THE DROUGHT OF 1988 AND BEYOND

Proceedings of a Strategic Planning Seminar
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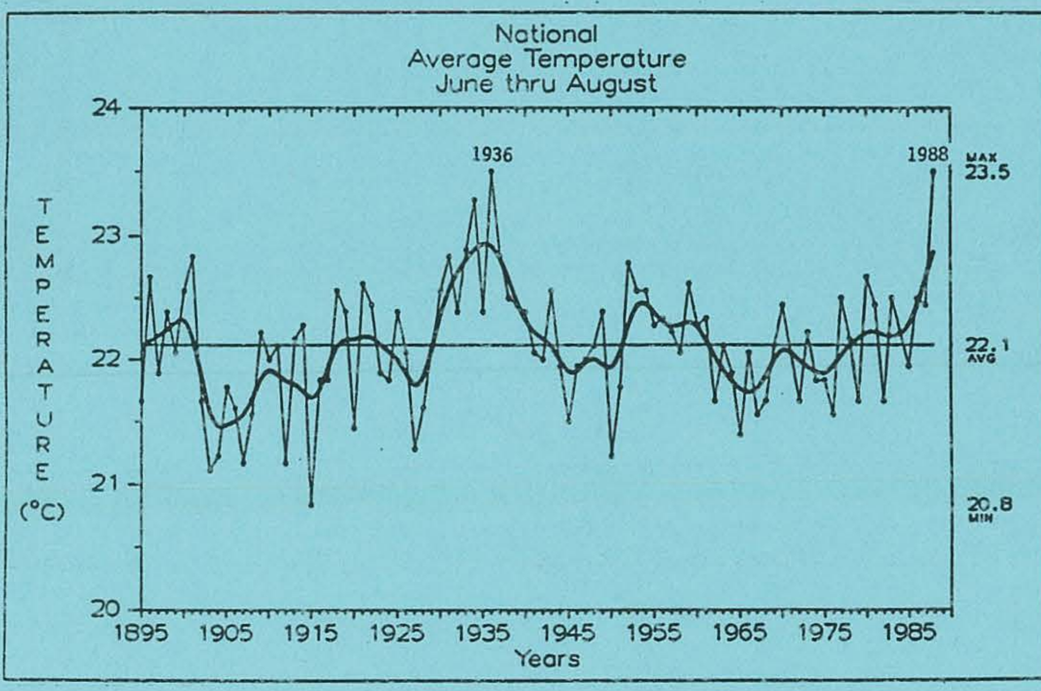

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Climate Program Office
Washington, DC

Cover figure:

National average Summer temperatures ($^{\circ}$C) over the contiguous United States. Figure is based on temperatures from June-August, 1895-1988. The average is represented by the horizontal line at 22.1°C (NCDC/NOAA).

OUTLINE

PREFACE

The extent, magnitude and impacts of the drought of 1988 in the United States and Canada were recently discussed at a seminar jointly organized by the National Climate Program Office (NCPO), Resources for the Future (RFF) and the Board of Atmospheric Sciences (BASC) of the National Academy of Sciences (NAS).[1] Information presented in this proceedings was drawn primarily from the seminar. Additional background material was provided by federal agencies, especially the Climate Analysis Center (CAC), the National Climate Data Center (NCDC) of NOAA, Regional Climate Centers (RCC), the Atmospheric Environmental Service (AES) of Canada, and the Congressional Research Service.

The drought of 1988 was widespread throughout the agricultural regions of the United States and Canada and had significant impacts on agricultural production, forestry, natural ecosystems, and water availability. The potential serious effects of the developing drought initiated a number of federal government responses. The Climate Analysis Center (CAC/NOAA) developed a Drought Advisory series to present a unified summary of drought conditions. Inputs were coordinated from NOAA offices, the Forest Service, United States Department of Agriculture, and six Regional Climate Centers. Eleven advisories were issued weekly between June 21 and August 31,

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[1]Abstracts of papers presented at this seminar are given in Appendix A.

1988. The Drought Advisories consolidated climatological and meteorological conditions (short-term and long-term drought, heat waves/extremes, historical and regional perspectives, current weather); hydrologic conditions (river and streamflow, reservoir storage, impacts); special conditions (forest and wild fires); outlooks (1-5 day, 6-10 day, 30-day, 90-day, 5-day forest fire and risk potential, general hydrologic and river basin). The final issue - Drought Advisory 88/12: Summary of Conditions and Impacts is included in its entirety in Appendix A.

The NCDC in Asheville, North Carolina helped put the 1988 drought in historical perspective. Ninety-four years of high quality temperatures and precipitation data from meteorological stations across the United States were used to compare the 1988 drought to serious droughts in the 1950's and 1930's. This perspective allows an initial assessment as to the origin of the 1988 drought, i.e., greenhouse gas induced, meteorological anomaly, or natural recurrent swings in the climate.

The White House announced the establishment of the Interagency Drought Policy Committee on June 15, 1988, consisting of the Departments of Agriculture, Interior, Army, and Energy, Tennessee Valley Authority, Federal Emergency Management Agency, Office of Management and Budget, and the Office of the Vice President. The Departments of State and Transportation, Council of Economic Advisors, and National Oceanic and Atmospheric Administration were added later. The Committee's initial meeting was held on June 20, 1988, at the Department of Agriculture and chaired by Secretary Richard E. Lyng. The Final Report of this

Committee[2] assesses the national effects of the drought, describes federal measurements taken to ameliorate its effects and identifies areas where effects of the drought are likely to continue. The Executive Summary of this report appears in Appendix A.

This proceedings focuses on the climatology of the drought over the North American continent, its historic context, and its relationship to global climate warming. The RCC's provided specific case studies of impacts at regional levels. A summary of Congressional actions related to the drought is also given. The proceedings was compiled by the National Climate Program Office.

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[2]The Drought of 1988: Final Report of the President's Interagency Drought Policy Committee, December 30, 1988. Copies available from the Department of Agriculture. Executive Summary included in Appendix A.

DROUGHT OF 1988 IN THE UNITED STATES AND CANADA

OVERVIEW

The climatology of the United States is characterized by recurrent and often severe droughts. The timing, severity and extent of the drought of 1988 falls within the climatological range of historic information. However, the drought of 1988, coming during a time of heightened concern about climate change and during a run of years when global average temperatures have been well above normal, raised concerns that this drought might be directly related to greenhouse global warming.

At this time, no scientific evidence points to a direct link between the 1988 drought and global warming. Nevertheless, the drought provides a good case study of possible future effects on the United States should such droughts become more frequent or more severe, as is projected by some general circulation models of the atmosphere. For this reason, the drought of 1988 should be the subject of study with respect to the capability of the scientific and social systems of the United States to respond to drought.

Past experience suggests that drought and its impact on society are quickly forgotten. Previous responses to drought in the United States by all levels of government have often been characterized by "crisis management." Although a General

Accounting Office (GAO) report published in 1979[3] called for the development of a national drought plan, little if any, action has occurred. State governments, until recently, have generally relied largely on the federal government for assistance.

The situation for the future may be different for a number of reasons:

- o Concern about global warming due to CO_2 and other trace gases is causing an assessment of the capability of American agriculture to maintain its high level of productivity under the possibility of more frequent drought.
- o Population shifts in the United States toward warmer and drier areas are raising concerns about the ability of society to meet urban and agricultural needs.
- o Growth of regional climate centers and increased emphasis on states playing a larger role in measuring climate impact. In 1988 approximately ten states had developed drought plans.
- o Growth of the private sector in marketing climate information and in promoting climate impact assessment.

National priorities that emerge from this report are to promote increased long-term monitoring of climate, enhanced

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[3]General Accounting Office, 1979. Federal Response to the 1976-1977 Drought: What Should be Done Next? Report to the Comptroller General. Washington, D.C. 29 pp.

drought research and prediction, and continued development of drought management plans at federal, regional, and state levels. Regional organizations can help state policy makers understand drought, coordinate data collection and information, enhance the flow of information concerning available drought management technologies and communicate regional assessment of drought conditions and impacts to the federal government. The report provides examples of the regional impact of drought as analyzed by Regional Climate Centers.

