Enhancing canopy temperature measurement precision with an uncalibrated thermal drone camera

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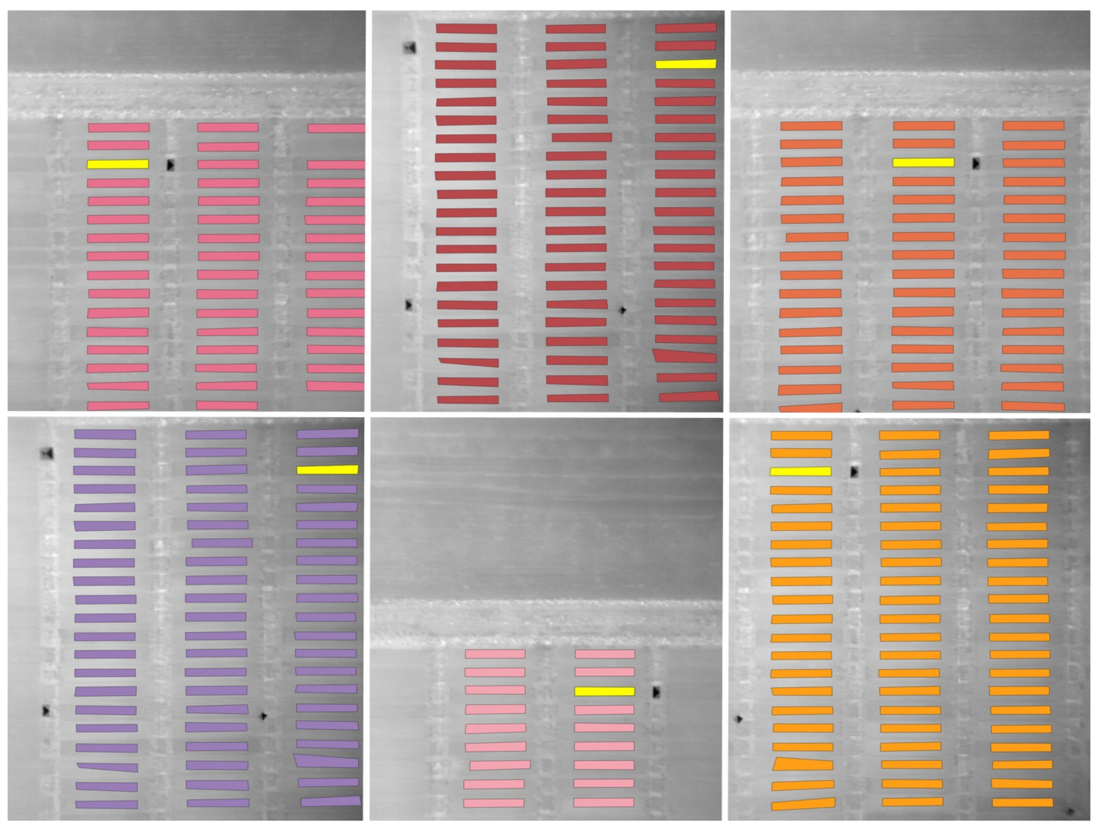
Airborne thermography

- Low canopy temperature (CT) of wheat is associated with higher yield in different conditions and different traits might lead to low CT.
- Main challenges for thermal surveys are the influence of wind, sunlight, clouds and air temperature on CT values. Thus, all genotypes should be measured in the shortest possible time span.
- Airborne thermography can cover a large area in a short time.
- Precise thermal cameras are heavy or need calibration.
- Uncalibrated thermal cameras produce noisy and inaccurate data due to sensor drift.

Tasks:

- Improve the quality of CT measurements on wheat with an uncalibrated airborne thermal camera.
- Better understand sources of short-term variability of CT.

Figure 1: The six thermal images on the right all contain the same plot of 1.5 m x 6 m (yellow) and they were recorded on the same flight. The plot was therefore recorded at different times and with different viewing geo-metries. Knowing the timing of each record and the geometric relationship allows to correct for temporal trends and to estimate the importance of geometric relation-ships.



