Heating/Cooling Degree Day Forecasts for BC Hydro Sales Regions Using a Probabilistic Model with Climate Inputs [Vol. 1, pages 1–84]

Roland V Wahlgren, BSc MA

Load Research Analyst

BC Hydro Customer Information Management—Load Analysis

BC Hydro, Burnaby, British Columbia

January 2010

BC hydro

FOR GENERATIONS

Context and Take-home Message

Audience: Analysts and forecasters responsible for implementing degree-day forecasting improvements

BC Hydro Context

- Degree-day forecasting accuracy could be better
- Degree-day forecasting errors have costs in BC Hydro's business model
- More accurate degree-day forecasting is beneficial for BC Hydro

Take-home (to your office) Message

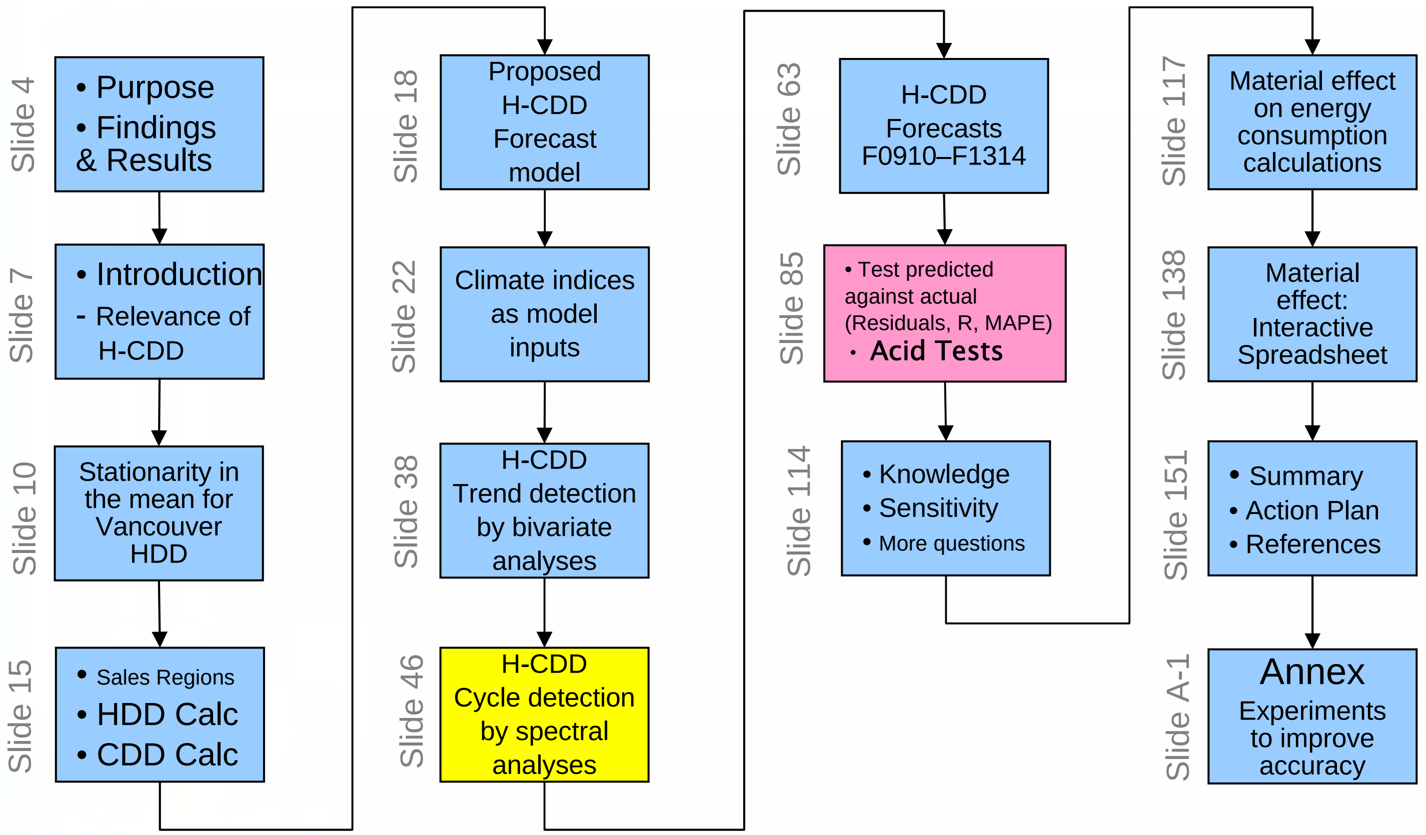
- Forecasting with moving average methods (as done now) gives acceptable accuracy but inherently offers limited scope for improvement
- Forecasting with new probabilistic model with climate signal inputs has potential for significant accuracy gains
  - Needs further research and development before operational use

This presentation has complete details for the scientist, engineer, or technologist

“Often, scientists present so much detailed information that even the most interested listener gets lost in it.”
— Helen Quinn, What is science? (‘Reference frame’ department, *Physics Today*, July 2009)

Helen Quinn is a theoretical particle physicist at SLAC National Accelerator Laboratory with interests in science education and public understanding of science.

Logical flow of this presentation



Purpose of this presentation

- Proposes a new method of forecasting heating and cooling degree days (HDD or CDD, H-CDD, or simply DD) while assessing accuracy of moving average methods of forecasting
  - 5-year (60 unique monthly) forecasts
  - Probabilistic model with climate inputs
    - Incorporated understanding of physical processes of regional climate system
      - Climate indices used as model inputs
    - SAS JMP software
  - Quantitative
    - Range of monthly HDD and CDD values presented to decision-makers
      - Confidence limits at 5% level
  - Tested by backcasts, an “acid test”, and “material effect” test
    - Quantitative evaluation of forecast quality
      - Backcasted HDD and CDD values compared to actual
      - “Acid test” comparison to 10-year moving average methods (static, dynamic) from two historical vantage points, one in a stationary period of global temperature anomalies, the other in a non-stationary period of anomalies
    - Degree Days’ material effect on energy and monetary value forecasts

Top Twenty Essential Findings and Results (1 of 2)

1. Stationarity or non-stationarity in the mean for HDD time series needs recognition when comparing old and new forecast models.
2. Climate indices were found in the literature that function as inputs to a probabilistic model for forecasting HDD
3. Monthly HDDs in all four sales regions showed statistically significant responses to various combinations of climate indices values
4. Decreasing trends in monthly HDD (significant at the 0.05 level) were observed in April, June, July, August, September, January, and March throughout BC—consistent with global warming trend
5. Spectral analysis of monthly HDDs showed matches with cycles observed in climate indices
6. Climate indices can be classified as derived from three levels of climate processes: Primary Global, Secondary Global, and Continental-scale. These processes influence HDDs in BC
7. Vancouver Airport HDDs are a reflection of the Global Mean Monthly Temperature Anomaly trend, especially since mid-1970s
8. HDD time series exhibited stationarity from circa 1953 through 1974 [analysis of variance (ANOVA), 0.05 level]
9. HDD time series had a decreasing trend from 1975 to 1998 (ANOVA 0.2 level, reflected ANOVA significant increasing global temperature trend)
10. HDD time series had stationarity in the mean from 1999 to 2008 (ANOVA test)

Top Twenty Essential Findings and Results (2 of 2)

11. Probabilistic models need a longer time series history than moving average (MA) models for optimum forecasting performance (e.g. 50 years vs. 20 years)
12. Moving average models have acceptable forecasting performance but their performance quality cannot be improved substantially (inherent in their mathematical design)
13. Proposed new model has better forecasting accuracy than moving average techniques if HDD time series has increasing or decreasing trend (developed testing tools for comparisons)
14. Risk of over or under-estimating HDD is inherent with moving average models; HDD trend from 2009 onwards is unknown
15. Only by using proposed new forecasting model is the risk of inappropriate use of MA models eliminated
16. HDD and CDD forecasts can be completely quantified with upper and lower confidence limits
17. HDD predicted values (using moving average and probabilistic methods) for the non-heating season often have uncertainties of same order of magnitude as the value
18. CDD predicted values (using moving average and probabilistic methods) often have uncertainties of same order of magnitude as the value
19. **New probabilistic model with climate inputs has potential for improved accuracy—that will count and make a difference to BC Hydro**— as understanding of climate processes and inputs improves with experience. Model is noticeably sensitive to varying climate inputs This is in contrast to the moving average models which are strictly empirical
20. Errors in HDD forecasts can have a material effect in context of BC Hydro's business model

BC hydro
FOR GENERATIONS

Focus on probabilistic model because it has greatest potential for accurate forecasting during an era experiencing global climate change (from Slide 17)

Introduction

Heating/Cooling Degree Day relevance to BC Hydro

Heating degree days (HDD) are used for calculating heating energy consumption by electric heaters while cooling degree days (CDD) are used for calculating cooling energy consumption by air-conditioning equipment. Increasing accuracy of HDD and CDD forecasts can improve operational efficiency of an energy utility such as BC Hydro.

Previous studies about HDD forecasting for BC Hydro

A report to BC Hydro, titled, *Evaluation of Alternative Projection Methods for Five Year Forecasts of Monthly Heating Degree Days*, was prepared by Mansfield Consulting Inc. in May, 1996. The report stated that HDD predictions, “play a key role in the development of B.C. Hydro’s forecasts of residential electricity consumption.” Mansfield limited their evaluations to five-year-ahead forecasts for the Lower Mainland region. At the time, BC Hydro’s HDD forecasts assumed monthly HDD would remain equal to the 30-year average of monthly HDD. Stationarity of the data was assumed.

Heating/Cooling Degree Day relevance to BC Hydro (continued)

The Mansfield report, based on data from 1937–1995,` observed Vancouver HDD data had not exhibited stationarity since about 1975, showing instead a yearly decrease. Forecasts of HDD and residential electricity consumption where therefore routinely higher than actual values.

Mansfield evaluated the following nine forecasting methods: 30-year averages updated every 10 years, 30-year averages updated annually, 15-year averages updated annually, 10-year averages updated annually, 5-year averages updated annually, 30-year medians updated annually, 15-year medians updated annually, 10-year medians updated annually, and 5-year medians updated annually. For BC Hydro to use a single method, Mansfield recommended the 10-year or 5-year median methods which would react relatively quickly to HDD trends.

For load forecasting, BC Hydro is using now 10-year moving averages of monthly HDD updated annually. This is a static moving average calculation whereby the first 10-year moving average forecast monthly HDD value is used as the forecast value for, say, five years worth of forecasts.

Heating/Cooling Degree Day relevance to BC Hydro (continued)

Proposed new method for BC Hydro HDD and CDD forecasting

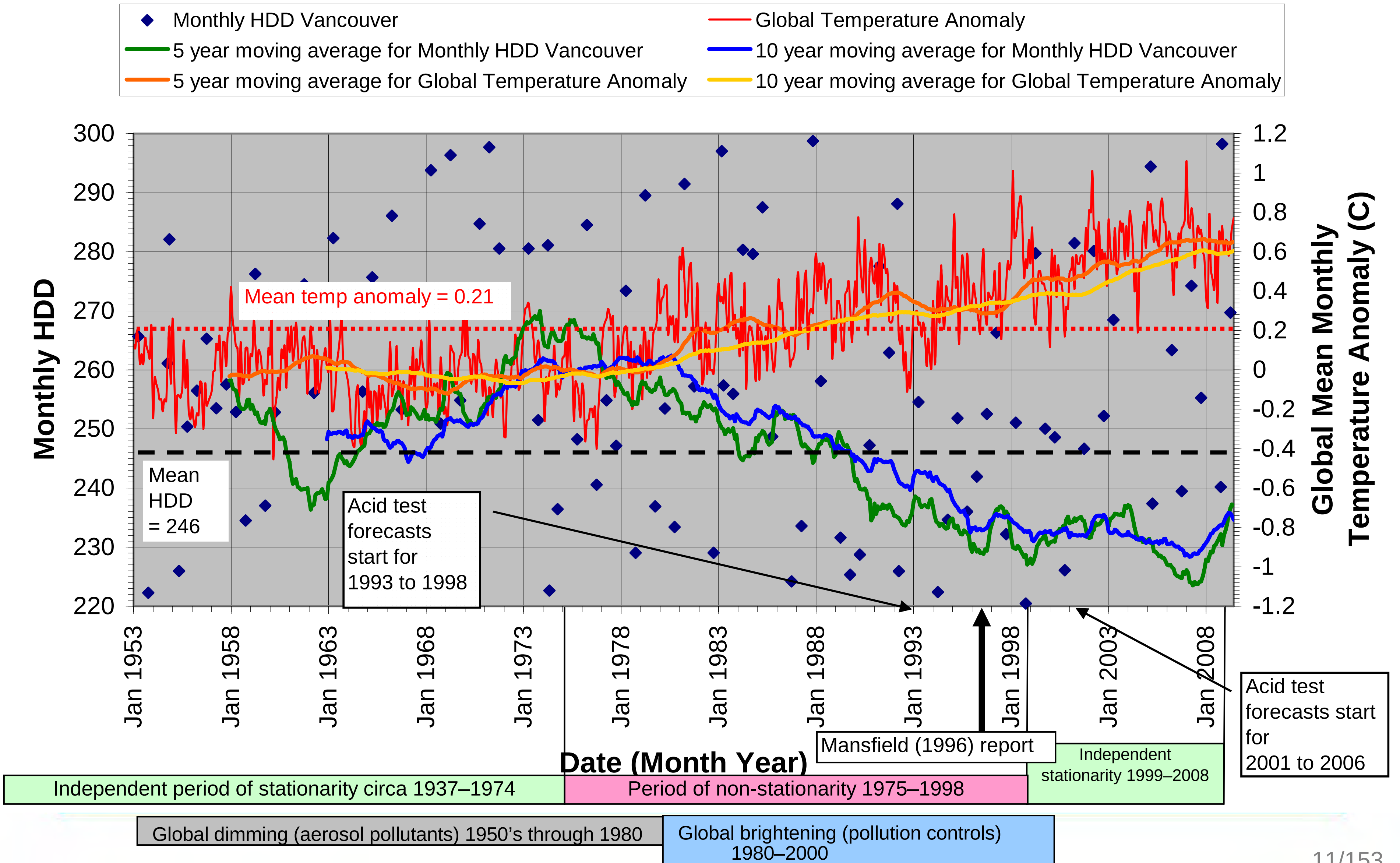
The work detailed in this presentation used advancements, in both statistical software and understanding of regional climate influences relevant to BC, made during the thirteen years following the Mansfield report.

The proposed new method for forecasting HDD and CDD is a simple climate model. It uses frequency domain analyses, an integrated autoregressive-moving average (ARIMA) probabilistic model, and climate indices data as inputs to the model with the intent to make forecasts more accurately than BC Hydro's existing 10-year moving average model. The SAS JMP ARIMA model handles data that is not stationary (i.e., trends of decreasing HDDs and increasing CDDs). The next section summarizes stationarity information for Vancouver.

All four BC Hydro sales regions were evaluated. **Sensitivity analyses proved that research effort will count for the company.** CDD forecasts were developed because increasing numbers of BC Hydro residential customers are now using air-conditioning equipment during the summer months.

Stationarity in the mean for Vancouver HDD

Stationarity in the Mean for Monthly HDD at Vancouver Airport Jan 1953 to Jun 2009



Stationarity chart notes (1 of 2)

- Reference for the period of stationarity from 1937 through 1974 and non-stationarity commencing 1975 was Mansfield (1996) in a report prepared for BC Hydro. Mansfield identified these periods using a graphical smoothing technique (locally weighted scatterplot smoothing or locally weighted polynomial regression “Lowess” or “LOESS” smoothing)
- Mansfield report was written from perspective of being in a period of non-stationarity
- Reference for the period of stationarity from 1999 through 2008 was Kerr (2009)
- Global dimming from aerosol pollutants countered global warming trends during the 1950’s until the 1980’s; Environmental regulations caused decreased in aerosol concentrations during the period 1980 to 2000, leading to global brightening, revealing the global warming trend (AGU, 2009)
- The two periods of stationarity were independent events

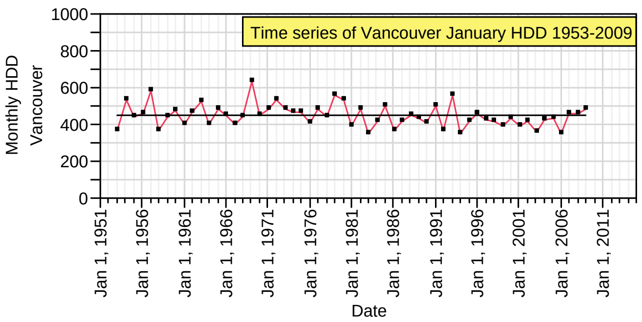
Stationarity chart notes (2 of 2)

- Trend statistics for 1953 through 1974 (Independent period of **stationarity**):
  - Global temperature; n = 264; F-statistic (0.240) < Fcritical (3.03); Trend not significant (0.05 level)
  - Global temperature; n = 264; F-statistic (0.240) < Fcritical (1.62); Trend not significant (0.2 level)
  - Monthly HDD; n = 264; F-statistic (0.084) < Fcritical (3.03); Trend not significant (0.05 level)
  - Monthly HDD; n = 264; F-statistic (0.084) < Fcritical (1.62); **Trend not significant** (0.2 level)
  - Even with the relaxed significance level, this period exhibited stationarity in HDD
- Trend statistics for 1975 through 1998 (Period of **non-stationarity**):
  - Global temperature; n = 288; F-statistic (137.227) > Fcritical (3.03); Increasing trend significant (0.05 level)
  - Global temperature; n = 288; F-statistic (137.227) > Fcritical (1.62); Increasing trend significant (0.2 level)
  - Monthly HDD; n = 288; F-statistic (1.799) < Fcritical (3.03); Decreasing trend not significant (0.05 level)
  - Monthly HDD; n = 288; F-statistic (1.799) > Fcritical (1.62); Decreasing **trend significant** (0.2 level)
  - Finding that the monthly HDD trend was significant at a relaxed level of 0.2 agreed with the qualitative visual impression of a downward trend in HDD during this period
- Trend statistics for 1999 through 2008 (Independent period of **stationarity**):
  - Global temperature; n = 120; F-statistic (21.536) > Fcritical (3.07); Trend significant (0.05 level)
  - Global temperature; n = 120; F-statistic (21.536) > Fcritical (1.63); Trend significant (0.2 level)
  - Global temperature trend being significant contradicts Kerr (2009) whose article was based on the HadCRUT3 temperature record corrected for ENSO events; Even so, Kerr's article alerted me to the possibility that the advantage of the probabilistic model (compared to moving average models) may be enhanced or diminished depending on whether it is forecasting in a period of stationarity or non-stationarity; While the contradiction was interesting to note, it was of no consequence in these analyses which focused on Degree Days
  - Monthly HDD; n = 120; F-statistic (0.035) < Fcritical (3.07); Trend not significant (0.05 level)
  - Monthly HDD; n = 120; F-statistic (0.035) < Fcritical (1.63); **Trend not significant** (0.2 level)
  - Even with the relaxed significance level, this period exhibited stationarity in HDD

Practical definition of “stationary time series”

A time series is stationary or exhibits stationarity in the mean if, “the mean, variance, and autocorrelations in the series are constant with time.” (Manly, 2001, page 212)

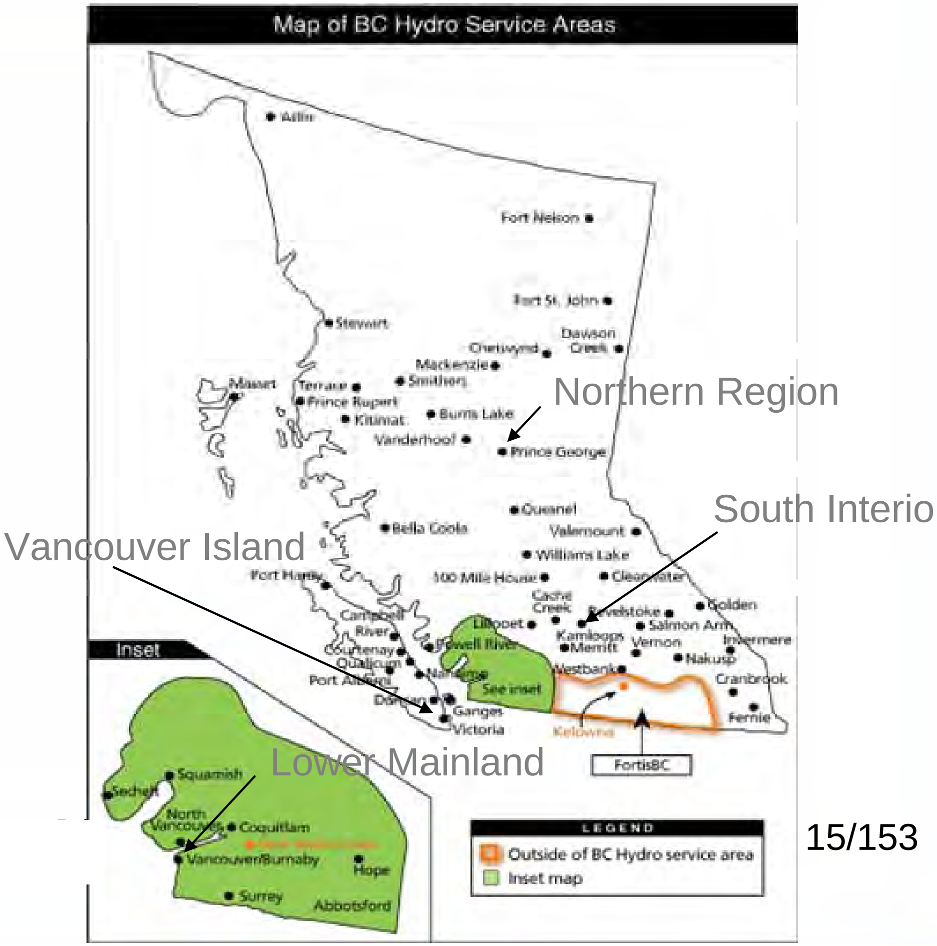
Autocorrelation refers to the phenomenon of a later time series value, separated by a time lag of defined period from an earlier value, being dependent on the earlier value.



