Near-Surface Lapse Rates

By Karl Philippoff


We are a private, nonprofit research and educational institution working to **advance the understanding** of Earth's weather and climate.

What are typical near-surface lapse rates on Mount Washington, and how do they vary on daily, monthly, and annual timescales?

Objectives:

- Establish baseline for average lapse rates expected at different time scales, as well as some measure of the variability about those averages
- Apply those results to other ongoing research within the White Mountains and greater New England area that deal with temperature variation with elevation

What is a lapse rate?

The decrease in a variable, typically temperature, with increasing altitude or elevation.

$$\pm \Delta T / \Delta z$$

Why does temperature generally decrease with elevation?

A: As an air parcel ascends from high to low pressure:

Parcel expands and does work but has gained no heat

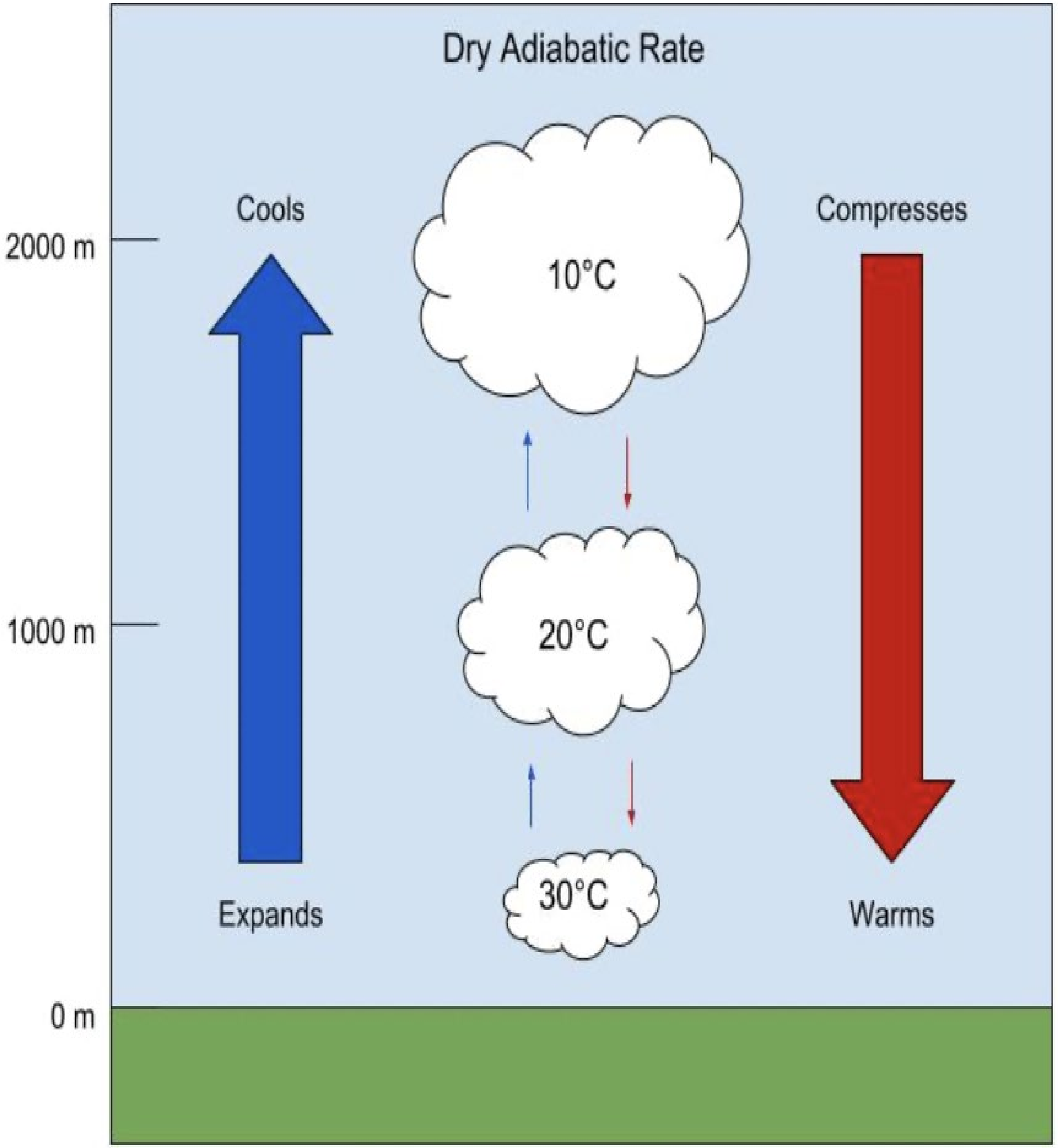
Energy expended by the parcel as it expands causes its temperature to decrease.

