Canadian Megadisasters:

An exploration of sensitivities and implications for the insurance industry

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AIR WORLDWIDE®

What Constitutes a “MegaDisaster” or Extreme Disaster Scenario?

What is the next Canadian “Black Swan” event?

Canada

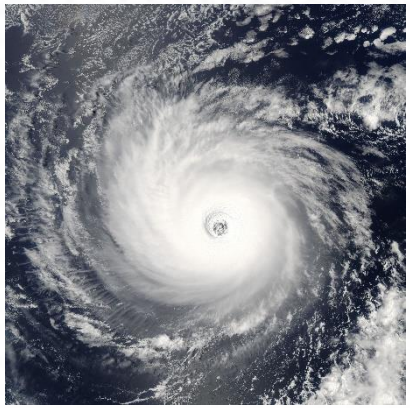
1998: Great North American Ice Storm, ~$1.5 Billion (CAD 1998)
- Some without power for over a month

2016: Fort McMurray Fire

2013: Calgary Floods, ~$1.7 Billion (CAD 2013)
- Total Damage ~ 5 Billion (CAD 2013)

Goal: Create a plausible, yet highly unlikely shock to the market

Our Focus Will Be on Winds Perils…



Tropical Cyclones

Winter Storms

Severe Thunderstorms

Step 1: Consider the Meteorology
Step 2: Consider the Exposure
Step 3: Consider Historical Experience

Tropical Cyclones

Consider the Meteorology: Tropical Cyclones

Sea Surface Temperatures (SST) > 26° C extending down to 50 m depth

Low vertical wind shear (change in wind with height)

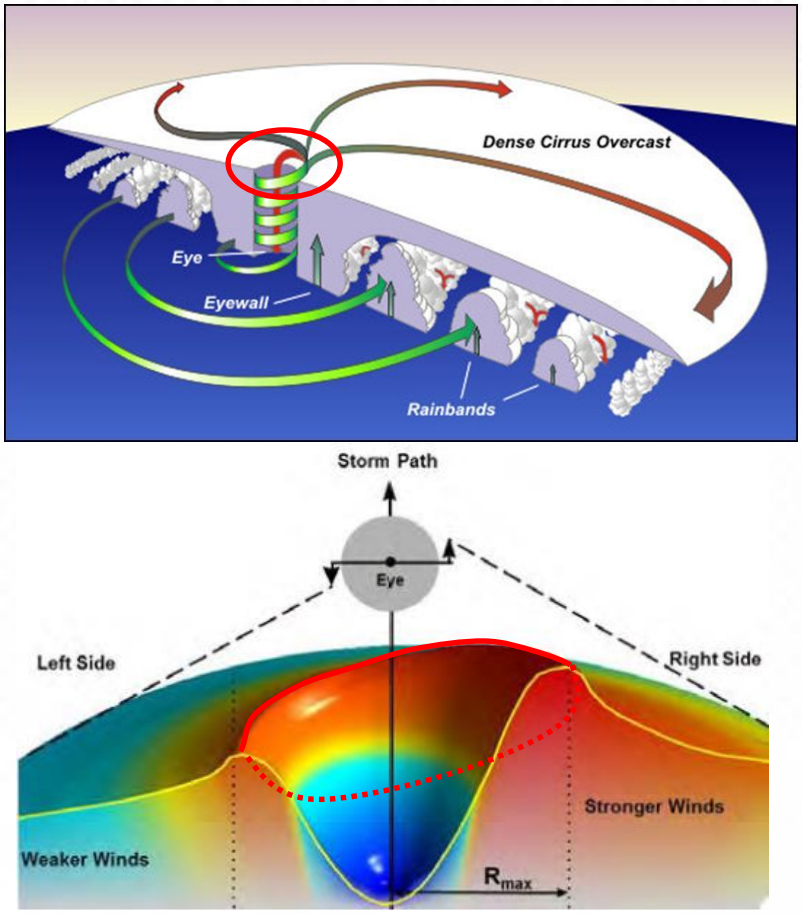
Atmospheric Instability (heat/moisture/kinematic)

Deep column moisture (sea surface to mid-levels ~ 7km+ AGL)

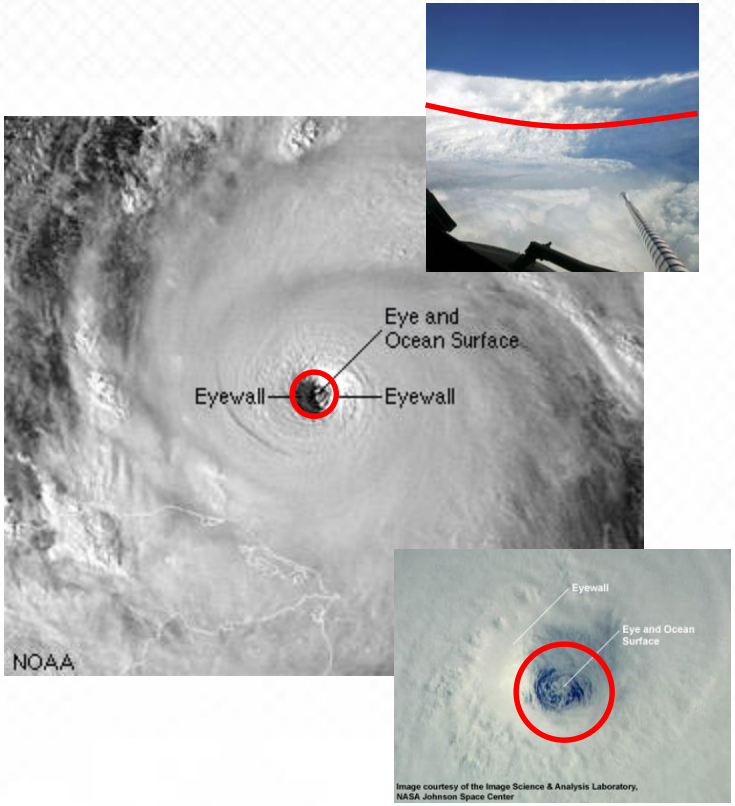
Away from the equator (need source of rotation: *Coriolis Force*)

Pre-existing convection/waves to trigger cyclogenesis

Consider the Meteorology: Anatomy of a Tropical Cyclone



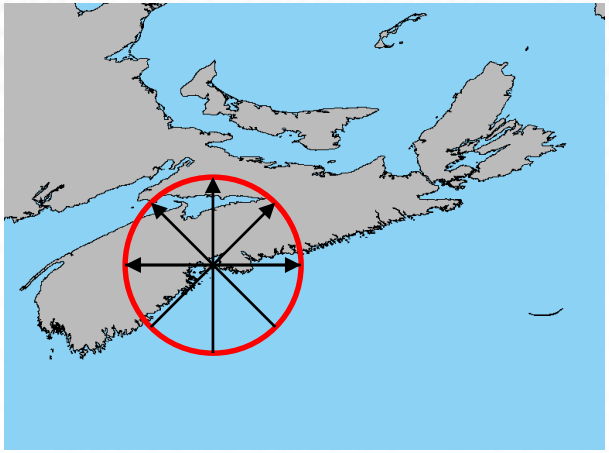
Schematic of typical tropical cyclone structure

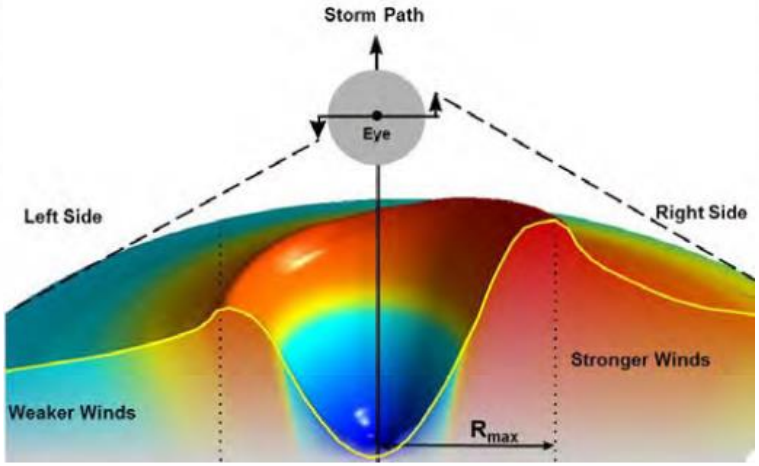


The eye and eye wall from visible satellite

Consider the Meteorology: Important Characteristics of a Tropical Cyclone Event

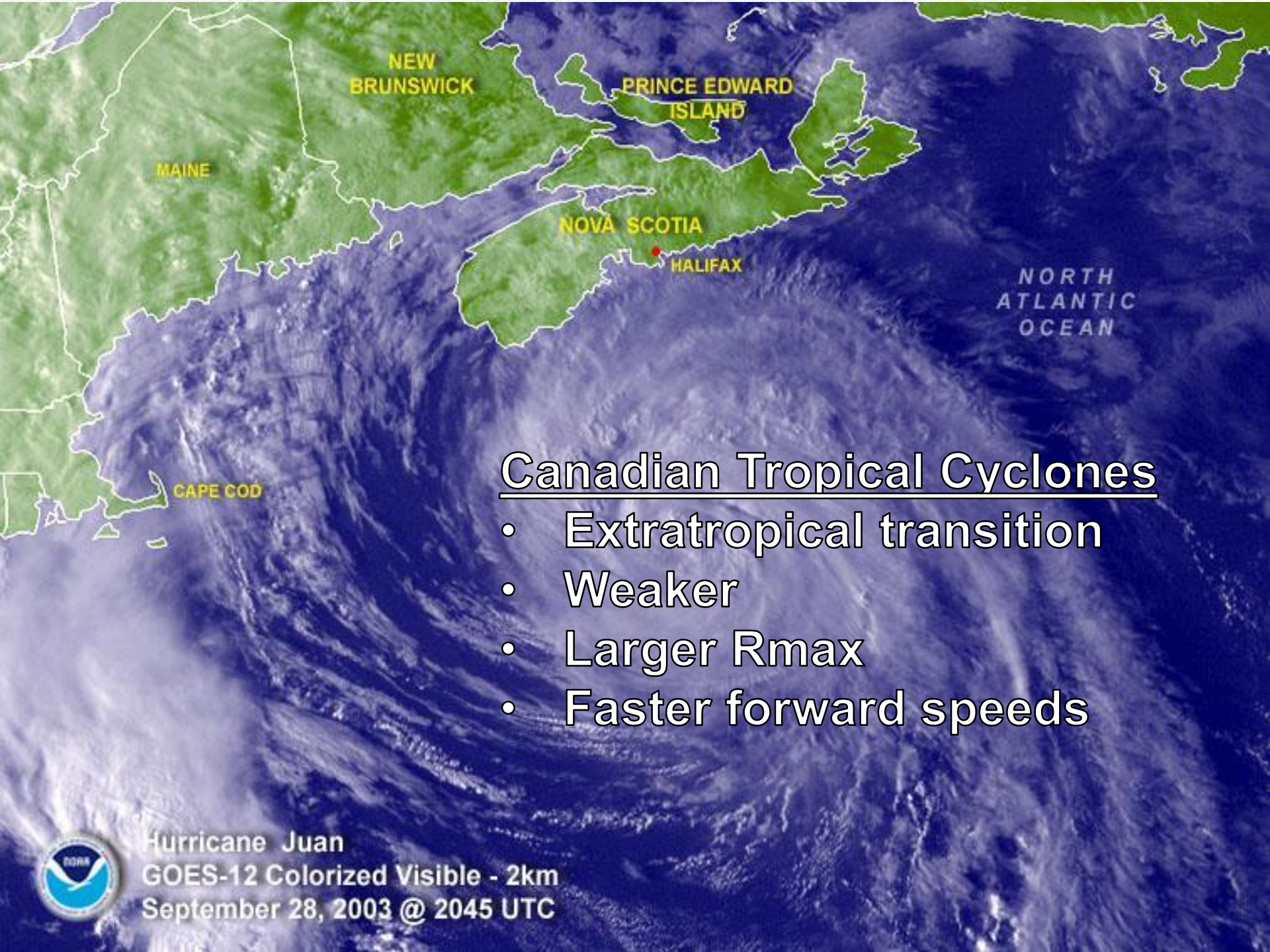
1. **Intensity**
2. **Asymmetry**
3. **Angle of Attack**
4. **Landfall Location**
5. **Forward speed**
6. **Duration**



