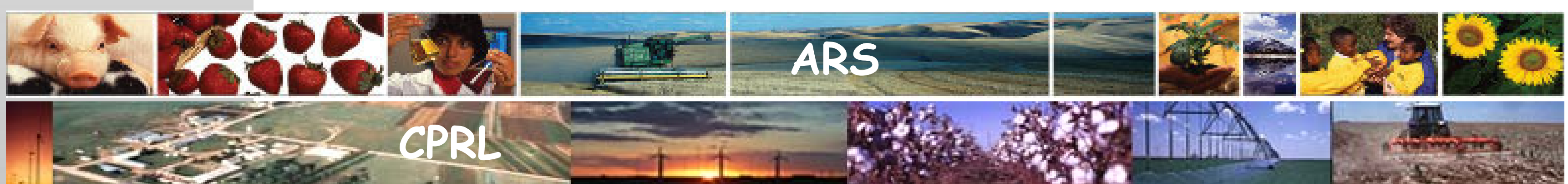
Irrigation Research for CIRE Meeting, Uvalde 21-22 May 2008

USDA-ARS
Conservation & Production Research Laboratory
Soil & Water Management Research Unit
Bushland, Texas



SWMRU Organization (~$5.2 M)

CRIS #1
Improving Soil and Water Management Practices in Cropping and Integrated Crop-Livestock Systems
6209-12130-002-00D (~$500 K) (~2 FTE)

CRIS #2
Irrigation Management and Automation for Increased Water Use Efficiency
6209-13000-012-00D (~$1.1 M) (~3+ FTE)

CRIS #3
Irrigation Management and Automation for Increased Water Use Efficiency
6209-13000-013-00D (~$3.6 M)) (~5 FTE)
ARS Bushland & Lubbock/Kansas State Univ./Texas AgriLife Research & Extension Service/Texas Tech Univ./West Texas A&M Univ.

Irrigation Research Staff

- Terry Howell, P.E.
  - Research Leader (Agric. Engr.)
    - Irrigation Technology
    - Evapotranspiration
    - Energy Balance
- R. Louis Baumhardt
  - Res. Soil Scientist
    - Deficit Irrigation
    - Crop Simulation
    - Residue Management
- José Chavéz [Post Doc]
  - Agricultural Engineer
    - Remote Sensing
    - Evapotranspiration
    - Energy Balance
- Paul Colaizzi, E.I.T.
  - Agricultural Engineer
    - Irrigation Technology
    - Remote Sensing
    - Evapotranspiration
    - Energy Balance

Irrigation Research Staff

- Steve Evett
  - Research Soil Scientist
    - Irrigation Automation
    - Soil Water Measurement
    - Evapotranspiration
    - Energy Balance
- Prasanna Gowda
  - Agricultural Engineer
    - Remote Sensing
    - Evapotranspiration
    - Energy Balance
    - Groundwater

Jairo Hernandez [Post Doc]
  - Agricultural Engineer
    - Remote Sensing
    - Evapotranspiration
    - Energy Balance
    - Groundwater
- Susan O'Shaughnessy
  - Agricultural Engineer
    - Irrigation Automation
    - Remote Sensing
    - Water Quality

Irrigation Research Staff

- Robert Schwartz
  - Research Soil Scientist
    - Evaporation
    - Soil Water Measurement
    - Soil Physical Properties
    - Energy Balance
- Judy Tolk
  - Research Plant Physiologist
    - Evapotranspiration
    - Energy Balance
    - Soil Water Deficits
    - Plant Water Relations
- Karen Copeland (Cat. III)
  - Soil Scientist
    - Evapotranspiration
    - Energy Balance
- Vacancy (Currently Open)
  - Agric. Engr., Soil Sci., Res. Hydraulic Engr.
    - Cropping Systems
    - Irrigation/Precipitation Management
    - Irrigation Technology
- Collaborators (retired)
  - Paul Unger, Soil Sci.
  - Don Dusek, Agronomist

Center Pivot Automation and Control

- Objective: Automatic irrigation scheduling based on crop water stress feedback
  - Methods & Methods:
    - Remote sensing of crop canopy temperature using wireless network sensor systems of infrared thermometers
      - TTT algorithm to trigger automatic irrigations
      - Scaling to map canopy temperature of field at a specific time
    - Development of wireless sensor modules
    - Integration of an embedded computer at pivot for remote control, data capture and real-time management
  - Preliminary results: with mesh networking, wireless sensors have application in sprinkler irrigation management

Wireless Network Systems:

Communication:

•Unicast vs. broadcast

•Routers

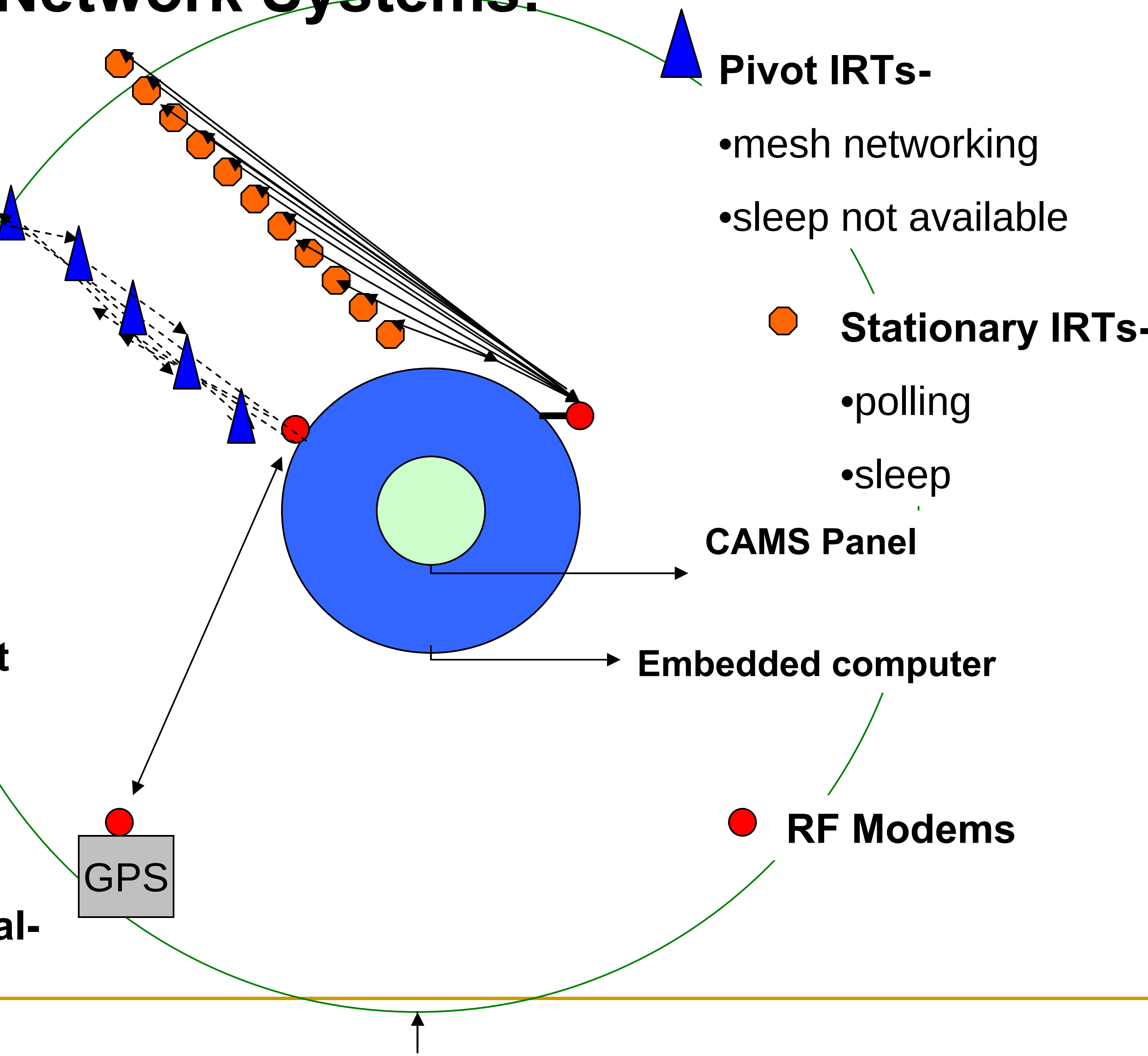
•Mesh capabilities

Data acquisition and management with VS 2005:

