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UPDATEABLE MODEL OUTPUT STATISTICS: AN EFFECTIVE TOOL FOR EVALUATION OF NWP FORECASTS

Marcel Vallée* and Laurence J. Wilson
Meteorological Research Branch, Meteorological Service of Canada, Dorval, Canada

1. INTRODUCTION.

The Canadian updateable model output statistics (UMOS) (Wilson and Vallée, 2002) has been running at the Canadian meteorological center (CMC) since 12 UTC, 14 September 2000. UMOS is the main statistical processing system for the output of the Canadian global multiscale model (GEM). It uses a MOS formulation (Glahn and Lowry, 1972), but provides also for rapid and frequent updating of the statistical equations so that they are kept current with respect to changes in statistical characteristics of the predictors, especially after model changes. A weighting scheme provides greater weight to more recent data from the newest model version, and helps ensure a rapid response of the forecasts to model changes, while ensuring that the effective sample size is always large enough to give stable statistical relationships.

Currently, the UMOS predictands are three hour spot 2m temperature, three hour 10m wind speed and direction, six hour probability of precipitation greater or equal than .2 mm. Two new predictands, the 12 hour probability of precipitation and cloud amount should be implemented this year. All of these predictands use multiple linear regression except for the categorical predictand cloud amount, which uses multiple discriminant analysis (MDA).

On 11 September 2001, an updated GEM model was implemented. CMC implemented a new surface modeling scheme known as ISBA (interactions, surface, biosphere, atmosphere) (Noilhan and Planton, 1989) in replacement of the previous force-restore module. This modification would be expected to have a direct impact on meteorological surface parameters forecast by UMOS. This paper describes the impact of this specific model change on the UMOS equations, and demonstrates the value of updateable statistical interpretation schemes to provide rapid assessment of the impacts of model changes to modellers and forecasters.

* Corresponding author address:
Marcel Vallée, Meteorological Research Branch,
2121 Transcanada highway, Dorval, Québec, Canada,
H9P 1J3; e-mail: marcel.vallee@ec.gc.ca

2. UMOS.

Unlike more standard statistical development where data are collected, then equations are developed, the UMOS procedure involves daily automatic preparation of the data for statistical processing. On an approximately weekly basis, equations are generated and used to forecast weather elements.

The system is divided into three main parts. The first component is the data processing and archiving, including spatial interpolation to stations, and computation of all spatially derived predictors such as gradient, advection, laplacian, etc. Predictors are generated from the surface, 1000Hpa, 925Hpa, 850Hpa, 700Hpa and 500Hpa levels. The daily collected data are archived for future development and also fed directly into the statistical processing component of UMOS.

The second component is the statistical processing module which begins with updating the sums of squares and cross-products matrix (SSCP). For MDA we updated the sums of squares and cross-products matrix with respect to the group means (SSCPW within groups) and the sums of squares and cross-products matrix with respect to the overall sample grand mean (SSCPB between groups).). These groups of SSCPW and SSCPB matrices are updated for each valid forecast time.

On a weekly basis, equations are generated according to the predictor control module. A subset of predictors is selected using forward stepwise screening for MLR and Mahanalobis-based forward selection for MDA.

The third module produces the daily statistical forecasts using the latest equations. Currently, UMOS generates forecast for almost 800 locations in Canada from 0 to 48 hours forecast time from the 00 UTC and 12 UTC GEM model run.

To ensure a smooth transition from MOS based on the old model to MOS based on the new model, the system includes a weighting scheme which is designed to emphasize data from the new model while they are relatively scarce, while using data from the old model to maintain a sufficiently large sample size to ensure stable statistical relationships.

3. ISBA SURFACE SCHEME.

The GEM model has a horizontal resolution in the uniform grid core of .22 deg (about 24km), a time step of 720 sec, and 28 vertical levels.