DROUGHT MEASUREMENTS

It was Palmer (1965)[4] who introduced the Palmer Drought Severity Index (PDSI). He described Meteorological Drought as an interval of time, generally of the order of months to years, during which the actual moisture supply at a given location consistently falls short of the climatological moisture supply. The PDSI represents a single all-purpose drought index that attempts to combine the impacts of soil moisture, groundwater shortage, and low streamflow. The composite PDSI index, usually shown as positive values for above normal soil moisture and negative values for below normal soil moisture, cannot be related easily to specific environmental or economic impacts. The PDSI is computed using a water budget model that considers precipitation and temperature for a given area over a period of months to years.

Agricultural Drought is a term often applied to deficiencies in the amount of water needed relative to that available for agricultural requirements. Agriculturists are usually concerned with soil moisture deficiencies as they relate to crop development and yield. Agricultural drought is defined as a period when soil moisture is inadequate to meet evapotranspirative demands so as to initiate and sustain crop growth. Another facet of agricultural drought is deficiency of water for livestock or

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[4] Palmer, W.C., 1965: Meteorological Drought. Research Paper 45. U.S. Department of Commerce, Washington, D.C., 58 pp.

other farming activities.

Hydrologic Drought refers to periods of below-normal streamflow and/or depleted reservoir storage. Depending on the duration of the event, hydrologic drought may include sustained low-flows. A low-flow event typically refers to a short period of low streamflow occurring on an annual basis. Closely related to the concept of low-flow in defining drought is the use of the number of consecutive months that a streamflow was deficient.

Economic Drought is the result of physical processes but concerns the areas of human activity affected by drought. The human effects, including the losses and benefits in the local and regional economy, are often a part of this definition.

There are impacts which are either combinations or after-effects of the above, such as increased damage due to forest fires under dry conditions associated with drought.

DROUGHT OF 1988 IN THE CONTIGUOUS UNITED STATES

During the early and mid-1980's the climate of the United States was unusually wet. High lake levels in the Great Salt Lake and Great Lakes Basin dominated national attention. In July 1983, for example, the entire nation was on the wet side of the drought scale, according to the PSDI. One year later, in July 1984, only a few percent of U.S. land area fell within the severe and extreme dry categories of the PDSI as shown in Figure 1a. About five percent of the continental U.S. experienced dry conditions during that year.

PDSI QUALIFICATIONS

	extreme moist spell	potential flood impact on economics
+4.0		
	very moist spell	
+3.0		
	unusual moist spell	
+2.0		
	moist spell	
+1.0		
	insipient moist spell	
+0.5		
	near normal	
0.0		
-0.5		
	insipient drought	no significant impact on local economies
-1.0		
	mild drought	
-2.0		
	moderate drought	
-3.0		
	severe drought	severe impact on local economies
-4.0		
	extreme drought	

Two years later, July 1986, drought conditions as shown in Figure 1b were more widespread and severe and covered Montana, Wyoming and Southern California spreading eastward away from the coast and northward through some of the mountainous areas. In the southeast, severe and extreme drought began to affect the entire region from Northern Florida to Southern New Jersey. Agricultural drought already had reached the stage where midwest farmers were shipping hay to farmers in Virginia and several other southern states so that their livestock could survive. Although drought conditions were more noticeable in large areas, a large portion of the United States remained within the range of normal or above normal moisture conditions. In July, 1986 the area actually covered by very dry conditions was less than 11%.

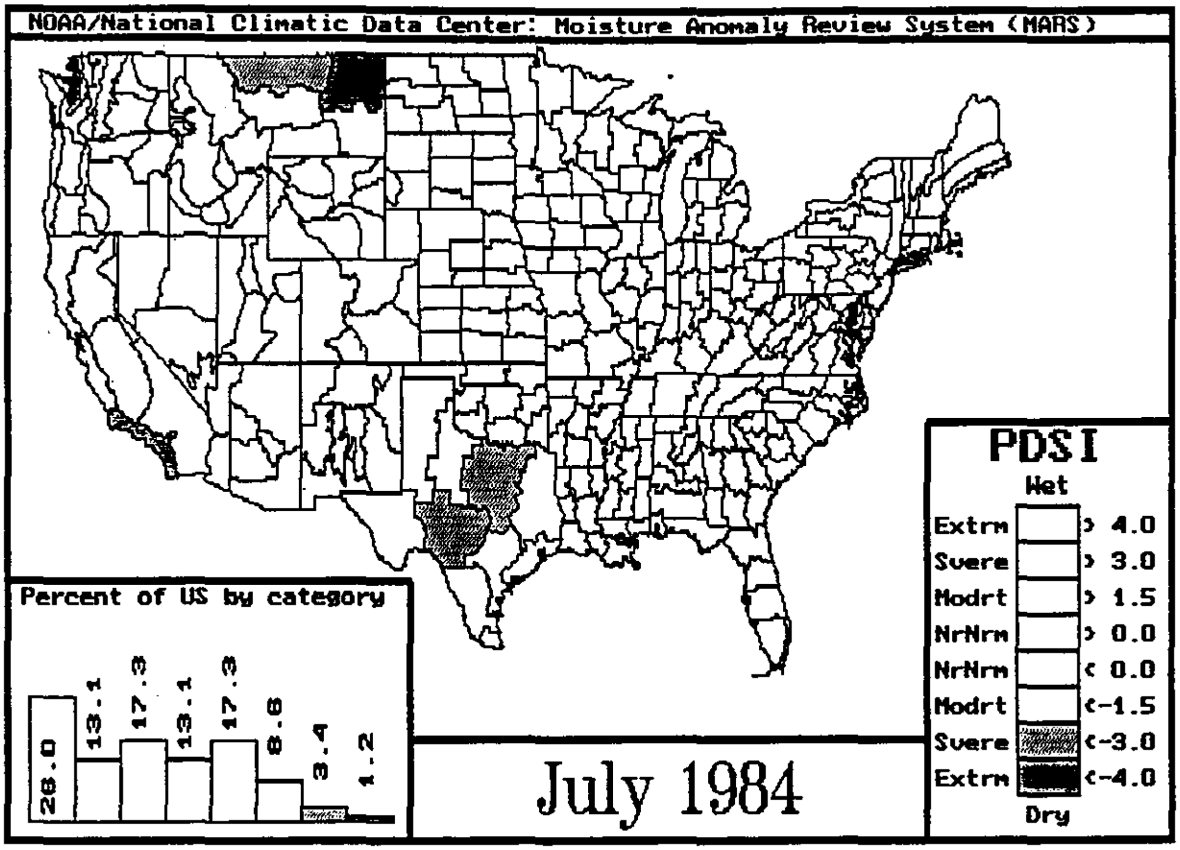
STATISTICS ON THE DROUGHT OF 1988

- Eleven states had all of their counties officially declared disaster areas;
- Streamflow was below normal (long term median) during June at 41 of the "large river" index stations across the US;
- Record lows in June were set for the Pee Dee River in South Carolina, the Tombigbee River in Alabama and the Scioto River in Ohio;
- The combined flow of the three largest rivers in the lower 48 states - Mississippi, St. Lawrence, and Columbia - were 45% below normal in June and the lowest combined June flow in 60 years.

By April, 1988 severe dry conditions began to develop in the northwest and upper midwest. One month later, May conditions became worse, and in June the area of extreme drought was

Figure 1a. Palmer Drought Severity Index maps calibrated to show only severe or extremely severe drought areas (shaded) for July 1984. Less than 5% of the U.S. experienced severe or extreme drought conditions. Figure generated at NOAA's NCDC by the Moisture Anomally Review System (MARS).

