12.14.2023

Appalachian Mountain Club
N.H. Mountain Snow Monitoring

FEMC 2023 Annual Meeting

Georgia Murray
Maya Shyevitch
Jordon Tourville
Sarah Nelson
Miriam Ritchie

BE OUTDOORS™
APPALACHIAN MTN CLUB

Georgia Murray
Staff Scientist

Jordon Tourville
Research Fellow

Maya Shyevitch
Research Intern

Miriam Ritchie
Research Assistant

Sarah Nelson
Director of Research

AMC'S Research Staff involved in snow monitoring.
Also key: AMC seasonal interns, hut caretakers, reservations department, CSO volunteers, and partners at the NWS.

AMC Research

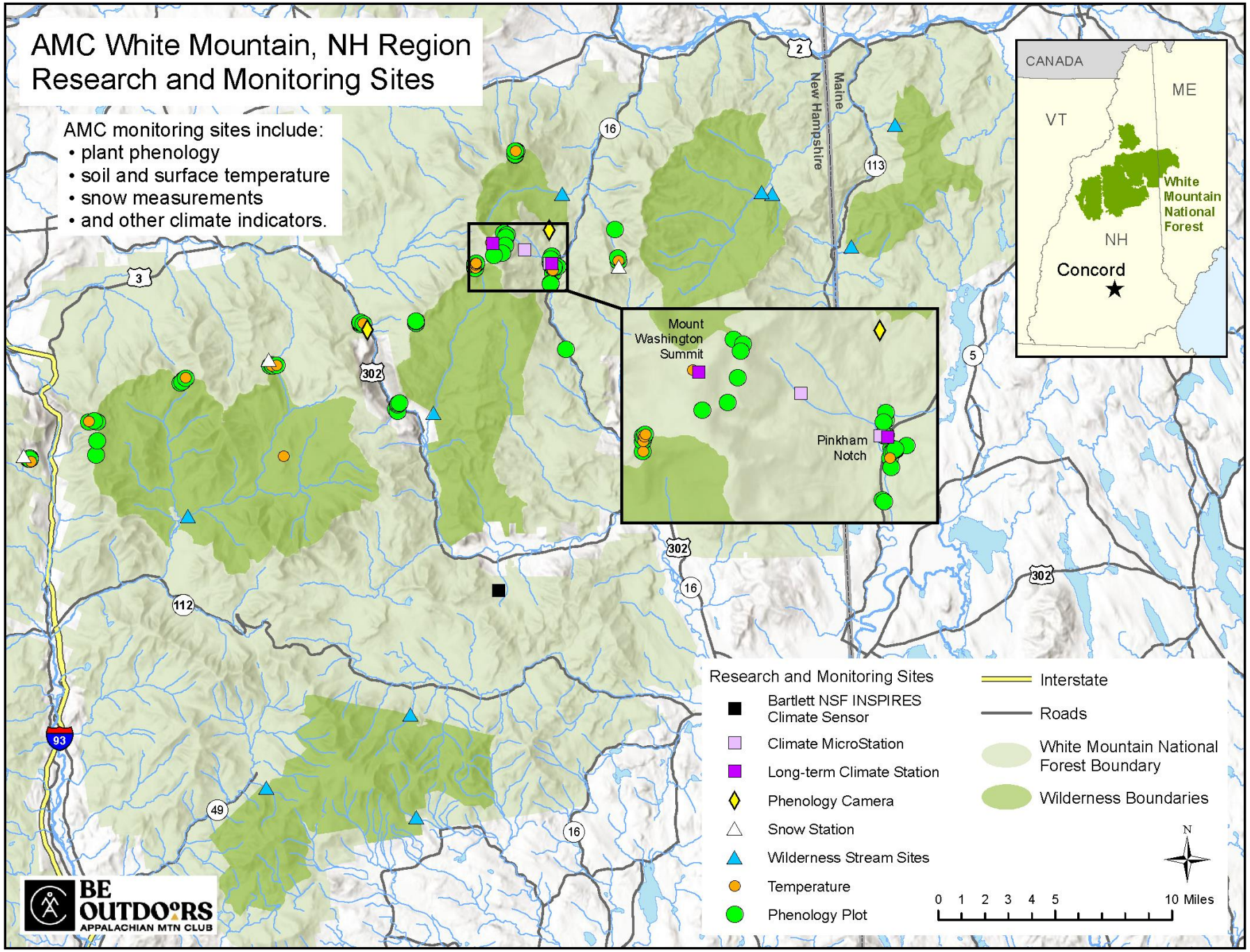
AMC Mountain Monitoring

Snow, Air & Soil Temperature, Soil Moisture, Plant Phenology, Water and Air Quality. **Citizen Science**

Photo: C. Griffin

AMC Research

Where



AMC Research

Why It Matters: Impacts of Changing Winters

The loss of cold and snow in places historically adapted to cold, snowy winters may reshape our social and ecological systems.

Courtesy of the Hubbard Brook Research Foundation

Winter climate change may fundamentally reshape the ecological and social fabric of the northern forest.

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APPALACHIAN MTN CLUB

Krumholtz

Along with birch-alder, the krummholz community represents a transition into the alpine zone from the spruce-fir forest below. Although there is little change in the species composition during this transition, the two dominant species (balsam-fir and black spruce) rapidly change their growth pattern and take on a dwarfed 'crooked wood' form. The krummholz community is generally found at lower elevations within the alpine zone, but isolated patches can occasionally be found at higher elevation sites that are protected from exposure to wind and rime ice.

Cliff

Like fellfield, one of the most obvious features of the cliff community is the thin vegetative cover. Although these steep areas make extensive plant growth difficult, various alpine plants survive among the ledges and cracks of these rocky faces. In addition, the extreme topography, exposure, and varying moisture create microhabitats for some unique species.

Cushion-Tussock

This is the community sought out by photographers and flower enthusiasts soon after the snows recede in the alpine zone. Tiny low-growing cushion plants, such as diapensia, alpine azalea, and Lapland rosebay, produce expansive mats of white, pink, and purple blooms. In contrast to the delicate floral show, the cushion-tussock community thrives among the most exposed areas. It is generally restricted to high elevation ridges, where persistent winds leave little or no snow cover during the long winter.

Herbaceous Snowbank

This diverse and unique community includes various lily, grass, fern and other non-woody species. Many of these herbaceous plants are more common at lower elevations and are generally unable to survive the harsh alpine climate. However, in areas where blowing snow accumulates and snowpack persists into the growing season, these more delicate plants are protected from late frosts and have a reliable source of water well into the summer. This community type is most commonly found on southeast facing ravine headwalls and areas that form a concave basin, but it is rare overall.

Feldfield

At first glance, the fellfield community may appear largely lifeless. Although these 'fields of rock' are partly a geologic phenomena, a closer look reveals that the rock surfaces support vast rock tripe (small black forms), map lichen (extensive yellow-green forms), and ring lichen (pale green semi-circles) colonies. In addition, a broad variety of alpine plants grow in the protected spaces between the various sized boulders. Topography does not appear to strongly affect the location of fellfield communities, which may have more to do with physical properties of the underlying rock.

Birch Alder

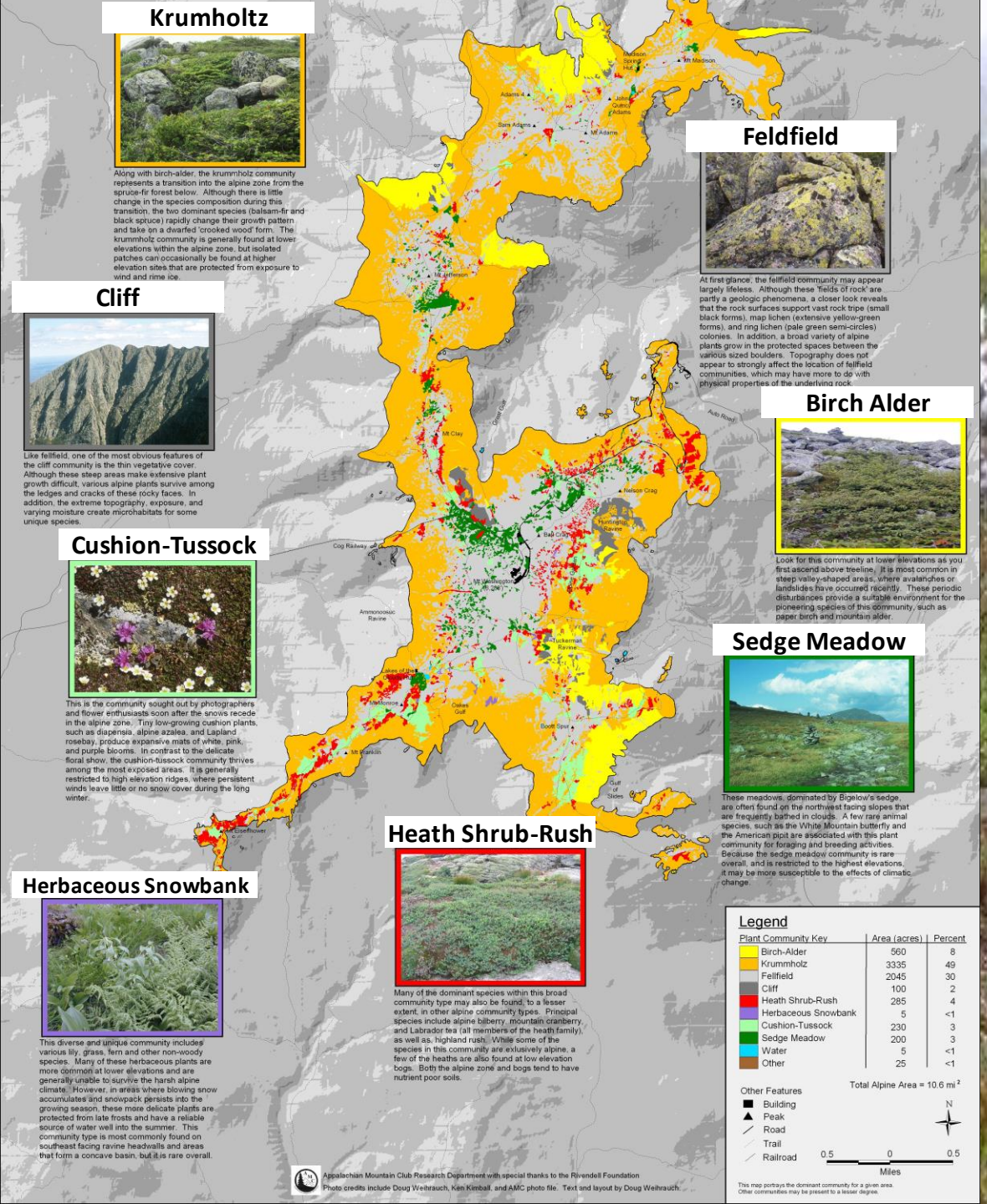
Look for this community at lower elevations as you first ascend above treeline. It is most common in steep valley-shaped areas, where avalanches or landslides have occurred recently. These periodic disturbances provide a suitable environment for the pioneering species of this community, such as paper birch and mountain alder.

