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A new model for operational winter road surface conditions forecasting in Météo-France

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ABSTRACT

During winter, snow presence on the road might have serious consequences on road traffic and security, especially in plain areas where snow occurrence frequency is quite lower than in mountainous areas, and consequently road users and road management services are less prepared. For road weather forecasting, Météo-France uses in an operational way since 2004 a specific model, ISBA-Route, a model which permits to simulate the behaviour of a road under the influence of atmospheric conditions. To improve this model and in aim to serve as a forecast tool for snow presence on road, this model was coupled with the detailed snow cover model CROCUS. The resulting ISBA-Route/CROCUS model permits to describe with accuracy the behaviour of the snow deposited on the road and its characteristics (height, density, liquid water content, grain type…). The ISBA-Route model is forced by human expertised atmospheric forecast, within the PEIR (Expertised Predictions for ISBA-Route) system, to produce operational forecast of road surface : temperature, water and ice content. To improve this operational system, a pre-operationally test was done during the 2012/2013 winter using the ISBA-Route/CROCUS model to provide predictions of snow occurrence, height and type on road at the France scale. During this winter, many significant snow events with high spatial extension and important snow amount occurred in France, and it permitted to conclude that the use of the ISBA-Route/CROCUS model will lead to significant improvements concerning snow prediction for road network. Consequently, this model is operationally used since the current 2013/2014 winter.

Keywords: Winter maintenance / Snow / Road surface conditions / Forecasting.

1 INTRODUCTION

During winter, snow presence on the road might have serious consequences on road traffic and security. Moreover, impact of snow presence on road is more important in plain areas, where snow occurrence frequency is quite lower than in mountainous areas, and consequently road users and road management services are less prepared. For example, in big urban areas several centimeters of snow are sufficient to stop totally road traffic and to limit consequently the economical activity. So this is a major problem and consequently important efforts have been done for several years to develop decision-making tools for road management in winter to predict road conditions, organize maintenance, and reduce the risk of accidents. Numerical models are used to predict road surface conditions. These models perform a resolution of the energy budget of a road, in a more or less complex way (surface energy budget, diffusion model, with or without water and ice budget…). For this purpose, a specific model was developed in France: the ISBA-Route/CROCUS model. This model permits to describe with accuracy the road surface temperature evolution, the water and ice road content and the behaviour of a snow layer deposited on a road. The model is presented in the first part of the paper. In the second part, the results of the operational forecast road conditions systems used by Météo-France are discussed. The last part of the paper focuses on the specific problem of the prediction of snow height and type on road surface.

2 BRIEF DESCRIPTION OF THE MODELS

The ISBA-Route/CROCUS coupled model consists in two coupled one-dimensional models : the soil model ISBA [1-2] and the snow model CROCUS [3-4]. ISBA-Route is the road adaptation of ISBA used in its multi-layer diffusion scheme version [5]. CROCUS is the detailed snow process model which originally was used for avalanche forecasting at Météo-France [6]. The validation of the model was done using data from a comprehensive experimental field campaign during the 1997/1998, 1998/1999 and 1999/2000 winters at the Météo-France Col de Porte (1320m, Chartreuse mountain range, French Alps) experimental site. The model evaluation consisted in the comparison of simulated (with observed meteorological data) and measured road surface temperature, 0.6 m deep temperature, snow depth and road/snow interface conditions for 60 snowfalls on experimental road events. The model evaluation was done using an experimental pavement corresponding to a relatively thick highway structure, for which the surface layer is constituted of semi-grainy bituminous concrete. This type of road composition was then used for the forecast over all of France. The ISBA-Route/CROCUS coupled model accurately simulated the road surface temperature, and the occurrence of the snow on the road. However, some discrepancies in term of the simulated snow height occurred. The simulation errors were mainly caused by uncertainties of the precipitation phase, difficulties in predicting the snow density or phenomena not taken into account by the model (e.g. snow transport by the wind). In addition, snowmelt was a bit too slow. On the roads, the snow coverage was actually spatially inhomogeneous, and lateral heat transfers enhanced the melting, especially when the underlying dark road surface began to appear. However, these discrepancies (late melting and snow depth uncertainty) where determined not to be critical for the projected application over all of France, which concerns primarily determination of the occurrence of snow on the road and the beginning of the snow coverage. More details concerning the experiments, the model and the validation can be found in [7].

