Probabilistic System Peak Modeling & Hourly Weather Model

Scott Albrechtsen
BC Hydro

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Why Do We Need a Probabilistic Forecast System?

- Impacts of extreme weather haven't been properly quantified (weather risk)
- BCH Load Forecast currently uses a Deterministic System Demand Tool
  - Substation Peaks with *Assumed* Coincidence Figures, & *Assumed* Weather
- Provides no confidence intervals or estimates of variation within forecasts.
- An *Assumed* Monthly Ratio scaling is applied to the System Peak for Monthly System Peaks
  - Again, no allowance for monthly variation between years.

The HELM Model

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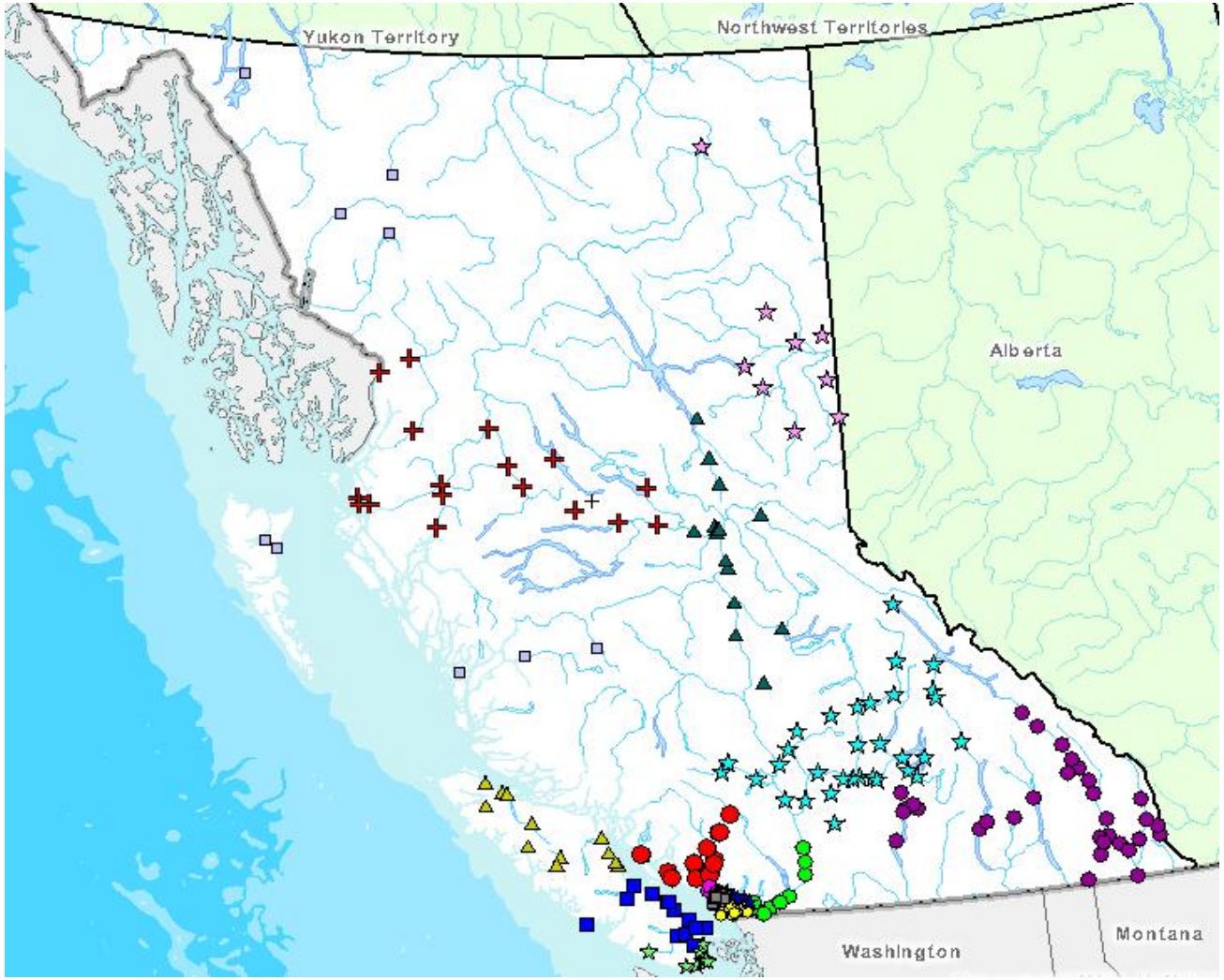
- In 1993, **EPRI** introduced the Hourly Electric Load Model (**HELM**)
- ***Forecasted hourly*** loads at the system, class, or end-use levels for the for short, medium, and long-term forecast horizons.
- Used Load Research ***load profiles*** modeled on any customer domain classifications in order to produce its forecasts.
- Reconcile a set of hourly loads to exogenously specified peaks, troughs, energy levels, or examine energy figures for specified hours.
- ***Weather normalized*** hourly weather, provided **simulations of hourly** transmission and distribution losses and the ability to calibrate outputted load shapes in backcasts against actual historical observations.
- Unfortunately, EPRI ceased to support HELM PC and the work involved in running the PC program.

Forecast Regions

- Dx Subs Map to 16 Forecast Regions within BC
- This is how the load forecast is done based on Dx Planning Sub Peak Figures



Load Research Profiles by “Site Type”

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- There are 67 customer site type domains used to categorize customer types.
- These map to one-to-many to 37 Load Research load profiles for BC
- The Energy figures can be summed by site type by each of the 16 forecast regions
- Energy Forecasts by site type and region as well as contingent weather are used as inputs to the model.

Energy Figures by "Site Type"

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Vancouver/ Burnaby	Fiscal 0506 kWh	Fiscal 0607 kWh	Fiscal 0708 kWh
Agriculture - Com	999,869	944,067	1,038,741
Agriculture – Residential	745,683	779,422	721,868
Chemical - Electro	0	0	0
Chemical - Other	12,978,258	14,396,821	11,747,221
Coal Mining	0	0	3922
Educational Services	30,295,710	30,636,065	30,415,711
Food Retail	184,579,189	187,986,521	183,814,248
Health Services	58,677,449	65,186,358	68,999,797
Hotels	144,883,801	149,243,080	144,632,790
Industrial - Cement Manufacturing	0	0	0
Industrial - Food & Beverages	206,520,220	215,548,152	215,982,378

Energy Figures by "Site Type"

BC hydro

Table 1: Fiscal Year Energy Consumption and Customer Mix:

Vancouver/ Burnaby	Fiscal 0506 kWh	Fiscal 0607 kWh	Fiscal 0708 kWh
Agriculture - Com	999,869	944,067	1,038,741
Agriculture - Res	745,683	779,422	721,868
Chemical - Electro	0	0	0
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Health Services	58,677,449	65,186,358	68,999,797
Hotels	144,883,801	149,243,080	144,632,790
Industrial - Cement Manufacturing	0	0	0
Industrial - Food & Beverages	206,520,220	215,548,152	215,982,378
Industrial - Heavy Manufacturing	62,349,812	67,077,703	61,742,496
Industrial - Light Manufacturing	164,935,691	169,397,082	168,877,250
Industrial - Other	41,489,746	50,250,448	52,927,345
Irrigation	0	0	0
Metal Mining	811,470	658,633	679,335
Municipal Pumping	27,589,067	26,186,832	22,866,736
Non-Buildings	136,592,793	142,224,849	144,446,158
Non-Food Retail	520,053,101	538,588,405	544,798,884
Nursing Home	53,491,259	55,311,763	56,382,246
Offices	1,316,973,471	1,400,144,299	1,439,183,437
Ornamental Street Lighting	5,000,473	4,750,195	5,012,730
Other Commercial	246,721,567	255,032,671	257,048,699
Overhead Street Lighting	0	0	0
Petroleum Refineries	0	0	0
Public Hospital	116,979,268	123,773,371	126,372,639
Public School	56,369,226	58,119,490	57,253,348
Pulp - Kraft	0	0	0
Pulp - Mechanical	0	0	0
Pulp - Paper	0	0	11694
Residential - High-Rise Apt Common (Elec Heat)	176,846,716	178,098,156	177,401,536
Residential - High-Rise Apt Common (Non-Elec Heat)	210,783,583	213,937,376	212,514,511
Residential - Low-Rise Apt Unconnected (Non-Elec Heat)	21,279,156	25,674,883	27,435,983
Residential - Mobile (Elec Heat)	108,007	73,211	52,842
Residential - Mobile (Non-Elec Heat)	4,387,377	4,417,513	4,191,762
Residential - Other (Elec Heat)	996,922	1,147,098	1,841,193
Residential - Other (Non-Elec Heat)	16,987,229	17,669,816	18,907,356
Residential - Row House Unconnected (Elec Heat)	31,022,996	34,318,473	37,563,817
Residential - Row House Unconnected (Non-Elec Heat)	45,749,091	49,209,530	49,027,458
Residential - Row Houses Common (Elec Heat)	10,841,119	10,850,566	10,803,163
Residential - Row Houses Common (Non-Elec Heat)	9,478,657	9,819,019	10,088,177
Residential - Row Houses Units (Elec Heat)	60,302,758	69,577,061	73,076,474
Residential - Row Houses Units (Non-Elec Heat)	34,515,964	40,889,916	42,993,232
Residential - Single/Duplex (Elec Heat)	263,563,637	291,804,449	293,532,254
Residential - Single/Duplex (Non-Elec Heat)	1,104,895,126	1,163,324,361	1,170,701,239
Restaurant	225,601,863	239,525,205	239,471,101
Street Lighting Services	0	0	0
Temp990	21,164,329	28,653,305	41,820,095
Traffic Light	124,527	130,297	130,612
Transportation	185,298,554	193,159,941	197,241,032
Unidentified	284,555,331	1,624,278	1,684,536
University/College	56,922,558	57,817,896	59,000,023
University/College - Tran	0	0	0
Warehouses	106,294,825	114,011,524	121,607,539
Warehouses-Cold	6,729,705	5,696,286	5,976,573
Warehouses-Process	52,572,389	55,293,914	46,209,925
Wood - Lumber	67,307,824	43,532,620	29,678,855
Wood - Other	35,698,087	51,892,197	31,087,468
Wood - Panel	147,298	146,896	152,017

