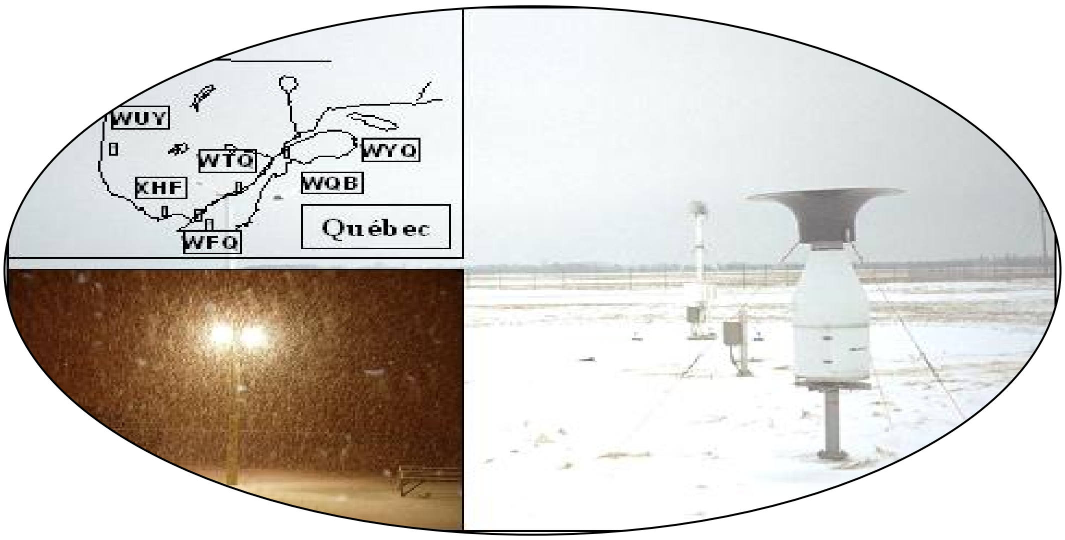
TP 14715E

# Winter Weather Impact on Holdover Time Table Format (1995-2006)




*Prepared for*
**Transportation Development Centre**

*In cooperation with*

Civil Aviation
Transport Canada

*Prepared by*

APS Aviation Inc.

October 2006
Final Version 1.0

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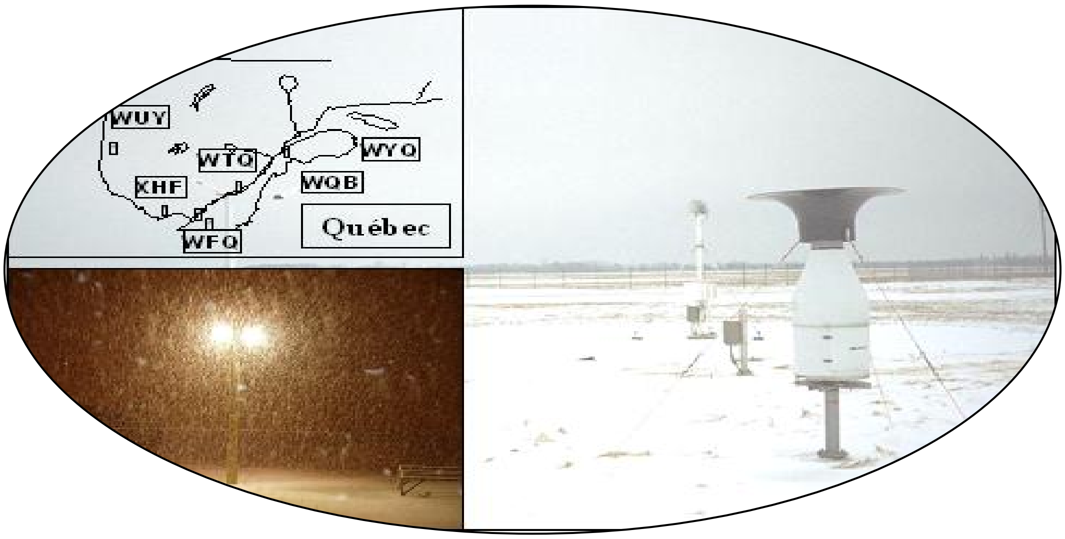


*by*

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APS Aviation Inc.

October 2006
Final Version 1.0

The contents of this report reflect the views of APS Aviation Inc. and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

The Transportation Development Centre does not endorse products or manufacturers. Trade or manufacturers' names appear in this report only because they are essential to its objectives.

## DOCUMENT ORIGIN AND APPROVAL RECORD

| | | |
|---|---|---|
| Prepared by: | David Youssef<br>Project Analyst | November 17, 2017<br>Date |
| Reviewed by: | John D'Avirro, Eng<br>Program Manager | November 17, 2017<br>Date |

Approved by: Jean Valiquette, President, APS Aviation Inc.

This report was prepared and signed by David Youssef, reviewed and signed by John D'Avirro, and approved and signed by Jean Valiquette in October 2006 as part of the first submission to Transport Canada (Final Draft 1.0). A final Transport Canada technical and editorial review was completed in September 2017; Jean Valiquette was not available to participate in the final review or to sign the current version of this report.

Un sommaire français se trouve avant la table des matières.

## PREFACE

Under contract to the Transportation Development Centre of Transport Canada, APS Aviation Inc. (APS) has undertaken a research program to advance aircraft ground de/anti-icing technology. The specific objectives of the APS test program are the following:

- To develop holdover time data for all newly-qualified de/anti-icing fluids;
- To evaluate whether holdover times should be developed for ice pellet conditions;
- To examine the effect of heated fluids on Type II/III/IV fluid endurance times;
- To evaluate if it is appropriate to apply fluid with a -3°C buffer (fluid with a freeze point 3°C above the ambient temperature) for the 1st step of a two-step application;
- To evaluate weather data from previous winters to establish a range of conditions suitable for the evaluation of holdover time limits;
- To assist in the testing of flow of contaminated fluid from aircraft wings during takeoff;
- To validate the laboratory snow test protocol with Type II and IV fluids;
- To develop performance specifications for an integrated weather system that measures holdover time;
- To provide support for the development of a standard that evaluates remote on-ground ice detection systems;
- To conduct general and exploratory de/anti-icing research;
- To conduct endurance time tests on non-aluminum plates; and
- To conduct endurance time tests in frost on various test surfaces.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2005-06 are documented in nine reports. The titles of the reports are as follows:

- TP 14712E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2005-06 Winter;
- TP 14713E Aircraft Deicing Research in Natural and Simulated Ice Pellet Conditions: Volume I and Volume II;
- TP 14714E Evaluation of Fluid Freeze Points in First-Step Application of Deicing Fluids;
- TP 14715E Winter Weather Impact on Holdover Time Table Format (1995-2006);
- TP 14716E Falcon 20 Trials To Examine Fluid Removed From Aircraft During Takeoff With Ice Pellets;
- TP 14717E Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2005-06;
- TP 14718E Implementation of Holdover Time Determination Systems;

- TP 14719E Aircraft Ground Icing Research General Activities During the 2005-06 Winter; and
- TP 14720E Aircraft Ground Deicing Fluid Endurance Times on Composite Surfaces.

In addition, the following two interim reports are being written:

- *Effect of Heat on Endurance Times of Anti-Icing Fluids; and*
- *Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions.*

This report, TP 14715E, has the following objective:

- To review the Holdover Time Table format using Winter Weather Data.

This objective was met by acquiring and analysing winter weather data from six meteorological stations in Quebec, Canada. This information was used to review and assess the format of the holdover time tables.

This research project has been funded by the Civil Aviation Group of Transport Canada.


## PROGRAM ACKNOWLEDGEMENTS

This multi-year research program has been funded by the Civil Aviation Group, Transport Canada with support from the Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City, NJ. This program could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Transportation Development Centre of Transport Canada, the Federal Aviation Administration, National Research Council Canada, the Meteorological Service of Canada, and several fluid manufacturers.

APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: George Balaban, Katrina Bell, Kim Bendickson, Stephanie Bendickson, Nicolas Blais, Michael Chaput, Sami Chebil, John D’Avirro, Jan Goraczkowski, Chris McCormack, Rob Petermann, Marco Ruggi, Joey Tiano, Larry Turner, and David Youssef.

Special thanks are extended to Barry Myers, Frank Eyre and Yagusha Bodnar, who on behalf of the Transportation Development Centre, have participated, contributed and provided guidance in the preparation of these documents.

## PROJECT ACKNOWLEDGEMENTS

The author of this report would like to acknowledge and thank the Meteorological Service of Canada for their diligence and commitment in providing all weather data required for this project.

Transport Canada　Transports Canada

# PUBLICATION DATA FORM

| | | |
|---|---|---|
| 1. Transport Canada Publication No.<br>TP 14715E | 2. Project No.<br>B14W | 3. Recipient's Catalogue No. |
| 4. Title and Subtitle<br>Winter Weather Impact on Holdover Time Table Format (1995-2006) | | 5. Publication Date<br>October 2006<br>6. Performing Organization Document No.<br>CM 2020.002 |
| 7. Author(s)<br>David Youssef | | 8. Transport Canada File No.<br>2450-BP-14 |
| 9. Performing Organization Name and Address<br>APS Aviation Inc.<br>6700 Cote-de-Liesse, Suite 102<br>Montreal, Quebec H4T 2B5<br>Canada | | 10. PWGSC File No.<br>TOR-4-37170<br>11. PWGSC or Transport Canada Contract No.<br>T8156-140243/001/TOR |
| 12. Sponsoring Agency Name and Address<br>Transportation Development Centre (TDC)<br>Transport Canada<br>330 Sparks St., 25th Floor<br>Ottawa, Ontario K1A 0N5<br>Canada | | 13. Type of Publication and Period Covered<br>Final<br>14. Project Officer<br>Antoine Lacroix |

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

Several research reports for testing of de/anti-icing technologies were produced for previous winters on behalf of Transport Canada. These are available from the Transportation Development Centre (TDC). Nine reports (including this one) were produced as part of this winter's research program. Their subject matter is outlined in the preface. This research project has been funded by the Civil Aviation Group of Transport Canada.


16. Abstract

This study examines the frequency of occurrence of the various winter weather conditions experienced during ground deicing of aircraft with a view to recommending and supporting immediate and future changes to the format of the holdover time tables for SAE Type I, II and IV anti-icing fluids.

Data were acquired from Meteorological Service of Canada (MSC) for six automated weather stations in the province of Quebec, Canada. A total of 7,563 hours of snowstorm data recorded between 1995-96 and 2005-06 and 511 hours of freezing rain and freezing drizzle data were analysed. The data set included 1,015 hours of snowstorm data from the 2005-06 winter.

In addition, data from an extensive hourly observation weather information database for Montreal was analysed in an attempt to determine the frequency of occurrence of ice pellet conditions. The observation period was from January 1, 1990 to December 31, 2001. It was found that the ice pellet occurrences accounted for less than two percent of all precipitation conditions during the winter months. Another dataset collected over the 2004-05 and 2005-06 winter seasons included 44 hours of ice pellet conditions; the results of this analysis indicate that the intensity of ice pellets is less than 25 g/dm²/h 87 percent of the time.

This report contains recommendations to continue the weather surveys.


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|---|---|
| 17. Key Words<br>Natural snow, precipitation rates, weather data, holdover time table format, frequency and distribution of deicing operations | 18. Distribution Statement<br>Limited number of copies available from the Transportation Development Centre |

| 19. Security Classification (of this publication) | 20. Security Classification (of this page) | 21. Declassification (date) | 22. No. of Pages | 23. Price |
|---|---|---|---|---|
| Unclassified | Unclassified | — | xvi, 58 apps | — |

CDT/TDC 79-005
Rev. 96



Canada

Transports Canada | Transport Canada

# FORMULE DE DONNÉES POUR PUBLICATION

| | | |
|---|---|---|
| 1. N° de la publication de Transports Canada<br>TP 14715E | 2. N° de l'étude<br>B14W | 3. N° de catalogue du destinataire |
| 4. Titre et sous-titre<br>Winter Weather Impact on Holdover Time Table Format (1995-2006) | | 5. Date de la publication<br>Octobre 2006<br>6. N° de document de l'organisme exécutant<br>CM 2020.002 |
| 7. Auteur(s)<br>David Youssef | | 8. N° de dossier - Transports Canada<br>2450-BP-14 |
| 9. Nom et adresse de l'organisme exécutant<br>APS Aviation Inc.<br>6700 Côte-de-Liesse, Suite 102<br>Montréal, Québec H4T 2B5<br>Canada | | 10. N° de dossier - TPSGC<br>TOR-4-37170<br>11. N° de contrat - TPSGC ou Transports Canada<br>T8156-140243/001/TOR |
| 12. Nom et adresse de l'organisme parrain<br>Centre de développement des transports (CDT)<br>Transport Canada<br>330 Sparks St., 25th Floor<br>Ottawa, Ontario K1A 0N5<br>Canada | | 13. Genre de publication et période visée<br>Final<br>14. Agent de projet<br>Antoine Lacroix |

15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)

Plusieurs rapports de recherche d'années antérieures sur les essais de technologies de dégivrage et d'antigivrage ont été produits pour le compte de Transports Canada. Ils sont disponibles du Centre de développement des transports (CDT). Le programme de la saison hivernale a donné lieu à neuf rapports (dont celui-ci). On trouvera dans la préface l'objet de ces rapports. Ce projet de recherche a été financé par l'Aviation civile de Transports Canada.

16. Résumé

La présente étude examine la fréquence des différents événements météorologiques hivernaux qui se produisent durant le dégivrage d'aéronefs au sol, dans le but de recommander et d'appuyer des changements immédiats et futurs au format des tableaux d'efficacité des liquides d'antigivrage de types I, II et IV de la SAE.

Les données, obtenues auprès du Service météorologique du Canada (SMC), provenaient de six stations météorologiques automatisées situées au Québec, Canada. Un total de 7 563 heures de données de précipitations neigeuses, enregistrées entre 1995-96 et 2005-06, et plus de 511 heures de données de pluie et bruine verglaçante, ont été analysées. Sont comprises dans l'ensemble de données plus de 1,015 heures de données de précipitations neigeuses recueillies au cours de l'hiver 2005-06.

De plus, les données d'une base de données complète d'observations météorologiques horaires pour Montréal ont été analysées pour établir la fréquence de conditions de granules de glace. La période d'observation était du 1er janvier 1990 au 31 décembre 2001. L'étude a démontré que les cas de granules de glace représentaient moins de deux pourcent de toutes les conditions de précipitation des mois d'hiver. Un autre ensemble de données recueillies au cours des sessions l'hiver 2004-06 et 2005-06 contenait 44 heures de conditions de granules de glace; les résultats de cette analyse démontrent que l'intensité des granules de glace est inférieure à 25 g/dm²/h, 87 pourcent du temps.

Ce rapport comprend des recommandations afin de faire suite aux enquêtes météorologiques.

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| 17. Mots clés<br>Neige naturelle, taux de précipitation, données météorologiques, tableau de durées d'efficacité, fréquence et répartition des opérations de dégivrage. | 18. Diffusion<br>Le Centre de développement des transports dispose d'un nombre limité d'exemplaires. |

| 19. Classification de sécurité (de cette publication) | 20. Classification de sécurité (de cette page) | 21. Déclassification (date) | 22. Nombre de pages | 23. Prix |
|---|---|---|---|---|
| Non classifiée | Non classifiée | — | xvi, 58 ann. | — |

CDT/TDC 79-005
Rev. 96



Canada

# EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC), APS Aviation Inc. (APS) undertook a study to evaluate precipitation data (precipitation rate/temperature data) from several winters to confirm the suitability of precipitation rate ranges used for holdover time (HOT) evaluation.

In addition, information collected from other research that relates to winter weather data has been compiled and is included in this report.

The information contained in this report can be used to further evaluate potential refinements to the format of the HOT tables.

## Description and Processing of Data

A total of 7,563 hours of storm data points were developed from precipitation gauge logs for natural snow, including 1 015 hours from the 2005-06 data. Freezing rain/drizzle precipitation events were used to develop 511 hours of data. Data were acquired from Meteorological Service of Canada (MSC) from instruments located at Montreal's Trudeau Airport and five other stations in the province of Quebec, Canada. The data were collected mostly from the winters of 1997-98 to 2005-06.

In addition, data from an extensive hourly observation weather information database for Montreal was analysed in an attempt to determine the frequency of occurrence of ice pellet conditions. The observation period was from January 1, 1990 to December 31, 2001.

## Results and Conclusions

The weather database gathered between 1995-96 and 2005-06 from six sites in Quebec showed that current snow precipitation rate limits of 10 and 25 g/dm$^2$/h are valid for moderate snow. The data analysis concluded that the column representing moderate snow in the HOT table encompasses only 23.9 percent of all snow events. This supports earlier data that led to the introduction of a light snow column in the Type I HOT table for precipitation rates of 4 to 10 g/dm$^2$/h. This column was used starting in the 2002-03 winter seasons.

Most snowfall events occur at rates less than 4 g/dm$^2$/h. A survey of actual winter operations conducted between 2000-01 and 2002-03 at a number of airports worldwide showed that snow comprises of 56 percent of all deicing operations. In order to use longer HOT in the light snow column, further introduction of a very light snow column in the Type I HOT table was recommended and accepted at the

2003 SAE G-12 meeting. Also, it was concluded for the Type I HOT table that the temperature row of *-3 C to -10ºC* should be replaced by two new temperature bands, *below -3 C to -6ºC* and *below -6 C to -10°C*. Selection of -6ºC as the temperature break was found to be the most operationally advantageous.

The limited database for freezing rain and drizzle indicates that the current temperature and rate limits for those conditions are valid. However, the database for these conditions is small and additional data would be useful.

The analysis of an hourly observation weather information database for Montreal showed that the ice pellet occurrences accounted for less than two percent of all precipitation conditions during the winter months. The dataset collected over the two winters 2004-05 and 2005-06 seasons included 96 hours of ice pellet conditions. During these two seasons, ice pellets occurred at ambient temperatures ranging from +1 to -9°C. The precipitation rate ranged between 1 and 73 $g/dm^2/h$, with 95 percent of the rates equal to or below 40 $g/dm^2/h$. Precipitation rates above 25 $g/dm^2/h$ represent only 13 percent of all the ice pellet occurrences.

The survey of actual winter operations showed that frost is the second most frequent type of deicing condition, and sufficient attention should be given to investigating and substantiating frost HOT, particularly for Type I fluids.

The format of the HOT tables has undergone several changes over the past five years, both major and minor. Those changes are documented in this report. No major changes were made to the HOT table format in 2005-06.

## Recommendations

The weather data survey has provided useful information and should be continued to generate more data, which is particularly needed for infrequent precipitation conditions such as ice pellets freezing rain and freezing drizzle. Also, discussions between the regulators and industry members are suggested to enable the development and the possible implementation of a proposed HOT table template that could be followed for future HOT testing.

## SOMMAIRE

En vertu d'un contrat avec le Centre de développement des transports (TDC) de Transports Canada (TC), APS Aviation Inc. (APS) a entrepris une étude pour évaluer les données de précipitation (données sur les taux et températures des précipitations) de plusieurs hivers, afin de confirmer la pertinence des plages de taux de précipitation utilisées pour l'évaluation des durées d'efficacité.

De plus, le présent rapport englobe aussi des données colligées à l'occasion d'autres recherches connexes.

L'information contenue dans ce rapport peut servir à évaluer la pertinence d'améliorations possibles à la présentation des tableaux des durées d'efficacité.

### Description et traitement des données

Des points de données de précipitations neigeuses ont été établis à partir de relevés nivométriques couvrant un total de 7 563 heures, dont 1 015 heures pendant l'hiver 2005-06. Des périodes de précipitation de pluie/bruine verglaçante ont servi à générer des points de données couvrant 511 heures. Ces données, obtenues auprès du Service météorologique du Canada (SMC), provenaient d'instruments situés à l'Aéroport Pierre-Elliott-Trudeau, Montréal et de cinq autres stations du Québec, Canada. Les données ne couvraient que les hivers 1997-98 à 2005-06.

De plus, les données d'une base de données complète d'observations météorologiques horaires pour Montréal ont été analysées pour établir la fréquence de conditions de granules de glace. La période d'observation était du 1$^{er}$ janvier 1990 au 31 décembre 2001.

### Résultats et conclusions

La base de données météorologiques recueillie entre 1995-96 et 2005-06 sur six emplacements du Québec a démontré que les limites actuelles de taux de précipitation de neige de 10 et 25 g/dm$^2$/h sont valides dans le cas de neige modérée. L'analyse des données a conclu que la colonne du tableau actuel de durées d'efficacité qui illustre la neige modérée ne couvre que 23.9 pourcent de tous les événements de neige. Cette analyse confirme les données précédentes qui ont mené à l'introduction d'une colonne de neige légère dans le tableau de durées d'efficacité des liquides de type I, pour les taux de précipitation de 4 à 10 g/dm$^2$/h. Cette colonne a servi à partir de la session d'hivers 2002-03.

La plupart des chutes de neige se produisent à un taux inférieur à 4 g/dm$^2$/h. Une étude des opérations hivernales actuelles, menée entre 2000-01 et 2002-03 à un certain nombre d'aéroports à travers le monde, a démontré que la neige fait l'objet

de 56 pourcent de toutes les opérations de dégivrage. Afin d'utiliser de plus grandes durées d'efficacité dans la colonne de neige légère, l'introduction d'une colonne additionnelle de neige très légère au tableau des durées d'efficacité des liquides de type I a été recommandée et acceptée à la réunion de 2003 du G–12 de la SAE. De plus, l'analyse a conclu que, pour le tableau de durées d'efficacité des liquides de type I, la rangée des températures de *-3 à -10ºC* devrait être retirée et remplacée par deux nouvelles rangées, *au-dessous de -3 à -6ºC* et *au-dessous de -6 à -10ºC*. Le choix de -6ºC comme température limite produit le mélange de durées d'efficacité le plus avantageux.

La base de données limitée sur la pluie et la bruine verglaçantes démontre que les limites actuelles de température et de taux sont valides dans ces conditions. Cependant, cette base de données est petite et des données additionnelles seraient utiles.

L'analyse d'une base de données d'observations météorologiques horaires à Montréal a démontré que les cas de granules de glace ne représentent que moins de deux pourcent de toutes les précipitations des mois d'hiver. L'ensemble des données recueillies au cours des hivers 2004-05 et 2005-06 comprenait 96 heures de conditions de granules de glace. Au cours de ces deux saisons, les granules de glace se sont formés à des températures ambiantes entre +1 et -9°C. Le taux de précipitation se situait entre 1 et 73 g/dm²/h, 95 pourcent des taux se situant à 40 g/dm²/h ou moins. Les taux de précipitation de plus de 25 g/dm²/h ne représentent que 13 pourcent de tous les cas de granules de glace.

L'enquête sur les opérations hivernales réelles a démontré que le givre est deuxième en importance parmi les conditions de dégivrage et suffisamment d'attention devrait être portée à l'étude et à la justification des durées d'efficacité dans le givre, en particulier pour les liquides de type I.

Le format des tableaux de durées d'efficacité a subi plusieurs changements, importants et mineurs, au cours des cinq dernières années. Ces changements sont documentés dans le présent rapport. Aucun changement important n'a été effectué au format des tableaux de durées d'efficacité en 2005-06.

## Recommandations

L'étude sur les données météorologiques a produit de l'information utile et devrait être poursuivie pour générer davantage de données. Ceci est particulièrement nécessaire dans les rares cas de précipitations sous forme de granules de glace, de pluie verglaçante et de bruine verglaçante. Des discussions entre les organismes de réglementation et les membres de l'industrie sont également recommandées, afin de permettre le développement et la mise en application possible d'un modèle de tableau de durées d'efficacité qui pourrait servir aux essais futurs sur les durées d'efficacité.

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# GLOSSARY

| | |
|---|---|
| APS | APS Aviation Inc. |
| FAA | Federal Aviation Administration |
| HOT | Holdover Time |
| LWE | Liquid Water Equivalent |
| MSC | Meteorological Service of Canada |
| NCAR | National Center for Atmospheric Research |
| NRC | National Research Council Canada |
| READAC | Remote Environmental Automatic Data Acquisition Concept |
| TC | Transport Canada |
| TDC | Transportation Development Centre |

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# 1. INTRODUCTION

Under winter precipitation conditions, aircraft are cleaned with a freezing point depressant fluid and protected against further accumulation by an additional application of such a fluid, possibly thickened to extend the protection time. Aircraft ground deicing had, until recently, never been researched and there is still limited understanding of the hazard and of what can be done to reduce the risks posed by the operation of aircraft in winter precipitation conditions. This "winter operations contaminated aircraft – ground" program of research is aimed at overcoming this lack of knowledge.

Over the past several years, the Transportation Development Centre (TDC), Transport Canada (TC) has managed and conducted de/anti-icing related tests at various sites in Canada; it has also coordinated worldwide testing and evaluation of evolving technologies related to de/anti-icing operations with the co-operation of the US Federal Aviation Administration (FAA), the National Research Council (NRC), Meteorological Service of Canada (MSC), several major airlines, and deicing fluid manufacturers. The TDC is continuing its research, development, testing and evaluation program.

Under contract to the TDC, with financial support from the FAA, APS Aviation Inc. (APS) has undertaken research activities to further advance aircraft ground de/anti-icing technology. As part of the 2005-06 winter research program on deicing, APS conducted an analysis of winter weather data collected between 1995-96 and 2005-06. This report contains the results of that analysis. It also encompasses all of the data presented in the 2004-05 TC report, TP 14444E, *Winter Weather Impact on Holdover Time Table Format (1995-2005)*, (1).

The work statement for this project is presented in Appendix A. It should be noted that item “b” was given lowest priority and subsequently was not completed. It is recommended that this analysis be done in the future.

## 1.1 Background

Holdover time (HOT) tables are developed as guidelines to be used by pilots in aircraft departure planning under different winter weather conditions. Each HOT table is composed of cells, with each cell containing a HOT range for a specific temperature range and category of precipitation. The time range in each cell is defined by a “lower” time and an “upper” time; these values represent the failure time of the fluid at the upper and lower precipitation rate range, respectively.

There are four standard types of fluid: Type I, Type II, Type III and Type IV. Aircraft are deiced using heated Type I and Type III fluids. Type II and Type IV fluids are anti-icing fluids that are applied following aircraft deicing, with Type II fluids being thicker and more viscous than Type I or Type III fluids. Type IV fluids are designed to provide the utmost in HOT protection.

The Type I, Type III and Type II/IV HOT table formats have undergone significant change since the early 1990s. While the changes have been made primarily to improve and address safety concerns of many individuals and organizations involved in the deicing industry, a structured approach has not been taken for implementing changes. In fact, many of the changes have been made on a year-by-year basis at industry meetings. These changes have been typically minor in nature, but after nearly ten years, the impact on HOTs is more significant. More recently, several changes have been made to improve and simplify the tables, while simultaneously ensuring that a high level of safety is maintained when the tables are used. Proposals for changes to the HOT tables have been made by TC, and these include new temperature breakdowns to better reflect winter precipitation conditions, expansion of the snow column to reflect its high usage, and removal of unnecessary HOT ranges in certain columns to result in a single value.

To substantiate these changes, a survey of airlines at several international airports was conducted. The survey provided information relating to the frequency of deicing operations as a function of weather condition and temperature. The analysis of the results from the 3-year airline survey are presented in Section 3 of the 2003-04 TC report, TP 14375E, *Winter Weather Impact on Holdover Time Table Format (1995-2004)*, (2).

The winter operations survey was conducted by APS on behalf of TC over three winters, 2000-01, 2001-02 and 2002-03. The combined survey results concluded that, for the reporting centers, the distribution of precipitation types under which deicing operations occurred was:

a) Snow 56 percent;

b) Frost 33 percent; and

c) Other 11 percent.

The *other* category consisted of freezing rain, freezing drizzle, freezing fog, cold-soaked wing and rime ice.

Several years ago, holdover times for snow were evaluated or developed using lower and upper precipitation rates of 10 and 25 g/dm²/h for all air temperatures (0, -3, -14 and -25°C). At that time, it was believed that precipitation rates of 10 to 25 g/dm²/h do not occur below -14°C. The data collected demonstrated that snow does occur at these high precipitation rates at low temperatures, however it occurs much less frequently than in warmer temperatures. As a result, it was concluded that the HOT rate limits of 10 and 25 g/dm²/h are representative of natural snow conditions and need to be maintained.

## 1.2 Objectives

The main purposes of this study in the winter of 2005-06 were to:

1. Further evaluate weather precipitation data (precipitation rate/temperature data) over several recent winters and substantiate the suitability of proposed data ranges for the evaluation of upper and lower HOT limits; and
2. Review the surveys of winter weather data and apply them to evaluate the format of the HOT tables.

## 1.3 Report Format

The following list provides descriptions of subsequent sections of this report:

a) Section 2 presents an analysis of the natural snow and freezing rain/drizzle data collected in 2005-06 from six stations in Quebec and provides, in conjunction with data from ten previous winter seasons, a distribution of precipitation events by temperature and precipitation rate. It also provides an analysis of the data collected under ice pellet conditions during the 2005-06 winter season;

b) Section 3 presents a summary of the findings from the operations survey data collected between 2000-01 and 2002-03, by showing the distribution of deicing operations worldwide;

c) Section 4 summarizes the current and proposed changes to the format of the HOT tables;

d) Section 5 presents a brief summary of the frost deposition rates measured in natural conditions;

e) Section 6 presents the conclusions; and

f) Section 7 presents the recommendations.

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# 2. DESCRIPTION AND ANALYSIS OF NATURAL SNOW, FREEZING RAIN/DRIZZLE AND ICE PELLET DATA

This section describes the methodology that has been used to collect natural snow, freezing rain/drizzle and ice pellet data over the past eleven years. The data processing and analysis is also presented in this section.

## 2.1 Methodology

### 2.1.1 Sources of Data and Test Sites

The precipitation events analysed in this report were extracted from the following:

a) The Dorval Remote Environmental Automatic Data Acquisition Concept (READAC) log for the years 1995 to 1999;

b) The data logs from 1998 to 2006 for the three CR21X stations at Rouyn, Pointe-au-Père (Mont-Joli), and Ancienne Lorette (Quebec City);

c) The data log from the Montreal-Trudeau International Airport CR21X station from 1998 to 2006;

d) The data logs for 2000 to 2006 from two additional CR21X stations located in High Falls (near Ottawa, Ontario) and Frelighsburg (in Quebec's Eastern Townships); and

e) An extensive hourly observation weather information dataset spanning between January 1, 1990 and December 31, 2001.

The data collected by APS from various sources extending back to the 1991-92 winter season are shown in Table 2.1. Each site where data were collected is identified on the map of Quebec shown in Figure 2.1. The data, starting with the 1995-96 winter season, is included in Appendix B, analysed and sorted by temperature ranges.

Unless otherwise specified, all precipitation rates analysed in this report were extracted from the CR21X data logs received from the MSC for each of the six Quebec weather stations that are part of this study.

## Table 2.1: Summary of Winter Weather Data

| PROJECT # | YEAR | PLATE PAN | READAC YUL | CR21X WUY (Rouyn) | WTQ (Dorval) | WQB (Québec) | WYQ (Pointe-au-Père) | WFQ (Frelighsburg) | XHF (High Falls) | CITY OF MONTREAL (Fisher/Porter) | OMBROMETER THIES | TIPPING BUCKET | YYZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1990/91 | Test period | | | | | | | | | | X[3] | |
| | 1991/92 | Test period | | | | | | | | X[6] | X[3] | | |
| | 1992/93 | Test period | | | | | | | | X[6] | X[3] | | |
| C1171 | 1993/94 | Test period | | | | | | | | X[1] (Three stations) | X[3] (Shielded) | | |
| CM1222 | 1994/95 | Test period | X[1] | | | | | | | | | | |
| CM1283 | 1995/96 | 15 min | X[2] | | | | | | | | | | X[4] |
| CM1338 | 1996/97 | 15 min | X[2] | | X[5] | | | | | | | | X[4] |
| CM1380 | 1997/98 | 5-15 min | X[2] | X[2] | X[2] | X[2] | X[2] | | | | | | |
| CM1514 | 1998/99 | 5-15 min | X[2] | X[2] | X[2] | X[2] | X[2] | | | | | | |
| CM1589 | 1999/00 | 5-15 min | | X[2] | X[5] | X[2] | X[2] | X[2] | X[2] | | | | |
| CM1680 | 2000/01 | 5-15 min | | X[2] | X[2] | X[2] | X[2] | X[2] | X[2] | | | | |
| CM1680(01-02) | 2001/02 | 5-15 min | | X[2] | X[2] | X[2] | X[2] | X[2] | X[2] | | | | |
| CM1747 | 2002/03 | 5-15 min | | X[2] | X[2] | X[2] | X[2] | X[2] | X[2] | | | | |
| CM1892 | 2003/04 | 5-15 min | | X[2] | X[2] | X[2] | X[2] | X[2] | X[2] | | | | |
| CM1892 | 2004/05 | 5-15 min | | X[2] | X[2] | X[2] | X[2] | X[2] | X[2] | | | | |
| CM2020 | 2005/06 | 5-15 min | | X[2] | X[2] | X[2] | X[2] | X[2] | X[2] | | | | |

(1) Data analysed for Transport Canada in 1996.

(2) Data used for this report.

(3) Unusable data - precipitation rate determined by this gauge was always lower than other instruments.

(4) Analysis completed by AES at YYZ.

(5) Unusable data - scattered data (gauge was not shielded).

(6) Data archived.

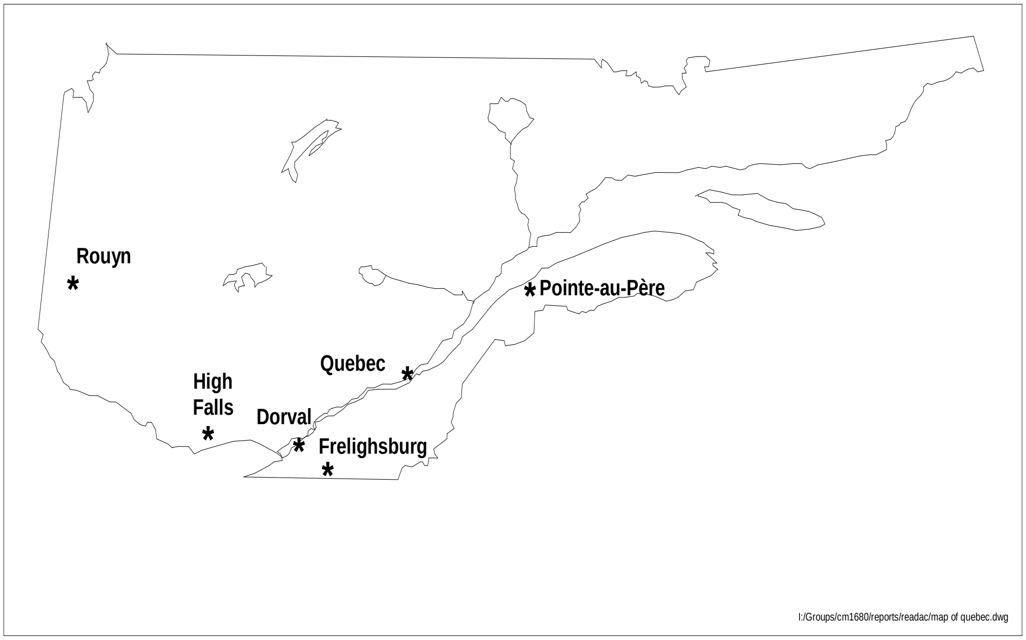


**Figure 2.1: Map of Precipitation Gauge Locations**

Two similar studies were conducted. One study was conducted by APS in the 1993-94 to 1994-95 winters using data collected from three weather stations located around Montreal. The MSC carried out a similar study in 1995 using data collected at the Lester B. Pearson International Airport in Toronto. Overall, the data sets from MSC and APS were found to be similar enough to merit a comparison for temperature ranges above -7°C. Below that temperature, the MSC data contains no high rate precipitation points. These two studies can be found in Appendices C and D of TC report TP 13993E*, Impact of Winter Weather on Holdover Time Table Format (1995-2002)*, (3).

### 2.1.2 Equipment

Over the years, both the READAC and CR21X stations have been used to measure precipitation rates. The READAC precipitation gauge consists of a bucket partially filled with an antifreeze compound so that it effectively captures snow. A weighing transducer shaft provides instantaneous displacement values of the bucket in terms of millimetres of precipitation. This shaft displacement is transmitted every 2.5 seconds and averaged every minute in an attempt to eliminate spurious data caused by gusts of wind and temperature-induced contraction and expansion of the sensor. The READAC instrument has a resolution of 0.5 mm (5 g/dm$^2$). In the 2003-04 winter, the use of the READAC equipment at Trudeau Airport was discontinued by the MSC.

The CR21X station operates on the same principle as the READAC station and has an accuracy of 0.1 mm (1 g/dm²). The station measures precipitation with a Fisher Porter precipitation gauge and the readings are logged with a CR21X data logger. A more detailed description of the CR21X equipment can be found in Appendix C.

Precipitation rates tend to fluctuate rapidly during snowstorms. The weight resolution of the READAC stations is less accurate in measuring rapid changes compared to the CR21X station. The data from the CR21X station therefore required less smoothing before it could be interpreted. The increased resolution of the CR21X weighing transducer allows better observation of short periods with heavy precipitation.

For this project, the measuring instruments used to record weather precipitation data were owned and operated by the MSC, and these instruments were calibrated according to their standards. The data were acquired for the purpose of this project.

### 2.1.3 Description of Analytical Methods

Precipitation rate data were averaged at intervals that correspond to three specified periods typically used in the HOT tables: 6 minutes for Type I fluids, 20 minutes for Type II fluids, and 35 minutes for Type IV fluids. For natural snow, data were classified into five temperature ranges: *above 0°C*, *0 to -3°C*, *-3 to -7°C, -7 to -14°C* and *-14 to -25°C*. For freezing rain/drizzle, data were classified into two ranges: *0 to -3°C* and *-3 to -10°C*.

Snowfalls at Trudeau Airport were tracked from 1995 to 2006 using the Monthly Meteorological Data Summary provided by the MSC. This summary includes meteorological data such as temperature, wind speed and direction, dew point temperature, and humidity on an hourly basis, and precipitation type and total accumulation on a daily basis. An example of the Monthly Meteorological Summary for Montreal is included in Appendix D. The last page of the summary (D-6) states whether it snowed on a particular day and the first page (D-1) provides the total snow accumulation for each day. Based on this information, the precipitation and temperature data were extracted from READAC logs on a minute-by-minute basis and added to a database. The CR21X data were treated in a similar way.

Starting in the winter of 2004-05, the number of Monthly Meteorological Data Summaries produced by MSC was reduced as the data were made available on the MSC website. As a result, for the 2004-05 winter season Monthly Summaries were used for Montreal, Quebec and Pointe-au-Père (Mont-Joli), and the information posted online was used for Rouyn, Frelighsburg and High Falls. In the winter of 2005-06, the Monthly Meteorological Data Summary for Pointe-au-Père became unavailable. The information posted online for this station was used. Information pertaining to Frelighsburg and High Falls was limited, so Sherbrooke and Ottawa data were used instead.

Periods of snowfall were identified using either the MSC summaries or the weather database available online, and snow accumulation data were added to the database along with ambient air temperatures. The temperatures were then linearly interpolated throughout the hour on a minute-by-minute basis.

### 2.1.4 Linearization of Cumulative Snow Weight Data

Precipitation rates were calculated in a two-step procedure.

First, using an algorithm developed by APS, the total precipitation for each snowfall was linearized to produce a smooth curve. Table 2.2 shows an example of linearized values for total snow accumulation.

Secondly, precipitation rates were calculated according to the linearized total snow accumulation values and the time between readings. This procedure is described in Section 2.3.

Figure 2.2 shows an output from the CR21X data logger recording the output from the precipitation gauges and the linearized data for a typical snowfall. The precipitation gauge output, sensitive to 1 g/dm², is plotted versus time to establish the periods of snowfalls.

As seen in Figure 2.2, intervals when snowfalls were interrupted for long periods of time were excluded from the analysis. Subsequent snowfalls were treated in a similar manner. The first and last indications of snowfall (first and last 1 g/dm²) were excluded due to uncertainty about the precise start and end time of the snowfall.

Periods of low-rate snow precipitation might have been overlooked due to long interruptions in bucket weight changes. It is difficult to establish whether these weight changes were due to constant low rate precipitation or long periods with no precipitation and short intervals of higher precipitation. The start and end of a snowstorm are difficult to establish because snow may start and end gradually at slow rates or abruptly at high rates. For several recent winters, light snowfalls over long periods of time were excluded. Starting with the 2000-01 winter season, it was established as a guideline that snowfalls with total precipitation of 2 cm over 6 hours were excluded; this analytical pattern was used for subsequent years.

## Table 2.2: Sample of Linearized READAC Data

| Location | Date | UTC Time | Temp (°C) | Type of Precip. | Total Snow Accumulation (g/dm²) | Linearized Total Snow Accumulation (g/dm²) |
|---|---|---|---|---|---|---|
| YUL | 14/12/1995 | 21:16 | -11.8 | S- | **40** | **40** |
| YUL | 14/12/1995 | 21:17 | -11.7 | S- | **40** | **40.16** |
| YUL | 14/12/1995 | 21:18 | -11.6 | S- | **40** | **40.31** |
| YUL | 14/12/1995 | 21:19 | -11.6 | S- | **40** | **40.47** |
| YUL | 14/12/1995 | 21:20 | -11.6 | S- | **40** | **40.63** |
| YUL | 14/12/1995 | 21:21 | -11.6 | S- | **40** | **40.78** |
| YUL | 14/12/1995 | 21:22 | -11.6 | S- | **40** | **40.94** |
| YUL | 14/12/1995 | 21:23 | -11.5 | S- | **40** | **41.09** |
| YUL | 14/12/1995 | 21:24 | -11.6 | S- | **40** | **41.25** |
| YUL | 14/12/1995 | 21:25 | -11.6 | S- | **40** | **41.41** |
| YUL | 14/12/1995 | 21:26 | -11.4 | S- | **40** | **41.56** |
| YUL | 14/12/1995 | 21:27 | -11.4 | S- | **40** | **41.72** |
| YUL | 14/12/1995 | 21:28 | -11.5 | S- | **40** | **41.88** |
| YUL | 14/12/1995 | 21:29 | -11.5 | S- | **40** | **42.03** |
| YUL | 14/12/1995 | 21:30 | -11.4 | S- | **40** | **42.19** |
| YUL | 14/12/1995 | 21:31 | -11.4 | S- | **40** | **42.34** |
| YUL | 14/12/1995 | 21:32 | -11.4 | S- | **40** | **42.50** |
| YUL | 14/12/1995 | 21:33 | -11.4 | S- | **40** | **42.66** |
| YUL | 14/12/1995 | 21:34 | -11.4 | S- | **40** | **42.81** |
| YUL | 14/12/1995 | 21:35 | -11.4 | S- | **40** | **42.97** |
| YUL | 14/12/1995 | 21:36 | -11.3 | S- | **40** | **43.13** |
| YUL | 14/12/1995 | 21:37 | -11.3 | S- | **40** | **43.28** |
| YUL | 14/12/1995 | 21:38 | -11.4 | S- | **40** | **43.44** |
| YUL | 14/12/1995 | 21:39 | -11.4 | S- | **40** | **43.59** |
| YUL | 14/12/1995 | 21:40 | -11.3 | S- | **40** | **43.75** |
| YUL | 14/12/1995 | 21:41 | -11.3 | S- | **40** | **43.91** |
| YUL | 14/12/1995 | 21:42 | -11.3 | S- | **40** | **44.06** |
| YUL | 14/12/1995 | 21:43 | -11.3 | S- | **40** | **44.22** |
| YUL | 14/12/1995 | 21:44 | -11.2 | S- | **40** | **44.38** |
| YUL | 14/12/1995 | 21:45 | -11.2 | S- | **40** | **44.53** |
| YUL | 14/12/1995 | 21:46 | -11.2 | S- | **40** | **44.69** |
| YUL | 14/12/1995 | 21:47 | -11.2 | S- | **40** | **44.84** |
| YUL | 14/12/1995 | 21:48 | -11.2 | S- | **45** | **45.00** |
| YUL | 14/12/1995 | 21:49 | -11.2 | S- | **45** | **45.29** |
| YUL | 14/12/1995 | 21:50 | -11.2 | S- | **45** | **45.59** |
| YUL | 14/12/1995 | 21:51 | -11.2 | S- | **45** | **45.88** |
| YUL | 14/12/1995 | 21:52 | -11.1 | S- | **45** | **46.18** |
| YUL | 14/12/1995 | 21:53 | -11.1 | S- | **45** | **46.47** |
| YUL | 14/12/1995 | 21:54 | -11.1 | S- | **45** | **46.76** |
| YUL | 14/12/1995 | 21:55 | -11.1 | S- | **45** | **47.06** |
| YUL | 14/12/1995 | 21:56 | -11.1 | S- | **45** | **47.35** |
| YUL | 14/12/1995 | 21:57 | -11.1 | S- | **45** | **47.65** |
| YUL | 14/12/1995 | 21:58 | -11.1 | S- | **45** | **47.94** |
| YUL | 14/12/1995 | 21:59 | -11.0 | S- | **45** | **48.24** |
| YUL | 14/12/1995 | 22:00 | -11.0 | S- | **45** | **48.53** |
| YUL | 14/12/1995 | 22:01 | -11.0 | S- | **45** | **48.82** |
| YUL | 14/12/1995 | 22:02 | -11.0 | S- | **45** | **49.12** |
| YUL | 14/12/1995 | 22:03 | -11.0 | S- | **45** | **49.41** |
| YUL | 14/12/1995 | 22:04 | -10.9 | S- | **45** | **49.71** |
| YUL | 14/12/1995 | 22:05 | -10.8 | S- | **50** | **50.00** |

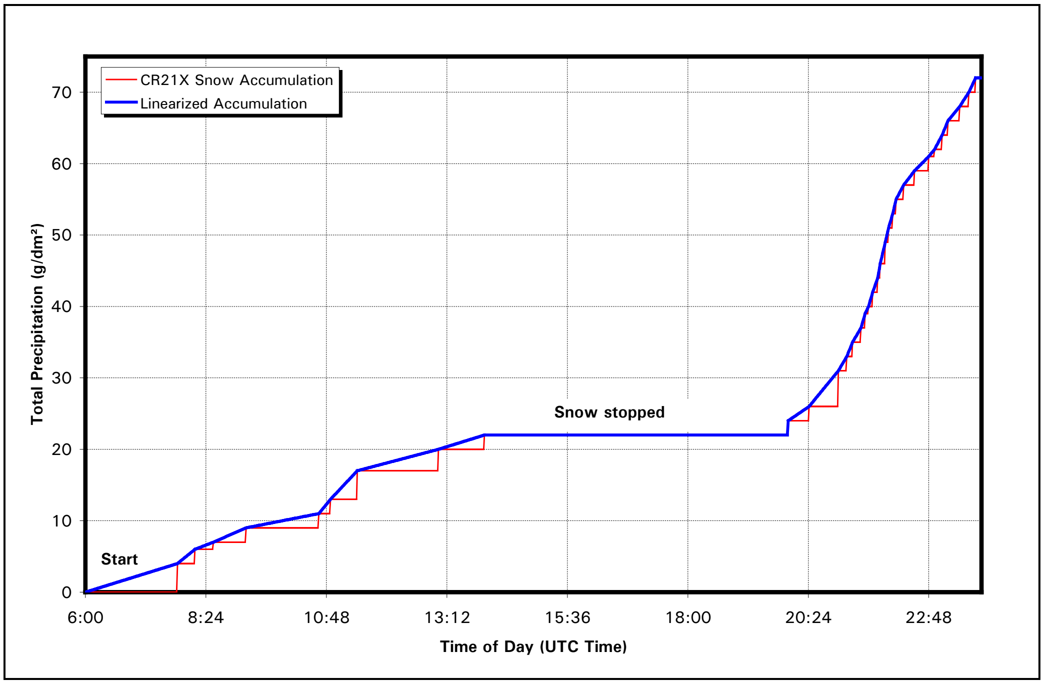


**Figure 2.2: CR21X Precipitation Gauge Cumulative and Linearized Precipitation**

## 2.2 Description and Processing of Natural Snow, Freezing Rain/Drizzle and Ice Pellet Data

### 2.2.1 Natural Snow

During the 2005-06 winter season, 60,949 data points were collected in natural snow conditions at six stations in Quebec. This represents 1,015 hours of snowfall and an average of approximately 169 hours of snowfall at each station. There has been an increase in usable data in recent years due to improvements in the CR21X stations.

