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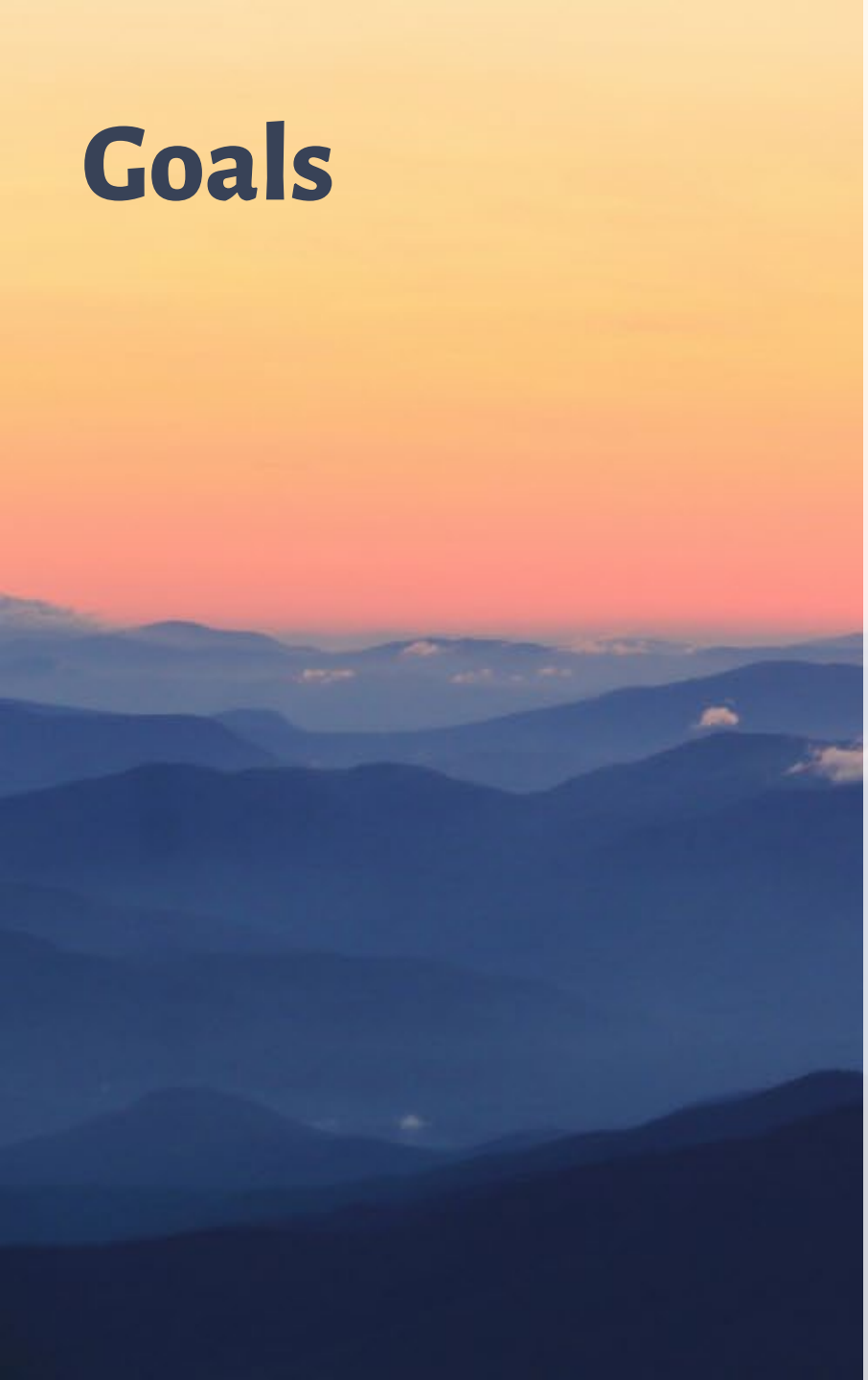
Significant Late Season Snow Events in the White Mountains

George Mousmoules

Goals



Understanding late-season significant snow event trends in the White Mountains

OBJECTIVES:

- Establish trends of significant late-season snow events at the summit and surrounding valleys
- Determine how the intensity and frequency of these events has been changing
- Generate visualizations to represent these trends
- Compare observed trends to previous model trends/forecasts and analyze outlier events

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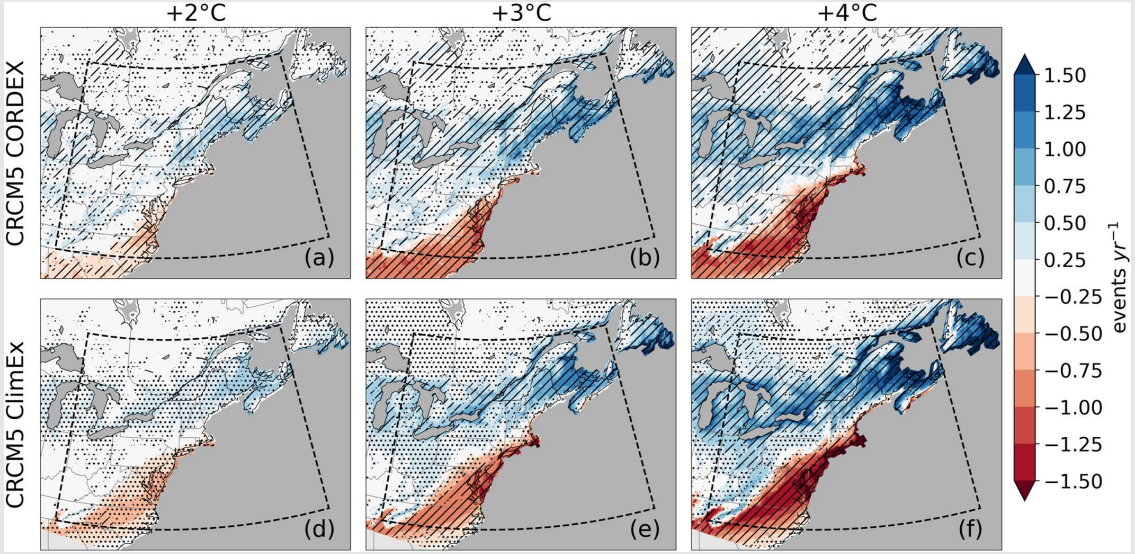
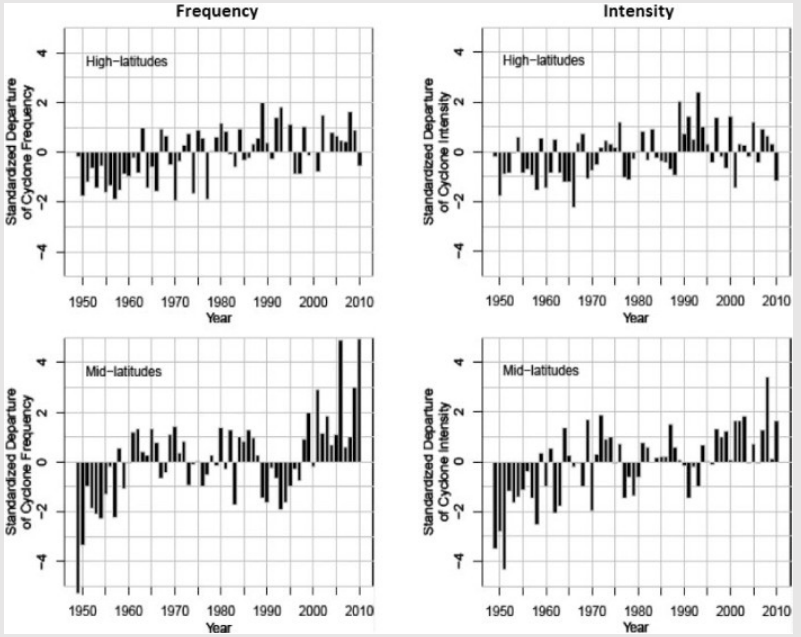
Motivation

- There have been multiple prior studies done using climate modeling
- Found significant storms would continue at same or increased rate
- Previous investigations based on observational data have found an increase in general storm intensity
- Mention Mt. Washington as a station experiencing high error