Regional Hourly Load Shapes

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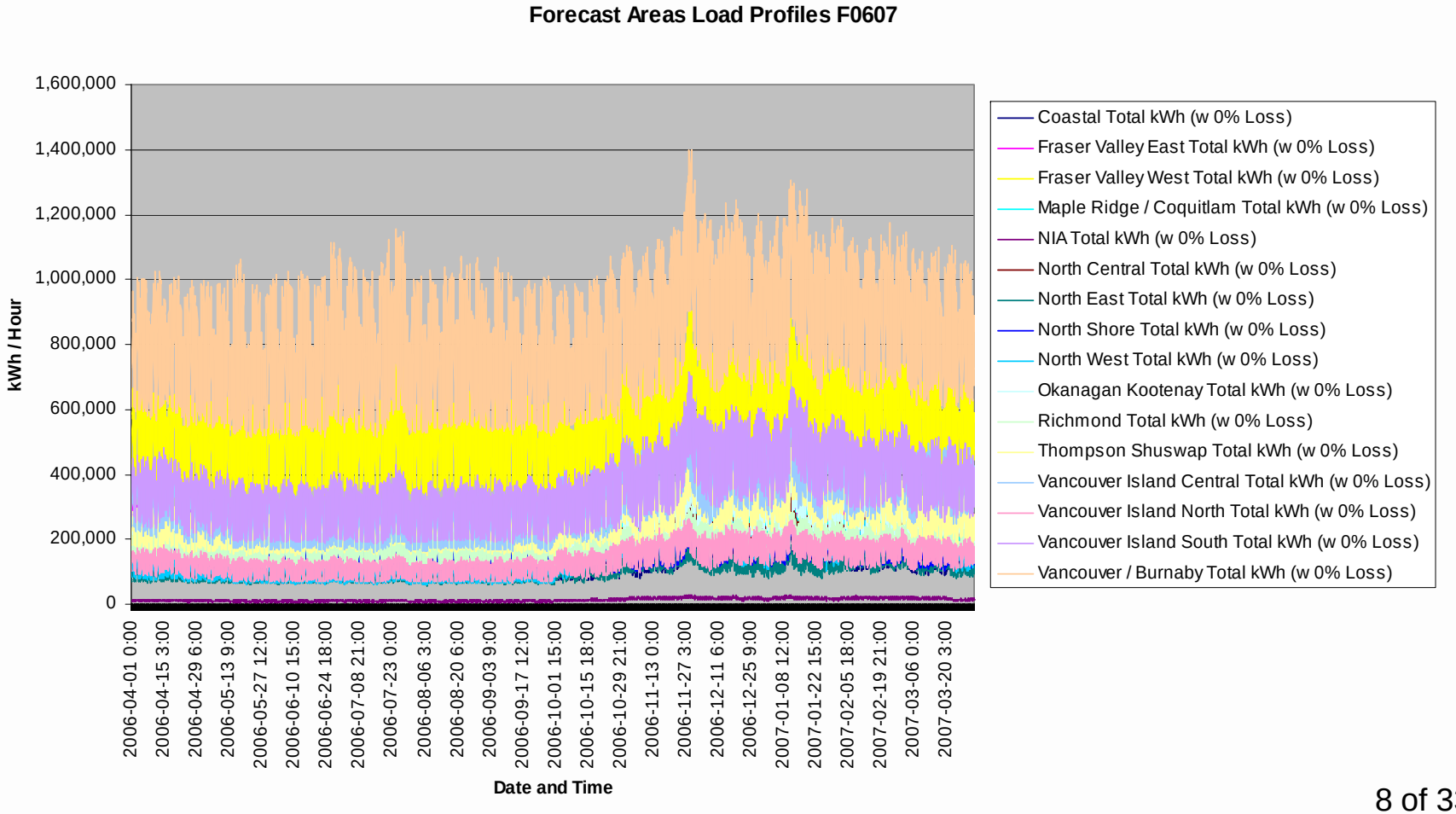
- After the energy figures are applied to the shapes, the aggregate regional hourly shapes are created.
- Can be tested for accuracy with SCADA metering (if available)



Regional Hourly Load Shapes

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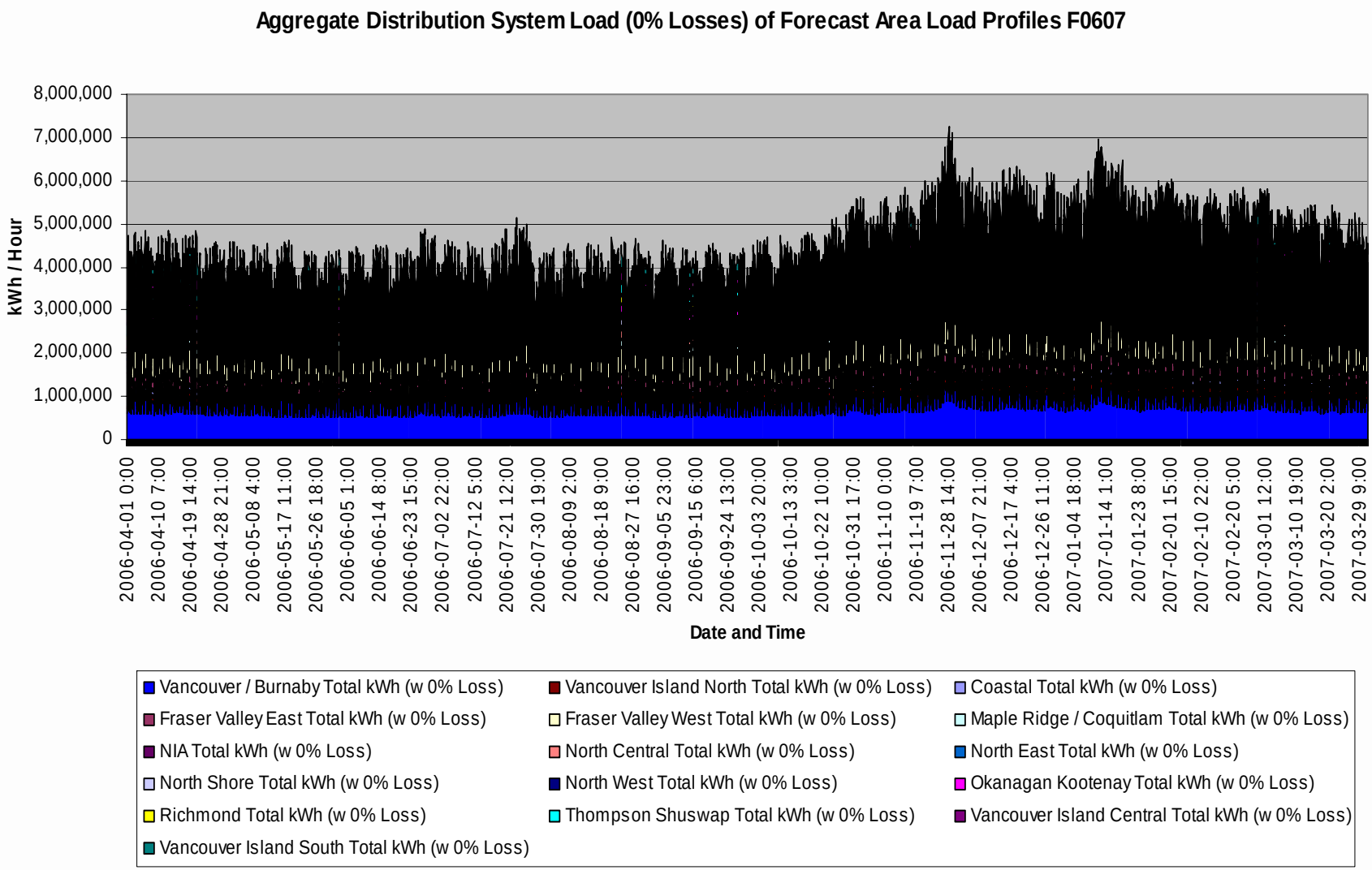

Weather Model: Weather Inputs

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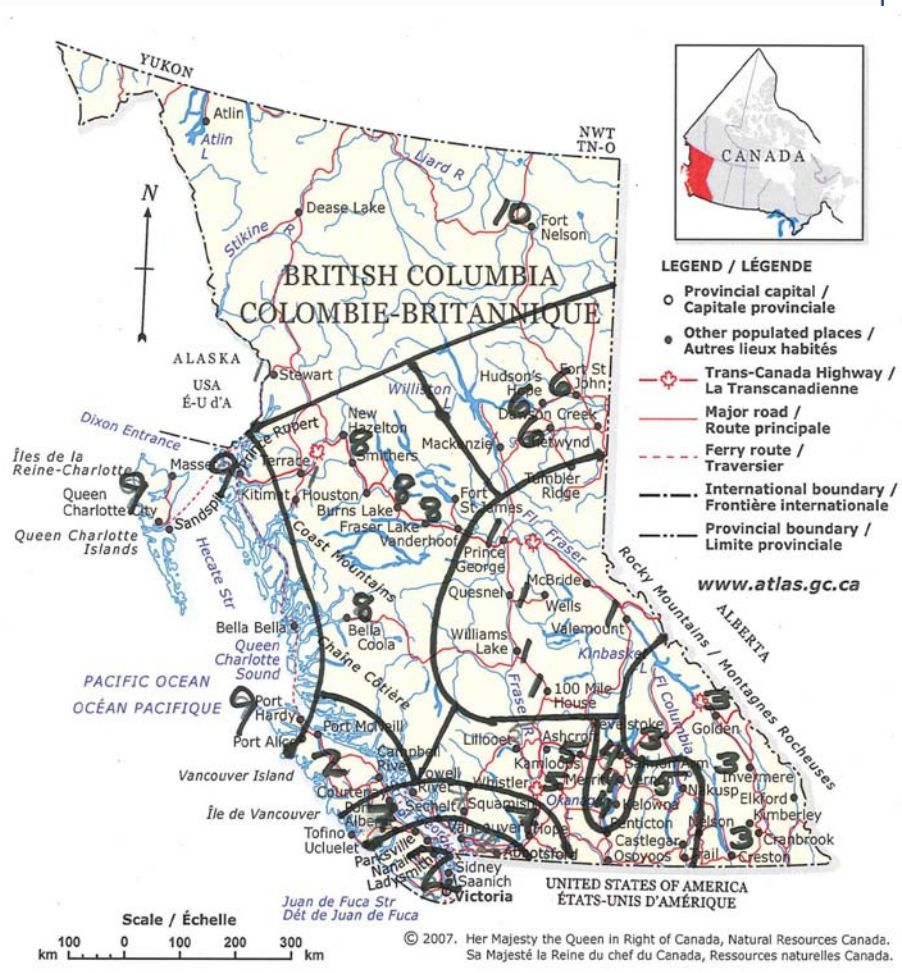
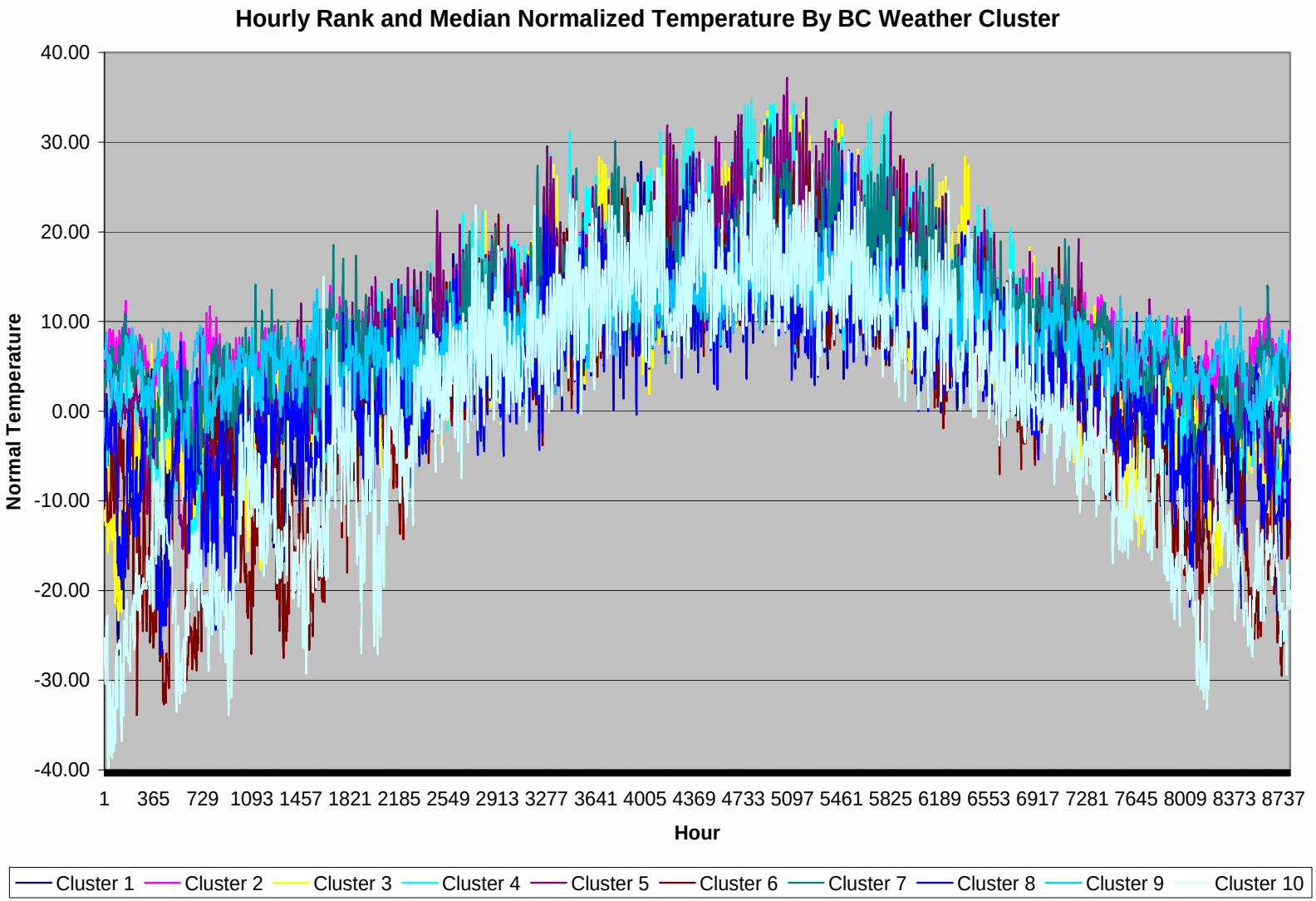
- A temperature clustering routine clustered 50+ weather stations province wide with weather data from 1994-2009.
- The minimization of log pvalue of the Pearson Chi-Sq function of the cluster tree says that 10 unique clusters of weather exist in BC.
- The temperature from the each station is weighted to the cluster by kWh consumption on a city level.
- Each weather cluster is a proxy for weather in different parts of the very large province.



