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Analysis of Fog Probability from a Combination of Satellite and Ground Observation Data

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Abstract—The Cloud Type product, developed by the Satellite Application Facility to support to nowcasting and very short-range forecasting (SAFNWC) of EUMETSAT and based on Météosat-8/SEVIRI, identifies cloud categories, and especially low and very low clouds which are first estimates of areas where fog is likely to occur. This cloud type is combined with precipitation information from radar data and with hourly diagnostic analyses of 2-metre relative humidity and 10-metre wind to elaborate an hourly analysis of fog probability. This analysis provides four levels of fog probability with a 3-kilometre horizontal resolution: No risk, low-level risk, medium-level risk and high-level risk. An evaluation of such fog probability analyses versus a one-year set of French hourly SYNOP reports shows encouraging results (potential of detection = 0.73 for low and medium and high-level risks), even if false alarm ratios remain high. Most of the non-detections occur at twilight and are due to satellite non-detections. Eventually, we show case studies that clearly illustrate the high potential of the method.

Key words: Fog analysis, data fusion, fog probability.

1. Introduction

Many business sectors have a pressing need in fog observation. Indeed, fog is a very dangerous phenomenon for all traffic activities, i.e., sea, air and land traffic. Apart from security concerns, each time a fog event disturbs any traffic, there is a huge economic impact, especially for air traffic.

Mandatory local needs are generally satisfied, e.g., by human observation or automatic measurement. Nevertheless, spatialized information on fog is not so often available. At least two approaches can be identified to fill this lack of information. On the one hand, visibility and fog can be processed through three-dimensional analysis and forecast models. For instance, the ''Rapid Update Cycle'' (RUC) is an operational regional analysis and forecast system developed by the National Center for Environmental Prediction (NCEP); a description of the RUC is given in BENJAMIN *et al.* (2004). Using an explicit scheme of the cloud microphysic describing the mixing ratios for cloud water, ice, rainwater, snow and graupel, the RUC

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elaborates a diagnosis on visibility. Other numerical weather prediction (NWP) mesoscale models have the same approach, e.g., the French AROME (Applications of Research to Operations at Mesoscale) mesoscale project also has a prognostic cloud microphysics scheme with five condensed water species (BOUTTIER *et al.*, 2006).

On the other hand, more pragmatic approaches tend to provide only two-dimensional visibility or fog occurrence diagnoses. Data fusion is a tunable and easy method to take benefits from various kind of data. For instance, the National Ceiling and Visibility (NCV) programme of the US National Oceanic and Atmospheric Administration produces analyses of ceiling and visibility on a two-dimensional grid corresponding to the RUC's one, using METAR and TAF reports, satellite and radar data (HERZEGH *et al.*, 2003).

We consider the detection by satellite imagers of areas where fog can be expected to occur as a key point in data fusion, for our purpose. Thanks to its various SEVIRI channels, Météosat-8 enables a large amount of subsequent products with a favourable resolution in space and time. Among these products, a detection of low clouds, and more generally an identification of the cloud types, is a first step forward. Ground observations are obviously needed to discriminate between low clouds and fog.

The objective of this study is to build a simple algorithm to elaborate analyses which quantify the probability of fog occurrence, at least over France. The algorithm will use the high potential of information of Météosat-8 and of the most relevant surface variables, which are to be found among already spatialized observations as far as possible. The analyses are expected to be used by French nowcasters. The algorithm should be as robust as possible, especially to be usable both during daytime and night-time, and provide high-resolution analyses.

Input and reference data are described in Section 2, as well as the algorithm we developed. Then an extensive evaluation of the analysis of fog probability is given in Section 3, including objective evaluation and case studies. Section 4 provides concluding remarks and prospects.

2. Methodology

2.1. In situ Reference Observations

We only considered observations over land. Indeed, as very few parameters are observed over sea, we have decided to limit our study to fog occurrence over land.

SYNOP data can be used as reference observations. As a matter of fact, if the information on "present weather" is given in the report, it clearly indicates whether fog has occurred or not (except for code of present weather equals to 76, 77 or 78, see WMO Manual on Codes).