Figure 1b. Palmer Drought Severity Index map calibrated to show only severe or extreme drought areas (shaded) for July 1986. About 11% of the U.S. experienced severe or extremely severe drought conditions. Figure generated at NOAA's NCDC by the Moisture Anomally Review System (MARS).


NOAA/National Climatic Data Center: Moisture Anomaly Review System (MARS)
Percent of US by category
28.0
13.1
17.3
13.1
17.3
8.8
3.4
1.2
July 1984
PDSI
Wet
Extrm > 4.0
Svere > 3.0
Modrt > 1.5
NrNrm > 0.0
NrNrm < 0.0
Modrt <-1.5
Svere <-3.0
Extrm <-4.0
Dry

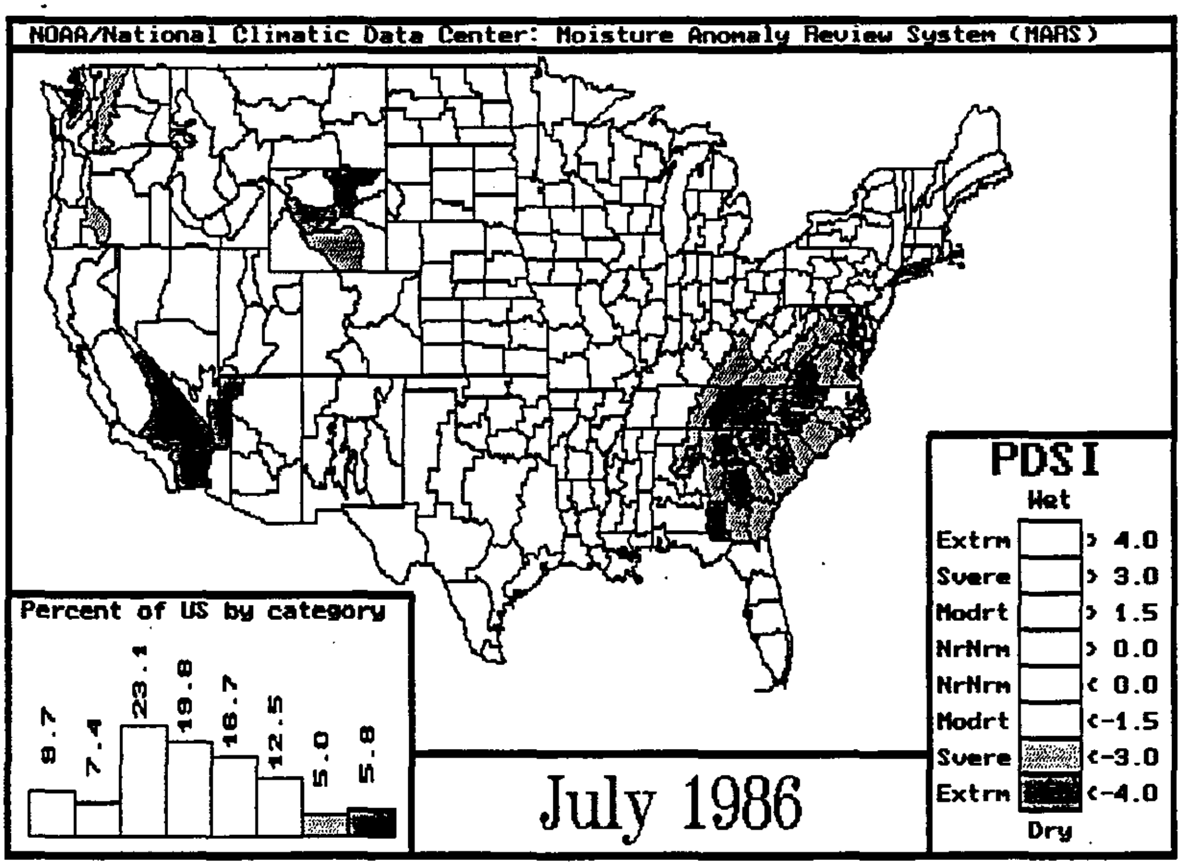
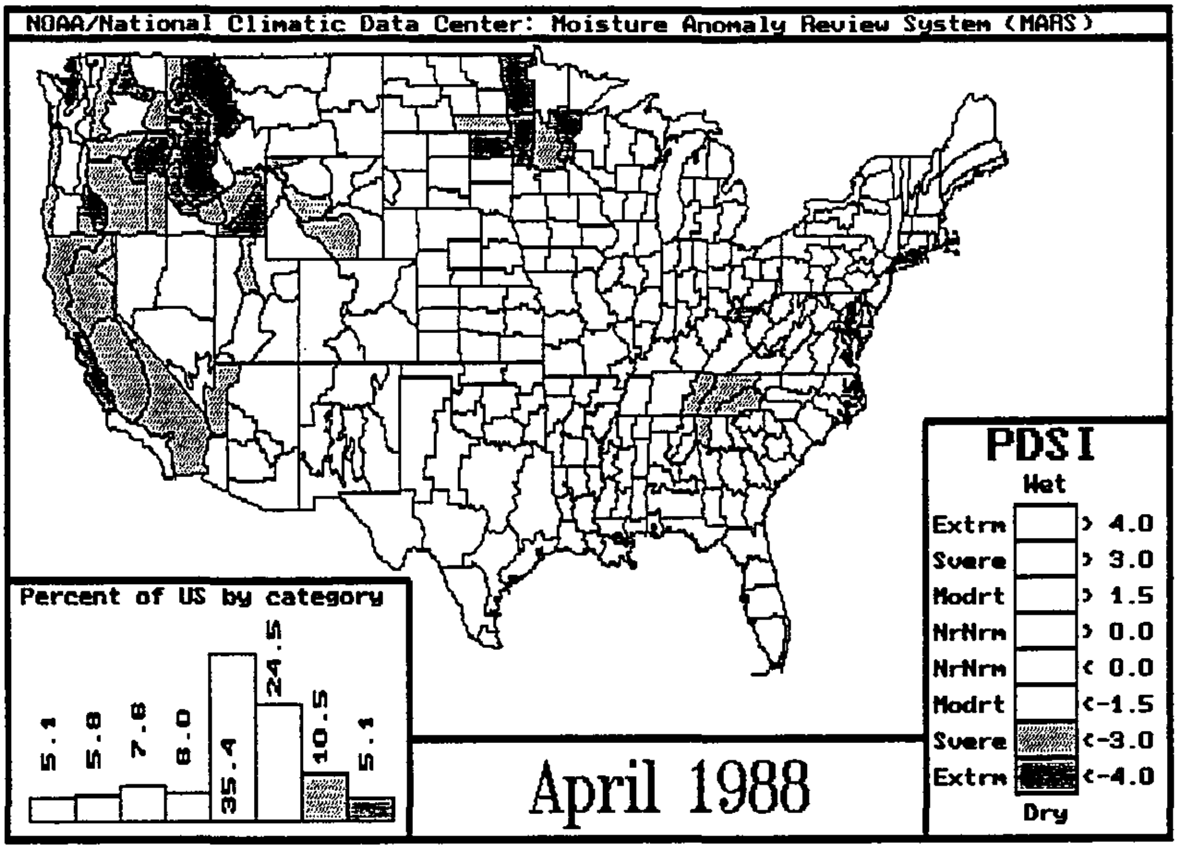

NOAA/National Climatic Data Center: Moisture Anomaly Review System (MARS)
Percent of US by category
8.7
7.4
23.1
19.8
16.7
12.5
5.0
5.8
July 1986
PDSI
Wet
Extrm > 4.0
Svere > 3.0
Modrt > 1.5
NrNrm > 0.0
NrNrm < 0.0
Modrt <-1.5
Svere <-3.0
Extrm <-4.0
Dry

Figure 2a. Palmer Drought Severity Index map calibrated to show only severe or extremely severe drought areas (shaded) for April 1988. Nearly 16% of the U.S. experienced severe or extreme drought conditions. Figure generated at NOAA's NCDC by the Moisture Anomally Review System (MARS).

