DATA APPENDIX

DATA ACQUISITION

Table 1.6.2 provides a summary of the rich variety of time series models that are presented in the book. To clearly explain how these classes of models can be fitted to real data sets for addressing a range of practical problems, illustrative applications are provided throughout the chapters. At the end of each chapter, exact references are given for the time series utilized in the applications to allow interested readers to obtain the data from the original publication sources. Most of the time series consist of hydrological and other kinds of environmental observations. Nonetheless, as noted in Section 1.6.1 many of the time series models described in the book can be employed by professionals working in fields outside of hydrology and environmental engineering, for application to their particular kinds of time series.

The authors would like to encourage readers to fit models to their own sets of data and use the applications given in the book as a guide. However, some readers may wish to gain confidence in practical time series analysis by fitting models to time series utilized in the applications. Accordingly, some representative time series are listed in this appendix.

To apply the time series models to data a flexible decision support system (DSS) is required. One such system is the MHTS (McLeod-Hipel Time Series) Package referred to in Section 1.7. Included with this package are many of the time series employed in the practical applications in the book.

Most of the datasets referred to in this book are archived in Statlib. This means they are available in electronic form to anyone who has access to e-mail. To obtain these datasets, send the following one-line message to **statlib@lib.stat.cmu.edu :**

send hipel-mcleod from datasets

Statlib is a system for the distribution of software, datasets and general information of interest to statisticians. For further information, one can contact:

Michael M. Meyer
Computing Services and Department of Statistics
Carnegie Mellon University
Pittsburgh, PA 15213
Tel: (412) 268-3108
mikem@stat.cmu.edu

Many environmental and other government agencies throughout the world generously furnish extensive data listings for little or no cost. In Canada and the United States, for instance, one can obtain extensive hydrological time series on CD ROM by contacting, respectively, the agencies given below.

In Canada:

S. Y. Shiau, D. W. Kirk and J. McIlhinney
Water Resources Branch
Environment Canada
Ottawa, Ontario, Canada K1A 0H3

In the United States of America:

J. R. Slack, A. M. Lumb and J. M. Landwehr
Water Resources Division
U. S. Geological Survey
Reston, Virginia, U. S. A. 22092

DATA LISTING

The data listed below consist of four sets of time series to which ARMA, ARIMA, three types of seasonal, and intervention models are fitted. Included with each listing of a time series are an explanation of the specific type of data, the reference in which the data are published, the number of the figure in which the series is plotted in this book, the type of model fitted to the data, and the numbers of the sections where model construction results are presented for the model fitted to the data set. Moreover, the data are listed sequentially from left to right starting with the top line and continuing on lower lines.

Stationary Nonseasonal Time Series

1. Average annual flows of the St. Lawrence River at Ogdensburg, New York in m^3/s from 1860 to 1957.

   Reference: Yevjevich (1963)
   Time Series Plot: Figures 2.3.1 and II.1
   Model Type: Constrained AR(3) model without ϕ_2
   Model Construction

   Identification: Section 5.4.2
   Estimation: Section 6.4.2
   Diagnostic Checks: Section 7.6.2

7788	8040	7733	7528	7528	6962	7699	6853	7051	7897
7331	6342	6710	7392	6540	7447	7133	7133	7331	6908
6567	7249	7106	7644	7160	7869	7617	6826	6962	7419
7331	6485	6853	6853	6117	6028	6171	6458	6458	6396
6424	6458	6853	6908	6737	6826	6908	7419	6819	6540
6199	6485	7303	6826	6260	6792	6826	6997	7106	6396
6628	6485	6144	6260	6062	5892	6396	6737	7222	7447
6171	6171	5892	5326	5183	5435	6062	6171	6117	5946
6028	6062	7024	6997	6853	7276	7276	7303	6826	6683
7644	7788	7331	7194	7249	7303	6826			

2. Annual Wolfer sunspot numbers from 1770 to 1869

Reference: Waldmeier (1961)
Time Series Plot: Figure 5.4.6
Model Construction

Identification: Section 5.4.3
Estimation: Section 6.4.3
Diagnostic Checks: Section 7.6.3

