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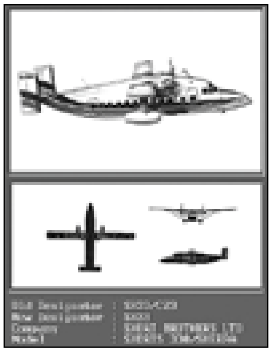

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THE APPLEMAN LINE

Putting your life in the hands of a tool to predict icing? You'd best know where that data is coming from.

by Scott C. Dennstaedt

Legal or not, some pilots knowingly enter icing for a brief period so long as there's some guarantee that they can swiftly find an altitude free of ice. Dozens of studies have closed in on the magic forecast showing where the ice will be and where it won't, but none of them are perfect.

Most of the research as been done by analyzing pilot reports of icing against data such as radiosonde (weather balloon) observations. The problem is that the icing reports and the weather balloon data may be dozens or even hundreds of miles apart. The result is a fuzzy picture of where icing will be when you need to bore a hole through the clouds.

Dewpoint Depression

In 1954 Herbert Appleman's research led to a simple formula to assess the potential for structural icing. Appleman found that when temperature was plotted against dewpoint, clouds lying between the lines of temperature equal to dewpoint (T = Td, the saturation line) and temperatures at 80-percent of dewpoint (T = 0.8 * Td, now known as the Appleman line) held supercooled liquid water when atmospheric temperatures were below 0 degrees C. The probability of icing in theses clouds was 95 percent. Appleman's research applied to stratiform cold clouds only, but other research suggests that this may apply to cumuliform clouds as well.

The spread of temperature and dew point predicts clouds containing supercooled liquid water.

This relationship between the spread of temperature and dewpoint — called *dewpoint depression* — predicts the presence of clouds containing supercooled liquid water droplets. What's even more important is that the amount of dewpoint depression that leads to icing is not constant. Bear with me through a little math to see what this means to you.

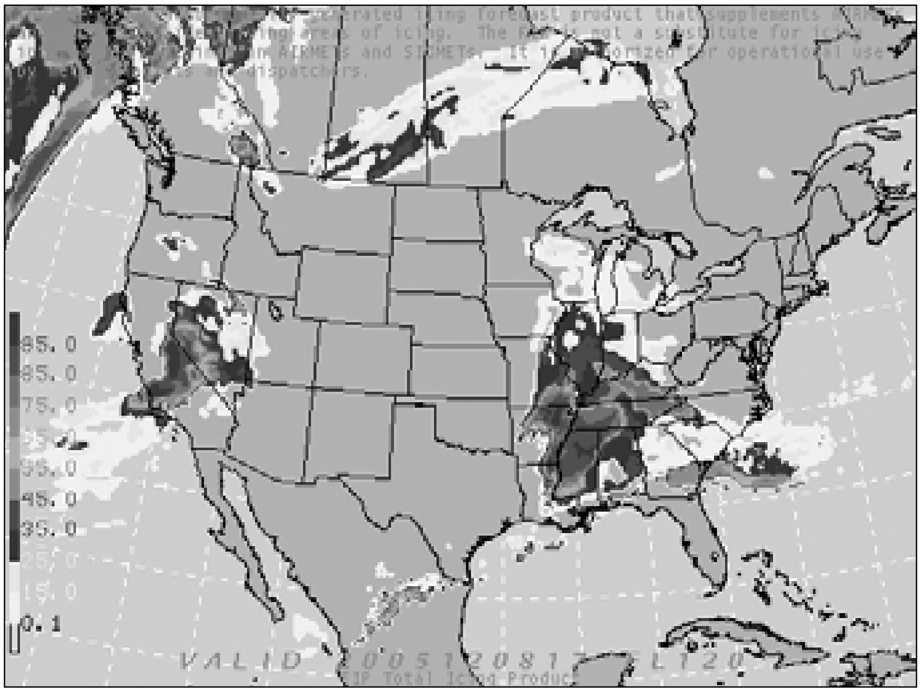
Imagine a parcel of air with a dewpoint of -5 degrees C. Apply the formula from above, and multiply this by 0.8 to obtain a temperature of -4 degrees C. An altitude with an ambient air temperature of -4 degrees C and a dewpoint temperature of -5 degrees C has a great potential to contain clouds with supercooled liquid water.