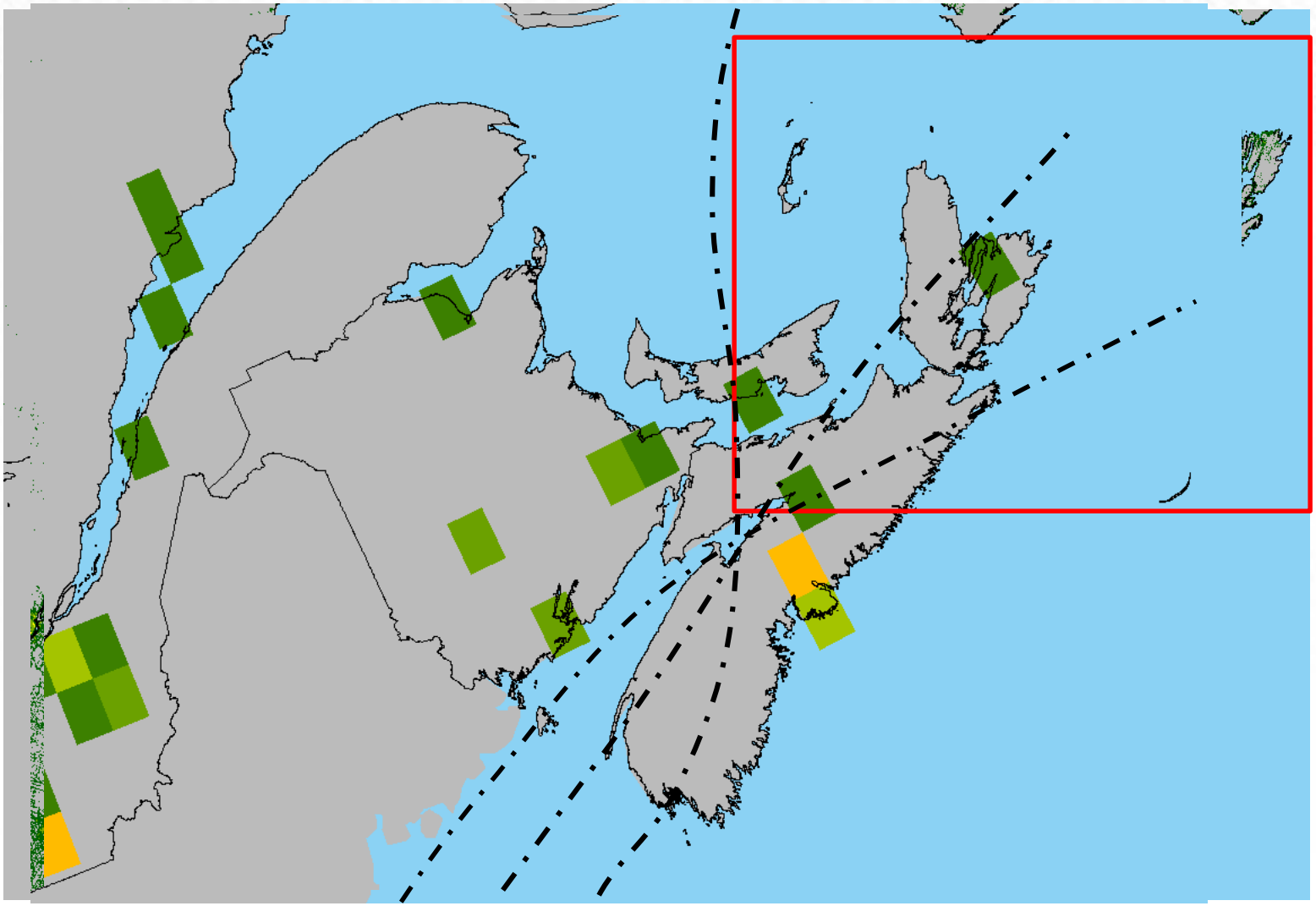


Saffir-Simpson Category	Maximum Sustained Wind Speed (km/h)*	Potential Damage
Tropical Storm	63 to 118	Minimal
Category 1	119 to 153	Minimal
Category 2	154 to 177	Moderate
Category 3	178 to 208	Extensive
Category 4	209 to 251	Extreme
Category 5	252 and higher	Catastrophic

**The mean of multiple wind speed measurements taken over one-minute time periods at a height of 10 meters above the ground*

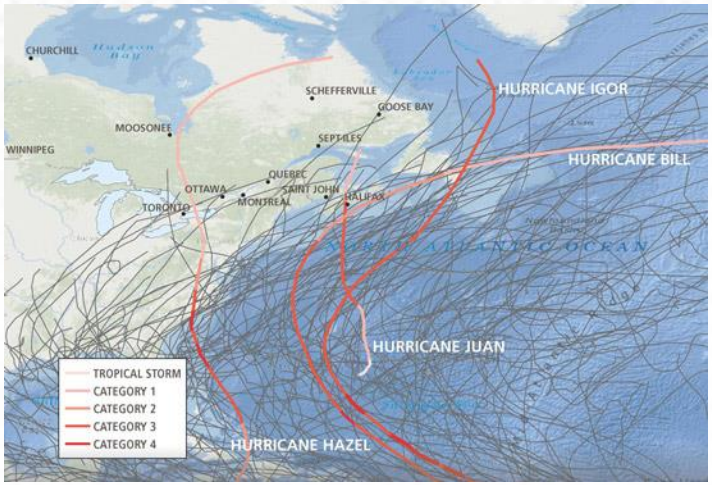

NEW BRUNSWICK
PRINCE EDWARD ISLAND
MAINE
NOVA SCOTIA
HALIFAX
NORTH ATLANTIC OCEAN
CAPE COD
Canadian Tropical Cyclones
• Extratropical transition
• Weaker
• Larger Rmax
• Faster forward speeds
Hurricane Juan
GOES-12 Colorized Visible - 2km
September 28, 2003 @ 2045 UTC

Consider the Exposure: Atlantic Canada

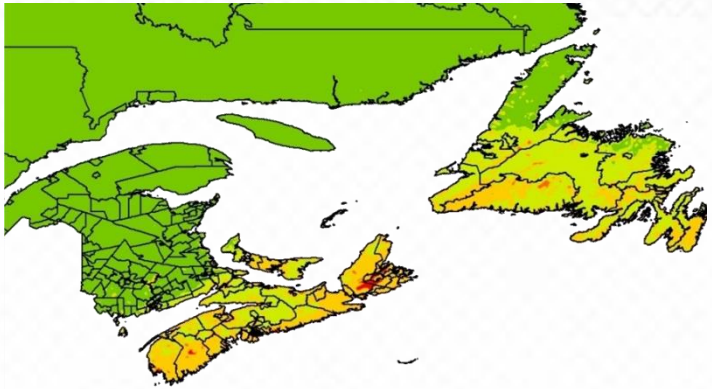


Consider Historical Experience:Tropical Cyclone Risk in Canada

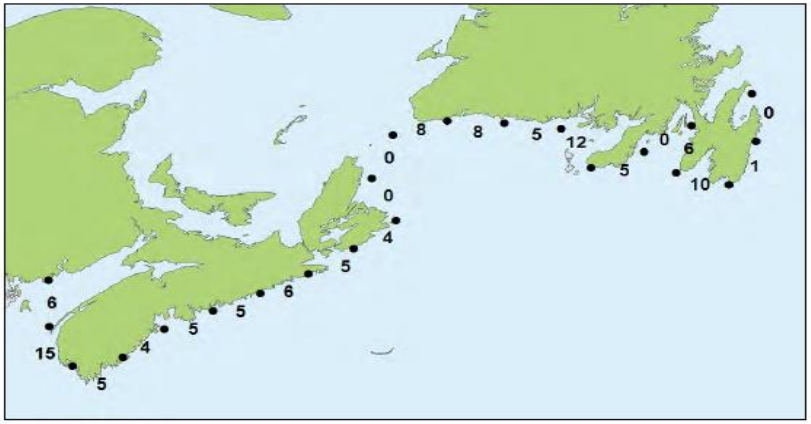
Historical Tracks



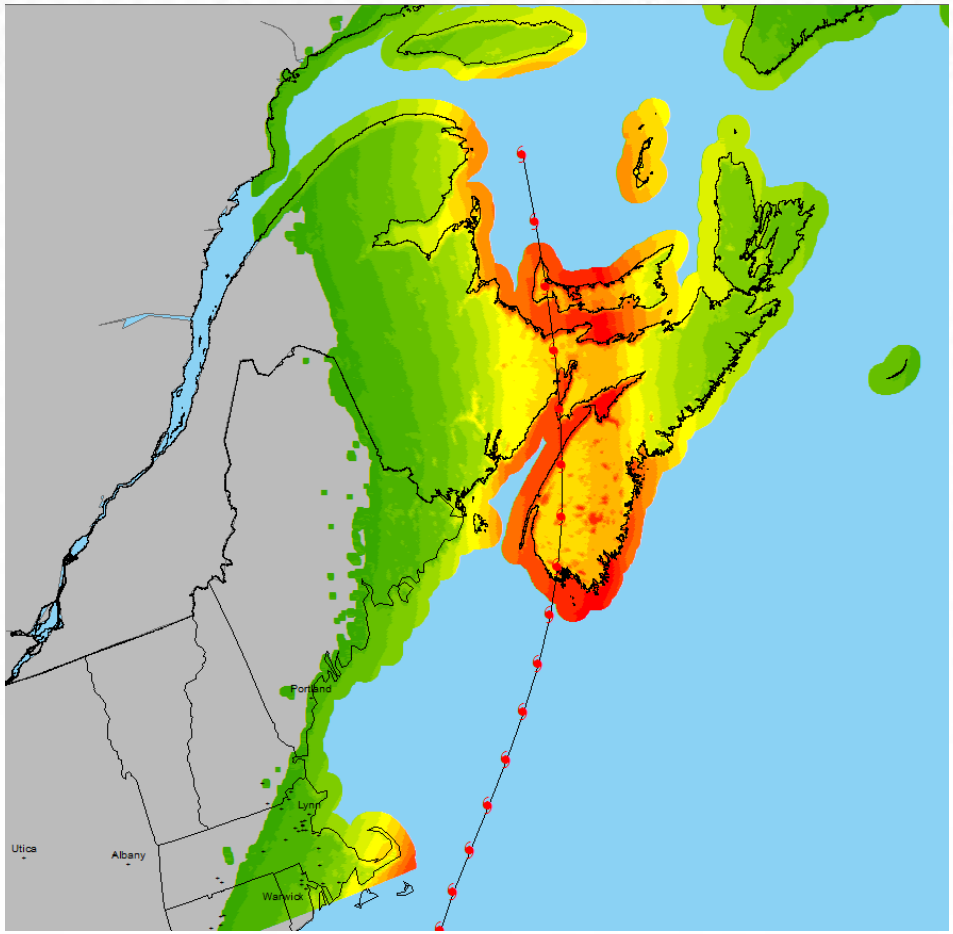
Loss Cost



Historical Landfalls: 1900-2012



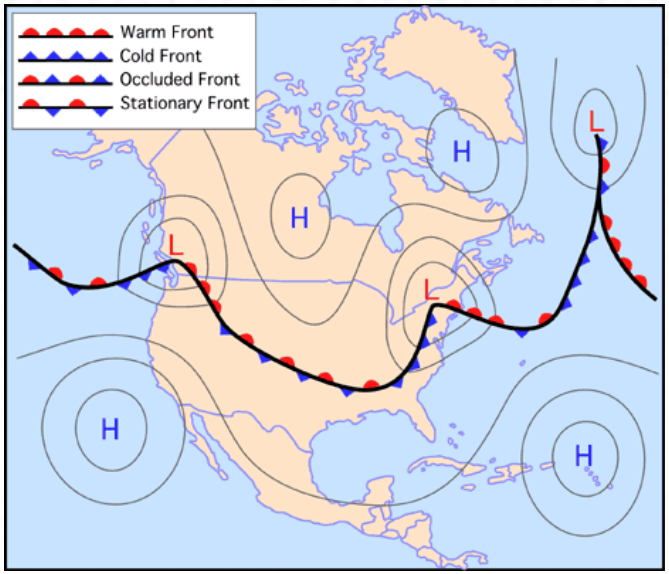
The Tropical Cyclone Extreme Disaster Scenario: The Halifax Howler



