A Multi-Model Approach to Operational NWP Bias Correction

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INTRODUCTION

Systematic Numerical Weather Prediction (NWP) model bias errors are well known, and it is common practice to calibrate the forecast outputs, using observations as the baseline.

There are numerous techniques for tuning the forecast outputs in order to automatically suppress bias errors. In our implementation, we are automatically combining information from various NWP model outputs and their bias-corrected derivatives, using multiple bias correction methods and automatic assessment of the model performance, in order to drive an optimum blended solution.

In our existing modus operandi, we suppress the bias error before the data is distributed to our products by leveraging manual quality control (by operational forecasters). Road weather forecasts also benefit from this quality control because atmospheric forecasts are provided as input to the RWIS subsystem for the generation of pavement temperature forecasts.

Recent internal investigations have resulted in a statistical technique which can substantially suppress inherent NWP model biases.

Real-time results show an approximately 20% reduction in MAE (Mean Absolute Error) of next-day temperature forecasts compared to operational Pelmorex forecasts.

OBJECTIVE

The objective is to strengthen our global forecasting foundation by "tuning" our forecasts (derived from NWP model data) using past observations. Comparison of previous forecasts with their verifying observations will yield statistical information describing past forecast errors, which will be used to:

1. Calibrate new forecasts in order to suppress errors;
2. Calculate weight coefficients for the model blending system which are based on forecast accuracy performance (the most accurate model gets the highest weighting in the forecast consensus blend);
3. Calculate probabilistic information for new product development
   - (e.g. forecast confidence intervals, probabilities)

Calibrated consensus forecasts enable us to provide a much higher level of information to consumers than traditional deterministic forecasts.

The first phase is based on research which focussed on the application of statistical methods to 2-metre temperature, dewpoint temperature and wind forecasts. Some features of our system include:

- Global coverage
- Location-specific and gridded data processing
- A 60-day rolling archive of forecasts and observations, fully supported and maintained 24x7
- Statistical algorithms include mean (bias error, mean absolute error), standard deviation (of errors, of forecast values), linear regression, Kalman filtering, probability, and confidence intervals
- Observational datasets, both measured (from in-situ observation stations) and estimated (from a "virtual observation" engine)
- Ability to "spread" derived statistical information across regular grid

CONCLUSIONS

Calibrated consensus forecasts enable us to provide a much higher level of information to consumers than traditional deterministic forecasts. Information about the statistical distribution of the forecast can be used to inform the end user about the uncertainty in the forecast; thus enhancing the value of the forecast. Probabilistic information can be automatically incorporated into end user decision making tools which combine weather information with other societal lifestyle datasets such as transportation data; providing the consumer with more information for optimizing their planning decisions. Key business advantages stemming from a well-calibrated consensus forecast generation system include;

- Maintaining a strong consumer confidence in the Pelmorex forecast brand via increased accuracy of our forecast content
- New higher-value products which combine probabilistic weather information with societal lifestyle datasets for better planning tools (e.g. travel decision tools incorporating weather forecast information)
- Calibration of forecasts using observations reduces the amount of manual quality control effort required (e.g. to remove "bias" errors which exist in the base NWP datasets)

METHOD & RESULTS

NWP Models → **Bias Corrector & Weight Generator** → **Blender** → **Forecaster** → **Product**

NWP Models: Dynamical & statistical NWP models ingested.

Bias Corrector & Weight Generator: Several bias correction techniques applied, using 45 days of historical forecast-observation pairs.

Model weights generated based on verification scores.

Blender: Bias-corrected values optimally combined using their corresponding model weights.

Forecaster: Fine-tuned by a 24/7 operational staff of meteorologists for Canadian locations.

