GENERAL SUMMARY ON THE CLIMATE OF CHIHUAHUAN DESERT NETWORK PARKS AND SOME NEARBY PROTECTED LANDS

By

William H. Reid, Ph.D.
NPS Chihuahuan Desert Network Biologist

M. Hildegard Reiser, Ph.D.
NPS Chihuahuan Desert Network Coordinator

Las Cruces, New Mexico

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I INTRODUCTION

This study is intended as a first step in examining and quantifying the climate of the Chihuahuan Desert Network Parks and some nearby protected lands.

There are seven Chihuahuan Desert Network (CHDN) parks: Amistad National Recreation Area (AMIS), Big Bend National Park (BIBE), Carlsbad Caverns National Park (CAVE), Fort Davis National Historic Site (FODA), Guadalupe Mountains National Park (GUMO), Rio Grande Wild and Scenic River (RIGR), and White Sands National Monument (WHSA). The RIGR*, a long, narrow, isolated and intermediate between AMIS and BIBE, is not included in this review.

Table 1. National Park Service units located in the Chihuahuan Desert Network.

Unit	Park code	Hectares	Acres
Amistad National Recreation Area	AMIS	23,186	57,292
Big Bend National Park	BIBE	324,226	801,163
Carlsbad Caverns National Park	CAVE	18,926	46,766
Fort Davis National Historic Site	FODA	192	474
Guadalupe Mountains National Park	GUMO	34,972	86,416
Rio Grande Wild and Scenic River	RIGR	2,090*	5,164*
White Sands National Monument	WHSA	58,168	143,733
	Totals	461,760	1,141,008

***** RIGR encompasses 315 river km (196 river miles) from the Chihuahua-Coahuila State Line in Mexico to the Terrell Val Verde County Line in the United States. Though for planning purposes and project implementation, the BIBE-RIGR overlap is considered and is limited to the 209 river km (127 river miles) between Big Bend and the Terrell Val Verde County Line.

The CHDN parks form a northwest to southeast, 500 km (340 mile) line through southern New Mexico, West Texas and into South Texas, and elevations range from 340 m (1,117 ft) to 2667 m (8749 ft) (table 2; figure 1 and 2).

Table 2. Minimum and maximum elevations (m) for each park unit, except RIGR, in the CHDN. Elevations were rounded to the nearest meter (m).

Park Unit	Min. Elev.	Max. Elev.	Elev. Span
AMIS	282	364	82
BIBE	548	2387	1839
CAVE	1096	1987	892
FODA	1487	1622	134
GUMO	1102	2667	1565
RIGR	360	616	56
WHSA	1185	1290	105

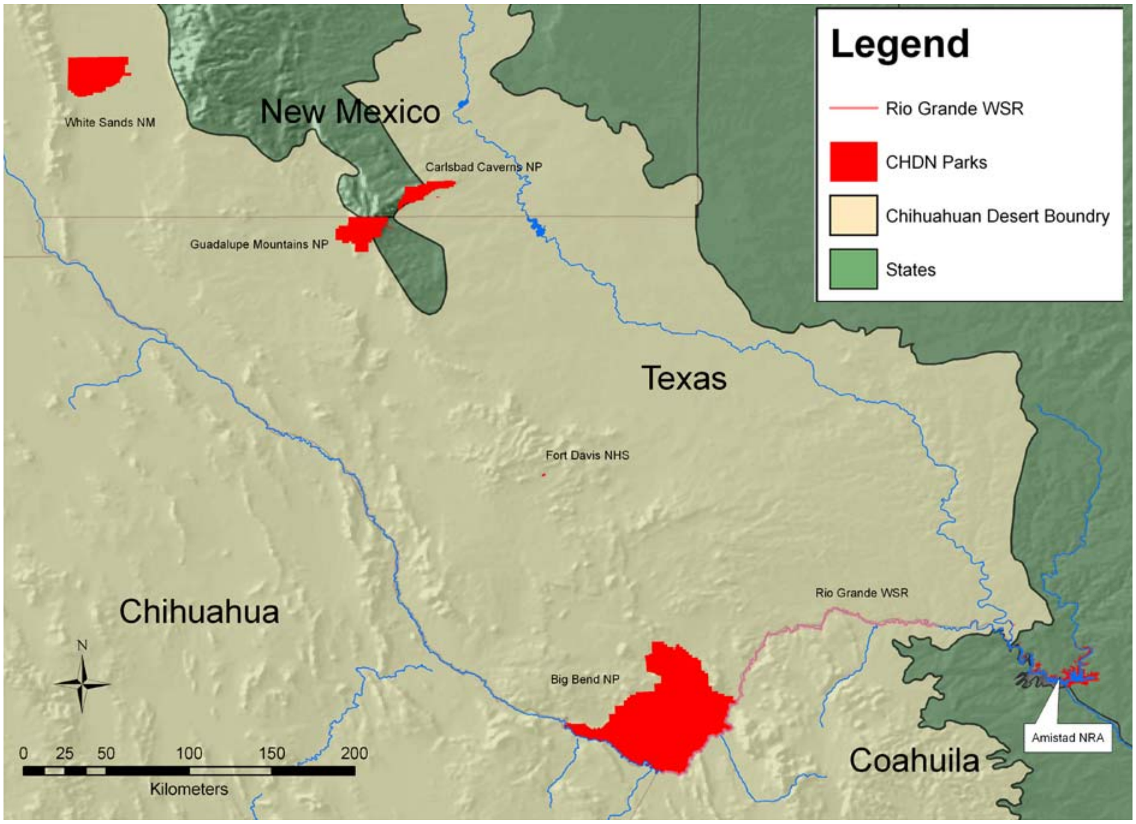

Figure 1. Map of CHDN park units.

