8.5

THE VALUE OF REAL-TIME MESOSCALE OBSERVATIONS TO EARLY RECOGNITION AND RAPID RESPONSE TO SHORT-TERM DROUGHT

Derek S. Arndt * and Howard L. Johnson
Oklahoma Climatological Survey, Norman, Oklahoma

1. INTRODUCTION

The Oklahoma Mesonetwork (Mesonet), developed through a partnership between the University of Oklahoma and Oklahoma State University, is a permanent mesoscale weather observation network. The Mesonet operates 114 stations on a continuous basis. Atmospheric variables (including rainfall) are recorded every 5 minutes at each site, producing 288 observations per variable per station per day (Brock et al. 1995).

Since the Mesonet was commissioned in March 1994, three short but intense dry episodes impacted Oklahoma's residents and economy. These occurred during winter 1995-96, summer 1998, and late-summer 2000, with durations varying from ten weeks to ten months. Significant wildfire outbreaks accompanied each episode, and each dry spell severely damaged one or more of Oklahoma's crops. However, because rainfall during the interim periods was well above normal, the episodes were masked by normal and above-normal annual rainfall statistics.

Oklahoma Mesonet data allowed the real-time observation of these events on the mesoscale, including the advent of real-time soil moisture data by the third episode. Mesonet information was incorporated into the state's drought response plan, which was written in the wake of the 1995-96 episode. With improvements in the dissemination of Mesonet data, confidence grew in the instrumentation and in the interpretation of data. As a result, state officials were able to monitor the evolution of successive episodes increasingly well. This enabled quicker recognition of, and response to, drought conditions across the state.

The Oklahoma Climate Survey makes available to the general public several drought-related Mesonet products, including rainfall and fire-weather products. Their most effective use to date has been by those agencies charged with the recognizance and mitigation of drought effects.

2. EPISODE DURATION, INTENSITY & IMPACT

In the eight-plus years since the Oklahoma Mesonet was commissioned, four dry episodes, increasingly called "flash droughts", have impacted Oklahoma. The latest of these four episodes impacted a similar region and the same economic sector as the first flash drought. Otherwise, the episodes have varied greatly in time of year and agro-economic sector.

2.1 *Winter – Spring 1995-96*

The first extended dry spell observed with the Oklahoma Mesonet occurred during the winter and spring of 1995-96 (Table 1). From October through May, statewide-averaged precipitation was 53% of normal, marking the driest October-May period in Oklahoma's climate history (since 1895). Counties in northern and western Oklahoma observed a more severe deficit.

This eight-month period coincided with the growing months of the state's winter wheat crop. As a result, this major component of the state's economy was decimated. The statewide-averaged winter wheat yield of 19.0 bu/acre was the smallest in years.

Massive sell-offs depressed prices in the cattle industry, another large component of the state's economy. Fire danger rose throughout the winter, as soils and dormant vegetation became increasingly dry. Wildfire ravaged prairie and forest landscape in February 1996.

TABLE 1

Drought 1995-96
October 1, 1995 through May, 1996

Climate Division	Total Rainfall	Departure from Normal	Percentage of Normal
Panhandle	5.38"	-4.42"	55 %
North Central	6.03"	-9.35"	39 %
Northeast	11.45"	-13.41"	46 %
West Central	5.33"	-9.42"	36 %
Central	9.95"	-11.08"	47 %
East Central	20.17"	-8.92"	69 %
Southwest	6.88"	-9.49"	42 %
South Central	13.21"	-11.32"	54 %
Southeast	23.42"	-10.51"	69 %
Statewide	**11.12"**	**-9.78"**	**53 %**

**Corresponding author address*: Derek S. Arndt, Oklahoma Climatological Survey; Norman, OK 73019; email: darndt@ou.edu

Oklahoma participated with other states during the early 1990s to establish a drought preparedness plan. However, the impacts of the 1995-96 episode crystallized the need for stronger drought management. An executive order from the governor's office established a standing Oklahoma Drought Management Team representing several state agencies.

