SCIENTIFIC NOTEBOOK #432

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Volume I – Precipitation Analyses

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Volume I, Pages 1-18

1 CDRs written 4/13/01
includes → bubo: J:\PrecipData*

SCIENTIFIC NOTEBOOK #432E

VOLUME I - PRECIPITATION ANALYSIS

2/15/01 RF

This volume of scientific ntbk #432E is devoted to precipitation as is important for shallow infiltration. Precipitation records in southern Nevada and onsite at Yucca Mountain will be analyzed to evaluate whether or not DOE is using meteorological records in their TSPA that adequately reflect the magnitudes, durations, variations, cyclical perturbations reflective of surrounding stations or likely future records over a 10,000 year span.

Collaborators on other portions of the precipitation analysis: David Woolhiser, Stuart Stothoff

All of this work is expected to be stored on WinNT box called bubo and in the directory J:\PrecipData*; some of data manipulation will be done on the bren SUN workstation.

Objective: Analysis of Precipitation Inputs

Precipitation Stations Used by Yucca Mountain Project Studies
Analysis of El Nino – Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) Signals
Analysis of Historical Variations

Objective is to analyze the precipitation data sets used by DOE and NRC as input to shallow infiltration models. Two climatic oscillations are addressed:

1. The El Nino - Southern Oscillation (ENSO), which uses sea surface temperatures in the south Pacific Ocean. The southern oscillation index (SOI) was obtained from Kelly Redmond (via David Woolhiser) who works at the Western Regional Climate Center (WRCC). The SOI is stored as J:\PrecipData\soi-table.txt and was imported into the spreadsheets noted below.

2. The Pacific Decadal Oscillation (PDO), which used sea surface temperature and pressure in the north Pacific Ocean below the Aleutian Islands. The PDO index was obtained on the web from ftp link at http://tao.atmos.washington.edu/pdo/ and is stored in J:\PrecipData\pdo-table.txt. The PDO index was assembled by Nate Mantua of the University of Washington.

Monthly values of precipitation were obtained from (i) the WRCC at the Desert Research Institute in Nevada, (ii) Nevada Test Site (NTS) (Air Resources Laboratory/Special Operations and Research Division), and (iii) the YMP data meteorological stations. Files from web pages were obtained between May 16 and May 22, 2000; files for the USGS stations (WX-? series, where the "?" is a wildcard for a single digit) were previously obtained as a data request from Chad Glenn (USGS Open-File Report 96-462):

http://www.wrcc.dri.edu/summary/climsmnv.html
http://wwwsord.nv.doe.gov/SORD_Rain.html
http://m-oext.ymp.gov/html/prod/db_tdp/sep/internet/default.htm

NTS Sites Obtained:

	Latitude	Longitude	Elevation
Desert Rock	36 37 16 N	116 01 33 W	3250 ft
Area 13 (Rainier Mesa)	37 11 28 N	116 12 55 W	7490 ft
4JA (Jackass Flats)	36 47 05 N	116 17 20 W	3422 ft

WRCC Coop Sites Obtained:

	Latitude	Longitude	Elevation
Beatty	36 55 N	116 45 W	3310 ft
Beatty8N	37 00 N	116 43 W	3550 ft
Amargosa Valley	36 34 N	116 28 W	2450 ft
Beowawe NV	40 36 N	116 29 W	4700 ft
Delta UT	39 23 N	112 34 W	4620 ft
Spokane WA (WSO)	47 38 N	117 32 W	2360 ft
Rosalia WA	47 14 N	117 22 W	2400 ft
St. John WA	47 06 N	117 35 W	1940 ft
Nogales AZ	31 21 N	110 55 W	3810 ft
Nogales-Old AZ	31 20 N	110 57 W	3900 ft
Nogales-6N AZ	31 25 N	110 57 W	3560 ft
Hobbs NM	32 42 N	103 08 W	3620 ft
Tucson Airport AZ	32 08 N	110 56 W	2580 ft

The NTS and WRCC COOP Stations

The files for the NTS and WRCC (COOP) sites were stored in the directories:

J:\PrecipData\Nts*
J:\PrecipData\Wrcc*

and were imported into the following Excel 97 SR-2 spreadsheets (the 2nd and 3rd spreadsheets were quickly created from the 1st one):

J:\PrecipData\soi-MetData.xls (analysis of sites for ENSO signals)
J:\PrecipData\pdo-MetData.xls (analysis of sites for PDO signals)
J:\PrecipData\soi-pdo-MetData.xls (analysis of sites for combination ENSO and PDO signals)

The NTS and COOP (WRCC) data were directly imported into spreadsheets, thus no further description is needed here. The precipitation values are all in units of inches.

The USGS WX-? and the R/EFPD YM Stations

The YM stations, both the DOE and the USGS (WX-? series), required aggregation from daily values to monthly values for each year. The raw data files are stored in :

J:\PrecipData\REFPDsites-Hourly\ZipFiles* and .\AsciiFiles*
J:\PrecipData\Flint*

For the WX-? series, stations WX-1, WX-2a,b, WX-3, WX-4a,b were aggregated and WX-5 was not. The precipitation column of the yearly summary file (called "Wx1_day.087" for the 1987 data from WX-1 station) was copied into a spreadsheet. The header file ("Wx1_hdr.087" for WX-1 1987 data; all the hdr files are identical) describes which column in the daily summary file contains the precipitation in millimeters. A matrix of monthly values were created using the SUM in Excel command over the appropriate range of julian days. The data source for the WX-? stations is:

Flint, A.L. and W.J. Davies. Meteorological Data for Water Years 1988-94 from Five Weather Stations at Yucca Mountain, Nevada. USGS Open-File Report 96-462, Denver, CO: U.S. Geological Survey. 1997.

There are nine R/EFPD stations, numbered 1-9; the acronym refers to Radiological/Environmental Field Programs Department. I obtained 48 files (quarterly reports of hourly data) on June 6, 2000 from the YMP data web page:
http://m-oext.ymp.gov/html/prod/db_tdp/sep/internet/default.htm
then search for "PRECIPITATION QUANTITY"

The data tracking numbers are listed on the following page. To actually use the data, I decided to go with a spreadsheet approach rather than reading in all the files into a fortran program to aggregate into monthly data. Reliable data was only available as hourly data for the period 1985-1997 (what, no 1998 or 1999 data??). The scattered daily records were only available for 1994-1997, partial; and some of those files had gibberish entries in the precipitation column. Of course, there were no monthly summaries. Confusion was possible since there are other meteorology stations with similar names (when grouped as "11 stations", the station numbers were #2, 6,8, 11, 18, etc...; these are different stations, which are not directly described in the YM Site Description (1998). Since the station numbers are 1-9, I believe that the files I got from the YMP data web page are the R/EFPD stations as described in CRWMS M&O (1998 and 1997).

CRWMS M&O. Yucca Mountain Site Description, Book 2 – Sections 4, 5. B00000000-01717-5700-00019 Rev 00. Las Vegas, NV (TRW Environmental Safety Systems, Inc. September 1998.

CRWMS M&O. Engineering Design Climatology and Regional Meteorological Conditions Report. B00000000-01717-5707-00066 Rev 00. Las Vegas, NV (TRW Environmental Safety Systems, Inc. October 1997.

