United States Department of Agriculture

Agricultural Research Service

Mapping ET in the High Plains of the United States

Prasanna H. Gowda

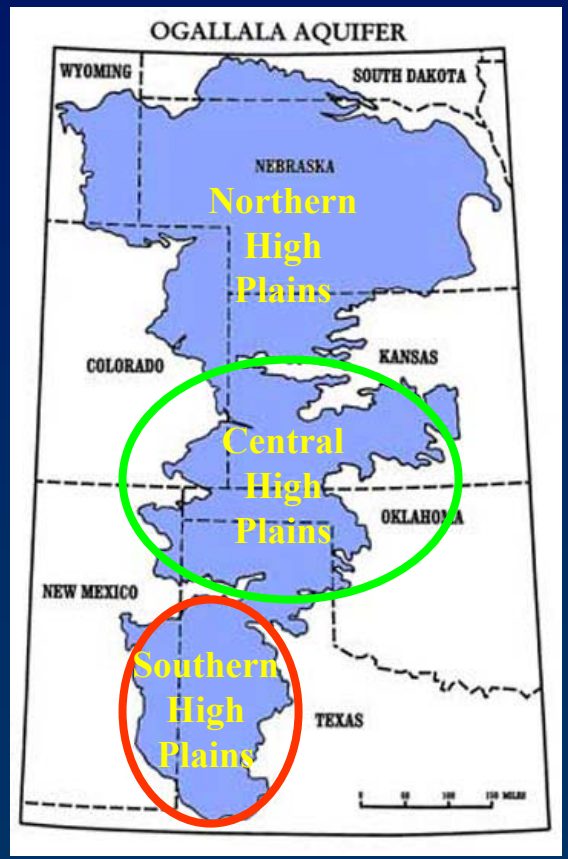
Conservation and Production Research Laboratory,
USDA-ARS, Bushland, TX

SOIL & WATER MANGEMENT RESEARCH

Background – Ogallala Aquifer Region

- Largest freshwater aquifer in the world
- Location
- Arid to semiarid

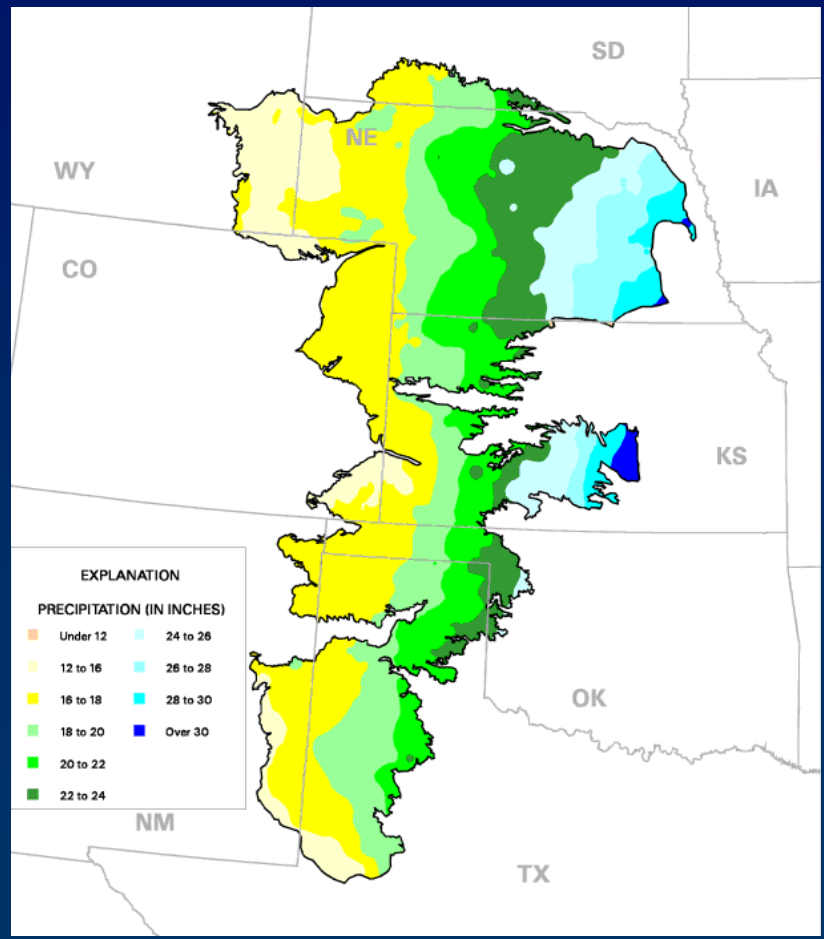
- Very high evaporative demand
- Crop water demand
  - Corn – 835 mm
  - Sorghum – 688 mm
  - Cotton – 647 mm
  - Wheat – 458 mm



Background – Ogallala Aquifer Region

- Rainfall: 366 – 813 mm
- Rainfall season
- Irrigation is needed

Precipitation (Inches)



Background

- Improve water use efficiency
- Requires improved irrigation scheduling techniques
- Need for high spatial and temporal resolution ET maps

Do we have the technology?