101	82	67	35	31	7	20	93	154	126
85	68	39	23	10	24	83	132	131	118
90	67	60	47	41	21	16	6	4	7
15	34	45	43	48	42	28	10	8	3
0	1	5	12	14	35	46	41	30	24
16	7	4	2	9	17	36	50	64	67
71	48	28	9	13	57	122	138	103	86
65	37	24	11	15	40	62	99	125	96
67	65	54	39	21	7	4	23	55	94
96	77	59	44	47	31	16	7	38	74

3. Average annual temperature data in degrees celcius for the English midlands from 1723 to 1970.

Reference: Manley (1953)
Model Types: AR(2) or MA(2)
Identification Graphs: Sections 2.5.4 and 3.3.2

9.77	9.27	8.66	9.34	9.94	9.52	9.26	10.04	9.85	9.69
10.47	9.80	9.54	10.30	9.92	9.81	9.20	6.84	9.30	8.36
9.81	8.78	8.81	8.61	9.82	8.77	9.44	9.69	8.42	9.19
9.08	8.83	8.54	8.77	8.95	8.95	10.00	9.83	10.00	9.58
8.93	8.72	8.50	8.62	8.69	8.93	8.77	8.51	8.55	9.15
9.24	9.07	10.09	9.01	9.08	9.20	10.40	9.09	10.20	8.01
9.28	7.83	8.54	8.25	9.28	9.21	8.91	9.44	9.27	9.19
9.09	9.89	8.67	9.02	9.00	9.61	7.89	9.23	9.60	8.95
9.05	9.57	8.97	9.80	8.64	8.84	8.93	8.76	9.67	8.20
8.71	7.75	9.06	7.87	8.89	9.84	9.23	8.55	9.51	10.05
8.37	9.31	9.72	10.07	9.46	10.30	8.16	8.69	10.09	9.47
9.49	10.47	9.55	8.86	8.82	8.05	8.68	8.97	8.71	9.22
9.06	8.59	8.26	10.15	9.22	9.42	9.30	9.10	9.14	9.80
8.37	9.31	8.02	9.08	10.07	9.12	9.61	7.89	9.12	9.17
9.67	8.85	9.69	9.65	9.02	10.38	9.62	8.98	9.05	9.75
8.98	9.30	9.43	9.51	9.17	9.24	7.42	9.09	8.56	9.45
9.02	9.83	8.57	8.69	8.27	8.22	8.99	8.73	8.49	8.17
9.97	9.30	8.65	9.33	9.42	10.07	9.69	9.56	9.11	8.83
9.32	9.00	9.13	9.43	8.84	9.36	8.55	9.12	10.05	9.36
9.78	9.88	8.93	9.18	8.51	9.51	8.48	9.57	10.47	8.67

9.08	9.27	9.17	9.72	9.20	9.57	9.01	9.43	8.99	9.38
9.83	9.99	9.72	9.32	9.57	10.18	9.68	9.05	9.09	9.05
10.03	9.57	10.27	9.45	9.57	10.01	10.62	9.41	9.27	9.09
9.84	9.22	9.28	8.83	10.02	9.42	10.48	9.73	9.94	8.59
8.47	9.47	8.95	9.45	9.61	9.30	9.26	9.57		

Nonstationary Nonseasonal Time Series

4. Average annual water use for New York City in litres per capita per day from 1898 to 1968.

Reference: Salas and Yevjevich (1972)
Time Series Plot: Figures II.2 and 4.3.8
Model Type: ARIMA(0,1,0)
Model Identification: Section 4.3.1

402.8	421.3	431.2	426.2	425.5	423.6	435.7	445.2	450.1	450.1
439.1	419.0	417.9	384.2	385.4	374.4	401.3	382.7	403.5	410.0
454.6	448.2	489.5	476.2	473.2	475.1	476.6	502.7	506.5	499.7
495.5	522.8	537.1	509.1	502.7	500.4	508.4	498.9	507.2	505.0
503.8	511.4	467.9	493.6	470.5	503.5	544.3	553.0	551.9	564.4
567.8	562.1	457.3	500.1	522.0	525.4	511.0	533.4	534.1	562.9
557.2	584.1	582.6	590.5	581.1	583.0	567.1	499.3	493.6	533.7
581.1									

Seasonal Time Series

5. Average Monthly flows of the Saugeen River in m^3/s at Walkerton, Ontario, Canada, from January, 1915, until December, 1976.

