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A Climatology of Rain-on-Snow Events On Mount Washington

By Charles Peachey

What are Rain-on-Snow events?

Plymouth State University's flooded lower campus after the December 18-19, 2023 ROS event

- **ROS events contribute to a large majority of floods in the PWN**
- **Can lead to high avalanche danger due to the freeze thaw cycle weakening a snow pack**
- **Hard to forecast the magnitude of the melt before an event**

(Dongyue *et al 2019)* (Freudiger *et al 2015)*

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How are Rain-on-Snow events defined?

Literature	Rainfall threshold/liquid precipitation (mm)	Snow cover threshold	Data	Research area
Liston and Hiemstra (2011)	≥3	SWE ≥5 mm	MERRA	North of 55°N
Cohen et al. (2015)	≥10	SCF ≥ 50%	MERRA	North of 50°N
Würzer et al. (2016)	≥20	SD≥25 cm	IMIS[a] network stations records	Switzerland
Trubilowicz and Moore (2017)	≥5	SWE ≥10 mm	Automated snow pillow sites records	South coastal British Columbia, Canada
Musselman et al. (2018)	≥10	SWE ≥10 mm	WRF[b] simulations	Western North America
Li et al. (2019)	≥3	SWE ≥10 mm	VIC[c] simulations	Conterminous United States
Vickers et al. (2022)	≥5	SWE ≥3 mm	seNorge[d]	Norway

- **Large variety of definitions between various ROS Studies**
- **Definitions depended on the goal of the study and the data available**
- **Almost all of them include data on precipitation totals, snow pack, and present weather or temperature data as a proxy for present weather type**

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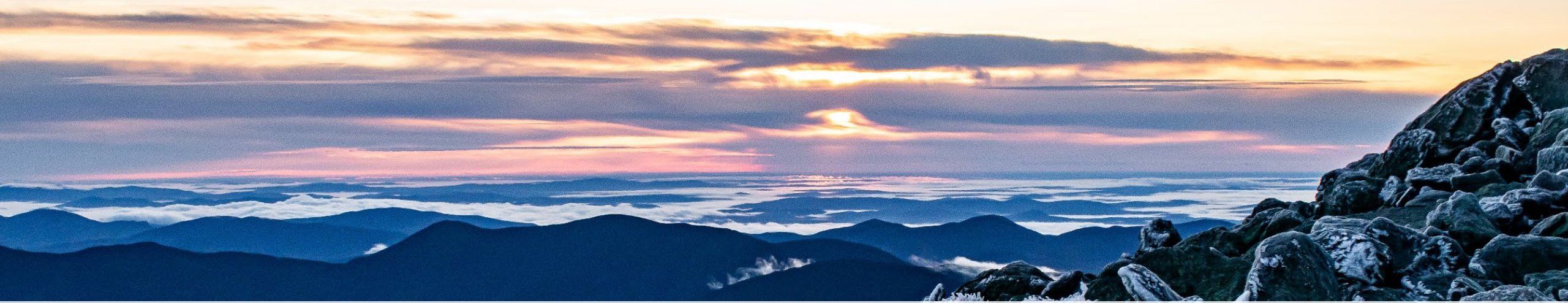
Have ROS events been increasing on the summit in recent decades and is there a seasonality to them?

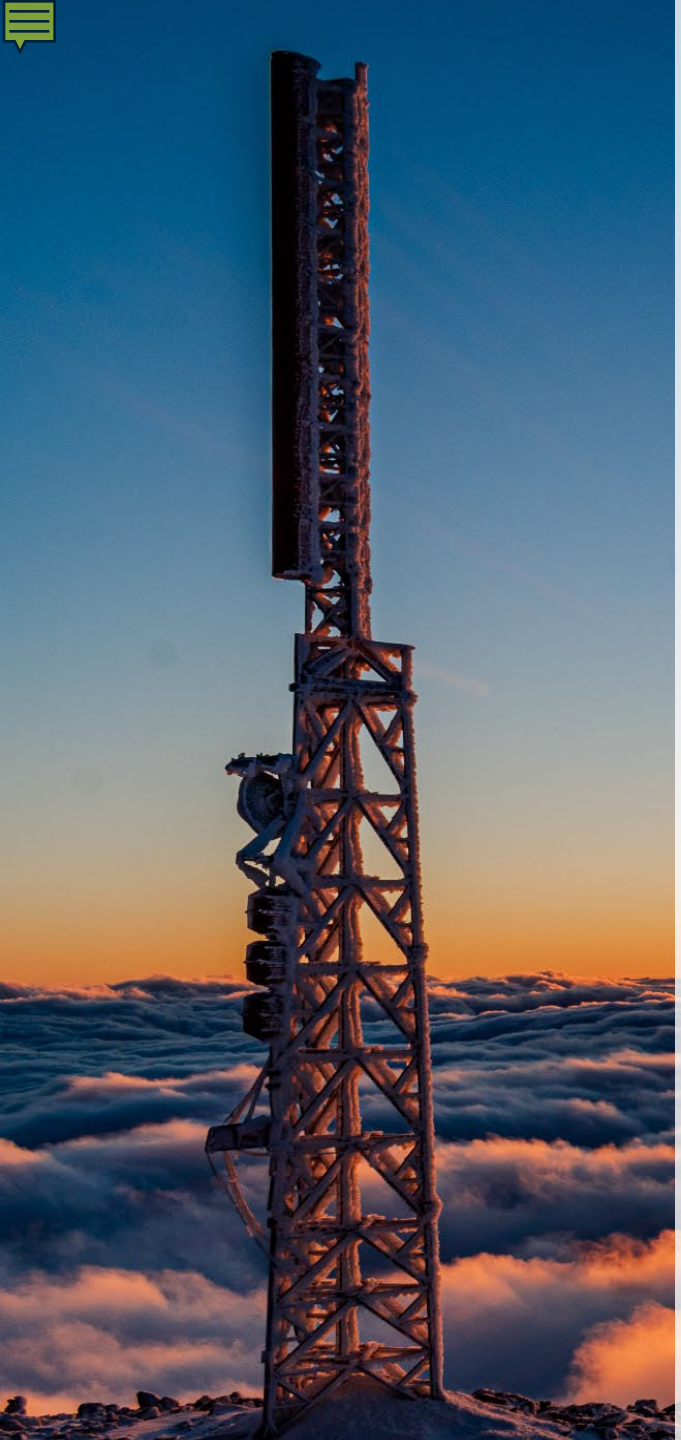


GOALS:

- What are the long-term ROS trends on Mount Washington?
- When do ROS events occur?
- What are some of the local effects of ROS Events

OBJECTIVES:

- Create two different climatology's and compare them to determine any differences
- Determine if there certain month and/or season that ROS are most prevalent
- Perform case studies with the new ROS data sets to evaluate the local effects of ROS events



Definition of a Rain-on-Snow Day

Daily Snow cover threshold:

- Minimum snow depth of 1 inch

Daily Rainfall Threshold:

- daily rainfall greater than 0.254 mm/0.1”

Liquid Precipitation :

- Rain, Drizzle, Hail, Freezing Rain, Ice Pellets, Ice Crystals

Definition of Rain-on-Snow Events

A “ROS Event” consists of one or more consecutive days where our definition of ROS was met

Definition of Winter Year

Defined as the eight month period from October to May and designated by the calendar year in which it ends

DATA

- Hourly present weather data was obtained from our B-16 archives
- 6 hourly precipitation total was obtained from our B-15 archives
- Stream gauge data was obtained from the USGS stream gauge archive

Methods

Combine all hourly observations with their corresponding 6-hourly synoptic observation

Combine all observations that occur on the same day

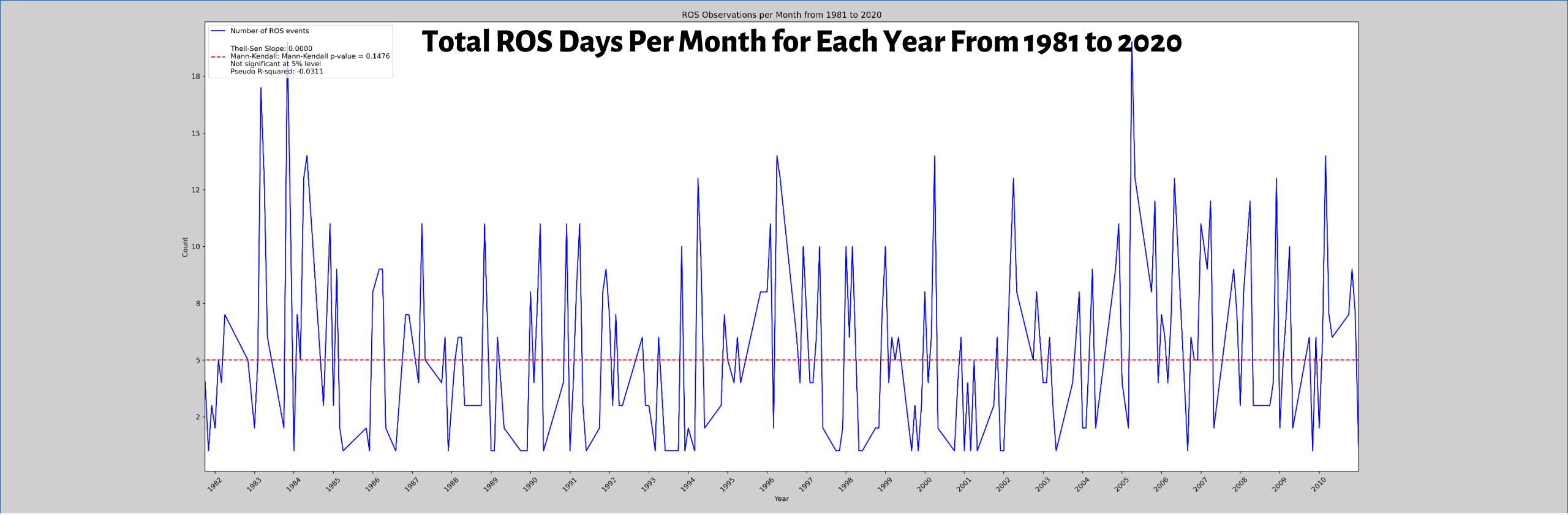
Filter out any observations that don't meet the criteria to be considered ROS

Convert the calendar year date to a "Winter Year" date

Calculate the amount of ROS Days per month and per winter year

Turn ROS Days into ROS events using our selected definition of ROS events

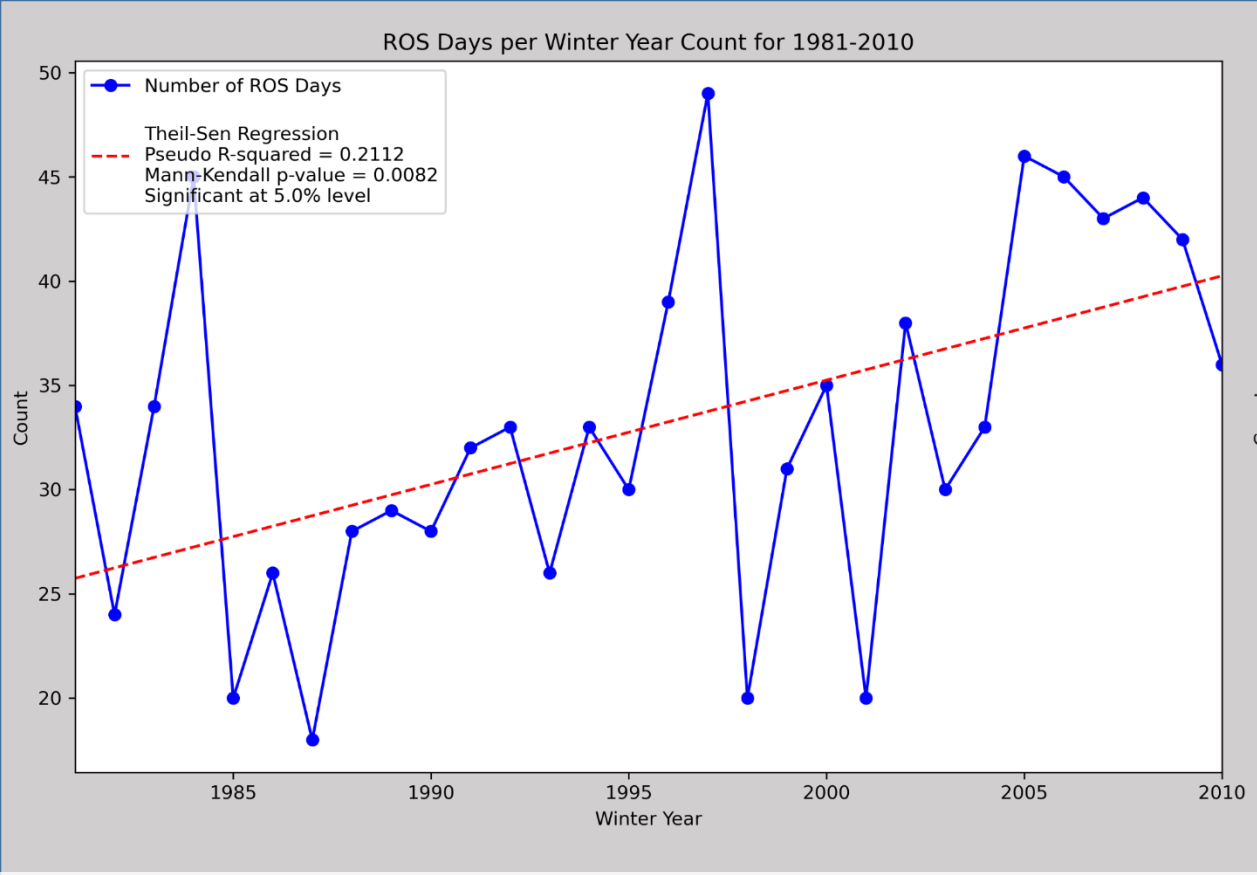
Calculate the statistics for all data sets and run Mann Kendall tests