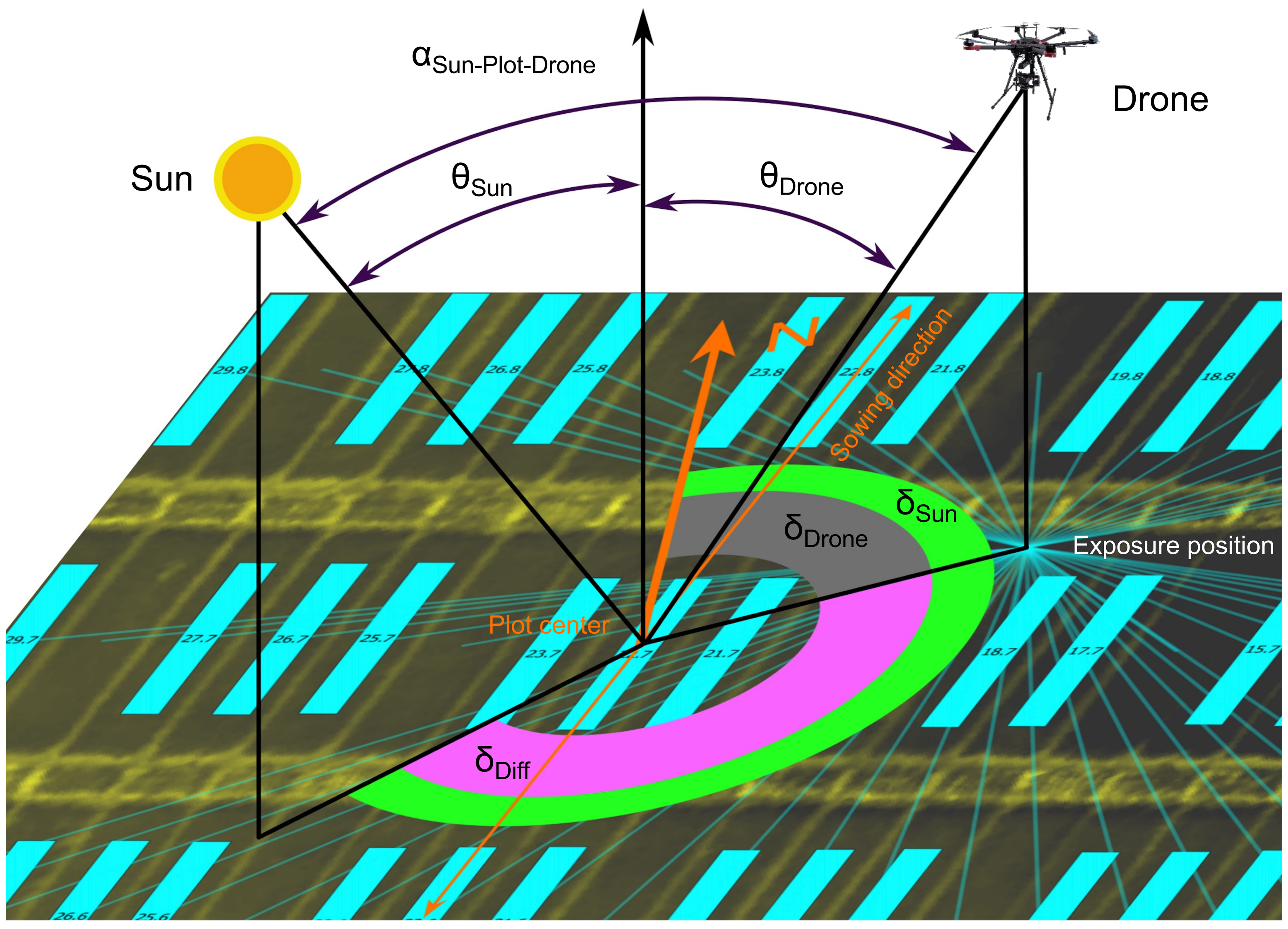


Figure 2: Illustration of some of the geometric relationships between sun, plots, drone and sowing direction that can be established by knowing the positions of the drone and the sun at time of exposure as well as the positions of the single plots. The different angles and distances of these relations may impact the final thermal signal. E.g., for a plot that is directly below the drone, soil might contribute more to the thermal signal than for a plot on the edges of the field of view as the apparent canopy cover increases. Depending on weather the soil is cooler or hotter than the plants, this might impact the apparent temperature of the canopy. Each plot appears on multiple images, allowing for the plot-wise examination of the effect of temporal trends and different viewing geometries.

Methods

- Thermal images were taken with a DJI Zenmuse XT thermal camera with a resolution of 640 x 512 pixels that was mounted on a DJI M200 drone.
- Flight hight was 40 m above ground, which resulted in a ground sampling distance of 5.2 cm.
- Flight planning was such that each spot in the field was recorded at least 9 times. A single flight took about 7 min.
- Multiple georeferenced thermal images for each plot were analysed in a ray tracing approach instead of analysing orthomosaics.
- Images were aligned to generate georeferenced orthomosaics. From these, the camera position and orientation for each image were estimated and the positions of single plots in the single images determined.

- Each plot was recorded on multiple images from multiple perspectives and at multiple points in time (Fig. 1 and Fig. 2) which enabled the estimation of temporal trends such as image-wise sensor drift (Fig. 3).
- Estimating and correcting for general temporal trends allowed for subsequent analysis of different factors mainly related to viewing geometry.