Four BCH Sales Regions

The climate of each region is represented by an Environment Canada weather/climate station. Heating and cooling degree days were calculated from hourly air temperature (dry bulb) data

Region	Airport Station	Hourly Air Temperature Data Period
Lower Mainland	Vancouver	1953–2009
Vancouver Island	Victoria	1953–2009
Northern Region	Prince George	1953–2009
South Interior	Kamloops	1994–2009



BChydro
FOR GENERATIONS

Heating Degree Day Calculations

Step 1: Calculate daily mean air temperature (dry bulb, ℃)

$$\bar{t}_{db} = \frac{\sum_{i=1}^{24} t_{db_i}}{24}$$

Step 2: Calculate daily heating degree days (kelvin·days) with respect to an 18℃ balance temperature. This temperature, "…represents average conditions in typical buildings in the past" (ASHRAE, 2005, p. 32.18).

$$Daily\_HDD = \sum_{j=1}^{24} \left(18 - \bar{t}_{db}\right)_j$$

Step 3: Calculate monthly heating degree days (kelvin·days)

$$Monthly\_HDD = \sum_{k=1}^{N} Daily\_HDD_k$$

where N = number of days in month

Step 4: Normalize HDD value for a 30.5 day month

Normalized HDD = (Monthly_HDD / N) × 30.5

Normalization for days in month is not done currently by BCH Load Forecast group

BC hydro FOR GENERATIONS

Cooling Degree Day Calculations

Step 1: Calculate daily mean air temperature (dry bulb, ℃)

$$\bar{t}_{db} = \frac{\sum_{i=1}^{24} t_{db_i}}{24}$$

Step 2: Calculate daily cooling degree days (kelvin·days) with respect to a 20℃ balance temperature. CDD uses a higher balance temperature than HDD to model the process of ventilating buildings to avoid mechanical cooling until a maximum outdoor temperature is sensed by the air-conditioning system (ASHRAE, 2005, p. 32.19).

$$Daily\_CDD = \sum_{j=1}^{24} \left(\bar{t}_{db} - 20\right)_j$$

Step 3: Calculate monthly cooling degree days (kelvin·days)

$$Monthly\_CDD = \sum_{k=1}^{N} Daily\_CDD_k$$

Step 4: Normalize CDD value for a 30.5 day month

Normalized CDD = (Monthly_CDD / N) × 30.5

Normalization for days in month is not done currently by BCH Load Forecast group

BC hydro
FOR GENERATIONS

Proposed H-CDD Forecast Model

Choices of monthly HDD or CDD forecasting models

Forecasting model type	Characteristics
Moving Average (Static)	Each month, although separated by one year, takes on **same predicted** HDD or CDD value for, say, five years of monthly HDD or CDD forecasts. Simple to implement in a spreadsheet; No provisions for dealing with non-stationarity in a Degree Day time series. See example, next slide
Moving Average (Dynamic)	Each month, separated by one year, takes on a **new predicted** HDD or CDD value for, say, five years of monthly HDD or CDD forecasts. Simple to implement in a spreadsheet; No provisions for dealing with non-stationarity in a Degree Day time series. See example, next slide
Integrated Auto Regressive Moving Average (ARIMA); **Probabilistic Model with Climate Inputs**	More complex than moving average models, but this is compensated for by: (1) the ability to deal with non-stationarity in the Degree Day time series; (2) ease of experimenting with physical process inputs such as climate indices which offers insights into ways of improving forecasting accuracy
Neural Nets (NNs)	Most complex of the four model types; Can be good predictor but NNs are strictly empirical; May obscure insights into physical processes affecting the Degree Day time series and consequent forecasting accuracy

Focus on probabilistic ARIMA model because it has greatest potential for accurate forecasting during an era experiencing global climate change

Static and Dynamic 10-year Moving Average Comparison

	A	B	C	D	E	F
	Apr-1993	255	258.7			0.01451
	May-1993	111	165.9			0.494595
	Jun-1993	72	84.6			0.175
	Jul-1993	53	30.3			0.428302
	Aug-1993	35	26.2			0.251429
	Sep-1993	106	112.1	Forecast year 1		0.057547
	Oct-1993	200	237.2			0.186
	Nov-1993	402	354.6			0.11791
	Dec-1993	412	458.0			0.11165
	Jan-1994	351	441.5			0.257835
	Feb-1994	433	409.3			0.054734
161	Mar-1994	324	336.2			0.037654
	Apr-1994	222	258.7			0.165315
	May-1994	130	165.9			0.276154
	Jun-1994	90	84.6			0.06
	Jul-1994	19	30.3			0.594737
	Aug-1994	8	26.2			2.275
	Sep-1994	74	112.1	Forecast year 2		0.514865
	Oct-1994	235	237.2			0.009362
	Nov-1994	393	354.6			0.09771
	Dec-1994	414	458.0			0.10628
	Jan-1995	413	441.5			0.069007
	Feb-1995	382	409.3			0.071466
173	Mar-1995	335	336.2			0.003582

Mar-1994: Cell C161 =0.1*(B41+B53+B65+B77+B89+B101+B113+B125+B137+B149)

Mar-1995: Cell C173 =C161

Static – forecast copied from year to year. Mar-1995 value remains equal to Mar-1994 value and so on

A	B	C	D	E	F	G
Apr-1993	255	258.7	258.7			0.01451
May-1993	111	165.9	165.9			0.494595
Jun-1993	72	84.6	84.6			0.175
Jul-1993	53	30.3	30.3			0.428302
Aug-1993	35	26.2	26.2			0.251429
Sep-1993	106	112.1	112.1	Forecast year 1		0.057547
Oct-1993	200	237.2	237.2			0.186
Nov-1993	402	354.6	354.6			0.11791
Dec-1993	412	458.0	458.0			0.11165
Jan-1994	351	441.5	441.5			0.257835
Feb-1994	433	409.3	409.3			0.054734
Mar-1994	324	336.2	336.2			0.037654
Apr-1994	222		258.9			0.166081
May-1994	130		168.7			0.297615
Jun-1994	90		84.6			0.060444
Jul-1994	19		28.5			0.501579
Aug-1994	8		26.9			2.365
Sep-1994	74		109.1	Forecast year 2		0.474459
Oct-1994	235		235.3			0.001362
Nov-1994	393		358.6			0.087634
Dec-1994	414		451.0			0.089372
Jan-1995	413		444.3			0.075666
Feb-1995	382		414.0			0.083848
Mar-1995	335		338.9			0.011701

Mar-1994: Cell D161=0.1*(B41+B53+B65+B77+B89+B101+B113+B125+B137+B149)

Mar-1995: Cell D173=0.1*(B53+B65+B77+B89+B101+B113+B125+B137+B149+D161)

Dynamic – first year same as static; calculation of average for month of Mar in following year drops monthly value from "year one" (B41) and includes monthly value from what was previously "year eleven" (D161). Mar-1995 value is now different from Mar-1994 value

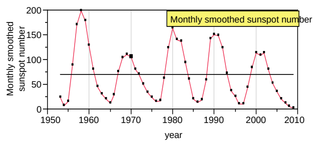
BC hydro FOR GENERATIONS

Transfer Function Model for HDD Forecasting

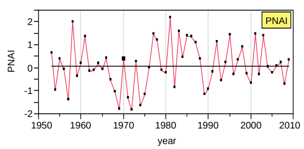
Monthly climate model uses as inputs those climate signals relevant to BC. This example is for January HDD, Vancouver

Inputs Series (Physical Processes)	Noise Series	Output / Forecast

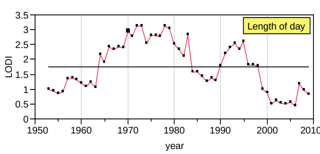
Monthly Smoothed Sunspot Number



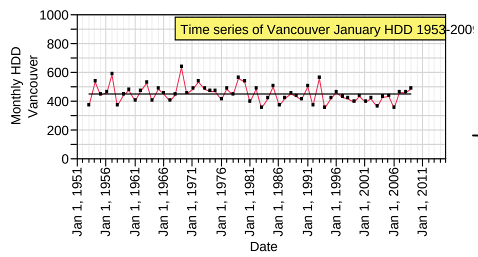
Pacific North American Index



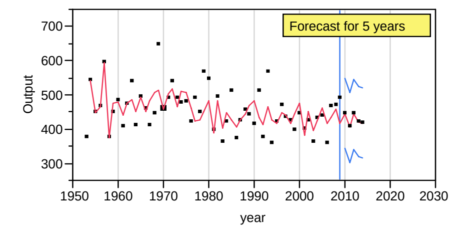
Earth's Angular Momentum Index



HDD Time Series at Station



Integrated autoregressive moving average (ARIMA) probabilistic transfer function model



Result: a five year forecast for monthly HDD, incorporating signals from physical processes operating in the regional climate of BC

Global Monthly Mean Temperature Anomaly was an additional input for some stations and months

BC hydro FOR GENERATIONS

Climate indices as model inputs

• Pacific North American Index
• Earth’s Angular Momentum Index
• Monthly Smoothed Sunspot Number
• Global Mean Monthly Temperature Anomaly

Climate indices

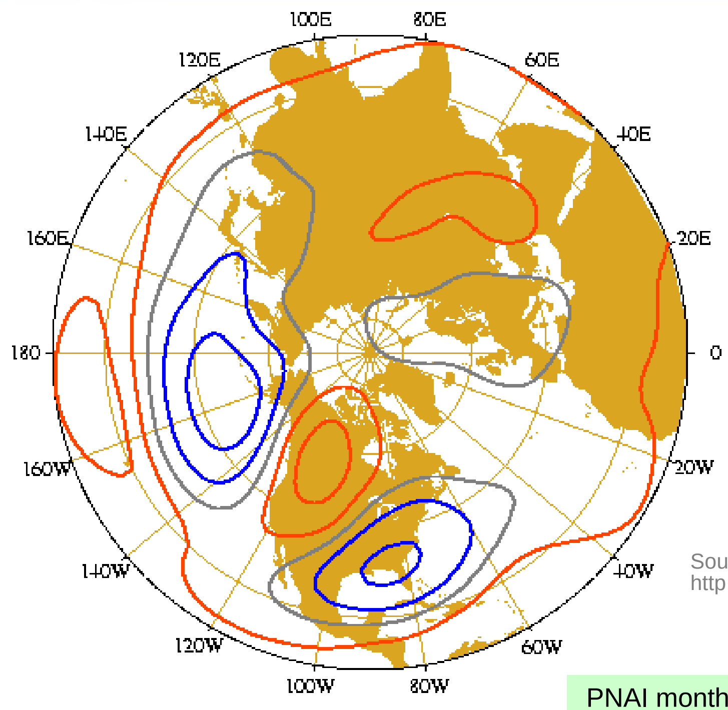
Climate indices, representing physical processes in BC's regional climate system, were used as inputs to the probabilistic model. Climatologists have developed several indices to characterize continental-scale atmospheric circulations (Rodionov and others, 2005). The following indices were tested by bivariate analyses to determine if they had significant correlations (at the 0.05 level) with HDD/CDD time series at Vancouver, Victoria, Prince George, or Kamloops. Tests were done for the entire time series (1953–2009; 1994–2009 for Kamloops) and by month for the time series periods. Four indices showed significant correlations for various months and climate stations and were used in the analyses They are in bold text.

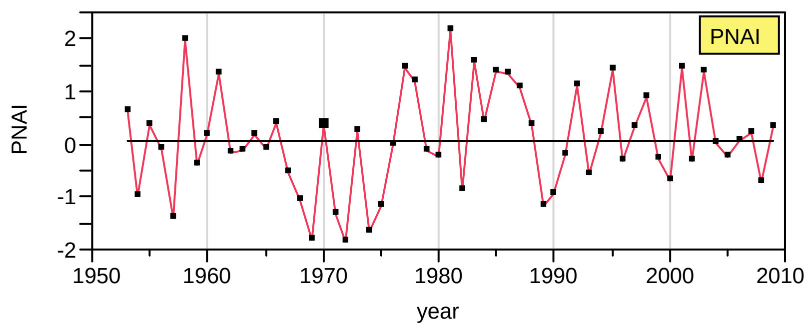
- **Monthly Smoothed Sunspot Number**
- **Global Mean Monthly Temperature Anomaly**
- Southern Oscillation Index
- Pacific Decadal Oscillation Index
- North Pacific Index
- Aleutian Low Pressure Index
- **Pacific North American Index**
- **Earth's Angular Momentum Index**

** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly DD and climate index's values simultaneously change together;*

Pacific North American Index

PNAI represents intensities of 4 major pressure cells surrounding North America (and BC). Intensities and geographical distribution of cells influences air temperature (therefore H-CDD) in BC





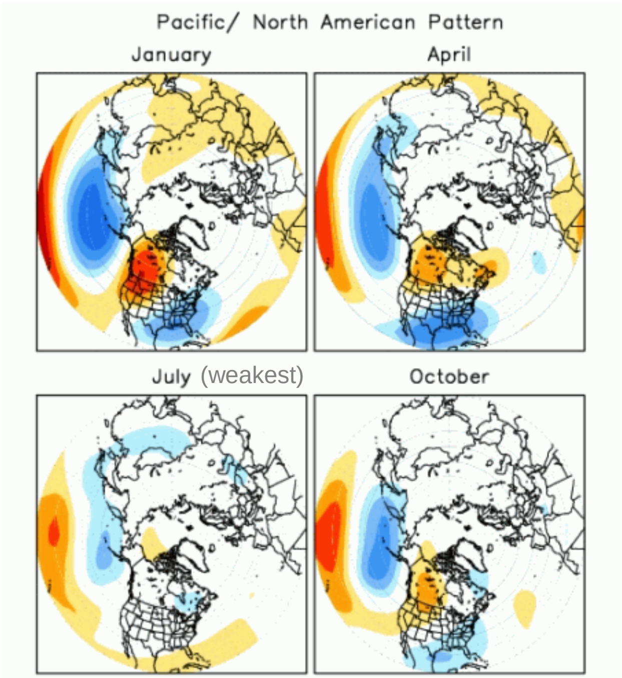
Source for graphic: Joint Institute for the Study of the Atmosphere and Ocean; http://jisao.washington.edu/data_sets/pna/

PNAI monthly data is available from the USA's NOAA / National Weather Service at http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/pna_index.html

BC hydro FOR GENERATIONS

Pacific North American Index (cont'd)

Positive phase



Seasonal views of the four low pressure cells surrounding and overlying BC.
Source: NOAA National Weather Service Climate Prediction Center;
http://www.cpc.ncep.noaa.gov/data/teledoc/pna_map.shtml

Key points (based on Data Set Summary by NASA Goddard Space Flight Center, Global Change Master Directory):

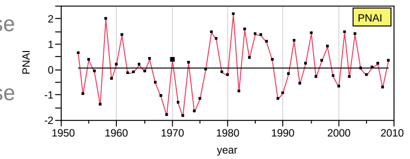
- PNA pattern coverage of Earth's surface is greatest in winter
- Aleutian Low contracts in Spring to Gulf of Alaska
- Subtropical low near Hawaii strongest in Spring
- PNA pattern weakest in June/July
- PNA pattern strengthens during late summer/fall

Additional information (from NOAA National Weather Service, Climate Prediction Center):

- PNA pattern is believed to be natural climate variability
- PNA is linked to El Niño / Southern Oscillation
- PNA positive phase → Pacific warm episodes (El Niño) → BC experiences above-average temperatures
- PNA negative phase → Pacific cold episodes (La Niña)
- PNA has minimal impact on BC's surface temperature variability in summer

Positive phase

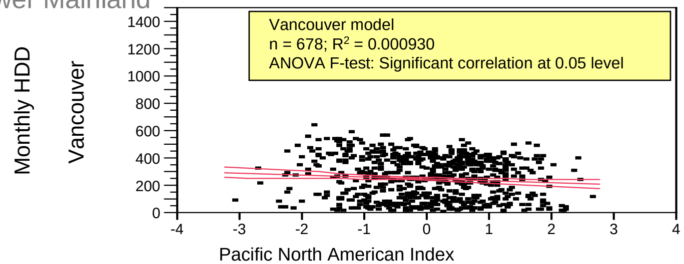
Negative phase



Pacific North American Index Bivariate* Analyses by Regions — HDD

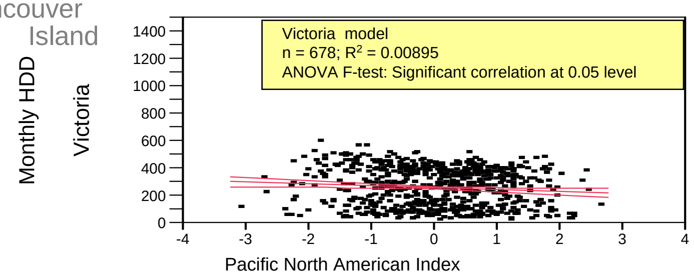
First, check correlations for full data set from 1953 to 2009. Next, do separate analyses for each region by month. This revealed significant correlations (0.05 level) between station's HDD and PNAI, as noted below each chart

Lower Mainland



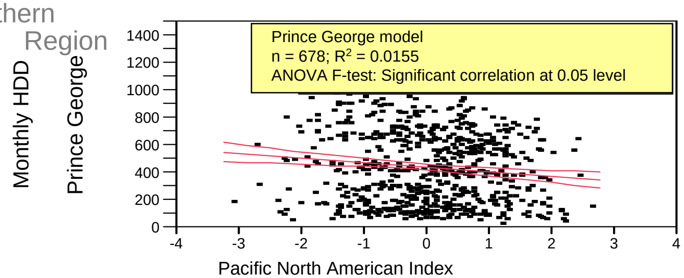
Significant months: all except Aug and Sep

Vancouver Island



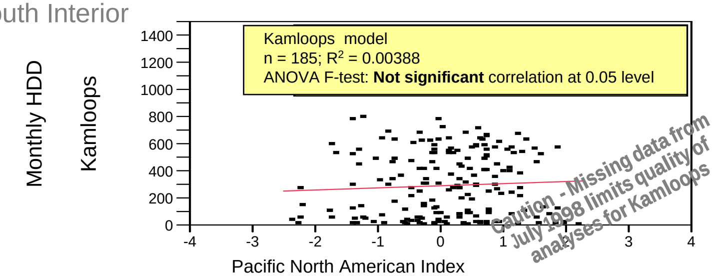
Significant months: all except Aug and Sep

Northern Region



Significant months: all except Jul, Aug, and Sep

South Interior



Significant months: Feb, Mar, Oct, Nov, and Dec

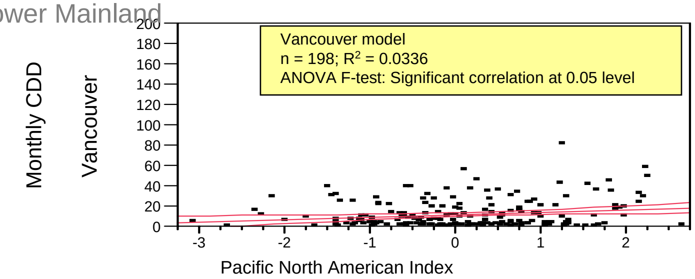
** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly HDD and PNAI values simultaneously change together; ANOVA = Analysis of Variance; F-test is an index of model significance*

BC hydro FOR GENERATIONS

Pacific North American Index Bivariate* Analyses by Regions — CDD

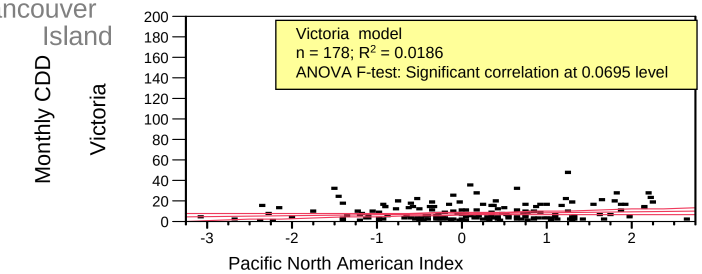
First, check correlations for full data set from 1953 to 2009. Next, do separate analyses for each region by month. This revealed significant correlations (0.05 level, unless marked) between station's CDD and PNAI, as noted below each chart

Lower Mainland



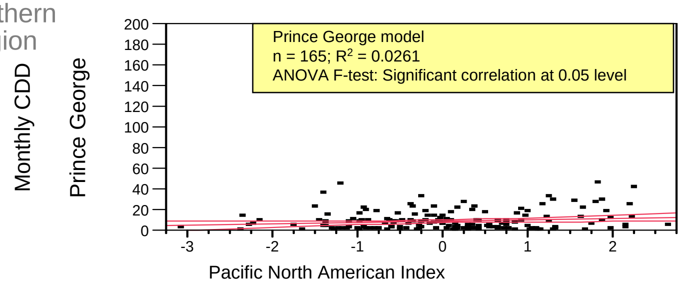
Significant months: Jun, Jul, and Aug (0.058)

Vancouver Island



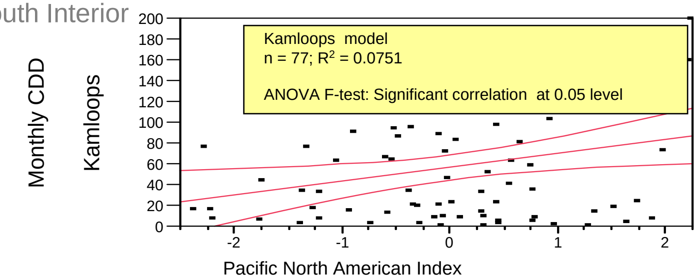
Significant months: Jun (0.395) and Jul (0.0987)

Northern Region



Significant months: Jun and Jul (0.307)

South Interior

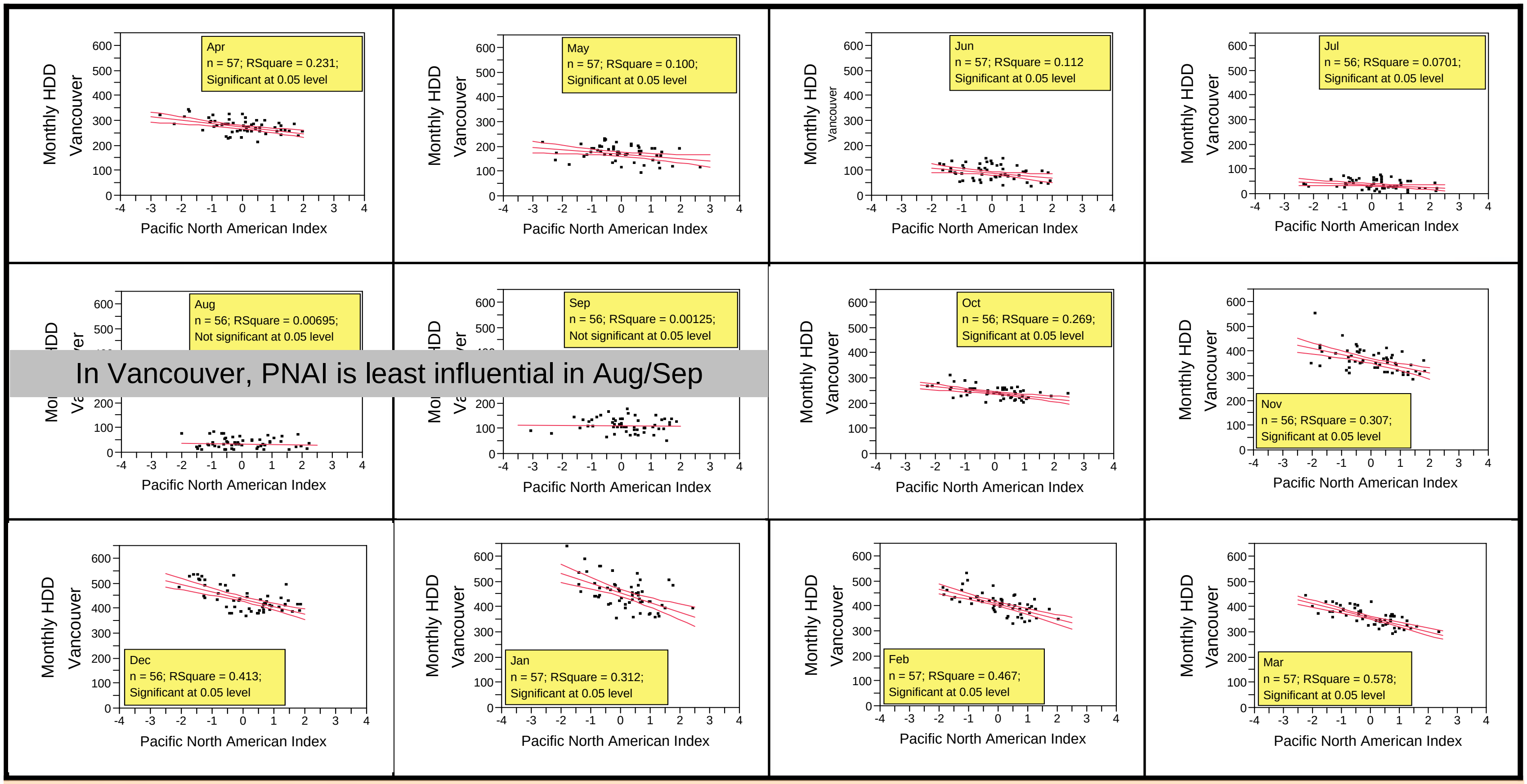


Significant months: Jul

** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly CDD and PNAI values simultaneously change together; ANOVA = Analysis of Variance; F-test is an index of model significance*

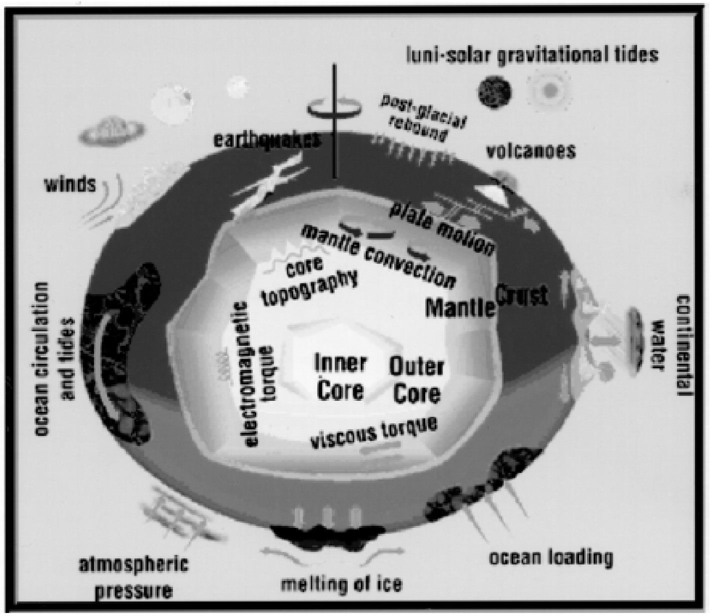
Pacific North American Index Bivariate* Analyses by Month)—Vancouver HDD example

Significant months: all except Aug and Sep. Charts show 0.05 confidence limits about the significant regression lines



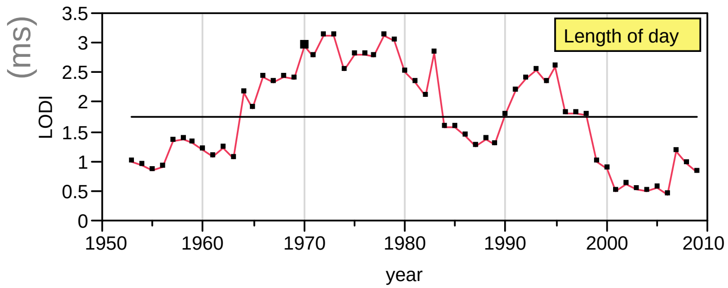
** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly HDD and PNAI values simultaneously change together; Model significance was quantified by Analysis of Variance F-test*

Length of Day Index (LODI): Earth's Angular Momentum



Geophysical fluid processes that involve large-scale mass transports and produce variations in Earth's rotation, gravity field, and geocentre.

Figure is from: Chao, B. F.; Dehant, V.; Gross, R. S.; Ray, R. D.; Salstein, D. A.; Watkins, M.M.; and Wilson, C. R. (2000) Space Geodesy Monitors Mass Transports in Global Geophysical Fluids. *Eos*, Transactions, American Geophysical Union, Vol. 81, No. 22, May 30, 2000, Pages 247, 249 – 250.