Clustered Weather



Weather Model

BC hydro

- Model the temperature response of the loads as a function of their proxy "actual" temperature

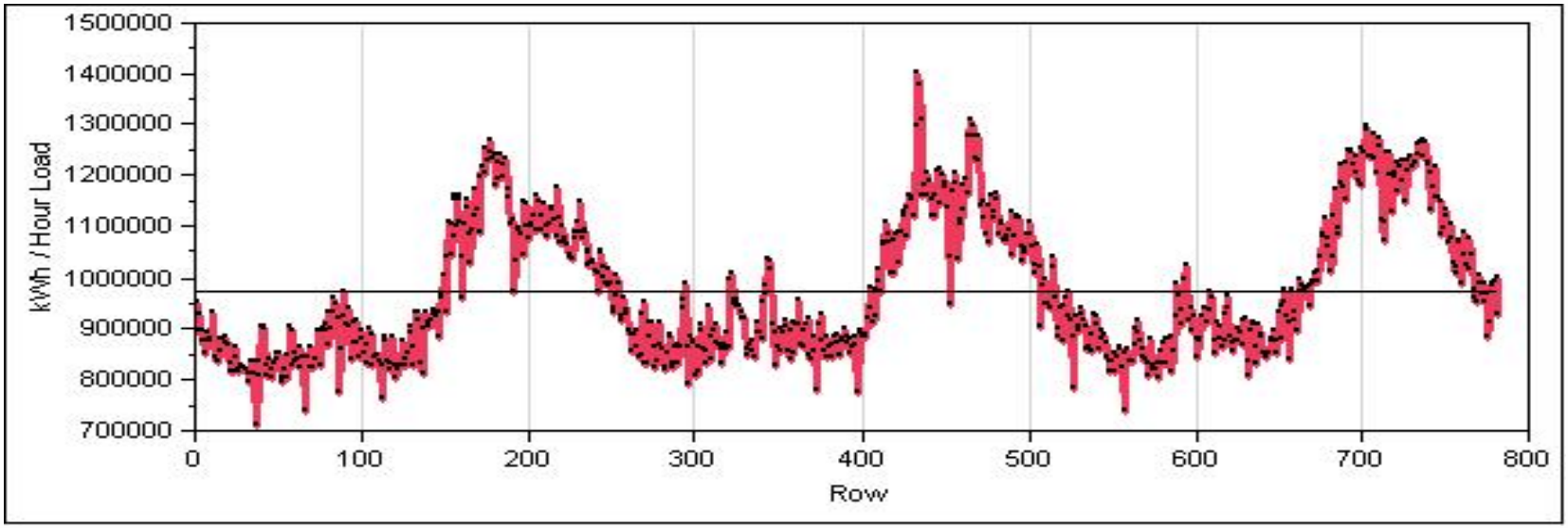
$$\hat{Y}_{iwt} = F\left[\left(\beta_{iw1}Temp_t + \beta_{iw2}Temp_{t-24} + \beta_{iw3}\sum_{t=1}^{24}\frac{Temp_{t,..t-24}}{24} + \beta_{iw4}Temp_t^2\right)\right]$$

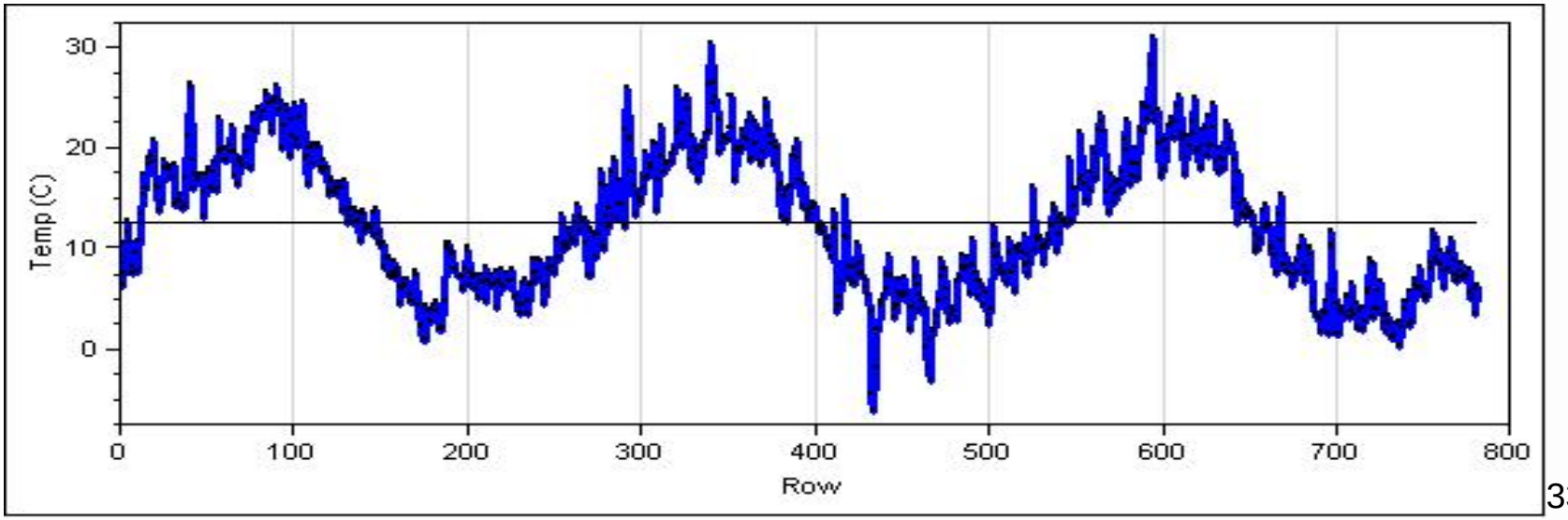
Where *i* is the region, *t* is the specific hour and *w* is a binary indicator for a weekday or weekend.

- 16 Forecast Regions, 24 Hours, 2 Weekdays or Weekends = 768 separate Weather Response Functions

Weather Model Example

Example: Vancouver / Burnaby, Hour=17, Weekdays





Weather Model Example

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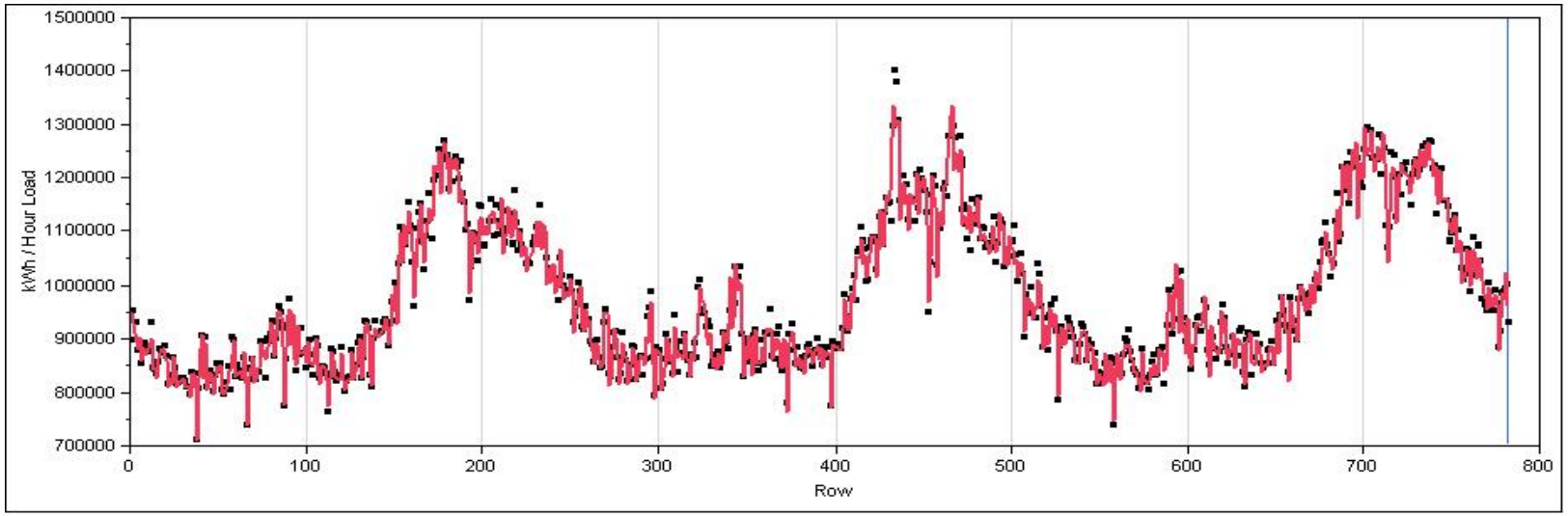
Model Results *Example: Vancouver / Burnaby, Hour=17, Weekdays*



Differing levels of goodness of fit for each separate model (768 models)

Regression Statistic	Mean	StDev	Minimum	Maximum
R Square	.858	0.059	.428	.948
MAPE	4.41%	.933%	2.78%	7.31%
Mean Abs Error (MW)	10.988	8.069	.341	45.110
Coeff of Variation	5.943	1.215	3.68	9.61

Weather Model

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- Model the temperature response then adjust the load based on contingent weather (Φ).
- Here the contingent weather is historical weather from 1995 to 2009 on an annual basis

$$\widetilde{YN}_{iwt} = \hat{Y}_{iwt} + \left[\begin{array}{l} \left(\beta_{iw1} Temp_t + \beta_{iw2} Temp_{t-24} + \beta_{iw3} \sum_{t=1}^{24} \frac{Temp_{t,..t-24}}{24} + \beta_{iw4} Temp_t^2 \right) \\ -\left(\beta_{iw1} \phi_t + \beta_{iw2} \phi_{t-24} + \beta_{iw3} \sum_{t=1}^{24} \frac{\phi_{t,..t-24}}{24} + \beta_{iw4} \phi_t^2 \right) \end{array} \right]$$

Where *i* was the specific shape, *t* is the specific hour and *w* is a binary indicator for a weekday or weekend.

