Appendix D

Statistical Analysis Of Simulation Results

The statistical analyses were performed in this study to quantify levels of uncertainty associated with simulation results. Means and standard deviations of the difference between observed and simulated temperatures were computed for the entire simulation period and for each two-month period for the duration of the simulation (01/01/1990 – 12/31/1994). The results are given in Tables D-1 through D-9. An analysis of the regression of observed results on simulated results was also performed. In the regression analysis, the linear relationship is constrained to pass through the origin of the coordinates at (X=0, Y=0) as shown in Figures D-1 through D-9. The results of the regression are shown Table D-10.

Certain statistics are also generated as part of the parameter estimation process. These include the theoretical and sample variance of the innovations process Figures D-10 through D-18 and the innovations process (Equation 12) (Figures D-19 through D-27).

When reviewing these statistics it is important to keep in mind that the means and standard deviations of the difference between observed and simulated are based on state estimates using the model in the *prediction* mode. That is, the state estimates from the model do not depend on prior observations. The statistics generated by the parameter estimation process are a result of using the model in the *filtering* mode. This means that the innovations sequence, the difference between observed and the systems update prior to filtering, is a function of previous observations and state estimates. In addition, the parameter estimation process attempts to estimates the bias in the observations.

Table D-1. Mean and standard deviation of the difference between observed and simulated temperatures at Wells Dam (Columbia River Mile 515.6) for the period 1990-1994. Observed data are from the total dissolved gas monitoring locations in the forebay of the dam at a depth of 15 feet. Dashes (---) indicate limited (N<10) data for computing statistics

Time Period	Mean Difference	Standard Deviation of Difference
January-February	---	---
March-April	-0.028	0.510
May-June	0.035	0.802
July-August	-0.136	0.529
September-October	0.494	0.488
November-December	---	--
Entire Year	0.009	0.677

Table D-2. Mean and standard deviation of the difference between observed and simulated temperatures at Priest Rapids Dam (Columbia River Mile 397.1) for the period 1990-1994. Observed data are from the total dissolved gas monitoring locations in the forebay of the dam at a depth of 15 feet. Dashes (---) indicate limited (N<10) data for computing statistics

Time Period	Mean Difference	Standard Deviation of Difference
January-February	---	---
March-April	0.320	0.999
May-June	-0.623	0.895
July-August	-0.499	0.880
September-October	0.855	0.433
November-December	---	--
Entire Year	-0.277	1.012

Table D-3. Mean and standard deviation of the difference between observed and simulated temperatures at McNary Dam (Columbia River Mile 292.0) for the period 1990-1994. Observed data are from the total dissolved gas monitoring locations in the forebay of the dam at a depth of 15 feet. Dashes (---) indicate limited (N<10) data for computing statistics

Time Period	Mean Difference	Standard Deviation of Difference
January-February	---	---
March-April	0.940	0.929
May-June	0.749	1.194
July-August	0.884	1.335
September-October	1.653	1.027
November-December	---	--
Entire Year	0.983	1.236

Table D-4. Mean and standard deviation of the difference between observed and simulated temperatures at John Day Dam (Columbia River Mile 215.6) for the period 1990-1994. Observed data are from the total dissolved gas monitoring locations in the forebay of the dam at a depth of 15 feet. Dashes (---) indicate limited (N<10) data for computing statistics

Time Period	Mean Difference	Standard Deviation of Difference
January-February	0.580	1.309
March-April	1.273	0.730
May-June	0.283	0.924
July-August	0.288	0.986
September-October	0.9425	0.646
November-December	---	---
Entire Year	0.560	1.021

Table D-5. Mean and standard deviation of the difference between observed and simulated temperatures at Bonneville Dam (Columbia River Mile 215.6) for the period 1990-1994. Observed data are from the total dissolved gas monitoring locations in the forebay of the dam at a depth of 15 feet. Dashes (---) indicate limited (N<10) data for computing statistics

Time Period	Mean Difference	Standard Deviation of Difference
January-February	---	---
March-April	0.909	1.002
May-June	0.413	1.248
July-August	-0.382	1.423
September-October	0.524	0.868
November-December	---	---
Entire Year	0.241	1.306

Table D-6. Mean and standard deviation of the difference between observed and simulated temperatures at Bonneville Dam (Columbia River Mile 215.6) for the period 1990-1994. Observed data are from the total dissolved gas monitoring locations in the forebay of the dam at a depth of 15 feet. Dashes (---) indicate limited (N<10) data for computing statistics

Time Period	Mean Difference	Standard Deviation of Difference
January-February	---	---
March-April	0.909	1.002
May-June	0.413	1.248
July-August	-0.382	1.423
September-October	0.524	0.868
November-December	---	---
Entire Year	0.241	1.306

Table D-7. Mean and standard deviation of the difference between observed and simulated temperatures at Lower Granite Dam (Snake River Mile 107.5) for the period 1990-1994. Observed data are from the total dissolved gas monitoring locations in the forebay of the dam at a depth of 15 feet. Dashes (---) indicate limited (N<10) data for computing statistics

Time Period	Mean Difference	Standard Deviation of Difference
January-February	---	---
March-April	1.052	1.388
May-June	-0.040	1.363
July-August	1.136	1.120
September-October	0.409	1.076
November-December	-0.133	0.203
Entire Year	0.588	1.320

Table D-7. Mean and standard deviation of the difference between observed and simulated temperatures at Little Goose Dam (Snake River Mile 70.3) for the period 1990-1994. Observed data are from the total dissolved gas monitoring locations in the forebay of the dam at a depth of 15 feet. Dashes (---) indicate limited (N<10) data for computing statistics

Time Period	Mean Difference	Standard Deviation of Difference
January-February	---	---
March-April	1.086	1.144
May-June	-0.196	1.167
July-August	0.131	1.532
September-October	-0.228	1.436
November-December	---	---
Entire Year	0.048	1.420

Table D-8. Mean and standard deviation of the difference between observed and simulated temperatures at Lower Monumental Dam (Snake River Mile 41.6) for the period 1990-1994. Observed data are from the total dissolved gas monitoring locations in the forebay of the dam at a depth of 15 feet. Dashes (---) indicate limited (N<10) data for computing statistics

Time Period	Mean Difference	Standard Deviation of Difference
January-February	---	---
March-April	1.543	0.900
May-June	0.027	0.884
July-August	-0.067	1.269
September-October	-0.036	0.933
November-December	---	---
Entire Year	0.124	1.187

Table D-9. Mean and standard deviation of the difference between observed and simulated temperatures at Ice Harbor Dam (Columbia River Mile 9.7) for the period 1990-1994. Observed data are from the total dissolved gas monitoring locations in the forebay of the dam at a depth of 15 feet. Dashes (---) indicate limited (N<10) data for computing statistics

Time Period	Mean Difference	Standard Deviation of Difference
January-February	---	---
March-April	1.784	1.021
May-June	0.155	0.888
July-August	0.192	1.190
September-October	0.625	1.093
November-December	---	---
Entire Year	0.407	1.202

Table D-10. Slope of line and R^2 for regression of observed temperature data on simulated results in the Columbia and Snake rivers for the period 1990-1994. Regression was constrained to force the straight line to pass through the origin (X (simulated)=0, Y (observed)=0).

Measurement Site	Slope of Line	R^2
Wells Dam	0.995	0.973
Priest Rapids Dam	0.999	0.940
McNary Dam	1.004	0.929
John Day Dam	0.995	0.976
Bonnevile Dam	0.995	0.904
Lower Granite Dam	1.005	0.931
Little Goose Dam	0.997	0.907
Lower Monumental Dam	0.992	0.923
Ice Harbor Dam	0.998	0.929

