Using remotely piloted aircrafts to evaluate potato water stress in Central Wisconsin

Logan Ebert[1], Alex Chisholm[2], Jacob Prater[2], Samuel Zipper[3], Ammara Talib[4], Ankur Desai[4], and Mallika Nocco[1]

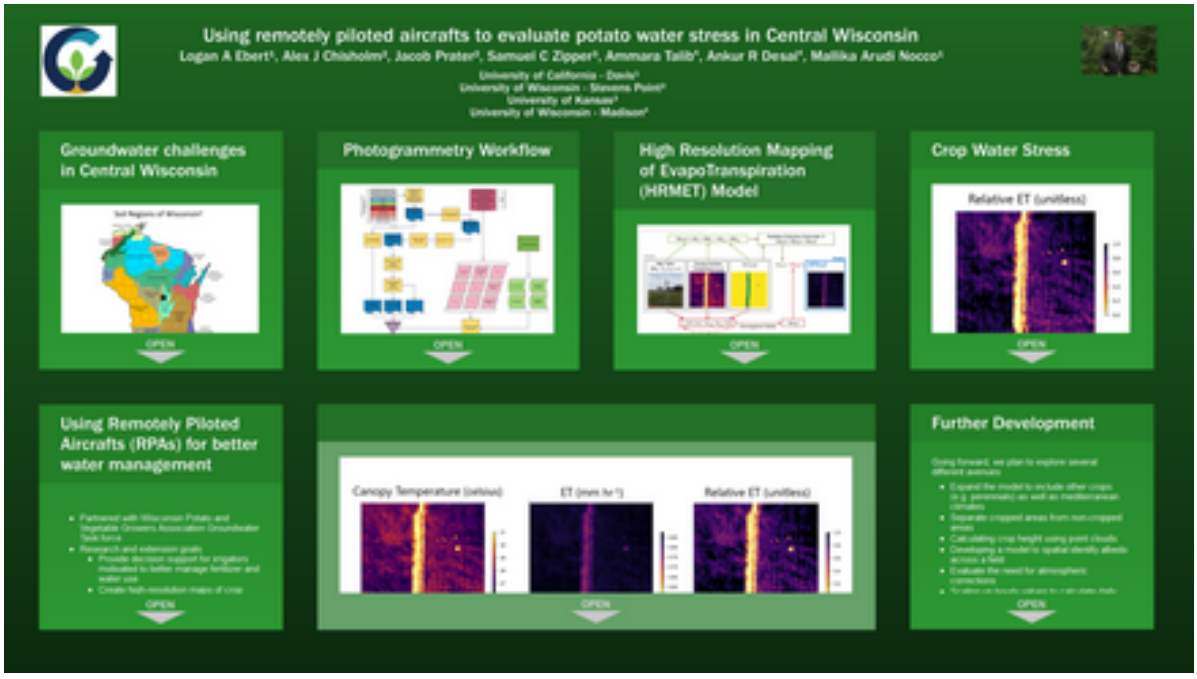
[1]University of California Davis
[2]University of Wisconsin Stevens Point
[3]University of Kansas
[4]University of Wisconsin Madison

November 25, 2022

Abstract

Groundwater depletion in Central Wisconsin, due in part to agricultural high-capacity wells, has sparked an interest in precision irrigation to reduce groundwater pumping without a significant reduction in yield. A key challenge for bridging precision irrigation research and application is how best to monitor water stress in real-time. Aerial and satellite imagery are potential solutions. Drawbacks of these methods include cost, spatiotemporal resolution, and cloud interference, especially in humid regions. Recent advancements in remotely piloted aircrafts (RPAs) have made frequent, low-flying imagery collection more economical and feasible than ever before. We partnered with the Wisconsin Potato and Vegetable Grower Association to generate high-resolution maps of crop water stress using remotely sensed thermal and multi-spectral RPA imagery. Data were collected at a commercially irrigated potato field in the Central Sands region of Wisconsin from June to August 2019. Missions were flown weekly using a quadcopter RPA system instrumented with a newly released, combined multispectral/thermal camera developed for agricultural applications. Each mission included flights at 30, 60, and 90 m above ground level to assess tradeoffs between resolution, area, and flight time. We used biophysical data from an eddy covariance system installed within the flight domain to validate crop water stress maps generated from the remotely sensed RPA data. Ground measurements of surface temperature and soil moisture were collected throughout the domain within fifteen minutes of each mission. Ongoing results will be used to develop best practices for integrating RPAs into precision irrigation programs.

