Development of a smart-and-connected irrigation system for rural communities in Nebraska

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UNIVERSITY OF Nebraska Lincoln

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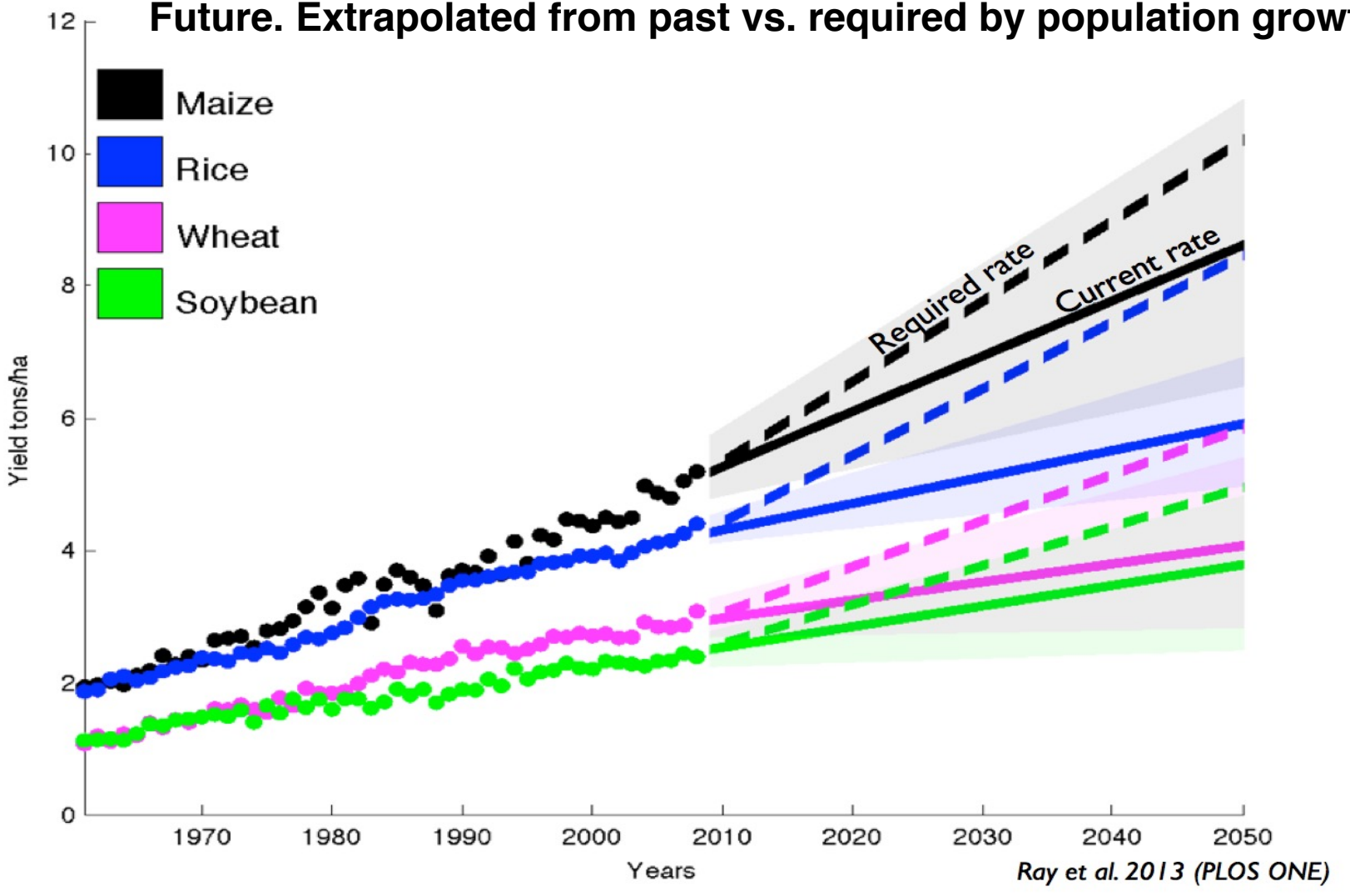
THE UNIVERSITY OF UTAH

Yield/ha, Past & Future

Future. Extrapolated from past vs. required by population growth



Ray et al. 2013 (PLOS ONE)