Dry adiabatic: 9.8℃/km

Moist adiabatic: ~6.5℃/km

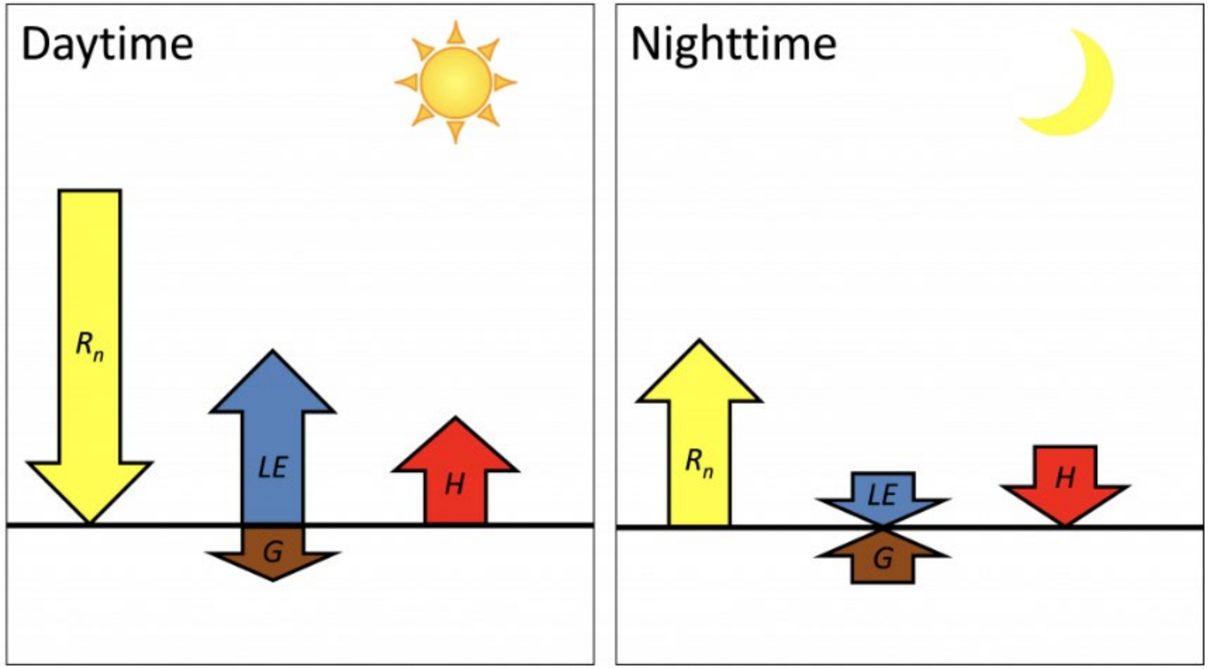
“Greater”→ more negative→sharper decrease w/ height

“Lesser”→ less negative→ shallower decrease w/ height



Air rises, expands, and cools at the dry adiabatic lapse rate, approximated as a 10°C decrease per km (created by Britt Seifert).

Near-surface vs. free-air lapse rates



Importance of surfaces:

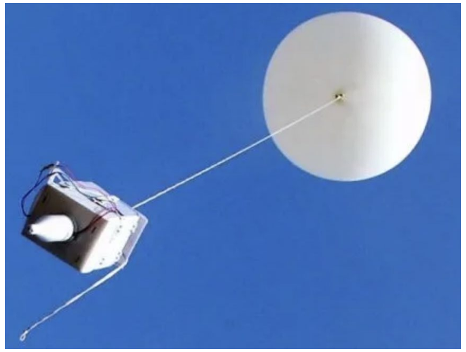
Absorb and emit radiation and change it to other forms of energy (e.g. H, LH)

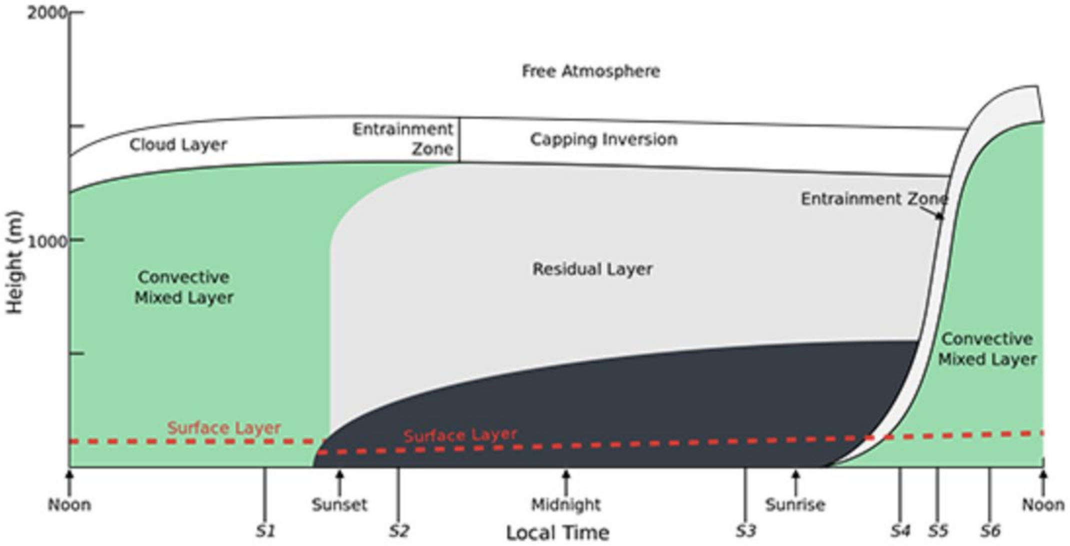
Where the organisms are (botanical/ecological impact felt)

Glaciers

Snow hydrology, avalanche forecasts, freezing line for mixed precipitation events

VS:





How is this research typically done?

Generally, use lower elevation stations, and extend that data up to higher elevations with the use of an estimated or theoretical lapse rate. In the absence of local or regional data, many researchers have used the 'standard atmosphere' lapse rate of 6.5℃/km

Then use highly resolved elevation data sets to 'fill-in' the temperatures over the highly resolved terrain