Using remotely piloted aircrafts to evaluate potato water stress in Central Wisconsin



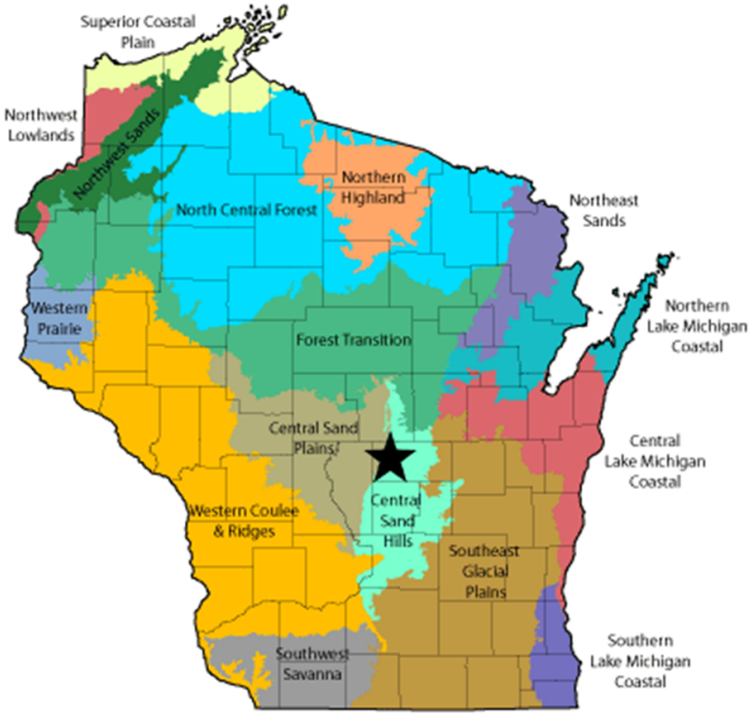
Logan A Ebert[1], Alex J Chisholm[2], Jacob Prater[2], Samuel C Zipper[3], Ammara Talib[4], Ankur R Desai[4], Mallika Arudi Nocco[1]

University of California - Davis[1]
University of Wisconsin - Stevens Point[2]
University of Kansas[3]
University of Wisconsin - Madison[4]

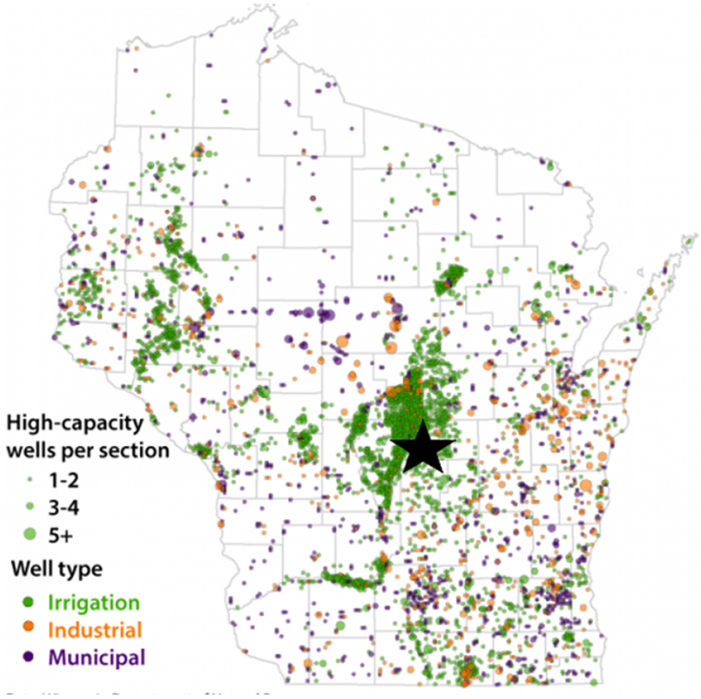
PRESENTED AT:

