A NEW APPROACH IN DELIVERING WEATHER INFORMATION TO WINTER ROAD MAINTENANCE CREWS WORKING FOR THE QUEBEC MINISTRY OF TRANSPORTATION

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Abstract

The Meteorological Service of Canada - Quebec region, in collaboration with the *ministère des Transports du Québe*c (or the Quebec Ministry of Transportation, hereafter referred to as the QMOT), has developed a new and, to our knowledge, unique way in North America of providing weather information adapted to the needs of winter road maintainers. In addition to the detailed specialized precipitations forecast, targeted for a specific point (sometimes including a 24-hour road surface temperature forecast), QMOT road maintainers receive a subjective so-called "confidence-index" from the weather forecasting professional, as well as a code designed to identify the nature of the weather system which has been forecast to influence the weather overall and at each particular point forecast. The confidence-index is intended to reflect the degree of confidence the forecaster has in the forecast and in the predicted evolution of the type of weather system he or she has identified. This confidence-index may vary from one point in the province to another depending on the weather system identified. All "classical" weather systems that could possibly affect the province have been catalogued, documented and explained to road maintainers. This approach is intended to be dynamic and to emphasize the responsibility of road maintainers in allowing them to anticipate the difficulties they will likely encounter with a particular type of weather system. The goal of this article is to explain the process used and the usefulness of such an approach.

Introduction

Any discussion of winter road maintenance must automatically take into account the impact of meteorological phenomena on roads. Traditionally, the meteorological information used by road maintainers in all countries to ensure mobility on the roads during the winter season have been more or less the same: air temperature, dew point or relative humidity, type, intensity and duration of precipitation, wind direction and wind speed. This information may vary in detail and accuracy. The source of the weather information can also vary widely, coming from national weather services, private weather services, general public information disseminated by national weather services, private radio stations, television and now the Internet.

All of these sources of weather information deliver the data--which may vary in the extent to which it is useful or adapted to their special needs--to operational road maintainers. Any winter road maintainer will agree that knowledge of meteorological parameters and phenomena is essential. However, until recently, very few road maintainers in the province of Quebec and all across Canada, where winters are surely among the most vigorous in the world, were aware of the degree of detail and accuracy that modern science and technology allow a professional meteorologist to actually obtain in a weather forecast. Most road maintainers were simply using weather information broadcast by radio and television stations. This general public weather information is far from reaching the high degree of detail and accuracy required for efficient and effective intervention on the road.

In this paper, a new kind of meteorological information is explained. The so-called “Type of Weather in Quebec” and the “Confidence Index” that are intended to:

A. Bring to winter road maintainers a higher degree of comprehension concerning the general “weather situation of the day”.
B. Increase their level of confidence in their own decision-making process.
C. Allow them to anticipate the kind of problems they might encounter in the coming hours.

In most cases, road maintainers have very limited general knowledge of meteorology. This fact is the biggest hurdle to overcome when introducing the new kind of information explained here. The main idea that initiated this development was suggested by Jean-Jacques Roussel, a French engineer from the m*inistère du logement et de l’équipement* in France. He acts as an expert-advisor to the QMOT in matters of winter road maintenance. This new way of presenting weather information on the part of the Meteorological Service of Canada - Quebec region (MSC-Q) is part of the more general approach to winter road maintenance initiated by the QMOT. This approach includes a substantial section devoted to training which will help to gradually introduce into the field the new type of information presented here. While the foundations of the information transmitted may be complex, what is transmitted to the end-user is intended to be as simple as possible, in order that it might be easily interpreted and understood. Before getting to the heart of the subject, here is some data about the geographical setting and climatology of the province of Quebec.

Climatology And Geographical Setting of Quebec

In describing Quebec, its inhabitants often quote this sentence from a popular local song, “My country is not a country, it’s winter” (translation). This sentence paints a true picture of the importance of the winter season to Quebecers.