Especially for ecological research and snow hydrology

Data Used

Jan 1st 2016-> Dec. 31st 2022

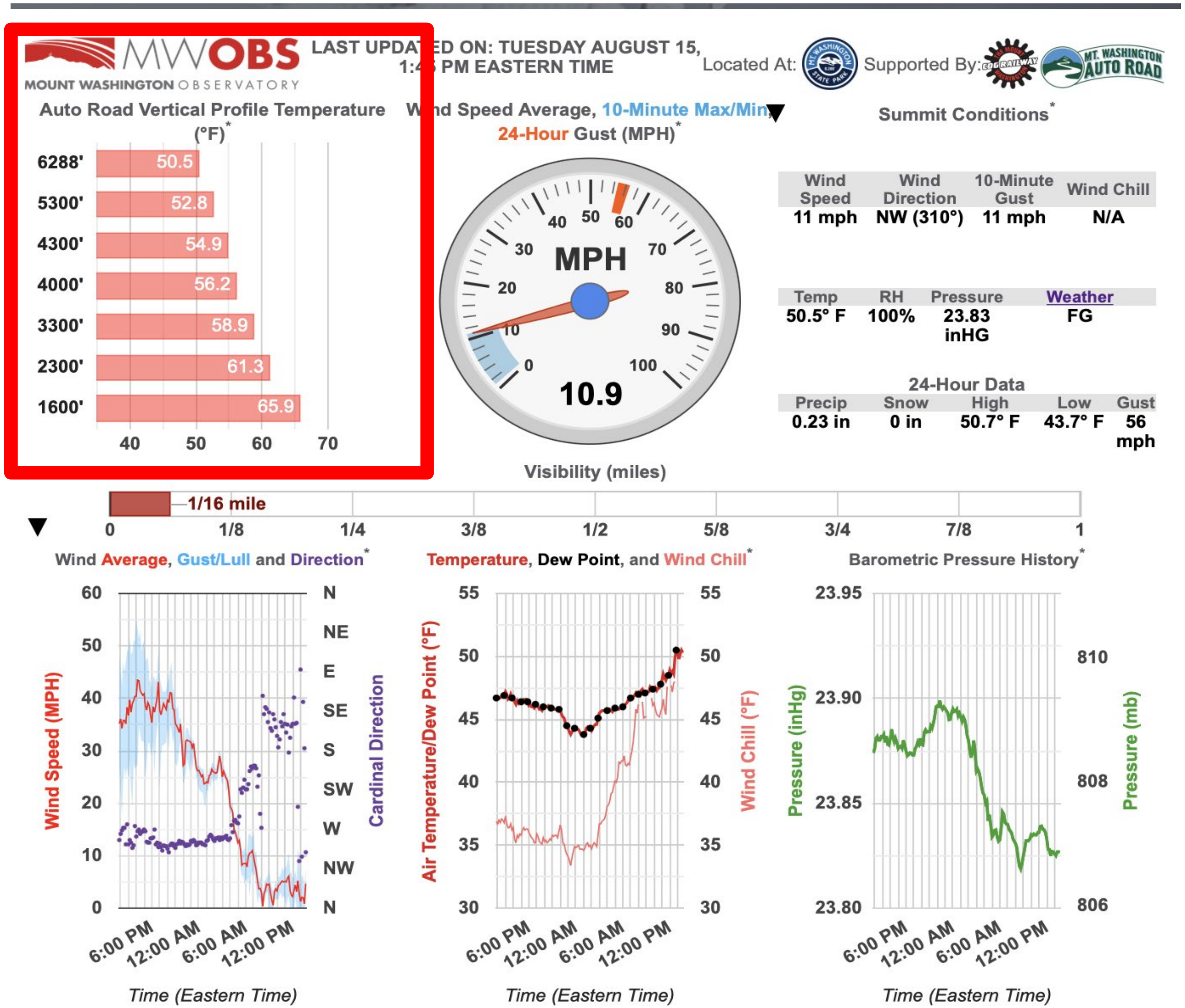
Mesonet stations measuring temperature every ~1000 feet up the Auto Road

Consistent aspect facing eastward on the leeward side of the mountain (prevailing winds are from the W->NW)

Data is relatively consistent and of excellent quality

Singular elevation for basin bottom

Experience nearly the same weather at the same time.



Methodology

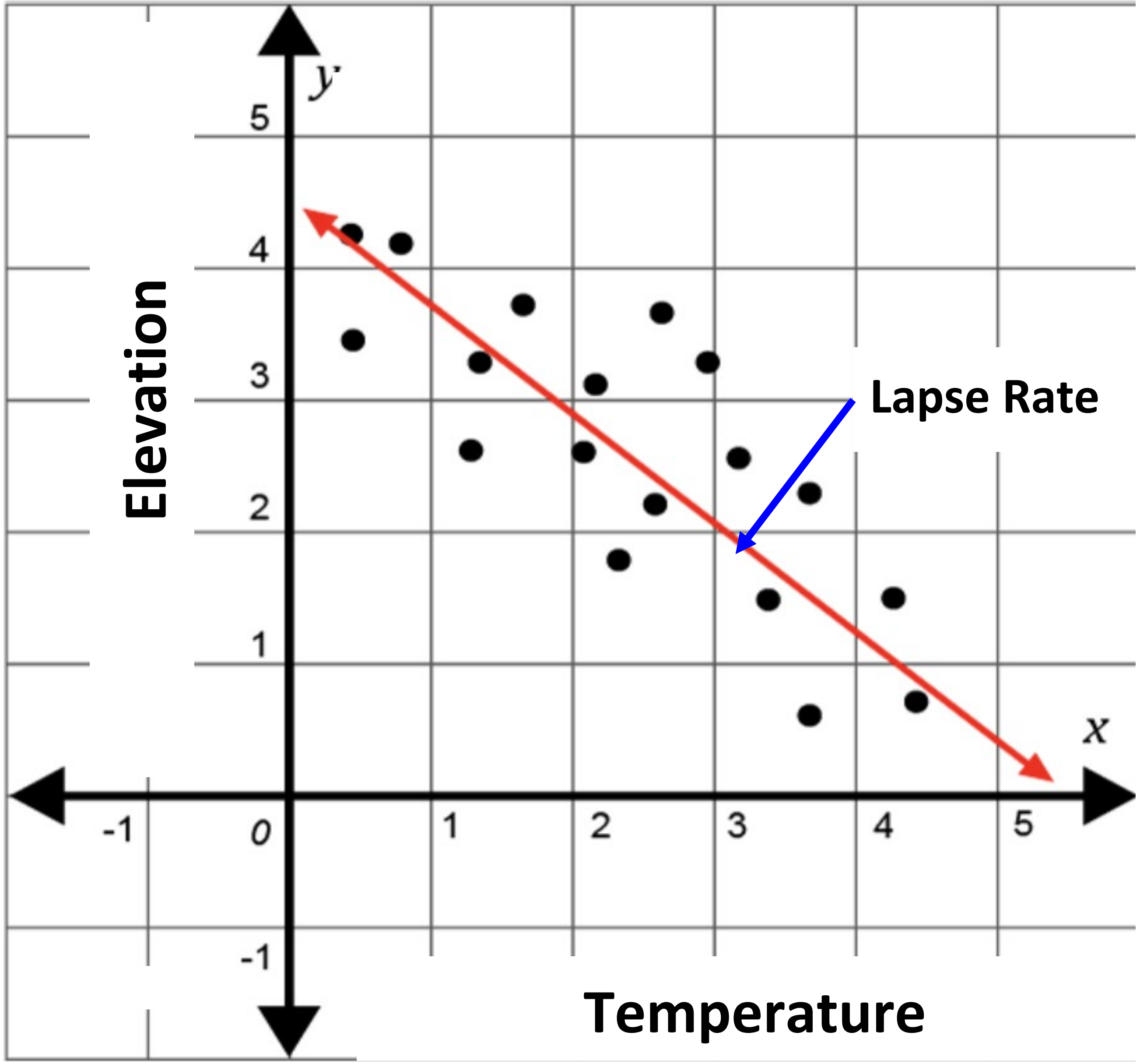
Excluded temperatures >< NH state records (106F, -50F), or days on which temperature at a single station >100F

