1.6 TOWARD A NEW CANADIAN MEDIUM-RANGE PREFECT-PROG TEMPERATURE FORECAST SYSTEM

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1. INTRODUCTION

At the Canadian Meteorological Centre (CMC), statistical adaptation of numerical weather prediction model outputs for spot temperature forecasts has been operationally produced for many years using a model output statistical (MOS) approach (Glahn and Lowry 1972) and/or a perfect-prog (PP) approach (Klein et al. 1959). Over the years, different needs, constraints and forecasting contexts justified the application of these two techniques in relation to their respective strengths and weaknesses. For example, in the ninety's the PP technique was favored for operational use over the MOS approach because the latter was too costly to maintain; the regression coefficients had to be recomputed every time the driving model changed (Brunet et al. 1987, 1988). This shortcoming of the MOS technique has been recently overcome with the development of an updateable MOS system (UMOS) (Wilson and Vallée 2002, 2003), so that the use of the MOS approach is now again fully operational at CMC in addition to the operational PP system.

But in spite of the advantages of the MOS approach, such as reliability and the ability of taking into account systematic model errors, its use for medium-range forecast (2 to 10 days) in a context of a ensemble forecasting system is questionable. In effect, MOS forecasts are known to lose sharpness at long projection times, since they tend toward the mean of the training sample. Then, when applied to each member of an ensemble of model outputs, the resulting MOS forecast ensemble would lose variance and extreme values, which are the main impetus of ensemble forecasting. Furthermore, the maintenance of a model dependent post-processing system such as MOS, even with an updateable MOS method, for a large number of models having various model errors is prohibitive. These drawbacks of the MOS approach motivated us to revisit the PP method for a possible application in a context of ensemble forecasting, in addition to current deterministic medium-range high-resolution model forecast system.

2. METHODOLOGY

Our new experimental PP system for spot temperature forecasts is based on classical multiple linear regression equations. A 31-year (1971-2001) subset of the NCEP/NCAR Reanalysis (Kalney et al. 1996) upper-air dataset is used as a dependent database for the training predictors. The use of this dataset represents an improvement upon the current operational PP system which was developed using 22 years of historical data (1963-1984) consisting of analyzed fields from various sources. The NCEP/NCAR reanalysis provided us a longer and a more stable database with better spatial and temporal resolution. Potential predictors in the dependent database include heights, temperatures, dew-point depression, winds at 1000, 925, 850, 700 and 500 hPa levels and also surface and sea-level pressure. Several other predictors were derived from this basic set. Predictors such as surface observations of the predictand at the target station and/or upstream stations were not included. Training predictands (2-m temperature) are taken from the CMC hourly surface-observation database.

The computation and application of the regression coefficients were performed using computer code already developed for the UMOS system. Twelve 'seasons' made of a 3-month running window was used to stratify the dependent database. Predictors are selected in developing stage using a forward stepwise selection approach. The addition of new predictors is stopped when the added reduction of variance becomes less than 0.5%. A maximum of nine predictors was imposed.

The driving NWP model serving as input for the predictors in our PP system is the operational CMC global grid-point model which has a horizontal resolution of ~100 km and 28 levels in the vertical. Before interpolation of the predictor fields at the station locations, a spatial filtering is performed to ensure that the resolution of the predictors is the same as in the dependent database (NCEP/NCAR resolution is T62 ~325 km). This is particularly important for derived predictors of the form of gradients or Laplacien. More precisely, the filtering procedure is as follows: First, the model horizontal fields are transformed in the spectral domain using triangularly truncated spherical harmonics. Only spectral coefficients up to T62 are computed and retained; this being exactly the spectral resolution of the NCEP/NCAR reanalysis. Then, these spectral coefficients are used to re-synthetize the physical fields on a global grid. The advantage of this spectral

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procedure is that it provides a uniform resolution everywhere on the globe in addition of giving a sharp control on which spatial scales are filtered out.

This new PP system has being tested on 100 Canadian stations spread across the country. At this stage, spot temperature predictions are produced twice daily (00 and 12 UTC cycles) for projection times up to 144 hours and at a 6-h time resolution (00, 06, 12 and 18 UTC).

