JP3.4 DROUGHT AND THE MODERNIZED COOPERATIVE OBSERVER NETWORK

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1. INTRODUCTION

Drought is a "creeping hazard" whose onset is often difficult to identify. Two main factors work against public awareness of a developing drought episode: 1) drought's onset is incipient, with the likelihood of further development often clouded by the uncertainty of long-term forecasts; and 2) drought onset often lacks the compelling imagery of threatening weather on shorter timescales. For these reasons, those responsible for making drought-related decisions often can't afford to wait for "word of mouth" to alert them to drought conditions.

In order to better serve their jurisdictions, businesses and clients, a proactive monitoring approach is usually best for drought decision-makers. To that end, the Oklahoma Climatological Survey (OCS) has aggressively approached the task of improving drought monitoring in Oklahoma. Real-time, high-quality, and highly-reliable automated data makes a comprehensive web-based product possible to decision-makers and the public. Because drought affects different interests on different scales, the product has been tailored to provide information across a spectrum of scales.

This presentation will describe the evolution of OCS drought monitoring tools and the philosophy behind them. The newest implementation of OCS drought monitoring tools will be detailed. Finally, we will give some observations about the relationship between modernization of the National Weather Service cooperative observer network and recent progress in elevating the emphasis on drought modernization.

2. EVOLUTION OF OCS DROUGHT PRODUCTS

The evolution of drought monitoring at OCS is not limited to technology or data availability. The philosophy behind OCS drought products has also changed and adapted to feedback from data clients.

2.1 Recent History of OCS Drought Monitoring

In the mid-1990s, the advent of real-time, high-quality data from the Oklahoma Mesonet (Brock et al., 1995) allowed OCS to deliver rainfall information less than a day after it was collected. This represented a marked improvement over pre-Mesonet days, when data was often only fully available in a "post-mortem" study of a drought episode.

The first drought episode during the Mesonet's existence came in the cool season of 1995-96. By spring 1996, OCS was delivering weekly maps depicting rainfall totals and comparison to normal. The maps were produced via a labor-intensive process involving several computers and graphics packages, and sent by facsimile to interested decision-makers and the media. During subsequent drought episodes in 1998 and 2000, OCS used the world-wide-web to deliver automatically-generated maps and climate-division-level tabular data on a daily basis. During the 16-month event of 2001-02, OCS provided data, maps, fire danger model output and smoke dispersion maps on a standalone drought monitoring web page. With each episode, the volume of drought-related Mesonet data available in near-real time increased dramatically (Johnson et al., 2002).

2.2 OCS Drought Monitoring Philosophy

For nearly ten years, OCS has monitored drought conditions using an expanding suite of real-time observations and products. During that time, self-assessment using feedback from information clients has helped forge a philosophy. The following six tenets guide the ongoing development of OCS drought monitoring efforts.

a. Drought is a social phenomenon

Perhaps the best and most widely accepted definition of drought is deceptively simple: It occurs when there is not enough water available to meet needs (Redmond 2002). This innocent definition dictates that responsible decision-makers, and those who provide their information, approach an understanding of drought through the lens of these needs.

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The impact of this tenet is an acceptance and understanding that, drought is primarily defined by its effect on society. A responsible drought monitoring professional must take care to understand the basics, and, if possible, the subtleties of water use and water issues in his jurisdiction. From a data and information perspective, this often means looking beyond the raw data or basic statistics into appropriately chosen indicators of drought impact.

b. Drought is relative in time, space and application

Much like atmospheric science, drought assessment must take into account an ongoing interplay between scales. For example, in Oklahoma, three intensifications of drought conditions have occurred in the last five years:

1. Summer 1998. A scale of ~6 months. Statewide impacts.
2. Late Summer 2000. A scale of ~2 months. Statewide impacts.
3. 2001-02. 12-14 months. Impact covered western half of the state.

Were these three separate events? Yes and no. To the state Fire Marshall, they were three separate and severe events. Each exacerbated fire conditions during its existence. To winter wheat farmers, they were three separate events whose impacts varied due to the time of year. The first, which began during the weeks before harvest, actually proved beneficial to the 1998 crop. The second stunted the planting of the 2001 crop, and the third severely damaged the 2002 crop. To the Army Corps of Engineers, which operates several reservoirs in Oklahoma, the period was essentially a single multi-year episode of varying intensity. Reservoir levels in southwestern Oklahoma dropped and failed to recover throughout the period. This impacted municipal water draws and irrigation availability.

c. Because drought is intimately tied to society, a long-term reference is vital

People have adjusted to nature over generations, and drought represents a departure of varying significance from nature's long-term signal. Long-term averages are a major component of virtually all drought assessment indices, whether in the form of 30-year normals (e.g., Palmer Index) or the entire long-term record (e.g., Standardized Precipitation Index).