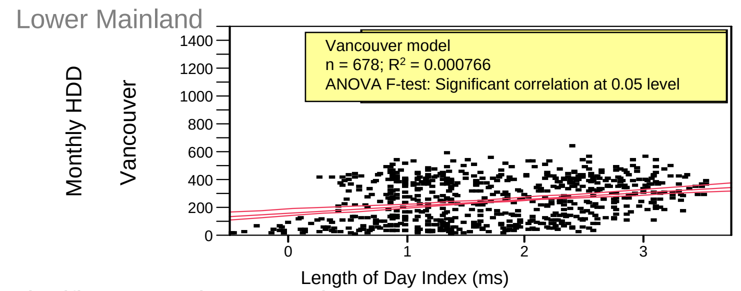
Index of major storm activity in Earth system (e.g. related to El Niño events). These events affect sea surface temperatures offshore BC, hence land air temperature and H-CDD across BC

LODI monthly data (starting 1962) is available from ANALYTICAL GRAPHICS, INC. # CENTER FOR SPACE STANDARDS & INNOVATION # EARTH ORIENTATION PARAMETERS (EOP) DATA at http://celestrak.com/SpaceData/eop19620101.txt

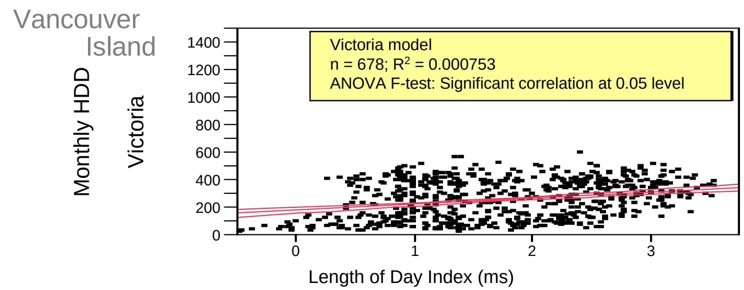
Annual values from 1953-1961 are available from Fisheries and Oceans Canada at http://www.pac.dfo-mpo.gc.ca/sci/sa-mfpd/climate/clm_indx_lod.htm

Length of Day (Earth's Angular Momentum Index) Bivariate* Analyses by Regions — HDD

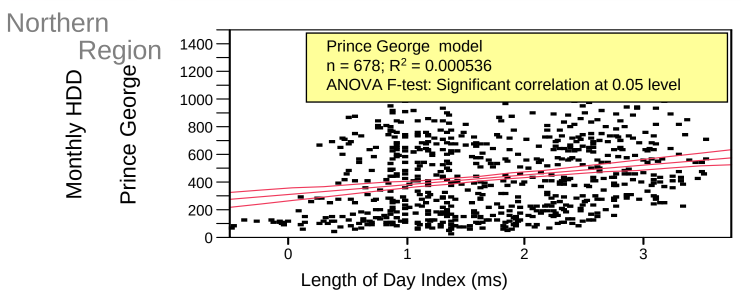
First, check correlations for full data set from 1953 to 2009. Next, do separate analyses for each region by month. This revealed significant correlations (0.05 level) between station's HDD and LODI, as noted below each chart



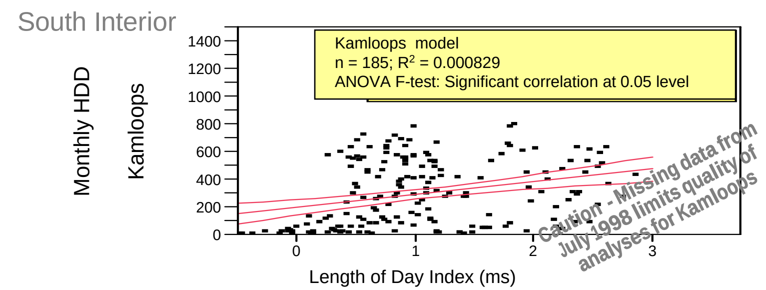
Significant months: Jul and Aug



Significant months: Jun, Jul, and Aug



Significant months: none



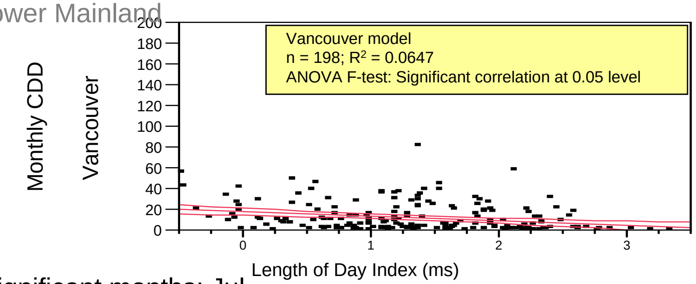
Significant months: none

** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly HDD and LODI values simultaneously change together; ANOVA = Analysis of Variance; F-test is an index of model significance*

Length of Day (Earth's Angular Momentum Index) Bivariate* Analyses by Regions — CDD

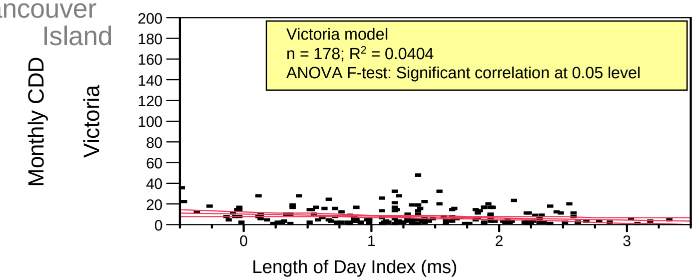
First, check correlations for full data set from 1953 to 2009. Next, do separate analyses for each region by month. This revealed significant correlations (0.05 level, unless marked) between station's CDD and LODI, as noted below each chart

Lower Mainland



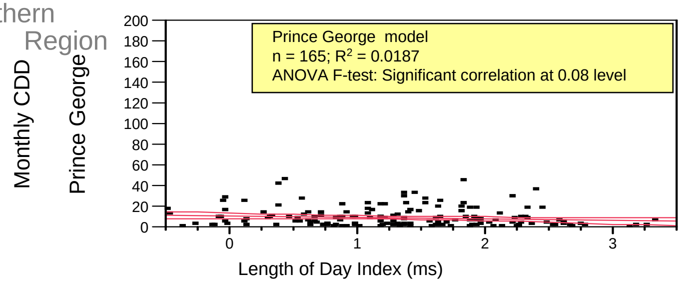
Significant months: Jul

Vancouver Island



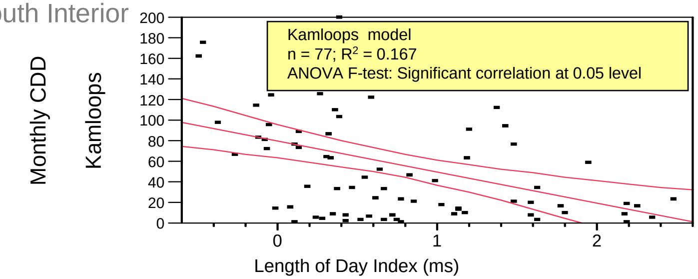
Significant months: Jun (0.190) and Jul (0.211)

Northern Region



Significant months: none

South Interior



Significant months: Jun (0.188) and Aug (0.0539)

** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly CDD and LODI values simultaneously change together; ANOVA = Analysis of Variance; F-test is an index of model significance*

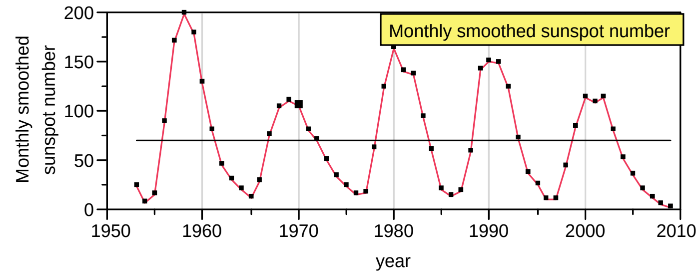
Monthly Smoothed Sunspot Number (MSSN)

Source for graphic: Australian Government IPS Radio and Space Services;

http://www.ips.gov.au/Solar/3/3/1

MSSN monthly data is available from Royal Observatory of Belgium, SIDC – Solar Influences Data Analysis Center at

http://sidc.oma.be/sunspot-data/



Sunspots are cooler regions of concentrated magnetic fields on the Sun's surface. As they increase in number, recent research* suggests the effect on the Earth is that:

-low-altitude cosmic radiation decreases

-Less aerosols (physical mechanism remains unclear) → 4– 5% less clouds

-Sunlight reaching oceans increases by 2 W/m^2 → Oceans warm

Other recent research** invoked stratospheric response of ozone to solar radiation forcing and described an amplifying mechanism reducing low level clouds

Southern Oscillation Index (El Niño/El Niña events) spectral analysis showed a peak related to the 11 year solar cycle of sunspot activity (later slide)

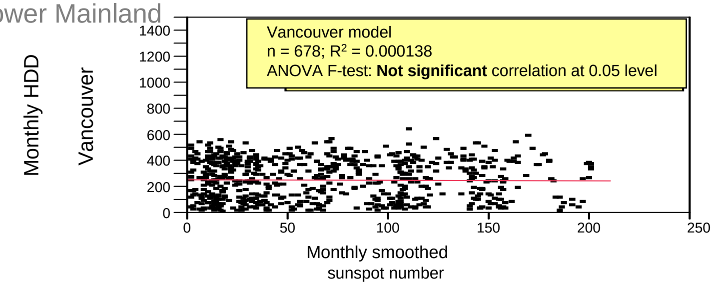
MSSN was used in analyses if a strong 11 year peak appeared in monthly HDD or CDD spectra by month

- *Technical University of Denmark (DTU) (2009, Oct 6). Cosmic Ray Decreases Affect Atmospheric Aerosols and Cloud. *ScienceDaily*. Retrieved Oct 7, 2009 from http://www.sciencedaily .com/releases/2009/08/090801095810.htm
- ** Meehl and others (2009) Amplifying the Pacific Climate System Response to a Small 11-Year Solar Cycle Forcing, *Science* **325**, 1114-1118 (28 August 2009)

Monthly Smoothed Sunspot No. Bivariate* Analyses by Region — HDD

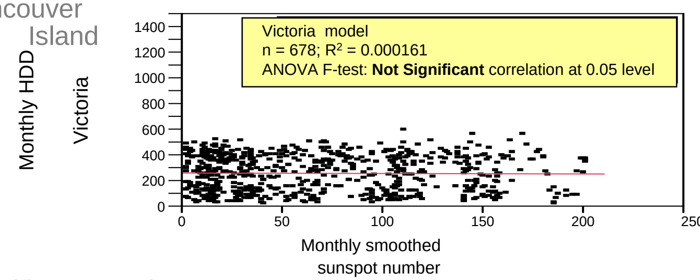
First, check correlations for full data set from 1953 to 2009. Next, do separate analyses for each region by month. This revealed significant correlations (0.05 level) between station's HDD and MSSN, as noted below each chart

Lower Mainland



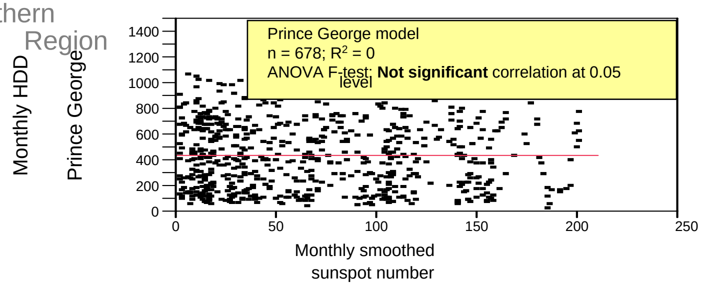
Significant months: none

Vancouver Island



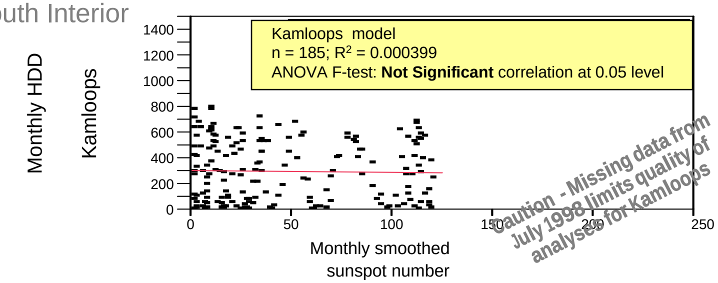
Significant months: none

Northern Region



Significant months: Feb

South Interior



Significant months: none

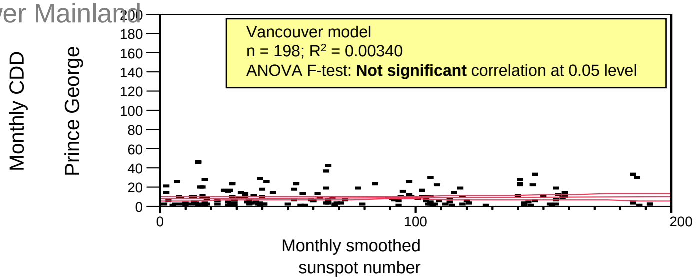
** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly HDD and MSSN values simultaneously change together; ANOVA = Analysis of Variance; F-test is an index of model significance*

BChydro FOR GENERATIONS

Monthly Smoothed Sunspot No. Bivariate* Analyses by Region — CDD

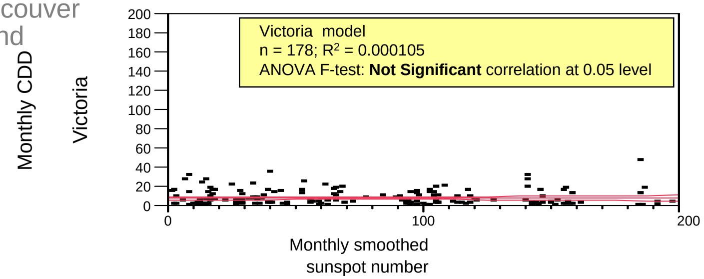
First, check correlations for full data set from 1953 to 2009. Next, do separate analyses for each region by month. This revealed significant correlations (0.05 level, unless marked) between station's CDD and MSSN, as noted below each chart

Lower Mainland



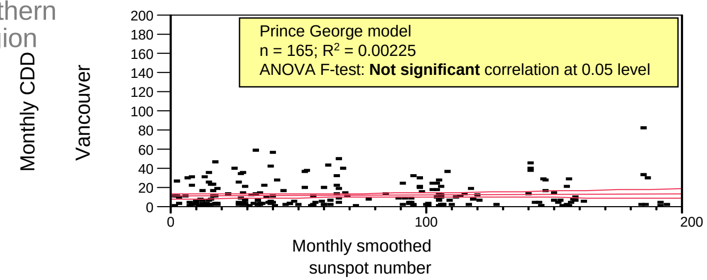
Significant months: Jun (0.119)

Vancouver Island



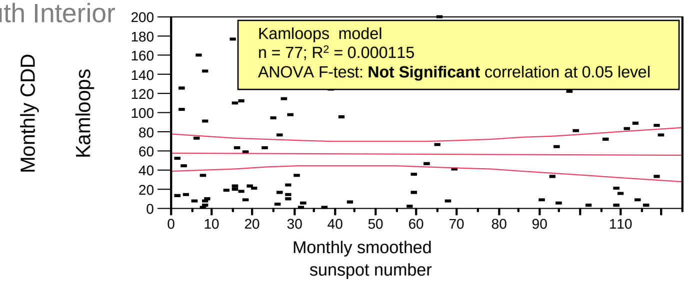
Significant months: Jun (0.201)

Northern Region



Significant months: Jun (0.200) and Sep (0.262)

South Interior

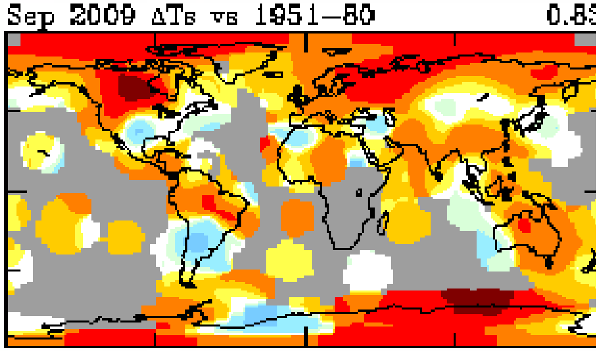


Significant months: Jul (0.205)

** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly CDD and MSSN values simultaneously change together; ANOVA = Analysis of Variance; F-test is an index of model significance*

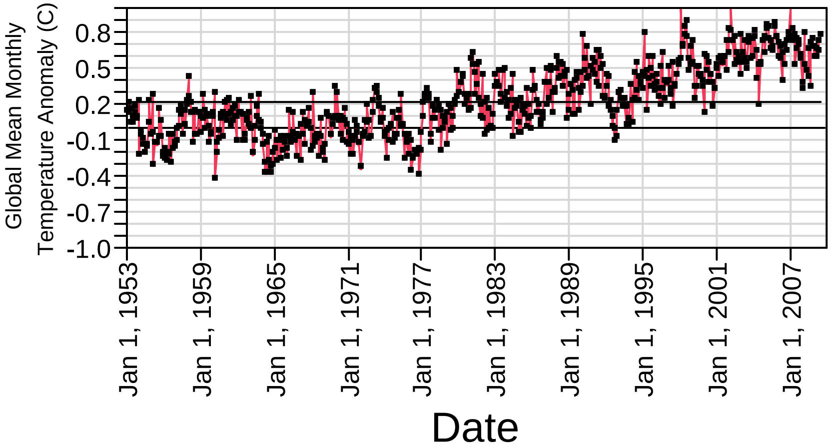
Global Mean Monthly Temperature Anomaly

"The NASA GISS Surface Temperature Analysis (GISTEMP) provides a measure of the changing global surface temperature with monthly resolution for the period since 1880, when a reasonably global distribution of meteorological stations was established." (Summary statement from Global Change Master Directory)



Source for graphic: NASA Goddard Institute for Space Studies;

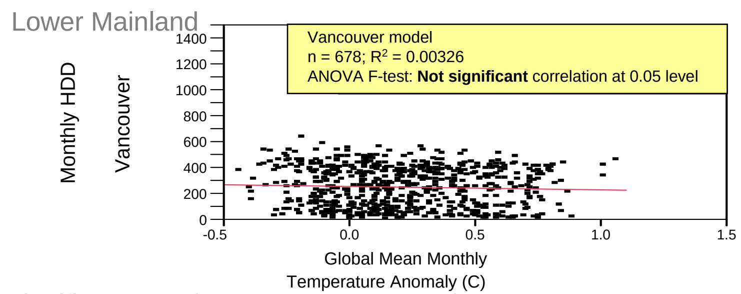
http://data.giss.nasa.gov/gistemp/



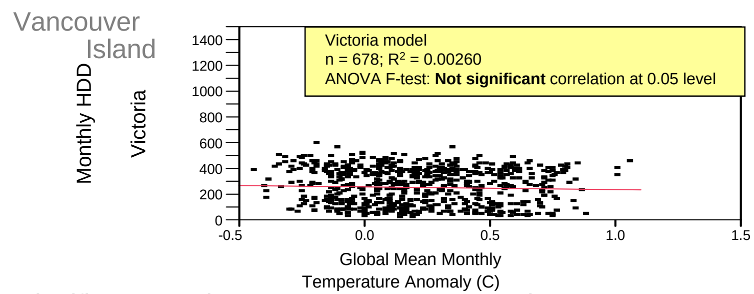
GMMTA monthly data is available from NASA's Goddard Institute for Space Studies (GISS), at http://data.giss.nasa.gov/gistemp/tabledata/GLB.Ts.txt

Global Mean Monthly Temp. Anomaly Bivariate* Analyses by Region — HDD

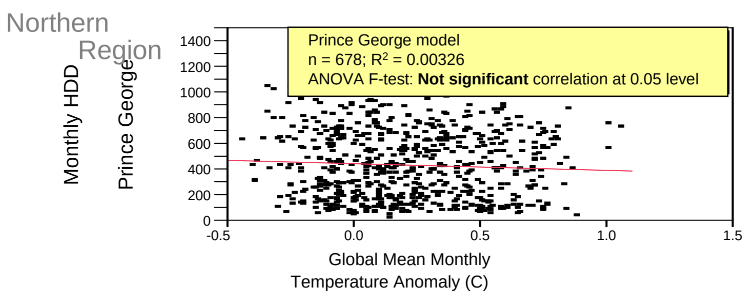
First, check correlations for full data set from 1953 to 2009. Next, do separate analyses for each region by month. This revealed significant correlations (0.05 level) between station's HDD and GMMTA, as noted below each chart



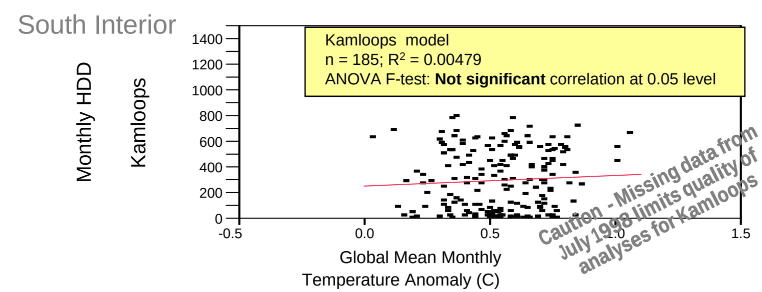
Significant months: all except May and Dec



Significant months: all except May, Oct, and Dec



Significant months: Jan, Feb, Mar, Apr, Aug, Dec



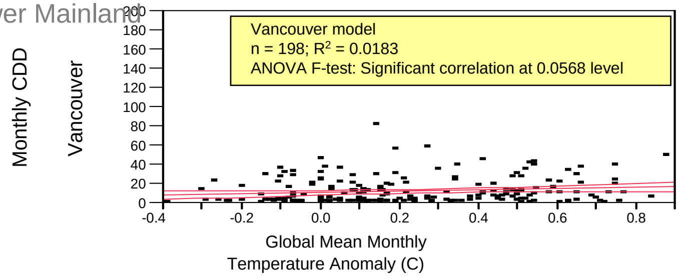
Significant months: Feb

** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly HDD and GMMTA values simultaneously change together; ANOVA = Analysis of Variance; F-test is an index of model significance*

Global Mean Monthly Temp. Anomaly Bivariate* Analyses by Region — CDD

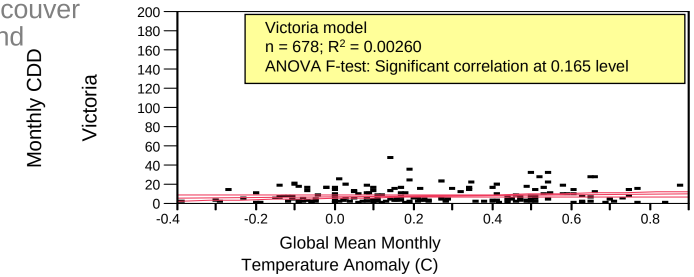
First, check correlations for full data set from 1953 to 2009. Next, do separate analyses for each region by month. This revealed significant correlations (0.05 level, unless marked) between station's CDD and GMMTA, as noted below each chart

Lower Mainland



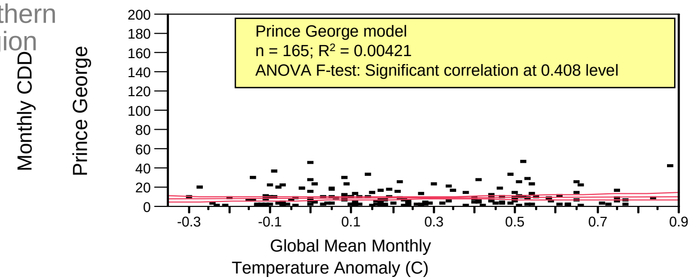
Significant months: Aug and Sep (0.269)

Vancouver Island



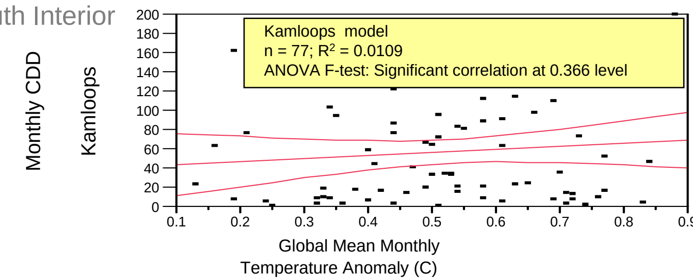
Significant months: Aug (0.280)

Northern Region



Significant months: Aug (0.293)

