Characterizing Near-Surface Lapse Rate in the White Mountains: Abrupt Shift in Modes between Warm and Cold Seasons

Jackson Hawkins, Henry Moskovitz, Karl Philippoff, Jay Broccolo *(Mount Washington Observatory, North Conway, NH)*

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Importance of Accurate Near-Surface Lapse Rates

- A near-surface lapse rates (NSLR) is the rate at which near-surface (2m) temperature changes with surface elevation.
- Key in many models, as a way to determine rain/snow line[1], ecological niches for organisms, and for hydrological models[2,3,4], especially in complex terrain.
- Better model inputs = better model outputs

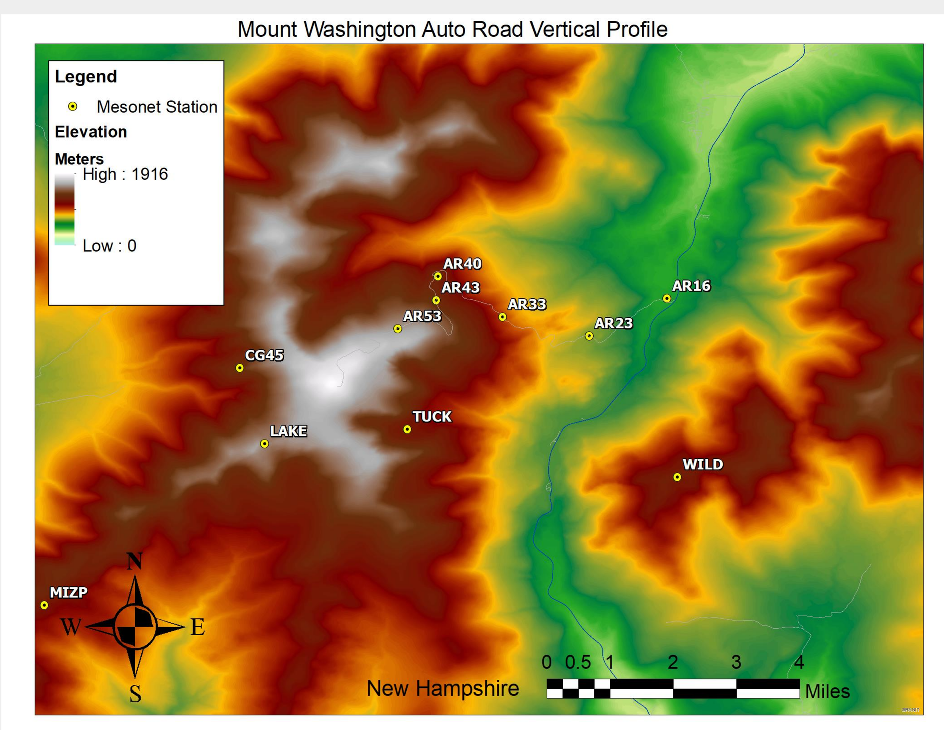

Figure 1. Elevation (shaded) with locations of mesonet stations around Mount Washington, NH.

Utilizing the Mount Washington Regional Mesonet

- The Mount Washington Regional Mesonet is a network of 17 remote weather stations across the White Mountains
- All stations record temperature, several also record windspeed and direction
- Analyzed 7 years of data from a subset of mesonet sites beside the AutoRoad on the eastern (leeward) slope of Mount Washington, between January 2016 -December 2022

Current Lapse Rate Practices & Shortcomings

- Many models in complex terrain use the environmental lapse rate (ELR)[5] to represent changes in temperature with elevation.
- The ELR (~6.5 C km^{-1}) represents a global annual average of lapse rates in the free atmosphere[5], meaning that it:
  - 1) Does not necessarily align with any one geographic region, leaving out variations in local geography and climate[3,6].
  - 2) May not represent conditions near elevated surfaces.
- By calculating a seasonal NSLR for the White Mountains, we can greatly improve the ability of models to represent this variable in this region.

