Why Ice Storms Aren't Cool:

New Research at the Hubbard Brook Experimental Forest

Lindsey Rustad, USFS

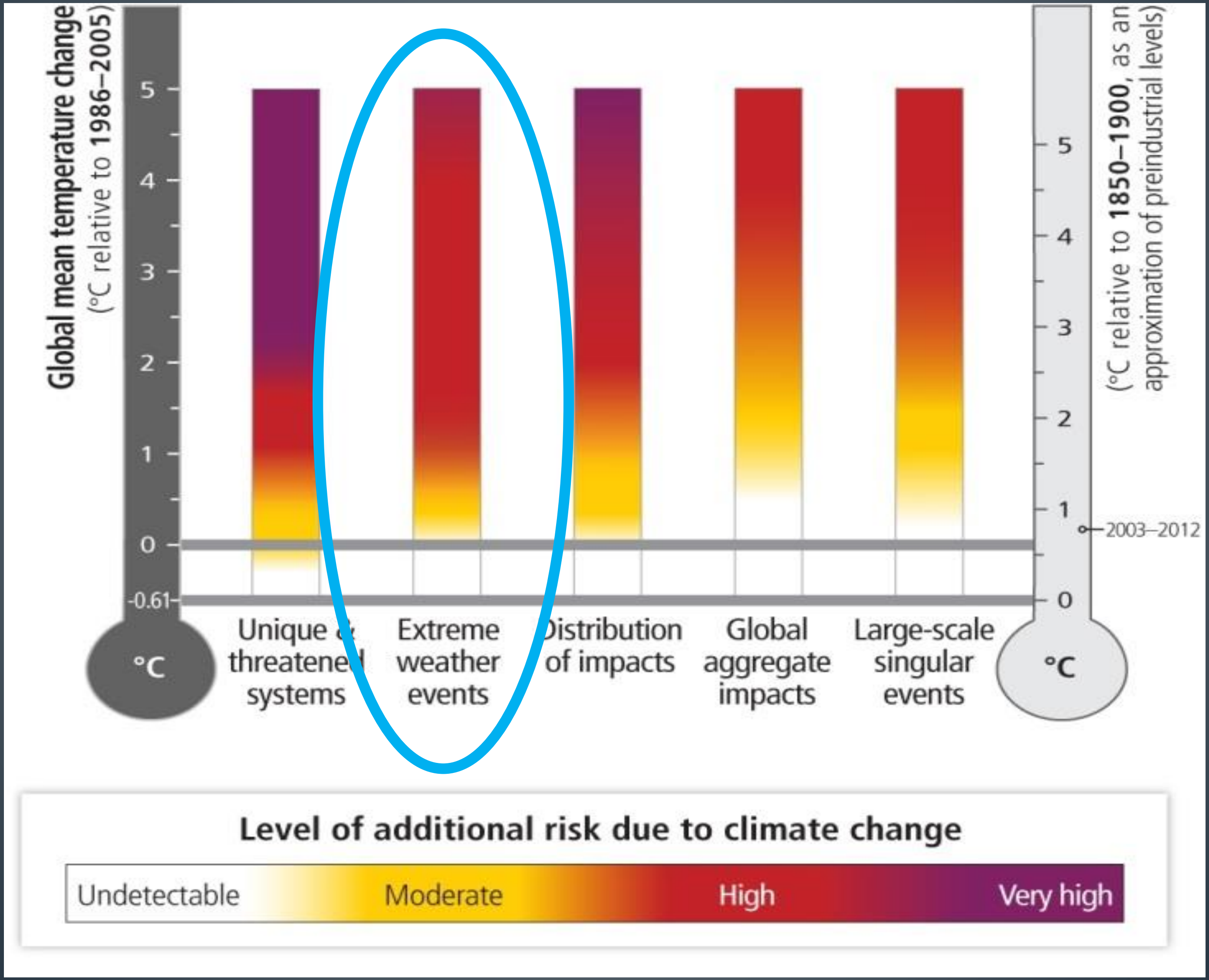
John Campbell (USFS), Charles Driscoll (Syracuse Univ), Paul Schaburg (USFS), Tm Fahey (Cornell Univ), Sarah Garlick (HBRF), Peter Groffman (Cary IES), Katharine Hayhoe (TX Tech), Robert Sanford (Univ. Southern Maine)

Ice Storms

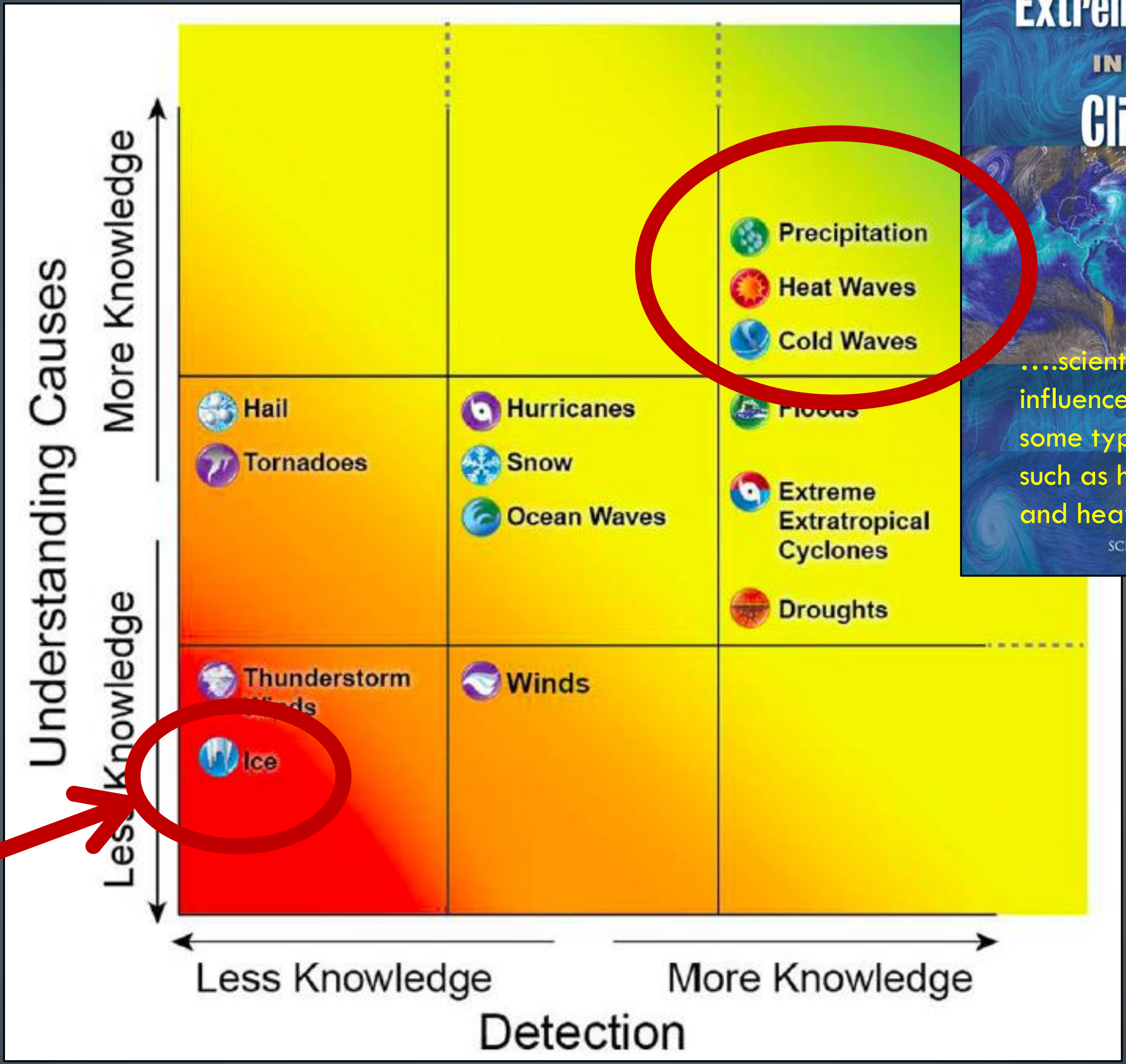
Today's Talks!

1. Why Should We Care?
2. What Do We Know?
3. What Do We Need to Know?
4. New Research & Request for Input!

Why Do We Care About Ice Storms?



