# Climate Change and the Future of Winter Road Performance in New England

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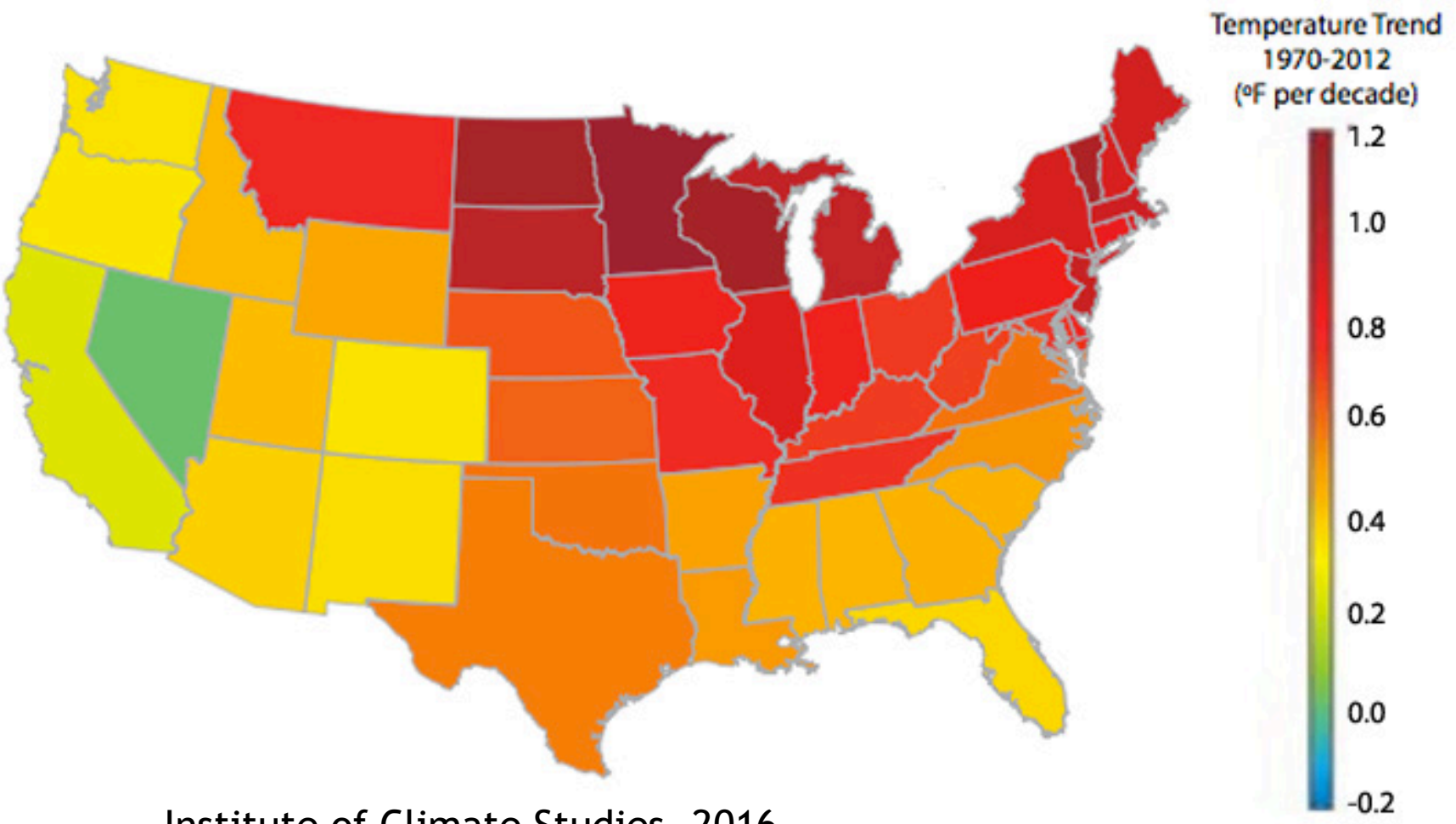
# Winter-Warming Accelerated in Every State But One