• **error checking**

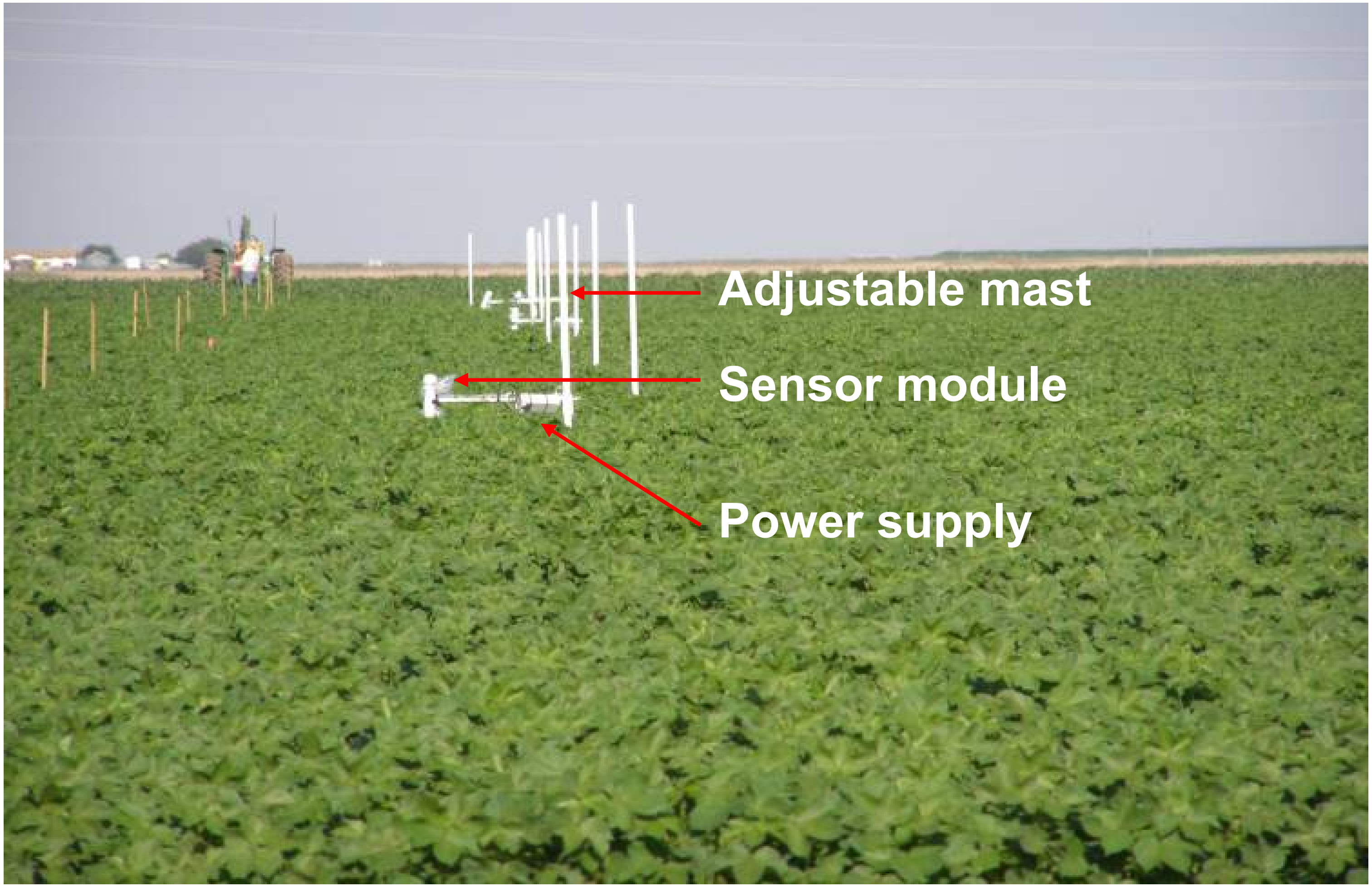
• **interpolation**

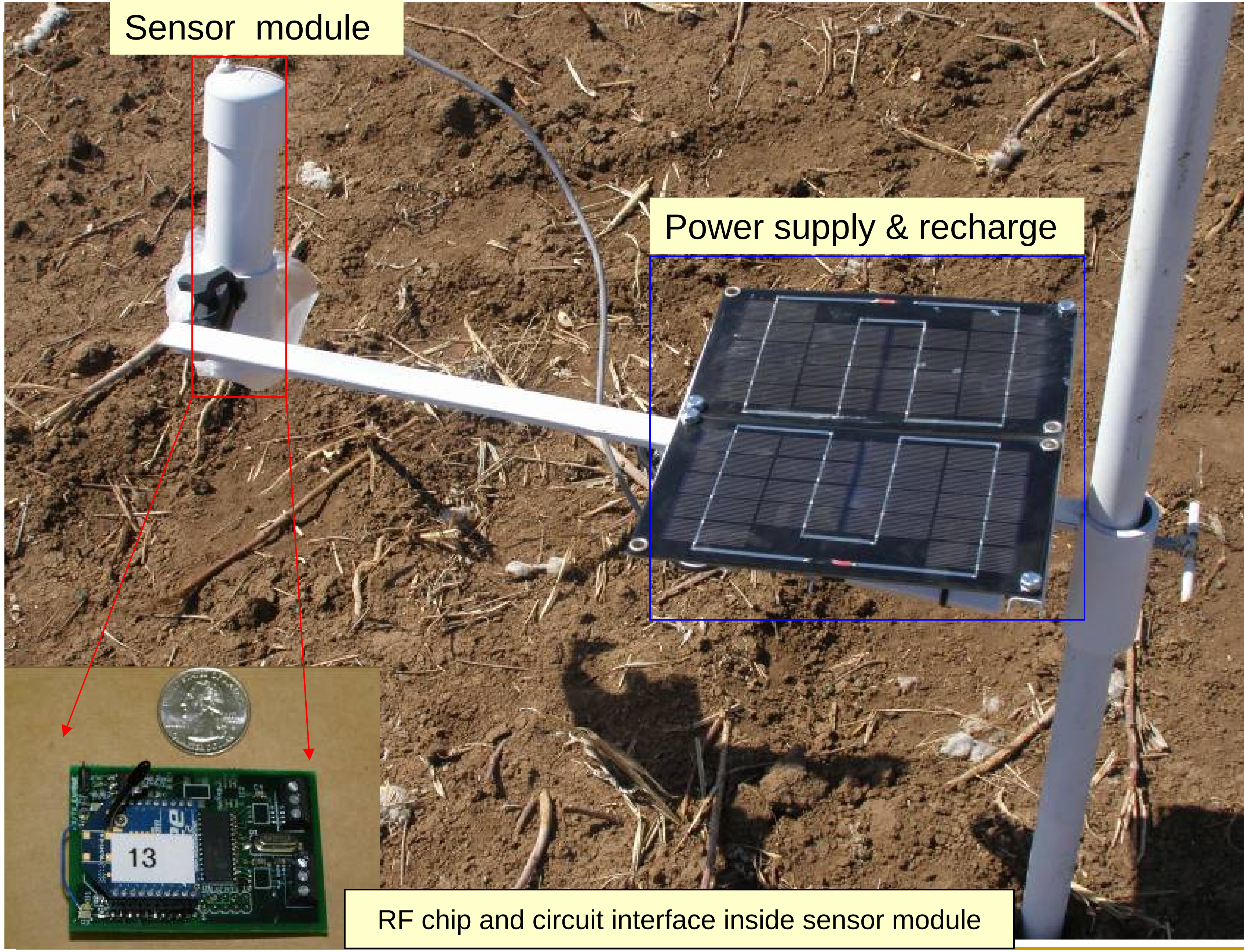
•**GUI interface real-time monitoring**



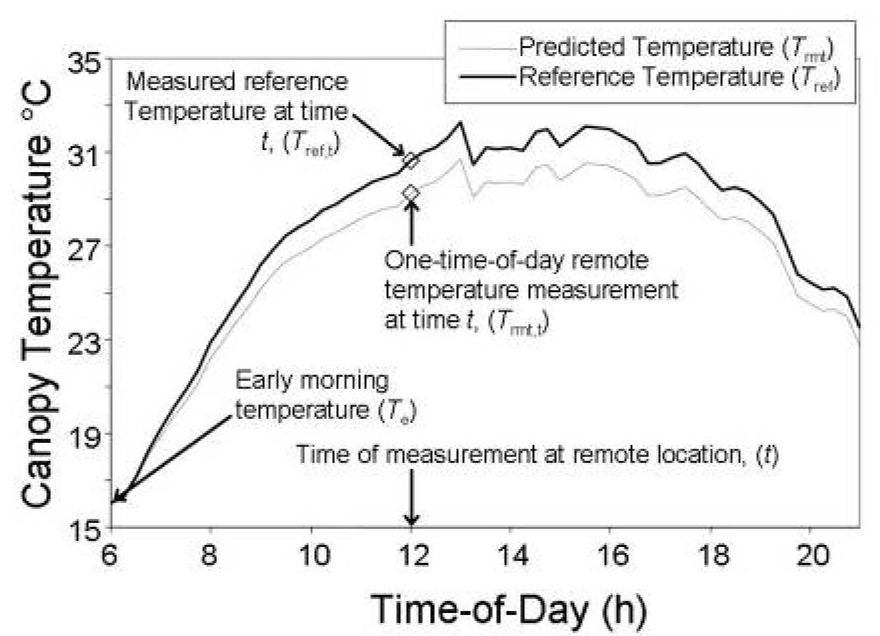