Sedge Meadow

These meadows, dominated by Bigelow's sedge, are often found on the northwest facing slopes that are frequently bathed in clouds. A few rare animal species, such as the White Mountain butterfly and the American pipit are associated with this plant community for foraging and breeding activities. Because the sedge meadow community is rare overall, and is restricted to the highest elevations, it may be more susceptible to the effects of climatic change.

Heath Shrub-Rush

Many of the dominant species within this broad community type may also be found, to a lesser extent, in other alpine community types. Principal species include alpine bilberry, mountain cranberry, and Labrador tea (all members of the heath family), as well as, highland rush. While some of the species in this community are exclusively alpine, a few of the heaths are also found at low elevation bogs. Both the alpine zone and bogs tend to have nutrient poor soils.



Legend

Plant Community Key	Area (acres)	Percent
Birch-Alder	560	8
Krummholz	3335	49
Fellfield	2045	30
Cliff	100	2
Heath Shrub-Rush	285	4
Herbaceous Snowbank	5	<1
Cushion-Tussock	230	3
Sedge Meadow	200	3
Water	5	<1
Other	25	<1

Total Alpine Area = 10.6 mi²

Other Features
- Building
- Peak
- Road
- Trail
- Railroad

N

0.5 0 0.5
Miles

This map portrays the dominant community for a given area. Other communities may be present to a lesser degree.

Appalachian Mountain Club Research Department with special thanks to the Rivendell Foundation
Photo credits include Doug Weihrauch, Ken Kimball, and AMC photo file. Text and layout by Doug Weihrauch.

AMC Research

Alpine plant phenology

Diapensia lapponica

Rhodadendron groenlandicum

Carex bigelowii

Vaccinium uliginosum

NH, VT and Maine Only

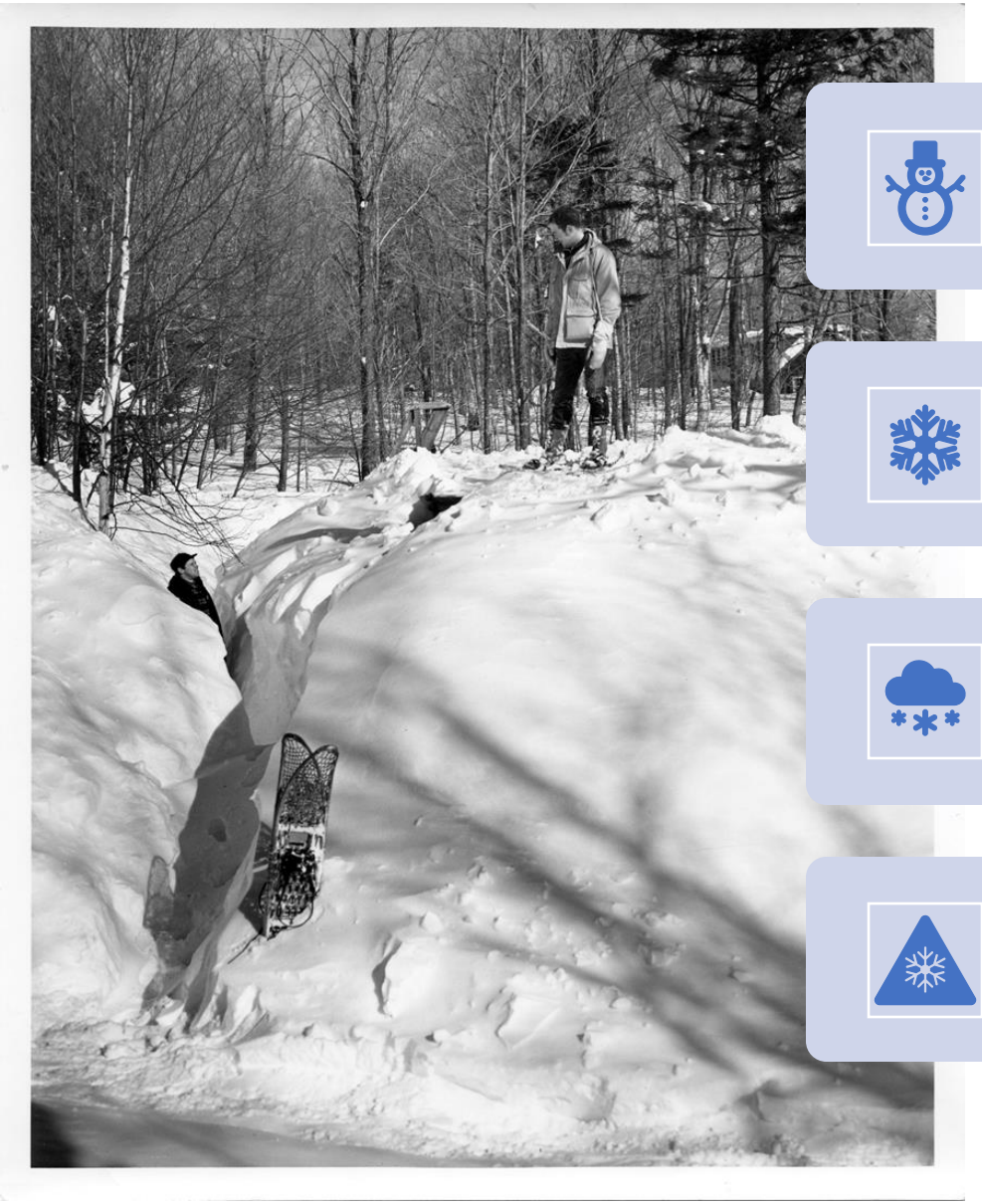
Vaccinium vitis-idaea

NH Only

Geum peckii

AMC Research

AMC's NH Mountain Snow Related Monitoring

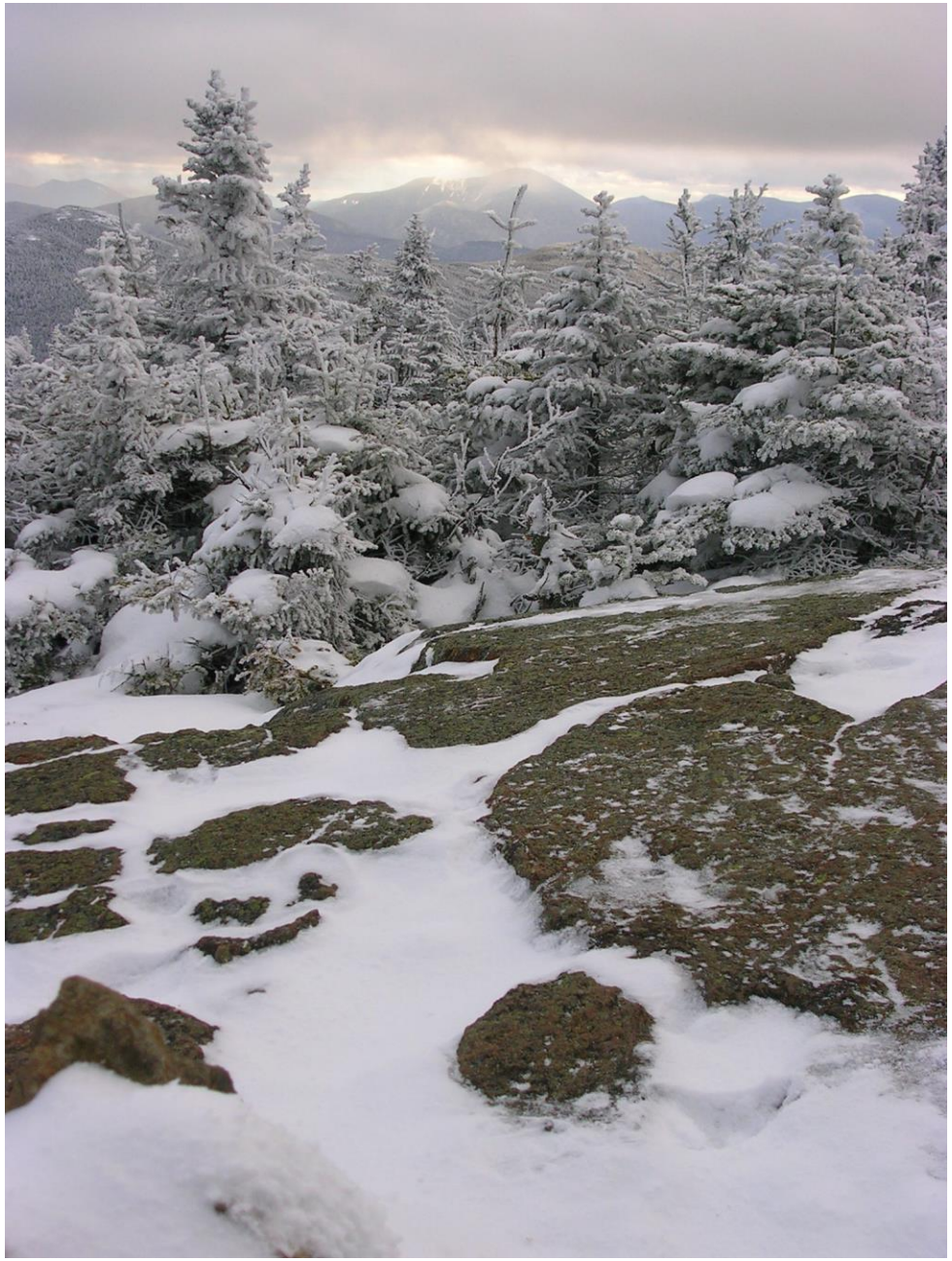


- Long-term Pinkham Notch, NH daily snow 1930-ongoing
- 3 Winter Huts, White Mountains daily snow earliest 1990-ongoing
- HOBOs Surface Air Temp. diurnal variation as proxy for snowmelt 2004/2007-ongoing
- Community Snow Observations, recreator random location snow depth 2017-ongoing