At least two other protected areas should be included in the discussion of climate patterns within the Chihuahuan Desert: the University of Texas - El Paso's Indio Mountains Research Station (IMRS), and the USDA ARS Jornada Experimental Range (JERE). These units' physical attributes (table 3) fall within the range of values found for the CHDN park units. Other land areas may be added in future revisions of this document.

Table 3. Physical attributes of IMRS and JERA.

Research Unit	Area (ha)	Min. Elev. (m)	Max. Elev. (m)	Elev. Span (m)
IMRS	15,783	900	1600	700
JERA	78,000	1189	2508	1319

The CHDN parks are distributed over a rather large geographic range. This distribution, deriving from historic events of park creation, forms a statistically significant straight line from northwest to southeast as shown in Figure 1 below.

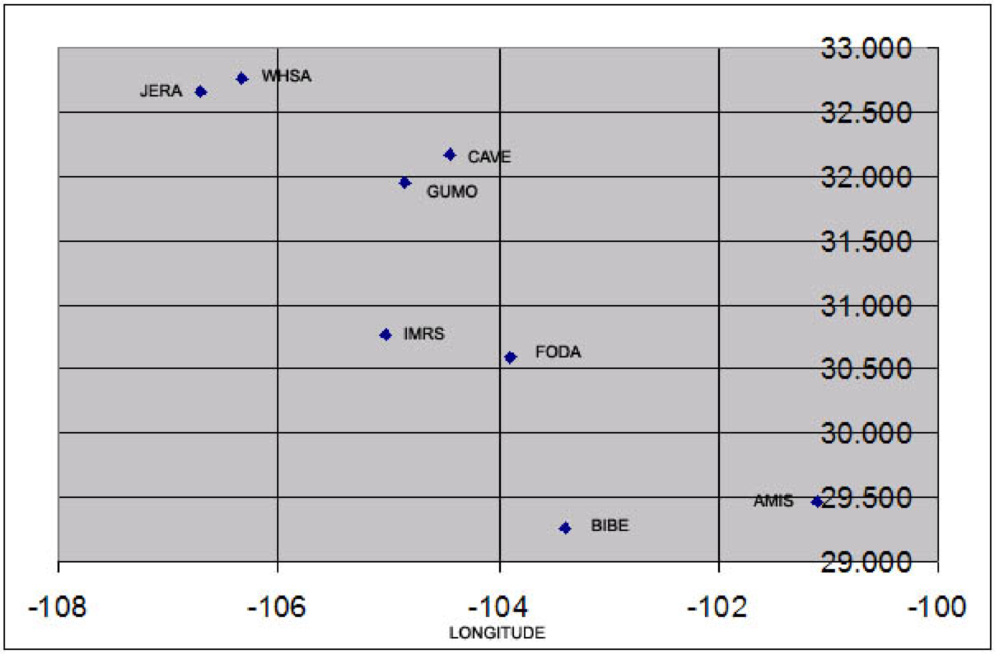

Figure 2. Latitude—longitude plot for the study sites.

The Chihuahuan Desert is characterized as a cold desert with annual precipitation usually somewhat above 200 mm, half of which falls in July to September monsoon thunderstorms (Ropelewski et al. 2005). This pattern of precipitation focused in summer and late summer is common to all the park units except AMIS, which has higher, more evenly distributed rainfall. Amistad NRA is primarily located in the biogeographic province known as Tamaulipan Shrubland, though it is influenced by both Chihuahuan Desert and Edward's Plateau biogeographical provinces (Rich, et al. 2004). AMIS is not usually considered within the Chihuahuan Desert Ecosystem (Rickets et al. 1999), however, many Chihuahuan Desert species extend into the park. Schmidt (1979, 1990, 1995) has conducted a detailed, climatic examination of the Chihuahuan Desert. Year-to-year and place-to-place precipitation is highly variable.

II CLIMATE

Weather data for Tables 4 -12 were drawn from available sources, most including two National Climatic Data Center (NCDC) 30 year summaries (NOAA 2002a and 2002b). For IMRS, data from Van Horn, Texas was used. The NCDC data for Dell City, Texas was used for describing GUMO's lower altitude Dunes Area. A 71 year data set for CAVE (Pate 2005) is included. Two data sets for the Jornada Experimental Range are included: (1) NCDC and (2) 81 years of historical data (which is available on line at http://jornada-www.nmsu.edu/studies/usda/datasets/CLIMATE/NOAA/usdaclim.htm).

