Techniques for Forecasting Freezing Drizzle: Based on the January 18 - 20, 2000 Episode in Juneau, Alaska

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Introduction:
Over the period January 18 - 20, freezing drizzle occurred in the local Juneau area for nearly 52 hours. This event, remarkable in its duration, created hazardous aircraft icing conditions in the Juneau area from the surface to about 2500 meters (8000 feet) above ground level (AGL). At this time, researchers from the National Center for Atmospheric Research (NCAR) were in town prepared to gather icing data using a specially equipped King Air aircraft from the University of Wyoming. Dr. Roy M. Rasmussen, of NCAR, gave a seminar at the Juneau National Weather Service forecast office postmortem to provide our forecasters with the details of his findings and training on techniques we might use for forecasting such conditions.

Event Summary:
Prior to the onset of the precipitation associated with this event, Juneau had been under clear skies, surface temperatures were -12 to -18°C (0 to 10°F), and winds were calm. Between 7:00 and 8:00 p.m. (local time) on January 17, a low-level stratiform cloud deck began to move in from the west and by 9:00 p.m., the Juneau International Airport (PAJN) was overcast at 4700 feet AGL. By 11:00 p.m., snow flurries were being observed at PAJN, and surface weather conditions continued to deteriorate. At 3:30 a.m. (18th), the ceiling and visibility had lowered to 600 ft obscured and 1 mile in light snow, at -8°C. Shortly thereafter, winds gradually picked up at the surface to 12 knots from the east, ceilings lifted again to near 2500 feet, temperatures rose to -4°C, and freezing drizzle began to be observed.

The airport carried a mix of light snow and freezing drizzle for the remainder of the day (18th), but the snow was not dendritic. It appeared that some of the larger drizzle droplets were freezing before reaching the ground (in needles) while most of the precipitation fell as supercooled liquid. As the event progressed, temperatures hovered at -2°C, winds were once again calm, and the drizzle was completely liquid. Finally, at 1:30 p.m. on the 20th, surface temperatures rose above freezing, and icing conditions on the ground abated; however, significant aircraft icing conditions aloft in the Juneau area continued off and on through the 23rd.

Icing Overview:
When an aircraft passes through an airmass containing supercooled liquid water, it will freeze instantly on the airframe. This in-flight icing increases the drag on the aircraft which can adversely affect the flight performance. Ice tends to form near the leading edges of aircraft surfaces, and deicing/anti-icing mechanisms like pneumatic boots are designed to combat this. If the icing goes beyond the pneumatic boots, the aircraft performance may be compromised enough to cause trouble.

There are three types of icing an aircraft may encounter in flight. Rime icing is rough, milky opaque ice formed by the instantaneous freezing of small supercooled water droplets. Rime ice is brittle and tends to break off with pneumatic boots. Clear icing is glossy, translucent ice formed by the relatively slow freezing of large supercooled droplets. This type of icing can be more hazardous as it forms a smooth, almost flexible, surface that does not easily break off. It is also more difficult to see and may not be detected by the pilot until it causes trouble. The third type, mixed icing, is a combination of riming and clear icing.

Supercooled Warm Rain Process:
Icing may be encountered anytime a sufficient lifting mechanism is at work in a moist atmosphere. Air parcels may be lifted by convection, terrain, fronts, smaller scale convergence boundaries, or larger scale cyclones. The most common synoptic situation under which freezing precipitation, in particular, occurs is when a cold (subfreezing) airmass is overridden by a warmer (above freezing) airmass - a typical warm front. More specifically, precipitation falls through a warm layer, deep enough to allow the precipitation to melt, then becomes supercooled in a shallow subfreezing layer just above the surface.

Various studies (Bocchiere 1980; Young 1978; and Huffman& Norman 1988) have shown that 25% to 40% of freezing precipitation events have occurred under atmospheric conditions where there was no above-freezing layer aloft, and consequently, there was no melting process involved. Juneau's January 18 - 20 freezing drizzle episode is one of these cases when freezing precipitation was produced in a subfreezing atmosphere. That is not to say that there was not a "warm" layer aloft in the Juneau case; the layer in question was warmer relative to the surface temperature but not above freezing.

