P8.7

# HEAVY CONVECTIVE RAIN EVENTS OVER QUÉBEC : A FORECASTING TOOL

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## 1. INTRODUCTION

Heavy convective rainfall events, generally leading to flash floods, account for almost half of summer severe convective reports over Québec. Depending on soil moisture content and terrain, it has been observed over the province that as little as 25mm in one hour could cause local flash floods. Although reports of more than 100mm are not uncommon over the province, MCSs and Maddox type synoptic patterns barely take place over the area.

In order to provide a forecasting tool making up for the lack of literature on the types of events occurring over the province, heavy convective rainfall events over Québec from 2002 and 2003 have been studied and then compared to a number of events prior to 2002. Results from this study intend to serve as a guide for forecasting such events. This forecasting tool lists particular operational ingredients (e.g. low-level jet, precipitable water, convergence line, etc), their favourable threshold values and positions next to each other as indicated by the operational version of the GEM model, as well as preferred sounding profiles and threshold values for related ingredients. Precipitation amount and areal extent categories have been set accordingly. Events have been split into diurnal types or nocturnal types, each having common features and threshold values leading to three forecast categories.

## 2. METHOD

On the operations desk, heavy convective rainfall reports over Québec have quantitatively been defined by precipitation amounts of 25mm or more in one hour or less, 40mm or more in 3 hours or less, and 50mm or more in 24 hours or less (although this last category rarely occurs over more than 12 hours). All 34 heavy convective rainfall events from 2002 and 2003 associated with the warm sector have been studied and compared to a number of events prior to 2002 and to several non-events from 2002 (i.e. with or without any other severe weather type reports). Cases were discriminated as diurnal or nocturnal since diabatic effects act much on daytime and early evening convection while night-time convection is greatly influenced by dynamic effects. The goal of the study was to establish favourable threshold values and features over a number of operationally available weather elements. This was obtained from soundings and the operational version of the GEM model (24km). Several authors have discussed convective rainfall, which work on occasion has allowed a more complete approach to this present study (Funk 1991, Junker et al 1999, Scofield et al 2000, Murphy 2001, Corfidi 2003). This study does not discriminate between storm structures, apart from the rejection of pulse storm events, since it is the total amount of precipitation that matters.

The forecasting guide resulting from this study lists all the essential ingredients favourable to the development of heavy convective rainfall with, more importantly, their threshold values and positions. The ingredients that proved to be influential are the low-level jet, upper level jet, precipitable water content, vertical shear, hydrostatic instability and surface convergence lines. Combining a few of these ingredients enables the forecaster to expect different heavy convective rainfall types according to areal extent and precipitation amounts. Areal extent categories are roughly split into “fairly small extent” (less than approximately 10 000 km², but more than localized) and “fairly large extent” (more than approximately 10 000 km²). Precipitation amounts are roughly categorized by “much more than 40 mm” (very high to extreme amount), “more than 40 mm” (high amount), and “from 25 mm in ≤1hr to 40 mm in ≤ 3hr” (moderate amount).

## 3. DIURNAL TYPE

The following lists the threshold values and positions of all the essential ingredients favourable to the development of heavy diurnal convective rainfall. Note that all of the below must be encountered for such development. All other patterns will lead to no worse than a localised event.

Sounding:
- precipitable water content ≥ 35mm;
- long narrow CAPE profile;

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- KI ≥ 34;
- weak to moderate vertical shear.

Low-level jet:

- magnitude ≥ 15 kt;
- intersecting a surface convergence line;
- parallel to the upper level jet (within 30°);
- temporal intensification preferred.

Precipitable water ridge axis:

- magnitude ≥ 35mm;
- heavy rain along or on left flank of axis, near and downstream of convergence line.

