Confused About Weather Station ET? Perhaps You Should Be

ET and crop coefficient data from various weather stations are not interchangeable.

by DR. PAUL W. BROWN

USE OF evapotranspiration (ET) data has been touted as the means by which golf course superintendents can refine and optimize irrigation management. Today, most superintendents in the Desert Southwest can access local ET data from a public weather network or their own on-site weather station. In many cases, ET from on-site weather stations is integrated into sophisticated computer software that directly controls daily course irrigation schedules. While the use of ET data often leads to improved irrigation management, better turf quality, and lower operating costs, widespread proliferation and use of ET derived from weather stations does pose some problems that need to be addressed to make this data more reliable and useful to superintendents. The focus of this article will be on an important but rarely discussed problem: the procedure used by the weather station or its attendant software to compute ET. We begin with an exploration of the problem, then summarize results of a recently completed study designed to provide solutions to the problem.

Misconceptions About ET

A common misconception among many in the turf industry is that a weather station actually measures turf ET. This is not the case. Weather stations monitor meteorological variables that impact turf ET, including solar radiation, wind speed, humidity, and temperature. The resulting weather data are then input into meteorological models that estimate *reference evapotranspiration*, which is commonly abbreviated ETo. ETo is defined as the water lost from a well-irrigated, tall (3-6"), cool-season grass (ryegrass or fescue) by the combined processes of transpiration and soil evaporation. Factors ranging from turf species to mowing height cause the ET from golf turf to differ from that of ETo. For example, a bermudagrass fairway turf maintained at a height of ½" would likely use less water than the much taller cool-season reference grass that supports a higher leaf area and interacts more readily with wind. We commonly employ a simple multiplicative adjustment factor known as the crop coefficient (Kc) to adjust or convert ETo to actual turf ET (ETa):

$$ETa = Kc \times ETo \quad \text{(Equation 1)}$$

The key to optimizing the use of weather stations on a golf course is the selection of appropriate crop coefficients. Crop coefficients often differ for tees, greens, fairways, and roughs; therefore, availability of the appropriate Kc is required to tailor irrigation for each type of turf. Crop coefficients are usually developed in controlled research studies where actual turf water use (ETa) is compared with values of ETo computed from meteorological parameters. Rearrangement of Equation 1 provides the mathematical basis for developing Kcs, and reveals that Kcs are dependent on *both* the measured value of turf water use (ETa) and the computed value of ETo:

$$KC = ETa/ETo \quad \text{(Equation 2)}$$

It is at this point where the problems and confusion develop with use of ETo derived from weather stations. The procedure for computing ETo is not standardized. While there are two general models used to estimate ETo — the modified Penman Equation and the Penman-Montieth Equation — the scientific community has developed and recommended numerous modifications to each general model to provide *better fits* to local data sets or local environmental conditions. Unfortunately, this scientific refinement has led to the publication of numerous procedures for estimating ETo, many of which generate different values of ETo when supplied with the same meteorological data.

The ETo computation problem is depicted in Figure 1, where data from a single meteorological station were used to compute ETo using modified Penman Equations employed by the public weather networks in Arizona (2), California (5), and New Mexico (4). Our experience with the ETo procedures provided by private vendors of

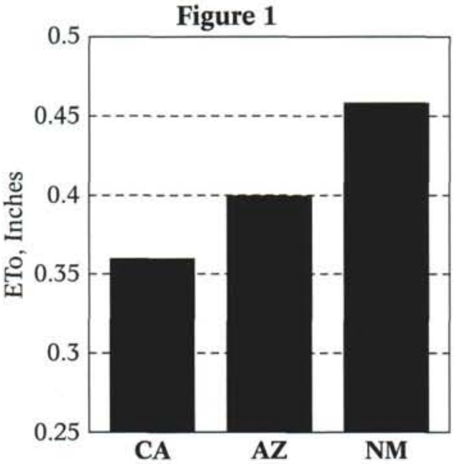
Weighing lysimeters are accurate to within 0.01" per day in measuring actual water use of the turfgrass (ETa) maintained under fairway management conditions.

weather stations and irrigation management software suggests ETo computation also is a problem with weather stations provided by the private sector.

