



CURRENT RESEARCH:

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

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What are Rain-on-Snow events?



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

- **Simply put, it is when rain falls on a pre-existing snowpack of a certain depth/extent**
- **ROS events contribute to a large majority of floods in the PWN**
- **Hard to forecast the magnitude of the melt before an event**

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

Why do Rain-on-Snow events matter to the ski community?

- **Can decimate snow packs through excessive and rapid snowmelt**
- **Can lead to high avalanche danger due to the freeze thaw cycle weakening a snow pack**
- **Can result in negative impacts to the local ski/winter tourism economy**

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 $\geq 50\%$	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

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:

- Look at the decadal trends and compare them to the long term change to see if there is a change
- 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**

Definition of Rain-on-Snow Events

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

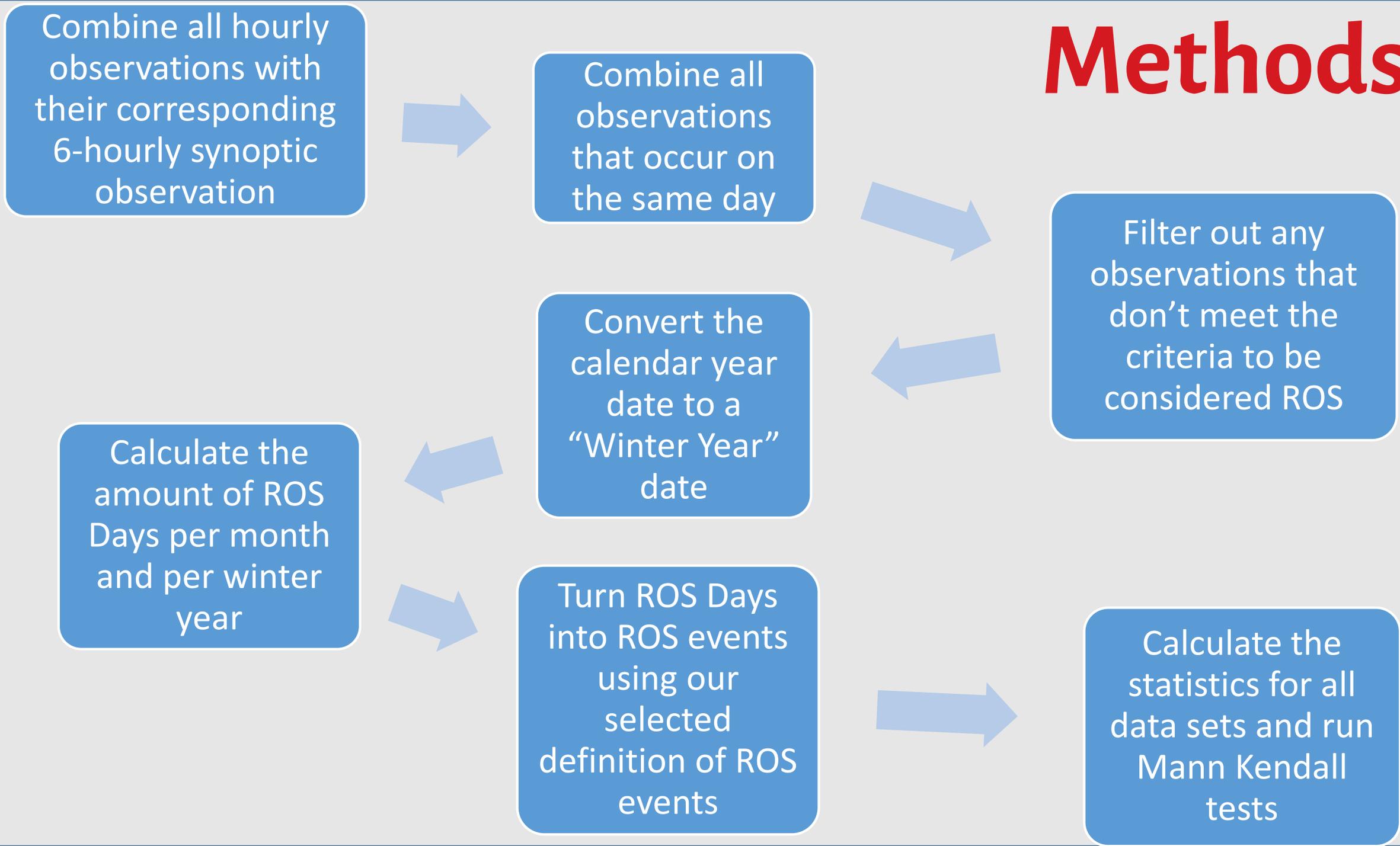
Definition of Winter Year

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

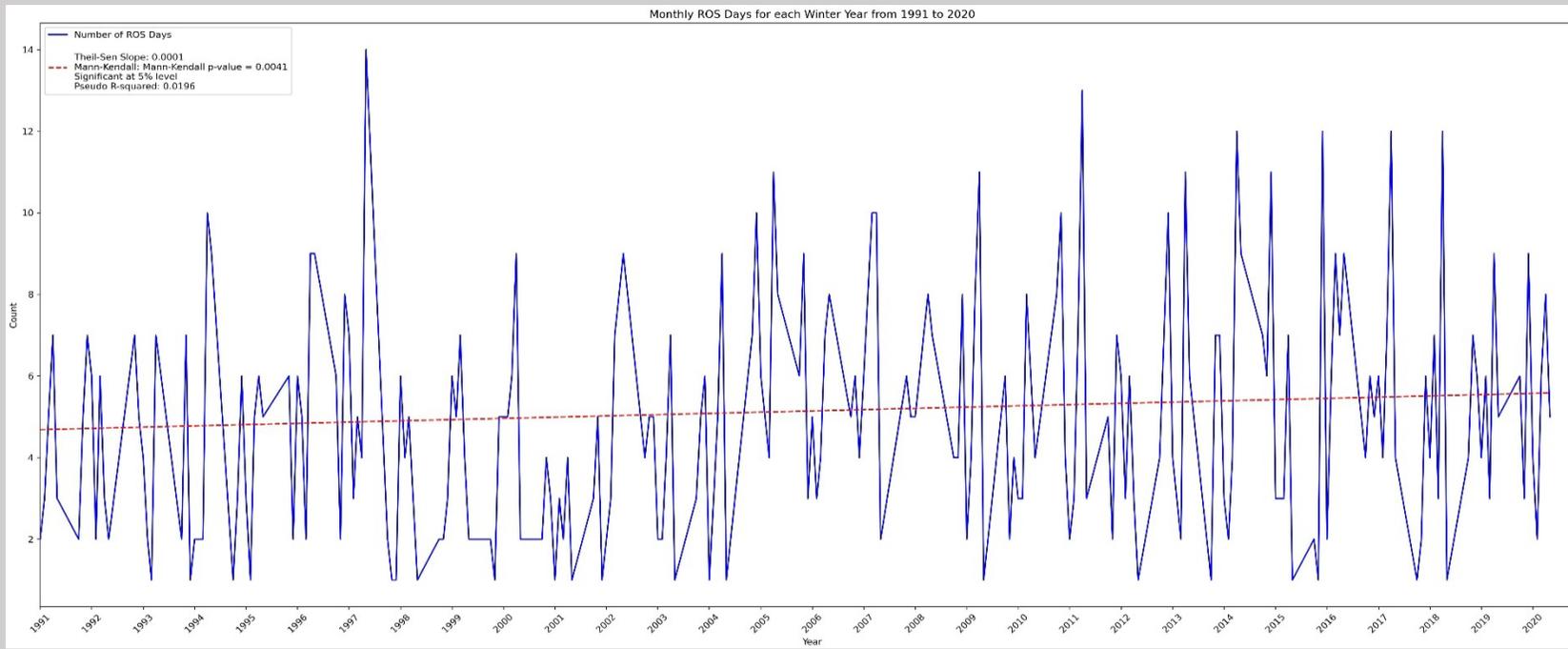
DATA

- 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



Total ROS Days Per Month for Each Year From 1981 to 2020



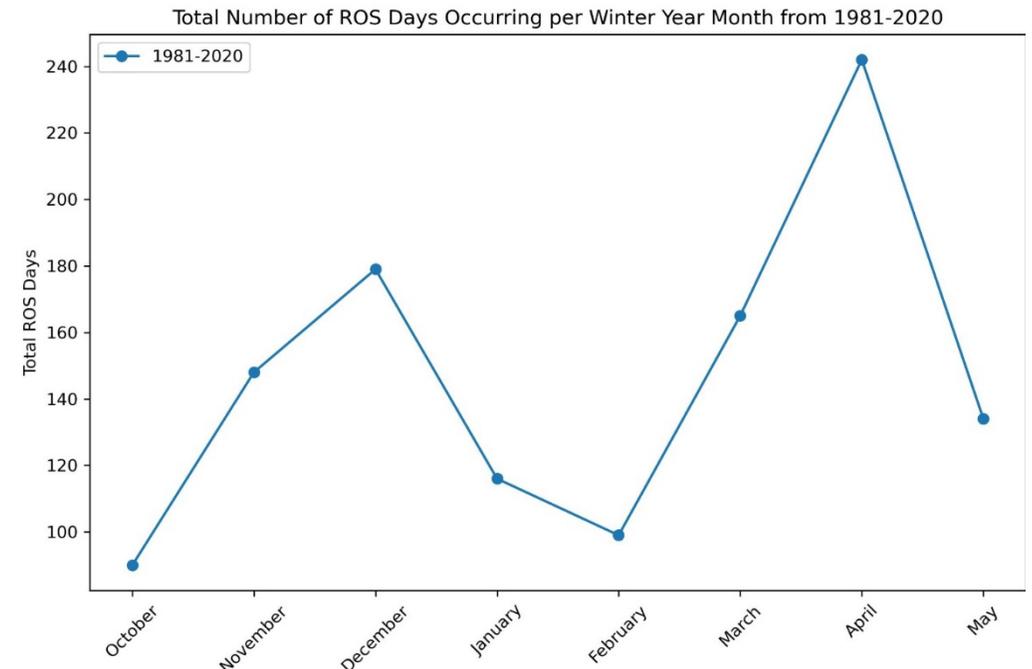
- **Large and sustained increase** from around 2005 – 2010
 - 2005 onwards seems to be shifting higher on the graph than prior to 2005
- **3 of the top 5** months with occurred from 2011 to 2020
- **Weak** long term trend
- **Statistically significant** long term trend at the 5% significance level

Variable	Value
Theil-Sen Slope	0.0001
Mann-Kendall P-Value	0.0041
Pseudo R-Squared	0.0196

Long Term Seasonality

- **2 different peaks** in total ROS Days
- **Very little events** happening in Oct., Jan., and Feb.
- **Oct.** can have some snow, but its snow pack is typically not sufficient enough to result in a ROS day
- **Initial peak** is around the change over from fall to winter weather
 - Thin snow pack, but can still be sufficient enough to produce ROS days
- **Secondary peak** corresponds to the changeover to spring weather
 - Snow pack is still sufficient enough for ROS days to occur