Extratropical Cyclones

AIR

Consider the Meteorology: Winter Storm Sub-perils



Canada Winter Storm

- **Frozen precipitation**
- **Wind**
- **Freezing rain**
- **Arctic temperatures**

Consider the Meteorology: **What Is Freezing Rain…?**

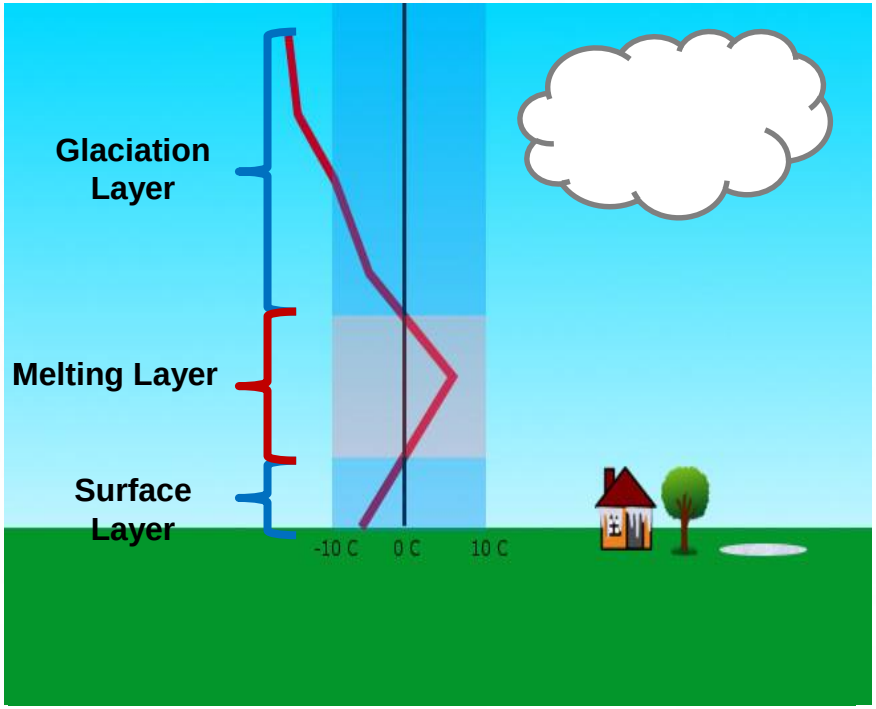
Freezing rain occurs when supercooled water falls onto surfaces and objects that have a below freezing temperature.

This is a particular concern for:

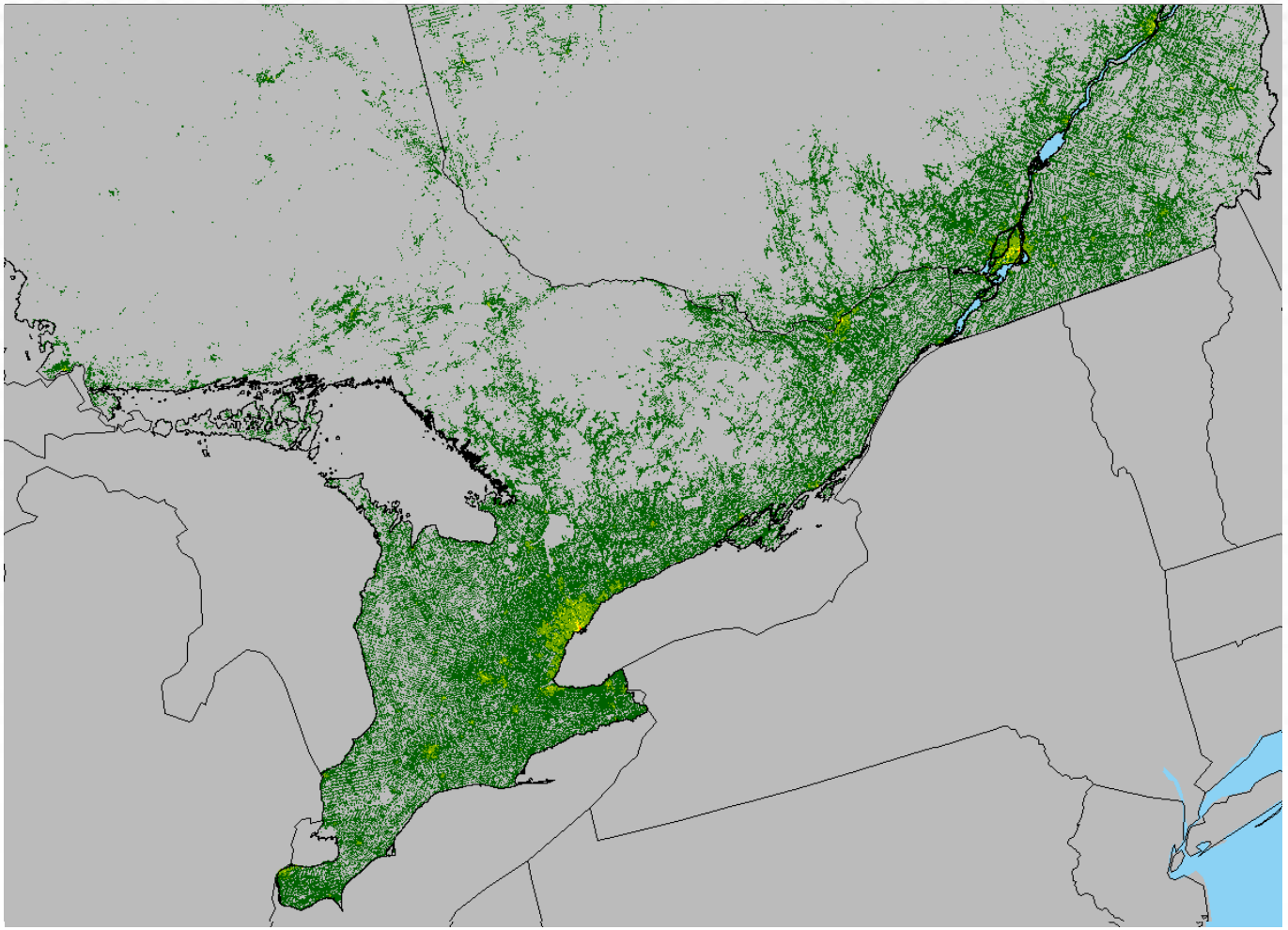
- Power transmission/distribution lines
- Trees/tree limbs
- Infrastructure/road safety
- Agriculture

Consider the Meteorology: **What Is Freezing Rain…?**

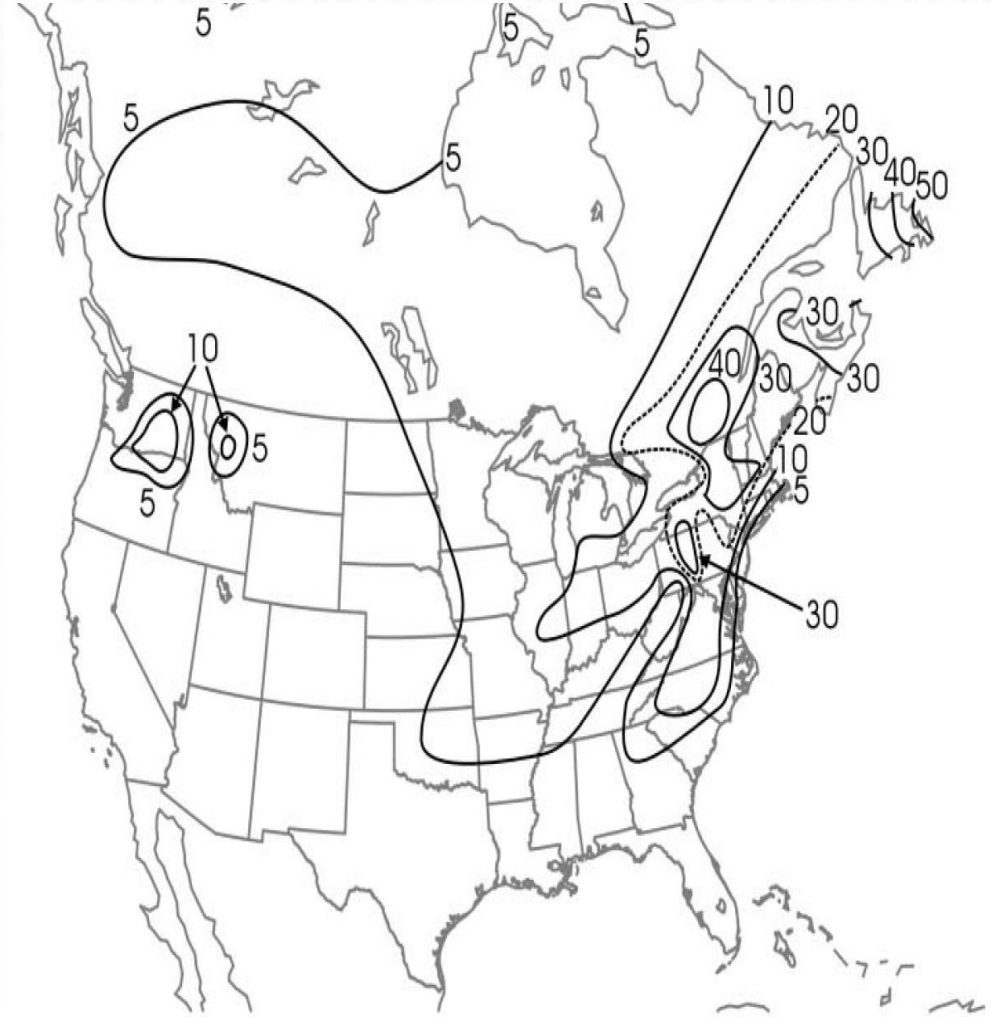
Freezing rain occurs when precipitation falls through a warm layer into a sub-zero layer near the surface.