On 11 September 2001, CMC implemented a new surface modeling scheme known as ISBA to replace the older “Force-Restore” module. The main purpose of ISBA is to determine the lower boundary conditions for the vertical diffusion of temperature, moisture and momentum. It also evaluates the evolution of the surface temperature, the mean deep-soil temperature, the near-surface soil moisture, the bulk soil moisture, the liquid water retained on the foliage of the vegetation canopy, the equivalent water content of the snow reservoir, the snow albedo, the relative snow density and the hydrological budget of the surface.

ISBA takes into account the surface fluxes of heat, moisture, and momentum over land, water, sea ice, and glaciers. The fluxes calculated over these four land types are combined over each grid tile according to their respective weight. These fluxes are then used as a lower boundary condition for the vertical diffusion. “Force-Restore” considers only one land type for each model grid tile.

Over land, ISBA uses the “Force-Restore” technique for the evolution of skin and daily mean surface temperatures, as well as for the superficial and deep soil volumetric water contents. The calculations for the surface fluxes over water are unchanged. Over sea ice, the surface temperature and fluxes are obtained from a 3-level thermodynamic sea ice model (surface and 2 internal levels). The model includes a snow cover on top of the ice, and realistic descriptions of the snow and ice physical properties during the winter and melting seasons. The presence of leads in the ice and melt ponds is also taken into account. Over glaciers, an approach similar to ISBA over land is taken with a 2-level “Force-Restore” method with physical parameters appropriate to thick ice and a possible snow cover on top.

The assimilation of soil variables has also undergone significant changes. Except for the snow water equivalent which is given by an external analysis, the initial conditions for ISBA’s other prognostic variables are carried on , or cycled, from the previous day’s integration. The same cycling strategy is used for the skin and deep surface temperatures of the glaciers, as well as for the superficial surface temperature of the sea ice. The depth of the sea ice is currently obtained from climatology. Further details of our implementation of the ISBA scheme are given in Bélair et al. 2002; and details of the latest version of GEM are described by Bélair et al. 2000.

4. OBJECTIVE EVALUATION.

The impact of the model change was evaluated using UMOS for a winter period. Two sets of equations were developed and tested on independent data. First, a set of winter season (7 November to 22 April) equations was developed using GEM model data from 1995 to March 31, 2001. This set is designated “UMold”. A second set of equations was developed (called “UMOS”) by allowing the blending of new model data into the development data according to the procedures described in Wilson and Vallée (2002). Thus, new model data from November 7, 2001 to the equation development date was included in these equations. The independent test period for both sets of equations was 3 January to 2 April, 2002. We ensured independence of the dataset by developing new updated UMOS equations each week and running both sets of equations for the next week of the independent test period. Equations were developed and run for the three predictands temperature, cloud amount and wind; results for the first two of these are shown here.

4.1 TEMPERATURE.

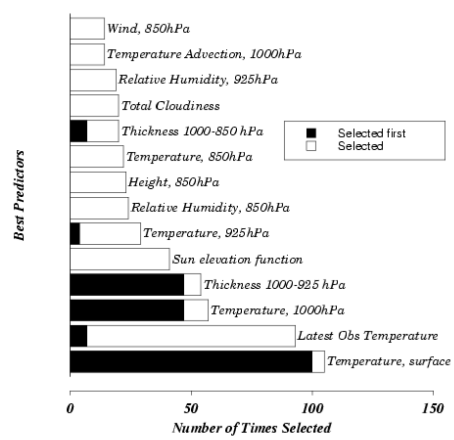

Figure 1: Histogram of most frequently chosen predictors for 18 h temperature forecasts, 00 UTC GEM model run, based on old model data (31/03/2001). The dark bar indicates that the predictor was selected first by the regression and the white bars indicate predictors that were selected.

