Lectures 13 Temperature and Thermodynamics, Part 3, Observations

Instructor: Dennis Baldocchi
Professor of Biometeorology
Ecosystem Science Division
Department of Environmental Science, Policy and Management
345 Hilgard Hall
University of California, Berkeley
Berkeley, CA 94720

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Topics to be Covered

Temperature and the Canopy Microclimate

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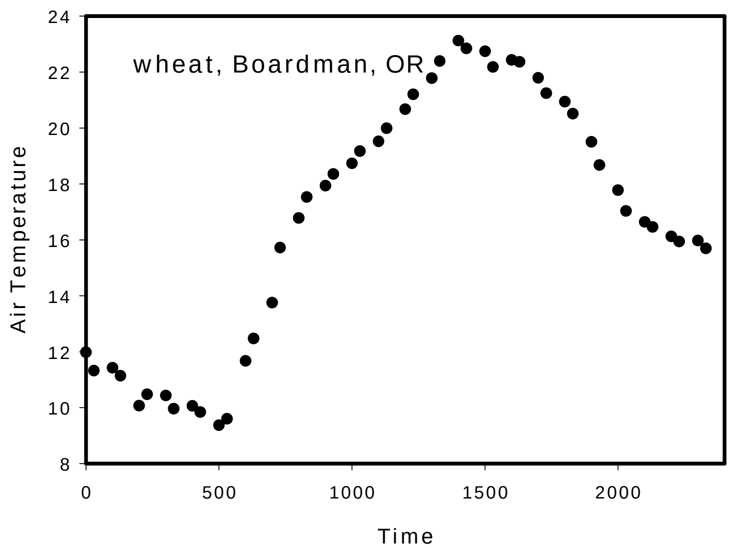
To measure temperature and avoid biases one must shield the thermometer from the sun and aspirate it, to minimize radiative effects.

On the course of a day, air temperature experiences a maximum and minimum value. Its magnitude will depend on the surface energy balance, depth of the planetary boundary layer, surface resistance and evaporative potential of the vegetation and soil.



Daily averages are climatological measures that are used by ecologists and biometeorologists. Generally the mean daily temperature computed by taking the average of the daily max and min. If the daily course has a non symmetrical daily course, it may cause this metric to be in error. In the next figure we compare estimates of daily average temperature using the max/min method with the 24 hour integration based average. Over the course of a year the two measures differ by less than 0.3 C, or a difference of 2% in terms of Centigrade.

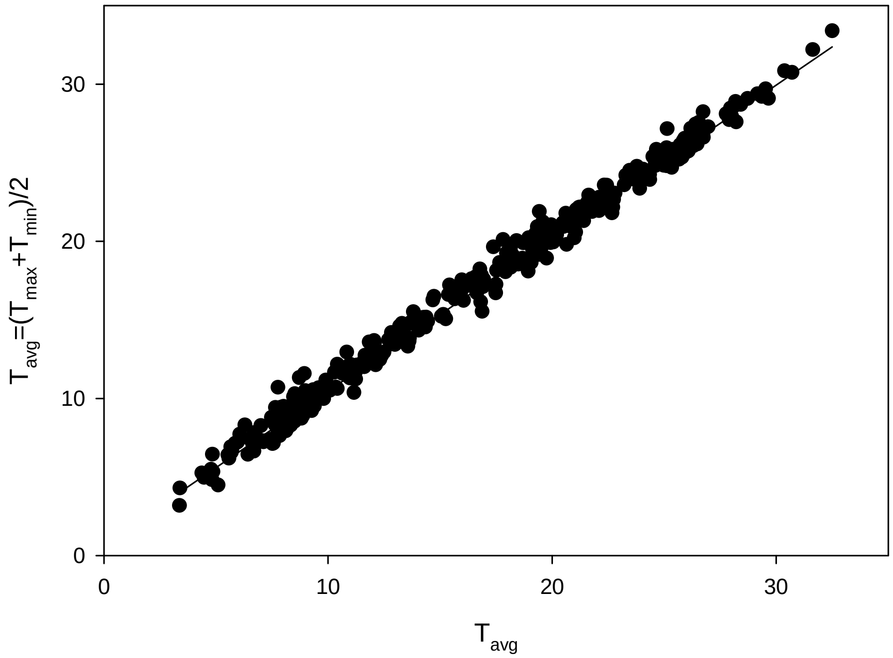


Figure 1Comparison of mean daily temperature based on max-min temperatures and the daily average of hourly measurements. slope 0.973, offset 0.738, r2 0.87