The distribution of the 2005-06 data points collected from the six meteorological stations is summarized in Table 2.3. The distribution by temperature of data points collected from all stations is listed in Table 2.4. The distribution is also shown in histogram format in Figure 2.3.

## Table 2.3: Distribution of 2005-06 Snow Data Points by Station

| Station | # of Data Points | % |
|---|---|---|
| Frelighsburg | 3,786 | 6.2 |
| Quebec | 13,935 | 22.9 |
| Montreal | 6,445 | 10.6 |
| Rouyn Noranda | 11,495 | 18.9 |
| Mont-Joli | 14,881 | 24.4 |
| High Falls | 10,407 | 17.1 |
| **Total** | **60,949** | **100** |

## Table 2.4: Distribution of 2005-06 Snow Data Points by Temperature

| Temperature Range | # of Data Points |
|---|---|
| Above 0°C | 8,067 |
| Between 0 and -3°C | 14,778 |
| Between -3 and -6°C | 18,452 |
| Between -6 and -10°C | 10,952 |
| Between -10 and -14°C | 4,629 |
| Between -14 and -25°C | 4,071 |
| **Total** | **60,949** |

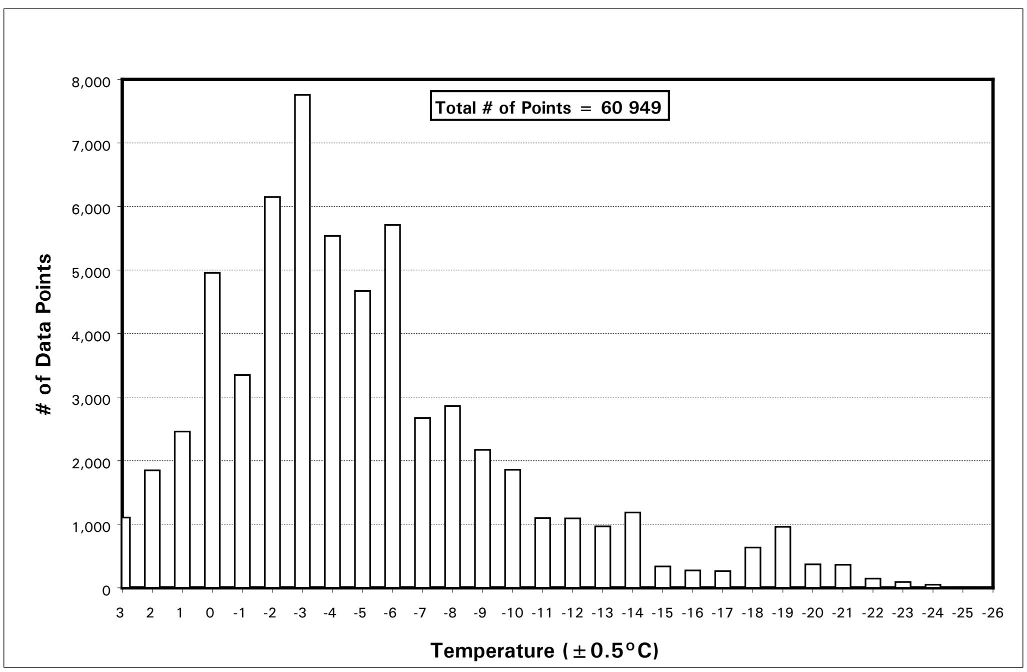


**Figure 2.3: Temperature Distribution for 2005-06 Winter – Natural Snow**

The following observations should be noted:

a) 13.2 percent of the snowfalls occurred at temperatures above 0°C;
b) 24.2 percent of the snowfalls occurred within the range of 0 to -3°C;
c) 30.3 percent occurred between -3 and -6°C;
d) 18.0 percent occurred between -6 and -10°C;
e) 7.6 percent occurred between -10 and -14°C; and
f) 6.7 percent occurred between -14 and -25°C.

This is a consolidated report, encompassing all data presented in TC report, TP 14444E, *Winter Weather Impact on Holdover Time Table Format (1995-2005),* (1). A total of 453,784 data points were collected for natural snow conditions from 1995-96 to 2005-06. On average, this represents over 160 hours of snowfall per year for each of the six stations in Quebec.

The distribution of snow data points over the eleven years of observation is illustrated in Table 2.5. The distribution of data points by temperature range is listed in Table 2.6. Figure 2.4 shows the temperature breakdown of all data points collected from the winters of 1995-96 to 2005-06 in natural snow.

**Table 2.5: Distribution of Snow Data Points (1996 to 2006)**

| Year | # of Data Points | % |
|---|---|---|
| 1995-98 | 39,426 | 8.7 |
| 1998-99 | 37,272 | 8.2 |
| 1999-00 | 43,927 | 9.7 |
| 2000-01 | 57,280 | 12.6 |
| 2001-02 | 55,026 | 12.1 |
| 2002-03 | 57,441 | 12.7 |
| 2003-04 | 47,779 | 10.5 |
| 2004-05 | 54,684 | 12.1 |
| 2005-06 | 60,949 | 13.4 |
| **Total** | **453,784** | **100** |

**Table 2.6: Temperature Distribution (1996 to 2006)**

| Temperature Range | # of Data Points |
|---|---|
| Above 0°C | 54,035 |
| Between 0 and -3°C | 119,975 |
| Between -3 and -6°C | 114,559 |
| Between -6 and -10°C | 93,818 |
| Between -10 and -14°C | 45,881 |
| Between -14 and -25°C | 25,516 |
| **Total** | **453,784** |

The following observations should be noted:

a) 11.9 percent of the snowfalls occurred at temperatures above 0°C;
b) 26.4 percent of the snowfalls occurred within the range of 0 to -3°C;
c) 25.2 percent occurred between -3 and -6°C;
d) 20.7 percent occurred between -6 and -10°C;
e) 10.1 percent occurred between -10 and -14°C; and
f) 5.6 percent occurred between -14 and -25°C.

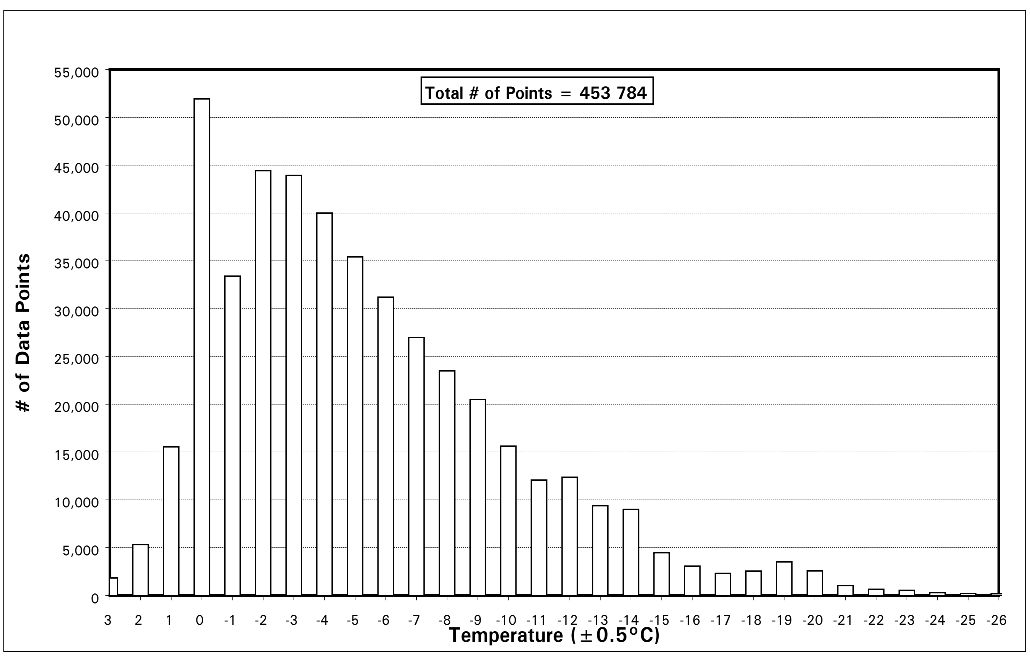


**Figure 2.4: Temperature Distribution for the 1996-2006 Winters – Natural Snow**

### 2.2.2 Freezing Rain/Drizzle

During the 2005-06 winter, 3,490 freezing rain/drizzle data points were collected in Montreal and at five other Quebec stations. These represent approximately 58 hours of freezing rain/drizzle data. The distribution of the 2005-06 data points by temperature range is given in Table 2.7. The distribution of the data by temperature range is shown in Figure 2.5.

**Table 2.7: Distribution of 2005-06 Freezing Rain/Drizzle Data Points by Temperature**

| Temperature Range | # of Data Points |
|---|---|
| Above 0ºC | 471 |
| Between 0 and -3°C | 1,892 |
| Between -3 and -6°C | 663 |
| Between -6 and -10°C | 464 |
| **Total** | **3,490** |

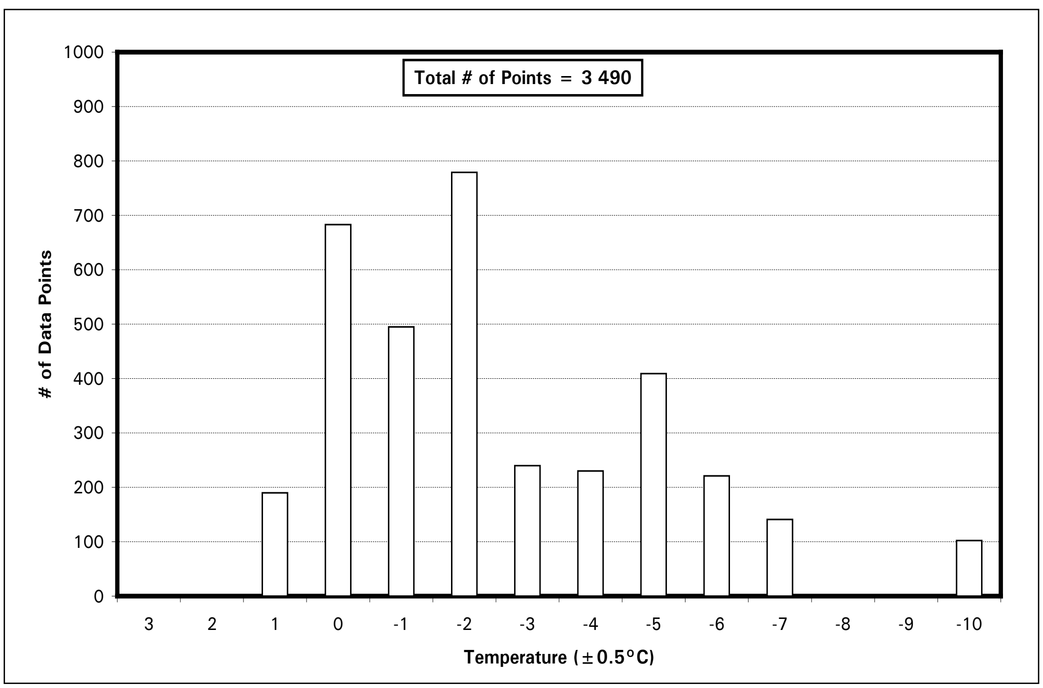


**Figure 2.5: Temperature Distribution for 2005-06 - Freezing Rain/Drizzle**

From 1996-97 to 2005-06, a total of 30,712 data points were collected for freezing rain/drizzle conditions. These represent approximately 511 hours of light freezing rain/drizzle data. Freezing rain/drizzle data were developed from CR21X and READAC logs. The 1998 ice storm data is included in this dataset.

The distribution of these data points over the ten years of observation is illustrated in Table 2.8. The distribution of data points by temperature range is listed in the Table 2.9, and by temperature in Figure 2.6. It should be noted that freezing rain/drizzle did not occur at temperatures below -10°C.

**Table 2.8: Distribution of Freezing Rain/Drizzle Data Points over the Last Ten Winters**

| Year | # of Data Points | % |
|---|---|---|
| 1996-00 | 13,381 | 43.6 |
| 2000-01 | 785 | 2.6 |
| 2001-02 | 5,465 | 17.8 |
| 2002-03 | 3,859 | 12.6 |
| 2003-04 | 2,229 | 7.3 |
| 2004-05 | 1,503 | 4.9 |
| 2005-06 | 3,490 | 11.4 |
| **Total** | **30,712** | **100** |

**Table 2.9: Distribution of Freezing Rain/Drizzle Data Points by Temperature 1996-97 to 2005-06**

| Temperature Range | # of Data Points |
|---|---|
| Above 0ºC | 5,819 |
| Between 0 and -3°C | 12,883 |
| Between -3 and -6°C | 9,157 |
| Between -6 and -10°C | 2,853 |
| **Total** | **30,712** |

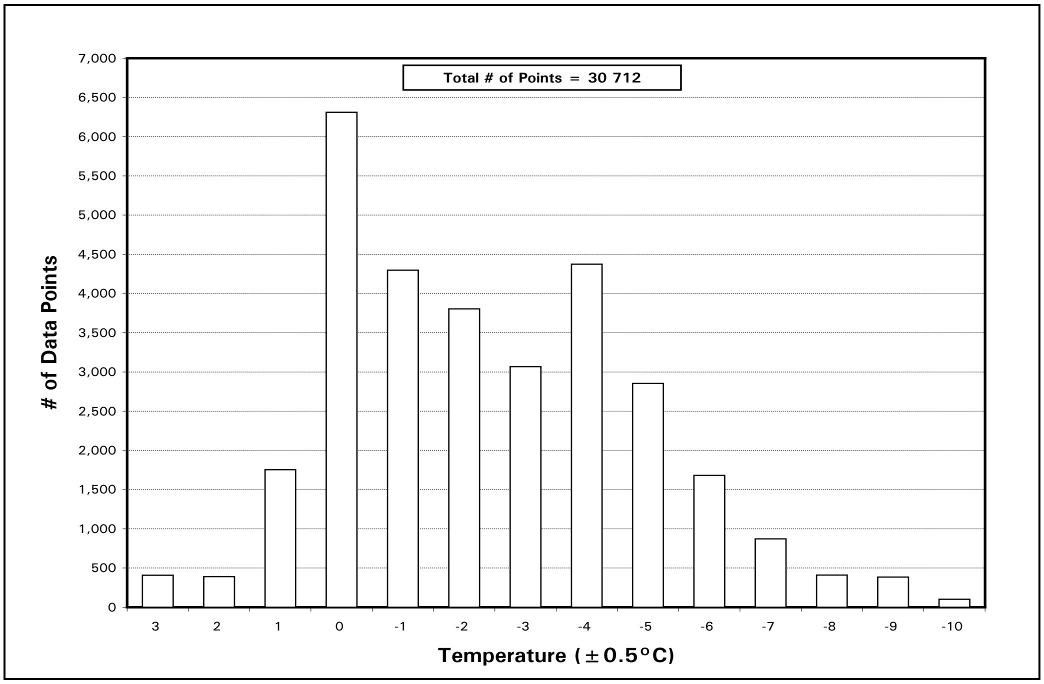


**Figure 2.6: Temperature Distribution for Freezing Rain/Drizzle 1997-2006**

### 2.2.3 Ice Pellets

As noted at the beginning of this section, APS acquired an extensive hourly observation weather information dataset from MSC. The observation period was from January 1, 1990 to December 31, 2001. This dataset is presented in more detail in Section 2.4. Among other parameters, the data contains observations related to the weather condition. The dataset for Montreal was analysed in an attempt to determine the frequency of ice pellet conditions during typical winter months. The months of October to April were selected for the analysis. The results are presented in Table 2.10.

**Table 2.10: Frequency of Occurrence of Ice Pellets between 1990 and 2001 (Montreal, Quebec)**

| | | # | % |
|---|---|---|---|
| 1. | Hourly Observations under Precipitation Conditions | 21,343 | 100.00 |
| 2. | Ice Pellet Observations (Ice Pellets and Ice Pellet Showers only) | 36 | 0.17 |
| 3. | Combined Ice Pellet Observations (Ice pellets mixed with other precipitation types excluding the observations accounted for at point 2.) | 376 | 1.76 |
| **4.** | **Total Ice Pellet Precipitation** | **412** | **1.93** |

The information presented in Table 2.10 was gathered exclusively from the 12-year dataset of hourly observations for Montreal, and does not include the CR21X data collected and analysed elsewhere in this report.

As can be seen in Table 2.10, ice pellet occurrences accounted for less than two percent of all precipitation conditions during winter months. Also, the ice pellet conditions occurred mostly mixed with other precipitation types, typically freezing rain, freezing drizzle and snow. The dataset provided by MSC does not contain information with respect to which was the predominant weather condition during these mixed precipitation events. Ice pellets as a stand-alone precipitation condition constituted only about 10 percent of the total time ice pellet conditions occurred.

From the CR21X data collected during the 2004-05 and 2005-06 winters, 5,747 ice pellet data points were collected at five Quebec stations (Montreal, Quebec, Pointe-au-Père, High Falls, and Rouyn-Noranda). These data points represent approximately 96 hours of ice pellet data. The ice pellet data were identified using the Monthly Summaries and the information provided on the MSC website. The distribution of data by temperature is shown in Figure 2.7.

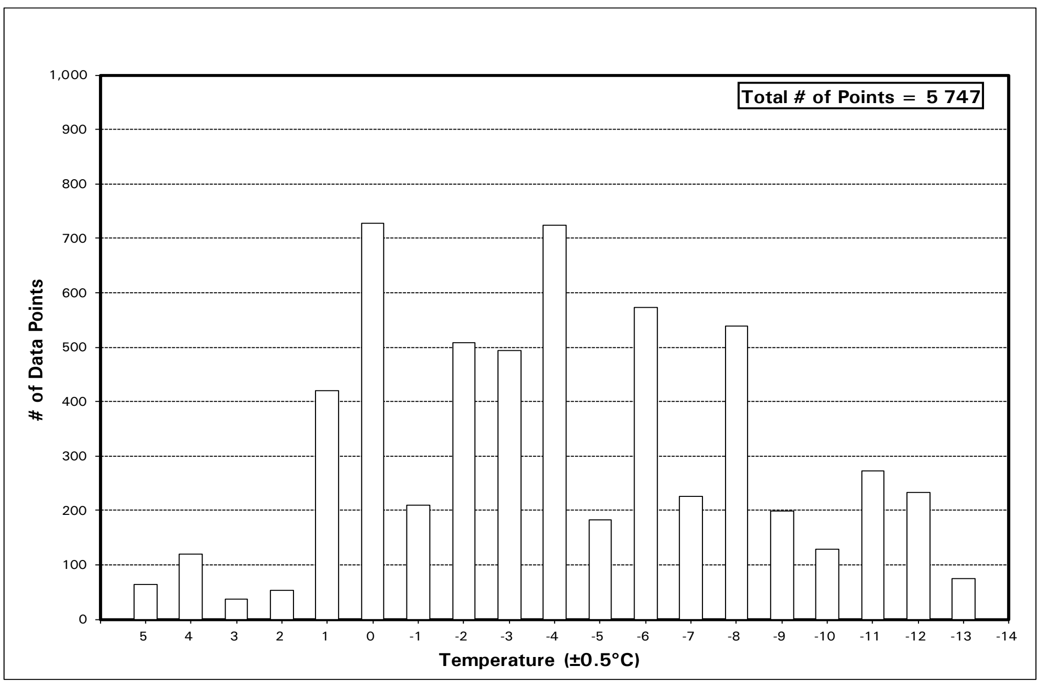


**Figure 2.7: Temperature Distribution for Ice Pellets in 2004-05 and 2005-06**

The distribution of ice pellet data points across the five meteorological stations is summarized in Table 2.11.

**Table 2.11: Distribution of 2004-05 and 2005-06 Ice Pellet Data Points by Station**

| Station | # of Data Points | % |
|---|---|---|
| Montreal | 1,929 | 33.4 |
| Quebec | 2,049 | 36.0 |
| Rouyn Noranda | 197 | 3.4 |
| Point au Peres | 694 | 12.0 |
| High Falls | 878 | 15.2 |
| **Total** | **5,747** | **100** |

Similar to the situation illustrated in Table 2.10, the ice pellet conditions occurred mostly mixed with other precipitation types. Periods of low-rate ice pellet precipitation might have been overlooked due to long interruptions in bucket weight changes. Short storms are also likely to have been overlooked as precipitation type is reported only on the hour.

The distribution of the 2004-05 and 2005-06 ice pellet data points by temperature range is given in Table 2.12. The table demonstrates that 67 percent of ice pellet data points in the two years occurred between 0 and -10°C.

**Table 2.12: Distribution of 2004-05 and 2005-06 Ice Pellet Data Points by Temperature**

| Temperature Range | 2004-05 | 2005-06 | Total | % |
|---|---|---|---|---|
| Above 0ºC | 918 | 332 | 1,250 | 21.8 |
| Between 0 and -10°C | 1,576 | 2,293 | 3,869 | 67.3 |
| Below -10°C | 628 | 0 | 628 | 10.9 |
| **Total** | **3,122** | **2,625** | **5,747** | **100.0** |

As mentioned previously, the dataset collected by MSC does not allow for a "clear-cut" division of isolated ice pellets vs. ice pellets mixed with other precipitation.

### *2.2.3.1 Additional Data on Ice Pellets*

An article published in the Weather and Forecasting Journal was reviewed to further investigate the characteristics of ice pellets. The article, *An Analysis of Freezing Rain, Freezing Drizzle, and Ice Pellets Across the United States and*

*Canada: 1976-1990* (4) analyses 14 years of ice pellet data collected from stations across North America. Data were collected in eleven stations in the United States and ten stations in Canada.

According to the analysis presented in the article, the majority of ice pellets (83 percent) occur in North America during the months of November to March. Ice pellets occur with the highest frequency in the north east, from New York to Newfoundland and from the Great Lakes to the east coast. In this region, the mean annual days with ice pellets ranges from 7 to 13 days and the mean annual ice pellet total duration ranges from 10 to 30 hours.

The analysis also concludes that the majority of ice pellet events are relatively short in duration: 65 percent of all ice pellet events last for one hour or less, and 84 percent last for two hours or less. Furthermore, ice pellets generally occur at warmer temperatures; approximately 60 percent of all events occurred at 0ºC or above.

### 2.2.4 Validity of Gauges for Recording Precipitation Data

The objective of this section is to evaluate and compare precipitation rates measured with the automated gauge used for this study to the plate pans used for measuring rates for endurance times.

Figure 2.8 shows a comparison of precipitation rates of the READAC gauge and the plate pans (described below) for a storm on January 15, 1999. Figure 2.9 illustrates another comparison during the same storm, this time using the CR21X gauge.

Figure 2.8 and Figure 2.9 show the precipitation rate over a 24-hour period. The 6-minute moving average rates calculated from the CR21X data show much more detail than the READAC. Higher rates were detected from this station because the smoothed data from the lower-resolution READAC station does not allow detection of rapid increases and decreases in rates.

Plate pan data collected from the APS test site located at Trudeau Airport are included in Figure 2.8 and Figure 2.9. The pans were placed at a 10º angle on test stands approximately 30 m away from the precipitation gauge. The rates from the pans are based on the weight of snow that collected in the pans during 10-minute periods. The rates were recorded at the end of each time interval, and each value is based on the average of the two simultaneous pan measurements.

Due to questions raised by MSC concerning the accuracy of precipitation gauges, a similar analysis was performed on the 2000-01 winter data. Following the same methodology, the CR21X gauge data were plotted against the plate pan data collected by APS at Trudeau Airport on January 11, 2001. The results are presented in Figure 2.10. Following this analysis, it was recommended that at least one verification should be made annually by comparing the rates obtained from the precipitation gauges and the plate pans.

For the 2002-03 winter, the recorded snow event took place on February 22, 2003 and the results are presented in Figure 2.11. For the 2003-04 winter, the recorded snow event took place on March 20, 2004 and the results are presented in Figure 2.12. For the 2004-05 winter, the recorded snow event took place on January 6, 2005 and the results are presented in Figure 2.13. Finally, for the 2005-06 winter, the recorded snow event took place on February 16, 2006 and the results are presented in Figure 2.14.

From each of these figures, it can be seen that the data points from the plate pans correlate well with the traces.

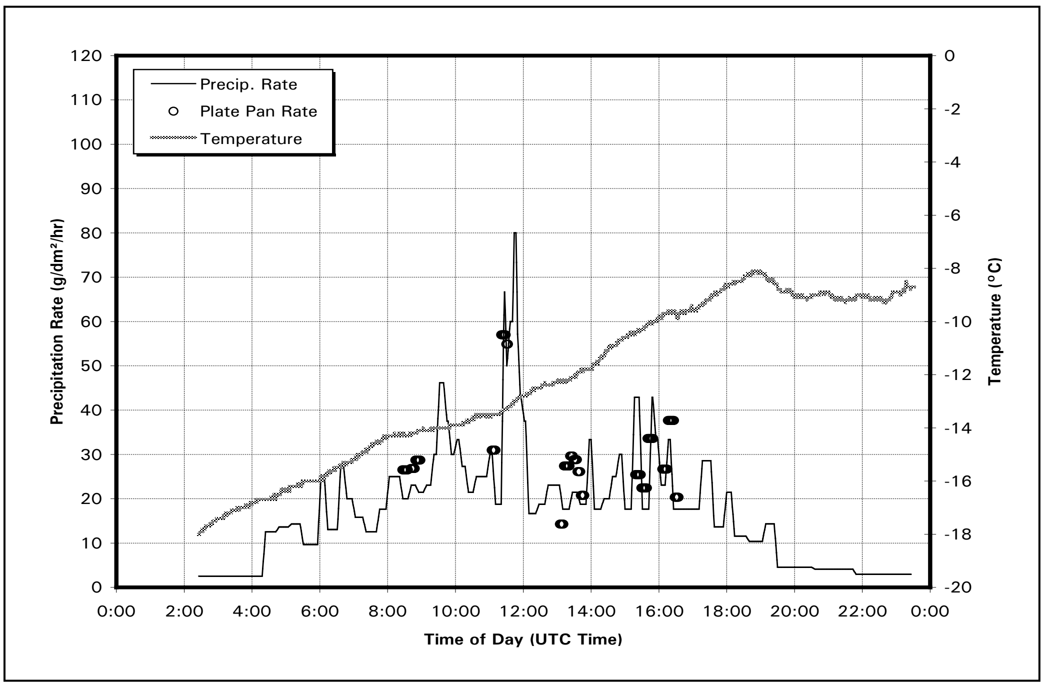


**Figure 2.8: READAC Precipitation Rate, January 15, 1999**

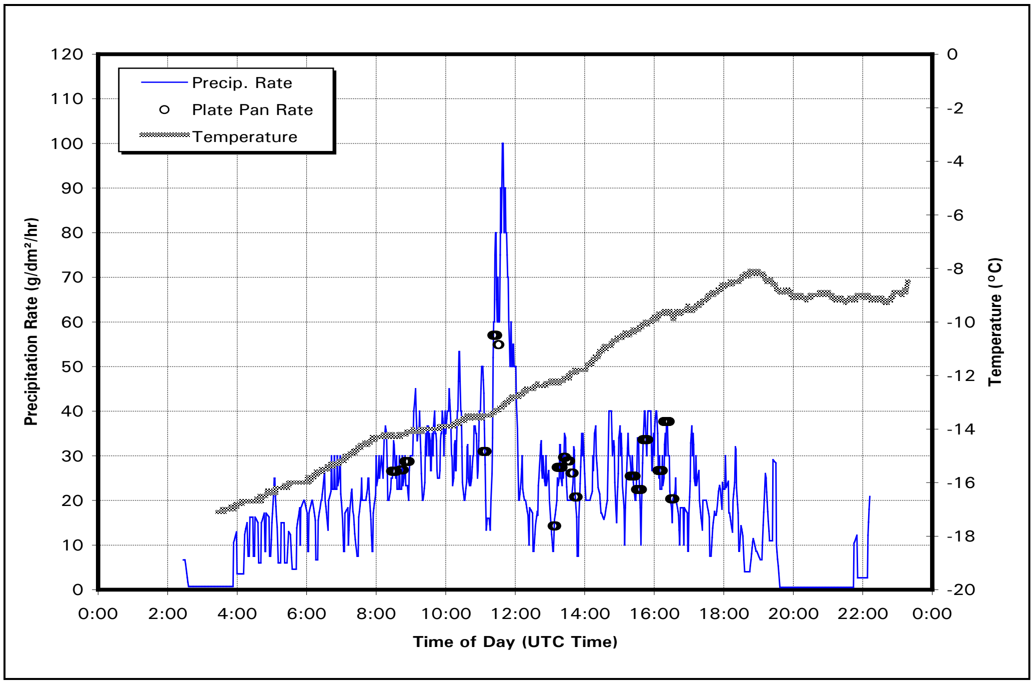


**Figure 2.9: CR21X Precipitation Rate, January 15, 1999**

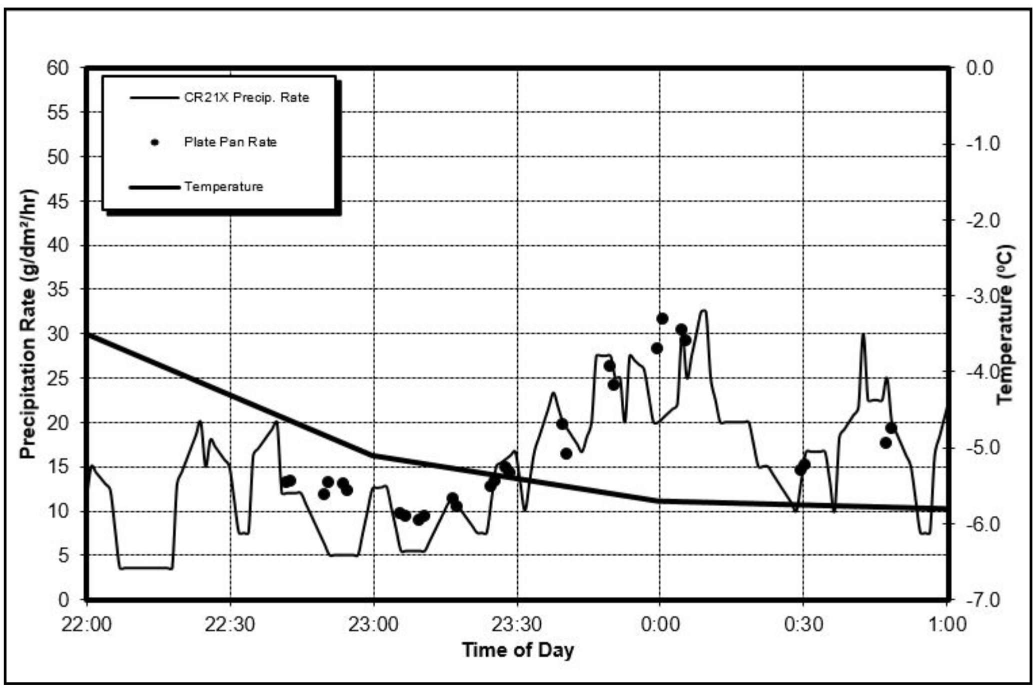


**Figure 2.10: CR21X Precipitation Rate, January 11, 2001**

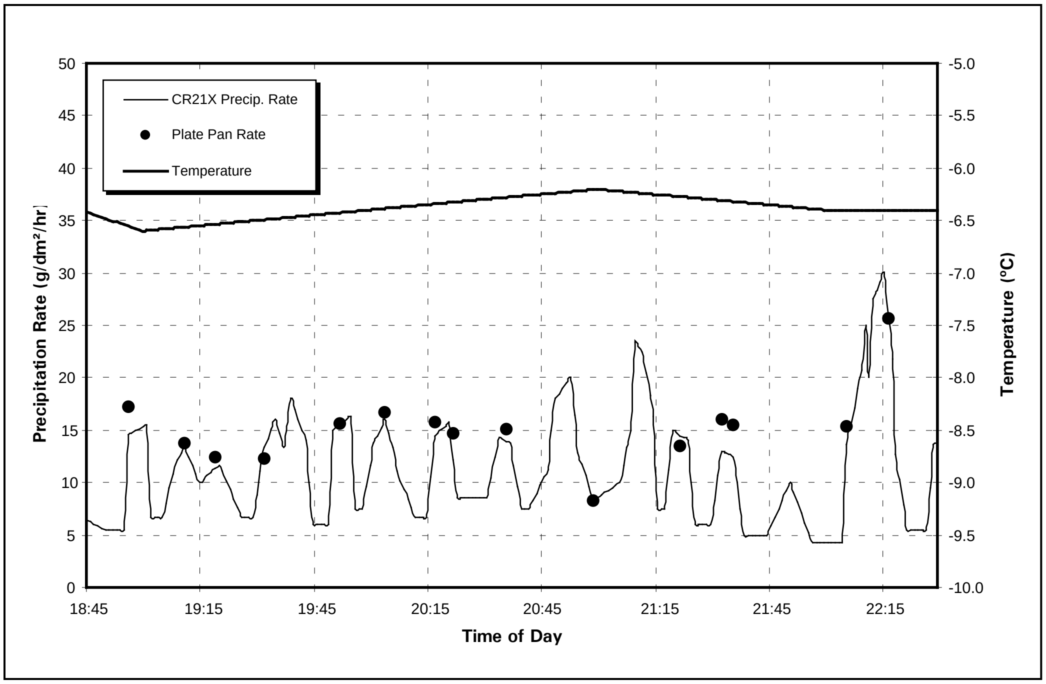


**Figure 2.11: CR21X Precipitation Rate, February 22, 2003**

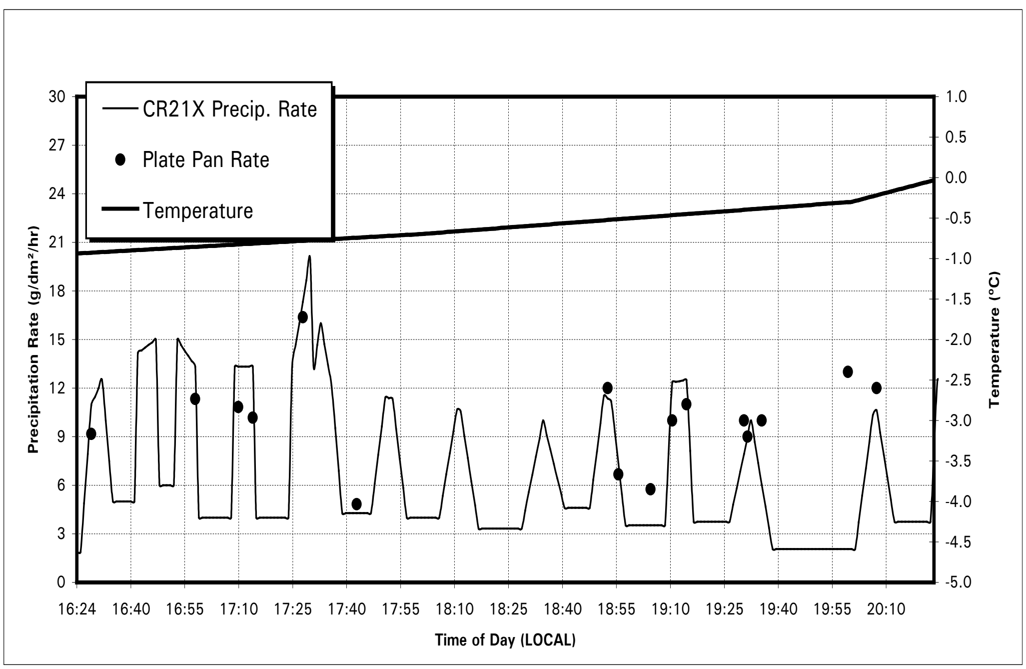


**Figure 2.12: CR21X Precipitation Rate, March 20, 2004**

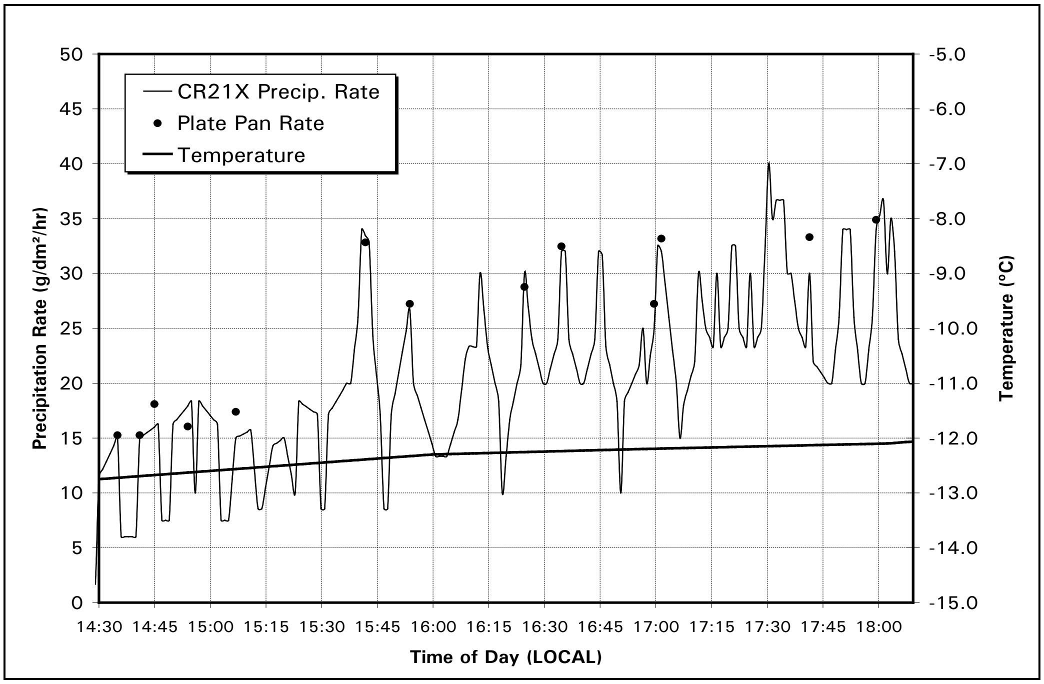


**Figure 2.13: CR21X Precipitation Rate, January 6, 2005**

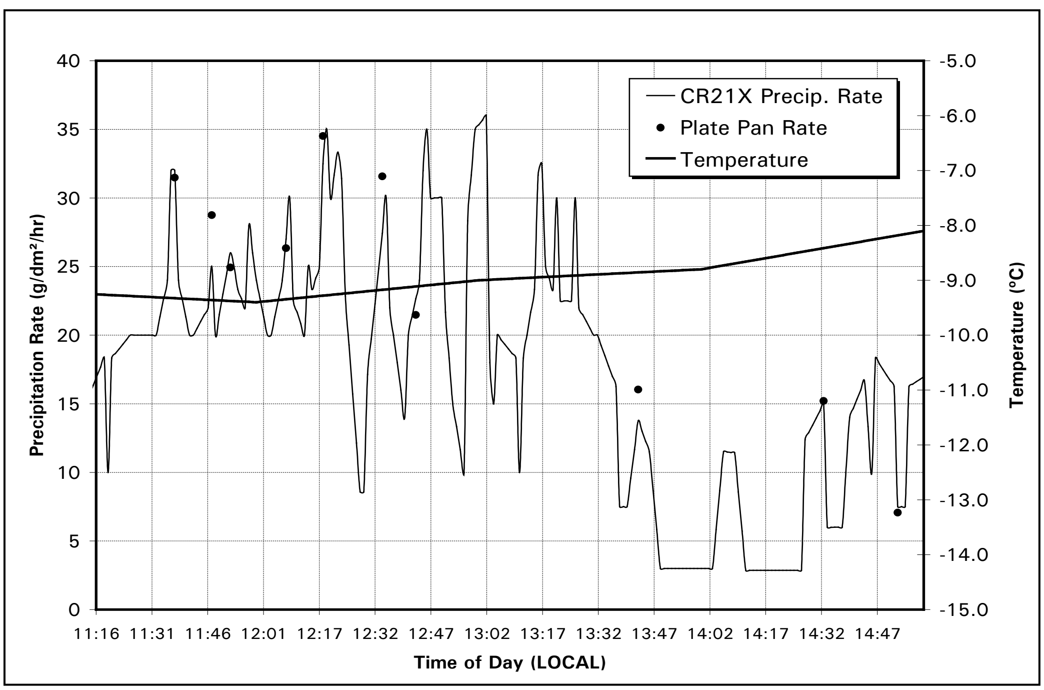


**Figure 2.14: CR21X Precipitation Rate, February 16, 2006**

During the January 6, 2005 snowstorm (Figure 2.13), the recorded wind speed was approximately 30 km/h. More precipitation accumulates in rate pans during high winds because the collection pans are facing into the wind. The small differences between the precipitation gauge trace and the plate pan points could be due to the 10º angle of the test stand. Despite the wind, the CR21X results are close enough to those of the collection pans that they can be used to analyse the precipitation data.

## 2.3 Analysis and Observations for Natural Snow, Freezing Rain/Drizzle and Ice Pellets

Precipitation rates were calculated from the weather data on a minute-by-minute basis using a moving average based on 6-, 20-, and 35-minute intervals. Table 2.13 shows minute-by-minute READAC data at Trudeau Airport for a 49-minute period on December 14, 1995. Also shown are the 6-minute, 20-minute, and 35-minute averages computed using the linearized accumulation. The average snow rates, used as data points, were calculated by taking the snow accumulation during a specific time interval and dividing it by the interval. The three intervals used for this analysis are represented by brackets in the column next to "Linearized Total Snow Accumulation" in Table 2.13. The average snow rate was recalculated every minute by moving the brackets down at one-minute intervals.

For each interval, the rate is calculated every minute using the following method:

$$Rate_i = \frac{W_i - W_{i-1}}{\Delta time}$$

Where:

| | |
|---|---|
| $Rate_i$ | is the rate at a given time; |
| $W_i$ | is the linearized bucket weight at that time; |
| $W_{i-1}$ | is the linearized bucket weight at a one-time interval before the given time; and |
| $\Delta time$ | is the length of the time interval (6, 20, or 35 minutes). |

A temperature was associated with the rate, based on the time and day at which the rate was measured. All rate and temperature data were added to a database that contained calculated precipitation rates classified by ambient temperature for all sites included in the study. The database was then sorted by temperature range (*above 0°C*, *0 to -3°C*, *-3 to -7°C*, *-7 to -14°C* and *-14 to -25°C*) and the probability for each precipitation rate at each temperature range was calculated using histograms and cumulative percentages.

## Table 2.13: Sample READAC Data and Analysis

| Location | Date | UTC Time | Temp (°C) | Type of Precip. | Total Snow Accumulation (g/dm²) | Linearized Total Snow Accumulation (g/dm²) | | Precipitation Rate (g/dm²/h) Moving Average Intervals 6 min | 20 min | 35 min |
|---|---|---|---|---|---|---|---|---|---|---|
| YUL | 14/12/1995 | 21:16 | -11.8 | S- | 40 | 40.00 | | ( a ) | ( b ) | ( c ) |
| YUL | 14/12/1995 | 21:17 | -11.7 | S- | 40 | 40.16 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:18 | -11.6 | S- | 40 | 40.31 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:19 | -11.6 | S- | 40 | 40.47 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:20 | -11.6 | S- | 40 | 40.63 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:21 | -11.6 | S- | 40 | 40.78 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:22 | -11.6 | S- | 40 | 40.94 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:23 | -11.5 | S- | 40 | 41.09 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:24 | -11.6 | S- | 40 | 41.25 | | 9.38 | [illegible] | [illegible] |
| YUL | 14/12/1995 | 21:25 | -11.6 | S- | 40 | 41.41 | | 9.38 | 9.38 | [illegible] |
| YUL | 14/12/1995 | 21:26 | -11.4 | S- | 40 | 41.56 | | 9.38 | 9.38 | [illegible] |
| YUL | 14/12/1995 | 21:27 | -11.4 | S- | 40 | 41.72 | | [illegible] | 9.38 | [illegible] |
| YUL | 14/12/1995 | 21:28 | -11.5 | S- | 40 | 41.88 | | 9.38 | 9.38 | [illegible] |
| YUL | 14/12/1995 | 21:29 | -11.5 | S- | 40 | 42.03 | | 9.38 | 9.79 | 13.16 |
| YUL | 14/12/1995 | 21:30 | -11.4 | S- | 40 | 42.19 | | 9.38 | 10.20 | 13.39 |
| YUL | 14/12/1995 | 21:31 | -11.4 | S- | 40 | 42.34 | | 9.38 | 10.62 | 13.48 |
| YUL | 14/12/1995 | 21:32 | -11.4 | S- | 40 | 42.50 | | 9.38 | 11.03 | 13.57 |
| YUL | 14/12/1995 | 21:33 | -11.4 | S- | 40 | 42.66 | | 9.38 | [illegible] | 13.66 |
| YUL | 14/12/1995 | 21:34 | -11.4 | S- | 40 | 42.81 | | 9.38 | [illegible] | 13.75 |
| YUL | 14/12/1995 | 21:35 | -11.4 | S- | 40 | 42.97 | | [illegible] | 12.27 | 13.84 |
| YUL | 14/12/1995 | 21:36 | -11.3 | S- | 40 | 43.13 | | 9.38 | 12.68 | 13.93 |
| YUL | 14/12/1995 | 21:37 | -11.3 | S- | 40 | 43.28 | | 9.38 | 13.10 | 14.02 |
| YUL | 14/12/1995 | 21:38 | -11.4 | S- | 40 | 43.44 | | 9.38 | 13.51 | 14.11 |
| YUL | 14/12/1995 | 21:39 | -11.4 | S- | 40 | 43.59 | | 9.38 | 13.92 | 14.20 |
| YUL | 14/12/1995 | 21:40 | -11.3 | S- | 40 | 43.75 | | 9.38 | 14.34 | 14.29 |
| YUL | 14/12/1995 | 21:41 | -11.3 | S- | 40 | 43.91 | | 9.38 | 14.75 | 14.38 |
| YUL | 14/12/1995 | 21:42 | -11.3 | S- | 40 | 44.06 | | 9.38 | 15.17 | 14.46 |
| YUL | 14/12/1995 | 21:43 | -11.3 | S- | 40 | 44.22 | | 10.75 | 15.58 | 14.55 |
| YUL | 14/12/1995 | 21:44 | -11.2 | S- | 40 | 44.38 | | 12.13 | 15.99 | 14.64 |
| YUL | 14/12/1995 | 21:45 | -11.2 | S- | 40 | 44.53 | | 13.51 | 16.41 | 14.73 |
| YUL | 14/12/1995 | 21:46 | -11.2 | S- | 40 | 44.69 | | 14.89 | 16.56 | 14.82 |
| YUL | 14/12/1995 | 21:47 | -11.2 | S- | 40 | 44.84 | | 16.27 | 16.72 | 14.91 |
| YUL | 14/12/1995 | 21:48 | -11.2 | S- | 45 | 45.00 | | 17.65 | 16.88 | 15.00 |
| YUL | 14/12/1995 | 21:49 | -11.2 | S- | 45 | 45.29 | | 17.65 | 16.62 | 14.85 |
| YUL | 14/12/1995 | 21:50 | -11.2 | S- | 45 | 45.59 | | 17.65 | 16.36 | 14.71 |
| YUL | 14/12/1995 | 21:51 | -11.2 | S- | 45 | 45.88 | | 17.65 | 16.10 | 14.56 |
| YUL | 14/12/1995 | 21:52 | -11.1 | S- | 45 | 46.18 | | 17.65 | 15.85 | 14.41 |
| YUL | 14/12/1995 | 21:53 | -11.1 | S- | 45 | 46.47 | | 17.65 | 15.59 | 14.26 |
| YUL | 14/12/1995 | 21:54 | -11.1 | S- | 45 | 46.76 | | 17.65 | 15.33 | 14.12 |
| YUL | 14/12/1995 | 21:55 | -11.1 | S- | 45 | 47.06 | | 17.65 | 15.07 | 14.18 |
| YUL | 14/12/1995 | 21:56 | -11.1 | S- | 45 | 47.35 | | 17.65 | 14.82 | 14.25 |
| YUL | 14/12/1995 | 21:57 | -11.1 | S- | 45 | 47.65 | | 17.65 | 14.56 | 14.32 |
| YUL | 14/12/1995 | 21:58 | -11.1 | S- | 45 | 47.94 | | 17.65 | 14.30 | 14.39 |
| YUL | 14/12/1995 | 21:59 | -11.0 | S- | 45 | 48.24 | | 17.65 | 14.04 | 14.45 |
| YUL | 14/12/1995 | 22:00 | -11.0 | S- | 45 | 48.53 | | 16.79 | 13.79 | 14.52 |
| YUL | 14/12/1995 | 22:01 | -11.0 | S- | 45 | 48.82 | | 15.93 | 13.53 | 14.59 |
| YUL | 14/12/1995 | 22:02 | -11.0 | S- | 45 | 49.12 | | 15.07 | 13.27 | 14.66 |
| YUL | 14/12/1995 | 22:03 | -11.0 | S- | 45 | 49.41 | | 14.22 | 13.01 | 14.72 |
| YUL | 14/12/1995 | 22:04 | -10.9 | S- | 45 | 49.71 | | 13.36 | 12.76 | 14.79 |
| YUL | 14/12/1995 | 22:05 | -10.8 | S- | 50 | 50.00 | | 12.50 | 12.50 | 14.86 |

( a ) = (40.94 - 40.00)*60 / 6
( b ) = (43.13 - 40.00)*60 / 20
( c ) = (45.88 - 40.00)*60 / 35

The snow weather data were graphed in two formats. In one format, the number of snow precipitation events was plotted against the precipitation rates (see Figure 2.15). The other format (Figure 2.16) plots the cumulative probability of snow over all possible precipitation rates. The figures shown correspond to the temperature range of -3 to -7°C for 20-minute rate calculations. Both plots used the corresponding period to calculate average precipitation rates.

