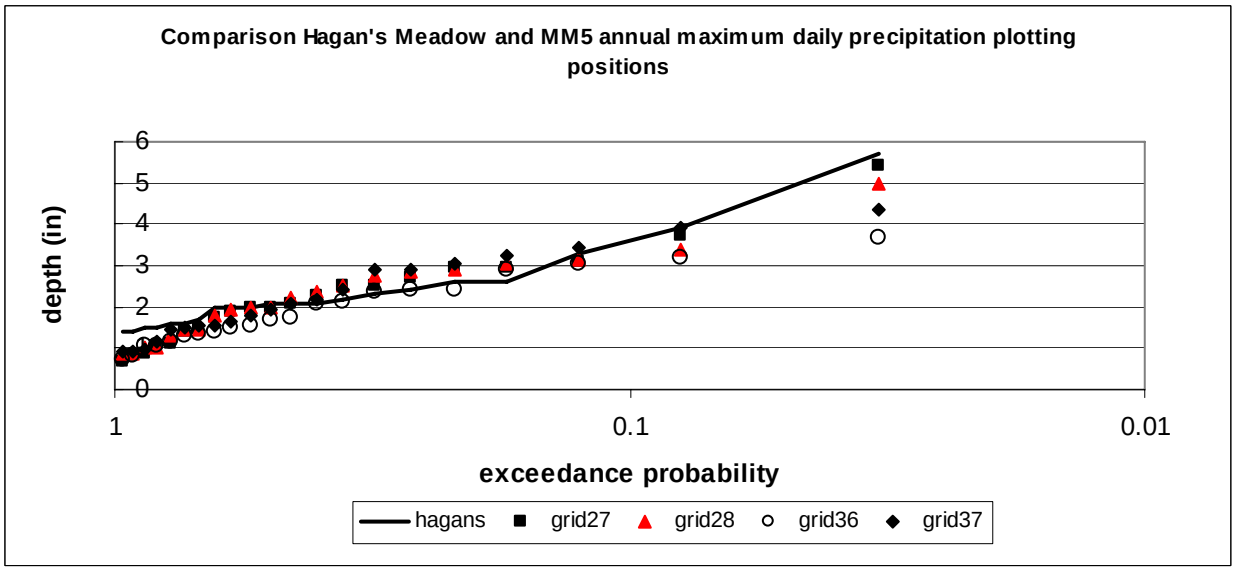

Figure 3.4: Comparison of Hagan's Meadow NOAA and MM5 annual daily maximum precipitation plotting positions

Table 3.2: Comparison top ranked Tahoe City (NOAA) gage versus MM5 simulated annual maximum precipitation (inches)

Date	Tahoe City	grid 105	[1]Pre/Post	grid 106	[1]Pre/Post
23-Dec-64	2.28	1.62	2.07	1.59	2.28
1-Feb-63	10.86	1.61	10.56	1.23	10.86
2-Jan-97	1.41	1.32	1.09	1.01	1.41
18-Feb-86	10.27	13.79	9.57	13.27	10.27
21-Jan-69	0.48	0.42	0.38	0.32	0.48

[1]Maximum of MM5 precipitation day preceding or after date shown

Table 3.3: Comparison top ranked Hagan's Meadow gage versus MM5 simulated annual maximum precipitation (inches)

Delete	Hagan's	grid27	[1]max other day	grid28	[1]max other day
18-Feb-86	5.7	3.21	5.40	2.67	4.97
5-Jan-82	3.9	0.16	0.45	0.19	0.41
[2]22-Dec-96	3.3	0.35	0.28	0.32	0.22
13-Jan-80	2.6	0.40	0.74	0.39	0.68
19-Feb-94	2.6	0.06	2.09	0.06	1.79

[1]Maximum of MM5 precipitation day preceding or after date shown
[2]January 1997 storm was not well measured for this date

Table 3.4: Comparison of Ward Creek #3 SNOTEL gage and MM5 grid 99 01 January 1997 event precipitation

Date	[1]grid 99	Ward Creek
29-Dec-96	0.88	1.30
30-Dec-96	0.63	2.50
31-Dec-96	0.62	3.70
1-Jan-97	1.28	1.90
2-Jan-97	1.30	9.00
3-Jan-97	0.49	4.00

[1]Daily precipitation (inches)

4. Seasonal analysis

The Corps (2004) comparison of depth-duration-frequency curves derived from MM5 simulations and NOAA14 focused on annual frequency curves. However, the Tetra Tech (2005) study indicated seasonal differences between gage recorded and MM5 simulated precipitation. The purpose of this section is to compare seasonal frequency curves to investigate if the differences between gage measured and simulated precipitation for individual events has a seasonal component.