Consider the Exposure: Ontario/Quebec



Consider Historical Experience: The History of Ice Storms in Canada



Median Number of Hours of Freezing Rain per Year

Date	Location	Ice Accumulation
1961	QC	35 mm
1986	ON	65 mm
1972	QC	40 mm
1983	QC	50 mm
1986	ON/QC	30 mm
1998	ON/QC/NB	100 mm
2002	ON	18 mm
2003	NB	60 mm
2013	ON	30 mm

Consider Historical Experience: The 98 North American Ice Storm

100+ mm ice accumulation

1.5 billion (CAD 1998) in insured losses

1,000+ transmission towers, 30K+ utility poles

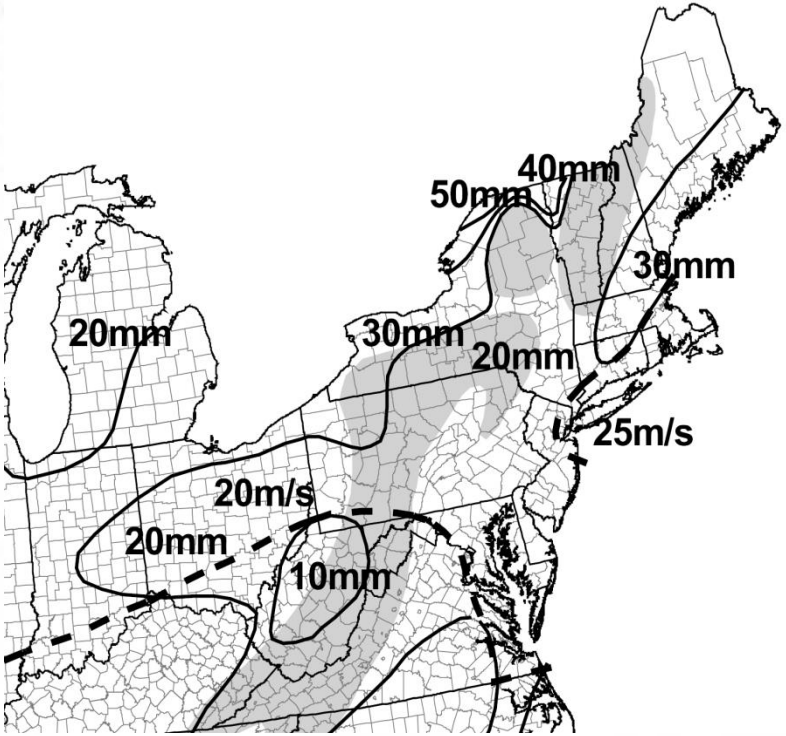
16%

4.7 million without power (some for about a month), 28 deaths

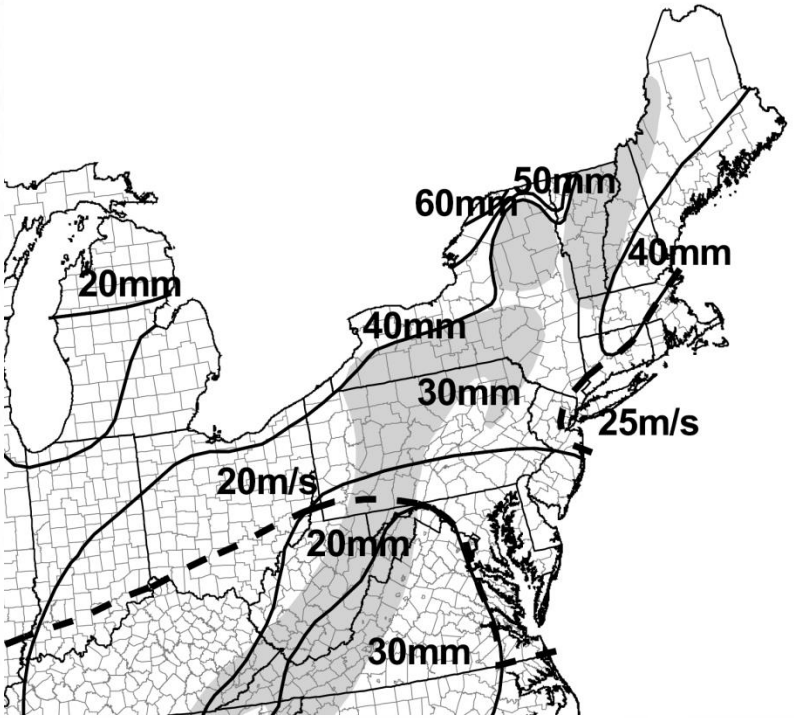
Largest deployment of the Canadian military since the Korean War

Consider Historical Experience: Ice Accumulation Return Periods

200-year
Equivalent Radial Ice Thickness



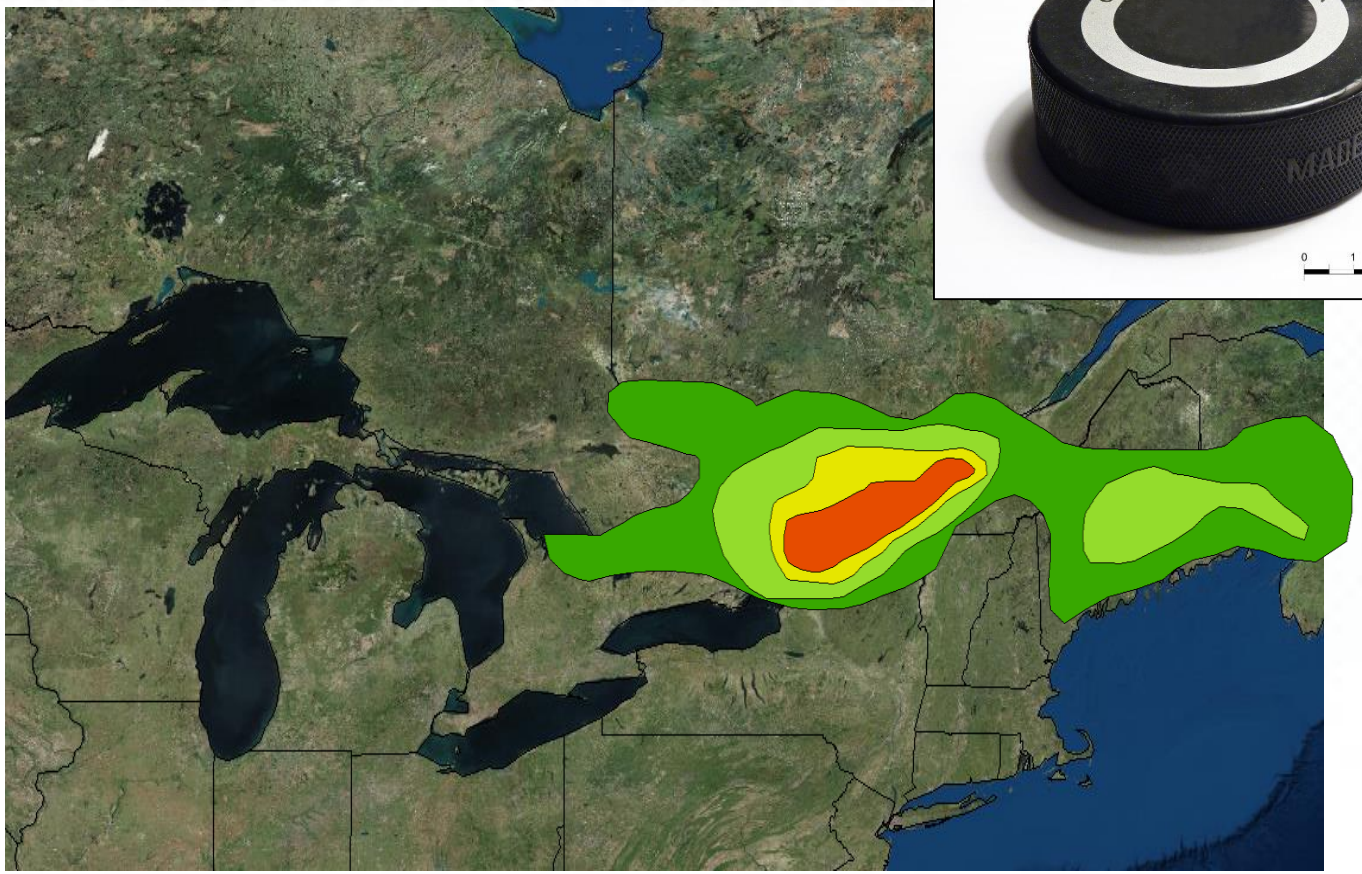
400-year
Equivalent Radial Ice Thickness



$$R_{eq} = (\text{Ice accumulation})/(\rho_i * \pi)$$

1998 Ice Storm → Ice accumulation = 100+ mm ≈ 35 mm R_{eq}

The Winter Storm Extreme Disaster Scenario: The Toronto Ice Storm



1998 Ice Storm → Ice accumulation = 100+ mm ≈ 35 mm R_{eq}

Severe Thunderstorms

Consider the Meteorology: Multiple Sub-Perils and Multiple Modes of Damage

Straight-Line Wind

- Localized or widespread
- 3-second gust
- Temporally variable
- 50–150 mph (80–240 km/hr)

Hail

- Strong core
- Different concentrations of different diameters
- Integrated damage over time and diameter: Total Kinetic Energy
- 1– 8+ inch (25 – 200 mm) diameter (quarter - bowling ball)

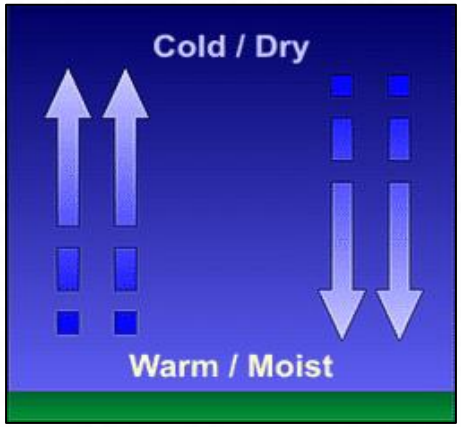
Tornado

- Strong, localized core
- Variable width and intensity over path
- Torsional and wind-load damage
- Rated F/EF1-F/EF5 (65-200+ mph or 100-320+ km/hr)

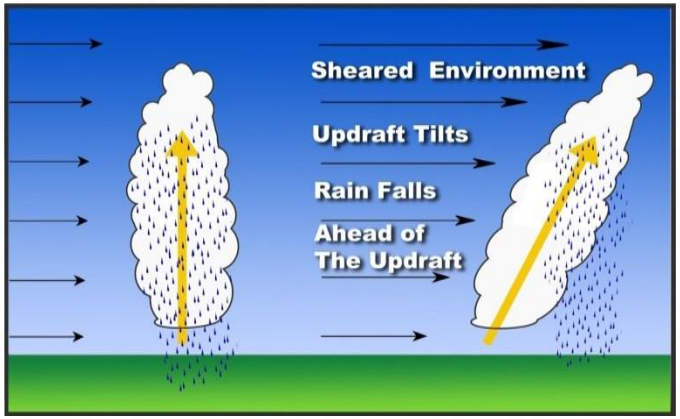
Consider the Meteorology : Severe Thunderstorm "Ingredients"

Severe Thunderstorms Require:

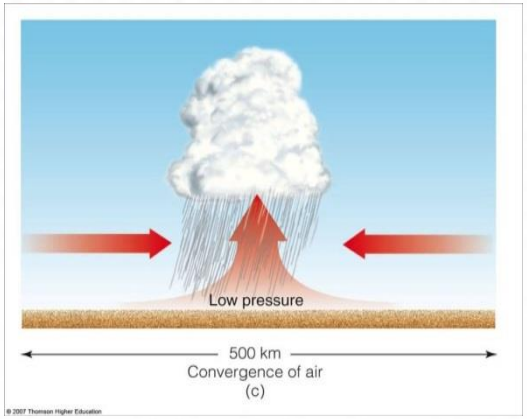
Instability (moisture, CAPE)