2.2. *Summer 1998*

The first three months, and the last three months, of 1998 were very wet relative to normal. However, the intervening six months ranked among Oklahoma's driest April-September periods of the 20th century (Table 2). The statewide-averaged rainfall was the third-least since 1895. While all of Oklahoma suffered from heat and lack of rainfall, conditions were particularly severe in parts of western, central, and all of southern Oklahoma. Three climate divisions (west-central, southwest and south-central) observed their driest such period. The period tied for the warmest in state history, and five climate divisions observed record-breaking average temperatures.

Because the episode began after the major winter wheat growth period, the 1998 winter wheat harvest was not adversely affected by this episode. In fact, Oklahoma's 1998 winter wheat yields were among the highest recorded. However, summer crops, such as peanuts, cotton and watermelon were severely impacted.

This was the first episode to be addressed by the state's standing Drought Management Team. To avoid the massive cattle sell-offs that occurred in 1996, Operation Haymaker was initiated. This project involved state-subsidized transport of hay from surplus regions to hay-depleted regions. The operation was hampered by logistical and implementation challenges, as both supply and demand exceeded expectations.

TABLE 2

Summer 1998 Episode April 1, 1998 through September 30, 1998			
Climate Division	Total Rainfall	Departure from Normal	Percentage of Normal
Panhandle	11.29"	-3.28"	78 %
North Central	15.40"	-3.46"	82 %
Northeast	21.87"	-2.47"	90 %
West Central	8.58"	-9.42"	48 %
Central	13.33"	-8.25"	62 %
East Central	18.35"	-6.09"	75 %
Southwest	5.54"	-13.03"	30 %
South Central	10.58"	-12.31"	46 %
Southeast	18.30"	-8.55"	68 %
Statewide	**13.83"**	**-8.55"**	**65 %**

TABLE 3

Summer 2000 Episode August 1, 2000 through September 30, 2000			
Climate Division	Total Rainfall	Departure from Normal	Percentage of Normal
Panhandle	0.66"	-4.01"	14 %
North Central	0.38"	-6.01"	6 %
Northeast	1.24"	-7.03"	15 %
West Central	0.04"	-5.93"	1 %
Central	1.15"	-5.74"	17 %
East Central	2.43"	-5.19"	32 %
Southwest	0.84"	-5.19"	14 %
South Central	0.90"	-6.20"	13 %
Southeast	2.66"	-5.13"	34 %
Statewide	**1.13"**	**-5.63"**	**17 %**

2.3. *Late Summer 2000*

The late-summer dry episode of 2000 was relatively short, but extreme in its lack of rainfall. August and September 2000 was the driest in Oklahoma's climate history for four of the state's nine climate divisions (Table 3). The statewide-averaged rainfall was one-sixth the normal value, and represented the lowest such total in Oklahoma's recorded climate history. The accompanying heat wave was intense, as maximum temperatures exceeded records into the first week of October.

Unlike the previous two episodes, the most severe effects occurred across the northwestern half of Oklahoma. West-central Oklahoma was particularly hard hit. Its two-month rainfall total of 0.04" averaged across the climate division was not only less than one percent of normal; it was less than ten percent of the previous record.

2.4 *Summer – Autumn – Winter 2001-02*

With the exception of a heavy freezing rain event in late January, much of western Oklahoma received very little precipitation for the nine-month period spanning June 2001 and February 2002. The episode's timing, intensity and areal extent resembled that of the 1995-96 episode, but with an

TABLE 4

Summer-Winter 2001-02 Episode June 1, 2001 through February 28, 2002			
Climate Division	Total Rainfall	Departure from Normal	Percentage of Normal
Panhandle	7.56”	-6.33”	54 %
North Central	11.56”	-8.45”	58 %
Northeast	20.79”	-7.17”	74 %
West Central	9.70”	-8.76”	53 %
Central	18.77”	-4.75”	80 %
East Central	26.72”	-2.66”	91 %
Southwest	10.49”	-8.88”	54 %
South Central	24.32”	-1.42”	94 %
Southeast	34.64”	+0.98”	103 %
Statewide	**18.23”**	**-5.24”**	**78 %**

earlier onset date. As of March 1, 2002, distressed conditions continued across the region (Table 4).