Reference: Environment Canada (1977)
Time Series Plot: Figure VI.1
Model Types: Deseasonalized and PAR Models with $\lambda = 0$
Model Construction

Deseasonalized Model: Section 13.4.2
PAR model: Section 14.4

16.03	30.30	35.40	41.91	14.70	9.20	7.96	11.95	18.63	21.69	22.57	23.19
69.38	37.10	35.96	125.73	46.16	35.11	12.37	7.84	6.91	9.29	12.18	24.49
16.40	13.22	76.46	82.97	32.85	27.84	57.77	11.81	7.70	13.31	10.73	8.27
7.90	20.95	95.71	67.11	23.98	12.88	6.80	4.84	11.78	12.71	25.82	46.72
28.60	17.73	90.05	53.52	44.17	13.93	9.46	8.13	7.19	10.34	24.18	25.15
14.72	14.72	115.53	63.43	23.02	12.91	19.45	9.46	7.11	12.74	32.56	43.89
40.78	16.03	109.02	50.69	28.09	19.71	13.20	9.12	7.14	11.33	12.06	23.19
13.96	14.72	69.94	92.03	20.27	13.71	12.37	8.58	8.41	7.65	8.86	9.71
8.98	8.21	42.76	103.36	70.51	21.49	11.07	9.29	10.25	7.50	10.48	25.85
23.73	15.91	40.21	89.20	63.15	18.94	14.61	13.51	12.01	9.32	8.13	19.88
10.14	30.02	72.77	41.06	14.67	12.09	10.00	8.27	8.86	18.38	60.31	26.62

