P3.20 A CLIMATOLOGICAL INVESTIGATION OF THE DIURNAL PATTERNS OF PRECIPITATION OVER THE COMPLEX TERRAIN OF WESTERN COLORADO

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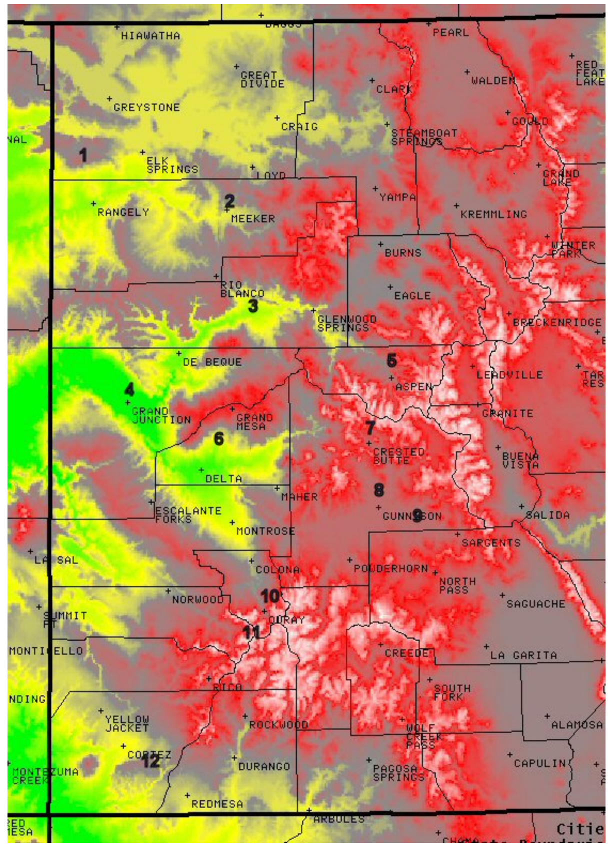
1. Introduction

Diurnal trends of precipitation have been investigated for many years (Wallace, 1975). A harmonic of the diurnal variability of precipitation over the central Rockies and adjacent Plains was documented by Riley et al. (1987). In this study, over mountain locations, the winter diurnal peak was seen during the early morning hours with a late afternoon peak during the summer season. The Plains locations east of the Rockies showed later bias. In two other studies over the central Intermountain west (Tucker, 1993; Astling, 1984), smaller scale investigations were conducted. Astling (1984) examined the diurnal signatures of precipitation over the Salt Lake City Valley using harmonic methods and compared these results with local wind circulations. The diurnal peak during the warm season over mountain locations (above 2100 m) was around 1430 MST with the peak lagging several hours over the valley locations. Astling found that winter diurnal trends tended to peak around 0700 MST, but the winter trend was strongly tied to frontal passages and synoptic-scale progression. Tucker (1993) used harmonic analysis to study summer diurnal precipitation variations in south-central New Mexico. This study showed a maximum diurnal peak in precipitation around midnight local time.

In this study, hourly precipitation patterns for several locations in the highly complex terrain of western Colorado will be analyzed for diurnal biases during various periods of record. As a benchmark, the Grand Junction record will provide the most reliable precipitation database, with specific analysis of the data from 1948 to the present. To gain a regional perspective, the precipitation patterns for numerous locations across western Colorado will be included in a comparative study during the same period of record.



Identifier	Location	Elevation (m)
1	Dinosaur NP	1804
2	Meeker	1902
3	Rifle	1615
4	Grand Junction	1481
5	Aspen	2438
6	Cedaredge	1902
7	Crested Butte	2707
8	Gunnison	2338
9	Cochetopa	2438
10	Ouray	2390
11	Telluride	2682
12	Mesa Verde	2167

Figure 1 and Table 1. Map of study locations with location identifier and elevation.

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A climatological review of diurnal precipitation patterns comparing different locations across western Colorado with varying elevations will be discussed. This study will also discern differences based on actual quantitative precipitation amounts. To examine more significant events, comparisons between events greater than 2.5 mm (0.10 inches) and 6.4 mm (0.25 inches) will be utilized. Finally, both seasonal and climatological biases will be taken into account, which will allow comparisons to address monsoonal and El Niño Southern Oscillation implications.

2. Site Location and Topography

The sites chosen for this study all reside west of the Continental Divide in western Colorado. Only locations with a significant climatological history of hourly precipitation data were selected with all stations possessing at least 55 years worth of precipitation records.