And

| | Motion | | Magnitude | | Amount |
|---|---|---|---|---|---|
| 1 | Slow LLJ (≤ 10kt) | + | LLJ ≥ 35kt | = | >> 40mm any extent |
| 2 | Slow LLJ (≤ 10kt) | + | LLJ ≤ 30kt | = | 25-40mm* large extent |
| 3 | Mod. LLJ (15-20kt) | + | LLJ ≥ 35kt | = | 25-40mm* large extent |

* rain amounts will greatly exceed 40mm with the presence of large precipitable water content (i.e. ≥50mm)

On August 5 2003, thunderstorms of variable intensities severely hit the Eastern Townships and the Beauce region (to the southeast of the St.Lawrence river valley), causing landslides and wash-outs of roads and bridges. The area received up to 130 mm in a few hours (fig 1). The next figures show the magnitude and position of the above mentioned elements related to the development of this event. According to the sea-level pressure field from the GEM 12Z on August 5 (fig 2), and as eventually observed, a weak trough (dashed line) rotates slowly through the sector of interest. Over the same period, a weak extension (20-25kt) of the southerly low-level jet stretches from the Atlantic towards the sector (fig 3). This low-level jet extension intersects the trough and lies almost parallel to the upper level circulation (fig 4). The precipitable water ridge axis (fig 5), of about 50 mm, extends southeast-northwest over the same location. Furthermore the GYX sounding indicates a favourably high precipitable water content (fig 6) of 46mm. Its CAPE profile is long and narrow while the KI is 34. Moreover, vertical shear is rather weak. Finally, the weak low-level jet being quasi-stationary in a highly humid environment (precipitable water ridge axis of 50mm) suggests a risk for a large extent of much more than 40 mm, as it was eventually observed.

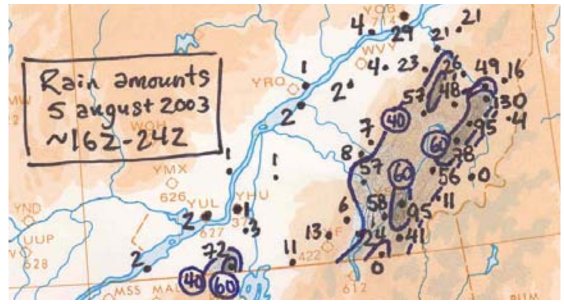


FIG 1. Total rain amounts on August 5 2003.

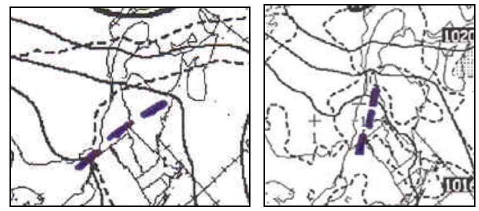

FIG 2. Sea-level pressure from GEM 5/08/03 12Z at 00h-12h.

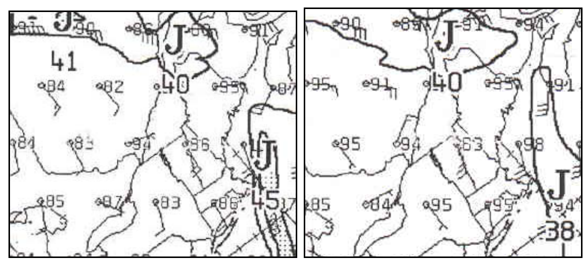

FIG 3. Low-level wind max - GEM 5/08/03 12Z at 06h-12h.

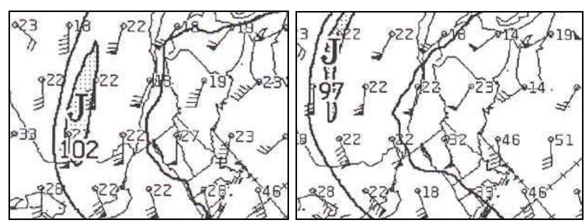

FIG 4. Upper level jet stream - GEM 5/08/03 12Z at 06h-12h.

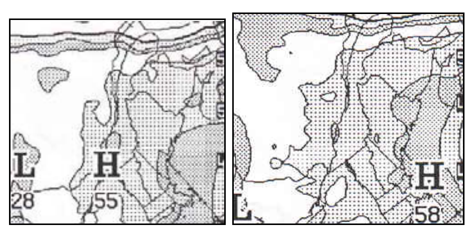

FIG 5. Precipitable water content - GEM 5/08/03 12Z 06h-12h.

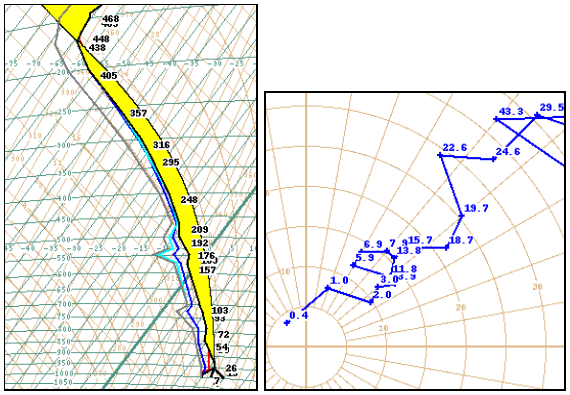

FIG 6. Sounding for GYX (300km southeast of the affected area) on 5/08/03 12Z.

