Ice Ice Baby - Predicting Freezing Rain and Wet Snow Icing Impacts

CoCoRaHS Webinar - Nov 11, 2021

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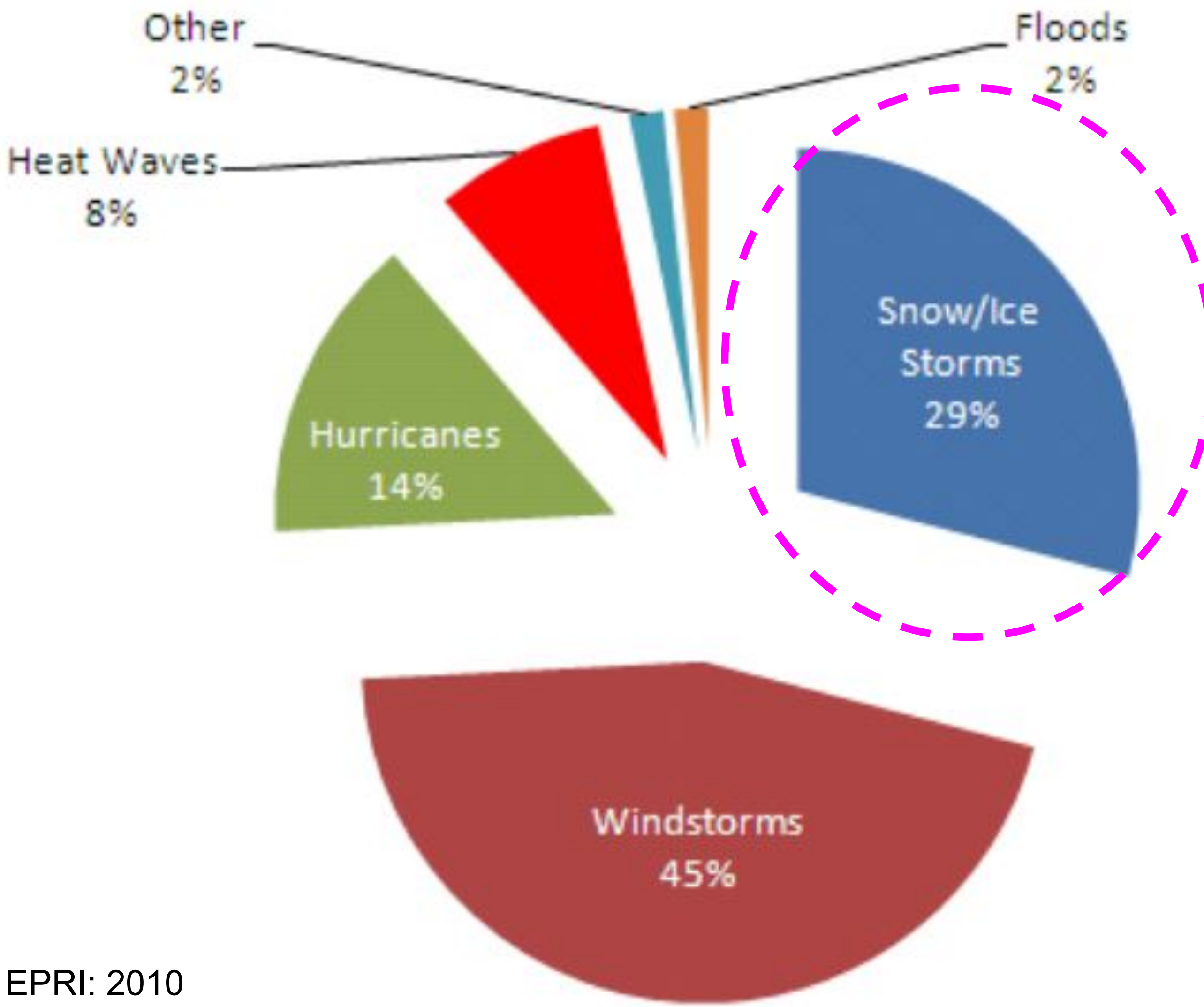
Northern Vermont UNIVERSITY

Thank you for your service - CoCoRaHS Observers!

https://media.cocorahs.org/images/CoCoRaHSCollage2020-750.png

Extreme Weather and Power Outages: USA



EPRI: 2010

Three Icing Types

1. Rime

2. Wet Snow

3. Freezing Rain

Rime Icing

- Need to be in the cloud
- More likely at higher elevations
- Ice grows into the wind as cloud droplets freeze on contact
- Difficult to predict with conventional weather forecast approaches
- Key signatures: Higher water content clouds, high winds, 20-32°F)

Wet Snow Icing

- Partially melted snow crystals stick and/or refreeze to surfaces
- Difficult to forecast fraction of snow that sticks or accretes
- Problematic on trees in/near ROW
- Key signatures: higher water content, isothermal atmosphere, rain to snow transitions, temps remaining around ~32°F)


Elíasson et al. (2000)


Montpelier Police Department
Like Page

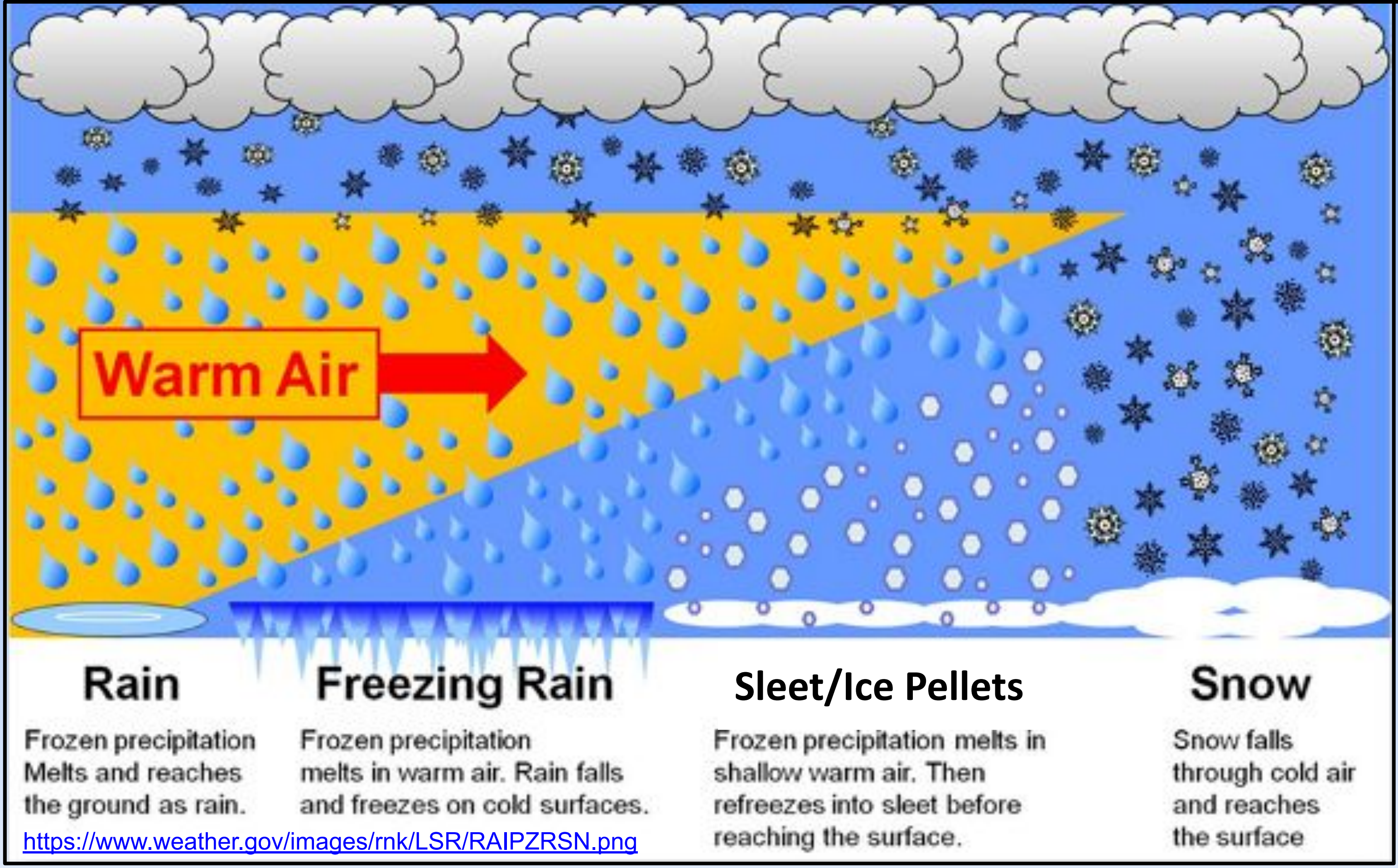
Freezing Rain Icing

- Most studied icing
- Rain freezes on contact, after falling through subfreezing layer
- Efficiency of ice formation depends on:
  - Air temperature
  - Wind speed
  - Precipitation rate
  - Material characteristics

Near Freezing Temperatures

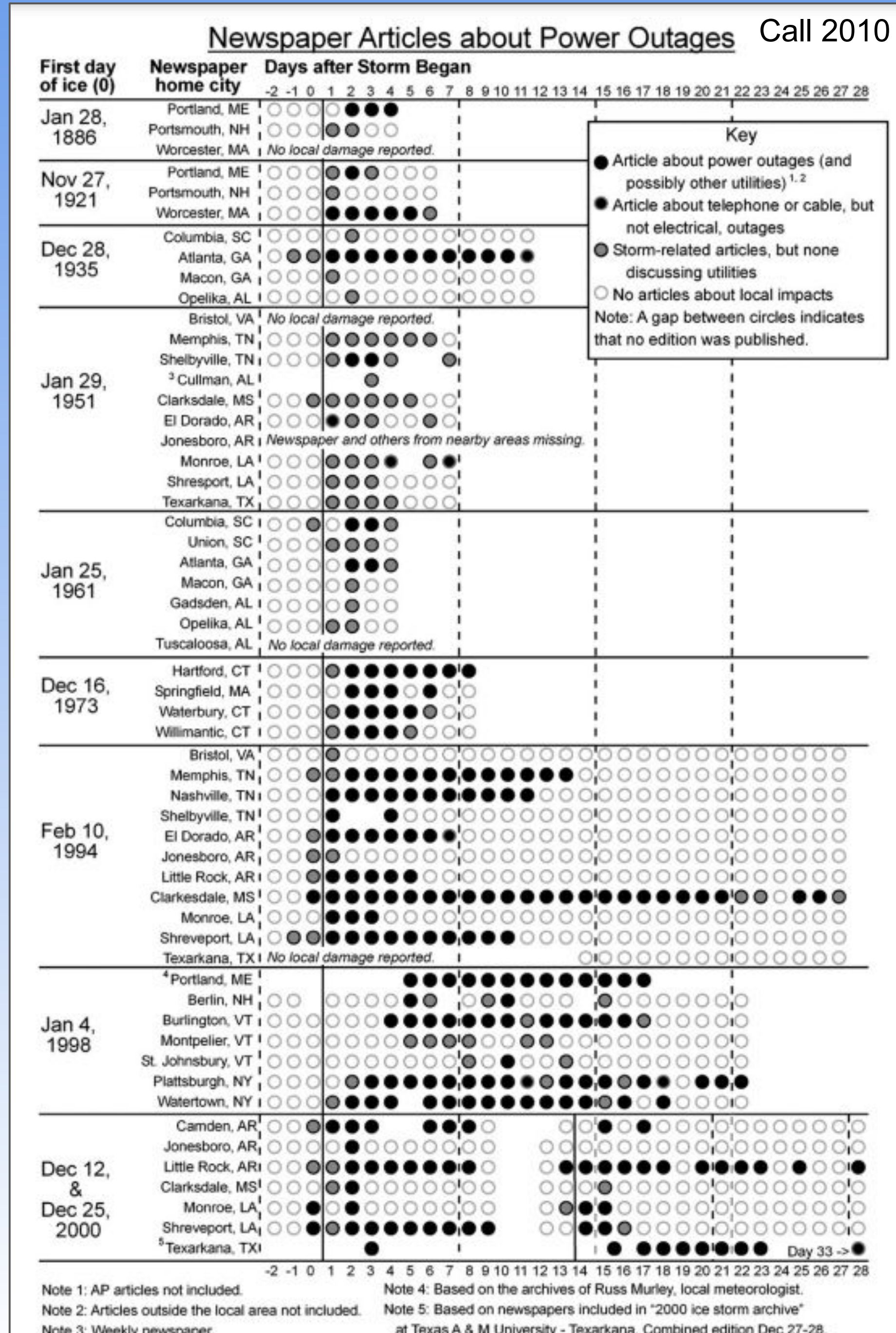
Below Freezing Temperatures

Thermal Structure and Precipitation Types



https://www.weather.gov/images/rnk/LSR/RAIPZRSN.png

Long duration freezing rain is actually fairly rare - cold air needs replenishing at the surface, since latent heat is released warming the air when water freezes at the surface.


