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A 4-year joint research program has been initiated in 2009 between the Laboratoire Central des Ponts et Chaussées (LCPC), some Laboratoires Régionaux des Ponts et Chaussées (LRPC) and Météo France. The main idea is to evaluate some tools, techniques and solutions that could be used to improve the safety of road users, and to help road managers in poor road weather conditions.

Tools and techniques are covering a very large scope of scientific fields, from image analysis, characterisation of weather phenomena such as rain or fog. Some work has been started on the use of cameras to appreciate the visibility in fog situations. Images analysis of the road as seen from a windshield in many weather situations are treated to build visibility thresholds. The pavement textures are analysed to determine their impacts both for the grip and the induced visibility with water sprayed by vehicles tires. Some of these tools are currently deployed on experimental sites all around the French territory.

Furthermore, numerical tools are currently used to obtain conventional forecast on road surface temperature and surface status. They are either based on usual weather forecasts and observations, and the energy balance analysis. In some cases some statistical and stochastic tools are implemented when data is available and meets quality requirements. A comparison between these tools is currently undertaken to establish their limits, and improve their outputs. As an example, the de-icers incidence will be included in the numerical model, along with some thermal mapping aspects.

All these aspects are developed to evaluate and to quantify hazards that could occur on roads in adverse weather conditions. These hazards are usually identified on specific spots. But the main difficulty is the extension to a whole itinerary. Météo France recently developed OPTIMA, a French Road weather information system (RWIS). It is a precise decision-making tool for anticipation and real-time follow-up of meteorological situations on 1 km road stretch sections. It also provides, every 5 minutes, forecast for the coming hour (time steps of 5 or 10 minutes are available), over the 120 000 km of the French major road network. One of the objectives is to implement within OPTIMA the results of the research work, such as grip and visibility alerts so as to inform both road users and managers, and so improve traffic. This would be possible through data transfer and meta-data relative to the road network within the tool.

PALM will be one of the main beneficiaries of the progress in the Road Weather Information System developed in 2008-229 by Météo-France: the approach OPTIMA, the road network georeferencing dedicated to the Road weather information.

Forecasting

OPTIMA (Road weather informations dedicated to road sections), is a global approach of data fusion and specific road weather algorithms implementation, to obtain the best road weather information, according to the state of art, on any point, any kilometre, of a road network.
In 2009, 120 000 km of road are concerned.

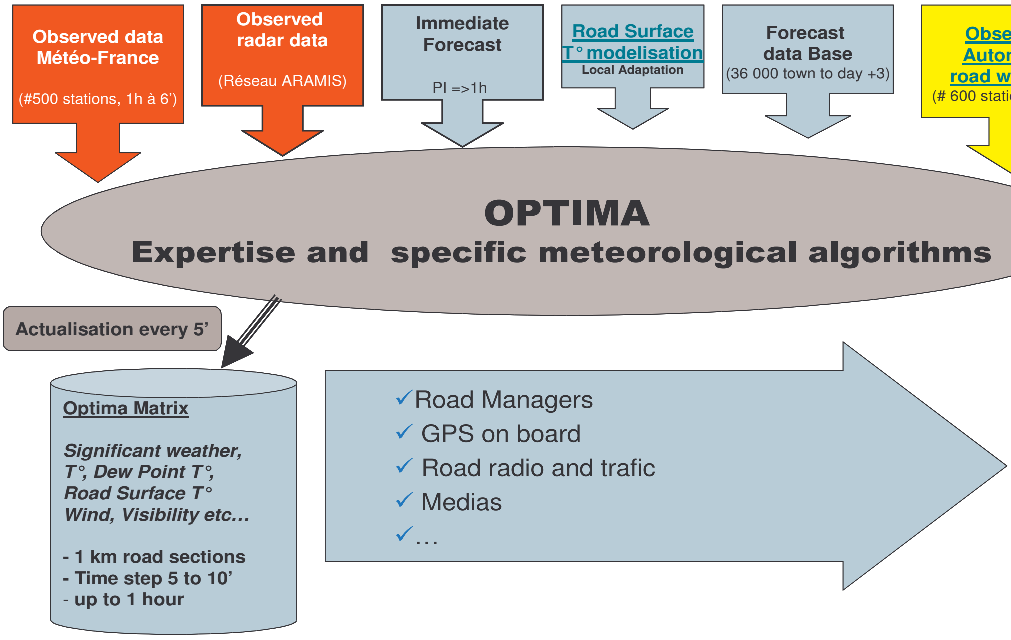


Figure 1: OPTIMA's global approach

The current outputs are available through dedicated extranet services where the informations are delivered through different kinds of zoom, or by alerting systems depending of the combined, or not, parameters occurrence over the chosen sections of the network.