Determined maximum, minimum, and average temperature at each station for each day

Fit line station data points to obtain lapse rates for Tmax/Tavg/Tmin over whole time interval

Combined them into daily, monthly, seasonal, and annual averages

Also examined temperatures every 10 minutes to understand daily cycle at each station.



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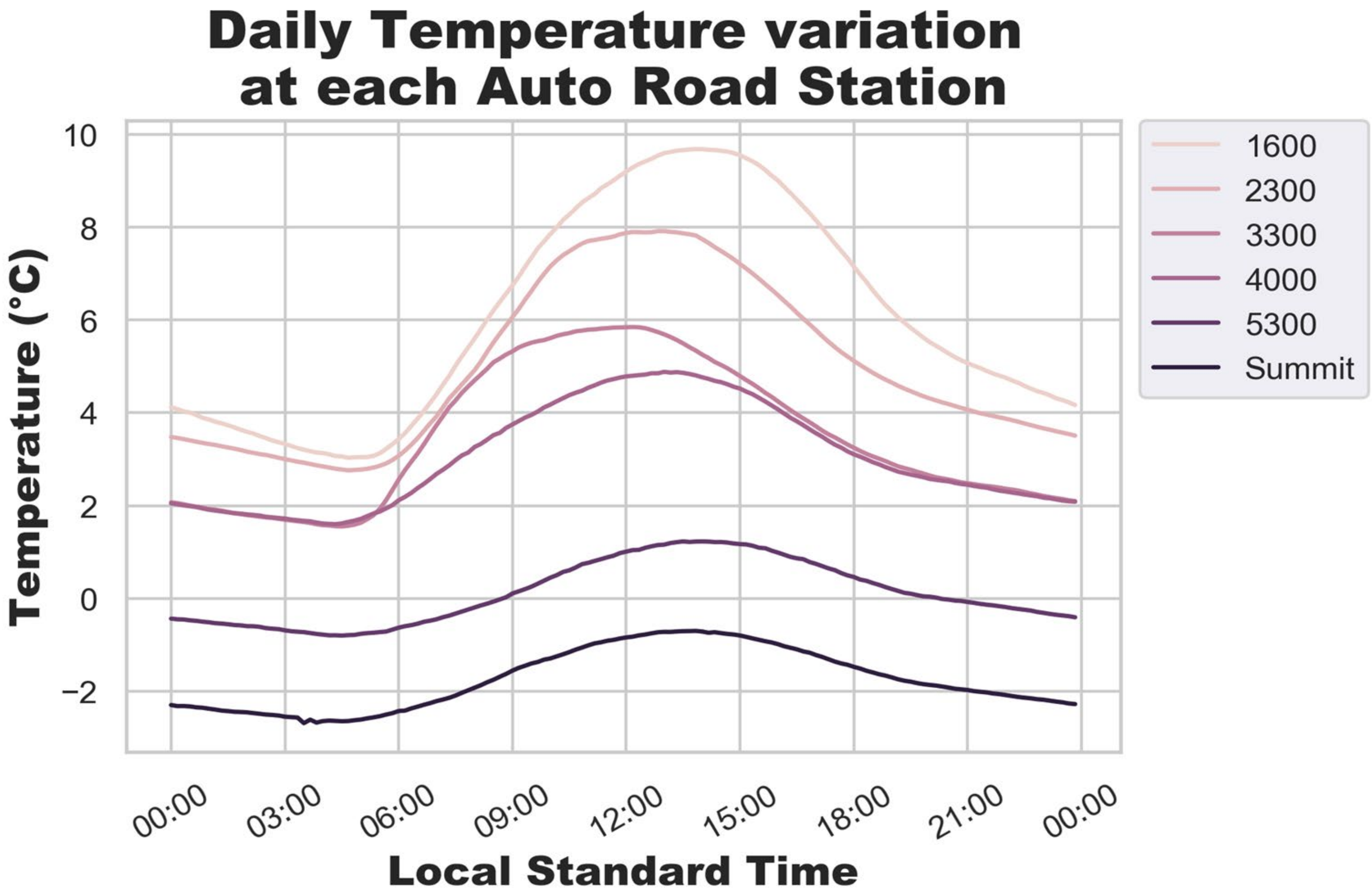
Daily Cycles

Constructed by taking averages every 10 minutes over the 7-year period→ solar day