Product: Saskatoon, SK -14°C Light flurries

- *Primarily CMC & NCEP model datasets*
- *Model availability depends on location, parameter & lead-time*
- *Data stored for ~60 days*

BIAS CORRECTION METHODS

- *45-day average bias*
- *45-day simple linear regression*
- *Kalman Filter (W = 0.02)*
- *Kalman Filter (W = 0.1)*

WEIGHTING FUNCTION

- *Mean absolute error (MAE) calculated using prior 45 days of forecast-observation pairs*
- *Weight = 1 / MAE* ^{8}

- *Per model, run-time, parameter, location & lead-time*

- *Run at specific times each day, ensuring new forecast values are available for operational meteorologists at regularly-scheduled times, regardless of NWP model availability or delays*

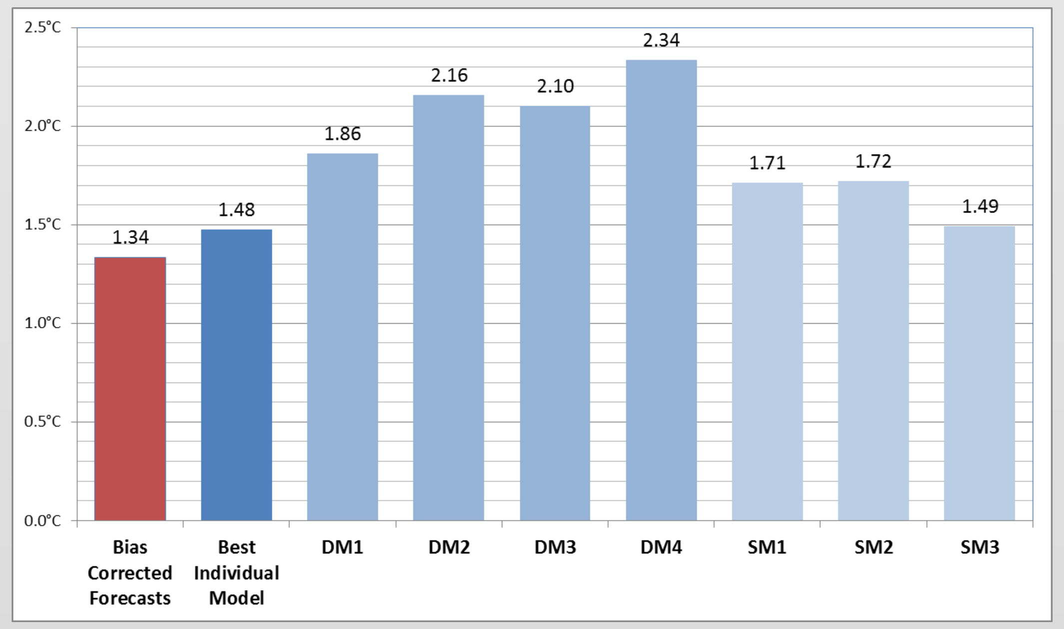


FIGURE 1: Bias-corrected forecast values vs. NWP models Mean absolute errors of next-day maximum temperature forecasts, averaged over 14 Canadian locations, from July 1, 2011 to June 30, 2012. A comparison of the bias-corrected forecast values vs. the best-verifying unbiased weather model per city. Each individual model is shown as well.