Institute of Climate Studies, 2016

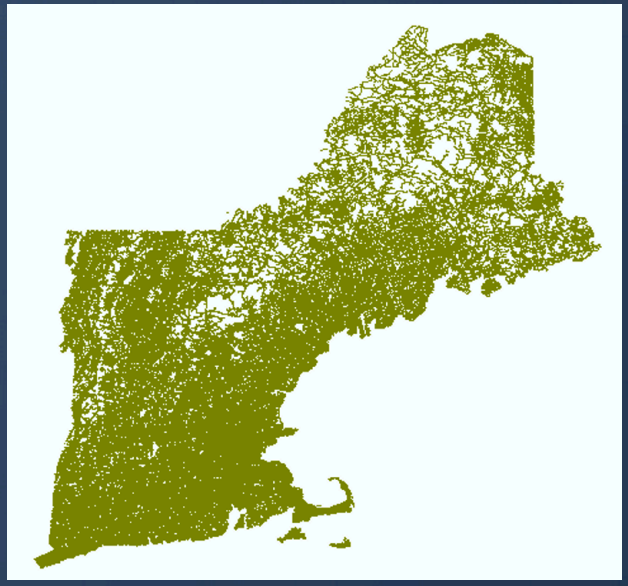
# Motivation

- Seasonal freeze-thaw (FT) occurs each spring in over half of all land totaling over 50 million $km^2$ globally.
- The landscape FT spring transition provides a significant change in water, energy, and carbon cycles including groundwater and surface water dynamics, exchange of latent and sensible heat controlled by vegetation, snow and soil processes, and larger scale atmospheric boundary layer and weather patterns.

Photo by Dan McAuley USGS

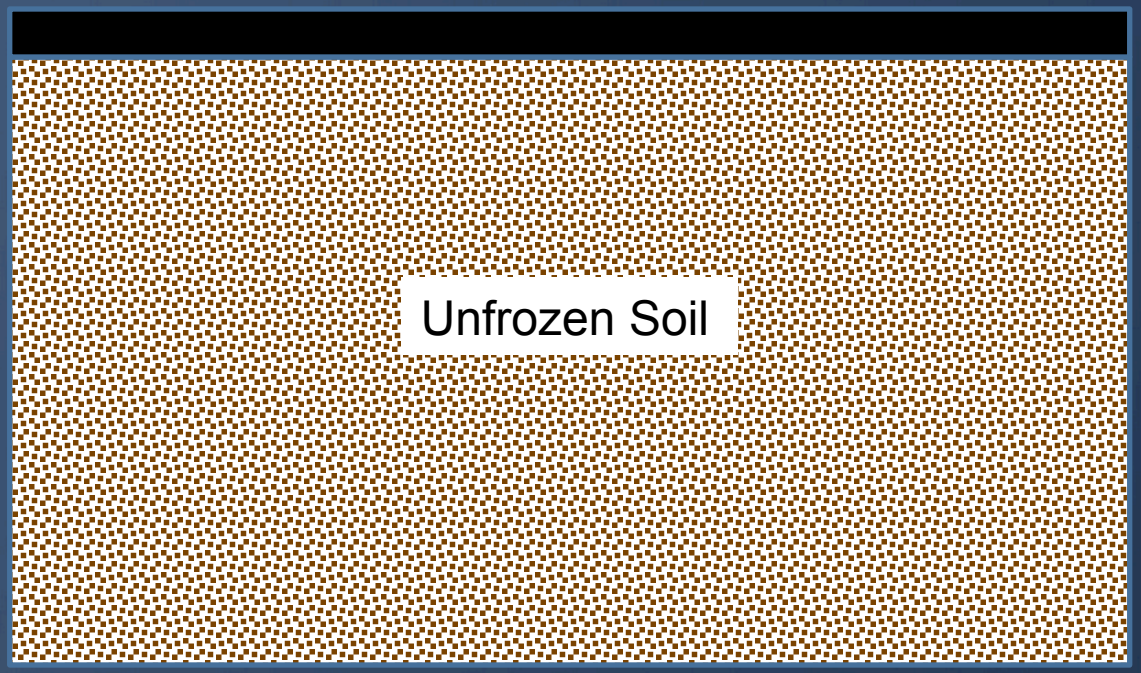
# Motivation

- Within that landscape, an extensive road network is embedded that constitutes a significant portion of the land area, fragmenting the landscape but providing connectivity for people and transportation of goods.
- In the United States alone, approximately half of the 4.8 million km of low-volume roads are located in seasonal frost areas.

