Precipitation Characteristics of the San Luis Valley during Summer 2006

Brian McNoldy[1]

Nolan Doesken[2]

Colorado Climate Center
Atmospheric Science Department
Fort Collins, CO 80523-1371

.

Funding for this research is provided by

The Colorado Water Conservation Board

February 2007

[1]Brian McNoldy, Research Associate, mcnoldy@atmos.colostate.edu, 970-491-8558

[2]Nolan Doesken, State Climatologist, nolan@atmos.colostate.edu, 970-491-3690

I. Introduction

The San Luis Valley in south-central Colorado is surrounded by the Sangre de Cristo Mountain Range to the east and the San Juan and La Garita Mountain Range to the west. As a result of these barriers, the valley is an extremely arid climate with most areas receiving between seven and nine inches of precipitation *annually*. The majority of precipitation falls during the summer months, particularly July and August when the North American Monsoon is active and feeding moisture into the area from the southwest. During these months, scattered afternoon thunderstorms can produce locally heavy rain and occasional hail.

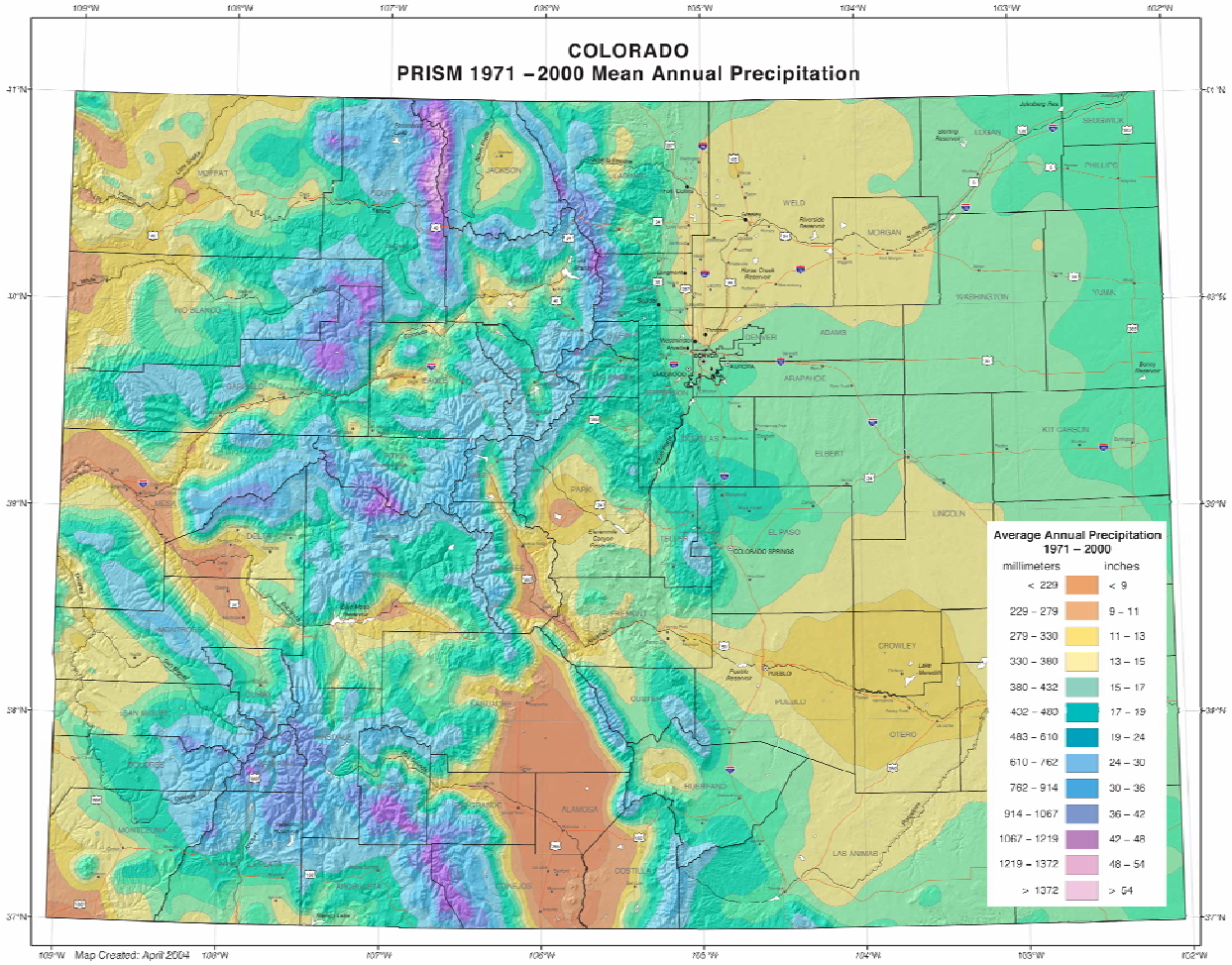
There are five counties included in the San Luis Valley: Alamosa County, southeast Saguache County, eastern Rio Grande County, eastern Conejos County, and western Costilla County. It covers approximately 7500 square miles and sits at an average elevation of 7500 feet. Although the valley itself is arid, the surrounding mountains provide snowmelt to support extensive farming in the valley.

