June 13, 2023

Infrared (FLIR) body temperature monitoring study in buffalo

Background

* Physiological changes due to infection, stress, and reproduction are often reflected in shifts in body temperature
* Monitoring animal body temperatures using thermal imaging remains an important goal, but faces difficulties in measuring accurate or repeatable measurements of individual temperatures.
* Complicating factors include:
  + Ambient conditions (discuss the influence of humidity, sunlight)
  + Distance to the animal (decay of thermal energy), and
  + The heterogeneity in radiation and reflectance across the body (skin, vascularization, hair, adipose tissue)
* One understudied factor is the size and heterogeneity of the thermal target
  + This affects its ability to be sensed because of averaging within the sensor (pixelation)
  + This is because (1) the
  + This also affects sampling accuracy of a moving or concealed target
* **A common factor of body temperature remote sensing is that thermal targets that best recapitulate core body temperature may not be large targets, and that proximity to animals will always be a complicating factor: Therefore, there is a likely tradeoff between the most accurate thermal targets and targets that can be sensed under non-invasive captive and field conditions.**
* We wanted to understand:
  + Pilot studies:
    - To understand where on the buffalo body can core body temperatures be measured most accurately, we compared rectal temperature (at capture) to thermal camera-based temperature for multiple body parts in Aug-Oct 2022. We found that a combination of left and right inner ear best predicted rectal temperature (n = 62, r2 = 0.5).
    - Since the inner ear is a small target, we will use an additional study to understand the degree of heterogeneity in this and a larger less predictive target (XXX), and how the estimated temperature changes with distance.
  + Core data collection
    - We will collect data on inner ear temperatures to test whether ‘remote’ body temperature data can be used to diagnose TB infection, and evaluate whether thermal cameras are sensitive enough to capture variation in responses to TB infection over time?
  + Ex situ size and heterogeneity study: Can we model the constraints of size and heterogeneity of a thermal target ex situ?
    - Does the size of the thermal target affect the decay rate of accurate thermal signal?
    - Does the heterogeneity of the thermal target affect the decay rate of accurate thermal signal?

Materials:

Protocol:

*In situ heterogeneity study*

1. On a focal sedated buffalo, insert a rectal instant read thermometer and allow the thermometer to come to a stable temperature (30-60 seconds)
2. For each following photo, have a second person hold an 8x8 grid (painted white and black in 2x2 cm squares) to estimate heterogeneity of the target later
3. Begin taking pictures of the:
   1. Eye (left, right)
   2. Inner ear (left, right)
4. Repeat these measurements at:
   1. 25 cm
   2. 1 m
   3. 2.5 m
   4. 5 m
5. For each individual, this should result in 16 photos (each about 5 seconds) or < <2 minute per buffalo in images
6. Based on time constraints, this should only be done for 2-3 buffalo per capture until we have data from ~5-6 animals.
7. Repeat for different individuals at capture time points as possible – targeting all buffalo by the end of the TB study

*Core data collection*

1. In the 1-2 days leading up to a capture, take photos of the inner ear (left, right or both) for each animal from the boma fence or walkway. Record the date, time, estimated distance from the target, ambient temperature, and the positioning of the animal (full sun, shade, etc).
2. On the capture day, take photos of inner and outer ears on the left and right side at 25 cm (the most accurate distance).
3. Photos need to be taken for all buffalo during a capture event.

*Ex situ study*

1. Fill a smooth-sided container (25 gallons) with warm water (38-45 C)
2. Record the temperature using the same rectal thermometer used *in situ*, and re-record between each trial – though the temperature should not change detectably.
3. Set up the filled contained on an array with the focal side not directly in sunlight
4. ***Distance:*** Mark distances from the container at .25, .5, 1, 2.5, 5, 10, 25, and 50 meters. Take one set of photos of the unobstructed target side at all distances close-far, then repeat for a total of three recordings per distance
5. ***Size:*** Using a cardboard box that is larger than the container with a cut-out with a 2.5x2.5cm, 5x5cm, 10x10cm, and 20x20cm squares, repeat the distance photos 3x (use paper and tape to cover the unused squares. Place the cardboard cutout so that there is a 2.5 cm gap between the container and the cutout
6. ***Heterogeneity:*** Tape cardboard cut-outs to the surface of the container that are 2cmx2cm (50x) , 5cmx5xm (8x) or 10cm (2x) within the 20cmx20cm cut out of the carboard box. Repeat the distance photos 3x with each of the square sizes. With each repeat, reshuffle the distribution of the cutouts.
7. With 8 distances in a control, 4 size experiments, and 3 heterogeneity experiments (8 experiments total) and three replicates, this should equal 192 photos. At approximately 5 seconds a photo and one minute for each setup, this should take about 30 minutes to complete.

Image numbers:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Experiment | Replicate | Temp | 0.25 | 0.5 | 1 | 2.5 | 5 | 10 | 25 | 50 |
| Distance | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Size: 2.5cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Size: 5cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Size: 10cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Size: 25cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Het: 2cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Het: 5cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Het: 10cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |

Data entry:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Experiment | Replicate | Temp | 0.25 | 0.5 | 1 | 2.5 | 5 | 10 | 25 | 50 |
| Distance | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Size: 2.5cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Size: 5cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Size: 10cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Size: 25cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Het: 2cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Het: 5cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |
| Het: 10cm | 1 |  |  |  |  |  |  |  |  |  |
|  | 2 |  |  |  |  |  |  |  |  |  |
|  | 3 |  |  |  |  |  |  |  |  |  |