Because people adjust, an objective measure of drought may have different impacts over time. For example, lessons learned during the great droughts of the 1930s radically changed farming practices. As a result, the impacts of the multi-year 1950s drought in Oklahoma were less severe, even though objective measures indicated a severity on par with the 1930s. On the other hand the recent "wet" decade of the 1990s has lessened Oklahoma's immediate experience with multi-year droughts. Thus, a return toward more historical conditions could trigger unanticipated societal responses.

d. New and emerging observational datasets should be explored

Soil moisture observations from the Oklahoma Mesonet show a promising contribution to drought monitoring in the state. The ability to see both topsoil and subsoil moisture conditions provides a valuable verification tool that is measured independently of other drought-related variables. The observations are particularly effective during drought recovery, when they help to provide guidance on whether precipitation events have indeed provided deep relief or have only infiltrated a few inches below the surface.

The soil moisture dataset also offers opportunities for drought-related research. Decomposing long-term events into individual episodes of precipitation and drying will isolate the building blocks of drought and recovery. Analyzing soil moisture behavior during episodes of drought and recovery should provide a greater understanding of the response of soil moisture to precipitation of varying intensity, duration and frequency.

e. Drought is a multi-faceted issue and requires a multi-faceted assessment

Assessing drought is like assessing illness: more than one type of assessment is often necessary. A medical doctor does not take a patient's temperature and make a diagnosis based on one measure. Instead, the doctor may use the temperature observation along with other observations *and* the results of patient-appropriate and symptom-appropriate tests. That is, the doctor uses one well-chosen indicator in concert with other well-chosen indicators. A responsible drought decision-maker (and those who supply his data) should take the same approach.

f. Deliver drought information, not just drought data

A survey of about 100 Oklahoma drought information consumers (Lawson 2002), as well as independent feedback from OCS consumers, indicated that the real-time information provided a large improvement in their drought decision-making activities. However, a common theme from many respondents was that ever-increasing amounts of data could become cumbersome if not provided in the context of experience or history. Simply put, as the technology associated with delivering high-quality drought data improved, the ability to overwhelm clients with volumes of numbers became a real problem.

Finding the best balance between data volume and usability is an ongoing effort at the Climate Survey. Because many drought managers are from non-meteorological or even non-scientific fields, OCS attempts to present information with sensitivity to the ways that adults process information. From an information perspective, several components of OCS's drought information suite overlap each other, with the anticipation that at least one will resonate with a particular learning style and experience base of an information consumer.

3. CURRENT OCS DROUGHT MONITORING EFFORTS

The state's drought management plan calls for the Oklahoma Water Resources Board (OWRB) to serve as the state's point agency for drought information. The OWRB chairs the group assigned to, among other tasks, "monitor current water availability and moisture conditions" in the state. OCS drought information tools are largely designed to support the OWRB in this role. Other institutional consumers include the state's Forestry Division, for the purposes of instituting Red Flag Fire Alerts and recommending gubernatorial burn bans, and the authors of the U.S. Drought Monitor (Svoboda et al. 2002). Feedback from these and other agencies, businesses and individuals helps OCS refine and improve its drought monitoring efforts.

3.1 The Oklahoma Mesonet

Real-time precipitation and soil moisture information is taken from the Oklahoma Mesonet (Brock et al., 1995). Daily summaries of Mesonet data are incorporated into various drought monitoring products, summary information, modeled fire danger conditions, smoke dispersion indices and other related products. Because Mesonet data arrive reliably and are carefully quality-assured (Shafer et al., 2000), they are favored for real-time drought-monitoring. For products and indices that require a long-term perspective, Mesonet data are compared to records from the National Weather Service's Cooperative Observer (COOP) Network.

3.2 Web Delivery of Information

An automated summary drought report is updated daily, during the overnight hours, and is immediately available via the world-wide-web. The timing and automation of the report is constructed such that drought decision-makers will have ready access to the latest precipitation, fire danger and soil moisture data as soon as they arrive at their desk. Each morning's report contains information complete through midnight of the previous night (i.e., the report delivered on the morning of the 9th incorporates data trough the 8th). The automation helps maximize the efficiency of the report-reader by eliminating the need to prompt (and wait for) action from OCS. It also helps OCS staff reduce the time spent preparing reports and focus on more valuable interpretive and explanatory support.

The summary report is delivered in three sections. Tabular information provides precipitation statistics, measures of their unusualness, and historical context on a climate-division level. Statewide maps provide an at-a-glance look at precipitation conditions, comparison to long-term averages as well as assessments of soil moisture, fire danger and smoke management conditions. Finally, a panel of related information provides links to relevant information and partners in Oklahoma drought monitoring.

