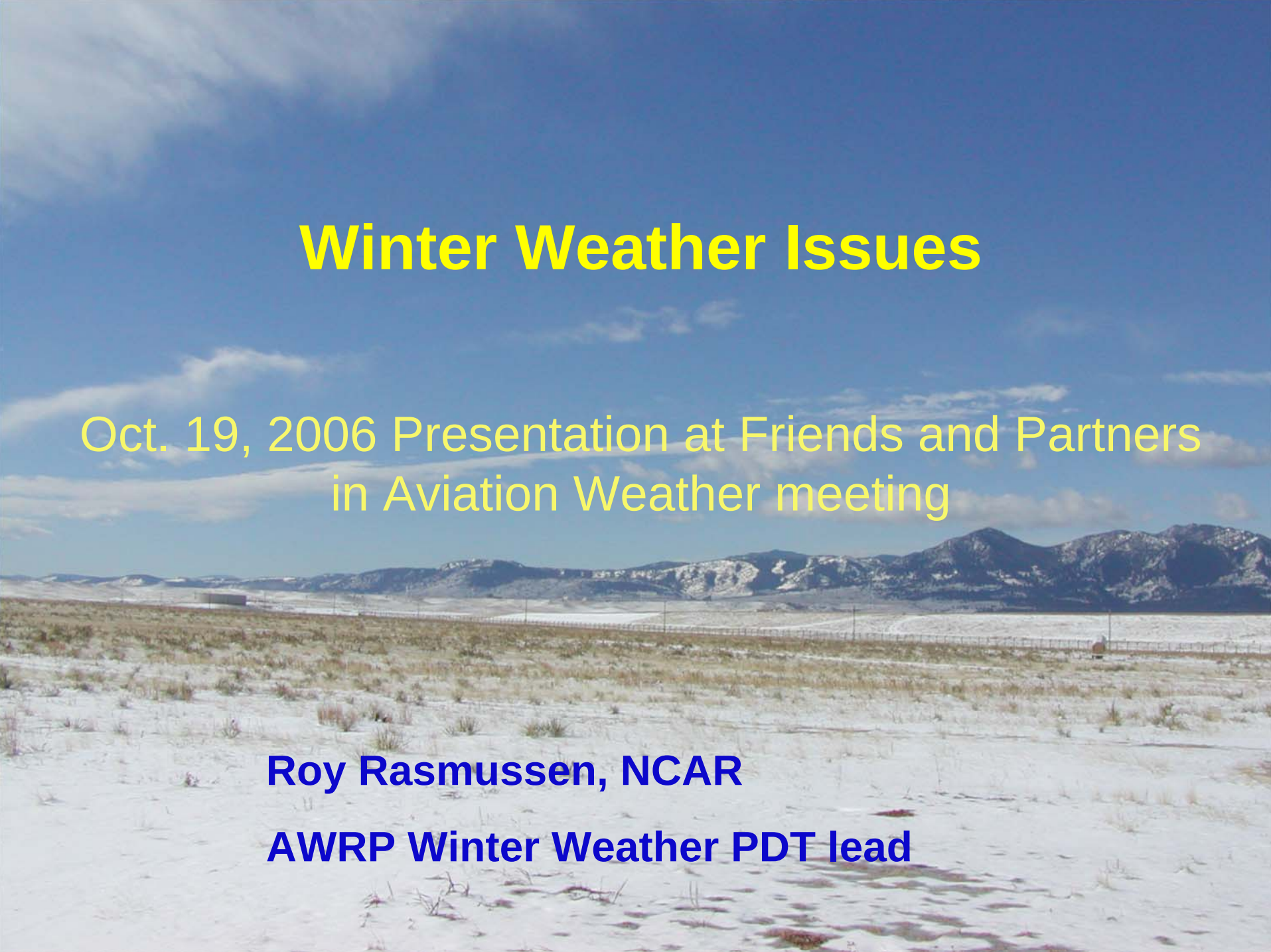


Winter Weather Issues

Oct. 19, 2006 Presentation at Friends and Partners in Aviation Weather meeting

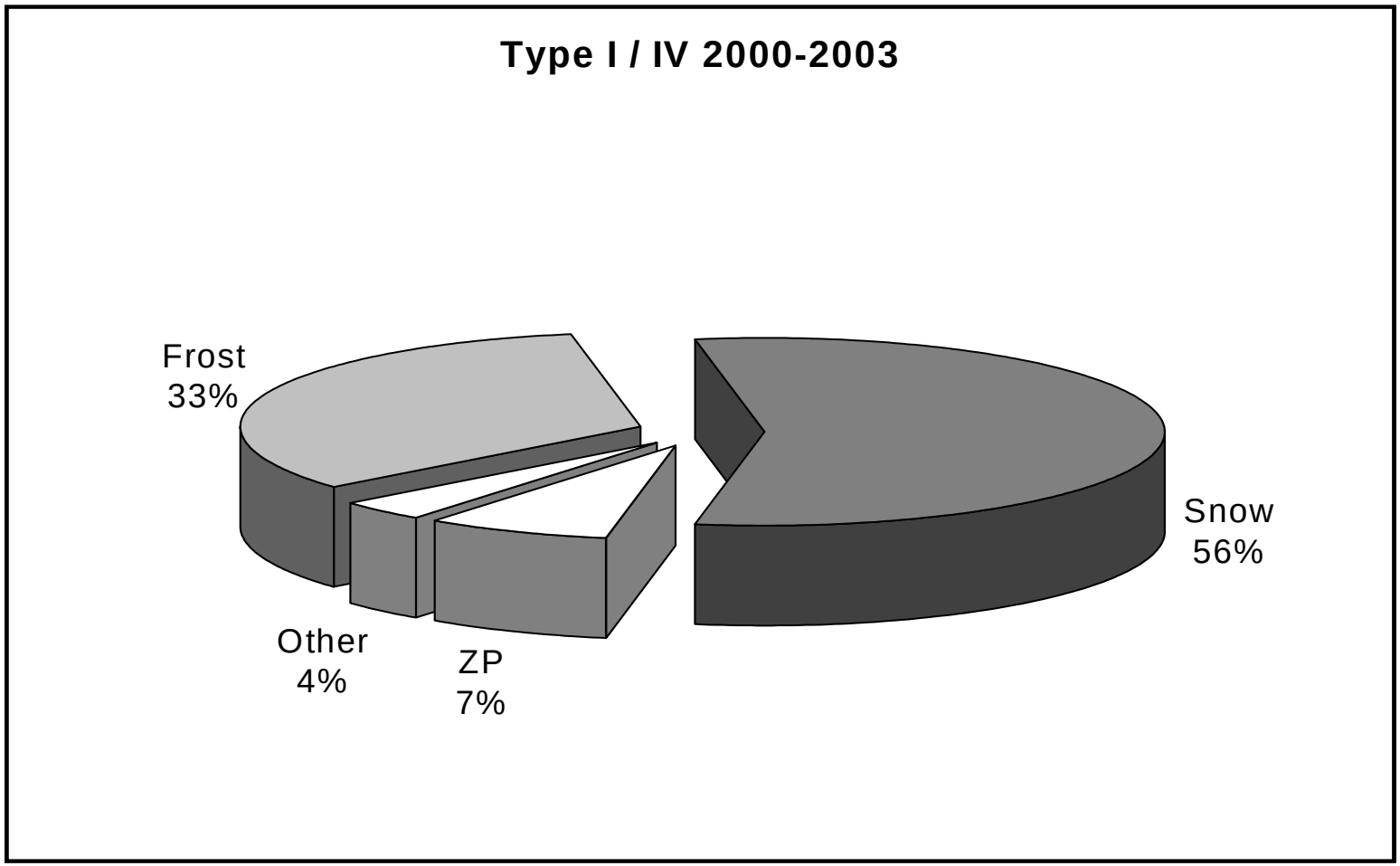
Roy Rasmussen, NCAR

AWRP Winter Weather PDT lead

Winter Weather Issues

1. Ice Pellets
2. Heavy Snow
3. Ingest of freezing drizzle by engines
4. Implementing real-time liquid equivalent rates one of the highest priority for the Ground Deicing Industry (2006 Portugal SAE Ground Deicing Meeting)
5. ASOS summary
6. Winter Weather Research PDT future

FREQUENCY OF DE/ANTI-ICING OPERATIONS (ALL AIRPORTS) – SURVEY 2000-03



FSAT 2006-2007

HOLDOVER TIME TABLES

ICE PELLET ALLOWANCE TIME

HEAVY SNOW PROCEDURES

WINTER 2006-2007

Winter 2006-07 Deicing/Anti-icing Guidance: Ice Pellet Allowance Time

Background

- "In October 2005, the FAA issued *Notices 8000.309, Dispatching During Precipitation Conditions of Ice Pellets, Snow Pellets, or Other Icing Events for which No Hold Over Times Exist;* and *8000.313, Parts 121 and 135 Operations Specifications for Deicing/Anti-icing Operations in Ice Pellets Without Deice/Anti-ice Fluids*. As a result of these notices, industry requested the FAA conduct research to obtain data to support relief for some of the current conditions for which no holdover times exist. That research was conducted during the winter season of 2005-06."

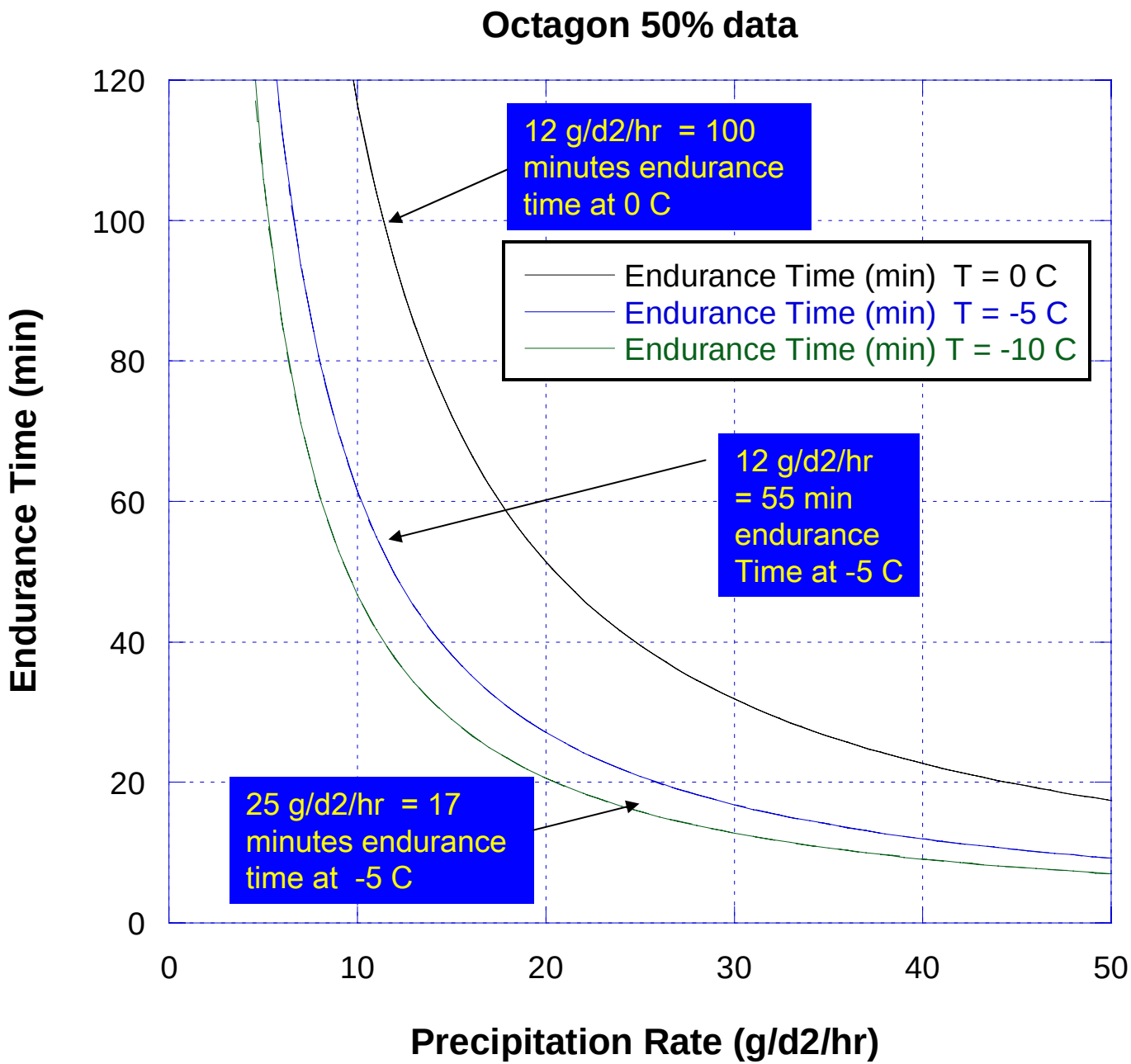
Ice Pellet testing results:

c. Operators with a deicing program approved in accordance with Title 14 of the Code of Federal Regulations (14 CFR) part 121, section 121.629, ***will be allowed, in light ice pellet conditions with no other form of precipitation present, up to 25 minutes after the start of the anti-icing fluid application to commence the takeoff*** with the following restrictions:

1. The aircraft critical surfaces must be free of contaminants, or the aircraft be properly deiced prior to the application of the anti-icing fluid.

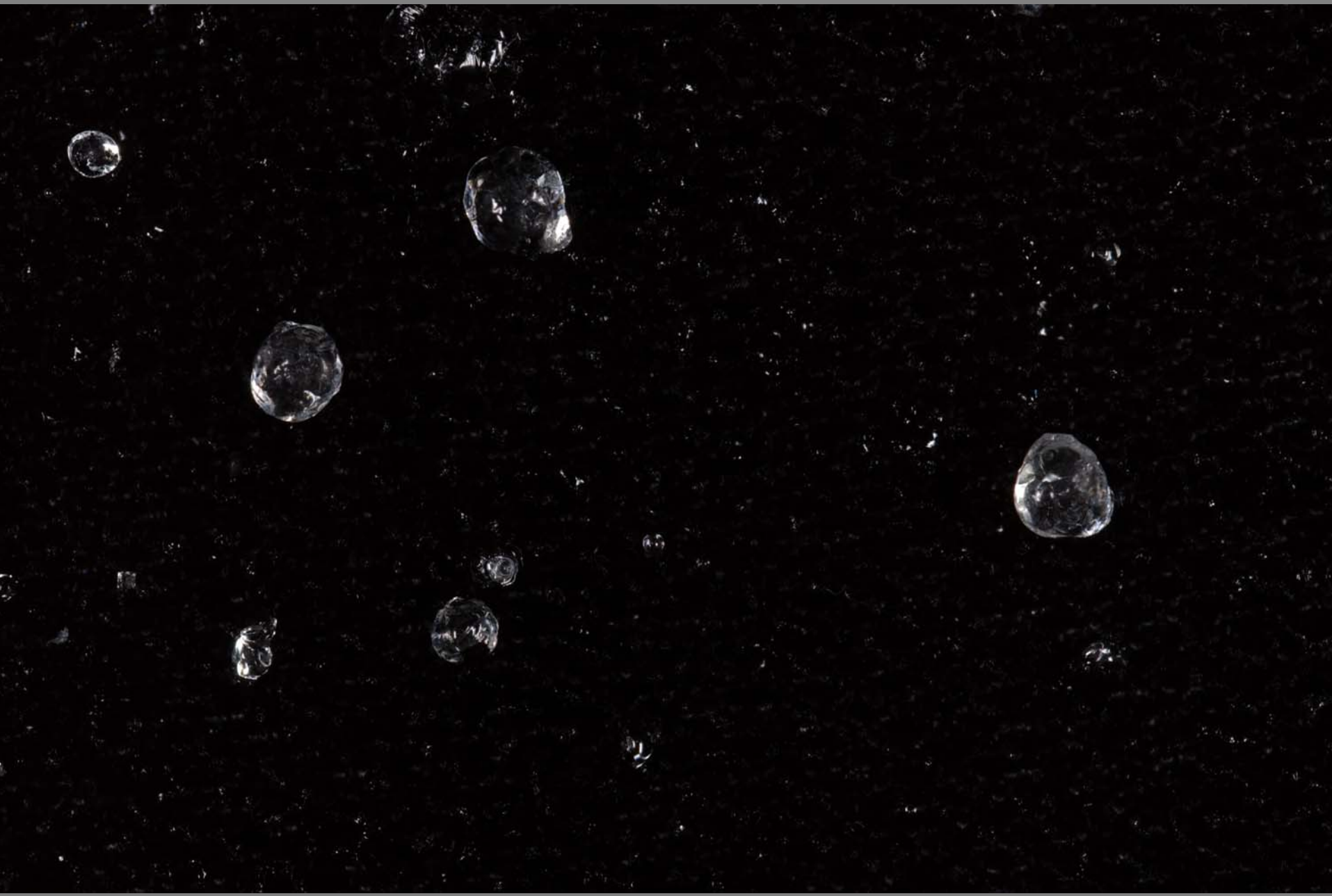
2. This allowance time, of up to 25 minutes, is valid only if the aircraft is anti-iced with undiluted Type IV fluid.