The central valley is heavily irrigated and utilized for farming: alfalfa, potatoes, barley and also spinach and lettuce. These delicate crops are especially sensitive to hail. Cost to farmers comes from hail-damaged crops and enhanced irrigation due to abnormally dry conditions. This report will look at

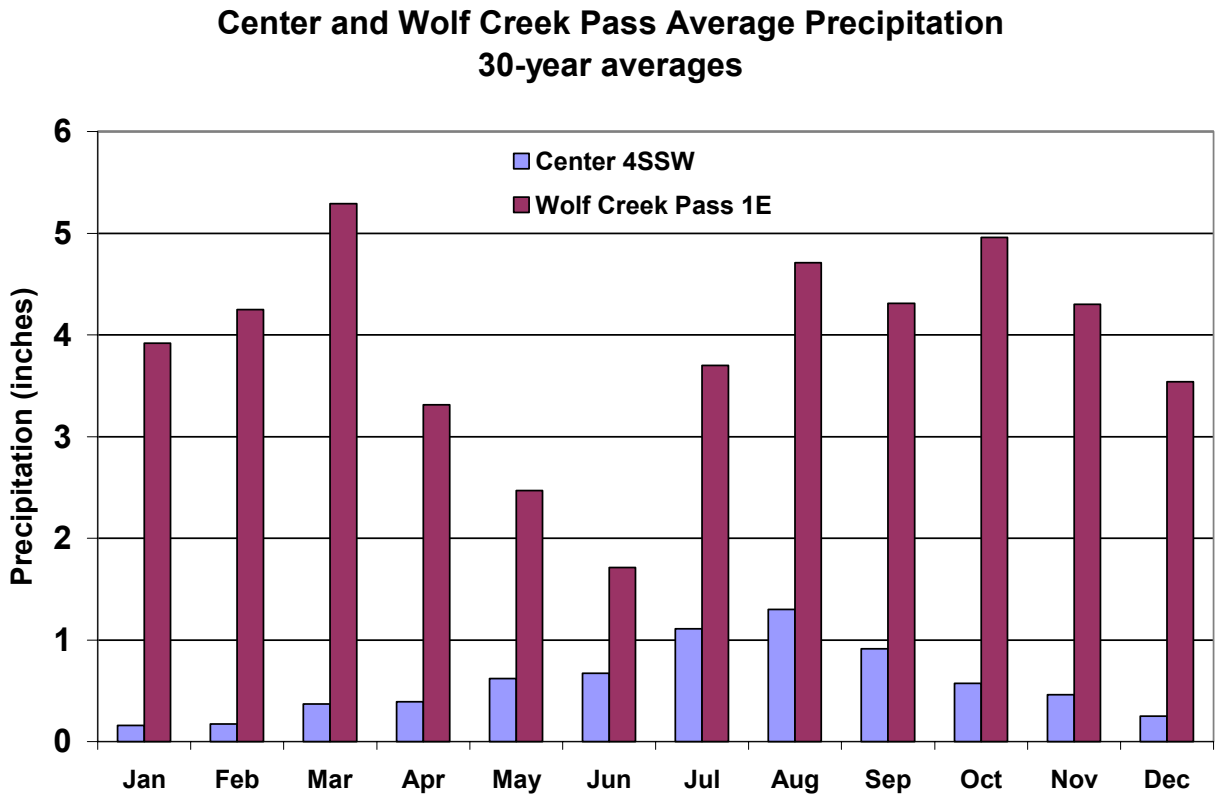
available hail and rain data between 15 June and 15 September, 2006, which is the growing season for these crops. Rainfall data were collected at sixty stations from five independent networks to find patterns, anomalies, and trends.

II. Climatology

Most of Colorado is arid or semi-arid; only the high terrain of the Rocky Mountains typically receives more than 20" or more of precipitation annually. The San Luis Valley is among the driest areas of the state, and by far, the largest areal coverage of the arid climate. The figure below shows the 30-year climate normal (1971-2000) of mean annual precipitation for the state. The San Luis Valley is shaded in the deepest orange (<9"), and most of the valley is actually at approximately 7 inch. Note that the surrounding mountain ranges receive 30-48" annually.