Forecasted parameters given by Optima
•Occurrence of precipitations
•The type of precipitations: freezing rain, snow, rain and snow together, hail, rain, drizzle
•The intensity of precipitations: light, moderate or strong
•Storm: occurrence and intensity
•Air temperature (T)
•Dewpoint temperature (Td)
•Temperature of surface of the road (Ts)
•Rain-snow boundary
•Wind (direction and strength)
•Squalls of wind
•Visibility lower than 200 m
•Height of snow on the road
•State of the road : dry, wet or frozen

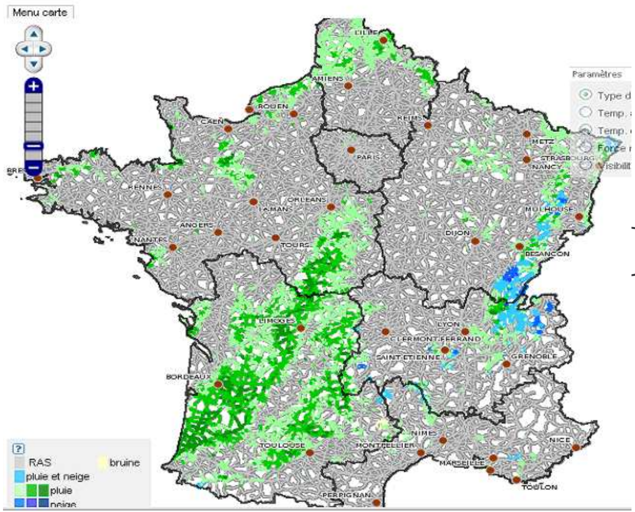


Figure 2: Global Visualisation

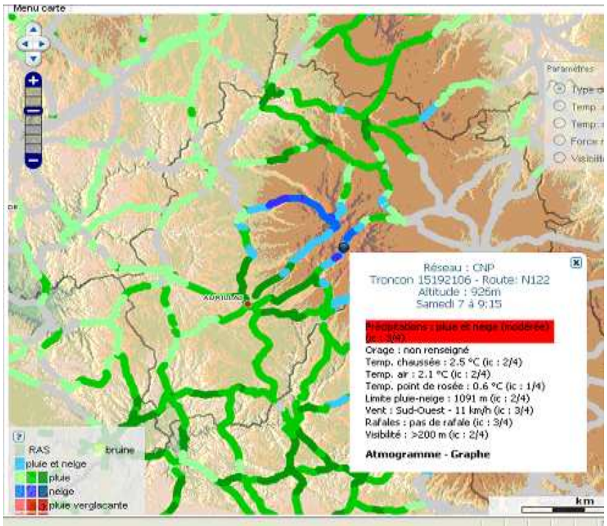


Figure 3: Road weather data and meta data by road section

As we see, OPTIMA is ready to incorporate:

- A scope of meta data dedicated to the road section, as thermal mappings, structure of the road, traffic, road treatments etc…
- New algorithms to take into account the progress of the state of art, and especially the PALM issues.

The next developments will focus on fine mesh road surface temperature forecasting, using the forecasts of the new generation high-resolution numerical weather prediction model AROME with a 2.5 km resolution. At the same time several efforts might be done to improve the operational road conditions forecasting with additional forecast products, as the prediction of snow on road surface (occurrence duration, height, type), and to account real conditions (traffic, de-icers) in models.

Physical models

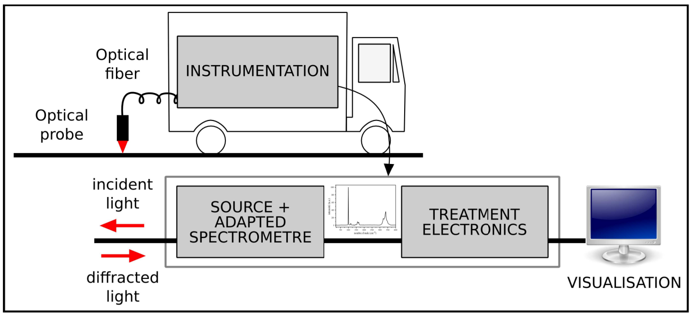


Figure 4: Typical implementation of the de-icer concentration sensor

In this context, the measurement of the surface temperature during winter by taking into account the de-icers quantities is nowadays a possibility introduced by Durickovic[1] in her thesis. The Nacl concentration is determinated by a specific instrument and based on spectroscopy. The signal is treated to extract pertinent information from the spectrum in order to be used directly by the computational system which displays the concentration value. This value

