Guidelines for HDD and CDD Forecasts

Using MS-Excel and SAS JMP Software

BC Hydro Customer Information Management—Load Analysis
BC Hydro, Burnaby, British Columbia

November 2009

Guidelines for HDD and CDD Forecasts

Using MS-Excel and SAS JMP Software

Table of Contents

HDD and CDD analysis guidelines

The purpose of this document was to provide guidelines for forecasting heating degree days (HDD) and cooling degree days (CDD). Three methods were addressed:

- Static Ten-year Moving Average Method;
- Dynamic Ten-year Moving Average Method; and
- Integrated Autoregressive-Moving Average (ARIMA) model.

The reader is invited to become familiar with the contents of the publications listed in the *Bibliography* and *References* sections of this document to make it easier to understand the discussions about the ARIMA model.

Illustrations of the moving average methods were based on data, supplied by BC Hydro Load Forecasting, for Vancouver Airport (Lower Mainland Sales Region) Apr 1981 to Mar 2001. The illustrations of the ARIMA model were from analyses of BC Hydro Load Analysis Vancouver Airport data from Jan 1953 to Mar 2001.

Static Ten-year Moving Average Method

This method was set up on a MS-Excel spreadsheet as illustrated in Fig. 1.

For completeness of forecast information, the standard error of the estimate (equivalent to standard deviation of the residuals) was calculated. Two standard deviations gave a 95% probability envelope about the forecast value. The upper and lower confidence limits (CL) at the 0.05 level were tabulated. The formula used was:

Standard error of the estimate = standard deviation of the residuals
= ((sum of the squares of the residuals)/(no. of items))$^{1/2}$ (1)

Residuals are the differences between actual monthly HDD and forecasted monthly HDD for a given month.

For example, for Apr-2001, the formula for the standard error value in cell D246 was:

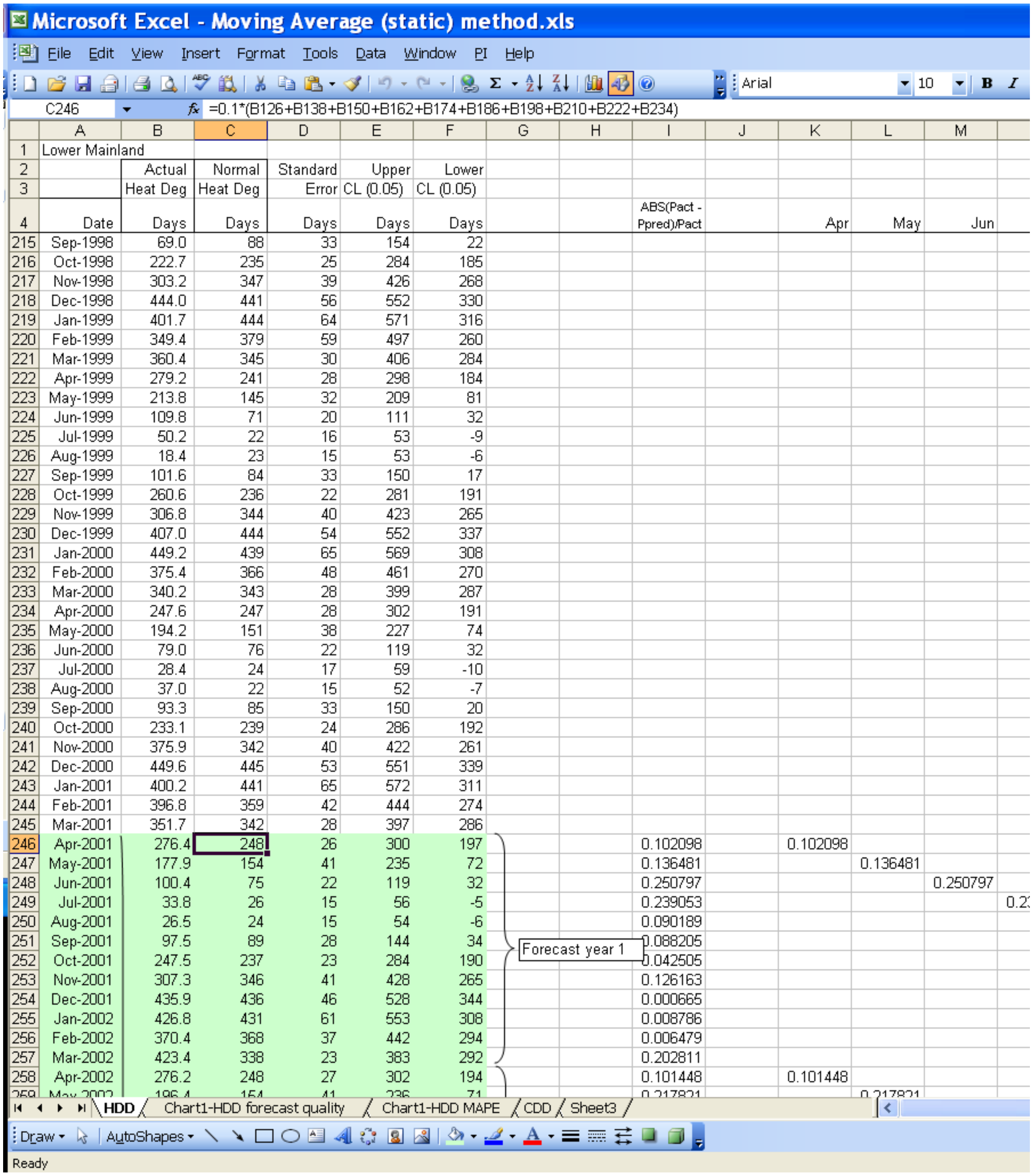
f_x=SQRT(((B126-C126)^2+(B138-C138)^2+(B150-C150)^2+(B162-C162)^2+(B174-C174)^2+(B186-C186)^2+(B198-C198)^2+(B210-C210)^2+(B222-C222)^2+(B234-C234)^2)/10) (2)

The formula for the Apr-2001 Upper CL was,

f_x= C246+2*D246 (3)

The formula for the Apr-2001 Lower CL was,

f_x= C246-2*D246 (4)



Lower Mainland

Row	Date	Actual Heat Deg Days	Normal Heat Deg Days	Standard Error Days	Upper CL (0.05) Days	Lower CL (0.05) Days	ABS(Pact - Ppred)/Pact	Apr	May	Jun	
215	Sep-1998	69.0	88	33	154	22					
216	Oct-1998	222.7	235	25	284	185					
217	Nov-1998	303.2	347	39	426	268					
218	Dec-1998	444.0	441	56	552	330					
219	Jan-1999	401.7	444	64	571	316					
220	Feb-1999	349.4	379	59	497	260					
221	Mar-1999	360.4	345	30	406	284					
222	Apr-1999	279.2	241	28	298	184					
223	May-1999	213.8	145	32	209	81					
224	Jun-1999	109.8	71	20	111	32					
225	Jul-1999	50.2	22	16	53	-9					
226	Aug-1999	18.4	23	15	53	-6					
227	Sep-1999	101.6	84	33	150	17					
228	Oct-1999	260.6	236	22	281	191					
229	Nov-1999	306.8	344	40	423	265					
230	Dec-1999	407.0	444	54	552	337					
231	Jan-2000	449.2	439	65	569	308					
232	Feb-2000	375.4	366	48	461	270					
233	Mar-2000	340.2	343	28	399	287					
234	Apr-2000	247.6	247	28	302	191					
235	May-2000	194.2	151	38	227	74					
236	Jun-2000	79.0	76	22	119	32					
237	Jul-2000	28.4	24	17	59	-10					
238	Aug-2000	37.0	22	15	52	-7					
239	Sep-2000	93.3	85	33	150	20					
240	Oct-2000	233.1	239	24	286	192					
241	Nov-2000	375.9	342	40	422	261					
242	Dec-2000	449.6	445	53	551	339					
243	Jan-2001	400.2	441	65	572	311					
244	Feb-2001	396.8	359	42	444	274					
245	Mar-2001	351.7	342	28	397	286					
246	Apr-2001	276.4	248	26	300	197	0.102098	0.102098			
247	May-2001	177.9	154	41	235	72	0.136481		0.136481		
248	Jun-2001	100.4	75	22	119	32	0.250797			0.250797	
249	Jul-2001	33.8	26	15	56	-5	0.239053				0.2
250	Aug-2001	26.5	24	15	54	-6	0.090189				
251	Sep-2001	97.5	89	28	144	34	0.088205				
252	Oct-2001	247.5	237	23	284	190	0.042505				
253	Nov-2001	307.3	346	41	428	265	0.126163				
254	Dec-2001	435.9	436	46	528	344	0.000665				
255	Jan-2002	426.8	431	61	553	308	0.008786				
256	Feb-2002	370.4	368	37	442	294	0.006479				
257	Mar-2002	423.4	338	23	383	292	0.202811				
258	Apr-2002	276.2	248	27	302	194	0.101448	0.101448			
259	May-2002	196.4	154	41	236	71	0.217821		0.217821		

Figure 1: The Apr-2001 value of 248 monthly HDD was the arithmetic mean of the previous ten Apr values in the monthly HDD time series. The formula, f_x, was shown in Excel's formula bar. The method was termed "static" because every April forecast for the next five years had the 248 value (see for example, cell C258 for Apr-2002)

The last part of the complete static moving average forecast is shown in Fig. 2. The Apr-2003, Apr-2004, and Apr-2005 monthly HDD forecast values remained static at 248 monthly HDD. This figure also shows how Mean Absolute Predicted Error (MAPE) values were calculated. The formula was:

$$\text{MAPE} = (1/N) \times \Sigma\, |(P_{\text{actual } i} - P_{\text{predicted } i}) / P_{\text{actual } i}|;\ \text{sum from } i = 1 \text{ to } i = N \qquad (5)$$

where $P_{\text{actual } i}$ = actual load on day i, $P_{\text{predicted } i}$ = forecast value of load on day i, N = total number of data (hours).

Microsoft Excel - Moving Average (static) method.xls

I282 f_x =ABS(B282-C282)/B282

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Lower Mainland													
2		Actual	Normal	Standard	Upper	Lower								
3		Heat Deg	Heat Deg	Error	CL (0.05)	CL (0.05)								
4	Date	Days	Days	Days	Days	Days			ABS(Pact - Ppred)/Pact		Apr	May	Jun	
263	Sep-2002	90.7	89	27	144	34	Forecast year 2		0.019846					
264	Oct-2002	257.5	237	22	280	194			0.079689					
265	Nov-2002	309.7	346	41	429	263			0.117436					
266	Dec-2002	393.5	436	39	514	359			0.108488					
267	Jan-2003	363.5	431	58	547	314			0.184457					
268	Feb-2003	375.2	368	34	436	300			0.01919					
269	Mar-2003	330.4	338	31	399	276			0.02158					
270	Apr-2003	262.4	248	25	299	198			0.054192		0.054192			
271	May-2003	167.1	154	42	238	69			0.08067			0.08067		
272	Jun-2003	50.9	75	20	115	35			0.4778				0.4778	
273	Jul-2003	9.2	26	14	53	-2			1.795652					1.79
274	Aug-2003	5.9	24	15	54	-5			3.086441					
275	Sep-2003	72.0	89	27	143	35	Forecast year 3		0.234722					
276	Oct-2003	197.7	237	19	276	198			0.198685					
277	Nov-2003	403.5	346	43	432	260			0.14233					
278	Dec-2003	421.8	436	39	514	358			0.034116					
279	Jan-2004	431.6	431	43	516	345			0.002433					
280	Feb-2004	350.9	368	32	433	303			0.048732					
281	Mar-2004	307.8	338	31	399	276			0.096589					
282	Apr-2004	206.0	248	25	299	198			0.204757		0.204757			
283	May-2004	119.6	154	38	230	78			0.284448			0.284448		
284	Jun-2004	45.0	75	21	117	33			0.671556				0.671556	
285	Jul-2004	5.2	26	13	52	0			3.946154					3.9
286	Aug-2004	5.0	24	16	55	-7			3.822					
287	Sep-2004	106.8	89	28	144	34	Forecast year 4		0.167603					
288	Oct-2004	222.4	237	19	276	198			0.065558					
289	Nov-2004	335.5	346	43	433	259			0.031505					
290	Dec-2004	392.2	436	36	509	364			0.112162					
291	Jan-2005	442.6	431	32	496	366			0.027225					
292	Feb-2005	383.3	368	32	432	304			0.039917					
293	Mar-2005	298.8	338	32	402	273			0.129618					
294	Apr-2005	235.2	248	25	299	197			0.055187		0.055187			
295	May-2005	115.8	154	38	230	77			0.326598			0.326598		
296	Jun-2005	75.1	75	23	121	30			0.001598				0.001598	
297	Jul-2005	16.1	26	14	54	-2			0.597516					0.5
298	Aug-2005	5.0	24	16	56	-8			3.822					
299	Sep-2005	100.1	89	26	141	37	Forecast year 5		0.111888					
300	Oct-2005	207.9	237	20	276	197			0.139875					
301	Nov-2005	370.6	346	43	431	261			0.06619					
302	Dec-2005	415.3	436	37	511	361			0.050301					
303	Jan-2006	362.6	431	32	494	367			0.187397					
304	Feb-2006	384.2	368	31	430	306			0.042166					
305	Mar-2006	355.1	338	34	406	269			0.049479					
306								MAPE =	39.64%		10.35%	20.92%	33.45%	131