Figure 2b. Palmer Drought Severity Index map calibrated to show only severe or extreme drought areas (shaded) for May 1988. Over 22% of the U.S. experienced severe or extreme drought conditions. The area experiencing extreme drought had increased by 8% since April. Figure generated at NOAA's NCDC by the Moisture Anomally Review System (MARS).


NOAA/National Climatic Data Center: Moisture Anomaly Review System (MARS)
Percent of US by category
5.1
5.8
7.6
8.0
35.4
24.5
10.5
5.1
April 1988
PDSI
Wet
Extrm > 4.0
Svere > 3.0
Modrt > 1.5
NrNrm > 0.0
NrNrm < 0.0
Modrt <-1.5
Svere <-3.0
Extrm <-4.0
Dry

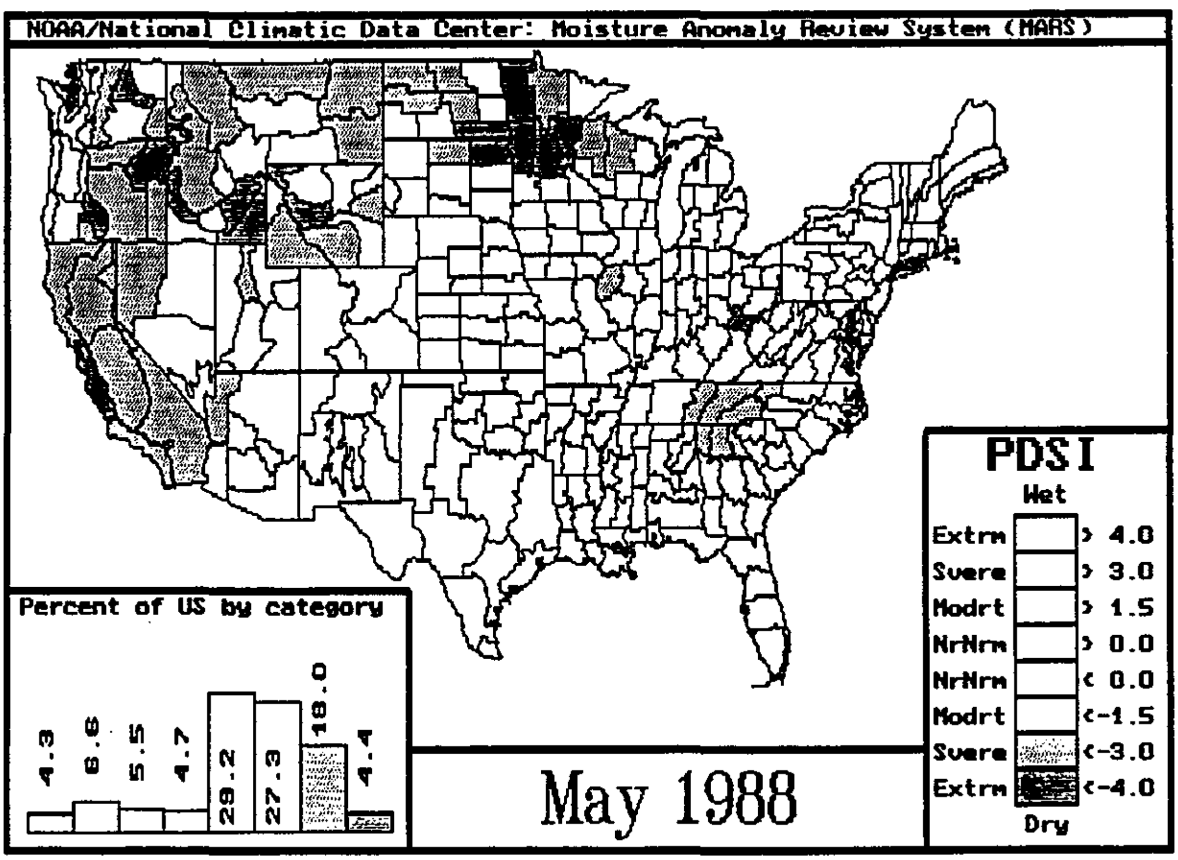
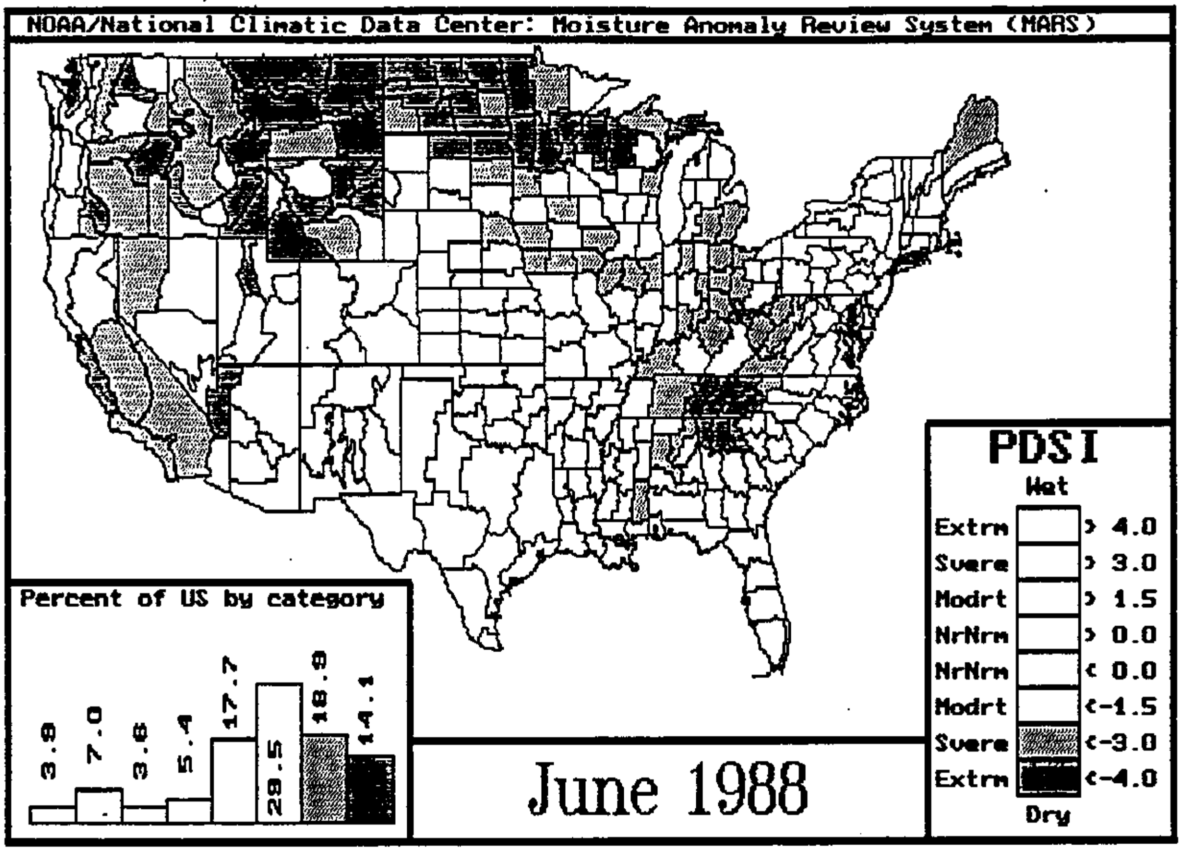
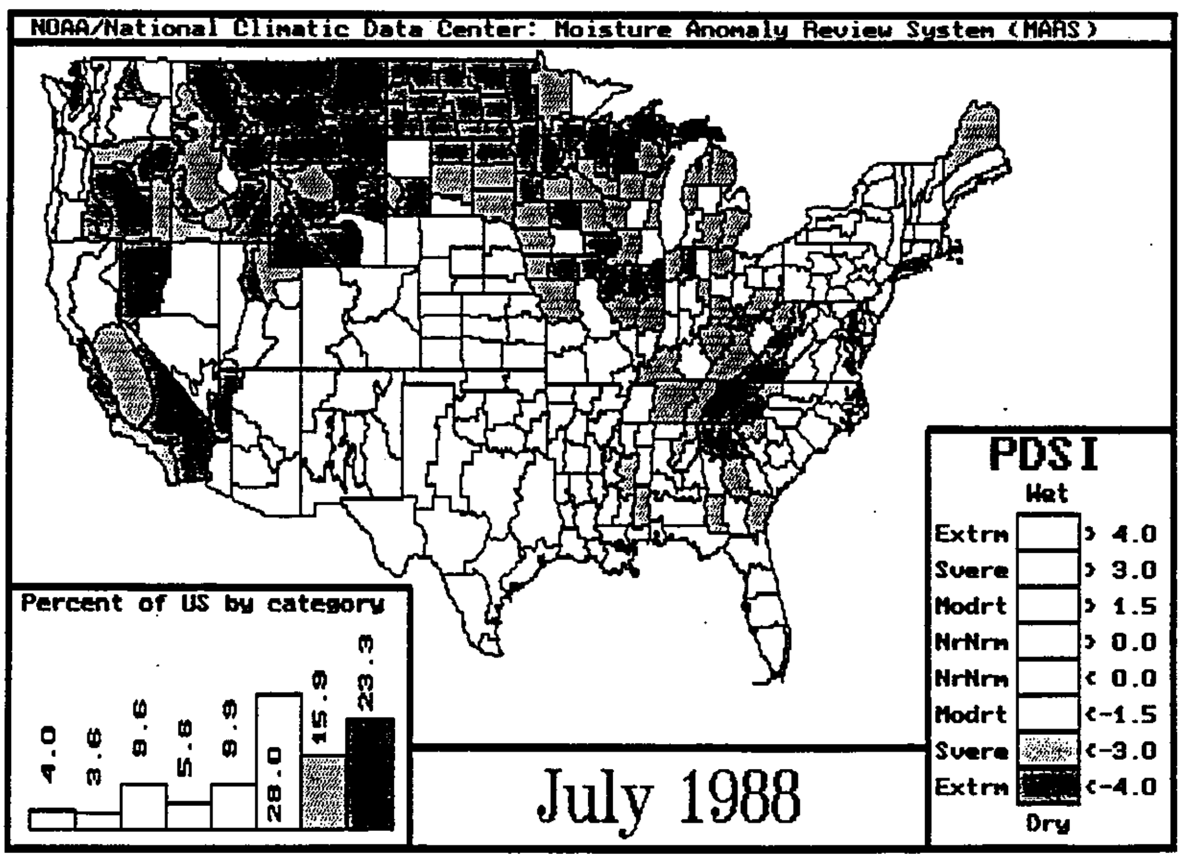

