Regional Empirical Seasonal Climate Prediction (REP) in Western Canada

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1. Introduction

In the socio-economic sectors affected by climate variability and change, seasonal climate predictions have great potential value. Moreover, climate predictions of temperature and precipitation are used for derived hydrological forecasts; for example, in Hamlet et. al. (2002) for the Columbia Basin.

The Meteorological Service Canada of Environment Canada (EC) has national responsibility for operational climate forecasting in Canada. Likewise, in the US the National Centers for Environmental Prediction (NCEP) and the International Research Institute (IRI) produce seasonal forecasts, and several experimental prediction centers and regional science centers of NOAA develop or utilize seasonal predictions such as the Center for Science and the Earth System at the University of Washington.

Although the climate signal is usually considered global, end-users need to reinterpret national forecasts for regional applications. Several years ago the Canadian Institute for Climate Studies (CICS) developed a commercial forecast product that would target specific regions and economic sectors. The Regional Empirical Prediction (REP) was a multiple linear regression method for seasonal forecasts of temperature and precipitation in Canada. Based on that experience, this paper documents the methodology, and presents some verification statistics to test the concept of regional climate predictions in Western Canada.

The REP method developed by CICS produced experimental forecasts for 47 target regions in Canada and the US (Appendix 1). From this set, 22 target regions across Canada were used for two commercial products. In this paper we are will focus on 11 target regions in Western Canada (Figure 1).

The commercial products that contained the REP forecast were:

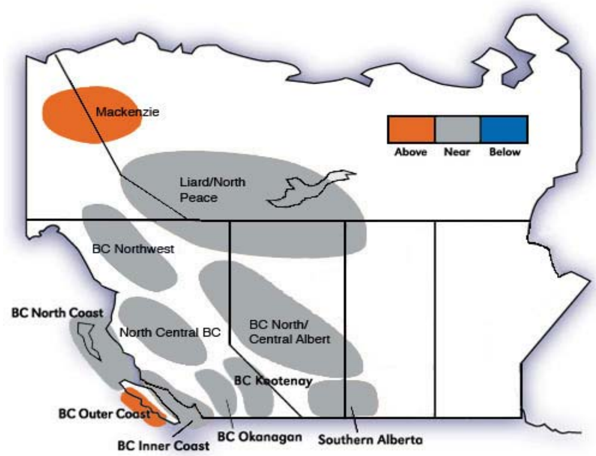

Figure 1 - Map of the REP seasonal forecast of temperature for the 2006-07 winter season for selected target regions in Western Canada.

- *Seasonal Climate Predictions* (1996-2003) six-page temperature and precipitation predictions across Canada as full colour maps of categorical predictions, tables of departures from normal, and a narrative description of upcoming seasonal temperature and precipitation trends over a three season (9-month) outlook period.

- *Seasonal Climate Bulletin* (1998-2005) four-page narrative, issued quarterly, which outlined the climatological basis for current seasonal climate trends, and included categorical predictions of temperature and precipitation across Canada.

- *Online seasonal climate predictions* (1996-2006) tables of predicted departures from normal and categorical predictions available via internet subscription only (included custom regions and derived parameters).

2. Examining user needs for regional empirical seasonal climate predictions

The motivation for the REP forecast originated at a workshop in June 1995 that was convened by CICS to assess objective seasonal climate predictions (Bernard, Kurz, and Dawson, 1995). Several leading climate experts as well as attendees from user groups were present.

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The objectives of the workshop were to:

1. Determine the degree to which seasonal climate conditions are predictable beyond natural variability;
2. Describe requirements of different user communities for objective seasonal climate predictions; and
3. Sketch out a range of potential test studies with which to assess the utility of seasonal extended range forecasts.

The Workshop concluded that several economic sectors needed skillful regional predictions accompanied by interpretation that included both knowledge of the skill and guidelines for appropriate use.

Motivated by the recommendations of the workshop, a regional empirical seasonal climate prediction (REP) was developed as a product for multiple users (Lee, 1996). In addition, site-specific predictions were developed for clients in the sectors of gas distribution, power generation, and alfalfa farming. These predictions were accompanied with guidance and access to the known level of skill.

The REP attempted to address three known concerns and factors identified in the case studies: a *disappointment* in forecast skill of traditional seasonal forecasts, a *discrepancy* in spatial resolution between what was available and needed, and a *deficiency* in utility of forecast variables.

- *Disappointment in forecast skill* – Future improvement in forecast skill is expected using dynamic numerical models. Empirical (statistical) methods provide a standard to surpass.