The Data Tracking Numbers (DTN) for the R/EFPD YM stations for the data files stored in the directory: J:\PrecipData\REFPDSites-Hourly*):

MO9905VAMMDD85.000
MO9905VMMDOD86.000
MO9903VALMM933.000
TM000000000001.077
MO9903VALMM964.000
MO98METDATA110.000
MO9905VMMDJM86.000
MO9905VMMDJM87.000
MO9903VALMM931.000
TM000000000001.065
MO9903VALMM961.000
TM000000000001.100
MO9905VMMDAJ86.000
TM000000000001.068
MO9903VALMM962.000
TM000000000001.104
MO9905VMMDJS86.000
MO9903VALMM932.000
TM000000000001.071
MO9903VALMM963.000
TM000000000001.107
MO9905VMMDAJ87.000
MO9905VMMDJS87.000
MO9905VMMDOD87.000
MO9905VMMDJM88.000
MO9905VMMDAJ88.000
MO9905VMMDJS88.000
MO9905VMMDOD88.000
MO9905VMMDJM89.000
MO9905VMMDAJ89.000
MO9905VMMDJS89.000
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MO9905VMMDJS91.000
MO9905VMMDOD91.000
MO9905VMMDJM92.000
MO9905VMMDAJ92.000
MO9905VMMDJS92.000
MO9905VMMDOD92.000
MO9905VMMDJM94.000
MO9905VMMDAJ94.000
MO9905VMMDJS94.000
MO9905VMMDOD94.000

After sorting through the confusion of the DOE web page with a mixture of incomplete daily data and 10-min data files, I proceeded to download 48 separate files of hourly data. Based on the files here, the table below shows when each R/EFPD meteorological station was active. The years of operation, coordinates, and station IDs are included in the following two tables:

year	R/EFPD sites
1985	1
1986	1
1987	1
1988	1
1989 (january-june)	1
1989 (july-december)	1-3, 5
1990	1-5
1991	1-5
1992 (january-march)	1-5
1992 (april-june)	1-5, 7
1992 (july-december)	1-8
1993	1-9
1994	1-9
1995	1-9
1996	1-9
1997	1-9

site	easting, m	northing, m	latitude	longitude	elevation ft	
1	550,784	4,077,374	36 50 34 N	116 25 50 W	3750 (1143)	NTS-60 (Midway Valley)
2	547,646	4,078,753	36 51 19 N	116 27 56 W	4850 (1478)	Yucca Mountain crest
3	548,874	4,078,701	36 51 17 N	116 27 06 W	4195 (1279)	Coyote Wash
4	553,117	4,079,779	36 51 51 N	116 24 15 W	4050 (1234)	Alice Hill
5	554,385	4,068,727	36 45 52 N	116 23 26 W	3125 (953)	Fortymile Wash
6	549,388	4,083,097	36 53 40 N	116 26 45 W	4315 (1315)	WT-6 (Yucca Wash)
7	552,800	4,077,847	36 50 49 N	116 24 28 W	3545 (1081)	Sever Wash
8	551,161	4,075,773	36 49 42 N	116 25 35 W	3710 (1131)	Knothead Gap
9	553,418	4,058,398	36 40 17 N	116 24 08 W	2750 (838)	Gate-510
North American Datum 1927 (NAD27); data from CRWMS M&O 1997 table 2-1						

To import and aggregate the hourly data to daily values:

1. used Winzip to unzip files one by one [yes, downloading and unzipping one by one is cumbersome because of the slow responding internet connection] and I renamed the files as I went [the web page assigns a file name based on an incremental numbering: zz_sep_?????.zip];
2. transferred files to UNIX and ran a foreach loop to do a "dos2unix" command;
3. since there are a total of 593,347 records in all the files combined, I did a foreach loop to catch all the SITE 1 entries in all of the files [foreach i(hour_*); cat $i | grep "SITE 1" >> site1.txt]; I had to form two separate files since there are 105,936 records for Site 1 (separated years 1985-1991 from 1992-1997→ site1a.txt and site1b.txt); note limitation of EXCEL 97 SR-2 of 65,000+ rows maximum
4. then unix2dos command and transfer back to WinNT for import into a spreadsheet.

In the spreadsheet workbook J:\PrecipData\REFPDsites-Hourly\site1-hourly.xls, worksheet "site1a", copy the following formulas throughout the rows:
column H [=IF(B24=9999," ", B24)] to eliminate the flag=9999 from summation & to track missing data;
column I [=IF(J24=" "," ",C24)] to print the date only when there is a cumulative precip in column J;
column J [=IF(D24=1,SUM(H1:H24)," ")]
noting that the time of 24:00:00 in column D when converted to a number is 1;
column K [=IF(D24=1,COUNT(B1:B24))-IF(D24=1,COUNT(H1:H24))].

An example is shown below.

A	B	C	D	E	F	G	H	I	J	K
	precip mm	date	time		site		precip no flags	date	cumulative precip	missing hours
21	0.762	10/1/1986	21:00	SITE	1		0.762			
22	0	10/1/1986	22:00	SITE	1		0			
23	0	10/1/1986	23:00	SITE	1		0			
24	0	10/1/1986	24:00:00	SITE	1		0	10/01/86	0.762	0
25	0	10/2/1986	1:00	SITE	1		0			0
26	0	10/2/1986	2:00	SITE	1		0			0
27	0	10/2/1986	3:00	SITE	1		0			0
28	0.254	10/2/1986	4:00	SITE	1		0.254			0
29	0	10/2/1986	5:00	SITE	1		0			0

Columns I, J, K are then copied/Special Paste (convert to values) into new spreadsheet "DailySummary" where they are sorted by date. This was similarly done with the site1b.txt portion of the Site 1 data. The 3 spreadsheets in the Excel workbook (site1-hourly.xls) are DailySummary, site1a, and site1b. This created a big file so it was saved and another file was opened to do the aggregation of daily data to monthly precipitation values to be used in the ENSO/PDO analysis.

This same process was done for Sites 1, 2, and 3 and stored in separate files for each site:
J:\PrecipData\REFPDsites-Hourly\site1-hourly.xls
J:\PrecipData\REFPDsites-Hourly\site2-hourly.xls
J:\PrecipData\REFPDsites-Hourly\site3-hourly.xls

The daily values of precipitation for Sites 1,2, & 3 were copied to a new spreadsheet file called:
J:\PrecipData\refpdSites.xls

To aggregate the daily data to monthly values, use the sumif(conditional range, condition, sum range) command for each year of daily data [e.g., for Site 1, cell entry 1987 and february, =SUMIF($E$403:$E$767,"2",$B$403:$B$767) where the 1987 data is in the rows 403-767 and february is the "2"nd month].

The only modification made to the monthly summary for Site 1 for missing data is for September and October of 1991, which had nearly 100% missing data. The large missing chunk for Site 3 was July-August 1989. Otherwise data gaps of partial days (up to ~ 2 days) were ignored (No infilling).

Analysis of YM Area Meteorological Station Data

The following section looks at variations in precipitation over time starting in order to assess the adequacy of input files for the shallow infiltration models. The following subsections discuss different scales of time (e.g., annual, decadal, century).

Decade to Century Scale Variations

Tree rings offer a means for studying the long-term variations of precipitation within a particular climate, specifically the modern climate. Two examples of tree ring data are shown in figure I-1 and I-2. There is a strong variation in precipitation, but it is difficult to determine where Yucca Mountain is in the cycle. The geographic variation of cycle position (wetter or drier) varies across North America (figure I-2).

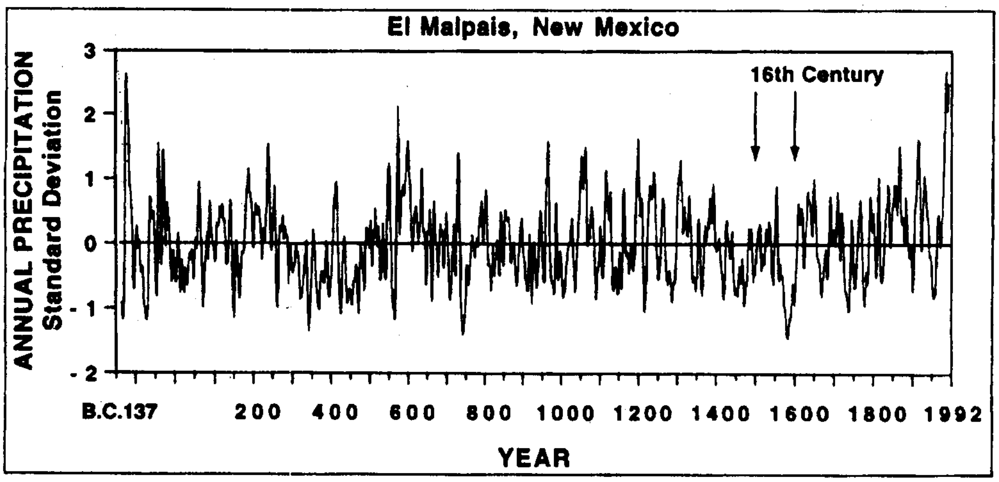


Figure II-1. Scanned in from EOS volume 81(12), 2000. Tree rings used to estimate annual precipitation.

