P12.1 IMPROVING FORECASTS OF INSTRUMENT FLIGHT RULE CONDITIONS OVER THE UPPER MISSISSIPPI VALLEY AND BEYOND

Steven Thompson* and Dan Baumgardt
NOAA/National Weather Service, La Crosse, Wisconsin

1. INTRODUCTION

Instrument flight rule (IFR) conditions are defined as surface visibility less than three statute miles and/or a cloud ceiling less than 1000 feet above ground level (AGL). Impacts on aviation during IFR conditions can include delays in airport departure and arrivals, additional fuel consumption and resulting cost and, most importantly, pilot and passenger safety. According to the National Transportation Safety Board, 21% of all aircraft accidents between 1994 and 2003 were weather-related. More importantly, low ceilings and visibilities were a factor in 63% of the fatal general aviation aircraft accidents from 1995-2000 (Pearson, 2002). Further, the Federal Aviation Administration documented that 63% of the national air traffic system delays were due to weather from September 2008 to February 2009. A subset of smaller airports within the United States reflected an even higher percentage of weather-related delays during that same time (approximately 75-85%, http://www.transtats.bts.gov).

Impacts from IFR conditions span the aviation community from general aviation to scheduled air carriers. The community utilizes National Weather Service (NWS) Terminal Aerodrome Forecasts (TAFs) heavily in planning activities across the continental United States (CONUS). The purpose of this work was to raise awareness in utilizing climatology, in concert with newly implemented aviation statistical guidance, to improve NWS forecasts of IFR conditions in TAFs. Forecast improvements through the use of these techniques would provide measurable benefits to the aviation community, enhancing safety and promoting more efficient use of the National Airspace System (NAS).

While this work was accomplished for two specific airport locations in the north-central United States, the forecast tools and strategies have application to the entire aviation forecast community. A brief discussion of the data used in the study will follow in section 2, with climatology and guidance forecast tools and strategies for cool season IFR forecasts discussed in section 3.

2. DATA AND METHODOLOGY

Hourly Meteorological Aviation Reports (METARs) for the period 1961-2009 were used to achieve climatological averages and percentiles for IFR conditions for the airport locations in La Crosse, WI (LSE) and Rochester, MN (RST) (Fig. 1). It should also be noted that due to partial station closure, observations from 1965-1972 were eliminated from the analysis [also 1978 and 1980 at RST; 1980-81 at LSE]. Additionally, those years where the database contained less than 98% of the hourly METARs were also removed from the National Climatic Data Center (NCDC) archive [1990 at RST; 1962-63, 1985, 1991 at LSE]. For incomplete hourly METARs, the NCDC archive contains interpolated observations between two actual observations. These "synthetic" observations in the NCDC archive were not used in the study.

An investigation into the behavior of IFR conditions in light measurable snow events was completed using hourly METARs. A measurable snow database was constructed to assess IFR climatology at LSE and RST for snowfall events totaling 12 mm (0.5 inches) to 76 mm (3.0 inches) from 1961-1990. The goal was to determine the impact and behavior of falling snow on IFR and Marginal Visual Flight Rule (MVFR) conditions. MVFR is defined as a surface visibility 3-5 statute miles and/or a cloud ceiling from 1000-3000 feet AGL. Snowfall events of 76 mm or less were targeted as they 1) are of higher frequency than those > 76 mm 2) provide challenging forecast decision points that impact the larger aviation community around the MVFR and IFR ceiling and visibility crtieria. Any hourly METAR

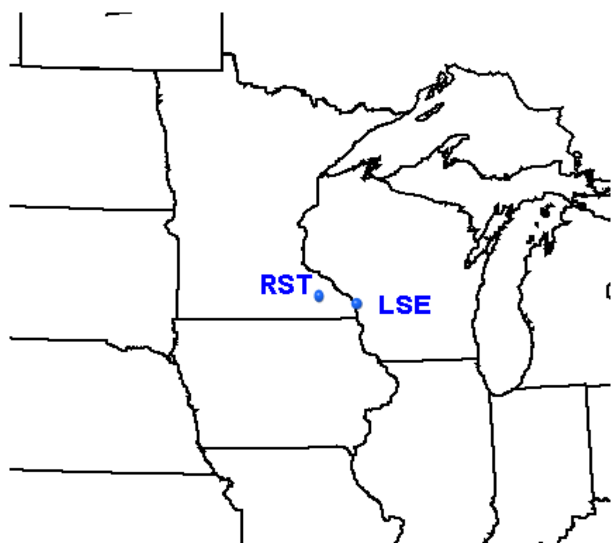

Fig. 1. Map of the METAR data locations used in this study: Rochester, Minnesota (RST) and La Crosse, Wisconsin (LSE).

