4.3 ADWICE - ADVANCED DIAGNOSIS AND WARNING SYSTEM FOR AIRCRAFT ICING ENVIRONMENTS

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1. INTRODUCTION

In-flight aircraft icing is a serious threat. The number of world-wide known accidents and serious incidents in which icing played in aviation a major role exceeds 800 (Mingione, 1998). Obviously, current protection systems and standard icing forecasting methods, which rely mostly on reported icing by pilots and the evaluation of radiosonde ascents, are inadequate to control the threat (Green, 1997).
Ice accumulation on aerodynamic surfaces during flying in supercooled clouds causes modification of the aerodynamics of the aircraft up to the point of uncontrolled flight. Naturally, the safest way would be to avoid the icing regions at all.
However, this would require to forecast the supercooled liquid water in clouds and to model a complete ice microphysics scheme. Only a few numerical weather prediction models however do include ice microphysics. The forecast quality of supercooled liquid water still is insufficient to completely rely on that quality for forecasting aircraft icing. Other methods to diagnose and forecast icing conditions are under development.
These methods rely on algorithms, which deduce the potential icing threat from measured (mainly radiosonde ascents) or forecast (numerical models) distributions of temperature and humidity. However, although these algorithms have a high probability of detection of icing as verified against pilot reports (PIREPS), they generally show large overforecasting, i.e. a high false alarm rate.

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This situation calls for the use of additional information to reduce the overforecast areas. Data fusion concepts have therefore been introduced with the aim to localize potential icing regions from a proper combination of numerical output data, satellite and radar data as well as surface observations (e.g. Bernstein, 1998).

2. THE RESEARCH & DEVELOPMENT PROJECT ADWICE

Following this concept, ADWICE, the Advanced Diagnosis and Warning system for aircraft ICing Environments, has been developed since 1998 in joint cooperation of the *Institut für Physik der Atmosphäre of DLR,* the *Deutscher Wetterdienst (DWD)*, and the *Institut für Meteorologie und Klimatologie (IMUK)* at the University of Hannover. To identify icing environments ADWICE merges the gridded forecast model data of the *Local Model* (LM; Doms and Schättler, 1999) of the DWD with observation data like SYNOP, Metar and radar data (Tafferner et. al. 2002).

2.1 USE OF THE NCAR/RAP ALGORITHM

Firstly, a slightly modified version of the NCAR/RAP algorithm (Thompson et al., 1997) is used to provide a first guess icing volume using forecast fields of temperature and humidity.
The algorithm is able to classify the weather and cloud situation into four different groups by checking the profiles of temperature and dewpoint temperature. So one gets a first guess icing volume with a horizontal grid distance of 7km and 36 vertical layers including four different icing classes: *freezing rain*, *stratiform*, *convective* and *general*.

2.1.1 FREEZING RAIN REGIME

Typical profiles of temperature and dewpoint indicate the *freezing rain* regime. On top of a warm layer with temperatue above zero, the so called warm nose, a relative moist layer exists where precipitation forms via the classical ice-phase process. Precipitating particles falling through the warm nose melt and become supercooled as the temperature in the layer underneath is below zero.

2.1.2 STRATIFORM ICING REGIME

If the algorithm detects temperature and moisture values ranging between set thresholds then *stratiform* icing is found. There is a moist layer with a relative humidity greater than 85% within a temperature range from -12°C to 0°C topped by an inversion, above which the air is relatively dry. In contrast to the freezing rain scenario where precipitation forms through the classical ice-phase process, here freezing drizzle can form within the moist layer via condensation-collision-coalescence, the so-called "warm-rain" process (Huffman and Norman, 1988; Strapp et. al.,1996).

2.1.3 CONVECTIVE ICING REGIME

By checking the stability of the atmosphere a *convective* icing situation can be detected. An unstable layer with temperature and humidity values moving in a set scope indicates such a situation. This scenario mimics an icing situation within relatively warm convective clouds where vertical moisture transport provides abundant supercooled droplets and the freezing rate is too slow to freeze all droplets.

2.1.4 GENERAL ICING REGIME

If none of the above icing regimes can be diagnosed, there is still a chance for icing whenever temperature and humidity lie within a certain range. If this is the case the algorithm detects *general* icing.

2.2 FUSION WITH OBSERVATION DATA

In a next step observation data like radar, synop and metar will be included in the system in order to reject or confirm the first guess icing field.

2.2.1 RADAR DATA

Conventional weather radar systems do detect precipitation size particles, thus radar data can be used as an important information to confirm or reject the first guess icing volume.

The following examples show how ADWICE uses the radar data: If the first guess states that there is freezing rain at the surface up to a certain level, and the radar finds reflectivity at this grid points, the radar data confirm the first guess.

If the algorithm detects *stratiform* icing and the reflectivity is greater than 18dBZ at this grid points ADWICE will reject the icing potential. The reason for the rejection is, that for radar echoes greater than 18dBZ it is known that the precipitation seen by the radar is formed by the classical ice-phase process. So we only have a solid or mixed phase cloud at temperatures below 0°C. Radar reflectivities up to 18dBZ confirm the *stratiform* icing because the radar might see even small drizzle with a high drop density.

2.2.2 SYNOP DATA

Synop data are data from weather observing stations and are used to confirm and reject the first guess icing volume.

For all gridpoints of the LM ADWICE searches for the nearest reporting station inside a radius of 70km and uses this weather information to confirm or reject the first guess icing potential. The distance between gridpoint and reporting synop station only depends on the density of the synop stations.

Using this technique to confirm or reject the first guess icing volume, more homogeneous correction is possible so that the corrected field does not show artificial inhomogeneous features.

ADWICE uses reports of precipitation similar to the radar information with the exception of drizzle precipitation. Drizzle is mostly not seen by the radar but is reported by the observation

stations. So in this case we can use this information too, for example confirming the *stratiform* icing regime. Beside this ADWICE checks if all dangerous synops like *freezing rain* and *freezing drizzle* are detected by the algorithm.
From synop data we get information about the clouds, too. Whenever there is no cloud observation there will be no icing in the vertical column above the observing station. Currently we prescribe a threshold of 4/8 for "cloudless" observations. In a similar way, the first guess can be rejected if there is an icing prediction below observed cloud base.

2.2.3 METAR DATA

Metar data are data from meteorological observation for aviation and are used similar to the synop data. ADWICE checks the metar data of icing relevant weather, precipitation and cloud information.

2.3 FUTURE DEVELOPMENT OF ADWICE

In future versions of ADWICE the liquid water content (LWC) as model data will be used directly for the detection of supercooled clouds. The date of integration and use of the LWC in ADWICE depends on the development of cloud microphysics integrated in the Local Model.
Other data e.g. from satellites may be used in future, too.

3. CONCLUSIONS

Summarising we get icing information from several data. The first guess icing volume produced by the NCAR/RAP algorithm using forecast model data from the Local Model is one of them. Up to now the first guess icing information is the main component. With some exceptions we only reject and confirm the first guess using the icing information we get from synop, metar and radar data. We are thinking about using the above documented icing information independently, giving each one an own probability of detection. Merging the likelihoods from all the different data we get a final icing probability at each grid point.
Of particular advantage for ADWICE are the grid resolution of the LM and the density of the observation stations in Middle Europe in particular in Germany.
ADWICE is in a preoperational testing phase at the German Weather Service. The first results that we got from this testing phase are promising. But there is still plenty of room to integrate new ideas.

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