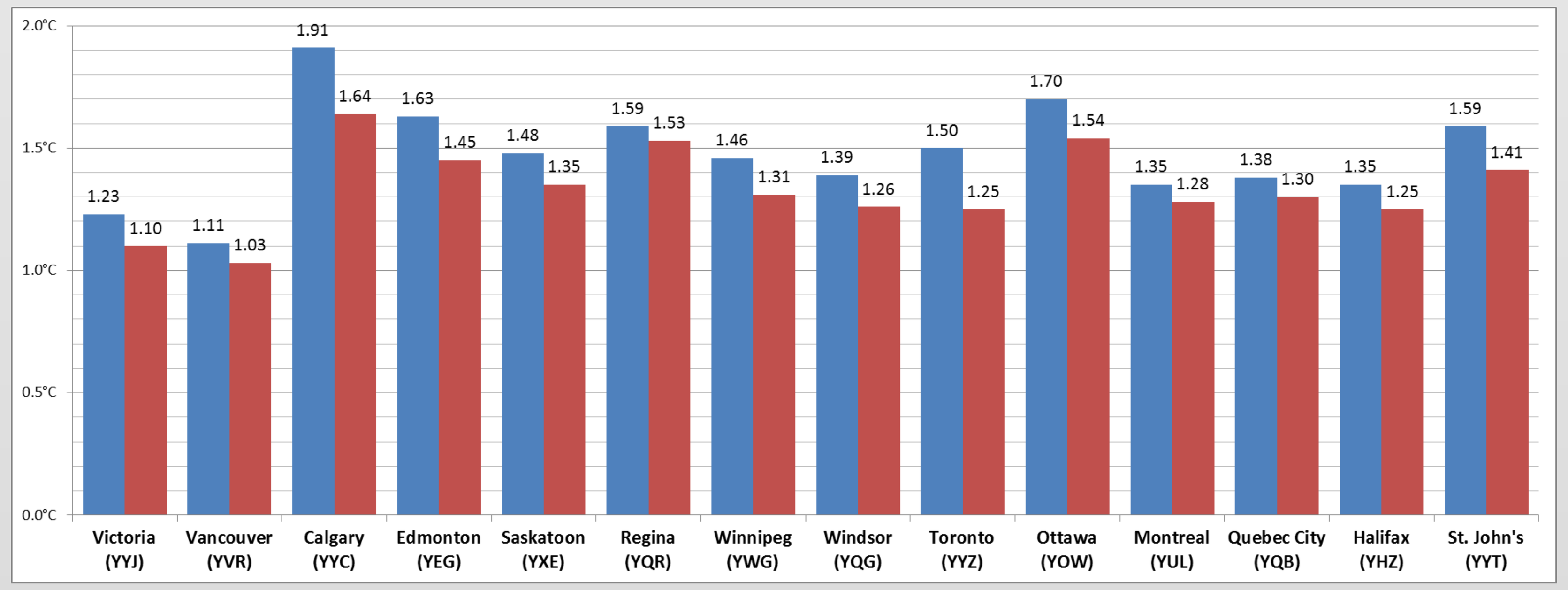
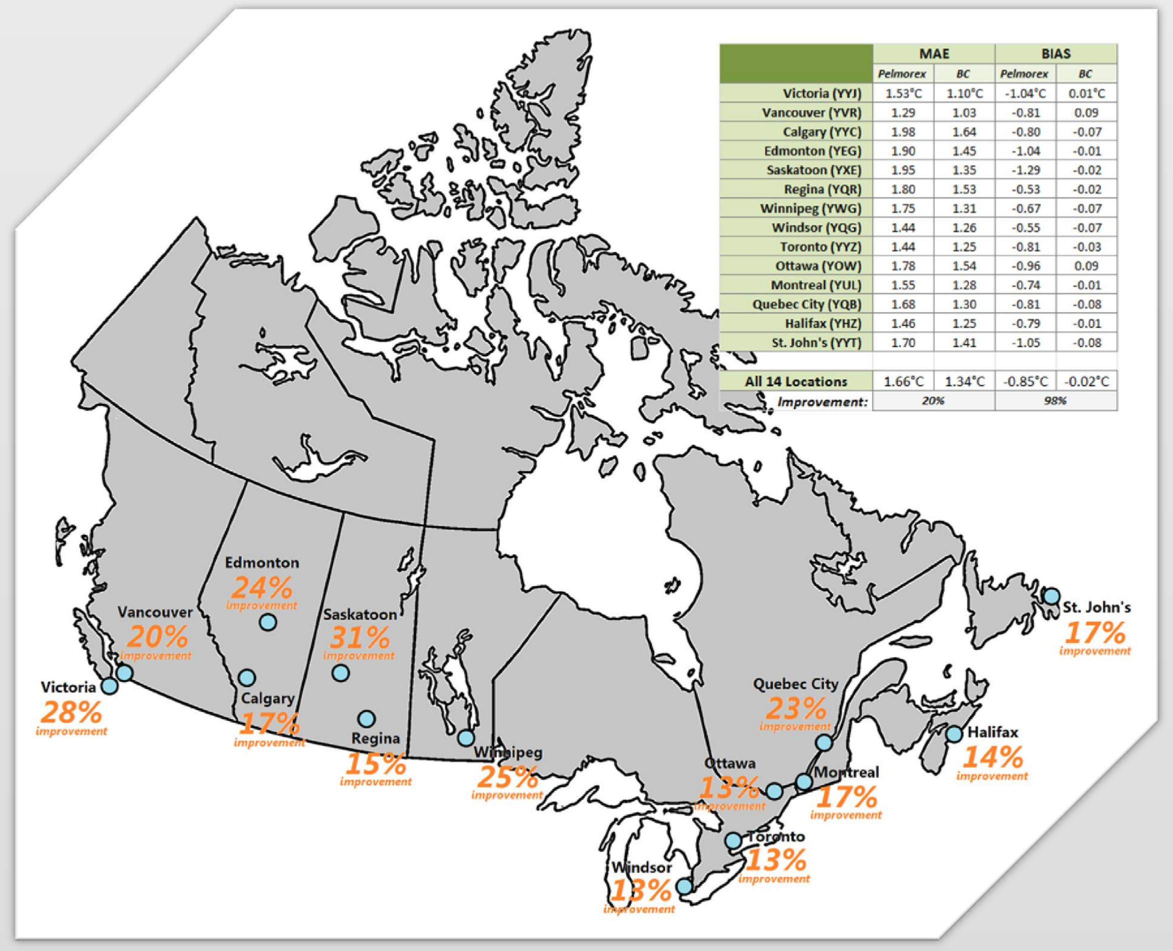