* *Corresponding author address:* Steven Thompson, NOAA/NWS, La Crosse, WI 54601;
email: steven.thompson@noaa.gov.

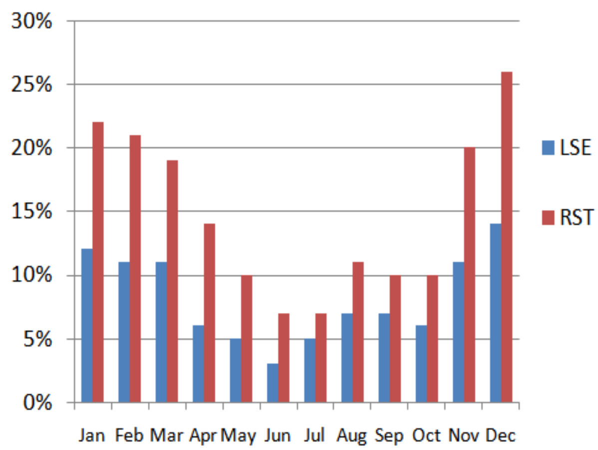

Fig. 2. Percentage of hourly surface observations by month with IFR conditions from 1973-2004 at LSE (blue) and RST (red).

with snow reported within the weather group, during the measurable period, was included in the analysis. The study identified 45 and 49 events at RST and LSE, respectively. The results for this investigation are discussed in section 3.3

The NWS's Meteorological Development Laboratory (MDL) redeveloped the Global Spectral model Localized Aviation Model Output Statistics (MOS) Program (LAMP) in 2005 with a special emphasis on aviation. The LAMP platform provides hourly updates of the Global Forecast System (GFS) from 1-25 hours. In this scheme, the latest observational data, such as radar, satellite and METAR, are utilized to update GFS MOS. Overall, verification statistics suggest LAMP provides improved IFR forecasts versus persistence and GFS MOS through 25 hours, with the greatest benefit coming in the first 9 hours (Rudack, 2005). Further, LAMP guidance for IFR conditions displays measurable improvement and reliable forecasts over the National Centers for Environmental Prediction's Weather Research and Forecasting Non-hydrostatic Mesoscale model and the Short-Range Ensemble Forecasting system (Rudack et. al., 2008). The LAMP real-time forecasts are provided both to NWS forecasters, through the Aviation Forecast Preparation System (AvnFPS) software, and online at MDL's web site: http://www.nws.noaa.gov/mdl/gfslamp/gfslamp.shtml.

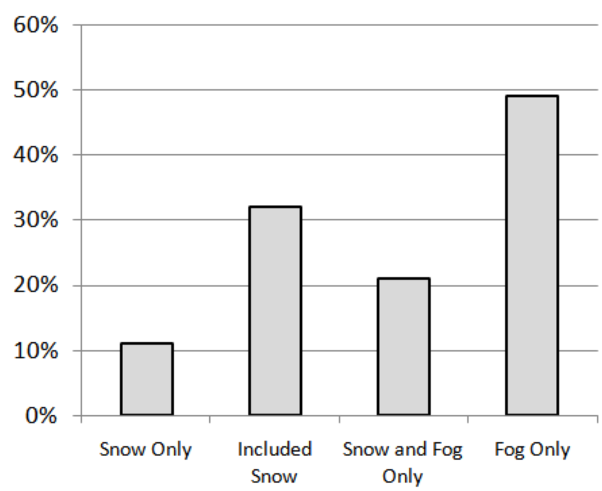

Fig. 3. Percentage of IFR conditions associated with various weather types from November through March from 2005-2009 at RST and LSE.