Wireless Infrared Thermometer Sensor Network System

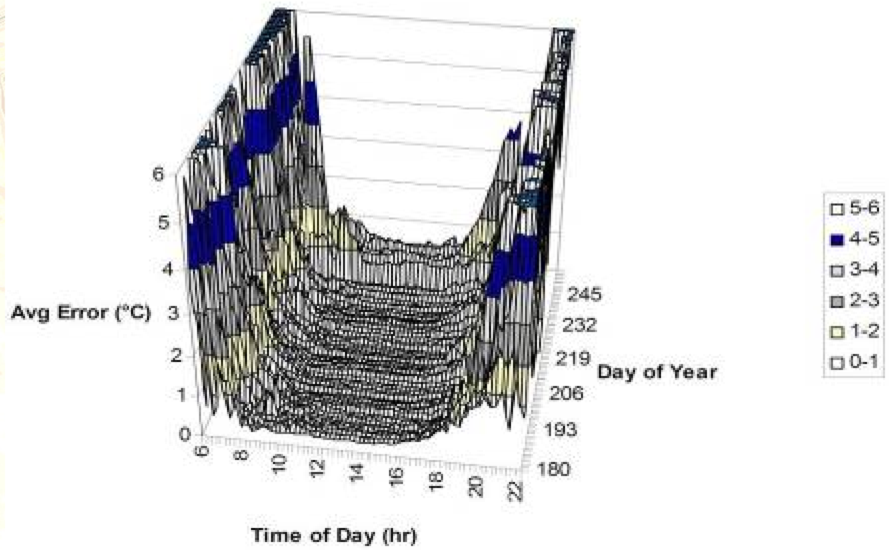
Field Network:

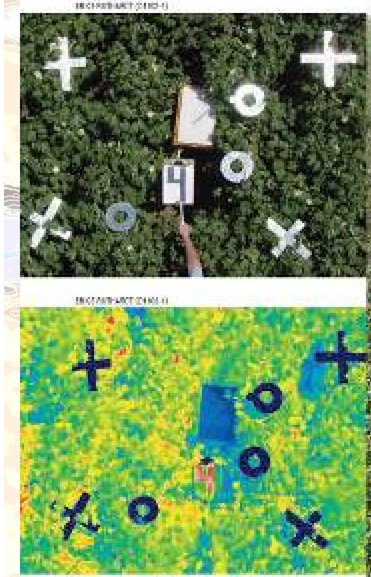



Sensor module
Power supply & recharge
13
RF chip and circuit interface inside sensor module