- Remote sensing based energy balance models
  - ➔ Need evaluation – submodel development
- Actual ET measurement
  - ➔ Lysimeters
  - ➔ Eddy Covariance systems
  - ➔ Bowen Ratio System
  - ➔ Scintillometer
- Data?

BEAREX07 - GOALS

- Evaluate Energy Balance based models for their ability to estimate ET at point, plot, field, and regional scales;

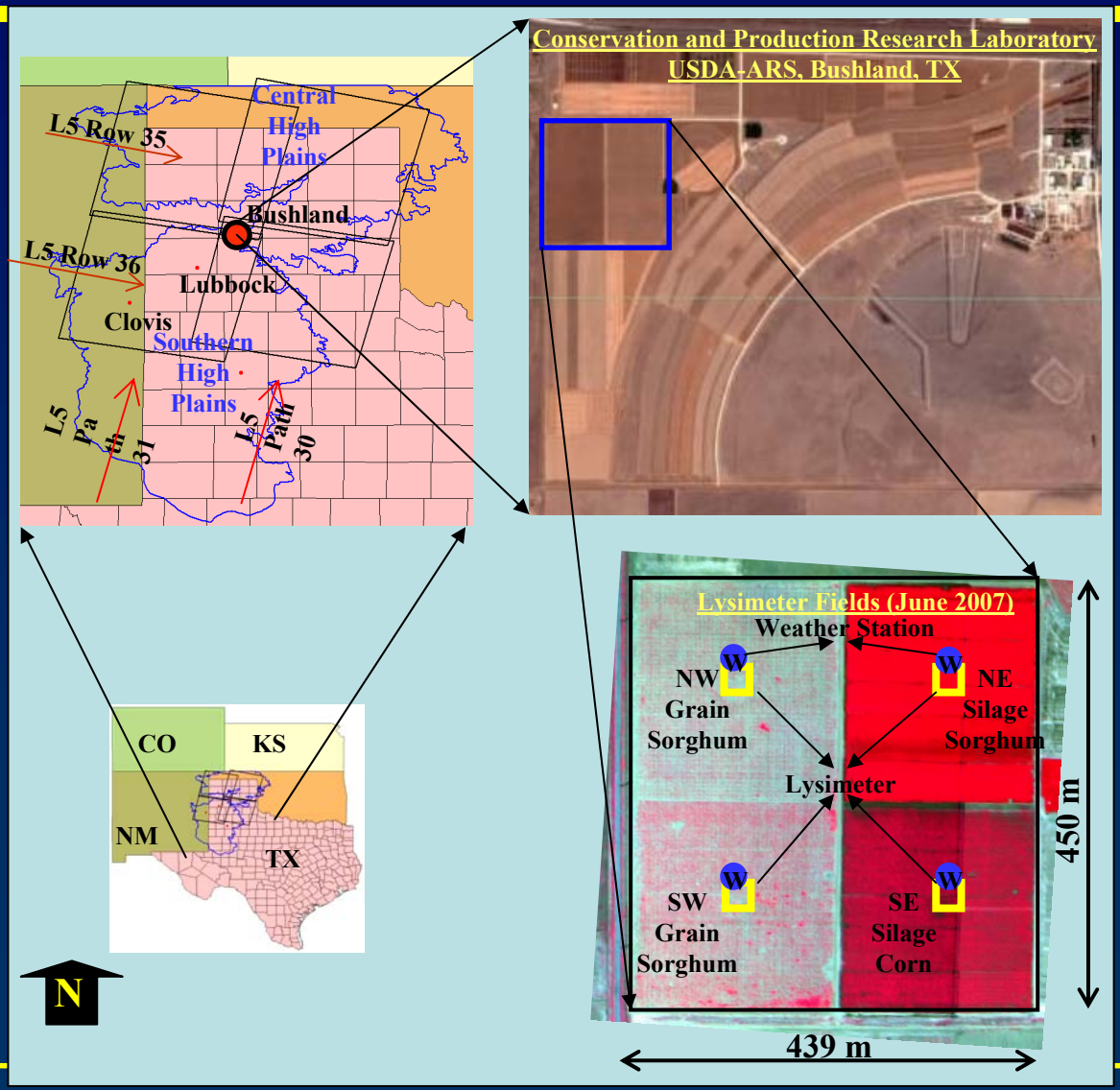
- Develop and evaluate algorithms to improve spatial resolution of surface temperature data derived from Landsat/ASTER/MODIS thermal images using high resolution visible, NIR and SWIR images;

BEAREX07 - GOALS

- Calibrate and validate Large Aperture Scintillometer (LAS) using lysimetric data for estimating latent heat flux as the residual of the land surface energy balance; and

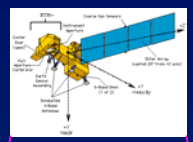
- Development of remote sensing based crop coefficients.

