

## Abstract summary

Atmospheric absorption of sound ( $\alpha$ , dB/m) is a function of  $N_2$  and  $O_2$  molecule excitation modes, temperature (T), pressure (P), relative humidity (RH), and acoustic frequency. It is a common misconception that atmospheric absorption is a significant limiting factor on SODAR data recovery. This study attempts to address this misconception. Analyses of over 700,000 hours of wind and meteorological data from Second Wind's Triton® Sonic Wind Profiler show that the average SNR at 120 m only drops below 10 (standard for reliability is 9), when  $\alpha > 0.09$  dB/m. From 89 locations worldwide we found that  $\alpha$  exceeds 0.09 dB/m only 2.4% of the time for high-frequency (~4.5 kHz) SODARs.

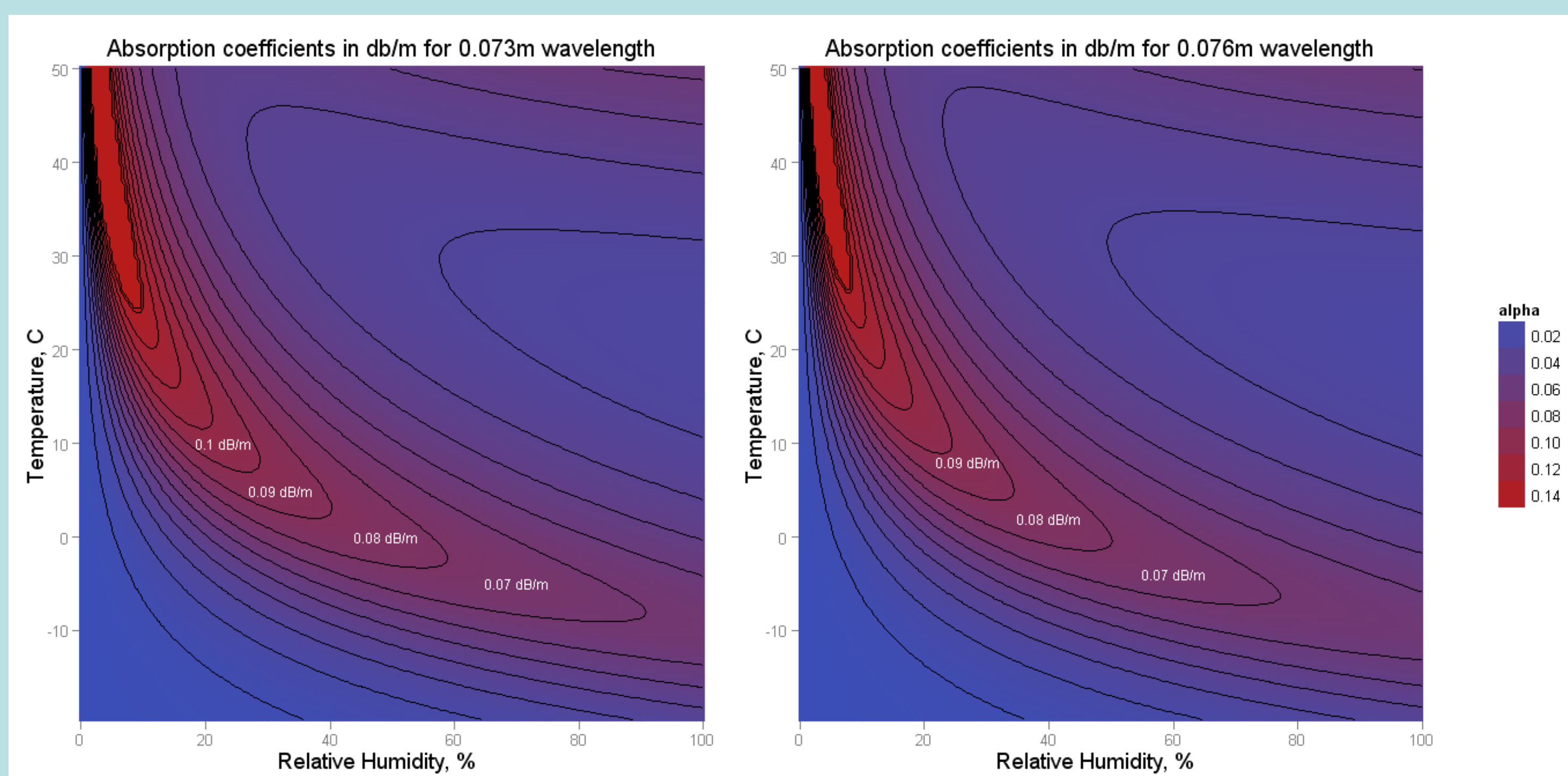
## Objectives

- 1) To calculate  $\alpha$  from meteorological data recorded by Triton at a wide variety of sites, and to describe the range and distribution of these measurements.
- 2) To characterize a general relationship between  $\alpha$  and Triton's Signal-to-Noise Ratio (SNR) at 120 m.
- 3) To describe the locations and conditions of those sites with frequent high  $\alpha$  events.