Distribution & Transmission Losses

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- Generation Losses (Distribution & Transmission) losses are assumed constant at 10%.
- This is an assumption: Losses will vary with load, season, temperature, time, imports & exports.
- Better modeling of losses will result in better model of system.
- These estimates are excluding load curtailment information

Backcast Accuracy F0506

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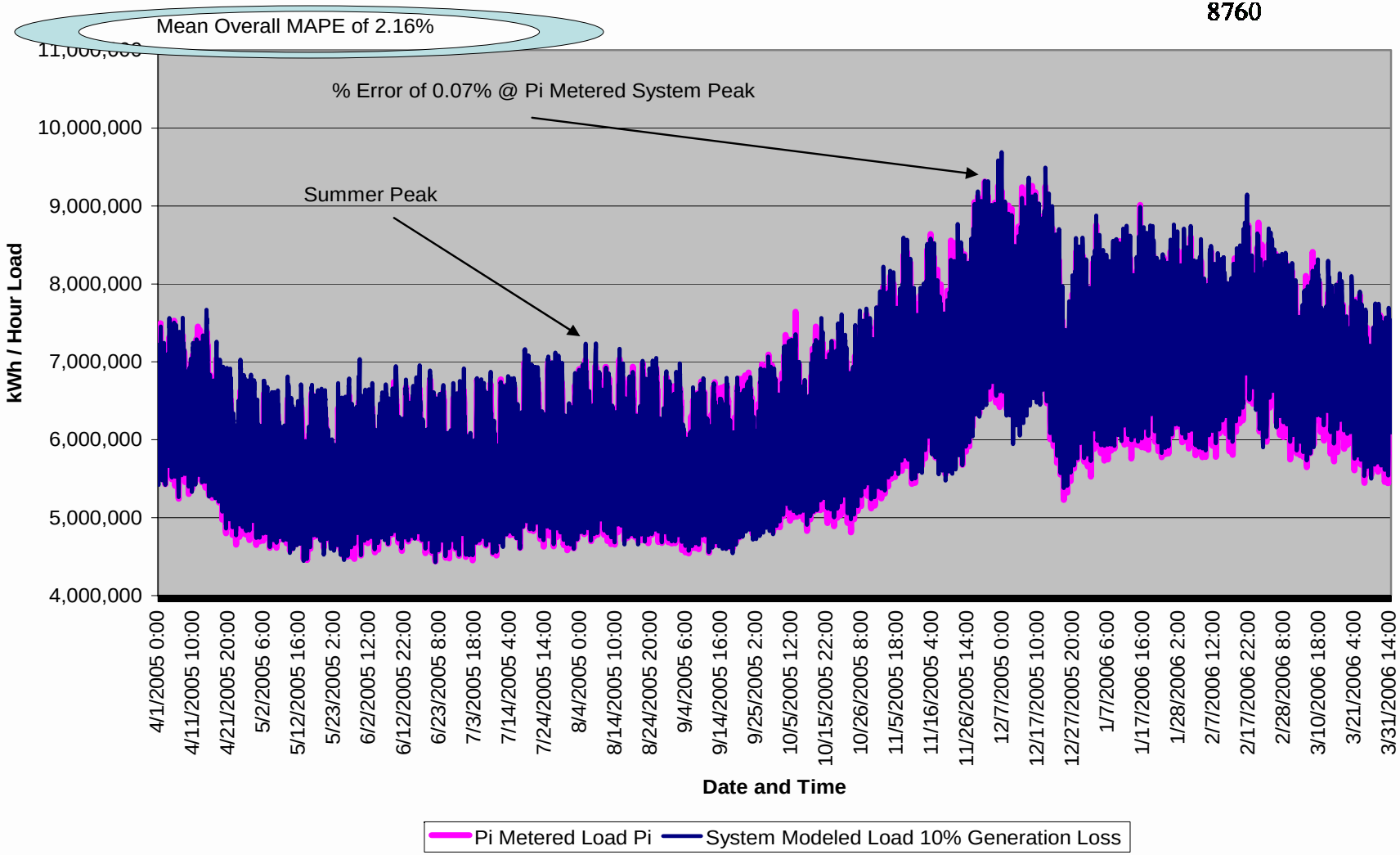
F0506