1 I. Durickovic – « Étude par spectroscpie Raman de la salinité résiduelle issue de l'épandage de fondants routiers sur une chaussée » – Thèse de 3ème cycle – Université de Metz.

can therfore be used to monitoring the pavement concentration or to control the spreader in order to accuratly treat the pavement.

The figure 5 show the good agreement between the measured concentration and a calibrated one, determinated by titration.

This lead to evaluate local concentration in less than 1 s with an error closed to 5%. Since this winter, first experiments are done on several roads of Nancy.

This information can therfore be introduced on ISBA, a forecast physical model based from Metéo-France. This one is governed by equation (1).

The term Φ means the flow associated with the phenomenon of sink / source of heat due to phase change. At the end of this study, it will include the influence of brine on phase transition and therefore on surface temperature.

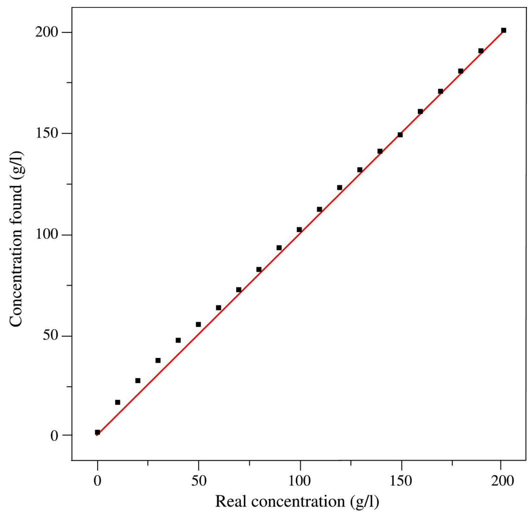


Figure 5: Correlation between calibrated and measured concentration

$$c_T \frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(\lambda \frac{\partial T}{\partial z}\right) + \Phi \qquad (1)$$

Statistical Models

The surface temperature forecasting can also be modelized by statistical models such as follows.

•we denote by D the starting time of the forecasting for a station S;

•for this station S and this time D, a linear regression of surface temperature Ts with respect Tair, HR, V, Ir and Sf is carried out with data of the station S for the period [D-N,D] where N is the numbers of days of the *learning period* (the choice of this parameter is discussed below). We have then the following expression :

$$T_s = a + bT_{air} + cHR + dV + eS_f + fI_r \qquad (2)$$

where a, b, c, d, e and f depend on D, S and N.

•we use the forecasted values of Tair, HR, V, Sf and Ir given by a meteorological weather prediction model which allow, using (2), to determine the forecasted road surface temperature.

Criterium to evaluate the approach

For each day D of the winter (2006-2007 for the present study) we have decided to start a 24-hours forecast at 5.00 pm. The coefficients of the statistical model are evaluated thanks to hourly data collected during the N previous days of the day D. The hourly absolute errors between forecasted T_{sf} and the observed ones T_{so} are calculated. We then compute for the winter the mean of these absolute hourly absolute errors and its variances. These criteria are more efficient from a practical point of view than the R² coefficient.

Comparison with a forecast physical model

In order to evaluate the statistical approach we have compared the forecast of the statistical model and the one obtained with a physical model (French model Préviroute developped by the Laboratoire des Ponts et Chaussées of Clermont-Ferrand) based on:

•a forecast of atmospherical variables (Tair, HR, etc) given by a meteorological weather prediction model;

•a 1D-modeling of the heat conduction in the road ;

•an energy balance at the road surface (conduction term, radiative fluxes, etc.).

In order to present the influence of radiative fluxes, we give in Figure 6 the results of the comparison in the case of a linear regression without Sf and Ir. N is experimentally taken to 15. We can observe a gap around 2 degrees between the physical and the statistical models in the middle of the days and 0.5 degree during the night.

