Scientific Notebook
597

CNWRA CONTROLLED COPY 597

MODELING PRESENT AND POSSIBLE FUTURE CLIMATES AT YUCCA MOUNTAIN

D. A. Woolhiser David A. Woolhiser

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

Purposely left blank DW 3-6-08

RL 4/14/2008

DAW 7-17-03

Simulate 50 yrs of present-day Yucca Mtn. Precipitation with perturbations by both SOI and PDO.

Control File: C:\SIMULATIONS-02\ YM181PER2.SIM

Output File: " " \YM181PER2.PTR

Simulation performed by C:\ CLIMAT02\ CLIMSIM-03.F95

Perform statistical analysis of output with STATCLIM2.F95

Control file: C:\CLIMAT02\ Y181P2STA.CON

output file: " " \Y181P2STA.OUT

Annual statistics (N=50yr)

	No Perturbation	PDO Perturbation	SOI + PDO Perturbation
Mean		181.31	189.05
Max.		295.1	378.0
Min		65.1	65.2
Std. Dev		58.38	70.54
CV.		0.32	0.373

Adding the SOI perturbations increased the variance for annual precipitation and for most months. This was usually achieved by increasing the weight of the upper tails of the distributions.

Conclusion: Given the increase in variance of simulated precipitation due to SOI and PDO perturbations, the simulated sequences can be used as input to KINEROS2 modeling of Upper Split Wash. This will provide a comparison with the deep percolation

DAW 7-17-03

estimates using the 9-yr. measured precipitation record.

DAW 8-7-03 100 yr. Simulation of deep percolation - Upper Split Wash

Objectives:

1) Simulate 100 yrs of precipitation input for KINEROS

Procedures:

a) Simulate 50yr sequence:

Completed. - output file is YM181PER2.PJR

See p 4. This will be repeated for a second 50-yr. sequence

b) Use procedures described in Scientific Notebook 363 p 80-81 to select significant summer storms and significant winter storm sequences.

DAW 8-8-03

The program COND7-3.BAS was used in work reported in scientific Notebook 363. However two changes have been made in the output of the climate simulation program so the reading input must be changed to include leap days and added parameter information in each line of simulated output.

Revise Program Input:

C:\CLIMATO2\BASIC PROGRAMS\COND7_3B.BAS → COND7_3C.BAS

CONTROL FILE FOR 1st 50yr simulation analysis: C:\SIMULATIONS_02\Y181P2.FIL

OUTPUT FILES: C:\SIMULATIONS_02\Y181P2SU.COM - Summer rainfall

" " \Y181P2WI.COM - Winter rainfall -

DAW 8-8-03 Precipitation simulation (con't)

The threshold for significant summer daily rainfall is 12.5 mm and the threshold for significant winter precipitation is 25.5 mm. These were the same thresholds previously used. The SOI and PDO perturbations were those for a 50-yr period beginning in 1946.

DAW 8-9-03

Examine output files

C:\SIMULATIONS_02\Y181P2SU.COM - Summer Season

There were 102 days with rain greater than 12.5 mm. The maximum was 61.28 mm. Note that the daily maxima for simulations without SOI-PDO perturbations were 38.56 mm and 33.55 mm for YUCSIMA.PTR and YUCSIMB.PTR respectively (see p81 of Sci. Notebook 363). This is further indication that the perturbations result in heavier tales of daily precipitation distributions and are therefore more realistic.

C:\SIMULATIONS_02\Y181P2WI.COM - Winter Season

For the winter period, days with precip ≥ 25.5 are identified. Also rain on two consequtive days will be considered as one event for disaggregation. Totals of 3 and 4-day sequences are also identified. For sequences of wet days > 4 a note is written in the file. The file YM181PER2.PTR is then examined to see if there is a 3-day sequence with depth ≥ 25.5 mm. If there is not, the storm is not considered for input to KINEROS2 model of Upper Split Wash

Dai 8-11-03

Examine Winter sequences:

ENDING DATE (mm of precipitation on each day of sequence)

Mar 21, 1946 4.18, 4.34, $\overbrace{11.02, 2.14, 9.85}^{\times}$, 0.54, 3.41

For the above sequence, the maximum 3-day depth was <25.4mm so the storm is not considered. The line is edited out in the file

Dec. 26, 1946 $\overbrace{3.39, 17.53, 1.04}^{\times}$, 1.37, 4.87, 0.84

Jan 8 1947 $\overbrace{4.16, 9.10, 10.6}^{\times}$, 0.30, 4.16, 1.08

√√ Feb 17, ~~1997~~ 1947 ok 1.71, $\overbrace{27.85, 0.84}^{ok}$, 1.74, 0.30 (below 32°F at night)

The 3-day total was 30.4 mm beginning on Feb 12, 1947 this was entered in the file with 7-day API = 0.00

√√ Feb 29, 1968 0.26, 4.16, $\overbrace{30.53, 0.24, 9.38}^{40.15}$, 1.97, 1.72, 1.31, 0.91, 1.07, 3.09

Feb. 20, 1968 (No snow)

Mar 30, 1969 $\overbrace{9.84, 8.81, 0.46}^{\times}$, 0.70, 9.33

√√ Jan 12, 1973 1.10, 0.69, $\overbrace{32.37, 0.86, 15.11}^{48.34}$ 7-day API = 34.96mm

Jan 9, 1973 (Snow)

√√ Mar. 18, 1979 0.23, $\overbrace{15.22, 13.37, 0.46}^{29.05}$, 2.01 API = 16.47

Mar 14, 1979 (No snow)

√√ Feb 24, 1980 3.43, 1.53, 3.37, 0.46, 2.87, $\overbrace{11.68, 11.27, 31.46}^{54.41}$ API = 11.66

Feb 21 (may be snow) Below 32°F at night

√√ Jan 26, 1982 0.83, 2.40, 0.93, $\overbrace{6.47, 22.39, 29.08}^{57.94}$ API = 4.16

Jan 23 (Snow)

Feb 4, 1986 0.52, $\overbrace{0.95, 5.16, 15.04}^{\times}$, 0.77, 2.93, 0.47

√√ Jan 12, 1987 1.86, 4.15, 4.75, 5.80, 0.73, $\overbrace{0.86, 8.10, 38.64}^{47.60}$ API = 17.29

F Jan 9 (below freezing in night)

√√ Feb 16, 1992; 11.06, 4.90, 0.59, $\overbrace{0.34, 5.01, 21.54}^{26.89}$ API = 26.57

Feb 13 (below freezing in night)

DAW 8-11-03 Winter precipitation sequences (Con't)

√√ JAN 31, 1993; $\overbrace{14.96, 8.90, 4.25}^{28.11}$, 1.57, 0.39, 0.49 API = 4.18

Jan 25, (No snow)

√√ Dec 14, 1995; 1.33, $\overbrace{16.15, 0.48, 19.95}^{36.58}$, 0.68 API = 1.33

Dec 10 (no snow)

√√ Jan 26, 1996; 0.29, $\overbrace{8.21, 17.09, 8.79}^{34.09}$, 3.14, 5.05 API = 0.29

Jan 21 possible snow

There were 39 days of sequences of 3-days with precipitation > 25.5 mm. Maximum was 64.57 mm in 3-days. Note: In referring to Scientific Notebook 444 pp 64 and 65 we see that for 2 simulated sequences of precipitation without SOI-PDO perturbations there were 29 winter day wet sequence for YUCSIMC.PTR and 36 with rain > 25.4 for YUCSIMD.PTR. Therefore this sequence is very similar considering sample variation.

DAW 8-13-03 Set up new directories for 100 yr USW simulation with simulated precipitation input with SOI-PDO perturbations.

C:\USW_03 — Directory for Upper Split Wash simulations 2003

" " \Y181PE_S (YM expected $\bar{P}$ = 181 mm, perturbations, 1st 50, summer) √

\Y181PE_W (" " " " " winter) √

DAW 8-13-03 Disaggregate Summer Storms

1) Copy Y181P2SU.com from simulations_02 to C:\USW-03\Y181PE_S ✓
2) " Y181P2WI.COM " " " " \Y181PE_W ✓

Ran program DAYDIS4.BAS with Y181P2SU.COM as input ✓
output is C:\USW_03\Y181PE_S\Y181P2SU.DUR ✓
Random number seed was 915

Now Run Program RAINSIM6.BAS
output goes to a floppy disk.

DAW 8-14-03
Copy all files from floppy disk to C:\USW_03\Y181PE_S
files are of form AUG15_53.PRE
Maximum intensity file is Y181P2SU.MAX

Set up Quattro Pro Spreadsheet for precipitation events and API notation. Directory C:\USW_03
File RUNFILE_E.QPW

DAW 8-18-03 Continue with Quattro Pro Spreadsheet RUNFILE_E.QPW
Note: In the file C:\USW_03\Y181PE_S\Y181P2SU.DUR
there was one case where more that one event on a multiple event day were greater than 12.7 mm. Because of the method used in RAINSIM6.BAS to assign names to the precipitation intensity files, only the second storm was saved in a *.PRE file. (OCT13_82.PRE)
The first file for the day was created by dissaggregation

DAW 8-18-03

with the random number seed 915 and stored as OCT13A82.PRE
The file for the second storm of the day was renamed OCT13B82.PRE
All of the 7-day antecedent precipitation was transferred
from the file Y181P2SU.DUR to the Quattro Pro file.
The spreadsheet has the columns:

Run No. Rundate Rainfile API *.PAR file *FIL *OUT R.O. Vol.
→ channel F Qp and Tp.

Because many of these events will not cause
runoff, the rainfall events will first be used as input
to plane 170. If runoff is less than 0.01 mm the
event will not be run with the entire watershed
See p 72 Sci Notebook 444 This will be consistent
with previous work.

Set up Control Files for single plane runs.
Test parameter files:

PLANEMJ.PAR May + June
PLANEJO.PAR July - Oct
PLANEN.PAR Nov.

The API option will be used.

For the results and further documentation
refer to p 169 of Sci. Notebook 444.

DAW 10-31-03 Compare monthly statistics of simulated precipitation series C and E

Simulation Series Monthly File

A

B

DAW 10-31-03

C Z:\ClimateMar_Sep\Yucpres\~~Forty~~ YucsimC.MON

D

E C:\CLIMAT02\Y18~~1~~P2STA.MON

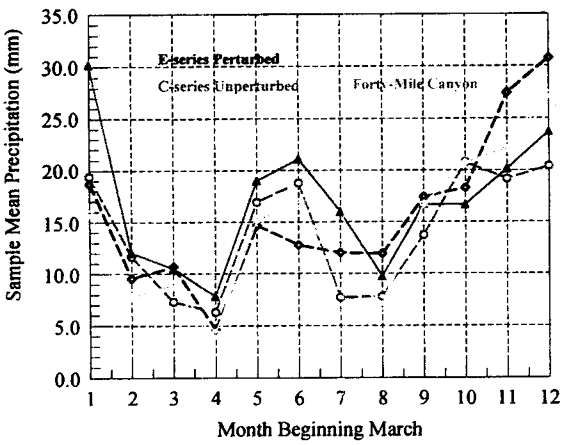
Measured Stations:

Forty-Mile Canyon: Z:\ClimateMar_Sep\Yucpres\FortyM~1.MON

Yucca Dry Lake: " " " " \YUCCA.MON

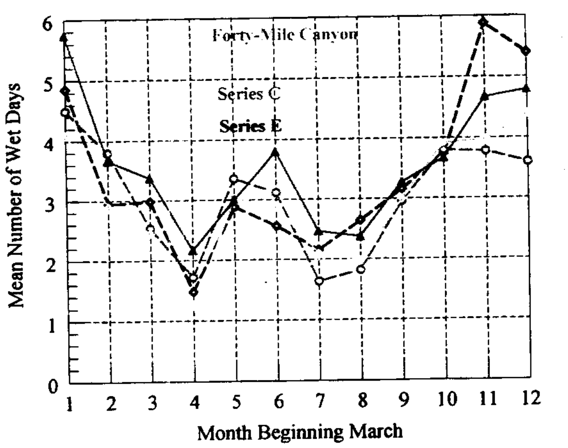
The files from the Zip disk were sent to SwRI in Mar. 2001.
The *.MON files were extracted from *.STA files

DAW 11-4-03 The mean ~~annual~~ DAW 11-4-03 monthly precipitation and the mean number of wet days per month are shown below.



Mean Monthly Precipitation - Two Measured Stations and Simulated Series C and E

File: C: | CLIMAT02 | E&CMONTH.PGW
daw 10-31-03



Mean Number of Wet Days Per Month Two Measured Stations and Simulated Series C and E

File: C: | CLIMAT02 | E&CNOWETDAY.PGW
daw 10-31-03

DAW 11-4-03

The annual statistics are shown below

Station or Simulated Sequence	MAP (mm)	Std. dev.	$\sigma/\sqrt{n}$
Forty-mile Canyon	203.8	88.6	14.0
Yucca Dry Lake	173.2	83.6	13.2
Sequence C	170.3	52.1	7.4
Sequence E	181.3	58.37	8.3

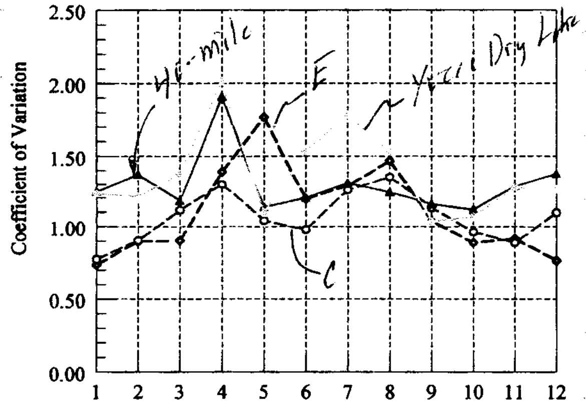
It is clear the both simulated sequences have smaller standard deviations of annual precipitation then the ~~simulated~~ measured DAW 11-4-03 sequences. MAP for sequence E is bounded by MAP for Forty-mile Canyon and Yucca Dry Lake.

An examination of the figure on p 11 showing monthly sample means shows that the means for sequences C and E are bounded by those for the weather stations for most months. The C series means are low for the months of Sept, Jan and Feb. while the E series means are low for August and high for Oct. Jan. and Feb. Given the large standard deviations, the standard deviations of the means, $\sigma/\sqrt{n}$, are also quite large. It is difficult to interpret differences for the E series because they represent a non-stationary series due to SOI + PDO perturbations ~~and~~ DAW 11-4-03 for a different period of record than Forty-mile Canyon and Yucca Dry Lake.

The monthly variation of mean number of wet days per month, (See Fig. on P11) reflects similar deviations.

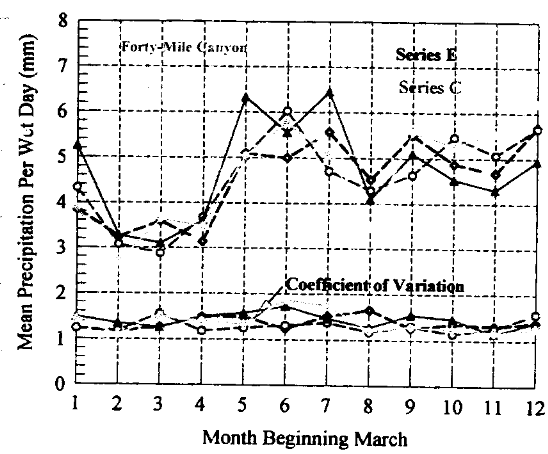
DAW 11-4-03

A plot of the coefficients of variation (CV) of the four series is shown below. CVs for the measured data are greater than for the simulated sequences for most months, especially in spring and winter. This is most likely due to model simplification. A second order Markov Chain would likely be more appropriate for these seasons. It is also possible that a chain dependent distribution of daily precipitation would provide a better fit. The rather good fit of the monthly mean values of the precipitation per wet day as shown below, suggests that improvements in the Markov Chain model would ~~be~~ DAW 11-4-03 ~~the~~ DAW 11-4-03 provide the greatest improvement for a limited number of additional parameters. This conclusion is reinforced by the comparison of CDFs for all days for Forty-mile ~~wash~~ Canyon DAW 11-4-03 and series E.



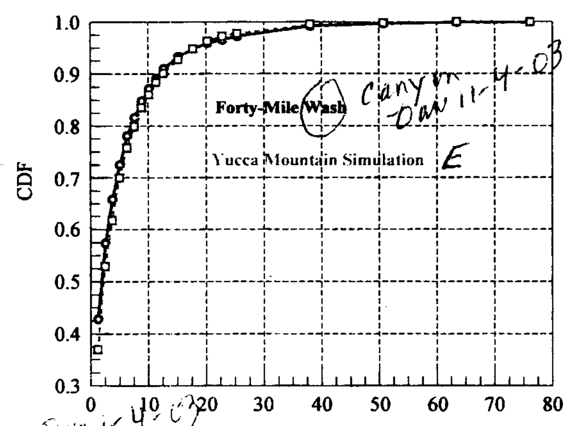
Coefficient of Variability of Monthly Precipitation
Two Measured Stations and Simulated Series C and E

File: C: | CLIMAT02 | E&CMONTHCV.PGW
daw 10-31-03



Precipitation per Wet Day and Coefficient of Variation,
Two Measured Stations and Simulated Series C and E

File: C: | CLIMAT02 | E&CWETDAY.PGW
daw 10-31-03



DAW 11-4-03 Canyon
Annual Cumulative Distribution Functions
Forty-Mile Wash and Simulated Yucca Mountain

File: C: | CLIMAT02 | DAILY_40&E.PGW
daw 11-3-03

DAW 12-8-03 Compare CDFs of daily and monthly Series E data with real Forty-mile Canyon Data and Yucca Dry Lake

First Create STATCLIM3.F95 to read only one col. of data (precipitation) and omit temp and radiation statistics. The variable DATACODE activated. If DATACODE=1 then only one column of data - daily precipitation
For Fortymile Canyon Data file is FORTYM~1.PTT is C:\SOI
data are in inches.
Control file: C:\CLIMATO2\FORTYSTAT.CON
output file: C:\CLIMATO2\FORTYSTAT.OUT
Saved as C:\CLIMATO2\STAT.CON for input to STATCLIM3
Requested CDFs of monthly precipitation and daily wet-day precipitation for each month.

DAW 12-9-03 Set up run for Yucca Dry Lake
Control file: C:\CLIMATO2\YUCCADLSTAT.CON
Output file: C: " \YUCCADLSTAT.OUT
40 yrs. precip file: C:\SOI\YUCCA.PTT 1959-98

To create CDFs of Monthly precipitation:
1. Use editor and select 2 cols from each CDF
2. Paste in temporary file C:\CLIMATO2\SLATE.DAT
3. Import Data to PSIPLOT

X_1 $F_1(x)$ X_2 $F_2(x)$ X_3 $F_3(x)$ X_4 $F_4(x)$ X_5 $F_5(x)$ X_6 $F_6(x)$

where 1 is for simulated YM, 2 is for Yucca Dry Lake
3 is for Forty-Mile Canyon

Daw 12-9-03

CDFs of precipitation per wet day

4 is for simulated YM, 5 is Yucca Dry Lake, 6 is Fortymile Canyon

For March: Data file is: C:\CLIMATO2\COMPAREMAR.PDW

CDF Monthly Total " " \COMMAR.PGW

CDF Monthly Total per wet day " " \COMDAYMAR.PGW

For January Data file is: C:\CLIMATO2\COMPAREJAN.PDW

CDF Monthly COMJAN.PGW

CDF Wet Day COMDAYJAN.PGW

For February: C:\CLIMATO2\COMPAREFEB.PDW

CDF Monthly COMFEB.PGW

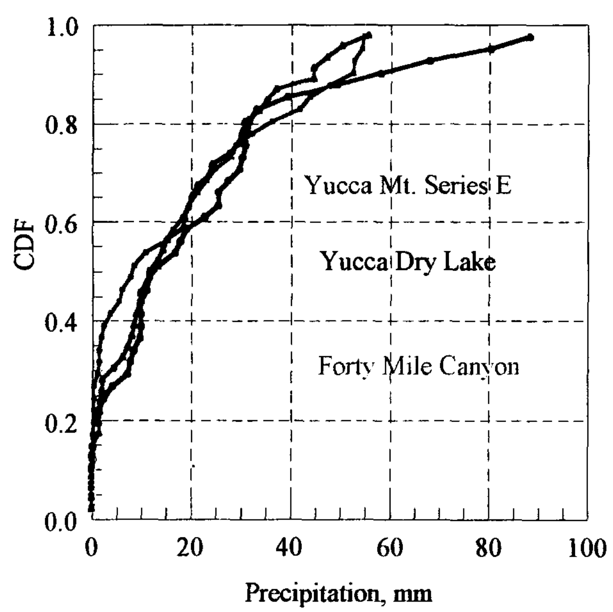
CDF Wet Day COMDAYFEB.PGW

Daw 12-10-03

For December C:\CLIMATO2\COMPAREDEC.PDW

" COMDEC.PGW

" COMDAYDEC.PGW



Cumulative Distribution Functions of December Precipitation

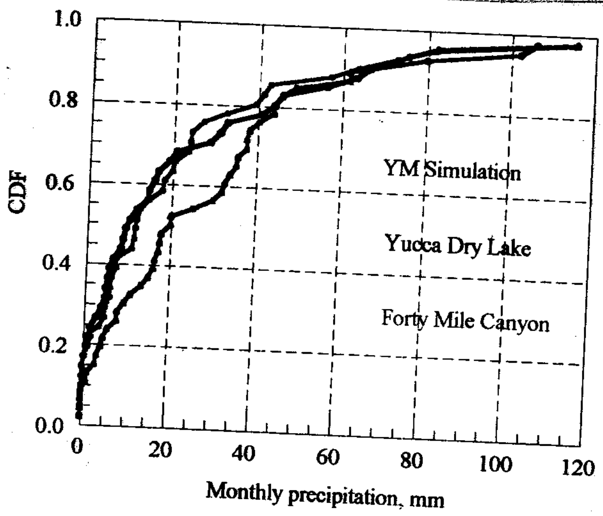
File: C: | CLIMAT02 | COMDEC.PGW
daw 12-10-03
Data: C: | CLIMATO2 | COMPAREDEC.PDW

The CDF of the simulated sequence follows the measured sequences very well until a CDF of 0.8. After that the series E has a much lighter tail

Similar figures are shown for Jan, Feb and Mar on p16

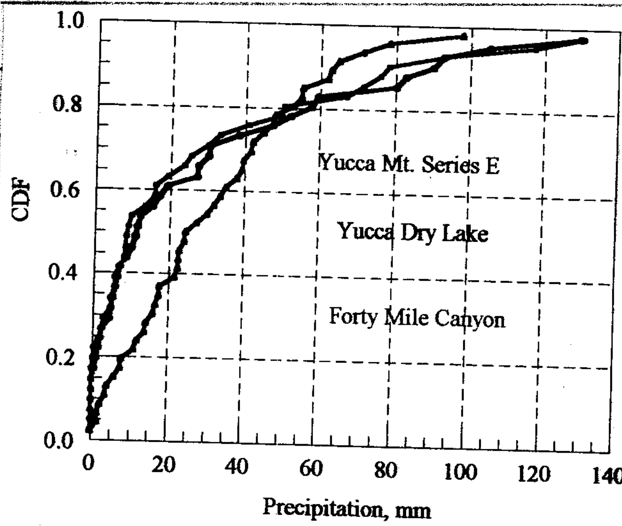
DAW 12-11-03 Precipitation Diagnostics (Con't).

These months are the most important contributors for infiltration in the 9-yr record, so it is important to determine the



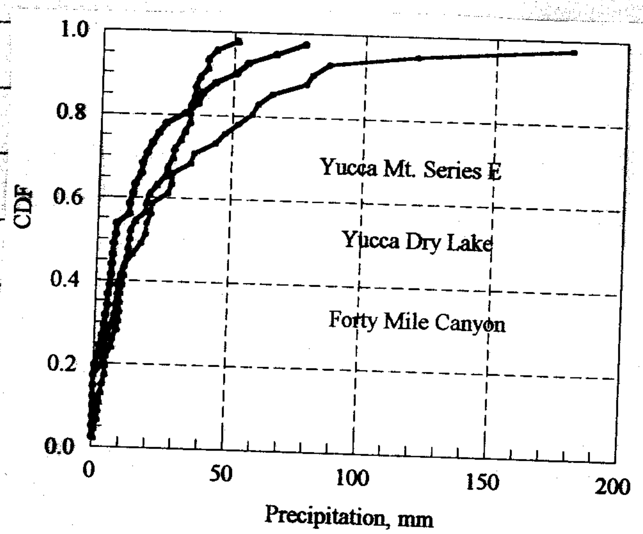
January Precipitation

File: C: | CLIMAT02 | COMJAN.PGW
DAW 12-9-03
Data: C: | CLIMAT02 | COMPAREJAN.PDW



Cumulative Distribution Functions of February Precipitation

File: C: | CLIMAT02 | COMFEB.PGW
daw 12-10-03
Data: C: | CLIMATO2 | COMPAREFEB.PDW



Cumulative Distribution Functions of March Precipitation

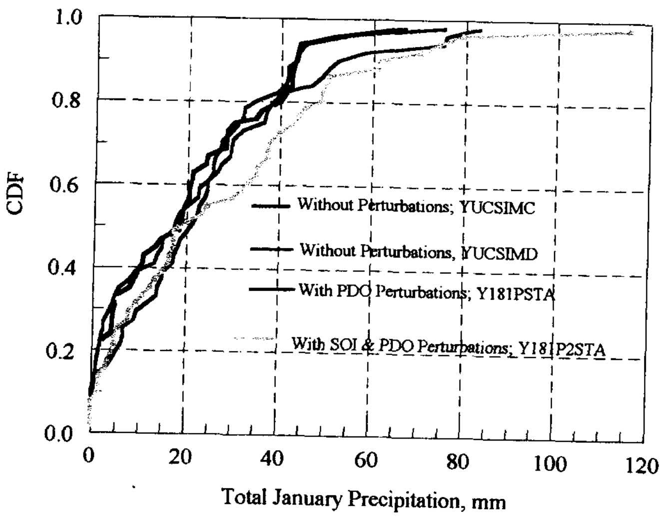
File: C: | CLIMAT02 | COMMAR.PGW
daw 12-10-03
Data: C: | CLIMAT02 | COMPAREMAR.PDW

differences and the reasons for the differences.

Except for Jan., all of the simulated distributions have lighter tails than CDFs of measured data. In Jan and Feb. the E series density function is not as skewed as those for the measured series

CDFs for four simulated sequences for the month of Jan are shown on p17. It is clear that the SOI and PDO perturbations lead to a heavier tail, but they reduce the probabilities of Jan. precipitation ≤ 10 mm.

DAW 12-11-03 Precipitation Diagnostics (Cont)



Cumulative Distribution Functions for January Precipitation Simulations for Present Climate, Yucca Mountain

File: C: | CLIMAT02 | JANMOCDF.PGW
Data: C: | CLIMAT02 | YUCSIMC.STA, YUCSIMD.STA, Y181PSTA.OUT & Y181P2STA.OUT
daw 7-16-03, 7-18-03

The questions that must be asked are:

1. Are these discrepancies due to a structural flaw in the MCME model. If so is it the occurrence process or the distribution of wet-day precipitation?

2) Do the simplification due to Fourier series fitting of parameters contribute, or is there a flaw in the parameter identification procedure?

3) Is the structure of the SOI-PDO perturbations contributing to the distortions, even though they result in greater CVs?

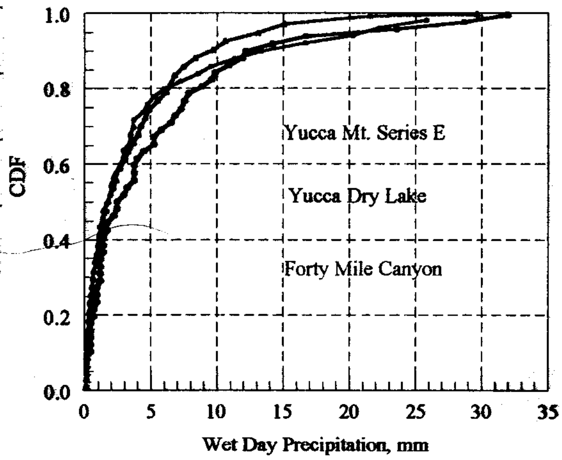
To examine these questions, first look at the distributions of precipitation per wet day for these four months.

DAW 12-12-03

CDFs for wet-day precipitation for Dec., Jan, Feb and Mar are shown on p 18. The series E CDF for Dec has a lighter tail than the measured stations. This could account for the same feature in the monthly CDFs on p 15.

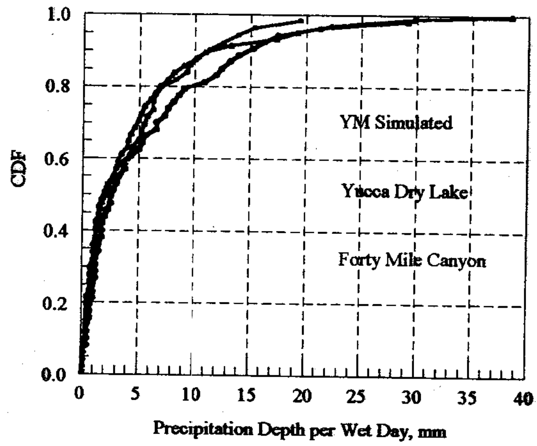
DAW 12-12-03 Precipitation Diagnostics (Cont)

The Series E CDF for January compares favorably with the Forty-Mile Canyon data, but deviates from the Yucca Dry Lake in the interval 5-15 mm (As does the Forty Mile Canyon).



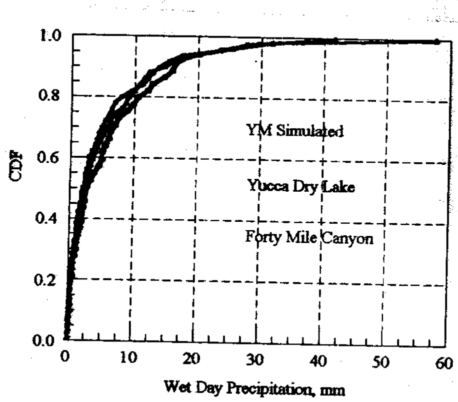
DECEMBER WET DAY PRECIPITATION

File: C:|CLIMAT02|COMDAYDEC.PGW
daw 12-10-03
Data: C:|CLIMAT02|COMPAREDEC.PDW



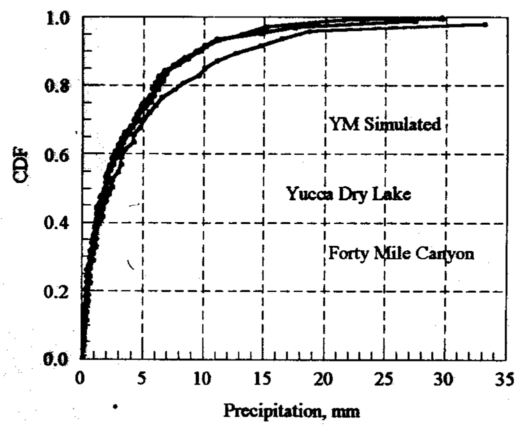
January Wet Day Precipitation

File: C:|CLIMAT02|COMDAYJAN.PGW
daw 12-9-03
Data: C:|CLIMAT02|COMPAREJAN.PDW



February Wet Day Precipitation

File: C:|CLIMAT02|COMDAYFEB.PGW
daw 12-9-03
Data: C:|CLIMAT02|COMPAREFEB.PDW



March Wet Day Precipitation

File: C:|CLIMAT02|COMDAYMAR.PGW
daw 12-9-03
Data: C:|CLIMAT02|COMPAREMAR.PDW

The Feb. CDF for series E is very close to the other two, while the Mar CDF is very close to Yucca Dry Lake. It appears the the wet-day distributions are not responsible for the deviations of the monthly CDFs for Feb. and Mar

DAW 12-12-03 Precipitation Diagnosis (Con't)

Now check the probability density functions of the number of wet days per month.

Programs STATCLIM2.F95 and STATCLIM3.F95 were modified to output the frequencies of 0, 1, 2 --- wet days per month for all months. The MSDOS editor is used to extract the tables from the output files and to import them to the plotting program. The plotting program sheet files are:

C:\CLIMATO2\YUCCOLWET.PDW

C:\ " \FORTYWET.PDW

C:\ " \YM181P2WET.PDW

DAW 12-12-03 DAW 12-12-03

Cumulative probability ~~density~~ mass functions (CPMFs) are compared for the three ~~stations~~ DAW 12-12-03 precipitation sequences

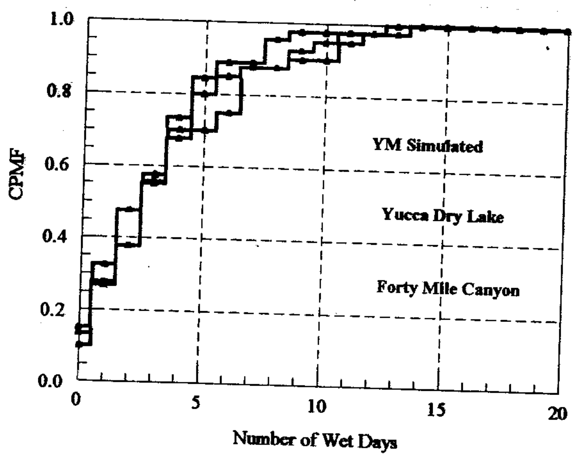
The form of the plot files: C:\CLIMATO2\F_N_XXX.PGW

where xxx is the month.

DAW 12-15-03

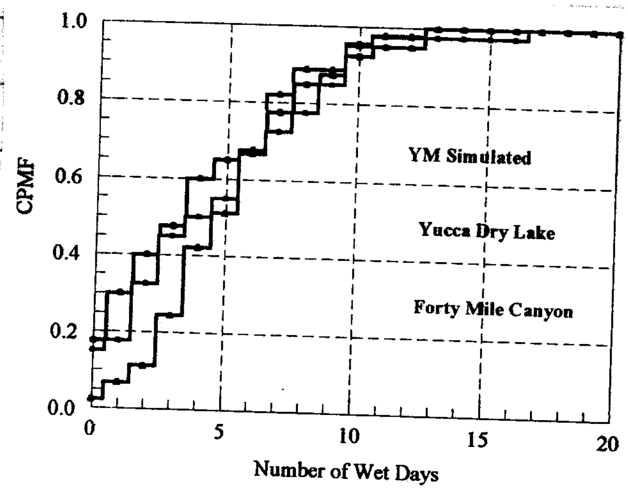
Cumulative probability mass functions for the number of wet days per month for Dec - Mar are shown on p 20. The simulated data show a lower probability of no rainy days for 3 of the four months. There is also a tendency for fewer wet days greater than 7 for three of the four months. This suggests that a higher-order Markov chain is appropriate for these months. These deviations in the CPMFs are consistent with the deviations of CDFs of monthly precipitation shown on pages 15 and 16.

DAW 12-15-03 Precipitation Diagnostics (Con't)



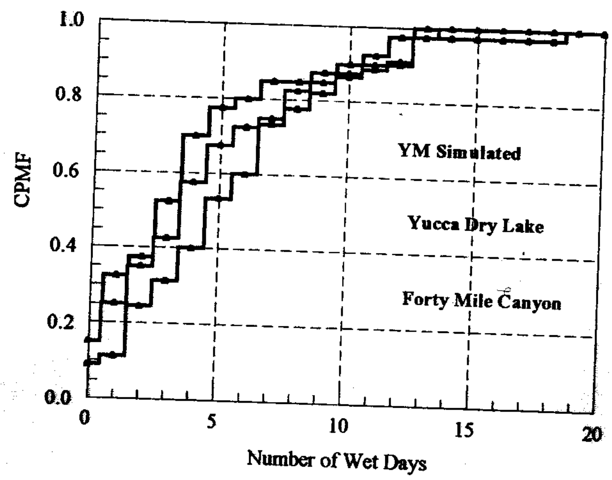
Cumulative Probability Mass Function, December

File: C:|CLIMAT02|F_N-DEC.PGW
dew 12-12-03
Data: C:|CLIMAT02| YM181P2WET.PDW, YUCCDLWET.PDW, FORTYWET.PDW



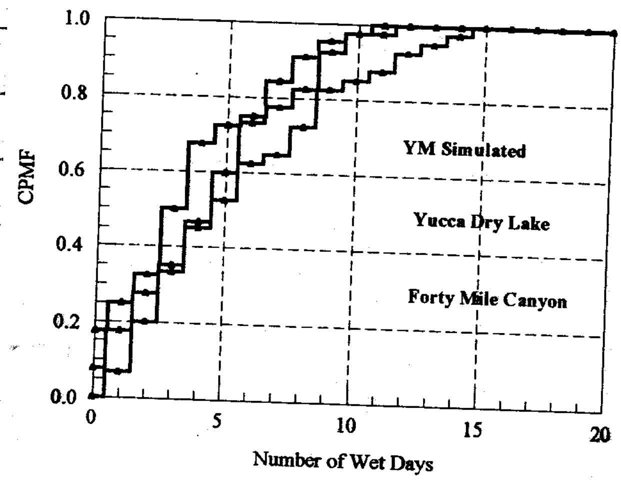
Cumulative Probability Mass Function, February

File: C:|CLIMAT02|F_N-FEB.PGW
dew 12-12-03
Data: C:|CLIMAT02| YM181P2WET.PDW, YUCCDLWET.PDW, FORTYWET.PDW



Cumulative Probability Mass Function, January

File: C:|CLIMAT02|F_N-JAN.PGW
dew 12-12-03
Data: C:|CLIMAT02| YM181P2WET.PDW, YUCCDLWET.PDW, FORTYWET.PDW

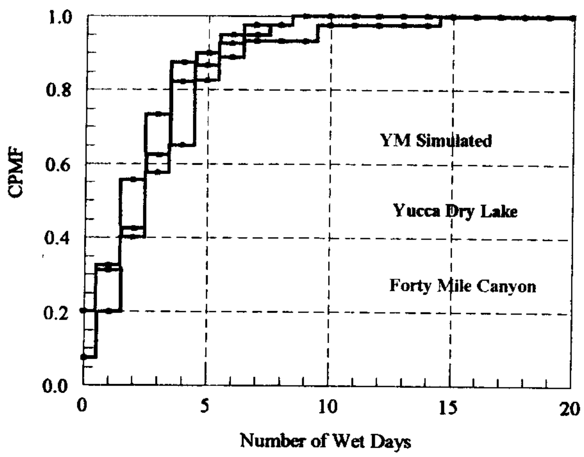


Cumulative Probability Mass Function, March

File: C:|CLIMAT02|F_N-MAR.PGW
dew 12-12-03
Data: C:|CLIMAT02| YM181P2WET.PDW, YUCCDLWET.PDW, FORTYWET.PDW

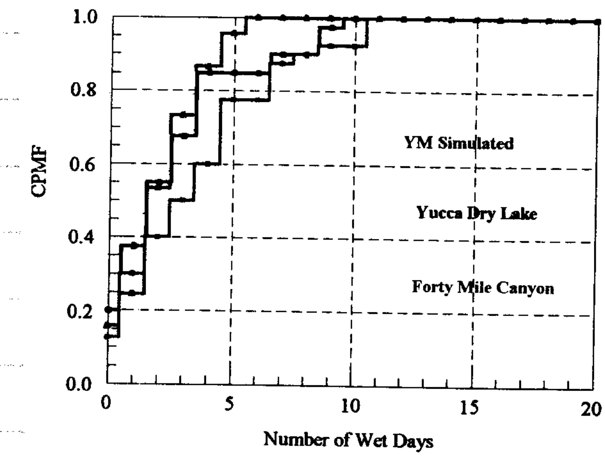
CPMF's for July - November are shown of pages 21 and 22 with the possible exception of August, the simulated functions are very close the the observed data. The importance of sampling variability is emphasized by deviations between the measured functions. In general one would expect

Daw 12-15-03 Precipitation Diagnostics (Cont)



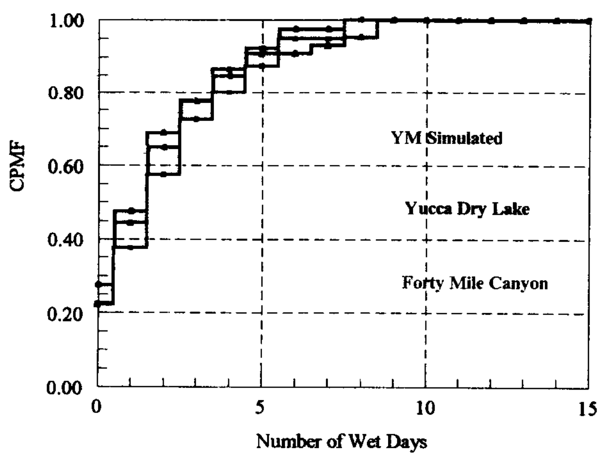
Cumulative Probability Mass Function, July

File: C:|CLIMAT02|F_N-JUL.PGW
daw 12-13-03
Data: C:|CLIMAT02| YM181P2WET.PDW, YUCCDLWET.PDW, FORTYWET.PDW



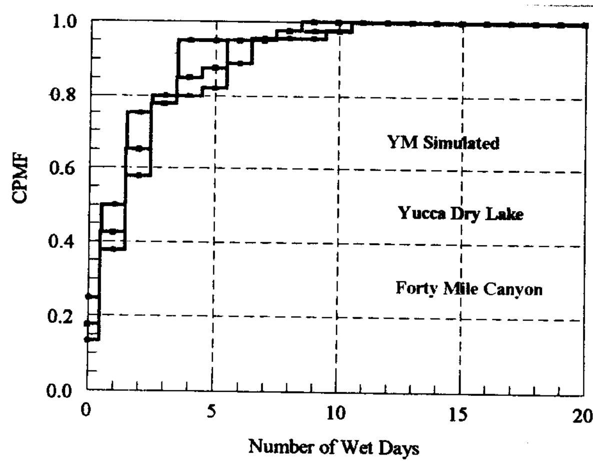
Cumulative Probability Mass Function, August

File: C:|CLIMAT02|F_N-AUG.PGW
daw 12-13-03
Data: C:|CLIMAT02| YM181P2WET.PDW, YUCCDLWET.PDW, FORTYWET.PDW



Cumulative Probability Mass Function, September

File: C:|CLIMAT02|F_N-SEP.PGW
daw 12-12-03
Data: C:|CLIMAT02| YM181P2WET.PDW, YUCCDLWET.PDW, FORTYWET.PDW

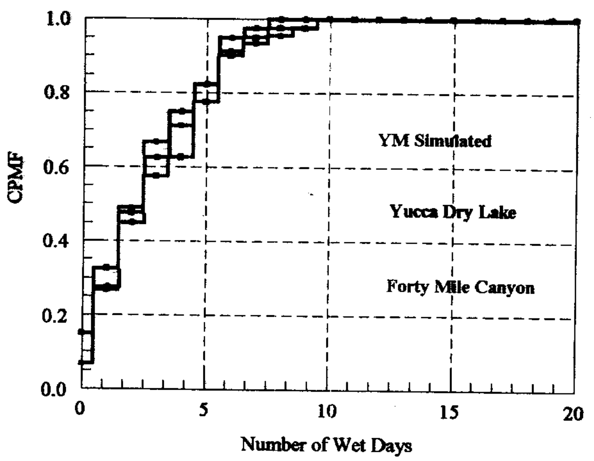


Cumulative Probability Mass Function, October

File: C:|CLIMAT02|F_N-OCT.PGW
daw 12-13-03
Data: C:|CLIMAT02| YM181P2WET.PDW, YUCCDLWET.PDW, FORTYWET.PDW

That 40-mile Canyon (blue line) would reflect a greater number of wet days than Yucca Dry Lake and the simulated series E because it has a greater mean annual precipitation.

