

Appendix S1

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APPENDIX S1

We provide an additional example using microclimate data measured along an elevation gradient in CO, USA to illustrate use of TrenchR. We first use a time series of air temperatures and wind speeds collected at multiple heights to examine profiles and surface roughness. We then use a time series of air and surface temperatures, wind speeds, and solar radiation collected at a single height to implement a biophysical model for grasshoppers and compare estimates to observations. R markdown files with the full code and the associated data are available at <https://github.com/trenchproject/TrenchRmanuscript/>.

Microclimate Models

We first examine how temperature and wind speed profiles can be used to scale conditions to the heights of organisms. We start by using wind speed variation across hours and heights to estimate surface roughness.

```
#estimate surface roughness based on wind velocity (m/s) at a vector of reference heights, zr (m)
z0= apply(C1.hr[, c("Wind0.25m","Wind0.5m","Wind1m","Wind1.5m")], FUN=surface_roughness, MARGIN=1, zr=c
```

We then calculate the temperature and wind speed profiles for a given hour using multiple, alternative functions in TrenchR.

```
#subset to day and hour
C1.sub= subset(C1.dayhr, C1.dayhr$day==10)
hr=10

#vector of heights
z.seq <- seq(0, 2, by = 0.1)

#estimate profiles using three different functions including the assumption of neutral and segmented pr
#T_r and u_r are temperatures (C) and windspeeds (m/s), respectively, at reference height zr (m).
#z0 is surface roughness (m); z is the height to scale to (m).
#T_s is surface temperature (C).

#temperature profiles
t.seq1= sapply(z.seq, FUN=air_temp_profile_neutral, T_r=C1.sub[hr,"Air0.5m"], z0=z0[hr], zr=0.5, T_s=C1
t.seq2= sapply(z.seq, FUN=air_temp_profile, T_r=C1.sub[hr,"Air0.5m"], u_r=C1.hr[hr,"Wind0.5m"], zr=0.5,
t.seq3= sapply(z.seq, FUN=air_temp_profile_segment, T_r=C1.sub[hr, c("Air0.25m","Air0.5m","Air1.0m","Ai

#windspeed profiles
u.seq1= sapply(z.seq, FUN=wind_speed_profile_neutral, u_r=C1.sub[hr,"Wind0.5m"], zr=0.5, z0=z0[hr])
```

```
#u.seq2= apply(z.seq, FUN=wind_speed_profile, u_r=C1.sub[hr,"Wind0.5m"], zr=0.5, z0=z0[hr])
u.seq3= apply(z.seq, FUN=wind_speed_profile_segment, u_r=C1.sub[hr, c("Wind0.5m","Wind1m","Wind1.5m")]
```

The temperature and wind speed profiles illustrate how temperatures generally decrease and wind speeds generally increase with height above the ground (Figure S1). Profiles can be fit as a single smooth function or segments.

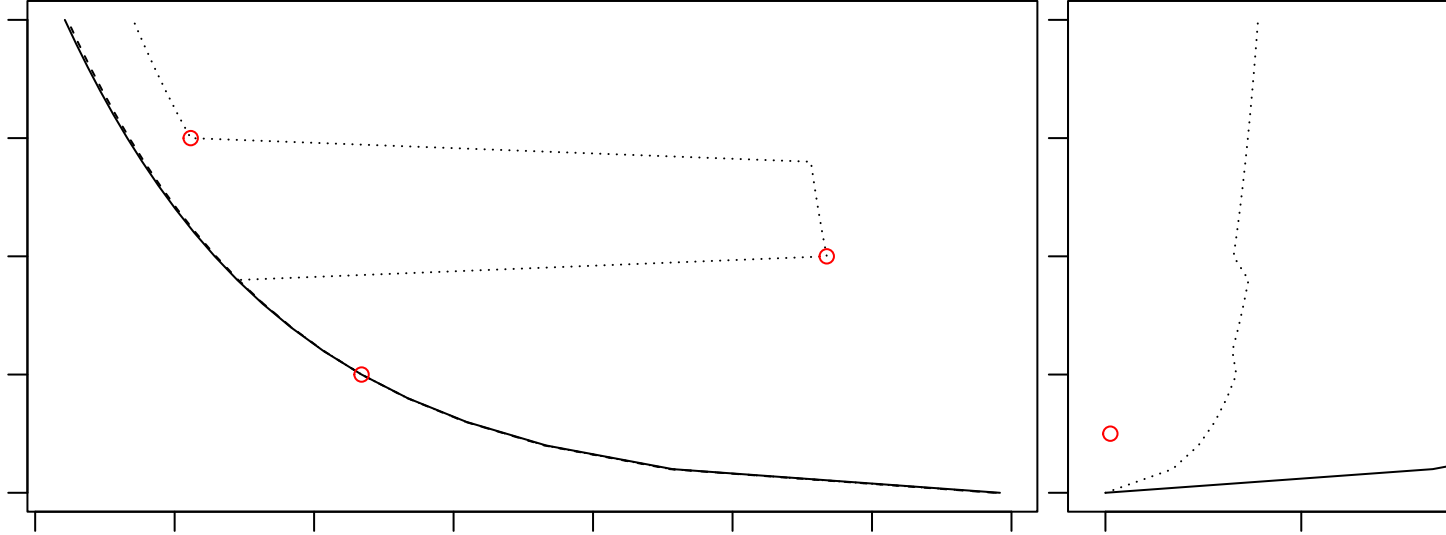


Figure S1. Temperature (top) and wind speed (bottom) profiles using similar continuous [solid: `air_temp_profile_neutral()`; dashed: `air_temp_profile()`] and segmented estimation [dotted: `air_temp_profile_segment()`]. The points indicate empirical points used for parameterization.

