ENVIRONMENT CANADA SEASONAL FORECASTS: PRODUCTS, METHODS, PROCEDURES AND VERIFICATION

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1. INTRODUCTION

In the Fall of 1995, the Canadian Meteorological Centre (CMC) began producing the Environment Canada seasonal temperature and precipitation anomaly forecasts using objective methods: dynamical models for season 1 and a statistical method for seasons 2 to 4. The objective of this paper is to present a snapshot of the current "When, What, Where, Who, Why and How" associated with the CMC seasonal forecasts. Used in combination with the other papers of the Extended Range Prediction Session of this Workshop, it is hoped that it will serve as a useful reference document for the CMC operational seasonal forecasts.

The reader is invited to consult the CMC seasonal forecasts web page at the following address www.cmc.ec.gc.ca/~cmcdev/saisons/seasons.html to view the forecasts and for various other information (skill, verification, climatology used, etc.).

2. WHEN ARE THE SEASONAL FORECASTS ISSUED?

The seasonal forecasts are issued on the first of December, March, June and September. Since the forecasts are issued approximately 21 days prior to start of the "official season", it might be more appropriate to call them "90-day" or "3-month" forecasts. However, the word "seasonal" is used because of the importance seasons have for the public and media.

3. WHAT ARE THE LEAD TIMES?

The forecast for season 1 is issued with zero lead time. The forecast for seasons 2 to 4 are issued with lead times of 3, 6 and 9 months respectively.

4. WHAT DO WE FORECAST?

For seasons 1 to 4, a 90-day temperature and precipitation anomaly outlook based on a priori 3-equally probable categories: "ABOVE NORMAL", "NEAR NORMAL" and "BELOW NORMAL".

5. HOW ARE THE ABOVE, NEAR AND BELOW NORMAL CATEGORIES DEFINED?

The categories correspond to +/- .43 standard deviation of the climatology:

ABOVE NORMAL: anomaly forecast is greater than +.43 standard deviation;

NEAR NORMAL: anomaly forecast is contained within + / - .43 standard deviation;

BELOW NORMAL: anomaly forecast is less than -.43 standard deviation.

6. WHAT CLIMATOLOGY DO WE USE?

It is important to clearly distinguish between the data used to produce the forecasts, and the data used to for verification. To **verify** the seasonal forecasts, Environment Canada's 1961 to 1990 Canadian Climate Normals are used. To **calculate** the forecast anomalies, the following are used:

For SEASON 1: The temperature and precipitation climatology are based on the Historical Forecast Project or HFP. In short, seasonal forecasts were produced for each of the seasons over a 26-year period from 1969 to 1994. NCEP's reanalysis project data (Kalnay et al., 1996) were used to define the initial input fields for the models. A set of forecasts was produced for each season during that period (104 in all). Each set consisted of a blend of 6 runs of the SEF and 6 runs of the GCMII (see section 7). Then, the average forecast for each season of the 26-year period was calculated to obtain the "climatology" of each model.

Why proceed this way? The reason is simple. When numerical models are run for long periods, they have a tendency to drift away from the climate of the "real" atmosphere towards a "model" climate which can be quite different from the "observed" one. To ensure that the anomalies predicted resemble the ones observed, the models' climate must be used to determine the forecast anomalies. This eliminates the models' bias which would otherwise introduce an artificial anomaly as a result of systematic errors.

For SEASONS 2 to 4: The temperature and precipitation climatology are based on Canadian station climatology data for the period 1956 to 1994.

7. MODELS AND TECHNIQUES USED TO PRODUCE THE SEASONAL FORECASTS

It is important to mention that the methods used to produced the temperature and precipitation anomaly forecasts have changed on a number of occasions over the years. We only present here what is currently used for the operational production.

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For SEASON 1:

a) Two models are used: the SEF (Spectral Éléments Finis model; Ritchie, 1991) and the GCMII (General Circulation Model; McFarlane et al., 1992).