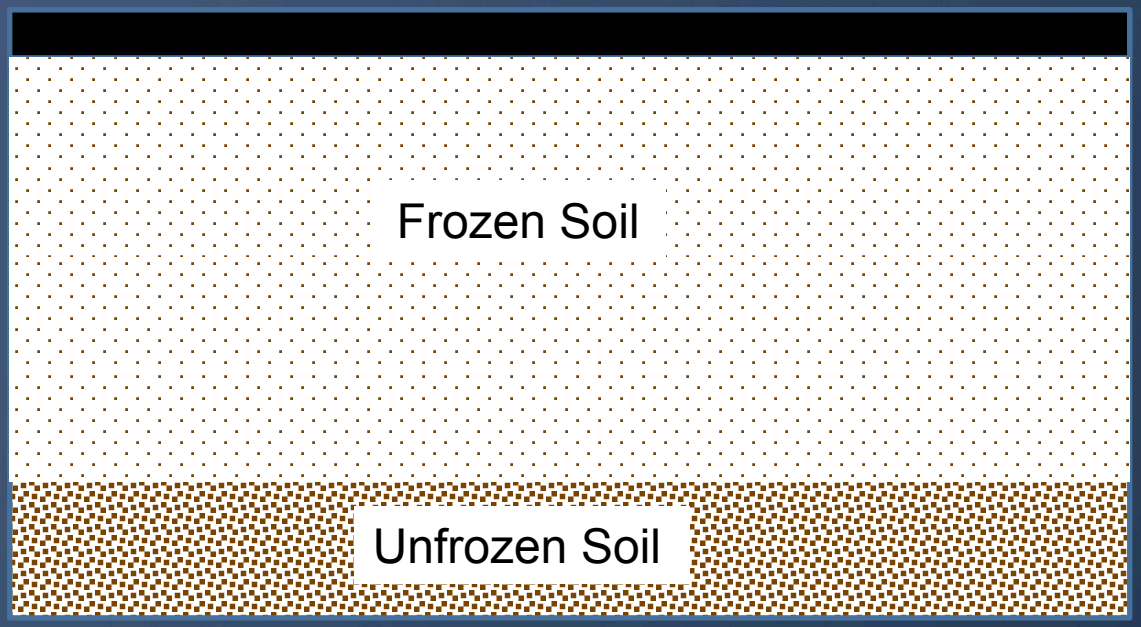


# Freeze-Thaw Process & Problems
# Low Volume Roads

Asphalt Surface

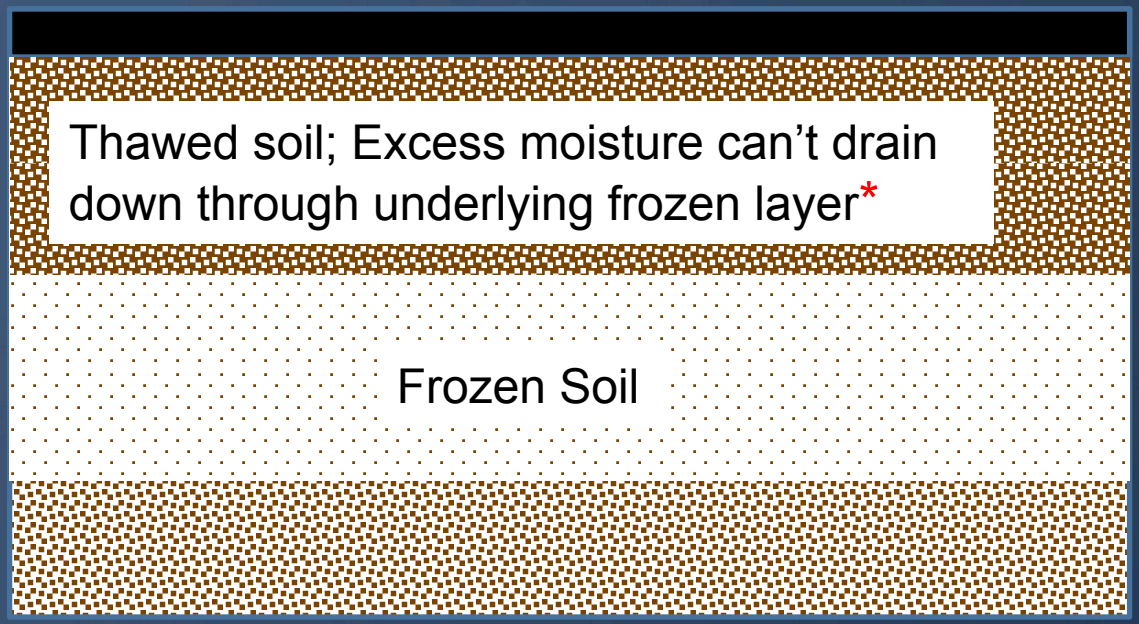


# During late fall, soils begin freezing from pavement surface downward




DOTs take advantage of increased strength & stiffness of frozen soil: Apply Winter Weight Premiums (WWP)