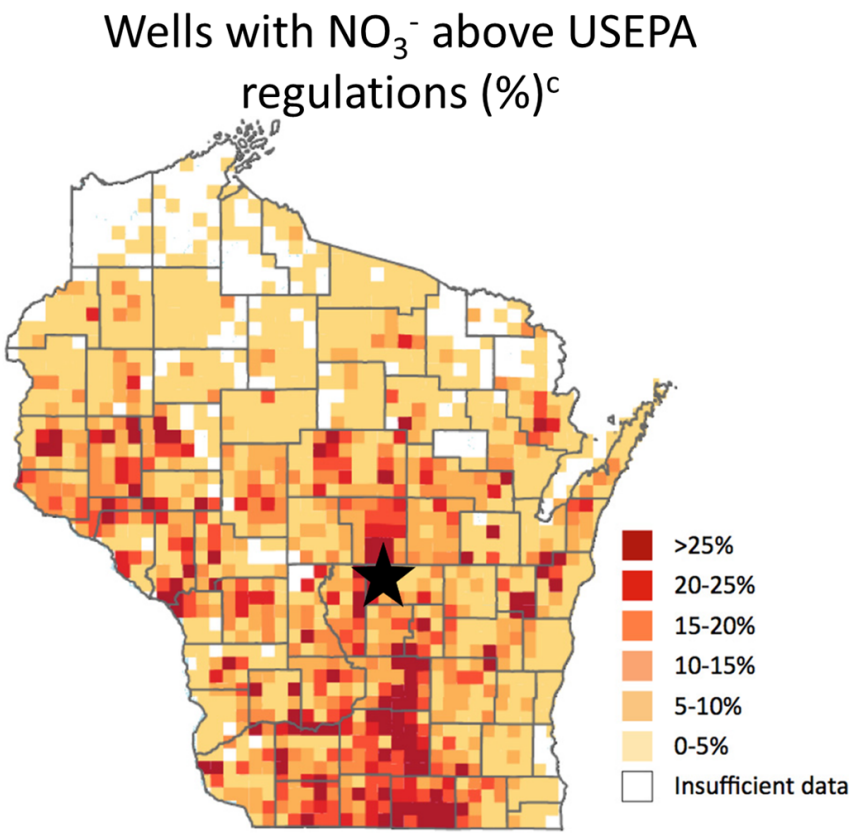
GROUNDWATER CHALLENGES IN CENTRAL WISCONSIN

Soil Regions of Wisconsin[a]

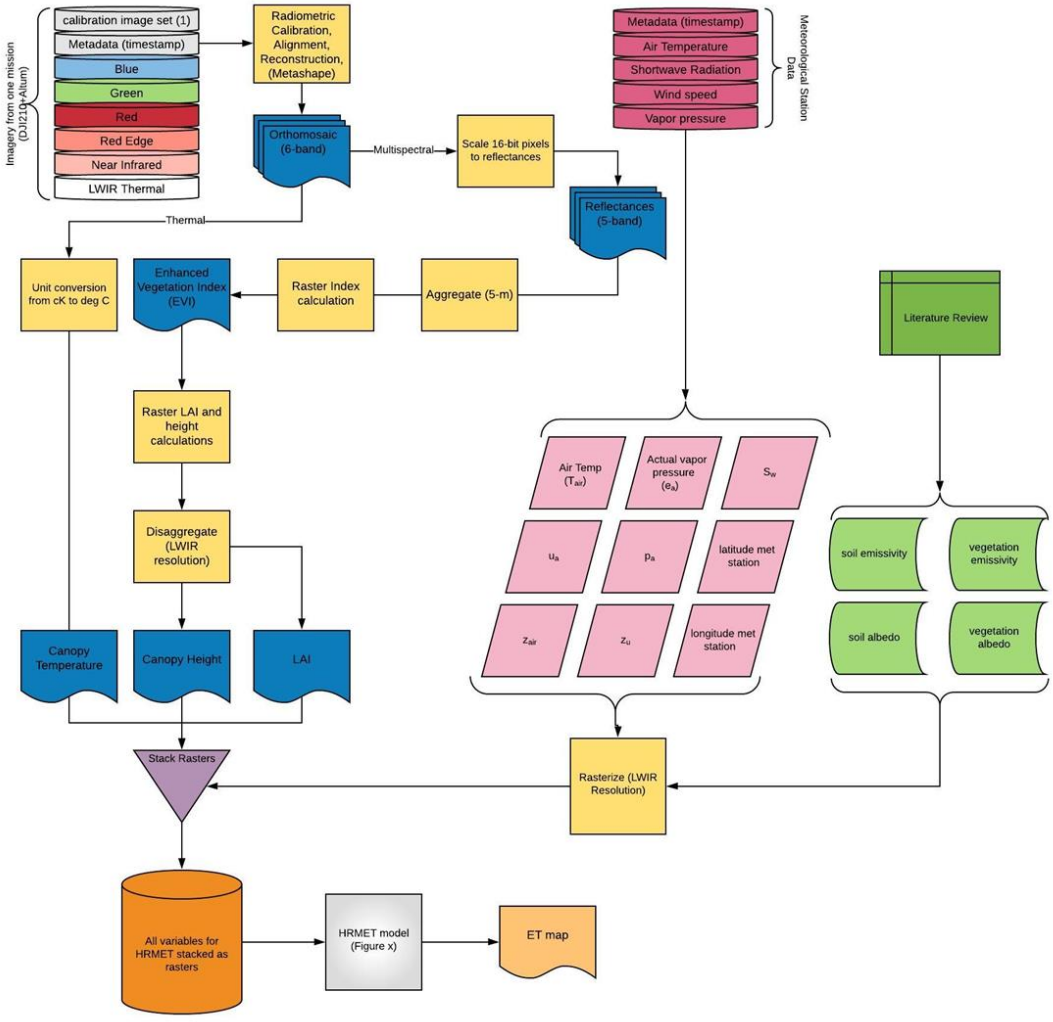


Wisconsin High-Capacity Wells[b]