Understanding of Extreme Weather I



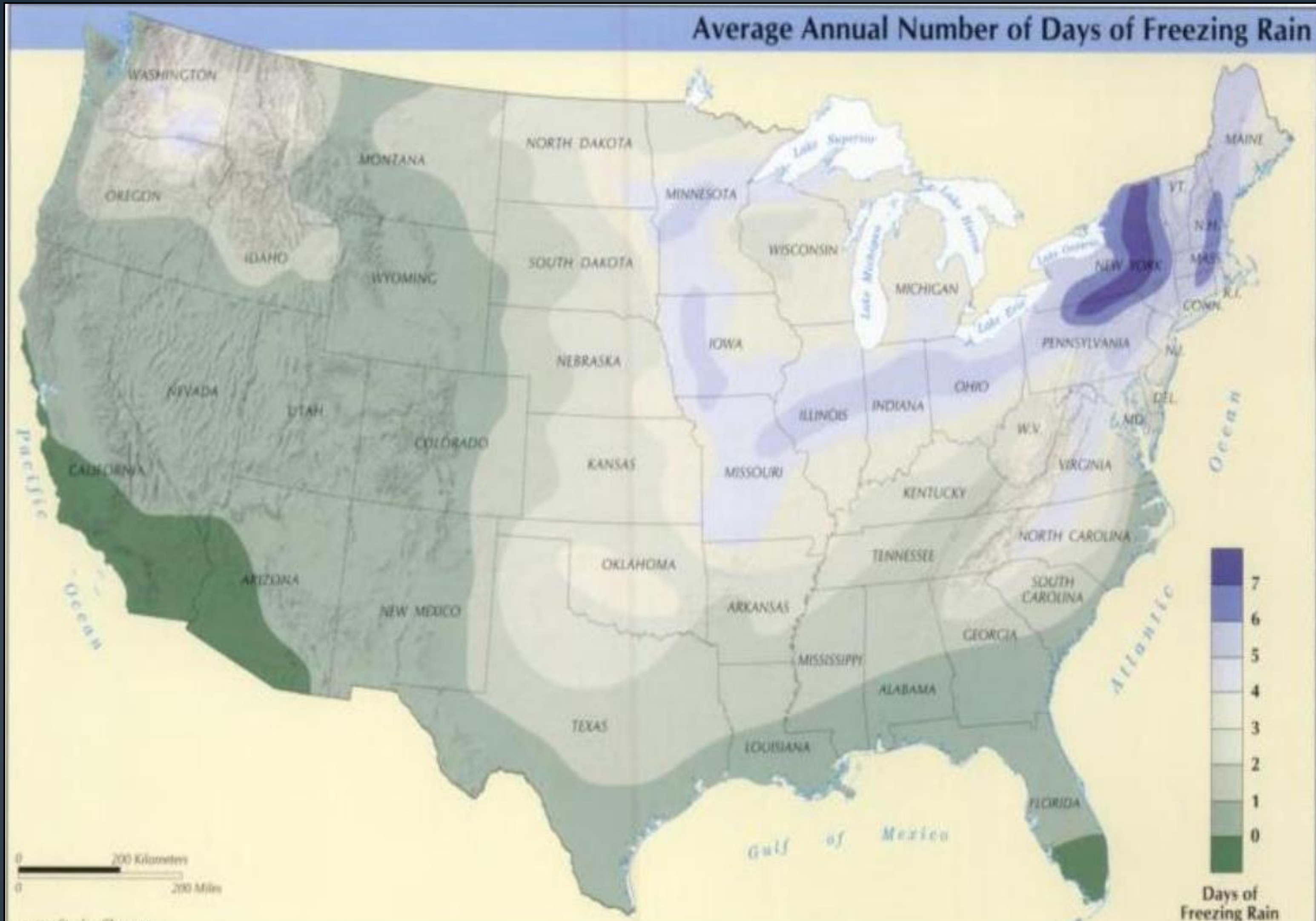
March 11, 2016

Ice Storms remain poorly understood

Why Do We Care?

Ice Storms are major agents of disturbance in north temperate and boreal forest ecosystems.

Why Do We Care?



Ice storms are prevalent in ice storm belt from TX to New England.

Why Do We Care?

Table 1. Major ice storms of the northeastern United States and Canada.

Year	Dates	Areas most affected
1886	Jan. 28-29	NH, ME
1921	Nov. 26-29	RI, MA
1929	Dec. 17-20	NY, NH, ME
1936	Mar. 17-19	NY, PA
1942	Dec. 29-30	CT, MA, VT, NH, NY
1948-49	Dec. 31-Jan. 5	NY
1953	Jan. 8-11	PA, NY, CT
1964	Dec. 4-11	NY, MA
1969	Dec. 26-27	MA, NH, VT
1973	Dec. 16-17	CT
1976	Mar. 2-5	NY
1979	Jan. 8-25	ME, NH
1983	Dec. 13-14	NY, QC
1986	Feb. 14-15	NH
1991	Mar. 3-6	NH, VT, NH, ME, QC
1998	Jan. 4-10	NY, NH, VT, CT, QC, ON
2008	Dec. 11-12	NY, NH, MA, ME, VT, CT
2013	Dec. 20-23	NY, VT, ME, QC, ON

Extreme Ice Storms have return intervals of 35-85 years

Moderate Ice storms have return intervals of 5-10 years

Why Do We Care?

- Account for roughly 60% of winter storm losses within the United States.

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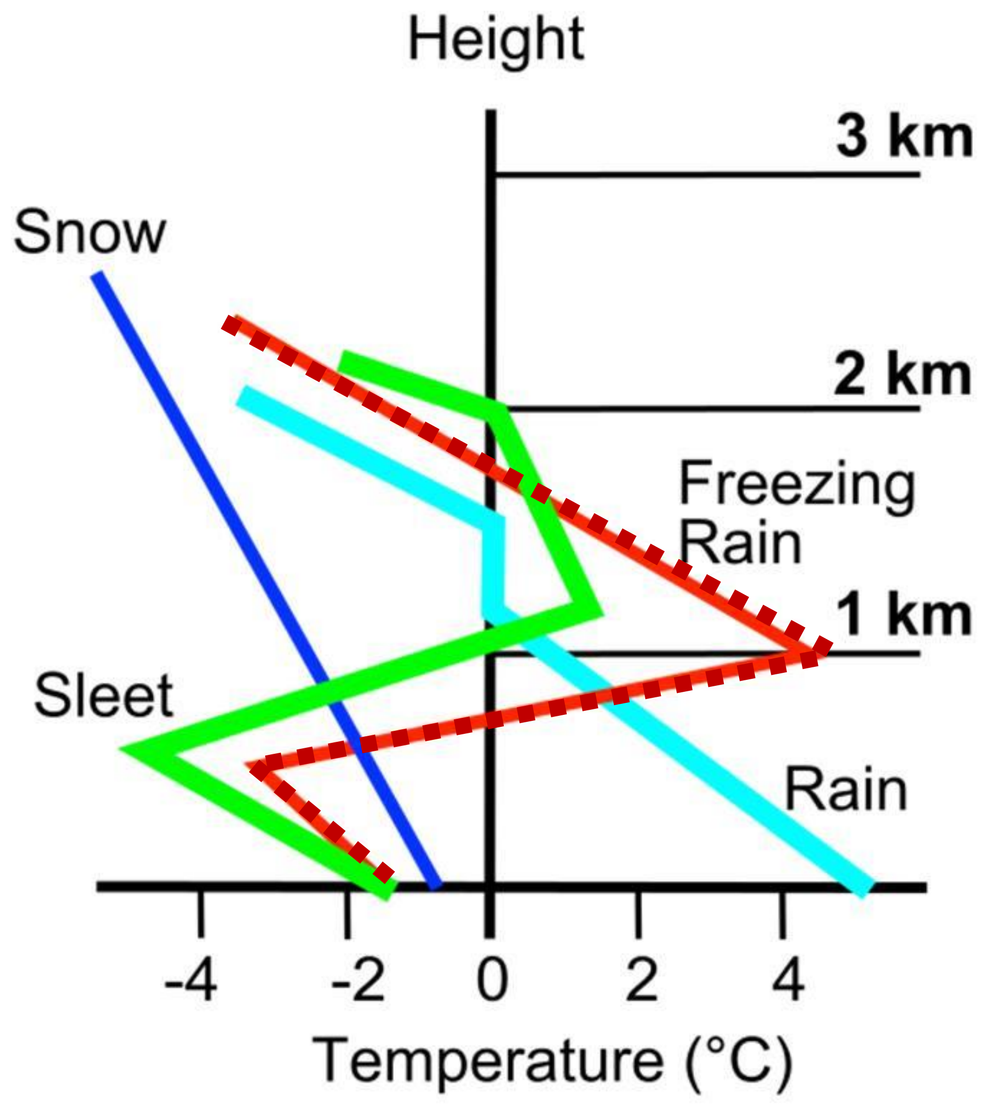
- Account for roughly 60% of winter storm losses within the United States.
- Have caused more than $16.3 billion in insured property losses between 1949 and 2000.
- Major infrastructure disruption.
- Loss of Life.