We can also extract information from maximum and minimum temperature to deduce thermal cooling and heating units, where temperature differences are summed for each hour that the observed temperature exceeds either a lower or upper threshold.

$$Chillhours = \sum_{0}^{24} T_{ref} - T(t)$$

With hourly measurements these chill or heat units can be deduced readily. What happens if you only have climate data of maximum and minimum temperature? We can inspect this problem graphically in Figure 2

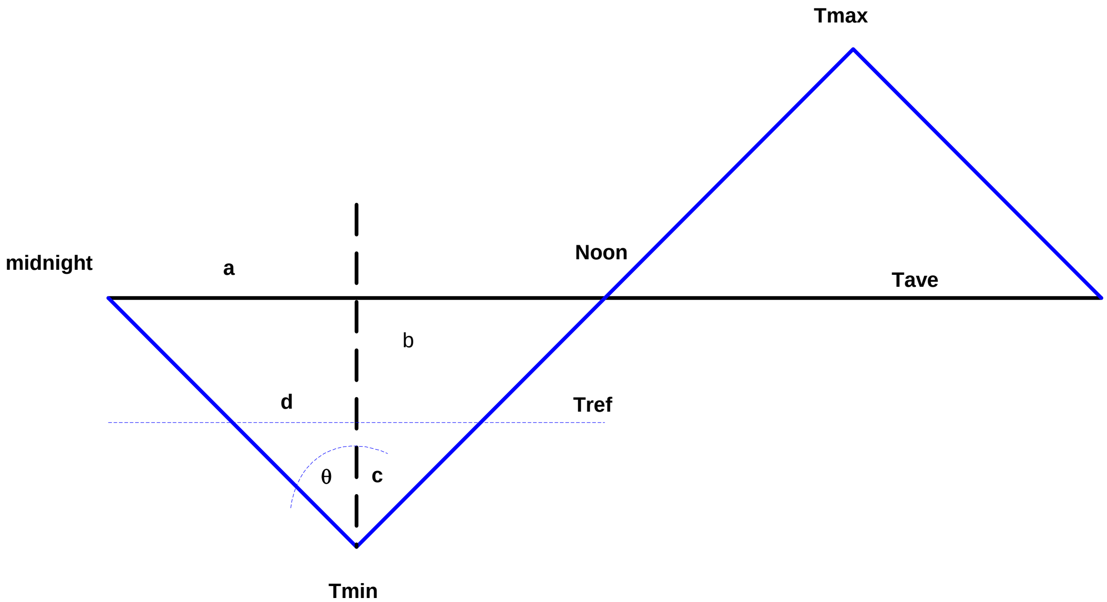


Figure 2 Conceptual diagram of the diural temperature course and summed chill units

We want to compute the number of hours that occur below the reference temperature. This can be done by applying some simple trigonometric concepts. First we know that length *a* is 6 hours and the length *b* is the difference between the daily average and minimum temperatures. So we can compute the tangent of the angle theta.

$$\tan\theta = \frac{a}{b} = \frac{6hr}{T_{ave} - T_{\min}}$$

Now we know the angle and the length *c* as the difference between the reference and the minimum temperatures so we can compute the length *d*, which is one-half the time below the reference temperature.

$$d = \frac{chillhours}{2} = \tan\theta \cdot (T_{ref} - T_{\min})$$

With this information at hand we can compute the summed chill hours based on the midpoint between Tref and Tmin.

$$\sum chillhours = d \cdot 2 \cdot (T_{ref} - \frac{T_{ref} + T_{\min}}{2})$$

How well does this simple method work. Figure 3 shows a comparison between summations of chill hours based on hourly met data and min-max data. There is a slight bias, but overall the correspondence is quite good.

Note that one can perform the same exercise for different thresholds and heating units. For those of you who will become managers of vineyards or other temperature dependent systems such as refrigeration and heating units, here is a simple way to use met data to produce higher level information.