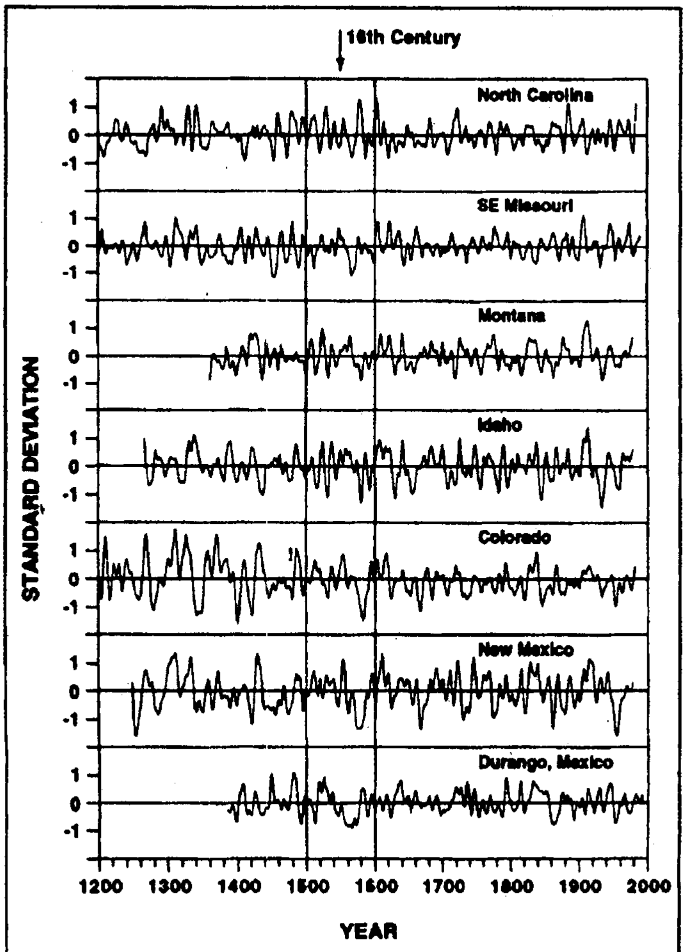


Figure I-2. Tree-ring data, also from EOS volume 81(12), 2000

Decade to Multi-Year Variations (ENSO & PDO)

There are a number of things to look at:

1. Long-term records and ENSO & PDO signal
2. Meteorological data used as input for infiltration and ENSO & PDO signal
3. YM station meteorological ENSO & PDO signal

From the SOI monthly-yearly matrix (J:\PrecipData\soi-table.txt), the June to July average SOI was compared to the annual average SOI. The WRCC ENSO webpage and Redmond and Koch, 1991 indicate that the June-November SOI correlates best with hydrologic data in the southwestern U.S. Figure I-3 is stored in soi-MetData.xls; it illustrates the relationship between annual and June-November SOI trends. Eliminating the December to May SOI values from the analysis leads to better correlation of SOI with hydrologic features in the North American continent. Figure I-4 given a better view of the cyclical nature of El Nino (negative values of SOI)

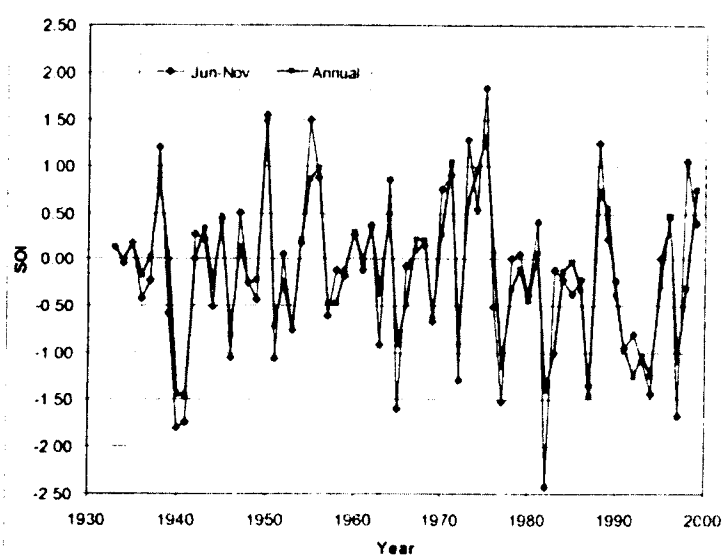


Figure I-3

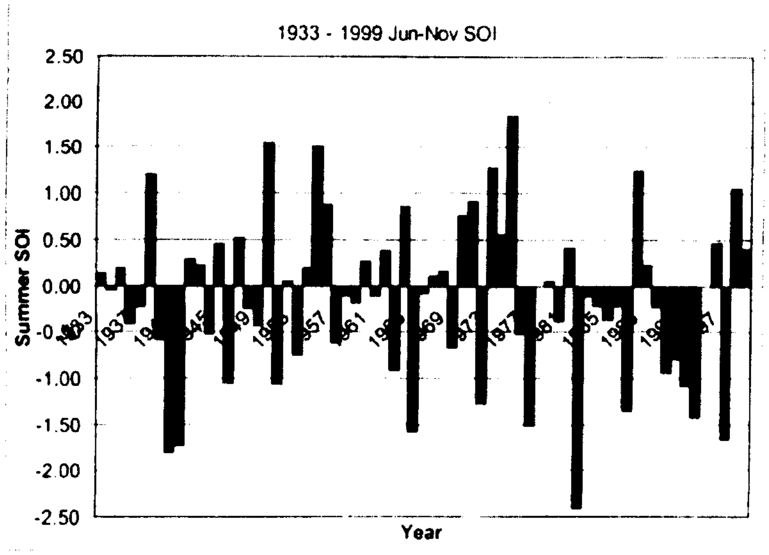


Figure I-4

From J:\PrecipData\soi-MetData.JNB from data in soi-MetData.xls, figure I-5 graphically illustrates the winter precipitation magnitude increase during El Nino years. There is overlap but the average is definitely greater than during La Nina years (which has a low, more uniform spread). The El Nino years with low winter precipitation were consistently the same years for each of the three sites: 4JA, Area12, and Desert Rock.

