

Integrating METRo into a winter maintenance weather forecast system covering Finland, Sweden and Russia

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ABSTRACT

Foreca has provided winter maintenance weather forecasts for several clients in Finland, Sweden and Russia for over ten years. METRo is a road forecast software distributed under the GPL license by Environment Canada. In 2010 Foreca started integrating the METRo model into its systems with the aim of improving road temperature and road condition forecasts. We describe how the METRo model was integrated into the work flow of duty meteorologists and how the model was modified to cope with the lack of subsurface temperatures in observations.

Keywords: METRo, road surface temperature forecast, road condition forecast, road weather forecast

1 INTRODUCTION

To summarize, METRo [1] is a road forecast software originally created in 1999 and distributed under the GPL license by Environment Canada. METRo uses road weather station observations and atmospheric forecasts as input and produces as output road surface and subsurface temperature forecasts and road condition forecasts.

Foreca's on-duty meteorologist's work station includes an editor which allows mouse-based manipulation of gridded weather data, such as precipitation or temperature fields. Prior to the introduction of the METRo road weather forecast model, road surface temperature was initialized once and then presented to the meteorologists for editing just like air temperature. A problem with this approach was that especially less experienced on-duty meteorologists felt that there was little they could contribute to the initial computer-generated road surface temperature forecast. When it was decided to integrate a new road forecast model into the system, it was decided to simultaneously aim for a work-flow change that would allow the meteorologists to concentrate on editing the atmospheric phenomena, such as cloudiness and precipitation, similar to the "manual mode" described in the original METRo paper. It was felt that in these areas meteorologists could contribute more naturally through their expertise in analysing satellite and radar imagery, and other observation sources such as road weather station network data.

Foreca relied on contacts made with METRo developers during the ROADIDEA-INCO project [4] when choosing the road weather model. The presentations of Seth Linden [2], [3] helped provide assurance about the deployment of METRo in an operational setting, while also highlighting some issues one should expect to encounter.

2 ROAD WEATHER FORECASTING WORK FLOW

2.1 Overview

The road weather forecasting work flow at Foreca is summarized in figure 1 below and explained in more detail in the following chapters.

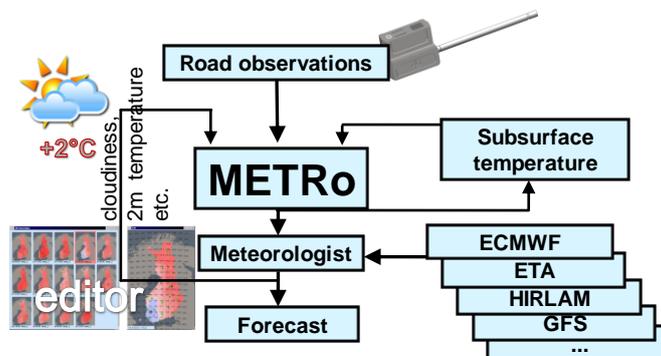


Figure 1. Road weather forecasting work flow at Foreca

2.2 Meteorologists' role

Foreca runs a 24/7 operation during the winter season. The on-duty meteorologist's shift proceeds as follows.

1. Orientation: meteorologist familiarizes himself with the weather situation, discussing with the previous shift's staff.
2. Forecast initialization: meteorologist evaluates the available numerical weather forecast models and decides which to use as the guidance for forecasting, e.g. ECMWF, WRF, etc. This decision has a large influence on the forecast and the saying is that "90% of the forecasting happens in the initialization". Initialization also includes the decision of using a Kalman filter vs. raw model.
3. Forecast editing: meteorologist opens the newly initialized forecast in the editor and fine tunes it. The editor allows loading of individual fields from any of the models, precipitation estimates from radar, SYNOP analyses, etc. For example, in this phase the meteorologist might replace the tail of the forecast with ensemble mean, or do nowcasting, such as reduce model cloudiness based on SYNOP analysis.
4. Commit: meteorologist commits the forecast to production.

If need arises, the meteorologist can at any time re-open the latest forecast, tune a parameter, and re-commit. Situations where such fine-tuning could be justified are for example summer shower location improvements based on radar data, or accounting for unexpected breaks in cloud cover as seen in SYNOPs or satellite images. It is possible for the meteorologist to complete the open – edit – commit cycle in under a minute.

The meteorologists do not have the option of editing road surface temperature directly. Instead the meteorologist can edit atmospheric parameters like cloudiness and air temperature, which will then affect the road surface temperature via METRO's forecasts. Figure 2 below provides a test example of this.

In the figure 2 top image, the raw model guidance has predicted that cloud cover around the marked station (red dot) will dissipate slightly (75% cloud cover) in the early morning. This did not happen, and complete cloud cover was observed throughout the night, so the meteorologist on duty edited the forecast and manually painted 100% cloudiness over the area, see figure 2 bottom image. The result can be seen in the road temperature graphs. According to the initial prediction, road surface temperature would drop to below -2 C in the morning, but after the edits it stays close to zero.