Vertical Wind Shear



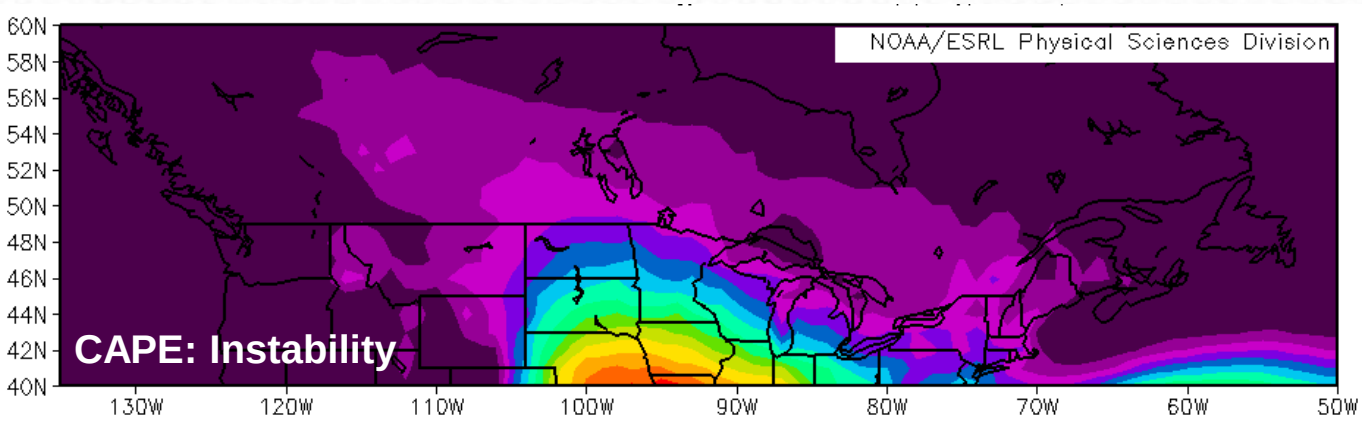
Lift

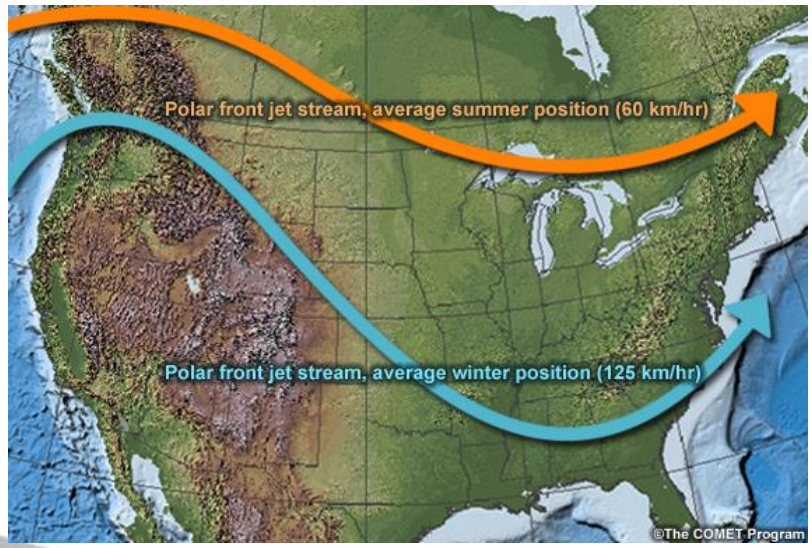


The collocation of these largely determines where severe thunderstorm activity occurs

Consider the Meteorology : Where Do These Ingredients Occur?

Where Do These Ingredients Occur in the Canadian Domain?

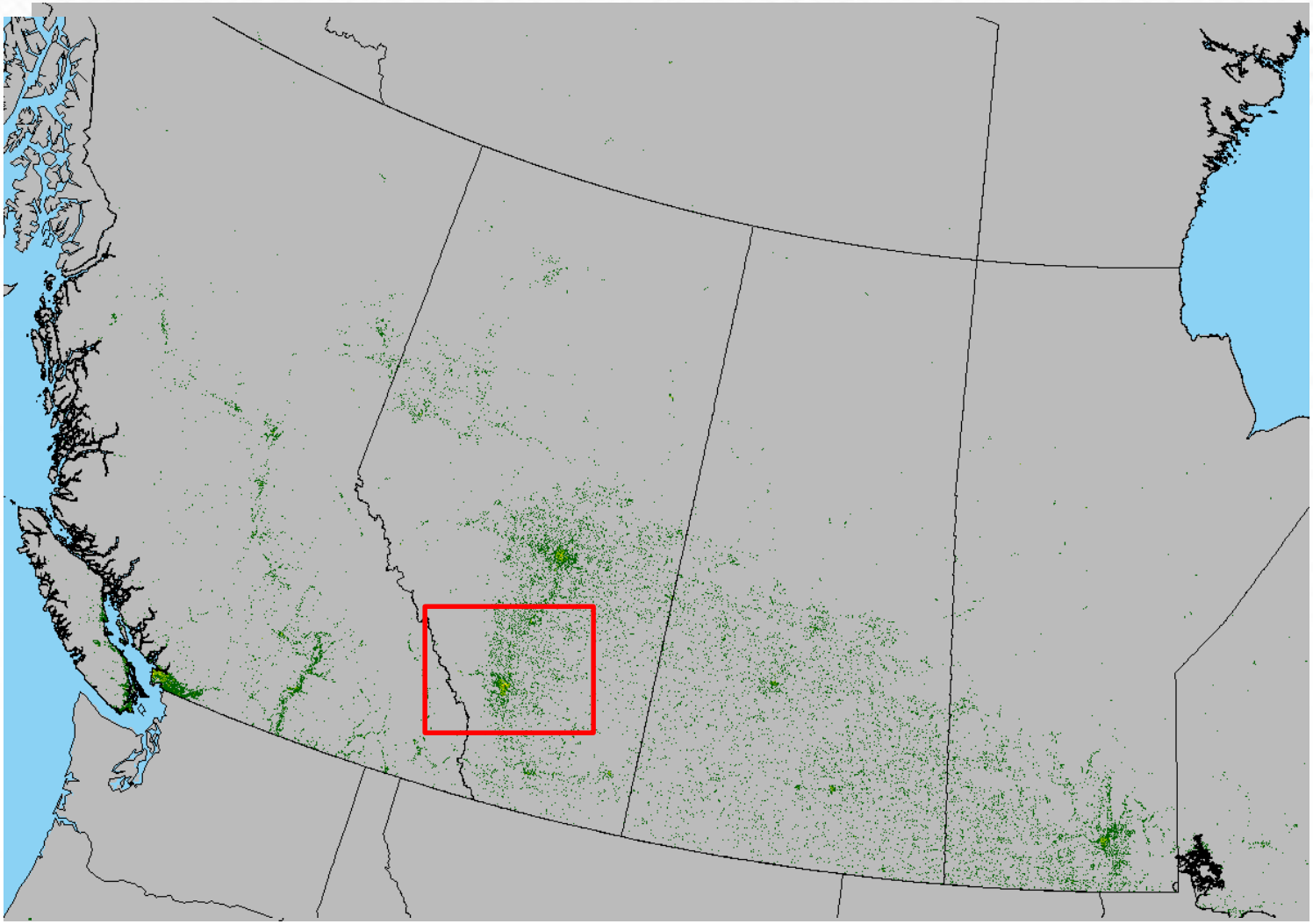




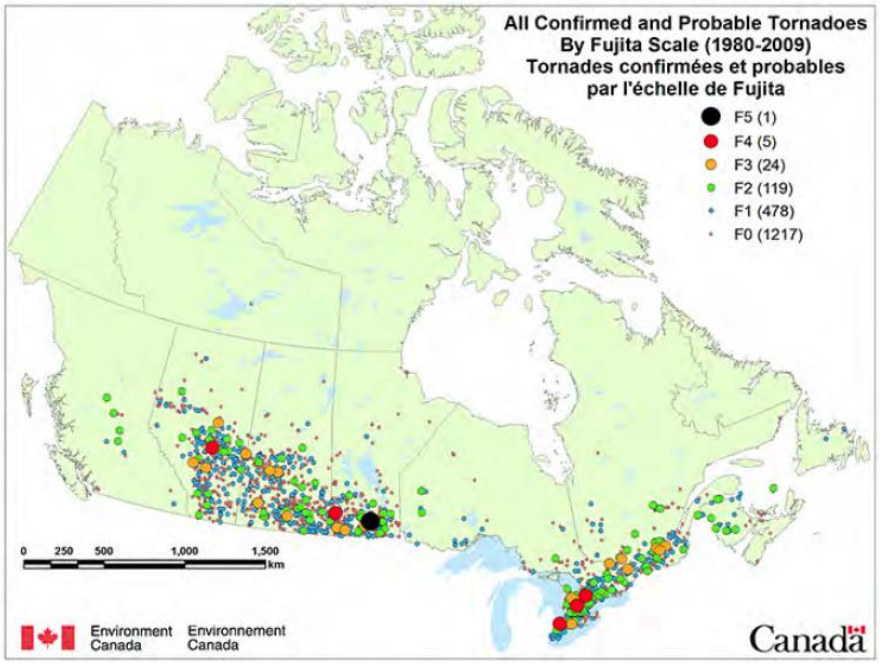
Jet Stream: Wind Shear

Topography: Lift

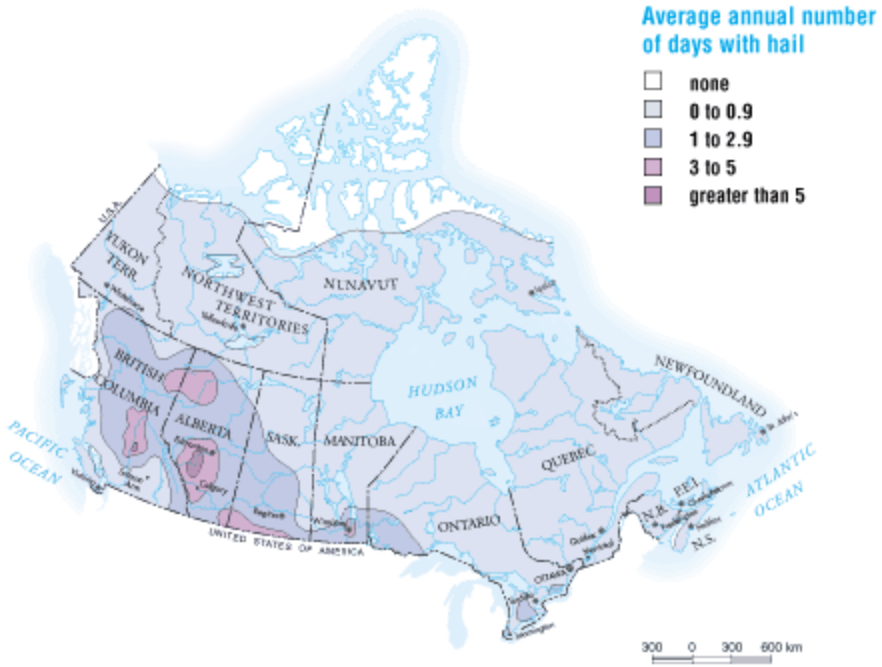
Consider the Exposure: Alberta



Tornado and Hail Activity in Canada

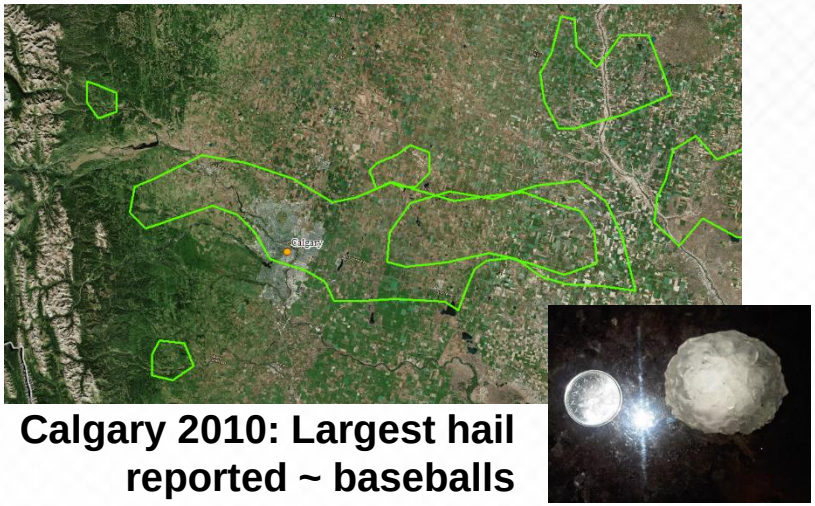


Confirmed and Probable Tornadoes (1980-2009)