Study Area

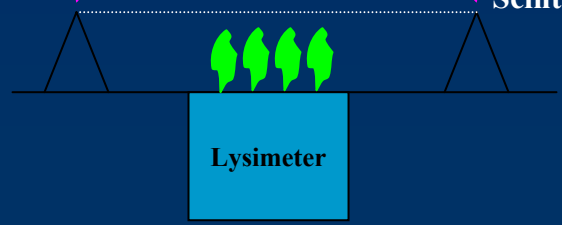

Central High Plains
L5 Row 35
Bushland
L5 Row 36
Lubbock
Clovis
Southern High Plains
L5 Path 31
L5 Path 30
CO
KS
NM
TX
N
Conservation and Production Research Laboratory
USDA-ARS, Bushland, TX
Lysimeter Fields (June 2007)
Weather Station
NW Grain Sorghum
NE Silage Sorghum
Lysimeter
SW Grain Sorghum
SE Silage Corn
450 m
439 m

BEAREX07

Visible & NIR
250 m
30 m
15 m
0.5 m



Thermal
1000 m
120 m
60 m
1.8 m

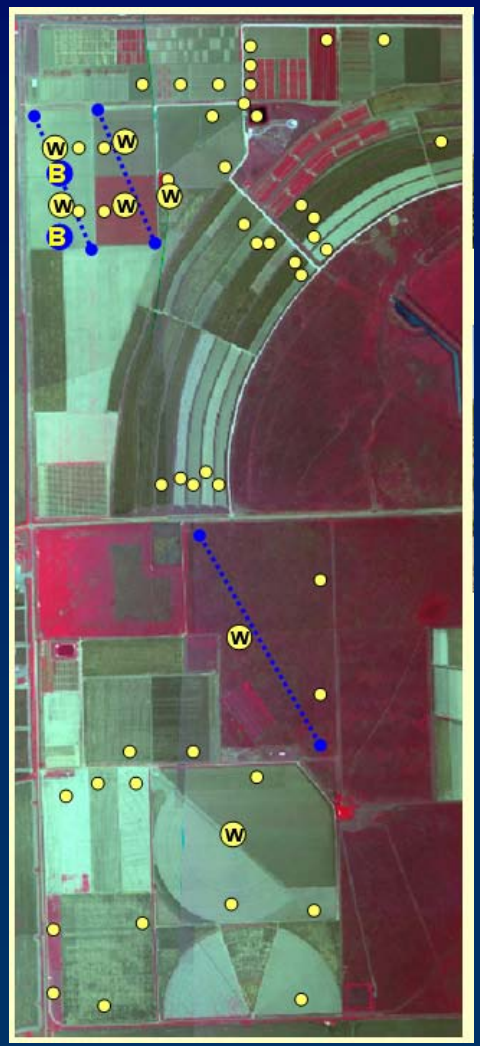


Collaborators:
CPRL-USDA-ARS
USDA-ARS, AZ
Utah State University
University of Texas

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

Ground truthing:
5 Lysimeters
3 Scintillometers

BEAREX07



Comprehensive groundtruth database
25 aircraft, 6 Landsat TM, and 2 ASTER images

BEAREX08 – Expanded Scope

- Solving energy balance closure problem with Eddy Covariance systems using lysimeter data.
  - USDA-ARS, Beltsville
  - USDA-ARS, Ames
  - University of Alabama
- Short crop on lysimeter fields - Cotton

Eddy Covariance Systems

Background

- Energy balance based remote sensing techniques
  - ➔SEBAL (Surface Energy Balance Algorithm for Land)
  - ➔METRIC (Mapping Evapotranspiration at High Resolution with Internalized Calibration)
  - ➔TSM (Two-Source Model)

Background

- Most of these energy balance models are very complex in nature
- Require complex atmospheric correction of remote sensing data
- Require extensive input that we may not have most of the time
- Turn around time

Background

- Efforts are being made to simplify spatial ET estimation procedure
- Simplified Surface Energy Balance (SSEB)
- Three-step procedure
- Never been tested against measured data

Objective

The main objective this study was to:

