ENSEMBLE FORECAST IMPLEMENTATION IN THE RMI ROAD WEATHER FORECASTING SYSTEM

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Summary

Road and highway maintenance actions, such as the clearing of snow and prevention of ice by salting, are necessary during winter to prevent accidents due to dangerous road weather conditions. To aid decision making by end users, observations from road weather stations (RWS) can be combined with models that forecast the road surface temperature and road condition during coming days. For forecasting, the use of dedicated road weather models (RWM's), forced with input from numerical weather prediction (NWP) models, is a standard approach. At the Royal Meteorological Institute of Belgium (RMI), a road weather forecasting system was developed in collaboration with the Royal Netherlands Meteorological Institute (KNMI). The KNMI RWM is a physical model, which was previously validated and compared with the Finnish RoadSurf model over the Netherlands [1]. This model was taken as the basis to develop a RWM for Belgian roads and highways in 2018, leading to the deployment of the RMI "GMS" system ("Gladheidmeetsysteem" in Dutch, or "Measuring system for slippery roads")[2]. This system is used operationally by the regional road and traffic management agencies in Flanders (Agentschap Wegen en Verkeer) and Wallonia (Météoroutes), and also by the RMI Weather Office.

Since winter 2022-2023, the system has been extended to an ensemble road weather forecasting system, with a mini-ensemble of different NWP models used to force the RWM. A first verification study was performed for winter 2023-2024, showing the potential added value of the mini-ensemble, and further developments are foreseen for the next years. We present a brief overview of the current operational system, first verification results, and plans for future developments.

Road Weather Model and GMS

The KNMI RWM [1] was calibrated for Belgian roads and highways, and adapted to make use of various available NWP models as input. Standard meteorological parameters are used as input, giving hourly output of RST, road surface condition and amount of water and ice on the road, up to 48 hours lead time. GMS forecasts are run every hour, assimilating RWS observations updated every 10 minutes. These include observed RST, air temperature and dewpoint temperature. A correction of the radiation input is performed based on RST errors during the past 2 hours. Road surface condition information from RWS is also used to initialize ice and water content on the road. Through a GIS-based interface, end users can consult forecasts for all RWS locations (about 55 stations in Wallonia and 90 in Flanders), in addition to RWS observations. Various map layers are available, including overlays of weather radar images for precipitation, satellite images for cloud cover and geolocated weather reports generated by citizens through the RMI weather app [3]. For Flanders, users can further consult a static thermal map and webcam images from highway cameras. An experimental version of the RWM was also developed and tested that makes use of car sensor observations [4]. An example of the end user web interface is shown in Figure 1. Users can click on a station to view detailed forecasts for that location, including the meteorological parameters mentioned above, plus information on wind speed and direction and falling precipitation (rain/snow). Information on predicted road surface condition is provided through color-coded icons, with dangerous conditions indicated in red (e.g., ice on the road).

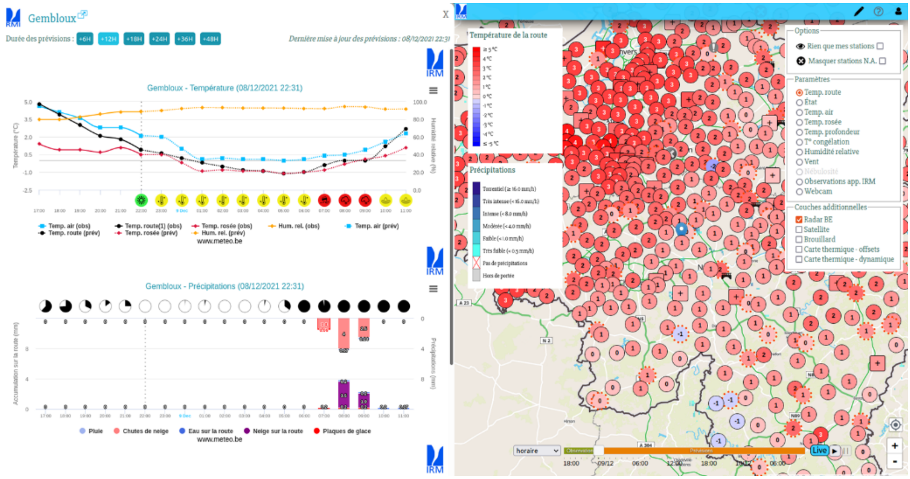

Fig. 1. End user web interface to the RMI road weather forecasting system. Forecasts for various meteorological variables for a specific station location shown on the left, map with different GIS layers on the right.