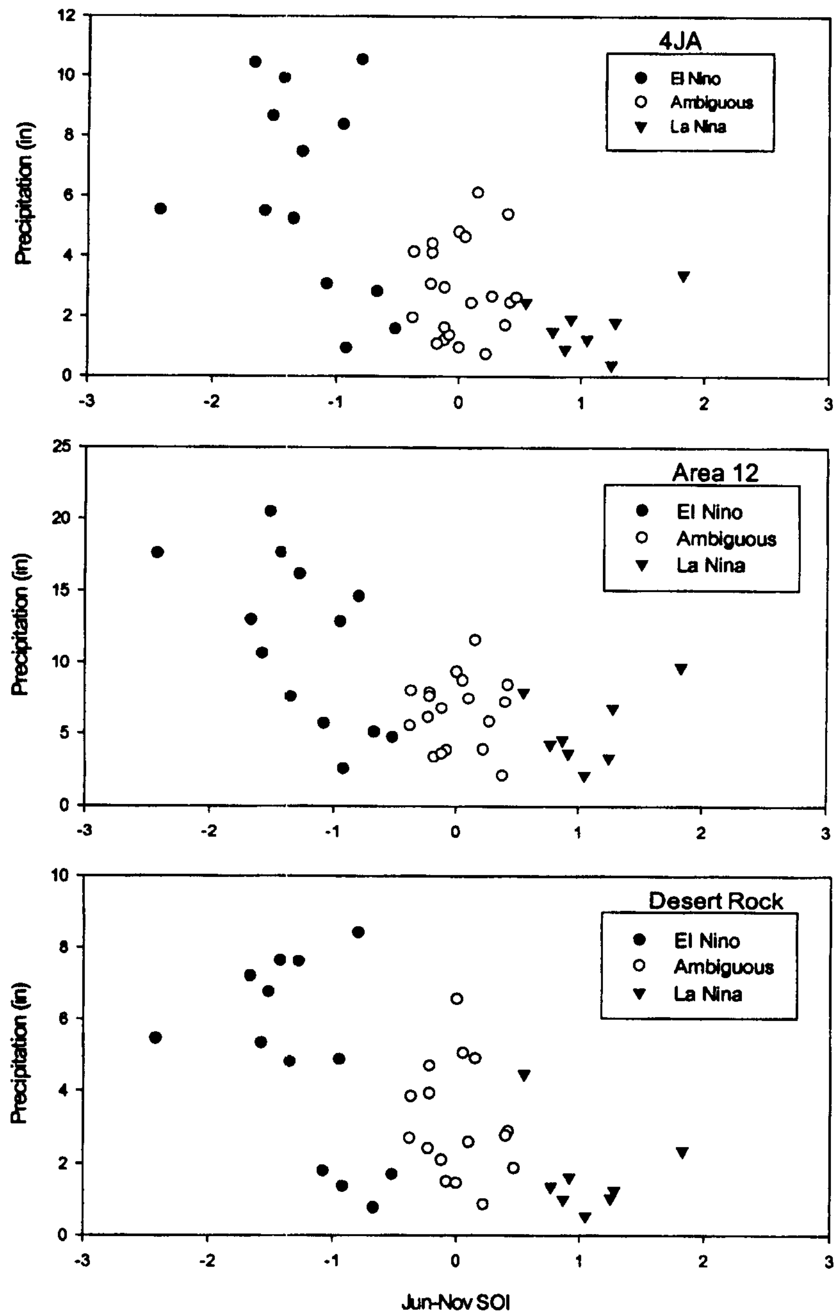


Figure I-5a,b,c

There is the simple observation that the 1990s were unusual in the 1933-1999 ENSO oscillation in that there were more El Nino years. This means that precipitation on the YM stations should be higher than typical since their records are dominantly 1990s only. Based on the following division (Kelly Redmond WRCC webpage for Terminology of El Nino and La Nina Winters [http://www.wrcc.dri.edu/enso/ensodef.html]):

Strong El Nino [SOI<-1.0
El Nino [-1.0<SOI<-0.5]
Ambiguous (Neither Nino, or Nada Nino) [-0.5<SOI,+0.5]
La Nina [+0.5<SOI<+1.0]
Strong La Nina [+1.0 <SOI]

Deccade	El Nino	(SE)	Nada Nino	La Nina	(SL)
1930s	1	(0)	5	1	(1)
1940s	4	(3)	4	2	(0)
1950s	3	(1)	4	3	(2)
1960s	3	(1)	6	1	(0)
1970s	3	(2)	2	5	(2)
1980s	2	(2)	7	1	(1)
1990s	5	(3)	4	1	(1)
SE = Strong El Nino & SL = Strong La Nina both in parentheses					

In sheet "1985-1997" of J:\PrecipData\soi-MetData.xls, a comparison was made of the short portion of longer records to see if the recent (1985-1996) record was wetter than earlier portions of the meteorological records for stations with longer records. Ambiguous results occurred. Two stations had wetter recent (Beatty and 4JA) values than the long term average; and two stations had drier recent (Amargosa Valley and Desert Rock) values than the overall average for the entire period of data collection.

Note also that the 4JA record, for Winter/Summer ratio, more closely matches the Site 2 and 3 (on YM, rather than Site 1 in Midway valley) for the period 1989-1996. Desert Rock does pretty good for Site 1 in both cases of "Winter/Summer Ratio."

	No. Years	Precipitation (mm)			Winter/Summer Ratio		
	Total Record	All Years	1986-1996	1989-1996	All Years	1986-1996	1989-1996
Amargosa Valley	24	116	108	97	2.04	2.3	3.5
Beatty	51	[illegible]	[illegible]	[illegible]	1.59	2.1	2.3
4JA	42	[illegible]	[illegible]	[illegible]	2.07	2.8	4.0
Desert Rock	37	148	140	137	1.46	1.8	2.1
Site 1 - YM	12	-	127	125	-	1.8	2.4
Site 2 - YM	8	-	-	157	-	-	4.0
Site 3 - YM	8	-	-	160	-	-	3.8

For each of the sites, the data from averaging the El Nino years versus all years in J:\PrecipData\soi-MetData.xls is plotted with the columns indicating the annual average, and the error bars indicating average winter precipitation for different categories. The blue square on the error bar is the winter average for El Nino years while the red circle is for the La Nina years. The cross bar on the error bar is the overall winter average. The winter months are defined as October through March. These 2 figures are plotted in spreadsheet"Summary-mm" of soi-MedData.xls, whereas the coefficient of variation figure is plotted in speadsheet "Summary" of the same Excel file. Note that 4JA has a stronger El Nino signal than does Desert Rock.

↳ for Figure I-6 RL 4/9/2008

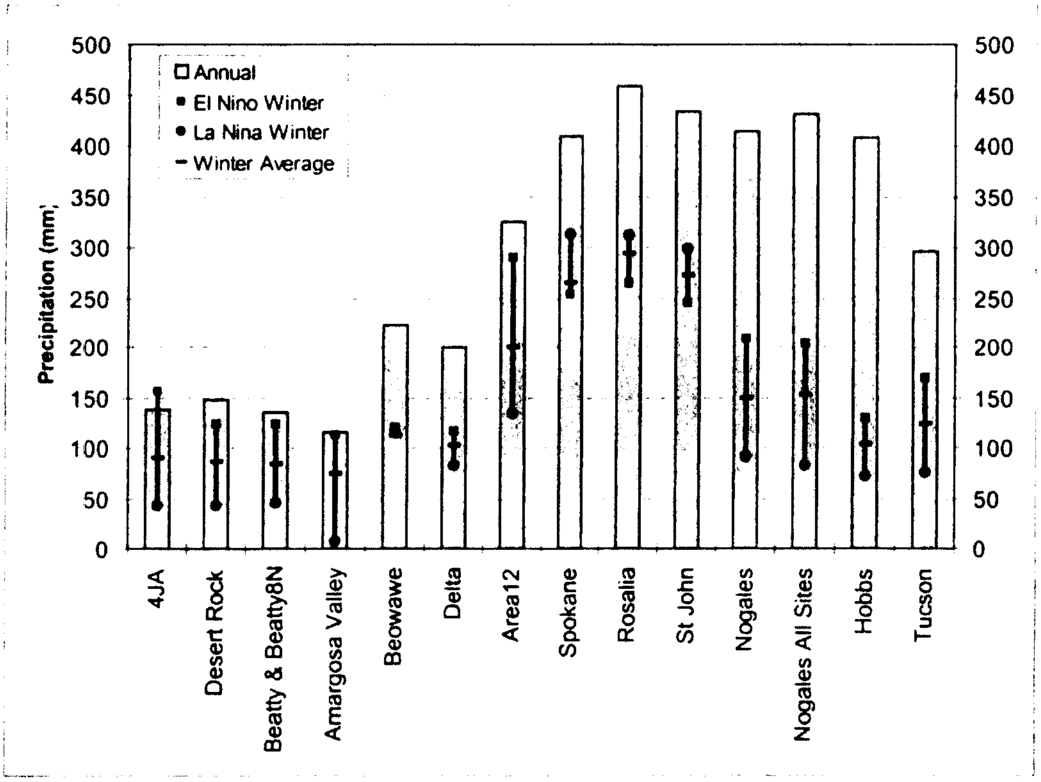


Figure I-6

Figure I-7 has a similar plot but included only stations near YM and stations on YM. Figure I-8 illustrates the coefficient of variation and how it varies for the modern, monsoonal, and glacial transition sites. The variation is strong for the YM sites and monsoonal sites, particularly for winter precipitation. The glacial transition sites have much less annual (and winter) variation .

The short records of the YM stations may lead to bias in the El Nino analysis, since they do not represent long term conditions. Hence, the very strong El Nino winter precipitation at all the sites, and conversely the very dry La Nina winters, may only reflect the prominent cluster of El Nino events during the 1990s.