Newspaper Articles about Power Outages
Call 2010
First day of ice (0)
Newspaper home city
Days after Storm Began
-2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Jan 28, 1886
Portland, ME
Portsmouth, NH
Worcester, MA
No local damage reported.
Nov 27, 1921
Portland, ME
Portsmouth, NH
Worcester, MA
Dec 28, 1935
Columbia, SC
Atlanta, GA
Macon, GA
Opelika, AL
Jan 29, 1951
Bristol, VA
No local damage reported.
Memphis, TN
Shelbyville, TN
3 Cullman, AL
Clarksdale, MS
El Dorado, AR
Jonesboro, AR
Newspaper and others from nearby areas missing.
Monroe, LA
Shresport, LA
Texarkana, TX
Jan 25, 1961
Columbia, SC
Union, SC
Atlanta, GA
Macon, GA
Gadsden, AL
Opelika, AL
Tuscaloosa, AL
No local damage reported.
Dec 16, 1973
Hartford, CT
Springfield, MA
Waterbury, CT
Willimantic, CT
Feb 10, 1994
Bristol, VA
Memphis, TN
Nashville, TN
Shelbyville, TN
El Dorado, AR
Jonesboro, AR
Little Rock, AR
Clarkesdale, MS
Monroe, LA
Shreveport, LA
Texarkana, TX
No local damage reported.
Jan 4, 1998
4 Portland, ME
Berlin, NH
Burlington, VT
Montpelier, VT
St. Johnsbury, VT
Plattsburgh, NY
Watertown, NY
Dec 12, & Dec 25, 2000
Camden, AR
Jonesboro, AR
Little Rock, AR
Clarksdale, MS
Monroe, LA
Shreveport, LA
5 Texarkana, TX
Day 33 ->
Key
Article about power outages (and possibly other utilities) 1, 2
Article about telephone or cable, but not electrical, outages
Storm-related articles, but none discussing utilities
No articles about local impacts
Note: A gap between circles indicates that no edition was published.
Note 1: AP articles not included.
Note 2: Articles outside the local area not included.
Note 3: Weekly newspaper.
Note 4: Based on the archives of Russ Murley, local meteorologist.
Note 5: Based on newspapers included in "2000 ice storm archive" at Texas A & M University - Texarkana. Combined edition Dec 27-28.

Total Number of Glaze Icing Storms 1928 to 1937

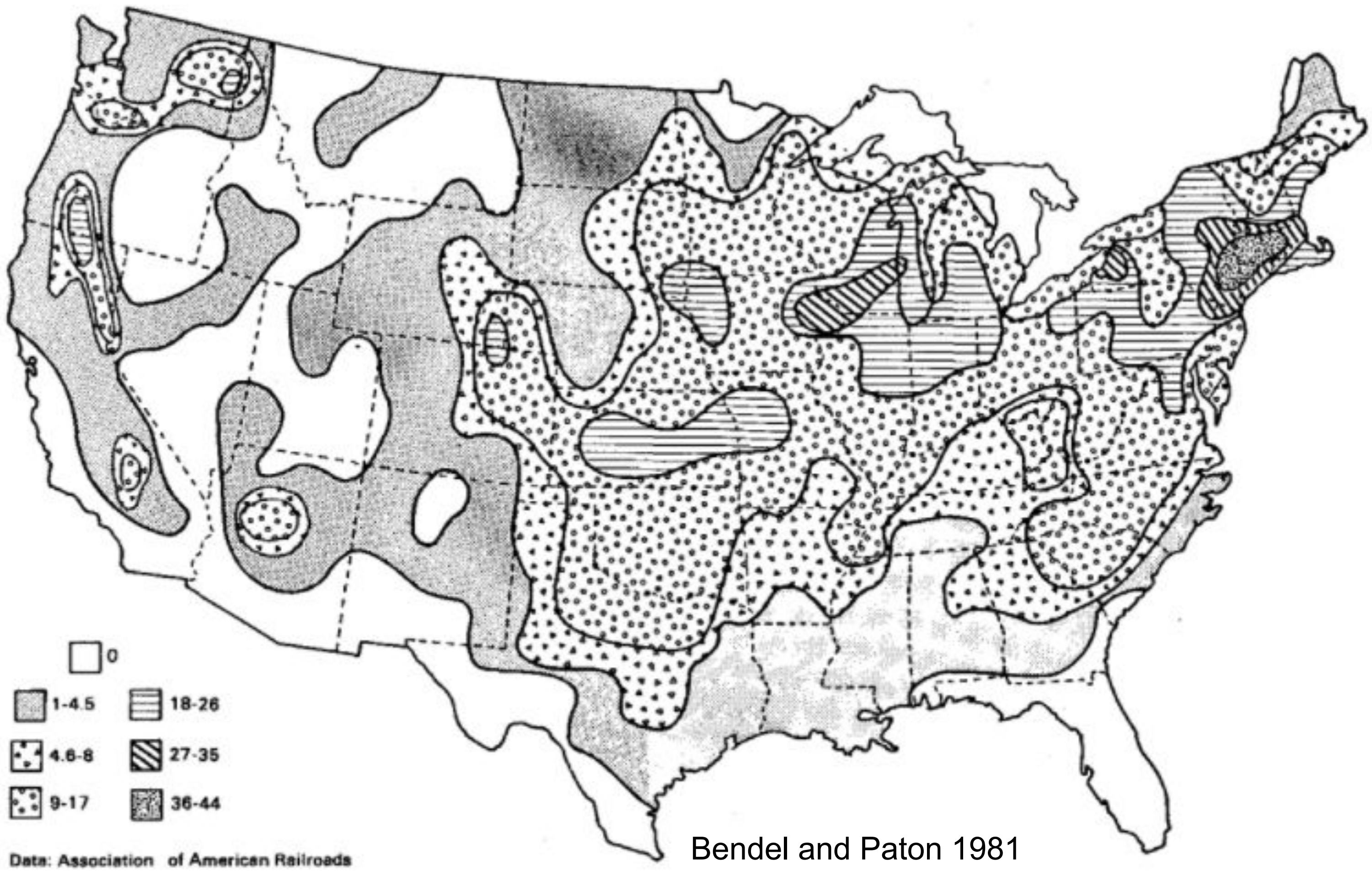
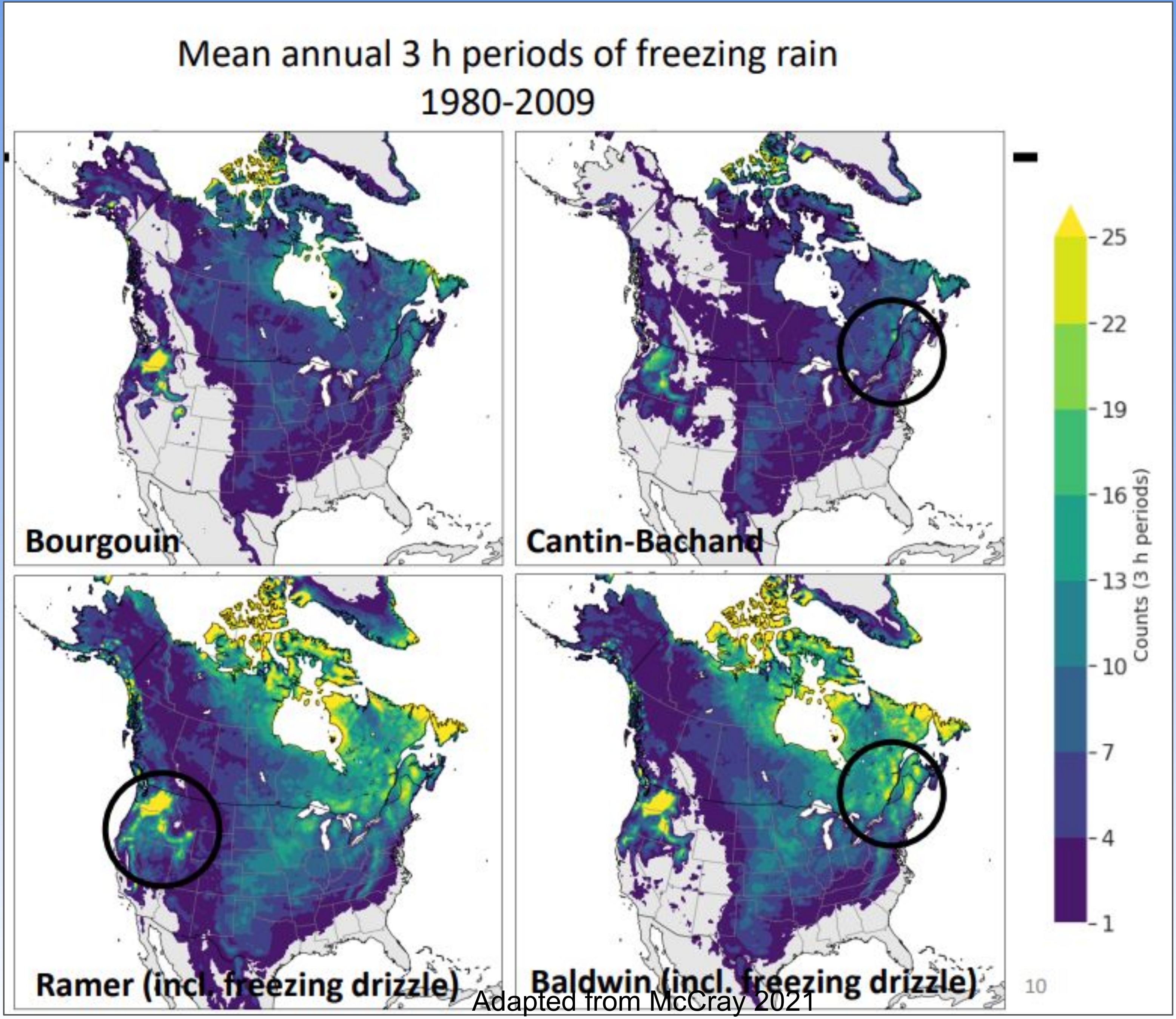
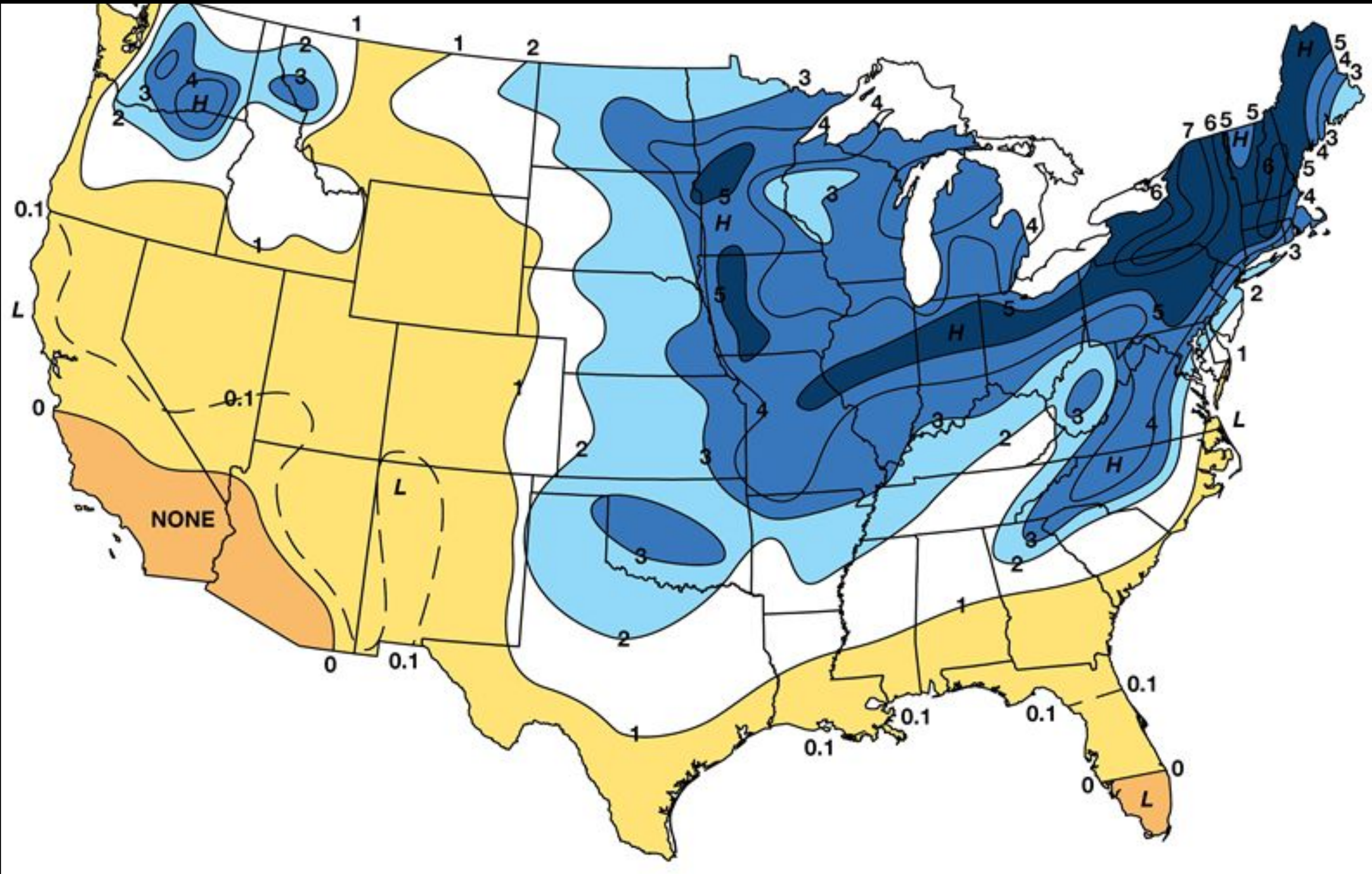


FIG. 1. Total number of glaze storms, without regard to ice thickness, observed during the 8-year period of the Association of American Railroads Study (Bennett, 1959).

