A Multiscale Analysis of *two* Atmospheric River-Related Ice Jam Floods on the Pemigewasset River in New Hampshire

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MOTIVATION

- Ice jams and associated flooding occur regularly in midlatitude regions during the winter/spring season and can have locally high societal and economic impacts.
- Two high-impact ice jam floods formed on Pemigewasset (Pemi) River in central New Hampshire on 26 Feb 2017 and 12 Jan 2018 (see Fig. 1 below)
- Purpose of this presentation is to implicate atmospheric rivers (ARs) and their antecedent conditions as a possible cause for ice jam flooding, given their associations with flooding, flash flooding, debris flows, and landslides across the western U.S.

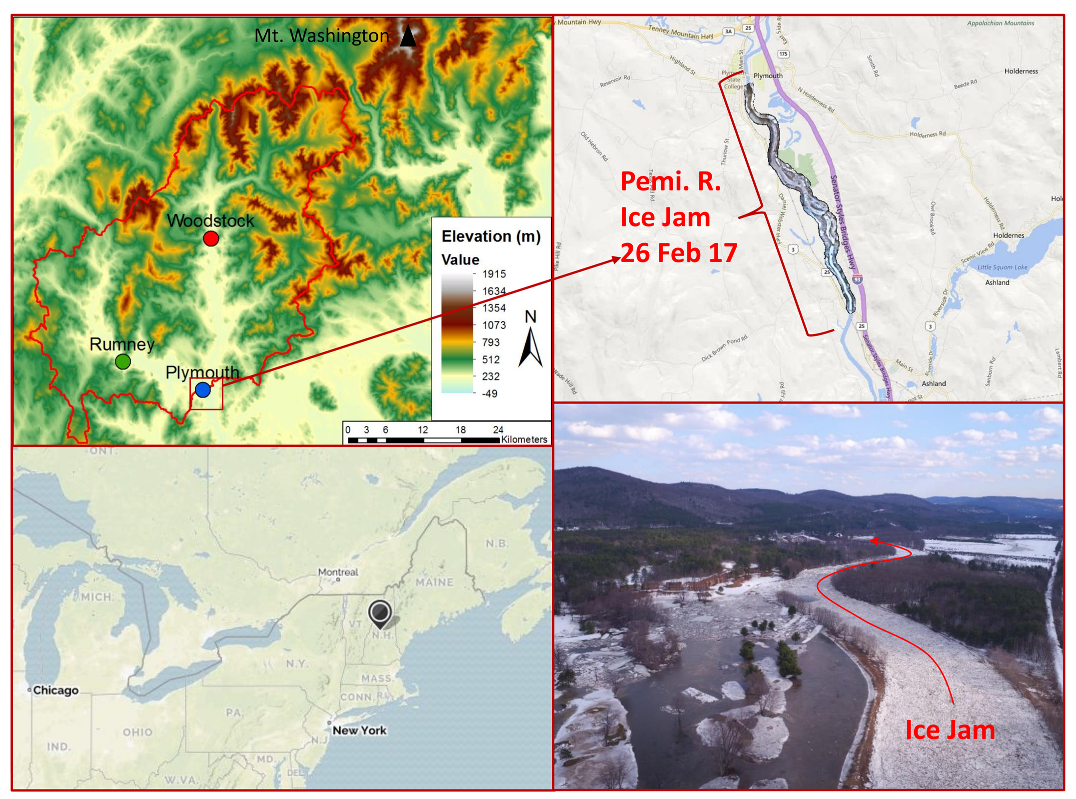


Figure 1: Bottom left) Wide-view of northeastern United States, indicating the location of Plymouth, NH. Top left) Elevation map of the Pemi. watershed (red) upstream of the USGS gage at Plymouth, with the locations of other key gage sites and Mt. Washington marked as well. Top right) Close-up of Pemi. River with USGS aerial photo of ice jam. Bottom right) USGS drone photo of ice jam and associated flooding in Ashland.