DLSE Modeled Load F0506 by Region vs. Pi Metered Load

$$MAPE = \frac{\sum \left| \hat{Y} - Y \right|}{8760}$$



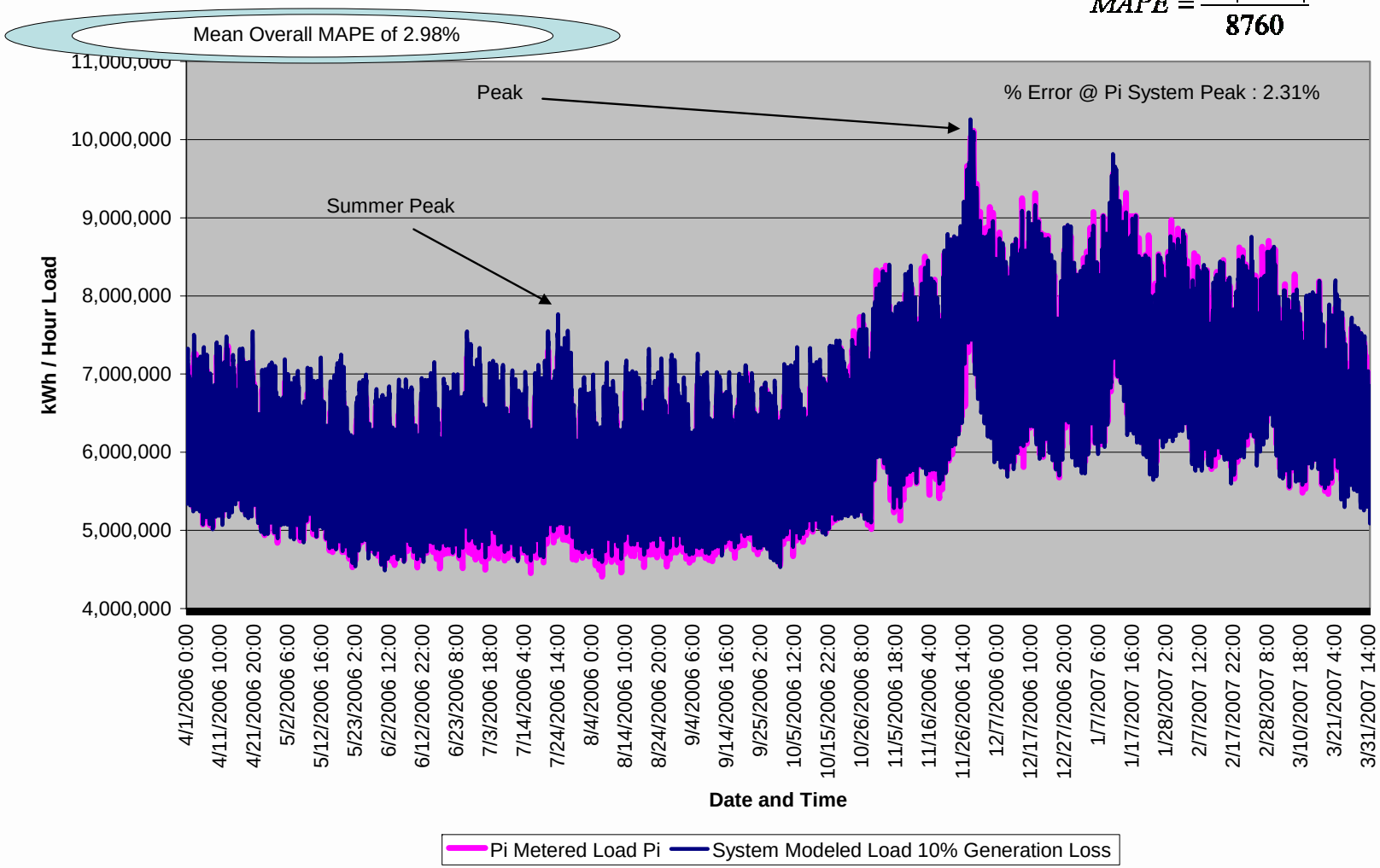
Backcast Accuracy F0607

BC hydro

F0607

DLSE Modeled Load F0607 by Region vs. Pi Metered Load

$$MAPE = \frac{\sum \left| \hat{Y} - Y \right|}{8760}$$



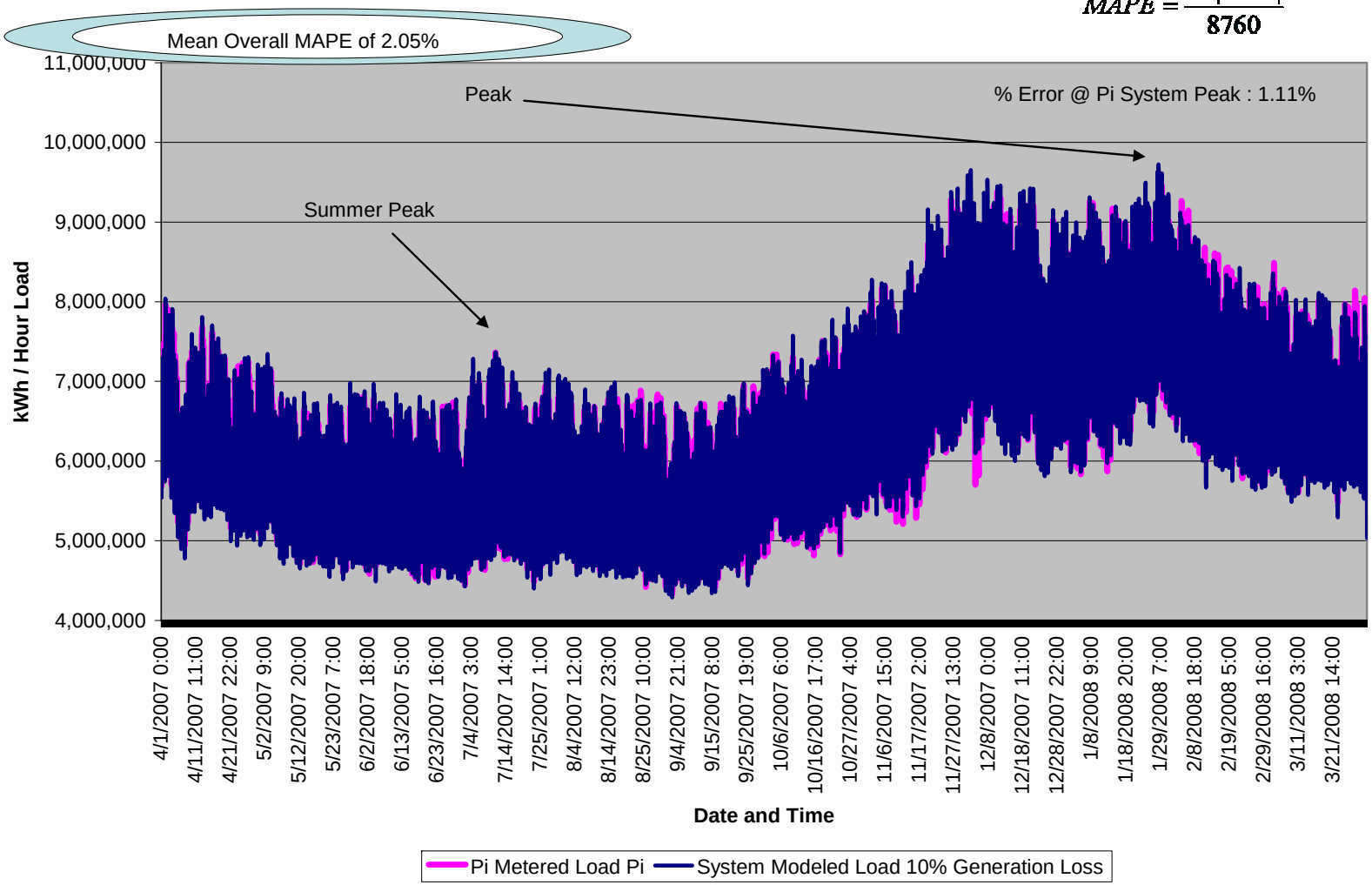
Backcast Accuracy F0708

BC hydro

F0708

DLSE Modeled Load F0708 by Region vs. Pi Metered Load

$$MAPE = \frac{\sum \left| \hat{Y} - Y \right|}{8760}$$



Accuracy of the Method at the Substation or Large Feeder Level

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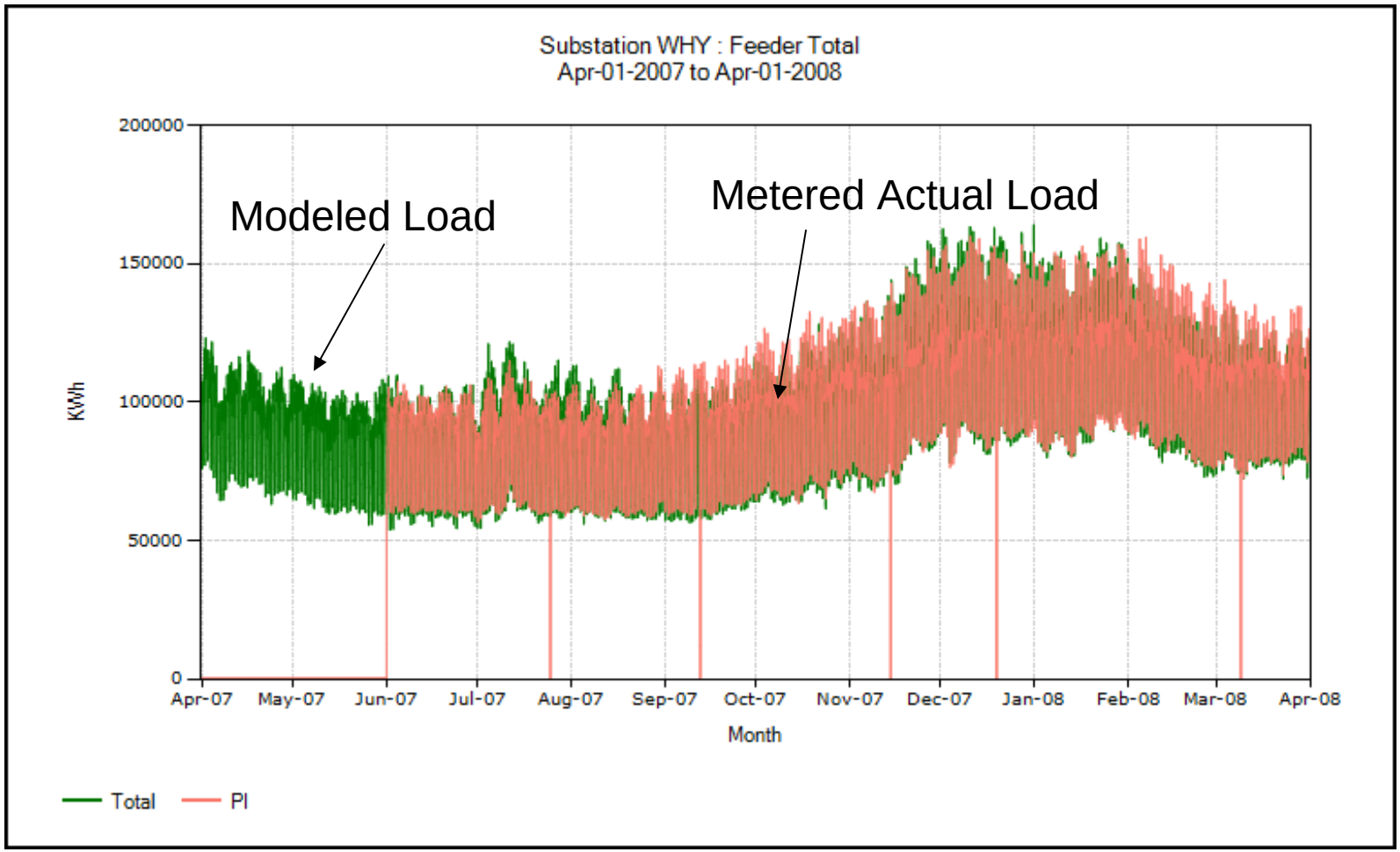
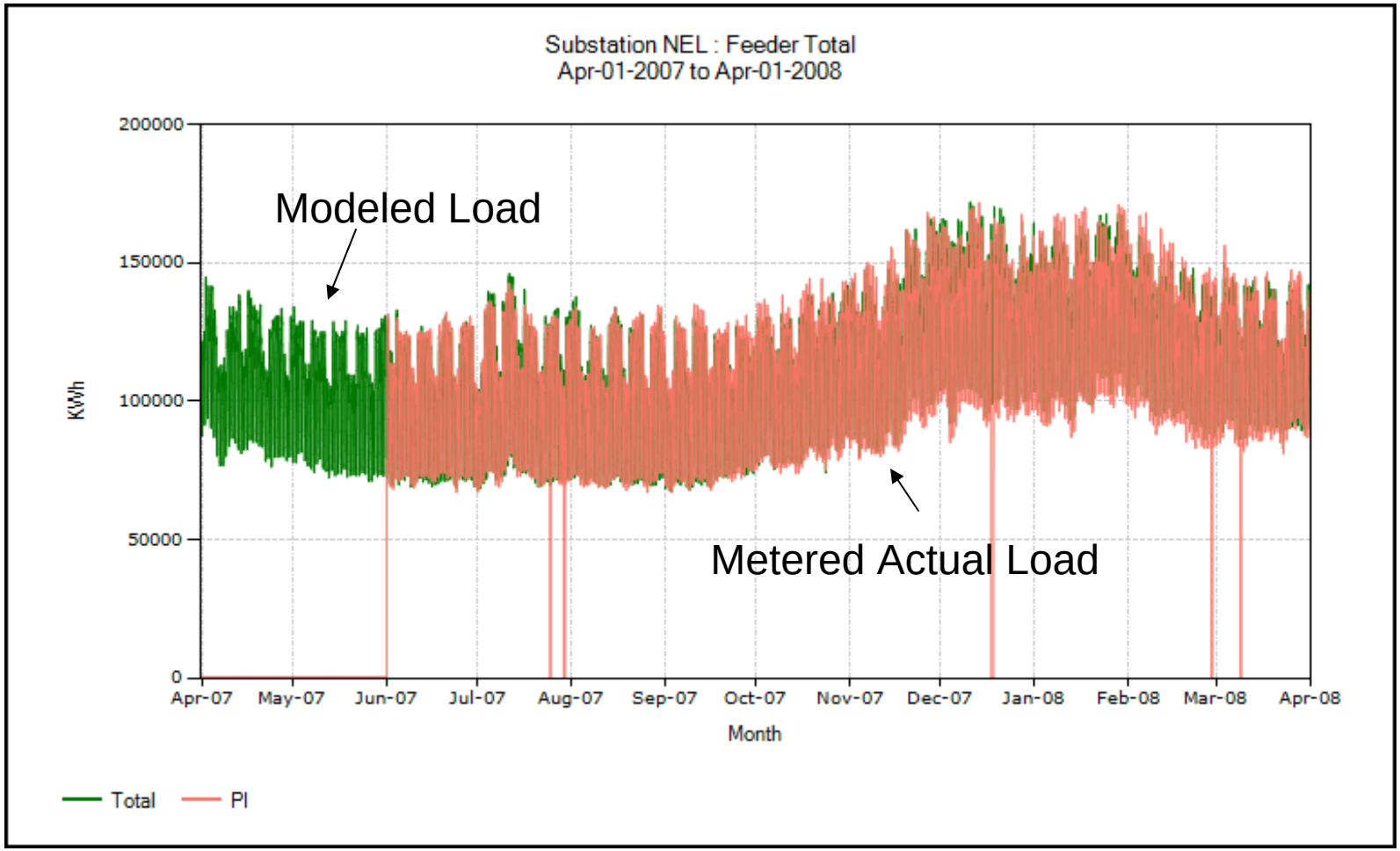
- Used by Distribution Planning as a sub / feeder load modeling tool