DAW 12-15-03 Precipitation Diagnostics (Cont)



Cumulative Probability Mass Function, November

File: C:|CLIMAT02|F_N-NOV.PGW
daw 12-13-03
Data: C:|CLIMAT02| YM181P2WET.PDW, YUCCDLWET.PDW, FORTYWET.PDW

DAW 8/23/04

On the basis of the conclusions presented in the precipitation diagnostics, it is desirable to analyze daily precipitation data using a 2nd order Markov Chain model. Such a model conditions the probability of a dry day on day i on the outcome on the 2 previous days ie:

$$P\{X_i=0 \mid X_{i-1}, X_{i-2}, X_{i-3} \cdots X_{i-n}\} = P\{X_i=0 \mid X_{i-1}, X_{i-2}\}$$

where $X_i = 0$ if day i is dry
$X_i = 1$ if day i is wet

The transition probability matrix can be defined by four parameters:

$$p_{000} = P\{X_i=0 \mid X_{i-1}=0, X_{i-2}=0\}$$
$$p_{100} = P\{X_i=0 \mid X_{i-1}=0, X_{i-2}=1\}$$
$$p_{010} = P\{X_i=0 \mid X_{i-1}=1, X_{i-2}=0\}$$
$$p_{110} = P\{X_i=0 \mid X_{i-1}=1, X_{i-2}=1\}$$

DAW 8/23/04 Second Order Markov Chain
The wet day probabilities

$$p_{ij1} = 1 - p_{ij0} \qquad i, j = 0, 1$$

Utilizing the notation of Woolhiser and Pegram (1979), the record at a station is the vector $\{X_t\}$ and is exactly S yrs long. thus $\underline{X}$ has a length $N = 365S$ elements. (where we omit leap days) To account for the fact that there are often days with no record (i.e. the data are missing), this must be considered.
For a missing record, $i, j, k = -1$
Let $\underline{\phi}_1$ be a vector whose elements are the coefficients of the Fourier series describing $p_{000}(n)$, $p_{100}(n)$, $p_{010}(n)$ and $p_{110}(n)$. We wish to find the estimate $\hat{\underline{\phi}}_1$ of $\underline{\phi}_1$ which maximizes the likelihood function $L_1(\underline{X} = \underline{x} \mid \underline{\phi}_1)$. This function is specified by the number of transitions of various types occurring on each of the calendar days $n = 1, 2, \cdots 365$.

Let $a_{ijk}(n)$ be the observed number of transitions from state i (=0 or 1) on day $n-2$ to state j (=0 or 1) on day n-1 to state k (=0 or 1) on day ~~x~~ n DAW 8/23/04 in the sample $\underline{X}$. a_{ijk} can be any of the integers $0, 1, 2, \cdots, S$ and their ensamble is an array of size 365×8.

Ref: Woolhiser, D.A and G.G.S. Pegram (1979) Maximum Likelihood Estimation of Fourier Coefficients to Describe Seasonal Variations of Parameters in Stochastic Daily Precipitation Models. Journ. Appl. Met. Vol 18, No 1. 34-42.

DAW 8/30/04 Second Order Markov Chain (Cont)

The logarithm of the likelihood, U can be written.

$$U = \log L\{\underline{X} = \underline{x} \mid \underline{\Phi}\} = \sum_{n=1}^{365} \Big\{ a_{000}(n) \log p_{000}(n) + a_{001}(n) \times \log[1 - p_{000}(n)]$$

$$+ a_{100}(n) \log p_{100}(n) + a_{101}(n) \log[1 - p_{100}(n)] + a_{010}(n) \log p_{010}(n)$$

$$+ a_{011}(n) \log[1 - p_{010}(n)] + a_{110}(n) \log p_{110} + a_{111}(n) \log[1 - p_{110}(n)] \Big\}$$

Note that if a daily record is missing, it will not affect the results directly.

The expressions above are consistent with an annual climatic cycle where the daily values of the four parameters can be described as step functions for months or seasons or by a finite Fourier series. If SOI and PDO series are used as perturbations, then $\{X\}$ is no longer stationary from year-to-year.

The log Likelihood function above can be written as

$$U = U_{000} + U_{100} + U_{010} + U_{110}$$

where each term is dependent on only one transition probability. This is useful for estimating the parameters describing seasonal variations because optimization can be performed on each term independently.

DAW 8/31/04

Given the four parameters required, P_{000}, P_{100}, P_{010} and P_{110}, a step function representation with monthly steps would require 48 parameters. A finite Fourier Series representation of the form

$$\theta_j(n) = C_{j0} + \sum_{k=1}^{m_j} \left\{ C_{jk} \sin\left(\frac{nk}{T} + D_{jk}\right)\right\} \qquad j = 1, 2, 3, 4$$

can be used. Here C_{j0} is the annual mean, C_{jk} is the k^{th} amplitude of the harmonic, D_{jk} is the k^{th} phase angle $T = 365/2\pi$ and m_j is the maximum number of harmonics required.

Because the transition probabilities are bounded by 0 and 1, it is useful to use the logit transform

$$G_{ijk}(n) = \log\left(\frac{P_{ijk}(n)}{1 - P_{ijk}(n)}\right)$$

which is bounded by $-\infty$ and $+\infty$.

Therefore:

$$P_{ijk}(n) = \exp\left[G_{ijk}(n)\right] / \left\{1 + \exp\left[G_{ijk}(n)\right]\right\}$$

The logit $G_{ijk}(n)$ is expressed as a Fourier Series

$$G_{ijk}(n) = \sum_{i=1}^{m_{ai}} a_i \phi_i(n); \quad \text{where } \phi_i(n) = \cos\{(i-1)\pi n/365\} \quad i = 1, 3, 5 \ldots$$

$$\phi_i(n) = \sin(i\pi n/365); \quad i = 2, 4, 6 \ldots$$

DAW 10-26-04 Second Order Markov Chain (Con't)

The program MCSO (MCMELOG) written originally by D.A. Woolhiser and others at the Southwest Watershed Research Center, ARS, USDA Tucson and modified for the P.C. by E. Moreno at the University of Cordoba, Spain was in FORTRAN 77. It was ported to FORTRAN 95 by D.A. Woolhiser over the period 8-30-04 to 10-25-04.
The FORTRAN95 program is MC2ME4—1.F95 in C:\CLIMAT04\ ~~MC2TEST~~ DAW 10/26/04 in the HP computer. Improvements were made in the Formats and details of the output to facilitate the analysis.

Task 1 Examine regional regressions between 2nd order Markov Chain parameters and mean annual precipitation (MAP).
Reference: Scientific Notebook 363 p 47.
Prostat file: MCMETSTPAR.PDW
Copy MCMETSTPAR.PDW to C:\CLIMAT04\MC2TEST ✓
Rename it: MC2METSTPAR.PDW ✓
Also: Copy NTSME2PHASE.PDW
Rename: NTSME2PHASE.PDW
Copy: NTSMCPHASE.PDW
Rename: NTSMC2PHASE.PDW
These summary files will be modified to include 2nd order MC parameters

Daw 10-26-04

Create a summary file of parameters C:\CLIMATO4\MC2TEST\MC2MEPAR.SUM by copying relevant information from the output files:

Daw 10-28-04

The program MC2ME4_1.F95 was used to identify the Markov Chain - Mixed exponential parameters for daily precipitation at a total of 16 sites in the Yucca Mtn region. The control files used for the analysis with only the first order Markov Chain were copied and renamed for these runs. All files are in C:\CLIMATO4\MC2TEST.

Estimates of the Fourier Series coefficients were obtained by maximizing the Log likelihood function (see p. 24) for 1, 2, 3, 4 and 5 harmonics. The number of harmonics with minimum AIC is chosen for each parameter and the overall log likelihood function is the sum of the log likelihoods for each parameter. A summary of the number of significant harmonics for each parameter for each station is shown below.

Comparison of 1st and 2nd Order Markov Chain Models Daw 10/28/04

STATION	Number of Significant Harmonics						AIC	
	G_{00}	G_{10}	G_{000}	G_{100}	G_{010}	G_{110}	1st	2nd
Adaven	4	1	4	1	1	1	7846.1	7826.2 *
Beatty	5	2	5	1	1	2	8312.7	8264.0 *
Cane Springs	5	2	5	1	2	2	7349.4	7299.8 *
Desert Rock	5	2	4	2	2	2	7194.1	7150.5 *
Buster Jangle	5	2	5	1	1	2	8312.7	8263.9 *
Caliente	5	1	5	2	1	1	10,229.4	10,200.7 *
Forty Mile Canyon	5	2	5	1	2	2	8921.3	8855.8 *
Goldfield	5	2	4	1	1	2	5390.7	5321.8 *
Jackass Flats	5	2	5	1	2	3	7677.9	7622.7 *
Las Vegas	5	1	5	5 †	2	1	9885.3	9807.3 *
Mercury	5	2	5	3	2	1	6422.3	6378.2 *
Ranier Mesa	5	2	5	1	3	2	9966.1	9918.4 *
Tippipah Springs	5	2	5	1	1	2	8847.6	8761.3 *
Tonopah	5	1	5	2	1	1	9071.5	9032.2 *
Well 5b	5	2	5	1	2	2	7320.5	7303.3 *
Yucca Dry Lake	5	1	5	1	1	1	8186.0	8151.3 *

† Harmonics 1, 2 and 5. 5 could be fitting noise

* - Minimum AIC

Daw 10-28-04

An examination of the table on p 27 reveals that the 2nd order process was superior to the first order Markov Chain for all stations according to the Akaike Information Criterion.

Daw 11-2-04

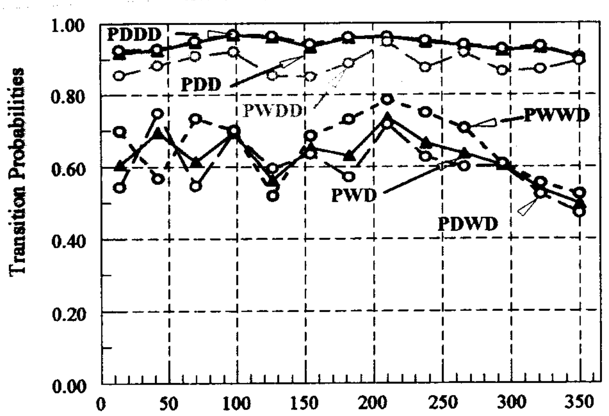
The following 3 stations were selected for more detailed graphical comparisons because they are the upper, mid and lower range of mean annual precipitation (MAP)

Well 5b: MAP = 123.3 mm ; NW = 32.7 days (mean annual number of wet days)

40-Mile Canyon N: MAP = 203.8 mm ; NW = 43.1 days

Ranier Mesa: MAP = 314.2 ; NW = 53.3 days

1st and second order Markov Chain transition probabilities for 28-day periods (29 for the 13th) are plotted for the three stations below and on p 29. For the figures, DDD is equivalent to 000 in mathematical notation; DWD is equivalent to 010, etc. If the process was truly 1st order PDDD and PDD would collapse onto PDD (with any differences being due to sample size differences) Similarly PWWD and PDWD would collapse on PWD. The periods with the greatest divergencies would have the strongest 2nd order effects. With the arid climatic conditions the

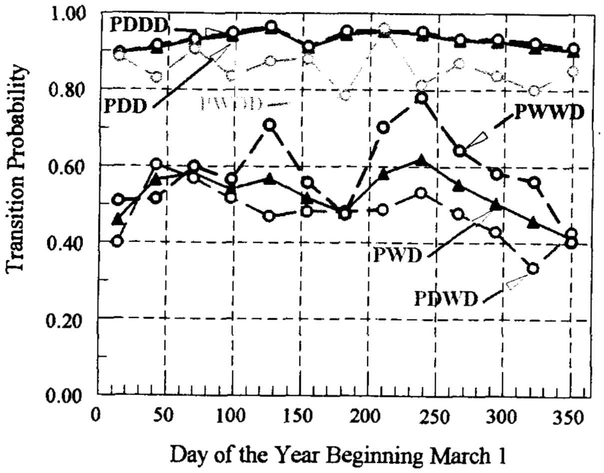


Day of the Year Beginning March 1.

28 Day Transition Probabilities, Ist & 2nd Order Markov Chains
Well 5B, NTS, NV.

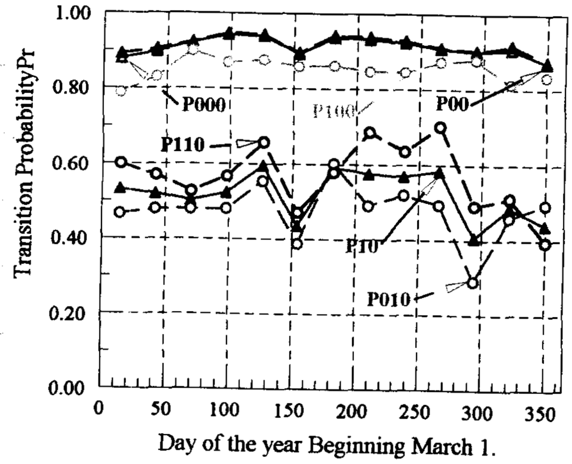
File: C|CLIMAT04|MC2TEST|WELLPERMC2.PGW
Data file: WELLPERMC2.DAT & WELL5BMC2.OUT
daw 10-29-04

-DAW 11-2-04



28 Day Transition Probabilities, Ist & 2nd Order Markov Chains
Forty Mile Canyon, NV.

File: C | CLIMAT04 | MC2TEST | FORTYPERMC2.PGW
Data file: FORTYPERMC2.DAT & FORTYMC2.OUT
daw 10-29-04



28 Day Transition Probabilities, Ist & 2nd Order Markov Chains
Ranier Mesa, NV.

File: C | CLIMAT04 | MC2TEST | RANIERPERMC2.PGW
Data file: RANIERPERMC2.DAT & RANIERMC2.OUT
daw 10-28-04

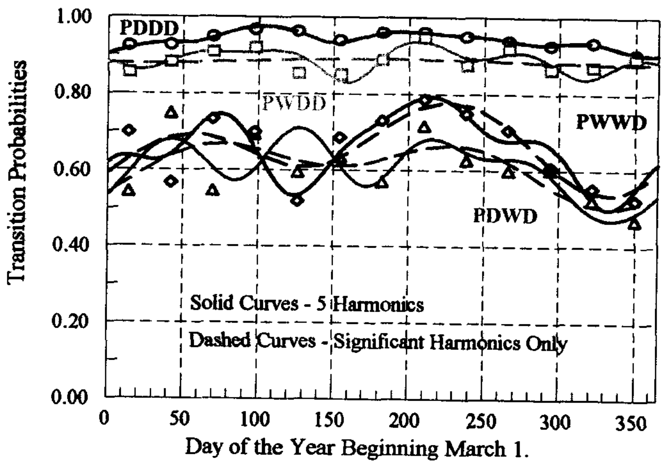
DAW 11-2-04

DDD and DD sequences ~~has~~ have the largest sample sizes and therefore have smaller variance than sequences with a wet day. The differences between PWWD or PDWD and PWD are greatest during the September - Dec period for all stations. PDD and PDDD differ in the 3rd decimal place with the probability of a wet day occurring after 2 dry days being slightly smaller than after only one dry day. However there is a substantially higher probability of a wet day if the first day was wet and this tendency continues throughout the year.

If we were to use period values of each transition probability we would have a total of 26 parameters for the 1st order MC and 52 parameters for the second order process.
With the Fourier series representation the parameters are reduced to from 12 to 16 for the 1st order and from 18 to 30 for the second order MC. The reduced number of parameters facilitates regional analyses.

DAW 11-2-04

The following figures show the period probabilities and the Fourier Series curves for 5 harmonics and the AIC optimum number of harmonics for each of the three stations



Daily Fourier and 28 Day Transition Probabilities, 2nd Order Markov Chains, Well 5B, NTS, NV.

File: C | CLIMAT04 | MC2TEST | WELLDAYMC2.PGW
Data file: WELLPERMC2.DAT, WELL5BMC2.DAT & WELL5BMC2B.DAT
daw 10-29-04 & 11-2-04

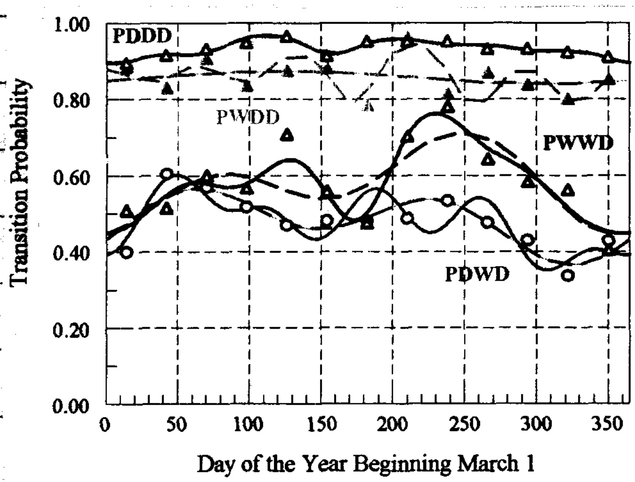
Significant harmonics

G_{DDD} – 5

G_{WDD} – 1

G_{DWD} – 2

G_{WWD} – 2



Five Harmonic & Significant HarmonicTransition Probabilities, 2nd Order Markov Chains. Forty Mile Canyon, NV.

File: C | CLIMAT04 | MC2TEST | FORTY_COMPARE.PGW
Data file: FORTYPERMC2.DAT, FORTYMC2B.DAT & FORTYMC2.OUT
daw 10-30-04

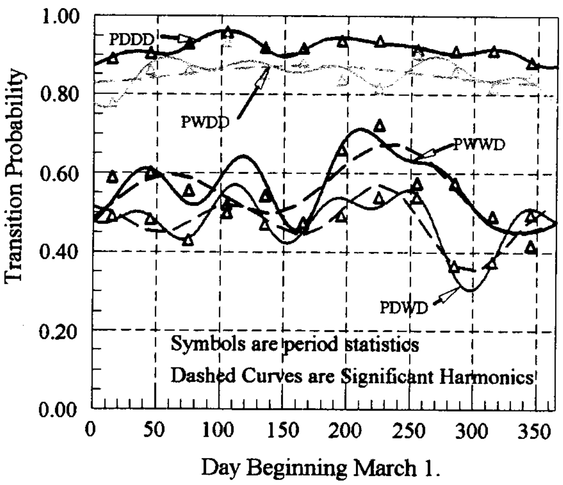
G_{DDD} – 5

G_{WDD} – 1

G_{DWD} – 2

G_{WWD} – 2

Daw 11-3-04



DAILY TRANSITION PROBABILITIES, 2ND ORDER MARKOV CHAIN
RANIER MESA, FIVE AND SIGNIFICANT HARMONICS

File: C | CLIMAT04 | MC2TEST | RANIER_DAYMC2.PGW
Data: C: | CLIMAT04 | MC2TEST | RANIERMC2.DAT & RANIERMC2B.DAT
drw 10 - 14 - 04 & 10 - 30 - 04

Significant harmonics

G_{DDD} - 5

G_{WDD} - 1

G_{DWD} - 3

G_{WWD} - 2

For the DDD transition probability 5 harmonics for G_{DDD} provides a very good fit to the period statistics with 2 fewer parameters than if we used the period statistics. For the WDD probability only 1 harmonic was significant and there is considerable scatter around the Fourier curve. Much of this can be attributed to noise due to much smaller sample size than for DDD. Again the period data are quite "noisy" for PDWD and PWWD, also reflecting smaller sample sizes. However, two to three (Ranier Mesa) harmonics were significant.

A review of the table on p 27 shows fairly consistent numbers of significant harmonics for all stations, indicating spatial coherence. Differences can probably be explained by sampling variations in an arid climate and differences in the length and starting year of the records. The significant harmonic of 5 for G_{DDD} for Las Vegas, should show 1, 2, 5

DAW 11-5-04 Regression Relationships between 2nd Order MC (MC2) parameters and mean Annual Precipitation (MAP)

Objective: To examine the relation between MC2 parameters and MAP

Reference: Regression relationships for 1st order Markov Chain (MC1) parameters and MAP, Scientific Notebook 363 p 47-53.

Procedure: Set up spreadsheet for PSI PLOT for MC2 parameters for 11 stations as used in the referenced pages

DAW 11-5-04

File: C:\CLIMATO4\MC2TEST\ ~~NTSMC2PHASE~~ MC2NTS.PDW

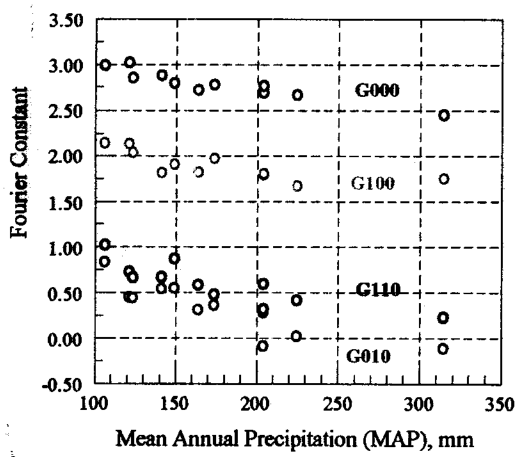
DAW 11-8-04

Use the linear regression program embedded in PSI Plot

Plots of the Fourier Constants for the four parameters versus MAP as shown below suggest that a linear relationship is appropriate. A table showing the regression coefficients and coefficients of determination (R^2) valuse is shown on p 33.

The first order statistics are those obtained 3/13/01 - Scientific Notebook 363 pp 47-53.

The relationships between the constants and MAP are significant explained variance ranging from 56.7% for G_{100} to 87.7% for G_{000}.



Fourier Constants for Logits of Second Order Markov Chain versus Mean Annual Precipitation. Yucca Mountain, NV Vicinity

File: C:|CLIMAT04|MC2TEST|FOURIER_CvsMAP.PGW
Data: C:|CLIMAT04|MC2TEST|MC2NTS.PDW
daw 11-5-04

TAW 11-8-04

Yucca Mountain Region Markov Chain parameter Regression Statistics:
Y = a + b*MAP, except for G_{10} where Y = a*exp(b*MAP)

Parameter	a	b	R^2
G_{00}	3.144	-0.00249	0.884
G_{10}	2.438	-0.01054	0.799
$C1_{G10}$	0.2685	-0.00342	0.196
$\phi1_{G10}$	-0.6024	-0.00303	0.282
G_{000}	3.220	-0.00248	0.877
G_{100}	2.2428	-0.00197	0.567
G_{010}	1.0578	-0.00417	0.745
G_{110}	1.1730	-0.00329	0.708

Regression analyses were also performed for the amplitudes of the first harmonic for each parameter and were statistically insignificant. The largest R^2 was for G_{C10} as shown.

The regression details are in files located in C:\CLIMAT04\MC2TEST\STATISTICS and include text files G000VSMAP, G100VSMAP, G010VSMAP and G110VSMAP. The table above is in the same directory and is entitled Regression-Table (Word Perfect file).

All of the control and output files for the 2nd order MC analysis are in the directory C:\CLIMAT04\MC2TEST and are:

- *.fil control file
- *.OUT Condensed output file
- *.DET Detailed output file - shows optimization iterations
- *.DAT Daily values of all parameters as defined by the optimized Fourier Series plus observed mean accumulated number of wet days and mean accumulated precipitation. Theoretical values for the accumulated days and precipitation assuming a 1st order MC are also shown.

DAW 11-08-04 2nd Order Markov Chain Analyses (Con't)

Conclusions:

1) The 2nd order process is statistically superior to the 1st order Markov Chain.

2) The Fourier constants for the logits of transition probabilities are significantly related to the MAP.

Next Step:

1) Add 2nd order routine to daily precipitation simulation routine. Run simulations to see if variance (annual & monthly) is increased

Simulation program is: MC2CLIMSIM_04.F95

Changes to be made:

1) Read in Fourier constants, amplitudes and phase angles for 2nd order Markov chain.

2) Simulate a second order sequence of wet or dry days instead of a first order sequence.

Note: This program is modified from CLIMSIM_04.F95 and also has capabilities of perturbing parameters with SOI and PDO.

A 50 yr record for Jackass Flats was simulated using program MC2CLIMSIM_04.F95. The Fourier series parameters for the first and second Markov Chains and the mixed exponential were those obtained by analyzing 40 years of record using program MC2ME4_1.F95.

Daw 11-15-04

The control file for the simulation run is:
C:\CLIMAT04\MC2TEST\ JACKASSMC2.FIL
All output files are in the same directory, and have the form: JACKASSMC2.* where * includes
.OUT Condensed output file
.DET Detailed " "
.DAT Data for plotting transition probabilities and ME parameters for each day

PARAMETER IDENTIFIABILITY

Daw 11-15-04

The 50 yr simulated precipitation record, ~~was~~ and the first 30 yrs and the first 40 years were used as input to MC2ME4-1.F95 to see if the known input parameters are closely fitted by the identified parameters, with length of record as a variable. This serves as a check on the 2nd order simulation program as well as the parameter identification program, MC2ME4-1.F95

The results for the 2nd order Markov Chain can be compared to those with the 1st order MC in scientific Notebook pp 70-74.

Daw 11-26-04

An option was added to MC2CLIMSIM_04.F95 so that the simulation of max and min daily temperature and radiation can be omitted. An integer variable TEMPRAD_CODE is included in the control file (*.SIM). If TEMPRAD_CODE=0 : no T_{max} T_{min} + Rad if the code = 1 than they are simulated.

Control file for Jackass Flats: C:\CLIMAT04\SIMULATION_04\JACKMC2PREB.SIM

DAW 12-7-04 Parameter Identifiability (Con't)

The program MC2ME4-1.F95 was run with input control files
C:\CLIMAT04\MC2TEST\JACKID30B.FIL and
" " " 40B.FIL
" " " 50B.FIL

The precipitation input file was the simulated 50-yr sequence: C:\CLIMAT04\SIMULATION-04\JACK-PREMC2B.PRE DAW 12/7/04

For the 40 yr. measured data the MAP was ~~142.6 mm~~ 140.8 mm DAW 12-7-04 with SD = ~~21.2 mm~~ 22.3 DAW 12-7-04
For the 50-yr simulation: MAP = 142.6 mm SD = 21.2 mm
A summary of the identified parameters is presented in
C:\CLIMAT04\SIMULATION-04\JACKASSMC2-ID.WPD

DAW 12-8-04

Parameter identification will be tested for 2 more stations:
Fortymile Canyon; MAP =
Ranier Mesa; MAP =
Procedure:
1. Simulate a daily precipitation series for each station
control files: C:\CLIMAT04\SIMULATION-04\FORTYMC2.SIM
" " \RANIERMC2.SIM

Output files for 2nd Order Process
FORTYSIMMC2.PRE
RANIERSIMMC2.PRE

2. Create control files for parameter identification
C:\CLIMAT04\MC2TEST\FORTYID50.FIL; *ID40.FIL; *ID30.FIL
RANGID50.FIL; " " " DAW 12-8-04

DAW 12-8-04 Parameter Identifiability Cont

3. Run Program MC2ME4-1.F95 with control files as shown on p 37

output files:

C:\CLIMAT04\MC2TEST\FORTY_ID50.OUT; *ID40.OUT; *ID30.OUT

" " RAN_ID50.OUT, etc.

The previous runs emphasize the effect of length of record on parameter variability. To examine the effect of sample variability with the same number of years of record, 2 independent 50yr simulations were performed for Forty mile canyon. Fourier Series parameters were identical.

Simulated Precipitation files

C:\CLIMAT04\SIMULATION_04\FORTSIMMC2B.PRE

" " \FORTSIMMC2C.PRE

Program MC2ME4_1.F95 was then run.

output files:

C:\CLIMAT04\MC2TEST\FORTYID50B.OUT

" " " 50C. "

The 2nd order MC parameters were copied from the output files for JACKASS Flats and are shown in the table on p 38.

Daw 12-8-04 Parameter Identifiability (Con't)

2ND ORDER MARKOV CHAIN PARAMETER IDENTIFIABILTY JACKASS FLATS

```
****************************************
 G000 ORIGINAL DATA
CONSTANT= 2.8838    5
 AMPLITUDE    PHASE ANGLE
  0.4168  -1.1185
  0.1474  -1.4421
  0.1614   2.7611
  0.1949  -0.4453
  0.1265  -1.8732
****************************************
 G000 50 YR SIMULATION
CONSTANT= 2.8418    5
 AMPLITUDE    PHASE ANGLE
  0.4459  -1.2087
  0.1891  -1.4673
  0.1921   2.4118
  0.2068  -0.5850
  0.1895  -1.4373
****************************************
 G000         40 YR SIMULATION
CONSTANT= 2.8490    5
 AMPLITUDE    PHASE ANGLE
  0.4574  -1.1178
  0.2056  -1.4430
  0.1536   2.3427
  0.1830  -0.7427
  0.1967  -1.2440
****************************************
 G000         30 YR SIMULATION
CONSTANT= 2.8555    5
 AMPLITUDE    PHASE ANGLE
  0.5229  -1.1434
  0.1787  -1.7109
  0.1446   2.0036
  0.2267  -0.7582
  0.1726  -1.2682
****************************************
****************************************
 G100         ORIGINAL DATA
CONSTANT= 1.8164    1
 AMPLITUDE    PHASE ANGLE
  0.2113  -2.2195
****************************************
 G100         50 YR SIMULATION
CONSTANT= 1.8218    1
 AMPLITUDE    PHASE ANGLE
  0.3843  -2.6029
****************************************
 G100         40 YR SIMULATION
CONSTANT= 1.7603    1
 AMPLITUDE    PHASE ANGLE
  0.3618  -2.5964
****************************************
 G100         30 YR SIMULATION
CONSTANT= 1.7093    1
 AMPLITUDE    PHASE ANGLE
  0.2952  -2.8519
****************************************
****************************************

 G010         ORIGINAL DATA
CONSTANT= 0.5414    2
 AMPLITUDE    PHASE ANGLE
  0.2406  -0.5852
  0.3005  -1.1337
****************************************
 G010         50 YR SIMULATION
CONSTANT= 0.5077    2
 AMPLITUDE    PHASE ANGLE
  0.2788  -0.4385
  0.3637  -0.8045
****************************************
 G010         40 YR SIMULATION
CONSTANT= 0.4799    2
 AMPLITUDE    PHASE ANGLE
  0.2195  -0.3854
  0.4267  -0.6717
****************************************
 G010         30 YR SIMULATION
CONSTANT= 0.5281    2
 AMPLITUDE    PHASE ANGLE
  0.2363  -0.4041
  0.4060  -0.9147
****************************************
****************************************
 G110         ORIGINAL DATA
CONSTANT= 0.6711    3
 AMPLITUDE    PHASE ANGLE
  0.2093  -2.0246
  0.3398  -0.3151
  0.3028  -1.5555
****************************************
 G110         50 YR SIMULATION
CONSTANT= 0.7831    2
 AMPLITUDE    PHASE ANGLE
  0.5475  -2.0489
  0.6094  -0.4068
****************************************
 G110         40 YR SIMULATION
CONSTANT= 0.7207    3
 AMPLITUDE    PHASE ANGLE
  0.4400  -1.7734
  0.5604  -0.0478
  0.3155  -1.2536
****************************************
 G110         30 YR SIMULATION
CONSTANT= 0.7002    2
 AMPLITUDE    PHASE ANGLE
  0.5010  -1.8548
  0.6225  -0.3008
****************************************
```

The parameters labeled "Original Data" were obtained by running program MC2ME4-1-F95 with 40 yrs of precipitation data from the Jackass Flats station. These parameters were then used to simulate 50-yrs of daily precipitation using program MC2CLIMSIM_04.F95 These then are the "known parameters." The program MC2ME4-1 was then run with 30, 40, and 50 yrs of the simulated data.

DAW 12-8-04

If the simulated series was long enough, the output parameters should approach the input parameters, subject to sampling error and numerical optimization approximations.

A review of the table reveals that the constants in the Fourier Series of G_{000}, G_{100}, G_{010} and G_{110} are reproduced well. The best result is for G_{000} which, in an arid climate, has the largest sample size. The analysis of the 50, 40 and 30 yr simulations all resulted in identifying 5 harmonics for G_{000}.

For G_{100} 1 harmonic was input and was identified for each case.
For G_{010} 2 harmonics were inputted and were identified for each case.
For G_{110} 3 " " ", but only 2 were identified for the 50 and 30-yr. simulations. This is probably due to sample variation.

DAW 12-9-04

The output files for the 3 - 50yr simulations for Forty Mile ~~Wash~~ Canyon (DAW 12-9-04) are summarized in the following table

DAW 12-10-04

File:C:\CLIMAT04\

constant term

SAMPLE	NWET	MAP(mm)	CV	C_G000	C_G100	C_G010	C_G110	C_ALPHA	C_BETA	C_MU
DATA	44.22	210.45	.39 ~~1.08~~	2.6932	1.7977	-0.0825	0.3181	0.3802	0.609	4.5194
SIM_1	44.60	205.25	.28 ~~1.05~~	2.6956	1.9158	-0.1149	0.2205	0.3546	0.5998	4.5113
SIM_B	46.00	222.62	.27 ~~1.05~~	2.6411	1.7628	-0.0142	0.3703	0.3684	0.6595	4.6009
SIM_C	44.26	207.76	.33 ~~1.07~~	2.6780	1.7015	0.0344	0.3054	0.4033	0.6859	4.4626

mean # of wet days

HAR = Number of harmonics

DATA				5.0000	1	2	2	0	1	4
SIM_1				4.0000	1	2	2	0	1	1
SIM_B				5.0000	1	4	2	0	2	4
SIM_C				5.0000	1	5	2	0	1	2

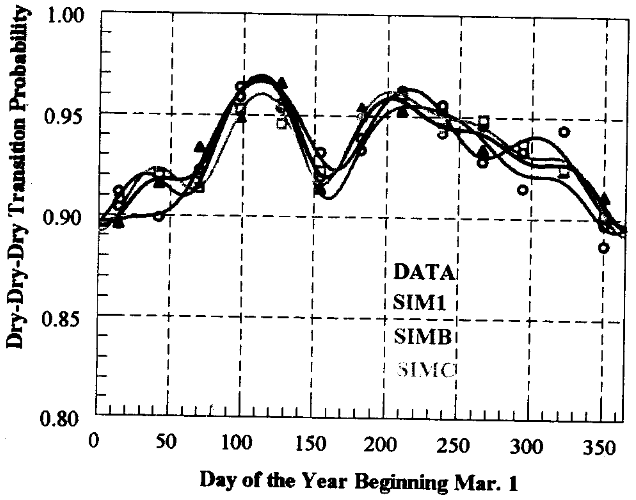
DAW 12-10-04

Note that the CV for simulated sequences is smaller than for station data.

An examination of this Table shows that the constant Fourier Series terms are very closely reproduced for G_{000}, G_{100}, α and μ with larger percentage differences between the average of the simulated data and the "known" parameter for G_{010}, G_{110} and β. However the absolute differences are small.

DAW 12-10-04 Parameter Identifiability (Con't)

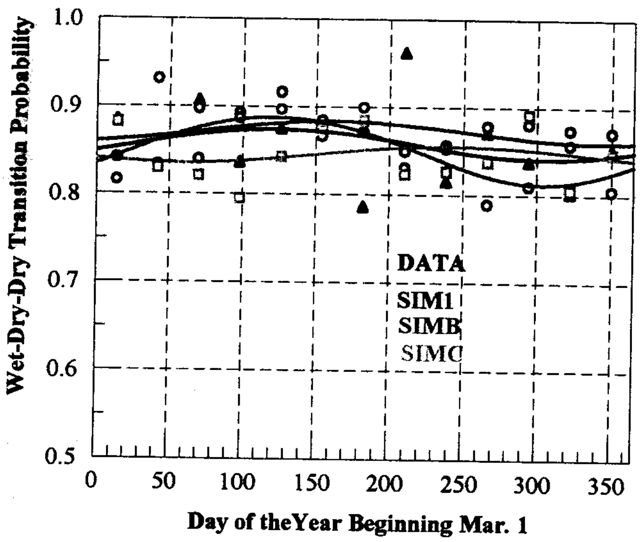
A better appreciation for the sampling variability inherent in estimating transition probabilities in an arid climate, as well as the ability of the algorithm to estimate significant harmonics of Fourier Series can be obtained from the following four figures.



ML Fitted Daily and Period Values of the Dry-Dry-Dry Transition Probabilities Forty Mile Canyon, NV. Observed and 50-yr Simulated Daily Series

File: C: | CLIMAT04 | MC2TEST | FORTYSIMPDDD.PGW
daw 12-9-04

Given that this station has an average of ~44 wet days per year, the transitions beginning with a D-D sequence will have the largest sample size. This is reflected in the adjacent figure. The symbols are the probabilities estimated for 13 periods. The scatter of the red, blue and green symbols is due to sampling variability, because they were all generated by the same stochastic process. Given this variability, the Fourier series fits are very good

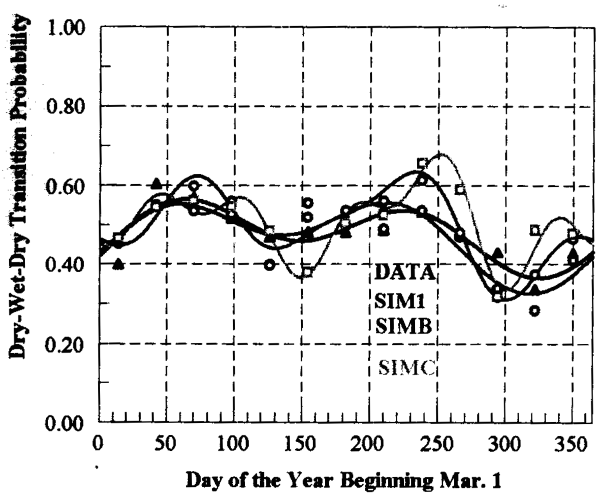


ML Fitted Daily and Period Values of the Wet-Dry-Dry Transition Probabilities Forty Mile Canyon, NV. Observed and 50-yr Simulated Daily Series

File: C: | CLIMAT04 | MC2TEST | FORTYSIMPWDD.PGW
DAW 12-9-04

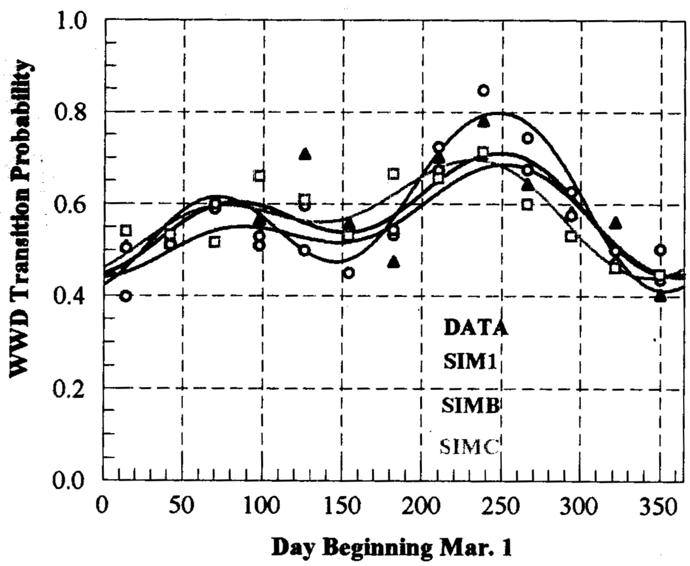
The transition beginning with a WD sequence has a smaller sample size and the seasonal variability is not pronounced, resulting in substantial sampling variability

DAW 12-10-04 Parameter Identifiability (Con't)



ML Fitted Daily and Period Values of the Dry-Wet-Dry Transition Probabilities
Forty Mile Canyon, NV. Observed and 50-yr Simulated Daily Series

File: C: | CLIMAT04 | MC2TEST | FORTYSIMPDWD.PGW
daw 12-9-04



ML Fitted Daily and Period Values of the Wet-Wet-Dry Transition Probabilities
Forty Mile Canyon, NV. Observed and 50-yr Simulated Daily Series

File: C: | CLIMAT04 | MC2TEST | FORTYSIMPWWD.PGW
daw 12-9-04

The transition beginning with a ~~W-D~~ D-W DAW 12/10/04 sequence has a more consistent seasonal pattern than the WDD sequence and has a lower probability of being followed by a dry day. Note that simulations B and C resulted in overfits because the input process had only 2 harmonics, while B resulted in 4 and C in 5. There is a tendency for the AIC to result in fitting of some "noise".

The transition beginning with a W-W sequence will have small sample size, especially during the drier periods. Again the Fourier fits are very good, given the sampling variation. Note that the daily pattern of P_{WWD} is represented by 5 parameters with the series representation as compared to 13 for a step function representation.

<u>Conclusion:</u> The MC2 parameter identification program and the MC2 simulation program are performing well. The MC2 process is superior to the MC1 precipitation counting process.

DAW 12-13-04 Effects of SOI and PDO on 2nd Order Markov Chain Process.

The table on p. 39 shows that the CVs of annual precipitation for the simulated data are smaller than for the observed data. This suggests that it may be fruitful to examine the effects of perturbations of logits G_{000}, G_{100}, G_{010} and G_{110} by SOI and PDO on the log likelihood functions. For effects on first order MC see Scientific Notebook 365 pp 70-72.

DAW 1-24-05

Program C:\SOI\SOIPDOMC2.F95 is the modified version of SOIPDOMC.F95 incorporating Log Likelihood functions for Logits G_{000}, G_{110}; G_{010} and G_{110}.

Procedure: First, examine impact of SOI + PDO on 2nd Order Markov chain (MC2) for Forty Mile Canyon

Control file: C:\SOI_PDO_05\FORTYSPMC2.FIL

This program performs a grid search for SOI Lags of 0, 30, 60 and 90 days and with the SOI coefficients a_{00}, a_{10} a_{000}, a_{100}; a_{010} and a_{110} varied over a range of ~~-0.25~~ -0.05 to ~~+0.15~~ +0.25 (DAW 1/24/05) with increments of 0.05. PDO coefficients b_{00}, b_{10}, b_{000}, b_{100}, b_{010} and b_{110} are varied from -0.25 to +0.15 with increments of 0.05.

