Understanding the Impacts of Ice Storms on Forested Ecosystems of the North Eastern and North Central Regions of the United States

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Ice storms are major causes of disturbance in northern forest ecosystems and are predicted to become more common under future climate change scenarios. This research offers novel new techniques for studying ice storm and new insights on potential future impacts.

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http://www.nsrcforest.org

Project Summary

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 followed a program of research to better understand the nature of ice storms and their impacts on northern forest ecosystems. Specifically, we: (1) convened an interdisciplinary workshop on ice storms, which included ecosystem scientists, climatologists, physical scientists, modelers, social scientists, and industry experts, to define the state-of- knowledge on ice storms, and examined the nature and extent of these storms in the Northeastern United States; (2) conducted the first ever ice storm manipulation experiment at the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire, and (3) developed machine-learning algorithms to identify the signature of ice storms in past synoptic weather systems in order to better predict the same based on future model simulations. Results highlight the significant impact these storms have had on our forest ecosystems, suggest that the frequency and severity will increase over time, and demonstrate a novel experimental tool to allow scientists to study these stochastic weather events in a controlled setting.

Background – Extreme Weather Events as the New Normal

Human-induced climate change has the potential to alter the prevalence and severity of *extreme weather events* such as heat waves, cold waves, wind storms, floods and droughts. A growing recognition exists within the global change community that these types of events can have an equal - or greater - impact on natural and managed ecosystems than the more gradual change(s in mean temperature and precipitation that are typically associated with climate change Although considerable progress has been made in understanding the ecological impacts of gradual increases in single and multiple drivers of global change, *much less is known about consequences of extreme weather events*. New experimental approaches are needed to provide in-depth understanding of cause-and-effect relationships between the severity and frequency of extreme events and ecosystem impacts.

Background – Prevalence of Ice Storms

Ice storms, also known as ‘glazing events’, are winter weather events common to temperate and boreal forest regions worldwide. In the U.S., ice storms are particularly prevalent in the broad “*ice belt*” that extends from east Texas to New England with the greatest risk for damage occurring in the northeastern states. One of the most devastating ice storms in recent history was “The Ice Storm of 1998”, which deposited up to 8^{+} cm of freezing rain across nearly 10 million hectares of land in the Northeast, extending from south-central New England to northwestern New York and southern Quebec, caused considerable damage to forests, paralyzed power grids, and left millions of people without power (Irland, 1998). Projections for the future occurrence of ice storms have been made for southeastern Canada and suggest a >40 % increase in freezing rain events by the 2050s as compared to the past 40 years.

Tree damage following the ice storm of January 1998 that affected much of the northeastern United States and southern Quebec, Canada. (Photo courtesy of U.S. Forest Service archives)

Background – Impact of Ice Storms on Forests

In forested ecosystems, ice storm damage is primarily characterized by branch and crown loss, with consequent wounding of trees, reductions in photosynthetic area, and large increases in coarse and fine woody debris. These direct impacts have a cascade of secondary effects including (i) decreased C assimilation and carbohydrate reserves needed for growth, wound closure and the production of plant protection compounds necessary to control the spread of pathogens; (ii) increased availability of C, calcium and nutrients from increased loads of decomposing organic matter; (iii) changes in microbial community composition and dynamics; (iv) increased exposure of trees to diseases and insect attack; and (v) changes in sub-canopy and forest floor light regimes and soil microclimate.

Tree damage following the ice storm injury.
(Photo courtesy of L. Rustad)

Methods

- **Spring 2011 – Ice Storm Experiment (ISE) Workshop**
  - An ISE workshop for 20 participants was convened at Hubbard Brook, NH on April 12, 2012 to discuss the most current research on ice storms on northern forest ecosystems.

- **Ice Storm Climatology**
  - We used machine-learning algorithms to identify unique ice storm climatology.

Methods

Winter 2010 – Ice Storm Trials: We successfully completed an ice storm trial, demonstrating that we could create glaze ice in forests.

