Seasonal Temperature Changes with Elevation on Mount Washington

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MWOBS MOUNT WASHINGTON OBSERVATORY

1. Introduction

The summit of Mount Washington is warming more slowly than the surrounding lower elevations of the Northeast, which is opposite to climate model projections and observations in other mountain ranges.
A looming scientific question is: *why*?

A hypothesis is that the exposure of the summit to the "free troposphere", an air mass that sits above the ground-based "boundary layer", for approximately half the year is imparting a slower warming at the summit. This research project takes a preliminary first step toward answering this question by finding methods to determine when Mount Washington is in the boundary layer.

•Temperature readings from the summit, and the bases of the Cog Railway (west side) and Auto Road (east side) from 2015-2016 were used to calculate lapse rates. The temperature difference of the mountain is a useful tool to determine when the summit is in the boundary layer.

2. Data

• Hourly air temperature data were gathered from three stations located on Mount Washington: Cog Base, Mount Washington summit and the Auto Road base (AR1600; 1600 feet asl)

• Each dataset contained hourly air temperature (°F) between January 1, 2015 and December 31, 2016.

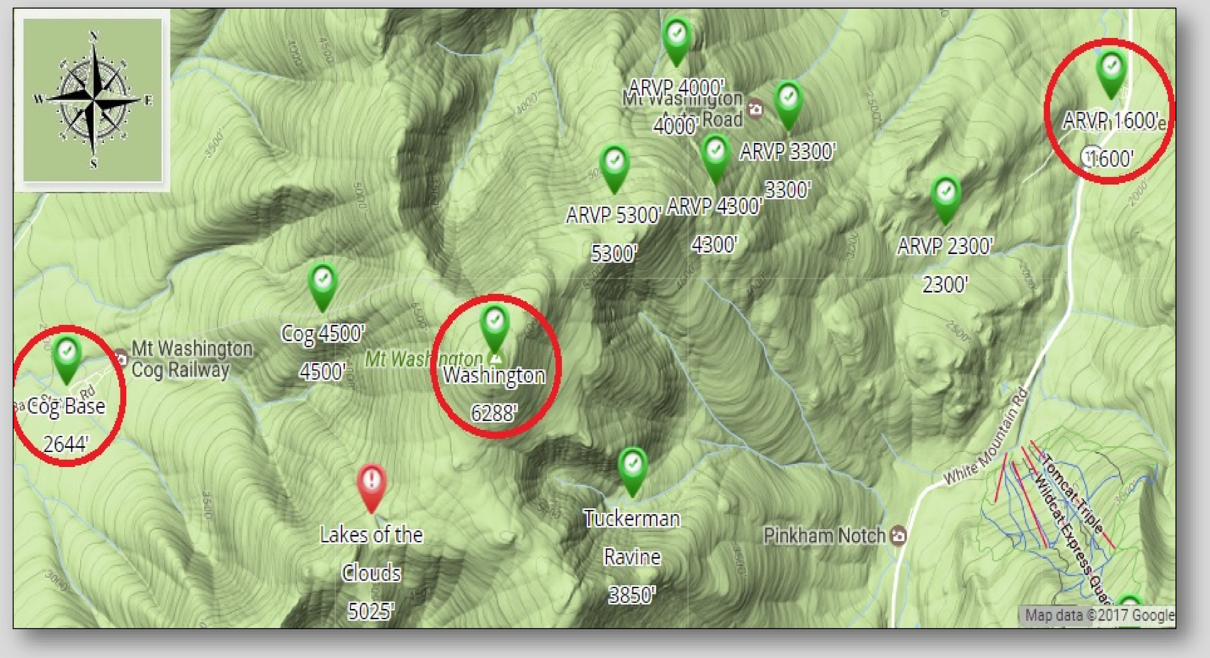

Figure 1: Map of the station locations.

3. Methodology

• Each data set was individually filtered to remove any erroneous data points and then interpolated.

• The lapse rates between two specified stations, CogBase to Summit and AR1600 to Summit, were calculated and plotted. Monthly and seasonal plots were made by averaging the lapse rates for each hour throughout the month/season.

$$\Gamma = -\frac{T\,(low\ station) - T(summit)}{z(low\ station) - z(summit)}$$

• Common statistics were calculated from those lapse rates, including maximum, minimum, mean and standard deviation.

4. Results

<u>Average Lapse Rates for both AR1600 to Summit and CogBase to Summit:</u>
• Spring and summer had greater lapse rates than fall and winter.

