

# Simulation of Evapotranspiration (ET) and Yield of Maize: an Inter-comparison Among 41 Maize Models

By

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For Presentation at American Society of Agronomy Annual Meetings

7 November 2022



## Round 2 Maize ET and Growth Datasets

Item	Mead	Bushland
Location	Mead, Nebraska, USA	Bushland, Texas, USA
Person(s)	Andy Suyker	Steve Evett
Treatments (levels)	12 crop-years	8 crop-years
Irrigation	Rain-fed and irrigated for 6 years	Two years, Drip and sprinkler irrigation
	Full and rain-fed	Full and 75% irrigation,
Evapotranspiration, ET	Eddy covariance	Lysimeters & Soil Water Balance

## Maize Datasets - continued

Item	Mead	Bushland
Phenology	Growth stages	Growth stages
Biomass	Bi-weekly	Bi-weekly
Leaf Area Index	Bi-weekly	Bi-weekly; height, width
Yield	Final	Final
Canopy Temp	No	Yes
Energy balance components	Yes, hourly	Rn, ET (15 m) Long $\uparrow\downarrow$ , Solar $\uparrow\downarrow$
Soil temperature	10, 30, 50, 100	2, 6, 100, 200 cm
Soil moisture	10, 25, 50, 100	10, 30, 50, 70, 90, 110, 130, 150, 170, 190, 210, 230

# Protocol

- **Blind phase #1** – Modelers furnished weather, management, soils, initial conditions, phenology data. Deadline – 29 February 2020 (was an error in plant population for Mead irrigated treatments in Phase 1)
- **Crop potential phase #2** – additionally provide LAI, biomass, yields for fully irrigated treatments. (Deadline 21 September 2020)
- **Non-stress water use phase #3** – additionally provide ET and soil moisture for fully irrigated treatments. (Deadline 11 December 2020)
- **All data phase #4** – additionally provide all ET, soil moisture, LAI, biomass, yield etc. for all treatment-years (Deadline 18 June 2021)

## List of Models Participating in Round 2

Agro-Hydrological & chemical & Crop system simulator,  
APSIM-SoilWat, AquaCrop, AqYield, ARMOSA, Biome-  
BGCMuSo, CropSyst4, Daycent, DSSAT-CSM-CERES-  
Maize(several “flavors”), DSSAT-CSM-IXIM(several “flavors”),  
ecosys, ExpertN-GECROS, ExpertN-SPASS, JULES, L5-SLIM-H,  
MaizsimDaily, MaizsimHouly, SALUS, SIMETAW#,  
SIMPLACE\_LINTUL5\_FAO56\_SLIM3\_CanopyT , STICS\_KETP,  
STICS\_ETP\_SW, SSM-icrop, SWB, Test\_Mod

# DSSAT Maize ET “Flavors”

- CERES-Maize
  - PET from ASCE alfalfa reference with dual crop coefficient
    - Ritchie (1972) soil E (1, DCAR)
    - Suleiman & Ritchie (2003, 2004) soil E (2, DCAS)
  - PET from ASCE grass reference with dual crop coefficient
    - Ritchie (1972) soil E (3, DCGR)
    - Suleiman & Ritchie (2003, 2004) soil E (4, DCGS)
  - PET from FAO-56 (Penman- Monteith)
    - Hydrus soil water balance (5, DCFH)
    - Ritchie (1972) soil E (6, DCFR)
    - Suleiman & Ritchie (2003, 2004) soil E (7, DCFS)
  - PET from Priestley-Taylor
    - Hydrus soil water balance (8, DCRH)
    - Ritchie (1972) soil E (9, DCRR)
    - Suleiman & Ritchie (2003, 2004) soil E (10, DCRS)

# DSSAT Maize ET “Flavors” - continued

- IXIM

- PET from ASCE alfalfa reference with dual crop coefficient
  - Ritchie (1972) soil E (11, DIAR)
  - Suleiman & Ritchie (2003, 2004) soil E (12, DIAS)
- PET from ASCE grass reference with dual crop coefficient
  - Ritchie (1972) soil E (13, DIGR)
  - Suleiman & Ritchie (2003, 2004) soil E (14, DIGS)
- PET from FAO-56 (Penman- Monteith)
  - Ritchie (1972) soil E (15, DIFR)
  - Suleiman & Ritchie (2003, 2004) soil E (16, DIFS)
- PET from Priestly-Taylor
  - Ritchie (1972) soil E (17, DIRR)
  - Suleiman & Ritchie (2003, 2004) soil E (18, DIRS)