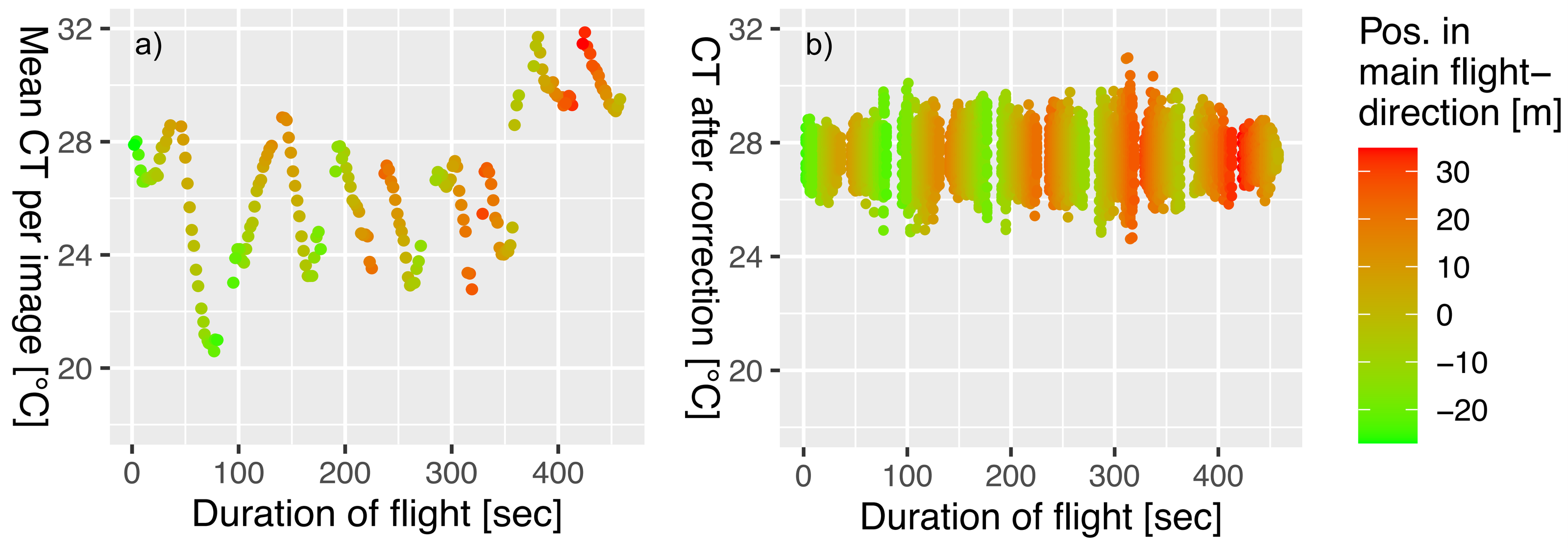


Figure 3: Strong variations of CTs can occur during one flight. They change in relation to different factors, e.g., to the main flight direction (a). Temporal trends can be corrected for by using linear regression where the single images exposure time of the single images serves as independent variable and the measured temperature of the single plots in individual images as dependent variable ($y = y_{ip} + u_i$; with y = image-wise measured plot temperature, y_{ip} = mean plot temperature over all images, u_i = image effect, i = image exposure time and p = plot). The corrected temperatures ($\hat{y}_{ip} = y - u_i$) can then be used for further analysis (b).

