13.3

SIGMA: DIAGNOSIS AND NOWCASTING OF IN-FLIGHT ICING – IMPROVING AIRCREW AWARENESS THROUGH FLYSAFE

Christine Le Bot *, Agathe Drouin, Christian Pagé
Météo France

1. INTRODUCTION

Icing is one of the major meteorological hazards a pilot wants to avoid. To accurately diagnose the extension of the icing areas, limit the number of false alarms and to quantify the intensity of icing, a system was developed at Météo France.

SIGMA *(*System of Icing Geographic identification in Meteorology for Aviation*)* gives real time cartography of the icing risk. SIGMA uses a combination of data from three different operational networks operated 24 hours a day: the numerical model (ALADIN), the Infrared satellite imagery (METEOSAT Second Generation) and the radar imagery (ARAMIS). Each kind of data can confirm or infirm the information deduced from the others. Then a 3D image of icing risk is elaborated.

In the scope of FLYSAFE, the icing diagnostic is made available to the flight crew using data link system. In order to lower the amount of data to be transferred to the cockpit, the gridded SIGMA output is converted into GML objects, an easily transportable format.

As new generation input data are now available, SIGMA is evolving. A new algorithm has been designed.

2. PRINCIPLE

2. 1 DATA PRESENTATION

RADAR

Météo France operational network (ARAMIS) is composed of 24 radars in centimetric waves. The information from the 24 radars, together with the information of foreign radars (covering the south of England, the Netherlands, Belgium, Luxembourg, the east of Germany, Switzerland, and the north of Spain) are put together every quarter of an hour to produce a « radar mosaic » image. Its resolution is 1536*1536 pixels of 1km of side. The intensity of the precipitations in mm/h is deduced from the reflectivity measurement. It must be reminded that liquid water returns a stronger signal than ice at equal size of particles. Moreover the value of an echo is proportional to the size and the number of particles.

SATELLITE

The IR images from METEOSAT8 with a resolution of 4 kilometres are produced every 15 minutes by the Spatial Meteorological Centre (CMS) of Météo-France located in Lannion. Each pixel is interpolated to obtain a 1536*1536 image (same size, resolution and projection than the radar image).

The brightness temperatures are calibrated between 100 and 355 °K, and are interpreted as the temperatures of the tops of the clouds. However these brightness temperatures are influenced by the various characteristics of the clouds. For instance, light cirrus might modify the perception of the clouds below. Clouds behave differently according to their thickness and the proximity of the ground. The satellite imagery does not always lead to a correct discrimination between the ground and a cloudy level. These different remarks must be taken into account when using the IR images.

NUMERICAL MODEL

At the beginning of SIGMA development the numerical model used was ALADIN, Météo France numerical model. The resolution of ALADIN is 0,1° (about 12 km). ALADIN runs 4 times a day. The ground temperature field calculated with the numerical model is used in SIGMA to characterise the ground on the satellite imagery.

The icing index (see figure a) derived from the model uses the humidity and temperature forecasted fields calculated at each grid point. This index was tuned, using the results of a climatological study on the occurrence of freezing precipitation on ground over Europe (Carrière et al 2000). This study showed that freezing precipitation occur more often when the temperatures are near –5°C and combined with high humidity rates. Their occurrence decreases when the temperature goes closer to the limits of the interval [-15°C, 0°C] or outside, and when the humidity is under or

Corresponding author address: C LeBot, Météo France, 42 Av coriolis, 31057Toulouse
Email: agathe.drouin@meteo.fr

equal to 80%. A table of 10 levels of risk was established.

As additional information, the upward vertical velocity, can be added, as it was noticed that a vertical velocity lower than -0,2 hPa/s favours the suspension of droplets and their growth. The icing index is then named “index-VV”.

The indexes are calculated at each levels between, 1000mb to 400 MB.

Data coming from the numerical model are processed to be in the same resolution and on the same domain than the “mosaic radar” image.

2. 2 SIGMA ALGORITHM

The algorithm is based on the theory of the warm tops clouds (*Pobanz et al.*, 1994). In fact, studies following icing campaigns over the United States, have shown that the risk to meet severe icing with large droplets is higher when associated with clouds to temperatures included in the interval [-15°C, 0°C]. If the temperature of the cloud tops is lower, the risk to meet icing remains, but the quantity of supercooled water seems less important, leading to less frequent cases of severe icing.

The IR satellite imagery (see figure b) is used to first identify the cloudy areas. However the IR images do not allow to distinguish directly the ground from the cloud cover. So this distinction is done by comparing the ground temperature forecast with the numerical model with the temperature given by the IR satellite imagery.

If the forecast ground temperature is lower or equal to the temperature observed by the satellite, it is supposed that the sky is clear. The icing risk is then non-existent.

Otherwise, the temperature is the temperature of the cloud tops. It is stored in one of three following intervals.