Importance and variety of irrigation

Ditch irrigation

Terraced Irrigation

Drip Irrigation

Sprinkler System

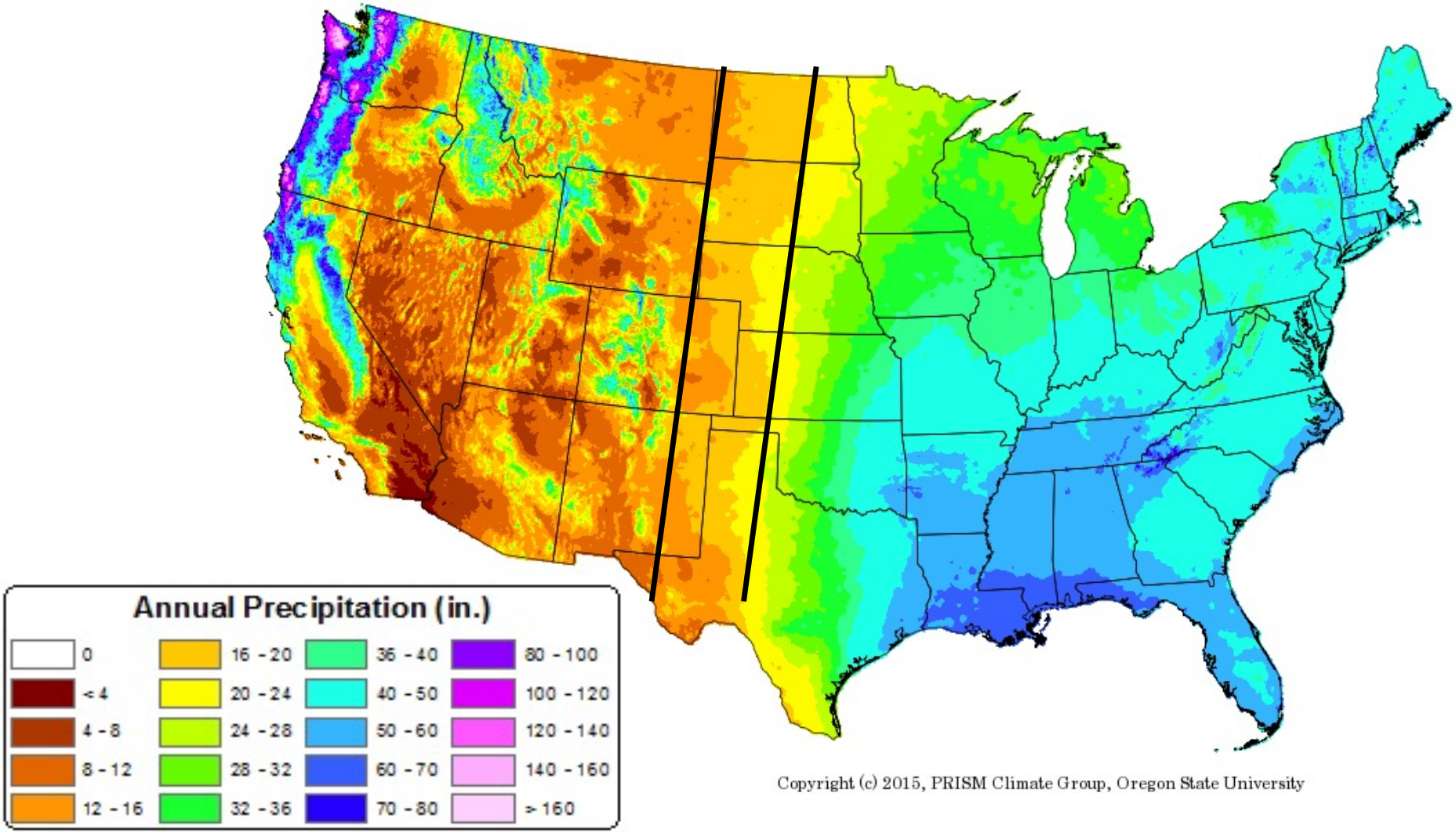
Central Pivot

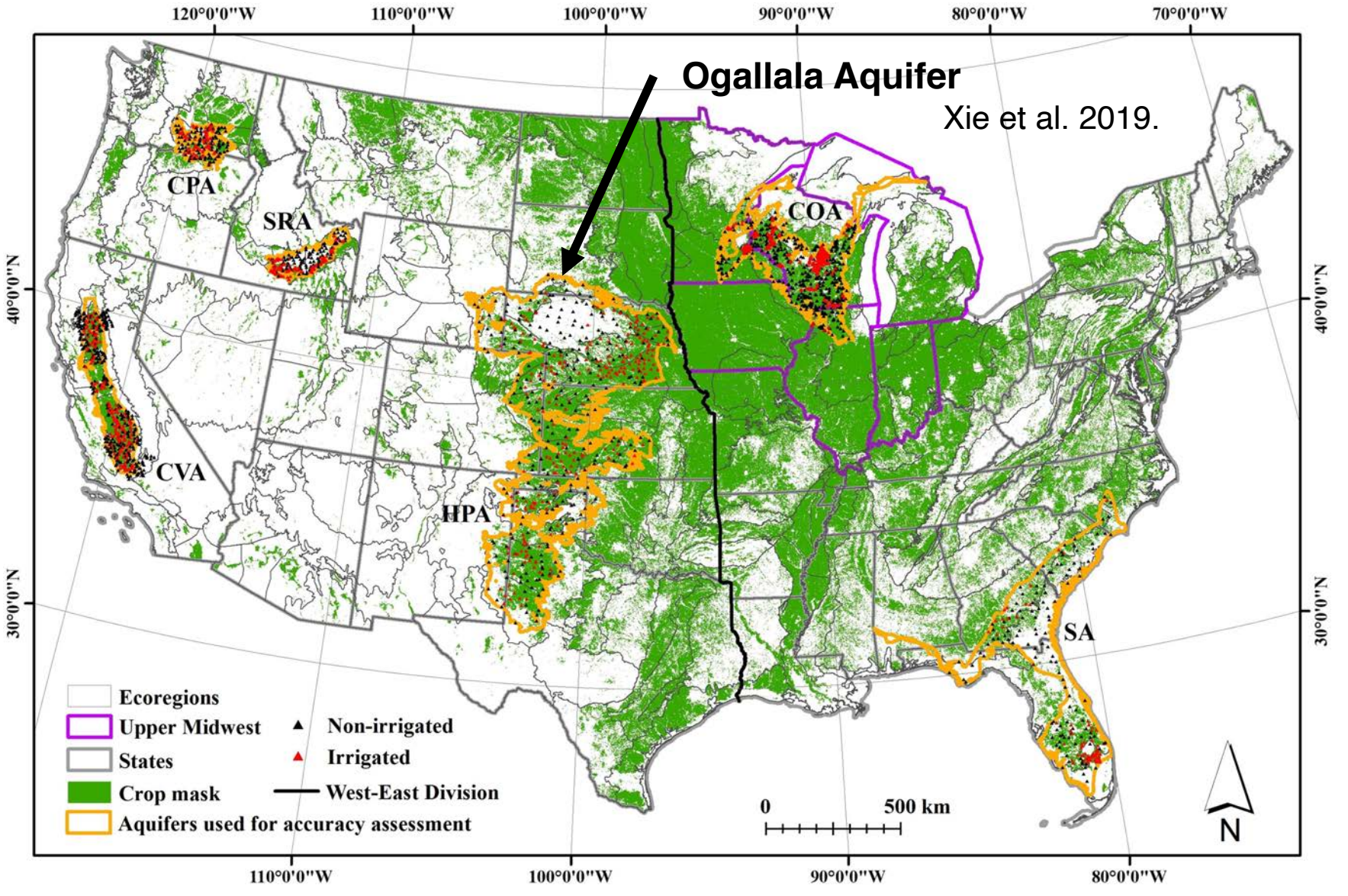
Flooding irrigation

~40% of food production is from irrigated farming (Cook et al., 2010).

30-yr Normal Precipitation: Annual

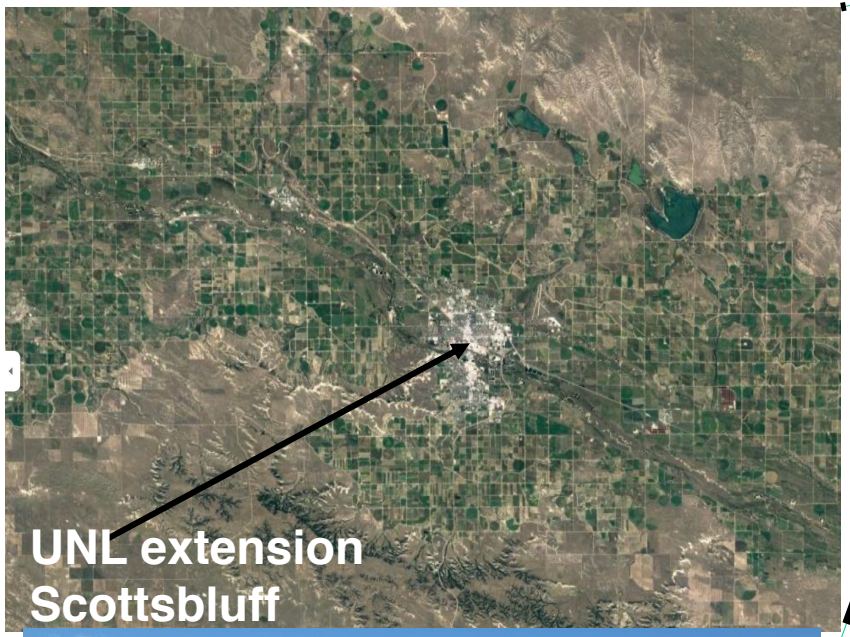
Period: 1981-2010

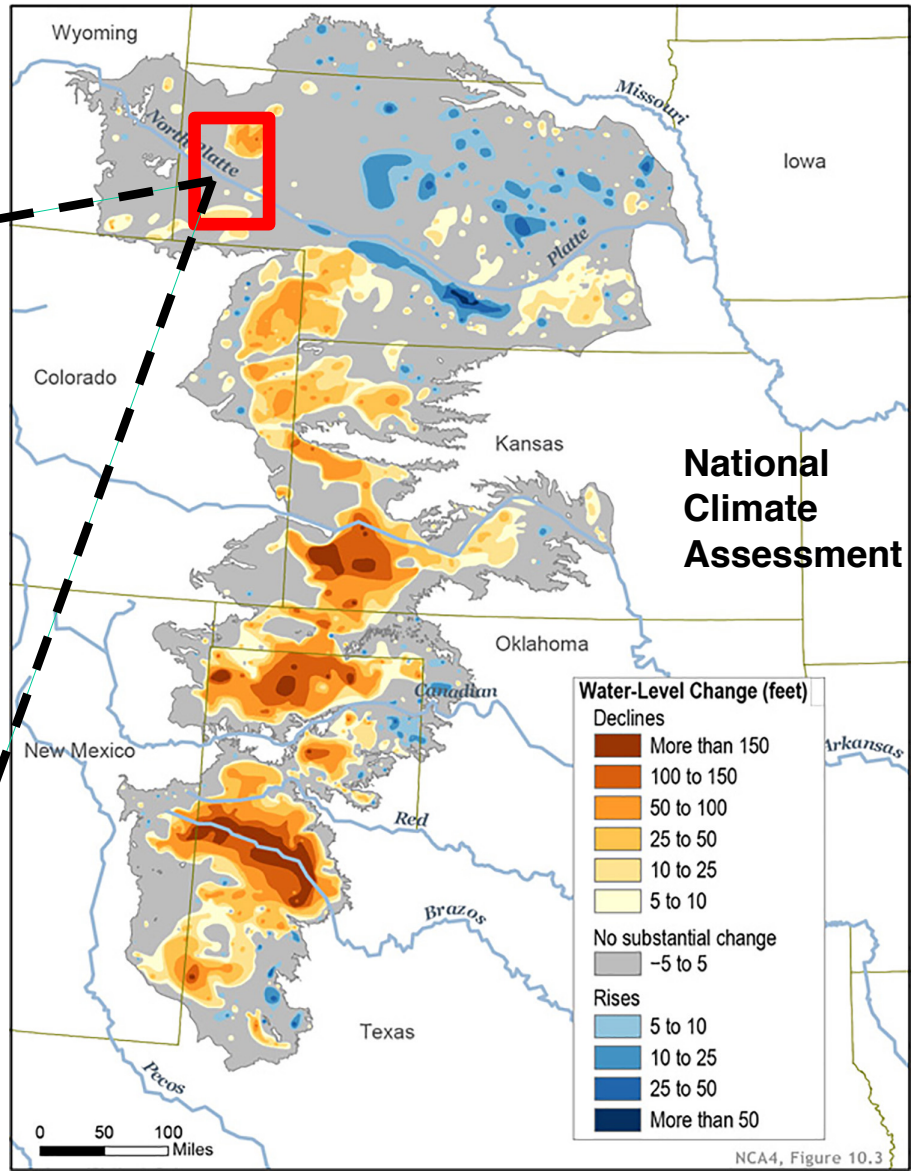



Ogallala Aquifer
Xie et al. 2019.
120°0'0"W
110°0'0"W
100°0'0"W
90°0'0"W
80°0'0"W
70°0'0"W
40°0'0"N
30°0'0"N
CPA
SRA
CVA
HPA
COA
SA
Ecoregions
Upper Midwest
States
Crop mask
Aquifers used for accuracy assessment
Non-irrigated
Irrigated
West-East Division
0
500 km
N