The comparison was made by computing daily maximum frequency curves for January, February and June-August for both the Tahoe City and Hagan's Meadow gages. As can be seen from figures 4.1- 4.6, MM5 under predicts the seasonal maximum daily precipitation likelihood for January, over predicts for February, and performs reasonably for June-August. Consequently, the under prediction of January event precipitation and over prediction of February precipitation shown in Tables 3.2 and 3.3 is not just a problem for a few top ranked events, but a persistent bias in the MM5 simulated data.

5. Conclusions/Recommendations

The comparison of MM5 simulated precipitation to both gage precipitation in this report and NOAA14 in the Corps (2004) study has shown the following:

- Maximum annual daily frequency curves tend to over estimate the precipitation for relatively rare precipitation events (events less frequent than 1/10 years). However, the overall form of the frequency curves are reasonable.
- As found in the Tetra Tech (2005) study, MM5 under predicts annual total precipitation.
- The under prediction in precipitation is generally due to seasonal prediction differences. For example, January maximum annual daily precipitation is significantly under predicted, as opposed to February maximum annual daily precipitation, which is over predicted.

These differences make the value of the MM5 period of record estimates questionable in runoff simulation application within the Lake Tahoe Basin.

Recommend that the MM5 model calibration be revisited. A peer review group should examine the value of the model for predicting precipitation with the Lake Tahoe Basin. The National Center for Atmospheric Research MM5 users group would be a contact to initiate the peer review. Depending on the peer review group recommendations, the calibration should attempt to improve the prediction of individual events (e.g., the 01 January 1997 storm), correctly represent the seasonality of precipitation, and eliminate the significant bias toward under-prediction of annual precipitation.

Re-calibrating MM5 is very important because it will provide not only better estimates of precipitation, but also, a valuable estimate of meteorologic variables, especially, temperature, across the study area. Without the estimates of meteorologic variables it will be virtually impossible to reasonably estimate precipitation-runoff hydrographs over a 40-year period of record within the basin. This period of record simulation is extremely important in studies being performed to estimate TMDLs for the study area.

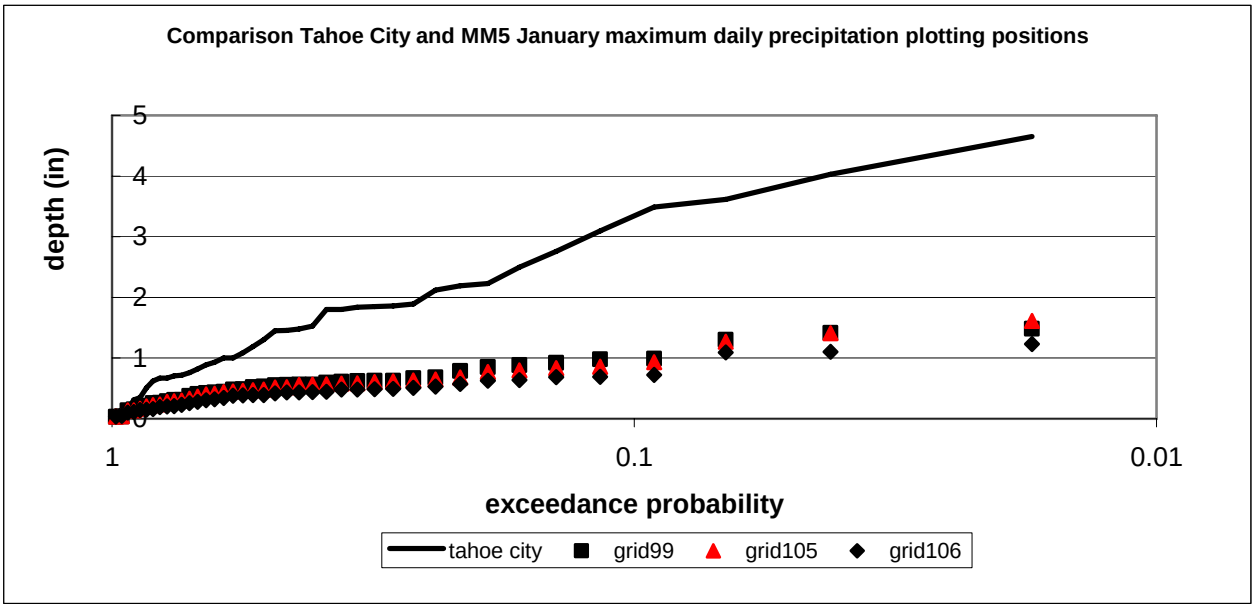

Figure 4.1: Comparison of Tahoe City NOAA and MM5 January daily maximum precipitation plotting positions

