FRUIT CROP PHYSIOLOGY
CORNELL GENEVA

Apple Tree Water Use in Northeastern Climates and an Online Water Balance System

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Changes that have led to more limitations due to water stress :

- Use of shallow dwarfing rootstocks.
- Need for rapid tree development after planting.
- Economic requirement for large crops of large fruit size from small-fruited high quality varieties.
- Increasing drought frequency due to climate change.

Local knowledge and models of water use in apples are needed to:

- Determine whether irrigation is of economic benefit.
- Design irrigation system capacities
- Determine daily or weekly water loss for irrigation scheduling.

THE PROBLEM

- How do you estimate the water use of apple trees in our climate, so you can irrigate appropriately?

- Need to drip irrigate only the trees, not the whole orchard.

- Hard to estimate from soil moisture with variable root distributions and cover crops.

• Estimating crop water use for irrigation commonly uses a crop coefficient, K_c, a fraction of the estimated evapotranspiration (ET_o), a grass as a reference.

• An equation that estimates the physics of water loss (the modified Penman-Monteith (P-M) equation) uses a grass as the reference plant. Actually works OK in arid climates, but not here.

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- This leads to the estimated ET_o values that are overwhelmingly controlled by sunlight radiation, but relatively insensitive to humidity.

- In tall irregular structures like apple orchards, the canopies of apple trees are highly coupled to the bulk air. This makes apple trees dependent on VPD and stomatal conductance as well as R_N. Consequently in humid climates the K_c from arid regions may be wrong.

The Test Orchard

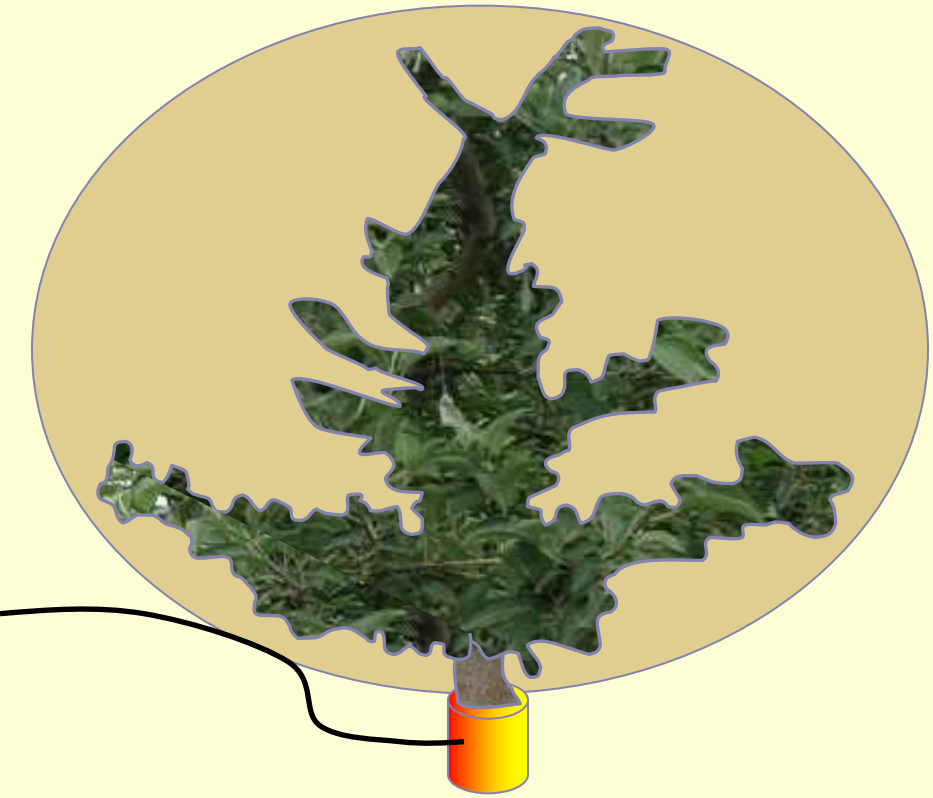
- Dwarf ‘Royal Empire’/M9
- Relatively large spindle training
- 6 x 14’ spacing, 518 trees/acre

Direct Measures of Tree Water Loss:

- Sap Flow Gauges – good for relative measures, but may be inaccurate.
- Gas Exchange Canopy Chambers – accurate but unnatural environment over the trees.

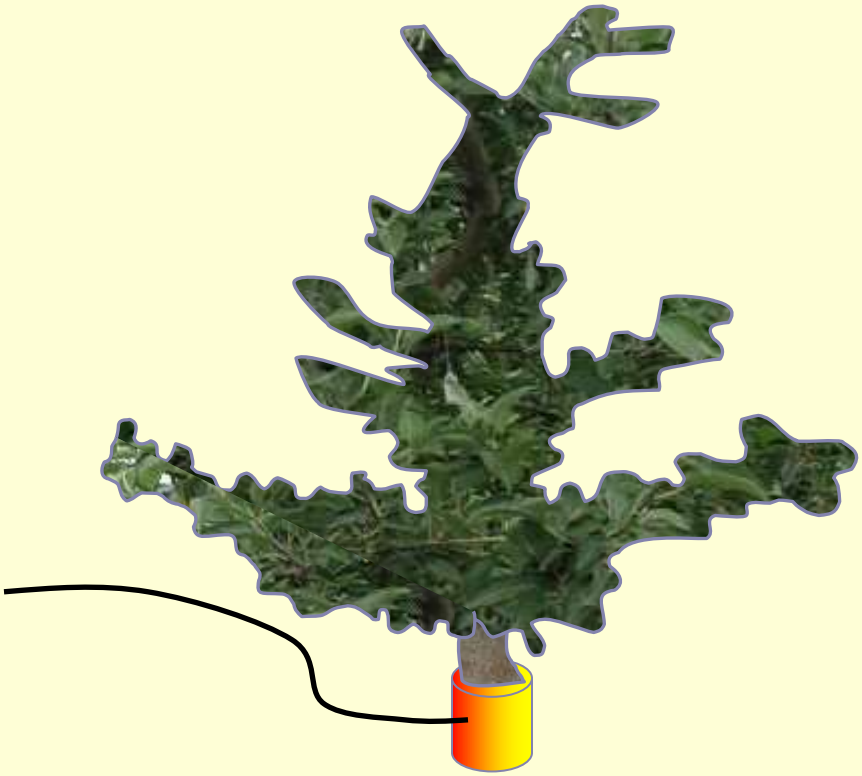
Use of Sap Flow Gauges Calibrated by Gas Exchange Canopy Chambers

Short period(s)



Calibration

Entire season



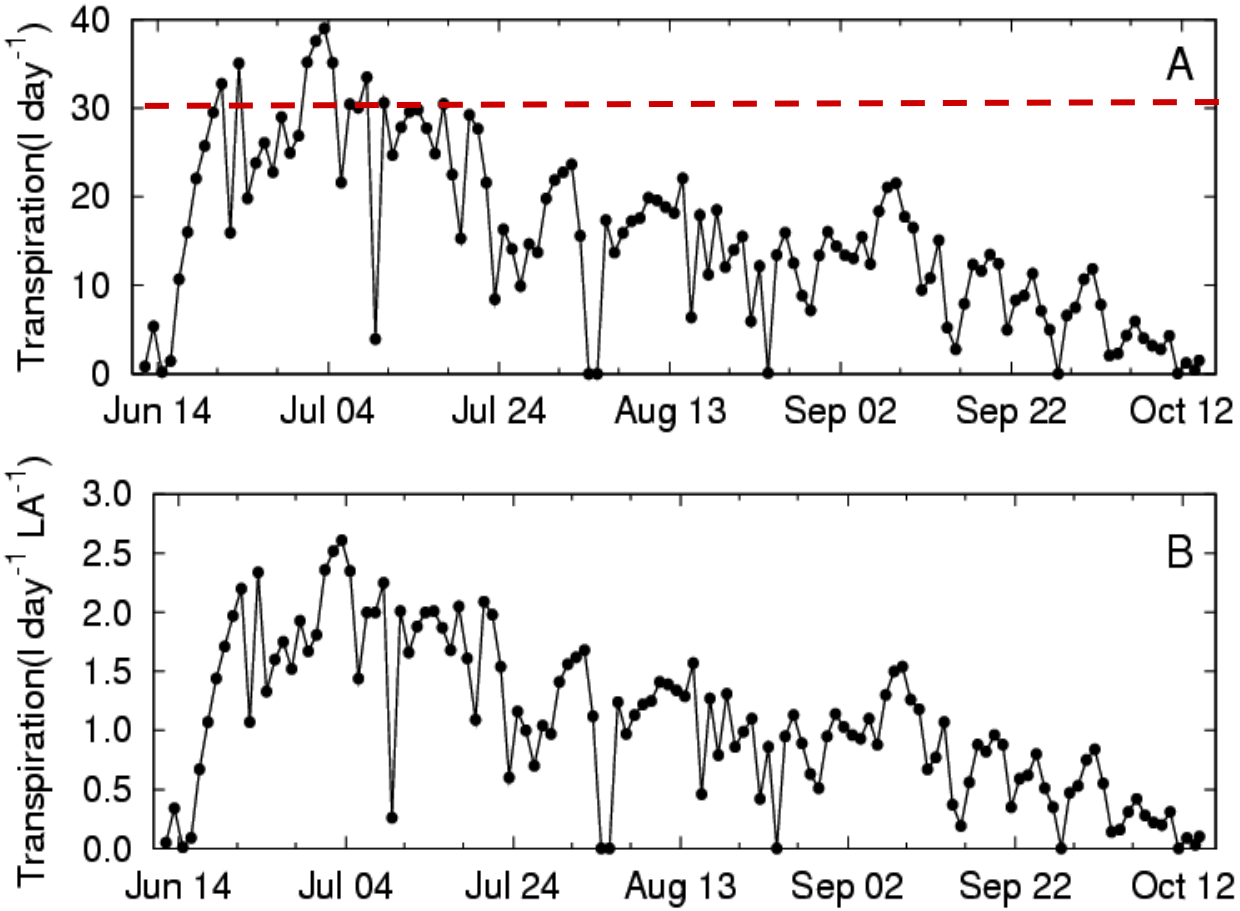
Direct Measurement

Meteorological Measurements Taken for Calculating Grass Water Use

- **Above-canopy**
  - Temp / Relative Humidity
  - Solar radiation
  - Wind speed
- **Inside-canopy**
  - Temp/ Relative Humidity
- **Open-field for reference**
  - Temp/ Relative Humidity

Daily Apple Tree Water Use During the Season
Geneva, NY (518 trees/acre)

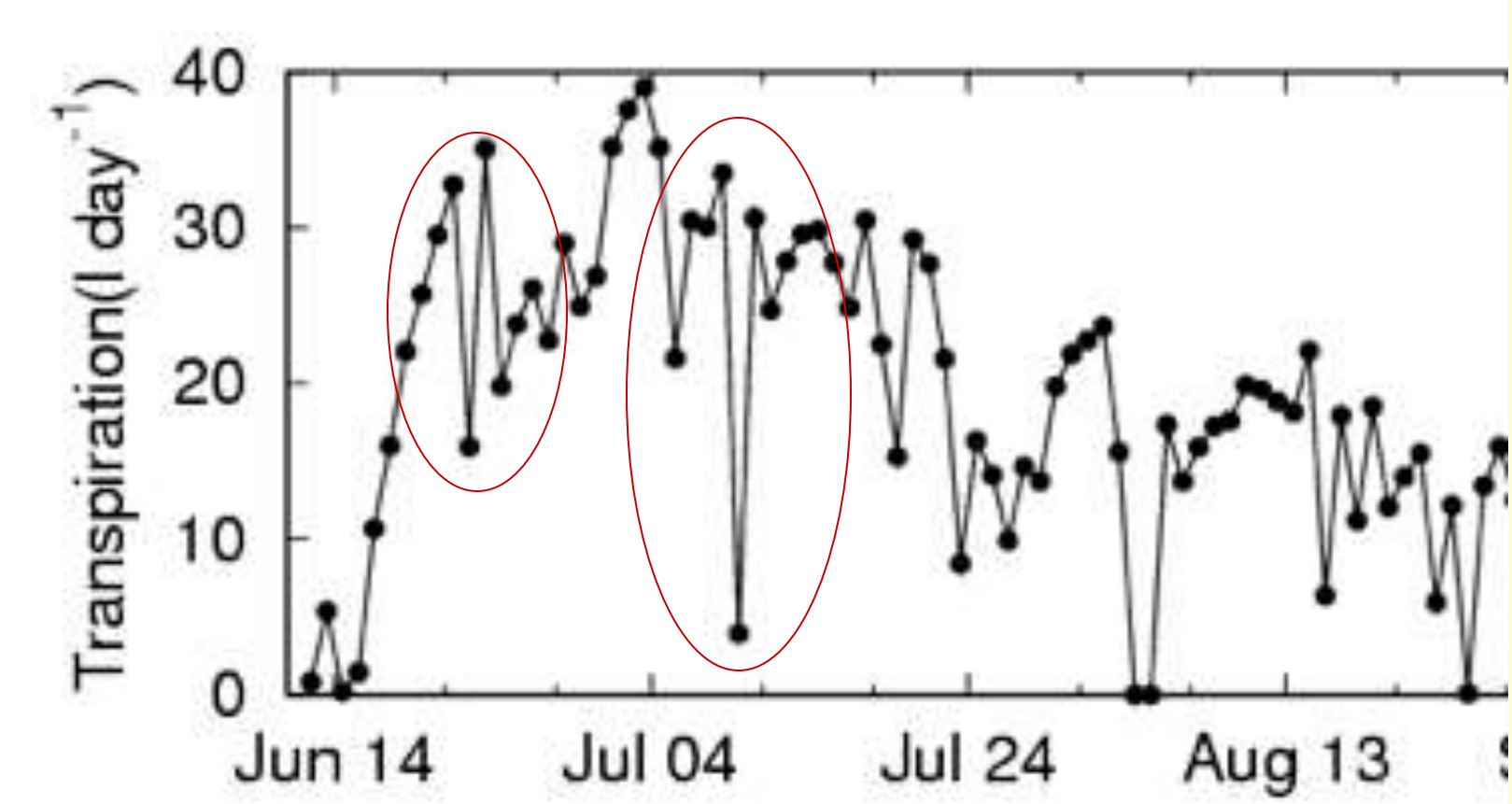
Tree Water Use



8 gal/tree/day
4,000 gal/ac
0.15 ac-in/day
=
56 gal/tree/wk
28,000 gal/wk
~1 ac-in/wk

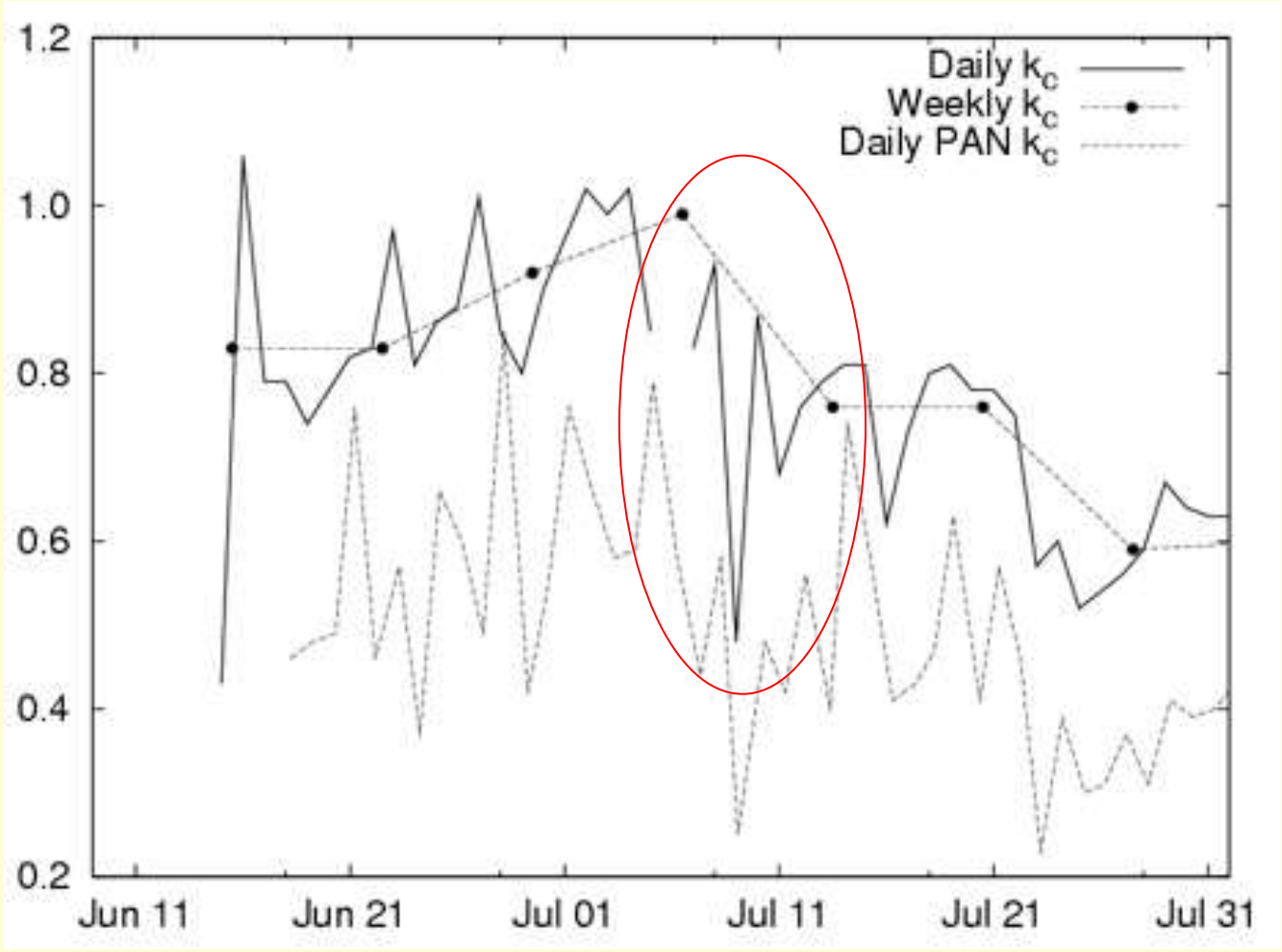
Date

Notice Day-to-Day Variability due to Variable Weather (sun, temp and humidity)



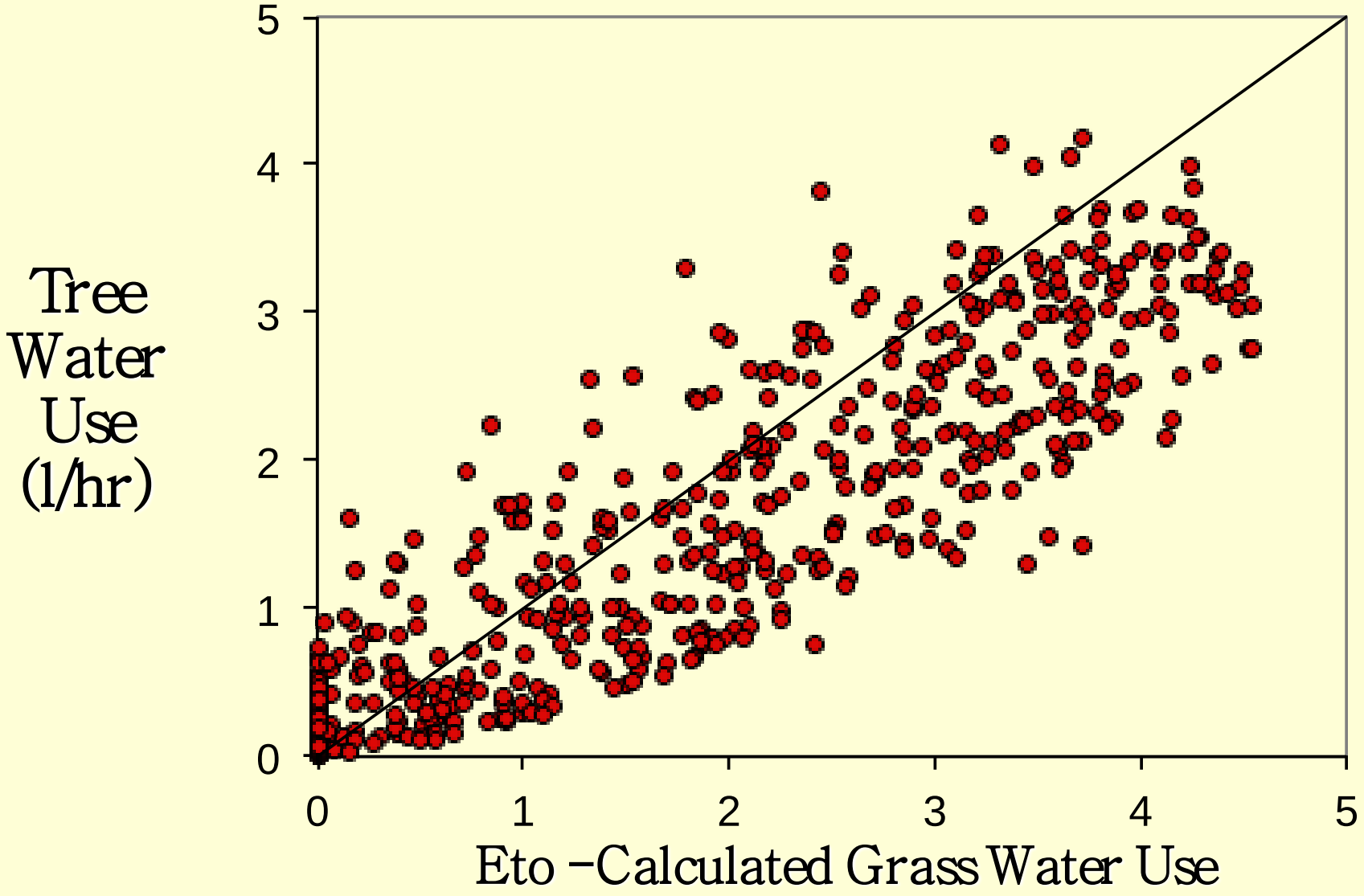
Apple Water Use

$ET_o \times K_{crop}$ method with crop coefficient is common but does not work for apple in a humid climate.

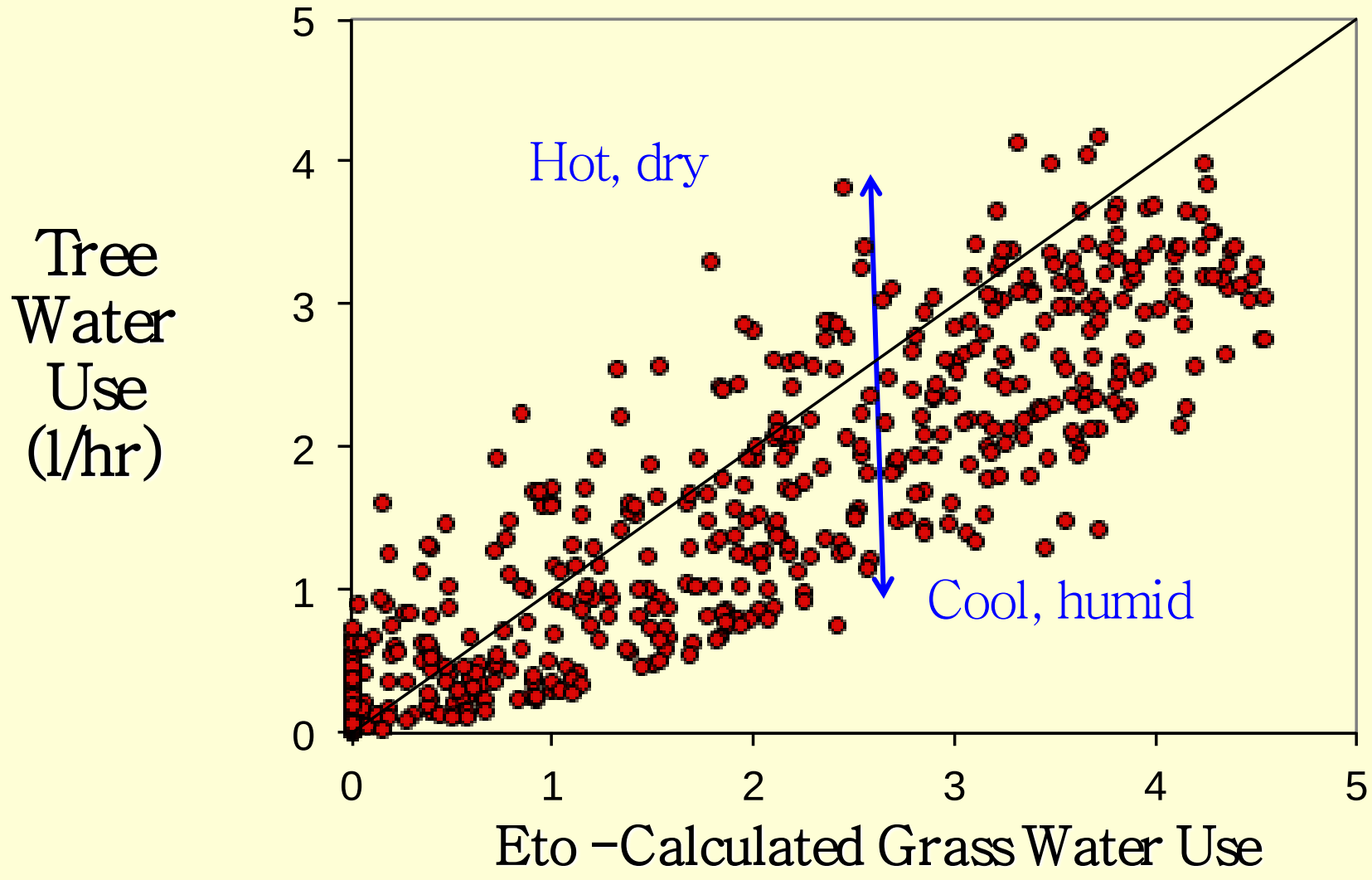


From: Dragoni et al. 2005

Apple Tree Water versus Calculated Grass Water Use



Conclusion – Grass is a crummy model of an apple tree!



At any estimated value, ex. 3 l/hr, the actual water use could vary from 1.5 to 4 l/hr.

Water is lost from variable pores on the bottoms of apple leaves. They respond to light, humidity and water stress.

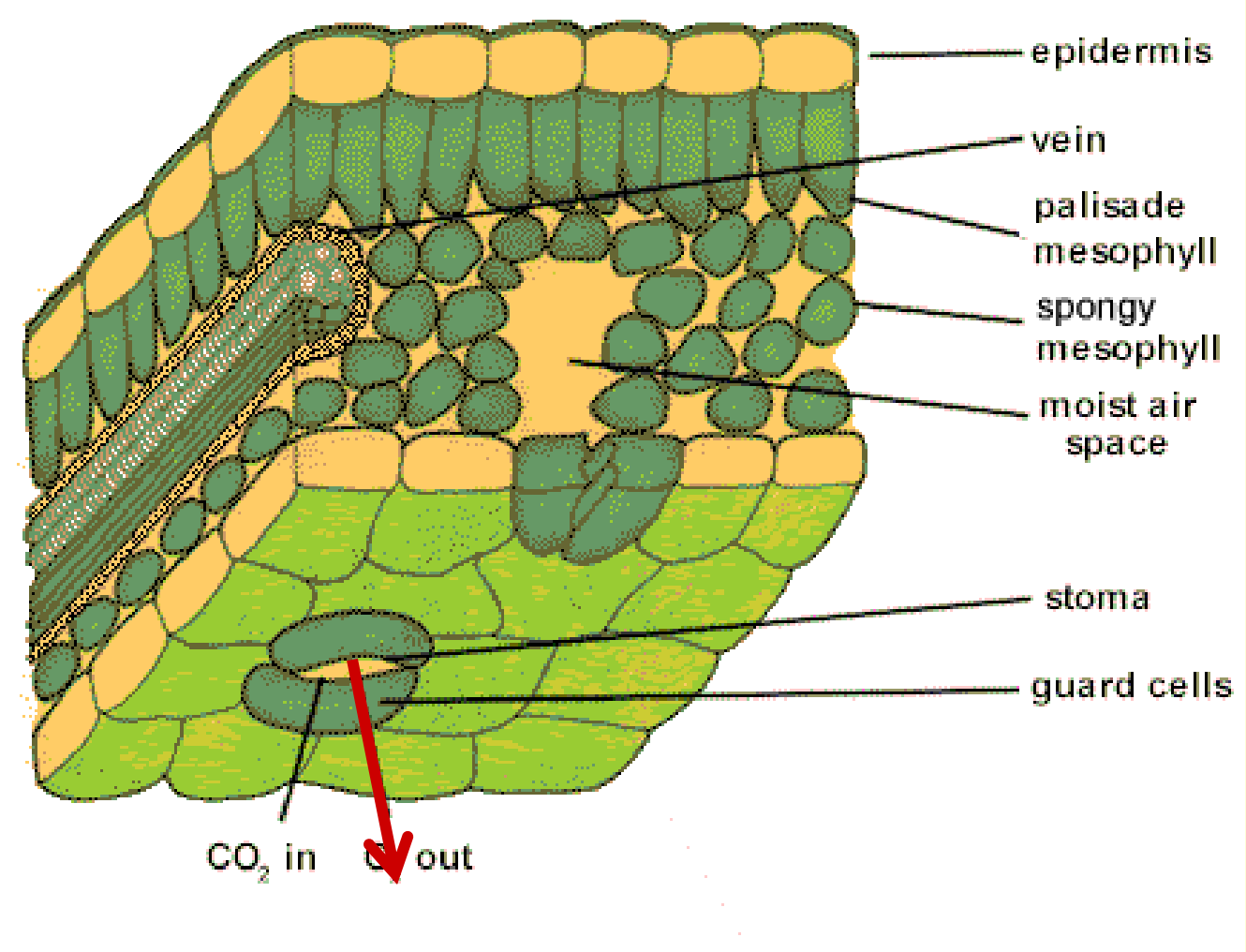
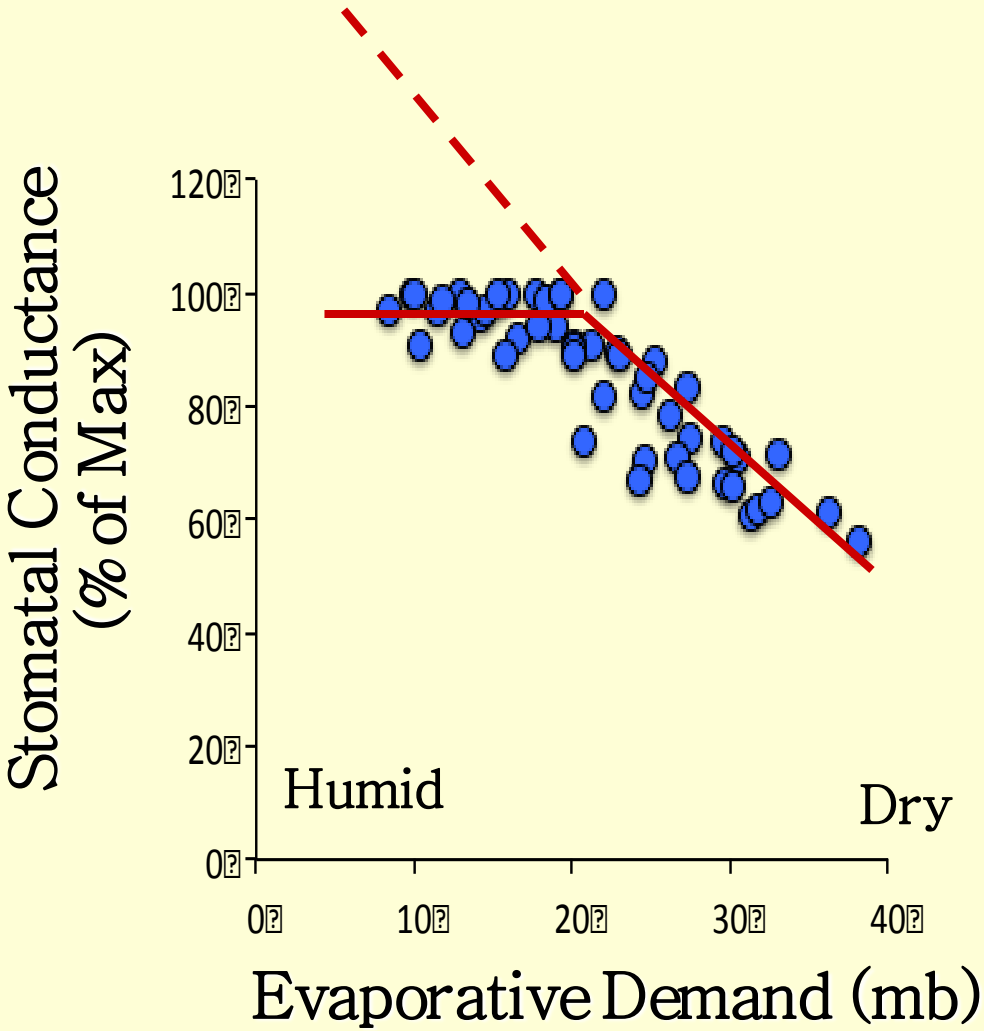
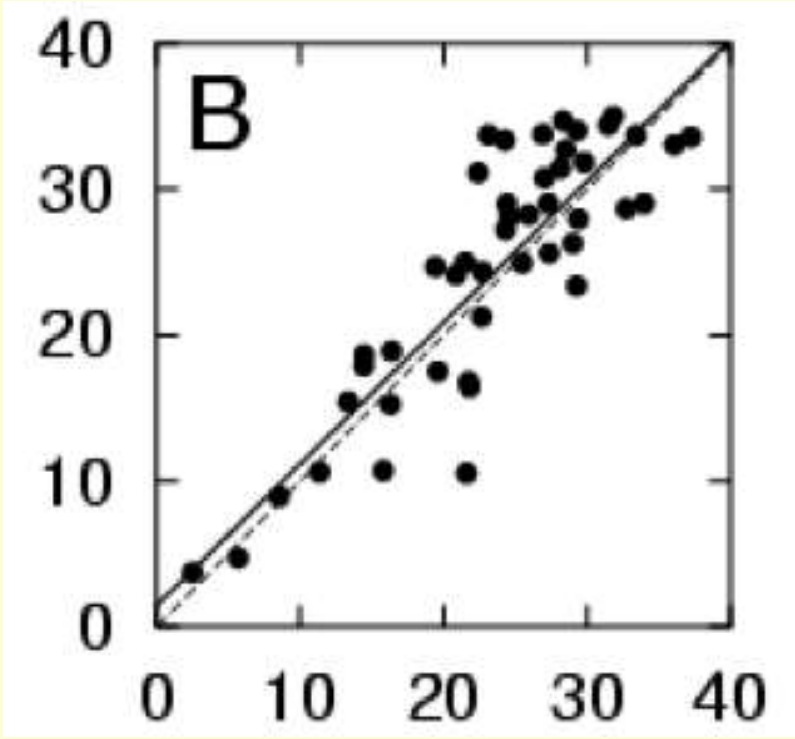


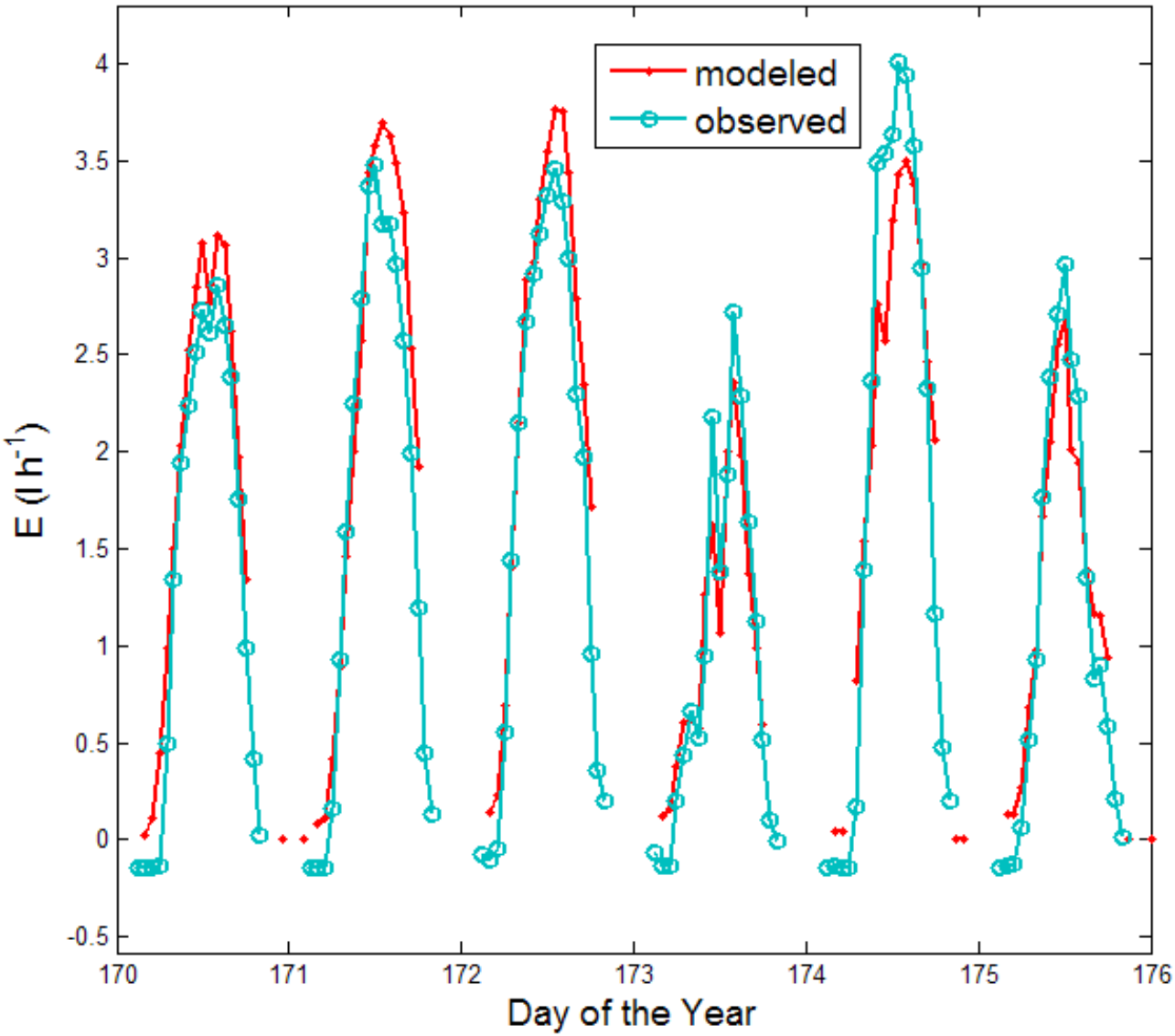
Image from: jsl66yx8.blog.163.com

Apple-Specific Penman-Monteith Equation

- much smaller boundary layer
- reduced radiation interception
- unique stomatal response to VPD







Time series of model estimates and measured transpiration (example of 5 days).

Getting the Models to Users

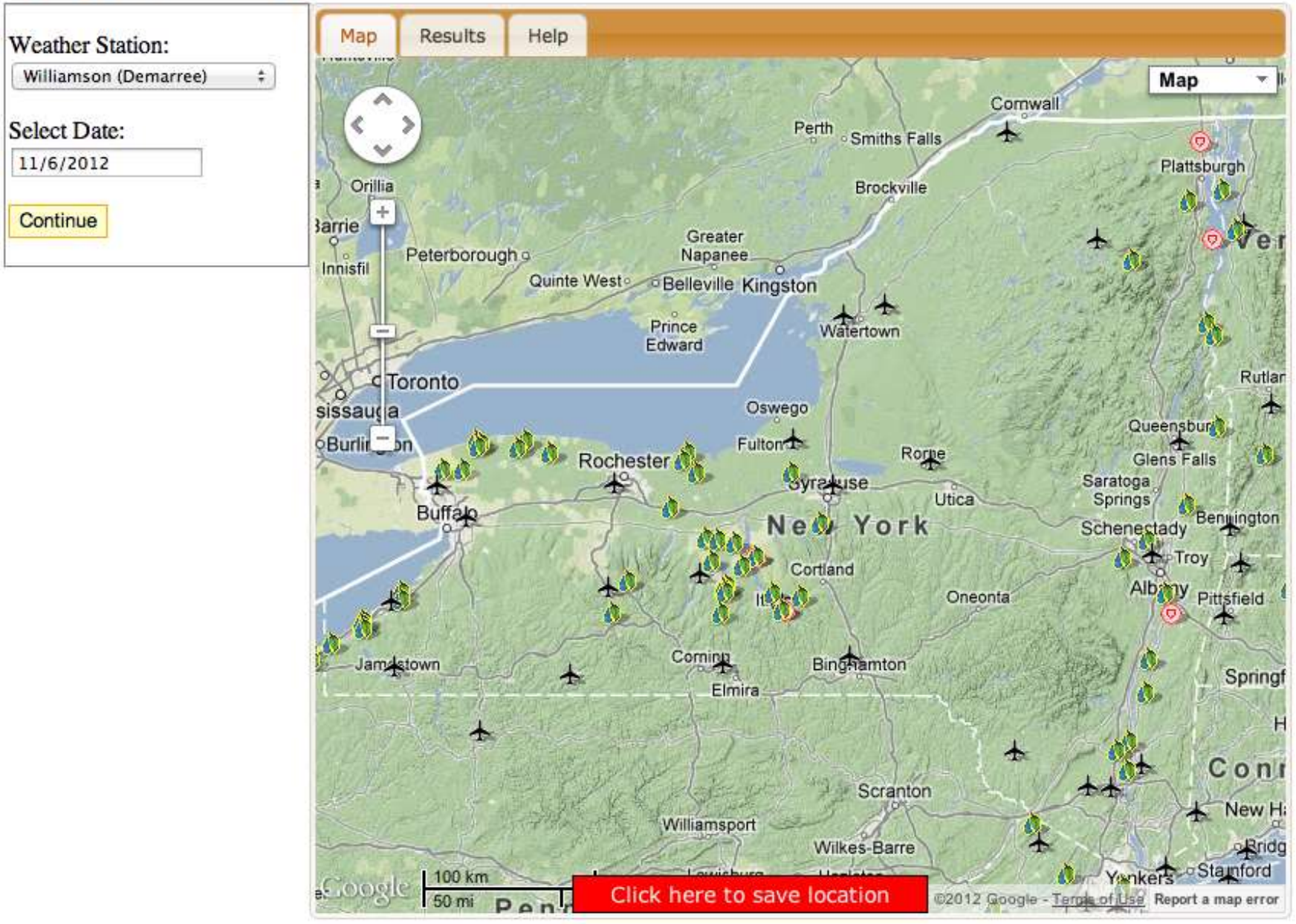
Collaboration with Dr. Art DeGaetano, Director

Online versions:

Apple-Specific Penman-Monteith Equation

Programmed to automatically calculate daily apple water use and water balance based on data from weather stations in the apple-growing regions.

NEWA Apple ET Model



http://newa.nrcc.cornell.edu/newaTools/apple_et

Weather Station:

Williamson (Demarree)

Select Date:

07/01/2014

Continue

Map | Results | More info

Apple ET Model for Williamson (Demarree)

Change green tip date or tree density and click "Calculate" to recalculate results. Changing "Age of Orchard" will automatically recalculate table.

Green tip date	In row spacing	Between row spacing	Trees per acre	Age of orchard	Water balance
4/17/2014	3 feet	12 feet	1210	Mature	

Apple Evapotranspiration Model Results

Date	Orchard ET (gallons)		Rainfall		Irrigation	Water Balance (gallons/acre)	
	per tree	per acre	inches	gallons/acre	gallons/acre	Daily	Cumulative
Jun 24	2.1	2549	0.31	5892	0	3343	0
Jun 25	0.3	411	0.47	8934	0	8523	0
Jun 26	2.8	3342	0.02	380	0	-2962	-2962
Jun 27	3.3	3960	0.00	0	0	-3960	-6922
Jun 28	3.9	4688	0.00	0	0	-4688	-11610
Jun 29	2.8	3428	0.14	2661	0	-767	-12377
Jun 30	2.7	3301	0.03	570	0	-2730	-15107
Jul 1	2.9	3494	0.00	0	0	-3494	-18601

Summary

- We cannot rely on current methods to estimate water needs for apples in cool humid climates
- We need to locally, or at least regionally, directly measure water use in apple orchards.
- We need to develop crop-specific modeling approaches that consider specific characteristics of fruit crops that are different from grass.
- We need to test this new model in different conditions.

Thanks to:
Dr. Art DeGaetano and
Keith Eggleston

Northeast Regional Climate
Center, Cornell

And Thank You!