……..


Octagon 50% data
Endurance Time (min)
Precipitation Rate (g/d2/hr)
0
20
40
60
80
100
120
0
10
20
30
40
50
12 g/d2/hr = 100 minutes endurance time at 0 C
Endurance Time (min) T = 0 C
Endurance Time (min) T = -5 C
Endurance Time (min) T = -10 C
12 g/d2/hr = 55 min endurance Time at -5 C
25 g/d2/hr = 17 minutes endurance time at -5 C

Ice Pellets Issue:

- After inspecting operations at many airlines during the winter 2005-2006, the FAA issued a Notice to Airman in October 2005 prohibiting operations during ice pellet conditions due to the fact that no holdover time exists for ice pellets.
- This notice had the potential to seriously impact operations at a number of airports such as Pittsburgh where such operations had been going on for many years (using a Pre-takeoff contamination check which allows 5 minutes to take off after the check).
- ATA requested a meeting on January 24, 2006 to discuss this issue as well as the heavy snow issue with the FAA.
- As a result, the FAA embarked on a test program for ice pellets through application of ice pellets on the wing of an aircraft during simulated takeoff.



Ice Pellet Issues: (cont.)

- **Based on testing, FAA has allowed a holdover time of 25 minutes during light ice pellet conditions only (no other type of precipitation present).**

- **Problem:**
  - ***Ice pellets mixed with other types of precipitation 70% of the time (18% freezing rain, 18% rain, 37% snow), conditions for which the new holdover times do not apply.***

  - ***The estimation of light ice pellet rates usually done by visibility. This technique as not been confirmed, nor has the over estimate of visibility at night been considered.***


Heavy Snow

Visibility Criteria for Snow Intensity

Visibility (Statute Mile)						
≥2 1/2	2	1 1/2	1	3/4	1/2	≤1/4
Very Light	Very Light	Light	Light	Moderate	Moderate	**Heavy**

HEAVY = Caution - no holdover time guidelines exist

Modified Visibility Criteria for Snow Intensity Based on Temperature and Day or Night

Time of Day	Temp. (°C)	Temp. (°F)	Visibility (Statute Mile) ≥2 1/2	2	1 1/2	1	3/4	1/2	≤1/4	
Day	colder/equal -1	colder/equal 30	Very Light	Very Light	Light	Light	Moderate	Moderate	**Heavy**	**Snow fall Intensity**
	warmer than -1	warmer than 30	Very Light	Light	Light	Moderate	Moderate	**Heavy**	**Heavy**	
Night	colder/equal -1	colder/equal 30	Very Light	Light	Moderate	Moderate	**Heavy**	**Heavy**	**Heavy**	
	warmer than -1	warmer than 30	Very Light	Light	Moderate	**Heavy**	**Heavy**	**Heavy**	**Heavy**	

NOTE: **Based upon technical report, "The Estimation of Snowfall Rate Using Visibility," Rasmussen, et al., Journal of Applied Meteorology, October 1999 and additional in situ data.**

HEAVY = Caution - no holdover time guidelines exist

Heavy Snow

B. Operators with a deicing program approved in accordance with 14 CFR part 121, section 121.629, will be allowed to take off in heavy snow conditions subject to the following restrictions:

1. ***The aircraft must be anti-iced with undiluted Type IV fluid.***
2. ***The aircraft critical surfaces must be free of contaminants, or the aircraft be properly deiced prior to the application of the anti-icing fluid.***
3. ***The operator must accomplish an approved tactile and/or visual check, as appropriate, of the aircraft critical surfaces within 5 minutes of takeoff.***
4. If this check is accomplished visually from within the aircraft, the view must be such that it is not obscured by de/anti-icing fluid, dirt, or fogging. If the critical surfaces cannot be seen due to snowfall, distance from the viewing position, or inadequate lighting, or for any other reason, the check must be a visual or tactile check conducted from outside the aircraft.
5. If a definitive fluid failure determination cannot be made using the checks prescribed, takeoff is not authorized. The aircraft must be completely deiced, and if precipitation is still present, anti-iced again prior to a subsequent takeoff.

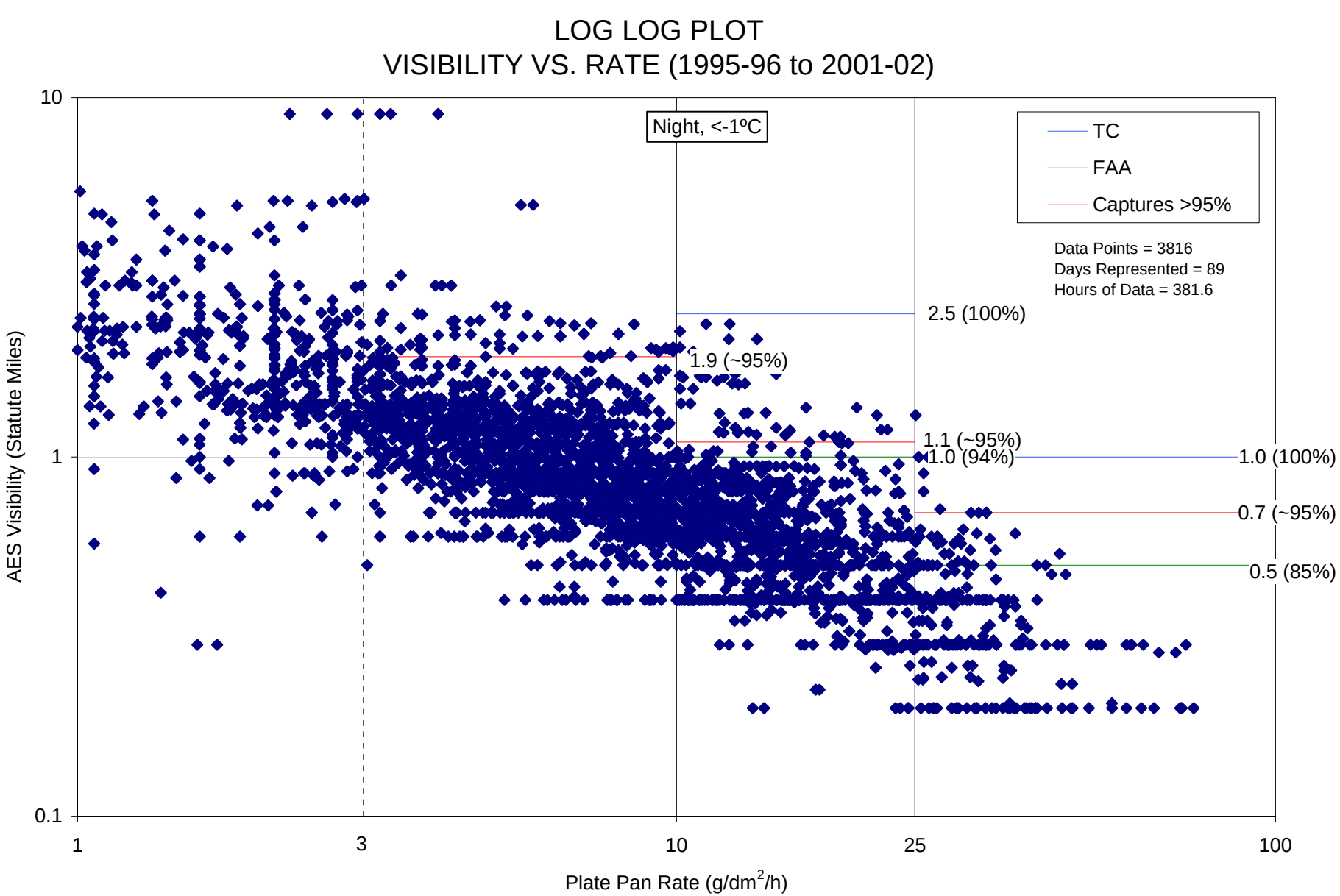
Heavy Snow Issue:

- The use of the modified visibility table has resulted in heavy snow being reported much more frequently than before (~10 times more often).

Need liquid equivalent rate in real-time!

contamination check as well. This year, FSAT allows for a pre-takeoff contamination check.

- Pilots are starting to ignore the modified visibility table, using the direct snowfall intensities from the METAR.


LOG LOG PLOT
VISIBILITY VS. RATE (1995-96 to 2001-02)
Night, <-1ºC
TC
FAA
Captures >95%
Data Points = 3816
Days Represented = 89
Hours of Data = 381.6
2.5 (100%)
1.9 (~95%)
1.1 (~95%)
1.0 (94%)
1.0 (100%)
0.7 (~95%)
0.5 (85%)
AES Visibility (Statute Miles)
10
1
0.1
1
3
10
25
100
Plate Pan Rate (g/dm2/h)

The lack of liquid equivalent and precipitation type real-time information updated every minute is having a significant impact on aircraft deicing operations and is a significant safety factor

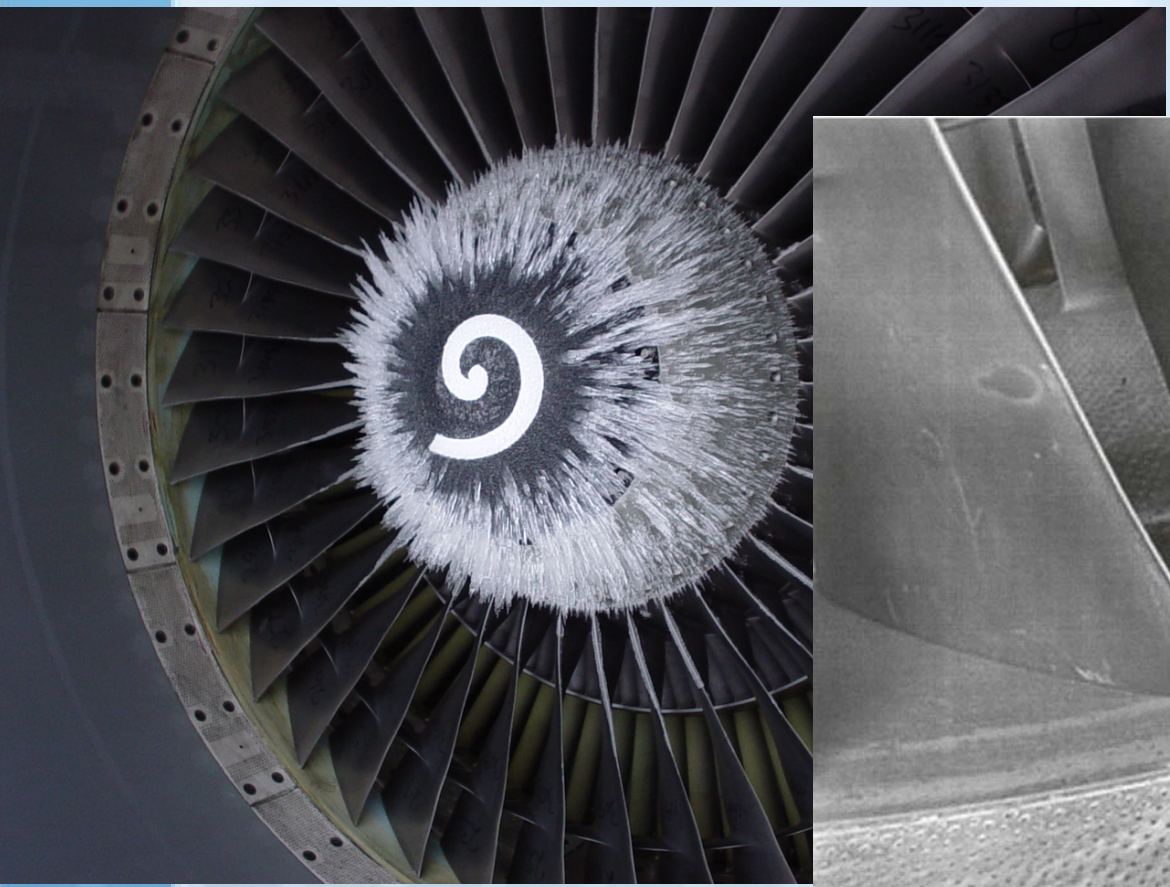
- **The liquid equivalent rate of snow, freezing rain, snow pellets, ice pellets, and freezing drizzle is the primary factor causing aircraft deicing fluids to fail.**

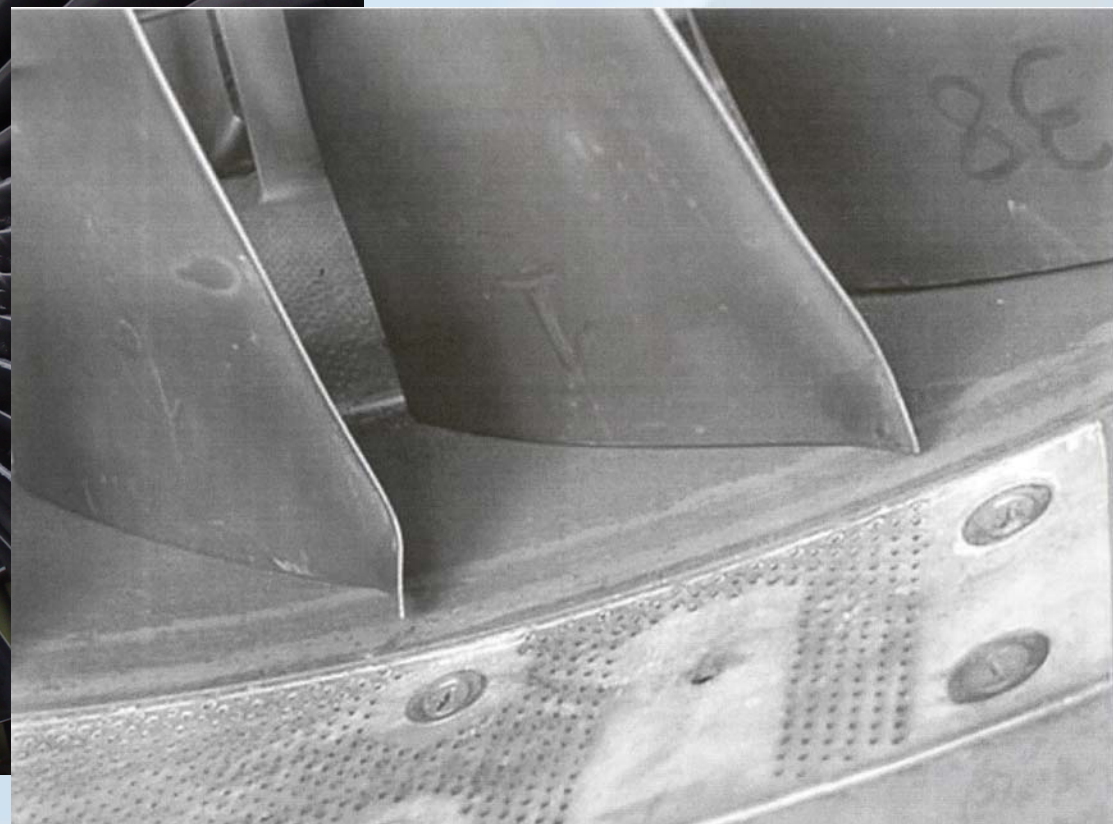
- **The current NWS estimates of snowfall and drizzle intensity available to pilots via METARS through ASOS and ATIS is based on visibility, not liquid equivalent.**

- **The use of a modified visibility table does not solve the problem, and in fact may make it worse!**

Freezing drizzle ingest into engines can cause significant damage to fan blades

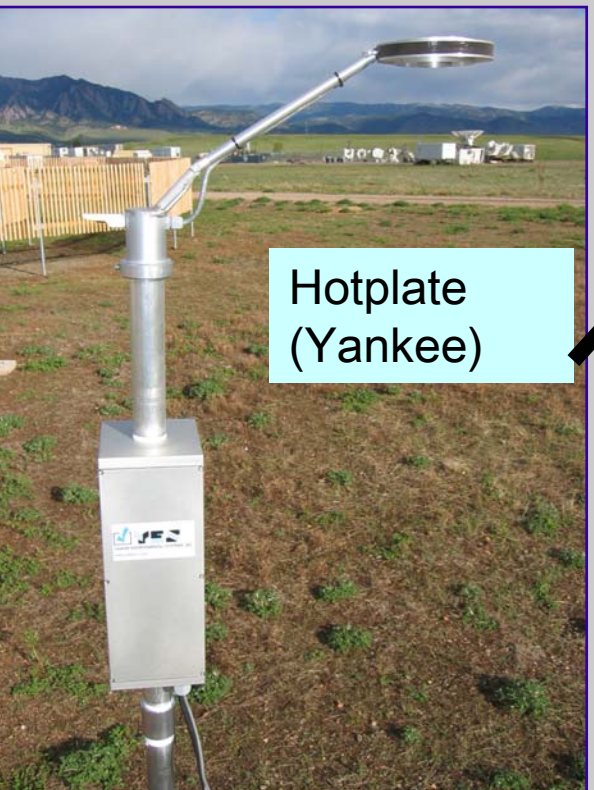
(light freezing drizzle reported by METAR, heavy freezing drizzle actually occuring, J. Aircraft paper just published, Rasmussen et al.)