Test forecast period

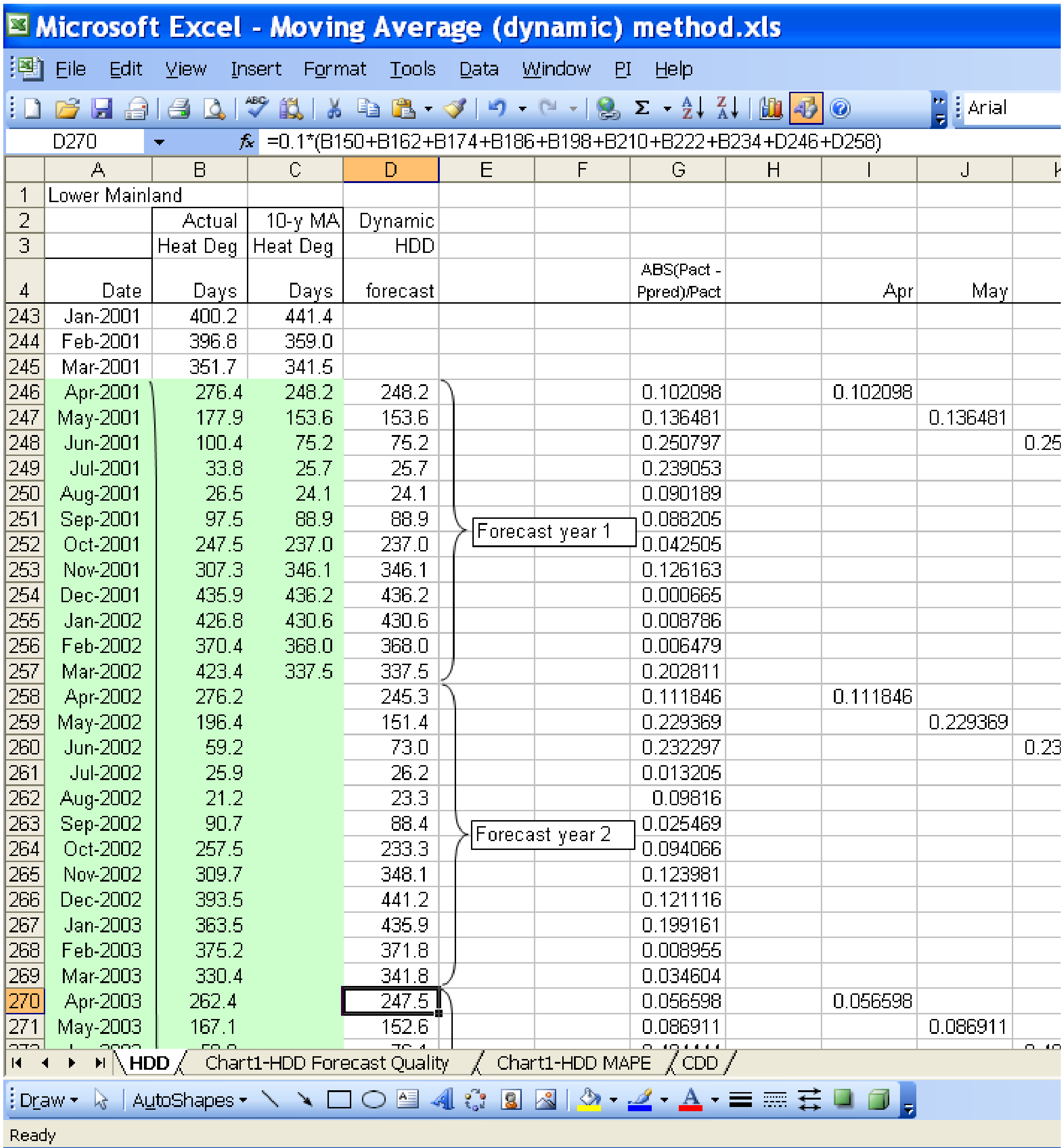
HDD / Chart1-HDD forecast quality / Chart1-HDD MAPE / CDD / Sheet3

Ready

Figure 2: Last part of static moving average forecast. Note how monthly values repeated each forecast year. The formula bar showed part of the formula for calculating Mean Absolute Predicted Error. The results of the formula in the bar were displayed in columns for each month, at the row corresponding to the month. The five results in each column were added and divided by five to yield the arithmetic means, displayed in the row containing the label "MAPE ="

Dynamic Ten-year Moving Average Method

In contrast to the static method, the dynamic method incorporated forecasted values as illustrated in Fig. 3. Standard error of the estimate could be added as in the static method.

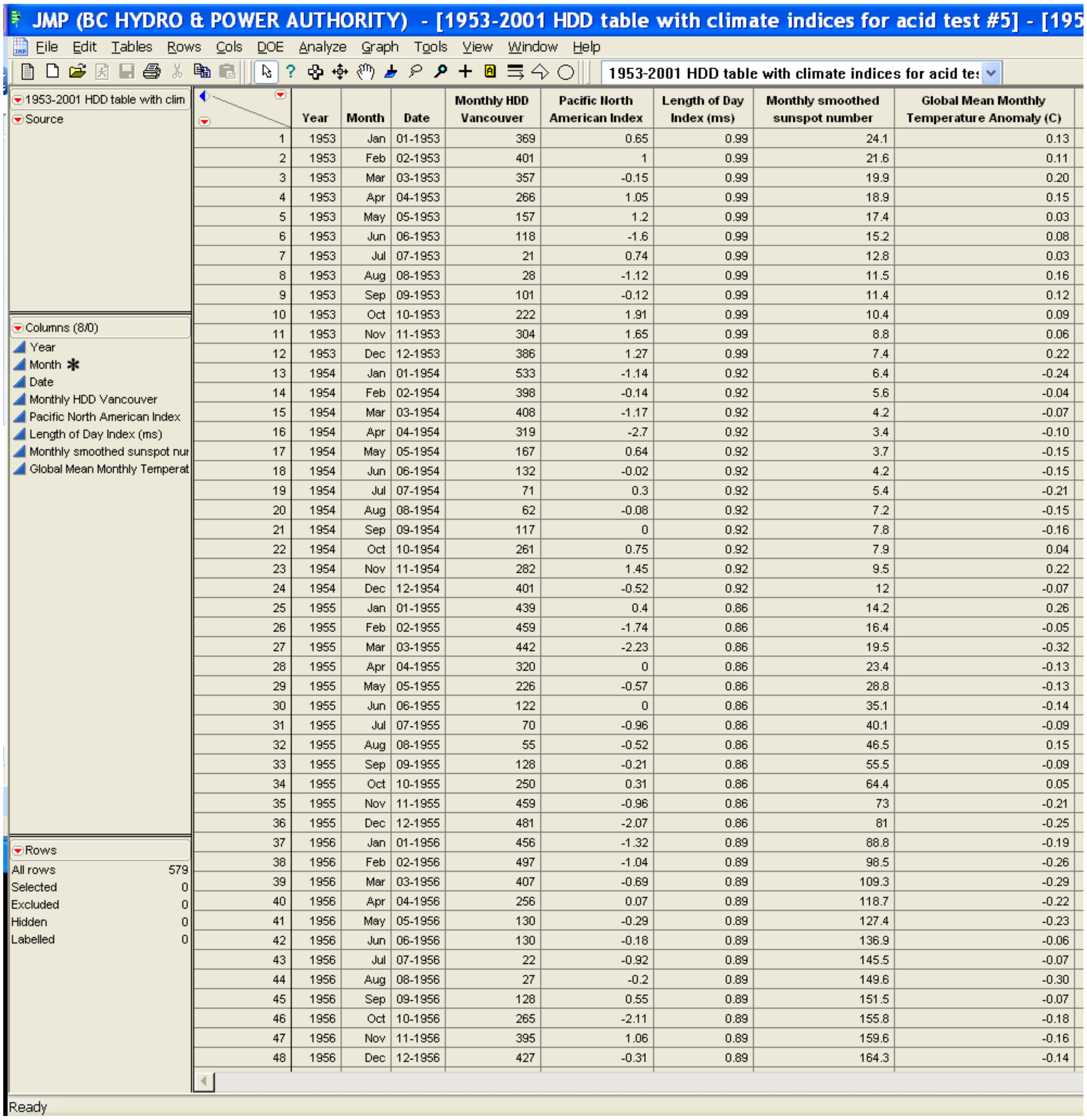


	A	B	C	D	E	F	G	H	I	J	K
1	Lower Mainland										
2		Actual	10-y MA	Dynamic							
3		Heat Deg	Heat Deg	HDD							
4	Date	Days	Days	forecast			ABS(Pact - Ppred)/Pact		Apr	May	
243	Jan-2001	400.2	441.4								
244	Feb-2001	396.8	359.0								
245	Mar-2001	351.7	341.5								
246	Apr-2001	276.4	248.2	248.2			0.102098		0.102098		
247	May-2001	177.9	153.6	153.6			0.136481			0.136481	
248	Jun-2001	100.4	75.2	75.2			0.250797				0.25
249	Jul-2001	33.8	25.7	25.7			0.239053				
250	Aug-2001	26.5	24.1	24.1			0.090189				
251	Sep-2001	97.5	88.9	88.9	Forecast year 1		0.088205				
252	Oct-2001	247.5	237.0	237.0			0.042505				
253	Nov-2001	307.3	346.1	346.1			0.126163				
254	Dec-2001	435.9	436.2	436.2			0.000665				
255	Jan-2002	426.8	430.6	430.6			0.008786				
256	Feb-2002	370.4	368.0	368.0			0.006479				
257	Mar-2002	423.4	337.5	337.5			0.202811				
258	Apr-2002	276.2		245.3			0.111846		0.111846		
259	May-2002	196.4		151.4			0.229369			0.229369	
260	Jun-2002	59.2		73.0			0.232297				0.23
261	Jul-2002	25.9		26.2			0.013205				
262	Aug-2002	21.2		23.3			0.09816				
263	Sep-2002	90.7		88.4	Forecast year 2		0.025469				
264	Oct-2002	257.5		233.3			0.094066				
265	Nov-2002	309.7		348.1			0.123981				
266	Dec-2002	393.5		441.2			0.121116				
267	Jan-2003	363.5		435.9			0.199161				
268	Feb-2003	375.2		371.8			0.008955				
269	Mar-2003	330.4		341.8			0.034604				
270	Apr-2003	262.4		247.5			0.056598		0.056598		
271	May-2003	167.1		152.6			0.086911			0.086911	

Figure 3: The Apr-2001 forecast was calculated as in the static method explained above. The formula for the dynamic HDD forecast for Apr-2003 incorporated the forecasted values for Apr-2001 (cell D246) and Apr-2002 (cell D258). The balance of the table with MAPE calculations operated similarly to the static version, Fig. 2

ARIMA Model Method

The motivation for using the more complex integrated autoregressive-moving average model to predict monthly HDD was to incorporate physical processes information about BC's climate (through climate indices values) in an effort to increase accuracy of the forecasts. SAS JMP software was used. An excerpt from the SAS JMP master data table Apr 1953 to Mar 2001 is shown in Fig. 4.