DAW 1-25-05 SOI + PDO Effects, Cont.

Output from program SOIPDOMC2.F95 is summarized below for three stations. If the log likelihood is increased by 6 or more, the perturbations exert a statistically significant effect according to the AIC.

FORTY MILE CANYON

UNPERTURBED LOG LIK FOR G00 = -3151.9150
UNPERTURBED LOG LIK FOR G10 = -1181.4259
UNPERTURBED LOG LIK FOR G000 = -2762.9846
UNPERTURBED LOG LIK FOR G100 = -361.2525
UNPERTURBED LOG LIK FOR G010 = -604.5029
UNPERTURBED LOG LIK FOR G110 = -564.9897

1st order log L = -4,333.35

****

Maximum Loglik = -3137.52905 for G00
at SOI coeff= 0.200000003 ; PDO coeff= 9.99999940E-02
at Lag = 30.0000000 Days

Δ = 14.39 *

Maximum Loglik = -1172.27856 for G10
at SOI coeff= 0.00000000E+00 ; PDO coeff= -0.200000003
at Lag = 0.00000000E+00 Days

Δ = 9.15 *

****

Maximum Loglik = -2752.90869 for G000
at SOI coeff= 0.150000006 ; PDO coeff= 4.99999933E-02
at Lag = 0.00000000E+00 Days

Δ = 10.07 *

Maximum Loglik = -357.770233 for G100
at SOI coeff= 0.200000003 ; PDO coeff= 4.99999933E-02
at Lag = 60.0000000 Days

Δ = 3.48

****

Maximum Loglik = -594.615234 for G010
at SOI coeff= 5.00000007E-02 ; PDO coeff= -0.250000000
at Lag = 30.0000000 Days

Δ = 9.89 *

Maximum Loglik = -562.620483 for G110
at SOI coeff= 5.00000007E-02 ; PDO coeff= -0.100000009
at Lag = 90.0000000 Days

Δ = 2.37

Maximum MC2 Loglik = -4267.91455

After reviewing this output it appears desirable to import the simplex optimization algorithm (subroutine ASIMPLX) to provide simultaneous optimization of the perturbation coefficients for each lag of the SOI.

Δ 1st + 2nd = 65.44

RANIER MESA

UNPERTURBED LOG LIK FOR G00 = -3252.6714
UNPERTURBED LOG LIK FOR G10 = -1323.5717
UNPERTURBED LOG LIK FOR G000 = -2825.0105
UNPERTURBED LOG LIK FOR G100 = -410.5521
UNPERTURBED LOG LIK FOR G010 = -673.8066
UNPERTURBED LOG LIK FOR G110 = -638.3562

MC1 Lik = 4,576.24

****

Maximum Loglik = -3240.26440 for G00
at SOI coeff= 0.150000006 ; PDO coeff= 4.99999933E-02
at Lag = 0.00000000E+00 Days

Δ = 12.41 *

Maximum Loglik = -1320.89807 for G10
at SOI coeff= 5.00000007E-02 ; PDO coeff= -5.00000082E-02
at Lag = 0.00000000E+00 Days

Δ = 2.67

****

Maximum Loglik = -2811.82739 for G000
at SOI coeff= 0.150000006 ; PDO coeff= 9.99999940E-02
at Lag = 0.00000000E+00 Days

Δ = 13.18 *

Maximum Loglik = -408.406097 for G100
at SOI coeff= -5.00000007E-02 ; PDO coeff= -0.150000006
at Lag = 90.0000000 Days

Δ = 2.14

****

Maximum Loglik = -671.947815 for G010
at SOI coeff= 0.100000001 ; PDO coeff= -7.45058060E-09
at Lag = 0.00000000E+00 Days

Δ = 1.86

Maximum Loglik = -635.365051 for G110
at SOI coeff= 5.00000007E-02 ; PDO coeff= -0.150000006
at Lag = 60.0000000 Days

Δ = 2.98

Maximum MC2 Loglik = -4527.54639

Δ MC1 MC2 = 48.69

JACKASS FLATS

UNPERTURBED LOG LIK FOR G00 = -2983.8621
UNPERTURBED LOG LIK FOR G10 = -839.5383
UNPERTURBED LOG LIK FOR G000 = -2621.4434
UNPERTURBED LOG LIK FOR G100 = -328.5877
UNPERTURBED LOG LIK FOR G010 = -526.2021
UNPERTURBED LOG LIK FOR G110 = -309.2865

MC1 L IK = -3,823.4

****

Maximum Loglik = -2963.17725 for G00
at SOI coeff= 0.200000003 ; PDO coeff= 4.99999933E-02
at Lag = 0.00000000E+00 Days

Δ = 20.69 *

Maximum Loglik = -832.153564 for G10
at SOI coeff= 0.150000006 ; PDO coeff= -0.100000009
at Lag = 120.000000 Days

Δ = 7.39 *

****

Maximum Loglik = -2604.48193 for G000
at SOI coeff= 0.200000003 ; PDO coeff= 9.99999940E-02
at Lag = 0.00000000E+00 Days

7 DAW 2-3-05

Δ = 1~~8~~.96 *

Maximum Loglik = -326.616333 for G100
at SOI coeff= 0.100000001 ; PDO coeff= -0.100000009
at Lag = 0.00000000E+00 Days

Δ = 1.97

****

Maximum Loglik = -520.090088 for G010
at SOI coeff= 0.200000003 ; PDO coeff= -0.100000009
at Lag = 120.000000 Days

Δ = 6.11 *

Maximum Loglik = -307.646362 for G110
at SOI coeff= 0.100000001 ; PDO coeff= -0.100000009
at Lag = 120.000000 Days

Δ = 1.64

Maximum MC2 Loglik = -3758.83472

Δ MC1 - MC2 = 64.57

DAW 1-27-05 SOI and PDO – 2nd Order Markov Chain (MC2)

Copy the program SOIPDOMC2.F95 to C:\CLIMAT04 and rename S_P_MC2OPT.F95.

Import subroutine ASIMPLX from program MC2ME4_1.F95 and create proper calling sequences.

DAW 2-3-05

Create Control files for Jackass Flats, Forty Mile Canyon and Ranier Mesa. Files are: C:\SOI_PDO_05\

JACK_OPT.FIL, FORTY_OPT.FIL and RANIER_OPT.FIL

All output files have the same name but extension is .OUT

Files with optimization details have extension .DET

A review of the *.DET files reveals that ASIMPLX declared an optimum for every case.

All runs were for perturbation every day.

Results were consistent with tables on p 43, except that the likelihoods were increased, as expected.

DAW 2-4-05 Continue with SOI-PDO perturbations with MC2

DAW 2-4-05

Objective: Complete the ~~2X~~ MC2 analysis with SOI-PDO perturbations for stations: Yucca Dry Lake, Las Vegas, RG4, Spokane, Hobbs and Nogales.

Use the MC2 parameters identified for Yucca Dry Lake and Las Vegas (see p 27). Use program MC2ME4_1.F95 to identify MC2 parameters for RG4, Spokane, Hobbs and Nogales

DAW 2-4-05

MC2 analysis for Walnut Gulch, AZ Raingage 4

Precipitation file is: C:\CLIMATO2\ARIZONA\rg004.3-2

in 16 col format

DAW 2-8-05
Control file is: C\CLIMAT04\MC2TEST\RG4MC2.FIL

output files are in same subdirectory with extensions .DAT, .DET, .OUT

MC1 AIC = 8818.96 ; MC2 AIC = 8794.48 ∴ MC2 is superior

For Hobbs, NM

Control file is: C:\CLIMAT04\MC2TEST\HOBBSMC2.FIL

DAW 2-9-05 MC1 AIC = 15851.95 ; MC2 AIC = 15058.37 ∴ MC2 is superior

For Nogales, AZ
DAW 2-9-05

Control file is: C:\CLIMAT04\MC2TEST\NOGALESMC2.FIL

output MC2OUT

For Spokane, WA for Nogales: MC1 AIC = 15807.6 ; MC2 AIC = 15734.06 ∴ MC2 is superior

C:\CLIMAT04\MC2TEST\SPOKANEMC2.FIL

First run with 110 yrs from 1890

MC1 AIC = 44356.66 ; MC2 AIC = 44141.99 ∴ MC2 is superior

Now examine SOI-PDO effects on 2nd Order MC

Yucca Dry Lake:

Control: C:\SOI_PDO-05\YUC_OPT.FIL

Output " " \YUC OPT.OUT ✓

Las Vegas: " \VEGAS_OPT.FIL

output " " VEGAS_OPT.OUT ✓

DAW 2-10-05 SOI + PDO MC2 (Con't)

Walnut Gulch AZ RG4.

Control C:\SOI_PDO-05\RG4_OPT.FIL ✓

Hobbs, NM

Control: C:\SOI_PDO-05\HOBBS_OPT.FIL ✓

Nogales, AZ

Control: C:\SOI_PDO_05\NOGALES_OPT.FIL ✓

SPOKANE, WA

Control: C:\SOI_PDO_05\SPOKANE_OPT.FIL ✓

Dan 2/14/05 SOI + PDO MC2 (Con't)

The results of the perturbation analyses are shown in the following table.

Station	Coefficient	G_{00}	G_{10}	G_{000}	G_{100}	G_{010}	G_{110}
Yucca Dry Lake	a	0.2118 †		0.210 †		0.1311	
	b	0.0414		0.0586		-0.0565	
	τ	0		0		0	
Ranier Mesa	a	0.154		0.1714			0.0516
	b	0.0642		0.0913 †			-0.1957
	τ	0		0			60
Forty Mile	a	0.1726	0.0003	0.1543	0.2063	0.0556	
	b	0.0791 †	-0.2008 †	0.0729	0.0387	-0.2670	
	τ	30	60	0	60	30	
Jackass Flats	a	0.2087	0.1477 †	0.2060		0.1807	
	b	0.0643	-0.0861	0.0814		-0.0981	
	τ	0	120	0		120	
Las Vegas	a	0.1945		0.2025			
	b	-0.0047		0.0015			
	τ	30		30			
RG4	a	0.1084		0.1176			
	b	-0.0609		-0.0743			
	τ	90		30			
Nogales, AZ	a ~~0.1209~~	0.1209		0.1256			
	b	0.0256 ✓		-0.0061			
	τ	90		90			
Hobbs, NM	a	0.0899		0.0797			
	b	-0.0403		-0.0444			
	τ	0		0			
Spokane, WA	a			0.0589	-0.1037		
	b			0.0635	-0.0661		
	τ			90	120		

In the above table the coefficients a_{ijk} and b_{ijk} refer to linear perturbations of the logits by the SOI and PDO respectively. Only coefficients that increased the log likelihood functions sufficiently to result in a minimum AIC are shown. The SOI + PDO perturbations lead to minimum AIC for G_{000} for all stations. The combination of a negative SOI and a negative PDO leads to increased frequency of wet days for the Nevada and Washington stations. The PDO coefficient is

DAW 2/14/05

negative (though small) for the stations most influenced by the monsoon, Therefore a negative SOI combined with positive PDO has greatest effect on frequency of wet days.

DAW 2/21/05 Prepare figures for Monsoon Climate, Forty Mile Canyon and Spokane showing daily values of transition probabilities for 1st + 2nd order Markov Chains

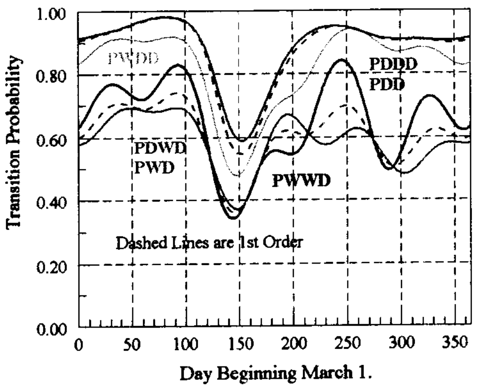
Figures are shown on p 49

Nogales, AZ. - The climate at this station is characterized by the monsoon season where P_{000} drops precipitously leading to a probability of 0.4 that two dry days will be followed by a wet day. At the same time the probability of a wet day following two wet days reaches a ~~minimum~~ maximum DAW 2-21-05 of about ~~0.75~~ →0.65, indicative of persistant DAW 2-21-05 thunderstorm ~~rather than frontal~~ activity.

Spokane, WA. The transition probability signature for this station is nearly the opposite of Nogales with a very low probability P_{001} on day 150 and low persistence (ie. max P_{110}).

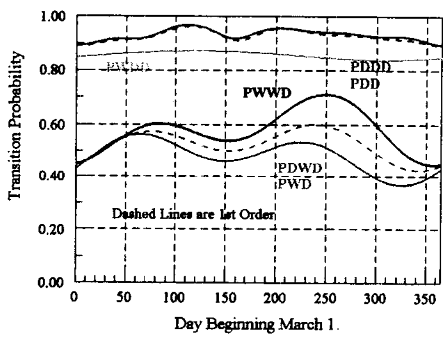
Forty mile Canyon. This station has considerably less precipitation than the other two as evidenced by the high value of P_{000}. There is some evidence of a monsoon effect (minimum of P_{000} at day 160 and increased persistence at the same time

The sesonal effects are more subdued than for Nogales and Spokane



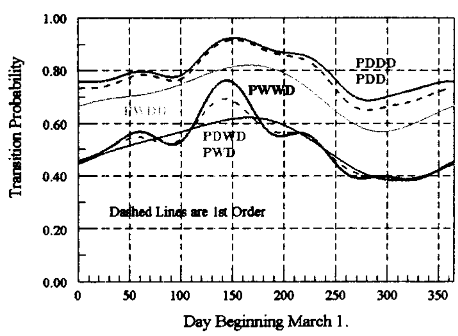
Daily Transition Probabilities, Nogales, AZ
1st and 2nd Order Markov Chains. Significant Harmonics

File: C | CLIMAT05 | MC2OUT | NOGALESMC2DAY.PGW
Data: C: | CLIMAT05 | MC2OUT | NOGALMC2.DAT
dww 2 - 21 - 05



Daily Transition Probabilities, Forty Mile Canyon, NV
1st and 2nd Order Markov Chains. Significant Harmonics

File: C | CLIMAT05 | MC2OUT | FORTYMC2DAY.PGW
Data: C: | CLIMAT05 | MC2OUT | FORTYMC2.DAT
dww 2 - 21 - 05



Daily Transition Probabilities, Spokane, WA
1st and 2nd Order Markov Chains. Significant Harmonics

File: C | CLIMAT05 | MC2OUT | SPOKANEMC2DAY.PGW
Data: C: | CLIMAT05 | MC2OUT | SPOKANEMC2.DAT
dww 2 - 21 - 05

The second order effects are apparent by the deviation between P_{00} and P_{000} and by differences between P_{100} and P_{000}. The first order persistence parameter P_{10} is usually between the second order parameters, P_{010} and P_{110}.

DAW 2-23-05 Examine the effects of 2nd Order MC and 2nd Order MC with SOI-PDO perturbations on simulated annual, monthly and daily precipitation statistics.

Objective: To see if these additions result in greater monthly and annual variances

Procedure:

1) Simulation: Use Program MC2CLIMSIM_04.F95

Perform 50yr simulations for 3 stations

Forty Mile Canyon, NV, Nogales, AZ and Spokane, WA

For Forty Mile Canyon simulate with and without perturbations using both 1st and 2nd order Markov Chains. Examine the differences in statistics and plan procedures for the other 2 stations.

Simulation program requires a control file specifying input and output files and perturbation parameters.

All files will be in directory C:\CLIMAT05\SIMULAT_05

Perturbation coefficients for Mixed Exponential from p 106, 107

DAW 2-24-05 Sci. Notebook 363.

For Forty Mile Canyon with perturbations:

Control File: FORTYMC2P.SIM ✓✓

without perturbation: FORTYMC2NP.SIM ✓✓

Input files C:\CLIMAT04\SIMULATION_04\FORTYMC2ME.FOU ✓

\FORTYMC2.FOU ✓

\FORTYMC1.FOU ✓

DAW 2-24-05

output files (2 for each run)

with perturbation: FORTY_SIMMC2P.PTR ✓✓ Second order MC

FORTY_SIMMC1P.PTR ✓✓ First order MC 208.9 44.22

No perturbation: FORTY_SIMMC2NP.PTR ✗✓

FORTY_SIMMC1NP.PTR ✗✓ E(AD) = 208.91 E(N) = 44.22

Input information is repeated at the beginning of output files to facilitate data checking. The editor is used to remove this information and add a descriptive line before using them as input to the statistical analysis program STATCLIM3.F95 ✓

For statistical analyses. Control files in C:\CLIMAT05\SIMULAT-05\OUTPUT

Control files: ✓FORTYSTATMC1P.CON ✓ FORTYMC1PSTAT.OUT

✓FORTYSTATMC1NP.CON ✓ FORTYMC1NPSTAT.OUT

✓FORTYSTATMC2P.CON ✓ FORTYMC2PSTAT.OUT

✓FORTYSTATMC2NP.CON ✓ FORTYMC2NPSTAT.OUT

To run STATCLIM3.F95 Copy control file (or save as) STAT3.CON ✓
Program searches for that file name

USW02 \CDFREAL \THICK.CDF

DAW 3-4-05

Simulations for Nogales, AZ

Control files:

without perturbation C:\CLIMAT05\SIMULAT-05\NOGALMC2.SIM

with perturbation " " \NOGALMC2P.SIM

MC2 FOURIER COEF FILE: C:\CLIMAT04\SIMULATION-04\NOGALESMC2.FOU ✓

" NOGALESMC1.FOU ✓

DAW 3-4-05 Continue 50-yr simulations
Nogales (Con't)
C:\CLIMATO4\SIMULATION_04\NOGALMC2ME.ECH ✓

DAW 3-7-05 Set up control file for perturbed simulation
File Name: C\CLIMATO5\SIMULAT_05\NOGALMC2PSIM ✓

Run program MC2CLIMSIM_04.F95
Output files:
MAN
C:\CLIMATO5\SIMULAT_05\NOGALSIMMC1.PTR MAP=417.14 59.6
" " \NOGALSIMMC1P.PTR
" " \ " MC2.PTR
" " \ " MC2P.PTR

For statistical Analyses
control files:
C:\CLIMATO5\SIMULAT_05\NOGALSTATMC1.CON
" NOGALSTATMC1P.CON
" NOGALSTATMC2.CON
" NOGALSTATMC2P.CON

DAW 3-8-05

Set up simulation files for Spokane, WA

Control files in C:\CLIMAT05\SIMULAT_05\

~~MC1 - No perturbation~~ ~~SPOKMC1.SIM~~ DAW 3-8-05

~~MC1 - perturbation~~ ~~SPOKMC1P.SIM~~ DAW 3-8-05

MC2 - No perturbation SPOKMC2.SIM - Includes MC1 ✓

MC2 - Perturbation SPOKMC2P.SIM - Includes MC1 ✓

Output files SPOKSIMMC1.PTR

SPOKSIMMC1P.PTR

SPOKSIMMC2.PTR

SPOKSIMMC2P.PTR

DAW 3-9-05 Statistical Analysis of Spokane Simulations

Control Files: in C:\CLIMAT05\SIMULAT_05\

SPOKSTATMC1.CON ✓

SPOKSTATMC1P.CON ✓

SPOKSTATMC2.CON ✓

SPOKSTATMC2P.CON ✓

Enter Annual statistics in file

C:\CLIMAT05\SIMULAT_05\ANNUAL_TABLE.DAT (Text file)

DAW 3-10-05 Simulate daily precipitation for Jackass Flats

This station is strongly affected by SOI-PDO

Control files: C:\CLIMAT05\SIMULAT_05\JACKASSMC2.SIM

" " \JACKASSMC2P.SIM

Dan 3-11-05

Annual Statistics for Data and First and Second Order Markov Chain 50-yr Simulations

	RECORD	MC1	MC1P*	MC2	MC2P*
Forty Mile Canyon,NV					
MAP (mm)	210.38	207.37	218.03	220.81	208.65
STD DEV	82.77	62.75	85.62	72.91	69.04
CV	0.39	0.30	0.39	0.33	0.33
MAX (mm)	398.8	330.0	447.2	472.2	415.9
MIN (mm)	67.3	80.7	76.7	101.2	95.7
Nogales, AZ					
MAP (mm)	404.33	428.87	442.49	429.47	438.31
STD DEV	99.39	89.31	93.85	95.25	99.59
CV	0.25	0.21	0.21	0.22	0.23
MAX (mm)	630.2	652.8	711.9	710.0	723.5
MIN (mm)	235.2	294.6	258.5	224.0	235.0
Spokane, WA					
MAP (mm)	384.28	405.67	404.07	418.06	408.58
STD DEV	82.97	62.91	57.20	43.83	57.69
CV	0.22	0.16	0.14	0.11	0.14
MAX (mm)	586.5	591.4	544.5	504.0	532.1
MIN (mm)	219.5	306.3	260.6	335.5	304.9
Jackass Flats, NV					
MAP (mm)	140.80	140.50	150.335	139.1	138.06
STD DEV	70.51	48.17	50.50	39.90	44.52
CV	0.50	0.343	0.336	0.286	0.322
MAX (mm)	321.1	316.2	273.5	234.6	261.3
MIN (mm)	30.0	47.2	69.5	43.0	51.1

* Occurrence process and mean of mixed exponential perturbed by SOI and PDO
MAP = Mean annual precipitation
STD DEV = Standard deviation (mm)
CV= Coefficient of variation
MAX = maximum annual precipitation
MIN = minimum annual precipitation

File: C:\CLIMAT05\SIMULAT_05\ANNUAL_TABLE.WPD

The statistics in the above table were obtained from the output files from the program STATCLIM3.F95 The names of the output files are listed in the control files specified on the previous pages (files have extension *.CON). The output files have the extension *.OUT.

Each of the simulated precipitation sequences were for 50 yrs The length of the real data varies. There is no consistent increase in the coefficient of variation of MAP due to higher order Markov chain or SOI-Perturbations. There appears to be an increase in the range of simulated annual precipitation from MC1 to MC2P.

DAW 3-14-05 Examine CDF's of monthly wet days and precipitation for critical months.

Procedure:

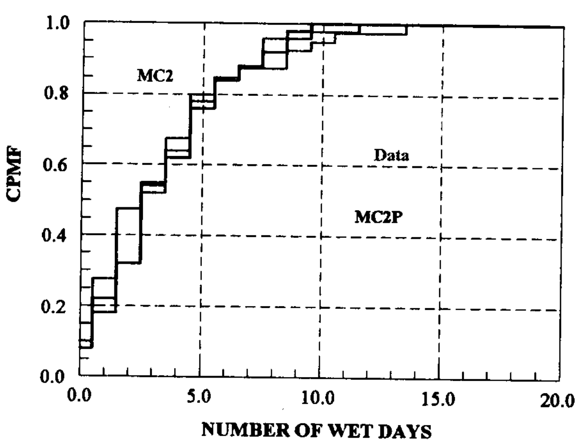
1) For wet days, use editor and extract data from table beginning in Col 74 of *.OUT file.
2) Copy from text file to PST PLOT file

3) CDF Files Created

C:\CLIMAT_05\FORTY_RE_WET.PDW - Data
\FORTY_MC2P_WET.PDW - 2nd order + perturb
\FORTY_MC2_WET.PDW - 2nd order MC.

DAW 3-17-05

Plots of the cumulative probability mass functions (CPMF's) were made for data, simulations with 2nd order Markov Chain (MC2) and MC2 with SOI-PDO perturbations MC2P for 5 months for Forty Mile Canyon - the station with MAP quite close to that of Yucca Mtn. The months chosen were Dec-Mar and August. These are the months that are most likely to have runoff and deep percolation. An examination of the five figures reveals that the MC2P functions are closer DAW 3-17-05 to those from data than are the MC2 functions. The simulations usually have a smaller probability of zero events than the data. The MC2P results

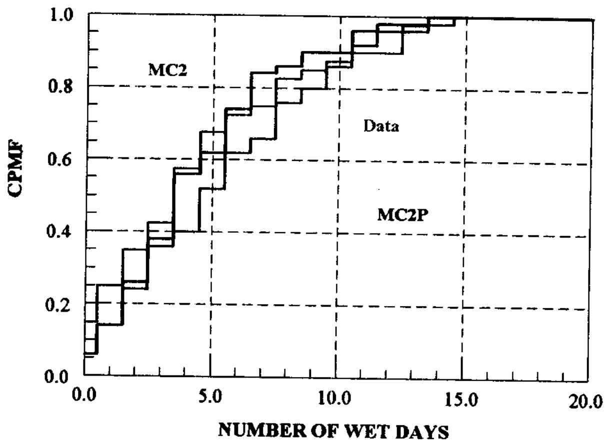


Forty Mile Canyon
Cumulative Probability Mass Function, December

File: C:|CLIMAT05|CDF_05|FORTYWETDEC.PGW

Data: C:|CLIMAT05|CDF_05|FORTY_RE_WET.PDW
|FORTY_MC2P_WET.PDW
|FORTY_MC2_WET.PDW

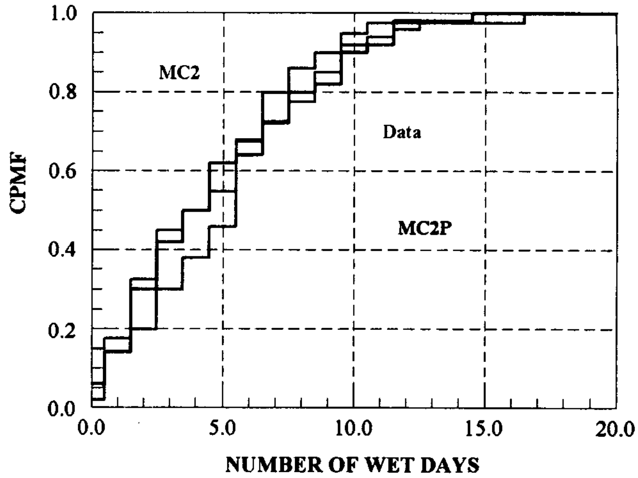
daw 3-18-05



Forty Mile Canyon
Cumulative Probability Mass Function, January

File: C: | CLIMAT05 | CDF_05 | FORTYWETJAN.PGW
daw 3-17-05

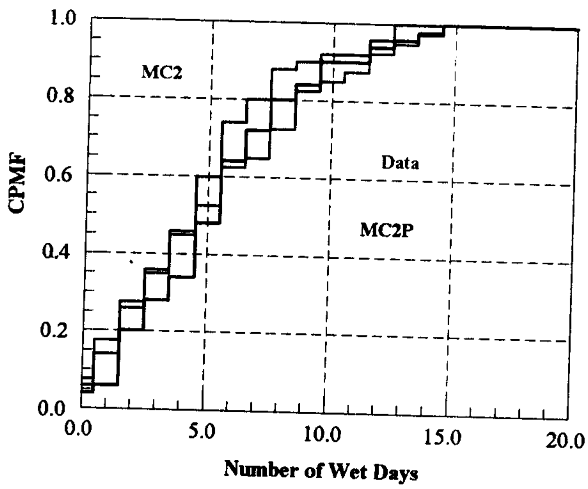
Data: C: | CLIMAT05 | CDF_05 | FORTY_RE_WET.PDW
| FORTY_MC2P_WET.PDW
| FORTY_MC2_WET.PDW



Forty Mile Canyon
Cumulative Probability Mass Function, February

File: C: | CLIMAT05 | CDF_05 | FORTYWETFEB.PGW
daw 3-17-05

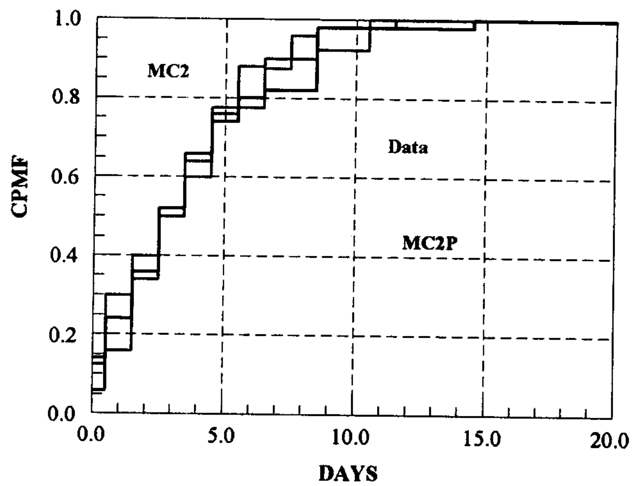
Data: C: | CLIMAT05 | CDF_05 | FORTY_RE_WET.PDW
| FORTY_MC2P_WET.PDW
| FORTY_MC2_WET.PDW



Forty Mile Canyon
Cumulative Probability Mass Function, March

File: C: | CLIMAT05 | CDF_05 | FORTYWETMAR.PGW

Data: C: | CLIMAT05 | CDF_05 | FORTY_RE_WET.PDW
| FORTY_MC2P_WET.PDW



Forty Mile Canyon
Cumulative Probability Mass Function, August

File: C: | CLIMAT05 | CDF_05 | FORTYWETAUG.PGW
daw 3-17-05

Data: C: | CLIMAT05 | CDF_05 | FORTY_RE_WET.PDW
| FORTY_MC2P_WET.PDW
| FORTY_MC2_WET.PDW

are closer to the data, however.
Because of the substantial sampling variability for 50-yr sequences

DAW 3-18-05

in such a dry climate, it is difficult to make definite conclusions. However the MC2P results are certainly within sampling error. The lower probability of zero wet days for MC2P could be explained by the use of a linear perturbation of the logit of P_{000}. A non-linear function may be superior but would require an additional parameter

The empirical probability mass functions for all other months are included in the data files referenced under the figures and also in the output (x.OUT) files for each station.

Prepare figures with monthly statistics for Forty Mile Canyon

Data were copied from x.OUT files

Mean number of wet days / month FORTY_MO_NO.PGW ✓✓

Mean monthly precipitation FORTY_MO_P.PGW ✓✓

Coefficient of variation of monthly precipitation FORTY_MO_CVP.PGW ✓✓

Mean precipitation per wet day FORTY_MO_MPWET.PGW ✓✓

Coefficient of variation of mean precip per wet day FORTY_MO_CVWET.PGW ✓✓

DAW 3-23-05 Continue with Graphics - CDFs of Monthly Precip

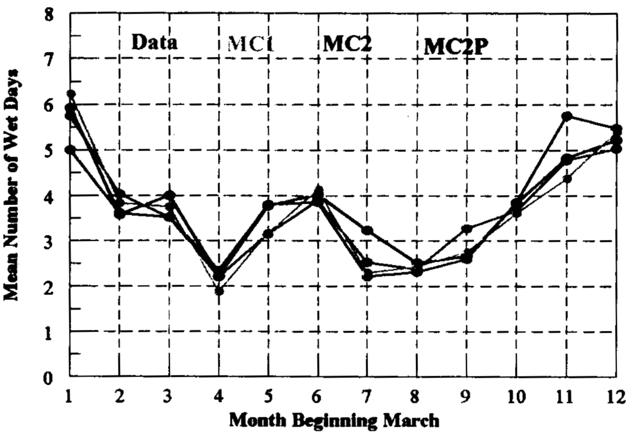
Data for CDF's for MAR, AUG, DEC, JAN and FEB copied from x.OUT files to new text files

Text files imported and merged to form single data file for each Month.

for Mar: C:\CLIMATE5\SIMULAT_05\FORTY_MAR_CDFP.PDW

Fig. created " " " .PGW

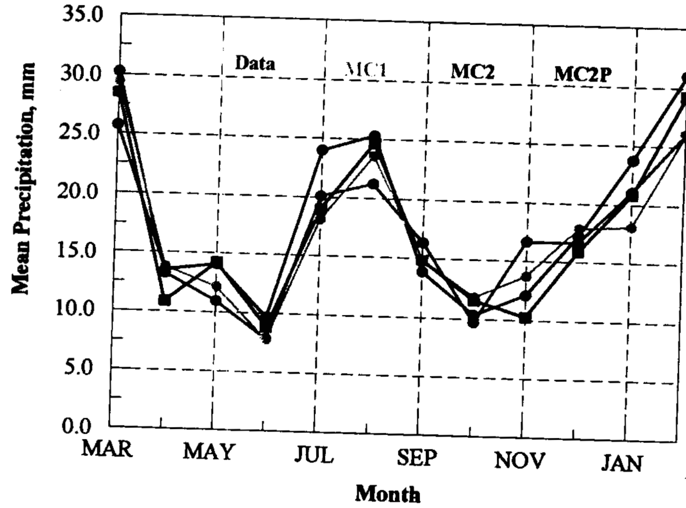
DAW 3-24-05 Statistical Comparisons for Forty Mile Canyon
Figures showing sample statistics are shown below and on following pages



Forty Mile Canyon
Monthly Mean Number of Wet Days

File: C: | CLIMAT05 | CDF_05 | FORTY_MO_NO.PGW
daw 3-22-05

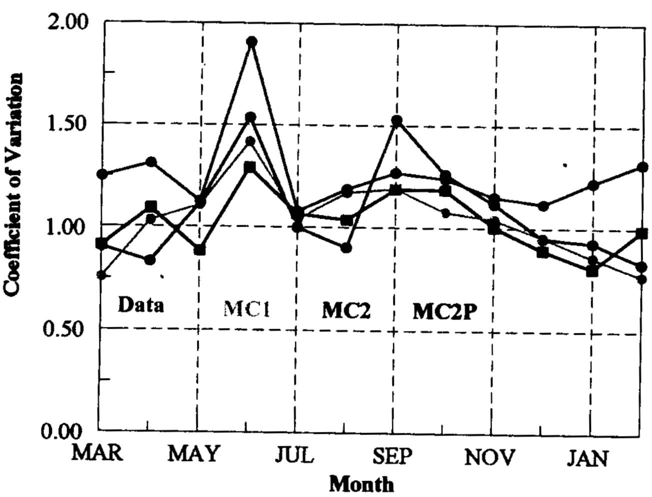
Data: C: | CLIMAT05 | SIMULAT__05 | FORTY_MO_RE.PDW
| FORTY_MO_MC1.PDW
| FORTY_MO_MC2.PDW
| FORTY_MO_MC2P.PDW



Forty Mile Canyon
Monthly Mean Precipitation

File: C: | CLIMAT05 | CDF_05 | FORTY_MO_P.PGW
daw 3-22-05

Data: C: | CLIMAT05 | SIMULAT__05 | FORTY_MO_RE.PDW
| FORTY_MO_MC1.PDW
| FORTY_MO_MC2.PDW
| FORTY_MO_MC2P.PDW



Forty Mile Canyon
Coefficient of Variation of Monthly Precipitation

File: C: | CLIMAT05 | CDF_05 | FORTY_MO_CVP.PGW
daw 3-22-05

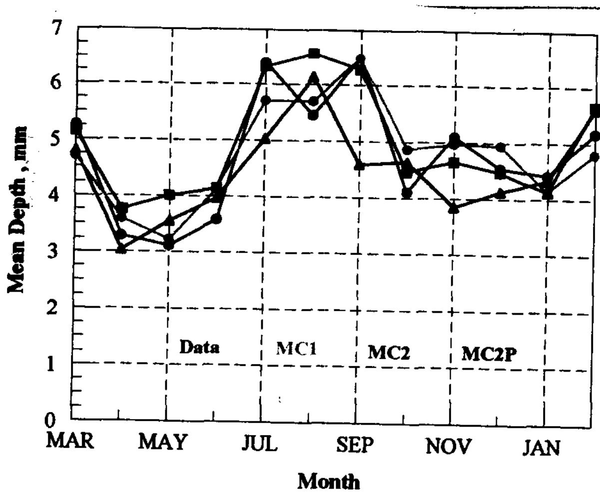
Data: C: | CLIMAT05 | SIMULAT__05 | FORTY_MO_RE.PDW
| FORTY_MO_MC1.PDW
| FORTY_MO_MC2.PDW
| FORTY_MO_MC2P.PDW

MC1 - 50 yr. Simulated with First Order Markov chain
MC2 - 50 yr. Simulated with Second Order Markov Chain
MC2P - 50 yr Simulated with second order Markov Chain with P00 and mean precipitation perturbed by SOI and PDO.
The monthly mean number of wet days is well-preserved by all techniques as is the monthly mean precipitation. However the variance is underestimated for most months - especially during winter.

Daw 3-24-05 Comparisons (Con't)

From the figures on p 55 and 56, it can be seen that part of this problem is the failure of the simulation models to estimate the frequency of 0 – 3 wet days. Of course sampling variability is substantial. The MC2 and MC2P sequences have smaller CV's than the data for Dec-Mar. The MC2 appears to give better results than the MC1.

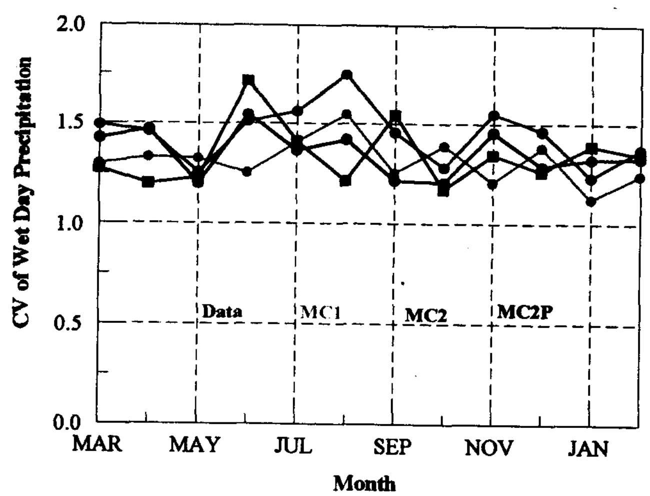
The mean monthly precipitation per wet day and the CV are shown below. The differences between MC1 and MC2 are due only to sampling variability. The variability is well-preserved except for July and August.



Forty Mile Canyon
Monthly Mean Precipitation per Wet Day

File: C: | CLIMAT05 | CDF_05 | FORTY_MO_MPWET.PGW
daw 3-22-05

Data: C: | CLIMAT05 | SIMULAT__05 | FORTY_MO_RE.PDW
| FORTY_MO_MC1.PDW
| FORTY_MO_MC2.PDW
| FORTY_MO_MC2P.PDW



Forty Mile Canyon
Coefficient of Variation of Precipitation per Wet Day

File: C: | CLIMAT05 | CDF_05 | FORTY_MO_CVWET.PGW
daw 3-23-05

Data: C: | CLIMAT05 | SIMULAT__05 | FORTY_MO_RE.PDW
| FORTY_MO_MC1.PDW
| FORTY_MO_MC2.PDW
| FORTY_MO_MC2P.PDW

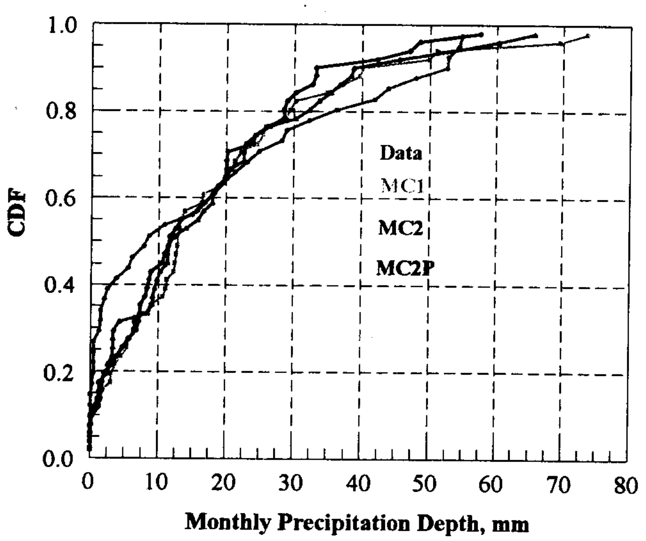
I aw 3/24/05 Graphics - CDFs of Monthly Precipitation
Examine months of Dec, Jan, Feb, Mar and August
1) Set up CDF data files in the form:
C:\CLIMAT05\SIMULAT_05\FORTY_XXX_CDFP.DAT (XXX = Mon)
Import to PsiPlot file with 8 cols

Data		MC1		MC2		MC2P	
Depth	CDF	Depth	CDF	Depth	CDF	Depth	CDF

Copy data from *.OUT files to temporary *.DAT files
March ✓
December ✓
Jan ✓
Feb

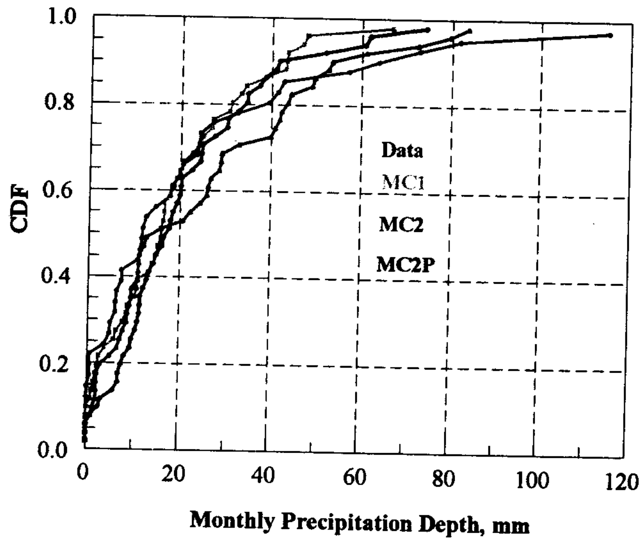
DAW 4/6/05 DAW 4/8/05
Create CDF files + graphics for Jan FORTY_JAN_CDFP.PGW

DAW 4/7/05 DAW 4/8/05
CDFs of monthly precipitation for Dec-Mar are shown on p 61 and CDFs for August are shown on p 62. For all months the distributions of the data are more highly skewed than for the simulated "data."
The greatest discrepancies are for the months of Dec and Feb. From the figures on p 58 we see that the mean number of wet days are very close for these two months as are the monthly mean precipitation. However the CVs for the simulated data are significantly lower than for historical data.