Ameriflux Maize Field NE1 at Mead, Nebraska,  
19 August 2019. Flux Tower Is Closest and Black  
Radiation Tower is Further Away

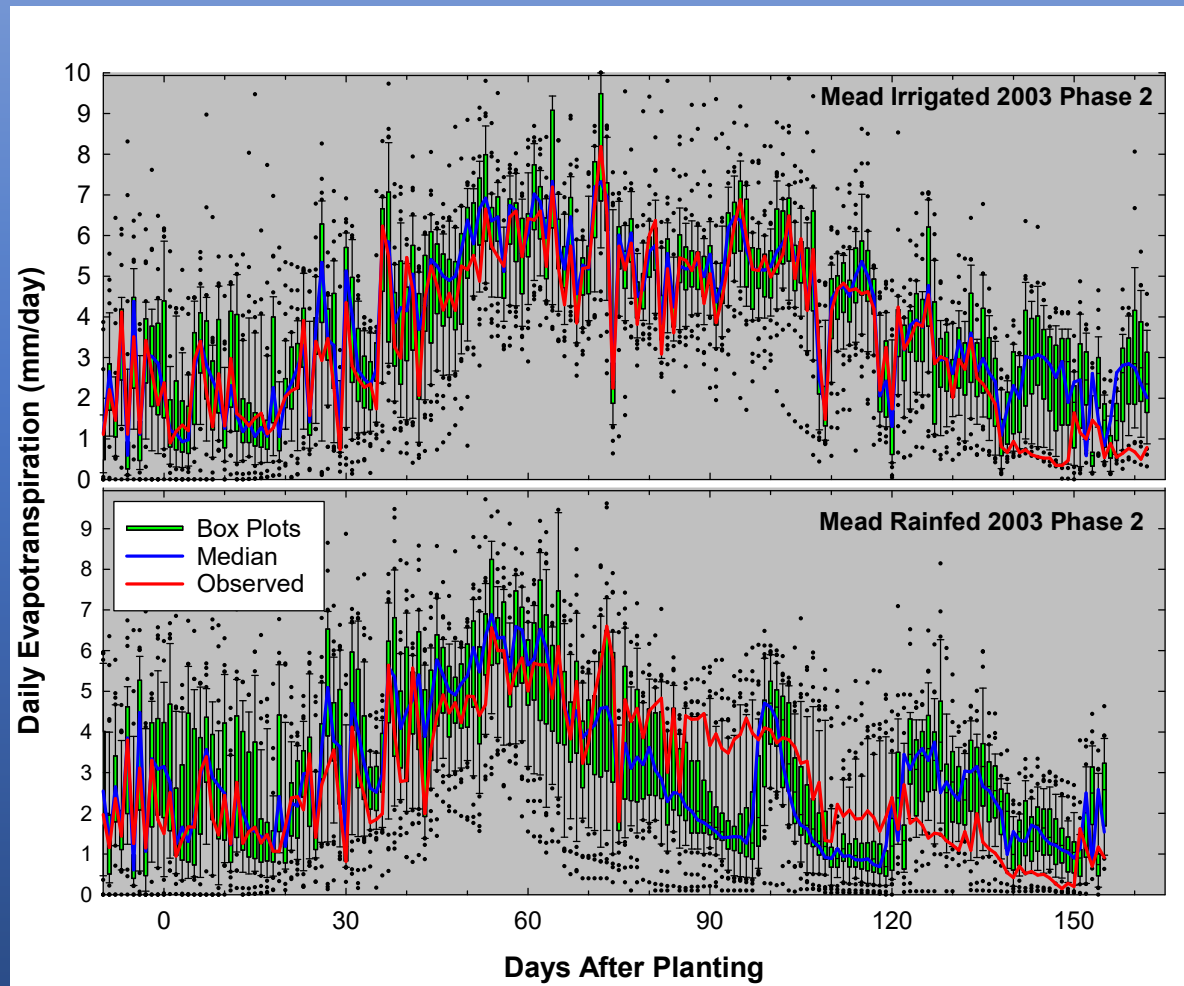




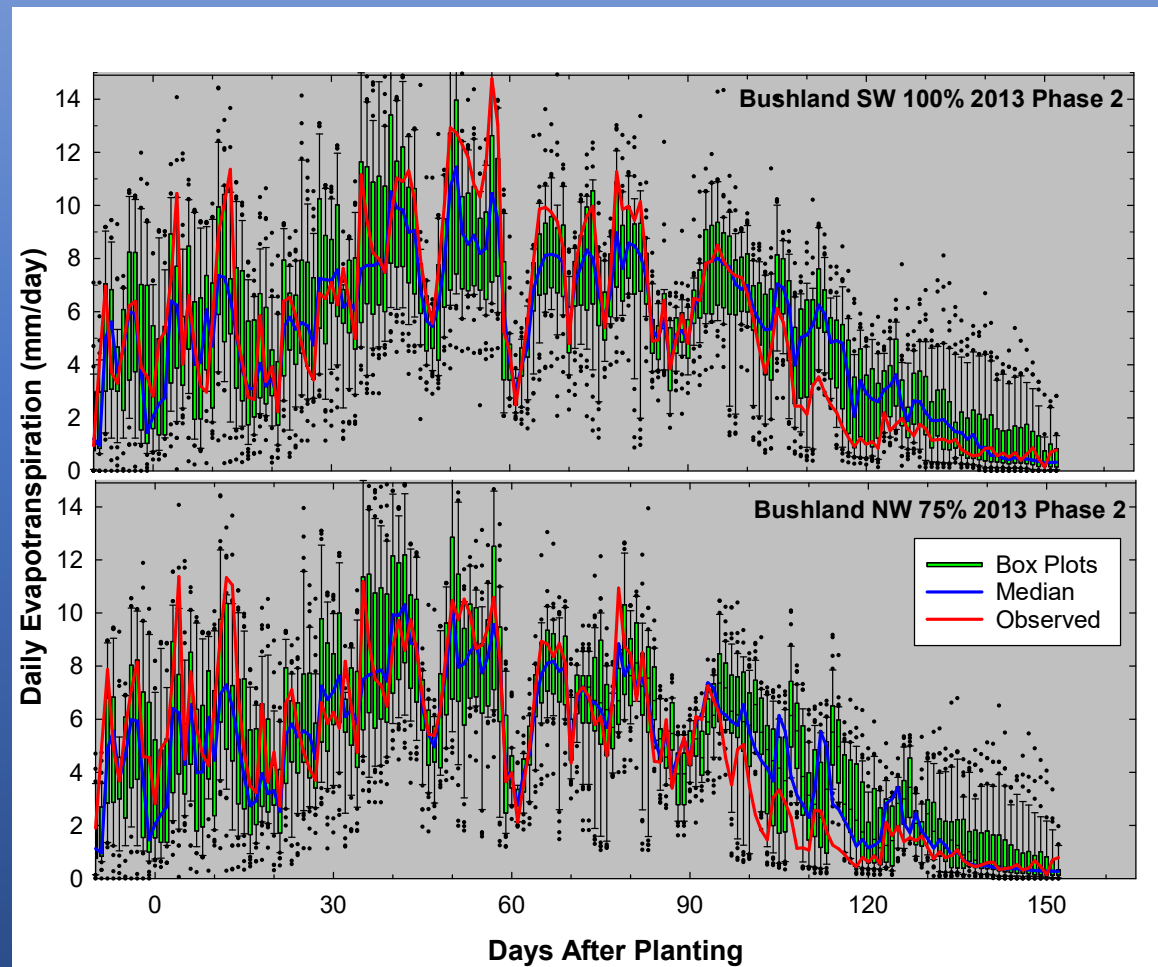
# Field at Bushland, Texas, USA with Weighing Lysimeters