NOTABLE INGREDIENTS

Both ice jams featured:

- 1-to-2-week antecedent period of below-normal temperatures and high snowfall
- 2-to-4-day antecedent period of above-normal/above freezing temperatures and dewpoint temperatures
- Amplified synoptic-scale flow with enhanced atmospheric water vapor/water vapor transport into New England
- Cold-frontal squall line, stratiform, or orographic enhanced precipitation immediately prior to ice jam
- Deep, ripening snowpack with large snow-water equivalent (SWE) losses across watershed

DATA/METHODS

This phenomenological study employed:

- Hourly weather observations from Mount Washington (KMWN; shown) and Plymouth (K1P1; not shown)
- NOHRSC Snow Data Assimilation System data (SNODAS)
- NCEP Climate Forecast System Reanalysis (CFSR) data
- USGS stream data discharge (not shown) and gage height (shown)
- NOAA/ESRL Snow-Level Radar at Plymouth State University
- NWS Gray (KGYX), Maine radar (shown) and soundings (not shown)
- Data plotted in MS Excel and NCAR Command Language

RESULTS

Antecedent Observations

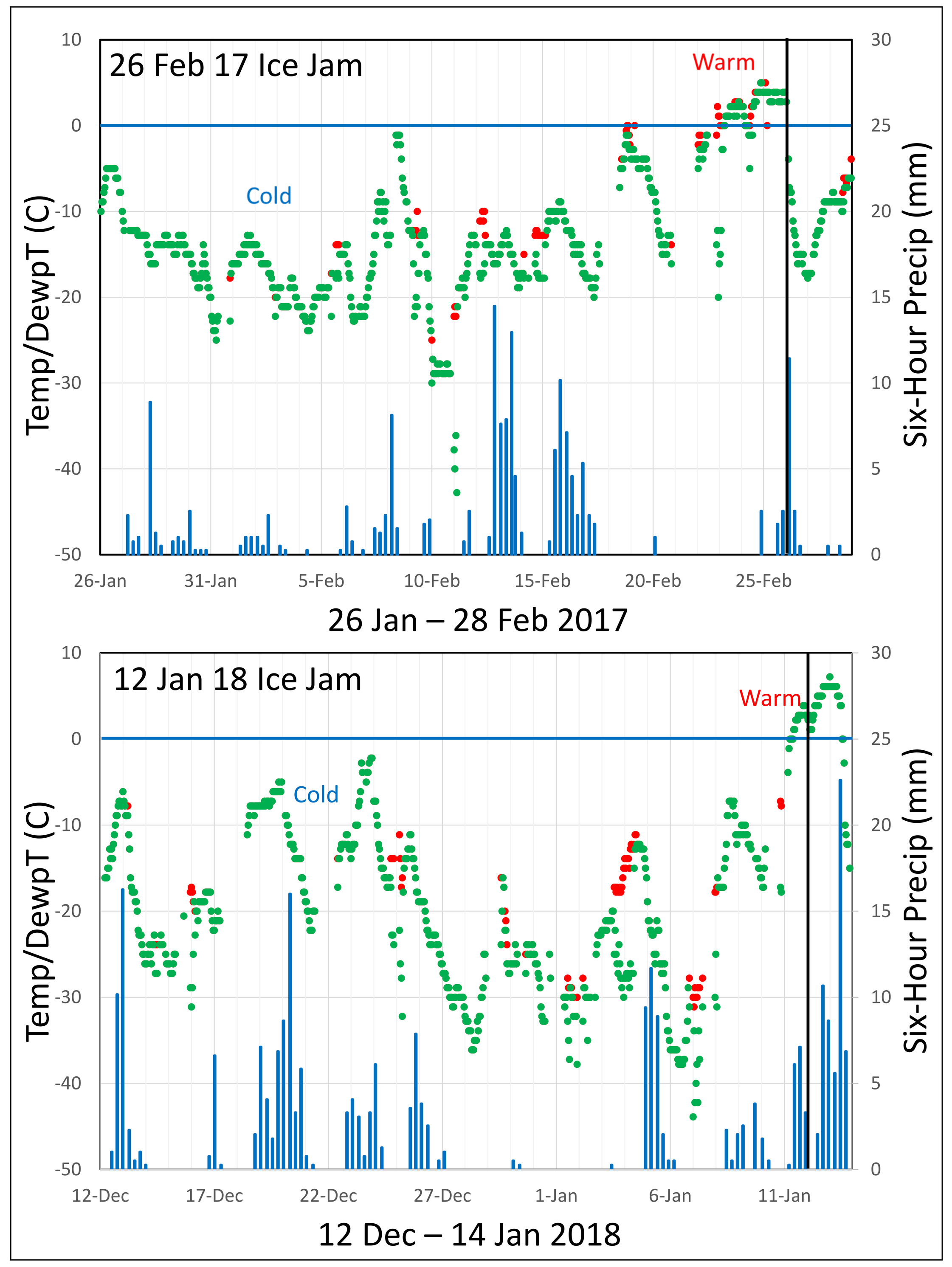


Figure 2: February 2017 (top) and January 2018 (bottom) weather observations from KWMN for period prior to ice jams showing temperature (red dots, °C), dewpoint temperature (green dots, °C), and 6-h precipitation totals (blue bars, mm).

