P6.12 CLIMATOLOGY OF ICING AREAS DERIVED FROM ERA40 ANALYSIS

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1 INTRODUCTION

In the current state of technologies, regular observations of icing conditions in altitude do not exist. Measurements collected during in-situ campaigns or surface observations are not numerous enough to establish a climatology. On the other hand, numerical models used for meteorological forecasts constitute a relevant data source to describe the state of the atmosphere in its three dimensions and to establish a climatology of the most favourable areas for icing conditions. An index which considers the favourable meteorological parameters for icing conditions was calculated from two sets of 10 and 13 years data, resulting from two different numerical models. That allows to highlight the potentially icing areas through the year. Thus obtained climatologies were both compared between them, and with a climatology calculated from CIP (Current Icing Potential), system developed by the National Center of Atmospheric Research (NCAR).

2 DATA USED PRESENTATION

2.1 Analysis and reanalysis

The use of a numerical model to carry out weather predictions supposes to have a three dimensional description of the atmosphere at a given time. It is the analysis. The performance of the forecast is very strongly conditioned by the initial state, consequently the analysis step is subject to very particular care.

All available observations (satellite, radiosoundings, surface observations) are assimilated by the model to compute an initial state. The state of the atmosphere thus obtained is consistent with used observations and the various laws governing the behaviour of the atmosphere. In that sense, the numerical model can be considered as an interpolator, able to propagate information resulting from the observations to the atmosphere. It is considered that an analysis constitutes the best three-dimensional description of the atmosphere at a given time.

The operational meteorological models derive directly benefit from the progress of the scientific community and are thus in constant evolution. In the same time, new data are used for the operational analysis as soon as they are available in real time. Periodically, reanalysis are processed. It consists in using the most powerful system of data assimilation to perform analysis on a past period, in general a few ten of years, by taking into account all available observations. One thus obtains a serie of successive states of the atmosphere presenting a better homogeneity, because they all were produced with the same assimilation system.

2.2 The reanalysis ERA40

The reanalysis ERA40 of the ECMWF (www.ecmwf.int) covers the period 1958-2001. It was carried out with a global model with a 1° resolution, that is to say a mesh of approximately 110km at the equator. Five vertical levels were used : 1000, 925, 850, 775 and 700hPA. Several parameters are available every 6 hours (00, 06, 12 et 18h UTC). The icing phenomenon is very dependant on the air mass, therefore no distinction between the various moments of the day was made. The last 13 years of reanalysis ERA40 were used for this study: 1989-2001.

2.3 Operational ARPEGE analysis

Like the ECMWF model, the numerical model ARPEGE offers a global coverage. In the mean time ARPEGE has been set to offer optimal performances on the Western Europe and the closest Atlantic Ocean: the mesh is tightened to 0,5°, nearly 50km in this area and, on the contrary, larger at the antipodes.

Data are extracted from the 5 consecutive low levels of the atmosphere : 1000hPa, 925hPa, 850hPa, 800hPa, 700 hPa. Every 12 hours analysis are extracted on a ten year period : 1994 – 2003.

3 ICING INDEX

Icing conditions are generally due to particular atmospheric conditions: supercooled water in the air. This state is very instable and, in the present state of our knowledge, it remains still impossible to forecast it in an absolute way.

The aim is to identify the areas for which the factors supporting icing conditions are joined together. This need exists too (and especially) for aviation forecasters : an index was developed, based on measurements made during international campaigns. It takes into account the conditions of temperature and moisture for which the risk of icing was observed, i.e intervals of temperature and moisture respectively between -15°C to 0°C and 80% to 100%. These intervals are representative of the most favourable conditions for icing occurence. However it must be noted that icing phenomenon can occur for lower temperatures and/or humidity.

The icing index varies from 0 (null risk) to 10 (very strong risk of supercooled water). It was calculated each day of 13 years (10 years for ARPEGE) at each available run ((0, 6, 12, 18 UTC and 0, 12 UTC), and a climatology was drawn up by using occurrence frequencies.

4 CLIMATOLOGY BASED ON CIP

A climatology based on a specific version of the CIP system developed by a research team of NCAR was calculated over Europe.