• Summer is the season closest to reaching the dry adiabatic lapse rate on average

<u>Average Lapse Rates for CogBase to Summit:</u>
Greatest maximum – May Greatest minimum – April
Lowest maximum – January Lowest minimum - September

<u>Average Lapse Rates for ARVP1600 to Summit</u>:
Greatest maximum– April Greatest minimum - April
Lowest maximum– December Lowest minimum - September

• August had greater average lapse rates from 0100 to 0700 than any other month; most months did not have lapse rates increase until 0500 to 0700. August does not follow any linear transition during July to September.

Lapse Rates (°C/km)		
	Summit and ARVP1600	Summit and CogBase
Max	13.505	11.667
Min	-7.650	-7.273
Mean	5.659	5.568
σ	3.152	3.172

Table 1: Bulk Statistics.

• Lapse rates maximize earlier in the afternoon on the AR1600 side while they maximize later in the afternoon on the CogBase side. This is due to the aspect, AR1600 is in a valley and receives more sun midday, and the west-facing CogBase receives more sun in the afternoon

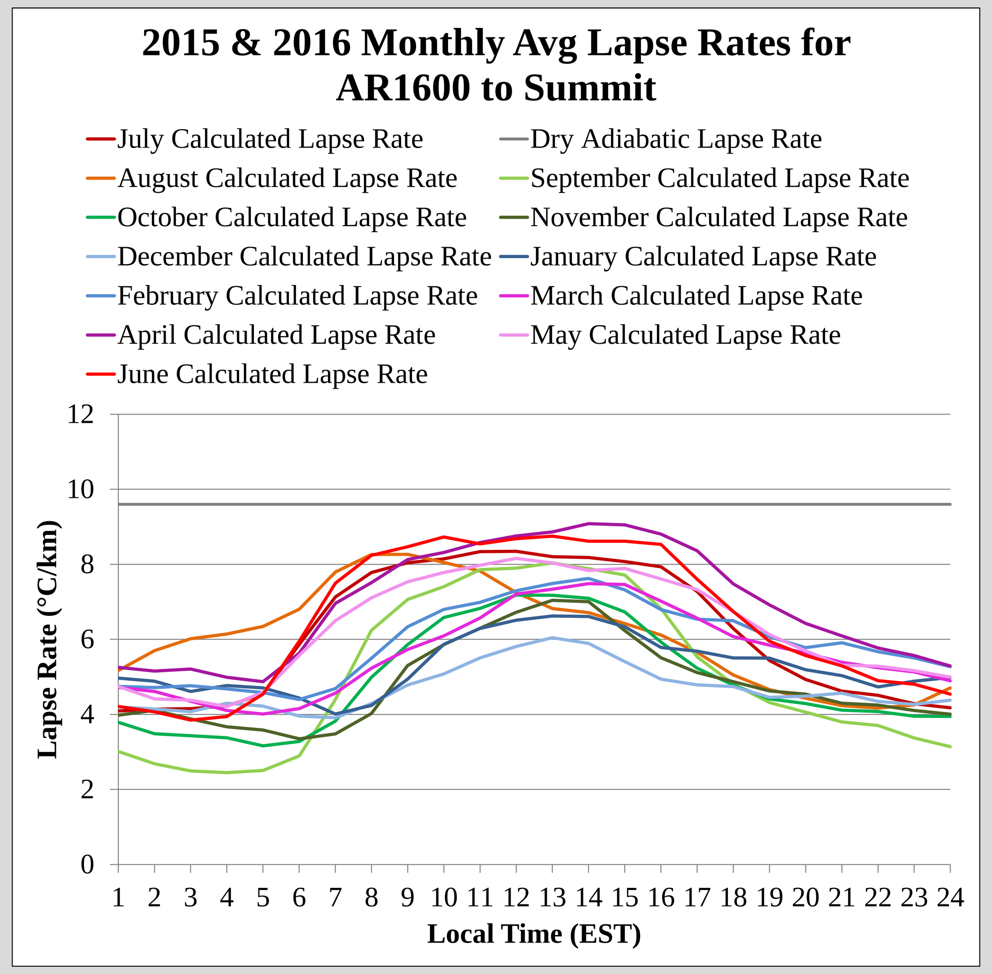

Figure 2: Average Monthly Lapse Rates for AR1600 to Summit.