3 OPERATIONNAL ROAD SURFACE CONDITIONS FORECASTING

Since the winter 2010/2011, winter road surface conditions forecasting was done thanks to a coupling of the ISBA-Route model with the numerical weather prediction model AROME [8], the AROME-ISBA-Route system called AIR. However, for this system it could be observed a positive mean error (equivalent to a cold bias of approximately 1°C) which was responsible to a quite poor quality of the forecast of the event “negative road surface temperature” with a very satisfactory probability of detection but with a quite high probability of false alarm for AIR system (approximately 40%). So, these results needed to be improved. The main source of large errors in prediction was a wrong prediction of atmospheric radiation (due to a wrong prediction of nebulosity). A way of improvement was envisaged, it consisted in using the expertise of human forecasters of Météo-France. So, since the 2012/2013 winter, a new approach for winter road conditions forecasting was implemented in Météo-France. The ISBA-Route model is forced by human expertised atmospheric forecast instead of a direct coupling with numerical weather prediction models. This system, called PEIR (Expertised Predictions for ISBA-Route), is operationally used with the ISBA-Route model (or ISBA-Route/Crocus model since the current winter) to predict road surface temperature and road surface water and ice content. This system is schematized in Figure 1.

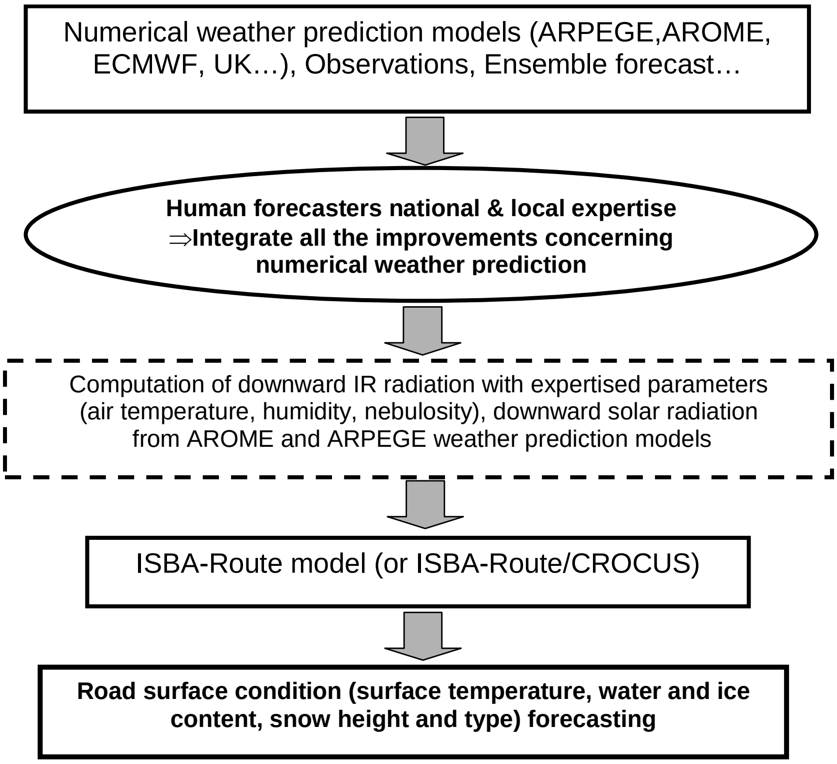

Figure 1. Simplified diagram of the PEIR Météo-France operational system for road surface conditions forecasting.

The post-event analysis of the 2012/2013 winter showed a significant benefit concerning the accuracy of the predictions. The comparison of this new PEIR system with the AIR system was done for the period from November 1st, 2012 to March 31, 2013 for a sample of approximately 150 road weather stations located all around France. Typical scores were computed: the mean error and the root mean square error, and the probabilities of false alarm and detection for the prediction of the event "negative road surface temperature". Moreover, in aim to improve results interpretation, the Heidke Skill Score was computed, because it takes into account in the same score the false alarms and the good detections, as opposite to the probabilities of false alarm and detection which can not be interpreted separately. The Heidke Skill Score characterize all the good predictions in comparison with the random prediction. It varies from $-\infty$ to 1, where 1 is the perfect prediction and 0 the random prediction score. Benefits during daily period is less significant than nocturnal period. This is due to the solar visible radiation (main parameter concerning diurnal road surface temperature heating), which is the unique parameter issued from the numerical weather prediction AROME model within the PEIR system, and which is the same for the two systems. So, and in order to compare with the 30 hour forecast of AIR, the scores were computed only for the first nocturnal prediction (from 18h UTC to 6h UTC), and are given in Table 1.

System	Mean Error (°C)	Root Mean Square Error (°C)	Probabilty Of Detection (%)	Probability of False Alarm (%)	Heidke Skill Score
AIR	1.5	2.28	96	36	0.62
PEIR	0.1	1.65	83	21	0.72

Table 1. Statistical scores of the AIR and PEIR operationnal road surface temperature systems.