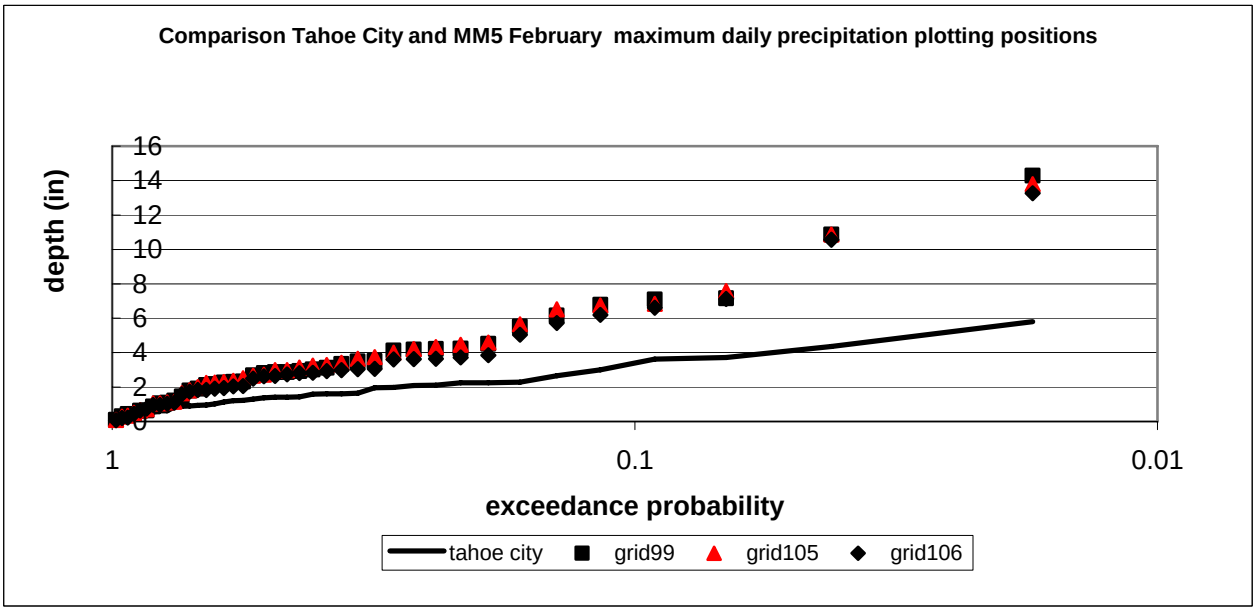

Figure 4.2: Comparison of Tahoe City NOAA and MM5 February daily maximum precipitation plotting positions