The dataset includes elevations which varied from a low point of 1478 m at Grand Junction to 2707 m at Crested Butte. Typically, these climatological sites were selected based on their location within a certain hydrological basin, such as Crested Butte, Gunnison, and Cochetopa. Some of the sites are found in valley locations, to the lee and windward side of mountain ranges, such as Telluride and Ouray. Most of the locations in the dataset are also associated with the population centers of western Colorado. See Figure 1 and Table 1 for a breakdown of locations, elevations and annual precipitation amounts at each location.

Finally, mountain locations, which often yield precipitation amounts five times greater than valley locations, were selected to determine if any diurnal biases existed between these sites.

3. Observation Collection Methods

The hourly precipitation data was collected from the National Climatic Data Center in Asheville, North Carolina for a period of record consisting of 1948 through 2005. These data were then ingested into spreadsheets and analyzed using rather simple statistical methods in hopes of finding some sort of signature within the data.

Most of the selected sites operated with automated rain gages through the entire period of concern. The sites initially started off with a tipping-bucket range gage and later switched to the Fischer-Porter rain gages, which only measure precipitation to the nearest one-tenth of an inch. The only exception to the precipitation recording methods at any site is with the Grand Junction location which is operated by National Weather Service personnel who have been stationed at that site for over 100 years.

To help eliminate noise from the data set and to make precipitation recording methods consistent, only events greater than 2.5 mm were analyzed, with a secondary cutoff at 6.4 mm which was used to focus on more extreme precipitation events. In addition, the precipitation data were combined into 3 h increments, with the study examining the diurnal trends during the eight 3 h periods between midnight and midnight local time.

4. Preliminary Results

Preliminary findings of the precipitation data show that several sites exhibited consistent diurnal patterns during the warm season, defined as the period of May through September, including Crested Butte, Gunnison, Telluride and Grand Junction. Precipitation maxima for events greater than 2.5 mm tended to peak during the afternoon and evening hours (1200 to 2100 MST), with Grand Junction (a low valley location) typically peaking up to 3 hours later than the higher valleys and mountain locations.

One significant outlier did exist with Ouray (high valley location in southwestern Colorado) showing a strong tendency for a precipitation peak in the 0000 to 0300 MST period. This diurnal trend at Ouray is interesting, especially since no other sites showed such strong tendencies during the warm season. One possible explanation for this trend may be due to the complex terrain surrounding the valley location where Ouray resides. This very narrow canyon is oriented from north to south, surrounded by rugged 3500 meter mountains on all but the northern face of the valley.

Significant precipitation across western Colorado is normally received from two sources, the winter snows (November through March) and monsoonal thunderstorms (July through September).

The winter season diurnal tendencies exhibited a shift from the monsoon season tendency with an afternoon and evening pattern to a primarily nocturnal tendency. The strongest shifts were noted at Mesa Verde, Telluride, Crested Butte, Grand Junction and Aspen**.**

Data from the transitional months of autumn (namely October) and spring (April through June) data were particularly noisy and showed no significant trends.

4.1 Winter Season

November begins the trend toward the nocturnal bias with lesser precipitation events beginning primarily between 0300 to 1200 MST. However, during events that produced greater than 6.4 mm beginning times were scattered across the clock and varied greatly from station to station. Similar findings appeared in the December data.

January, typically the snowiest month on the Western Slope, seems to have been the month with the most concentrated beginning times, those being 0600 to 1200 MST. The northwest portion of Colorado, primarily plateau locations, showed an especially strong signal between the hours of 0900 to 1200 MST. Events producing 6.4 mm or more were not so conclusive, and were generally between the hours of 0600 and 1800 MST.

February, one of the driest months in western Colorado, showed great variability in time and location for both lighter and heavier precipitation events. However, northwest Colorado continued to show a strong signal toward late morning and early afternoon.

March, one of two of the wettest months across western Colorado, again showed concentrations of >2.5 mm precipitation events beginning from just before sunrise to noon. Events greater than 6.4 mm were varied throughout the day.

4.2 Monsoon Season

By July, the data indicated a distinct shift to afternoon beginning times for precipitation. July precipitation beginning times showed a significant maximum between 1500 and 1800 MST for both 2.5 mm and 6.4 mm. Two exceptions were Grand Junction and Rifle where a strong signal was indicated between 1800 and 2100 MST for the lighter precipitation events. Nearly the same patterns existed in August.