South Interior



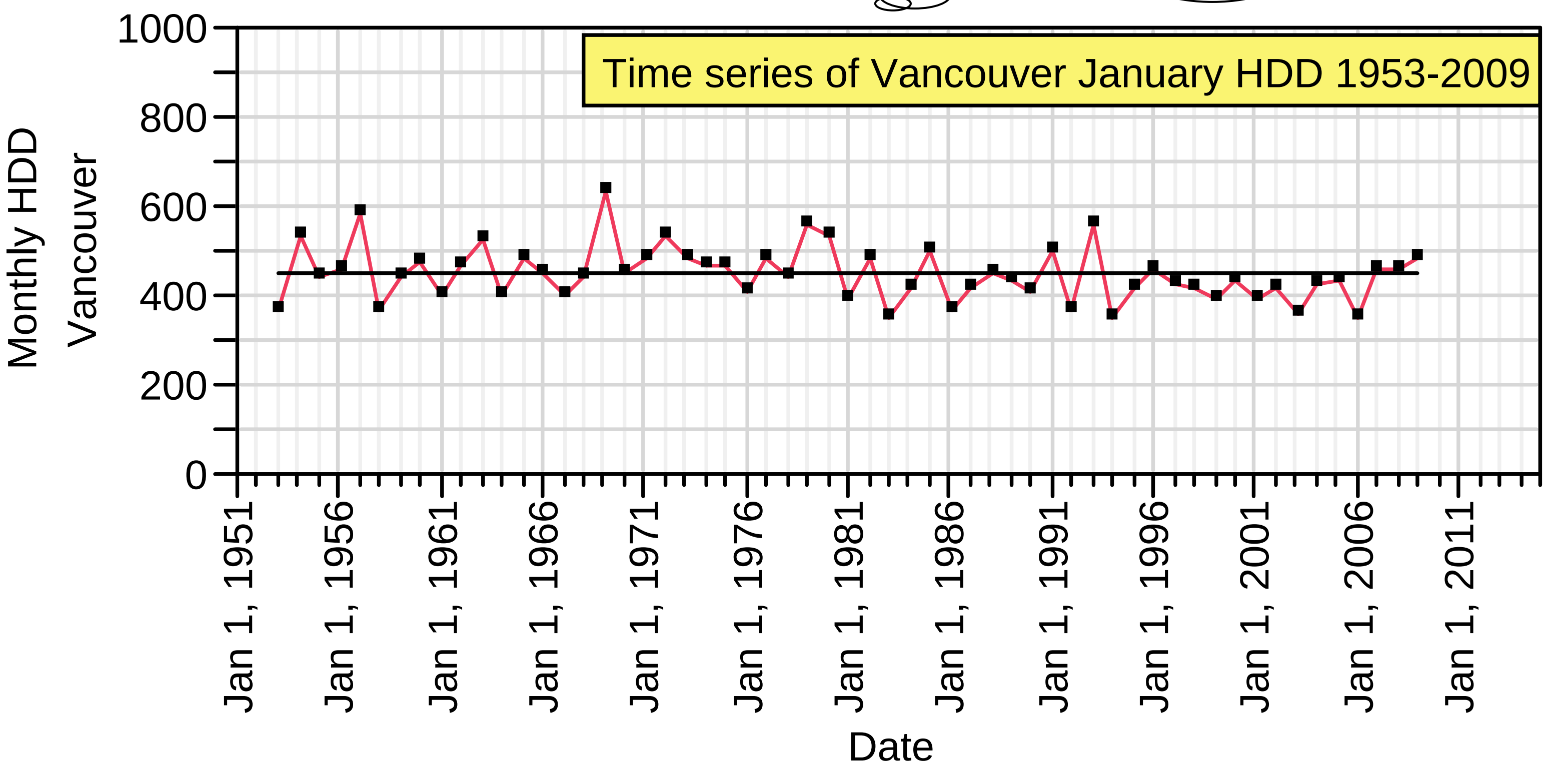
Significant months: Jul (0.341) and Aug (0.186)

** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly CDD and GMMTA values simultaneously change together; ANOVA = Analysis of Variance; F-test is an index of model significance*

H-CDD Trend Detection by Bivariate Analyses

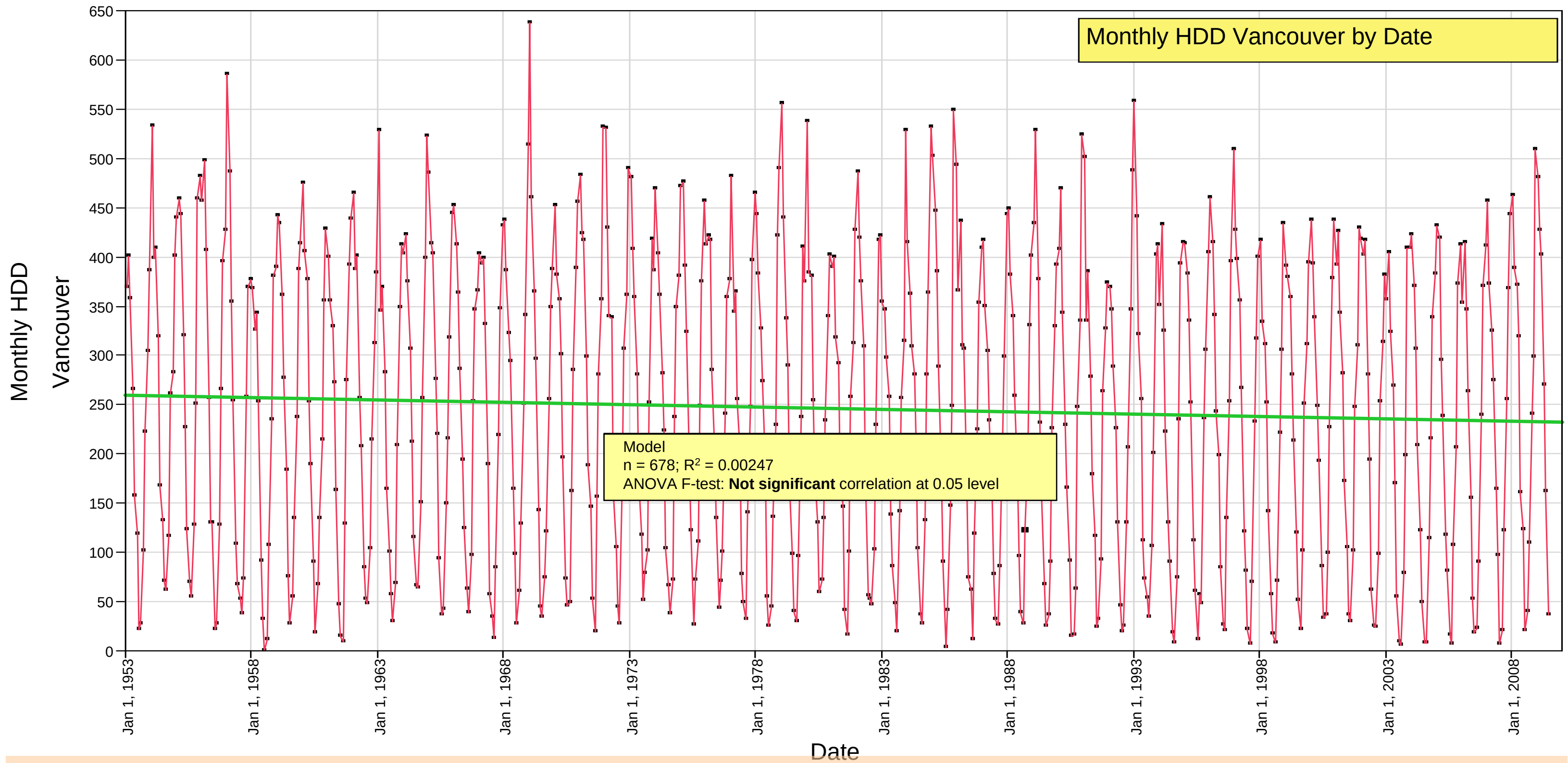
HDD time series

Gather information about ***climate trends and cycles*** to improve HDD forecasts



HDD trend detection by bivariate* analyses of time series

Vancouver HDD time series trend 1953–2009 not significant — similar results for Victoria, Prince George, and Kamloops.
But, HDD trends *are* revealed when climate station data is examined **month by month** (next 3 slides).

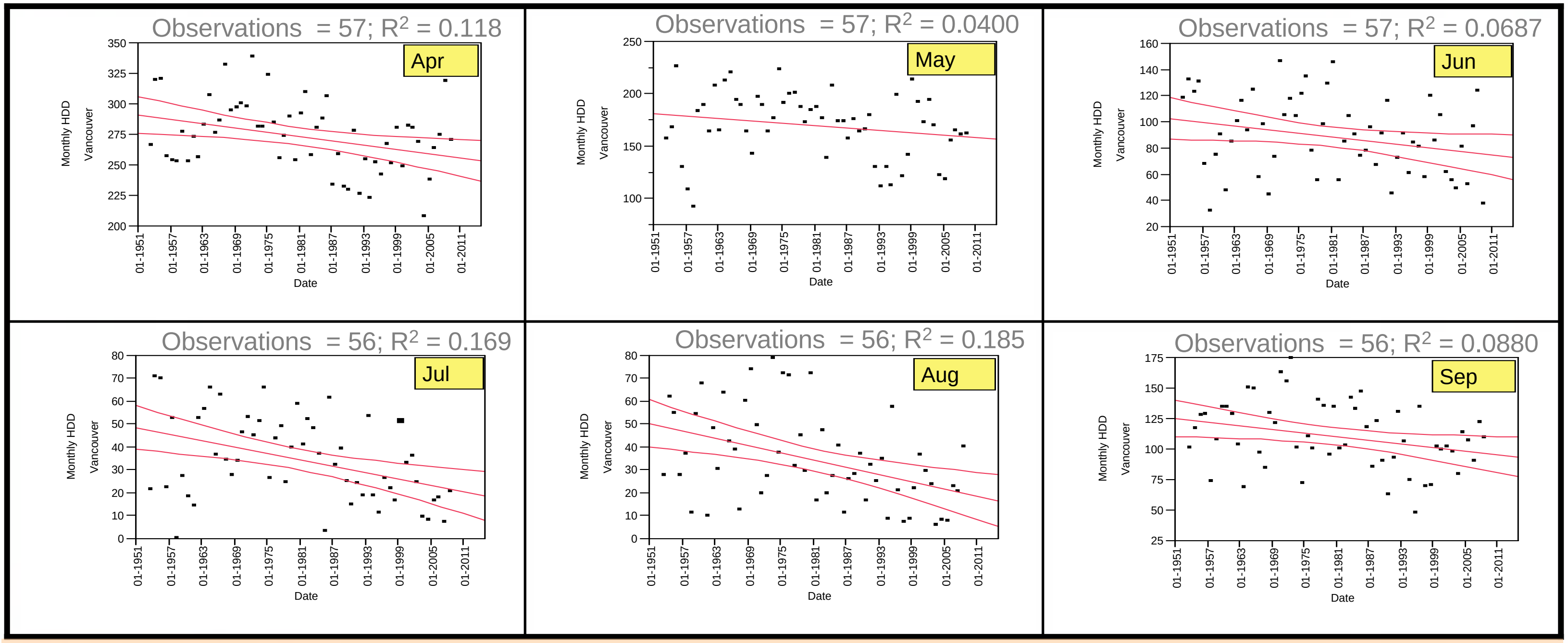


** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly HDD varies over time. ANOVA = Analysis of Variance; F-test is an index of model significance*

HDD trend detection by bivariate* analyses (monthly)

Example: Vancouver HDD, Apr–Sep

HDD trends are revealed when data is examined by month. Significant decreasing trends were found for the 7 months Apr, Jun, Jul, Aug, Sep, Jan, and Mar. These charts show 0.05 confidence curves about the linear fit. Decreasing regional HDDs are consistent with global temperature trends.

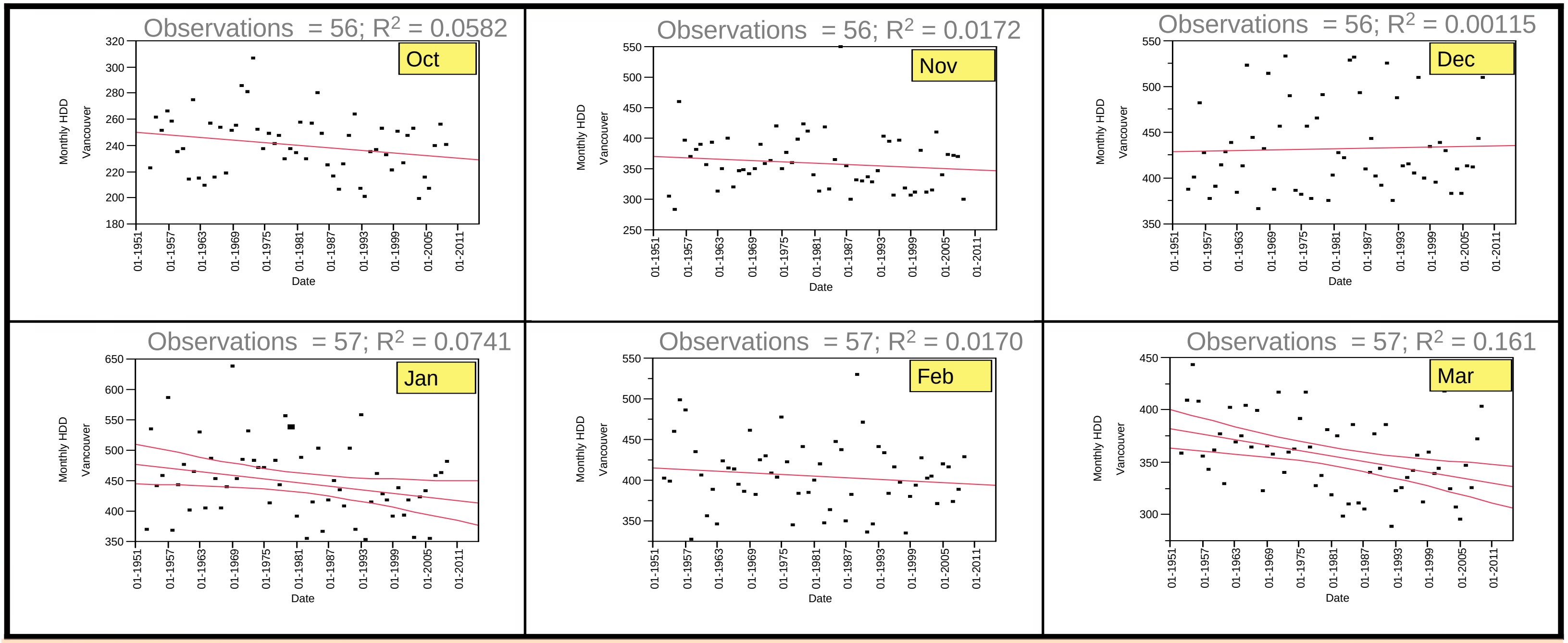


** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly HDD varies over time; ANOVA = Analysis of Variance; F-test is an index of model significance*

HDD trend detection by bivariate* analyses (monthly)

Vancouver HDD, Oct–Mar

HDD trends are revealed when data is examined by month. Significant trends were found for the months whose charts have 0.05 confidence curves about the linear fit.



** Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly HDD varies over time; ANOVA = Analysis of Variance; F-test is an index of model significance*

HDD trend summary for the four sales regions

Decreasing HDD in Jan, Mar and Apr are likely to have the most effect on consumption of electricity by electric heaters. The lack of trends in Kamloops data may be a result of the relatively short observation period (16 years) compared to the other three regions (57 years). ***Decreasing HDD are consistent with observed global climate change warming temperature trends***

Month/Station	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Lower Mainland: Vancouver 1953-2009	▼	▬	▼	▼	▼	▼	▬	▬	▬	▼	▬	▼
Vancouver Island: Victoria 1953-2009	▼	▬	▼	▼	▼	▬	▬	▬	▬	▼	▬	▼
Northern Region: Prince George 1953-2009	▼	▬	▼	▬	▼	▬	▬	▬	▬	▼	▬	▬
South Interior: Kamloops 1994-2009	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬

Caution - Missing data from July 1998 limits quality of analyses for Kamloops

▼ Decreasing HDD significant at 0.05 level

▬ Trend in HDD not significant at 0.05 level

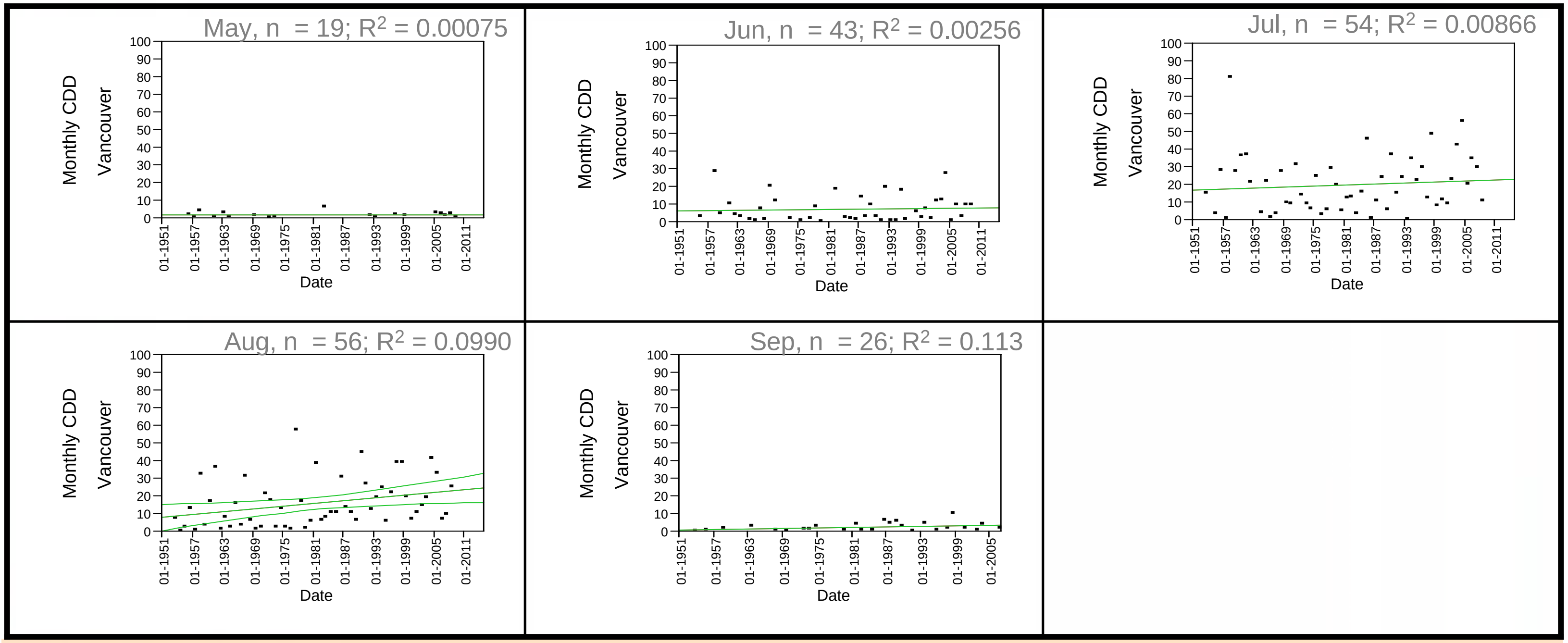
BC hydro FOR GENERATIONS

Roland V Wahlgren, Load Research Analyst
BC Hydro Customer Information Management—Load Analysis

CDD trend detection by bivariate* analyses (monthly)

Vancouver CDD, May to Sep

CDD trends are revealed when data is examined by month. Significant trends were found for the months whose charts have 0.05 confidence curves about the linear fit.



* *Bivariate analysis is a statistical technique for exploring the association between two variables. Here, association is based on how monthly HDD varies over time; ANOVA = Analysis of Variance; F-test is an index of model significance*

CDD trend summary for the four sales regions

Increasing CDD in May through Sep were likely to have the most effect on consumption of electricity by cooling systems. ***Increasing CDD were consistent with observed global climate change warming temperature trends***

Month/Station	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Lower Mainland: Vancouver 1953-2009		▬	▬	▬	▲	▬						
Vancouver Island: Victoria 1953-2009		▬	▬	▬	▬	▬						
Northern Region: Prince George 1953-2009		▬	▬	▬	▬	▬						
South Interior: Kamloops 1994-2009		▬	▬	▬	▬	▬						

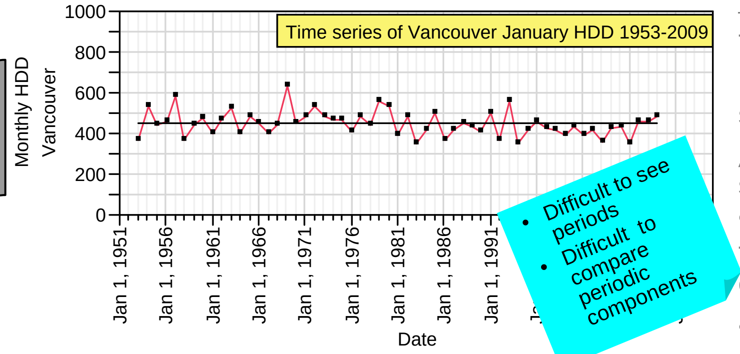
▲ Increasing CDD significant at 0.05 level

▬ Trend in CDD not significant at 0.05 level

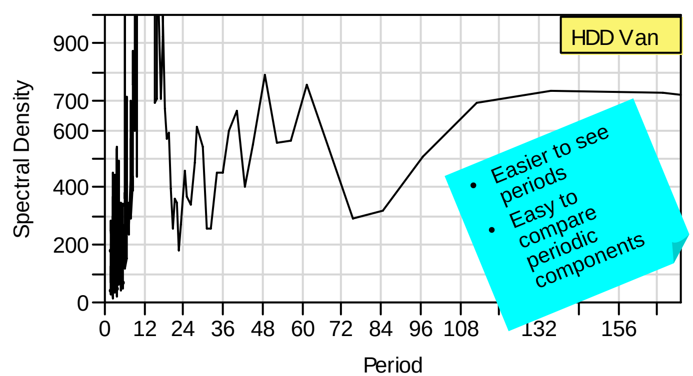
H-CDD Cycle Detection by Spectral Analyses

HDD cycle detection by spectral analyses

Plotting monthly HDD values against time (date) is natural and intuitive. This is called *time domain analysis*.



Software transforms time domain to frequency domain (using a Fourier transform method)



Months (each vertical grid- line is 1 year)

Time domain view of data

The formula, Monthly HDD Vancouver = f (date),

is the *function* or *signal* describing how HDD varied with time. This signal is shown in the time series chart (left). Periods are difficult to see and compare.

A signal can be the sum of several other signals or components. The HDD signal at a climate station was the result of energy gains or losses by the atmosphere surrounding the station.

The local atmosphere at a station gained or lost energy in response to various climatic components, each with their signal:

• Energy from sun or human-caused climate change (Monthly Smoothed Sunspot Number signal or Global Monthly Mean Temperature Anomaly signal)

• Movement and distribution of cyclones (low pressure systems) and air masses (various climate index signals)

Frequency domain view of data (spectral density vs. period or frequency)

The purpose of transforming from time to frequency domain was to quantify the portion of a signal's power (energy per unit time or density) falling within given frequency bins. Bins showed up as peaks and valleys according to the distribution of the signal's power for the duration of the observations (in this case, 1953-2009).

Frequency = 1/period.

For example, a period of 11 years = 132 months = 0.0076 cycles/month

A peak at 60 months meant a relatively strong HDD signal was repeated every 5 years.

Periodicities (cycles) in the data and relative strengths of periodic components were revealed, making it easier to decide, by visual inspection and comparison, which climate components were influencing the HDD signal at a climate station.

BC hydro
FOR GENERATIONS

HDD cycle detection by spectral analyses (continued)

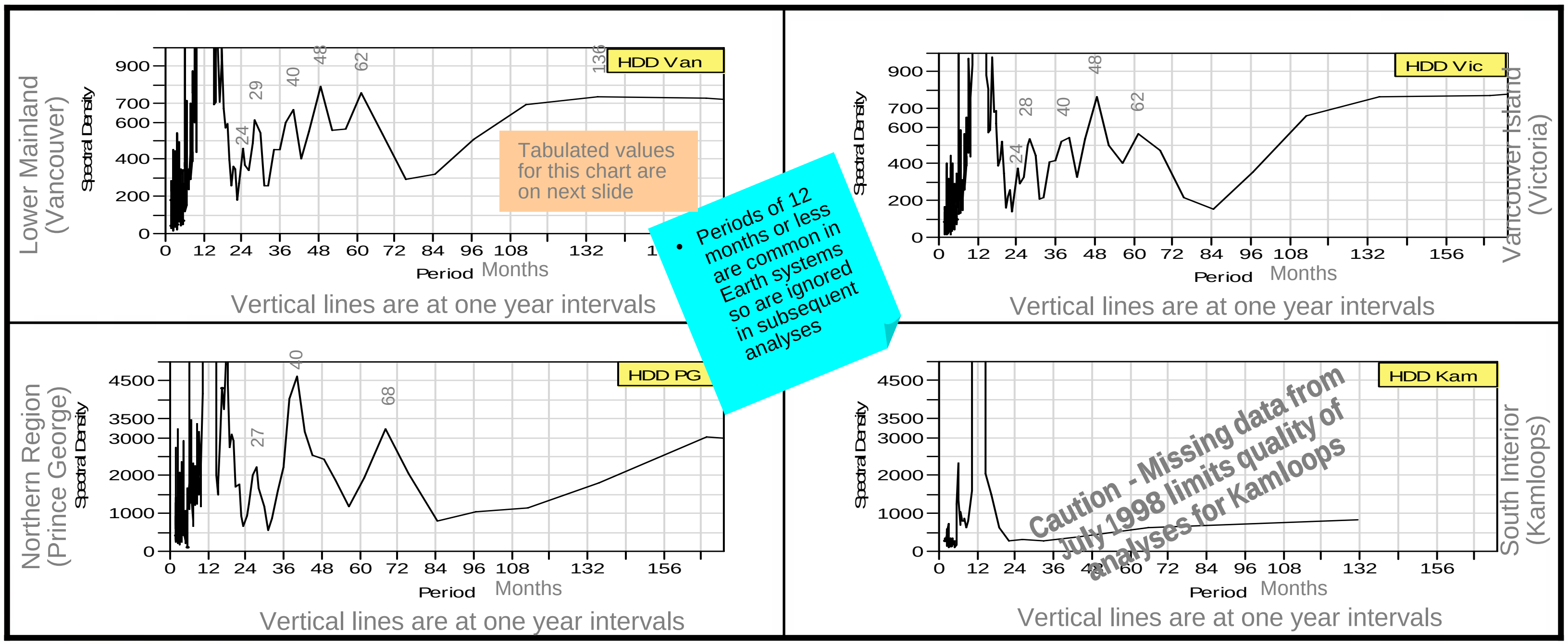
The next slide shows:

- Spectral density “signature” was not identical for BC Hydro’s four sales regions. Why?
  - Influences on regional climates are different
  - Cycles and trends are different
  - HDDs are different

- Peaks represent various climate components (to be explained on a later slide). Relative importance of various climate components differed between regions

HDD cycle detection by spectral analyses (for 1953–2009 data)

Note: For ease of viewing peaks (values in months), spectral density scale was not kept constant between charts. The scale provides relative values to compare peaks within a single chart



Charts show results from analyses on 1953–2009 data set for each station. Periods are in months.

