Weather Data Integrity Assessment

Standard Procedures and Guidelines

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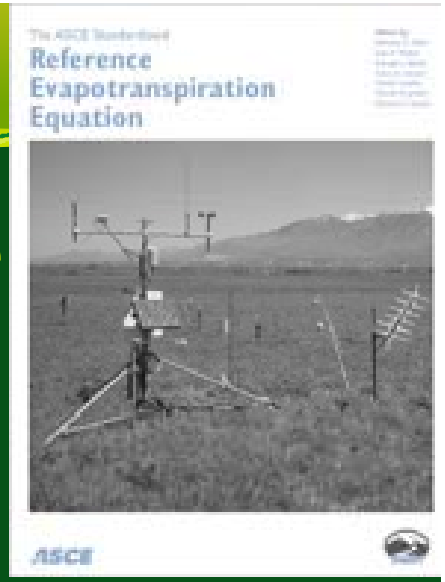
Ft Collins CO

COLORADO DIVISION OF WATER RESOURCES
DEPARTMENT OF NATURAL RESOURCES

ASCE Standardized Reference Evapotranspiration Equation

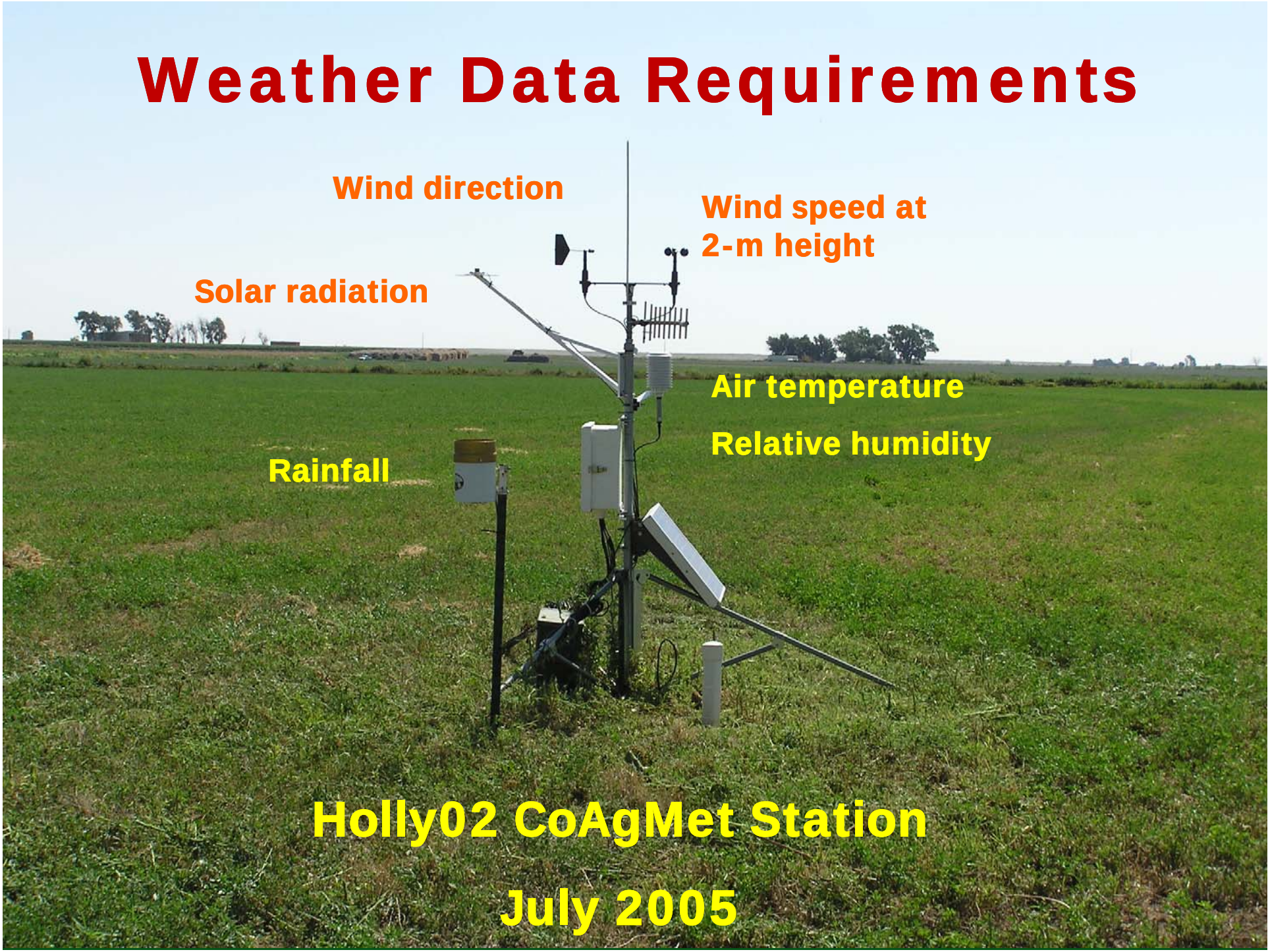


$$ET_{sz} = \frac{0.408\,\Delta(R_n - G) + \gamma \frac{C_n}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + C_d\, u_2)}$$

- Based on ASCE Penman-Monteith Eqn.
- ET for hypothetical standardized reference crop

  ET_{os} :12 cm tall grass OR ET_{rs} :50 cm tall alfalfa
- Reference ET is converted to crop ET using crop coefficients
- Simplified and standardized computations for variables

Weather Data Requirements



Sensitivity Analyses

- Many sensitivity studies of various versions of Penman combination equation
- Sensitivity coefficient--% relative input variable change (error) transmitted to model output (ET)
  - Results vary seasonally and with climate

net radiation	**0.50 - 0.90**
air temperature	**0.20 – 0.50**
vapor pressure deficit (air temp, relative humidity)	**0.25 – 0.50**
wind speed at 2 m	**0.10 – 0.30**

Sensitivity Analyses

- Sensors maintained within manufacturer's specifications of accuracy:
  - ET_r error due to systematic (sensor calibration bias) and random measurement errors less than 6%
  - New, re-conditioned, re-calibrated sensors found to measure within manufacturer's specifications of accuracy resulting in ET_r error less than 4% (Ley et al., 1994b)

Weather Data Assessment

- Data collection environment/station siting
- Weather data quality
- Weather station density

Weather Data Assessment

- Data collection environment/station siting
  - Weather data intended for reference ET estimation should be collected at weather stations sited over and downwind of vegetation that approximates a well-watered, clipped green grass surface in an open, irrigated setting → "reference" site
  - Green, irrigated fetch in the primary wind direction → conditions air temperature and humidity in the boundary layer above the evaporating surface
  - Ideally 100 m of well-watered fetch in all directions
  - Horizontal separation distance from any obstacle should be minimum 10x the height of the obstacle