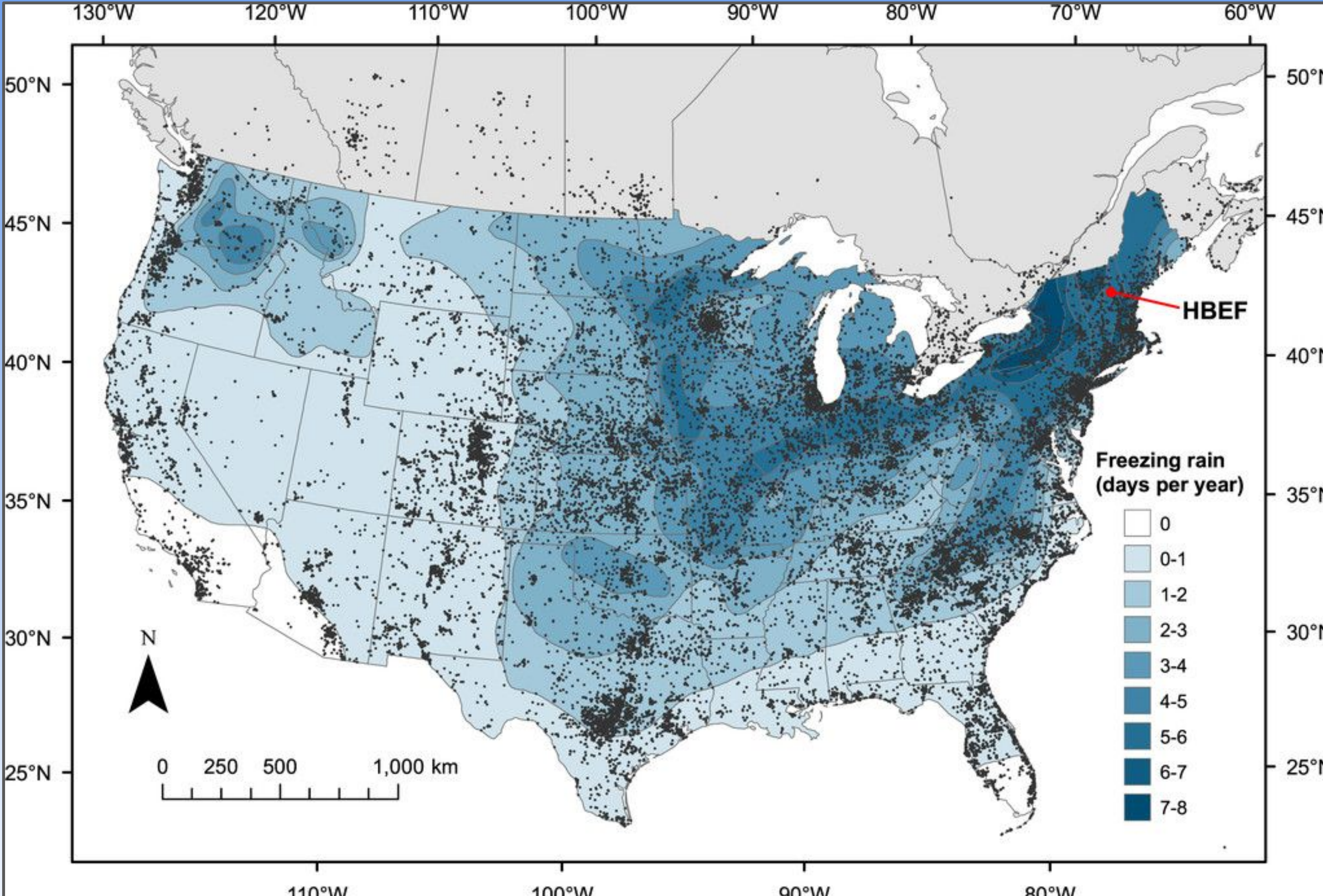


Adapted from McCray 2021

Average Number of Days with Freezing Rain (1948-2000)

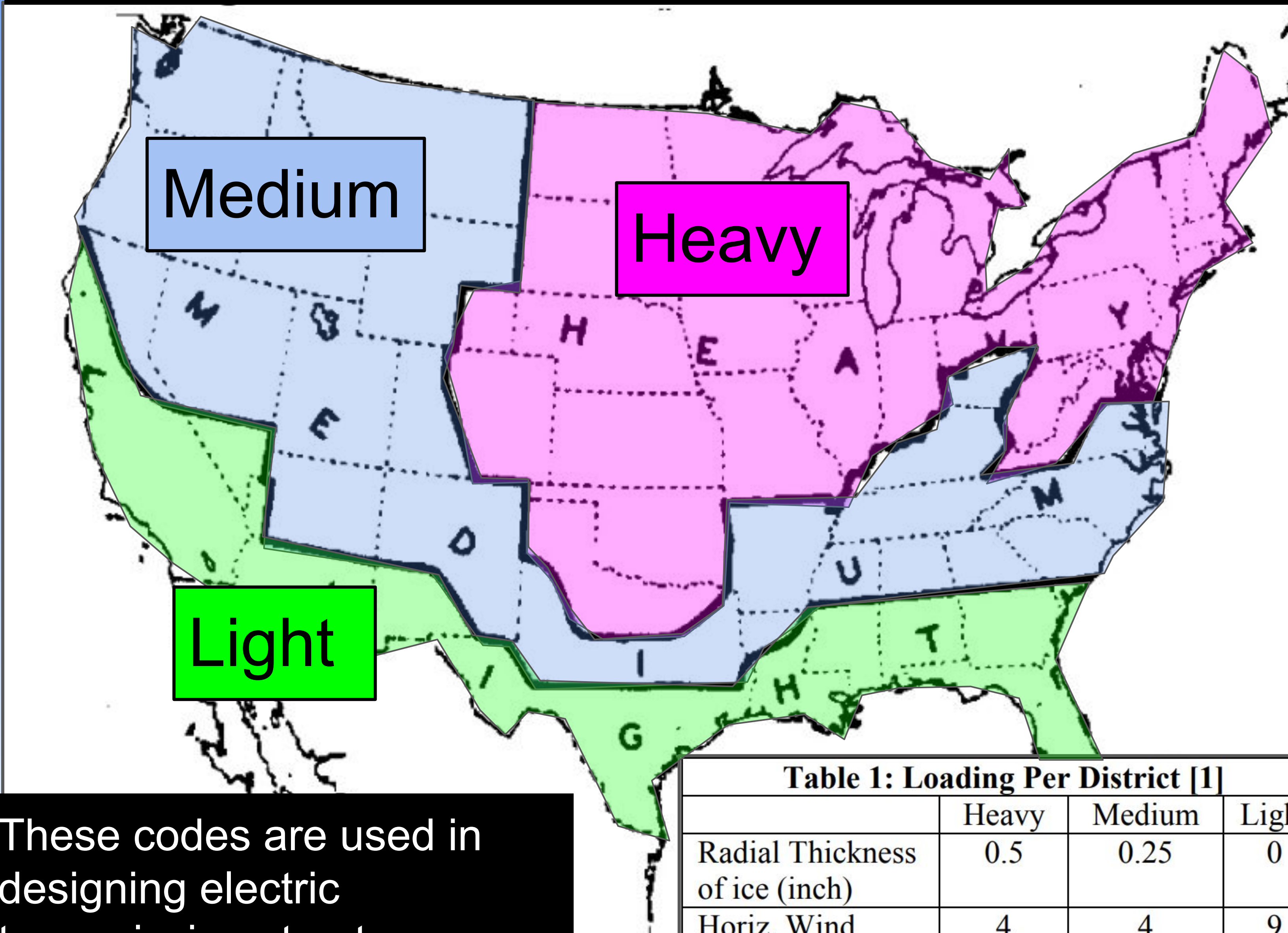


The average annual number of days with freezing rain, based on 1948-2000 data. *From Changnon and Karl, 2003.*



130°W
120°W
110°W
100°W
90°W
80°W
70°W
60°W
50°N
45°N
40°N
35°N
30°N
25°N
HBEF
Freezing rain (days per year)
0
0-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
N
0 250 500 1,000 km
110°W
100°W
90°W
80°W

National Electric Safety Code (NESC) - Ice Loading Zones (2002)



These codes are used in designing electric transmission structures.

Table 1: Loading Per District [1]

	Heavy	Medium	Light
Radial Thickness of ice (inch)	0.5	0.25	0
Horiz. Wind Pressure (lb/ft^2)	4	4	9
Temp.	0°F	15°F	30°F

50-Year Ice Storm - Ice Loading Map

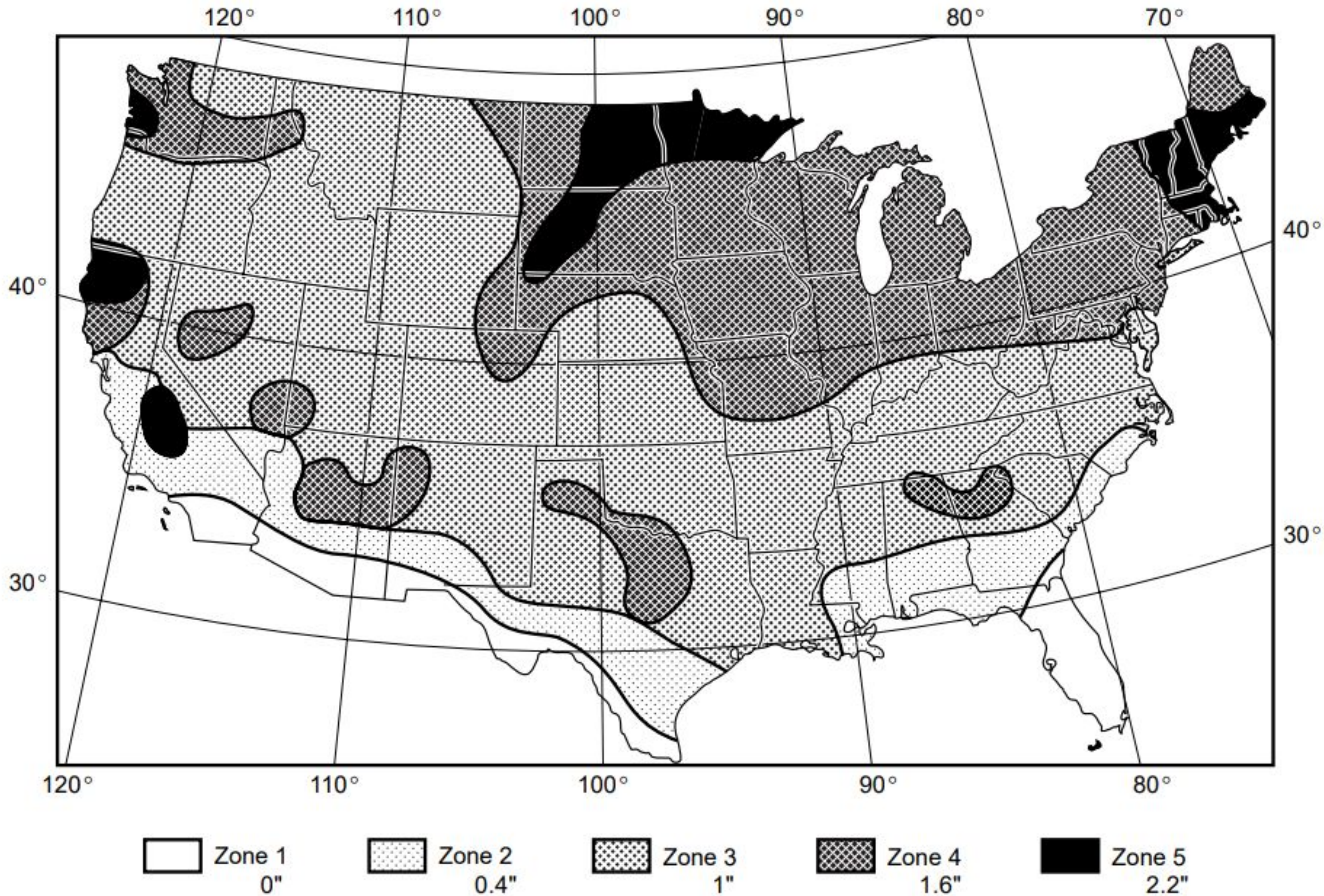


Figure 3. 50-year return-period ice-load map from ASCE 74 (1991).