Situated at the northeastern tip of the North American continent, the province of Quebec extends from the 45th to the 62 nd parallel of latitude north and from the 57th to the 80th W meridian of longitude west. It is bordered to the south by the northeastern states of the United States of America. To the southeast are the maritime provinces of Canada and the Gulf of St-Lawrence which is a large sea inlet reaching deep into the Quebec territory. Toward the northeast are the North Atlantic Ocean and the Hudson Strait. This strait opens into a vast interior sea called the Hudson Bay which borders the entire northwestern half of the province and greatly influences the climate of the northern half of the province. From the end of December to late spring, this broad interior sea is completely iced over. Finally, the province of Ontario borders Quebec to the west and the southwest. In the heart of winter, the entire western and northern part of Quebec are affected by weather systems coming from a large continental area spreading more than two thousand kilometres to the west. To the north, this wide continental area extends well beyond the polar circle, thus allowing very cold and very dry air masses to find their way toward the southernmost regions, owing to deep low pressure systems. A second major factor influencing the climate of the province is the proximity of the Atlantic Ocean, to the southeast. This ocean contributes very significantly to the humidity content of the air masses travelling over the southern part of the province, brought by the weather systems coming from the east coast of North America.

The sheer size and geographical setting of Quebec account for the fact that its climate is influenced by a wide range of air masses that make the temperature fluctuate from one extreme to another within very short periods of time. In the southernmost part of the province, where the vast majority of the road network is concentrated, it is very common to see the temperature climbing from minus 20 to plus 3 degrees Celsius in less than 12 hours, followed by a rapid drop to minus 20 or lower within the following 12 hours. When these extreme temperature changes take place at the same time as a broad range of precipitation types and weather phenomena such as snow, ice pellets, freezing rain, rain, blowing and drifting snow or high winds, this does not facilitate the task of the personnel dedicated to maintaining mobility on the roads.

A Typical Quebec Winter Season:

A. On average and depending upon the area, between 2.5 and 3.5 meters of snow and as much as 6 meters of snow in the mountains, which, at road level, reach a maximum altitude of about 800 metres.
B. Between 60 to 100 days of measurable snow precipitation, which means, on average, one snowfall every three days from the first of November to the end of April.
C. 10 to 15 days annually (November to April) of measurable freezing precipitation (supercooled droplets which freeze when they reach the ground).
D. 5 to 15 days of measurable rain precipitation (precipitation of rain when the air temperature is above zero but which could nevertheless freeze on the ground when the ground temperature is below zero).
E. Daytime maximum temperatures ranging between minus 3 and minus 12 from south to north in the mid-winter period (December to February inclusively).
F. Daily mean temperatures lower than the freezing point from November to March over most of the province.

This is a portrait of the severity of winter in Quebec. Considering the wide variety of weather systems influencing the weather across the province of Quebec, it is easy to foresee that any development that might help road maintainers understand the weather situation of the day in their decision making process will be welcome, especially if it gives them insight into the possible impact on the road network that they are responsible for.

This is the idea that lead us to classify and characterize every meteorological system that could potentially influence the weather across the province. Naturally, the atmosphere being what it is, even though we categorize a certain number of weather types, there is no such thing in nature as two exactly similar weather systems. In addition, the facility to forecast weather phenomena and parameters vary widely from one type to another as well as from one weather system to another even if both are of the same type. These facts lead the professional meteorologist to a variable degree of confidence in the weather forecast he or she is issuing to the client. Up until now, there has been no way for meteorologists to provide clients with any insight into the degree of confidence they had concerning their forecast. All forecasts seemed to have the same level of confidence. In the approach undertaken with the QMOT, the development and the introduction of a simple « confidence index » was a big step forward for road maintainers in their comprehension of the varying complexity involved in producing an accurate weather forecast.

History

Environment Canada, which is a federal ministry, has been offering specialized weather forecasts to municipalities for many years. Due to rising demand, especially from the city of Montreal, this service has been expanded from its very simple beginnings, when it was free-of-charge and offered only to major cities.

Demand for the service has been growing continuously for about the last ten years. The Meteorological Service of Canada, and more specifically in the Quebec region, has gone from offering a passive service at the beginning of the 90’s, answering only specific requests received, to becoming more pro-active in the last six years. All municipalities and contractors across the province are now offered the same specialized forecast at labour cost recovery. This forecast gives, in very detailed fashion, all the significant weather parameters and phenomena identified as pertinent by winter road maintainers.

Naturally, given that the QMOT is a major player in maintaining mobility on the roads during the winter season, the same type of specialized forecast was also offered to all QMOT service centres in the province. In this way, even before the pilot-project was initiated last year, some links had already been already established between individual service centres of the QMOT and the MSC-Q. However, these links were often very limited and a general vision was still missing when it came to

the whole issue of lending meteorological support to winter road maintenance carried out by the QMOT over the entire province.