FIGURE 2: MAE Improvement vs. best single-model bias correction method Mean absolute errors of next-day maximum temperature forecasts for 14 Canadian locations, from July 1, 2011 to June 30, 2012. A comparison of the best verification score achieveable using a single model & single bias-correction method vs. the bias-corrected forecast values generated using the method described above (all NWP models, all available bias-correction methods, optimally blended using a verification-based weighting scheme).



	MAE		BIAS	
	Pelmorex	*BC*	*Pelmorex*	*BC*
Victoria (YYJ)	1.53°C	1.10°C	-1.04°C	0.01°C
Vancouver (YVR)	1.29	1.03	-0.81	0.09
Calgary (YYC)	1.98	1.64	-0.80	-0.07
Edmonton (YEG)	1.90	1.45	-1.04	-0.01
Saskatoon (YXE)	1.95	1.35	-1.29	-0.02
Regina (YQR)	1.80	1.53	-0.53	-0.02
Winnipeg (YWG)	1.75	1.31	-0.67	-0.07
Windsor (YQG)	1.44	1.26	-0.55	-0.07
Toronto (YYZ)	1.44	1.25	-0.81	-0.03
Ottawa (YOW)	1.78	1.54	-0.96	0.09
Montreal (YUL)	1.55	1.28	-0.74	-0.01
Quebec City (YQB)	1.68	1.30	-0.81	-0.08
Halifax (YHZ)	1.46	1.25	-0.79	-0.01
St. John's (YYT)	1.70	1.41	-1.05	-0.08
All 14 Locations	1.66°C	1.34°C	-0.85°C	-0.02°C
Improvement:	*20%*		*98%*	

FIGURE 3: Improvement vs. Pelmorex forecasts Next-day maximum temperature forecasts. Retroactive improvement in MAE verification scores compared to Pelmorex operational forecasts of similar lead-time, from July 1, 2011 to June 30, 2012.

FUTURE

Future phases of this multi-model, optimal blending approach will include the addition of all weather parameters required to generate all weather-related Pelmorex products.

Current research is loosely focussed on cloud cover, precipitation amounts, precipitation types, and convective parameters for all lead-times. A focus on nowcasting (0- to 6-hour lead-times) is currently underway as well, widening the scope of potential dataset types & calibration methods.

Some of the key areas of research & development currently being explored include:

- ingestion of ensemble NWP models
- more complex bias correction methods (multi-linear regression, reforecast methods, analogs)
- the handling of non-Gaussian distributed parameters (cloud cover, precipitation, etc.)
- Optimizing weighted blending scheme for all types of weather information
- better methods to distribute point information across a regular grid

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