- *Discrepancy in geographical resolution* – Predictions are needed that are sensitive to continental and global signals, but are applicable to the region of interest to a specific user.

- *Deficiency in utility* – The primary variables of temperature and precipitation are not sufficient for many users. In many cases a relatively simple transformation makes a climate forecast more useful; e.g., degree-days instead of temperature, or an estimate of frost-free days.

From a user's viewpoint, "skill" of the forecast is paramount, since financial gains and losses depend on the forecast. Even with low skill, uncertain or biased forecasts, some advantage may still be gained by utilizing forecasts (with other factors) frequently and repeatedly. However, the current skill and the constraint of the annual cycle may require decades to achieve benefits. This length of time is incompatible with most investors' patience.

Another approach is to compensate for low skill by hedging the decision with another investment that would compensate when the forecast decision was wrong, but not be too costly when the decision was right. An investment in weather futures is an example.

In any case, useful "skill" depends on more than accuracy. For example, aviation forecasts are evaluated in terms of Accuracy, Bias, and Consistency (ABC; Sammartino, 2005; Rodenhuis, 2006) which is equally applicable for uncertain seasonal climate forecasts. For the seasonal forecast, the *accuracy* of categorical forecasts may be described by *percent correct* (or other skill score). The user is protected from *bias* by presenting anomalies from the climatology (normal), or is warned of bias by *reliability diagrams* that show historical bias. Finally, repeated forecasts of the same season with different lead times hold the opportunity to examine *consistency*. Little work has been done to improve forecast consistency.

The REP methodology incorporated procedures to address each of the ABCs as follows:

- *Accuracy* – focused on target regions with similar climatology and response to a climate signal

- *Bias* – used anomalies from climatology

- *Consistency* – repeated forecasts for the same season with different lead times. (In addition, consistency is forced by averaging the output over 4 adjacent projections.)

The REP served its largest number of users when it was sold as a commercial product from 1996-2006. While no longer sold as a product, a review of the strengths and weaknesses of a client-oriented prediction method provides some valuable lessons. In this paper, we will present results for temperature in Western Canada.

3. Methodology

The REP was developed originally for temperature and precipitation for target regions in Western Canada. It was then expanded across Canada and also used for custom client regional and site-specific predictions including the US Pacific Northwest. The history of the development of the REP included an interesting investigation into the use of neural networks (Hourston, 1997). However, multiple linear regression (MLR) was more robust, comprehensible and superior in each of the ABCs of skill listed above. The neural network prediction itself was used as an MLR predictor but performance was roughly comparable with and without it as a predictor. The use of the neural network prediction was discontinued in order to reduce cost of computations and facilitate interpretation of regression predictors (Murdock, 1999).

3.1. Predictors and data

Choice of predictors

The REP forecast was built on multiple linear regression (MLR) using fifteen predictor variables. The predictors were determined following a literature review (Lee, 1995) of the relationships between seasonal temperature and precipitation anomalies in Canada and the Pacific sea surface temperatures (SSTs).

Lee divided the principal sources of influence on the climate of Western Canada (following Leather et. al., 1991) into two categories:

1. atmospheric tropical-extratropical interaction induced by tropical ocean variability (e.g., El Nino), and
2. atmospheric variability produced within the extratropics itself and teleconnections within the mid-latitudes (e.g. Pacific North American pattern).

Lee (1995, 1996) presented justification for incorporating Pacific SSTs and some additional predictors into REP. Two tropical Pacific SSTs represent the influence of El Nino/Southern Oscillation (ENSO), and three mid-latitude SSTs at key locations represent the teleconnections. Anomalies were selected at 1° grid boxes at the recommended locations (with the exception of Nino3.4 which is a larger region). Using SSTs from key locations isolates the SST signal and reduces the number of predictors required by the MLR. In addition to the global predictors (Pacific SSTs), two regional predictors were used: persistence and antecedent precipitation. The final predictor is referred to as an analogue predictor; it is the composite response to ENSO. All predictors are shown in Figure 2. The seasons predicted are defined as Spring (M,A,M), Summer (J,J,A), Fall (S,O,N), and Winter (D,J,F).

