Irrigation Scheduling Using the Oklahoma Mesonet

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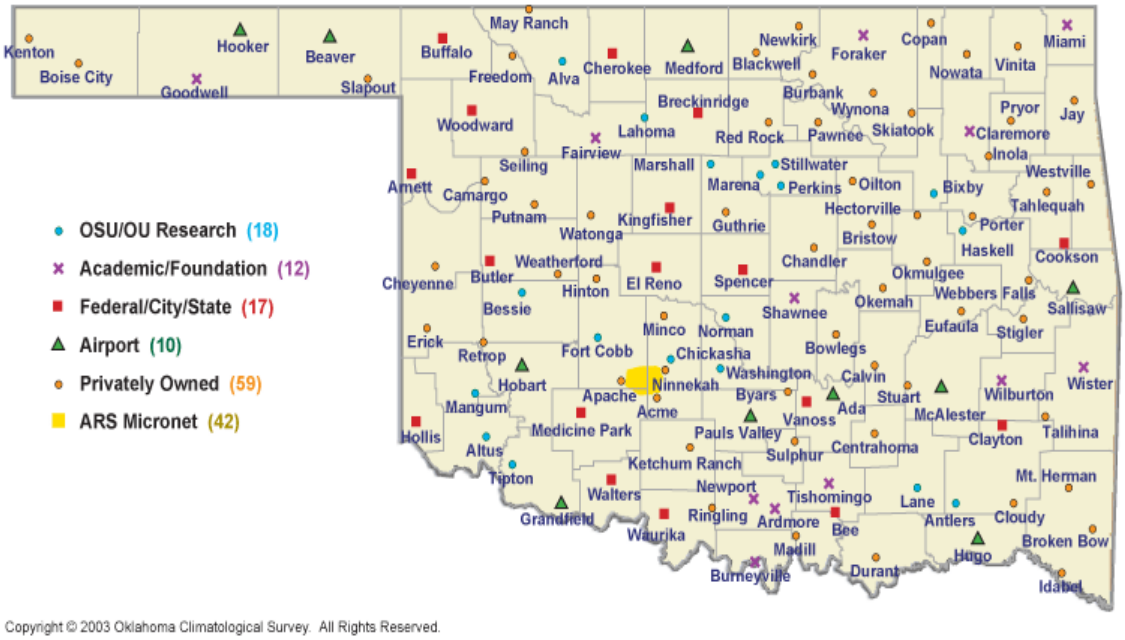
Evapotranspiration estimates are one of the value-added weather products available on the Oklahoma Mesonet agricultural website (http://agweather.mesonet.org/). Daily reference evapotranspiration estimates from the Penman-Monteith equation are posted for irrigation managers who use water balance scheduling methods. Daily evapotranspiration estimates calculated using crop coefficients based on user-supplied planting dates and maturity periods for the major crops of Oklahoma are posted to pages dedicated specifically to that crop. Daily and cumulative water use for major crops are reported in a tabular output which allow agricultural producers and homeowners to estimate water use by crops and turf grass for periods from one day to several days. The Oklahoma Mesonet is a network of 117 automated weather stations that cover all 77 counties in Oklahoma with an average station spacing of 30 km. Data are beamed by radio to a central processing site every 5 minutes, error-checked and posted on the Mesonet website.

Introduction

The Oklahoma Mesonet is a statewide network of 117 automated weather stations that has been operational since 1994 (Brock et. al., 1995). The network is a cooperative effort between the University of Oklahoma and Oklahoma State University. The stations have an average spacing of 30 km and are distributed throughout all 77 counties of Oklahoma. (Figure 1.)

Figure 1. Distribution of Mesonet weather stations in 2003.