Periodogram example (Vancouver Monthly HDD 1953–2009; SAS JMP output)

	Period	Frequency	Angular Frequency	Sine	Cosine	Periodogram	Spectral Density
	.	0	0	0	0	0	5140.3581
Fundamental	678	0.00147493	0.00926723	12.9498062	-4.7801824	64595.645	3942.52637
2nd harmonic	339	0.00294985	0.01853447	-1.1545304	3.40665152	4386.05486	1631.86685
3rd harmonic	226	0.00442478	0.0278017	1.53205422	4.8161241	8658.81986	635.161816
4th harmonic	169.5	0.00589971	0.03706894	4.81613168	2.63842346	10223.0205	732.46436
5th harmonic	135.6	0.00737463	0.04633617	1.55290062	4.51000688	7712.81355	734.597685
etc.	113	0.00884956	0.05560341	3.86402655	4.28165867	11276.2594	694.696478
	96.86	0.01032448	0.06487064	3.07052726	2.07370288	4653.92125	505.295144
	84.75	0.01179941	0.07413788	-3.0309183	-2.2397524	4814.8023	317.919951
	75.33	0.01327434	0.08340511	-0.5097053	2.17846923	1696.87389	290.481964
	67.8	0.01474926	0.09267235	-2.5201989	-3.536385	6392.66599	535.724554
	61.64	0.01622419	0.10193958	3.25545824	-5.1104389	12446.2473	754.186653
	56.5	0.01769912	0.11120682	-3.9750647	-1.9338691	6624.39532	565.303595
	52.15	0.01917404	0.12047405	-1.9333739	-2.0703413	2720.21995	557.655636
	48.43	0.02064897	0.12974129	-5.7062478	3.81261918	15965.9944	788.240046
	45.2	0.02212389	0.13900852	-3.8260866	0.13801464	4969.05749	547.592218
	42.38	0.02359882	0.14827576	1.69474287	-1.3817368	1620.87767	401.647491
	39.88	0.02507375	0.15754299	-5.2246852	2.83488359	11978.1921	664.342147
	37.67	0.02654867	0.16681023	0.3547795	4.78861336	7816.2167	598.833874
	35.68	0.0280236	0.17607746	-2.6125694	0.72094095	2490.04811	451.274684
	33.9	0.02949853	0.1853447	3.10054748	-4.4218171	9887.2268	452.690207
	32.29	0.03097345	0.19461193	1.16315559	0.30505263	490.189944	257.122884
	30.82	0.03244838	0.20387917	-2.4616862	0.08576137	2056.79915	255.833383
	29.48	0.0339233	0.2131464	-4.258432	-2.4938224	8255.80019	539.612799
	28.25	0.03539823	0.22241364	-4.5743412	2.07674274	8555.49814	611.793726
	27.12	0.03687316	0.23168087	-2.5867368	3.03227044	5385.31033	486.994705
	26.08	0.03834808	0.24094811	2.73992627	-2.7736463	5152.90501	339.039179
	25.11	0.03982301	0.25021534	-1.0301446	1.70985471	1350.84752	369.815691
	24.21	0.04129794	0.25948258	-4.9335593	2.70643371	10734.3641	460.469501
	23.38	0.04277286	0.26874981	-0.9790922	0.05882984	326.145966	268.253758
	22.6	0.04424779	0.27801705	1.93707161	-1.5602331	2097.24855	180.600687
	21.87	0.04572271	0.28728428	-2.4881287	2.69308177	4557.33757	350.378913
	21.19	0.04719764	0.29655152	-4.2575882	-0.8672491	6400.0414	360.037731
	20.55	0.04867257	0.30581875	0.71918653	-1.2906621	740.049898	258.928375

Data table has these columns:

Period

is the period of the ith harmonic, $1 / f_i$.

Frequency

is the frequency of the harmonic, f_i.

Angular Frequency

is the angular frequency of the harmonic, $2\pi f_i$

Sine

is the Fourier sine coefficients, a_i

Cosine

is the Fourier cosine coefficients, b_i

Periodogram

is the periodogram, $I(f_i)$.

Spectral Density

is the spectral density, a smoothed version of the periodogram.

(Information from SAS JMP documentation)

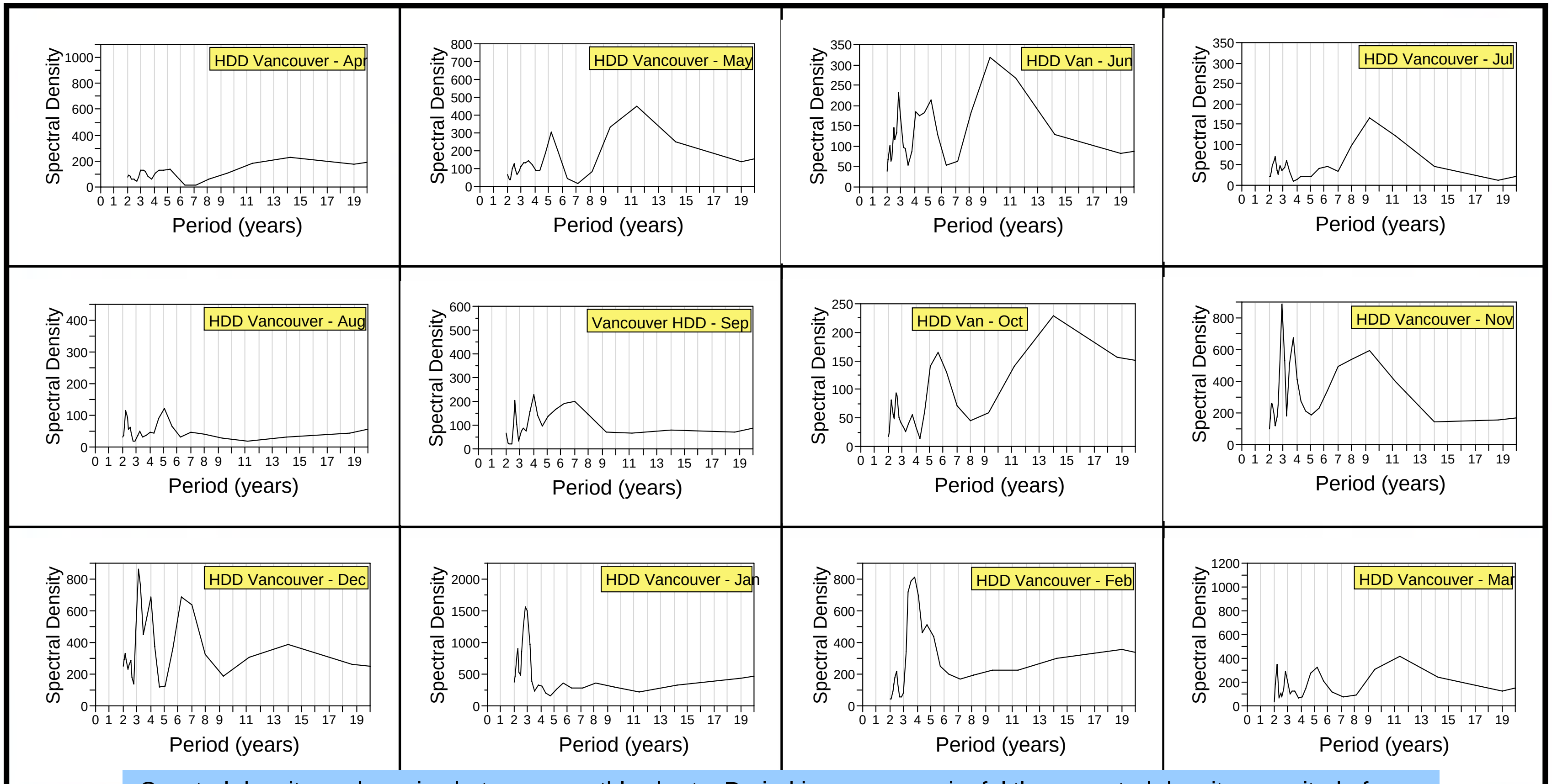
HDD cycle detection by spectral analyses (monthly)

The next slide shows, using Vancouver as an example, that:

- Spectral density "signature" was not identical between months. Why?
  - Seasonal intensity changes of the 4 low pressure cells defining the Pacific North American pattern
  - Seasonal shifts in geographical position of the PNA pattern elements
- Peaks represent various climate components (to be explained on a later slide). Relative importance of various climate components differed between months

HDD cycle detection by spectral analyses (monthly)—Vancouver HDD example

Note: For ease of viewing peaks, spectral density scale was not kept constant between monthly charts. The scale provides relative values to compare peaks within a single month's chart

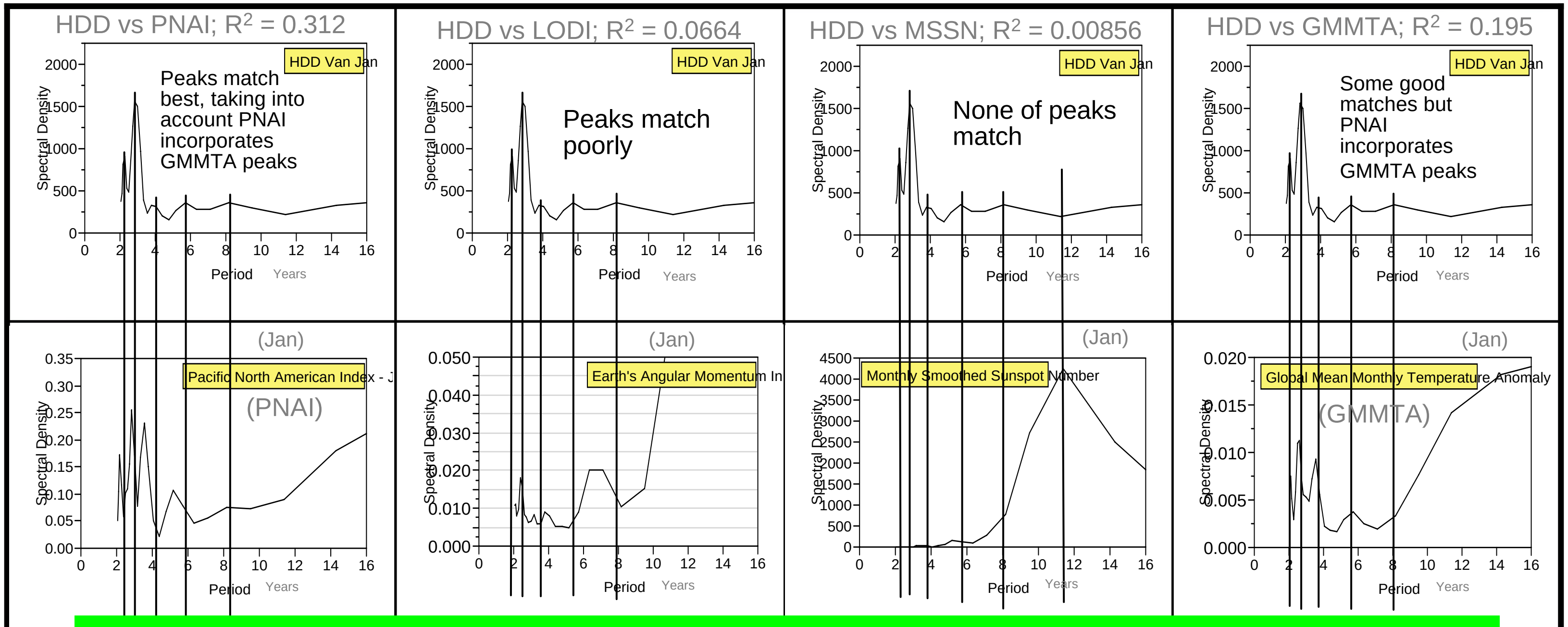


Spectral density scale varies between monthly charts: Period is more meaningful than spectral density magnitude for determining which components of regional climate system are influencing monthly HDDs at climate station.

Spectral analysis – month by month inspection

Method: For same month, compare each climate index spectrum to HDD spectrum (visually inspect peaks and check alignments). On this basis, decide which climate indices to use as inputs to probabilistic climate model. Bivariate analyses for station's HDD and climate indices (as discussed earlier) can reinforce decision. Alignments of period values can be checked exactly on periodogram tables (earlier slide) which tabulate the data from which spectral density charts are produced

R^2 values from bivariate analyses are shown at top each column (n = 57)



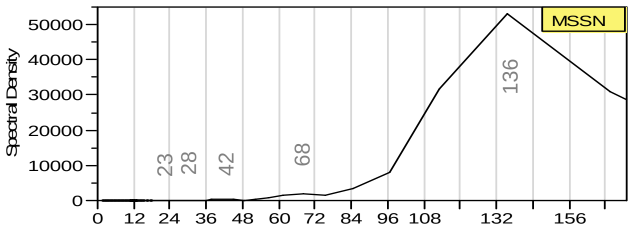
Conclusion: Chose to use only PNAI for the monthly HDD model for Vancouver (Jan). *Reasons: Best match of peaks; reinforced by relatively high R^2 value from earlier bivariate analyses.*

BC hydro FOR GENERATIONS

Roland V Wahlgren, Load Research Analyst
BC Hydro Customer Information Management—Load Analysis

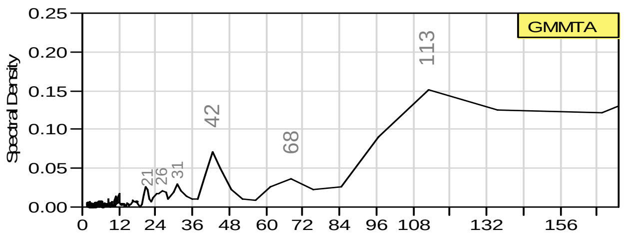
Spectra of climate indices 1953–2009 (1 of 4)

These spectra are from full set of data years, these are not spectra by month



Months

Vertical lines are at one year intervals



Months

Vertical lines are at one year intervals

Monthly Smoothed Sunspot Number (MSSN)

- External (to Earth) climate forcing input
- 136 month (approximately 11 years) cycle
- Periodogram (tabulation of spectral density) prominent peaks (months): 136, 68, 42, 28, and 23

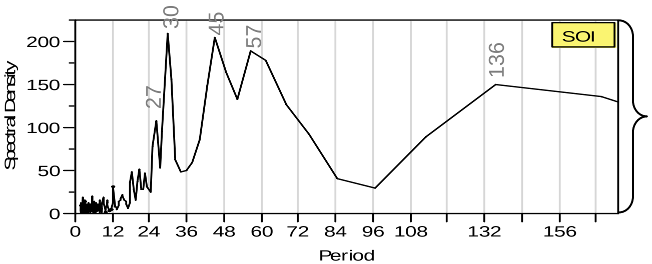
Peaks 136, 113, 68, 28, 26, 23, and 21 are apparent in some of the climate indices spectra shown on following slides

Global Mean Monthly Temperature Anomaly

- External and internal climate forcing input
- Strongest peak is for a 113 month (9 years) cycle
- Periodogram prominent peaks (months): 113, 68, 42, 31, 26 and 21
- External forcing related to solar cycle (peaks 68 and 42 also appear in solar cycle)
- Internal forcing related to human-driven climate change

Spectra of climate indices 1953–2009 (2 of 4)

These spectra are from full set of data years, these are not spectra by month



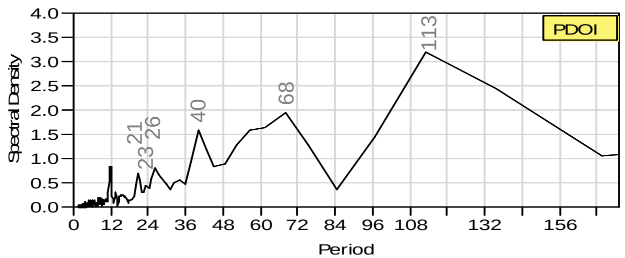
Months

Vertical lines are at one year intervals

Peaks 30 and 45 show up in some of the following climate indices

Southern Oscillation Index

- Periodogram prominent peaks (months): 136, 57, 45, 30, and 27
- Shows a peak from Monthly Smoothed Sunspot Number (136)



Months

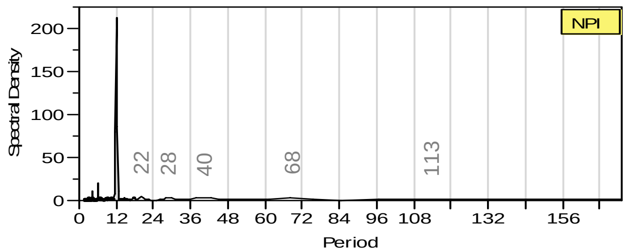
Vertical lines are at one year intervals

Pacific Decadal Oscillation Index

- Periodogram prominent peaks (months): 113, 68, 40, 26, 23, and 21
- Shows a peak from Global Mean Monthly Temperature Anomaly (113)

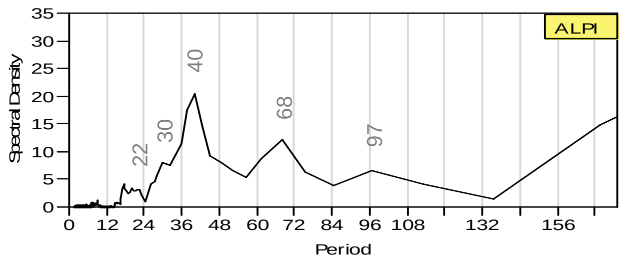
Spectra of climate indices 1953–2009 (3 of 4)

These spectra are from full set of data years, these are not spectra by month



Months

Vertical lines are at one year intervals



Months

Vertical lines are at one year intervals

North Pacific Index

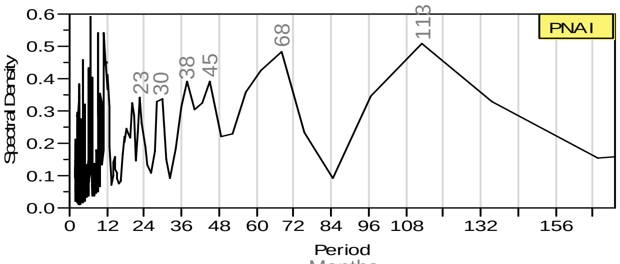
- Strong inter-annual peak (12.1 months)
- Periodogram prominent peaks (months): 113, 68, 40, 28, and 22
- Shows the 68 month peak from Monthly Smoothed Sunspot Number and Global Mean Monthly Temperature Anomaly

Aleutian Low Pressure Index

- Periodogram prominent peaks (months): 97, 68, 40, 30, and 22
- Shows the 68 month peak from Monthly Smoothed Sunspot Number and Global Mean Monthly Temperature Anomaly

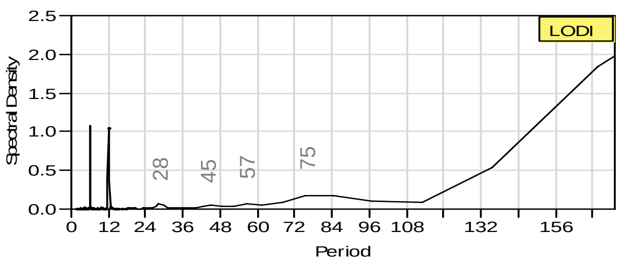
Spectra of climate indices 1953–2009 (4 of 4)

These spectra are from full set of data years, these are not spectra by month



Months

Vertical lines are at one year intervals



Months

Vertical lines are at one year intervals

Pacific North American Index

- Periodogram prominent peaks (months): 113, 68, 45, 38, 30, and 23
- Shows peaks from Monthly Smoothed Sunspot Number (68 and 23)
- Shows a peak from Global Mean Monthly Temperature Anomaly (113)
- Shows peaks from Southern Oscillation Index (45 and 30)

Earth's Angular Momentum Index

- Periodogram prominent peaks (months): 75, 57, 45, and 28
- Shows peaks from Southern Oscillation Index at 57 and 45 months
- Shows peak from Monthly Smoothed Sunspot Number at 28 months

Spectral peak summary for climate indices

PNAI is the only index to include peaks representing all three of MSSN, GMMTA, and SOI

Primary global climate processes | Secondary global climate processes | Continental-scale climate processes

Peak (months)	Peak (years)	Monthly Smoothed Sunspot Number	Global Mean Monthly Temperature Anomaly	Southern Oscillation Index	Length of Day (Earth's Angular Momentum) Index	Pacific Decadal Oscillation Index	North Pacific Index	Aleutian Low Pressure Index	Pacific North American Index
21			X			X			?
22							X	X	
23	1.9	X				X			X
26	2.2		X			X			
27	2.3			X					
28	2.3	X			X		X		
30	2.5			X				X	X
31	2.6		X						
38	3								X
40	3					X	X	X	
42	4	X	X						
45	4			X	X				X
57	5			X	X				
68	6	X	X			X	X	X	X
75	6				X	?			
97	8							X	?
113	9		X			X	X		X
136	11	X		X					

?

Cycles originate with these processes | These processes embed cycles from global processes

? = cycles apparently unrelated to global climate processes; further investigation in literature is required

BChydro FOR GENERATIONS

Roland V Wahlgren, Load Research Analyst
BC Hydro Customer Information Management—Load Analysis

GMMTA + SOI together accounted for greatest number of peaks in this set of indices; This was relevant to Acid Test No. 6 experiment, Slide 112.