Ice growth on trees is complex

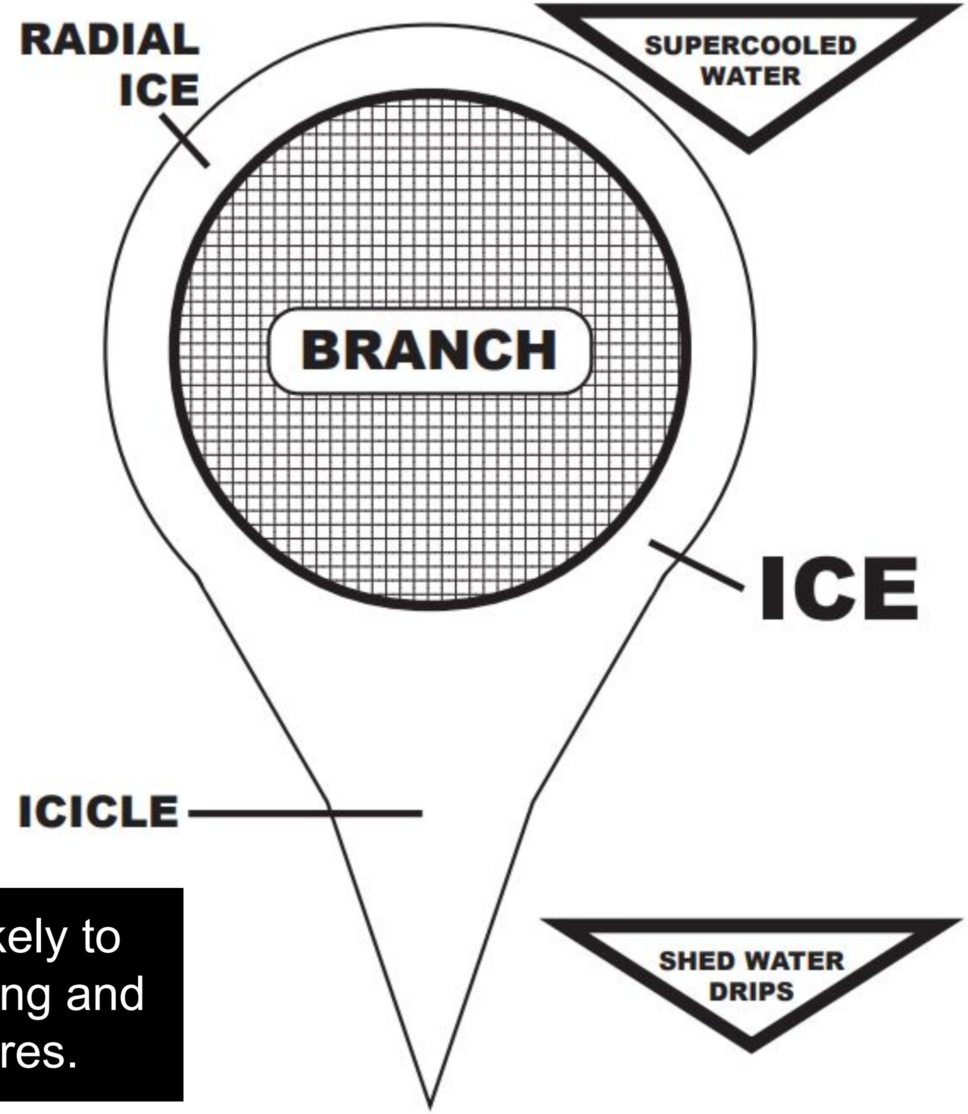
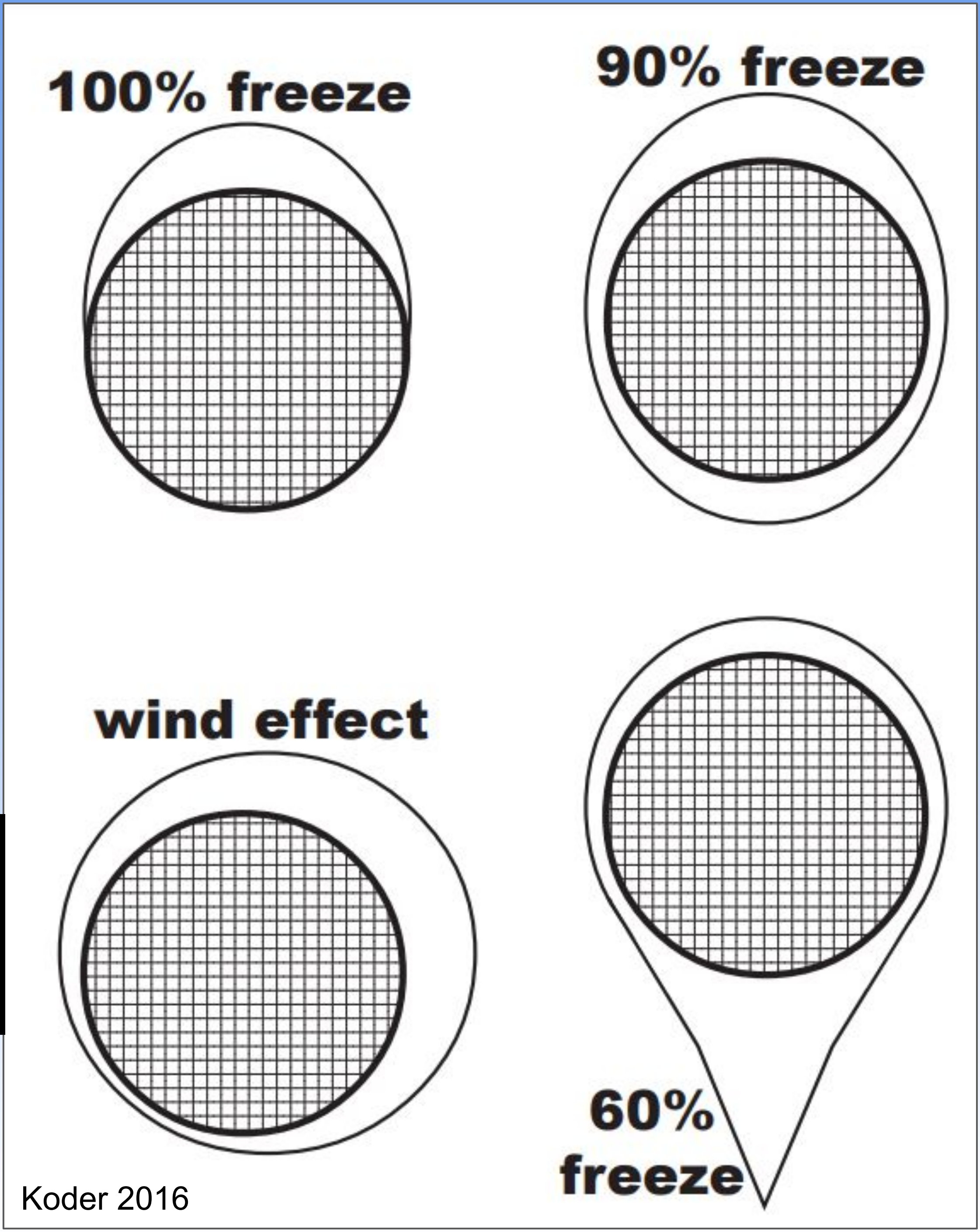


Figure 2: Glaze ice on tree branch cross-section (with surface below freezing) in freezing rain.
(after Makkonen 1998)

Koder 2016

Icicles are more likely to form around freezing and warmer temperatures.

Winds act to distort ice growth



Winds generally spread ice around branches

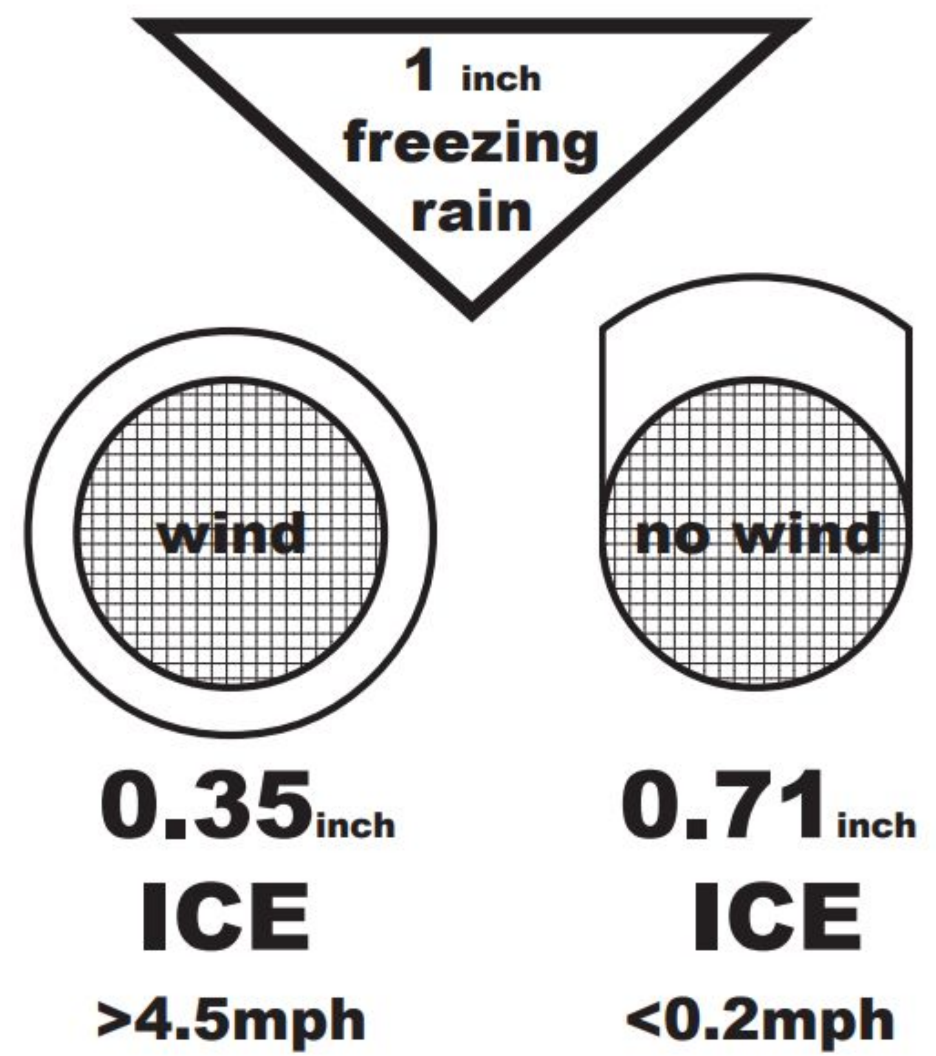


Figure 11: Ice accumulation on branches with wind and no wind.
(same depth of freezing rain intercepted & uniform dry growth form ice)
(Jones 1996) (Yip 1995)

Koder 2016

Most commonly adopted method for converting freezing rain to ice thickness...

VOLUME 31 WEATHER AND FORECASTING AUGUST 2016

Analysis of Ice-to-Liquid Ratios during Freezing Rain and the Development of an Ice Accumulation Model

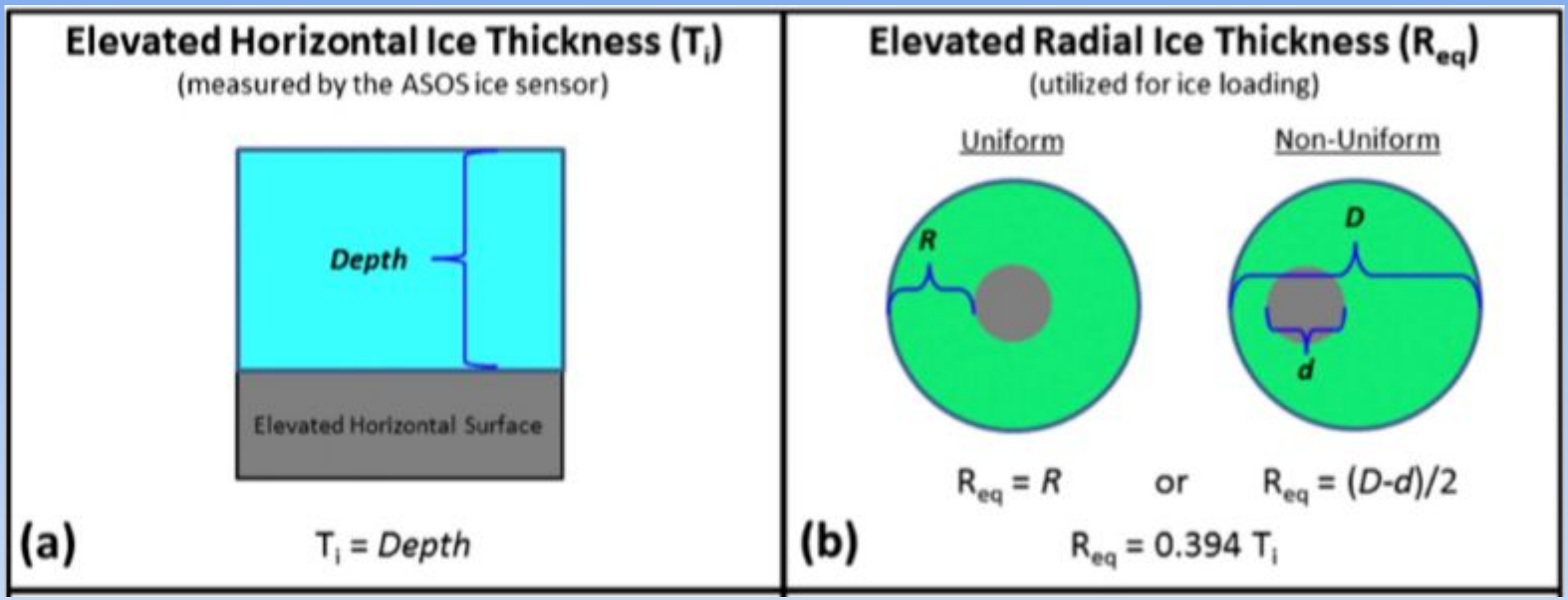
KRISTOPHER J. SANDERS AND BRIAN L. BARJENBRUCH

NOAA/National Weather Service, Topeka, Kansas

FRAM - Freezing Rain Accumulation Model: Converts freezing rain to ice thickness values using three variables:

1. Wet bulb temperature
2. Precipitation rate
3. Wind speed

Ice Thickness vs. Radial Ice Thickness



There's a lot of confusion around understanding ice thickness. When most folks talk about ice thickness, they are referring to the maximum one-dimensional ice on an elevated surface. However, for engineering applications radial ice thickness is used for design standards around icing.

