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Analysis of fog occurrence on A75 Motorway, with weather station data in relation to satellite observation

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Abstract

Transport is often disturbed in wintertime by fog occurrence causing delay. Fog may also be responsible for dramatic accidents causing injuries and fatalities. Fog forecast remains a difficult task. Satellite observation combined with surface measurements by a network of road weather stations could provide short-term information that could be useful to assist traffic authorities in taking decisions relating to traffic control measures or driver information. The analysis method has been tested on some case studies on the motorway E11-A75 in Auvergne region in France. Weather stations data are presented and connected to satellite images analysis in order to improve the estimation of visibility distribution.

1. Introduction

Fog occurrence may have a major impact on traffic safety on motorways. It also has an economic impact, by causing major delays in the transport of goods and passengers. Airline companies or traffic managers require more efficient forecasts of fog occurrence and visibility level. Forecasts of visibility levels would therefore assist traffic authorities in making decisions relating to driver information and traffic control measures. In order to improve forecasting methods, input data are required and satellite data have to be connected to ground observation measurements. This paper will present ground observations based upon weather station data. The analysis method is tested on some case studies on the motorway E11-A75, thanks to a network of 15 weather stations along the 300 km of motorway. In the highest area that is between 580 and 1100 m, the value of the relative humidity has been analyzed in relation to the visibility measured by a diffusometer. One particular fog event of December 2009 is selected and analyzed in this paper. The surface measurements help to discriminate between low clouds and fog. Satellite images allow to identify cloud types and are taken into account to establish a map of the risk of fog occurrence. The goal of the Météo-France fog analysis is to establish a spatialization of visibility distribution.

2. Data fusion product

A product has been developed by Météo-France/Observing Systems Direction in order to provide an hourly quantitative information about visibility, whatever the phenomenon behind the decline in visibility (fog, rain, low cloud), at each point of the domain (French emerged lands with a geographical resolution of 3 km). The first step is to spatially distribute the observed visibilities, using a multi-linear regression on meteorological and geographical predictors. One of those meteorological predictor is the Cloud Type category (developed by the French Centre de Météorologie Spatiale (CMS) of Météo-France, to provide a detailed analysis of observed clouds, [1]. In a second step, the visibility distribution is treated as a log-normal distribution whose parameters are estimated using a relationship established over 2 years of data. Thus, we will be able to provide both deciles of visibility (capped at 10000m) and the probability of observing visibilities below a given threshold (cf. Figure 1).

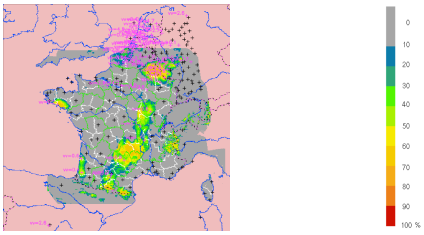
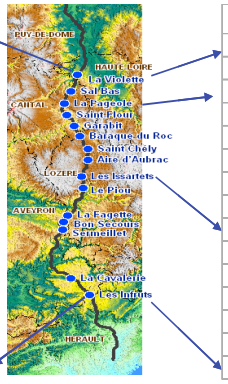


Figure 1 : Probability of observing visibilities below a specified threshold - December, 11 2009 18 UTC

3 . The Motorways 75 and the weather stations

The entire route of the motorway A75, between Clermont-Ferrand to Beziers, is about 300 km long. The mountainous part is about 200 km, it is equipped with a network of 15 weather stations. Figure 2 shows the position of these stations on a relief map, with the corresponding distances in kilometres. On the right the altimeter readings show that the stations ranged between altitudes of 580-1100 m. Figure 3 shows the longitudinal section of the A75 in the department of Cantal, indicating a motorway route with a mountain pass at an altitude of about 1100m (Col de la Fageole). This portion of the route is often affected by fog formation. One can also observe the longitudinal distribution of the 6 road weather information systems, spaced about ten miles. This area was already the test section of a preliminary study [2].

