TSWIFT – A scanning tower-based hyperspectral instrument to capture diurnal and seasonal physiological plant response

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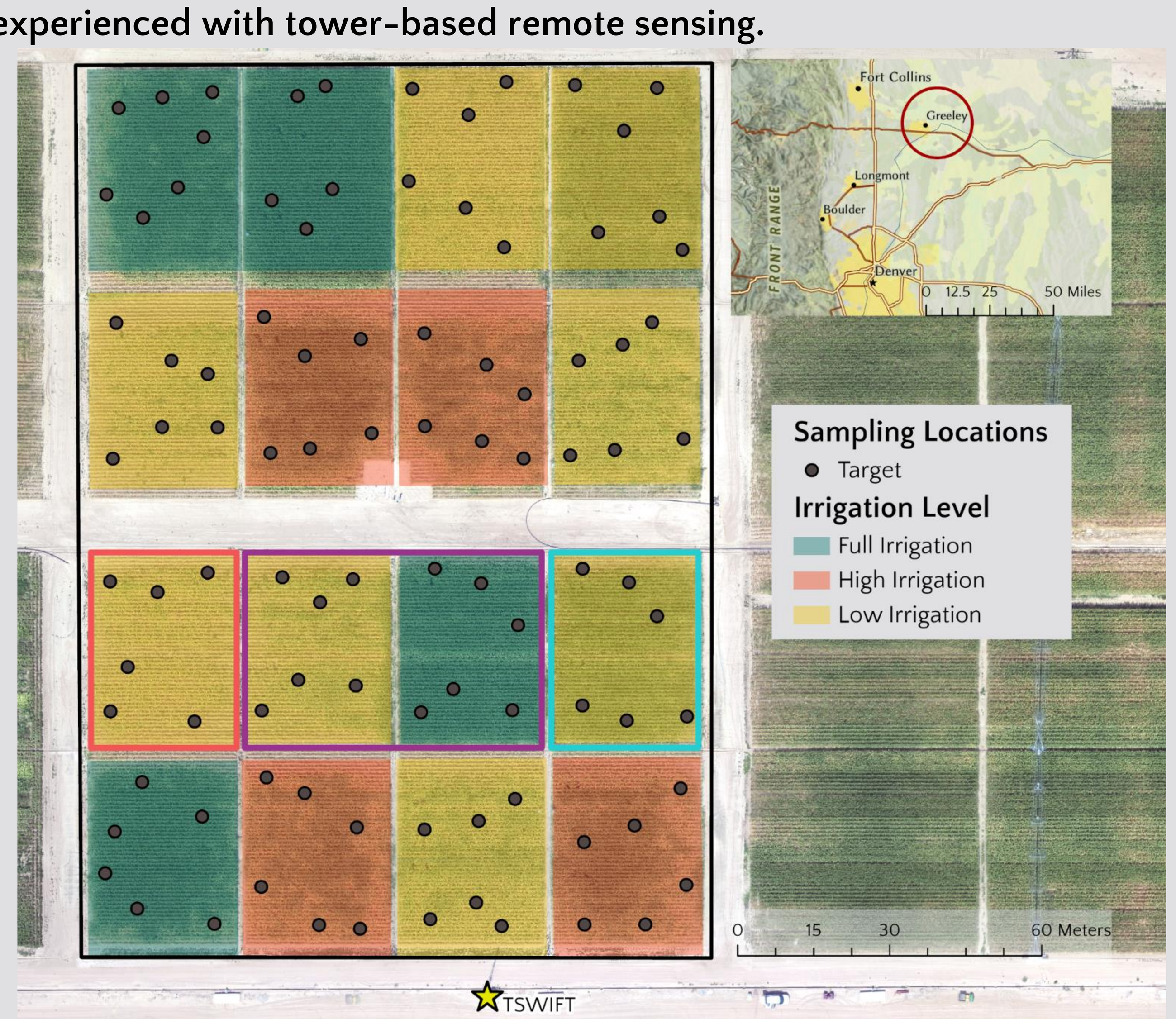
Plant OPTICS LAB
Observation Platforms To Interpret Complex ecoSystems

