Synoptic-Scale Analysis of Freezing Rain Events in Montreal, Quebec

Gina Ressler, Shawn Milrad, Eyad Atallah, and John Gyakum

Department of Atmospheric and Oceanic Sciences, McGill University, Montreal, Quebec, Canada
Motivation

- Freezing rain is a major environmental hazard in eastern Canada/US
  - 1998 Ice Storm - $3 billion in damage, left over one million people without power
- Especially common in the St. Lawrence River Valley (SLRV)
- More insight – better forecasts

Median annual hours of freezing rain from 1979 to 1990 (Fig. 2, Cortinas et al. 2004)
DJF observed surface winds at Montreal, Quebec (YUL) 1979-2002

Courtesy of Alissa Razy
Weather Scenario for Freezing Rain

Cold northeasterly flow at the surface

Warm southeasterly flow aloft

Adapted from Milton and Bourque 1999
Objectives

- Our knowledge of freezing rain at Montreal has been derived primarily from case study analyses.

- Goals:
  - Construct a complete list of freezing rain events for the time period 1979-2008.
  - Identify key synoptic-scale features of typical Montreal freezing rain events.

Montreal, December 2008
Data and Methodology

- Environment Canada hourly surface observations at Montreal, Quebec (CYUL) for the period 1979-2008
- National Centers for Environmental Prediction (NCEP) North American Regional Reanalysis (NARR) dataset

Montreal, QC
December 2009
Data and Methodology

- 163 synoptically independent events
- Most are short-lived
- 98% “light” intensity
- Severe events ≡ 6 or more hours of freezing rain per event
- 46 severe events
Manual Synoptic Partitioning

- 46 severe events were partitioned according to the location and tilt of the long-wave 500-hPa trough axis.
Manual Synoptic Partitioning

West, n=10
Central, n=16
East, n=20

Long-wave absolute vorticity maxima for west (blue), central (green), and east (red) synoptic types
500-hPa height (m; contoured), 500-hPa absolute vorticity (10^{-5} s^{-1}; shaded)

\[ t = 0 \text{ h} \]
500-hPa height (m; contoured), 500-hPa absolute vorticity ($10^{-5}$ s$^{-1}$; shaded)

$t = 0$ h

<table>
<thead>
<tr>
<th>Variable</th>
<th>West</th>
<th>Central</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of events (n)</td>
<td>10</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>Median freezing rain hours (h)</td>
<td>11.5</td>
<td>9.0</td>
<td>8.5</td>
</tr>
<tr>
<td>Median duration (h)</td>
<td>25.5</td>
<td>12.5</td>
<td>12.0</td>
</tr>
</tbody>
</table>
MSLP (hPa; solid), 1000-500-hPa thickness (m; dashed), thickness anomalies (m; shaded), 99% confidence interval for anomalies (red dashed)

$t = -48 \text{ h}$
MSLP (hPa; solid), 1000-500-hPa thickness (m; dashed), thickness anomalies (m; shaded), 99% confidence interval for anomalies (red dashed)

$t = -24 \text{ h}$
MSLP (hPa; solid), 1000-500-hPa thickness (m; dashed), thickness anomalies (m; shaded), 99% confidence interval for anomalies (red dashed)

t = 0 h

West, n=10

East, n=20
Precipitable water (mm; shaded), water vapour transport (kg m\(^{-1}\) s\(^{-1}\); arrows), water vapour transport convergence (-2x10\(^{-7}\) kg m\(^{-1}\) s\(^{-1}\); contoured)

\[ t = -48 \text{ h} \]
Precipitable water (mm; shaded), water vapour transport (kg m\(^{-1}\) s\(^{-1}\); arrows), water vapour transport convergence (-2x10\(^{-7}\) kg m\(^{-1}\) s\(^{-1}\); contoured)

\[ t = -24 \text{ h} \]
Precipitable water (mm; shaded), water vapour transport (kg m$^{-1}$ s$^{-1}$; arrows), water vapour transport convergence (-2x10$^{-7}$ kg m$^{-1}$ s$^{-1}$; contoured)

$t = 0 \text{ h}$
MSLP (hPa; solid), 1000-850-hPa thickness (m; dashed), 1000-850-hPa frontogenesis (K (100km)$^{-1}$ (3h)$^{-1}$; shaded)

$t = 0 \, h$
MSLP (hPa; solid), 1000-850-hPa thickness (m; dashed), 1000-850-hPa frontogenesis (K (100km)$^{-1}$ (3h)$^{-1}$; shaded)

$t = +12 \text{ h}$
MSLP (hPa; solid), 1000-850-hPa thickness (m; dashed), 1000-850-hPa frontogenesis (K (100km)$^{-1}$ (3h)$^{-1}$; shaded)

$t = +24$ h

West, n=10

East, n=20
Composite Analysis Conclusions

- **WEST composite**
  - Long upper-level wavelength: slower eastward movement
  - Southwesterly geostrophic flow: moisture from the Gulf of Mexico
  - Valley-enhanced frontogenesis

- **EAST composite**
  - Short upper-level wavelength: faster eastward movement
  - Southeasterly geostrophic flow: moisture from the East Coast
  - Passage of a midlatitude cyclone

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*For sustained freezing rain, there must be a pressure gradient force aligned with the St. Lawrence River Valley – whether it results from a cyclone, anticyclone, or couplet.*
Just one caveat...
Southerly channeling!

Plymouth State Weather Center

Sea level Pressure (mb)

WXP analysis for 12Z 28 FEB 11

INTerval: 2.0

LO: 996.4  HI: 1024.5
Southerly channeling!

Plymouth State Weather Center
Southerly channeling!

Plymouth State Weather Center

Surface Winds (knt)  Analysis for 12Z 28 FEB 11

<table>
<thead>
<tr>
<th>Time</th>
<th>Winds</th>
<th>Visibility</th>
<th>Overcast</th>
<th>Temperature</th>
<th>Pressure</th>
<th>Remarks</th>
<th>Station</th>
<th>Location</th>
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<tbody>
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<td>M05/M08</td>
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<td>A2965 RMK</td>
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</table>

Map showing weather conditions with a red circle highlighting specific area.