The affected area contains Oklahoma's "Wheat Belt", the state's primary winter wheat growing region. The episode's summer onset allowed soil conditions to become very distressed across the affected region by autumn. As a result, planting practices were altered, and much of the crop had to be "dusted in" at an undesirably shallow depth. Mid-season crop reports, and forecasts for the 2002 yield, were pessimistic.

3. THE OCS RESPONSE AND "PRESPONSE"

With each episode, the OCS response and "presponse" evolved. Based on experience and feedback, products were improved or added to help facilitate the rapid dissemination of information to serve drought-related functions of state agencies, as well as the general public.

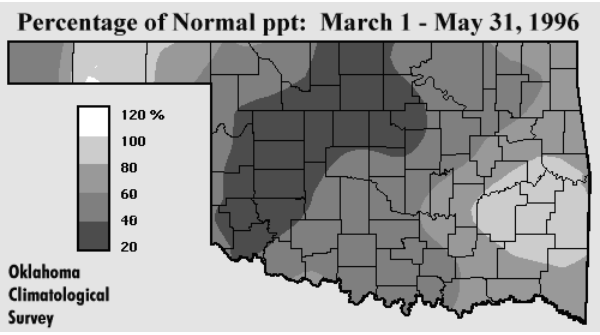

Figure 1. Percentage of normal rainfall, March-May, 1996. Graphics similar to this were issued weekly by OCS during the drought of 1995-96.

3.1 *Winter – Spring 1995-96*

Beginning midway through the episode, the Oklahoma Climatological Survey made use of the real-time nature of Mesonet data and the emerging importance of the Internet. A rainfall update featuring graphics and tables was made available to the public via facsimile, then later on the worldwide web (Fig. 1). This "Oklahoma Drought Update" was updated manually on a weekly basis. Although public use was limited, state agencies such as the Oklahoma Water Resources Board (OWRB) and the Oklahoma Dept. of Agriculture's Forestry Division (OFD) did consume the data.

3.2 *Summer 1998*

By 1998, OCS had automated and renamed the Oklahoma Drought Update. The "Oklahoma Rainfall Update", part of the regular OCS suite of products, was updated on a daily basis. The

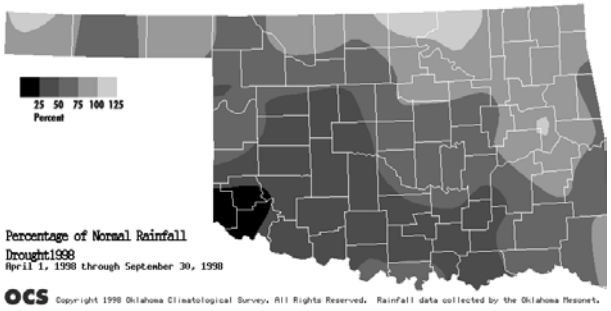

Figure 2. Percentage of normal rainfall, April-September, 1998. Graphics similar to this were issued daily by OCS during the drought of 1998 and in subsequent events.

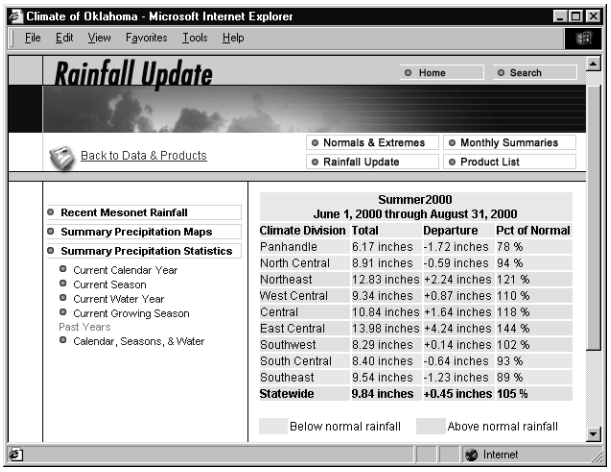

Figure 3. The Oklahoma Rainfall Update. This product is updated daily.

graphics were larger and more detailed than those used in 1996 (Figs. 2 and 3). Tabular information was added to the graphical presentation, along with a limited number of water resources links. Soil moisture sensors were installed at about 50 Mesonet sites by the end of the 1998 dry episode, but they played no role in drought management and mitigation decisions. The Oklahoma Rainfall Update was supplemented with the Recent Mesonet Rainfall product, which provides tabular Mesonet rainfall data for specific intervals (7-day through 90-day). The Recent Mesonet Rainfall product is also updated daily.

