



# Detecting Trends in Evapotranspiration in Colorado

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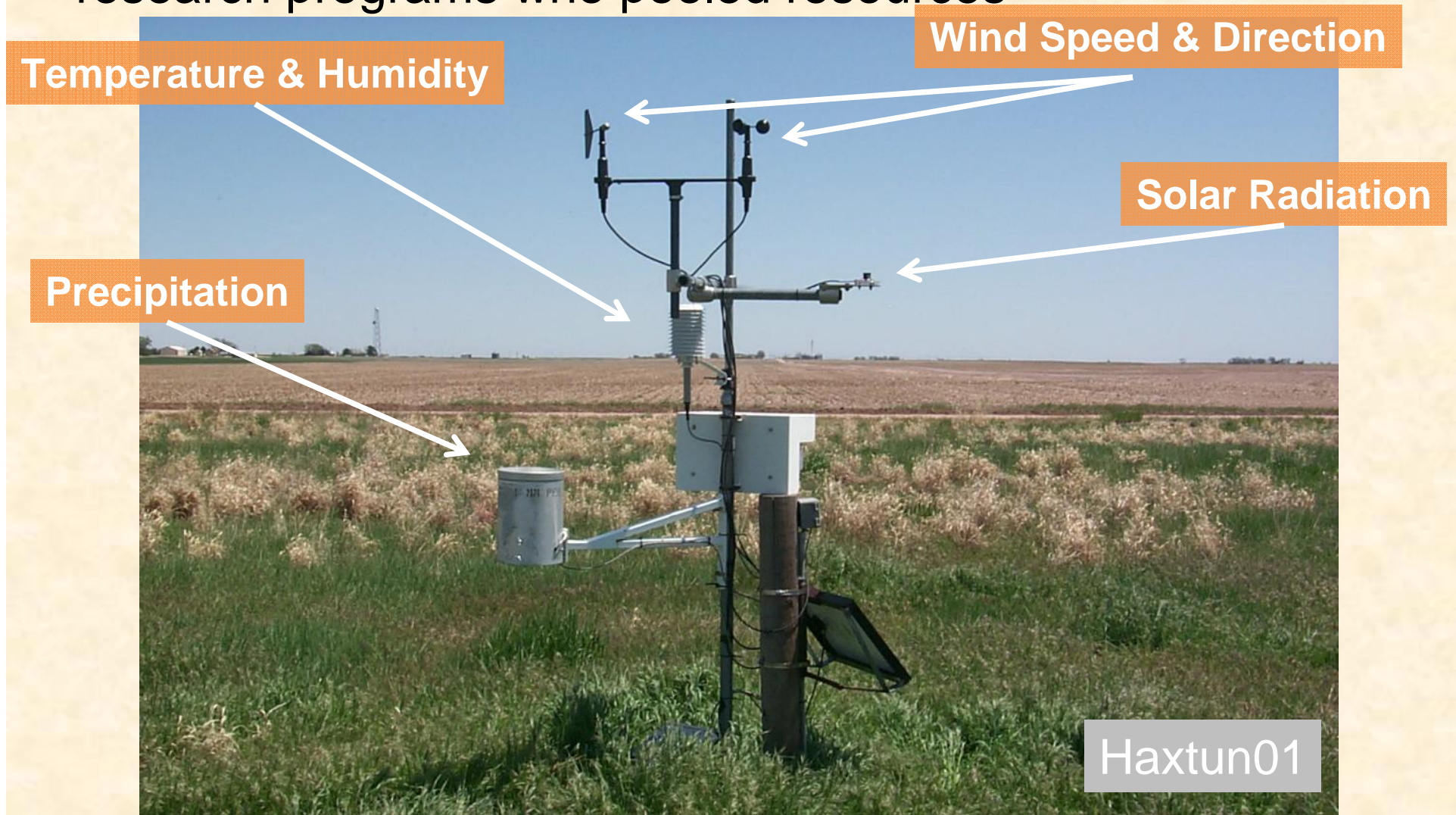
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Presented at Colorado Water Congress Annual Convention, January 24, 2008,  
Denver, Colorado

Funding provided by Colorado Water Resources Research Institute

# Introduction to CoAgMet

- Colorado Agricultural and Meteorological Network (CoAgMet) was founded in 1989 by two independent agricultural research programs who pooled resources

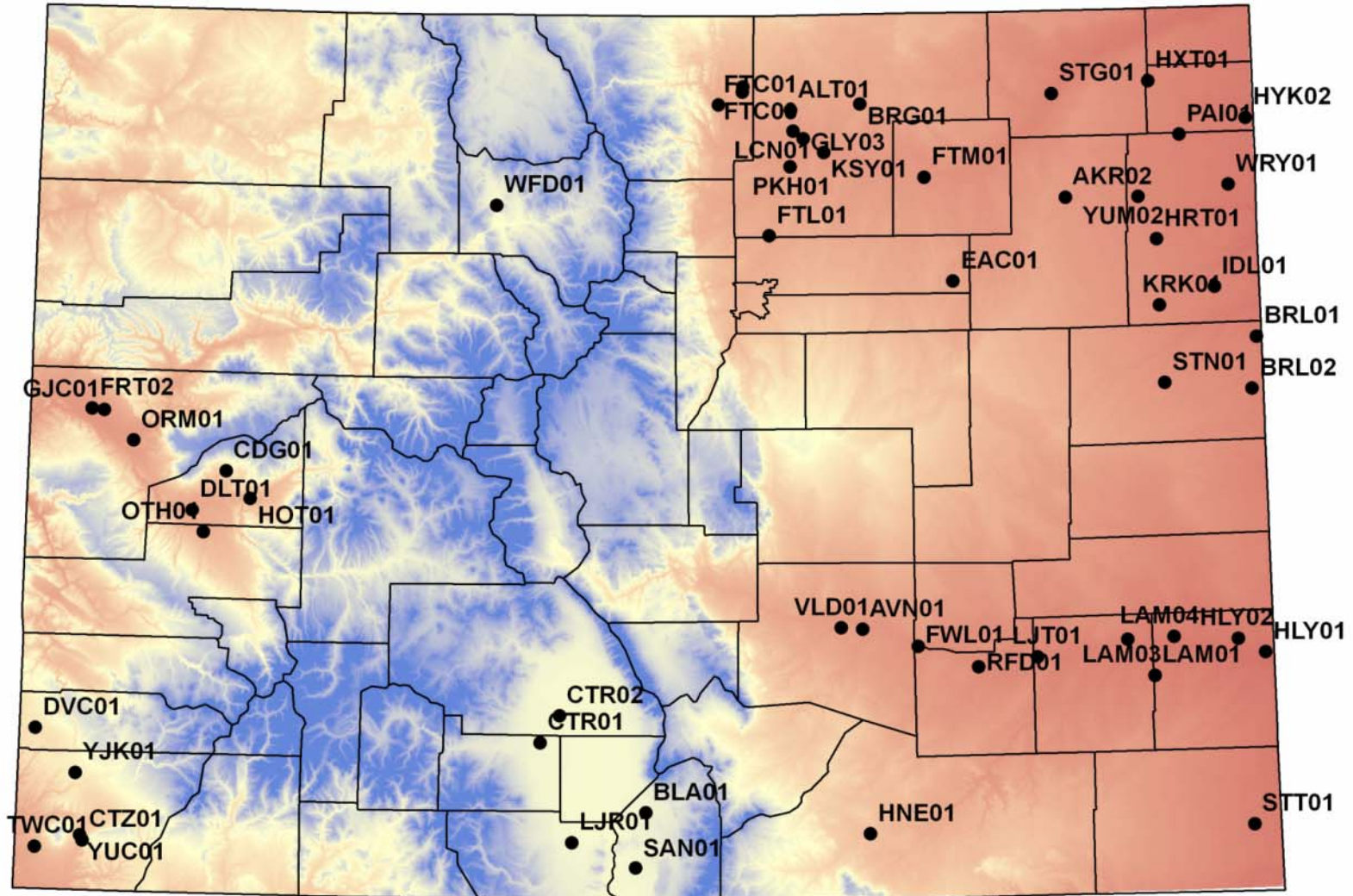


# CoAgMet Overview



- Weather data are available beginning in 1992 with 17 stations
- As of 2008 there are 60 active stations primarily in irrigated agricultural geographic areas
- Currently CoAgMet is a loose federation of motivated organizations with a shared interest in weather data, serving Colorado's diverse agricultural needs