1. Background

- Tower Spectrometer on Wheels for Investigations with Frequent Timeseries (TSWIFT) retrieves high spatiotemporal optical-based plant response data.
- TSWIFT was deployed at the USDA's Limited Irrigation Research Farm (LIRF) to collect hyperspectral and solar-induced fluorescence (SIF) measurements of drought-stressed maize.
- Complexities of plant structure and phase angle impact the spectral signal collected by TSWIFT.

Objective: Develop an empirical model to rectify sun and sensor viewing angle-induced effects experienced with tower-based remote sensing.



The sampling routine of TSWIFT at LIRF, Greeley, CO. The red, purple, and cyan outlines correspond to the following figures with matching backgrounds.

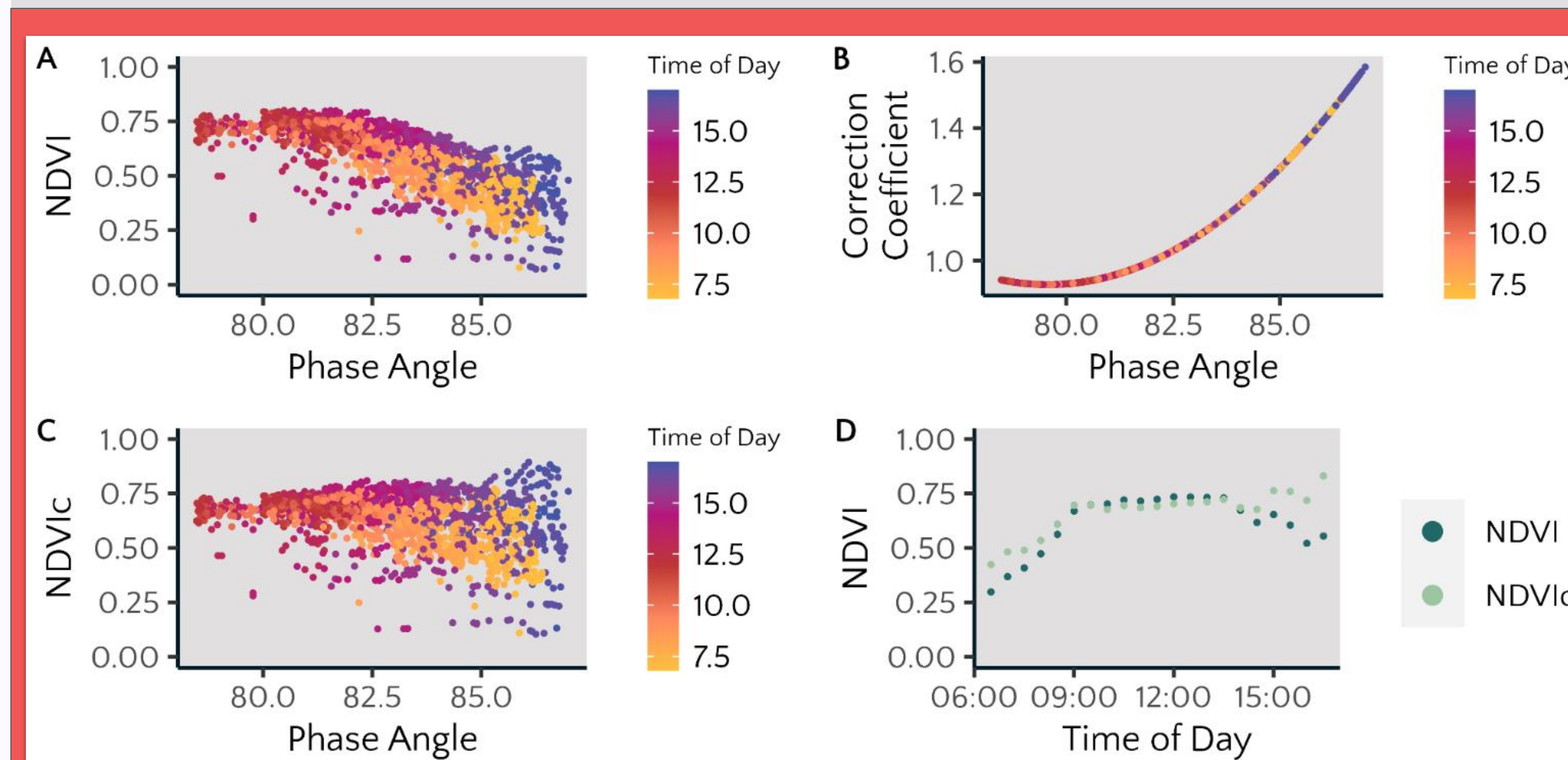
2. Methods

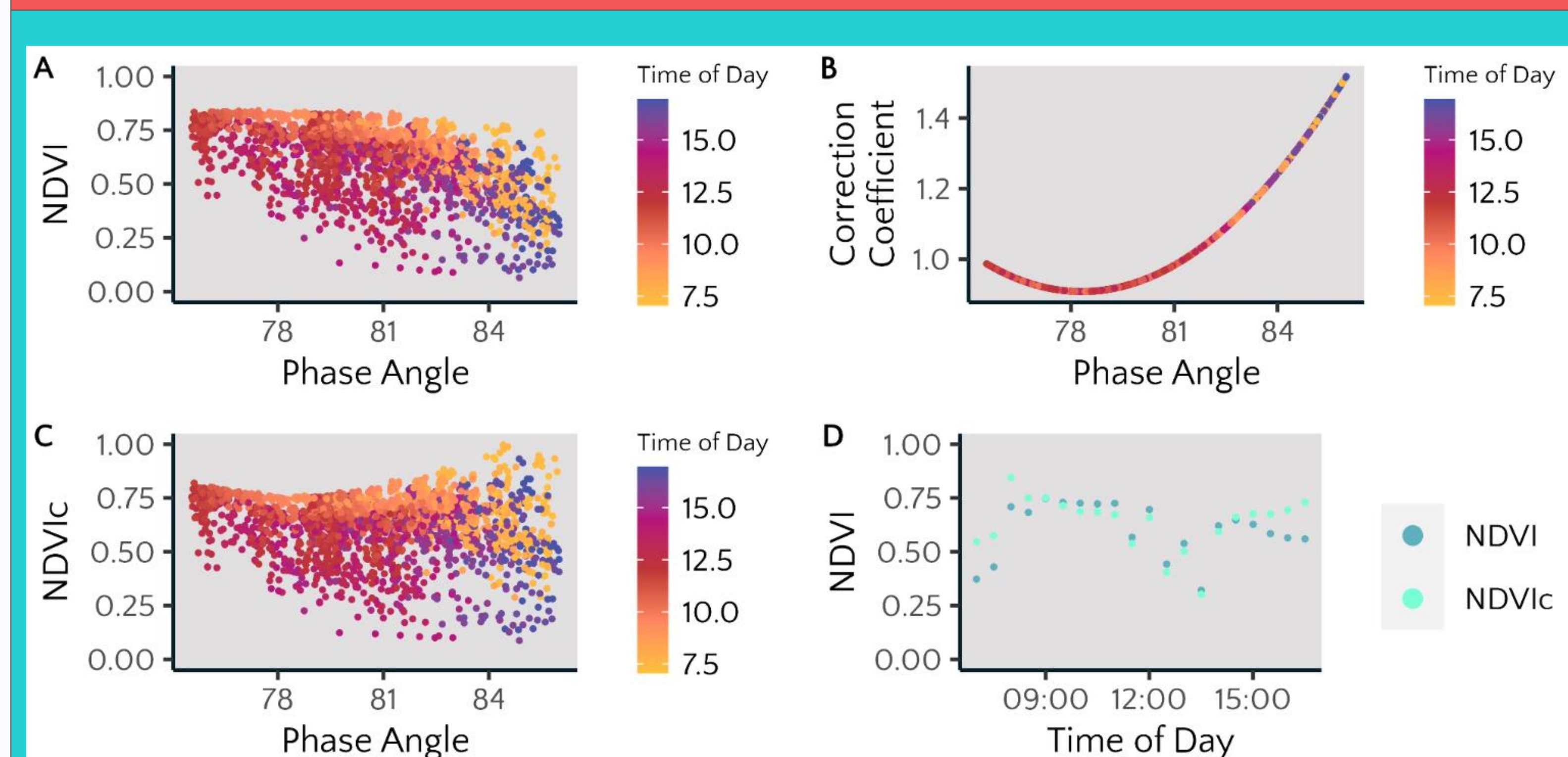
- Three irrigation treatments: Full, High, and Low
- Continuous spectral retrievals from 0700-1700 h, sampling 96 targets with a 33-minute return time
- TSWIFT scanning head: collocated RGB camera and 2D telescoping unit (20 cm² FOV)