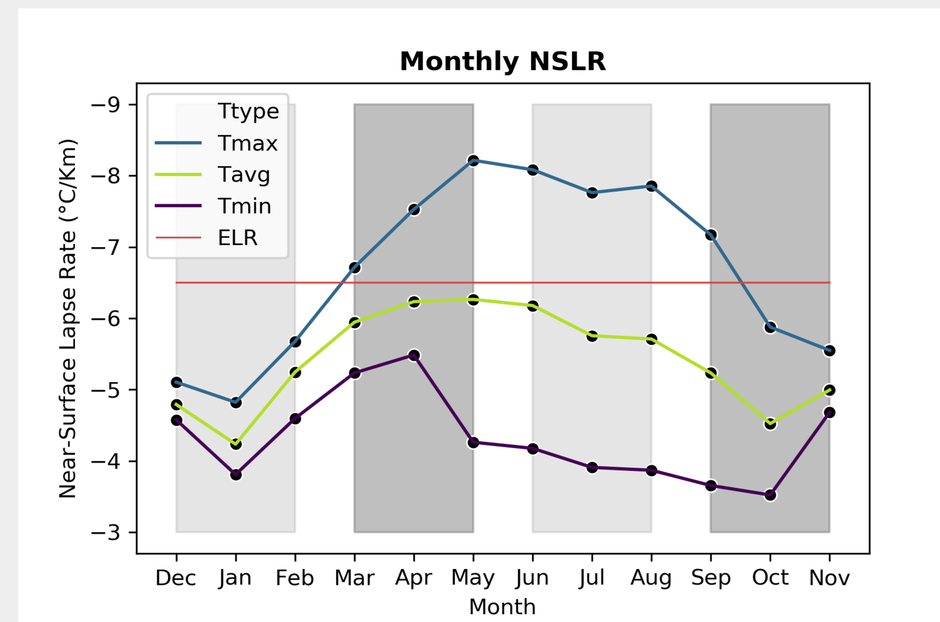

Figure 2. Monthly breakdown of NSLR to maximum, minimum, and average temperatures. Gray shaded areas represent meteorological seasons. Orange dashed line represents the environmental lapse rate.

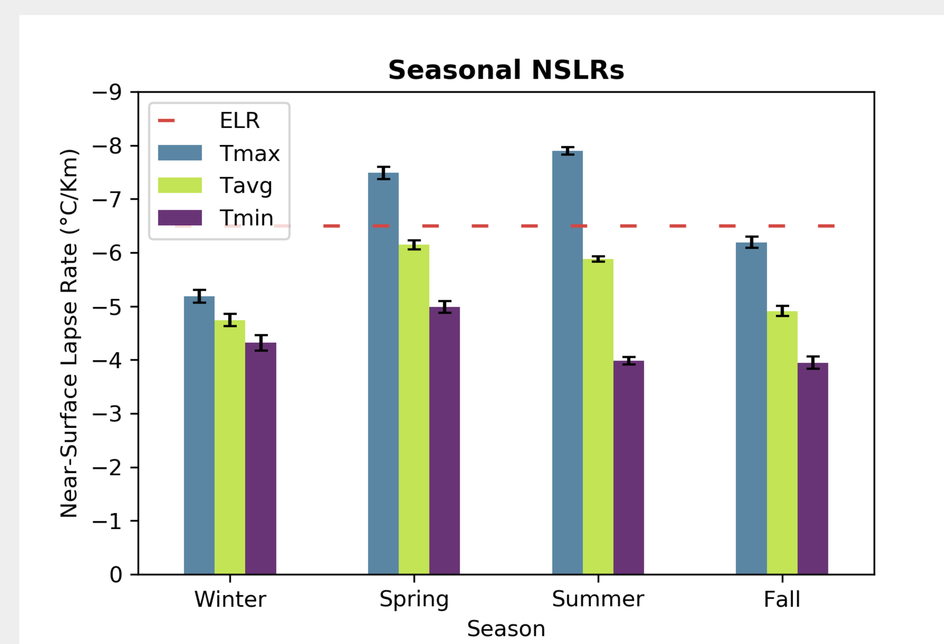

Figure 3. Bar chart showing near-surface lapse rate in the White Mountains based on daily maximum, average, and minimum temperatures. Error bars represent standard error of the mean.