Multivariate correlations for climate indices

	MSSN	GMMTA	SOI	LODI	PDOI	NPI	ALPI	PNAI
MSSN	1	-0.02	-0.01	0.04	0.01	-0.01	-0.04	0.03
GMMTA	-0.02	1	-0.17	-0.43	0.25	-0.13	0.37	0.19
SOI	-0.01	-0.17	1	-0.11	-0.39	0.14	-0.18	-0.15
LODI	0.04	-0.43	-0.11	1	0.01	-0.14	-0.16	-0.05
PDOI	0.01	0.25	-0.39	0.01	1	-0.17	0.43	0.35
NPI	-0.01	-0.13	0.14	-0.14	-0.17	1	-0.15	-0.43
ALPI	-0.04	0.37	-0.18	-0.15	0.43	-0.15	1	0.19
PNAI	0.03	0.19	-0.15	-0.05	0.35	-0.43	0.19	1

Correlation coefficients, R

0.nn = significant correlation at 0.05 level

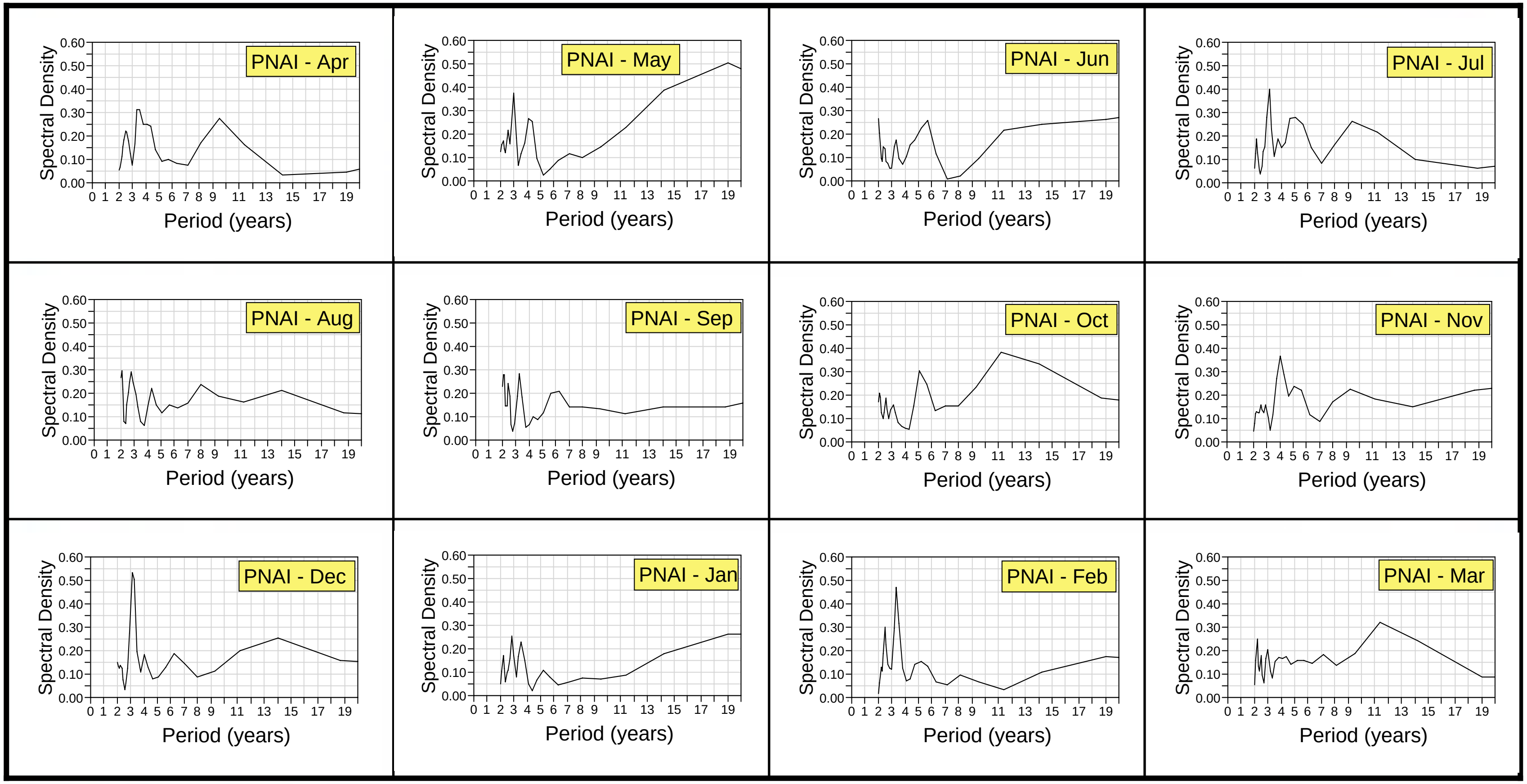
0.nn = not significant correlation at 0.05 level

ALPI = Aleutian Low Pressure Index
GMMTA = Global Monthly Mean Temperature Anomaly
LODI = Length of Day Index (Earth's Angular Momentum changes in response to major storm events usually related to El Nino/La Nina)
MSSN = Monthly Smoothed Sunspot Number
NPI = North Pacific Index
PDOI = Pacific Decadal Oscillation Index
PNAI = Pacific North American Index
SOI = Southern Oscillation Index

- Conclusion: Monthly smoothed sunspot number is independent of all the other inter-related indices which, unlike MSSN, operate entirely within the boundaries of the Earth's land-ocean-atmosphere systems

Climate index spectra can vary from month to month—PNAI example

Note: Spectral density scale was kept constant between charts. The scale provides relative values to compare peaks from month to month for the Pacific North American Index (PNAI)



Spectra for Monthly HDD Analyses

Comparing the spectra from monthly HDD and monthly climate indices guided decisions on inputs when setting up the ARIMA model transfer functions. The table shown here recorded the decisions about climate index inputs that were made during this project. ***During the winter heating months (Nov–Mar), the only climate input used in the model was PNAI.***

GMMTA = Global Monthly Mean Temperature Anomaly

LODI = Length of Day Index (Earth's Angular Momentum changes in response to major storm events usually related to El Nino/La Nina)

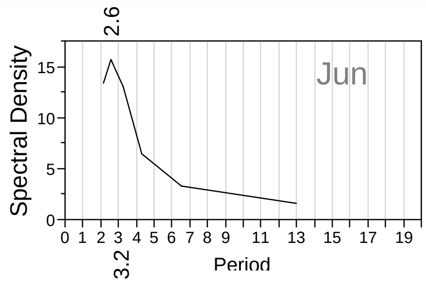
MSSN = Monthly Smoothed Sunspot Number

PNAI = Pacific North American Index

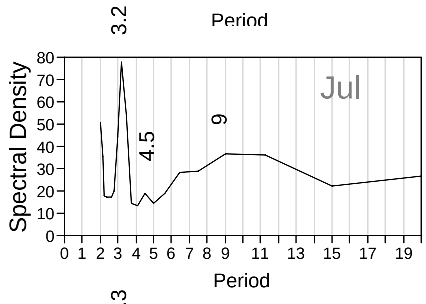
Month/Station	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Lower Mainland (Vancouver)	PNAI	PNAI	PNAI + GMMTA	PNAI	PNAI	PNAI + LODI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI
Vancouver Island (Victoria)	PNAI	PNAI + MSSN	PNAI + GMMTA	PNAI + LODI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI
Northern Region (Prince George)	PNAI + MSSN	PNAI + MSSN	PNAI + MSSN	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI
South Interior (Kamloops)	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI	PNAI

BC hydro FOR GENERATIONS

Spectra for monthly CDD analyses —Vancouver example (refer to table of peaks, slide 56)



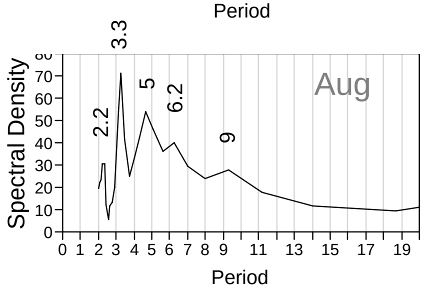
Peak at 2.6 years corresponds to GMMTA



Peak at 3.2 years is an unexplained cycle. See table, slide 58

Peak at 4.5 years corresponds to SOI and LODI

Peak at 9 years corresponds to GMMTA and PNAI



Peak at 2.2 years corresponds to GMMTA

Peak at 3.3 years is an unexplained cycle. See table, slide 58

Peak at 5 years corresponds to SOI

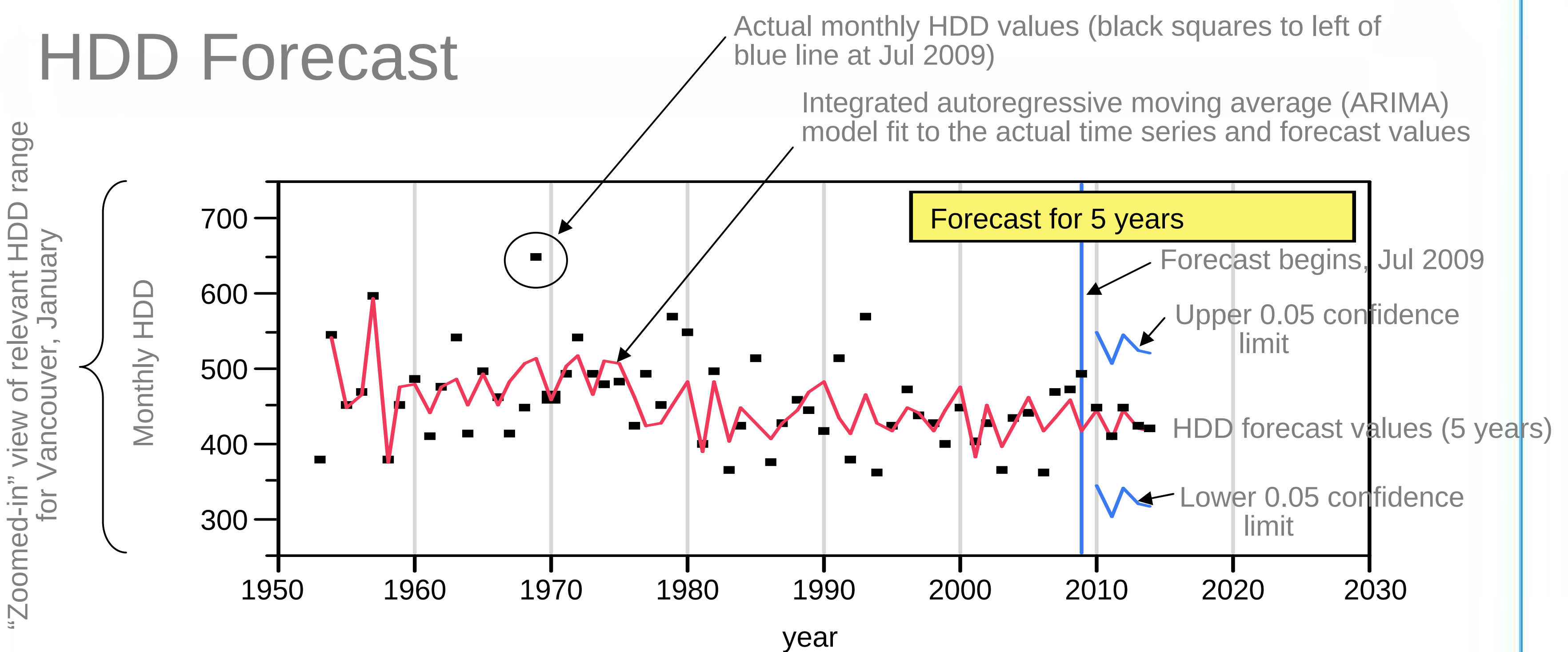
Peak at 6.2 years corresponds to MSSN, GMMTA, and PNAI

Peak at 9 years corresponds to GMMTA and PNAI

H-CDD Forecasts
for F0910 through F1314

Classification of months into Summer, Winter, and Shoulder seasons, according to number of heating degree days, was done using the hierarchical clustering tool in the JMP software. A separate classification was done for each fiscal year, yielding a five-year forecast for the seasons.

HDD Forecast



This example of a forecast chart is for HDD Vancouver, January. For each climate station, 12 different forecast models were produced, one for each month. A total of 60 monthly HDD forecast values were calculated for each climate station.

Lower Mainland Region Monthly HDD Forecast F0910–F1314

Summary of Vancouver Airport Forecast

HDD	ARIMA-based forecast for five fiscal years														
Month	**F0910**	**Up CL**	**Lo CL**	**F1011**	**Up CL**	**Lo CL**	**F1112**	**Up CL**	**Lo CL**	**F1213**	**Up CL**	**Lo CL**	**F1314**	**Up CL**	**Lo CL**
Apr	265	*313*	*217*	261	*309*	*213*	240	*290*	*190*	261	*315*	*207*	288	*344*	*232*
May	170	*218*	*122*	220	*268*	*172*	221	*271*	*171*	187	*239*	*135*	175	*227*	*123*
Jun	54	*100*	*8*	35	*81*	*-11*	53	*99*	*7*	81	*127*	*35*	65	*111*	*19*
Jul	24	*58*	*-10*	18	*52*	*-16*	23	*59*	*-13*	24	*60*	*-12*	23	*61*	*-15*
Aug	37	*69*	*5*	0	*34*	*-34*	9	*43*	*-25*	26	*60*	*-8*	32	*72*	*-8*
Sep	79	*133*	*25*	93	*151*	*35*	101	*161*	*41*	102	*162*	*42*	117	*179*	*55*
Oct	244	*280*	*208*	242	*282*	*202*	241	*281*	*201*	240	*280*	*200*	240	*280*	*200*
Nov	359	*437*	*281*	359	*437*	*281*	359	*437*	*281*	359	*437*	*281*	359	*437*	*281*
Dec	410	*486*	*334*	421	*497*	*345*	435	*511*	*359*	426	*502*	*350*	423	*499*	*347*
Jan	440	*550*	*330*	442	*552*	*332*	438	*548*	*328*	459	*571*	*347*	430	*542*	*318*
Feb	431	*481*	*381*	413	*463*	*363*	381	*431*	*331*	408	*464*	*352*	411	*471*	*351*
Mar	358	*394*	*322*	339	*379*	*299*	326	*366*	*286*	315	*355*	*275*	345	*387*	*303*
Total	**2871**	***3519***	***2223***	**2843**	***3505***	***2181***	**2827**	***3497***	***2157***	**2888**	***3572***	***2204***	**2908**	***3610***	***2206***

Summer

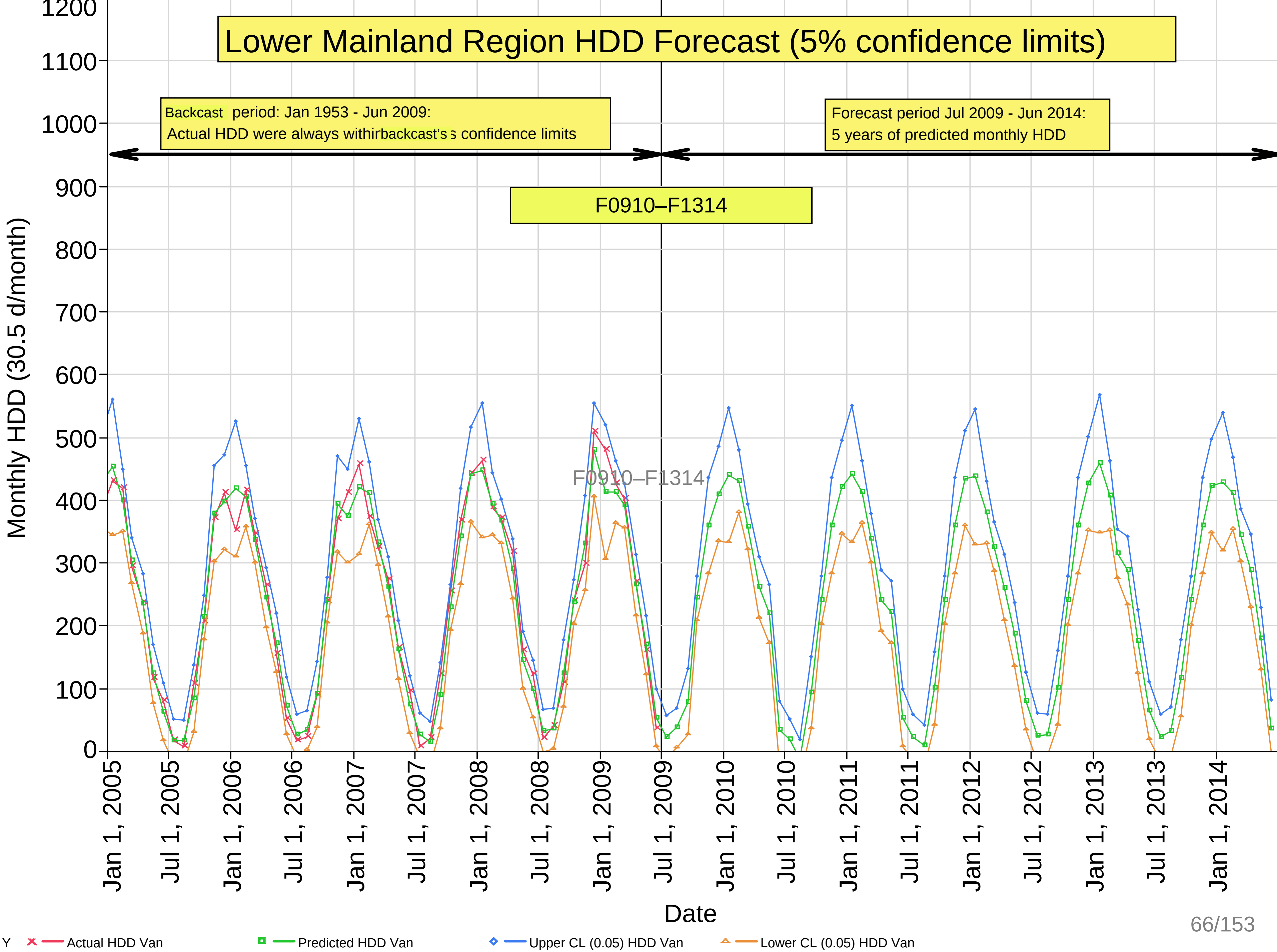
Winter

Shading denotes month in shoulder season

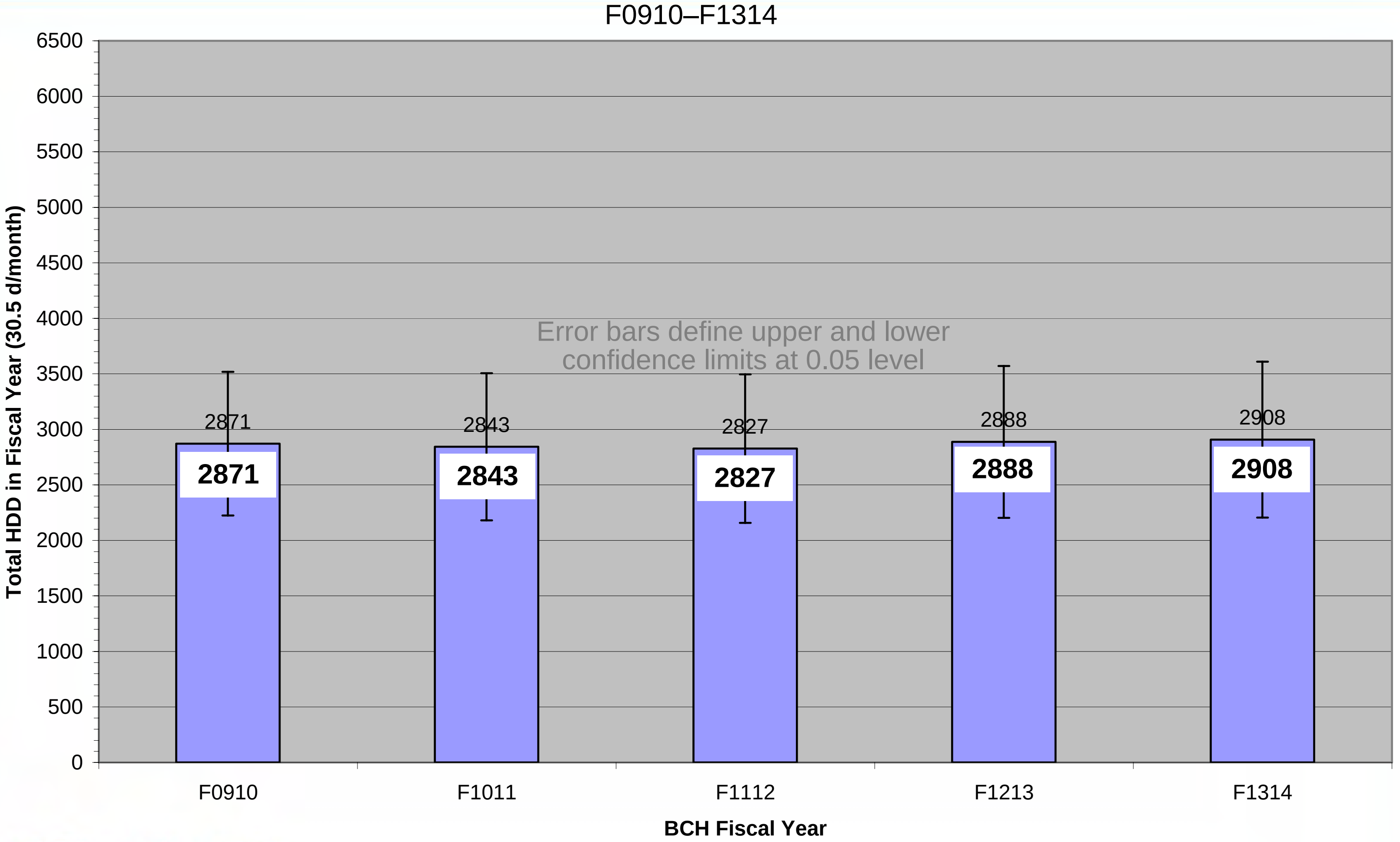
Up CL = Upper confidence limit (5%)
Lo CL = Lower confidence limit (5%)

Negative degree day values are interpreted as a forecast of zero

BC hydro FOR GENERATIONS


Lower Mainland Region HDD Forecast (5% confidence limits)
Backcast period: Jan 1953 - Jun 2009:
Actual HDD were always withirbackcast's s confidence limits
Forecast period Jul 2009 - Jun 2014:
5 years of predicted monthly HDD
F0910–F1314
F0910–F1314
Monthly HDD (30.5 d/month)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Jan 1, 2005
Jul 1, 2005
Jan 1, 2006
Jul 1, 2006
Jan 1, 2007
Jul 1, 2007
Jan 1, 2008
Jul 1, 2008
Jan 1, 2009
Jul 1, 2009
Jan 1, 2010
Jul 1, 2010
Jan 1, 2011
Jul 1, 2011
Jan 1, 2012
Jul 1, 2012
Jan 1, 2013
Jul 1, 2013
Jan 1, 2014
Date
Y
Actual HDD Van
Predicted HDD Van
Upper CL (0.05) HDD Van
Lower CL (0.05) HDD Van

Forecast Annual HDD
Vancouver Airport



Lower Mainland Region Monthly CDD Forecast F0910–F1314

Summary of Vancouver Airport Forecast

CDD	ARIMA-based forecast for five fiscal years														
Month	**F0910**	***Up CL***	***Lo CL***	**F1011**	***Up CL***	***Lo CL***	**F1112**	***Up CL***	***Lo CL***	**F1213**	***Up CL***	***Lo CL***	**F1314**	***Up CL***	***Lo CL***
Apr	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
May	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Jun	9	*9*	*9*	7	*21*	*-7*	7	*21*	*-7*	7	*21*	*-7*	7	*21*	*-7*
Jul	34	*60*	*8*	36	*62*	*10*	28	*54*	*2*	12	*36*	*-12*	45	*71*	*19*
Aug	19	*49*	*-11*	25	*55*	*-5*	24	*54*	*-6*	23	*53*	*-7*	26	*56*	*-4*
Sep	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Oct	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Nov	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Dec	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Jan	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Feb	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Mar	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Total	**62**	***118***	***6***	**68**	***138***	***-2***	**59**	***129***	***-11***	**42**	***110***	***-26***	**78**	***148***	***8***

Summer

Winter

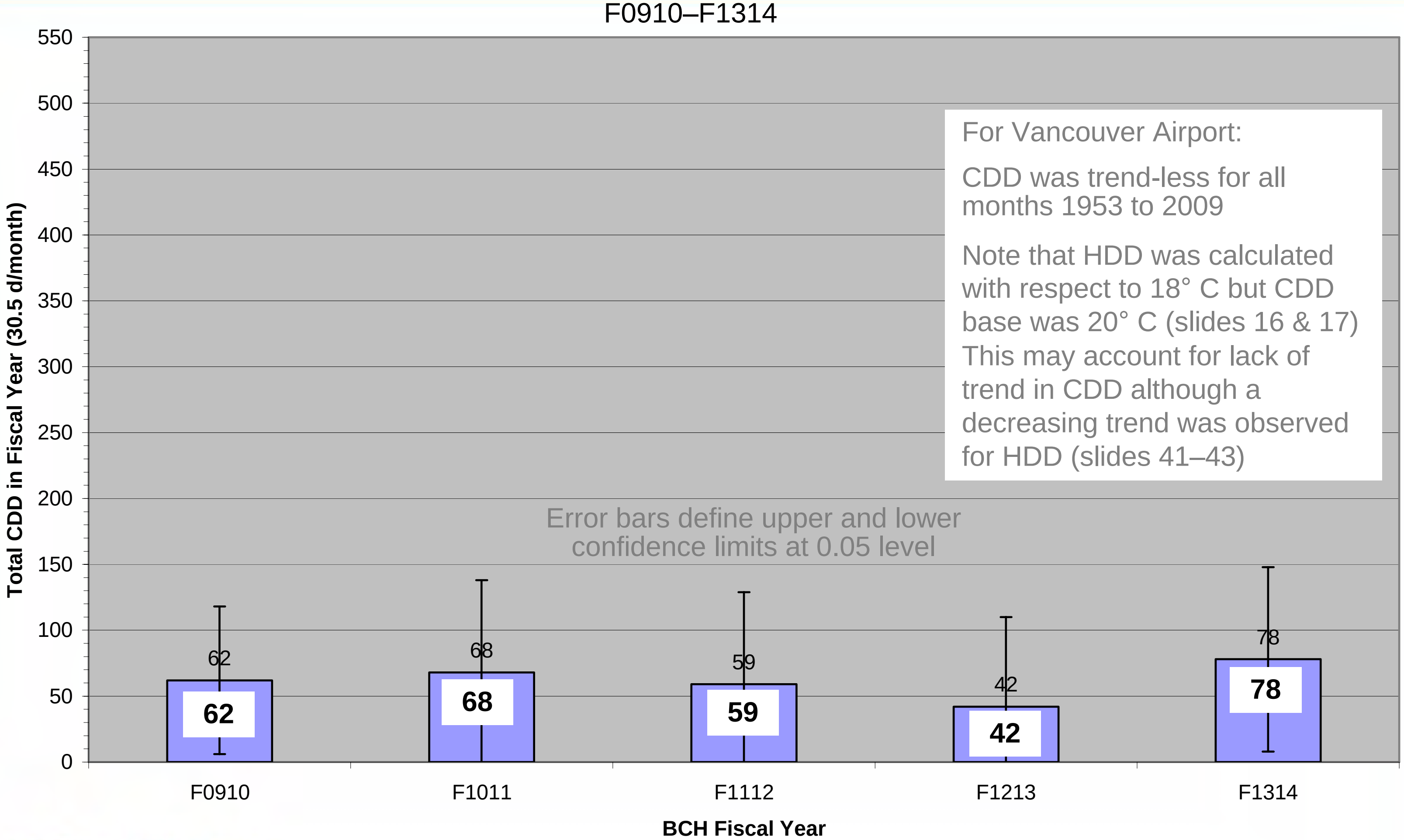
Shading denotes month in shoulder season