NOAA/National Climatic Data Center: Moisture Anomaly Review System (MARS)
Percent of US by category
4.3
6.6
5.5
4.7
29.2
27.3
18.0
4.4
May 1988
PDSI
Wet
Extrm > 4.0
Svere > 3.0
Modrt > 1.5
NrNrm > 0.0
NrNrm < 0.0
Modrt <-1.5
Svere <-3.0
Extrm <-4.0
Dry

Figure 2c. Palmer Drought Severity Index map calibrated to show only severe or extreme drought areas (shaded) for June 1988. 33% of the U.S. experienced severe or extreme drought with a 10% increase since May in the area with severe drought. Figure generated at NOAA's NCDC by the Moisture Anomally Review System (MARS).

Figure 2d. Palmer Drought Severity Index map calibrated to show only severe or extreme drought areas (shaded) for July 1988. 36% of the U.S. experienced severe or extreme drought. This area began to gradually decrease with rains in August. Figure generated at NOAA's NCDC by the Moisture Anomally Review System (MARS).



NOAA/National Climatic Data Center: Moisture Anomaly Review System (MARS)
Percent of US by category
3.8
7.0
3.6
5.4
17.7
28.5
18.9
14.1
June 1988
PDSI
Wet
Extrm > 4.0
Svere > 3.0
Modrt > 1.5
NrNrm > 0.0
NrNrm < 0.0
Modrt <-1.5
Svere <-3.0
Extrm <-4.0
Dry



NOAA/National Climatic Data Center: Moisture Anomaly Review System (MARS)
Percent of US by category
4.0
3.6
9.6
5.6
9.9
28.0
15.9
23.3
July 1988
PDSI
Wet
Extrm > 4.0
Svere > 3.0
Modrt > 1.5
NrNrm > 0.0
NrNrm < 0.0
Modrt <-1.5
Svere <-3.0
Extrm <-4.0
Dry

widespread. The drought sequence for the months April, May, June and July, 1988 are shown as Figures 2a, b, c, and d, respectively. By July, 1988 a major shift over most of the nation from wetness to dryness had occurred, and the effect and severity of the drought was being compared by the news media to the drought of the 1930's. A significant part of the United States now experienced some level of dry conditions. All of Southern California was marked by severe or extreme drought. Drought conditions covered all of Montana, and spread eastward throughout almost all of the upper midwest into the Great Lakes Region. Drought conditions in the U.S. formed a large inverted "U"-shaped pattern from California through the upper Great Plains and into the southeast. Despite several years of continuous dry conditions in the southeast, portions of Virginia were still able to produce a crop of hay so that shipments could be made to farmers in the midwest in order to return their favor of 1986 and 1987.

But the drought of 1988 was firmly established by May. In July, over thirty-nine percent (39%) of the nation had severe or extreme drought while an additional twenty-eight (28%) percent had moderate drought. Figure 3 shows that the area covered by drought in 1988 was several times greater than drought conditions in the U.S. over the past 4 years. In fact, the national cumulative precipitation, that is, the summation and arithmetic average of all weather observing stations' precipitation data, was below the climatological norm for every month during 1988. Figure 4 graphs the difference between the 1988 and normal