	Year	Month	Date	Monthly HDD Vancouver	Pacific North American Index	Length of Day Index (ms)	Monthly smoothed sunspot number	Global Mean Monthly Temperature Anomaly (C)
1	1953	Jan	01-1953	369	0.65	0.99	24.1	0.13
2	1953	Feb	02-1953	401	1	0.99	21.6	0.11
3	1953	Mar	03-1953	357	-0.15	0.99	19.9	0.20
4	1953	Apr	04-1953	266	1.05	0.99	18.9	0.15
5	1953	May	05-1953	157	1.2	0.99	17.4	0.03
6	1953	Jun	06-1953	118	-1.6	0.99	15.2	0.08
7	1953	Jul	07-1953	21	0.74	0.99	12.8	0.03
8	1953	Aug	08-1953	28	-1.12	0.99	11.5	0.16
9	1953	Sep	09-1953	101	-0.12	0.99	11.4	0.12
10	1953	Oct	10-1953	222	1.91	0.99	10.4	0.09
11	1953	Nov	11-1953	304	1.65	0.99	8.8	0.06
12	1953	Dec	12-1953	386	1.27	0.99	7.4	0.22
13	1954	Jan	01-1954	533	-1.14	0.92	6.4	-0.24
14	1954	Feb	02-1954	398	-0.14	0.92	5.6	-0.04
15	1954	Mar	03-1954	408	-1.17	0.92	4.2	-0.07
16	1954	Apr	04-1954	319	-2.7	0.92	3.4	-0.10
17	1954	May	05-1954	167	0.64	0.92	3.7	-0.15
18	1954	Jun	06-1954	132	-0.02	0.92	4.2	-0.15
19	1954	Jul	07-1954	71	0.3	0.92	5.4	-0.21
20	1954	Aug	08-1954	62	-0.08	0.92	7.2	-0.15
21	1954	Sep	09-1954	117	0	0.92	7.8	-0.16
22	1954	Oct	10-1954	261	0.75	0.92	7.9	0.04
23	1954	Nov	11-1954	282	1.45	0.92	9.5	0.22
24	1954	Dec	12-1954	401	-0.52	0.92	12	-0.07
25	1955	Jan	01-1955	439	0.4	0.86	14.2	0.26
26	1955	Feb	02-1955	459	-1.74	0.86	16.4	-0.05
27	1955	Mar	03-1955	442	-2.23	0.86	19.5	-0.32
28	1955	Apr	04-1955	320	0	0.86	23.4	-0.13
29	1955	May	05-1955	226	-0.57	0.86	28.8	-0.13
30	1955	Jun	06-1955	122	0	0.86	35.1	-0.14
31	1955	Jul	07-1955	70	-0.96	0.86	40.1	-0.09
32	1955	Aug	08-1955	55	-0.52	0.86	46.5	0.15
33	1955	Sep	09-1955	128	-0.21	0.86	55.5	-0.09
34	1955	Oct	10-1955	250	0.31	0.86	64.4	0.05
35	1955	Nov	11-1955	459	-0.96	0.86	73	-0.21
36	1955	Dec	12-1955	481	-2.07	0.86	81	-0.25
37	1956	Jan	01-1956	456	-1.32	0.89	88.8	-0.19
38	1956	Feb	02-1956	497	-1.04	0.89	98.5	-0.26
39	1956	Mar	03-1956	407	-0.69	0.89	109.3	-0.29
40	1956	Apr	04-1956	256	0.07	0.89	118.7	-0.22
41	1956	May	05-1956	130	-0.29	0.89	127.4	-0.23
42	1956	Jun	06-1956	130	-0.18	0.89	136.9	-0.06
43	1956	Jul	07-1956	22	-0.92	0.89	145.5	-0.07
44	1956	Aug	08-1956	27	-0.2	0.89	149.6	-0.30
45	1956	Sep	09-1956	128	0.55	0.89	151.5	-0.07
46	1956	Oct	10-1956	265	-2.11	0.89	155.8	-0.18
47	1956	Nov	11-1956	395	1.06	0.89	159.6	-0.16
48	1956	Dec	12-1956	427	-0.31	0.89	164.3	-0.14

Figure 4: Excerpt from SAS JMP data table with climate index values for the Pacific North American Index (PNAI), Length of Day Index (LODI), Monthly Smoothed Sunspot Number (MSSN), and Global Mean Monthly Temperature Anomaly (GMMTA)

To obtain maximum benefit from the following sections, the reader is invited especially to refer to the presentation document, *Heating/Cooling Degree Day Forecasts for BC Hydro Sales Regions Using a Probabilistic Model with Climate Inputs* (Wahlgren, 2009), for explanations about time series, spectral densities, and climate indices. Some familiarity with SAS JMP and ARIMA is assumed—the other publications in the *Bibliography* and *References* are readable and useful.

Using standard JMP procedures, a model was set up with inputs as displayed in Fig 5.

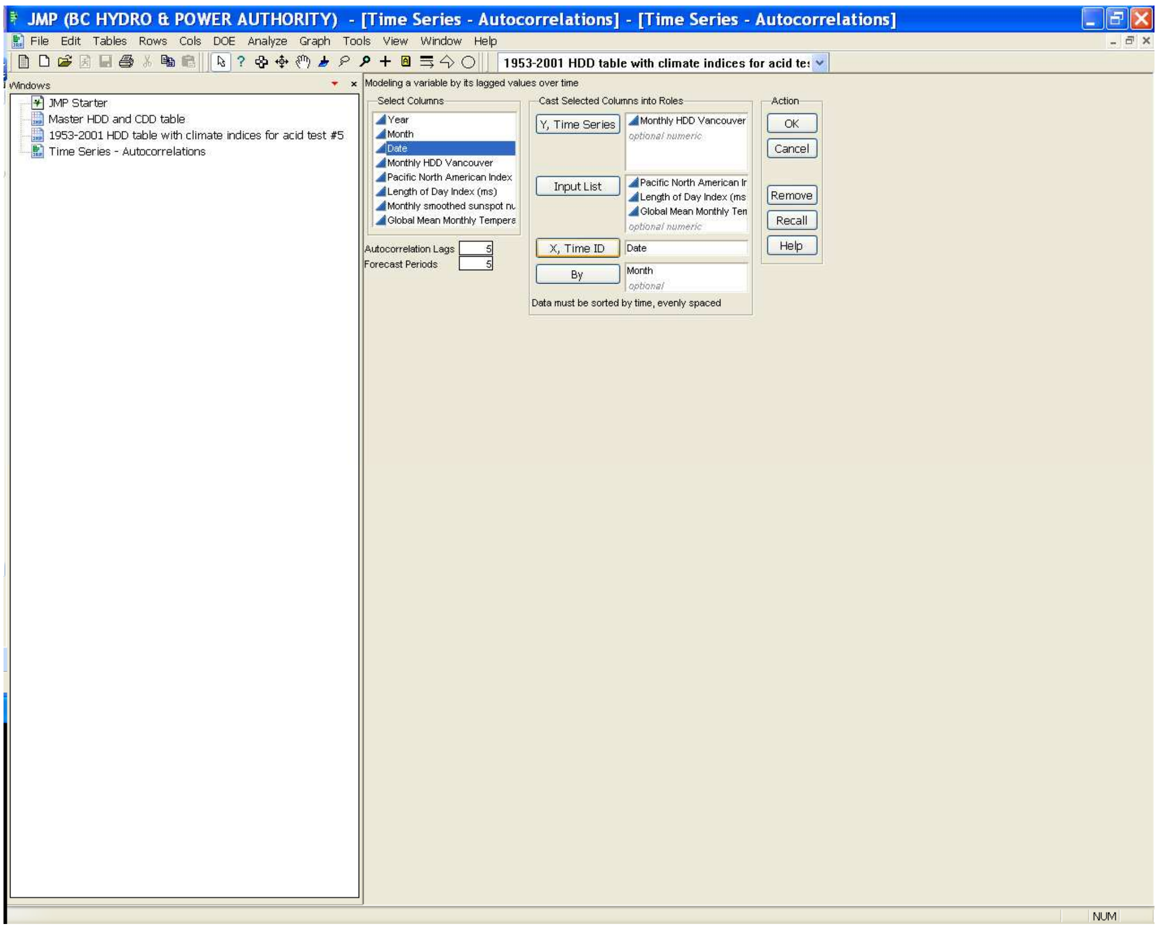


Figure 5: Model set up with inputs. Set Autocorrelation Lags and Forecast Periods each to 5 years because five year forecasts were made. A rule of thumb was to set these values to a maximum of N/4, where N was the number of data points. From 1953 to 2001 there were 49 data points for each month. Although 49/4 = 12, the value 5 was appropriate and avoided "information overload" in the following analyses

At this point, spectral densities for the time series and climate inputs were checked for interesting cases of coinciding peaks (Figs. 6 through 9).

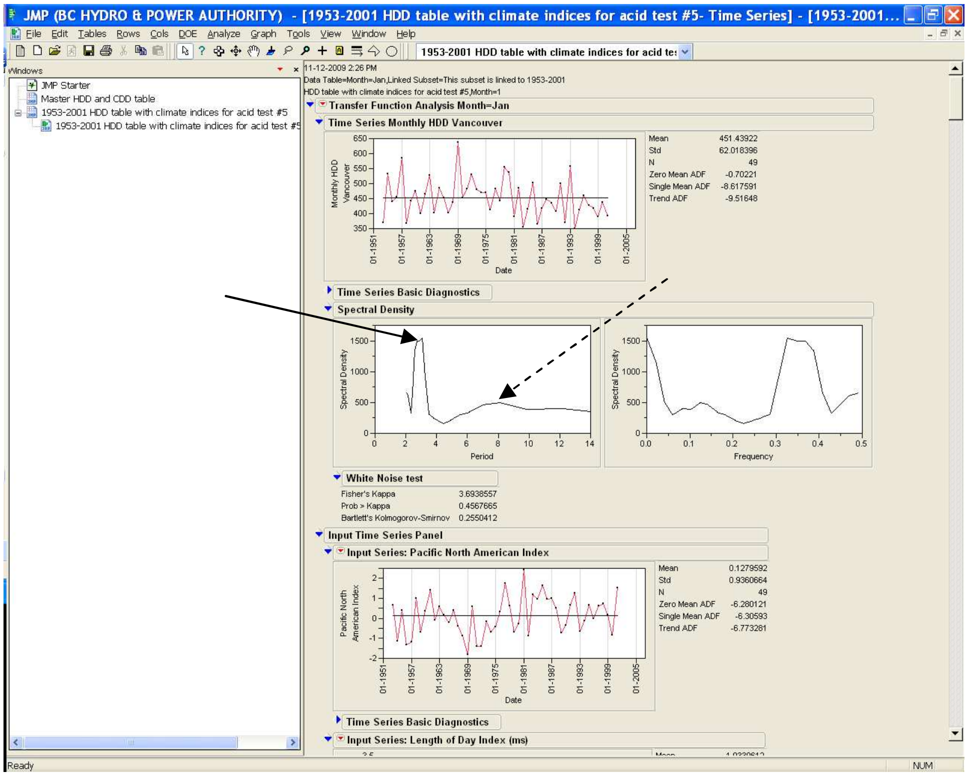


Figure 6: Spectral density for HDD Vancouver for months of Jan 1953 to 2001. A strong peak was evident for a 3-year cycle (solid arrow). A weaker peak distinguished a cycle with a period of about 8 years (dashed arrow)

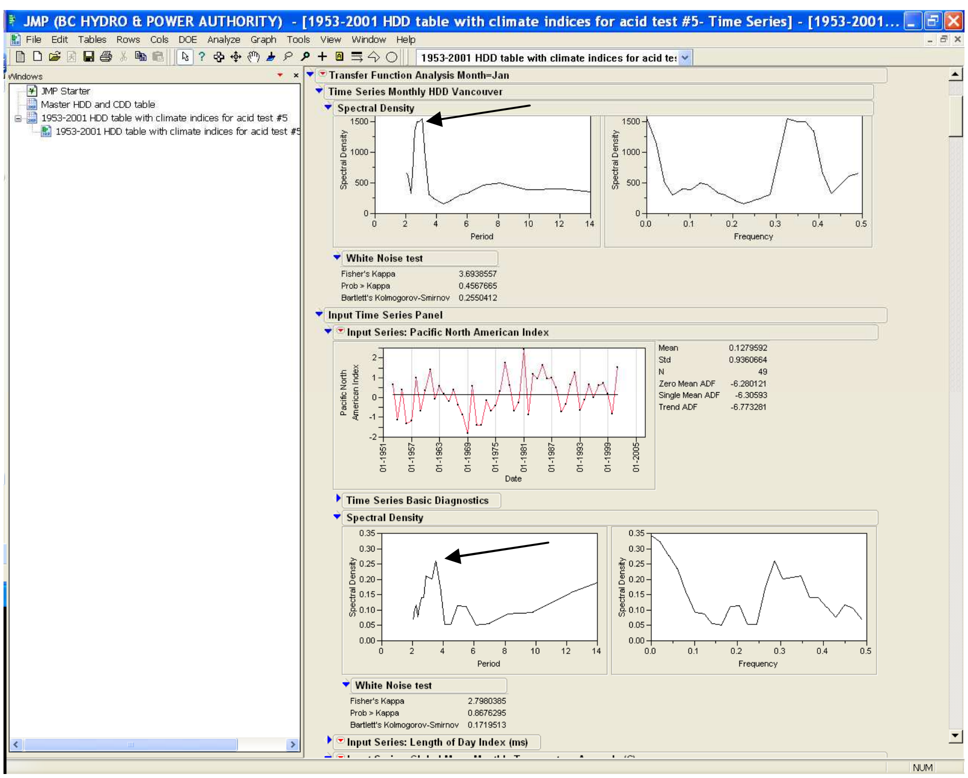


Figure 7: Spectral density for the Pacific North American Index (PNAI) for months of Jan 1953 to 2001. The HDD values appeared to be responding to the 3-year cycle in PNAI values (arrows)