# In late winter/early spring, soils begin thawing




Critical Period:
Reduced strength & stiffness

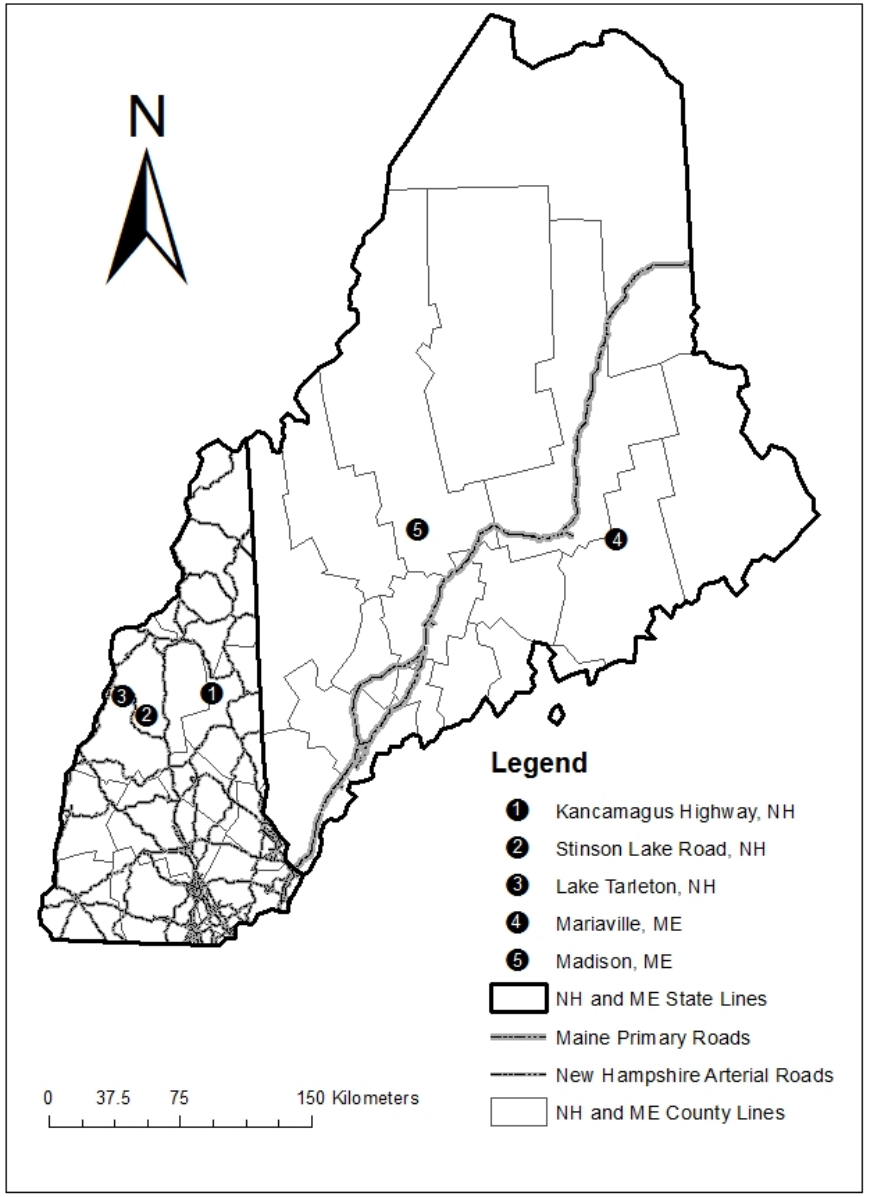
DOTs Apply Spring Load Restrictions (SLR)