Irrigation Automation

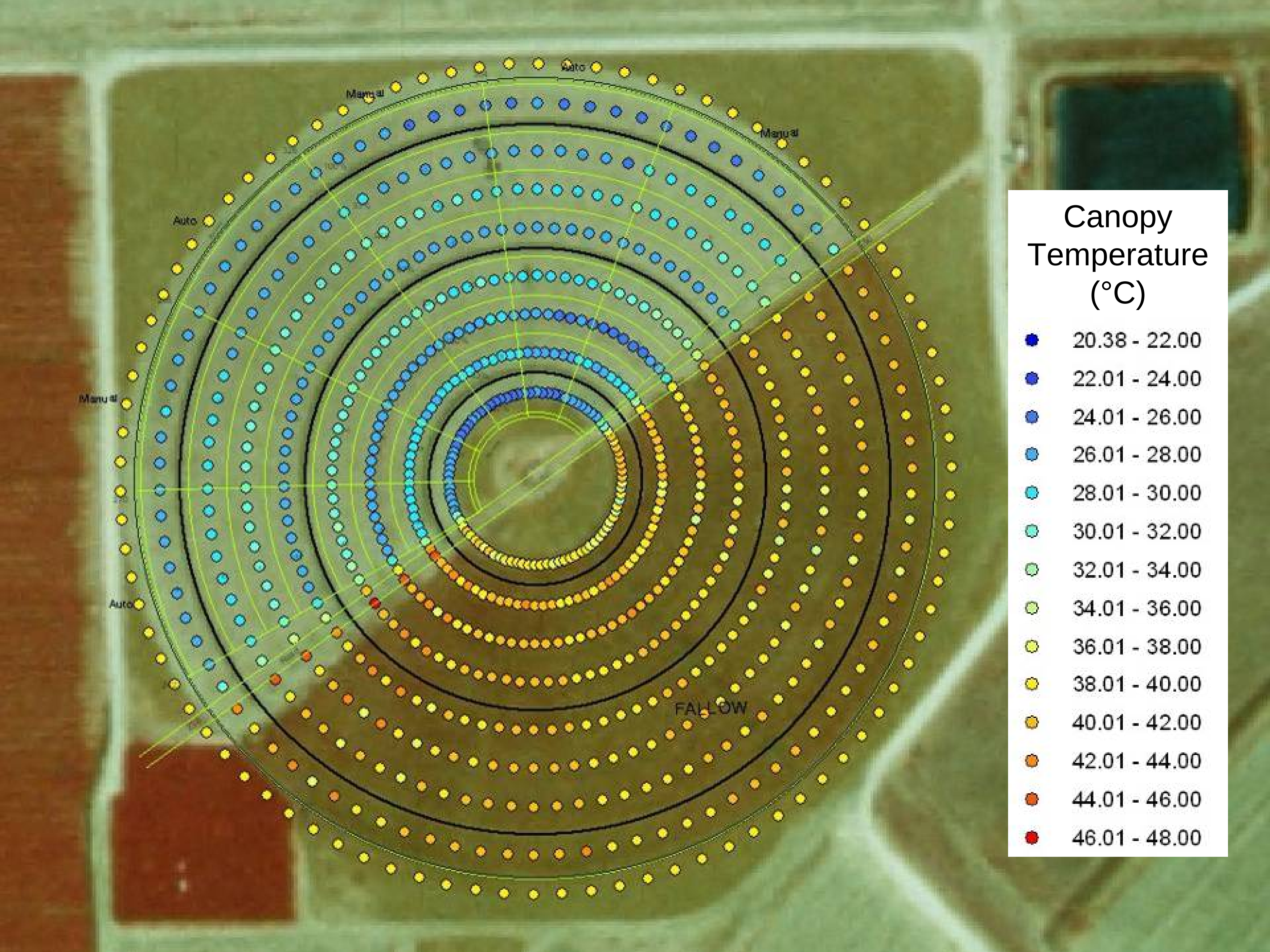






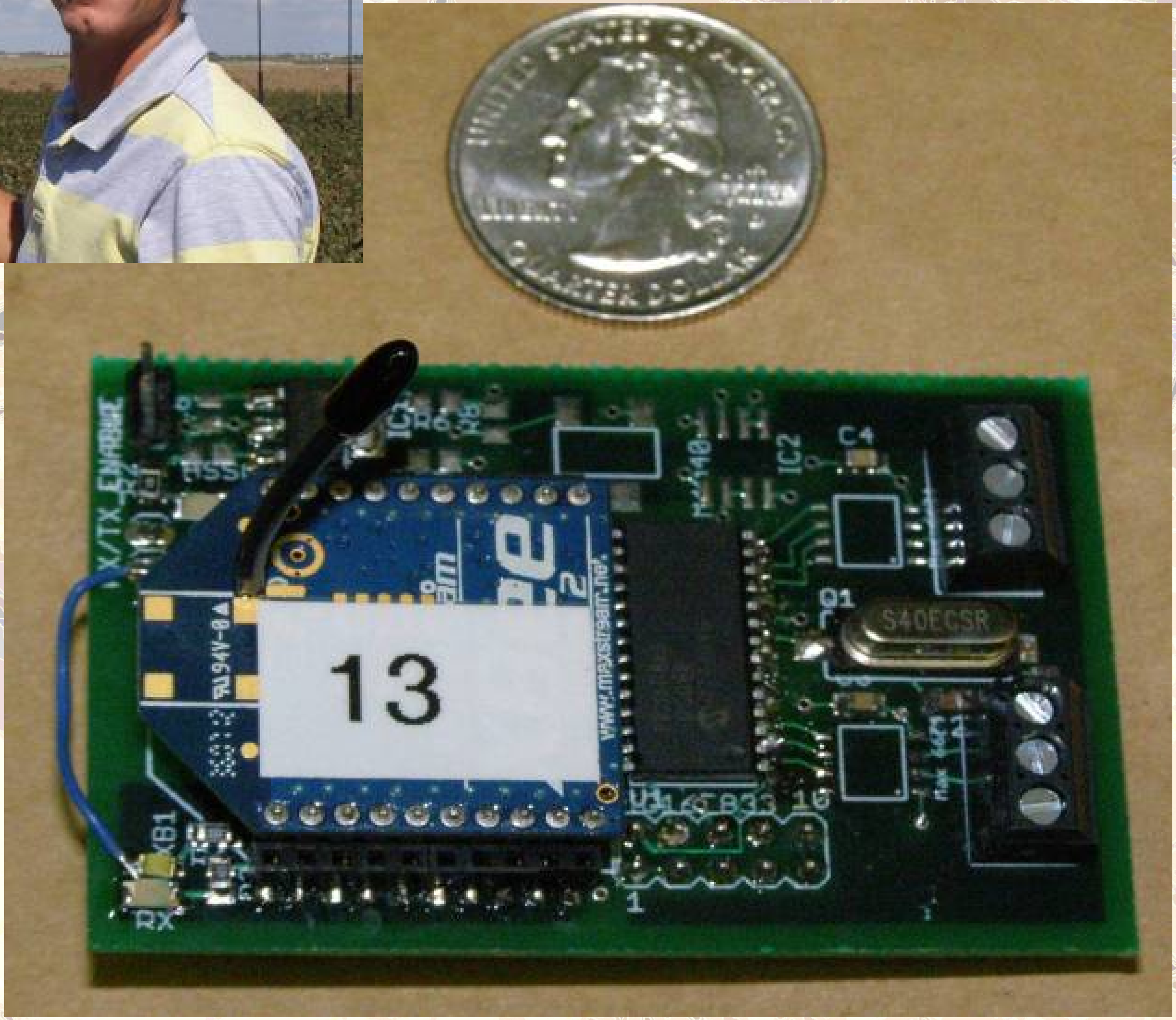
The crosses visible in the photo (above, top) and in the infrared (IR) image (above, bottom) are for coregistration of the images from the two cameras. Coregistration allows identification of individual leaves. The circles are placed around individual leaves, which were later cut for determination of leaf water potential, a key indicator of plant water stress. In the IR image, the reddish areas are at 44°C, the leaves within the circles are at 33°C, and the blue rectangle (white in the color photograph) is a wet reference surface at 26°C. Scientists determined the relationships among leaf water potential, leaf temperature determined by the infrared camera, and multispectral measurements, which are useful in automating irrigation applications for efficient water use. The plot received the normal full irrigation amount.

Technician Brice Ruthardt takes vertical images in the infrared and ordinary spectrums of cotton under water stress. Agricultural engineers Susan O'Shaughnessy (left) and Terry Howell (center) are taking multispectral measurements while soil scientist Steve Evett holds a reference target.