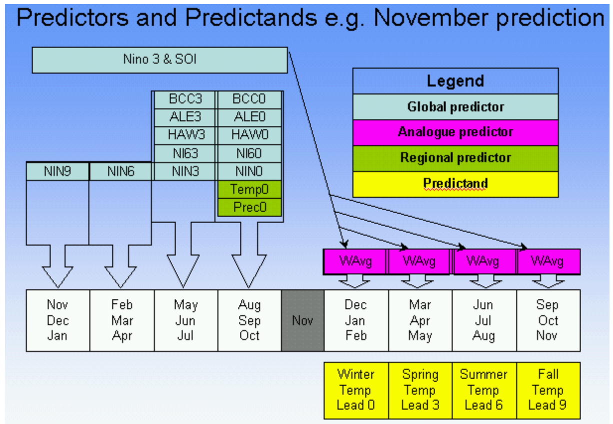

Figure 2 - Schematic of predictors and predictands (example for REP issued in mid-November – data available to end of October).

Description of predictors

The five SST locations were termed BCC, ALE, HAW, NIN, and NI6. The locations of the Pacific SST predictors are as follows:

1. BC Coast (BCC): 50°N 130°W
2. Aleutian low (ALE): 40°N 170°W
3. Hawaii (HAW): 30°N 165°W
4. Nino 6 (NI6): 0°N 145°E
5. Nino 3.4 (NIN): average over 120°W-170°W and 5°S- 5°N

BCC measures the most recent state of teleconnection to the tropical event, plus mid-latitude influences of air masses. ALE and HAW measure the strength of the PNA teleconnection to mid-latitude seasonal climate. Finally, NIN is the Nino3.4 anomaly, which measures the state of the ENSO, while NI6 assists with indicating the strength of the event from conditions in the western tropical Pacific.

Each Pacific SST predictor is a three-month average because the forcing, like the response, is expected to be seasonal. Predictors are obtained from consecutive, non-overlapping periods (chosen to reduce the degree of linear dependence of the predictors on each other). Predictors are denoted by the number of months of lag between the three-month period and the last month of available data. For example, to represent the SST at Nino3.4, four predictors (NIN0, NIN3, NIN6, and NIN9) represent the lag time of 0, 3, 6, and 9 months between SST anomalies and the month in which the prediction was prepared. For the remaining Pacific SSTs, only the two most recent periods were used as predictors at each location (BCC0, BCC3, ALE0, ALE3, HAW0, HAW3, NI60, and NI63).

The regional temperature persistence predictor (Temp0) consists of the average temperature anomaly for the region of the most recent three months. The regional antecedent precipitation anomaly (Prec0) is included as a proxy for soil moisture that would be expected to influence vegetation and the surface energy and moisture balance.

The final predictor (WAvg) is the regional composite response to ENSO (for the season being predicted). It is the weighted average response, rather than an average. The weighting was applied according to an "analogue" score (Chen, 1997) for similarity of the most recent 12 months of the ENSO signal. This analogue score was based on the RMSE and correlation coefficients for the past year's Nino 3 and Southern Oscillation Index (SOI) as compared to historical years. (A recent example of best analogue scores is shown in Figure 8 for the recent winter season.)

Data sources

The following data sources were used for development of MLR coefficients and cross-validation of predictions:

1. Temperature and Precipitation: Meteorological Service of Canada Archive
2. NIN, Nino 3, and SOI: Climate Prediction Center, NOAA
3. NI6 (1950-1982): Reynold's Optimum Interpolation SST dataset (Reynolds and Smith, 1994)
4. BCC, ALE, HAW (1950-1982): Comprehensive Ocean Atmosphere Data Set (COADS) ship-based observations (Woodruff et. al., 1993)
5. BCC, ALE, HAW, NI6 (1983-1993): National Meteorological Center satellite analysis

For carrying out the operational predictions, the following sources of current data were used:

1. Antecedent temperature and precipitation: Meteorological Service of Canada
2. NIN, Nino 3, and SOI: Climate Prediction Center, NOAA
3. BCC, ALE, HAW, NI6: National Meteorological Center satellite analysis

3.2. Selection of predictors

MLR coefficients were selected independently for each region, season, and lead. An automated system for selection of predictors in each case was developed (Park, 1998). The selection of predictors is an iterative process that does not simply choose the most skillful model. Rather, the system mimics expert climate and statistical knowledge and includes steps to remove predictors with cross-correlation, considers the degrees of freedom available to the regression, and is robust to outliers (Davidson, 1999).

3.3. Prediction lead time

The REP seasonal predictions were issued every month for each of the seasons defined earlier. Thus, each season is predicted twelve times, with a lead of between (*) to 11 months, as shown in Table 1. (The example in Figure 2 is an example from the row, *November*, in Table 1.) The months used for the lag 0 and lag 3 predictors are also indicated (Lag 6 and 9 predictors are the two preceding three-month periods, but are not shown in the table.)

3.4. Predictands

The forecast variables for the commercial prediction product were temperature and precipitation and were the primary output of the REP methodology. An evaluation of temperature skill is made in Section 4.