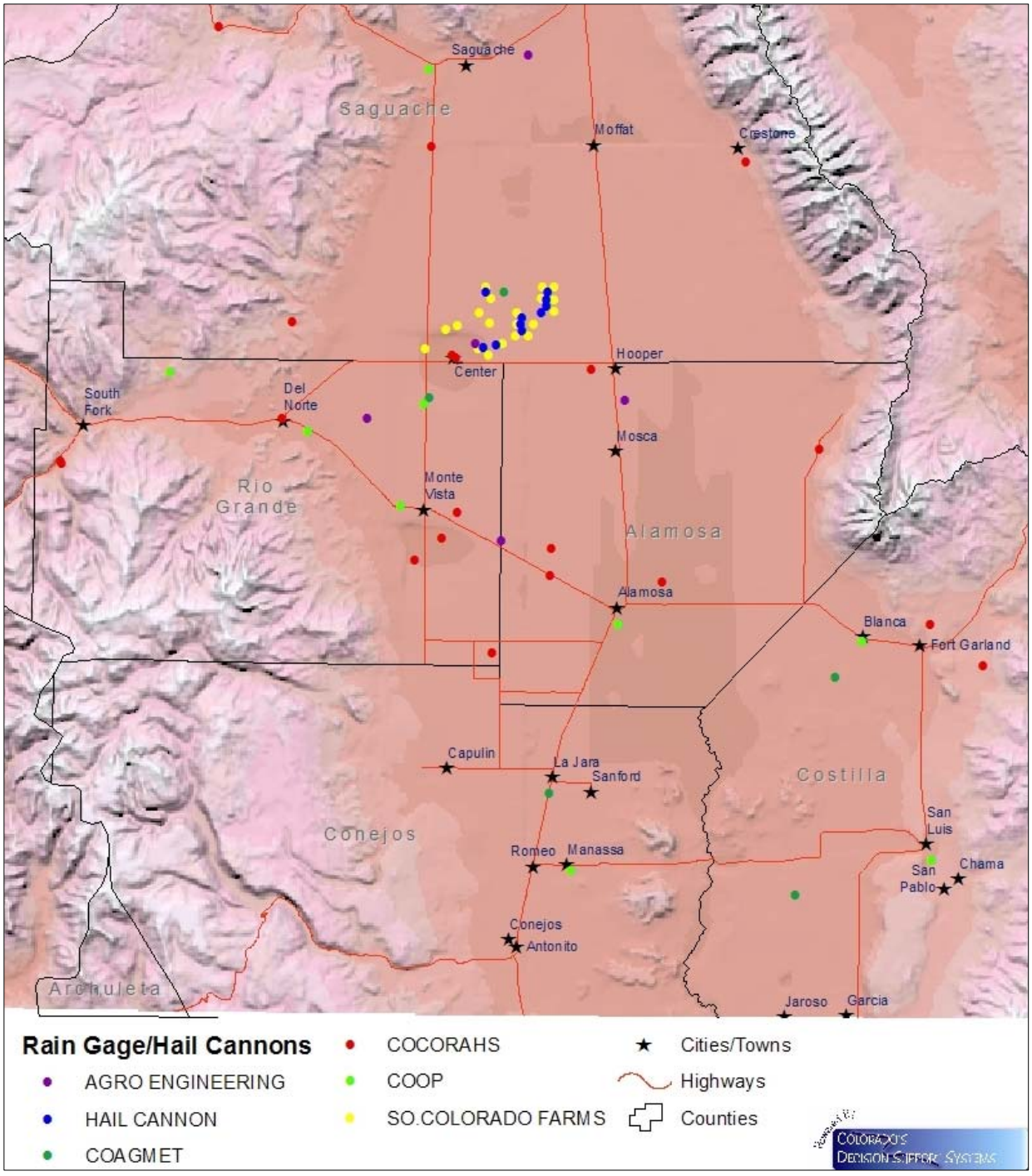
There are strong seasonal patterns in the precipitation that falls in this area. The figure below shows the average precipitation each month (rain and the melted water content of snow) at the long-term weather station at Colorado State University's San Luis Valley Research Center near Center, Colorado compared to the average monthly precipitation in the mountains observed at the Wolf Creek Pass 1E weather station. These two stations depict both the driest and the wettest areas of southern Colorado.



III. Data

Data used in this study come from five precipitation networks. Southern Colorado Farms (SCF) operated an extensive network of rain gauges and hail pads during the period between 19 June and 15 September. Daily rainfall amounts were recorded as well as hail occurrence and size at twenty of their fields located near Center, CO. Agro Engineering (AGRO) provided daily precipitation totals at five locations scattered around the Valley. The National Weather Service Cooperative Observer Program (COOP) has ten stations in the San Luis Valley. The Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS) had twenty stations in the valley during the summer of 2006 that reported regularly. And the Colorado Agricultural Meteorological Network (CoAgMet) has five stations in the valley, for a total of sixty stations. The growing season as defined is 93 days long, and unfortunately, some of the precipitation reports are missing numerous days. Only 49 of the 60 stations contain at least 90% of possible daily reports. The nominal observing time is 0700 local time, and this was the case for all but seven stations, all in the COOP network. For automated stations such as those in the AGRO and COAGMET networks, hourly data were retrieved so daily values ending at 0700 could be computed. There are also hail data available from certain stations in the COCORAHS and SCF networks. The map below shows the distribution of the various stations in the five networks; each network is denoted by a different color. The hail cannons shown on the map as blue dots will be described later.

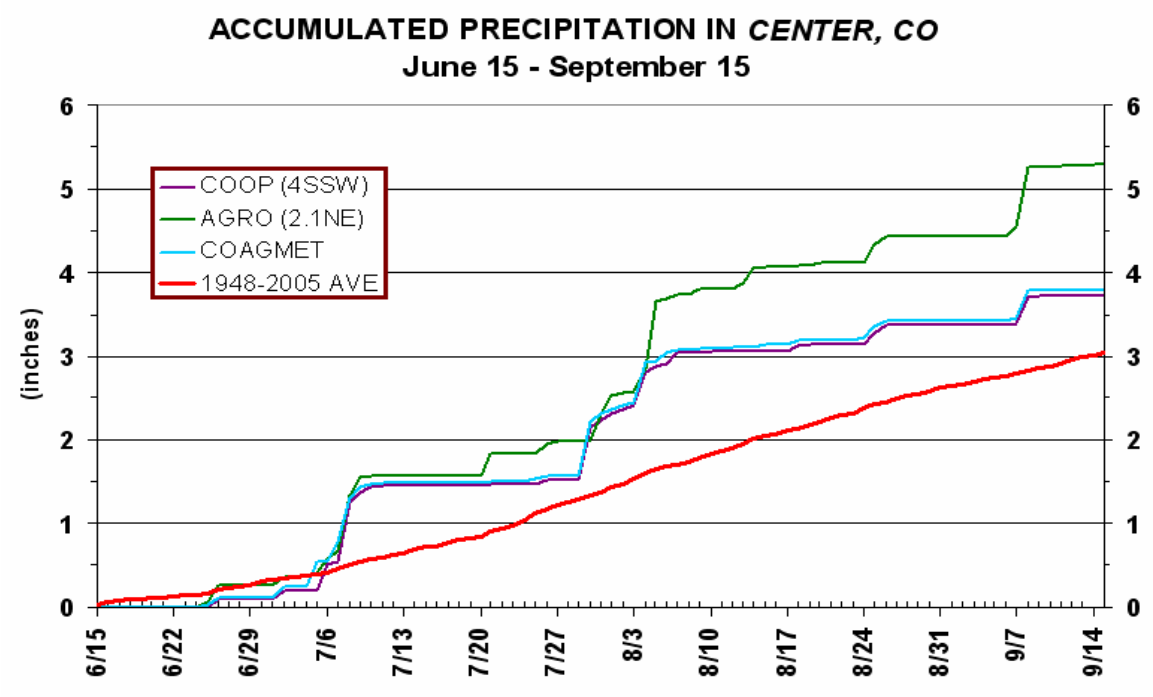
The table that follows provides the list of stations used in this study, their locations, precipitation totals (PREC), days with measurable precipitation (#MEAS), days with a non-measurable “trace” of precipitation (#TRACE), days with missing data (#MISSING), the nominal observing time for that station (OBS TIME), and the distance and direction to the nearest city (DESCRIPTION).