21.66	17.56	27.04	128.84	51.54	21.35	11.07	15.18	13.93	25.23	59.75	27.47
19.11	17.13	87.22	34.55	36.25	21.27	13.96	9.06	8.24	9.94	15.83	29.17
29.45	19.82	67.39	111.29	25.34	14.38	31.71	30.02	13.93	40.21	60.60	58.33
64.28	27.30	128.56	137.05	66.54	19.34	16.65	7.84	5.78	6.65	14.81	13.59
46.44	66.83	55.78	85.80	40.78	23.73	12.83	4.81	3.71	5.30	5.21	8.64
7.28	8.83	14.58	70.23	23.45	10.36	7.90	6.97	6.14	9.37	30.02	47.29
64.56	67.96	47.01	83.53	29.45	11.98	19.00	18.32	24.15	20.59	45.31	53.24
38.23	26.05	30.87	93.45	42.76	15.52	8.10	6.46	5.83	7.87	13.22	28.88
33.98	19.40	45.87	105.90	21.07	9.32	5.49	4.11	5.01	4.56	10.70	8.41
20.53	13.03	73.62	21.46	15.29	22.54	8.27	4.62	4.39	4.81	17.02	12.37
8.50	8.47	63.15	62.86	32.28	12.74	6.20	5.32	9.46	12.88	17.73	39.93
56.92	54.93	20.33	70.51	30.30	10.79	8.27	9.26	7.99	12.35	14.58	11.64
13.73	67.39	96.56	41.34	24.24	15.38	6.43	6.31	7.33	5.44	5.61	5.83
19.26	14.16	39.36	107.60	26.25	12.63	12.77	9.71	5.69	10.70	19.43	10.73
9.20	8.61	8.75	118.65	52.67	35.40	12.71	9.37	13.11	18.35	34.55	44.46
34.26	20.67	15.29	99.11	16.82	9.94	5.78	6.43	7.53	29.45	43.32	34.55
22.65	14.58	102.22	67.39	44.17	40.21	10.51	7.62	15.94	21.75	43.89	25.91
32.28	48.70	98.54	117.80	89.48	30.87	18.43	15.66	11.75	9.97	26.53	16.08
22.65	25.63	35.68	92.03	38.51	18.12	8.95	5.97	7.16	5.61	12.09	10.17
10.14	11.84	94.01	50.97	58.62	40.49	38.23	10.70	16.42	54.37	32.28	18.58
52.95	35.11	112.42	27.64	19.11	11.86	7.22	6.37	5.92	6.82	8.66	10.79
23.36	31.71	37.10	208.41	88.91	48.70	23.62	12.49	10.05	10.08	11.27	19.17
10.62	16.03	139.89	59.75	29.17	11.75	10.19	7.19	5.49	8.13	18.49	11.50
44.46	34.83	87.50	58.62	18.77	10.17	8.95	5.69	7.42	9.77	9.09	75.61
71.64	27.38	58.33	132.24	27.13	19.45	15.38	8.83	7.82	9.12	24.10	52.67
59.75	33.70	75.32	143.85	38.79	20.47	19.65	10.22	17.44	35.11	53.24	35.96
63.71	31.71	51.25	116.38	32.85	13.73	9.29	9.60	7.90	6.43	13.03	29.45
25.29	26.08	83.25	42.19	46.16	44.17	40.49	11.13	11.98	11.24	10.22	18.41
14.02	61.73	98.26	112.13	28.60	19.45	8.52	9.29	17.81	101.37	36.81	26.56
33.41	24.95	73.34	107.60	26.36	18.09	7.19	5.38	4.30	7.96	18.32	17.02
11.81	10.53	32.85	126.01	55.22	18.01	13.20	9.85	15.43	11.67	11.81	31.71
21.86	26.93	49.27	44.46	24.35	21.24	31.43	6.65	16.40	18.63	33.13	48.99
21.18	15.66	30.58	49.84	11.92	7.67	5.64	5.52	6.71	6.68	11.16	11.58
13.28	13.71	34.83	133.66	50.40	17.05	10.96	12.94	12.15	19.85	48.99	34.83
34.26	27.33	23.50	147.81	75.04	36.53	13.39	9.00	7.48	8.61	12.97	8.21
6.14	16.71	46.16	45.31	30.30	23.13	16.42	11.38	9.94	8.61	16.11	24.89
15.09	14.53	41.63	65.98	19.34	9.97	6.94	5.95	6.91	11.10	18.80	15.52
9.85	8.35	63.43	60.88	46.44	14.81	10.65	8.72	7.31	6.74	13.59	9.40
22.99	16.48	44.46	42.76	17.95	9.29	7.79	13.14	6.48	6.46	8.86	21.07
17.30	39.36	30.30	110.72	44.17	12.18	9.03	9.94	10.99	24.75	41.63	61.16
32.56	35.40	70.23	47.86	29.45	20.78	7.39	8.10	7.31	9.06	23.19	43.32
36.25	24.24	39.64	97.41	24.10	51.82	33.41	18.55	16.57	33.13	63.15	61.45
25.99	56.07	70.79	52.10	28.60	16.79	10.73	14.98	15.21	16.74	33.70	46.72
35.40	39.36	47.57	119.21	67.11	25.43	16.48	10.42	7.79	12.97	23.62	16.28
11.16	16.48	19.88	109.59	30.30	13.11	20.53	8.86	16.11	23.25	26.36	29.45
15.23	19.40	41.06	122.90	29.45	18.80	13.56	9.71	9.46	8.66	11.47	26.05
22.00	17.27	21.38	125.44	37.10	21.75	17.56	10.51	8.33	16.23	21.04	30.58

59.47	30.58	95.43	50.97	35.11	24.13	11.47	9.06	6.57	8.55	22.14	23.19
31.15	24.21	75.32	83.82	61.73	19.00	12.69	9.57	7.99	11.44	23.70	16.11
30.30	26.11	50.97	124.59	39.64	16.48	11.24	12.20	19.06	12.80	15.86	39.08
15.60	40.21	150.36	60.88	35.68	16.91	23.64	11.24	16.20	19.85	29.45	19.00

6. Average monthly water consumption in millions of litres per day from 1966 to 1988 for the city of London, Ontario, Canada.