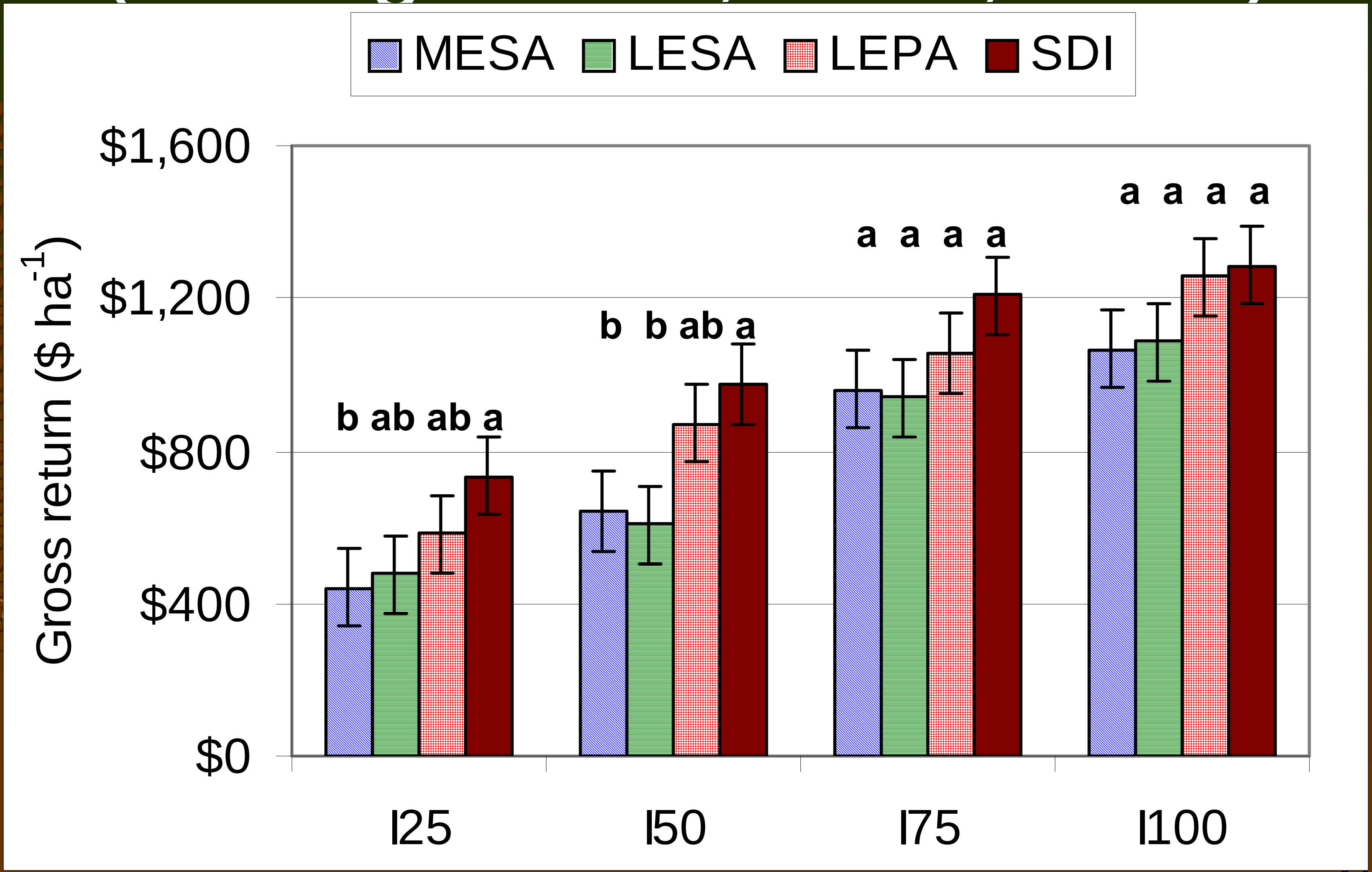

Canopy Temperature (°C)
20.38 - 22.00
22.01 - 24.00
24.01 - 26.00
26.01 - 28.00
28.01 - 30.00
30.01 - 32.00
32.01 - 34.00
34.01 - 36.00
36.01 - 38.00
38.01 - 40.00
40.01 - 42.00
42.01 - 44.00
44.01 - 46.00
46.01 - 48.00
Auto
Manual
FALLOW

Gen I in field

Gen II Prototype

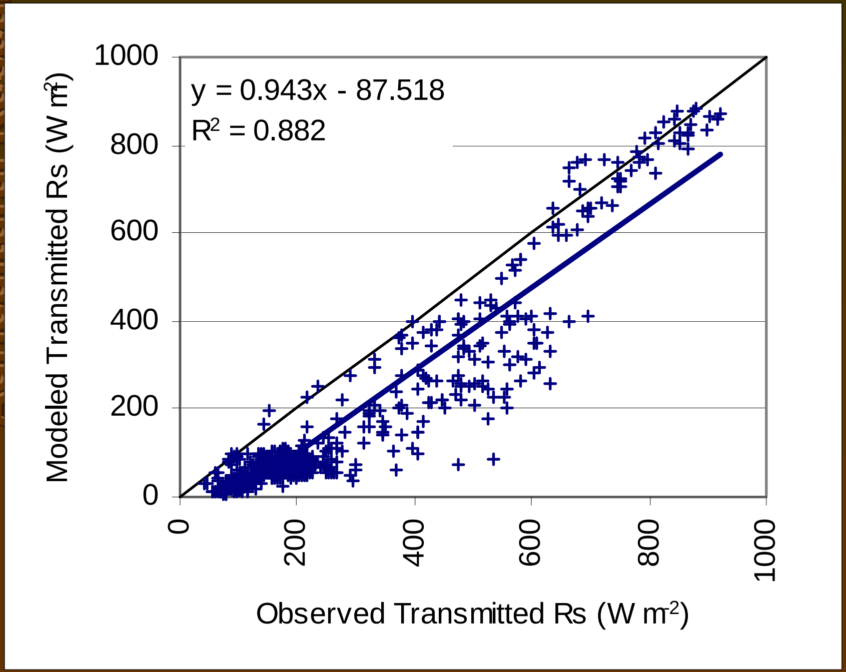


Gross Return
(average 2003, 2004, 2006)

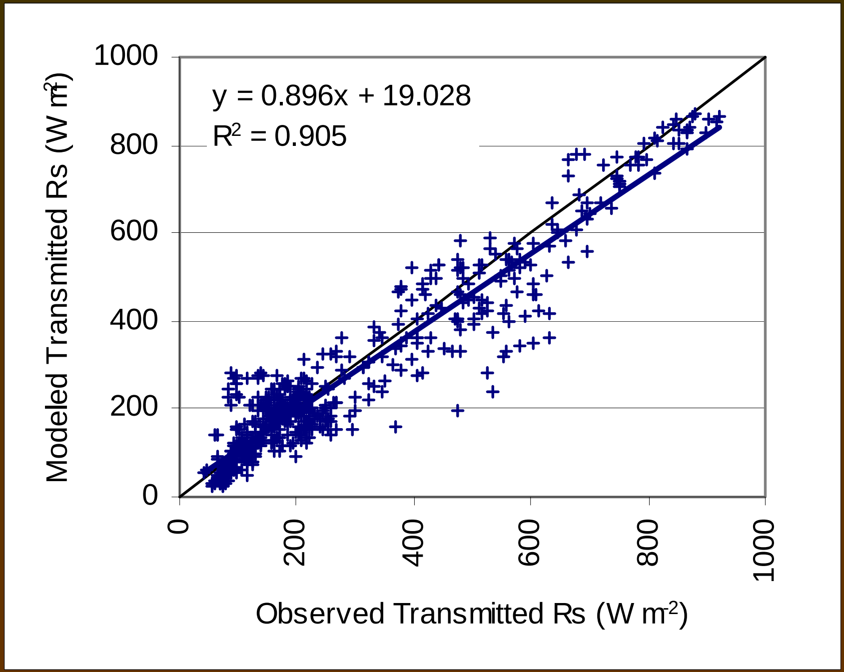


Transmitted shortwave radiation (T-Rs) through a corn canopy

Commonly used simple model greatly under predicts T-Rs



Improved agreement by accounting for PAR, NIR, direct, diffuse, and sun-canopy angles

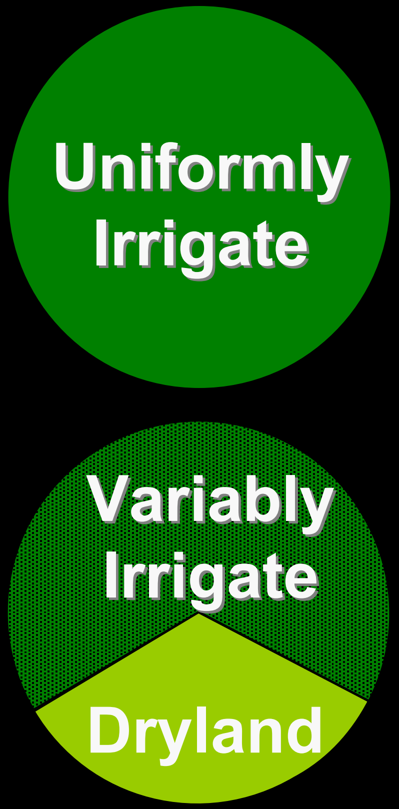


SIMULATIONS

- We simulated growth and yield of grain sorghum with SORKAM and cotton using GOSSYM.
- Input weather data was from long-term (1959-2000) records at Bushland included: daily solar irradiance, maximum and minimum air temperature, precipitation, and wind run.
- Crop culturing practices (e.g., planting date and population, row spacing, and fertility) were typical for use on a Pullman soil.