September indicated more variability. Although precipitation beginning times were primarily afternoon and evening, and the hours of 1500 to 1800 MST were the most common for both 2.5 mm and 6.4 mm events, the exceptions increased. One particular outlier was Rifle, which tended to have a high number of events in the 0600 to 0900 MST time frame.

Three examples of the diurnal tendencies detected have been included in Table 2.

4.3 Spatial Biases

Precipitation biases were also noted spatially between sites as one moved from north to south. Northern sites tended to exhibit less seasonal variability versus sites located in southwest Colorado. In addition, timing differences between the precipitation events greater than 2.5 mm showed only a minor shift of +/- 3 hours from season to season. Whereas, the southern sites exhibited a much larger spread in diurnal precipitation from season-to-season, with the most pronounced shift in data found between the monsoon season and the winter season.

5. Conclusion

This ongoing study examined diurnal precipitation trends in western Colorado. Preliminary findings showed the diurnal precipitation maxima tend to peak during the warm-season late afternoon and evening hours. Valley locations, such as Grand Junction, tended to show a peak of occurrences up to 3 hours later than the higher locations. One outlier in this warm-season trend is the town of Ouray which shows a peak during the 0000 to 0300 MST. The cool-season diurnal trend shifts to a primary nocturnal maximum**.**

During the cool season, the patterns shifted to more nocturnal events with the majority of all the lower valleys seeing more significant precipitation events ending before mid-morning. Mountain locales showed a slightly longer duration, with events last through midday, before tapering off during the afternoon hours.

Further analysis needs to be completed, including applying a harmonic analysis to the data, and utilizing cumulative methods, all of which have been presented in prior climatological studies. In addition, future investigations will be conducted into possible scenarios as to why western Colorado experiences such a dramatic shift in diurnal precipitation patterns from one season to the next.

Crested Butte, Colorado – 2707 meters								
Month/Avg.	Observation Time (LST)							
	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24
Jan 68.1mm		3	3	1	2	8	9	10
Feb 59.4mm	9	2		1X	3	10	8	8
Mar 59.7mm		1	2	3	8	9-10	9-10	
Apr 45.2mm	8-9	2	1		8-9	3	10	
May 36.8mm	8	10		1	2	3		9
Jun 33.8mm	10	9	8		2X	1X	3	
Jul 50.3mm	8	10	9		2X	1X	3X	
Aug 54.6mm	10	9	8		2X	1X	3	
Sep 51.6mm	9-10		8	2-3	1	2-3		9-10
Oct 38.6mm			3	1-2	1-2	8	9	10
Nov 44.2mm	8		2	1	3	9	10	
Dec 56.6mm	10	2	3	1			8-9	8-9
Ouray, Colorado – 2390 meters								
Jan 43.4mm	1X		2	9	10	3	8	
Feb 43.9mm	1		3	9	10		2	8
Mar 57.2mm	1X	8	2		10	3		9
Apr 52.6mm	1X	9-10		3	9-10	2		3
May 44.7mm	1		2-3	9	10X	2-3		8
Jun 29.2mm	3	9			10	1-2	1-2	8
Jul 53.3mm	10X	8		3		1	2	9
Aug 58.2mm	10	8		9	3	1X	2	
Sep 51.3mm	1	10	8	9		9	8	
Oct 54.6mm	1X	10	8	8		2-3	2-3	9
Nov 52.3mm	1	10	8-9		3	2		8-9
Dec 41.1mm	2	10	9		1	3		8
Grand Junction, Colorado – 1481 meters								
Jan 15.5mm	2-3		1				2-3	
Feb 14.7mm	1							
Mar 20.8mm		2	10		8-9		8-9	1
Apr 20.1mm	3	1-2	10		1-2	10	10	
May 20.1mm	2-3	1	9	2-3	8	10	2-3	8
Jun 11.2mm	9	9	9	3	10	2	3	1
Jul 15.5mm	10	8-9	8-9			1X	2	
Aug 25.2mm	2	9	10	8	3	1X		
Sep 24.1mm	10	9	3	3	1X	2	8	3
Oct 22.9mm		9	10	1			8	
Nov 16.3mm				10	10	10	1-2	1-2
Dec 14.5mm	2	1	3	3	10	10	10	10

Ranking of the greatest number of precipitation events > 2.5 mm (1, 2 or 3)
Ranking of the lowest number of precipitation events > 2.5 mm (8, 9 or 10)
X denotes strong signal

Table 2. Diurnal precipitation patterns exhibited at Crested Butte, Ouray and Grand Junction, CO

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