Reference: Public Utilities Commission (1989) of London
Time Series Plot: Figure VI.2
Model Type: SARIMA(1,0,1)×(0,1,1) with $\lambda = -0.75$
Model Construction: Section 12.4.2

76.83	77.74	80.47	79.56	82.28	100.92	113.20	90.92	86.83	82.74
83.65	80.92	83.19	83.65	83.65	83.65	86.83	100.47	91.38	101.38
95.92	88.19	88.19	80.47	80.92	79.56	80.92	88.19	91.83	96.38
97.29	102.29	99.10	92.74	87.29	85.47	91.38	92.74	89.56	88.65
93.20	99.56	109.11	124.56	115.47	96.38	92.29	86.83	87.29	85.92
85.92	88.65	91.83	112.29	101.83	125.02	102.74	95.01	91.83	86.38
87.29	88.19	89.10	89.10	103.65	127.75	125.47	125.47	109.11	100.01
95.01	85.01	86.83	86.83	86.83	86.83	100.47	111.38	105.47	102.74
105.01	96.38	94.10	86.83	92.74	93.20	95.47	96.38	99.56	120.47
123.20	114.11	120.93	102.74	101.83	95.47	100.01	100.01	98.20	100.01
103.65	114.56	134.11	131.84	113.65	107.29	102.29	94.56	97.29	98.20
95.47	100.47	116.38	117.29	140.93	120.02	111.38	108.65	105.92	99.10
101.83	102.74	102.74	105.47	108.65	139.57	110.47	118.65	120.02	109.11
108.20	101.38	106.38	108.65	107.74	105.92	129.56	139.11	125.93	123.65
118.65	110.47	110.02	100.47	104.1	106.6	105.5	107.5	117.9	136.3
156.8	135.8	130	117.5	115.8	105.5	111.6	113.2	113.1	112.5
120	147.6	149.9	131.2	134.6	122.2	117.7	106.8	111.5	111.3
109.5	112.1	127	135.9	150.4	135.6	134.9	124.1	120.8	112.8
117.4	118.6	119.2	119.7	128.6	142.8	170	145.9	140.1	128.7
123.4	114.6	120.2	122	121.3	123.2	141.1	129.7	152.4	141.9
137	129	124.6	117.3	122.7	121	122	122	126.3	158.1
164.9	143.3	151.4	136.8	133.1	124.8	132.6	130.2	129.6	129.7
133.7	148.3	155.1	157.2	147.2	142.7	135.9	123.8	132.3	132.7
130.7	129.9	145.5	156.6	161.7	156	146.1	136.8	132.5	129.5
129.5	134.7	136.6	138.4	149.6	159.5	171.4	162.1	163.1	152.4
145.5	133.9	136.6	139.4	141.2	144.9	181.4	187	211.4	178.1
168	154.4	150.4	139.4	144.7	143	148.3	152.7	173.3	226.3
218.2	184.6	174.9	161.4	161.4	145.8				

7. Average monthly concentrations of atmospheric CO_2 measured in molefractions in ppm at the Mauna Loa Observatory in Hawaii from January, 1965, to December, 1980.

Reference: Keeling et al. (1982) and Bacastow and Keeling (1981)
Time Series Plot: Figure VI.3
Model Type: SARIMA$(0,1,1)\times(0,1,1)_{12}$
Model Construction: Section 12.4.3