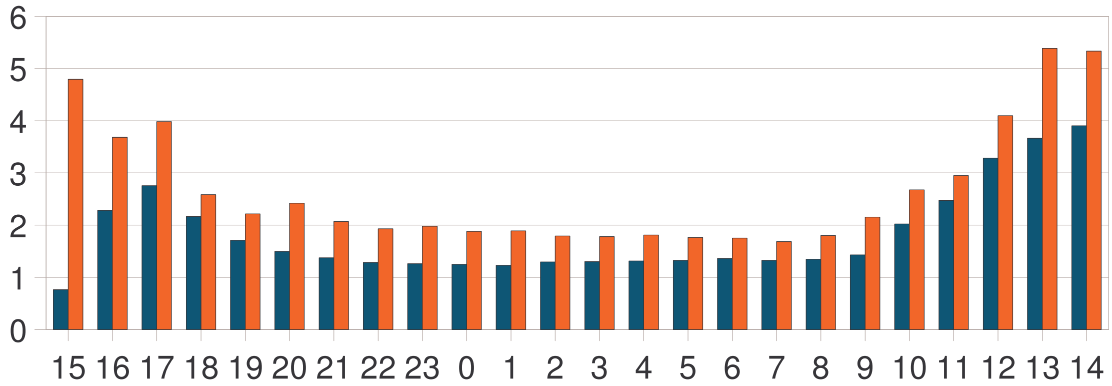


Figure 6: Hourly means of the absolute error for the physical model (blue) and statistical model (red)

The influence of the radiative fluxes is shown in Figure 7. We notice that the previous gaps of 2 degrees and 0.5 degree can be filled by the introduction of the radiative fluxes in the model what was not take into account in *Sherif and al.*[2]. Note that the R^2 is equal to 0.93 which is significantly better than 0.83 given in *Sherif and al.*

2 A. Sherif, Y. Hassan, M. Alkoka, A Statistical Approach for Winter Maintenance Operations: A Case Study for the City of Ottawa, *Annual Conference of the Canadian Society for Civil Engineering*, Montréal, Québec, Canada, *June 5-8, 2002*

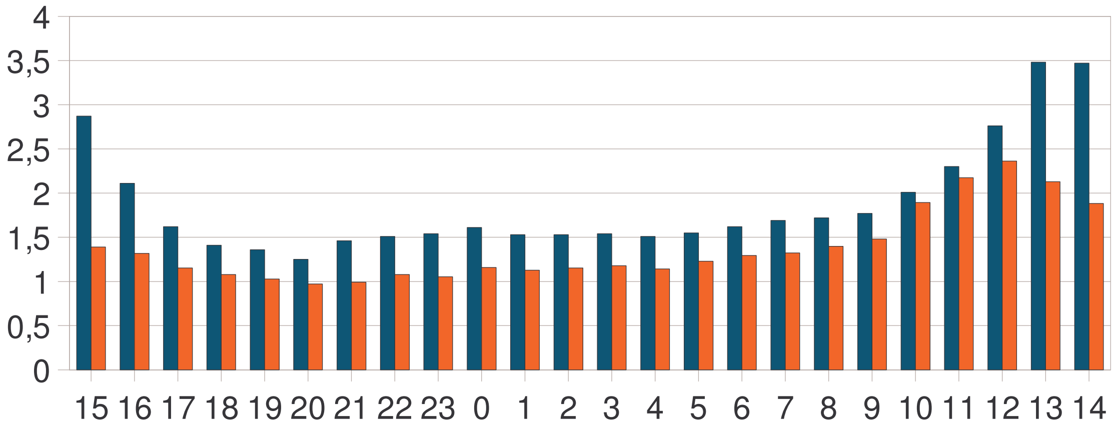


Figure 7: Hourly means of the absolute error for the statistical model by using the radiative fluxes (red) and not (red)

Road grip

The presence of water on road causes grip decrease, as well as splash & spray phenomena by the vehicle tires, which induces a visibility losses.