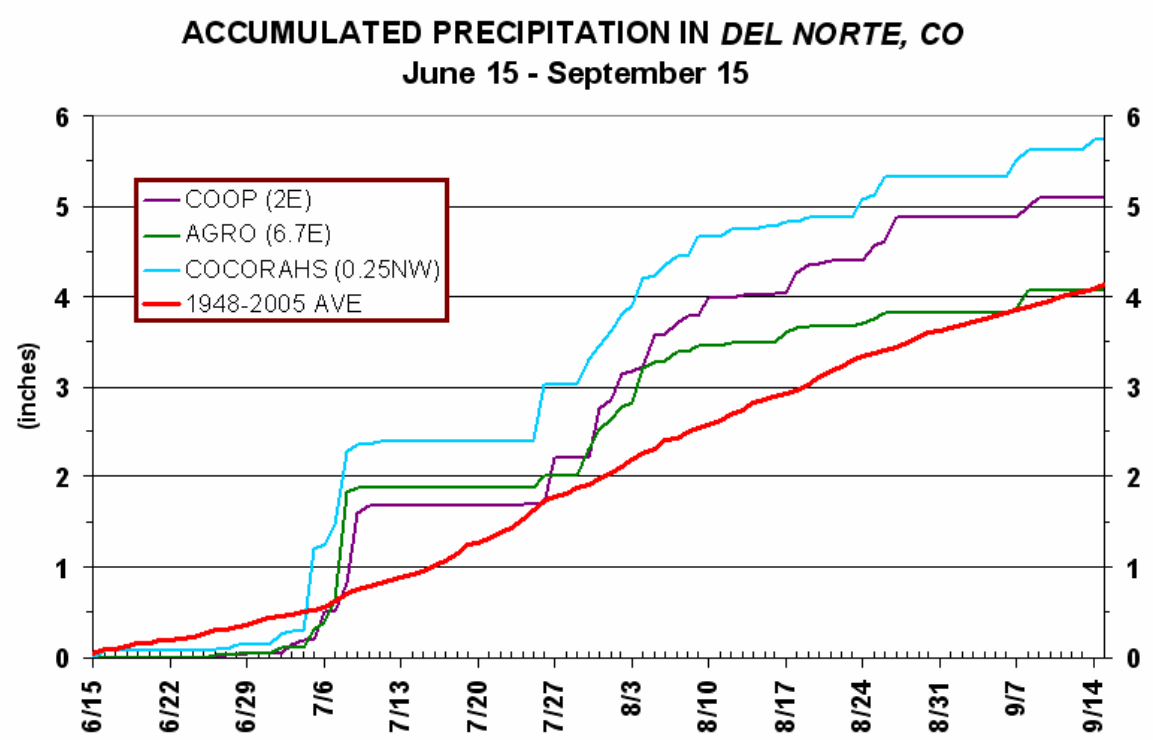

Saguache
Saguache
Moffat
Crestone
Hooper
Center
South Fork
Del Norte
Mosca
Monte Vista
Rio Grande
Alamosa
Alamosa
Blanca
Fort Garland
Capulin
La Jara
Sanford
Costilla
San Luis
Conejos
Romeo
Manassa
San Pablo
Chama
Conejos
Antonito
Archuleta
Jaroso
Garcia
Rain Gage/Hail Cannons
AGRO ENGINEERING
HAIL CANNON
COAGMET
COCORAHS
COOP
SO.COLORADO FARMS
Cities/Towns
Highways
Counties
Colorado Decision Support Systems