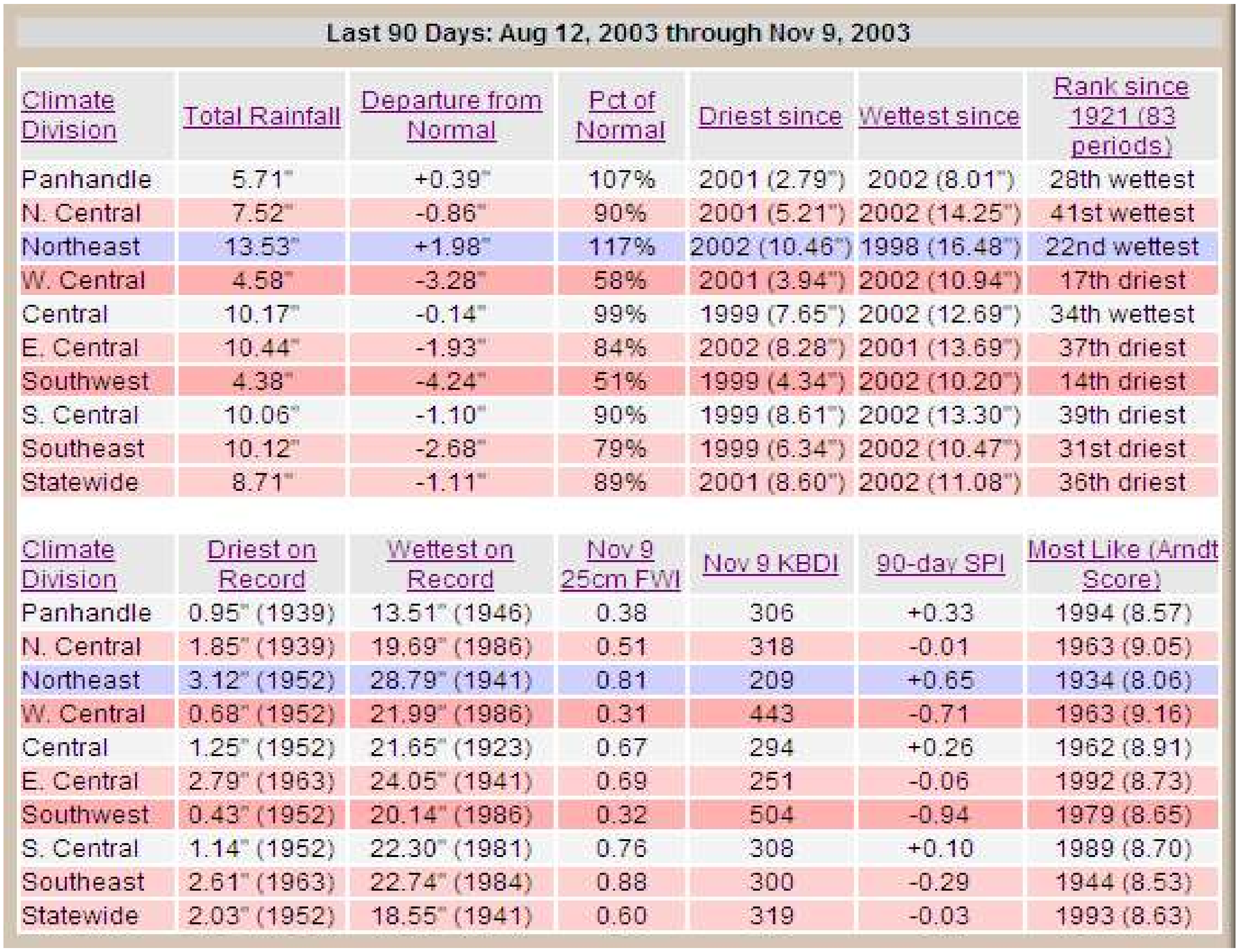
a. Tabular Information

Because different interests are sensitive to drought on different timescales and during specific times of the year, information is available for ten "seasons" (Table 1). These seasons range from a few weeks to 365 days. For each season, drought information is arranged by climate division.

More than a dozen descriptive indicators are available for each climate division for each season, ranging from basic statistics to application-specific indices (Fig. 1). The arrangement and variety of data were chosen to help non-scientists better assimilate the complex information by appealing to their personal and/or corporate experience. To that end, on-line help and educational material is available for each component (Fig. 2).