It might be observed in Table 1 that the improvement due to the use of expertised atmospheric forecast is significant with an important decrease of root mean square error or mean error and above all a decrease of the probability of false alarm (21% instead of 36% for the AIR system) which is fundamental for road managers, because of the cost of an unnecessary road treatment. Moreover, the PEIR system permitted a significant extension of the forecast range (3 days versus 30 hours for the AIR system) with a good predictability (not significant decrease of the forecast scores for the second and third days).

4 SNOW PRESENCE ON ROAD PREDICTION WITH THE ISBA-ROUTE-CROCUS MODEL

4.1 The snow potential

Until the 2013/2014 winter, the operational snow prediction on road was done thanks to a parameter called "Snow Potential". This parameter is computed thanks to two forecasted parameters : the snow precipitation and the air temperature. According to the air temperature, a snow quality (dry, wet, moist, powder) is determined with an associated density. And consequently, this determined density permits to transform the snow precipitation into a snow height on the road : the snow potential. So, this snow potential might be seen as the height of snow on the road, without accounting for melting, metamorphism or mechanical effects (settling). This is a parameter of interest for road managers, however additional information are necessary for winter maintenance services, as the moment of snow sticking on road, snowmelt, water content of the snow… So, a way of improvement is to use the ISBA-Route/CROCUS model described in section 2.

4.2 The use of ISBA-Route-CROCUS for operational prediction

Following the same principle of the PEIR system described in section 3, a new system is available since the winter 2013/2014 in Météo-France for the forecast of snow presence on the French road network. This system use the expertised atmospheric forecast and the ISBA-Route/CROCUS model to perform a forecast of snow type on the road (height, density, snow water content, grain type, snow/road interface configuration…) in aim to serve decision-makers for snow treatments. An example of improvement due to the use of the ISBA-Route/CROCUS model is given for an event which occurred early in the winter from 27 to 28 October 2012. Figure 2 represents the comparison of the snow potential and the snow height on road simulated with the ISBA-Route/CROCUS model. The snow potential computation and the simulation were done in an analysis mode, with same analyzed atmospheric data (based on data fusion of numerical weather models, radar data and soil observations).

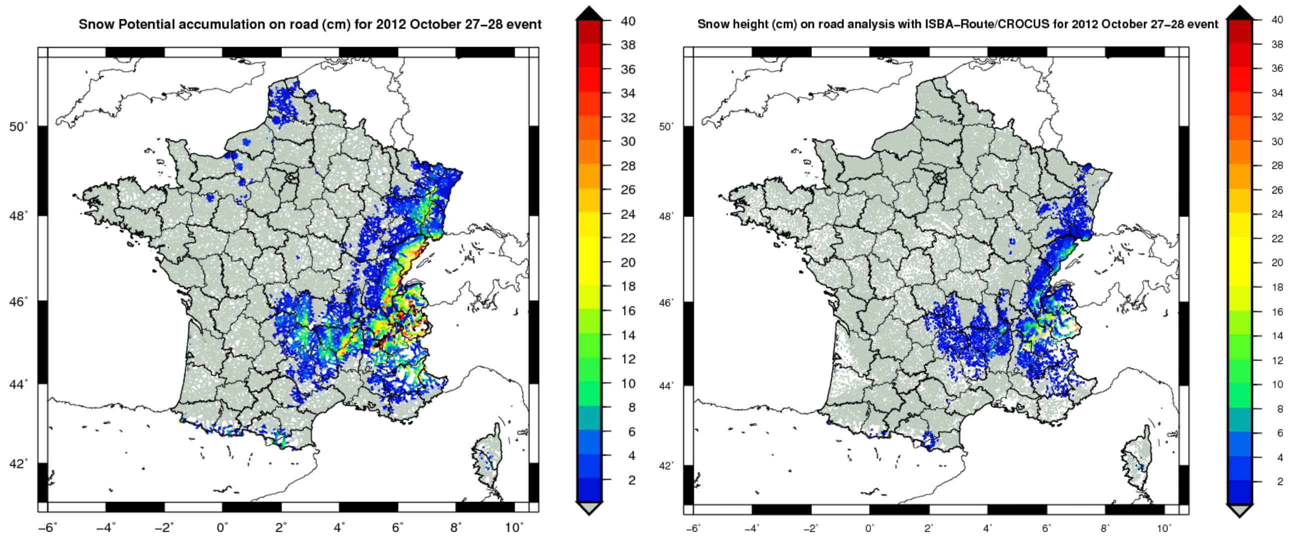

Figure 2. Comparison for the October 27-28, 2012 event of the snow potential on the road (left panel, road network scale) and the analysis of snow height on road done with the ISBA-Route/CROCUS model (right panel, French cities scale).