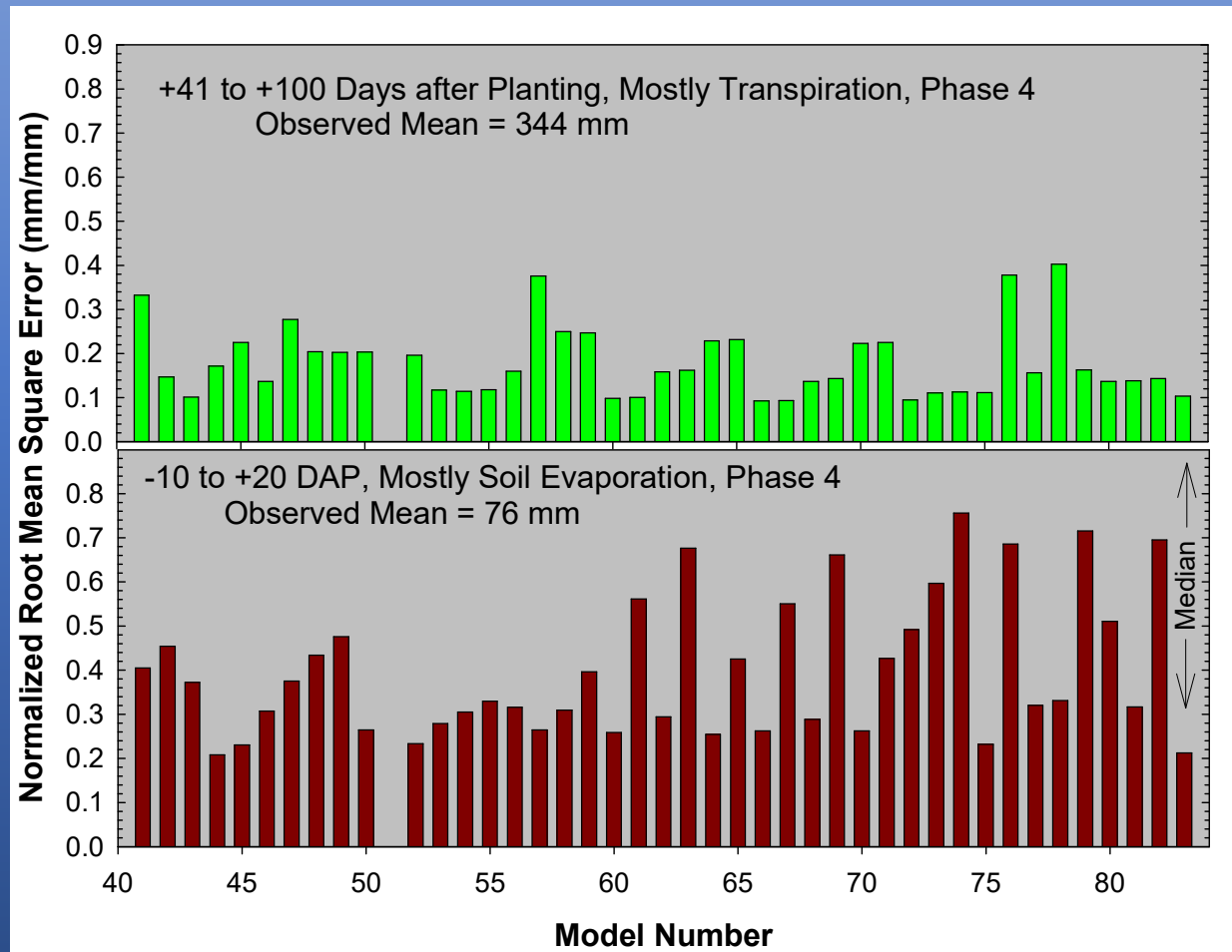
Daily ET versus days after planting. Upper – Irrigated field NE2 in Mead for 2003; Lower – Rainfed field NE3 at Mead for 2003. Phase 2