# Study Goals and Methods

- Science Question: How will climate change affect freeze-thaw beneath roadways?
- Engineering Analysis: Apply Climate Model Output to Engineering Pavement Freeze-Thaw Models
- Applications Question: How will these changes affect DOTs' operations & maintenance and do existing policies support their ability to adapt to future conditions?
- Policy Analysis: Semi-structured interviews were conducted with approximately 20 DOT and road agents

# Study Sites

1. Kancamagus, NH (KAN)
2. Lake Tarleton, NH (LAK)
3. Stinson Lake Rd, NH (STI)
4. Mariaville, ME (MAR)
5. Madison, ME (MAD)

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# Engineering Model

## Modified Version of US Army Corps of Engineers Model 158

## Air Freezing & Thawing Indices

*FI*, *CFI* are the daily & cumulative freezing index

$T_{ref}$ = reference temperature
(often taken as 32°F, but may vary)

$T_{avg,i}$ = average air temperature

$$FI_i = T_{ref} - T_{avg,i}$$

$$CFI_n = \sum_{i=1}^{n} FI_i$$

Apply WWP When CFI > 280°F days

*TI*, *CTI* are the daily & cumulative thawing index

$$TI_i = T_{avg,i} - T_{ref}$$

$$CTI_n = \sum_{i=1}^{n} \left( \text{Daily Thawing Index} - 0.5 \times \text{Daily Freezing Index} \right)$$

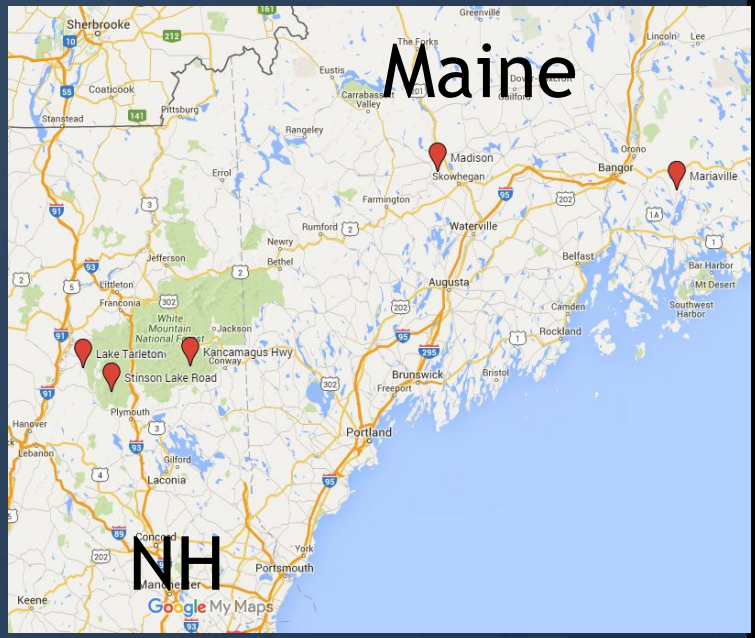
Apply SLR When CTI > 25°F days

Operational Guidelines
MnDOT (2009)