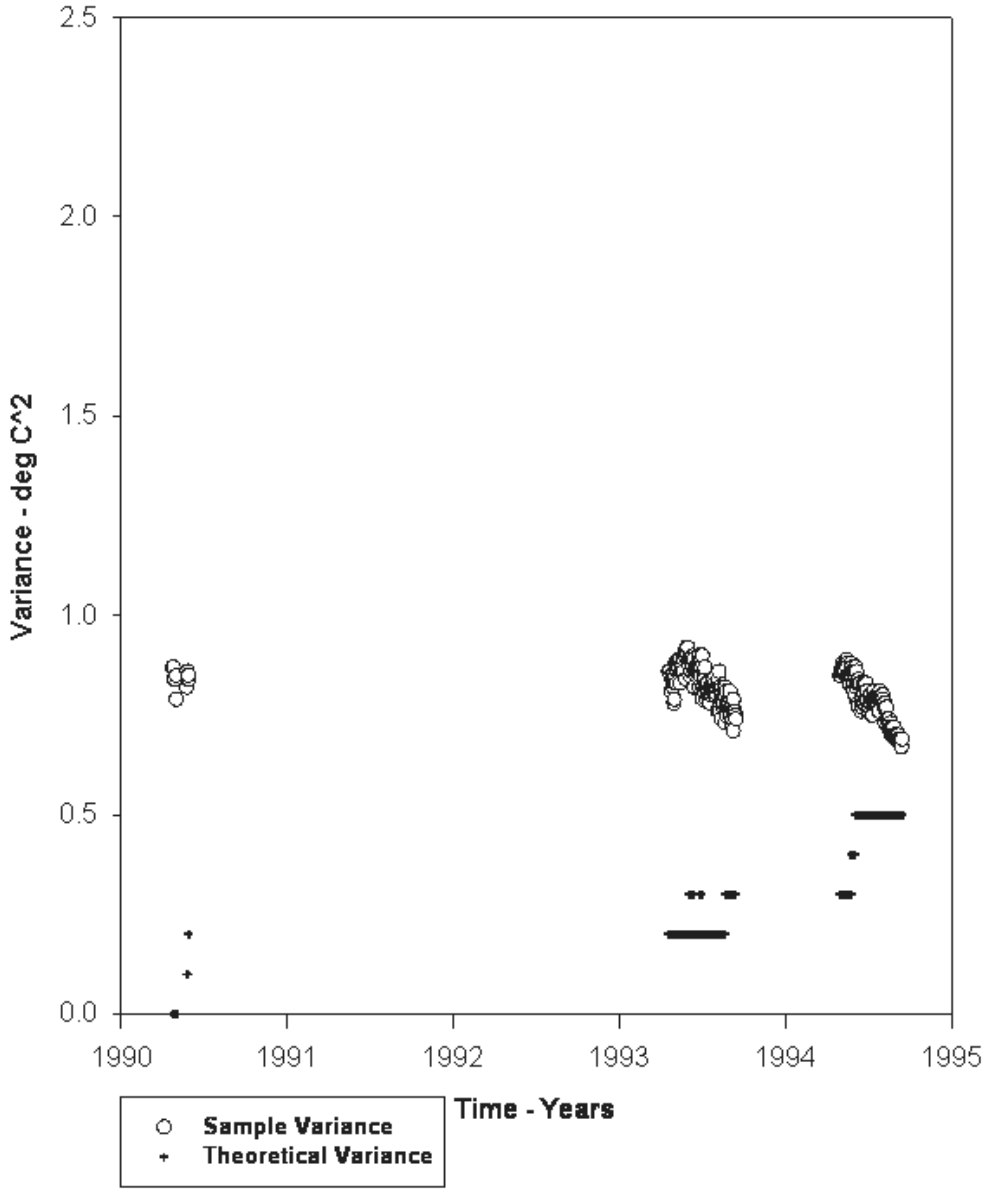

Figure D-10. Theoretical and sample variance of innovations sequence at Wells Dam - 1990-1995

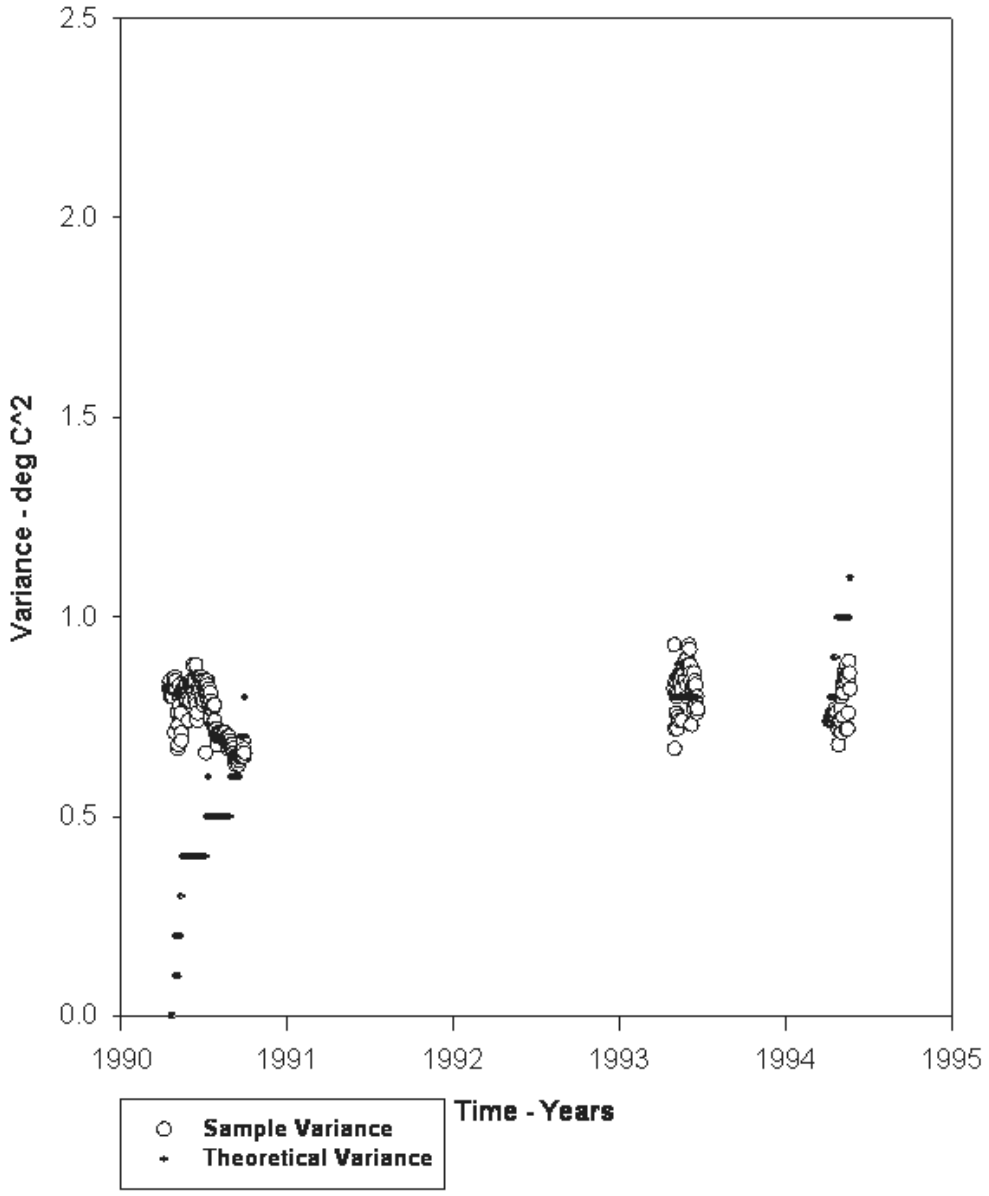

Figure D-11. Theoretical and sample variance of innovations sequence at Priest Rapids Dam - 1990-1995

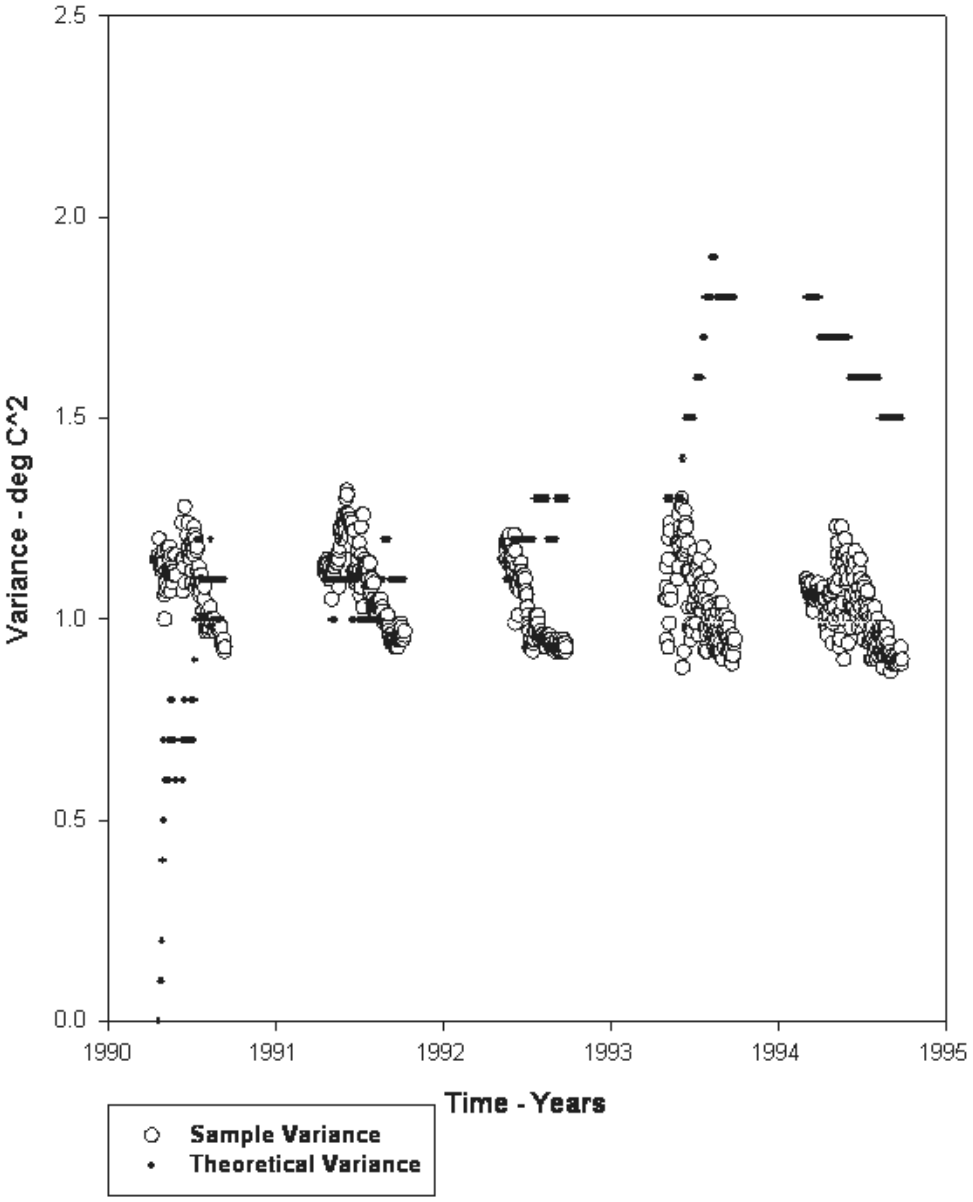

Figure D-12. Theoretical and sample variance of innovations sequence at McNary Dam - 1990-1995