CONCLUSION

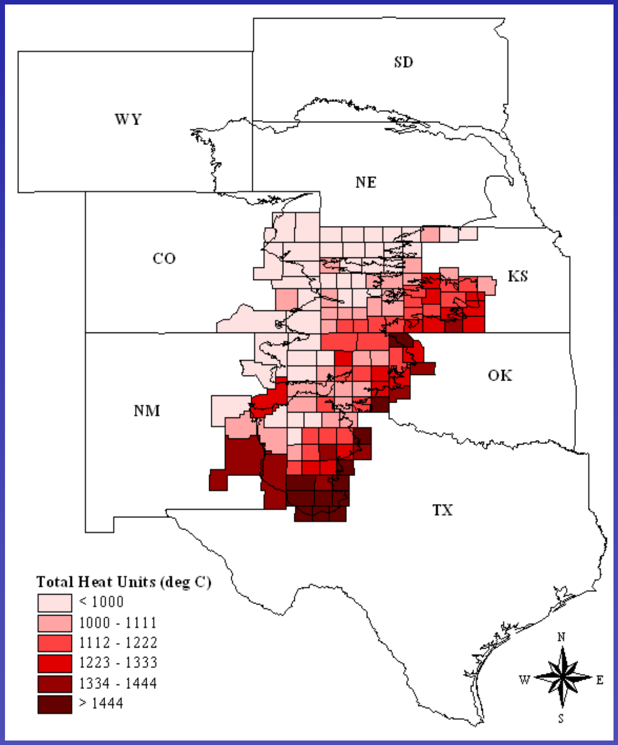
- As irrigation water resources decline, crop yields and water use efficiency can be maintained or increased by converting uniform deficit irrigation (water spreading) to variable irrigation (concentrating water) on a part of the field with a complementary dryland area.

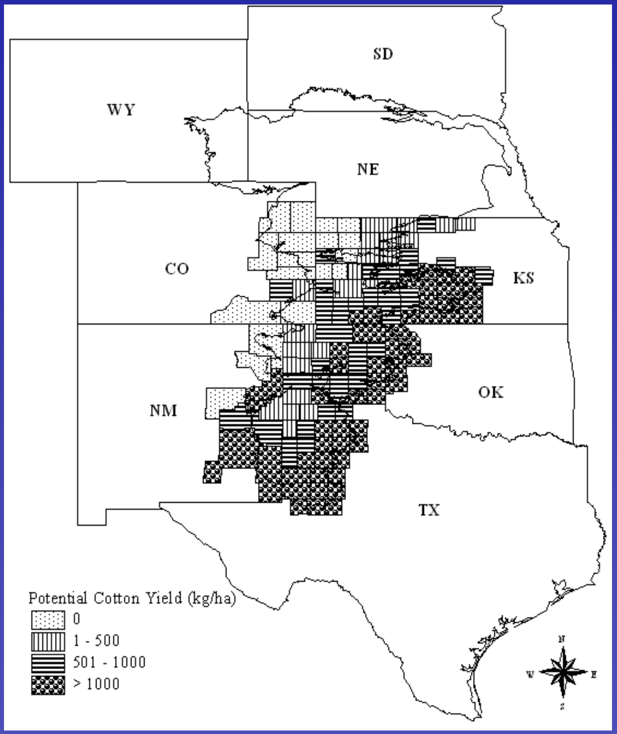


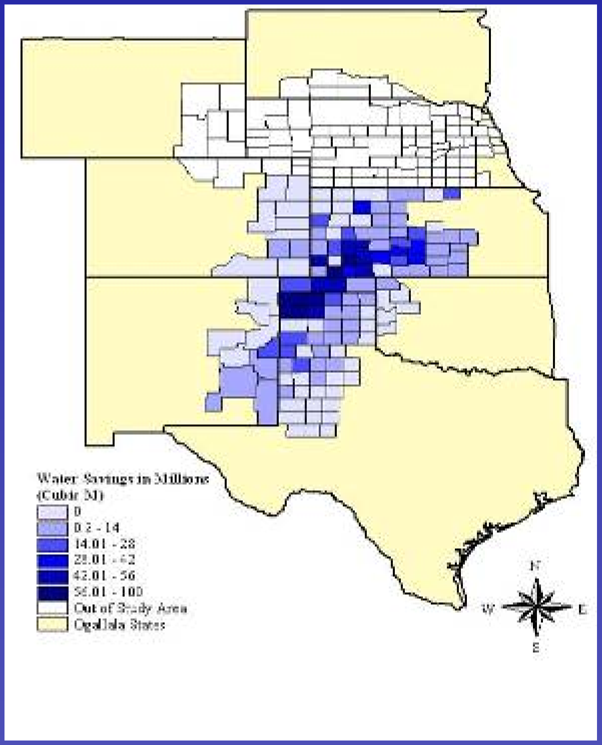
Research Projects (Gowda)

- Development of Landsat TM-based tillage and LAI models for the Texas High Plains
- Suitability of cotton as an alternative crop in the Ogallala Aquifer Region
- GIS database development – Filling the knowledge gaps
- Rainfall variability in the Ogallala Aquifer Region
- Bushland Evapotranspiration and Agricultural Remote Sensing Experiment 2007 (BEAREX07)
- Groundwater modeling project

Suitability of Cotton as an alternative Crop in the Ogallala Aquifer Region







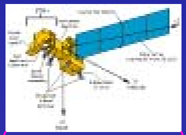
Suitability of cotton as an alternative crop in the Ogallala Aquifer Region (Gowda, Baumhardt, Esparza, Howell, and Marek, 2007; Agronomy Journal; In In Press)

Heat unit availability for cotton production in the Ogallala Aquifer Region (Esparza, Gowda, Baumhardt, Howell and Marek, 2007; Journal of Cotton Science; In Press)

Bushland Evapotranspiration And Agricultural Remote Sensing Experiment 2007 (BEAREX07)

Collaborators:
CPRL-USDA-ARS
USDA-ARS, Maricopa, AZ
Utah State University
University of Texas, Austin

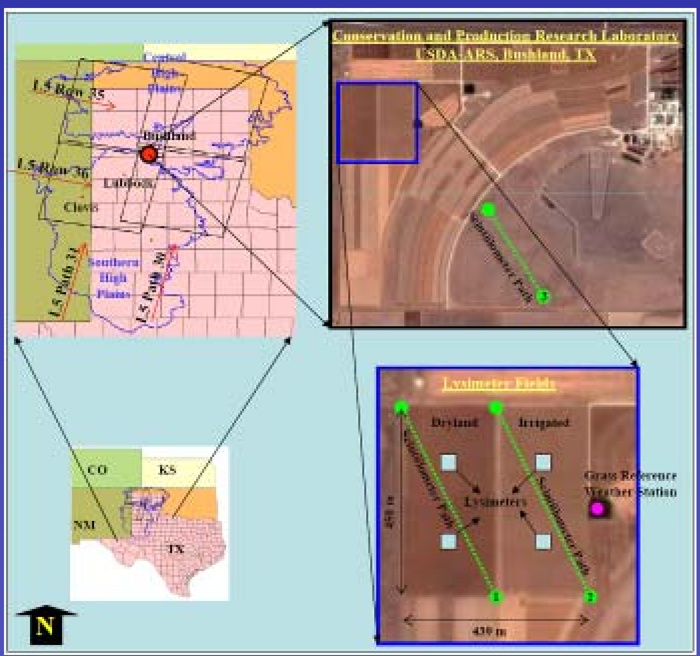
Visible & NIR
250 m
30 m
15 m



Thermal
1000 m
90 m
60 m

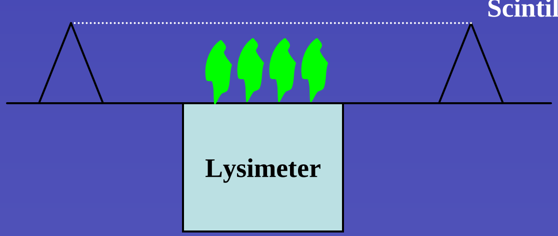
Remote Sensing Data Acquisition
Aircraft imagery
ASTER Satellite
Landsat 5 Satellite
MODIS
AVHRR
Aircraft