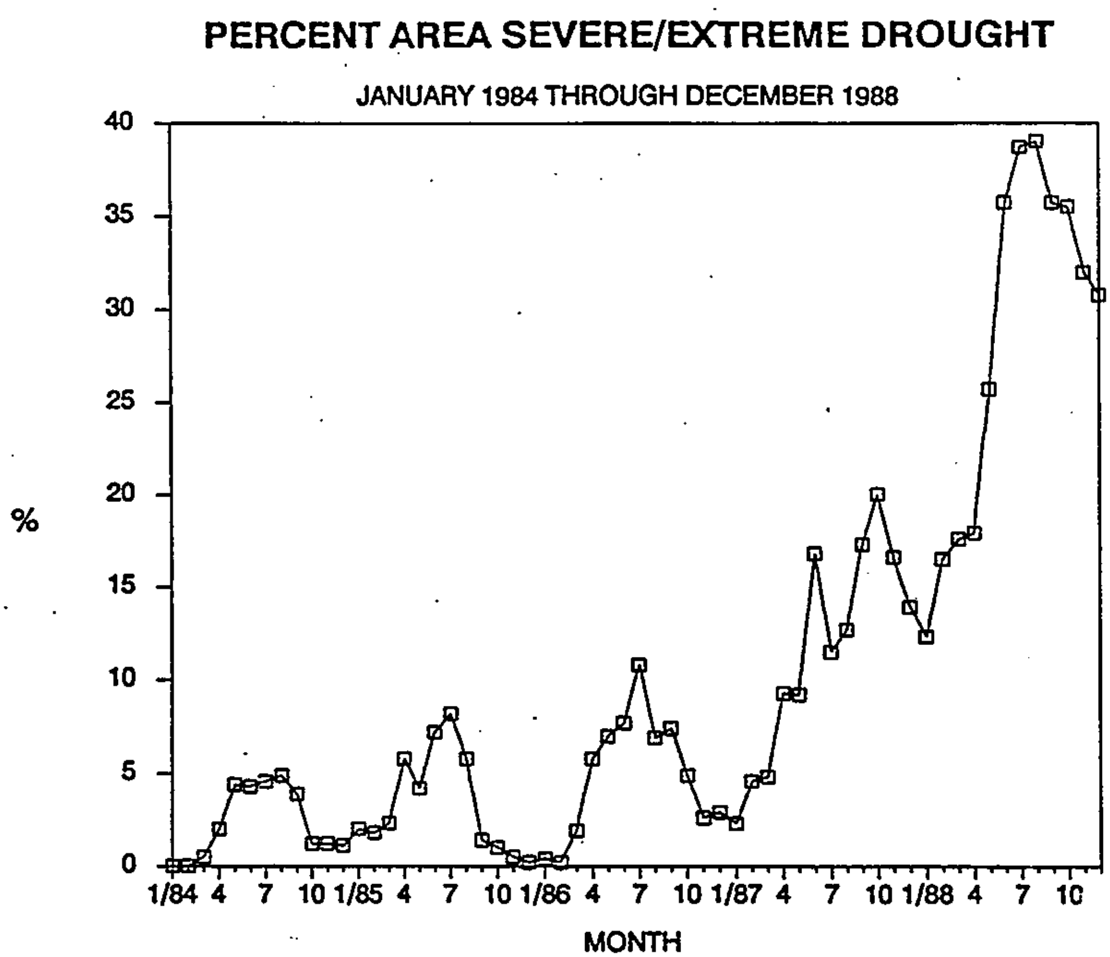


Figure 3. Percentage area of the contiguous United States covered by severe or extreme drought from January 1984 to December 1988. (NCDC/NOAA).

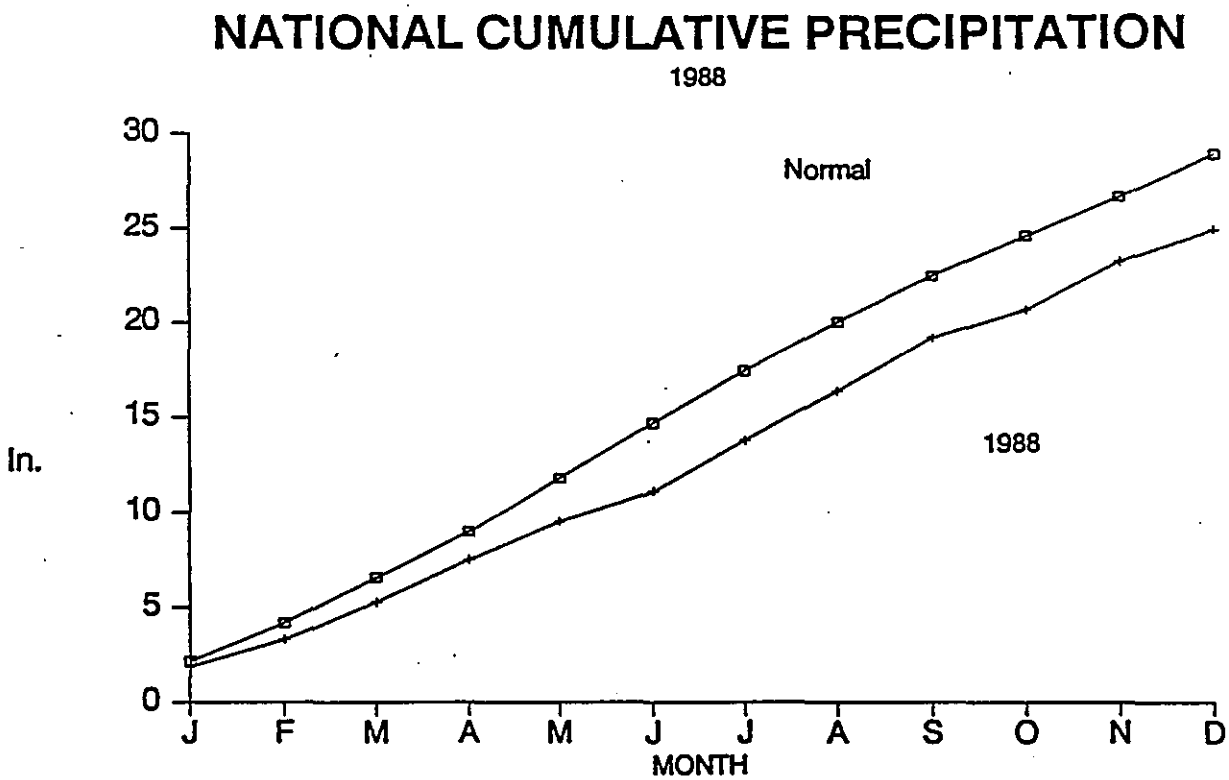


Figure 4. National cumulative precipitation (inches) for the contiguous United States based on a long term average (top line) and the 1988 national cumulative precipitation (bottom line). (NCDC/NOAA).

cumulative precipitation showing a steady increase throughout the year resulting in a nearly 3 and 1/2 inch overall deficit by December. Over the last five years, this deficit has been most acutely felt in the southeast U.S. as illustrated in Figure 5. There, Georgia, Alabama, North and South Carolina, and Tennessee were as much as 20% below cumulative precipitation amounts.

JANUARY CLIMATE IN PERSPECTIVE

Preliminary calculations show that January 1989 was the tenth warmest and twentieth driest January for the nation as a whole, based upon the 95-year record of climate data archived at NOAA's National Climatic Data Center.

The preliminary monthly data also show that approximately 31 percent of the contiguous United States are still in the severe or extreme long-term drought category. There have been only ten other Januaries this century that have had more of the nation in severe or extreme drought (see table below).

Year	Percent Area
January 1935	47.2%
January 1955	47.2%
January 1957	44.1%
January 1940	42.8%
January 1934	36.6%
January 1964	33.6%
January 1954	33.0%
January 1956	32.3%
January 1977	32.1%
January 1902	32.0%
January 1989	31.2%