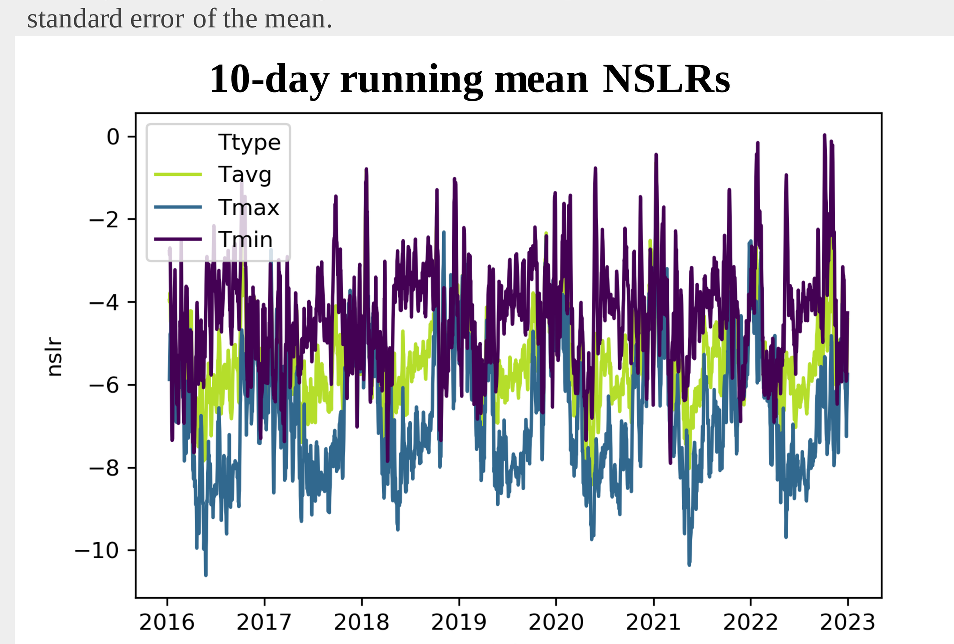

Figure 4: Line plot showing 10-day running means of maximum, minimum, and average temperature lapse rates between Jan. 1, 2016 and Dec. 31, 2022.

Results

Initial Seasonal NSLR Calculation

- Daily NSLRs were calculated from 6 sites ranging from 1600' to 6267' at approximately 1000 foot intervals
  - Used linear least-squares regression
- Daily NSLRs were grouped and averaged by meteorological season (DJF, MAM, JJA, SON) to derive seasonal NSLRs, and an overall average
- Process was repeated for maximum, minimum, and average temperatures

Additional Comparisons and Findings:

- A 1-sample t-test was used to compare each seasonal NSLR to the ELR (-6.5°C/Km). All were found to be significantly different.
- According to 10-day rolling means, appear to be an abrupt switch, not necessarily tied to a fixed date, between 'cold' season and 'warm' season lapse rates
- Overall average lapse rate of 5.5 C km^{-1} is in good agreement with most other studies of lapse rates in the White Mountains and New England region
- Extended research to include radiosonde data (00Z and 12Z) from Maniwaki, Ontario, and Gray, ME. Seasonal pattern is broadly similar, though seasonal variation in minimum (~12Z) lapse rates is not nearly as flat as shown on Mount Washington.