Key Observations Results:

- Prolonged 1-to-2-week period of below-freezing T/T_d prior to ice jams
- >100 mm of precipitation (snow) in weeks prior to ice jams
- T/T_d warm to above freezing (at 1917 m ASL) in 2-to-4 days prior to ice jam (associated with 100 to 150 mm of SWE loss across Pemigewasset River watershed; not shown). Valley T/T_d increase to >10C
- Ice jams occur in association with or immediately following a ~20-to-50-mm rain event

2017 … In-situ Synoptic Conditions … 2018

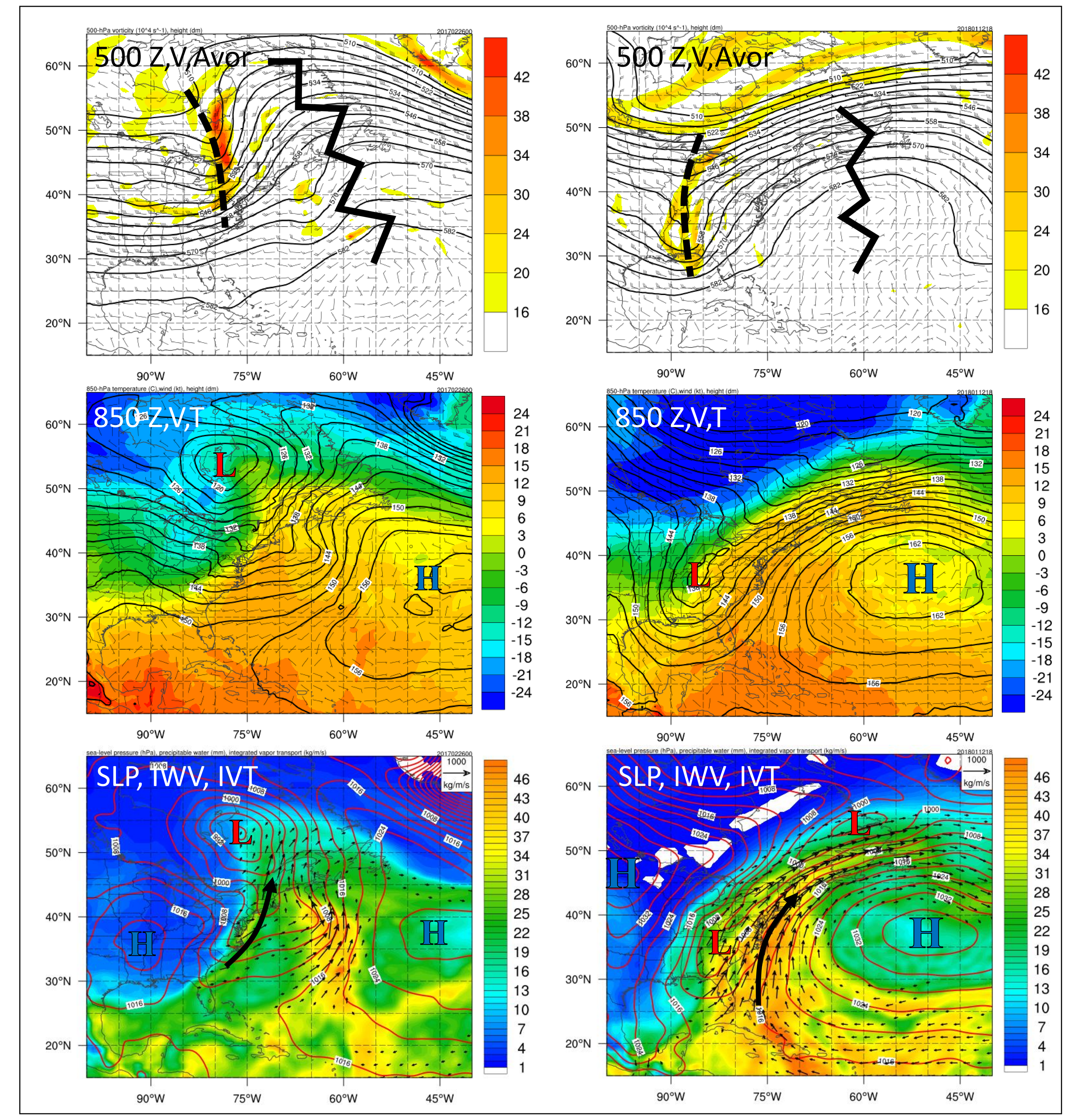


Figure 3: 00Z/26 Feb 2017 (left) and 18Z/12 Jan 2018 (right). Top: 500-hPa geo. heights (black lines, dam), abs. vorticity (color scale, 10^{-5} s^{-1}) and wind (kts). Middle: 850-hPa geo. heights (black lines, dam), temperature (color scale, °C), and wind (kts). Bottom: SLP (red lines, hPa), IWV (color scale, mm), and IVT (arrows, kg/m/s).