# Colorado Agricultural Meteorological Network (CoAgMet)



As of January 2008

# Typical Weather Stations

## Cortez



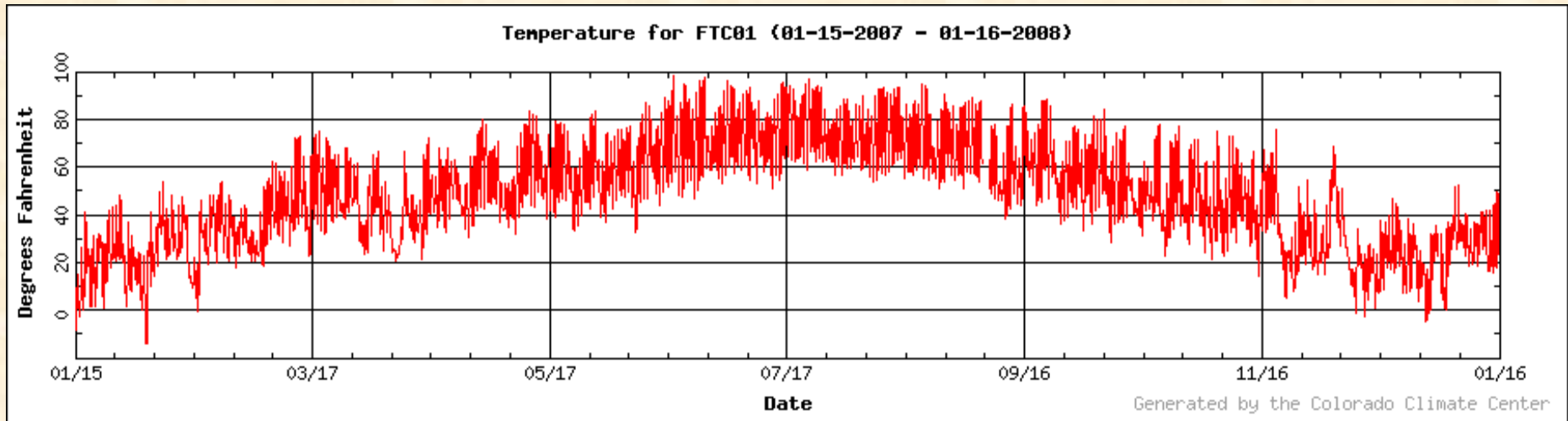
## Fort Collins AERC



# CoAgMet Data Plots

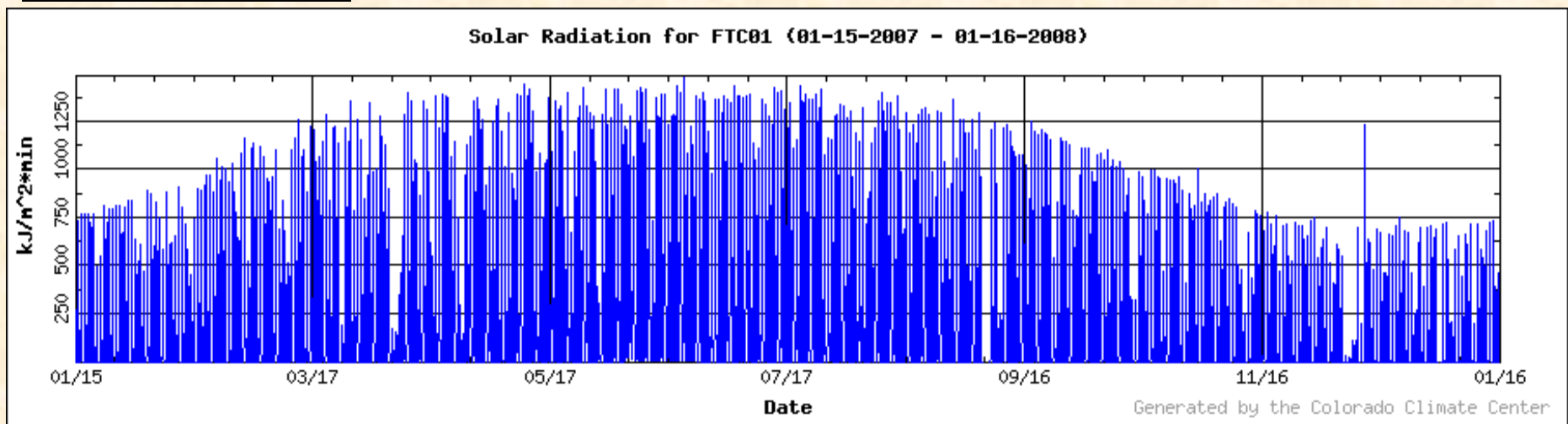
## *FTC01 Fort Collins AERC*

### Temperature



### Solar Radiation

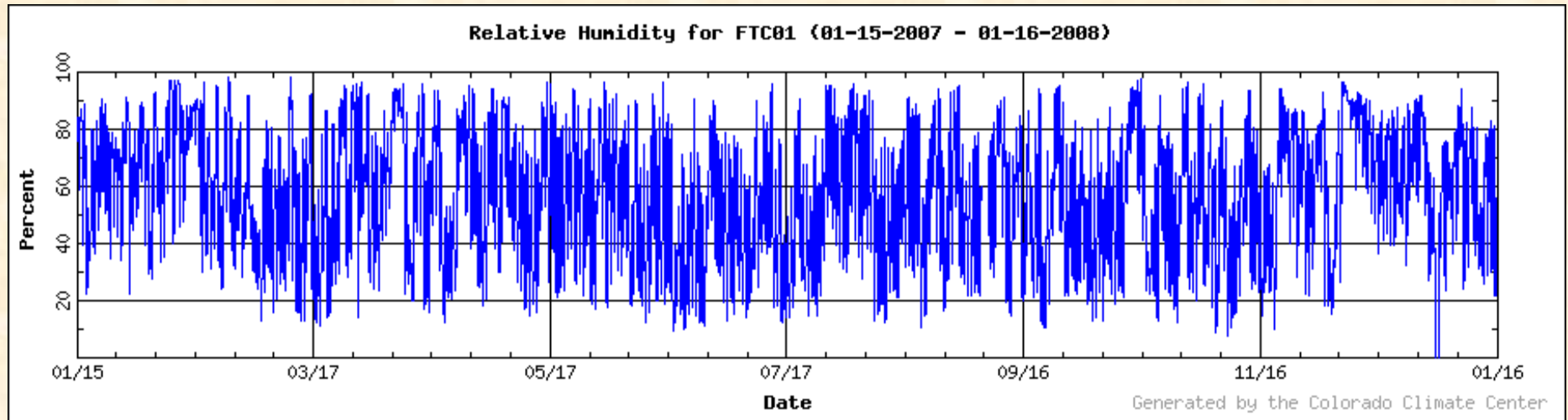
Updated: 16 Jan., 2008



# CoAgMet Data Plots

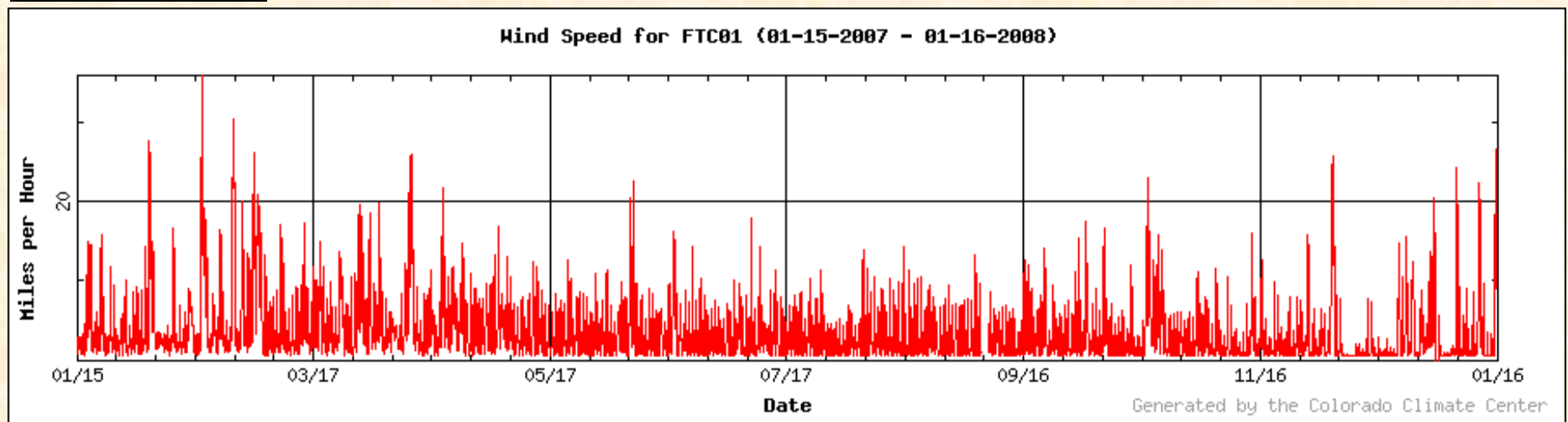
*FTC01 Fort Collins AERC*

## Relative Humidity



## Wind Speed

Updated: 16 Jan., 2008



# Hourly Data Access: <http://ccc.atmos.colostate.edu/~coagmet/>



## CoAgMet Hourly Data Access Results



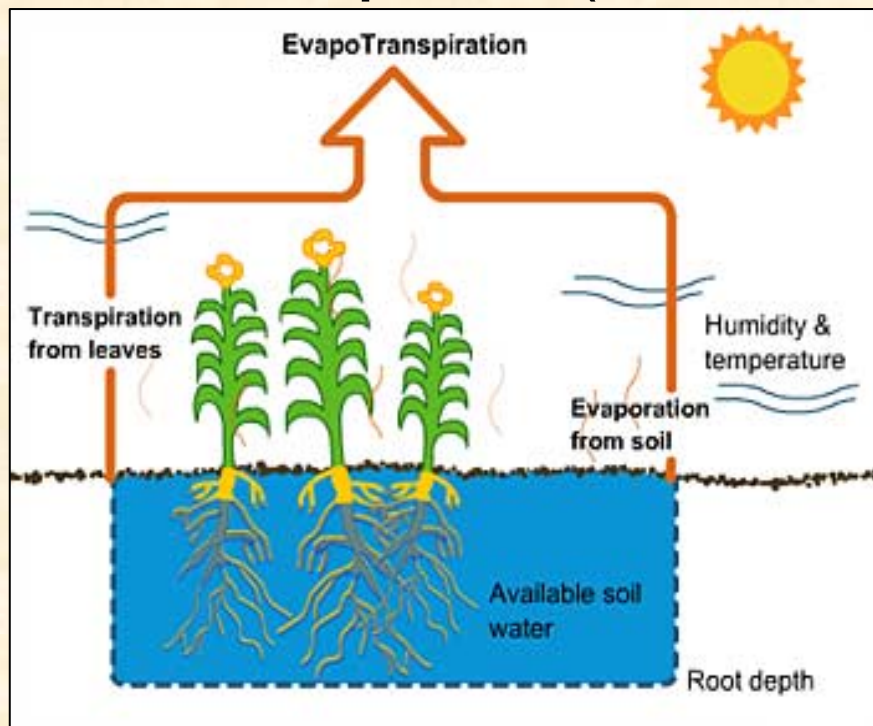
**Station ID:** FTC03      **Station Name:** CSU - ARDEC  
**Latitude:** 40.6525      **Longitude:** 105  
**Elevation:** 5110 ft      **Location:** 6 mi NE Fort Collins  
**Owner:** CSU Agricultural Experiment Station  
**Sponsors:** CSU Ag Experiment Station - Fort Collins  
 CSU Agricultural Research Development and Education

Mean Temp degF	RH %	Vapor Press mb	Solar Rad Lgly	Wind Spd mph	Wind Dir deg	Wind Dir Stdd	Precip in	5cm Soil degF	15cm Soil degF	Wind Gust mph
36.8	74.5	5.52	0	10	175	9	0.00	46.3	45.6	16
35.5	79.9	5.62	0	6	172	11	0.00	44.9	44.4	13
34.7	80.5	5.47	0	3	139	9	0.00	44.3	43.4	8
34.6	68.3	4.62	0	4	43	22	0.00	44.0	42.9	11
33.7	53.3	3.48	0	7	22	10	0.00	43.6	42.4	12
32.6	54.5	3.41	0	4	46	12	0.00	43.1	41.8	9
30.8	56.8	3.31	0	0	60	49	0.00	42.2	41.2	2
27.5	67.8	3.43	0	2	13	24	0.00	40.9	40.1	5
26.5	75.6	3.68	5	2	9	20	0.00	39.8	39.0	4
32.5	56.0	3.47	17	4	11	16	0.00	41.2	39.5	13
35.7	34.4	2.43	17	8	355	15	0.00	43.5	41.4	15
39.4	29.3	2.40	39	10	348	16	0.00	46.1	43.7	16
41.3	29.0	2.56	43	11	320	18	0.00	49.7	48.0	18
43.2	26.9	2.56	42	10	320	15	0.00	51.4	51.0	18
44.6	25.3	2.53	36	7	274	24	0.00	52.4	53.0	16
44.0	27.2	2.66	27	9	190	13	0.00	52.3	53.7	13
42.5	31.2	2.88	15	7	194	11	0.00	51.0	52.3	11