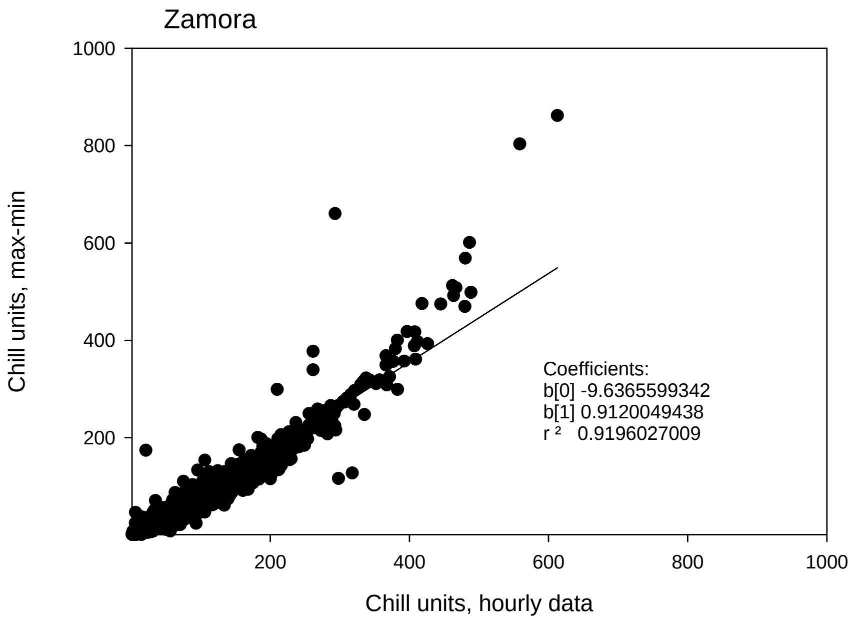


Figure 3

Spatial data on temperature and its climatic variation is another piece of information needed by clients of atmospheric data. There is now a web site called DAYMET.ORG that produces 1 km resolution weather data.

Temperature will vary with depth in a forest canopy and the shape of the profile will depend on time of day, season and depth of the canopy. For a tall canopy the temperature profile over the forest and in the upper reaches as there is radiative cooling and the surface is cooler than the overlaying air. This stability dampens turbulences and inhibits turbulent exchange of mass and energy. But deep in the canopy, the soil temperature lags the change in air temperature and there can be a convective layer, where temperature decreases with elevation. This situation is like the daytime temperature profile with shows a decrease with height at all levels.

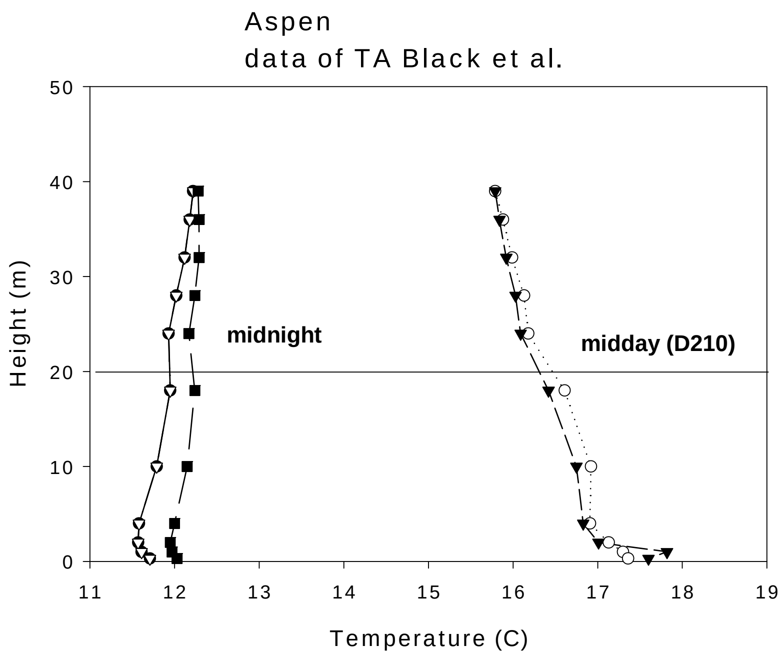


Figure 4 Temperature profiles within and above an aspen forest in Canada.

Using detailed biophysical models, we can also explore temperature differences between the air, sun and shade leaves. Depending on height, exposure, wind speed and radiation, leaf temperature can either exceed or be less than air temperature.