Projected mean changes in the number of annual snowfall events exceeding 10% of the climatological mean annual snowfall (McCray et al. 2023)



Time series of extratropical storm frequency and intensity during the cold season for high latitudes (60°–90°N) and midlatitudes (30°–60°N) of the Northern Hemisphere (Vose et al. 2014)

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Data

- The Observatory B16 Daily Archives provided all summit data
- The Pinkham Notch Visitor Center station provided all notch data
    - Both provided daily precipitation, snowfall, and snow depth records
    - Snow depth used as a sanity check
- The period of study included the years 1995-2024
    - Establish 30-year climatology
- Each year focused on March 1st-June 30th

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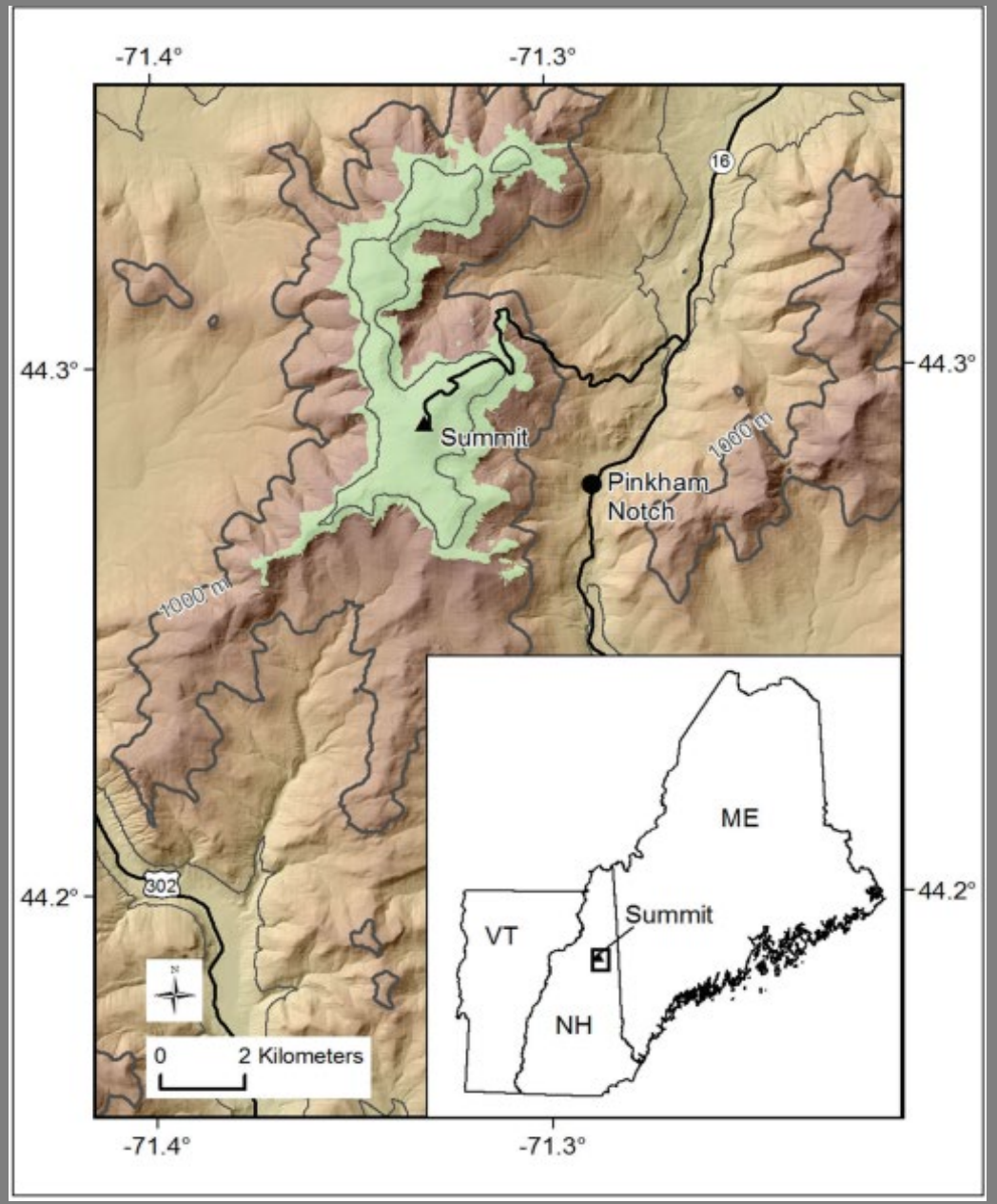
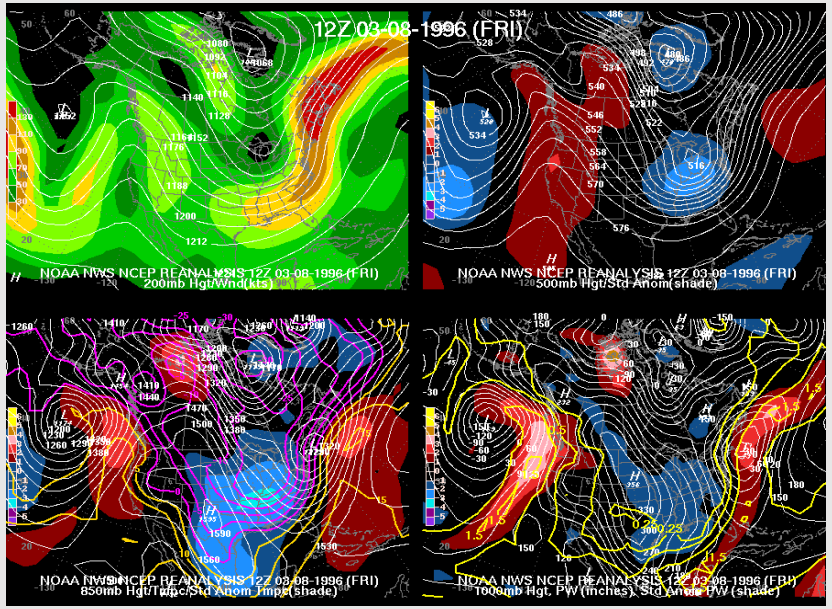
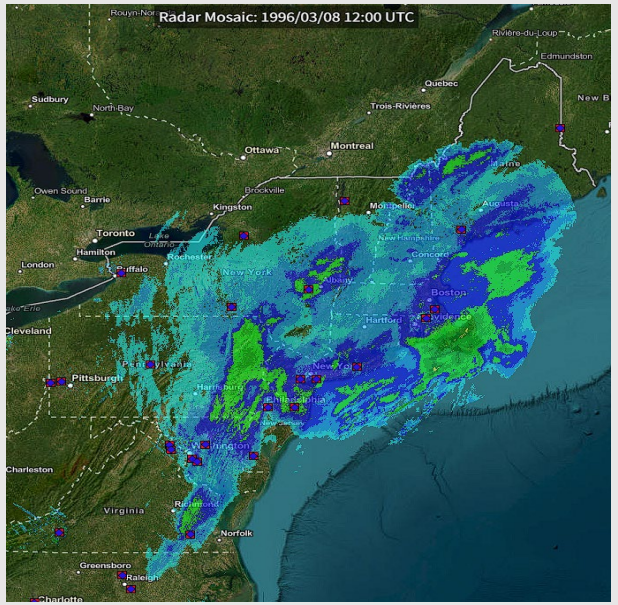
Locations



Data Cleaning & Organization

- Python v3.12 was used to clean and organize data into usable files
- All values of a “trace” were counted as zero
- Multi-day events were manually determined using upper air and surface analysis charts