37.4	42.1	3.16	2	5	189	9	0.00	49.1	49.9	8
32.2	55.5	3.41	0	3	157	17	0.00	46.5	46.7	5
29.8	61.2	3.41	0	1	92	15	0.00	44.2	44.1	3
25.4	73.3	3.41	0	2	358	15	0.00	42.3	42.0	4
23.7	77.3	3.36	0	2	347	9	0.00	40.8	40.3	3
21.5	77.7	3.08	0	2	359	11	0.00	39.4	38.9	4
20.3	81.5	3.06	0	3	347	9	0.00	38.2	37.6	4



# Assumption:

- Weather observations can be used to approximate evapotranspiration (ET) rates
  - Critical climatic variables: air temperature, humidity (vapor pressure), solar radiation, wind speed (wind run)



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# Key Findings From Literature Review

- Simple temperature and day length-based models that only require monthly climate inputs have been used for decades to estimate evapotranspiration rates – i.e. Blaney-Criddle, (1950)
- Physically based models have become increasingly popular with the advent of field-specific automated weather stations
- The Food and Agricultural Organization of the United Nations (FAO) proposed the Penman-Monteith method as standard

Jensen D. T., *et al.*, 1997

# ASCE Penman-Monteith Variables

- Daily mean temperature (F)
- Mean daily vapor pressure (mb)
- Mean daily solar radiation (Lgly)
- Cumulative daily wind run (mi)
  
- Irmak, *et al.* (2006) sensitivity analysis found **humidity & wind** to be the most sensitive climatic variables

# Data Sources for the Study:

- Colorado Agricultural Meteorological Network  
(**CoAgMet**)

[ccc.atmos.colostate.edu/~coagmet](http://ccc.atmos.colostate.edu/~coagmet)

- Northern Colorado Water Conservancy District  
(**NCWCD**)

[www.ncwcd.org/ims/ims\\_weather\\_form.asp](http://www.ncwcd.org/ims/ims_weather_form.asp)



Cortez01

# Our Challenge

- With existing CoAgMet weather data, how well can we estimate year to year variations in reference ET and consumptive use?
- Can we detect trends in reference ET over time?