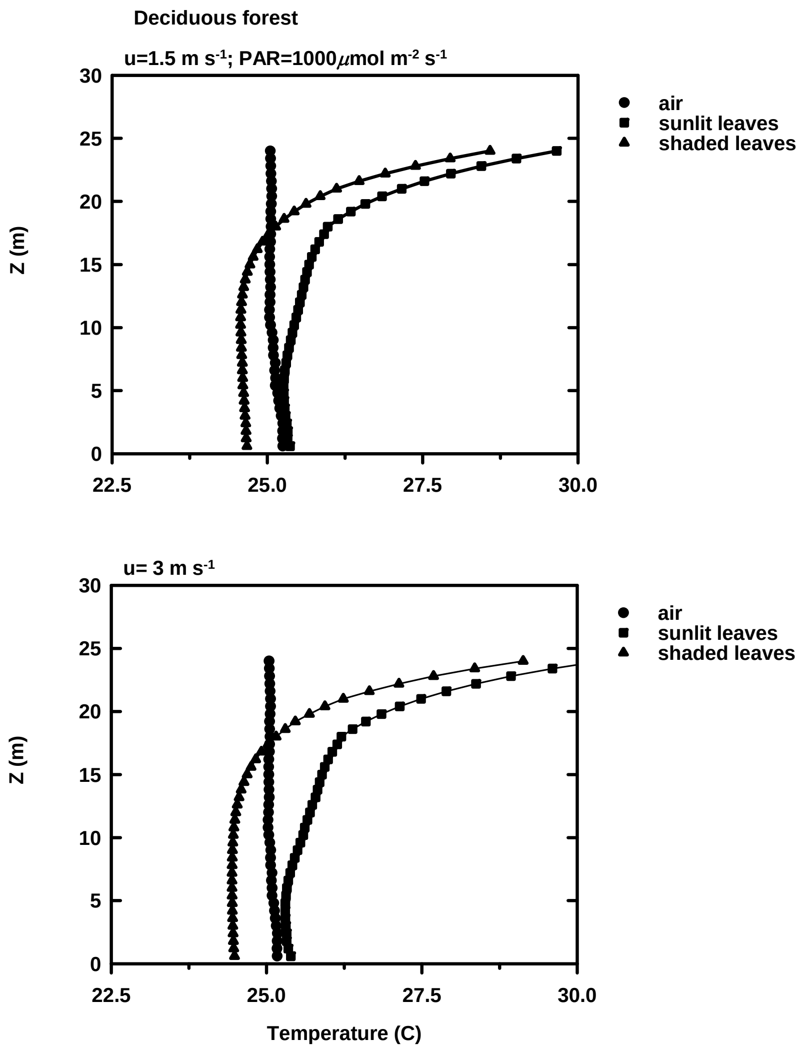
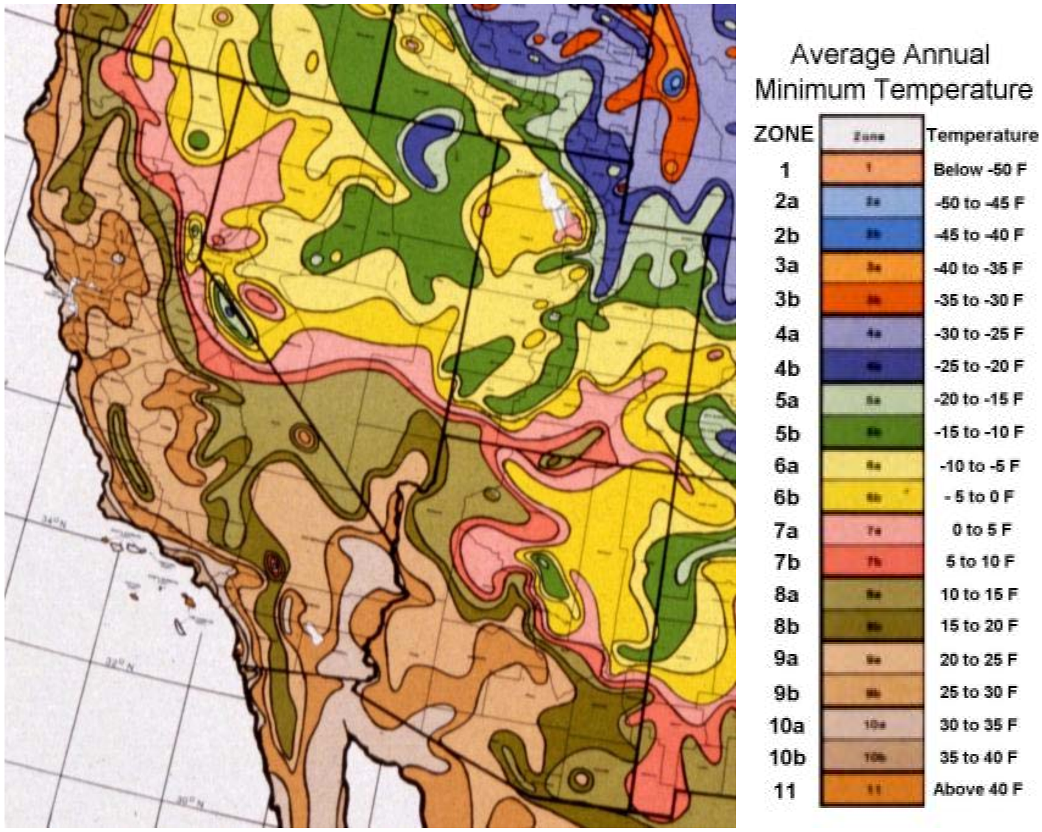


Figure 5 Computations of air and leaf temperature based on the Canoak model



Diurnal Temperature Range, An Indicator of Stress

Global modelers need to infer surface activity from indirect metrics, that can easily be measured by meteorologists. Recently, Bonfils et al. related the diurnal temperature range with gross primary productivity.

