9.6 ANALYSIS OF PROBLEMATIC IIDA ICING DIAGNOSES IN THE PACIFIC NORTHWEST

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1. INTRODUCTION

Several recent formal and informal studies have been conducted to verify the NCAR Integrated Icing Diagnosis Algorithm (IIDA; McDonough and Bernstein 1999) using observations of icing from pilot reports (PIREPs) and research aircraft (e.g. Brown et al 1999, Bernstein et al 2000). From a regional verification study of IIDA, it became apparent that IIDA's performance varies somewhat by region of the United States (Kane et al 2000). In particular, IIDA was less efficient and sometimes underestimated the potential for icing in the Pacific Northwest (PNW), especially when deep synoptic storms affected the area.

In an effort to examine some aspects of algorithm performance more closely, a supplemental PIREP program was initiated with several regional airlines. The purpose of this effort was to obtain more frequent icing PIREPs over a few cities for altitudes at which icing most frequently occurs. In this paper, supplemental and standard PIREPs from the PNW are compared with standard weather data as well as IIDA input datasets and output icing potential fields. The study was designed to assess the data that were used by IIDA to calculate icing potential during these episodes, why some PIREPs were missed, and what could be done to improve IIDA's performance in the PNW.

2. DATA SETS USED

2.1 IIDA icing potential and RUC model fields

IIDA is a physically-based, situational technique that produces an icing product by combining satellite, surface, and radar observations with several fields from the Rapid Update Cycle (RUC) model. The algorithm defines the icing field in terms of icing "potential" with values from zero (no potential) to 1.0 (very likely). RUC relative humidity (RH) and temperature (T) fields are examined to identify the profiles used by IIDA. Data used had 25 mb vertical and 40 km horizontal spacing.

2.2 Pilot Reports (PIREPs)

PIREPs of icing are vital in that they are typically the only way to verify the presence or absence of icing at a specific time and location. Standard PIREPs have some drawbacks, however, as they typically do not provide high resolution information in time or space and they grossly underreport the absence of icing. To improve upon this, a supplemental PIREP program was initiated at several regional commuter airlines in key parts of the country, including SkyWest (PNW), Air Wisconsin (Rocky Mountains, High Plains, Midwest) and COMAIR (Midwest). These "regionals" all fly (or flew) twin-propellor aircraft, including the Embraer 120 and Dornier 328. The relatively short routes flown by these aircraft requires them to spend a high percentage of their flight time at common icing altitudes. This, in combination with the high frequency of flights and the fact that the aircraft are protected by boots, rather than heated leading edges, allows them to provide frequent and relatively consistent icing reports derived from reliable visual cues. Pilots were asked to provide both positive and negative icing reports on both climb and descent at key airports (e.g. Seattle). Overall, the under sampling of "negative" icing in standard PIREPs was clearly evident, as the proportion of negative PIREPs taken in the PNW during the program was 38%, compared to 67% for the supplemental PIREPs (Brown et al, 2001). In the study presented here, both datasets are used to provide the maximum number of observations.

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3. ANALYSIS TECHNIQUE

The technique used to analyze this data involved extracting the icing potential at the four grid points surrounding the airport of interest. The maximum icing potential value was taken from the points, and the heights were then averaged. Results were plotted as a time-height cross-section over each particular day with the PIREPs overlaid. For days when the algorithm appeared to perform poorly, synoptic weather patterns and nearby soundings were examined to establish what type of problems existed and what could be done to solve them.

4. CASE STUDY #1 – SEATTLE, WASHINGTON

4.1 Overview of Case

Between 1200 UTC on 1 February 2000 and 0000 on 2 February 2000 (all times UTC), IIDA diagnosed icing in a layer from 5000 to 20,000 ft, with the highest icing potentials between 6,000 and 13,000 ft (Fig. 1, all heights MSL). The PIREPs valid for this time period showed that a deep layer of icing did exist, but it extended up to ~23,000 ft. Also the bulk of the moderate or greater PIREPs were between 12,000 and 22,000 ft. While IIDA captured 55 of 61 PIREPs, overall, it completely missed 6 positive PIREPs and had relatively low icing potentials (<0.5) for the locations of many of the remaining 55 PIREPs.