Western Nebraska

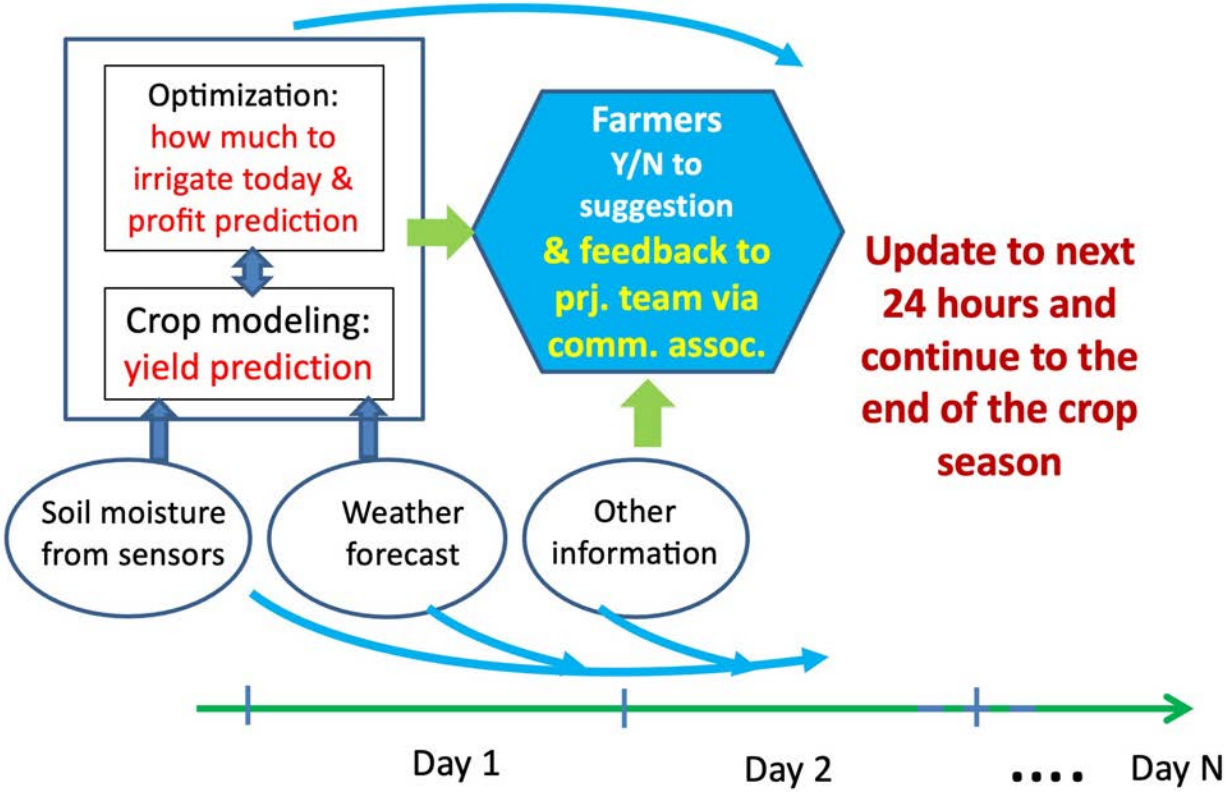
~ 50 km x 30 km





The smart-and-connected irrigation system

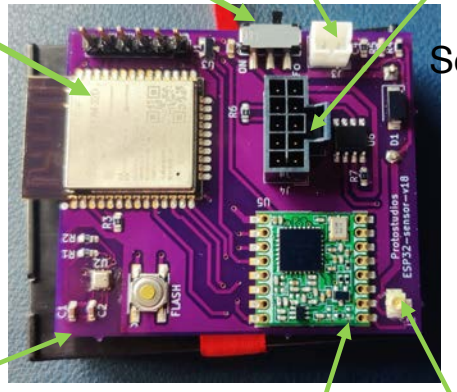
- Low-cost IoT-based sensors to measure soil moisture & temperature, air pressure, RH, and temperature
- Weather prediction model (WRF-Chem) run at 3 km resolution in real time
- Crop modeling for yield prediction and possible water deficit
- Optimization of irrigation schedule and delivery to stakeholders.

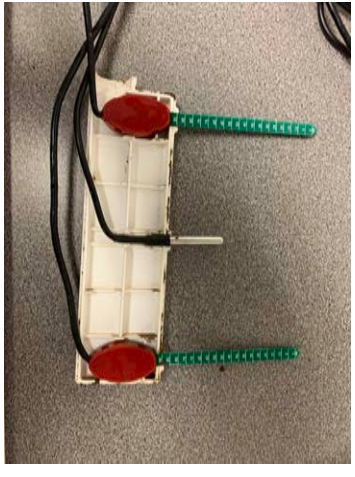


Key: community engagement; close collaboration between project team and local communities

Canopy Sensor Development

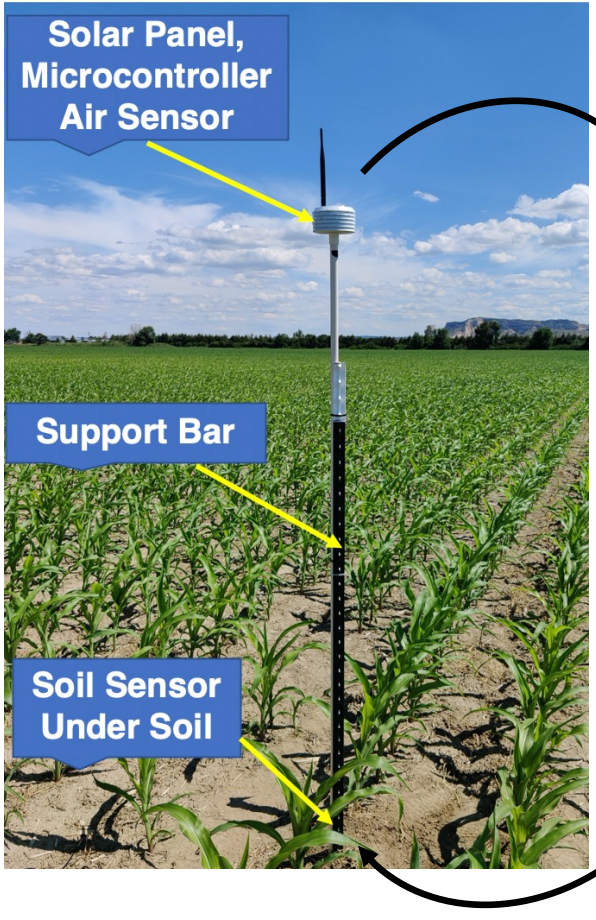
- Temperature, RH, pressure at 2 m
- Soil moisture at 5 cm and 20 cm
- Soil temperature at 10 cm

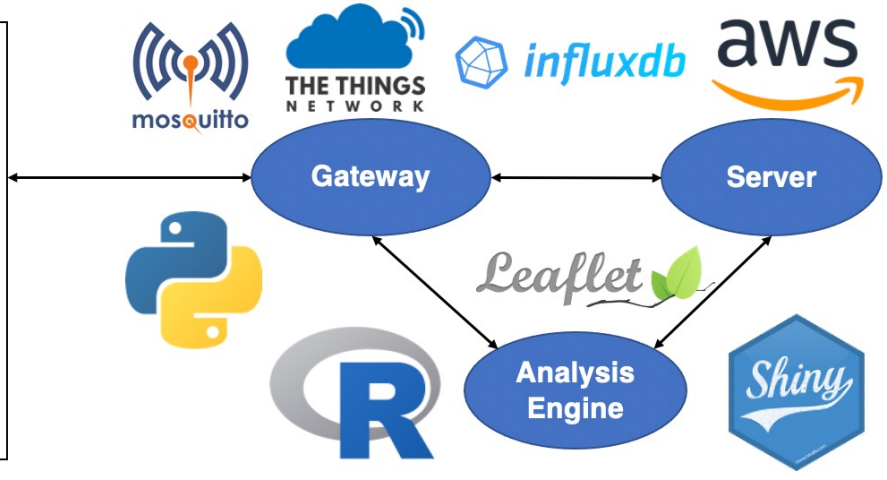




Microcontroller: ESP32
Weather: BME280 (deployed) / BME680 (in testing)