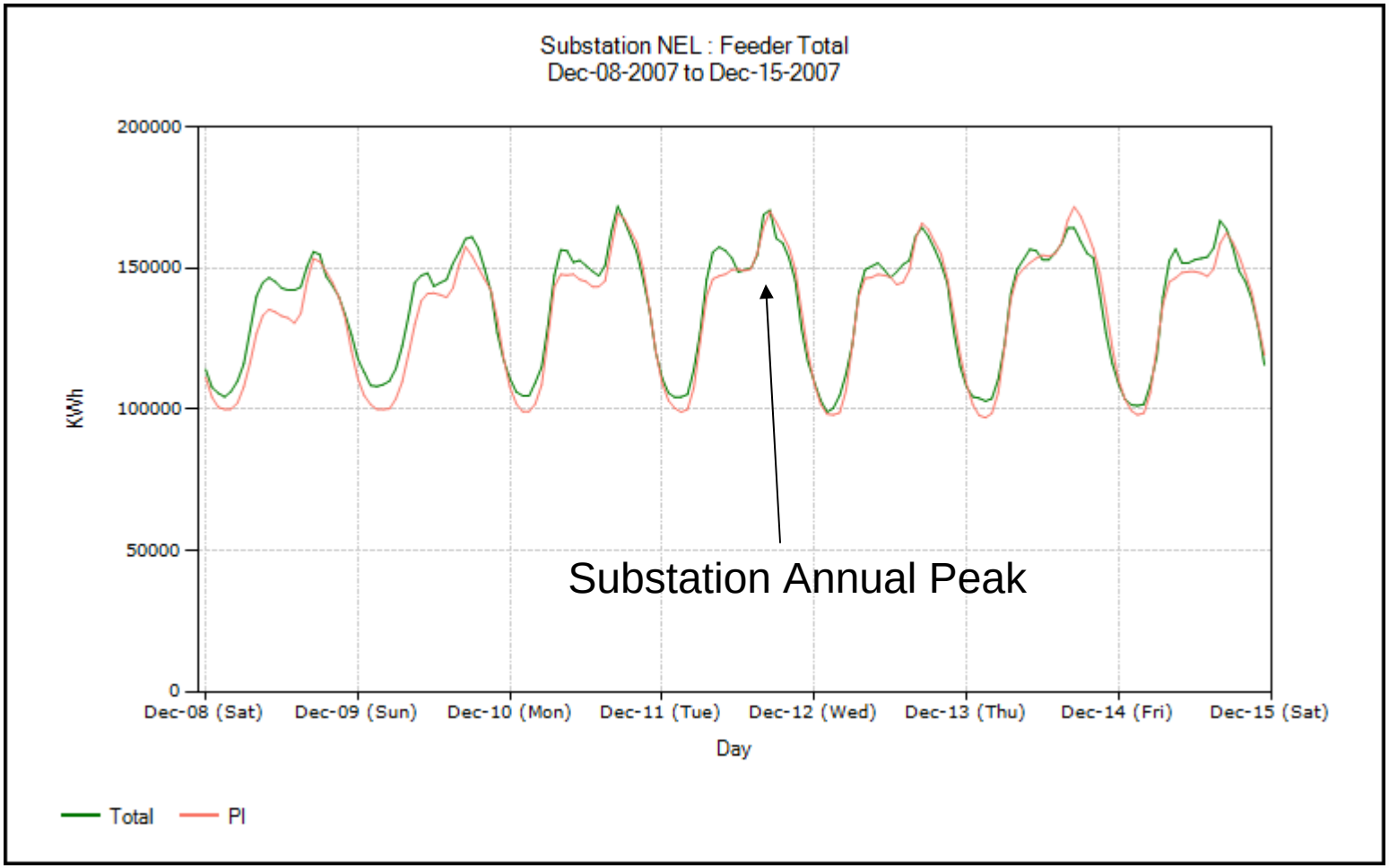


Accuracy of the Method at the Substation or Large Feeder Level

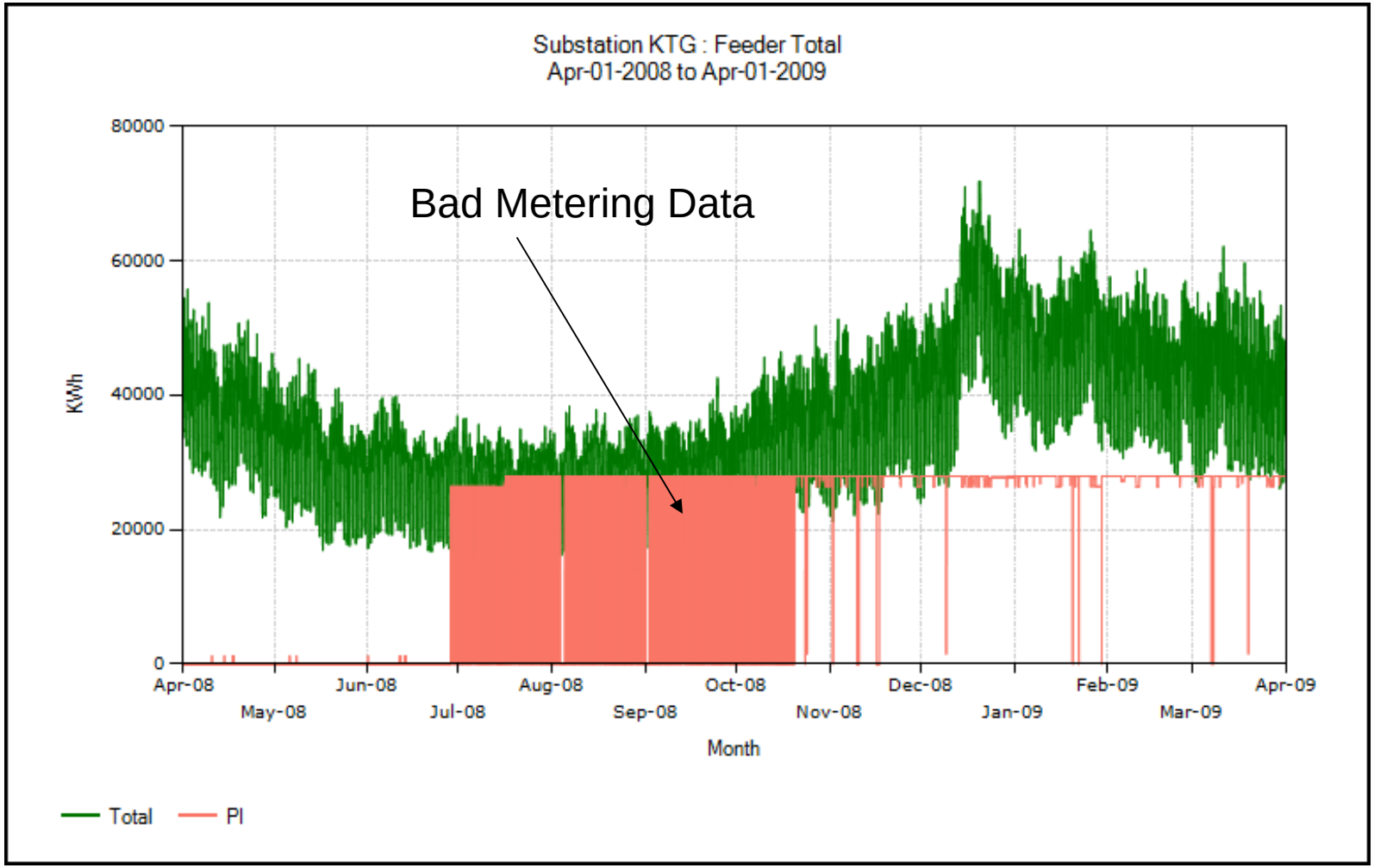


Accuracy of the Method at the Substation or Large Feeder Level (@ Peak)

BC hydro



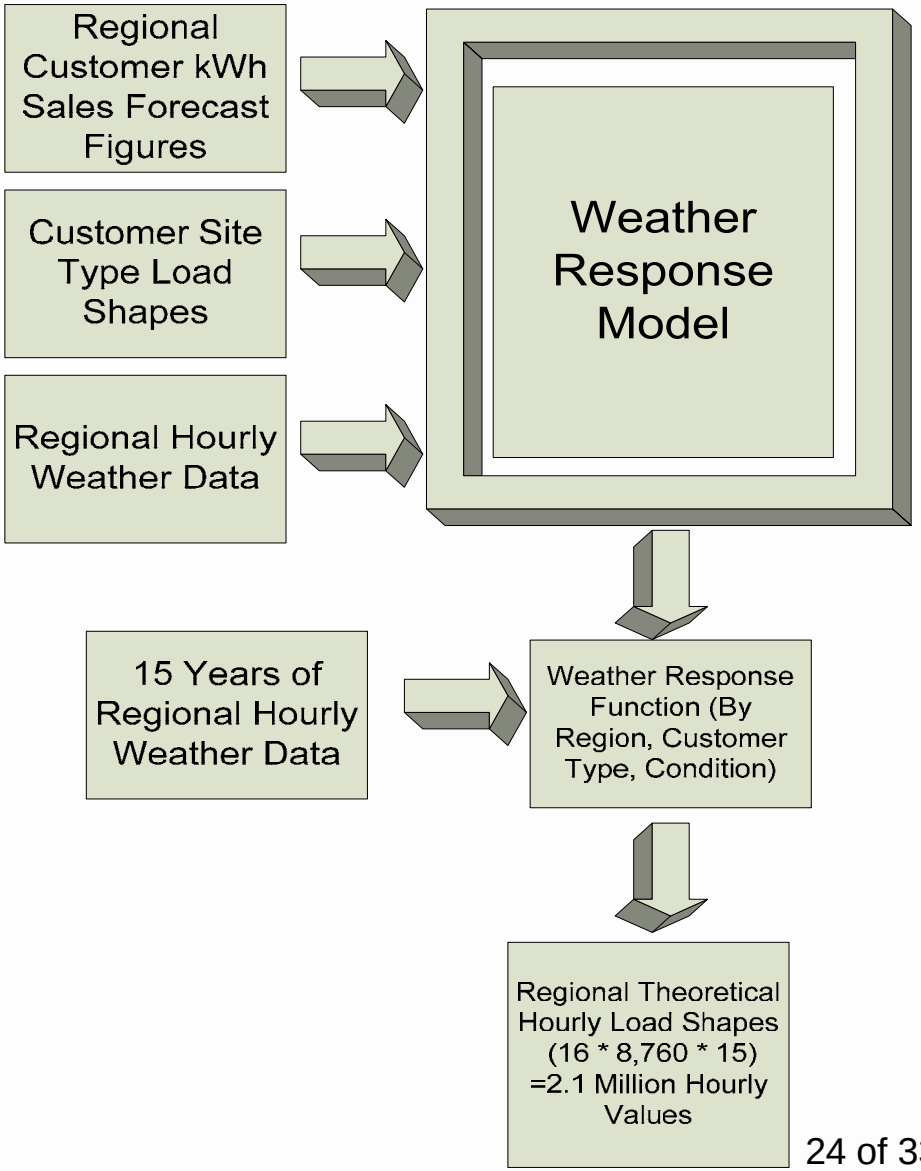
Accuracy of the Method at the Substation or Large Feeder Level



Weather Simulations

- We use Regional kWh Forecasts (From LF)
- Load Research Site type Load Shapes
- Regional Hourly Weather Data
- 15 Years of Regional Hourly Weather

