Ice Storms

• Caused by an accumulation of freezing rain
• Among the most devastating winter weather events
• Can halt air and ground transportation
• Can weigh down and snap power lines and trees
Readings on ice storms

Forecasting freezing rain

- Freezing rain tends to occur in very narrow (10 to 160 km) bands
- Small changes in temperature, wind speed, and moisture content can dramatically alter the location, intensity and duration of freezing rain
Supercooled water

- Water does not necessarily freeze at 0 deg C
- Ice does, however, melt at 0 deg C
- For water to freeze, ice nuclei (microscopic dust particles, soot, etc.)
- Ice nuclei are most effective at producing ice at temperatures less than -10 deg C
- There are very few ice nuclei in small raindrops
- When the temperature falls below 0, the droplets ‘supercool’
Supercooled water

- When supercooled droplets come into contact with a surface, such as a road or sidewalk, they freeze onto that surface.
- Freezing rainstorms occur when supercooled drizzle or rain fall onto objects and freeze.
See the link to the following animation:

• [http://www.youtube.com/watch?v=fSPzMva9_CE](http://www.youtube.com/watch?v=fSPzMva9_CE)
Synoptic conditions for an Ice Storm

- Occurs to the north of a warm front and to the west of a surface cyclone (about 72% of the events)
- North of a cold front in a cold-air dome associated with a high pressure system (about 52% of the events)
- Many Ice Storms are associated with each of the above! (see attached maps)
Synoptic Conditions for the Formation of Freezing Rain

(A) Mid-Latitude Cyclone
71% of severe and 72% of all events

(B) Cold Air Dome
66% of severe and 52% of all events
The most severe freezing rain events combine a cyclone to the south with a high pressure system to the north. The strong gradient increases surface flow.
Vertical temperature structure during an Ice Storm

• Normally, the temperature decreases with increasing elevation

• During freezing rain events, however, the temperature increases with height near the surface, and then, farther above, the temperature decreases with height

• The layer in which the temperature increases with height is called an inversion
Atmospheric stability (see notes on tornadoes)

Examples of Stability

- **STABLE**
- **NEUTRAL**
- **UNSTABLE**
How does an inversion form?

- Warm, moist air from the south flows above the dome of cold air
- At each location, precipitation forms as snow
- At point D, all precipitation falls as snow
- At point A, all ice melts and the precipitation is rain
Freezing rain and ice pellets

- At point C, the snow partially melts in the shallow warm layer aloft. The supercooled water refreezes on the existing ice nuclei, resulting in ice pellets (sleet is a US term)
- At point B, the snow melts completely in the deep warm layer. Once the water falls into the cold (less than 0 deg) near-surface layer, it is supercooled and freezes on impact with the surface (freezing rain)
Winter Precipitation

Synoptic Conditions for
Severe Freezing Rain Event

The most severe freezing rain events combine a cyclone to the south with a high pressure system to the north. The strong gradient increases surface flow.
What makes an ice storm so severe?

- Persistence
- Intensity
- Phase (supercooled water)
- Location
Anatomy of an ice storm

The ice storm that has gripped Quebec and Eastern Ontario all week has been strong both in the amount of rain it has dropped and its endurance. Here's why:

1. One after another through the week, three warm-air masses move up from the Gulf of Mexico, taking moisture north to Ontario and Quebec.

2. A stationary mass of cold air forces the warm air to rise, causing precipitation to begin.

3. Precipitation falls in different forms depending on the temperature of the air that it meets on the way down:

   - **WARM AIR**: Warm air melts snow into rain over Quebec and eastern Ontario. The bank of cold air supercools it, keeping it in liquid form but a few degrees below 0. When it hits cold objects on the ground, it freezes quickly, and this is freezing rain.

   - **COLD AIR**: Precipitation falls through cold air over P.E.I., causing a snow storm.