Now crank down the dewpoint to -15 degrees C and repeat the calculation. Multipling the dewpoint temperature of -15 degrees C by 0.8 yields a temperature of -12 degrees C. Therefore, at a temperature of -12 degrees C and a dewpoint anywhere between -12 and -15 degrees, a cloud containing supercooled liquid water is highly likely.

It's the Spread

A key factor here is dewpoint depression, calculated by subtracting the dewpoint temperature from the temperature. At air temperatures of -5 degrees, a dewpoint depression of 1 degree indicates likely icing. At -15, the potential for icing is high at dewpoint depressions of 3 degrees C or less.

This is the Appleman relationship. At colder temperatures, supercooled liquid water can exist with lower values of relative humidity or larger dewpoint depressions. In other words, you must allow for a larger



***Left:** The Forecast Icing Potential (FIP) is only one of many predictive models and over-predicts some ice while missing other icing events.*

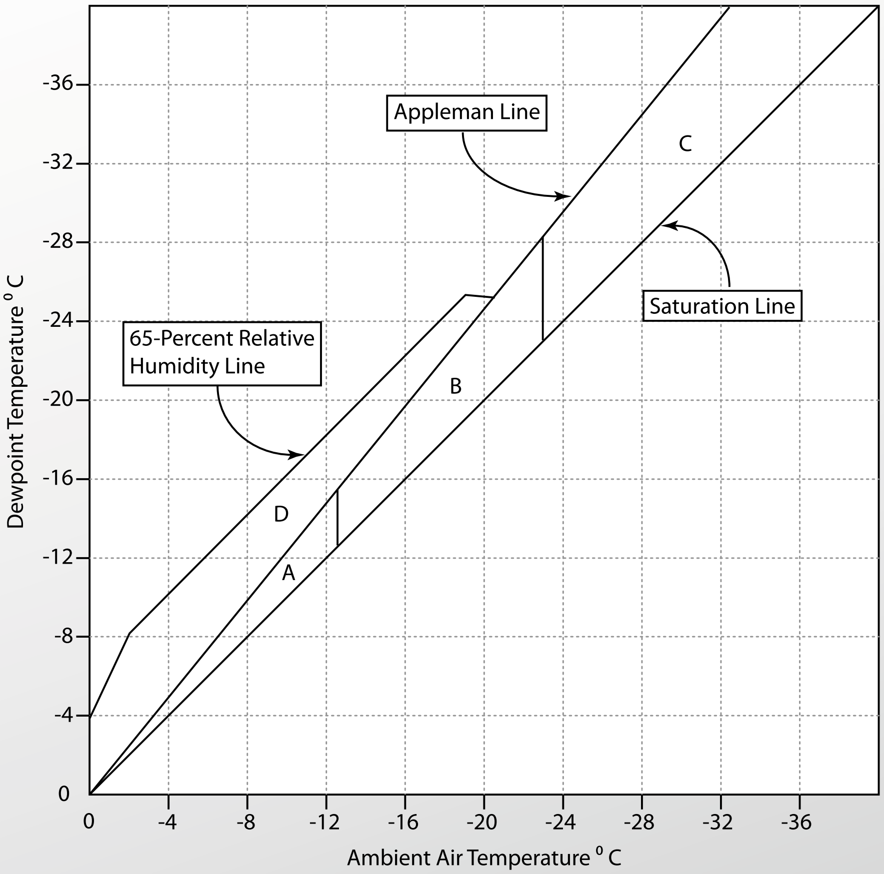
temperature dewpoint spread when the temperature aloft is colder.

