J1.7 AN INFERRED ICING CLIMATOLOGY. PART III: ICING AIRMETS AND IIDA

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1. INTRODUCTION

A climatology of icing conditions would provide a better understanding of the phenomena that result in aircraft icing. As discussed in part I of this series (Young et al. 2002), the only direct observations of icing events are pilots' reports (PIREPs), which are non-systematic and spatially biased (Kane et al. 1998). Fortunately, icing forecasts and diagnoses can also provide information on climatological characteristics of aircraft icing. In this paper, the official Aviation Weather Center (AWC) forecasts of icing conditions, (i.e. icing AIRMETs), and the Integrated Icing Diagnostic Algorithm (IIDA; McDonough and Bernstein 1999), are used to assess the climatological characteristics of aircraft icing.

None of these sources directly and systematically measure aircraft icing, so they are not ideal. However, taken together they can paint a reasonably good picture of the climatological nature of aircraft icing conditions.

Section 2 describes the data and methods used to develop the climatology. Contour maps of the relative frequencies of AIRMETs are presented in Section 3 for the winter seasons in addition to individual months. Section 4 shows the relative frequencies of icing conditions as determined by IIDA. In the final section, these climatologies are compared and contrasted to those presented in parts I and II of this series (Young et al. 2002; Bernstein and McDonough 2002) and future work is discussed.

2. DATA AND METHODS

This paper assesses a climatology based on the relative frequency of forecasted or diagnosed icing during the winter seasons/months. Details about the AIRMET data and IIDA data are included in the next two subsections, respectively. Methods used to determine the relative frequency of icing based on each type of data are described in the third subsection.

2.1 AIRMET data

AIRMETs are official 6-hour outlooks issued by the National Weather Service's Aviation Weather Center (AWC). The bulletins are generally issued at four standard times throughout the day; however, if exceptionally severe weather occurs or if a previous bulletin needs to be updated, the AWC will issue AIRMETs at a non-standard issuing time (NWS 1991).

For the purpose of this study, icing AIRMETs for the continental US (CONUS) issued during the winter months (i.e. November through March) from 1994-2000 are evaluated. Table 1 displays the number of AIRMETs per season, from 1994-2000.

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Table 1: Counts of AIRMETs issued during winter (Nov-Mar) seasons.

Winter Season	Number of AIRMETs
1994-1995	2626
1995-1996	2836
1996-1997	3705
1997-1998	3539
1998-1999	3362
1999-2000	3388

AIRMETs are two-dimensional polygons along with base and top altitudes that define a three-dimensional region of expected icing conditions with moderate or greater (MOG) severity. Once an AIRMET has been issued, it is valid for 6 hours or until it is amended or cancelled, whichever comes first. Figure 1 shows an example of icing AIRMETs valid at a single time.

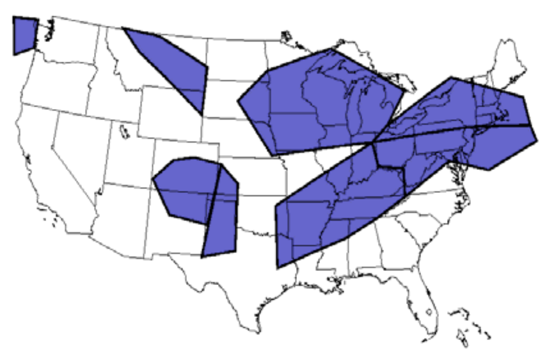

Figure 1: Example of icing AIRMETs.

2.2 IIDA Data

IIDA is an icing diagnosis that combines satellite and radar data, surface observations, recent PIREPs, and numerical weather prediction model fields from the Rapid Update Cycle (RUC), to diagnose locations of icing conditions (Benjamin et al. 1999). IIDA then produces an icing potential value on a continuous range of (0,1) for each of the RUC grid points. Creation of a dichotomous icing/no icing diagnosis is accomplished here by applying a threshold of 0.25.

IIDA data were only available for January 15, 2000 through April 15, 2000 and December 2000 through March 2001. For this period, 2759 hourly diagnoses of icing are available. An example of IIDA valid at the same time as the AIRMET example (Figure 1) is shown in Figure 2. The scale goes from 0 (no icing) to 1 (highest icing potential). The maps clearly show that the AIRMETs and IIDA agree on the icing locations. The differences in the format of the two are also apparent.

