Testing Crop Models for Accurate Prediction of Evapotranspiration and Crop Water Use

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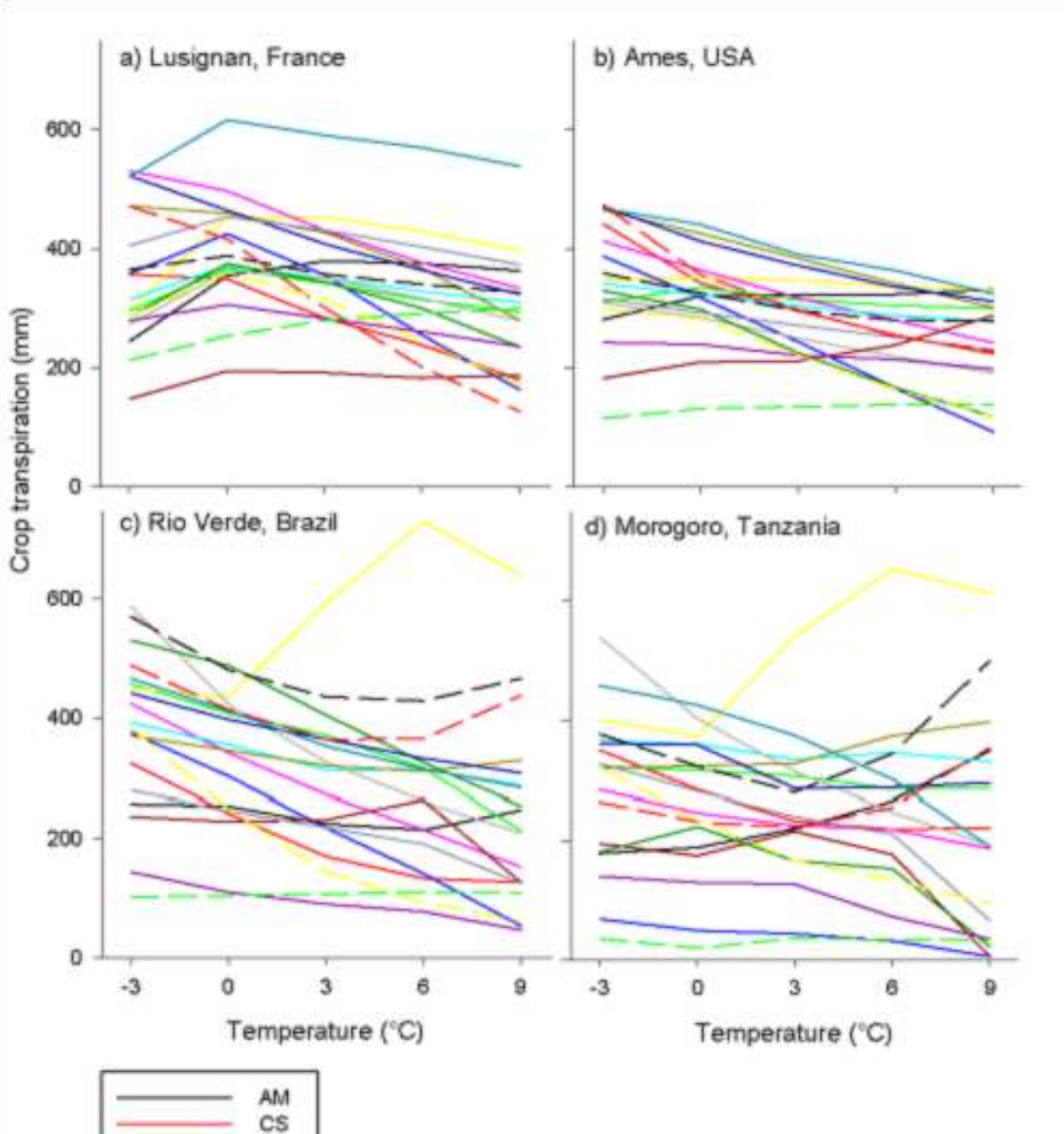
Introduction

- **Background:** – Crop models vary in methods used to predict dry matter growth and evapotranspiration, and in methods for climate effects on evapotranspiration. Tend to use same methods within a given model platform.
- **Objectives of this talk:**
  - The Problem: models vary greatly in predicted ET
  - Overview of some methods for ET equations, especially transpiration-efficiency (TE)
  - Illustrate several ET methods in same model platform
  - Testing of multiple ET methods in same model platform against data
  - New AgMIP crop model pilot to test multiple crop models to against ET, soil water, & crop data

Models show large differences in ET



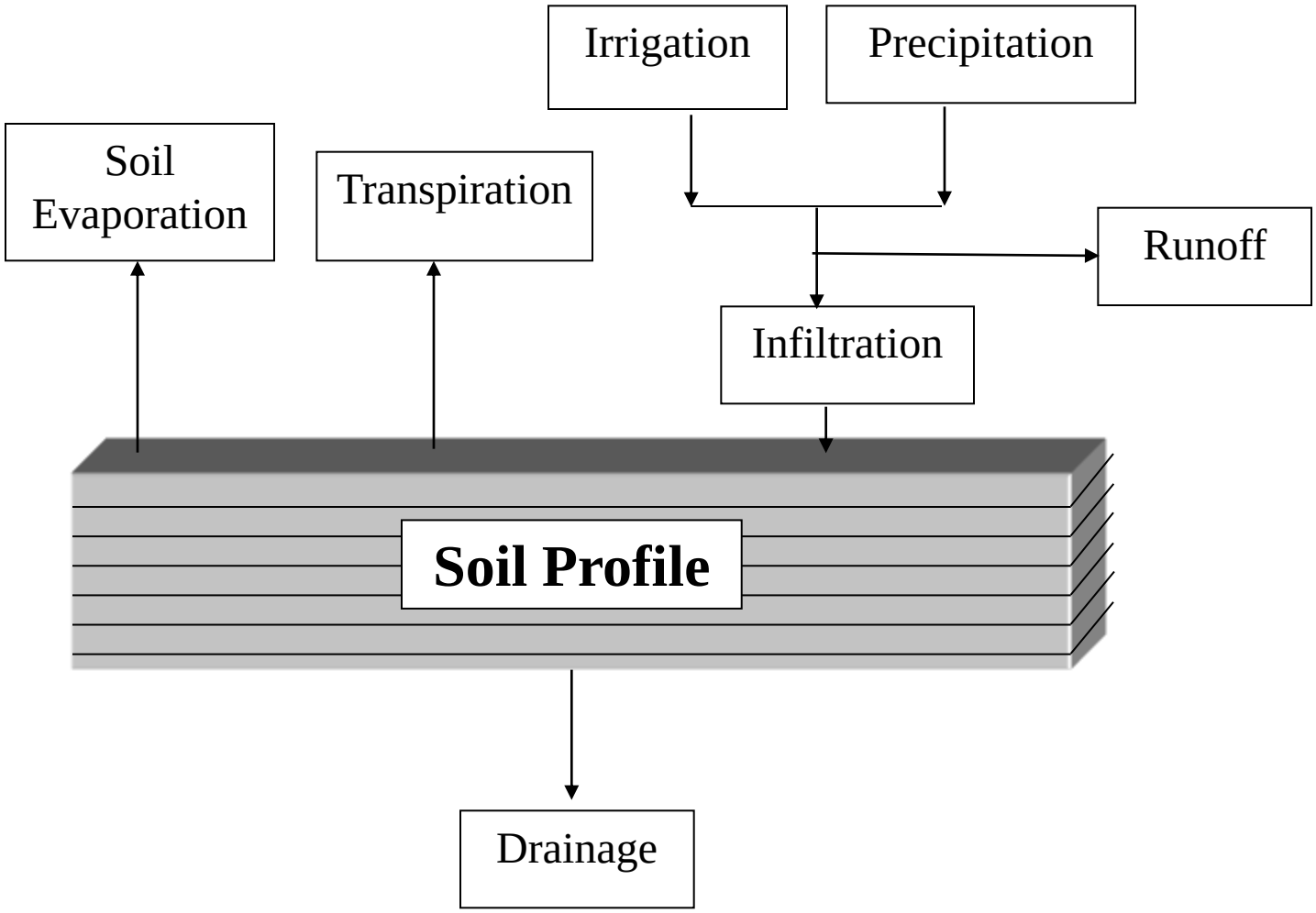
23 maize models simulate large differences in transpiration at a given site. Which model is correct? Higher, more variable for transpiration at warmer sites.

Source of Variation?

1) ET method,
2) E vs T,
3) Soil water supply,
4) TE value used.

Test against data!!!