Sunnyside 07/21/99 NW


31. 7. 2002 0


7. 10. 20

Weather Data Assessment

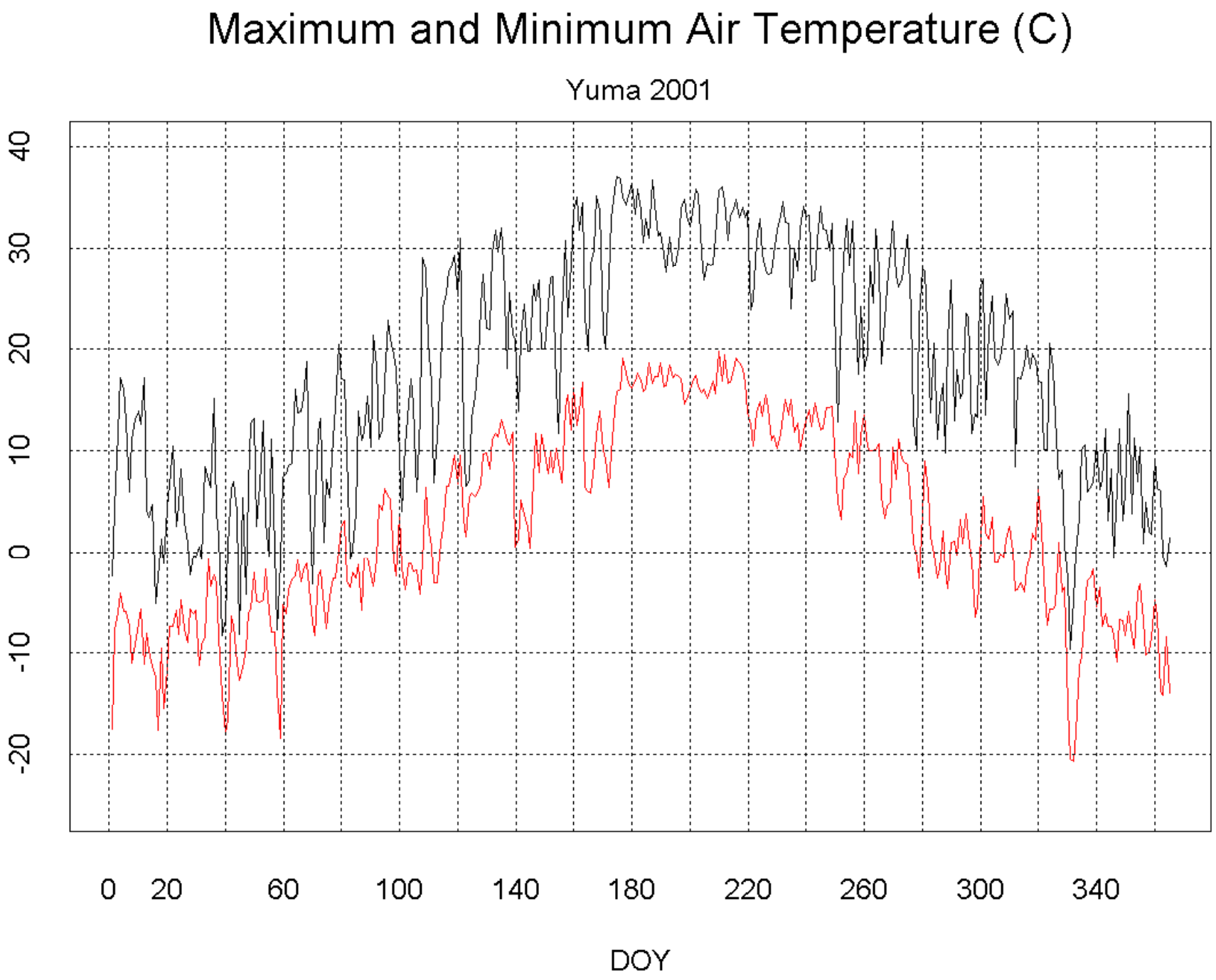
- Weather data quality
  - All data need quality assessment
  - Detailed QA/QC procedures available
    (e.g. EWRI, 2005; Allen, 1996)
  - Typical QC procedures may not identify sensor measurement bias
  - Poor data → poor results

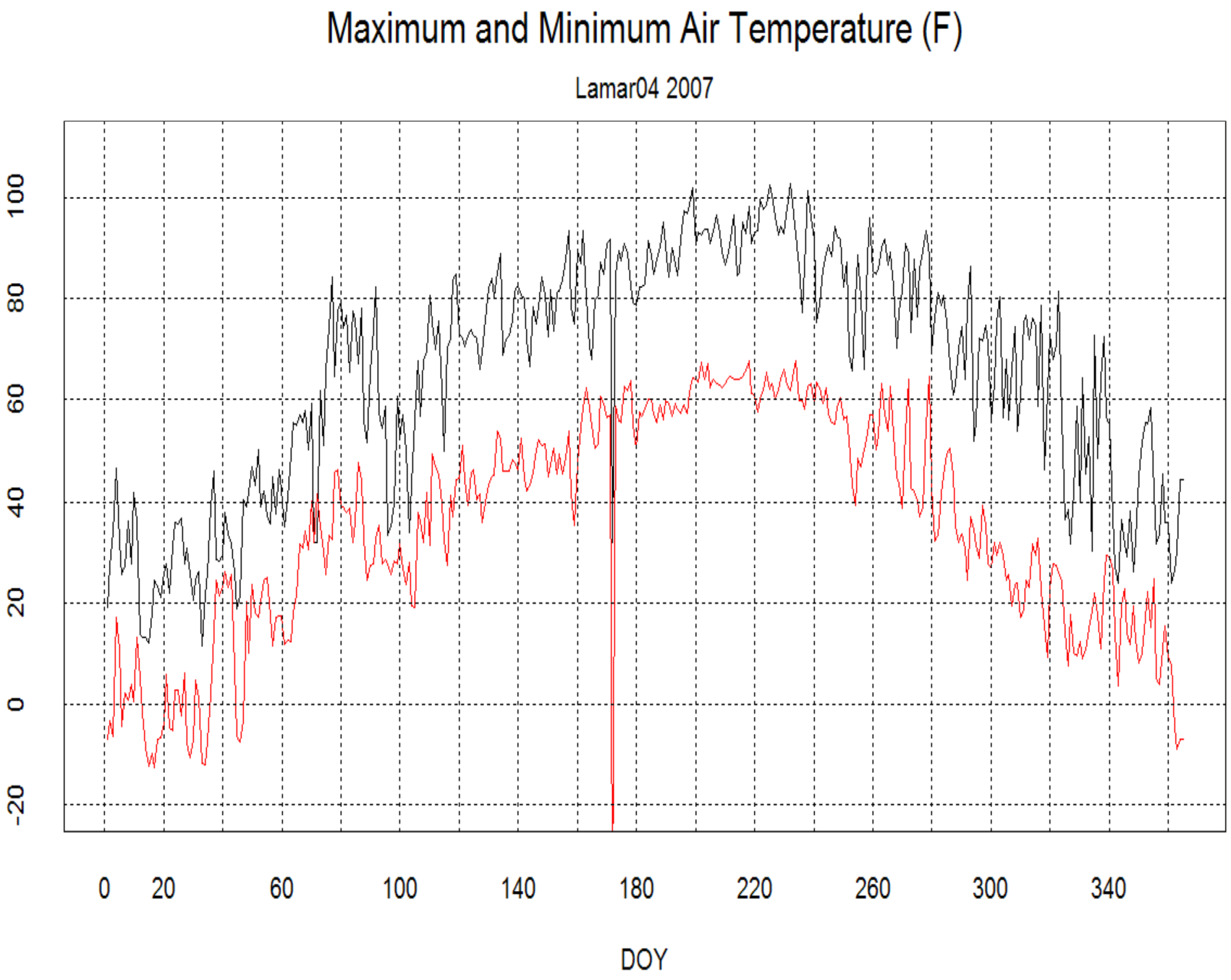
Visual Screening

- Plot data versus time
- Check for “reasonableness”
- Consider environmental impacts at measurement site
  - knowledge of station siting and environment
  - station location data and photos
- Compare measured data with physically known ranges or constraints

Air Temperature

- Thermistors or thermistor combined with RH sensor
- Housed in naturally ventilated cotton region shelter or multiplate radiation shield
- Generally a stable, uniform sensor
- ± 0.4 °C (-20 to +60 °C) typical accuracy


Maximum and Minimum Air Temperature (C)
Yuma 2001
40
30
20
10
0
-10
-20
0
20
60
100
140
180
220
260
300
340
DOY


Maximum and Minimum Air Temperature (F)
Lamar04 2007
100
80
60
40
20
0
-20
0
20
60
100
140
180
220
260
300
340
DOY

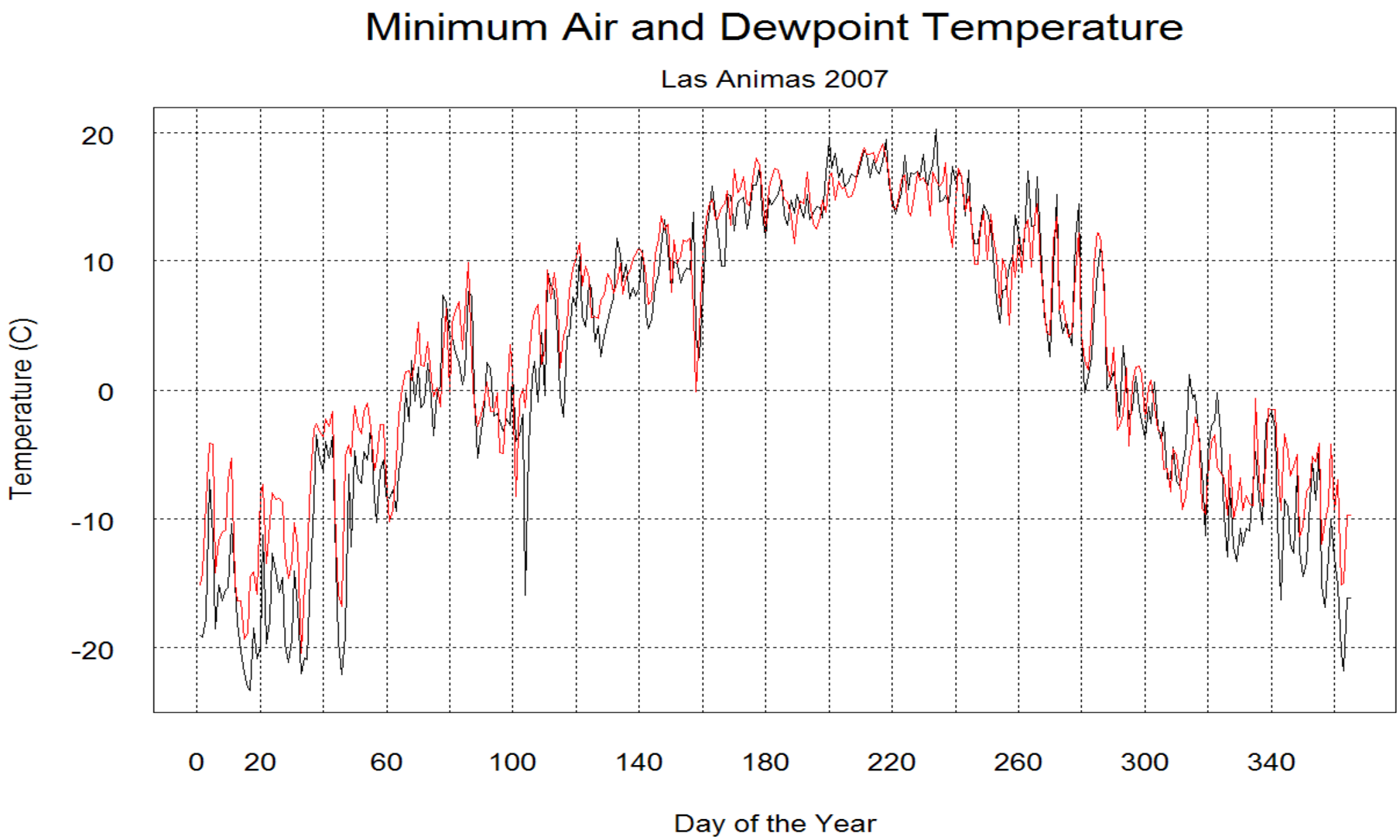
Dewpoint Temperature (T_{dew}) /Relative Humidity (RH)

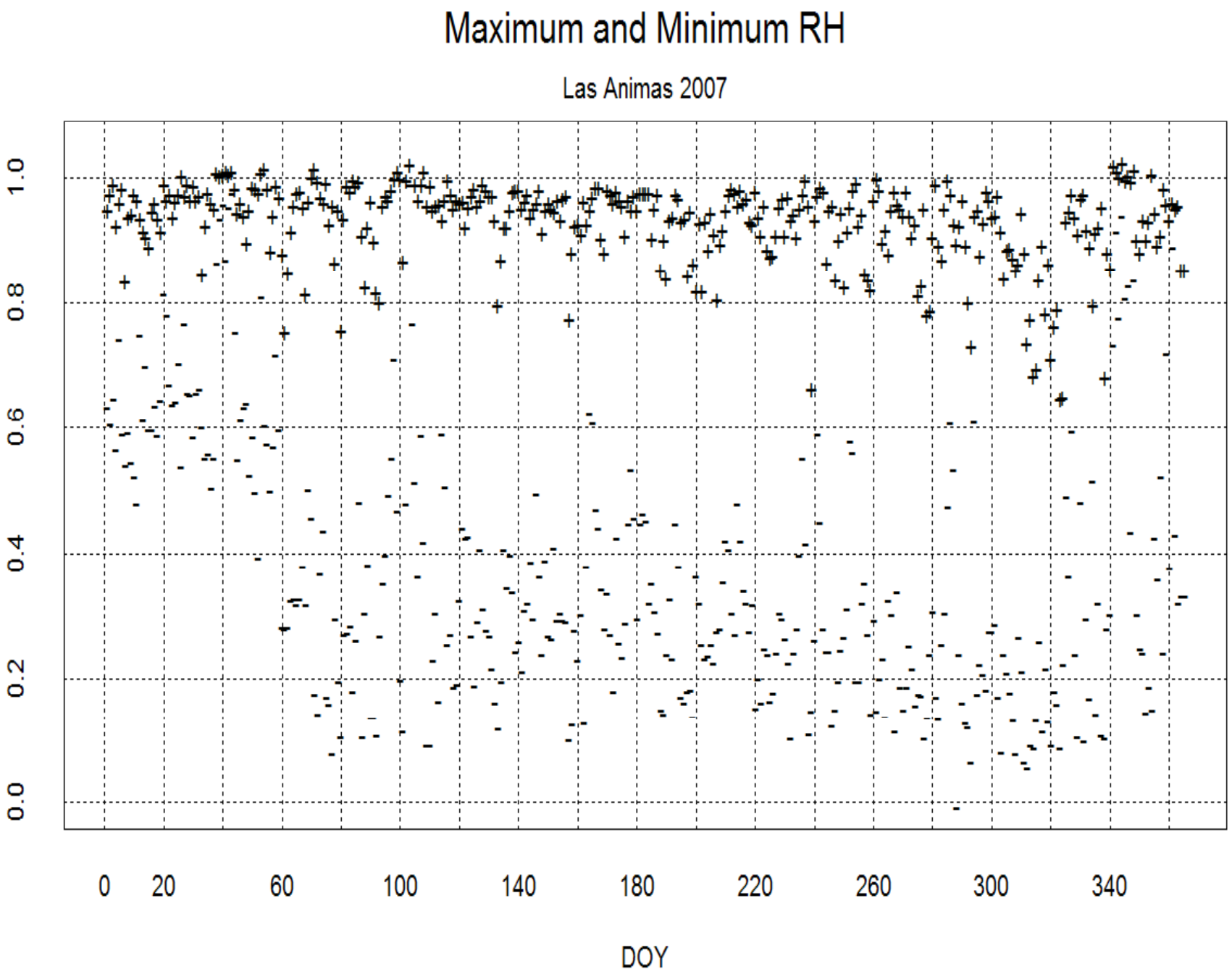
- Typically combined with air temp sensor
- Housed in naturally ventilated cotton region shelter or multiplate radiation shield
- Newer generation capacitance sensors are stable but require periodic recalibration
- ± 2% RH (0 to 90% RH)
- ± 3% RH (90 to 100% RH)

Dewpoint Temperature (T_{dew}) /Relative Humidity (RH)

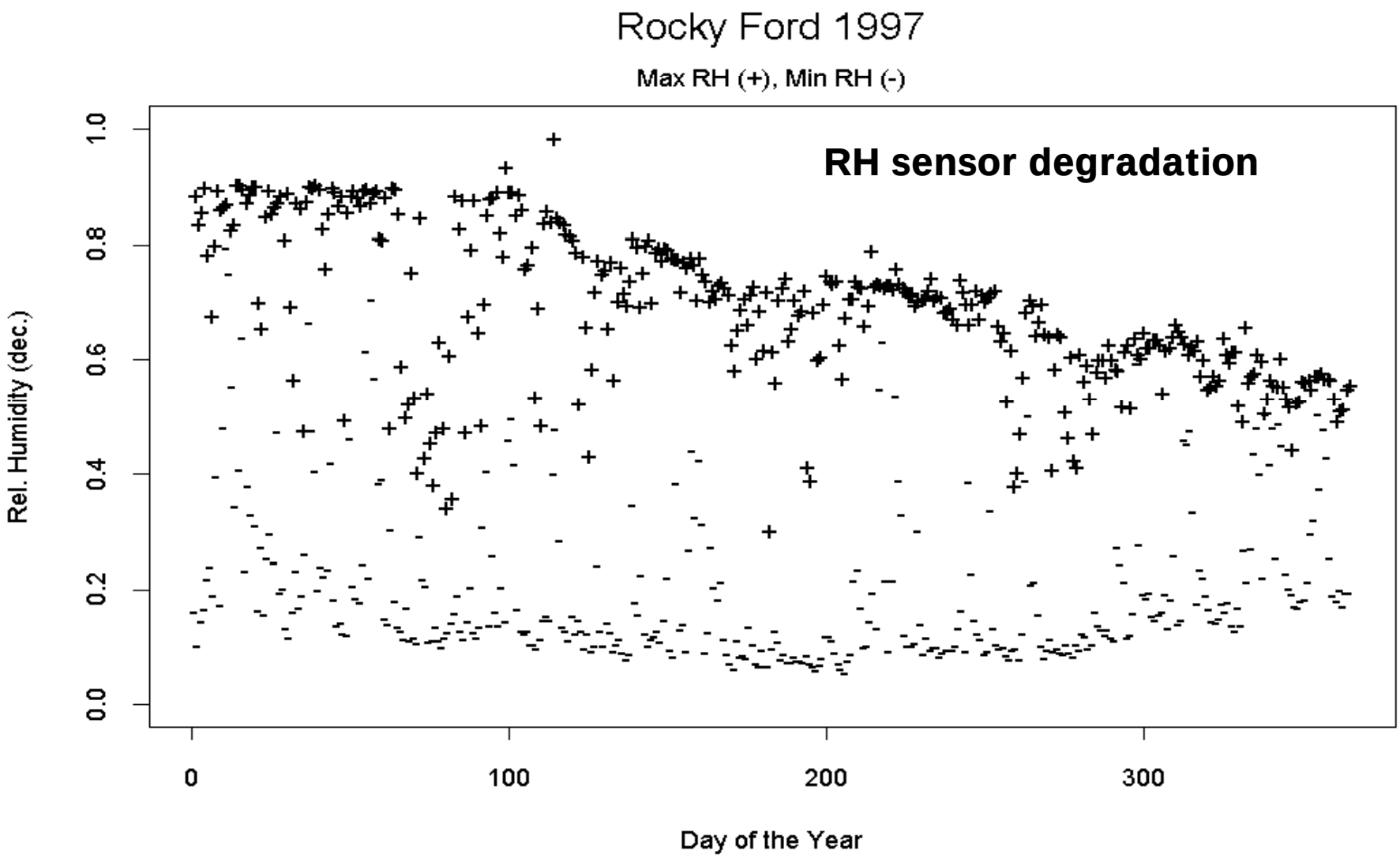
- Plot daily T_{min} versus daily T_{dew}
  - Actual vapor pressure of the air typically computed and logged with each measurement of air temp and RH
  - T_{dew} computed from vapor pressure
  - In a "reference" environment, T_{dew} should approach to within 2-5 °C below T_{min} in arid/semi-arid regions
- Plot daily max RH and min RH
  - Daily max RH:
    - reference environment ➔ 90-100%
    - Consistently in excess of 100%, correct all data when >102-103%
  - Daily min RH values less than 5-10% in arid climates

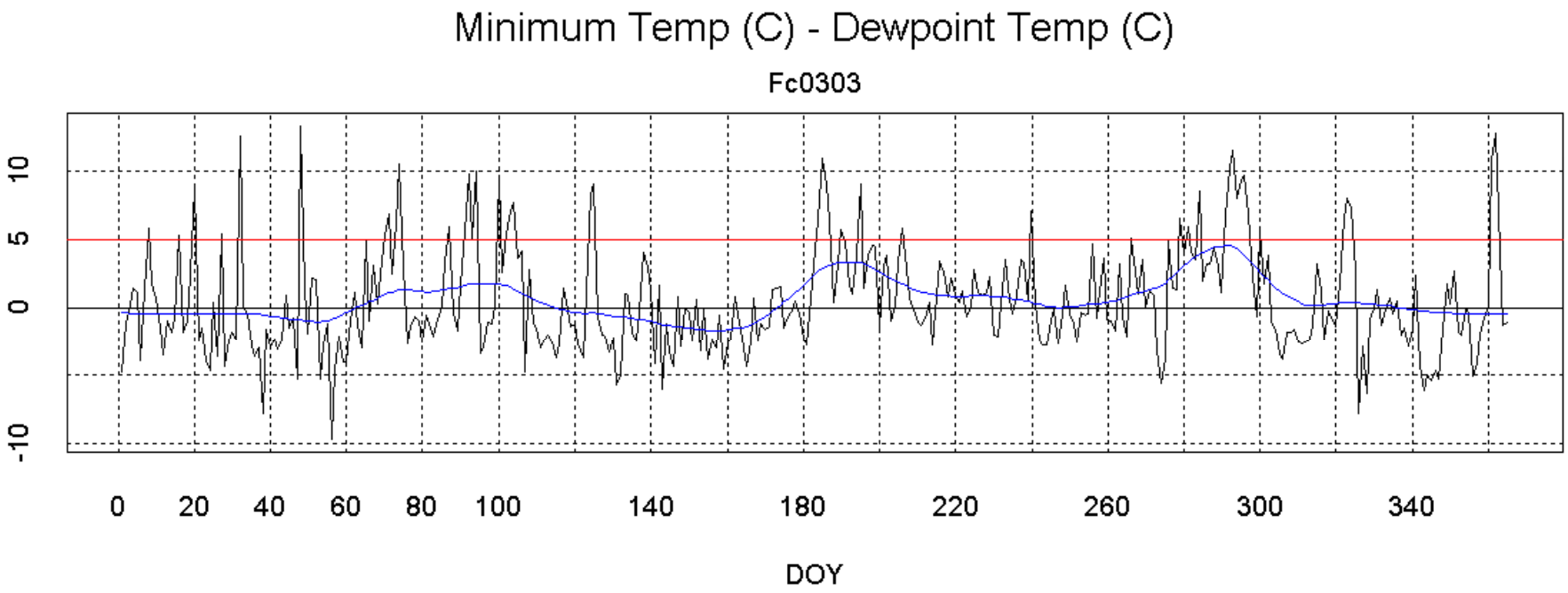
Comparison of T_{min} and T_{dew} at the Las Animas CoAgMet station during 2007. The small differences between the two data sets, particularly during the growing season, indicates this is a well-watered reference type environment



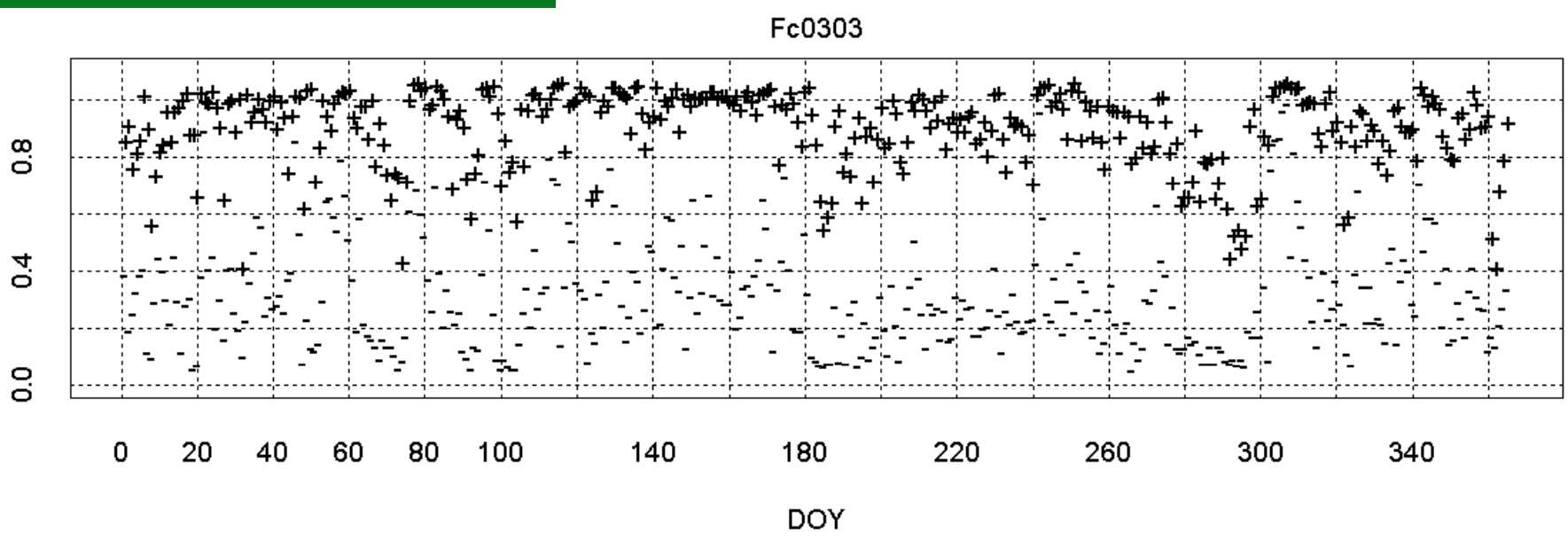

Maximum and Minimum RH
Las Animas 2007
1.0
0.8
0.6
0.4
0.2
0.0
0
20
60
100
140
180
220
260
300
340
DOY

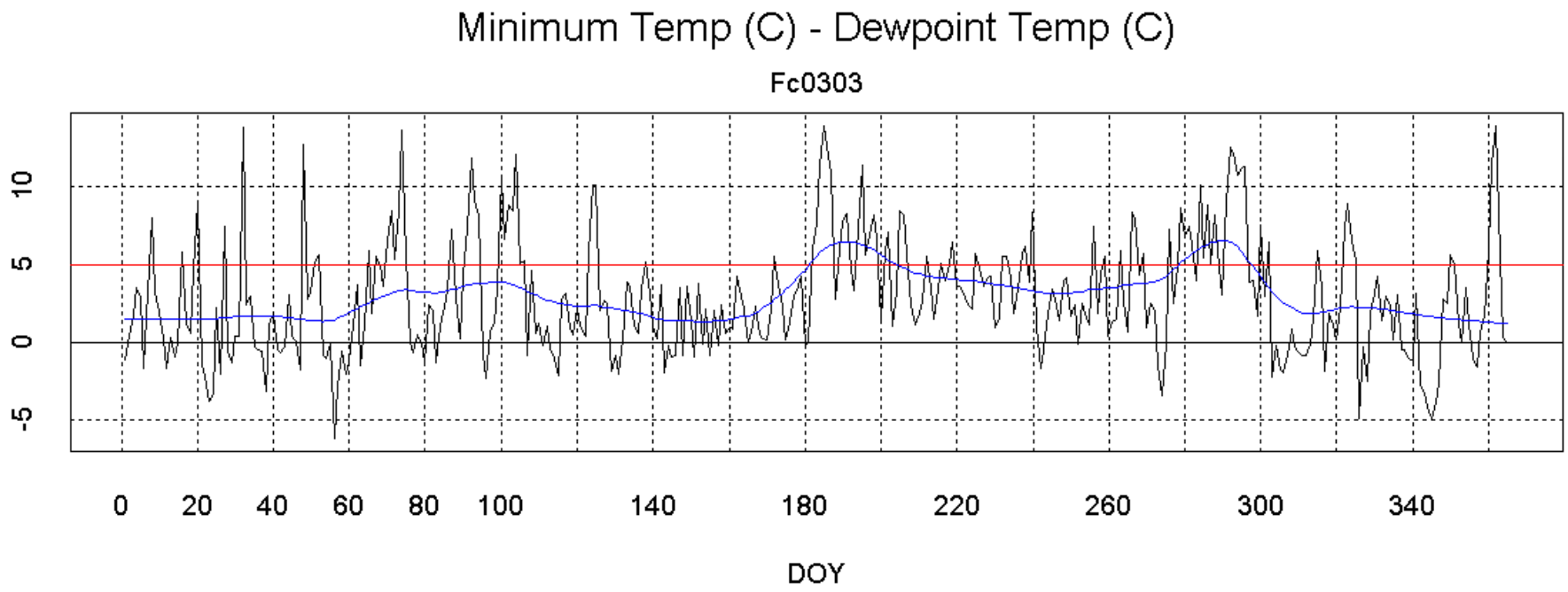
Used periods of good RH data to develop regression relationship of dewpoint temperature with daily minimum temperature. Then used regression to estimate dewpoint temperature during periods of poor RH sensor performance.



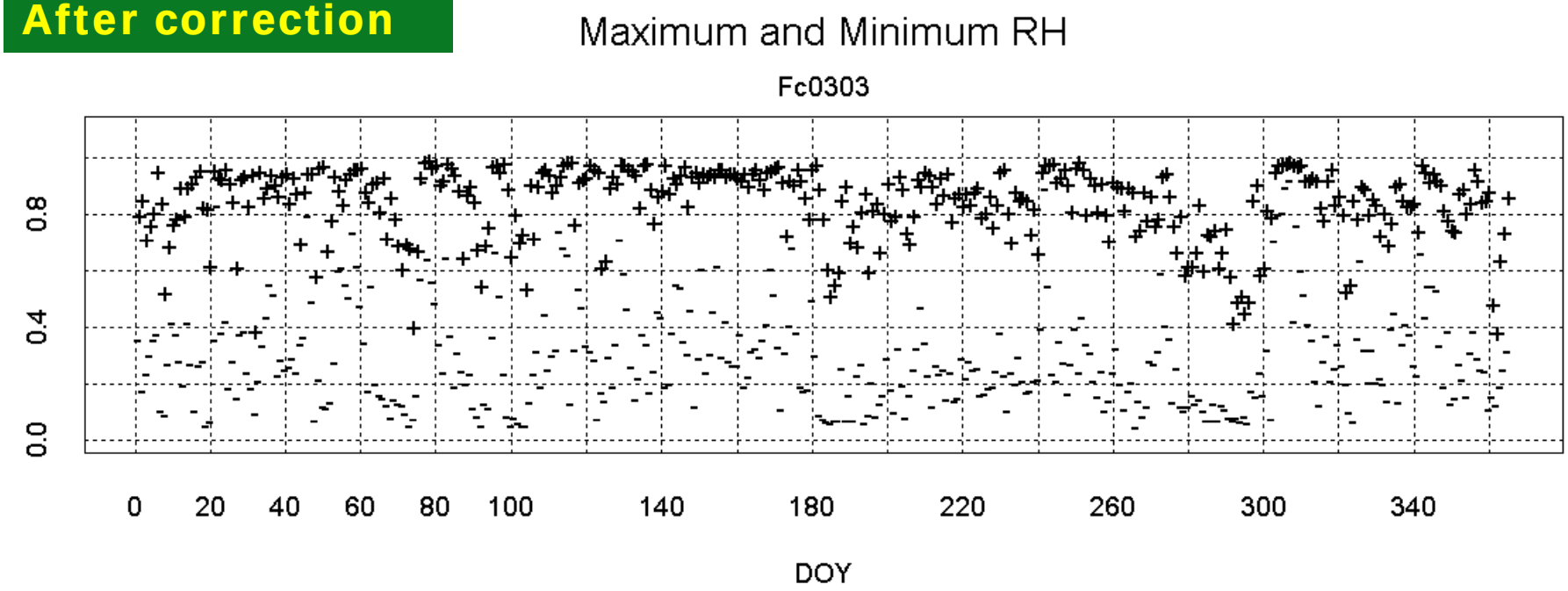


Many max RH > 103%





After correction



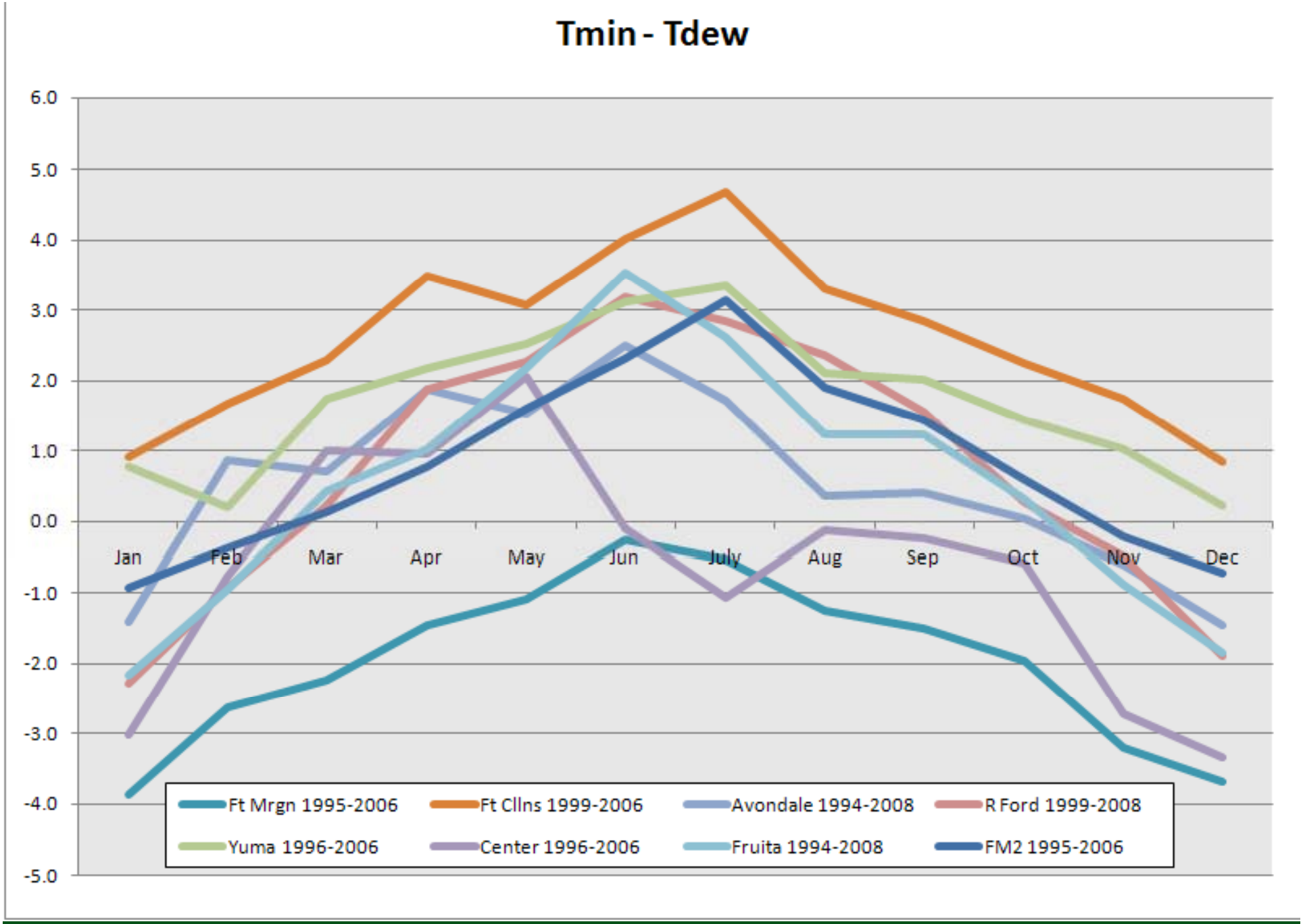
Non-Reference Site Conditions

- Adjustments to temp/RH data may be warranted
- Constrain dewpoint temperature:

$$T_{dew} = T_{min} - K_o$$

where K_o ~ 2 – 5 °C in dry climates, and
~ 0 °C in humid climates

- Compute K_o at known reference sites
- May overpredict T_{dew} and actual vapor pressure

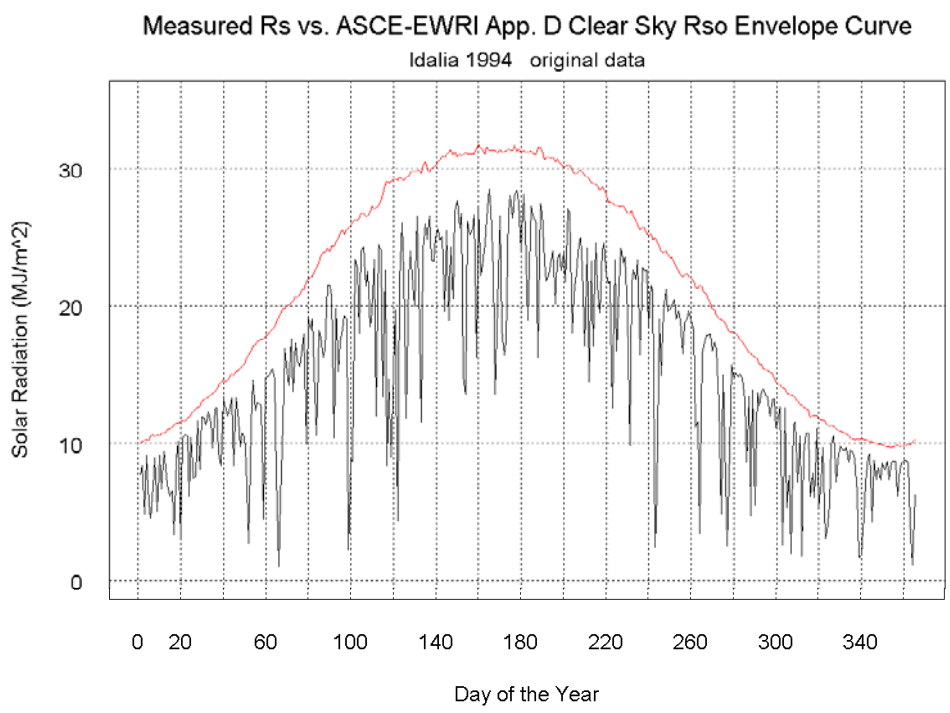

Tmin - Tdew
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
Jan
Feb
Mar
Apr
May
Jun
July
Aug
Sep
Oct
Nov
Dec
Ft Mrgn 1995-2006
Ft Cllns 1999-2006
Avondale 1994-2008
R Ford 1999-2008
Yuma 1996-2006
Center 1996-2006
Fruita 1994-2008
FM2 1995-2006

Solar Radiation

- Typical: silicon cell pyranometer
- Must be maintained level and installed high enough to avoid shading from other instruments
- Requires periodic cleaning
- Typical error: ± 3%
- Maximum: ± 5%

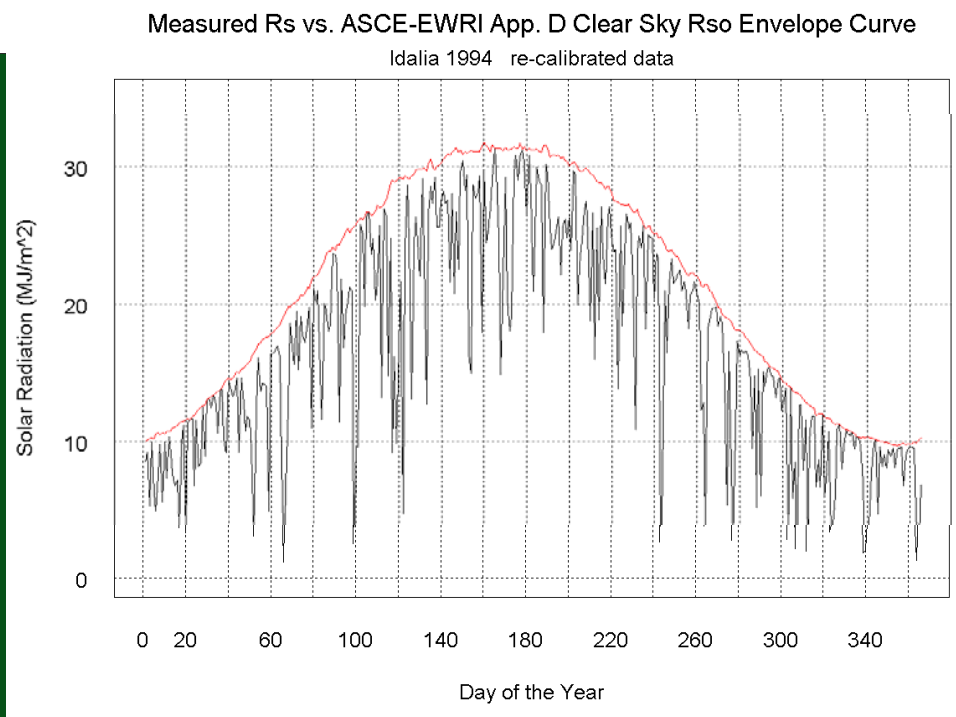
Solar Radiation

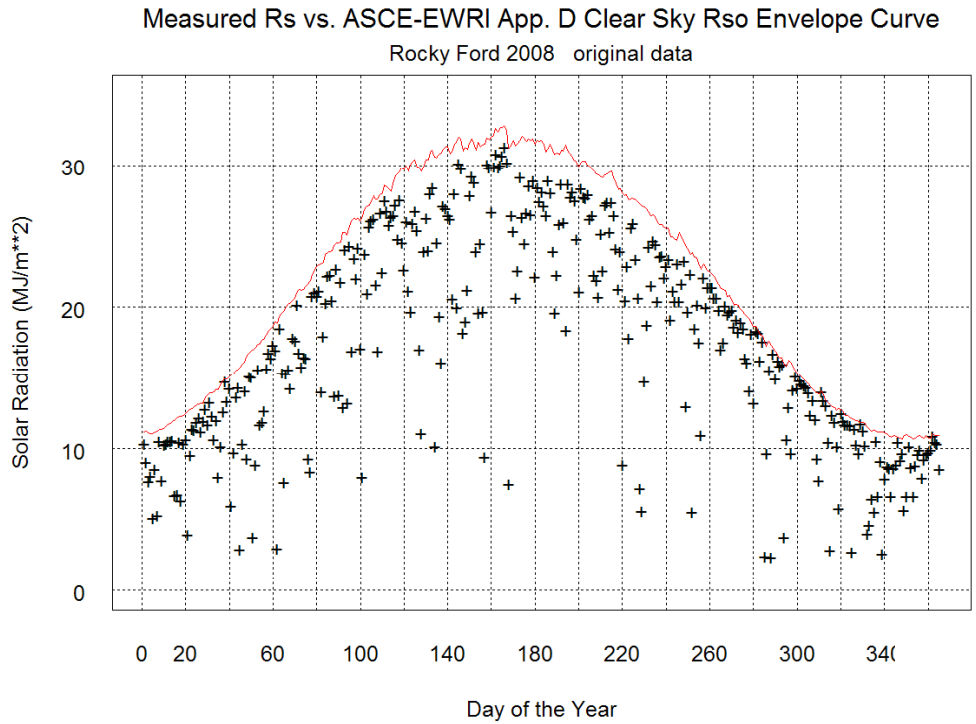
- Plot measured solar radiation against estimated “clear sky” solar radiation
- Clear sky solar radiation (App. D, ASCE-EWRI; 2005):
  - Sun angle
  - Atmospheric thickness
  - Atmospheric water vapor
  - Extra-terrestrial radiation (dependent on day of the year and latitude)
- Highest measured values (clear days) should “bump” up against clear sky envelope
  - If measured “upper” values routinely above or below the clear sky envelope by >3%, data should be adjusted