Season	***Dates***
Current Season	Since Mar 1, Jun 1, Sep 1 or Dec 1
Current Growing Season	Since Mar 1 or Sep 1
Year to Date	Since Jan 1
Water Year to Date	Since Oct 1
Last 30 Days	Moving window
Last 60 Days	Moving window
Last 90 Days	Moving window
Last 120 Days	Moving window
Last 180 Days	Moving window
Last 365 Days	Moving window

Table 1. The ten seasons for which OCS drought monitoring information is updated daily.

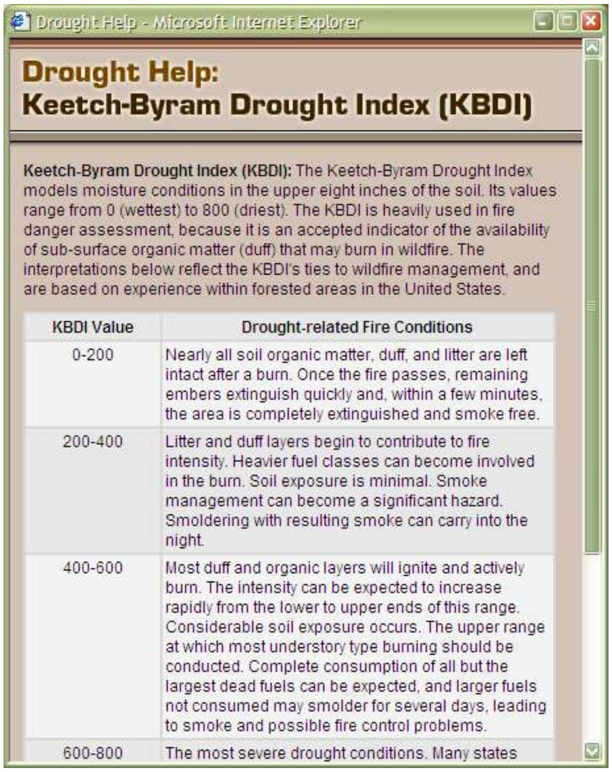


Last 90 Days: Aug 12, 2003 through Nov 9, 2003

Climate Division	Total Rainfall	Departure from Normal	Pct of Normal	Driest since	Wettest since	Rank since 1921 (83 periods)
Panhandle	5.71"	+0.39"	107%	2001 (2.79")	2002 (8.01")	28th wettest
N. Central	7.52"	-0.86"	90%	2001 (5.21")	2002 (14.25")	41st wettest
Northeast	13.53"	+1.98"	117%	2002 (10.46")	1998 (16.48")	22nd wettest
W. Central	4.58"	-3.28"	58%	2001 (3.94")	2002 (10.94")	17th driest
Central	10.17"	-0.14"	99%	1999 (7.65")	2002 (12.69")	34th wettest
E. Central	10.44"	-1.93"	84%	2002 (8.28")	2001 (13.69")	37th driest
Southwest	4.38"	-4.24"	51%	1999 (4.34")	2002 (10.20")	14th driest
S. Central	10.06"	-1.10"	90%	1999 (8.61")	2002 (13.30")	39th driest
Southeast	10.12"	-2.68"	79%	1999 (6.34")	2002 (10.47")	31st driest
Statewide	8.71"	-1.11"	89%	2001 (8.60")	2002 (11.08")	36th driest

Climate Division	Driest on Record	Wettest on Record	Nov 9 25cm FWI	Nov 9 KBDI	90-day SPI	Most Like (Arndt Score)
Panhandle	0.95" (1939)	13.51" (1946)	0.38	306	+0.33	1994 (8.57)
N. Central	1.85" (1939)	19.69" (1986)	0.51	318	-0.01	1963 (9.05)
Northeast	3.12" (1952)	28.79" (1941)	0.81	209	+0.65	1934 (8.06)
W. Central	0.68" (1952)	21.99" (1986)	0.31	443	-0.71	1963 (9.16)
Central	1.25" (1952)	21.65" (1923)	0.67	294	+0.26	1962 (8.91)
E. Central	2.79" (1963)	24.05" (1941)	0.69	251	-0.06	1992 (8.73)
Southwest	0.43" (1952)	20.14" (1986)	0.32	504	-0.94	1979 (8.65)
S. Central	1.14" (1952)	22.30" (1981)	0.76	308	+0.10	1989 (8.70)
Southeast	2.61" (1963)	22.74" (1984)	0.88	300	-0.29	1944 (8.53)
Statewide	2.03" (1952)	18.55" (1941)	0.60	319	-0.03	1993 (8.63)

Fig. 1. The tabular portion of the Oklahoma Drought Update. The statistics for each column are updated daily. Colors indicate relative surplus or deficit versus normal precipitation.