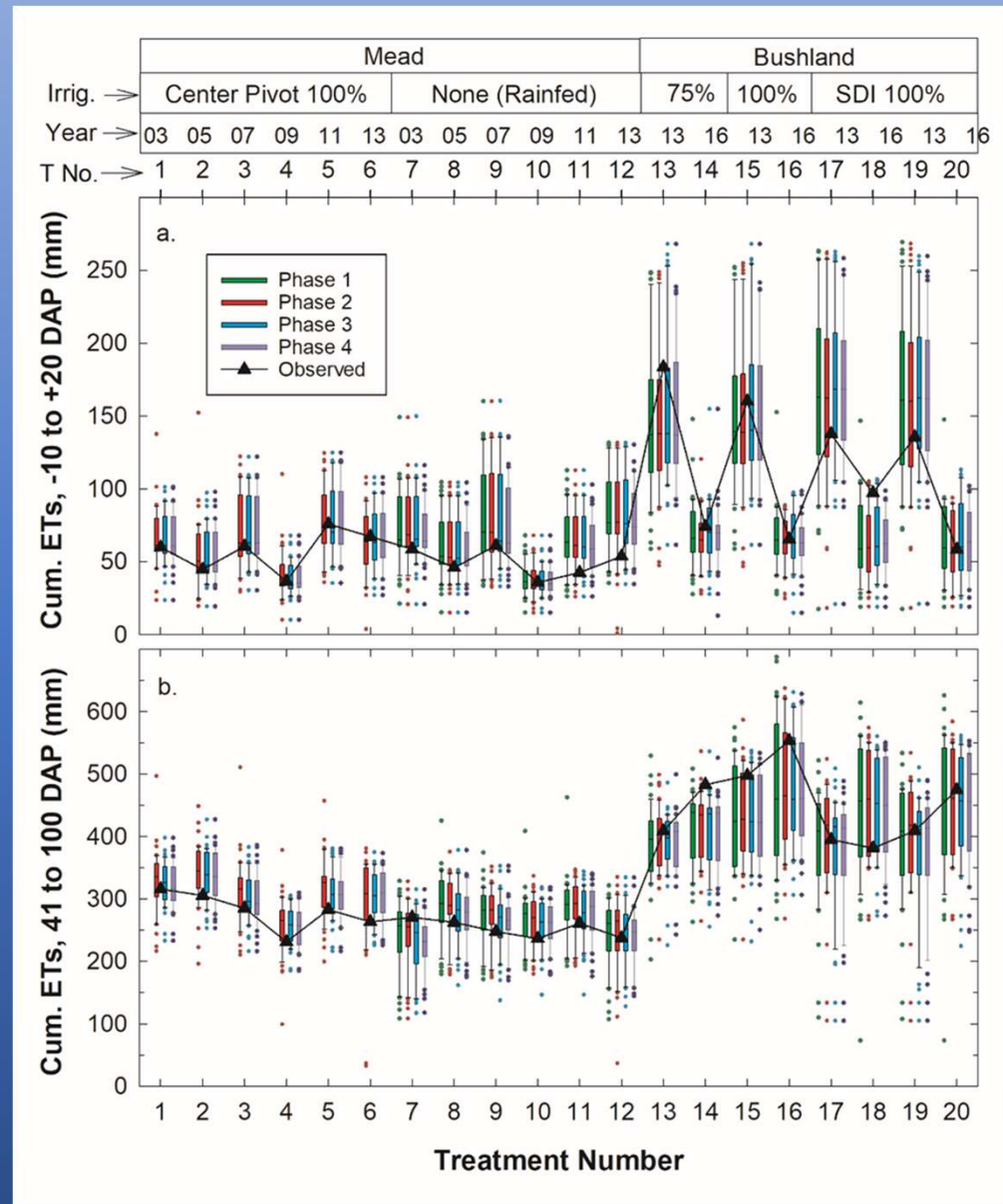
Daily ET versus days after planting. Upper - irrigated at 100% of soil moisture replacement at Bushland for 2013; Lower – at 75% replacement. Phase 2.



