JP1.14 # A NEW ALGORITHM TO ESTIMATE AIRCRAFT ICING IN THE HIRLAM-MODEL

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1. ABSTRACT

A new index to estimate aircraft icing from operational meteorological models has been developed by Swedish meteorologists. Although rather simple it takes into account, directly or indirectly, all the principal meteorological variables for icing. The index has been evaluated during two winter seasons and is now operational in the Swedish HIRLAM model. A lucid presentation of the index is used.

2. INTRODUCTION

A small working group of meteorologists in a joint project between the Swedish Armed Forces and the Swedish Meteorological and Hydrological Institute has made a study on aircraft icing from the forecasting point of view.
The output from that project, which ended in 1999, was an updated forecaster's guide (only in Swedish) to be used when forecasting icing on aircraft and helicopters within and below clouds.
It is still very important that the forecaster is trained to recognise the weather situations, which are likely to cause ice accretion - for icing below clouds that is the only method.
To estimate icing conditions in clouds an icing index from a numerical model may be a useful tool although you have to be aware that such an index will not solve the whole forecast problem. A new icing algorithm was developed by the working group.

3. A NEW ICING ALGORITHM

Already more than 5 years ago when cloud-water was introduced into the numerical models a test with a simple index including liquid water content from the model was made at the Swedish Meteorological and Hydrological Institute,

Index A = 5 + ln cw, where ln is the natural logarithm and cw is the total amount of cloud-water (g/kg)

The index was calculated for every gridpoint in the Swedish HIRLAM model (22x22 km and 31 levels) and gave a number from 1 to 5 provided that the amount of cloud-water was high enough. The number could then be used as an indicator of the expected icing intensity in a suitable temperature interval.

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Index A was a fairly good indicator of areas where icing conditions might be expected although the horizontal extension sometimes seemed too large and the area with the strongest icing intensity was not always well defined. However, the working group wanted to take into account, directly or indirectly, all the main meteorological variables for icing:

- temperature.
- amount of liquid water.
- size of the droplets.

The vertical velocity was chosen as a substitute for the droplet size, which is not available from the numerical models. Index A was modified to an Index B using the vertical velocity, w, from the model according to Table 1.

The reasons to give the vertical velocity a relatively strong influence on the index are two:

- positive vertical velocity increases the likeliness that most of the cloud-water is subcooled.
- updrafts in the order of tens of cm/s favour the production of big cloud drops up to the size of drizzle, which we know increase the intensity of the icing.

Index B gives a number from 0-9, which could be calibrated to icing intensity.

4. PRESENTATION

It is very important that the index is displayed for the forecaster in a lucid way, which makes the information easy to use. The working group suggested a plot model, which is now used in Sweden. The highest intensity at any level is plotted as a coloured symbol in the gridpoint. The lower and upper limits of the icing layer as well as the level of maximum intensity are also plotted. In this way the colours give you the horizontal distribution and the maximum intensity of the icing risk and the numbers give you the vertical extent of the icing layer. An example of the numerical icing forecast is enclosed in Figure 1.

5. EVAULATION

Index B has been operational in Sweden for two years. It is calculated at every gridpoint where the HIRLAM model has cloud-water and the temperature at the same time is below 0 °C. It gives a value from 0 to 9 depending on cloud-water and vertical velocity. Evaluation of an icing index in a strict objective way is not possible. Therefore the evaluation has been made subjectively by the aviation forecasters. According to experiences from two winter seasons in Sweden the index B can roughly be translated into the ICAO definitions of icing intensity according to Table 2.

The index only considers the meteorological factors and does not take into account for instance the speed of the aircraft or the use of available de-icing devices. Therefore the forecast should be translated as risk for a certain degree of icing at an aircraft flying at low to moderate speed and not using any de-icing device. At direct briefing for a pilot the Met officer may adjust the forecast to the type of aircraft and operational aspects.

It has been noticed that the index has a tendency to overestimate the icing intensity at high altitudes e g at low temperatures. Probably that is due to a combination of operational and meteorological reasons. Aeroplanes operating at high altitude generally fly with high speed and thus the icing risk is reduced by the frictional heating of the airframe. Low temperature also increases the likeliness that the cloud-water has turned into the frozen state.

Although the index originally was supposed to consider only the meteorological factors it has recently been adjusted according to these operational experiences. An easy way was to reduce the amount of liquid water linearly between -15 and -40 °C. Thus index A was changed to a slightly modified version, where the total amount of cloud-water, cw, is replaced by a reduced amount, cwr, when the temperature is below -15°C with a formula

cwr = cw * (40+T)/25 where T is the temperature in °C.

It should be mentioned that the index has been evaluated only in the present version of the HIRLAM model in Sweden. It should not be used operationally in other models and in other climatic zones without proper testing.

6. SUMMARY AND CONCLUSION

An icing index can be constructed in many ways but it is important that the main meteorological variables governing the intensity of the icing is included. To estimate icing conditions in clouds such an index from a numerical model may be a useful tool although you have to be aware that an index will not solve the whole forecast problem.
However, the experience of the Swedish index in the present version of the HIRLAM model is that it can be used as a forecast as good as, or sometimes even better than the man made, in situations with lows, fronts and orographical updrafts.
In convective situations the index does not always add very much extra information.
The vertical resolution of the model is still not good enough to allow forecasting of severe icing in inversions, which may be a dangerous case sometimes in winter, at least in Sweden.