Table 4. Mean annual precipitation and mean annual temperature for all units. The NOAA data are for 1971 through 2000. CAVE data are 1934 through 2004, and JERA data are 1932 through 2003.

UNIT (source)	Length (yrs)	Precip. (mm)	Temp. (˚C)
AMIS (NOAA)	30	482	20.7
BIBE (NOAA)	30	359	19.2
CAVE (NOAA)	30	438	16.5
CAVE (park)	71	365	17.4
FODA (NOAA)	30	403	15.9
GUMO (NOAA)	30	394	15.4
GUMO (NOAA)	30	398	14.9
GUMO (NOAA near Dunes)	30	231	16.5
WHSA (NOAA)	30	262	15.0
IMRS (NOAA nearby town)	30	304	16.4
JERA (in house)	82	304	16.2
JERA (NOAA)	30	291	14.6

In the park data below, precipitation and temperature re the means over the period of record, which is 30 years for the NOAA data.

Table 5. Amistad NRA (NOAA data location: Amistad Dam, Alt.: 353 m). Mean $\pm$ one standard deviation.

Month	Precip. (in.)	Precip. (mm)	Temp. (˚F)	Temp. (˚C)
Jan	0.57	14.48	50.3	10.2
Feb	0.83	21.08	55.1	12.8
Mar	1.02	25.91	63.0	17.2
Apr	1.30	33.02	70.4	21.3
May	2.22	56.39	77.4	25.2
Jun	2.42	61.47	82.7	28.2
Jul	1.97	50.04	85.0	29.4
Aug	2.19	55.63	84.7	29.3
Sep	2.85	72.39	79.6	26.4
Oct	1.81	45.97	70.1	21.2
Nov	1.06	26.92	59.5	15.3
Dec	0.75	19.05	52.4	11.3
Mean	**1.58 $\pm$ 0.75**	**40.20 $\pm$ 19.13**	**69.2**	**20.7**
Annual	**18.99**	**482.35**		

Table 6. Big Bend NP (NOAA data location: Panther Junction, Alt.: 1140 m). Mean ± one standard deviation.

Month	Precip. (in.)	Precip. (mm)	Temp. (˚F)	Temp. (˚C)
Jan	0.43	10.84	49.0	9.4
Feb	0.51	12.85	53.6	12.0
Mar	0.32	8.06	60.8	16.0
Apr	0.55	13.86	67.9	19.9
May	1.46	36.79	75.8	24.3
Jun	1.90	47.88	80.6	27.0
Jul	2.26	56.95	81.2	27.3
Aug	2.34	58.97	79.7	26.5
Sep	1.86	46.87	75.2	24.0
Oct	1.53	38.56	66.8	19.3
Nov	0.57	14.36	57.3	14.1
Dec	0.51	12.85	50.0	10.0
Mean	**1.19 ± 0.78**	**29.90 ± 19.61**	**66.5**	**19.2**
Annual	**14.24**	**358.85**		

Table 7a. Carlsbad Caverns NP (NOAA data location: Near headquarters, Alt.: 1343 m). Mean ± one standard deviation.

Month	Precip. (in.)	Precip. (mm)	Temp. (˚F)	Temp. (˚C)
Jan	0.42	10.67	44.1	6.7
Feb	0.49	12.45	48.1	8.9
Mar	0.26	6.60	54.5	12.5
Apr	0.53	13.46	61.6	16.4
May	1.50	38.10	70.0	21.1
Jun	2.25	57.15	76.9	24.9
Jul	2.10	53.34	77.9	25.5
Aug	2.65	67.31	76.5	24.7
Sep	3.64	92.46	70.8	21.6
Oct	2.28	57.91	62.6	17.0
Nov	0.55	13.97	52.2	11.2
Dec	0.57	14.48	45.2	7.3
Mean	**0.44 ± .12**	**36.48 ± 28.45**	**61.7**	**16.5**
Annual	**17.24**	**437.90**		

Table 7b. Carlsbad Caverns NP (Park database, Location: Bat Draw, Alt.1349m). Mean ± one standard deviation.

Month	Precip. (in.)	Precip. (mm)	Temp. (˚F)	Temp. (˚C)
Jan	0.45	11.30	44.9	7.2
Feb	0.43	10.92	48.5	9.1
Mar	0.41	10.31	54.7	12.6
Apr	0.59	15.04	62.6	17.0
May	1.42	35.99	70.8	21.5
Jun	1.71	43.51	77.3	25.2
Jul	2.06	52.40	78.5	25.8
Aug	2.38	60.53	77.6	25.3
Sep	2.90	73.58	71.7	22.1
Oct	1.40	35.43	63.6	17.6
Nov	0.57	14.35	53.2	11.8
Dec	0.48	12.27	46.8	8.2
Mean	**1.23 ± 0.88**	**31.30 ± 22.25**	**62.5**	**17.0**
Annual	**14.80**	**364.34**		

Table 8. Fort Davis NHS (NOAA data location: City of Fort Davis, Alt.: 1366 m). Mean ± one standard deviation.