3. TOWARD IFR IMPROVEMENT

3.1 *Climatology of IFR Conditions*

Climatology has been successfully used for several years as an aid in aviation forecasting. In fact, the U.S. Air Force (USAF) developed climatology tables during the 1960s in order to support weather forecast operations at USAF bases around the world. Climatology suggests IFR conditions are most prevalent from November through March at LSE and RST (Fig. 2), with a lower frequency of occurrence from April through October. For a subset of cool season METARs from November through March 2005-2009, fog was the weather element found to cause the most frequent IFR conditions at LSE and RST (Fig. 3, 49%). Weather systems producing snow accounted for approximately 30% of all IFR conditions.

3.2 *Climatology of IFR Conditions in Light Snow*

For observations containing light snow in the weather group within the 30 year climatology, a spectrum of cloud ceiling heights were calculated. The cloud ceiling climatology, categorized by visibility, can provide forecasters with statistically-relevant thresholds or 'windows' to include in their TAF for an upcoming light snow period (Figs. 4 and 5). For example, the centered

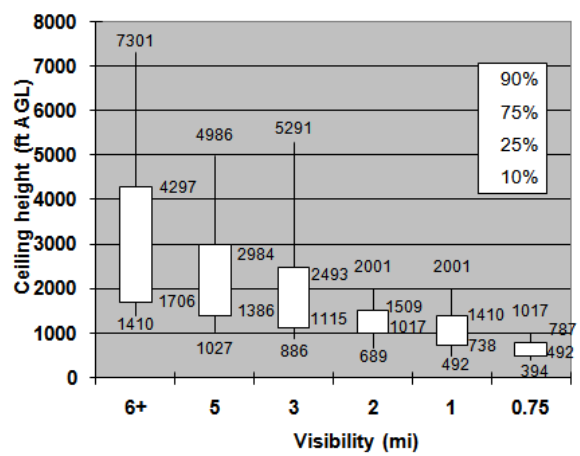

Fig. 4. Box and whiskers of the LSE ceiling heights observed for hourly METARs from 1961-1990 for various visibilities when light snow was included as the weather element. The 10th, 25th, 75th, and 90th percentiles are shown.

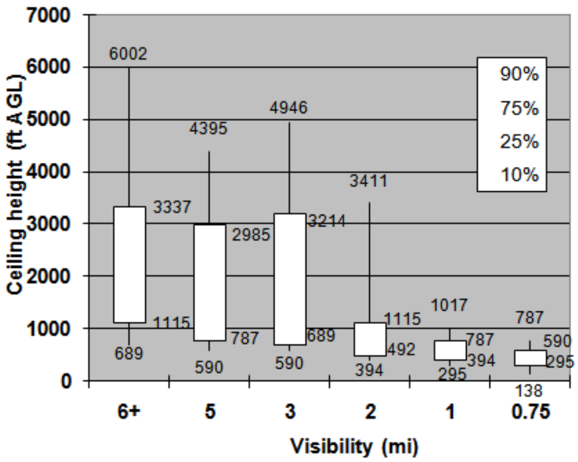

Fig. 5. Same as Fig. 4 except for RST.

50% of the climatological population (25-75th percentile) of METARs suggests a cloud ceiling between 400 and 800 feet above ground level (AGL) at RST when light snow occurs reducing the visibility to 1 mile (Fig. 5). These data were arranged into a reference table (not shown) providing operational forecasters with a spectrum of cloud ceiling values to assist in TAF preparation.

3.3 *Climatology of Measurable Snow Events*

Evaluation of the light measurable snow events described in section 2 indicate that at LSE and RST, IFR conditions occurred for 67 percent and 72 percent of the hours within the event, respectively, compared to MVFR conditions (Fig. 6). These findings strongly suggest that utilizing IFR as a prevailing condition in the TAF at LSE and RST for measurable snow events provides the best forecast outcome. Further, it was found that a large majority of the IFR 12-76 mm measurable snowfall events produced IFR visibilities at snow onset time (67 and 70% at RST and LSE, respectively, Fig. 7). Approximately 90% of the events produced IFR conditions at both sites within 2 hours of snow onset time (88% and 94% at LSE and RST, respectively).