REP issued	Predictor months		Prediction lead (months) for the season predicted			
	Lag 3	Lag 0	Spr	Sum	Fall	Win
Jan	$J^{-1}AS$	$O^{-1}ND$	1	4	7	10
Feb	$A^{-1}SO$	$N^{-1}DJ$	0	3	6	9
Mar	$S^{-1}ON$	$D^{-1}JF$	*	2	5	8
Apr	$O^{-1}ND$	JFM	10	1	4	7
May	$N^{-1}DJ$	FMA	9	0	3	6
Jun	$D^{-1}JF$	MAM	8	*	2	5
Jul	JFM	AMJ	7	10	1	4
Aug	FMA	MJJ	6	9	0	3
Sep	MAM	JJA	5	8	*	2
Oct	AMJ	JAS	4	7	10	1
Nov	MJJ	ASO	3	6	9	0
Dec	JJA	SON	2	5	8	*

Table 1 - Months used for predictors and lead-time for each season predicted. The superscript (-1) indicates a starting month of three-month period in calendar year preceding month prediction is issued, and (*) indicates a prediction prepared at beginning of predicted season (albeit not using any data from the predicted season).

3.5. Derived predictands

Several additional parameters were developed with the intention that they would be more directly applicable for many users. These predictions of derived variables were available only through custom subscriptions:

- number of days of rainfall above .2 mm, 5 mm, 10 mm, 25 mm
- greatest one-day snowfall, number of days of snowfall above several thresholds, number of days with snow depth above several thresholds
- extreme max/min temperature, number of days with frost, number of days with temperature below –10°C, frost free season
- various degree days, sunshine, visibility, wind, relative humidity, soil moisture
- number of days with freezing rain, thunderstorms, hail, fog, haze

Two examples of cross-validated skill (1953-1992) are shown below. Figure 3 shows confidence in prediction skill for 3 months lead prediction (in August) for winter of the number of days of snowfall above 5 cm. Figure 4 shows skill for a zero lead prediction (in November) for winter of the number of days with thunderstorms in winter. As shown in the legend, confidence in prediction skill is assigned based on a confidence level test for significance of difference in skill of REP above the 33% expected for climatology (near normal). For example, 95th percentile confidence level ($p<.05$) shown in Figure 4 for BC Inner Coast corresponds to a cross-validated percent correct skill score of 47%. Further discussion of the skill and application of these extensions to the REP forecast are beyond the scope of this paper.

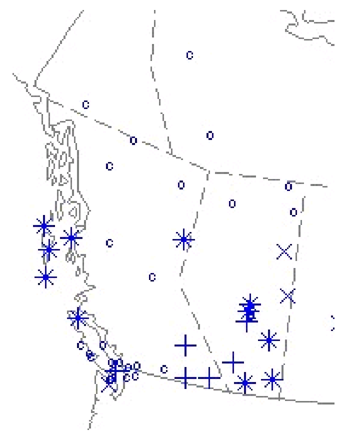

Figure 3: Forecast confidence in August of number of days with snowfall above 5 cm in following winter (DJF). (See legend in Fig 4 for interpretation of

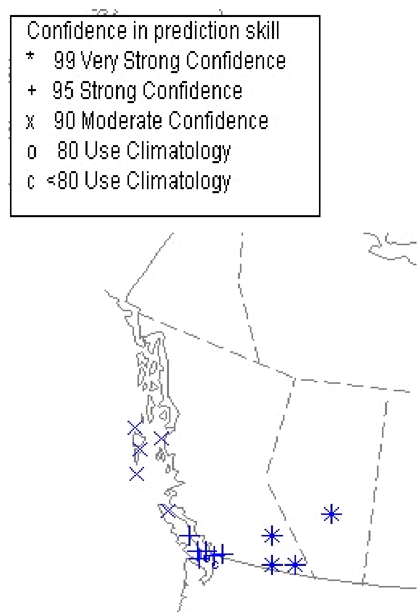

Figure 4 – Forecast confidence in November of number of days with thunderstorms in the following winter (DJF)

4. Results for seasonal temperature forecasts

The historical skill results were compiled for REP using cross validated hindcasts. The results for the selected target regions of Figure 1 are presented below. We limit this presentation to the winter season (although there is no impediment to an analysis of all seasons). Similar results from the operational seasonal forecast for a 25-year period from Environment Canada were applied in the target regions and presented for comparison. For one region (Kootenay) the effect of increasing lead-time was examined.

Subsequently, the forecast results for REP during the 11 years of commercial operations were examined and compared to a climatological forecast. A comparison with the operational forecast from Environment Canada has not yet been completed.