The cross-section of RH, with the -10C and -25C isotherms and PIREPs overlaid, indicates that all of the PIREPs missed occurred at altitudes with T<–25C. This is below the minimum temperature at which IIDA will indicate icing because of the rarity of icing events at such low temperatures. The RUC also forecast relatively dry air (<70% RH) from 10,000 to 18,000 ft between 1800 and 2000, causing IIDA to lower the icing potentials.

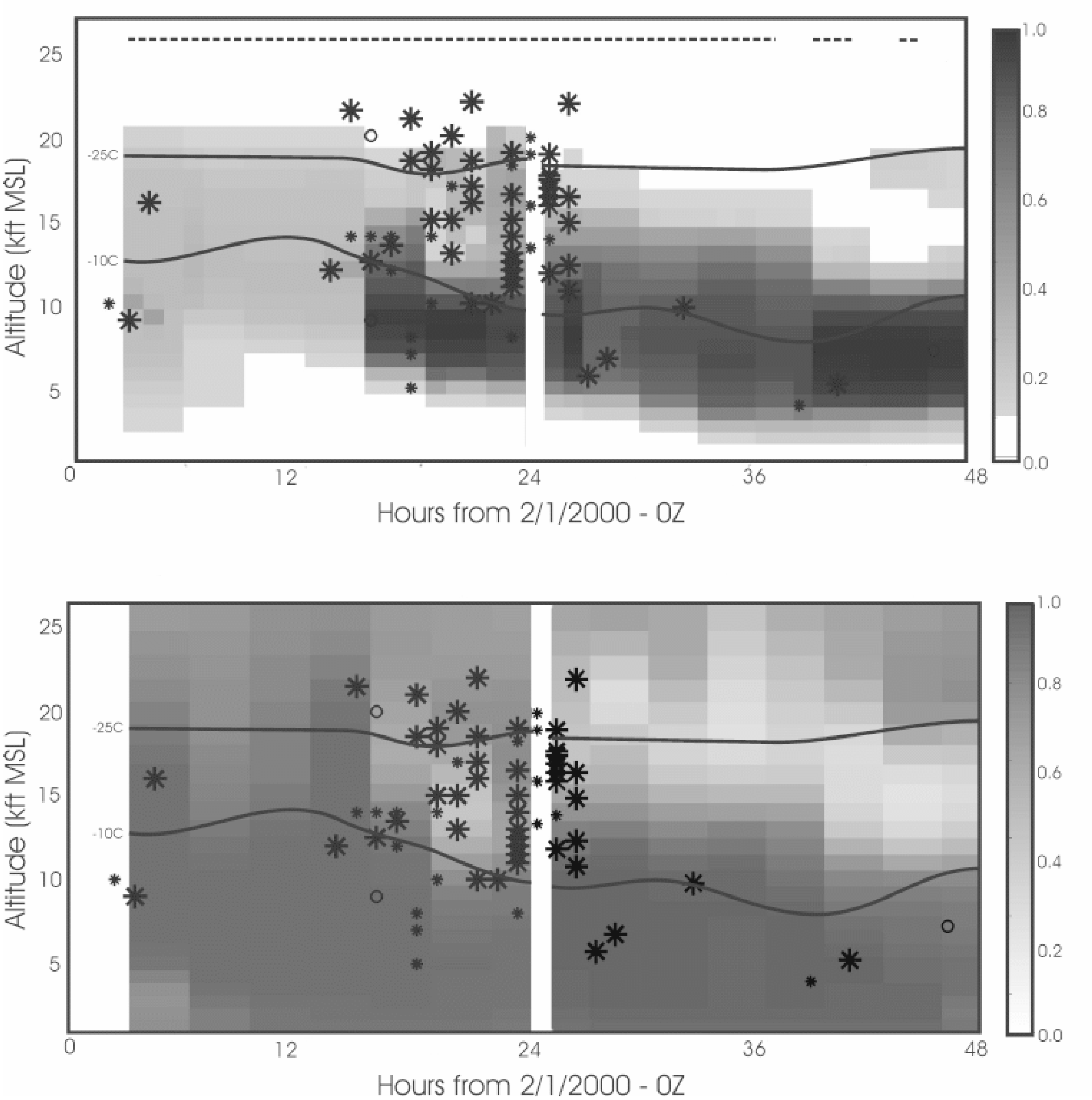

Figure 1. Time-height cross-section of (a) IIDA icing potential and (b) RUC model RH. The solid lines are the -10C and -25C isotherms. Large and small asterisks represent moderate or greater and light or less icing PIREPs, respectively. Open circles represent negative icing PIREP. IIDA icing potentials were missing where the entire column is white.

4.2 Analysis of Quillayute WA (KUIL) Soundings

The 1200 KUIL sounding from 01 FEB 2000 showed a deep, nearly saturated moisture profile to well above 300mb, with a dry layer present at ~10–17,000 ft (Fig. 2a). At 0000, the profile was saturated up to 13,000 ft with a shallow, non-saturated layer near 4,500 ft and moist, but unsaturated air up to ~22,000 ft (Fig. 2b). Based upon the multitude of PIREPs present in the 10-20,000 ft altitude band between ~1500 and 2400 on 01 FEB, it is clear that the RUC underestimated the relative humidity. This appears to have been due to the model maintaining the dry layer observed at these altitudes throughout the 1200 model run forecasts (IIDA used forecasts from the 1200 run for this case between 1500 and 2300 because archives of the 1500 and 1800 runs forecasts were not available). Poor estimate of RH and the relatively cold temperatures further aloft caused IIDA to underestimate the icing potential over Seattle.