Software and firmware

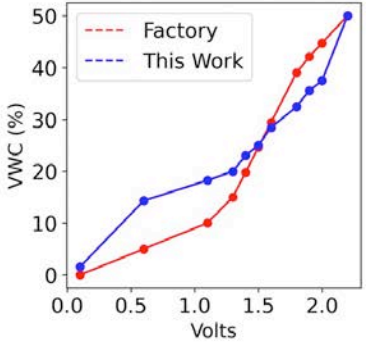




Soil temperature

Soil moisture

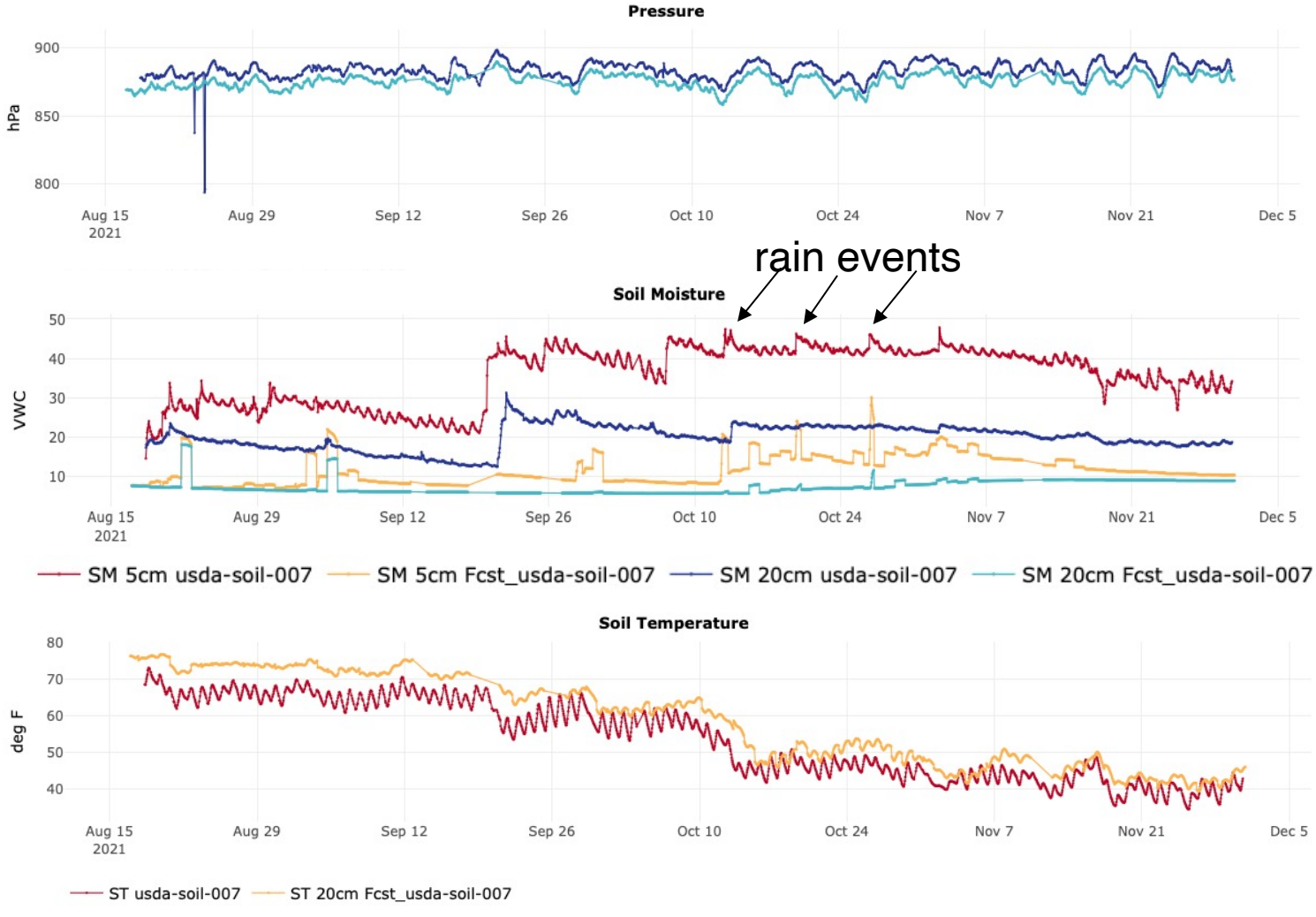
SM calibration curve



Cope with challenges in the irrigated crop field

- Air temperature needs to be measured in an open air environment.
- But, Stevenson Screen doesn't work in irrigated environment where water can penetrate the screen from the side and the below and damage the sensor.
- **Solution**: (a) put air sensor in the closed case to transmit the soil data only.
  (b) Put canopy sensor in the nearby field that is not irrigated.

3-month continuous measurements



Weather forecast & evaluation with sensor data in near real time

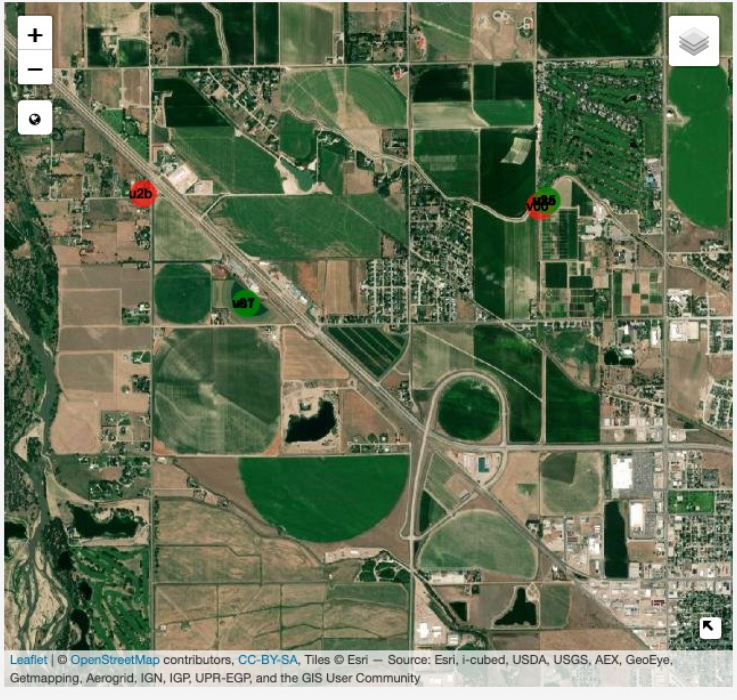
https://esmc.uiowa.edu

Home | Weather Predictions | Data Access | Citizen Data | LANCE | Satellite Data | Tutorials | I-DARE | About Us

UIOWA ESMC

Click on the circles to explore the sensors observations

Note: red suggests the need to change the battery, but COVID-19 pandemic made it difficult. We are in the processing to recover it.

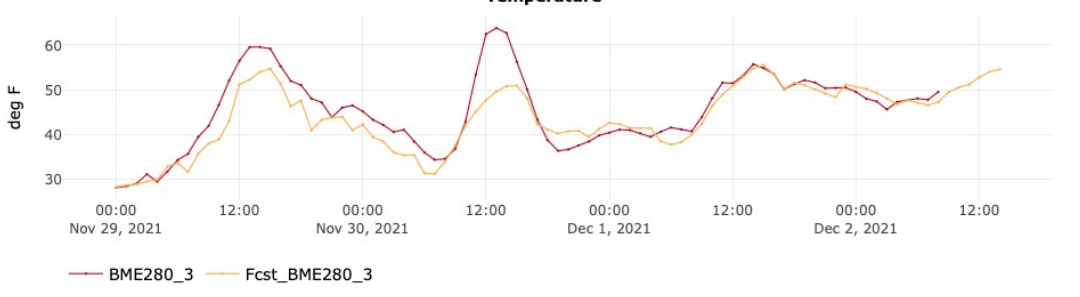


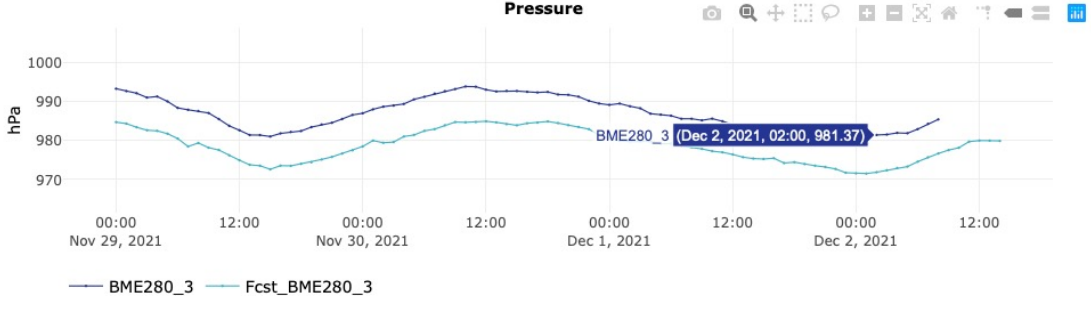
Citizen environmental monitoring & forecast data