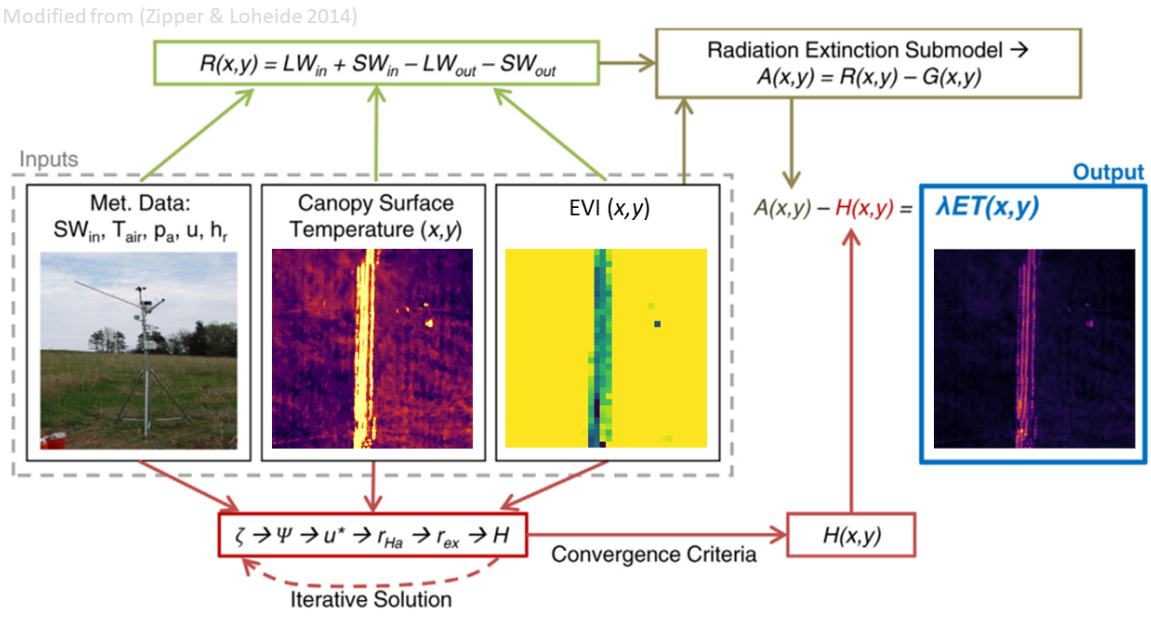


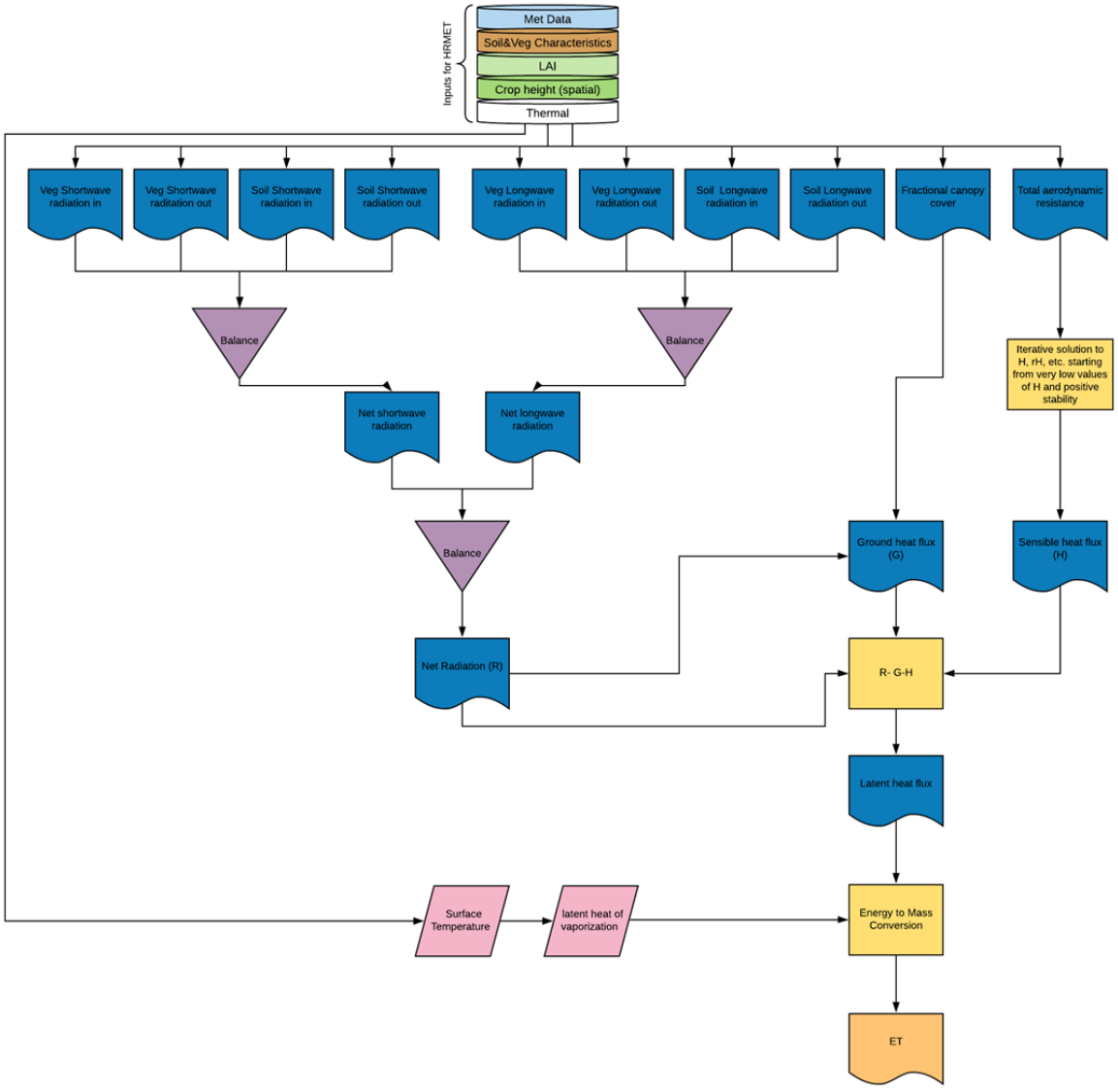

Wells with NO_3^- above USEPA regulations (%)[c]
>25%
20-25%
15-20%
10-15%
5-10%
0-5%
Insufficient data