# Global Climate Model Output
# Baseline and Future Air Temperature

## Climate Model Output

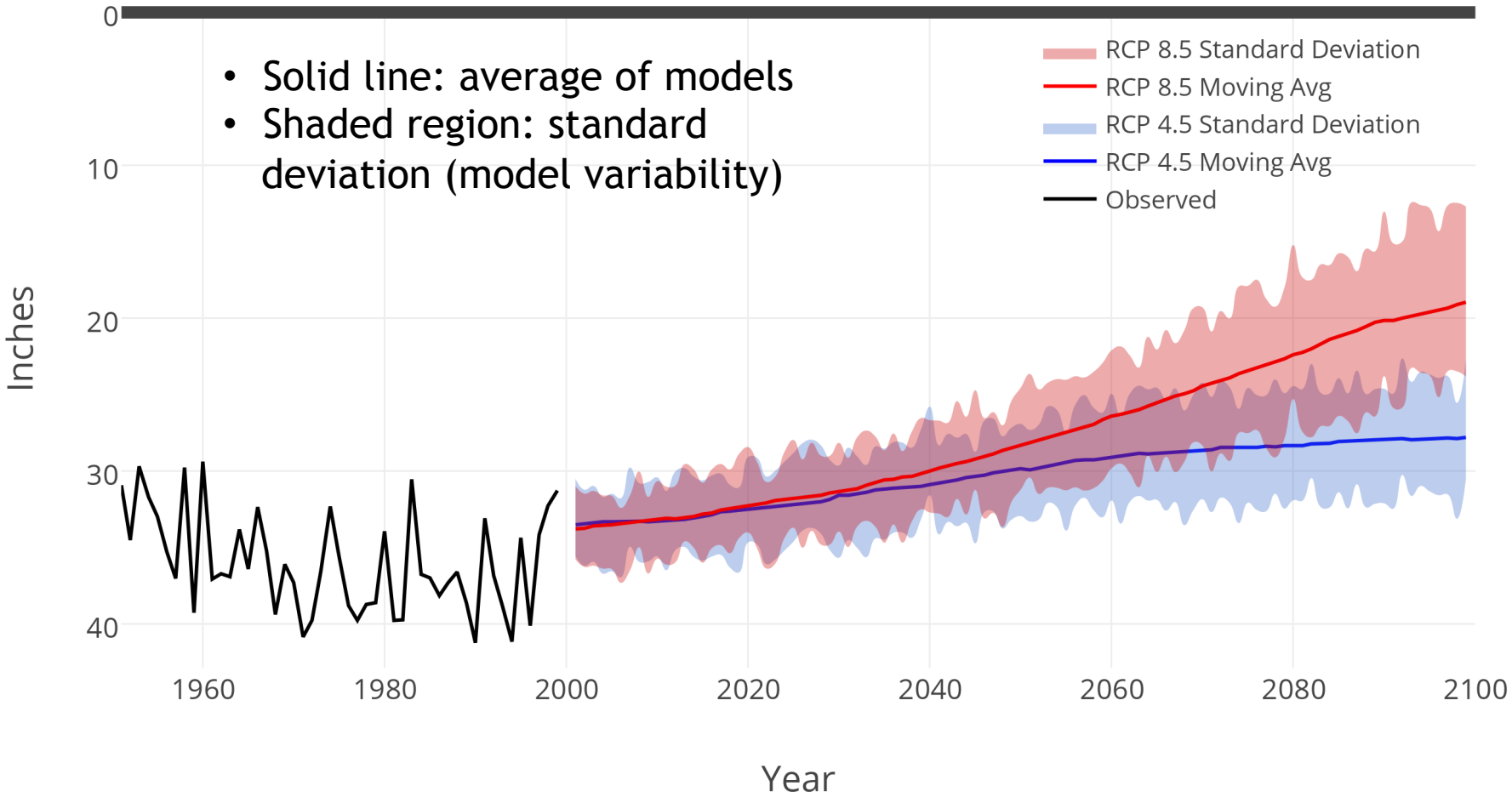
- Source: Bureau of Reclamation, downscaled using BCCA method (Bias Correction/Constructed Analogues)
- GCMs: 20 CMIP5 Models RCP 4.5 & 8.5
- Variable: Daily average temperature
- Scale: 1/8 degree
- Time Frame:
  - Baseline = 1950-1999
  - Future = 2000-2099