Ensemble road weather forecasting system

Since the winter of 2022-2023, the GMS system was expanded to an ensemble road weather forecasting system. Currently, this is a multi-model ensemble consisting of five weather models, which are used to generate an uncertainty interval for the road surface temperature forecasts, communicated to end users together with the deterministic RST forecast. Table 1 shows the five NWP models and their resolution. The model “MBG” consists of the “best model”, chosen and adapted by the RMI Weather Office forecasters, and blended with the RMI nowcasting system INCA-BE.

Table 1. NWP models used in the ensemble road weather forecasts.

NWP model		Resolution
1.	Alaro 1.3	1.3 km
2.	Arome 1.3	1.3 km
3.	ECMWF HIRES	~9 km
4.	UK Met Office UM Global	~10 km
5.	RMI MBG	varies

An example of an RST forecast with uncertainty bound from the operational GMS is provided in Figure 2.

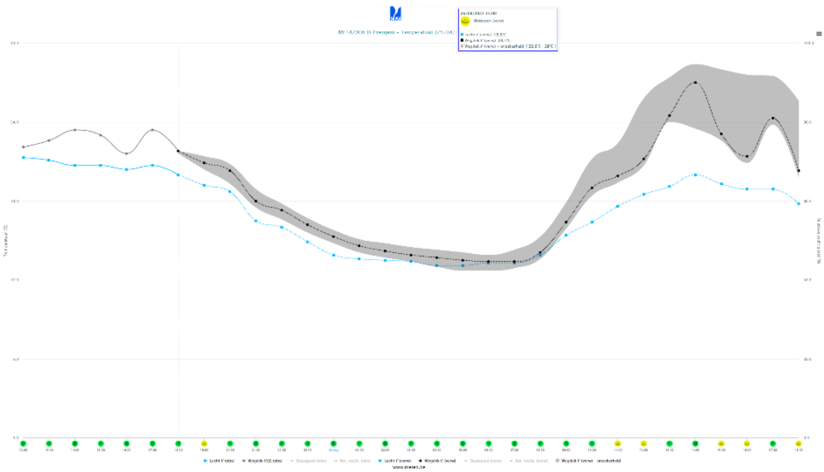

Fig. 2. Example of a GMS road surface temperature forecast, for station Evergem, 26/8/2023, 15:00 local time, with uncertainty bound derived from the mini-ensemble forecast.

Verification

A first verification study was conducted for the winter months December 2023 – January 2024: a period where freezing temperatures and snowfall events occurred. We focus here just on the skill of the mini-ensemble at predicting sub-zero nightly minimum temperatures. Future validation will extend this to actual slippery road conditions, which depend on multiple meteorological variables. Table 2 shows verification scores for the 18 UTC forecasts of the nightly minimum RST, averaged over all stations, for the individual models and the ensemble mean.

Table 2. Verification of minimum RST forecasts of 18 UTC .

NWP model		RMSE (°C)
1.	Alaro 1.3	1.15
2.	Arome 1.3	1.02
3.	ECMWF HIRES	1.00
4.	UK Met Office UM Global	1.11
5.	RMI MBG	0.94
6.	Ensemble mean	0.87

The ensemble mean performs best as quantified by the RMSE. The overall CRPS of the ensemble is given by 0.52 °C, which is less than the mean absolute error (MAE) of each individual model (not shown).

We also investigated the relative economic value (REV) of the probabilistic RST forecasts for the event threshold RST < 0°C, as function of the user cost/loss ratio [5]. Figure 3 shows as example the REV envelope (using the optimal decision threshold for each cost/loss ratio). We find that the REV of the ensemble is higher than that of the individual deterministic models, for small and large cost/loss ratios.

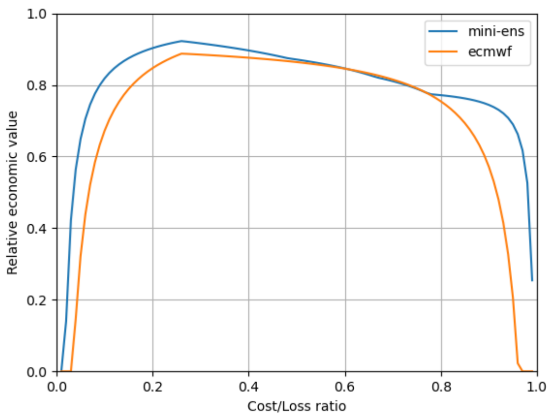

Fig. 3. Relative economic value of forecasting the event: nightly minimum RST < 0°C (18 UTC), comparing ECMWF and the mini-ensemble forecast.

Our preliminary verification results are encouraging; however more work is needed to demonstrate the added value for predicting dangerous road conditions. End users have reacted favourably to the inclusion of uncertainty bounds, and we will consider how to use probabilistic information in a more comprehensive way in the future, without sacrificing usability of the system by non-expert users.

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References

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