The evolution of the 1998 also led to the development of the OCS/Mesonet Ticker. The Ticker is a daily, largely informal e-publication sent to over 100 individuals representing state and federal agencies, media organizations, the academic community and private citizenry. Its audience and application has expanded, by design, to include all relevant meteorological and climatological phenomena. However, it remains a valuable dissemination tool during subsequent flash drought episodes.

3.3 *Late Summer 2000*

By summer 2000, soil moisture sensors had been installed at 100 of the Mesonet's 114 sites. Mesonet soil moisture observations revealed that portions of Oklahoma had not fully recovered from the effects of the summer of 1998 by the onset of the summer 2000 episode. In those regions, the impacts of drought and heat were established more quickly and severely than in other regions of Oklahoma. Soil moisture observations were used daily by the OWRB in their role as the lead agency in Oklahoma's Drought Management team (Fig. 4).

In addition to the Oklahoma Rainfall Update, OCS established the "Drought 2000 Update". This product contained additional tables and graphics relative to the Rainfall Update. It also featured a more comprehensive set of links to national and state drought management/mitigation resources.

3.4 *Summer – Autumn – Winter 2001-02*

OCS coverage during the fourth flash drought during the Mesonet's existence was very similar to that during the third.

The "Drought 2001 Update", the 2001 version of the "Drought 2000 Update", was expanded to include output from the Oklahoma Fire Danger Model (OKFD) and the Oklahoma Dispersion Model (Fig. 5). Both models were developed for Mesonet data at Oklahoma State University and implemented at OCS. OKFD products include the Burning Index (BI) and Keetch-Byram Drought Index (KBDI). The BI estimates wildfire intensity, should wildfire occur. The KBDI is an indicator of soil moisture in the top eight inches of the soil, and used heavily by the fire management community to estimate the contribution of sub-surface organic material to wildfire fuel. The Oklahoma Dispersion Model applies to smoke management decisions during drought episodes. Rainfall values for expired finite periods (i.e., "August 2001" versus "Since August 2001") were added to the rainfall

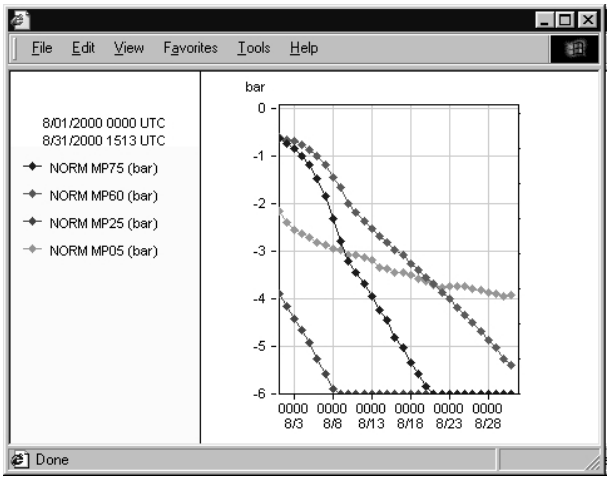

Figure 4. Soil Moisture (matric potential) at the Norman Mesonet site during August 2000. This data was available to the Oklahoma Water Resources Board during Oklahoma's late summer 2000 dry episode.