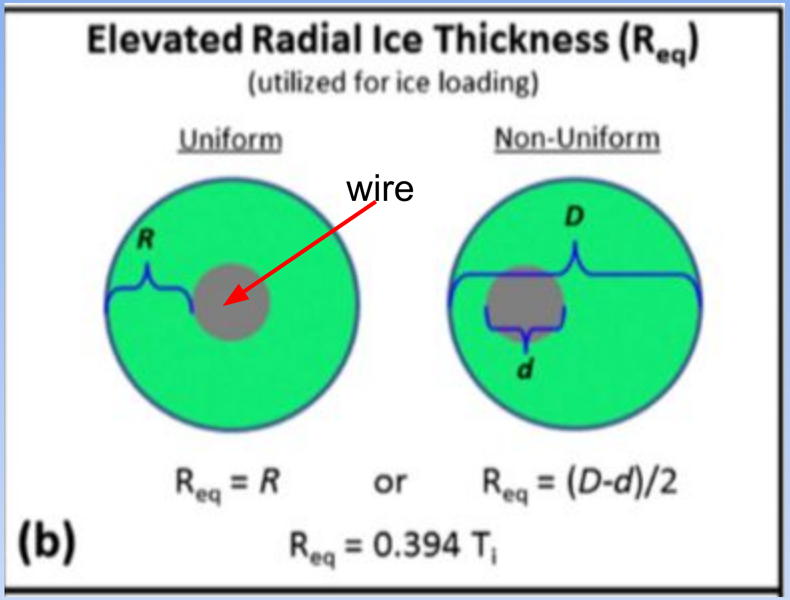
Measuring ice accretion is difficult

Ice Thickness – Largest one-dimensional ice growth aka "elevated flat ice"

Radial Ice – Average ice thickness distributed completely around a cylinder

Ice Thickness vs. Radial Ice Thickness

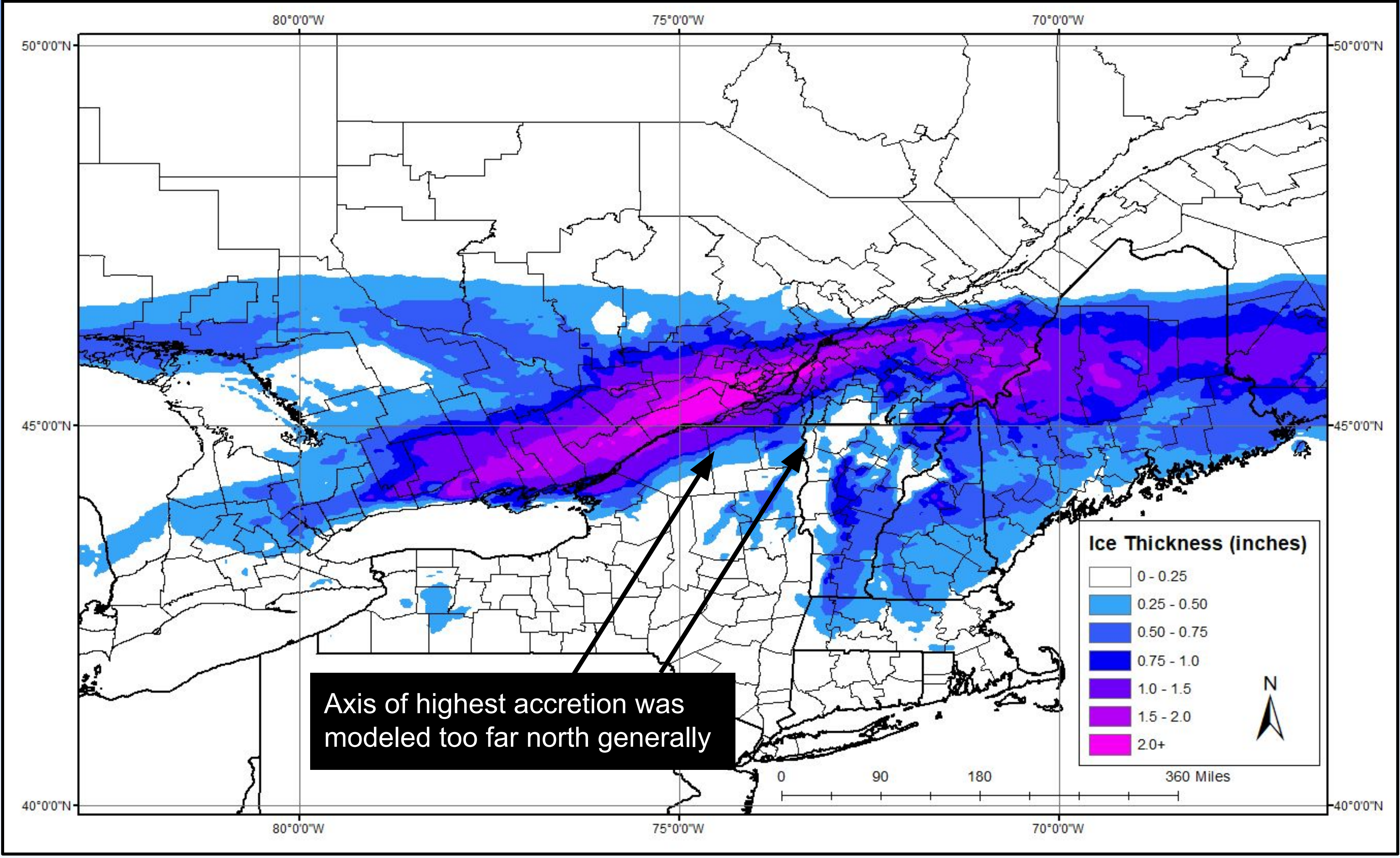
Example of one-dimensional ice thickness



Radial ice thickness distributes ice around a cylinder (wire), and is approximately 39% of value of one-dimensional ice thickness.

For example: 0.5” of radial ice = 1.27” of one-dimensional ice

January 5-10, 1998 Modeled Total Ice Thickness (inches)



January 5-10, 1998 Observed Total Ice Thickness (inches)

Table 4. Possible effect of elevation on ice load.

Station	Elevation range (ft)	Ice load (in.)
Burlington, VT	340–900	1.1
	900–	1.2
Barre, VT	1160–1720	0.2
	1720–	1.1
Hanover, NH	500–780	0.0
	780–1060	0.8
	1060–1340	0.9
	1340–	1.0
Concord, NH	340–900	0.1
	900–1460	0.5
	1460–	0.6
Portland, ME	100–660	0.5
	660–	0.9
Brunswick, ME	80–630	0.6
	630–	0.7
Augusta, ME	350–	0.8
Bangor	190–	1.2

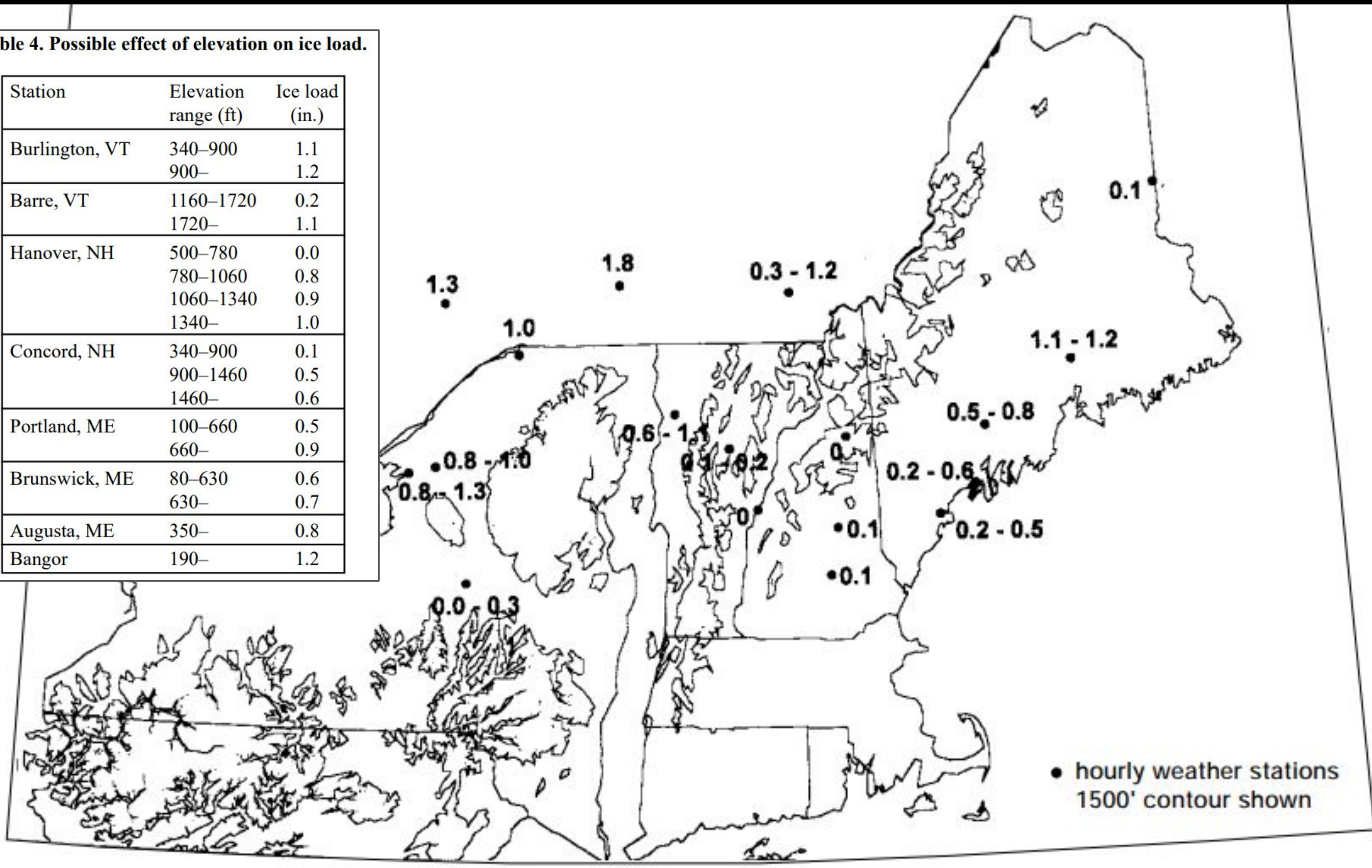


Figure 20. Ice loads at weather stations in the United States and Canada in the January ice storm.

Jones and Mulherin 1998

a. Crescent on one side (photo Jones).

b. Large accretion on windward side of car antenna (photo Jones).