Local Conditions for Ice Storms

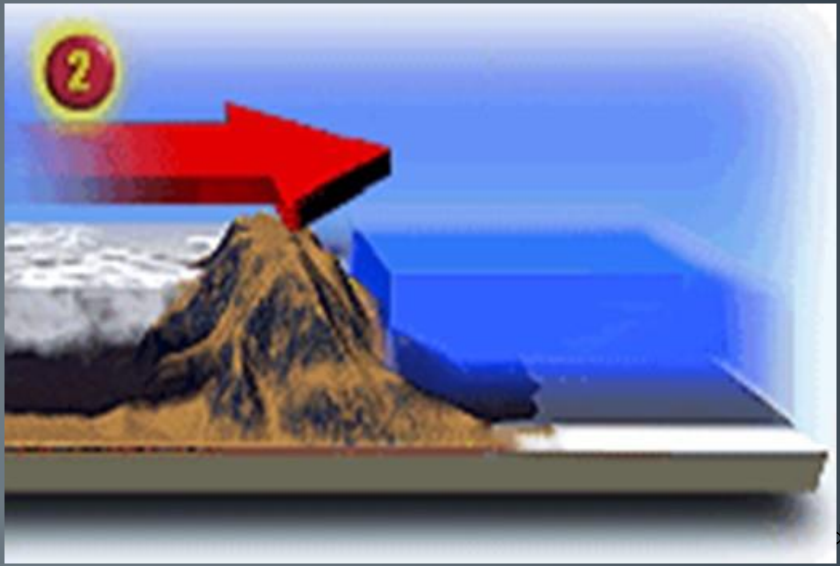


Cold Air

Warm Air

Cold Air

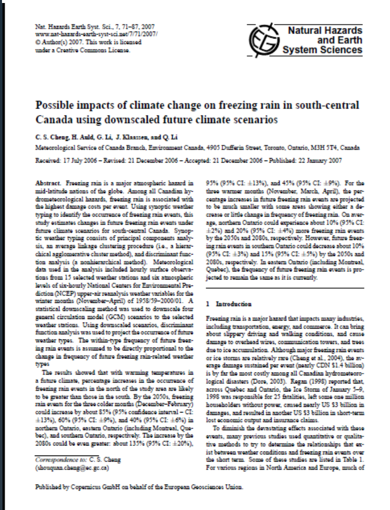
Cold Air Damming/Override



day)

Future Projections

Cheng et al. 2007



Nat. Hazards Earth Syst. Sci., 7, 71–87, 2007
www.nat-hazards-earth-syst-sci.net/7/71/2007/

Natural Hazards and Earth System Sciences

Possible impacts of climate change on freezing rain in south-central Canada using downscaled future climate scenarios

C. S. Cheng, H. Auld, G. Li, J. Klaassen, and Q. Li
Meteorological Service of Canada Branch, Environment Canada, 4905 Dufferin Street, Toronto, Ontario, M3H 5T4, Canada

Received: 17 July 2006 – Revised: 21 December 2006 – Accepted: 21 December 2006 – Published: 22 January 2007

Abstract. Freezing rain is a major atmospheric hazard in mid-latitude nations of the globe. Among all Canadian hydrometeorological hazards, freezing rain is associated with the highest damage costs per event. Using synoptic weather typing to identify the occurrence of freezing rain events, this study estimates changes in future freezing rain events under future climate scenarios for south-central Canada. Synoptic weather typing consists of principal components analysis, an average linkage clustering procedure (i.e., a hierarchical agglomerative cluster method), and discriminant function analysis (a nonhierarchical method). Meteorological data used in the analysis included hourly surface observations from 15 selected weather stations and six atmospheric levels of six-hourly National Centers for Environmental Prediction (NCEP) upper-air reanalysis weather variables for the winter months (November–April) of 1958/59–2000/01. A statistical downscaling method was used to downscale four general circulation model (GCM) scenarios to the selected weather stations. Using downscaled scenarios, discriminant function analysis was used to project the occurrence of future weather types. The within-type frequency of future freezing rain events is assumed to be directly proportional to the change in frequency of future freezing rain-related weather types.

The results showed that with warming temperatures in a future climate, percentage increases in the occurrence of freezing rain events in the north of the study area are likely to be greater than those in the south. By the 2050s, freezing rain events for the three colder months (December–February) could increase by about 85% (95% confidence interval – CI: ±13%), 60% (95% CI: ±9%), and 40% (95% CI: ±6%) in northern Ontario, eastern Ontario (including Montreal, Quebec), and southern Ontario, respectively. The increase by the 2080s could be even greater: about 135% (95% CI: ±20%), 95% (95% CI: ±13%), and 45% (95% CI: ±9%). For the three warmer months (November, March, April), the percentage increases in future freezing rain events are projected to be much smaller with some areas showing either a decrease or little change in frequency of freezing rain. On average, northern Ontario could experience about 10% (95% CI: ±2%) and 20% (95% CI: ±4%) more freezing rain events by the 2050s and 2080s, respectively. However, future freezing rain events in southern Ontario could decrease about 10% (95% CI: ±3%) and 15% (95% CI: ±5%) by the 2050s and 2080s, respectively. In eastern Ontario (including Montreal, Quebec), the frequency of future freezing rain events is projected to remain the same as it is currently.

1 Introduction

Freezing rain is a major hazard that impacts many industries, including transportation, energy, and commerce. It can bring about slippery driving and walking conditions, and cause damage to overhead wires, communication towers, and trees due to ice accumulation. Although major freezing rain events or ice storms are relatively rare (Cheng et al., 2004), the average damage sustained per event (nearly CDN $1.4 billion) is by far the most costly among all Canadian hydrometeorological disasters (Dore, 2003). Regan (1998) reported that, across Quebec and Ontario, the Ice Storm of January 5–9, 1998 was responsible for 25 fatalities, left some one million householders without power, caused nearly US $3 billion in damages, and resulted in another US $3 billion in short-term lost economic output and insurance claims.

To diminish the devastating effects associated with these events, many previous studies used quantitative or qualitative methods to try to determine the relationships that exist between weather conditions and freezing rain events over the short term. Some of these studies are listed in Table 1. For various regions in North America and Europe, much of

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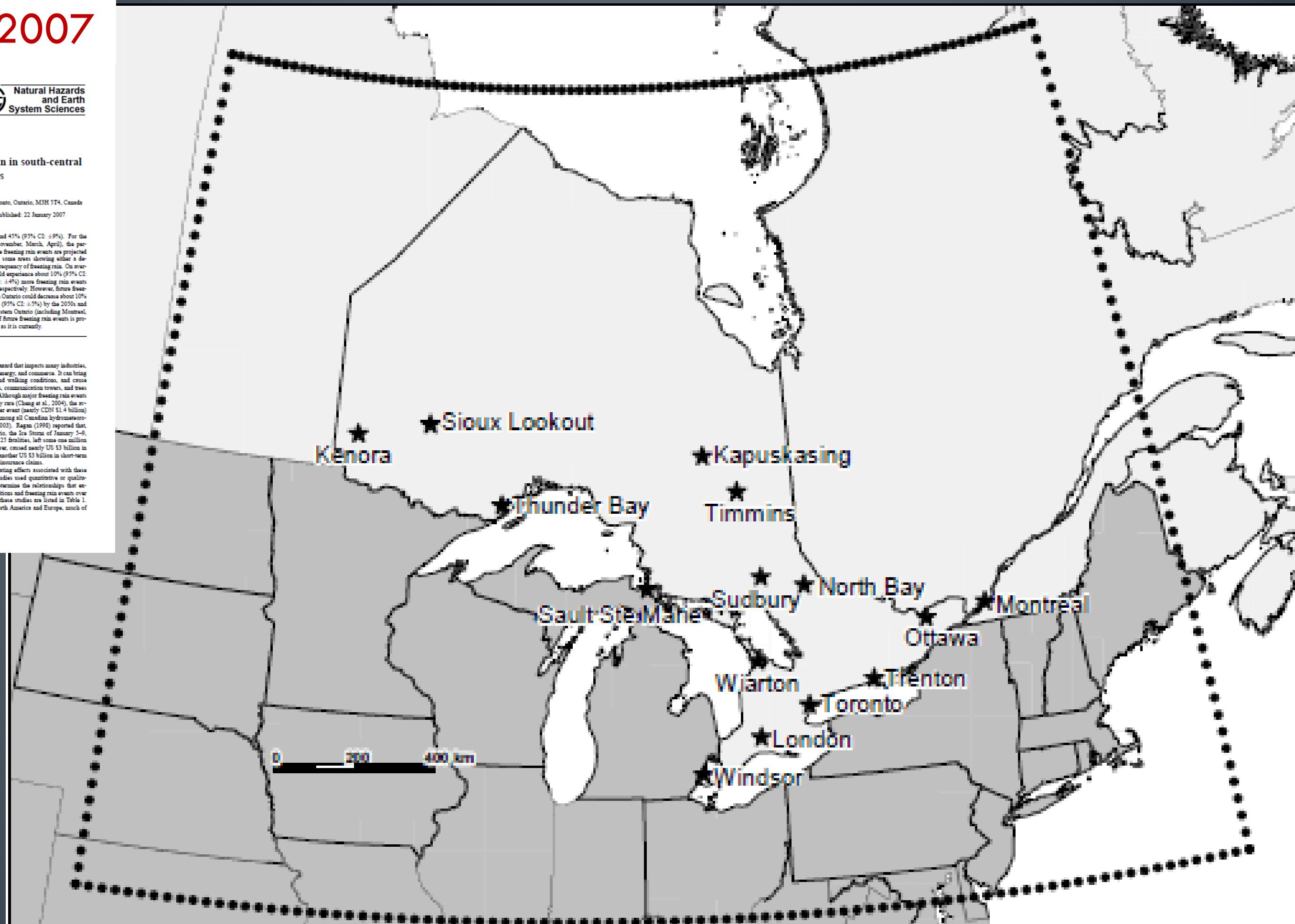


Used statistical downscaling techniques for 15 sites during period 1959 – 2001.