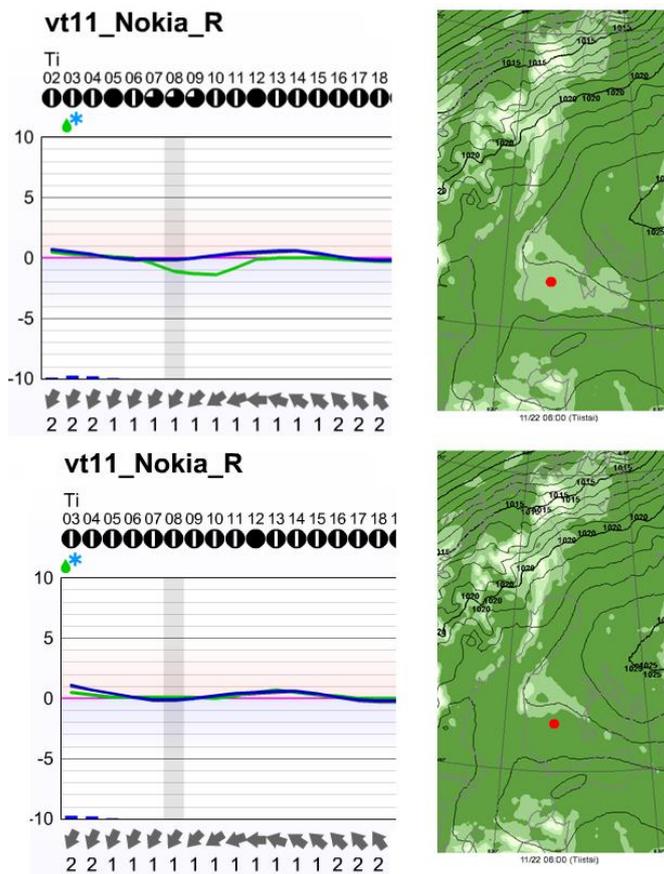


Figure 2. The effect of cloud cover editing on road surface temperature

2.3 METRo model's role

Due to METRo's coupling feature, its short term forecasts are excellent. To get the benefit of this good nowcasting ability, a new METRo run is triggered either by the arrival of new observations or by the commit of a new atmospheric forecast. Such frequent updates would not be feasible if the meteorologists directly needed to edit the road temperature.

As of this writing, the set-up at Foreca uses road observations from the past 48 h and a minimum of 4 h overlap with atmospheric forecasts. METRo is only run for road weather station locations.

None of the road weather stations operated by Foreca's customers provide subsurface temperatures (sst) as expected by METRo. To compensate, METRo's forecasts are used as pseudo-observations, i.e. METRo is run iteratively to generate the sst. When a new station is added, zero Celsius is provided as a starting value, and the sst stabilizes within a day, forced by the surface temperature. A problem with METRo temperature profile initialization caused this scheme to initially produce bad results with longer forecasts, but the problem was resolved with a relatively simple code modification, see chapter 3 for details.

3 MODIFICATIONS TO METRO

Foreca originally installed METRo version 3.2.5 in 2010. When verifying previous winter's re-forecast data it was noticed that in the autumn there seemed to be a cold bias in the forecasts that grew steadily with forecast length. In late spring there was a correspondingly growing warm bias. Since the effect was difficult to see in per-station case studies due to diurnal effects, verifications of forecasts starting at every hour of the day were averaged, which cancels out any day - night variations. This approach showed the suspected bias clearly; see figure 3 below, which shows the average of 193313 forecasts for 275 road weather stations in Finland during January 2010.