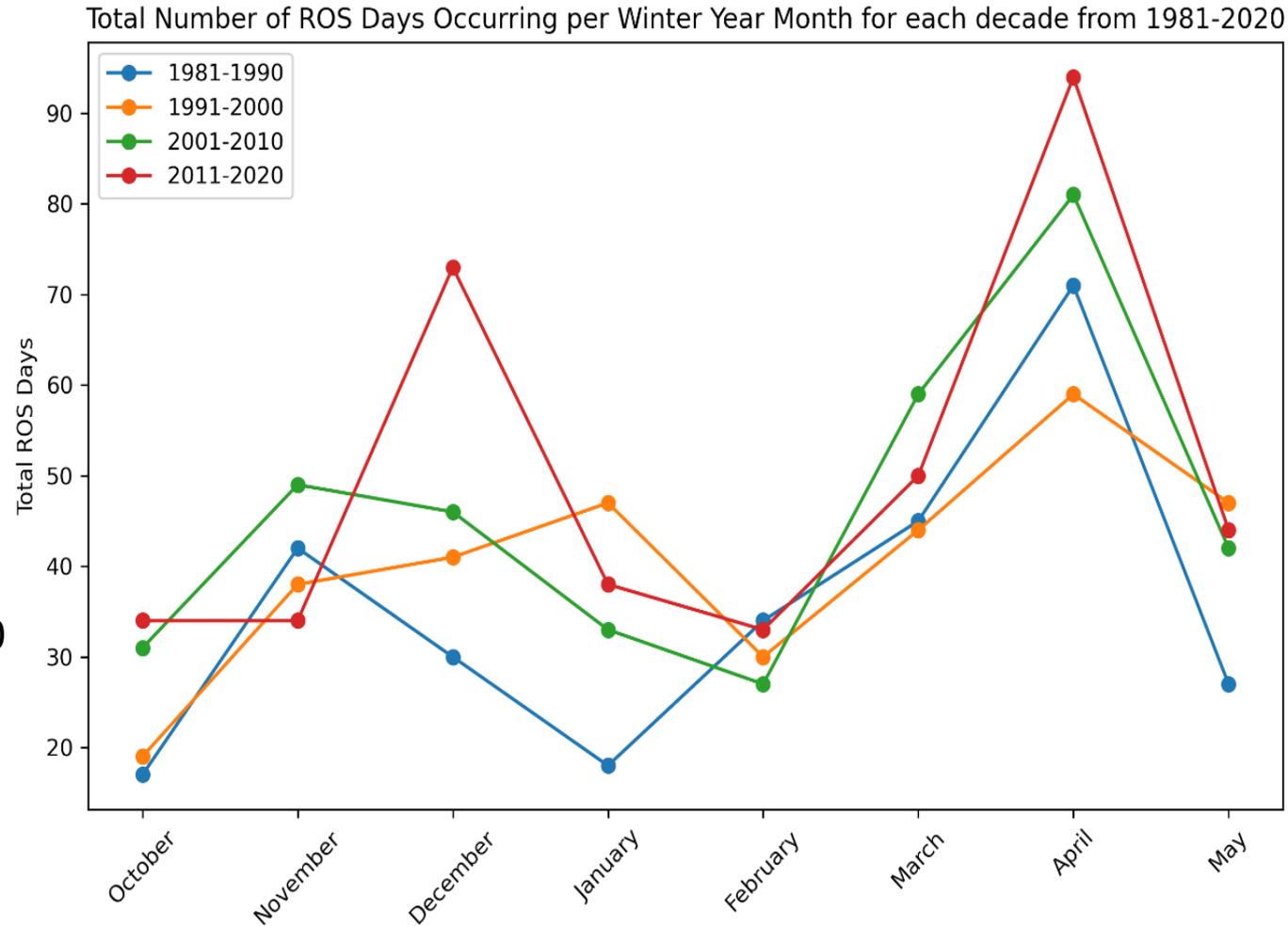
Month	ROS Days	Avg. ROS Days/Month
October	90	2.9
November	148	4.9
December	178	5.7
January	116	3.7
February	99	3.5
March	165	5.3
April	242	8.0
May	134	4.3



Decadal Trends

- **Dual peaks** are still evident
- **Most recent decade** was the only one to initially peak in DEC.
 - All others initially peaked in NOV
- **Increasing amount** of ROS days with each decade
 - **~41% more ROS days** in 2011-2020 v.s 1981-1990

Time Range	Total ROS Days
1981-1990	284
1991-2000	325
2001-2010	368
2011-2020	400



Comparing ROS Event Statistics

Time Range	Avg. Duration (days)	Avg. Max Snow Depth (in)	Avg. Minimum Snow Depth (in)	Avg. Total Snowfall (in)	Average Total Liquid Precip (in)
1981-2020	1.7	7.3	6.3	3.0	1.06
1981-1990	1.7	6.3	5.4	3.0	1.33
1991-2000	1.7	6.3	5.4	3.0	1.33
2001-2010	1.7	8.2	7.1	3.2	1.06
2011-2020	1.8	9.8	8.2	3.0	0.87

- ROS events have been occurring w/ **deeper snow pack recently**
- They are **relatively short lived** events through all decades
- The amount of **liquid equivalent precipitation is decreasing** during recent decades
- ROS events seem to be **occurring later into the year** over time

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 ROS events that occur on the summit are short lived, but can still be very impactful**



Questions?