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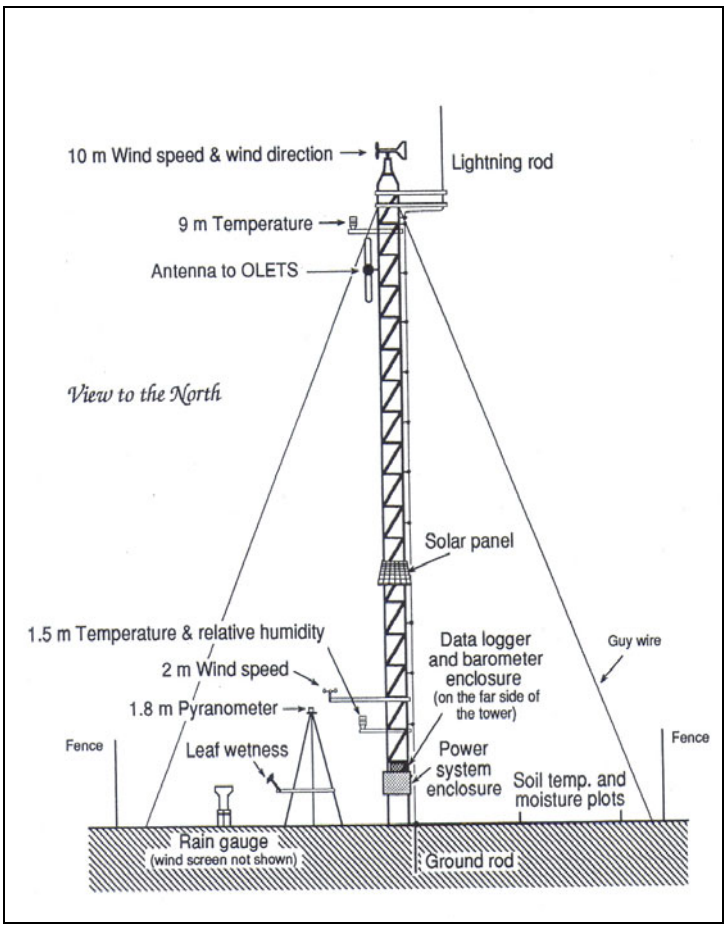
The Mesonet stations collect a wide array of weather data for meteorological, environmental and agricultural research, as well as for public safety purposes (Elliott, et. al., 1994). The data are collected every 15 seconds for a 5-minute period. The 5-minute averages are then sent by radio to the nearest Oklahoma Law Enforcement Telecommunication Service (OLETS) station and then relayed to the Mesonet central computer in Norman, OK. (Figure 2)

Figure 2. Mesonet station configuration and measured parameters.



Weather Parameters Measured

Core Parameters
(measured at all sites)

- Solar Radiation
- Air Temperature (1.5 m)
- Relative Humidity (1.5 m)
- Wind Speed (10 m)
- Wind Direction (10 m)
- Rainfall
- Barometric Pressure
- Soil Temperature (10 cm bare)
- Soil Temperature (10 cm grass)

Supplemental Parameters
(measured at about half of the sites)

- Air Temperature (9 m)
- Wind Speed (2 m)
- Soil Moisture
- Soil Temperature (5 cm bare)
- Soil Temperature (5 cm grass)
- Soil Temperature (30 cm grass)

The raw data are analyzed for quality assurance and processed into a variety of end products. The raw data and end products are posted to a number of Mesonet websites within 10 minutes of collection in most cases. Some of the data are available on websites which require a user's fee, while others are free to the general public.

Agweather Page
The Agweather webpage (http://agweather.mesonet.org) is a public webpage which houses a wide variety of agriculture-related weather information available through Mesonet. The weather data and products on the Agweather webpage are organized in seven general categories: Weather, Soils, Livestock, Rangeland, Crops, Horticulture, Forestry. Users can find an array of weather related information and products related to each category on the appropriate sub-page.

On the Weather page raw data, summaries and end products for the current measurement period can be viewed. One of the end products available is Standardized Reference Evapotranspiration (ET_{sz}).

Reference Evapotranspiration

The Standardized Reference Evapotranspiration (ET_{sz}) calculation used on Mesonet webpages follows the recommendation of the Standardization of Reference Evapotranspiration Task Committee of the Environmental and Water Resources Institute of the American Society of Civil Engineers (ASCE) in their final report of July 9, 2002. A complete explanation of the computation process is viewable on-line by clicking on the information button (? INFO) in the upper right-hand corner of the appropriate webpages. Both short (ET_{os}) and tall (ET_{rs}) crop reference values are available for use in computer-based irrigation scheduling programs. These reference ET values, plus many of the weather-dependent intermediate variables used to compute them, are available on the reference ET webpage (Figure 3).