Future Projections

Cheng et al. 2007

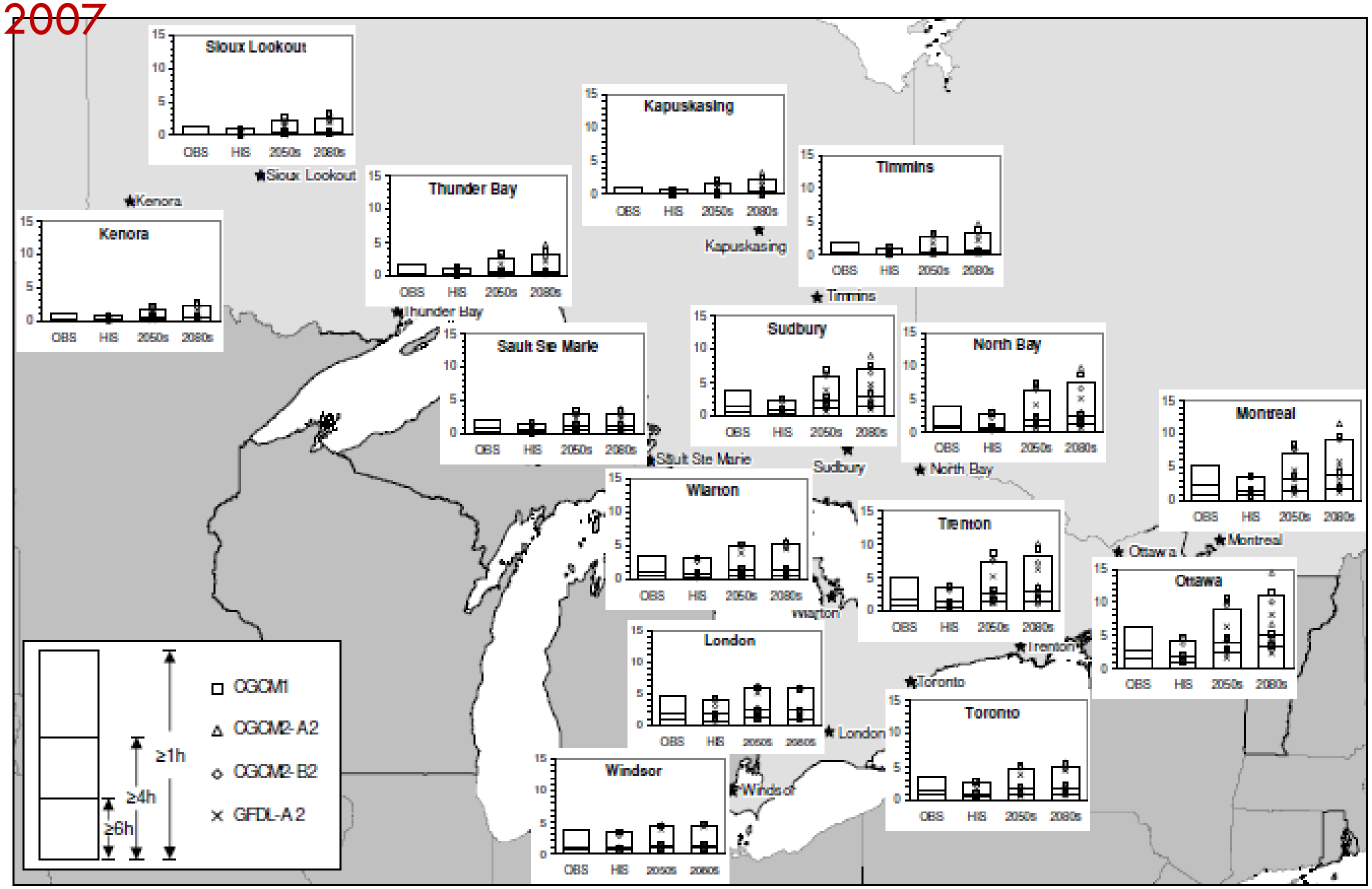
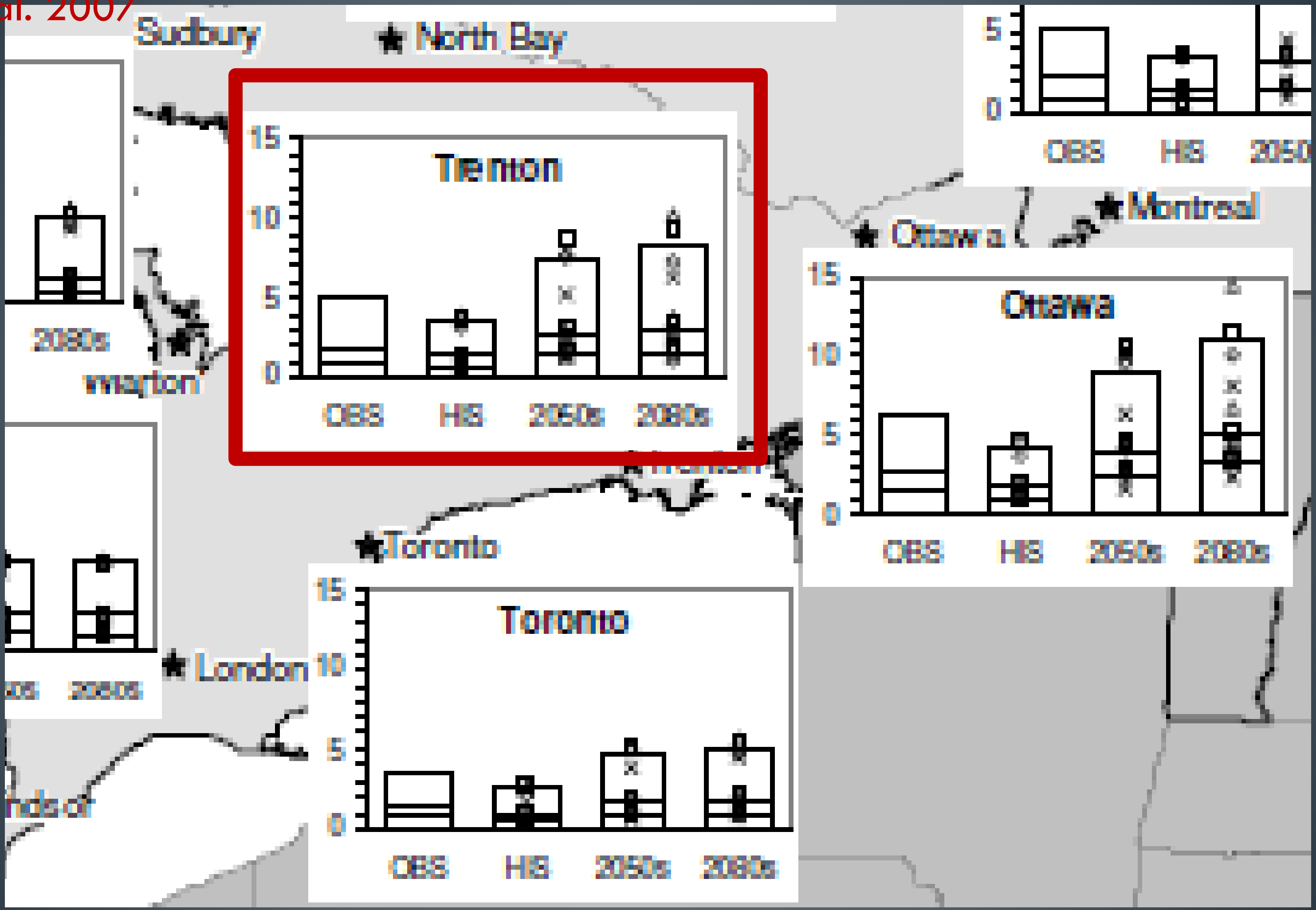


Fig. 5. Mean three-month total number of freezing rain events that occurred ≥1, ≥4, and ≥6 h during a day under the current climate during the period December–February, 1961–2000 (the left two bars) and future time periods (2040–2069, 2070–2089) (the right two bars). OBS represents observation and HIS is CGCM historical runs.