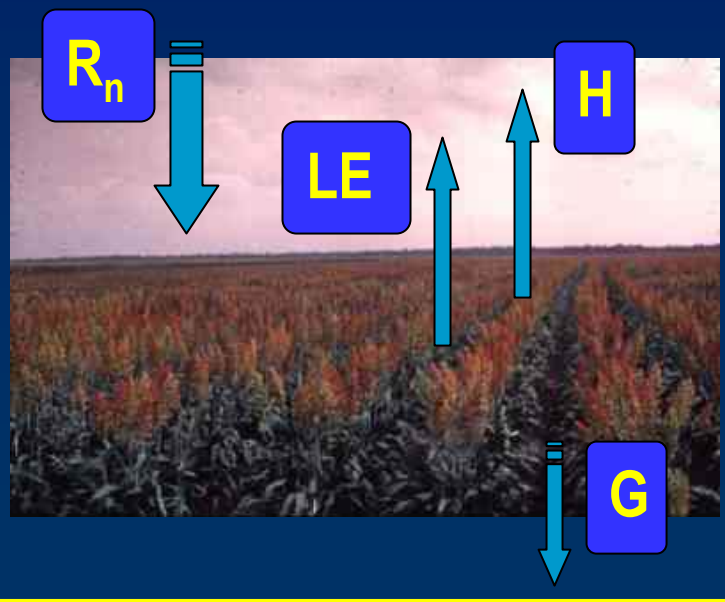
Evaluate four energy balance models (SEBAL, METRIC, SSEB, and TSM) using lysimeter data and Landsat 5 TM images covering a major portion of the Texas High Plains.

Materials and Methods - Theory

Energy Balance Equation

$$\lambda E = R_n - G - H$$

$$E = \lambda E / \lambda$$



Materials and Methods - Theory

- **SEBAL**
  - Proposed by Bastiaanssen et al (1998)
  - H varies linearly between the hot and cold pixels on the image
  - Hot pixel – Bare soil
    - LE or ET = 0.0 $H_{hot} = R_n - G$
  - Cold pixel – Water surface or well irrigated crop
    - $H_{Cold} = 0.0$

Materials and Methods - Theory

- **METRIC**
  - Modification to SEBAL
  - Proposed by Allen et al (2007)
  - H varies linearly between the hot and cold pixels on the image
  - Hot pixel – Bare soil
    - LE or ET ≠ or = 0.0 $H_{hot} = R_n - G - LE$
  - Cold pixel – Well irrigated crop preferably Alfalfa
    - $H_{Cold} = 0.0$ and $ET = 1.05\ ET_r$

Materials and Methods - Theory

- **Two Source Model**
  - Proposed by Norman et al., 1995 and Kustas and Norman (1999)
  - No need to identify hot and cold pixels
  - Sensible and latent heat fluxes of canopy and soils are estimated separately
  - Iterative procedure using radiometric surface temperature and vegetation cover fraction

Materials and Methods

- Simplified Surface Energy Balance (SSEB)
  - ➔ Proposed by Senay et al. (2007) and extended and validated by Gowda et al. (2008)
  - ➔ LE also varies linearly between the hot and cold pixels
  - ➔ It is based on the logic that temperature difference between soil surface and air is linearly related to soil water