Figure 3. Reference ET page for a single Mesonet station.

Seasonal Evapotranspiration Data Back to Map

This season's evapotranspiration data for **Goodwell** through **2005-07-11**

DATE: Date
STNM: Station Number
STID: Station ID
LAT: Station Latitude [deg]
LON: Station Longitude [deg]
ELEV: Station Elevation [m]
ETOS: Reference ET, Short [in]
ETRS: Reference ET, Tall [in]
ETCOOL: Cool Season Grass ET [in]
ETWARM: Warm Season Grass ET [in]
PANEVAP: Pan Evaporation [in]
TMAX: Maximum Temperature [F]
TMIN: Minimum Temperature [F]
RHMAX: Maximum Relative Humidity [pct]
RHMIN: Minimum Relative Humidity [pct]
RAIN24: 24-Hour Rainfall [in.]
RSOL24: 24-Hour Incident Solar Radiation [MJ/m2]
RSO: Clear Sky Solar Radiation [MJ/m2]
RA: Top of Atmosphere Radiation [MJ/m2]
TDEW24: 24-Hour Average Dew Point Temperature [C]
TAVG: 24-Hour Average Temperature [F]
RHAVG: 24-Hour Average Relative Humidity [pct]
WS2AVG: 24-Hour Average Wind Speed at 2m [m/s]
PAVG: 24 Hour Average Station Pressure [kPa]
RNET: 24-Hour Net Radiation [MJ/m2]
G: Soil Heat Flux [MJ/m2]
VPD: Avg Vapor Deficit [kPa]
DELTA: Slope of Vapor Pressure Curve [kPa/C]
GAMMA: Psychometric Constant [kPa/C]
KP: Pan Evaporation multiplier

DATE	STNM	STID	LAT	LON	ELEV	ETOS	ETRS	ETCOOL	ETWARM	PANEVAP	TMAX	TMIN	RHMAX	RHMIN	RAIN24	RSOL24	RSO	RA	TDEW24	TAVG	RHAVG	WS2AVG	PAVG	RNET	G	VPD	DELTA	GAMMA	KP
2005-07-11	37	GOOD	36.60	-101.60	996	0.27	0.37	0.25	0.17	0.30	90	64	84	36	0.00	24.94	30.32	41.10	15.52	77.04	58.58	3.72	90.19	14.65	0.00	1.66	0.19	0.0600	0.7249
2005-07-10	37	GOOD	36.60	-101.60	996	0.35	0.49	0.32	0.21	0.52	94	62	91	29	0.00	28.42	30.36	41.16	15.04	77.90	54.44	5.60	90.01	16.26	0.00	1.93	0.19	0.0599	0.6617
2005-07-09	37	GOOD	36.60	-101.60	996	0.32	0.45	0.30	0.20	0.47	92	68	89	31	0.00	26.57	30.40	41.22	16.95	80.23	59.86	5.22	90.14	15.66	0.00	1.82	0.21	0.0599	0.6849
2005-07-08	37	GOOD	36.60	-101.60	996	0.29	0.38	0.27	0.18	0.39	94	60	96	29	0.00	27.98	30.44	41.27	16.61	76.94	64.13	3.55	90.27	16.43	0.00	1.71	0.19	0.0600	0.7418
2005-07-07	37	GOOD	36.60	-101.60	996	0.30	0.40	0.30	0.20	0.40	92	62	93	27	0.00	28.04	30.48	41.32	14.32	76.57	56.06	5.04	90.14	16.41	0.00	1.82	0.19	0.0599	0.6836
2005-07-06	37	GOOD	36.60	-101.60	996	0.27	0.36	0.25	0.17	0.36	90	59	96	32	0.00	26.37	30.51	41.37	15.39	74.52	69.30	3.65	90.27	15.46	0.00	1.51	0.18	0.0600	0.7489
2005-07-05	37	GOOD	36.60	-101.60	996	0.22	0.30	0.20	0.14	0.30	84	58	97	34	0.79	20.75	30.55	41.42	14.72	70.84	70.13	4.16	90.58	12.64	0.00	1.13	0.16	0.0602	0.7357
2005-07-04	37	GOOD	36.60	-101.60	996	0.24	0.30	0.22	0.15	0.31	86	56	96	39	0.00	27.28	30.58	41.46	14.96	71.26	65.24	2.88	90.27	16.00	0.00	1.20	0.16	0.0600	0.7630
2005-07-03	37	GOOD	36.60	-101.60	996	0.39	0.56	0.36	0.24	0.50	100	65	96	10	0.00	29.79	30.61	41.50	14.00	82.31	49.55	4.06	89.54	16.11	0.00	2.60	0.22	0.0595	0.6700
2005-07-02	37	GOOD	36.60	-101.60	996	0.33	0.46	0.31	0.21	0.48	94	59	96	29	0.53	29.72	30.63	41.53	15.44	76.74	62.41	4.94	89.95	17.11	0.00	1.84	0.19	0.0598	0.6083
2005-07-01	37	GOOD	36.60	-101.60	996	0.27	0.36	0.25	0.17	0.36	91	58	96	26	0.07	26.09	30.66	41.57	15.15	74.81	64.38	3.51	90.15	15.31	0.00	1.58	0.18	0.0600	0.7433