## 4. NOCTURNAL TYPE

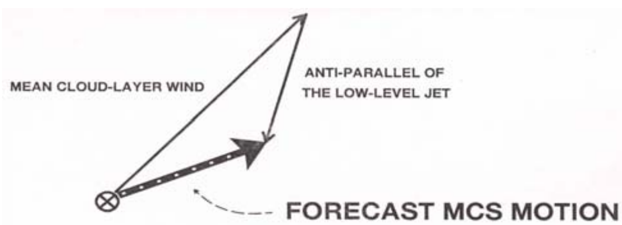


FIG 7. Schematic of Corfidi's vector technique for the forecast of MCS motion. MCS centroid is depicted by the cross symbol. (Corfidi 2003).

According to Corfidi (2003), MCS motion can be forecast by a vectorial subtraction of the low-level jet from the mean cloud-layer wind (using winds at 850mb, 700mb, 500mb, and 300mb) (fig. 7). From this concept, the present study demonstrated that the Corfidi method can also estimate the forecast motion of the heart of a thunderstorm complex such as trailing storms, slow-moving thunderstorm complexes, etc.

The following lists the threshold values and positions of all the essential ingredients favourable to the development of heavy nocturnal convective rainfall. As for diurnal types, all of the below must be encountered for such development and all other patterns will lead to no worse than a localised event.

Sounding:
- precipitable water content ≥ 35mm;
- long narrow CAPE profile;
- KI ≥ 34;
- weak to moderate vertical shear;
- Corfidi's MCS-motion ≤ 20kt.

Low-level jet:
- magnitude ≥ 15kt;
- slow motion (≤ 10kt);
- intersecting a sfc or low-level convergence line;
- temporal intensification preferred.

Precipitable water ridge axis:
- magnitude ≥ 35mm;
- heavy rain along or on left flank of axis, near and downstream of convergence line.

And

| | Alignment | | Magnitude | | Amount |
|---|---|---|---|---|---|
| 1 | LLJ/ULJ > 30° | + | LLJ ≤ 30kt | = | >> 40mm large extent |
| 2 | LLJ/ULJ parallel | + | LLJ ≥ 35kt | = | ≥ 40mm large extent |
| 3 | LLJ/ULJ parallel | + | LLJ ≤ 30kt | = | ≥ 40mm small extent |

During the night of 23-24 July 2001, several light to moderate thunderstorms hit the fairly large area of the Saguenay and Lac-St-Jean regions (north of Québec City), giving heavy rainfall amounts with reports of up to 88mm (fig 8). The next figures show how all the above mentioned elements trigger the development of this event. The sea-level pressure field from the GEM on 23 July 12Z (fig 9) shows, as eventually observed, a weak trough oriented northwest-southeast through the sector and moving slowly eastward. The low-level jet (fig 10) intersects this trough and extends parallel to the upper level jet (fig 11). The precipitable water ridge axis (fig 11), exceeding 40 mm, lies east-west over the same location. Furthermore the WMW sounding indicates a favourably high precipitable water content (fig 12) at 37mm. Its CAPE profile is long and narrow while the KI is 34. Vertical shear is rather weak and provides an MCS-motion of about 15kts. Finally, the strong low-level jet (45kt) parallel to the upper level jet suggests a risk for a large extent of more than 40 mm, as it was eventually observed.