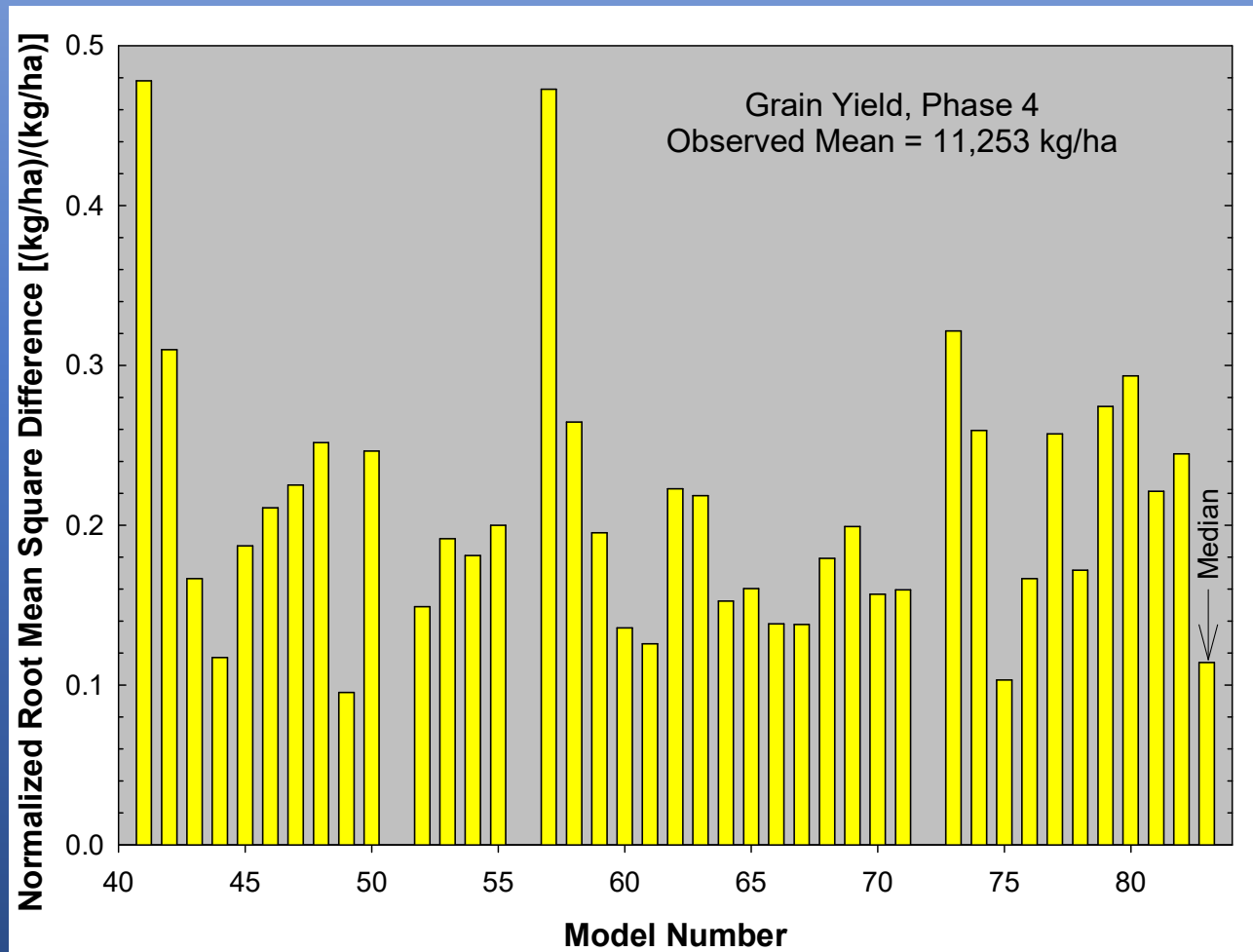
# Normalized Root Mean Square Error of Cumulative ET for 40 Models for all 20 Treat.-Years for Mostly Closed Canopy Transpir. (top) and for Mostly Bare Soil Evap. (bottom), Phase 4



**Cumulative simulated evapotranspiration (ETs) for all 20 treatment-years over:**  
**(a) -10 to +20 days after planting (mostly E)**  
**(b) 41 to 100 day after planting (mostly T)**