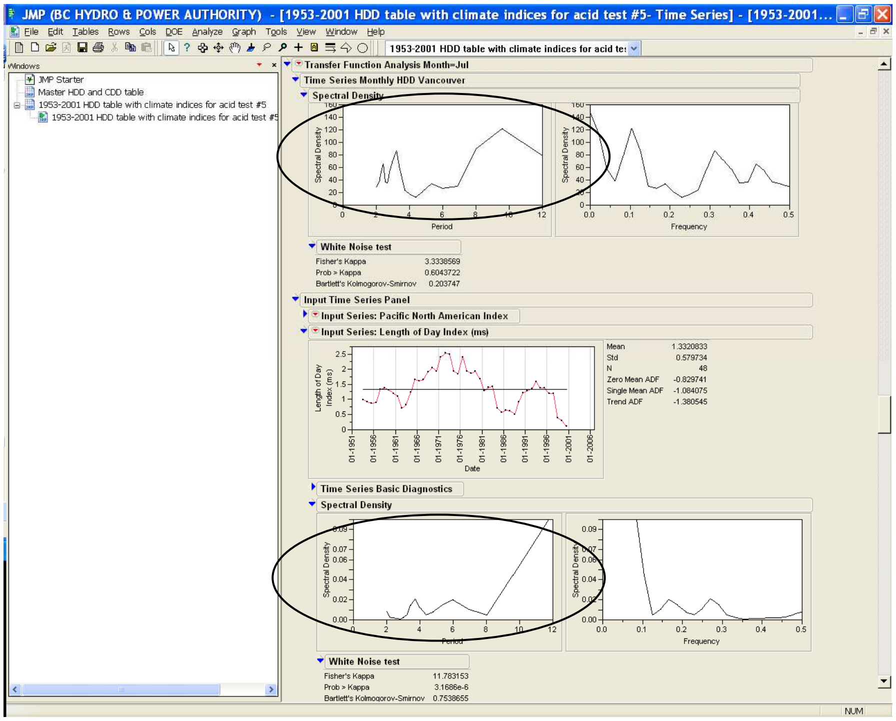


Figure 8: Spectral density for Length of Day Index (LODI) for months of Jul 1953 to 2001. There was no clear match evident between HDD and LODI peaks

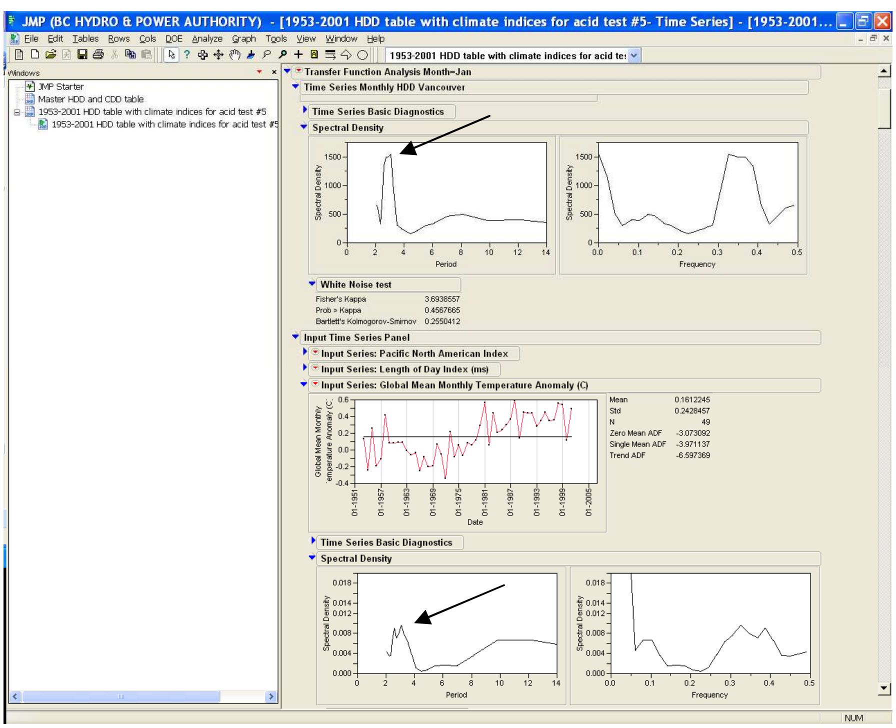


Figure 9: Spectral density for Global Monthly Mean Temperature Anomaly (GMMTA) for months of Jan 1953 to 2001. There was a 3-year peak match between HDD and GMMTA (arrows). This peak also appeared in the spectra for PNAI (Fig. 7)

Now Transfer Function was selected (Fig. 10).

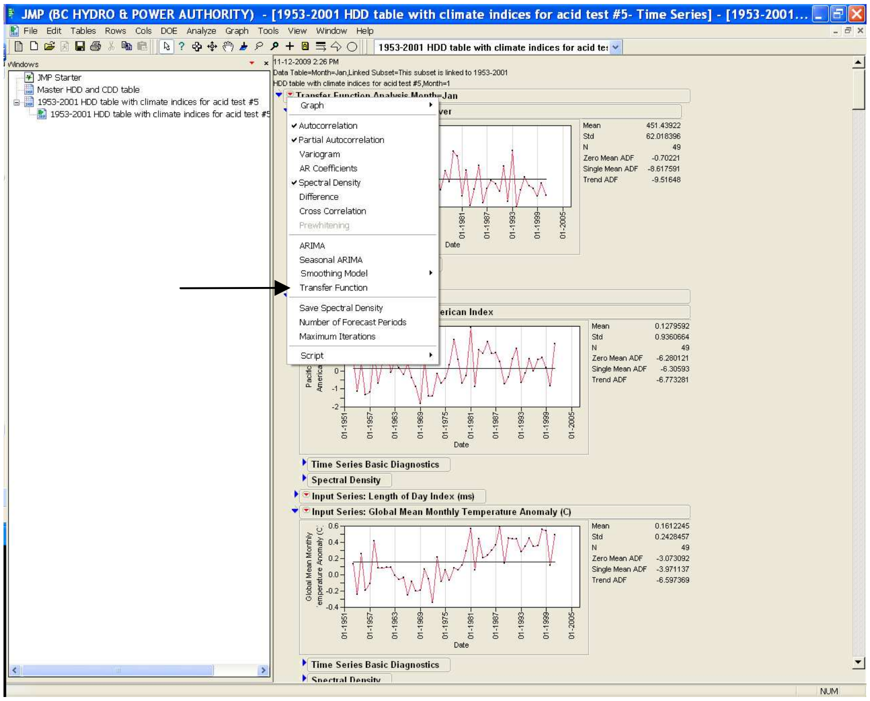


Figure 10: "Transfer Function" selected (arrow)

Transfer Function inputs were selected (Fig. 11).

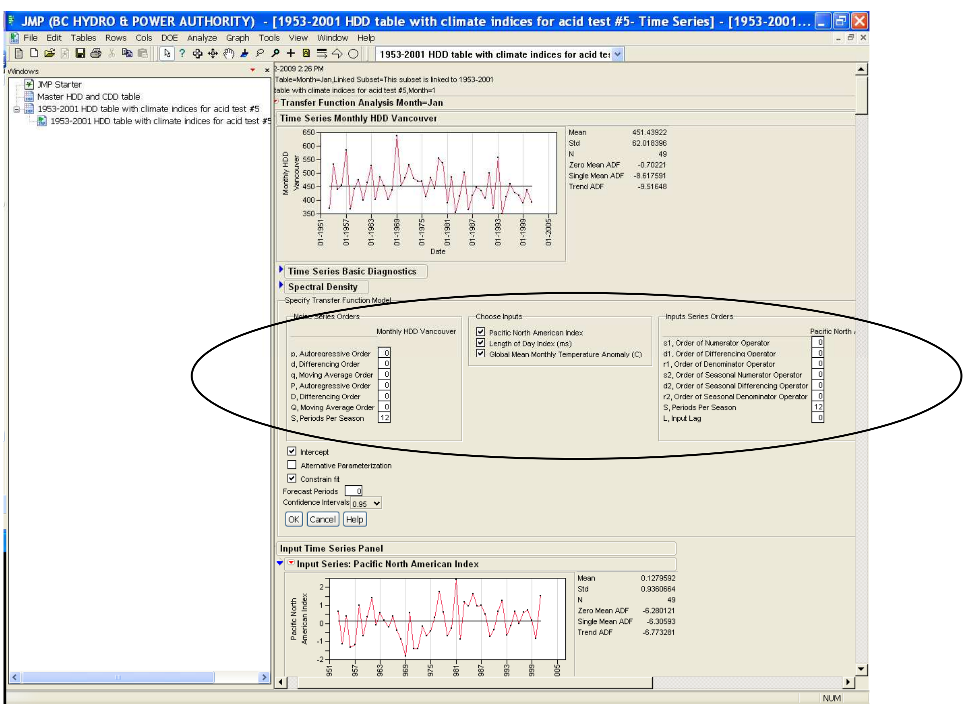


Figure 11: Chose Transfer Function inputs — to do this examined "Time Series Basic Diagnostics" as explained in the caption for Fig. 12. Forecast Periods input box was updated from "0" to "5"

Time Series Basic Diagnostics were examined for the HDD Vancouver time series (Fig. 12) and a model was tried giving the result shown in Fig. 13.

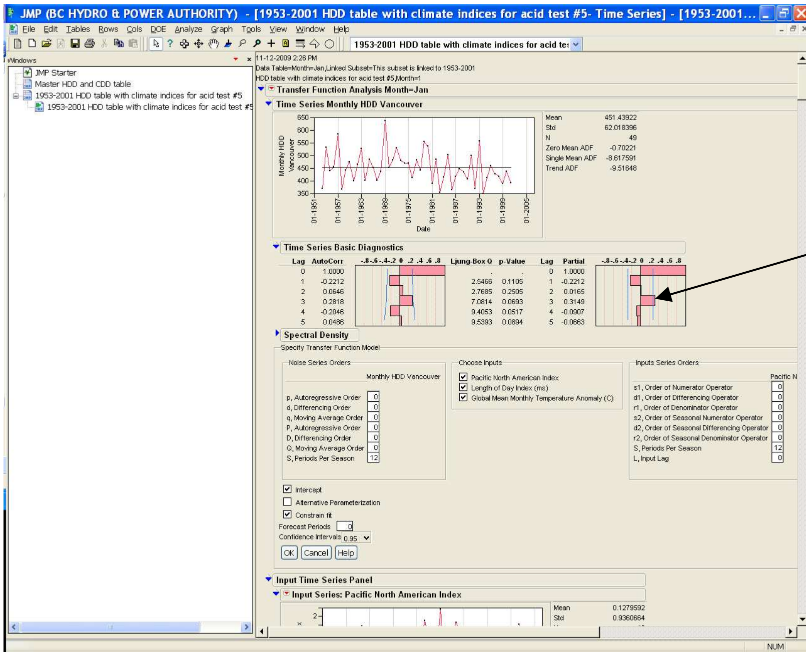


Figure 12: Time Series Basic Diagnostics Partial Autocorrelation Function (chart on right) showed a significant positive deviation at lag 3 (arrow). The solid blue lines represented ± 2 standard errors for approximate 95% confidence limits. Positive deviations were characteristic of an autoregressive (AR) signature. In this case the order of the AR process was 3. Therefore an AR(3) model was tried

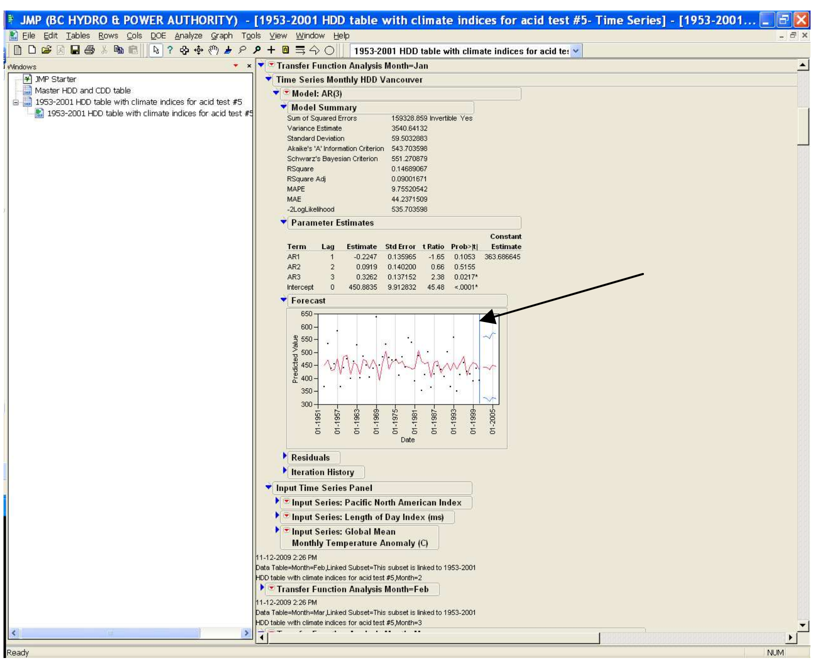


Figure 13: Results for AR(3) model. To the left of the vertical blue separating line (arrow) the one-step-ahead forecasts (red line) were overlaid with the input data points (black dots). To the right of the line were the future values forecast by the model (red line) and the 95% confidence intervals for the forecasts (blue lines)

AR and MA orders were determined for PNAI (Figs. 14–16) and GMMTA (Figs. 17–18).