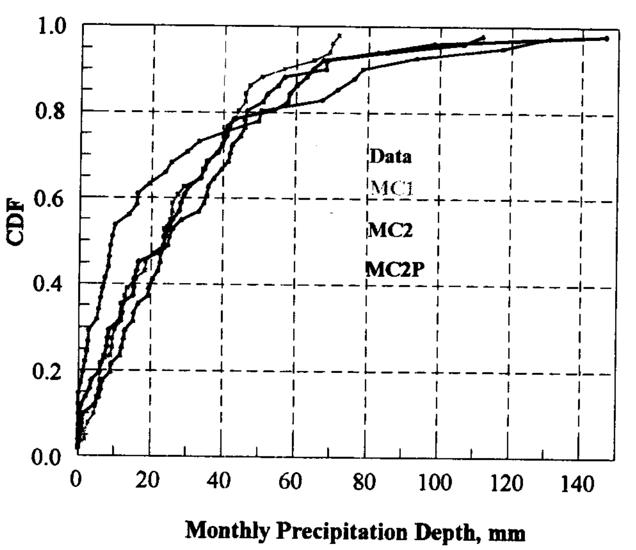
Forty Mile Canyon
Cumulative Distribution Function, December

File: C: | CLIMAT05 | CDF_05 | FORTY_DEC_CDFP.PGW
daw 3-23-05
Data: C: | CLIMAT05 | SIMULAT_05 | FORTY_DEC_CDFP.PDW



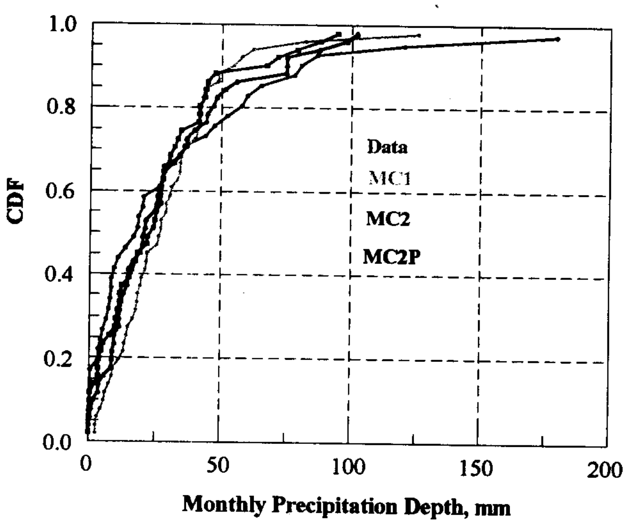
Forty Mile Canyon
Cumulative Distribution Function, January

File: C: | CLIMAT05 | CDF_05 | FORTY_JAN_CDFP.PGW
daw 4-06-05
Data: C: | CLIMAT05 | SIMULAT_05 | FORTY_JAN_CDFP.PDW



Forty Mile Canyon
Cumulative Distribution Function, February

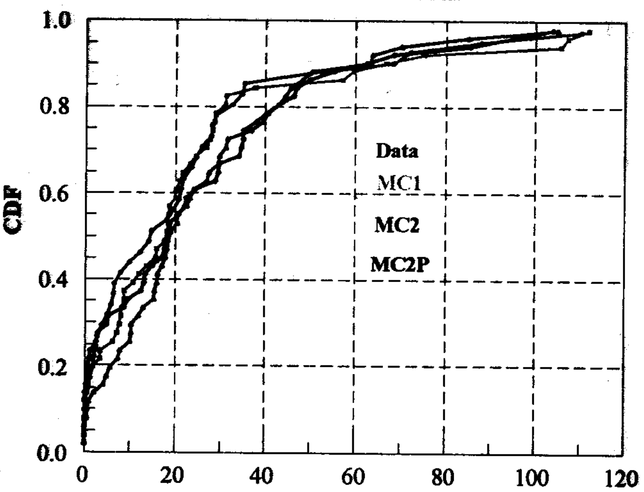
File: C: | CLIMAT05 | CDF_05 | FORTY_FEB_CDFP.PGW
daw 4-07-05
Data: C: | CLIMAT05 | SIMULAT_05 | FORTY_FEB_CDFP.PDW



Forty Mile Canyon
Cumulative Distribution Function, March

File: C: | CLIMAT05 | CDF_05 | FORTY_MAR_CDFP.PGW
daw 3-23-05
Data: C: | CLIMAT05 | SIMULAT_05 | FORTY_MAR_CDFP.PDW

Daw 4-7-05



Forty Mile Canyon
Cumulative Distribution Function, August

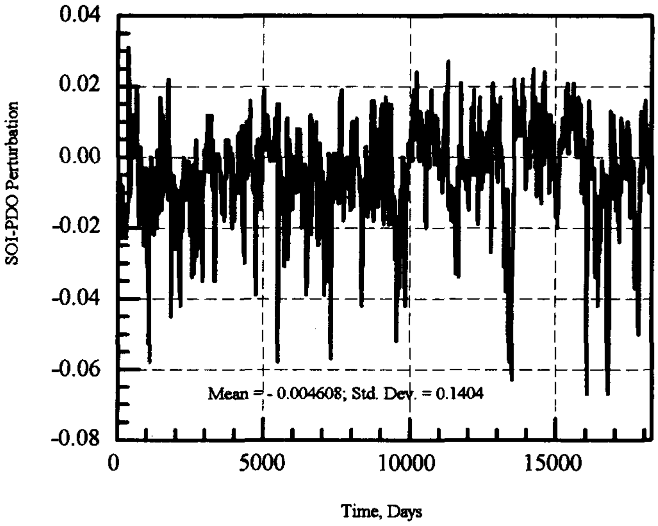
File: C:|CLIMAT05|CDF_05|FORTY_AUG_CDFP.PGW
daw 4-07-05
Data: C:|CLIMAT05|SIMULAT_05|FORTY_AUG_CDFP.PDW

Part of this deviation can be explained by the deficiency of small numbers of wet days as exhibited by the probability mass functions shown on pages 55 and 56. The assumption that the distributions of precipitation per wet day are independent may also be a contributing factor.

Daw 4-8-05

An additional factor should be considered for the model with SOI-PDO perturbations. In the existing model the SOI and PDO perturbations are added to the logits of the transition probabilities, and the transformation to probabilities is very non-linear. If we examine the figure showing the time series of perturbations of the dry-dry transition probability for Jackass Flats (See p 141 of Scientific Notebook 363) and figure on p 63, we see that the perturbations are biased negative. This asymmetry would result in a greater number of wet days. One approach that could be attempted is as follows:

DAW 4-8-05



Perturbation of the dry-dry transition probabilities by SOI and PDO
Jackass Flats, NV 50-year simulation.

File: C: | SOI | JACK_P00PERT.PGW
daw 3/24/03

For the first order Markov Chain:

If both SOI and PDO are positive:

$$G_{ii}'(t) = G_{ii}(t) + a_{iiplus}[SOI(t-\hat{\tau}_{ii})] + b_{iiplus}PDO(t).$$

If both are negative:

$$G_{ii}'(t) = G_{ii}(t) + a_{iineg}SOI(t-\hat{\tau}_{ii}) + b_{iineg}PDO(t)$$

with obvious variations where the signs of SOI and PDO are not the same. This would require two additional parameters for each transition probability and would likely be most significant for probabilities that are large (P_{00} and P_{000}).

DAW 4-15-05 Exploratory Study of Asymmetric response of MC1 and MC2 parameters to SOI and PDO.

A new directory C:\CLIMAT05\ASYMMETRIC will be used for control and output files.

Program S_P_MC2OPT.F95 was modified to optimize 4 perturbation coefficients for each parameter. The program is S_P_MC2OPT05.F95

For an exploratory study control files were set up for 5 stations; two near Yucca Mtn, 2 with monsoon characteristics and one Northwestern St.
File names are:

control	output	Detail of optimization
FORTY_OPT2.FIL	*.OUT	*.DET
JACK_OPT2.FIL	"	"
RG4_OPT2.FIL	"	"
HOBBS-OPT2.FIL	"	"
SPOKANE_OPT2.FIL	"	"

DAW 4-19-05 For this analysis both SOI and PDO effects were examined simultaneously and perturbations were permitted for every day.

DAW 4-20-05 Also analyze Ranier Mesa + Nogales, AZ + Las Vegas, NV

RANIER_OPT2.FIL
NOGALES_OPT2.FIL
VEGAS_OPT2.FIL

DAW 4-20-05

Results of the asymmetric analysis are summarized in C:\CLIMAT05\ASYMMETRIC\SUMMARY.TXT (Now Word Perfect) Summaries for 3 stations near Yucca Mtn are show below + on p 66

FORTY MILE CANYON

Lag A00 B00 LogL 0/0
30. 0.1726 0.0791 -3137.0942

Lag A00 B00 ANEG00 BNEG00 LogL 0/0
0. 0.0731 0.1990 0.2403 -0.0755 -3132.7693 *

Lag A10 B10 LogL 1/0
60. 0.0003 -0.2008 -1172.2725 *

Lag A10 B10 ANEG10 BNEG10 LogL 1/0
30. -0.0917 -0.1555 0.0036 -0.2959 -1171.4032

SECOND ORDER

Lag A000 B000 LogL 00/0
0. 0.1543 0.0730 -2752.6428

Lag A000 B000 ANEG000 BNEG000 LogL 00/0
0. 0.0289 0.2002 0.2377 -0.0703 -2748.5688 *

Lag A100 B100 LogL 10/0
60. 0.2063 0.0387 -357.7530 *

Lag A100 B100 ANEG100 BNEG100 LogL 10/0
60. 0.2195 0.2383 0.2743 -0.1636 -356.1784

Lag A010 B010 LogL 01/0
30. 0.0556 -0.2670 -594.5689

Lag A010 B010 ANEG010 BNEG010 LogL 01/0
30. -0.1900 -0.0447 0.2078 -0.5023 -591.3539 *

Lag A110 B110 LogL 11/0
90. 0.0458 -0.1196 -562.5844 *

Lag A110 B110 ANEG110 BNEG110 LogL 11/0
120. 0.1996 -0.1559 -0.0174 -0.0675 -561.9153

RANIER MESA, NV

Lag A00 B00 LogL 0/0
0. 0.1545 0.0642 -3240.1372 *

Lag A00 B00 ANEG00 BNEG00 LogL 0/0
0. 0.0628 0.1293 0.2075 -0.0029 -3238.3313

Lag A10 B10 LogL 1/0
0. 0.0608 -0.0549 -1320.8363 *

Lag A10 B10 ANEG10 BNEG10 LogL 1/0
0. 0.1030 -0.0114 0.0629 -0.0833 -1320.1907

SECOND ORDER

Lag A000 B000 LogL 00/0
0. 0.1714 0.0914 -2811.5190

Lag A000 B000 ANEG000 BNEG000 LogL 00/0
0. 0.0457 0.1595 0.2366 0.0058 -2809.3342 *

Lag A100 B100 LogL 10/0
90. -0.1615 -0.2091 -407.6417 *

Lag A100 B100 ANEG100 BNEG100 LogL 10/0
120. -0.2820 -0.0817 0.0004 -0.3107 -407.4865

Lag A010 B010 LogL 01/0
0. 0.1106 0.0183 -671.8989 *

Lag A010 B010 ANEG010 BNEG010 LogL 01/0
60. 0.2268 -0.0089 -0.0125 0.0540 -671.8168

Lag A110 B110 LogL 11/0
60. 0.0516 -0.1257 -635.2935 *

Lag A110 B110 ANEG110 BNEG110 LogL 11/0
60. -0.1250 -0.0062 0.1374 -0.2769 -633.9588

An asterisk indicates improvement in the AIC statistic.

DAW 4-21-05 Improvements were:

Forty Mile Canyon : G_{00}, G_{000}, G_{010}

Ranier Mesa : G_{10}. G_{000},

Jackass Flats : G_{00}, G_{000}

For the other stations improvements were

Nogales AZ : G_{00}, G_{101}

DAW 4-21-05

Spokane, WA : Goo

Hobbs, N.M. : None

Walnut Gulch RG4 : Goo

JACKASS FLATS, NV

Lag A00 B00 LogL 0/0
0. 0.2088 0.0643 -2963.0391

Lag A00 B00 ANEG00 BNEG00 LogL 0/0
0. 0.1726 0.1568 0.2486 -0.0506 -2960.5046 *

Lag A10 B10 LogL 1/0
120. 0.1477 -0.0861 -832.1171 *

Lag A10 B10 ANEG10 BNEG10 LogL 1/0
120. 0.2801 -0.0380 0.1436 -0.1447 -830.6422

SECOND ORDER

Lag A000 B000 LogL 00/0
0. 0.2060 0.0814 -2604.3091

Lag A000 B000 ANEG000 BNEG000 LogL 00/0
0. 0.1486 0.1863 0.2573 -0.0346 -2601.9106 *

Lag A100 B100 LogL 10/0
90. -0.1902 -0.2291 -325.6351 *

Lag A100 B100 ANEG100 BNEG100 LogL 10/0
90. -0.4008 -0.1548 -0.0901 -0.3420 -324.9649

Lag A010 B010 LogL 01/0
120. 0.1807 -0.0981 -520.0411 *

Lag A010 B010 ANEG010 BNEG010 LogL 01/0
120. 0.3465 -0.0491 0.1566 -0.1406 -518.7555

Lag A110 B110 LogL 11/0
120. 0.0894 -0.0897 -307.6216 *

Lag A110 B110 ANEG110 BNEG110 LogL 11/0
120. 0.0989 -0.0203 0.1204 -0.1888 -307.3589

Conclusion: There are modest improvements in AIC for stations near Yucca Mtn when the perturbation coefficients are asymmetric, especially for the Goo Logit transitions. For the monsoon stations and Spokane, effects are minimal and inconsistent. This may reflect the location of Yucca Mtn. in the climatic transition zone.

DAW 4-22-05

One final aspect of the MC2 must be considered. In the study of SOI-PDO perturbations completed, both indices have been used to perturb parameters simultaneously. They should also be studied individually.

DAW 4-25-05

Program S_P_MC2OPT05.F95 was copied to C:\CLIMAT05\SOI_PDO and the name was changed to MC2_SPOPT05.F95

Code was added so that log likelihood functions were optimized with only SOI and only PDO perturbations for G000, G101, G011 and G110.

DAW 4-26-05

Program S_P_MC2OPT05.F95 was run for the following stations: (Files are in C:\CLIMAT05\Asymmetric

Control files	Output	Detailed optimization
✓✓FORTY_OPT3.FIL	FORTY_OPT3.OUT	*.DET
✓✓Hobbs_OPT3.FIL	*.OUT	*.DET
✓✓JACK_OPT3.FIL		
✓RANIER_OPT3.FIL		
✓R64_OPT3.FIL	Also ✓YUCCA_OPT3.FIL	
✓SPOKANE_OPT3.FIL	✓VEGAS_OPT3.FIL	
✓NOGALES_OPT3.FIL		

DAW 4-28-05 Continue runs beginning with Ranier Mesa.

Prepare table showing results in condensed form.

Data entered manually in Table form.

DAW 5-2-05 Examine effects of asymmetrical coefficients on SOI perturbations of mean of the mixed exponential distribution.

Modifications were made to program S-PDOME2.F95

1. Copy program to c:\CLIMAT05\Asymmetric
2. Change name to S-PDOME-05.F95
3. include ASIMPLX optimization subroutine to replace a grid search
4. Add section for asymmetrical coefficients for SOI ie

If SOI is positive:

$$\mu'(t) = \mu(t) + C_1 PLUS[SOI(t-\tau)]$$

If SOI is negative

$$\mu'(t) = \mu(t) + C_1 Neg[SOI(t-\tau)]$$

5. Examine only SOI perturbation
6. Examine only PDO perturbation

DAW 5-3-05 Run following stations

Control File	Output file	
FORTY-MESPOPT1.FIL	*.OUT ✓	in C:\CLIMAT05\Asymmetric
JACK-MESPOPT1.FIL	*.OUT ✓	

DAW 5-4-05 Run following stations.

RAN-MESPOPT1.FIL *.OUT ✓

RG4-MESPOPT1.FIL *.OUT ✓

Results are entered into Table

C:\CLIMAT05\Asymmetric\SOI-PDO-ME-Table.wpd

DAW 5-4-05

Tentative conclusion:

1) From this sample of stations, it appears that asymmetrical perturbation of the mean ($\mu(t)$) of the mixed exponential distribution is not useful. Although the coefficients identified are different they do not result in a significant improvement in the log likelihood function over only a single perturbation coefficient. This is not too surprising because there is no transformation of the mean as contrasted to the perturbations of the logits of transition probabilities for the 2nd order Markov Chain.

2) Addition of the ASIMPLX optimization procedure results in a more accurate identification of perturbation coefficients as compared to the grid search procedure.

DAW 5-7-05

In examining the Log Likelihood functions obtained for the mixed exponential distribution by programs S_PMC2OPT05.F95 and the parameter identification program MC2ME4_1.F95 I note differences. This is due to the fact that the likelihoods are calculated in units of inches in MC2ME4_1.F95 and in millimeters in S_P_MC2OPT05.F95. The reason is as follows: The Log Likelihood function is:

$$\text{Log } L = \sum \log\left[\frac{\alpha e^{-x/\beta}}{\beta} + \frac{(1-\alpha)e^{-x/\delta}}{\delta}\right]$$ where x is precip − Thres

on a wet day and α, β and δ are the parameter values on that day. If we assume that the units in the above equation are inches, we can write the same expression in millimeters

(See p74)

Daw 5-16-05 Discussion of SOI-PDO Perturbations on MC2.

Tables of results for four stations near Yucca Mtn are shown below and on p 71.

SOI - PDO Perturbations Of Second Order Markov Chain - Ranier Mesa, NV

Perturbation		SOI			PDO		Log L	Lag
	Pos.	+&-	Neg.	Pos.	+&-	Neg.		Days
G000								
Both (4) **	0.0457		0.237	0.159		0.0057	-2809.33	0
SOI *	0.055		0.1795				-2813.74	0
PDO				0.0276		0.0518	-2824.22	
Both (2) *		0.171			0.0914		-2811.52	0
G100								
Both (4)	-0.282		0.0004	-0.082		-0.311	-407.49	120
SOI	-0.0428		-0.1038				-409.99	90
PDO				-0.1037		-0.188	-409.13	
Both (2) **		-0.161			-0.209		-407.64	90
G010								
Both (4)	0.227		-0.013	-0.0089		0.054	-671.82	60
SOI **	0.182		0.0749				-671.55	0
PDO				0.0225		-0.0597	-673.54	
Both (2)		0.111			0.183		-671.90	0
G110								
Both (4) *	-0.125		0.137	-0.0062		-0.277	-633.95	60
SOI	0.0497		0.1099				-636.78	60
PDO *				-0.1239		-0.1783	-635.57	
Both (2) **		0.0516			-0.126		-635.29	60

* Significant improvement
** Superior according to AIC

File: C:\CLIMAT05\ASYMMETRIC\RANIER_TABLE.wpd

SOI - PDO Perturbations Of Second Order Markov Chain - Forty Mile Canyon, NV

Perturbation		SOI			PDO		Log L	Lag
	Pos.	+&-	Neg.	Pos.	+&-	Neg.		Days
G000							-2762.79	
Both (4) **	0.0289		0.2377	0.200		-0.0703	-2748.57	0
SOI *	0.0426		0.1415				-2755.16	0
PDO				0.0527		-0.0153	-2762.38	
Both (2) *		0.154			0.0730		-2752.64	0
G100								
Both (4) *	0.219		0.274	0.238		-0.163	-356.18	60
SOI **	0.351		0.1632				-357.40	60
PDO				0.0057		-0.1739	-360.56	
Both (2) *		0.206			0.039		-357.75	60
G010								
Both (4) **	-0.190		0.208	-0.0447		-0.502	-591.35	30
SOI *	0.0837		0.1583				-601.14	30
PDO *				-0.238		-0.359	-594.57	
Both (2)		0.055			-0.267		-594.57	30
G110								
Both (4)	0.200		-0.017	-0.156		-0.067	-561.91	120
SOI	0.211	0.056					-563.34	120
PDO **				-0.238		-0.359	-562.82	
Both (2) *		0.046			-0.120		-562.58	90

* Significant improvement
** Superior according to AIC

File: C:\CLIMAT05\ASYMMETRIC\FORTY_TABLE.wpd

Daw 5-19-05

Let us examine the results for consistency. For perturbations of G000, the SOI-PDO perturbations with asymmetric coefficients are superior according to AIC. For the three stations near Yucca Mtn, the negative coefficient for SOI is always greater than the positive coefficient, while the positive coefficient for PDO is always greater than the negative.

For G_{100} the superior AIC resulted from symmetric perturbations of both SOI + PDO for Ranier Mesa and Jackass Flats with both coefficients having a negative sign.

DWW 5-19-05

SOI - PDO Perturbations Of Second Order Markov Chain - Jackass Flats, NV

Perturbation		SOI			PDO		Log L	Lag
	Pos.	+&-	Neg.	Pos.	+&-	Neg.		Days
G000								
Both (4) **	0.149		0.257	0.186		-0.0346	-2601.91	0
SOI *	0.1967		0.1770				-2606.68	0
PDO				0.0298		-0.0197	-2621.20	
Both (2) *		0.206			0.0814		-2604.31	0
G100								
Both (4)	-0.401		-0.0901	-0.155		-0.342	-324.96	90
SOI *	0.3561		0.1032				-326.35	0
PDO				-0.123		-0.182	-327.41	
Both (2) **		-0.190			-0.229		-325.63	90
G010								
Both (4) *	0.347		0.157	-0.0491		-0.141	-518.76	120
SOI **	0.421		0.157				-519.57	120
PDO *				-0.141		-0.212	-523.24	
Both (2) *		0.181			-0.0981		-520.04	120
G110								
Both (4)	0.0989		0.1203	-0.0203		-0.189	-307.56	120
SOI	0.2296		0.112				-307.88	120
PDO				-0.123		-0.179	-308.08	
Both (2)		0.0894			-0.0896		-307.62	120

* Significant improvement
** Superior according to AIC

File: C:\CLIMAT05\ASYMMETRIC\JACKASS_TABLE.wpd

SOI - PDO Perturbations Of Second Order Markov Chain - Las Vegas, NV

Perturbation		SOI			PDO		Log L	Lag
	Pos.	+&-	Neg.	Pos.	+&-	Neg.		Days
G000								
Both (4) ***	0.222		0.222	0.0727		-0.0743	-2571.41	30
SOI *	0.280		0.180				-2574.61	30
PDO		DWW 5-19-05		-0.0398		-0.0920	-2587.64	
Both (2) **		0.0202			0.0015		-2573.26	30
G100								
Both (4)	0.514		0.0069	-0.148		0.0476	-304.96	0
SOI * *	0.454		0.071				-305.43	0
PDO				-0.125		-0.124	-306.77	
Both (2)		0.102			-0.076		-306.20	60
G010								
Both (4) *	0.113		0.186	0.198		0.0448	-477.57	60
SOI	0.132		0.105				-479.02	60
PDO				0.0683		0.0476	-480.09	
Both (2) **		0.153			0.126		-477.84	60
G110								
Both (4)	0.157		0.118	0.0194		0.0227	-198.08	120
SOI	0.147		0.113				-198.09	120
PDO				-0.0643		0.0271	-198.64	
Both (2)		0.124			0.0198		-198.09	120

* Significant improvement
** Superior according to AIC
*** Note that SOI + and - coefficients are equal

File: C:\CLIMAT05\ASYMMETRIC\VEGAS_TABLE.wpd

For Forty Mile Canyon the asymmetric perturbation by SOI only was most significant and both coefficients were positive, as were the symmetric coefficients for SOI and PDO. These results appear to be inconsistent.

For G_{010} the asymmetrical perturbations by SOI lead to some consistentcy.

For G_{110} Asymmetric perturbations by PDO are most consistent

There are many similarities between the patterns of significant coefficients for Las Vegas as compared with the other three. However the impact of PDO appears to be significant (given the magnitude of the coefficient only for the symmetric perturbation of G_{010}.

There is no consistent pattern of SOI lags

DAW 5-20-05 SOI-PDO Perturbations

In Scientific Notebook 363 pp 102-103 seasonal effects were examined for the Forty Mile Canyon Data for the 1st Order Markov Chain. It would be appropriate to check these effects for MC2.

a null period for SOI of Apr-Sept was tried

Null begin = 32 Null end = 183

Try for Forty Mile Canyon

Control File: C:\CLIMAT05\Asymmetric\FORTY_OPT4.FIL

Output File: " " FORTY_OPT4.OUT

No significant or consistent improvement

Try for Jackass Flats

" \JACK_OPT4.FIL

" \JACK_OPT4.OUT

Again no consistent improvement

ZL 4/14/2008

Daw 6-2-05 SOI-PDO Perturbations

Perturbation analysis for Yucca Dry Lake

Control file: C:\CLIMAT05\Asymmetric\YUCCA_OPT3.FIL

output " " " .OUT

The increases in Log Likelihood functions with SOI-PDO perturbations are substantial. Consider Forty Mile Canyon. The increase in Log Likelihood due to periodic fitting for G_{000} was 17.7 as harmonics were increased from 1 to 5 while the additional increase due to SOI-PDO perturbations was 14.4.

One would expect regional coherence of perturbations if the SOI-PDO perturbations are really significant. The table below shows coefficients for 5 Nevada stations for parameter G_{000}.

Station	Coefficients a_{000}^{+}	a_{000}^{-}	b_{000}^{+}	b_{000}^{-}	Increase of Log L.	Period of Record Perturbed
Ranier Mesa	0.0457	0.237	0.159	0.0057	15.68	1960-98
Forty Mile Canyon	0.0289	0.238	0.200	-0.0703	14.41	1960-98
Jackass Flats	0.149	0.257	0.186	-0.0346	19.53	1959-98
Yucca Dry Lake	0.147	0.268	0.178	-0.0791	22.19	1959-98
Las Vegas	0.222	0.222	0.0727	-0.0743	17.92	1957-97
Ave	0.1185	0.244	0.1591	-0.051		

It is clear that SOI-PDO perturbations are highly significant for G_{000} for all stations.

DAW 6-7-05 Effect of units on log Likelihood functions for mixed exponential distribution

If we write the expression on the bottom of p 69 in units of mm we get

$$\text{Log } L = \sum \log \left[\frac{\alpha e^{\frac{-25.4x}{25.4\beta}}}{25.4\beta} + \frac{(1-\alpha) e^{\frac{-25.4x}{25.4\delta}}}{25.4\delta} \right]$$

$$= \sum \log \left\{ \frac{1}{25.4} \left[\frac{\alpha e^{-x/\beta}}{\beta} + \frac{(1-\alpha) e^{-x/\delta}}{\delta} \right] \right.$$

$$= \sum \log \left(\frac{1}{25.4} \right) + \log \left[\frac{\alpha e^{-x/\beta}}{\beta} + \frac{(1-\alpha)}{\delta} e^{-x/\delta} \right]$$

Therefore the log likelihood in units of mm will equal the log likelihood in units of inches + the number of wet days multiplied by $\log\left(\frac{1}{25.4}\right)$

or:

$$\text{Log } L(\text{mm}) = \log L(\text{inches}) - \text{NWET} * 3.23475.$$

For example. Forty mile Canyon

NWET = 1745 days $-\text{NWET} \times 3.23475 = -5644.20$

Log L (mm) = -4056.75

Log L (inches) = 1587.88

$-5644.20 + 1587.88 = -4056.75$ check !!

Daw 6-8-05 Complete SOJ-PDO Perturbation analysis. Program S_PDOME_05.F95

Station	Control File			
Yucca Dry Lake	C:\CLIMAT05\ASYMMETRIC\YUC_MESPOPT1.FIL	✓		
Las Vegas	" " \VEGAS_MESPOPT1.FIL	✓		(NS)
Nogales	" " \NOG_ "	✓		
Hobbs, NM	" " \HOBBS_ "	✓		
Spokane, WA	" " \SPOKANE_ "	✓		(S)?

Daw 6-9-05 Examine coherence of perturbation coefficients for mixed exponential. for stations in the Yucca Mtn. Region

Perturbation coefficients for the stations where SOJ-PDO effects are shown in the table on p 76.

A single asterisk indicates that the improvement in the log Likelihood is significant; a double asterisk shows the model with minimum AIC.

A comparison with the table for MC2 perturbations on p 73 reveals that the SOJ-PDO is not as strong or as consistent for perturbations of the mean of the mixed exponential. All stations except Las Vegas had at least one formulation that resulted in a significant increase in Log Likelihood.

~~Daw 6-10-05~~ Daw 6-10-05

DAW 6-9-05 SOI - PDO effects, - Mixed Exponential

SOI and PDO Perturbations Of the mean of the mixed exponential Distribution

Station	Perturbation	SOI +	SOI	SOI-	PDO	Log L	Lag, Days
Forty Mile	Both (2) *		-0.0009		0.3241	-4008.79	0
	SOI (1)		-0.2522			-4009.50	120
	SOI (2)	-0.2873		-02404		-4009.47	120
	PDO (1) **				0.3187	-4008.80	
Jackass	Both (2) **		-0.2633		0.4386	-2881.91	30
	SOI (1) *		-0.4337			-2885.89	30
	SOI (2) *	-0.5094		-0.3471		-2885.55	30
	PDO (1) *				0.5588	-2884.65	
Ramier Mesa	Both (2) *		-0.2050		0.3548	-4985.21	120
	SOI (1) *		-0.3772			-4987.44	120
	SOI (2) *	-0.4069		-0.3363		-4987.40	120
	PDO (1) **				0.4401	-4986.18	
RG4	Both (2) *		-0.4577		-0.1924	-5652.15	90
	SOI (1) **		-0.4014			-5653.13	90
	SOI (2) *	-0.4624		-0.3600		-5653.04	90
	PDO (1)				-0.0185	-5658.87	
Yucca Dry Lake	Both (2)		-0.1101		0.0796	-3406.14	30
	SOI (1) **		-0.2704			-3405.15	120
	SOI (2)	-0.3053		-0.2465		-3405.13	120
	PDO (1)				0.1481	-3406.67	
Nogales, AZ	Both (2) *		-0.4372		0.1048	-8143.24	60
	SOI (1) **		-0.4660			-8143.47	60
	SOI (2) *	-0.5079		-0.4280		-8143.41	60
	PDO (1)				0.2439	-8147.44	

ΔLogL1 ΔLogL2(1 harmonic → opt)

3.42 19.29
11.58 12.47 92.9%

4.67 34.30 13.6%

5.76 16.22

2.32 19.31 12.0%

5.45 17.23

Station	Perturbation	SOI +	SOI	SOI-	PDO	Log L	Lag, Days
Hobbs, NM	Both (2) *		-0.2519		0.5700	-8194.37	30
	SOI (1) *		-0.4140			-8199.54	30
	SOI (2) *	-0.6385		-3128		-8199.08	30
	PDO (1) **				0.6315	-8195.41	
Spokane, WA	Both (2)		0.0523		0.1278	-15976.34	60
	SOI (1)		-0.0042			-15977.02	120
	SOI (2) *A	0.0919		-0.1712		-15971.38	120
	PDO (1)				0.00214	-15977.22	

7.24 28.7

5.87 24.98

R C:\CLIMAT05\Asymmetric\SOI_PDO_METable.wpd

DAW 6-10-05

An indication of the relative importance of the perturbations can be determined by comparing

→ aw 6-10-05

the magnitudes of Log likelihood increases due SOI-PDO perturbations to the magnitude of the log likelihood increases obtained during the parameter identification process. These quantities are found in the *.DET files and are shown on p 76. The ratios ΔLogL1/ΔLogL2 range from 12.0% for Yucca Dry Lake to 97.9% for Jackass Flats.

SOI coefficients are negative for all (except Los Vegas) Nevada Stations and for Arizona and New Mexico. Therefore a negative SOI (el Nino) will lead to an increase in the mean daily rainfall given a wet day. The SOI signal is not apparent for Las Vegas Nv or Spokane WA
The PDO coefficients are all positive except for RG4, leading to an increased depth with positive PDO.

→ aw 6-13-05 Summary of combined effect of SOI and PDO for stations near Yucca Mtn. If we consider the matrices below we can identify the combinations of SOI and PDO that reinforce or conflict with each

Occurrence Process

G_{000}

SOI \ PDO	+	−
+	R-Dry	Con
−	Con	R-wet

Mean Depth

μ

SOI \ PDO	+	−
+	CON	R-Dry
−	R-wet	CON

Con = conflict
R = reinforce

Daw 6-13-05 Combined effects of SOI + PDO

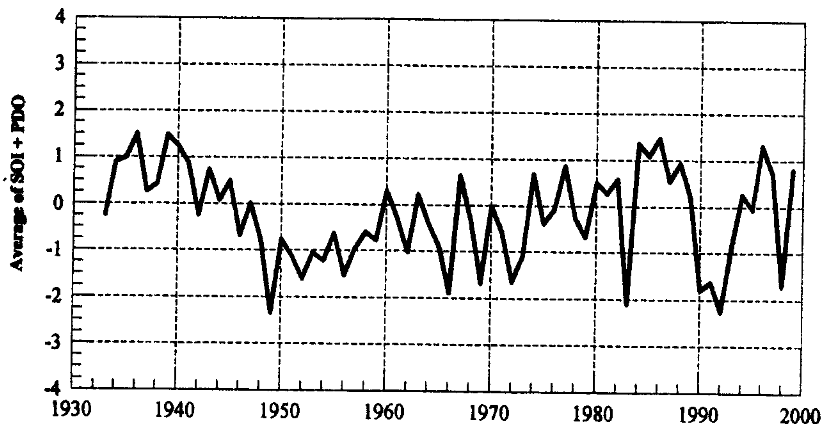
To get a graphical portrayal of the periods of reinforcement and conflict, import files into PSIPLOT
First save files C:\SIMULATIONS_02\ SOIDATA.PFC
" " \ PDOLatest.TXT

as

C:\CLIMAT05\Asymmetric\ SOIDATA.DAT
" " \PDO_LATEST.DAT

Edit the files so they have concurrent periods of record 1933 - 1999.

After importing the data into PSI Plot and examining the averages of SOI+PDO for Jan, Feb and Mar. The indices are concurrent, i.e. no SOI Lag.



Average of SOI + PDO for Jan, Feb and Mar
Jackass Flats, NV
File: C:|CLIMAT05|ASYMMETRIC|JACK_SOIPDO_J_M.PGW
DAW 6-13-05

This time series suggests that the frequency of wet days as related to the transition probability P_{000} would be reduced in the period 1933 - 1946 and would be increased for 1947-59

DAW 6-13-05 Combined effects of SOI and PDO

However the sum of SOI and PDO is not the best indicator because of the difference in magnitudes of coefficients. Indeed, one might argue that the PDO has no effect when negative (see table p 73)

DAW 6-14-05

The effect of perturbations can be determined by simulating precipitation with asymmetric perturbation coefficients.

Program MC2CLIMSIM_04.F95 was modified to include asymmetric coefficients. Revised program is

C:\CLIMAT05\SIMULAT-05ASYM\MC2CLIMSIM_05.F95

Simulate precipitation:

DAW 6-14-05

Forty Mile Canyon

Control file C:\CLIMAT05\SIM~~ULAT~~-05ASYM\FORTYMC2_1.SIM

Output files: " " " \FORTYMC1_1.PRE

" " " " \FORTYMC2_1.PRE

The above simulation was done without perturbations of μ to see the effect of perturbation of occurrence parameters.

DAW 6-16-05 Now perturb μ as well

From Table p.76 see that PDO perturbation is most significant

$C_q = 0.3187$

Control file \SIM_05ASYM\FORTYMC2-2.SIM

DAW 6-16-05 SOI-PDO Perturbations
Simulation of 50 yrs for Forty Mile Canyon
Examine statistical characteristics of Transition probabilities.

Note:
A mistake was detected in the control file and in a call statement in the program MC2CLIMSIM_05
These were corrected on 6-20-05.

	Cyclic P_{000}	Perturbed P_{000}	DAW 6-20-05
mean	0.9338	~~0.9273~~	0.933
S.D	0.0195	~~0.0313~~	0.0237
Max	0.969	~~0.775~~	0.979
Min	0.895	~~0.727~~	0.823

	P_{100}	$\tilde{P}_{100}$	DAW 6-20-05
mean	0.8575	~~0.8513~~	0.8547
SD	0.0118	~~0.0275~~	0.0338
Max	0.874	~~0.975~~	0.951
Min	0.840	~~0.747~~	0.678

	P_{010}	$\tilde{P}_{010}$	DAW 6-20-05
mean	0.4798	~~0.5403~~	0.5130
SD	0.0588	~~0.1276~~	0.1054
Max	0.565	~~0.921~~	0.828
Min	0.366	~~0.227~~	0.219

	P_{110}	$\tilde{P}_{110}$	DAW 6-20-05
mean	0.5769	~~0.5403~~	0.5984
SD	0.0760	~~0.1276~~	0.1065
Max	0.565	~~0.921~~	0.881
Min	0.366	~~0.227~~	0.327

DAW 6-16-05

statistical Characteristics of mean of mixed exponential

	μ (mm)	$\tilde{\mu}$
mean	4.519	4.468
SD	0.823	0.891
Max	6.05	6.95
Min	2.85	2.16

As one would have expected the pertubed transition probablities and means have larger standard deviations and greater ranges than the cyclic series.

~~Three~~ Two DAW 6-16-05 of the four perturbed transition probablitres have smaller means than the cyclic means reflecting the particular sequence of SOIs and PDOs and sampling variation.

DAW 6-17-05

Complete a statistical analysis of the simulated data for Forty Mile Canyon with asymmetric perturbations

Objective: compare with results described on pages 50-62

Analysis Program: STATCLIM3.F95

Procedure:

1) Copy Control file C:\CLIMAT05\SIMULAT-05\FORTYSTATMC2P.CON
   to " " \SIM-05ASYM

Rename to FORTYMC2P-2.CON

output FORTYMC2P_2.STA

DAW 6-18-05

statistical analyses of simulated precipitation for Forty Mile Canyon. Asymmetrical perturbations by SOI-PDO

~~For a 50-yr simulation SOI-PDO (1946-95)~~

~~MAP = 234.36 mm SD = 90.32 CV = 0.385~~ DAW 6-20-05

~~Max: 544.9 mm Min 76.4 mm~~

~~If these statistics are compared with those in the table on p54 we see that the CV of annual precipitation is well preserved. The mean of the simulated data is larger than that for the sample data. However, due to the nonstationarity of SOI + PDO, the mean will be dependent on time. The simulated maximum for the simulated data is much larger than that for the data. This is also true for previous simulations MC1P, MC2 and MC2P.~~ DAW 6-20-05

DAW 6-20-05 After corrections were made in *.CON file and call statement in the program, results were:

MAP = 202.86 mm SD = 66.74 CV = 0.329

Max = 451.8 Min = 66.7 DAW 6-20-05

New control and ~~output~~ output file names are:

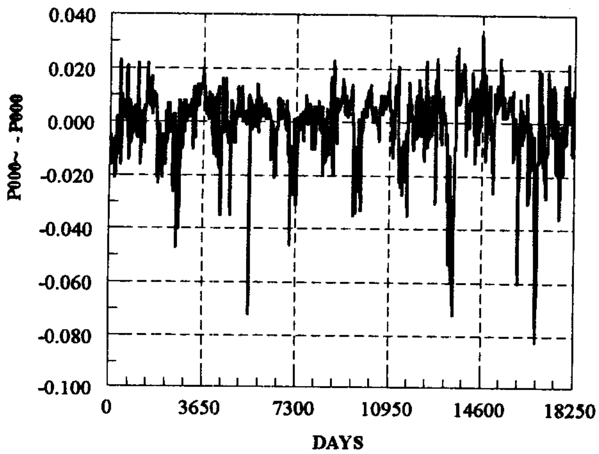
C:\CLIMAT05\SIM_05ASYM\FORTYMC2P_2B.*

If these statistics are compared with those in the table on p 54 we see that the mean is well-preserved and maximum and minimum statistics appear reasonable. However the CV of annual precipitation is still underestimated 0.329 vs 0.39.

DAW 6-21-05

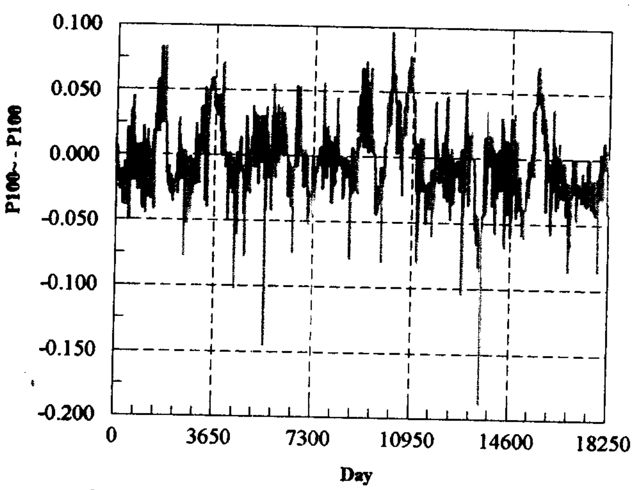
Prepare graphical representation of perturbation deviations.

SOI - PDO induced perturbations are shown below and on p 84 for the four transition probabilities and the mean of the mixed exponential. The symbol $P_{000}^{\sim}$ refers to the perturbed sequence. For P_{000} the negative perturbations are much larger than the positive perturbations From p. 80, if we examine the probability of a wet day following two dry days $(1-P_{000})$ we find for the unperturbed series the max = 0.105 and the minimum is 0.031. For the perturbed sequence, the max = 0.177 and the min is 0.021.



SOI - PDO Perturbations of Transition Probability
Forty Mile Canyon - 50 Year Simulation

File: C:|CLIMAT05|SIM_05ASYM|P000_DEVB.PGW
Data: C:|CLIMAT05|SIM_05ASYM|FORTYMC2P_2B.PDW
dsw 6 - 21 - 05



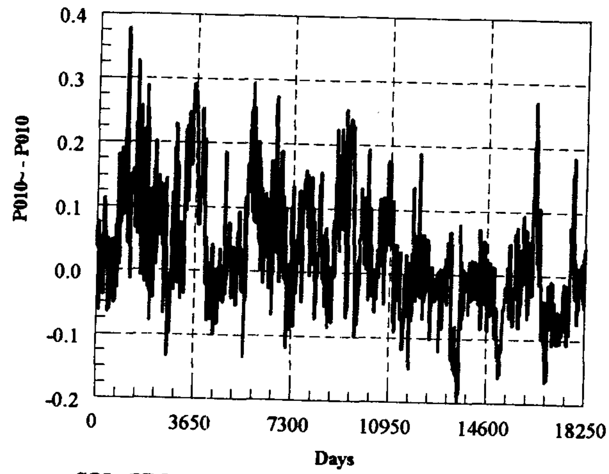
SOI - PDO Perturbations of Transition Probability P100
Forty Mile Canyon - 50 Year Simulation

File: C:|CLIMAT05|SIM_05ASYM|FORTYMC2_2BP100_DEV.PGW
Data: C:|CLIMAT05|SIM_05ASYM|FORTYMC2P_2B.PDW
dsw 6 - 21 - 05

An examination of the perturbation for P_{100}, P_{010} and P_{110} reveals an interesting phenomenon i.e. for the last 20 years of the simulated sequence, the combinations of SOI and PDO lead to higher probabilities of a wet day following two day sequences of 10, 01, and 11. This should reflect the nonstationarity

DAW 6-21-05

DAW 6-21-05



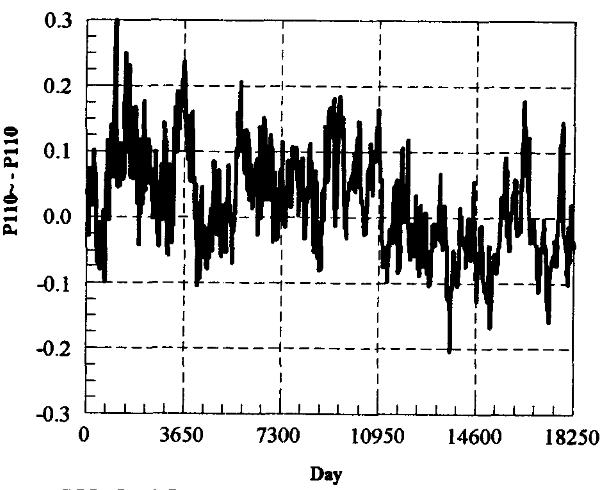
SOI - PDO Perturbations of Transition Probability P010
Forty Mile Canyon - 50 Year Simulation

File: C: | CLIMAT05 | SIM_05ASYM | FORTYMC2_2BP010_DEV.PGW
Data: C: | CLIMAT05 | SIM_05ASYM | FORTYMC2P_2B.PDW
dew 6 - 21 - 05

of the measured data and should also be apparent in the simulated data.

