FORECASTING OF ROAD SURFACE CHARACTERISTICS IN FRANCE

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1. INTRODUCTION

During winter, many roads located in cold or temperate regions (e.g. North America, Europe) are subject to severe climatic conditions associated with snow and ice. These conditions have serious consequences on driving conditions, reducing the traffic flow dramatically. Each country submitted to winter maintenance uses road weather forecasting system for help to organize the maintenance services. It consists of a prediction of road surface characteristics associated to a road weather station. The forecast models focussed mainly on road surface temperature and ice, and these models do not distinguish snow of ice. So, they did not account for the highly variable thermal fluxes during snow deposition and the snow-road interface properties.

A research project, called Gelcro, has been initiated in France in 1995, which joins the expertise of the Centre d'Etudes de la Neige (CEN/Météo-France), the Centre d'Etudes Techniques de l'Equipement (CETE) in Lyon and Nancy, the Laboratoire Central des Ponts et Chaussées (LCPC) and the Direction Départementale de l'Equipement de l'Isère (DDE 38). This project permitted to increase the knowledge of the snow behaviour on pavement, notably processes related to road-snow interface physics (Borel 2000, Muzet et al. 2000), and to develop a model able to account for these phenomena. The model resulted of an adaptation of the ISBA-DF model (Noilhan and Planton 1989, Noilhan and Mahfouf 1996, Boone et al. 2000) to road problematic (ISBA-Route), coupled with the CROCUS (Brun et al. 1989, 1992) snow model.

This model (Bouilloud and Martin 2006) was validated with measured data from the Gelcro experiments. This paper focus especially on the main interest of the project, the use for prediction. Prediction results were first considered in comparison with experimental results used for the validation. Then the results obtained with the spatialized version of the model at the France scale for the 2005/2006 winter were analysed. However, it is important to notice that at this stage of the project, the model does not take into account effects of the traffic and de-icers applications.

2. FORECASTING ON THE COL DE PORTE EXPERIMENTAL SITE

2.1 Principle

The experiments of the project permitted to build a comprehensive database constituted of 60 snowfall on road events (from winter 1997/1998 to 1999/2000). So, the ISBA-Route/CROCUS coupled model was used in forecasting conditions on the experimental site, in aim to compare results with measurement, and validation results (e.g. results obtained with measured meteorological forcing). We used here the two modes of the SAFRAN (Durand et al. 1993) model to produce a forecast of road surface conditions : the forecast mode (with permits the downscaling of numerical weather models forecast) for meteorological conditions forecasting, and the analysis mode (which is a correction of predictions thanks to available measurements) for initialisation. The forecast period is 24 hour, from 0600 UTC day D to 0600 UTC day D+1. The ISBA-Route/CROCUS coupled model ran with the forecasted forcing of the SAFRAN model. The road initialisation (temperature, water and ice content) at 0600 UTC resulted from the simulation of the previous day with the analysed SAFRAN forcing. A definition of the "snow presence on road" event should be

adopted. A snow presence on road consisted in the case of a 6 hour continuous snow presence on the road during the period, or in the case of the snow presence since at least 2 hours at the end of the period. No height criterion was introduced in the definition, since road are cleared of snow by maintenance services as soon as the snowfall hold on the road.

2.2 Results

Tab. 1 gives results of snow presence and road surface temperature forecasting for three types of simulations (with measured forcing, with analysed forcing and with forecasted forcing).

Table 1: Scores of road surface temperature (Mean Error, Root Mean Square Error) and snow presence on road (Probability Of Detection, False Detection Ratio, False Alarm Ratio) simulations with measured, analysed or forecasted forcing.