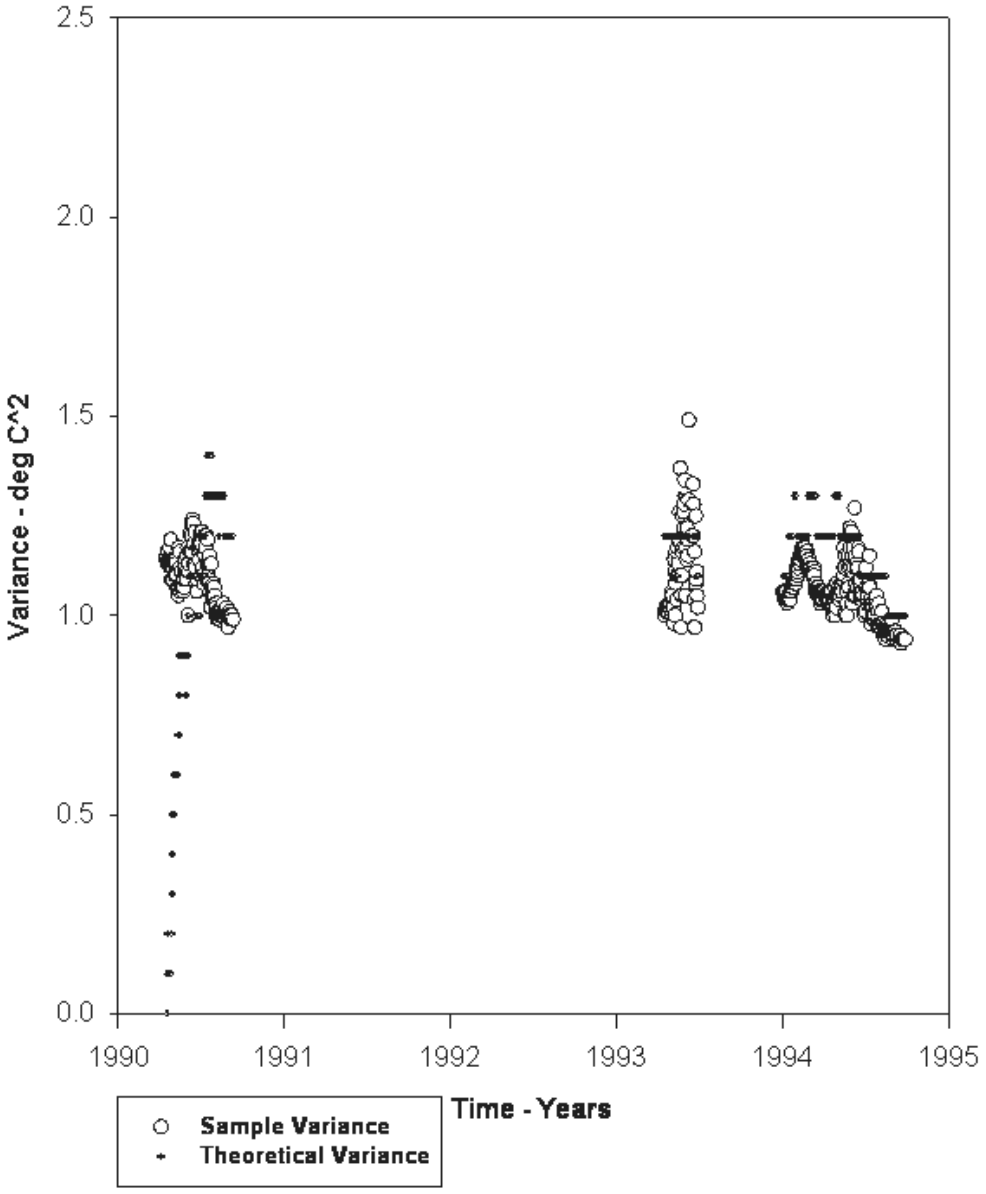

Figure D-13. Theoretical and sample variance of innovations sequence at John Day Dam - 1990-1995

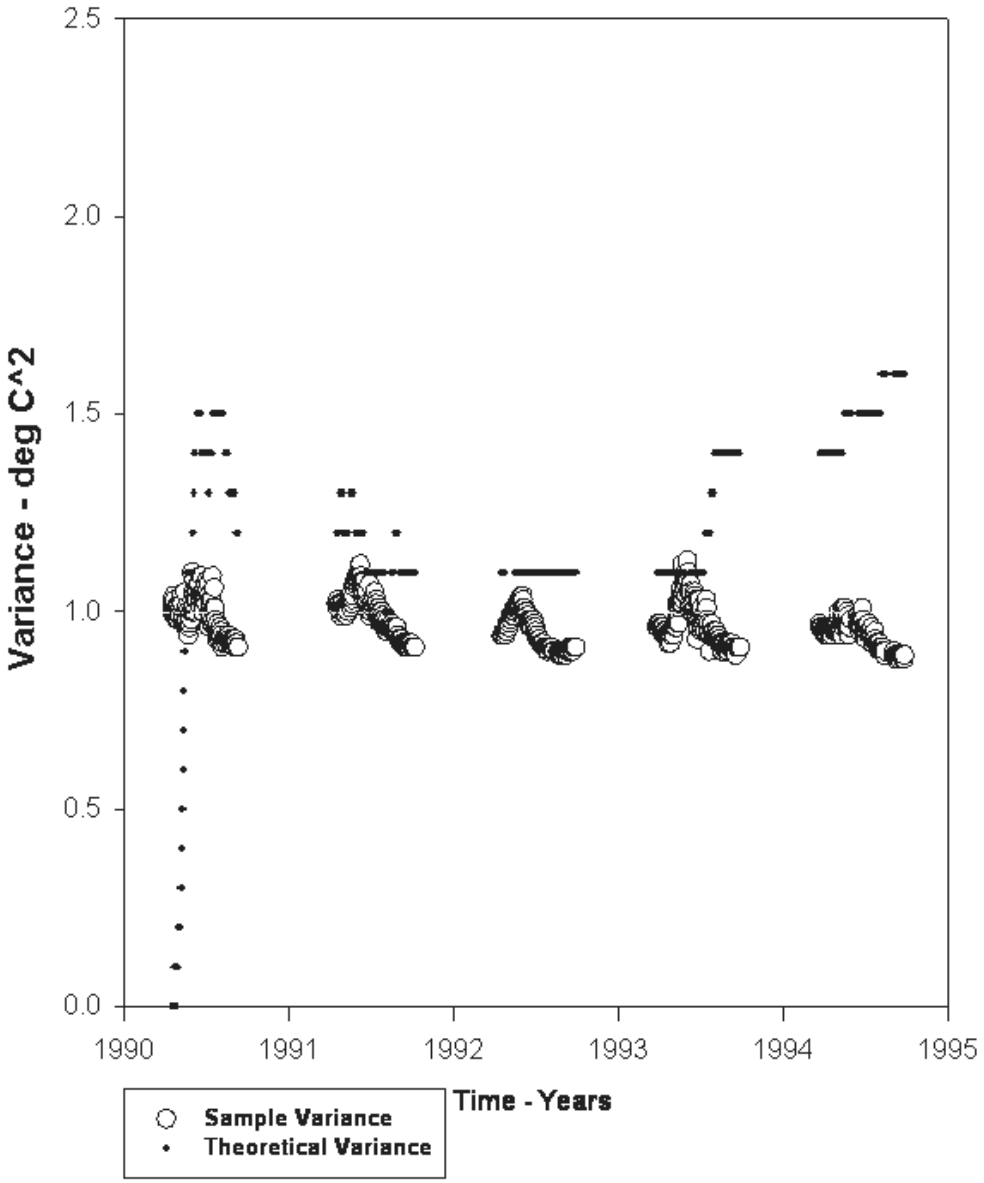

Figure D-14. Theoretical and sample variance of innovations sequence at Bonneville Dam - 1990-1995