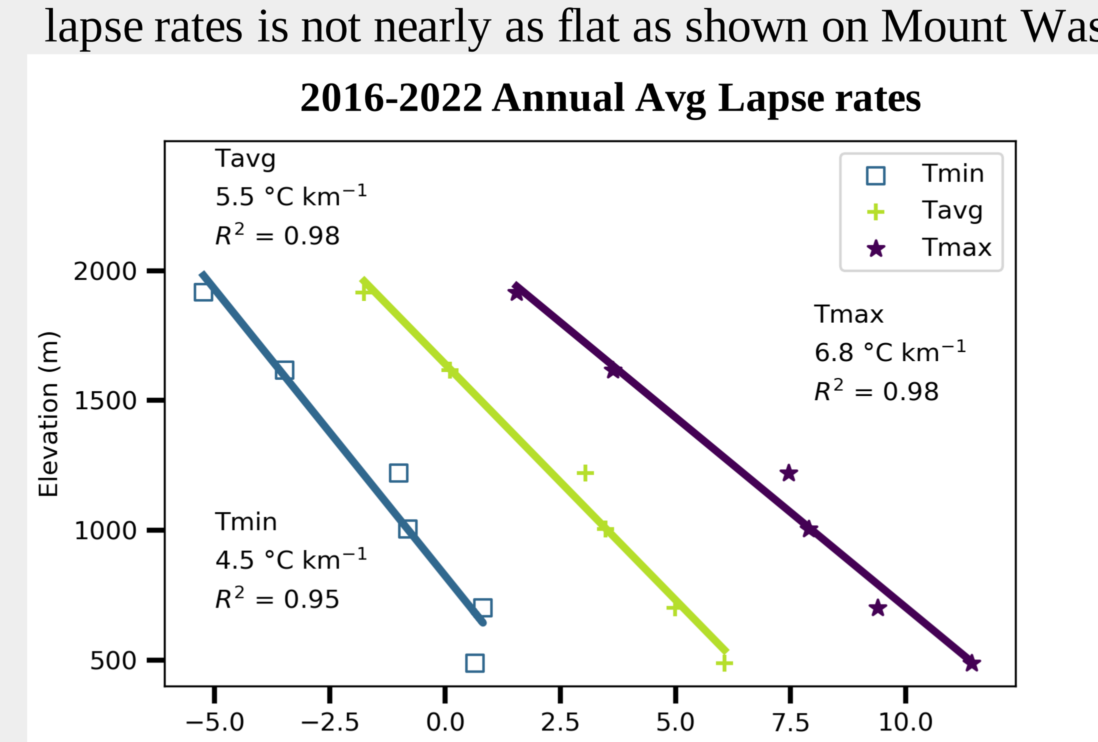

Figure 6: Scatter plot of overall average (2016-2022) minimum, maximum, and mean station temperature and their respective lapse rates.

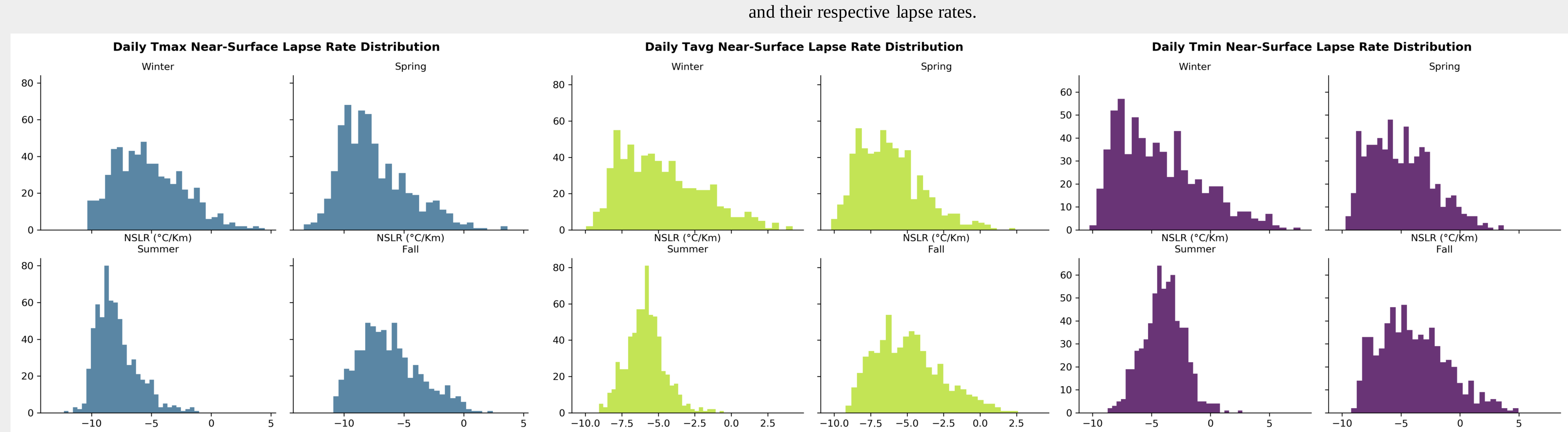

Figure 5. Histograms showing the non-normal distribution of daily NSLR data for each temperature type and season.