Original solar radiation data for Idalia site for 1994 plotted with ASCE-EWRI App. D clear sky solar radiation envelope

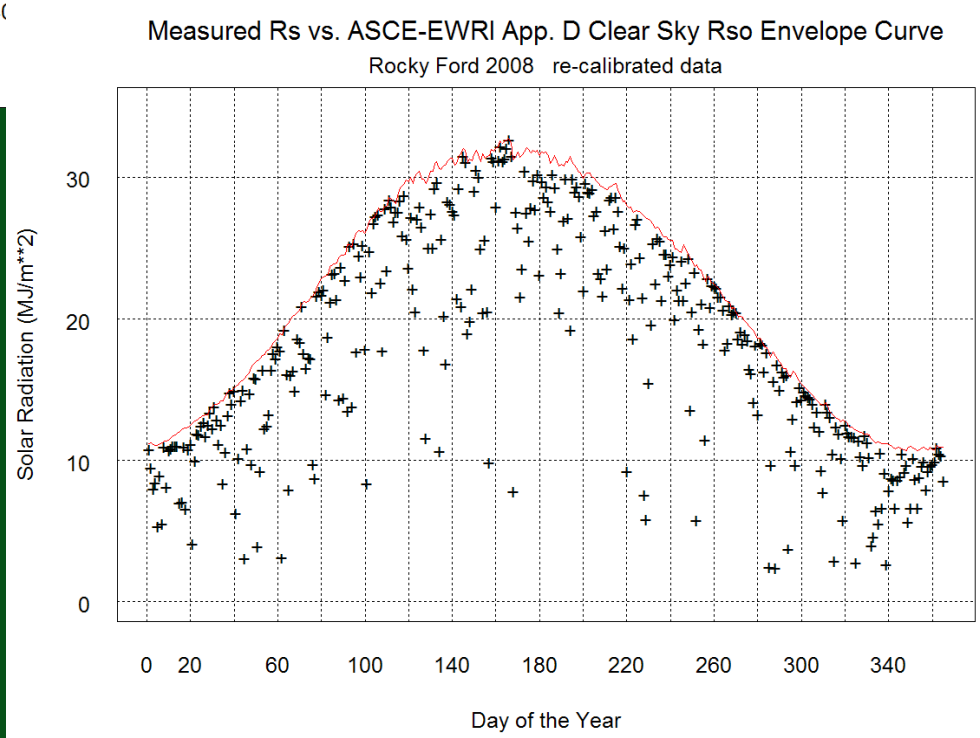
Re-calibrated solar radiation data for Idalia CoAgMet station for 1994; calibration factor of 1.10 applied entire year





Original solar radiation data for Rocky Ford CoAgMet station for 2008 plotted with ASCE-EWRI App. D clear sky solar radiation envelope

Re-calibrated solar radiation data for Rocky Ford CoAgMet station for 2008; calibration factor of 1.04 applied days 1-273



Wind Speed

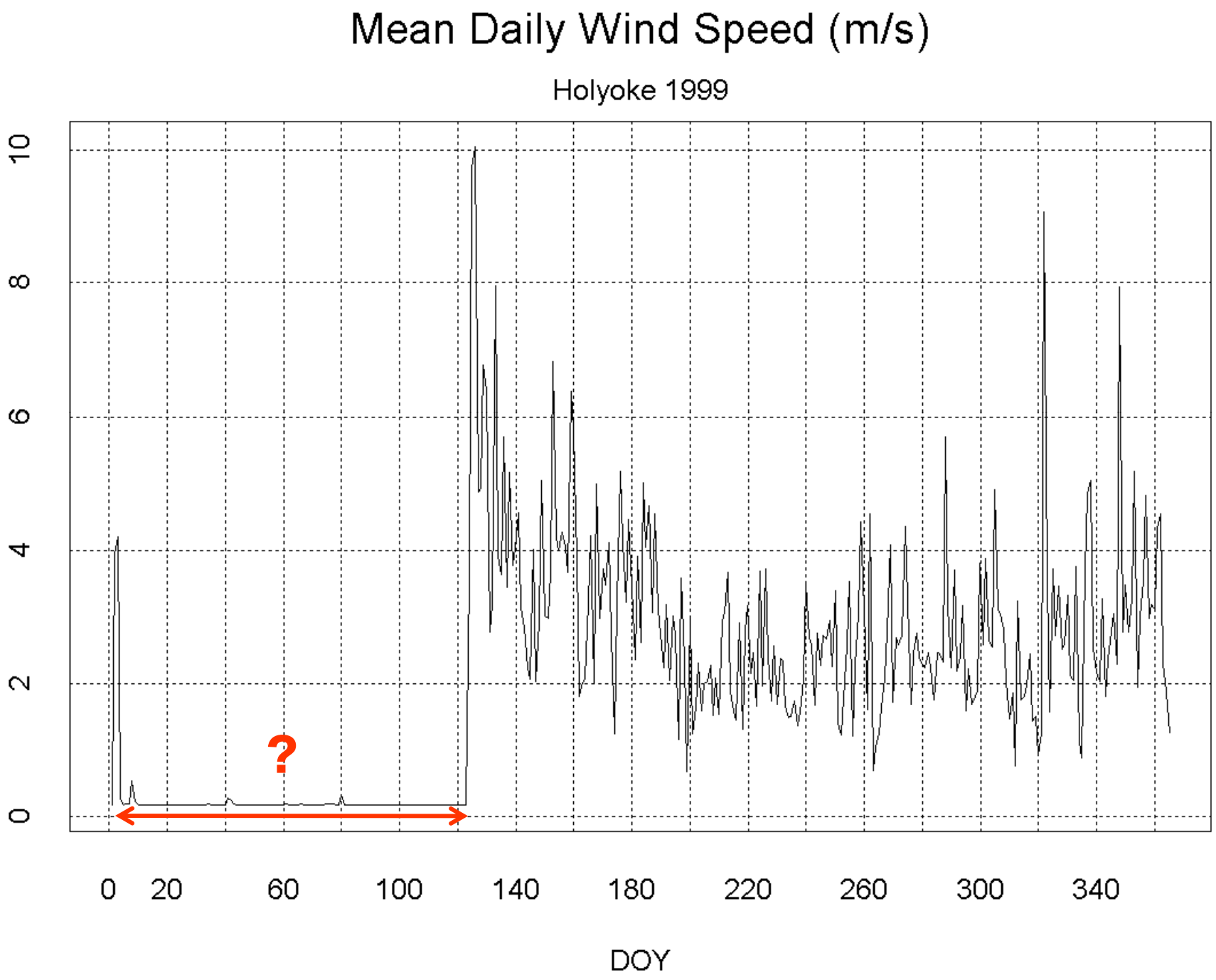
- Typical: rotating cup or propellor-type anemometer
- Switch closure; AC sine wave
- ± 0.1 m/s to ± 0.5 m/s accuracy
- Bearings fouling/fatigue
- Frequent (annual) replacement