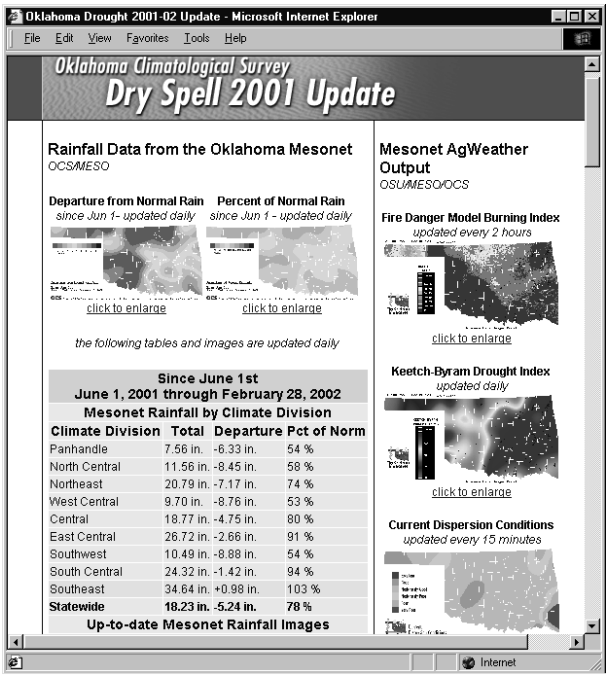

Figure 5. The Oklahoma Drought 2001-02 Update. Rainfall data was updated daily, fire danger index, drought index and dispersion conditions were updated several times per day.

statistics section to assist the data-gathering process during the submission of reports and relief requests by state and local agencies.

4. OCS DROUGHT PRODUCTS: EXTERNAL USE AND REVIEW

The OCS drought products have evolved in their six years and four drought episodes to better meet the needs of state decision-makers, media and citizenry. Three agencies that rely on Mesonet-based drought information are the OWRB, OFD and the National Drought Mitigation Center (NDMC). Additionally, the University of Oklahoma's Science and Public Policy Program recently conducted a survey of local and state officials. This survey was conducted to "provide further insight into drought mitigation at the state level" (Lawson, 2002). Feedback from these sources can help assess the value of, and role of, drought-related Mesonet products in the larger picture.

4.1 *The Oklahoma Water Resources Board*

The OWRB, the state's water management agency, serves as the point agency during the developmental stages of a drought episode. The agency's public information officer coordinates the general monitoring activities of the Oklahoma Drought Management Team. Through the Oklahoma Water Resources Bulletin, he streams information from multiple sources to other members of the Drought Team and interested parties in the executive and legislative branches of the Oklahoma state government. By necessity, the Bulletin becomes more frequent when drought conditions are ongoing or imminent. He makes frequent use of the OCS rainfall products when compiling these periodic drought reports. It is common for the tabular rainfall data of the OCS Rainfall Update (or Drought Update) to populate the front page of the Bulletin. He also uses the OCS/Mesonet Ticker as an information source to keep him abreast of potentially developing episodes during interim periods.

Familiarity with the OCS/Mesonet rainfall products has served another purpose at the OWRB. The spatial, and especially temporal, resolution of Mesonet rainfall data is instrumental to the agency's decisions regarding surface water rights administration.

While the OWRB's drought monitoring coordinator characterized the OCS rainfall products as "very useful", he would like to see a feature that allows the user to request rainfall information for a customizable date range. He believes this feature would help him better define drought and related episodes, particularly when preparing a post-event summary.

4.2 *The Oklahoma Department of Agriculture's Forestry Division*

The OFD's drought-related responsibilities focus on wildfire assessment and mitigation. These responsibilities include the issuance of Red Flag Fire Alerts on a county-by-county level. These alerts do not demand compulsory behavior from the citizenry, but instead advise that extra precautions are needed to burn materials outdoors. The OFD's Director also advises the Governor on issuance of a Burn Ban, a county-by-county gubernatorial action that carries monetary or imprisonment penalties for setting open fires.

The OFD uses several OCS products during drought episodes. These products include the KBDI and the OKFD's burning index, particularly during the growing season. They often use the mid-term Mesonet rainfall products (24-hour rainfall, 72-hour rainfall, etc.) when deciding whether to rescind a Red Flag Fire Alert. The OFD occasionally consult the tabular Mesonet rainfall data to verify their assessment of the long-term situation. However, they prefer the Tulsa River Forecast Center's long-term rainfall products, as they provide an additional and independent source (to the Mesonet fire danger products) of rainfall data.