The histogram in Figure 2.15 indicates that snow events with low precipitation rates occurred much more frequently than those with high precipitation rates for the temperature range shown.

The cumulative probability in Figure 2.16 indicates that over 97 percent of all the natural snow events in the data had precipitation rates below 25 g/dm$^2$/h for 20-minute rate intervals.

A complete set of plots for all temperature ranges and rate durations for natural snow and freezing rain/drizzle is included in Appendix B. As previously mentioned, this report encompasses all the data presented in TC report, TP 14444E, *Winter Weather Impact on Holdover Time Table Format (1995-2005),* (1). For consistency purposes, the data in Appendix B is presented using the same temperature ranges used in the previous versions of this report. Moreover, changing the temperature breakdowns to reflect the values in the TC HOT table for Type I fluids (i.e. change -7°C to -6°C), does not produce a major change in the charts. These temperature ranges will also be used in the remainder of this section.

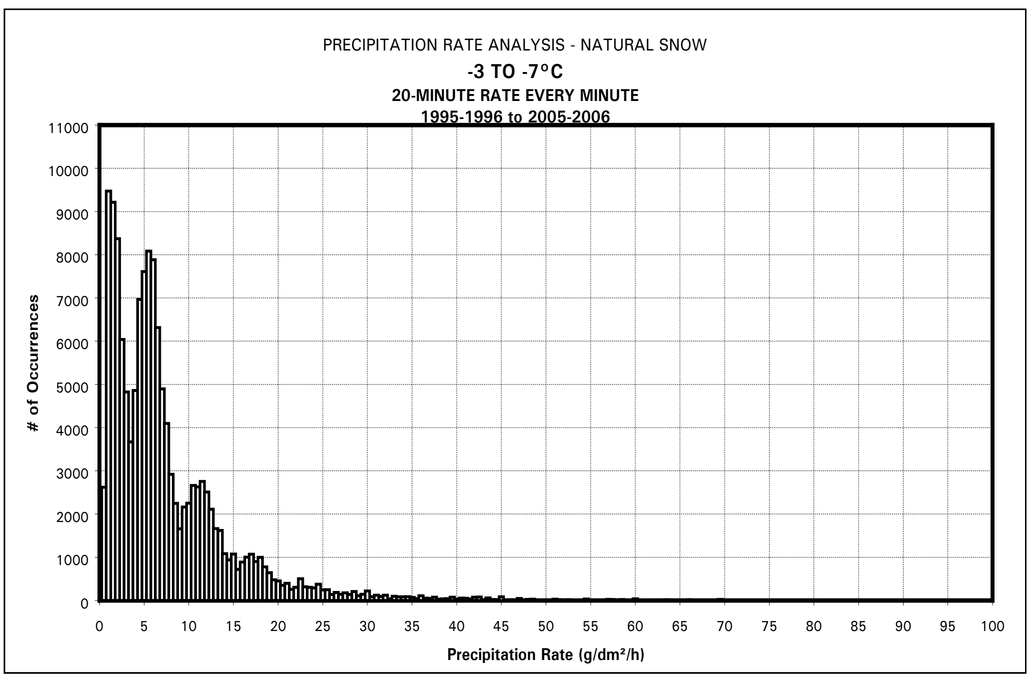


**Figure 2.15: READAC and CR21X Analysis – Natural Snow Histogram**

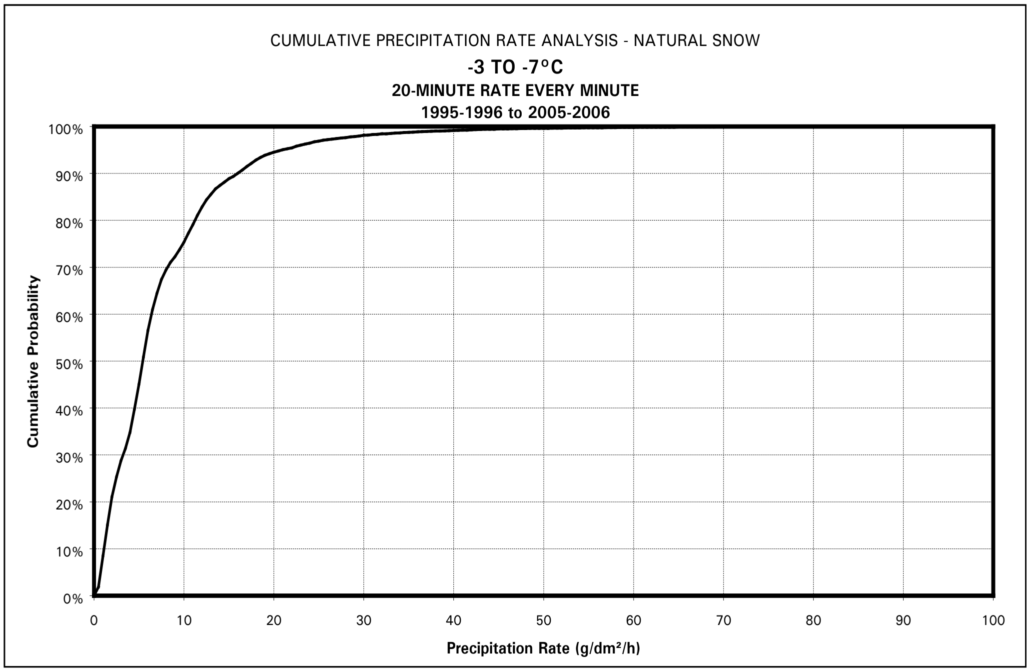


**Figure 2.16: READAC and CR21X Analysis – Natural Snow Cumulative Probability**

## 2.3.1 Natural Snow

The analysis in this section incorporates the snow data set from eleven winters: winter of 1995-96 to winter of 2005-06.

The 95$^{th}$ percentiles for several temperature ranges for natural snow conditions are shown in Table 2.14. The rates in this table represent the rate below which 95 percent of all snowfalls occurred in a specific temperature range for a given rate duration. For example, in the temperature range of *-3 to -7ºC* for duration of 20 minutes, the 95$^{th}$ percentile is 21 g/dm$^2$/h. This indicates that 95 percent of the 20-minute rates recorded between *-3ºC to -7ºC* were equal to or less than 21 g/dm$^2$/h.

On December 16, 2005, an intense snowstorm was recorded at most of the six meteorological stations, resulting in a larger representation of high rates in the 2005-06 winter data set relative to previous winter data sets. Partly as a result of this high-rate storm, many of the values in Table 2.14 are slightly higher than the values reported last year.

**Table 2.14: 95th Percentile in Each Temperature Range – Natural Snow**

| Temperature Range | 95th Percentile Precipitation Rate (g/dm²/h) | | |
|---|---|---|---|
| | 6 min | 20 min | 35 min |
| Above 0°C | 22 | 22 | 21 |
| 0°C to -3°C | 23 | 23 | 22 |
| -3°C to -7°C | 21 | 21 | 20 |
| -7°C to -14°C | 22 | 22 | 22 |
| -14°C to -25°C | 21 | 21 | 21 |

### *2.3.1.1 Heavy Snow*

Snow is categorized as heavy when precipitation rates exceed 25 g/dm²/h. The heavy snow category was broken into two categories to better represent the actual conditions that occur. These categories are as follows:

a) Heavy snow: between 25 and 50 g/dm²/h; and

b) Very Heavy snow: greater than 50 g/dm²/h.

Table 2.15 shows the occurrence of snow at precipitation rates greater than 25 g/dm²/h in different temperature ranges.

**Table 2.15: Heavy Snow (>25 g/dm²/h) Occurrence by Temperature Range**

| Temperature Range | Occurrence of Heavy Snow (>25 g/dm²/h) | | |
|---|---|---|---|
| | 6 min | 20 min | 35 min |
| Above 0°C | 3.5% | 3.2% | 3.2% |
| 0°C to -3°C | 3.7% | 3.6% | 3.5% |
| -3°C to -7°C | 3.3% | 3.0% | 2.9% |
| -7°C to -14°C | 3.4% | 3.4% | 3.5% |
| -14°C to -25°C | 2.5% | 2.6% | 2.7% |

The analysis of the data shows that overall, slightly more than 3 percent of all snowstorm events occur at precipitation rates greater than 25 g/dm²/h. This is also illustrated with the 6-minute data given in Figure 2.17.

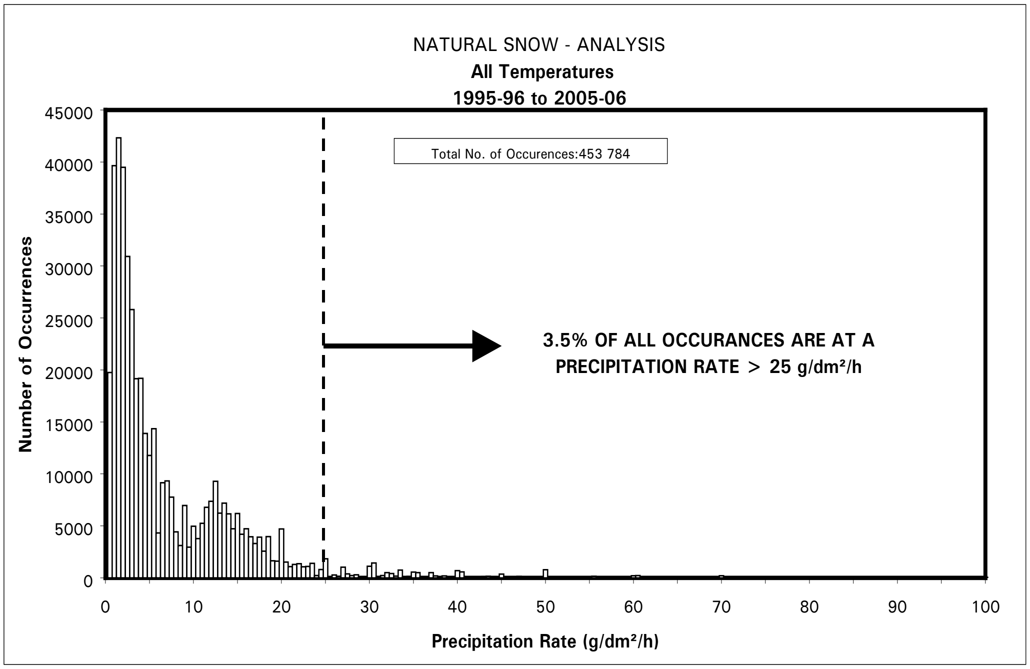


**Figure 2.17: Snow Analysis at High Precipitation Rates**

Table 2.16 shows the occurrence of snow at precipitation rates greater than 50 g/dm$^2$/h at different temperature ranges.

**Table 2.16: Heavy Snow (>50 g/dm$^2$/h) Occurrence by Temperature Range**

| Temperature Range | Occurrence of Heavy Snow (>50 g/dm$^2$/h) | | |
|---|---|---|---|
| | **6 min** | **20 min** | **35 min** |
| Above 0°C | 0.55% | 0.65% | 0.62% |
| 0°C to -3°C | 0.54% | 0.55% | 0.51% |
| -3°C to -7°C | 0.42% | 0.38% | 0.31% |
| -7°C to -14°C | 0.37% | 0.37% | 0.30% |
| -14°C to -25°C | 0.15% | 0.12% | 0.18% |

The analysis of the data shows that overall, about 0.4 percent of all snowstorm events occur at precipitation rates greater than 50 g/dm²/h. This is also illustrated with the 6-minute data given in Figure 2.18.

Figure 2.19 shows the cumulative probability of snow occurrences for data from 1995-2006.

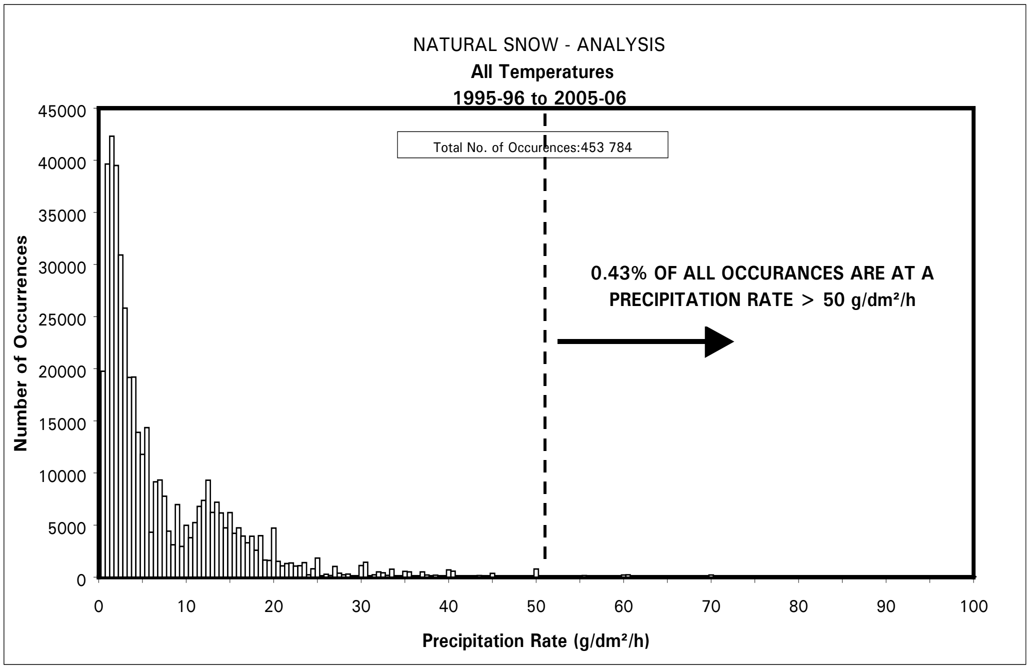


**Figure 2.18: Snow Analysis at Very High Precipitation Rates**

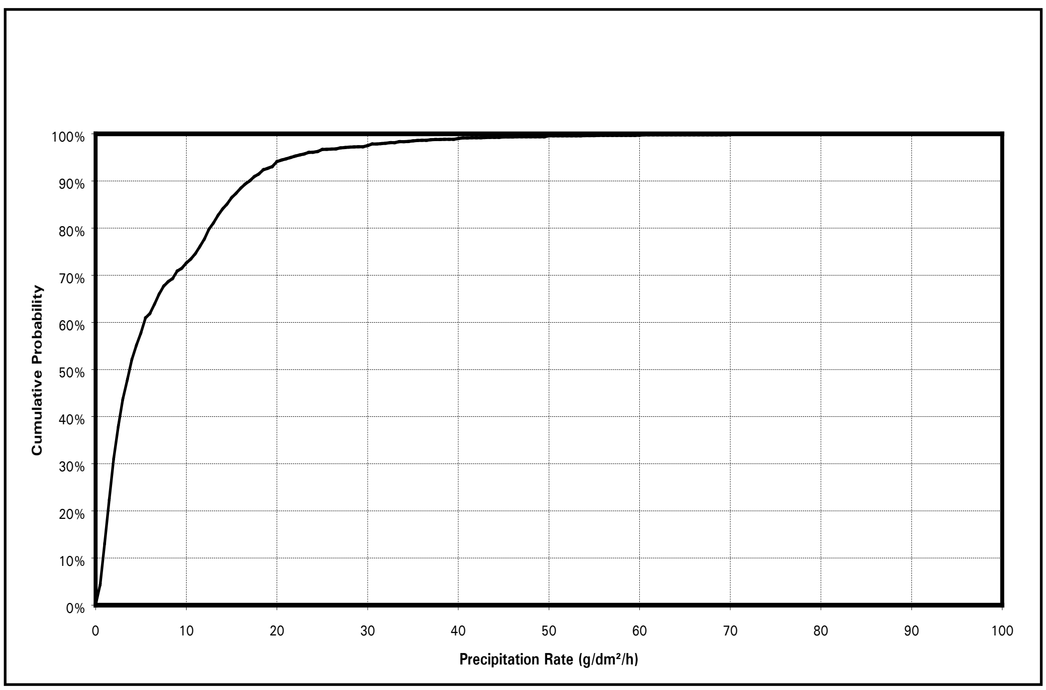


**Figure 2.19: Cumulative Probability of Snow Occurrences 1995-2006**

#### *2.3.1.2 Division of Very Heavy Snow Category*

Snow is categorized as very heavy when precipitation rates exceed 50 g/dm²/h. 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 on aircraft safety. There is a need to define the upper precipitation rate limit to obtain the lowest number in the holdover time range for heavy snow.

For this reason, the very heavy snow data (greater than 50 g/dm²/h) was divided into two categories to demonstrate the percentage of snow data exceeding 75 g/dm²/h and 100 g/dm²/h.

Table 2.17 shows a breakdown of this data. It shows that rates greater than 75 g/dm²/h represent only 0.13 percent of the entire dataset. In addition, rates greater than 100 g/dm²/h represent only 0.05 percent of the dataset.

**Table 2.17: Percentage of Snow Data Exceeding 75 and 100 g/dm²/h**

| 1` | # of Data Points | % |
|---|---|---|
| >0 g/dm²/h (all) | 453 040 | 100 |
| >75 g/dm²/h | 551 | 0.12 |
| >100 g/dm²/h | 193 | 0.04 |

#### *2.3.1.3 Natural Snow at Cold Temperatures*

The general shape of the curve for the cumulative probability of occurrence at colder temperatures is similar to that of the curves drawn for other temperatures, as shown in Figure 2.20. The chart shows that high precipitation rates occur equally at all temperature breakdowns.

The coldest temperature interval was divided into three smaller intervals (the data is shown in Appendix B):

a) -14 to -18°C;

b) -18 to -22°C; and

c) -22 to -25°C.

High precipitation rates were more common in the *-14 to -18°C* range, but a few high-rate snowfalls were recorded in the other two ranges, as seen in Figure 2.21.

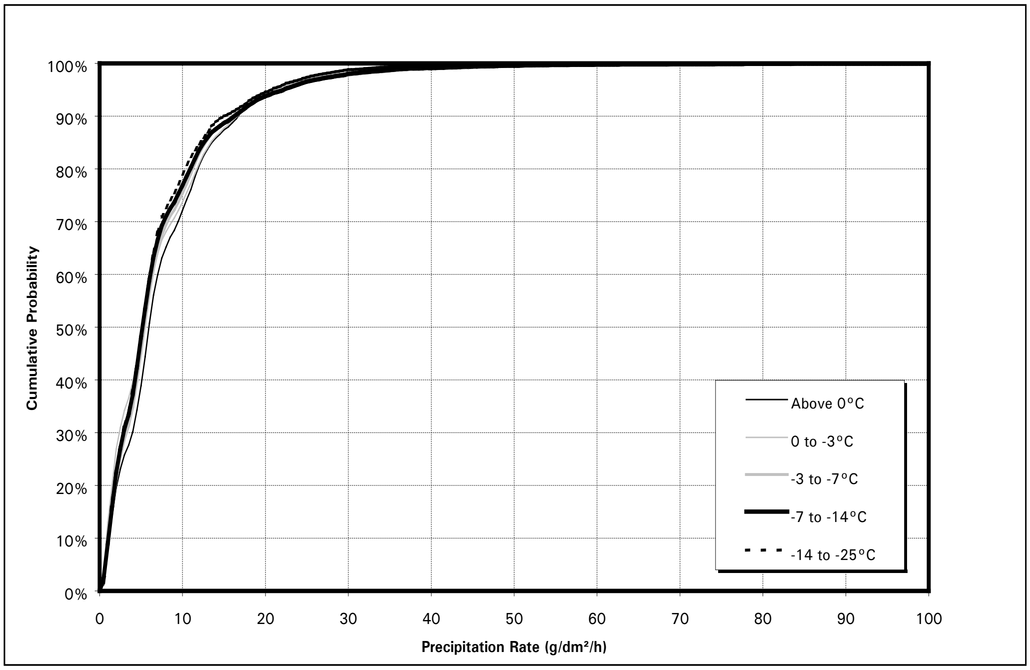


**Figure 2.20: 20-Minute Rate Every Minute, All Temperature Ranges**

Based on these results, consideration should be given to reformatting the HOT tables by dividing the *-14 to -25°C* interval, as precipitation rates were significantly lower at temperatures below -18°C and occurrences less frequent. However, the number of potential deicing operations at these lower temperatures needs to be considered.

For each cold temperature interval the percentage of occurrences when the precipitation rates were above 25 g/dm2/h is shown in Table 2.18.

**Table 2.18: Percentage of Heavy Snow Occurrences In Cold Temperatures – Natural Snow**

| Temperature Range | Percent of Occurrences when Rate is above 25 $g/dm^2/h$ | Percent of -14 to -25°C Data Points in Each Temperature Range | Percent of Total Data Points in Each Temperature Range |
|---|---|---|---|
| -14 to -18°C | 2.6% | 59.8% | 3.3% |
| -18 to -22°C | 2.5% | 34.2% | 1.9% |
| -22 to -25°C | 2.5% | 6.0% | 0.3% |
| | **Total** | **100%** | **5.6%** |

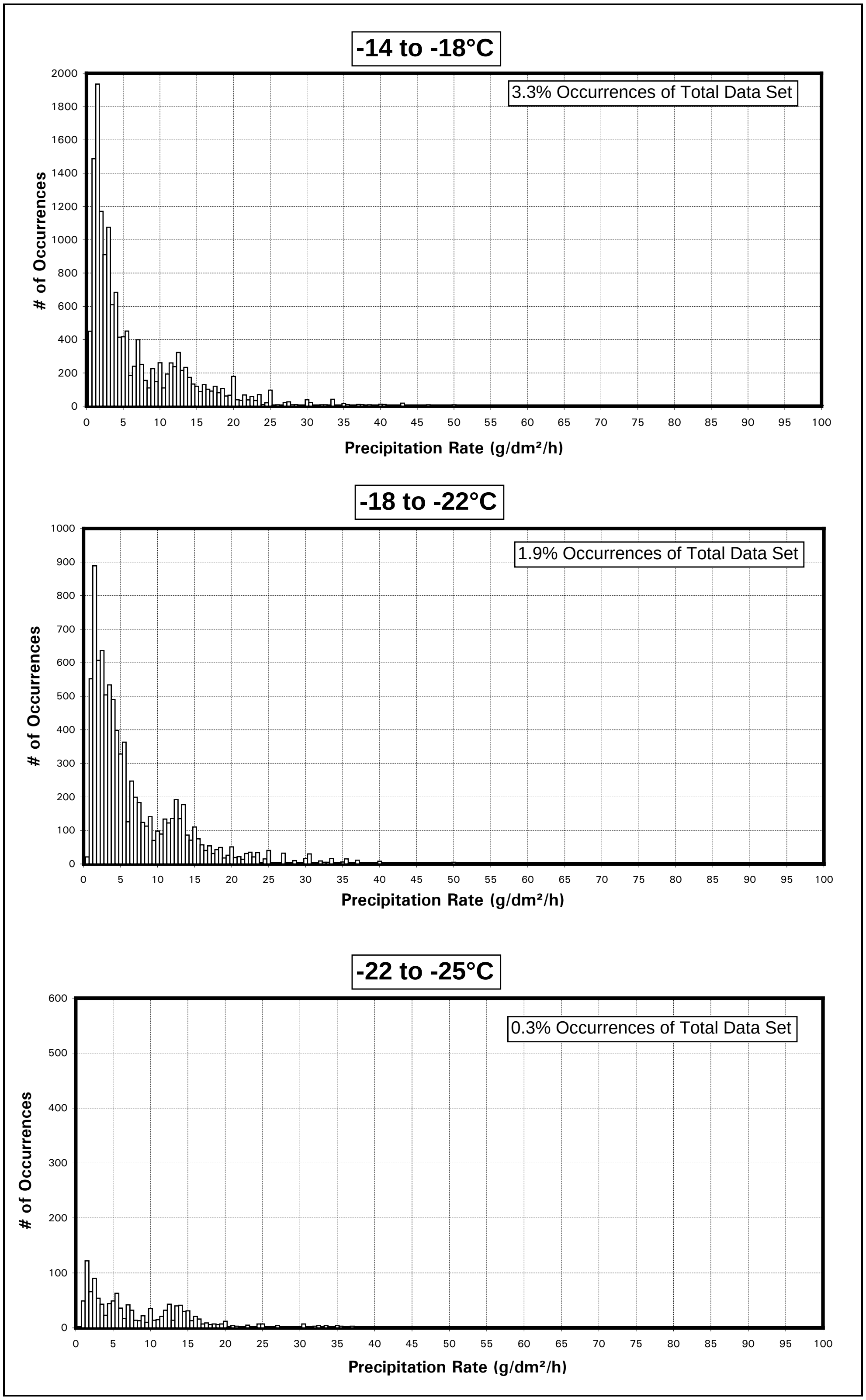


**Figure 2.21: Subdivision of -14 to -25°C – Snow Data**

#### *2.3.1.4 Probability of Snow Events for Holdover Time Table Temperature Ranges*

In an attempt to find the optimum temperature breakdowns for the HOT tables, the snow dataset (453 784 data points) was divided into 1°C intervals. In addition, each temperature range was split into precipitation rate ranges using 1 g/dm²/h increments. The results were translated into percentages to determine the probability of snow occurrence in each cell of the new table. The outcome is shown in Table 2.19.

The probability of snow event occurrences in each of the HOT temperature ranges of the HOT tables is shown in Tables Table 2.20 and Table 2.21. Table 2.20 corresponds to the temperature ranges of Type I fluid and Table 2.21 to the ranges of Type II and Type IV fluids. These two tables were created from the data in Table 2.19.

There were no data available for natural snow conditions below -25°C. In addition, each of the tables provides probability data for snowfall as a function of very light, light, moderate, and heavy snow.

For Type I fluids, 84.3 percent of snow events occurred above -10°C, justifying the current temperature break at -6°C. According to the Type I table categorization, 52.0 percent of the rates were classified as very light snow.

The probability of snow events for the Type IV table are 38.3 percent in the newly introduced *-3°C and above* temperature band and 56.0 percent for the range of *-3 to -14°C*.

The analysis presented in this report is based on data collected over ten years of observation from six meteorological stations across Quebec. A similar weather information database, comprised of hourly measurements over a 12-year period for two stations (Montreal and La Grande), was used for different projects and is discussed in Subsection 2.4. It has been included in this report for documentation purposes.

## Table 2.19: Probability (%) of Natural Snow Occurrence – 1995-96 to 2005-06

| TEMP (ºC) | RATE OF PRECIPITATION (g/dm²/h) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *0 to 1* | *1 to 2* | *2 to 3* | *3 to 4* | *4 to 5* | *5 to 6* | *6 to 7* | *7 to 8* | *8 to 9* | *9 to 10* | *10 to 11* | *11 to 12* | *12 to 13* | *13 to 14* | *14 to 15* | *15 to 16* | *16 to 17* | *17 to 18* | *18 to 19* | *19 to 20* | *20 to 21* | *21 to 22* | *22 to 23* | *23 to 24* | *24 to 25* | *>25* | *Total* | *Cumulative* |
| ***above 0*** | 1.50 | 1.91 | 1.42 | 0.97 | 0.63 | 0.52 | 0.49 | 0.35 | 0.27 | 0.20 | 0.24 | 0.36 | 0.46 | 0.41 | 0.34 | 0.29 | 0.23 | 0.20 | 0.18 | 0.20 | 0.08 | 0.08 | 0.07 | 0.06 | 0.07 | 0.38 | **11.9** | **11.9** |
| ***0 to -1*** | 1.04 | 1.62 | 1.01 | 0.70 | 0.43 | 0.31 | 0.29 | 0.19 | 0.18 | 0.13 | 0.17 | 0.26 | 0.31 | 0.26 | 0.23 | 0.18 | 0.15 | 0.13 | 0.10 | 0.10 | 0.04 | 0.04 | 0.04 | 0.03 | 0.04 | 0.28 | **8.2** | **20.1** |
| ***-1 to -2*** | 1.47 | 1.45 | 0.91 | 0.59 | 0.50 | 0.35 | 0.36 | 0.22 | 0.21 | 0.14 | 0.18 | 0.25 | 0.24 | 0.24 | 0.22 | 0.19 | 0.15 | 0.14 | 0.10 | 0.12 | 0.05 | 0.05 | 0.05 | 0.03 | 0.05 | 0.32 | **8.6** | **28.7** |
| ***-2 to -3*** | 1.14 | 1.76 | 1.10 | 0.86 | 0.58 | 0.37 | 0.43 | 0.26 | 0.22 | 0.15 | 0.19 | 0.27 | 0.34 | 0.31 | 0.24 | 0.20 | 0.16 | 0.15 | 0.14 | 0.14 | 0.07 | 0.07 | 0.05 | 0.03 | 0.06 | 0.33 | **9.6** | **38.3** |
| ***-3 to -4*** | 1.25 | 1.78 | 1.26 | 0.85 | 0.57 | 0.35 | 0.42 | 0.29 | 0.20 | 0.18 | 0.17 | 0.32 | 0.36 | 0.29 | 0.22 | 0.17 | 0.14 | 0.11 | 0.10 | 0.12 | 0.05 | 0.05 | 0.04 | 0.03 | 0.05 | 0.36 | **9.7** | **48.1** |
| ***-4 to -5*** | 0.92 | 1.29 | 1.00 | 0.66 | 0.45 | 0.34 | 0.35 | 0.23 | 0.16 | 0.11 | 0.16 | 0.25 | 0.26 | 0.25 | 0.23 | 0.19 | 0.14 | 0.12 | 0.12 | 0.15 | 0.05 | 0.06 | 0.04 | 0.03 | 0.06 | 0.29 | **7.9** | **56.0** |
| ***-5 to -6*** | 1.04 | 1.22 | 0.98 | 0.68 | 0.49 | 0.37 | 0.35 | 0.22 | 0.19 | 0.13 | 0.16 | 0.23 | 0.25 | 0.18 | 0.16 | 0.13 | 0.11 | 0.10 | 0.10 | 0.11 | 0.05 | 0.04 | 0.03 | 0.02 | 0.03 | 0.22 | **7.6** | **63.6** |
| ***-6 to -7*** | 0.72 | 1.17 | 0.84 | 0.57 | 0.38 | 0.31 | 0.25 | 0.17 | 0.15 | 0.11 | 0.13 | 0.20 | 0.20 | 0.17 | 0.16 | 0.12 | 0.09 | 0.09 | 0.07 | 0.07 | 0.03 | 0.02 | 0.02 | 0.01 | 0.02 | 0.20 | **6.3** | **69.8** |
| ***-7 to -8*** | 0.72 | 1.16 | 0.78 | 0.45 | 0.33 | 0.25 | 0.19 | 0.13 | 0.12 | 0.11 | 0.12 | 0.17 | 0.18 | 0.16 | 0.13 | 0.10 | 0.06 | 0.06 | 0.05 | 0.06 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 | 0.23 | **5.7** | **75.5** |
| ***-8 to -9*** | 0.58 | 0.74 | 0.64 | 0.41 | 0.27 | 0.22 | 0.20 | 0.14 | 0.11 | 0.10 | 0.12 | 0.17 | 0.18 | 0.15 | 0.12 | 0.09 | 0.08 | 0.07 | 0.06 | 0.05 | 0.02 | 0.03 | 0.01 | 0.01 | 0.02 | 0.13 | **4.7** | **80.2** |
| ***-9 to -10*** | 0.55 | 0.67 | 0.52 | 0.36 | 0.24 | 0.16 | 0.16 | 0.09 | 0.08 | 0.09 | 0.07 | 0.13 | 0.14 | 0.13 | 0.09 | 0.08 | 0.07 | 0.06 | 0.05 | 0.06 | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.11 | **4.0** | **84.3** |
| ***-10 to -11*** | 0.43 | 0.61 | 0.41 | 0.27 | 0.14 | 0.10 | 0.09 | 0.07 | 0.06 | 0.05 | 0.06 | 0.10 | 0.09 | 0.06 | 0.05 | 0.04 | 0.05 | 0.05 | 0.04 | 0.05 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 | 0.08 | **3.0** | **87.3** |
| ***-11 to -12*** | 0.26 | 0.55 | 0.36 | 0.23 | 0.13 | 0.10 | 0.11 | 0.06 | 0.04 | 0.04 | 0.04 | 0.08 | 0.07 | 0.05 | 0.04 | 0.05 | 0.03 | 0.03 | 0.03 | 0.04 | 0.01 | 0.02 | 0.02 | 0.01 | 0.03 | 0.08 | **2.5** | **89.8** |
| ***-12 to -13*** | 0.27 | 0.56 | 0.36 | 0.23 | 0.13 | 0.10 | 0.11 | 0.06 | 0.04 | 0.04 | 0.04 | 0.08 | 0.07 | 0.05 | 0.04 | 0.05 | 0.03 | 0.03 | 0.03 | 0.04 | 0.01 | 0.02 | 0.02 | 0.01 | 0.03 | 0.09 | **2.5** | **92.3** |
| ***-13 to -14*** | 0.30 | 0.45 | 0.26 | 0.16 | 0.11 | 0.07 | 0.07 | 0.07 | 0.04 | 0.03 | 0.04 | 0.08 | 0.07 | 0.05 | 0.03 | 0.03 | 0.03 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.10 | **2.1** | **94.4** |
| ***-14 to -15*** | 0.20 | 0.29 | 0.17 | 0.10 | 0.09 | 0.06 | 0.05 | 0.03 | 0.02 | 0.03 | 0.03 | 0.04 | 0.05 | 0.04 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.03 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.05 | **1.4** | **95.8** |
| ***-15 to -16*** | 0.12 | 0.22 | 0.07 | 0.07 | 0.03 | 0.02 | 0.03 | 0.02 | 0.01 | 0.04 | 0.02 | 0.02 | 0.03 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | **0.8** | **96.7** |
| ***-16 to -17*** | 0.13 | 0.08 | 0.06 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.03 | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | **0.6** | **97.2** |
| ***-17 to -18*** | 0.09 | 0.09 | 0.10 | 0.05 | 0.02 | 0.02 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | **0.5** | **97.7** |
| ***-18 to -19*** | 0.04 | 0.09 | 0.09 | 0.08 | 0.04 | 0.04 | 0.04 | 0.03 | 0.02 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.03 | **0.7** | **98.4** |
| ***-19 to -20*** | 0.04 | 0.10 | 0.12 | 0.08 | 0.06 | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | **0.7** | **99.1** |
| ***-20 to -21*** | 0.07 | 0.09 | 0.02 | 0.04 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.4** | **99.5** |
| ***-21 to -22*** | 0.02 | 0.04 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.2** | **99.7** |
| ***-22 to -23*** | 0.02 | 0.04 | 0.02 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | **0.1** | **99.8** |
| ***-23 to -24*** | 0.02 | 0.04 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.1** | **99.9** |
| ***-24 to -25*** | 0.05 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.1** | **100.0** |
| ***Total*** | **13.0** | **18.0** | **12.5** | **8.5** | **5.7** | **4.1** | **4.1** | **2.7** | **2.2** | **1.8** | **2.0** | **3.1** | **3.4** | **2.9** | **2.4** | **2.0** | **1.6** | **1.4** | **1.2** | **1.4** | **0.6** | **0.6** | **0.5** | **0.4** | **0.6** | **3.3** | | |
| ***Cumulative*** | **13.0** | **31.0** | **43.5** | **52.0** | **57.7** | **61.8** | **65.9** | **68.6** | **70.8** | **72.6** | **74.6** | **77.7** | **81.1** | **84.1** | **86.4** | **88.4** | **90.0** | **91.4** | **92.7** | **94.1** | **94.7** | **95.2** | **95.7** | **96.1** | **96.7** | **100.0** | | |

**Table 2.20: 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 | 19.4% | 7.8% | 9.8% | 1.3% | **38.3%** |
| below -3 to -6 | 12.9% | 5.4% | 6.0% | 0.9% | **25.2%** |
| below -6 to -10 | 10.9% | 4.4% | 4.8% | 0.7% | **20.8%** |
| below -10 | 8.8% | 3.1% | 3.4% | 0.5% | **15.8%** |
| **Total** | **52.0%** | **20.6%** | **24.1%** | **3.3%** | **100.0%** |

**Table 2.21: 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 |
|---|---|---|---|---|---|
| -3 and above | 19.4% | 7.8% | 9.8% | 1.3% | **38.3%** |
| below -3 to -14 | 29.5% | 11.6% | 13.0% | 1.9% | **56.0%** |
| below -14 to -25 | 3.1% | 1.2% | 1.2% | 0.1% | **5.6%** |
| below -25 | 0.0% | 0.0% | 0.0% | 0.0% | **0.0%** |
| **Total** | **52.0%** | **20.6%** | **24.1%** | **3.3%** | **100.0%** |

### 2.3.2 Freezing Rain/Drizzle

The 95th percentile for two temperature ranges is shown in Table 2.22 for freezing rain/drizzle. In the temperature range of *0 to -3°C* for duration of 20 minutes, the 95th percentile is 30 g/dm$^2$/h. This indicates that 95 percent of the 20-minute rates recorded between *0°C to -3°C* were equal to or less than 30 g/dm$^2$/h.

**Table 2.22: 95th Percentile in Each Temperature Range – Freezing Rain/Drizzle**

| Temperature Range | 95th Percentile Precipitation Rate (g/dm²/h) | | |
|---|---|---|---|
| | 6 min | 20 min | 35 min |
| 0 to -3°C | 33 | 30 | 28 |
| -3 to -10°C | 27 | 26 | 25 |

The 6-minute 95th percentile was 27 g/dm$^2$/h for the *-3 to -10°C* range and 33 g/dm²/h for the *0 to -3°C* range.

Using the weather dataset provided by MSC, a separate analysis was conducted for freezing rain and freezing drizzle. The freezing rain and freezing drizzle events were tracked from 1997-98 to 2002-03 using the Monthly Meteorological Data Summary provided by MSC. The analysis methodology was identical to the one described in Sections 2.1.3 and 2.1.4. Over six winters, from 1997-98 to 2002-03, 22 freezing drizzle events and 44 freezing rain events were identified. The analysis, indicating the event durations and the temperature and precipitation rate distributions of data points per condition, is presented in Section 2.4 of TC report, TP 14375E, *Winter Weather Impact on Holdover Time Table Format (1995-2004)*, (2).

### 2.3.3 Ice Pellets and Mixed Precipitation

As presented in Section 2.2.3, 5,747 ice pellet data points were collected for Montreal and four other Quebec stations (Quebec, Pointe-au-Père, High Falls, and Rouyn-Noranda) during the 2004-05 and 2005-06 winters. The analysis methodology was identical to that described in Sections 2.1.3 and 2.1.4.

In total, 28 ice pellet events, representing approximately 96 hours of ice pellet data, were identified. Twelve of these events occurred during the winter of 2004-05; sixteen of these events occurred during the winter of 2005-06. Figure 2.22 illustrates the distribution of event duration for ice pellet conditions during the 2004-05 and 2005-06 winters.

The vast majority of the ice pellet data includes ice pellets in combination with other precipitation types, typically freezing rain, freezing drizzle or snow.

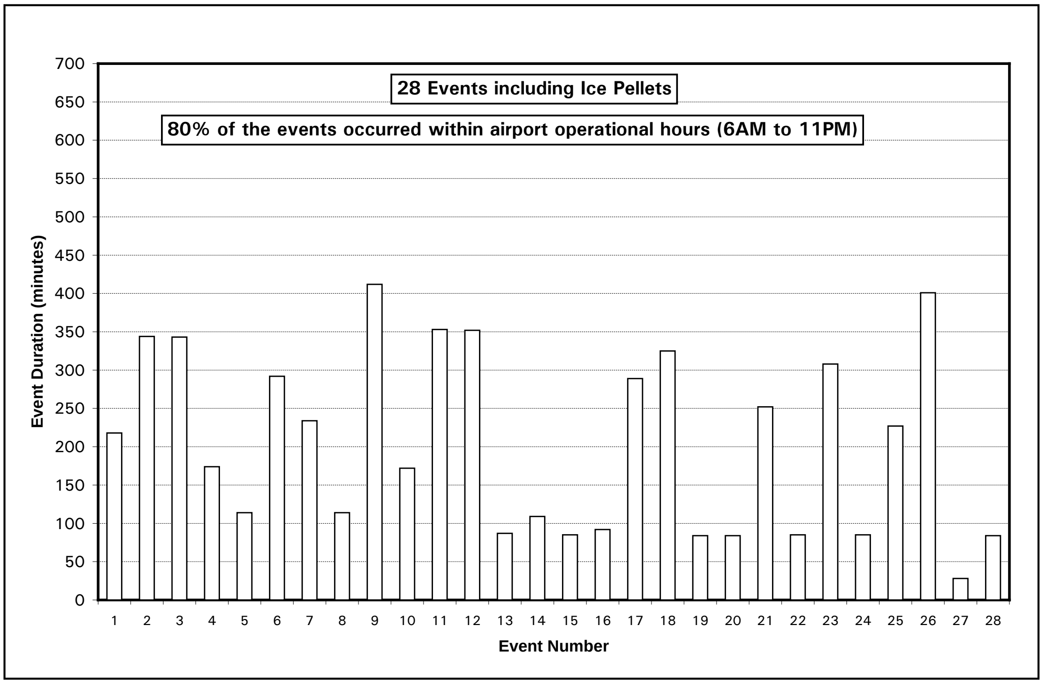


**Figure 2.22: Distribution of Ice Pellet Event Duration – 2004-05 and 2005-06**

As indicated in Figure 2.22, a large proportion of ice pellet events occur in the typical operating hours of most airports. It should be noted that the data in Figure 2.22 represents data collected from longer storms. There were likely other storms of shorter duration that could not be tracked.

Using the minute-by-minute temperature data from the CR21X file, precipitation rates were calculated. The precipitation rate distribution is presented in Figure 2.23. Figure 2.24 plots the cumulative probability of precipitation over all possible precipitation rates.

Ninety-five percent of the 6-minute rates were equal to or below 40 g/dm$^2$/h. Precipitation rates above 25 g/dm$^2$/h represent only 13 percent of all the ice pellet occurrences.

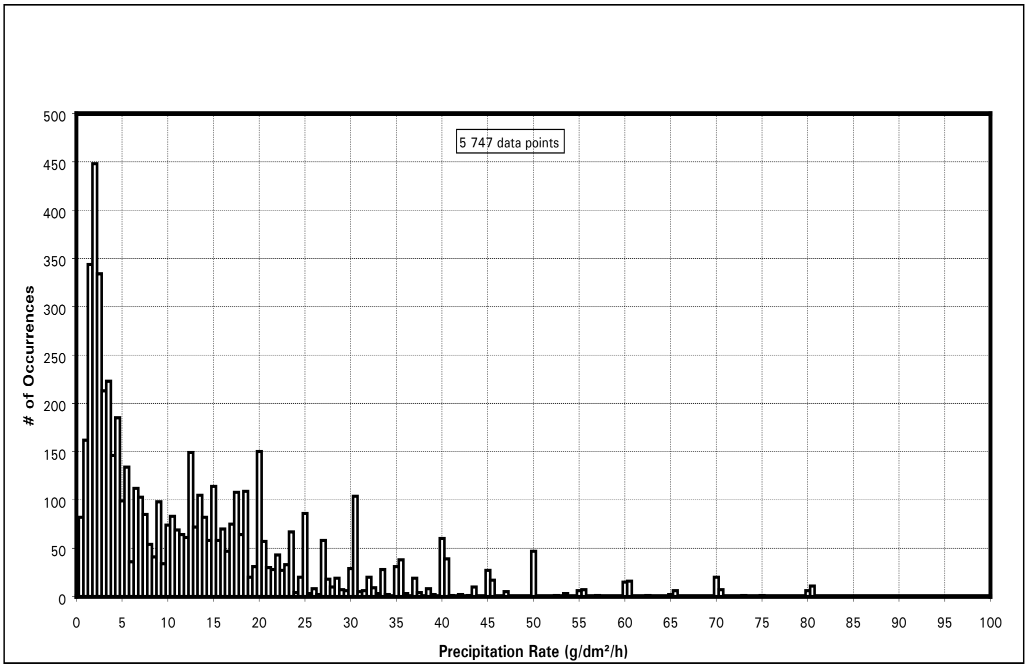


**Figure 2.23: Precipitation Rate Analysis – Ice Pellets**

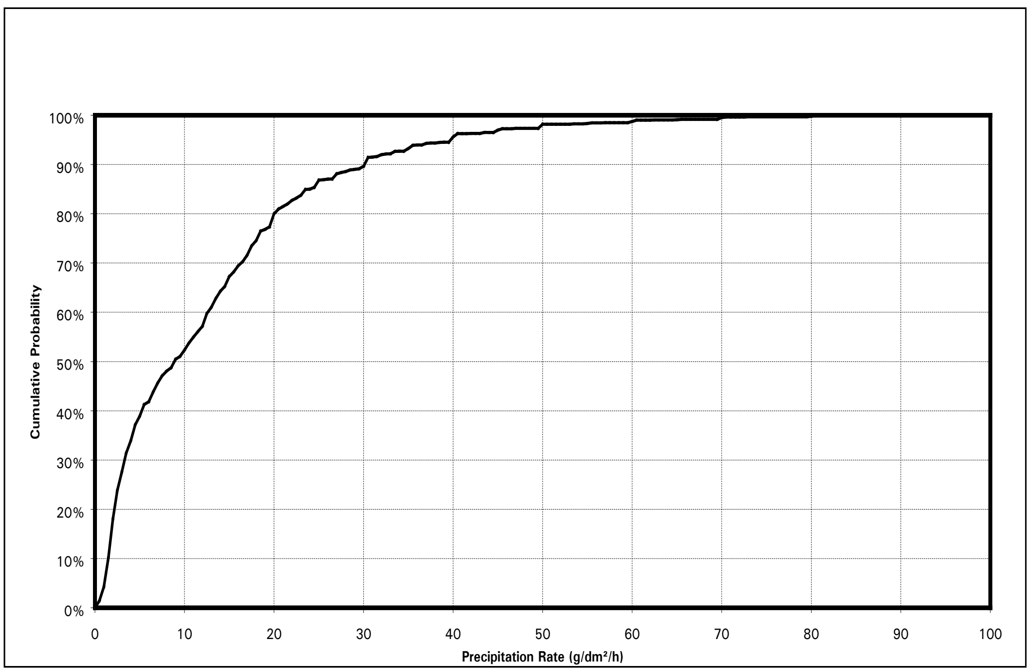


**Figure 2.24: Cumulative Precipitation Rate Analysis – Ice Pellets**

#### *2.3.3.1 Isolated Ice Pellet Events*

Because ice pellets most often occur in combination with other precipitation types, an attempt was made in 2005-06 to investigate pure ice pellet events. This was done to better understand the conditions under which ice pellets occur. The data is approximate, as the methodology used to collect data does not allow for exact determination of the occurring precipitation.