# • Grouped Regions

North Central

Lower S Platte

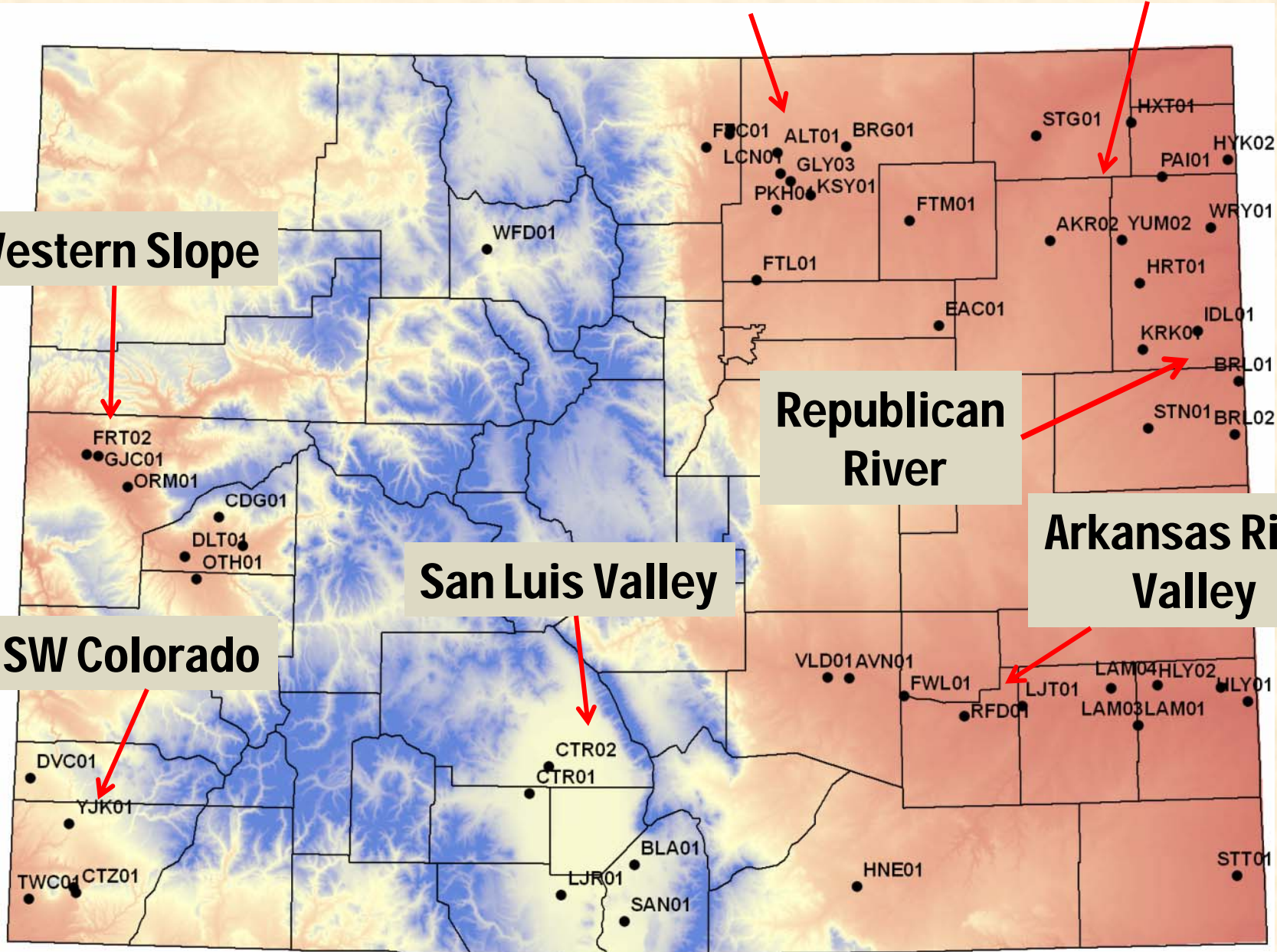
Western Slope

Republican River

Arkansas River Valley

San Luis Valley

SW Colorado

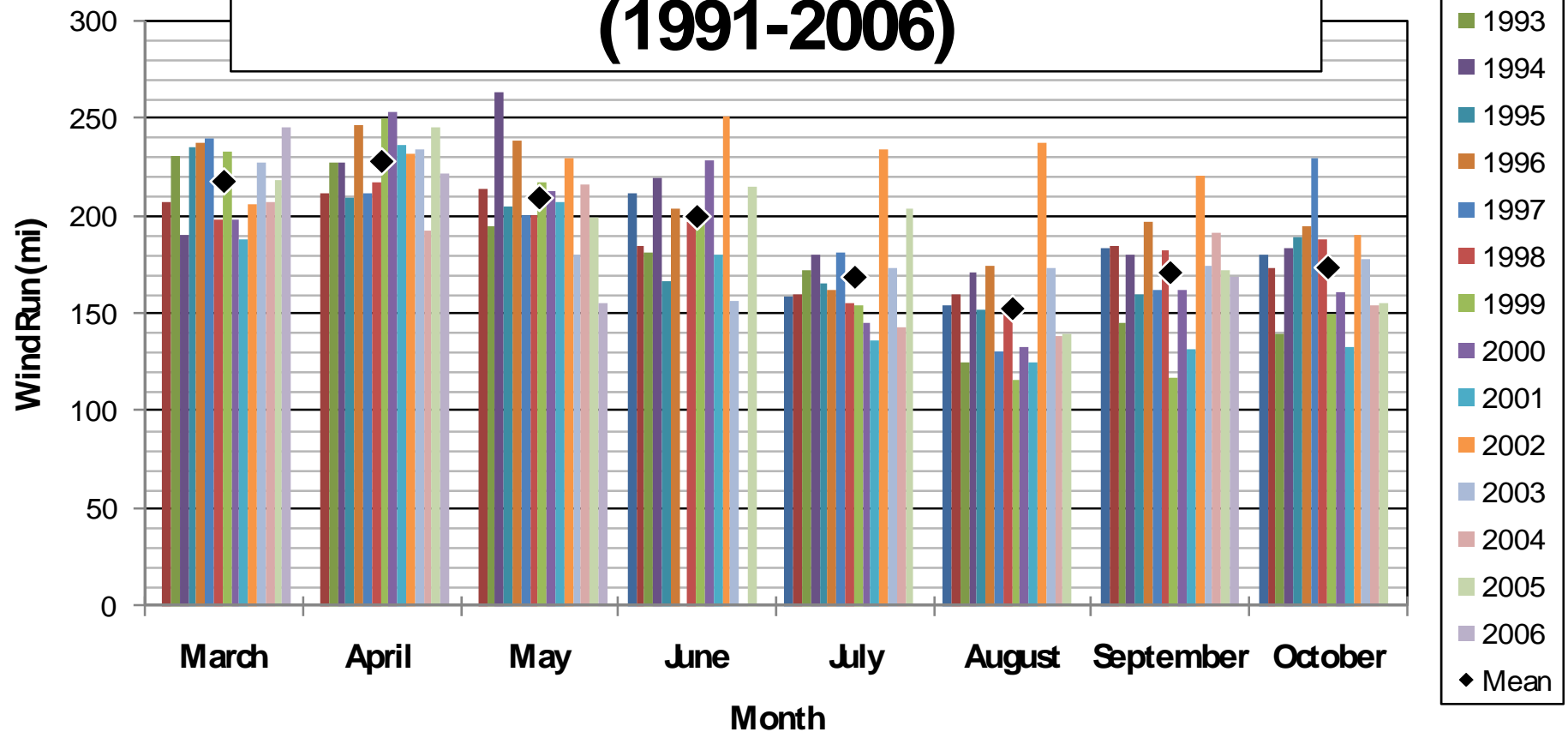


# Methods

- For each year, monthly mean values of Temperature, Humidity, Solar radiation, and Wind were calculated from daily data for each station
- Months with 3 or more days with missing data were omitted



# IDALIA MEAN MONTHLY WIND RUN (1991-2006)

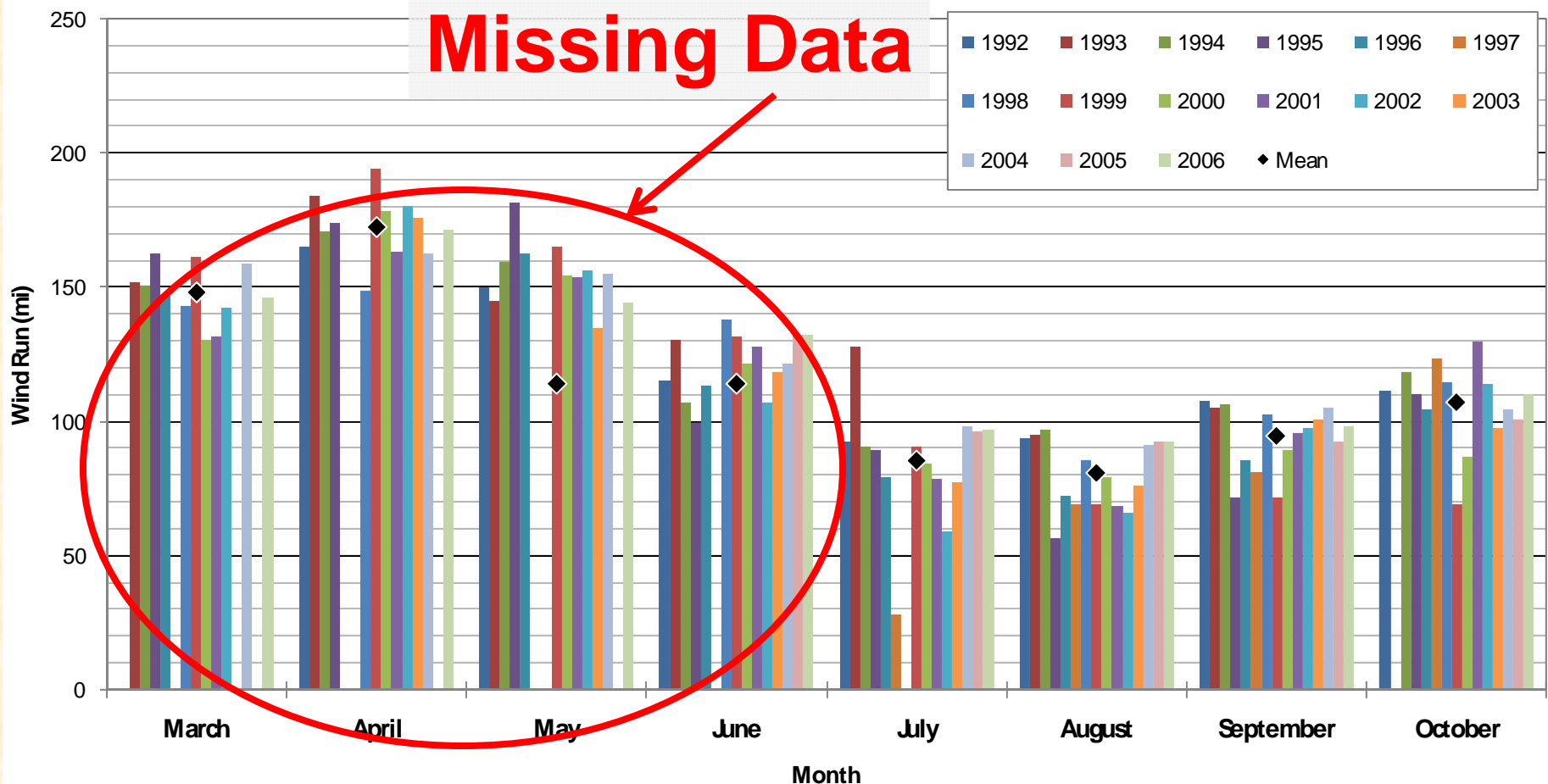


- Idalia shows typical seasonal wind patterns and year to year variations
- Note: Higher than normal winds during the 2002 drought year



- Unfortunately, data are not complete at all stations

Peckham, Mean Monthly Wind Run (May-Sept)