PHOTOGRAMMETRY WORKFLOW

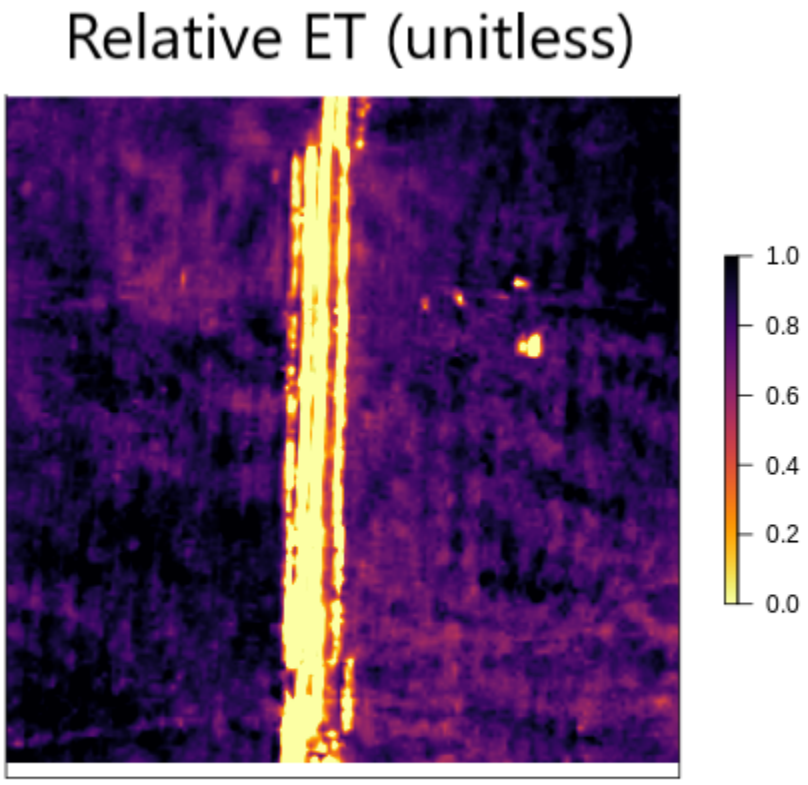


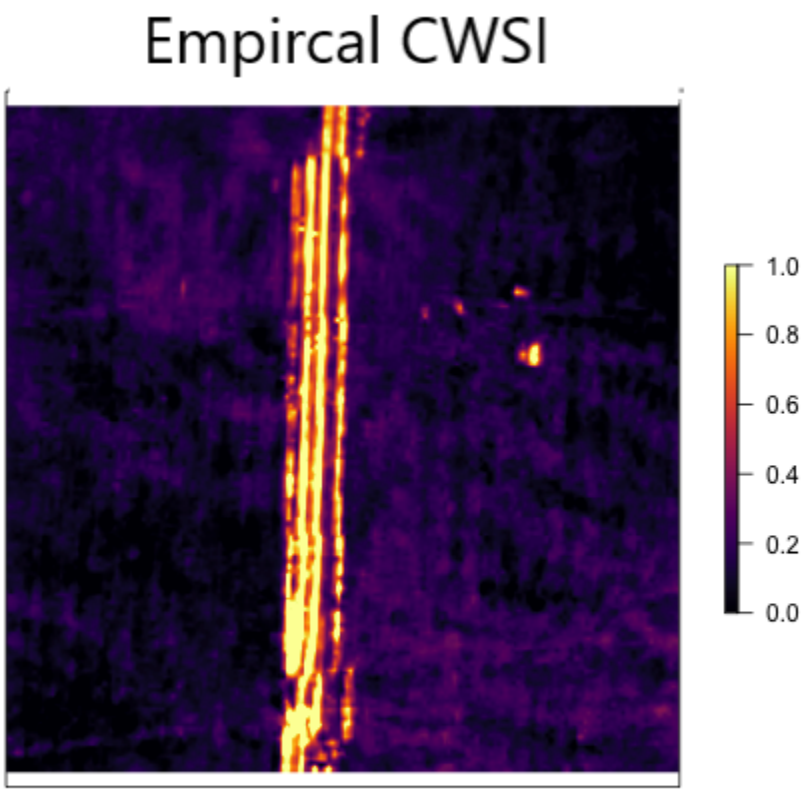
HIGH RESOLUTION MAPPING OF EVAPOTRANSPIRATION (HRMET) MODEL

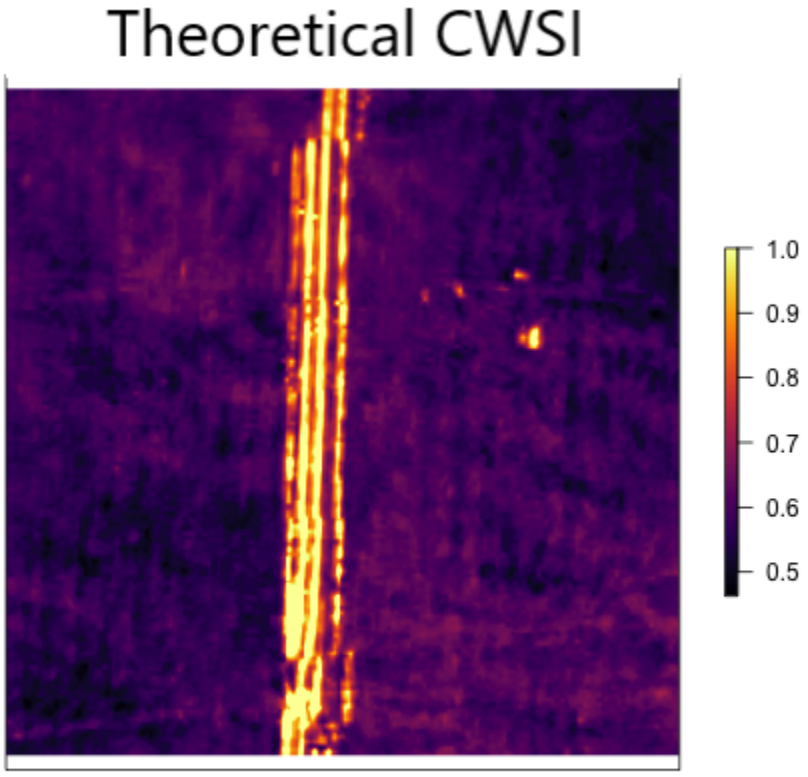



Inputs for HRMET
Met Data
Soil&Veg Characteristics
LAI
Crop height (spatial)
Thermal
Veg Shortwave radiation in
Veg Shortwave raditation out
Soil Shortwave radiation in
Soil Shortwave radiation out
Veg Longwave radiation in
Veg Longwave raditation out
Soil Longwave radiation in
Soil Longwave radiation out
Fractional canopy cover
Total aerodynamic resistance
Balance
Balance
Iterative solution to H, rH, etc. starting from very low values of H and positive stability
Net shortwave radiation
Net longwave radiation
Balance
Ground heat flux (G)
Sensible heat flux (H)
Net Radiation (R)
R- G-H
Latent heat flux
Surface Temperature
latent heat of vaporization
Energy to Mass Conversion
ET