## Methodology

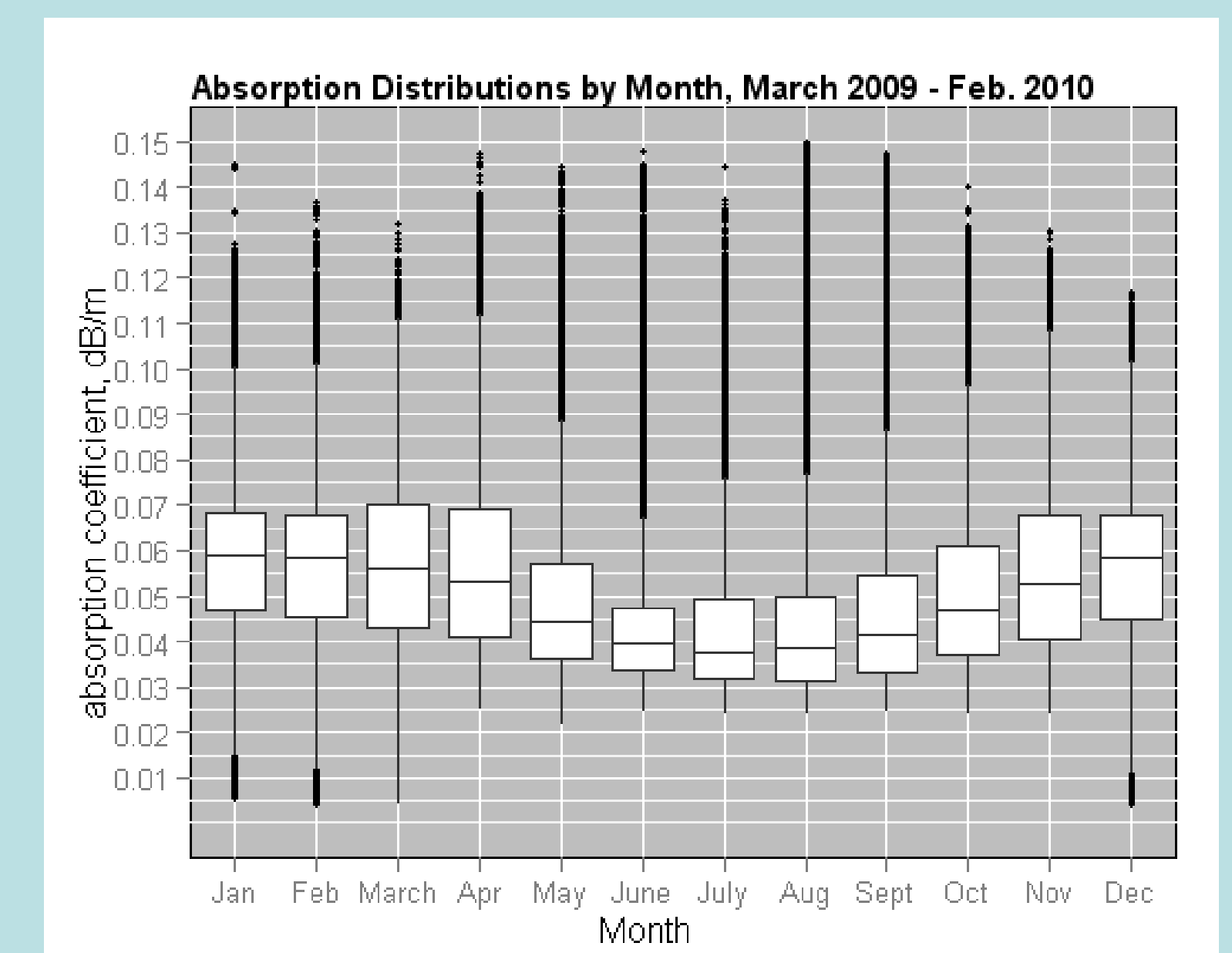
### Absorption Coefficient Calculation

- Triton uses only two fixed wavelengths during operation, 0.076 m or 0.073 m, while varying frequency with T.
- $\alpha$  depends on transmit frequency, so this temperature dependence is built in to the calculation.
- $\alpha$ 's dependence on P is negligible, but its dependence T and RH is quite dynamic.
- From this graph, the conditions that lead to extreme  $\alpha$ -values can be generally described as "hot and dry".
- Note the difference in elongation of the 0.07 dB contour.