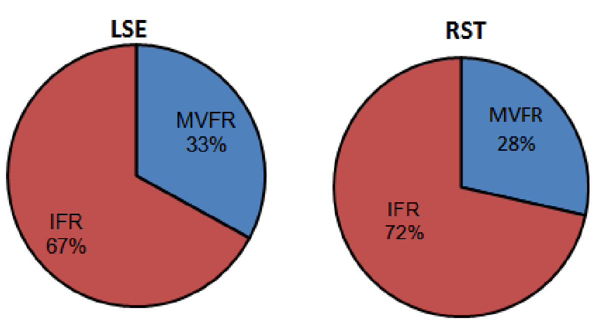

Fig. 6. Percentage of observations with IFR or MVFR conditions for 12-76 mm (0.5-3.0 in.) measurable snow events between 1961-1990, for LSE (left) and RST (right).

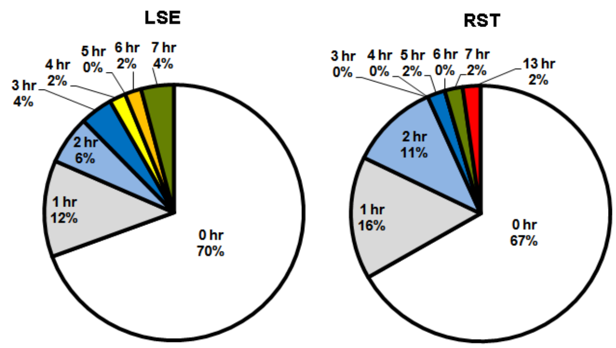

Fig. 7. Number of hours after initial snow onset that IFR visibility occurred for 12-76 mm (0.5-3.0 in.) measurable snow events between 1961-1990, where IFR was observed, for LSE (left) and RST (right).

These findings provide strong foundation for aviation forecasts in lighter measurable snow events suggesting that IFR conditions are likely, and that TAFs should contain IFR visibilities within 2 hours of the expected snow onset time at LSE and RST. Because the IFR onset time research was based on reductions to IFR visibility in snow, the authors believe these findings and methodologies could be applied at other TAF sites that experience measurable snowfall. However, it is cautioned that large geographical differences, or airport locations, could influence direct application. Local climatological studies would provide more accurate application to other airport locations.

3.4 *Case Study - Utilizing Climatology and LAMP Guidance*

LAMP is a data set that has shown improvement over GFS MOS in the first few hours of the forecast, which corresponds to the most critical TAF period of 0-6 hours. Within the CONUS aviation community, most flights are completed within 6 hours of the planning briefing. LAMP provides both aviation-relevant probabilistic and categorical guidance such as surface visibility and cloud ceiling height at points across the CONUS.

The snow event of 9 January 2009 provided an excellent opportunity to utilize climatology and LAMP guidance in preparation of the TAF for LSE and RST. For this particular case, the RST TAF was specifically chosen, as this site typically has more frequent occurrences of IFR conditions than LSE due to its elevated airport placement (approximately 200 m higher). The snow event produced 56 mm (2.2 in.) of snow at RST, allowing the findings of section 3.3 to be applied. Primary forecast concerns were associated with the onset of snow and attendant lowering of visibility. Since the 9 January 2009 case had a high predictability of 12-76 mm of measurable snowfall, confidence was high that surface visibility would be reduced to less than three statute miles (IFR) based on the findings presented in section 3.3. Further, historical events (e.g., climatol-

KRST 081720Z 0818/0918 18006KT P6SM SCT070
FM090600 13009KT 5SM BR OVC030
FM090700 13010KT 2SM –SN OVC020
FM090900 12011KT 1 1/2SM –SN BR OVC010
FM091400 11010KT 3/4SM –SN BR OVC009=

Table 1. 1800 UTC 8 January 2009 LAMP guidance-generated TAF valid for the period 1800 UTC 8-9 January 2009 for RST. Bold indicates the first forecast hour with IFR conditions (0700 UTC).

KRST 081730Z 0818/0918 28008KT P6SM SKC
FM082200 26005KT P6SM SCT070
FM090500 17007KT P6SM BKN120
FM090700 12010KT 5SM -SN OVC020
FM090900 12010KT 1 1/2SM -SN BR OVC010=

Table 2. 1730 UTC 8 January 2009 NWS-issued TAF valid for the period 1800 UTC 8-9 January 2009 for RST. Bold indicates the first forecast hour with IFR conditions (0900 UTC).

