



*Sensitivity of Reference ET to
Weather Station Sensor Accuracy*

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Water Management Research Unit

Fort Collins, CO



United States Department of Agriculture
Agricultural Research Service

*Innovations in
Irrigation Water
Management
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Background

- ❑ Sensor inaccuracy → high ET_{ref} error
- ❑ Of examples in literature that examine ET sensitivity
 - Few use sensor accuracy as bounds
 - Nearly all vary one variable at a time, two at most

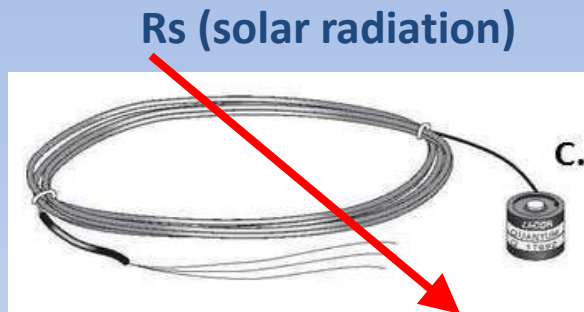
Objectives:

- ❑ Evaluate sensitivity of ASCE Standardized Reference ET Equation ET_{os} based on sensor accuracy:
 - Local sensitivity (max. error range)
 - Global Sensitivity Analysis (GSA) – two methods
 - Two locations: semi-arid (Colorado), and humid (Florida)



DeJonge, K.C., M. Ahmadi, J.C. Ascough II, K.D. Kinzli. 2015. Sensitivity analysis of reference evapotranspiration to sensor accuracy. *Computers and Electronics in Agriculture* 110: 176-186.

ASCE Standardized Reference ET



$$\square ET_{sz} = \frac{0.408\Delta(R_n - G) + \gamma \frac{C_n}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + C_d u_2)}$$

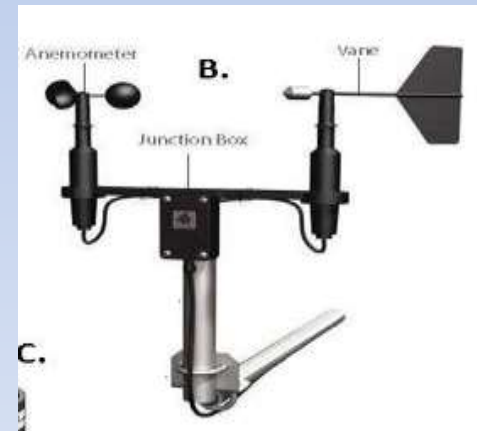
u2 (wind)

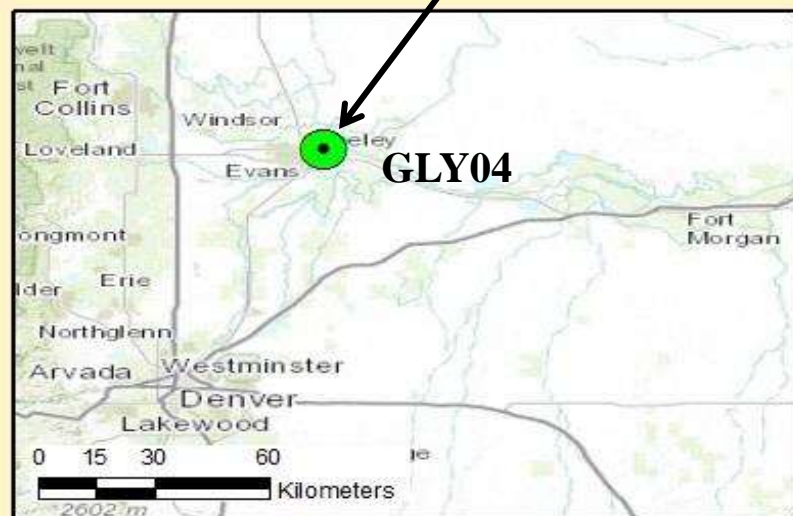
□ Daily time steps

□ Short reference (ET_{os})

- Custom VBA model
- Verified with RefET

□ Daily values aggregated into monthly averages



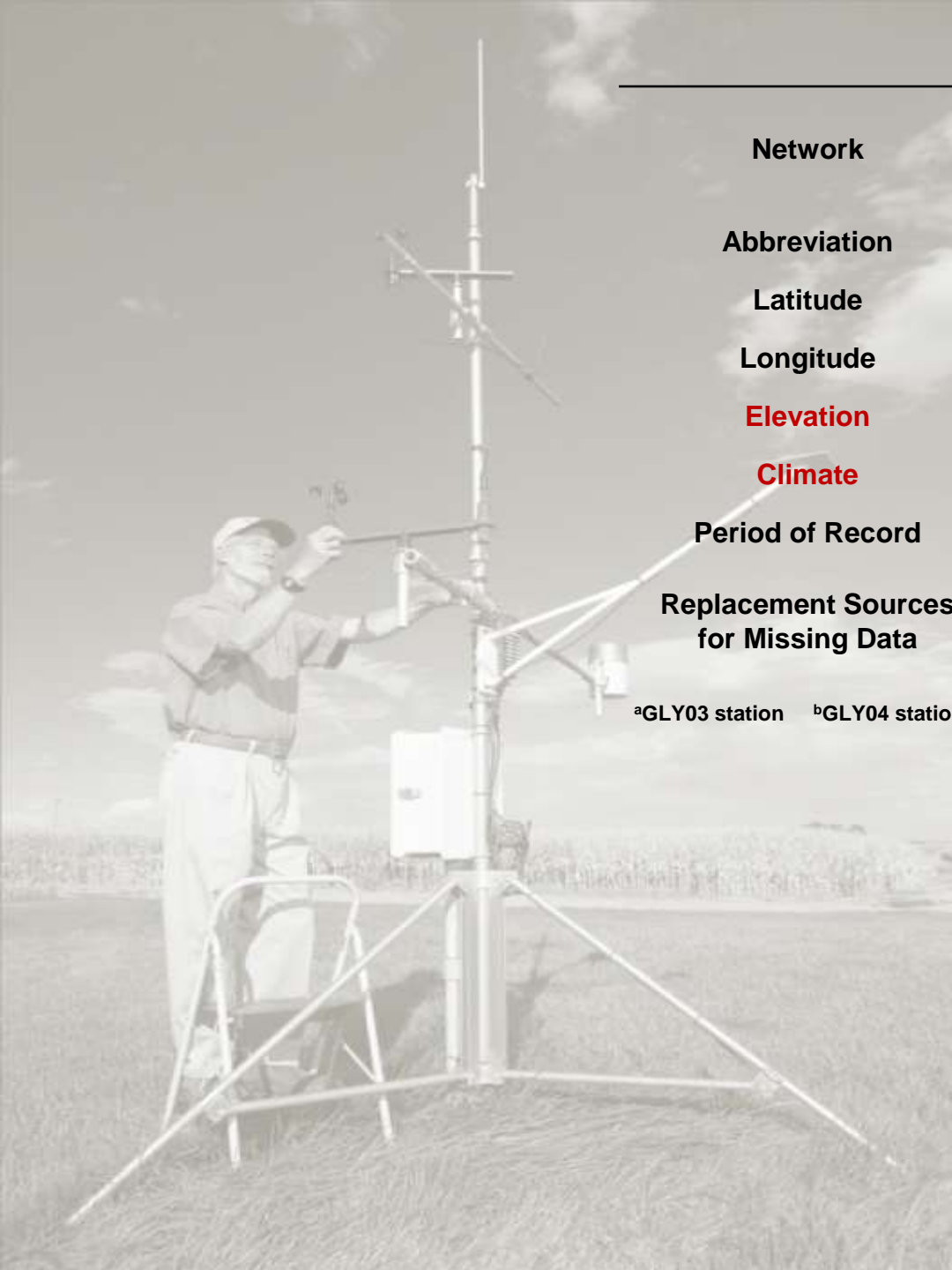


CoAgMet-GLY04



FAWN-Immokalee





Network

Abbreviation

Latitude

Longitude

Elevation

Climate

Period of Record

**Replacement Sources
for Missing Data**

^aGLY03 station ^bGLY04 station

Greeley, Colorado

Colorado Agricultural
Meteorological Network

CoAgMet

^a40.4394° N, ^b40.4487° N

^a104.647° W, ^b104.638° N

^a1426.5 m, ^b1427.4 m

Semi-arid

^a1993-2005, ^b2006-2012

WindGen software,
LCN01 (Lucerne, CO)