STATION ID	LAT	LONG	PREC	#MEAS	#TRACE	#MISSING	OBS TIME	DESCRIPTION
AGRO ENGINEERING								
AGR01	37.545	106.038	1.20	28	0	0	0700	Monte Vista 6.4ESE
AGR02	37.770	106.077	5.29	36	0	0	0700	Center 2.1NE
AGR03	37.706	105.862	3.52	35	0	0	0700	Saguache 7.4ENE
AGR04	38.101	106.005	2.64	31	0	0	0700	Mosca 3.8NNE
AGR05	37.683	106.231	4.07	29	0	0	0700	Del Norte 6.7E
COAGMET								
BLA01	37.391	105.557	4.72	35	0	0	0700	Blanca 8SW
CTR01	37.391	106.144	3.78	32	0	0	0700	Center
CTR02	37.829	106.038	4.59	33	0	0	0700	Center
LJR01	37.255	105.964	1.67	14	0	50	0700	La Jara 2S
SAN01	37.142	105.611	5.58	32	0	0	0700	Mesita 2N
COCORAHS								
AM01	37.505	105.966	3.76	31	2	21	0700	Alamosa 5.8WNW
AM06	37.741	105.910	6.17	36	8	0	0700	Hooper 1.9W
AM07	37.500	105.804	6.11	34	4	16	0700	Alamosa 4.1ENE
AM10	37.652	105.579	5.91	45	6	1	0700	Great Sand Dunes 7SSW
AM11	37.536	105.966	2.84	13	0	56	0700	Alamosa 6.9NW
CS07	37.406	105.343	6.77	45	2	0	0700	Fort Garland 5.2ESE
CS09	37.452	105.420	5.92	46	0	5	0700	Fort Garland 1.6NNE
RG02	37.546	106.122	5.75	37	6	1	0700	Monte Vista 2.7SSE
RG05	37.628	106.673	7.91	41	9	0	0700	South Fork 4.1SW
RG07	37.522	106.161	5.30	35	6	1	0700	Monte Vista 4.1S
RG08	37.626	106.671	6.71	33	7	21	0700	South Fork 3.1SW
RG09	37.681	106.355	5.73	33	3	0	0700	Del Norte 0.25NW
RG10	37.577	106.100	2.24	26	2	7	0700	Monte Vista 2.4E
RG13	37.416	106.048	5.54	29	0	22	0700	Estrella 7.5WNW
SA02	37.980	105.689	8.32	48	16	3	0700	Crestone 1.2SSE
SA04	37.756	106.110	3.40	24	0	19	0700	Center 0.3N
SA05	38.129	106.455	6.64	35	0	25	0700	Saguache 17.3W
SA08	37.995	106.143	4.43	17	0	35	0700	Saguache 6.3S
SA11	37.792	106.341	6.22	38	9	5	0700	LaGarita 5.6WSW
SA12	37.753	106.106	2.56	18	0	25	0700	Center 0.3ENE
NWS COOP								
ALA	37.450	105.867	4.99	36	12	0	0700	Alamosa 2S
BLA	37.433	105.517	6.28	41	2	0	0800	Blanca
CRE	37.983	105.683	8.41	48	11	0	1700	Crestone 1SE
CTR	37.700	106.150	3.72	30	0	0	0000	Center 4SSW
DEL	37.667	106.317	5.11	33	15	0	0700	Del Norte 2E
GSD	37.733	105.517	7.48	42	4	0	0800	Great Sand Dunes
MAN	37.167	105.933	6.58	32	4	1	1700	Manassa
MON	37.583	106.183	5.21	31	10	1	0700	Monte Vista 2W
SAG	38.083	106.150	5.41	11	32	0	0800	Saguache
SAN	37.183	105.417	0.11	2	1	77	1000	San Luis 1S
SOUTHERN COLORADO FARMS								
FLD01	37.792	105.993	6.22	33	0	4	0700	
FLD06	37.807	105.965	4.90	28	0	4	0700	
FLD09	37.823	105.983	3.95	31	0	4	0700	
FLD10	37.821	105.965	4.33	31	0	4	0700	
FLD11	37.835	105.982	3.90	30	0	4	0700	
FLD12	37.835	105.965	4.15	31	0	4	0700	
FLD13	37.779	106.019	6.55	35	0	4	0700	
FLD14	37.779	106.002	6.45	35	0	4	0700	
FLD15	37.792	106.019	6.70	33	0	4	0700	
FLD19	37.806	106.019	5.44	32	0	4	0700	
FLD21	37.791	106.103	6.27	30	0	4	0700	
FLD22	37.786	106.120	6.26	29	0	4	0700	
FLD24	37.806	106.073	6.08	32	0	4	0700	
FLD25	37.793	106.057	5.42	33	0	4	0700	
FLD26	37.764	106.074	5.69	33	0	4	0700	
FLD29	37.821	106.057	6.76	32	0	4	0700	
FLD30	37.835	106.063	6.75	31	0	4	0700	
FLD32	37.763	106.149	4.82	30	0	4	0700	
FLD36	37.756	106.058	4.77	32	0	4	0700	
FLD38	37.770	106.038	5.55	33	0	4	0700	

For the 3-month period involved in this study, accumulated daily precipitation data are shown for two stations in the central valley: Center and Del Norte. These National Weather Service COOP stations were chosen for their historical records, complete 2006 records, and representative locations. In each plot, the station long-term mean (1948-2005) is shown for the official National Weather Service Cooperative Observer site (COOP) as a thick red line, and values from other nearby networks' stations are plotted with thin lines, including the 2006 totals from the COOP stations. Since the stations are not co-located, the long-term average may differ among the sites, but this gives a visual generalization of how the 2006 summer precipitation compared to a nearby average value. In Center, the long-term mean total precipitation for 15 June – 15 September is about 3 inches. The COOP and COAGMET stations reported about 3.7 inches (123% of normal) in 2006, and the AGRO station reported 5.3 inches (176% of normal). A similar story is found in Del Norte, where the normal total is about 4.1 inches, and while the AGRO station reported almost exactly the average amount, the COOP and COCORAHS stations were 124% and 139% above normal, respectively. The conclusion from this is that the summer of 2006 was notably wetter than normal.

Using the full data record at Center, CO, a time series of precipitation during the summer months (June - September only) is presented below. A clear multi-decadal signal can be seen with the aid of the five-year running mean trendline: relatively dry in the 1950s, again in the 1970s, and another period ongoing since the late 1990s. There are interrupted by wetter eras, also lasting approximately ten to fifteen years. The summer of 2006 was the wettest since 1999, although substantial interannual variability makes it challenging, if not impossible, to determine if another “wet” era is beginning. The full-record average precipitation for June – September is 3.76 inches.