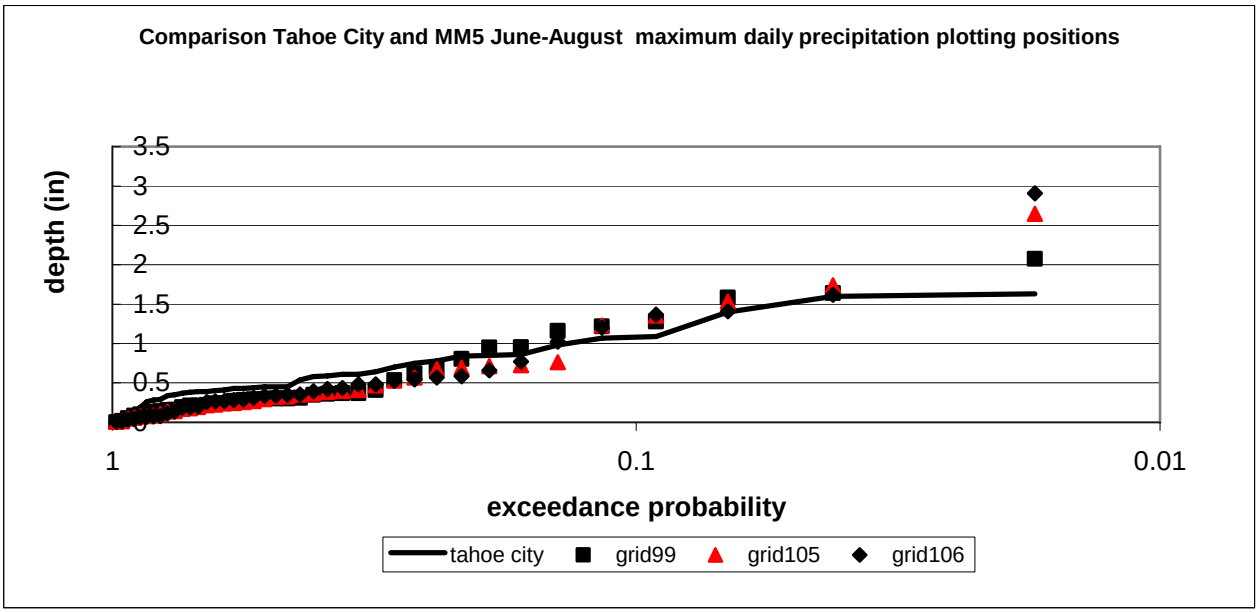

Figure 4.3: Comparison of Tahoe City NOAA and MM5 June- August daily maximum precipitation plotting positions

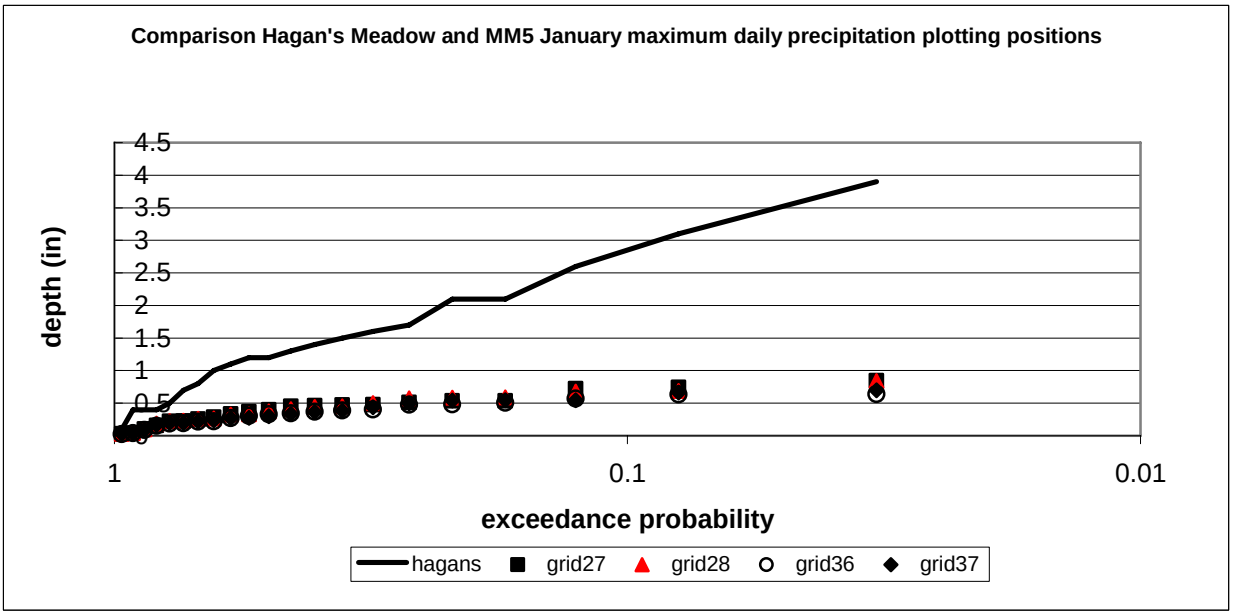

Figure 4.4: Comparison of Hagan's Meadow NOAA and MM5 January daily maximum precipitation plotting positions