### Seasonal Variation of Absorption Coefficients

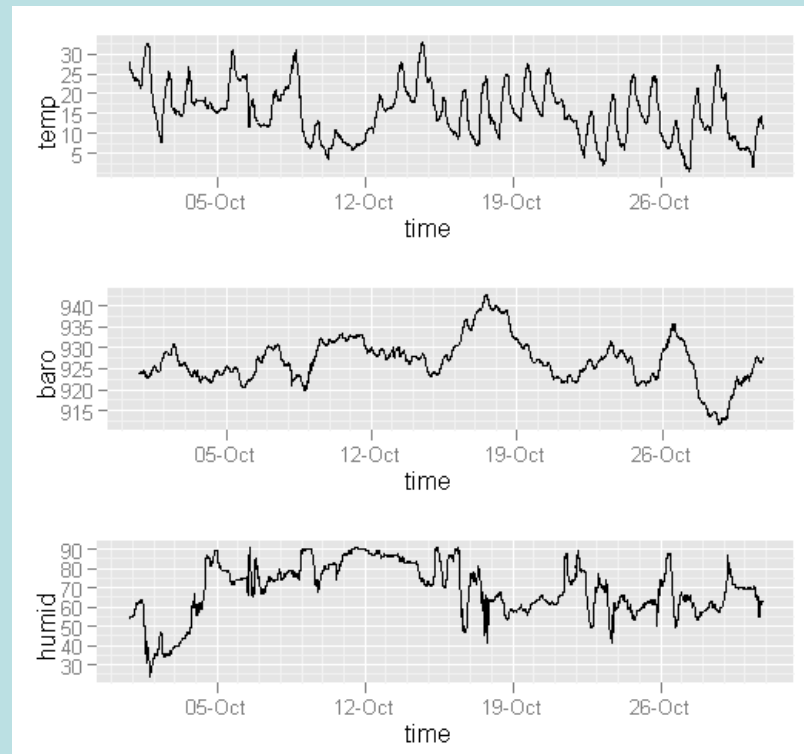
- Just as T, P, and RH vary with the seasons, so does  $\alpha$ .
- Some locations experience a broad range of  $\alpha$ -values during one season, but not during others.
- The data used in this study is specific months at specific locations when  $\alpha$ -values are widely distributed, including values in exceedance of 0.09 dB/m.



For example, here the same Triton experiences a very wide range of  $\alpha$ -values in April and a very narrow range in August of 2009. Only the April data was used in this case:

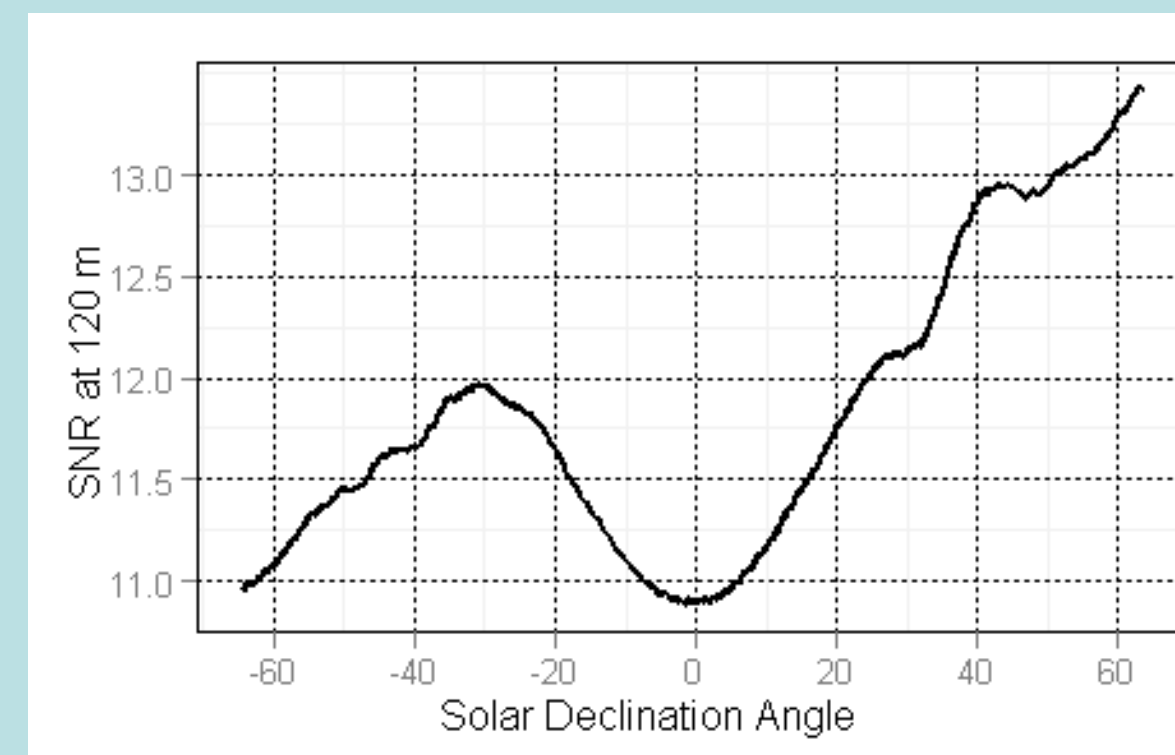
### Sensor Scrutiny

- The Triton collects ambient temperature, barometric pressure, and relative humidity measurements every ten minutes.
- Data was downloaded from 89 units worldwide and carefully screened to eliminate faulty sensor readings and to include a variety of conditions.