The authors have developed a PC-based checkbook irrigation scheduling program that interfaces with the Mesonet webpage and automatically downloads daily reference ET. That information is combined with a basal crop coefficient(K_{cb}), a soil water availability coefficient (K_a), and a soil surface wetness coefficient (K_s), which are all stored in a field-specific file that keeps the most recent soil water conditions of the crop root zone, to provide a crop ET estimate corrected for specific soil water conditions.

Many horticultural producers in the state have traditionally used scheduling programs based on pan evaporation. To assist these producers, estimates pan evaporation for the Mesonet site developed from reference ET and pan coefficients are also available on this webpage.

Crop Evapotranspiration

Under the Crops sub-page an array of weather-related information for each of the major agronomic crops produced in Oklahoma is available, including disease and insect development models, degree-day calculators and crop evapotranspiration (ET_c) models. The ET_c calculation uses the short crop reference (ET_{os}) and an appropriate crop coefficient (K_c). In some cases the K_c values are calculated from relationships that have been locally calibrated, while for some crops the K_c's are determined from general relationships recommended by the United Nations Food and Agriculture Organization (Allen, et. al., 1998).

The specific K_c relationship is determined when the user chooses a crop from the *Crops* menu. The actual daily value of the K_c is determined based on the date of the computation, the planting date and maturity/season length information provided by the user. No adjustments are made for reduced soil water availability or wet soil surface conditions. Daily and cumulative ET_c during the season are presented in a table with the most recent day at the top (Figure 4). This crop water use information, combined with the allowable soil water deficit (as determined by the available water holding capacity of the root zone soil, the crop rooting depth and maximum fraction of water that can be depleted) or the expected effective depth of irrigation allows the irrigation manager to determine when to initiate irrigation.

Figure 4. Crop ET example page from the Mesonet website.

Evapotranspiration for corn for Goodwell

Station	Date	Number of Days	Evapotranspiration (inch)	Accumulated Evapotranspiration (inch)	Rainfall (inch)	Accumulated Rainfall (inch)	Water Balance (inch)
GOOD	2005-07-11	1	0.35	0.35	0.00	0.00	-0.35
GOOD	2005-07-10	2	0.45	0.80	0.00	0.00	-0.80
GOOD	2005-07-09	3	0.41	1.21	0.00	0.00	-1.21
GOOD	2005-07-08	4	0.38	1.59	0.00	0.00	-1.59
GOOD	2005-07-07	5	0.43	2.02	0.00	0.00	-2.02
GOOD	2005-07-06	6	0.35	2.37	0.00	0.00	-2.37
GOOD	2005-07-05	7	0.29	2.66	0.79	0.79	-1.87
GOOD	2005-07-04	8	0.31	2.97	0.00	0.79	-2.18
GOOD	2005-07-03	9	0.51	3.48	0.00	0.79	-2.69
GOOD	2005-07-02	10	0.43	3.92	0.53	1.32	-2.60
GOOD	2005-07-01	11	0.35	4.27	0.07	1.39	-2.88
GOOD	2005-06-30	12	0.46	4.73	0.00	1.39	-3.34
GOOD	2005-06-29	13	0.60	5.33	0.00	1.39	-3.94
GOOD	2005-06-28	14	0.60	5.93	0.00	1.39	-4.54
GOOD	2005-06-27	15	0.53	6.47	0.00	1.39	-5.08
GOOD	2005-06-26	16	0.46	6.92	0.00	1.39	-5.53
GOOD	2005-06-25	17	0.44	7.36	0.00	1.39	-5.97
GOOD	2005-06-24	18	0.50	7.87	0.00	1.39	-6.48
GOOD	2005-06-23	19	0.51	8.38	0.00	1.39	-6.99
GOOD	2005-06-22	20	0.46	8.84	0.00	1.39	-7.45
GOOD	2005-06-21	21	0.38	9.22	0.00	1.39	-7.83
GOOD	2005-06-20	22	0.38	9.61	0.00	1.39	-8.22
GOOD	2005-06-19	23	0.44	10.05	0.00	1.39	-8.66
GOOD	2005-06-18	24	0.38	10.42	0.00	1.39	-9.03
GOOD	2005-06-17	25	0.36	10.78	0.00	1.39	-9.39
GOOD	2005-06-16	26	0.38	11.17	0.00	1.39	-9.78

For the example shown in Figure 4, if the corn crop had a fully developed root depth of 48 inches in a sandy loam soil with an available water capacity of 0.125 inches of available water per inch of soil and a maximum of 40% of the soil water in the root zone can be depleted before water stress affects crop performance, the allowable water deficit is 2.4 inches. Looking down the water use table, the manager can see that cumulative water use of the crop is 2.37 inches since July 6. If the crop was last irrigated on July 6, it is time to irrigate again. If the last irrigation occurred on July 7, the manager can see that based on the most recent ET_c values he has one more day until irrigation must be initiated. Similarly, if the irrigation manager likes to apply no more than 1.25 inches of net water depth with his center pivot system, he can see that after 3 days it is time to irrigate and apply 1.21 inches of water.

The crop ET table also includes daily and cumulative rainfall amounts measured at the Mesonet weather station site, allowing the calculation of a water balance for the site. Users are advised that no adjustment has been made for effective rainfall is made in this calculation. They are also advised that the high spatial variability in rainfall, especially the rainfall from single-cell thunderstorms in the Southern Plains region, makes this information of limited value. They are instead advised to maintain a rain gauge at the site of each field they are irrigating.

The authors acknowledge that there are certain limitations inherent in this approach to predicting actual crop ET_c because adjustments for soil water availability and soil surface wetness are ignored. However, no bookkeeping is required by the user and no files need to be stored on the user's computer to use this method. It is our belief that a simple irrigation scheduling system of reasonable accuracy that requires minimal feedback from the user is more likely to be used consistently by irrigators who have not previously used a weather-based scheduling method than a more accurate, but more complicated system.

Future Improvements

The evapotranspiration products currently available on the Mesonet website include reference ET for short and tall reference crops, and the primary crops of economic importance in Oklahoma. At this time there are ET estimates for eight agronomic crops (alfalfa, corn, cotton, grass hay, peanuts, sorghum, soybeans and wheat), three fruit and nut crops (grapes, peaches, and pecans), three vegetable crops (general small vegetables, tomatoes and watermelons), and two turf crops (cool season grasses and warm season grasses). As time and resources permit ET products for additional crops will be added.

Discussions have been initiated with Mesonet managers about making system resources available for field specific scheduling data. This would set aside storage space that would allow irrigation managers to keep water budget files for individual irrigation systems on-line.

Summary

The Oklahoma Mesonet has implemented a simplified, on-line evapotranspiration modeling system that allows irrigators to use near-real-time weather data to estimate crop water use. The system provides daily reference ET estimates, as well as estimates of actual crop ET for potential conditions for all of the major crops of economic importance in Oklahoma. The listing of cumulative crop ET that the user can adjust for planting date and crop maturity group permits

reasonably accurate timing of irrigation events with minimal effort required of the irrigation manager.

References

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