Key Synoptic Results:

- Amplified 500-hPa geopotential heights featuring negatively tilted upper-level troughs over the Great Lakes Region/Eastern North America
- Warm mid-tropospheric airmass with 850-hPa T > 9–12C and southerly/southwesterly, unidirectional wind shear
- Corridor of enhanced IWV >30–40 mm and IVT magnitude >600–1000 kg/m/s; appears to be a joint contribution from both cyclonic and anticyclonic flow between Great Lakes low-pressure and Atlantic high-pressure systems

Hydrologic Response

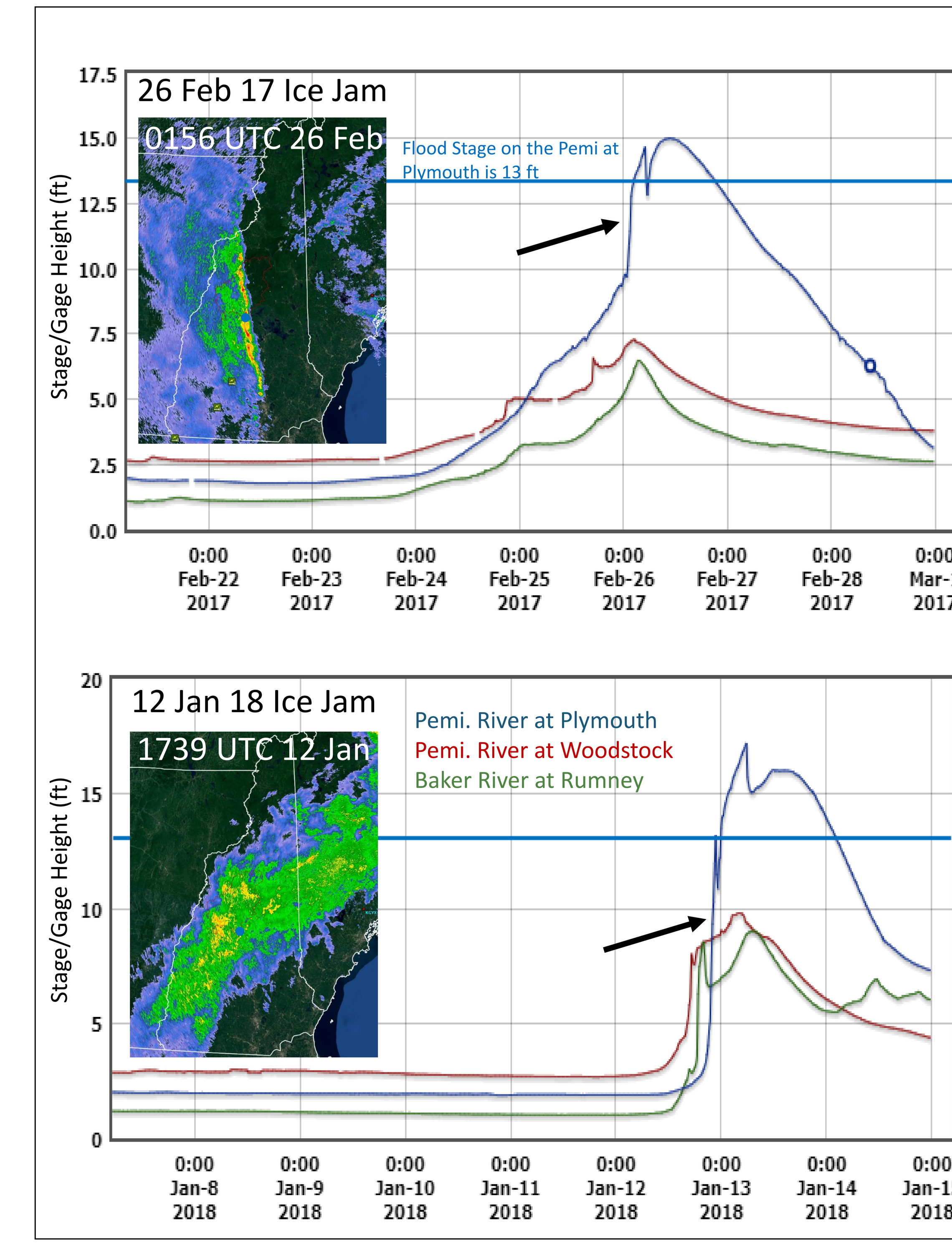


Figure 4: Stage/Gage height (ft) analyses for USGS stream gage sites at Woodstock NH (red), Plymouth NH (blue) on the Pemi River and at Rumney NH (green) on the Baker River. The time is noted as being displayed in EST.