AMC Research

1935-2018 Warmer Winter Temperatures across the region

Site or region	Warming over **84 years** (°F)
Mount Washington, NH	+2.3 ns
Pinkham Notch, NH	**+ 3.4**
New Hampshire	**+ 4.2**
Northeast	**+ 2.5**
Contiguous US	**+ 2.5**

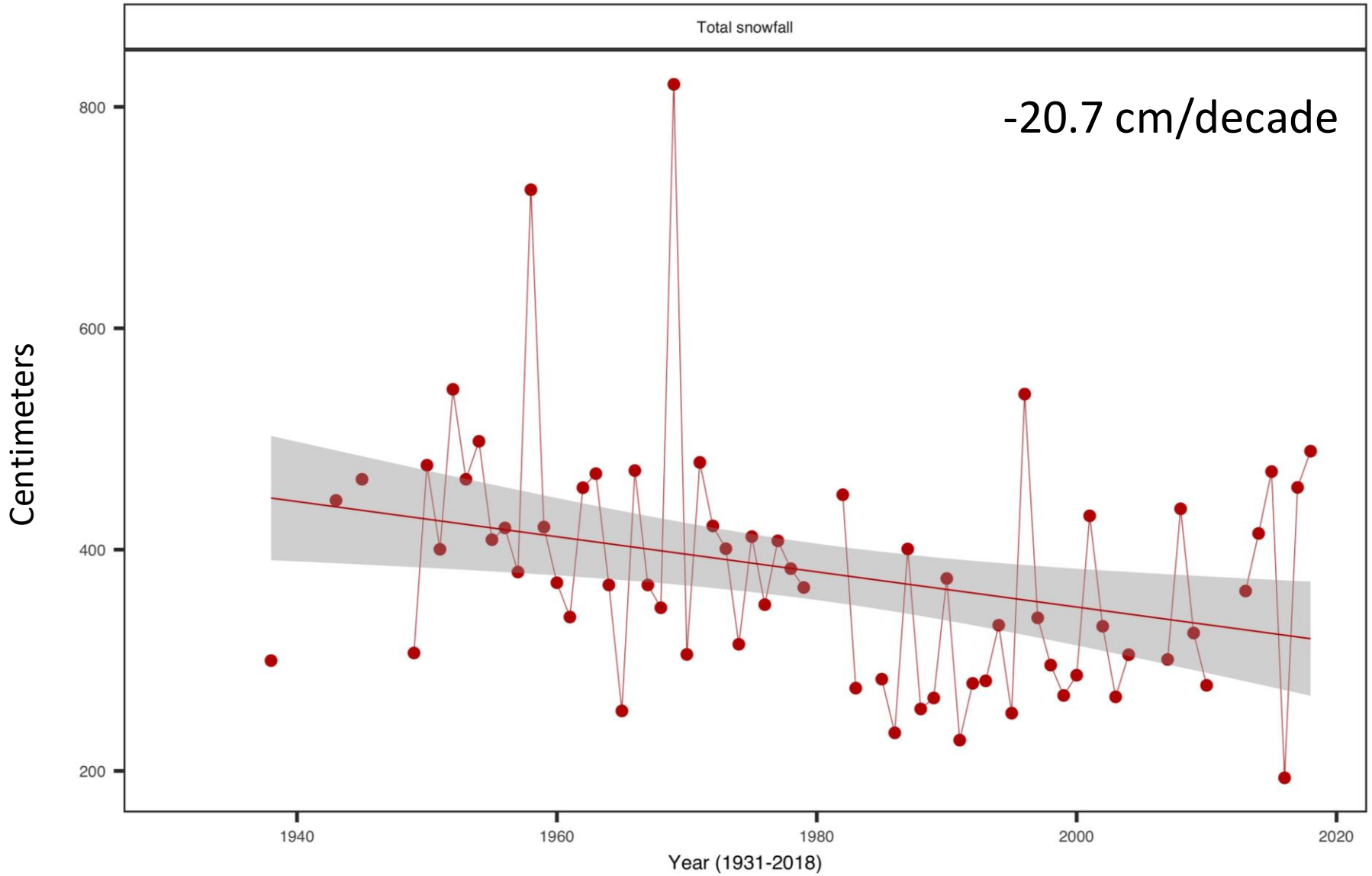


Murray et al. 2021. Climate Trends on the Highest Peak of the Northeast: Mount Washington, NH. *Northeastern Naturalist.*

NOAA Climate at a Glance Time Series

AMC Research

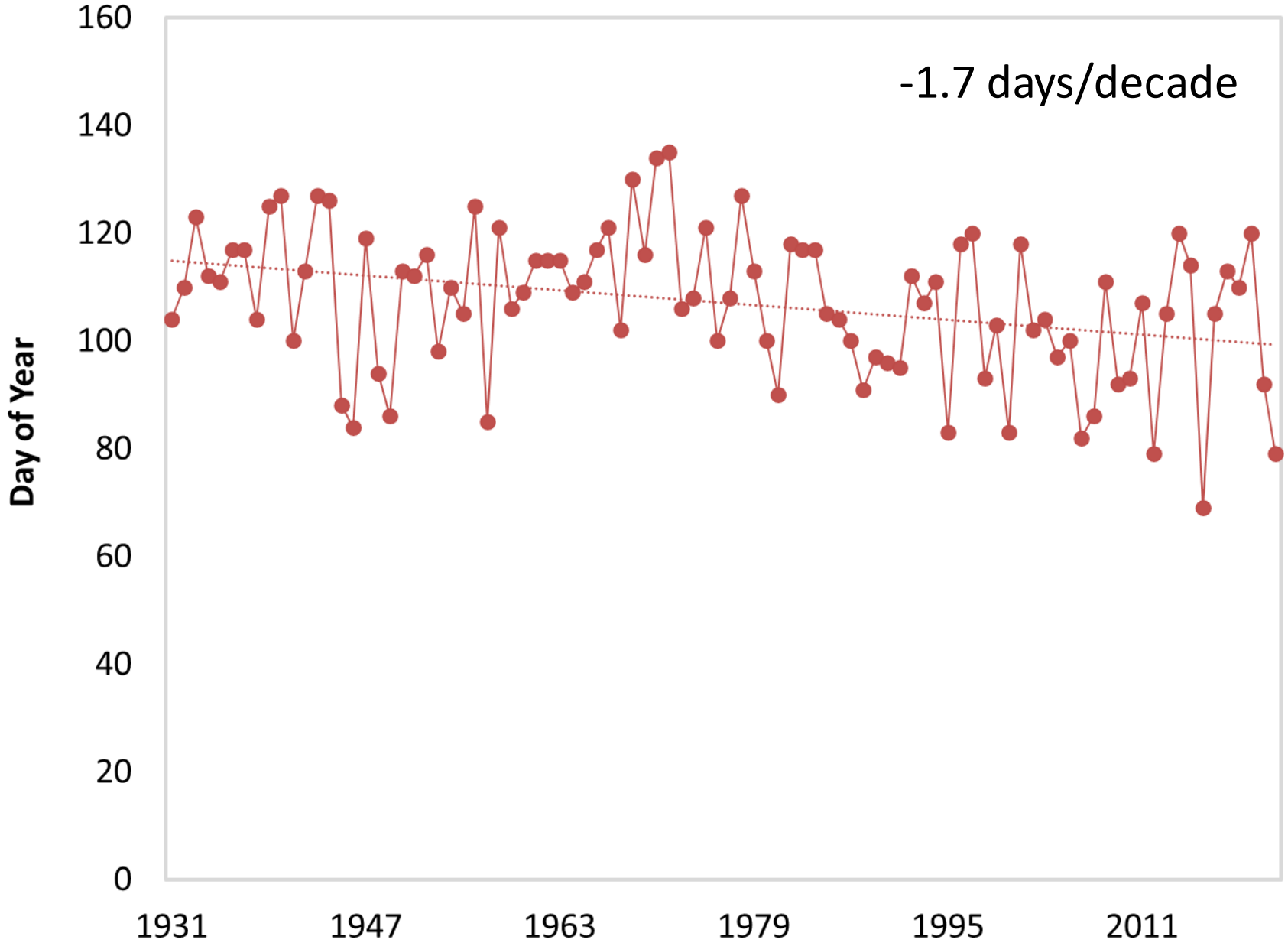
Long-term Pinkham Notch, NH Total Snowfall



Murray et al. 2021. Climate Trends on the Highest Peak of the Northeast: Mount Washington, NH. *Northeastern Naturalist.*

AMC Research

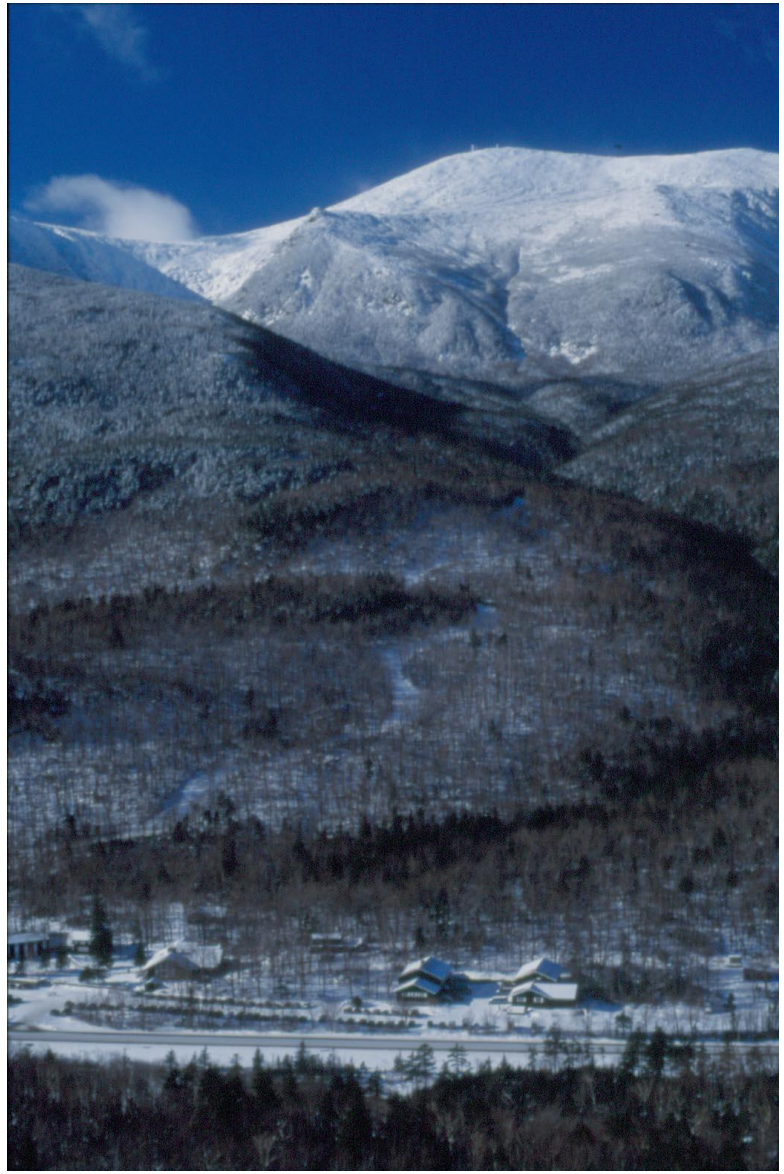
Long-term Pinkham Notch, NH Day of Snowmelt