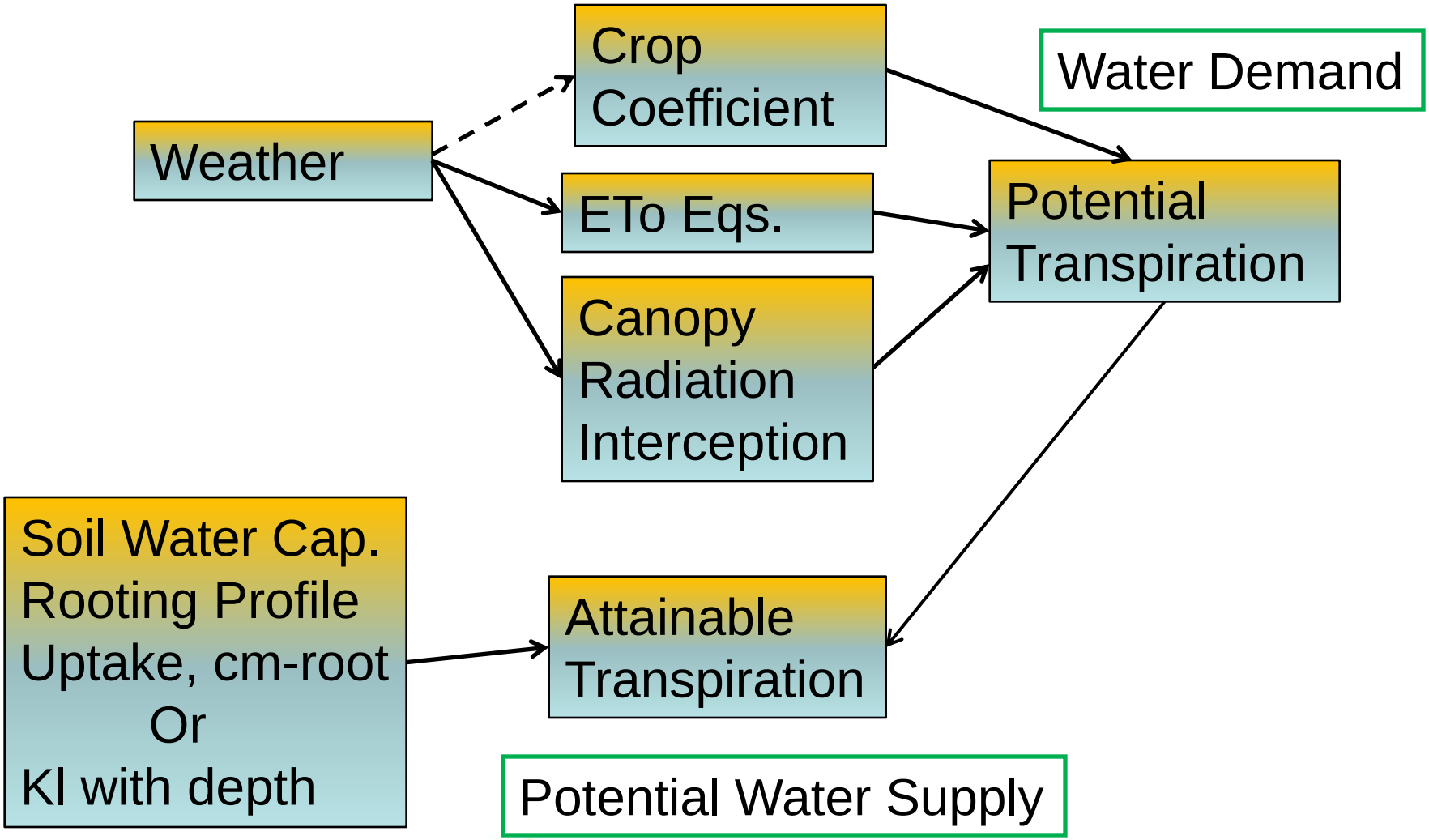
Hydrologic Cycle Processes Simulated



How Can the Models Go Wrong or Compensate

1. Energy Balance method? (ETo equations)
2. Extinction coefficient (need K for total energy, not PAR), to allocate to potential Trans. and potential soil E.
3. Soil water holding capacity
4. Rooting depth
5. Method for water uptake by roots (Cowan or Kl)
6. Run-off & Infiltration into soil (runoff curve # does not account for residue or crop cover)
7. Insufficient upward flux from saturated soil layers
8. Soil evaporation method
9. Transpiration efficiency equations, if used

Models of Actual Transpiration



Two ET Methods (PT vs. TE) in same Platform

- AgMaize in DSSAT Platform
  - Standard DSSAT (FAO-56 or Priestley-Taylor)
  - TE method: compute aboveground CGR (after leaf-to-canopy assimilation, growth & maint respiration).
  - TE method: Pot Trans = f (CGR/TE); TE=f(daily vpd)

- CSM-CROPGRO in DSSAT Platform
  - Standard DSSAT (FAO-56 or Priestley-Taylor)
  - TE method: compute total CGR (leaf-to-canopy assimilation, subtracting growth & maint respiration)
  - TE method: Pot Trans = f (CGR/TE); TE=f(daily vpd), modifying C-3 TE, account for roots & senesce?

Modifying CSM-CROPGRO Code for TE Method

1. Compute daily gross photosynthesis
2. Subtract maintenance respiration
3. Use Penning de Vries conversion efficiencies (veg) to convert from CO2 (CH2O) to daily dry matter (total CGR)
4. First issue (reduce CGR by 10, 20, or 30%, account for roots and senesced tissues?)
5. Compute VPD-day = 0.75 * [Esat(Tmax) – Esat (Tmin)]. Issue # 2 (leaf temp is less than Tmax, how much?)
6. Compute TE = 4.78 * VPD-day**(-0.57) Issue # 3 (correct?)
7. Wreq = CGR / TE
8. EOP = Wreq, rather than EOP from PT or FAO-56.
9. Actual EP = Min (WREQ, TRWUP)
10. Actual Pgross reduced by ratio of EP/EOP

Transpiration-use efficiency (*w*), *Da is daily vpd*

$$B = wT = kT / D_a$$

Tanner and Sinclair

$$B = wT = \frac{\alpha T}{D_a^{\beta}}$$

CropSyst, B from T

$$T = BD_a / k$$

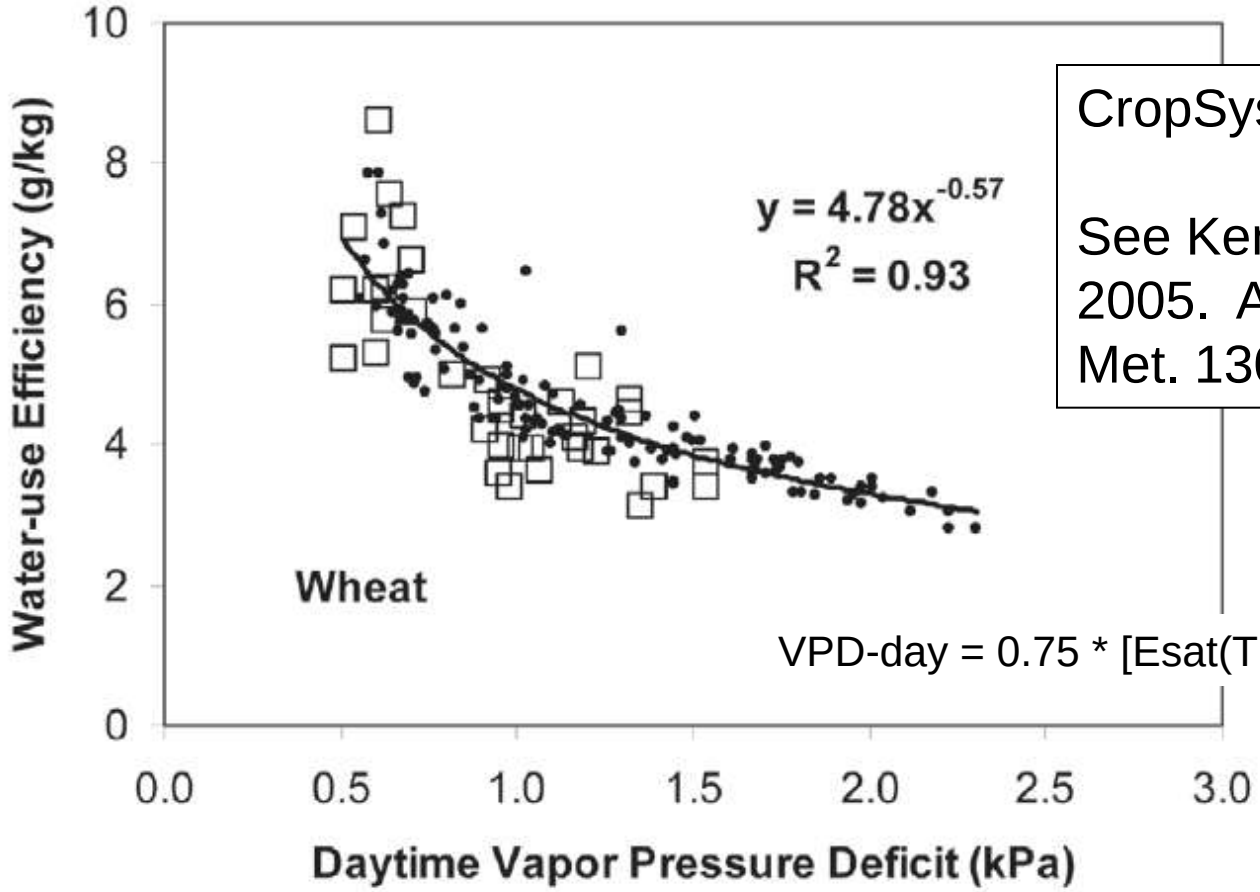
APSIM, T from B (CGR)

SSA = Sinclair-Stockle-APSIM approach for TE

Water-use Efficiency versus Daily Vpd

C-3 TE = 4.78* VPD-day**(-0.57

C-4 TE = 7.44 * VPD-day**(-0.42)



CropSyst – Stockle

See Kemanian et al. 2005. Ag. & For. Met. 130:1-11.