The SEF is the same model as the one used for the monthly (30-day) forecasts (Desautels et al., 1996). It has a spectral truncation at T63 and 23 vertical levels. This model has also been used in sensitivity studies of sea-surface temperature forcing (Peng et al., 1995, Dugas et al., 1995). The GCMII is also a spectral model, with a lower resolution (truncation at T32 and 10 vertical levels) and different physics.

b) 6 runs of the SEF model and 6 runs of the GCMII model are done. For both models, the first run is done 96 days prior to issuing the forecast and the subsequent 5 runs are each done with a one day lag (95, 94, 93, 92 and 91 days respectively prior to issuing);

c) Both models use the same CMC atmospheric analyses as initial fields. However, they differ in the way they use the analyzed surface fields. Surface forcing, crucial in controlling the seasonal atmospheric variability, has to be treated carefully. The treatment of the Sea Surface Temperatures anomalies (SSTA), ice and snow cover is done in the following way:

The CMC does not currently use an ocean model to forecast the SSTA Chen *et al*, 1997 have shown that persisting the SSTA over the first three months of a forecast is as good as using forecast SSTA. Thus, the average observed SSTA in the 30-day period prior to issuing the forecast are persisted throughout the forecast period and are added to the evolving SST climatology. The SSTA are obtained from the CMC global analysis of mean monthly SST. Data from ships, buoys and satellites are assimilated to produce these analyses.

For the SEF model: For the snow and ice covers, the anomalies observed just prior to the issuing of the forecast are gradually returned to zero (e.g. to climatology) by the end of the first month of the forecast period.

For the GCMII model: The treatment of the ice cover is done in the same way as for the SEF model. The snow line at analysis time is set using CMC's snow analysis. After, the snow cover is taken care of by the model, as it is a prognostic variable.

d) To obtain the seasonal <u>temperature</u> anomaly forecast, the following steps are followed:

For each of the SEF and GCMII models:

1. Extract the 1000-500 hPa thickness for each of the 6 runs;

2. Calculate the average thickness for the 6 runs over the season (90 days);

3. Calculate the average thickness anomaly by subtracting the thickness climatology of the appropriate model;

4. Divide the thickness anomaly of step 3 by the model climatology standard deviation. This is done to give both models equal weights. Otherwise, one model might be much more "active" than the other and completely dominate the forecast;

5. Multiply the result of step 4 by the standard deviation of the NCEP reanalysis climatology over the HFP period. This is done to give the correct amplitude to the anomaly forecasts. Otherwise, the near normal category would be overestimated;

6. Combine the two models ensemble means using a method called the Best Linear Unbiased Estimation or BLUE (Derome et al, 2000). The idea behind the BLUE is simple: a better forecast can be obtained if the models are blended using their individual strengths. A weighted average of two model ensemble means is computed using statistically determined weights. Based on all the predictions made with the HFP, optimal weights were determined for each model in order to minimize the forecast errors over Canada. The weights assigned are space dependent and are calculated for each season. Thus, if the relative skill of the two models changes from one season to another, the method can adjust the weights accordingly. The BLUE method was implemented operationally starting with the Spring 1999 forecast.

7. Calculate a term called the "residual". This is required because the BLUE method does its calculations in what is know as a "truncated space" and some residual information which can contribute significantly to the quality of the forecast would be left behind otherwise;

8. Add the results of steps 6 and 7 to obtain the average thickness anomaly forecast for the season;

9. Convert the thickness anomaly forecast to a surface temperature anomaly forecast using a linear regression relationship;

10. Determine the category of the anomaly (below, near or above normal) by comparing with +/- .43 standard deviation of the Canadian Climate Normals for the period 1961 to 1990.

e) To obtain the precipitation anomaly forecast, the following steps are taken for both the SEF and GCMII (note that the BLUE technique is **not** used for this):

1. Extract the forecast precipitation for each of the 6 runs;

2. Calculate the average precipitation for the season (90 days);

3. Calculate the average precipitation anomaly by subtracting the precipitation climatology of the appropriate model;

4. Divide the predicted precipitation anomaly by the model seasonal precipitation climatology standard deviation. This is done to give both models equal weights. Otherwise, one model might be much more "active" than the other and completely dominate the forecast;

5. Average (sum divided by 2) the result obtained in step 4 for both models;

6. Multiply the result of step 5 by a correction factor to make the forecast categories, a priori, equally probable. Otherwise, the normal category would be overestimated;

7. The above, near and below normal categories correspond to areas for which the value of step 6 is greater than .43, within +/- .43 and less than .43.