Up CL = Upper confidence limit (5%)
Lo CL = Lower confidence limit (5%)

Negative degree day values are interpreted as a forecast of zero

BC hydro FOR GENERATIONS

Forecast Annual CDD
Vancouver Airport



BC hydro FOR GENERATIONS

Vancouver Island Region Monthly HDD Forecast F0910–F1314

Summary of Victoria Airport Forecast

HDD	ARIMA-based forecast for five fiscal years														
Month	**F0910**	***Up CL***	***Lo CL***	**F1011**	***Up CL***	***Lo CL***	**F1112**	***Up CL***	***Lo CL***	**F1213**	***Up CL***	***Lo CL***	**F1314**	***Up CL***	***Lo CL***
Apr	292	*338*	*246*	267	*313*	*221*	258	*304*	*212*	251	*297*	*205*	268	*314*	*222*
May	189	*235*	*143*	252	*298*	*206*	268	*314*	*222*	212	*260*	*164*	228	*276*	*180*
Jun	88	*136*	*40*	105	*153*	*57*	75	*123*	*27*	96	*146*	*46*	113	*169*	*57*
Jul	41	*71*	*11*	63	*93*	*33*	70	*100*	*40*	41	*71*	*11*	56	*86*	*26*
Aug	87	*133*	*41*	45	*91*	*-1*	25	*73*	*-23*	0	*48*	*-48*	48	*98*	*-2*
Sep	127	*177*	*77*	138	*190*	*86*	131	*183*	*79*	130	*182*	*78*	130	*182*	*78*
Oct	257	*287*	*227*	227	*263*	*191*	248	*284*	*212*	270	*306*	*234*	261	*297*	*225*
Nov	346	*396*	*296*	396	*448*	*344*	322	*376*	*268*	365	*425*	*305*	370	*436*	*304*
Dec	467	*527*	*407*	417	*479*	*355*	450	*520*	*380*	457	*527*	*387*	438	*508*	*368*
Jan	427	*511*	*343*	433	*519*	*347*	433	*519*	*347*	430	*516*	*344*	432	*518*	*346*
Feb	400	*460*	*340*	382	*444*	*320*	405	*469*	*341*	407	*471*	*343*	393	*457*	*329*
Mar	364	*406*	*322*	334	*380*	*288*	334	*380*	*288*	353	*399*	*307*	359	*405*	*313*
Total	**3085**	***3677***	***2493***	**3059**	***3671***	***2447***	**3019**	***3645***	***2393***	**3012**	***3648***	***2376***	**3096**	***3746***	***2446***

Summer

Winter

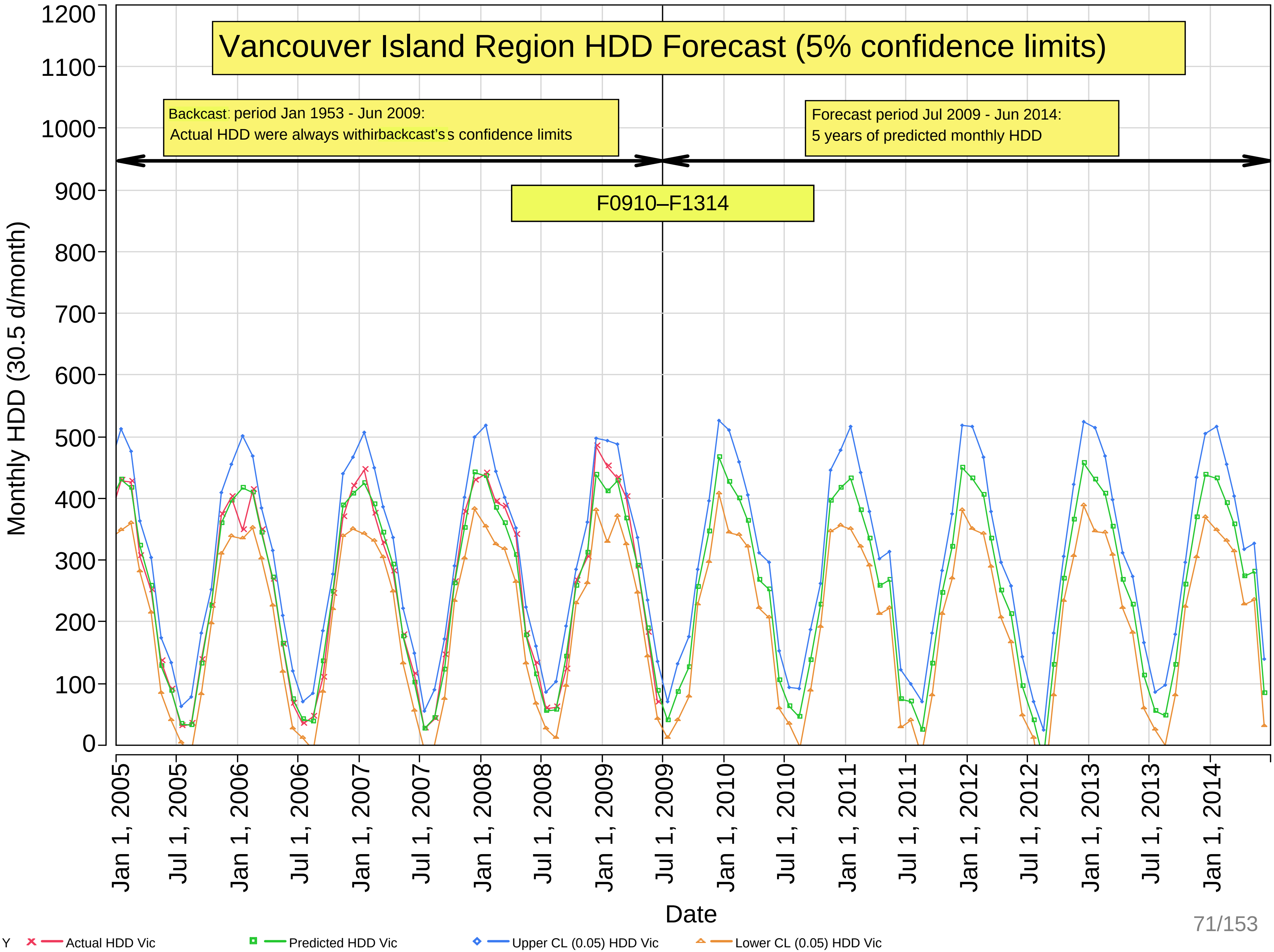
Shading denotes month in shoulder season

Up CL = Upper confidence limit (5%)
Lo CL = Lower confidence limit (5%)

Negative degree day values are interpreted as a forecast of zero

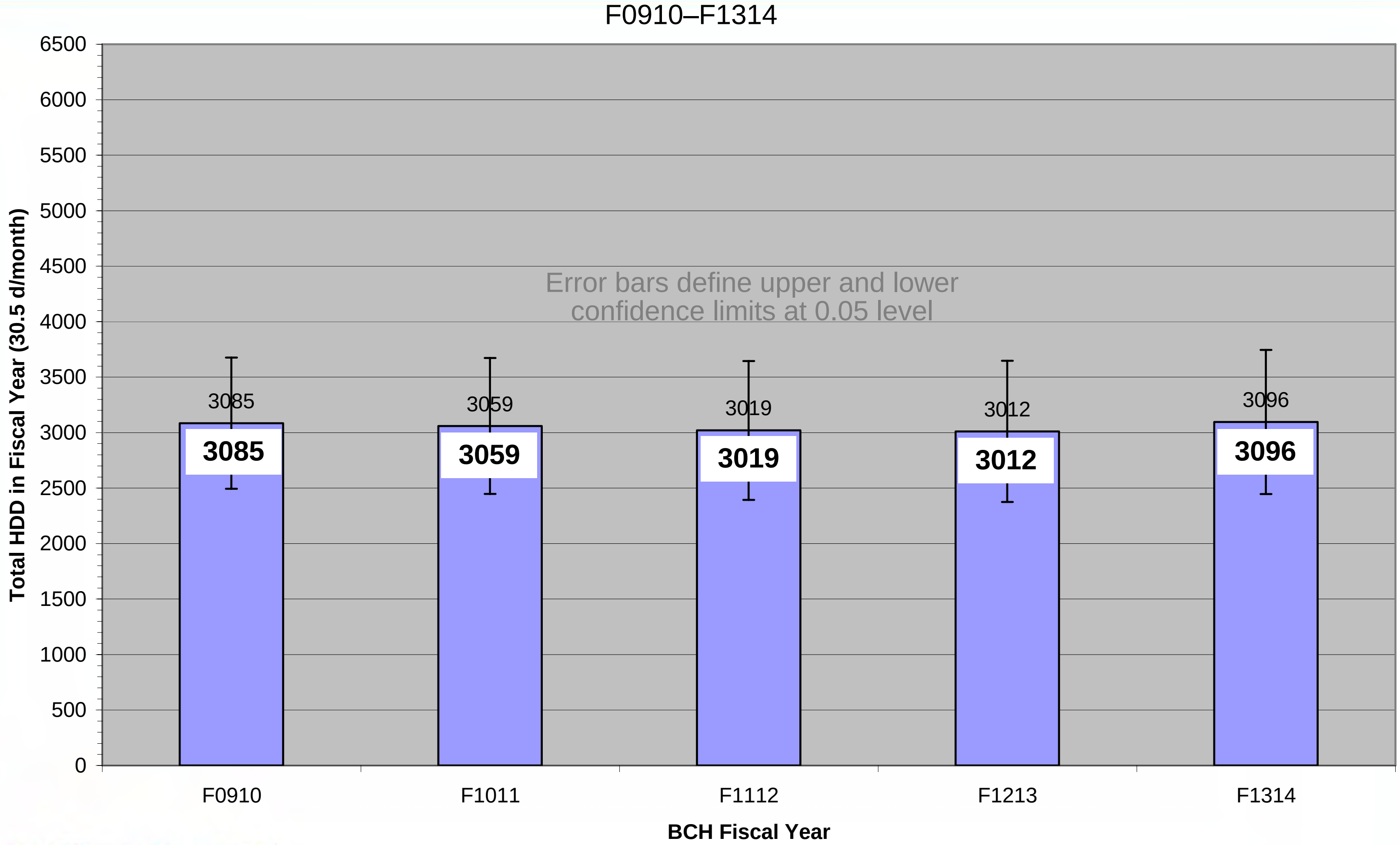
BC hydro FOR GENERATIONS

Roland V Wahlgren, Load Research Analyst
BC Hydro Customer Information Management—Load Analysis



Vancouver Island Region HDD Forecast (5% confidence limits)
Backcast: period Jan 1953 - Jun 2009:
Actual HDD were always withirbackcast’s s confidence limits
Forecast period Jul 2009 - Jun 2014:
5 years of predicted monthly HDD
F0910–F1314
Monthly HDD (30.5 d/month)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Jan 1, 2005
Jul 1, 2005
Jan 1, 2006
Jul 1, 2006
Jan 1, 2007
Jul 1, 2007
Jan 1, 2008
Jul 1, 2008
Jan 1, 2009
Jul 1, 2009
Jan 1, 2010
Jul 1, 2010
Jan 1, 2011
Jul 1, 2011
Jan 1, 2012
Jul 1, 2012
Jan 1, 2013
Jul 1, 2013
Jan 1, 2014
Date
Y
Actual HDD Vic
Predicted HDD Vic
Upper CL (0.05) HDD Vic
Lower CL (0.05) HDD Vic

Forecast Annual HDD
Victoria Airport



Roland V Wahlgren, Load Research Analyst
BC Hydro Customer Information Management—Load Analysis

Vancouver Island Region Monthly CDD Forecast F0910–F1314

Summary of Victoria Airport Forecasts

CDD	ARIMA-based forecast for five fiscal years														
Month	**F0910**	***Up CL***	***Lo CL***	**F1011**	***Up CL***	***Lo CL***	**F1112**	***Up CL***	***Lo CL***	**F1213**	***Up CL***	***Lo CL***	**F1314**	***Up CL***	***Lo CL***
Apr	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
May	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Jun	15	*15*	*15*	6	*18*	*-6*	6	*18*	*-6*	6	*18*	*-6*	6	*18*	*-6*
Jul	12	*32*	*-8*	12	*32*	*-8*	12	*32*	*-8*	12	*32*	*-8*	12	*32*	*-8*
Aug	5	*15*	*-5*	0	*12*	*-12*	0	*12*	*-12*	5	*17*	*-7*	13	*25*	*1*
Sep	2	*6*	*-2*	2	*6*	*-2*	2	*6*	*-2*	2	*6*	*-2*	2	*6*	*-2*
Oct	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Nov	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Dec	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Jan	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Feb	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Mar	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Total	**34**	***68***	***0***	**20**	***68***	***-28***	**20**	***68***	***-28***	**25**	***73***	***-23***	**33**	***81***	***-15***

Shading denotes month in shoulder season

Summer

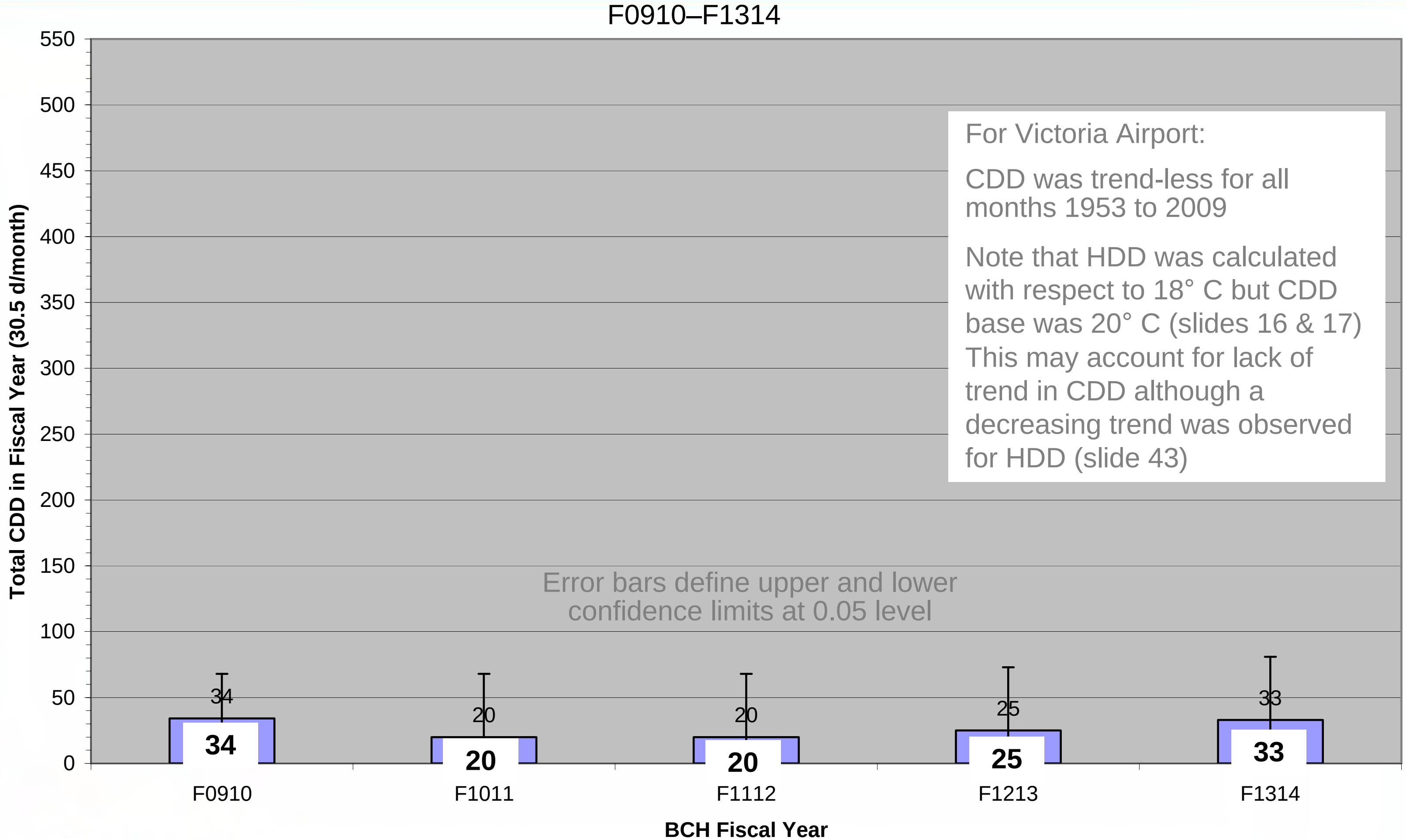
Winter

Up CL = Upper confidence limit (5%)
Lo CL = Lower confidence limit (5%)

Negative degree day values are interpreted as a forecast of zero

BChydro FOR GENERATIONS

Forecast Annual CDD
Victoria Airport



Roland V Wahlgren, Load Research Analyst
BC Hydro Customer Information Management—Load Analysis

Northern Region HDD Monthly Forecast F0910–F1314

Summary of Prince George Airport Forecast

HDD	ARIMA-based forecast for five fiscal years														
Month	**F0910**	***Up CL***	***Lo CL***	**F1011**	***Up CL***	***Lo CL***	**F1112**	***Up CL***	***Lo CL***	**F1213**	***Up CL***	***Lo CL***	**F1314**	***Up CL***	***Lo CL***
Apr	447	*501*	*393*	442	*496*	*388*	396	*450*	*342*	363	*417*	*309*	400	*454*	*346*
May	282	*366*	*198*	329	*413*	*245*	261	*345*	*177*	316	*404*	*228*	195	*283*	*107*
Jun	127	*205*	*49*	117	*195*	*39*	128	*206*	*50*	151	*229*	*73*	143	*221*	*65*
Jul	100	*146*	*54*	96	*146*	*46*	77	*127*	*27*	67	*119*	*15*	81	*133*	*29*
Aug	133	*197*	*69*	102	*168*	*36*	129	*197*	*61*	117	*187*	*47*	109	*185*	*33*
Sep	259	*323*	*195*	282	*350*	*214*	328	*404*	*252*	292	*368*	*216*	305	*381*	*229*
Oct	423	*459*	*387*	395	*437*	*353*	414	*458*	*370*	358	*402*	*314*	430	*476*	*384*
Nov	530	*612*	*448*	547	*629*	*465*	515	*603*	*427*	490	*578*	*402*	654	*752*	*556*
Dec	799	*959*	*639*	762	*922*	*602*	805	*965*	*645*	797	*957*	*637*	802	*962*	*642*
Jan	797	*1027*	*567*	737	*969*	*505*	740	*974*	*506*	886	*1126*	*646*	774	*1014*	*534*
Feb	654	*798*	*510*	574	*718*	*430*	684	*844*	*524*	658	*818*	*498*	641	*817*	*465*
Mar	598	*696*	*500*	571	*669*	*473*	576	*676*	*476*	582	*684*	*480*	580	*682*	*478*
Total	**5149**	***6289***	***4009***	**4954**	***6112***	***3796***	**5053**	***6249***	***3857***	**5077**	***6289***	***3865***	**5114**	***6360***	***3868***

Summer

Winter

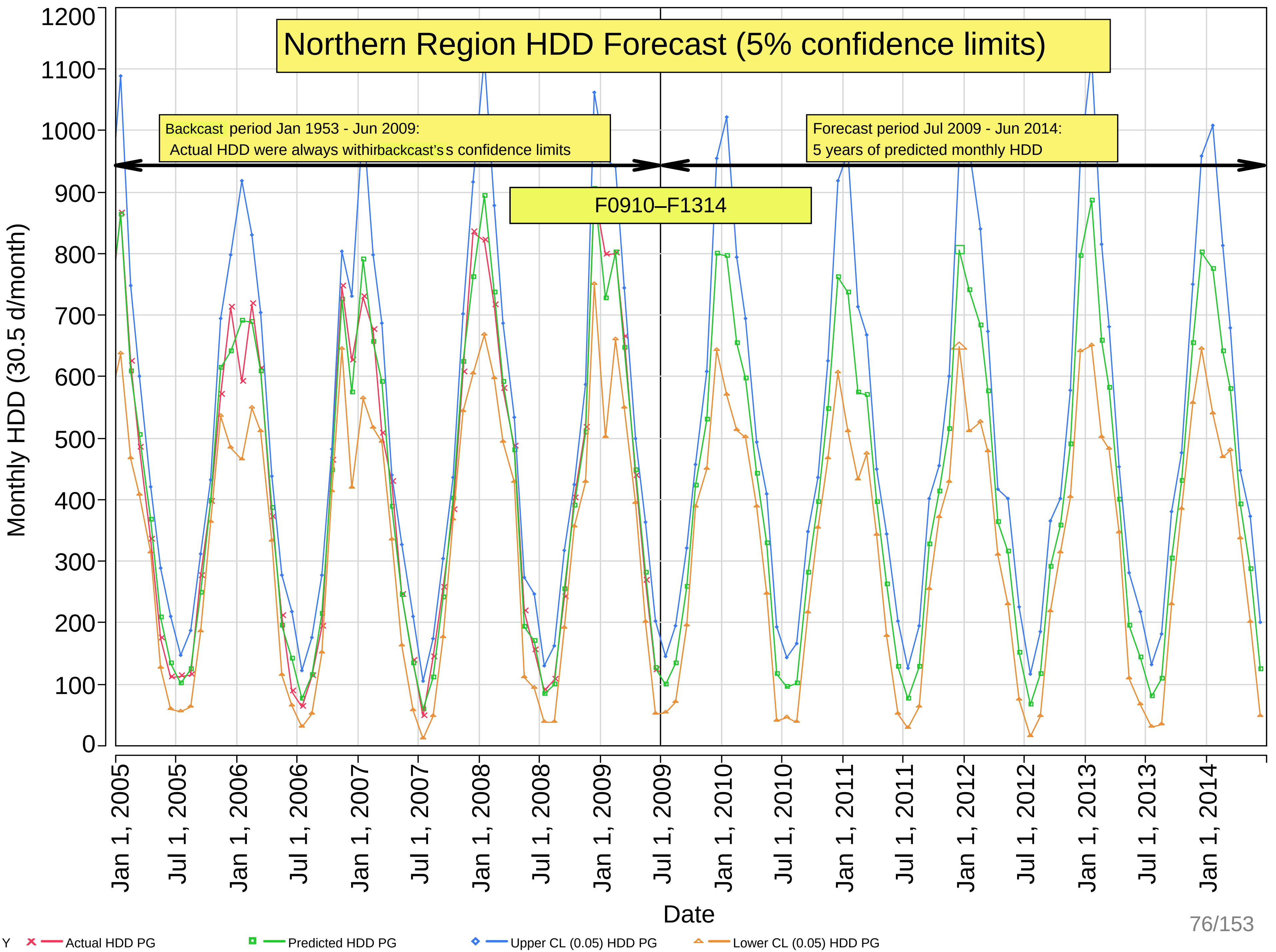
Shading denotes month in shoulder season

Up CL = Upper confidence limit (5%)
Lo CL = Lower confidence limit (5%)