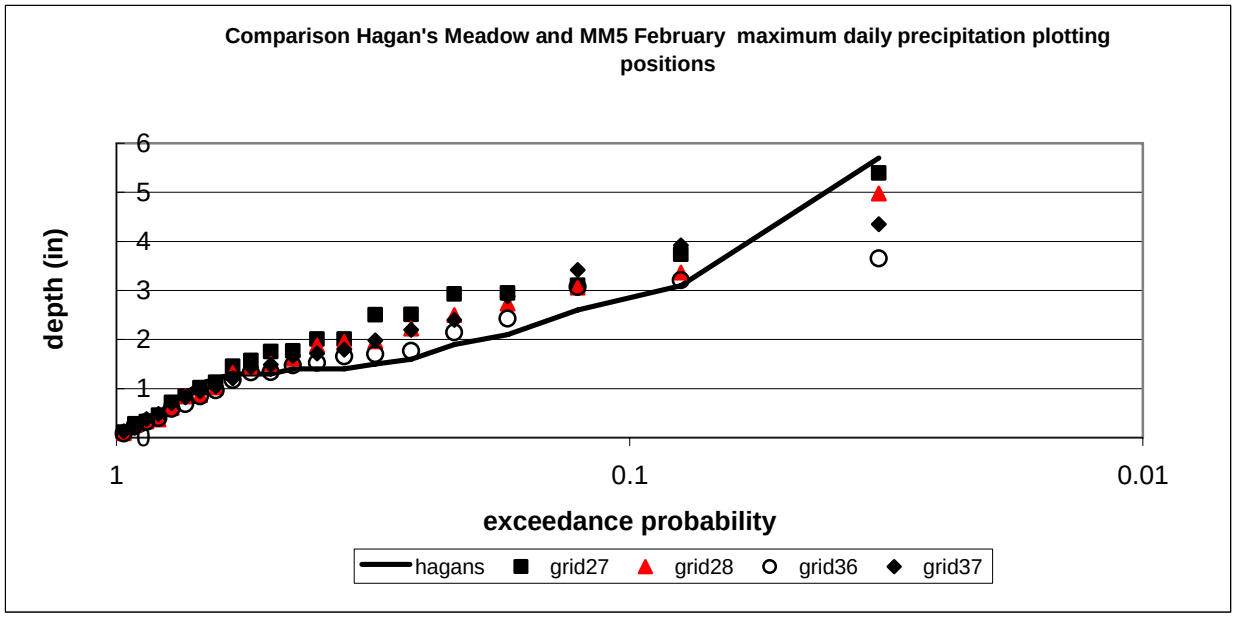

Figure 4.5: Comparison of Hagan's Meadow NOAA and MM5 February daily maximum precipitation plotting positions

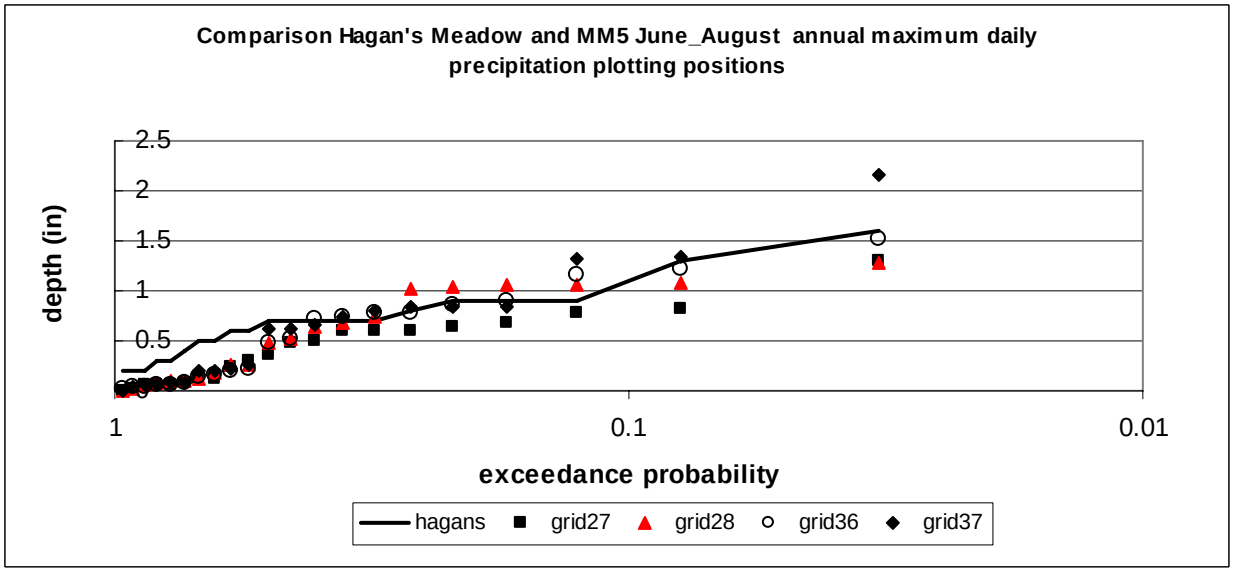

Figure 4.6: Comparison of Hagan's Meadow NOAA and MM5 June - August daily maximum precipitation plotting positions