Statistical downscaling techniques suggest 40-85% increase in freezing rain by 2050s

Future Projections

Cheng et al. 2007



Statistical downscaling techniques suggest 40-85% increase in freezing rain by 2050s

Forest Susceptibility to Ice Storm Damage

Tree Characteristics

- Mechanical properties of wood
- Canopy architecture
- Hardwood vs softwood
- Rooting Depth
- Regeneration Pattern

Weather Variables

- Temperature during storm
- Temperature after storm
- Soil moisture/saturation prior to storm
- Wind speed and duration after storm

"The Ice Storm" of 1998

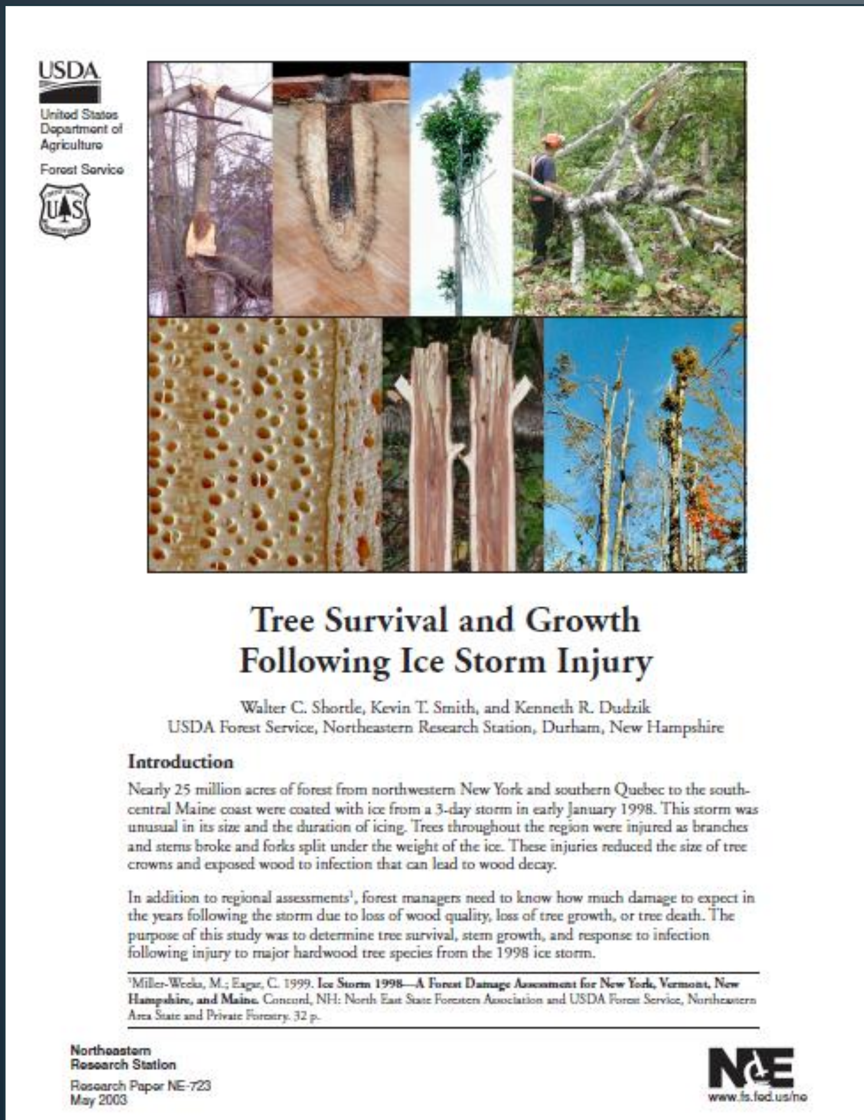
- Jan 4 – 10, 1998
- Northeastern US and southeastern Canada
- >40,000 sq miles
- 3.1 – 5.1 inches ice
- ~ $2.2 Billion
- 44 fatalities

"The Ice Storm" of 1998

Hubbard Brook Studies

- Canopy leaf area (Rhoads et al. 2002).
- Canopy structure, regeneration, and species composition (Weeks et al. 2009).
- Fine roots (Rhoads et al. 2002).
- Soil temperature, (Likens et al. 2004).
- Soil moisture and N dynamics (Houlton et al. 2003).
- Soil solution and stream water nitrate (NO_3^-) (Houlton et al. 2003).

"The Ice Storm" of 1998



USDA
United States Department of Agriculture
Forest Service

Tree Survival and Growth Following Ice Storm Injury

Walter C. Shortle, Kevin T. Smith, and Kenneth R. Dudzik
USDA Forest Service, Northeastern Research Station, Durham, New Hampshire

Introduction

Nearly 25 million acres of forest from northwestern New York and southern Quebec to the south-central Maine coast were coated with ice from a 3-day storm in early January 1998. This storm was unusual in its size and the duration of icing. Trees throughout the region were injured as branches and stems broke and forks split under the weight of the ice. These injuries reduced the size of tree crowns and exposed wood to infection that can lead to wood decay.

In addition to regional assessments[1], forest managers need to know how much damage to expect in the years following the storm due to loss of wood quality, loss of tree growth, or tree death. The purpose of this study was to determine tree survival, stem growth, and response to infection following injury to major hardwood tree species from the 1998 ice storm.

[1]Miller-Weeks, M.; Eagar, C. 1999. **Ice Storm 1998—A Forest Damage Assessment for New York, Vermont, New Hampshire, and Maine.** Concord, NH: North East State Foresters Association and USDA Forest Service, Northeastern Area State and Private Forestry. 32 p.

Northeastern Research Station
Research Paper NE-723
May 2003
www.fs.fed.us/ne

Regional Studies

- 90-100% least damage maple and ash survived
- Trees that lost < ½ crown survived
- Trees that were healthier to start with survived
- Trees with deep, healthy root systems survived
- Conifers > Ash > Maple = Beech > Birch

In Sum

- Ice storms are major causes of disturbance.
- They occur around the world.
- We understand local meteorological conditions.
- We are beginning to understand larger scale conditions.
- We know something about impacts on forests.
- We have some understanding of how forests recover from these events.

What Do We Need to Know?

- What will be future occurrences, extent, and severity of ice storms?
- What are the short-term direct and indirect physical and biogeochemical impacts of ice storms?
- What are longer-term legacy effects on forest structure and function?

New Ice Storm Experiments

ISE

ice storm

experiment

Trials - 2010

Pilot ISE - 2011

A novel ice storm manipulation experiment in a northern hardwood forest

Lindsey E. Rustad and John L. Campbell

Abstract: Ice storms are an important natural disturbance within forest ecosystems of the northeastern United States. Current models suggest that the frequency and severity of ice storms may increase in the coming decades in response to changes in climate. Because of the stochastic nature of ice storms and difficulties in predicting their occurrence, most past investigations of the ecological effects of ice storms across this region have been based on case studies following major storms. Here we report on a novel alternative approach where a glaze ice event was created experimentally under controlled conditions at the Hubbard Brook Experimental Forest, New Hampshire, USA. Water was sprayed over a northern hardwood forest canopy during February 2011, resulting in 7–12 mm radial ice thickness. Although this is below the minimum cutoff for ice storm warnings (13 mm of ice) issued by the US National Weather Service for the northeastern United States, this glaze ice treatment resulted in significant canopy damage, with 142 and 218 g $C \cdot m^{-2}$ of fine and coarse woody debris (respectively) deposited on the forest floor, a significant increase in leaf-on canopy openness, and increases in qualitative damage assessments following the treatment. This study demonstrates the feasibility of a relatively simple approach to simulating an ice storm and underscores the potency of this type of extreme event in shaping the future structure and function of northern hardwood forest ecosystems.

Résumé : Les tempêtes de verglas sont la cause d'une perturbation naturelle importante dans les écosystèmes forestiers du nord-est des États-Unis. Les modèles actuels indiquent que la fréquence et la sévérité des tempêtes de verglas pourraient augmenter au cours de la prochaine décennie en réaction aux changements climatiques. Parce que les tempêtes de verglas sont par nature aléatoire et que leur occurrence est difficile à prédire, la plupart des travaux de recherche passés portant sur les effets écologiques des tempêtes de verglas dans cette région ont été basés sur des études de cas à la suite de tempêtes majeures. Cette étude porte sur une approche alternative originale qui consiste à produire expérimentalement dans des conditions contrôlées un épisode de verglas à la forêt expérimentale de Hubbard Brook, au New Hampshire, É.-U. La canopée d'une forêt de feuillus nordiques a été arrosée avec de l'eau en février 2011 provoquant la formation de glace dont l'épaisseur radiale a atteint 7 à 12 mm. Bien que cela soit sous le seuil minimal (13 mm de glace) pour que le Service météorologique nationale des États-Unis lance un avis de tempête de verglas pour le nord-est des États-Unis, ce traitement a provoqué des dommages importants entraînant le dépôt sur la couverture morte de respectivement 142 et 218 g $C \cdot m^{-2}$ de débris ligneux fins et grossiers, une augmentation significative de l'ouverture de la canopée feuillue et des augmentations dans les évaluations des dommages qualitatifs à la suite du traitement. Cette étude démontre la faisabilité d'une approche relativement simple pour simuler une tempête de verglas et fait ressortir la capacité de ce type d'événement extrême d'influencer de façon déterminante la structure et la fonction à venir des écosystèmes forestiers de feuillus nordiques.