For SEASONS 2 to 4:

In November 1996, CMC began producing seasonal temperature and precipitation anomaly forecasts for seasons 2 to 4 (3 to 9 months lead times) at Canadian stations using a the statistical technique of Canonical Correlation Analysis or CCA (Barnston, 1993; Shabbar and Barnston, 1996. Also, see Session 4 paper by Amir Shabbar).

The analyzed field of SSTA over the previous twelve months are used to forecast the temperature and precipitation anomalies at various lead times. The SSTA are obtained from the CMC global analysis of mean monthly SST, for each of the 12 months preceding the date on which the forecast is issued. Data from ships, buoys and satellites are assimilated to produce these analyses. The SSTA are averaged spatially over 10 X 10 degree grid cells and over three-month periods. The statistical relationships between the observed SSTA and the subsequent temperature and precipitation anomalies have been developed from a 39-year data set (1956 to 1994). Equations are available to generate forecasts for lead times of up 9 months. The CCA forecasts are produced for 51 selected Canadian stations for temperature, and 69 stations for precipitation. These are then used to produced anomaly forecasts maps over Canada.

8. SKILL OF THE SEASONAL FORECASTS

The seasonal anomaly forecasts are of interest but of limited use if one can not give some estimate of confidence (e.g. what is the likelihood of a forecast being in the correct category?). This is why the forecasts skill must always be used with the forecasts themselves. The skill was established based on the HFP runs. Skill maps (percent correct) for the seasonal temperature and precipitation anomaly forecasts for seasons 1 to 4 are posted on the web page.

9. VERIFICATION OF THE FORECASTS

The verification of the seasonal temperature and precipitation anomaly forecasts for season 1 is shown below (it has not yet been done for seasons 2 to 4). The forecast category (above, near and below normal) is compared with the observed category at a number of stations using Environment Canada's 1961 to 1990 Canadian Climate Normals. It is then expressed as a percent correct: ratio of the number of stations for which the forecast is in the correct category divided by the total number of stations. A chance forecast would produce on average 33.3%. It is important to mention that the methods used to produced the temperature and precipitation anomaly forecasts have evolved over time. The BLUE method for temperature was implemented for the Spring 1999 forecast.

SEASON 1	TEMP. ANO (170 stations)	PCPN ANO (130 stations)
Autumn 1999	51%	32%
Summer 1999	58%	41%
Spring 1999	30%	34%
Winter 1998-99	60%	31%
Autumn 1998	20%	22%
Summer 1998	27%	22%
Spring 1998	43%	52%
Winter 1997-98	88%	44%
Autumn 1997	58%	24%
Summer 1997	35%	26%
Spring 1997	44%	29%
Winter 1996-97	61%	39%
Autumn 1996	32%	------
Summer 1996	42%	------

Although statistically small to draw definite conclusions, these numbers are consistent with the findings of the HFP: seasonal forecasts have some skill at forecasting temperature anomalies and little skill when it comes to forecasting precipitation anomalies. The corresponding maps and a breakdown by region is available on the web page.

10. CONCLUSION

This paper presented a snapshot of the current situation with respect to Environment Canada's seasonal forecasts. Many challenges remain and addressing these will require considerable scientific and technical work. At the same time, it must be said that that considerable work has already been taken to set up a robust and reliable operational production system for seasonal forecasts. The scientific and technical contributions of various research, development and operational groups at Environment Canada are key elements of this success. The important collaborative effort of these groups is hereby acknowledged.

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