Materials and Methods

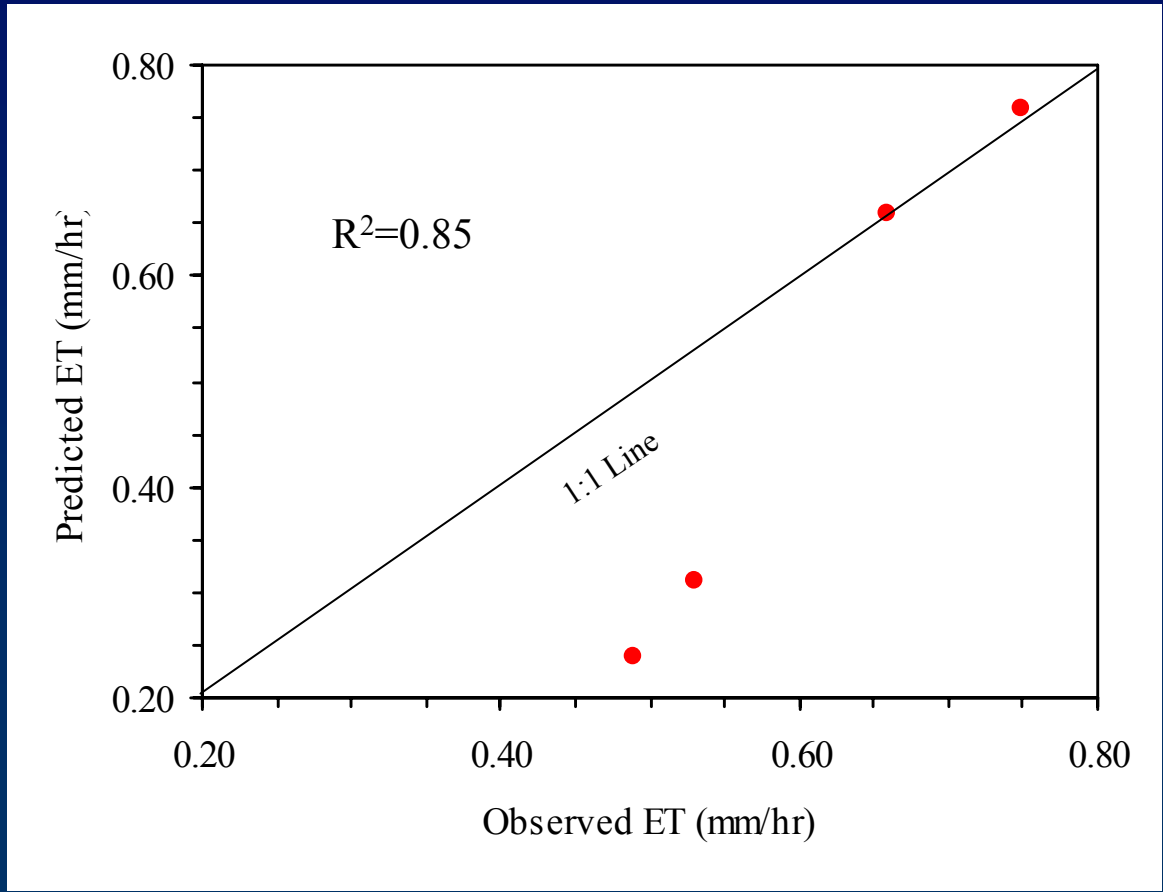
- SSEB - Three steps
  - I Step – Identification of hot and cold pixels on the image
    - Cold pixel - Water or irrigated crop
    - Hot pixel – Bare soil
  - II Step - Estimation of ET Fraction
    - $ET_f = (T_H - T_X) / (T_H - T_C)$
  - III Step - Estimation of daily ET values
    - $ET_a = ET_f \ x \ 1.1 \ ET_o$