319.32	320.36	320.82	322.06	322.17	321.95	321.20	318.81	317.82	317.37
318.93	319.09	319.94	320.98	321.81	323.03	323.36	323.11	321.65	319.64
317.86	317.25	319.06	320.26	321.65	321.81	322.36	323.67	324.17	323.39
321.93	320.29	318.58	318.60	319.98	321.25	321.88	322.47	323.17	324.23
324.88	324.75	323.47	321.34	319.56	319.45	320.45	321.92	323.40	324.21
325.33	326.31	327.01	326.24	325.37	323.12	321.85	321.31	322.31	323.72
324.60	325.57	326.55	327.80	327.80	327.54	326.28	324.63	323.12	323.11
323.99	325.09	326.12	326.61	327.16	327.92	329.14	328.80	327.52	325.62
323.61	323.80	325.10	326.25	326.93	327.83	327.95	329.91	330.22	329.25
328.11	326.39	324.97	325.32	326.54	327.71	328.73	329.69	330.47	331.69
332.65	332.24	331.03	329.36	327.60	327.29	328.28	328.79	329.45	330.89
331.63	332.85	333.28	332.47	331.34	329.53	327.57	327.57	328.53	329.69
330.45	330.97	331.64	332.87	333.61	333.55	331.90	330.05	328.58	328.31
329.41	330.63	331.63	332.46	333.36	334.45	334.82	334.32	333.05	330.87
329.24	328.87	330.18	331.50	332.81	333.23	334.55	335.82	336.44	335.99
334.65	332.41	331.32	330.73	332.05	333.53	334.66	335.07	336.33	337.39
337.65	337.57	336.25	334.39	332.44	332.25	333.59	334.76	335.89	336.44
337.63	338.54	339.06	338.95	337.41	335.71	333.68	333.69	335.05	336.53
337.81	338.16	339.88	340.57	341.19	340.87	339.25	337.19	335.49	336.63
337.74	338.36								

Time Series Containing an Intervention

8. Average annual flows in m^3/s of the Nile River at Aswan, Egypt. Average yearly values are calculated for the water year from October 1 to September 30 for each year from October 1, 1870, to September 30, 1945. From 1903 onwards there was a drop in the mean level of the Nile flows because of the construction of the Aswan Dam.

Reference: Hurst et al. (1946)
Time Series Plot: Figure 19.2.1
Model Type: Intervention model having a step intervention and an AR(1) noise term
Model Construction: Section 19.2.4

3958.043	3369.694	3485.242	3437.691	3702.352	3817.610
2875.578	3054.686	4724.150	3834.007	3076.773	2965.759
3461.708	3141.010	3371.237	2988.425	3607.541	2946.083
2709.200	3294.848	3556.615	3653.934	3846.064	3713.637
4252.313	3657.503	3639.370	3197.722	3112.749	2353.684
2843.652	2194.926	2689.428	2950.906	2247.877	2628.279
2491.126	2792.630	3321.469	3058.062	2889.853	2495.273

1648.823	1981.963	2411.072	3035.203	3556.133	3261.959
2377.893	2394.964	2499.999	2610.242	2743.633	2744.116
2338.637	2494.984	2474.440	2446.373	2963.059	2732.252
2205.150	2681.808	2580.535	2954.378	3025.944	2902.777
2642.457	2860.242	2665.412	2306.905	1848.090	2569.540
2503.954	2438.753	2211.130			

9. Average monthly phosphorous data in mg/l from January, 1972, until December, 1977, for measurements taken by the Ontario Ministry of the Environment downstream from the Guelph sewage treatment plant located in the Grand River basin, Ontario, Canada. In February, 1974, a pollution abatement procedure was brought into effect by implementing conventional phosphorous treatment at the Guelph station. The man-induced intervention of phosphorous removal decreased the mean level of the series after the intervention date. Values that are underlined indicate where there are missing data points. The value written above a line is the monthly average across all of the years.

   Source: Ontario Ministry of the Environment, Toronto, Ontario, Canada
   Time Series Plot: Figures 1.1.1 and 19.1.1
   Model Type: Intervention model having a step intervention component, four missing value terms and a SARMA$(0,5)\times(0,1)_{12}$ noise term fitted to the logarithmic data.

.4700	.5100	.3500	.1900	.3300	.1524	.3650	.6500	.8250	1.0000	.3850	.9000
.2950	.1400	.2200	.2000	.1400	.4000	.2144	.4950	1.1000	.5900	.2700	.3000
.3064	.0650	.2400	.0580	.0790	.0650	.1200	.0910	.0580	.1200	.1200	.1100
.4600	.1500	.0860	.0280	.1342	.1100	.3600	.1800	.0650	.1300	.1200	.1900
.1500	.1070	.0470	.0550	.0800	.0710	.1210	.1080	.1690	.0660	.0790	.1040
.1570	.1400	.0700	.0560	.0420	.1160	.1060	.0940	.0970	.0500	.0790	.1140

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