It might be seen in Figure 2 that some discrepancies exist between the two parameters (snow potential and snow height simulated with ISBA-Route-CROCUS). Indeed, the spatial extension is quite higher for snow potential accumulation, and in the same way snow heights are quite higher for snow potential. This is due to the type of event. Indeed, this event occurred in October so melting effects (atmospheric fluxes and road/snow conduction fluxes) were very important. As the snow potential doesn’t take into account these effects, it resulted in an overestimation (extension and height) of this snow event. An example of use of the ISBA-Route/CROCUS model in operational conditions, for the prediction of snow height and type on road is given in Figure 3 for an event which occurred from December 7 to December 8, 2012. In Figure 3 are given the forecast of the snow height and the analysis (i.e. simulation with atmospheric analysis fields) during the 24 hour period, from December 7, 6 UTC to December 8, 6 UTC. It is important to notice that some assumptions are associated to this system : the road is snow free at the beginning of the event, and only natural conditions are considered (e.g. without accounting for road de-icing, snow removals by road managers or traffic).

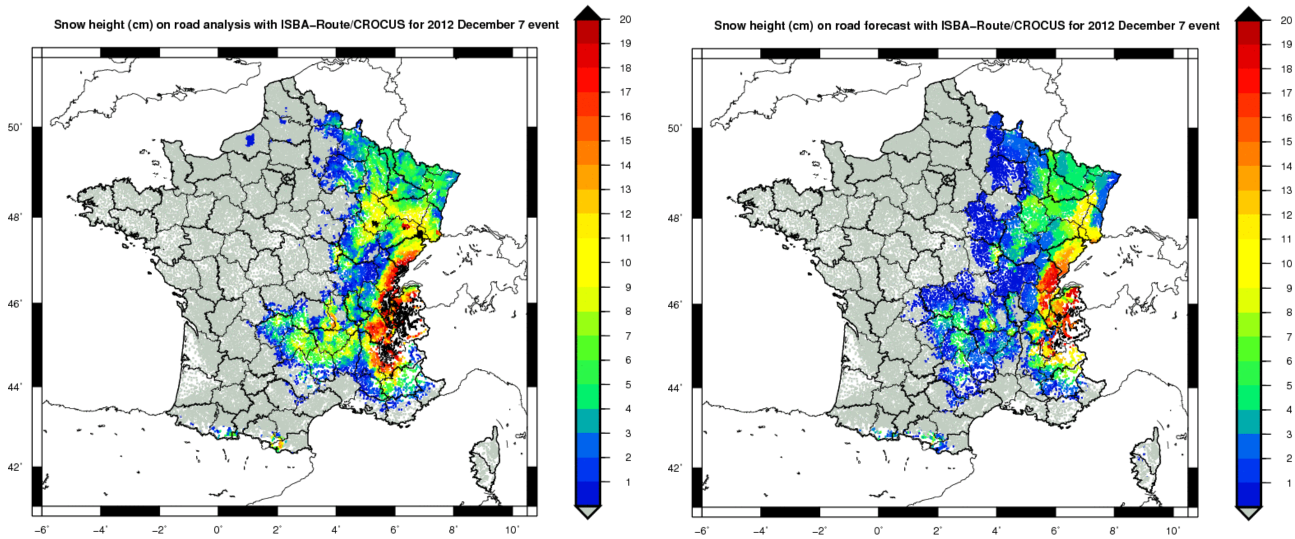

Figure 3. Comparison for the December 7-8, 2012 event of the snow height on the road analysis (left panel) and the forecast, done with the ISBA-Route/CROCUS model (right panel).

It might be seen in Figure 3 that the snow height on road forecasting is quite close to the analysis of the event. Indeed, especially for plain areas (for example in North-East of France), the spatial extension and the snow height magnitude order are quite close for this event (even if some discrepancies exists, especially in mountainous areas). When a “snow on road” event is defined by a snow height on the road at the 24 hour range forecast greater than 1 cm, the comparison of the forecast with the analysis lead to high statistical scores, with a detection ratio of 82% and a false alarm ratio of 6% (and a Heidke Skill Score of 0.82). These results have been observed for other events, and consequently, this model is used operationally since the current winter (2013/2014). It might serve as a decision making tool for human forecasters of Météo-France, and to improve the current automatic forecasting parameter dedicated to snow for road managers : the snow potential. The model will permit to improve the snow potential parameter by taking into account for melting effects, snow transformation (for example freezing of a water saturated snow), natural settling… This development is integrated into the geolocalised information system dedicated to nowcasting and forecasting for the French road sections : OPTIMA [9,10]. An example of operational visualization within the OPTIMA decision-making tool of the 24 hour forecast of the 2 parameters : “Snow potential” and “Snow height on road” is given in Figure 4 for a road section located in France, for the November 6, 2013, and for the 16h UTC run.