Biophysical models

We next illustrate quantifying operative environmental temperatures, which are estimated body temperatures for grasshoppers in the specified environments. We read and process time series of environmental data to estimate the zenith angle, the angle between the sun's rays and the vertical, across days of the year and hours.

```
#Calculate zenith
dat$psi= zenith_angle(dat$J, lat=dat$lat, lon=dat$lon, hour=dat$hour)
```

We scale the air temperature and wind speed from a reference height of 0.5m to grasshopper height (0.001m).

```
z<-0.001 #specify distance from ground

#scale temperature T_r from reference height zr=0.5m to grasshopper height based on windspeed u_r, surf
dat$Tgrass <- air_temp_profile(T_r=dat$Temp, u_r=dat$Wind, zr=0.5, z0=0.02, z=z, T_s=dat$SoilTemp)

#scale wind to grasshopper height
dat$Ugrass= wind_speed_profile_neutral(u_r=dat$Wind, zr=0.5, z0=0.02, z=z)
```

We then use biophysical models to estimate body temperatures based on air and surface temperatures, wind speed, and solar radiation. We first use a biophysical model specifically configured for grasshoppers.

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```
#where psa_dir, psa_ref, psa_air, psa_g are the proportions surface area exposed to direct radiation fr
#Qabs is the solar and thermal radiation absorbed (W);
#epsilon is longwave infrared emissivity of skin (proportion);
#H_L is the convective heat transfer coefficient (W m^-2 K^-1);
#ef is the enhancement factor, used to adjust H_L to field conditions;
#K is thermal conductivity.
```

We aggregate the data and plot average conditions across sites (Figure S2). The simplifying assumptions in the biophysical model implementation reduce alignment with the observed temperatures of grasshoppers, but the divergence of grasshopper temperatures from air temperatures at 2m and, to a lesser extent, air temperatures at grasshopper height demonstrate the importance of implementing biophysical models.

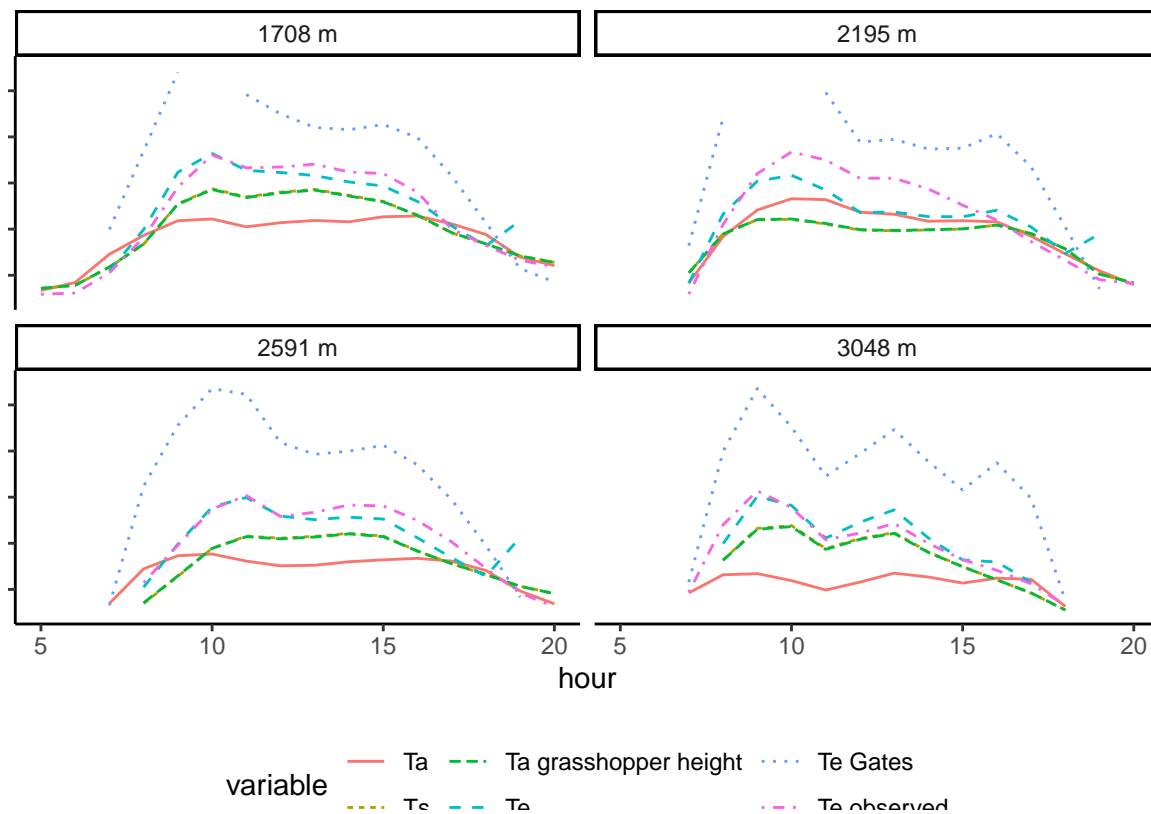


Figure S2. Diurnal temperature variation averaged across days in August varies across the elevations of CO sites (panels) and the type of temperature (C). Microclimate models indicate that the air temperatures experienced by grasshoppers near the ground (T_a grasshopper height) is generally above air temperatures (T_a) and close to surface temperatures (T_s). Body temperatures estimated by a grasshopper specific biophysical model (T_e) are fairly similar to but sometimes less than the body temperatures of a physical grasshopper model implanted with a thermistor (T_e observed). The general biophysical models that makes simplifying assumptions (T_e Gates) tends to overestimate body temperatures.