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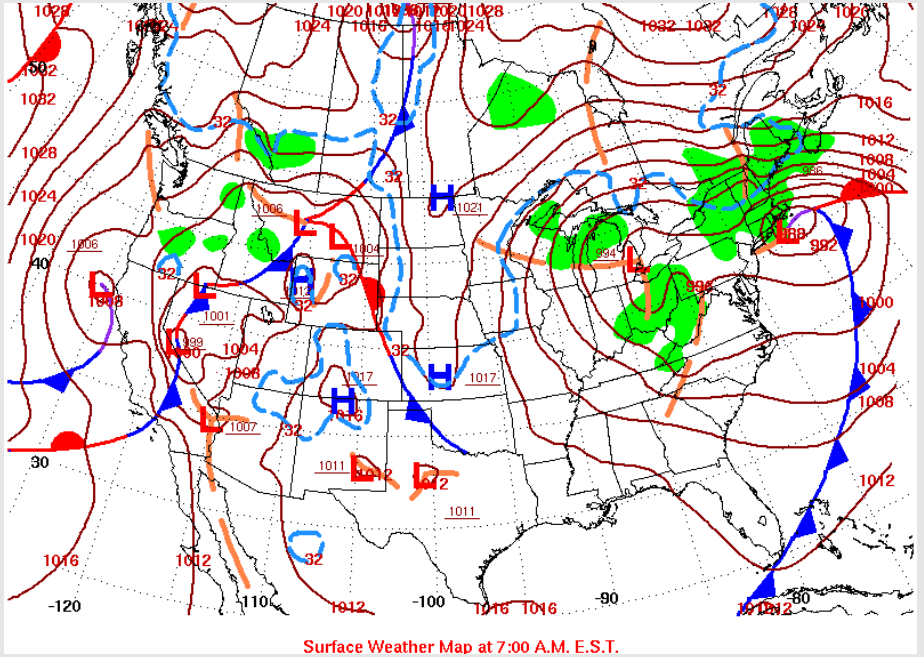
Analysis: Identifying the 90th Percentiles of Daily Data

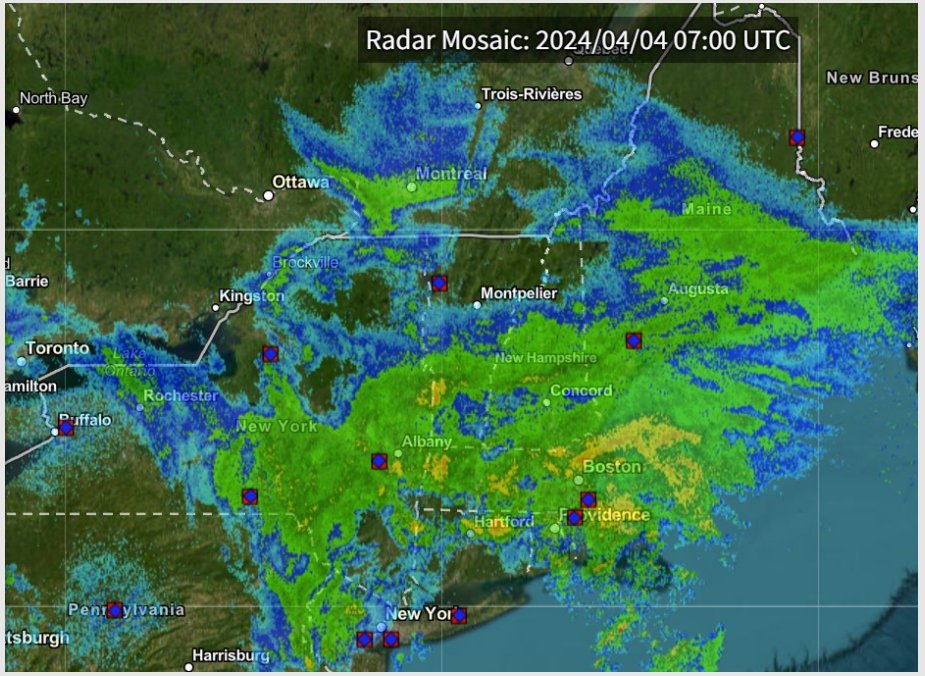
- The days with values meeting or exceeding percentile were sorted into separate documents
- Some events split over multiple days meaning they were over counted by code
- Some events qualify for snowfall but not precipitation and vice versa

date	water_equivalent	snow_fall	snow_depth_6am
3/7/1996	0.32	6.9	5
3/8/1996	0.44	5.7	9
3/20/1996	1.45	8.4	4
4/8/1996	0.58	7	8
4/10/1996	1.99	23.1	9
4/14/1996	0.71	5.5	12
4/16/1996	2.44	11.3	12
4/17/1996	1.32	9.4	14
5/12/1996	1.19	7.5	1
3/6/1997	1.56	13.6	10
3/8/1997	0.64	6.9	8
3/12/1997	0.78	8.4	10
3/26/1997	1.02	6.1	14
3/31/1997	0.67	5.6	5
4/18/1997	2.55	12.5	4
4/19/1997	1.18	5.5	8
4/28/1997	2.23	15	7
5/7/1997	3.75	18.9	9
5/16/1997	2.53	13.2	9
5/21/1997	1.16	8.2	7
5/22/1997	3.02	15.5	9
5/23/1997	1.2	6.8	13
3/14/1998	1.48	17	5
3/15/1998	0.62	8.5	5
3/19/1998	0.67	5.8	7
3/22/1998	0.52	6	7
4/25/1998	1.25	6.7	3
3/6/1999	0.53	7.2	2
3/15/1999	0.81	7.1	4
3/22/1999	6.03	23.7	7
3/2/2000	0.68	6.7	4
4/21/2000	1.34	9.7	0
3/22/2001	1	5.8	20
3/23/2001	0.85	7.5	22
4/1/2002	0.79	5.8	14
5/2/2002	1.15	6.7	5
5/13/2002	1.51	7.3	2

Defining Significant Events

- Significant events were defined based on snowfall
- The systems had to have at least one day where snowfall met or exceeded the 90th percentile
- Resulted in a variety of different systems
- 2024 demonstrated this well





Analysis: Running Averages of Snowfall & Precipitation

$$SMA_k = \frac{p_{n-k+1} + p_{n-k+2} + \cdots + p_n}{k} = \frac{1}{k}\sum_{i=n-k+1}^{n} p_i$$

date	3_day_avg_water_equivalent	3_day_avg_snow_fall	3_day_avg_snow_depth_6am
3/1/1995			
3/2/1995			
3/3/1995	0	0	10
3/4/1995	0	0	10
3/5/1995	0.04	0	9
3/6/1995	0.08	0.2	9
3/7/1995	0.09	0.2	9
3/8/1995	0.75	0.2	8
3/9/1995	0.8	0.5	5
3/10/1995	0.8	0.7	3
3/11/1995	0.13	0.9	2
3/12/1995	0.05	0.4	2
3/13/1995	0.03	0.3	2
3/14/1995	0.04	0	2
3/15/1995	0.03	0	1
3/16/1995	0.07	0.2	1
3/17/1995	0.05	0.3	1
3/18/1995	0.05	0.3	1
3/19/1995	0.02	0.2	1
3/20/1995	0	0	1
3/21/1995	0.21	1.1	1
3/22/1995	0.29	1.9	1
3/23/1995	0.33	2.3	2
3/24/1995	0.13	1.3	2
3/25/1995	0.25	1.7	3
3/26/1995	0.22	1.3	3
3/27/1995	0.2	1.2	4
3/28/1995	0	0	4
3/29/1995	0	0	4
3/30/1995	0.05	0.3	4
3/31/1995	0.08	0.6	3
4/1/1995	0.08	0.6	3
4/2/1995	0.02	0.3	3

- To account for multi-day events running average was used
- Code skipped first 2 and 4 days of each year to ensure overlapping did not occur
- Aided in identifying years when long-duration events were more common
- Ensured one large event was not counted multiple times
- Sorted results into separate documents