This CIP version uses observed data issued from radiosoundings (from 1980 to 1994, 336 sites distributed over Europe, two observations a day) and from weather stations. From these two data types, the system carries out the vertical analysis of the atmosphere and classes it according to its profile type and consequently its icing capacities. The Current Icing Potential is described in details in Bernstein (2004). The calculated frequencies show a icing risk at any altitude anywhere around the sounding site within a 100km radius.

5 COMPARISON BETWEEN THE ERA40 RESULTS AND ARPEGE AND CIP RESULTS

Results issued from the three systems are similar. They show on their common domain, Europe, the same areas of interest.

To illustrate this fact, the figure 2 shows the maps of the maximum value between 1000hPa and 700hPa, obtained for January calculated by the climatology based on ERA40, ARPEGE. The CIP results are superposed on the ERA40 and ARPEGE maps in the colour plots.

The distribution of low and high frequencies are similar on the three datasets showed on the superimposition (fig 2). Thus the Scandinavian countries, Iceland, Scotland and all the eastern Europe from western Russia to the eastern part of France, are particularly favourable to icing conditions. On the other hand, the Mediterranean area is protected. A great similarity between ARPEGE and ERA40 behaviour can be pointed out, but one must keep in mind that ARPEGE resolution is better than ERA40 one, so that areas appear more detailed with ARPEGE. Frequencies are of the same order. However ERA40 frequencies are overestimated in a rate ranging from 10% to about 20% within high values areas.

This ERA40 tendency to accentuate the icing percentage compared to ARPEGE is not only true in January but also visible during the other months. In spite of a different methodology, results issued from CIP agree as far as the frequencies distribution is concerned. Thus some particular characteristics appear on the three (CIP, ARPEGE or ERA40 based) climatologies.

For example, the CIP based frequencies show a contrast between 24% on the north of the Italy and 51% on the nearest observation point, over Slovenia. This same particularity is present on the two model based climatologies.

In the same way, on the south-eastern part of France, CIP indicates a value of 18% on the seaside, whereas ERA40 and ARPEGE indicate an interval from 20% to 30%. Northern percentages reach 45% for CIP and 40% to 50% for ERA40 and ARPEGE.

There are other common elements, as over Denmark : 50% for CIP, and a range from 50% to 60% for ARPEGE and a range from 60% to 70% for ERA40, which tends to overestimate in high values.

On the other hand, there is a great difference between CIP and ARPEGE/ERA40, on the northern part of Europe north of 70°N of latitude. CIP indicates values around 20% when ARPEGE and ERA40 show frequencies over 80%. However, in the eastern area on a wide ERA40 field, it can be noticed that the frequencies decrease. ERA40 values are again in agreement with CIP values from 60° of longitude.