# Evolution of the Maximum Frost Depth

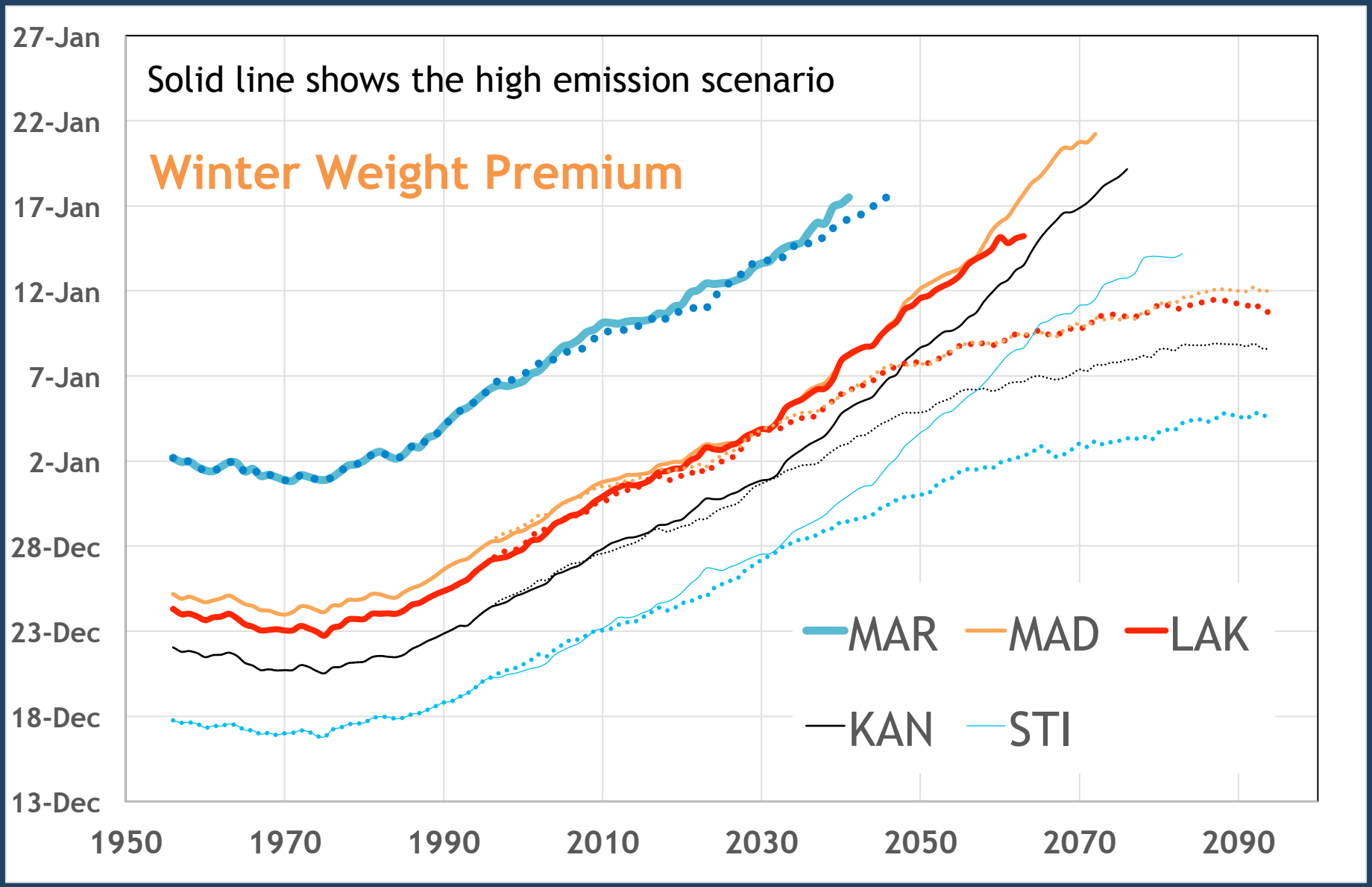
## 20 Climate Models using RCP 4.5 and RCP 8.5

Historical and Projected Maximum Frost Depth in Madison, ME Based on RCP 4.5 and RCP 8.5