Note the rapid increase to peak at lower elevations

More muted at higher elevations→ becoming more like a balloon



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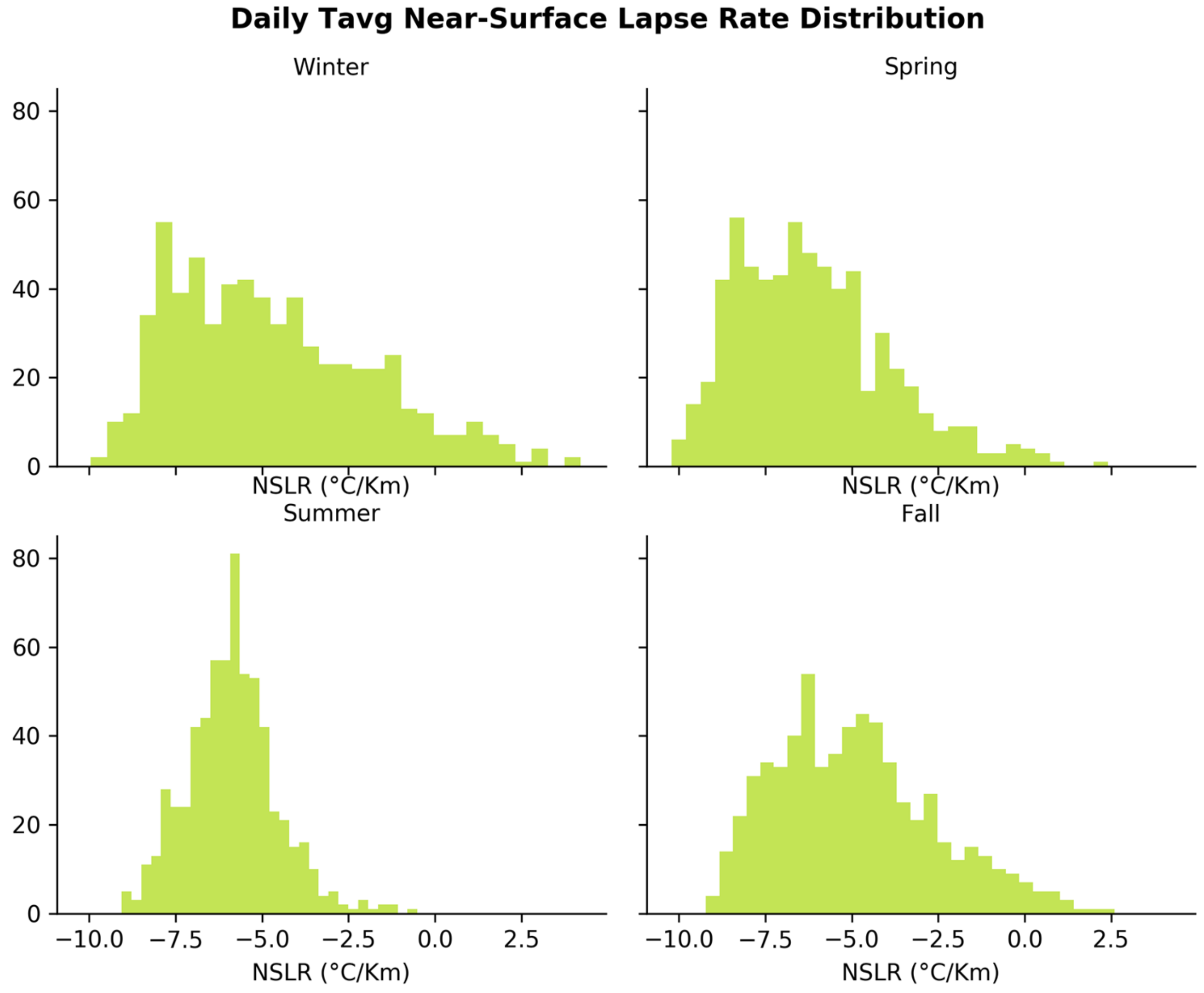
Daily Lapse Rate Histograms

Substantial daily variation about mean lapse rates (peaked vs. flattened)

Winter more variable than summer

Spring and fall are transition seasons between two extremes.