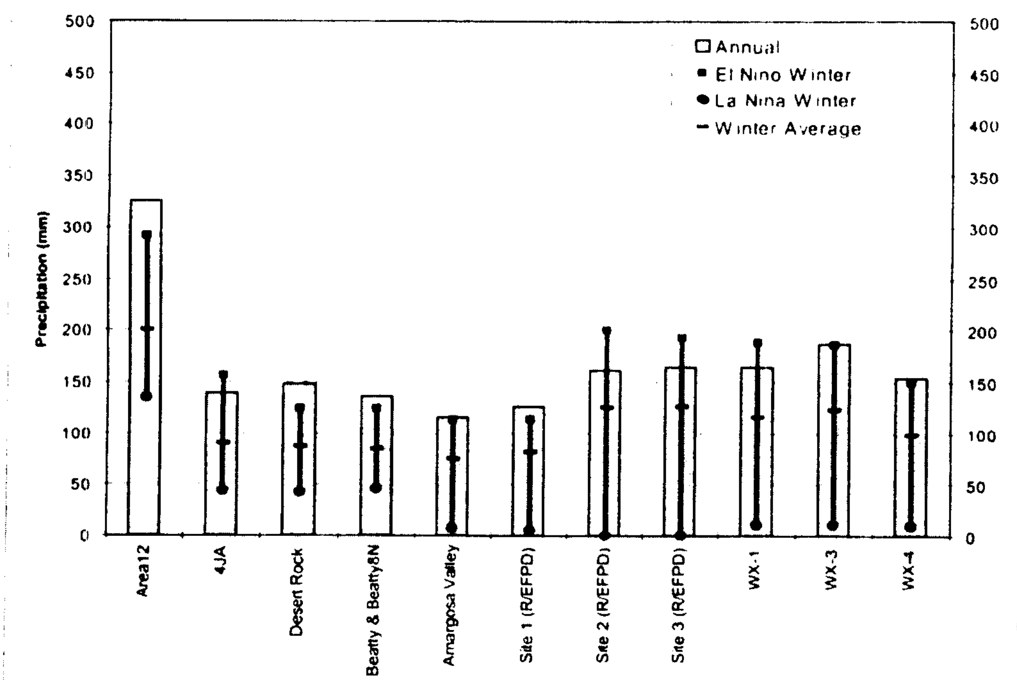


Figure I-7

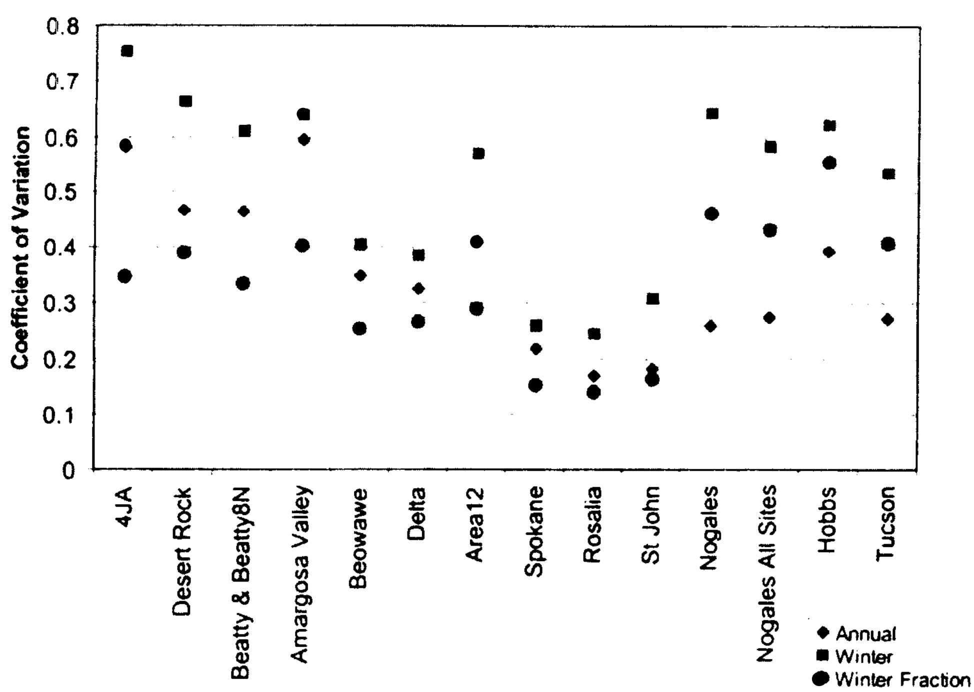
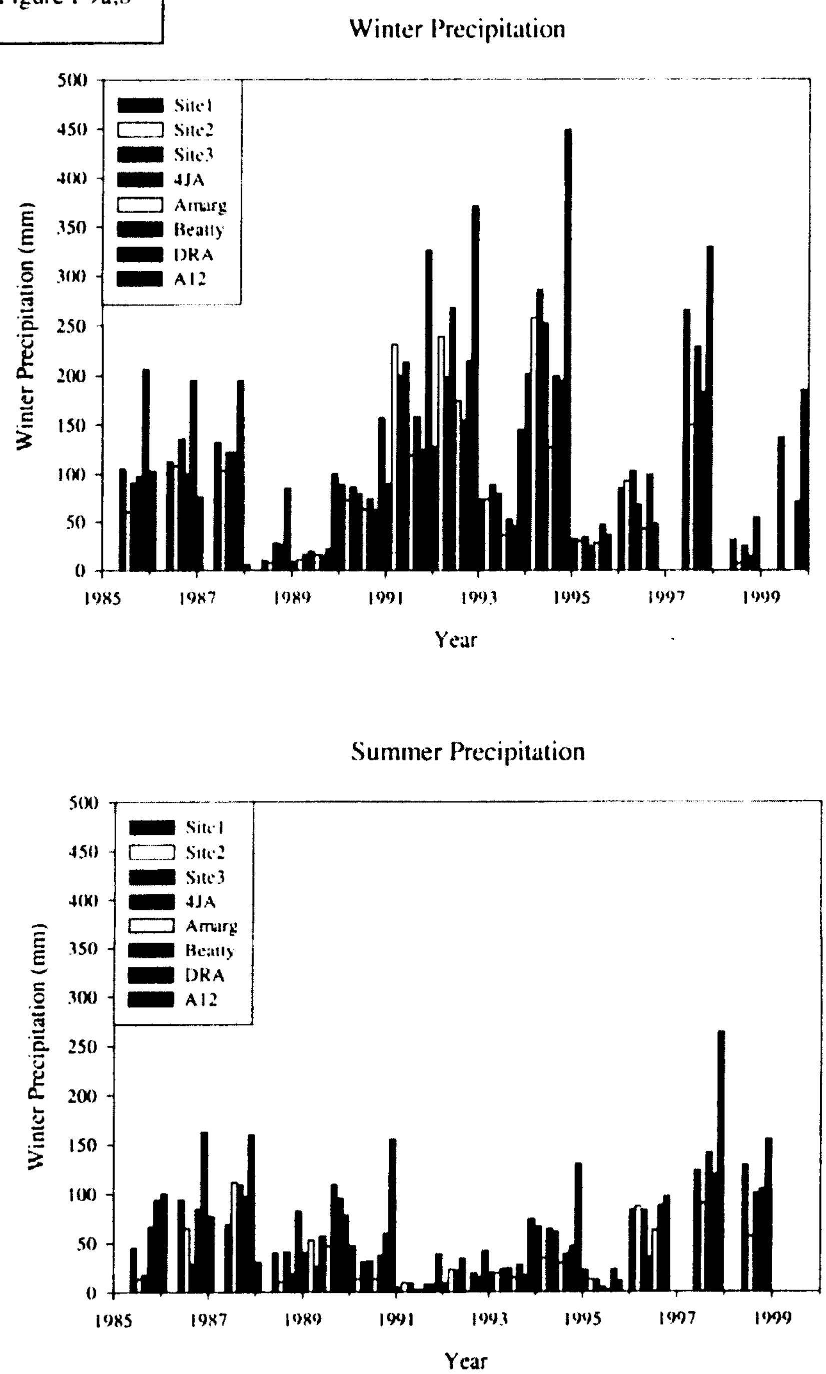


Figure I-8

Copied the season sums from the YM and selected NTS site (transformed inches to millimeters where appropriate) into SigmaPlot 5.0: J:\PrecipData\seasonalYMP.JNB. Figure I-9 illustrates the seasonal differences for YM and YM area stations.