Using the hourly observations of atmospheric data provided by MSC, data were selected that occurred 15 minutes before and 15 minutes after any hour that the MSC observer noted ice pellets and no other precipitation types. This was done because an assumption was made that this type of precipitation did not necessarily last throughout the hour.

Based on the above methodology, 496 data points were extracted from all ice pellet events. This represents approximately 8.3 hours of data from all six meteorological stations. The pure ice pellet activity accounts for 19 percent of all ice pellet activity in 2005-06.

The distribution of pure ice pellet activity is shown by temperature in Table 2.23. It shows that 90.5 percent of ice pellet data points in 2005-06 occurred between 0 and -10°C.

**Table 2.23: Distribution of 2005-06 Pure Ice Pellet Data by Temperature**

| Temperature Range | Data Points | % |
|---|---|---|
| Above 0ºC | 47 | 9.5 |
| Between 0 and -10°C | 449 | 90.5 |
| Below -10°C | 0 | 0.0 |
| **Total** | **496** | **100.0** |

## 2.4 Weather Information Database – La Grande and Montreal

An extensive dataset was acquired by APS from the MSC. The hourly data contains weather observations for two meteorological stations in Quebec, Montreal and La Grande, from January 1, 1990 to December 31, 2001. The data contains observations of the following parameters: visibility, wind speed, wind direction, dew point, relative humidity, atmospheric pressure, cloud opacity, cloud amount and weather condition.

This dataset of weather information was used for different projects. The specific use of the dataset in each project is described in TC report, TP 14444E, *Winter Weather Impact on Holdover Time Table Format (1995-2005),* (1).

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# 3. WINTER OPERATIONS SURVEY

Between 2000-01 and 2002-03, APS conducted an annual survey on behalf of TC in an attempt to collect data on actual deicing operations at several worldwide stations. TC was seeking this information in support of a review of the HOT table temperature and weather condition breakdowns so that future research and development could be aimed at conditions where an important number of operations occur worldwide. In addition, the intent was to identify where improvements could be made to the HOT table format.

To acquire a worldwide representation of deicing operations, TC distributed the survey to a number of fluid users. The combined results from the three surveys provided data for 112,535 deicing operations (Type I Table) and 86,853 anti-icing operations (Type II/IV Table). The de/anti-icing operations were sorted by weather condition: frost, freezing fog, snow, freezing drizzle, light freezing rain, and other (snow pellets, snow grain, ice pellets, rime ice). A detailed analysis of the results for each year analysed by weather condition, temperature and fluid type was completed and can be found in Section 3 of TC report, TP 14375E, *Winter Weather Impact on Holdover Time Table Format (1995-2004),* (2).

Figure 3.1 demonstrates the combined results of the three annual surveys. The number of de/anti-icing operations that occurred under snow precipitation was 56 percent, thus substantiating the belief that snow represents the most significant weather condition for de/anti-icing operations worldwide. Frost accounted for 33 percent of de/anti-icing operations; freezing precipitation, including freezing fog, freezing drizzle, light freezing rain, and rain on cold-soak wing accounted for 7 percent of operations; and the remaining 4 percent of operations were conducted due to other forms of freezing precipitation.

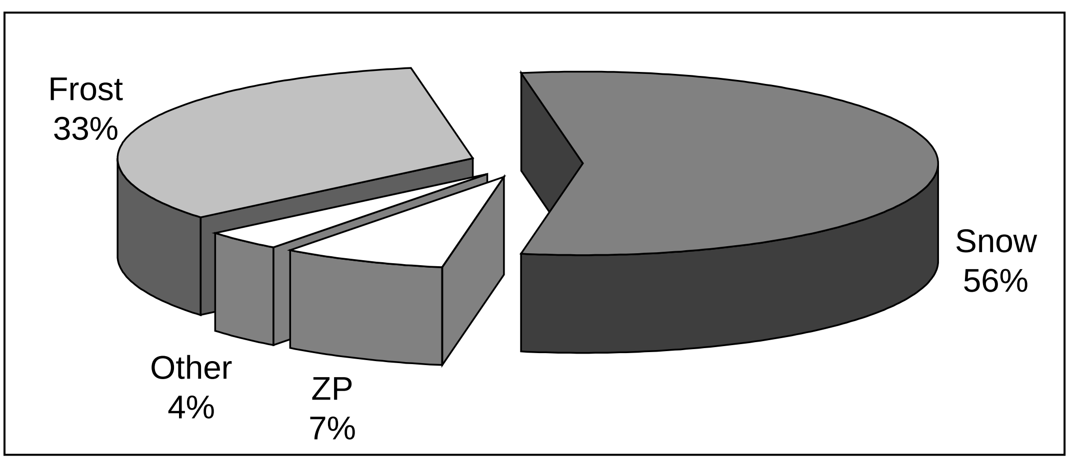


**Figure 3.1: Frequency of De/Anti-icing Operations (All Airports) – Combined Results of 2000-01 to 2002-03 Surveys**

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# 4. CHANGES TO THE FORMAT OF THE HOLDOVER TIMES TABLES

This section presents a summary of the changes made to the HOT table format over the last five years. These changes are described in detail in related reports. The titles of these reports are provided. Changes to the table format, agreed upon by the industry members in a certain year, are reflected in the HOT tables of the following winter season.

## 4.1 Changes in 2001-02

In 2001-02, the Type I fluid HOT table format underwent a thorough examination. Research in previous years had indicated a need to make changes to the format. Some of the changes were presented and accepted by the community, while others were not formally accepted. The two major changes made to the format of the 2002-03 Type I fluid HOT table were:

a) Modifying the split point between the two warmest temperature ranges from 0°C to -3°C (temperature ranges change from *above 0°C* and *0°C* to *-10°C* to *above -3°C* and *-3°C* to *-10°C*); and

b) Addition of a column for light snow.

A detailed study providing the reasoning and justification behind these changes was conducted and can be found in Section 6 of TC report, TP 13993E, *Impact of Winter Weather on Holdover Time Table Format (1995-2002),* (3).

## 4.2 Changes in 2002-03

In 2002-03 the format of the 2003-04 Type I tables was further reviewed and two significant changes were implemented:

a) A new temperature range was introduced by splitting the *-3 to -10°C* interval into *below -3 to -6°C* and *below -6 to -10°C* temperature ranges; and

b) Apart from the existing *light snow* and *moderate snow* columns, a new *very light snow* column was introduced.

A detailed analysis which justifies these two major changes was conducted and can be found in Section 4 of TC report TP 14146E, *Winter Weather Impact on Holdover Time Table Format (1995-2003)*, (5).

## 4.3 Changes in 2003-04

A new Type III generic table was introduced in 2003-04. The development of the new table is described in Section 5 of TC report, TP 14374E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2003-04 Winter* (6). Values in the new 2004-05 Type III generic HOT guidelines were generally based on the HOTs of Clariant Safewing MP III 2031 ECO.

## 4.4 Changes in 2004-05

In 2004-05, rows for 75/25 and 50/50 dilutions were added to the 2005-06 Type III generic HOT guidelines and several changes were made to the format of the 2005-06 Type II/IV tables. These changes included merging the first two temperature rows, changing the title of the snow column to *Snow or Snow Grains*, changing the title of the frost column to *Active Frost* and moving the viscosity information from the fluid-specific tables to a separate viscosity table.

These changes are described in detail in the TC report, TP 14443E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2004-05 Winter* (7).

## 4.5 Changes in 2005-06

No major changes were made to the HOT table format in 2005-06.

## 4.6 Future Changes

This section looks at changes that may be made to the holdover time table format in the future.

### 4.6.1 Potential Changes to HOT Table Values

A three-year survey of worldwide fluid users showed that the majority of the de/anti-icing operations occur under snow precipitation, thus substantiating that snow represents the most significant weather condition for deicing operations worldwide. Table 4.1 shows the results from the survey by weather condition and temperature range. The temperature ranges in Table 4.1 reflect the format changes implemented in the 2005-06 HOT tables. The percentage values in the table are re-calculated after the exclusion of the frost column. As can be seen in Table 4.1, in the absence of the frost column, snow accounts for over 83 percent of all deicing operations.

**Table 4.1: Usage of HOT Table, Excluding Frost**

| OAT (°C) | FREEZING FOG | SNOW | FREEZING DRIZZLE | LIGHT FRZ. RAIN | RAIN ON COLD SOAKED WING | OTHER | Total |
|---|---|---|---|---|---|---|---|
| -3 and above | 2.4% | 52.8% | 3.5% | 2.9% | 1.4% | 1.3% | 64.2% |
| -3 to -14 | 1.5% | 28.1% | 1.4% | 1.2% | 0.0% | 1.4% | 33.6% |
| -14 to -25 | 0.0% | 2.2% | 0.0% | 0.0% | 0.0% | 0.0% | 2.2% |
| below -25 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Total | 3.8% | 83.1% | 4.9% | 4.1% | 1.4% | 2.7% | 100.0% |

The weather conditions in the highlighted section of Table 4.1 represent more than 87 percent of all deicing operations. In other words, the cells in the highlighted section of the table are utilised more than 87 percent of the time when deicing operations take place in precipitation conditions excluding frost.

It could be envisioned that in the future, the endurance times of new deicing fluids will be tested in these cells only, as they account for the vast majority of precipitation conditions requiring deicing. The remaining cells in the table will be replaced by generic values and will be the same for all fluid-specific HOT tables. An example of this vision is described in more detail in the TC report, TP 14719E, *Aircraft Ground Icing Research General Activities During the 2005-06 Winter* (8).

### 4.6.2 Heavy Snow

Pressure has been mounting on regulators in recent years to provide de/anti-icing fluid holdover time guidelines for heavy snow conditions. Heavy snow is currently covered in the various holdover time tables by a caution note that states that "No Holdover Time Guidelines Exist".

In the analysis of winter weather conditions presented in Section 2, heavy snow conditions accounted for approximately 3.5 percent of all the snow events. The values provided in Figure 2.17 are believed to be highly representative of global snow distributions. At 3.5 percent, the percentage of air carrier operations that occur in heavy snow conditions is thereby similar to that of freezing fog (3.8 percent), freezing drizzle (4.9 percent) and light freezing rain (4.1 percent) conditions (see Table 4.1). Holdover time values have been provided for each of these conditions, and therefore it seems reasonable that the air carrier community has indicated a desire for TC and the FAA to examine the possibility of providing holdover time values for heavy snow conditions as well.

HOT values in the current holdover time guidelines are determined by plotting fluid endurance time data points collected in natural snow conditions versus rate of precipitation, and then using regression analysis to calculate the fluid endurance times at two pre-selected rate limits. These regression curves could be used to determine fluid holdover times in heavy snow. For example, Figure 4.1 shows the regression curves developed for most commercially available Type IV fluids, including the extrapolated portion of the curves in heavy snow beyond rates of 25 g/dm²/h.

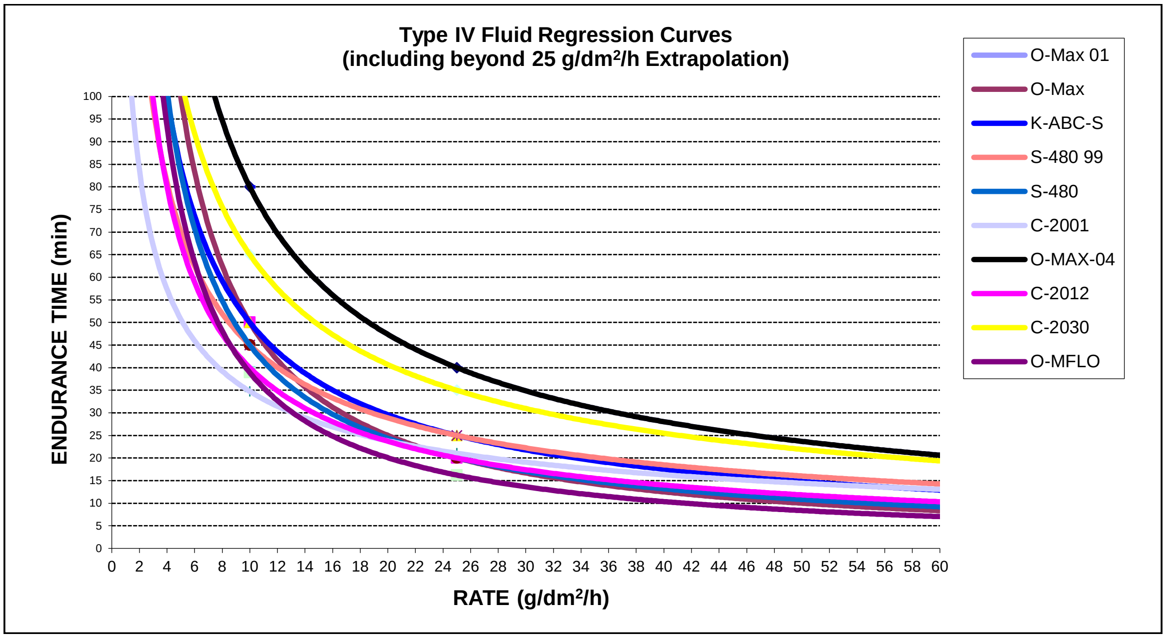


**Figure 4.1: Type IV Fluid Regression Curves in Snow (Neat Fluid, -3°C to -14°C) including 25 g/dm2/h**

Because natural snow data at heavy snow rates of precipitation is often very limited, holdover times for heavy snow could also be generated by conducting simulated snow tests with the National Center for Atmospheric Research (NCAR) snowmaker. This data could then be validated by comparing it to the regression data.

Due to the high liquid water equivalent (LWE) of snow at high rates of precipitation and the short holdover times that subsequently result, the SAE G-12 HOT Workgroup proposed (Lisbon, May 2006) that no holdover time guidelines in heavy snow be provided until equipment to measure LWE was operationally available at airports. It was the view of the HOT Workgroup that longer and more precise holdover time information could be provided in many other winter operating conditions in addition to heavy snow if the LWE were known.

An example of a potential Type IV fluid holdover time table, including holdover times in heavy snow, has been included in Table 4.2.

**Table 4.2: Example Of Type IV Fluid Holdover Time Table in Snow**

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Holdover Times for Snow Conditions Based on TC Visibility Chart (hours:minutes) | | | | |
|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Very Light Snow | Light Snow | Moderate Snow | Heavy Snow | Very Heavy Snow |
| -3 and above | 27 and above | 100/0 | 2:00 | 1:15 – 2:00 | 0:35 – 1:15 | 0:20 – 0:35 | CAUTION: No holdover time guidelines exist |
| | | 75/25 | 1:35 | 0:55 – 1:35 | 0:20 – 0:55 | 0:10 – 0:20 | |
| | | 50/50 | 0:35 | 0:15 – 0:35 | 0:05 – 0:15 | 0:00 – 0:05 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 1:15 | 0:40 – 1:15 | 0:20 – 0:40 | 0:15 – 0:20 | |
| | | 75/25 | 0:55 | 0:35 – 0:55 | 0:15 – 0:35 | 0:05 – 0:15 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 1:00 | 0:30 – 1:00 | 0:15 – 0:30 | 0:05 – 0:15 | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | |

### 4.6.3 Snow Pellets

Snow pellets are defined as small white and opaque grains of ice. These grains are either spherical or conical. Their diameter is approximately 2-5 mm. Snow pellets are brittle, easily crushed and tend to either bounce or break on hard ground. It was observed that snow pellets tend to occur during snow conditions, and not during freezing rain, freezing drizzle, or ice pellet conditions. Currently, no holdover times exist for snow pellets.

Natural snow pellets were observed during endurance time testing conducted at the APS test site in Montreal on February 16, 2006 and March 3, 2006. During both events, the temperature was approximately -10 °C, and the snow pellet event lasted less than 15 minutes. It was observed that the snow pellets were instantly absorbed once in contact with the fluid and then began to dissolve. The behaviour of the snow pellets once in contact with the fluid was similar to that of natural snow.

A preliminary comparative study was conducted to investigate the time required to dissolve equal masses of natural sintered snow and simulated snow pellets (lightly packed shaved ice) in comparison to ice pellets. 30 mg of each sample was lightly packed and dropped into deicing and anti-icing fluid. The results showed that the dissolving time for both snow and snow pellets were comparable, however both were less in comparison to ice pellets.

Snow data used to generate snow holdover times may already include snow pellets. Snow pellet events are usually brief, therefore endurance time testing conducted during snow conditions with a transition into snow pellets would not have been discarded unless the condition was severe. In addition, Falcon 20 testing showed that ice pellet contamination is completely removed from the wing at rotation speeds, therefore snow pellets, being less dense, should also be completely removed. For these reasons, it has been suggested that the HOT values for natural snow be applicable to natural snow pellets.

Further analysis of the CR21X data should be conducted to quantify the percentage occurrences of snow pellets in comparison to other forms of winter precipitation.

# 5. EVALUATION OF FROST AND FOG DEPOSITION RATES IN NATURAL CONDITIONS

This chapter contains an account of the tests conducted in previous winter seasons to collect frost and fog deposition rates in natural conditions.

## 5.1 Measurement of Frost Deposition Rates in Natural Conditions

Frost deposition rate measurements were conducted in three previous test seasons. During the first two seasons, the winters of 2001-02 and 2002-03, APS conducted tests to establish test parameters that reflect natural environment conditions for active frost. Rates of natural frost accretion were documented to enable specification of frost intensity for fluid endurance time testing. The rates were measured using an insulated white-painted aluminum surface that was found to be representative of aircraft wing surfaces.

In the last of the three seasons, the winter of 2003-04, APS conducted frost endurance tests outdoors using insulated white-painted aluminum surfaces. The rates of frost accretion were documented.

The data collected during these winters was analysed in an attempt to determine the expected icing intensities in a natural environment. A full account of the frost deposition rates that were measured during frost testing, along with the results and analysis of the data collected, can be found in Section 5 of TC report, TP 14375E, *Winter Weather Impact on Holdover Time Table Format (1995-2004)*, (2).

## 5.2 Study to Quantify Freezing Fog Deposition Rates

Natural freezing fog deposition rate measurements were conducted during previous test seasons. It was concluded that current HOT table precipitation rate limits of 2 and 5 g/dm$^2$/h are conservative, with rates measured during actual fog conditions closer to 1 g/dm$^2$/h. For an account of testing from previous years, refer to TC report TP 13993E, *Impact of Winter Weather on Holdover Time Table Format (1995-2002)*, (3).

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# 6. CONCLUSIONS

Data gathered over eleven years from six sites in Quebec form the basis for the winter weather analysis discussed in this report. The data confirms that the long-established HOT table snow precipitation rates of 10 and 25 $g/dm^2/h$ are valid limits at all temperature ranges for the *moderate snow* range. However, the data analysis also emphasizes that this range encompasses only 24 percent of all snow events, and snowfall at rates less than 10 $g/dm^2/h$ accounts for over 73 percent of all snow events. It is also significant that snow comprises 56 percent of all deicing operations worldwide. The addition of the 2005-06 CR21X data did not significantly change the precipitation rate distribution calculated in previous years for both natural snow and freezing rain/drizzle.

A three-year survey of worldwide fluid users showed that the percentage of deicing operations occurring in ice pellet conditions is very small. However, there is a significant interest in the industry for endurance time testing under ice pellet conditions, originating especially from operators that have a high volume of flights in the overnight hours.

There is interest in providing values in the HOT tables for heavy snow. It was found that 3.1 percent of snow events occur at rates between 25 and 50 $g/dm^2/h$. There is some discussion that these limits, or perhaps the more conservative limits of 25 to 75 $g/dm^2/h$, be used to develop HOTs for heavy snow.

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# 7. RECOMMENDATIONS

Recommendations related to specific subjects are offered.

## 7.1 Weather Data Survey

It is recommended that:

- This survey be continued in order to generate more data, which is particularly needed for relatively infrequent precipitation conditions such as ice pellets, snow pellets, freezing drizzle and freezing rain.

## 7.2 HOT Table Format

It is recommended that:

- A workgroup be assembled to discuss the development and the possible implementation of a proposed HOT table template that could be followed for future HOT testing.

## 7.3 Snow Pellets

It is recommended that:

- Snow pellets be added to the natural snow column of the HOT tables. It may be useful to verify whether the historical endurance time data includes cases with snow pellets mixed in with snow.

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# REFERENCES


1. Moc, N., *Winter Weather Impact on Holdover Time Table Format (1995-2005),* APS Aviation Inc., Transportation Development Centre, Montreal, October 2005, TP 14444E, XX (to be published).

2. Moc, N., *Winter Weather Impact on Holdover Time Table Format (1995-2004),* APS Aviation Inc., Transportation Development Centre, Montreal, December 2004, TP 14375E, XX (to be published).

3. Moc, N., Alwaid, A., *Impact of Winter Weather on Holdover Time Table Format (1995-2002)*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2002, TP 13993E, XX (to be published).

4. Cortinas, J.V., Jr., B.C. Bernstein, C.C. Robbins and J.W. Strapp, 2003: *An Analysis of Freezing Rain, Freezing Drizzle, and Ice Pellets Across the United States and Canada: 1976-1990*. *Wea. Forecasting,* 19, 377-390.

5. Moc, N., *Winter Weather Impact on Holdover Time Table Format (1995-2003),* APS Aviation Inc., Transportation Development Centre, Montreal, October 2003, TP 14146E, XX (to be published).

6. Bendickson, S., *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2003-04 Winter,* APS Aviation Inc., Transportation Development Centre, Montreal, December 2004, TP 14374E, XX (to be published).

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8. Bendickson, S., Bell, K., Youssef, D., and D'Avirro, J., *Aircraft Ground Icing Research General Activities During the 2005-06 Winter,* APS Aviation Inc., Transportation Development Centre, Montreal, October 2006, TP 14719E, XX (to be published).

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# APPENDIX A

# TRANSPORTATION DEVELOPMENT CENTRE
# WORK STATEMENT EXCERPT
# AIRCRAFT & ANTI-ICING FLUID
# WINTER TESTING 2005-06

# TRANSPORTATION DEVELOPMENT CENTRE
# WORK STATEMENT EXCERPT
# AIRCRAFT & ANTI-ICING FLUID
# WINTER TESTING 2005-06

## 5.1 WEATHER RESEARCH

### 5.1.1 Evaluation of Winter Weather Data

a) Collect more data from the six weather stations in Quebec, with emphasis on freezing drizzle, freezing rain, and ice pellets;

b) Analyze current database for frequency of occurrence in other conditions such as snow pellets;

c) Analyze the data collected and report the findings; and

d) Provide any resulting recommendations that may have an impact on the HOT table format.

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# APPENDIX B

# WINTER WEATHER DATA 1995-96 TO 2005-06

# WINTER WEATHER DATA

# 1995-96 TO 2005-06

The following charts include the complete rate data analysis, subdivided by temperature ranges for both snow and freezing rain. A histogram of points and a cumulative probability chart are included for each rate calculation interval in all temperature ranges.

The lowest holdover time temperature range for snow conditions (-14°C to -25°C) was subdivided into three ranges. The charts for this analysis are also included.

## INDEX

### SNOW



### LIGHT FREEZING RAIN / DRIZZLE



### COLD SNOW SUBDIVISION

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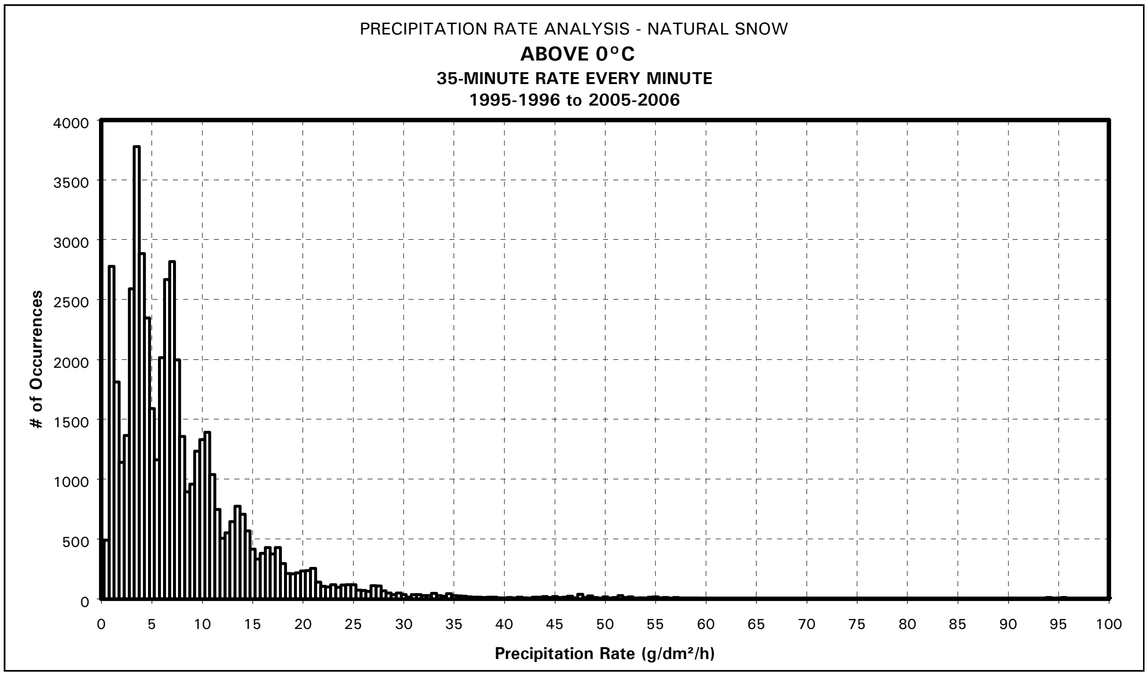
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1995-1996 to 2005-2006
# of Occurrences
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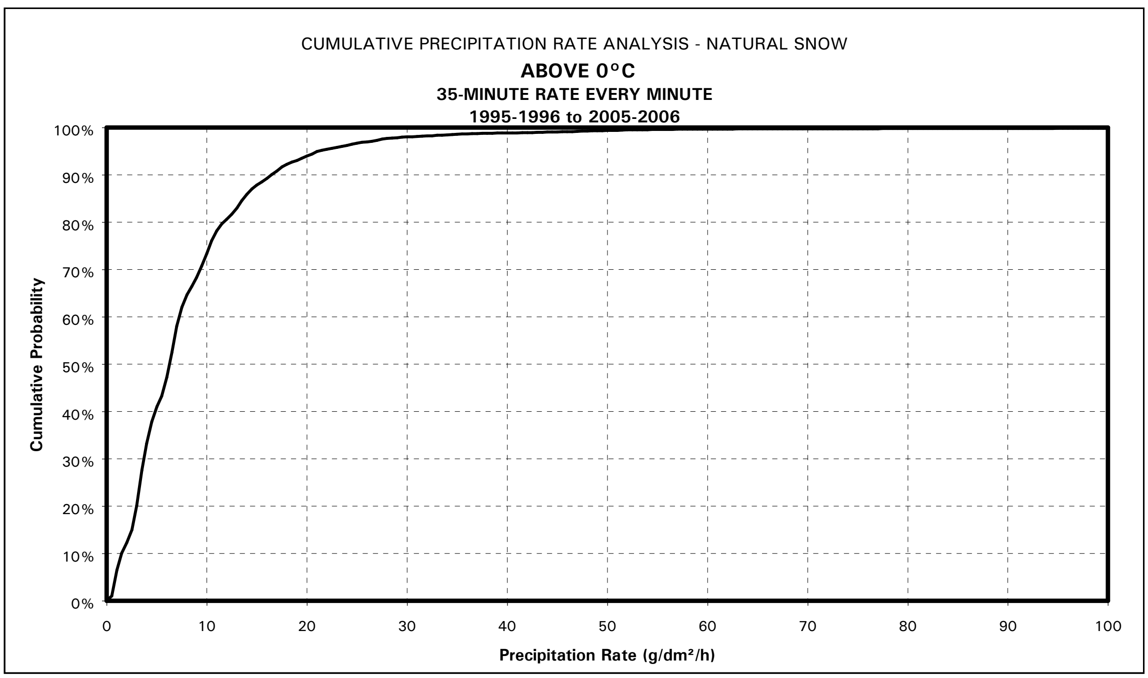
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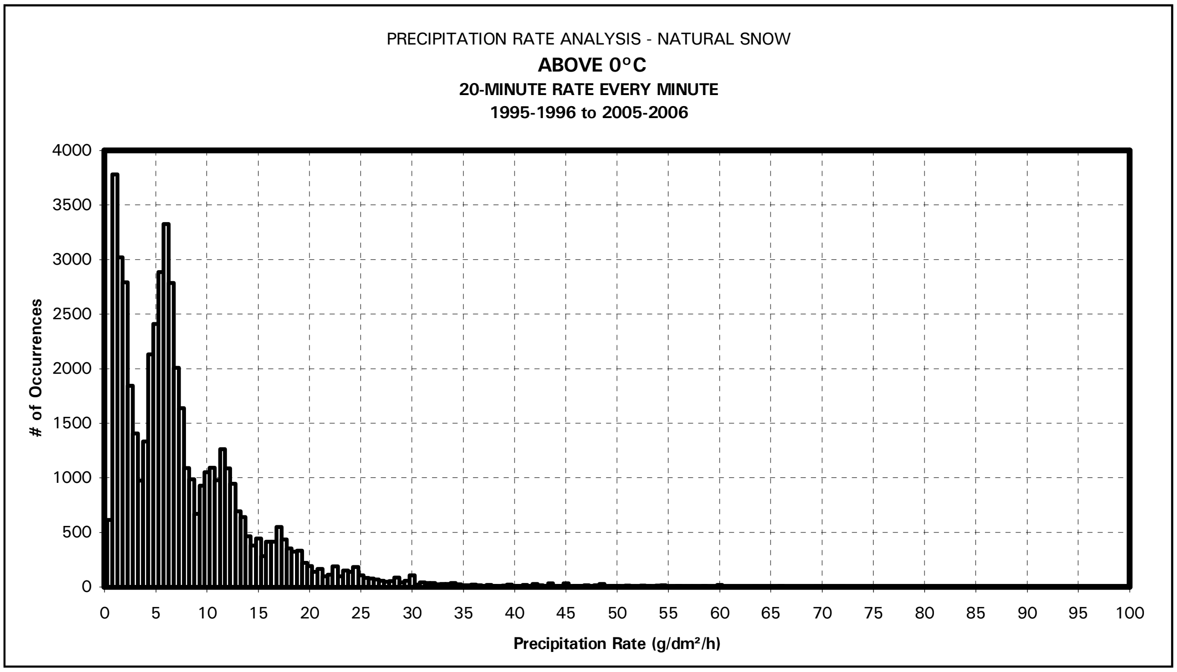
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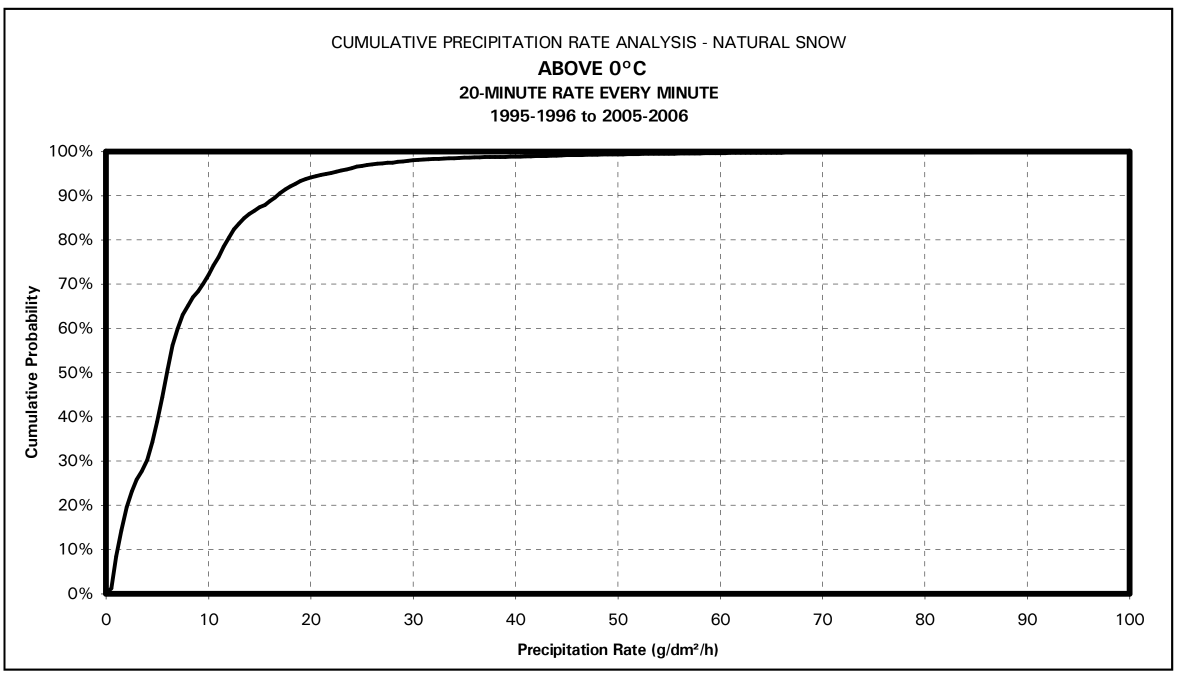
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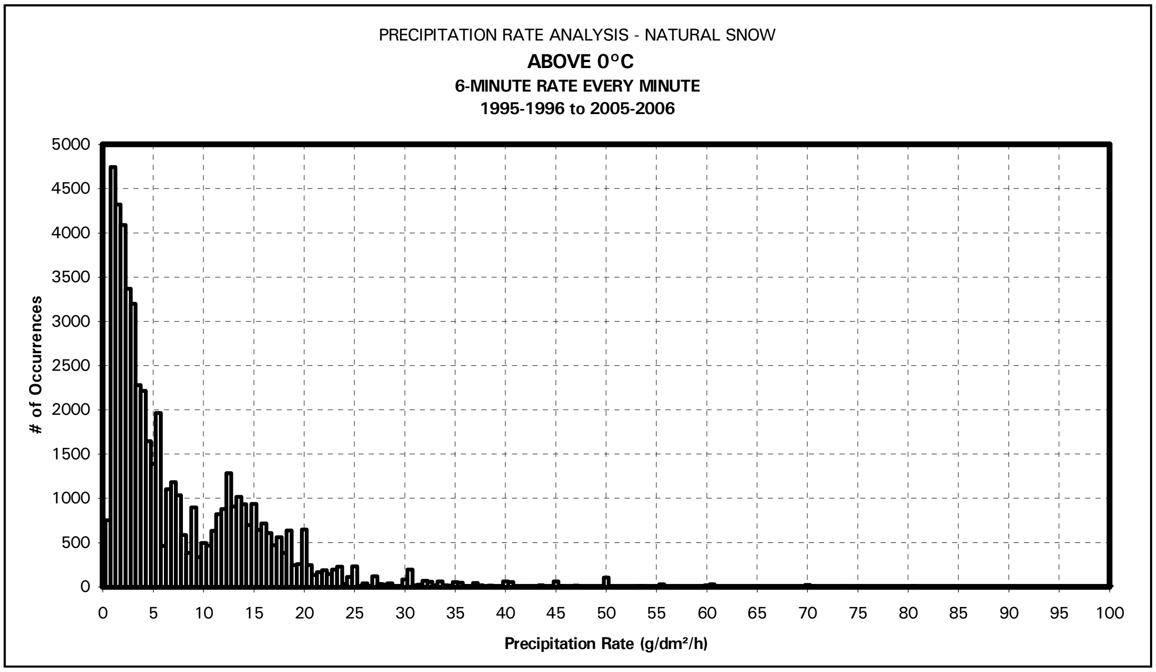
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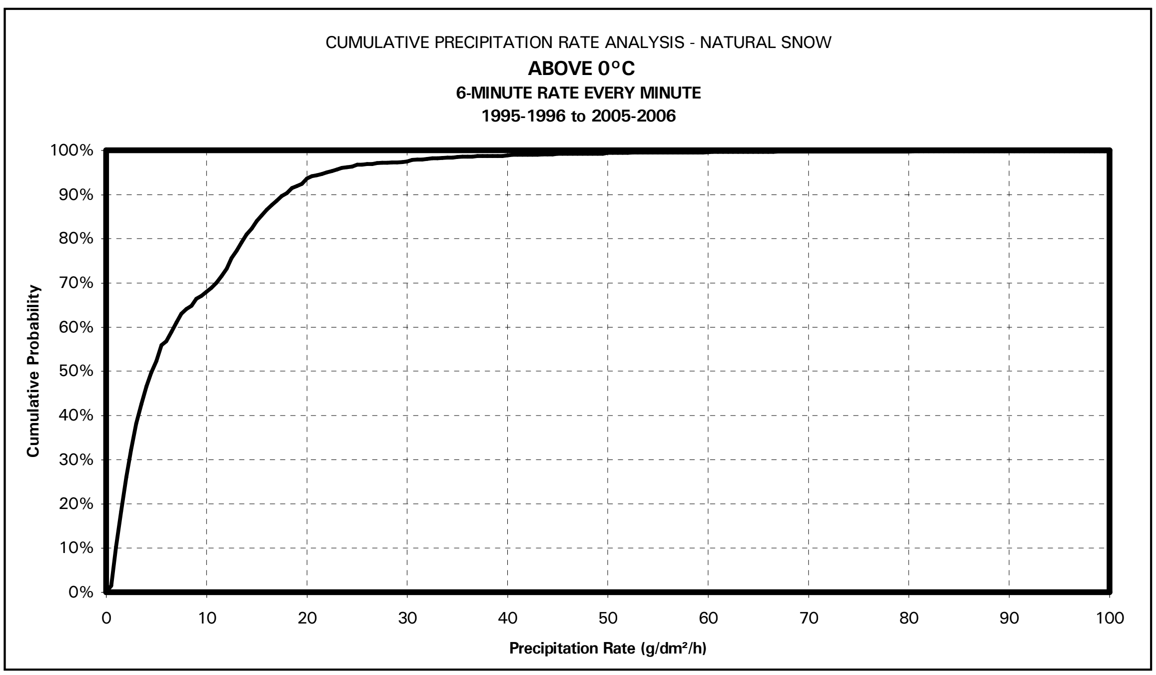
Precipitation Rate (g/dm²/h)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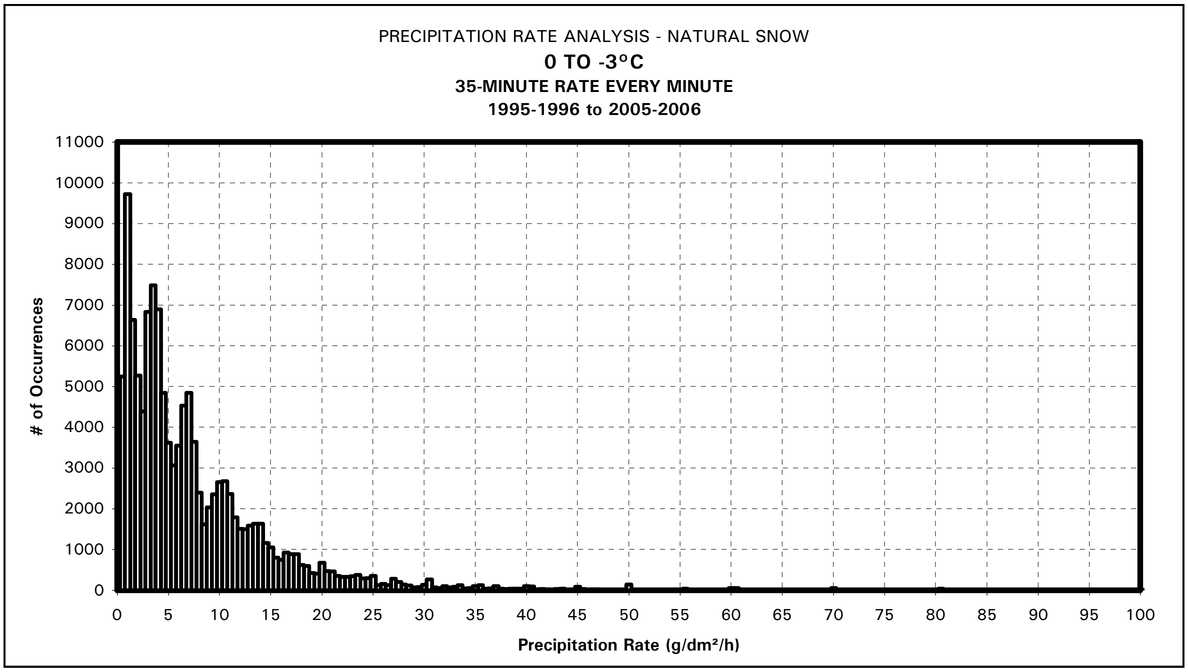
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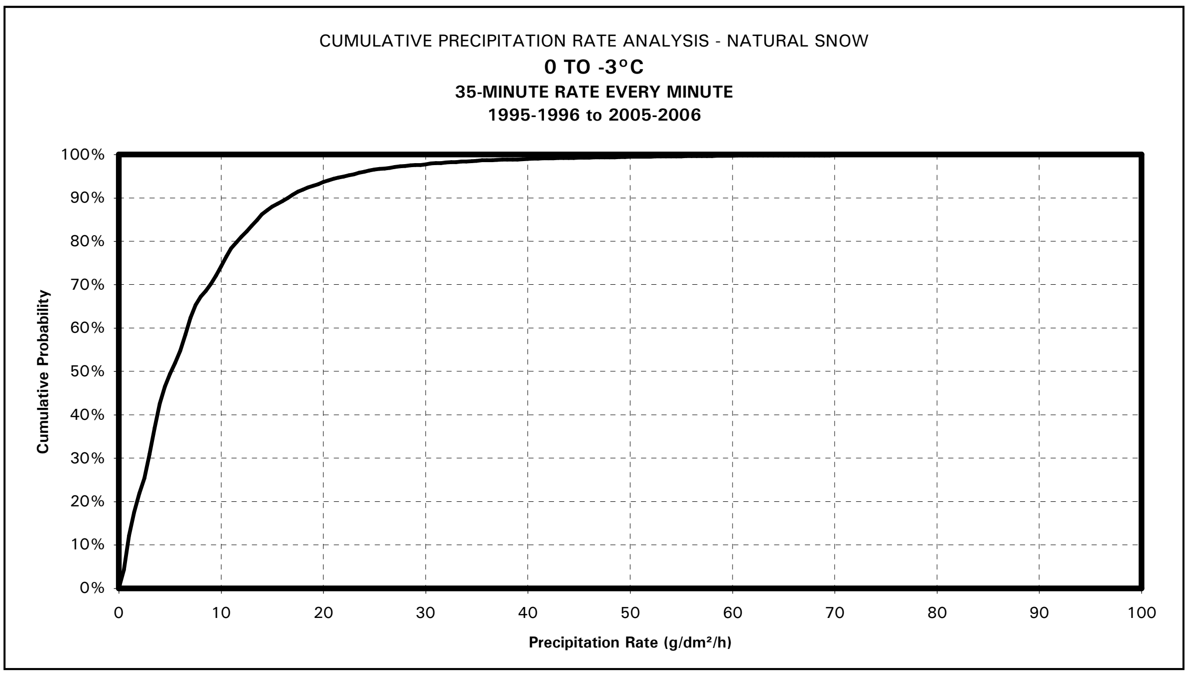
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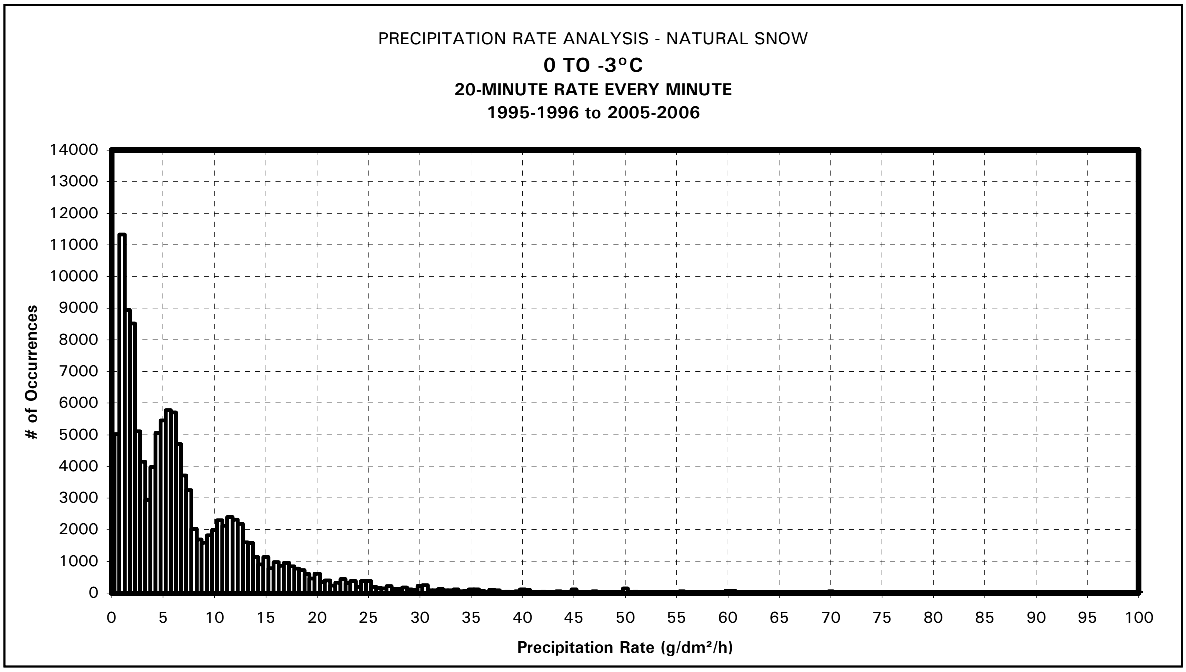
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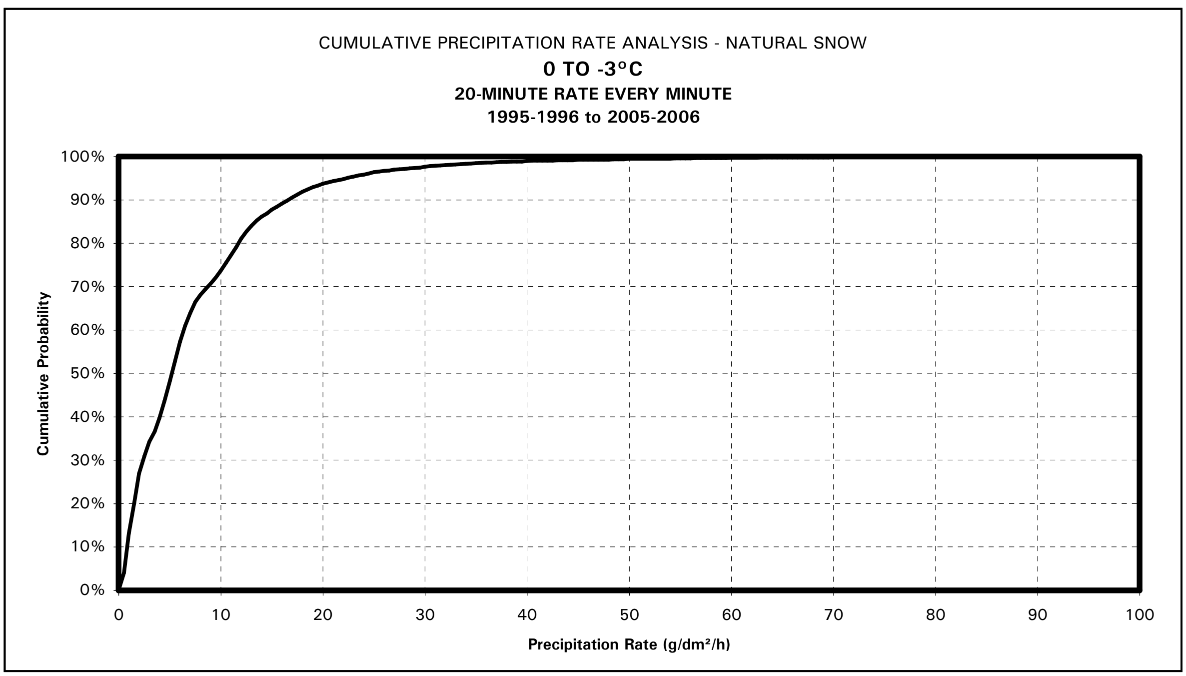
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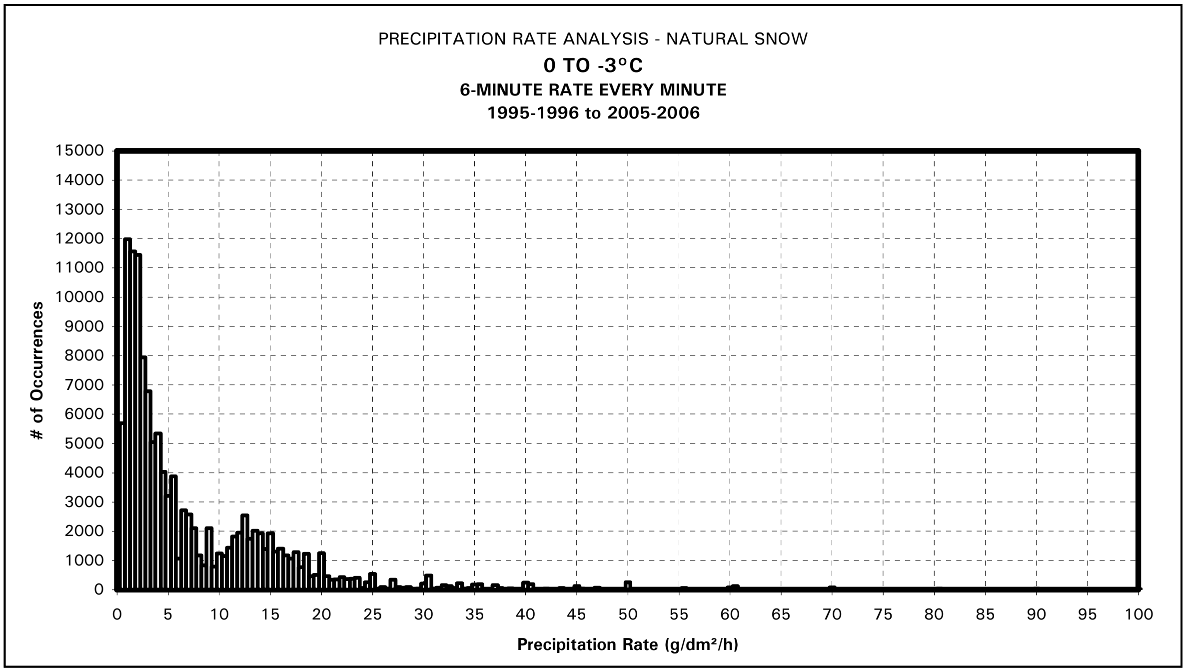
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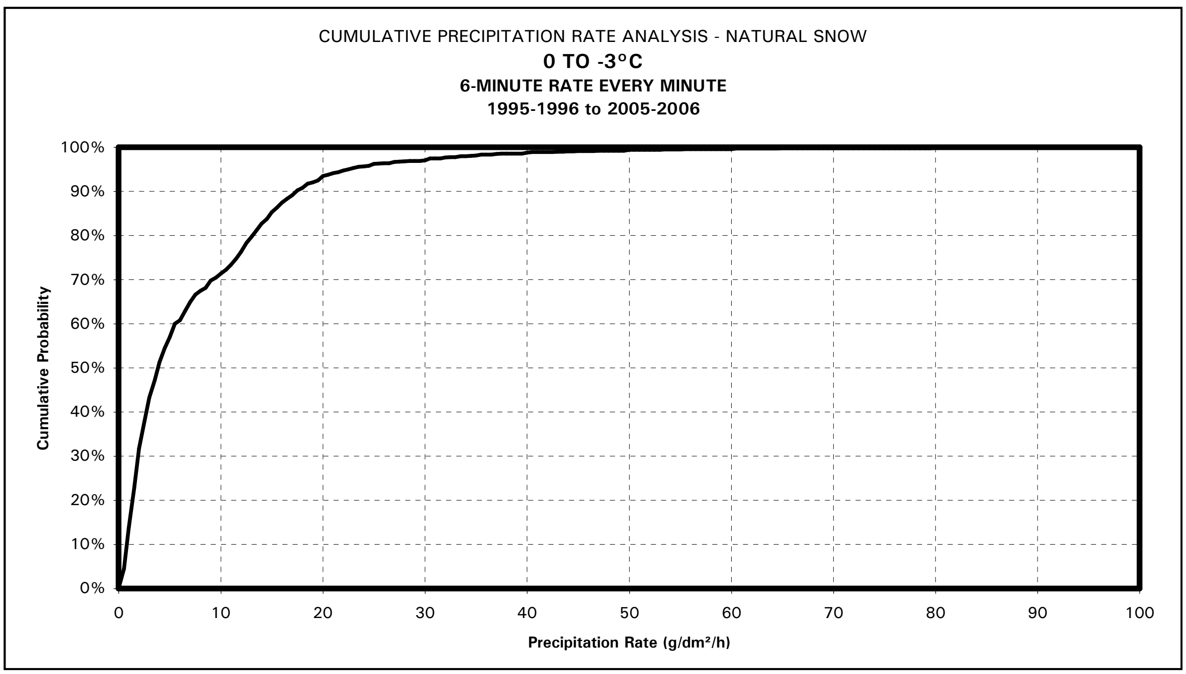
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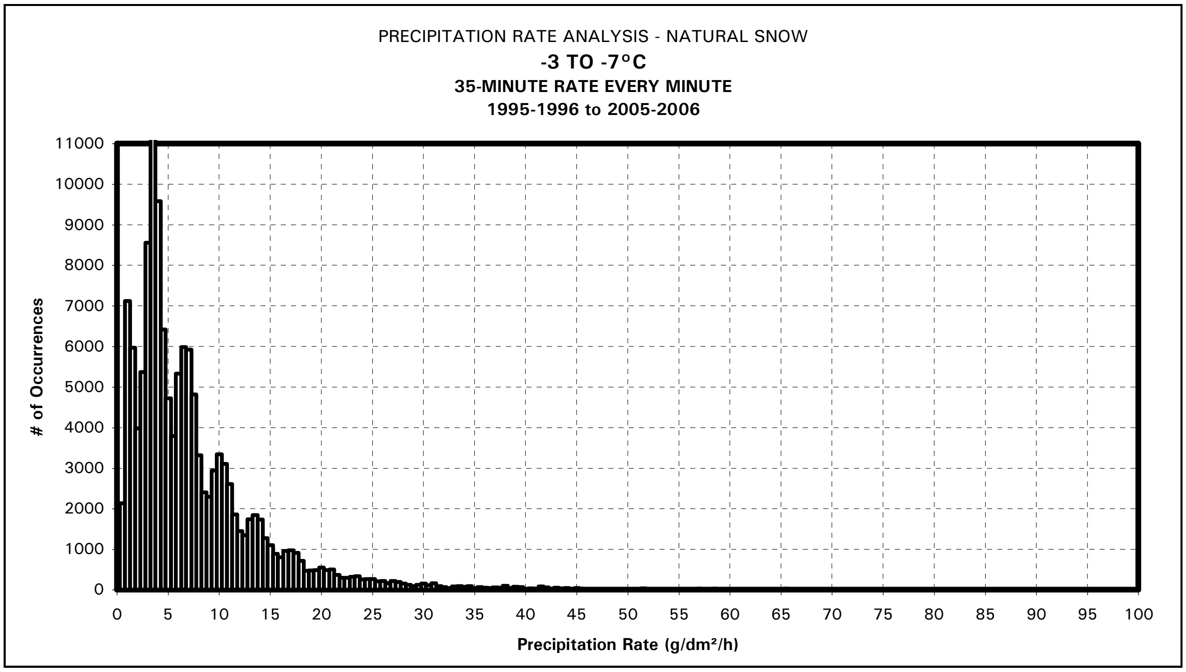
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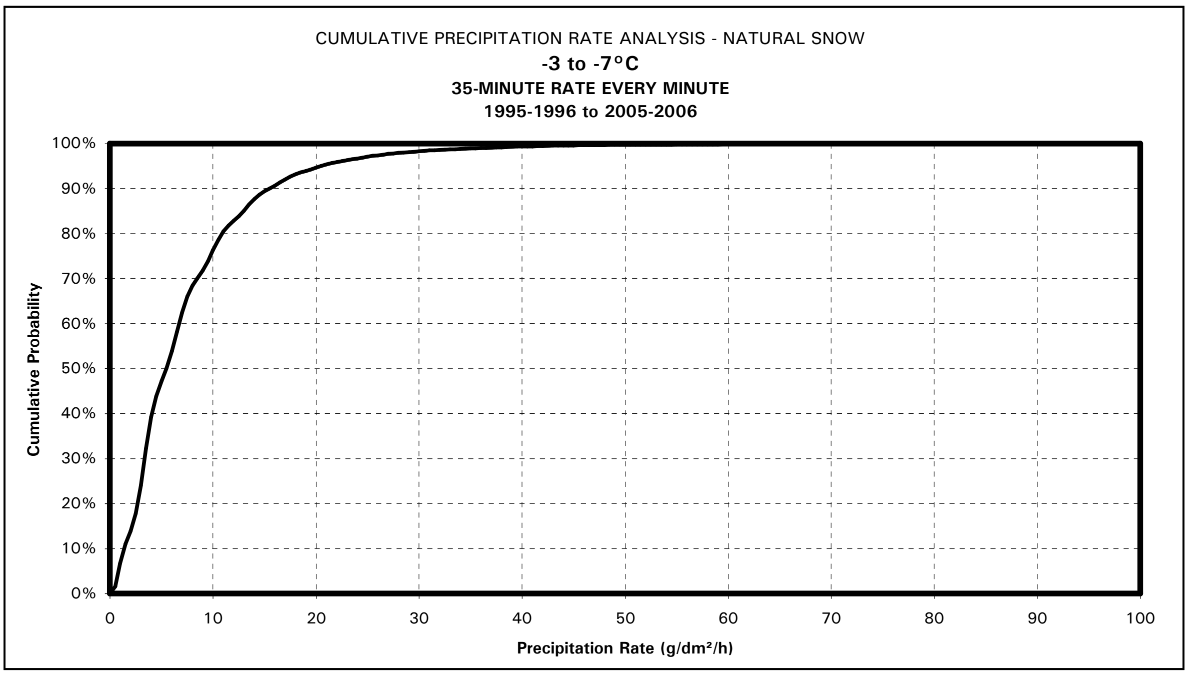
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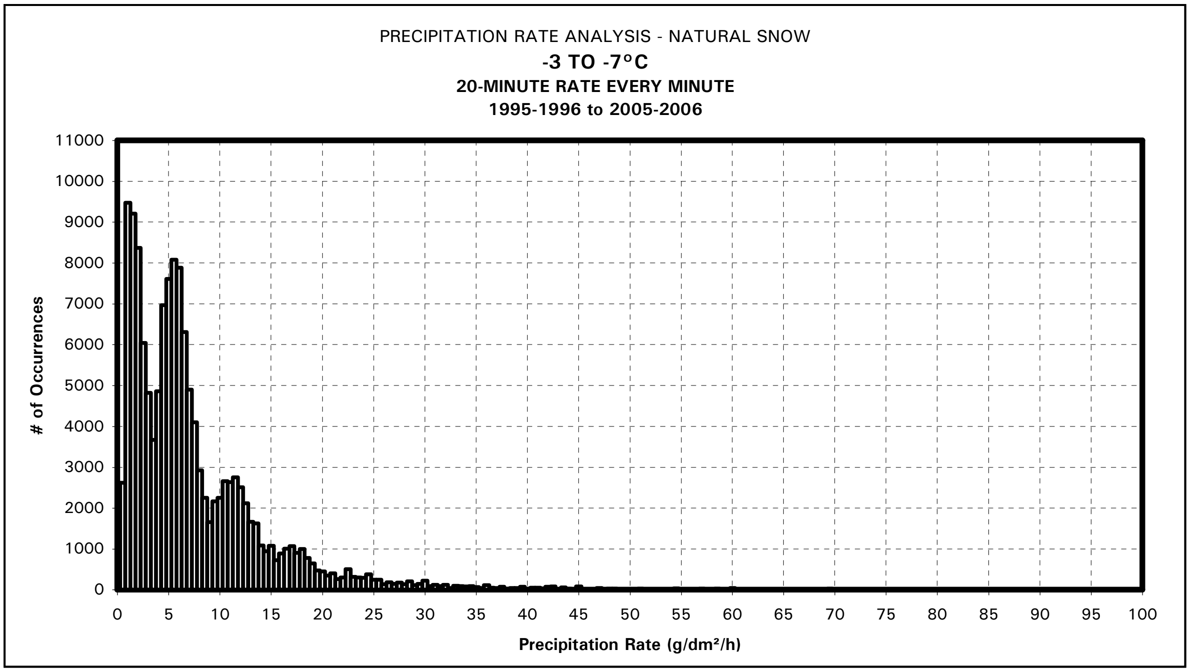
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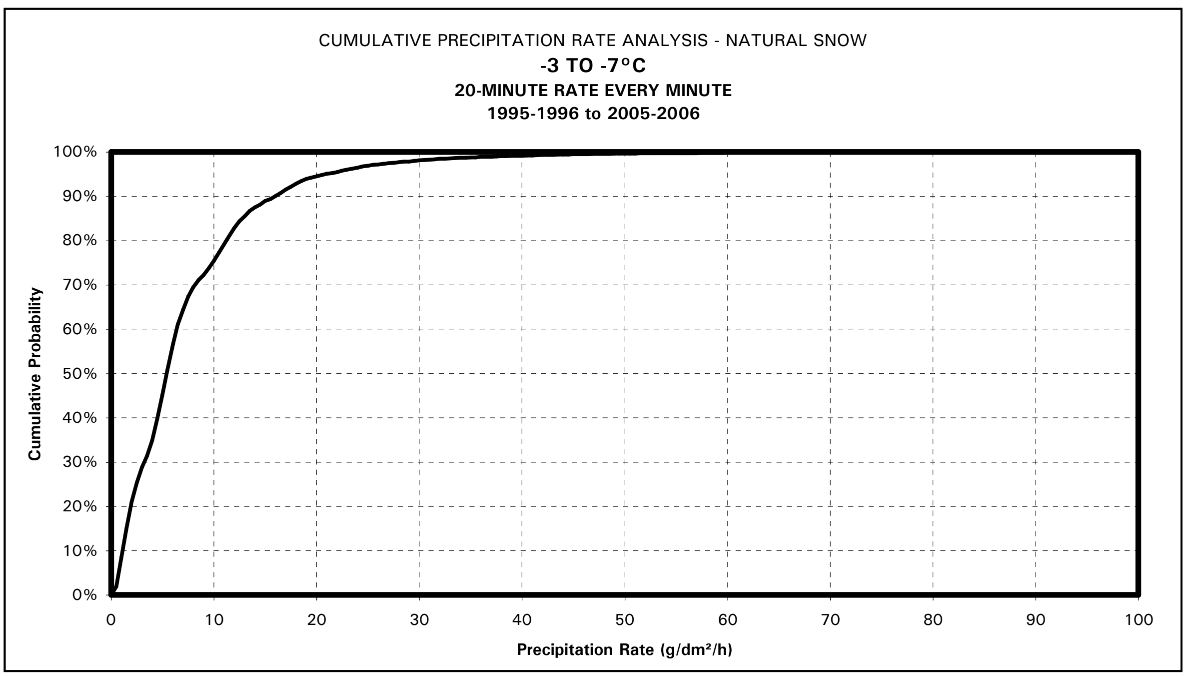
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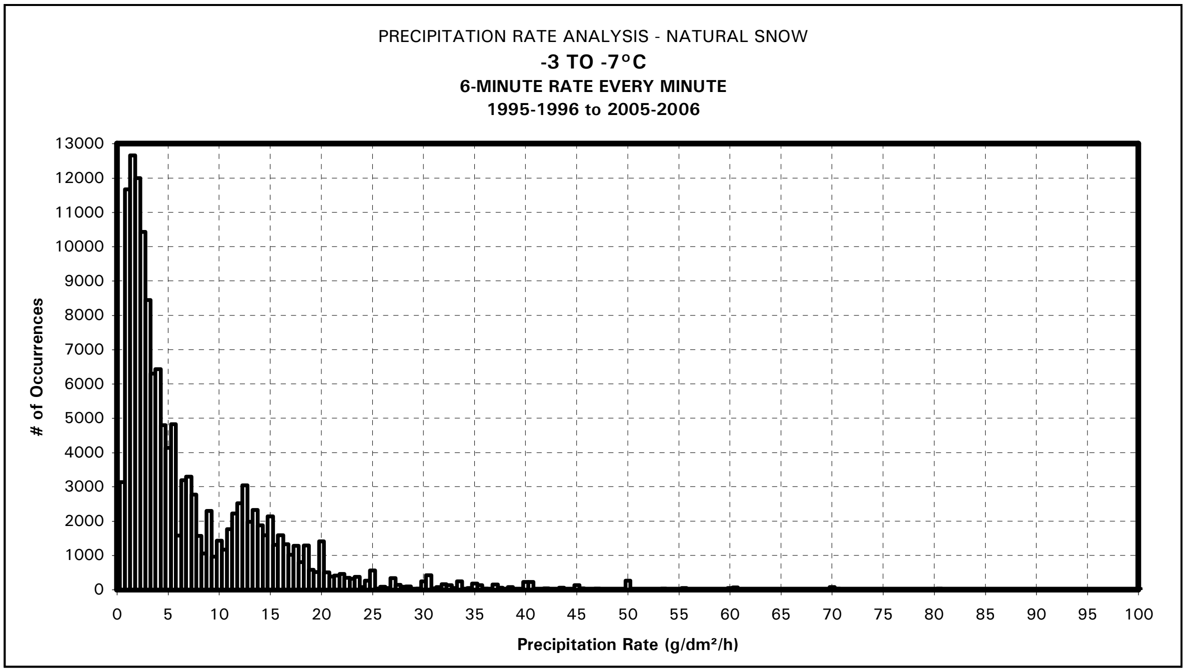