Groundtruthing:
5 Lysimeters
3 Scintillometers



1.0 m
0.5 m

1.8 m
4.5 m



Remote sensing based energy balance algorithms for mapping ET: Current status and challenges (Gowda, Chavez, Evett, Colaizzi, Howell and Tolk; Transactions of ASABE; Invited Paper; Accepted)

ET mapping for agricultural water management: Present status and challenges (Gowda, Chavez, Evett, Colaizzi, Howell and Tolk; Irrigation Science; Accepted)

Aerodynamic Temperature Modeling

LAS and lysimeters to Obtained measured H

$$U_2 = U_1 \frac{\ln\left(\frac{2-d}{Z_{om}}\right)}{\ln\left(\frac{1-d}{Z_{om}}\right)}$$

$H = \rho_a \; C_{pa} \; (T_{aero} - T_{air}) / r_{ah}$

$T_{aero} \Rightarrow f(T_s, T_{air}, LAI, U)$

$$H = \rho_a C_p \left(\overline{T_a' w'}\right)$$

T_{aero} Modeling

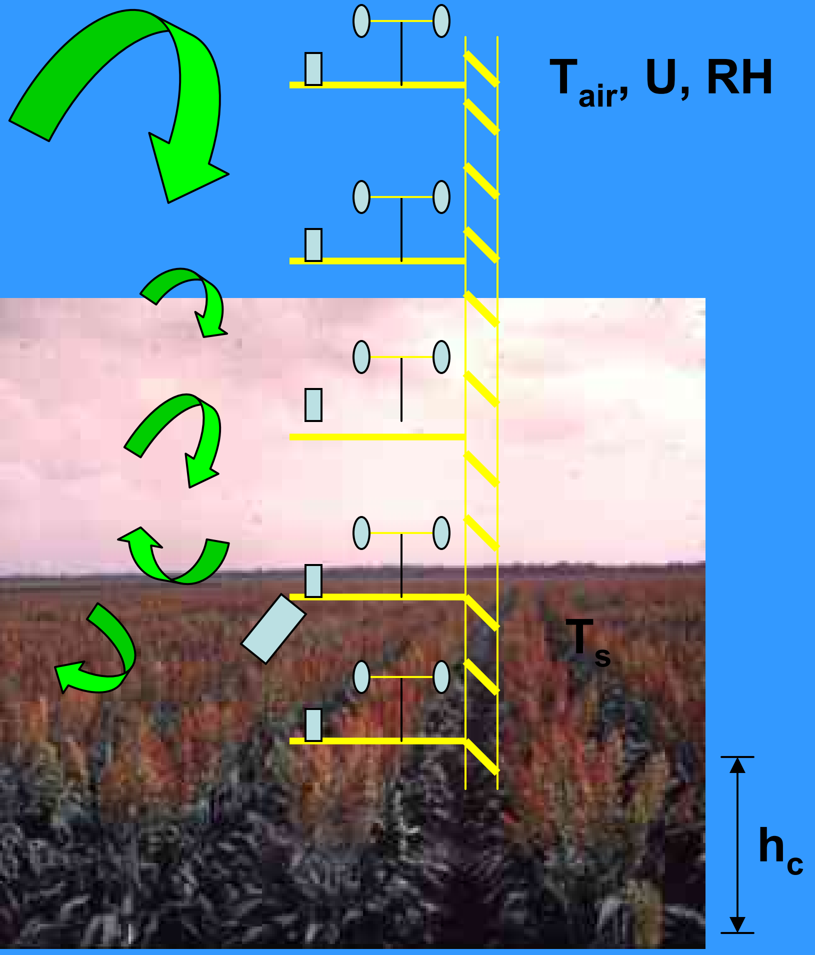
$H = \rho_a \; C_{pa} \, (T_{aero} - T_{air}) \, / \, r_{ah}$

$H = \rho_a \; C_{pa} \, \beta \, (T_s - T_{air}) \, / \, r_{ah}$

$\beta = 1 \, / \, EXP(L/(L-LAI)-1)$

$T_{aero} = (aT_s + b)$

$T_{aero} \Rightarrow f(T_s, T_{air}, LAI, U)$

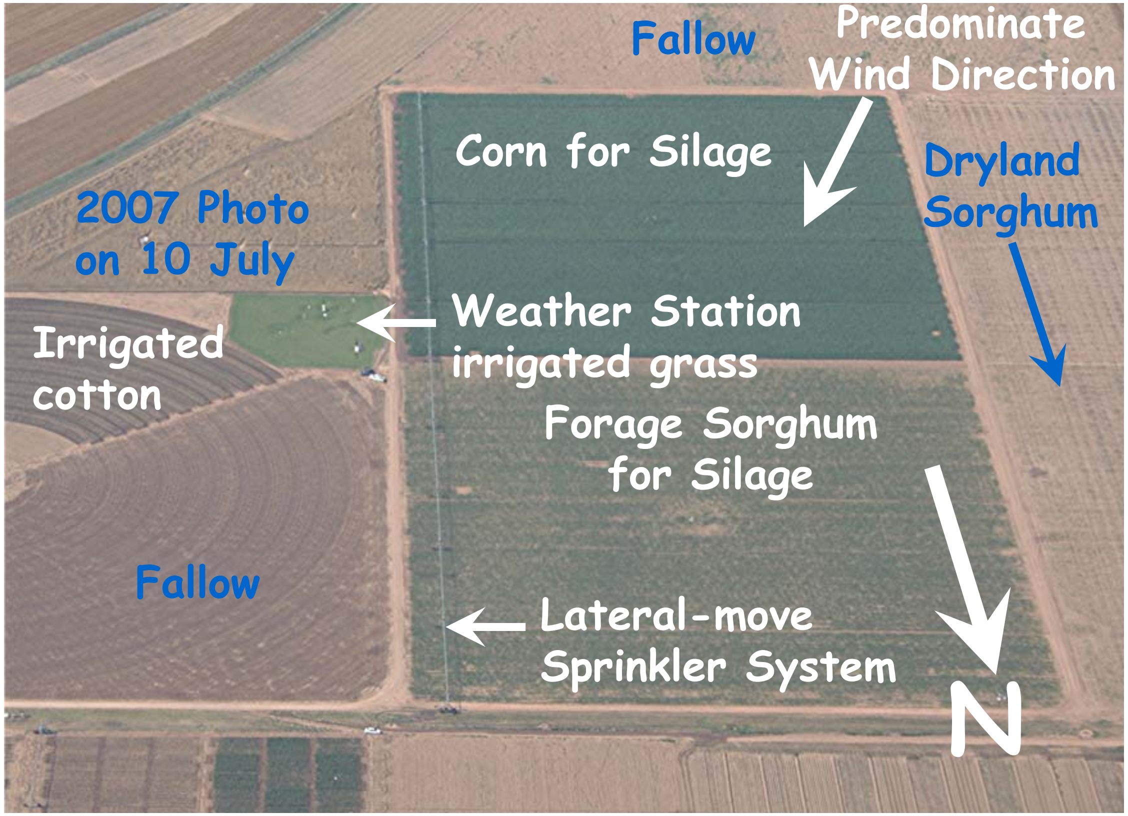


$$U_2 = U_1 \frac{\ln\left(\frac{2-d}{Z_{om}}\right)}{\ln\left(\frac{1-d}{Z_{om}}\right)}$$