Similarly the first 30 years shows lower probabilities of a wet day following two-day sequences 10, 01 and 11.

· Perturbations of the mean of the mixed exponential distribution of precipitation depth given a wet day show a similar pattern, with smaller means during the first 30 years and larger during the last 20 years.

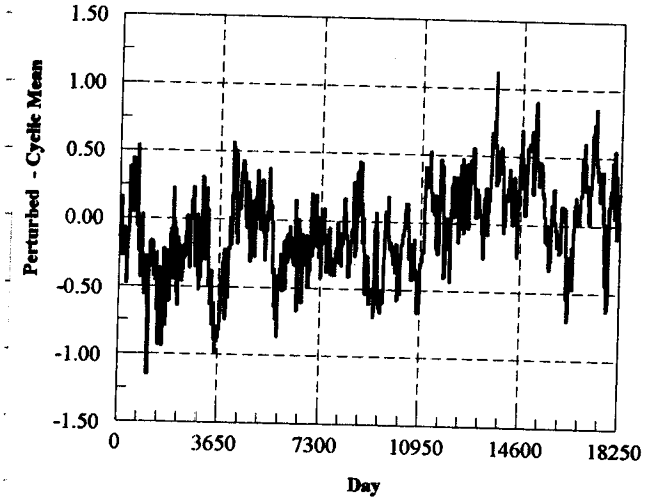


SOI - PDO Perturbations of Transition Probability P110
Forty Mile Canyon - 50 Year Simulation

File: C: | CLIMAT05 | SIM_05ASYM | FORTYMC2_2BP110_DEV.PGW
Data: C: | CLIMAT05 | SIM_05ASYM | FORTYMC2P_2B.PDW
dew 6 - 21 - 05

This nonstationarity is also shown in the plot of annual precipitation vs years on p 85. A linear regression shows that about 16% of the variance is explained by the linear trend.

DAW 6-21-05

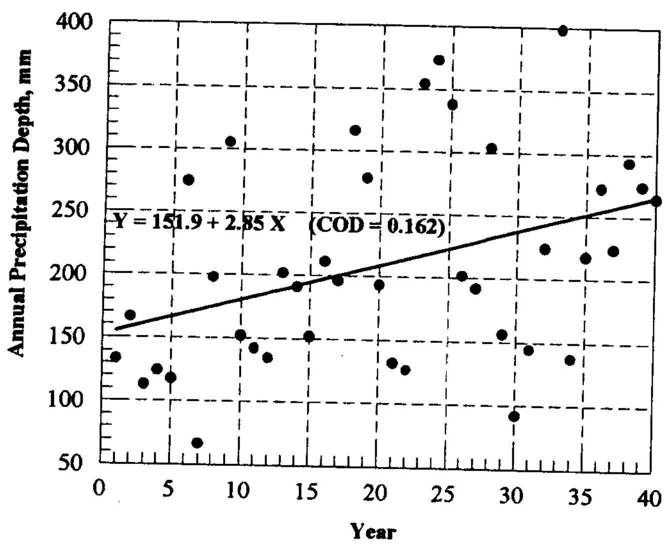


SOI - PDO Perturbations of Mean Daily Precipitation
Forty Mile Canyon - 50 Year Simulation

File: C: | CLIMAT05 | SIM_05ASYM | FORTYMC2_2MUDEV.PGW
Data: C: | CLIMAT05 | SIM_05ASYM | FORTYMC2P_2B.PDW
daw 6 - 21 - 05

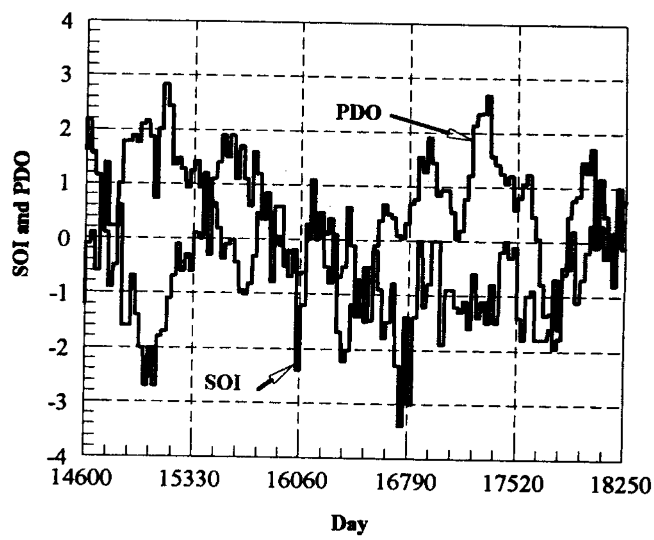
The data in the Fig below are yearly values for the daily data used to identify the cyclic components of the MC2-ME model as well as the perturbation coefficients. Note yearly periods are Mar-Feb with leap days excluded.

A plot of the SOI and PDO for the last 10 yrs of the simulated record is shown below. Note the combinations of large positive PDO and large



Annual Precipitation vs Time
Forty Mile Canyon, NV

File: C: | CLIMAT05 | SIM_05ASYM | FORTY_REAL_ANNUAL.PGW
Data: C: | CLIMAT02 | FORTY_ANNUAL.PDW
daw 6 - 21 - 05



Time Series of Monthly SOI and PDO
Last 10 years of Simulated Data (1987 - 1996)

File: C: | CLIMAT05 | SIM_05ASYM |SOI_PDO_LAST10.PGW
Data: C: | CLIMAT05 | SIM_05ASYM | FORTYMC2P_2B.PDW
daw 6 - 21 - 05

negative SOI.

DAW 6-27-05

For Forty Mile Canyon.

Check hypothesis that the mean of the first 20 yrs is the same as the mean of the second 20 yrs

Mean of 1st 20 = μ_1 = 183.98

Var, = σ_1^2 = 4575.94

Mean of 2nd 20 = μ_2 = 236.75

σ_2^2 = 8019.16

Test that difference of two means = 0.

$$Z = \frac{\mu_1 - \mu_2}{\sqrt{\frac{\sigma_1^2}{20} + \frac{\sigma_2^2}{20}}} = \frac{52.77}{25.09} = 2.10$$

at 0.05 level H_0 is rejected if $Z > 1.96$

For the simulated 50-yr series.

$H_0: \mu_{30} = \mu_{20}$ when μ_{30} = mean of first 30 yrs

μ_{20} = mean of second 20 yrs

DAW 6-27-05

$$Z = \frac{188.98 - 223.68}{\sqrt{\frac{2416.27}{30} + \frac{7040.32}{20}}} = 1.67$$

$1.67 < 1.96$ ∴ H_0 cannot be rejected.

DAW 6-29-05 Add analysis with SOI + PDO perturbations with 1 coefficient and independent, ie

$\tilde{G}_{ijo}(t) = G_{ijo}(t) + a_{ijo}\, SOI(t-\tau)$ - 2 parameters coef + lag

$\tilde{G}_{ijo}(t) = G_{ijo}(t) + b_{ijo}\, PDO(t)$ - 1 parameter

These additions were added to program MC2_SPOPT05.F95 and runs documented on p 67 were rerun with the same control files. The output files now are in the form of the updated program.

DAW 7-8-05

Summaries of results are found in the following Tables.

Discussion of results in draft manuscript C:\SWRI_REPORTS_05\SOI_PDO_MC2ME
Word Perfect

21

Table 2
SOI - PDO Perturbations Of Second Order Markov Chain - Forty Mile Canyon, NV

Perturbation		SOI			PDO		Log L	Lag
	A_{ijo}	a_{ijo}	α_{ijo}	B_{ijo}	b_{ijo}	β_{ijo}		Days
G000							-2762.99	
Both (4) **	0.0289		0.2377	0.200		-0.0703	-2748.57	0
SOI (2) *	0.0426		0.1415				-2755.16	0
SOI (1) *		0.1302					-2754.85	0
PDO (2)				0.0527		-0.0153	-2762.38	
PDO (1)					0.207		-2762.80	
Both (2) *		0.154			0.0730		-2752.64	0
G100							-361.25	
Both (4) *	0.219		0.274	0.238		-0.163	-356.18	60
SOI (2) *	0.351		0.1632				-357.40	60
SOI (1) **		0.1948					-357.83	60
PDO (2)				0.0057		-0.1739	-360.56	
PDO (1)					-0.0689		-360.98	
Both (2) *		0.206			0.039		-357.75	60
G010							-604.50	
Both (4) *	-0.190		0.208	-0.0447		-0.502	-591.35	30
SOI (2) *	0.0837		0.1583				-601.14	30
SOI (1) *		0.1401					-601.31	30
PDO (2) *				-0.238		-0.359	-594.57	
PDO (1) **					-0.2926		-594.97	
Both (2) *		0.055			-0.267		-594.57	30
G110							-564.99	
Both (4)	0.200		-0.017	-0.156		-0.067	-561.91	120
SOI (2)	0.211		0.056				-563.34	120
SOI (1)		0.0874					-563.90	120
PDO (2)*				-0.1323		-0.1569	-562.82	
PDO (1) **					-0.1389		-562.83	
Both (2)		0.046			-0.120		-562.58	90

* Significant improvement over unperturbed model.
** Superior according to AIC

Jaw 7-8-05

Table 3 Perturbation Coefficients for G_{000}, Nevada Stations

Station	A_{000}	α_{000}	B_{000}	β_{000}	Log Lik Increase	Period of Record Perturbed
Ranier Mesa	0.0457	0.237	0.159	0.0057	15.68	1960-94
Forty Mile Canyon	0.0289	0.238	0.200	-0.0703	14.41	1960-98
Jackass Flats	0.149	0.257	0.186	-0.0346	19.53	1959-98
Yucca Dry Lake	0.147	0.268	0.178	-0.0791	22.19	1959-98
Las Vegas	0.222	0.222	0.0727	-0.0743	17.92	1957-97
Averages	0.1185	0.244	0.1591	-0.0510		

Table 4a. Increase of Log likelihood functions due to SOI and PDO effects for G_{010}, Nevada Stations

Station	SOI & PDO (4)	SOI (2)	SOI(1)	PDO (2)	PDO(1)	SOI & PDO (2)
Ranier Mesa	2.83	2.48	2.20**	0.26	0.069	1.91
Forty Mile Canyon	13.15*	3.36*	3.01*	9.93*	9.53**	9.93*
Jackass Flats	7.45*	6.63*	5.32*	2.96*	2.85**	6.16*
Yucca Dry Lake	5.68*	4.86**	3.50*	1.42	1.41*	3.80*
Las Vegas	2.84	2.57	1.38	0.318	0.307	1.39

* Significant improvement over unperturbed model.
** Superior according to AIC

Table 4b. Increase in Log likelihood functions due to SOI and PDO effects for G_{110}, Nevada Stations

Station	SOI & PDO (4)	SOI (2)	SOI(1)	PDO (2)	PDO(1)	SOI & PDO (2)
Ranier Mesa	4.33	1.65	1.42	2.78*	2.98**	3.06*
Forty Mile Canyon	3.07	1.64	1.09	2.16	2.15**	2.17
Jackass Flats	1.93	1.41	1.30	1.20	1.17**	1.66
Yucca Dry Lake	2.93	0.887	0.283	0.136	0.006	0.303
Las Vegas	0.661	0.647	0.640	0.0975	0.025	0.653

* Significant improvement over unperturbed model.
** Superior according to AIC

Table 5. SOI and PDO Perturbation Coefficients for G_{010}, Nevada Stations

Station	SOI(1) a_{010}	PDO (1) b_{010}	SOI Lag, days
Ranier Mesa	0.114	-0.023	0
Forty Mile Canyon	0.140	-0.293	30
Jackass Flats	0.213	-0.169	120
Yucca Dry Lake	0.147	-0.115	0
Las Vegas	0.111	0.062	60
Average	0.145	-0.108	

Table 6. Perturbation Coefficients for G_{000}, Arizona and New Mexico Stations

Station	a_{000}	b_{000}	Log Likelihood Increase	Period of Record Perturbed
Nogales, AZ	0.126	-0.0061	8.44	1934-82
RG4, AZ	0.118	-0.074	13.14	1955-94
Hobbs, NM	0.0797	-0.0444	9.42	1938-97
Averages	0.108	-0.0415		

DAW 7-8-05

26

Table 7. SOI and PDO Perturbations Of the mean of the mixed exponential Distribution

Station	Perturbation	SOI C_1	PDO C_2	Log L	Lag, Days
Forty Mile	none			-4012.22	
	Both (2) *	-0.0009	0.3241	-4008.79	0
	SOI (1)	-0.2522		-4009.50	120
	PDO (1) **		0.3187	-4008.80	
Jackass	none			-2893.49	
	Both (2) **	-0.2633	0.4386	-2881.91	30
	SOI (1) *	-0.4337		-2885.89	30
	PDO (1) *		0.5588	-2884.65	
Ranier Mesa	none			-4990.84	
	Both (2) *	-0.2050	0.3548	-4985.21	120
	SOI (1) *	-0.3772		-4987.44	120
	PDO (1) **		0.4401	-4986.18	
Yucca Dry Lake	none			-3407.47	
	Both (2)	-0.1101	0.0796	-3406.14	30
	SOI (1) **	-0.2704		-3405.15	120
	PDO (1)		0.1481	-3406.67	
Las Vegas	none			-2387.66	
	Both (2)	-0.230	-0.0849	-2386.48	
	SOI (1)	-0.193		-2386.59	
	PDO (1)		0.0415	-2387.63	
Nogales, AZ	none			-8148.92	
	Both (2) *	-0.4372	0.1048	-8143.24	60
	SOI (1) **	-0.4660		-8143.47	60
	PDO (1)		0.2439	-8147.44	

Station	Perturbation	SOI	PDO	Log L	Lag, Days
RG4, AZ	none			-5658.89	
	Both (2) *	-0.4577	-0.1924	-5652.15	90
	SOI (1) **	-0.4014		-5653.13	90
	PDO (1)		-0.0185	-5658.87	
Hobbs, NM	none			-8202.65	
	Both (2) *	-0.2519	0.5700	-8194.37	30
	SOI (1) *	-0.4140		-8199.54	30
	PDO (1) **		0.6315	-8195.41	
Spokane, WA	none			-15977.24	
	Both (2)	0.0523	0.1278	-15976.34	60
	SOI (1)	-0.0042		-15977.02	120
	PDO (1)		0.00214	-15977.22	

These results were incorporated into the paper "Combined Effects of the Southern Oscillation Index and the Pacific Decadal Oscillation on a Stochastic Daily Precipitation Model"
File : C:\SWRI-REPORTS-05\SOI-PDO-MC2ME.WPD
The manuscript (on a CD) was sent to Randall Fedors for review.

Date 7-21-05 Re-examine Report "Stochastic Weather Simulation for Future Climate Conditions at Yucca Mountain, Nevada"
File: C:\SwRI_Journal Papers\FUT climate 0_2 Rev. wpd
The analyses used to develop the findings in the above paper can be found in Scientific Notebook 365, 14–61.

After reviewing the paper, the following short comings were identified.

1) The parameter adjustments to get a target expected annual precipitation include only the annual mean of the dry-dry transition probability, P_{00}, and the annual mean of the mean daily precipitation minus a threshold, $\bar{\mu}$. The annual mean of the wet-dry transition probability, P_{10} is not included so there is no adjustment of the mean persistence parameter.

2) The adjustments to get a target expected mean annual precipition are done simultaneously for the occurrence process (MC1) and the parameter $\bar{\mu}$, with a arbitrary weighting factor of 0.5. Because of the problems encounted with the Spokane climate, it may be advantageous to adjust $\bar{P}_{00}$ and $\bar{P}_{10}$ to match a target mean number of wet days and then to adjust $\bar{\mu}$ to match the target mean annual precipitation

3) The procedure is limited to the 1st order Markov chain (MC1).

DAW 7-22-05 Future Climate (Con't.)

Items 1) and 2) can be corrected with little additional effort. Item 3 would require considerable effort.

Task: Address Items 1) and 2).

In the present manuscript the following two criteria are used to fit the change in seasonality for a proposed changed climate:

1) The normalized expected number of wet days function for the target station should closely follow that of the analog station.

2) The normalized expected accumulated precipitation function for the target station should closely follow that of the analog station.

An additional criterion might be added:

3) The ratio of DAW 7-22-05 of mean annual precipitation, MAP, to the mean annual number of wet days, MAN for the target station should match that for the analog station.

Let us examine the ratio R = MAP/MAN for several stations:

Sta	R	Sta.	R.	Sta.	R.
Ranier Mesa	5.29				
Buster Jangle	4.28	Yucca Dry Lake	4.81	RG4, AZ	5.67
Cane Springs	5.36	40 Mi. Canyon	4.73	Nogales, AZ	7.00
Desert Rock	4.47	Mercury	4.26	Hobbs, NM	9.28
Jackass Flat	4.39	Las Vegas	3.98	Spokane, WA	3.78
Tippipah Springs	5.11				
Well 5B	3.71				

DAW 7-22-05 Future Climate (cont.)

The range of MAP/MAN for the Nevada Stations is quite large (3.77 - 5.29) with the larger values corresponding to higher elevation stations.
The range for the monsoon stations (3.67 to 9.28) is also quite large. Note that is ratio with dimension (L in mm) is indicative of the average precipitation per wet day.

Let us consider the consequences of criterion 3 on p 91.
If MAP is increased by 10% and R is preserved for the case where MAP = 200 mm and MAN = 50 days then

$$\frac{200+20}{50+\Delta N} = R = 4.0$$

$50+\Delta N = 220/4 = 55$ days. Thus all of the increase in MAP is achieved by adjusting the number of wet days.
If R is increased by 10% all of the increase in MAP is due to an increase in wet-day precipitation.
If R is increased by 5%, the increase is apportioned equally between the number of wet days and precipitation per wet day. This would be nearly equivalent to the procedure used in the Scientific Notebook 365 except both $\bar{p}_{00}$ and $\bar{p}_{10}$ could be adjusted to get MAN.

In retrospect, it appears that using the local Yucca Mtn regression results of parameters with MAP is correct if considering changes in MAP with present day seasonality. The temperature regressions with elevation will be valid for all seasonalities

DAW 7-22-05 Future Climate (Cont)

and can be adjusted for future climate change. However for major changes in seasonality and number of wet days, it is preferable to simply use the Fourier Coefficients for MCS and μ for the ~~target~~ DAW 7-22-05 analog station with appropriate adjustments of $\bar{P}_{00}$, $\bar{P}_{10}$ and $\bar{\mu}$ to obtain a target MAP and MAN.

For adjustment of MAN:

DAW 7-22-05

$$E\{N(t)\} = \sum_{i=1}^{t} \left[P\{X(i-1)=0\} \cdot \underset{P_{01}}{P_{0p}(i)} + P\{X(i-1)=1\} \cdot P_{11}(i) \right]$$

For MAN, $t = 365$ Define to error function

$E(MAN) = E\{N(365)\} - MAN$ where MAN is the target

we wish $E(MAN) \rightarrow 0$

we wish to adjust $\bar{G}_{00}$ and $\bar{G}_{10}$ to achieve $E(MAN)=0$

Given a trial value of parameters G_{00} and G_{10}, get E

then we wish to iterate

$$w_1 E + \frac{\partial E}{\partial G_{00}} \Delta G_{00} = 0$$

$$(1-w_1)E + \frac{\partial E}{\partial \bar{G}_{10}} \Delta \bar{G}_{10} = 0$$

where w is a weighting factor, $0 \leq w \leq 1$

Now we need an approximate expression for $\frac{\partial E}{\partial G_{00}}$ and $\frac{\partial E}{\partial G_{10}}$

DAW 7-25-05 Future Climate (Con't)

From Scientific Notebook 363 p 37 we have

$$\frac{\partial E}{\partial G_{00}} = \frac{\partial E}{\partial P_{00}} \frac{d P_{00}}{d G_{00}} \times 365$$ for the MC1 counting process

If we use the approximation that P_{00} and P_{10} are constants

or $$\frac{\partial E}{\partial G_{00}} = \frac{-P_{10}}{(1+P_{10}-P_{00})^2} \frac{e^{G_{00}}}{(1+e^{G_{00}})^2} \times 365$$

the following identities can be substituted

$$P_{10} = \frac{e^{G_{10}}}{(1+e^{G_{10}})} \quad \text{and} \quad P_{00} = \frac{e^{G_{00}}}{(1+e^{G_{00}})}$$

Similarly:

$$\frac{\partial E}{\partial G_{10}} = \frac{\partial E}{\partial P_{10}} \frac{d P_{10}}{d G_{10}} \times 365$$

$$= \frac{-P_{00}}{(1+P_{10}-P_{00})^2} \frac{e^{G_{10}}}{(1+e^{G_{10}})^2} \times 365$$

The next question is: "What weighting factor, w, is appropriate.

DAW 7-26-05 Future Climate (Cont)

One objective approach would be to weigh the corrections to $\bar{G}_{00}$ and $\bar{G}_{10}$ according to their likelihood functions, which are related to sample size.

If we consider the resulting weights for 3 stations Spokane, WA, Jackass Flats NV and WG4, AZ.

Station	LG_{00}	LG_{10}	ω	$(1-\omega)$
Spokane	-13,828	-8,329	0.62	0.38
Jackass 8-11-05	-2983	-838	0.78	0.22
~~WG-4~~ DAW Nogales	-5492	-2389	0.70	0.30
DAW 8-11-05 ~~Nogales~~ WG4	- ~~54~~ DAW 8-11-05 3133	-1260	0.71	0.29

We see that the weighting factor for $\bar{G}_{10}$ is larger for the wetter stations. From the equations of p 93 we get the corrections $\Delta\bar{G}_{00}$ and $\bar{\Delta}_{G_{10}}$ as

$$\Delta\bar{G}_{00} = -\omega E \Big/ \left(\frac{\partial E}{\partial \bar{G}_{00}}\right)$$

$$\Delta\bar{G}_{10} = -(1-\omega) E \Big/ \left(\partial E / \partial \bar{G}_{10}\right)$$

Program SEASON5.F95 was created from SEASON4.F90 (referred to in Scientific Notebook 363 p 39). Modifications include: 1) Input value for target mean number of wet days 2) Iterate $\bar{G}_{00}$ and $\bar{G}_{10}$ to achieve target with input variable WEIGHT and (1-WEIGHT).

DAW 7-27-05 Future Climate (Cont)

After some progress was made on SEASON5.F95, breaking it into several subroutines, I decided on a new approach. When the objective is to change the mean annual number of wet days and/or the mean annual precipitation for the analog station, the control file will specify the MCME parameter files for the analog station for the base station as well. The code, STA-OPTION is set to 1 if the regional regressions are to be used, or is set to zero if the analog station with adjustments is to be used

DAW 8-11-05

The new program is C:\CLIMAT05\SEASON_05\SEASON5_2.F95

Testing procedure:

1) STA-OPTION = 1 files in above directory
Control file: YUC_SPOK4B2.CON
output files " .SEA + *.DAT
Analog: SPOKANE Base: Yucca Mtn adjusted

2) STA-OPTION = 0
Control file: YUC_SPOK4C.CON
Analog: Spokane Base: Spokane same MAP and MAN as Spokane MAN = 112 days MAP = 424 mm

3) Control file: YUC-SPOK4D.CON STA-OPTION = 0
Analog: Spokane; Base: Spokane
Target MAN = 100 days TARGET MAP = 400 mm

DAW 8-11-05 (cont)

An interesting test of the adjustment of MAN and MAP would be to run two stations with similar seasonality but different MAN and MAP but to adjust target values to match the other station. As an example, consider Walnut Gulch RG4 and Nogales, AZ.

DAW 8-11-05

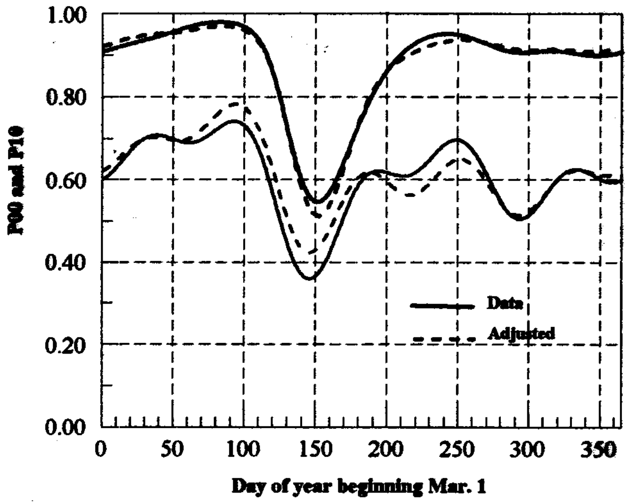
1) Control file C:\CLIMAT05\SEASON_05\ ~~W~~RG4ADJUSTA.CON
   Analog: RG4 ; Base: RG4
   For RG4 MAN = 53.57 MAP = 302.26 mm
   For Nogales MAN = 58.84 MAP = 411.72 mm
   From table on p 95 we see that the WEIGHT factor is nearly the same 0.70 for Nogales and 0.71 for WG4
   Target MAN = 58.84 Target MAP = 411.72 mm

DAW 8-12-05

2. Control File: C:\CLIMAT05\SEASON-05\NOGAL-ADJUSTA.CON
   Analog: NOGALES ; BASE: NOGALES STA-OPTION = 0
   MAN = 53.57 MAP = ~~3~~ 302.26 DAW 8-12-05

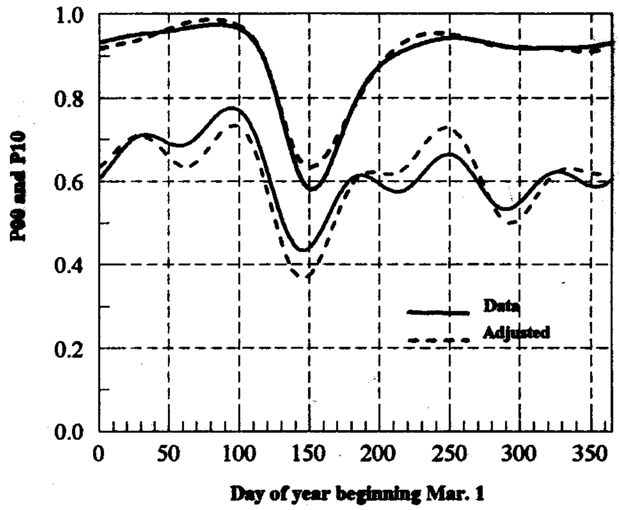
Compare output with C:\CLIMAT04\MC2OUT\NOGALMC2.DAT
Prepare Figures shown on p 98 + 99.

DAW 8-12-05



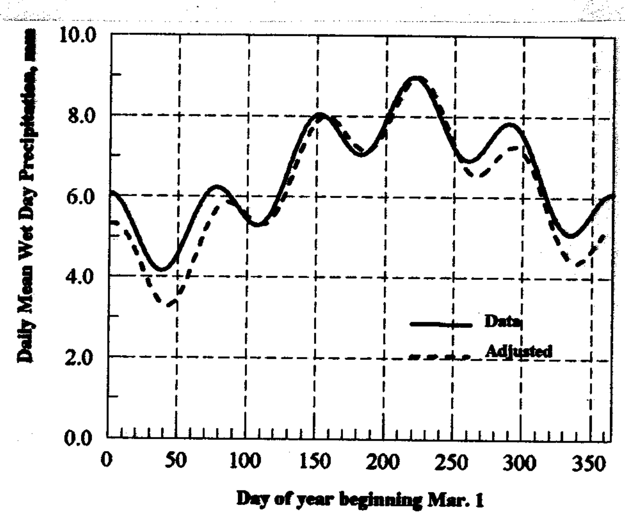
Transition Probabilities for Nogales as Adjusted from RG4

File: C: | CLIMAT05 | SEASON_05 | RG4toNogalesMC1.PGW
daw 8-12-05
Data: C: | CLIMAT05 | SEASON_05 | RG4ADJUSTA.DAT
C: | CLIMAT04 | MC2OUT | NOGALMC2.DAT



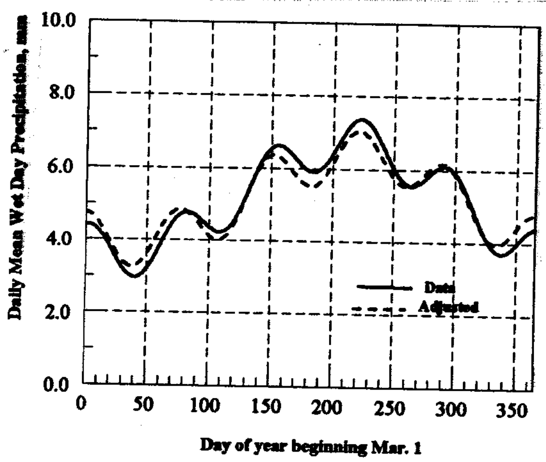
Transition Probabilities for RG4 as Adjusted from Nogales, AZ

File: C: | CLIMAT05 | SEASON_05 | NogalesToRG4MC1.PGW
daw 8-24-05
Data: C: | CLIMAT05 | SEASON_05 | NOGAL_ADJUSTA.DAT
C: | CLIMAT04 | MC2TEST | RG4MC2.DAT



Wet Day Precipitation for Nogales, AZ as Adjusted from RG4

File: C: | CLIMAT05 | SEASON_05 | RG4toNogalesMU.PGW
daw 8-12-05
Data: C: | CLIMAT05 | SEASON_05 | RG4ADJUSTA.DAT
C: | CLIMAT04 | MC2OUT | NOGALMC2.DAT

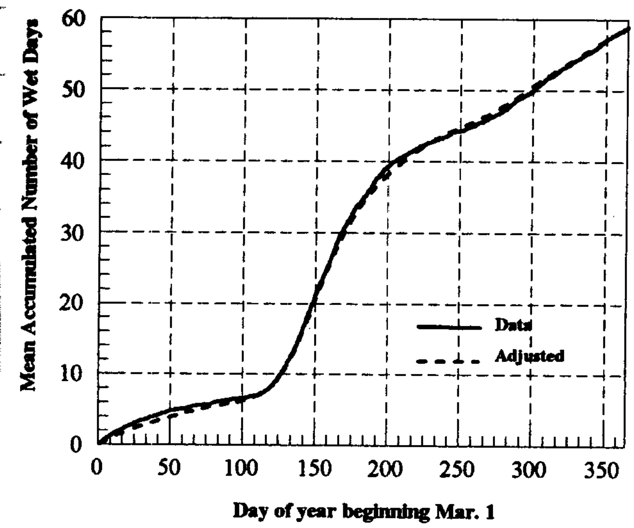


Wet Day Precipitation for RG4, AZ as Adjusted from Nogales

File: C: | CLIMAT05 | SEASON_05 | NogalestoRG4Mu.PGW
daw 8-24-05
Data: C: | CLIMAT05 | SEASON_05 | NOGAL_ADJUSTA.DAT
C: | CLIMAT04 | MC2TEST | RG4MC2.DAT

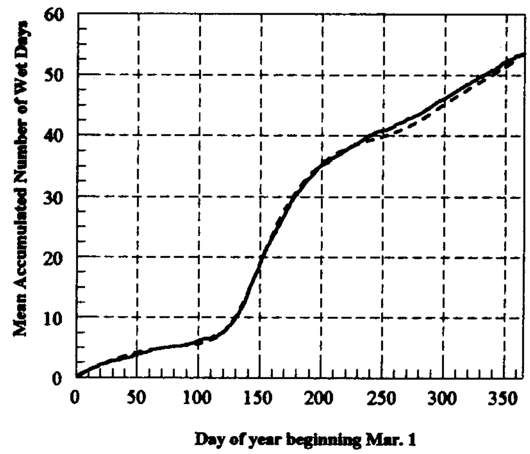
For discussion see p 100 DAW 8/25/05

DAW 8-12-05



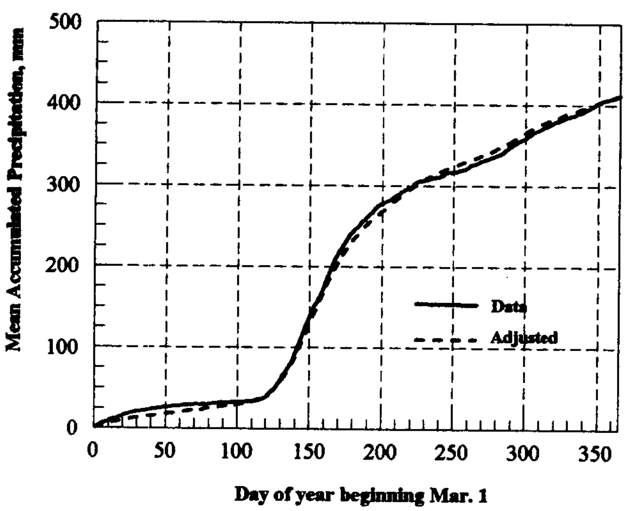
Accumulated Wet Days for Nogales, AZ as Adjusted from RG4

File: C: | CLIMAT05 | SEASON_05 | RG4toNogalesWetDays.PGW
daw 8-12-05
Data: C: | CLIMAT05 | SEASON_05 | RG4ADJUSTA.DAT
C: | CLIMAT04 | MC2OUT | NOGALMC2.DAT



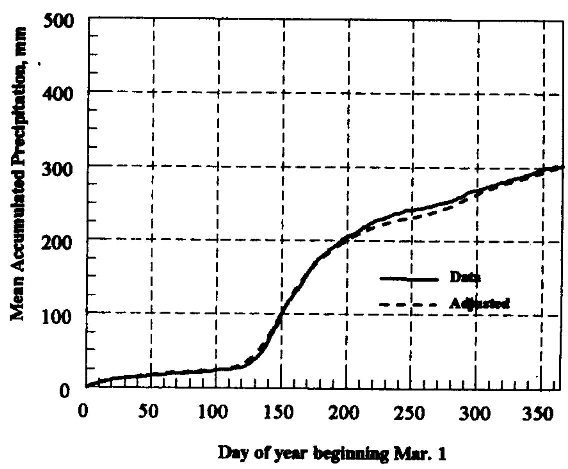
Accumulated Wet Days for RG4, AZ as Adjusted from Nogales

File: C: | CLIMAT05 | SEASON_05 | NogalestoRG4WetDays.PGW
daw 8-24-05
Data: C: | CLIMAT05 | SEASON_05 | NOGAL_ADJUSTA.DAT
C: | CLIMAT04 | MC2TEST | RG4MC2.DAT



Accumulated Precipitation for Nogales, AZ as Adjusted from RG4

File: C: | CLIMAT05 | SEASON_05 | RG4toNogalesAccumP.PGW
daw 8-12-05
Data: C: | CLIMAT05 | SEASON_05 | RG4ADJUSTA.DAT
C: | CLIMAT04 | MC2OUT | NOGALMC2.DAT



Accumulated Precipitation for RG4, AZ as Adjusted from Nogales

File: C: | CLIMAT05 | SEASON_05 | NogalestoRG4AccumP.PGW
daw 8-24-05
Data: C: | CLIMAT05 | SEASON_05 | NOGAL_ADJUSTA.DAT
C: | CLIMAT04 | MC2TEST | RG4MC2.DAT

For discussion see p 100 DAW 8/25/05

DAW 8-24-05

Now prepare figures showing the observed RG4 data with estimates as adjusted from Nogales

~~Nogs~~ DAW 8-24-05 RG4 data from C:\CLIMAT04\MC2test\RG4MC2.DAT

DAW 8-25-05

The comparable figures are pasted on pages 98 and 99.

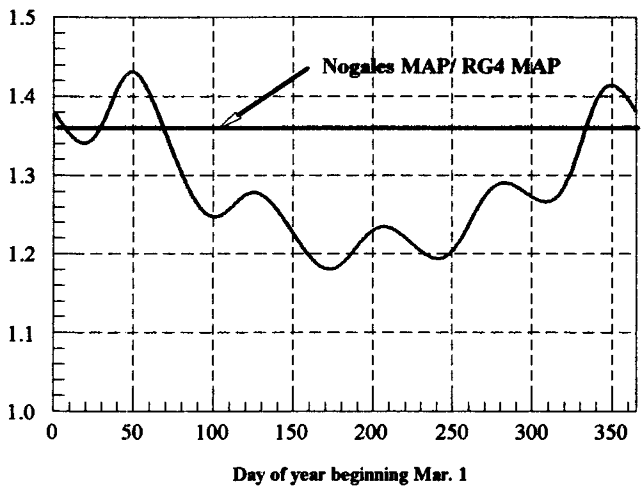
If we examine the Fourier Series representations of the transition probabilities on top of p 98 we see that the adjusted values have the same number of harmonics as those identified for each station. The fits are not perfect, of course, because there are real differences in the records due to different periods of record as well as sampling variability. It is worth noting that the deviations are smaller than those due to record length as shown on the figure on p 74 of scientific notebook 363.

For the mean wet-day precipitation on bottom of p 98 we see that again the number of harmonics are identical and that the adjusted values are very close to the values identified by the data during the monsoon period (days 100 - 200). The deviations are greater for the Nogales as adjusted from RG4 for the period Feb through May than for RG4 as adjusted from Nogales.

The mean accumulated number of wet days and the mean accumulated precipitation curves are very close for each adjustment.

DAW 8-26-05

To develop a precipitation input sequence for modern climate at Yucca Mtn, Hevesi (2000) scaled the precipitation amounts for the gage 4JA simulated 100-yr sequence using the ratio of MAP at YM (181 mm) and 4JA (140 mm) in order to account for orographic effects. This approach neglects the observed increase in number of wet days and assumes this ratio to be a constant throughout the year.
The relationship between MAP and MC2 parameters is documented in scientific notebook 363 p 14. To examine Hevesi's second assumption, I have plotted the ratio of Fourier series fits of mean daily precipitation for Nogales to mean daily wet day precipitation for RG4.



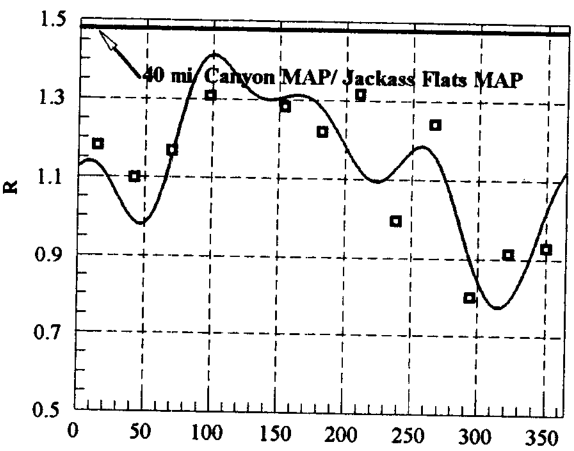
Ratio of Nogales, AZ Mean Wet Day Precipitation to RG4, AZ Mean Wet Day Precipitation

File: C: | CLIMAT05 | SEASON_05 | RATIONOGALTORG4MU.PGW
daw 8-25-05
Data: C: | CLIMAT05 | SEASON_05 | RG4ADJUSTA.DAT
C: | CLIMAT04 | MC2OUT | NOGALMC2.DAT

From this figure it is clear that increasing daily precipitation mean by a factor of relative MAPs would be a poor approximation for these monsoon climate stations. The ratio, R is below the MAP ratio (1.36) for most of the year, reflecting changes in number of wet days and first order persistence

Daw 8-26-05

To check this result for the Yucca Mtn area, the ratios were plotted for 40 mile Canyon (MAP=140.8 mm) and Jackass Flats (MAP=208.9mm) R=1.48.
The ratio of the Fourier Series fits as well as ratios of the sample means for 28 day periods are shown in the following figure.



Ratio of 40 mi Canyon, NV, Mean Wet Day Precipitation to Jackass Flats, NV Mean Wet Day Precipitation

File: C: | CLIMAT05 | SEASON_05 | RATIO40ToJackMU.PGW
daw 8-26-05
Data: C: | CLIMAT04 | MC2TEST | FORTYMC2.DAT
C: | CLIMAT04 | MC2TEST | JACKASSMC2.DAT

Again, it is clear that multiplication by a constant ratio would be inappropriate. It is interesting that the ratio is < 1.0 from days 280 – 350. Could this be caused by poor measurement of snow at the higher elevation gage 40 mile Canyon?
It is also apparent that the seasonal variations of the ratios are much different for these Nevada stations than they are for the Arizona stations

RL 4/14/2008

DAW 8-29-05 Future Climate (Con't)

Conclusions:

1) The technique adapted for adjusting MCME parameters to achieve target mean annual precipitation (MAP) and mean annual number of wet days (MAN) while preserving the seasonal variations of $E\{N(t)\}$ and $E\{S(t)\}$ appears to be working well.

2) Utilizing weighting factors for corrections of mean G_{00} and mean G_{10} based upon the ly likelihood functions is an objective procedure and it appears to give satisfactory results as demonstrated by the figures on p 98 and 99.

3) The technique used by Hevesi (2000) to develop precipitation sequences for modern climate at Yucca Mtn is inappropriate as it does not adjust the number of wet days and increases daily precipitation by a constant factor. The analyses shown on pp 101 and 102 shows that there is a significant seasonal variation in the ratios of mean daily precipitation amounts.

Hevesi, Joseph A. (Draft 2000) Simulation of Net Infiltration for Modern and Potential Future Climates. ANL-NBS-HS-000032 57 pp.

DAW 10-21-05

Simulation of daily precipitation, T_{max}, T_{min} and Radiation for 40-mile Canyon adjusted to elevation of Yucca Mtn + with SOI and PDO perturbations. Program MC2CLIMSIM_05.F95

Procedure:

1) Prepare control file

Save C:\CLIMAT05\SIM_05ASYM\FORTYMC2-2B.SIM

as: " " FORTYMC2_2C.SIM

SET TEMPRAD_CODE =1 ; T_{max}, T_{min} and Rad will be simulated

Output files will be \FORTYMC2.