1) TSWIFT self-contained on a trailer with a telescoping tower and climate-controlled HVAC cabinet
2) Scanning head pans 360° azimuth and tilts -45° to 90° zenith with a 30x optical zoom
3) RGB photos are captured for each spectral retrieval, images captured on July 20, 2022
   a) Low Irrigation Treatment b) Full Irrigation Treatment - see purple outlines

3. Phase Angle Correction

- Fundamental Assumption: NDVI as a proxy of greenness is invariant throughout a single day
- Solar noon NDVI values were used as a reference to calculate a ratio between all retrievals for a given day for each target
- A robust regression model with bisquare weighting between NDVI ratio and Phase Angle was used to determine the correction coefficient
- A new model was ran for each treatment plot
- NDVI corrected (NDVIc) = NDVI (raw/observed) * Correction Coefficient





Subplots A and C display every retrieval for one month (07/19 /2022 - 08/19/2022). Subplot D compares the 30-minute median of NDVI and NDVIc on 08/05/2022.

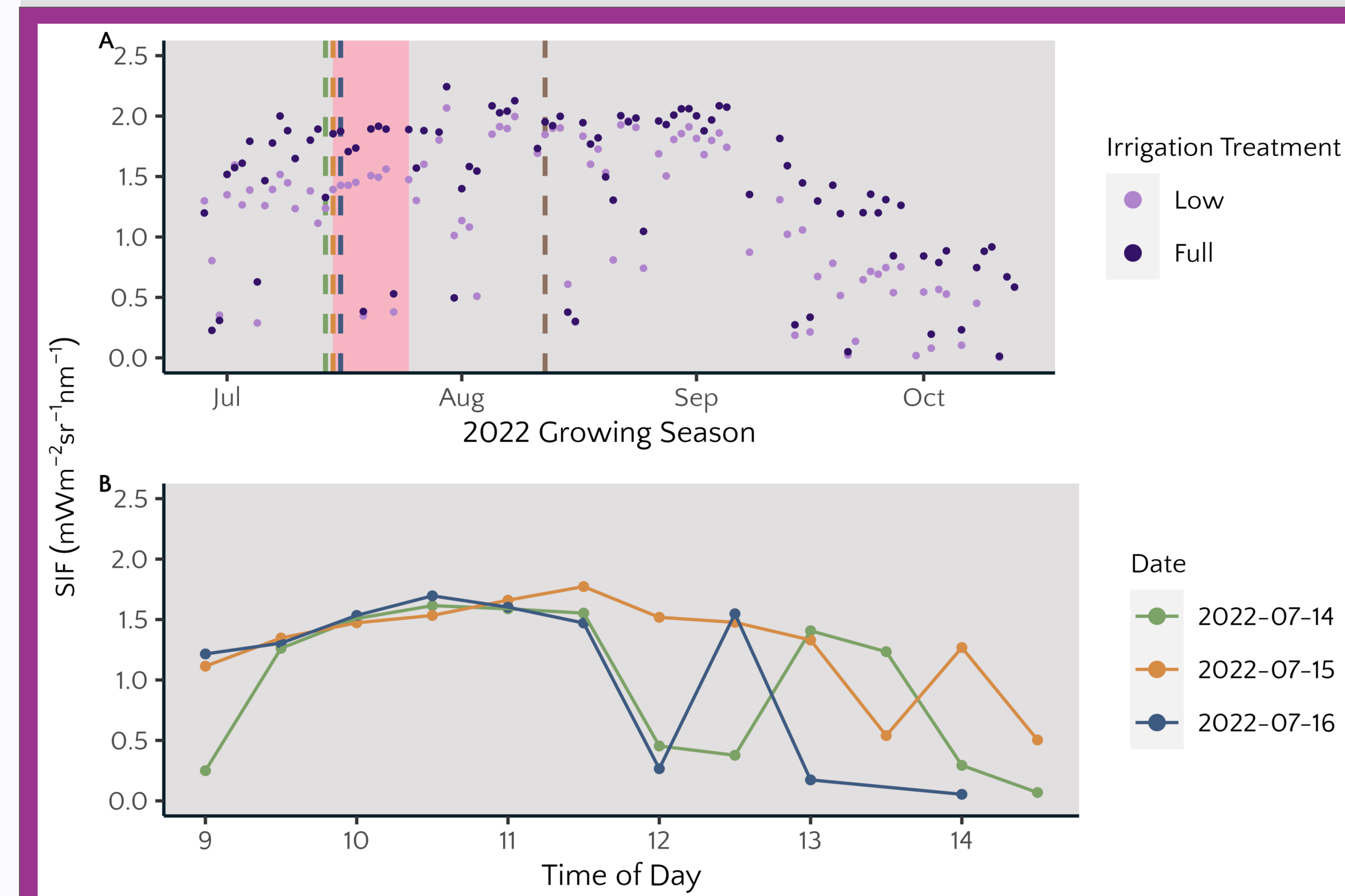
Red Panel:
The correction coefficient increases NDVIc in the early morning and late afternoon (high phase angles).

Blue Panel:
The correction coefficient increases late afternoon NDVIc above observed values overcorrecting for angular effects.

4. Seasonal and Diurnal Variation of SIF

- High spatiotemporal resolution of TSWIFT enables the tracking of plant response seasonally, diurnally, and across irrigation treatments

The observed SIF values, when compared across treatments, converge during irrigation events and diverge throughout periods of drought



A. The first pink region represents a nine-day drought period where the Low Irrigation Treatment did not receive water (07/16 - 7/25). The brown dashed line (8/12) signifies the last irrigation event for the Low Treatment for the season. The green, orange, and blue dashed lines correspond to the dates displayed in plot B. The data displayed are the daily medians.

B. Each point-line represents the 30-minute median for the day before, during, and after an irrigation event. Drastic changes in retrieved SIF values could be attributed to variable sky conditions.

5. Conclusions

A phase angle correction minimizes the impacts of sun-sensor geometry on tower-based remote sensing to offer improved monitoring of plant driven responses to their environment.

- Each treatment plot required its own correction because potential phase angle overlap between different field locations at varying times throughout the day.
- Future work will focus on developing a method to increase the model's sensitivity to the sun angle

Acknowledgements

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References

Wong, C.Y.S., Jones, T., McHugh, D.P. et al. TSWIFT: Tower Spectrometer on Wheels for Investigating Frequent Timeseries for high-throughput phenotyping of vegetation physiology. Plant Methods 19, 29 (2023). https://doi.org/10.1186/s13007-023-01001-5

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