= 2.1 Million Hourly Observations to do modeling



Probabilistic Model: Historical Iterations

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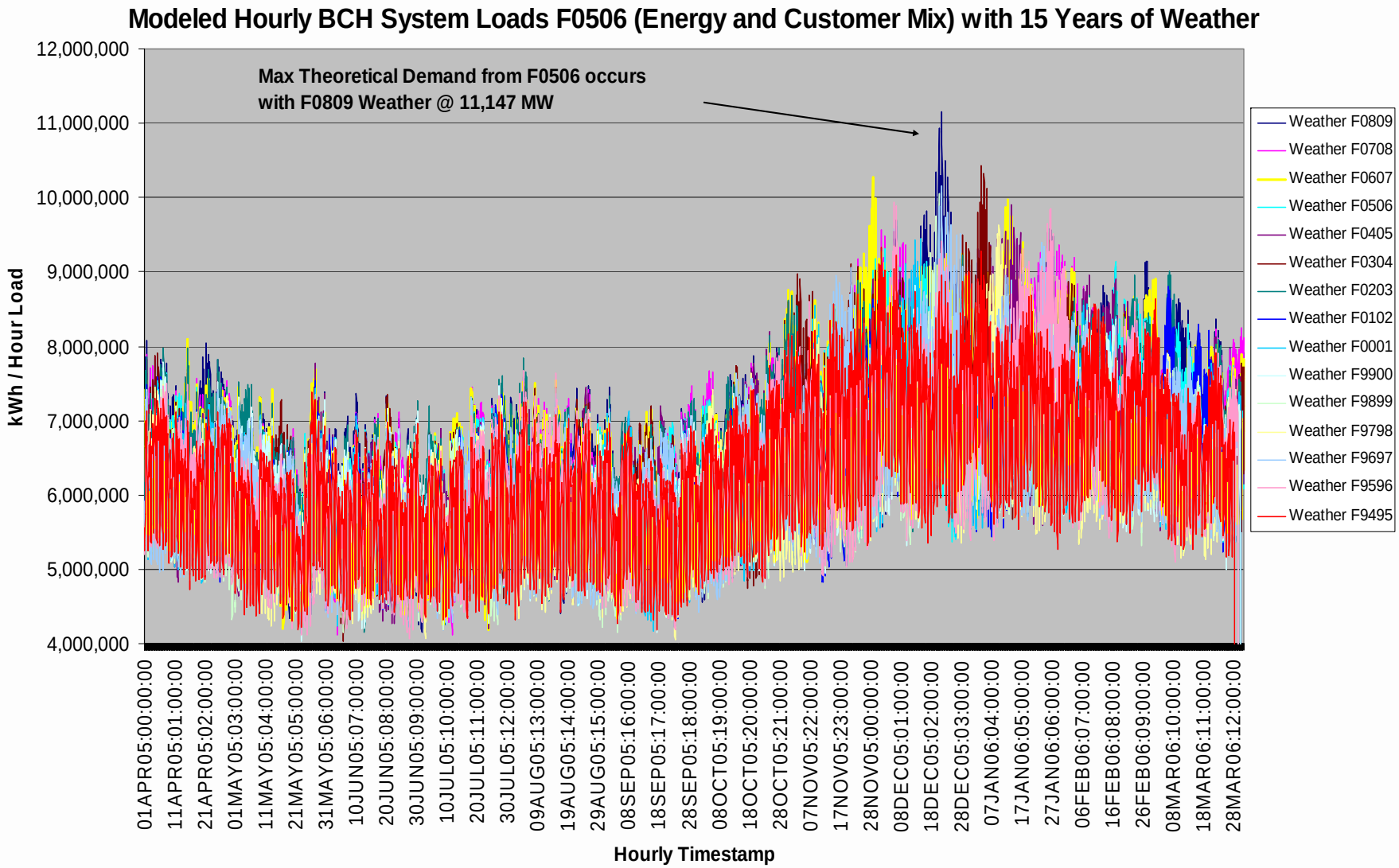
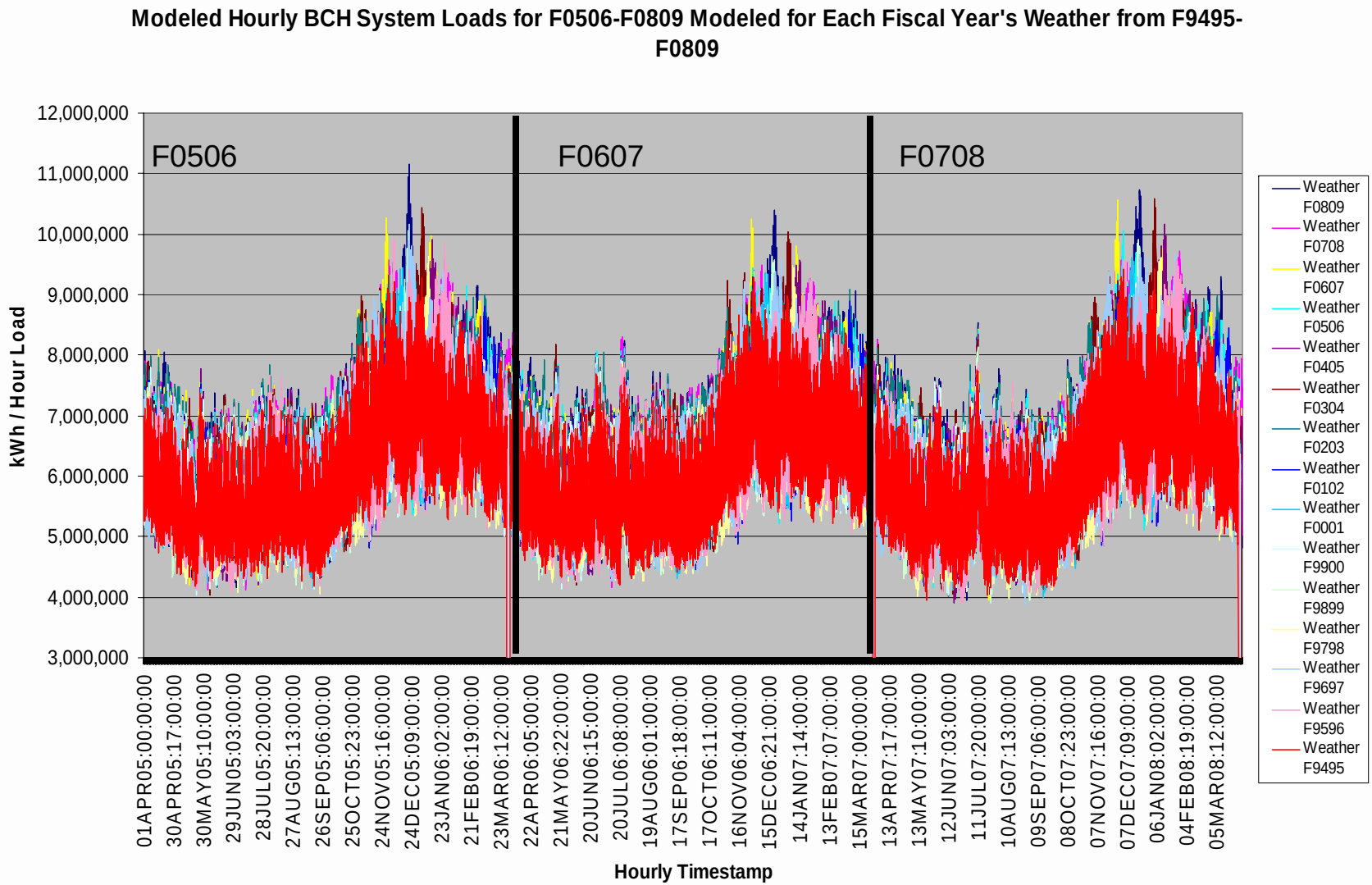
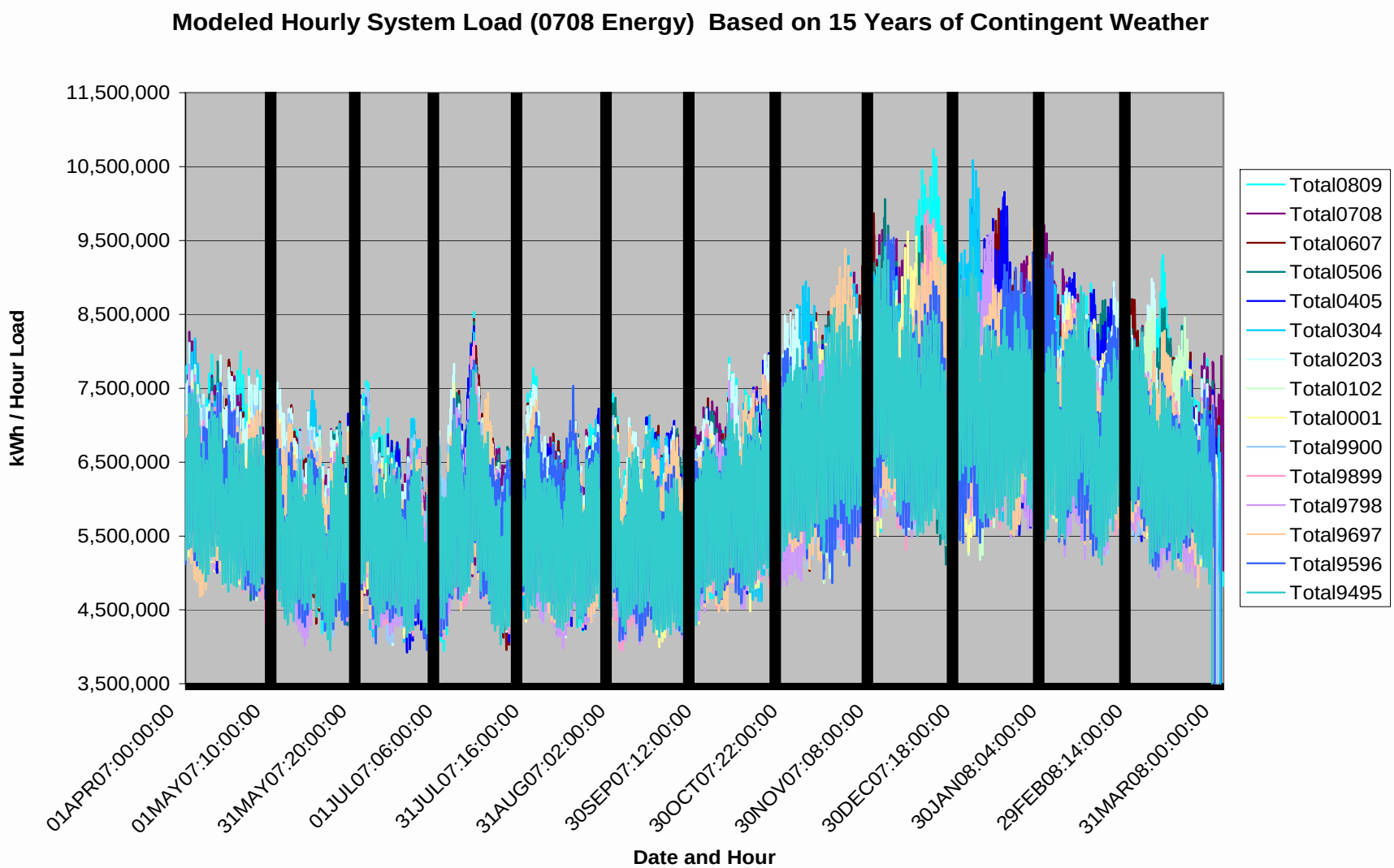