Month	Precip. (in.)	Precip. (mm)	Temp. (˚F)	Temp. (˚C)
Jan	0.43	10.92	44.8	7.1
Feb	0.35	8.89	48.6	9.2
Mar	0.34	8.64	54.0	12.2
Apr	0.50	12.70	61.1	16.2
May	1.46	37.08	68.8	20.4
Jun	1.79	45.47	74.9	23.8
Jul	2.95	74.93	75.3	24.1
Aug	2.97	75.44	73.4	23.0
Sep	2.76	70.10	68.9	20.5
Oct	1.29	32.77	61.3	16.3
Nov	0.49	12.45	51.5	10.8
Dec	0.53	13.46	45.8	7.7
Mean	**1.32 ± 1.06**	**33.57 ± 26.94**	**60.7**	**15.9**
Annual	**15.86**	**402.84**		

Table 9a. Guadalupe Mountains NP (NOAA data for Pine Springs near park headquarters. Alt.: 1707 m   Mean ± one standard deviation.

Month	Precip. (in.)	Precip. (mm)	Temp. (˚F)	Temp. (˚C)
Jan	0.47	11.938	41.4	5.22
Feb	0.69	17.526	45.1	7.28
Mar	0.39	9.906	50.0	10
Apr	0.41	10.414	57.6	14.22
May	0.91	23.114	65.7	18.72
Jun	1.43	36.322	73.2	22.89
Jul	2.57	65.278	73.7	23.17
Aug	3.08	78.232	72.1	22.28
Sep	2.25	57.15	67.0	19.44
Oct	1.5	38.1	59.3	15.27
Nov	1.13	28.702	48.9	9.39
Dec	0.83	21.082	42.0	5.56
Mean	**1.76 ± 1.47**	**33.15± 22.74**	**58.0 ± 6.83**	**15.0**
Annual	**21.06**	**397.76**	**16.66**	

Table 9b. Guadalupe Mountains NP Dunes (NOAA data location: Dell City, TX, Alt: 1149 m). Mean ± one standard deviation.

Month	Precip. (in.)	Precip. (mm)	Temp. (˚F)	Temp. (˚C)
Jan	0.34	8.64	42.3	5.7
Feb	0.32	8.13	47.3	8.5
Mar	0.25	6.35	53.6	12.0
Apr	0.16	4.06	61.0	16.1
May	0.99	25.15	70.7	21.5
Jun	0.92	23.37	78.9	26.1
Jul	1.35	34.29	81.1	27.3
Aug	1.44	36.58	78.8	26.0
Sep	1.46	37.08	72.3	22.4
Oct	0.92	23.37	62.0	16.7
Nov	0.49	12.45	49.8	9.9
Dec	0.46	11.68	42.1	5.6
Mean	**0.76 ± 0.48**	**19.26 ± 12.25**	**61.7**	**16.5**
Annual	**9.10**	**231.14**		

Table 10a. White Sands NM (NOAA data location: Near Headquarters, Alt.: 1218 m). Mean ± one standard deviation.

Month	Precip. (in.)	Precip. (mm)	Temp. (˚F)	Temp. (˚C)
Jan	0.59	14.99	39.1	3.9
Feb	0.37	9.40	43.7	6.5
Mar	0.27	6.86	50.4	10.2
Apr	0.28	7.11	58.0	14.4
May	0.48	12.19	67.6	19.8
Jun	0.97	24.64	76.9	24.9
Jul	1.34	34.04	79.8	26.6
Aug	2.11	53.59	77.3	25.2
Sep	1.40	35.56	70.9	21.6
Oct	1.08	27.43	59.4	15.2
Nov	0.60	15.24	46.0	7.8
Dec	0.84	21.34	38.3	3.5
Mean	**0.86 ± 0.55**	**21.87 ± 14.03**	**59.0**	**15.0**
Annual	**10.33**	**262.38**		

Table 10b. White Sands NM (In-park recorded data location: Near Headquarters, Alt.: 1218 m) for the period 1990 through 2003. Mean ± one standard deviation.

Month	Precip. (in.)	Precip. (mm)
Jan	0.54	13.72
Feb	0.32	8.13
Mar	0.33	8.38
Apr	0.37	9.40
May	0.47	11.94
Jun	1.02	25.91
Jul	1.18	29.97
Aug	1.41	35.81
Sep	1.34	34.04
Oct	0.78	19.81
Nov	0.39	9.91
Dec	0.93	23.62
Mean	**0.76 + 0.41**	**19.22 ± 0.37**
Annual	**9.08**	**232.16**

Table 11. Indio Mountains Research Station (NOAA data location: Van Horn, TX, Alt.: 1255 m). Mean + one standard deviation.

Month	Precip. (in.)	Precip. (mm)	Temp. (˚F)	Temp. (˚C)
Jan	0.39	9.91	42.7	5.9
Feb	0.33	8.38	47.3	8.5
Mar	0.16	4.06	53.7	12.1
Apr	0.24	6.10	60.8	16.0
May	0.71	18.03	69.6	20.9
Jun	1.25	31.75	77.5	25.3
Jul	2.11	53.59	78.3	25.7
Aug	2.30	58.42	76.5	24.7
Sep	2.23	56.64	70.8	21.6
Oct	1.27	32.26	61.8	16.6
Nov	0.46	11.68	50.8	10.4
Dec	0.53	13.46	43.2	6.2
Mean	**1.00 + 0.81**	**25.36 + 20.65**	**61.1**	**16.2**
Annual	**11.98**	**304.29**		

Table 12. Jornada Experimental Range (NOAA data location: Near Headquarters, Alt.: 1300 m). Mean + one standard deviation.