The mechanism for producing freezing precipitation when there is no above-freezing layer aloft is called the supercooled warm rain process - SWRP (Huffman & Norman 1988). The SWRP explains how liquid water can form and persist at subfreezing temperatures. It is known that in a warm cloud (with temperatures above freezing), hydrometeors grow by vapor condensation, coalescence, and collision. Depending on atmospheric conditions, a cold cloud (partially or totally subfreezing) may contain ice crystals, supercooled liquid water droplets, or both. Ice crystals will tend to scrub out the supercooled water droplets, as they will act as freezing nuclei at temperatures of 0°C or cooler. So, in order to have a high concentration of supercooled liquid water droplets in a cloud, you must have little or no ice crystals present.

There are two major factors that determine whether or not a cold cloud will contain supercooled liquid water droplets or ice crystals: droplet size and cloud temperature. First, drizzle will not normally form if droplet sizes are 30 micrometers (m) or less. Large droplets (>200 m) can freeze at temperatures as high as -5°C, but for smaller droplets (40 to 100 m), freezing nuclei typically activate at temperatures between -10 and -15°C (Wallace & Hobbs, 1977). So a cloud having a temperature from 0 to -10°C is not likely to form ice crystals if they are not already preexisting and if large droplets are not present. Also, at -15°C, dendritic ice crystals tend to form, and these will continue to grow at the expense of the supercooled liquid water droplets as they descend through the cloud as snow. For the SWRP to occur, the atmosphere above the "supercooled" cloud must be dry, as any snow falling from cloud layers aloft would quickly scrub away the supercooled liquid water droplets

Drizzle droplets grow most efficiently in relatively "clean" air having a low concentration of condensation nuclei (CCN). The lower the CCN, the more rapidly drizzle droplets will grow through collision-coalescence as they descend through the cloud. This clean air environment is conducive to the production of the large supercooled droplets specific to this icing case. Typically, maritime air has a CCN of 100 nuclei per cubic cm of air (/cc), mainly salt particles, and continental air has a CCN closer to 400 /cc, primarily dust and other particulates. In the Juneau case, the aircraft measured droplet concentrations ranging from as low as 3 /cc upward to 80 /cc!

Forecast Techniques:
To forecast freezing drizzle, one should first look for the following parameters:

- clean air (low CCN)
- no to low ice crystal content
- dry air above the cloud top
- cloud top temperatures near -10°C
- a source of mesoscale uplift

Given this particularly sensitive temperature and liquid water content criteria, it is necessary to identify the synoptic weather pattern and mesoscale conditions which might meet these thresholds.

In the Juneau case, there was a 500-mb ridge upstream over the North Pacific and Bering Sea and a cut off upper low to the south offshore of the Oregon coast, which provided Southeast Alaska with dry northerly, though fairly diffluent, flow aloft. This ridge began to progress eastward over time, but the axis of the upper ridge remained west of the panhandle throughout the event. Prior to the event, 850- to 700-mb flow was weak and offshore (dry) over Southeast Alaska under the influence of low pressure (an inverted trough) along the British Columbia coast, but the flow became westerly over the approaching ridge, which was broad and flat at these levels. This change in the low- to mid-level flow pushed warmer maritime moisture from the Gulf of Alaska inland over the shallow arctic airmass in place at the surface over Southeast Alaska. An 850-mb height analysis at 12Z on the 18th also revealed that a trough had developed in the lee of the St. Elias - Fairweather mountain range over the Glacier Bay - Icy Strait area just west of Juneau. This stationary terrain-induced feature may have provided or enhanced the mesoscale lifting mechanism needed to initiate and sustain drizzle production in the maritime airmass, while the atmosphere above the 700-mb level remained dry under prevailing northerly flow.

Very close to the onset of freezing drizzle in Juneau, the Yakutat (PAYA) sounding (see Figure 1) showed saturated conditions from the surface to about the 715-mb level with dry air above, and temperatures near the top of the moist layer were at -10°C. Additionally, infrared satellite imagery showed extensive low-level cloud cover across the eastern Gulf of Alaska and northern portion of the panhandle with clear air above, and the cloud top temperatures over this layer were sampled at -8 to -12°C.