Average Annual Hail Days

Recent Canadian Hailstorms



Calgary 2010: Largest hail reported ~ baseballs

Recent Hailstorm Losses

Quebec (2008) $137.2 million

Sask. (2008) $144.9 million

Edmonton (2004) $198.5 million

Alberta (2010) $569.6 million

Calgary (2012) 578.2 million

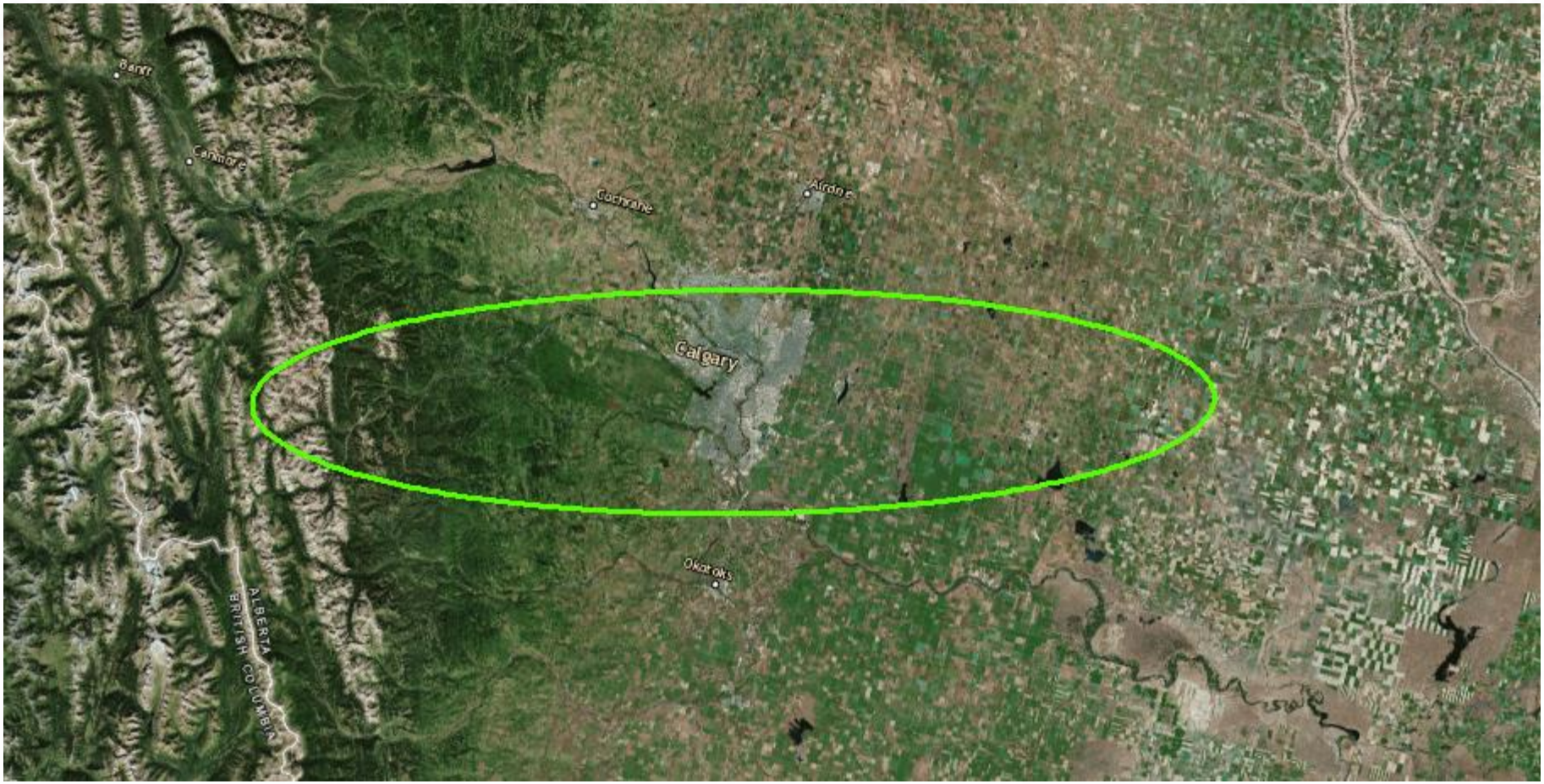
Airdrie (2014) $568.9 million

Source: ICLR

Calgary 2012: Largest hail reported ~ 50-60mm

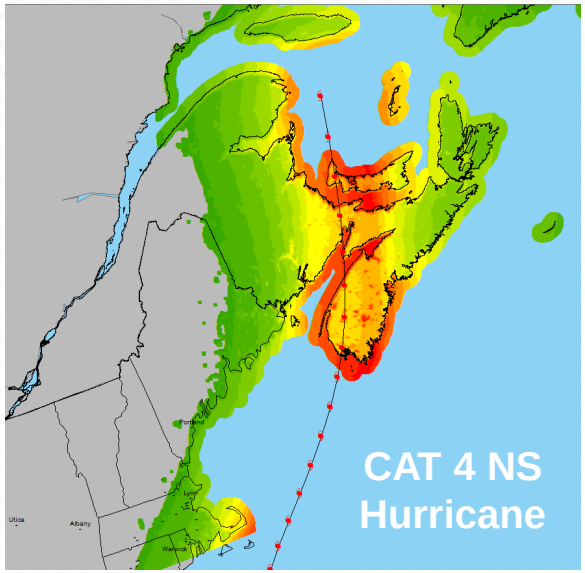
~100 mm Hailstones (max reported in 1991 storm)

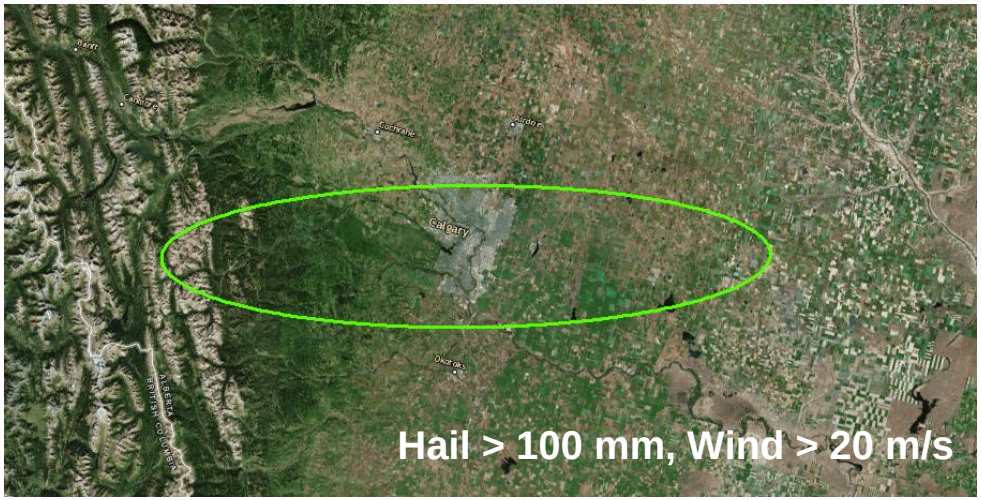
The Severe Thunderstorm Extreme Disaster Scenario: The Calgary Hailer