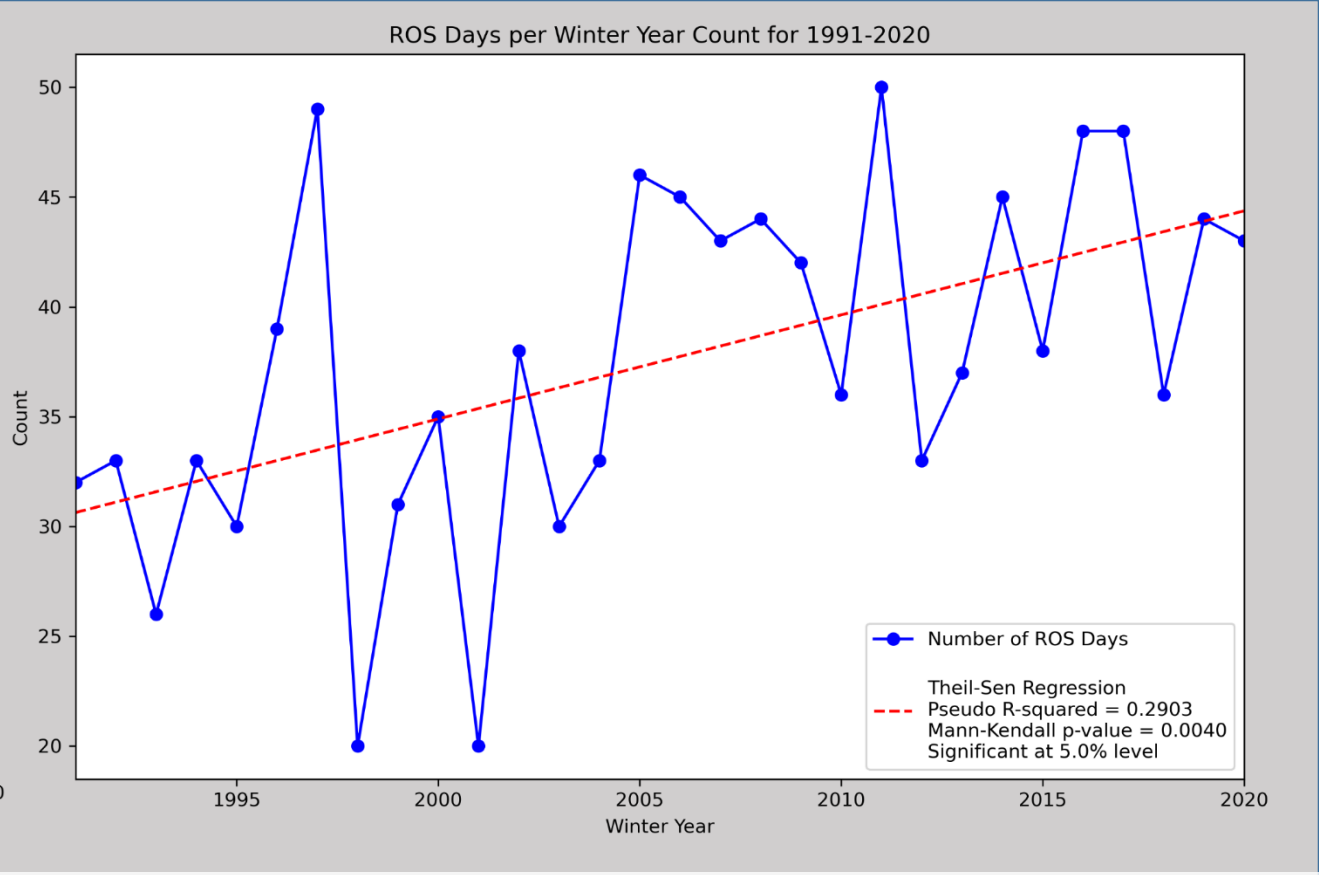


Provide some sort of data table here

- **Large and sustained increase from around 2005 – 2010**
- **3 of the top 5 months with occurred from 2011 to 2020**
- **Weak long term trend**
- **27% more ROS Days in 2001-2020 than 1981-2000**

Years	Total ROS Days	Avg. ROS Days per Year
2001-2020	935	31.2
1981-2000	773	25.8





- Reduced the resolution of the data down to the total ROS days per year
- Turned the calendar years into winter years
  - Will help remove the bias of the months with little to no
- 1981-2010 had 19 years with at least 25 ROS days
- 1991-2020 had 26 years with at least 25 ROS days
  - 37% more years w/ at least 25 ROS days than 1981-2010