[Traduit par la Rédaction]

Introduction

Extreme events

Human-induced climate change has the potential to alter the prevalence and severity of extreme climate events such as heat waves, cold waves, wind storms, floods, and droughts (IPCC 2007). A growing recognition and concern exists within the global change community that these types of events can have equal — or greater — impact on natural and managed systems than the more gradual change in means that are typically associated with climate change (Katz and Brown 1992; Dale et al. 2001; Arnone et al. 2011). Although considerable advances have been made in the past few decades on understanding and modeling the impacts of gradual or small step increases in single and multiple drivers of global change on terrestrial and aquatic ecosystems (Rustad 2006, 2008; Luo and Hui 2008; Leuzinger et al. 2011), less is known about short- and longer term consequences of extreme events. These events pose a unique challenge to the research and modeling community due to their heterogeneous nature in time and space. By definition, they have relatively long return intervals (e.g., "the 100 year flood") and although we can identify broad regions susceptible to different natural disturbance regimes (e.g., areas popularly known as "hurricane alley" in the mid-Atlantic ocean, or "the ice belt" of North America), the actual occurrence is often local and regionally patchy. Long-term research and monitoring programs at a single site, such as those that have been effective at docu-

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Lindsey Rustad and John Campbell

US Forest Service

Experimental Design

4 plots (15 X 15 m)

2 treatment and 2 reference

Measurements

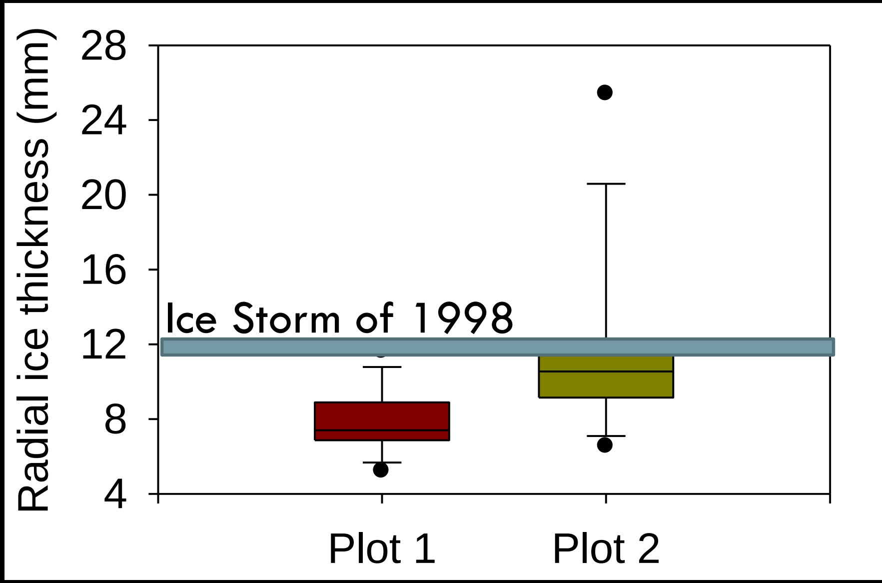
- Ice thickness
- Throughfall
- Fine litter
- Coarse litter
- Crown damage assessment
- Hemispherical photographs

Feb 9, 2011 from 7:00 to 10:30am (1:45 on each plot)

Temperature range (7 to 16 °F)

Spray reached top of canopy (~60 ft)

Ice Accretion

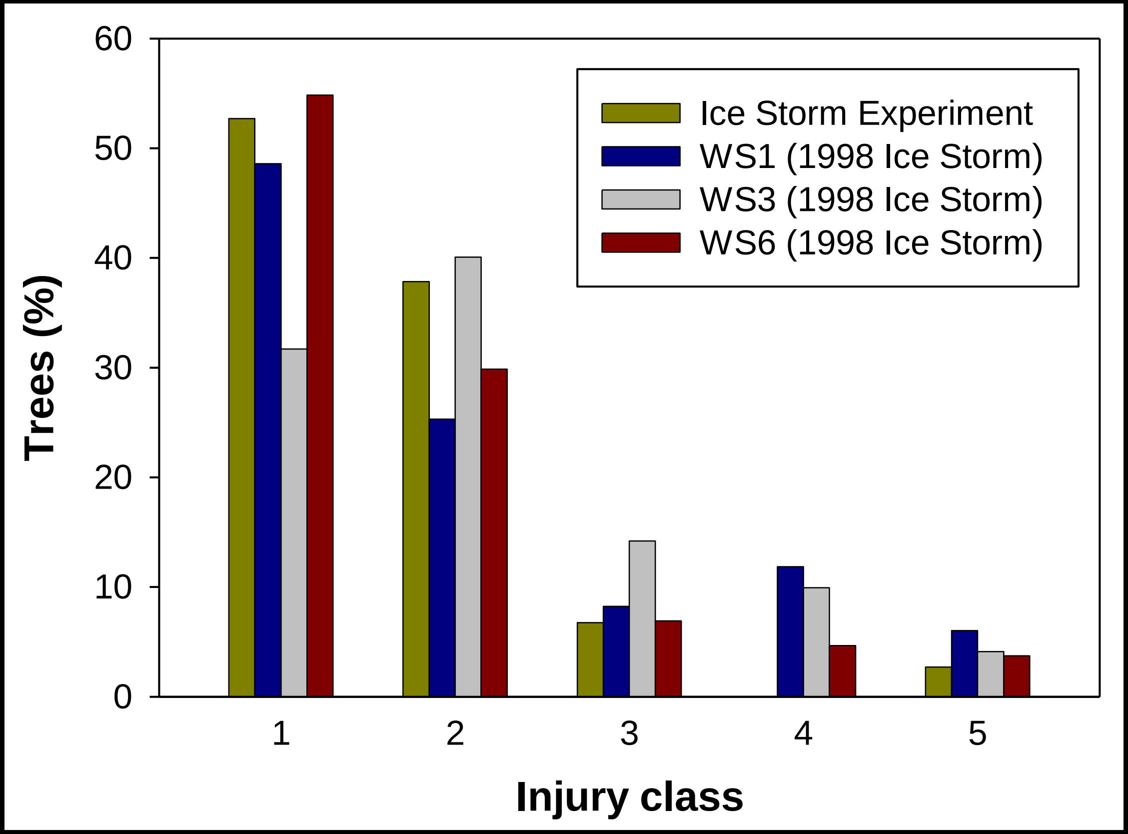


Fine and Coarse Litter (g C m^{-2})

	Ice Storm Experiment	1998 Ice Storm*	Annual Mean*
Fine Litter (<2 cm)	142 ± 29	—	171
Coarse Litter (>2 cm)	217 ± 107	434**	20

*Fahey et al. 2005
**Most severely damaged zone

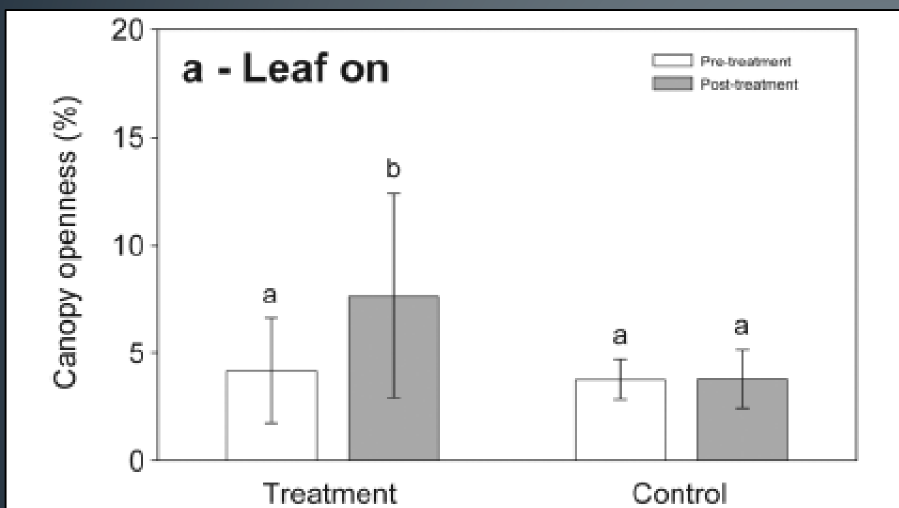
Crown Injury

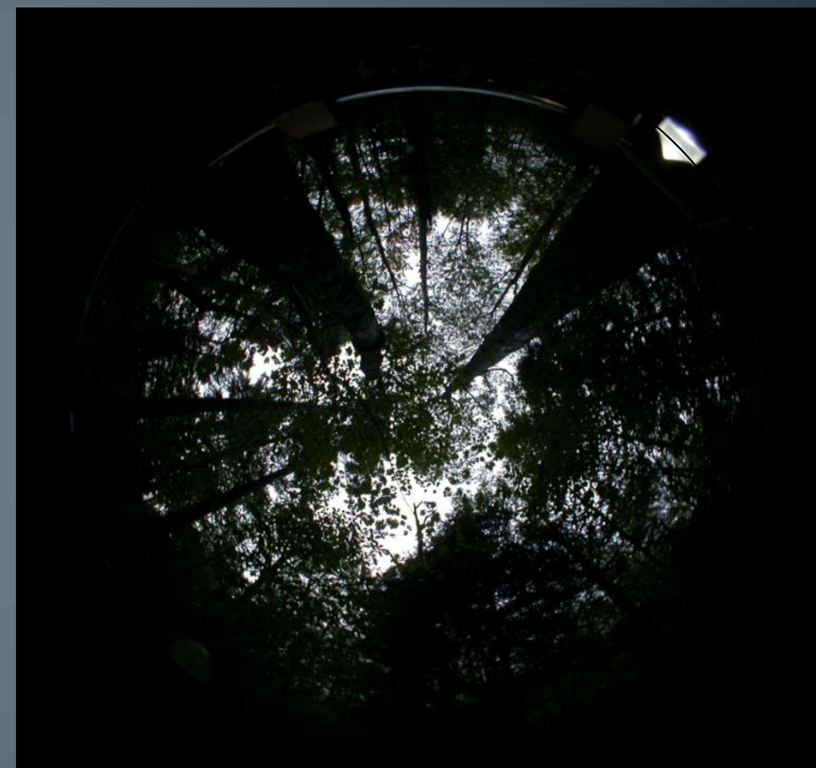


Injury classes:

1 = no damage
2 = 1-50%
3 = 50-75%
4 = 75-99%
5 = dead

Hemispherical photographs





Pilot ISE - 2011

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Corresponding author: Lindsey E. Rustad (e-mail: lrustad@fs.fed.us).