AMC Research

Long-term Pinkham Notch, NH Snow Season Changes Since 1930

- Maximum snowpack depth declined ~50%
- Total snowfall declined ~25%
- Snowpack melted 2 weeks earlier

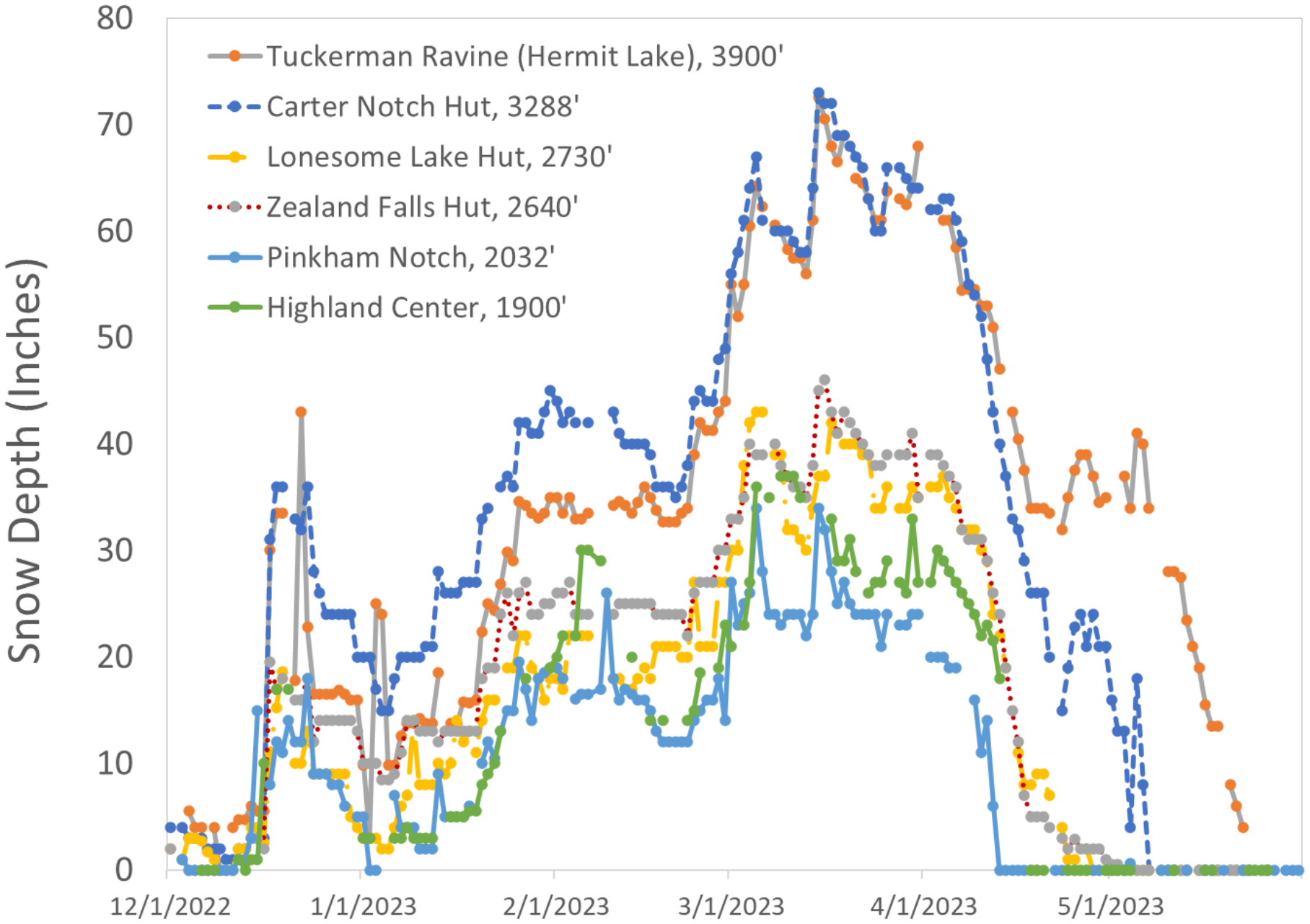


AMC Research

Murray et al. 2021. Climate Trends on the Highest Peak of the Northeast: Mount Washington, NH. *Northeastern Naturalist.*

AMC NH Huts and Lodges Snow Monitoring , NH

Location	Elevation (feet)	Start of Snow Stake Record	Start of HOBO Record
Pinkham Notch	2032	1930	2007
Highland Center	1900	1990*	2007
Tuckerman Ravine Hermit Lake Shelter	3900	1990	NA
Carter Notch Hut	3288	1991	2011
Zealand Falls Hut	2640	1990	2010
Lonesome Lake Hut	2730	2007	2010*
*** Data have significant gaps**			

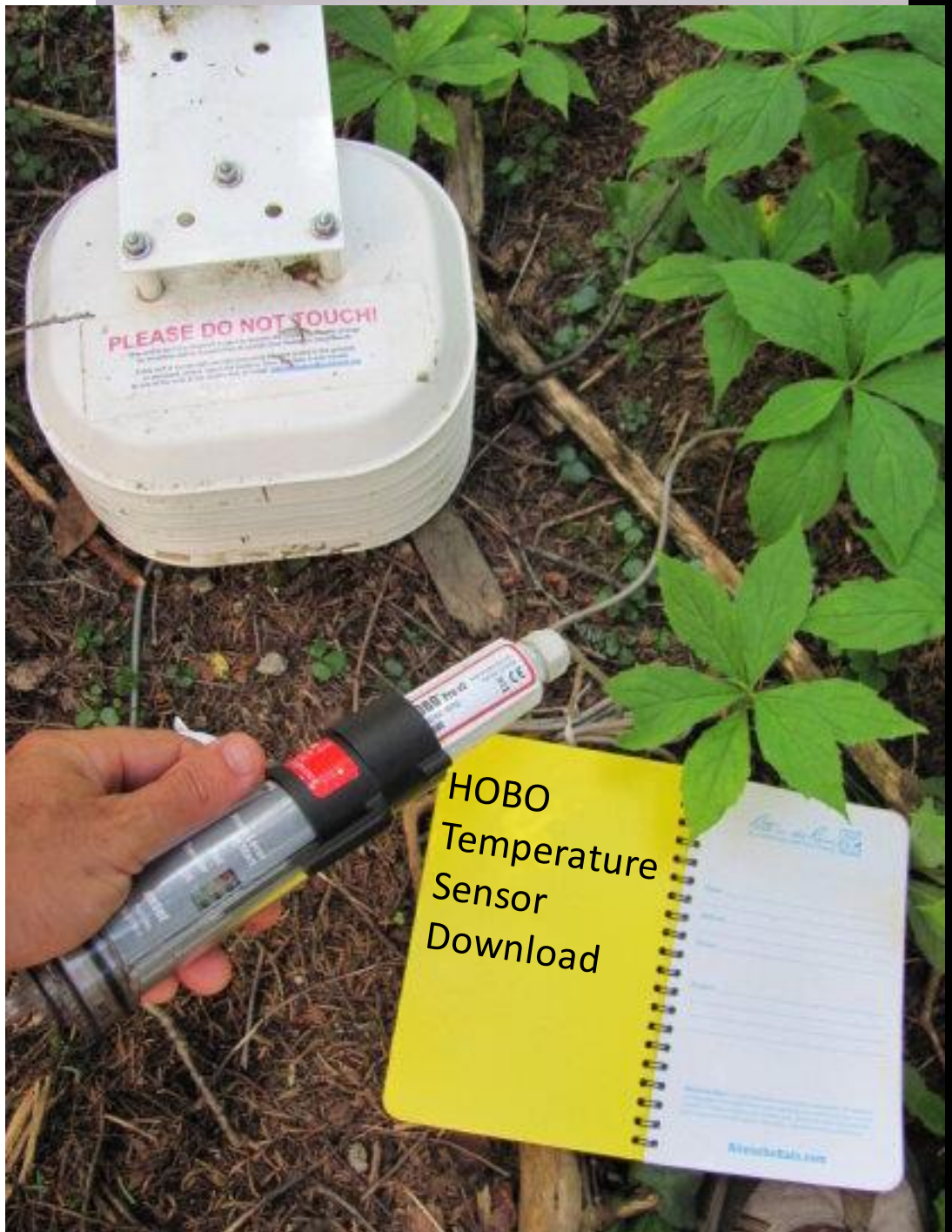


Carter Notch Dec. 2023

Snow Melt Timing…
HOBOs vs. Snow Stakes

- Snow stakes
  - In canopy opening
  - Snowmelt = bare ground for at least 4 consecutive days

- HOBO
  - Under light canopy, paired with phenology plots
  - Snowmelt = when surface temperature fluctuates diurnally