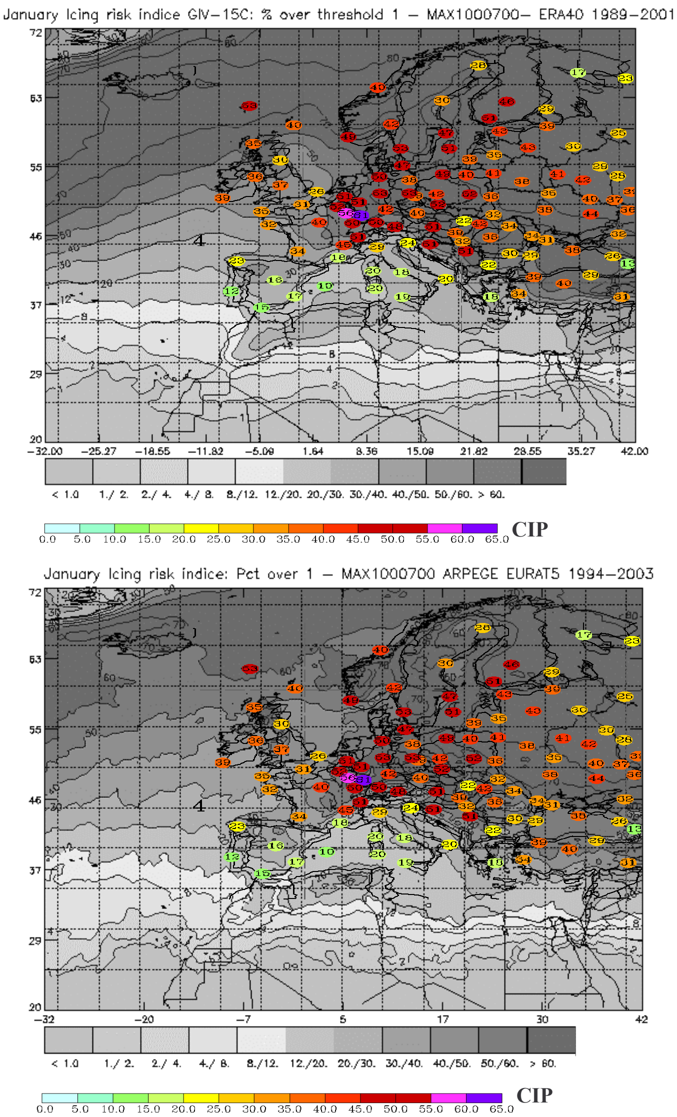

Figure 1: *Icing conditions frequencies on the layer 1000-700hPa in January, at the top : ERA40, at the bottom : ARPEGE. CIP results are plotted in colour.*

6 ERA40 RESULTS ON THE GLOBE

6.1 Horizontal distribution

The horizontal distribution of areas favourable to icing conditions, shows a certain number of characteristics remaining all year long. It consists in two large quite distinct areas, starting from the mid latitudes of each hemisphere and extending towards the poles. Figure 2 is an example of this particular distribution on the globe for January. The percentages indicated in this paragraph were calculated by considering the maximum value of the icing index, on the layer 1000hPa - 700hPa. One considers that there are icing conditions since the icing index indicates the value 1.

In the northern hemisphere, the zone where the frequencies are significant (more than 20%) extends starting from 35°N up to 85°N for every winter months. This zone moves northward during summer season, starting then from 45°N in its southern part. From November to March, the distribution is not entirely zonal as it is from April to October. In winter two large zones seem to be protected from icing conditions: the northern Canada and the north-eastern China, because temperatures occurring there are too low. Some interesting cores are located on the North American continent (the area of the great lakes and the north of the Rockies) with percentages from 30% to 40% of cases, and the northern part of Europe with Iceland and Scandinavia. In these areas the percentage of cases calculated on a layer from 1000hPa to 700hPa, is at least 70% during the winter and 40% in summer. The rest of Europe is concerned with 40% during winter. But frequencies decrease down to 12 to 20% in summer. A characteristic of the coastal countries (France, Spain, Italy) is to present frequencies approximately 10% lower than over the rest of Europe.

In the southern hemisphere, the zonal distribution is more regular than the one in the northern hemisphere, due to the small number of continents which could interfere with atmospheric flow. The position centred around the 55°S, varies in latitude from 45°S in January to 30°S in July. Over the continents, the southern part of South America shows a core of frequencies centred on the Andes cordillera. Australia is protected from the icing conditions except in its most southern part from May to October (20% to 30%).

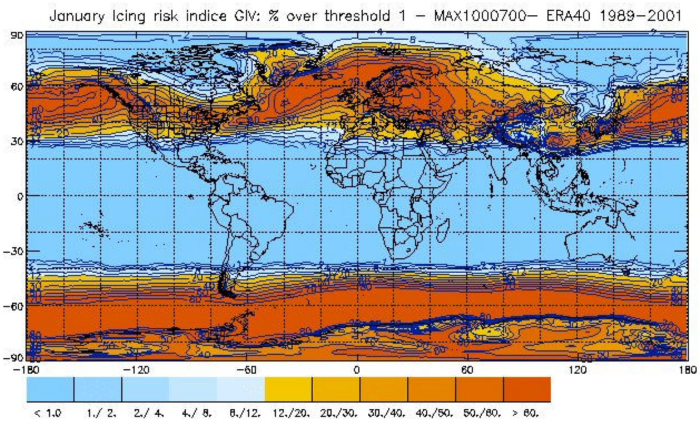

Figure 2: *Icing conditions frequencies from ERA40, over the globe, on the layer 1000-700hPa in January.*