Drought Help:
Keetch-Byram Drought Index (KBDI)

Keetch-Byram Drought Index (KBDI): The Keetch-Byram Drought Index models moisture conditions in the upper eight inches of the soil. Its values range from 0 (wettest) to 800 (driest). The KBDI is heavily used in fire danger assessment, because it is an accepted indicator of the availability of sub-surface organic matter (duff) that may burn in wildfire. The interpretations below reflect the KBDI's ties to wildfire management, and are based on experience within forested areas in the United States.

KBDI Value	Drought-related Fire Conditions
0-200	Nearly all soil organic matter, duff, and litter are left intact after a burn. Once the fire passes, remaining embers extinguish quickly and, within a few minutes, the area is completely extinguished and smoke free.
200-400	Litter and duff layers begin to contribute to fire intensity. Heavier fuel classes can become involved in the burn. Soil exposure is minimal. Smoke management can become a significant hazard. Smoldering with resulting smoke can carry into the night.
400-600	Most duff and organic layers will ignite and actively burn. The intensity can be expected to increase rapidly from the lower to upper ends of this range. Considerable soil exposure occurs. The upper range at which most understory type burning should be conducted. Complete consumption of all but the largest dead fuels can be expected, and larger fuels not consumed may smolder for several days, leading to smoke and possible fire control problems.
600-800	The most severe drought conditions. Many states

Fig. 2. An example of a help window for one of the drought table categories.

i. basic statistics

The first columns in the table provide cursory precipitation statistics for the season, specifically: total precipitation, departure from normal and percentage of normal precipitation.

ii. historical perspective

While basic statistics are probably the most broadly used category of statistics across the spectrum of drought decision-makers, they lack context. Raw statistics can also be misleading, especially for decision-makers who lack the climatological expertise to interpret them. To help provide such a context, four data columns place the season's rainfall total in historical perspective.

For the chosen season of interest, all analogous "peer seasons" from Oklahoma's history are reconstructed using daily precipitation data for each climate division (e.g., for the 90-day period ending May 9th, all available 90-day periods ending May 9th are reconstructed). The customer is then presented with the most recent seasons that were more extreme (wetter or drier) than the current. The rank of the current season among its peers (e.g., "4th driest of 83 such seasons on record") is also presented to give an assessment of the historical significance of the season. This rank is also presented in terms of its percentile rank (not shown in Fig 1).

For example, for a chosen season, several Oklahoma climate divisions may show strikingly similar percentage-of-normal values. However, due to regional differences in the traditional variability of precipitation during that season, these percentage-of-normal values may represent significantly different departures from the long-term signal for their respective regions. This was indeed the case in Oklahoma during spring of 2003 (Fig. 3).

iii. period-of-record extremes

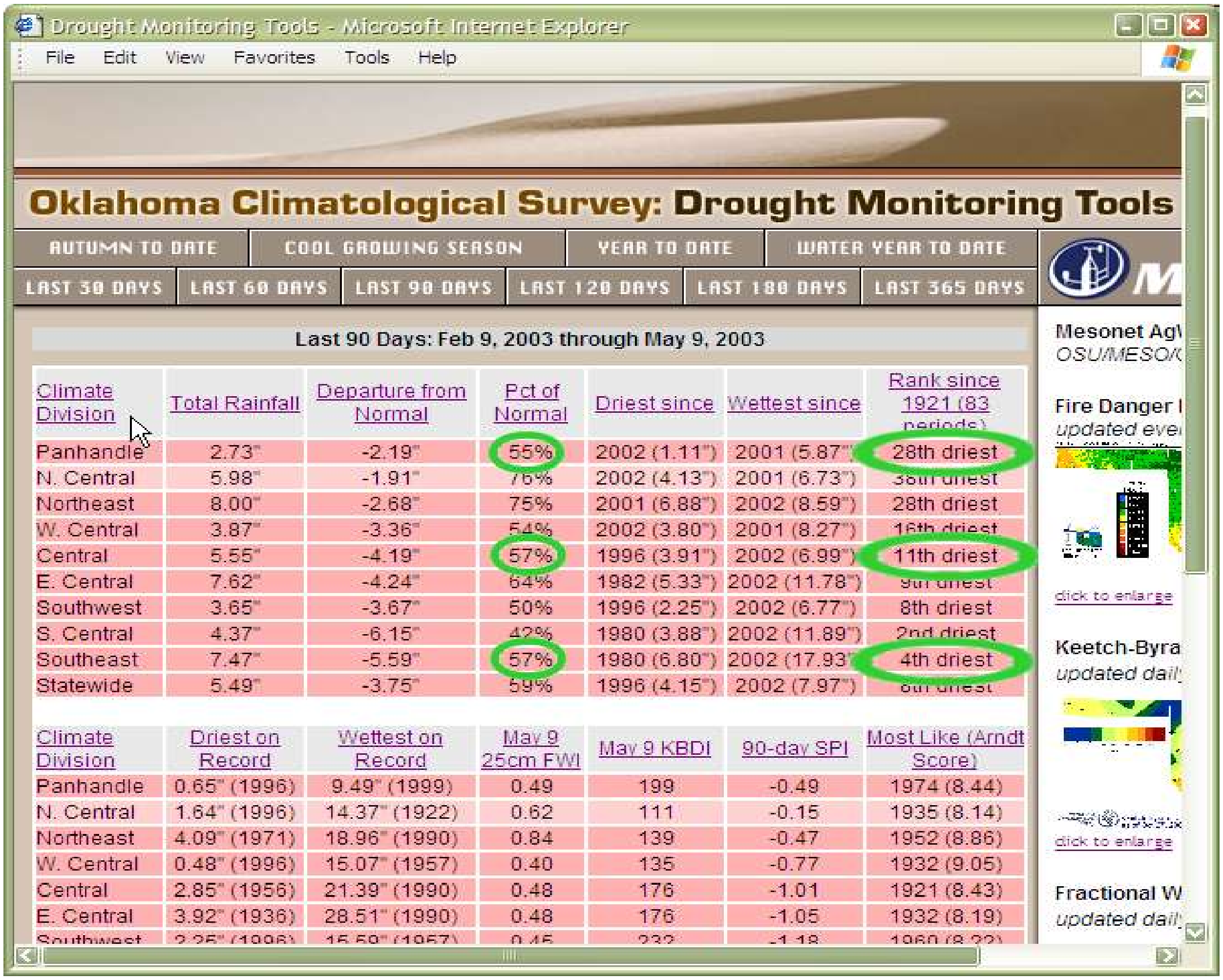
In order to provide more historical "bracketing" of the current season of interest, the extremes from the period of record are indicated. These wettest and driest such seasons provide a historical bracket which addresses the notion "How bad can it get this time of year?" by answering a slightly different question, specifically "How bad has it been this time of year?"