Finally, the results for the recent winter season are presented and compared to observed categories (above, near, and below normal).

In addition to accuracy and bias, forecast *consistency* was forced by averaging the raw prediction with those from the previous three lead times to obtain the final result. This was necessary to reduce the noise in the output and avoid spurious and misleading predictions.

To illustrate the effect of the forced consistency, consider the prediction for BC Kootenays Winter 2006-07. For prediction leads 7 through 0, the raw and final predictions are compared in Table 2 below. The average change from month to month in the raw predictions is 0.64°C, whereas the average change from month to month in the ensemble predictions is 0.26°C.

Lead	7	6	5	4	3	2	1	0
Raw Prediction (°C)	-.91	-.93	-.35	1.1	.09	.67	1.1	.69
Final Prediction (°C)	-1.0	-1.0	-.77	-.28	-.03	.37	.73	.64

Table 2 - Comparison of raw predictions to final predictions for Winter 2006-07 Temperature (°C) leads 7 through 0.

4.1. Cross validation

Cross-validation of the REP method was performed for all seasons and all target areas and all lead times during 1953-1992. Although the skill from cross validation may be inflated (Michaelson, 1987; Barnston and Van den Dool, 1993), it may be compared with the cross-validated results from the operational forecast of Environment Canada (EC). The skill values were taken from the published results (Fig. 5) of cross validation by EC (albeit from a different period, 1969-1994), and subjectively estimated for each of the target regions. This comparison is qualitative and not a definitive comparison. The results are presented in Table 3 for winter season and zero lead-time only.

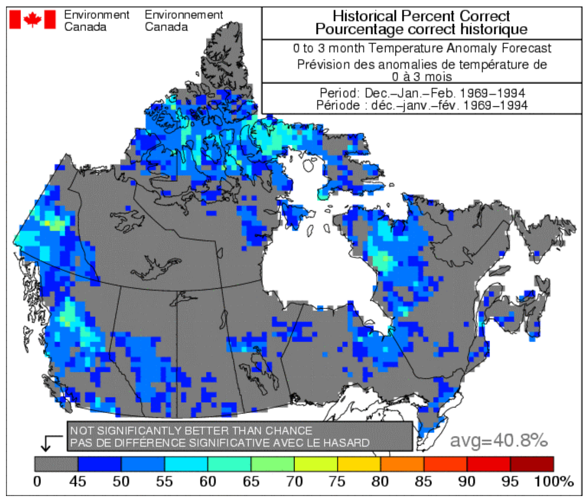

Figure 5: The cross-validation results for the operational seasonal forecasts for the winter season (DJF) and zero lead time (Environment Canada).

Skill at regional targets

The eleven target regions in Western Canada for the REP regional climate product are shown in Figure 1. For the winter seasonal forecast, the accuracy of seasonal forecasts of temperature with zero lead is presented in Table 3. The period of cross validation for the REP was 40 years (1953-1992). The period for the operational EC forecast was 25 years (1969-1994).

The results indicate a similar overall level of skill for the REP and EC predictions in Western Canada, but with differences in the locations exhibiting skill.

Target Region	REP RMS error (°C)	REP Skill (%corr)	EC Skill (%corr)
1. BC Inner Coast	1.15	42.5	45
2. BC Outer Coast	0.95	**52.5**	45
3. BC North Coast	1.23	**55.0**	NS
4. BC North Central	2.51	42.5	65
5. Okanagan	1.51	55.0	59
6. Kootenay	1.43	**57.5**	NS
7. BCNorth-Central Alberta	2.70	**60.0**	47
8. Southern Alberta	2.86	47.5	50
9. Northwest BC	3.16	47.5	50
10. Liard/North Peace	2.21	**52.5**	NS
11. Mackenzie	1.95	**50**	NS

Table 3: The cross-validated accuracy (percent correct) of the seasonal forecast of temperature with zero-lead time for the winter season for 11 target regions in Western Canada. The accuracy (bold type) indicates REP scores that exceed the scores from the operational forecast, Environment Canada (EC). The EC skill was estimated subjectively for the target areas. NS indicates a score of less than 45% correct which is interpreted as "no skill".

Influence of lead time

One of the target areas that exhibited better skill results for zero-lead in the winter season was the mountainous Kootenay region in SE British Columbia (Region #6). The results from cross-validation were examined for the influence of forecast lead time on the seasonal forecast of temperature, and are shown in Table 4.