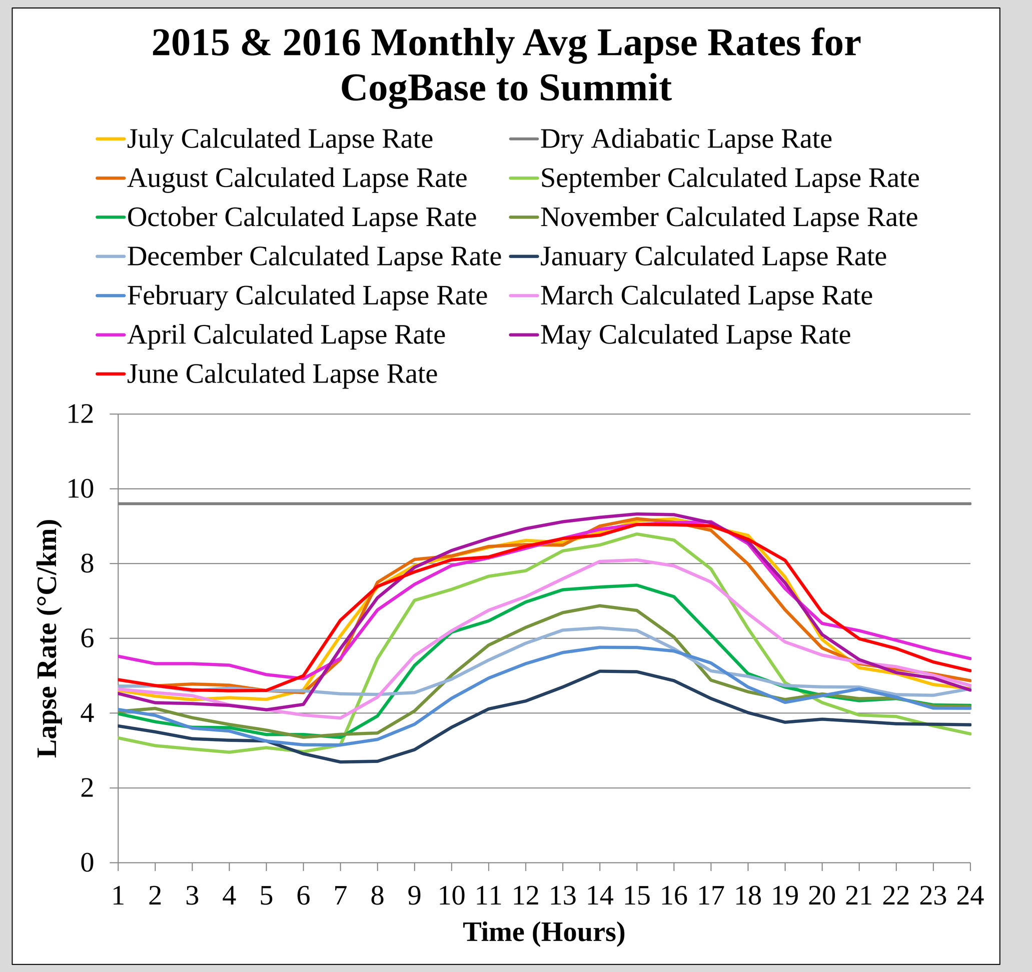

Figure 3: Average Monthly Lapse Rates for CogBase to Summit.

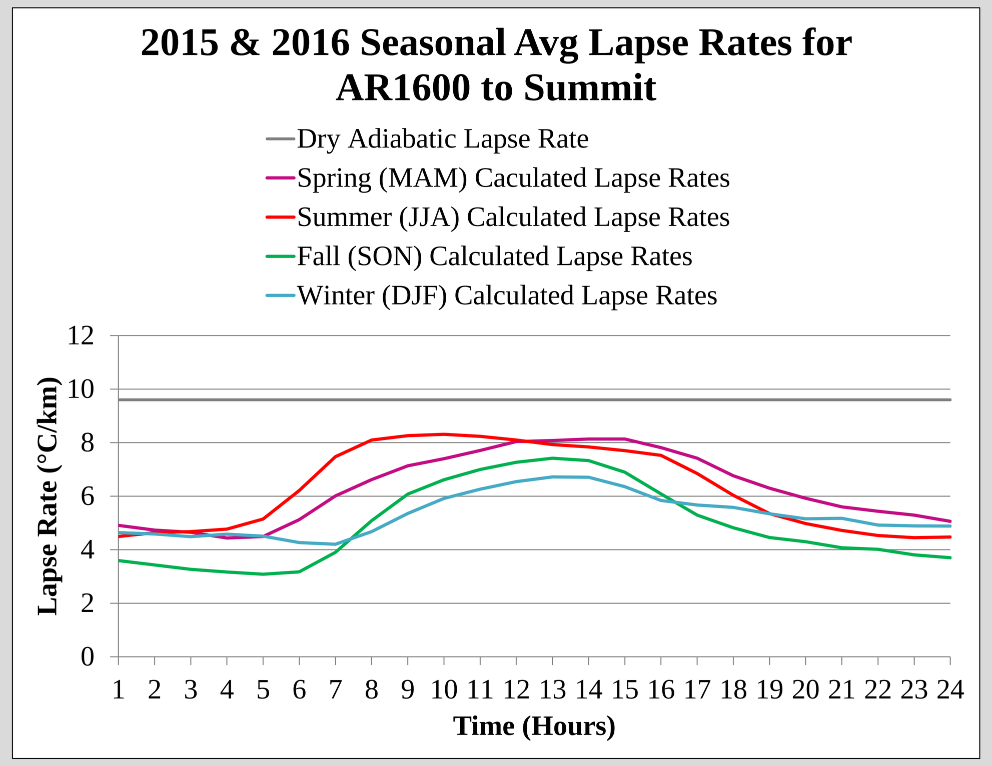

Figure 4: Average Seasonal Lapse Rates for AR1600 to Summit.