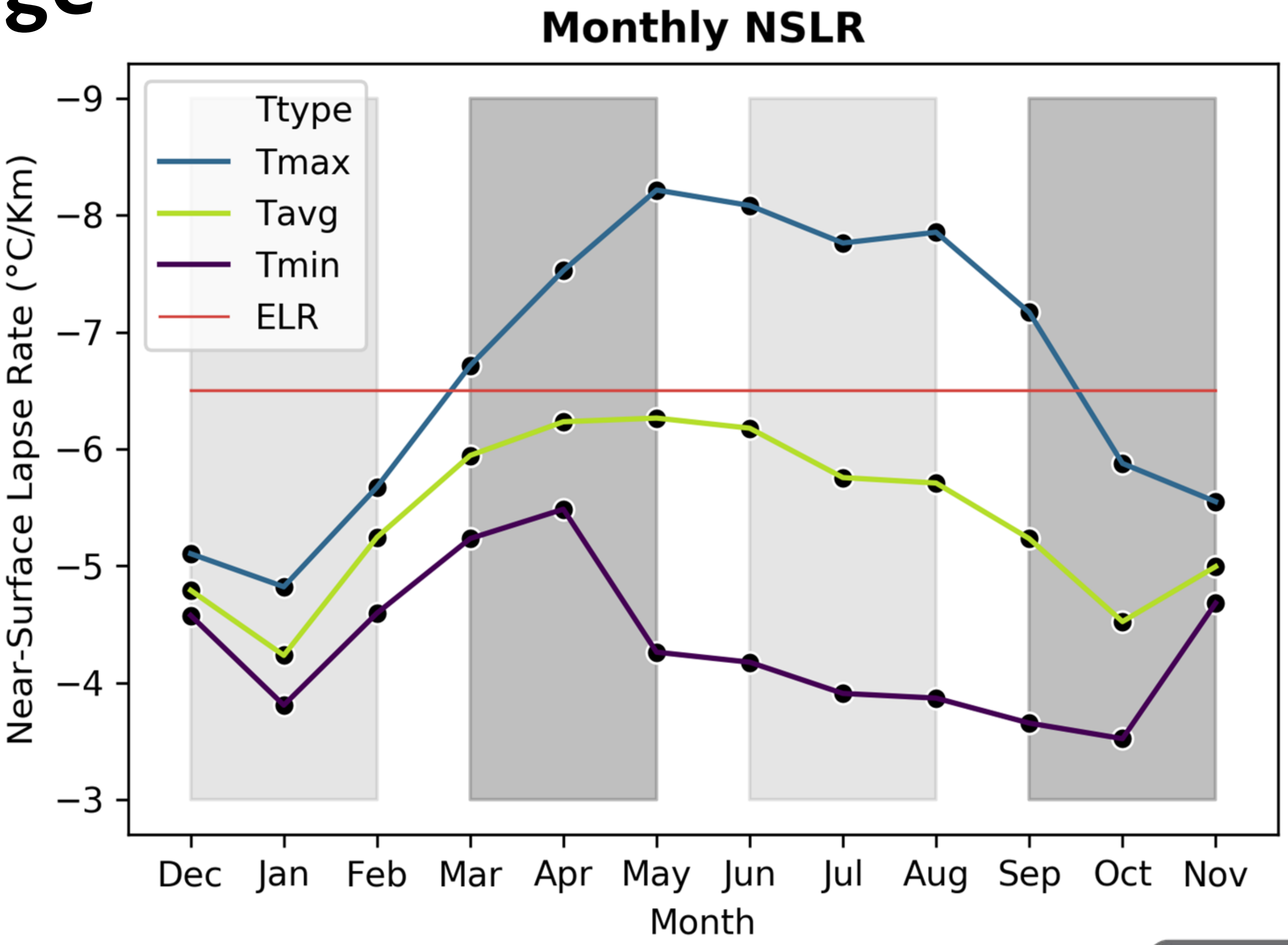
Monthly Average

Winter months are highly constrained

Summer months much more spread apart

Relatively narrow transition zones

(Gray rectangles denote seasons)



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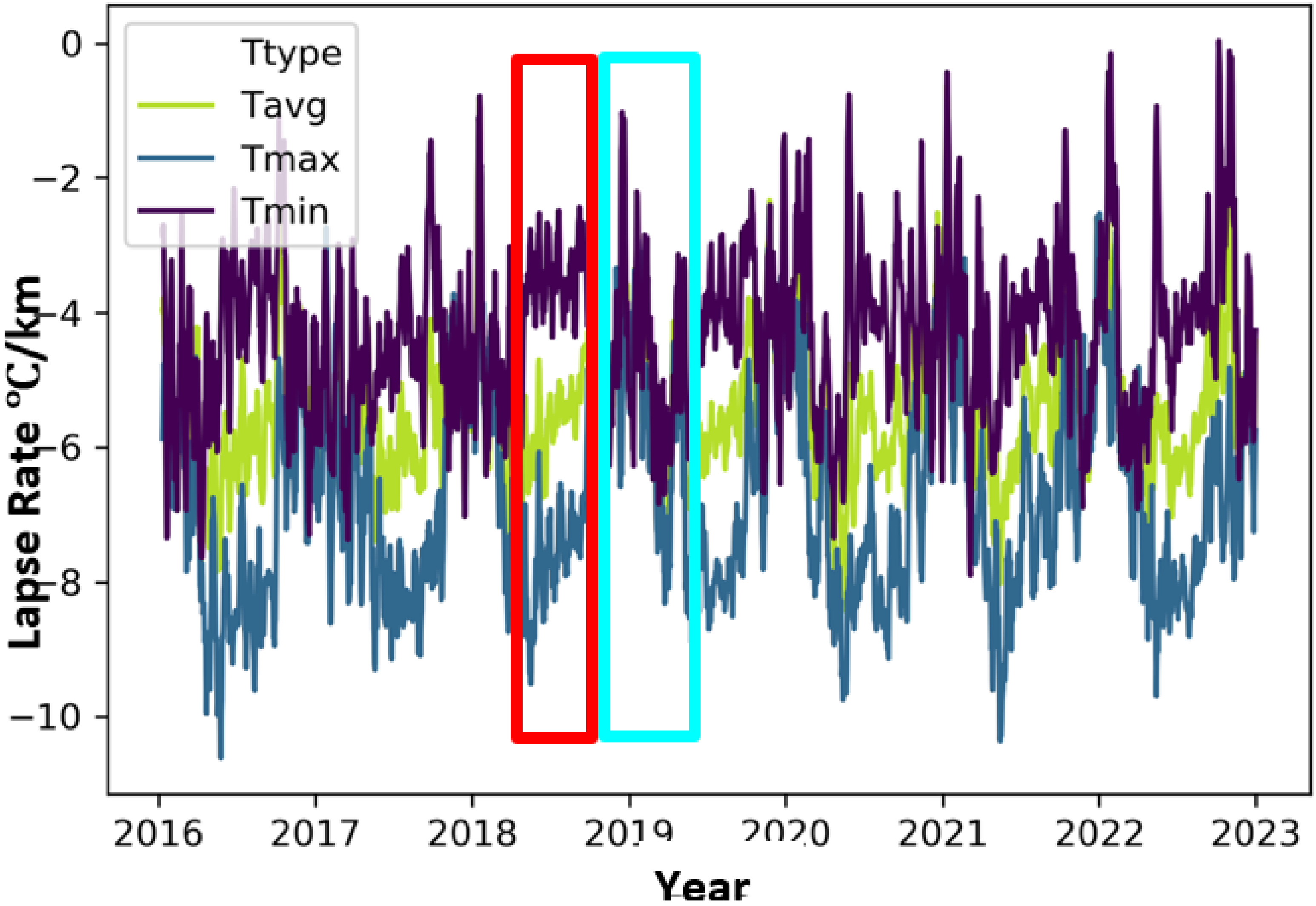
10-Day Running Averages

2 modes

"Summer"

"Winter"