- First interval : cloud tops with positive temperatures. This type of cloud is free of icing conditions.
- Second interval : cloud tops with temperature between 0° C and -15° C.
- Third interval : cloud tops with temperatures under -15 °C. The risk to meet very severe icing conditions is less important than with clouds in the second interval.

When the cloudy areas prone to icing are identified, an additional information coming from the icing index is superimposed . The index describes the areas where both the humidity and temperature conditions are in favour of the formation of icing. The index is used to describe the maximal horizontal extension of the icing areas, all vertical levels merged. So far, it is not possible to operationally match the level of the cloud layer determined by the satellite imagery and the level where the numerical index forecasts icing. Then it is assumed that the two levels are the same.

It has been shown, by daily use, that the numerical index has a tendency to overestimate the extension of the icing areas. Consequently, when the icing index takes a null value, the risk of finding icing conditions is considered as null. A non null index identifies the presence of icing.

Finally to improve the detection of icing areas the radar information (see figure c) is taken into account. It shows the presence of precipitations or in the cases of low echoes, the possibility to have droplets in suspension. The radar signal is processed in four categories:

- a low level represents drizzle or super cooled water in suspension,
- a moderate level of precipitations represents freezing rains,
- a high level represents very strong freezing rains,
- a null level.

The « null radar echo» information is kept. It simply indicates that the radar doesn’t “see” any target on the trajectory of its beam, and not that there are no precipitations, in suspension or not.

After processing, an image for each model level is obtained (see figure d), which shows the cloudy areas with humidity and temperature conditions favorable to icing. The radar echoes show the areas where a risk to find super cooled water droplets in suspension or precipitating exists.

3. IMPROVEMENTS

3. 1 ICING OBJECTS

Within the FLYSAFE project, a major objective was to provide up to date meteorological information to the on board crew during the flight.

The in flight icing risks gridded fields produced on ground is not a compact format.

To lower the amount of data to be transmitted on board, the icing risk gridded fields are converted into icing risk objects with three levels of severity (see figure e).

3. 2 NEW INPUT DATA

Since a few years, new data are available. For example, the new channels of the satellite Meteosat Second generation allow to elaborate new products, such as cloud classification or icing cloud product. In addition the old products are improved.

New observations techniques such as Doppler radar or volumetric radar enable to retrieve information on height of the bright band, precipitations microphysics, or maximum reflectivity.

In the meantime, Météo France has developed an innovative non hydrostatic NWP model AROME . This new model provides high temporal and spatial resolution temperature and humidity fields, as well as cloud microphysics.

Some of these new input data are not available on the full SIGMA domain. This has lead to provide improved diagnostics on smaller domains on which all new observations are available, especially volumetric radar. That's why SIGMA is now computed over small domains corresponding to airport terminal manoeuvering area.

3.3 REDESIGNED ALGORITHM

The new SIGMA algorithm uses all these new input data and is able to adapt to their unavailability.

Each kind of data is used to add a specific information as well as to consolidate information extracted from the other input sources. Moreover, in the new algorithm, more emphasis is put on observations than on NWP data.

4. CONCLUSION

SIGMA has been designed as a nowcasting tool for identification of in flight icing areas. This data fusion methodology has shown good results and need to be improved by using new materials.

Within Flysafe, SIGMA developments include the use of new generation observations such as volumetric radar image and high resolution Meteosat Second Generation satellite imagery, as well as new Meteo France meso scale non hydrostatic NWP model AROME. SIGMA algorithm has been redesigned to be able to take advantage of these new observation input data and numerical model information.

Calibration and evaluation of the new SIGMA algorithm will go further during next year with the two flight tests campaigns to be held in February and August 2008 in the scope of FLYSAFE.

5. REFERENCES

1. Bernstein, B. 1997: "A regional climatology of freezing precipitation for the contiguous United States. Statistical verification of forecast icing risk indices", Proceedings Tenth Conference on Applied Climatology,Reno, Nevada, 20-24 October

2. Bernstein, B.C. and F. McDonough et al, 2005: Current icing Potential 2005: Algorithm Description and comparison with aircraft observations Journal of applied Meteorology, July, vol44, pp969-986

3. Carrière Jean-Marie, Lainard Claude, Le Bot Christine and Robart Florent 2000:"A climatological study of surface freezing precipitations in Europe", Meteorological Applications 7, 229-238

4. Le Bot Christine 2003: " SIGMA : System of Icing Geographic identification in Meteorology for Aviation ", Proceedings SAE icing conference, Chicago.