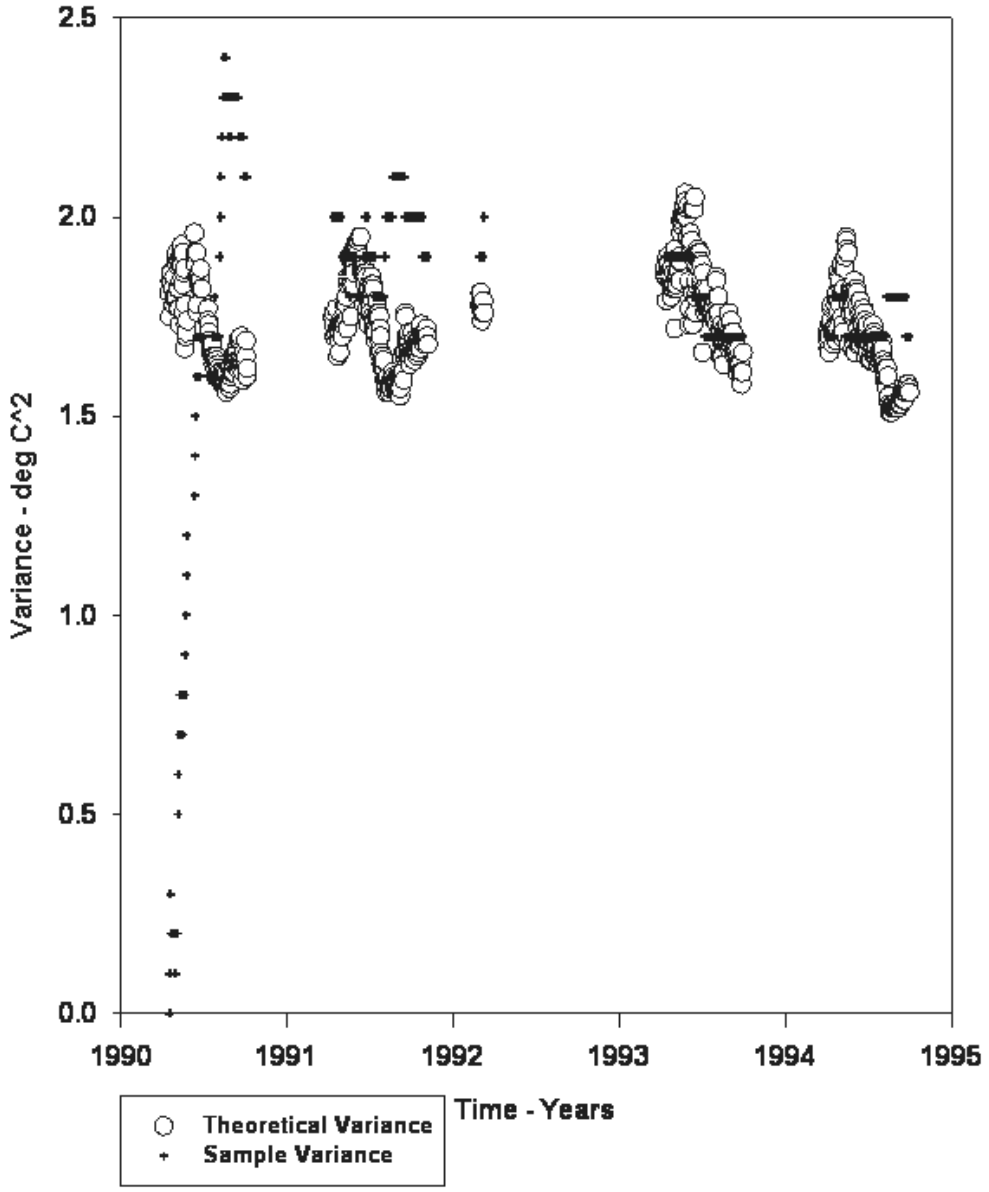

Figure D-15. Theoretical and sample variance of innovations sequence at Lower Granite Dam

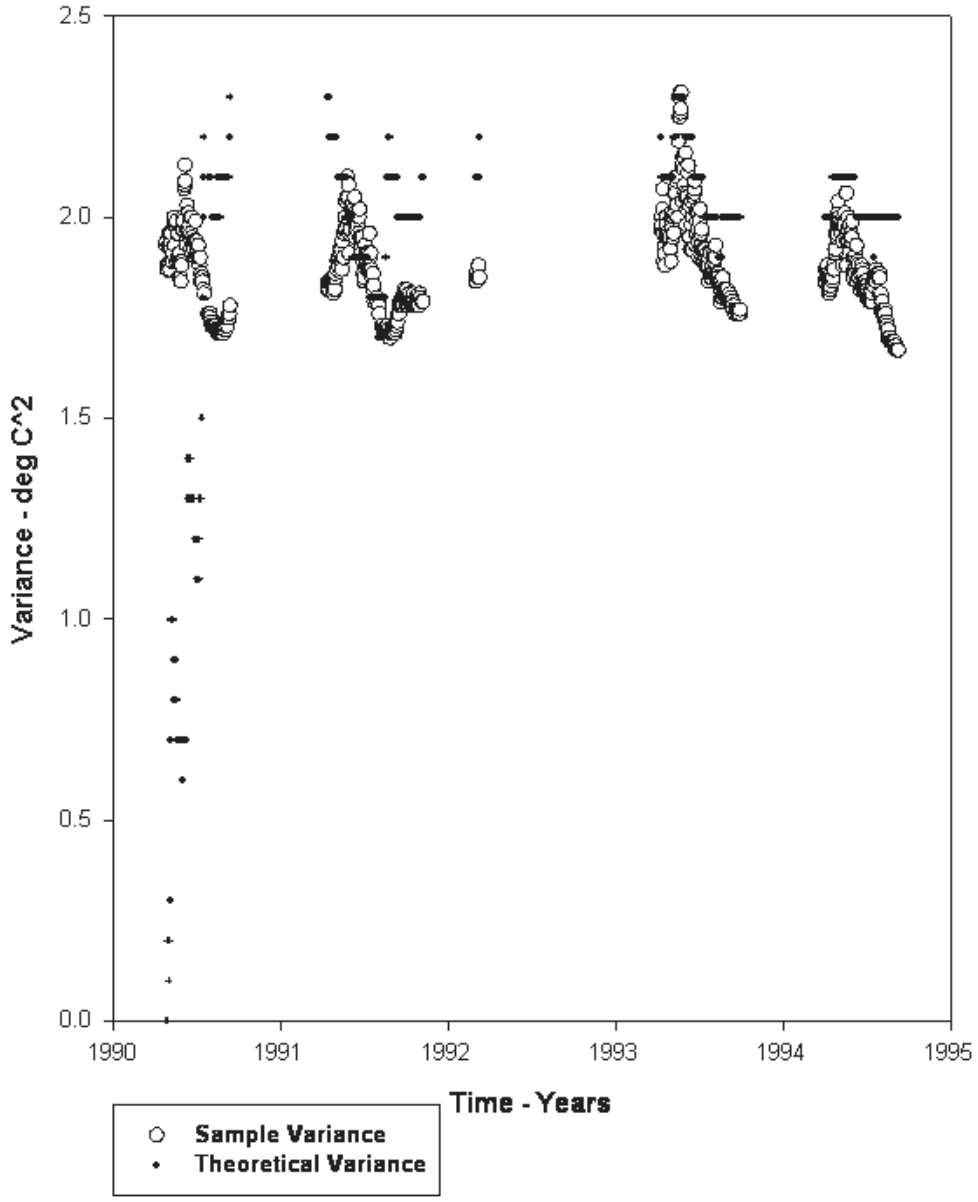

Figure D-16. Theoretical and sample variance of innovations sequence at Little Goose Dam - 1990-1995

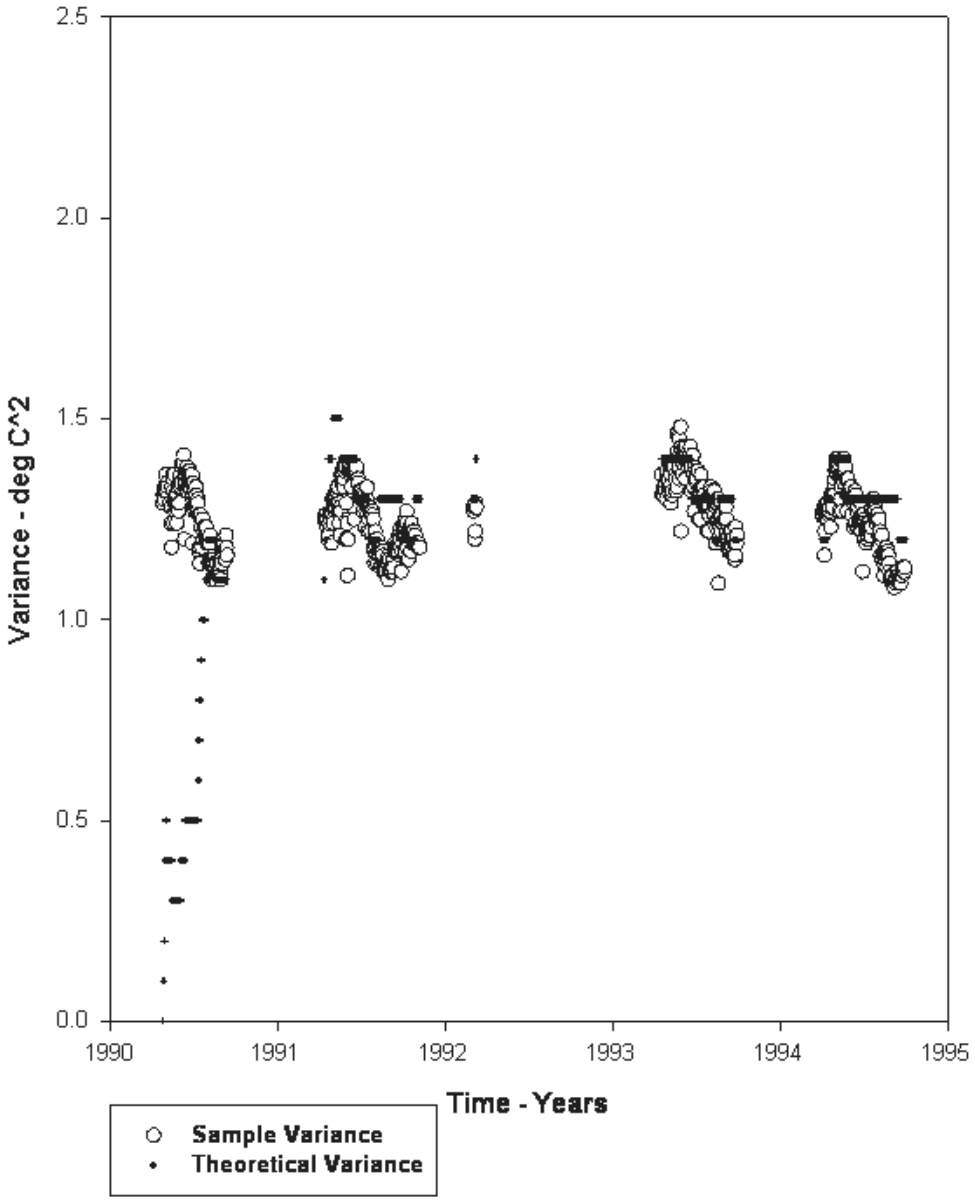

Figure D-17.
Theoretical and sample variance of innovations sequence at Lower Monumental Dam - 1990-1995