Month	Precip. (in.)	Precip. (mm)	Temp. (˚F)	Temp. (˚C)
Jan	0.58	14.73	39.0	3.9
Feb	0.38	9.65	43.4	6.3
Mar	0.26	6.60	49.7	9.8
Apr	0.22	5.59	56.9	13.8
May	0.48	12.19	65.6	18.7
Jun	0.93	23.62	74.7	23.7
Jul	2.09	53.09	78.7	25.9
Aug	2.52	64.01	76.3	24.6
Sep	1.36	34.54	70.2	21.2
Oct	1.12	28.45	58.9	14.9
Nov	0.61	15.49	46.6	8.1
Dec	0.89	22.61	39.0	3.9
Mean	**0.95 + 0.72**	**24.21 + 18.40**	**58.3**	**14.6**
Annual	**11.44**	**290.58**		

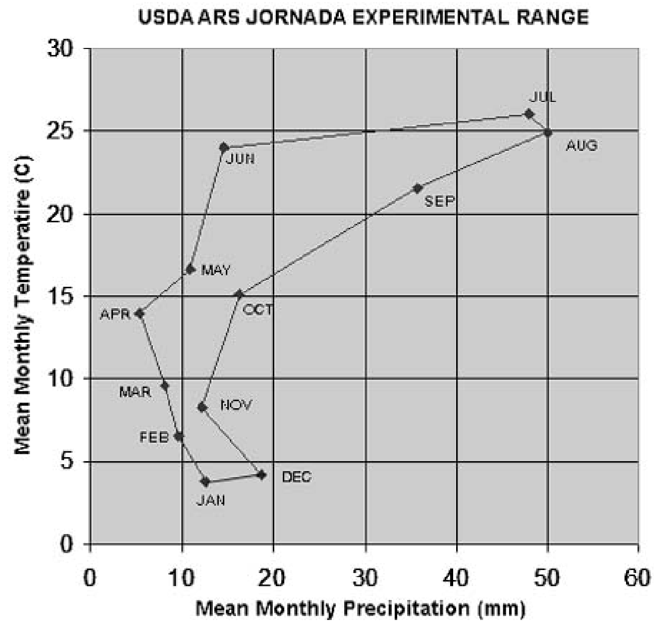

Figure 3. Climograph plot showing mean monthly temperature (Y axis) plotted against mean monthly precipitation for the Jornada Experimental Range. The shape of the polygon formed is typical of the Chihuahuan Desert, with a single precipitation excursion in July, August and September.

III CLIMATIC VARIABILITY

Precipitation in the Chihuahuan Desert is highly variable. This phenomenon can primarily be attributed to the North American Monsoon System (NAMS) (Ropelewski et al. 2005). The monsoon accounts for at least 50% of the summer rainfall for much of western Mexico from near 20˚ N through the states of Nayarit, Sinaloa and Sonora (Adams and Comrie 1997), and nearly 40% of seasonal rainfall in southern Arizona and New Mexico in the United States (Figure 3). Some locations in Mexico receive as much as 70% of their annual rainfall associated with the NAMS during July, August and September (Douglas et al. 1993).