# Normalized Root Mean Square Error of Grain Yield of 39 Models for all 20 Treatment-Years, Phase 4



## Normalized root mean square errors (nRMSE) of the 18 “flavors” of the DSSAT family models:

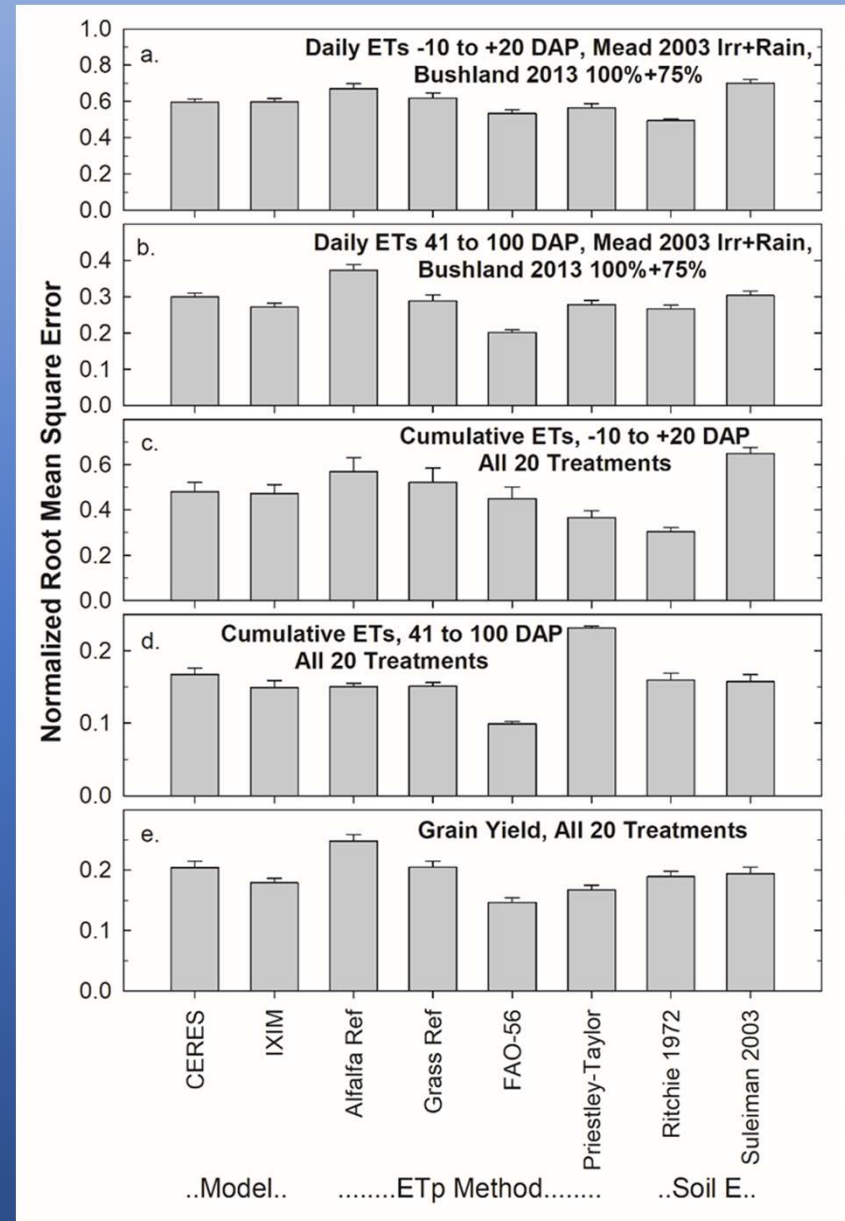
(a) -10 to +20 days after planting (DAP) (mostly soil E) of daily ETs for all four phases for Mead 2003 and the 100% and 75% MESA irrigated data for Bushland 2013.

(b) 41 to 100 DAP periods (mostly canopy T) of daily ETs for all four phases for all four phases for Mead 2003 and the 100% and 75% MESA irrigated data for Bushland 2013.