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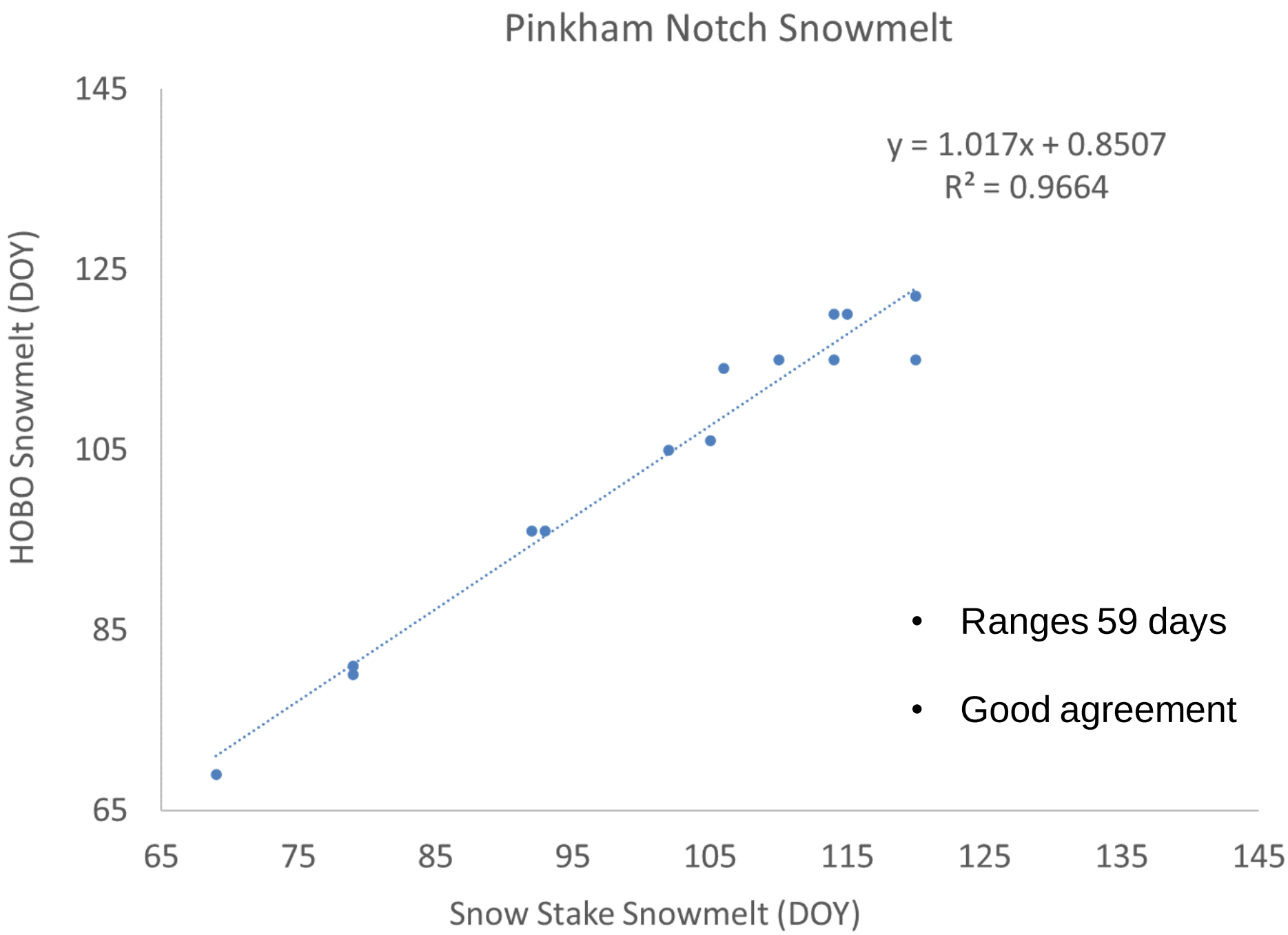
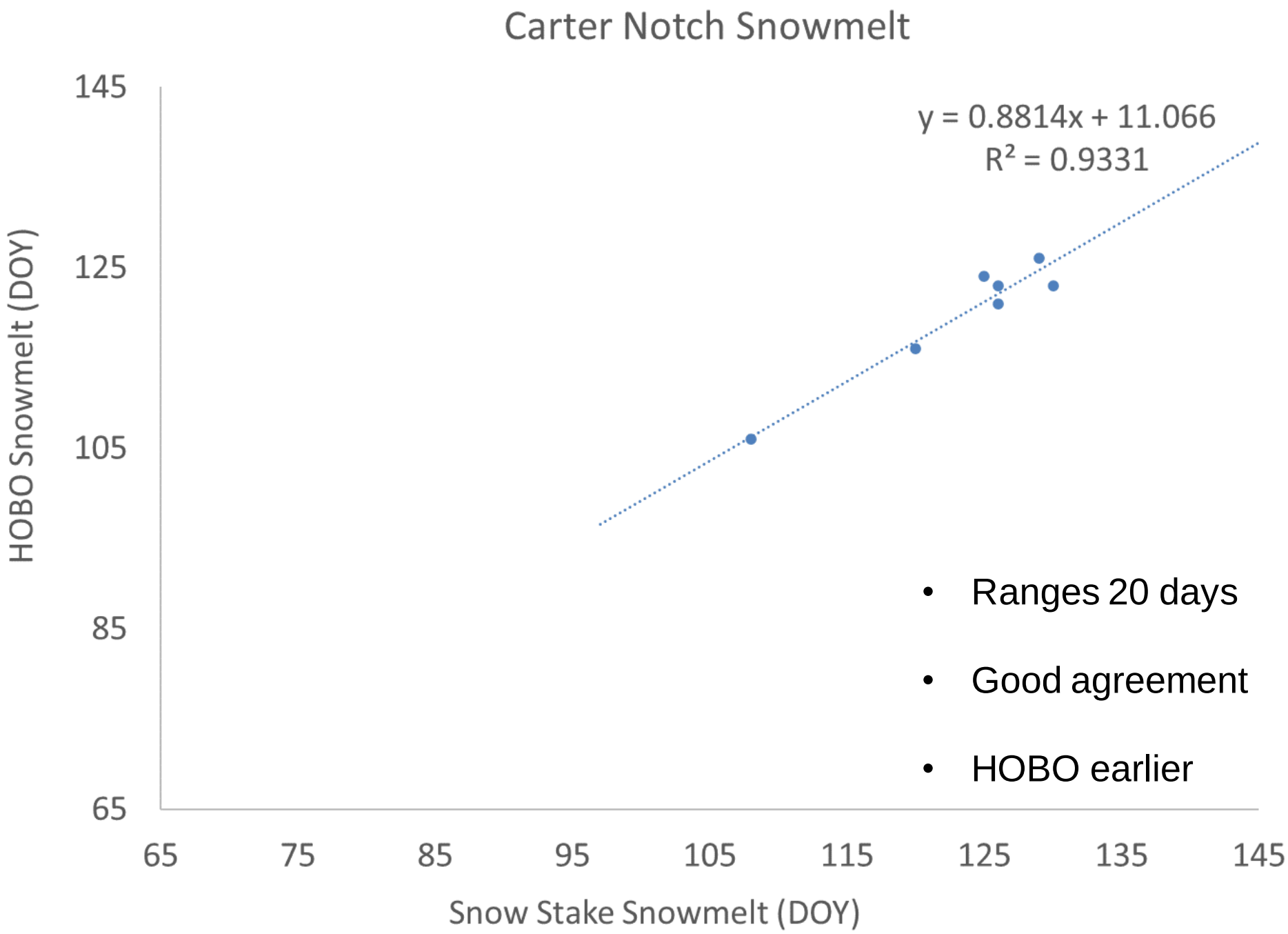
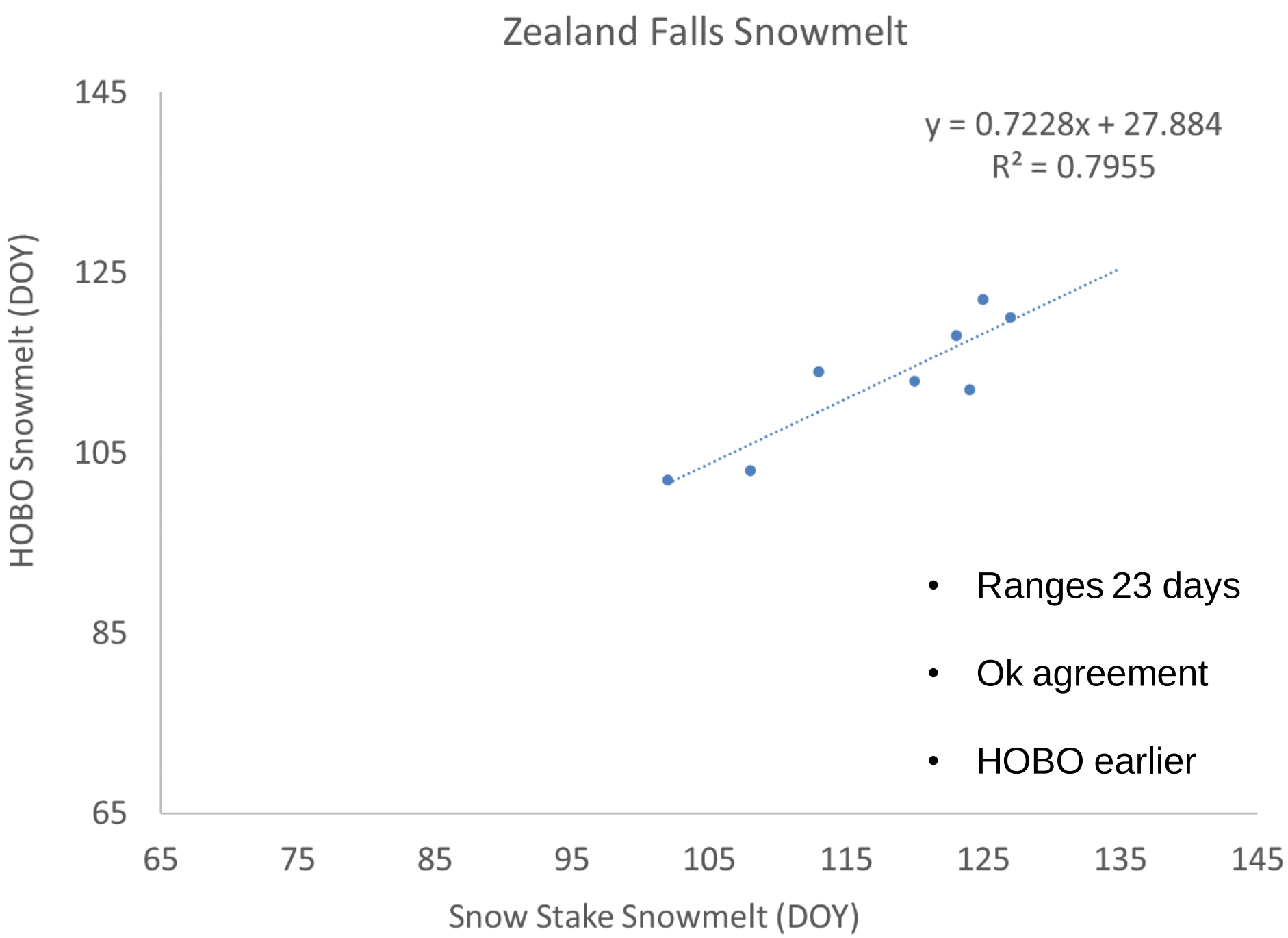