Wind Speed

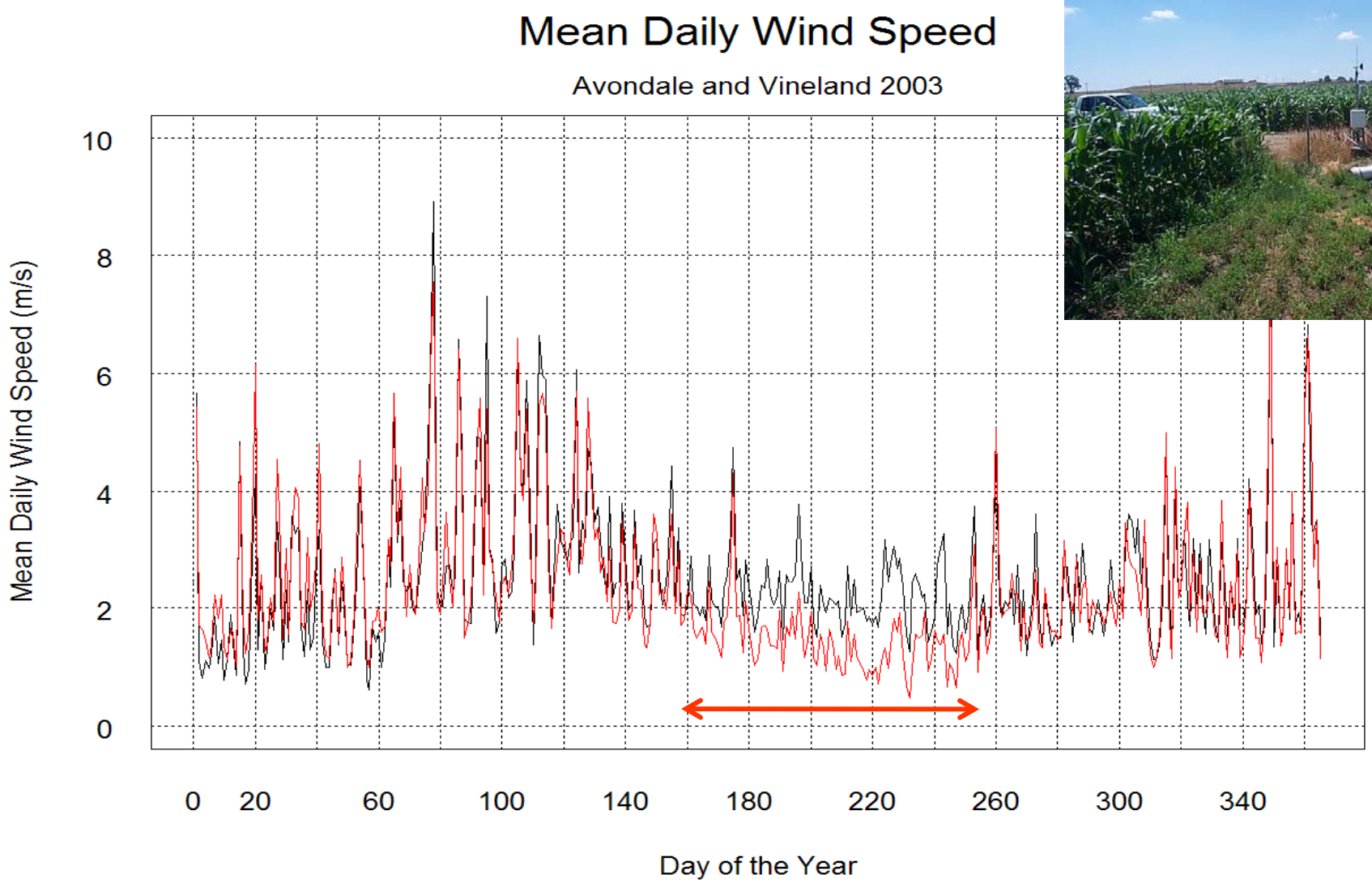
- Wind speed at 2 m height over and downwind of a smooth measurement surface such as well-watered, clipped grass
- Wind speed measured at other than 2 m height (but over specified smooth surface condition) can be adjusted to 2 m height using standard logarithmic wind speed profile theory

Wind Speed

- Difficult to assess without duplicate instruments
- Comparison to nearest neighbor sites can be effective when both are in large, open homogeneous regions
- Visually inspect for consistently low readings (i.e., anemometer threshold values)
  - indicates “frozen” bearings,
  - or, increased starting threshold due to dirty bearings


Mean Daily Wind Speed (m/s)
Holyoke 1999
0
2
4
6
8
10
?
0
20
60
100
140
180
220
260
300
340
DOY

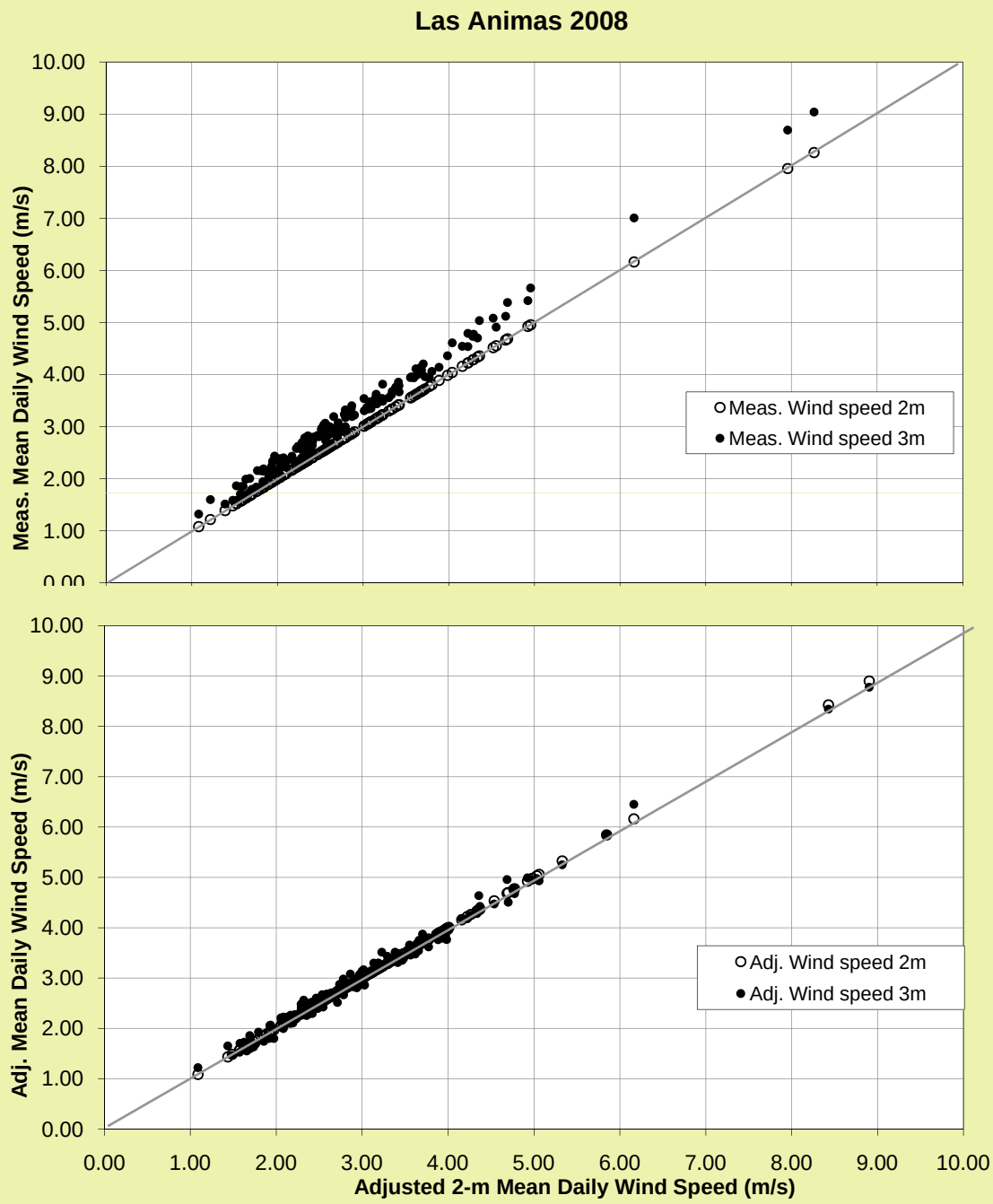
Comparison of Avondale (black) and Vineland (red) measured mean daily wind speeds during 2003. Sheltering of Vineland anemometer by nearby corn crop caused low mean daily wind speeds (~days 160 – 255)



- NCWCD and lower Arkansas Valley CoAgMet stations located in commercial alfalfa fields
- Wind speed measurement height
  - NCWCD: 3 m
  - CoAgMet: 2 m
- Alfalfa crop height > 30 cm
  - Creates more drag
  - Reduces wind speeds measured at 2 m height

Las Animas CoAgMet Station

- Wind speeds at 2 m and 3 m height
- Translation algorithm to compute equivalent wind speed at 2 m over grass
- Results indicate a "neutral" wind speed measurement height of about 2.70 to 2.75 m



Weather Data Assessment

- Weather station location and density
  - How many electronic weather stations
  - Where should they be located
  - To what spatial extent is a station representative
  - Highly dependent on:
    - Topography
    - Prevailing weather patterns, convective summer storms, season of the year
    - Geography (e.g., distance from front range) /land use
    - Time step (data applications)

Weather Station Location and Density

- EXAMPLE : Studies of established weather station networks. Station spacing required to maintain 90% spatial correlation in DAILY variables and ET
- High Plains AWDN (Hubbard, 1994); Northern CO (Harcum and Loftis, 1987); Central Washington (Ley, 1995); Southeastern Colorado (Hill and Ley, 2002)

Weather Station Location and Density

Variable (daily)	(mi)
Max air temp	60-120
Solar radiation	20-40
Min air temp, dewpoint, mean daily wind speed	10-30
Reference ET	20-40

High Plains AWDN (Hubbard, 1994); Northern CO (Harcum and Loftis, 1987); Central Washington (Ley, 1995); Southeastern Colorado (Hill and Ley, 2002)