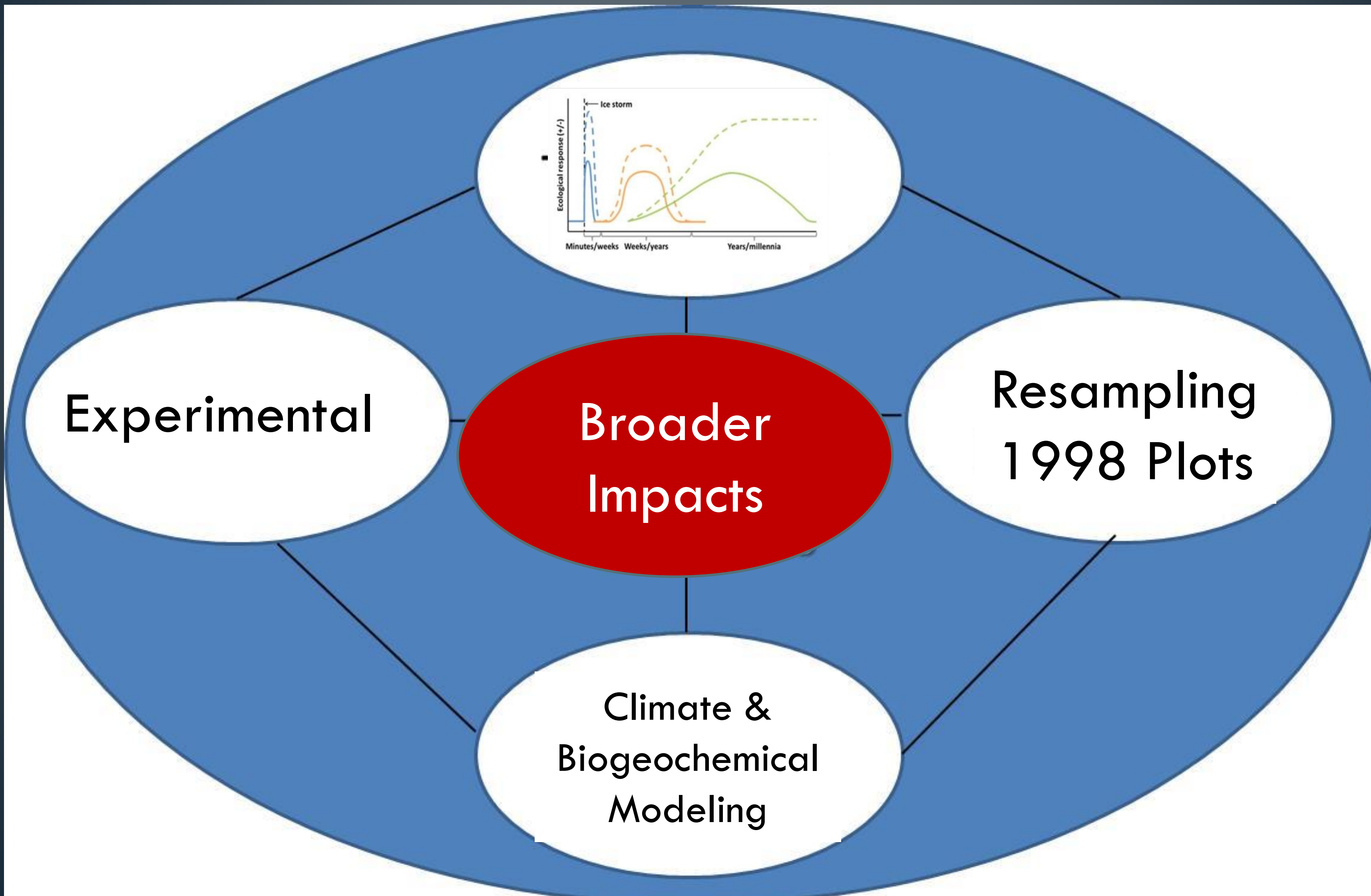
Understanding the Impacts of Ice Storms on Forest Ecosystems of the Northeastern United States

PIs:

Lindsey Rustad
John Campbell
Charles Driscoll
Tim Fahey
Sarah Garlick
Peter Groffman
Katharine Hayhoe
Robert Sanford
Paul Schaburg

ISE Crew 2015

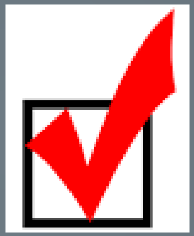
Full ISE!


Ice storm
Ecological response (+/-)
Minutes/weeks
Weeks/years
Years/millennia
Experimental
Broader Impacts
Resampling 1998 Plots
Climate & Biogeochemical Modeling

Global Climate Models

Do we expect to see a change in frequency and severity of ice storms in the northeastern US?

1. Use advanced machine learning techniques to build classification models to determine large-scale atmospheric circulation patterns resulting in ice storms.



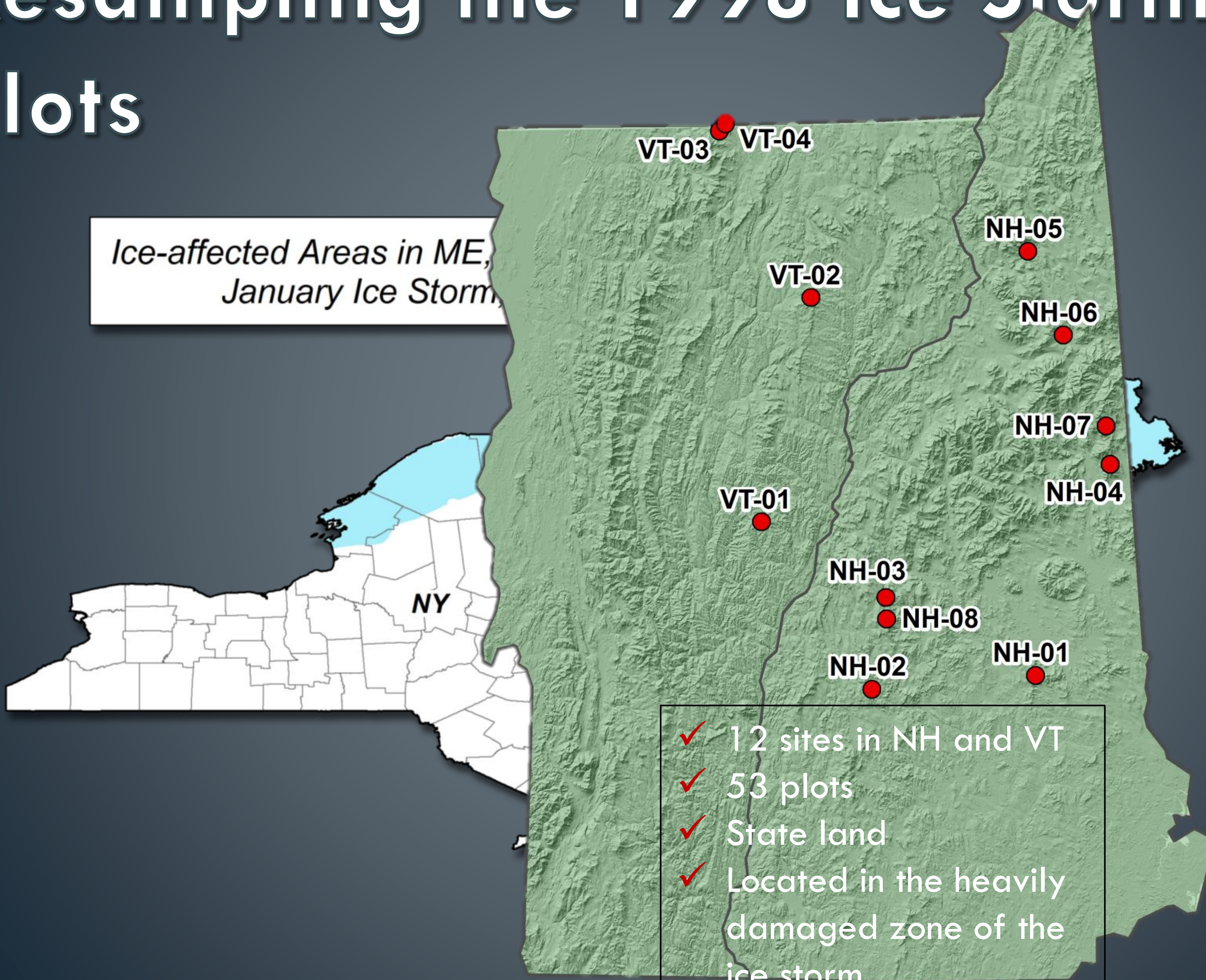
2. Apply classification models to global climate models (GCM) to hind cast ice storms.
3. Apply classification models to GCMs to project future occurrence of ice storms.