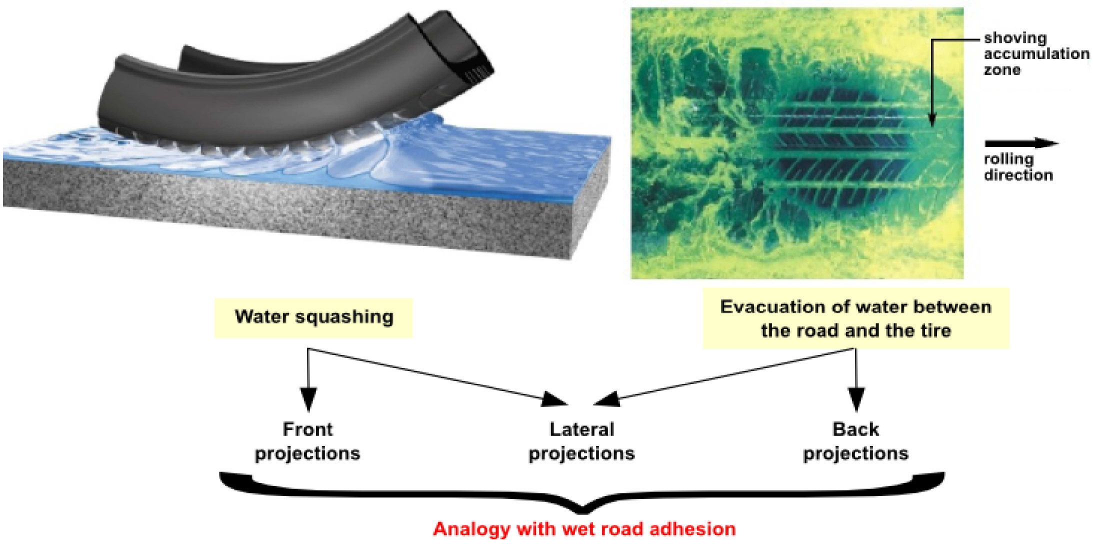
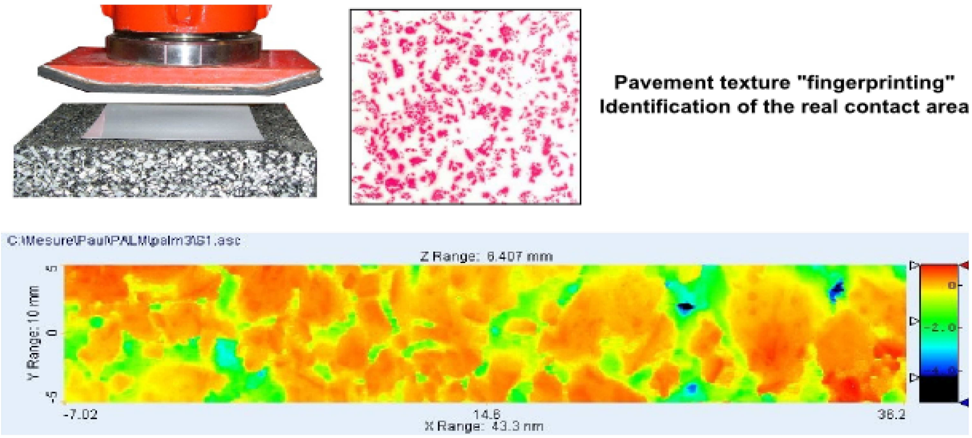


Figure 8: Phenomenon of water squashing (front and back projections)

In order to quantify these visibility and grip decreases, it is important to know the amount of water that is present, as well as the pavement influence on the mobilisation of water.
The pavement textures are analysed and digitized in order to calculate the water volume that it is possible to stock under the tire as a function of the penetration depth.



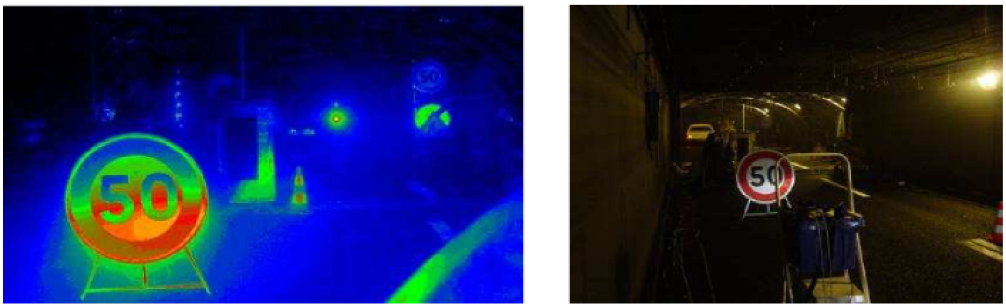
Contact surface

Calculation of the water volume that can be contained under the tire

Figure 9: Water volume estimation of a road pavement by a "fingerprint" method

Visibility

Some work has been started on the use of cameras to appreciate the visibility in fog situations. Images analysis of the road as seen from a windshield in many weather situations are treated to build visibility thresholds.



Infrared camera image **Videophotometer image**

Atmosphere caracterisation in fog situations

Figure 10: Atmosphere characterisation of fog situations