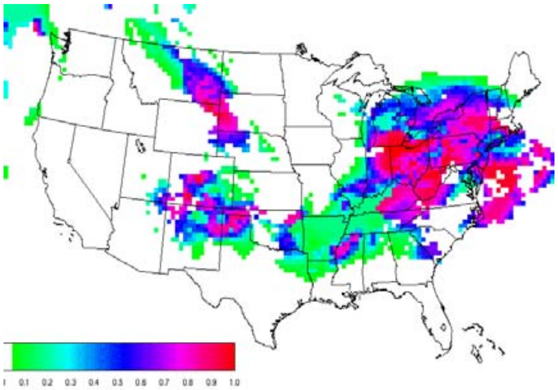

Figure 2: Example of IIDA gridded icing diagnosis.

2.3 Methods

For both the AIRMETs and IIDA, the climatology is based on the percent of time that various cities are covered by an icing AIRMET or an IIDA diagnosis of icing at any altitude. The results at the city locations were then contoured to give us an estimate of the icing likelihood across the CONUS.

Figure 3 shows the locations of the 131 cities that were used to determine the climatology. For part I of this series (Young et al. 2002), the cities were chosen both for their size and coverage of the CONUS. For this paper, the same cities were used in order to match the other climatologies, making the results more directly comparable.

Figure 3: Locations of the 131 cities used to determine the climatologies.

Using the AIRMETs, a climatology is determined based on the relative frequency of icing days. An icing day was declared if the city was covered by an AIRMET during any portion of the day.

Determining the percent of the time an icing hazard was covering a city using IIDA is somewhat more complicated. First the 0.25 threshold is applied to create dichotomous values at each grid point. Then an icing hazard is declared if icing exists in at least 5 continuous layers in the vertical for any grid point within a 100 km radius of the city. Since IIDA uses the RUC pressure level data, the thickness of the layer of icing varies with altitude. However, five continuous pressure levels define a layer of icing at least 100mb deep. Finally, IIDA is updated hourly with the RUC. For the climatology, the relative frequency of hourly IIDA assessments that indicated an icing hazard for the period of interest is computed and contoured.

3. ICING CLIMATOLOGY BASED ON AIRMETS

Figure 4 shows the contours of proportion of days with icing, as forecast by AIRMETs, across the CONUS for the winter seasons of 1994-2000. This map shows that for most of the country, the proportion of icing days increases with increasing latitude. However, in the central part of the country (e.g. Nebraska, Kansas, Oklahoma), the proportion of icing days is lower than for similar latitudes in the eastern and western parts of the country. For the winter season, the Pacific Northwest has the maximum percent of icing days.

Figure 4: Proportion of AIRMET icing days during winter seasons 1994 - 2000.

Figures 5 through 7 are contour maps of the proportion of icing days, as forecast by AIRMETs, in November, January, and March of 1994 through 2000, respectively. The monthly maps show that the percent of icing days increases from November to January and decreases from January to March. Also, the minimum in the central part of the CONUS that is evident in the winter season is less evident in the March contours. Maps of December and February showed similar patterns but have been excluded for the sake of brevity.

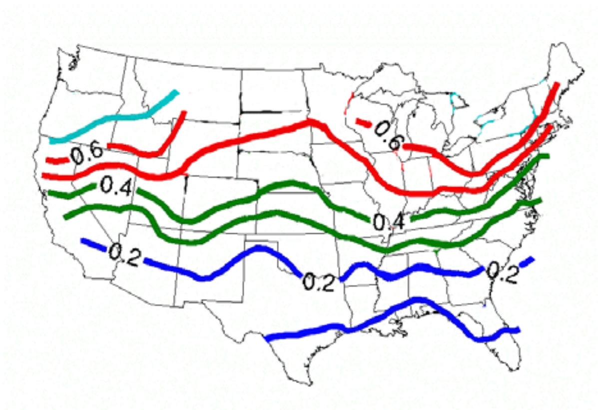

Figure 5: Proportion of AIRMET icing days during November 1994 - 1999.

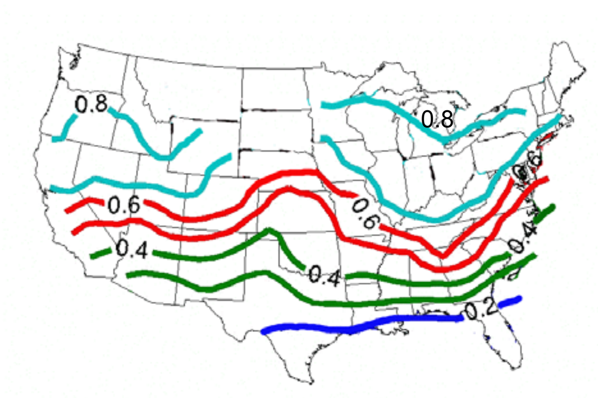

Figure 6: Proportion of AIRMET icing days during January 1995 - 2000.