Katharine Hayhoe

Resampling the 1998 Ice Storm Plots

How have northeastern forests recovered from the Ice Storm of 1998 18 years later?

Resampling the 1998 Ice Storm Plots



- 12 sites in NH and VT
- 53 plots
- State land
- Located in the heavily damaged zone of the ice storm

Will provide insights on forest resilience to an ice storm

John Campbell

Sarah Geromini

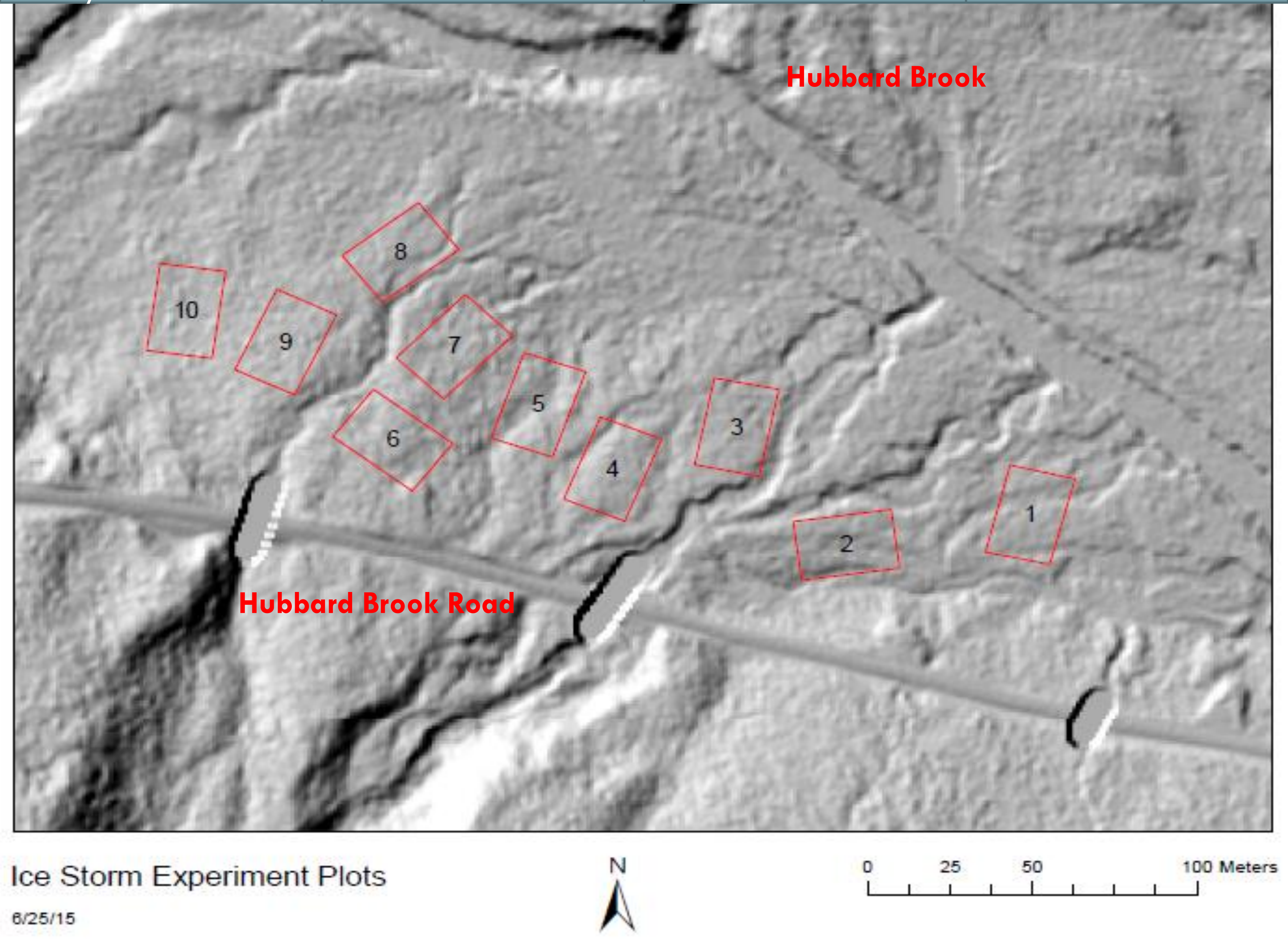
John Campbell

Ice Storm Experiment

A Field Plot Study to Evaluate the Effects of a Simulated Ice Storm on a Northern Hardwood Forest at Hubbard Brook

Approach:

- 10 60 x 90 ft plots in Hubbard Brook Valley
- Treatments:
  1. reference
  2. 0.25 inch glaze ice in one event in year 1
  3. 0.5 inch glaze ice in one event in year 1
  4. 0.75 inch glaze ice in one event in year 1
  5. 0.5 inch glaze ice in one event in year 1 & 2
- Monitor soil climate, chemistry, vegetation response


Hubbard Brook
8
10
9
7
5
6
3
4
1
2
Hubbard Brook Road
Ice Storm Experiment Plots
6/25/15
N
0
25
50
100 Meters

Instruments and measurements

- **Resample Plots**
  - 2 soil respiration collars
  - Lysimeter
  - Ground water well
  - Trace gas
  - 3 soil temperature and moisture probes (5 cm, 10 cm, 30 cm)
  - Litterfall
  - Coarse woody debris (CWD)
- **Destructive Sampling Plots**
  - Root ingrowth cores
  - Nitrogen mineralization
  - Foliar and woody litter decomposition
  - CWD
- **Plot Level**
  - Foliar sampling
  - Tree cores: carbohydrate storage and dendrochronology
  - Forest Inventory
  - LAI/Canopy openness

Photo credits: Joe Klementovich


Kawasaki


DAN

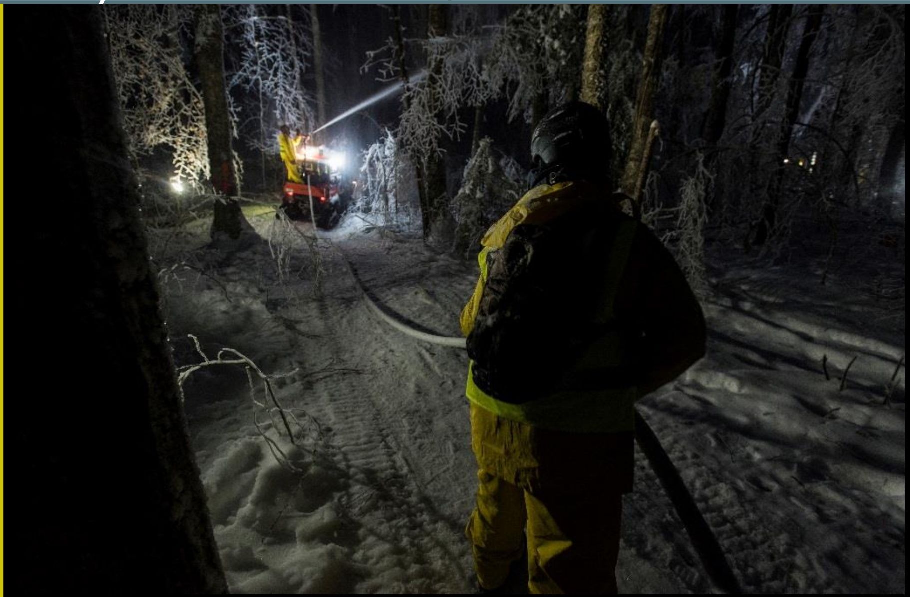


Photo credits: Joe Klementovich & Lindsey Rustad


LET'S
DO
THIS.


Retevis

Plot Data

Treatment Date	Plot	Treatment	Target Ice Diameter (in)	Measured Ice Diameter (in)	Ice Density (g/cm^3)	Throughfall depth (in)	Days of Ice on Plots
11-Feb	2	low	0.25	0.25	0.7	1.1	5
11-Feb	6	low	0.25	0.26	0.6	1.2	5
28-Jan	3	mid	0.5	0.40	0.6	2.4	6
29-Jan	10	mid	0.5	0.28	0.7	2.6	5
18-Jan	1	mid_x_2	0.5	0.38	0.8	1.4	13
18-Jan	8	mid_x_2	0.5	0.49	0.8	1.3	13
28-Jan	5	high	0.75	0.59	0.7	3.9	6
29-Jan	9	high	0.75	0.47	0.7	4.8	5

Rapid Initial Recovery from Ice Loads?

Hemispheric Photos

Before

After

Broader Impacts

1. Ice Storm Roundtable [YOU CAN HELP!]
2. Video and photography projects
3. Universal Design for Learning (UDL)


Kawasaki
https://youtu.be/81-btZTWpoA

Questions?