If you're wondering how a cloud can exist with such a large temperature dewpoint spread, it can't. Relative humidity in most clouds is a couple of tenths above 100 percent (the air is supersaturated). But remember the radiosonde data and the reports of icing are from different parcels of air. The accuracy of the measurements isn't all that great, either. What this means is that in areas where the temperature and dewpoint are both predicted to fall between the saturation line and the Appleman line, structural icing in clouds is almost certain.

Another study done by Schultz and Politovich in 1992 took Appleman's research further. They found that temperatures from 0 to -20 degrees C and a relative humidity greater than 50 percent encompassed 87 percent of pilot-reported icing. Focusing a bit tighter, a temperature range of -2 to -15 degrees C and relative humidity greater than 65 percent included 71 percent of the pilot-reported icing.

Where Will the Icing Be?

Once you're in the air, staying out of the clouds when it's between 0 degrees C and – 22 degrees C will avoid most icing. When you're planning a flight, look at the temps and dew points aloft. If *both* items fall within areas A, B, C, or D, then any clouds along that route will probably coat your wings.



Approximately 50 percent of pilot reports of icing occur in Area A. This area represents the highest probability of icing assuming *stratiform clouds*. About 20 percent of pilot reported icing occurs in Area B. Icing is less probable in this area. Area C represents about 10 percent of the occurrences of icing, with the very low temps making it a rarity. There are considerable reports of icing (20 percent) that occur in Area D. The Appleman relationship is encapsulated by Areas A, B and C. Area D is a portion of the relationship described by Schultz and Politovich.