Freezing precipitation has also been observed in Juneau, although for a much shorter duration (typically 30 minutes to 2 hours), in advance of a mature occlusion. Again, this event requires a very specific set of atmospheric conditions, but it is not uncommon in this region. Assume a dry, subfreezing airmass is in place over Southeast Alaska. As the frontal boundary approaches the panhandle, it is preceded by a ridge at low levels, which brings this "warm" and "clean" maritime air onshore over the cold surface air. The essential dry layer aloft may be maintained, at least briefly, by the easterly (and in this case, downslope) flow ahead of the frontal system. In this situation, the dry layer may be hidden from infrared view by high-level clouds associated with the system, but no precipitation can be falling from cloud layers above the "supercooled" maritime layer or the precipitation will fall as snow.

There are several methods forecasters may employ to anticipate this type of event. In the short term, soundings and infrared satellite imagery (cloud top temperature sampling) will be the best source of detailed information regarding cloud temperatures. Assuming a subfreezing atmosphere, forecasters can utilize soundings and infrared satellite imagery to identify two of the key characteristics of the supercooled warm rain process, namely the presence of low-level clouds with cloud top temperatures between -8 and -12°C and dry air above (typically from 700-mb level up). High-level cloud cover may mask the low clouds from infrared view and temperature sampling, but will not inhibit the SWRP unless they are precipitating.

In the longer term, modeled vertical cross-sections of temperature and relative humidity (RH) in a time series (see Figures 2 & 3) can be an excellent tool. In a vertical cross-section, forecasters may examine low- to mid-level RH fields plotted with isotherms to anticipate this pattern of high RH (80-90%) at low levels, dry air (RH 70%) above the 700-mb level, and temperatures near the top of the moist layer of -8 to -12°C.

While, modeled and real-time sounding data does not indicate factors like CCN, droplet size, and ice crystal content, these things can be inferred with an understanding of the source of the airmass in question and the environment you are forecasting. Of course, the other requisite conditions regarding low CCN and a source of mesoscale uplift must be considered in each case. Ultimately, it would be most pragmatic to identify synoptic and mesoscale weather patterns within your forecast area which may lead to these atmospheric conditions.