VPD-day = 0.75 * [Esat(Tmax) – Esat (Tmin)]

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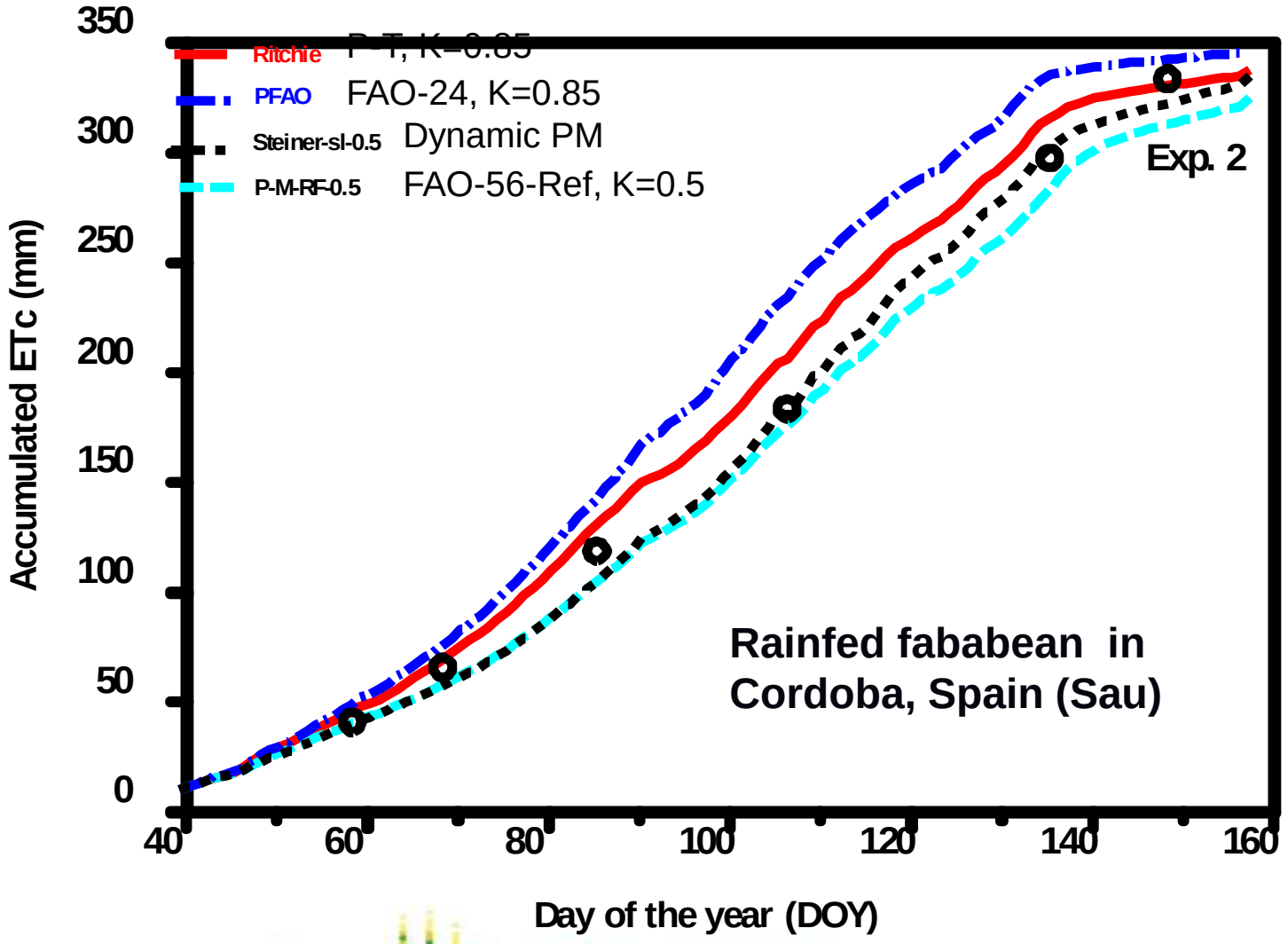
Tests Against Water-limited Studies

- AgMaize in DSSAT Platform – against maize data
  - 1982 Gainesville water by N treatments
- Sensitivity of SSA-TE parameters in CSM-CROPGRO
- CSM-CROPGRO in DSSAT Platform – against legumes
  - 1978 Gainesville, FL Soybean (Irrigated treatment and a severe terminal drought treatment)
  - 1988 Ames, IA Soybean (severe drought)
  - Faba bean
  - Peanut
  - Dry bean

Testing ET equations for Fababean to ET from Soil H2O Balance, Sau et al., 2005, Agron J. 96:1243-1257



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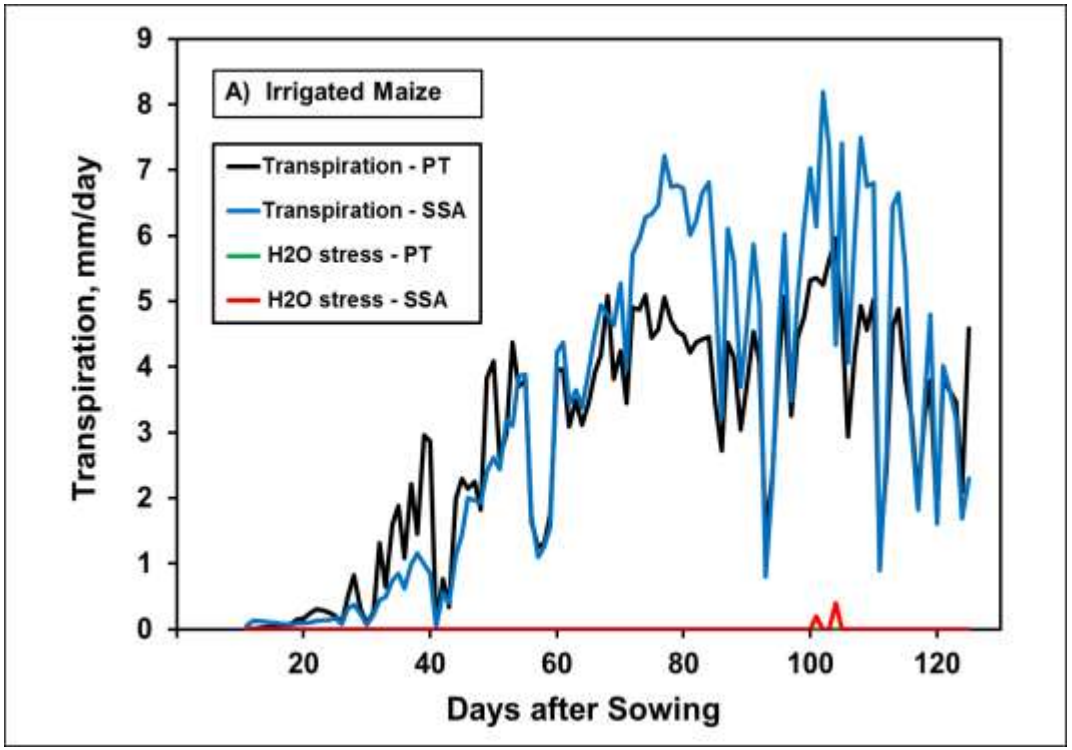
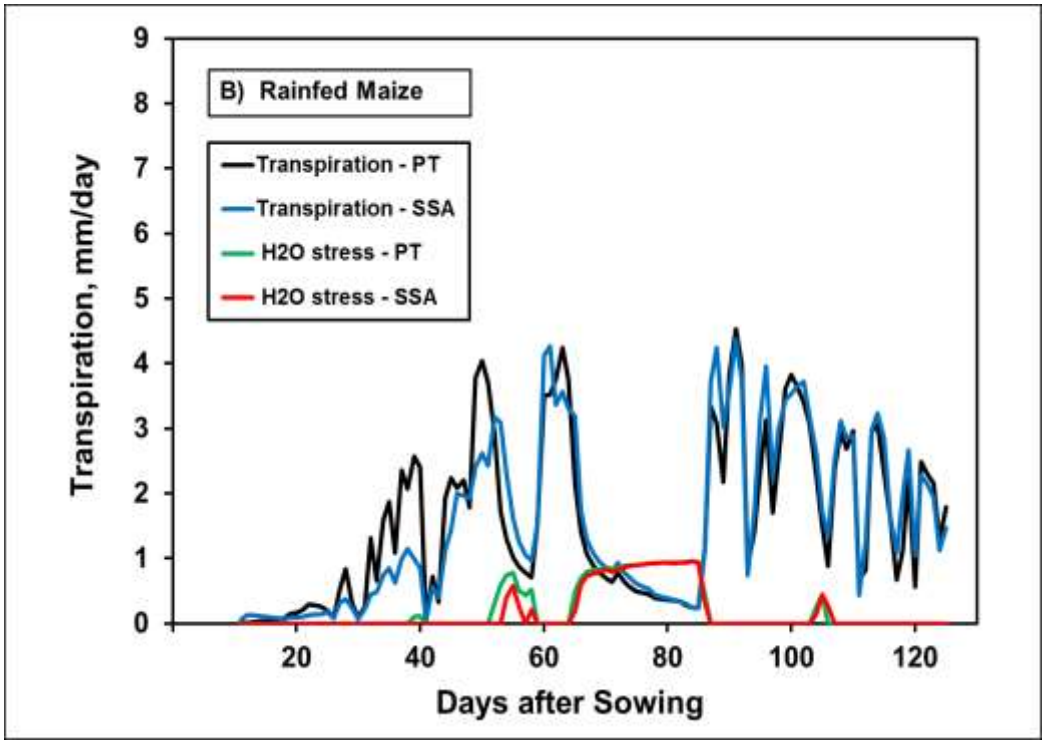
AgMaize – Simulated Transpiration with Priestley-Taylor or TE Method (Sinclair-Stockle-APSIM)