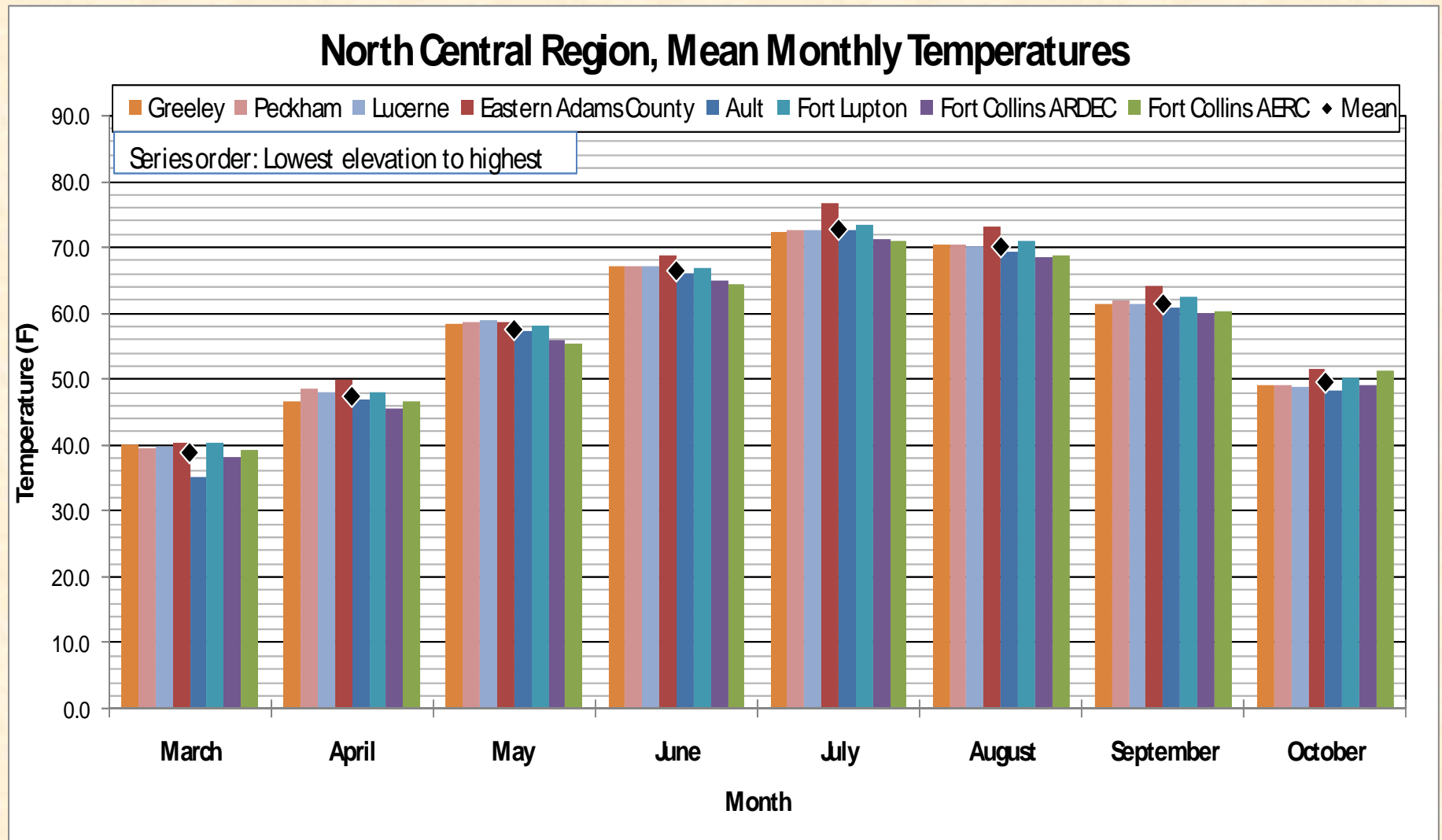
# Methods

- Average monthly values were calculated for available time-series and grouped by region
- Stations with less than 5 years of data were omitted from time series analysis
- Data quality assessments were completed for all variables



# Methods:

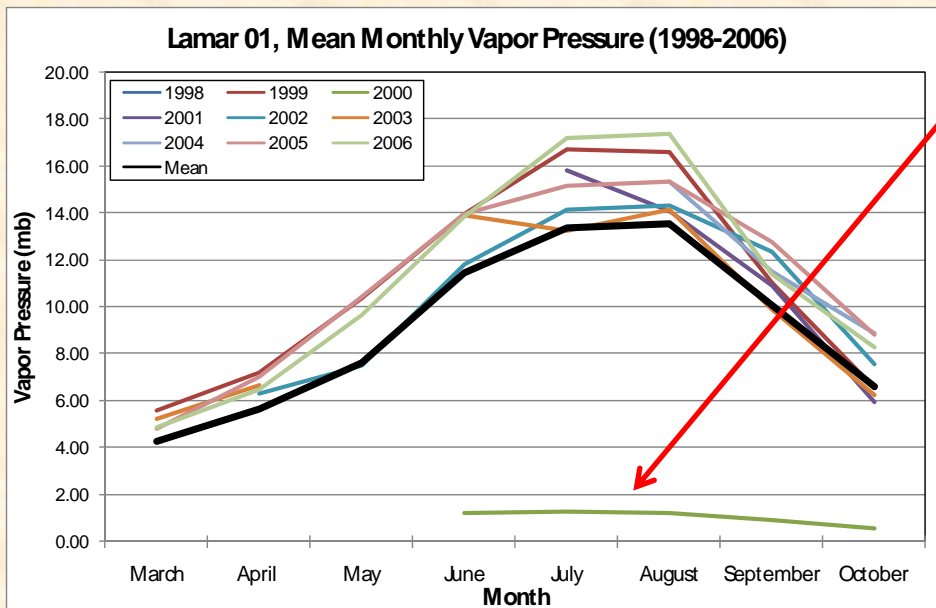
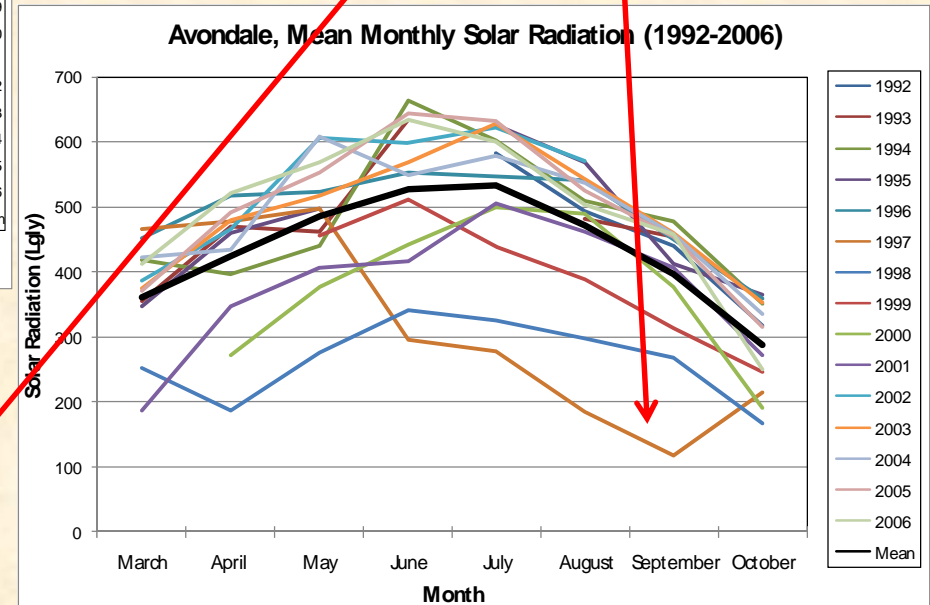
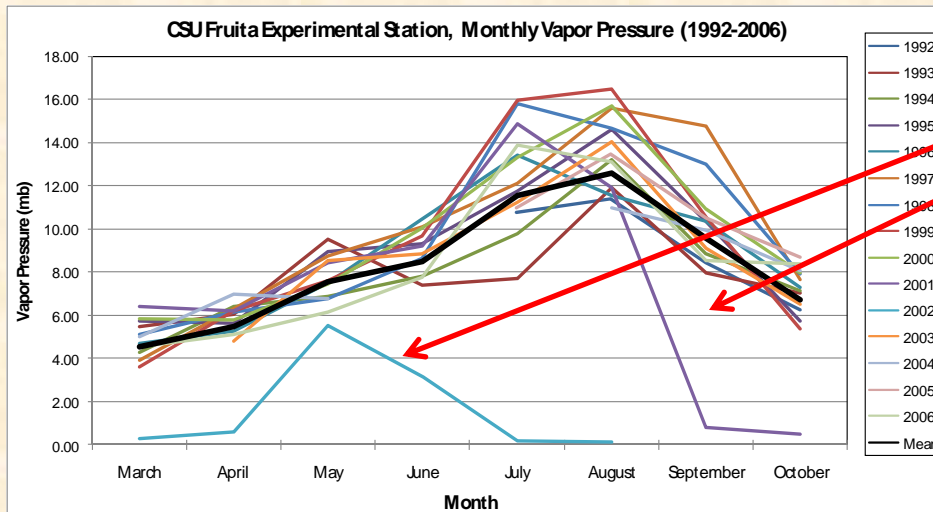
- A regional temperature comparison for the North Central region