CROP WATER STRESS

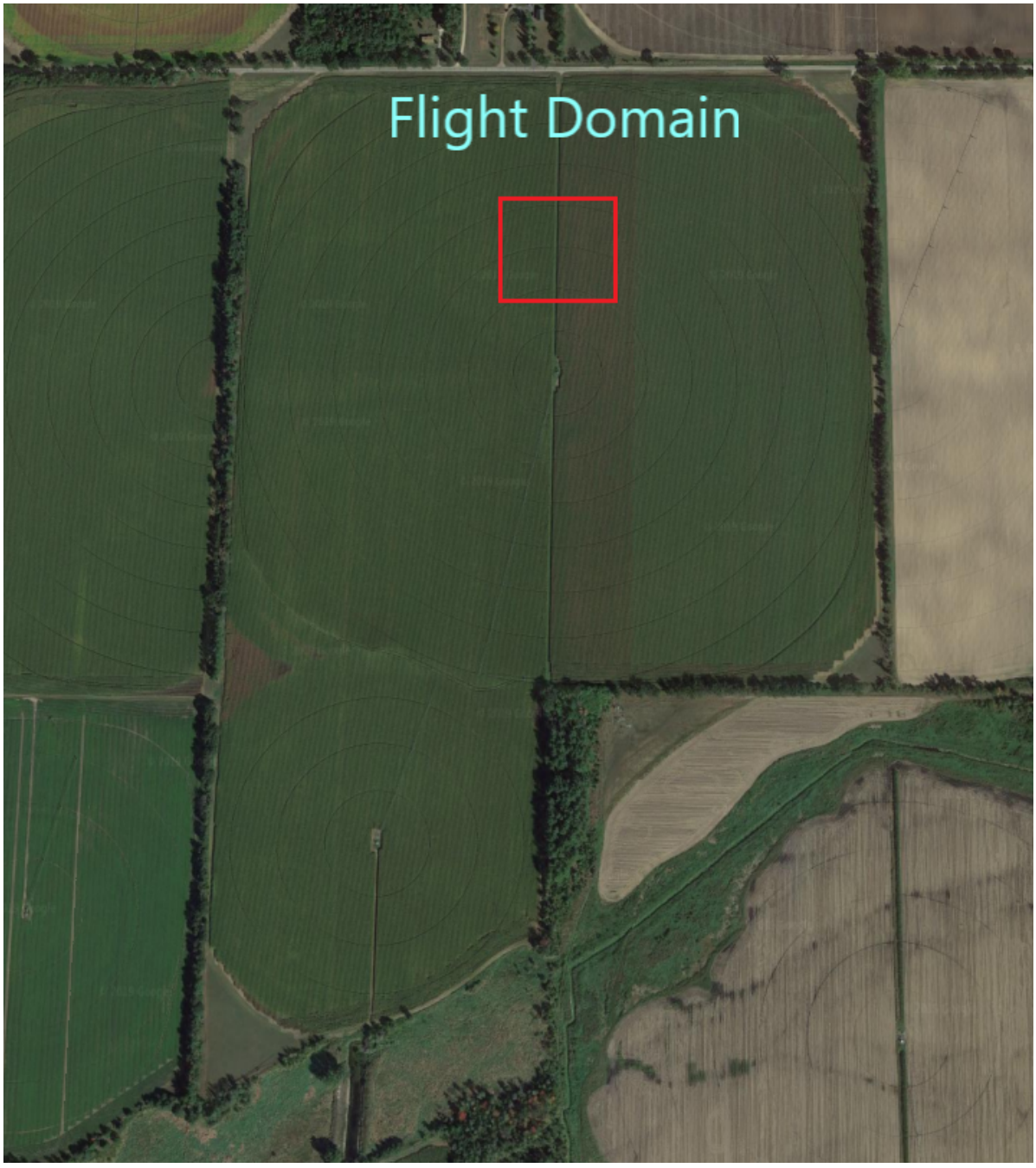


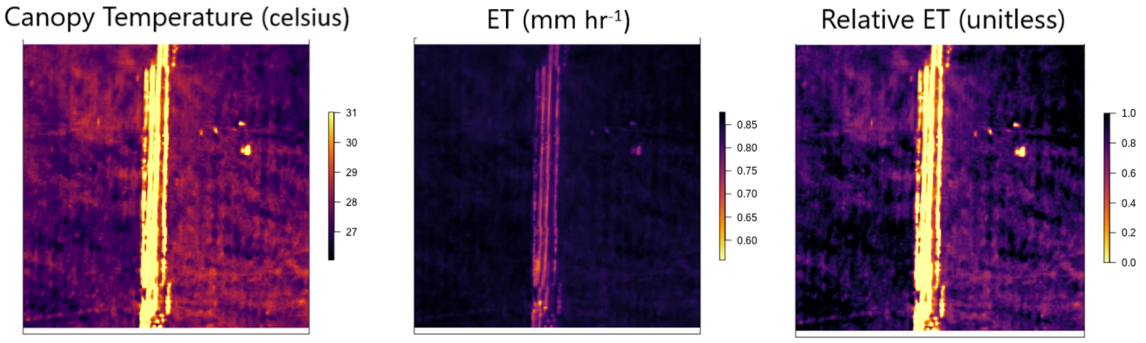

Empircal CWSI
1.0
0.8
0.6
0.4
0.2
0.0

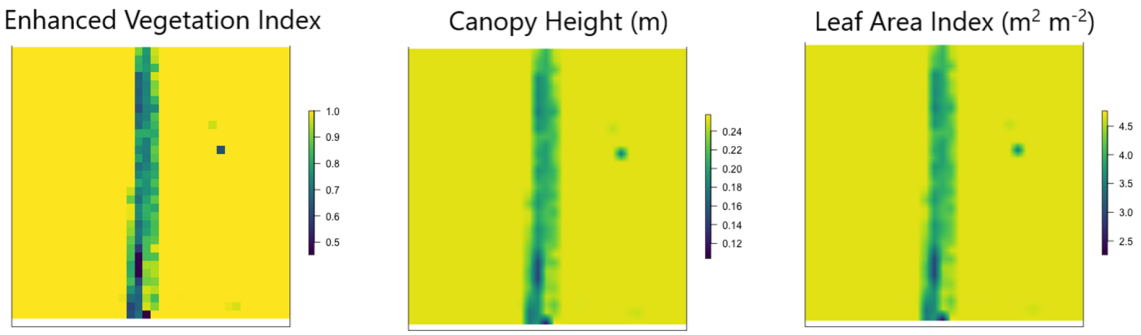

Theoretical CWSI
1.0
0.9
0.8
0.7
0.6
0.5

USING REMOTELY PILOTED AIRCRAFTS (RPAS) FOR BETTER WATER MANAGEMENT

- Partnered with Wisconsin Potato and Vegetable Growers Association Groundwater Task force
- Research and extension goals
  - Provide decision support for irrigators motivated to better manage fertilizer and water use
  - Create high-resolution maps of crop water stress using cutting edge Remotely Piloted Aircraft (RPA) technology
- Eight missions throughout the 2019 growing season over a commercial potato field in Waushara County, WI


Flight Domain


Canopy Temperature (celsius)
31
30
29
28
27
ET (mm hr-1)
0.85
0.80
0.75
0.70
0.65
0.60
Relative ET (unitless)
1.0
0.8
0.6
0.4
0.2
0.0


Enhanced Vegetation Index
1.0
0.9
0.8
0.7
0.6
0.5
Canopy Height (m)
0.24
0.22
0.20
0.18
0.16
0.14
0.12
Leaf Area Index (m2 m-2)
4.5
4.0
3.5
3.0
2.5

FURTHER DEVELOPMENT

Going forward, we plan to explore several different avenues

- Expand the model to include other crops (e.g. perennials) as well as mediterranean climates
- Separate cropped areas from non-cropped areas
- Calculating crop height using point clouds
- Developing a model to spatial identify albedo across a field
- Evaluate the need for atmospheric corrections
- Scaling up hourly values to calculate daily water use

Special thank you to:

- WPVGA Groundwater Task Force
- Heartland Farms
- The David H. Smith Conservation Research Fellowship
- Austin Ruzic
- Dr. Alex Mandel (UC- Davis)
- Dr. Jingyi Huang (UW-Madison)

ABSTRACT

Groundwater depletion in Central Wisconsin, due in part to agricultural high-capacity wells, has sparked an interest in precision irrigation to reduce groundwater pumping without a significant reduction in yield. A key challenge for bridging precision irrigation research and application is how best to monitor water stress in real-time. Aerial and satellite imagery are potential solutions. Drawbacks of these methods include cost, spatiotemporal resolution, and cloud