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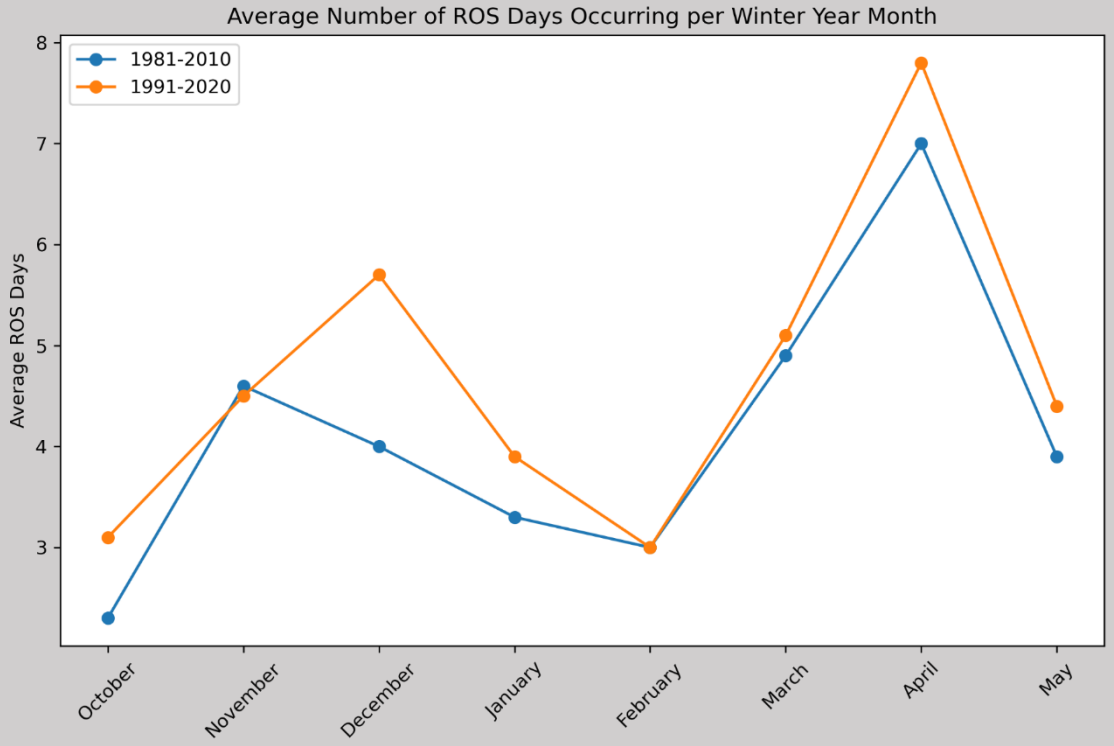


Avg. # of ROS Days per Winter Month

1981 – 2010	Average Number Per Month
December	4.0
January	3.3
April	7.0

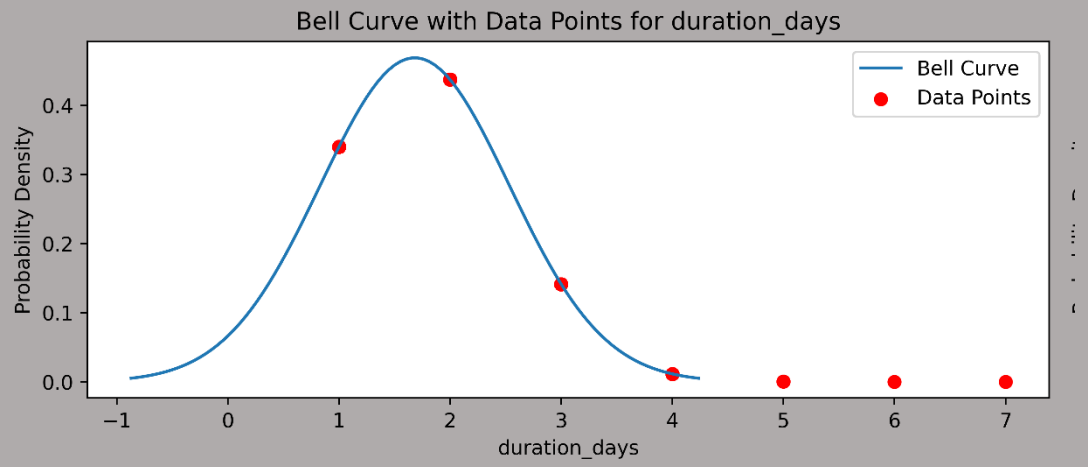
1991 – 2020	Average Number Per Month
December	5.9
January	4.1
April	8.1

- There are two distinct spikes within the winter year
- Greatest increase occurred during December
- Little to no events happened during June, July, August, and September
- There are 17% more events during the 1991-2020 climatology than the 1981-2010

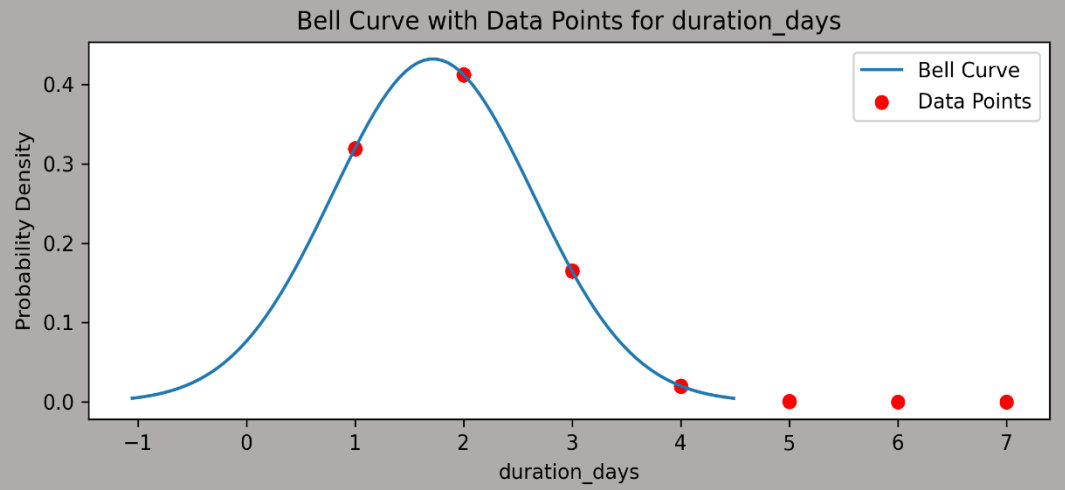
	1981 – 2010	1991 – 2020
Total # of days w/ ROS	1016	1190
Total during JJAS	17	23
% Total during JJAS	2	2