4.3 Analysis of Synoptic Weather Patterns

An analysis of synoptic weather charts at standard levels (850, 700, 500mb) showed a deep, strong synoptic system impacting the Seattle area during the period. The charts for 1200 UTC on 1 FEB showed a trough to the west of Seattle with 50, 60 and 110 kt southwesterly winds around at 850, 700 (Fig. 3) and 500mb, respectively. The trough approached slowly and the strong southwest winds continued at 0000 on 2 FEB. Some cooling was evident aloft during this 12hr period, and the bulk of the PIREPs occurred then.

The combination of the wind direction and speed with the orientation of the mountainous terrain in this area, as well as the position of the upper-level trough suggests that substantial upward vertical velocities were probably present during this time period. The RUC model forecast vertical velocity fields support this.

4.4 Case study #1 summary

Initial examination of IIDA on this case showed a under-diagnosis of icing between 1200 on 01 FEB 2000 and 0000 on 02 FEB 2000. The six missed PIREPs at T<-25C can possibly be attributed to the synoptic weather pattern set up at that time. The soundings showed a deep layer of moisture coupled with synoptic and topographically induced lift. Such lift can allow supercooled liquid to form and persist at relatively cold temperatures where glaciated conditions are usually expected. Although this is only one case, these situations are common in the PNW, indicating that it may be useful to employ indications of upward vertical velocity to better diagnose icing at cold temperatures. Cold icing has been observed in other locations when strong upward motion and/or very clean air are present.