Immokalee, Florida

Florida Automated
Weather Network

FAWN

26.462° N

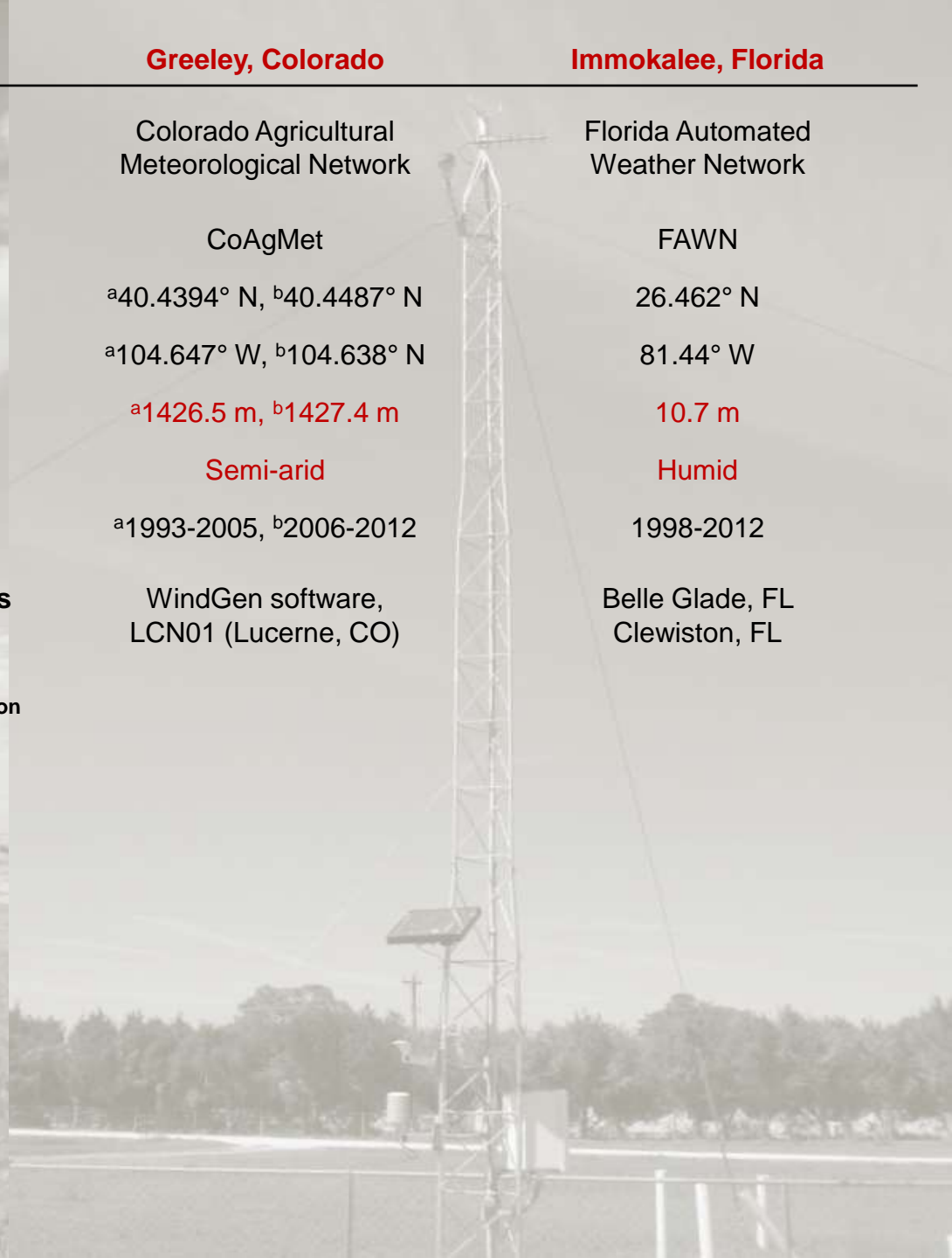
81.44° W

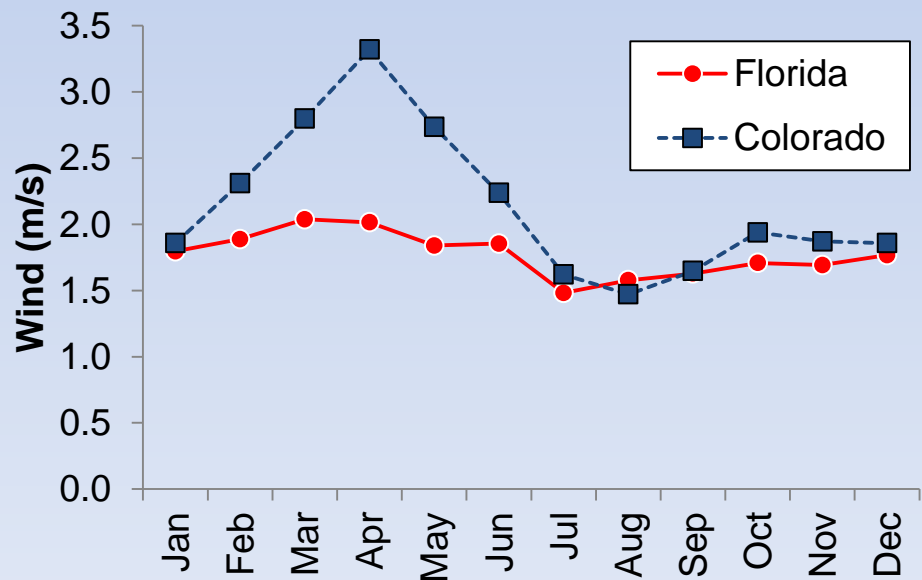
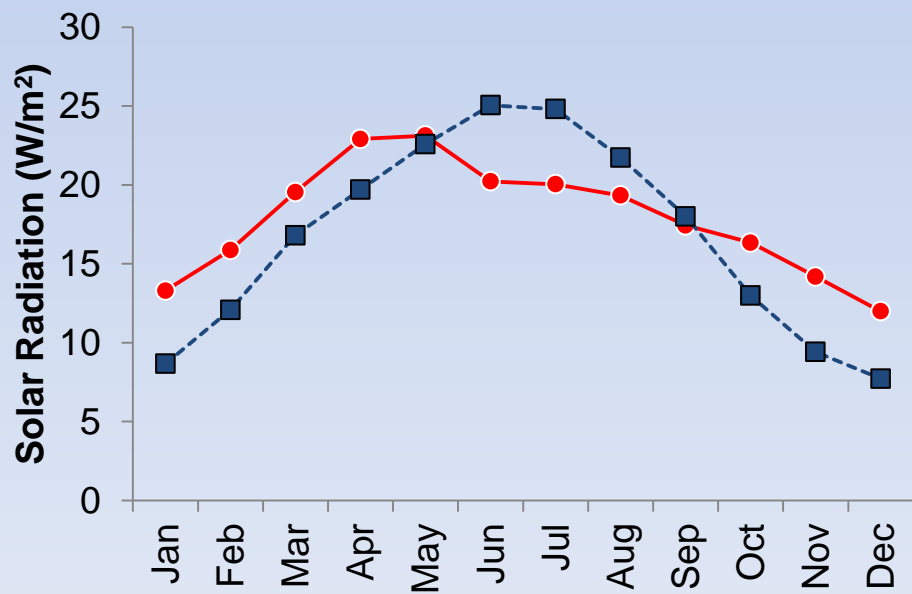
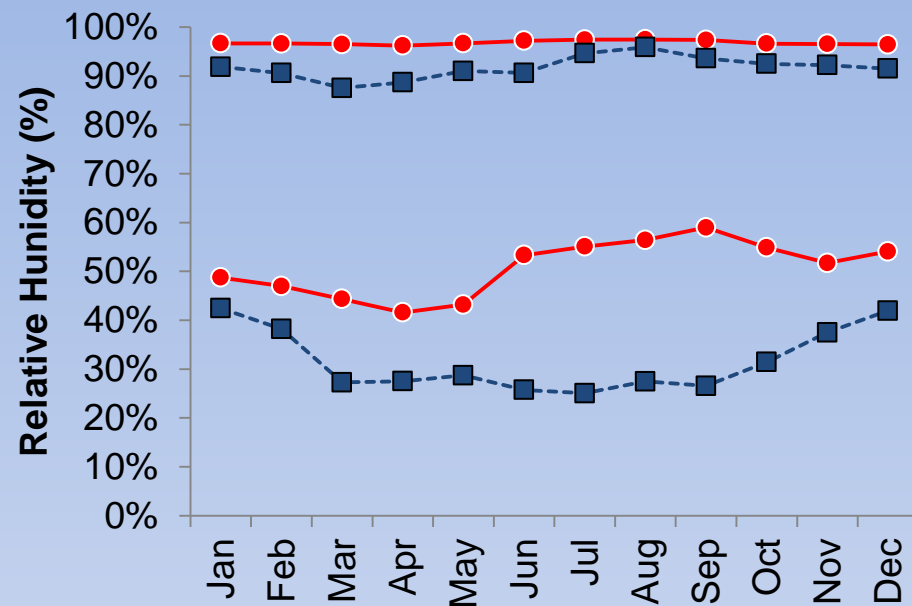
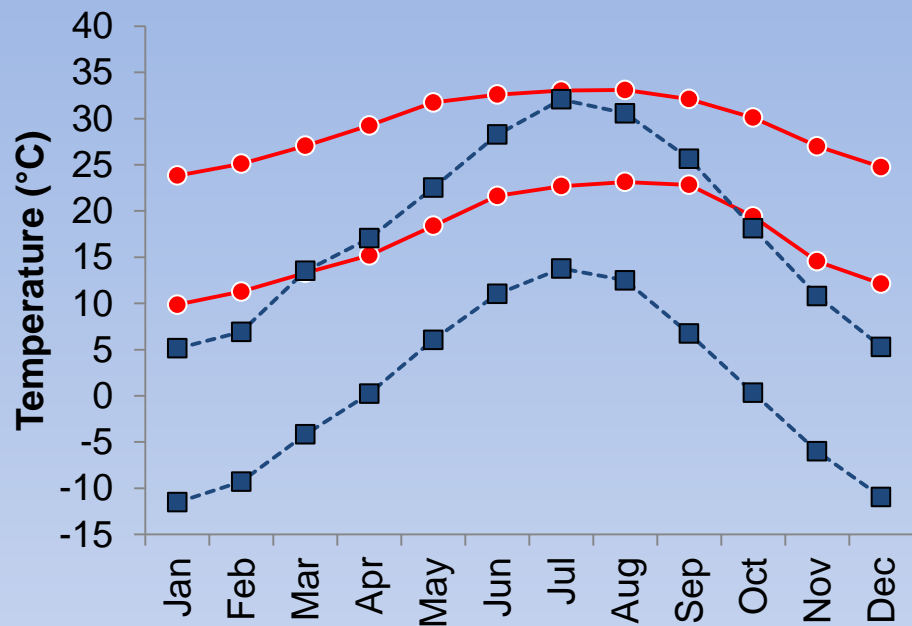
10.7 m

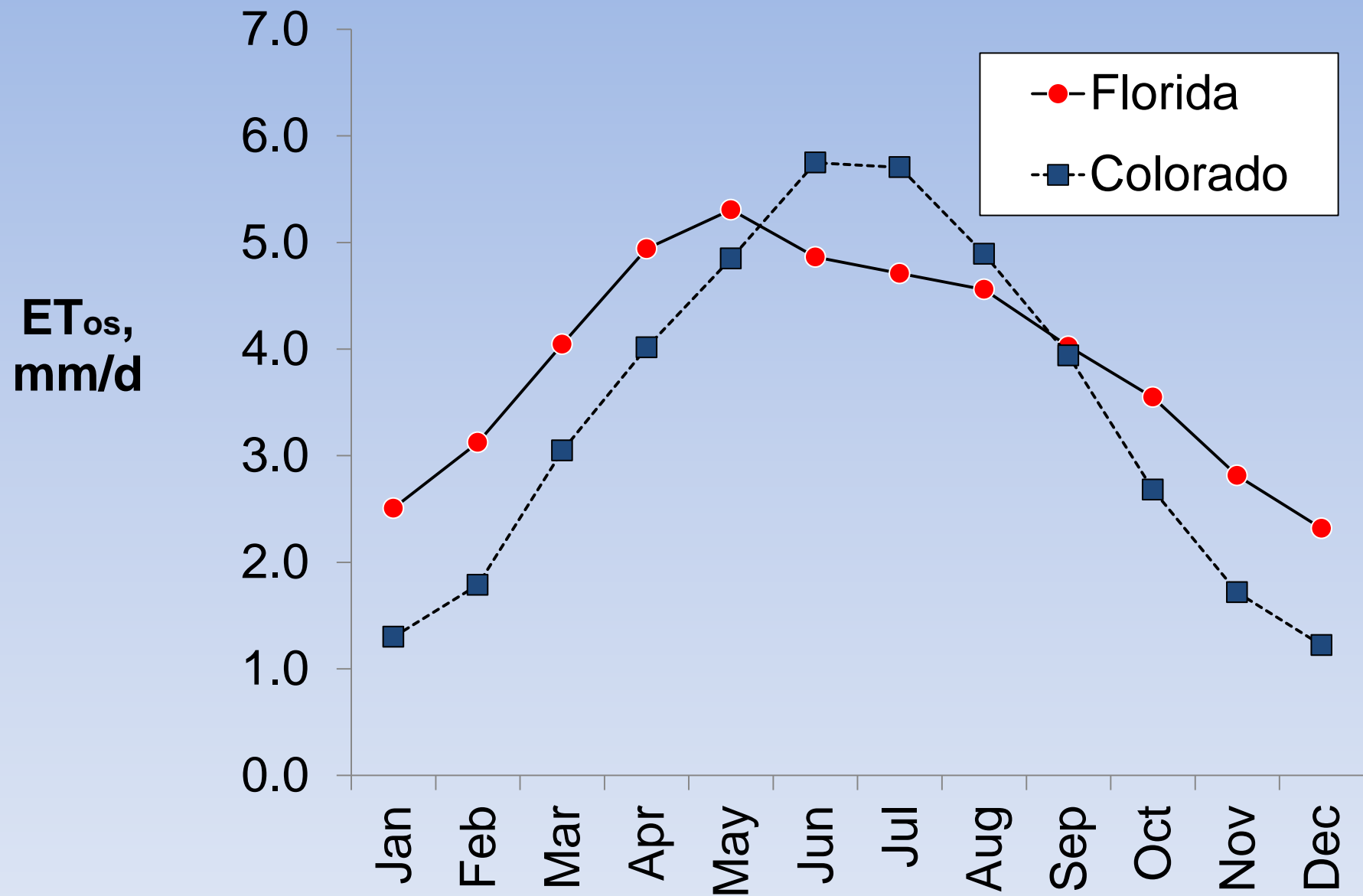
Humid

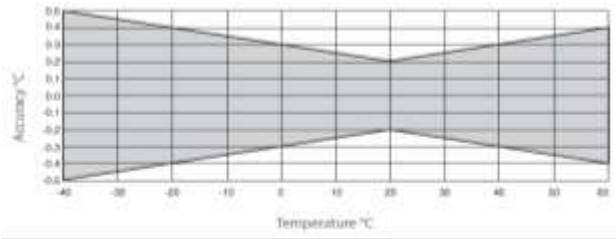



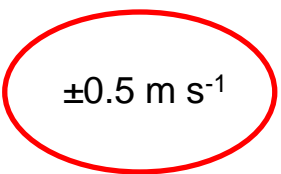


1998-2012

Belle Glade, FL
Clewiston, FL







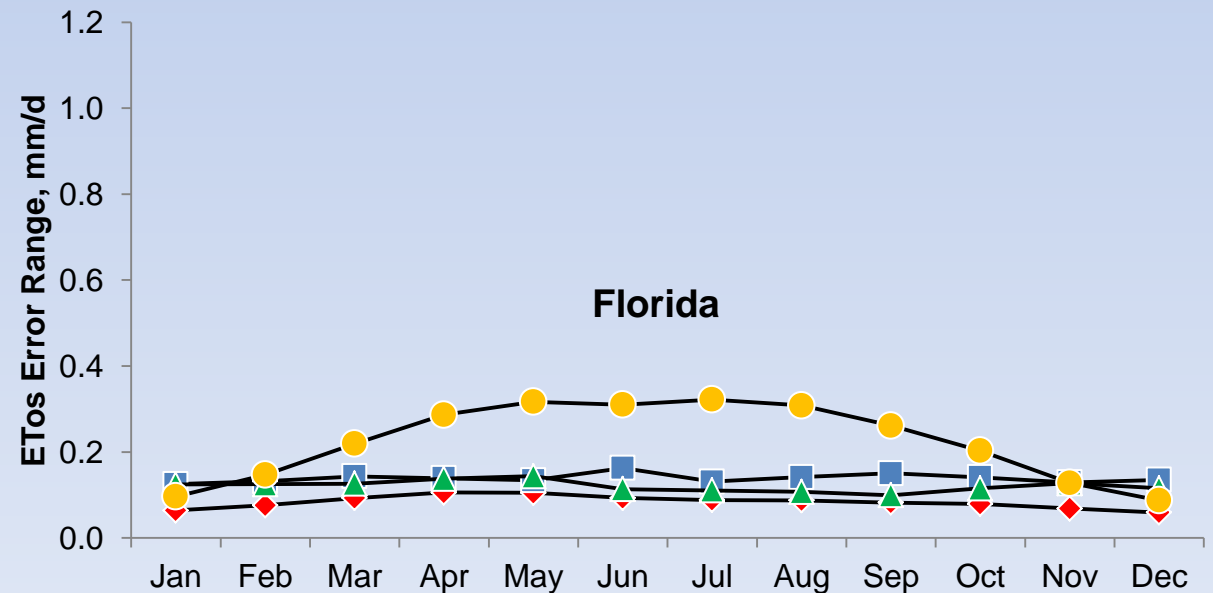
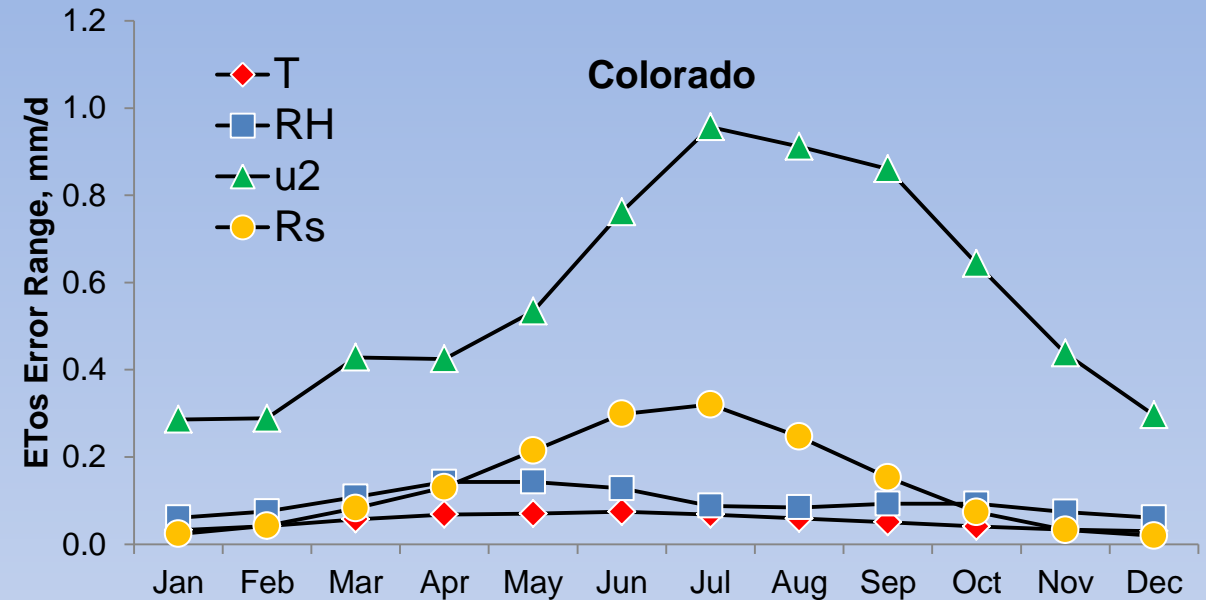
		CoAgMet (Colorado)		FAWN (Florida)	
Reading	Unit	Sensor	Quoted Accuracy	Sensor	Quoted Accuracy
Temperature	°C	Vaisala HMP45C		Campbell  CS215	$\pm 0.4^{\circ}\text{C}$ from $+5^{\circ}$ to $+40^{\circ}\text{C}$ $\pm 0.5^{\circ}\text{C}$ when $< -40^{\circ}$ and $> +70^{\circ}\text{C}$
Humidity	%	Vaisala HMP45C	$\pm 2\%$ RH (0 to 90% RH) $\pm 3\%$ RH (90 to 100% RH)	 Campbell Scientific CS215 	$\pm 2\%$ RH (0 to 90% RH) $\pm 4\%$ RH (90 to 100% RH)
			Temperature dependence: $\pm 0.05\%$ RH/ $^{\circ}\text{C}$		Temperature dependence: $< \pm 2\%$ over -20° to $+60^{\circ}\text{C}$
Wind Speed	m s^{-1}	R.M.Young Wind Sentry	 $\pm 0.5 \text{ m s}^{-1}$	Vaisala 425A 	$\pm 0.135 \text{ m s}^{-1}$ (0 to 4.47 m s^{-1}) $\pm 3\%$ (4.47 to 49.2 m s^{-1}) $\pm 5\%$ (above 49.2 m s^{-1})
Colorado error greater than Florida for wind $< 16.7 \text{ m/s}$					
Solar Radiation	MW m^{-2}	LI-Cor LI200X	$\pm 5\%$ maximum $\pm 3\%$ typical	 LI-Cor LI200X	$\pm 5\%$ maximum $\pm 3\%$ typical

Local Sensitivity

Evaluate single
variable at a time

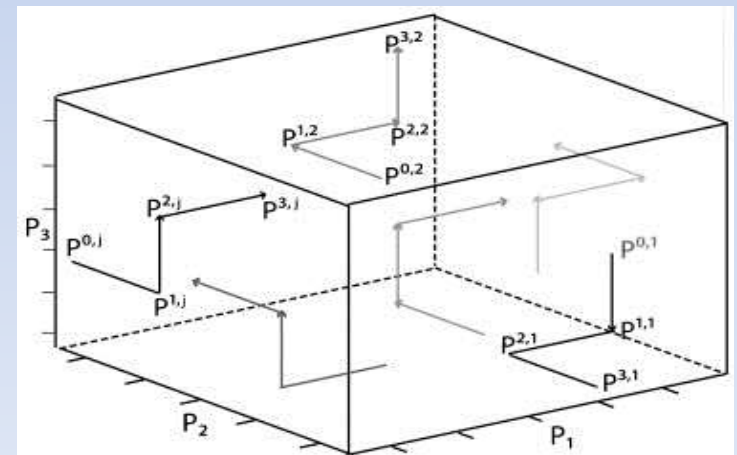
“worst case” error limits
applied to single input and
 ET_{os} equation

Error Range is difference
between ET_{os} values, using
accuracy limits



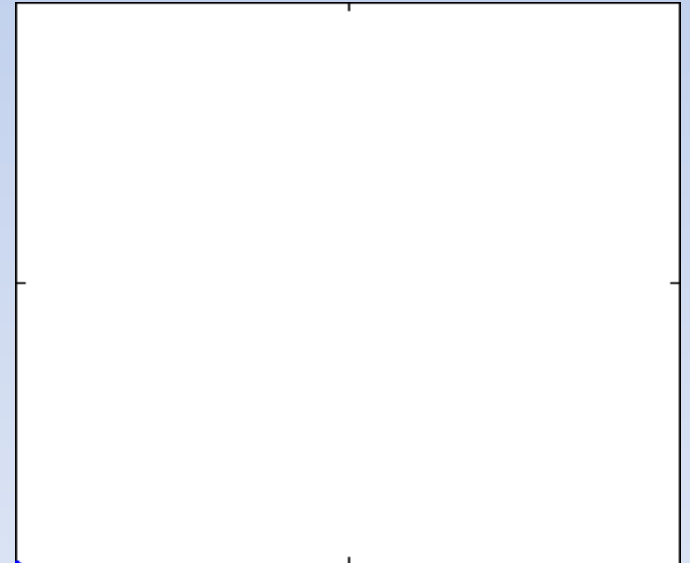
Morris GSA

- ❑ Evaluates variance of “one at a time” linear sensitivities – but is “global” SA
- ❑ Gives two outputs:
 - μ – overall sensitivity
 - σ – interaction and/or nonlinearity
- ❑ Computationally “cheap”



EFAST GSA

- ❑ “Extended Fourier Amplitude Sensitivity Test”
- ❑ Variance-based
- ❑ Systematically covers entire parameter space
- ❑ Computationally “expensive”



Simple GSA Example:

$$a = b = c = 2$$

Accuracy ± 1 for each input

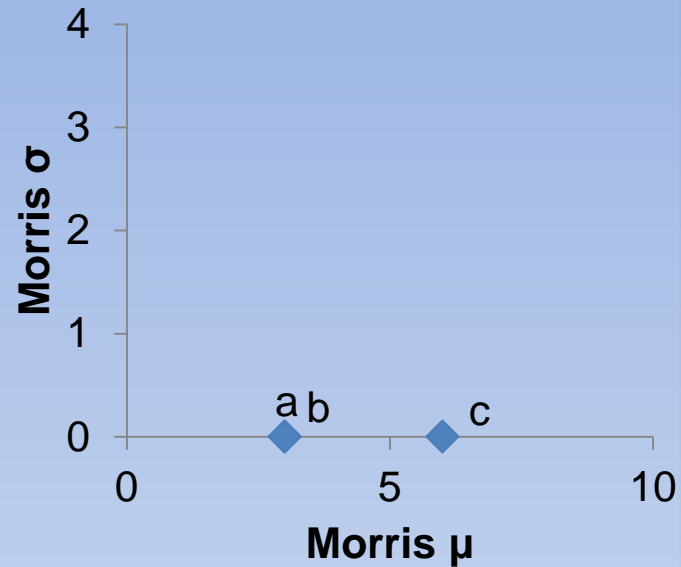
1) $z = a + b + 2c$

2) $z = a + b + c^2$

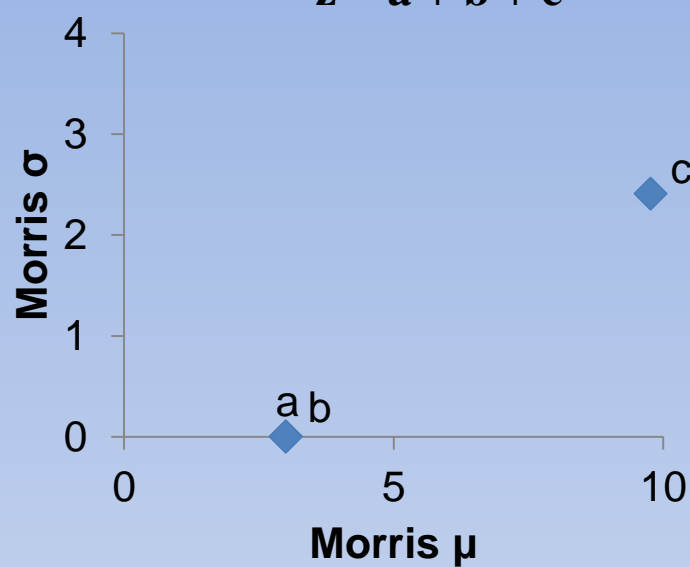
3) $z = a + c + b * c$

Expected value $(z) = 8$, for all 3 examples

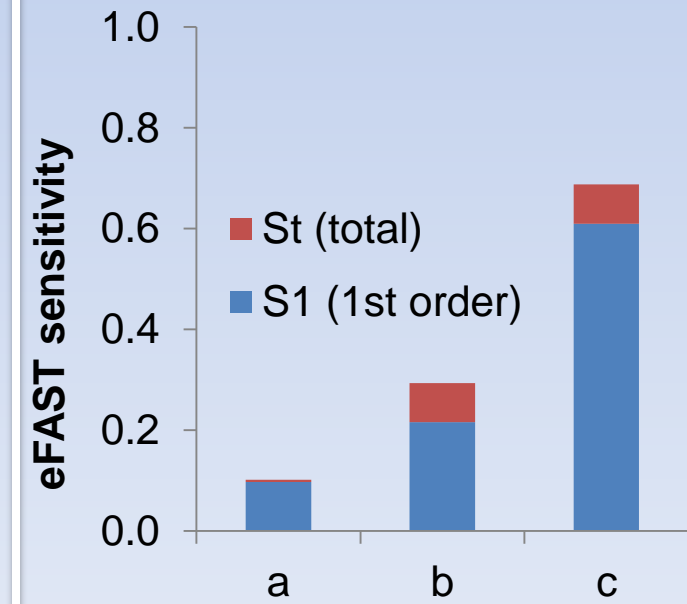
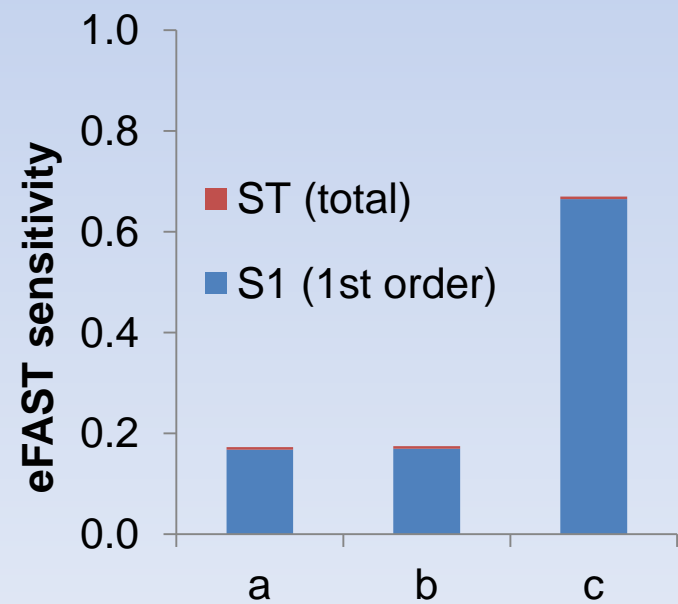
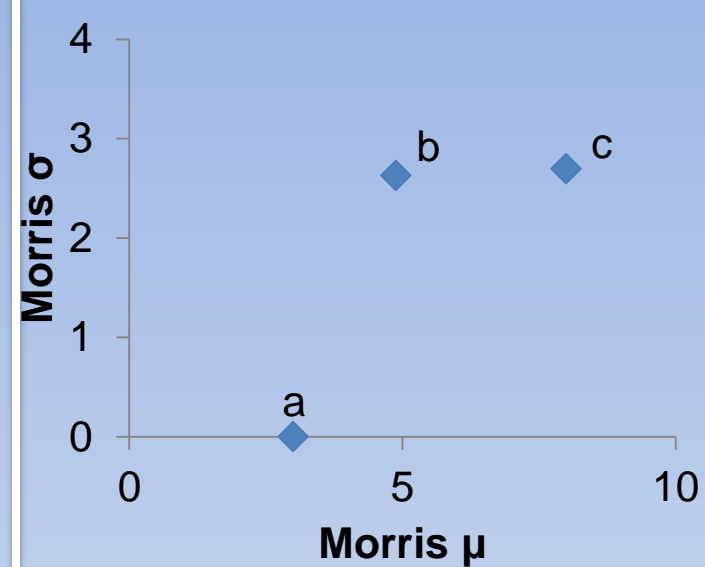
$$z = a + b + 2c$$



$$z = a + b + c^2$$



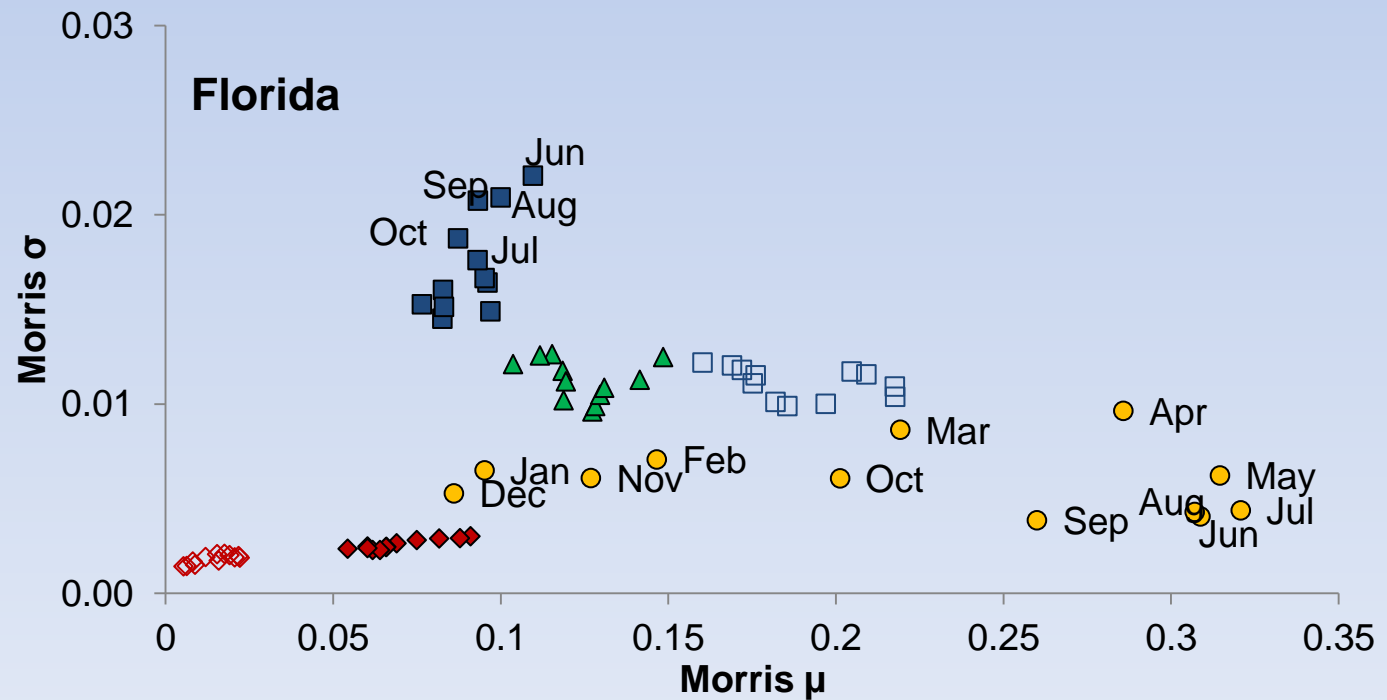
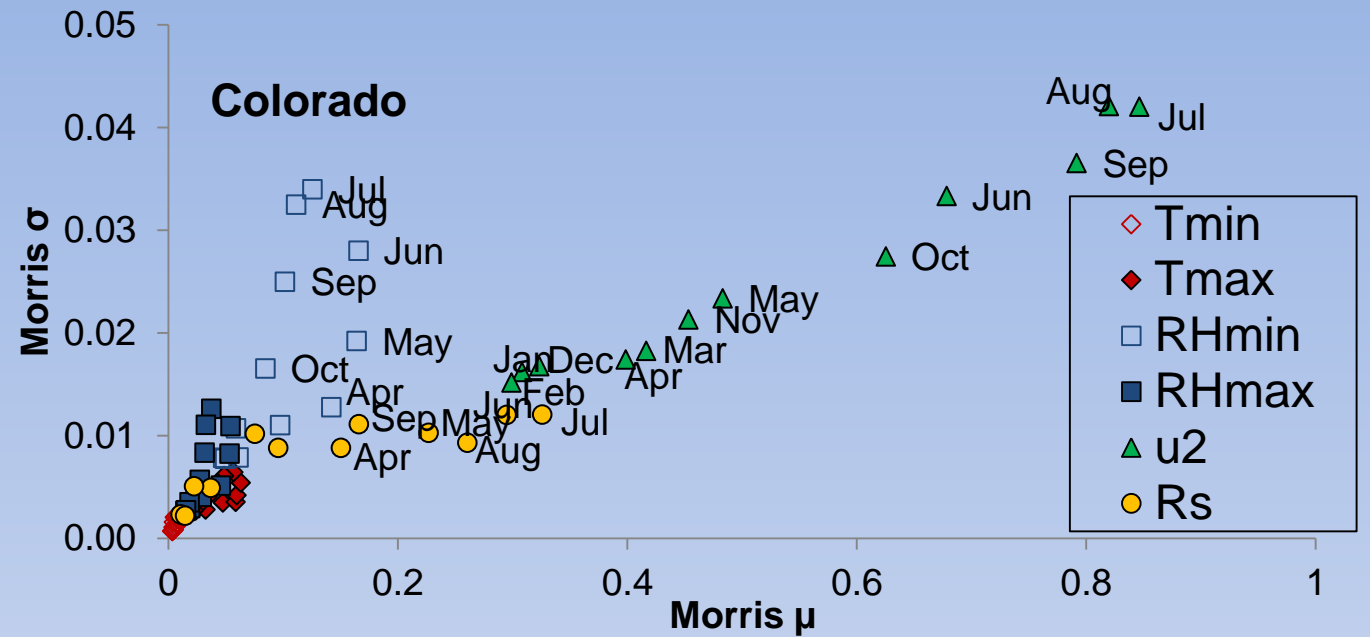
$$z = a + c + b*c$$



Morris GSA

μ – overall
sensitivity

σ – interaction
and/or
nonlinearity

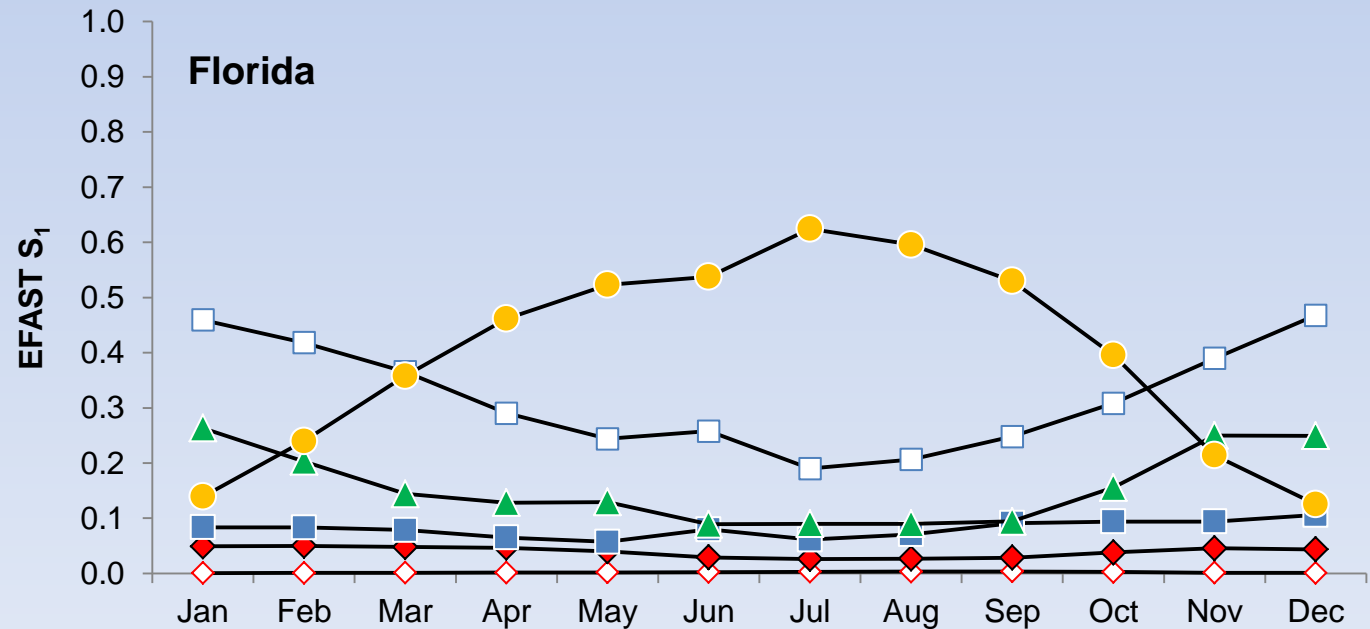
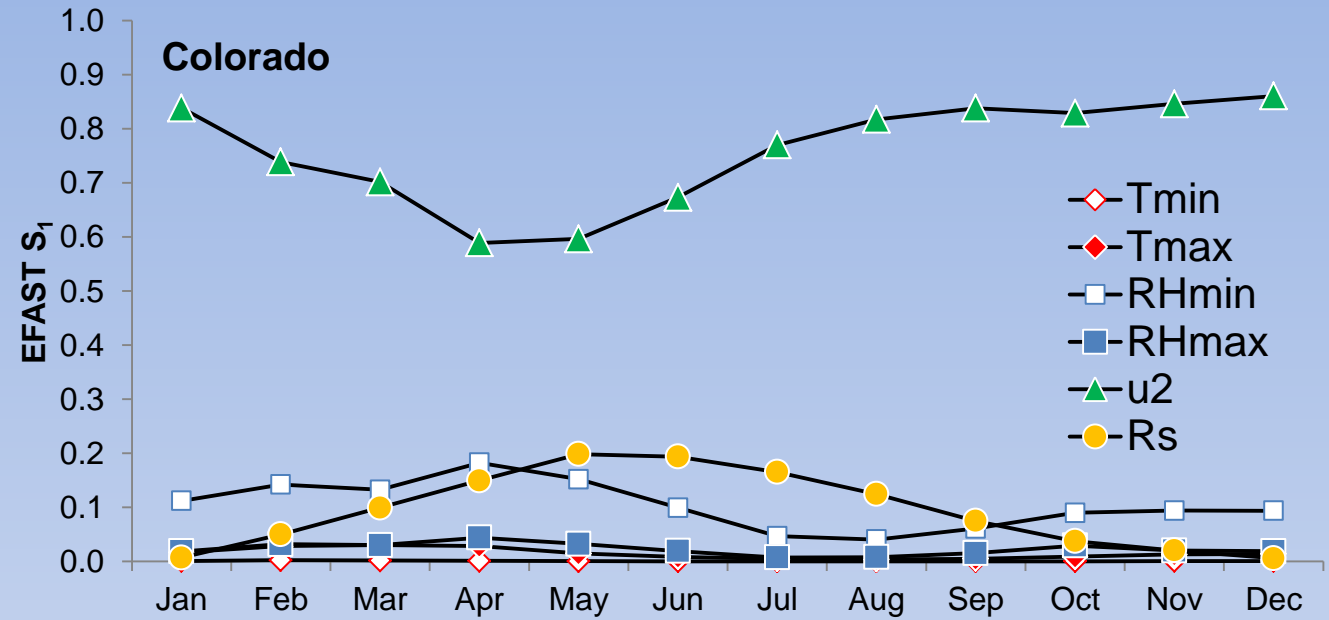
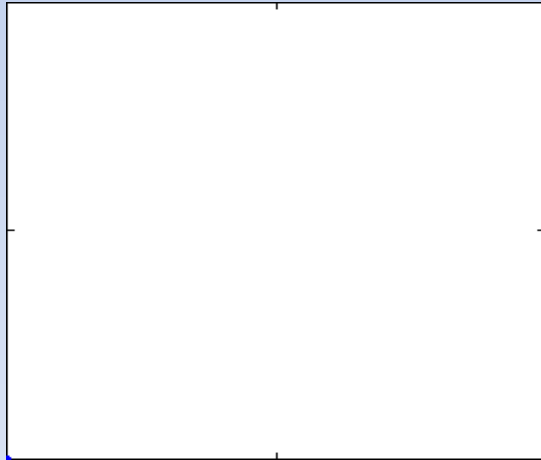


EFAST GSA

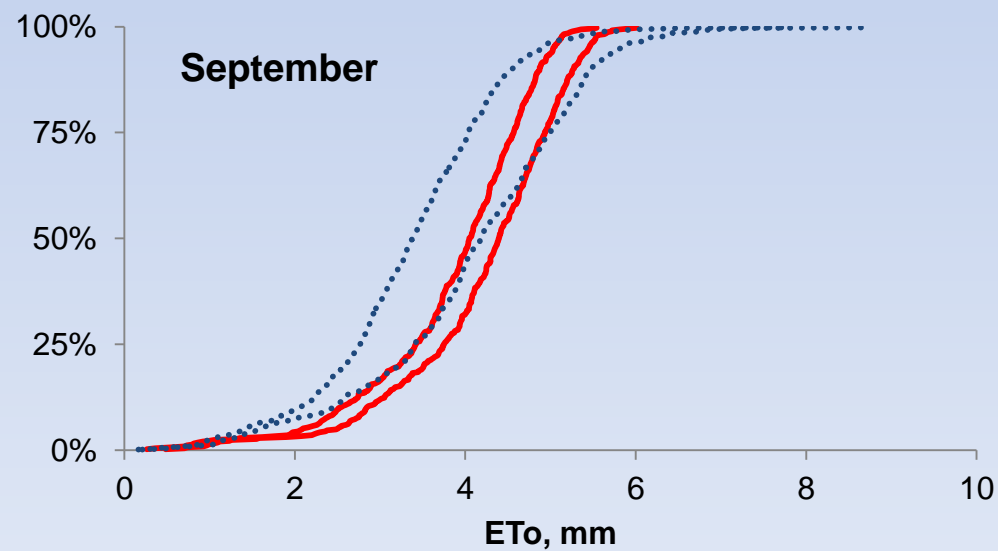
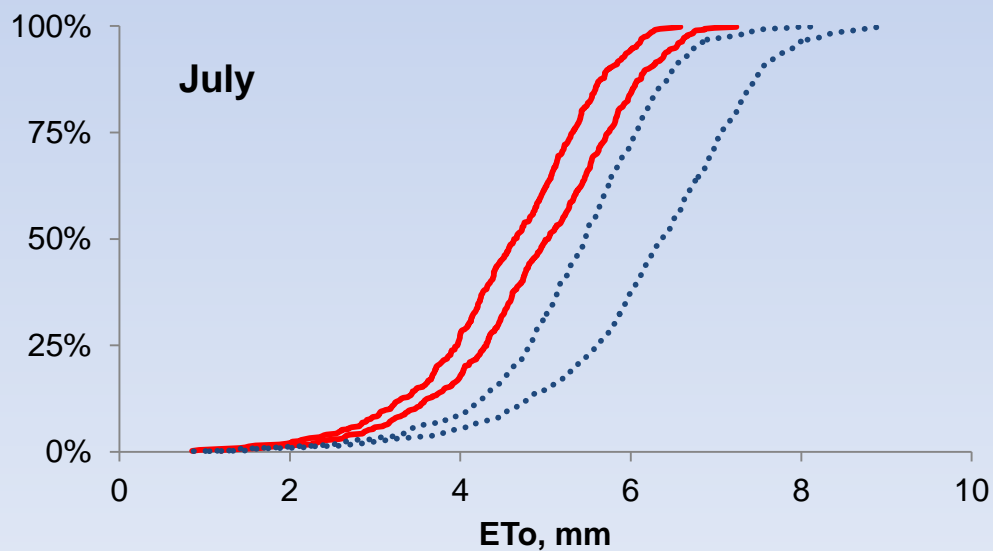
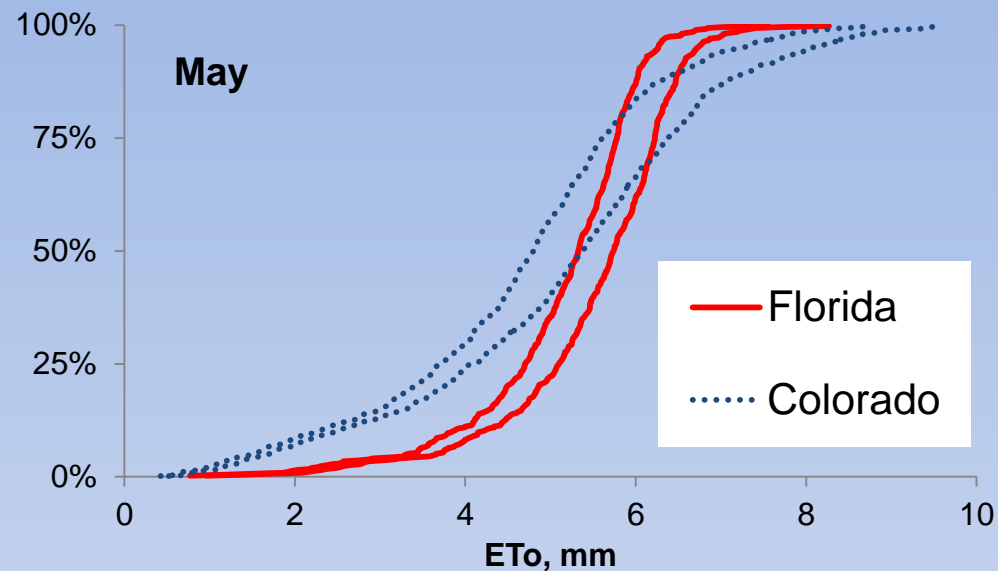
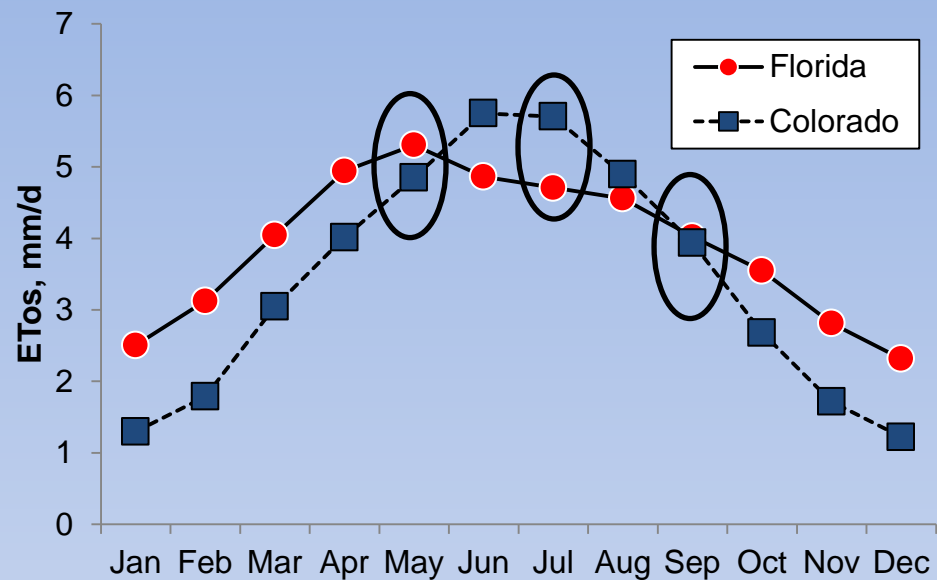
Extended Fourier
Amplitude Sensitivity
Test

Variance-based

Computationally
“expensive”



Uncertainty Analysis

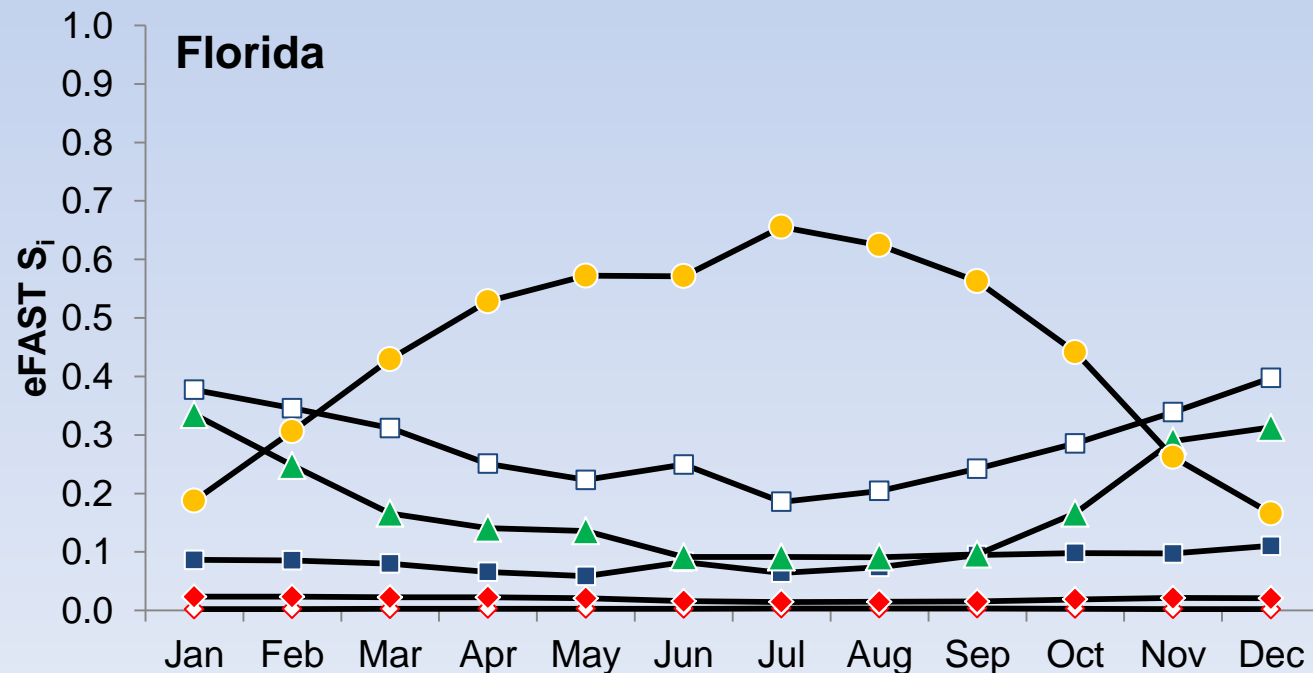
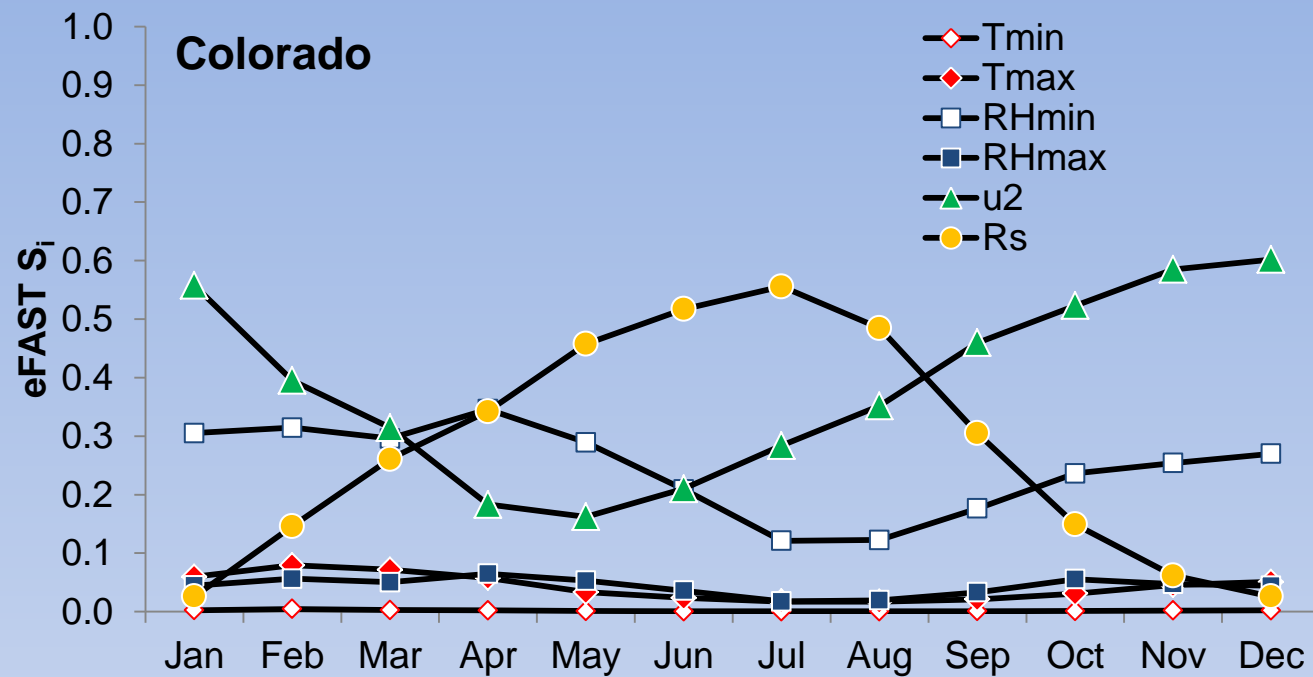


EFAST GSA

(using best-case sensor set)

Rs most important in summer

Regional weather can also affect sensitivity



ETo Sensitivity - Conclusions

- ❑ SA of all sensor networks is recommended
 - “local” SA may be enough to evaluate basic accuracy for ET_{os}
- ❑ Manufacturers should provide more information regarding “accuracy”
 - interval vs. range, distribution, thresholds, etc.
- ❑ CoAgMet should consider upgrade of wind sensors
 - Has been done on some key stations

DeJonge, K.C., M. Ahmadi, J.C. Ascough II, K.D. Kinzli. 2015. Sensitivity analysis of reference evapotranspiration to sensor accuracy. *Computers and Electronics in Agriculture*. DOI 10.1016/j.compag.2014.11.013

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Thank You!

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Sensitivity analysis of reference evapotranspiration to sensor accuracy

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8. Introduction

In irrigated agriculture, accurate and consistent estimates of crop evapotranspiration (ET) are vital to efficient water management. As the field scale ET can be used for irrigation scheduling, whereas at regional scale knowledge of evapotranspiration (ET) components can be used to evaluate regional water resources planning and distribution. However, because ET is very difficult to measure directly, it is often estimated using models based on climatic input, which unfortunately can be highly variable. The most common method to estimate ET, is to measure a reference evapotranspiration (ET_{ref}) and then estimate the crop ET by multiplying with a crop coefficient (K_c). The K_c is strongly crop specific, and can vary with several parameters affecting ET such as leaf area, and soil climate conditions, and crop density

[Dowdell and Kanas, 2003]. While many methods seem to calculate coherence *ET*, physically based approaches such as the *PSD* (Petersen-Moncrieff [Giles et al., 1998]) require more input data but are generally accepted as the most accurate estimators. The American Society of Civil Engineers-Eurocode and Swiss Research Institute (ASCE-EWI) created a standardized version of the Petersen-Moncrieff method for coherence *ET* calculation [ASCE, 2000], which has notable similarities with respect to methodology and nomenclature with *ET* authors [Giles et al., 2000].

Hold error accuracy is of paramount importance when determining reference ET using a physical model. Seneviratna and Alirol (2002) evaluated reference ET estimates using both the Priestly-McJannet (Allen et al., 1988) and Hargreaves (Hargreaves and Samani, 1985; Hargreaves et al., 1983) methods. They concluded that the more data intensive (e.g., temperature, humidity, solar radiation, wind speed) Priestly-McJannet method is recommended if accurate weather data collection is feasible and available. If data accuracy is questionable, the simpler (e.g.,

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