- Ranges 59 days
- Good agreement

AMC Research



AMC Research



- Ranges 23 days
- Ok agreement
- HOBO earlier

AMC Research

AMC Research

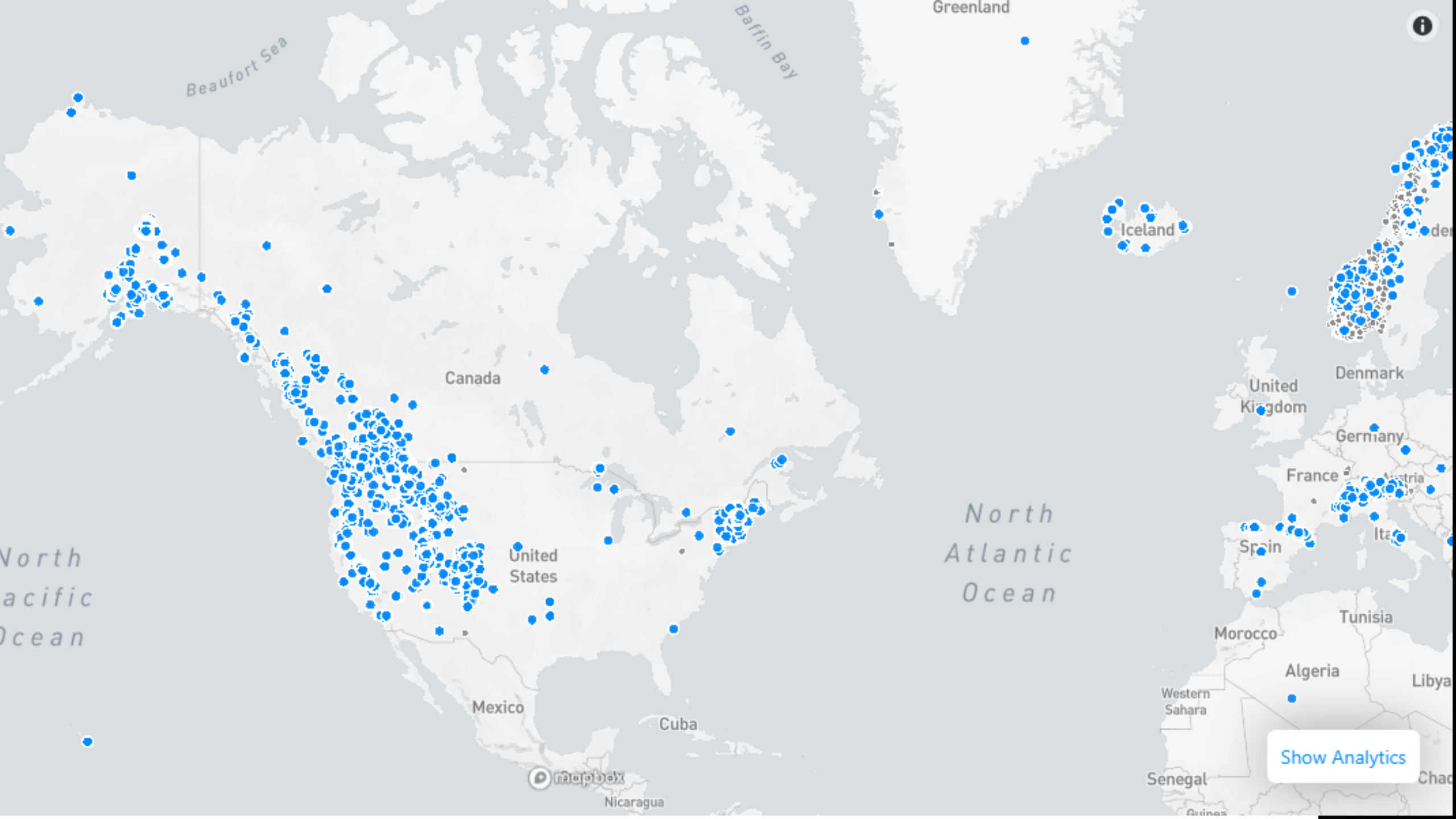
Community Snow Observations

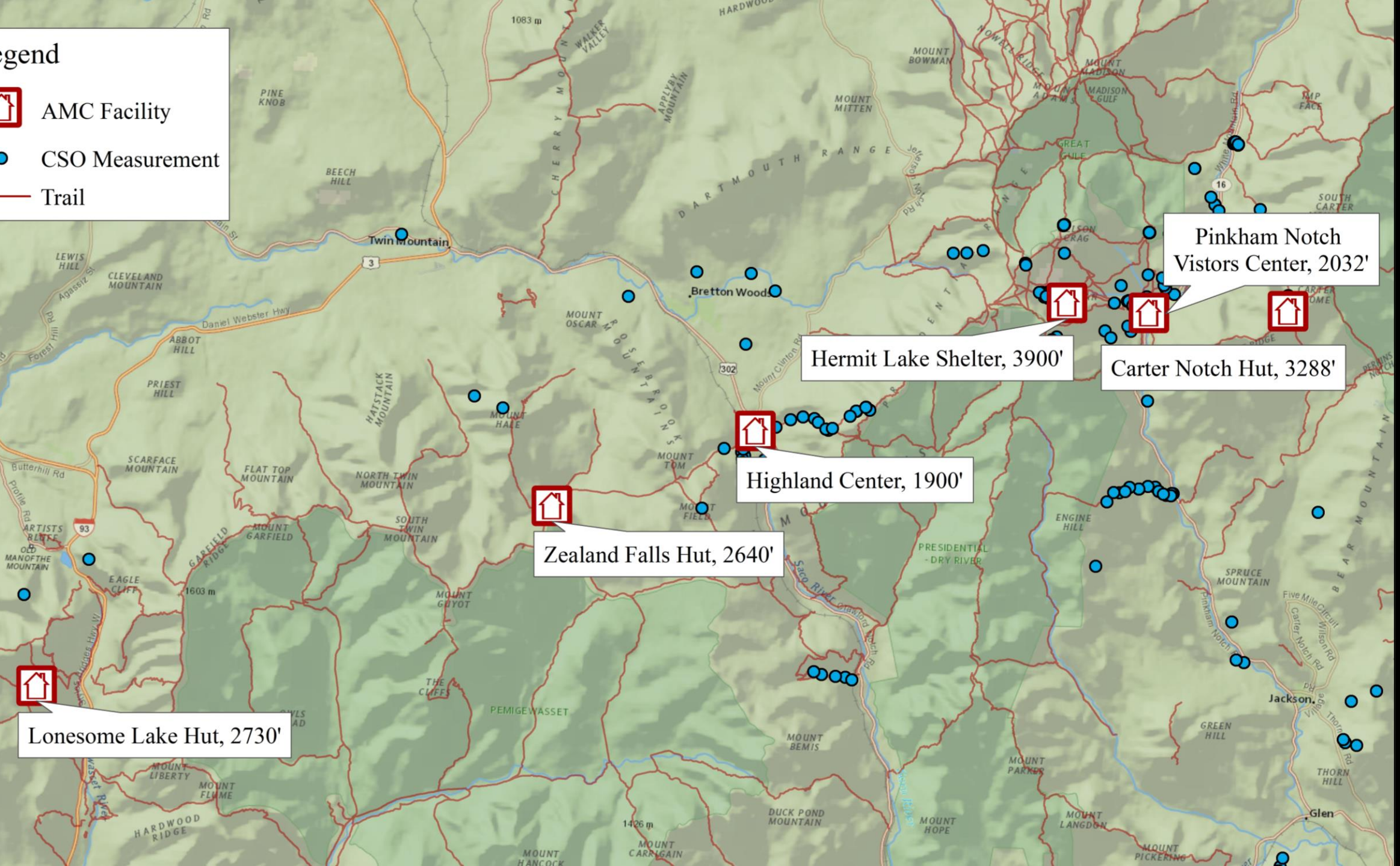
CSO is a community science campaign to measure snow.

Make your backcountry travels count! We need your help measuring snow depths in mountain places too vast for researchers to monitor. But we also want to know the snow depth near urban areas - *anytime, anywhere* is our motto.

www.communitysnowobs.org

Crumley, R. L., Hill, D. F., Wikstrom Jones, K., Wolken, G. J., Arendt, A. A., Aragon, C. M., Cosgrove, C., and Community Snow Observations Participants: *Assimilation of citizen science data in snowpack modeling using a new snow data set: Community Snow Observations*, Hydrol. Earth Syst. Sci., 25, 4651–4680, https://doi.org/10.5194/hess-25-4651-2021, 2021.