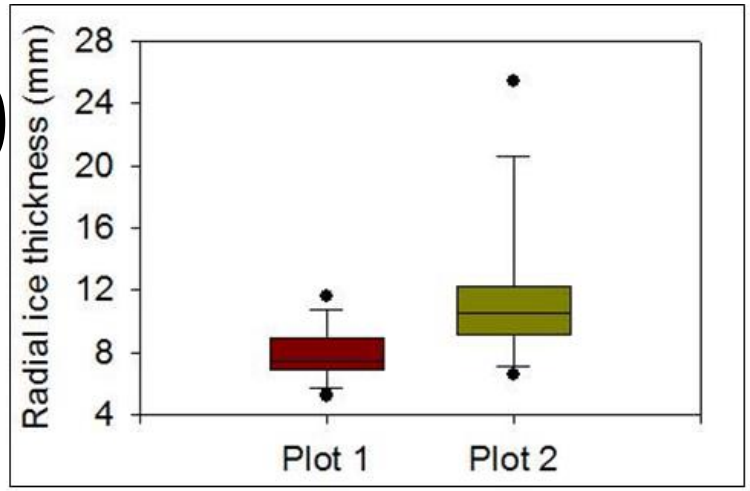
Methods

Winter 2011 – Ice Storm Experiment: We successfully completed the first ever full forest ice storm experiment, replicating the 1998 ice storm, and further demonstrating that we could create glaze ice in forests.

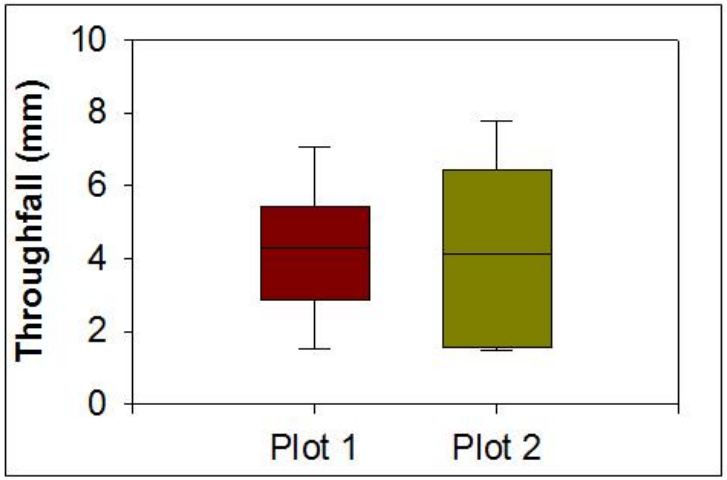
Results/Project outcomes

Ice Storm Experiment

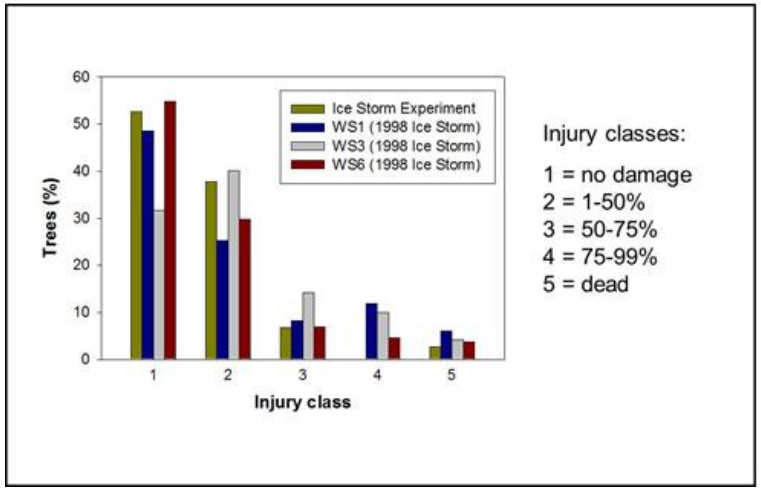
(a)



(b)



(c)



(d)

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

Results show (a) boxplots of radial ice thickness (mm), (b) boxplots of throughfall depth (mm), (c) crown injury class for experiment and 1998 ice storm, and (d) inputs of coarse and fine woody debris follow experimental ice treatments. This study demonstrated the feasibility of performing ice storm simulations in mature northern hardwood forests.