PR (km)
63.2
76.3
86.2
96.3
104.5
112.8
124.3
132.4
144.9
153.8
179.3
184.9
193.0
235.5
252.5



Station	Altitude(m)
1 - La Violette	580
2 - Sal Bas	800
3 - La Fageole	1110
4 - Saint-Flour	800
5 - Garabit	820
6 - Baraque du Roc	980
7 - Saint-Chély	985
8 - Aire d'Aubrac	939
9 - Les Issartets	1100
10 - Le Piou	890
11 - La Fagette	900
12 - Bon Secours	826
13 - Sermeillet	800
14 - La Cavalerie	780
15 - Les Infruts	782

Figure 2: The 15 Weather stations on motorway E11-A75

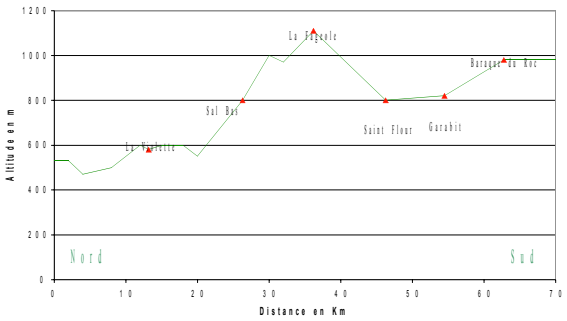


Figure 3: Altitude profiles of the highest section of the motorways E11-A75 with the 6 weather stations

4. Case study : December, 9 and 10 2009

4.1 Description of the meteorological situation

December 9, 2009 : altitude, the axis of a ridge is positioned on France and shifts slowly eastward. Surface, the warm sector of a wave covers a large part of the country. After undulating, the cold front sinks on the Northwest. It is reactivated by the dynamics of altitude during the night of December 9 to 10.

December 10, 2009 : a dynamic thalweg associated with a cold front runs quickly on the north. Then it plunges along the eastern borders. The rear of the cold front is inactive ; then, pressure increases quickly with the establishment of a ridge near the Atlantic where pressure increases in the lower layers.

Regarding the area studied, a cloud band extends Auvergne, with morning fog. Thus, on December 9 and 10, some observers report instances of fog near A75 (daily data).

4.2 Satellite data

Low clouds are detected on the A75 on December, 9 at 22 and 23 UTC (cf. Figure 4). As of December, 10, 00 UTC, clouds located at higher levels mask any low clouds. Thereby the analysis of the situation can not be based only on satellite images. Establishing a diagnosis requires merging data from different sources, including surface measurements.

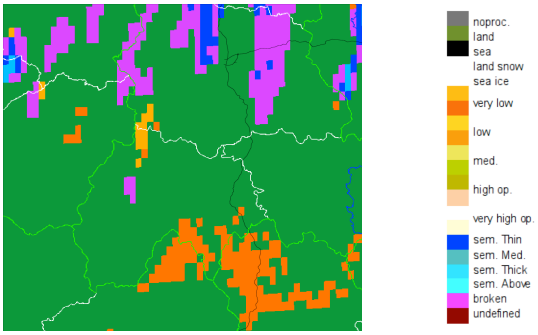


Figure 4 : Cloud Type Product - Centre de Météorologie Spatiale de Météo-France (satellite data reception and processing centre) – December, 09 2009 23 UTC

4.3 Spatialization of visibilities

Above all, it is important to note that the proposed maps do not represent an absolute reference. They are an estimate of the probability of observing visibilities below a given threshold.

We present maps of probability of observing visibility less than 1000m and compare them to the available data (weather stations on Motorway 75). The values measured by Motorway weather stations are plotted in blue. Visibility (vv) is expressed in km and is rounded to the lower hm. Relative humidity (Hu) is expressed in %.

In a first step, Figure 5 shows the map obtained by taking only the synoptic observations (threshold : 1000m). The probabilities seem to be under-estimated. This is particularly evident in the case of station 3 (probability less than 10%).

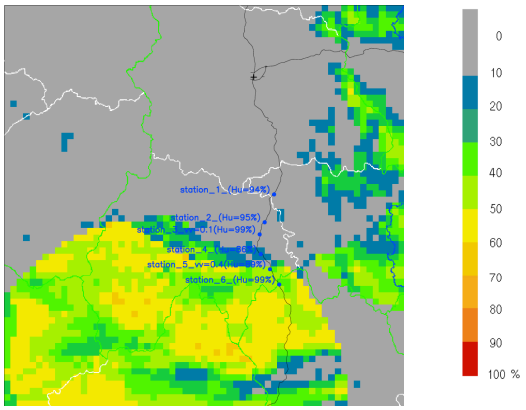


Figure 5. Probability of observing visibilities below 1000m (synoptic observations) - December, 09 2009 23 UTC

The quality of these maps depends partly on the number of point of observation where visibility is available. This is the reason why, in a second step, visibilities measured by Motorway weather stations were added to those of the synoptic network. It allows to improve the spatialization (especially in the case of station 3), as shown in Figure 6.

