Predicting the Impact of Climate Change on Ice Jams in Waterways

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Abstract

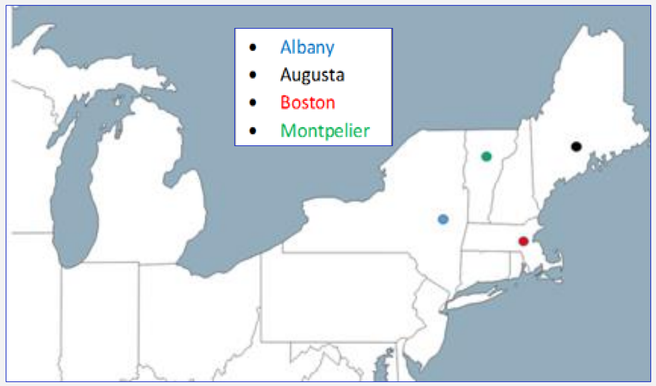
An ice jam is a dam on a river formed by blocks of fragmented ice. Knowledge of ice jams is important in the design of structures being built near waterways, as these fragments of ice can cause significant damage if not properly accounted for. Being able to predict where ice jams are likely to occur can have a huge benefit on hydraulic and structural engineering. In this study, we downloaded historical temperature data in four different locations within the northeastern United States. In addition, we downloaded the bias-corrected future temperature using three emission scenarios and four climate models. In the next step, we used Stefan's equation to make a comparative study of historical and future ice jam conditions. Our analysis indicated that ice jams would significantly decrease in the late part of the century and the period of winter will be shortened due to future climate change.

Project Goals

- Use past climate data to estimate historical ice jams
- Download projected future temperatures to predict ice jam occurrence in four locations:
  - Albany, New York
  - Augusta, Maine
  - Boston, Massachusetts
  - Montpelier, Vermont
- Analyze trends in ice thickness from 1950-2080
- Identify why there are changes in ice thicknesses over time
- Determine if there is a shift in the timing of ice jam occurrences when comparing historical and future data

Methodology

- Determine stations to analyze that are in the Northeast U.S. and are in close proximity to rivers that experience frequent ice jams
  - For example, the Mohawk River, which lies near Albany, NY, experiences ice jams annually
- Collect data from National Climatic Data Center and Scripps Institute of Oceanography
  - Four Climate Models
    - bcc-csm1-1
    - gfdl-cm3
    - gfdl-esm2g
    - hadgem-ao
  - Three Scenarios
    - rcp4.5 = Low carbon emissions
    - rcp6.0 = Moderate carbon emissions
    - rcp8.5 = High carbon emissions
- Use Excel to analyze the data
  - Calculate historic and future average daily temperature
  - Use average temperatures to determine AFDD
  - Use AFDD and C = 0.3 to calculate ice thickness