ROS Event Statistics

1981 - 2010



1991 - 2022



Climatology	Avg. Duration (days)	Avg. Max Snow Depth (in)	Avg. Minimum Snow Depth (in)	Avg. Total Snowfall (in)	Average Total Liquid Precip (in)
1991-2020	1.7	7.6	6.5	3	0.99
1981-2010	1.7	6.3	5.5	3	1.13

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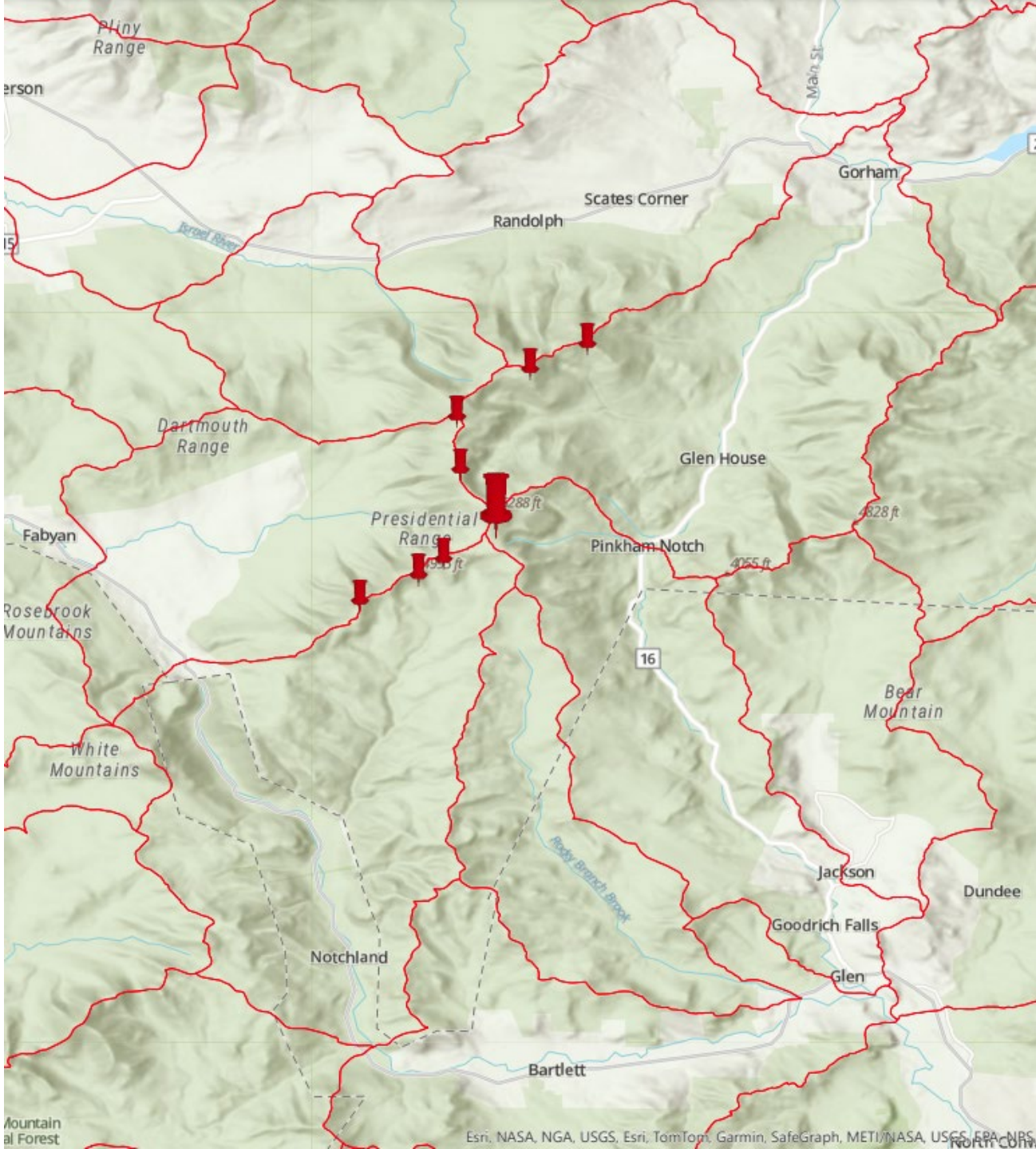
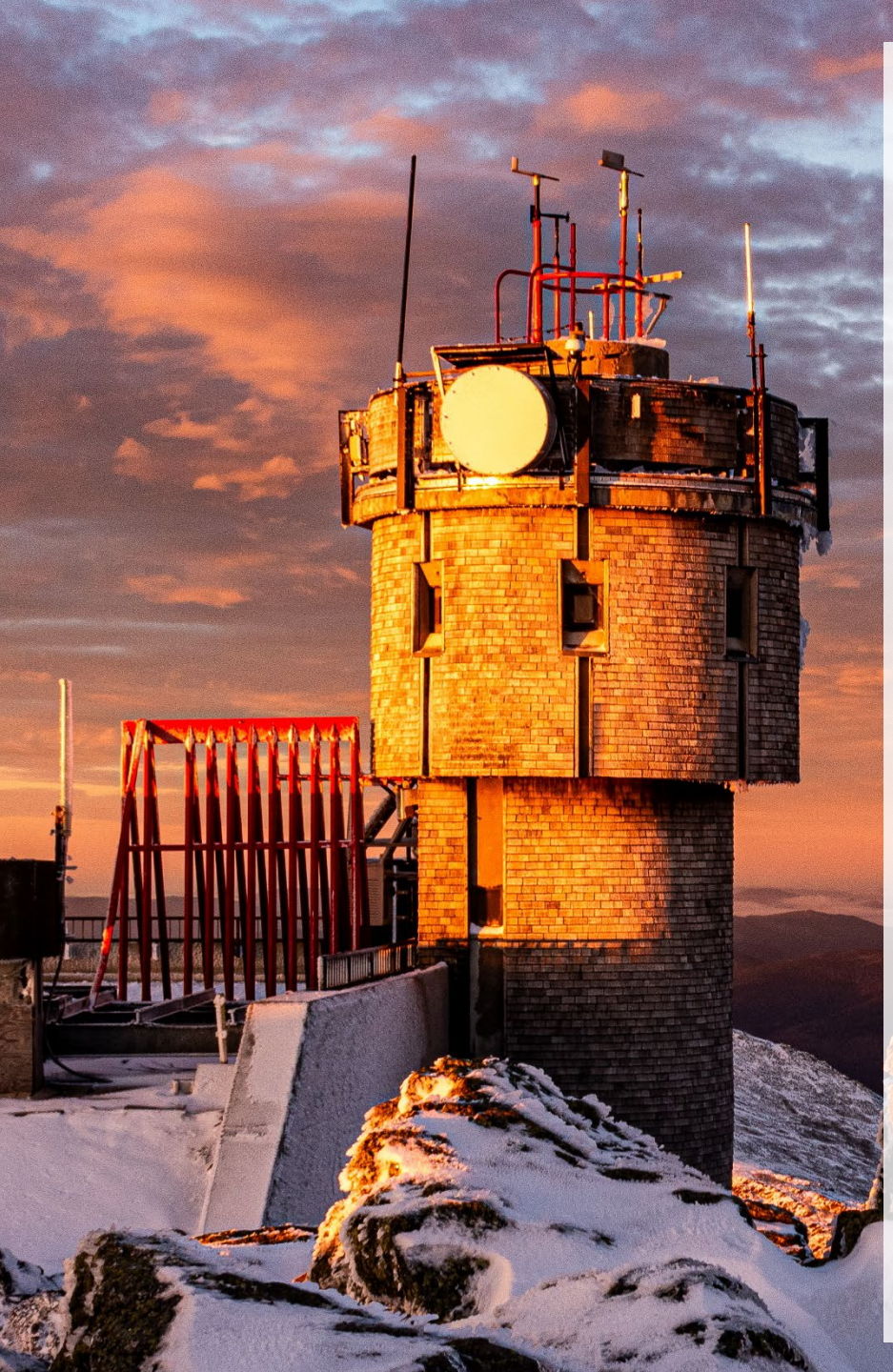
On going work: Case Studies

- Using calculated basin characteristics to determine expected duration and extent of runoff
    - slope, aspect, mean elevation
- Comparing expected values to actual data from USGS streamflow records at 3 relevant gauges,





CONCLUSIONS

1. A warming winter season has made ROS events more prevalent later in the year (December)
2. In recent decades, there has been a noticeable increase in the amount of ROS events that occur at the summit
3. The most common times of the year for ROS events to occur are the early winter and mid to late spring
4. Most of the ROS events that occur on the summit are short lived

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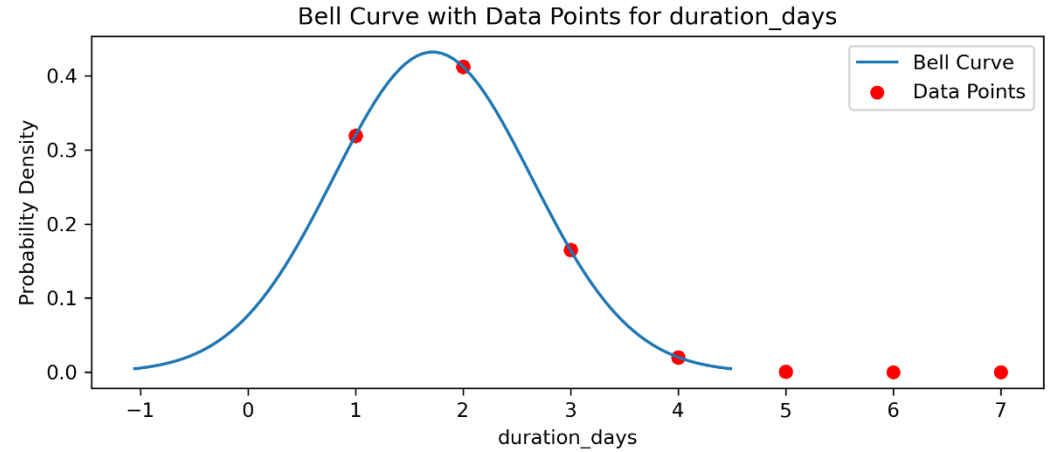
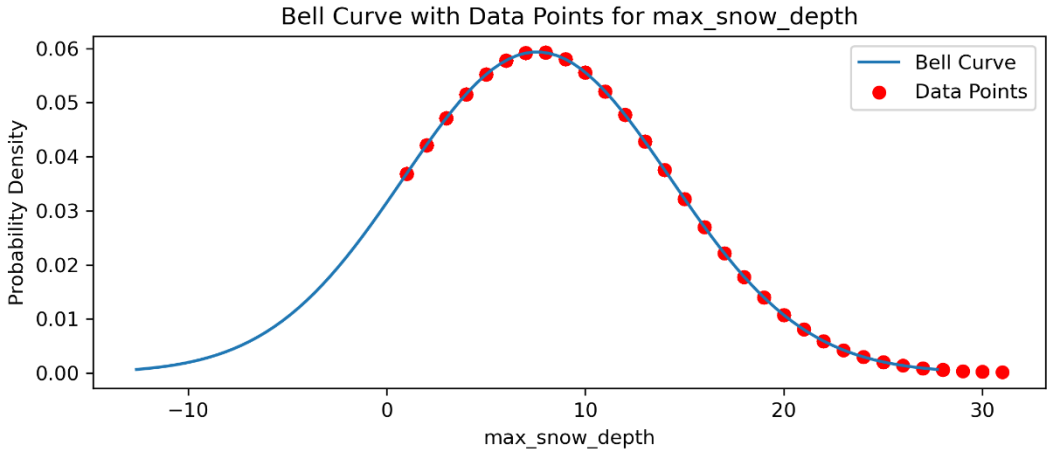
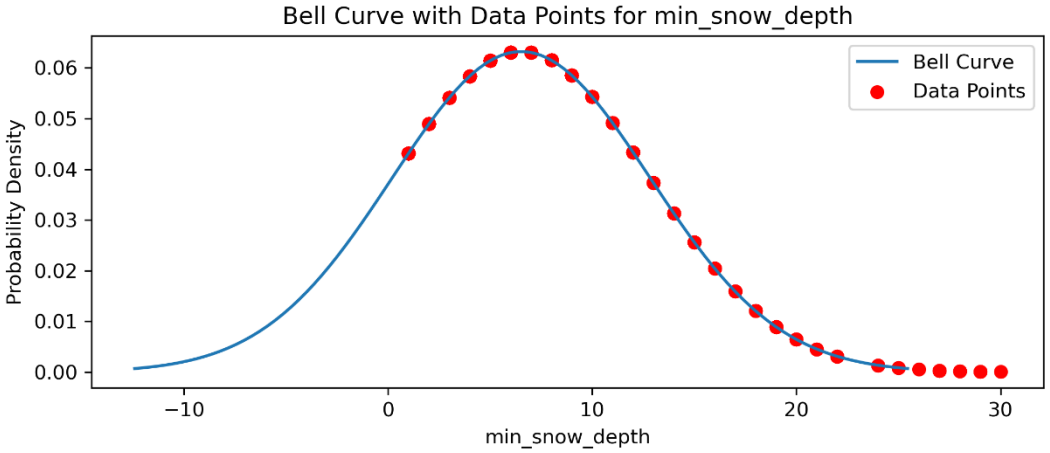
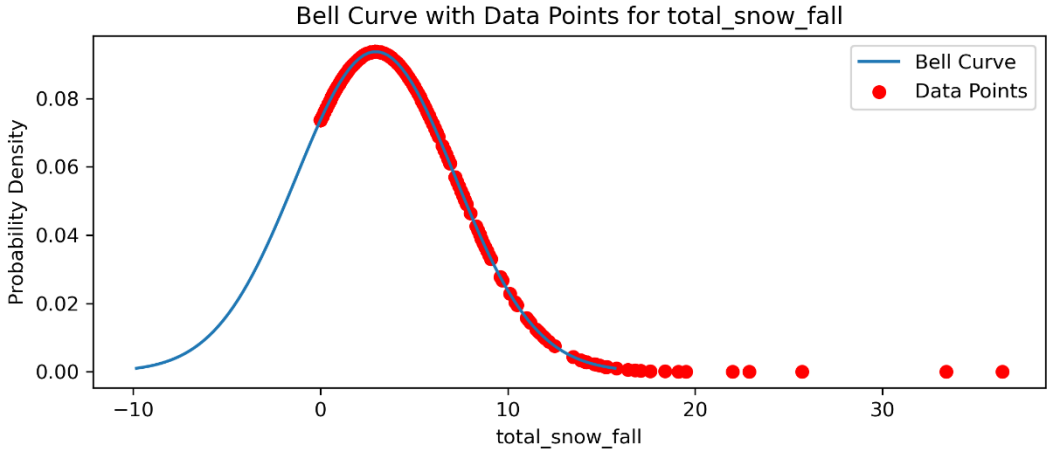
Questions?