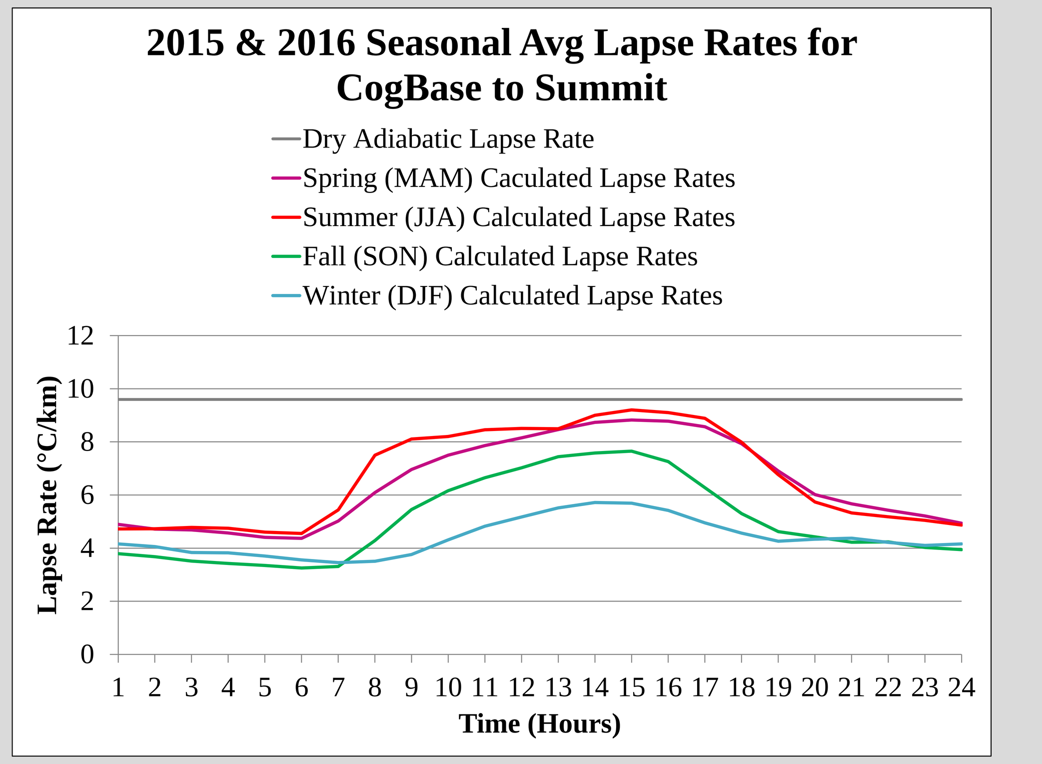

Figure 5: Average Seasonal Lapse Rates for CogBase to Summit.

5. Conclusions

• On average, the air is stable on Mount Washington during nights and in fall and winter because the average lapse rates are significantly lower than dry adiabatic. During these times, cold stable air typically resides in the valleys.

• An unstable atmosphere (i.e., high lapse rates) has significant atmospheric turbulence and vertical mixing. As a result, spring and summer seasons experience the greatest and deepest mixing of air. The mixing often extends from the valleys up to 9000 feet.

• The magnitude of lapse rates between AR1600 to Summit and CogBase to Summit are different but their seasonal variability is similar since it predominantly varies with solar angle.

• The west side of Mount Washington (CogBase) is typically the windward side (a northwest wind is most frequent). The CogBase to Summit had greater lapse rates than the AR1600 to Summit lapse rates during spring, summer and fall indicating lapse rates are greater on the windward side than the leeward side. The more narrow and sheltered valley on the Auto Road side favors the formation and persistence of cool shallow air more than on the Cog Railway side. This is a plausible cause of the lower lapse rates on the AR side.

6. Future Work

• Using a longer period of data will increase confidence in the results of this climatological analysis

• Calculating the environmental lapse rates from more stations on Mount Washington would give a more detailed thermal profile of the lower troposphere.

• Mount Washington lapse rates can be compared with those at other mountains in the Northeast, such as Mount Mansfield, VT and Whiteface Mountain, NY.

7. Acknowledgements

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8. References

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