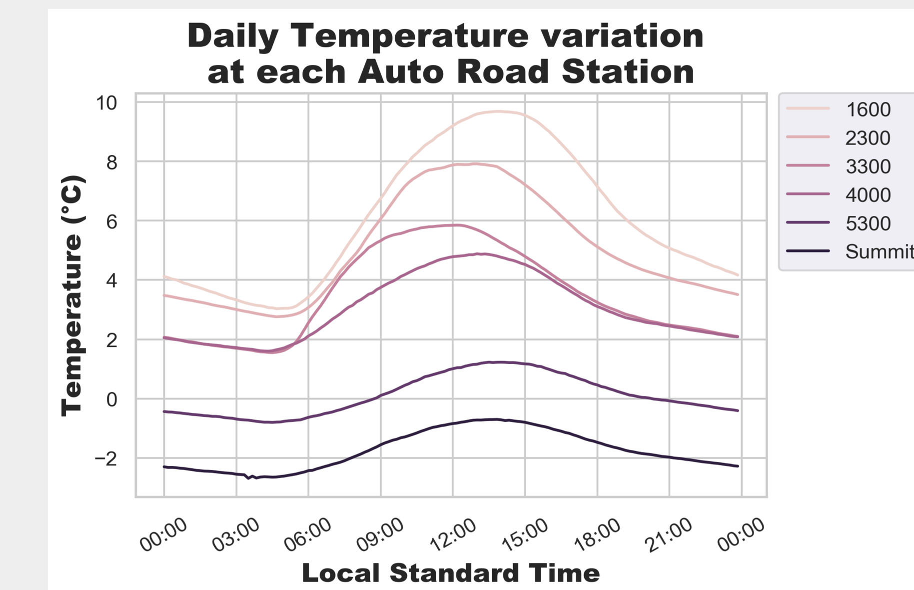

Figure 7: Overall average temperature variation over 24 hours at each station versus. local standard time, with data sampled at 10 minute intervals, 2016-2022.

Key Findings

- **Nearly all** seasonal NSLRs and the average annual NSLRs are **significantly different from the ELR**.
- NSLR is **steepest between May-September** for all temperature types and **shallowest in the winter**.
- **Abrupt shift in 'warm' mode vs. 'cold' mode** with values **relatively consistent in each mode**
- Seasonal variation is **similar to** that seen in **radiosonde observations** from Gray, ME, and Maniwaki, Ontario from 2016-2022.

Further Work

- Categorize NSLRs based on precipitation for rain/snow line determination and forecasting
- Analyze data from the windward (i.e. western) slope of Mount Washington, to determine role of wind exposure on NSLR
- Calculate LRs with respect to Pinkham Notch COOP station to be able to extend the data back to the 1930s.
- Track the formation of inversions at high temporal resolution

Acknowledgements & Sources

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1. Gardner, A. S., Sharp, M. J., Koerner, R. M., Labine, C., Boon, S., Marshall, S. J., ... & Lewis, D. (2009). Near-surface temperature lapse rates over Arctic glaciers and their implications for temperature downscaling. *Journal of Climate*, *22*(16), 4281-4298.
2. Minder, J. R., Mote, P. W., & Lundquist, J. D. (2010). Surface temperature lapse rates over complex terrain: Lessons from the Cascade Mountains. *Journal of Geophysical Research: Atmospheres*, *115*(D14).
3. Tercek, M. T., Rodman, A., Woolfolk, S., Wilson, Z., Thoma, D., & Gross, J. (2021). Correctly applying lapse rates in ecological studies: comparing temperature observations and gridded data in Yellowstone. *Ecosphere*, *12*(3), e03451.
4. Murray, G. L., Colgan, A. M., Nelson, S. J., Kelsey, E. P., & Kimball, K. D. (2021). Climate trends on the highest peak of the Northeast: Mount Washington, NH. *Northeastern Naturalist*, *28*(sp11), 64-82.
5. Stone, P. H., & Carlson, J. H. (1979). Atmospheric lapse rate regimes and their parameterization. *Journal of Atmospheric Sciences*, *36*(3), 415-423.
6. Rosas-Chavoya, M., López-Serrano, P. M., Hernández-Díaz, J. C., Wehenkel, C., & Vega-Nieva, D. J. (2021). Analysis of Near-Surface Temperature Lapse Rates in Mountain Ecosystems of Northern Mexico Using Landsat-8 Satellite Images and ECOSTRESS. *Remote Sensing*, *14*(1), 162.