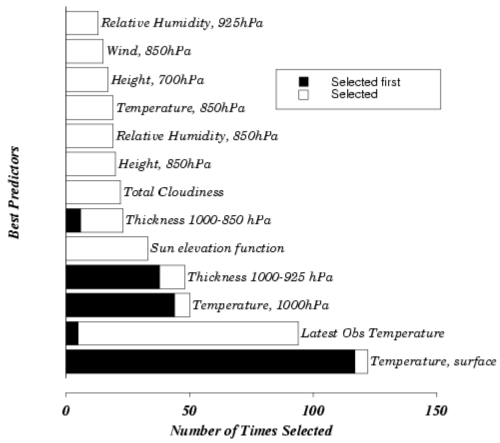

Figure 2: Same as figure 1 except, based on blended old and new model data (28/03/2002)

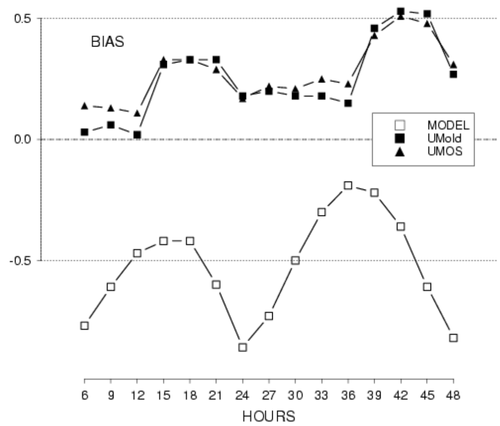

Figure 3: Bias of UMOS, UMOS based on old model (UMold) and GEM 2m temperature forecasts as a function of projection time for about 220 stations, 00 UTC run, for the period of 3 January 2002 to 2 April 2002

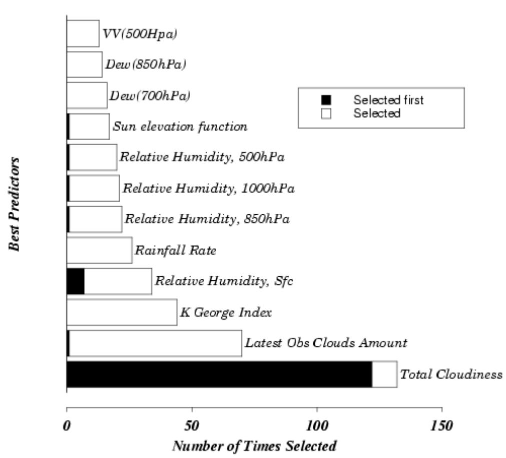

Figure 4: Histogram of best predictors for cloud amount, 18 h forecast from the 00 UTC GEM model run, based on old model data (31/03/2001). The dark bar indicates that the predictor was selected first by the regression and the white bars indicate predictors that were selected.

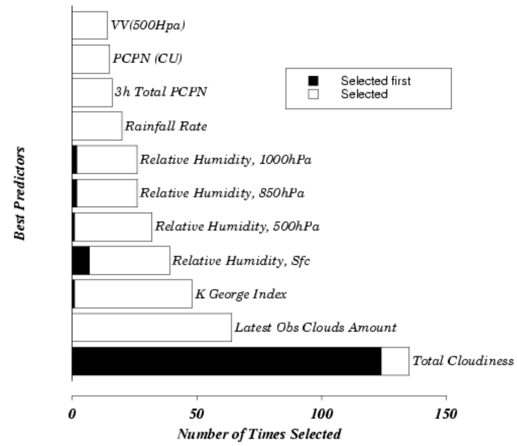

Figure 5: Same as figure 5 except, based on blended new model and old model data (28/03/2002).

There were 19 predictors submitted and we used the screening forward stepwise stopping criterion for adding predictors into the equations to generate the UMOS equations. In general, UMOS selected about 3 to 4 predictors, and responded quickly to ISBA by selecting low level predictors affected by the new scheme. Also, the predictor selection results clearly indicate that UMOS equations are extremely stable, keeping the same predictors through the update cycle.