Simulation type	Snow presence on road			Road surface temperature	
	POD	FDR	FAR	ME (°C)	RMS (°C)
observed forcing	95. 5%	0.9%	4.5%	0.5	2.8
analysed forcing	90.9%	3.2%	14.9%	1.8	4.1
forecast	68.2%	5.5%	28.6%	2.4	4.8

Road surface temperature simulated with observed forcing was the more accurate among the three simulations, with a RMS of approximately 3°C. This result was already discussed in a previous work (Bouilloud and Martin 2006). The simulated road surface temperature is less accurate for the simulation with analysed or forecasted forcing. The improvement of error is important, even for the simulation with analysed forcing. This is due to the solar shadows which are considered in measured forcing, contrary to analysis or forecast. This lead to an error associated to important solar radiation. So, this problem is not essential for road maintenance services, which interest particularly to frost risk, with negative temperatures.

A particular interest was given to the simulation of the "snow presence on road event". Concerning the simulation with measured forcing, 4 wrong simulations were numbered among the 60 events. These cases were close to the limit of the adopted definition. Indeed, snowfall happened here at the end of the period, and in one case (either measurement or simulation) the holding of the snow was slightly greater than 2 hours. It was therefore defined as a "presence of snow" case, and as an "absence of snow" in the other case. However, the majority of cases of snow presence on the road were reproduced with the observed forcing, so statistical results were very good for this simulation as shown in Table 1. Simulation with analysed forcing decreased slightly the results, but they are still very high, with a probability of detection of approximately 90%. The forecast of the event " was satisfactory, with a probability of detection of approximately 70% and a false alarm ratio of approximately 30%.

3. FORECASTING AT THE FRANCE SCALE

Conditions of the ISBA-Route/CROCUS coupled model at the France scale were similar to the Météo-France operational SAFRAN-ISBA-Route (SIR) suite, for road surface temperature forecasting. The horizontal resolution of the SAFRAN model for this application is 8km, and the time range for the forecast is 24 hours (from 0600 UTC to 0600 UTC). To test model capacity in road surface temperature and snow presence on road forecasting, a simulation of the 2004/2005 winter was conducted. This winter was particularly interesting in France, because of the important amount of snow presence on road events whose led to road network difficulties, particularly in plain areas. Results were compared with measurement of different road stations for several freeways in France (A4, A10, A20, A40). It is important to notice that road surface sensors are submitted to traffic and salt presence, and would take them into account, while the model would not.

3.1 Road surface temperature forecasting

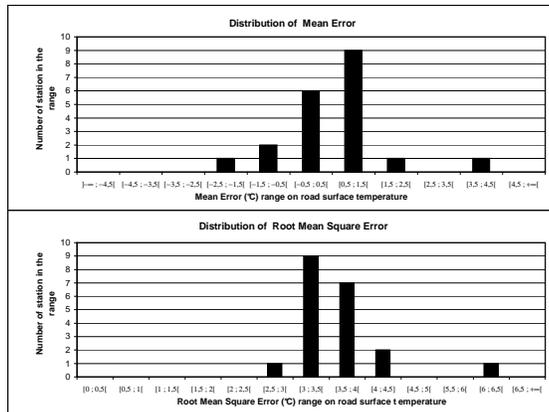Statistical results for the sample of road weather stations are given in Fig. 1.

Figure 1: Distribution of global mean error (top) and root mean square error (bottom) on road surface temperature fir the forecast.

Statistical results showed that results were relatively similar for all the stations, with a mean error between −0.5°C and 1.5°C and a root mean square error between 3°C and 4°C. One station of the A40 freeway presented very different and very worse results than others. The road surface temperature simulated (with analysed forcing or the forecast) was very superior to measurement. The bad simulations relative to this station might be due to the station situation in a place submitted to very important local effects (wind or sun radiation absence), not taken into account in this study. Another possible cause is a valley effect. Indeed, is the freeway being located in the French Alps, a temperature inversion (with colder temperature in valley than in altitude) might be possible there, undetected by the weather forecast model, nor by the SAFRAN model. Concerning the A10 station, an important cold bias appeared. However, it could be noticed that concerning this station, the temperature measurement quality appeared relatively debatable. Moreover, the concerned station was the single one of this freeway, so any certain conclusion could be deduced.