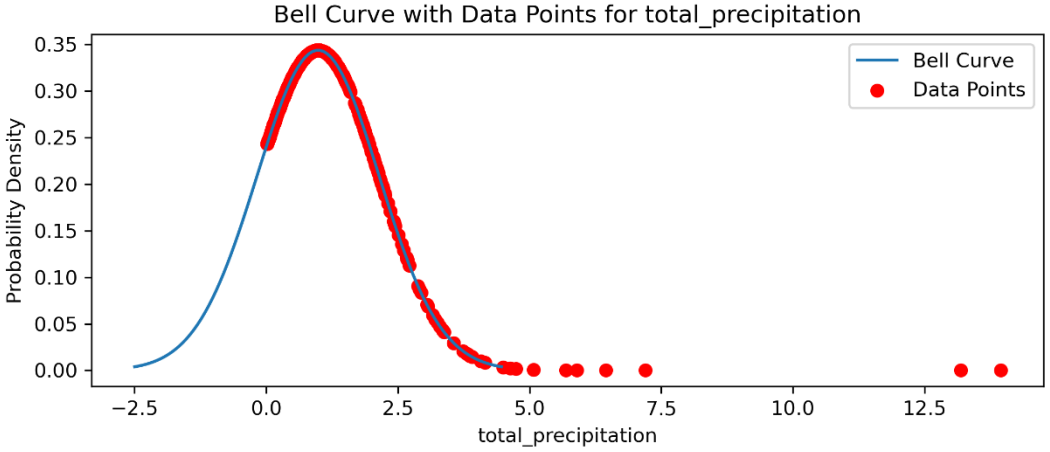
Extra Graphs and Figures



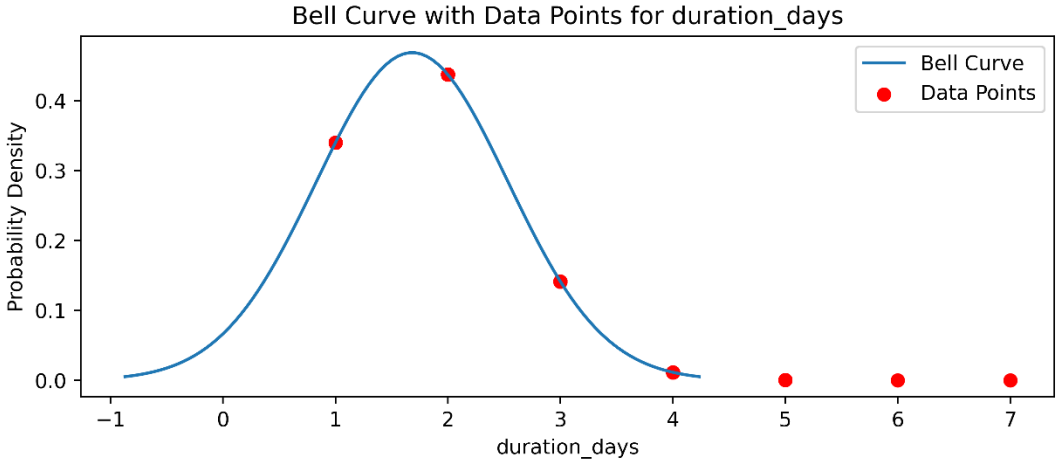


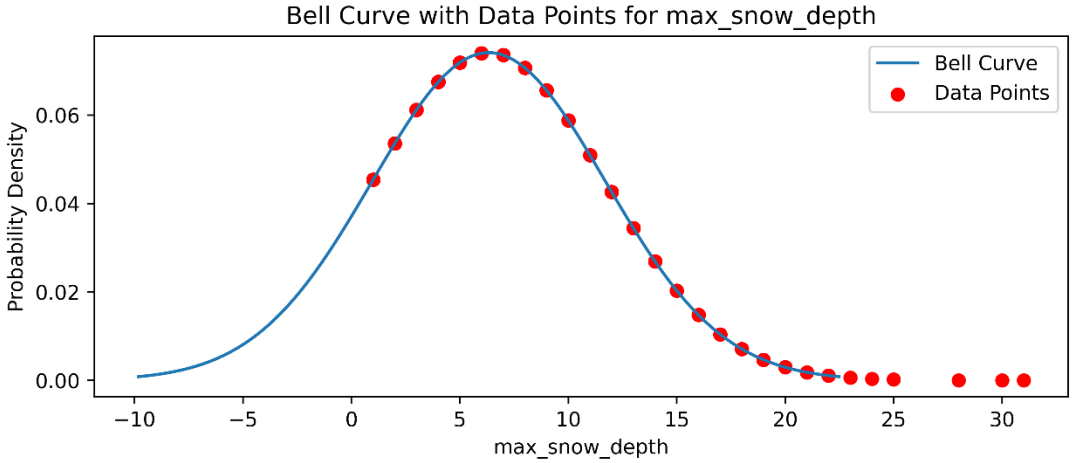


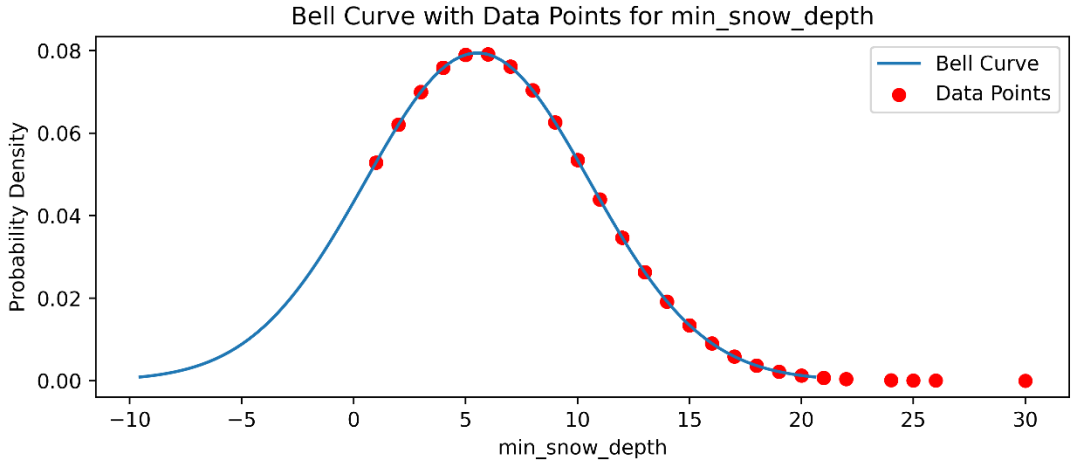