Precipitation Type sensor (Vaisala PWD-22) EPI sensor

All Precip Checktime System



Hotplate (Yankee)

Freezing Rain sensor (Goodrich)

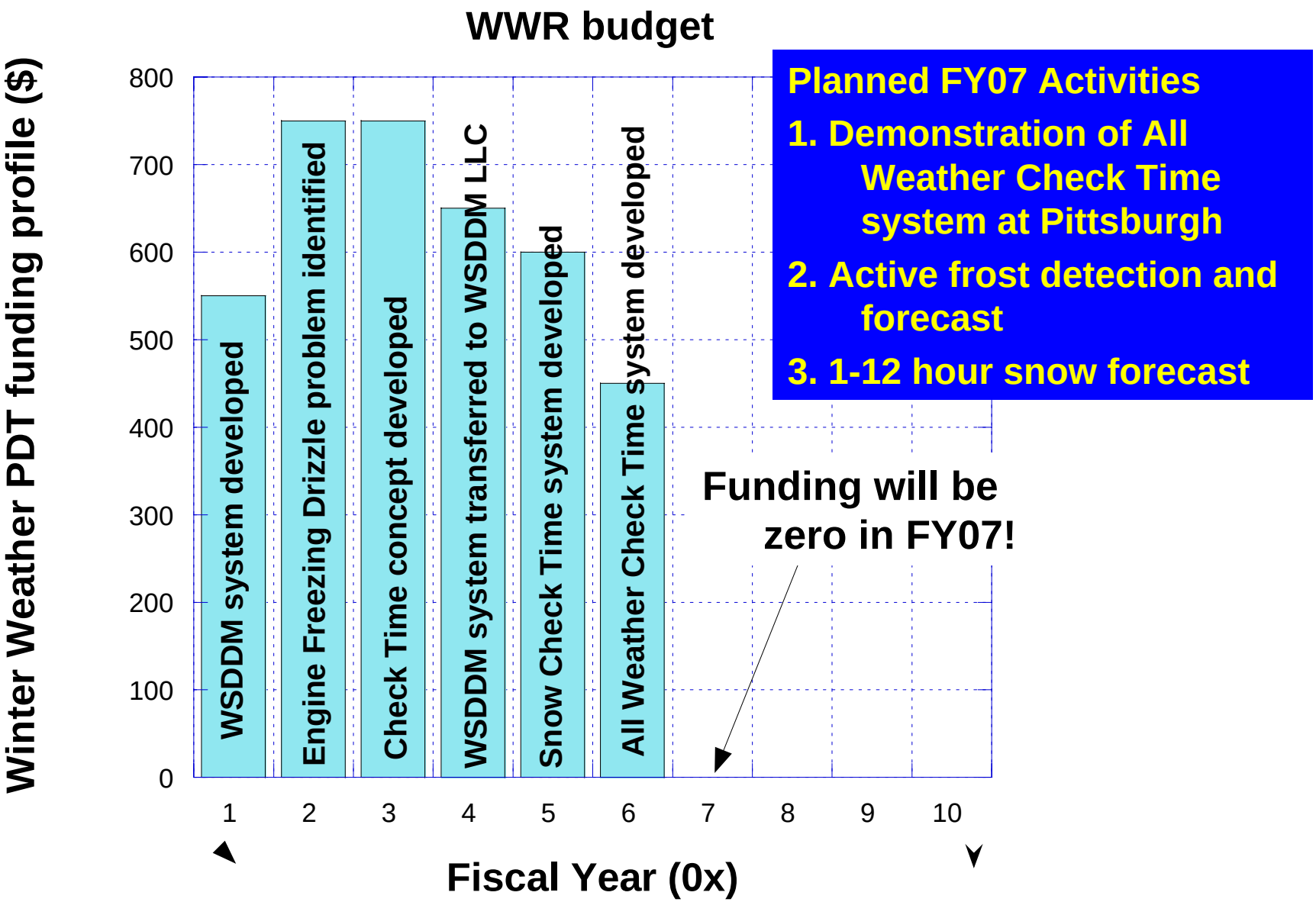
- Holdover Time determination
- Checktime determination

Weighing Snowgauge (GEONOR)

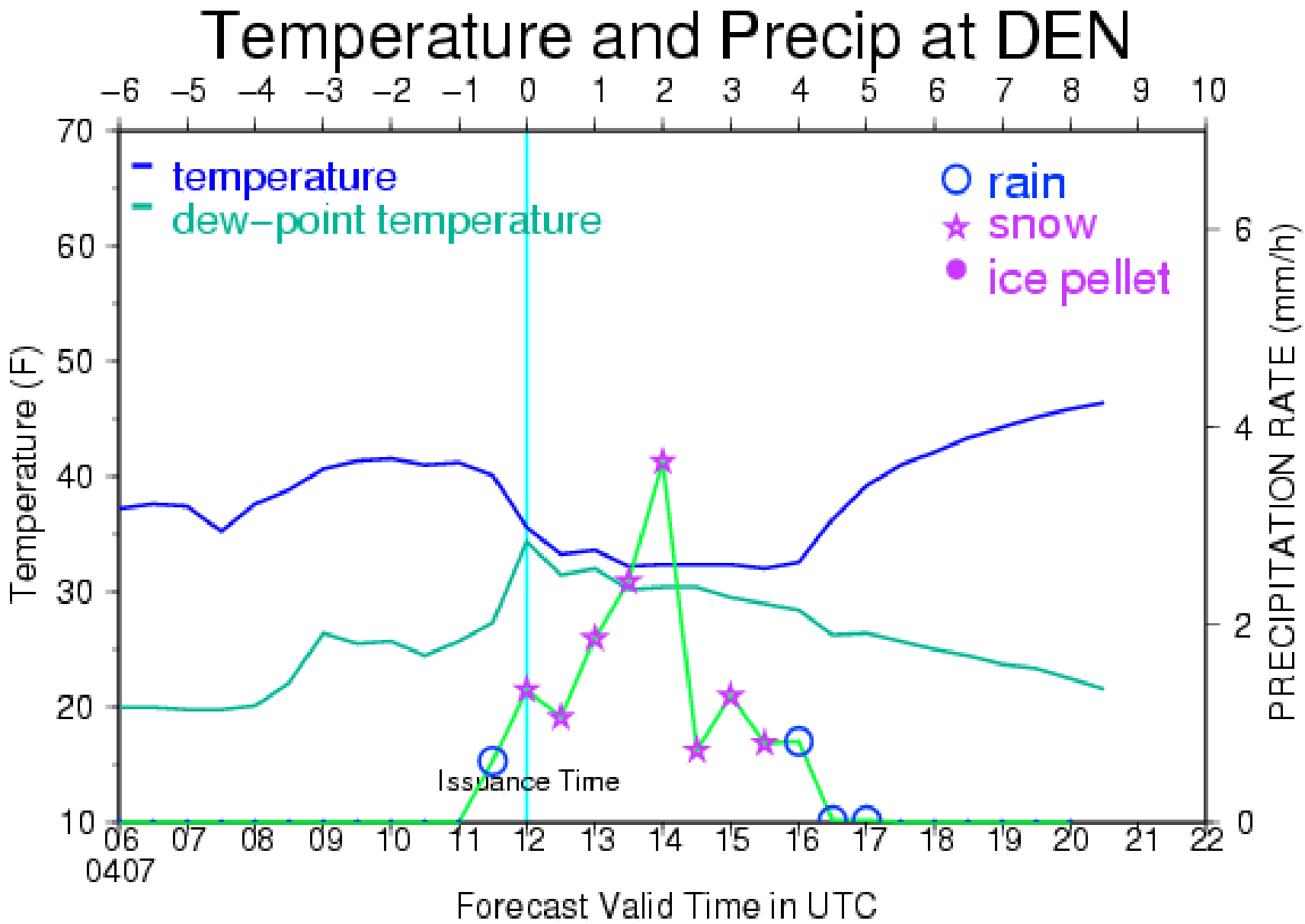
ASOS Winter Issues

1. **Enhanced Precipitation Indicator**
   - Will Enable freezing drizzle detection and rate, ice pellet detection and rate and snow pellet detection, hail detection.
   - Demonstration test at limited # of sites (focused on hail and ice pellet detection) this winter.
   - FAA needs to commit to fund in order for this sensor to be deployed (business case not compelling). NWS will not deploy without FAA funding.

2. **Liquid Equivalent based snowfall rate still not implemented!**
   - National Weather Service has proposed to implement at sites with liquid equivalent gauges, but FAA has not accepted.


WWR budget
Winter Weather PDT funding profile ($)
800
700
600
500
400
300
200
100
0
WSDDM system developed
Engine Freezing Drizzle problem identified
Check Time concept developed
WSDDM system transferred to WSDDM LLC
Snow Check Time system developed
All Weather Check Time system developed
Funding will be zero in FY07!
1
2
3
4
5
6
7
8
9
10
Fiscal Year (0x)
Planned FY07 Activities
1. Demonstration of All Weather Check Time system at Pittsburgh
2. Active frost detection and forecast
3. 1-12 hour snow forecast


Checktime (c)2006 NCAR
Type 1 CHECK TIME: 15:27 - 39 minutes
04/24/06 16:06:00
Site Time (Local) Temp (F) Dew pt (F) RH (%) Wind (deg) Speed (kts) Rate (mm/hr) Wx TREND (10 min)
PIT1 16:03 30.6 29.7 97 357 3 0.2 -SN DOWN
5 mm/hr
Precip Rate
mm/hr
PIT1 15:27
13:30
14:00
14:30
15:00
15:30
16:00
Fluid: Type 1 Type 4 Octagon 100% Octagon 75% Octagon 50%
Surface Weather History
PIT1 Precip Rate (in/hr) 04/24/06 12:30 to 04/24/06 16:41 UTC
PIT1 12 Hr Precip Accum
PIT1 Temperature (F)
PIT1 Humidity (%)
PIT1 Wind
PIT1 Wind
PIT1 FZ Precip
Nil FR FZFG- FZDZ- FZRA +
PIT1 Wx Type
FG HZ DZ UP - RA +TS -SN+ PE
Freezing drizzle
Ice Pellets
Light Snow


Temperature and Precip at DEN
−6 −5 −4 −3 −2 −1 0 1 2 3 4 5 6 7 8 9 10
70 60 50 40 30 20 10
temperature
dew−point temperature
rain
snow
ice pellet
Temperature (F)
PRECIPITATION RATE (mm/h)
6 4 2 0
Issuance Time
06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22
0407
Forecast Valid Time in UTC

Need for METAR to report liquid equivalent rates instead of intensities based on visibility

The following proposal was made to the FAA in the summer of 2003.

1. The current visibility based definition of light, moderate and heavy snow is inadequate for aircraft deicing purposes because it doesn't give a reliable indication of the liquid equivalent rate of snowfall. The liquid equivalent rate is the primary factor causing deicing fluids to fail, and is critical to know in order to determine the correct holdover time for the conditions.
2. Need the FAA to make it a requirement to use the following definition of snowfall intensity operationally:

   Light: Less than or equal to 10 $g/d^2/hr$

   Moderate: Between 10 and 25 $g/d^2/hr$

   Heavy: Greater than or equal to 25 $g/d^2/hr$

   and to report these conditions operationally every 1 minute.

Result:

Meetings with the Office of the Federal Coordinator of Meteorology

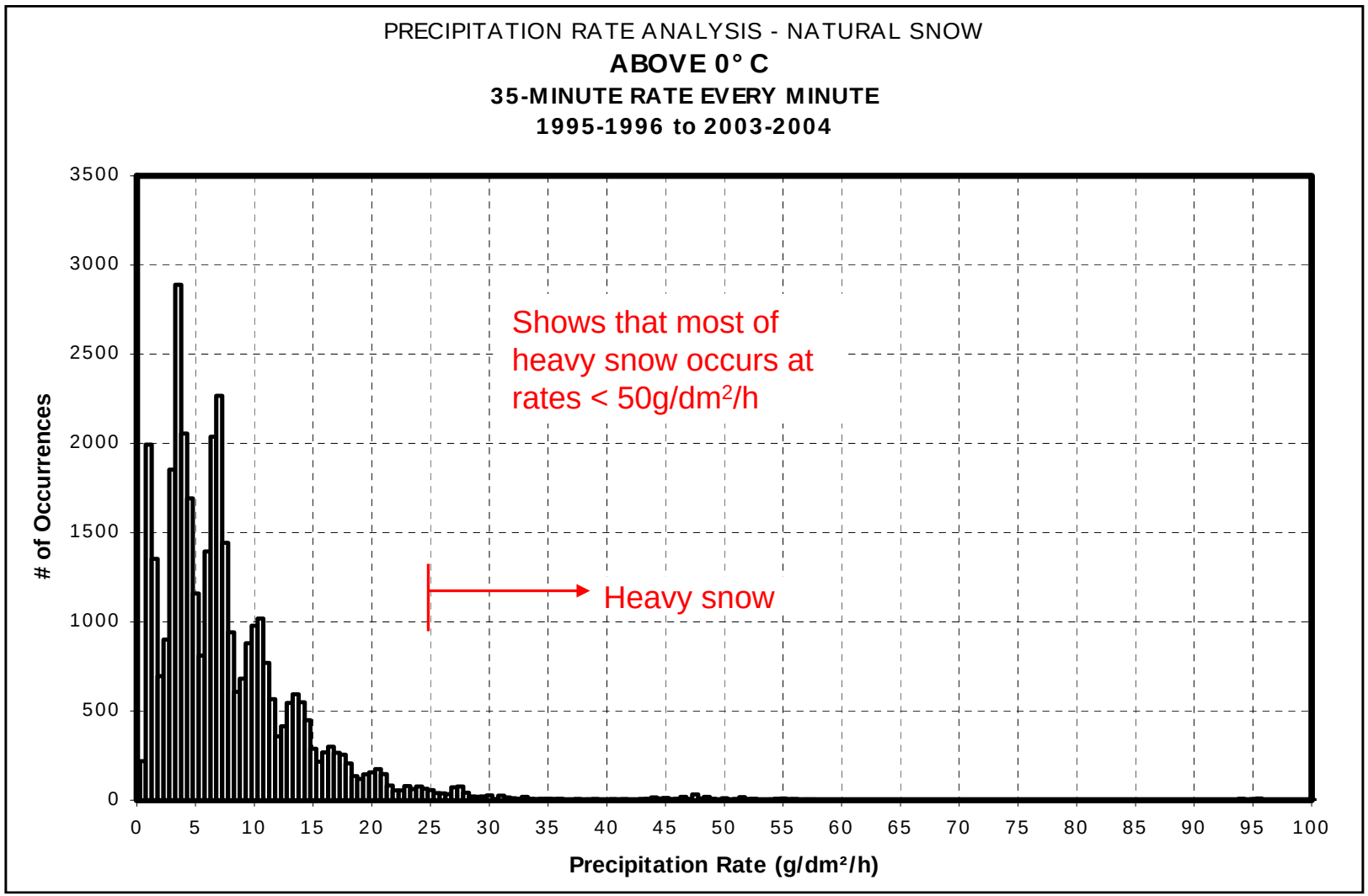
All agencies agree in principal to this change.