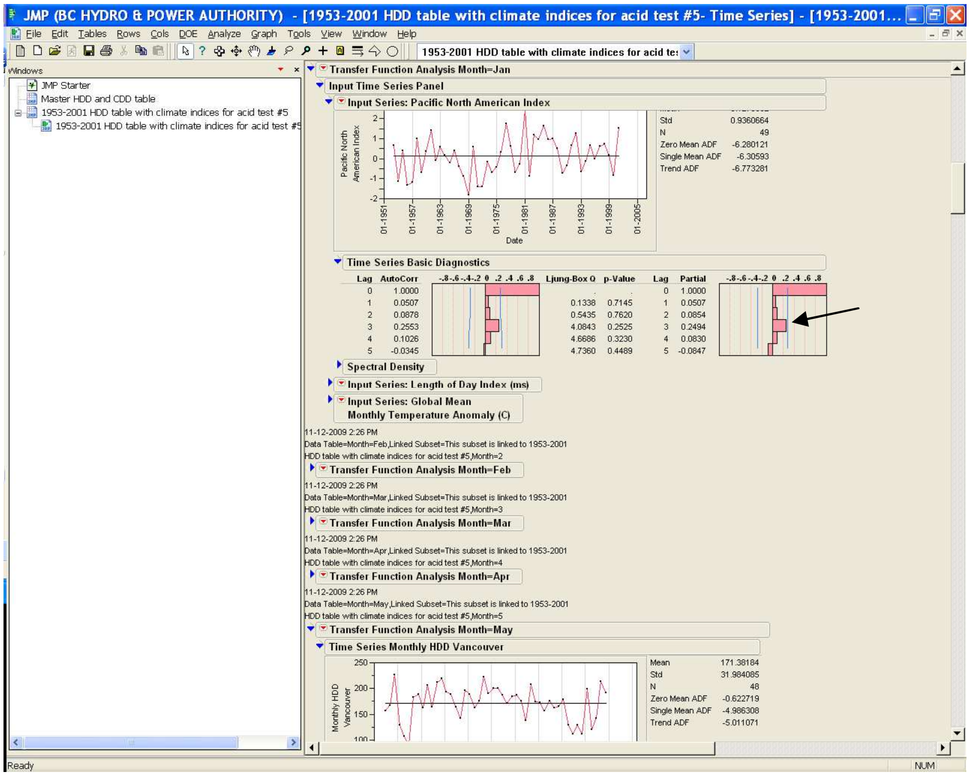


Figure 14: An AR(3) model was also a possibility for the Jan PNAI time series (arrow)

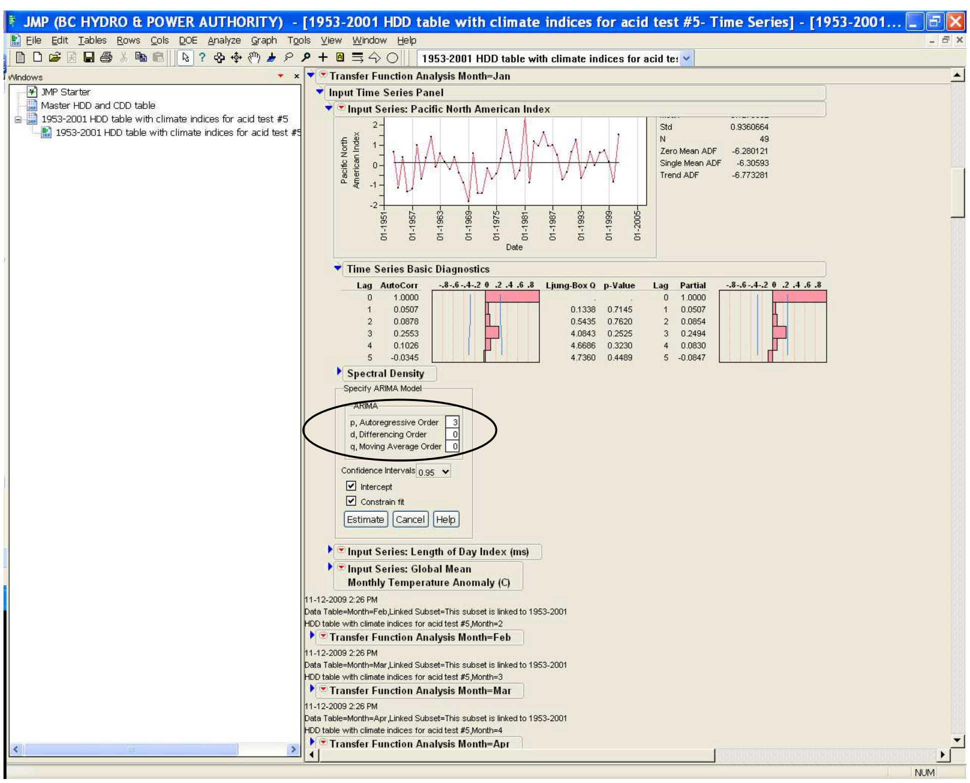


Figure 15: Input for AR(3) PNAI model specified the autoregressive order as 3

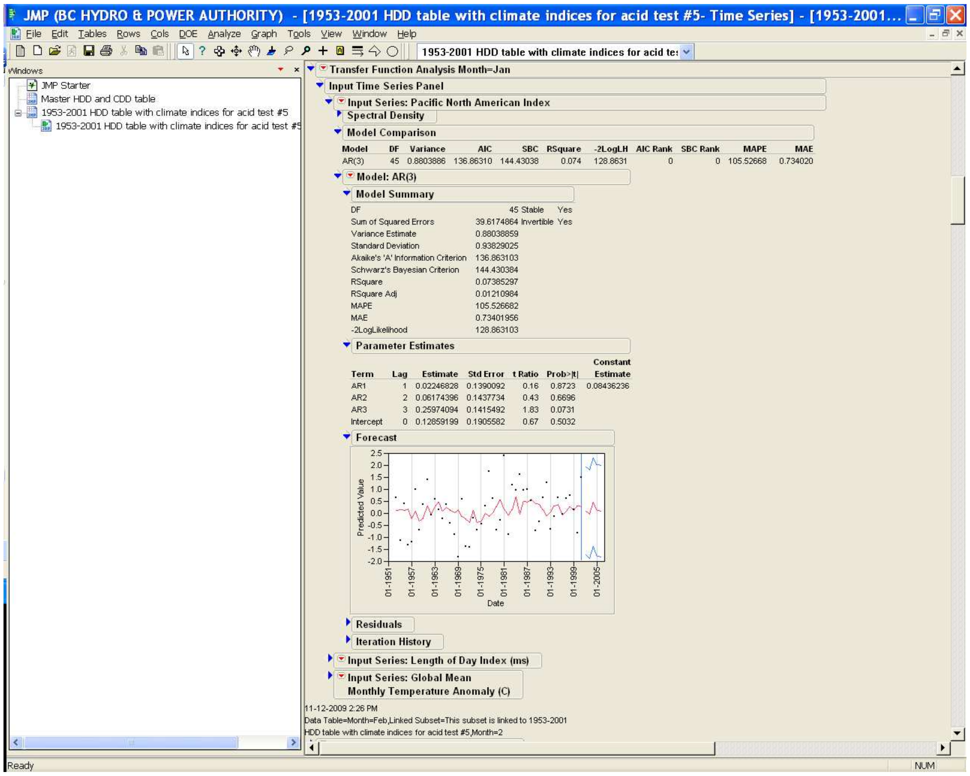


Figure 16: Result of AR(3) model for PNAI

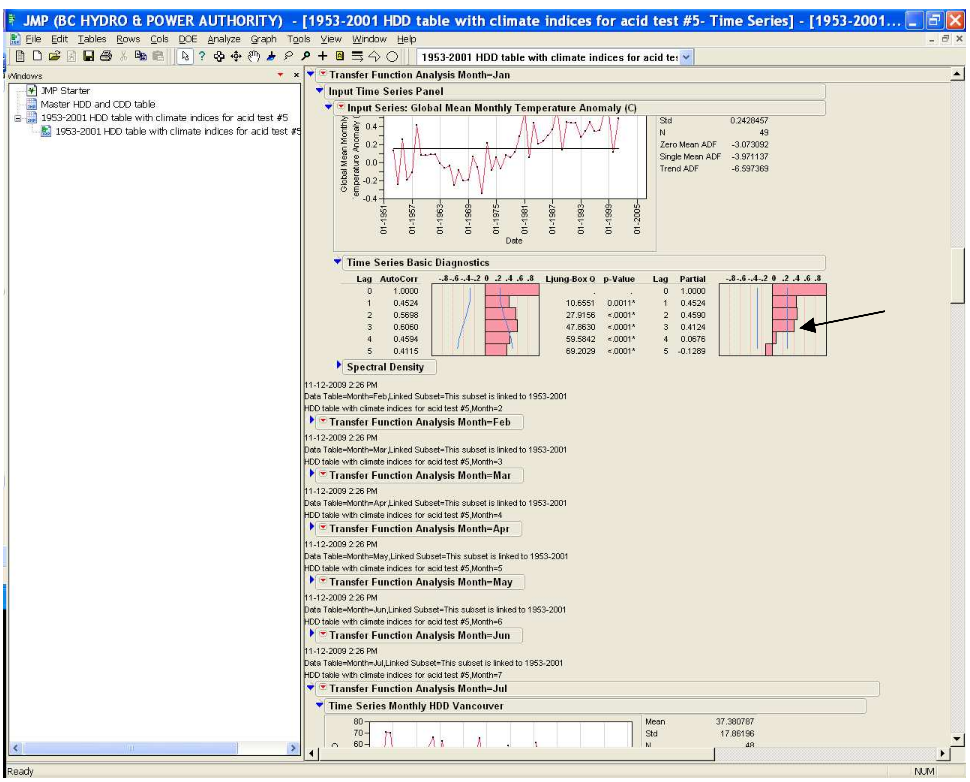


Figure 17: GMMTA was likely to need an AR(3) model as suggested by the abrupt decrease in magnitude of positive deviations in the partial autocorrelation function chart after lag 3 (arrow)

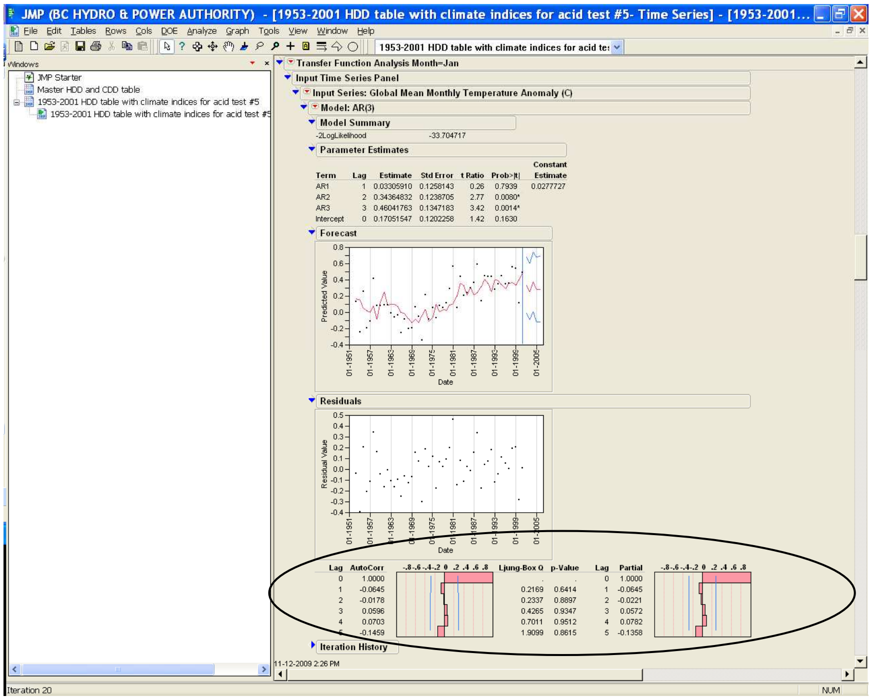


Figure 18: Result of AR(3) model. Notice how both the autocorrelation function (ACF) and partial autocorrelation function (PACF) plots showed no significant deviations, confirming a correctly chosen model

Now all the Transfer Function Inputs were available (Fig. 19):

Noise Series Order—Monthly HDD Vancouver was AR(3) and
Input Series Orders—PNAI was AR(3) and GMMTA was AR(3).

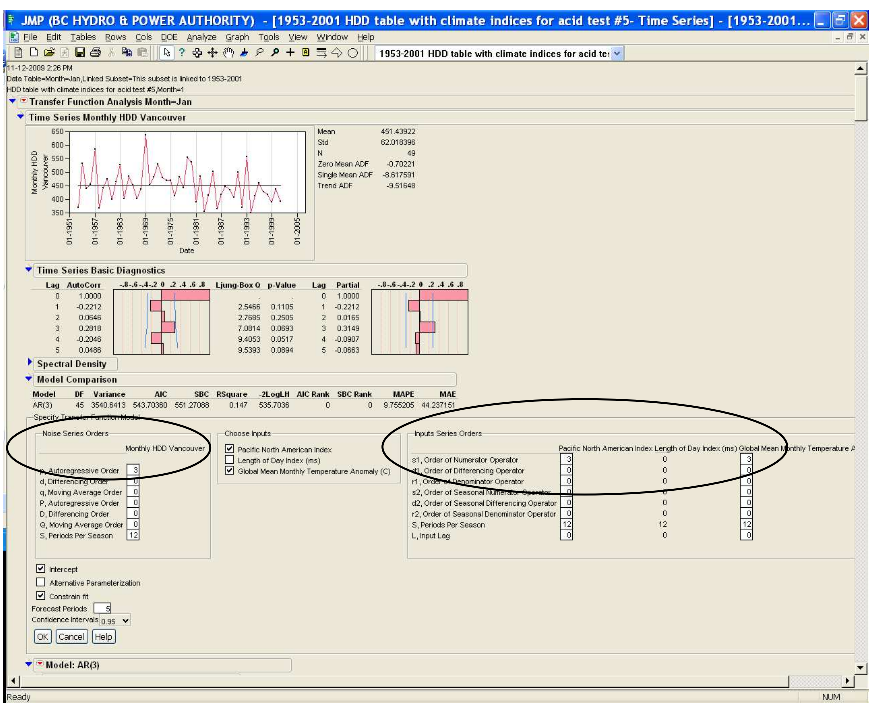


Figure 19: Inputs to transfer function

To update the “Inputs Variables” in the Transfer Function (TF; Fig. 20) collect the forecast data that was collected for PNAI (Figs. 21–22) and GMMTA (Fig. 23) for input to the TF (Fig. 24). The HDD forecast values were now available (Fig. 25).

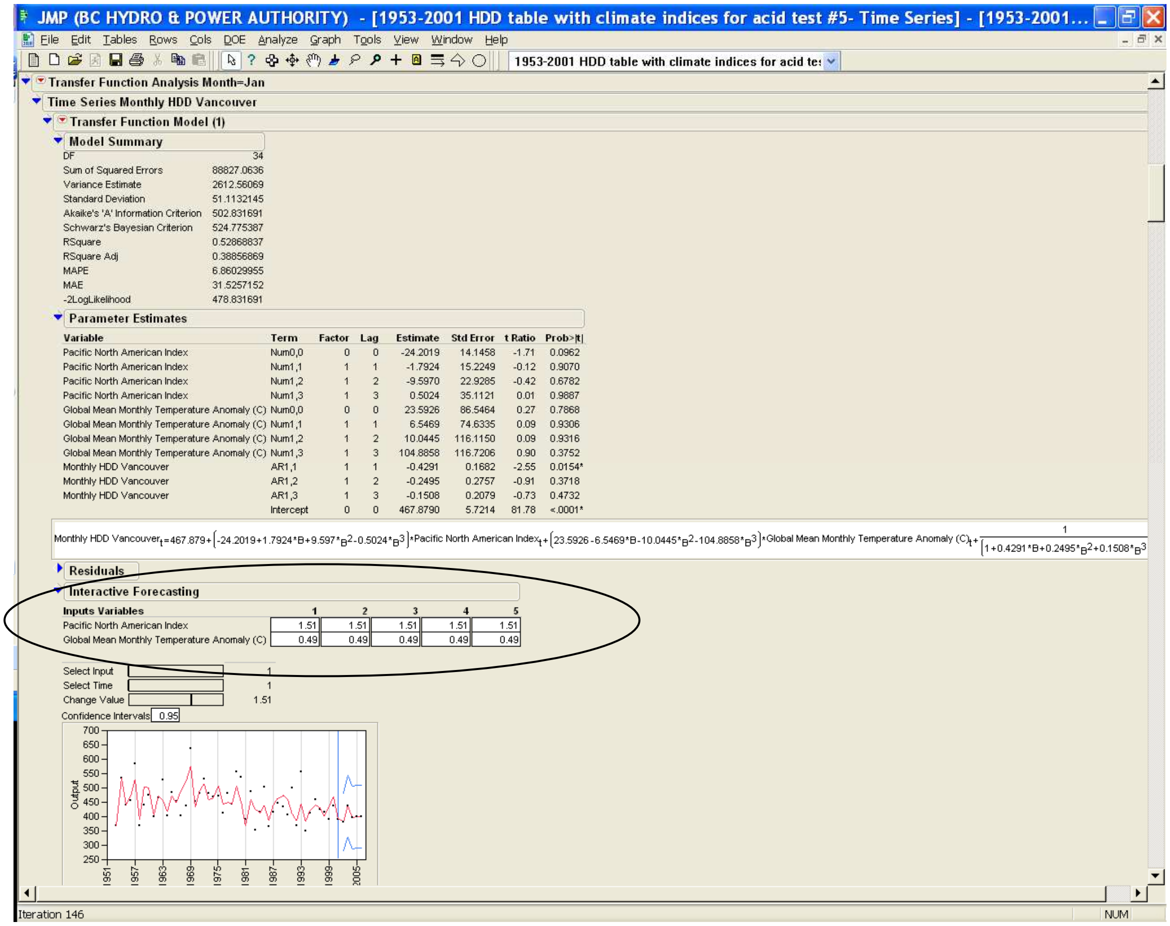


Figure 20: Transfer Function results. The “Inputs Variables” were updated by ten manual entries

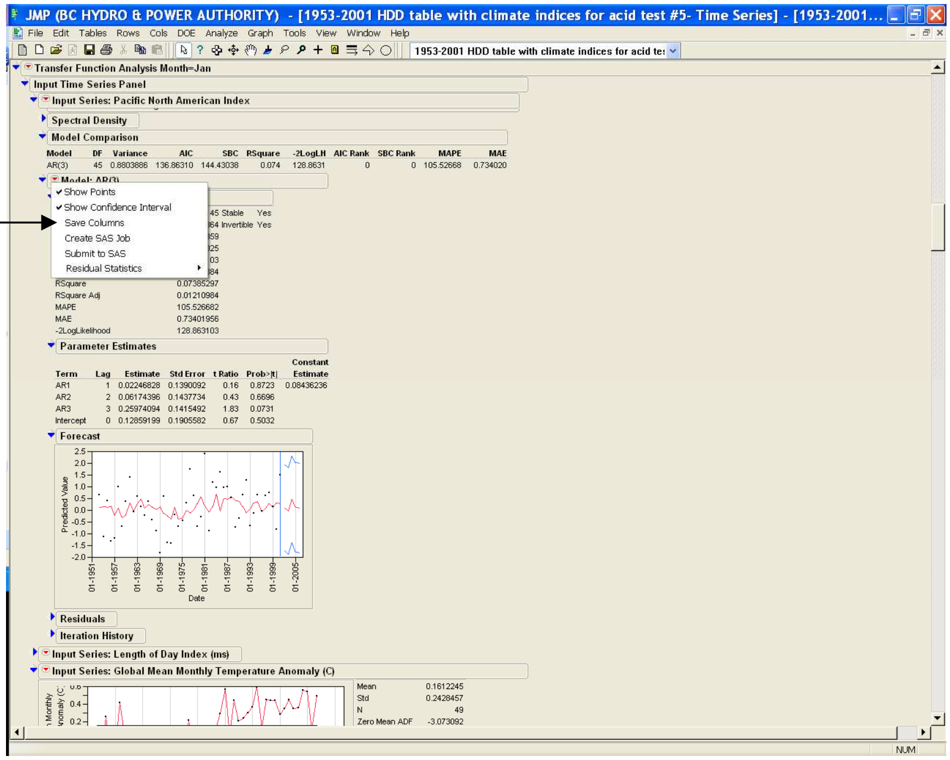


Figure 21: "Save Columns" (arrow) was selected to get data for PNAI AR(3)

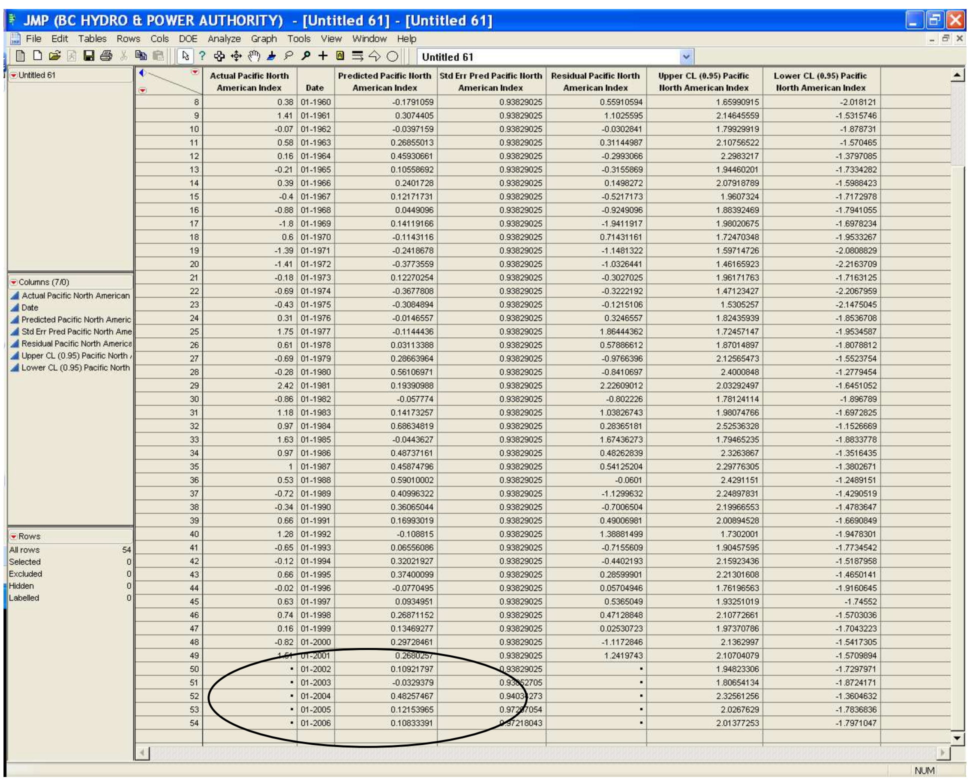


Figure 22: Predicted Jan PNAI for the next five years 2002 to 2006 were found in rows 50 to 54 in the 'Predicted Pacific North American Index' column