2) Find appropriate parameter file for Temperature and radiation. The file c:\SIMULATIONS_02\MON3_4.DAT was used to simulate these items for a monsoon climate. Individual values were estimated from Hanson et al. (1994) or from regressions with elevation documented in Scientific Notebook #363 p. 18 + 19.

DAW 10-24-05

Simulated output without other information saved as FORTYMC2-2C.DAT

Parameter and perturbation coefficients saved as FORTYMC2-2C.INF (In above directory + Text files)

These 2 files were sent to Stuart Stothoff on 10-24-05.

DAW 10-24-05

Simulation of daily precipitation, Tmax, Tmin and Radiation for Walnut Gulch, AZ RG4.

RG4: El = 1278 m, yrs. record = 40

MAN = 54.2 days MAP = 307.4 mm

DAW 10-25-05

Program MC2_SPOPT05.F95 was modified to examine SOI-PDO Impacts of the form:

$$\hat{G}_{ij\delta}(t) = G_{ij\delta}(t) + a_{i\gamma c}\, SOI(t-\tau) + b_{i\gamma c}\, PDO(t)$$

Control file C:\CLIMAT05\ASYMMETRIC\RG4_OPT3.FIL was run. Perturbation coefficients in file " \RG4_OPT3.OUT

DAW 10-26-05 Prepare control file:

C:\CLIMAT05\SIM_05ASYM\RG4MC2P-1.SIM

Program MC2CLIMSIM_05.F95 was run with above control file

2nd Order MC output file is \RG4MC2P-1.PTR

Save simulated output w/o other info as: \RG4MC2P-1.DAT

Parameter and perturbation coefficients saved as \RG4MC2P-1.INF

Both are text files

Check statistics

Import RG4MC2P_1.DAT into PSIPLOT

Obtain column statistics

MAP = 290.3 mm Max daily = 60.14

Min " = 0

DAW 10-26-05 Check statistics of simulated data for RG4.

MAN = 51.08 days

$\overline{T}_{max}$ = 69.34 °F   max T_{max} = 119.0 °F
min T_{max} = 0.8 °F

$\overline{T}_{min}$ = 40.93°F   max T_{min} = 74.7 °F
min T_{min} = -11.6 °F

$\overline{Rad}$ = 471.67 Langleys   max = 890
min = 33

$\overline{P}_{000}$ =	0.897	S.D. = 0.088	max = 0.976	min = 0.642
$\tilde{P}_{000\,ave}$ =	0.896	S.D. = 0.0906	max = 0.983	min = 0.532
P_{100} =	0.849	S.D. = 0.124	max = 0.96	min = 0.505
$\tilde{P}_{100ave}$ =	0.846	S.D. = 0.126	max = 0.967	min = 0.429
P_{010} =	0.591	0.0883	0.773	0.479
$\tilde{P}_{010}$ =	0.640	0.116	0.921	0.365
P_{110} =	0.651	0.0985	0.791	0.466
$\tilde{P}_{110}$	0.649	0.1097	0.862	0.299
$\overline{\mu}$	4.958 mm	1.204	7.16	2.70
$\tilde{\mu}$	5.062	1.283	8.31	1.83

DAW 10-26-05 Check statistics of simulated data for 40-Mile Canyon

MAP = 198.45 mm Max = 86.77 mm July 31 yr 36

MAN = 41.54 days

	Mean	std. dev	max	min
Tmax	62.30°F	19.06°F	119.1°F	8.5°F
Tmin	40.86°F	14.37°F	75.5°F	−7.8°F
Rad	477.70 L	193.03	890	33
P_{000}	0.934	0.0195	0.969	0.895
$\tilde{P}_{000}$	0.933	0.0237	0.979	0.823
P_{100}	0.857	0.0118	0.874	0.840
$\tilde{P}_{100}$	0.855	0.0338	0.951	0.678
P_{010}	0.480	0.0588	0.565	0.366
$\tilde{P}_{010}$	0.513	0.1054	0.828	0.219
P_{110}	0.577	0.076	0.711	0.445
$\tilde{P}_{110}$	0.582	0.0840	0.790	0.377
μ	4.519	0.873	6.05	2.85
$\tilde{\mu}$	4.468	0.891	6.95	2.16

DAW 10-27-05 Additional Analyses of the effects of SOI and PDO on daily precipitation

As demonstrated on pages 70-76 the effects of SOI-PDO are fairly consistent for the Nevada stations investigated. Because there was only one station analyzed in the Pacific Northwest and 2 stations analyzed in Arizona it would be desirable to increase the number of station in those locations.

Go to the web site of the Western Regional Climate Center and locate stations with desirable quality and record lengths. http://www.wrcc.dri.edu

From Arizona Station Data Inventory

	Sta. No.	Sta. Name	Lat	Long	El (ft)	Start yy mm	Obs Typ tpwseh		End yy mm
	027773-7	Bisbee 2	3125	10953					
✓	022659-7	Douglas ~~FAA~~ Airport	3121	10932	0401	49 02	UU	U	57 11
	"	"	"	"	0404	57 11	UU	U	89 05
	"	" DAW 10-27-05	"	"	0404	89 05	12	U	99 99
	0273~~90~~88-7	Safford	3250	10943	0290	48 07	UU		73 06
✓	027390-7	Safford Exp. Farm	3249	10941	0295	48 07	UU	U	84 02
	" DAW 10-27-05	Safford Agr Ctr	"	"	"	84 02	UU	U5	99 99
✓	028796~~7~~-7	Tucson Camp Ave	3217	11057	0233	49 02	UU		86 12
	"	"	"	"	"	86 12	12		99 99

DAW 10-27-05

From Washington Station Data Inventory

Sta No	Sta name	Lat	long	El(ft)	Start yy mm	Obs Typ t p w s e h		End yy mm
✓ 458928-8	Walla Walla FAA	4606	11817	0119	49 01	UU		61 12
"	"	"	"	"	6701	UU		82 01
"	"	"	"	"	8201	UU		88 05
"	"	"	"	"	8805	12		99 99
✓ 459465-~~87~~	Yakima WSO	4634	12032	0106	4801	UU	UU	67 12
" -8	"	"	"	0105	6801	UU	UU	87 11
" -8	"	"	"	0106	8711	12	5U	99 99

DAW 10-27-05

DAW 11-2-05

Sta No	Sta name	Lat	long	El(ft)	Start yy mm	Obs Typ		End yy mm
✓ 456789-9	Pullman 2 NW	4646	11712	0255	4806	UU U	U	6308
" -0	"	"	"	"	6309	" "	"	8201
" "	"	"	"	0254	8201	" "	"	8603
" "	"	"	"	"	8603	12 U	7	9999
458009-5	Stampede Pass WB	4717	12120	0396	4801	UU	U	7709
"	" WSMO	"	"	"	7709	"	"	8104
"	" WSCMO	"	"	"	8104	"	"	9999

Sta	Av. Max Temp(°F)	Av Min Temp	Av Total P(in)	Av Snowfall (in)
Pullman	57.5	36.7	21.26	28.5 (Some missing)
Spokane (1891-2005)	58.0	38.0	16.04	41.0 (good)
Stampede	45.6	33.5	85.99 (2,184mm)	439.3 (missing data mid 90s)
Walla Walla	63.5	43.4	19.34	17.2 (")
Yakima	63.1	36.4	8.15	23.9 (Some missing)
Douglas AZ 022664	79.4	45.2	14.41 (230.6mm)	0 (good data)
Safford	80.0	46.3	9.08	1.0 (good data)
Tucson	84.2	50.3	11.69	0.4 (Some missing)

DAW 10-31-05

After reviewing the control file for RG4 (see p105-106) I note the the mixed exponetial mean was perturbed by both SOI + PDO I created a new file RG4MC2P-2.SIM with only SOI (see table p 89).

MAP = ~~303.67~~ 287.19 mm (DAW 10-31-05) MAN = 51.74 days

Max daily = ~~76.48~~ mm 67.08 mm (DAW 10-31-05) Aug 21, 37

13.08 mm on previous day

Diagnostic analysis of the new 50-yr. simulation follows

Obtained by importing text file into PsiPlot & getting column information

	Mean	Std. dev.	Max	Min	
T_{max}(°F)	69.07	19.09	114.9	5.2	
T_{min}(°F)	40.77	14.67	75.8	-10.1	
Rad(Ly)	473.03	187.5	890	33	(apparently upper + lower bounds)
P_{000}	0.897	0.088	0.976	0.642	
$\tilde{P}_{000}$	0.896	0.091	0.983	0.532	
P_{100}	same as p 106				
$\tilde{P}_{100}$	0.846	0.126	0.967	0.429	
P_{010}	same as p106				
$\tilde{P}_{010}$	0.640	0.116	0.921	0.365	
P_{110}	same as p106				
$\tilde{P}_{110}$	0.649	0.110	0.862	0.299	
μ(mm)	same as p106				
$\tilde{\mu}$(mm)	5.070	1.270	8.08	1.87	

Note: The perturbed parameters are identical to those on p106 except for $\tilde{\mu}$ which is now only perturbed by the SOI. Variations in temperature + radiation statistics are due to sampling variability.

DAW 10-31-05

On 10-27-05 I dowloaded the following files from the internet

C:\CLIMAT05\PDO_latest.htm Jan 1900 – Sept 2005
from: http://jisao.washington.edu/pdo/PDO.latest

and
C:\CLIMAT05\SOI-signal-ascii.htm Jan, 1866 – Apr., 2005

from http://www.cgd.ucar.edu/cas/catalog/climind/SOI.signal.ascii

With this combination, it will be possible to simulate 100 yrs of precipitation, T_{max}, T_{min} and Radiation with SOI-PDO perturbations. It will also be possible to reexamine SOI-PDO impacts on Spokane with longer period of record

DAW 11-2-05

Prepare SOI ASCII file (above) for SOI-PDO analysis
1. Rename to SOI_1866.txt in C:\CLIMAT05 ✓
2. Remove header information ✓ DAW 11-2-05

Prepare PDO ASCI file (above) for SOI-PDO analysis DAW 11-2-05
1. Rename to C:\CLIMAT05\PDO_00-~~0205~~ 2005.txt ✓
2. Remove header information and add same headings as C:\SIMULATIONS_02\SOIdata.PFC ✓
2. Remove header information and add same headings as " \PDO_latest.txt ✓

Note: In comparing the new SOI file with the previous file I find differences.! They are from different sources
PDO files are consistent

DAW 11-2-05

Given a longer SOI time series, reexamine the impact of SOI and PDO on Spokane, WA. using program MC2_SPOPT05.F95

Procedure:

1) Control file

DAW 11-2-05

Rename file: C:\CLIMAT05\Asymmetric\SPOKANE_OPT~~2~~3.FIL

to: " " \SPOKANE_OPT4.FIL

Spokane data start Mar 1, 1890, end Feb 28, 2002

I compared the SOI values in the new file SOI_1866.TXT with values in C:\SIMULATIONS_02\SOIdata.PFC and found differences as noted on p. 111. The old data had been obtained from Dr. Kelley Redmond, Regional Climatologist at Western Regional Climate Center (WRCC) and were annotated as coming from CAC - Climate Analysis Center. I then went to the web and found that there are several versions of the SOI. Possible sources are UCAR, NASA, NCEP, COADS-based and "Walker and Bliss." I sent an e-mail to Dr. Redmond asking if the CAC data set had been extended back to the late 1800's and if he has an opinion regarding the techniques used to derive the various indecies from Tahiti-Darwin pressure data. Until I receive a response I will wait before further analysis

DAW 11-3-05

Ordered daily data for Douglas, Safford and Tucson, AZ plus Pulman, Walla Walla and Yakima, WA. from Western Regional Climate Center. Contact was Dorothy Miller, Database/Accounting Mgr (775) 674-7010.

The following files were downloaded to C:\Analog-precip

douglas-dly.htm	pullman-dly.htm	all as AOL HTML Documents
safford-dly. "	walla-dly. "	
tucson-dly. "	yakima-dly. "	

These files have a different data format than those obtained earlier Nogales, AZ., for example. The station number doesn't precede the year, mo, day on each line and the code "OM" for observation missing is not in the same column as precipitation, Tmax and Tmin.

The program DAYREAD2.BAS was copied to DAYREAD3.BAS and the code was modified to accomodate these format changes. DAYREAD3.BAS will read a line at a time from the data files and convert it to a format required for program C:\CLIMAT04\MC2ME4-1.F95

DAW 11-4-05 Prepare input files for MC2ME4_1.F95

This is a 2 step procedure.

douglas-dly $\xrightarrow{\text{copy + edit}}$ douglas.txt ✓ $\xrightarrow{\text{Dayread 3.BAS}}$ douglas.PTT ✓

safford-dly ⟶ safford.txt ✓ ⟶ safford.PTT ✓

Tucson-dly ⟶ tucson.txt ✓ ⟶ tucson.PTT ✓

pullman-dly ⟶ pullman.txt ✓ ⟶ PULLMAN.PTT ✓

walla-dly ⟶ walla.txt ✓ ⟶ WALLA.PTT ✓

yakima-dly ⟶ yakima.txt ✓ ⟶ YAKIMA.PTT ✓

DAW 11-4-05

Because there may be block missing periods of record, we wish data to begin on Mar 1 and leap days should be eliminated, editing is required.

DOUGLAS.PTT delete to 3-1-1949 ✓

delete leap days ✓

Records 3/1/49 to 2/28/51 gap 3/1/65 to 2/28/94 gap 3/1/02 to 2/28/04

Entire record, as edited, may be used to identify MC2ME parameters, but only period 3/1/65 to 2/28/94 can be used to identify SOI-PDO perturbation parameters (unless program is modified) Time of reading 6am til 12/01/64; 6pm til 11/23/81; 5pm til 2/01/94; 7pm til 6/2/2005; 5pm til end.

DAW 11-7-05

SAFFORD.PTT Delete to 3-1-1949 ✓ Delete leap days ✓ (0.0 in deleted)

Check continuity of record. Number data rows on 2/28/2005 is 20440. This would be 56 years. Check!

There is a change in time of reading at 10/01/1963 from 6 am to 6 pm. Also a change from 6pm to 8 am on 1/01/1982 and a change from 8am to 5am on 6/01/05

TUCSON.PTT delete to 3/1/49 ✓ Delete leap days ✓ (No precip on leap days)

Check continuity of record.

12/31/57 to 3/1/59

3/1/49 to 2/28/57 (gap) ~~June~~ July missing in 1963, ∴ remove 3/1/63 to 2/28/64 ✓ DAW 11-7-05

Data missing Oct 1986 ∴ remove 3/1/86 to 2/28/87

" " Nov + Dec 2003 ∴ remove 3/1/03 to 2/28/2004

DAW 11-7-05

∴ There is a total of 52 yrs. for MC2ME parameter identification
For perturbations use 3/1/64 to 2/28/86

Note: For this station the missing records are rather short. One could insert lines with the -99.9 code. This would affect computations of monthly and annual sums of wet days and total precipitation, but would not affect the log likelihood functions in program S_P_OPT05.F95 because transitions with missing data are ignored.

For this station create a second file with missing lines inserted for perturbation analysis. Save TUCSON.TXT as TUCSON2.TXT

Run program DAYREAD3.BAS get TUCSON2.PTT

DAW 11/8/05 ~~198~~ 1958 is missing. Too long to insert -99. code for SOI-PDO?

Replace July '63 with -99. codes ; Replace Oct. '86 with -99.0 codes

Replace Nov. + Dec. with -99.0 codes ∴ 54 yrs for MCZME analyses and 1959-2003 for SOI-PDO analysis.

PULLMAN.PTT delete to 3/1/1941 ✓ Delete leapdays ✓ (0.67 inches deleted)

6 days missing 7/22 - 7/28, 1950. Insert 6 days with neg precip code

5 days missing 12/27 - 12/31, 1956 + 1/1 - 1/3 1957 (+3 more)

3 days missing 6/13 - 6/15, 1956 All ~~Paste~~ DAW 11/7/05 inserted with -99. code

8 days missing 12/1 - 12/8 1957 " "

1 day missing 6/1/62 Month of July missing 1974

31 days missing 3/1 - 3/31, 1994

31 " " 3/1 - 3/31, 1997

64 years with missing lines inserted with -99 code
1941 - 2004

6 am 1941 - 4/30/1955; 6pm 5/1/1955 - 12/31/81; 8 am 1/1/82 - 11/30/94

24hr 12/1/94 - 12/31/94; 8 am 1/1/95 - 1/31/2000; 20h 2/1/2000 - 2/29/2000; 8h till end

DAW 11-7-05

WALLA.PTT

delete to 3/1/50✓ delete leap days✓ (0.49 inches deleted)

DAW 11-8-05

Check continuity of record

3/31/1951 missing - insert record with -99. codes

8/7/1959 " " " "

period 2/23/95 to 2/28/99 missing

insert 2/23/95 - 2/28/95 with -99. codes. This will

give a complete record to 2/28/95 for SOI-PDO study

Record from 3/1/99 to 2/28/01 is complete, but ignore

for both MC2ME + SOI-PDO studies

Check starting times (time of reading)

18h 3/1/50-5/31/50; 6h 6/1/50-6/30/50; 18h 7/1/50-12/31/81; 24h 1/1/80-end

YAKIMA.PTT delete to 3/1/47✓; delete leap days✓ (0.12 inches deleted)

Record is continuous from 3/1/47 to 2/28/2005 58 yrs

Check time of reading.

18h 3/1/47-12/31/81; 24h 1/1/82-end of record

DAW 11-8-05 MC2ME parameter identification

1. Prepare control files for MC2ME4-1.F95
Control files and output files will be in directory C:\CLIMATO5\MC2ME
Douglas, AZ DOUGLASMC2.FIL ✓✓

DAW 11-9-05

SAFFORD, AZ	SAFFORDMC2.FIL ✓✓	
TUCSON, AZ	TUCSONMC2.FIL ✓✓	52 yrs
TUCSON2, AZ	TUCSON2MC2.FIL ✓✓	with -99. codes 54 yrs
PULLMAN, WA	PULLMANMC2.FIL ✓✓	MAP=537.9mm, MAN=113.7 days
WALLA WALLA, WA	WALLAMC2.FIL ✓✓	4? yrs MAP=493.9mm; MAN=106.5 days
YAKIMA, WA	YAKIMAMC2.FIL ✓✓	MAP=208.0 mm; MAN=69.4 days

2. Run program MC2me4_1.F95 with above control files
All runs completed.
output files of form *.OUT - summarized output data
*.DET - detailed data from optimization
*.DAT - Annual daily values of parameters + data averages

DAW 11-10-05
Create summary files with means, amplitudes + phase angles
MC1 and MC2 : C:\CLIMATO5\MC2ME\MC1+MC2SUMMARY.TXT
ME : C:\CLIMATO5\MC2ME\MESUMMARY.TXT
Obtained by copying from *.OUT files
Purpose: To facilitate creating of Fourier Coefficient (*.FOU) files
for input to SOI, PDO analysis.
DOUGLASMC2.FOU ✓; DOUGLASMC1.FOU; DOUGLASME.FOU

Dave 11-10-05 Continue creating Fourier Files for MC1, MC2 and ME in C:\CLIMAT05\MC2ME

TUCSONMC1.FOU ✓; TUCSONMC2.FOU ✓; TUCSONME.FOU ✓

TUCSON2MC1.FOU ✓; TUCSON2MC2.FOU ✓; TUCSON2ME.FOU ✓

SAFFORDMC1.FOU ✓; SAFFORDMC2.FOU ✓; SAFFORDME.FOU ✓

PULLMANMC1.FOU ✓; MC2 ✓ ME ✓

WALLAMC1.FOU ✓ MC2 ✓ ME ✓

YAKIMAMC1.FOU ✓ MC2 ✓ ME ✓

Make graphical comparisons of P_{000}, P_{100}, P_{010} and P_{110} for Arizona stations. Files are AZ_PDDD.PGW, AZ_PWDD.PGW, AZ_PDWD.PGW and AZ_PWWD.PGW

For PDDD, there is virtually no difference between TUCSON and TUCSON2, reflecting only different record lengths. Douglas shows a more pronounced effect of the monsoon season

For PWDD, there is greater variability between stations, due to climate differences and smaller sample size

For PDWD, Douglas shows a great variability because 5 harmonics were identified, as compared with only one for Safford and Tucson. This is probably an overfit.

For PWWD, Douglas had 2 significant harmonics versus one each for Tucson and Safford.

DAW 11-11-05 Create Control files for SOI-PDO perturbation analysis: Program for analysis is MC2_SPOPT05.f95

C:\CLIMAT05\Asymmetric\DOUGLAS_OPT.FIL ✓
output will be in C:\SOI_PDO_05

\SAFFORD_OPT.FIL ✓ 1949-98
\TUCSON2OPT.FIL ✓ 1959-98
\PULLMAN_OPT.FIL ✓ 1941-98
\WALLA_OPT.FIL ✓ 1950-94
\YAKIMA_OPT.FIL ✓ 1947-98

RUN PROGRAM MC2_SPOPT05.f95

C:\SOI_PDO_05\DOUGLAS_OPT.OUT ✓
" \SAFFORD_OPT.OUT ✓
" \TUCSON2_OPT.OUT ✓
" \PULLMAN_OPT.OUT ✓
" \WALLA_OPT.OUT ✓
" \YAKIMA_OPT.OUT ✓

DAW 11-15-05 Identify perturbation coefficients for mixed exponential distribution Program S_PDOME_05.F95
Control files in C:\CLIMAT05\AYSMMETRIC
DOUGLASMEOPT.FIL ✓✓, TUCSON2MEOPT.FIL ✓✓, SAFFORDMEOPT.FIL ✓✓
PULLMANMEOPT.FIL ✓, WALLAMEOPT.FIL, YAKIMAMEOPT.FIL
Output files will be in directory C:\SOI_PDO_05\
and will be of the form DOUGLASMEOPT.OUT or *.DET

Daw 11-16-05 Continue SOI-PDO Analysis

Program S_PDOME_05.F95 was run for each of the stations on p119. and results were summarized

Now check effects of longer SOI and PDO series

First Run MC2_SPOPT05_F95 with control file
C:\CLIMATO5\Asymmetric\SPOKANE_OPT4_FIL (See p 112)

No try Spokane with new SOI + PDO but the same record length as SPOKANE_OPT3.FIL
New control file is SPOKANE_OPT5.FIL

Daw 11-18-05
Rerun SPOKANE_OPT3.FIL
Runs SPOKANE_OPT3.FIL and SPOKANE_OP5.FIL have the same record length (1934-1998) but have different SOI series.
The same perturbation cases for G000 led to the same significance and PDO(2) had the minimum AIC for both cases
For G100 the UCAR series resulted in Both(4) leading to a significant improvement while the CAC series did not. However both showed Both(2) as min. AIC.
For G010 SOI(1) was marginally significant ($\Delta \log L = 2.10$) for CAC but was not for UCAR ($\Delta \log L = 1.99$).
All other perturbation cases for G010 and G110 were insignificant for both series.

DAW 11-18-05

File SPOKANE_OPT4.FIL has a longer record (1901-2001) and uses the UCAR SOI series.

For G_{000}, it identified PDO(2) as AIC minimum as was the case for *_OPT3 and *_OPT5 with some differences in the coefficients

For G_{110} Both(4) had min AIC while for the other 2 cases Both(2) had the min. AIC.

DAW 11-22-05

Rerun RG4_OPT3.FIL, NOGALES_OPT3.FIL, HOBBS_OPT3.FIL

Save as and update

RG4_OPT4.FIL ✓, NOGALES_OPT4.FIL ✓, HOBBS_OPT4.FIL ✓

OUTPUT in C:\CLIMAT05\

DAW 11-23-05 Interpretation of SOI-PDO effects for 3 regions.

Two aspects must be considered:

1) Coherence of MC2ME parameters within each region
2) Coherence of SOI-PDO perturbation coefficients within each region

One way to evaluate the coherence of MC2ME parameters is to compare the number of significant harmonics for G_{000}, G_{100}, G_{010}, G_{110}, α, β and μ for each regional grouping.

DAW 11-25-05

A summary of Fourier Series Constants and number of significant harmonics for the MC2ME model for each station is shown in the following table. The data are arranged by region and regional averages of the constants are shown. File: C:\CLIMATO5\MC2ME\MC2ME_COHERENC.WPD

	G_{000}		G_{100}		G_{010}		G_{110}		α		β		μ	
Station	Mean	N_{har}	Mean	N_{har}	Mean	N_{har}	Mean	N_{har}	Mean	N_{har}	Mean	N_{har}	Mean	N_{har}
40 Mile	2.69	5	1.80	1	-0.083	2	0.318	2	0.380	0	0.607	1	4.51	4
Jackass	2.88	5	1.82	1	0.541	2	0.671	3	0.323	0	0.403	0	4.02	2
Ranier	2.46	5	1.76	1	-0.10	3	0.230	2	0.307	1	0.686	1	5.50	3
Yucca	2.78	5	1.98	1	0.362	1	0.479	1	0.396	1	0.752	2	4.52	2
Las Vegas	3.00	5	2.19	3	0.840	2	1.025	1	0.345	1	0.370	0	3.70	3
Average	2.76		1.90		0.311		0.545		0.350		0.564		4.45	
Douglas	2.29	5	1.69	2	0.217	2	0.445	2	0.350	0	0.798	1	5.43	1
Nogales	2.37	5	1.70	5	0.358	5	0.662	5	0.307	0	1.365	1	6.36	2
RG4	2.42	4	1.97	4	0.385	2	0.651	2	0.283	0	1.053	1	4.96	2
Safford	2.32	4	2.00	3	0.346	1	0.606	1	0.357	0	0.621	2	4.05	1
Tucson	2.50	5	1.86	3	0.548	1	0.738	1	0.317	0	1.494	2	6.25	1
Hobbs	2.36	4	1.88	1	0.767	5	0.846	5	0.328	1	1.530	2	8.29	1
Average	2.38		1.85		0.437		0.668		0.324		1.144		5.89	
Pullman	1.43	5	0.96	2	-0.0256	3	-0.0054	3	0.248	0	1.305	2	4.47	2
Spokane	1.44	5	0.89	2	0.0361	5	0.0959	5	0.153	0	0.174	2	3.47	2
Walla	1.52	5	0.96	2	0.0739	1	0.158	1	0.160	0	0.298	1	4.58	3
Yakima	1.99	4	1.45	2	0.400	3	0.215	3	0.215	0	0.150	1	2.73	2
Average	1.59		1.07		0.121		0.139		0.194		0.482		3.81	

The total number of parameters required for each station varies from 31 (Safford, AZ) to 51 (Nogales, AZ). If all parameters were estimated monthly, 84 would be required, so the Fourier Series representation is parsimonious. The greatest variation within a climatic group is due to differences in MAN and MAP. For example Yakima has lower precipitation than the other Washington stations leading to higher constant values for the MC2 parameter

DAW 11-25-05

and lower values of the ME mean.
Las Vegas and Safford have similar differences in their respective groups.

DAW 12-9-05 Examine impact of seasonality.
Approach: The variates NULL_START and NULL_END in input to program MCZ-SPOPT05.F95 are set at 366 and 1 if perturbations are effective for the entire year. For control file: C:\CLIMAT05\Asymmetric\FORTY_OPT4.FIL they were set at 32 and 183 meaning that perturbations were not effective between day 32 (Apr. 1) and day 183.
Procedure: For 1 station in each region set up control files to create null periods Apr. + May, June + July, Aug + Sept. Compare the increase in Loglikelihoods for each MCZ and ME parameter with unperturbed increases. Current program MCZ-SPOPT05.F95 only nulls SOI perturbations

Stations: 40-Mile Canyon, RG4 and Pullman

Null Period	Null_Start	NULL_END
Apr, May	32	92
June, Jul	92	153
Aug, Sept	153	214

Create New Directory C:\CLIMAT05\NULLTEST
Control and output files will reside in this directory
Modify program MCZ-SPOPT05.F95 to Nullify PDO effects for the same period. Copy to above directory and rename MCZ-SPOPT05-2.F95
Changes made ✓

DAW 12-9-05 Continue studying Seasonal effects

Also modify MC2_SPOPT05.F95 to include null PDO ✓

DAW 12-12-05 To identify independent seasonal effects as well as interacting effects, follow this procedure

1) SOI seasonal effects
Set up 3 control files with null periods for SOI as shown on p 123. Output will yield Log likelihood changes for SOI only as well as SOI with null periods with continuous PDO perturbation.

2) PDO Seasonal effects
Set up 3 control files with PDO null periods as shown on p 123. Output will yield log likelihood changes for PDO only as well as PDO with null periods with continuous SOI perturbation

3) Take the combination of SOI null period (independent) and independent PDO null periods that result in maximum LogL increases and create 1 control file.

File naming strategy:

1) SOI Seasonal

	DAW 12-12-05 SOI Null days	
C:\CLIMAT05\NULLTEST\PULLMAN_OPTS1.FIL	32-92	✓
" " " _OPTS2.FIL	92-153	
" " " _OPTS3.FIL	153-214	

Examine SOI(3) and SOI(2) perturbations

DAW 12-12-05 Seasonal effects MC2

2) PDO seasonal

	PDO Null days
C:\CLIMATO5\NULLTEST\POLLMAN_OPTP1.FIL	32-92
" " " _OPTP2.FIL	92-153
" " " _OPTP3.FIL	153-214

Examine PDO(2) and PDO(1) perturbations

Output will have extensions *.OUT and *.DET

Increase in Log Likelihood for Pullman, WA

		All year	OPTS1	OPTS2	OPTS3
G_{000}	SOI(3)	4.32 **	2.94	4.38 *	5.85 **
	SOI(2)	2.59 *	1.14	3.54 **	3.84 *
G_{100}	SOI(3)	3.20 **	4.89 **	3.23 **	2.61 NS
	SOI(2)	0.77	2.48	1.48 NS	1.22 NS
G_{010}	SOI(3)	0.72	0.61	0.76 NS	1.28 NS
	SOI(2)	0.33	0.45	0.61 NS	1.09 NS
G_{110}	SOI(3)	3.0~~8~~ 9 ** DAW 12-12-05	3.97 **	2.63 NS	3.00 *
	SOI(2)	1 ~~2~~.83 ** DAW 12-12-05 NS DAW 12-12-05	3.75 ** DAW 12-13-05	1.33 NS	2.22 **
Σ Sig. increases		10.61	8.64 / 11.58	7.61	8.07
G_{000}	PDO(2)	3.27 **	4.37 **	4.53 *	4.71 **
	PDO(1)	0.94	1.80 *	3.69 **	2.24
G_{100}	PDO(2)	0.04	1.99	0.39	~~2.02~~ 0.076 DAW 12-12-05
	PDO(1)	0.38	1.47 **	0.19	~~0.50~~ 0.740 DAW 12-12-05
G_{010}	PDO(2)	1.40	0.64	0.53	2.02 **
	PDO(1)	0.26	0.003	0.03	6.50
G_{110}	PDO(2)	0.66	0.24	0.75	0.73
	PDO(1)	0.03	0.04	0.06	1.49 **
Σ Sig. Increases		3.27	5.84	3.69	8.22

Total Increase 4.95

DAW 12-12-05

Set up control files for RG4.
Use the same file naming convention as shown on pp 124,125
Control + Out files will be in
C:\CLIMAT05\NULLTEST\ RG4_OPTS*.FIL
RG4_OPTS*.OUT
RG4_OPTP*.FIL
" " *.OUT

Increase in Loglikelihood

		All Year	OPTS1	OPTS2	OPTS3	
G000	SOI(3)	10.97 *	9.79 *	15.76 *	11.34 **	
	SOI(2)	10.71 **	9.55 **	15.70 **	11.27 **	
G100	SOI(3)	1.52	1.27	1.50	0.78	
	SOI(2)	1.36	1.14	1.27	0.70	
G010	SOI(3)	2.44	2.33	2.65	1.32	
	SOI(2)	2.21 **	1.79	1.77	1.31	
G110	SOI(3)	0.92	1.30	0.66	0.81	
	SOI(2)	0.65	0.47	0.31	0.54	
	Σ Sig. Δ Log L	12.92	9.55	15.70 *** ✓	11.27	
G000	PDO(2)	7.22 *	4.18 *	9.69 *	5.34 *	
	PDO(1)	7.19 **	3.90 **	9.30 **	5.29 **	
G100	PDO(2)	1.51	0.016	0.003	0.0004	
	PDO(1)	1.36	0.0008	Neg	0.0003	
G010	PDO(2)	0.15	0.30	1.21	0.002	
	PDO(1)	0.016	0.06	0.25	0.003	
G110	PDO(2)	1.01	1.01	0.93	0.60	
	PDO(1)	0.65	0.69	0.72	0.009	Total Increase
		7.19	3.90	9.30 *** ✓	5.29	4.89

Dan 12-13-05

Set up control files for 40 MILE CANYON

Form will be: c:\CLIMATOS\NULLTEST\40_OPTS1.FIL

" " 40_OPTS*.OUT

40_OPTP*.FIL

" " .OUT

Increase in Log Likelihood

		All Year	OPTS1	OPTS2	OPTS3
G_{000}	SOI(3)	8.31*	10.87*	8.31	8.74*
	SOI(r)	8.15**	10.52**	8.30**	8.63**
G_{100}	SOI(3)	3.85*	4.08*	3.18*	4.00**
	SOI(r)	3.42**	3.20**	3.05**	2.17*
G_{010}	SOI(3)	3.33*	2.71	3.01*	3.53*
	SOI(r)	3.17**	2.15**	3.01**	3.44**
G_{110}	SOI(3)	1.65	2.92	0.95	2.79
	SOI(r)	1.10	2.03*	0.95	1.97
		14.74	17.90 ✓	14.36	16.16

		All Year	OPTP1	OPTP2	OPTP3	
G_{000}	PDO(r)	0.62	0.74	0.55	0.32	
	PDO(l)	0.20	0.23	0.04	0.05	
G_{100}	PDO(r)	0.69	1.09	0.47	0.99	
	PDO(l)	0.27	0.25	0.29	0.51	
G_{010}	PDO(r)	9.88*	8.82*	8.86*	8.14*	
	PDO(l)	9.47**	8.79**	8.17**	7.93**	
G_{110}	PDO(r)	2.13*	0.86	2.27*	1.43**	
	PDO(l)	2.12**	0.85	2.22**	1.43**	Total Increase
		11.59 ✓	8.79	10.39	9.57	3.16

Create 40MC2BEST1.FIL with OPTS1 + All yr PDO

DAW 12-14-05

Now set up control files with optimum null periods for SOI and PDO From existing files we already have results for Pullman: SOI(none) and PDO (OPTP3) and for Forty Mile: SOI(OPTS1) and PDO (none)

For RG4 set up file C:\CLIMAT05\NULLTEST\RG4BEST.fil ✓

Conclusion:

Examination of the output files reveals that the combinations of optimum null periods for SOI and PDO result in no significant improvement in log likelihood functions for all three stations studied. This contrasts with Woolhiser et al. (1993) who found small but significant effects for several stations. However their analysis was for a first order Markov Chain, so it is possible that with a 2nd order chain, and a better fit (higher likelihood), the effects of seasonality of the 1st order chain were captured by the 2nd order chain with no seasonal effects. Another factor could be the reduction in sample size for the 2nd order Markov chain

DAW 12-16-05 Check this conclusion by setting up files PULLMC2BEST1.FIL with OPTS1 and OPTP3

Check of PULLMC2BEST1.OUT verifies above conclusion ✓

Also create RG4MC2BEST1.FIL with OPTS2 and OPTP2

This does result in Log L increase with SOI(2) the best model ✓

40 Mile 40MC2BEST1.OUT slight improvement with OPTS1

DAW 12-15-05 Examine seasonal effects for mean of mixed exponential, μ, for 3 stations

For PULLMAN, WA files of form

C:\CLIMAT05\NULLTEST\PULLMEOPTS1.FIL

" " " S2." etc

" " " P1." etc

Run program S_PDOME_05.F95 (modified for NULL PDO)

Increase in Log likelihood (Pullman, WA)

	All Yr.	OPTS1	OPTS2	OPTS3	PULLMEBEST
μ SOI-PDO(3)	6.25	9.73	4.84	4.90	10.70 **
SOI(2)	5.28	8.95 **	3.37	4.12	8.94
SOI(3)	6.05	9.87	3.55	4.64	9.87
PDO(1)	3.31	3.32	3.09	3.31	5.44

	All Yr.	OPTP1	OPTP2	OPTP3
μ SOI-PDO(3)	6.25	8.08 **	5.96	5.62
SOI(2)	5.28	5.28	5.28	5.28
SOI(3)	6.05	6.05	6.05	6.05
PDO(1)	3.31	5.43	2.63	1.94

For Pullman, W. omitting perturbations of both SOI and PDO during Apr+May improves log lik by 4.45 units.

For Forty Mile Canyon files of form

C:\CLIMAT05\NULLTEST\40ME_OPTS1.fil etc

DAW 12-15-05 Seasonality, μ

Increase in Log likelihood Forty Mile Canyon

	All yr.	OPTS1	OPTS2	OPTS3	OPTS4
μ SOI-PDO(3)	3.43	4.26	3.74	4.13	3.43
SOI(r)	2.72	2.53	1.89	2.67	2.13
SOI(3)	2.75	3.17	2.49	2.82	2.80
PDO(1)	3.42**	3.42**	3.42	3.42	3.42

		OPTP1	OPTP2	OPTP3
μ SOI-PDO(3)	3.43	4.27	2.86	3.29
SOI(r)	2.72	2.72 →		
SOI(3)	2.75	2.75 →		
PDO(1)	3.42**	3.23	1.43	2.20

Because PDO(1) is AIC minimum, conclude that there is no seasonal effect

DAW 12-16-05 Try combination of OPTS1 and OPTS2 call file 40ME_OPTS4.FIL

Response shown in OPTS4 Col. verifies no seasonal SOI effect

Now set up control files for RG4 of form

C:\CLIMATOFS\NULLTEST\RG4MEOPTS1.FIL etc.

DAW 12-15-05

Increase in log likelihood for R64

	All yr	OPTS1	OPTS2	OPTS3	~~OPTS4~~
μ SOI-PDO(3)	6.74	9.64	10.97 **	4.81	12.85
SOI(2)	5.76	8.63 **	9.70	4.19	11.77
SOI (3)	5.86	8.75	9.84	4.34	12.26
PDO(1)	0.075	0.0773	0.034	0.029	

μ SOI-PDO(3)	6.74	8.01	7.20	8.24
SOI(2)	5.76	7.18	7.18	7.18
SOI(3)	5.86	7.18	7.18	7.18
PDO(1)	0.075	0.17	0.033	0.0312

12-16-05

As indicated by the very small increase in Log L due to PDO, concentration should be placed on SOI. OPTS2 results in the greatest Δ LogL for a 2 month null period. However it would be useful to try two null periods a) Opts2 period and b) OPST1 + OPTS2.

Create ~~2~~ 1 new control files in same directory DAW 12-16-05

* OPTS4.fil would have an SOI null period from day 32 to day 153 ie Apr - July.

	C_1+	C_1	C_1^-	C_2	Lag
μ SOI PDO (3)		-0.6966		-0.1637	90
SOI (2)		-0.6306			90
SOI (3)	-0.4566		-0.7547		90

DAW 12-20-05 Set up simulation for
Forty mile canyon
First update program MC2CLIMSIM_05.F95
New file is MC2CLIMSIM_06.F95
in C:\CLIMAT05\NULLTEST
changes made are:
1.) Change formats for reading Fourier Coefficients for MC1 and ME distribution.
2) Add option of harmonics for ALPHA
3) Add option of PDO null periods for both MC2 + ME

Create control file:
C:\CLIMAT05\NULLTEST\FORTYMC2_3.SIM

DAW 12-21-05 Check Program C:\CLIMAT05\NULLTEST\MC2CLIMSIM_06.F95
Run with above control file
output for MC2 is \FORTYMC2_3.OUT ✓
input for graphing program \FORTYMC2_3.DAT ✓

DAW 12-22-05
Import FORTYMC2-3.DAT into PSEPLOT ✓
Diagnostic checks:
1) Average number of wet days/yr (MAN) = 45.2** / 44.6*
2) Average annual precipitation (MAP) = 216.34** mm / 207.0
3) Mean max daily temp. (MT_{max}) = 69.4°F std. dev = 19.2°F** / 68.9°F
4) Mean min daily " (MT_{min}) = 40.9°F S.D. = 14.5°F** / 40.6°
Note: The temperature parameters were adjusted for the elevation of Yucca Mtn.

DAW 12-22-05

5) Mean daily solar radiation (MDS) = 476** Langleys / 477
S.D. = 192.9

Note: Items with ** were statistics obtain with perturbation of μ by the PDO.

6) Mean SOI = -0.153 Max = 3.0 Min = -3.5

7) Mean PDO = -0.162 Max = 3.51 Min = -3.6 Feb. yr. 3

Date of max. PDO is July of yr. 38 day # 13628

Date of max SOI is June of yr 5 day # 1553

Date of min SOI is Feb. of yr 37 day # 13478

Create Cols. P000~-P000 (DELP000); P100~-P100 (DELP100); P010~-P100 (DELP010); P110~-P110 (DELP110); Mu~-Mu (DELMU)

Save as C:\CLIMATE5\NULLTEST\FORTYMC2_3.PDW

Now create plots similar to those on p 83-85.

DAW 12-23-05

Examine the extremes of perturbed and cyclic transition parameters

	Max Cyclic	Min Cyclic	Max Perturbed	Min Perturbed
P_{000}	0.969	0.895	0.980	0.797
P_{100}	0.874	0.840	0.968	0.755
P_{010}	0.565	0.366	0.800	0.219
P_{110}	0.711	0.445	0.862	0.177
μ (mm)	5.99	2.82	6.96	2.08

All for Forty Mile Canyon SOI + PDO from 1946-1995

Daw 12-26-05 Statistical Analysis of Simulated daily Precipitation, etc.

Use program statclim3.f95

Control file: C:\CLIMAT05\NULLTEST\FORTMC2P_3.CON

Forty Mile Canyon FORTYMC2-3.DAT

MAP (mm) 207.0

Std. dev (mm) 61.58

CV 0.30

Max (mm) 398.2 mm

Min (mm)

Test for stationarity:

H_0: $\mu_{A30} = \mu_{A20}$ where $\mu_A 30$ = mean of 1^{st} 30 yrs

$\mu_A 20$ = mean of 2^{nd} 20 yrs

$$Z = \frac{\mu_1 - \mu_2}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}} = \frac{186.92 - 237.02}{\sqrt{\frac{2827.8}{30} + \frac{3880.07}{20}}} = 2.95$$

$2.95 > 1.96$ ∴ Null hypothesis is rejected!

at 0.05 sig. level

Conclusion: PDO and SOI perturbations can account for non-stationarity of precipitation.