The pilot-project set up at the QMOT, and all the effort focussed on establishing a system of assistance for decision-making to ensure winter practicability of the roads (SADVH - French acronym) have been a welcome step in contributing to a better structural relationship between the federal and provincial departments involved. This project has also enhanced the mutual understanding of both partners. It allows meteorologists to become aware of the specific needs of winter road maintainers and, on the other hand, it gives road maintainers a better understanding of the difficulties encountered by the meteorologist trying to generate an accurate weather forecast. Road maintainers can also get a sense of what uncertainties are associated with each different weather situation.

Product Development

While working on the preparation of a weather, meteorologists use all their scientific, climatological and geographical knowledge. They are assisted each step along the way by numerical models that are becoming more and more sophisticated. These models simulate the evolution of the entire atmosphere around the earth for the coming hours and days. The "art" of weather forecasting rests on the meteorologist's capacity to integrate all of these elements to produce a weather bulletin which is the most comprehensive and the most precise possible, putting together all the significant weather phenomena and parameters. Nevertheless, even when maximum effort has been invested in this task, the forecast always retains some degree of uncertainty.

The MSC-Q was asked by the QMOT to work on upgrading the meteorological services offered to the QMOT service centres. This new development is part of the more general SADVH approach put in place by the QMOT. While doing a needs analysis during the first phase of the project, it was clearly identified by the users that they wish to receive the best weather forecast possible. In some cases, the confidence of road maintainers toward weather forecasts was rather low. Thus, there was a need to establish greater confidence in weather forecasting on the part of road maintainers. The means chosen were:

1) Promoting as much communication as possible between the weather forecaster and operational road maintainers.
2) Optimizing the weather bulletin content
3) Upgrading the road maintainers' knowledge of weather phenomena
4) Giving road maintainers a way to assess the higher or lower accuracy of the weather forecast they receive.

Points 1 and 2 will not be discussed here. The third point is an essential condition for attaining the fourth one. The fourth point was addressed by developing two new types of weather information that are supplied daily to road maintainers during the winter season within the SADVH pilot project.

The principle is as follows: road maintainers receiving the weather forecast should be enabled to make decisions with the highest possible degree of confidence. To do so, they must be able to judge the level of confidence they can put in the weather forecast which they have received from the meteorologist. They must be enabled to optimize their treatment of the road while not overloading their employees as well as intervening in an efficient and effective manner. To reach these goals, they should be able to identify which areas of their territory could be problems areas. These areas can change depending on the weather system involved. Before now, there was no indication in the weather bulletin as to which areas might be more sensitive depending on the type of weather system.

To respond to this need, all possible weather systems that could influence the weather in Quebec south of the 55^{th} parallel north were identified, classified and catalogued in 14 types of weather systems. This classification was, in a sense, a formal way of gathering the knowledge of all operational meteorologists working in Quebec, knowledge that was acquired through experience and

training. This knowledge had never been organized in such a way that it could be used to assist in winter road maintenance.

Steps Followed:

a) *Identification of all meteorological systems:* The source of systems, their trajectories and the distinctive temperatures of the air masses involved are the main features used to determine the classification.
b) *Map visualisation:* Parameters used for classification: source, trajectory and distinctive temperatures are shown on a map of the northeastern portion of North America. This allows for better visualization of the meteorological system described.
c) *Simplified description of the weather type:* This description includes: i) A broad-scale description called a synoptical description of the system. ii) A general representation of the possible evolution of every significant meteorological parameter such as the air temperature and the dew point at the meteorological shelter level as well as the wind direction and speed at 10 meters and finally iii) a description of meteorological phenomena generally associated with this weather type.
d) *An insight into the extent of difficulty in generating an accurate weather forecast with this weather type and a general evaluation of the follow-up of the situation that could be needed:* This part indicates the level of confidence generally associated with some meteorological parameters and/or phenomena usually associated with this weather type: the level of difficulty in forecasting amount of precipitation, beginning and ending times for the precipitation, types of precipitation, etc.
e) *Indication of the "normal" transition of this weather type to a second weather type usually observed after the type described:* Some clues are given as to what weather type will usually follow the type described. It helps in being able to assess how the system-of-the-day compares with the more general description of the weather type classification.

Figure -1- is an example of the description of one weather type, as available to the user.