Time zone: America/Chicago

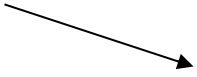
Plots | Data

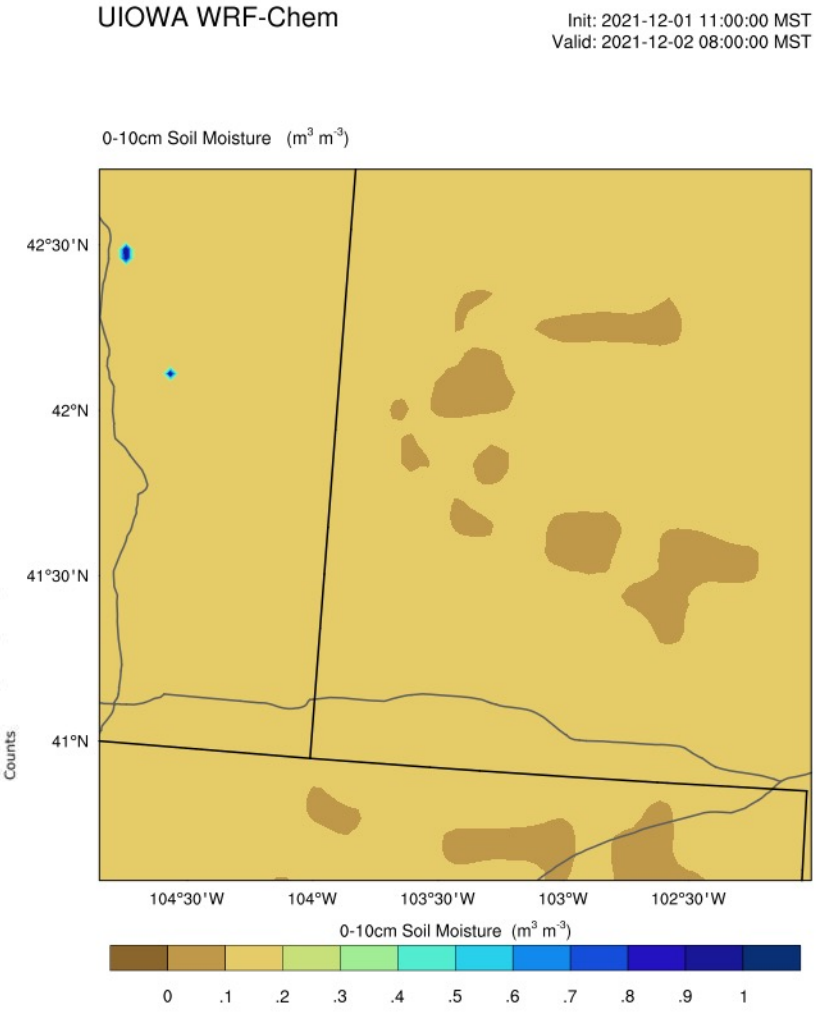
Refresh



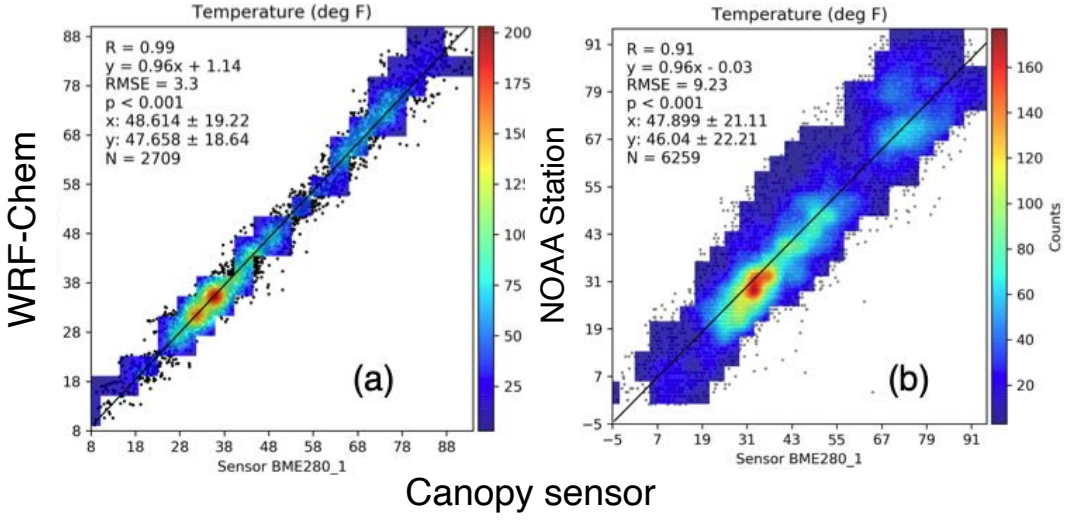


Soil moisture forecast at 3 km resolution

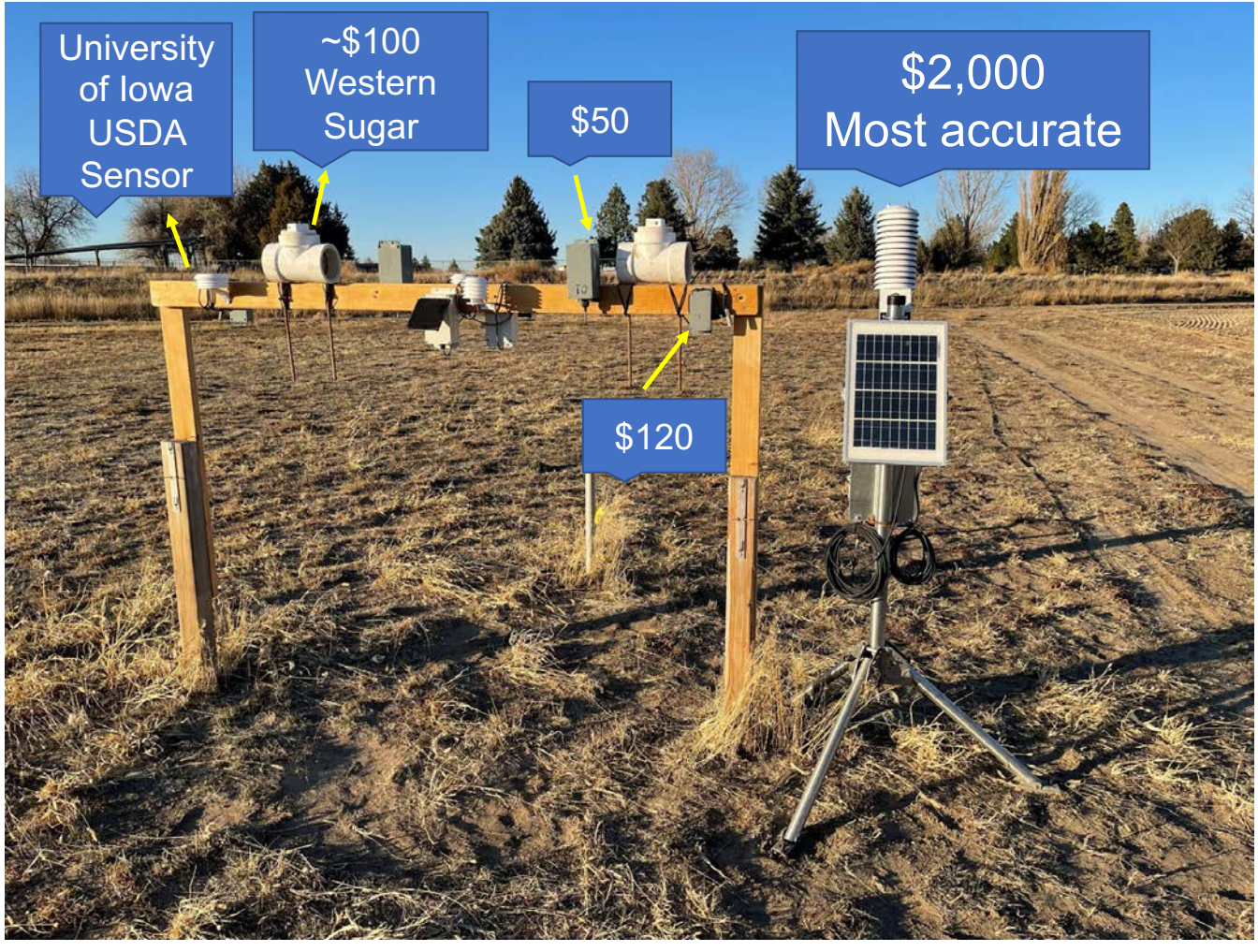




Temperature Intercomparison

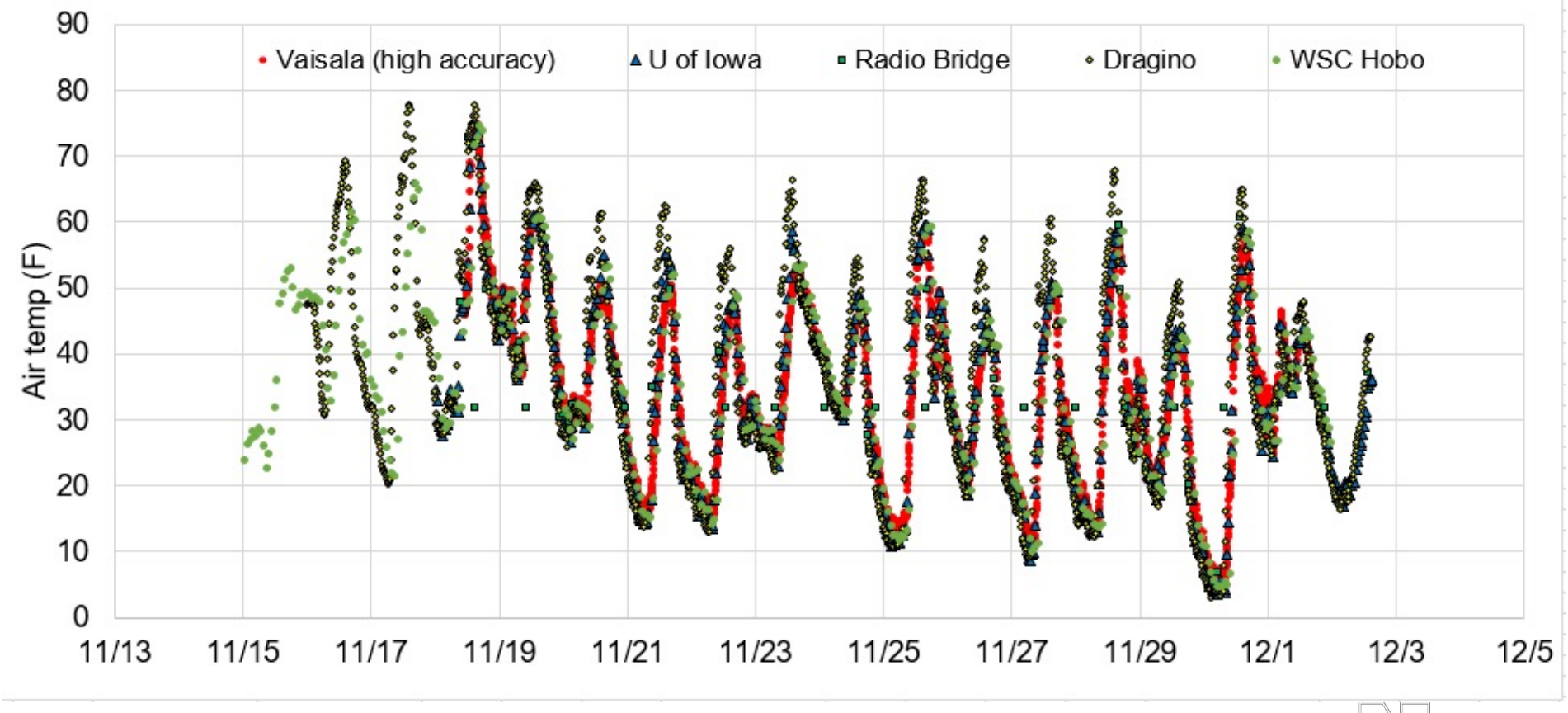


Testing temp and RH sensors