The National Weather Service proposed a new criteria to determine light, moderate, heavy snow at surface station sites (ASOS) that have liquid equivalent gauges.

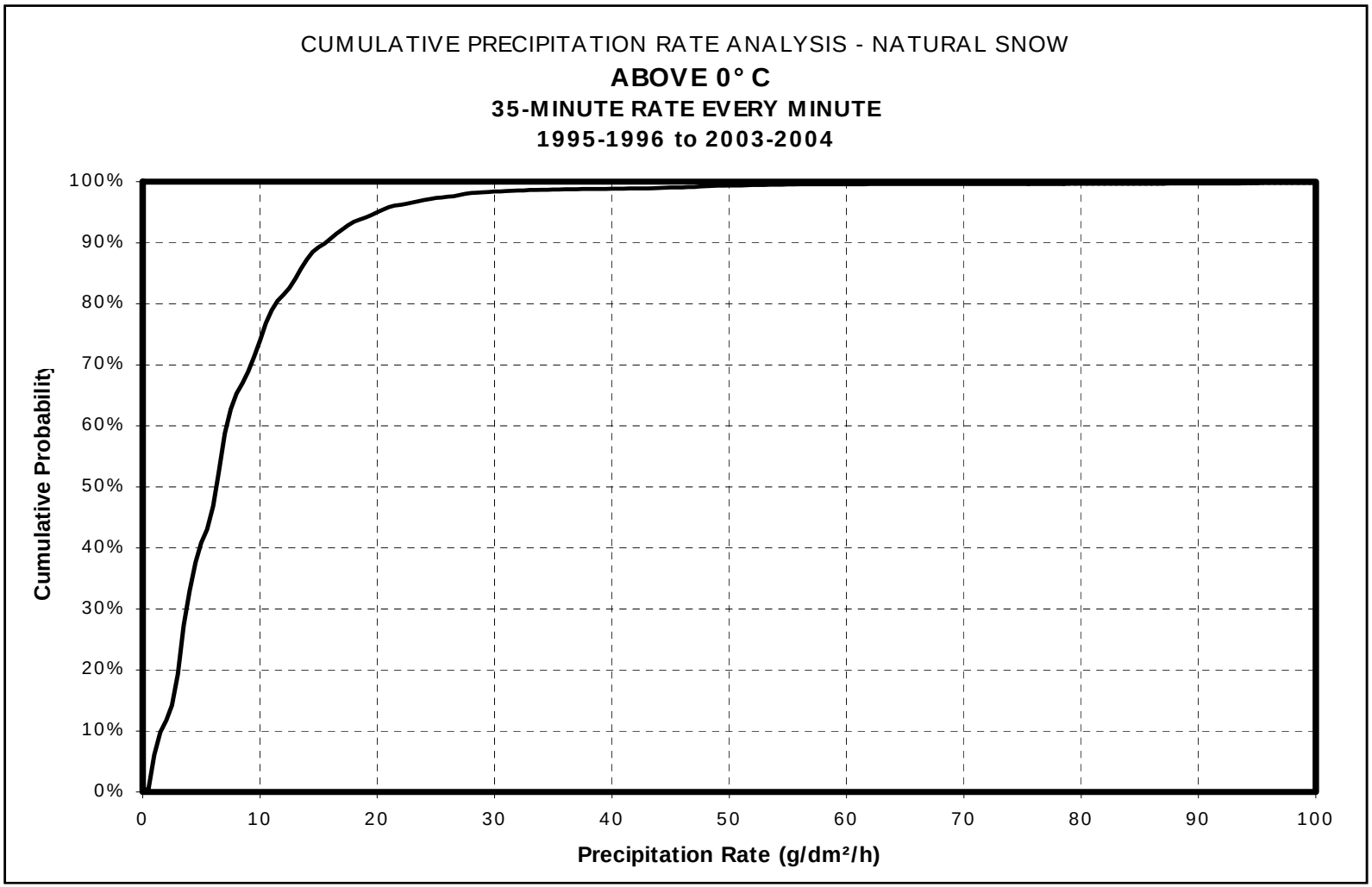
The installation of the new OTT liquid equivalent gauge at all NWS ASOS sites could provide liquid equivalent rates at all major airports impacted by winter weather.

The FAA, however, has subsequently objected to this definition, so no changes have been made.

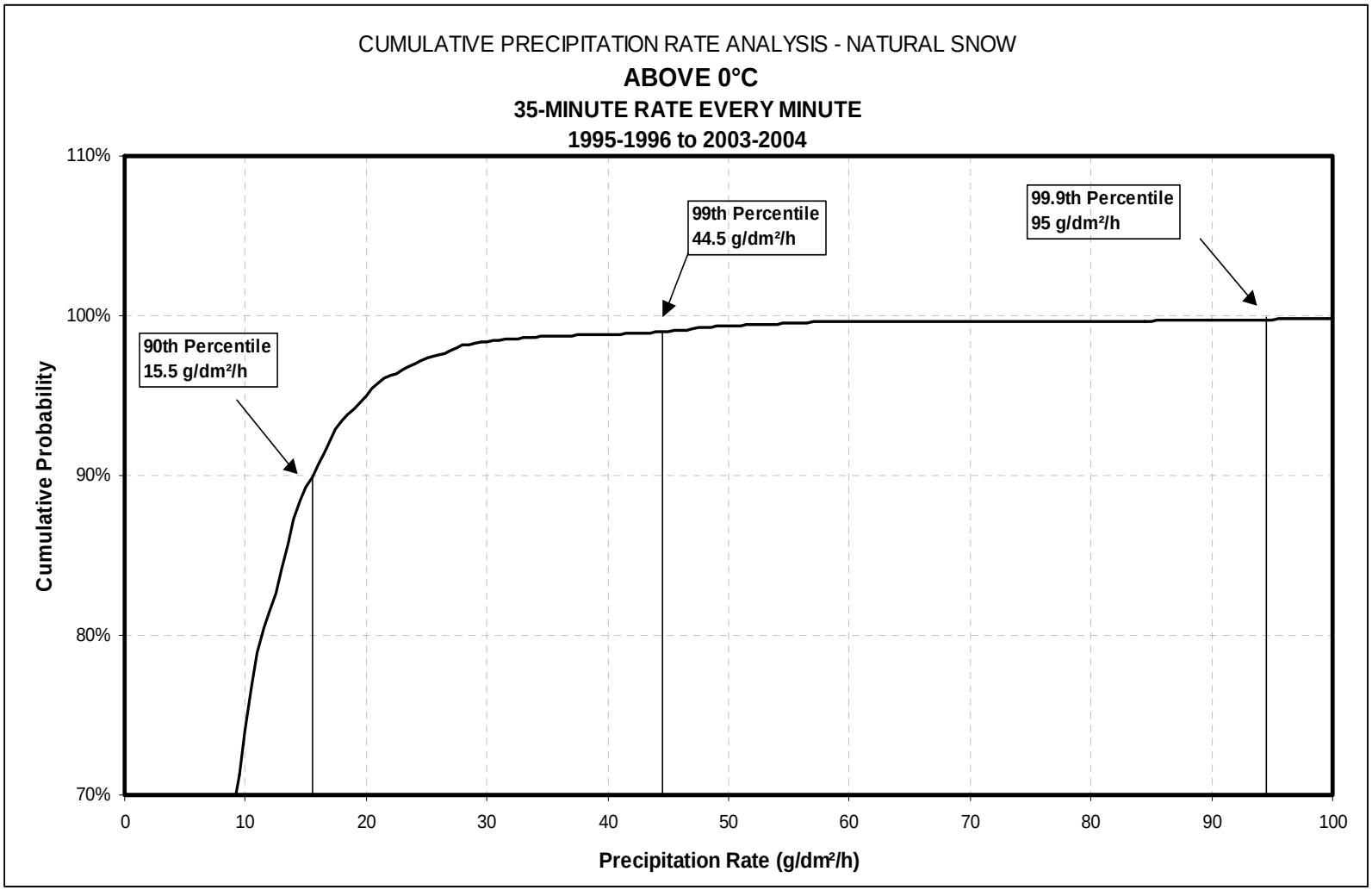
PRECIPITATION RATE ANALYSIS
NATURAL SNOW - ABOVE 0ºC



CUMULATIVE PRECIPITATION RATE ANALYSIS NATURAL SNOW ABOVE 0ºC



CUMULATIVE PRECIPITATION RATE ANALYSIS NATURAL SNOW ABOVE 0ºC



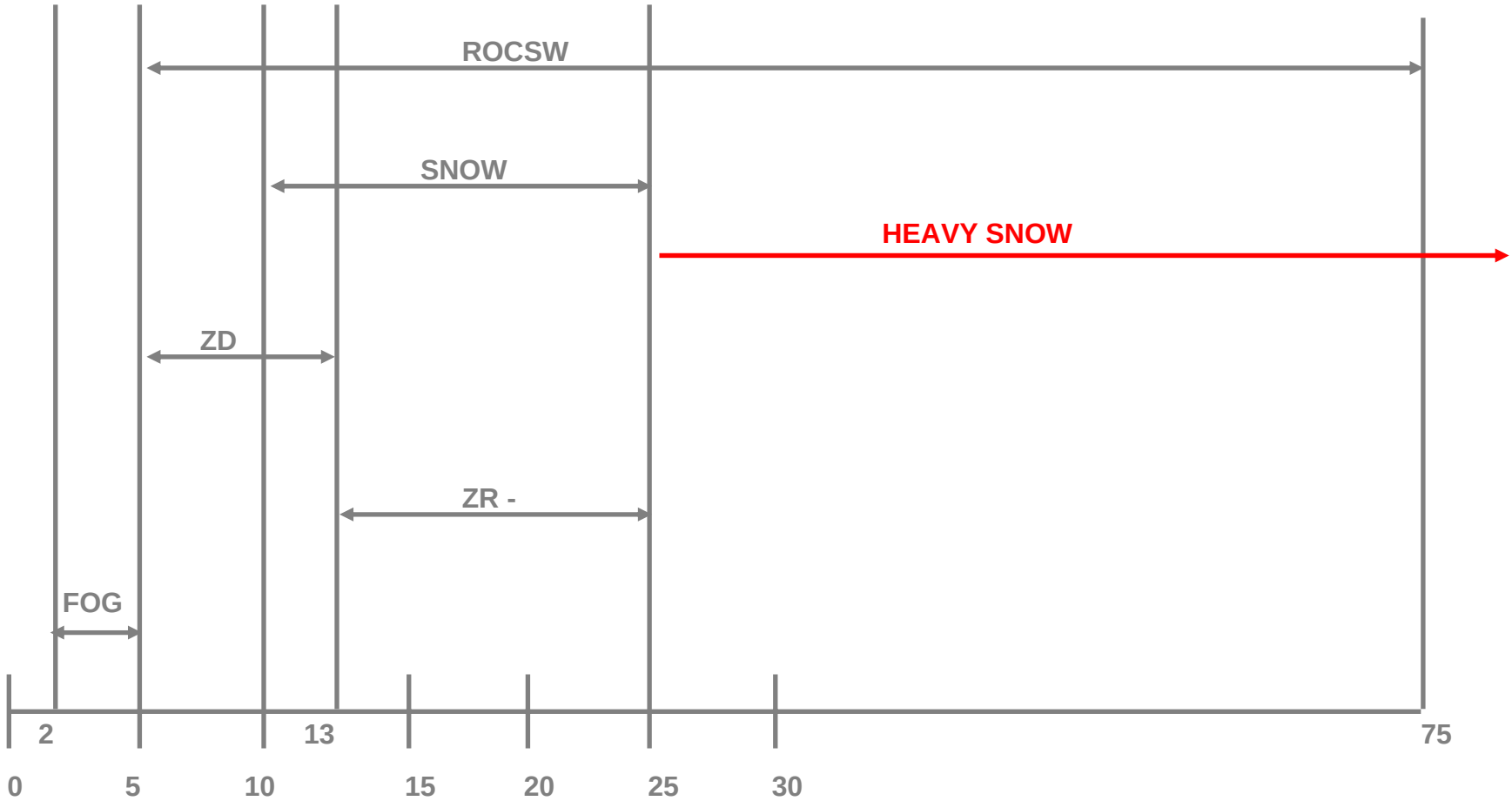
PROBABILITY OF SNOW IN EACH HOT TABLE TEMPERATURE RANGE – TYPE I FLUIDS

Temperature (° C)	Very Light Snow	Light Snow	Moderate Snow	Heavy Snow	Total
-3 and above	20.1%	8.0%	9.9%	1.2%	**39.2%**
below -3 to -6	12.4%	5.2%	6.1%	0.8%	**24.4%**
below -6 to -10	11.6%	4.1%	4.9%	0.6%	**21.2%**
below -10	9.0%	2.6%	3.1%	0.5%	**15.2%**
Total	**53.2%**	**19.9%**	**24.0%**	**3.0%**	**100.0%**