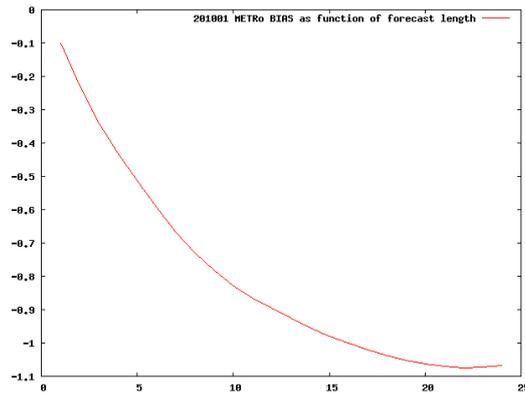


Figure 3. Bias grows as function of forecast length

Investigation revealed a problem with METRo temperature profile initialization. The initialization is based on two values: surface temperature and 40 cm subsurface temperature (sst). METRo uses 27 layers to model the road bed, and the layers get progressively thicker downwards. The bottom layer is 20 meters of sand and starts at 115 cm depth. The problem is that the METRo initialization code sets the temperature of all the deep road layers (those below the sst layer) to the same value as the sst. This is not a big problem if real sst observations are available, and the forecasts are not very long. In the absence of real sst observations, however, the sst can drift badly if there is no forcing from the bottom. For instance, if the initial surface temperature and sst are both -20 C, METRo will produce a uniform temperature distribution of -20 C for the entire grid, including the bottom layer. Measured road temperature profiles were not available for this study from Finland, but Swedish Vägverket publishes frost depth measurements [5] that clearly reveal the METRo initialization to be unrealistic. At 115 cm depth the temperatures typically do not go below zero before there have been several months of cold weather. In the autumn it is possible to have surface temperatures of -20 C and at one meter depth a temperature of +10 C, which results in an error of 30 degrees Celsius for the bottom layer temperature when using the METRo default initialization scheme. In longer forecasts such a discrepancy starts to show in the results, as can be seen in figure 3 above. The situation is reversed in the spring, when the deep soil temperatures are colder than the surface.

Figure 4 below shows the air and road surface temperatures for the entire 2009 – 2010 winter season and the preceding summer, averaged over all road weather stations in Finland. As can be seen, the winter colds started mid-December, so the above described discrepancy in bottom layer temperatures is prominent in January.

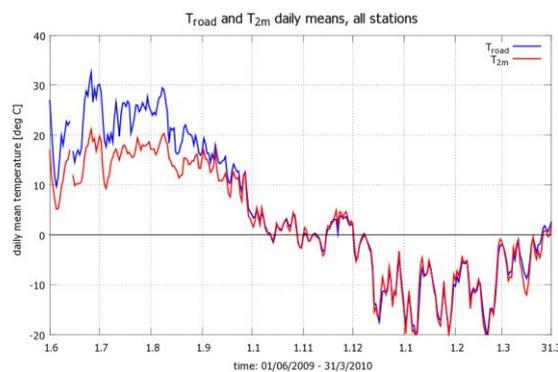


Figure 4. Season 2009 – 2010 air and road surface temperatures

A simple one-liner fix was implemented in METRo for testing: the bottom-most layer's temperature is forced to a constant value typical of winter deep soil temperatures. According to the Swedish Vägverket data, a good first guess for winter months seemed to be zero Celsius. The same forecasts were re-run with otherwise the same input data, but the METRo bottom layer was initialized to 0 C at the beginning of the forecasts. The verification results are shown in figure 5. As can be seen, bias at +24 hours is reduced from -1.1 C to -0.4 C. RMS was reduced by a similar amount.

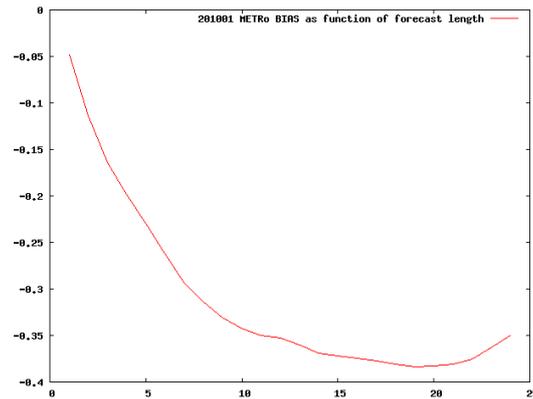


Figure 5. Bias after fixing METRo bottom layer temperature to zero Celsius

Some bias remains, which could be attributed to bias in the atmospheric forecasts, or incorrectly guessed bottom layer temperature. To better understand the error sources, the next project will be to re-calculate the same data set with perfect prognosis approach. Foreca is also working with Finnish road authority to get some measurements of deep road temperatures in Finland, which could be used to improve the crude zero Celsius guess.

4 CONCLUSIONS

Foreca has successfully integrated METRo into its forecasting work flow in manual mode, i.e. using manually edited cloudiness and air temperature as input. The change has been received positively by the on-duty meteorologists.

The METRo current version (3.2.6) is a useful source of road forecasts for winter maintenance as such if subsurface temperature (sst) observations are available. If subsurface observations are not available and longer length forecasts are desired, the current version needs modifications to make sure the temperature profile initialization is realistic. Improving the bottom layer initialisation would likely yield a small benefit also in cases where the sst observations are available.

We would also like to repeat the wish expressed by Linden et al. [2] that METRo should accept an alternative high performance input format in addition to the current XML format. Now a single 24h METRo run for one road weather station site takes about a second, and 80-90% of the time is spent on XML input/output processing. Foreca currently runs METRo for approximately 1400 road weather station sites, so the computational cost limits METRo's applications and causes unnecessary latency in forecasts. For instance, we would like to provide meteorologists with a near real-time display of road surface temperature in response to atmospheric forecast editing, but this is not feasible at the moment.

5 REFERENCES

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