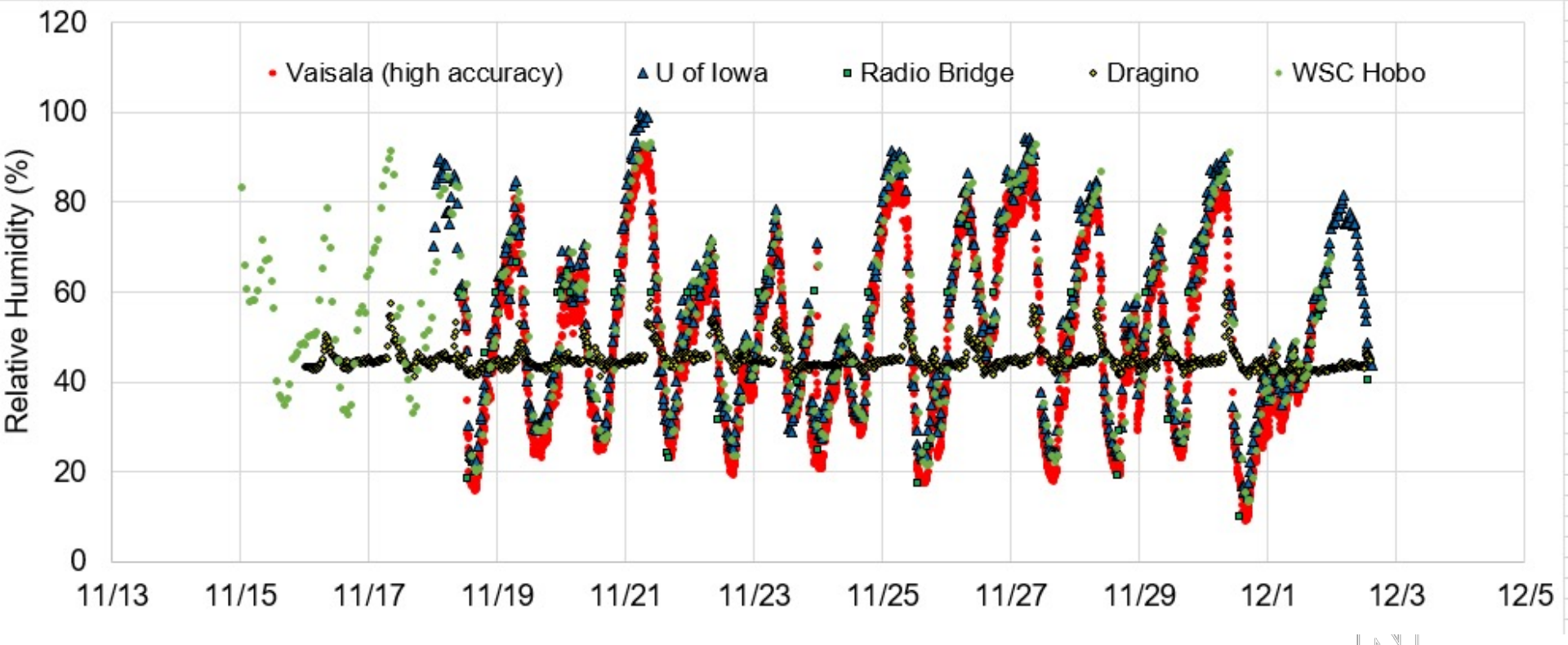


Courtesy:
Prof. Xin Qiao
U. Nebraska - Lincoln

Temperature

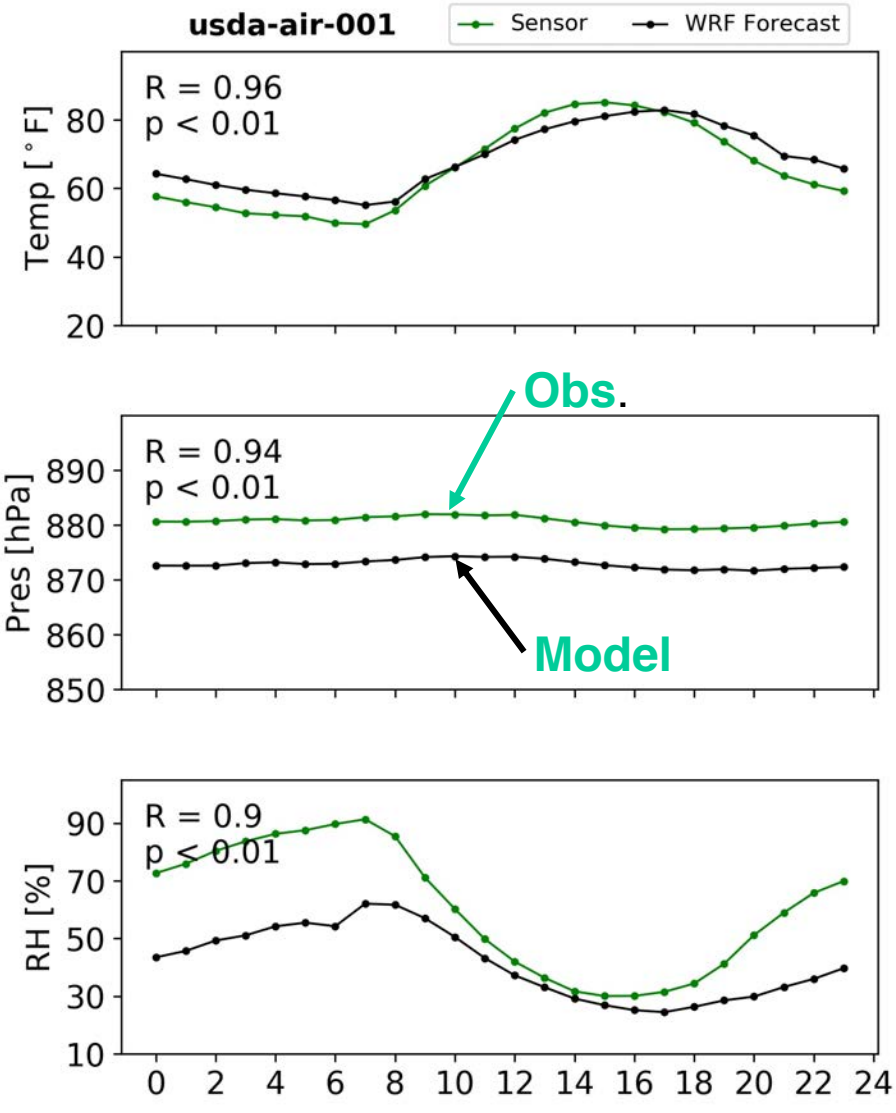


Relative humidity



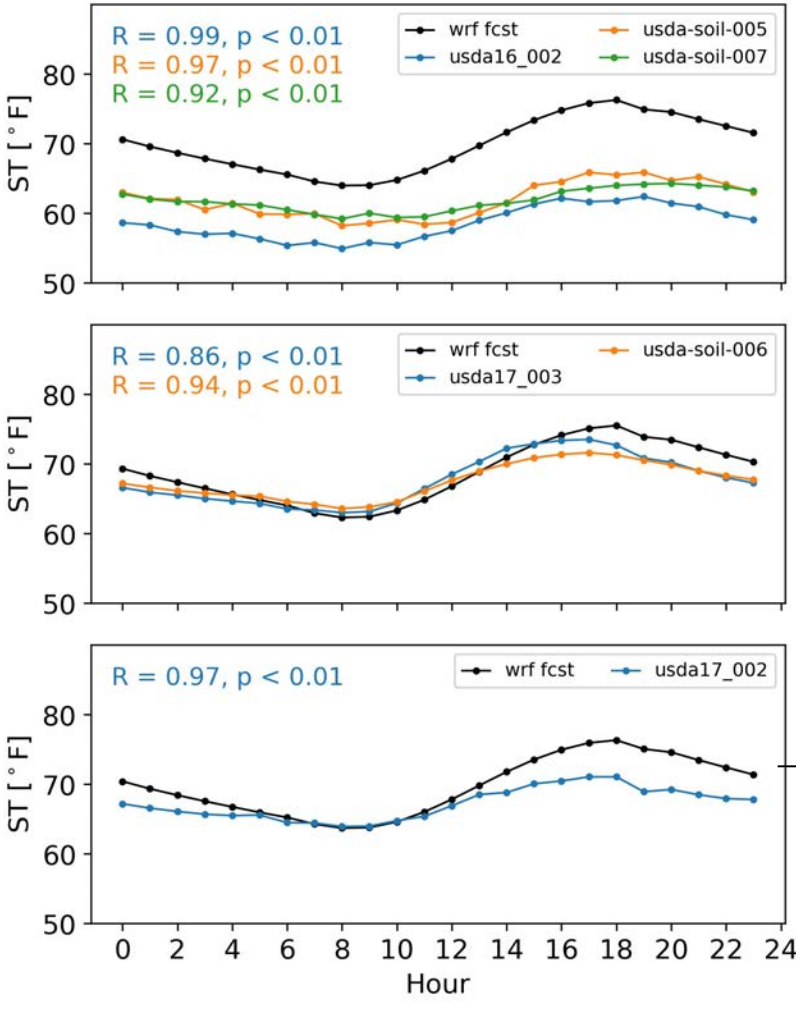
Forecast Evaluation

Air temperature, RH, and Pressure



Forecast Evaluation

Soil temperature, 10 cm below surface



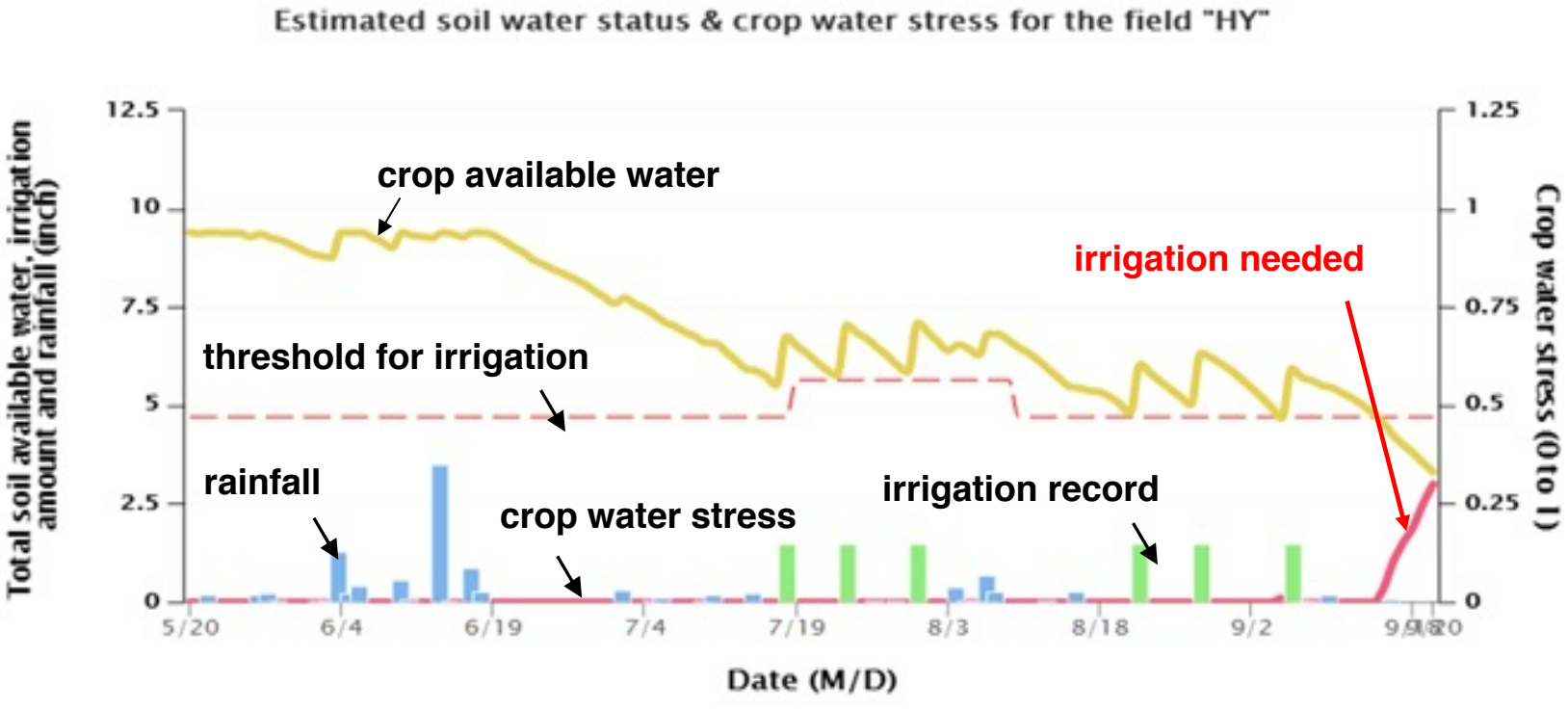
Irrigated

Rainfed