ET Computation

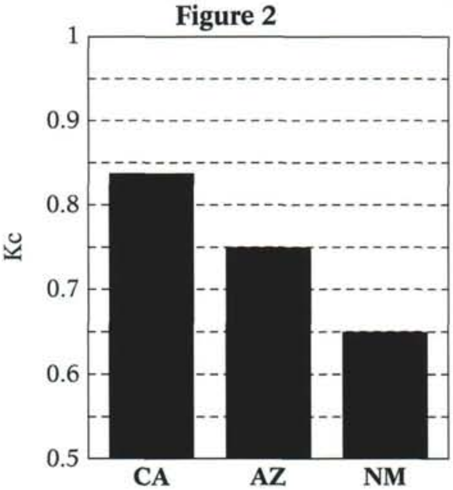
While the ETo computational problem may seem trivial or academic to some, the problem does generate negative consequences on at least two fronts. The most imporant consequence is practical in nature and relates to our ability to effectively transfer and use Kcs developed in regional research studies. Suppose, for example, that on

Figure 1



Reference evapotranspiration (ETo) for 19 June 1996 at Tucson, Arizona, computed using the modified Penman Equations used by CIMIS (CA), AZMET (AZ), and New Mexico Climate Center (NM).

Figure 2



Bermudagrass crop coefficients (Kcs) developed for 19 June 1996 at Tucson, Arizona, using lysimeter measurements of actual water use and ETo values computed using the modified Penman Equations used by CIMIS (CA), AZMET (AZ), and New Mexico Climate Center (NM).

the day depicted in Figure 1, Arizona researchers also measured an actual turf water use (ETa) of 0.30". From Equation 2, the crop coefficient appropriate for the Arizona procedure would be 0.30"/0.40" or 0.75. However, if a golf course in New Mexico takes the Kc of 0.75 and applies it to the ETo available from the New Mexico Climate Center, one would seriously overestimate fairway water use. The appropriate Kc for New Mexico needs to take into account their ETo procedure and thus would be 0.30"/0.46" or 0.65.

The bottom line on Kcs: they must be paired with the ETo procedure utilized during their development. We feel that much of the bad press given to Kcs results from the failure to recognize the need to adjust/modify Kcs for the method of ETo computation.

A second negative consequence of differing procedures for estimating ETo rests in the realm of regulation. Governmental agencies charged with regulating water use are beginning to use ETo as a means of assessing and regulating water use and allocation, especially in water-short regions such as the Desert Southwest. If in the future water allocations to golf courses are set based on ETo and Kcs, then it will be in everyone's interest that the problems and procedures required to deal with the ETo computation problem be resolved in a sound, scientific manner. Failure to do so will produce additional and unnecessary legal and political wrangling over the issue of golf course water requirements.

Solutions on the Horizon

At this point we have only addressed the problem of ETo computation, not the solutions. Fortunately, solutions to the problem are beginning to emerge. An obvious solution would be to develop a standard procedure for computing ETo. The scientific community is presently moving forward with such a proposal that would utilize a standard form of the Penman-Montieth Equation to estimate ETo (1). Development of a standard procedure should minimize future problems with ETo computation, provided both the scientific community and the commercial suppliers of weather stations and irrigation management software accept the procedure. However, in the interim, we need some means of interpreting and normalizing the numerous ETo procedures in existence at this time so superintendents and the regulatory

On-site weather stations are often integrated with computer software that can automatically adjust operating times of irrigation sprinklers.

community can make better use of ETo data.

A research study presently underway at the University of Arizona Karsten Desert Turf Facility is focused on providing this needed interim assistance to golf courses that utilize ETo data from public or private weather stations. Two large weighing lysimeters, each planted to Tifway bermudagrass and maintained in accordance with fairway standards, provide daily values of ETa.

The lysimeters are overseeded in October with an intermediate ryegrass that serves as the winter turf surface. Automated weather stations are located adjacent to the lysimeter facility and provide the necessary meteorological data for computation of ETo.

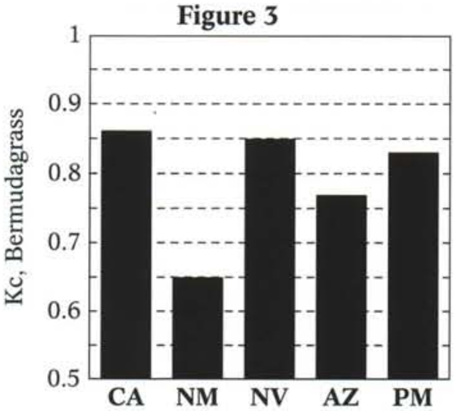
Appropriate crop coefficients have been developed for ETo procedures used by the California Irrigation Management Information System (CIMIS) (5), the Arizona Meteorological Network (AZMET) (2), the New Mexico Climate Center (4), and the ET Feedback System used in Las Vegas (3) during the early 1990s. A fifth procedure for computing ETo, a version of the Penman-Montieth Equation recommended as an international standard, also is included in the study. Results from this study clearly drive home the point that crop coefficients must be matched to the ETo computation procedure.

Figure 3 presents the appropriate seasonal crop coefficients for bermudagrass fairways during the summer months of May through September for each of the five aforementioned methods of computing ETo. It is important to remember that the turf water use data used to compute the Kc and the weather data used to compute ETo are the same for all five methods presented in Figure 3. The variation in seasonal Kc is totally a function of the procedure used to compute ETo.