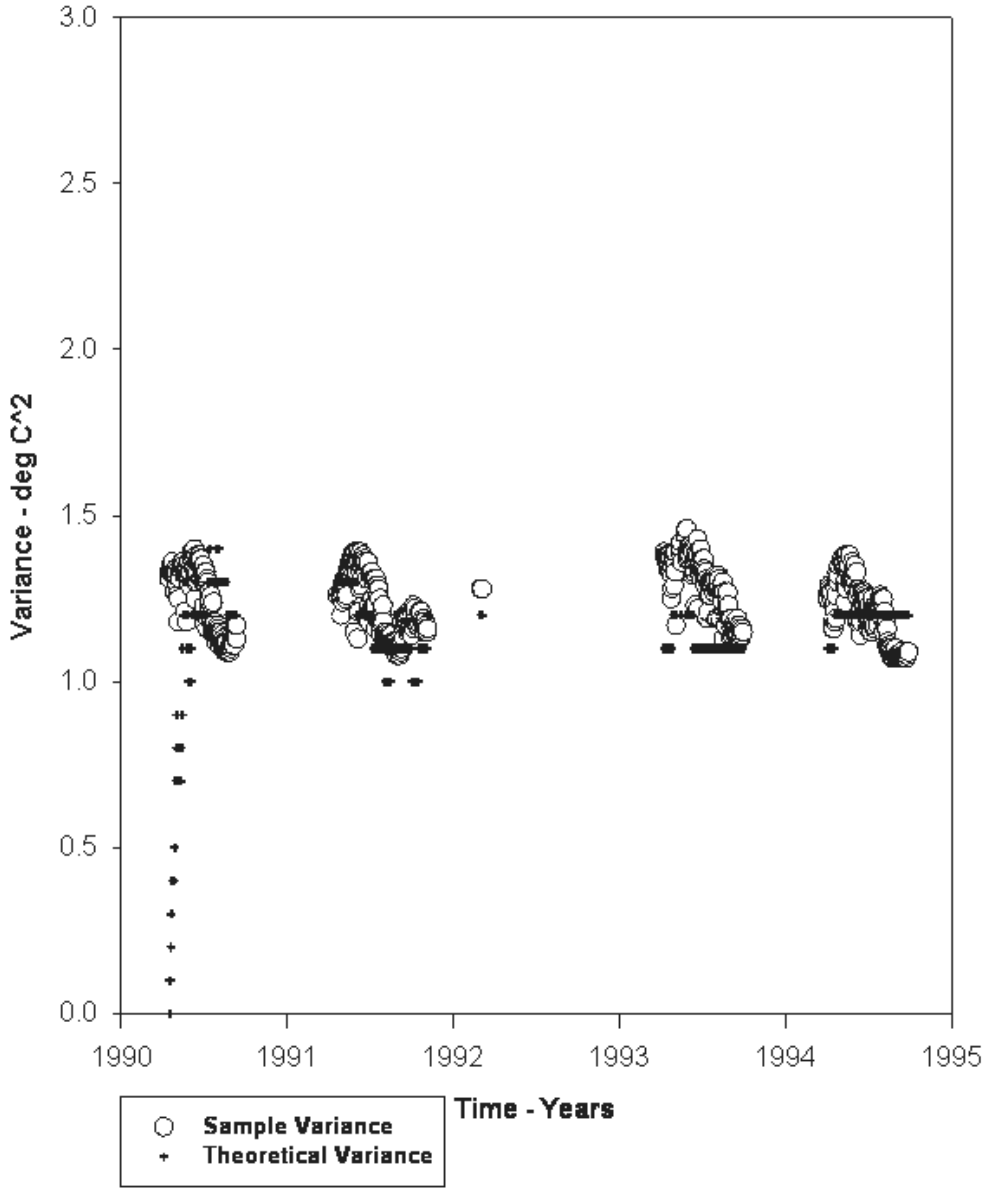

Figure D-18. Theoretical and sample variance of innovations sequence at Ice Harbor Dam - 1990-1995