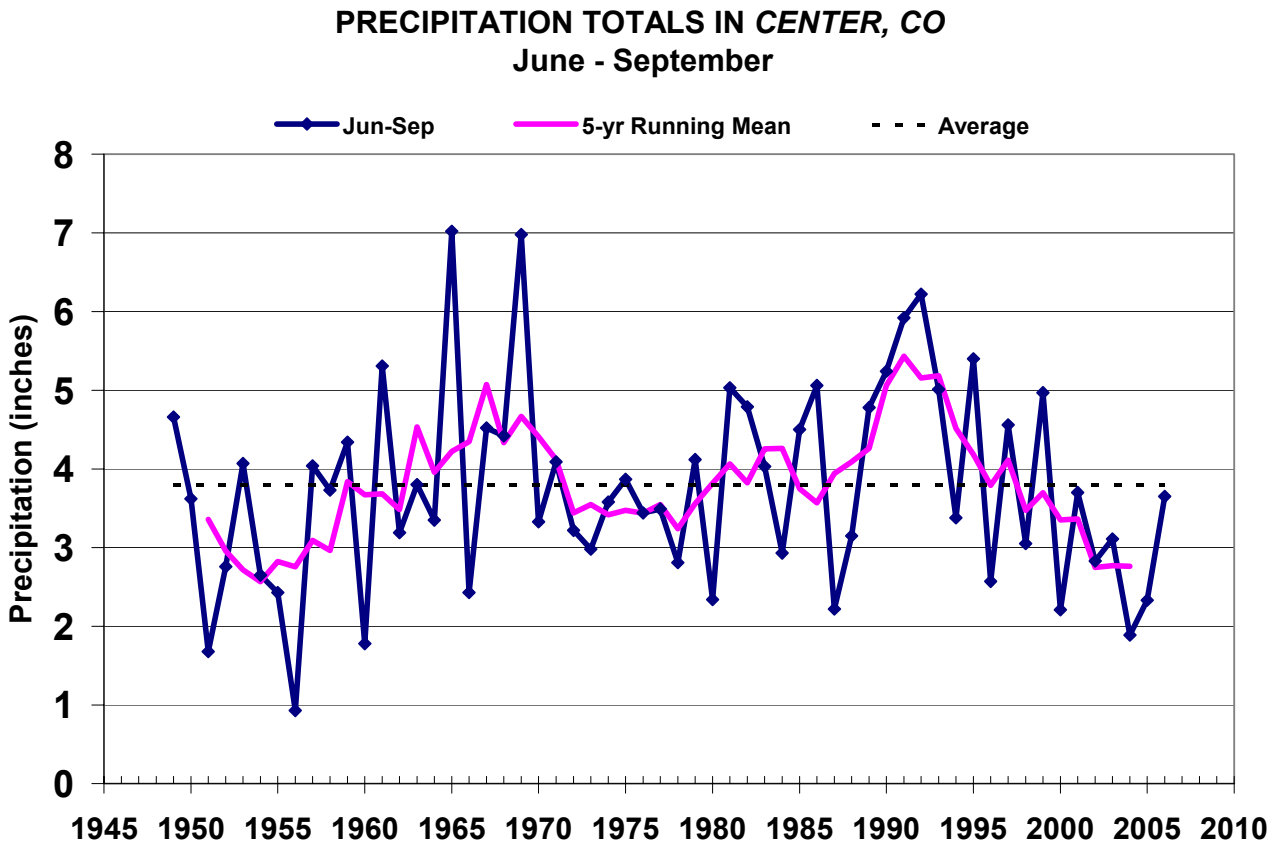




Hail is a very spotty phenomenon. Despite the seemingly large number of reporting stations in the valley, it is still likely that some storms went undetected. CoCoRaHS showed a total of 14 hail reports among the 20 stations and 93 days. Hail was reported by CoCoRaHS observers on 11 days with the first report on July 3 and the final report

on September 15th. Multiple stations reported hail on 3 dates – July 22, July 26, and September 8. We believe that all the hail reports and hail pads collected during summer 2006 by CoCoRaHS volunteers have been turned in. However, data processing is still ongoing and a few additional reports may still appear.

Photo of one of Southern Colorado Farm's hail cannons in use during the 2006 growing season.