# Methods:

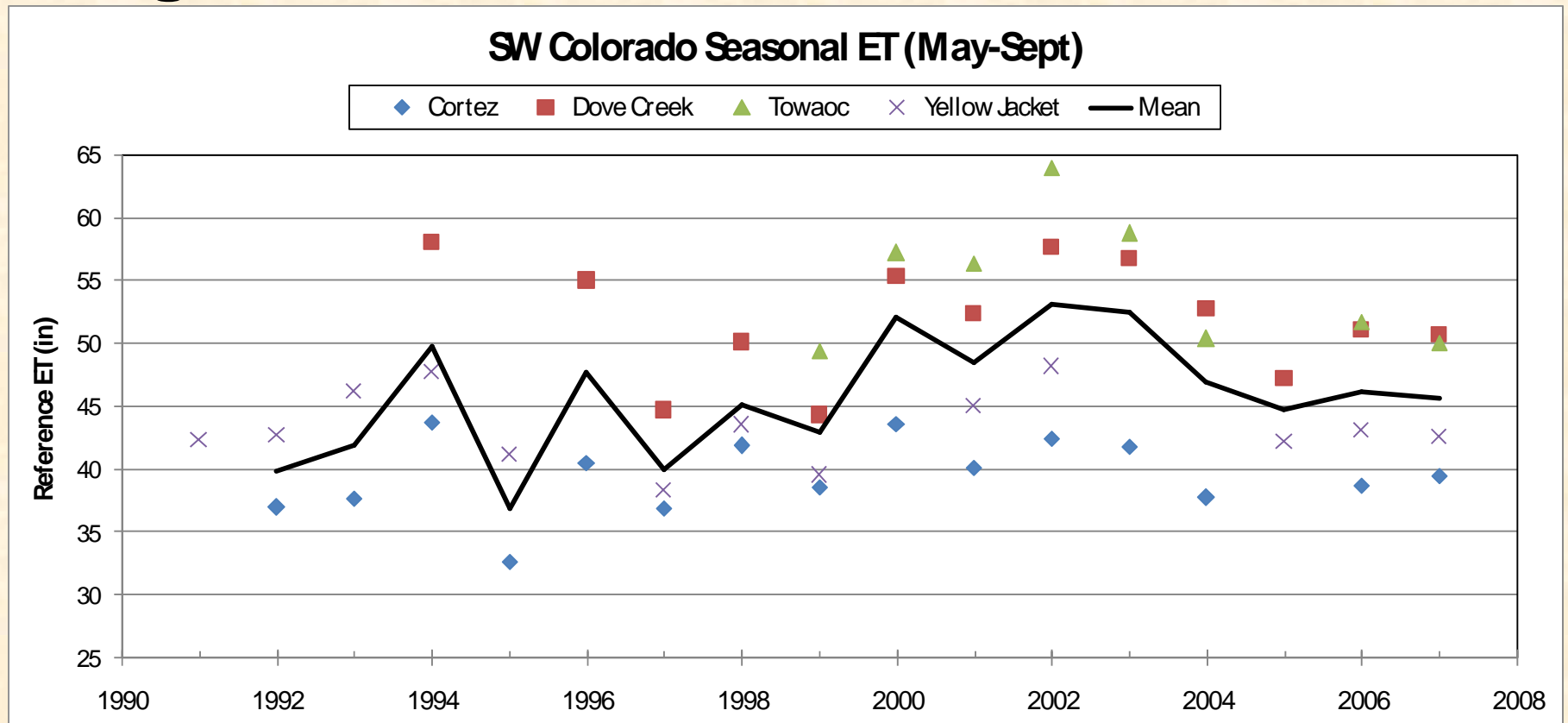
# Questionable Data ??

## Data quality assessment



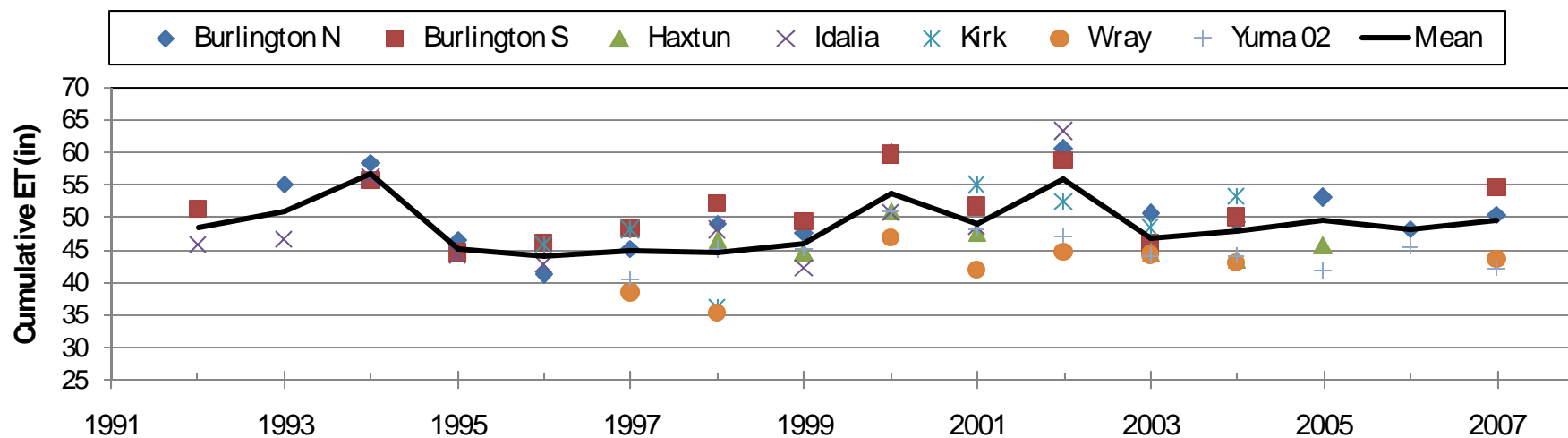
# Methods:

- Computed seasonal (May-Sept.) alfalfa reference ET for all complete years
- Time series reference ET plots were made for all regions