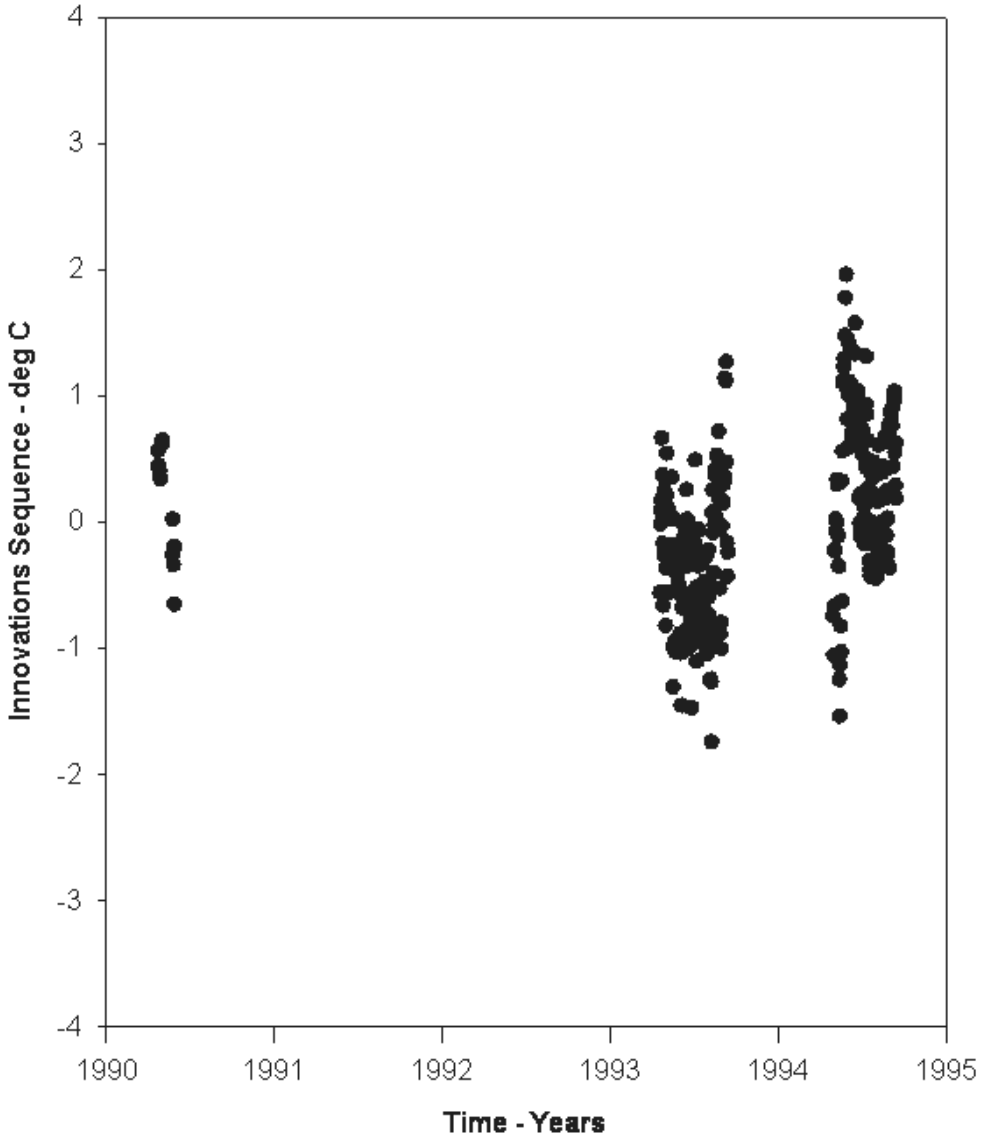

Figure D-19. Innovations sequence for Wells Dam - 1990-1995

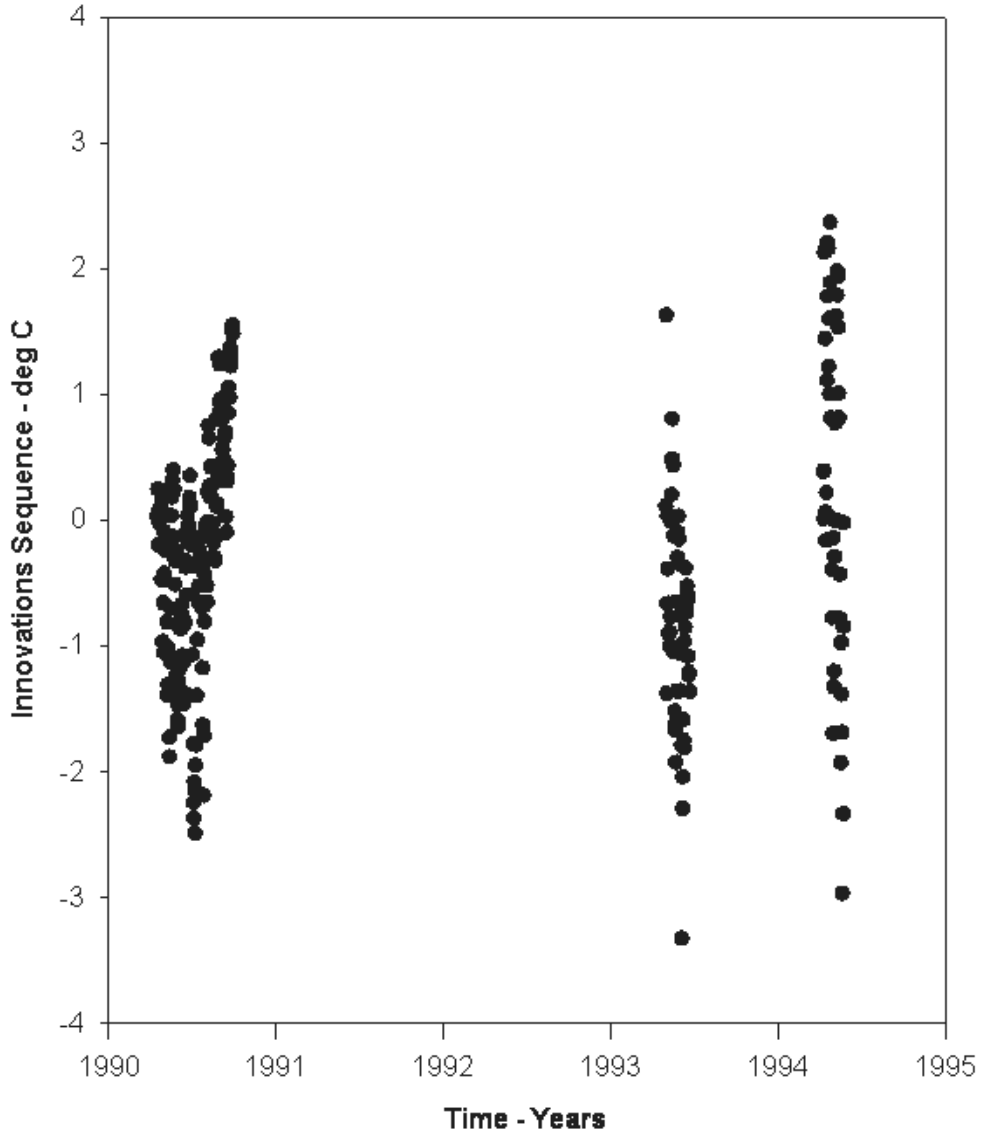

Figure D-20. Innovations sequence for Priest Rapids Dam - 1990-1995

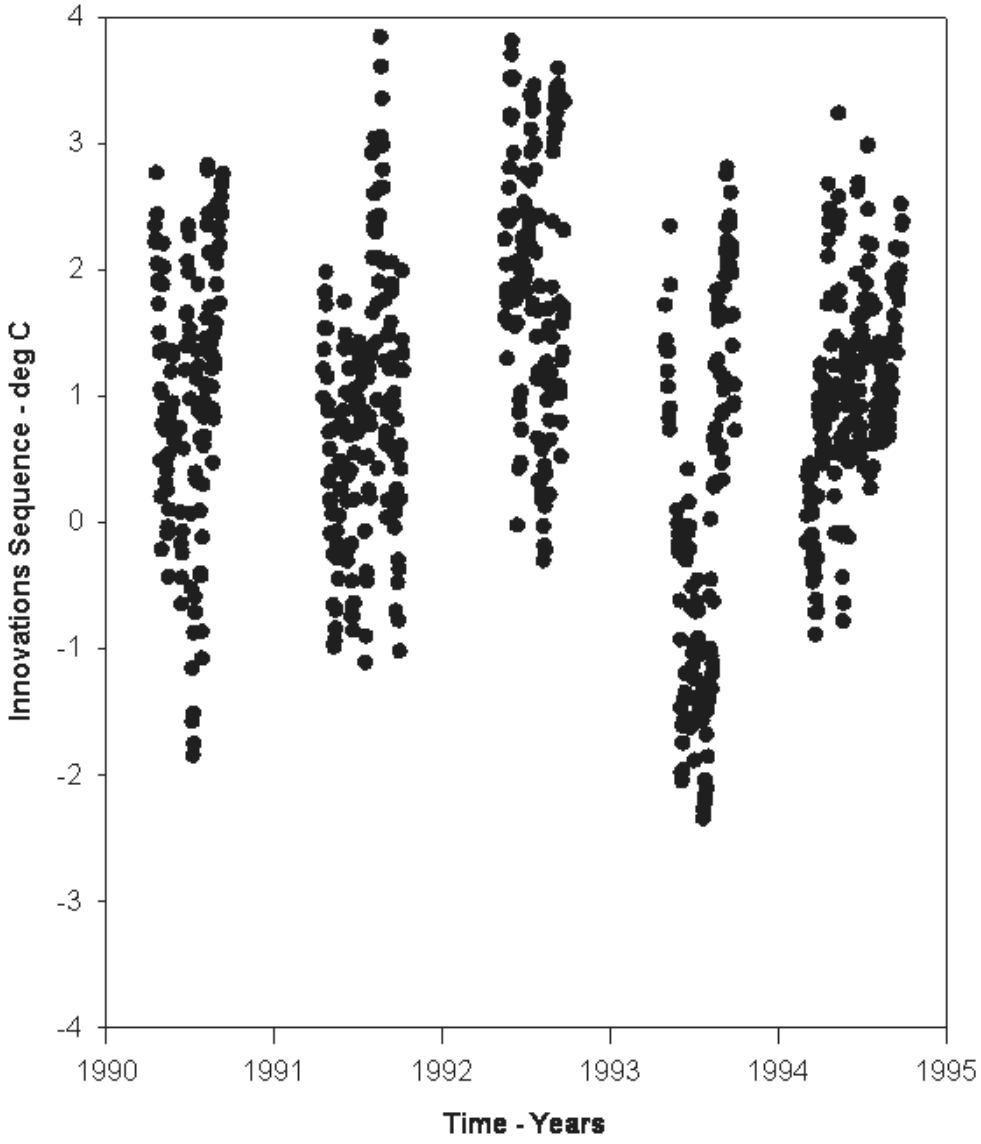

Figure D-21. Innovations sequence for McNary Dam - 1990-1995