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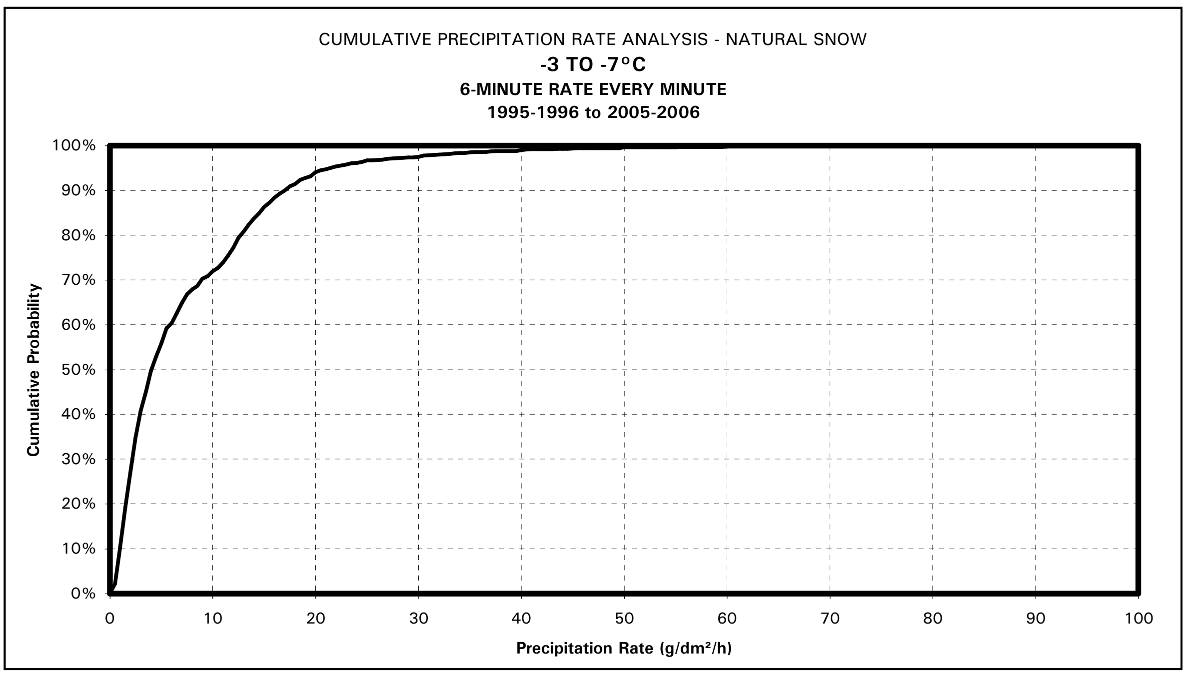

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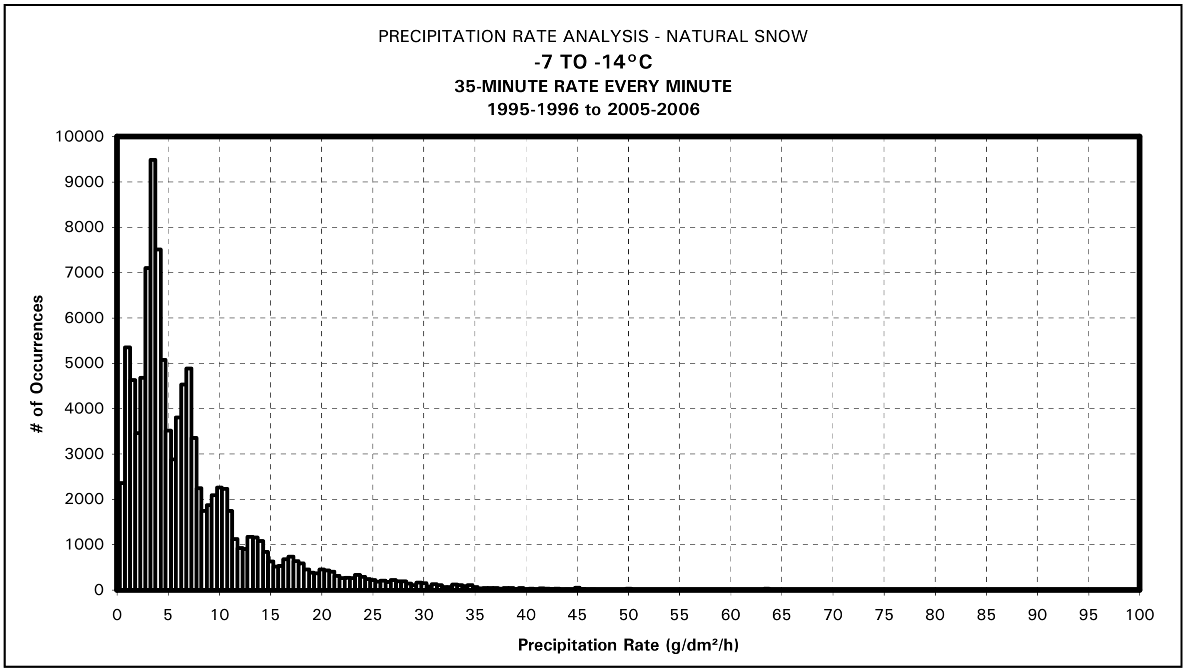
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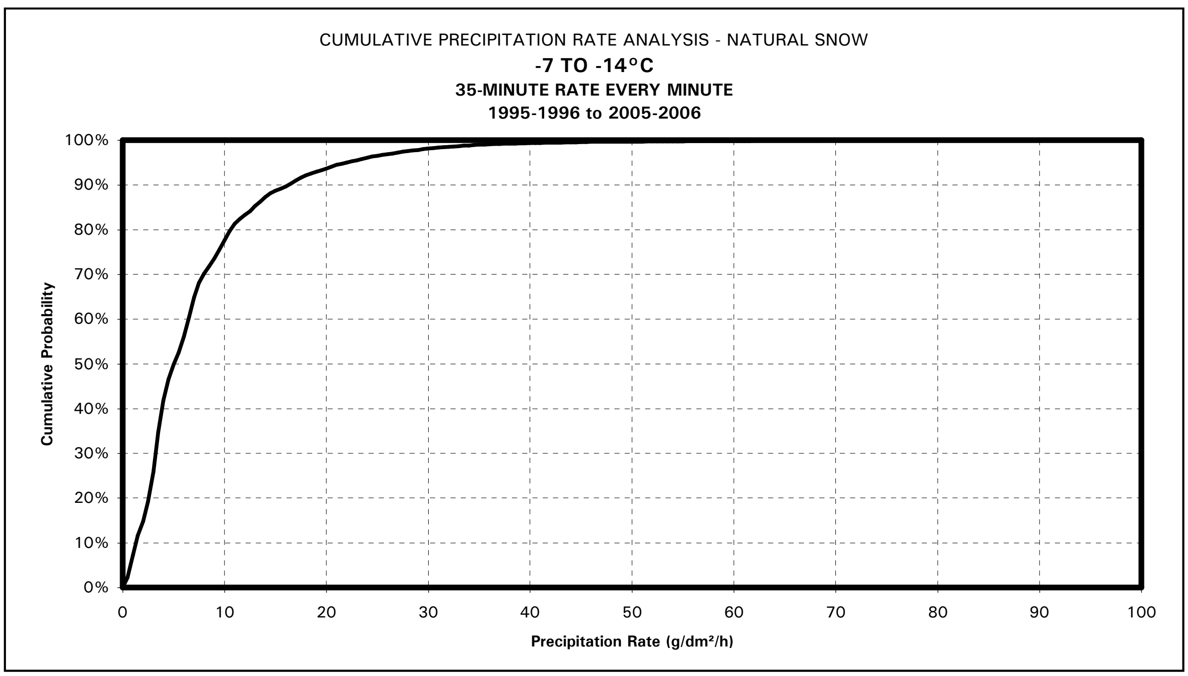
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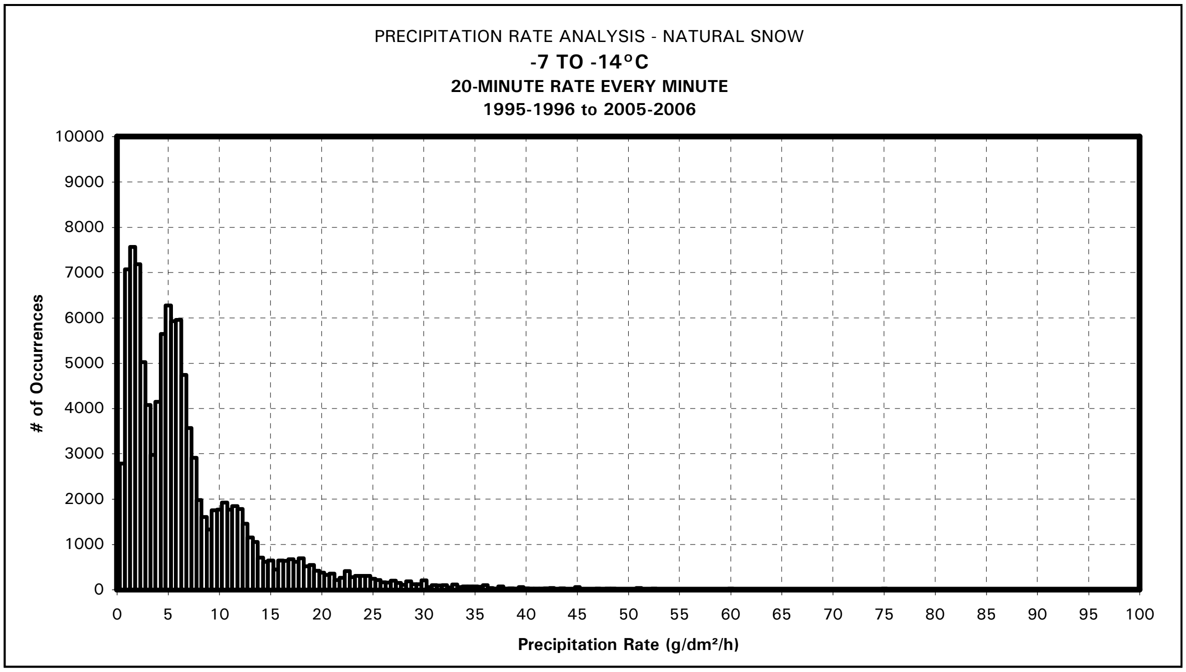
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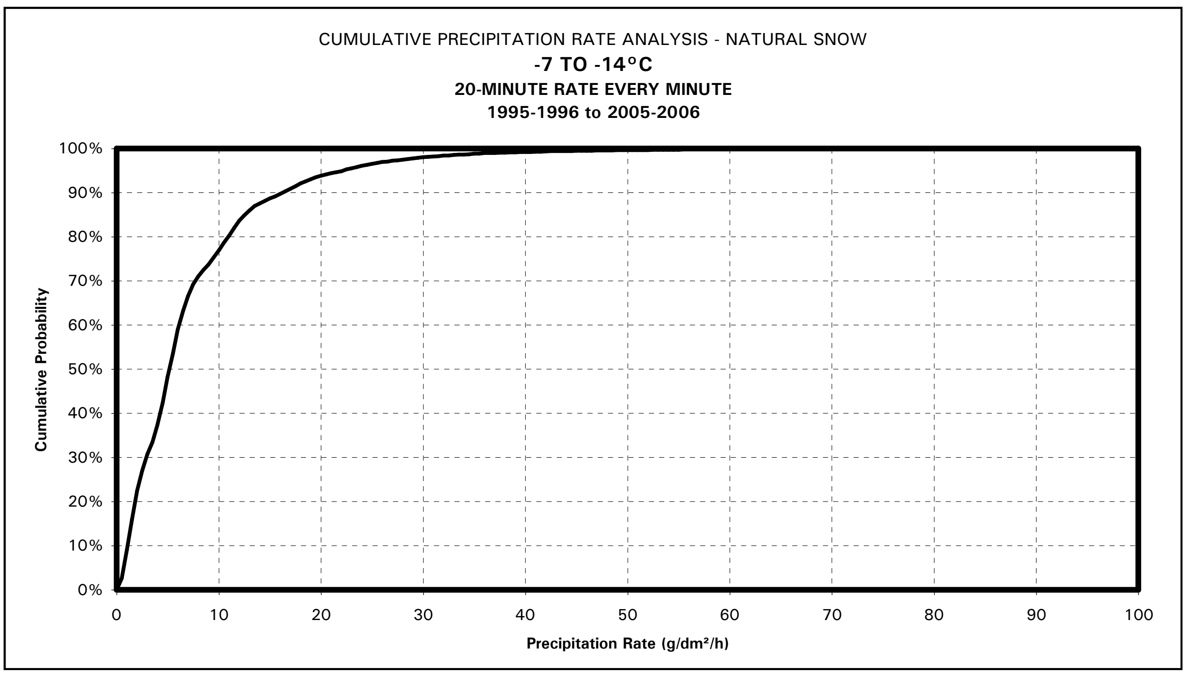
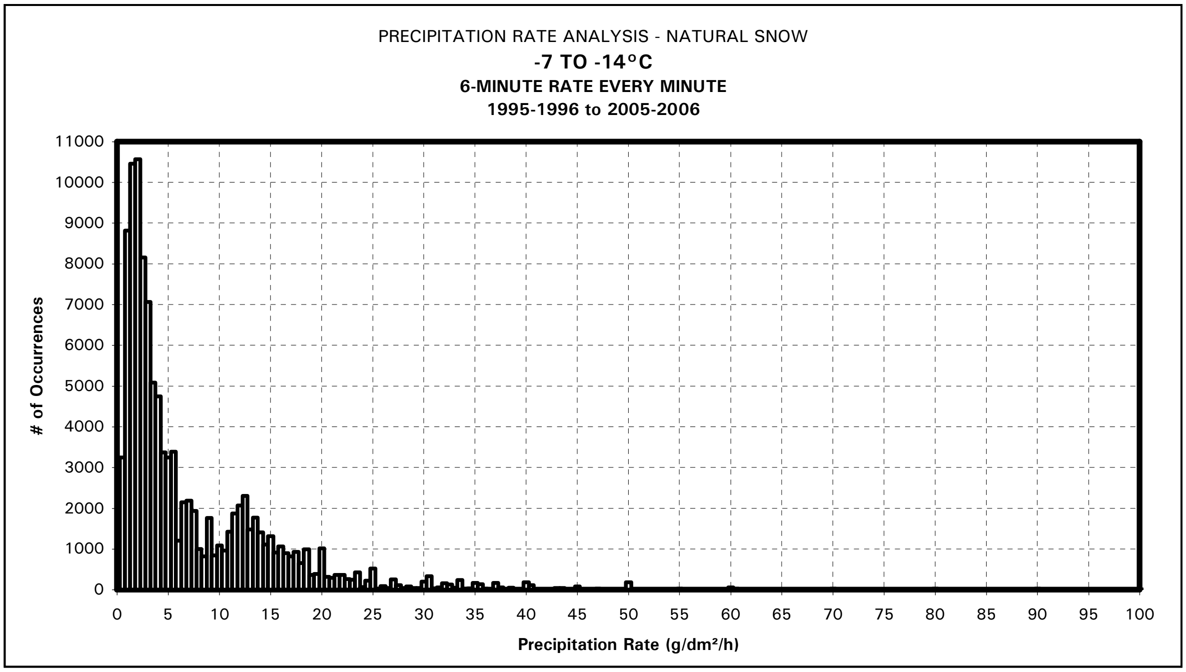
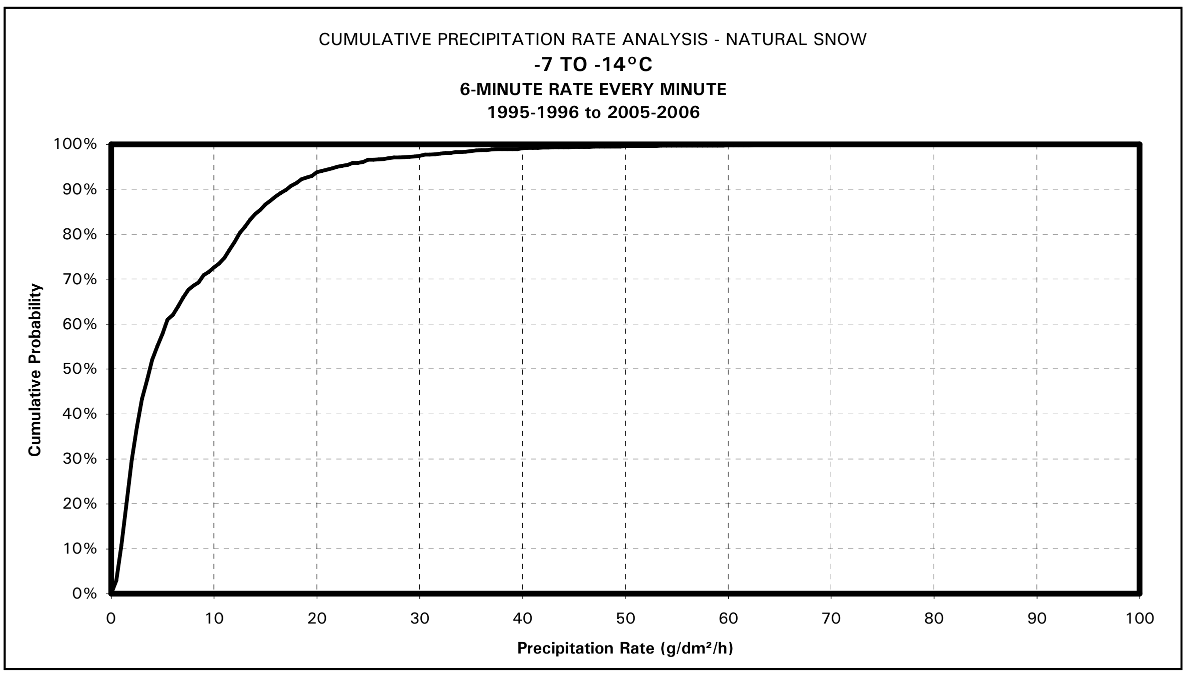
Precipitation Rate (g/dm²/h)

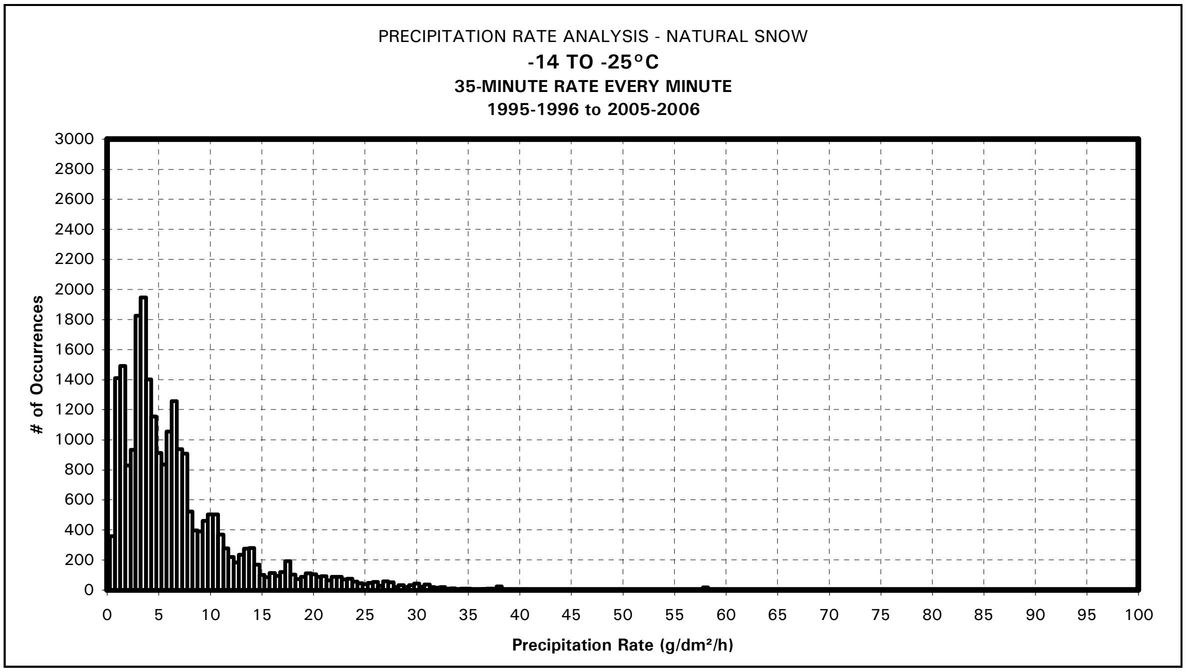

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-7 TO -14°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)



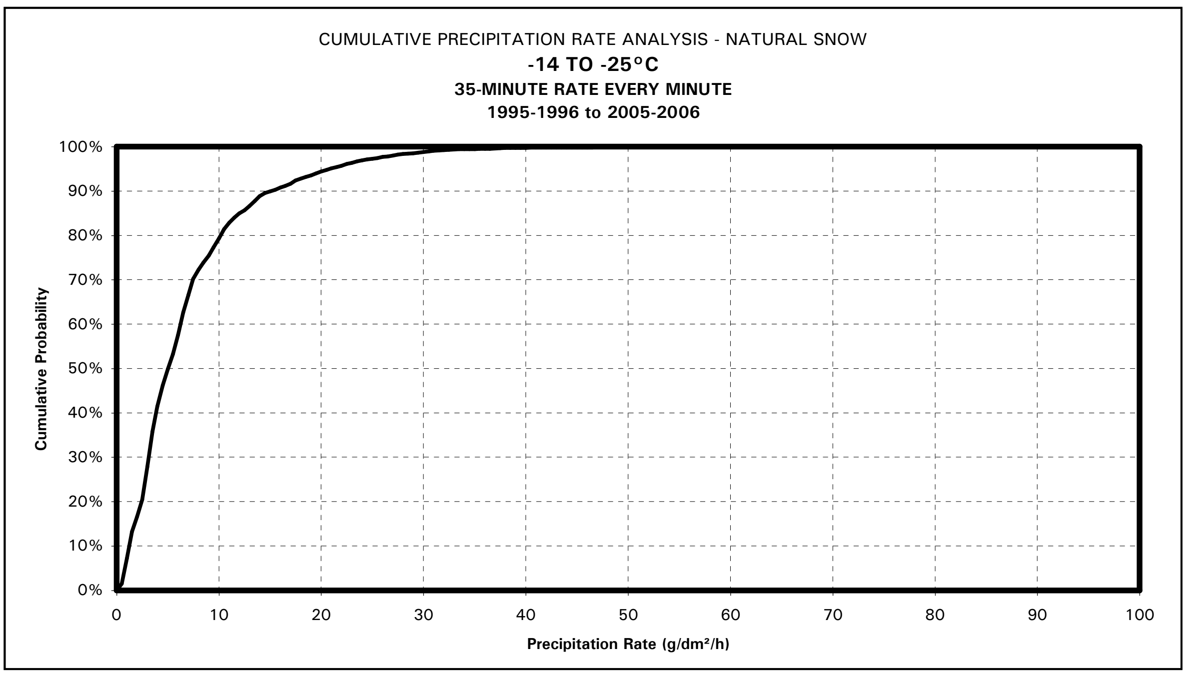
PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-7 TO -14°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
Precipitation Rate (g/dm²/h)

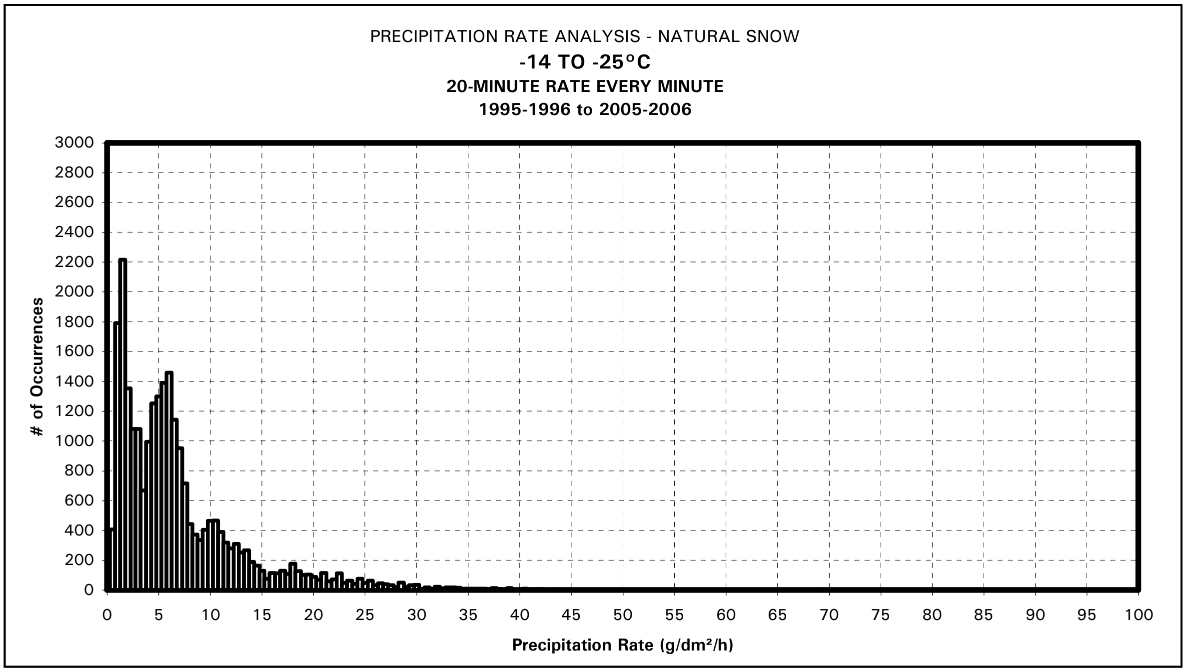
CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-7 TO -14°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
Precipitation Rate (g/dm²/h)



PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
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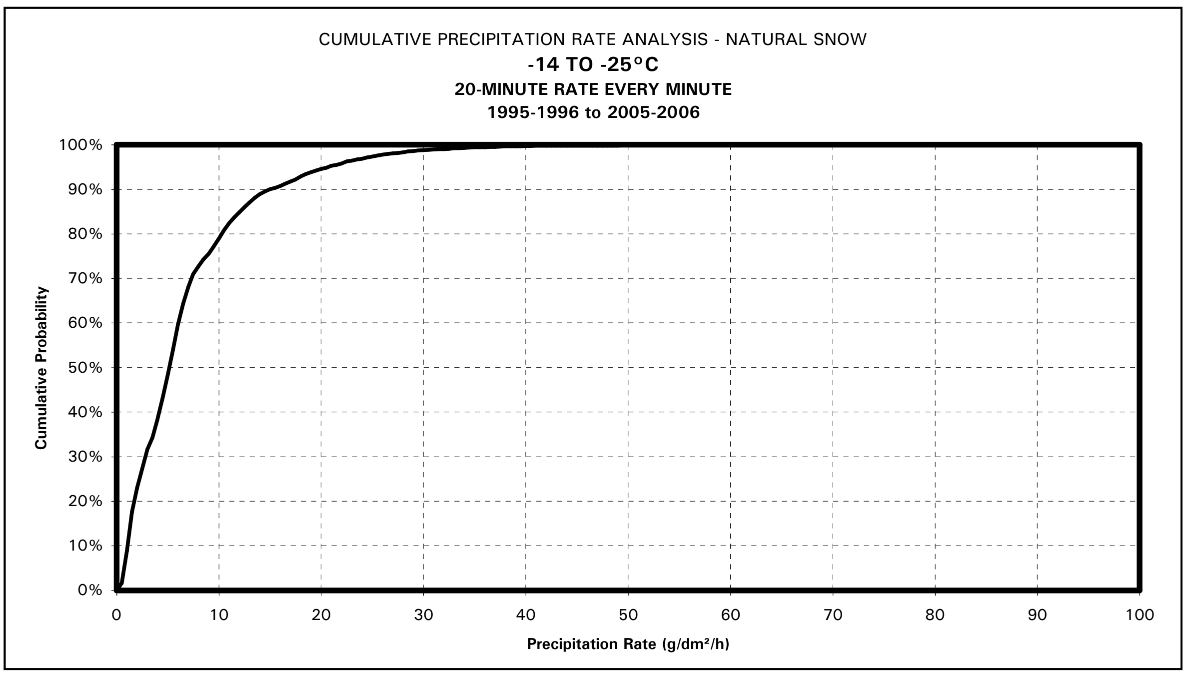
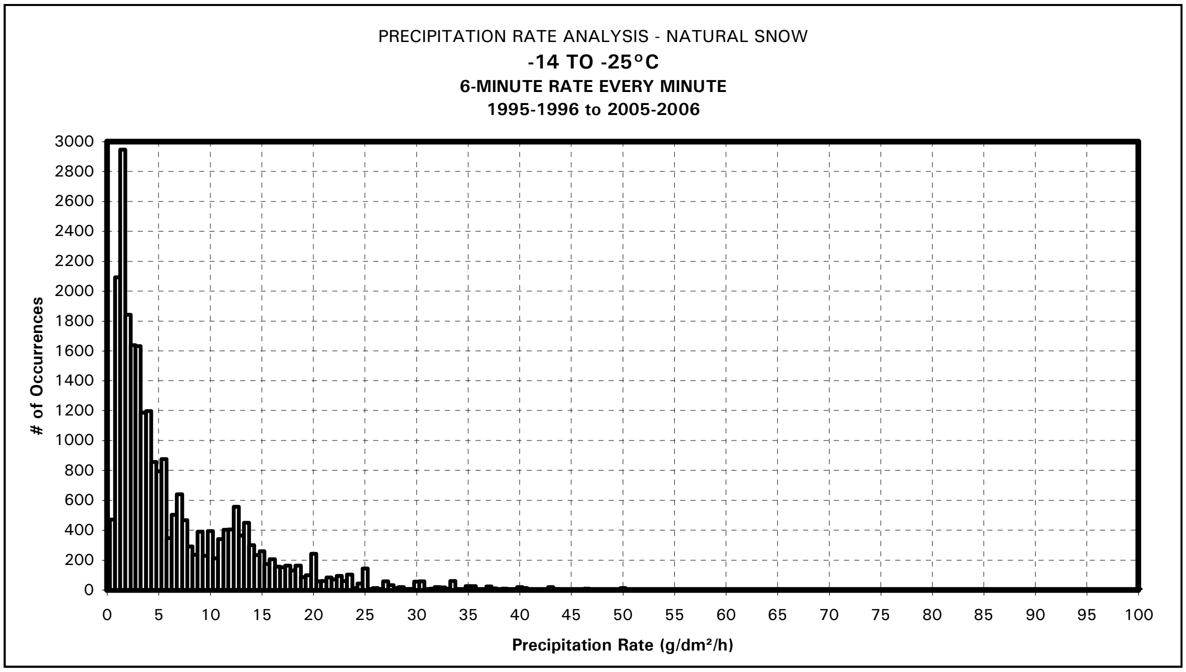
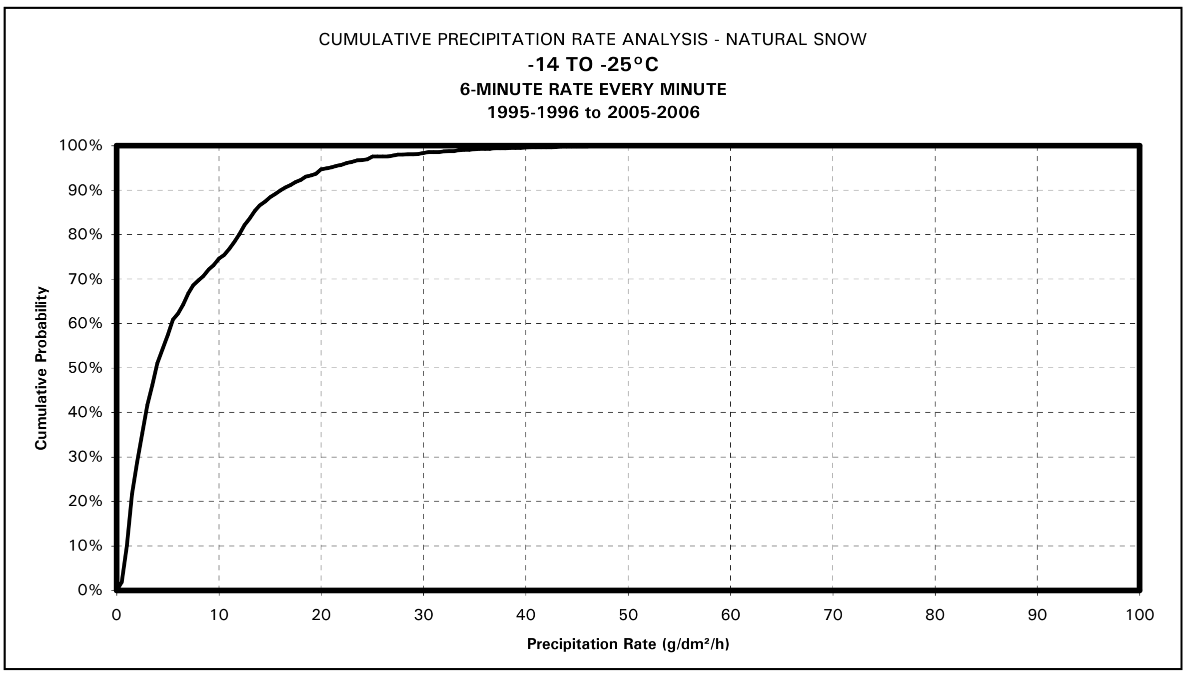
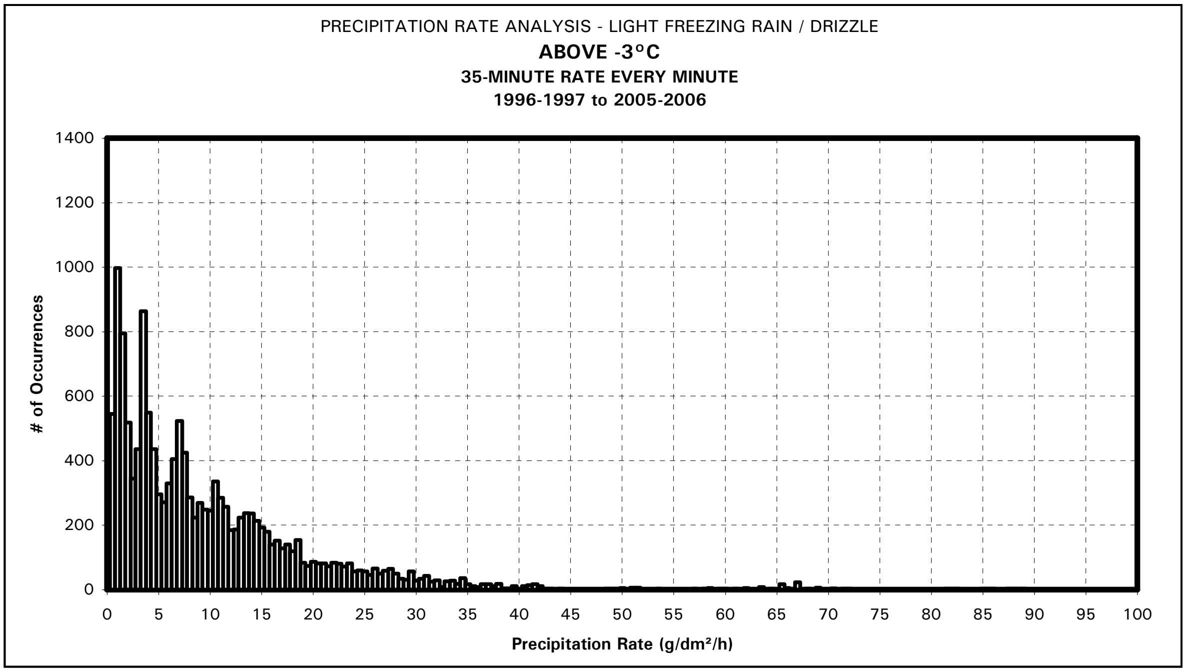
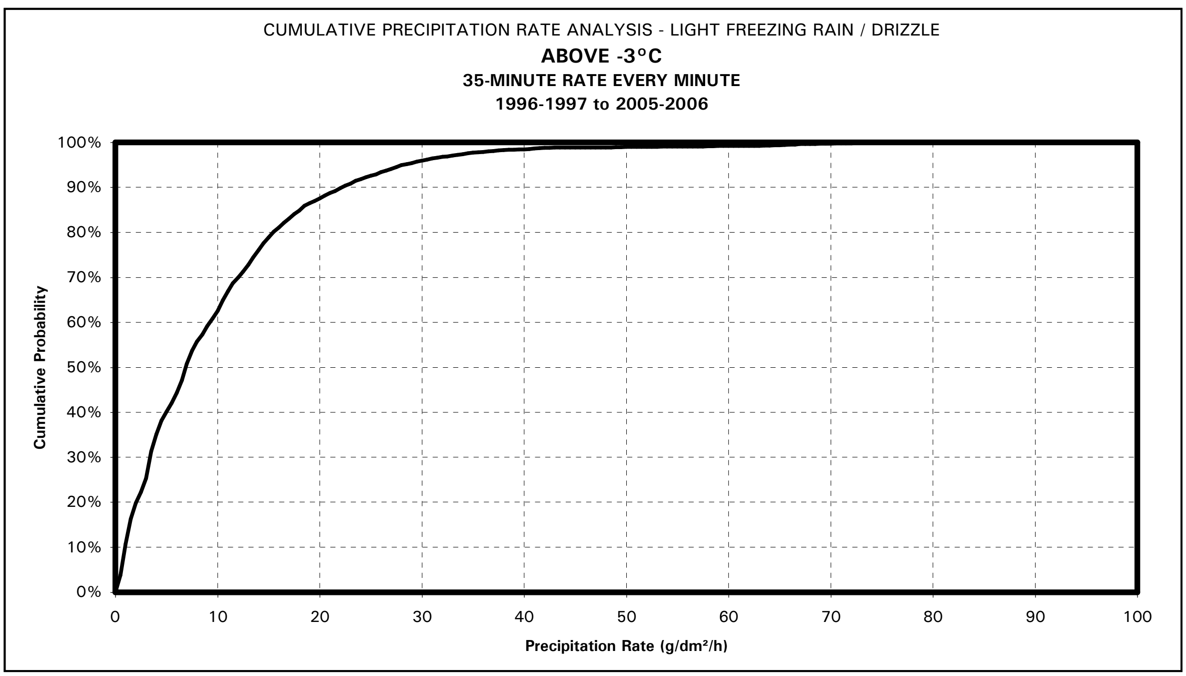
Precipitation Rate (g/dm²/h)

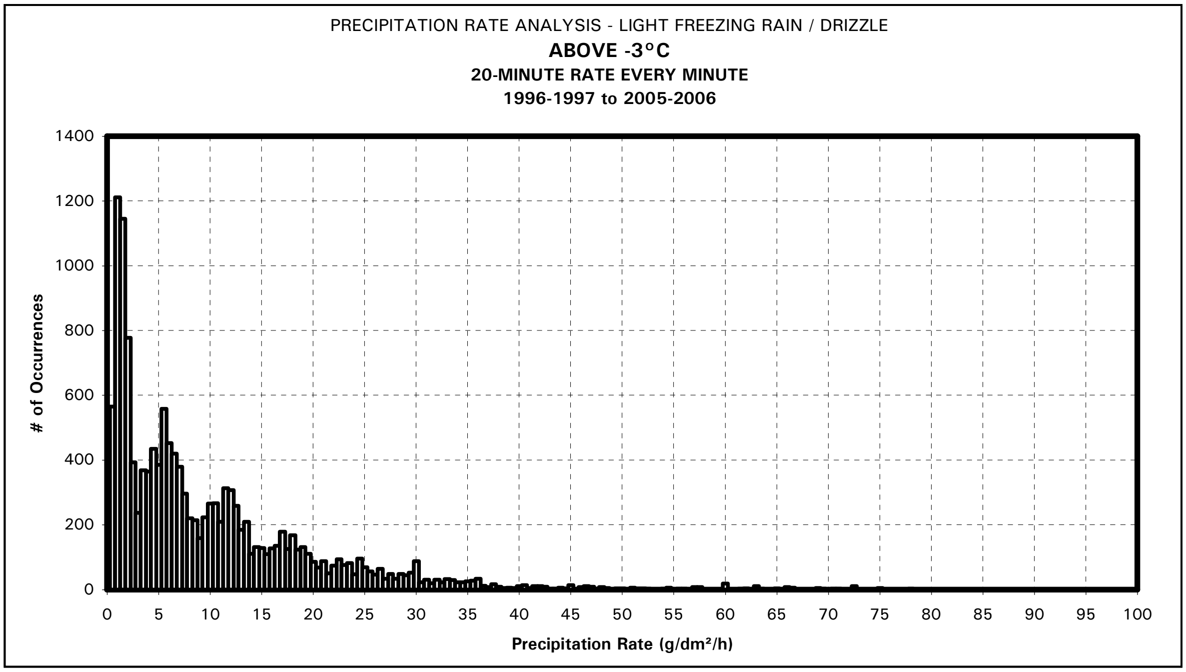

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

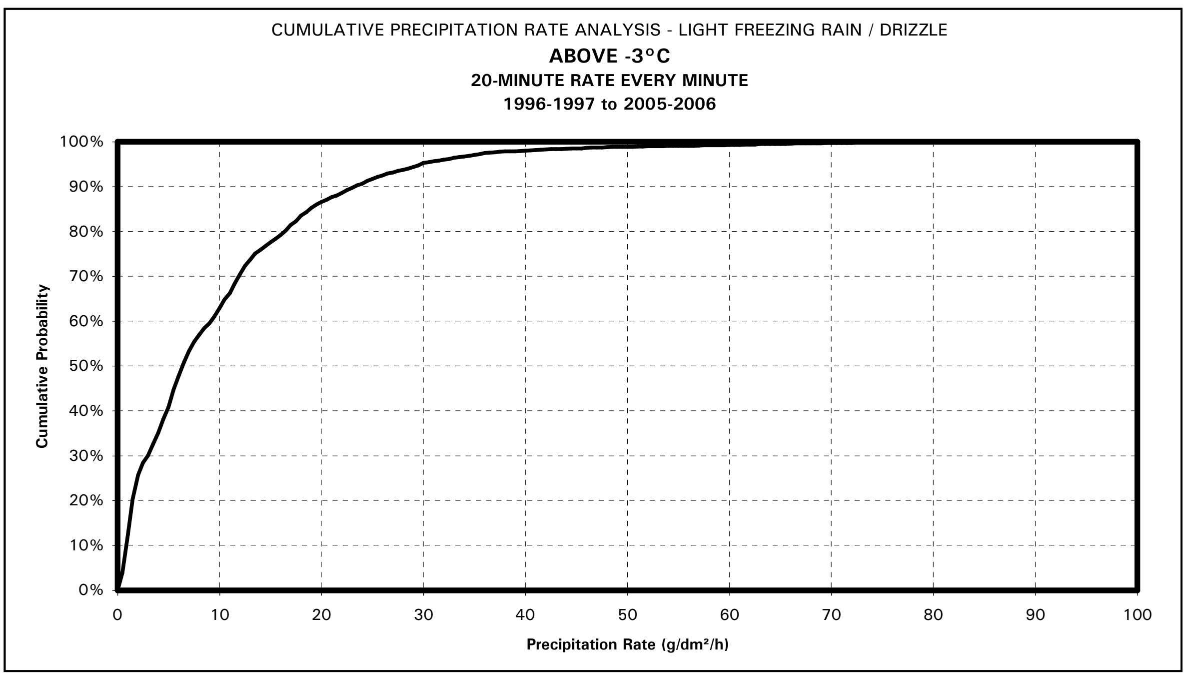

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
ABOVE -3°C
35-MINUTE RATE EVERY MINUTE
1996-1997 to 2005-2006
# of Occurrences
0
200
400
600
800
1000
1200
1400
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Precipitation Rate (g/dm²/h)

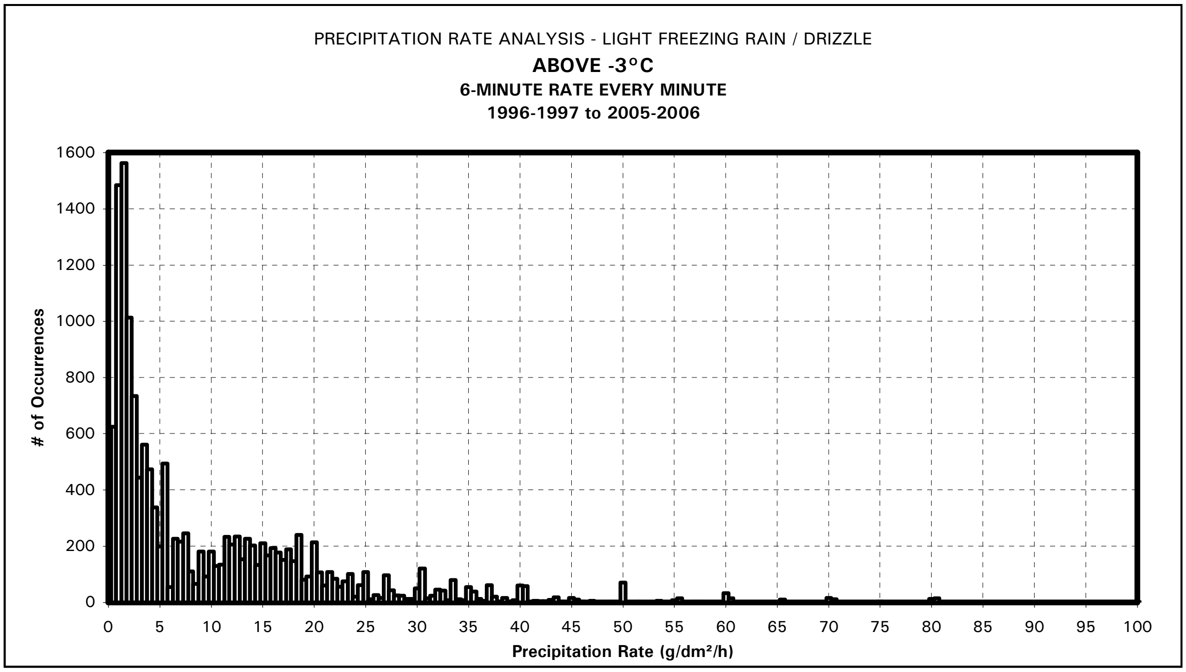

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
ABOVE -3°C
35-MINUTE RATE EVERY MINUTE
1996-1997 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0
10
20
30
40
50
60
70
80
90
100
Precipitation Rate (g/dm²/h)

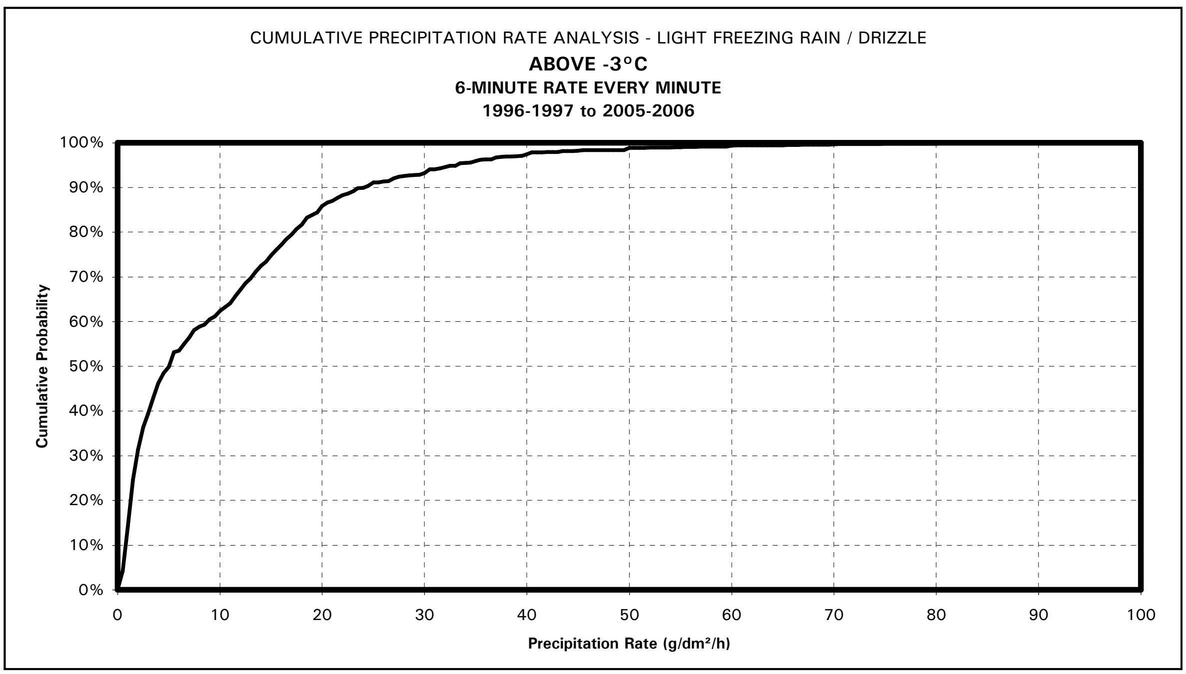


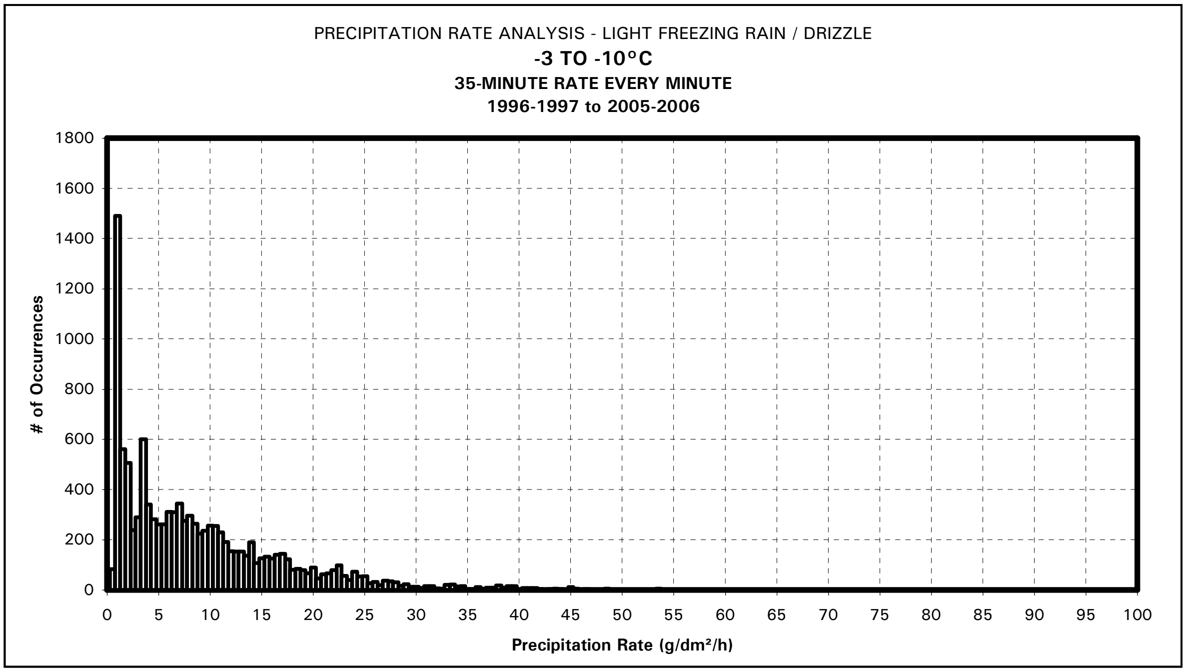
PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
ABOVE -3°C
20-MINUTE RATE EVERY MINUTE
1996-1997 to 2005-2006
# of Occurrences
0
200
400
600
800
1000
1200
1400
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

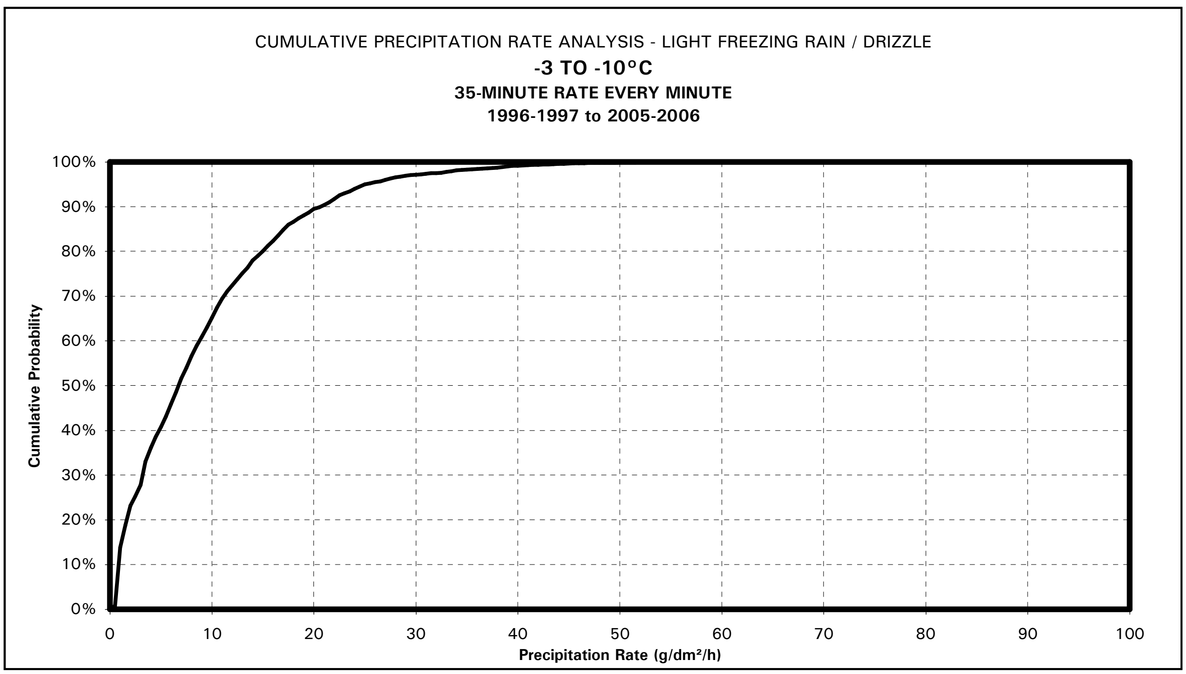



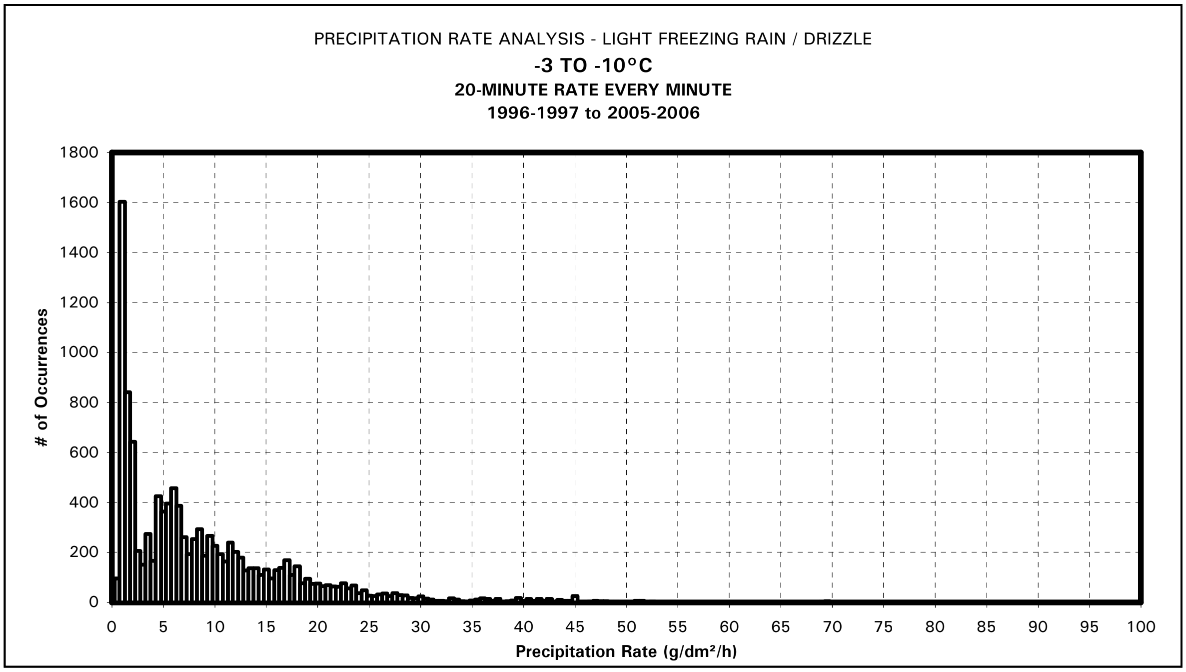
CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
ABOVE -3°C
20-MINUTE RATE EVERY MINUTE
1996-1997 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

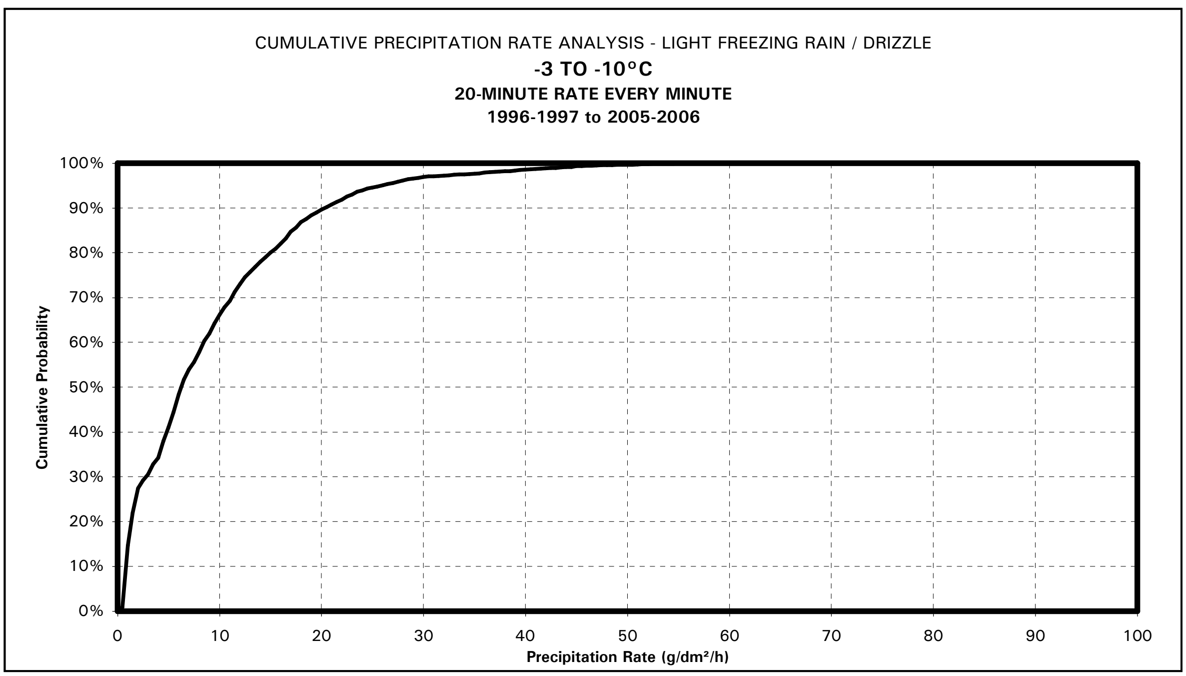

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
ABOVE -3°C
6-MINUTE RATE EVERY MINUTE
1996-1997 to 2005-2006
# of Occurrences
0
200
400
600
800
1000
1200
1400
1600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

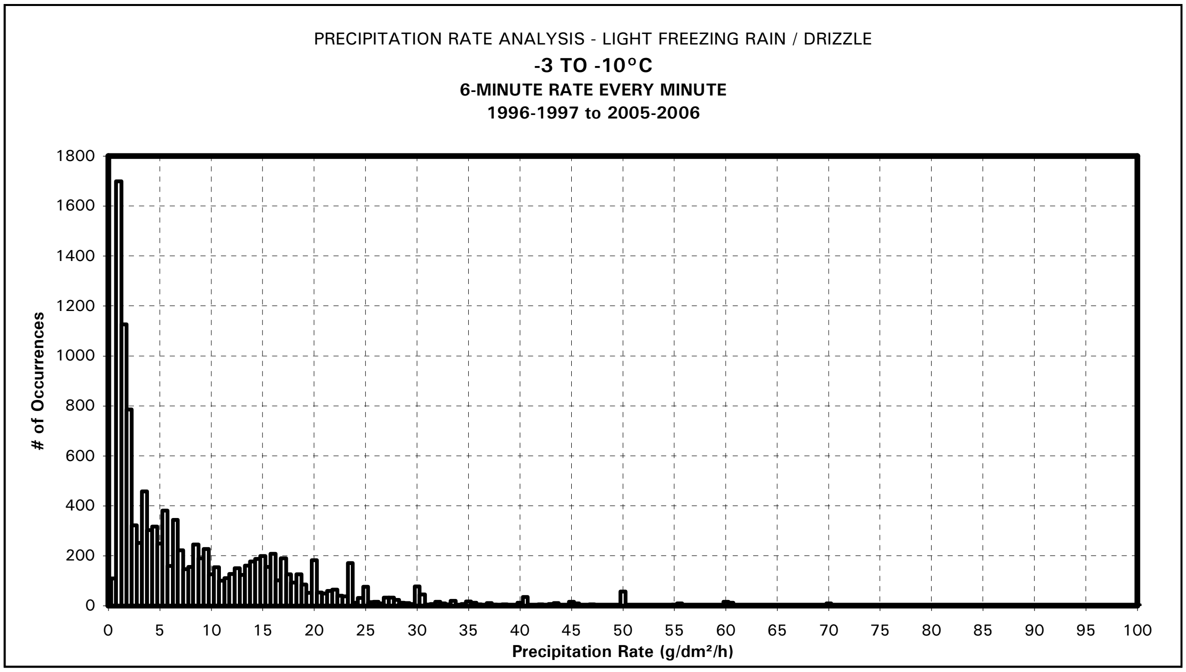

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
ABOVE -3°C
6-MINUTE RATE EVERY MINUTE
1996-1997 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

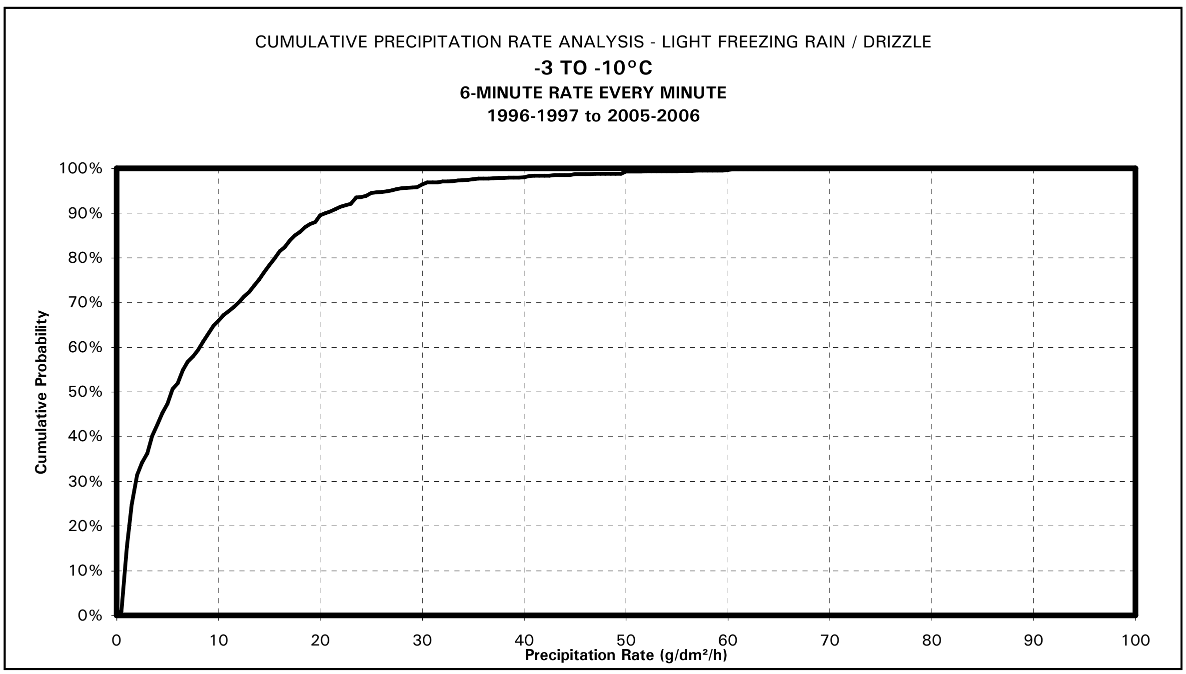

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
35-MINUTE RATE EVERY MINUTE
1996-1997 to 2005-2006
# of Occurrences
0
200
400
600
800
1000
1200
1400
1600
1800
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Precipitation Rate (g/dm²/h)

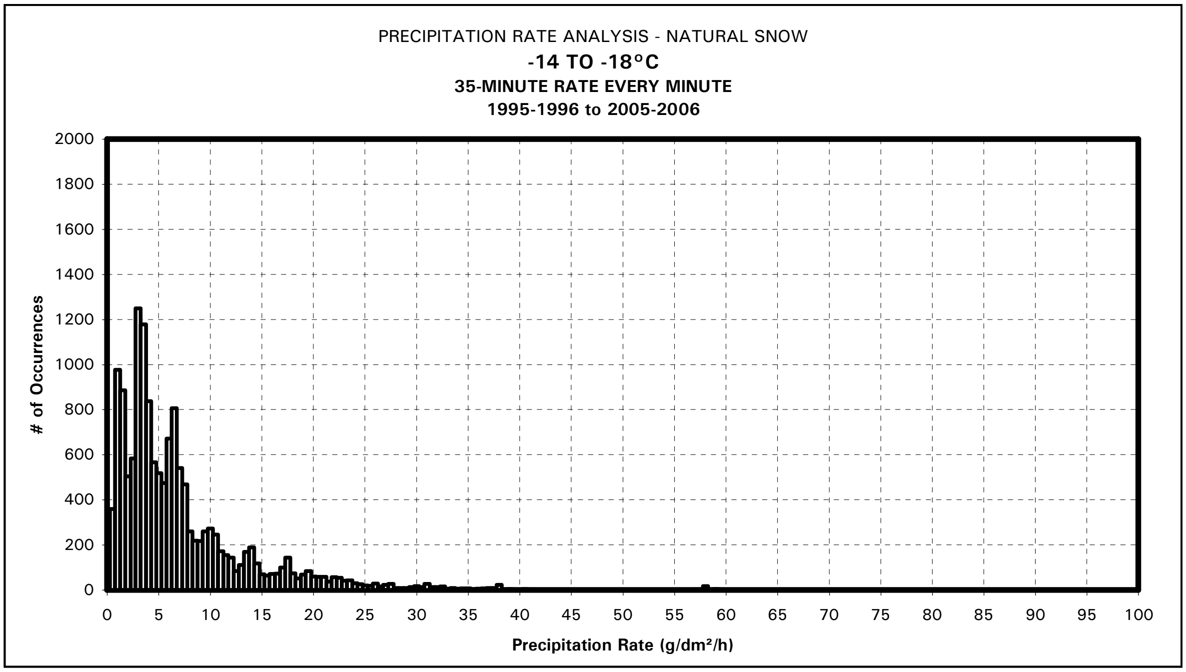

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
35-MINUTE RATE EVERY MINUTE
1996-1997 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0
10
20
30
40
50
60
70
80
90
100
Precipitation Rate (g/dm²/h)

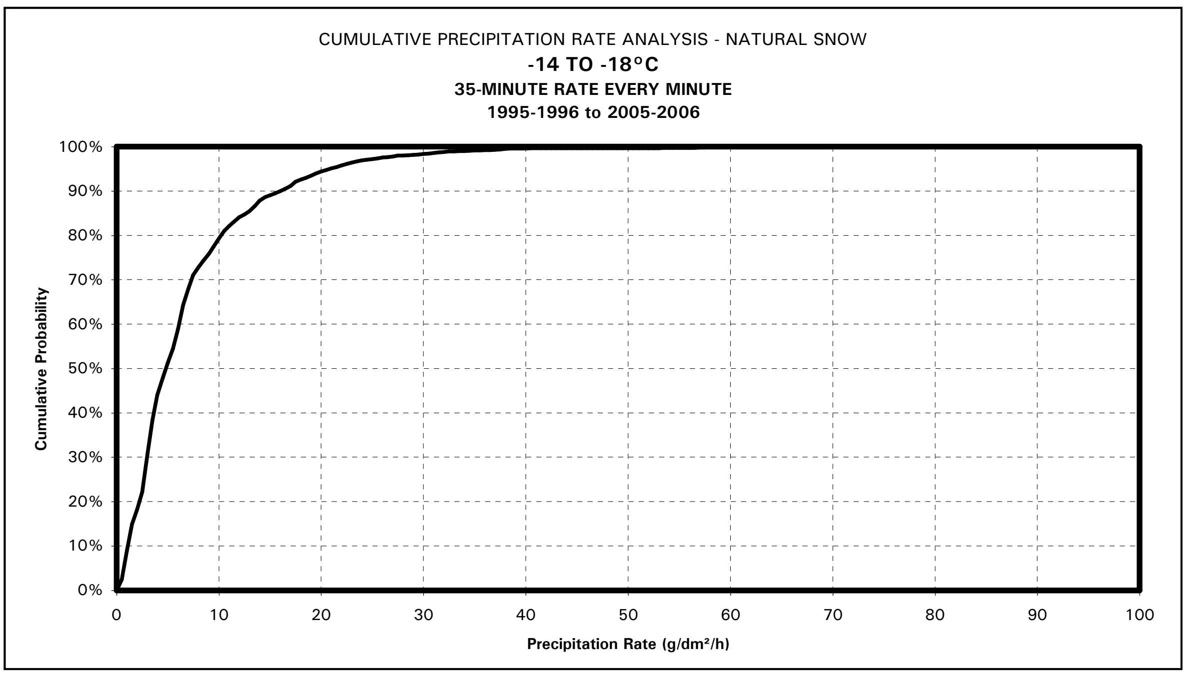

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
20-MINUTE RATE EVERY MINUTE
1996-1997 to 2005-2006
# of Occurrences
0
200
400
600
800
1000
1200
1400
1600
1800
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

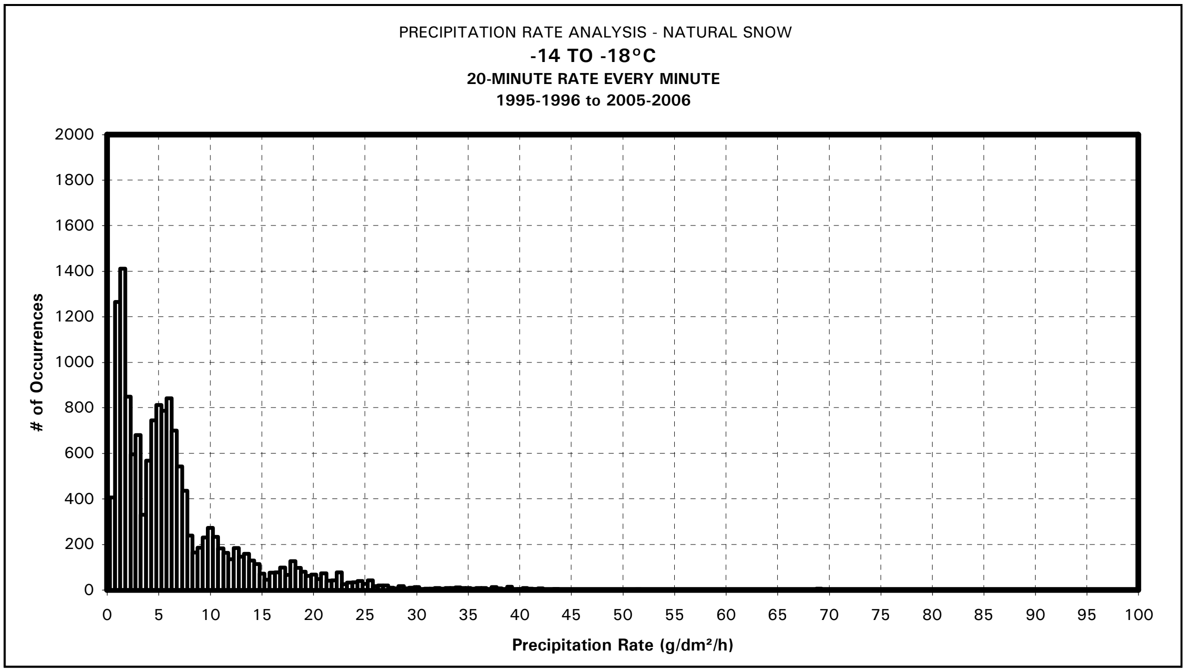

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
20-MINUTE RATE EVERY MINUTE
1996-1997 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

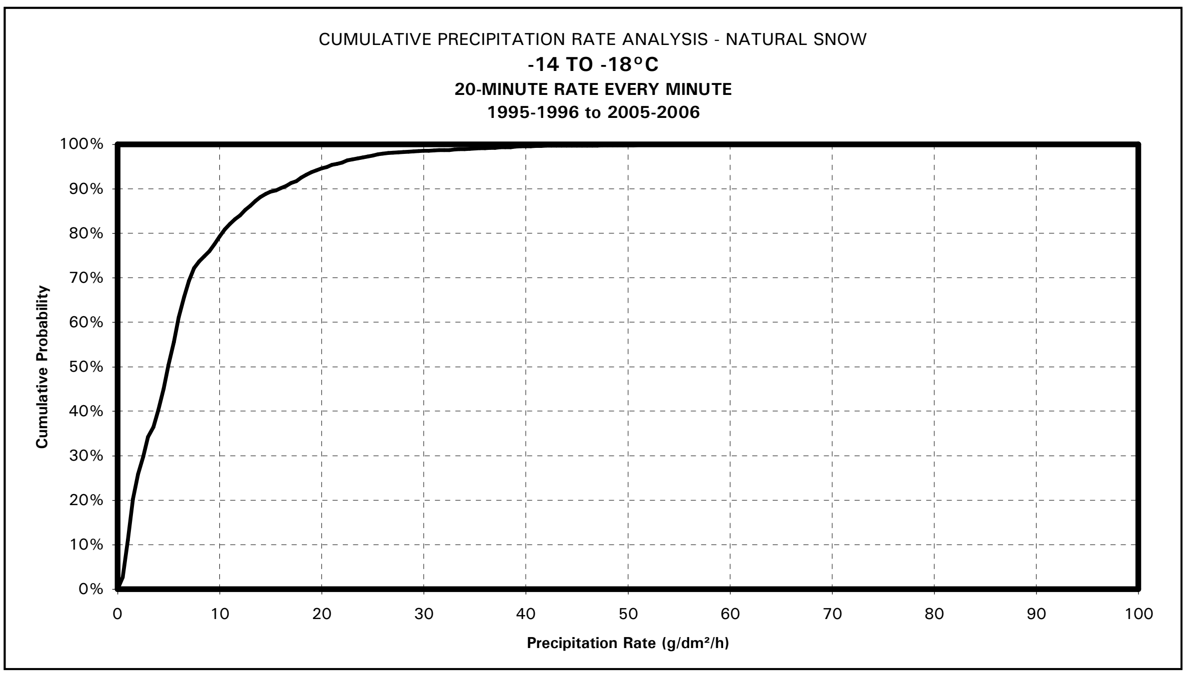

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
6-MINUTE RATE EVERY MINUTE
1996-1997 to 2005-2006
# of Occurrences
0
200
400
600
800
1000
1200
1400
1600
1800
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)


CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
6-MINUTE RATE EVERY MINUTE
1996-1997 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Precipitation Rate (g/dm²/h)


CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
10
20
30
40
50
60
70
80
90
100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)


CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
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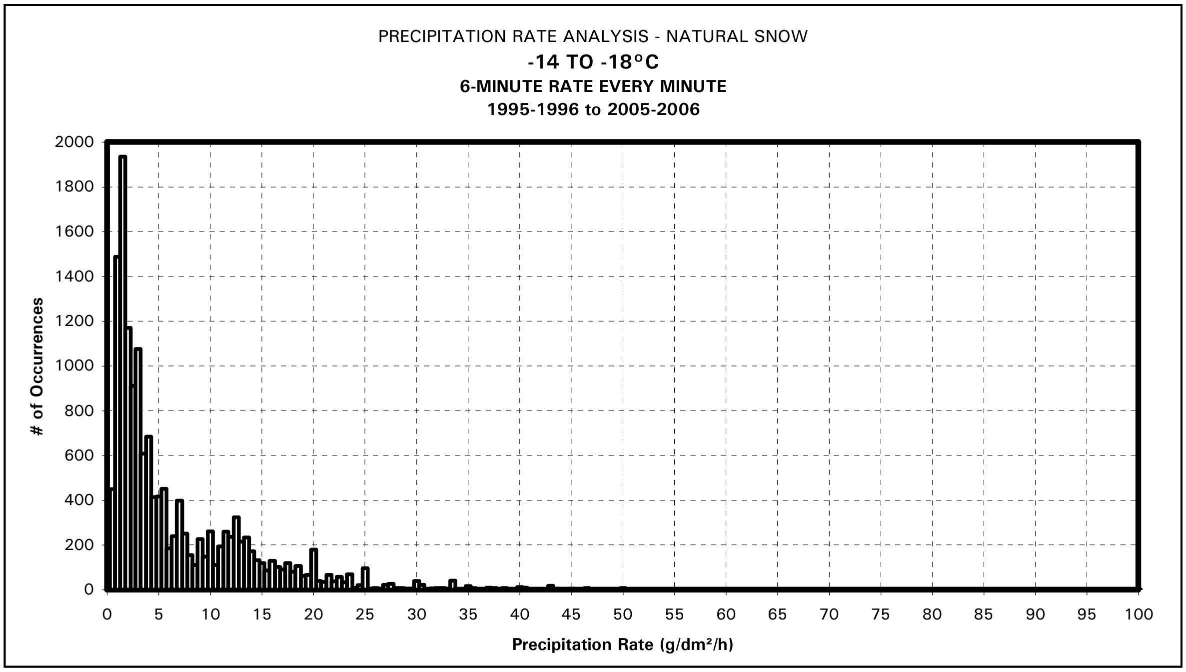
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
5
10
15
20
25
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35
40
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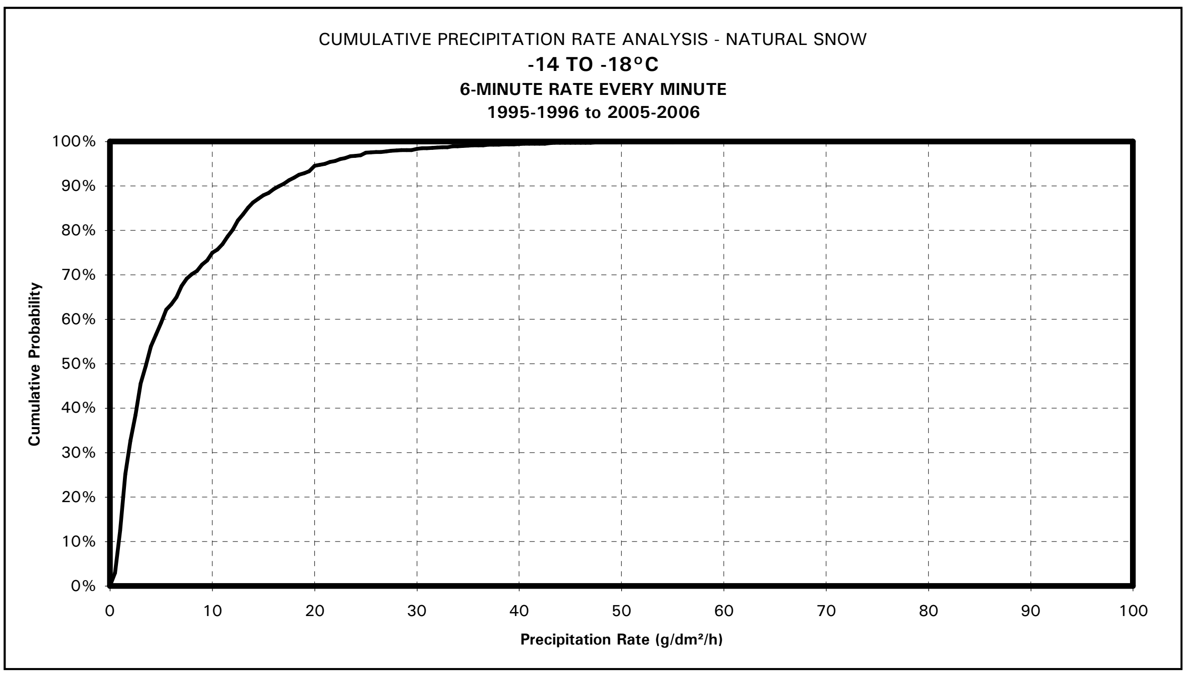
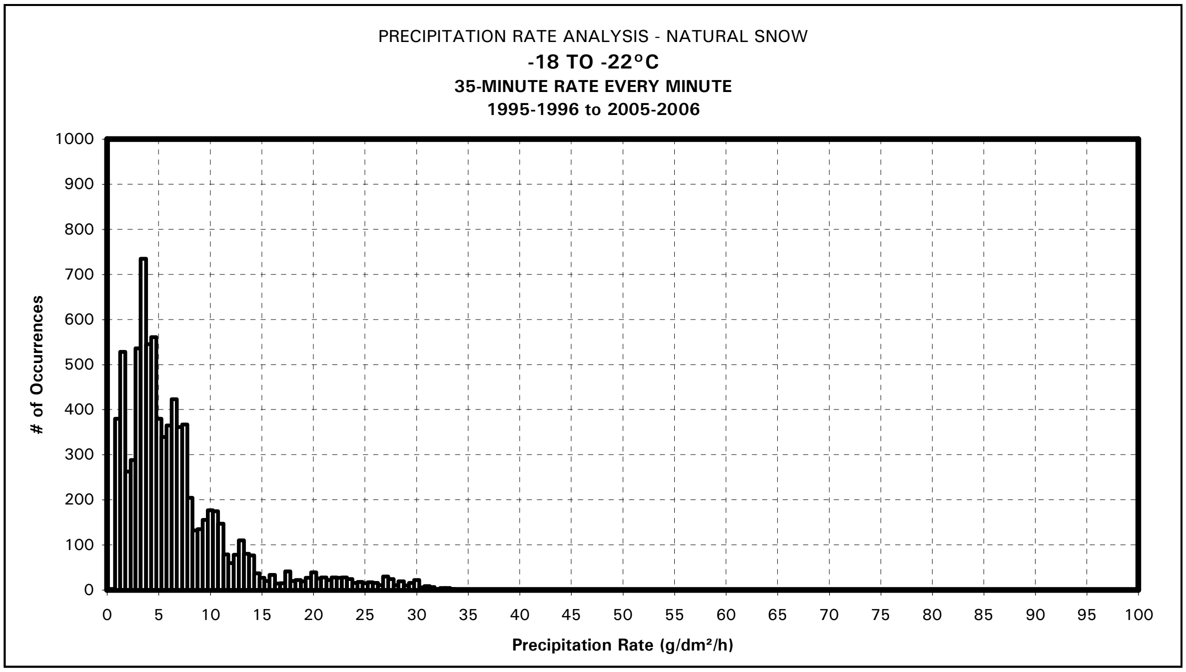
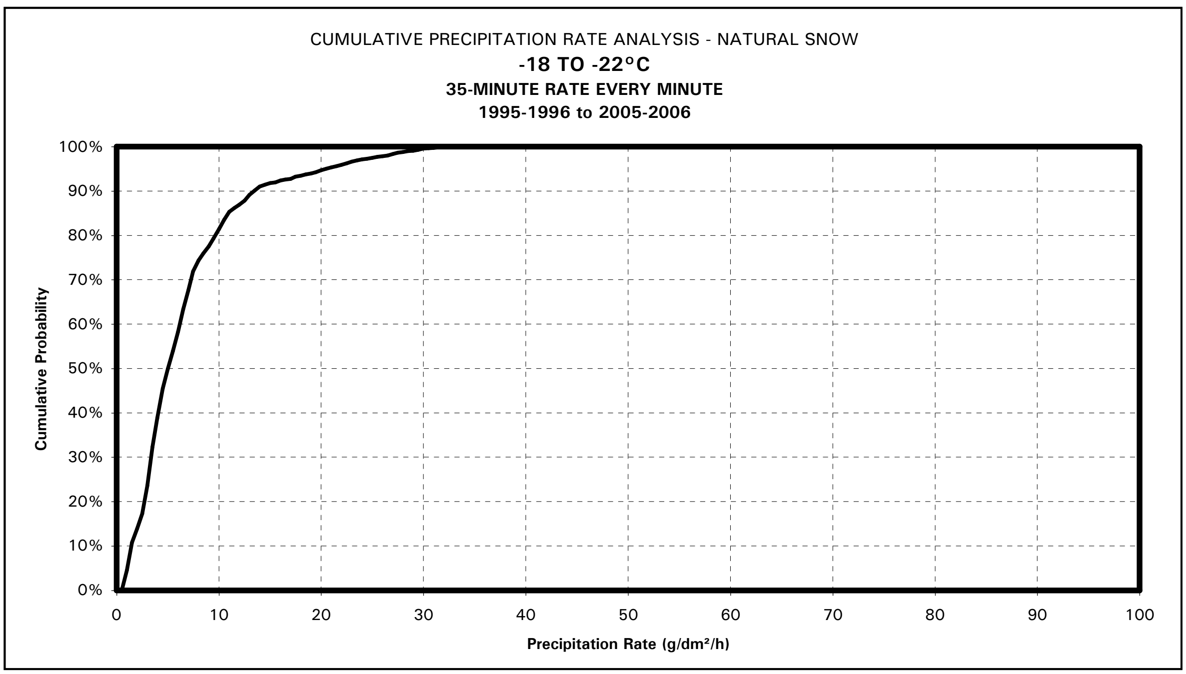
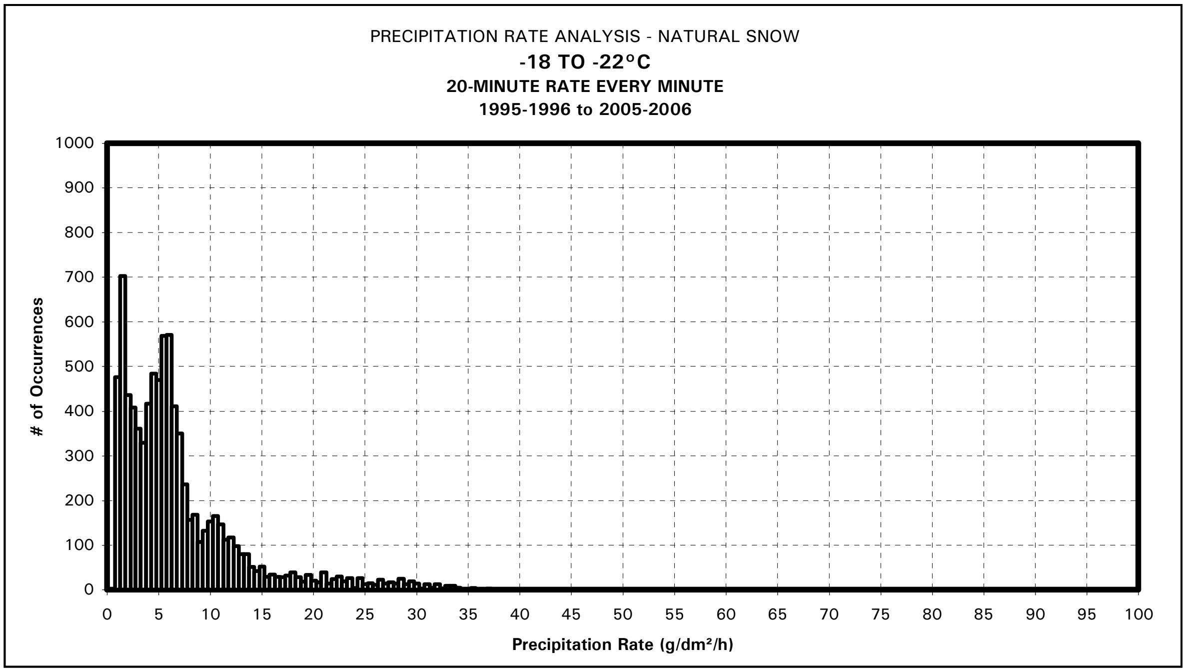
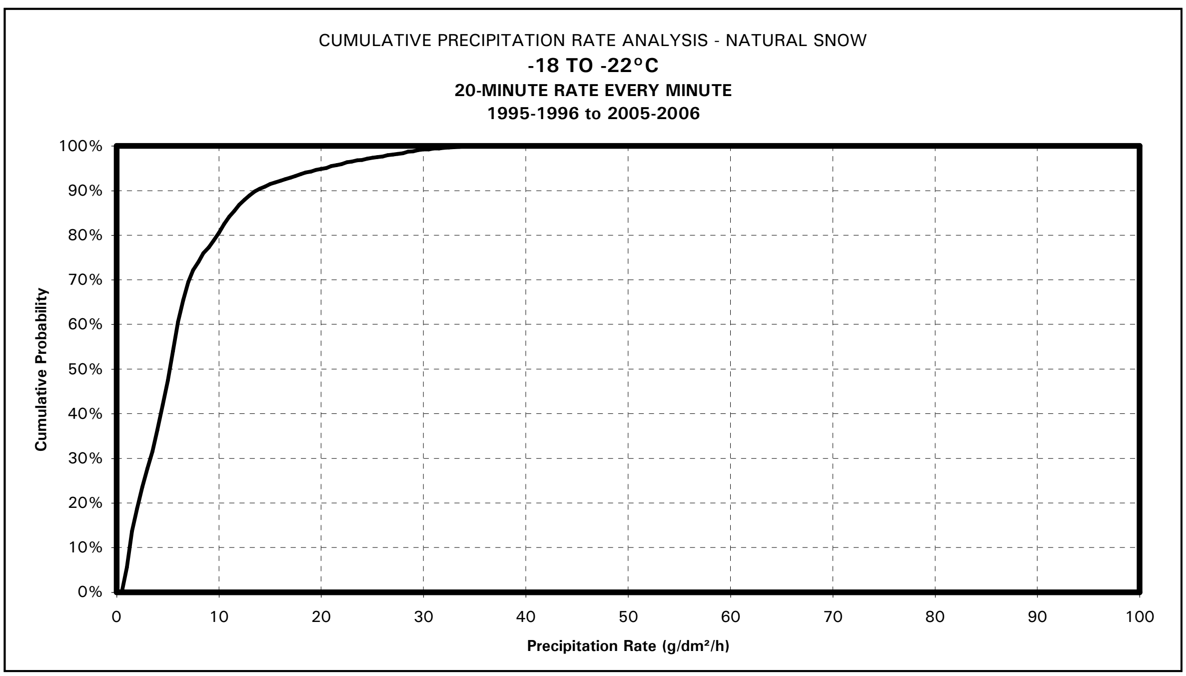
65
70
75
80
85
90
95
100
Precipitation Rate (g/dm²/h)

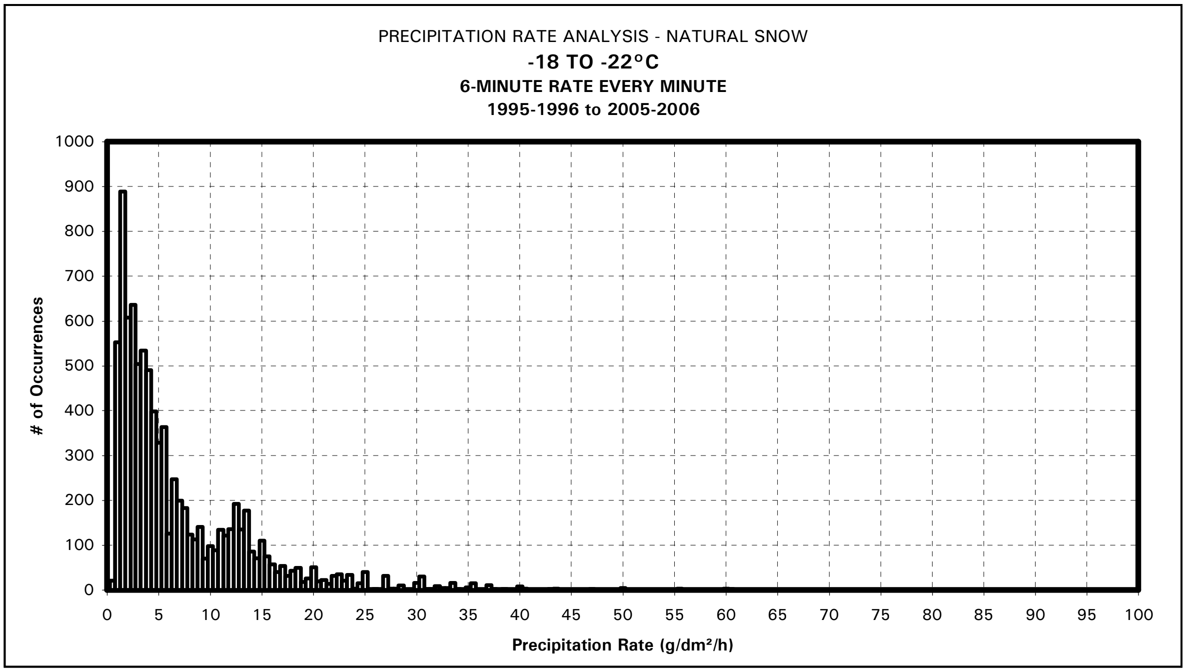

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0
10
20
30
40
50
60
70
80
90
100
Precipitation Rate (g/dm²/h)

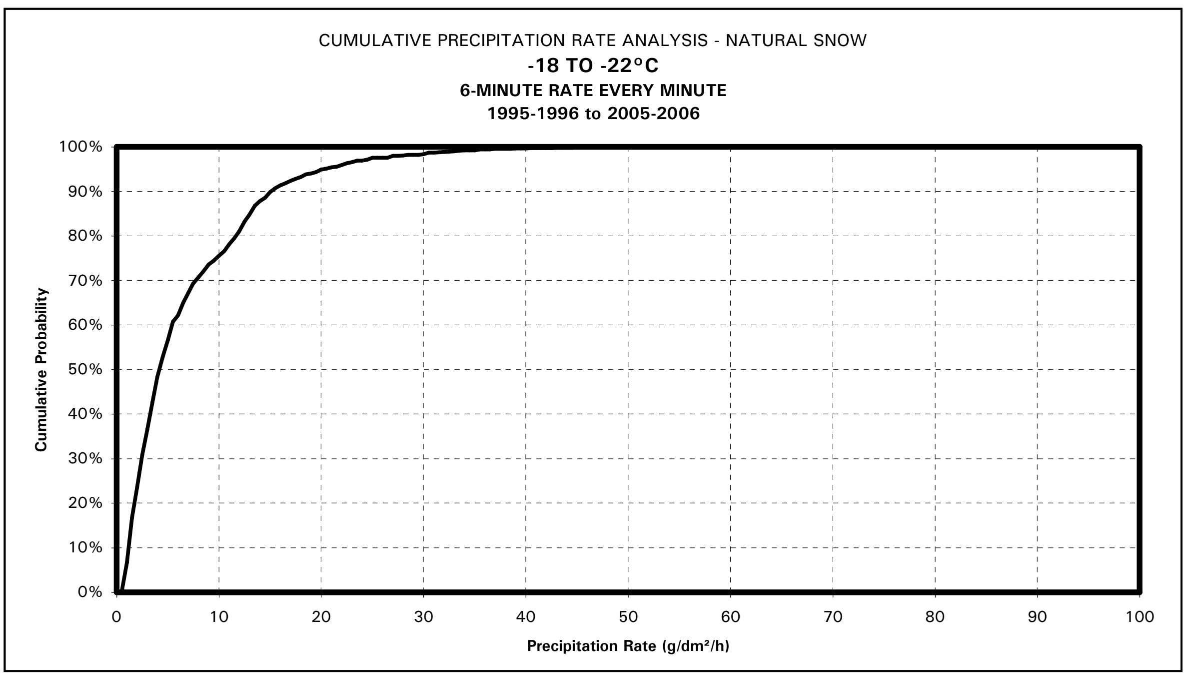

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
0
100
200
300
400
500
600
700
800
900
1000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

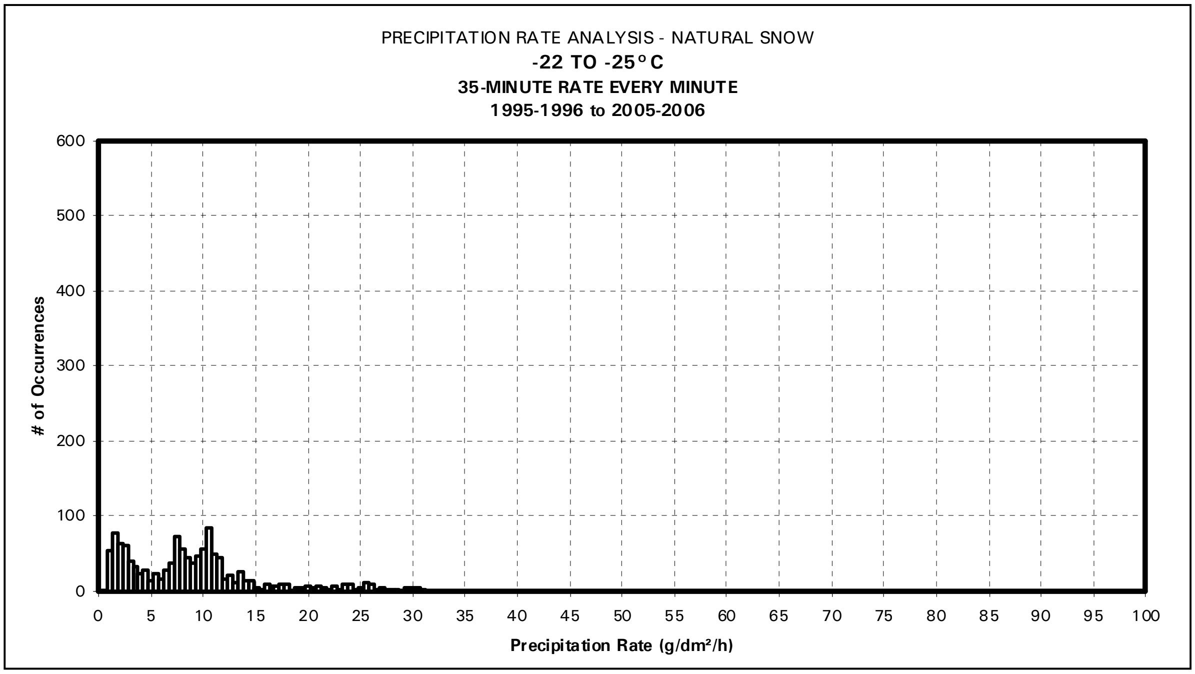

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

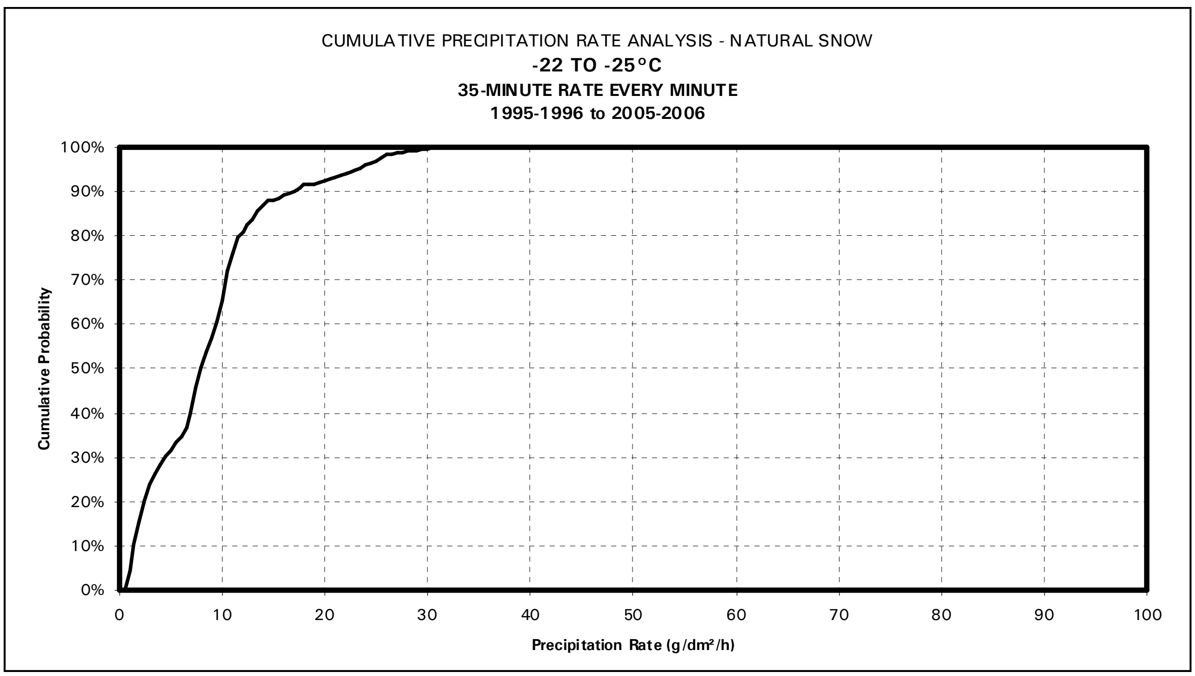

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
0
100
200
300
400
500
600
700
800
900
1000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

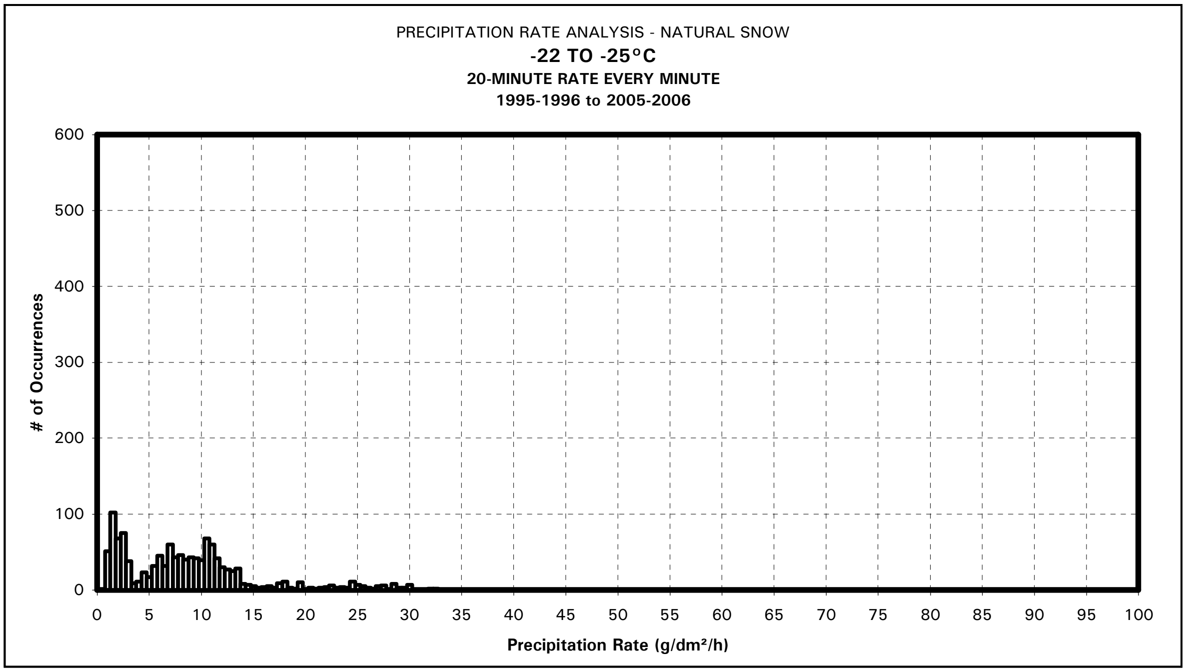

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
0
100
200
300
400
500
600
700
800
900
1000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

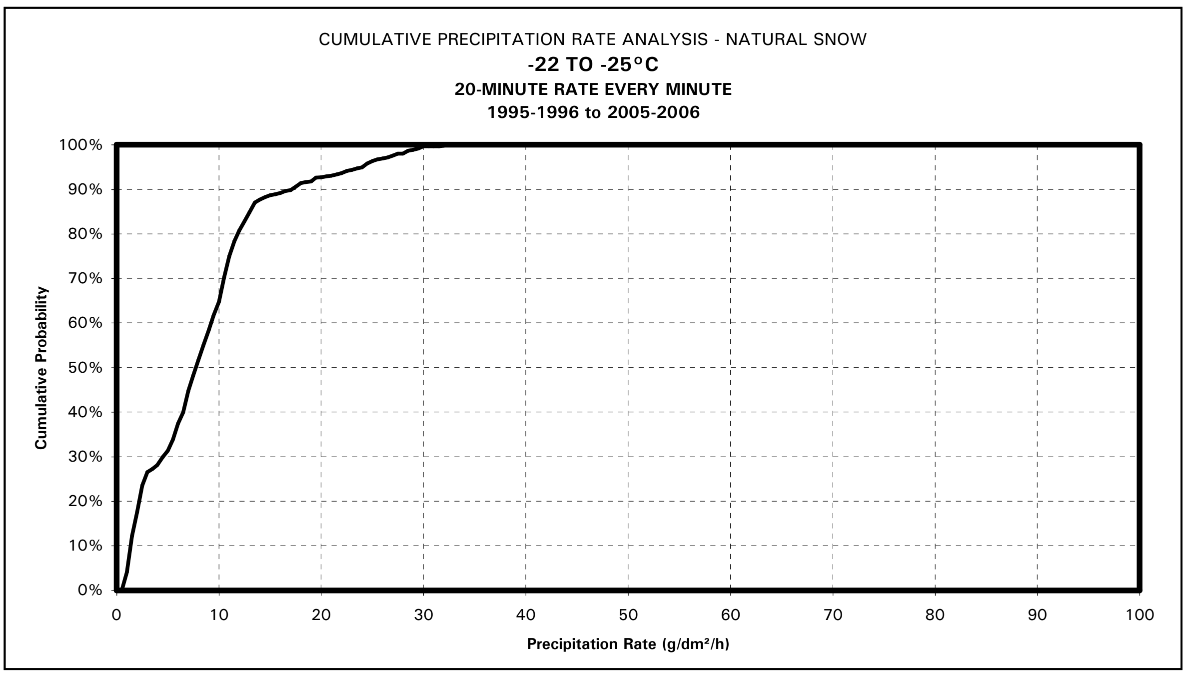

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
0
100
200
300
400
500
600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

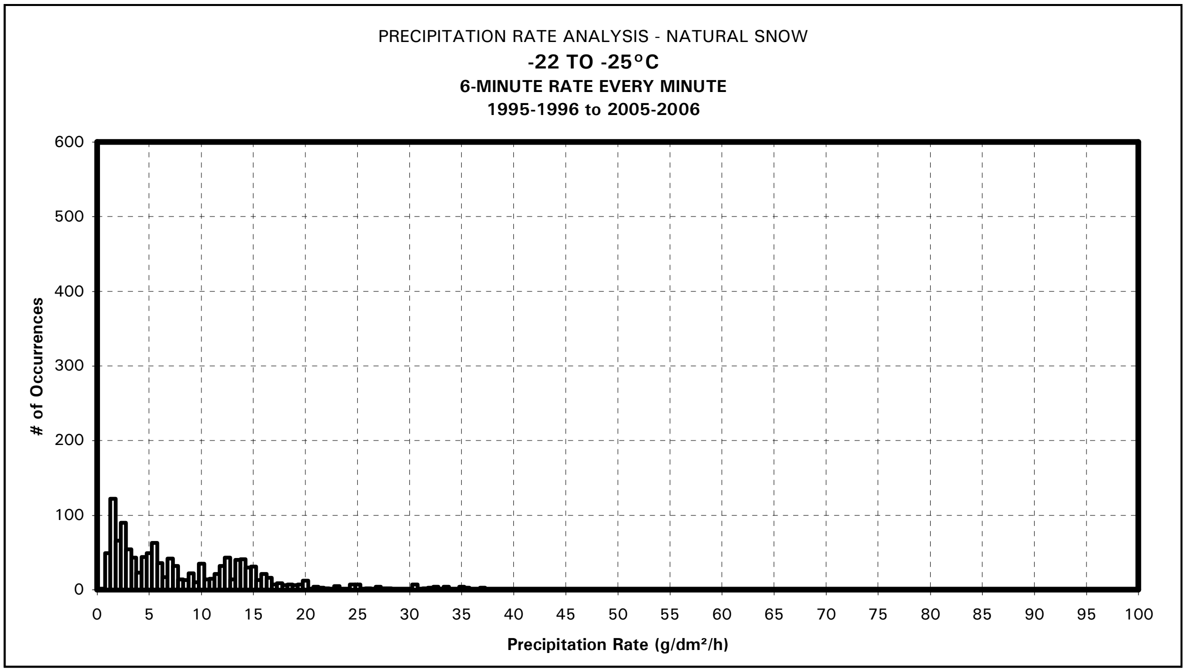

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

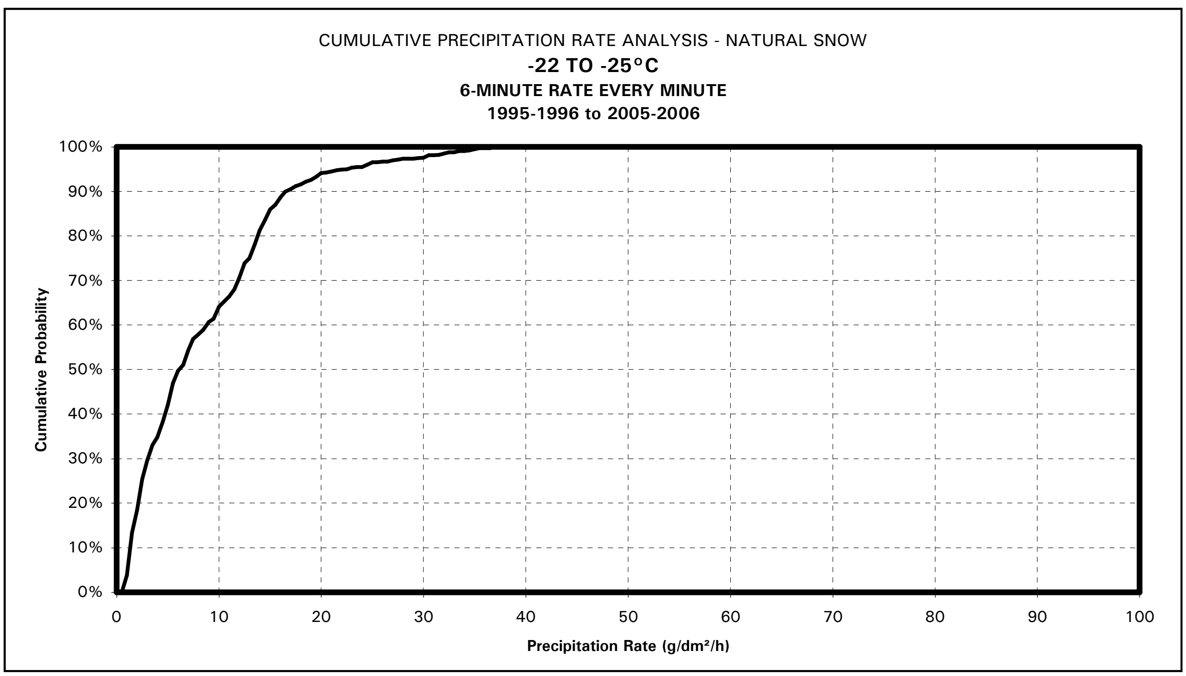


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
0
100
200
300
400
500
600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
# of Occurrences
0
100
200
300
400
500
600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)


CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2005-2006
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

# APPENDIX C

# CR21X AUTOMATIC DATA ACQUISITION STATION

# CR21X AUTOMATIC DATA ACQUISITION STATION

*Source: Most of the info was researched and obtained from various web sites.*

Observations of hourly precipitation amount are extremely useful tools for diagnostic and research purposes. In Canada, such observations are made at a number of sites, the most common being from Meteorological Service of Canada stations around the country.

The meteorological station at Dorval Airport (Photo 1) uses a Fisher/Porter (500 mm) precipitation gauge as a precipitation gauge and also a tipping bucket rain gauge.

**Photo 1**

The Fisher/Porter (F&P) precipitation gauge, developed by the Belfort instrument Company (Photo 2), is designed to work for many years in remote and harsh environments. The F&P gauge weighs the precipitation it collects in a large metal bucket. This bucket sits atop a mechanism that records the amount of precipitation (Photo 3). The recording & transmitting precipitation gauge converts the weight of collected precipitation into the equivalent depth of accumulated water in conventional units of inches or millimeters. An 8-inch (20.3 cm) diameter, knife-edge orifice collects all forms of precipitation. Rain travels through a funnel into the galvanized weighing bucket. The funnel is removed during the winter season to collect snow. When sub-freezing temperatures are expected, the bucket is partially filled with an antifreeze compound, which allows snow and ice to melt and be accurately measured. A weighing transducer provides instantaneous displacement values of the bucket in terms of millimeters of precipitation. This shaft displacement is transmitted every 5 seconds and averaged every minute in an attempt to eliminate spurious data caused by gusts of wind and temperature-induced contraction and expansion of the sensor. The readings are automatically logged with a CR21X data logger. The CR21X station has an accuracy of 0.1 mm (1 g/dm²).

**Photo 2**

**Photo 3**

Precipitation rates tend to fluctuate rapidly during snowstorms. The data from the CR21X station required less smoothing before it could be interpreted. The increased resolution of the CR21X weighing transducer allows better observation of short periods with heavy precipitation.

# APPENDIX D

## EXAMPLE OF MONTHLY METEOROLOGICAL SUMMARY
## MONTREAL - DORVAL

ENVIRONNEMENT CANADA
SERVICE MÉTÉOROLOGIQUE DU CANADA
ENVIRONMENT CANADA
METEOROLOGICAL SERVICE OF CANADA

## SOMMAIRE MÉTÉOROLOGIQUE MENSUEL
## MONTHLY METEOROLOGICAL SUMMARY

### Montreal/P E Trudeau Int'l A

FEVRIER 2005
FEBRUARY 2005

LAT : 45'28 N LONG : 73'45 W ALTITUDE : 35.7 MÈTRES (NMM) ÉLÉVATION : 35.7 MÈTRES (ASL) HEURE NORMALE UTILISÉE / STANDARD TIME USED : DE L'EST / EASTERN

| DATE | TEMPÉRATURE / TEMPERATURE: MAXIMALE / MAXIMUM °C | MINIMALE / MINIMUM °C | MOYENNE / MEAN °C | DEGRÉS-JOURS / DEGREE-DAYS: DE CHAUFFE / HEATING Base 18°C | DE CROISSANCE / GROWING Base 5°C | DE RÉFRIGÉRATION / COOLING Base 18°C | HUMIDITÉ REL / REL. HUMIDITY: MAXIMALE / MAXIMUM % | MINIMALE / MINIMUM % | ORAGE / THUNDERSTORM | PRÉCIPITATIONS / PRECIPITATION: PLUIE (HAUTEUR) / RAINFALL mm | NEIGE (HAUTEUR) / SNOWFALL cm | PRÉCIP. TOTAL / TOTAL PRECIP mm | NEIGE AU SOL / SNOW ON GROUND cm | VENTS / WINDS: VITESSE MOYENNE / AVERAGE SPEED Km/h | DIRECTION DOMINANTE / PREVALING DIRECTION | VITESSE MOYENNE MAX SUR 2 MIN ET DIRECTION / MAX 2 MIN MEAN SPEED AND DIRECTION Km/h | | INSOLATION EFFECTIVE / BRIGHT SUNSHINE HEURES / HOURS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -3.4 | -16.8 | -10.1 | 28.1 | | | 91 | 51 | | | | | 6 | 5.8 | SW | SW* | 11 | 5.4 |
| 2 | -0.7 | -8.5 | -4.6 | 22.6 | | | 85 | 61 | | | | | 6 | 5.9 | NNE | NNE* | 11 | 4.1 |
| 3 | -1.1 | -10.5 | -5.8 | 23.8 | | | 89 | 66 | | | | | 6 | 8.3 | N | NNE* | 13 | 2.2 |
| 4 | 3.3 | -10.8 | -3.8 | 21.8 | | | 85 | 47 | | | | | 6 | 5.1 | SW | SW* | 11 | 9.0 |
| 5 | 1.3 | -7.4 | -3.1 | 21.1 | | | 93 | 66 | | | | | 4 | 5.5 | SSW | SW* | 11 | 8.1 |
| 6 | 4.6 | -8.0 | -1.7 | 19.7 | | | 93 | 63 | | | | | 3 | 7.7 | NNE | ENE* | 13 | 5.2 |
| 7 | 6.4 | -3.3 | 1.6 | 16.4 | | | 86 | 50 | | | | | 2 | 3.3 | NNE* | NNE | 11 | |
| 8 | 4.2 | 1.4 | 2.8 | 15.2 | | | 97 | 64 | | 2.2 | | 2.2 | 1 | 7.1 | SSE | W* | 15 | |
| 9 | 2.0 | -4.2 | -1.1 | 19.1 | | | 96 | 61 | | | 1.0 | 1.0 | TR | 14.5 | W | NE | 31 | |
| 10 | -4.2 | -9.1 | -6.7 | 24.7 | | | 92 | 46 | | | 9.8 | 9.8 | 2 | 30.9 | NNE | NNE | 46 | |
| 11 | 0.1 | -12.1 | -6.0 | 24.0 | | | 66 | 39 | | | | | 6 | 19.1 | W | WNW | 33 | 9.6 |
| 12 | 0.3 | -7.7 | -3.7 | 21.7 | | | 89 | 63 | | | 0.2 | 0.2 | 6 | 17.4 | W | W* | 31 | 2.9 |
| 13 | -3.7 | -12.9 | -8.3 | 26.3 | | | 83 | 53 | | | 1.0 | 1.0 | 6 | 12.2 | SW | SW | 24 | 9.8 |
| 14 | 2.1 | -13.0 | -5.5 | 23.5 | | | 88 | 54 | | 0.2 | 1.0 | 1.2 | 6 | 22.9 | E | SE | 43 | 0.6 |
| 15 | 4.0 | 1.7 | 2.9 | 15.1 | | | 95 | 76 | | 0.6 | TR | 0.6 | 4 | 19.9 | SW | SW | 41 | |
| 16 | 3.4 | -7.9 | -2.3 | 20.3 | | | 99 | 75 | | 3.6 | 9.4 | 13.0 | TR | 11.5 | N* | NW* | 19 | |
| 17 | -1.8 | -11.3 | -6.6 | 24.6 | | | 88 | 52 | | | TR | TR | 6 | 6.8 | W* | NW | 15 | 9.5 |
| 18 | -6.2 | -16.8 | -11.5 | 29.5 | | | 92 | 60 | | | 4.2 | 4.2 | 9 | 18.7 | WSW | WSW | 35 | 1.2 |
| 19 | -5.0 | -19.4 | -12.2 | 30.2 | | | 93 | 47 | | | 0.4 | 0.4 | 8 | 16.1 | SW | SW | 26 | 6.0 |
| 20 | -12.1 | -19.6 | -15.9 | 33.9 | | | 57 | 37 | | | | | 7 | 11.2 | W* | NNW | 19 | 10.0 |
| 21 | -4.9 | -14.6 | -9.8 | 27.8 | | | 90 | 50 | | | 9.6 | 9.6 | 7 | 20.6 | NE | NE* | 30 | |
| 22 | -2.1 | -8.7 | -5.4 | 23.4 | | | 91 | 71 | | | 0.4 | 0.4 | 9 | 8.0 | SW | WNW | 13 | 2.4 |
| 23 | -5.8 | -15.0 | -10.4 | 28.4 | | | 84 | 56 | | | | | 9 | 13.5 | W | WSW* | 24 | 9.9 |
| 24 | -8.3 | -20.8 | -14.6 | 32.6 | | | 88 | 45 | | | | | 9 | 8.6 | NE | NE | 17 | 7.2 |
| 25 | -5.2 | -15.7 | -10.5 | 28.5 | | | 83 | 36 | | | | | 9 | 10.2 | NNE | NNE | 20 | 9.9 |
| 26 | -2.0 | -18.7 | -10.4 | 28.4 | | | 80 | 39 | | | | | 9 | 6.2 | W | SW* | 15 | 8.7 |
| 27 | -5.2 | -14.8 | -10.0 | 28.0 | | | 65 | 39 | | | | | 9 | 18.3 | W | W | 33 | 10.3 |
| 28 | -5.3 | -14.7 | -10.0 | 28.0 | | | 67 | 44 | | | | | 9 | 19.8 | NE | NE* | 31 | 0.4 |
| | MOY -1.6 MEAN | MOY -11.4 MEAN | MOY -6.5 MEAN | TOTAL 686.7 | TOTAL | TOTAL | MOY 86 MEAN | MOY 54 MEAN | TOTAL | TOTAL 6.6 | TOTAL 37.0 | TOTAL 43.6 | | MOY 12.7 MEAN | DOMINANTE W PREVALING | MAXIMALE NNE MAXIMUM | 46 | TOTAL 132.4 |
| NORMALE NORMAL | -4.3 | -13.4 | -8.9 | 758.2 | 0.9 | 0.0 | | | 0 | 18.4 | 43.8 | 59.7 | | 15.0 | WSW | | | 123.9 |