Beaufort Sea
Baffin Bay
Greenland
Iceland
Canada
United States
Mexico
Cuba
Nicaragua
North Atlantic Ocean
North Pacific Ocean
Denmark
United Kingdom
Germany
France
Spain
Tunisia
Morocco
Algeria
Western Sahara
Senegal
Show Analytics



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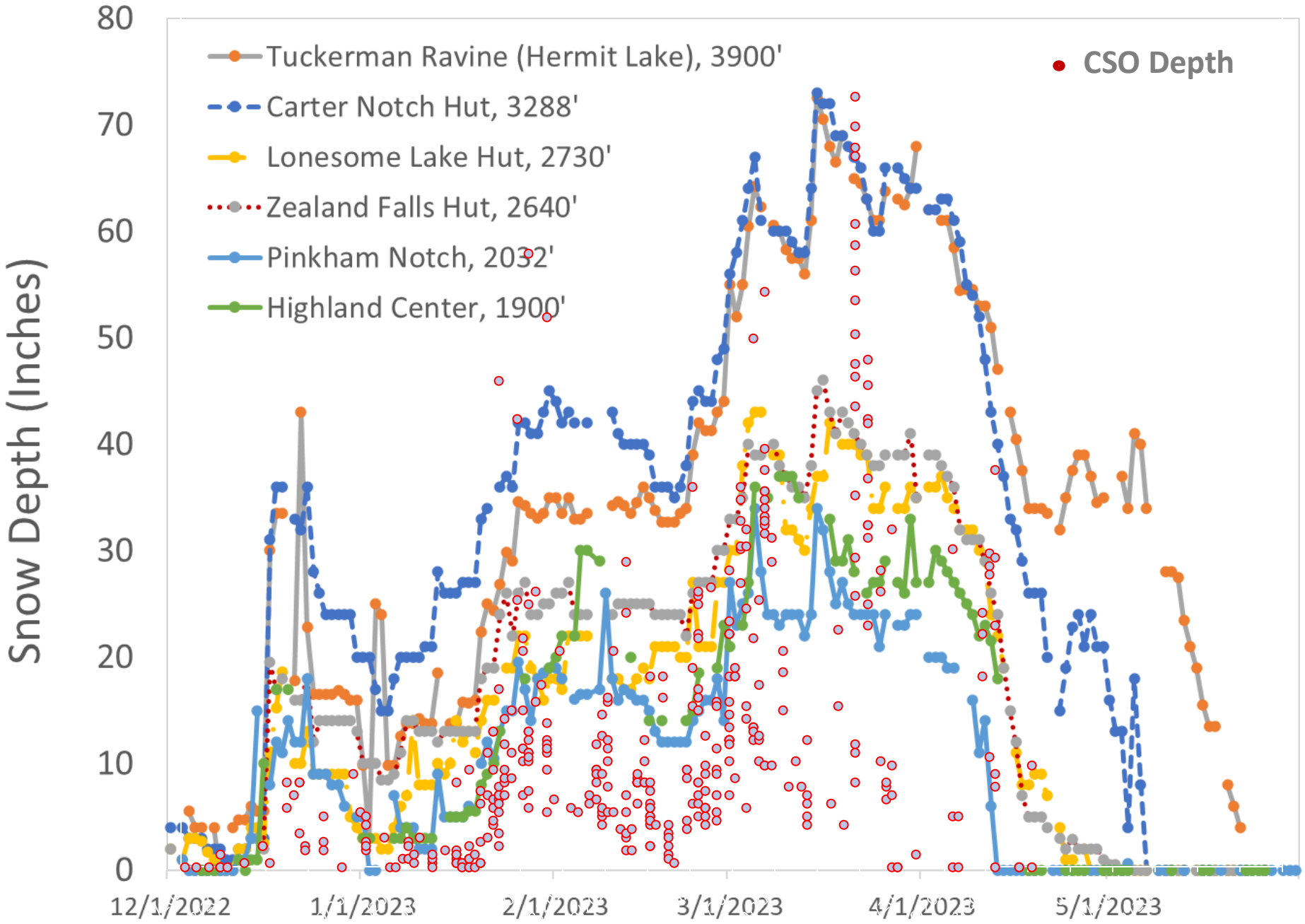

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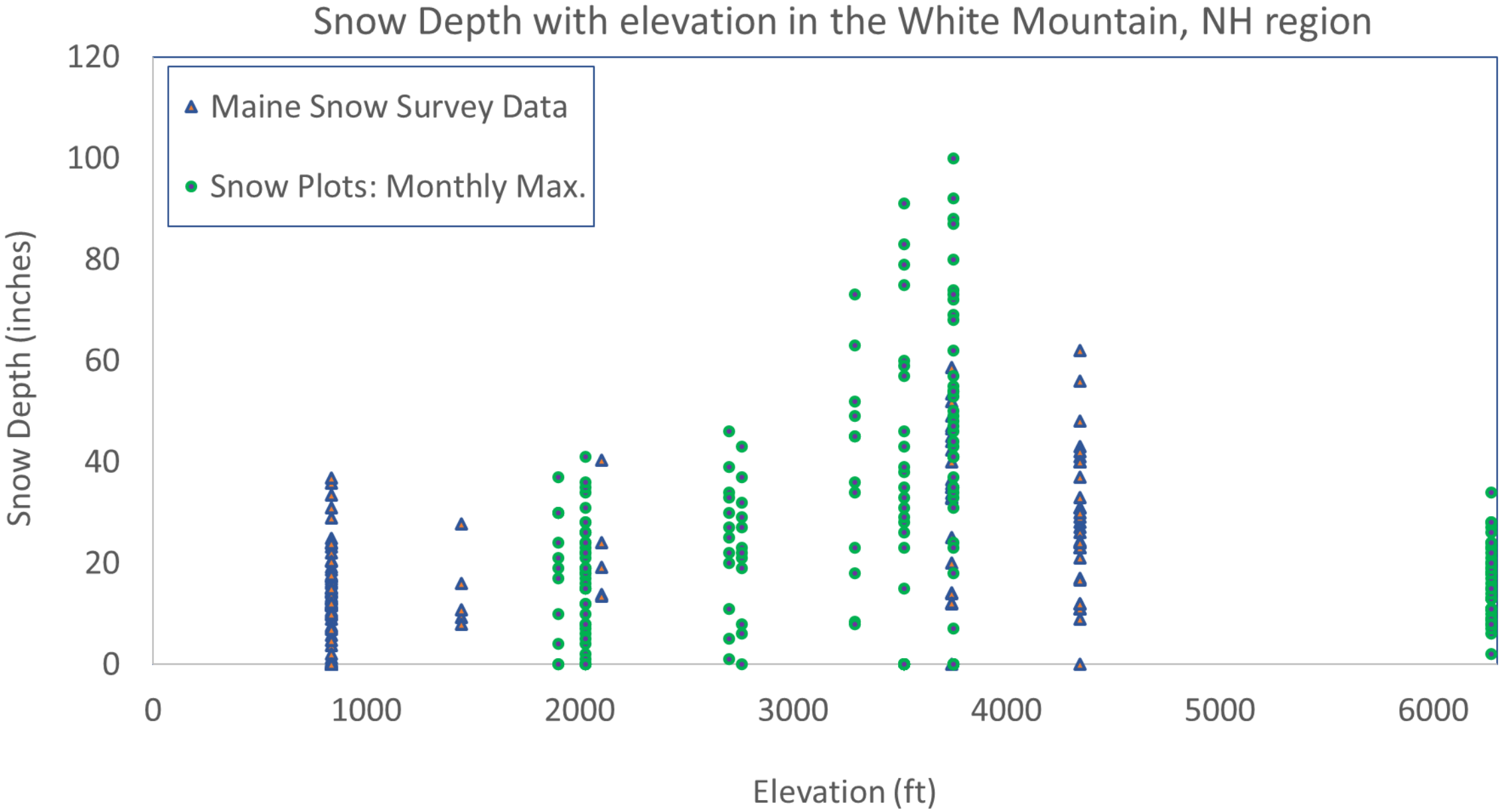

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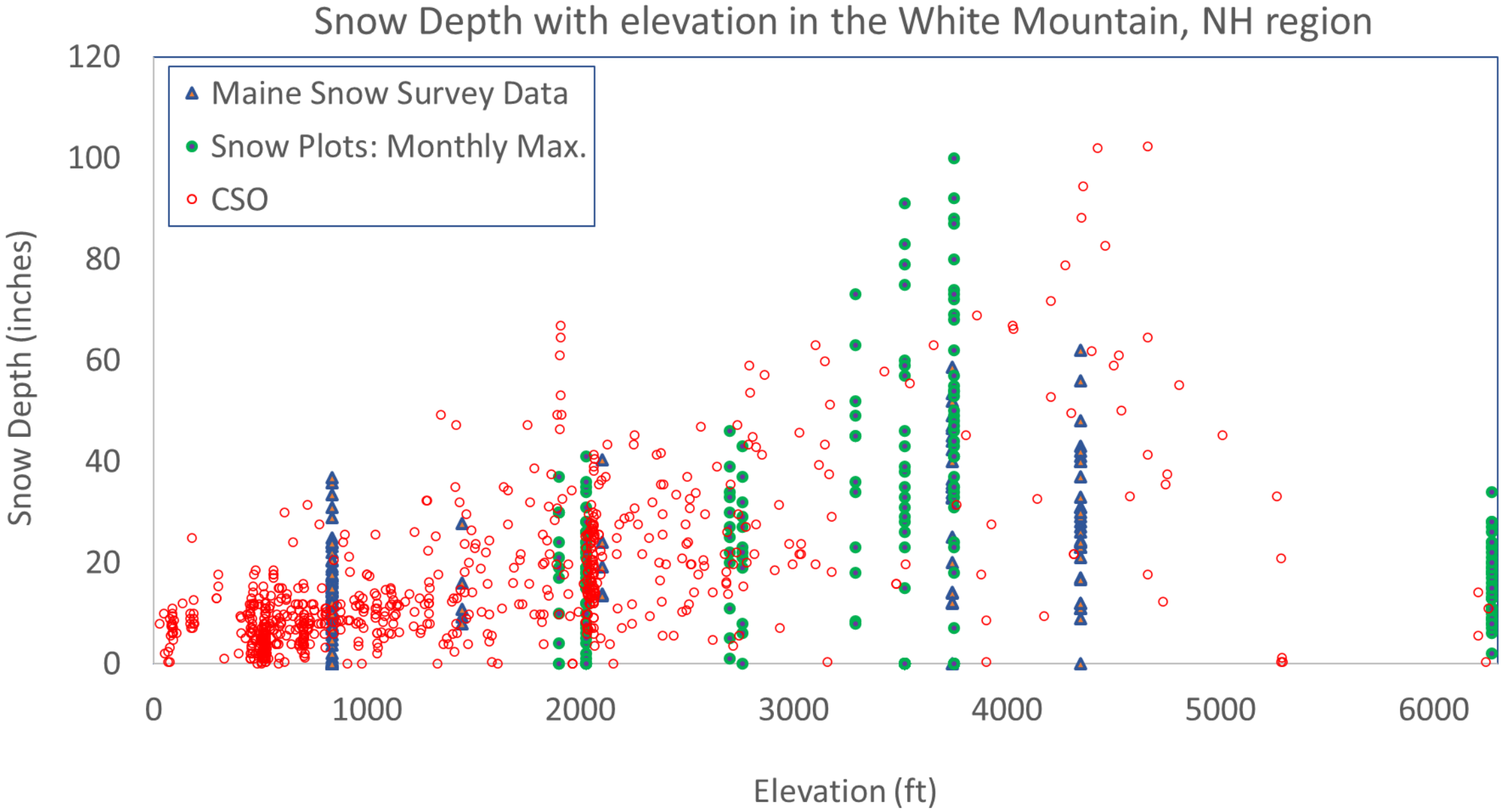