Though transitions between are not strictly date-specific



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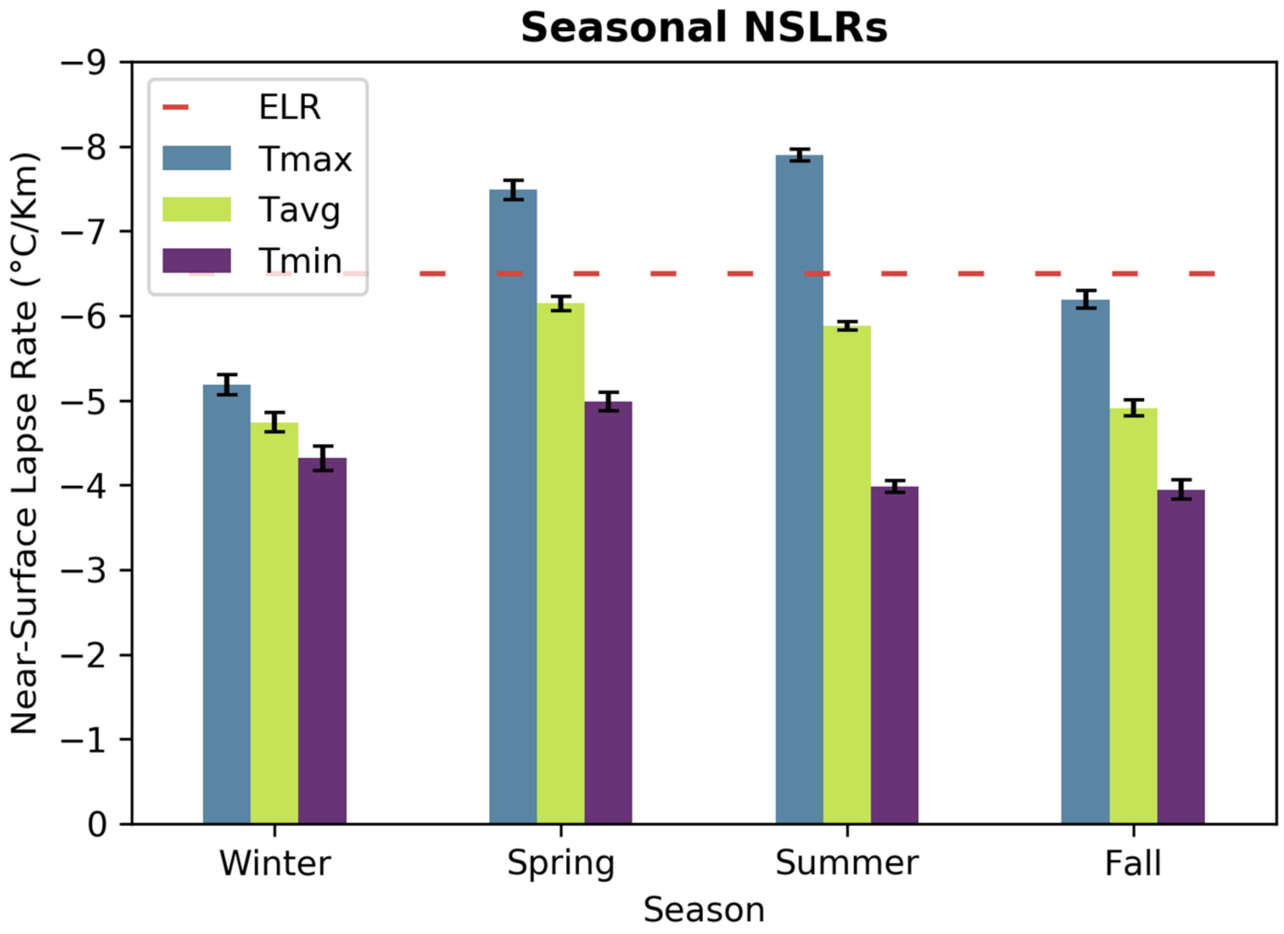
Seasonal Average Lapse Rate

Greatest spread between winter and summer, with spring more summer-like and fall more winter-like.

Tmin does not change all that much from winter to summer, but Tmax matches the solar cycle much better, and much more pronounced change winter→ summer