iv. application-specific indices

Three indices that have specific uses in drought-sensitive communities are included. The Keetch-Byram Drought Index (KBDI) provides information for fire professionals on the dryness of the uppermost layers of topsoil. The KBDI is most often used to estimate the amount of subsurface organic material that can burn in a wildfire. The Fractional Water Index (FWI) is a soil moisture indicator developed at OCS in recent years (Illston et al., 2004). The FWI is used by the state's Water Resources Board to assess conditions related to baseflow. The Standardized Precipitation Index (SPI) was developed at the Colorado Climate Center (McKee, et al., 1993, 1995) to help assess the unusualness of an episode. The SPI performs statistical assessments of the long-term record for a place or area and returns an indication of the likeliness of occurrence of the event in question. The SPI is often used for weekly and monthly assessments. OCS has modified it to operate daily over a moving N-day window, where N is determined by the number of days in the season of interest.

v. analog seasons

An analog season is the peer season from Oklahoma's climate history whose precipitation characteristics most strongly match that of the



Last 90 Days: Feb 9, 2003 through May 9, 2003

Climate Division	Total Rainfall	Departure from Normal	Pct of Normal	Driest since	Wettest since	Rank since 1921 (83 periods)
Panhandle	2.73"	-2.19"	55%	2002 (1.11")	2001 (5.87")	28th driest
N. Central	5.98"	-1.91"	76%	2002 (4.13")	2001 (6.73")	36th driest
Northeast	8.00"	-2.68"	75%	2001 (6.88")	2002 (8.59")	28th driest
W. Central	3.87"	-3.36"	54%	2002 (3.80")	2001 (8.27")	16th driest
Central	5.55"	-4.19"	57%	1996 (3.91")	2002 (6.99")	11th driest
E. Central	7.62"	-4.24"	64%	1982 (5.33")	2002 (11.78")	9th driest
Southwest	3.65"	-3.67"	50%	1996 (2.25")	2002 (6.77")	8th driest
S. Central	4.37"	-6.15"	42%	1980 (3.88")	2002 (11.89")	2nd driest
Southeast	7.47"	-5.59"	57%	1980 (6.80")	2002 (17.93")	4th driest
Statewide	5.49"	-3.75"	59%	1996 (4.15")	2002 (7.97")	8th driest