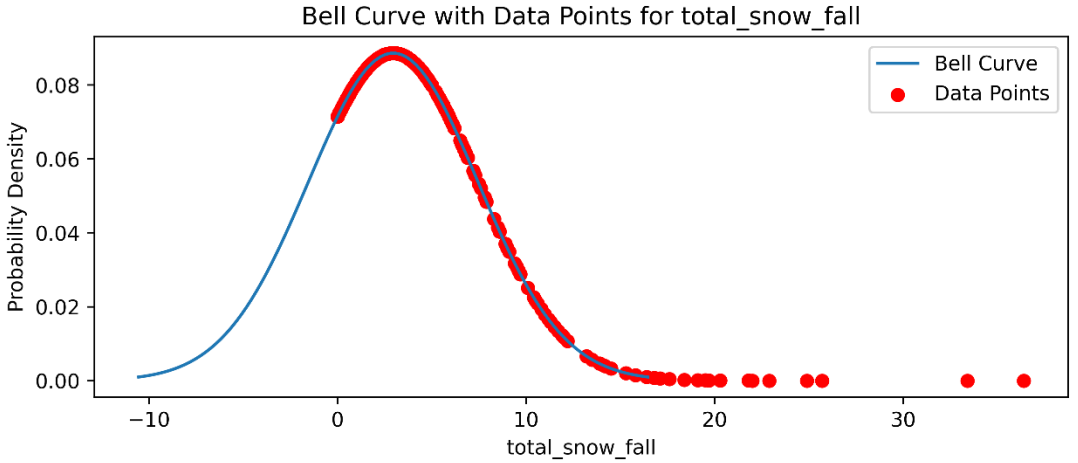


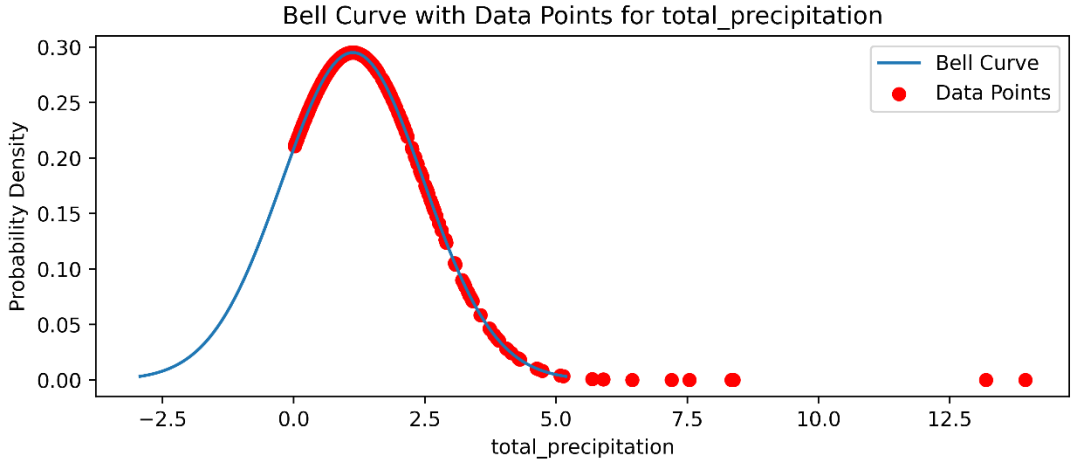
1991-2020 Stats











1981-2010 Stats

Total ROS Days per Winter Year