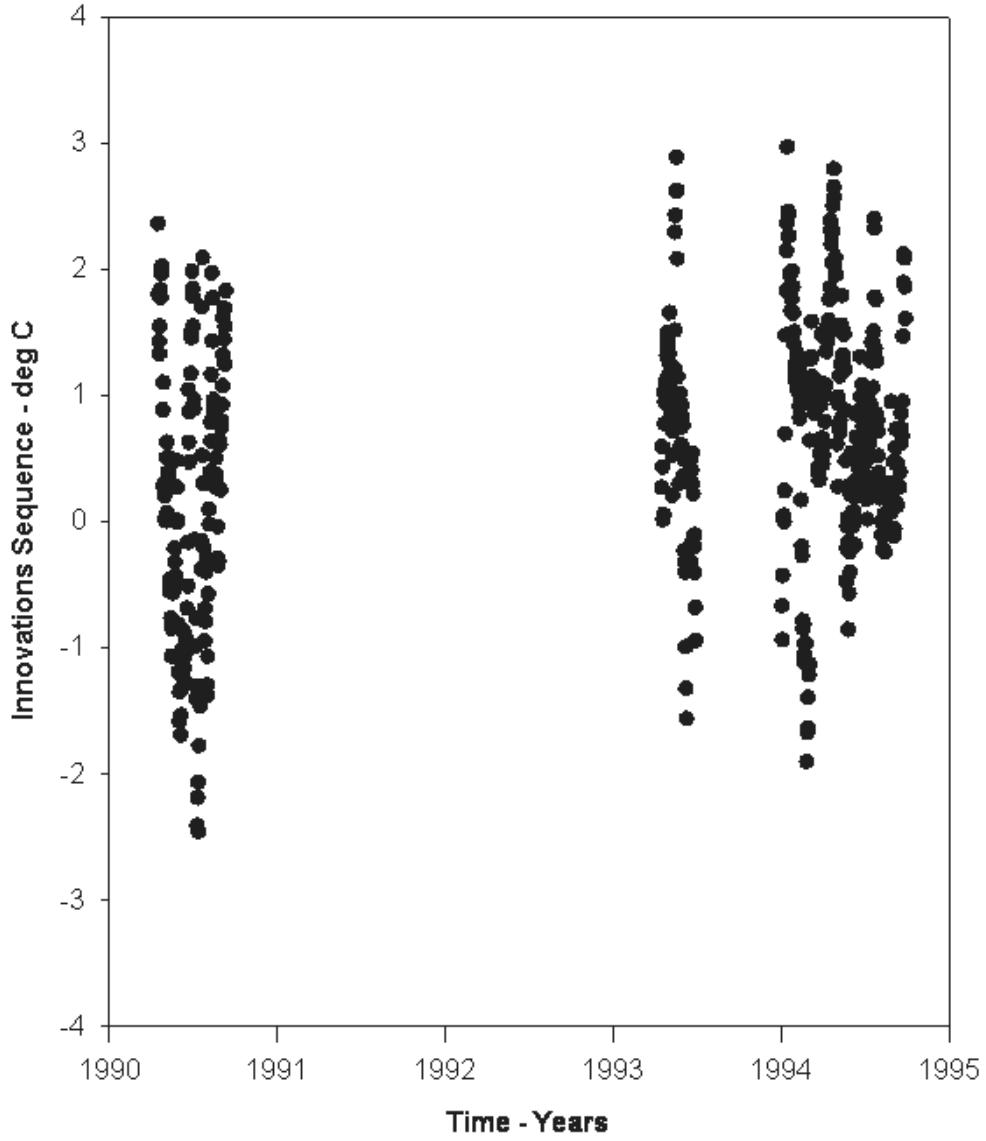

Figure D-22. Innovations sequence for John Day Dam - 1990-1995

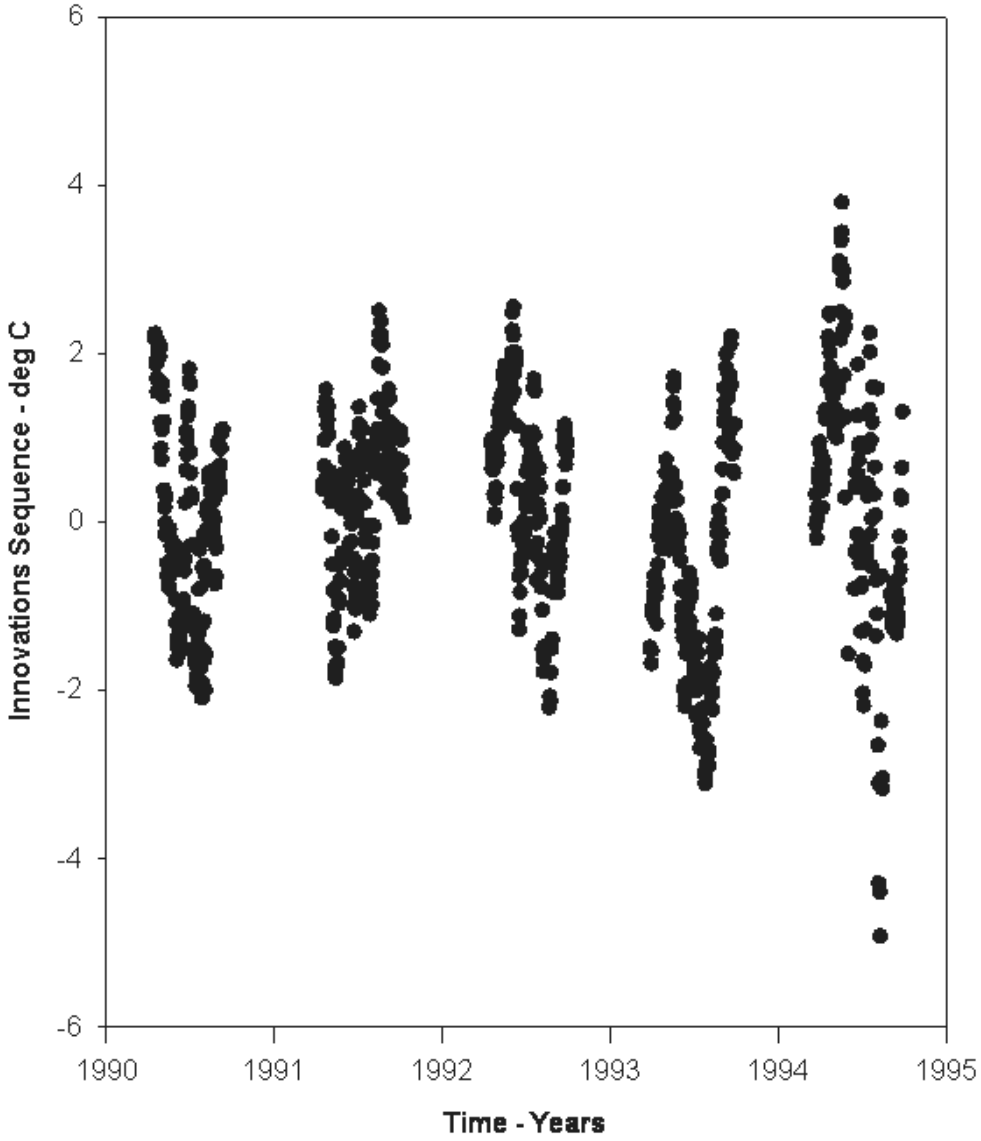

Figure D-23. Innovations sequence for Bonneville Dam - 1990-1995

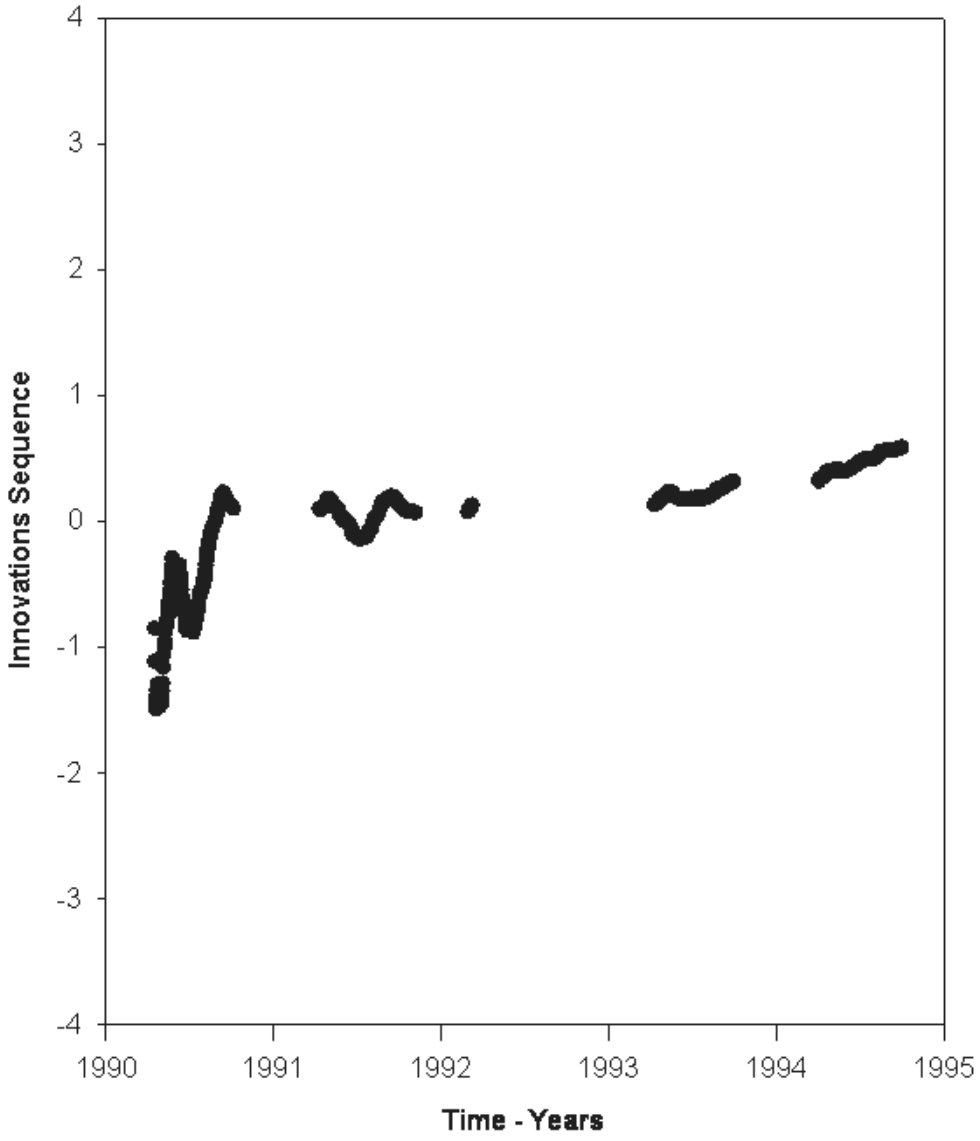

Figure D-24. Innovations sequence at Lower Granite Dam - 1990-1994