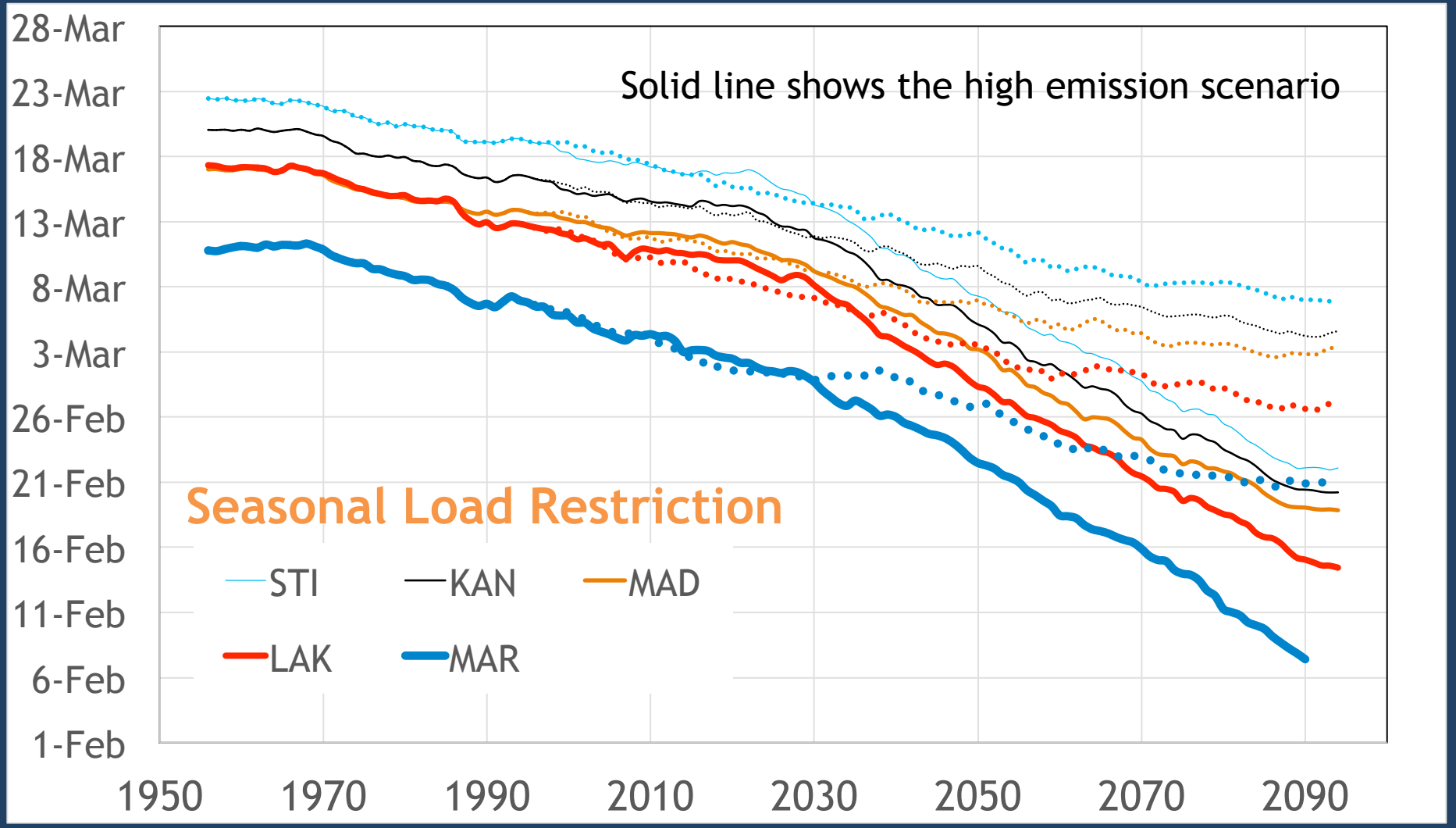
# Evolution of CFI Threshold Exceedence Dates

## 20 Climate Models using RCP 4.5 and RCP 8.5



# Evolution of CTI Threshold Exceedence Dates

## 20 Climate Models using RCP 4.5 and RCP 8.5



# Summary

| Length of freezing season for five sites and standard deviation across 20 climate models | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Periods | STI-4.5 | SD | MAD-4.5 | SD | MAR-4.5 | SD | KAN-4.5 | SD | LAK-4.5 | SD |
| Baseline (1970-1999) | 93 | 2.1 | 79 | 1.9 | 64 | 2.9 | 85 | 2.6 | 80 | 2.7 |
| EarlyCentury (2000-2029) | 83 | 4.0 | 70 | 4.6 | 52 | 5.0 | 76 | 4.2 | 69 | 6.1 |
| MidCentury (2030-2059) | 73 | 6.8 | 59 | 7.0 | NA | NA | 66 | 6.7 | 57 | 6.8 |
| EndCentury (2060-2089) | 65 | 9.1 | 54 | 6.2 | NA | NA | 59 | 7.3 | 49 | 8.2 |

- WWPs are occurring later
  - By 2050, they will be recommended one to two weeks later
  - By 2075, they will be recommended as late as Mid February or not at all
- SLRs are steadily occurring early
  - By 2050, they will be recommended approximately one to two weeks earlier
  - By 2100, they will be recommended as early as Mid February

# Conclusions

Changing winter temperatures will impact existing road networks' ability to support heavier traffic and change the timing of winter weight premiums and spring load restrictions.

The ability to adapt to the changing conditions is highly dependent on existing & future policies. Some policies would be well served by information about climate change in order to change legislated dates or to revise policies.

This study's results for existing low volume road networks has broader value for transport globally and seasonal access to sensitive lands as well as secondary impacts.

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# Thank You

For more information, please visit theicnet.org

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