3. RESULTS

Comparisons between this new PP (NEW_PP), the current operational PP (OPE_PP) and the direct model output (DMO) have been performed using objective verifications for winter 2002-2003 (December-January-February) and summer 2003 (June-July-August). We present the bias (forecast minus observation) and an improvement skill score (ISS) defined as,

$$\text{ISS} = \left[1 - \frac{\sum (F-O)^2}{\sum (C-O)^2}\right] \quad \text{X } 100,$$

where F stands for the forecasts, O for the observations, and C for the climatology. This skill score is intended to measure the ability of the system to forecast spot temperatures when compare to a simple minded forecast made of climatological values. Only the forecasts produced in the 00 UTC cycle are displayed, since similar results are obtained in the 12 UTC cycle

Figure 1a shows the ISS for winter. The first feature easily noticeable is that both the experimental NEW_PP and the current OPE_PP system outperform forecasts made from the direct model output. Secondly, the NEW_PP yields somewhat better ISS in the medium forecast time range but is significantly worse than the OPE_PP between 0 to 48 h. This is probably due to the fact that the OPE_PP system allows for surface observed predictors at the target station and/or upstream stations as opposed to the NEW_PP. These "surface predictors" permits to take into account persistence and also simple translation of weather systems.

Fig. 1b shows the ISS for summer. Again, both the NEW_PP and the OPE_PP largely outperform the DMO. Comparing the NEW_PP and the OPE_PP we find that the NEW_PP yields similar or somewhat better results in the 12- to 108-h time range. The superiority of the OPE_PP between 0- and 48-h in winter is far less apparent in summer. On the other hand, the OPE_PP is slightly better after 120-h. It has been found that this relatively better performance of the OPE_PP near the end of the forecast period in summer was due to the application of a post-processing scheme on the OPE_PP output. The scheme involved gradually forces, throughout the forecast period, the temperature forecasts to tend toward climatology, imitating a MOS property. Some tests made have demonstrated (not shown here) that the ISS of the NEW_PP can also be enhanced by this scheme but its use for ensemble forecasting would reduce the ensemble variance. Therefore, it has been decided to avoid its utilization for the NEW_PP.

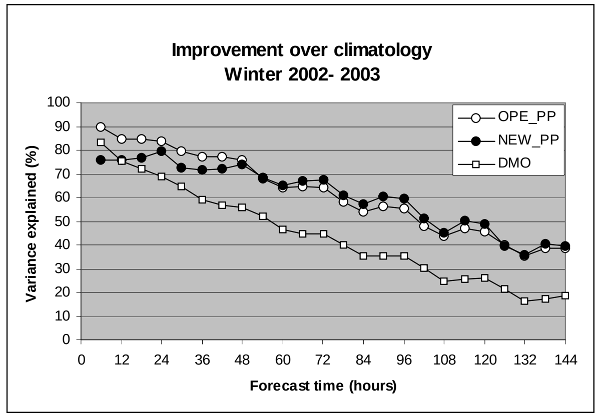

Figure 1a: Improvement of spot temperature forecasts over climatology (% of variance explained) as a function of forecast time in winter 2002-2003; *Open squares*: direct model output (*DMO*); *Open circles*: operational PP system (*OPE_PP*); *filled circles*: Experimental new PP system (*NEW_PP*).

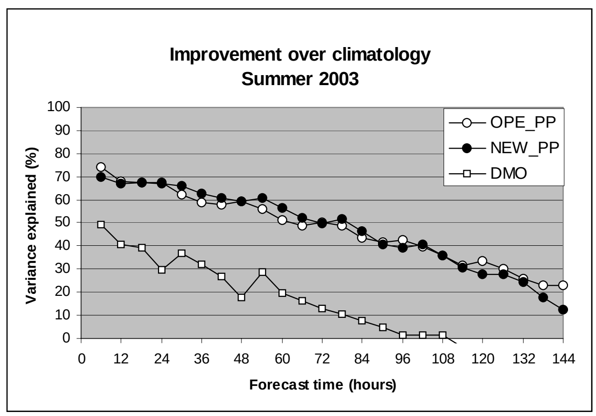

Figure 1b: Same as in Fig. 1a but for summer 2003.