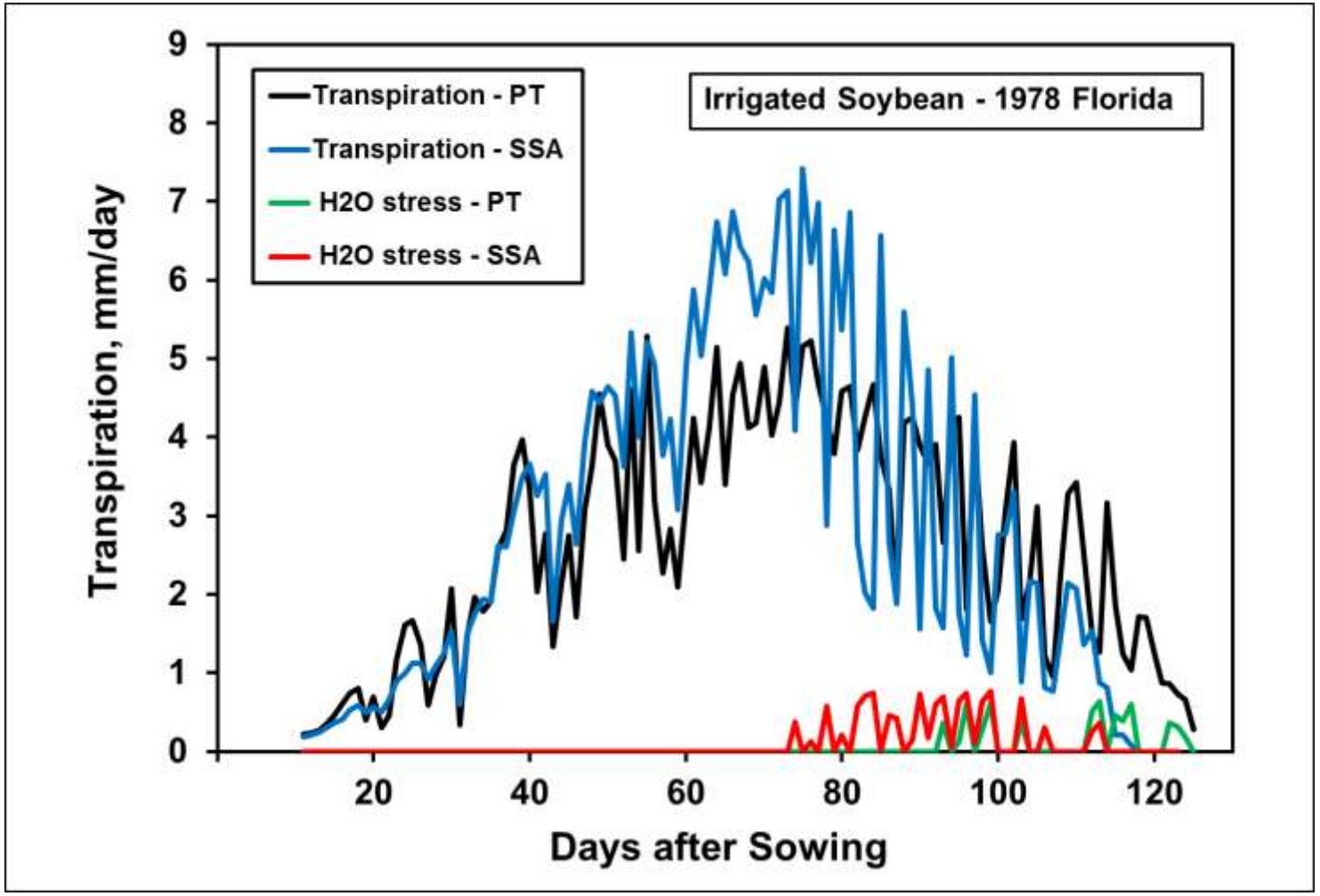
Shift in pattern: The SSA method has less transpiration at start of season, but higher rate during peak crop growth, for optimum irrigated crop grown April to July in Gainesville, FL. TE Eq from Stockle.

AgMaize – Simulated Transpiration with Priestley-Taylor or TE Method (Sinclair-Stockle-APSIM)

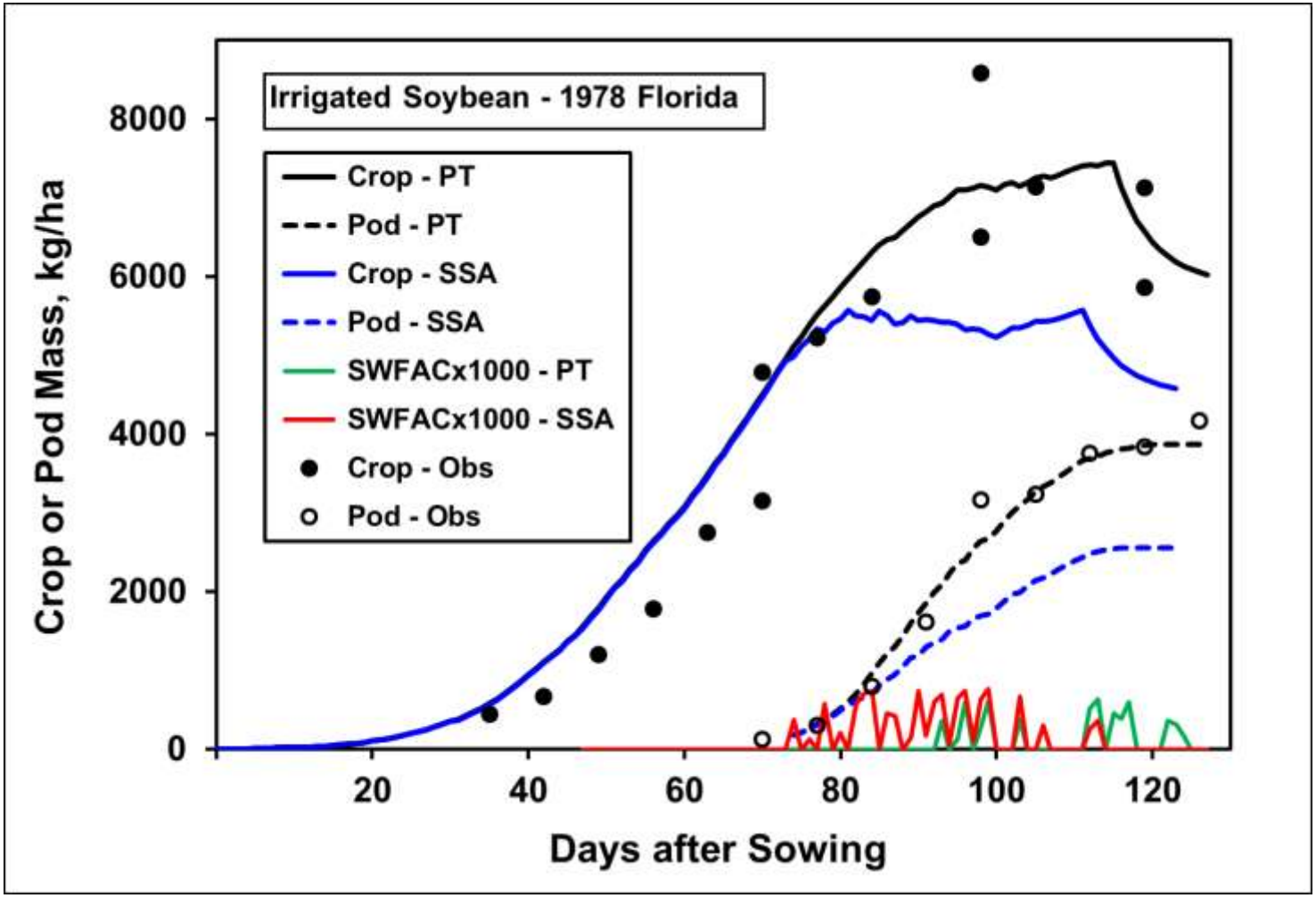


Rainfed maize grown April to July in Gainesville, FL: SSA method has less transpiration at start of season (like irrigated crop). SSA method had a delayed onset of water deficit near anthesis and higher yield.