— *S. D.*

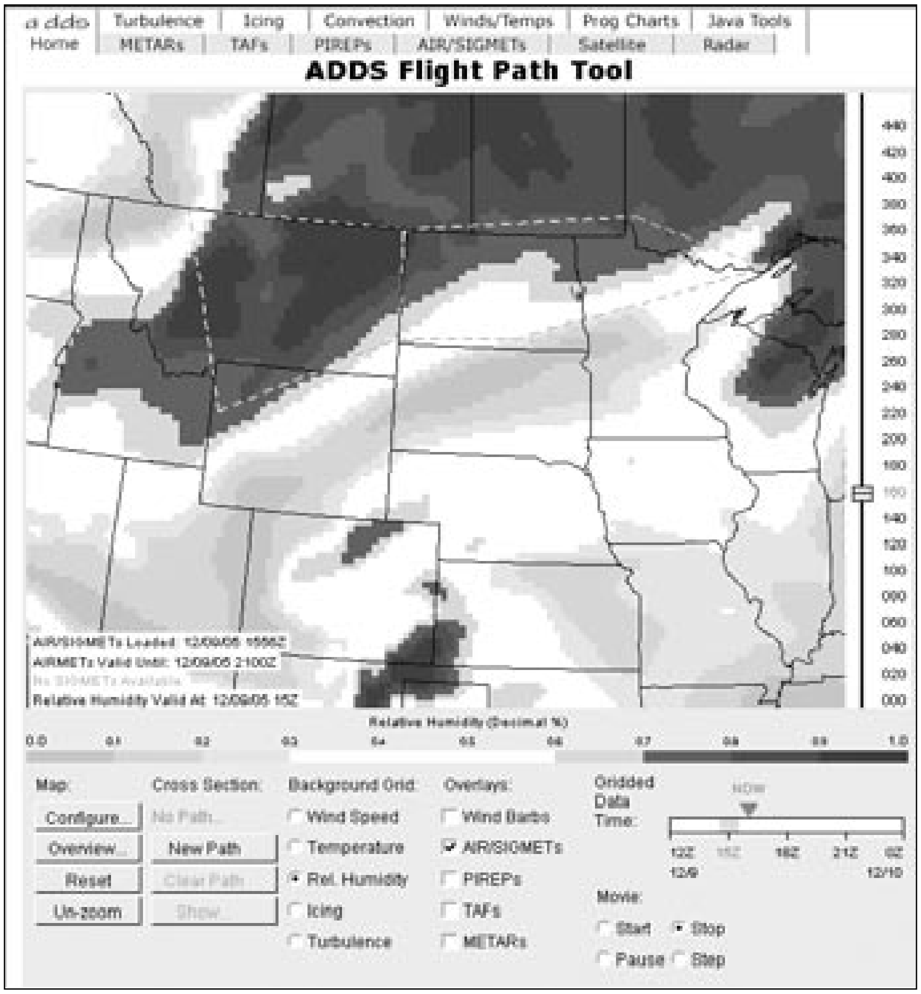
Enter the Real World

These numbers have some limits and some blind spots. While it is possible to get supercooled water droplets below -40 degrees C or colder, especially in towering cumuliform clouds; icing is very unlikely below -22 degrees C in stratiform clouds. Similarly, it is possible to experience structural icing in the 0 to +2 degrees C range. There are a rather small number of reports of structural icing in this range. This can be explained either by aerodynamic heating or by errors associated with measuring dewpoint temperatures near freezing.

The smaller the dewpoint depression, the greater the icing potential. There are many cases of structural icing reports at temperatures between -2 degrees C and -20 degrees C with dewpoint depressions larger than what Appleman predicted, but in most cases these were still above 65-percent relative humidity.

That's a lot of numbers. What does it mean to you? Let's look at one of the latest and greatest icing forecast tools, the ADDS Forecast Icing Potential (FIP) derived from the Rapid Update Cycle (RUC) weather prediction model (See "Cyber Ice Revisited," November 2005 *IFR*). Here's how it relates to temperature and dewpoint.

The RUC model runs and produces a 12-hour forecast extending from the surface up to the top of the atmosphere. The FIP takes slices of this forecast for 50 pressure surfaces — essentially 50 altitudes — in the troposphere and lower stratosphere. The forecast variables include temperature, dewpoint and relative humidity.



***Left:** Found on the same ADDS Web site as the FIP, the Flight Path Tool gives you forecast temps and relative humidity for 1000-foot slices of the sky. Stay out of areas predicted to be between zero and -22 degress C and over 60-percent relative humidity and your icing potential is nearly zero. You can toggle between temps and humidity as well as explore several hours into the future.*

If every altitude in the stack has relative humidity values of less than 70 percent then FIP will assume cloud-free air in the entire column. No clouds means no icing.

If clouds do exist in the column, the FIP starts at the tropopause (the top of the model) and works toward the ground until it finds a forecast relative humidity of 70 percent or greater. This marks the top of the highest cloud layer.

Next, the same column of air is examined from 1000 feet AGL upward to establish the lowest cloud base. This occurs where the forecast relative humidity in the column that is 80 percent or greater. Cloud layers in between are predicted by searching for temperature and dewpoint variations that meet certain criteria.

Clouds don't necessarily mean icing and a variety of criteria are applied to these clouds to see if icing may exist. For example, if the temperature in the cloud layer identified above is warmer than 0 degrees C or colder than -25 degrees C it doesn't fit the test for temperature. However, if the forecast vertical velocity in the cloud is large (indicating the potential for a vertically-developed cumulus cloud) FIP may still derive an icing potential even at -25 degrees C.

Limits and Options

Models are not perfect due to resolution, averaging and other inaccuracies. FIP must use lower relative humidity thresholds, which ultimately lead to over-forecasting the potential for icing — even so far as to predict icing in a cloud-free area. Thresholds are put into place to limit this but they may not catch all possible icing outcomes. The FIP available on the Icing tab of the ADDS Web site is limited to 3000-foot increments. Other tools offer more options.