Probabilistic Model: Historical Iterations

BC hydro



Probabilistic Model: Monthly Models



Hourly Analysis: Peaks and Valleys

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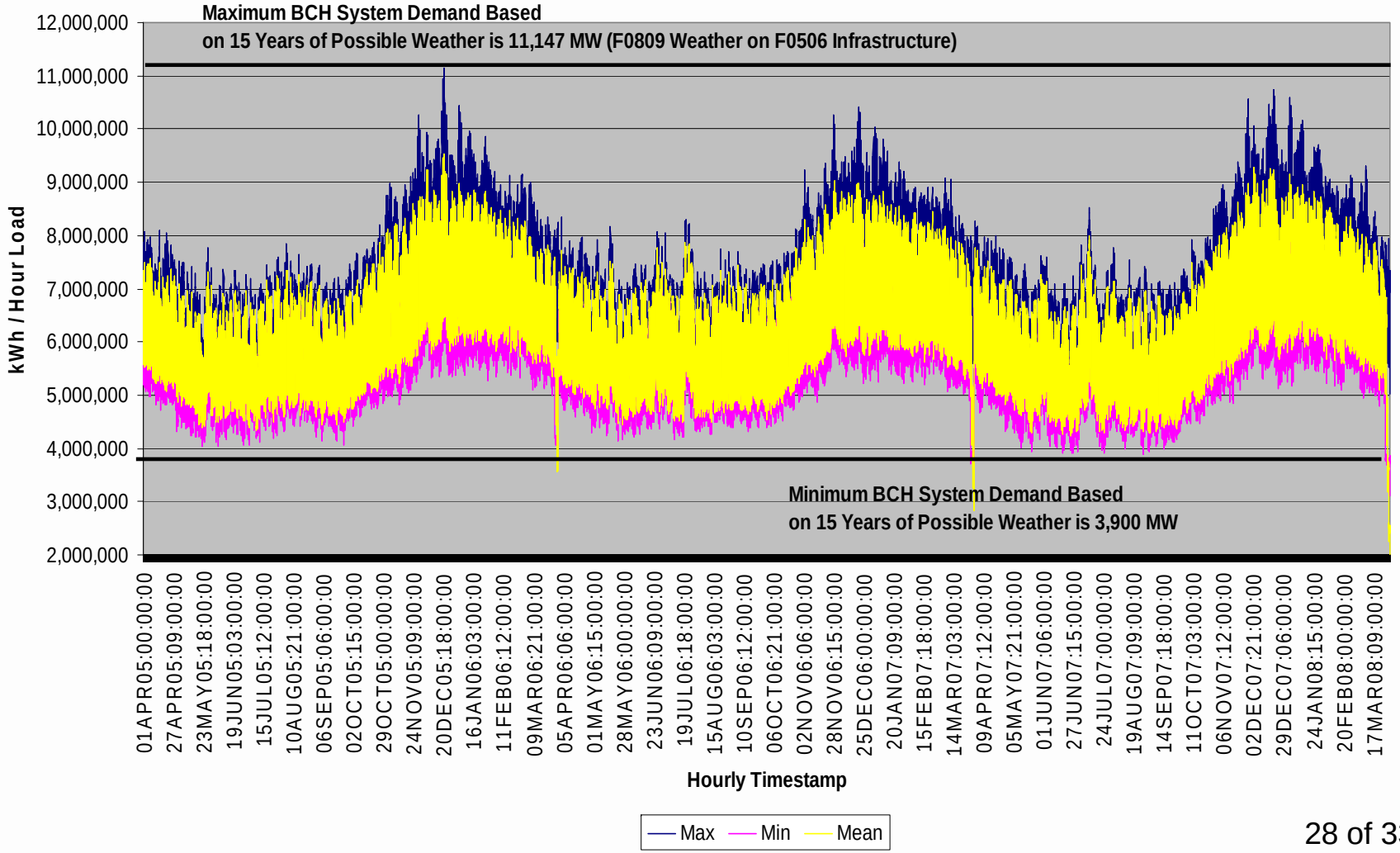
Max, Min, Mean of Modeled Hourly BC Hydro System Loads for F0506-F0809 Based on 15 Years of Historical Weather (Modeled on a Forecast Region Basis)



Distribution of Modeled System Annual Peak Demand

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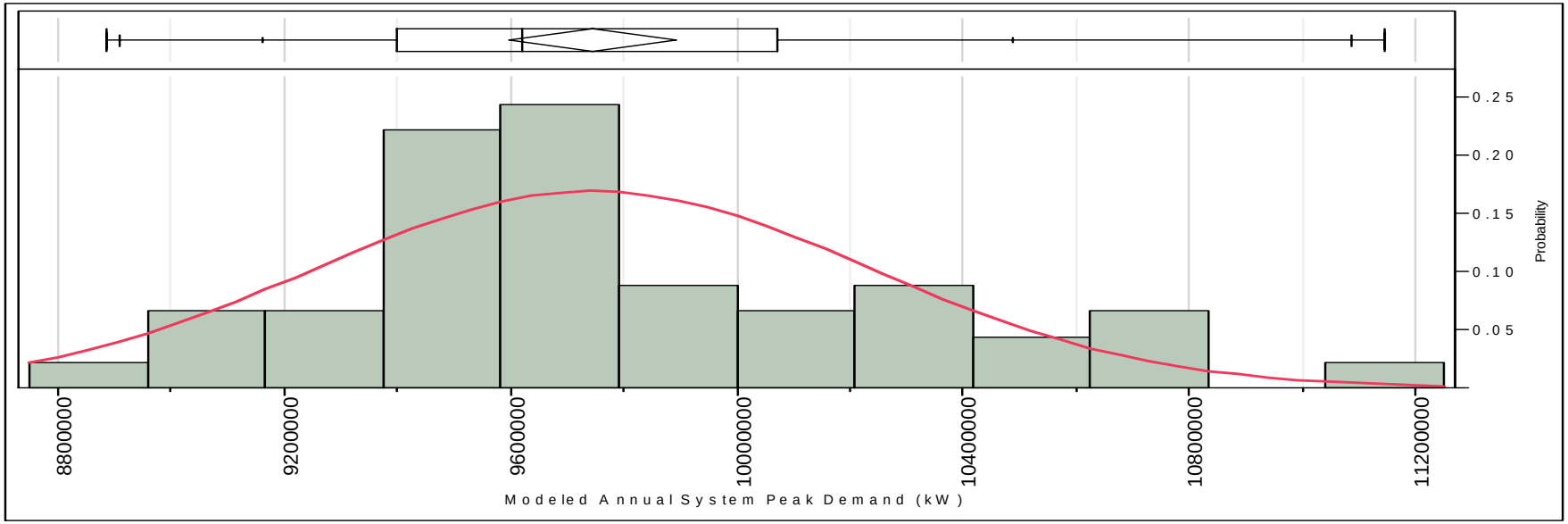

Mean	9,745,965
Std Dev	490,911
Std Err Mean	73,181
U 95% Mean	9,893,451
L 95% Mean	9,598,479
N	45

Maximum	11,146,620
97.5%	11,085,195
90.0%	10,487,789
75.0%	10,070,308
50.0% Median	9,622,671
25.0%	9,399,883
10.0%	9,162,127
2.5%	8,907,882
Minimum	8,886,005

Region to System Coincident Factors

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- Can provide probabilistic estimates of Regional Coincidence Factors for Load Forecast
- These are applied to Regional Forecasts for the Annual System Forecast
- These are very useful to Load Forecast
- 3 Year Infrastructure (F0506-F0708) with 15 Years of simulations each (N=45 Annual CFs)

Forecast Region	Mean CF	Standard Deviation	Min CF	Max CF	N
Coastal	0.98	0.02	0.91	1.00	45
Fraser Valley East	0.97	0.03	0.91	1.00	45
Fraser Valley West	0.98	0.02	0.94	1.00	45
Maple Ridge Coquitlam	0.98	0.02	0.94	1.00	45
Non-Integrated	0.90	0.09	0.66	1.00	45
North Central	0.95	0.04	0.83	1.00	45
North East	0.91	0.08	0.68	1.00	45
North Shore	0.98	0.02	0.94	1.00	45
North West	0.89	0.09	0.65	1.00	45
Okanagan Kootenay	0.96	0.03	0.86	1.00	45
Richmond	0.97	0.03	0.89	1.00	45
Thompson Shuswap	0.96	0.04	0.87	1.00	45
Vancouver Island Central	0.96	0.03	0.88	1.00	45
Vancouver Island North	0.96	0.03	0.88	1.00	45
Vancouver Island South	0.98	0.02	0.91	1.00	45
Vancouver / Burnaby	0.97	0.02	0.91	1.00	45

Substation to Region Coincident Factors

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Sub Code	Forecast Region	Regional Peak Time F0506	Sub Peak Time F0506	Sub load @ Regional Peak F0506 (kW)	Max Sub Load F0506 (kW)	Regional Max Load F0506 (kW)	Sub Coincident Factor F0506
BND	Vancouver / Burnaby	06DEC2005:17:00	06DEC2005:17:00	**116,849**	**116,849**	**1,328,210**	**1.00**
CSN	Vancouver / Burnaby	06DEC2005:17:00	19DEC2005:17:00	**64,967**	**65,433**	**1,328,210**	**0.99**
CSQ	Vancouver / Burnaby	06DEC2005:17:00	28JUL2005:12:00	**109,354**	**129,977**	**1,328,210**	**0.84**
DGR	Vancouver / Burnaby	06DEC2005:17:00	01DEC2005:17:00	**160,610**	**162,968**	**1,328,210**	**0.99**
GDK	Vancouver / Burnaby	06DEC2005:17:00	19DEC2005:17:00	**18,506**	**18,651**	**1,328,210**	**0.99**
HPN	Vancouver / Burnaby	06DEC2005:17:00	06DEC2005:17:00	**127,196**	**127,196**	**1,328,210**	**1.00**
KI1	Vancouver / Burnaby	06DEC2005:17:00	17FEB2006:10:00	**45,595**	**46,291**	**1,328,210**	**0.98**
LOH	Vancouver / Burnaby	06DEC2005:17:00	19DEC2005:17:00	**47,093**	**47,214**	**1,328,210**	**1.00**
MAN	Vancouver / Burnaby	06DEC2005:17:00	19DEC2005:17:00	**169,331**	**171,076**	**1,328,210**	**0.99**
MUR	Vancouver / Burnaby	06DEC2005:17:00	15DEC2005:09:00	**156,733**	**158,402**	**1,328,210**	**0.99**
NEL	Vancouver / Burnaby	06DEC2005:17:00	06DEC2005:17:00	**172,097**	**172,097**	**1,328,210**	**1.00**
SPG	Vancouver / Burnaby	06DEC2005:17:00	06DEC2005:17:00	**139,878**	**139,878**	**1,328,210**	**1.00**

Conclusions

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- The procedure provides a robust data set for detailed analysis and probability analysis
- Minimizes assumptions
- Can attach theoretical levels of statistical confidence around published figures
- Can refute or support past forecast methods

Questions?