**SOMMAIRE DE DEGRÉS-JOURS / DEGREE-DAY SUMMARY**

| AU-DESSOUS DE 18 °C / BELOW 18°C | ANNÉE EN COURS / THIS YEAR | NORMALE / NORMAL | AU-DESSUS DE 5°C / ABOVE 5°C | ANNÉE EN COURS / THIS YEAR | NORMALE / NORMAL |
|---|---|---|---|---|---|
| TOTAL DU MOIS / TOTAL FOR MONTH | 686.7 | 758.2 | TOTAL DU MOIS / TOTAL FOR MONTH | | 0.9 |
| ACCUMULÉS DEPUIS LE 1er JUILLET / ACCUMULATED SINCE JULY 1st | 3207.0 | 3370.2 | ACCUMULÉS DEPUIS LE 1er AVRIL / ACCUMULATED SINCE APRIL 1st | 2141.5 | 2066.9 |

| JOURS AVEC PRÉCIPITATIONS TOTALES / DAYS WITH TOTAL PRECIPITATION (mm): 0,5 ou plus / or more | 1,0 ou plus / or more | 2,0 ou plus / or more | 10,0 ou plus / or more | 50,0 ou plus / or more | JOURS AVEC CHÛTES DE NEIGE / DAYS WITH SNOWFALL (cm): 0,2 ou plus / or more | 1,0 ou plus / or more | 2,0 ou plus / or more | 10,0 ou plus / or more | 50,0 ou plus / or more |
|---|---|---|---|---|---|---|---|---|---|
| 9 | 8 | 5 | 1 | | 10 | 7 | 4 | | |

Canada

1. Normale/Normal 1971-2000
2. Journée climatologique/Climatological Day (01h00HNE à/to 01h00HNE)
3. (AUTO) : mesures d'une station automatique/data from automatic station
4. TR = Trace M = Manquant/Missing E = Estimé/Estimated C = Calme/Calm
5. Pas de valeur/No entry = Pas d'événement/No occurence
6. * = indique la première de plusieurs valeurs valides/indicates first of many valid values
7. c = correction

Données horaires non controlées
Hourly data not validated
Les précipitations ont un seuil mesurable de 1,0 mm
Measurable threshold of precipitation is 1,0 mm

Creation : 4 MARS 20
Created : MARCH 4 20

## RELEVÉS COMPARATIFS À / COMPARATIVE RECORDS AT : Montreal/P E Trudeau Int'l A — FEVRIER 2005 / FEBRUARY 2005

| | UNITÉS / UNITS | CE MOIS-CI / THIS MONTH — RELEVÉ / VALUE | JOUR / DAY | ANNÉE PRÉCÉDENTE / PREVIOUS YEAR — RELEVÉ / VALUE | JOUR / DAY | NORMALE / NORMAL | RECORD POUR LE MOIS / RECORD FOR THE MONTH — MAXIMUM ABSOLU / HIGHEST EVER — RELEVÉ / VALUE | JOUR / DAY | ANNÉE / YEAR | MINIMUM ABSOLU / LOWEST EVER — RELEVÉ / VALUE | JOUR / DAY | ANNÉE / YEAR | DEPUIS / SINCE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEMPÉRATURE MAXIMALE / HIGHEST TEMPERATURE (MAXIMUM) | °CELSIUS | 6.4 | 7 | 5.5 | 29 | | 15.0 | 22 | 1981 | | | | 1941 |
| TEMPÉRATURE MINIMALE / LOWEST TEMPERATURE (MINIMUM) | °CELSIUS | -20.8 | 24 | -24.0 | 15 | | | | | -33.9 | 15 | 1943 | 1941 |
| TEMPÉRATURE MENSUELLE MOYENNE / MEAN MONTHLY TEMPERATURE | °CELSIUS | -6.5 | | -7.9 | | -8.9 | -1.6 | | 1981 | -14.1 | | 1993 | 1941 |
| HAUTEUR TOTALE MENSUELLE DE PLUIE / TOTAL MONTHLY RAINFALL | mm | 6.6 | | 2.8 | | 18.4 | 87.0 | | 1981 | 0.0 | | 1993 | 1941 |
| HAUTEUR TOTALE MENSUELLE DE NEIGE / TOTAL MONTHLY SNOWFALL | cm | 37.0 | | 37.2 | | 43.8 | 132.4 | | 1960 | 11.4 | | 1978 | 1941 |
| PRÉCIPITATION TOTALE MENSUELLE / TOTAL MONTHLY PRECIPITATION | mm | 43.6 | | 39.6 | | 59.7 | 174.5 | | 1960 | 7.7 | | 1978 | 1941 |
| NOMBRE DE JOURS AVEC PRECIPITATION MESURABLE / NO OF DAYS WITH MEASURABLE PRECIPITATION | | 12 | | 12 | | 14 | 21 | | 1960 | 2 | | 1984 | 1941 |
| HAUTEUR DE PLUIE MAXIMALE EN UNE JOURNÉE / GREATEST RAINFALL IN ONE DAY | mm | 3.6 | 16 | 1.4 | 21 | | 31.5 | 25 | 1961 | | | | 1941 |
| HAUTEUR DE NEIGE MAXIMALE EN UNE JOURNÉE / GREATEST SNOWFALL IN ONE DAY | cm | 9.8 | 10 | 13.2 | 3 | | 39.4 | 16 | 1954 | | | | 1941 |
| PRÉCIPITATION MAXIMALE EN UNE JOURNÉE / GREATEST PRECIPITATION IN ONE DAY | mm | 13.0 | 16 | 14.2 | 3 | | 39.4 | 16 | 1954 | | | | 1941 |
| HAUTEUR DE PLUIE ENREGISTRÉE EN : / MAXIMUM RAINFALL RECORDED IN : | | | | | | | | | | | | | |
| 5 MINUTES | mm | | | | | | 1.0 | 24 | 1975 | | | | de/from |
| 10 MINUTES | mm | | | | | | 1.3 | 9 | 1990 | | | | 1943 |
| 15 MINUTES | mm | | | | | | 5.0 | 16 | 1983 | | | | à/to |
| 30 MINUTES | mm | | | | | | 5.0 | 16 | 1983 | | | | 1990 |
| 60 MINUTES | mm | | | | | | 5.3 | 22 | 1974 | | | | |
| 24 HEURES CONSÉCUTIVE / CONSECUTIVE HOURS | mm | | | | | | | | | | | | |
| VITESSE MOYENNE DU VENT / MEAN WIND SPEED | KM/H | 12.7 | | 17.2 | | 15.0 | 22.2 | | 1976 | 10.9 | | 1987 | 1953 |
| VITESSE MAXIMALE (MOYENNE SUR 2 MIN.) / MAXIMUM SPEED (2 MIN. MEAN) | KM/H | NNE 46 | 10 | WSW 54 | 4 | | NNE 80 | 26 | 1961 | | | | 1953 |
| POINTE DE VENT MAXIMALE / MAXIMUM GUST SPEED | KM/H | NNE 61 | 10 | WSW 69 | 4 | | WSW 138 | 25 | 1956 | | | | 1955 |
| TOTAL DES HEURES INSOLATION / TOTAL HOURS OF SUNSHINE | HEURES | 132.4 | | 157.3 | | 123.9 | 205.6 | | 1987 | 73.7 | | 1981 | 1969 |
| PRESSION MOYENNE À LA STATION / MEAN STATION PRESSURE | kPa | 101.58 | | 101.59 | | 101.27 | 101.91 | | 1955 | 100.31 | | 1958 | 1953 |
| PRESSION MAXIMALE À LA STATION / GREATEST STATION PRESSURE | kPa | 103.24 | 2 | 103.56 | 17 | | 104.67 | 13 | 1981 | | | | 1953 |
| PRESSION MINIMALE À LA STATION / LEAST STATION PRESSURE | kPa | 99.50 | 12 | 99.33 | 21 | | | | | 96.58 | 25 | 1956 | 1953 |

### DONNEES CLIMATOLOGIQUES CE MOIS-CI POUR LES 10 DERNIÈRES ANNÉES / CLIMATOLOGICAL DATA THIS MOUNTH FOR THE PAST 10 YEARS

| ANNÉE / YEAR | TEMPÉRATURE MAXIMALE / MAXIMUM TEMP. | TEMPÉRATURE MINIMALE / MINIMUM TEMPERATURE | TEMPÉRATURE MOYENNE / MEAN TEMPERATURE | HAUTEUR DE PLUIE / RAINFALL | HAUTEUR DE NEIGE / SNOWFALL | PRÉCIPITATION TOTALE / TOTAL PRECIPITATION | VITESSE MOYENNE DES VENTS / MEAN WIND SPEED | VITESSE MAXIMALE DES VENTS / MAXIMUM WIND SPEED | HEURES D'ENSOLEILLEMENT / SUNSHINE HOURS | DEGRÉS-JOURS DE CHAUFFE / HEATING DEGREE-DAYS | DEGRÉS-JOURS DE CROISSANCE / GROWING DEGREE-DAYS | DEGRÉS-JOURS DE RÉFRIGÉRATION / COOLING DEGREE-DAYS | A.S.N / S.A.S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1996 | 7.5 | -23.6 | -7.9 | 52.4 | 17.4 | 72.7 | 14.9 | WNW 52 | 133.3 | 752.3 | | | 176.1 |
| 1997 | 8.2 | -28.3 | -7.9 | 35.9 | 70.5 | 96.4 | 14.2 | SW 50 | 106.4 | 725.3 | | | 206.3 |
| 1998 | 5.9 | -19.7 | -3.8 | 16.5 | 27.2 | 63.8 | 12.5 | W 39 | 137.5 | 610.7 | | | 190.4 |
| 1999 | 9.1 | -19.0 | -5.1 | 20.6 | 15.5 | 44.3 | 13.2 | SSE 41 | 152.8 | 647.1 | | | 122.8 |
| 2000 | 10.9 | -21.6 | -7.0 | 8.2 | 67.1 | 73.0 | 18.0 | SW 54 | 149.3 | 725.4 | 2.2 | | 154.8 |
| 2001 | 8.8 | -23.3 | -8.7 | 30.1 | 44.0 | 74.2 | 18.0 | W 76 | 114.5 | 747.0 | | | 188.6 |
| 2002 | 11.4 | -18.8 | -5.0 | 18.2 | 19.0 | 41.2 | 18.5 | SW 67 | 105.3 | 643.3 | 1.0 | | 94.8 |
| 2003 | 4.1 | -25.9 | -10.8 | 19.0 | 31.9 | 62.8 | 19.4 | WSW 63 | 149.7 | 805.6 | | | 131.9 |
| 2004 | 5.5 | -24.0 | -7.9 | 2.8 | 37.2 | 39.6 | 17.2 | WSW 54 | 157.3 | 750.8 | | | 137.0 |
| 2005 | 6.4 | -20.8 | -6.5 | 6.6 | 37.0 | 43.6 | 12.7 | NNE 46 | 132.4 | 686.7 | | | 128.4 |

*Avis / Note :*

- * : Nouveau record / New record
- # : Station manuelle / Manual station
- A.S.N : Accumulation Saisonnière de Neige / S.A.S = Season Accumulation Snowfall

## TEMPÉRATURE / TEMPERATURE

TEMPERATURE HORAIRE
HOURLY TEMPERATURE

### Montreal/P E Trudeau Int'l A

FEVRIER 2005
FEBRUARY 2005

| DATE | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -119 | -141 | -146 | -137 | -147 | -154 | -151 | -138 | -136 | -138 | -99 | -86 | -65 | -54 | -40 | -36 | -41 | -44 | -39 | -35 | -40 | -43 | -46 | -41 |
| 2 | -47 | -45 | -48 | -49 | -54 | -56 | -57 | -58 | -55 | -47 | -34 | -30 | -27 | -20 | -15 | -10 | -9 | -11 | -21 | -32 | -46 | -32 | -60 | -73 |
| 3 | -79 | -84 | -88 | -91 | -98 | -92 | -99 | -100 | -98 | -89 | -67 | -50 | -44 | -32 | -22 | -17 | -17 | -23 | -29 | -35 | -36 | -38 | -43 | -50 |
| 4 | -46 | -50 | -53 | -79 | -62 | -76 | -72 | -103 | -85 | -64 | -36 | -16 | 2 | 15 | 19 | 19 | 22 | 10 | 2 | -11 | -34 | -34 | -30 | -43 |
| 5 | -65 | -63 | -64 | -68 | -63 | -68 | -59 | -67 | -58 | -46 | -31 | -8 | -2 | 10 | 10 | 11 | 3 | -1 | -19 | -31 | -30 | -39 | -46 | -41 |
| 6 | -51 | -59 | -59 | -47 | -68 | -57 | -58 | -43 | -57 | -27 | -16 | -7 | 18 | 17 | 32 | 22 | 19 | 16 | 5 | -3 | -10 | -13 | -12 | -14 |
| 7 | -15 | -18 | -22 | -25 | -24 | -24 | -25 | -25 | -15 | -3 | 20 | 32 | 44 | 53 | 60 | 54 | 55 | 45 | 36 | 39 | 35 | 33 | 30 | 34 |
| 8 | 32 | 29 | 27 | 24 | 40 | 21 | 18 | 15 | 16 | 18 | 20 | 26 | 25 | 24 | 18 | 32 | 26 | 25 | 24 | 27 | 25 | 23 | 21 | 21 |
| 9 | 22 | 19 | 16 | 12 | 7 | 3 | 1 | -3 | -3 | -7 | -10 | -13 | -10 | -6 | -3 | -9 | -13 | -13 | -10 | -3 | -5 | -11 | -19 | -25 |
| 10 | -34 | -42 | -46 | -51 | -51 | -53 | -57 | -58 | -60 | -61 | -60 | -59 | -57 | -57 | -45 | -54 | -54 | -54 | -52 | -50 | -50 | -42 | -53 | -59 |
| 11 | -84 | -85 | -81 | -96 | -97 | -104 | -112 | -108 | -106 | -90 | -67 | -52 | -15 | -4 | -2 | -6 | -9 | -14 | -29 | -39 | -48 | -52 | -56 | -56 |
| 12 | -67 | -67 | -75 | -70 | -62 | -56 | -54 | -46 | -43 | -37 | -29 | -21 | -12 | -3 | -2 | 1 | 1 | -3 | -3 | -14 | -32 | -27 | -25 | -28 |
| 13 | -26 | -37 | -50 | -66 | -75 | -87 | -106 | -122 | -123 | -111 | -103 | -98 | -88 | -85 | -78 | -73 | -77 | -77 | -86 | -91 | -97 | -102 | -104 | -117 |
| 14 | -120 | -120 | -114 | -111 | -111 | -124 | -119 | -126 | -112 | -102 | -89 | -59 | -49 | -39 | -22 | -18 | -10 | -3 | 0 | 4 | 9 | 11 | 15 | 16 |
| 15 | 18 | 18 | 20 | 22 | 23 | 25 | 33 | 28 | 28 | 27 | 31 | 35 | 37 | 33 | 33 | 32 | 28 | 37 | 33 | 35 | 33 | 35 | 32 | 26 |
| 16 | 26 | 27 | 23 | 24 | 22 | 23 | 23 | 19 | 12 | 5 | 3 | 3 | 2 | 3 | 3 | 6 | 8 | 2 | -3 | -11 | -17 | -25 | -32 | -52 |
| 17 | -69 | -72 | -79 | -86 | -88 | -97 | -112 | -107 | -98 | -80 | -71 | -65 | -61 | -52 | -31 | -30 | -43 | -49 | -59 | -65 | -68 | -68 | -65 | -71 |
| 18 | -67 | -68 | -64 | -66 | -74 | -90 | -86 | -87 | -84 | -91 | -94 | -89 | -108 | -111 | -118 | -110 | -118 | -122 | -129 | -131 | -137 | -144 | -147 | -154 |
| 19 | -163 | -168 | -169 | -174 | -178 | -179 | -182 | -190 | -177 | -156 | -140 | -121 | -106 | -87 | -78 | -66 | -57 | -52 | -56 | -58 | -60 | -75 | -91 | -101 |
| 20 | -116 | -125 | -132 | -151 | -159 | -161 | -182 | -189 | -165 | -157 | -152 | -142 | -137 | -133 | -131 | -127 | -126 | -126 | -127 | -130 | -142 | -139 | -135 | -134 |
| 21 | -127 | -123 | -133 | -142 | -143 | -145 | -145 | -143 | -143 | -135 | -122 | -102 | -75 | -63 | -61 | -57 | -51 | -51 | -80 | -91 | -88 | -85 | -86 | -90 |
| 22 | -88 | -87 | -86 | -85 | -86 | -84 | -81 | -80 | -79 | -72 | -66 | -55 | -51 | -41 | -36 | -27 | -22 | -26 | -29 | -58 | -60 | -56 | -63 | -51 |
| 23 | -54 | -62 | -71 | -80 | -92 | -122 | -131 | -135 | -124 | -121 | -115 | -108 | -98 | -97 | -90 | -85 | -82 | -83 | -90 | -100 | -108 | -120 | -140 | -143 |
| 24 | -131 | -134 | -143 | -156 | -161 | -156 | -178 | -189 | -174 | -134 | -104 | -100 | -97 | -89 | -88 | -87 | -88 | -93 | -95 | -93 | -107 | -102 | -104 | -117 |
| 25 | -119 | -123 | -131 | -139 | -147 | -147 | -146 | -151 | -142 | -126 | -119 | -108 | -94 | -85 | -76 | -72 | -55 | -71 | -81 | -85 | -95 | -105 | -121 | -118 |
| 26 | -134 | -147 | -154 | -158 | -152 | -157 | -180 | -160 | -153 | -131 | -106 | -90 | -69 | -64 | -50 | -46 | -52 | -54 | -65 | -67 | -76 | -97 | -109 | -108 |
| 27 | -123 | -112 | -134 | -125 | -120 | -123 | -120 | -123 | -116 | -109 | -97 | -92 | -83 | -74 | -63 | -59 | -54 | -56 | -70 | -77 | -84 | -90 | -103 | -112 |
| 28 | -109 | -114 | -116 | -124 | -137 | -108 | -105 | -99 | -92 | -80 | -70 | -65 | -62 | -58 | -60 | -60 | -61 | -59 | -59 | -61 | -62 | -62 | -63 | -60 |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | |

*Avis / Note :* Unités / Units: 0.1 °C M = Manquant / Missing

Lire / Read -123 = -12.3 °C -1 = -0.1 °C 0 = 0.0 °C 12 = +1.2 °C 123 = 12.3 °C

Heure normale locale : Est
Local standard time: Eastern

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**Services climatologiques et de qualité de l'air / Climate and Air Quality Services**
100 Alexis Nihon, 3e
Ville St-Laurent, QC - H4M 2N8 Télécopieur / Fax : (514) 283-2264
Courrier éléctronique / Email : *Climat.Quebec@ec.gc.ca*
Renseignements climatologiques / Climate Information : 1-900-565-1111 (2,99 $ / minute)

## VENTS / WINDS

VENTS HORAIRES (KM/H)
HOURLY WINDS (KM/H)

Montreal/P E Trudeau Int'l A

FEVRIER 2005
FEBRUARY 2005

| DATE | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | RAFALE MAX / PEAK GUST | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | | | | | | | Heure / Time | Jour / Day |
| 1 | C 0 | W 4 | SSW 7 | SW 11 | C 0 | N 4 | C 0 | SSW 11 | SW 11 | C 0 | SSW 9 | S 6 | S 4 | SW 4 | SW 6 | SSW 7 | SW 11 | SW 6 | SSW 7 | SSW 6 | SW 9 | SSW 7 | SW 4 | SW 4 | | | |
| 2 | C 0 | SW 6 | SW 6 | SW 7 | SW 4 | C 0 | C 0 | C 0 | C 0 | C 0 | C 0 | N 4 | N 6 | NNE 7 | NNE 7 | NNE 11 | NNE 11 | NE 11 | NE 11 | NNE 7 | N 6 | NE 11 | NNE 7 | N 7 | | | |
| 3 | N 9 | NNE 9 | N 7 | NNE 9 | N 4 | ENE 4 | N 9 | NNE 13 | NE 13 | NE 11 | NNE 9 | NNE 7 | N 9 | N 7 | NNE 9 | N 7 | NNW 6 | N 7 | NNE 11 | NNE 9 | N 11 | N 9 | N 9 | NNE 6 | | | |
| 4 | N 7 | N 7 | C 0 | C 0 | NNE 6 | NNW 7 | C 0 | C 0 | NW 6 | NNW 4 | NNW 6 | N 4 | SW 4 | WSW 4 | SW 11 | WSW 9 | SW 9 | WSW 7 | SW 11 | SW 11 | SSW 7 | C 0 | W 4 | SSW 7 | | | |
| 5 | C 0 | SW 6 | SSW 7 | S 7 | SSW 9 | SSW 7 | WSW 7 | W 7 | W 4 | NW 6 | C 0 | S 4 | SSW 4 | SW 7 | SW 11 | SSW 7 | SW 11 | SW 9 | S 4 | W 4 | SE 4 | C 0 | C 0 | ENE 6 | | | |
| 6 | WNW 4 | N 4 | N 4 | C 0 | NE 6 | N 7 | N 11 | ENE 13 | N 6 | C 0 | NE 6 | NNE 9 | NE 7 | ESE 6 | ENE 6 | NNE 11 | NNE 9 | NE 9 | N 6 | N 9 | NNE 11 | NNE 13 | NNE 11 | NNE 11 | | | |
| 7 | N 6 | NNE 7 | NNE 9 | NNW 9 | NNE 11 | N 6 | C 0 | C 0 | C 0 | C 0 | C 0 | C 0 | C 0 | SSE 4 | SSW 6 | S 7 | C 0 | SW 4 | C 0 | S 4 | C 0 | C 0 | C 0 | ESE 6 | | | |
| 8 | ENE 6 | ESE 6 | C 0 | C 0 | NNE 7 | C 0 | N 7 | N 6 | C 0 | SE 4 | SSE 7 | SSE 4 | WNW 4 | SSE 13 | SE 4 | SSW 11 | SSE 4 | WNW 4 | SSE 13 | SSE 9 | W 15 | WSW 13 | SW 9 | W 9 | | | |
| 9 | W 15 | W 13 | W 17 | W 19 | W 19 | W 17 | W 13 | W 13 | W 13 | W 15 | WNW 15 | W 6 | NW 7 | WNW 4 | NNE 11 | ESE 6 | SSW 9 | C 0 | C 0 | ENE 13 | ENE 17 | NE 26 | NE 26 | NE 31 | NE 37 | 1 | 10 |
| 10 | NE 26 | NE 24 | NNE 30 | NE 33 | NE 31 | NNE 35 | NNE 41 | NNE 43 | NE 39 | NNE 46 | NNE 44 | NNE 35 | NNE 35 | NNE 39 | NNE 35 | NNE 33 | NNE 33 | NNE 26 | NNE 30 | N 19 | N 15 | N 28 | N 24 | N 19 | NNE 61 | 9 | 10 |
| 11 | NNW 13 | NNW 15 | NW 13 | NW 13 | NW 13 | W 11 | W 13 | W 15 | W 9 | SW 17 | WSW 15 | SW 13 | W 19 | W 17 | WNW 28 | WNW 30 | WNW 33 | WNW 28 | W 26 | W 28 | W 28 | W 15 | W 17 | W 19 | WNW 44 | 16 | 11 |
| 12 | W 22 | W 17 | SSW 11 | WSW 11 | WSW 22 | WSW 20 | WSW 17 | W 19 | W 19 | WSW 17 | WSW 13 | W 26 | W 31 | W 30 | W 31 | W 19 | W 22 | W 20 | WSW 15 | WNW 7 | WNW 9 | NW 9 | WNW 11 | WNW 9 | W 33 | 12 | 12 |
| 13 | NW 13 | NW 17 | NNW 17 | NNE 17 | NNE 15 | NNW 22 | NNW 13 | NNW 9 | NW 9 | NNW 7 | WNW 7 | NW 7 | W 9 | SW 24 | WSW 13 | SW 20 | SW 20 | SW 15 | SW 13 | WSW 7 | SW 11 | SW 6 | SW 9 | SSW 9 | | | |
| 14 | SSE 7 | ESE 7 | ESE 4 | E 7 | E 9 | E 9 | E 15 | E 9 | E 6 | NE 20 | NE 17 | E 15 | E 22 | ESE 28 | SE 26 | SE 35 | SE 43 | SSE 35 | SE 37 | SSE 35 | SSE 33 | SSE 30 | SSE 37 | SSE 30 | SE 57 | 16 | 14 |
| 15 | SE 24 | SSE 24 | SSE 22 | SSE 22 | SSE 30 | S 17 | SW 28 | SW 31 | SW 41 | WSW 28 | WSW 30 | WSW 31 | SW 39 | SW 22 | SSW 20 | SSW 11 | SSW 11 | WSW 4 | SSW 11 | SW 7 | S 13 | SSW 17 | SSW 15 | S 13 | SW 56 | 8 | 15 |
| 16 | S 9 | SW 6 | ESE 4 | SE 6 | C 0 | N 9 | N 13 | N 7 | NNW 13 | N 11 | NNW 13 | N 11 | WNW 9 | W 11 | WNW 13 | WNW 15 | W 15 | NW 15 | NW 15 | NW 19 | NNW 11 | NNW 19 | NW 17 | WNW 13 | NW 32 | 19 | 16 |
| 17 | W 7 | WNW 9 | W 9 | W 11 | W 13 | WNW 7 | NW 15 | N 4 | N 7 | C 0 | C 0 | NNE 7 | C 0 | NNE 4 | NNW 4 | WSW 9 | WSW 6 | S 7 | SSE 9 | SSE 13 | SE 7 | ESE 7 | SE 9 | SE 11 | | | |
| 18 | E 4 | C 0 | ENE 4 | C 0 | NNE 9 | N 7 | N 4 | W 6 | WSW 19 | WSW 24 | WSW 24 | WSW 24 | WSW 30 | WSW 33 | WSW 35 | WSW 26 | W 28 | WSW 28 | WSW 26 | W 26 | W 19 | W 19 | W 15 | W 15 | WSW 44 | 14 | 18 |
| 19 | W 13 | W 15 | WSW 11 | WSW 9 | SW 11 | SW 13 | W 17 | W 7 | W 11 | SW 19 | SW 19 | SW 22 | SW 19 | SSW 20 | SSW 17 | SW 13 | WSW 22 | SW 26 | SW 22 | WSW 22 | WNW 17 | NW 15 | NW 13 | NW 17 | SW 33 | 18 | 19 |
| 20 | NW 13 | WNW 11 | NNW 19 | NW 9 | NNW 9 | N 15 | N 7 | NNW 7 | NW 4 | W 9 | W 9 | W 11 | W 13 | WSW 11 | SW 17 | SW 17 | SSW 15 | SW 9 | SW 9 | ESE 6 | ESE 9 | ESE 9 | ESE 13 | E 11 | | | |
| 21 | E 15 | NE 15 | NE 19 | NE 26 | NE 28 | NE 30 | NE 30 | NE 26 | NE 30 | NE 30 | NE 24 | NE 22 | ENE 19 | E 17 | E 22 | E 24 | E 19 | E 13 | N 15 | NNE 11 | N 13 | N 17 | NNE 22 | N 13 | NE 39 | 6 | 21 |
| 22 | N 11 | N 13 | N 9 | WNW 9 | W 9 | W 7 | SW 6 | SW 9 | SW 11 | WSW 11 | C 0 | W 9 | SSW 9 | S 11 | SW 11 | SW 11 | SW 9 | WSW 7 | W 9 | WNW 4 | W 7 | C 0 | SW 4 | WNW 7 | | | |
| 23 | NW 9 | WNW 13 | NW 11 | WNW 13 | NW 13 | WNW 9 | WNW 9 | NW 7 | N 7 | NNW 13 | WNW 11 | W 15 | W 13 | WSW 24 | W 22 | W 24 | W 22 | W 22 | WSW 17 | W 20 | W 13 | W 15 | W 9 | WNW 9 | W 33 | 14 | 23 |
| 24 | NW 7 | C 0 | N 4 | C 0 | N 7 | C 0 | C 0 | N 6 | N 7 | NNE 7 | NE 7 | E 7 | NE 7 | NE 6 | NE 6 | NE 11 | ENE 11 | E 13 | NE 17 | NE 9 | NNE 13 | ENE 15 | NE 11 | NNE 15 | | | |
| 25 | NNE 13 | NNE 15 | NNE 15 | NNE 15 | NNE 13 | NNE 17 | NNE 13 | NNE 19 | NNE 17 | NNE 20 | NE 15 | NNE 9 | N 7 | ENE 4 | NE 9 | ENE 6 | C 0 | SW 9 | WSW 9 | SW 11 | WSW 6 | WSW 4 | WSW 6 | SW 4 | | | |
| 26 | SSW 7 | SW 9 | W 4 | WSW 7 | C 0 | C 0 | W 6 | C 0 | N 4 | N 6 | NNE 4 | E 4 | C 0 | C 0 | C 0 | C 0 | SW 13 | SW 15 | SW 13 | SW 7 | W 15 | W 13 | W 11 | W 11 | | | |
| 27 | W 7 | W 9 | W 11 | W 9 | W 15 | W 15 | W 17 | WNW 15 | WNW 24 | W 22 | W 22 | WSW 26 | W 28 | W 33 | W 26 | W 28 | W 28 | W 24 | WSW 24 | WSW 19 | W 19 | WSW 6 | ESE 6 | WSW 4 | W 44 | 14 | 27 |
| 28 | WSW 7 | SW 11 | C 0 | ENE 4 | C 0 | E 7 | ESE 6 | ESE 7 | E 9 | E 13 | NE 24 | NE 24 | NE 22 | ENE 24 | NE 30 | NE 26 | NE 28 | NE 30 | NE 30 | NE 31 | NE 31 | NE 30 | NE 28 | NE 26 | NE 39 | 18 | 28 |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | |

*Avis / Note:* C = Calme / Calm M = Manquant / Missing

Heure normale locale : Est
Local standard time : Eastern

## HUMIDITÉ / HUMIDITY

POINTS DE ROSÉE HORAIRES / HOURLY DEW POINTS — Montreal/P E Trudeau Int'l A — FEVRIER 2005 / FEBRUARY 2005

| DATE | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -150 | -163 | -166 | -152 | -162 | -168 | -169 | -155 | -148 | -159 | -144 | -137 | -129 | -132 | -127 | -123 | -121 | -109 | -105 | -101 | -95 | -89 | -84 | -90 |
| 2 | -82 | -85 | -81 | -91 | -84 | -82 | -81 | -79 | -78 | -75 | -72 | -71 | -72 | -71 | -71 | -66 | -64 | -76 | -79 | -80 | -87 | -84 | -91 | -96 |
| 3 | -103 | -108 | -111 | -113 | -119 | -109 | -115 | -115 | -113 | -105 | -92 | -86 | -85 | -80 | -76 | -71 | -69 | -74 | -78 | -85 | -80 | -82 | -89 | -91 |
| 4 | -89 | -93 | -95 | -108 | -99 | -105 | -104 | -123 | -106 | -95 | -85 | -92 | -83 | -84 | -69 | -74 | -78 | -86 | -94 | -86 | -82 | -88 | -89 | -91 |
| 5 | -93 | -88 | -93 | -96 | -94 | -97 | -78 | -79 | -67 | -59 | -59 | -55 | -49 | -44 | -46 | -45 | -49 | -51 | -49 | -58 | -50 | -59 | -60 | -58 |
| 6 | -67 | -74 | -74 | -60 | -83 | -67 | -67 | -58 | -69 | -47 | -40 | -39 | -30 | -30 | -32 | -24 | -26 | -28 | -30 | -33 | -36 | -40 | -41 | -41 |
| 7 | -40 | -43 | -48 | -46 | -48 | -47 | -48 | -45 | -36 | -25 | -27 | -26 | -24 | -20 | -35 | -26 | -33 | -26 | -30 | -27 | -25 | -23 | -27 | -23 |
| 8 | -22 | -15 | -15 | -14 | -21 | -9 | -10 | -7 | 1 | 1 | 5 | 17 | -20 | 19 | 1 | 26 | 17 | -20 | 19 | 22 | 21 | 18 | 16 | 17 |
| 9 | 18 | 14 | 10 | 3 | -7 | -13 | -17 | -21 | -24 | -31 | -30 | -29 | -26 | -29 | -49 | -32 | -35 | -36 | -35 | -67 | -71 | -64 | -76 | -81 |
| 10 | -68 | -59 | -61 | -68 | -67 | -70 | -72 | -74 | -75 | -77 | -75 | -72 | -70 | -71 | -62 | -67 | -68 | -65 | -63 | -64 | -65 | -104 | -151 | -132 |
| 11 | -135 | -141 | -143 | -148 | -153 | -163 | -163 | -162 | -160 | -149 | -133 | -123 | -132 | -120 | -112 | -125 | -125 | -134 | -125 | -118 | -121 | -125 | -127 | -130 |
| 12 | -128 | -128 | -126 | -115 | -103 | -95 | -84 | -64 | -64 | -60 | -55 | -57 | -57 | -58 | -62 | -61 | -58 | -57 | -58 | -51 | -47 | -54 | -56 | -56 |
| 13 | -60 | -80 | -75 | -91 | -131 | -145 | -164 | -167 | -168 | -165 | -163 | -160 | -167 | -149 | -150 | -143 | -151 | -156 | -153 | -156 | -158 | -157 | -159 | -152 |
| 14 | -153 | -156 | -151 | -148 | -146 | -145 | -155 | -155 | -145 | -150 | -141 | -136 | -126 | -108 | -89 | -85 | -71 | -63 | -42 | -23 | -16 | -9 | -8 | -5 |
| 15 | -2 | 1 | 4 | 6 | 9 | 9 | 9 | 10 | 3 | 1 | -2 | -1 | -2 | -3 | 0 | 1 | 3 | 3 | 3 | 4 | 2 | 4 | 17 | 18 |
| 16 | 19 | 19 | 17 | 21 | 21 | 21 | 18 | 15 | 7 | 1 | 0 | 0 | 0 | 1 | 0 | 3 | 2 | -3 | -12 | -31 | -30 | -60 | -70 | -80 |
| 17 | -96 | -101 | -108 | -109 | -114 | -120 | -128 | -126 | -127 | -122 | -132 | -137 | -134 | -120 | -116 | -108 | -107 | -97 | -103 | -118 | -115 | -110 | -101 | -106 |
| 18 | -107 | -105 | -110 | -90 | -87 | -105 | -99 | -98 | -101 | -118 | -117 | -114 | -140 | -137 | -146 | -148 | -157 | -160 | -159 | -175 | -181 | -195 | -197 | -201 |
| 19 | -223 | -223 | -226 | -227 | -229 | -229 | -228 | -232 | -223 | -217 | -208 | -202 | -198 | -172 | -152 | -128 | -115 | -109 | -83 | -68 | -75 | -131 | -155 | -185 |
| 20 | -195 | -199 | -210 | -230 | -248 | -253 | -254 | -253 | -254 | -244 | -254 | -254 | -251 | -247 | -238 | -238 | -239 | -227 | -236 | -231 | -228 | -224 | -219 | -219 |
| 21 | -224 | -219 | -215 | -219 | -219 | -198 | -184 | -179 | -174 | -162 | -151 | -126 | -93 | -76 | -77 | -75 | -69 | -69 | -98 | -107 | -104 | -101 | -104 | -107 |
| 22 | -107 | -105 | -104 | -105 | -107 | -105 | -104 | -101 | -91 | -91 | -91 | -86 | -87 | -83 | -79 | -70 | -67 | -66 | -64 | -79 | -83 | -75 | -84 | -70 |
| 23 | -73 | -90 | -107 | -117 | -128 | -147 | -155 | -156 | -160 | -175 | -166 | -167 | -158 | -160 | -154 | -155 | -151 | -155 | -158 | -156 | -160 | -167 | -183 | -179 |
| 24 | -168 | -169 | -172 | -180 | -185 | -183 | -193 | -214 | -194 | -166 | -163 | -181 | -173 | -173 | -178 | -181 | -185 | -183 | -186 | -190 | -178 | -192 | -192 | -179 |
| 25 | -176 | -182 | -184 | -191 | -198 | -212 | -213 | -213 | -205 | -187 | -180 | -177 | -167 | -169 | -166 | -162 | -183 | -154 | -158 | -153 | -160 | -157 | -162 | -156 |
| 26 | -172 | -169 | -181 | -193 | -189 | -192 | -208 | -187 | -185 | -177 | -168 | -202 | -152 | -161 | -158 | -165 | -156 | -162 | -156 | -161 | -168 | -167 | -167 | -165 |
| 27 | -177 | -178 | -186 | -185 | -184 | -186 | -191 | -197 | -194 | -194 | -182 | -185 | -178 | -175 | -172 | -177 | -172 | -170 | -161 | -152 | -168 | -172 | -176 | -189 |
| 28 | -191 | -190 | -196 | -192 | -193 | -165 | -155 | -154 | -159 | -163 | -158 | -160 | -157 | -159 | -155 | -163 | -159 | -162 | -158 | -156 | -162 | -165 | -158 | -150 |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | |

*Avis / Note:* Unités / Units : 0,1 °C M = Manquant / Missing

HUMIDITÉS RELATIVES HORAIRES RELEVÉE À : / HOURLY RELATIVE HUMIDITIES AT :

| DATE | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 78 | 83 | 85 | 88 | 88 | 89 | 86 | 87 | 91 | 84 | 70 | 66 | 60 | 54 | 51 | 51 | 54 | 60 | 60 | 60 | 65 | 70 | 75 | 69 |
| 2 | 76 | 74 | 78 | 72 | 79 | 82 | 83 | 85 | 84 | 81 | 75 | 73 | 71 | 68 | 66 | 66 | 66 | 61 | 64 | 69 | 73 | 67 | 79 | 84 |
| 3 | 83 | 83 | 83 | 84 | 85 | 87 | 88 | 89 | 89 | 88 | 82 | 76 | 73 | 69 | 66 | 66 | 68 | 68 | 69 | 68 | 71 | 71 | 70 | 73 |
| 4 | 72 | 72 | 72 | 80 | 75 | 80 | 78 | 85 | 85 | 79 | 69 | 56 | 53 | 48 | 52 | 50 | 47 | 49 | 48 | 57 | 69 | 66 | 64 | 69 |
| 5 | 80 | 82 | 80 | 80 | 79 | 80 | 86 | 91 | 93 | 91 | 81 | 70 | 71 | 67 | 66 | 66 | 68 | 69 | 80 | 82 | 86 | 86 | 90 | 88 |
| 6 | 88 | 89 | 89 | 91 | 89 | 93 | 93 | 89 | 91 | 86 | 84 | 79 | 70 | 71 | 63 | 72 | 72 | 72 | 77 | 80 | 82 | 82 | 81 | 82 |
| 7 | 83 | 83 | 82 | 85 | 84 | 84 | 84 | 86 | 86 | 85 | 71 | 66 | 61 | 59 | 50 | 56 | 53 | 60 | 62 | 62 | 65 | 67 | 66 | 66 |
| 8 | 68 | 73 | 74 | 76 | 64 | 80 | 82 | 85 | 90 | 88 | 90 | 94 | 72 | 96 | 88 | 96 | 94 | 72 | 96 | 97 | 97 | 96 | 96 | 97 |
| 9 | 97 | 96 | 96 | 94 | 90 | 89 | 88 | 88 | 86 | 84 | 86 | 89 | 89 | 84 | 71 | 84 | 85 | 84 | 83 | 62 | 61 | 67 | 65 | 65 |
| 10 | 77 | 88 | 89 | 88 | 88 | 88 | 89 | 88 | 89 | 88 | 89 | 90 | 90 | 90 | 88 | 91 | 90 | 92 | 92 | 90 | 89 | 62 | 46 | 56 |
| 11 | 66 | 64 | 61 | 66 | 63 | 62 | 66 | 64 | 64 | 62 | 59 | 57 | 40 | 41 | 43 | 40 | 41 | 39 | 47 | 54 | 56 | 56 | 57 | 56 |
| 12 | 62 | 62 | 67 | 70 | 73 | 74 | 79 | 87 | 85 | 84 | 82 | 76 | 71 | 66 | 64 | 63 | 64 | 67 | 66 | 76 | 89 | 82 | 79 | 81 |
| 13 | 77 | 72 | 83 | 82 | 64 | 63 | 62 | 69 | 69 | 64 | 61 | 60 | 53 | 60 | 56 | 57 | 55 | 53 | 58 | 59 | 61 | 64 | 64 | 75 |
| 14 | 76 | 74 | 74 | 74 | 75 | 84 | 74 | 79 | 76 | 68 | 66 | 54 | 55 | 59 | 60 | 60 | 63 | 64 | 73 | 82 | 83 | 86 | 85 | 86 |
| 15 | 87 | 88 | 89 | 89 | 90 | 89 | 84 | 88 | 84 | 83 | 79 | 77 | 76 | 77 | 79 | 80 | 84 | 78 | 81 | 80 | 80 | 80 | 90 | 94 |
| 16 | 95 | 94 | 96 | 98 | 99 | 99 | 96 | 97 | 96 | 97 | 98 | 98 | 99 | 99 | 98 | 98 | 96 | 96 | 94 | 86 | 91 | 77 | 75 | 81 |
| 17 | 81 | 80 | 80 | 83 | 81 | 83 | 88 | 86 | 79 | 72 | 62 | 56 | 56 | 59 | 52 | 55 | 61 | 69 | 71 | 66 | 69 | 72 | 75 | 76 |
| 18 | 73 | 75 | 70 | 83 | 90 | 89 | 90 | 92 | 87 | 81 | 83 | 82 | 77 | 81 | 80 | 73 | 73 | 73 | 78 | 69 | 69 | 65 | 66 | 67 |
| 19 | 60 | 62 | 61 | 63 | 64 | 65 | 67 | 69 | 67 | 59 | 56 | 51 | 47 | 50 | 55 | 61 | 63 | 64 | 81 | 93 | 89 | 64 | 60 | 50 |
| 20 | 52 | 54 | 52 | 51 | 46 | 45 | 53 | 57 | 46 | 47 | 41 | 38 | 37 | 37 | 40 | 39 | 38 | 42 | 39 | 42 | 48 | 48 | 49 | 49 |
| 21 | 44 | 44 | 50 | 52 | 52 | 64 | 72 | 74 | 77 | 80 | 79 | 82 | 87 | 90 | 88 | 87 | 87 | 87 | 87 | 88 | 88 | 88 | 87 | 87 |
| 22 | 86 | 87 | 87 | 85 | 85 | 85 | 83 | 85 | 91 | 86 | 82 | 79 | 76 | 72 | 72 | 72 | 71 | 74 | 77 | 85 | 84 | 86 | 85 | 86 |
| 23 | 86 | 80 | 75 | 75 | 75 | 82 | 82 | 84 | 74 | 64 | 66 | 62 | 61 | 60 | 60 | 57 | 57 | 56 | 58 | 63 | 65 | 68 | 70 | 74 |
| 24 | 74 | 75 | 78 | 82 | 82 | 80 | 88 | 80 | 84 | 77 | 62 | 51 | 54 | 50 | 48 | 46 | 45 | 48 | 47 | 45 | 56 | 47 | 48 | 60 |
| 25 | 62 | 61 | 64 | 65 | 65 | 57 | 57 | 59 | 59 | 60 | 60 | 57 | 55 | 51 | 48 | 48 | 36 | 51 | 54 | 58 | 59 | 65 | 71 | 73 |
| 26 | 73 | 83 | 80 | 74 | 73 | 74 | 79 | 80 | 76 | 68 | 60 | 40 | 51 | 46 | 42 | 39 | 44 | 42 | 48 | 47 | 48 | 56 | 62 | 63 |
| 27 | 64 | 58 | 65 | 61 | 59 | 59 | 55 | 54 | 52 | 49 | 50 | 47 | 46 | 44 | 42 | 39 | 39 | 40 | 48 | 55 | 51 | 51 | 55 | 53 |
| 28 | 51 | 53 | 51 | 57 | 62 | 63 | 67 | 64 | 58 | 51 | 49 | 47 | 47 | 45 | 47 | 44 | 46 | 44 | 45 | 47 | 45 | 44 | 47 | 49 |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | |

*Avis / Note:* Unités / Units : pourcent /percent (%) M = Manquant / Missing

- Résumé / Summary -

| Sommaire quotidien de février 2005<br>Aéroport International de Montréal/Dorval | | Daily summary for February 2005<br>Montreal/Dorval International Airport | |
|---|---|---|---|
| Date | | Date | |
| 1 - | Continuation de l'é pisode de smog débuté le 31 janvier 2005. Ennuagement en soirée. | 1 - | Continuation of smog event beginning January 31th, 2005. Clouding over in the evening. |
| 2 - | Smog. Doux. | 2 - | Smog. Mild. |
| 3 - | Smog. Doux. | 3 - | Smog. Mild. |
| 4 - | Smog. Ensoleillé. Très doux. | 4 - | Smog. Sunny. Very mild. |
| 5 - | Smog. Généralement ensoleillé. Très doux. | 5 - | Smog. Generally sunny. Very mild. |
| 6 - | Smog. Très doux. | 6 - | Smog. Very mild. |
| 7 - | Smog. Très doux. | 7 - | Smog. Very mild. |
| 8 - | Fin de l'épisode de smog. Pluie ou bruine intermittente débutant le matin et cessant en soirée. Très doux. | 8 - | End of smog event. Intermittent rain or drizzle beginning in the morning and ending at the end of the day. Very mild. |
| 9 - | Faible neige en matinée et en fin de journée. Très doux. | 9 - | Light snow during the morning and at the end of the day. Very mild. |
| 10 - | Neige cessant en soirée. Doux. Venteux causant de la poudrerie. | 10 - | Snow ending in the evening. Mild. Windy causing blowing snow. |
| 11 - | Ensoleillé. Doux. | 11 - | Sunny. Mild. |
| 12 - | Neige intermittente. Doux. | 12 - | Intermittent snow. Mild. |
| 13 - | Neige cessant durant la nuit. Ensoleillé. | 13 - | Snow ending during the night. Sunny. |
| 14 - | Faible neige débutant en après-midi, se transformant en grésil en soirée puis en pluie. Doux. Venteux. | 14 - | Light snow beginning in the afternoon, changing into ice pellets in the evening then into rain. Mild. Windy. |
| 15 - | Faible pluie se terminant le matin et recommençant en fin de journée. Très doux. Venteux. | 15 - | Light rain ending early in the morning and then starting over at the end of the day. Very mild. Windy. |
| 16 - | Pluie débutant tôt la nuit devenant mêlée au grésil et à la neige le matin, se changeant en neige en matinée et se terminant en soirée. Le tout accompagné de brouillard. Très doux. | 16 - | Rain beginning early in the night, becoming mixed with ice pellets and snow early in the morning, changing into snow around mid-morning and ending in the evening. Foggy. Very mild. |
| 17 - | Ensoleillé. Ennuagement graduel. Faible neige débutant en fin de journée. Doux. | 17 - | Sunny. Increasing cloudiness. Light snow beginning at the end of the day. Mild. |
| 18 - | Neige cessant en soirée. | 18 - | Snow ending in the evening. |
| 19 - | Averses de neige débutant en après-midi et se terminant en soirée. | 19 - | Snow showers beginning in the afternoon and ending in the evening. |
| 20 - | Ensoleillé. Froid. | 20 - | Sunny. Cold. |
| 21 - | Faible neige débutant en matinée. Venteux. | 21 - | Light snow beginning in the morning. Windy. |
| 22 - | Neige se terminant en fin de matinée. Quelques flocons en fin de journée. | 22 - | Snow ending at the end of the morning. Few flurries at the end of the day. |
| 23 - | Ensoleillé. | 23 - | Sunny. |
| 24 - | Ensoleillé. Froid. | 24 - | Sunny. Cold. |
| 25 - | Ensoleillé. | 25 - | Sunny. |
| 26 - | Généralement ensoleillé. | 26 - | Mostly sunny. |
| 27 - | Ensoleillé. Froid. | 27 - | Sunny. Cold. |
| 28 - | Couvert. Froid. | 28 - | Overcast. Cold. |