PROBABILITY OF SNOW IN EACH HOT TABLE TEMPERATURE RANGE – TYPE II and TYPE IV FLUIDS

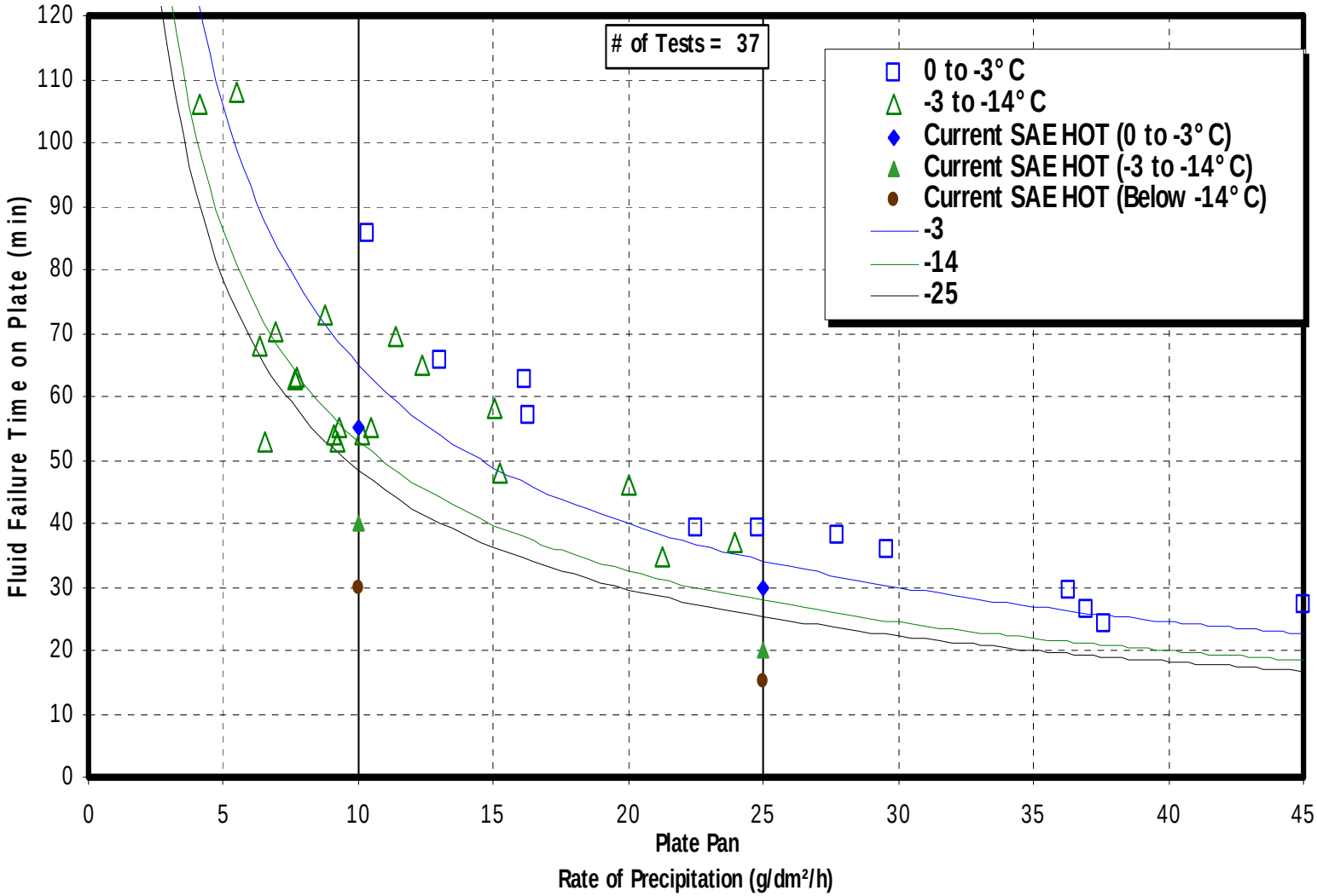
Temperature (° C)	Very Light Snow	Light Snow	Moderate Snow	Heavy Snow	Total
above 0	5.8%	2.3%	3.2%	0.3%	**11.7%**
0 to -3	14.3%	5.6%	6.7%	0.9%	**27.5%**
below -3 to -14	29.9%	11.0%	13.1%	1.8%	**55.6%**
below -14 to -25	3.2%	0.9%	1.0%	0.1%	**5.2%**
below -25	0.0%	0.0%	0.0%	0.0%	**0.0%**
Total	**53.2%**	**19.9%**	**24.0%**	**3.0%**	**100.0%**

PRECIPITATION RATE LIMITS FOR THE EVALUATION OF FLUID HOLDOVER TIMES

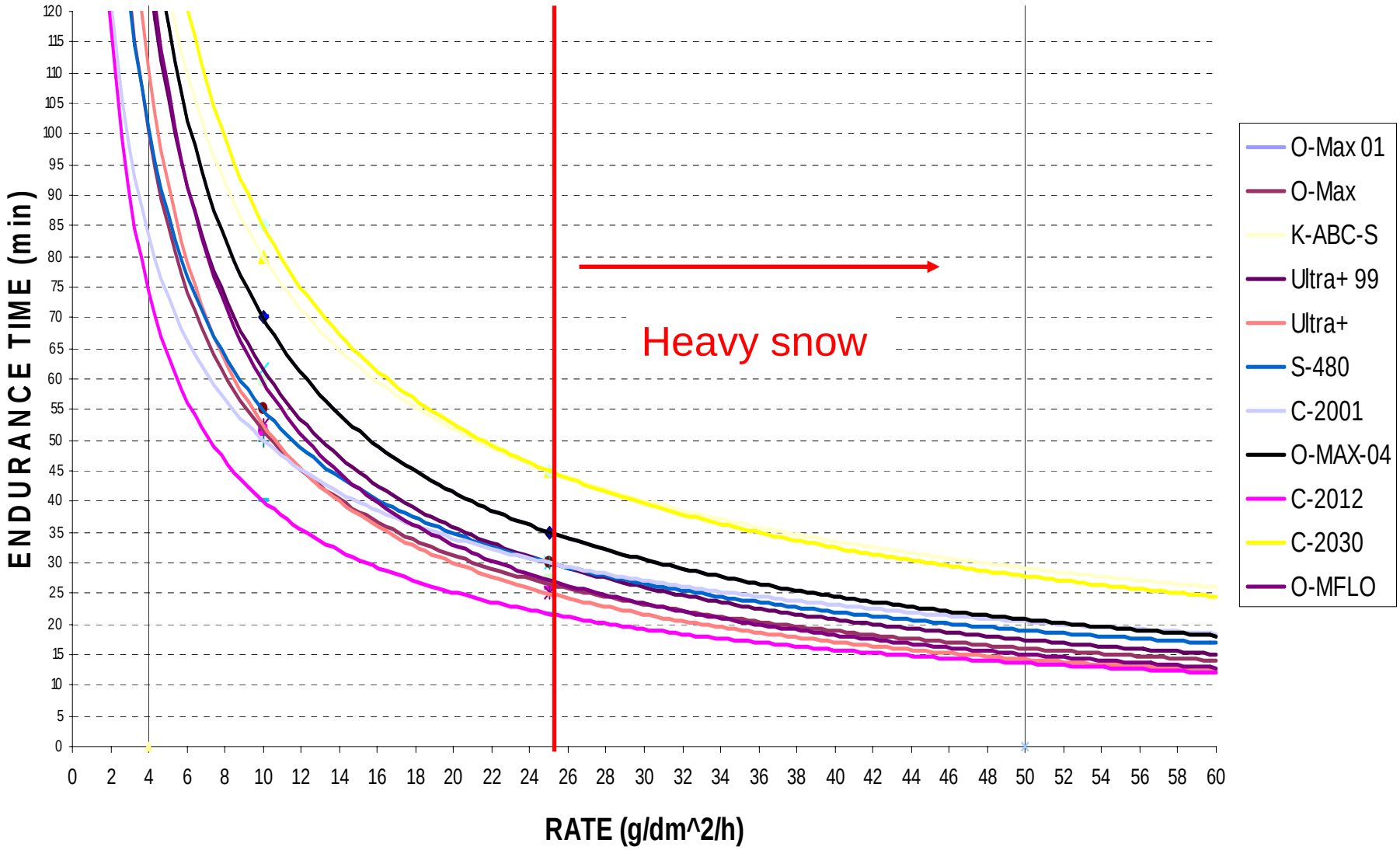


METHOD OF DATA ANALYSIS

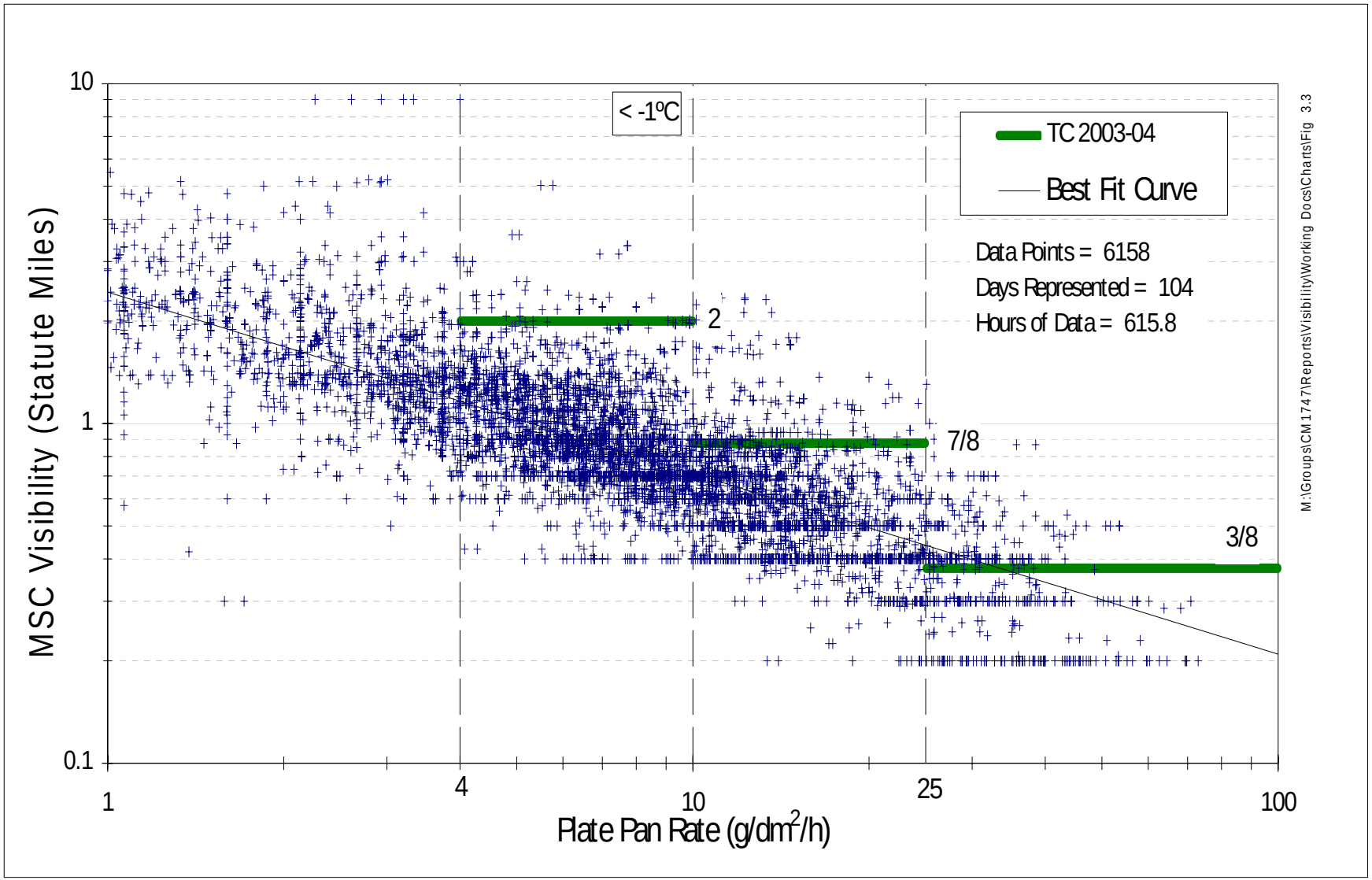
Regression analysis that provides a power law relationship is used for each fluid and each dilution for each weather condition



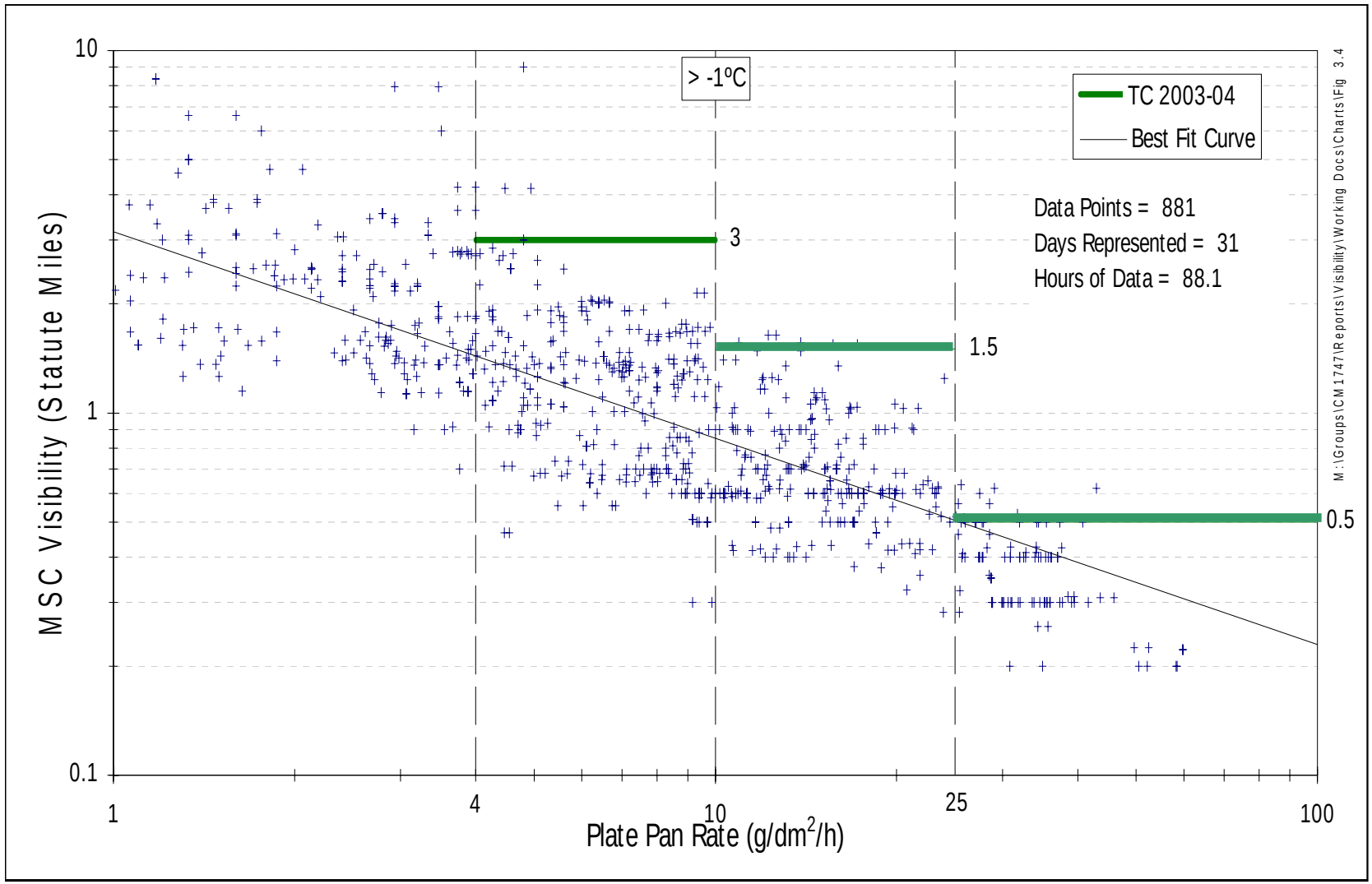
TIV NEAT FLUID, SNOW, -3 C TO -14 C



2003-04 TC VISIBILITY BOUNDARIES BELOW -1°C



2003-04 TC VISIBILITY BOUNDARIES ABOVE -1°C



PRECIPITATION RATE

VERSUS

VISIBILITY

ACTUAL REPORTED EVENT - YUL

16 DECEMBER 2005 1137Z

Reported Temperature, Precipitation: -8.0°C, Snow
Snow intensity based on reported METAR visibility (1/2): Moderate

APS Calculated rate of precipitation: 74.3 g/dm^2/h
Snow intensity based on rate: Heavy

HOLDOVER TIME TABLES (MODERATE)

Type IV: 25 to 55
Type I: 4 to 6

ACTUAL HOLDOVER TIME BASED ON RATE

Type IV: +/- **10**
Type I: +/- **2**

APS Aviation Inc.