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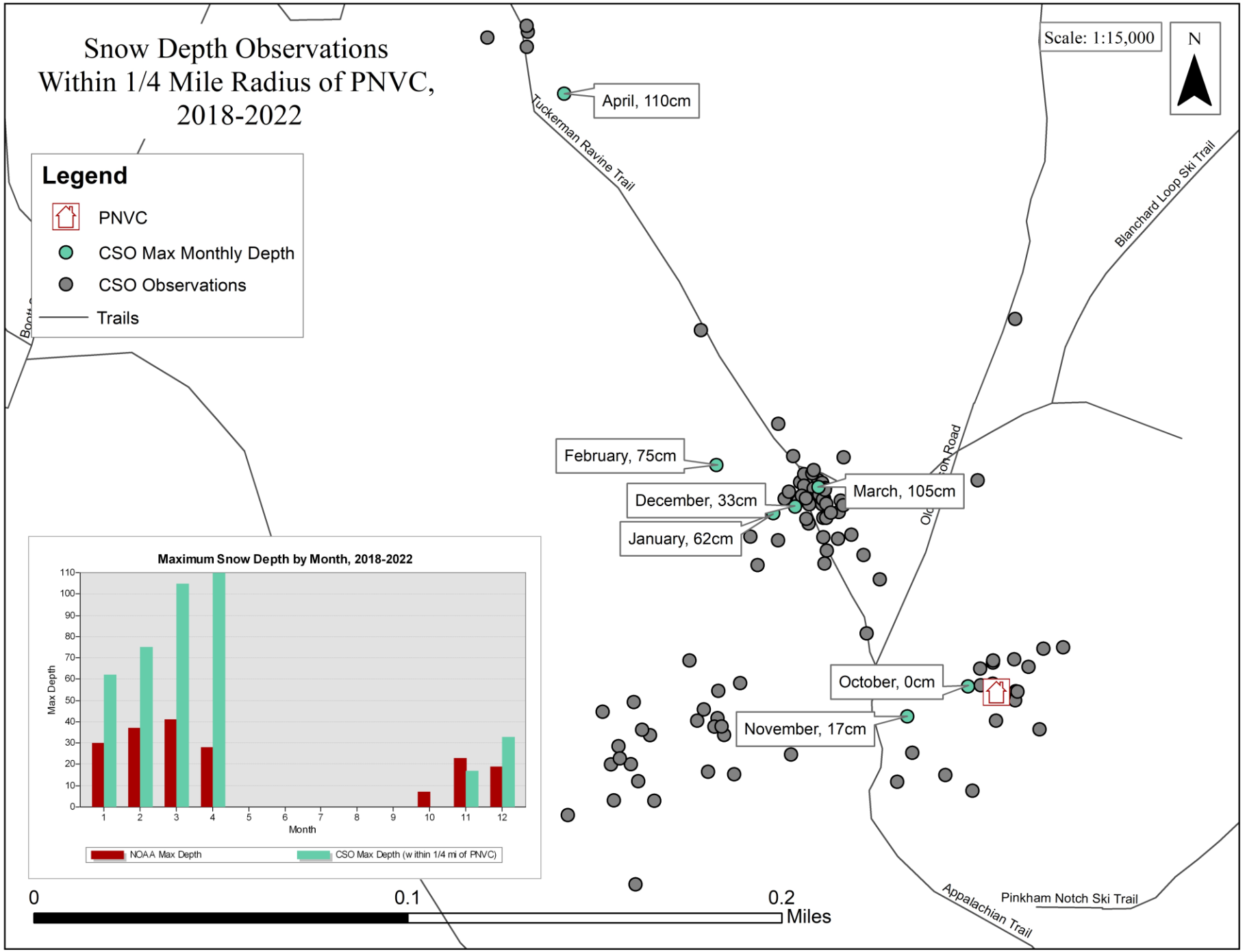

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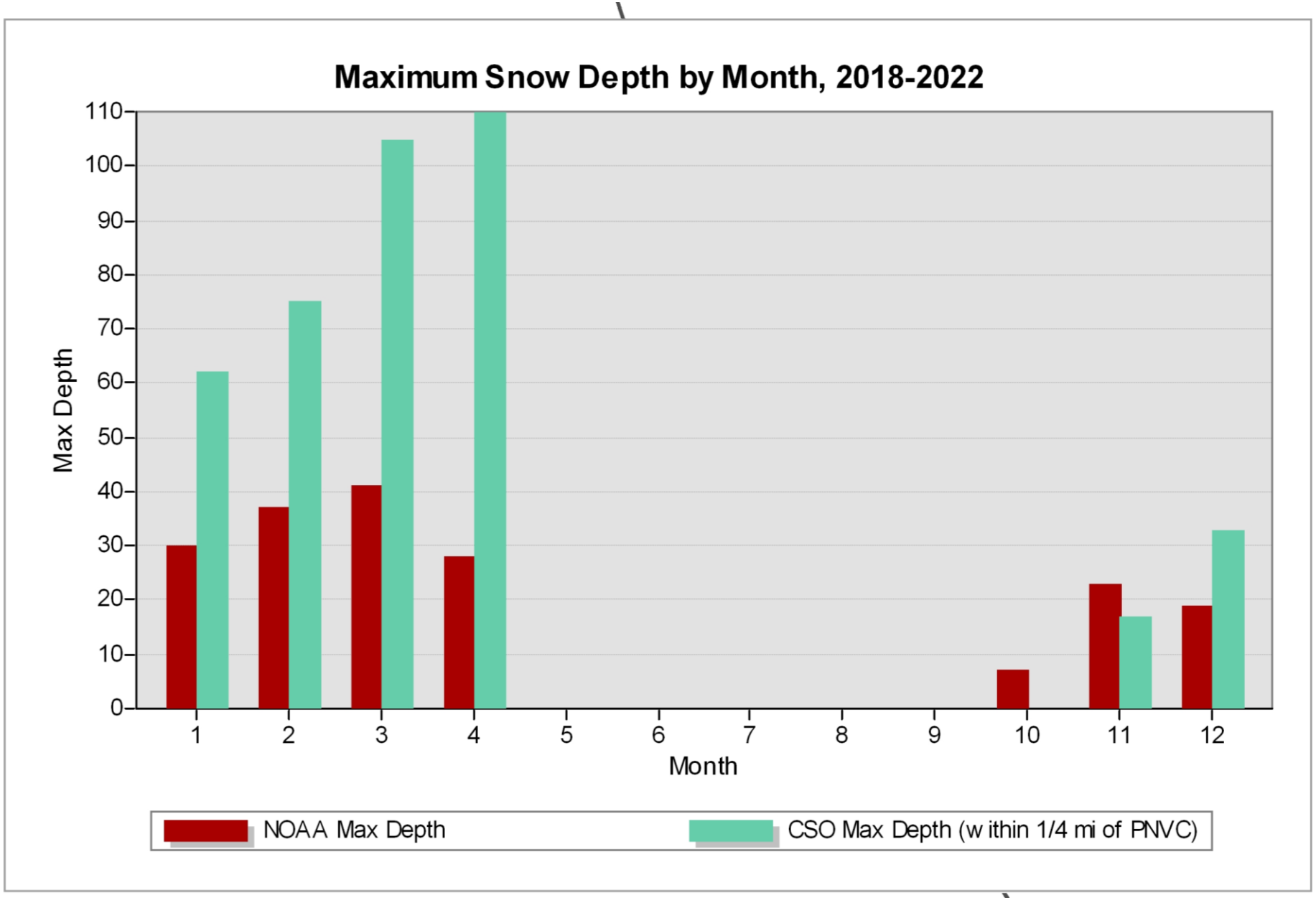
Maximum Snow Depth by Month, 2018-2022
Max Depth
110
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
Month
NOAA Max Depth
CSO Max Depth (within 1/4 mi of PNVC)

On the Horizon @ AMC Research

- Satellite imagery for snowmelt
- Merge snow data streams in Whites into one model
- Continue to promote CSO
  - Contests! Feb. SnowBlitz!
- Linking snow depth and melt timing with plant phenology

NESS (Northeast Snow Study)

AMC Research

Feasibility study to expand Automated Snow and Weather Monitoring System to the Northeastern US

With federally appropriated funding through the United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS), the University of New Hampshire and collaborators will assess the community needs for designing a coordinated network of automated snow and weather measurement stations in the East, similar to the western US SNOTEL network. The NESS project's ultimate goal is to comprehensively monitor snowpack, weather and hydrological variables across elevational gradients and mountain ranges in the region. The network would include applications in:

- streamflow, groundwater and soil moisture forecasting,
- forest fire risk,
- snow and climate monitoring,
- climate model validation and data assimilation,
- remote sensing calibration and validation,
- wildlife and forest health,
- winter recreational use,
- enhancing our understanding of seasonal transitions and dynamics.

NESS (Northeast Snow Study)

Feasibility study to expand Automated Snow and Weather Monitoring System to the Northeastern US

Don't have data but interested in NESS or the potential for collecting such data?

Please indicate your interest by filling out this brief survey via the link or QR code.

https://bit.ly/NESSinterest

Are you collecting snow or climate data in the region?

Please tell us what you are monitoring, where by filling out this brief form via the link or QR code. https://bit.ly/NESSdata

AMC Research

Carter Notch Dec. 2023

Acknowledgments

FEMC
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Kyler Phillips, Huts Education Coordinator
AMC Winter Caretakers
Mount Washington Observatory
CSO Ambassadors
CSO Volunteers
AMC Reservations

AMC Research