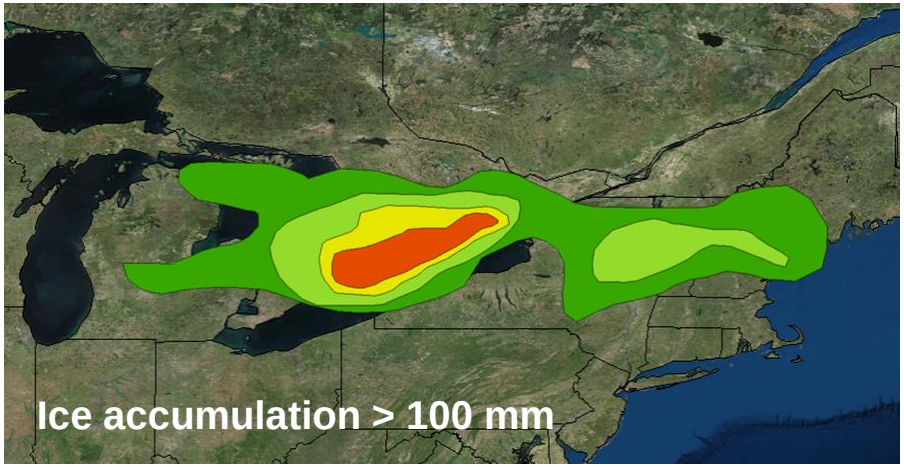


Duration: 10 mins **Maximum Hail Size: 100 mm** **Horizontal Wind: 20 m/s**

The Three Extreme Disaster Scenarios

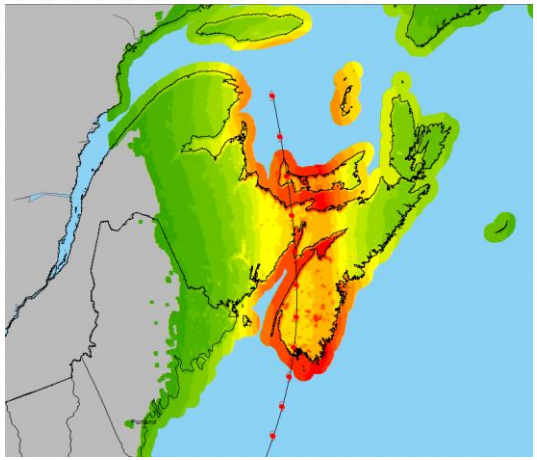




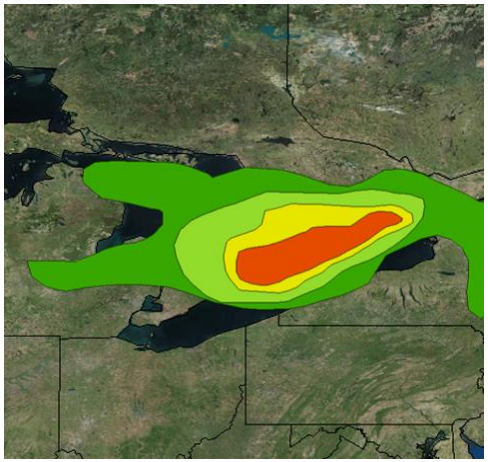


Extreme Disaster Scenario (EDS) Impacts

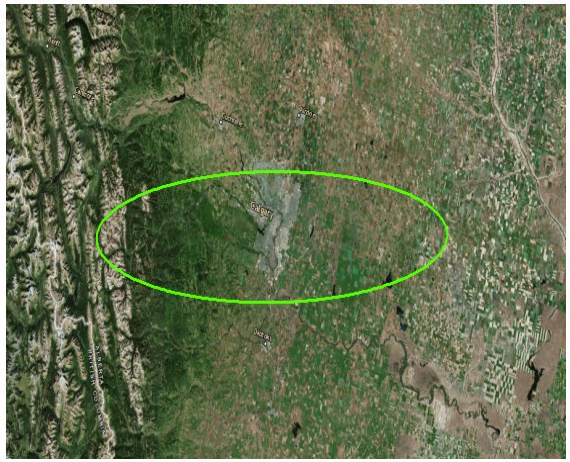
EDS Loss: The BIG Reveal



Total Loss
$32.5 Billion



Total Loss
$26.2 Billion

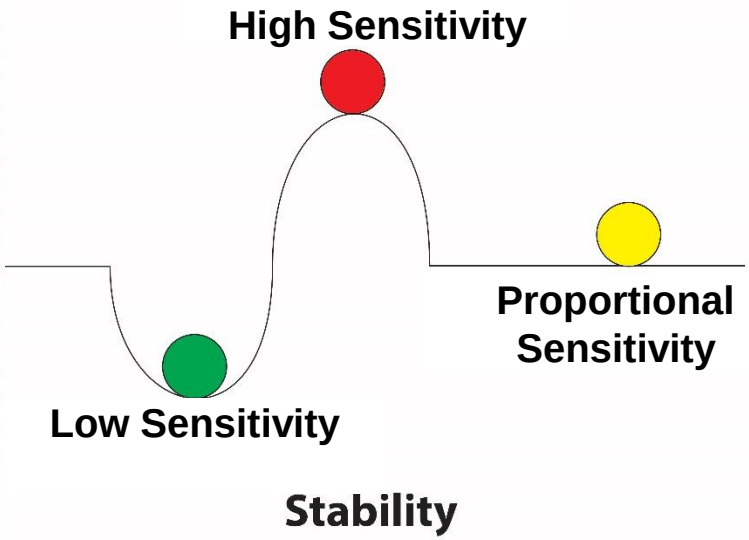


Total Loss
$13.6 Billion

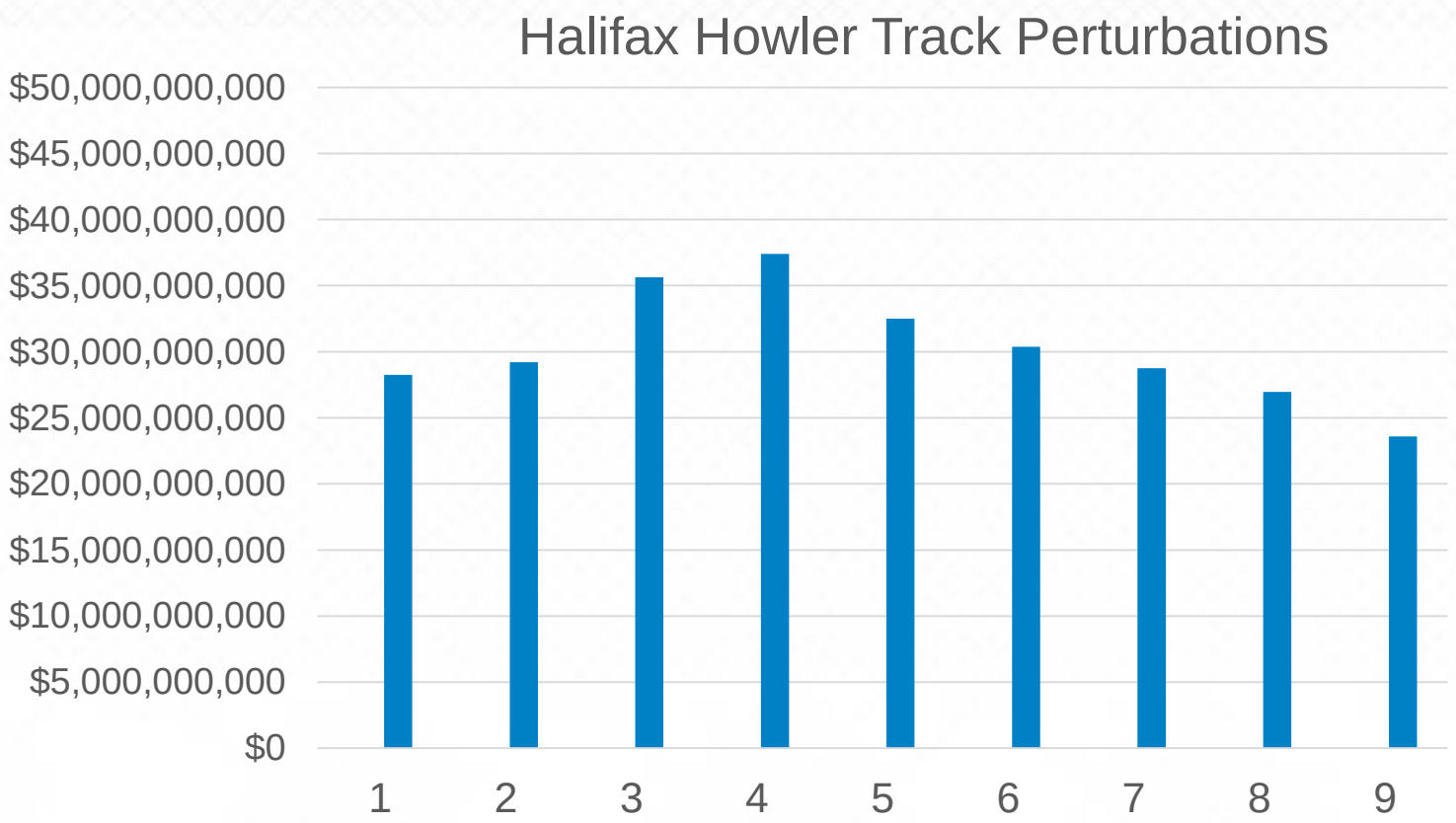
But is this really the end of the story???

Losses Can be Sensitive to Small Perturbations

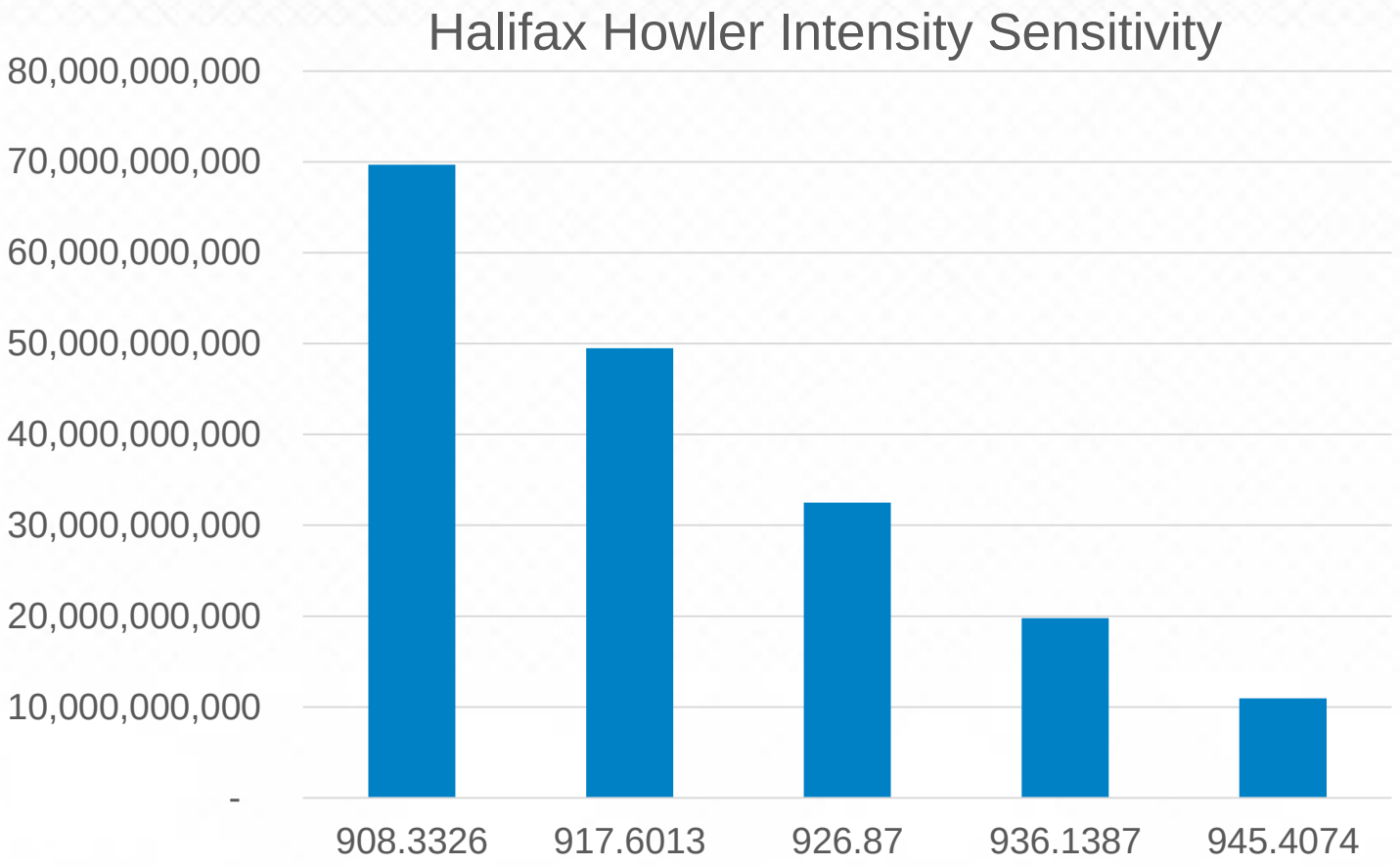
Perturbations: Small shifts in intensity or location that could potentially have a significant effect on resultant losses



Landfall Location can Make a Modest Difference



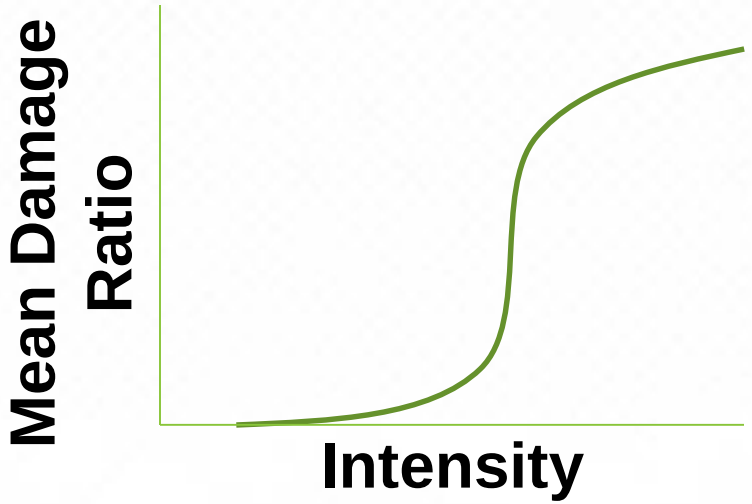
How Loud is the Howler “Howling”?