DAW 1-10-05

Archived files from 11-18-05 to 1-10-05 in Backup hard disk

1-24-06 Equilibrium Probabilities of a wet day - MC2

The technique being used in MC2 programs for estimates of equilibrium probabilities of a wet day are approximate. The following procedure should result in more accurat values.

Refer to p 22 for notation. For a second order, non-homogeneous Markov chain the state space can be defined as

00 state 1   See D.R. Cox and H.D. Miller. 1977. The Theory of
10 state 2   Stochastic Processes. Science Paperbacks,
01 state 3   Chapman and Hall, London. p 133
11 state 4

Here 0 refers to a dry day and 1 to a wet day on successive days. Consider the 3-day sequence 000. This can be considered as a transition from state 1 (00) to state 1 (00). Similarly 101 represents a transition from state 2(10) + state(3) 01. Thus the transition probability matrix can be written

time $t+1$

	state		1(00)	2(10)	3(01)	4(11)				
time t	00	1	$P_{000}(t)$	0	$1-P_{000}(t)$	0	P_{11}	$P_{12}=0$	P_{13}	$P_{14}=0$
	10	2	$P_{100}(t)$	~~$1-P_{100}(t)$~~ 0	$1-P_{100}(t)$ ~~0~~ DAW 1-24-06	0	$= P_{21}$	$P_{22}=0$	P_{23}	$P_{24}=0$
	01	3	0	$P_{010}(t)$	0	$1-P_{010}(t)$	$P_{31}=0$	P_{32} ~~=0~~	$P_{33}=0$	P_{34} ~~=0~~ DAW 1-24-06
	11	4	0	$P_{110}(t)$	0	$1-P_{110}(t)$	$P_{41}=0$	P_{42}	$P_{43}=0$	P_{44}

where $P_{ijk}(t)$ is represented by a Fourier Series

Note that day $t+1$ is wet if in state 3 or 4 and is dry in states 1 and 2.

Daw 1-24-06

Let $P_j(i)$ = probability of being in state j at time i
$j = 1, 2, 3, 4 \quad i = 1, 2 \cdots 365$

Then $P_W(i) = P_3(i) + P_4(i)$ $\quad P_W$ = probability (equilibrium) of wet
$P_D(i) = P_1(i) + P_2(i)$; $\quad P_W + P_D = 1$

The 4 state MC specified on p136 is irreducible because all states intercommunicate (Cox & Miller p101). However it is nonhomogeneous because the transition probabilities are functions of time.

Suppose at time $t = 365$ (end of year) the probability of being in each state is given by the vector

$P_1(365)$
$P_2(365)$
$P_3(365)$
$P_4(365)$

Then on day 1 the probabilities are obtained by multiplying the initial vector by $\overline{M}(1)$.

$P_1(1) = P_1(365) \times P_{11}(1) + P_2(365) \times P_{21}(1)$ Daw 1-24-06
$P_2(1) = P_3(365) \times P_{32}(1) + P_4(365) \times P_{42}(1)$
$P_3(1) = P_1(365) \times P_{13}(1) + P_2(365) \times P_{23}(1)$
$P_4(1) = P_3(365) \times P_{34}(1) + P_4(365) \times P_{44}(1)$

In general

$P_1(t) = P_1(t-1) P_{11}(t) + P_2(t-1) P_{21}(t)$
$P_2(t) = P_3(t-1) P_{32}(t) + P_4(t-1) P_{42}(t)$
$P_3(t) = P_1(t-1) P_{13}(t) + P_2(t-1) P_{23}(t)$
$P_4(t) = P_3(t-1) P_{34}(1) + P_4(t-1) P_{44}(t)$

DAW 1-24-06

Objective: Write a FORTRAN 95 program to calculate the probability of a wet day for $t = 1, 2 \cdots 365$.

Procedure:

1) Start with $P_1(365) = 1/2$ Annual prob. of dry day
$P_2(365) =$ "
$P_3(365) = 1/2$ Annual prob of wet day
$P_4(365) = 1/2$ Annual prob of wet day

2) Using the multiplication indicated on p136, calculate $P_j(i)$ for $i = 1, 365$ for 2 yrs. then check ~~sto~~ to DAW 1-25-06 see if convergence has been achieved on day 1, 2 -- 10.

DAW 1-27-06

Program C:\CLIMAT05\MC2ME\EQVAL-PROB.F95 was completed on 1-26-06. Three years of matrix multiplication were performed all 4 states reached equilibrium on the 13th day of year 1.

Program will automatically read C:\CLIMAT05\MC2ME\EQVALPROB.FIL

Output will be C:\CLIMAT05\MC2ME\EQUALPROB.EQU for test case

Output file can be specified in the control file or can be saved as: *.EQU for identification.

Forty Mile Canyon: C:\CLIMAT05\MC2ME\FORTYMC2C.EQU

Walnut Gulch: " " \RG4MC2C.EQU

DAW 2-15-06 Climate Change

Objective: Investigate the possibility of adjusting parameters in a 2nd Order Markov chain to reach a target mean annual number of wet days (MAN) with seasonality of an analog station

Procedures: Refer to p 93. Assume that mean parameters can be adjusted to reach a target MAN

1.) Adjust parameters $\bar{p}_{000}$, $\bar{p}_{100}$, $\bar{p}_{010}$ and $\bar{p}_{110}$ by adjusting the logit transforms $\bar{G}_{000}$, $\bar{G}_{100}$, $\bar{G}_{010}$ and $\bar{G}_{110}$.

From p. 135 the transition probability matrix for constant parameters:

		time t+1 ① 00	② 10	③ 01	④ 11
time t	① 00	$\bar{p}_{000}$	0	$1-\bar{p}_{000}$	0
	② 10	$\bar{p}_{100}$	0	$1-\bar{p}_{100}$	0
	③ 01	0	$\bar{p}_{010}$	0	$1-\bar{p}_{010}$
	④ 11	0	$\bar{p}_{110}$	0	$1-\bar{p}_{110}$

DAW 2-21-06

Unfortunately, for the second order Markov chain (MC2), there is no convenient approximation for the expected number of wet days in the year such as that shown on p 93. However, the equilibrium probabilities can be calculated numerically using the relationships on pgs 136 + 137.

DAW 2-21-06

The expected number of wet days at time t can then be expressed as:

$$E\{N(t)\} = \sum_{i=1}^{t} P\{X(i)=1\}$$

where $P\{X(i)=1\}$ is given by the sum of $P_3(i)$ and $P_4(i)$

DAW 3-13-06

Program C:\CLIMATE_06\SEASON6_1.F95 was adapted from C:\CLIMATE_05\SEASON_05\SEASON5_2.F95 to include the 2nd order Markov chain occurrence process. The algorithms for calculating the equilibrium probabilities of wet days were imported from program C:\CLIMAT05\MC2ME\EQUALPROBMC2.F95.

Partial derivative $\frac{\partial MAN}{\partial \bar{G}_{000}}$, $\frac{\partial MAN}{\partial \bar{G}_{100}}$, $\frac{\partial MAN}{\partial \bar{G}_{010}}$ and $\frac{\partial MAN}{\partial \bar{G}_{110}}$ are estimated by finite difference techniques.

DAW 3-14-06

The iterative procedure to adjust $\bar{G}_{000}$, $\bar{G}_{100}$, $\bar{G}_{010}$ and $\hat{G}_{110}$ to match the target MAN is as follows:

Define an error function -

$F(\hat{N} - N_T) = \epsilon$ where $\hat{N}$ is the estimated MAN and N_T is the target. We wish to find the zero crossing, i.e. $\epsilon = 0$.

Given beginning values $\bar{G}_{ijo}(i)$ we wish to adjust them by a Newton-Raphson procedure, where the corrections are apportioned by weights

$w_1 \epsilon + \frac{\partial \epsilon}{\partial \bar{G}_{000}} \Delta \bar{G}_{000} = 0$; $w_2 \epsilon + \frac{\partial \epsilon}{\partial \bar{G}_{100}} \Delta \bar{G}_{100} = 0$; $W_3 \epsilon + \frac{\partial \epsilon}{\partial \bar{G}_{010}} \Delta \bar{G}_{010} = 0$, etc

where the sum of weights, w_i, $= 1$.

DAW 3-14-06

For this application, it seems appropriate to assign weights, w_i, $i=1-4$, proportional to the likelihood functions for the appropriate parameters.

For a test case, use the adjustment of RG4 parameters to match MAN and MAP for Nogales, AZ. See p. 97.
For appropriate weights see C:\CLIMATO5\MC2ME\RG4MC2C.OUT

Parameter	G_{000}	G_{100}	G_{010}	G_{110}	Sum
Log likelihood	-2617	-499	-719	-532	-4367
Weights	0.599	0.114	0.165	0.122	1.0

Note that the weights are related to sample size.

Diagnostic Checks: For first trial
Adjusting RG4 to Nogales MAN + MAP
Data files: C:\~~SE~~ CLIMATE_06\MC2SEASON.DAT (DAW 3-14-06)
C:\CLIMATO5\MC2OUT\NOGALMC2.DAT

Plot files: All in C:\CLIMATE_06\

TEST1.PGW	Normalized accumulated number of wet days
TEST2.PGW	" " precipitation
TEST3.PGW	MC2 parameters adjusted and Nogales
TEST4.PGW	Accumulated precipitation
TEST5.PGW	" number of wet days
TEST6.PGW	ME parameter, μ adjusted and nogales plus β.

DAW 3-14-06

A review of these figures shows that the expected number of wet days $E\{n(t)\}$ and the normalized $E^*\{n(t)\}$ functions (Figs Test1.PGW + TEST5.PGW) do not match as well as they did for the first order MC. (see p 99). However the expected accumulated precipitation functions, $E\{S(t)\}$ and $E^*\{S(t)\}$ (Figs. TEST4.PGW and TEST2.PGW) show very close fits.

DAW 3-15-06 Checking

DAW 3-16-06 "

DAW 3-21-06

Program error found and corrected. Adjustments made to error criteria for fitting target MAN + MAP.

Updated plot files TEST1.PGW – TEST6.PGW using corrected output.

Tested regression option with RG4 as analog and targets

MAN = 411.72 mm MAP = 50.84

Control file C:\CLIMATE_06\MC2SEASON2.CON

weights: $w_1 = 0.599$, $w_2 = 0.114$, $w_3 = 0.165$, $w_4 = 0.122$

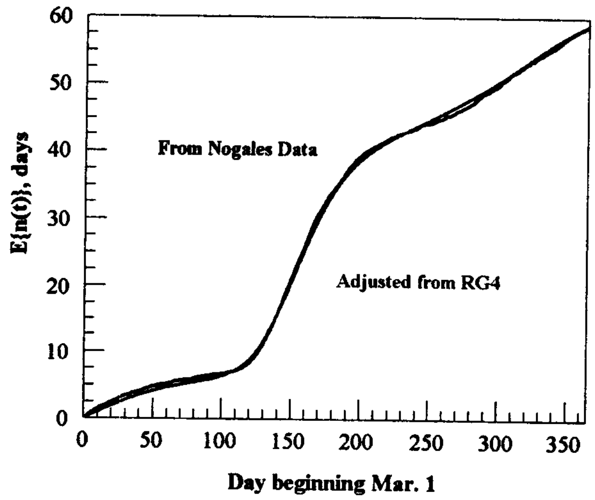
Adjusting Nogales to RG4 MAN = 53.57 and MAP = 302.26 mm

Control file C:\CLIMATE_06\MC2SEASON3.CON

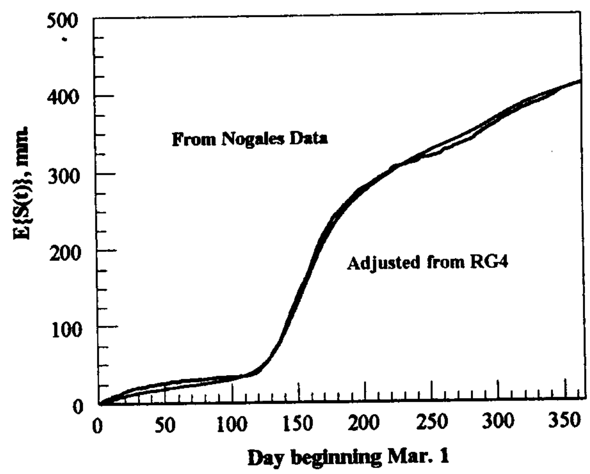
Same weights as above

TMW 3-21-06 Test for Arizona Stations

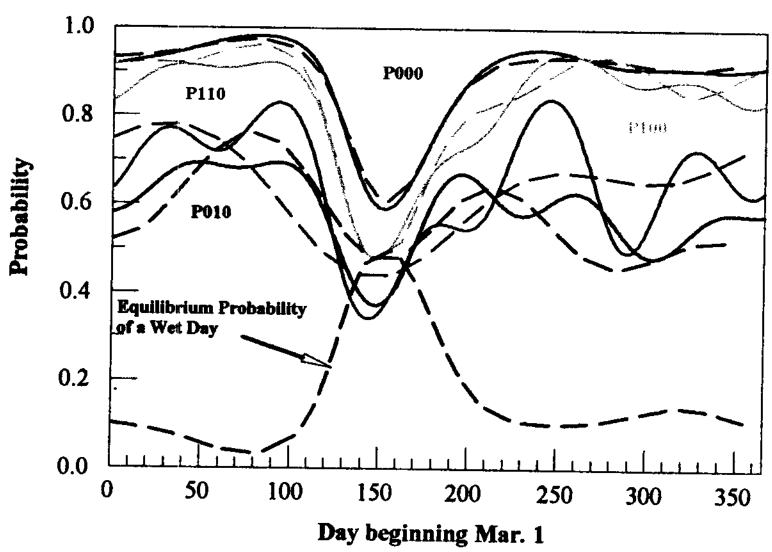
The accumulated expected number of wet days $E\{n(t)\}$ and accumulated precipitation function $E\{S(t)\}$ for Nogales, AZ data and for Nogales as adjusted from RG4 are shown below. Clearly an excellent fit has been achieved in each case.



Expected Accumulated Number of Wet Days for Nogales, AZ and as Adjusted from RG4



Expected Accumulated Precipitation for Nogales, AZ and as Adjusted from RG4

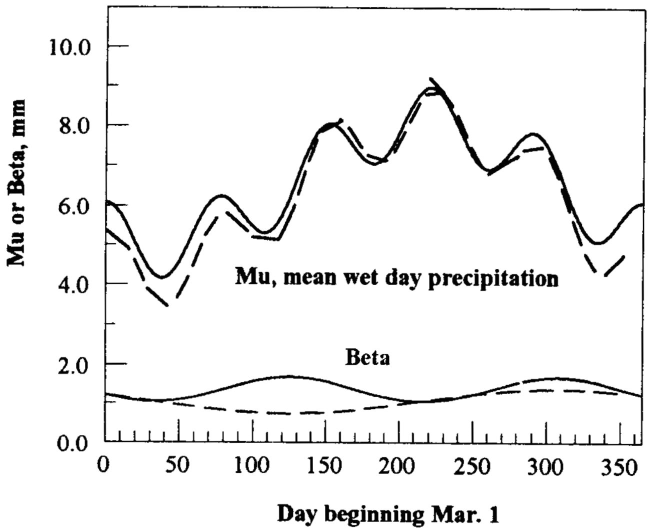


Markov Chain Transition Probabilities
Nogales, AZ as Adjusted from RG4
Solid- Identified for Nogales
Dashed- Adjusted from RG4

The fitted and adjusted MC2 parameters in the adjacent figure indicate a rather satisfactory fit, especially for P_{000}. For the other 3 parameters, the adjusted values are smoothed versions of the fitted values, DMW 3-21-06

which is inevitable, given that more significant harmonics were identified for Nogales.

Observed (fitted to Nogales) and adjusted functions of μ (Mu) and β are shown below



Mixed Exponential Parameters
Nogales, AZ as Adjusted from RG4
Solid- Identified for Nogales
Dashed- Adjusted from RG4

The adjusted μ is slightly below that fitted for Nogales with deviations related to those in $E\{n(t)\}$ and $E\{S(t)\}$. The deviations in β reflect the differences in harmonics identified for RG4 and Nogales. Given that these stations have differences in MAN and MAP as shown below, I conclude that the fit is good.

Station	MAN (days)	MAP (mm)
Nogales	58.84	411.72
RG4	53.57	302.26

DAW 3-24-06 Continue MC2-ME Climate Change

Objective: Evaluate effectiveness of procedure for current Yucca Mtn. climate and for adjustment of MAN and MAP for N.W., ie eastern Washington State.

Procedure:

1) Current Yucca Mtn. - Two cases use two stations as analogs and adjust to a third station.

Analog 1. - Ranier Mesa, MAN=53.31, MAP=314.20mm

Adjust to 40-Mile Canyon. MAN=43.05 MAP=203.78mm

Analog 2. Jackass Flats MAN=32.16 days, MAP=140.80mm

Set up control file for Analog 1

File name: C:\CLIMATE_06\RANIER_TO_40.CON ✓

OUTPUT " " \ " " " .SEA ✓

" " " " " .DAT ✓

Set up control file for Analog 2. - Jackass Flats

File name: C:\CLIMATE_06\JACK_TO_40.CON ✓

output " " " .SEA + *.DAT ✓

Examine a third station as base station. - Tippipah Springs MAN= 43.9 days MAP= 224.28. Use the same analog stations

Control files

C:\CLIMATE_06\RANIER_TO_TIP.CON

" \JACK_TO_TIP.CON

DAW 4-4-06 Further tests of regression approach for current conditions and future climate at Yucca Mtn. assuming no change in seasonality.

Two cases will be examined:

1) Specify MC2ME parameters for current climate and seasonality with MAP = 181 mm.
2) Specify MC2ME parameters with an increase of 150 mm and current seasonality

An additional regression was performed using data from the Yucca Mountain region, relating MAN to MAP. Both a linear and ~~an exponen~~ DAW 4-4-06 power relationship were examined. Results are shown in the following figure (p.147). The power relation led to a slightly greater R^2, so was adopted. Therefore in program season6-1.F95 the following will hold if STA-OPTION = 1

TARGET_NWET = 1.547* TARGET_P** 0.6161

Use Tippipah Springs (MAN = 43.9 days, MAP = 224.3 mm) as the analog station. Note these values are between the proposed MAP

Set up control files

C:\CLIMATE-06\TIP_TO_181.CON

C:\ " \TIP-TO-331.CON

Output will have extensions .SEA and .DAT

Daw 4-5-06 Climate Change (con't)

To compare regression results with adjustments based only on specified MAP and MAN, create two new control files with STA_OPTION = 0

C:\CLIMATE_06\TIP_TO_181B.CON

" " \TIP_TO_331B.CON

The regression results were compared with the $E^*\{N(n)\}$ and $E^*\{S(n)\}$ fitting. For the dimensional $E\{N(n)\}$ and $E\{S(n)\}$ the results were indistinguishable as were the equilibrium wet day probabilities. For MC2, P_{000} functions were very close for both cases. For TIP_to-331, P_{100}, P_{010} and P_{110} were slightly lower for the regression, while for TIP_TO_181, the regression results were slightly higher for P_{010} and P_{100} but were the same for P_{110}.

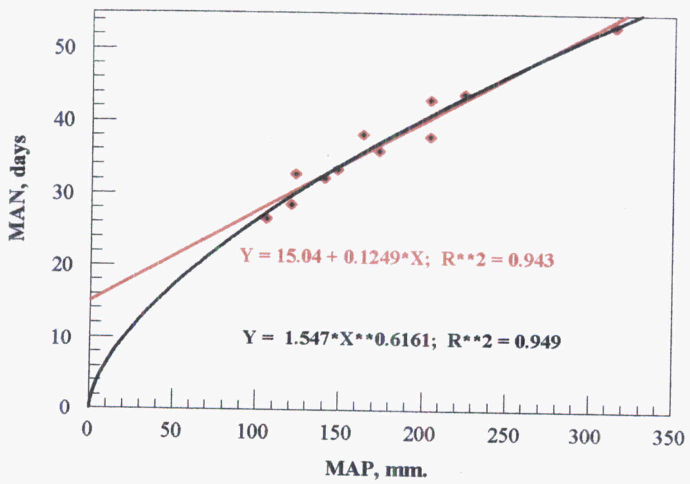
A closer examination reveals that for TIP_TO_331 the ratio P_{000B}/P_{000} is < 1, thus compensating for the differences in P_{100}, P_{010} + P_{110}.

For the mixed exponential $\mu(n)$ there was not a consistent difference. However, $\overline{\beta}(n)$ was different reflecting the regression effect.

Alpha was not changed for either case

Figures on following pages.

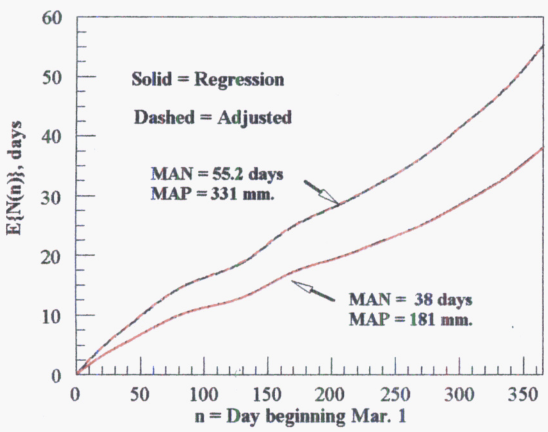
DAW 4-6-06



Relationship Between Mean Annual Number of Wet Days and Mean Annual Precipitation, Yucca Mountain Region

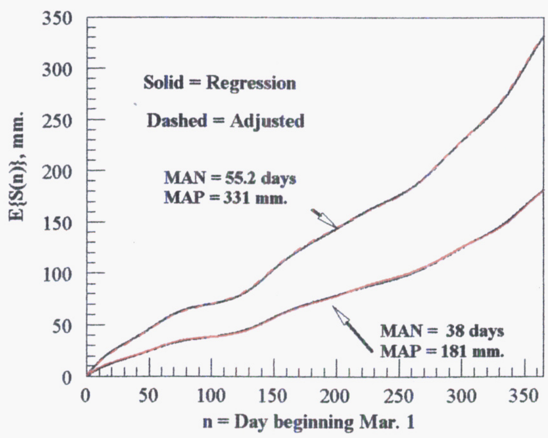
File: C: | CLIMAT04 | MC2TEST | MANvsMAP.PGW
daw 3-24-06

Word perfect file of following figs. in C:\CLIMATE_06\FIGS_TIP_TO_181+331.WPD



Expected Accumulated Number of Wet Days by Regression and as Adjusted from Tippipah Springs, MAN = 43.9 Days; MAP = 224.3 mm.

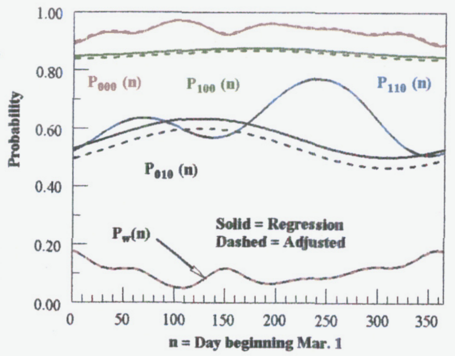
File: C: | CLIMATE_06 | TIP_181_1.PGW
Data: C: CLIMATE_06 | TIP_TO_181.DAT, TIP_TO_331.DAT
TIP_TO_181B.DAT, TIP_TO_331B.DAT



Expected Accumulated Precipitation by Regression and as Adjusted from Tippipah Springs, MAN = 43.9 Days; MAP = 224.3 mm.

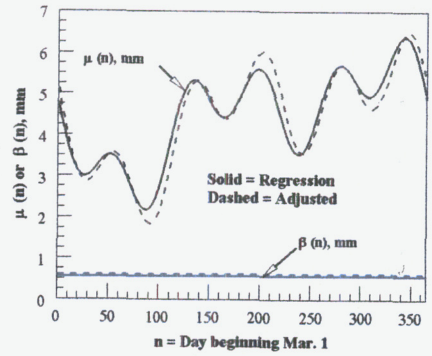
File: C: | CLIMATE_06 | TIP_181_2.PGW
Data: C: CLIMATE_06 | TIP_TO_181.DAT, TIP_TO_331.DAT
TIP_TO_181B.DAT, TIP_TO_331B.DAT

DAW 4-6-06



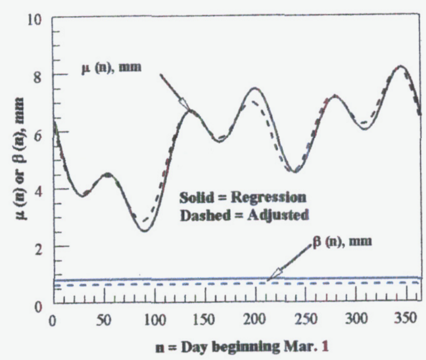
Markov Chain Parameters for MAN = 38 Days by Regression and as Adjusted from Tippipah Springs, MAN = 43.9 Days; MAP = 224.3 mm.

File: C: | CLIMATE_06 | TIP_181_3.PGW
Data: C: CLIMATE_06 | TIP_TO_181.DAT, TIP_TO_331.DAT
TIP_TO_181B.DAT, TIP_TO_331B.DAT



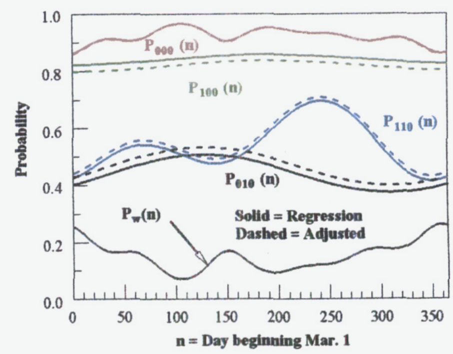
Mixed Exponential Parameters for MAP = 181 mm. by Regression and as Adjusted from Tippipah Springs, MAN = 43.9 Days; MAP = 224.3 mm.

File: C: | CLIMATE_06 | TIP_181_4.PGW
Data: C: CLIMATE_06 | TIP_TO_181.DAT, TIP_TO_331.DAT
TIP_TO_181B.DAT, TIP_TO_331B.DAT



Mixed Exponential Parameters for MAP = 331 mm. by Regression and as Adjusted from Tippipah Springs, MAN = 43.9 Days; MAP = 224.3 mm.

File: C: | CLIMATE_06 | TIP_331_MU.PGW
Data: C: CLIMATE_06 | TIP_TO_331.DAT
" , TIP_TO_331B.DAT



Markov Chain Parameters for MAN = 55.2 Days by Regression and as Adjusted from Tippipah Springs, MAN = 43.9 Days; MAP = 224.3 mm.

File: C: | CLIMATE_06 | TIP_331_MC2.PGW
Data: C: CLIMATE_06 | TIP_TO_331.DAT
" , TIP_TO_331B.DAT

Conclusion: The differences between parameters obtained by regression from Yucca Mtn. vicinity and those obtained by adjusting parameters from an analog station are probably insignificant. The functions $E\{N(n)\}$ and $E\{S(n)\}$ obtained by both methods have insignificant differences.

T AW 4-6-06 Test for Washington stations

station	MAN (days)	MAP (mm)	*.DAT file in:
Spokane	111.5	408.8	CLIMAT04\MC2TEST
Pullman	113.7	537.9	CLIMAT05\MC2ME
Walla Walla	106.5	493.9	" "
Yakima	69.4	208.0	C:\CLIMAT05\MC2ME

Adjust Yakima to Spokane

CONTROL FILE: C:\CLIMATE_06\YAK_TO_SPOK.CON

Adjusting weights: (for Yakima)

	G_{000}	G_{100}	G_{010}	G_{110}	α	β	μ
Log L	-5314	-1166	-1523	-1161			
No. Har.	4	2	1	3	1	2	3
wts	0.58	0.127	0.166	0.127	(from YAKIMAMC2.OUT)		

Adjust Pullman to Spokane

Control file: C:\CLIMATE_06\PULL_TO_SPOK.CON

	G_{000}	G_{100}	G_{010}	G_{110}	α	β	μ
LogL	-5742	-1996	-2281	-2618			
No. Har	5	2	2	3	1	4	3
Wts	0.454	0.158	0.180	0.207			

Day 4-17-06 Examine changes in Fourier terms (constants, amplitudes and phase angles) for MC2 and ME for MAPT > MAP and MAPT < MAP

For MAPT > MAP, use JACK_TO_TIP.SEA
For MAPT < MAP use RANIER_TO_TIP.SEA

The following table shows the changes as MAP and MAN are adjusted up or down.

Changes in Fourier Constants, Amplitudes and Phase Angle C:\CLIMATE_06\PAR_CHANGE_TIP.QPW

Jack to Tip

Parameter	Initial Value	Final Value	Difference	
G000	2.884	2.643	-0.241	-8%
Amp1	0.4168	0.431	0.0142	-3
Phase1	-1.1185	-1.0916	0.0269	2.4
Amp2	0.1474	0.1467	-0.0007	
Phase2	-1.442	-1.4914	-0.0494	
Amp3	0.1614	0.1734	0.012	
Phase3	2.761	2.695	-0.066	
Amp4			0	
Phase4				
G100	1.816	1.584	-0.232	-12.9%
Amp1	0.2113	0.2177	0.0064	-0.6%
Phase1	-2.2195	-2.2332	-0.0137	
Amp2			0	
Phase2				
Amp3				
Phase3				
Amp4				
Phase4				
G010	0.5414	0.327	-0.2144	-40%
Amp1	0.2406	0.2457	0.0051	-2%
Phase1	-0.5852	-0.5724	0.0128	
Amp2	0.3005	0.2943	-0.0062	
Phase2	-1.1337	-1.152	-0.0183	
Amp3			0	
Phase3			0	
Amp4			0	
Phase4				
G110	0.6711	0.3141	-0.357	
Amp1	0.2093	0.2071	-0.0022	
Phase1	-2.2046	-2.014	0.1906	
Amp2	0.3398	0.338	-0.0018	
Phase2	-0.3151	-0.3494	-0.0343	
Amp3	0.3208	0.3208	0	
Phase3	-1.5555	-1.5555	0	
Amp4			0	
Phase4				
MU	4.02	4.7301	0.7101	
Amp1	0.7394	0.8205	0.0811	
Phase1	2.9948	2.9623	-0.0325	
Amp2	0.79602	0.9259	0.12988	
Phase2	2.2558	2.4019	0.1461	
Amp3			0	
Phase3			0	
Amp4			0	
Phase4				

Ran to Tip

Parameter	Initial Value	Final Value	Difference
G000	2.4567	2.6271	0.1704
Amp1	0.2941	0.2846	-0.0095
Phase1	-1.1175	-1.13	-0.0125
Amp2	0.1594	0.1561	-0.0033
Phase2	-1.384	-1.3772	0.0068
Amp3	0.2077	0.199	-0.0087
Phase3	3.1138	3.1008	-0.013
Amp4	0.1686	0.1686	0
Phase4	0.3371	0.3371	0
Amp5	0.1738	0.1738	0
Phase5	-1.2139	-1.2139	0
			0
G100	1.7555	1.9133	0.1578
Amp1	0.1793	0.1775	-0.0018
Phase1	-1.3063	-1.2936	0.0127
Amp2			0
Phase2			0
Amp3			0
Phase3			0
Amp4			0
Phase4			
G010	-0.145	0.0372	0.1822
Amp1	0.1323	0.132	-0.0003
Phase1	-0.9049	-0.8906	0.0143
Amp2	0.1665	0.1698	0.0033
Phase2	0.4401	0.4198	-0.0203
Amp3	0.2272	0.2288	0.0016
Phase3	2.1231	2.1521	0.029
Amp4			0
Phase4			
G110	0.2297	0.3812	0.1515
Amp1	0.1973	0.2011	0.0038
Phase1	-1.9719	-1.9767	-0.0048
Amp2	0.3252	0.3259	0.0007
Phase2	-0.3322	-0.3227	0.0095
Amp3			0
Phase3			0
Amp4			0
Phase4			
MU	5.504	4.6701	-0.8339
Amp1	1.114	1.0018	-0.1122
Phase1	2.5378	2.5547	0.0169
Amp2	1.3287	1.1487	-0.18
Phase2	2.2054	2.1092	-0.0962
Amp3	0	0.0109	0.0109
Phase3	0	2.9316	2.9316
Amp4	0.8636	0.7765	-0.0871
Phase4	-3.2816	-3.0648	0.2168

For an increase in MAN, the Fourier constants for G_{000}, G_{100}, G_{010} and G_{110} are all decreased to provide more frequent rainfall with more persistence. The amplitudes of the harmonics are increased slightly and phase angles are changed slightly. For a decrease the changes are the opposite. The final parameter values are quite close except for G_{010} with the estimates provided by Ranier result in greater persistence.

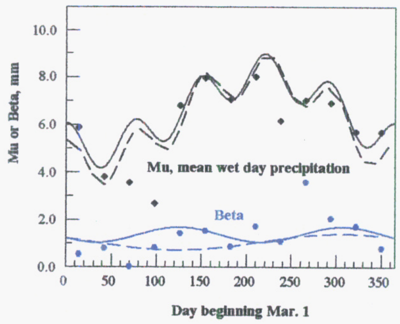
DAW 4-13-06

~~Revised vers~~ DAW 4/13-06

For the mixed exponential distribution, if MAP is to be increased, the constant term $\bar{\mu}$ increases and the amplitudes also increase. The reverse occurs for decreases in MAP (i.e. Ranier to Tippipah).

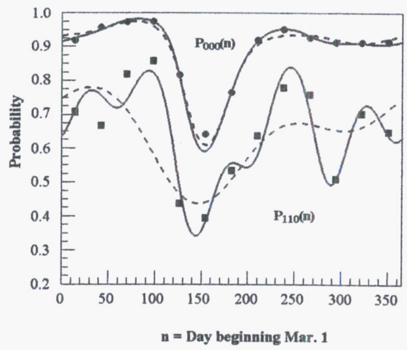
For the 2nd order MC, the weighting scheme, based on log likelihood ratios, appears to be satisfactory.

Revised versions of figures shown on pgs 142-143 are shown below. These also include sample parameter values from the Nogales record. It should be noted that there will be a great deal of sample variation for MC2 parameters G_{100}, G_{010} and G_{110} and ME parameters μ and β during the portions of the year when $P_{000} > 0.95$ because there are few wet days



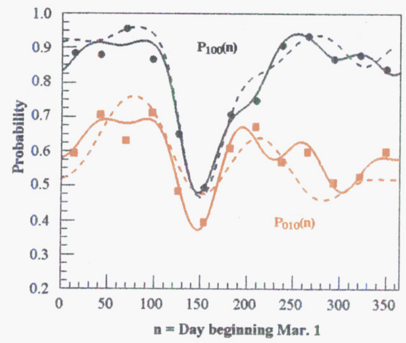
Mixed Exponential Parameters
Nogales, AZ as Adjusted from RG4
Solid- Identified for Nogales
Dashed- Adjusted from RG4

File: C: | CLIMATE_06 | TEST6.PGW
Data: C: | CLIMATE_06 | MC2SEASON.DAT
C: | CLIMAT05 | MC2OUT | NOGALMC2.DAT
C: | CLIMAT05 | MC2ME | NOGAL_ME_PERIOD.DAT



Markov Chain Parameters P_{000} and P_{110} for Nogales, AZ and as Adjusted from RG4

File: C: | CLIMATE_06 | P000_P110_RG4_NOG.PGW
Data: C: | CLIMATE_06 | MC2SEASON.DAT
C: | CLIMAT05 | MC2OUT | NOGALMC2.DAT
C: | CLIMAT05 | MC2ME | NOGAL_MC2_PERIOD.DAT

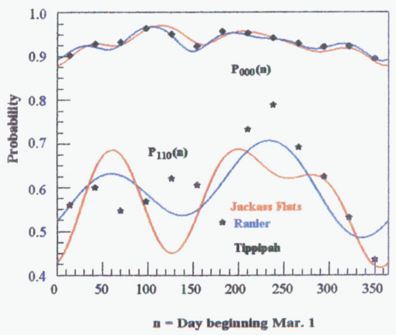


Markov Chain Parameters P_{100} and P_{010} for Nogales, AZ and as Adjusted from RG4

File: C: | CLIMATE_06 | P010_P100_RG4_NOG.PGW
Data: C: | CLIMATE_06 | MC2SEASON1.DAT
C: | CLIMAT05 | MC2OUT | NOGALMC2.DAT
C: | CLIMAT05 | MC2ME | NOGAL_MC2_PERIOD.DAT

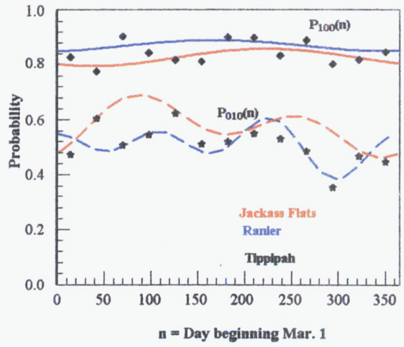
DAW 4-13-06

MC2ME parameter values estimated by adjusting parameters for Jackass Flats and Ranier Mesa to MAN and MAP of Tippipah Springs are shown below. Symbols refer to sample values from the Tippipah record.



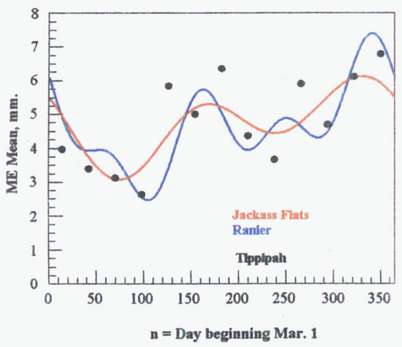
Markov Chain Parameters P_{000} and P_{110} for Tippipah Springs and as Adjusted from Jackass Flats and Ranier Mesa

File: C: | CLIMATE_06 | P000_AND_P110_TIP.PGW
Data: C: CLIMATE_06 | JACK_TO_TIP.DAT, RANIER_TO_TIP.DAT
C: | CLIMAT05 | MC2TEST | TIPPIPAH_MC2_PERIOD.DAT



Markov Chain Parameters P_{100} and P_{010} for Tippipah Springs and as Adjusted from Jackass Flats and Ranier Mesa

File: C: | CLIMATE_06 | P100_AND_P010_TIP.PGW
Data: C: CLIMATE_06 | RANIER_TO_TIP.DAT, JACK_TO_TIP.DAT
C: | CLIMAT05 | MC2TEST | TIPPIPAH_MC2_PERIOD.DAT



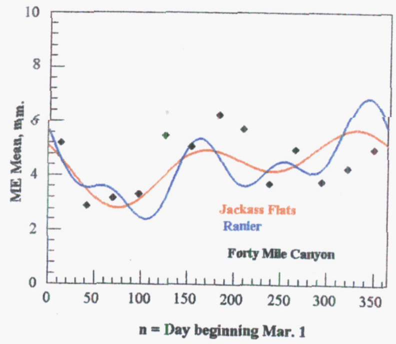
Mixed Eponential Parameter, μ, for Tippipah Springs and as Adjusted from Jackass Flats and Ranier Mesa

File: C: | CLIMATE_06 | ME_RJ_TO_TIP.PGW
Data: C: CLIMATE_06 | JACK_TO_TIP.DAT, RANIER_TO_TIP.DAT
C: | CLIMAT05 | MC2TEST | TIPPIPAH_ME_PERIOD.DAT

Again P_{000} is closely fit in each case. In general the fit obtained from the wetter station (Ranier Mesa) is superior.

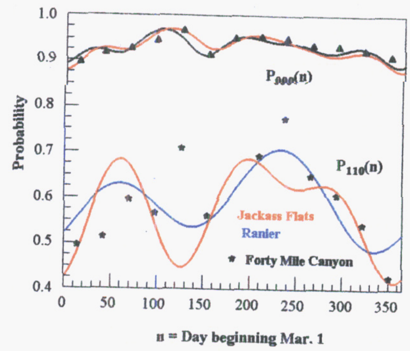
DAW 4-13-06

Figures similar to those on p152, but for estimates at Forty Mile Canyon are shown below.



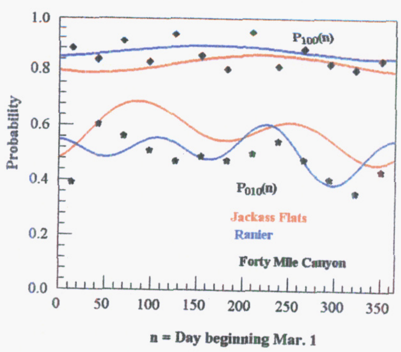
Mixed Exponential Parameters for Forty Mile Canyon and as Adjusted from Jackass Flats and Ranier Mesa

File: C: | CLIMATE_06 | ADJ_40_4.PGW
Data: C: CLIMATE_06 | JACK_TO_40.DAT, RANIER_TO_40.DAT
C: | CLIMAT05 | MC2TEST | FORTY_ME_PERIOD.DAT



Markov Chain Parameters P_{000} and P_{110} for Forty Mile Canyon and as Adjusted from Jackass Flats and Ranier Mesa

File: C: | CLIMATE_06 | ADJ_40_7.PGW
Data: C: CLIMATE_06 | JACK_TO_40.DAT, RANIER_TO_40.DAT
C: | CLIMAT05 | MC2TEST | FORTY_MC2_PERIOD.DAT



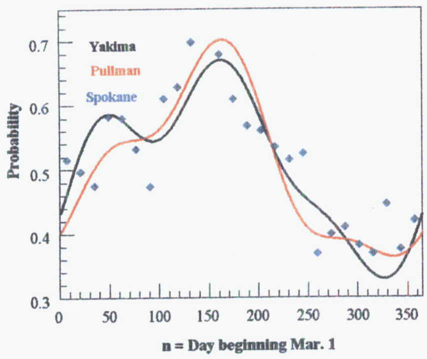
Markov Chain Parameters P_{100} and P_{010} for Forty Mile Canyon and as Adjusted from Jackass Flats and Ranier Mesa

File: C: | CLIMATE_06 | ADJ_40_5.PGW
Data: C: CLIMATE_06 | JACK_TO_40.DAT, RANIER_TO_40.DAT
C: | CLIMAT05 | MC2TEST | FORTY_MC2_PERIOD.DAT

The adjusted parameters are very similar to those on the previous page

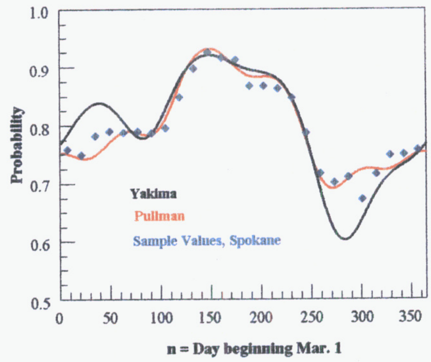
Daw 4/13/06

Adjusted and sample values for MC2ME parameters for Spokane, WA, with analog stations Yakima WA and Pullman WA are shown below.