interference, especially in humid regions. Recent advancements in remotely piloted aircrafts (RPAs) have made frequent, low-flying imagery collection more economical and feasible than ever before. We partnered with the Wisconsin Potato and Vegetable Grower Association to generate high-resolution maps of crop water stress using remotely sensed thermal and multi-spectral RPA imagery. Data were collected at a commercially irrigated potato field in the Central Sands region of Wisconsin from June to August 2019. Missions were flown weekly using a quadcopter RPA system instrumented with a newly released, combined multispectral/thermal camera developed for agricultural applications. Each mission included flights at 30, 60, and 90 m above ground level to assess tradeoffs between resolution, area, and flight time. We used biophysical data from an eddy covariance system installed within the flight domain to validate crop water stress maps generated from the remotely sensed RPA data. Ground measurements of surface temperature and soil moisture were collected throughout the domain within fifteen minutes of each mission. Ongoing results will be used to develop best practices for integrating RPAs into precision irrigation programs.

REFERENCES

a) Corn Agronomy. Univeristy of Wisconsin - Madison.
2014 http://corn.agronomy.wisc.edu/Management/L005.aspx
(http://corn.agronomy.wisc.edu/Management/L005.aspx). Accessed November 2019

b) Prengaman, K. 2013. “High-capacity wells possibly lowering some lake levels”, Wisconsin State Journal July 22nd https://madison.com/wsj/news/local/environment/high-capacity-wells-possibly-lowering-some-lake-levels/article_21b14f00-dd4e-5ed5-9ac1-a5d41e1f399f.html

c) Luczaj, J., Masarik, K., 2015. Groundwater quantity and quality issues in a water-rich region: Examples from Wisconsin, USA. Resources 4, 323–357.
https://doi.org/10.3390/resources4020323

Zipper, S. C., & Loheide, S. P. (2014). Using evapotranspiration to assess drought sensitivity on a subfield scale with HRMET, a high resolution surface energy balance model. Agricultural and Forest Meteorology, 197, 91–102. https://doi.org/10.1016/j.agrformet.2014.06.009