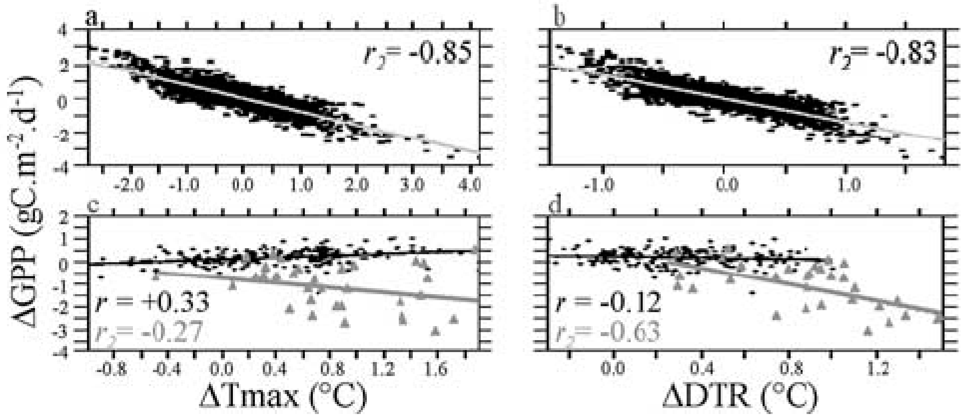
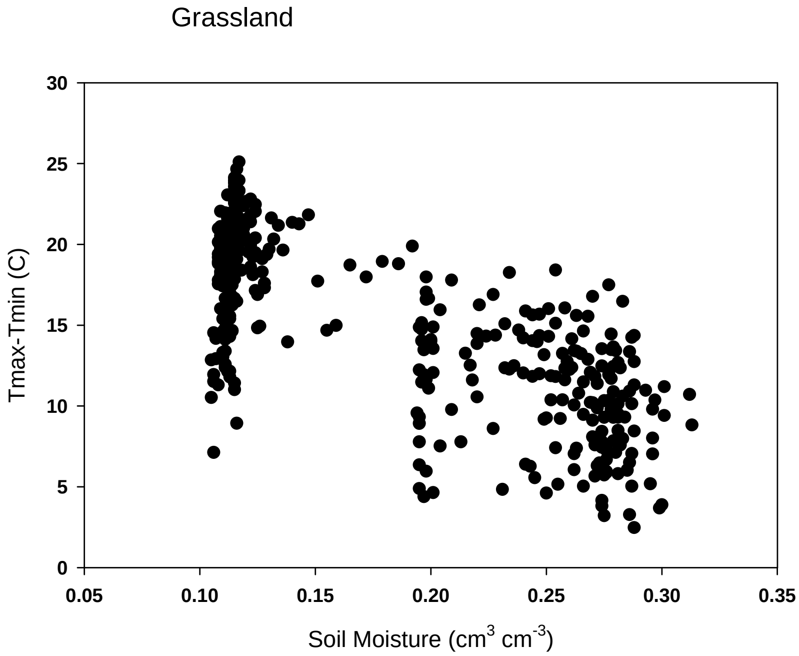


Figure 2. Scatter plots between 5-year running mean JAS anomalies in GPP versus Tmax and GPP versus DTR using clear-sky summers for warm (a–b) and cool (c–d) broad-leaved deciduous forests. Regression is calculated for very dry events (gray triangles) selected according to the normalized β ($\beta' < -2$) and for the other events (black, $\beta' > -2$).

Figure 6 After Bonfils et al. GRL(Bonfils et al., 2004)

Using data from our grassland study in the Sierra Nevada foothills, we observe a trend in the upper envelope of the data for the temperature range to increase as soil moisture dries, but the relation is noisy.



Summary

- Inside dense forests at night, the thermal stratification will be stable in the upper portion of the canopy, but can be unstable near the forest floor causing the layers to become decoupled.
- Simple trigonometric principles can be used to compute summed heat and chill hours based solely on maximum and minimum temperature measurements.

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