Results/Project outcomes

Ice Storm Climatology

Hayhoe and colleagues have made ground-breaking advances in developing machine learning classification algorithms for a selection of climatological variables from NOAA's high-resolution (~25 km; 3 hr intervals) North American Regional Reanalysis (NARR). *These algorithms are capable of identifying ice storms in evaluation data sets with 89% to 92% accuracy*. She has further applied these algorithms to historical simulations from two coarser-scale (~100km) global CMIP5 global circulation models (GFDL-CM3 and CCSM4) and was able to identify ice storms with accuracies ranging from xx to yy% (the lower accuracy reflecting the coarser scale of the data). ***These analyses strongly suggest that ice storms have unique synoptic-scale signatures that can be objectively identified with novel machine learning techniques.***

Implications and applications in the Northern Forest region

Ice storms are a major historical cause of forest disturbance and are expected to increase in frequency, severity, and extent in the future. As such, it is imperative to better understand the short and longer term impacts of these agents of change on the region's forests. This study demonstrated the feasibility of simulating an extreme ice storm-in a mature northern hardwood forest. Total amount of water added, ice accretion, and basic metrics of response (coarse woody debris, canopy damage assessments) were remarkably similar in the simulation compared to a natural event occurring in 1998 for which extensive site specific information was available. The experimental technique described here has the advantage that it could allow for future icing event simulations of different intensity and frequency in different forest types. Further, results from the ice storm climatology work has promise for forecasting future occurrence of these types of storms allowing for land managers and the public to be better prepared.

Given the powerful and yet aesthetic nature of ice storms, results from this study will be of interest to an unusually broad audience of scientists, forest managers, utility companies, and private land owners.

Future directions

- Modeling study – Further evaluate machine learning algorithms to predict the frequency, severity, and spatial distribution of ice storms in the future.

- Proposal for larger scale experiment – Use ice storm methodology developed in this project to more fully understand the short and longer term impacts of ice storms on a northern hardwood forest ecosystems.

List of products

- **Publications:**
  - Rustad, L.E., and Campbell, J.L. 2012. A novel ice storm manipulation experiment in a northern hardwood forest ecosystem. Canadian Journal of Forest Resources, 35:1402-1410 (selected as "Editor's Choice" for the month).
  - Rustad, L.E. and Campbell, J.L., 2011. Ice Storm Research at the Hubbard Brook Experimental Forest, Forest Service Experiment Forest and Ranges Newsletter http://www.fs.fed.us/research/efr/documents/newsletters/efr_newsletter_2011_10.pdf

- **Follow up Proposals:**
  - Fahey, T.; Rustad, L.E.; Campbell, J.L.; Shortle, W.; Schaberg, P; Groffman, P. Understanding the Impacts of Ice Storms on Forest Ecosystems of the North Eastern United States. Submitted to NSF Ecosystems, August 1, 2012 ($1,200,000; pre-proposal accepted; full proposal declined).
  - Driscoll, C.T..; Rustad, L.E.; Campbell, J.L.; Fahey, T.; W.; Schaberg, P; Hayhoe, K.. Understanding the Impacts of Ice Storms on Forest Ecosystems of the North Eastern United States. Submitted to NSF Ecosystems, January 9, 2014 (Pre-proposal under review).

- **Presentations:**
  - Rustad, L.E., and Campbell, J.L. A novel ice storm manipulation experiment in a northern hardwood forest ecosystem. BIOGEOMON, Northport Maine, July 16, 2012. (volunteered poster)
  - Rustad, L.E., and Campbell, J.L. A novel ice storm manipulation experiment in a northern hardwood forest ecosystem. Soil Science Society of America Annual Meetings, October 20-14, 2012, Cincinnati, Ohio (volunteered poster)
  - Rustad, L.E., and Campbell, J.L. A novel ice storm manipulation experiment in a northern hardwood forest ecosystem. LTER All Scientist's Meeting, September 10-13, 2012, Estes Park, Colorado (volunteered poster)