Fig. 2a and 2b display the biases for winter and summer, respectively. The DMO shows the larger biases in addition of a pronounced diurnal cycle. Comparing the OPE_PP and the NEW_PP, we find that the OPE_PP is the one that exhibits the smallest biases especially during summer. On the other hand, our NEW_PP has systematic biases showing a diurnal cycle in the range of +/- 0.4 deg. C. The correlation between the NEW_PP and the DMO suggests that the driving model is responsible for this cycle behavior. The reason for the absence of this bias cycle in the OPE_PP as well as the smaller values of its biases could be explained by another post-processing scheme applied on the OPE_PP output. The scheme does a bias correction based on biases calculated during the last few days preceding the forecast. This self-correction helps in reducing long term biases but can be temporally detrimental when weather regime changes rapidly. For this reason, it was decided to stay away of that correction scheme for our NEW_PP.

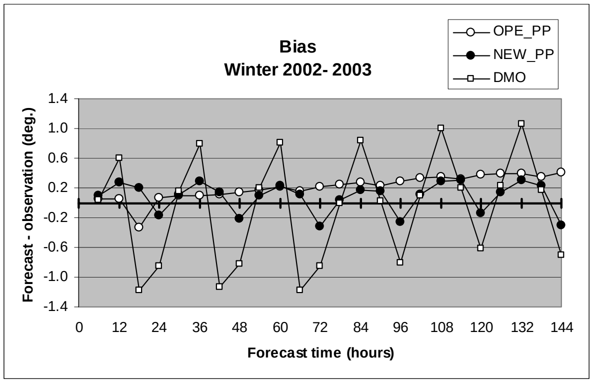

Figure 2a: Bias of spot temperature forecasts as a function of forecast time for winter 2002-2003 (units: deg. Celsius); Symbols have the same meaning as in Figs.1a-b.

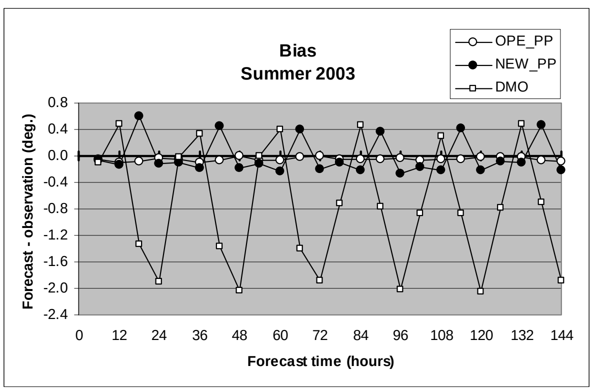

Figure 2b: Same as in Fig. 2a but for summer 2003.

4. SUMMARY

The main objective of this project is to develop a suitable statistical adaptation tool that would be appropriate for medium range NWP model output in a ensemble (low and medium resolution) forecasting context but also applicable to deterministic medium-range high-resolution models. To do so, the PP technique was chosen over the MOS approach because of the sharpness property of the former as well as the easiness of maintenance for ensemble forecasting. Furthermore, a special care has been taken to ensure resolution compatibility between the training NCEP analyses and the NWP prediction model output. In effect, we believe that resolution compatibility should be maintained between the dependent predictor fields employed during the developmental stage and those used during the forecasting stage. This is particularly true with high-resolution regional forecast models but also with global models since their resolutions are now approaching a few tens of km of grid-spacing. The procedure employed in this project makes use of global spectral filtering, which is a novelty.

We also took advantage of the availability of the NCEP/NCAR reanalyses in the development stage. This is an improvement compared to what was used for the current CMC operational PP system. The old historical database was not homogenous and was based on the 1966-1984 period.

The preliminary results shown here are encouraging. Future works include: the treatment of temperature anomalies (relative to climatological means) as predictand instead of the temperature itself, extension to 3-h forecast intervals (instead of 6-h intervals) and application to ensembles.

Finally, the results shown here demonstrate once again that statistical post-processing of numerical model output is still valuable and that in spite of the continuous improvement of the treatment of boundary layer processes in numerical weather prediction models.

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