Figure 1 and 2 show the predictors selected for all the 220 Canadian stations. The most frequently chosen predictors are listed. The dark bar indicates the frequency with which predictor is selected first, while the other indicates the predictor was selected by the regression Figure 1 represents the last equation update on 28 March 2002 and figure 2 represent the last equation updated with data based on old model only (31 March 2001). Selection of the surface model temperature predictor has increased as new model data was entered, indicating a better model temperature prediction using the ISBA scheme. Figure 3 shows the bias in degrees over all forecast time and all stations, based on independent data. The GEM model shows a diurnal cold bias and both UMOS forecasts tend to adjust for this leading to a warm bias by 48 hours. The day 2 forecasts are less biased in the new model, which suggests the bias has been reduced in the new model with respect to the old model. Forecasts based only on the old model overcorrect the bias.

4.2 CLOUD AMOUNT.

Cloud amount is different from temperature because we treat it as a multi-category predictand. MDA was used to forecast probabilities of occurrence of 4 different categories, clear (0 to 1 tenth), scattered (2-5), broken (6-9), and overcast (10 tenths). A pool of 40 predictors was submitted to MDA to find the best discriminant functions to maximize separation of groups while minimizing within group dispersion. The Mahalanobis distance was used as a criterion to select 4 to 6 predictors within each discriminant function. They were chosen to concentrate the discriminant information in the predictors into a few new variables, which are linear combinations of the original ones.

Figure 4 and 5 show the best predictor selection for clouds based on old model data and new model data blended with old model data respectively. Mostly, the model's total cloudiness is selected, but the addition of new model data causes a slightly increased tendency to use low level moisture predictors.. Since the model does not predict cloud amount, Tables 2 and 3 below show only a two-way comparison of the forecast performance of the UMOS forecasts based on old model data and blended new plus old model data respectively. Table 2 shows a positive impact using data from the latest version of the model in terms of percentage correct (PC) and the Heidke skill score (HSS, skill with respect to chance) over all forecast times. Table 3 presents the verification in terms of bias, probability of detection (POD) and False alarm rate (FAR) for the 12 hours forecast projection over the same Canadian stations. This table shows an improvement in bias for all categories. The POD and FAR values are similar between the two versions of UMOS.

Time	Percentage Correct % (PC)		Heidke Skill Score (HSS)	
	UMold	UMOS	UMold	UMOS
03	47.08	48.59	0.288	0.305
06	41.36	44.01	0.211	0.240
09	40.97	43.82	0.203	0.234
12	41.35	43.07	0.210	0.231
15	40.01	40.71	0.198	0.207
18	40.46	40.94	0.203	0.209
21	40.26	40.71	0.201	0.207
24	40.23	40.95	0.200	0.210
27	39.11	41.30	0.184	0.210
30	37.62	40.18	0.163	0.191
33	37.95	40.31	0.162	0.188
36	38.51	39.97	0.171	0.189
39	37.29	37.93	0.161	0.170
42	37.73	37.95	0.166	0.169
45	37.65	38.07	0.166	0.171
48	37.72	38.18	0.166	0.172

Table 2: Percentage Correct and Heidke Skill Score from 0 hour to 48 hours forecasts for every 3 hours of cloud amount based of UMOS and UMOS old model (UMold) for about 220 stations, 00 UTC run, for the period of 3 January 2002 to 2 April 2002

12 hr. fcst	CLR	SCT	BKN	OVC
UMold BIAS	0.71	1.20	1.05	1.13
UMOS BIAS	0.80	1.12	1.04	1.10
UMold POD	0.41	0.30	0.25	0.59
UMOS POD	0.47	0.29	0.25	0.59
UMold FAR	0.13	0.22	0.19	0.24
UMOS FAR	0.14	0.21	0.18	0.23

Table 3: Bias, probability of detection (POD) and false alarm rate (FAR) for 12 hours forecasts of cloud amount for the same run, number of stations and time period as table 2. Sample size = 10150

5. CONCLUSION.

The use of statistical interpretation methods such as UMOS improve forecasts with respect to numerical models. An updateable scheme is responsive and adaptive to model changes, which means UMOS is a useful tool to quantify the impact in the early stages of a model change. We have shown that some of the benefits claimed for the recent implementation of ISBA in the GEM model have been passed on to the UMOS forecasts of temperature, and to a lesser extent, cloud forecasts.

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