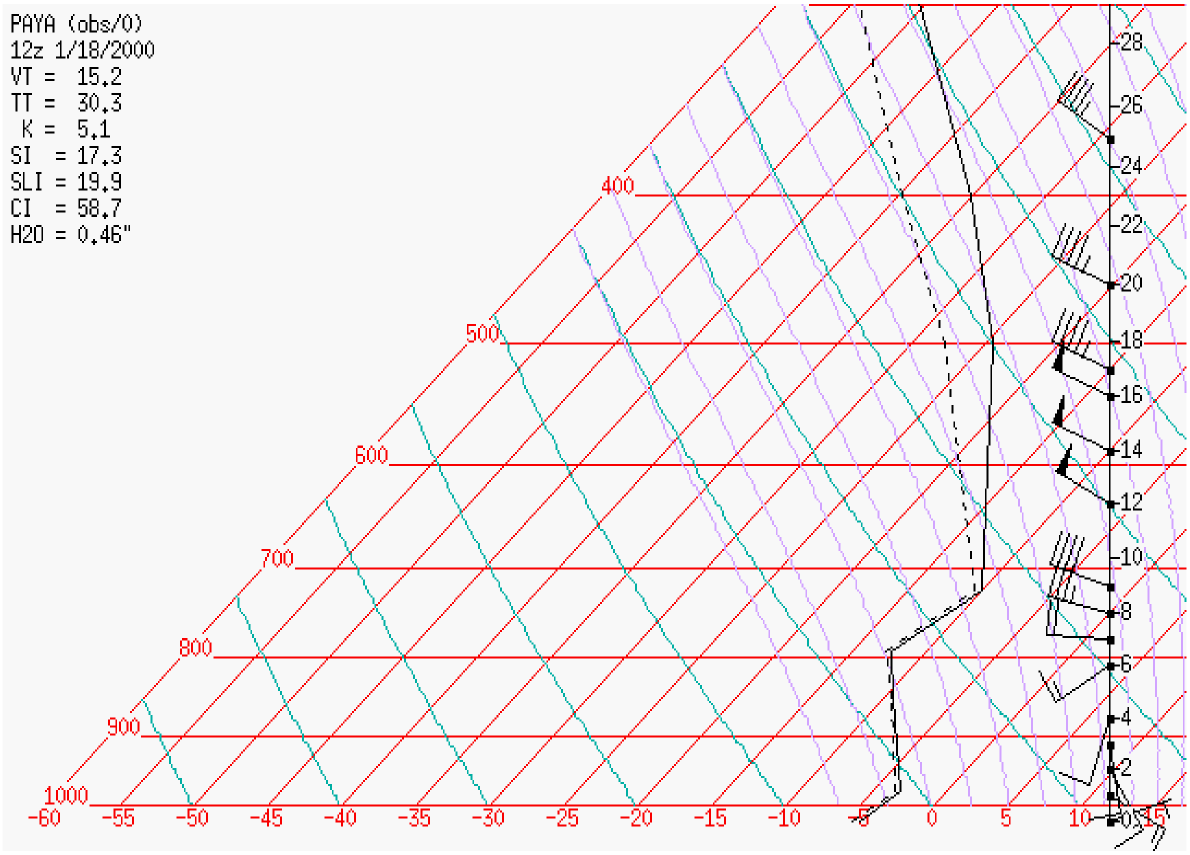

Figure 1. The Yakutat sounding just prior to the onset of freezing drizzle in Juneau. Yakutat is the closest upper air site to Juneau - approximately 180 nautical miles to the northwest. The atmosphere is saturated to about the 715-mb level and dry above. Note the temperature near the top of the moist layer is near -10°C.