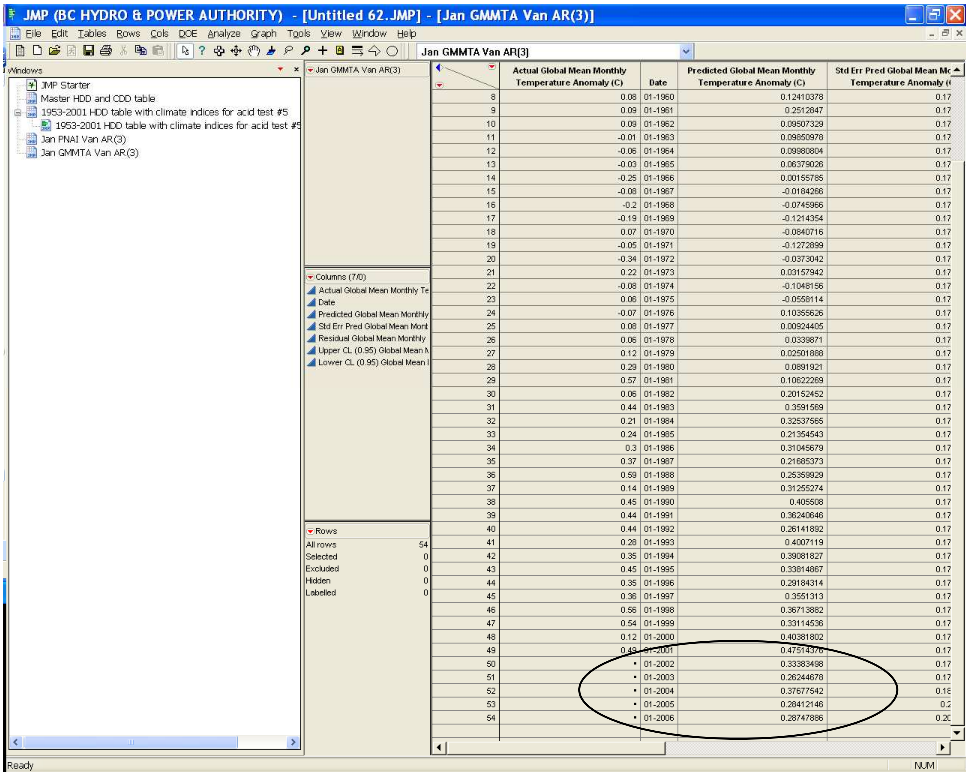


Figure 23: Predicted values for GMMTA for 2002 to 2006 were in the last five rows of the table

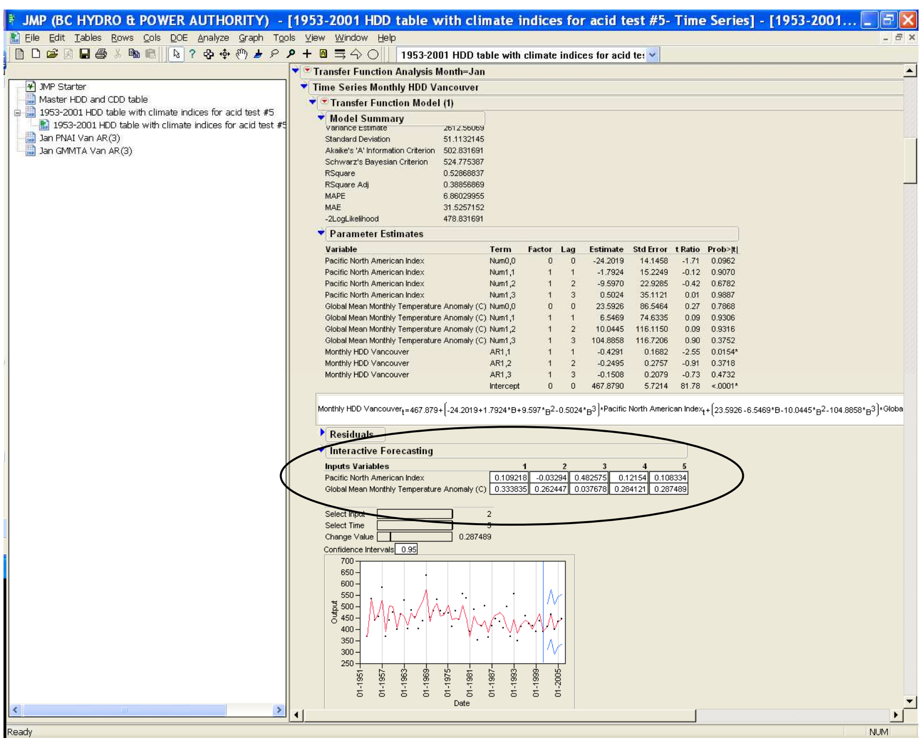
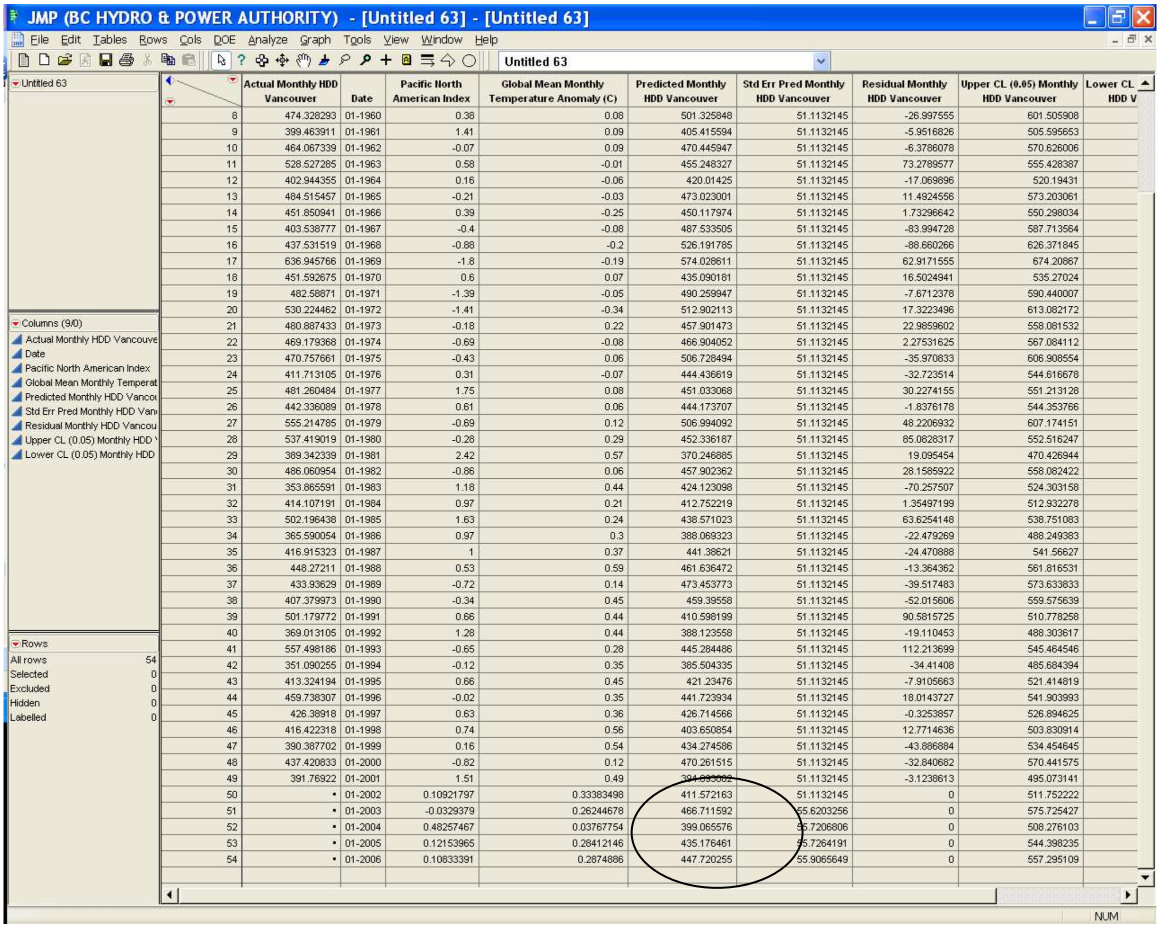


Figure 24: "Transfer Function" was selected and updated with "Inputs Variables" manually as shown here. The PNAI and GMMTA forecast values were from the last five rows of Figs. 22 and 23 respectively



	Actual Monthly HDD Vancouver	Date	Pacific North American Index	Global Mean Monthly Temperature Anomaly (C)	Predicted Monthly HDD Vancouver	Std Err Pred Monthly HDD Vancouver	Residual Monthly HDD Vancouver	Upper CL (0.05) Monthly HDD Vancouver	Lower CL HDD V
8	474.328293	01-1960	0.38	0.08	501.325848	51.1132145	-26.997555	601.505908	
9	399.463911	01-1961	1.41	0.09	405.415594	51.1132145	-5.9516826	505.595653	
10	464.067339	01-1962	-0.07	0.09	470.445947	51.1132145	-6.3786078	570.626006	
11	528.527285	01-1963	0.58	-0.01	455.248327	51.1132145	73.2789577	555.428387	
12	402.944355	01-1964	0.16	-0.06	420.01425	51.1132145	-17.069896	520.19431	
13	484.515457	01-1965	-0.21	-0.03	473.023001	51.1132145	11.4924556	573.203061	
14	451.850941	01-1966	0.39	-0.25	450.117974	51.1132145	1.73296642	550.298034	
15	403.538777	01-1967	-0.4	-0.08	487.533505	51.1132145	-83.994728	587.713564	
16	437.531519	01-1968	-0.88	-0.2	526.191785	51.1132145	-88.660266	626.371845	
17	636.945766	01-1969	-1.8	-0.19	574.028611	51.1132145	62.9171555	674.20867	
18	451.592675	01-1970	0.6	0.07	435.090181	51.1132145	16.5024941	535.27024	
19	482.58871	01-1971	-1.39	-0.05	490.259947	51.1132145	-7.6712378	590.440007	
20	530.224462	01-1972	-1.41	-0.34	512.902113	51.1132145	17.3223496	613.082172	
21	480.887433	01-1973	-0.18	0.22	457.901473	51.1132145	22.9859602	558.081532	
22	469.179368	01-1974	-0.69	-0.08	466.904052	51.1132145	2.27531625	567.084112	
23	470.757661	01-1975	-0.43	0.06	506.728494	51.1132145	-35.970833	606.908554	
24	411.713105	01-1976	0.31	-0.07	444.436619	51.1132145	-32.723514	544.616678	
25	481.260484	01-1977	1.75	0.08	451.033068	51.1132145	30.2274155	551.213128	
26	442.336089	01-1978	0.61	0.06	444.173707	51.1132145	-1.8376178	544.353766	
27	555.214785	01-1979	-0.69	0.12	506.994092	51.1132145	48.2206932	607.174151	
28	537.419019	01-1980	-0.28	0.29	452.336187	51.1132145	85.0828317	552.516247	
29	389.342339	01-1981	2.42	0.57	370.246885	51.1132145	19.095454	470.426944	
30	486.060954	01-1982	-0.86	0.06	457.902362	51.1132145	28.1585922	558.082422	
31	353.865591	01-1983	1.18	0.44	424.123098	51.1132145	-70.257507	524.303158	
32	414.107191	01-1984	0.97	0.21	412.752219	51.1132145	1.35497199	512.932278	
33	502.196438	01-1985	1.63	0.24	438.571023	51.1132145	63.6254148	538.751083	
34	365.590054	01-1986	0.97	0.3	388.069323	51.1132145	-22.479269	488.249383	
35	416.915323	01-1987	1	0.37	441.38621	51.1132145	-24.470888	541.56627	
36	448.27211	01-1988	0.53	0.59	461.636472	51.1132145	-13.364362	561.816531	
37	433.93629	01-1989	-0.72	0.14	473.453773	51.1132145	-39.517483	573.633833	
38	407.379973	01-1990	-0.34	0.45	459.39558	51.1132145	-52.015606	559.575639	
39	501.179772	01-1991	0.66	0.44	410.598199	51.1132145	90.5815725	510.778258	
40	369.013105	01-1992	1.28	0.44	388.123558	51.1132145	-19.110453	488.303617	
41	557.498186	01-1993	-0.65	0.28	445.284486	51.1132145	112.213699	545.464546	
42	351.090255	01-1994	-0.12	0.35	385.504335	51.1132145	-34.41408	485.684394	
43	413.324194	01-1995	0.66	0.45	421.23476	51.1132145	-7.9105663	521.414819	
44	459.738307	01-1996	-0.02	0.35	441.723934	51.1132145	18.0143727	541.903993	
45	426.38918	01-1997	0.63	0.36	426.714566	51.1132145	-0.3253857	526.894625	
46	416.422318	01-1998	0.74	0.56	403.650854	51.1132145	12.7714636	503.830914	
47	390.387702	01-1999	0.16	0.54	434.274586	51.1132145	-43.886884	534.454645	
48	437.420833	01-2000	-0.82	0.12	470.261515	51.1132145	-32.840682	570.441575	
49	391.76922	01-2001	1.51	0.49	[illegible]	51.1132145	-3.1238613	495.073141	
50	•	01-2002	0.10921797	0.33383498	411.572163	51.1132145	0	511.752222	
51	•	01-2003	-0.0329379	0.26244678	466.711592	55.6203256	0	575.725427	
52	•	01-2004	0.48257467	0.03767754	399.065576	55.7206806	0	508.276103	
53	•	01-2005	0.12153965	0.28412146	435.176461	55.7264191	0	544.398235	
54	•	01-2006	0.10833391	0.2874886	447.720255	55.9065649	0	557.295109	

Figure 25: “Save Columns” was selected for the Transfer Function to see the HDD predictions in the last five rows underneath the ‘Predicted Monthly HDD Vancouver’ column. Values for Standard Error as well as Upper and Lower Confidence Limits (0.05 level) were tabulated

An example of a moving average signature in the time series was illustrated by the data for Feb 1953–2001 (Fig. 26). There was sometimes ambiguity in model results. How this may be dealt with was considered in the captions for Figs. 27 through 29.

