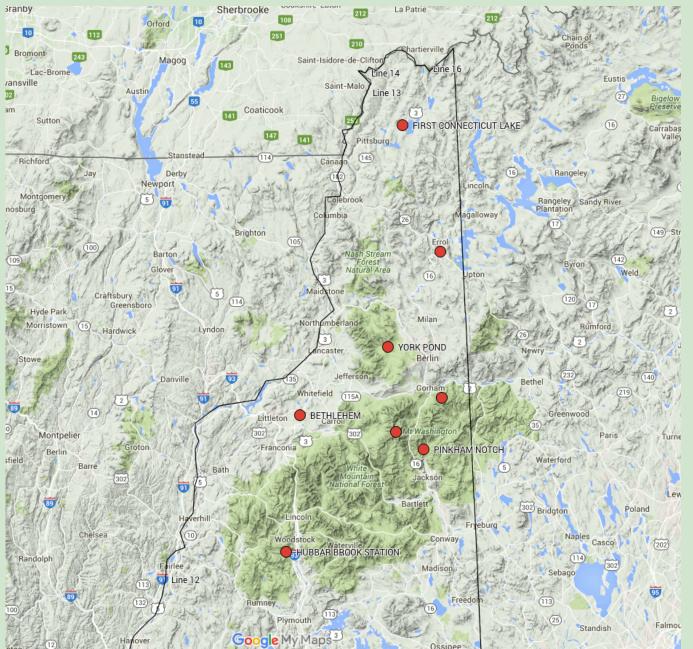
# Northern NH Snow Records from 1930 to 2015

# Plymouth State

### 1. Introduction

Climate change is expected to have severe negative impacts on the winter tourism industry, as states around the country experience inconsistent snowfall and rising temperatures.

New Hampshire relies on winter tourism. Snow is currency and climate change is expected to contribute to warmer winters, reduced snowfall, and shorter snow seasons. (Burakowski and Magnusson, 2012).



Map shows the measurement locations:

- 1. First Connecticut Lake
- 2. Errol
- 3. York Pond
- 4. Gorham
- 5.Bethlehem
- 6. Mount Washington
- 7. Pinkham Notch
- 8. Hubbard Brook (Stations 2 and

Map created using Google My Maps.

Five National Weather Service (NWS) snow monitoring stations from New Hampshire (Mount Washington, Pinkham Notch, First Connecticut, York Pond and Bethlehem) with records spanning at least 60 years through 2015 were tested for changes in snow season and depth.

Average snow depth for three USGS (Errol, Gorham, and Pinkham) and two Hubbard Brook Research Station (Stations 2 and 17) sites were also included for the months of February and March.

#### 2. Methodology

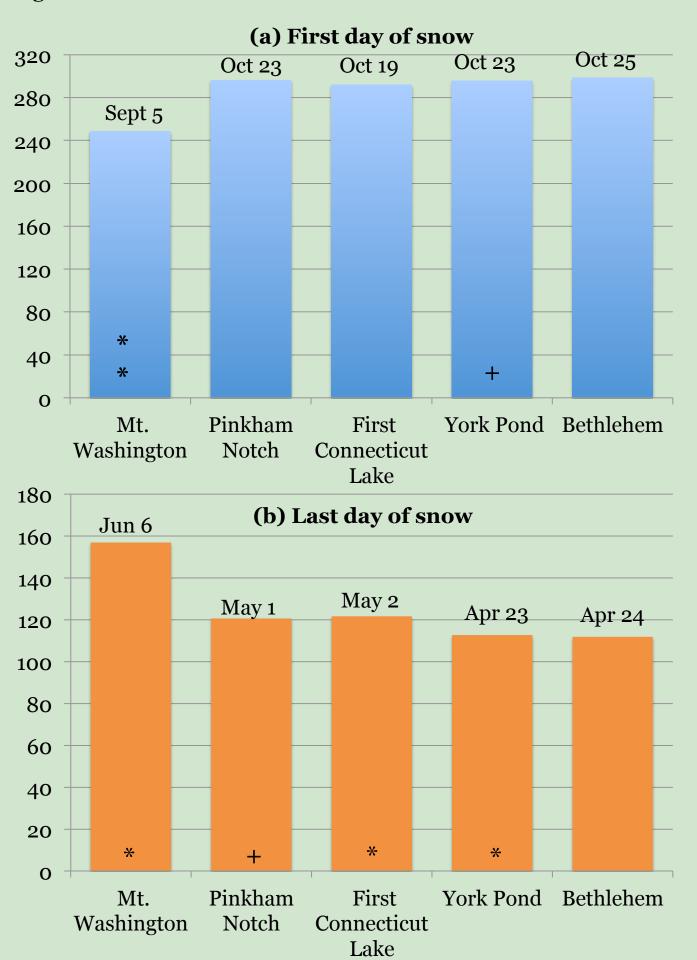
- Parameters examined were first and last days of snow, continuous snow cover, and snowpack depth following the methodology described in Seidel et al (2009).
  - Snow season was defined using the year associated with January (Ex.: the season of 1 July 2014 – 30 June 2015 is winter 2015)
  - First and last days of snow. The first variable was calculated using simply the first and last dates during a season that a snowfall, including trace amounts, was reported.
  - Start and end of snow pack are the dates after witch and before which there was a continuous cover of at least 2.54 cm, allowing a "thaw" period of no more than 4 days.
- Season length was calculated for both start and end of snow pack and first, and last day of snow.
- Sen's slope and the Mann Kendall non-parametric tests were used to examine trends in snow cover, first and last day of snow and season length.