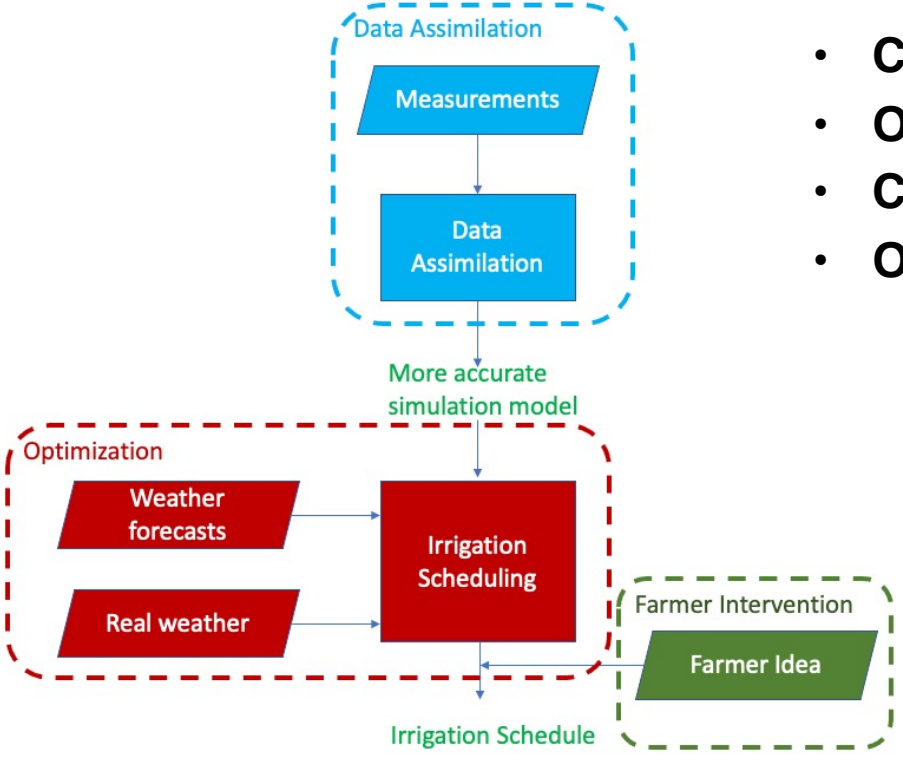
irrigated

Irrigated fields clearly has lower soil moisture and is not captured by the model.

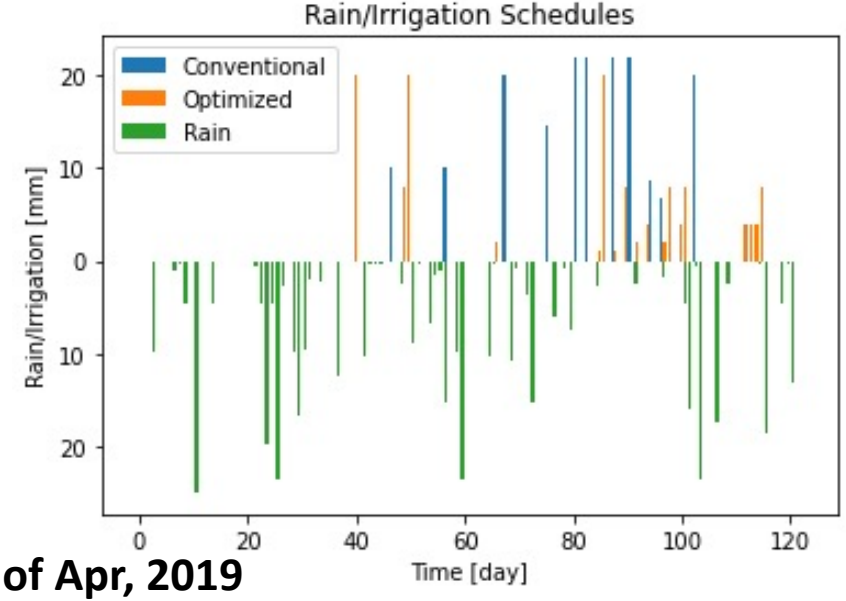
Crop Modeling



Irrigation Scheduling Optimization: Preliminary Results



- Conventional: 178 mm
- Optimized: 106 mm
- Conventional Dry Matter: 13842 kg/ha
- Optimized Dry Matter: 15211 kg/ha