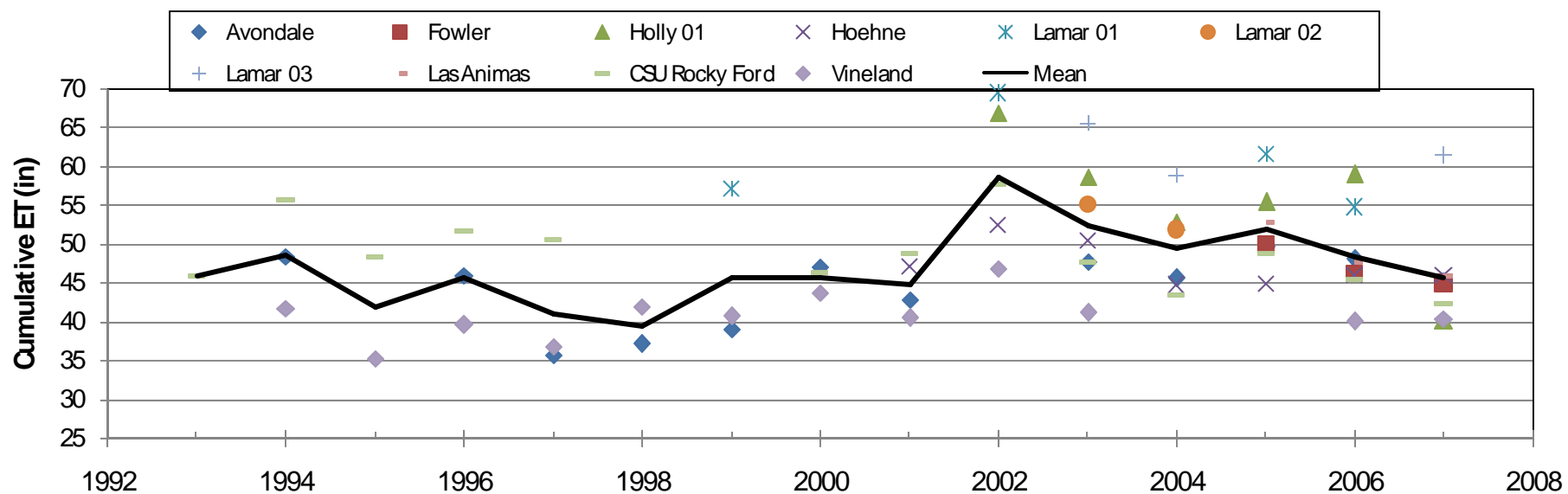


# Results: Seasonal Reference ET Time Series

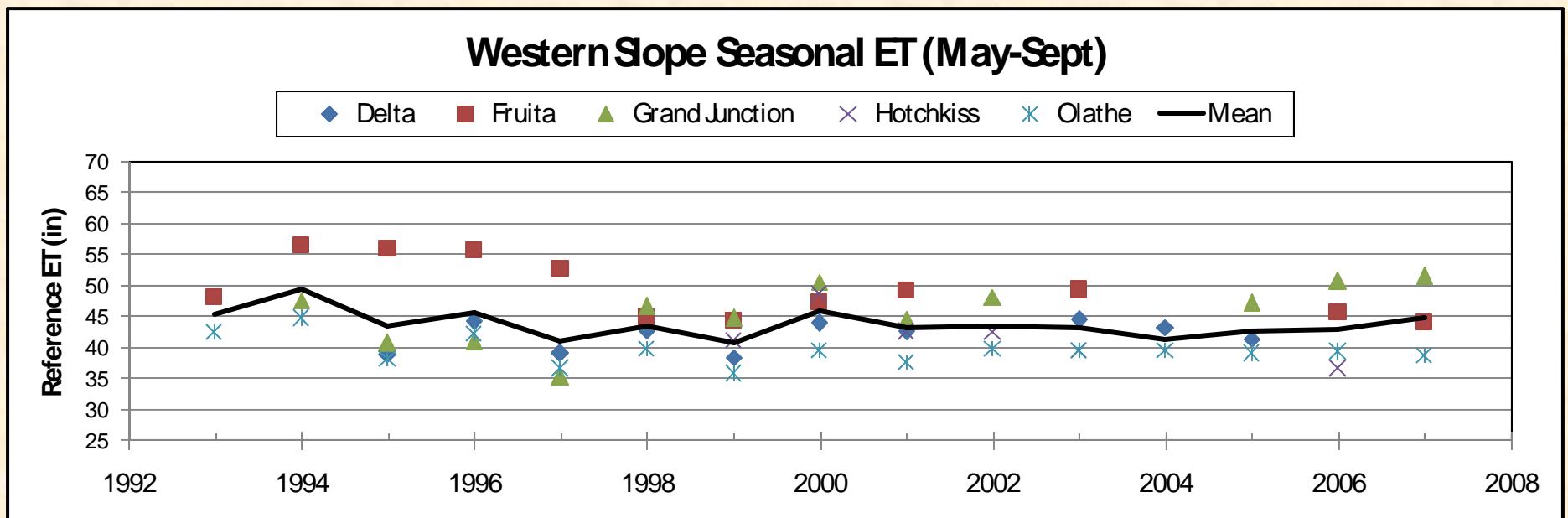
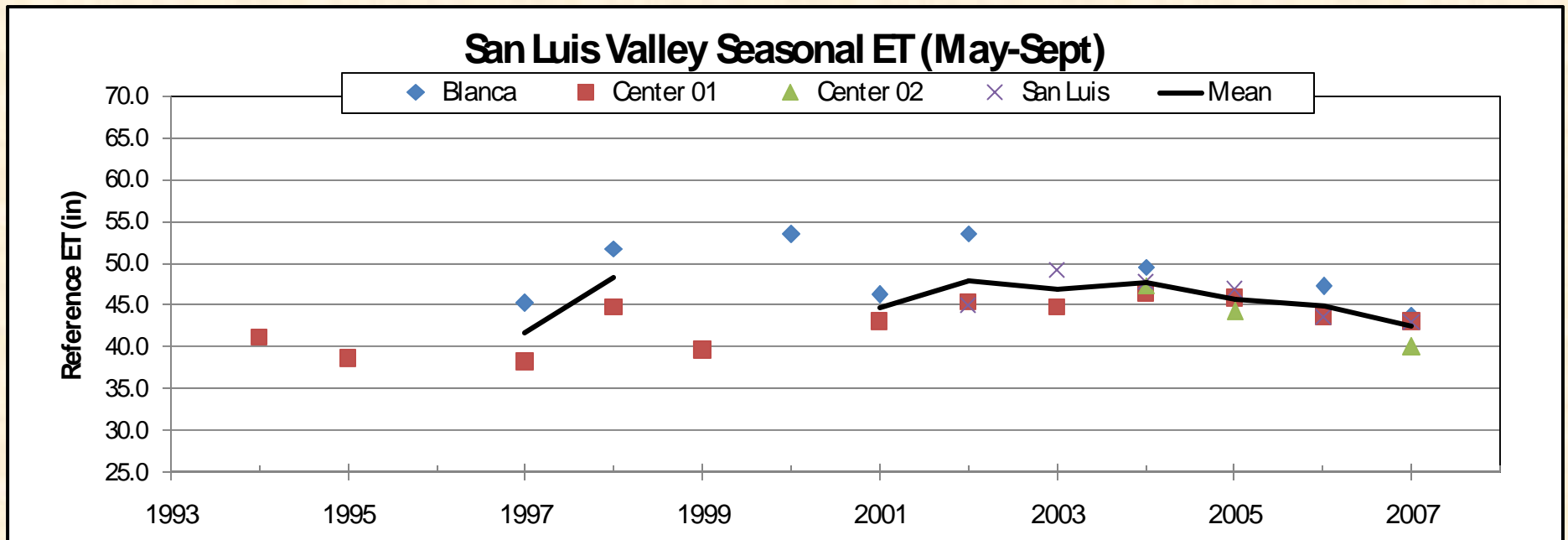
## Republican River Basin Seasonal Reference ET (May-Sept)



## Arkansas Valley Seasonal Reference ET (May-Sept)



# Results: Seasonal Reference ET Time Series



# CoAgMet and NCWCD

- CoAgMet's results were compared to a similar weather network in Northern Colorado
- The Northern Colorado Water Conservancy District (NCWCD) weather station network is a “gold standard” for ET comparison due to their high standards for siting, maintenance, and calibration

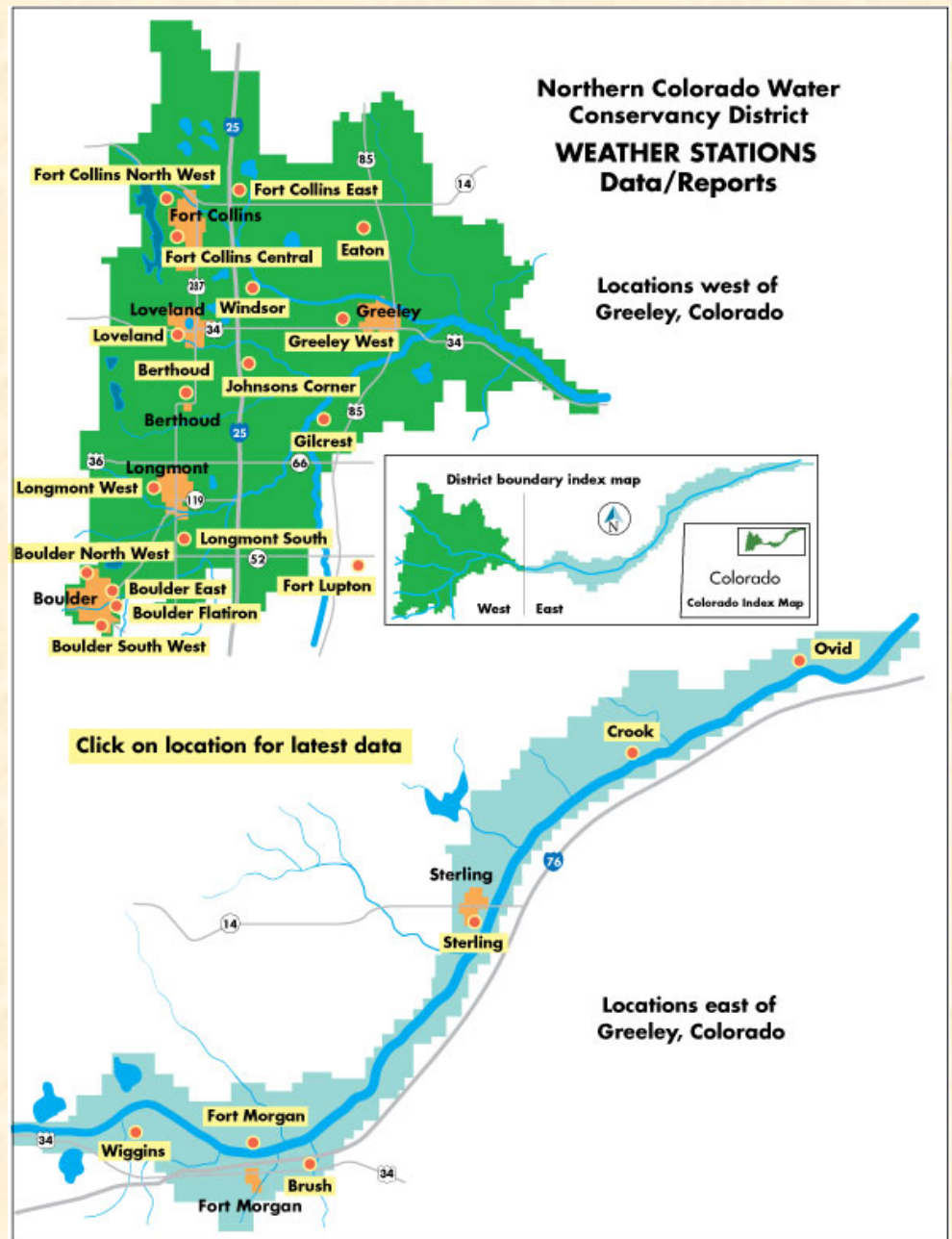




# NCWCD Weather Stations



[www.ncwcd.org](http://www.ncwcd.org)