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### 3. Snowfall and Snow Depth

- All snowfall and snow depth trends are shown in Table 1. The stations that showed significant trends are:
- The first day of snow at Mount Washington occurs 4 days/decade later in autumn and the last day of snow occurs 2 days/decade earlier in the spring.
- At Pinkham Notch the last day of snow occurs 1.8 days/decade earlier.
- At First Connecticut Lake the first snow occurs 1.2 days/decade later and the last snow ends 2 days/ decade earlier.
- At York Pond the first snow occurs 2 days/decade later, and the last snow ends 3 days/decade earlier.
- At Bethlehem the first snow occurs 6 days/decade later, and the last snow ends 3 days/decade earlier.

Figure 1. Average first (a) and last (b) day of snow for 1950-2015. Mann Kendal test was used to calculate the significance of the trends.



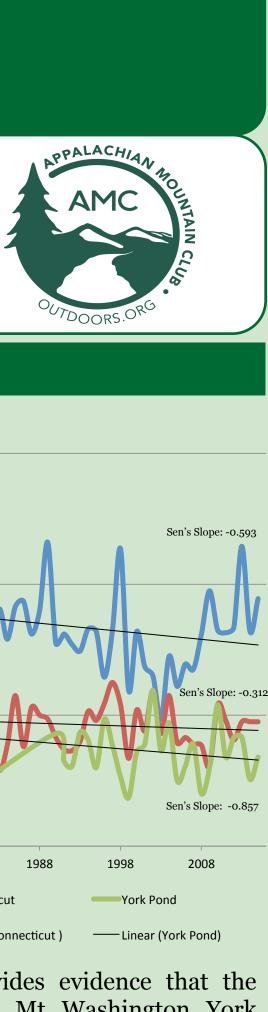
Asterisks denote significance for the Sen's slope fit at thresholds of *p*≤0.001<sup>\*\*\*</sup>, *p*≤0.01<sup>\*\*</sup>, *p*≤0.05<sup>\*</sup>, *p*≤0.10 +

When trends were evaluated starting in 1950, we lost statistical significance compared to the data in Table 1.

Station		Sno	wfall	Snow Cover		
		First	Last	First	Last	
Mount Washington (1949-2015)	Mean	Sep 6 [249]	Jun 6 [157]	Nov 22 [326]	Apr 30 [120]	
	Std. Dev.	27	13	28	22	
	Sen's Slope	0.405	-0.197	0.098	0.074	
	Trend	4 days	-2 days	1 day	1 day	
	P-Value	< 0.01	< 0.05	0.284	0.373	
Pinkham Notch	Mean	Oct 23 [296]	Apr 30 [120]	Nov 28 [332]	Apr 19 [109]	
(1930-2015)	Std. Dev.	16	13	16	13	
	Sen's Slope	0.019	-0.063	0.074	-0.176	
	Trend	0.2 day	-1 day	1 day	<b>-1.8</b> days	
	P-Value	0.764	0.218	0.284	<0.001	
First Connecticut Lake (1930-2015)	Mean	Oct 17 [290]	May 3 [123]	Nov 24 [328]	Apr 24 [ 114]	
	Std. Dev.	14	13	12	12	
	Sen's Slope	0.121	-0.143	0.074	-0.037	
	Trend	1.2 days	-1.4 days	1 day	o.4 day	
	P-Value	<0.05	<0.01	0.177	0.509	
York Pond	Mean	296 (Oct 22)	113 (Apr 22)	N/A*	N/A	
(1949 – 2015)	Std. Dev.	17	16	N/A	N/A	
	Sen's Slope	0.185	-0.250	N/A	N/A	
	Trend	2 days	-2.5 days	N/A	N/A	
	P-Value	<0.05	<0.05	N/A	N/A	
Bethlehem	Mean	Oct 24 [297]	Apr 23 [113]	Dec 10 [344]	Apr 2 [92]	
(1931 – 2011)	Std. Dev.	16	13	20	16	
	Sen's Slope	0.590	-0.333	-0.118	-0.032	
	Trend	6 day	-3.3 day	-1 day	o days	
	P-Value	<0.001	<0.001	0.1556	0.6312	