Figure I-9a,b

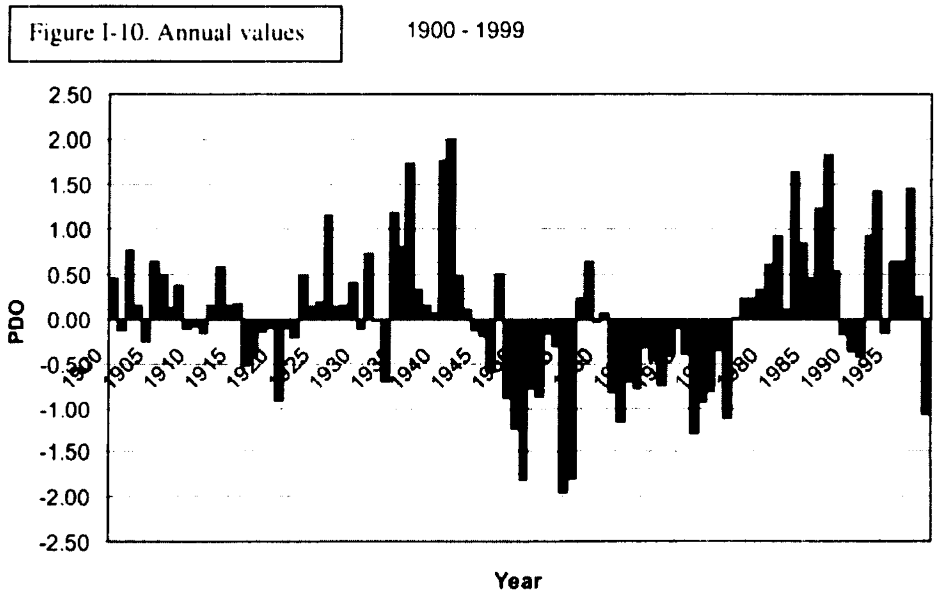


Pacific Decadal Oscillation

J:\PrecipData\pdo-MetData.xls for all PDO data and figures.

The pacific decadel oscillation (PDO) analysis needs to be completed at some later time. Positive PDO values lead to enhanced El Nino cycles and negative values lead to reduced El Nino magnitudes. Figure I-10 shows that the PDO cycle is less noisy than the SOI cycle.

Figure I-10. Annual values



There is likely less of a lag in the PDO (derived from ocean surface conditions below the Aleutians) than for the SOI.lag, hence I tried the August to November PDO for comparison. It is not clear how much difference this will make any analysis of hydrological data.

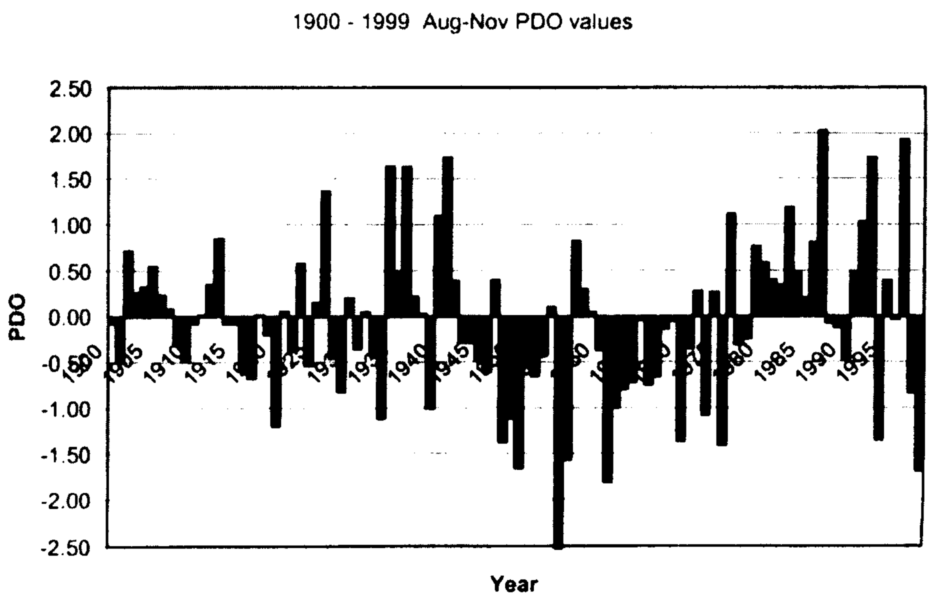
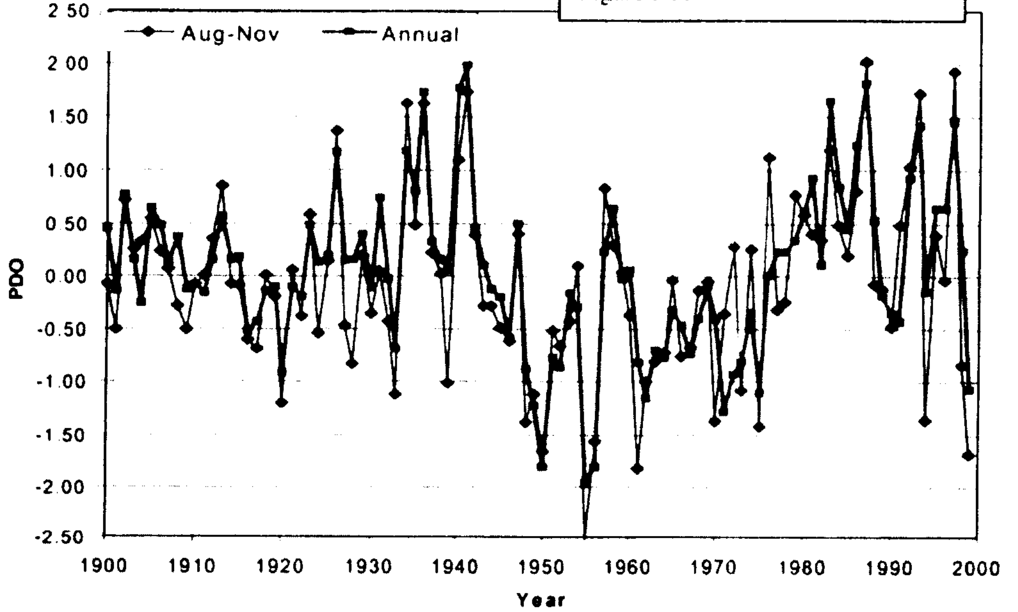


Figure I-11 tracks the difference between the annual PDO and the August-November PDO values.

Figure I-11



The relationship between August-November PDO values and precipitation at YM and near YM stations is shown in figure I-12

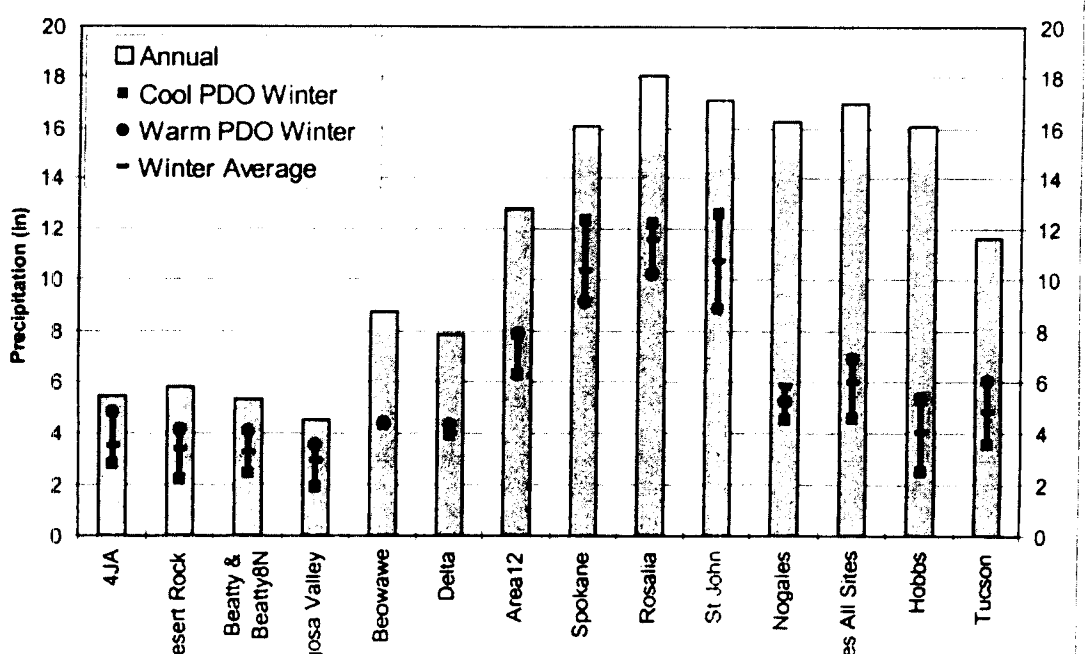


Figure I-12

In J:\PrecipData\soi-pdo-MedData.xls, the comparison of PDO and SOI values was plotted as shown in figure I-13.