Materials and Methods

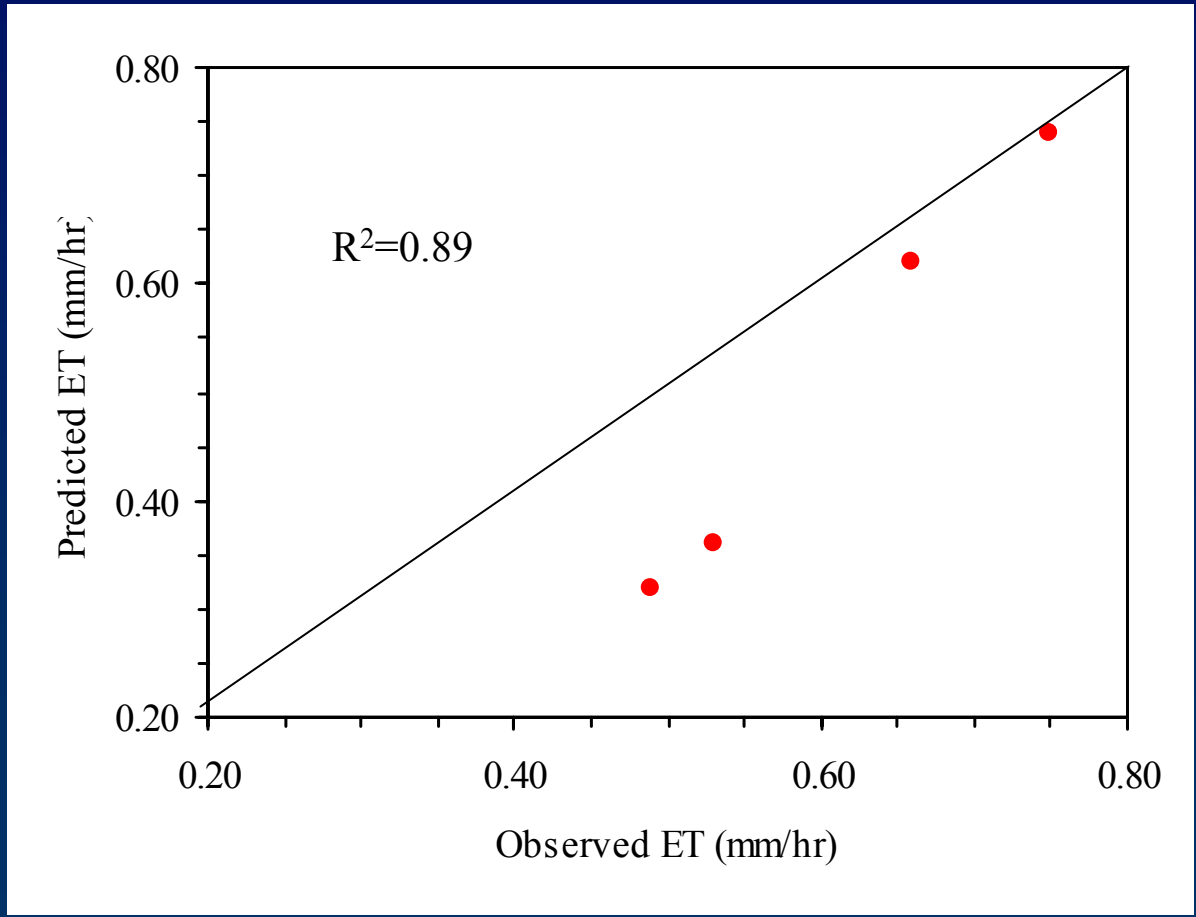
- Landsat TM data – 2006 and 2007

No.	Acquisition Date (DOY*)	Daily ET_o (mm)	u (m/s)	RH (%)
1	April 18, 2006 (108)	8.3	5.81	17.6
2	May 20, 2006 (140)	9.1	3.55	22.9
3	June 05, 2006 (156)	12.6	5.71	21.0
4	July 23, 2006 (204)	6.3	2.76	68.1
5	August 8, 2006 (220)	7.6	3.83	50.9
6	August 24, 2006 (236)	6.9	3.66	59.8
7	September 25, 2006 (268)	3.9	1.81	57.9
8	October 11, 2006 (284)	3.1	1.87	78.3
9	March 04, 2007 (63)	4.0	3.9	51.8
10	May 23, 2007 (143)	6.6	4.51	63.5
11	June 08, 2007 (159)	6.6	4.95	54.2
12	July 10, 2007 (191)	8.0	3.5	50.1
13	July 26, 2007 (207)	8.0	4.52	57.4
14	August 11, 2007 (223)	7.9	3.88	55.3