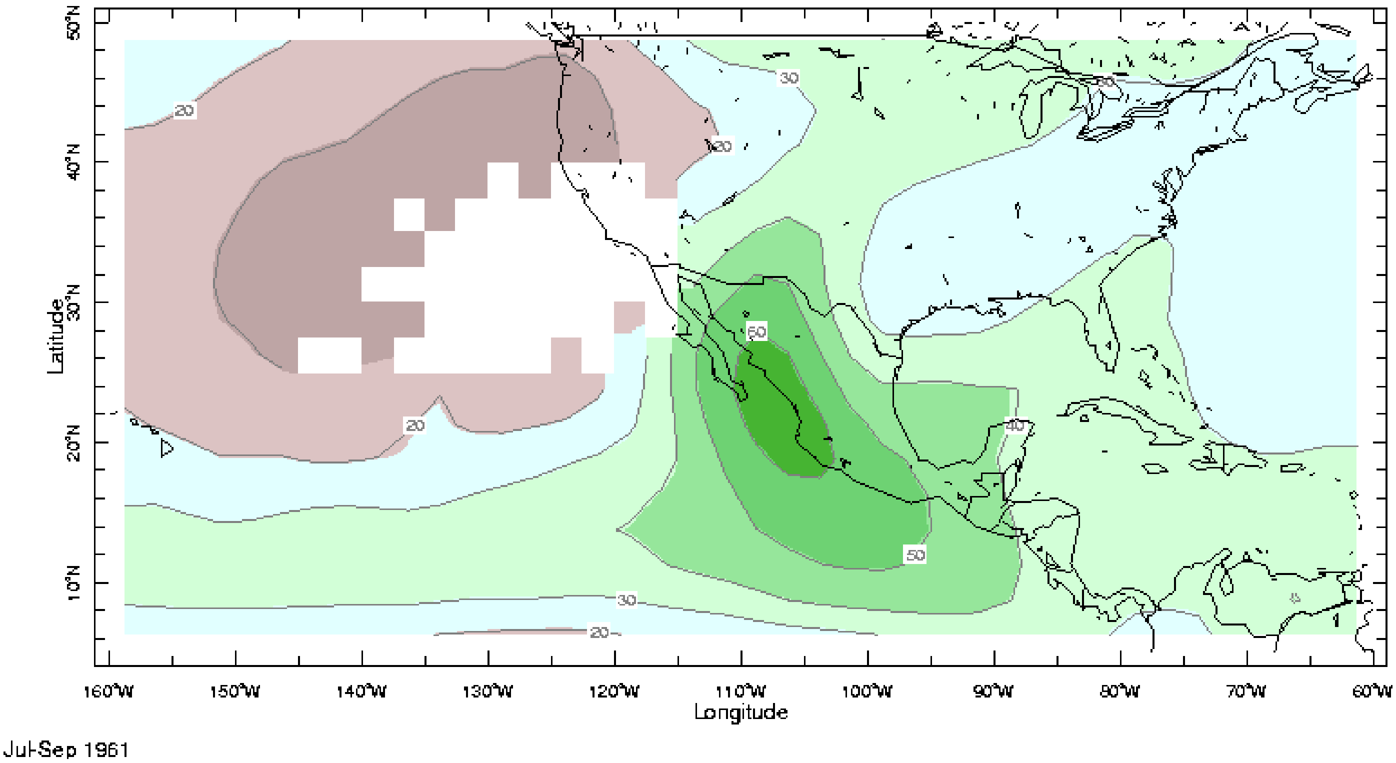

Figure 4. Percent of annual rainfall falling in the heart of the North American Monsoon season (July - September). The 50 % level is shown in dark green, CAMS_OPI data, Xie and Arkin (1997). (From Ropelewski et al 2005).Analysis by Janowiak and Xie (2003) suggests that the monsoon rainy season persists for approximately 100-days from late June through September. August is the rainiest monsoon month over much of the region. By September the rains have substantially retreated to the south, and drier conditions return to the region by October.

For one of the parks in the CHDN, Pate (2005) showed the extreme range in annual precipitation (6 to 45 inches) for Carlsbad Caverns NP for the years 1935 – 2004 (Figure 4).

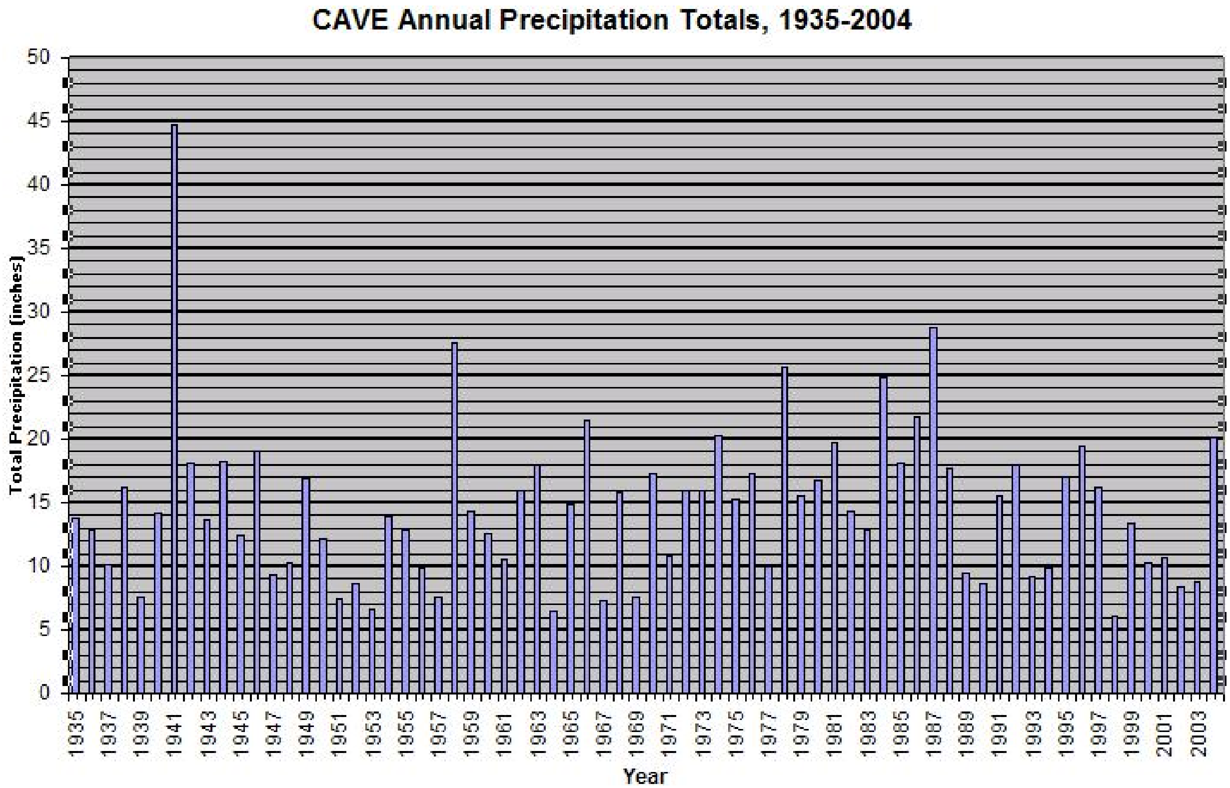

Figure 5. Total annual precipitation (in inches) for the years 1935 – 2004, Carlsbad Caverns National Park, New Mexico.