The introduction of this type of information into winter road maintenance management is totally innovative. A lot of training will be required before such a concept can be introduced into the daily data sent to road maintainers. This training was started as part of the SADVH pilot project, but will have to continue for years before these new concepts have been completely assimilated. In addition, in order for the new information to be really useful operationally, every service centre will have to take note of the real effects and particular problems related to each weather type within its own territory. It is easy to understand that it will likely require a few years to gather this information and that a structured method of gathering the information needs to be put in place. This is exactly what was initiated within the pilot project.

Once all weather types had been identified and documented, a "catalogue" of all weather types across the province of Quebec was drawn up. Every weather type is described in a one-page format, such as that shown in Figure -1-.

This description is accompanied by a second page, where road maintainers can comment and gather notes on particular operational problems encountered with the weather type in question. This is a way of accumulating the experience of older employees and allowing it to be passed on to those with less experience. We anticipate that tendencies will show up with time and that these tendencies will help in identifying the areas where problems usually arise with a given weather type. It could also be possible to define an objective evaluation of the reliability of the weather forecast received according to weather type. This reliability will be a direct reflection of the difficulties encountered by the meteorologist in putting out an accurate forecast with each weather type.

Confidence Index

At the same time the weather type catalogue was introduced, a second parameter, which is as new as the first one, was also supplied to the user as part of the SADVH pilot project. In fact, there is really nothing new in stating that a weather forecast can be more or less accurate. What is really new is the fact that meteorologists can now send their real feeling about the weather situation by using the confidence-index. For the meteorologist, it is, in a way, simply saying out loud what has been kept in his or her mind up to now. Saying outright that he or she has very low confidence in the forecast may feel like an admission of weakness from the meteorologist's point of view. However this information is a necessity to road maintainers who have to work and make operational decisions based on this forecast. We can identify here that training on this subject is also required for the meteorologist. The indication of high or low confidence that a meteorologist has in the forecast he or she has issued will reinforce the confidence of the road maintainer in his or her own decision and, in addition, this information will generate a better understanding of the complexity of the weather situation. When the confidence index is high, the road maintainer may decide to sit back and wait until the forecast starting time of the precipitation approaches, or, conversely, to stay alert and ready when the index indicates low confidence on the part of the forecaster.

To keep the information as simple as possible, three confidence levels have been defined:

LEVEL A:

High level of confidence. The weather type forecast matches the one described in the weather type catalogue to a high degree. The meteorologist is very confident that the data within the forecast bulletin will be close to reality and that the gap between observations and forecast elements will be low.

LEVEL B:

Moderate level of confidence. The weather type forecast may show some discrepancies when compared to the general description of the weather type. The meteorologist is anticipating wider discrepancies between observations and forecast elements. Consultation with the meteorologist would be advised if significant operational decisions must be taken.

LEVEL C:

Low level of confidence. The evolution of the weather system is totally unusual or difficult to forecast accurately for any number of reasons. The meteorologist has a low degree of confidence in his or her forecast and anticipates large discrepancies between observations and forecast elements. REMAIN VIGILANT and talk regularly with the meteorologist, especially if the beginning or ending time that was forecast for the precipitation is approaching and if significant, sometimes costly, operational decisions must be taken.

Application

The application of such a new system requires many steps:

1) Basic meteorological training for road maintainers
2) Training in weather types
3) Training in the meaning and the utilisation of the confidence index
4) Distributing and explaining the weather type catalogue to users.
5) Sensitizing weather forecasters as to the usefulness of this type of information for road maintainers.
6) Determining a way to deliver and present the information to the user.

Training is a key element in the SADVH pilot project being undertaken by the QMOT. Points 1 to 3 above are part of this training program. Before and at the beginning of the winter of the first year, many training sessions were held for all service centres participating in the pilot project. Unfortunately, the portion of the training presenting and explaining the weather type classification and

the confidence index had to be shortened due to a lack of time. As a result, further training will be required at the beginning of the second year of the project. Nevertheless, considering the fact that the large block of training on general meteorology and on specific road parameters and phenomena made up quite a chunk of information to assimilate in themselves, we decided to introduce these new concepts more gradually. They were introduced in the regular weather forecast bulletin transmitted to every QMOT service centre a little later in the season. This allowed for a gradual integration of these two new concepts.