AREA OF CONCERN

- At the high rates of precipitation experienced in heavy snow conditions, any deviation from an accurate assessment of the snow intensity could have detrimental effects

- True significance of Heavy Snow Rates:

  - 25 g/dm^2/h is equivalent to 2.5 mm of water or 2.5 cm of snow per hour
  - 50 g/dm^2/h is equivalent to 5 mm of water or 5 cm of snow per hour
  - 75 g/dm^2/h is equivalent to 7.5 mm of water or 7.5 cm of snow per hour

DATA COLLECTION TO EXAMINE FLIGHT CREW DECISIONS IN WINTER OPERATING CONDITIONS

OPERATIONAL DATA COLLECTION

- Objective: To gather operational information to evaluate actual flight crew de/anti-icing fluid decisions in comparison to optimal decisions based on scientific measurements
  - November 2004 to April 2005
  - November 2005 to April 2006
- Data for 1459 departures at YUL were collected

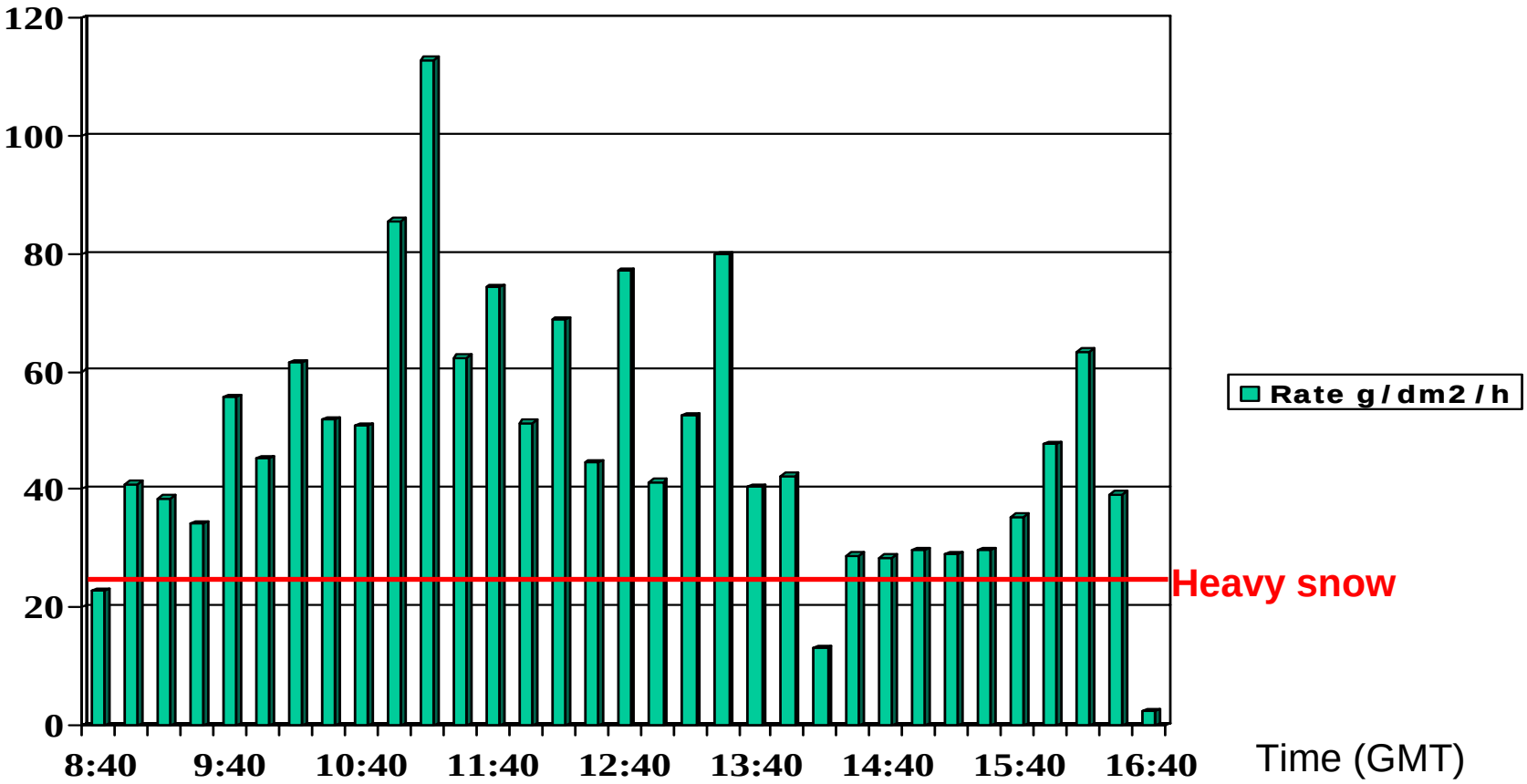
APS Aviation Inc.

DECEMBER 16, 2005

- Heavy snow conditions prevailed at YUL for nearly 8 consecutive hours
  - 0855Z to 1640Z
  - Rates between 29 g/dm^2/h and 113 g/dm^2/h
- Data for 33 departures at YUL were collected

APS Aviation Inc.

DECEMBER 16, 2005



EXAMPLE – EXCEEDED HOLDOVER TIME

16 DECEMBER 2005

Narrowbody
METAR Temperature, Precipitation: -6.0°C, +Snow
METAR Visibility: 1/8 SM
Calculated rate of precipitation: 50.2 g/dm^2/h
Fluid treatment: Type IV
Current holdover time table range (MS): 25 to 55 minutes
Aircraft heldover time: 45 minutes

HOLDOVER TIME BASED ON RATE

Type IV: 15 minutes

APS Aviation Inc.

EXAMPLE – EXCEEDED HOLDOVER TIME

16 DECEMBER 2005

Narrowbody
METAR Temperature, Precipitation: -7.0°C, Snow BLSN
METAR Visibility: 1/2 SM
Calculated rate of precipitation: 77.1 g/dm^2/h
Fluid treatment: Type IV
Current holdover time table range (MS): 25 to 55 minutes
Aircraft heldover time: 20 minutes

HOLDOVER TIME BASED ON RATE

Type IV: 10 minutes

APS Aviation Inc.

UNDERSTANDING THE PROBLEM

Calculated rate of precipitation: 77.1 g/dm^2/h

Aircraft heldover time: 20 minutes

HOLDOVER TIME BASED ON RATE: 10 minutes

Typical Stabilized Type IV Fluid Film Thickness: 1 to 2 mm

Snowfall during heldover time of aircraft: 2.57 mm LWC

Ice Pellets

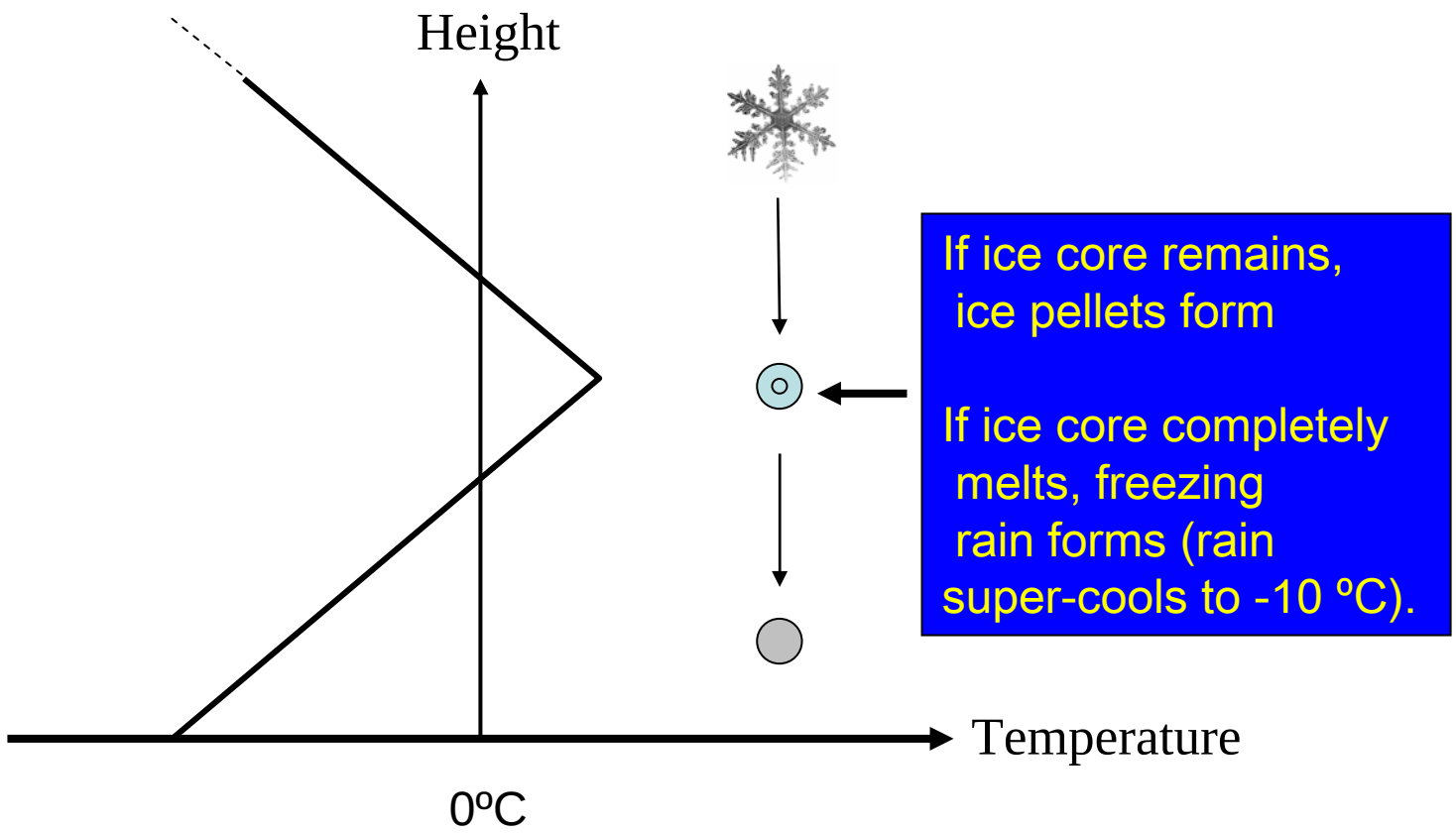
"A type of precipitation consisting of transparent or translucent pellets of ice, 5 mm or less in diameter. They may be spherical, irregular, or (rarely) conical in shape. Ice pellets usually bounce when hitting hard ground and make a sound upon impact."

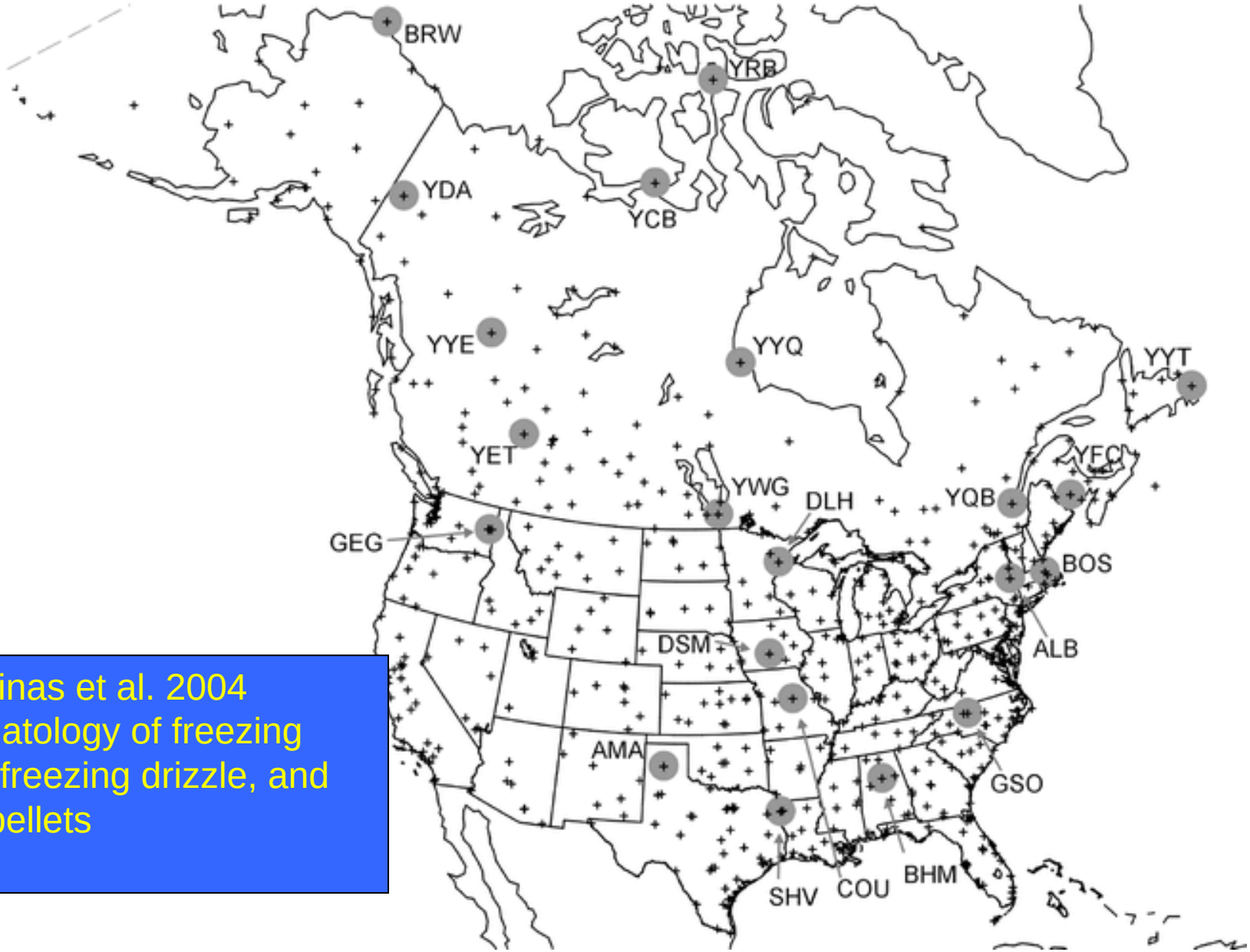
AMS *Glossary of Meteorology*

Ice pellets are most often formed by the freezing of raindrops.
As a result, size distribution of ice pellets similar to that of rain.

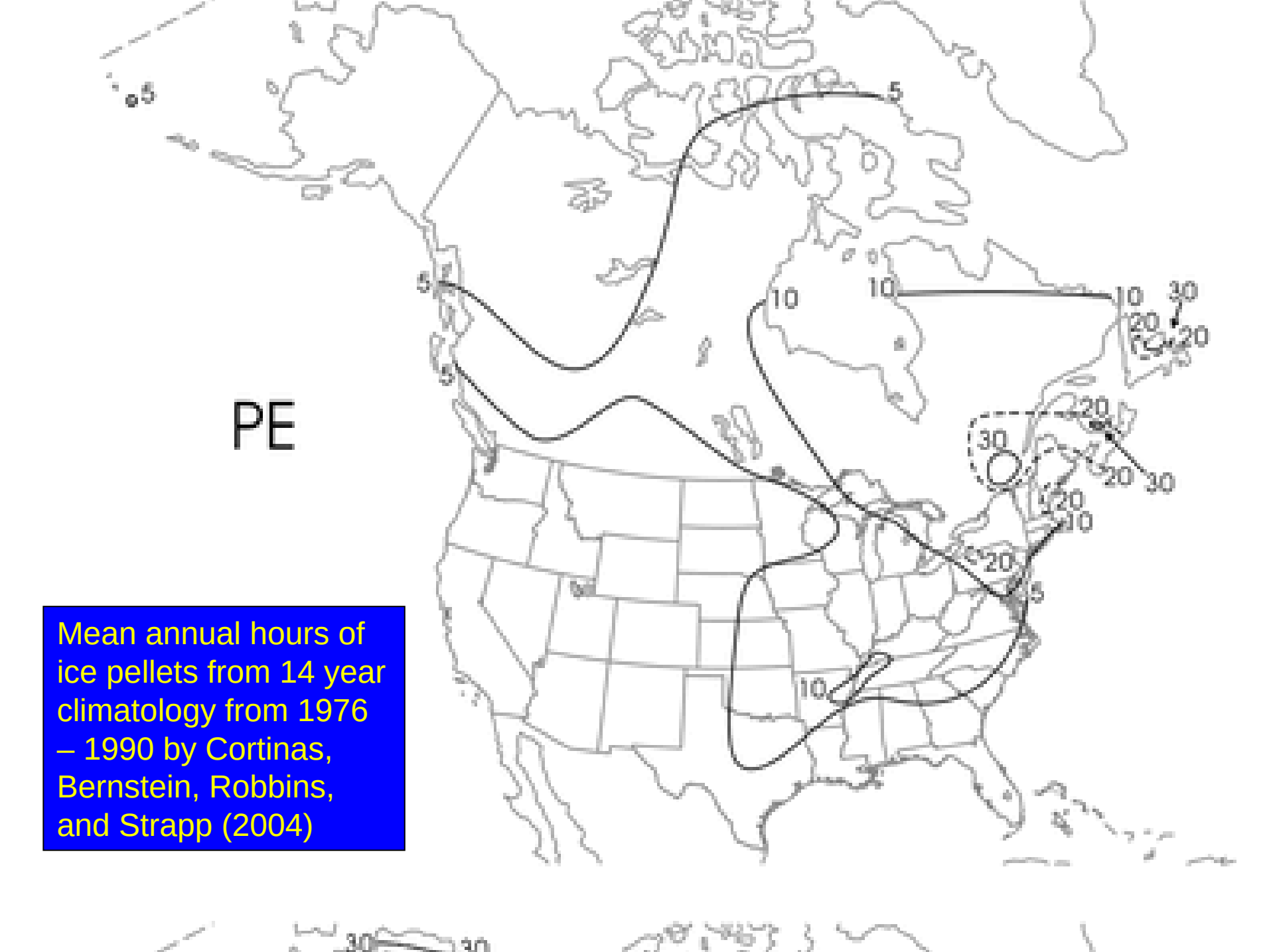
Ice Pellet Formation

Vertical Temperature Profile:

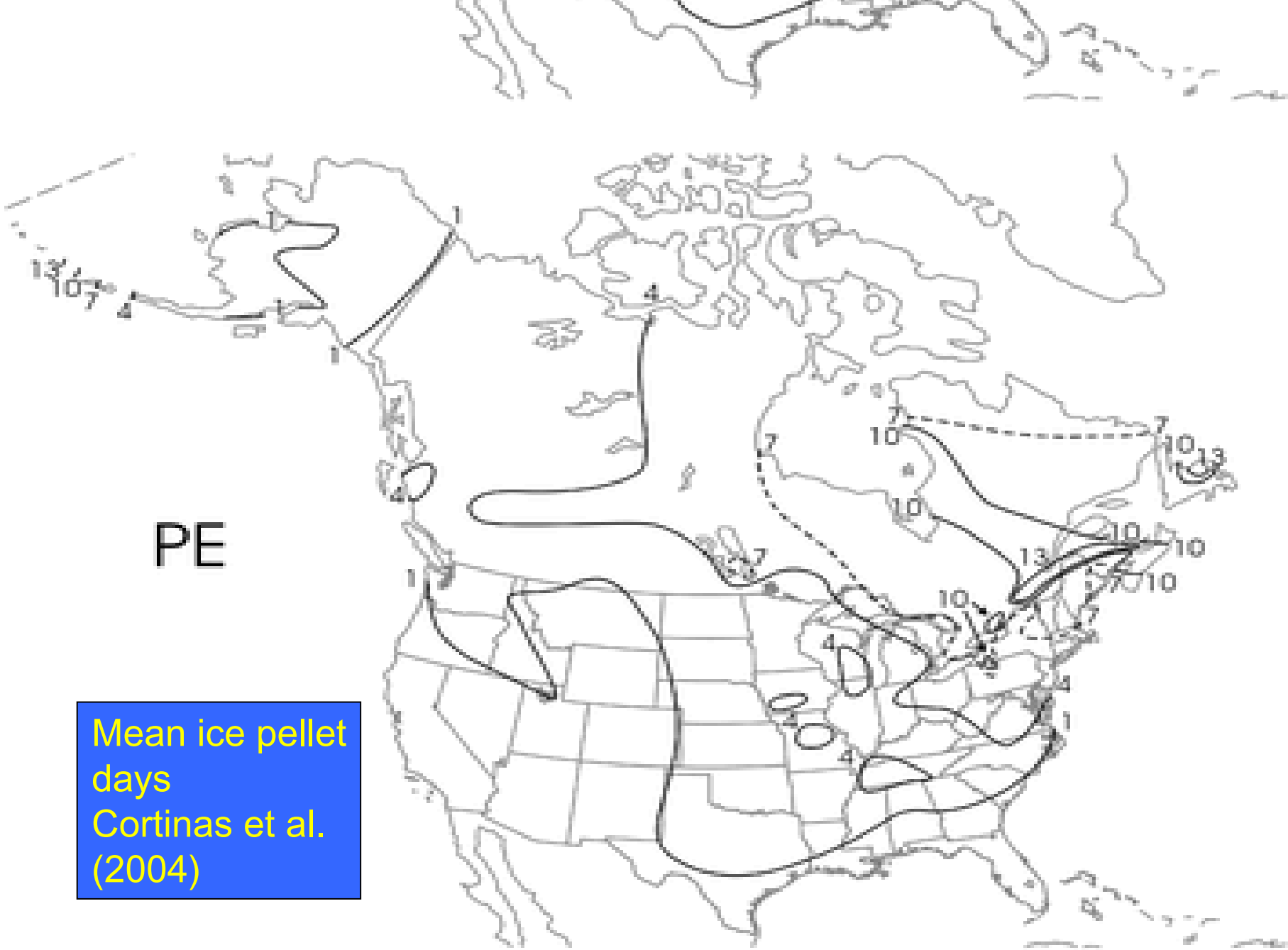




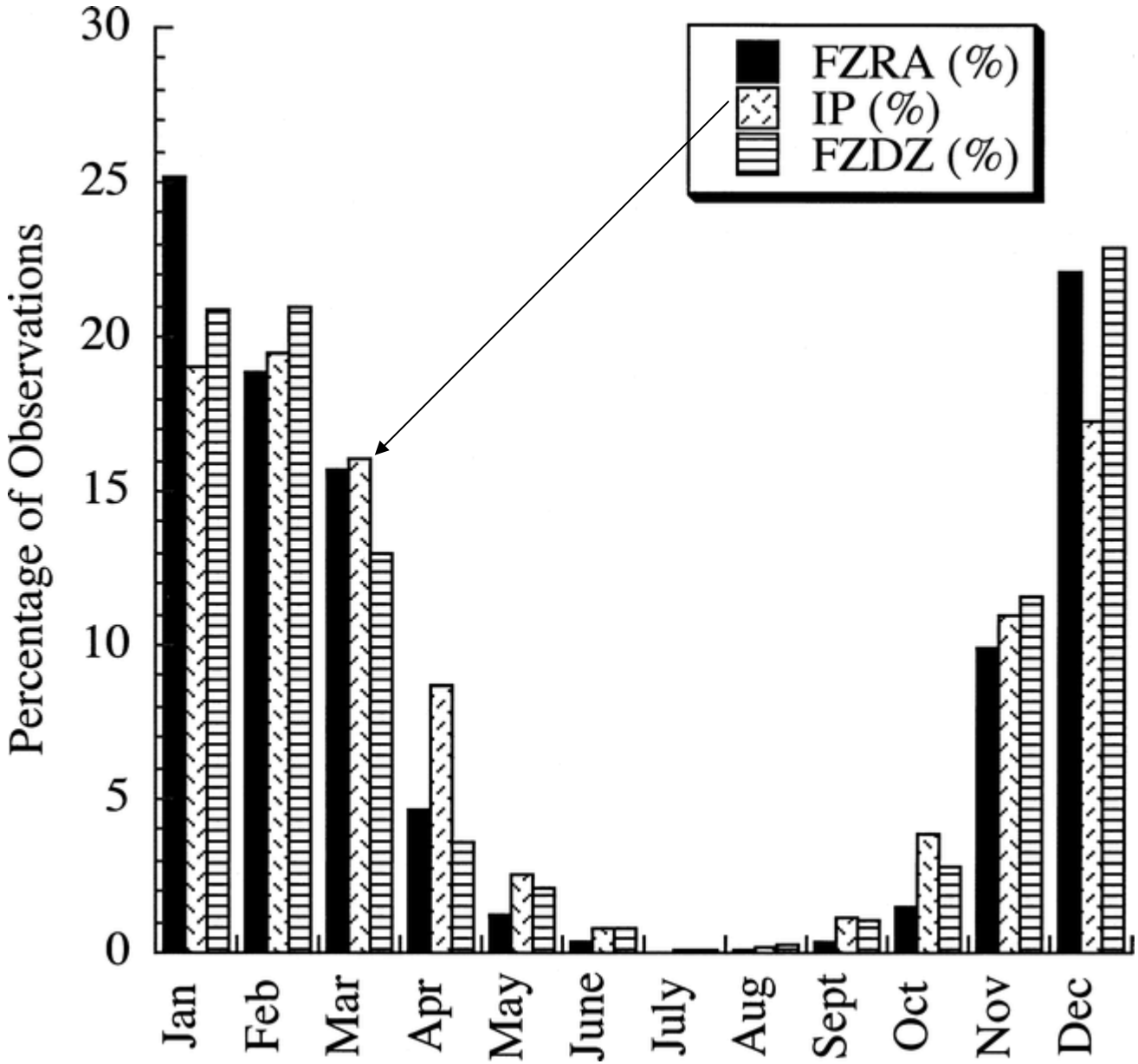
Cortinas et al. 2004
Climatology of freezing rain,freezing drizzle, and ice pellets

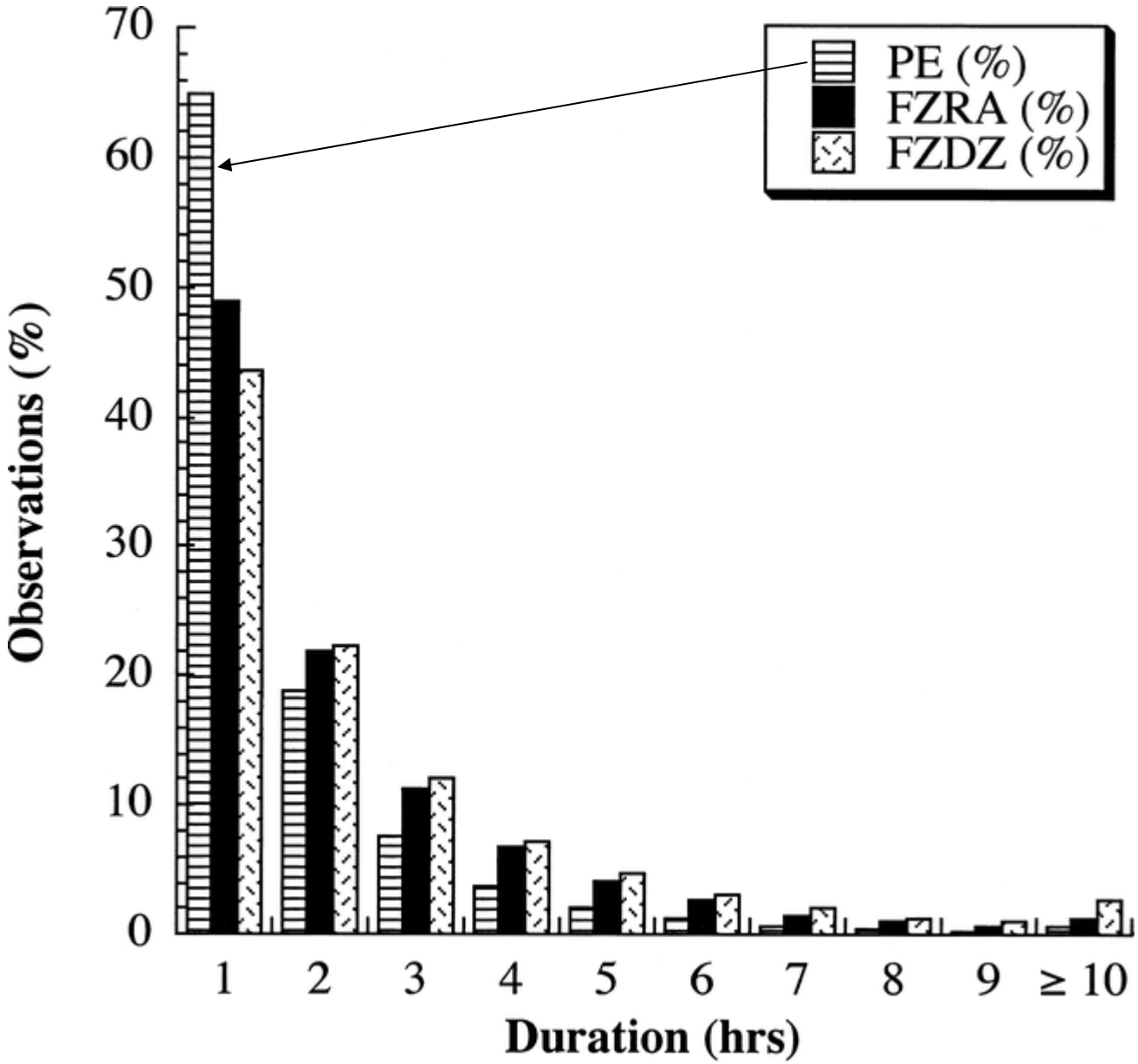


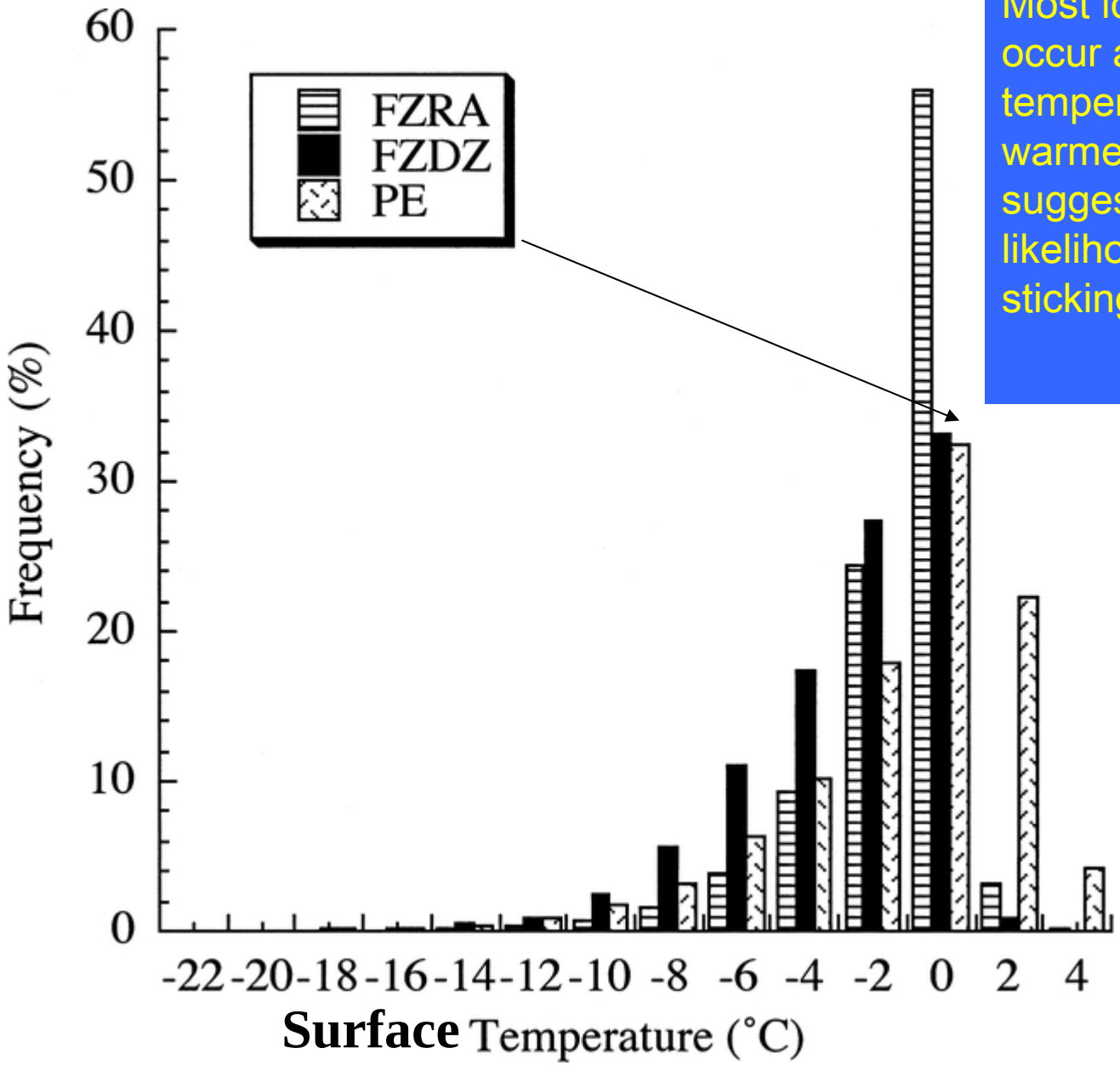
Mean annual hours of ice pellets from 14 year climatology from 1976 – 1990 by Cortinas, Bernstein, Robbins, and Strapp (2004)



Mean ice pellet days
Cortinas et al. (2004)


FZRA (%)
IP (%)
FZDZ (%)
Percentage of Observations
0
5
10
15
20
25
30
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec


PE (%)
FZRA (%)
FZDZ (%)
Observations (%)
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
≥ 10
Duration (hrs)



Most ice pellets occur at temperatures warmer than 0 ºC, suggesting high likelihood of sticking to a wing!