The EC seasonal forecast uses a complex blend of numerical model forecasts for the zero lead, and uses empirical method (CCA, Canonical Correlation Analysis) for lead times of 3 months and greater. The REP methodology was used for all lead times (as shown in Table 1).

The results show some skill in the REP method as compared to the operational seasonal forecast. Furthermore, this table demonstrates consistency of repeated forecasts that gives the user additional information to guide decision-making as the forecast season is approached.

Lead Time (months)	REP RMS error (°C)	REP Skill (% corr)	EC Skill (% corr)
0	1.43	57.5	NS
1	1.45	52.5	--
2	1.42	60.0	--
3	1.26	57.5	47.5
4	1.49	60.0	--
5	1.62	60.0	--
6	1.61	57.5	NS

Table 4: The accuracy (percent correct) of the seasonal temperature forecast with different lead times for the winter season for the Kootenay region. The EC skill was estimated from an independent cross-validation study. NS indicates a score of less than 45% correct and indicates "no skill".

4.2. Prediction verification (1996-2006)

During the operational phase, the REP method was used to predict seasonal temperature and precipitation in the target areas. The results were posted on the web site for the Canadian Institute for Climate Studies (CICS) after 1996. Note: the verification includes predictions from an experimental version of REP was used (1996-1998) and the final operational version (1999-2006). The detailed verification results are publicly available:
www.cics.uvic.ca/index.cgi?/Products/Verification

The record of skill for the REP seasonal temperature forecast for the winter season with zero lead time for each of the target regions is summarized in Table 5. The BC Kootenay region used as an example here has among the lowest skill in winter, despite large cross-validated skill displayed in Table 3 above. This result reinforces the importance of verifying predictions against observations.

These results show a substantial advantage to the REP forecast at selected sites when compared to a climatological forecast. However, the Heidke Skill Score is barely positive overall, indicating the relatively short period of verification. Note that the poor performance of climatology in some regions is due to recent climate trends; comparison to an alternative definition of climatology would likely be a more challenging test (Livezey et. al., 2007). A comparison with the operational forecast from Environment Canada has not been completed.

Target Region	REP Skill (%corr)	Clim Skill (%corr)	Heidke Skill Score	EC Skill (%corr)
1. BC Inner Coast	18	18	-0.23	
2. BC Outer Coast	**22**	11	-0.17	
3. BC North Coast	**60**	40	0.4	
4. BC North Central	**40**	20	0.1	
5. Okanagan	**45**	36	0.18	
6. Kootenay	36	45	0.04	
7. BC North-Central Alberta	55	55	0.33	
8. Southern Alberta	**36**	9	0.04	
9. Northwest BC	**50**	10	0.25	
10. Liard/North Peace	**30**	10	-0.05	
11. Mackenzie	**30**	10	-0.05	
Average all regions	**36**	**21**	**0.04**	

Table 5: The accuracy of the experimental REP regional temperature forecast for the winter season for zero lead time. The cases where the REP is superior to a climatology forecast are shown in bold.

It is also useful to compare the verification of anomaly forecasts with the categorical forecasts. An example is shown in Figure 6 for the Kootenay target region showing the time series for all REP seasonal forecasts with zero lead time (4 per year) during the experimental period of 11 years. The lack of correlation between the forecast and observations for the Kootenay region is apparent. The figure is also useful to illustrate that the discrete nature of the categorical boundaries can result in a discrepancy between RMS error and percent correct (such as in Table 4).

4.3. The winter season of 2006-07

The REP forecast is no longer available as a commercial product. However, the experimental forecasts continue to be produced for subsequent analysis. The results for the winter season just concluded (DJF) 2006-07 are shown in Table 6. (The forecasts are shown as a map in Figure 1.)

The observed temperature categories are shown in Figure 7. They will be compared to the operational forecasts from Environment Canada when the verification data becomes publicly available at http://www.weatheroffice.ec.gc.ca/saisons/index_e.html#verification

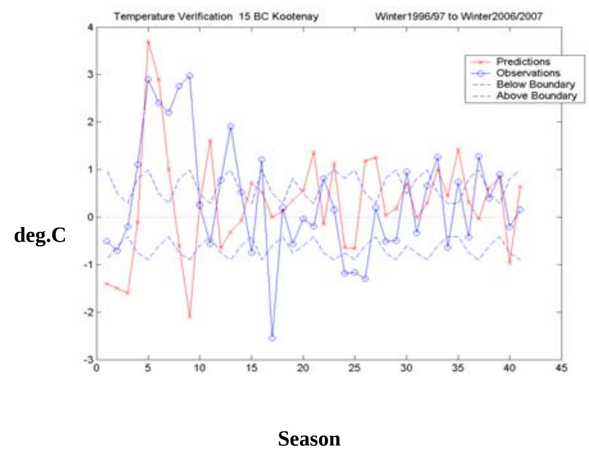

Figure 6: A time series (1996-2006) by the REP seasonal temperature forecasts for all (4) season for the Kootenay region. The boundaries between the 3 categories (Near, Above, and Below Normal) are indicated by the dashed line.