The specialized weather forecasts being transmitted at present are alphanumeric messages in the form of a table of elements. The forecast time period is divided into 4 twelve-hour periods that are further divided into 3-hour periods, thus allowing for a great number of details to be specified about each of the weather elements within the forecast period. This product can be sent to the client using a variety of telecommunications tools such as fax, e-mail, coded messages transmitted on the air using radio waves (Weathercopy) and, lastly, the Internet. Some of these modes of transmission have restricted the use of a more graphical and visual means of presentation. In future, we plan to develop a product which will be much easier to use and more graphical. The data on weather types and the corresponding confidence index have been added to the bottom of the current weather bulletin. The information supplied gives at a glance the complete forecast evolution of the weather types and confidence index indicated by the meteorologist for the coming 48 hours. It is important to note that the confidence index may vary over time.

The form used is as follows:

```
++++++++++++++++++++++++++
+ WEATHER TYPE FORECAST  +
++++++++++++++++++++++++++

   HISTORY       //              FORECAST
  ------TODAY---//---EVENING--NIGHT---/---TUESDAY---/--WEDNESDAY--

HR ----06-09-12-   //-15-18-21-24-03-06-/-09-12-15-18-/-24-06-12-18-24-
TYPE   7   7  12    //  12 12 13 13 13 13    13 13 13 13    13 13 12 12 12
CONFIDENCE ----//  A  A  A   A  A  A     A  A  A  A      A  B   B  B  B
```

COMMENTS: the meteorologist’s comments on the situation (if needed).

COMMENTS OF THE USER: Section allowing the user to comment on the forecast.

It can be noted that the data transmitted to the user includes a historical section. By referring to this section, the user can check to see whether the weather type that is affecting the region was the same type that was forecast. It will also be possible for the user to note down any remarks in his or her catalogue corresponding to the right weather type.

This historical section leads to another interesting possible application concerning the characterization of winter severity according to the weather types that affected each individual part of the province. During the training sessions that preceded the SADVH pilot project, an exercise based on identifying “road climatological areas” was held based on the knowledge that experienced people at QMOT service centres have accumulated throughout the years about the characteristic behaviours of roads during the winter season. A road climatological area, so defined, represents a relatively homogeneous section of road that has approximately the same behaviour. Points were defined close to the middle of these areas. These points could be used by the meteorologist to do a point forecast that would be representative of the entire road climatological area. Using the historical part of the forecast for each road climatological area, it would be possible to describe the entire winter over a specific area by a series of weather types. This is an application of weather-type information that could be further explored.

Preliminary Results

Due to the fact that the introduction of weather types and the confidence index started almost in the middle of the season and that training was rather limited, the real impact of this new information is somewhat difficult to evaluate after the first year. Nevertheless, some comments gathered during evaluation sessions held close to the end of the winter were very interesting and many of them were positive. Many participants did however confess that they had not really assimilated the new data, in particular the information related to weather types.

The confidence index proved to be a much simpler concept to assimilate and was greeted much more favourably on the part of the users. Many of them mentioned that they gradually got used to looking at this information and that they found it very useful. Some mentioned that they had gained greater confidence in the weather forecast. The confidence index allowed them to assess when they could trust the forecast and when, on the contrary, they would need to remain more alert. Only a couple of users mentioned using the weather type catalogue regularly in order to better assimilate this concept. The majority mentioned that they wish to have more training on both subjects.

Conclusion

The approach presented here is innovative and promising. Even though the 2000-2001 experience was rather limited, preliminary results and comments gathered during the evaluation sessions of the project lead us to believe that we can be optimistic about the future usefulness of these new concepts. The anticipated gain is worth the effort that must be invested. These gains include a better understanding of weather phenomena associated with each weather type and, above all, greater confidence on the part of winter road maintainers in their decision-making process and, in the end, better decisions that will most likely lead to monetary savings and better utilisation of manpower. Winter 2001-2002 will be the second year of the project and will surely lead to a more complete evaluation.