Climate Division	Driest on Record	Wettest on Record	May 9 25cm FWI	May 9 KBDI	90-day SPI	Most Like (Arndt Score)
Panhandle	0.65" (1996)	9.49" (1999)	0.49	199	-0.49	1974 (8.44)
N. Central	1.64" (1996)	14.37" (1922)	0.62	111	-0.15	1935 (8.14)
Northeast	4.09" (1971)	18.96" (1990)	0.84	139	-0.47	1952 (8.86)
W. Central	0.48" (1996)	15.07" (1957)	0.40	135	-0.77	1932 (9.05)
Central	2.85" (1956)	21.39" (1990)	0.48	176	-1.01	1921 (8.43)
E. Central	3.92" (1936)	28.51" (1990)	0.48	176	-1.05	1932 (8.19)
Southwest	2.25" (1996)	15.59" (1957)	0.45	232	-1.18	1960 (8.22)

Fig. 3. Rainfall statistics for the 90-day period ending May 9, 2003. Percentage of normal precipitation for the period is in quite similar for three Oklahoma climate divisions, but the historical significance of these values is markedly different.

current season of interest. A likeness index score, ranging from 0-10, is also provided to give an indication of the strength of the match. This component is designed to refer to the information client's personal or corporate memory of the impact of the analog season's precipitation patterns, and the [consequences of the] decisions made during the season.

The analog season is calculated using a a test involving three components. The first component compares total rainfall during the season of interest with all peer seasons. The second assesses the general character of precipitation events during the season of interest with its peer seasons. It does so by comparing the number of events exceeding certain thresholds. The final component examines quartile dates to compare how precipitation was distributed in time the season of interest and peer seasons. Each component is combined and a likeness score is computed for each peer season. The peer season with the greatest likeness score is the analog season.

In addition to the long-term analog seasons, or "best match", the highest score from the last ten years is also computed. This "best recent match" puts current conditions in the more-recent perspectives of many decision-makers.

b. Maps of Precipitation and Drought-Related Conditions

A set of eight maps accompanies the tabular information for each season. Clicking on these maps brings up a full-scale, full-color map in a separate window.

i. precipitation maps

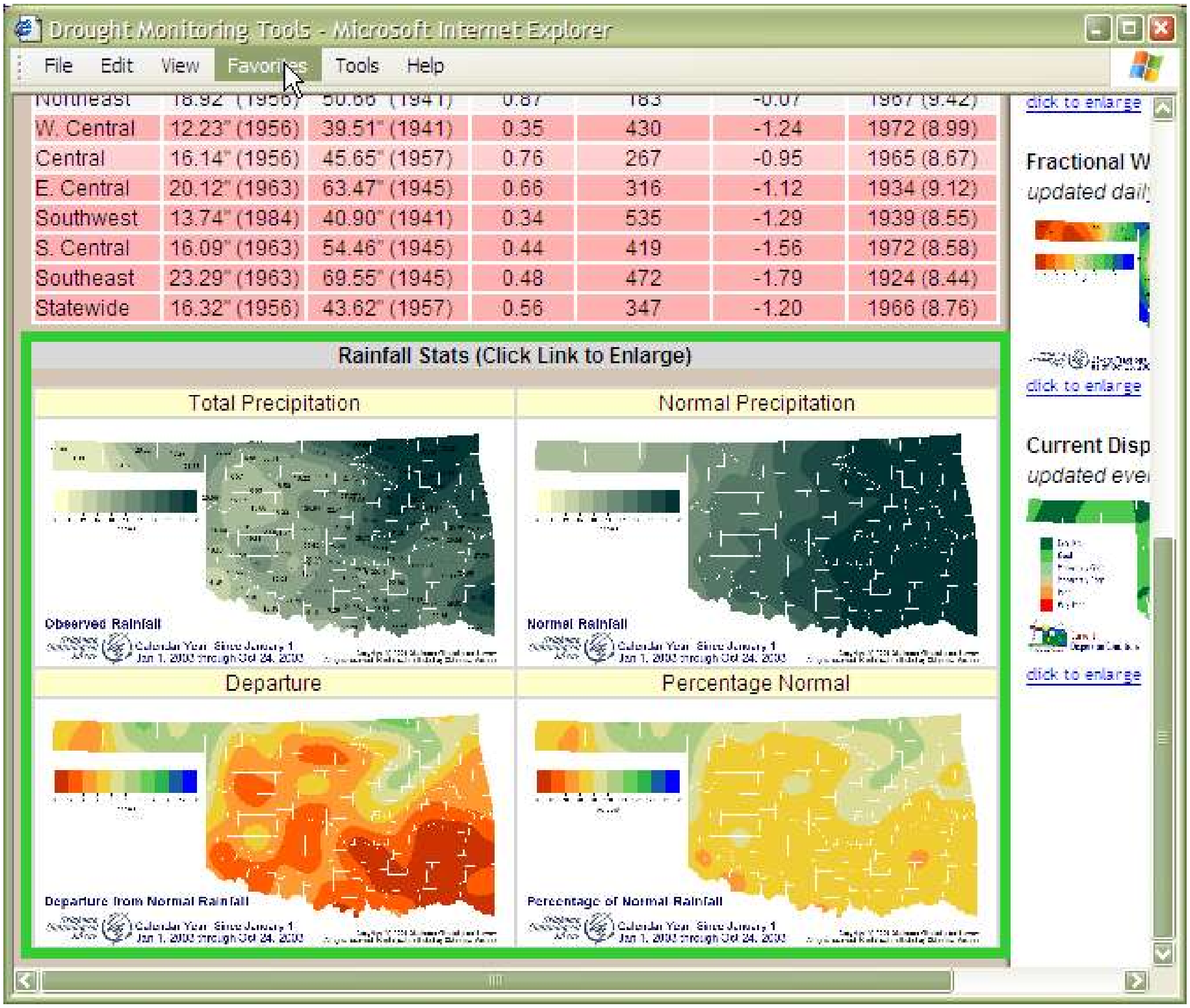
Four maps display precipitation conditions across the state for the season of interest (Fig. 4). These maps show total precipitation, normal precipitation, the departure from normal and the percentage of normal precipitation for the period.