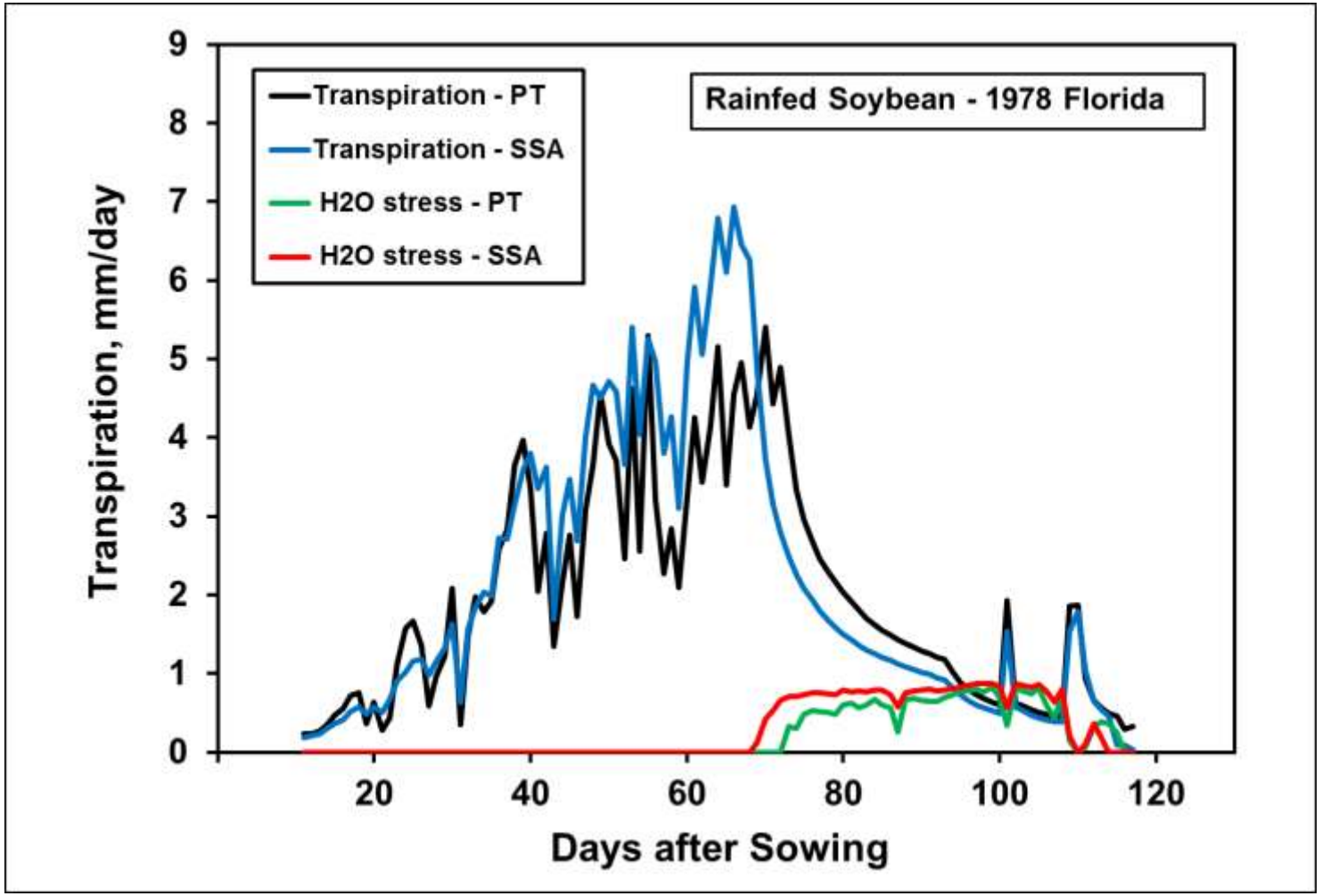
Soybean, Florida Irrigated: C-3 default TE eq



Soybean, Florida Irrigated: C-3 default TE eq



Soybean, Florida Terminal Drought: C-3 default TE eq



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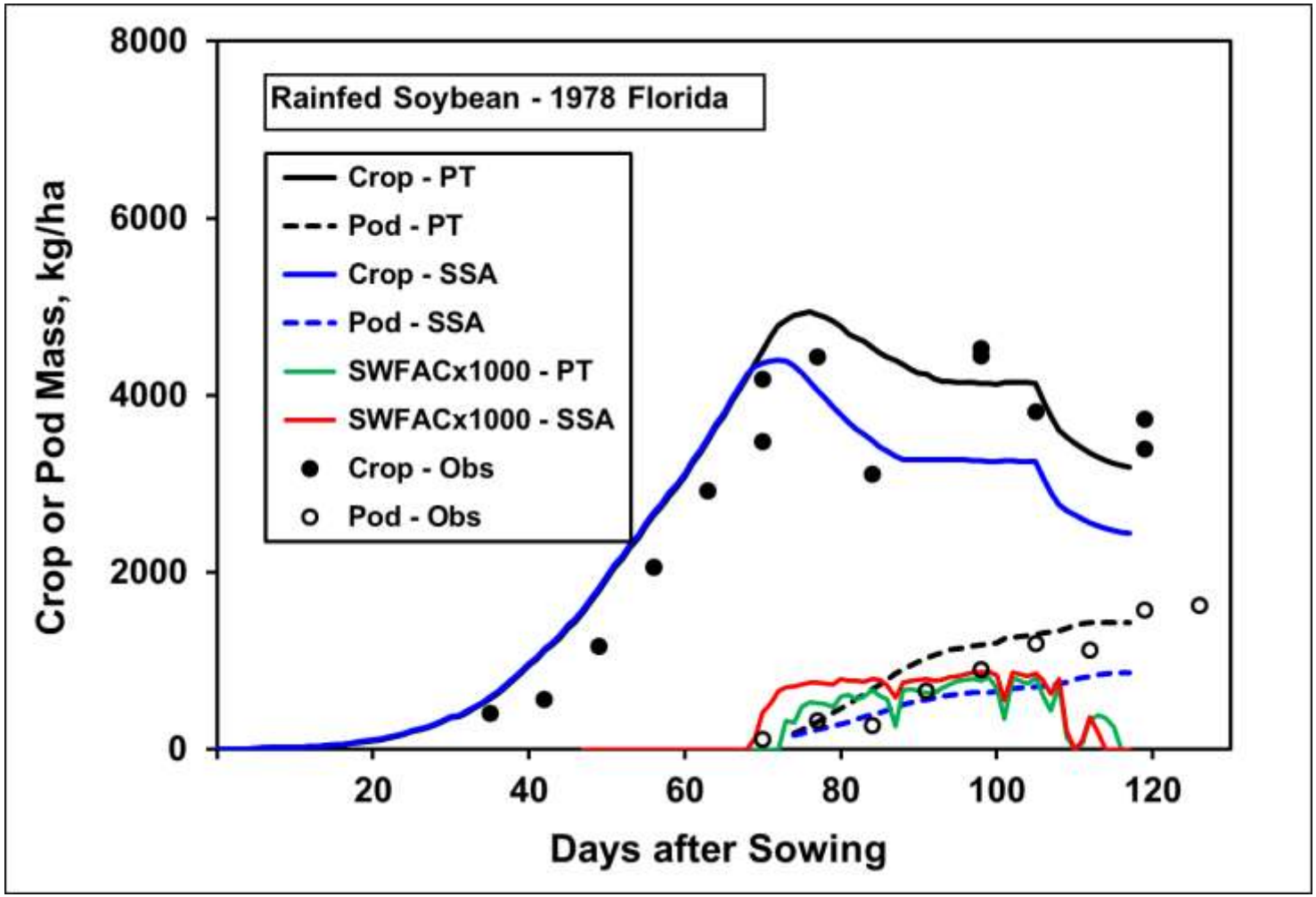
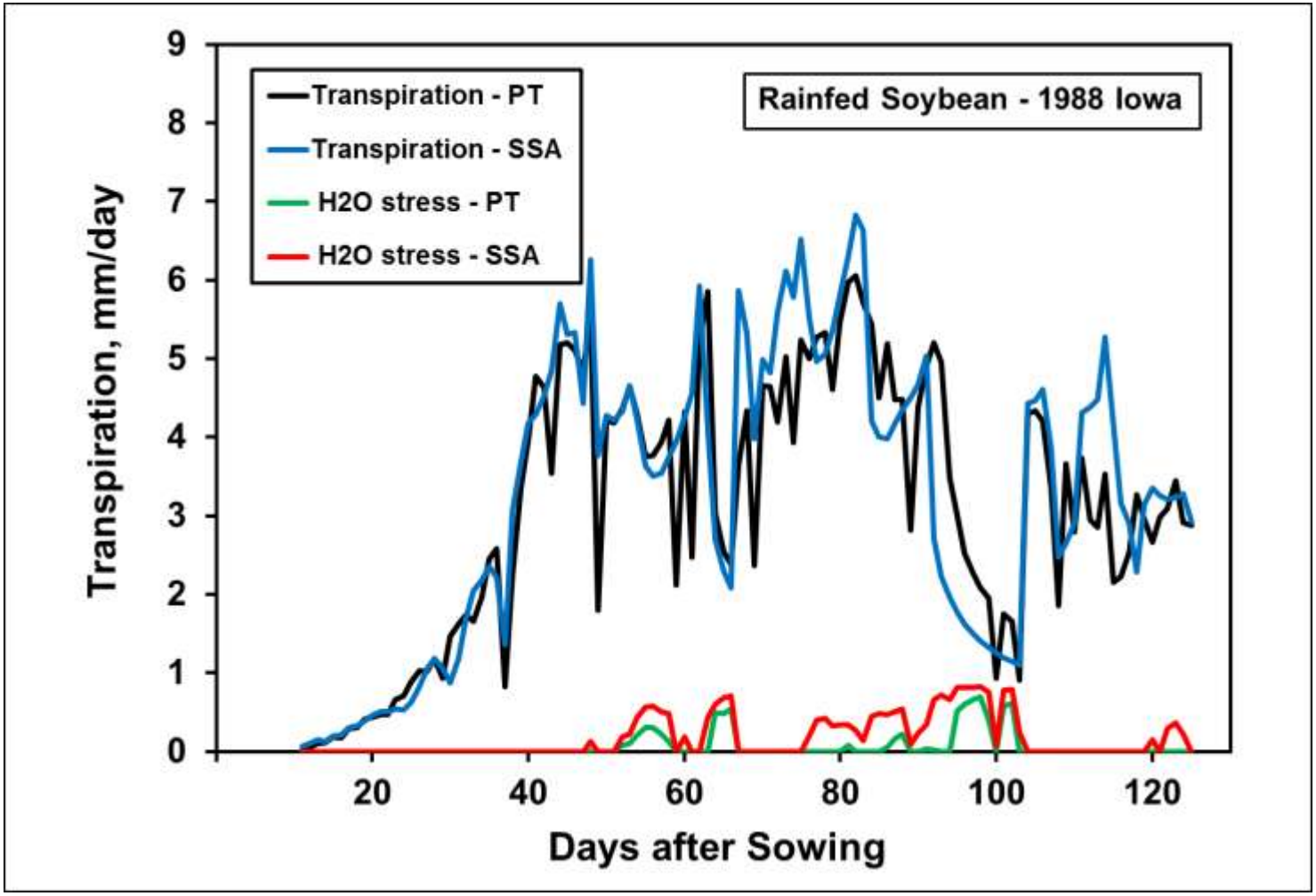
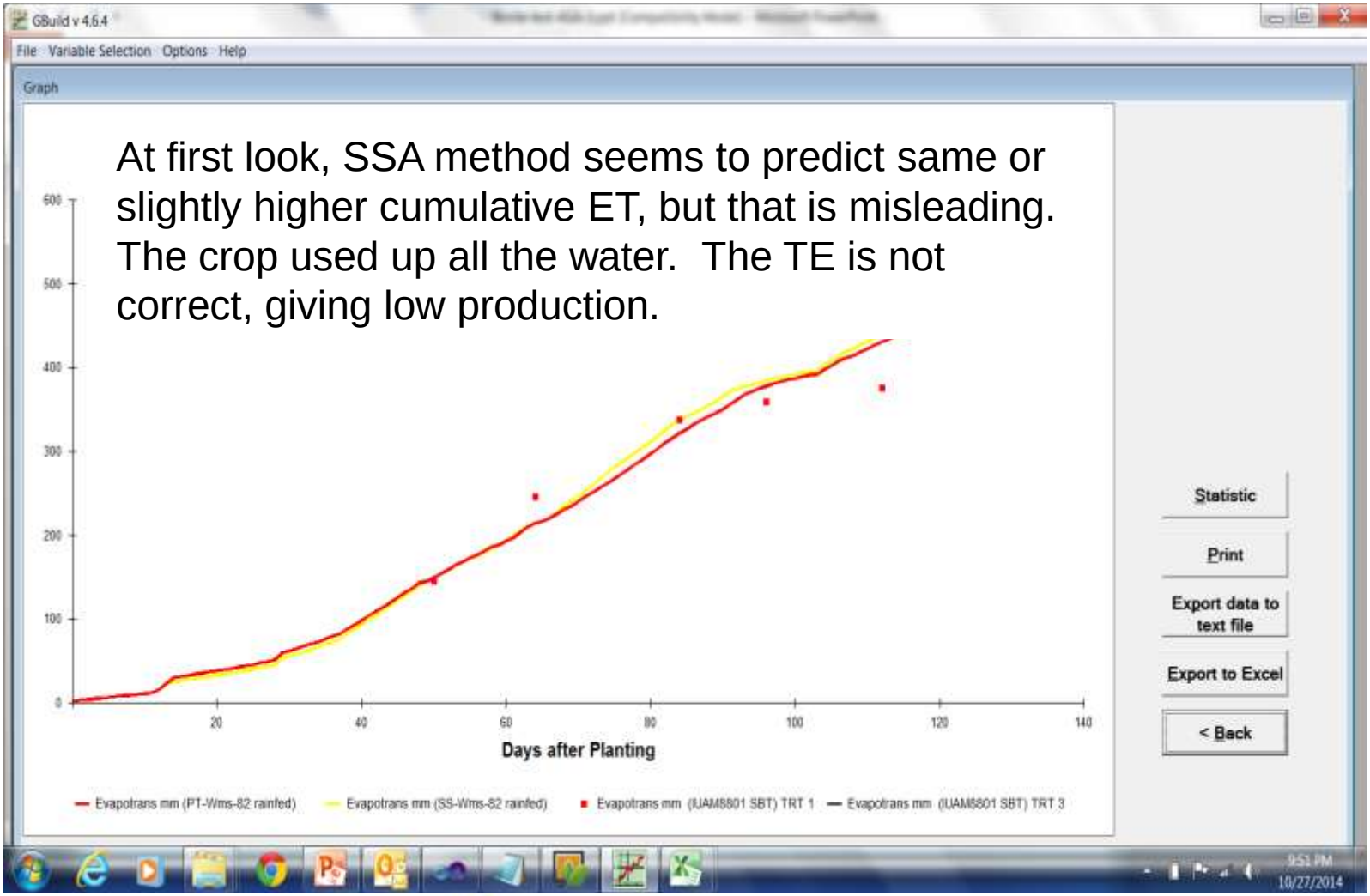


Soybean, Iowa 1988 Drought: C-3 default TE eq.



Soybean, Iowa 1988 Drought: C-3 default TE eq



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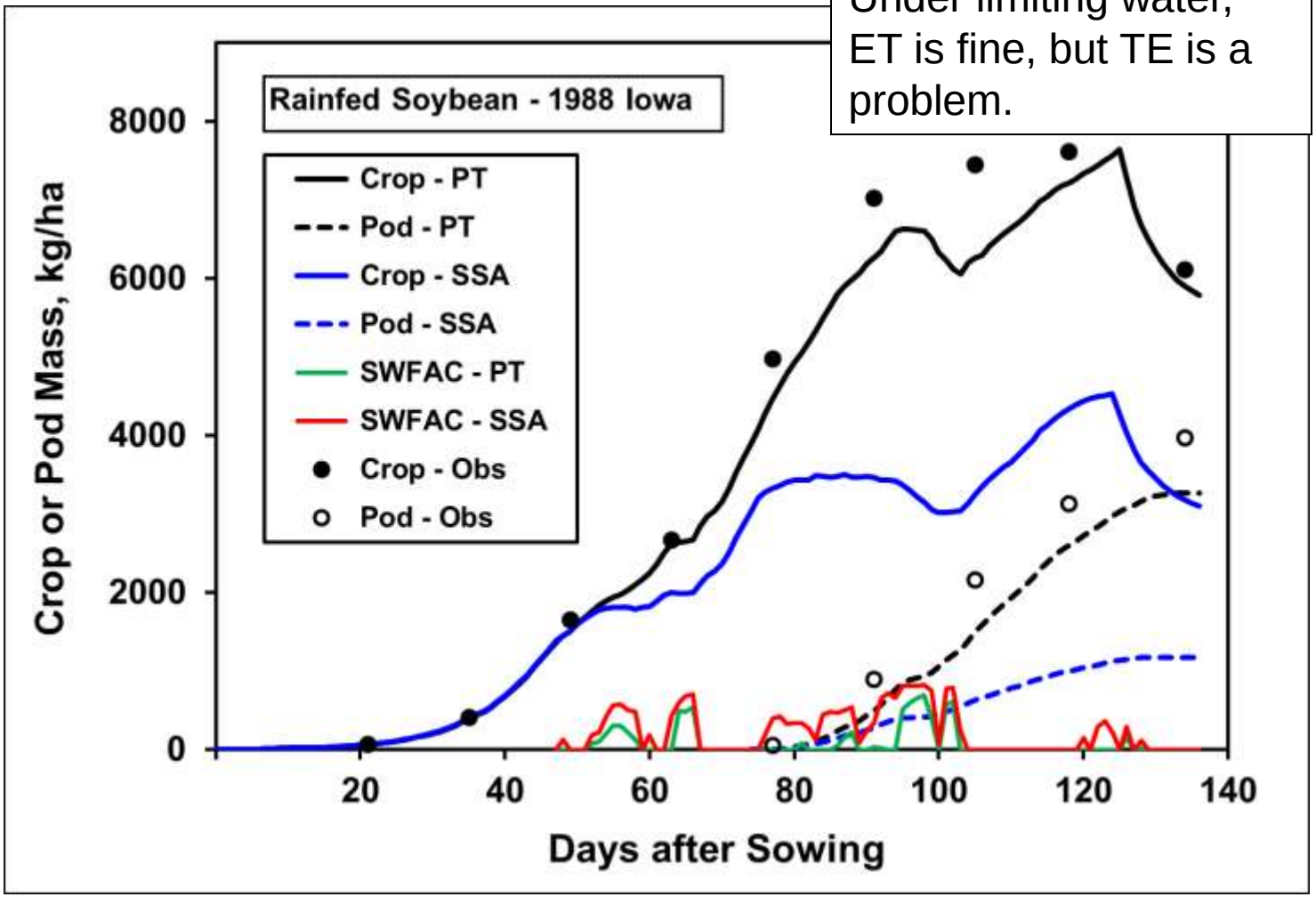
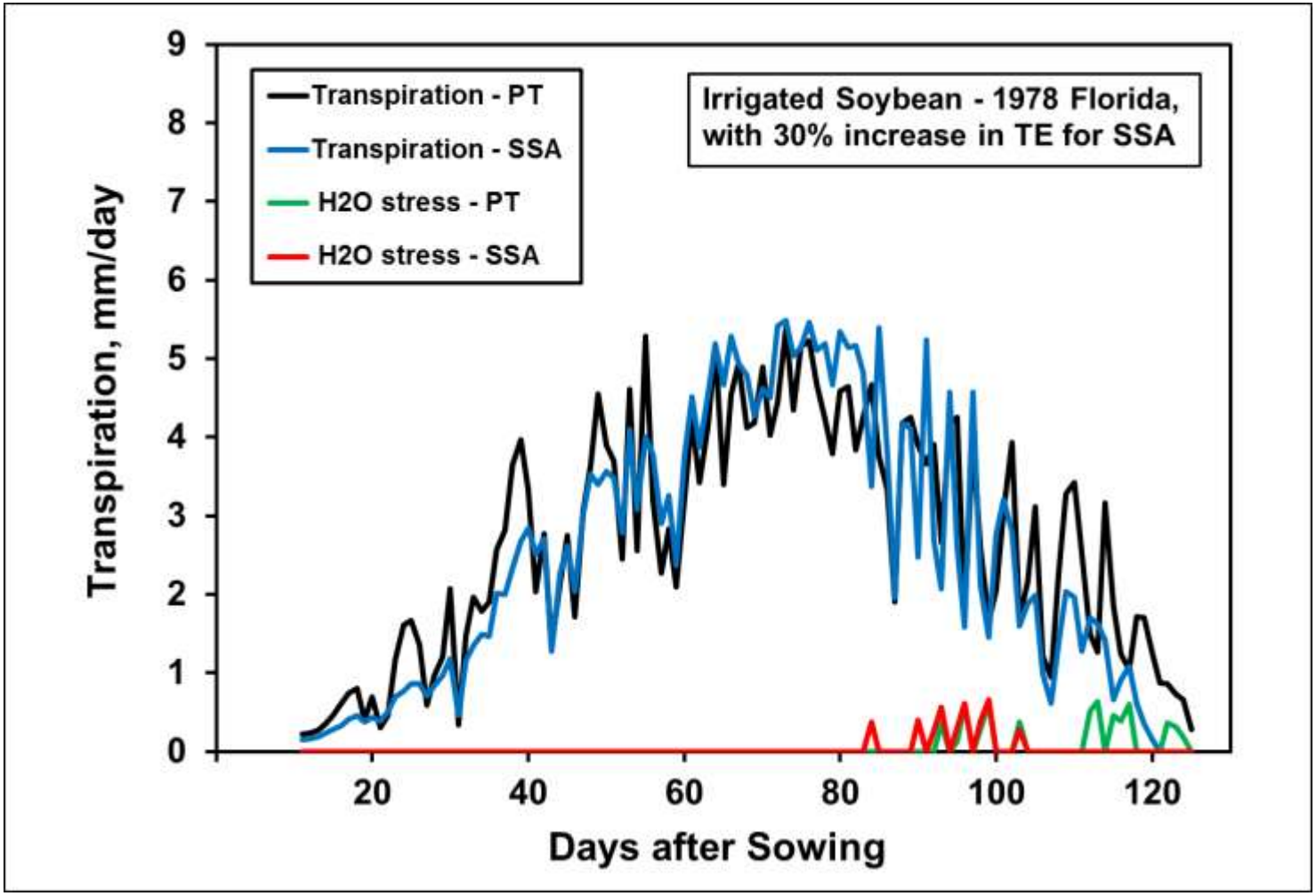
Soybean, Iowa 1988 Drought: C-3 default TE eq

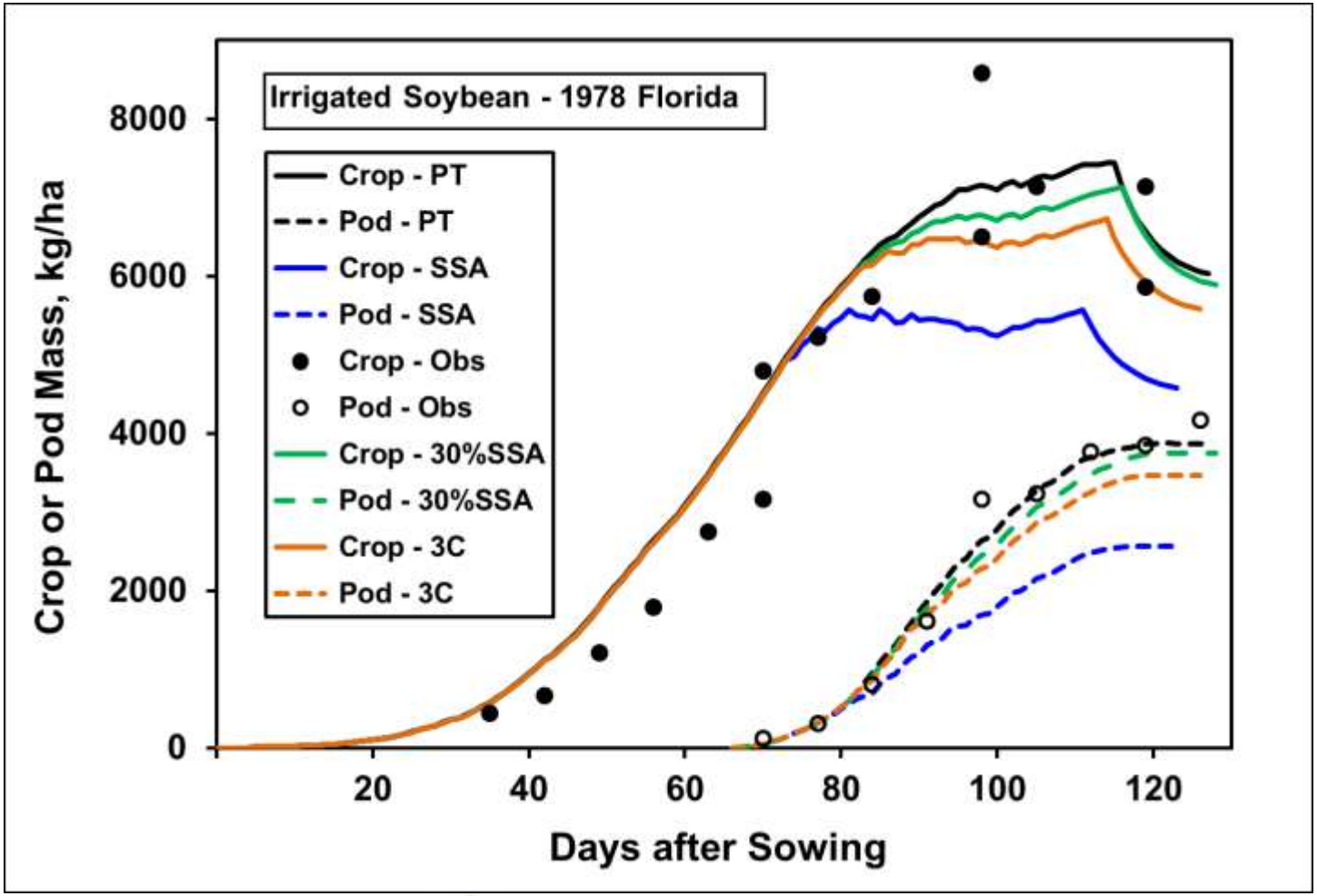
Under limiting water, ET is fine, but TE is a problem.