$$H = \rho_a C_p \left(\overline{T_a' w'}\right)$$

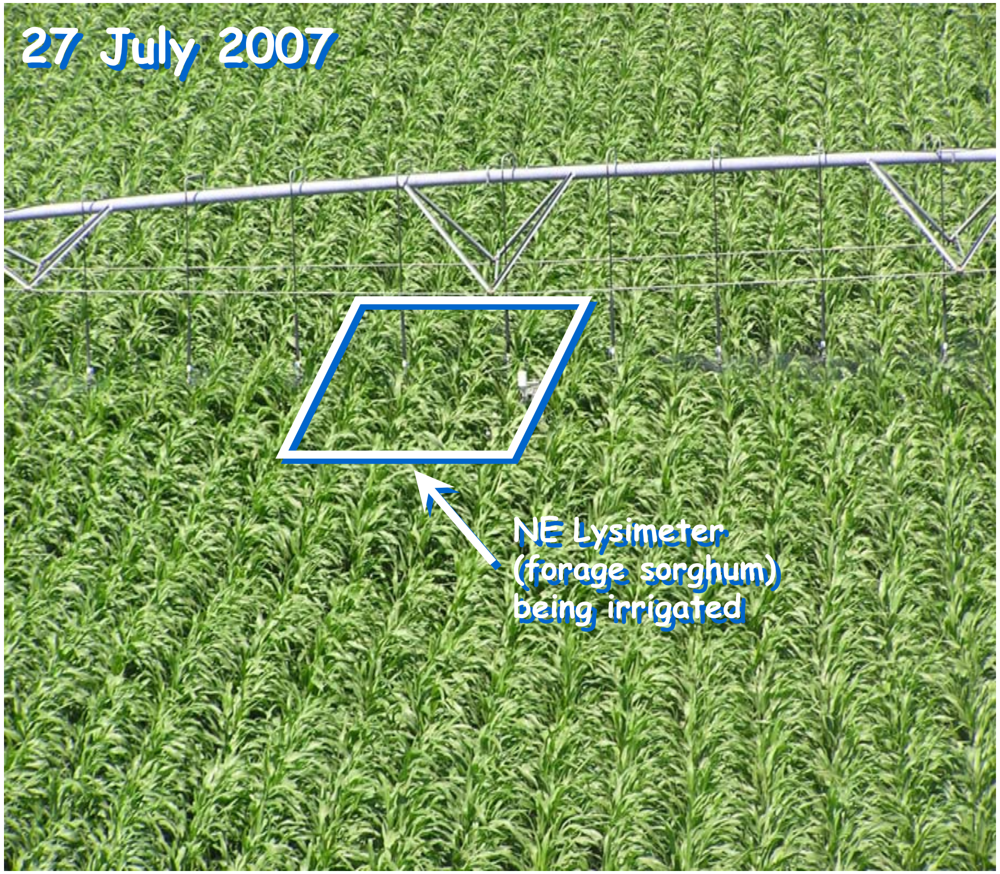
USDA-ARS-Conservation & Production Research Laboratory, Bushland, Texas

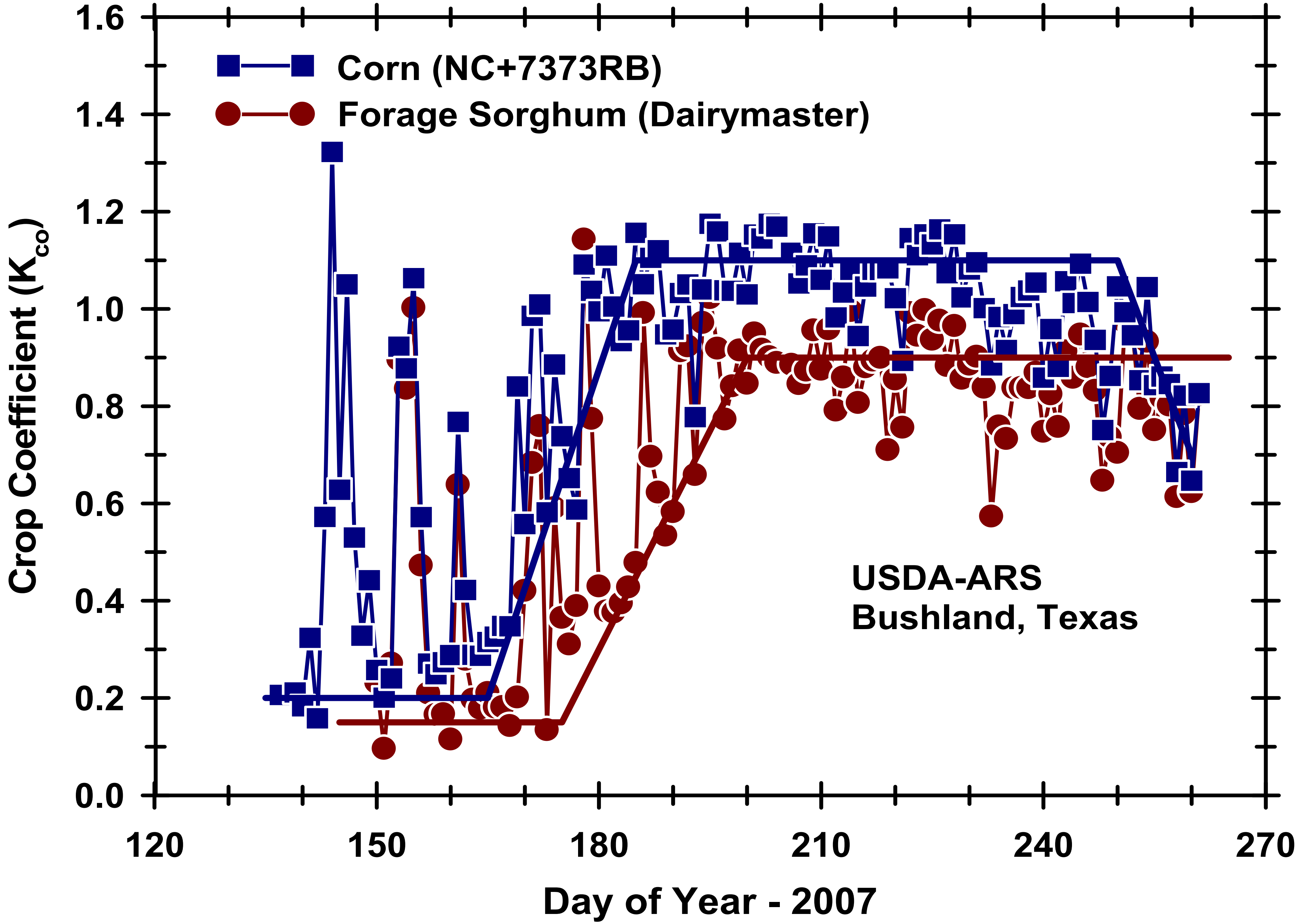
- Pullman clay loam soil
- Sprinkler irrigated
- 4.4 ha fields (210 m x 210 m)
- Two weighing lysimeters
- Furrow diked



Data

- Lysimeters
  - 3 m x 3 m x 2.3 m deep monoliths
  - counter-balanced scales
  - load cells
- Crop data
  - leaf area index
  - crop height
  - biomass (dry matter)
  - yield
- Soil water
  - neutron soil water meter
- Weather station data




Corn (NC+7373RB)
Forage Sorghum (Dairymaster)
USDA-ARS
Bushland, Texas
Crop Coefficient (K_{co})
Day of Year - 2007
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
120
150
180
210
240
270

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The End!

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http://www.cprl.ars.usda.gov