**TABLE 1**: First/Last snowfall and Start/End of snow cover

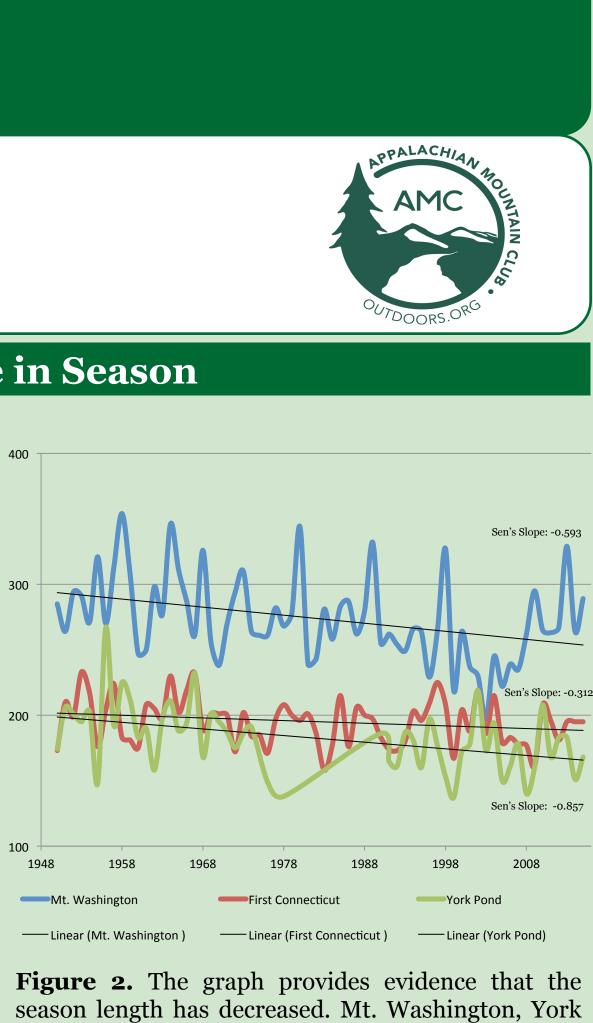
\*Start and End of Snow Cover for York Pond could not be calculated because we were missing a significant number of





Changes in snowfall season are shown for the 3 sites that had significant trends, Figure 2.

- The first snow starts on average 2.7 days /decade later (Mann-Kendall test, p< 0.1) and it ends 2.3 days /decade sooner.
- Mount Washington lost 6 days/decade from the snowfall season, while First Connecticut lost 3 days/decade and York Pond, 8 days/decade.



Pond and First Connecticut show significant change in season length (Mann-Kendall test, p< 0.05)

#### **5.** Snow Depth for the Months of February and March

Errol, Gorham, and Pinkham USGS sites, as well as Hubbard Brook (Station 2 and 17) were tested for change over time in snowpack depth for the months of February and March. Four out of five had a significant decrease (on average 1.34 inches/decade, p<0.05) in snowpack over time, Table 2.

	First Year	Last Year	Ν	Mean (inches)	Std. Dev.	Sen's Slope	Max Snow (inches)	Trend (+/- inches)
Errol	1911	2015	104	27.79	7.453	- 0.080	32.78	- 1
HB Stat 17	1966	2015	49	31.27	10.41	- 0.211	39.29	- 2
HB Stat 2	1956	2015	59	19.95	8.994	- 0.196	27.22*	- 2
Gorham	1937	2015	63	21.15	11.43	- 0.044	24.07	- 0.5
Pinkham Notch	1935	2015	78	28.73	12.8	- 0.110	31.91	- 1.1

**Table 2**. \*We don't have enough statistical evidence ( $p \le 0.342$ ) to conclude that Hubbard Brook Station 2 lost 2 inches from snow depth/decade.

#### **6.** Conclusions

Long term snow records from northern New Hampshire show significant trends largely indicating shorter snow cover, shorter overall snow season and less snow depth. This supports concerns that climate change is altering winter in a region that relies on snow.

#### **7. References and Data Sources**

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