In addition to this pattern of highly variable annual precipitation, for any particular individual year, NAMS shows considerable interannual variability (Ropelewski et al. 2005). Some summary statistics by month show that the standard deviation by year for that same period is usually as great, or nearly as great as the mean for that month (Table 13).

Table 13. Carlsbad Caverns NP precipitation (in inches) by month (sent by Dale Pate, CAVE staff, 2005).

Month	Mean	Min.	Max.	Std. Dev.
Jan	0.45	0	2.44	0.50
Feb	0.43	0	2.44	0.50
Mar	0.41	0	3.59	0.64
Apr	0.60	0	3.59	0.60
May	0.60	0	5.81	0.60
Jun	1.71	0	8.52	1.66
Jul	2.06	0.03	5.96	1.50
Aug	3.38	0.10	11.71	2.13
Sep	2.89	0	12.37	2.29
Oct	1.40	0	5.12	1.37
Nov	0.56	0	4.50	0.58
Dec	0.48	0	3.56	0.58

Variability in the NAMS rains have also been related to variations in the threat of wildfires as well as being a factor in public health including Valley Fever and more recently the spread of dengue fever (Ray et al. 2003). Impacts to park ecosystems by changing fire dynamics and spread or incidence of certain diseases have been identified as vital signs in the National Park Services' Inventory and Monitoring Program's Ecological Framework (http://science.nature.nps.gov/im/monitor/docs/Ecological_Monitoring_Framework.doc).

This variability in precipitation in desert locations, particularly during the monsoon season is also a constant impediment to biological research. Investigators are repeatedly frustrated as they attempt to correlate biotic trend data with local climate. Precipitation measurements at one park or town location may have little to do with precipitation a few miles away. There is a paucity of data that would permit analysis of this phenomenon. The only data in hand are the monthly summaries for about 80 years for one location on the Jornada Experimental Range. The source data (in English units) are available on line at the Jornada web site (http://usda-ars.nmsu.edu/data-info/data_index.htm). Below, data are presented that illustrate the secular variability in precipitation. Note both the magnitude of standard deviation in comparison with the mean and the wide range of monthly values.

Table 14. Jornada Experimental Range monthly precipitation. (S. D. = standard deviation. all units are millimeters, mm.)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	12.55	9.61	8.12	5.37	10.96	14.61	47.98	50.07	35.77	24.27	12.15	18.65
S. D.	11.20	9.06	9.68	8.44	15.62	18.19	31.50	33.44	28.63	20.83	14.68	19.23
Min.	0.00	0.00	0.00	0.00	0.00	0.00	6.35	1.52	0.00	0.00	0.00	0.00
Max.	42.67	39.88	55.12	51.31	91.19	75.69	147.32	167.13	114.05	86.61	77.72	100.33

Data for Bat Draw at Carlsbad Caverns NP (Pate 2005) spanning almost 71 years (1934 through early 2005) shows a mean of 373 mm, a range of 154 to 1135 mm and a standard deviation of 160 mm. It is of note, however, that these data show a statistically *insignificant* secular decrease of 0.05 mm per year (P = 0.955).

Another dimension of variability is the natural differences in precipitation with altitude. Some of the study units have a wide altitude range.

Table 15. Altitude range of the study units. All measurements are in meters (m).

Unit	Min. Elev.	Max. Elev.	Elev. Span
AMIS	282	364	82
BIBE	548	2387	1839
CAVE	1096	1987	892
FODA	1487	1622	134
GUMO	1113	2667	1554
WHSA	1185	1290	105
IMRS	900	1600	700
JERA	1189	2508	1319

Normally, temperature decreases with altitude at the adiabatic lapse rate, about 6.5 C per 1000 m in relatively dry air. Also, precipitation changes with altitude, both by (1) increases in precipitation as air rises over a mountain and (2) “rain shadow” effects as it falls.

Data for two sites, GUMO headquarters area (Pine Springs) and Dell City (adjacent to the GUMO Sand Dunes) illustrate this variability. Note this does not use the NOAA data set for headquarters.

Table 16. Precipitation difference between Guadalupe Mountains NP Sand Dunes area (as measured at Dell City, TX) and Park Headquarters. P = precipitation in mm; DP = difference in precipitation between the two sites.