The lower icing potentials from 1800 to 2200 on 01 FEB 2000 appear to be attributable to errors in the RUC RH forecasts. The 1200 soundings did show a dry layer

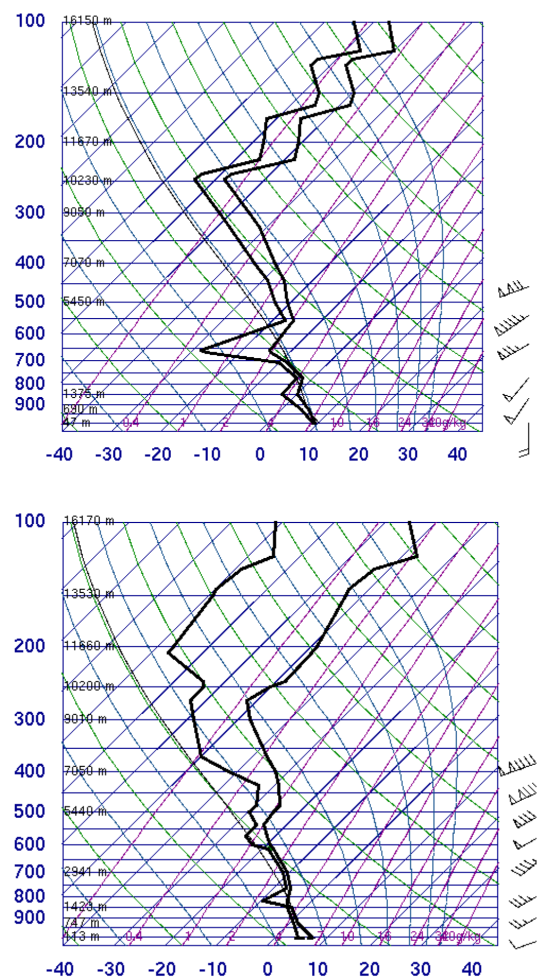

Figure 2. KUIL soundings from (a) 1200 on 01 FEB and (b) 0000 on 02 FEB 2000.

at 10-17,000 ft but the 0000 soundings showed that the same layer became saturated or nearly so later. The air mass obviously had changed during this time period, however RUC was not able to pick up on the change until the next model cycle when the new soundings were ingested.

5. CASE STUDY #2 – PORTLAND, OREGON

There were some instances where IIDA over-forecasted the icing potential, including one on 25 March 2000 over Portland, Oregon. IIDA identified a layer of fairly high icing potential (>0.5) that sloped downward from 12,000 to 4,000 ft between 1600 and 2400. The five available PIREPs were also at this time and altitude, but none indicated the presence of icing. The 1200 sounding from Salem OR (KSLE, not shown) had a saturated layer that existed from the surface to about 5,000 feet. However, essentially none of this layer had subfreezing temperatures, with minimum temperatures near 0C. A second, thin cloud deck was apparent in the 10-12,000 ft layer, with –7C < T < -5C. A very dry layer was evident between the two cloud decks.

Early in the day, the only subfreezing clouds appeared to be thin, though the RUC RH fields indicated deeper moisture. GOES-8 observed clouds at a variety of temperatures between –7C and –30C near Portland, suggesting the presence of variable cloud tops in the 12-20,000 ft altitude range. With this information in hand, IIDA diagnosed some potential for icing at these altitudes. The 10-12,000 ft layer was likely to contain some SLW; thus the high icing potentials (a measure of the likelihood of *any* SLW that may cause icing to exist) at those altitudes were correct.

The RUC RH forecast used by IIDA between 1200 and 1400 (derived from the 0900 run) gave a somewhat different picture, with deep moisture from ~10,000 ft up to at least 22,000 ft, a marginal dry layer between 10,000 and 5,000 ft, and nearly saturated conditions below 5,000 ft. The 1200 run corrected this. The 0000 KSLE sounding from 26 MAR 2000 indicated a saturated layer from 2,000 to 4,500 feet, with T<0C from 3,000 to 4,500 ft, and a minimum temperature of –3C at cloud top. The clouds were marginally subfreezing, and aircraft ascending through them would likely only briefly encounter sufficiently cold conditions for ice to accrete, depending upon airspeed.