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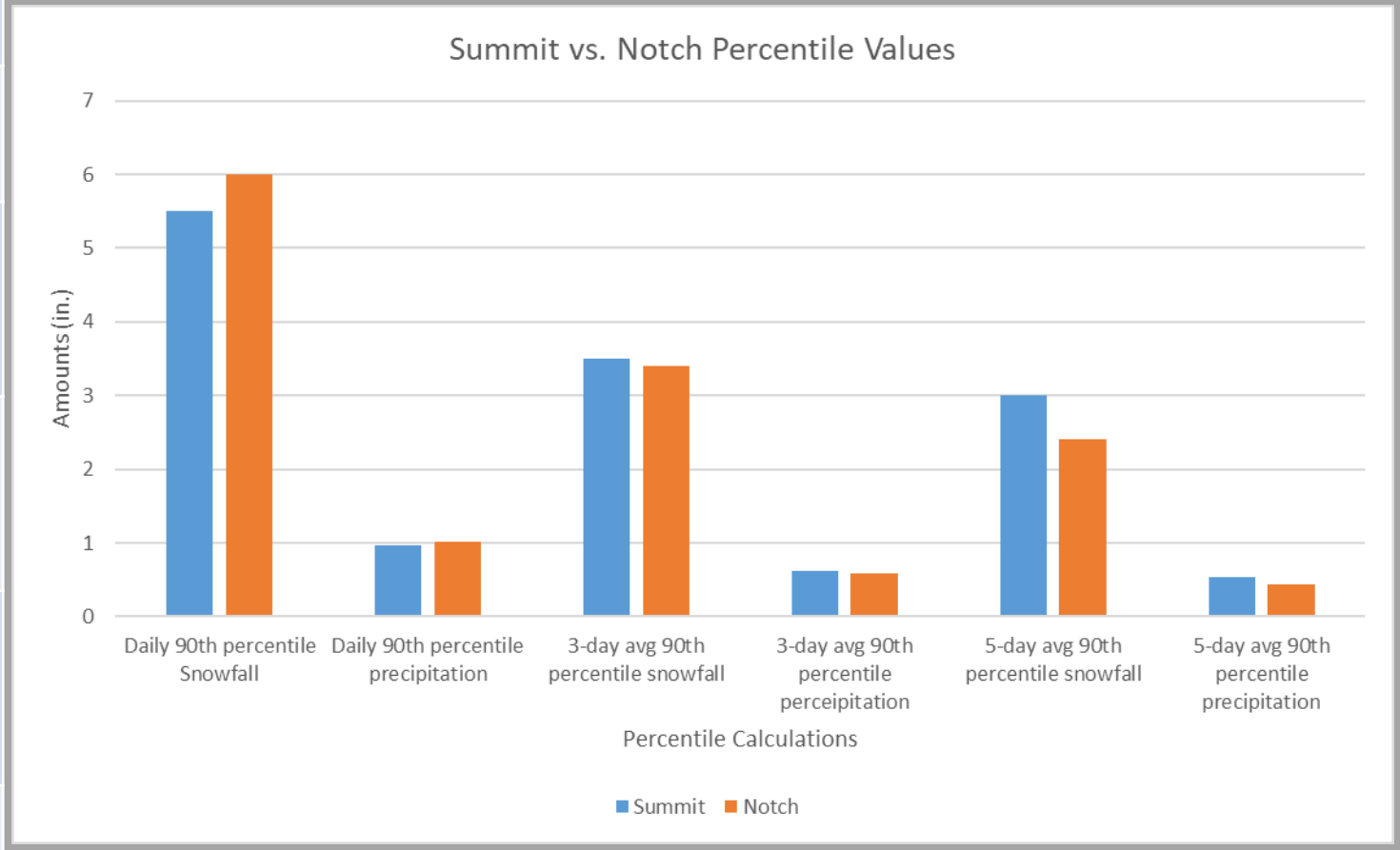
Results: Snowfall & Precipitation Percentiles

Calculations	Summit (in.)	Notch (in.)
Daily Snowfall	5.5	6
Daily Precipitation	0.96	1.02
3-Day Running Average Snowfall	3.5	3.4
3-Day Running Average Precipitation	0.62	0.58
5-Day Running Average Snowfall	3	2.4
5-Day Running Average Precipitation	0.53	0.44



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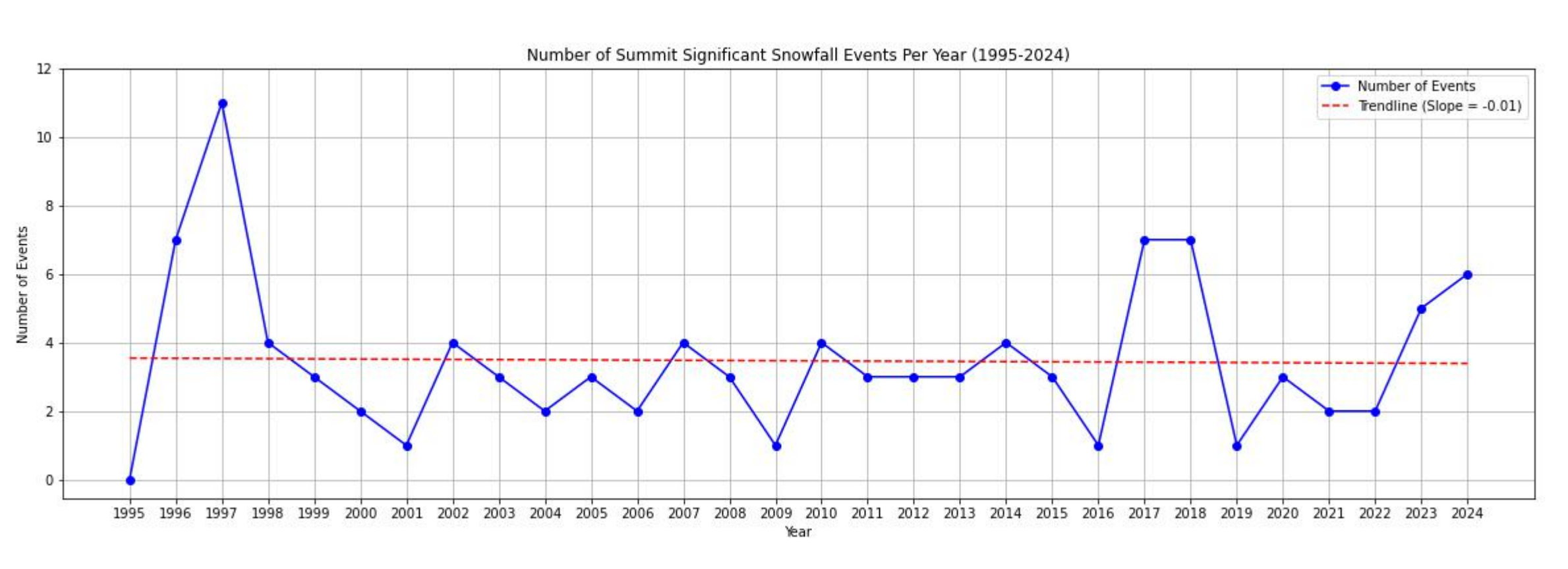
Results: Frequency of Events



- Peaks in 1997, 2017, 2018, and 2024
- Overall trend indicates a consistent amount of significant events
- Occurred despite a shortening winter season
- Aligns with climate model predictions

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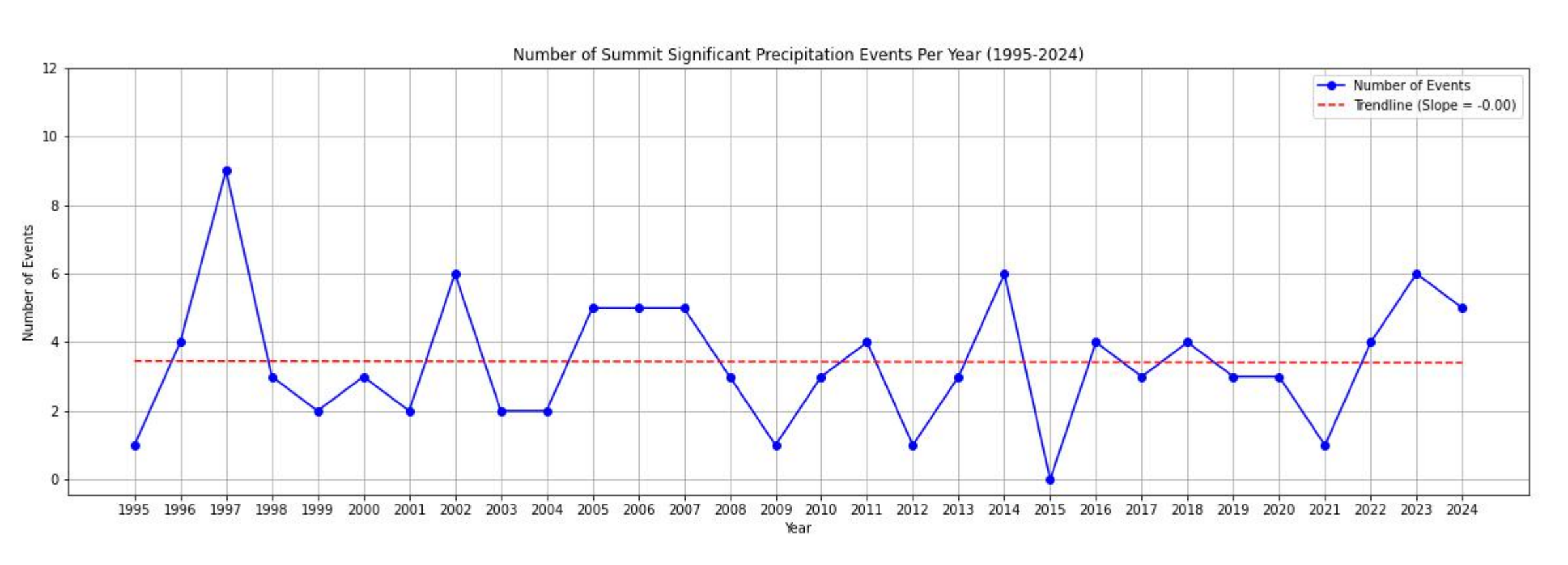
Results: Frequency of Events