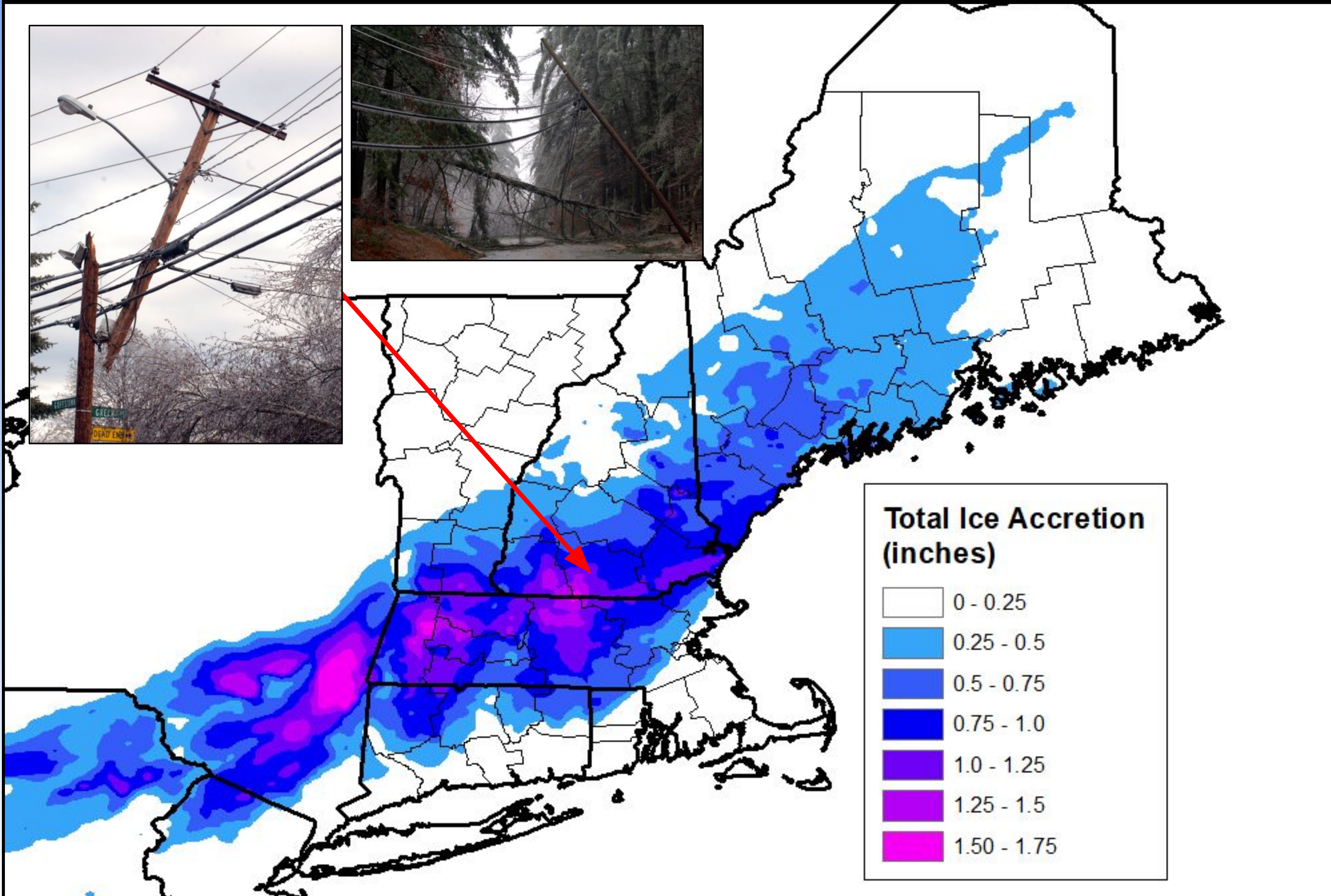
c. Icicles on wire fence (photo Mulherin).

d. Knobby accretion on Triplex (photo Mulherin).

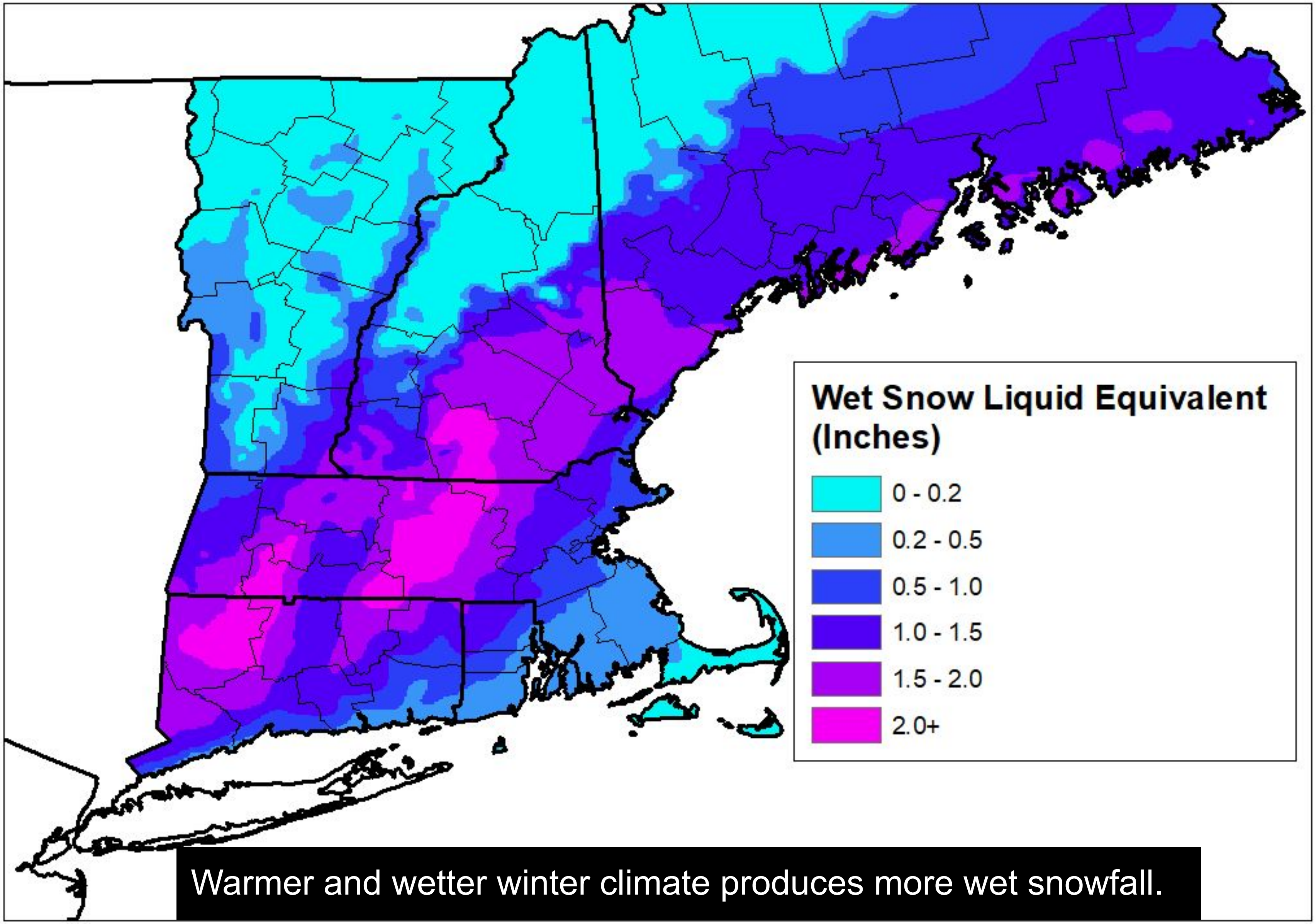
Jones and Mulherin 1998

Figure 9. Examples of ice accretion shapes, January 1998 ice storm.

December 11 & 12, 2008 Total Ice Thickness

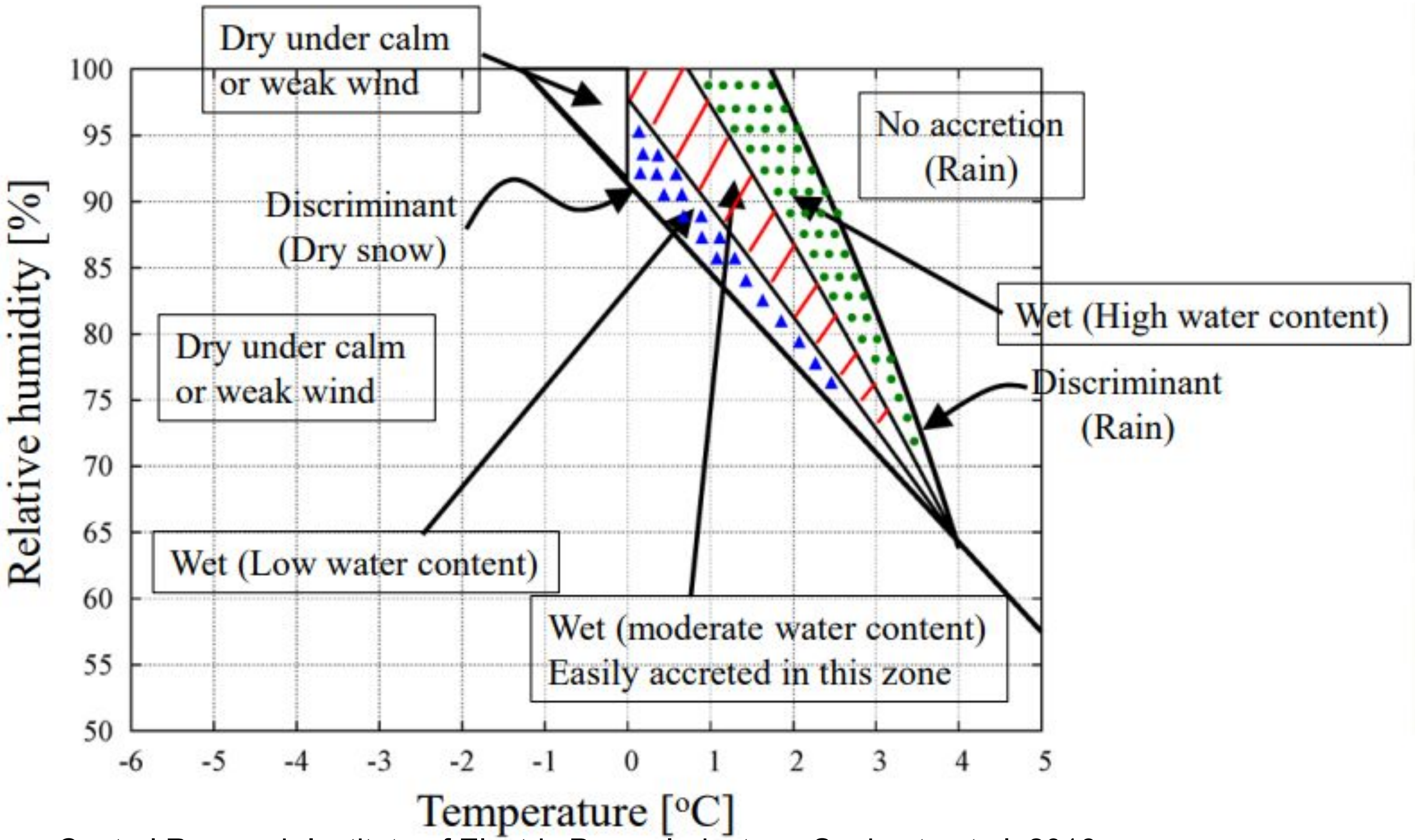


October 29-30, 2011 Wet Snow Icing Accretion



Warmer and wetter winter climate produces more wet snowfall.

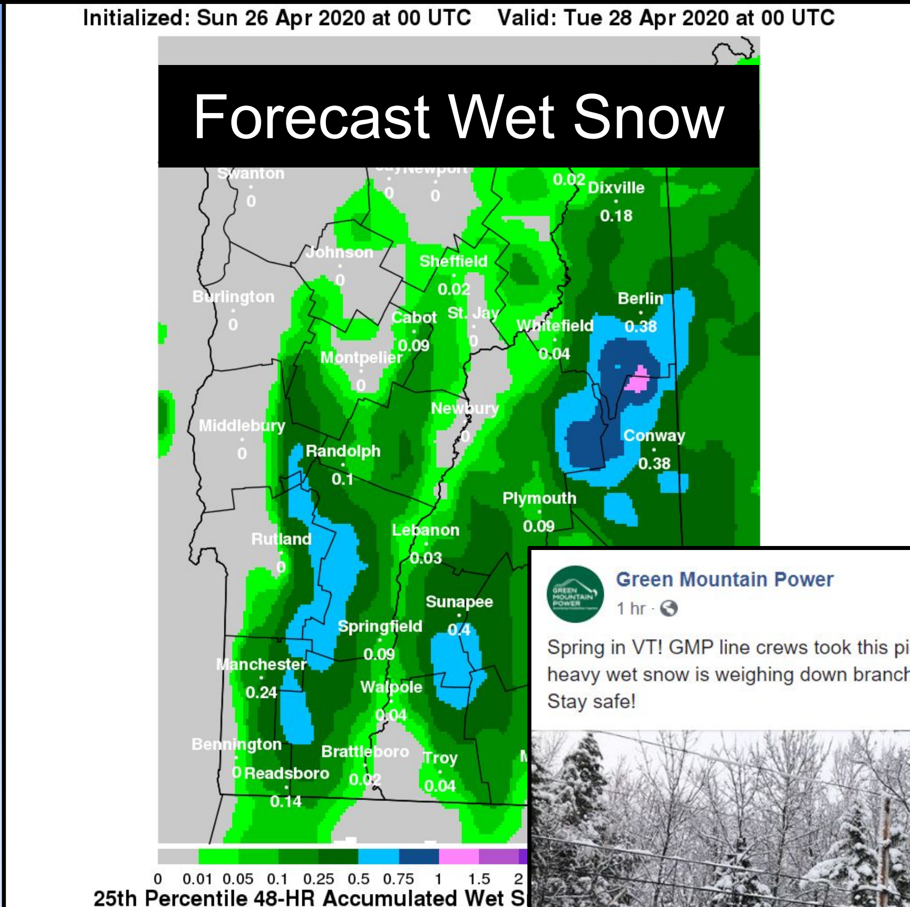
Method for Detecting Wet Snowfall Icing using Humidity and Temperature