The Forestry Division considers OCS/Mesonet to be a "very good partner" in their wildfire risk assessment and mitigation practices, and also use OCS products during interim periods. They would like to use a product much like the Recent Mesonet Rainfall product, but with user-definable begin and end dates. They also believe that incorporating forecast data would further improve the value of the OKFD products by adding a predictive element.

4.3 *The National Drought Mitigation Center*

The NDMC stresses the awareness of, and preparation for, drought impacts on the local, state and federal level. Its weekly e-publication, The U.S. Drought Monitor, focuses on established and emerging drought conditions across the nation. The Monitor, published by a rotating panel of editors from several agencies, relies heavily on feedback from professionals in the field.

An NDMC climatologist who serves on the Monitor panel began using OCS/Mesonet products during the rapid-onset event of late summer 2000.

His usage of the Oklahoma products increases when drought is an emerging issue in the region. The temporal resolution provides the greatest value to the NMDC climatologist. The daily updates provide him with the most current rainfall information as he enters his publication cycle, and a fresh update before he finalizes his report.

The NDMC climatologist "likes the detail" from the OCS/Mesonet drought products, but suggested several improvements. Because different agencies use several different indices trigger action, he believes the sole use of the KBDI as a drought index leaves an "interpretation gap" that could be addressed by the inclusion of more indices. He would like to see the Standardized Precipitation Index and the Palmer Drought Index used as companions to the KBDI. He also echoed the desires of the OWRB and OFD professionals by suggesting an addition of a user-defined begin and end date to supplement the "canned" dates offered by the current Mesonet rainfall products.

4.4 *Oklahoma Drought Survey Analysis*

To investigate the communication and mitigation of drought-related threats in the state, the University of Oklahoma's Science and Public Policy Program surveyed more than 800 volunteers and professionals representing a cross-section of local, county and state agencies. 87 recipients responded to the survey, and the results were published in late February as the Oklahoma Drought Survey Analysis (Lawson, 2002).

A very preliminary look at the Analysis reveals that officials tend to value information from state government sources and personal experience as more reliable than other sources. While most respondents did not identify Mesonet data as a primary drought indicator, some of the most popular and most trusted drought-related tools were actually part of the Mesonet suite (KBDI, Fire Danger Model, total rainfall).

5. SUMMARY AND FUTURE PLANS

Feedback from the interviewed professionals and anonymous survey respondents seems to indicate that the Oklahoma Mesonet's drought-related products work very well as part of a larger drought-mitigation institution. Local officials seem to trust and rely on the information provided by the state government's drought task force, and the participants of that task force seem to trust and rely heavily on Mesonet and Mesonet-derived data. There seems to be a need to more strongly identify Mesonet products that are available to the general public. The results from the Oklahoma Drought Survey Analysis also indicate a need to support the release of drought-related products with a stronger educational effort toward intelligent and appropriate use of particular products.

State and national drought monitoring agencies profess a near-unanimous desire for user-defined (versus "canned") date ranges on several Mesonet products. These desires will receive priority in OCS's future iterations of drought-related Mesonet products. The utility of additional drought indices, such as Palmer and the Standardized Precipitation Index, will also warrant future attention by OCS. Finally, because summer drought episodes are often accompanied by severe heat in the Southern Plains, a temperature product analogous to some of the "versus normal" rainfall products is being considered.

6. ACKNOWLEDGEMENTS

The authors thank the following for graciously giving their time: Mark Shafer, Senior Staff Climatologist, OCS; Brian Vance, Environmental Programs Manager, OWRB; Patrick McDowell, Assistant Director, OFD; Mark Svoboda, Climatologist, NDMC.

The authors also thank Mark Meo, J. Scott Greene, and Mark Morrissey and Carlie Lawson of the OU Science and Public Policy Program for their assistance.

7. REFERENCES

Brock, F.V., K.C. Crawford, R.L. Elliott, G.W. Cuperus, S.J. Stadler, H.L. Johnson, M.D. Eilts, 1995: The Oklahoma Mesonet: A Technical Overview. *J. Atmos. Ocean. Tech.*, **12**, 5-12.

Lawson, C.L., 2002: *Oklahoma Drought Survey Analysis*, Science and Public Policy Program, University of Oklahoma, Norman, Oklahoma.