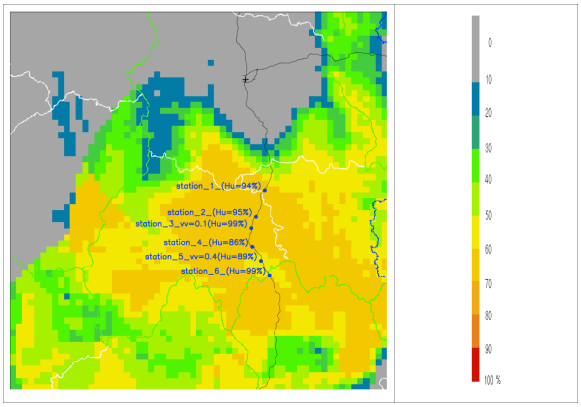


Figure 6. Probability of observing visibilities below 1000m (synoptic observations and data from road weather stations) - December, 09 2009 23 UTC

Thus, integrating data from Motorway 75 stations, and more generally, from all stations belonging to road managers, should improve the spatialization of visibilities. However it is necessary to ensure the reliability of these data (maintenance criteria, but also characteristics of the sensors).

4.4 Weather station data

For all the weather stations we have standard measurements of air temperature, relative humidity, wind speed and direction, and only for stations 3 and 5, visibility data are available from a diffusometer. Then we will focus on the data of these 2 stations. The figures 7 and 8 give the time evolution of the relative humidity (left axis) and of the visibility (right axis) during the night of the 9 to the 10 December for weather station 3 and 5.

At station 3 (figure 7), col de la Fageole, the atmosphere is saturated at 100% with very dense fog. The visibility is reduced at 50m for 3 hours and then increase to 900 m with some local fog benches during the night .

At station 5 (figure 8) Garabit, the atmosphere is a little less saturated at about 90% with moderate fog. The visibility is reduced at 450m for all the studied period.

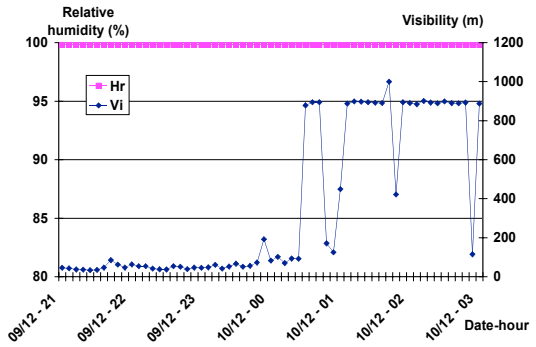


Figure 7: Time evolution of relative humidity and visibility at station 3 from 09/12 at 21h to 10/12 at 03h

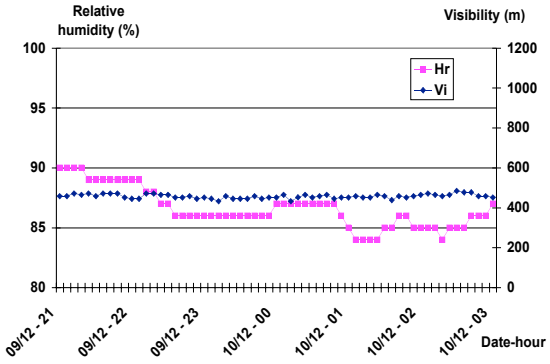


Figure 8: Time evolution of relative humidity and visibilityat station 5 from 09/12 at 21h to 10/12 at 03h

6. Summary and Conclusions

The paper presents the results of a joint study between department of transport and the national weather service Meteo-france. The purpose of the project is to improve some new data fusion product dedicated to fog occurrence and estimation of visibility distribution. This type of product could be useful for traffic authorities. A case study is analysed on the motorway E11-A75 in Auvergne region in France. Weather stations data are presented and connected to satellite images analysis. A first test of the product is made by taking only the synoptic observations. It shows an underestimation of the ground situation at the road weather station. In a second step, visibility measured by Motorway weather stations were added to those of the synoptic network. It allows to improves the spatialization of fog and by a better probability to observe fog below 1000 m visibility. This kind of analyse will be continued on other case study in order to validate these first results.

Acknowledgements

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References

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