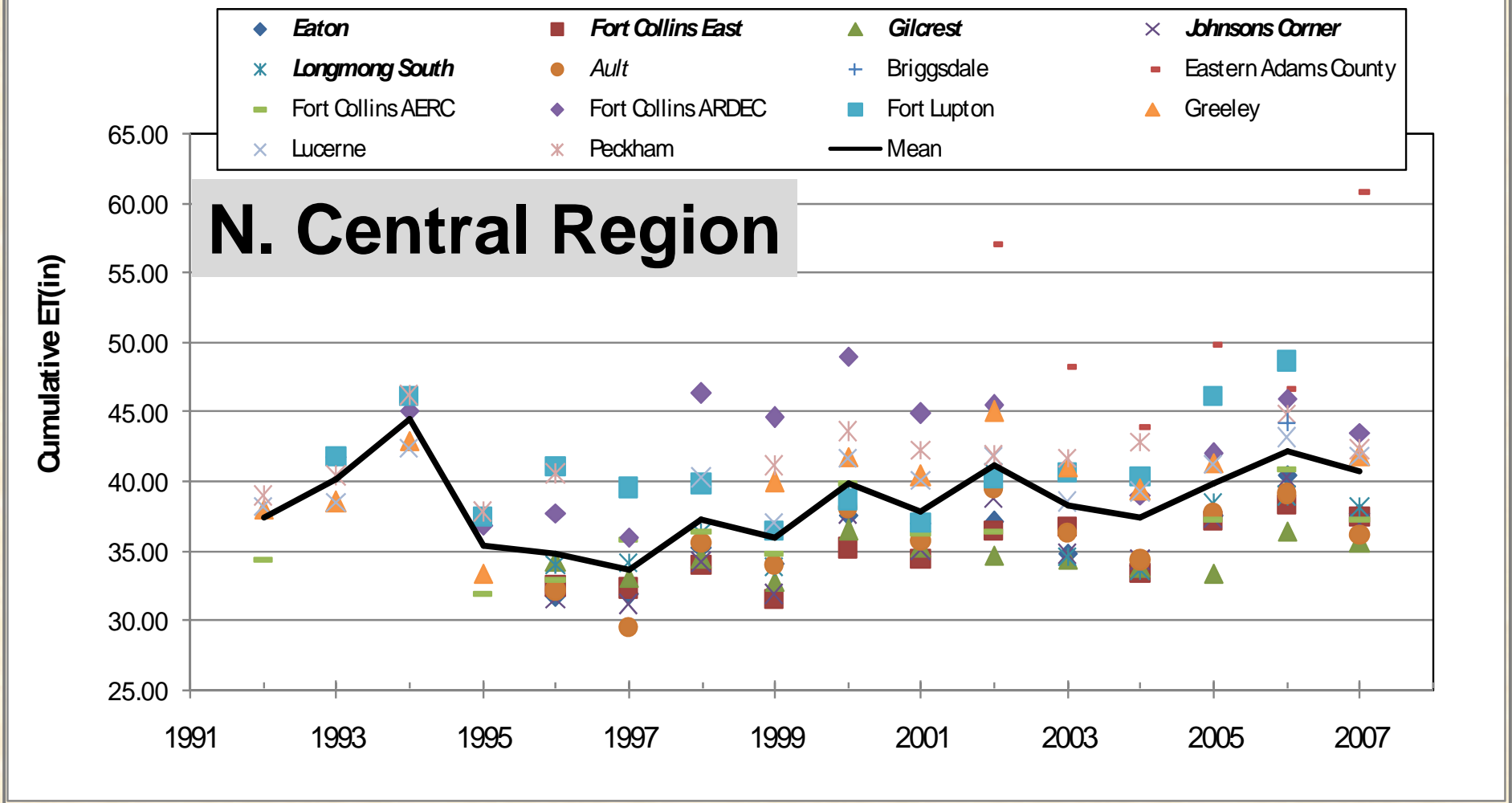


# NCWCD Weather Stations Summary

- 24 Stations throughout the North Central and Lower S. Platte regions
  - 10 Alfalfa sites
  - 13 Turf grass sites
  - 1 Dry-land Pasture site
- NCWCD stations measure all ASCE Penman-Montieth weather variables
- NCWCD emphasizes high standards for station maintenance, siting, and data quality
- Close proximity of CoAgMet and NCWCD provides opportunity to compare data and ET estimates

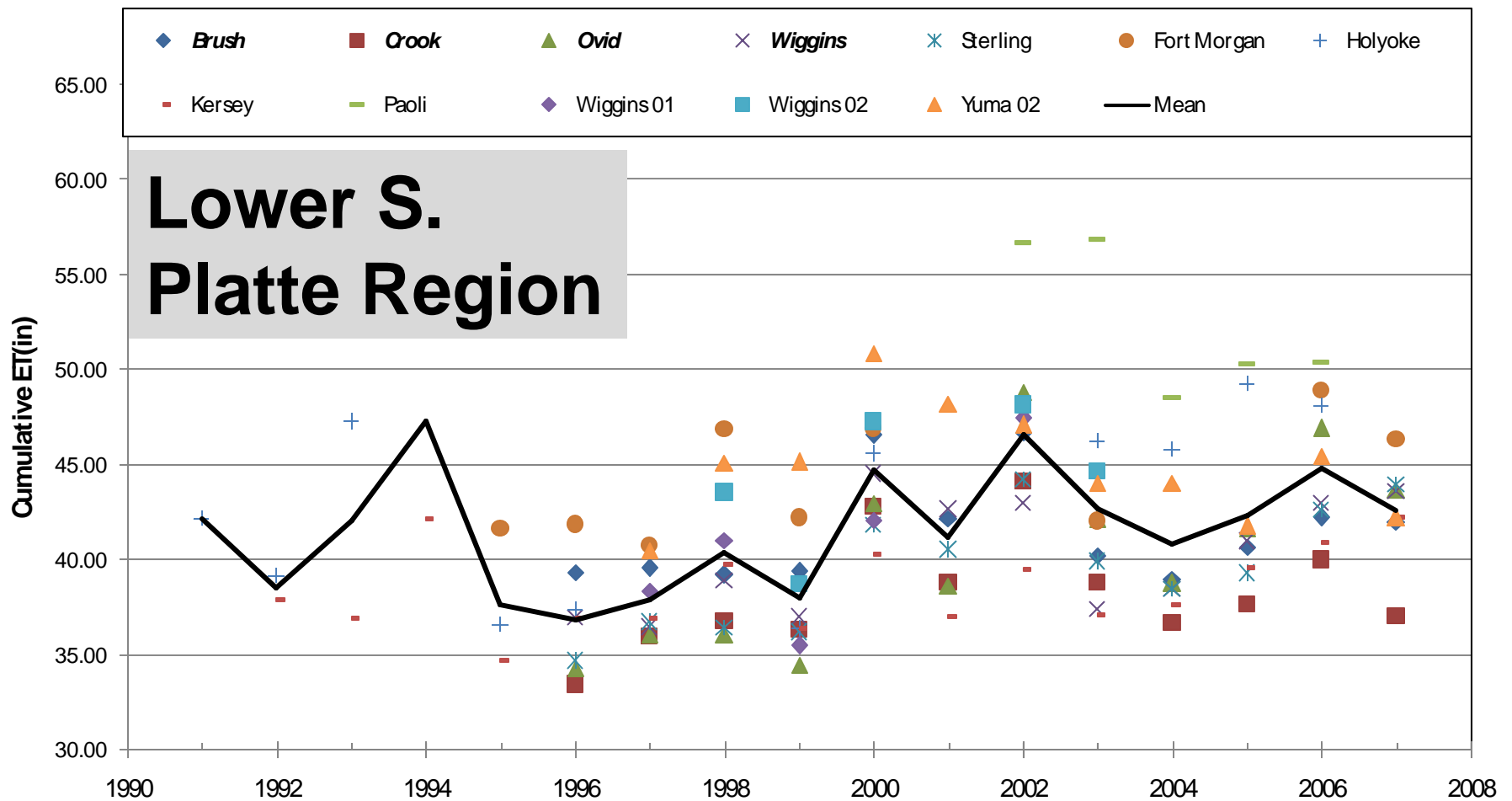
# Reference ET Comparison: NCWCD versus CoAgMet

**CoAgMet and NCWCD North Central Seasonal ET (May-Sept)**



# Reference ET Comparison: NCWCD versus CoAgMet

CoAgMet and NCWCD Lower SPlatte Seasonal ET (May-Sept)



# Preliminary Conclusions

- Year to year variations in reference ET are apparent but generally less than 15%
- 2002 showed the highest ET rates at most sites
- Within each region, the magnitude of estimated reference ET varies considerably among stations but variations are well correlated
- When compared to NCWCD, CoAgMet shows systematically higher ET rates and more variability among stations
- Interannual variations in ET are well correlated between CoAgMet and NCWCD

## **Preliminary Conclusions (continued)**

- CoAgMet has the potential to provide year to year variations in reference ET for irrigation scheduling and water resource assessments
- Missing data, infrequent instrument calibration, and unrepresentative siting for some stations have compromised the ability for long-term ET applications
- Improvements in station maintenance and exposure are encouraged so that CoAgMet can become a more valuable resource for Colorado water managers

# What's Ahead?

- Independent sensitivity and statistical analysis
- CoAgMet ET computation verification
- Enhance network capabilities
  - Instrument sighting, maintenance, and calibration
- Provide serially complete data for best stations



# Acknowledgements

- Funding for this research was provided by the **Colorado Water Resource Research Institute**
- Dr. Harold Duke, USDA, ARS, *Retired*
- Troy Bauder, CSU, Dept. Soil and Crop Science
- June Caves, NCWCD
- Wendy Ryan, Odie Bliss, and John Kleist, Colorado Climate Center



# Literature Cited:

Blaney, H. F., and Criddle, W. D., 1950. Determining water requirements in irrigated areas from climatological and irrigation data. *U.S.D.A. Soil Conservation Service Rep. SCS-TP 96*, Washington, DC, 49.

Irmak, S., Payero, J.O., Derrel, L.M., Irmak, A., Howell, T.A., 2006. Sensitivity Analyses and Sensitivity Coefficients of Standardized Daily ASCE-Penman-Monteith Equation. *Journal of Irrigation and Drainage Engineering*. Nov-Dec., pp. 564-578.

Jensen, D. T., Hargreaves, G.H., Temesgen, B., Allen, R. G. 1997. Computation of  $ET_0$  Under Non-Ideal Conditions. *Journal of Irrigation and Drainage Engineering*. 123: 5 pp. 394-400.

## CoAgMet

<http://ccc.atmos.colostate.edu/~coagmet/>

## NCWCD

[http://www.ncwcd.org/ims/ims\\_weather\\_form.asp](http://www.ncwcd.org/ims/ims_weather_form.asp)