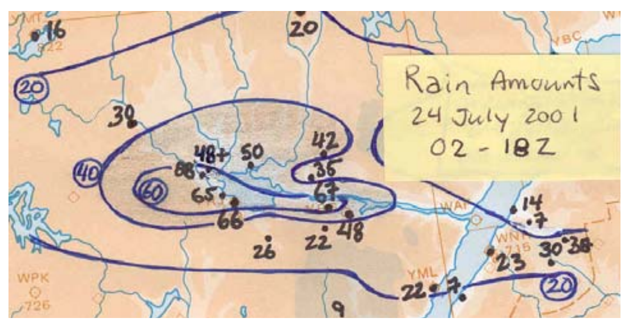


FIG 8. Total rain amount on 24 July 2001

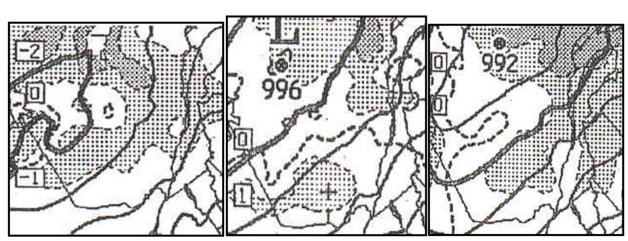

FIG 9. Sea-level pressure and pressure tendency from GEM 23/07/01 12Z at 12h, 18h, 24h.

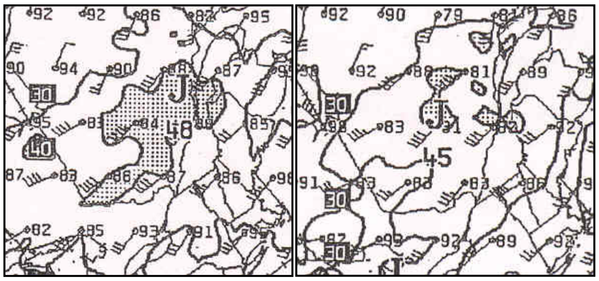

FIG 10. Low-level winds and jet from GEM 23/07/01 12Z at 18h and 24h.

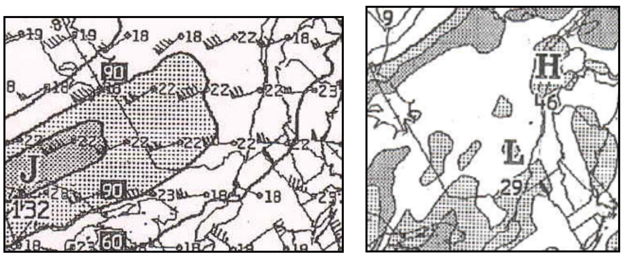

FIG 11. High-level jet stream and precipitable water from GEM 23/07/01 12Z at 18h.

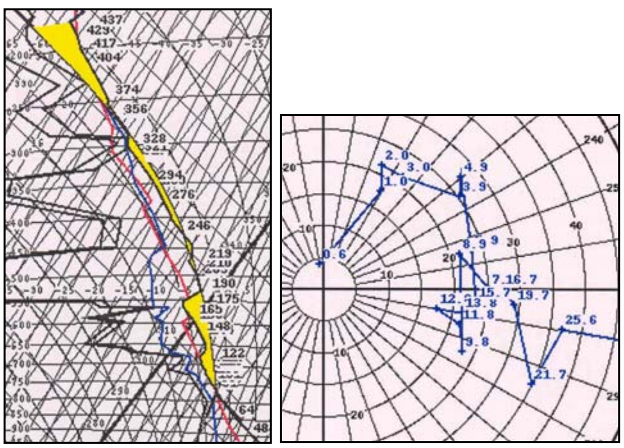

FIG 12. Sounding for WMW (400km southwest of the affected area) on 24/07/01 00Z.

## 5. SUMMARY AND DISCUSSION

This forecast tool enables the recognition of patterns favourable to the development of warm sector heavy convective rainfall events. The guide underlines the importance of a slow-moving low-level jet parallel to the upper level jet in a very moist, moderately unstable and weakly sheared environment. Heavy rainfall likely occurs near a surface or low-level convergence line in the whereabouts of the precipitable water ridge axis.

Several processes must take place in order to favour a high rainfall rate. A weak vertical environmental shear slows the weather system as well as the components responsible for convection, allowing the rain to fall over the same area. In addition, this weak shear coupled with parallel low-level and upper-level jets reduces dry air entrainment, and consequently restricts in-cloud evaporation of the rain drops. High drop density develops with a long narrow CAPE profile as it indicates slow updraft acceleration. Collision and coalescence processes thus take place over a longer period of time. These processes easily prevail when the environment contains high humidity, as pointed out by high magnitudes of precipitable water content, and when humidity is advected by the low-level jet towards the convergence axis. In addition, a lifting condensation level close to the surface limits evaporation under the cloud base.

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