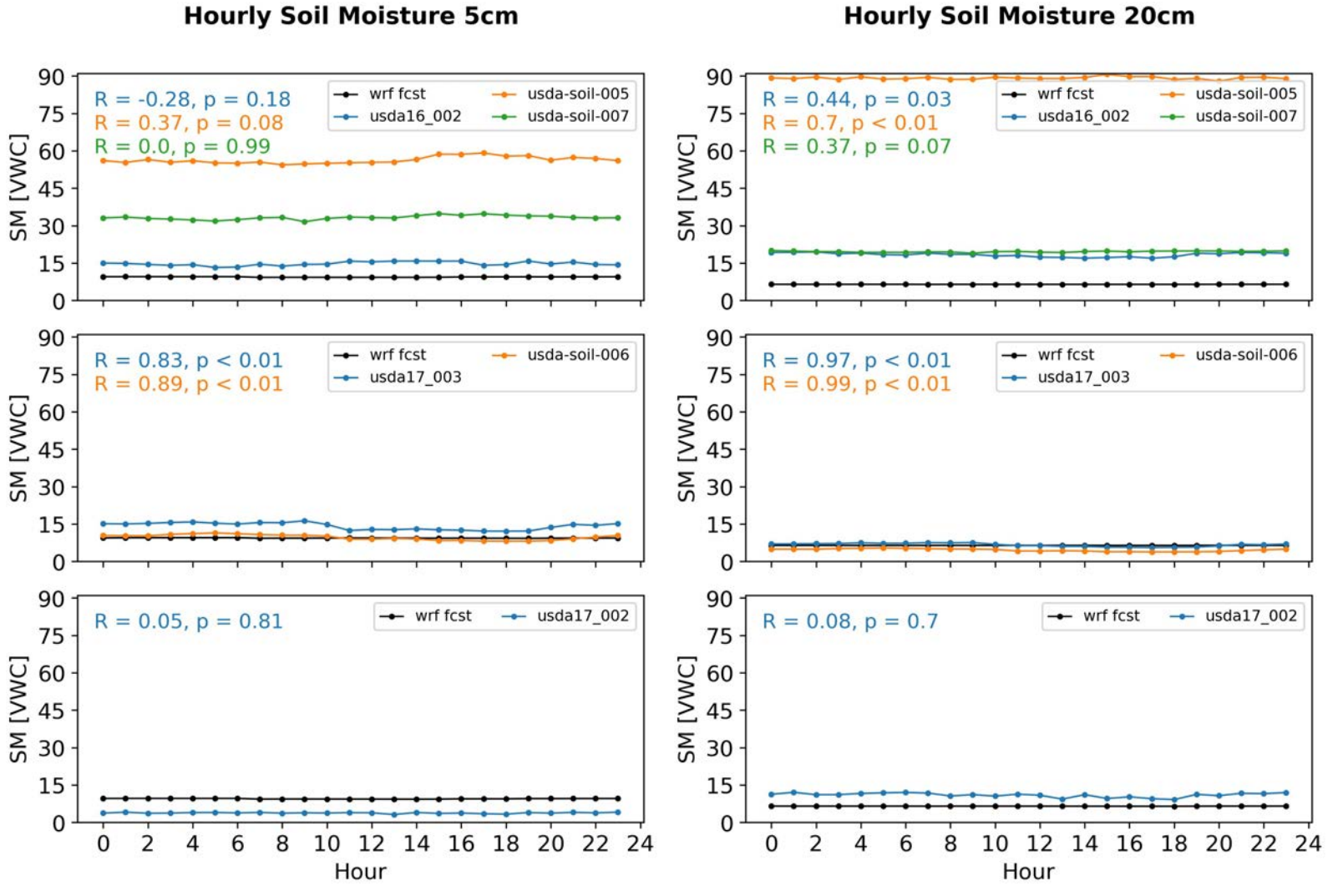


26th of Apr, 2019

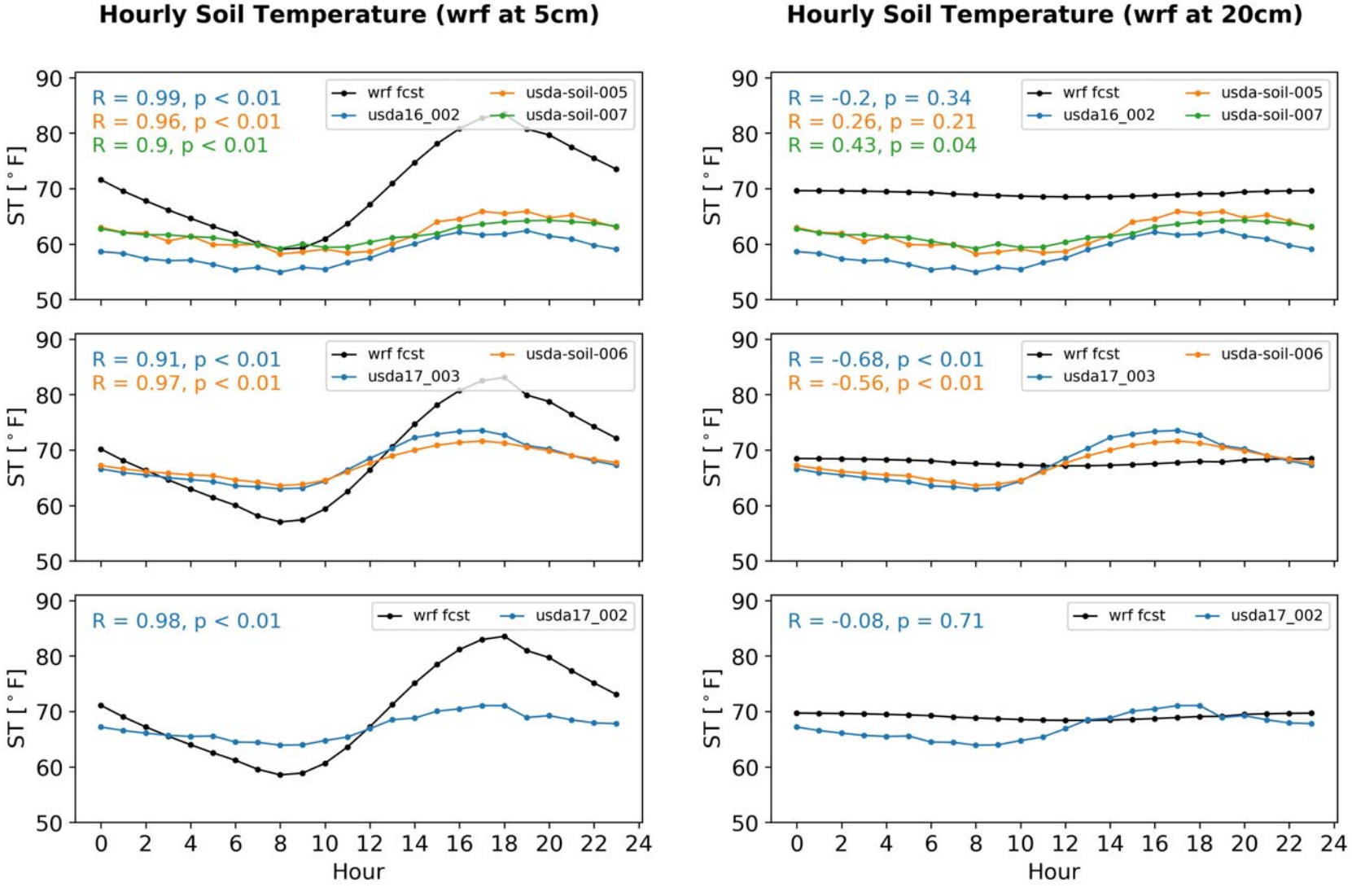
Thank you !

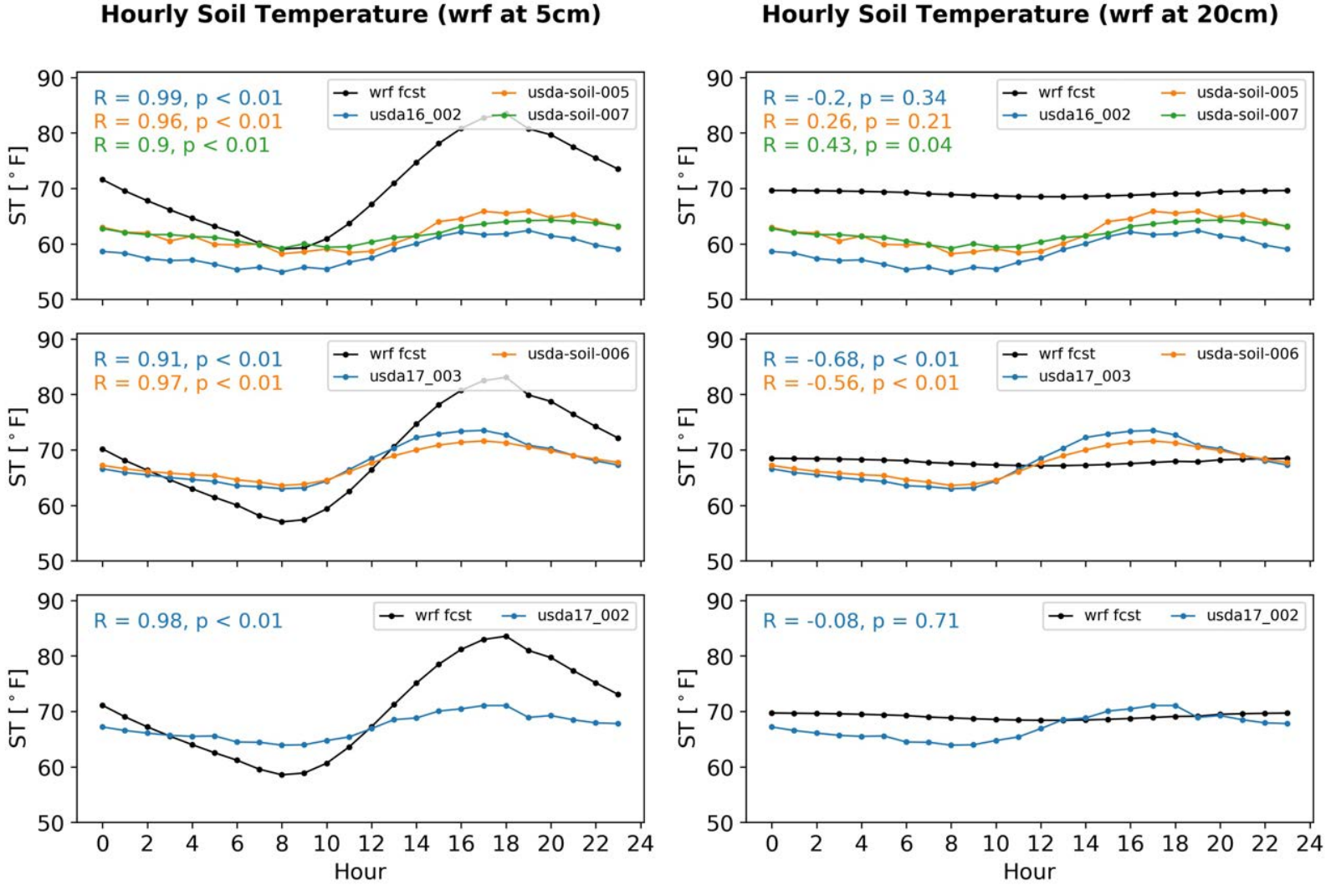
United States Department of Agriculture
National Institute of Food and Agriculture

Award #: 2019-67021-29227


Hourly Soil Moisture 5cm
Hourly Soil Moisture 20cm
SM [VWC]
Hour
R = -0.28, p = 0.18
R = 0.37, p = 0.08
R = 0.0, p = 0.99
R = 0.44, p = 0.03
R = 0.7, p < 0.01
R = 0.37, p = 0.07
R = 0.83, p < 0.01
R = 0.89, p < 0.01
R = 0.97, p < 0.01
R = 0.99, p < 0.01
R = 0.05, p = 0.81
R = 0.08, p = 0.7
wrf fcst
usda16_002
usda-soil-005
usda-soil-007
usda17_003
usda-soil-006
usda17_002


MMATIC


Hourly Soil Temperature (wrf at 5cm)
Hourly Soil Temperature (wrf at 20cm)
R = 0.99, p < 0.01
R = 0.96, p < 0.01
R = 0.9, p < 0.01
wrf fcst
usda16_002
usda-soil-005
usda-soil-007
R = -0.2, p = 0.34
R = 0.26, p = 0.21
R = 0.43, p = 0.04
R = 0.91, p < 0.01
R = 0.97, p < 0.01
usda17_003
usda-soil-006
R = -0.68, p < 0.01
R = -0.56, p < 0.01
R = 0.98, p < 0.01
usda17_002
R = -0.08, p = 0.71
ST [° F]
Hour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ST [° F]
Hour
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wrf fcst
usda16_002
usda-soil-005
usda-soil-007
usda17_003
usda-soil-006
usda17_002