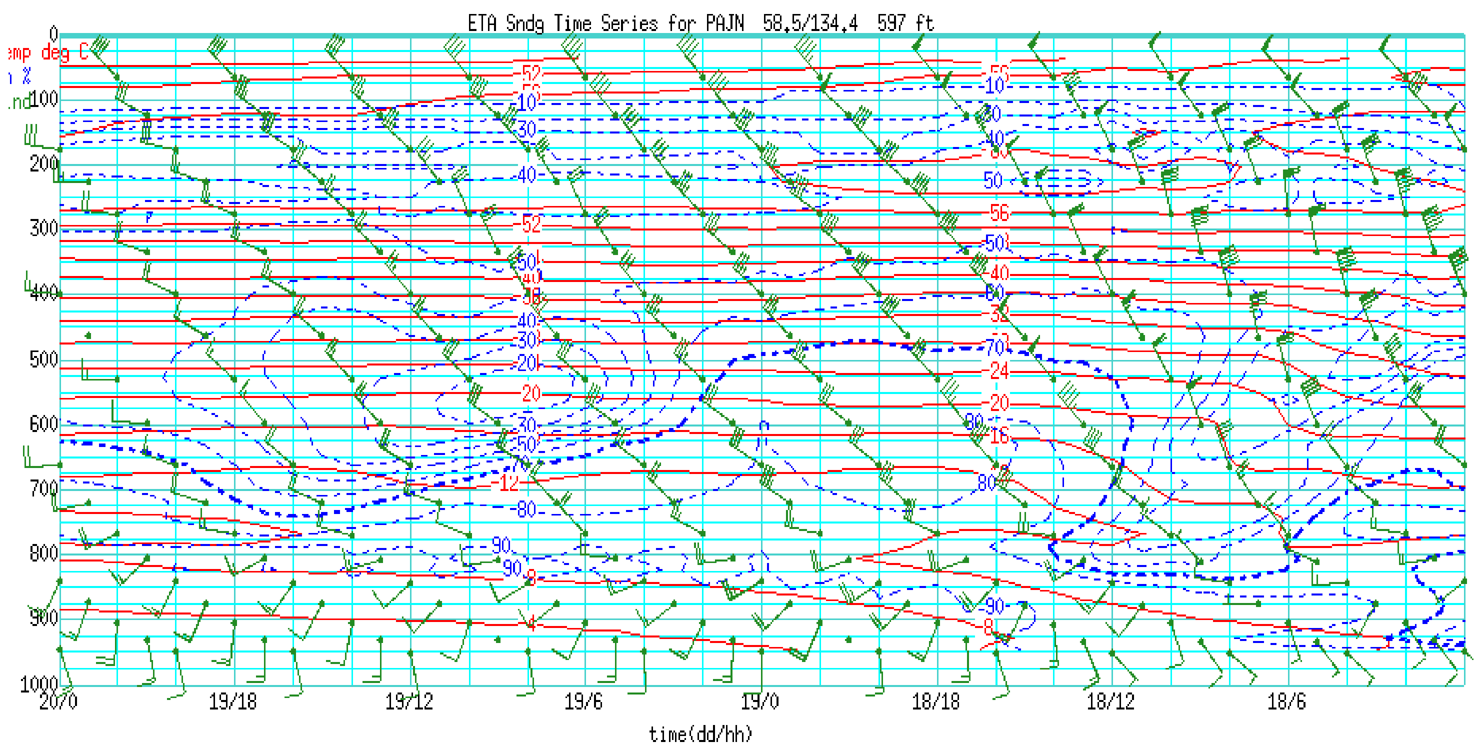

Figure 2. This time series shows the ETA model vertical cross section at Juneau with temperature, relative humidity, and wind from the 00Z run on January 18, 2000 (over 12 hours prior to the onset of freezing drizzle). Pressure is plotted in millibars along the y-axis, time is plotted from the right to left by day of the month and hour in universal time, temperature is the solid line in degrees Celsius, relative humidity is the dashed line in percent, and total wind speed and direction are shown in barbs.

This provides a good representation of the intrusion of the warm moist airmass over the shallow arctic boundary (about 18/12Z) and the subsequent modification of the low-level airmass. Note that the model is forecasting a deeper layer of moisture (up to 500-mb level) from 18/12Z to 19/10Z than is ideal for the SWRP. Beyond that time, conditions look very favorable for the SWRP as the atmosphere above the 700-mb level is dry and temperatures near the top of the moist layer are in the -8 to -12°C range.