Diagrams are schematic and not to scale. Sources: Weather By Day, Environment Canada.
A recent ice storm affected parts of the new England states on Nov. 16-18:

- About 30 mm of ice
- 130,000 customers without power (some for as much as four days)
- Damage estimates not yet final, but likely to be greater than 10 million dollars
The Ice Storm of 1998

• 93% of freezing rain storms in North America last for less than 5 hours, yet the 1998 ice storms endured for nearly 5 **days**!

• Freezing rain occurred for more at than 80 hours at Ottawa and Montreal (about **double** the **annual** average)

• A nearly stationary frontal system existed to the south of the Saint Lawrence River Valley for five days

• Warm, moist air flowed over a cold air dome in the Saint Lawrence River Valley
Fig. 1. Surface synoptic pattern over New York and New England at six hours on 5–10 Jan 1998 [(a)–(f), respectively.] The locations of six hourly reporting stations used in subsequent analyses are shown in (a).
Time series of temperature and wind soundings for Ottawa, Ontario for the period of January 4 through January 9, 2000; Shaded red region indicates temperatures greater than 0 deg C; vertical axis extends from the surface to 3 km above the ground.
Origins of the warm and moist air that is essential for producing the heavy precipitation:

- The following animation illustrates that some of the air responsible for the precipitation over Montreal originated in the eastern Atlantic ocean with a history of passage off the east coast of Africa.
- The total amount of time involved in the animation is 10 days.
Intensity of the Ice Storm

- 85 mm in Ottawa
- 73 mm in Kingston
- 108 mm in Cornwall
- 100 mm in Montreal
- All during a 5-day period (double the largest previous ice storms)
- Reports of thunder during the Ice Storm!
Location

• The Ice Storm produced more than 1 billion dollars in damage
• Had the storm shifted its impact by only 100 km, the damage would have been only minor
Ice Storm of 1998 accumulated precipitation (mm) for the six-day Period ending at 7 AM, January 10, 1998; The 0 deg C temperature Lines (isotherms) at 1.5 km are shown in solid. The 0 deg isotherms At the surface are shown in dashed.
Impacts of the 1998 Ice Storm

• More than 25 fatalities, mostly from hypothermia
• 900,000 without power in Quebec, 100,000 without power in Ontario
• 100,000 took refuge in shelters
Impacts of the Ice Storm

- Millions of residents forced into mobile living, visiting relatives to take a hot shower, or to share a meal
- 14,000 troops deployed to assist the clean up and evacuation, and security
Impacts of the Ice Storm

- Millions of trees were downed
- 120,000 km of power and telephone lines
- 130 major transmission towers, each worth $100,000
- 30,000 wooden utility poles at $3,000 each
Impacts of the Ice Storm

- Infrastructure of the electrical grid had to be rebuilt, not just repaired
- Massive livestock losses
- Agriculture devastated with many maple syrup producers losing their livelihood
Climatology of Ice Storms
(median number of hours per year that freezing rain is reported in North America)

- Preferred areas include the Saint Lawrence River Valley, Newfoundland, the eastern Great Lakes, the eastern valleys of the Appalachians, the Mississippi River, and inland sections east of the Cascade Mountains
- (from Cortinas et al. 2004)
The topography (terrain) of North America (m)
Montreal (YUL) has a particular vulnerability to ice storms because of its location in the Saint Lawrence Valley.
The wind directions are nearly *bimodal*. Basically, there are two wind directions (southwesterly and northeasterly)
Mitigation:

• Listen to the media for freezing rain warnings (as much as a day in advance)
Safety measures (if power and heat are lost):

• Close off unneeded rooms
• Stuff towels in cracks under doors
• Cover windows at night
• Eat to maintain energy for heat; drink fluids to avoid dehydration
• Wear layers of loose-fitting, lightweight, warm clothing; remove layers to avoid overheating, perspiration and subsequent chills
• If using an alternate heat source, use fire safeguards, and properly ventilate
Readings on ice storms:

• http://www.msc.ec.gc.ca/media/icestorm98/index_e.cfm
• http://lwf.ncdc.noaa.gov/oa//reports/janstorm/janstorm.html
• Rauber, Walsh, and Charlevoix, chapter 11.