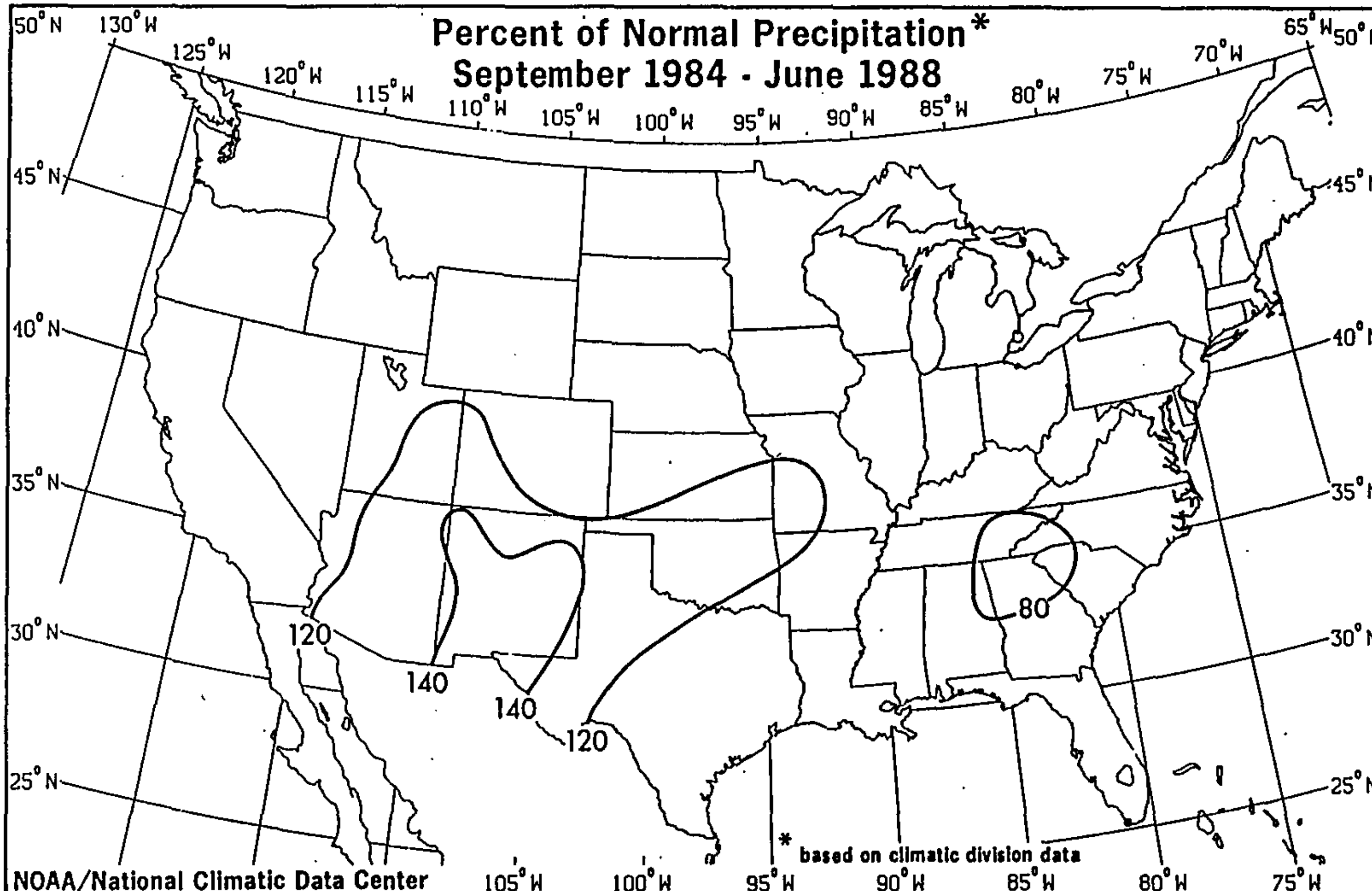


Figure 5. **Percent of normal precipitation received for the period September 1984 to June 1988. A four-state region of the southeast was about 20% below normal whereas a large area of the southwest was averaging 20 to 40 percent above normal (NCDC/NOAA).**

PRAIRIE DROUGHT OF 1988 IN CANADA

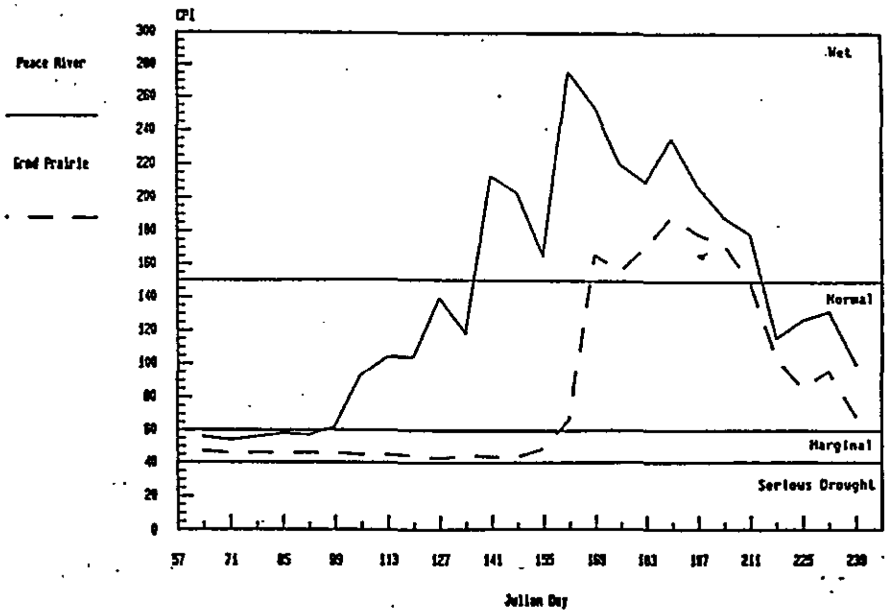
Drought conditions extended well into Southern Canada with major agricultural effects. The last significant period of wet weather occurred during the Summer of 1987. During the Fall and early Winter period of 1987, a strong upper atmospheric ridge established itself over Western North America resulting in a very mild Winter over the Canadian Prairies. The ridge also effectively blocked out all major Winter storms so that most of the southern prairies had little or no snow cover. Chinooks dominated Southern Alberta; the soil was bare; the Winter Olympics at Calgary suffered a chronic shortage of snow. As a result, wind and mild temperatures caused some soil erosion. Soil moisture reserves on the prairies were very low as the Spring of 1988 approached. Throughout April and May the dryness became readily visible. Shallow wells began to fail. Crops had stunted growth. Many municipalities experienced water shortage problems. The drought persisted through the planting, germination, and early growing periods throughout the southern portions of Alberta. During May and June, a major heat wave covered Southern Manitoba and Southeastern Saskatchewan. Temperature records were broken during the month with highs in the 40's (^{o}C) in some parts of Saskatchewan.

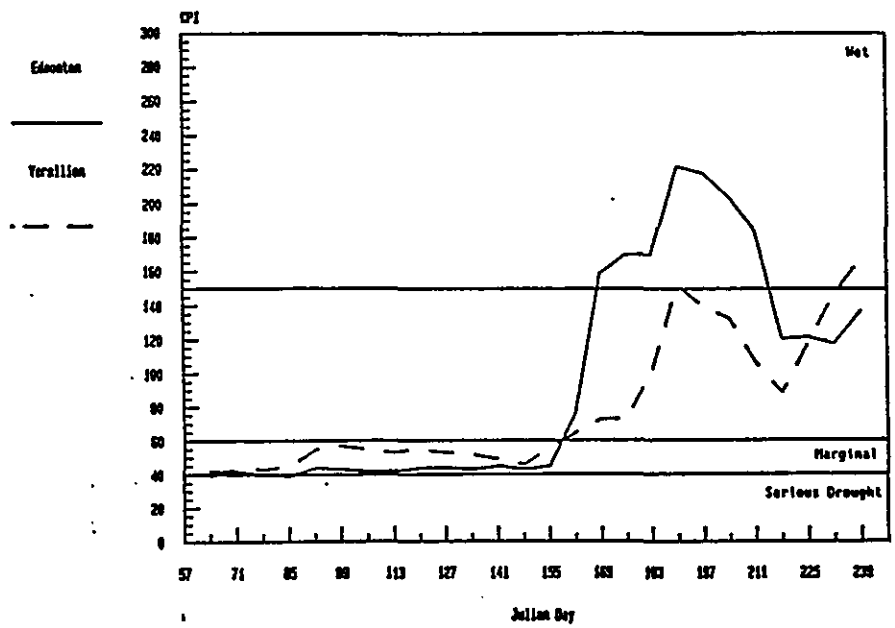
By the end of May, rain had returned to the north central regions. By mid-July it had reached the south-central regions. The most southerly regions of Alberta had not experienced a drier year since 1961. Some towns within this region recorded

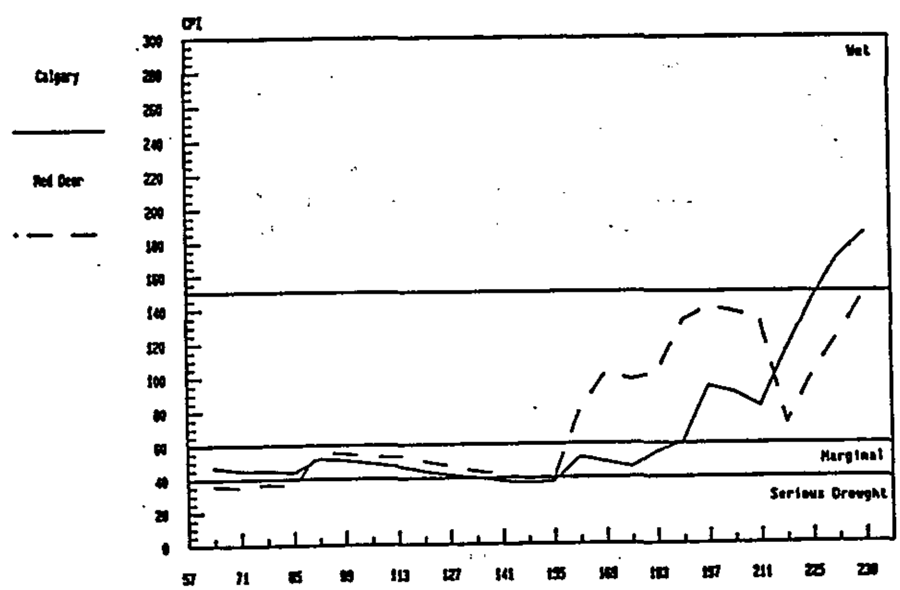
Figure 6a. Cumulative Precipitation Index (CPI) for Peace River (solid line) and Grand Prairie (dashed line), Alberta, Canada. Normal on this index is the horizontal line at 150. The year is 1988. (AES, Canada).