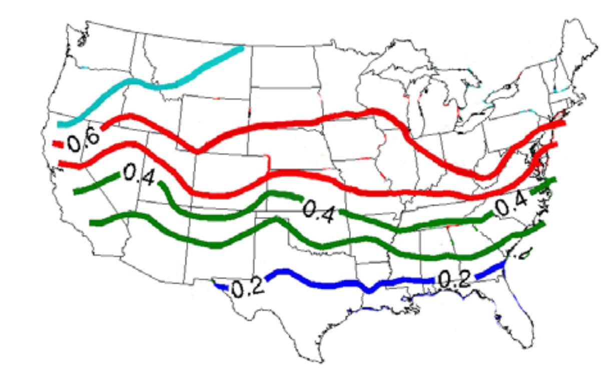

Figure 7: Proportion of AIRMET icing days during March 1995 - 2000.

4. CONTOURED CLIMATOLOGY BASED ON IIDA

Figure 8 shows the contoured values of the percent of time that IIDA diagnosed icing at the locations of the 131 cities for the entire period. Overall, the percentages are lower than for the AIRMETs. Additionally, the contour lines are flatter across the central and eastern portions of the CONUS than those based on the AIRMETs. This difference may be due to the method of declaring an icing hazard or to the difference in the time periods available for each type of data.

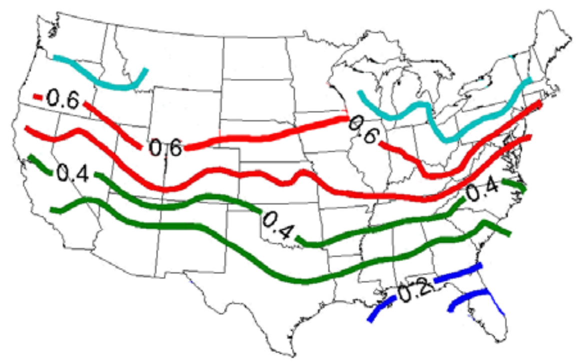

Figure 8: Proportion of IIDA icing hours during Jan 15-Mar 15, 2000 and Dec 2000 – Mar 2001.

5. CONCLUSIONS AND FUTURE WORK

The patterns evident in the climatologies developed in the three papers in this series are quite similar (Young et al. 2002; Bernstein and McDonough 2002). The Pacific Northwest and the states bordering the Great Lakes are particularly icing prone. Icing potential generally decreases with latitude (in the CONUS). Icing is somewhat less frequent in the drier Western High Plains regions of the country. The similarities in the patterns of the climatologies suggest that they can be used individually or in aggregate form.

The approaches used in the three papers differ in many ways, making the similarities in the results at once more surprising and more believable. The actual values of the contours, (i.e. the estimated proportions of icing time), differ somewhat between the various climatologies. This is most likely due to differences in the approaches used. The total number of seasons available for analysis varied from 30 winter seasons for the sounding-based climatology to only two for the IIDA climatology. The frequency of availability of the data varied from hourly (IIDA) to twice daily (soundings). The AIRMET forecast regions are large, while the IIDA, PIREPs, and soundings are fairly localized. Therefore, the AIRMET results are less likely to show small-scale variability than the results of the other studies. Nonetheless, these climatologies seem to be in general agreement about the relative frequency of icing across the CONUS.

While they are generally similar, the AIRMET, sounding and IIDA climatologies differ along the eastern slopes of the Rocky Mountains. The sounding climatology shows a strong minimum in the Rockies. In contrast, the AIRMET results have a weak minimum just east of the Rockies, in the central CONUS, while IIDA is fairly consistent across the CONUS with no evident minimum.

As always with climatological studies, the future work includes addition of more years of data as they become available. Ideally, one or more of these approaches will be incorporated into automated icing forecast algorithms. Additionally, these techniques can be applied to estimate the icing climatology in new areas of study outside the CONUS, particularly in Alaska. Higher resolution climatologies based on the AIRMETs and IIDA are also planned.

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