With the chart of the likely areas for icing in hand, you can check out a Skew-T diagram (See "Build Your Own Forecast," January 2005 *IFR*) or check out the ADDS Flight Path Tool (http://adds.aviationweather.noaa.gov/flight_path/index.php). The Flight Path Tool provides a 1000-foot vertical resolution of icing potential. It also provides temperatures and relative humidity.

No forecast is perfect, but you can look at the predicted temps and dewpoints along your route at 1000-foot increments and compare them to the chart with the Appleman line to see the likelihood of any clouds on the route containing ice. If you want to be extra careful, plan your flight to stay out of the green areas of relative humidity (60-percent or more) and you're extremely unlikely to encounter any clouds that could cause icing.

The most significant misunderstanding I see with FIP is that too many pilots interpret the dark red colors as severe icing. The icing potential values for FIP that are available on ADDS only represent the likelihood of icing (in percent) and does not directly reflect an indication of icing intensity. A dark red value (value near 100 percent) simply implies a high potential of structural icing which could be light, moderate, or severe.

Still in the experimental stage at the moment is an icing severity value FIP product that attempts to differentiate between light, moderate, and severe icing potential. Icing severity is problem that can only be solved on the cloud-scale level and is largely a function of both the liquid

(continued on page 23)

QUIZ ANSWERS *(questions on page 19)*

1. c. The ASOS program is a joint effort between the FAA, NWS, and the Department of Defense to provide the official weather observation for the NWS. An AWOS can also allow an airport to qualify for alternate minimums.

2. d. AUTO signifies an unattended observation, and identifies the system as one capable of reporting present weather. (*AIM* 7-1-12 (d)(4))

3. d. This is an automated report, so the maximum visibility is 10SM. For a METAR with 20SM visibility, the report must have been augmented by a human observer. Also, reported cloud heights over 5,000 feet are rounded to the nearest 500 feet up to 10,000 feet and nearest 1,000 feet above 10,000 feet. (*ASOS Users Guide*, *AIM* 7-1-32 (b)(6)(b), *Federal Meteorological Handbook*)

4. c. Freezing fog is simply an application of the obstruction to visibility rules. This does not imply icing conditions, although you may find it there. (*ASOS Users Guide*, *AIM* Figure 7-1-7, *Aviation Weather Services* NWSPD 10-8)

5. c. The wind sensor (wind speed and direction) is typically installed at a height of 27 or 33 feet depending on site-specific restrictions. (*ASOS Users Guide*) Admittedly, d is a viable answer, too.

6. c. ASOS continuously measures wind speed every second and averages these every 5 seconds. Five-second averages are rounded to the nearest knot and are retained for two minutes. The two-minute wind speed is what's broadcast on the radio, played on telephone dial-in message, and appears in METAR/SPECI reports. (*ASOS Users Guide*)

7. c. Vertical visibility (VV) is the distance a person can see vertically into an obscuring phenomena. Fog or precipitation returns laser back-scatter signals and cannot be processed as a definite cloud return. (*ASOS Users Guide*, *AIM* 7-1-32 (b)(9)(d), *Pilot's Handbook of Aeronautical Knowledge*)

8 d. Cloud-to-ground lightning strikes between 10 miles and 30 miles are reported "LTG DSNT xx," where "xx" is the direction in octants. (*Federal Meteorological Handbook* No. 1 12-7-1 (j)(2)(c), *AC 00-43E* Section 2)

9. a. The ASOS official report (METAR) transmits at 53 minutes past the hour. No reports are issued between 47:20 and 53:20 after the hour, so the observation can be prepared, edited and transmitted. (*ASOS Users Guide*)

THE APPLEMAN LINE

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water content in the cloud and the distribution of droplet size.

Believe it or not, pilots can help forecasters by filing accurate pilot reports with Flight Watch or Flight Service (see "Got PIREP?," October 2004 *IFR*). All of this research depends on pilot reports. It doesn't matter if you encounter light icing or are flying between icing layers or are on top; report your flight conditions accurately and report them often. There just may be a research meteorologist or two interested in what you have to say.

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