3.2 Perspective for snow presence on road forecasting at the France scale

Freeway stations are not eq ght sens nce on road validation was a problem. In aim to appreciat odel for s ad forecasting, a validation was done thanks to press infor ance mea the problematic as possible (snow precipitation occurrenc e on natu from 28 december 2004 at 0600 UTC to 29 december 200 esented as 2.
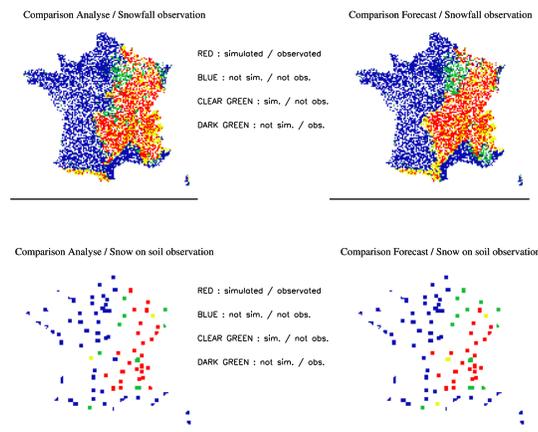

Figure 2: Comparison of the simulation (with analysed forcing and forecast) of snow presence on road with snowfall occurrence (top) and snow on natural soil observation (bottom).

According to a French newspaper (NouvelObs) archives, the road traffic was disturbed by snow in the south-east quarter of the country. Results with analysed and forecasted forcing showed that the model simulated snow presence in this region. The press archives were dated from 18 December at 17 UTC and at this moment, the article indicated that the perturbation was moving in the North direction. This could explain the presence of snow in the simulation in the North-East quarter of the country. These results were reinforced by the comparison with snowfall occurrence observation. The forecasted snow presence on road seemed to be representative of the event, even if it seemed to be geographically too vast. The comparison with observation showed that the forecasted event seemed to be too large at the east of Paris. However, it was impossible to determine if the event did not exist in this zone or if the snow observed had melting on the road. For the grid points with an human observation, a contingency table was established, comparing snow presence on road in simulation and snow presence on natural soil in observation. Statistical scores were calculated from this contingency table. The relatively high probability of detection (approximately 69%) and the relatively low false alarm ratio (approximately 11.5%) confirmed that this event seemed to be forecasted with accuracy.

4. CONCLUSION

The ISBA-Route/CROCUS coupled model was developed in aim to serve as an operational model for road maintenance services for forecasting of road surface characteristics in winter. Main interest of this model is its ability in simulating snow behaviour on road. Moreover, this model needs only meteorological conditions forecasting to produce a road surface forecast. So, the forecast is less expensive than forecast system associated to road weather stations. Forecasting on the experimental site permitted to conclude that the model was able to predict the majority of snow presence on road events, with a detection rate and a wrong alarm rate respectively of approximately 70% and 30%. The incorrect predictions were essentially due to a wrong forecast of meteorological data. Road surface temperature forecast on experimental site was satisfactory, with a root mean square error of approximately 5°C. These results permitted to consider an operational application for the model. In this aim, the model was spatialized at the France scale with a 8 km horizontal resolution, and a simulation of the 2004/2005 winter was done. Validation of the road surface temperature was done thanks to measurement issued from freeways road weather station. Predictions were relatively homogeneous for all the stations, with a root mean square error of approximately 4°C. Concerning the snow presence, first results at the France scale were encouraging, but a larger validation should be enterprise. This is a relatively difficult problem. Indeed, road weather stations are rarely equipped with snow depth sensors, and moreover, when they are, reliability of measurement is debatable (technically and because of the data hiding due to salt brine). Use of archived data seems to be very difficult, because snow presence on road data are rarely archived, so it needs to regroup archives of all the road maintenance services. Another way of validation, is the use of the model in real-time forecasting. In parallel, research need to continue in aim to improve the model. Indeed, a model parameterization of the traffic and the de-icers is primordial to appreciate sensitivity of these factors, to conclude to a possible interest of a parameterization of these factors in the model for an operational use.

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