	Dunes	**HQ**	**Difference**
Month	**P**	**P**	**DP**
Jan	8.64	11.94	3.30
Feb	8.13	17.53	9.40
Mar	6.35	9.91	3.56
Apr	4.06	10.67	6.61
May	25.15	23.11	-2.04
Jun	23.37	36.32	12.95
Jul	34.29	65.28	30.99
Aug	36.58	78.23	41.65
Sep	37.08	57.15	20.07
Oct	23.37	38.10	14.73
Nov	12.45	28.70	16.25
Dec	11.68	17.02	5.34
Annual	**231.14**	**393.95**	**162.81**

The relation between altitude and precipitation is illustrated by the plot below (Figure 5). Note that Amistad NRA is in a different climatic regime, and was not included in the regression. The regression implies that 1000 m altitude change produces a 231 mm increase in annual precipitation in the northern Chihuahuan Desert. This implies that precipitation at GUMO's maximum altitude is 597 mm (23.5 inches).

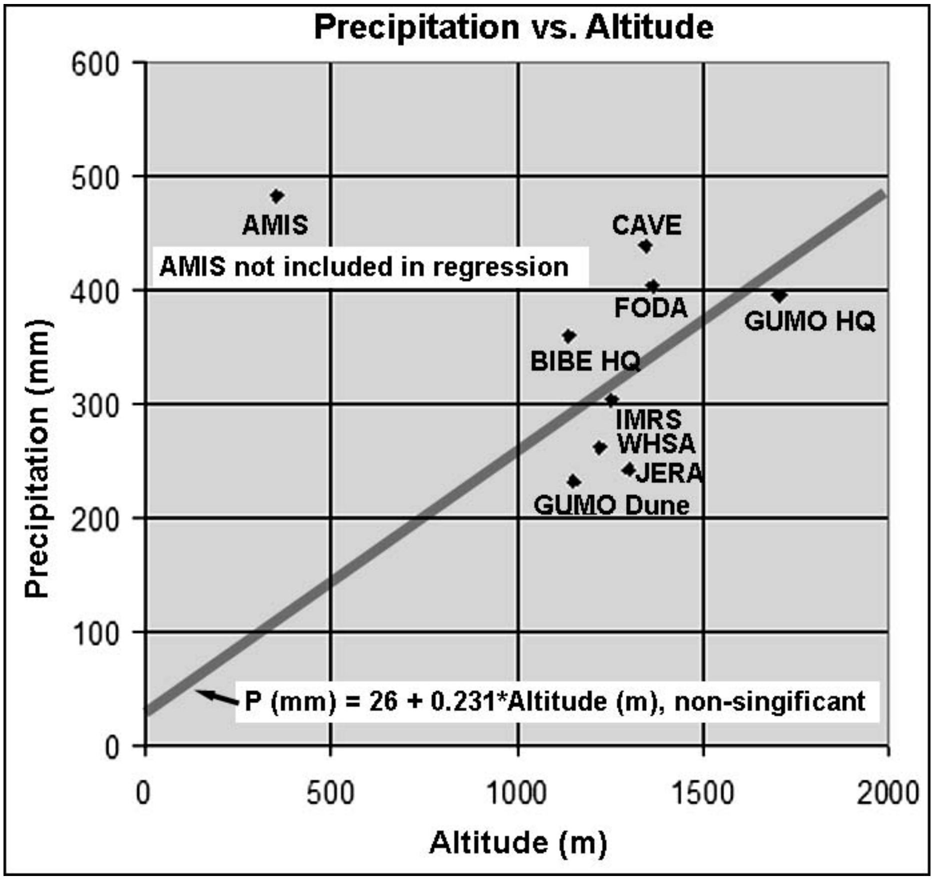

Figure 6. Relationship between altitude and precipitation for land units located in the Chihuahuan Desert.

Overall, this variability will remain as an obstacle to achieving greater precision in, and understanding of, ecological processes in the CHDN parks, as well as interpreting biological monitoring data collected through the long-term monitoring program. Only greatly improved remote techniques or ground sensing in a relatively fine grid, such as Mesonet in Oklahoma may result in significant improvement. For studies in a limited number of locations, it is probable that inexpensive stand-alone systems (such as Hobo units) will come to include the full range of climatic parameters.

IV CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- It is noted that a more proper term for the climate of these lands is cold semi-desert.
- All of the locations, except AMIS have climates fitting the typical Chihuahuan Desert pattern of about half the annual precipitation falling from July to September. Another similar pattern is slow warming with low precipitation from January through May.
- All of the localities show great precipitation variability.

Recommendations

- As the CHDN begins monitoring park vital signs involving populations of specific organisms, it may be revealed that trends are driven by climate change. It is suggested that the CHDN investigate steps that will bring park climatic data into a uniform central data base. These data should include NOAA data from on site or nearby recording sites.
- Some parks--GUMO for one--record temperature data on drum paper charts. For reasons of limited budget, these are simply archived in files. Extant technologies will permit digital recording with monthly downloads. It is suggested that the CHDN discover each park unit’s current practices to permit later upgrading to a uniform, standard protocol with modern equipment.
- As resources permit, it is recommended that all park data be gathered and digitized. GUMO for example, has five stations, some with records of substantial length that are not included in this study.

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