ii. drought-related conditions

Four maps display statewide conditions connected to drought. The Oklahoma Fire Danger Model's Burning Index (Carlson, et al., 2002) provides information, updated every two hours, on wildfire danger and potential severity. Smoke dispersion conditions modeled from Oklahoma Mesonet data are updated every 15 minutes (Carlson and Arndt, 1998). Statewide maps of FWI and KBDI values (described above) are also available.

c. Related Information

Many agencies, both inside and outside Oklahoma, provide additional expertise in monitoring drought conditions in the region, including information beyond the scope of OCS drought monitoring efforts. Forecast information, burn restrictions and economic assessments, in addition to other measures, are all part of the drought management process. Therefore, the OCS drought monitoring presence includes links to a comprehensive set of additional information, and the agencies that supply it.



Northeast	18.92" (1956)	50.66" (1941)	0.87	183	-0.07	1967 (9.42)
W. Central	12.23" (1956)	39.51" (1941)	0.35	430	-1.24	1972 (8.99)
Central	16.14" (1956)	45.65" (1957)	0.76	267	-0.95	1965 (8.67)
E. Central	20.12" (1963)	63.47" (1945)	0.66	316	-1.12	1934 (9.12)
Southwest	13.74" (1984)	40.90" (1941)	0.34	535	-1.29	1939 (8.55)
S. Central	16.09" (1963)	54.46" (1945)	0.44	419	-1.56	1972 (8.58)
Southeast	23.29" (1963)	69.55" (1945)	0.48	472	-1.79	1924 (8.44)
Statewide	16.32" (1956)	43.62" (1957)	0.56	347	-1.20	1966 (8.76)

Fig. 4. Four statewide maps showing (clockwise from upper left) total precipitation during the period, normal precipitation for the period, percentage of normal precipitation and departure from normal precipitation.

4. MODERNIZATION OF THE COOPERATIVE OBSERVER NETWORK

The tools described above, employed by OCS to monitor drought conditions in Oklahoma, could similarly be applied to any state or region. Key components to a successful implementation of these tools are (1) real-time (at least daily) precipitation information, (2) long-term historical records for comparisons, and (3) other variables, including soil moisture, humidity, temperature, winds and solar radiation.

If at least the first two of these conditions exist, the basic suite of tools can be employed. The variables included in the third conditions allow additional supporting products, such as fire danger, smoke dispersion and FWI.

Unfortunately, most daily precipitation observations are not quality-assessed and available until months after they are observed. The modernized COOP network could solve this impediment. At its most basic level, daily reporting of temperature and precipitation, with adequate quality assurance, would provide a good input into drought monitoring capabilities. If expanded to include other variables (e.g., Crawford et al. 2004), even more would be possible.

Decisions are being made right now about the direction of future observing systems, particularly with regards to modernizing the National Weather Service Cooperative Observer Network (COOP). At the same time, legislation in Congress is pending with regards to drought planning and monitoring. The Drought Preparedness Act of 2003 calls for a national drought monitoring network.

The needs of the drought network dovetail nicely with plans for the coop modernization, but the planning for both must be integrated at the earliest stages. The modernized coop network would provide real-time rainfall, temperature, and perhaps other important variables such as humidity, wind speed, solar radiation, and even soil moisture. A dense network of real-time observations would allow monitoring incipient drought conditions on an unprecedented scale.

Much of the drought monitoring technique and technology developed at OCS are transportable to any state or region with reliable daily precipitation data and a robust long-term climate record.

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