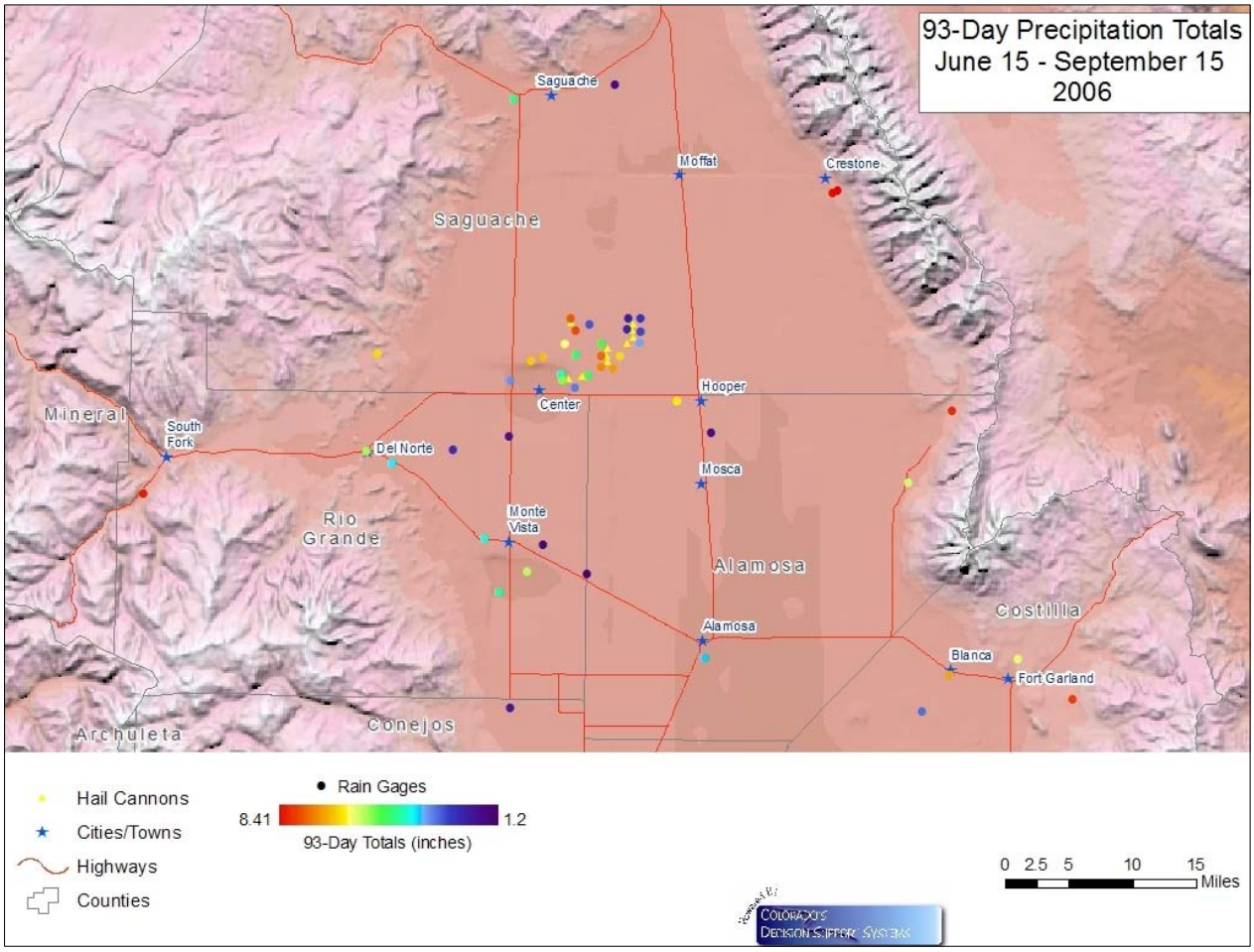


SCF had a total of 50 hail reports among their 20 stations and 89 reporting days (2.8% of daily reports had hail). Keep in mind that SCF was extremely concerned about hail and may have been watching more closely than other stations in the valley. There was no severe hail reported (defined by the National Weather Service as maximum stone diameter >0.75"), but a few instances of 0.5" hail reports at Center, Del Norte, and Great Sand Dunes (on 22 July, 26 July, and 5 July, respectively). At the SCF fields, there were 8 days with hail reported, sometimes only at one field, but on 26 August, 15 of the 20 fields involved in the study were hit by hail. On that same day, the only COCORAHS station to be hit by hail was the one near Hooper (AM06), and 0.25" hailstones were reported. Despite the seemingly small stones (from a National Weather Service perspective), several of the storms had sufficient quantity, size and hardness of hail stone to cause significant crop damage. Estimates of crop losses during the summer of 2006 can be obtained from SCF farm staff.