The lack of positive icing PIREPs is not a certain indicator that no SLW was present over Seattle. Both soundings certainly suggest the possible presence of marginal icing at various altitudes. The fact that the 5 PIREPs available all noted a lack of icing suggests that even if the conditions were right for icing, it was not significant and/or cold enough to warrant reporting.

6. CONCLUSIONS

The first case study in this analysis was a case of moderate and greater icing over the Seattle area. The results showed that it may be useful to extend icing potentials to the T<-25C range when significant lift is present and supercooled liquid water production may exceed depletion. However, if an algorithm consistently indicated icing in clouds at T<-25C, over-warning would become a serious problem.

Model RH clearly posed a problem at more typical icing temperatures in case #1. It is important to recognize that the case discussed here was along the West Coast, near the western end of the RUC domain, where upstream measurements are sparse. Instances of low RH in icing clouds have forced the IIDA RH interest map to be non-zero in sub-saturated conditions and gradually approach 0.0 as RH approaches 25%, even though icing is only expected in very high RH situations. A plot showing the distribution of RUC RH values for positive icing PIREPs (Fig. 4) demonstrates the need for inclusion of such low RH values in IIDA. Since soundings of moisture and temperature are only taken every twelve hours, a large change in the weather pattern may cause significant errors in the model forecasts of RH. At this point, IIDA has to depend upon RUC RH to indicate the potential for cloud presence between the observed cloud top and base.

The second case study brings to light a different problem: diagnosing high icing potential in marginal icing situations. Upgrades to IIDA that allow it to use cloud layer depth and other features to differentiate between clouds with lower and higher water contents may improve upon this problem. Such features must be considered by situation, as some thin stratus clouds can contain significant LWC and even SLD. The warm end of the IIDA temperature interest map may also need to be revisited.

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8. ACKNOWLEDGEMENTS

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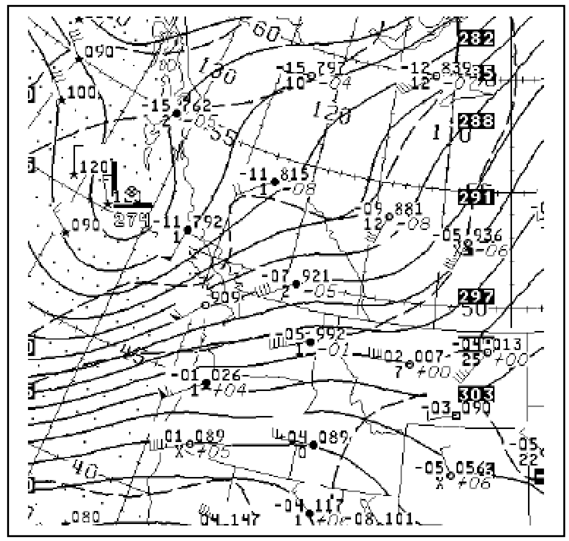

Figure 3. 700mb synoptic chart valid for 1200, 01 FEB 2000.

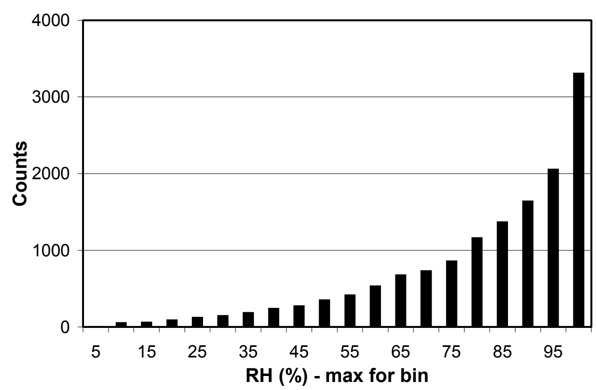

Figure 4. Distribution of positive icing PIREPs with RUC model derived relative humidity.