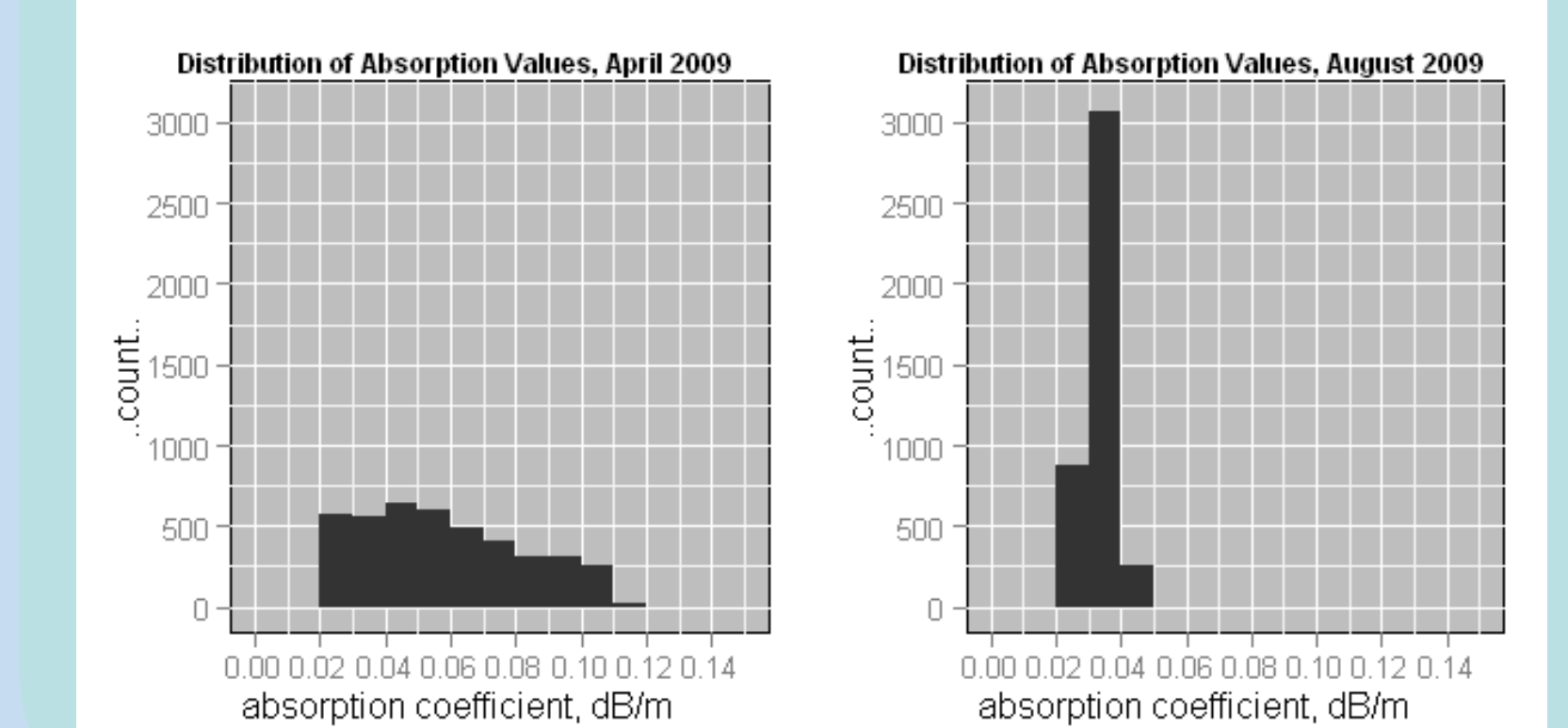


- SODARs depend on vertical temperature gradients ( $T_v$ ) and turbulent eddies for acoustic reflections.
- $T_v$  is determined by atmospheric stability, which is in turn driven by solar radiation during the day, and radiative cooling of the ground at night.
- Stable conditions typically occur during the nighttime; unstable condition during the daytime; and, neutral conditions at dawn and dusk

### Solar Declination Angle and Atmospheric Stability



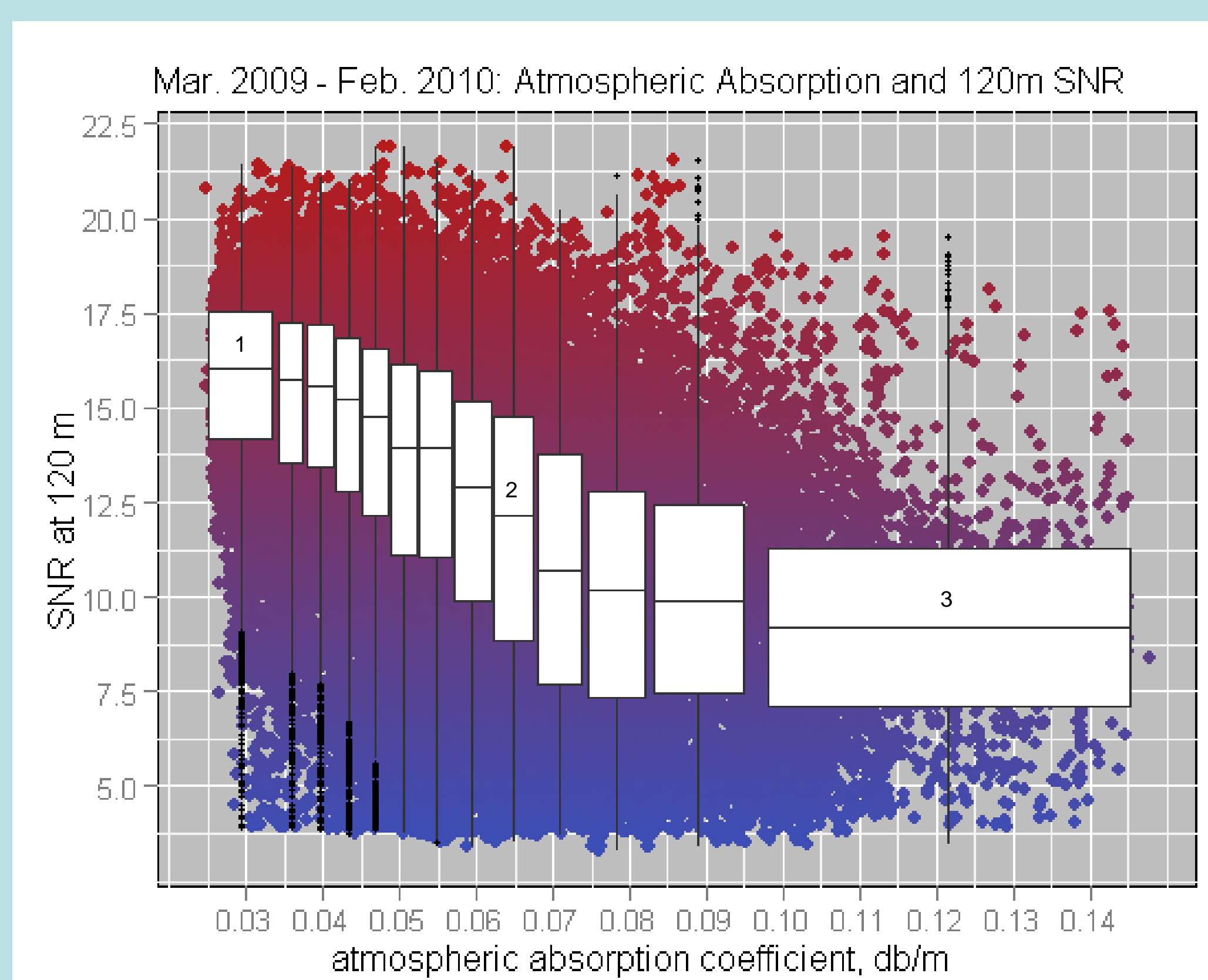
- This plot shows SNR at 120 m versus solar declination angle (dec).
- In this study, only data with  $dec > 20$  is used in order to ensure relatively uniform, unstable atmospheric characteristics and to isolate the relationship between  $\alpha$  and SNR.
- It is interesting to note that in early stages of this study, no relationship between  $\alpha$  and SNR could be established – only when isolating unstable conditions did the relationship emerge.



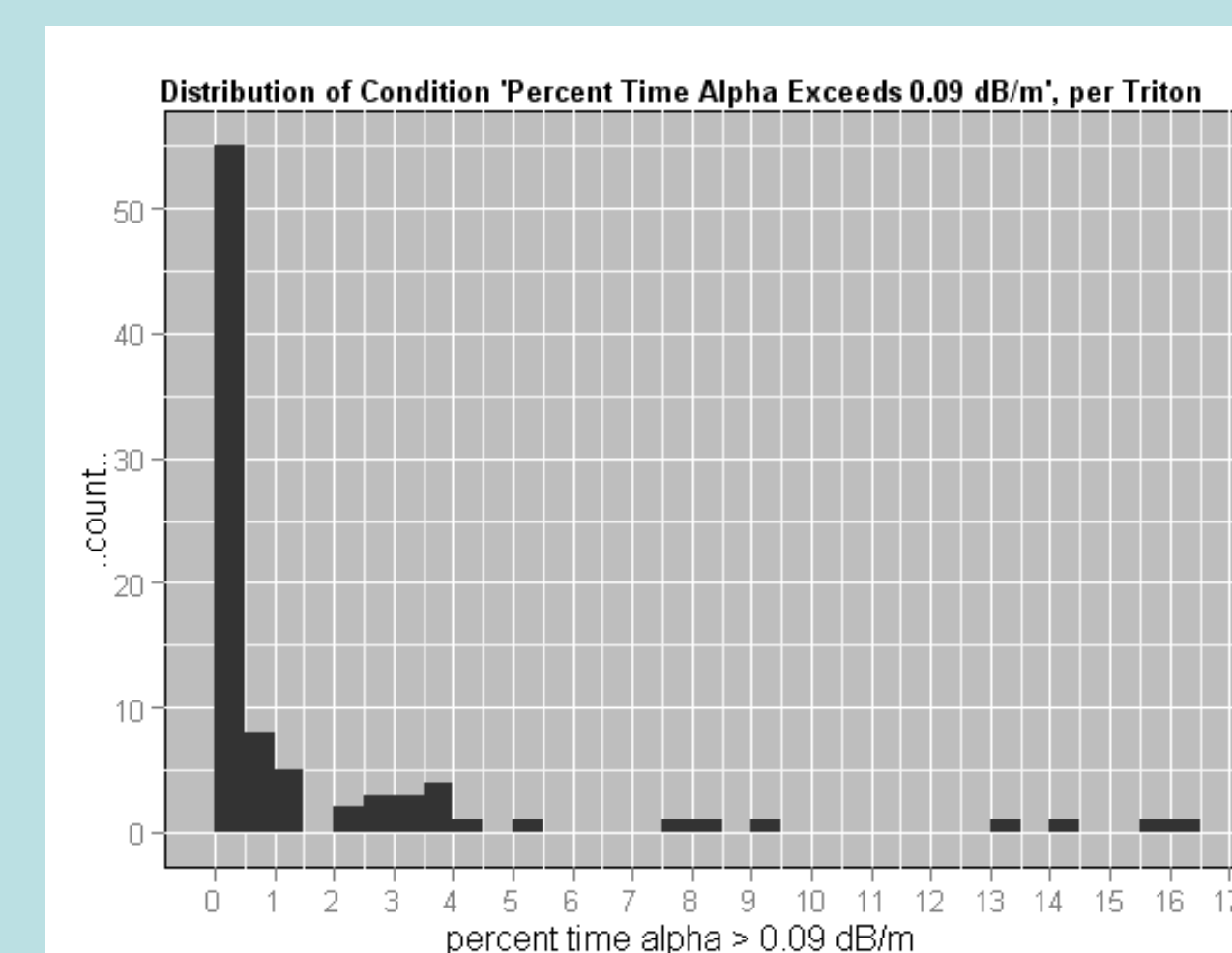
## Results

### Performance Characteristics

- Each data point represents one ten-minute average of SNR at 120 m on the y-axis and the corresponding calculated  $\alpha$  on the x-axis.
- Each box in the plot at left represents 21 days worth of data (~3000 data points).
- The width of each box indicates its range.
- The median SNR clearly decreases with increasing absorption, as does the maximum value.
- The average SNR at 120 m for  $\alpha > 0.096$  dB/m was 9.37
- The Triton rates data it acquires from 0%-100% based on a Q-factor which takes into account the SNR and the quantity of valid spectra recovered from the 10-minute averaging period. High quality data has a Q-factor > 90%.
- The high quality data recovery rate for  $\alpha < 0.035$  dB/m (1) was 96.5%.
- The high quality data recovery rate for  $0.062$  dB/m  $< \alpha < 0.068$  dB/m (2) was 79.0%.
- The high quality data recovery rate for  $\alpha > 0.096$  dB/m (3) was 62.2%.



### Distribution



Of the 89 locations analyzed:

- 61 had  $\alpha > 0.09$  dB/m less than 1% of the time
- 20 had  $\alpha > 0.09$  dB/m between 1% and 5% of the time
- 7 had  $\alpha > 0.09$  dB/m between 5% and 15% of the time

### Geography



Data available from U.S. Geological Survey, EROS Data Center, Sioux Falls, SD.

Of the units with  $\alpha > 0.09$  dB/m more than 3% of the time:

- All were in the Western United States: Wyoming, Montana, Idaho, California, New Mexico, Texas, and Oklahoma.
- The average elevation was 1415 m.

## Observations / Conclusions

- Atmospheric absorption has a clear, attenuating effect on SODAR signal.
- High absorption events are quite rare, the vast majority of sites being almost completely unaffected by them.
- Seasonal variation indicates that data loss associated with high absorption would be limited to certain times of year.
- Those sites with high absorption are climatically similar and can be characterized as high elevation and arid.

- During times of extreme absorption, the data recovery rate remained relatively high (62.2%). Though this dataset uses exclusively midday data, which typically has an excellent data recovery rate, the high yield indicates that the attenuation associated with absorption is not enough to be a primary limiting factor in SODAR performance. However, in tandem with other local conditions such as high ambient noise, neutral atmospheric conditions, or complex terrain, absorption could reduce data recovery rates.

## References

1. Salomons, Erik M. *Computational Atmospheric Acoustics*. Dordrecht: Kluwer Academic Publishers, 2001.
2. Kindler et al. "Operational Characteristics of SODARs – External Meteorological Influences." Proc. 12th International Symposium on Acoustic Remote Sensing and Associated Techniques of the Atmosphere and Oceans, Cambridge, UK: 2004.
3. Bradley, Stuart. *Atmospheric Acoustic Remote Sensing*. Boca Raton: CRC Press, 2008.