Target Region	Pred Anom (°C)	Obs Anom (°C)	Pred Cat	Obs Cat	EC Fcst
1. BC Inner Coast	0.3	0.9	N	A	
2. BC Outer Coast	0.5	0.6	A	A	
3. BC North Coast	0.4	0.4	N	N	
4. BC North Central	1.1	3.4	N	A	
5. Okanagan	-0.2	0.5	N	N	
6. Kootenay	0.6	0.2	N	N	
7. BC North-Central Alberta	1	3	N	A	
8. Southern Alberta	1.2	2.1	N	A	
9. Northwest BC	1.5	3	N	A	
10. Liard/North Peace	0.8	4.3	N	A	
11. Mackenzie	2.4	3.7	A	A	
Average all regions	**0.3**	**0.9**			

Table 6: Forecast and observed temperature anomalies and categorical values for the REP seasonal prediction for zero lead time for DJF 2006-07 for selected target areas.

4.4. Analogue years

The highest scoring analogue years used in the WAvg predictor are mild-moderate warm ENSO events (Figure 8). The observed temperatures shown in Table 6 and Figure 7 for the winter season (2006-07) are generally consistent with expectations from these analogues. The REP predictions generally under-predicted the magnitude of the warm response in winter. Although the average under-prediction was 0.6^{o}C, the response was generally quite close to the near-above boundary, so the categorical predictions were correct in only 4 of the 11 regions. It must be noted that the precipitation response in the region (not shown) was not typical for a warm ENSO.

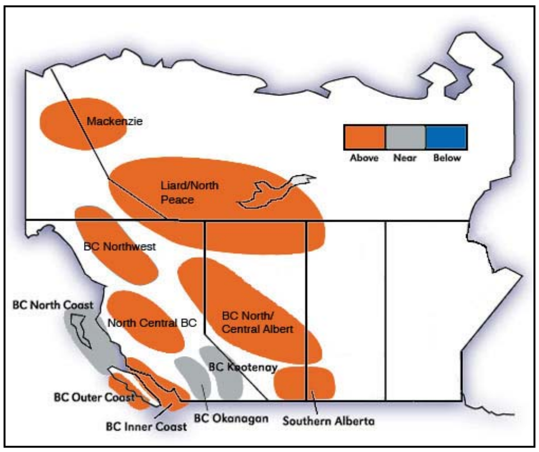

Figure 7: Verification map of temperature anomalies in the target regions for the 2006-2007 winter season.

5. Conclusions

From the advice of users we have made some attempt to address the limitations of seasonal climate prediction: disappointment in skill, discrepancy in resolution, and deficiency in utility. The objective of the REP methodology was to increase accuracy, reduce bias, and improve consistency (A, B, C).

The REP methodology of empirical seasonal predictions was developed for selected target regions. Analysis of skill in Western Canada for temperature forecasts in the winter season at zero lead time is better than a climatological forecast in most regions. Hindcast results suggest that the REP is comparable at a qualitative level to the operational seasonal deterministic forecast of Environment Canada using dynamical models.

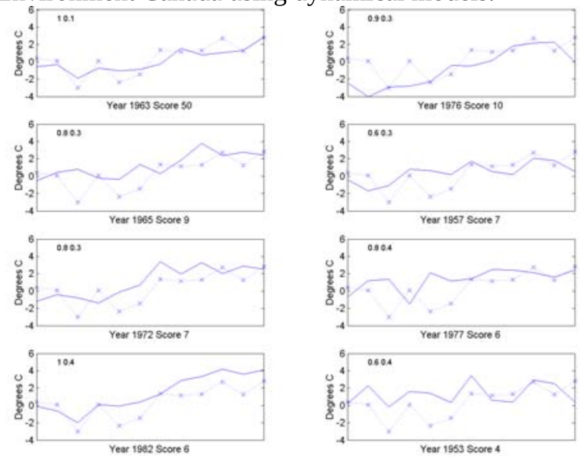

Figure 8: Analogue PCA and ENSO scores determined by Chen (1007). PCA= a*SOI + b*NINO3, where the coefficients a=-.9343^{o}C and b=0.3564 are based on the first principal component of the covariance of SOI and NINO3 anomalies since 1950. Score is based on PCA correlation and RMSE of past 12 months to historical years (displayed in top left corner of each graph). Dashed lines are PCA for the past 12 months (November 2005 to October 2006). Solid lines are PCA for the historical year (ending October).