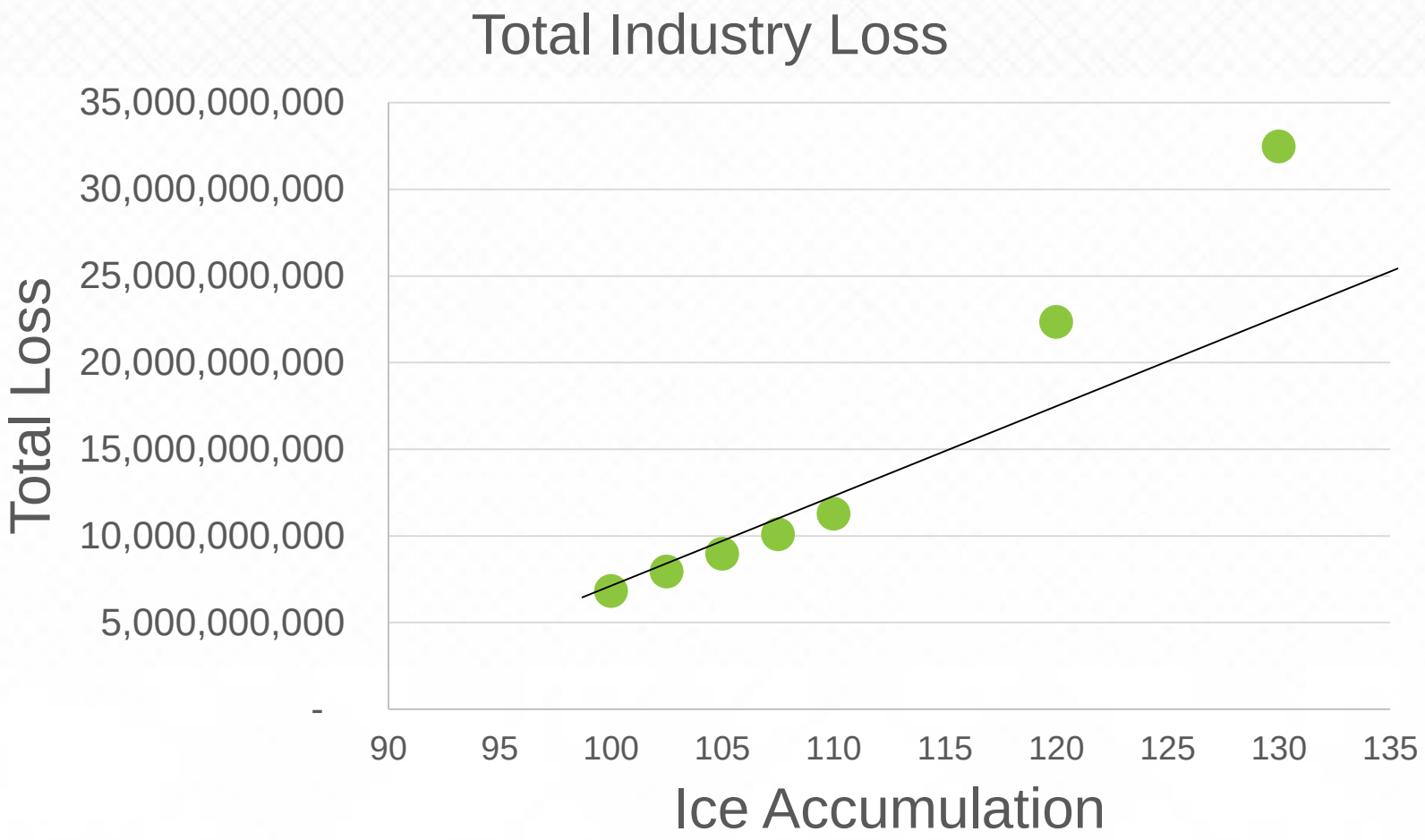
Why the Dramatic Difference in Losses?

Damage is related to maximum wind speed… but not LINEARLY…

- **Exhaustion curves may be different by intensity**
- **Certain mitigation measures fail at certain thresholds**
- **Secondary Uncertainty is a function of intensity**

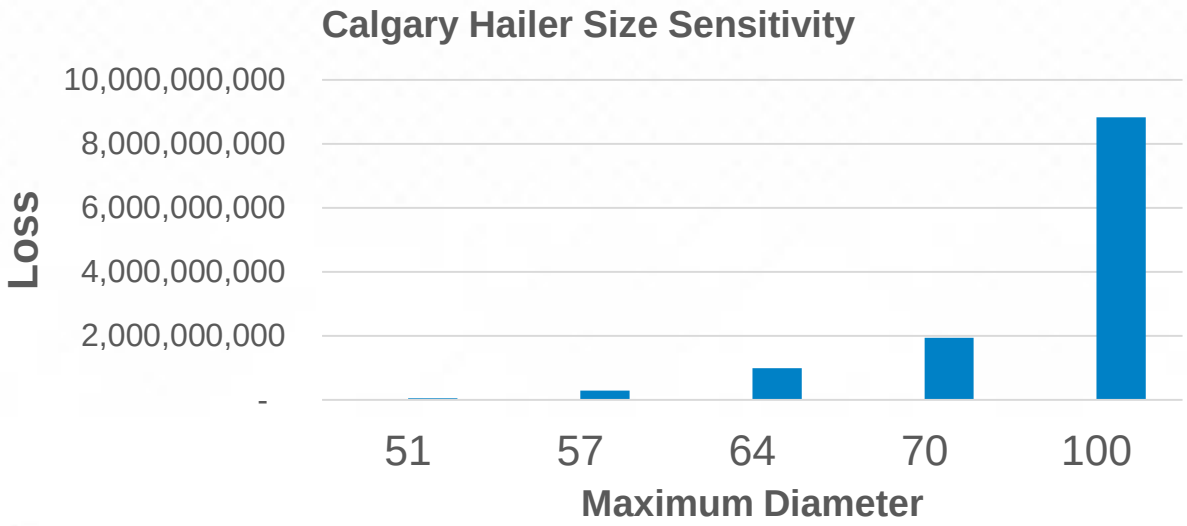


Toronto Ice Storm Intensity Sensitivity



The Calgary Hailer: Hail Size Sensitivity

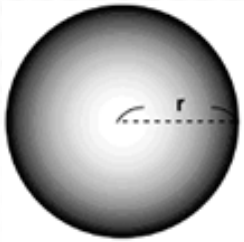
	51 mm	57 mm	64 mm	70 mm	100 mm
Avg.	46,346,813	292,594,258	989,020,434	1,939,645,424	8,824,948,113
Median	52,577,225	330,427,486	1,119,528,473	2,196,856,910	9,983,564,814
Max	75,307,116	476,751,788	1,609,533,263	3,155,400,929	14,361,999,683
Min	681,681	4,379,145	14,516,183	28,326,644	131,267,693



Let's Go Back to Classic Kinematics

$$KE = \frac{1}{2}mv^2$$

m = mass → Density x Volume
v = velocity → Gravity = Drag (v_{term})

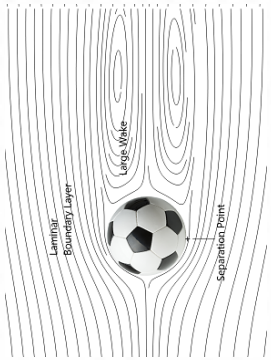


$$V = \frac{4}{3}\pi r^3$$

$$\frac{1}{6}\pi D^3$$

Making a few more assumptions…

$$v_{term} \approx 4.33 * D^{\frac{1}{2}}$$



Mass ~ D^3
Velocity ~ $D^{1/2}$

$$KE = \frac{1}{2}mv^2 \rightarrow KE \sim D^4$$

Let's Go Back to Classic Kinematics

What does this mean for hail size perturbations???



+10% Diameter → KE_{new} ~ (1.10)^4 KE_{old} → 1.5x increase in KE

+20% Diameter → KE_{new} ~ (1.20)^4 KE_{old} → 2.0x increase in KE

+400% Diameter → KE_{new} ~ (4.00)^4 KE_{old} → 256x increase in KE

Energy increase non-linearly with Diameter

Damage increases non-linearly with Energy

Putting it All Together

	51 mm	57 mm	64 mm	70 mm	100 mm
Avg.	46,346,813	292,594,258	989,020,434	1,939,645,424	8,824,948,113
Median	52,577,225	330,427,486	1,119,528,473	2,196,856,910	9,983,564,814
Max	75,307,116	476,751,788	1,609,533,263	3,155,400,929	14,361,999,683
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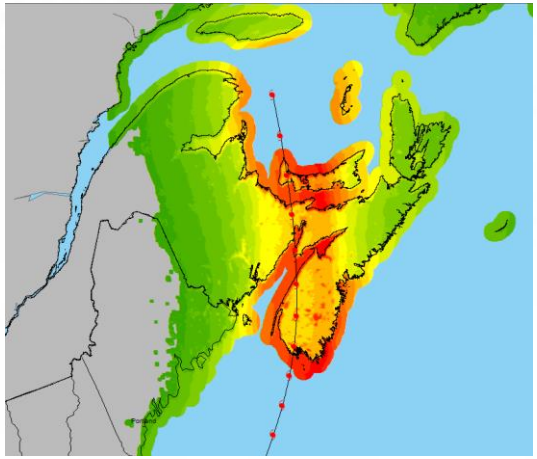
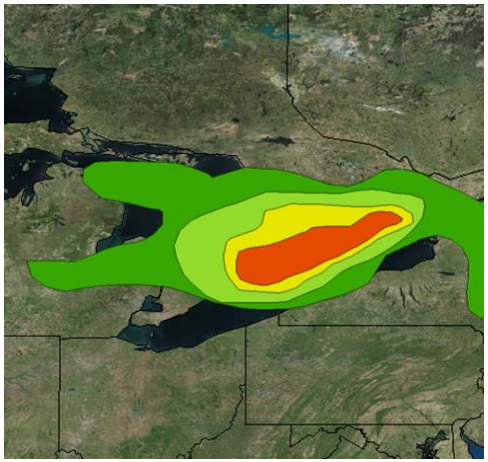
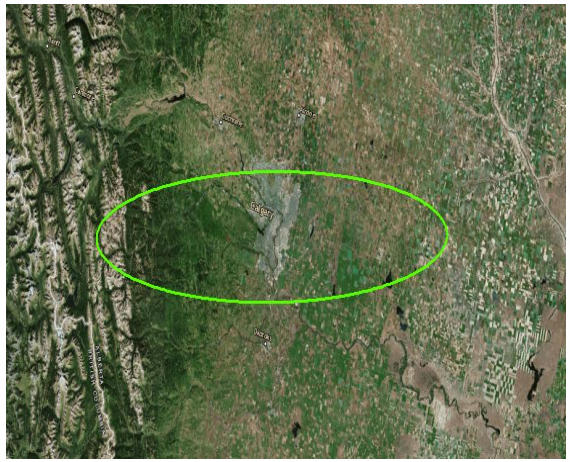


Total Loss
$32.5 Billion



Total Loss
$26.2 Billion



Total Loss
$13.6 Billion

What this Means for Risk Management

- Every generation has it's "Scenario that won't ever happen", which inevitably happens

- Robust risk management demands the examination of these events, even if their probability is very low

- Proper evaluation of the meteorology and historical experience can assist in evaluating the feasibility of these extreme scenarios

- The sensitivity (hence uncertainty) of a given event can vary greatly depending on the peril and parameter of interest.

Questions?

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