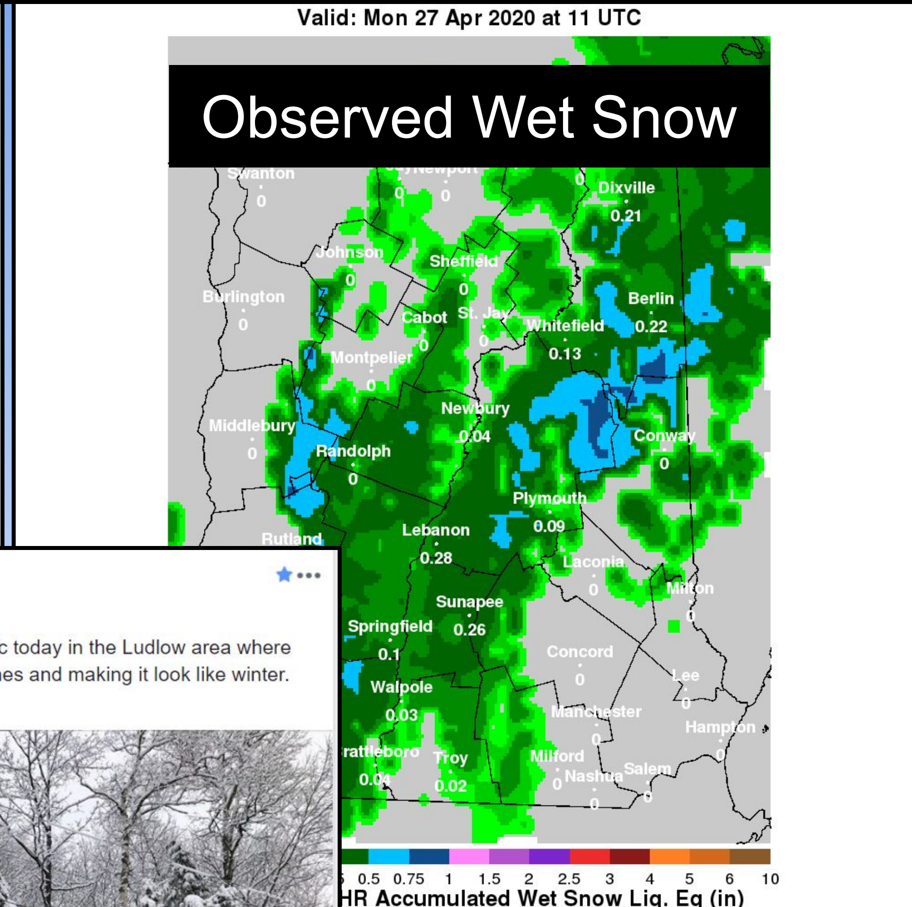


Central Research Institute of Electric Power Industry - Sugimota et al. 2016

Wet snowfall risks are likely 3x to 4x the overall risks of outages than freezing rain in the Northeast US.

Wet Snow Forecast Example





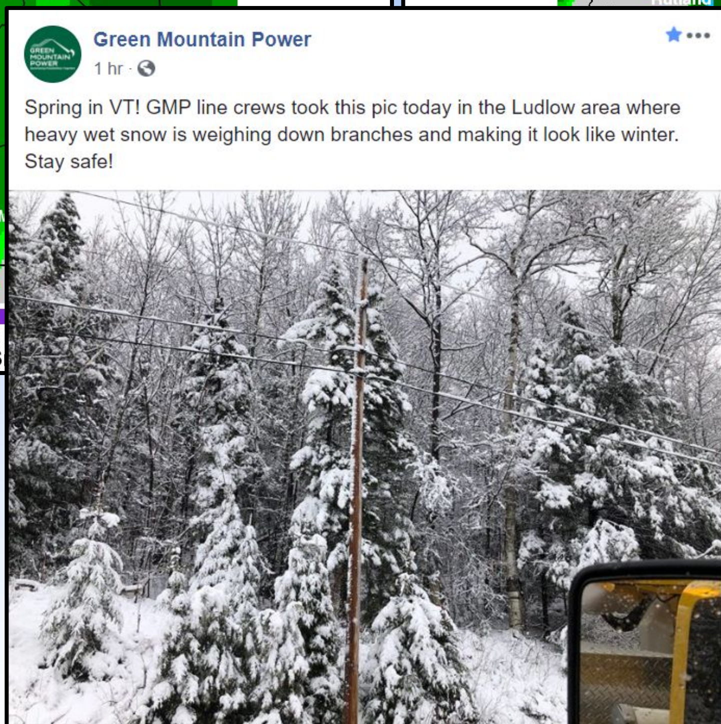
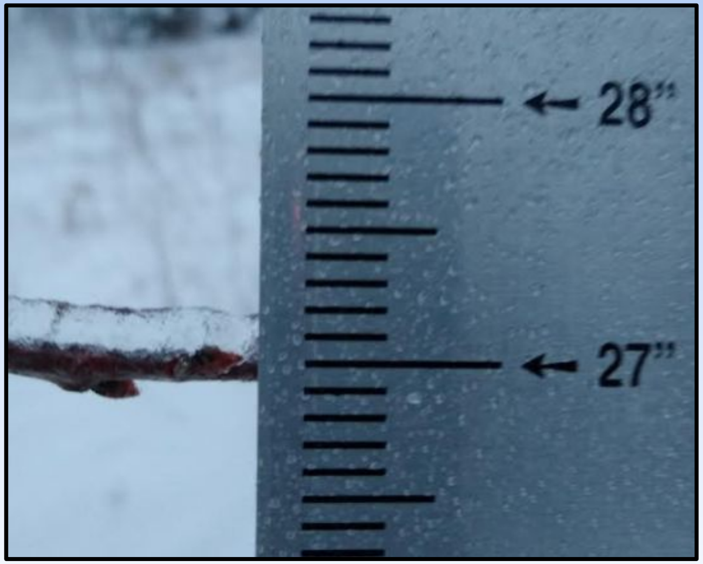


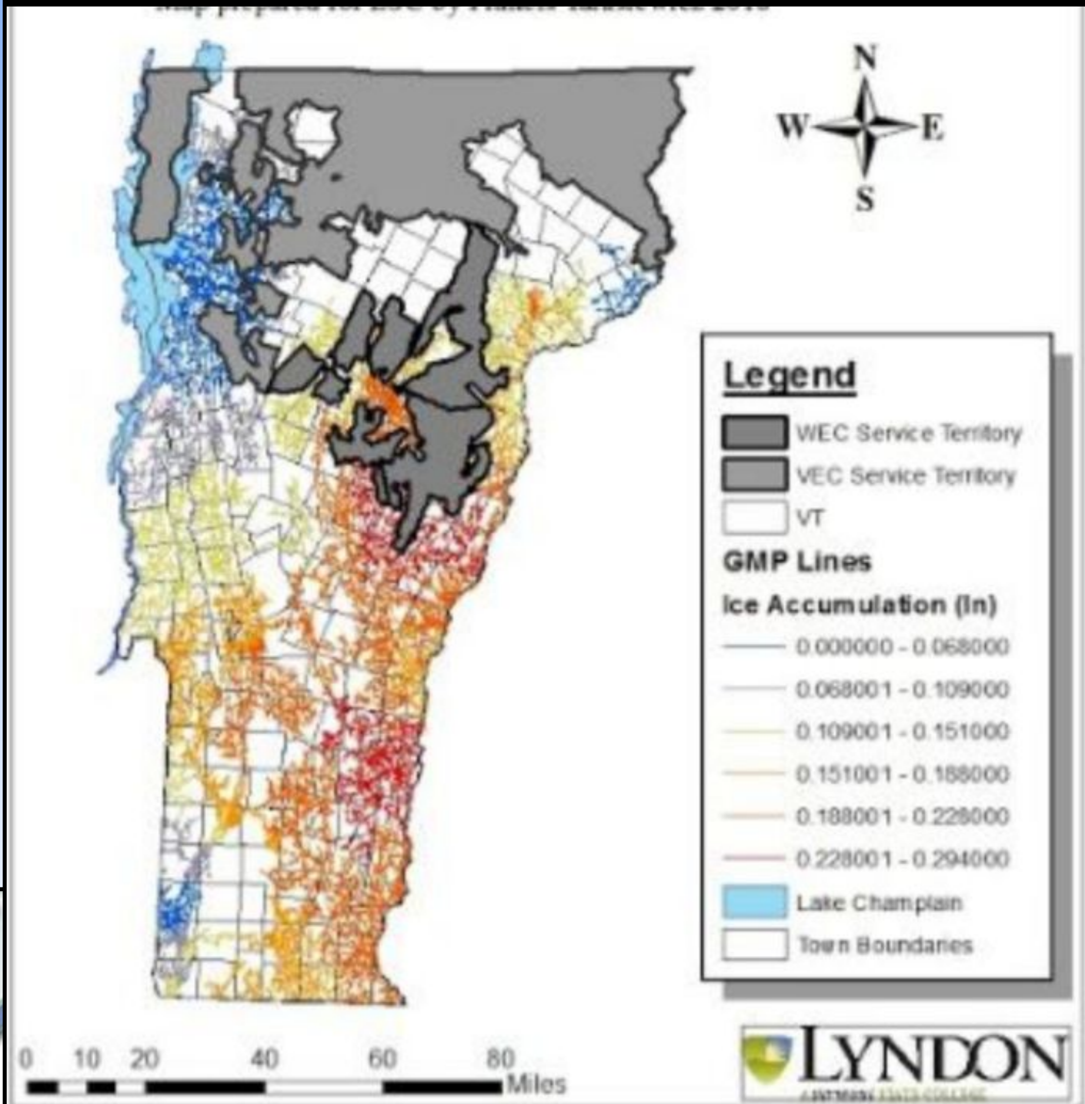
Table used by Vermont CoCoRaHS observers to estimate ice accretion

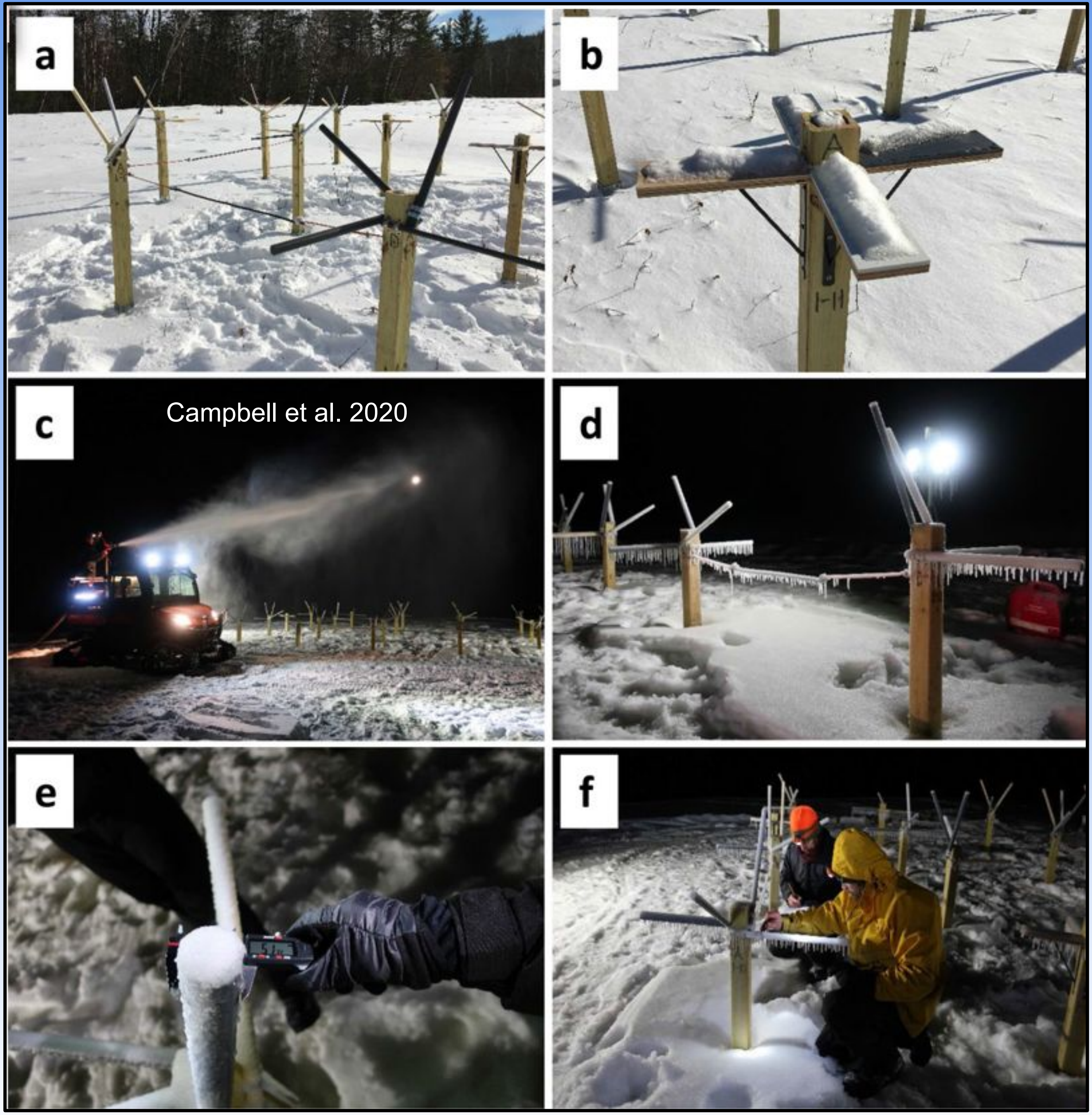
Category	Ice Thickness (inches)	Description
0	zero	no ice or a trace
1	0.01-0.05"	enough to be annoying scraping off your car & look pretty on bushes, shrubs
2	0.06-0.10"	shrubs and other non-native shrubbery weighed down, trees manage ok
3	0.11-0.15"	small tree branches start to bend
4	0.16-0.20"	small and medium branches bend, a few small branches may fail
5	0.21-0.25"	birch trees are starting to bend, minor branch damage to weak trees
6	0.26-0.30"	birch trees sag moderately, small and large limbs start to break, ~5-10% branch loss
7	0.31-0.40"	birch trees bent nearly completely, ~10-20% branch loss on small and large limbs
8	0.40-0.50"	moderate to significant tree damage, most trees have some damage



Citizen Science - Ice Observations

Dec 23, 2017 Ice Thickness





https://journals.ametsoc.org/view/journals/apme/59/9/jamcD190280.xml

National Weather Service - Current Limitations of Ice and Wet Snow Forecasts

- Lead time limited to 72 hours for ice
- Lacking probabilistic ice accretion forecasts
- No way to determine wet snow accretion from total snowfall
- No good products for precipitation that starts as freezing rain - “rapid onset freezing rain”

The first 0.01” of ice is the worst for transportation applications.