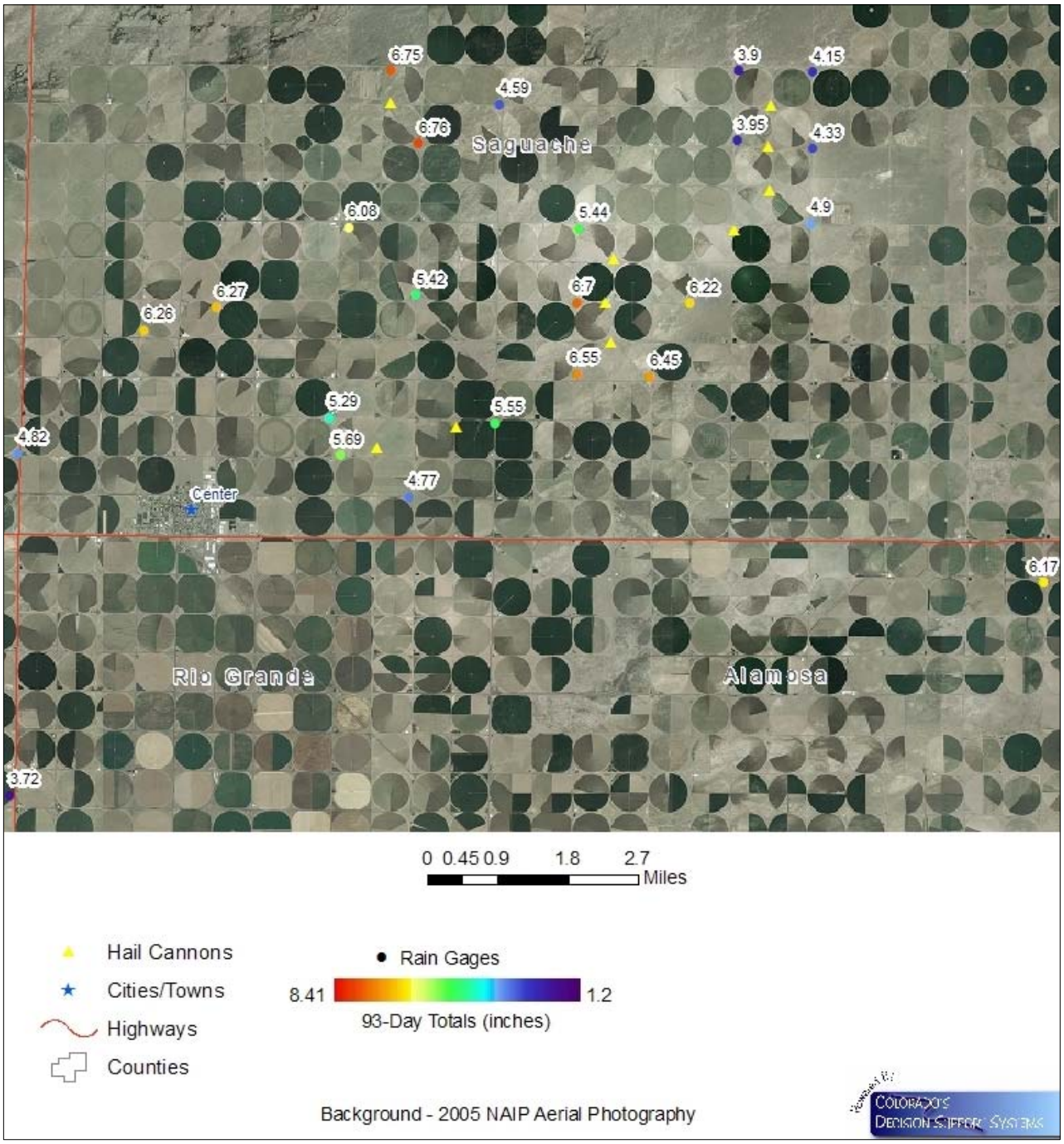
SCF operated ten hail cannons during the growing season of 2006. They were utilized on 17 days, seven of which actually had hail fall on the fields. Hail fell on the fields only one day when the cannons were not activated. Hail cannons are devices that emit a loud shockwave upward every four seconds into approaching, developing thunderstorm clouds, with the intent of disrupting the hailstone formation process. More details of hail cannon operation during the 2006 growing season are available in the summary report provided by SCF to the Colorado Water Conservation Board.

The following map shows the precipitation totals from the 93-day period of interest, from all of the available stations in the entire San Luis Valley. Stations with >10% missing data were omitted, which brings the number of stations to 49 instead of 60. Station dots are colored according to precipitation totals on the color bar at the bottom of the image; warm colors are higher amounts, while cool colors are lower amounts. Higher amounts are typically found toward the periphery of the valley, closer to the mountains; however, there are some higher totals in the interior reported by the SCF network on the order of 6.25"-6.75" during the three months (recall the average is about 3" for this period). SCF

stations to the northeast and southwest of the center of the array experienced less precipitation, typically within the 3.9”-5.7” range.



Due to the high concentration of stations to the northeast of Center, and the hail cannons, the next map is zoomed in over the SCF network, and plotted over aerial true-color imagery. It is still displaying the totals from the entire 93-day period of interest: 15 June – 15 September 2006, from all available stations.


6.75
3.9
4.15
4.59
6.76
Saguache
3.95
4.33
6.08
5.44
4.9
5.42
6.7
6.22
6.27
6.26
6.55
6.45
5.29
5.55
4.82
5.69
4.77
Center
6.17
Rio Grande
Alamosa
3.72
0 0.45 0.9 1.8 2.7
Miles
Hail Cannons
Cities/Towns
Highways
Counties
Rain Gages
8.41
1.2
93-Day Totals (inches)
Background - 2005 NAIP Aerial Photography
COLORADO'S
DECISION SUPPORT SYSTEMS

IV. Summary and Recommendations

During the growing season of 2006, the San Luis Valley experienced above-normal rainfall, ranging between 110 to 184% of normal, with an average of 147%. From the combination of data sources, hail was report somewhere in the valley on 15 out of 93 days. Hail was reported on SCF fields a total of 8 days during the data collection period. Locally highly-variable precipitation patterns once again illustrate the need for high-density precipitation networks. Even within the relatively closely-packed fields in the SCF network, there was a range of 3.90” to 6.76” of precipitation. The SCF network of twenty fields reported an average of 5.55” of rainfall during the three-month growing season, compared to the normal 3.29” at the nearest COOP station (Center 4SSW). The COOP station itself reported 3.72” during 2006's growing season, only slightly above normal.

This collaborative data collection effort resulted in an excellent data set to assess the general characteristics of precipitation and the frequency and approximate severity of hail during the summer of 2006. In particular, the data collected by SCF provides a dense network for examining local variations in rain and hail. However, the lack of a comparable dense network of rain and hail monitoring stations upwind, crosswind and downwind of SCF makes it difficult to reach quantitative, albeit preliminary, conclusions regarding the impact of hail cannons on rain and hail patterns. Should interest in this topic and the use of hail cannons continue, we hope that a more aggressive data collection network in a radius of approximately 15 miles from the center of the farm could be established for future years.

V. Acknowledgements

Carolyn Fritz at the Colorado Water Conservation Board was instrumental in generating the maps shown in this report. Kelley Thompson provided daily precipitation data from the Agro Engineering network. Funding for the study is from the Colorado Water Conservation Board.