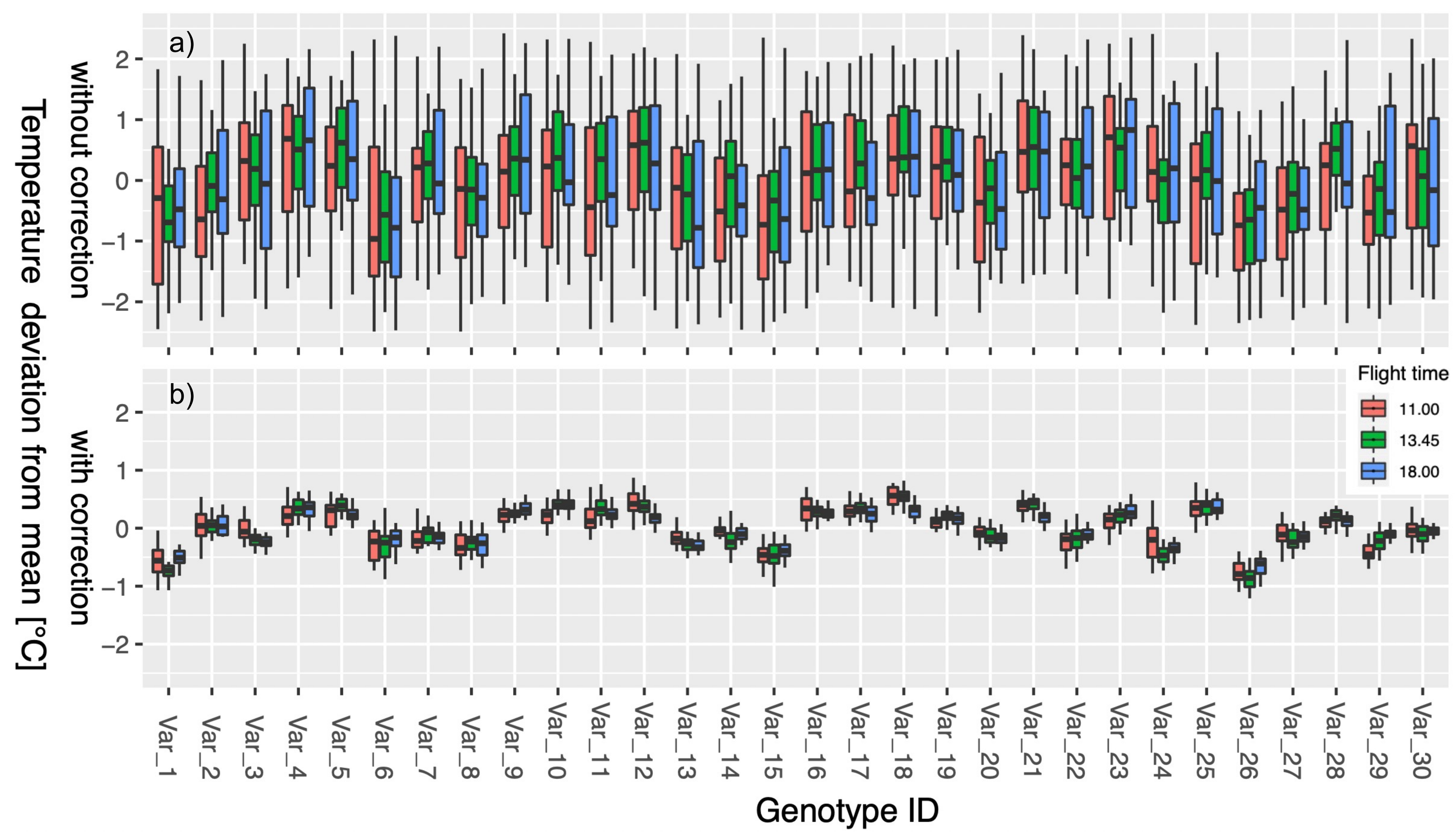


Figure 4: The CT shown were measured for 30 varieties at three different times of the same day. (a) shows the original CT values and (b) shows corrected CT. Correcting for temporal trends narrows the range of temperatures for each plot and increases the genotype-specific differences.

Preliminary results

- Preliminary analysis showed that this approach is suitable to measure genotype-specific relative CT differences (Fig. 4) and Cullis broad sense heritabilities of CT higher than 0.9 can be reached.
- First trends on the relationship between CT and viewing geometry could be established (Fig. 5) but seem to be highly dependent on instantaneous environmental conditions.
- In a next step, linear mixed modelling will be applied to disentangle temporal drift and spatial gradients and to determine the interplay of geometric relationships with environmental conditions.

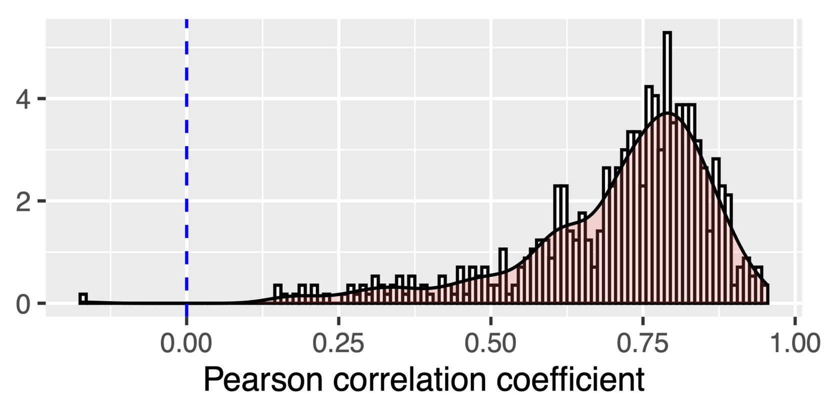


Figure 5: For all plots of one flight, the correlations of CT and the angle that spans between sun, plot and drone were calculated and the histogram on the left indicates that for this flight, there was a strong positive correlation between them for most of the plots.

Summary

- CT is an interesting trait but it's challenging to measure it properly.
- Applying ray tracing on aerial uncalibrated thermal images allows to estimate and correct for temporal trends such as sensor drift.
- High heritabilities (> 0.9) can be reached with this approach.
- Preliminary results suggest that temporal trends (most likely sensor drift) is the most important factor to be considered. Other factors such as spatial trends and angle relationships must be further examined in depth.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme.