Sensitivity of Reference ET to Weather Station Sensor Accuracy

Kendall DeJonge

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Water Management Research Unit

Fort Collins, CO

Innovations in Irrigation Water Management since 1911

USDA ars United States Department of Agriculture
Agricultural Research Service

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)

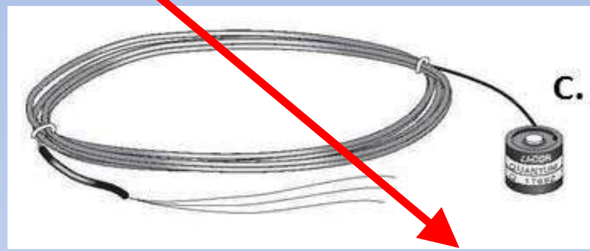
DeJonge, K.C., M. Ahmadi, J.C. Ascough II, K.D. Kinzli. 2015. Sensitivity analysis of reference evapotranspiration to sensor accuracy. *Computers and Electronics in Agriculture* 110: 176-186.

ASCE Standardized Reference ET

Rs (solar radiation)

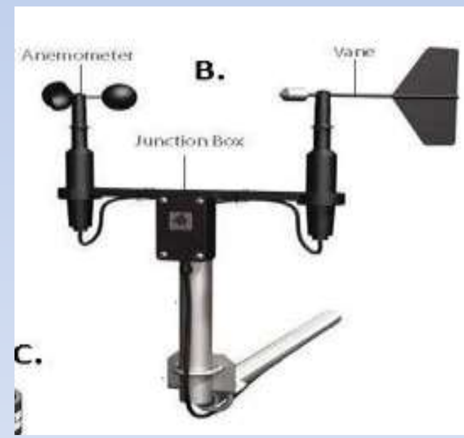
T (temperature)

RH
(relative humidity)

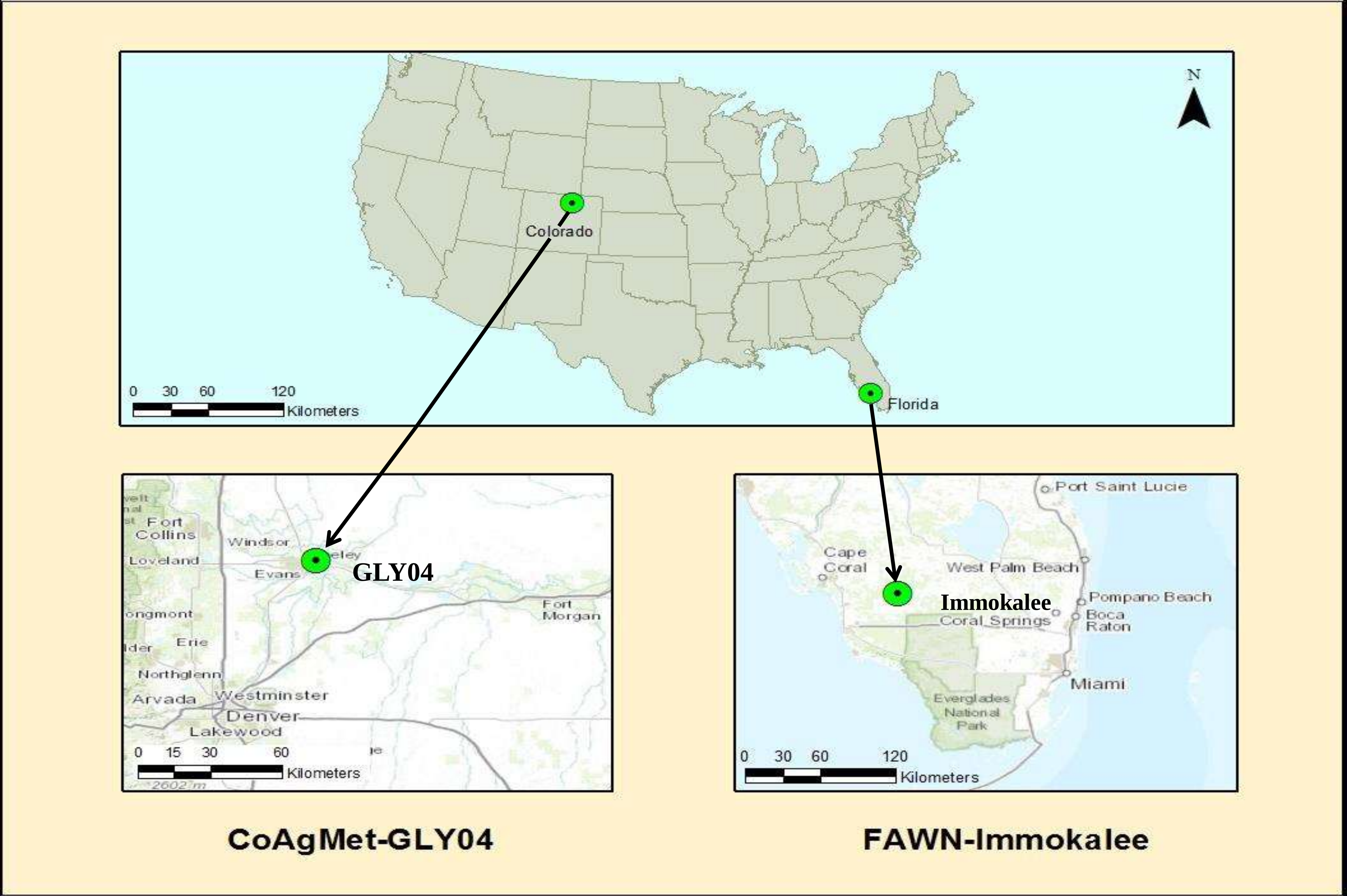


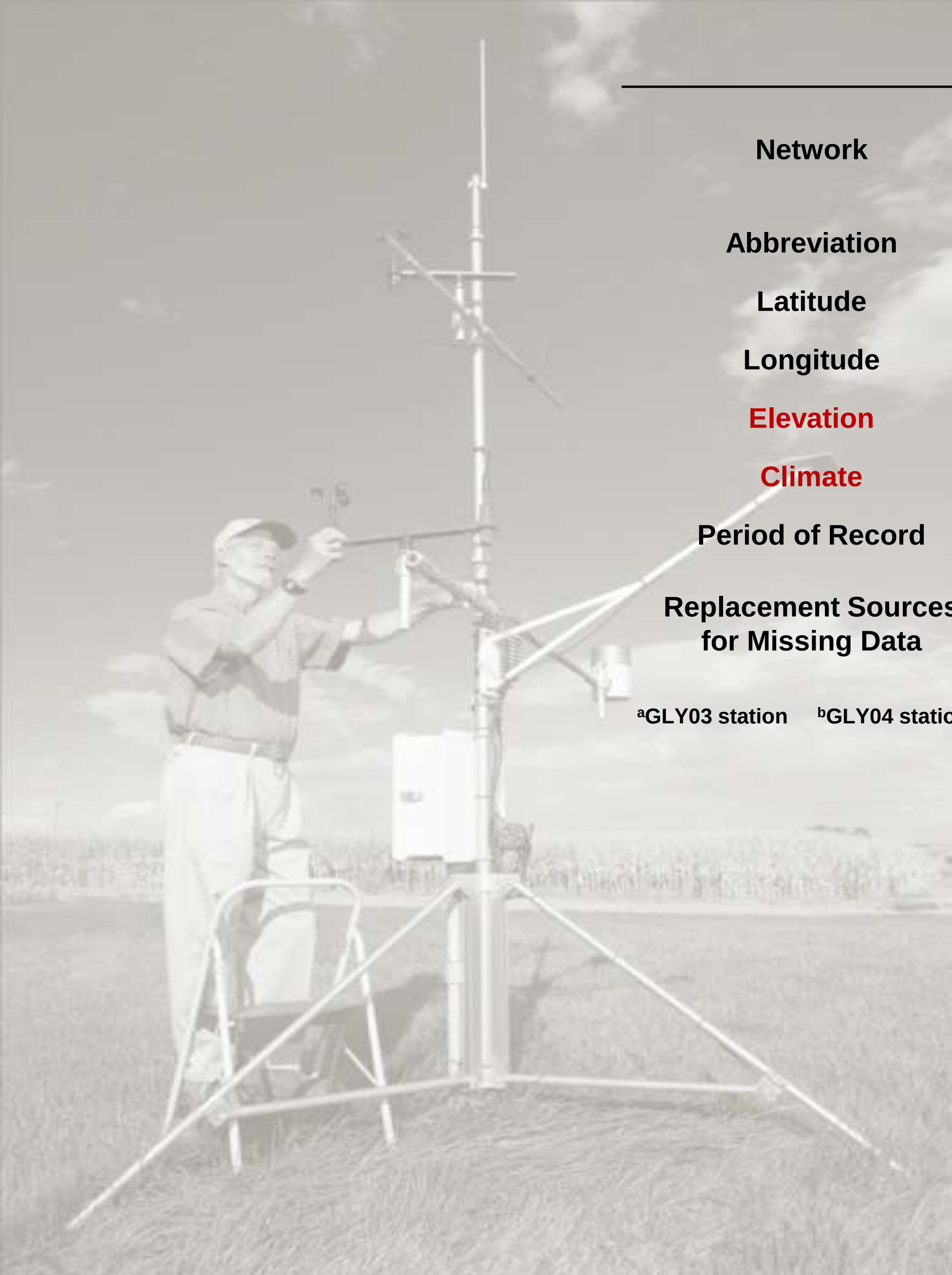
- $ET_{sz} = \dfrac{0.408\Delta(R_n - G) + \gamma \frac{C_n}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + C_d u_2)}$

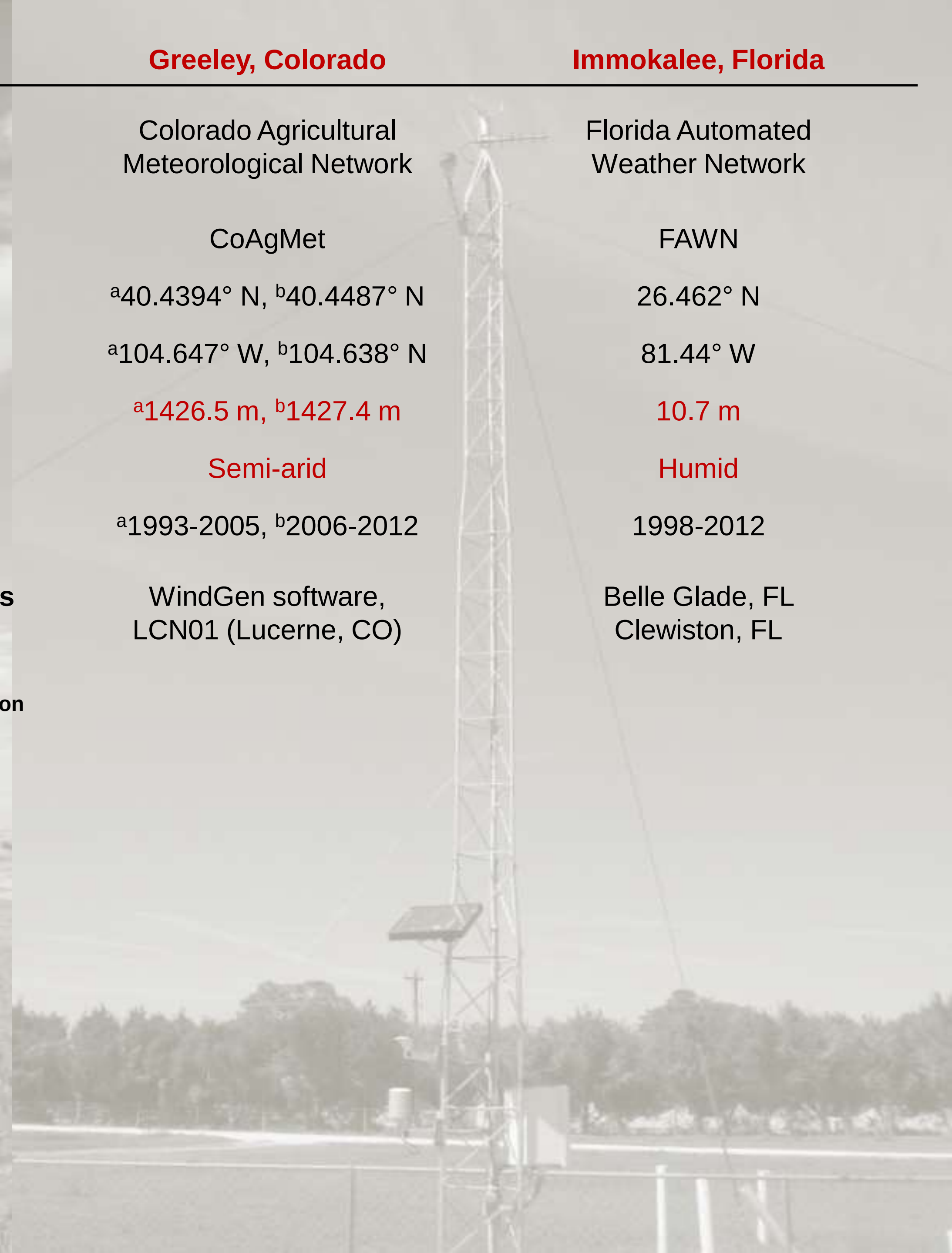
u2 (wind)



- Daily time steps
- Short reference (ET_{os})
  - Custom VBA model
  - Verified with RefET
- Daily values aggregated into monthly averages

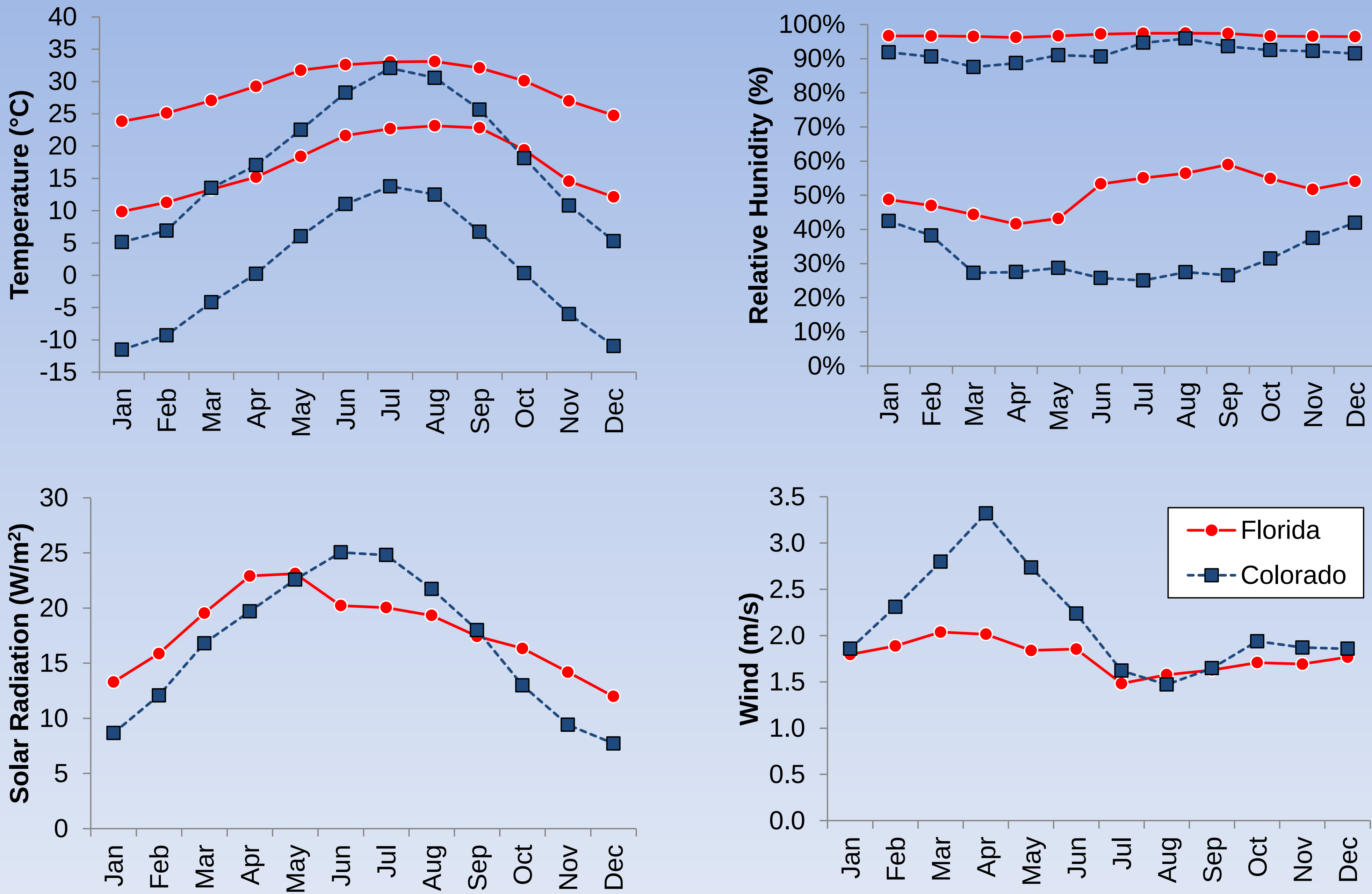

N
Colorado
Florida
0 30 60 120
Kilometers
Fort Collins
Windsor
Loveland
Evans
GLY04
Fort Morgan
Erie
Northglenn
Arvada
Westminster
Denver
Lakewood
0 15 30 60
Kilometers
Port Saint Lucie
Cape Coral
West Palm Beach
Immokalee
Pompano Beach
Coral Springs
Boca Raton
Miami
Everglades National Park
0 30 60 120
Kilometers
CoAgMet-GLY04
FAWN-Immokalee



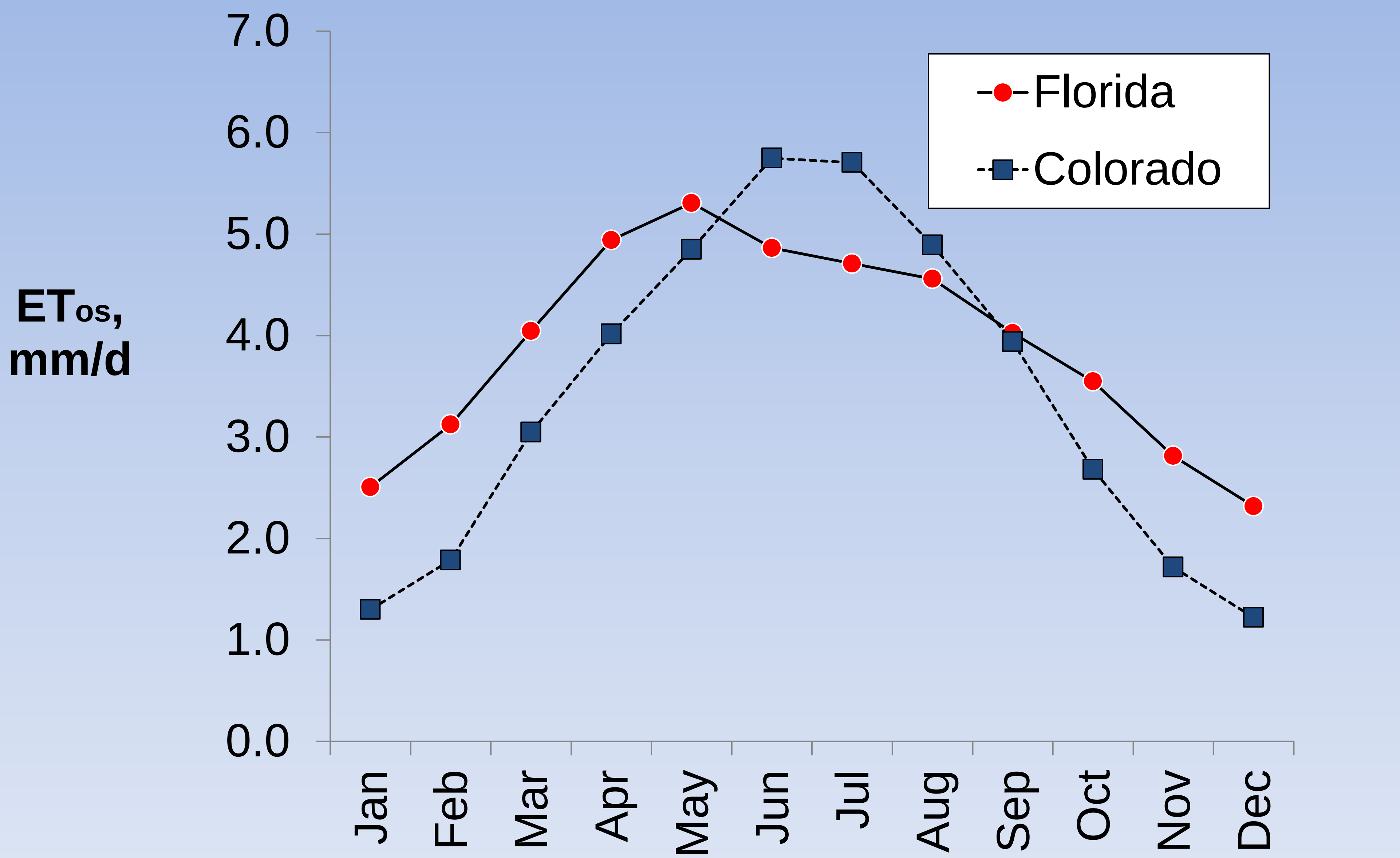


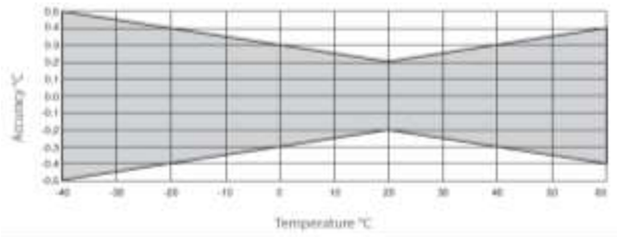
	Greeley, Colorado	Immokalee, Florida
Network	Colorado Agricultural Meteorological Network	Florida Automated Weather Network
Abbreviation	CoAgMet	FAWN
Latitude	[a]40.4394° N, [b]40.4487° N	26.462° N
Longitude	[a]104.647° W, [b]104.638° N	81.44° W
Elevation	[a]1426.5 m, [b]1427.4 m	10.7 m
Climate	Semi-arid	Humid
Period of Record	[a]1993-2005, [b]2006-2012	1998-2012
Replacement Sources for Missing Data	WindGen software, LCN01 (Lucerne, CO)	Belle Glade, FL Clewiston, FL

[a]GLY03 station **[b]GLY04 station**



Temperature (°C)
40
35
30
25
20
15
10
5
0
-5
-10
-15
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Relative Hunidity (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Solar Radiation (W/m²)
30
25
20
15
10
5
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Wind (m/s)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Florida
Colorado


ETos,
mm/d
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Florida
Colorado
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

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

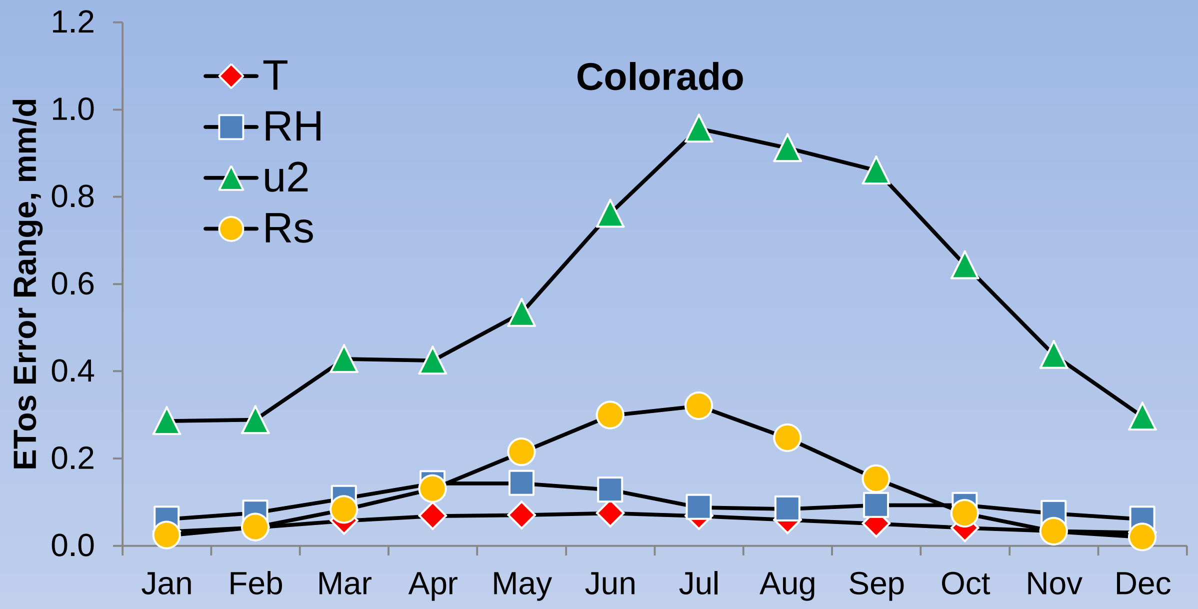
Colorado error greater than Florida for wind < 16.7 m/s

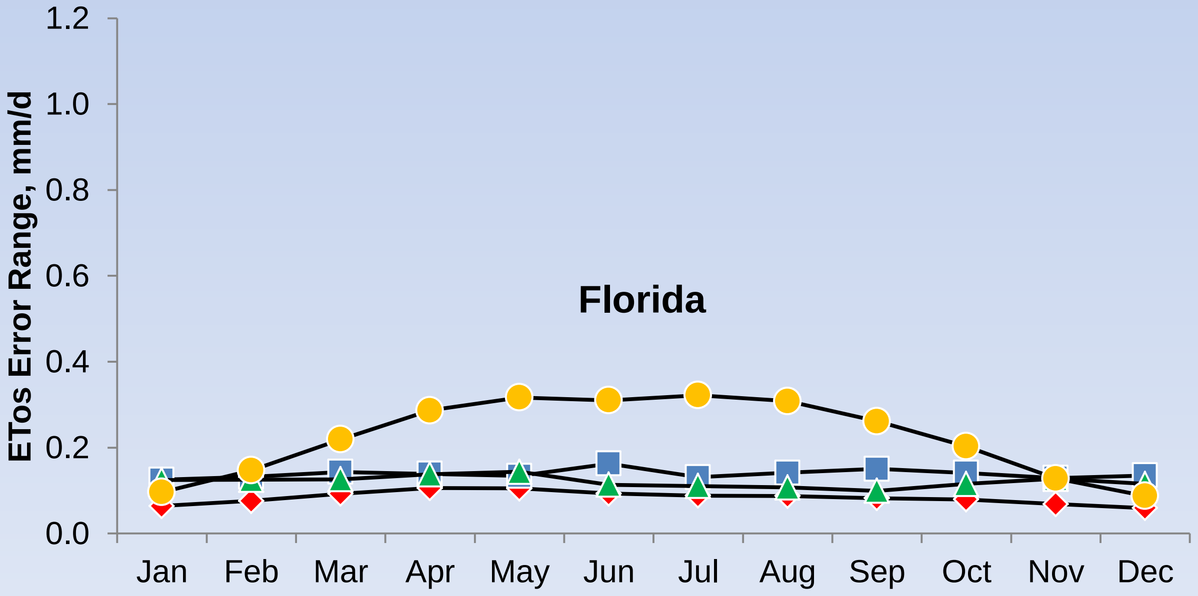
Local Sensitivity

Evaluate single variable at a time

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

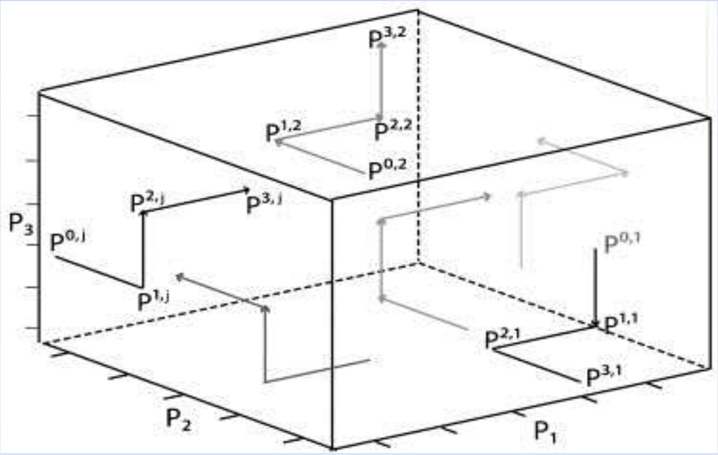
Error Range is difference between ET_{os} values, using accuracy limits





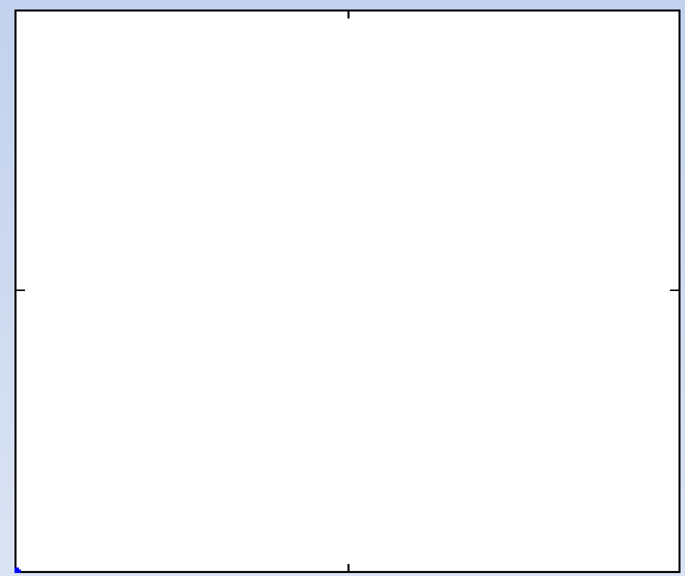
Morris GSA

- 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”



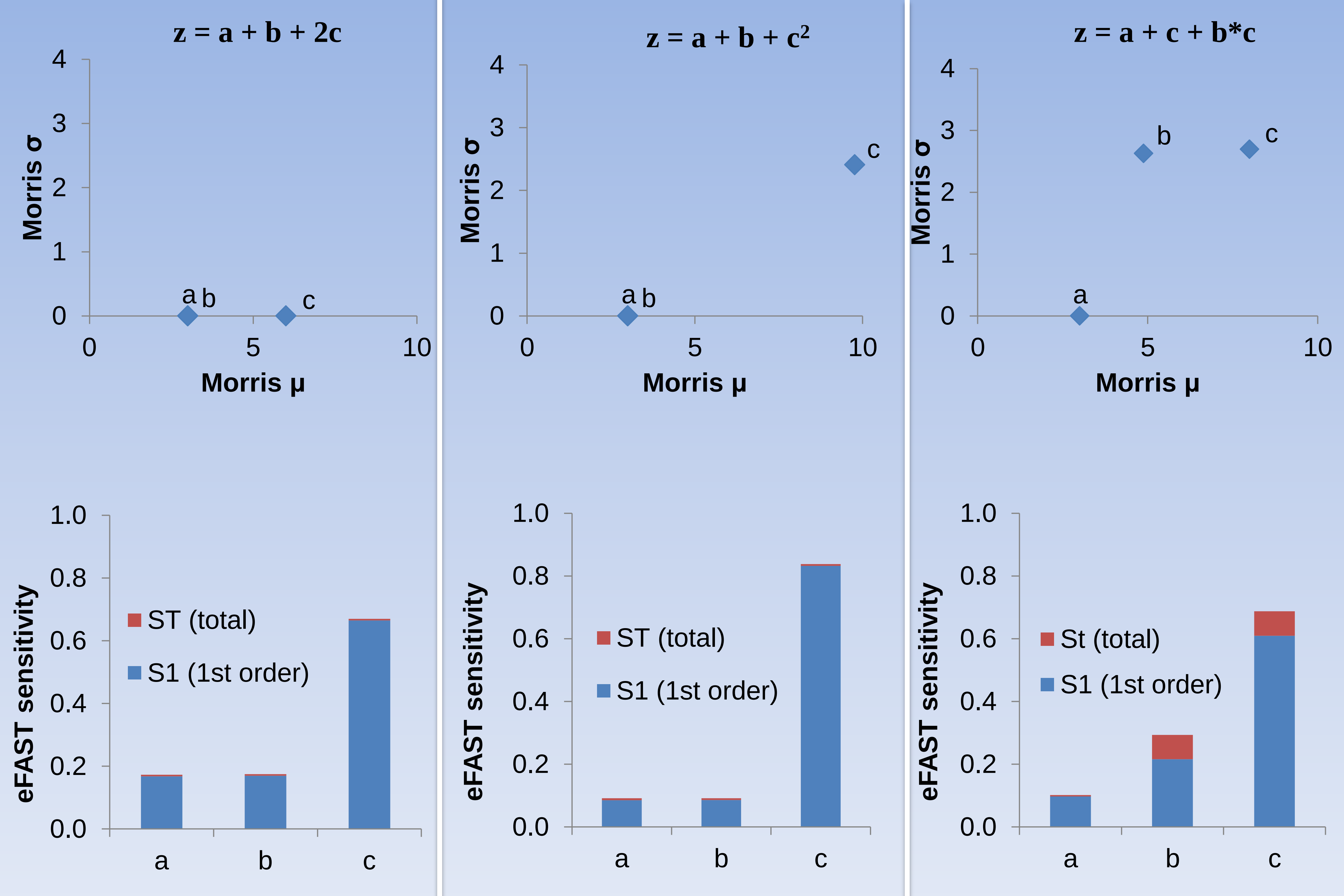
Simple GSA Example:

$a = b = c = 2$

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

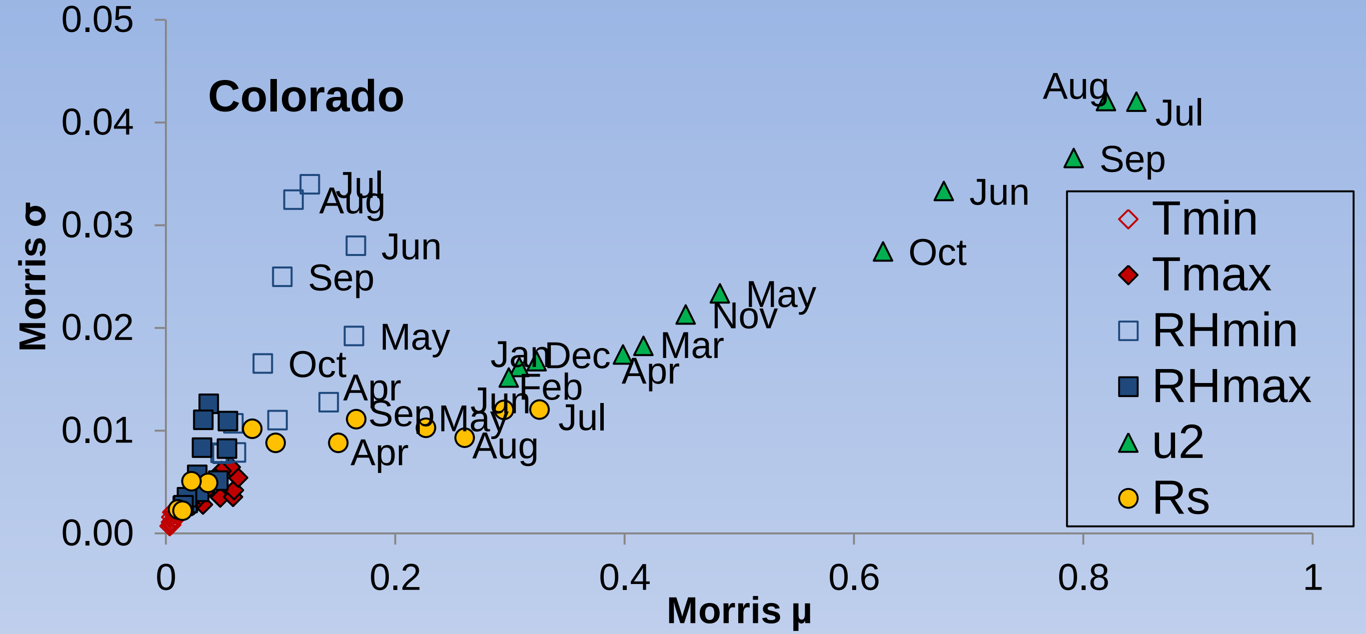


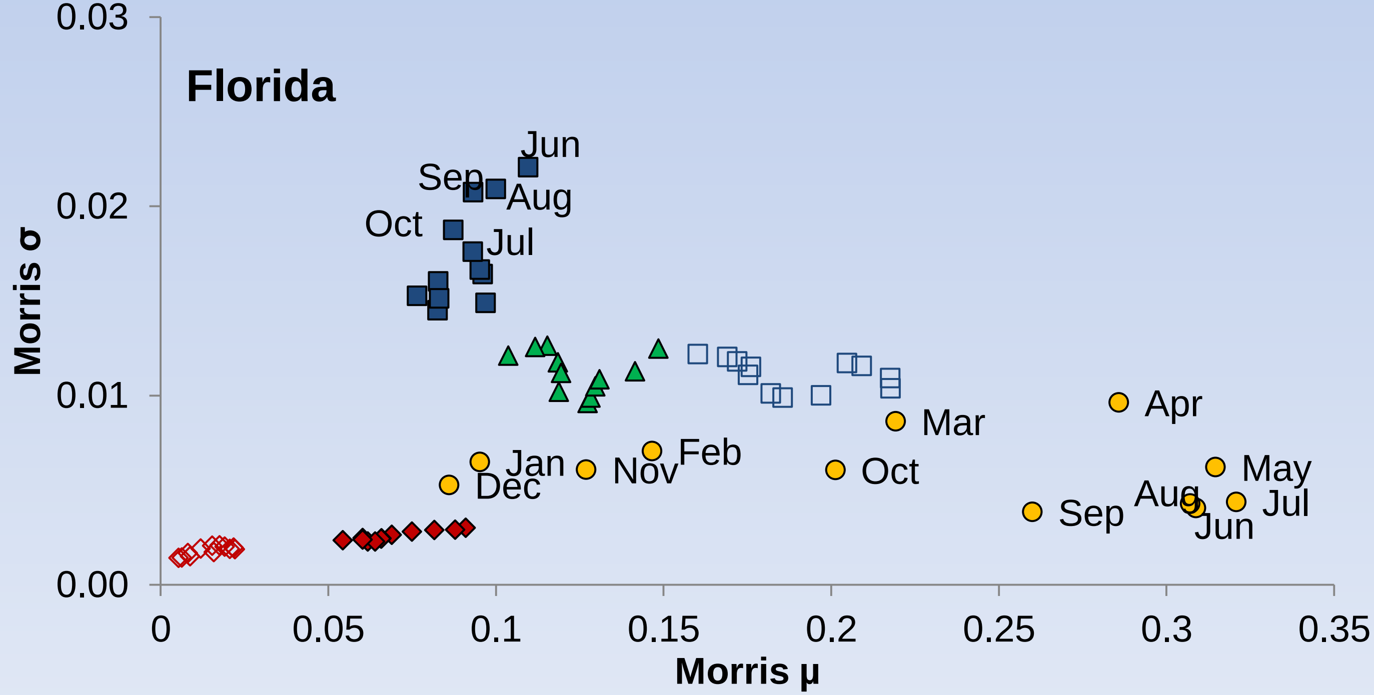
z = a + b + 2c
z = a + b + c²
z = a + c + b*c
Morris σ
Morris μ
a
b
c
0
1
2
3
4
5
10
eFAST sensitivity
ST (total)
S1 (1st order)
St (total)
0.0
0.2
0.4
0.6
0.8
1.0

Morris GSA

μ – overall sensitivity

σ – interaction and/or nonlinearity



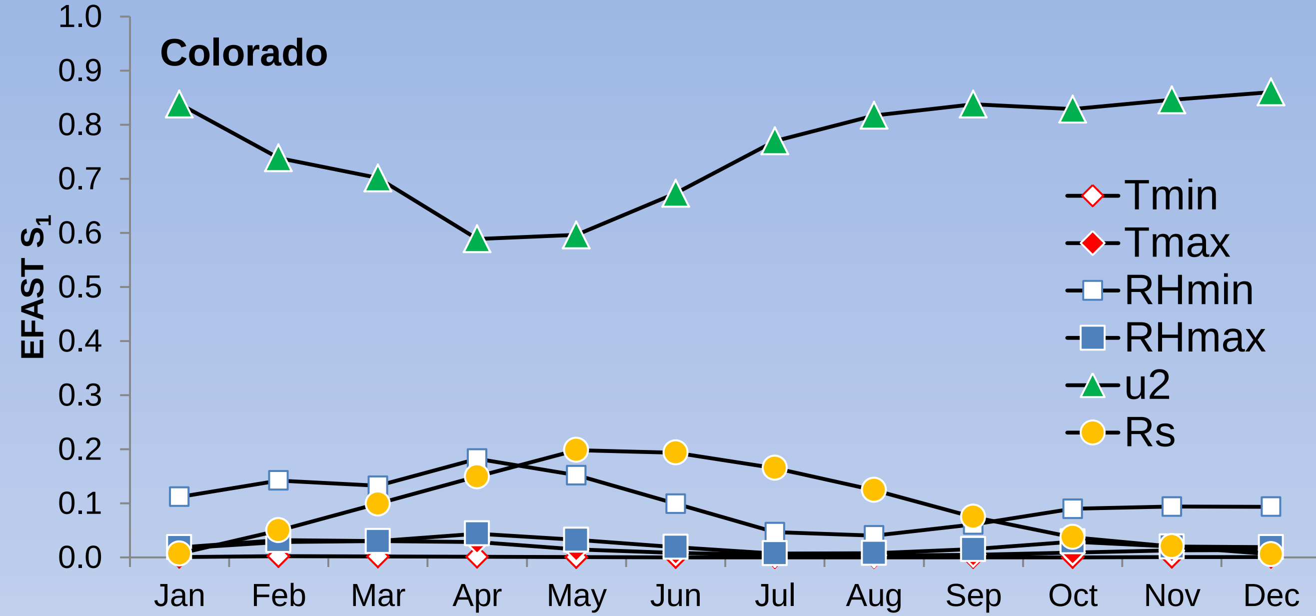


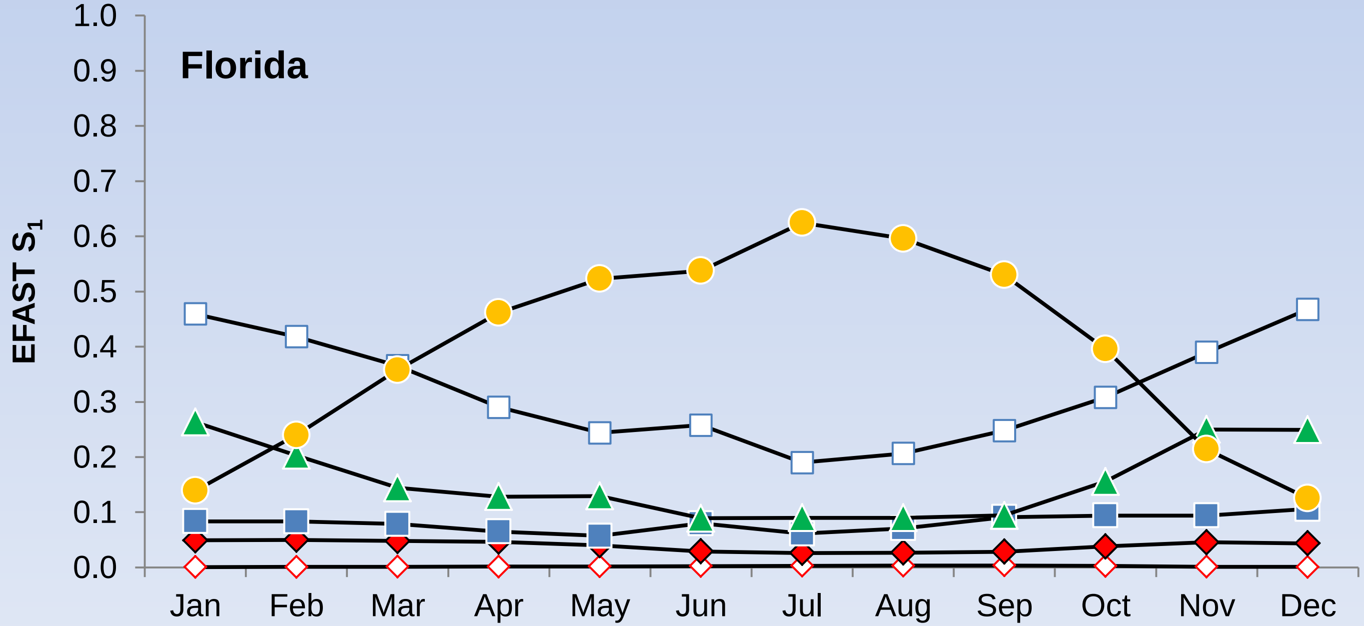
EFAST GSA

Extended Fourier Amplitude Sensitivity Test

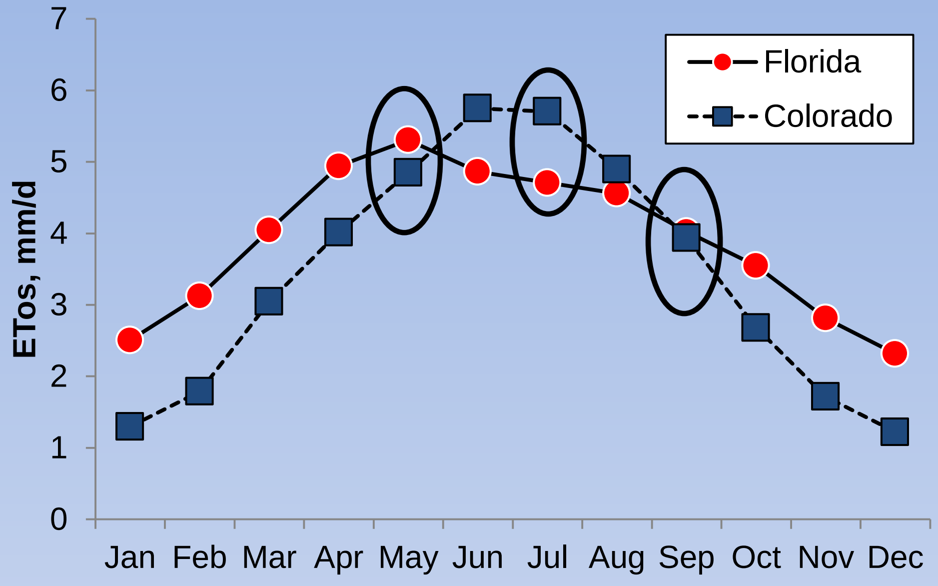
Variance-based

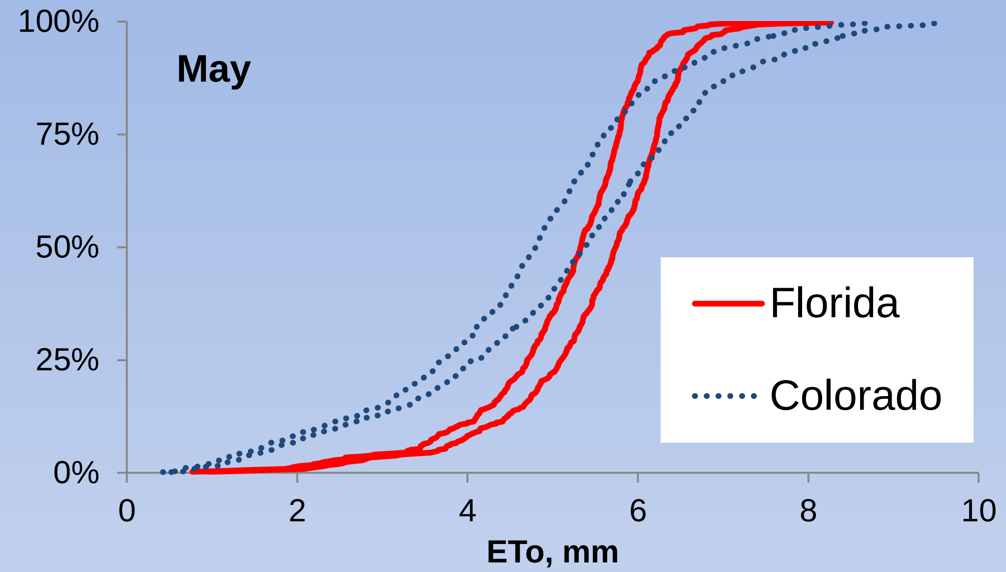
Computationally "expensive"

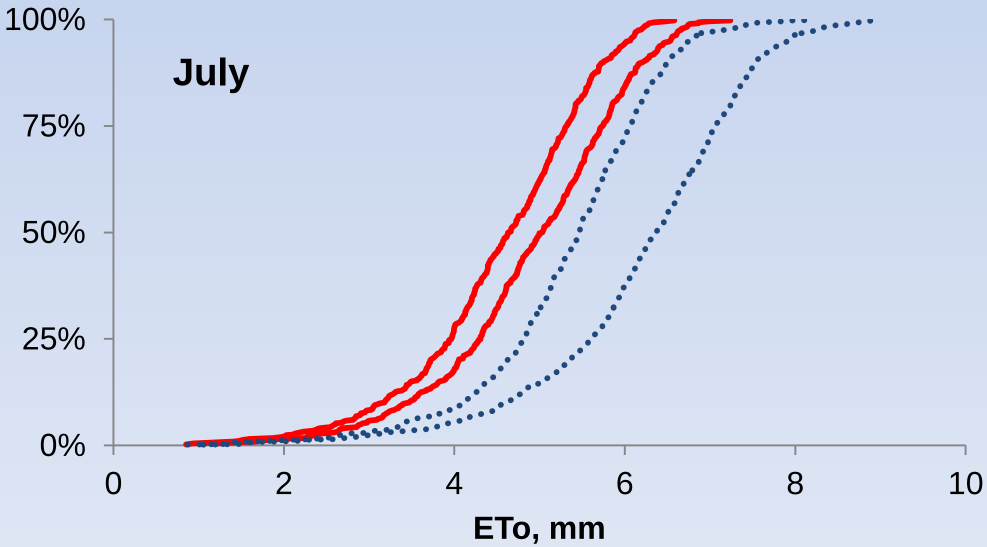


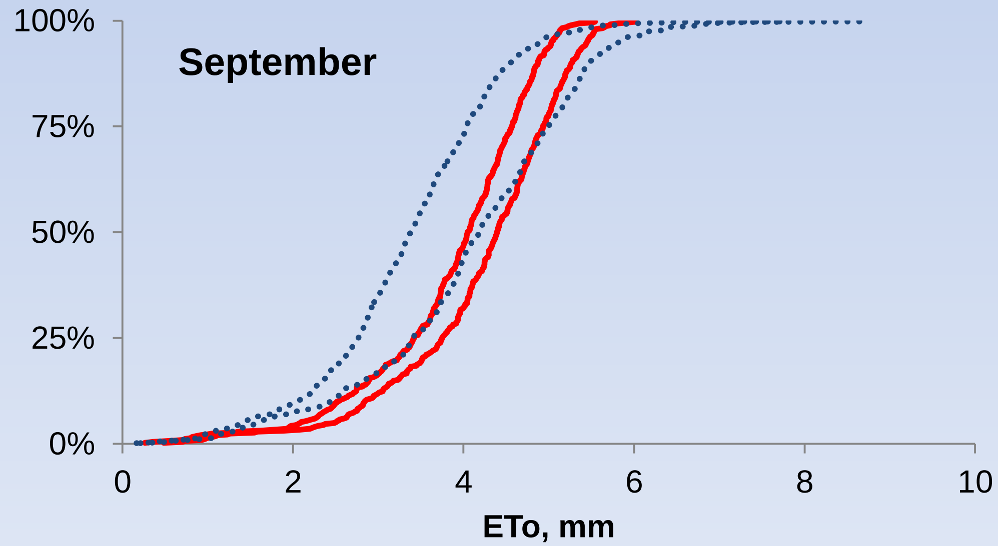


Uncertainty Analysis





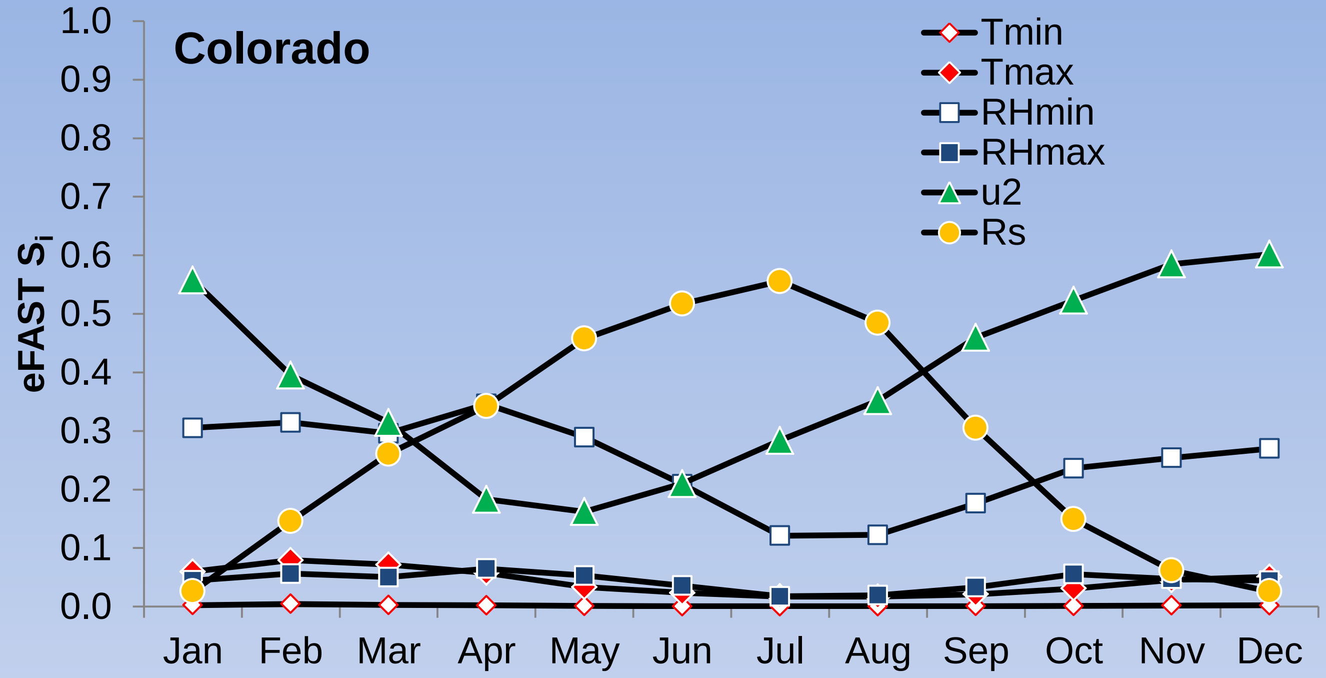


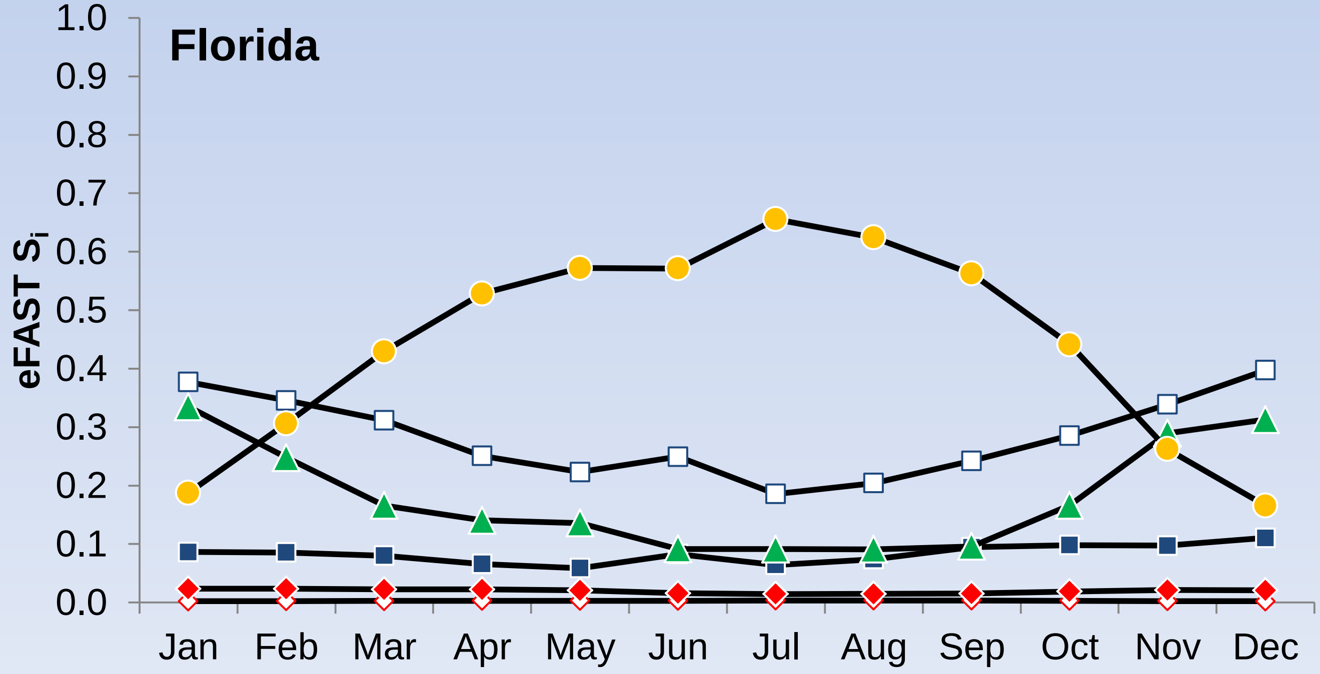


EFAST GSA
(using best-case sensor set)

Rs most important in summer

Regional weather can also affect sensitivity





ETo Sensitvity - Conclusions

- SA of all sensor networks is recommended
  - "local" SA may be enough to evaluate basic accuracy for ETos

- 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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Sensitivity analysis of reference evapotranspiration to sensor accuracy

Kendall C. DeJonge, Mehdi Ahmadi, James C. Ascough II, Kristoph-Dietrich Kinzli

Thank You!

kendall.dejonge@ars.usda.gov