5. Pobanz Brenda, Marwitz John, Politovitch Marcia K 1994: "Conditions Associated with large-drop regions", Journal of applied Meteorology, Nov, vol33, pp1366-1372

6. FIGURES

Icing diagnostic and input data for the 2006/11/09 at 10UTC

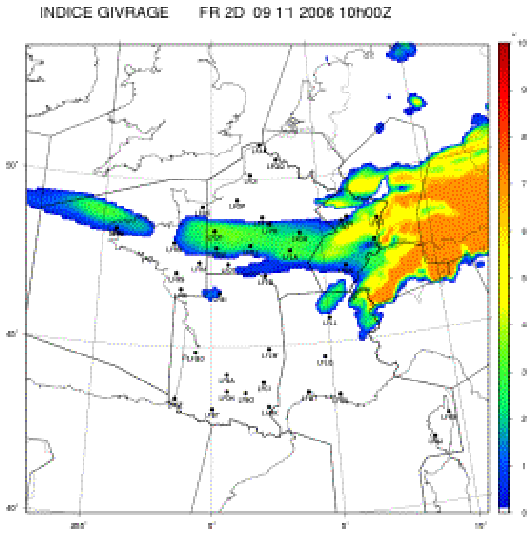

Figure a) index based on numerical model

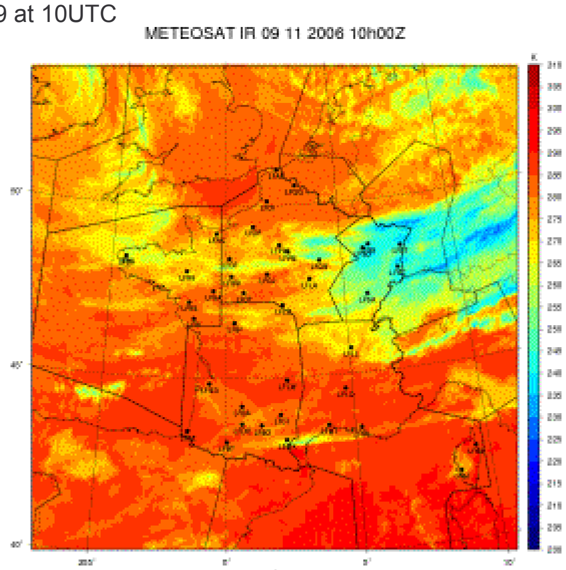

Figure b) Infra-Red satellite

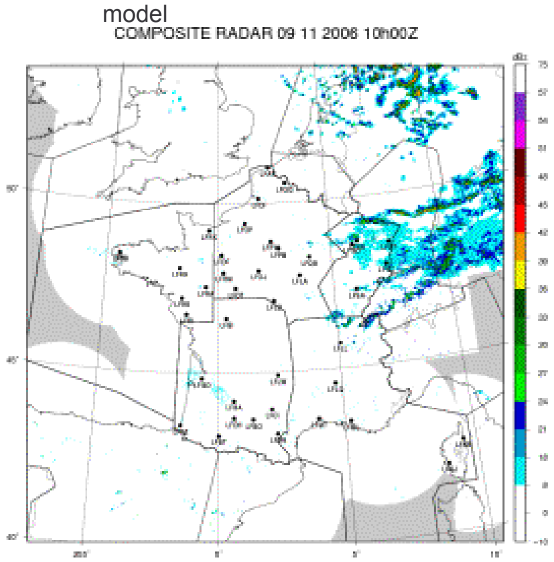

Figure c) radar image

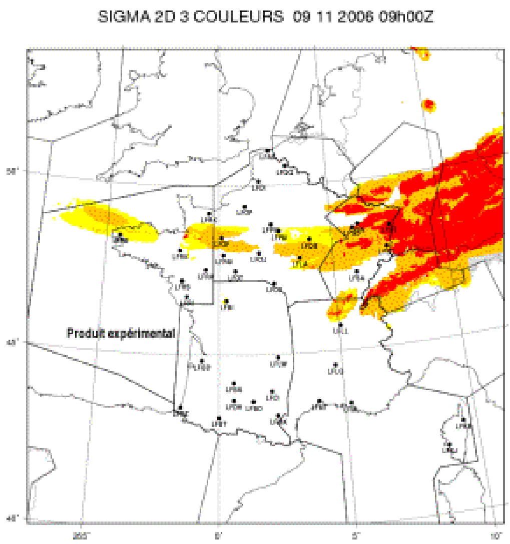

Figure d) icing diagnostic

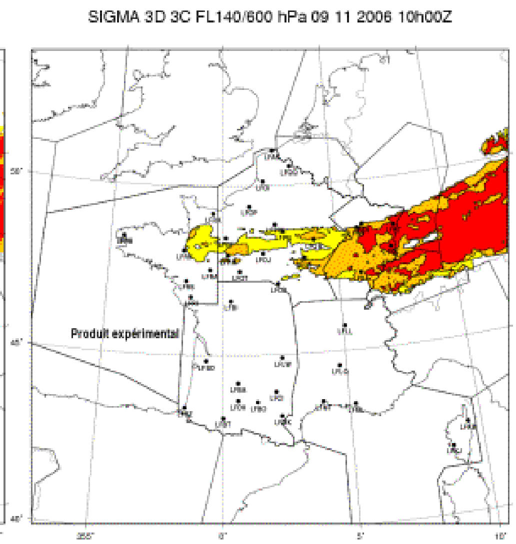

Figure e) icing diagnostic in objects