- Peaks in 1997, 2002, 2014, and 2023
- Overall trend indicates a consistent amount of significant events
- Aligns with climate model predictions

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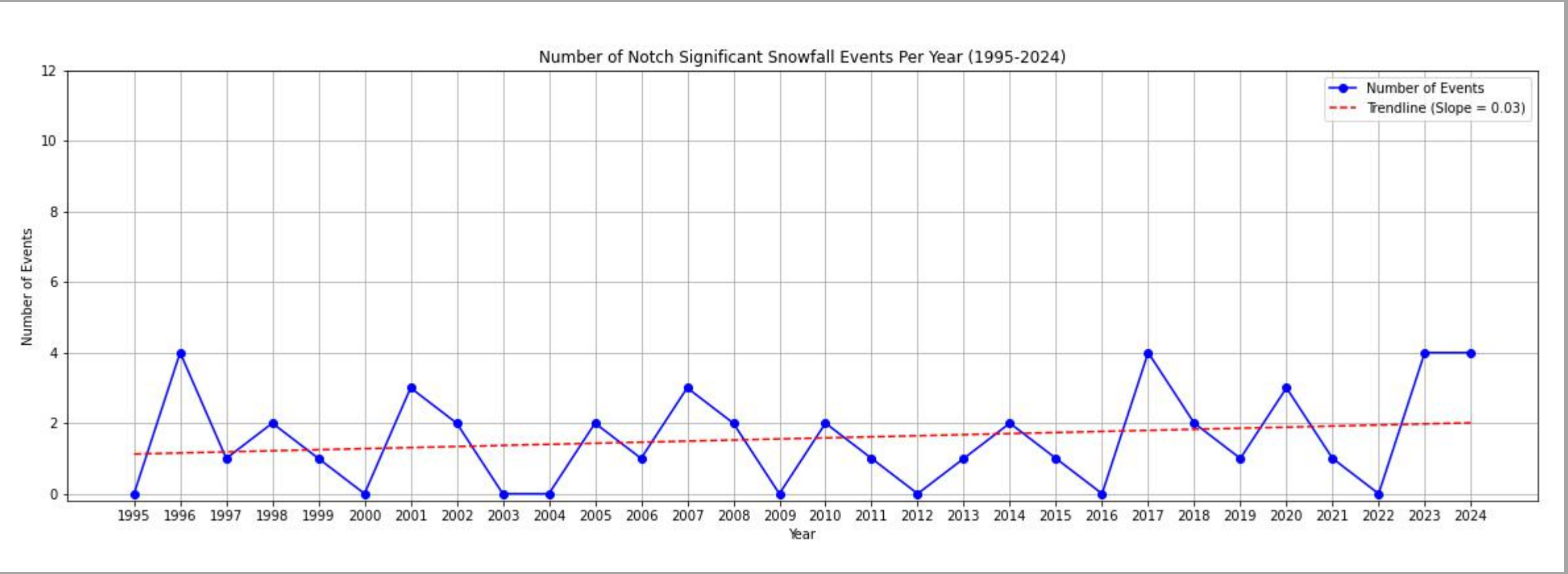
Results: Frequency of Events



- Peaks in 1996, 2017, 2023, and 2024
- Overall trend indicates a slight increase in the amount of significant events
  - Roughly 0.5 more events now than 30 years ago
  - Occurred despite a shortening winter season
  - Aligns with climate model predictions

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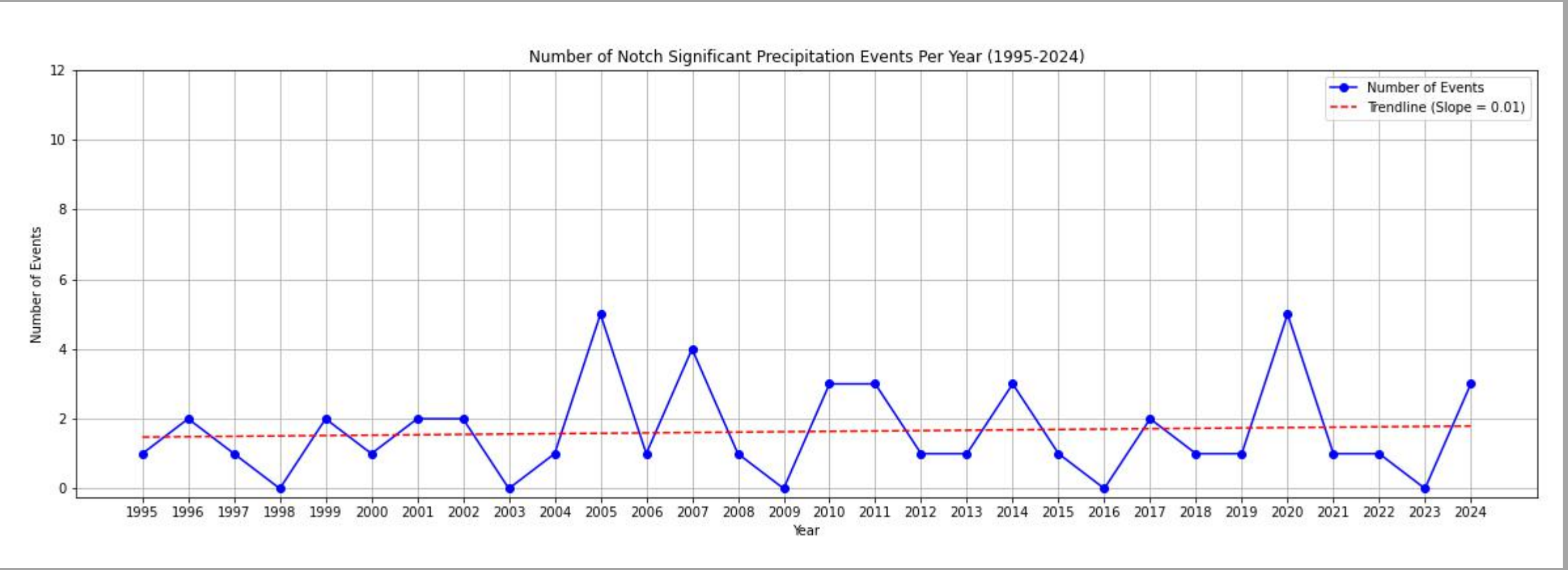
Results: Frequency of Events



- Peaks in 2005, 2007, and 2020
- Overall trend indicates a consistent amount of significant events
- Aligns with climate model predictions