Cloud-water is parameterized in the numerical models and different condensation schemes may not always produce the same amount of cloud-water. Therefore the Swedish index should not be used in other numerical models without proper test and evaluation.
An icing index from a model always should be considered an aid for the forecaster and not a readymade forecast. A forecaster's guide on icing and a close co-operation with the pilots are also essential parts to ensure good forecasting.

w (cm/s)	< 0	0-10	10-20	20-30	> 30
Index B	A -1	A+1	A+2	A+3	A+4

Table 1. Index A modified to an index B using the vertical velocity, w, from the model.

ICAO	No icing	Lgt	Lgt-Mod	Mod	Mod-Sev	Sev
Index B	0-1	2-3	4	5-6	7	8-9

Table 2. Correlations between Index B and ICAO icing intensity according to evaluation in the Swedish version of the HIRLAM model.

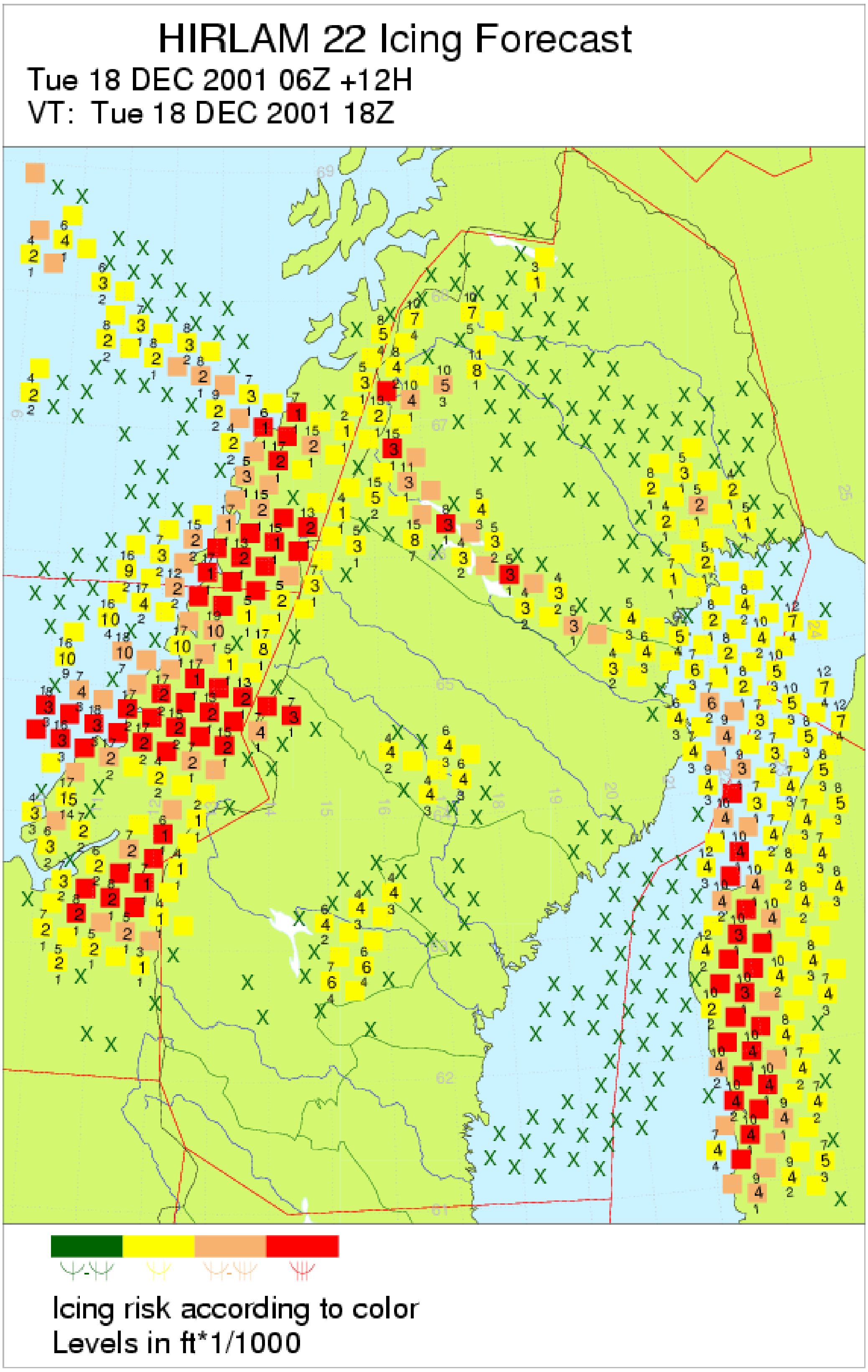

Figure 1. An example of the numerical icing forecast. The highest intensity at any level is plotted as a coloured symbol in the gridpoint. Only index values 4 and more are used. Index 4 is plotted with a green X, 5-6 with a yellow square, 7 with an orange square and 8-9 with a red square. In each square the level of maximum icing intensity is plotted in thousands of feet (nearest to the level of the model). Above and below the square the highest level and the lowest level of index > 4 are plotted. In this way the colours give you the horizontal distribution and the maximum intensity of the icing risk and the numbers give you the vertical extent of the icing layer.