Matches modes seen in 10-day rolling averages

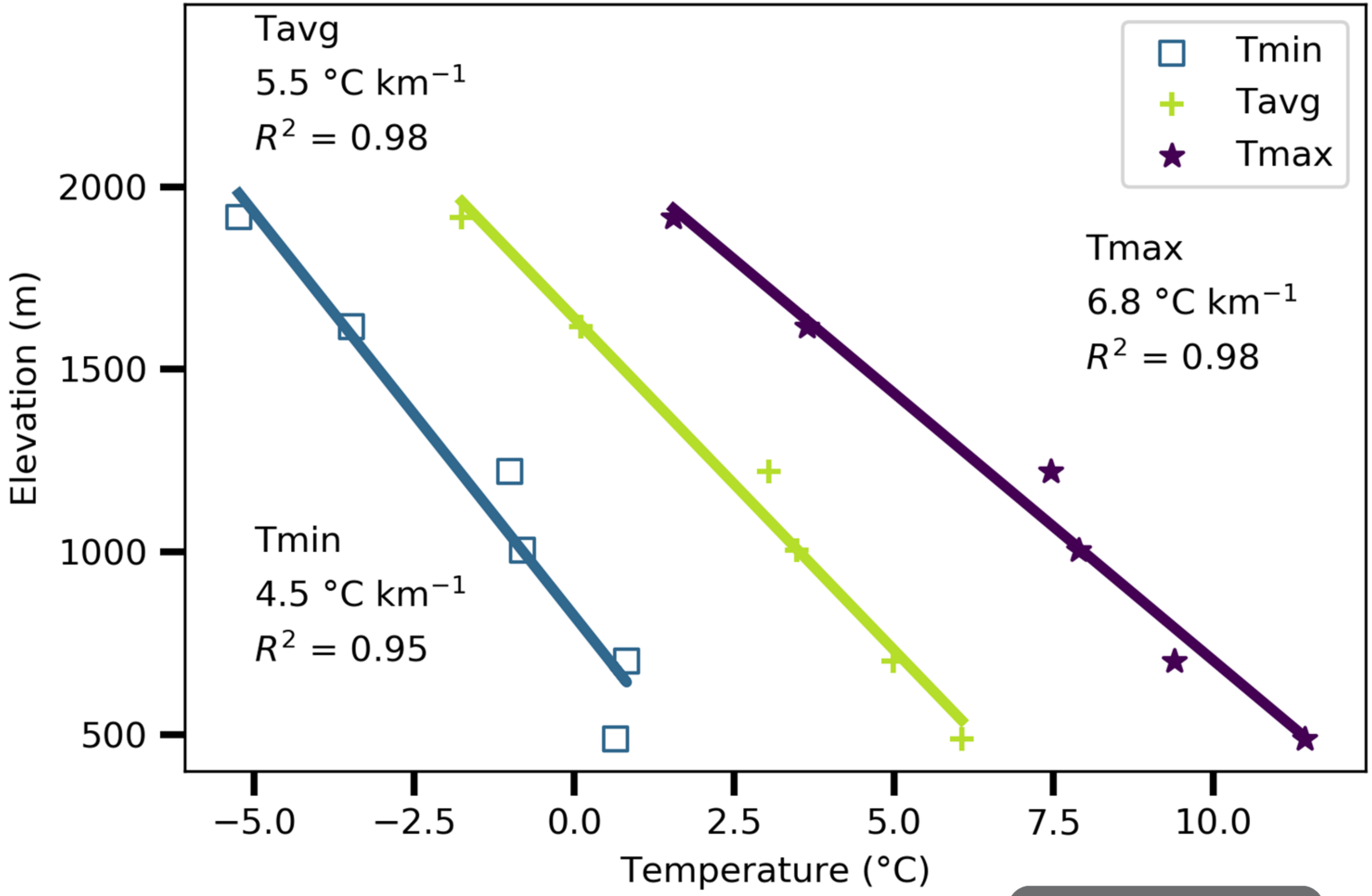


Annual Average Lapse Rate

-Tmax > Tmin at annual scale, likely to do with inversions and cold-air pooling, especially at lower elevations in winter time

1000m station→ could be because of Wildcat Range influencing the maximum height of the inversion

Preliminary data suggesting quite stable over interannual timescale as well, and potentially greater with higher annual average temperature.



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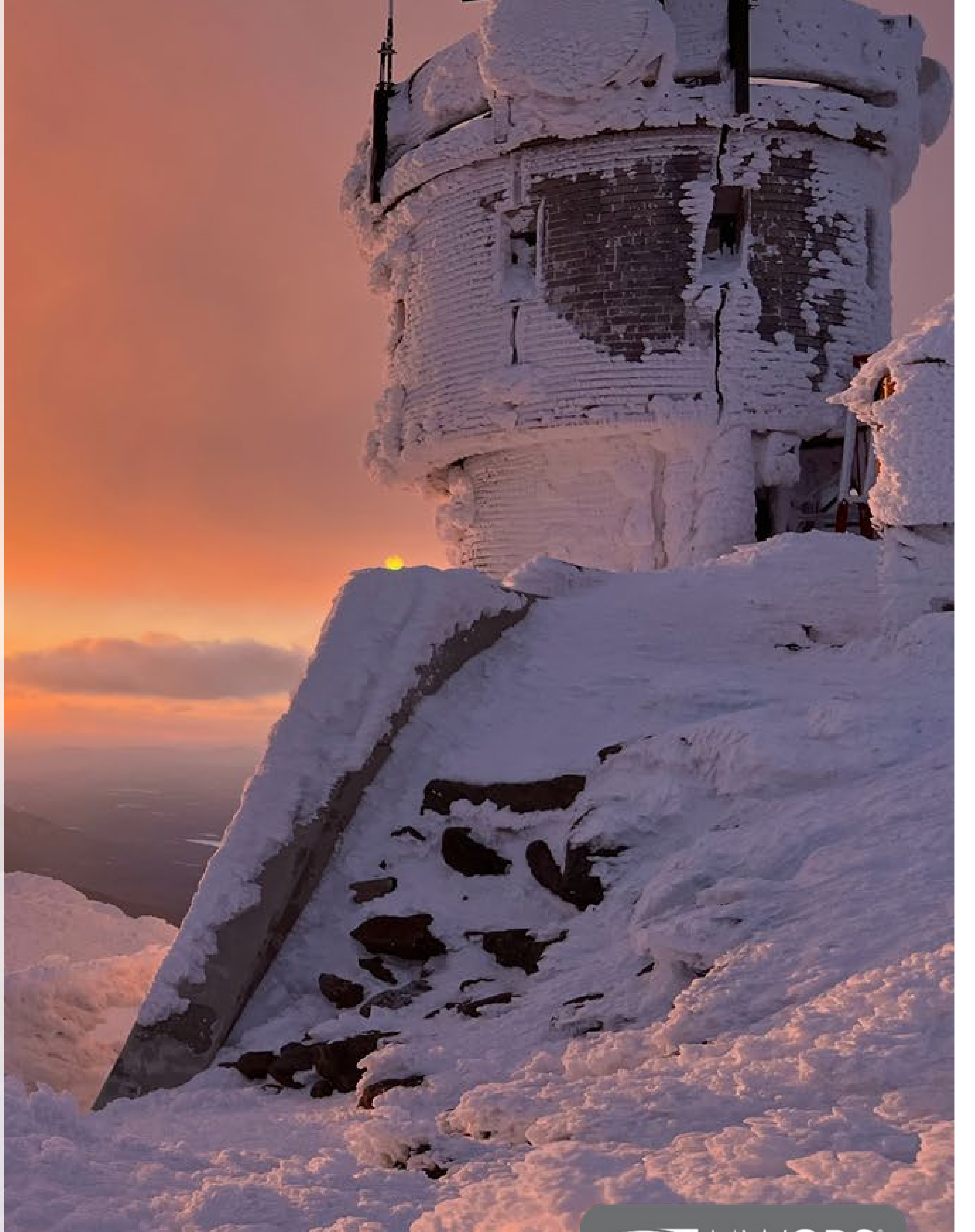
- More data→ possibly extend down the Cog railway to note differences

in windward/leeward sides

- Track the formation of inversions

- Looking at the profile during precipitation events could lead to better forecasting of where the freezing line may set up for icing events

- Use this data to better quantify the climatological niches of plants and animals within the New England region



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Questions? Thank You!