General risk scale for ice and concurrent wind loading

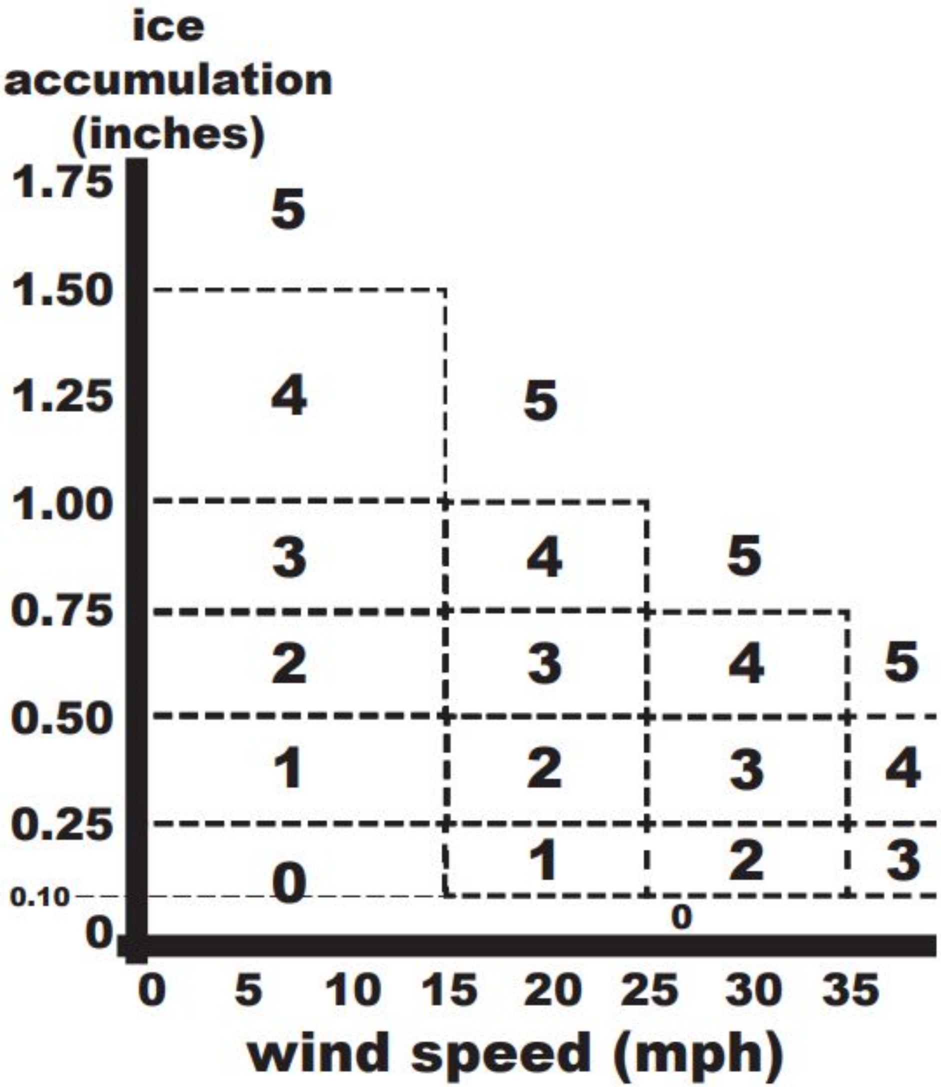
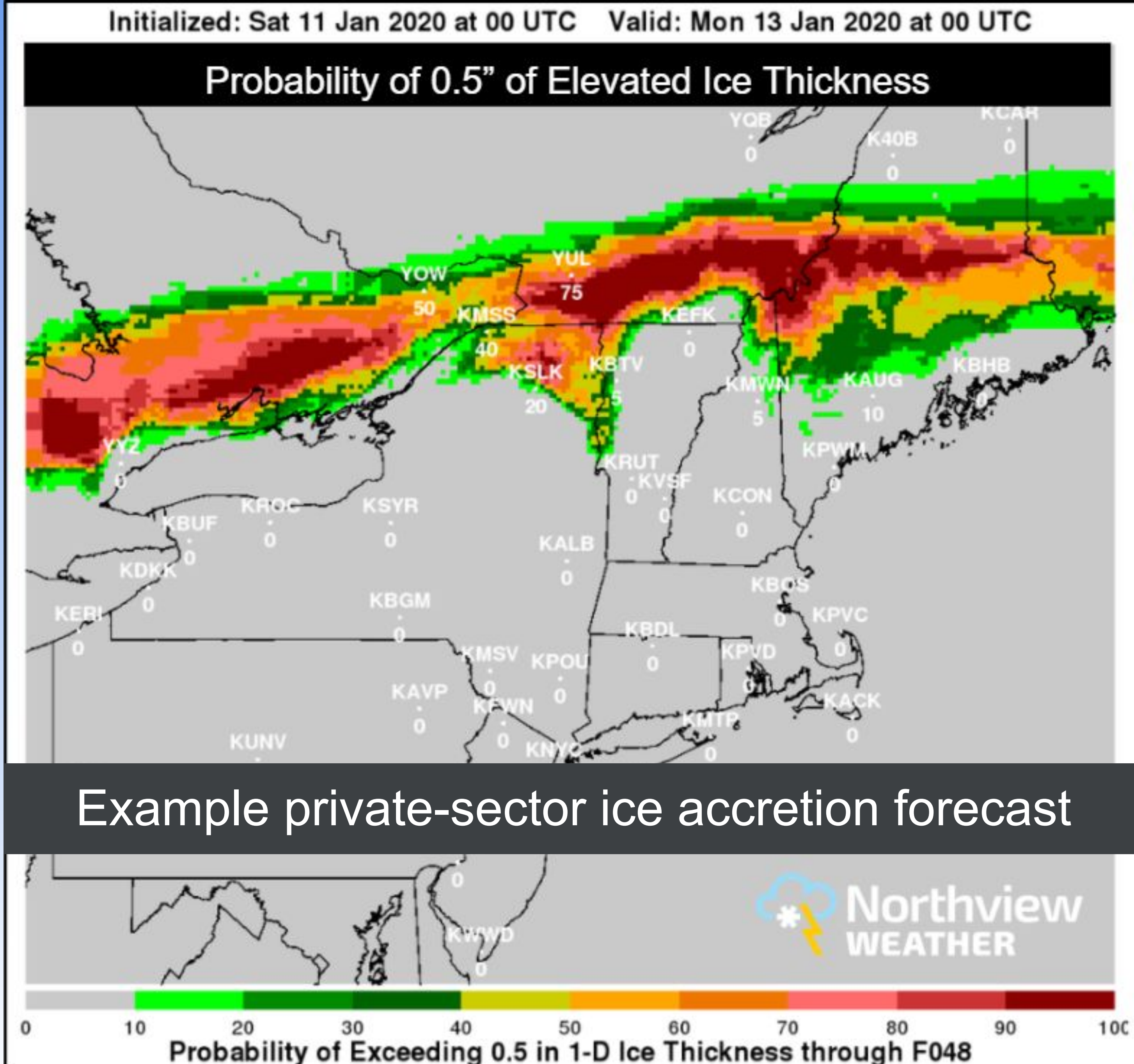


Figure 18: Determining SPIA Index severity catagories using ice accumulation (inches) and wind speed (mph).
(derived from NOAA 2009)

Sperry-Piltz Ice Accumulation Index (SPIA)

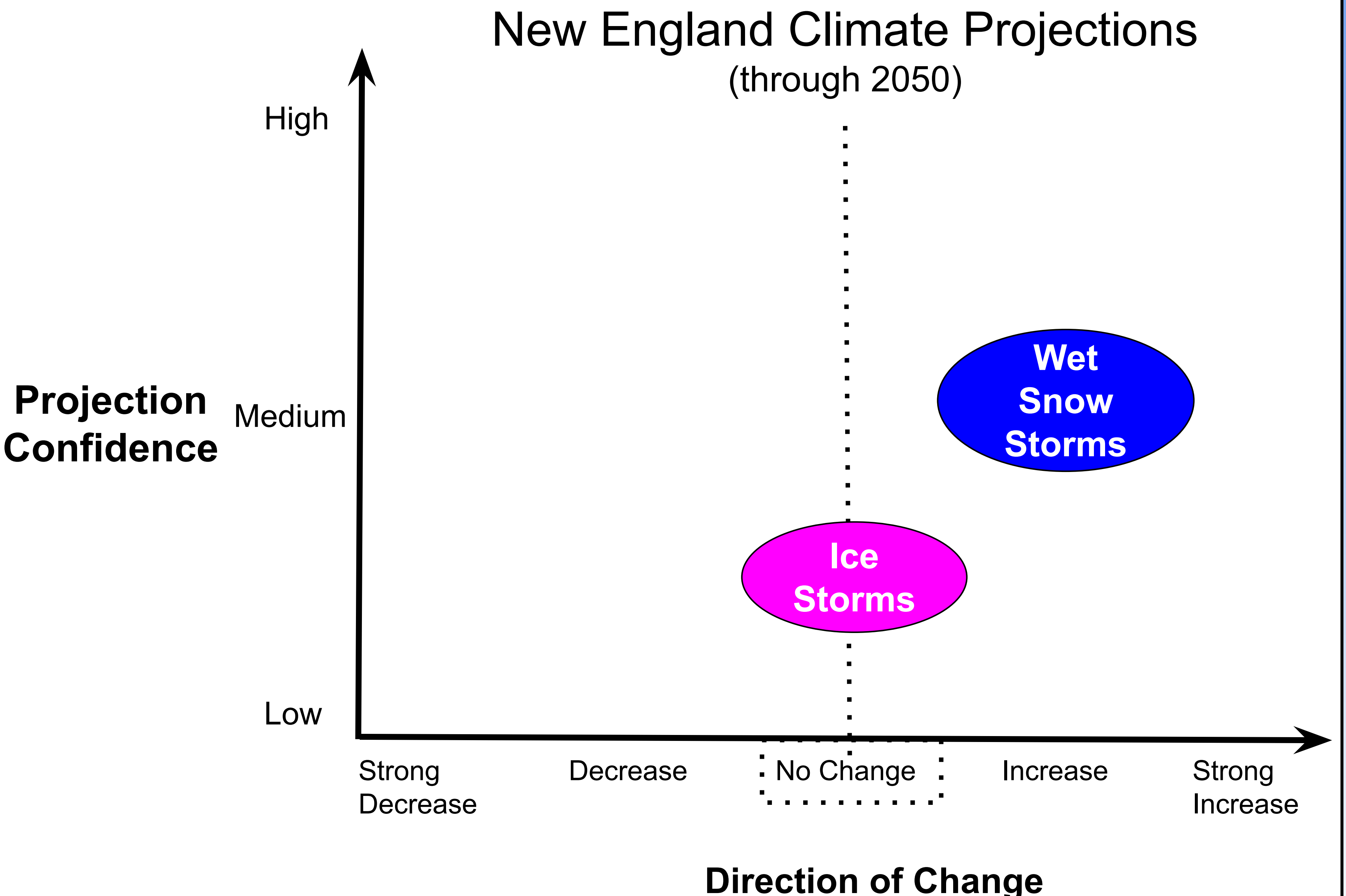
ICE DAMAGE INDEX	DAMAGE AND IMPACT DESCRIPTIONS
0	Minimal risk of damage to exposed utility systems; no alerts or advisories needed for crews, few outages.
1	Some isolated or localized utility interruptions are possible, typically lasting only a few hours. Roads and bridges may become slick and hazardous.
2	Scattered utility interruptions expected, typically lasting 12 to 24 hours. Roads and travel conditions may be extremely hazardous due to ice accumulation.
3	Numerous utility interruptions with some damage to main feeder lines and equipment expected. Tree limb damage is excessive. Outages lasting 1 – 5 days.
4	Prolonged & widespread utility interruptions with extensive damage to main distribution feeder lines & some high voltage transmission lines/structures. Outages lasting 5 – 10 days.
5	Catastrophic damage to entire exposed utility systems, including both distribution and transmission networks. Outages could last several weeks in some areas. Shelters needed.



Example private-sector ice accretion forecast

Conducting Research on Ice - Hubbard Brook, NH

Wet snow and ice risks and climate change



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First responder to the future.