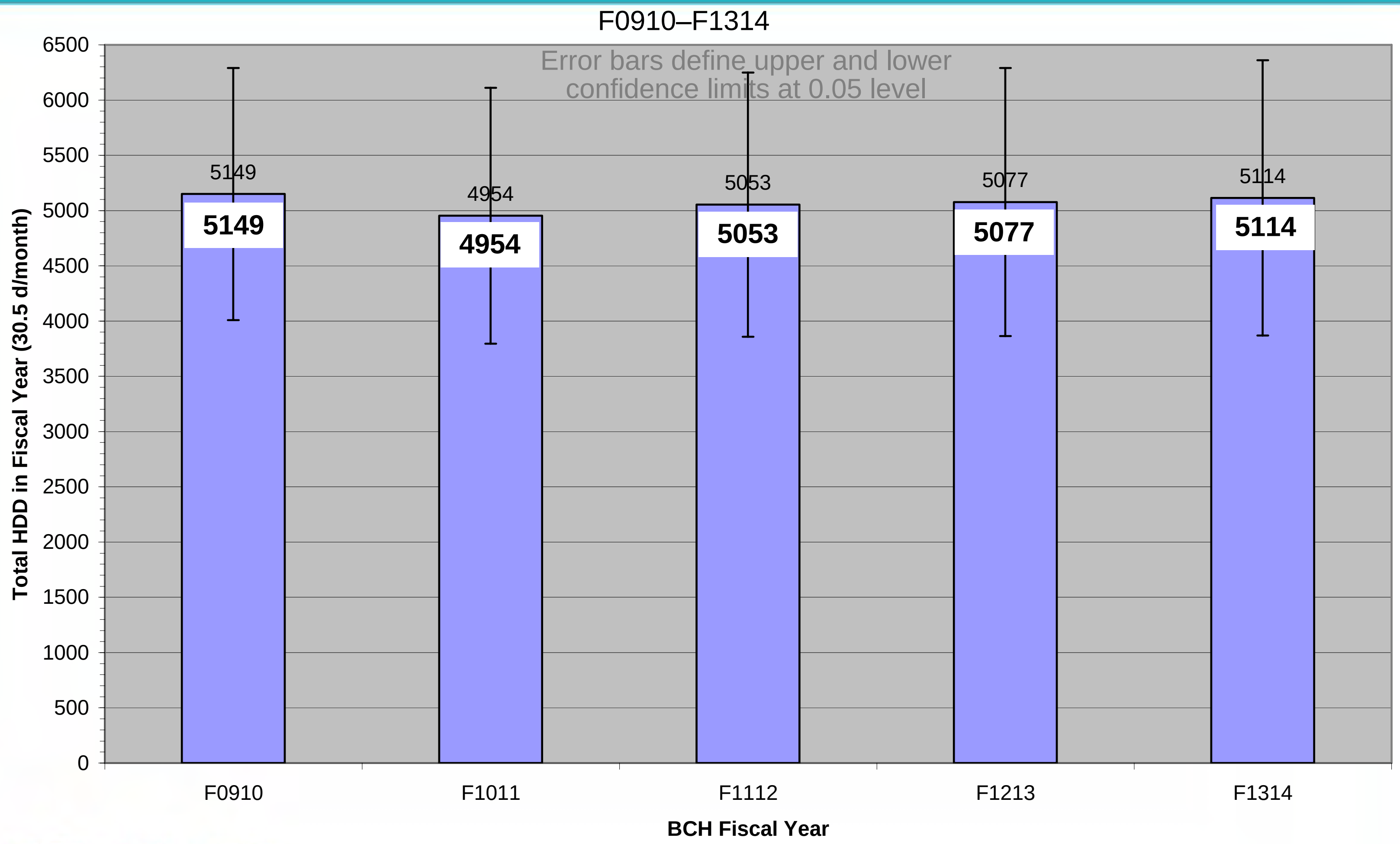
Negative degree day values are interpreted as a forecast of zero

BC hydro FOR GENERATIONS

Roland V Wahlgren, Load Research Analyst
BC Hydro Customer Information Management—Load Analysis


Northern Region HDD Forecast (5% confidence limits)
Backcast period Jan 1953 - Jun 2009:
Actual HDD were always withirbackcast's s confidence limits
Forecast period Jul 2009 - Jun 2014:
5 years of predicted monthly HDD
F0910–F1314
Monthly HDD (30.5 d/month)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Jan 1, 2005
Jul 1, 2005
Jan 1, 2006
Jul 1, 2006
Jan 1, 2007
Jul 1, 2007
Jan 1, 2008
Jul 1, 2008
Jan 1, 2009
Jul 1, 2009
Jan 1, 2010
Jul 1, 2010
Jan 1, 2011
Jul 1, 2011
Jan 1, 2012
Jul 1, 2012
Jan 1, 2013
Jul 1, 2013
Jan 1, 2014
Date
Y
Actual HDD PG
Predicted HDD PG
Upper CL (0.05) HDD PG
Lower CL (0.05) HDD PG

Forecast Annual HDD
Prince George Airport



BC hydro
FOR GENERATIONS

Roland V Wahlgren, Load Research Analyst
BC Hydro Customer Information Management—Load Analysis

Northern Region Monthly CDD Forecasts F0910–F1314

Summary of Prince George Airport Forecasts

CDD

	ARIMA-based forecast for five fiscal years														
Month	**F0910**	***Up CL***	***Lo CL***	**F1011**	***Up CL***	***Lo CL***	**F1112**	***Up CL***	***Lo CL***	**F1213**	***Up CL***	***Lo CL***	**F1314**	***Up CL***	***Lo CL***
Apr	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
May	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Jun	1	*1*	*1*	6	*20*	*-8*	6	*20*	*-8*	6	*20*	*-8*	6	*20*	*-8*
Jul	12	*34*	*-10*	12	*34*	*-10*	12	*34*	*-10*	12	*34*	*-10*	12	*34*	*-10*
Aug	9	*25*	*-7*	9	*25*	*-7*	9	*25*	*-7*	9	*25*	*-7*	9	*25*	*-7*
Sep	1	*3*	*-1*	1	*3*	*-1*	1	*3*	*-1*	1	*3*	*-1*	1	*3*	*-1*
Oct	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Nov	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Dec	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Jan	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Feb	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Mar	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*	0	*0*	*0*
Total	**23**	***63***	***-17***	**28**	***82***	***-26***	**28**	***82***	***-26***	**28**	***82***	***-26***	**28**	***82***	***-26***

Summer

Winter

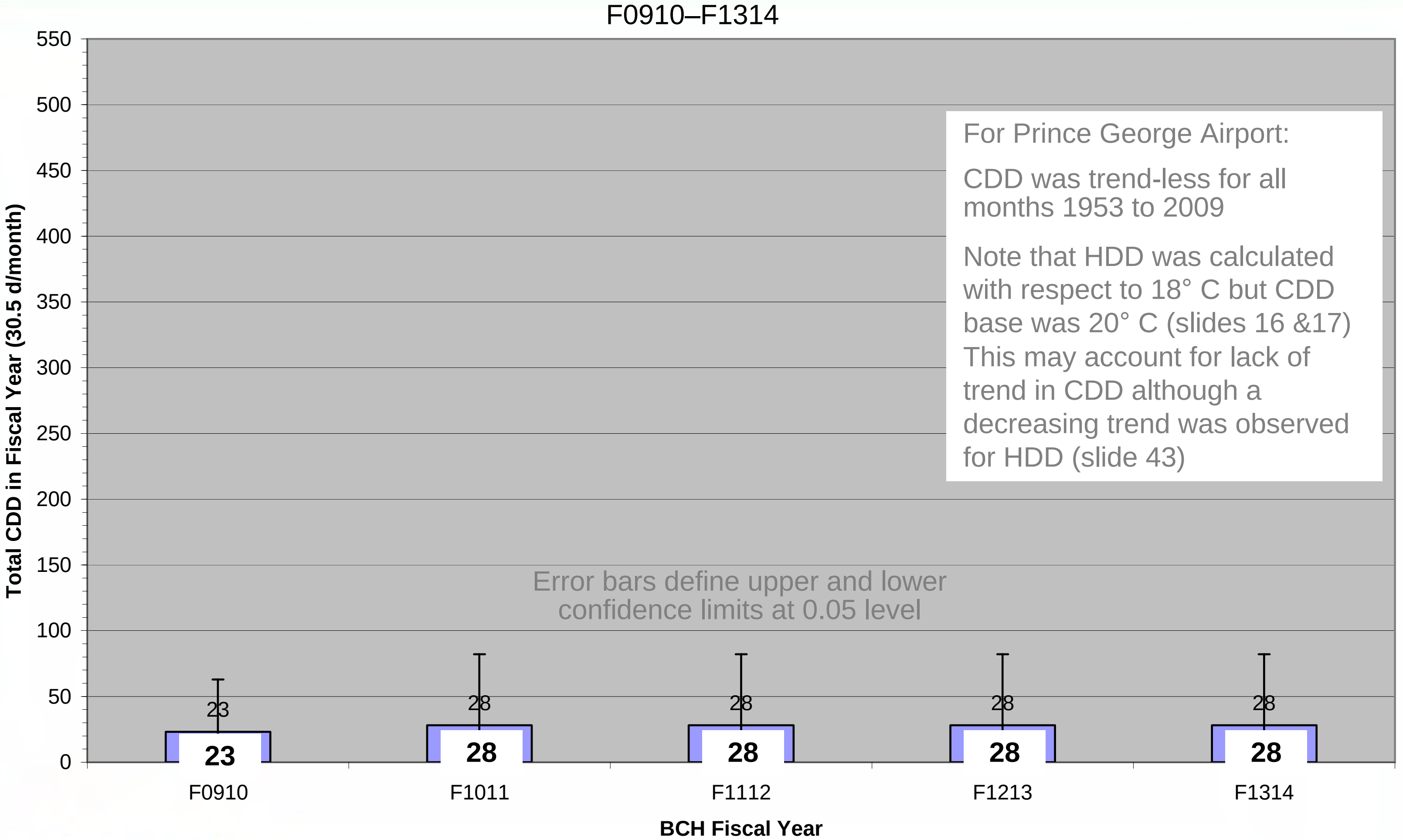
Shading denotes month in shoulder season

Up CL = Upper confidence limit (5%)
Lo CL = Lower confidence limit (5%)

Negative degree day values are interpreted as a forecast of zero

BC hydro
FOR GENERATIONS

Forecast Annual CDD
Prince George Airport



South Interior Region Monthly HDD Forecast F0910–F1314

Summary of Kamloops Airport Forecast

HDD	ARIMA-based forecast for five fiscal years														
Month	**F0910**	***Up CL***	***Lo CL***	**F1011**	***Up CL***	***Lo CL***	**F1112**	***Up CL***	***Lo CL***	**F1213**	***Up CL***	***Lo CL***	**F1314**	***Up CL***	***Lo CL***
Apr	263	*305*	*221*	181	*223*	*139*	206	*250*	*162*	171	*233*	*109*	290	*352*	*228*
May	103	*261*	*-55*	188	*346*	*30*	39	*197*	*-119*	103	*273*	*-67*	224	*424*	*24*
Jun	13	*49*	*-23*	58	*94*	*22*	39	*81*	*-3*	43	*89*	*-3*	43	*93*	*-7*
Jul	0	*10*	*-10*	3	*21*	*-15*	6	*28*	*-16*	5	*31*	*-21*	7	*33*	*-19*
Aug	2	*16*	*-12*	0	*18*	*-18*	11	*29*	*-7*	6	*28*	*-16*	6	*28*	*-16*
Sep	98	*98*	*98*	47	*47*	*47*	57	*57*	*57*	19	*19*	*19*	43	*43*	*43*
Oct	460	*522*	*398*	283	*345*	*221*	242	*366*	*118*	191	*315*	*67*	139	*263*	*15*
Nov	449	*449*	*449*	500	*500*	*500*	502	*502*	*502*	456	*456*	*456*	450	*450*	*450*
Dec	575	*701*	*449*	465	*591*	*339*	550	*676*	*424*	652	*778*	*526*	631	*757*	*505*
Jan	585	*719*	*451*	602	*762*	*442*	626	*786*	*466*	626	*786*	*466*	626	*786*	*466*
Feb	614	*700*	*528*	565	*651*	*479*	388	*474*	*302*	306	*392*	*220*	350	*436*	*264*
Mar	339	*385*	*293*	414	*460*	*368*	421	*467*	*375*	339	*385*	*293*	426	*472*	*380*
Total	**3501**	***4215***	***2787***	**3306**	***4058***	***2554***	**3087**	***3913***	***2261***	**2917**	***3785***	***2049***	**3235**	***4137***	***2333***

Summer

Winter

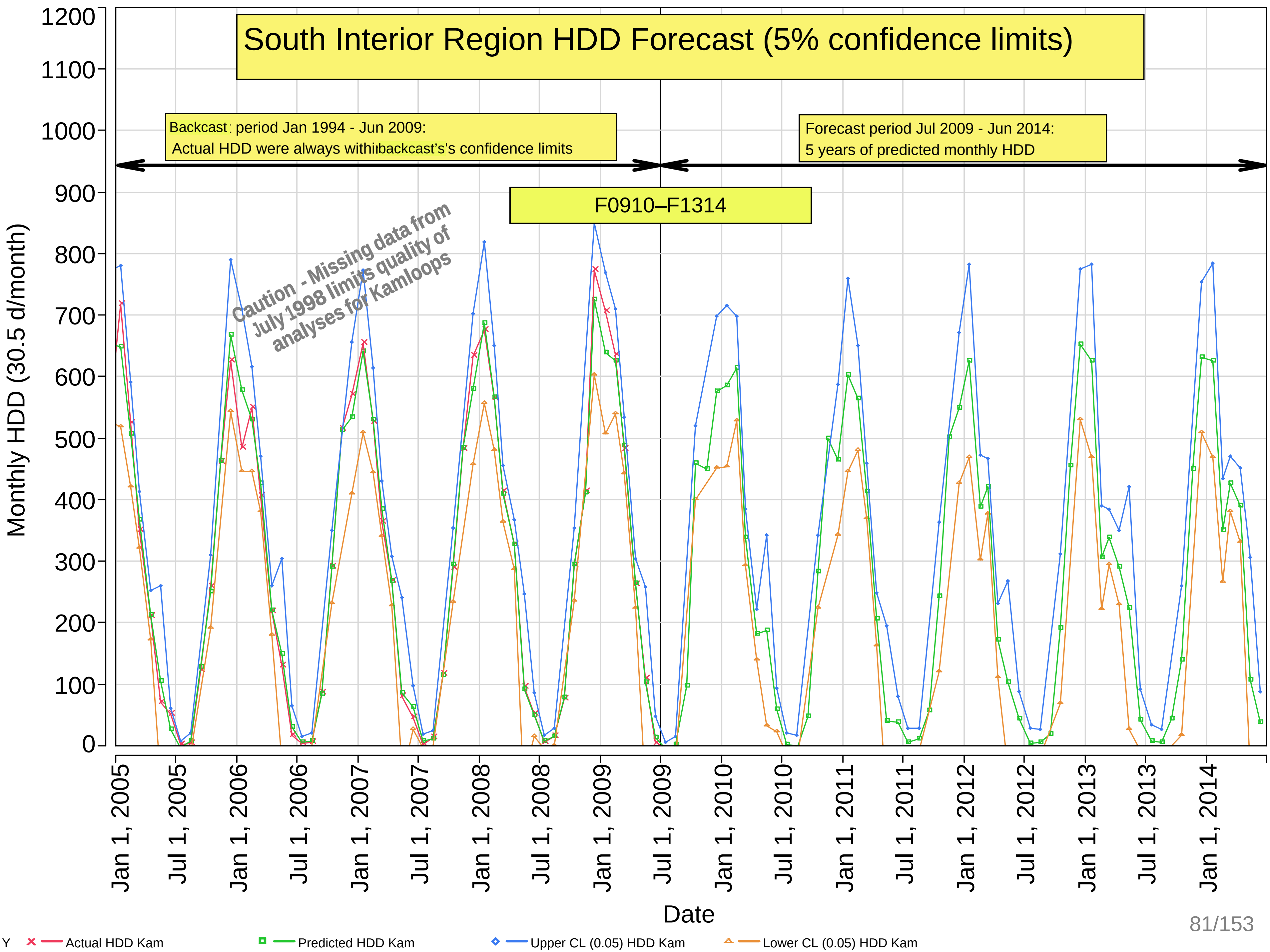
Shading denotes month in shoulder season

Up CL = Upper confidence limit (5%)
Lo CL = Lower confidence limit (5%)

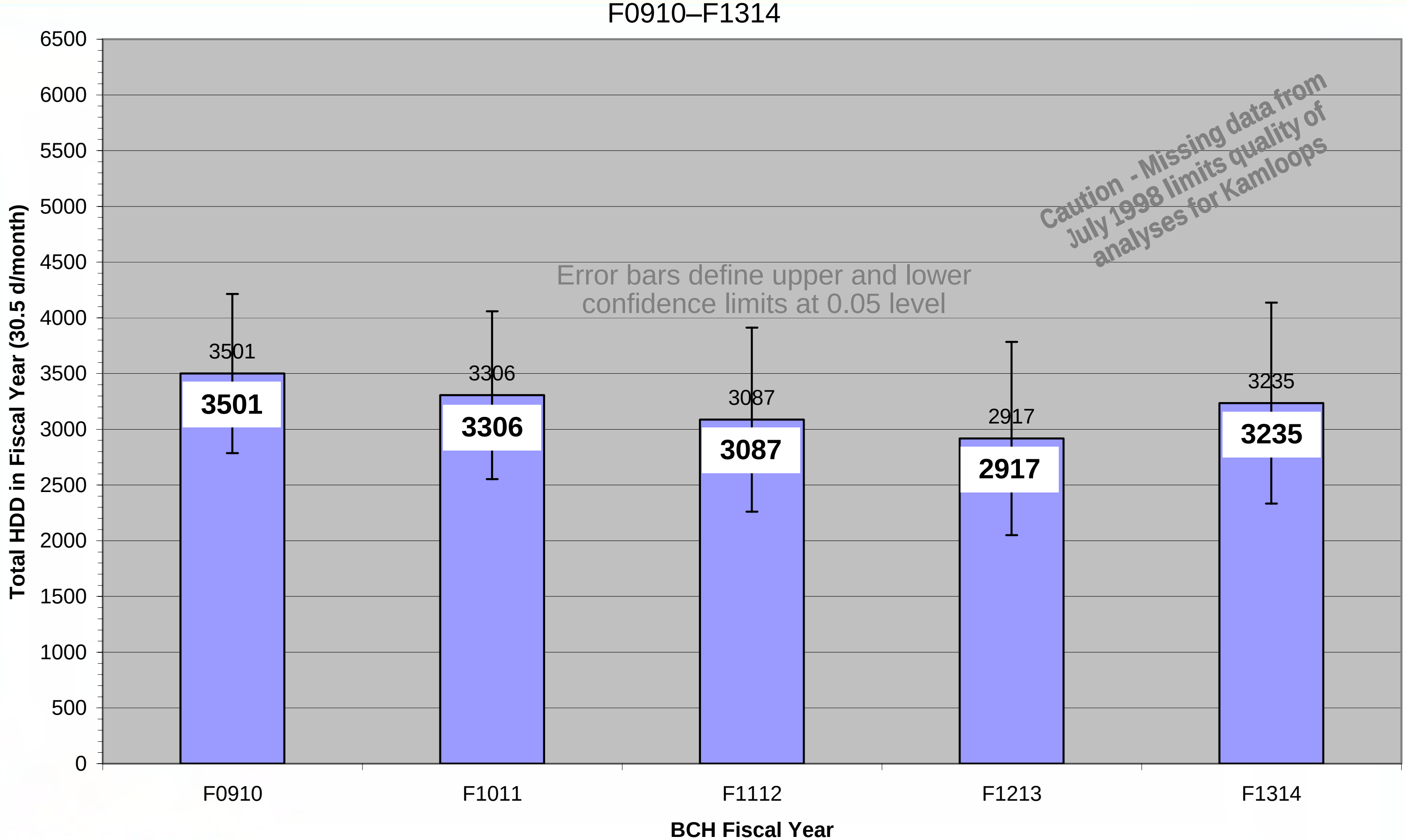
Negative degree day values are interpreted as a forecast of zero

Caution - Missing data from July 1998 limits quality of analyses for Kamloops

BC hydro
FOR GENERATIONS


South Interior Region HDD Forecast (5% confidence limits)
Backcast: period Jan 1994 - Jun 2009:
Actual HDD were always withi backcast's's confidence limits
Forecast period Jul 2009 - Jun 2014:
5 years of predicted monthly HDD
F0910–F1314
Caution - Missing data from July 1998 limits quality of analyses for Kamloops
Monthly HDD (30.5 d/month)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Jan 1, 2005
Jul 1, 2005
Jan 1, 2006
Jul 1, 2006
Jan 1, 2007
Jul 1, 2007
Jan 1, 2008
Jul 1, 2008
Jan 1, 2009
Jul 1, 2009
Jan 1, 2010
Jul 1, 2010
Jan 1, 2011
Jul 1, 2011
Jan 1, 2012
Jul 1, 2012
Jan 1, 2013
Jul 1, 2013
Jan 1, 2014
Date
Y
Actual HDD Kam
Predicted HDD Kam
Upper CL (0.05) HDD Kam
Lower CL (0.05) HDD Kam

Forecast Annual HDD
Kamloops Airport



BC hydro FOR GENERATIONS

Roland V Wahlgren, Load Research Analyst
BC Hydro Customer Information Management—Load Analysis

South Interior Region Monthly CDD Forecast F0910–F1314

Summary of Kamloops Airport Forecasts

Identical values for each fiscal year are an artifact of analyses with smaller 1994-2009 data set which required simpler ARIMA models

CDD — ARIMA-based forecast for five fiscal years

Month	F0910	Up CL	Lo CL	F1011	Up CL	Lo CL	F1112	Up CL	Lo CL	F1213	Up CL	Lo CL	F1314	Up CL	Lo CL
Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	12	12	12	11	25	-3	11	25	-3	11	25	-3	11	25	-3
Jun	51	51	51	45	93	-3	45	93	-3	45	93	-3	45	93	-3
Jul	120	188	52	120	188	52	120	188	52	120	188	52	120	188	52
Aug	97	161	33	97	161	33	97	161	33	97	161	33	97	161	33
Sep	12	38	-14	12	38	-14	12	38	-14	12	38	-14	12	38	-14
Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**292**	**450**	**134**	**285**	**505**	**65**	**285**	**505**	**65**	**285**	**505**	**65**	**285**	**505**	**65**

Summer

Winter

Shading denotes month in shoulder season

Up CL = Upper confidence limit (5%)
Lo CL = Lower confidence limit (5%)

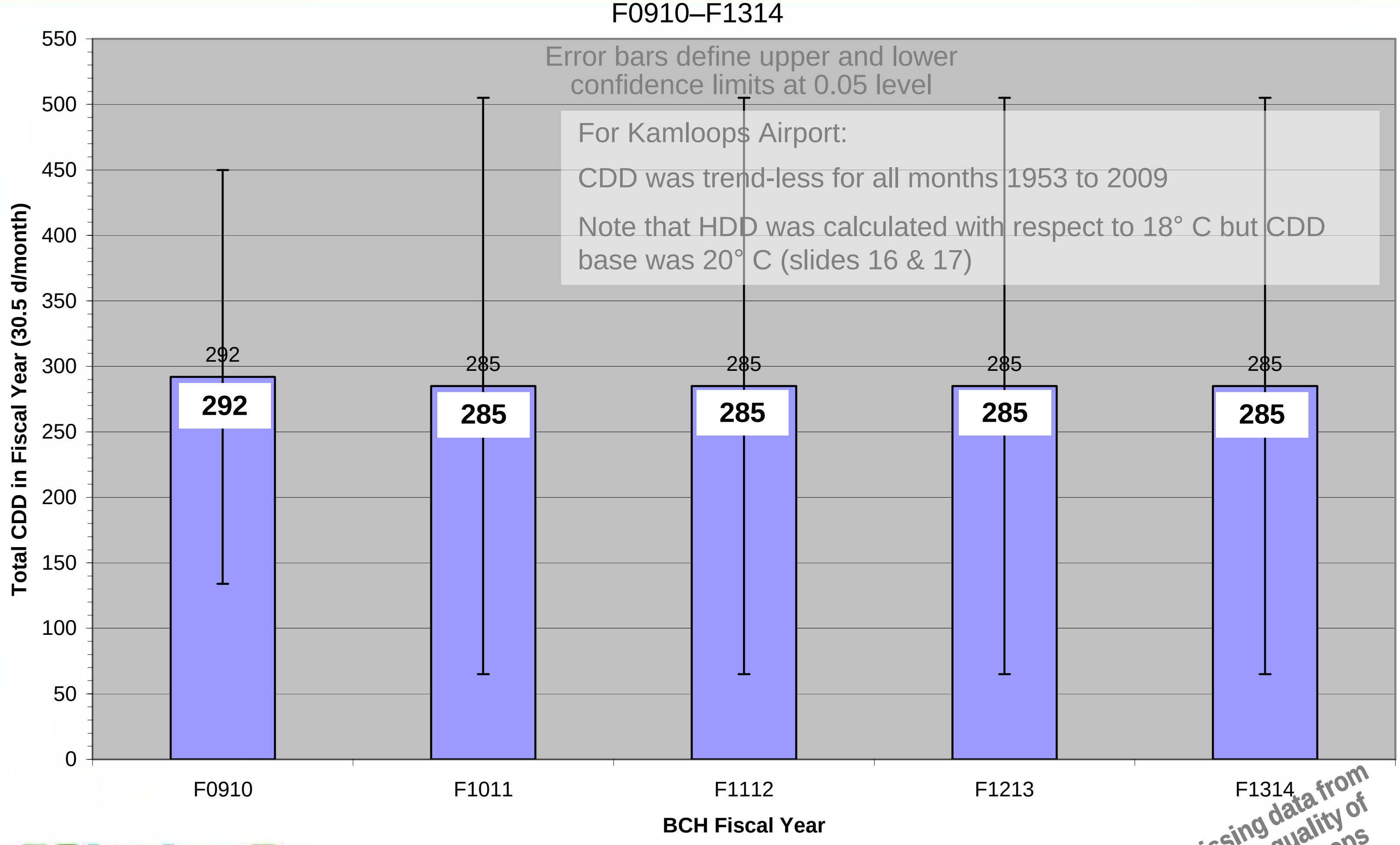
Negative degree day values are interpreted as a forecast of zero

Caution - Missing data from July 1998 limits quality of analyses for Kamloops

BC hydro FOR GENERATIONS

Roland V Wahlgren, Load Research Analyst
BC Hydro Customer Information Management—Load Analysis

Forecast Annual CDD
Kamloops Airport



Caution - Missing data from July 1998 limits quality of analyses for Kamloops

Roland V Wahlgren, Load Research Analyst
BC Hydro Customer Information Management—Load Analysis

BC hydro FOR GENERATIONS