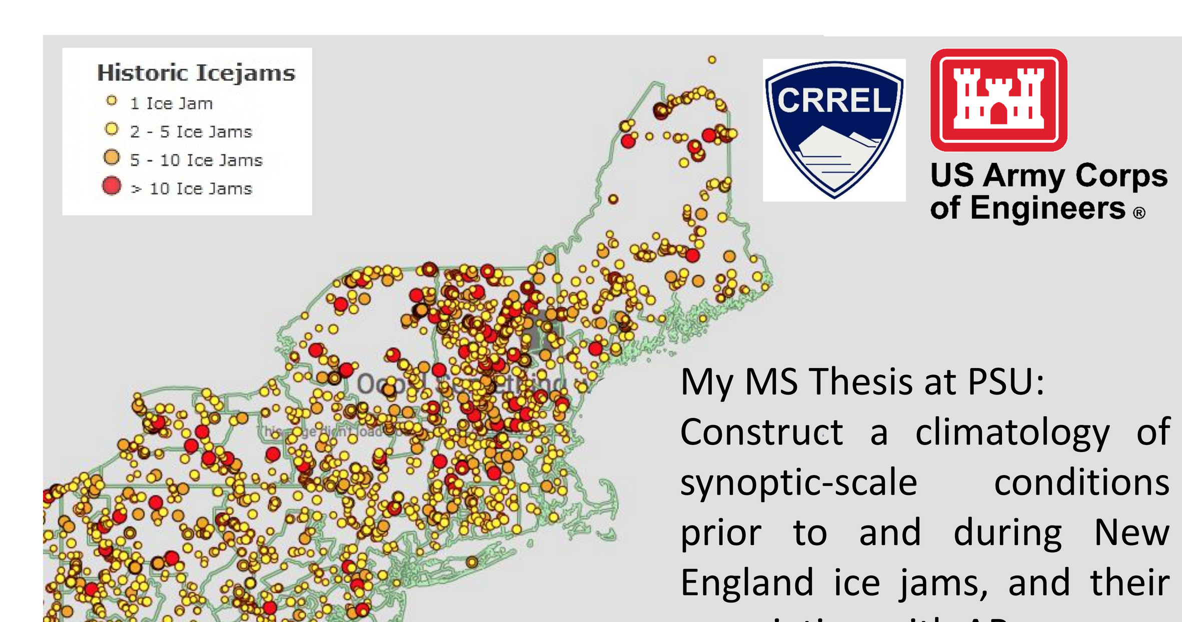
Key Hydrologic Results:

- Sudden increases in stream gage heights at Plymouth associated with ice jam development downstream in Ashland
- Some gage height traces illustrates ice jam breakup and reformation
- 2017 event features enhanced streamflow/increasing gage heights associated with SWE loss prior to precipitation event that triggered ice jam
- 2018 event more sudden increases in streamflow/increasing gage heights associated with more intense precipitation

CONCLUSIONS

- Climatological preconditioning of region for an ice jam/flood occurred in 3 stages:
  1. Initial cold period with multiple snowstorms to develop ice in river beds and a deep snowpack (SWE), respectively
  2. Intermediate warm period primes/ripens snowpack for SWE release into streams
  3. Snow/ice break-up triggered by synoptic precipitation associated with frontal passage (or excessive runoff due to SWE loss)
- Precipitation in the Pemigewasset watershed immediately prior to ice jam formation fell entirely as rain with snow levels >2 km, and was orographically enhanced by the White Mountains associated with low-level southerly flow
- Combination of precipitation and SWE loss led to enhanced runoff/streamflow prior to ice jams; majority of SWE loss at 1000–3000 feet ASL
- Once ice jam formed, gage heights rose rapidly and exceeded flood stage
- February 2017 ice jam and flood event initiated impact-based decision support services among Towns of Plymouth & Holderness with New Hampshire Homeland Security & Emergency Management, Plymouth State University, and the National Weather Service. Collaboration led to positive outcomes (i.e., minimal flood damages) during subsequent floods in July 2017, October 2017, and January 2018.

FUTURE WORK



My MS Thesis at PSU: Construct a climatology of synoptic-scale conditions prior to and during New England ice jams, and their association with ARs

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