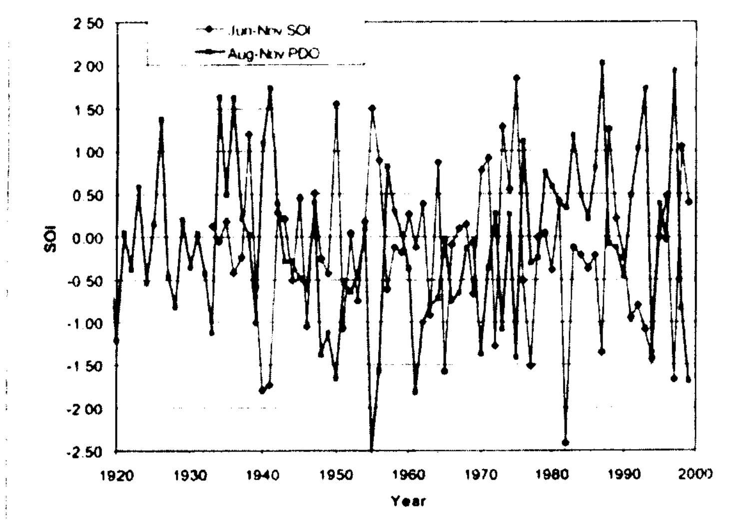
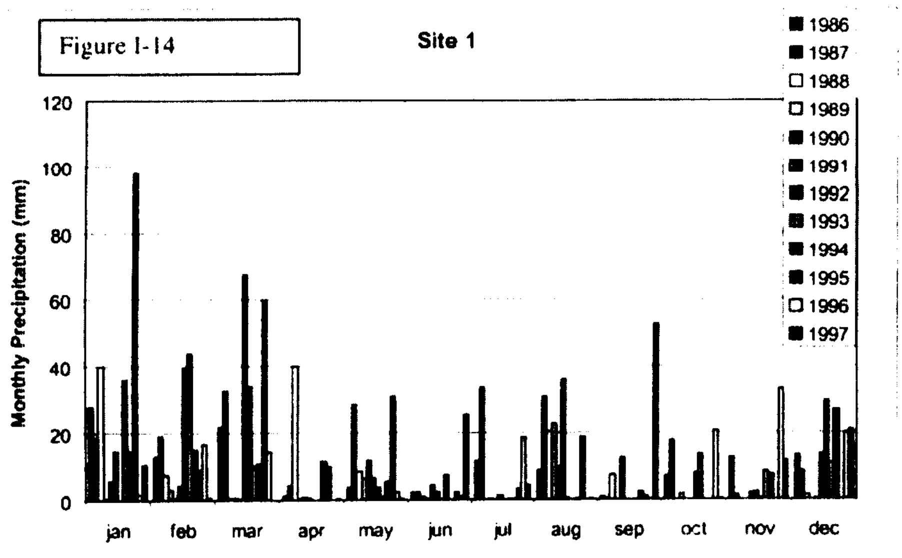


Figure I-13

Winterle and Illman wanted daily records for YM stations plotted for their poster or papers. First I gave them an idea of how much variation there was in monthly values between the years (figure I-14).

Figure I-14



Then I gave Winterle and Illman plots of daily precipitation events at two sites (Site 1 and Site 3, figure I-15a,b). They decided the daily value was what they were looking to incorporate into their models of pulsed boundary conditions atop/within the Tiva Canyon for PTn modeling.

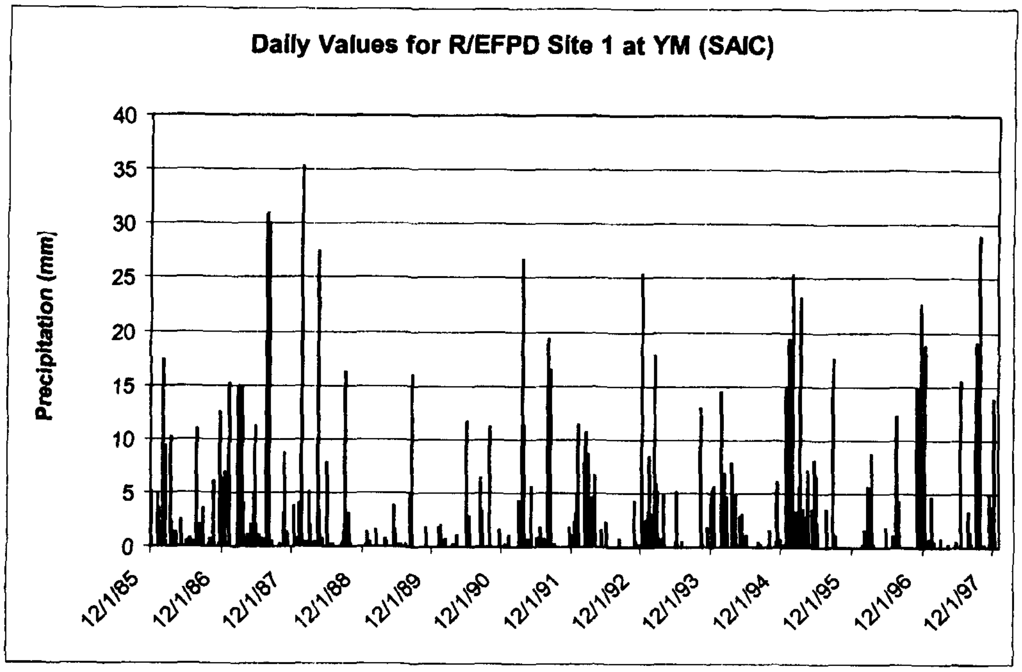
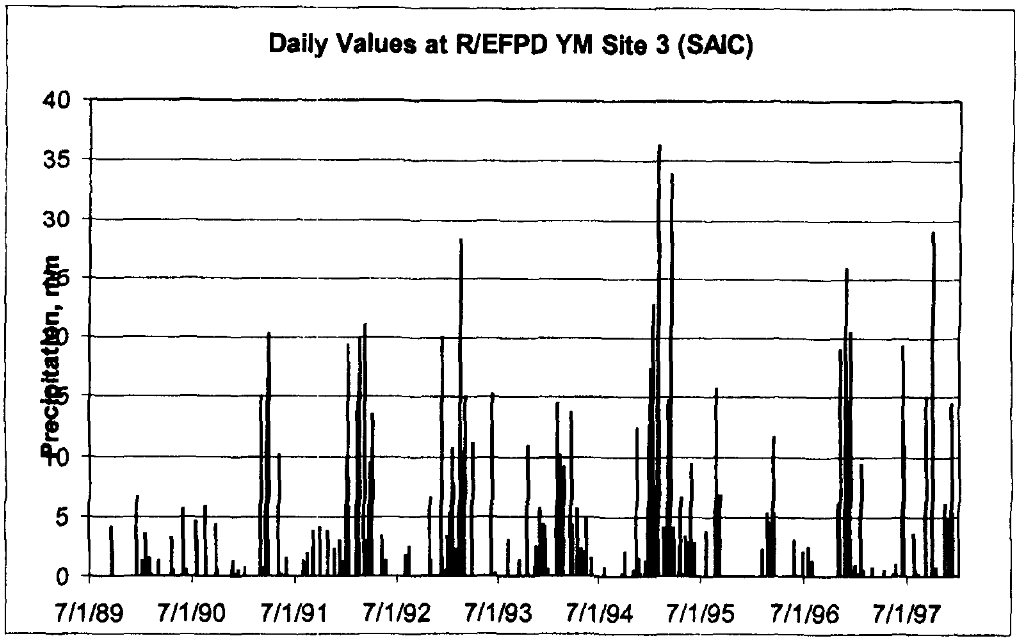


Figure I-15a,b



Short Records Versus Long Records at Stations Across Southern Nevada

J:\Precipitation\historicalVariations.JNB (SigmaPlot version 5.0) derived from .\historicalVariations.xls. Visual comparison of the YM short record with the longer records of nearby stations, and the Mina station: this really illustrates the uncertainty of using nearby stations (figure I-16). And similarly, for stations across southern Nevada (figure I-17, next page).