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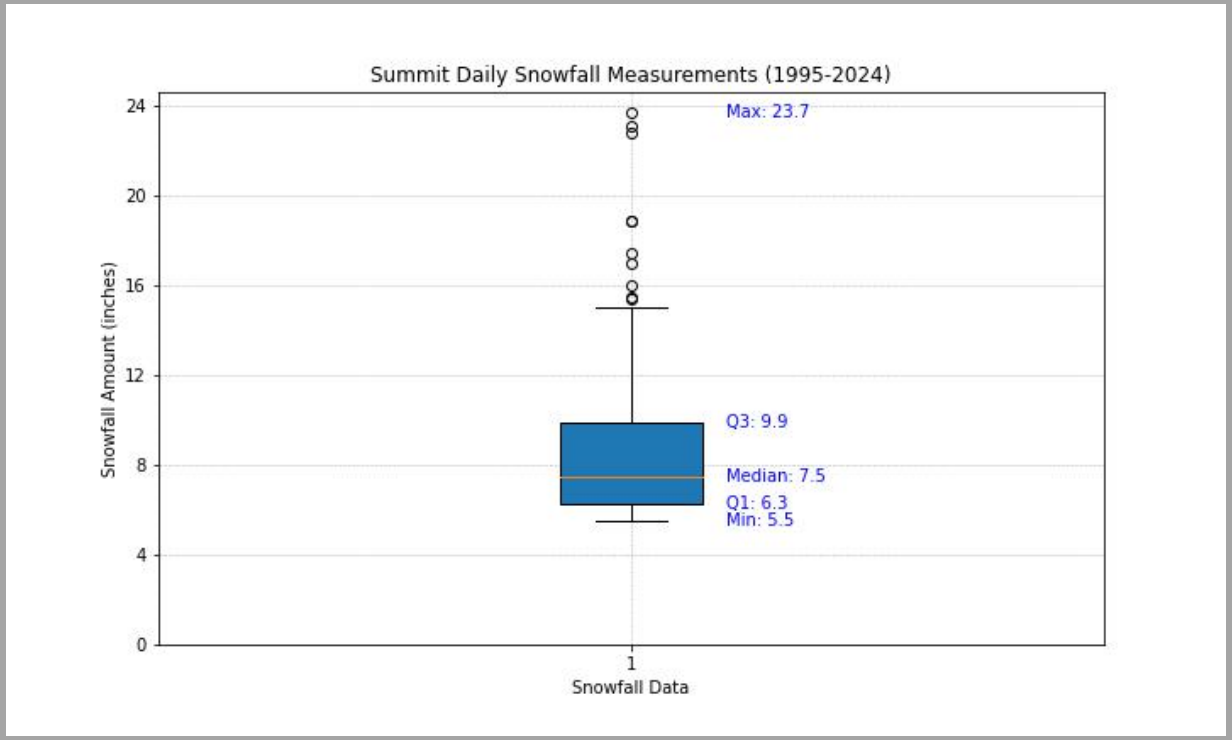
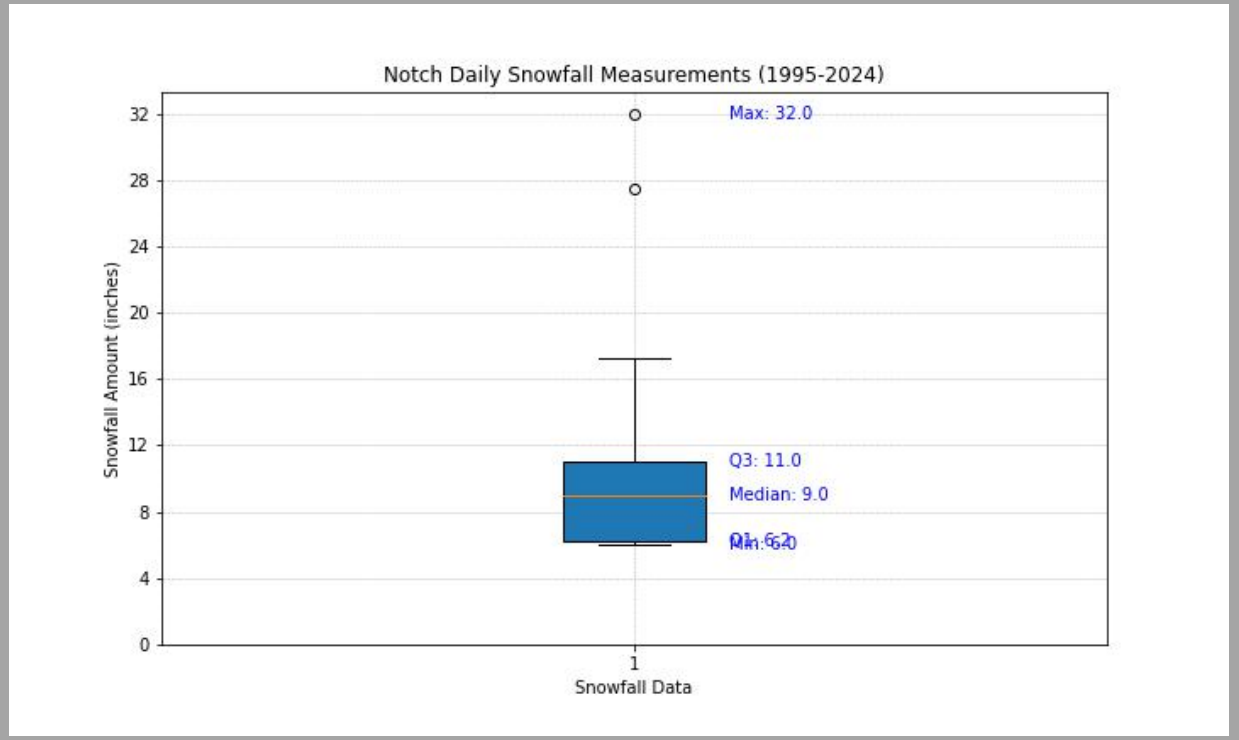
Results: Intensity of Events





- The summit has far more outliers
- Majority of daily snowfall for major events is between 6 and 10 inches
- Larger maximum for the Notch