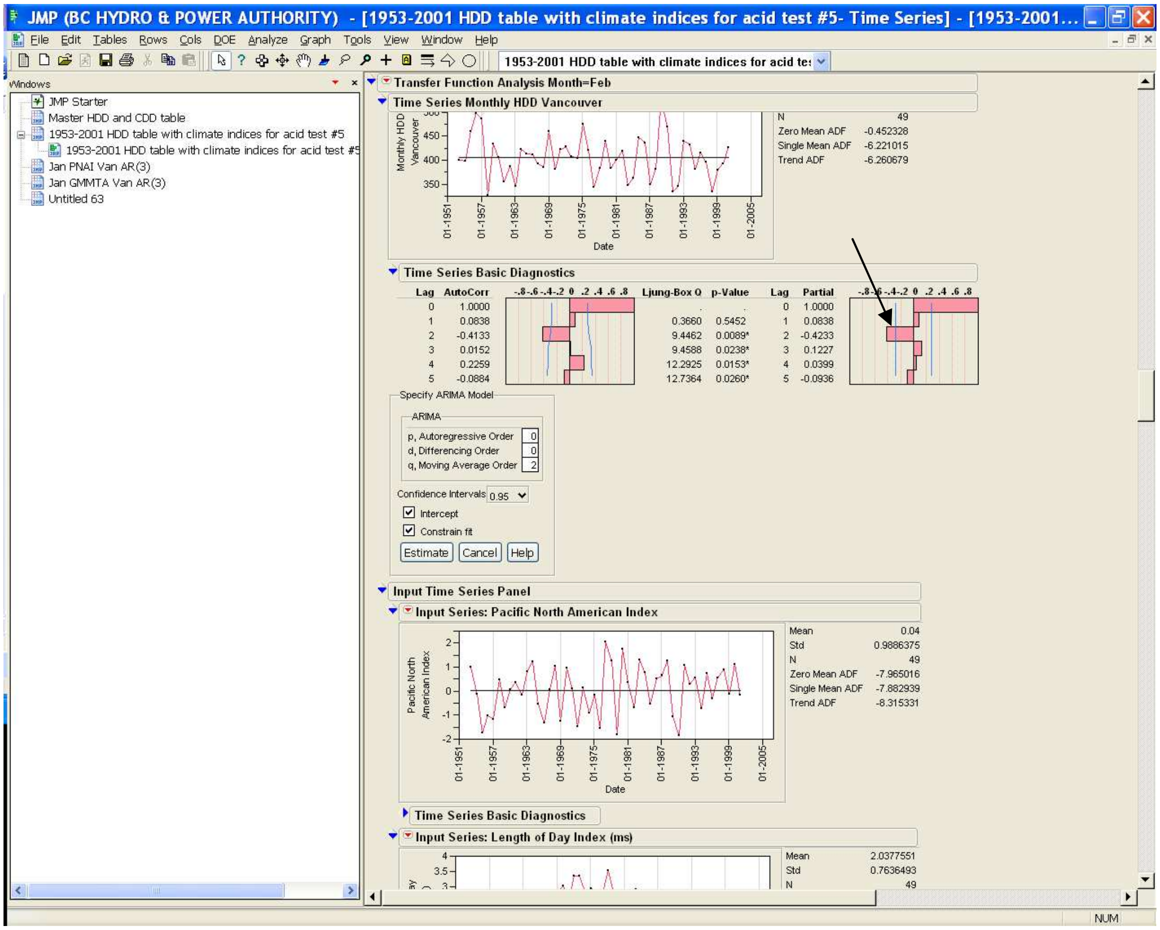


Figure 26: Feb HDD had a significant negative deviation (arrow) which was a moving average (MA) signature. The order of the MA process was 2 or perhaps 3, suggesting models MA(2) or MA(3)

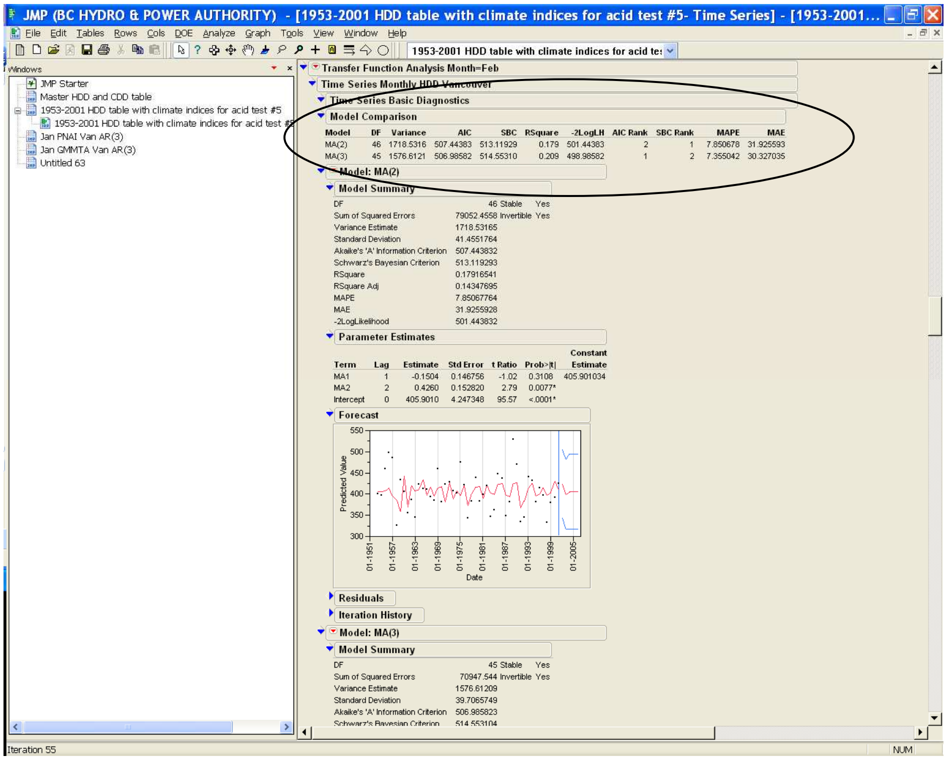


Figure 27: Example of model comparison – chose MA(3) – it had a lower standard variance and higher R^2 value. (AIC) Aikake's 'A' Information Criterion was lower than for the MA(2) model. Therefore, MA(3) had Rank 1 in terms of AIC. Interestingly, Schwarz's Bayesian Criterion disagreed with the AIC, forcing the analyst to choose, using judgement based on experience

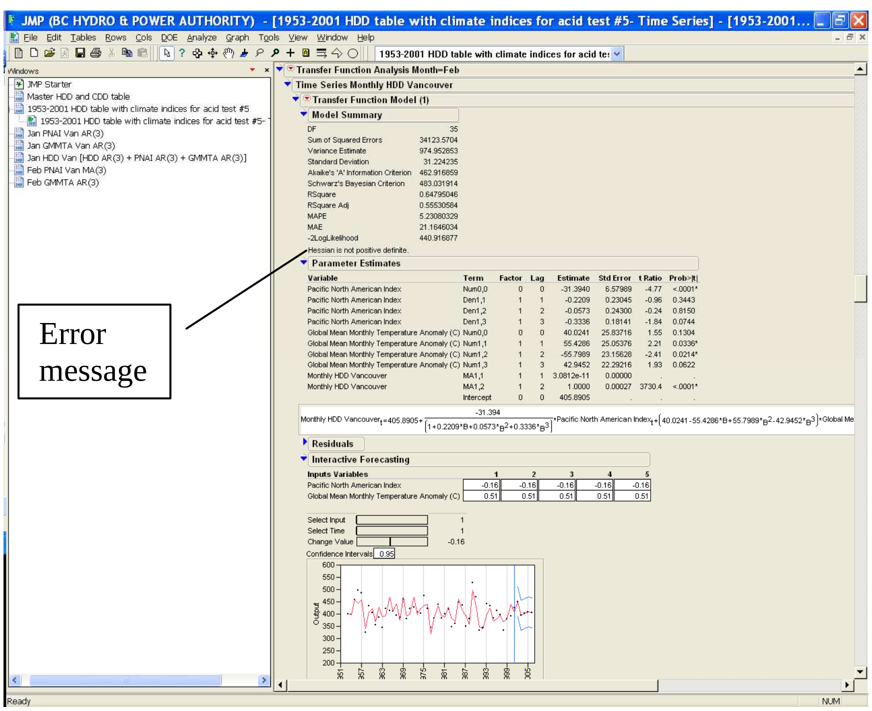


Figure 28: Sometimes the Transfer Function Model assisted in choosing between ambiguous Noise Series Orders or Inputs Series Orders. Here was an example of model failure – because tried using HDD MA(2) instead of MA(3) for the Noise Series Order

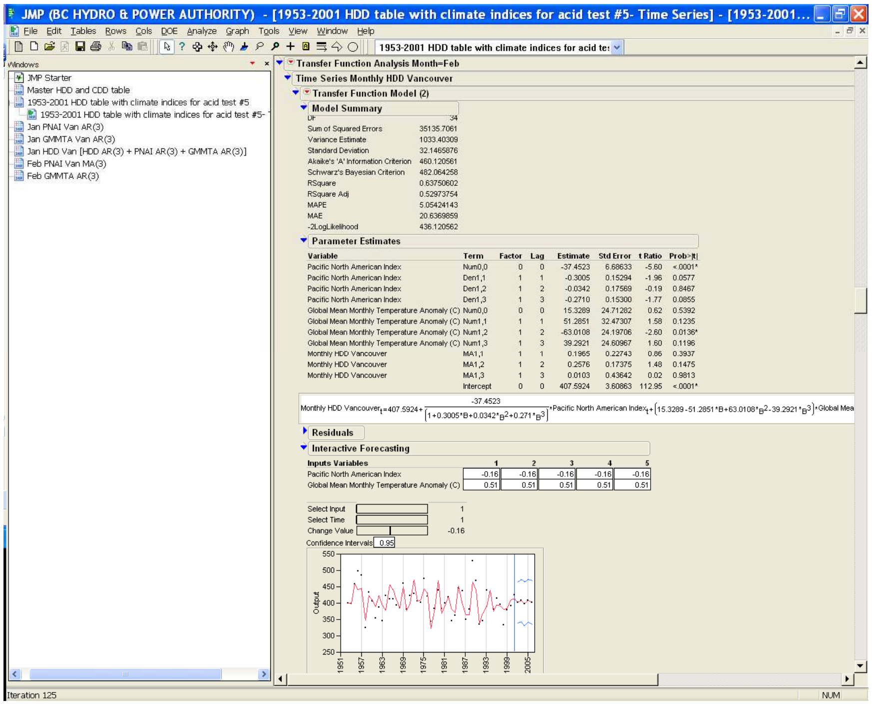


Figure 29: The Transfer Function Model worked with MA(3)

Similar procedures were followed for the remaining months.

Take care not to "over-fit" the data (NIST/SEMATECH, 2009) by including extra, unnecessary terms in the model.

Bibliography

Decision 411 Forecasting notes from the web site http://www.duke.edu/~rnau/411arim.htm (Duke University, Durham, North Carolina, USA)

SAS JMP Statistics and Graphics Guide: Time Series Analysis (Available online via the SAS JMP Help facility)

Senter, Anne (date?) Time Series Analysis (Available at http://userwww.sfsu.edu/~efc/classes/biol710/timeseries/timeseries1.htm

References

NIST/SEMATECH (2009). *NIST/SEMATECH e-Handbook of Statistical Methods*, http://www.itl.nist.gov/div898/handbook/, Accessed November 8, 2009

Wahlgren, R. V. (2009) *Heating/Cooling Degree Day Forecasts for BC Hydro Sales Regions Using a Probabilistic Model with Climate Inputs.* MS-PowerPoint Presentation. Available at BC Hydro's Load Research Online Library