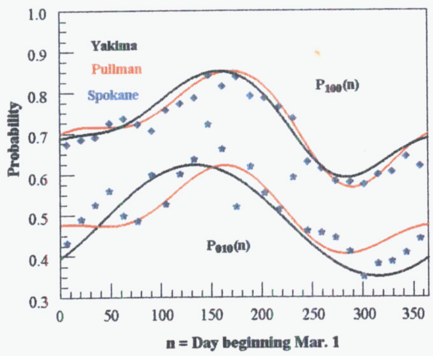
Markov Chain Parameter, P_{110} for Spokane and as Adjusted from Yakima and Pullman,

File: C: | CLIMATE_06 | SPOK_P110.PGW
Data: C: CLIMATE_06 | YAK_TO_SPOK.DAT, PULL_TO_SPOK.DAT
C: | CLIMAT05 | MC2TEST | SPOKANEMC2.DAT



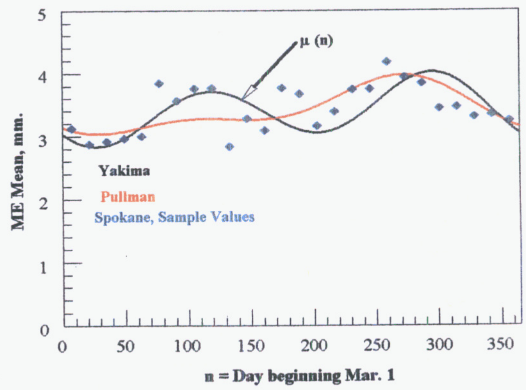
Markov Chain Parameter, P_{000} for Spokane and as Adjusted from Yakima and Pullman,

File: C: | CLIMATE_06 | SPOK_P000.PGW
Data: C: CLIMATE_06 | YAK_TO_SPOK.DAT, PULL_TO_SPOK.DAT
C: | CLIMAT05 | MC2TEST | SPOKANEMC2.DAT



Markov Chain Parameters, P_{100} and P_{010} for Spokane and as Adjusted from Yakima and Pullman,

File: C: | CLIMATE_06 | SPOK_P100ANDP010.PGW
Data: C: CLIMATE_06 | YAK_TO_SPOK.DAT, PULL_TO_SPOK.DAT
C: | CLIMAT05 | MC2TEST | SPOKANEMC2.DAT



Mixed Exponential Parameters for Spokane and as Adjusted from Yakima and Pullman,

File: C: | CLIMATE_06 | ME_YP_TO_S.PGW
Data: C: CLIMATE_06 | YAK_TO_SPOK.DAT, PULL_TO_SPOK.DAT
C: | CLIMAT05 | MC2TEST | SPOKANEMC2.DAT

Again the estimates adjusted from the wetter station, Pullman are superior. One plausible reason is that even for the same record length, the data from the wetter station have greater sample size for G_{100}, G_{010}, G_{110} and μ, and thus the Fourier Series coefficients are more reliable.

DAW 4/25/06 Adjust the Variance of the mixed Exponential Distribution

The variance of the mixed exponential is:

$$\sigma^2 = 2\alpha\beta^2 + 2[1-\alpha]\delta^2 - \{\alpha\beta + [1-\alpha]\delta\}^2$$

See Woolhiser et al. 1993 Water Resour. Res Vol 29 No 4 p 1288

Objective: Devise an algorithm to adjust α and β to fit a target variance (or coefficient of variation) given a value of the mean, μ where

$$\mu = \alpha\beta + (1-\alpha)\delta$$

One should note that the variance of the mixed exponential is unbounded if $\alpha \to 0$.

If this approach works it is possible to retain second order statistics of an adjusted station.

Procedure:

1) Given μ and starting values of α and β, minimize the ~~sum of~~ DAW 4/25/06 squared difference between the calculated σ^2 and the target value.

2) write program VARMAY.F95 using ASIMPLX algorithm to reach the minimum

DAW 4-27-06.

Program completed and tested

Note that the value of the mean shown on p 154 (for example) includes the value of the threshold (~~2.032~~ 0.2032 mm) and that DAW 4/27/06

α, β refer to $y' = (y - \text{threshold})$

DAW 4-28-06

Example: Data from output file: C:\CLIMATE_06\JACK_90_40.DAT

At Day 3

$\alpha = 0.3219$, $\beta = 0.402$, $\mu + 0.2032 = 5.0370$ $CV = 1.3431$

$\sigma^2 = [(5.037 - 0.2032)\,1.3431]^2 = 42.149$

Test 1 Trial $\alpha = 0.32$, $\beta = 0.40$ variance is matched

but final $\alpha = 0.3257$, $\beta = 0.4209$

Test 2 Trial $\alpha = 0.29$, $\beta = 0.40$ variance is matched

but final $\alpha = 0.3188$, $\beta = 0.3541$

Therefore results are sensitive to starting values. This is probably related to the products of β and α that appear in the expression for variance

~~DAW 4-~~ DAW 4/28/06 An alternate approach would be to use a Newton-Raphson scheme and find the zero crossing of

F = Calculated variance - target variance

Thus:

$$F + \frac{\partial F}{\partial \alpha}\Delta\alpha + \frac{\partial F}{\partial \beta}\Delta\beta = 0$$

If apportioned equally: $\Delta\alpha = \dfrac{-0.5F}{\partial F/\partial\alpha}$; $\Delta\beta = -\dfrac{0.5F}{\partial F/\partial\beta}$

DMW 4-28-06

This approach was programmed but did not lead to improvement.
Conclusion: Because of the mathematical properties of the mixed exponential distribution, it would be unproductive to follow this further.

DMW 5-16-06 Disaggregation of daily precipitation

Problem: Although the procedures described in the previous section enable simulation of daily precipitation sequences with desired MAP, MAN and seasonality in both the MC2 process and the ME distribution, daily precipitation does not have the appropriate time resolution for input to KINEROS2 or the continuous version of KINEROS2.

Procedure:

1) Literature review of possible disaggregation schemes to produce rainfall at a maximum of hourly resolution.

DMW 5-17-06

A web search revealed many sources of information, many relating to the problem of spatial and temporal dissaggregation of results of global climate models. These techniques may be too generalized to apply to Yucca Mtn studies.

I also found a bibliography of sources through 1996 with approximately 130 entries.

DAW 5-23-06 Disaggregation

An internet search revealed a source of information that will be useful if disaggregation at an hourly scale with durations in hours is adequate. The source is:
http://www.hydro.washington.edu/Lettenmaier/Models/VIC - -
- - /Documentation/p-disag.html

I downloaded the following files from this site (Into c:\CLIMATE-06\disaggregation)

hp-hour ; hp-dur ; hly-prep.inf (Text files)

The file hly-prep.inf contains a list of U.S. stations that have hourly precipitation data and were analyzed by Maurer, et al. 2002. They obtained the data from Earthinfo hourly precipitation CDs.

Maurer, E.P., A.W. Wood, J.C. Adam, D.P. Lettenmaier, and B. Nijssen, 2002, A Long-Term Hydrologically-Based Data set of Land Surface Fluxes and States for the Conterminous United States, J. Climate 15(22), 3237-3251.

The Nevada listing of hourly stations from hly-prep.inf is shown on p 159. The information includes Latitude and longitude as well as the station number. In the lookup files hp-hour and hp-dur, the station number refers to the order number in hly-prep.inf. For example Nogales, AZ is number 773 and ~~Snoqual~~ DAW 5-23-06 Yelem, WA is No

TAW 5-23-06

NEV_STA

39.4950	-117.0703	2014.5	NV	507	AUSTIN
40.6167	-116.8833	1384.7	NV	691	BATTLE MOUNTAIN 4 SE
37.3478	-114.5431	1043.1	NV	2557	ELGIN
40.8394	-115.7939	1549.4	NV	2573	ELKO FCWOS
39.2950	-114.8453	1909.9	NV	2631	ELY ASOS
36.0789	-115.1553	648.7	NV	4436	LAS VEGAS AP
40.1833	-118.4667	1212.4	NV	4698	LOVELOCK
38.9667	-119.7667	1436.2	NV	5191	MINDEN
36.5489	-114.4583	381.2	NV	5846	OVERTON
37.2692	-115.1197	1037.0	NV	5880	PAHRANAGAT W L REFUGE
41.0667	-114.5333	1840.1	NV	6148	PEQUOP
39.4839	-119.7711	1343.2	NV	6779	RENO AIRPORT
40.4661	-118.3047	1261.2	NV	7192	RYE PATCH DAM
35.4661	-114.9217	1079.7	NV	7369	SEARCHLIGHT
38.7839	-117.1742	1715.6	NV	7620	SMOKEY VALLEY
39.0403	-116.1989	2183.8	NV	7640	SNOWBALL RANCH
41.1006	-114.9736	1738.5	NV	8988	WELLS
40.9019	-117.8072	1310.6	NV	9171	WINNEMUCCA AIRPORT

Excerpt from hly-prcp.inf

The table hp-dur includes all stations listed in hly-prcp and shows CDFs of precipitation duration for 5 precipitation bins: 0.-5; 5-10; 10-15; 15-20 and ≥ 20 mm/d and 4 seasons 1=DJF; 2=MAM; 3=JJA; 4=SON. The columns are:
1=STA NO.; 2=Bin; 3=Season; 4-28 > CDF for hours 1-24

The table hp-hour has a similar arrangement, except the CDF is for rainfall occurrence for each of 24 hours.

A program for disaggregation written in "C" was also downloaded. The disaggregation logic is rather simple, given a daily rainfall amount, the bin and season are determined. A random number is generated and compared the table hp-dur to get the number of hours of duration. Then another random number is generated and the hour of the median is determined from hp-hour. After adjusting so the rain cannot start before hr. 1 or end after hr 24, the daily

DAW 5-23-06

rainfall is distributed uniformly over the duration. The resulting precipitation sequence consists of a series of "box cars" of precipitation intensity. With this simplification, there can be only one event per day and there is no variation of intensity within the storm.

This technique would probably be reasonably accurate where runoff is caused by saturation-induced overland flow, but would have drawbacks where Hortonian flow is significant. The advantage is that all the analyses of hourly precipitation data has been completed and it would be easy to either add this disaggregation scheme to the daily precipitation simulation program or to write a disaggregation program with daily precipitation (from data or simulated) as input.

DAW 5-25-06

A portion of the duration table for Nogales, AZ is shown on the next page. This table was extracted from table hp-dur. and column labels were added. As an example this table shows that the probability that the duration of precipitation was =< 4 hrs in August (season 3) if the daily rainfall was 25 mm (bin 5) would be 0.4051. In reality such a storm could have occurred in several showers, but the disaggregation model would consider only a continuous shower.

DAW 5-25-06

C:\CLIMATE_06\Disaggregation\NOGAL_DUR.txt

Sta NO	Bin	Season	Hr 1	Hr 2	Hr 3	Hr 4	Hr 5	Hr 6
773.0000	1.0000	1.0000	0.0000	0.3535	0.5808	0.7121	0.8333	0.9040
773.0000	1.0000	2.0000	0.0000	0.4800	0.6300	0.7900	0.8900	0.9600
773.0000	1.0000	3.0000	0.0000	0.5431	0.7792	0.8959	0.9315	0.9695
773.0000	1.0000	4.0000	0.0000	0.5065	0.6883	0.7987	0.9026	0.9481
773.0000	2.0000	1.0000	0.0000	0.0303	0.3636	0.5303	0.5303	0.6061
773.0000	2.0000	2.0000	0.0000	0.0541	0.3243	0.5405	0.6216	0.7297
773.0000	2.0000	3.0000	0.0000	0.1383	0.5160	0.6915	0.8138	0.9043
773.0000	2.0000	4.0000	0.0000	0.0986	0.4507	0.5634	0.6338	0.6901
773.0000	3.0000	1.0000	0.0000	0.0000	0.0256	0.1282	0.3590	0.5897
773.0000	3.0000	2.0000	0.0000	0.0000	0.0667	0.1333	0.4000	0.6000
773.0000	3.0000	3.0000	0.0000	0.0641	0.3333	0.6026	0.7179	0.8205
773.0000	3.0000	4.0000	0.0000	0.0370	0.3333	0.5556	0.7778	0.8148
773.0000	4.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0625	0.4375
773.0000	4.0000	2.0000	0.0000	0.0000	0.0000	0.0000	0.1667	0.1667
773.0000	4.0000	3.0000	0.0000	0.1304	0.2899	0.5217	0.6957	0.7681
773.0000	4.0000	4.0000	0.0000	0.1176	0.2353	0.2941	0.5294	0.7059
773.0000	5.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0526	0.1579
773.0000	5.0000	2.0000	0.0000	0.0000	0.0000	0.2500	0.2500	0.2500
773.0000	5.0000	3.0000	0.0000	0.0253	0.2278	0.4051	0.6076	0.7595
773.0000	5.0000	4.0000	0.0000	0.0000	0.0294	0.2059	0.2353	0.4118

A portion of the hour of occurrence CDF table is shown below. This table was extracted from table hp-hour. This table shows that the probability that the time of the middle of the event was =< 4 hrs is 0.1034.

C:\CLIMATE_06\Disaggregation\NOGAL_HOUR.txt

Sta. No.	Bin	Season	Hr 1	Hr 2	Hr 3	Hr 4
773.0000	1.0000	1.0000	0.0557	0.1187	0.1855	0.2430
773.0000	1.0000	2.0000	0.0436	0.1000	0.1348	0.1870
773.0000	1.0000	3.0000	0.0605	0.1075	0.1411	0.1667
773.0000	1.0000	4.0000	0.0324	0.0737	0.1062	0.1357
773.0000	2.0000	1.0000	0.0461	0.1009	0.1412	0.1873
773.0000	2.0000	2.0000	0.0185	0.0494	0.1049	0.1605
773.0000	2.0000	3.0000	0.0317	0.0616	0.0880	0.1144
773.0000	2.0000	4.0000	0.0340	0.0748	0.1122	0.1565
773.0000	3.0000	1.0000	0.0328	0.0657	0.0985	0.1460
773.0000	3.0000	2.0000	0.0326	0.0761	0.1413	0.1957
773.0000	3.0000	3.0000	0.0439	0.0912	0.1351	0.1622
773.0000	3.0000	4.0000	0.0187	0.0561	0.0841	0.1215
773.0000	4.0000	1.0000	0.0261	0.0696	0.1043	0.1304
773.0000	4.0000	2.0000	0.0000	0.0000	0.0000	0.0000
773.0000	4.0000	3.0000	0.0142	0.0390	0.0709	0.0887
773.0000	4.0000	4.0000	0.0515	0.1031	0.1649	0.2268
773.0000	5.0000	1.0000	0.0347	0.0695	0.1042	0.1467
773.0000	5.0000	2.0000	0.0000	0.0196	0.0392	0.0784
773.0000	5.0000	3.0000	0.0230	0.0517	0.0747	0.1034
773.0000	5.0000	4.0000	0.0187	0.0487	0.0824	0.1066

DAW 5-30-06

Although the daily precipitation disaggregation technique utilized by Maurer, et al. (2002) is superior to no disaggregation, it doesn't capture the temporal variability of rainfall intensity within storms. Boughton (2005) describes a technique that overcomes this deficiency, but still has only an hourly resolution.

Boughton, W. 2005. Generation of hourly rainfalls for design flood estimation. Proc. Engr. Australia, 29th Hydrology and Water Resources Symposium, 21-23 Feb 2005, Canberra, Australia.

Boughton's technique is based upon the ratio of the maximum hourly rainfall to the total daily rainfall, designated as R. For daily precipitation ≥ 15 mm, the average R, showed consistent spatial variation for Australia, with a distribution around the average that also varied depending on location. Boughton (2005) also presented a procedure to distribute the daily precipition minus the maximum hourly precipitation to the remaining 23 hours of the day.

DAW 5-31-06 Options to be considered, in developing precipitation input series for Upper Split Wash modeling.

a) Utilize the daily precipitation model MC2ME to generate daily sequences for hypothesized future climates and disaggregate to n-hour storms of constant intensity with the tables of Maurer et al (2002).

b) Start with series generated in option a) but utilize additional hourly of 15 minute rainfall data to further disaggregate the storm rainfall.

DAW 5-31-06 Options (con't)

c) Utilize the break point (non-uniform time increment) data available from ARS in Tucson, AZ and Boise, ID to estimate parameters for disaggregation. This would require a substantial amount of time.

d) Locate other models that could utilize 15-min precip data

DAW 6-6-06

R.E. Smith sent an attached file with the format for precipitation that will be utilized for the continuos version of KINEROS2.

DAW 6-19-06 Daily Disaggregation Modeling

Daily to hourly

Objective. Adapt program of Maurer et al. (2002) to FORTRAN95 with input from simulations with program C:\CLIMAT05\SIM_05ASYM\MC2CLIMSIM-05.F95

DAW 6-27-06

Program HOUR_DISAG.F95 has been completed and tested with simulated precipitation data and CDF tables for NOGALES, AZ. Files are in C:\CLIMATE_06\DISAGGREGATION

Printouts of a control file and a partial output file are shown on p164.

Dar 6-27-06 Daily to Hourly Disaggregation

File C:\CLIMATE_06\DISAGGREGATION\NOGAL_DISAG.CON \STA_DISAG.CON

```
CONTROL FILE FOR NOGALES
C:\CLIMATE_06\DISAGGREGATION\NOGAL_DISAG.CON
C:\CLIMATE_06\DISAGGREGATION\NOGAL_DUR.TXT      - Duration CDF
C:\CLIMATE_06\DISAGGREGATION\NOGAL_HOUR.TXT     - Occurrence Time CDF
C:\CLIMAT05\SIM_05ASYM\NOGAL_DISAGTEST.PTR      - Input Precip file
C:\CLIMATE_06\DISAGGREGATION\NOGAL_DISAG.OUT    - output file
NYEARS  DATACODE PCODE
2       20  0
Format for R.E. Smith
BIN = 1 SEASON= 2
RANDOM NUMBER FOR DUR = 0.371334881
DURATION= 1                                  Diagnostic Info
RANDOM NUMBER FOR TIME = 0.312837750
MID_TIME= 9
HALFDUR= 0
 1 4 19  2 0  0.47     (YR, MO, DAY, # of Depth-Time pairs, CODE. Rain depth)
 0.00 480.00  0.47 540.00  0.00  0.00  0.00  0.00  0.00  0.00  - Depth-Time pairs
BIN = 1 SEASON= 2
RANDOM NUMBER FOR DUR = 0.607027709
DURATION= 2
RANDOM NUMBER FOR TIME = 0.175381616
MID_TIME= 4
HALFDUR= 1
RANDOM NUMBER FOR EVEN DUR = 0.837204754
 1 5 4  3 0  1.16
 0.47 180.00  1.05 240.00  1.63 300.00  0.00  0.00  0.00  0.00
BIN = 3 SEASON= 2
RANDOM NUMBER FOR DUR = 0.217734799
DURATION= 4
RANDOM NUMBER FOR TIME = 0.115781739
MID_TIME= 3
HALFDUR= 2
RANDOM NUMBER FOR EVEN DUR = 0.562166929
 1 5 27  5 0  14.01
 1.63  60.00  5.13 120.00  8.64 180.00  12.14 240.00  15.64 300.00
```

Note: Diagnostic information will not be included when output file format is finalized.

Dar 6-27-06

Sent e-mail request to S. Stothoff ~~requ.~~ for his required format.

Sent e-mail to Dr. José Salas of CSU to set up appointment to discuss his work on hourly disaggregation.

DAW 6-27-06 Disaggregation (con't)

A portion of an output file for Smith's format is shown below.

Time min. / mo / day / 2 pairs in next day / Code / total depth of following rain

yr / cum depth / time

```
Simulated Monsoon case, year 16, to be used in Opus
 0
 1916    5 4     2    0  0.84
 0.00  780.0   0.84  900.0
 1916    5 5     2    0  5.95
 0.84  780.0   6.79  900.0
 1916    529     2    0  7.20
 6.79  780.0  13.99  900.0
 1916    530     2    0  5.52
13.99  780.0  19.51  900.0
 1916    619     2    0  5.12
19.51  780.0  24.63  900.0
 1916    625     2    0  0.21
24.63  780.0  24.84  900.0
 1916    626     2    0  1.11
24.84  780.0  25.95  900.0
 1916    7 7    21    0  26.25       ! first storm
25.95  780.0  26.55  787.8  28.02  795.5  29.59  803.2  32.57  811.0
36.41  818.8  39.91  826.5  40.37  834.3  40.40  842.0  40.63  849.8
40.91  857.5  41.73  865.2  43.31  873.0  43.94  880.8  45.17  888.5
47.19  896.2  48.01  904.0  48.45  911.8  49.25  919.5  50.30  927.2
52.20  935.0
 1916    7 8    21    0  25.14
52.20  840.0  52.30  841.5  53.59  842.9  56.47  844.3  60.03  845.8
61.85  847.2  62.55  848.7  63.82  850.2  66.40  851.6  69.25  853.0
70.26  854.5  72.27  856.0  73.20  857.4  73.70  858.8  74.00  860.3
74.27  861.8  74.58  863.2  75.22  864.7  75.75  866.1  76.31  867.5
77.34  869.0
 1916    7 9     2    0  0.25
77.34  780.0  77.59  900.0
 1916    712     2    0  0.94
77.59  780.0  78.53  900.0
 1916    714     2    0  5.82
78.53  780.0  84.35  900.0
 1916    715     2    0  8.75
84.35  780.0  93.10  900.0
 1916    716     2    0  2.61
93.10  780.0  95.71  900.0
 1916    722     2    0  4.54
95.71  780.0 100.25  900.0
 1916    723     2    0  0.36
100.25 780.0 100.61  900.0
 1916    724     2    0  0.39
100.61 780.0 101.00  900.0
 1916    727     2    0  1.92
```

– 29th

– 5-30

6-19

6-25

6.26

21 pairs in storm

7-7

5 pairs / line

1440 min/day

DT DT DT DT

(START-1)60

DWL 10-26-06 Scientific Papers Documenting the Analyses of SOI-PDO perturbations

A paper entitled "Combined Effects of the Southern Oscillation Index and the Pacific Decadal Oscillation on a Stochastic Daily Precipitation Model" has been completed and recieved reviews by SWRI and NRC.

The Word Perfect Document is
DWL 10-26-06
C:\CLIMATOS\~~PDE~~ SOI_PDOMC2ME3E.wpd
and has been edited to conform to the requirements of Journal of Climate

RL 4/14/2008

DW 10-26-06 Scientific Paper Documentation

"Stochastic Precipitation Simulation for Future Climate Conditions"

The Word Perfect Document is:

C:\SWRI-Journal Papers\Journ of Hydrology\FUT_PRECIP_06 JHydrol.

on 10-6-06 I sent 1 hard copy + 1 CD to Stothoff for SWRI reviews

DW 12-12-06

I received the SWRI review of the above manuscript. It questioned the use of the SIMPLEX routine for adjusting parameters of the mixed exponential function to minimize the sum of squares of differences between the normalized expected precipitation functions $E^*\{S(n)\}$; $n=1,2\cdots365$ between the analog and target stations. The point was that SIMPLEX is a linear programming technique while $E^*\{S(n)\}$ functions have non-linearities. This is a valid question and should be addressed.

Two approaches are possible:

1) Utilize a non-linear optimization scheme.

2) Test the SIMPLEX application by numerical tests. This could be achieved by using the Fourier coefficients for the target station with perturbations as the analog station parameters to see if they will converge to the target station parameters.

Approach 2) would require much less effort and seems feasible given the rather good fits achieved previously.

Dan 12-12-06 Test of optimization procedure

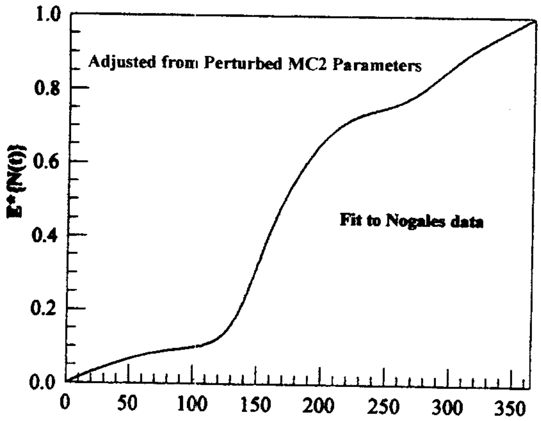
Program to be used: C:\CLIMATE_06\Season6_1.f95

Test 1: Use parameters for Nogales, AZ as target station
perturb these parameters for the analog station.
Procedure:
1. Edit control file for adjusting Nogales parameters
to MAN and MAP for RG4
File: C:\CLIMATE_06\MCZSEASON3.CON
Save as: " " \OPT_TEST1.CON ✓
change names of output files ✓
Copy files: C:\CLIMAT04\SIMULATION_04\NOGALESMCZ.FOU
C:\CLIMAT05\MCZME\NOGALESME.FOU
To: C:\CLIMATE_06 ✓
Change names to NOGALMCZPER.FOU ✓
NOGALMEPER.FOU ✓
Perturb MCZ parameters; there are 5 harmonics for
each parameter For all transition probabilities
+10% G_{000}, G_{010}, C_1, C_3, C_5, ϕ_2, ϕ_4
−10% G_{100}, G_{110}, C_2, C_4, ϕ_1, ϕ_3, ϕ_5

Dan 12-14-06

Season6_1.f95 was run with above example. The expected accumulated number of wet days and the expected accumulated precipitation were matched very closely, but comparisons of the parameter function G_{000}, G_{100}, G_{010} and G_{110} showed difference as shown on the following figures.

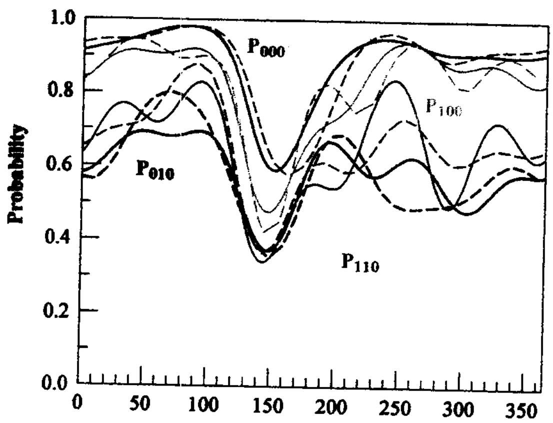
—DAW 12-15-06 Test of optimization Procedure (Con't)



Dimensionless Number of Wet Days, MC2 Nogales, AZ and as Adjusted from Perturbed Nogales Parameters

File: C:|CLIMATE_06|OPT_TEST1_NSTAR.PGW
Data: C:|CLIMATE_06|OPT_TEST1.DAT
daw 12-15-06

The dimsionless curves $E^*\{N(t)\}$ for Nogales and as adjusted from perturbed values of the MC2 parameters are nearly indistinuishable. This shows that ASIMPLX is very effective in minimizing the sum of squares of differences objective function.



MC2 Parameters for Nogales, AZ and as Estimated from Perturbed Initial Values

File: C:|CLIMATE_06|OPT_TEST1_MC2.pgw
daw 12-14-06

However the adjusted MC2 parameter functions differ from those identified for Nogales. This perhaps shouldn't be too surprising because there is a limited amount of information in the $E^*\{N(t)\}$ curve while there were were 44 free parameters to adjust.

Conclusion: The optimizing scheme is working well, but there may be many solutions that will meet the error criterion, depending on initial conditions.

TAW 1-3-07 Response to Review of Manuscript "Stochastic Precipitation Simulation ---- (Con't)

For the intended applications of this program, the strategy for optimization seems to work very well. (see figs pgs 147-154). Note that the greatest changes are in the Fourier constant for all parameters. (see Table p150). Changes in phase angles are small ~2% so the ±10% change (perturbation) in the test p168-169 is very severe.

Comment #3 by the reviewer asks for clarification of the transition from Eq 7 to Eq. 8.

Eq. 7 The expected total precipitation in m days

$$E\{S(m)\} = \sum_{n=1}^{m}$$

where: $S(m) = \sum_{n=1}^{m} X(n)\,Y(n)$; $E\{S(m)\} = E\left\{\sum_{n=1}^{m} X(n)\,Y(n)\right\}$

Because $Y(n)$ is not depended on previous values of $X(n)$

$$E\{S(m)\} = \sum_{n=1}^{m} E\{X(n)\}\,E\{Y(n)\}$$

$$E\{X(n)\} = P_w(n) = P\{X(n)=1\}$$

DAW 1-3-07

$$P\{X=1\} = P\{X(n-2)=0;\ X(n-1)=0\}[1-P_{000}(n)]$$
$$+\ P\{X(n-2)=1;\ X(n-1)=0\}[1-P_{100}(n)]$$
$$+\ P\{X(n-2)=0;\ X(n-1)=1\}[1-P_{010}(n)]$$
$$+\ P\{X(n-2)=1;\ X(n-1)=1\}[1-P_{110}(n)]$$

DAW 1-25-07

The paper "Combined Effects of the Southern Oscillation Index and the Pacific Decadal Oscillation on a Stochastic Daily Precipitation Model" (file: C:\CLIMATO5\PDO-SOSPaper\SOI_PDOMC2ME3E.wpd was submitted electronically to the American Meteorological Society on 12/21/2006. To send manuscripts to reviewers they render the Word Perfect file to a pdf file. Unfortunately their software did not make a perfect conversion, i.e. several equations were moved or were unintelligible. Finally I published the wpd manuscript file to a pdf file and the paper has been sent to an associate editor of Journal of Climate.
Today I sent a wpd file and a pdf file of the submitted version to Stothoff.
File names: SOI-PDOMC2ME3ERev2.wpd .pdf.

DAW 4-24-07

On 4-19, I received an e-mail from an associate editor of Journ. of Climate with a tentative acceptance of the paper "Combined Effects of the Southern Oscillation Index ..." subject to revisions. Comments from 2 reviewers were also received.

DAW 4-24-07 Revisions of Manuscript
C:\CLIMAT05\PDO_SOIPAPER\SOI_PDO_MC2MERev2.wpd
copied to
C:\SWRI_Journal Papers\
and name changed to SOI_PDO_MC2MERev3.wpd

DAW 4-30-07
To respond to reviewer A, I have created a figure showing two years of daily values of P_{000}, perturbed P_{000}, SOI and PDO for Fortymile Canyon.
Data file: C:\CLIMAT05\SIM05_ASYM\FORTYMC2_2B.PPW (See p. 83). This should help the reader understand the general concept and will illustrate nonstationarity of the perturbed P_{000} sequence.

DAW 5-7-07
To respond to reviewer B, I have updated two figures. One shows probability mass functions (cumulative) for the month of ~~Sep~~ Jan. DAW 5-7-07 for Fortymile Canyon, the other shows CDFs of total monthly precipitation for the same month and station. See pgs 56 and 61.

DAW 5-25-07 Revision (Con't)

I noted that the figures shown on p56 + 57 were from the analysis of simulated data that didn't include the asymmetric coefficients. New simulations were performed on 6-20-05 (See p. 87)

Output file: C:\CLIMAT05\SIM_05ASYM\FORTYMC2P_2B.*

From the *.STA import the wet day statistics to PSI PlOT data sheet \MC2P_SPRING.DAT

Convert to (same directory) \FORTMC2P_2BWET.PDW

DAW 6-4-07 Revision of SOI-PDO paper (con't)

In preparing a new section entitled "Goodness of fit" in response to a reviewers comment, a question arose regarding the reason that for some station's the AIC for the mixed exponential with step function parameters was superior to the Fourier representation. Possible reasons include: length of record for dry climates, the number of periods (13 or 26) or the optimization strategy. To check this out, I ran 3 more parameter identifiability computer runs with the simulated Fortymile Canyon series (See p 35). Previous runs had used 13 periods - for these runs I used 26 periods.

A PSIPLOT summary file is in: C:\CLIMAT04\MC2TEST\AICBICFORTY1D.PDW

The AIC has been criticized for overfitting so the Bayesian Information Criterion (BIC) was also calculated. The BIC is given by:

$$BIC(m) = -2 \ln M_m + k_m \ln n$$

where M_m is the likelihood for the m^{th} model, k_m is the number of parameters and n is record length

DAW 6-14-07 Revision

The BIC was developed by:

Schwarz, G., 1978. Estimating the dimension of a model, Ann. Stat. 6, 461-464.

The summary is shown on the adjacent table. Run number codes show No of yrs ie (ID30) and 26 means 26-14-day periods, otherwise 13 periods. For the mixed exponential there are 3 parameters, α, β & θ so for 13 periods we have a total of 39. The 3 - 50-yr runs are independent, the 30 and 40 yr. runs are part of FORTYID 50.

According to the AIC, the period representation was superior for all but 2 runs. However, the BIC shows that the Fourier representation is always superior. The reduction in the number of parameters by the Fourier representation is significant, i.e. 9 vs 39 for FORTYID50C and 9 vs. 78 for FORTYID50C26.

C:\CLIMAT04\mc2test\AICBICFORTYID.PDW

Log L periods · # Parameters · Yrs of record · BIC period · Log Likelihood Fourier · Fourier Params · Best AIC · Best BIC

RUN NO	PERLIK	PARPER	AICPER	NYRS	BICPER	FORLIK	PARFOR	AICFOR	BICFOR	BESTAIC	BESTBIC	NWET	AVEP	CV
FORTYID30	1301.00	39.00	-2524.00	30.00	-2469.36	1247.00	7.00	-2480.00	-2470.19	PER	FOR	45.33	209.30	0.29
FORTYID3026	-3225.00	78.00	6606.00	30.00	6715.29	-3305.00	9.00	6628.00	6640.61	PER	FOR			
FORTYID40	1696.00	39.00	-3314.00	40.00	-3248.13	1643.00	7.00	-3272.00	-3260.18	PER	FOR	44.85	206.70	0.28
FORTYID4026	-4319.00	78.00	8794.00	40.00	8925.73	-4362.00	9.00	8742.00	8757.20	FOR	FOR			
FORTYID50	2063.00	39.00	-4048.00	50.00	-3973.43	2007.00	7.00	-4000.00	-3986.62	PER	FOR	44.60	205.25	0.28
FORTYID5026	-5400.00	78.00	10956.00	50.00	11105.14	-5443.00	9.00	10904.00	10921.21	FOR	FOR			
FORTYID50B	2031.00	39.00	-3984.00	50.00	-3909.43	2000.00	13.00	-3974.00	-3949.14	PER	FOR	46.00	226.60	0.27
FORTYID50B26	-5623.00	78.00	11402.00	50.00	11551.14	-5691.00	11.00	11404.00	11425.03	PER	FOR			
FORTYID50C	2055.00	39.00	-4032.00	50.00	-3957.43	2004.00	9.00	-3990.00	-3972.79	PER	FOR	44.26	207.76	0.33
FORTYID50C26	-5311.00	78.00	10778.00	50.00	10927.14	-5396.00	9.00	10810.00	10827.21	PER	FOR			

C:\CLIMAT04\mc2test\AICBICFORTYID.PDW

DAW 3-6-08

This terminates the entries in this notebook

Notebook sent to S. Stothoff 3-6-08

David A. Woolley

RL 4/14/2008

ADDITIONAL INFORMATION FOR SCIENTIFIC NOTEBOOK NO. 444 & 597

Document Date:	7/17/03
Availability:	Southwest Research Institute® Center for Nuclear Waste Regulatory Analyses 6220 Culebra Road San Antonio, Texas 78228
Contact:	Southwest Research Institute® Center for Nuclear Waste Regulatory Analyses 6220 Culebra Road San Antonio, TX 78228-5166 Attn.: Director of Administration 210.522.5054
Data Sensitivity:	■"Non-Sensitive" ☐ Sensitive ☐"Non-Sensitive - Copyright" ☐ Sensitive - Copyright
Date Generated:	4/13/2001
Operating System: (including version number)	Windows
Application Used: (including version number)	KINEROS2
Media Type: (CDs, 3 ½, 5 1/4 disks, etc.)	1CD
File Types: (.exe, .bat, .zip, etc.)	.mod; .exe; .map; .wpd; .zip
Remarks: (computer runs, etc.)	Various figures, maps, computer runs, papers, and reports. CD located with Notebook 444.

David A. Woolhiser
Hydrologist
2833 Sunstone Drive
Fort Collins, CO 80525-5691
970 482-7810
September 20, 2007

Dr. Stuart Stothoff
Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78238-5166

SUBJECT: Copies of pages of Scientific Notebooks #444 and #597 for 3-15-07 to 9-20-07.

Stuart,

Enclosed are copies of pages 213-220 of Notebook 444 and pages 171-174 of Notebook 597. These pages cover work performed during the period from 3-15-07 to 9-20-07. Electronic files for this period are being sent on a CD under separate cover.

David A. Woolhiser

David A. Woolhiser, Ph.D.

ADDITIONAL INFORMATION FOR SCIENTIFIC NOTEBOOK NO. 597 # 444

Document Date:	7/17/03
Availability:	Southwest Research Institute® Center for Nuclear Waste Regulatory Analyses 6220 Culebra Road San Antonio, Texas 78228
Contact:	Southwest Research Institute® Center for Nuclear Waste Regulatory Analyses 6220 Culebra Road San Antonio, TX 78228-5166 Attn.: Director of Administration 210.522.5054
Data Sensitivity:	■"Non-Sensitive" □ Sensitive □"Non-Sensitive - Copyright" □ Sensitive - Copyright
Date Generated:	9/16/2003 through 3/19/2004
Operating System: (including version number)	Windows
Application Used: (including version number)	WordPerfect
Media Type: (CDs, 3 ½, 5 1/4 disks, etc.)	1 CD
File Types: (.exe, .bat, .zip, etc.)	.wpd; .pdf; .zip; .ASCII text
Remarks: (computer runs, etc.)	Various files with various extensions and attachments to notebook. CD located with Notebook 444.

ADDITIONAL INFORMATION FOR SCIENTIFIC NOTEBOOK NO. 444 & 597 & 363

Document Date:	7/17/03
Availability:	Southwest Research Institute® Center for Nuclear Waste Regulatory Analyses 6220 Culebra Road San Antonio, Texas 78228
Contact:	Southwest Research Institute® Center for Nuclear Waste Regulatory Analyses 6220 Culebra Road San Antonio, TX 78228-5166 Attn.: Director of Administration 210.522.5054
Data Sensitivity:	■"Non-Sensitive" ☐ Sensitive ☐"Non-Sensitive - Copyright" ☐ Sensitive - Copyright
Date Generated:	09/16/2003
Operating System: (including version number)	Windows
Application Used: (including version number)	WordPerfect 8.0
Media Type: (CDs, 3 ½, 5 1/4 disks, etc.)	1CD
File Types: (.exe, .bat, .zip, etc.)	.exe; .bas; .pgw; .wpd
Remarks: (computer runs, etc.)	Various files and attachments to notebook. CD located with Notebook 444.

David A. Woolhiser
Hydrologist
2833 Sunstone Drive
Fort Collins, CO 80525-5691
970 482-7810
March 14, 2007

Dr. Stuart Stothoff
Center for Nuclear Waste Regulatory Analysis
Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78228

SUBJECT: Computer files sent to SWRI documenting work done on Scientific Notebooks #444 and #597 for the period 9-16-06 to 3-14-07.

Stuart,

The files included on this CD are related to work documented in the above cited notebooks. Some of the files included may not be mentioned specifically in the notebooks (intermediate files, files referred to in control files, etc.) but I have included them in the interest of saving time. There are files from the previous periods as well - I simply copied the entire folder.

Dave

David A. Woolhiser

ADDITIONAL INFORMATION FOR SCIENTIFIC NOTEBOOK NO. 444 & 597

Document Date:	7/17/03
Availability:	Southwest Research Institute® Center for Nuclear Waste Regulatory Analyses 6220 Culebra Road San Antonio, Texas 78228
Contact:	Southwest Research Institute® Center for Nuclear Waste Regulatory Analyses 6220 Culebra Road San Antonio, TX 78228-5166 Attn.: Director of Administration 210.522.5054
Data Sensitivity:	■"Non-Sensitive" □ Sensitive □"Non-Sensitive - Copyright" □ Sensitive - Copyright
Date Generated:	9/16/2006 through 3/14/2007
Operating System: (including version number)	Windows
Application Used: (including version number)	WordPerfect
Media Type: (CDs, 3 ½, 5 1/4 disks, etc.)	1 CD
File Types: (.exe, .bat, .zip, etc.)	.wpd; .bas; .exe; .pgw; .fil; .out; .doc
Remarks: (computer runs, etc.)	Various files and attachments to notebook. CD located with Notebook 444.

ADDITIONAL INFORMATION FOR SCIENTIFIC NOTEBOOK NO. 597

Document Date:	7/17/03
Availability:	Southwest Research Institute® Center for Nuclear Waste Regulatory Analyses 6220 Culebra Road San Antonio, Texas 78228
Contact:	Southwest Research Institute® Center for Nuclear Waste Regulatory Analyses 6220 Culebra Road San Antonio, TX 78228-5166 Attn.: Director of Administration 210.522.5054
Data Sensitivity:	■"Non-Sensitive" ☐ Sensitive ☐"Non-Sensitive - Copyright" ☐ Sensitive - Copyright
Date Generated:	3/19/2004 through 9/7/2004
Operating System: (including version number)	Windows
Application Used: (including version number)	WordPerfect
Media Type: (CDs, 3 ½, 5 1/4 disks, etc.)	2 CD
File Types: (.exe, .bat, .zip, etc.)	.wpd; .qpw; .pgw; .zip; ASCII text
Remarks: (computer runs, etc.)	Various files with various extensions and attachments to notebook. CD located with Notebook 444.

David A. Woolhiser
Hydrologist
2833 Sunstone Drive
Fort Collins, CO 80525-5691
970 482-7810
September 15, 2006

Dr. Stuart Stothoff
Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78238-5166

SUBJECT: Copies of pages of Scientific Notebook 597 for 3-23-06 to 9-15-06.

Stuart,

Enclosed are copies of pages 144-165 of Notebook 597. These pages cover work performed during the period from 3-23-06 to 9-15-06. No additions were made in Notebook 444 during this period. Electronic files for this period are being sent on a CD under separate cover.

David A. Woolhiser

David A. Woolhiser, Ph.D.

David A. Woolhiser
Hydrologist
2833 Sunstone Drive
Fort Collins, CO 80525-5691
970 482-7810
September 15, 2006

Dr. Stuart Stothoff
Center for Nuclear Waste Regulatory Analysis
Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78228

SUBJECT: Computer files sent to SWRI documenting work done on Scientific Notebook 597 for the period 3-23-06 to 9-15-06.

Stuart,

The files included on this CD are related to work documented in the above cited notebooks. Some of the files included may not be mentioned specifically in the notebooks (intermediate files, files referred to in control files, etc.) but I have included them in the interest of saving time. There are files from the previous period as well - I simply copied the entire folder. No entries were made in Scientific Notebook 444 during this time period.

David A. Woolhiser

Dave