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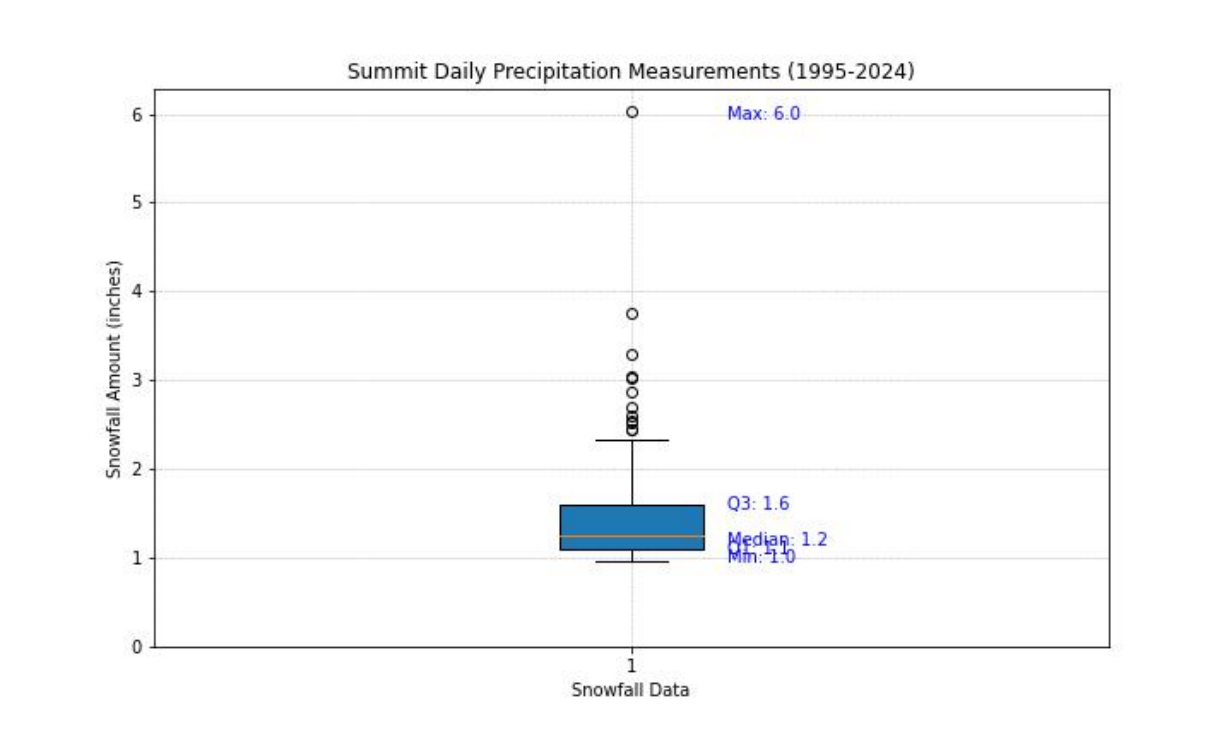
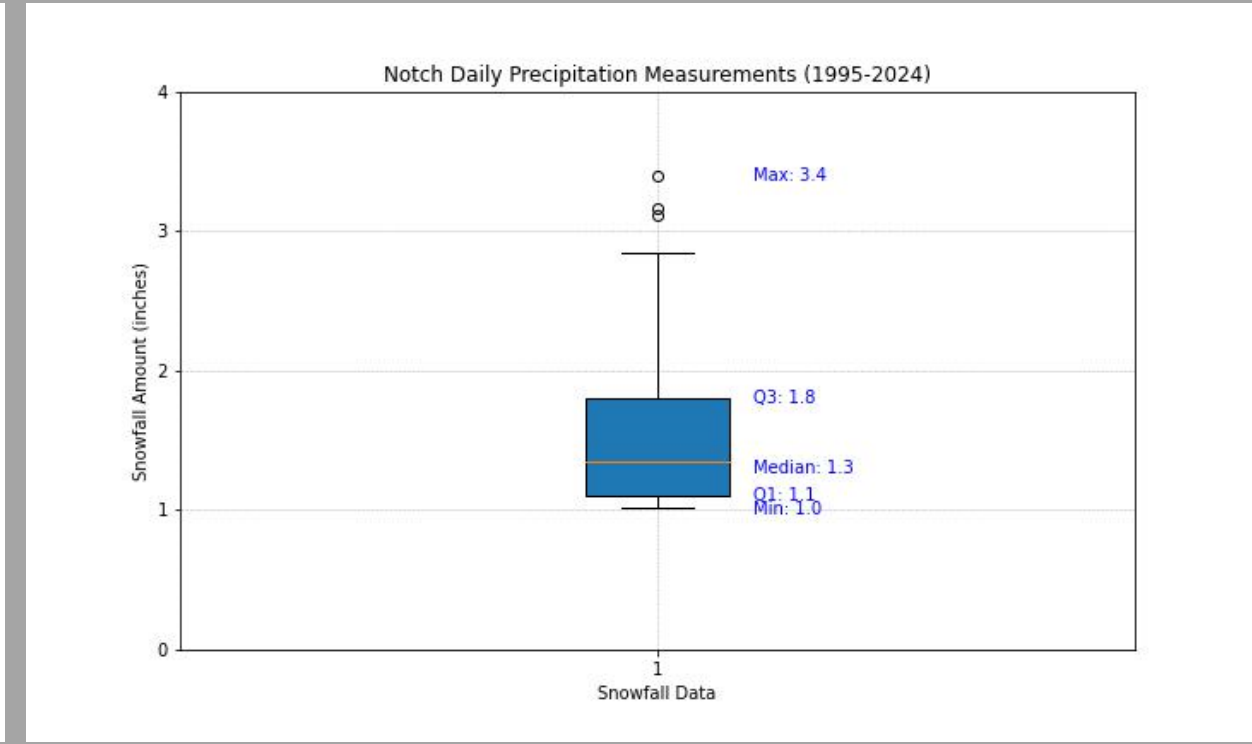
Results: Intensity of Events





- Both locations experience similar median totals
- More outliers for the summit
- The Q1 and Q3 values are closer between stations than snowfall

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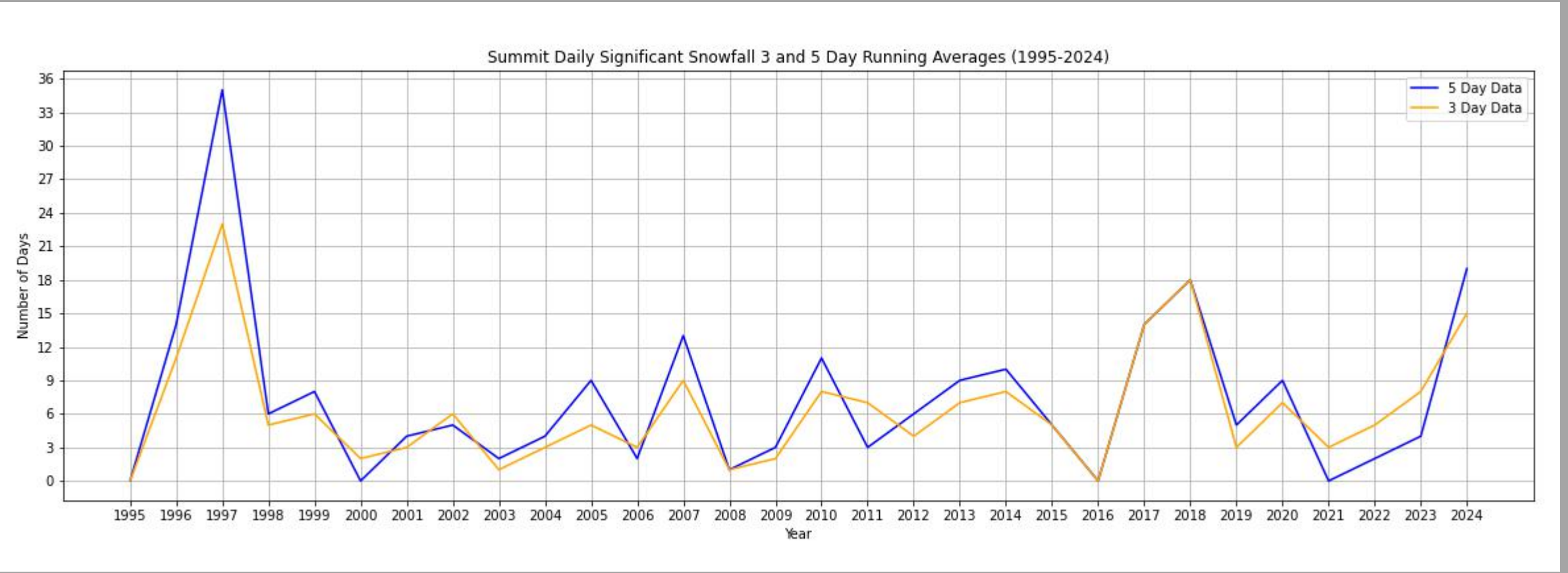
Results: Duration of Events



- Years with more events also saw more longer duration events
- Follow each other closely
- Large upticks at start and end of dataset

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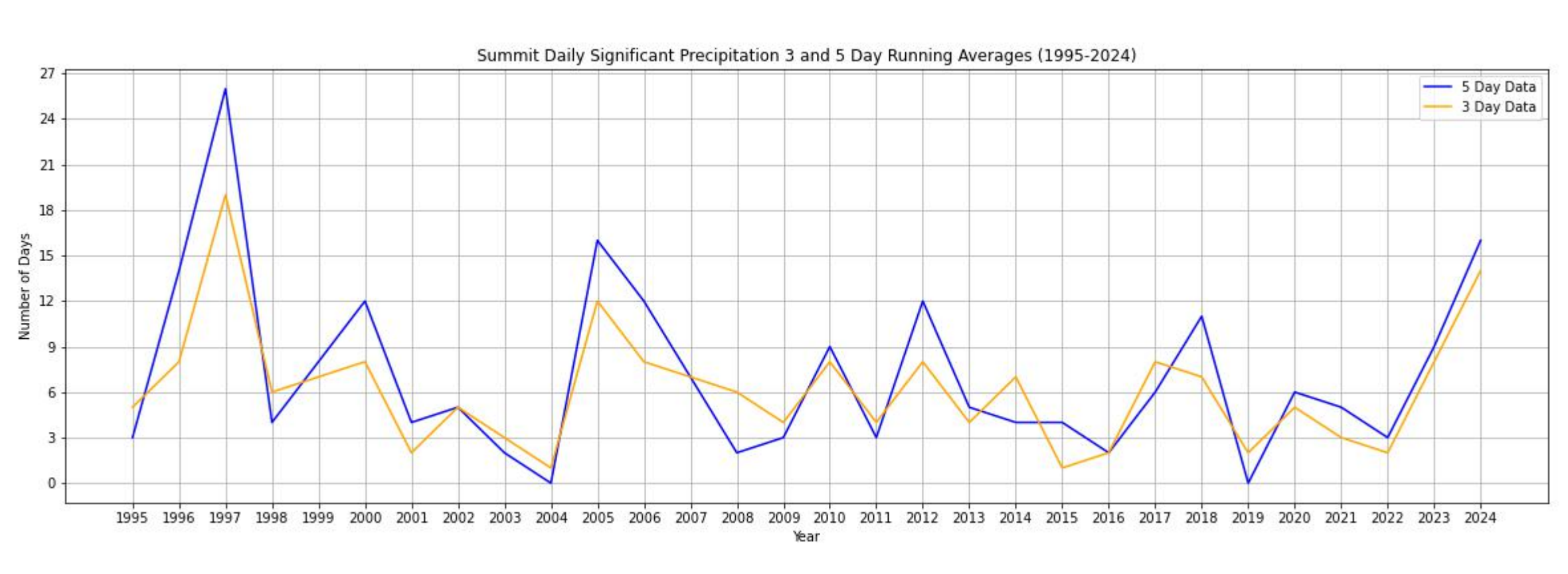
Results: Duration of Events