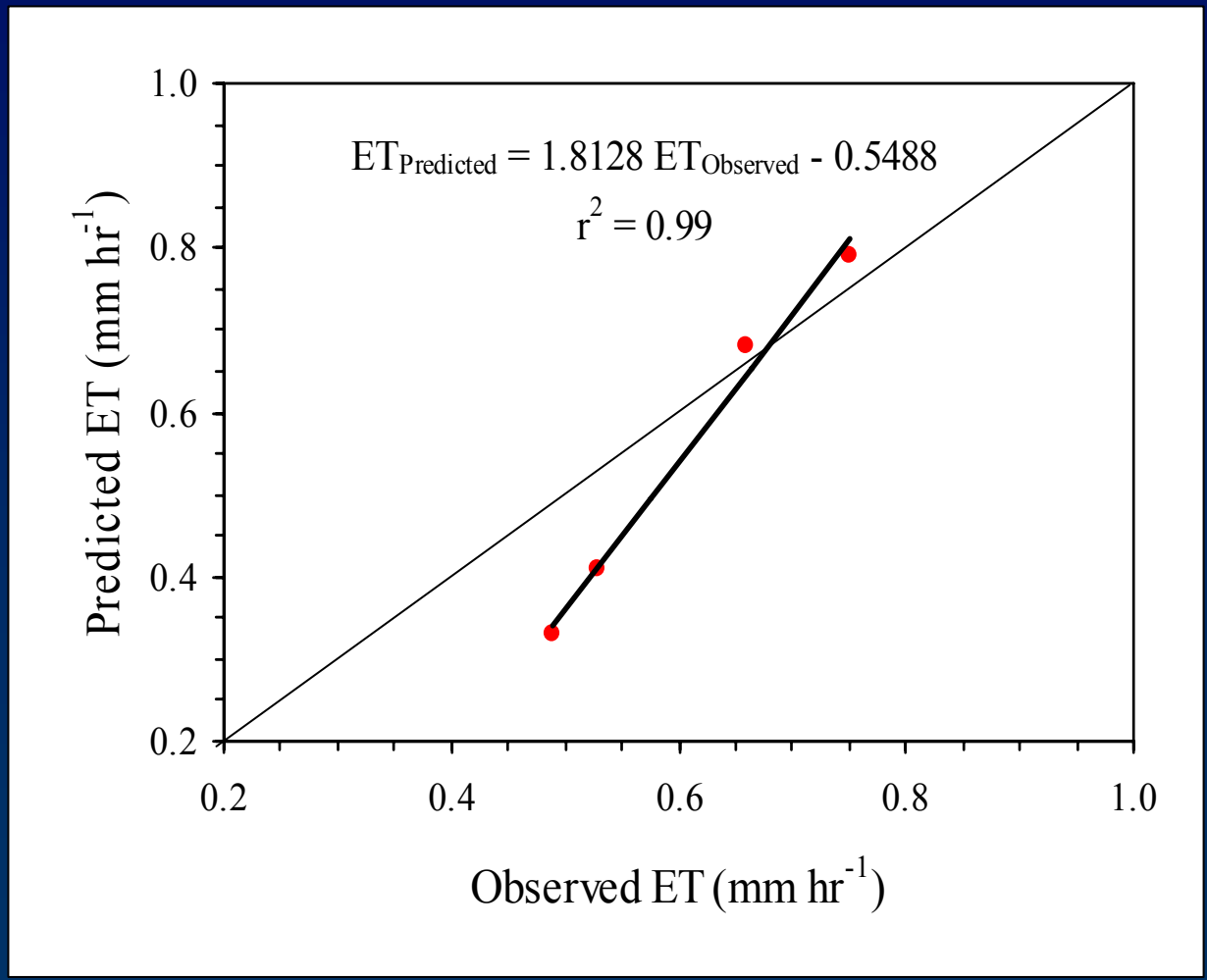
Preliminary Results - SEBAL



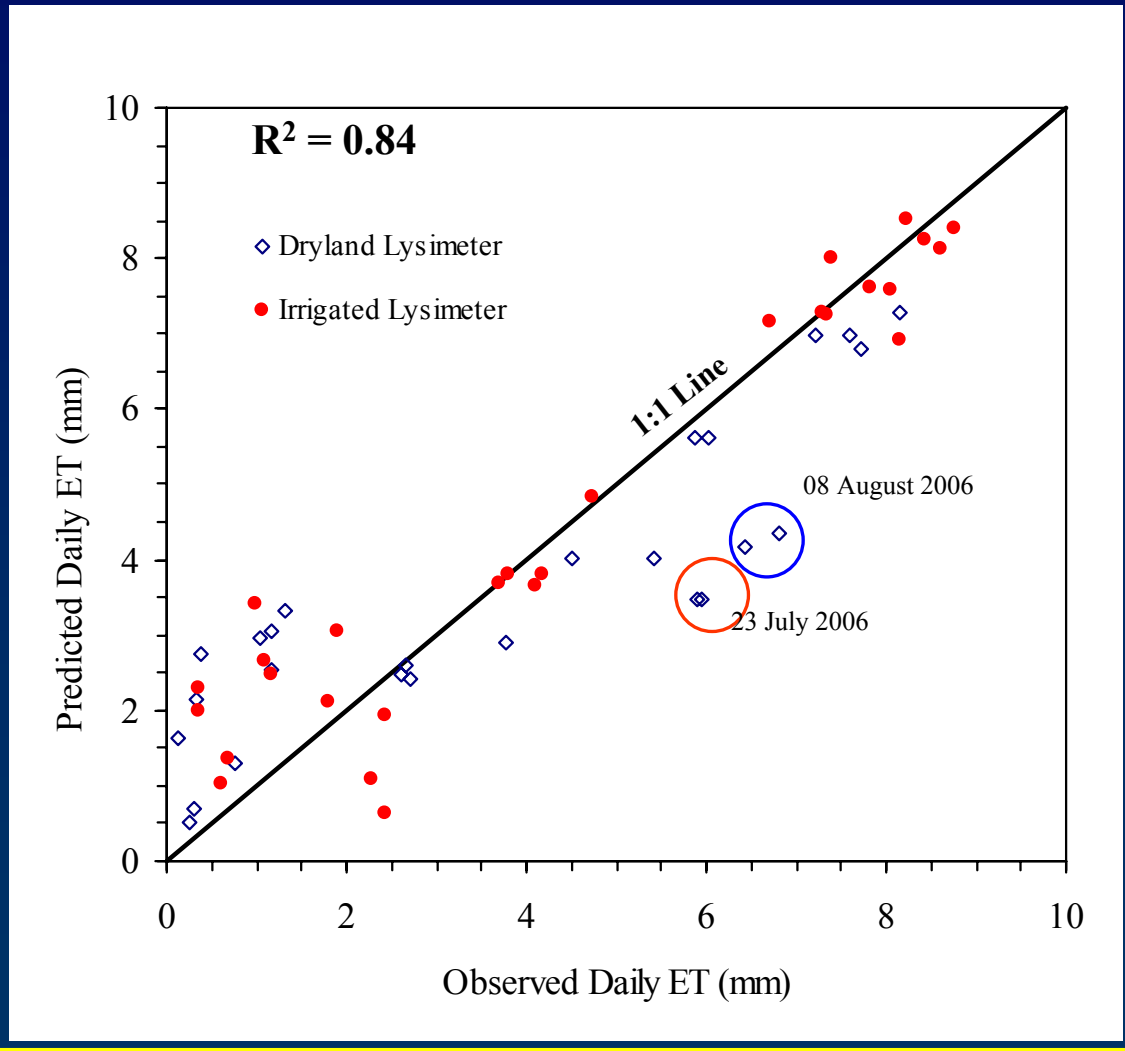
Preliminary Results - METRIC



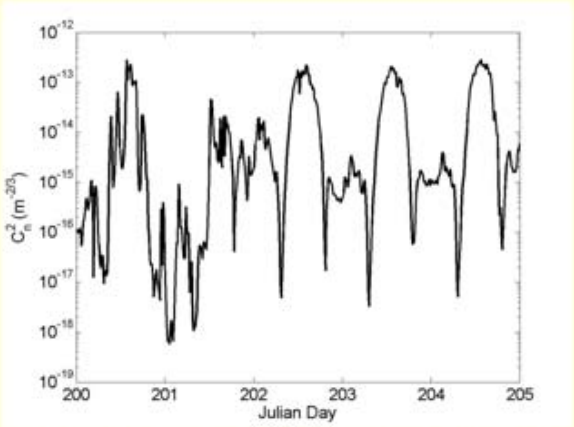
Preliminary Results - TSM



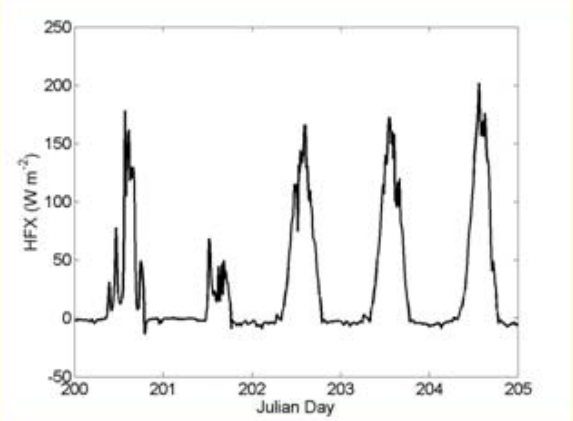
Preliminary Results - SSEB



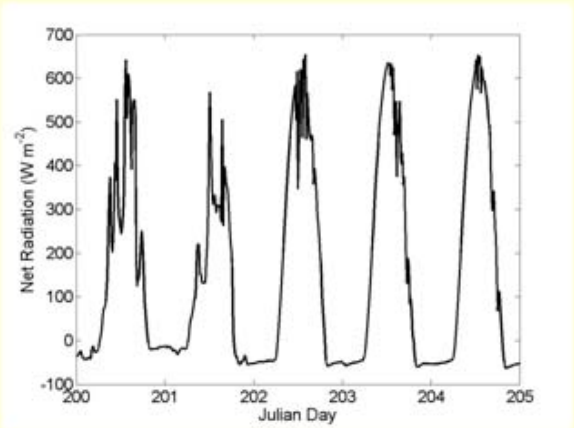
Preliminary Results - Scintillometer



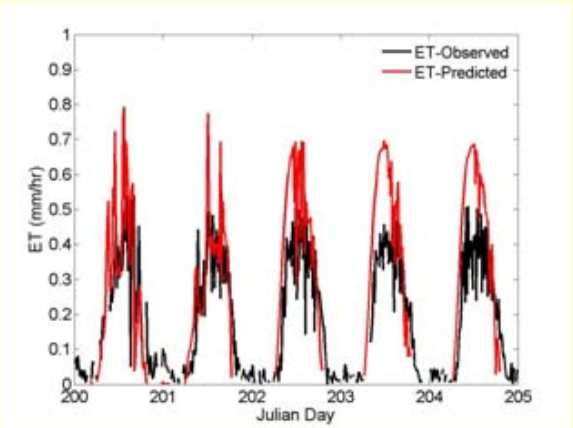
Structural Parameter of Refractive Index of Air



LAS-Estimated Sensible Heat Flux



Observed Net Radiation



Lysimeter Observed Vs. LAS-Predicted Evapotranspiration Rates

Conclusions

- ET predictions using SEBAL, METRIC, TSM, and SSEB were comparable.
- In METRIC, SEBAL and SSEB, ET predictions are sensitive to selection of hot and cold pixels.
- All four models are suitable for suitable for estimate ET in the Texas High Plains, however, further evaluation is needed under different agrimeteorological conditions.

Ongoing Research

- Model evaluation
  - SEBS
  - Triangle method
  - Aerodynamic temperature method
- Remote sensing data
  - Aircraft data
  - Landsat TM
  - ASTER
  - MODIS
- Disaggregation of low resolution thermal data

Questions