Figure 4 presents a similar picture for winter Kcs when the bermudagrass is overseeded with ryegrass. The data in Figures 3 and 4 show the danger of using a Kc provided by another scientist or superintendent without first identifying the ETo procedure that was used to produce the Kcs. In the extreme case presented in Figure 3, if a Kc appropriate for New Mexico's ETo were used in California with CIMIS ETo, we should expect significant under-irrigation to result. In contrast, if one applies the Kc appropriate for California to ETo in New Mexico, one would likely over-irrigate the turf by nearly 30%.

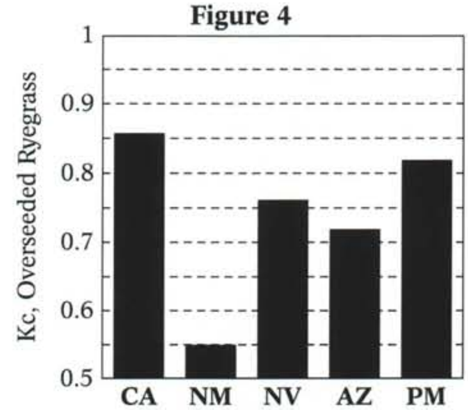
The Arizona study also is working to find a solution for superintendents who operate their own weather stations. The large number of commercial suppliers of weather stations/irrigation management software and a reluctance on the part of some suppliers to release trade secrets precluded us from directly developing Kc values and correction factors for commercial equipment. Instead, we chose to develop a data set

Figure 3



Seasonal bermudagrass crop coefficients (Kcs) developed for five regional procedures used to estimate ETo. CA: California (CIMIS), NM: New Mexico, NV: Nevada (ET Feedback), AZ: Arizona (AZMET), PM: Penman-Montieth.

Figure 4



Seasonal crop coefficients (Kcs) for overseeded ryegrass developed for five regional procedures used to estimate ETo. CA: California (CIMIS), NM: New Mexico, NV: Nevada (ET Feedback), AZ: Arizona (AZMET), PM: Penman-Montieth.

that contains both weather data and actual values of turf ET. This data set is presently being finalized for publication and release via the University of Arizona and the USGA. The availability of such a data set allows the manufacturers of weather stations and/or irrigation management software to 1) compare their ETo computations with those procedures evaluated in the Arizona study, and 2) develop Kc values for a common fairway turf system in the Desert Southwest. We anticipate that many of the commercial suppliers of weather stations and irrigation management software will utilize this data set to provide Kcs and ETo translation factors for existing owners of their products.

The concept of basing irrigations on ETo values derived from automatic weather stations is a proven technology. The problems associated with computation of ETo add to the difficulty of using and improving ET-based irrigation management systems; however, future efforts to standardize the computation of ETo should help eliminate this problem in the future. We encourage the turf industry to seriously consider adopting a standard ETo procedure to facilitate effective use of regional research on turf water management and to minimize potential problems with the regulatory community. We also suggest that future studies aimed at developing Kcs collect and provide access to meteorological data required for computation of ETo so public weather networks and commercial suppliers of irrigation management equipment can develop Kcs appropriate for their procedures of computing ETo. Simply using the Arizona data set will not provide Kcs appropriate for many temperate or humid regions, and using arid region climate data to compare ETo methods in humid regions may not provide legitimate translation factors.

References

Allen, R. G., M. Smith, L. S. Pereira, and A. Perrier. 1994. An update on the calculation of reference evapotranspiration. ICID Bulletin 43(2):35-92.

Brown, P. W. 1998. AZMET computation of reference crop evapotranspiration. AZMET Web Page: http://ag.arizona.edu/asmet.html.

Devitt, D. A., R. L. Morris, and D. C. Bowman. 1992. Evapotranspiration, crop coefficients, and leaching fractions of irrigated desert turfgrass systems. Agron. J. 84:717-723.

Sammis, T. 1996. Penman's Equation referenced to grass. New Mexico Climate Center Website: http://weather.nmsu.edu/math/penmans.html. New Mexico St. Univ.

Snyder, R., and W. Pruitt. 1985. Estimating reference evapotranspiration with hourly data. California Irrigation Management Information System Final Report. R. Snyder et al. (eds.). Land, Air, and Water Resources Papers 10013-A, Univ. of California-Davis. Chpt. VII:1-3.

DR. PAUL BROWN *is the Extension Biometeorologist at the University of Arizona. He oversees the operation of the Arizona Meteorological Network (AZMET), a public weather network that supplies weather information to turf managers and agricultural producers located in southern Arizona. He has been actively involved in efforts to assess the water requirements of desert turfgrasses for the past five years.*