Further analysis of the other seasons (Spring, Summer, Fall) for the 11 years of commercial operation are not expected to change this result significantly.

Notwithstanding the focus on specific target regions of interest, and some improvement in the utility of seasonal forecasts, the disappointment remains -- a gap in skill between what is needed and what can be delivered.

Future work could include verification against a stricter standard than the 1961-1990 climatology, analysis of predictors chosen, extension of analysis into the US Pacific Northwest, and analysis of skill in derived predictands.

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Appendix 1 – Target Regions and Observing Stations for REP seasonal climate prediction.

Target Regions and **Observing Stations**	Longest historical data record
WESTERN CANADA	
1. BC Inner Coast	**1889-1992**
VICTORIA INT'L A	
ABBOTSFORD A	
COMOX A	
AGASSIZ CDA	
VANCOUVER INT'L A	
NANAIMO A	
2. BC Outer Coast	**1908-1992**
ESTEVAN POINT	
AMPHITRITE POINT	
TOFINO A	
3. BC North Coast	**1908-1992**
LANGARA	
PORT HARDY A	
CAPE ST JAMES CS	
SANDSPIT A	
PRINCE RUPERT A	
4. BC North Central	**1942-1992**
SMITHERS A	
PRINCE GEORGE A	
5. BC Okanagan	**1941-1992**
PENTICTON A	
6. BC Kootenay	**1898-1992**
CASTLEGAR A	
REVELSTOKE A	
CRANBROOK A	
7. BC North/Central Alberta	**1942-1997**
FORT ST JOHN A	
EDMONTON INT'L A	
EDMONTON NAMAO A	
CORONATION A	
8. Southern Alberta	**1883-1997**
LETHBRIDGE A	
MEDICINE HAT A	
9 BC Northwest	**1942-1996**
DEASE LAKE	
WHITEHORSE A	
10. Liard/North Peace	**1883-1997**
WATSON LAKE A	
FORT NELSON A	
FORT SIMPSON A	
HIGH LEVEL A	
FORT SMITH A	
FORT CHIPEWYAN A	
11. Mackenzie	**1943-1997**
INUVIK A	
NORMAN WELLS A	
Calgary	**1884-1992**
CALGARY INT'L A	
Edmonton Municipal	**1937-1992**
EDMONTON MUNI A	
Sooke Watershed	**1913-1992**
SHAWNIGAN LAKE	
Victoria	**1940-1992**
VICTORIA INT'L A	
Victoria Gonzales	**1898-1988**
VICTORIA GONZALES HTS	

CANADA	
Eastern Prairies	**1883-1997**
REGINA A	
WINNIPEG INT'L A	
KENORA A	
Central Prairies	**1942-1992**
FORT MCMURRAY A	
COLD LAKE A	
PRINCE ALBERT A	
THE PAS A	
James Bay	**1913-1993**
MOOSONEE	
AMOS	
VAL D'OR A	
Southern Ontario	**1930-1993**
LONDON A	
KINGSTON A	
WINDSOR A	
TORONTO PEARSON INT'L A	
TRENTON A	
MUSKOKA A	
Gaspe/N.B./P.E.I.	**1895-1993**
FREDERICTON A	
MONCTON A	
CHARLOTTETOWN A	
GASPE A	
Northern Manitoba	**1943-1997**
LYNN LAKE A	
THOMPSON A	
CHURCHILL A	

PNW	
Columbia River Basin	**1895-1998**
BOISE WSFO AIRPORT	
MISSOULA WSO AP	
IDAHO FALLS FAA ARPT	
SPOKANE WSO AIRPORT	
LIBBY 1 NE RANGER STN	
KALISPELL WSO AIRPORT	
CASTLEGAR A	
CRANBROOK A	
REVELSTOKE A	
Pacific Northwest Coast	**1950-1998**
SEATTLE	
PORTLAND WSFO	
Pacific NW Cascades	**1939-1998**
SPOKANE WSO AIRPORT	
YAKIMA WSO AP	
BURNS WSO CITY	
BOISE WSFO AIRPORT	
Pacific Northwest Rockies	**1899-1998**
KALISPELL WSO AIRPORT	
CRANBROOK A	
MISSOULA WSO AP	
IDAHO FALLS FAA ARPT	
OTHER	
Chicago	**1896-1999**
CHICAGO	