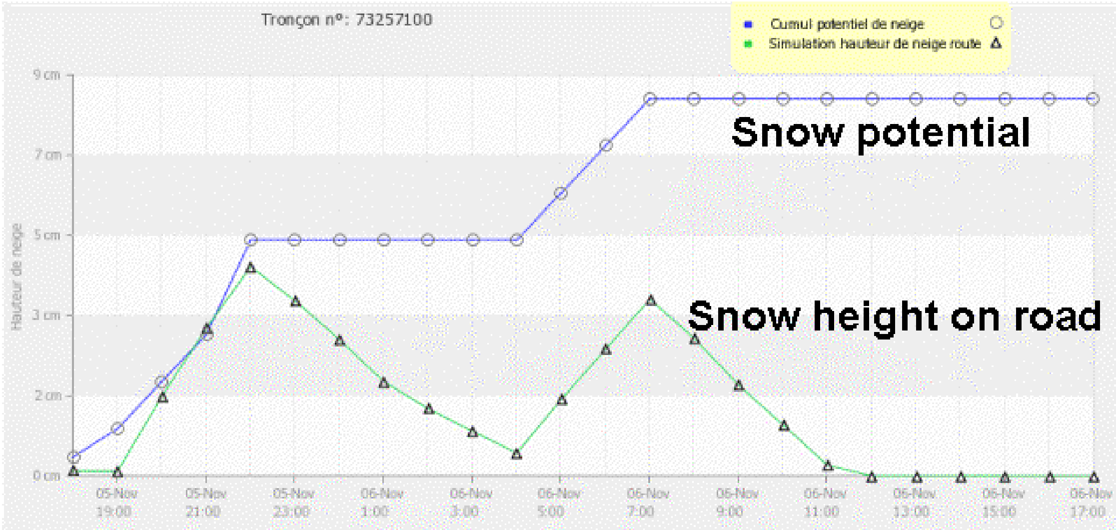

Figure 4. Example of time evolution differences between the forecast of snow potential on the road (blue line) and the forecast of snow height on road done with the ISBA-Route/CROCUS model (green line) for a French road section, for the November 6, 2013, 16h UTC forecast.

It might be seen in Figure 4 that the behaviour of the forecasted snow height with ISBA-Route-CROCUS was relatively different from the forecasted snow potential accumulation. For this road section, snowmelt was relatively high with the whole of the snowfall which was melting (caused by road/snow conduction and heat transfer with atmosphere), resulting in a nil snow height on the road at the end of the event, in comparison with approximately 8 cm for the forecasted snow potential. Moreover, it can be observed a time delay of 3 hours between the beginning of the snowfall and the moment when snow was sticking on road surface. So these kind of information (high snowmelt, time delay for snow sticking…) might be very interesting for road managers, so the ISBA-Route/CROCUS model might have consequent interest for an operational use.

5 CONCLUSIONS

The ISBA-Route road model was coupled with the high-resolution and nonhydrostatic mesoscale model AROME. This AROME-ISBA-Route system, used since 2010, was associated to a too high probability of false alarm for negative road surface temperature predictions, which was problematic for road managers. So, a way of improvement using human expertised atmospheric forecast was implemented since the 2012/2013 winter. This new system, called PEIR (Expertised Predictions for ISBA-Route) permitted to significantly improve the road surface temperature prediction compared to the raw numerical model prediction. A significant decrease of the cold bias, and consequently a decrease of false alarm amount, was observed. Following the same principle, a new improvement was implemented with the use of the ISBA-Route/CROCUS model, which was developed with the primary goal of predicting the snow occurrence on road. Some tests were done at the France scale to evaluate the behaviour of the model with the expertised atmospheric forecast. It had been observed that these predictions will probably be very useful in an operational way and consequently this model is used operationally since the 2013/2014 winter. Next steps concerning this topic will be dedicated to improve the model. Indeed, the model didn't consider real conditions as traffic or road de-icing. Some parameterizations will be introduced during following years to take into account these real conditions. Moreover, some research works are undertaken in aim to improve the forecast for specific locations (bridges, shadow areas) and to use the forecasted parameters to discriminate the road surface conditions (dry/wet/ice/frost/snow type…) in link with the associated slipperiness road conditions.

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