(c.) -10 to +20 DAP cumulative ETs for Phase 4 for all 20 treatment-years

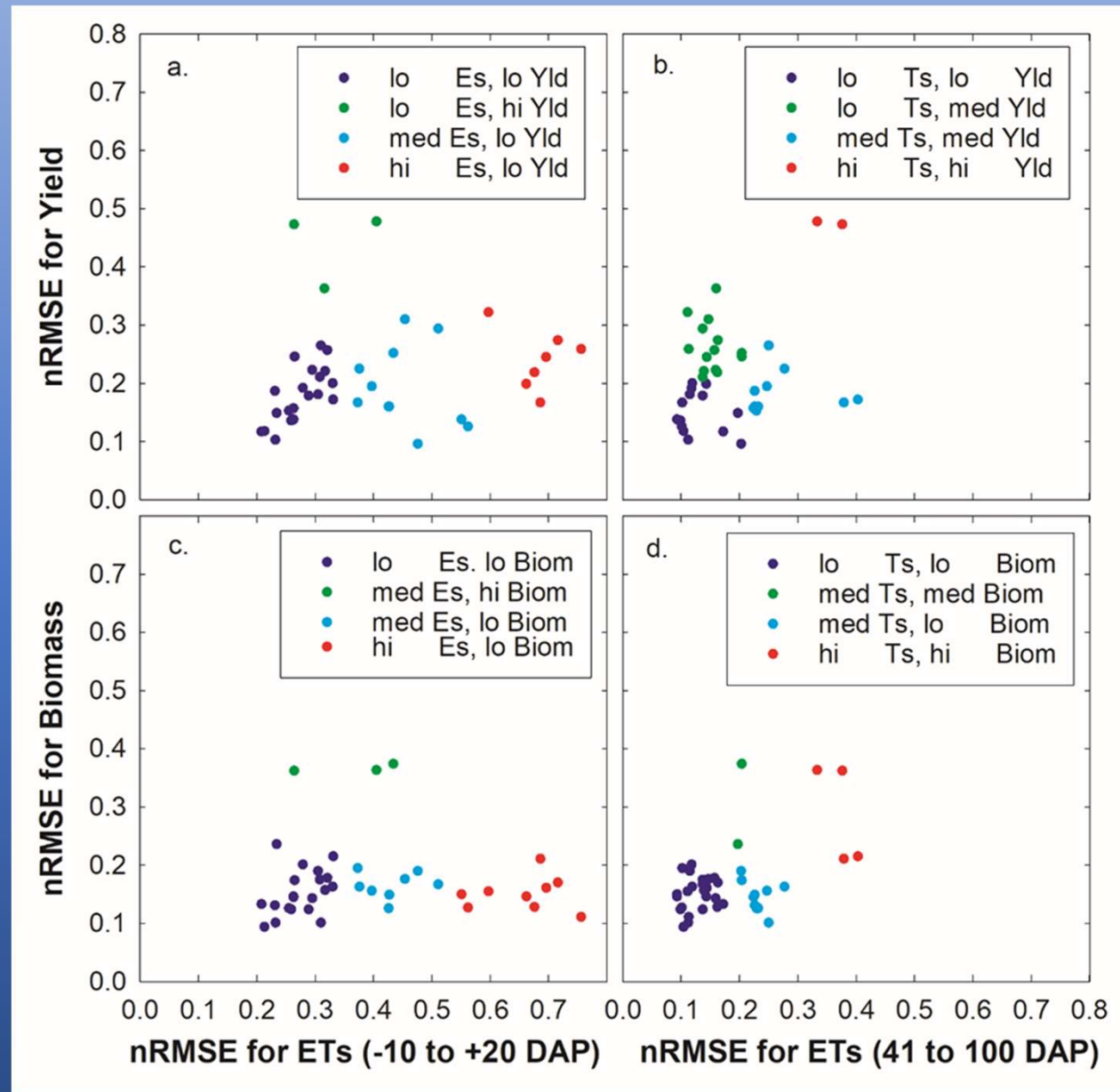
(d.) 41 to 100 DAP cumulative ETs for Phase 4 for all 20 treatment-years

(e) Grain yields for Phase 4 for all 20 treatment-years.



K-means cluster analyses of nRMSE for all 20 treatments for 41 models (+median) revealed clusters of best models for:

- a. Yield & ETs for soil E
- b. Yield & ETs for crop T
- c. Biom & ETs for soil E
- d. Biom & ETs for crop T





## Eight Models (+median) That Are In “Best” Clusters In All Four Graphs of Previous Slide

- AHC -- Agro-Hydrological & chemical & Crop system simulator
- AMSW – APSIM-SOIL\_WAT
- CS – CropSyst4
- DIFR – DSSAT-CSM-IXIM with FAO-56 and Ritchie soil E
- DCFR – DSSAT-CSM-CERES with FAO-56 and Ritchie soil E
- DIGR – DSSAT-CSM-IXIM w ASCE grass std. eq. & Ritchie soil E
- ECOS – ecosys
- XNSM -- Expert-N - SPASS

## Characteristics of the Eight “Best” Models

- APSIM uses transpiration efficiency x biomass accumulation
- ecosys uses energy balance
- All the rest use variations of Penman-Monteith
- All eight or their ancestors have been widely used for a long time, thereby enabling improvement over a wide range of environmental conditions.

# Conclusions

1. Daily ET values varied by a factor of 4 among models at midseason.
2. Variability was very high at the beginning of the seasons, when soil E was dominant.
3. Median of all models was generally a good predictor, but some models were better than the median for some cases.
4. Older Ritchie-2-stage model for soil E (Ritchie, 1972) was consistently better than the newer Sulieman and Ritchie (2003, 2004; DSSAT default) method.
5. FAO-56 method for simulating potential ET was better than Priestly-Taylor and than ASCE with grass or alfalfa reference crop coefficients.
6. Many models failed to sufficiently reduce transpiration after maturity.
7. Eight models (+median) were identified were best at simulating (1) soil E, (2) canopy T, (3), biomass, and (4) yield. All eight or their ancestors have been widely used for a long time, thereby enabling improvement over a wide range of environmental conditions.

Thank you for your attention!