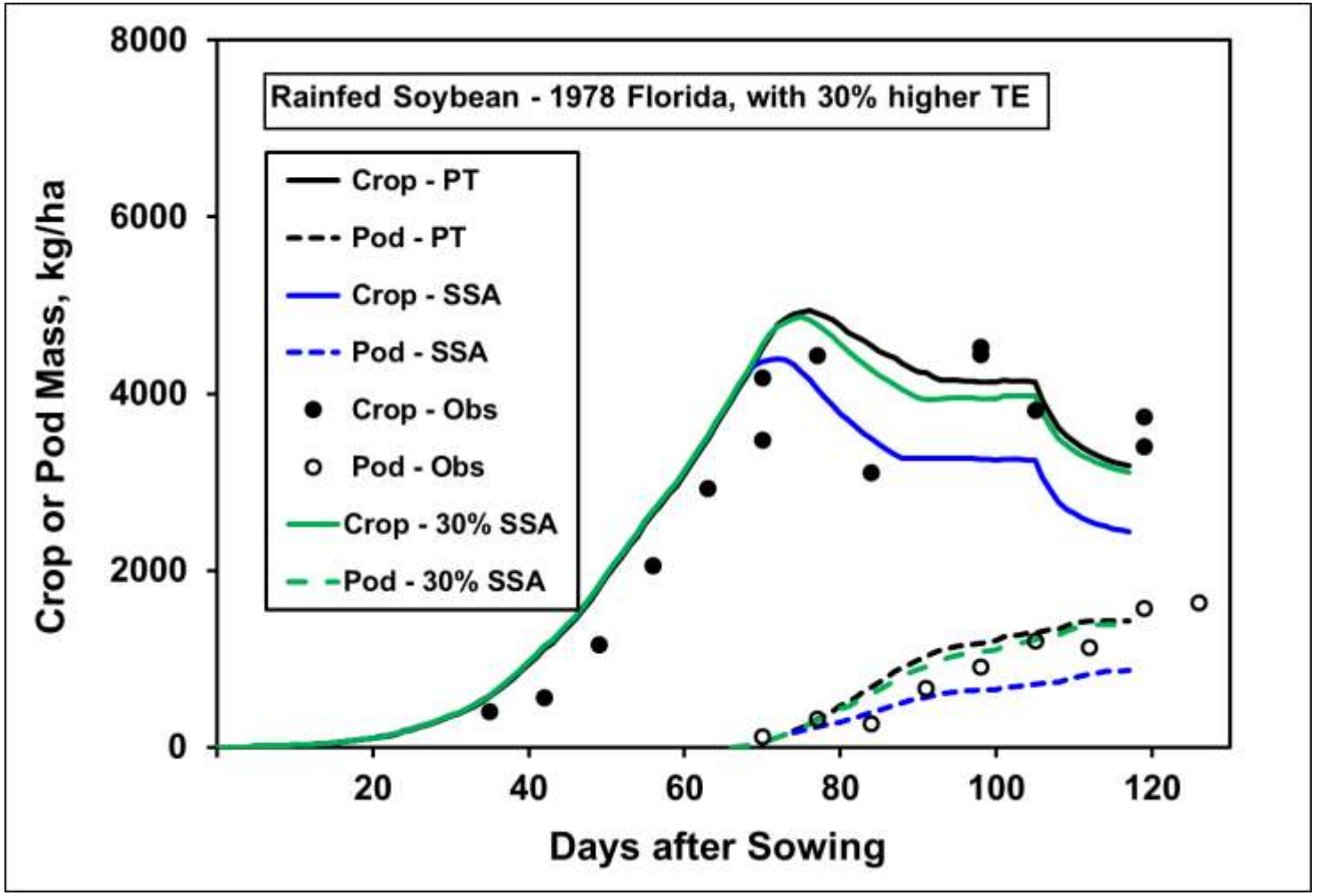
Soybean, Florida Irrigated: with 30% higher TE C-3 eq



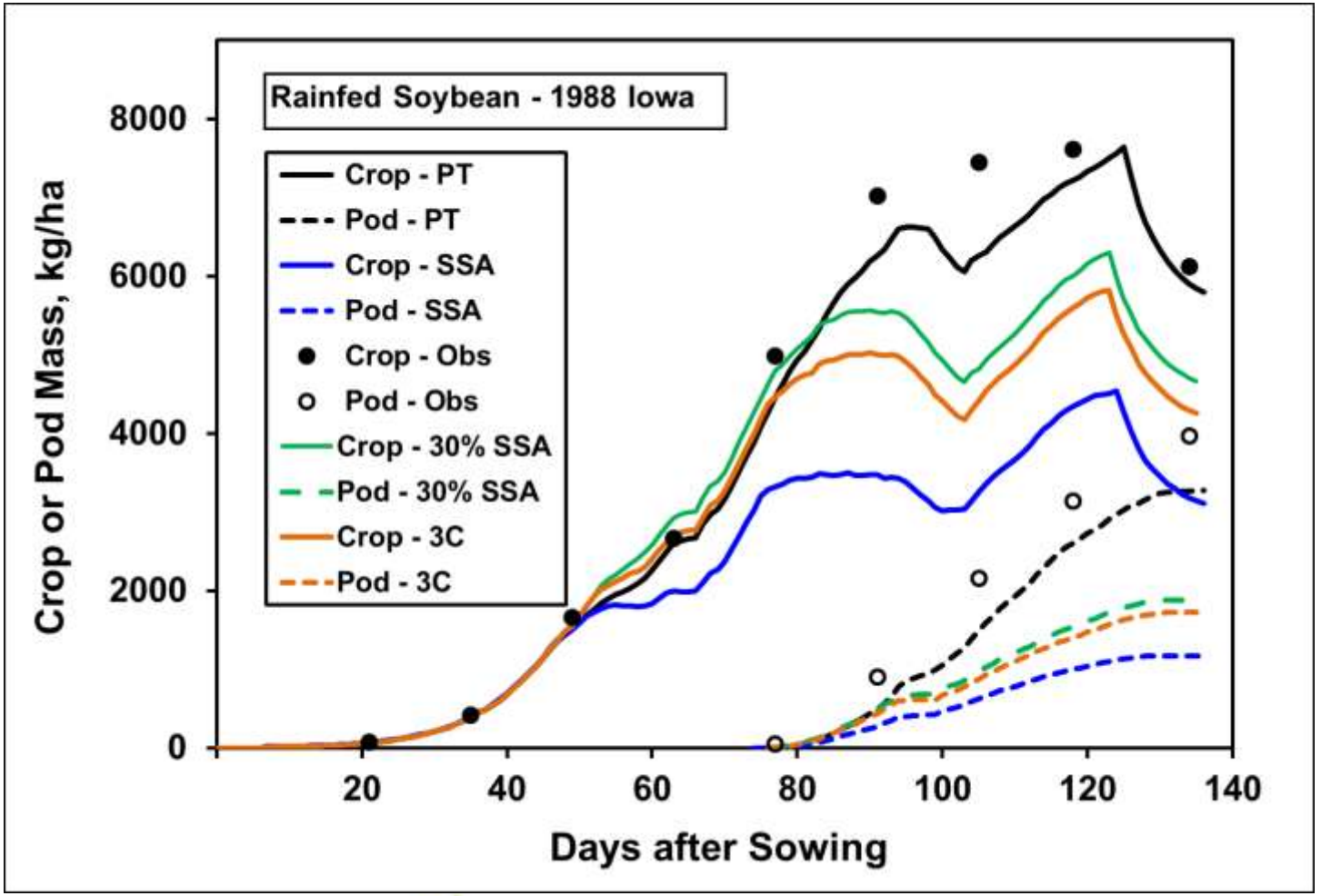
Soybean, Florida Irrigated: PT, default SSA, 30% higher TE-SSA , or 3C lower Tmax to mimic lower leaf temp



Soybean, Florida Terminal Drought, 30% higher TE



Soybean – Iowa 1988: PT, default SSA, 30% higher TE-SSA , or 3C lower Tmax to mimic lower leaf temp



Other Grain Legumes

Responses with default TE eq (SSA method) for other legumes

- Peanut, with much higher CGR than soybean or dry bean, always predicts too high T coming from CGR (SSA method). So, species differences must exist.
- Dry bean in Florida's dry warm spring showed too high Tr.
- Faba bean, less so. Is it because spring climate is cooler?
- In general, a 20-30% increase in TE is needed (that is more than the amount allocated to roots). Or combination: 15% less PG (to roots), 0.67 in VPD equation, and -1.5C from Tmax

Concerns for assumptions in TE method:

- Method assumes foliage Esat is at air temperature. Leaf temperature varies with VPD. Try Idso Tleaf vs VPD?
- Based on sunlit LAI assumption, ignores shaded leaves (their respiration assumed "equivalent" to maintenance respiration.

Conclusions and Needs

Crop Models vary considerably in their prediction of ET

- They vary in absolute ET, as a function of method, soil water extraction, and rooting allowed.
- There are many ways to go wrong (ET method, soil E method, extinction coefficient, TE vs VPD, runoff, rooting, DUL-LL), yet models may have other compensations allowing reasonable yield response.

Important Needs

- Need to test crop models against real ET data, because some models have quite different ET values
- Need to test models against CO2-FACE data on ET and biomass increase, as models vary considerably on transpiration reduction caused by rising CO2.

AgMIP Crop Water-ET Team

AgMIP Crop-Water-ET Team is being organized, to test crop ET prediction and crop water use against observed data, across multiple crop models and across crops.

Co-Leaders (J. L. Hatfield, Laj Ahuja, and K. J. Boote)

Activities

- Multi-model testing for prediction of ET, E, T, & soil H20
- Testing modules within platforms, for predicting ET, E, T, and soil water uptake

Crop Water Use - ET Data (any crop, any location)

- Instantaneous ET (or E & T) measured by lysimeters, eddy flux, & Bowen ratio systems.
- Season-long ET-water use from soil water balance.
- Indirect: simulated vs obs. soil water content & biomass over time under rainfed, assuming WUE is correct.