METAR	KRST	090554Z	10SM	-SN	OVC042
SPECI	KRST	090614Z	4SM	-SN	OVC024
SPECI	**KRST**	**090621Z**	**1 3/4SM**	**-SN**	**OVC016**
SPECI	KRST	090625Z	1 1/4SM	-SN	OVC014
SPECI	KRST	090638Z	1SM	-SN	OVC010
(...snow continues at 1SM…)					
METAR	KRST	091254Z	2SM	-SN	OVC012
SPECI	KRST	091318Z	2SM	-SN	BKN016
SPECI	KRST	091328Z	2SM	-SN	OVC014
METAR	KRST	091354Z	2SM	-SN	OVC055
SPECI	KRST	091432Z	8SM		OVC055

Table 3. Surface METARs at RST for the period 0554 UTC 9 January 2009 to 1432 UTC 9 January 2009. Bold indicates the first hour of IFR conditions (0621 UTC).

ogy) suggested that visibilities would fall below IFR within 0-2 hours of snow onset (refer to Fig. 7).

LAMP guidance, available to the forecaster around 1730 UTC 8 January 2009, suggested the onset of snow around 0700 UTC 9 January 2009 (Table 1). Further, the LAMP guidance forecast the visibility to fall below three statute miles immediately with snow onset, consistent with the climatological findings at RST. The LAMP guidance further indicated IFR conditions in snow would persist through the morning hours of 9 January 2009.

Using the LAMP guidance and climatology as foundation, the RST TAF issued at 1730 UTC 8 January 2009 incorporated snow beginning at 0700 UTC 9 January 2009 (Table 2). Two hours after snow onset, visibility was forecast to drop to 1 1/2 statue miles (SM), and remain IFR through 1800 UTC 9 January 2009. Based on surface METAR observations (Table 3), the 1800 UTC 8 January 2009 TAF provided snow onset time and the trend to IFR accurately. However, the rapid decrease in visibility to IFR conditions was forecast to occur two hours after snow onset in the RST TAF. The METAR observations indicated IFR occurred within 30 minutes of snow onset, which both the LAMP guidance and climatology forecast. Overall, the RST TAF did provide the aviation community with a lead time of approximately 12 hours.

4. SUMMARY

IFR conditions have the highest frequency of occurrence in the Upper Mississippi Valley during the winter months, November through March, with fog being the major weather contributor. However, weather involving snow also contributes to IFR conditions in cool season (about 30%). A study of 12-76 mm measurable snowfall events at LSE and RST for the period 1961-1990 revealed two distinct findings: 1) measurable snow events have a direct correlation to IFR conditions and 2) approximately 90% of IFR visibilities occur rapidly, or within 2 hours of snow onset with little difference between the two airports investigated. These findings strongly suggest the TAF utilize IFR as prevailing conditions when confidence is high in light measurable snow events (<76 mm or 3 in.). It follows that IFR conditions be forecast quickly after snow onset.

In addition to climatology, LAMP guidance has the potential to further enhance the predictability of IFR conditions. This is due in large part to the fact that LAMP utilizes the latest observational data to update GFS MOS, and provides guidance critical to aviation forecasts of cloud ceiling heights and visibility. The La Crosse, Wisconsin NWS has taken the initiative to utilize an infusion of climatology and LAMP guidance in order to prepare the best forecast outcome in the TAF. An example of this was presented for the 9 January 2009 light snow event, which produced 56 mm of snow at RST. In this case, the TAF at RST had a lead time of approximately 12 hours until onset of IFR conditions, along with a trend of a steady decrease in visibility after snow onset. LAMP and climatology would have suggested a slightly more accurate, and rapid deterioration, to IFR conditions in snow (within an hour).

It is critical that NWS meteorologists use a variety of data in their forecast preparation process. This is especially true for situations where IFR conditions are expected to impact the TAF site. Based on the findings presented in this paper, climatology and LAMP offer a solid baseline of data to promote higher predictability of details important to the TAF during the cool season at RST and LSE. Because of the availability of LAMP guidance and hourly historical METAR records for many locations, this work can be applied to sites beyond the Upper Mississippi River Valley. For light snowfall events, the visibility deterioration IFR climatology is believed to be applicable directly to sites in the regional area and possibly beyond.

As technological advances are made in aircraft and air traffic control, a high degree of accuracy will be expected of NWS aviation forecasts. In particular, accurate forecasts of IFR conditions in the TAF will have a significant impact on enhancing safety of pilots and passengers and promoting efficient use of the NAS.

5. ACKNOWLEDGEMENTS

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