- Follows summit snowfall closely
- Summit experiences more snowfall event days than precipitation
- Averages match trends observed in daily data

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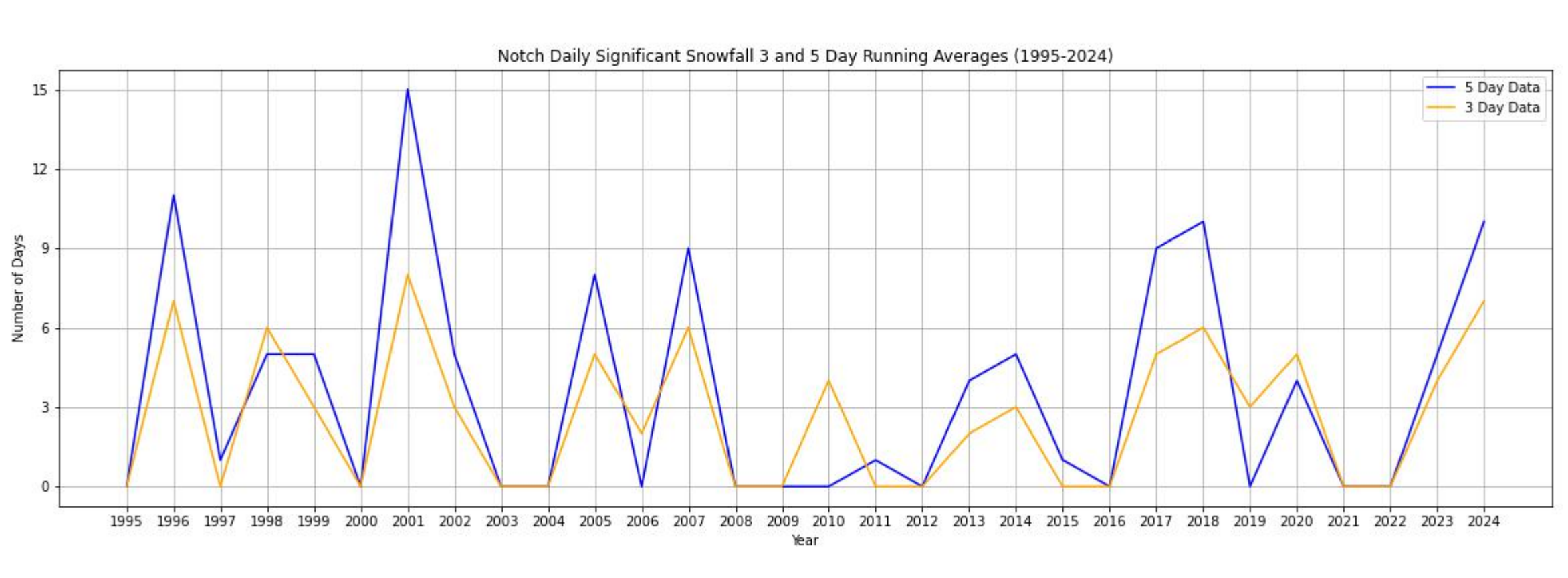
Results: Duration of Events



- The Notch has a more variable dataset
- More zero values
- Years with more events also saw more longer duration events

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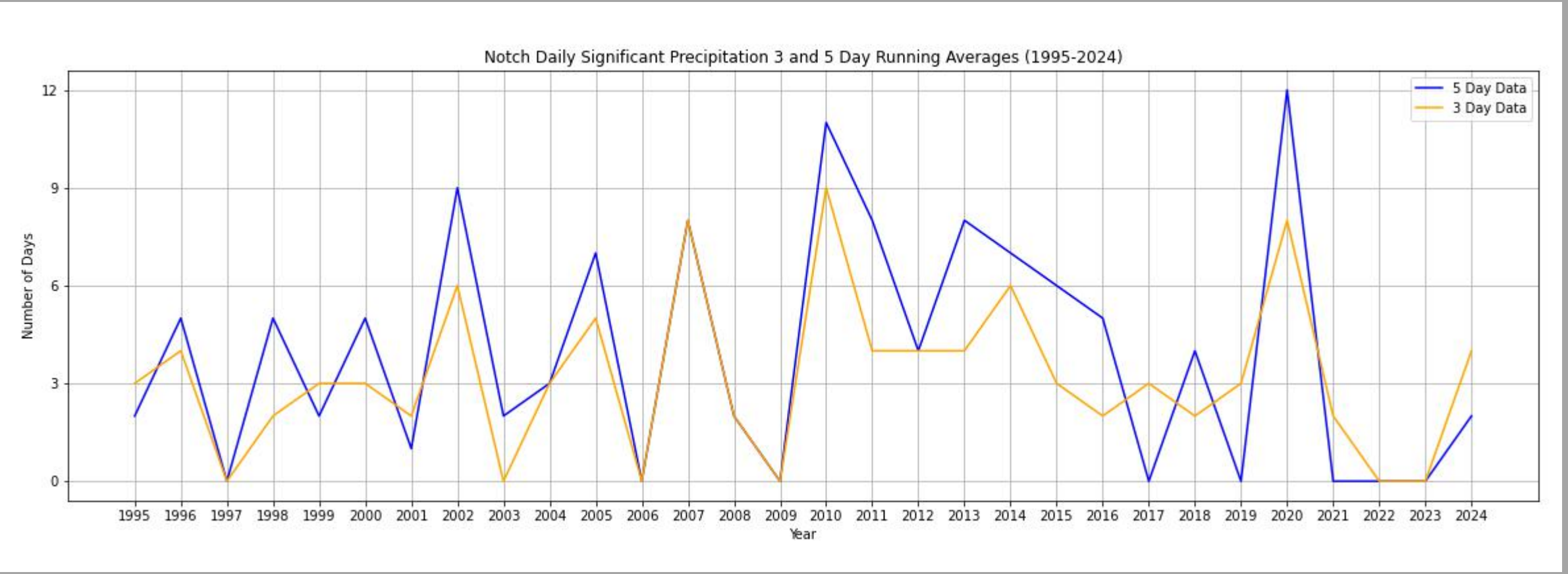
Results: Duration of Events



- Does not match as well as summit data did with snowfall
- Supports years with higher frequency had longer duration events
- Why data must be checked for counting single event multiple times

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Conclusions

- Steady rate of significant snow events at the summit
- Significant snowfall events are slowly increasing in Pinkham Notch
- Supports predictions by climate models
- Frequent changes in number of events per year
- Surge in events in the last few years
- More likely that storms will last longer in more active years
- Pinkham Notch experiences some effects from blowing snow off mountains

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Future Work

OBJECTIVES:

- Identify causes for increases and decreases in significant events for different years
- Utilize alternative methods for identifying events
- Expand the dataset further back to generate more significant trends
- Include more stations in the White Mountains
- Perform case studies on the highest precipitation and snowfall events
- Investigate the effects of windblown snow on Pinkham Notch's measurements

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Thank You!