Figure I-16

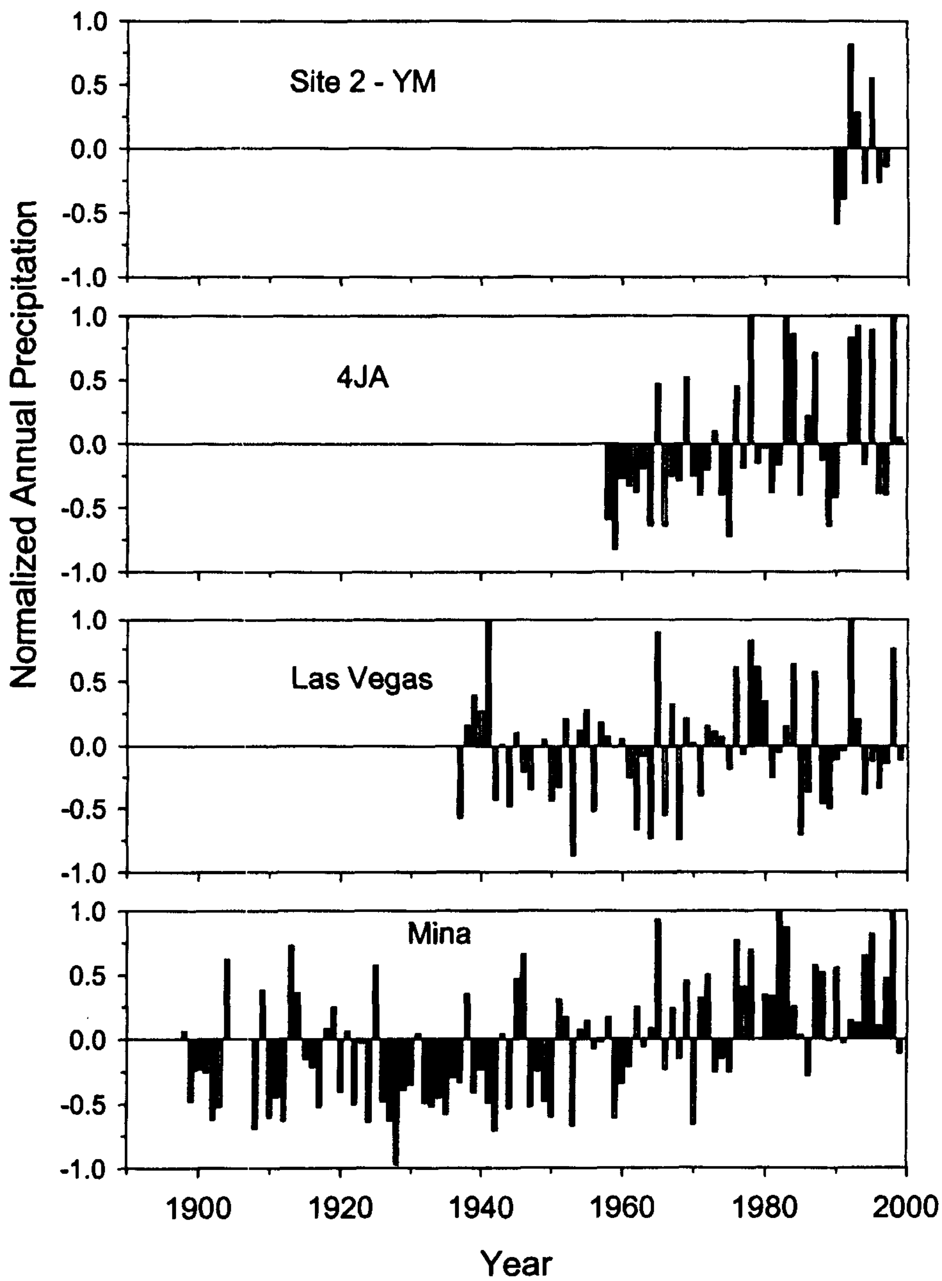
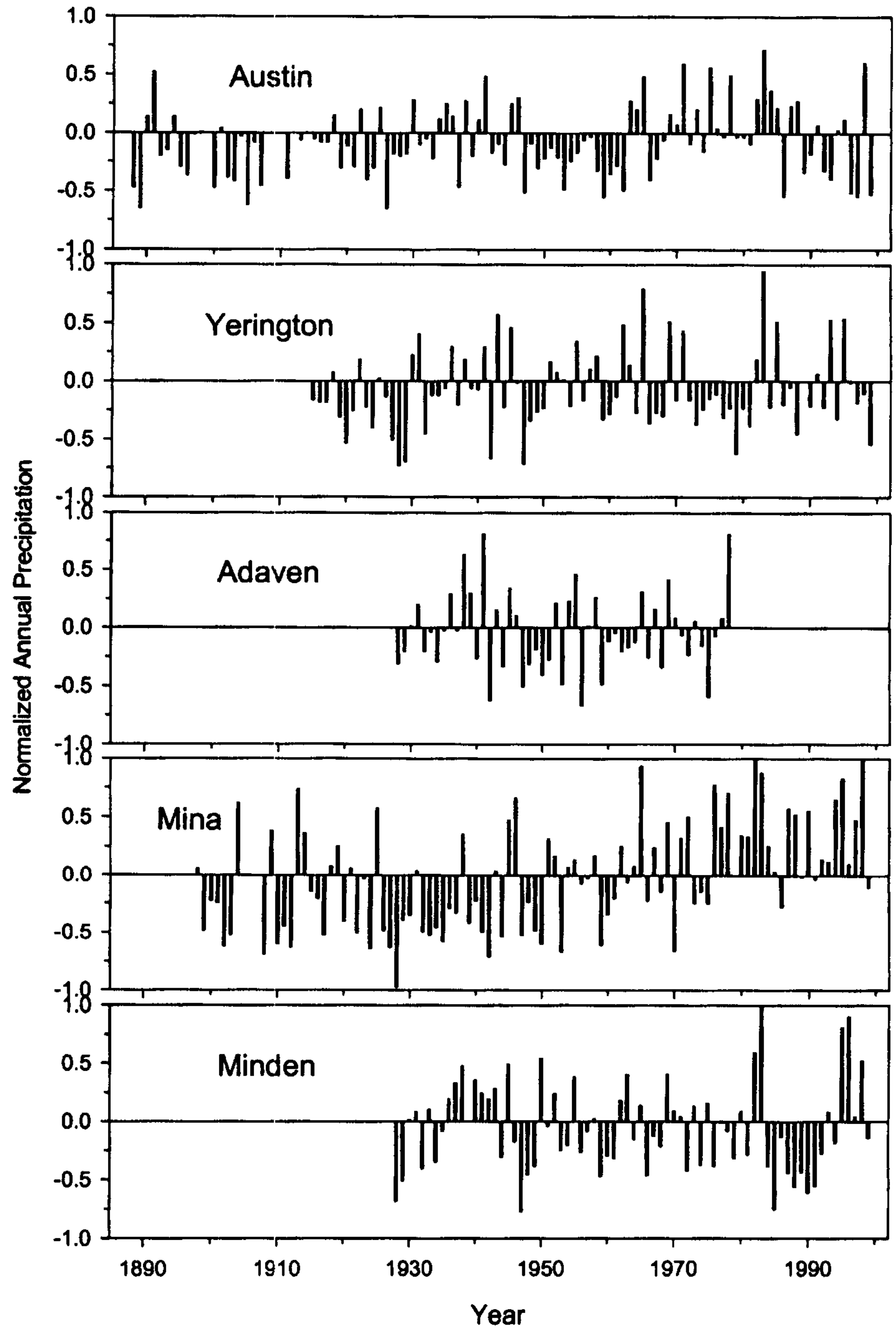


Figure I-17


Austin
Yerington
Adaven
Mina
Minden
Normalized Annual Precipitation
1.0
0.5
0.0
-0.5
-1.0
1890
1910
1930
1950
1970
1990
Year

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