6.2 Vertical distribution.

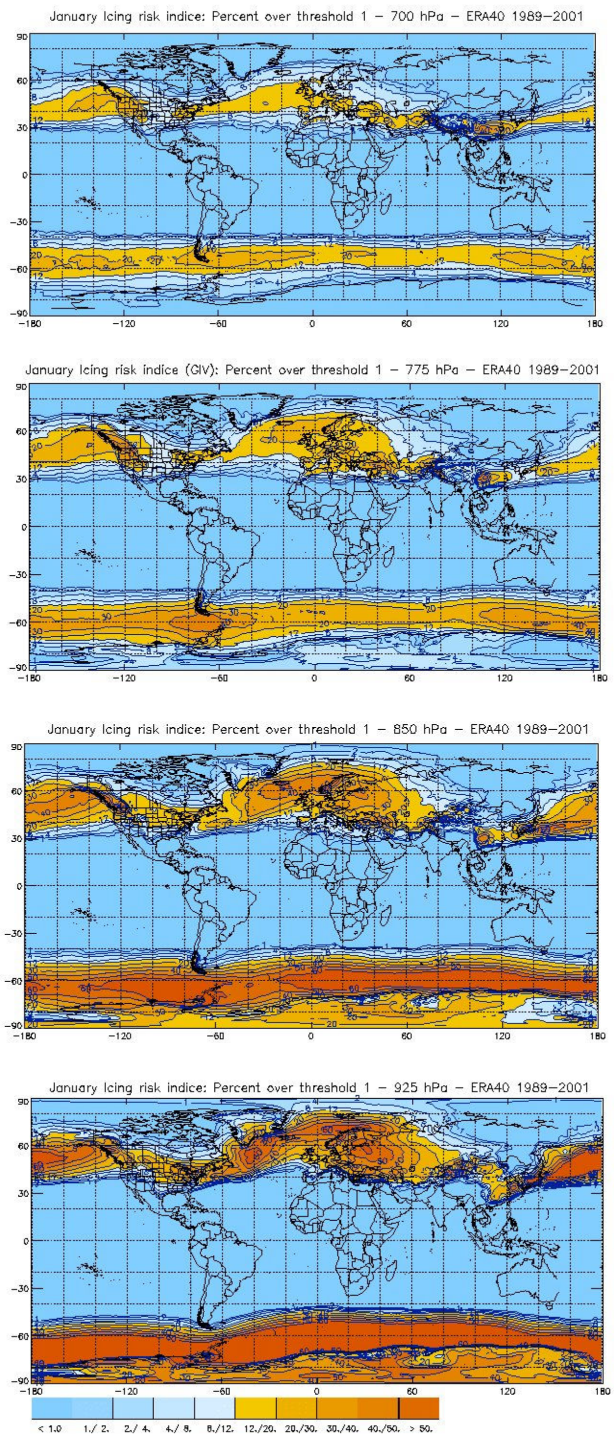

Figure 3 *: Icing conditions frequencies in January, from ERA40 results. Up to down the levels 700, 775, 850, 925 hPa.*

The variation with altitude of icing conditions frequencies is observed all through the year. This can be explained by the season-depending temperature evolution in the altitude. Thus 925 hPa is the privileged level during the winter (until March included). It is necessary to reach the level 775hPa to find the highest frequencies in summer (July, August, September included). October and November are months for transition. The cores of the strongest values are located at 925hPa, whereas at 850hPa a greater area is concerned by icing conditions. Figure 3 presents, the potentially icing conditions occurrences at various levels (925, 850, 775, 700hPa) for January. During this month, the maximum is at the level 925hPa.

7 CONCLUSION

There are no homogeneous and regular observations of icing conditions on a global scale. Nevertheless, considering the current state of the art about aviation icing, numerical weather prediction model computed analysis and reanalysis allow to provide a new approach of an icing climatology at a rather fine resolution. This model based climatology approach is in agreement with another climatology (Current Icing Potential) basically based on atmosphere profile observation.

At this stage, the method has provided a tool to highlight some world areas as particularly favourable to icing - such as northern Europe or Canada – and to study the seasonal evolution of icing parameter in these areas.

Next step will be to carry on with the comparison of the CIP and ERA40 results over others areas in the world, and to enlarge this study by using other observation and identification methods of icing areas.

8 ACKNOWLEDGMENTS

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9 REFERENCES

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