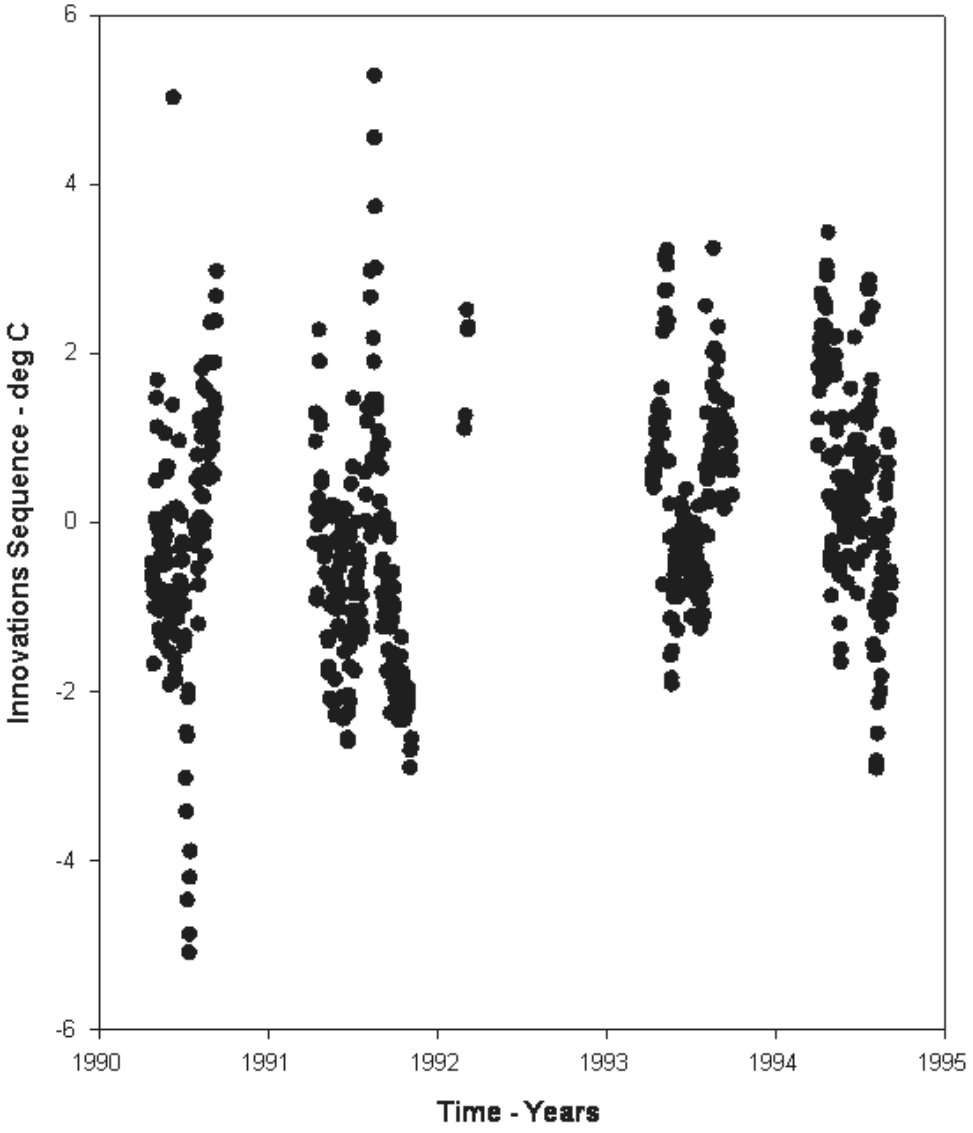

Figure D-25. Innovations sequence for Little Goose Dam - 1990-1995

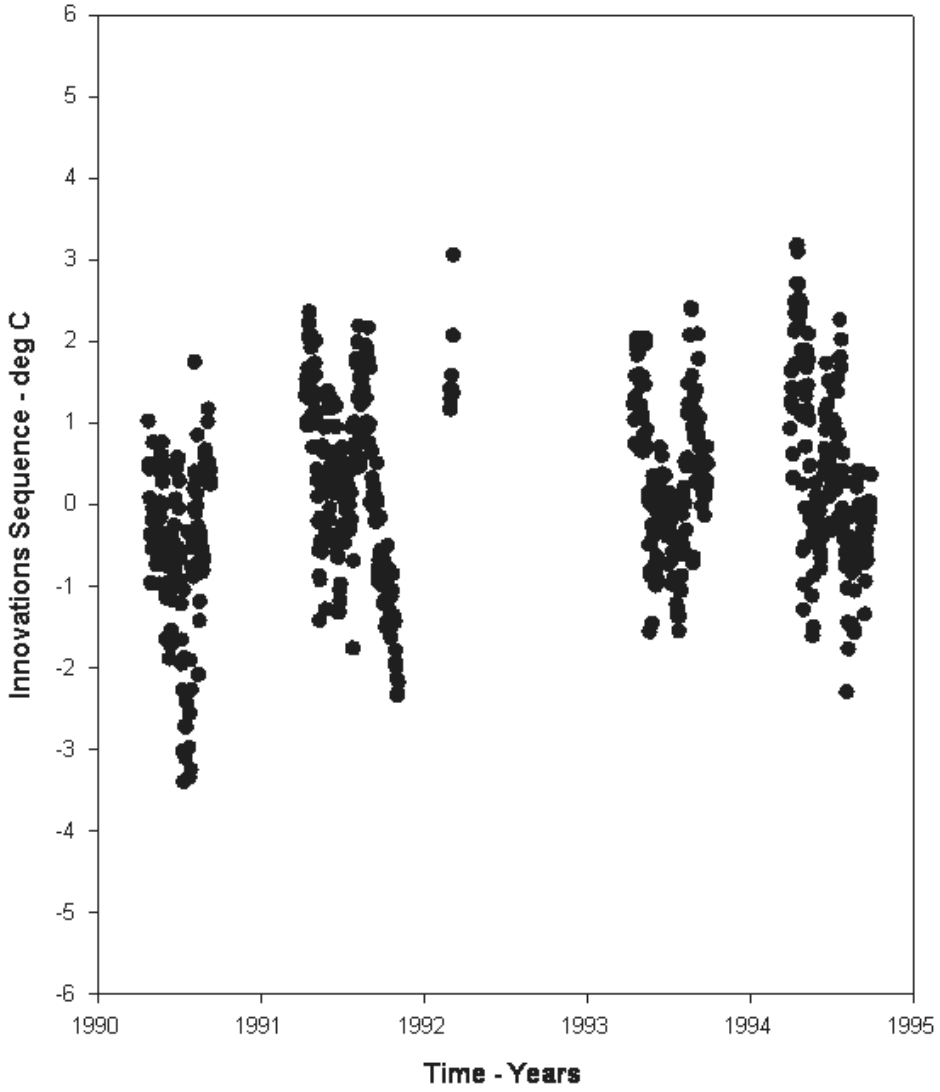

Figure D-26. Innovations sequence for Lower Monumental Dam - 1990-1995

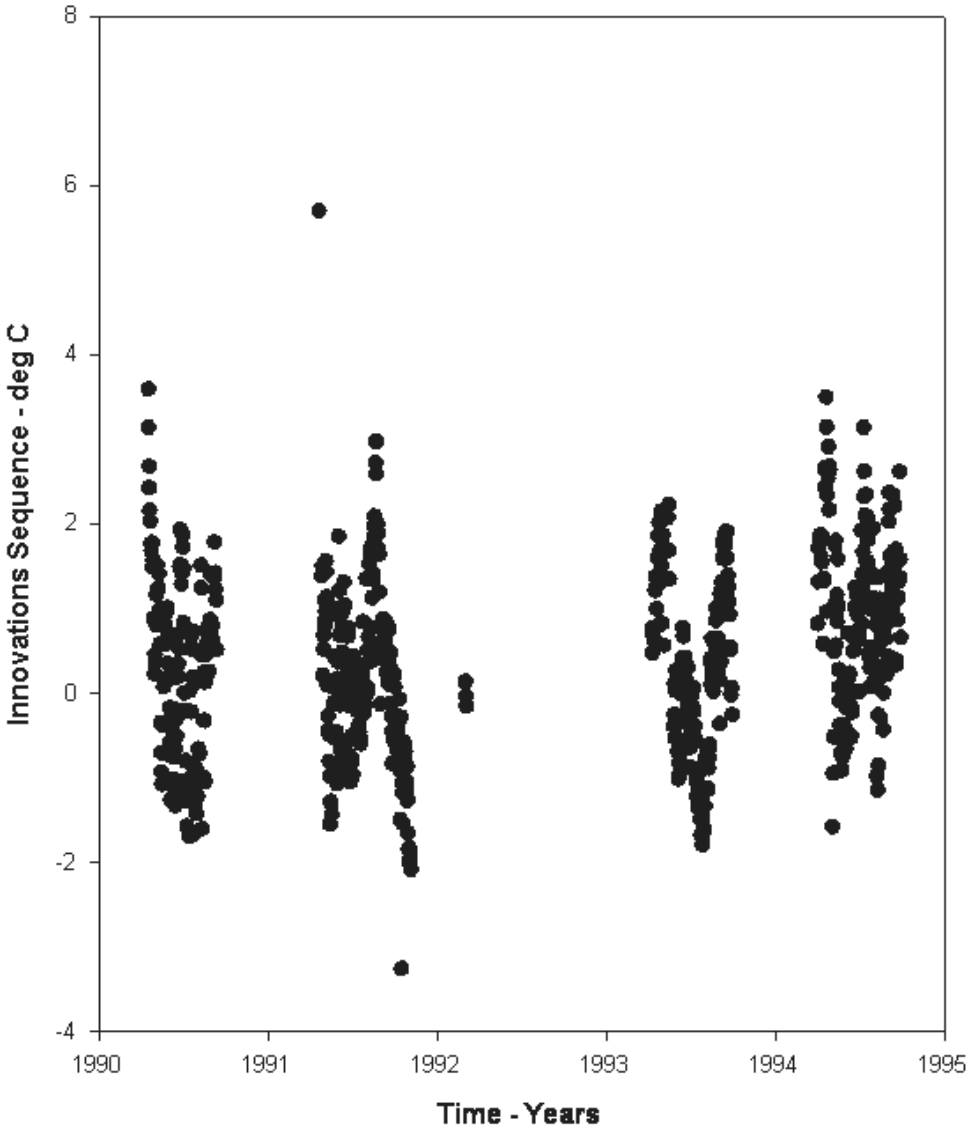

Figure D-27. Innovations sequence for Ice Harbor Dam - 1990-1995