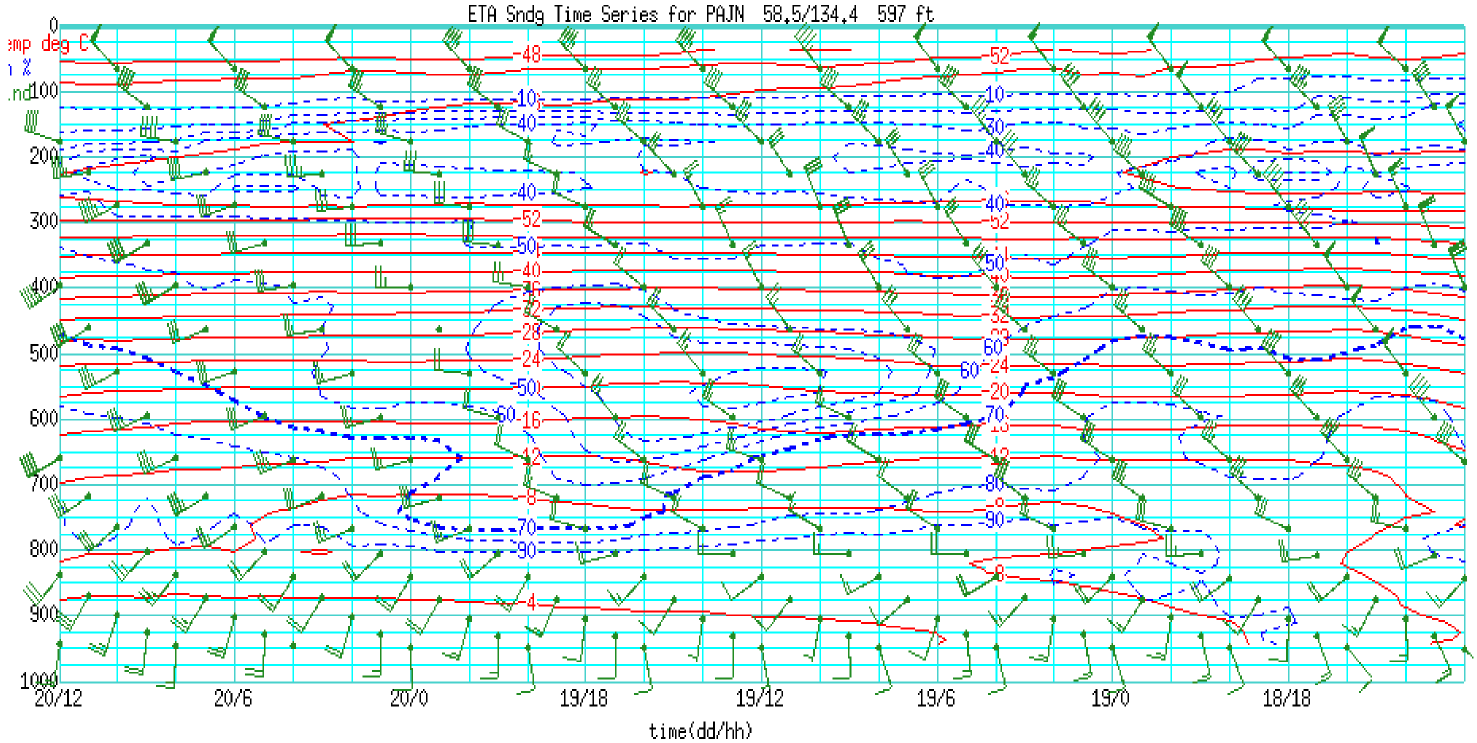

Figure 3. This is the same ETA model time series from the 12Z run on January 18, 2000, just prior to the onset of the freezing drizzle in Juneau. Again, the model has a deeper moisture layer at the initialization through about 19/12Z, and this corresponds with the time period when a mix of freezing drizzle and light snow was observed at the airport. The RH and temperature fields begin to take on the characteristics of the SWRP thereafter, when pure freezing drizzle occurred in Juneau.

<u>Conclusions:</u>
Other than being exceptional in its duration, the January 18 -20 freezing drizzle episode in Juneau was found to quite typical, exhibiting characteristics common to the "supercooled warm rain process" for producing freezing precipitation. The freezing drizzle observed for nearly 52 hours at the Juneau International Airport and the resulting hazardous aircraft icing conditions occurred in a subfreezing atmosphere due to the efficient production of large supercooled droplets.

Data collected by NCAR researchers indicated that Southeast Alaska has particularly clean air, having a very low concentration of condensation nuclei, and this is likely to be the case over other coastal areas of Alaska as well. This fact, in addition to the prevalence of shallow cold airmasses at the surface over land and relatively warm maritime air over the Gulf of Alaska, suggests that freezing drizzle is a significant forecast issue during winter months over portions of Alaska.

There are several useful data sources available to aid in this forecast process. Forecasters may utilize model cross-sections of relative humidity and temperature to anticipate the likelihood of freezing drizzle for longer term forecasts, and soundings and satellite imagery are excellent tools for use in the shorter term. Another important consideration for forecasters is to learn to identify potential synoptic and mesoscale patterns which may be conducive to this particular weather hazard in their area of responsibility.

References

Bocchieri, Jr. R., 1980: The objective use of upper air soundings to specify precipitation type. *Mon. Wea. Rev.*, 108, 596-603.

Huffman, G. J., and G. A. Norman, Jr., 1988: The supercooled warm rain process and the specification of freezing precipitation. *Mon. Wea. Rev.*, 116, 2172-2181.

Rassmussen, R. M., et al., 1995: The 1990 Valentine's Day Arctic Outbreak Part I: mesoscale and microscale structure and evolution of a Colorado front range shallow upslope cloud. *Jour. Appl. Meteor.*, 34, 1481-1488.

Wallace, J. M., and P. V. Hobbs, 1977: *Atmospheric Science: An Introductory Survey*, Academic Press, 467 pp.

Young, W. H., 1978: Freezing precipitation in the southeastern United States. M.S. Thesis, Texas A&M University, 123 pp.

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