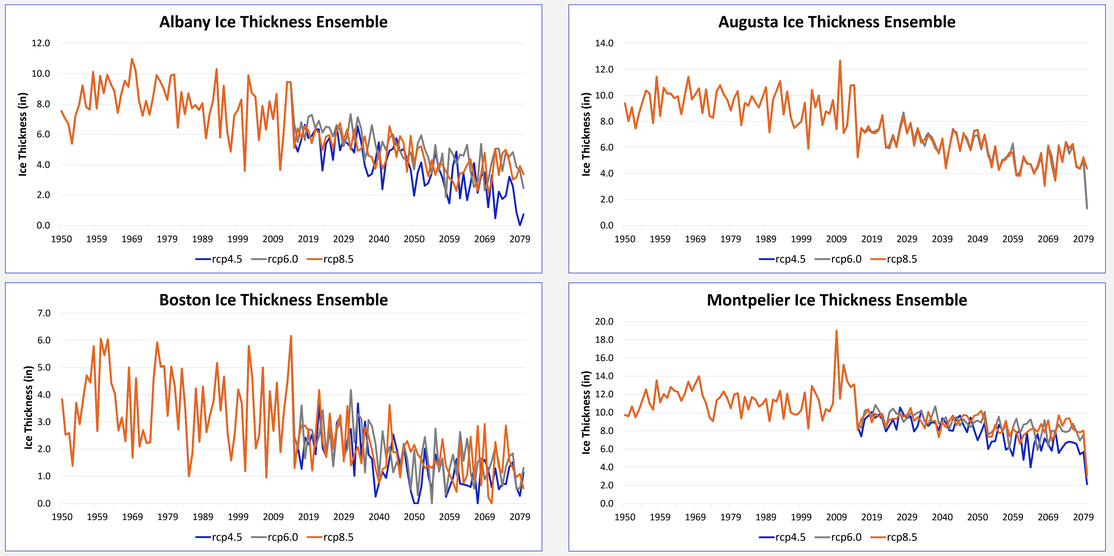


Figure 1. Ice Thickness Ensembles using Four Climate Models and Three Scenarios

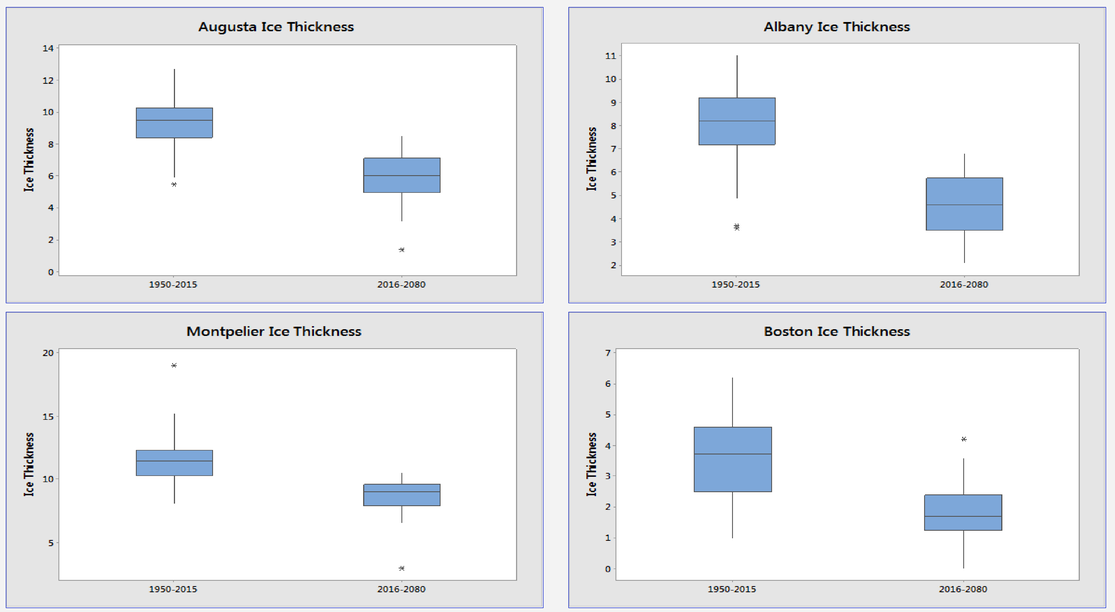


Figure 2. Comparison of Ice Thickness using Historical Data and Future Climate Projections

Figure 3. AFDD Start Date and Max Date using Historical Data and Future Climate Projections

Calculations

- AFDD = Average degrees below freezing over a one day period
  - Ice only forms during positive FDD
  - Long span of positive FDD produces thicker, more abundant ice growth

$$AFDD = 32 - Temperature\ (°F)$$

$$Ice\ Thickness\ (in) = C \times \sqrt{AFDD}$$

Results

- **Figure 1**
  - Illustrates that each emissions scenario yielded a similar trend in future ice thickness
  - High carbon emissions did not necessarily indicate a lower ice thickness
- **Figure 2**
  - Shows a projected decrease in ice thickness from 2016-2080 compared to historical data
  - The trend remains similar at each of the four stations, implying that the same trend could be expected throughout all of the northeastern region of the United States
- **Figure 3**
  - Shows that the start date for AFDD is shifting to later in the winter
  - The start date from 1950-2015 was typically in November or December, while the future start date is projected to be in December or January
  - The maximum AFDD is projected to shift from March to February
  - The combination of a later AFDD start date and earlier AFDD Max date imply that future winters will become shorter in the Northeast
- Lower future ice thicknesses imply that the chance of an ice jam is reduced
- Reduced likelihood of ice jam suggests that future design of hydraulic infrastructure will not have to consider ice jams as strongly as present day

Applications and Future Research

- This research can be used as an indicator of the future effects of global warming on the design of hydraulic structures
- Understanding the likelihood of an ice jam will affect the overall design of bridge pillars, dams, and other infrastructure in or around a waterway
- Similar approach could also be used to determine snowfall accumulation and the effects it would have on infrastructure

Mohawk River Ice Jams

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