TYPE -5-
LOW

Trajectory:

Southwest - northeast

Temperature regime:

Temperate

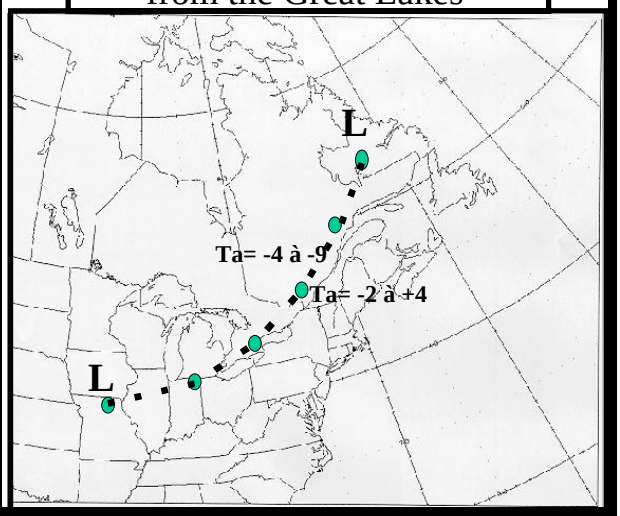
AIR MASSES INVOLVED:

- **Continental arctic**
- **Maritime arctic, sometimes maritime polar**

Development stage:

Stable or deepening

Type -5-
Southwest low coming from the Great Lakes



Type -5- **Detailled Description** Type -5-

CATEGORY : LOW
REGIME : TEMPERATE

Synoptical Description

- Southwestern low travelling over the Great Lakes having a typical trajectory from the American midwest toward the St-Lawrence Valley or to the north of it
- Speed of low: moderate (30 to 50 km/h).
- Precipitation well defined in time: around 12 hours north of the trajectory, less to the south
- Sections north of the Abitibi are often free of any precipitation

Variation of meteorological parameters

Ta: Before arrival of low: Generally moderately cold (-10)

- Trend of Ta

1. Slow rise and poorly defined to the northwest of the trajectory.
2. Slowly rising with warm front approaching but rapidly rising after its passage over area close to and south of St-Lawrence River. Ta in the warm sector often above zero.
3. At the cold front crossing: rapid drop in the first hour (3 to 5 degrees) then dropping slowly at a rate of about 1°C/h.

Td:

- Spread between Ta and Td of 5 to 10 degrees before system arrival then lowering to 1 to 3 degrees under solid precipitation or freezing rain.
- Td tends to be equal to Ta in the warm sector south of low

Winds (in general)

- When low is approaching: Strong northeast in the St-Lawrence Valley (30 to 60 km/h).
- Possibility of very strong southerly wind (60-80 km/h) just after warm front passage in Richelieu Valley. Violent winds over mountains even to the north of the warm front

Associated meteorological phenomena

- Significant freezing rain and/or ice pellet event over most areas but more specifically along the St-Lawrence Valley and the Saguenay Valley. Very short period of freezing rain south of St-Lawrence Valley.
- Very windy conditions with blowing snow close to the St-Lawrence Valley.
- Heavy snow to the northwest of the trajectory (typically 15-20 cm)

Type-5- Type-5-

General quality of the forecast with this weather type

AMOUNTS OF PRECIPITATION:

- Mountainous Sectors south of St-Lawrence River: Amount of snow generally more significant after the low has gone through, with the setting up of upslope northwesterlies, rather than with the approach of warm front. Very often a small but still measurable amount of snow will fall (2 to 5 cm) followed by rain, sometimes freezing (1 to 2 hours) then a second more significant snow event that will last many hours at a rate of 0.5 to 1.0 cm per hour.

SYNCHRONISATION OF PRECIPITATION

- The ending time of the second snow event will be more variable and difficult to forecast accurately over the Appalachian mountains. Precipitation generally at very low level and difficult to detect on radar.
- Low moving at a moderate speed from an area well covered with radar and surface observing sites. Starting and ending time of precipitation generally accurate especially within the 12-hour time frame but even at longer term except for sections south of the St-Lawrence River as mentioned.
- Forecast transition time from snow to rain generally accurate within the first 12 hours of the forecast.

Short-range follow-up suggested (less than 6 hrs ahead)

- The starting times are generally well forecast so people should start to be on alert only 1 to 2 hours before forecast starting time. Over mountains south of St-Lawrence River a very close follow-up of the situation is required toward the end of the precipitation. If necessary consult the meteorologist. Elsewhere the end of precipitation is generally well marked.

Normal evolution: change to type 14, sometimes 7

- A change to type 7 will often keep the freezing precipitation over the extreme southwestern sections of the province. Snow amounts in the mountains south of the St-Lawrence River will then be much more significant due to this second low pressure system.

Figure: -1-: Example of a weather type description as found in the WEATHER TYPE CATALOGUE available to every QMOT operational road maintainer participating in the SADVH pilot project.