% of Mixed Observations

- TABLE 1. Frequency (%) of concurrent precipitation observations. Columns may not add up to 100% since more than one type of precipitation can be reported (FZRA, freezing rain; FZDZ, freezing drizzle; PE, ice pellets; DZ, drizzle; RA, rain; SN, snow; T, thunder; none, no other precipitation type)

	FZRA (%)	FZDZ (%)	PE (%)	SP(%)
FZRA	-	1	18	1.4
FZDZ	2	-	3	1.5
PE	18	2	-	1.4
DZ	0	0	1	1.2
RA	0	1	18	11.5
SN	14	24	37	8.3
Thunder	1	0	1	0
Hail	0	0	0	0.05
Snow pellets	0	0	0	-
None	69	73	30	75

Intensity of ice pellets or rain

Intensity	Criteria
Light	Up to 25 g/d^2/hr
Moderate	25 to 75 g/d^2/hr
Heavy	Greater than 75 g/d^2/hr

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Office of the Federal Coordinator for Meteorological Services and Supporting Research

Estimating Intensity of ice pellets

(typically used by observers since ASOS does not automatically sense ice pellet type or rate)

Intensity	Criteria
Light	Scattered pellets that do not completely cover an exposed surface regardless of duration. Visibility is not affected.
Moderate	Slow accumulation of the ground. Visibility reduced by ice pellets to less than 7 statute miles
Heavy	Rapid accumulation on ground. Visibility reduced by ice pellets to less than 3 statute miles

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Ice pellet rates estimated by visibility need to be verified!

Example: Ice pellet event occurred at Montreal, Dorval airport on January 18, 2006 (last week) from 0128 to 0200 UTC

Estimated intensity: Light
Estimate visibility: 10-15 statute miles

Actual mass accumulation: 50 g/d^2/hr (measured in a pan by APS Aviation)
Actual intensity based on this rate: Moderate

Thus, the actual rate was likely twice the estimated rate by visiblity!
(light by visibility, moderate by rate)

Possible cause for this descrepancy: Difference in visibility between day and night.

Event occurred at night, when the visibility is twice as high, thus the 10-15 mile visibility should actually have been 5-7 miles, which is moderate intensity.

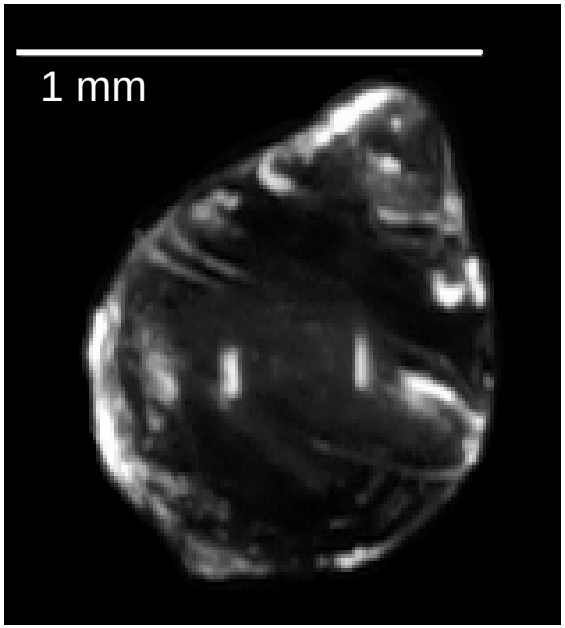
Overall Summary

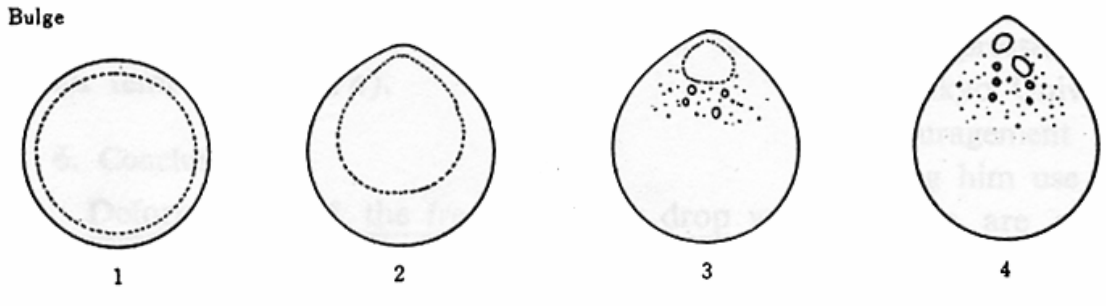
Ice pellet weather events occur during warm fronts due to partial snow melting and re-freezing in a cold layer below a warm nose

Ice pellet even duration is usually < one hour with a surface temperature > 0 C. This suggests that ice pellets are highly likely to adhere to a wing surface.

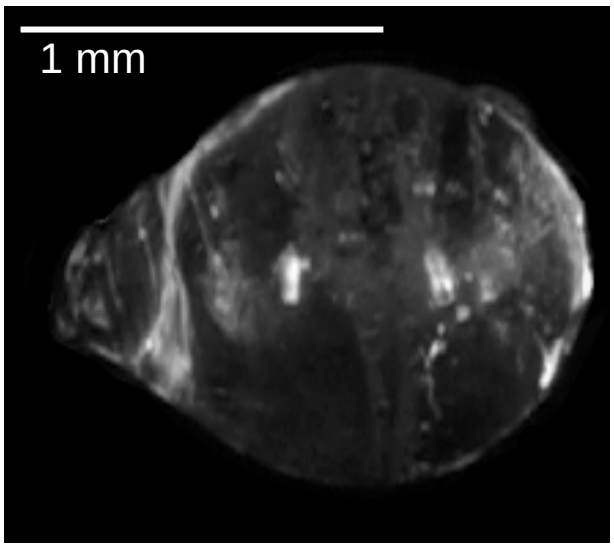
Ice pellet intensity is usually done by an observer using visibility as a criteria for rate. Ice pellet case from Montreal last week suggests that ice pellet rates may be under estimated using visibility, thus a careful evaluation of the technique to estimate ice pellet rate needs to be done.

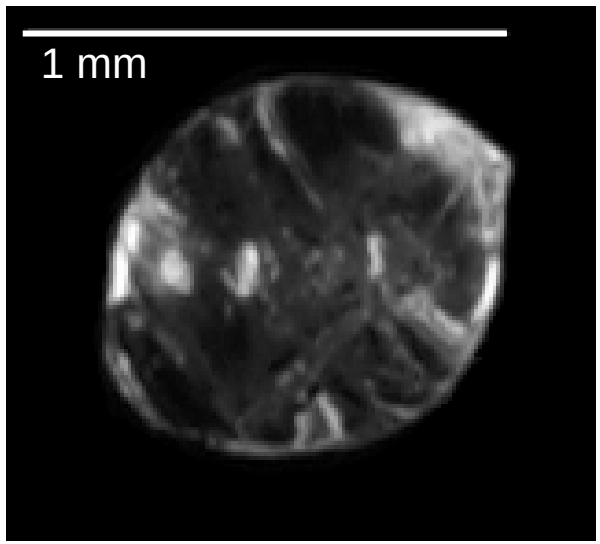
Particles with Bulges – 250 cases

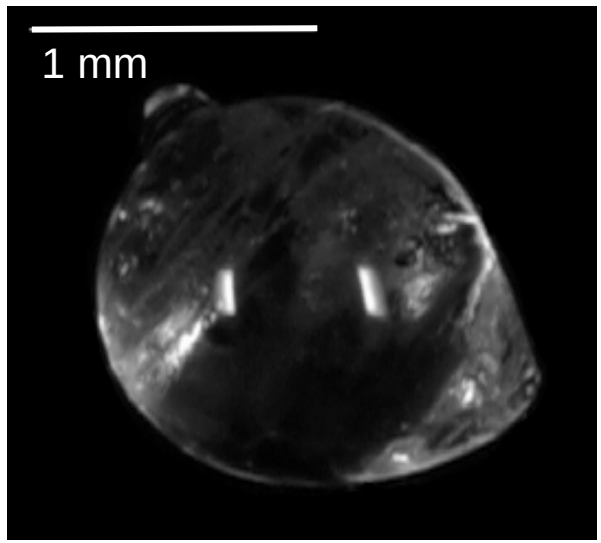




Source: Takahashi (1975)







Summary

The images of 1023 particles were analyzed from a 4 hour ice pellet event:

- Average size of 1 mm.
- At most 15% of the particles were spherical.
- Most ice pellets were bulged, fractured, irregular or had spicules.
- Approximately 9% of the particles were aggregates with between 2 and 5 components.

Overall Summary

Ice pellet weather events occur during warm fronts due to partial snow melting and re-freezing in a cold layer below a warm nose

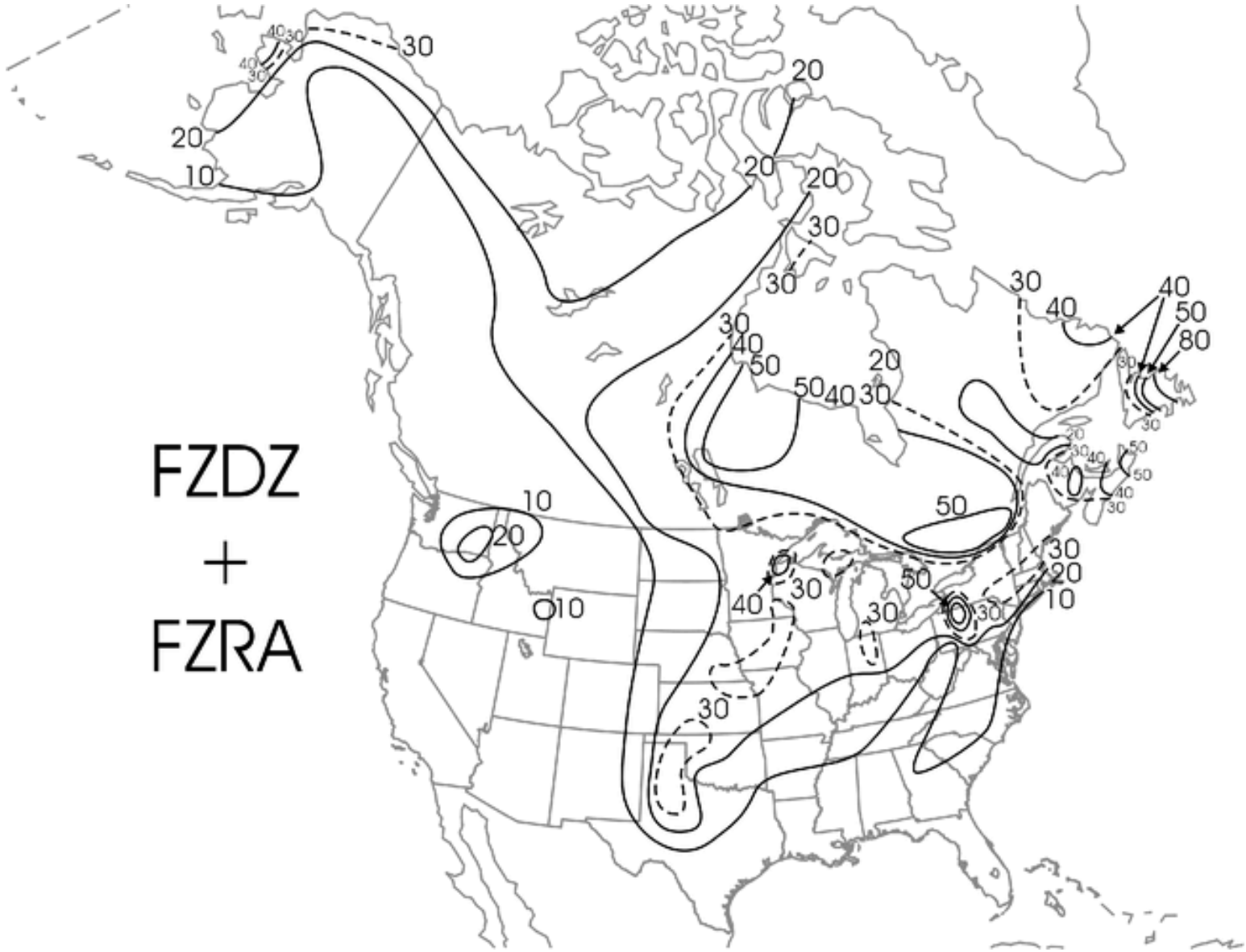
Ice pellet even duration is usually < one hour with a surface temperature > 0 C. This suggests that ice pellets are highly likely to adhere to a wing surface.

Ice pellet intensity is usually done by an observer using visibility as a criteria for rate. Ice pellet case from Montreal last week suggests that ice pellet rates may be under estimated using visibility, thus a careful evaluation of the technique to estimate ice pellet rate needs to be done.

Concluding Remarks

Some preliminary points can be made in terms of the formation of ice pellets during this event:

- Many appear to be formed by freezing from the outside in.
- Some particles join to form aggregates, others do not at the same time.
- Variety of shapes and formation mechanisms present simultaneously at the surface.


FZDZ
+
FZRA

Visibility Based Snowfall Chart

Modified Visibility Criteria for Snow Intensity Based on Temperature

Day or Night

TABLE 7. SNOWFALL INTENSITIES AS A FUNCTION OF VISIBILITY

Time of Day	Temp. (°C)	Temp. (°F)	Visibility (Statute Mile) ≥1 1/4	1	3/4	1/2	≤1/4	Snowfall Intensity
Day	≤-1	≤ 30	Light	Light	Light	Moderate	**Heavy**	
	> 1	> 30	Light	Light	Moderate	**Heavy**	**Heavy**	
Night	≤ -1	≤ 30	Light	Light	Moderate	**Heavy**	**Heavy**	
	> -1	> 30	Light	Moderate	**Heavy**	**Heavy**	**Heavy**	

NOTE: **Based upon technical report, "The Estimation of Snowfall Rate Using Visibility,"**

Rasmussen, et al., Journal of Applied Meteorology, October 1999.

FAA TYPE I HOLDOVER TIME GUIDELINE

Table 1. FAA Guideline for Holdover Times Anticipated for SAE Type I Fluid Mixture as a Function of Weather Conditions and OAT.

CAUTION: THIS TABLE IS FOR DEPARTURE PLANING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature (**OAT**)		**Approximate Holdover Times Under Various Weather Conditions (hours: minutes)**								
°C	**°F**	**Active Frost**	**Freezing Fog**	**Very Light Snow◆◆**	**Light Snow◆◆**	**Moderate Snow◆◆**	****Freezing Drizzle**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other‡**
-3 and above	27 and above	0:45	0:11 - 0:17	0:18-0:22	0:11 - 0:18	0:06 - 0:11	0:09 - 0:13	0:02 - 0:05	0:02 - 0:05*	CAUTION: No holdover time guidelines exist
below -3 to –6	below 27 to 21	0:45	0:08 - 0:13	0:14-0:17	0:08 - 0:14	0:05 - 0:08	0:05 - 0:09	0:02 - 0:05	CAUTION: Clear ice may require touch for confirmation	
below -6 to –10	below 21 to 14	0:45	0:06 - 0:10	0:11-0:13	0:06 - 0:11	0:04 - 0:06	0:04 - 0:07	0:02 - 0:05		
below -10	below 14	0:45	0:05 - 0:09	0:07-0:08	0:04 - 0:07	0:02 - 0:04				