Figure 6b. Cumulative Precipitation Index (CPI) for Edmonton (solid line) and Vermialion (dashed line), Alberta, Canada. The normal CPI is 150. The year represented is 1988. (AES, Canada).

Figure 6c. Cumulative Precipitation Index (CPI) for Calgary (solid line) and Red Deer (dashed line), Alberta, Canada. The normal of CPI is 150. The year represented is 1988. (AES, Canada).


CPI
Peace River
Grnd Prairie
Wet
Normal
Marginal
Serious Drought
Julian Day


CPI
Edmonton
Vermilion
Wet
Marginal
Serious Drought
Julian Day


CPI
Calgary
Red Deer
Wet
Marginal
Serious Drought

their driest year ever. Drought trends during 1988 for Southern Canada can be seen by referencing Figures 6a, b, and c which show the Cumulative Precipitation Index (CPI). The CPI is the percentage of actual precipitation to the normal over an eight week period. The figures show near serious drought until early June when a series of significant rainstorms began to remoisten the soil. The Figure shows a series of six Alberta towns from north to south. Peace River is the furtherest north while Red Deer is the most southerly station. The CPI indicates the cessation of drought conditions over the most northerly stations first. In general, precipitation over the southern prairies began breaking the drought about early July, according to this figure.

Environment Canada[5] (1988b) reports that the present decade may rival the "dirty thirties" as the driest period in the history of Western Canada. Although the thirties were slightly drier than the eighties, the margin of difference is very small. It remains to be seen how weather patterns for 1989 will influence the comparison.

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[5]Environment Canada, 1988b: The Thirties vs. the Eighties: Dryness Comparison; Climatological Briefing Note, Central Region, Scientific Services Division, Canada.

HISTORICAL PERSPECTIVE: COMPARISON TO THE 1930's AND 1950's

The climatology of the United States is characterized by recurrent droughts. Extensive intervals of drought have occurred repeatedly since 1900 and earlier as reconstructed from tree ring records. In this historic context, the drought of 1988, the third most severe of the century, is well within the bounds of the historical precipitation record as shown in Figure 7. The NCDC prepared the 94-year historical perspective of the drought using National Weather Service (NWS) annual cumulative precipitation data. The figure shows many occurrences of below average annual precipitation. The 1983-1988 precipitation curve represents one of the greatest declines in annual precipitation for the data record. For the same period (1895-1988) the average temperature for June-August, shown in Figure 8, has been on the rise since 1965 with the largest single jump occurring in 1988 and rivaling temperature rises occurring in 1936 and 1950.

From a hydrologic point of view, the drought of 1988 may be a harbinger of things to come. The national Palmer Hydrologic Drought Index (PHDI) for the period 1895-1988 is shown in Figure 9a. The PHDI is more appropriate than the PDSI for portraying droughts over a 100-year period. It is based on the same hydrologic model as the PSDI except that it respond is configured to more slowly to moistening and drying conditions of the land. Figure 9a shows a relatively minor precipitation deficit and PHDI index of -3 compared to previous drought periods, especially the droughts occurring in the 1930's and mid-1950's. Figure 9b shows

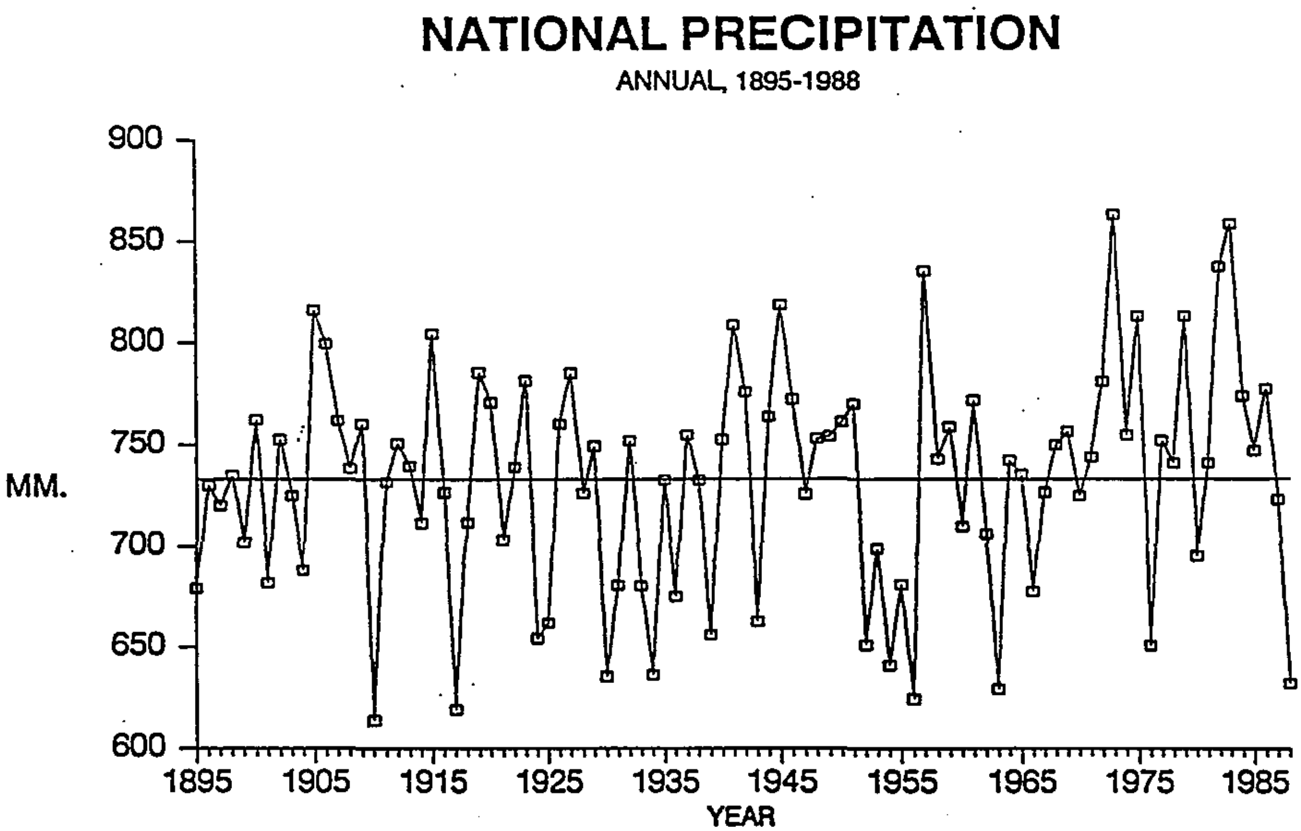


Figure 7. The U.S. national annual precipitation (mm) from 1895-1988. The national average for this period is represented by the horizontal line at about 730 mm. Note the strong interannual variability in observed rainfall and repeated frequencies of drought conditions (less than 650 mm per year) NCDC/NOAA.

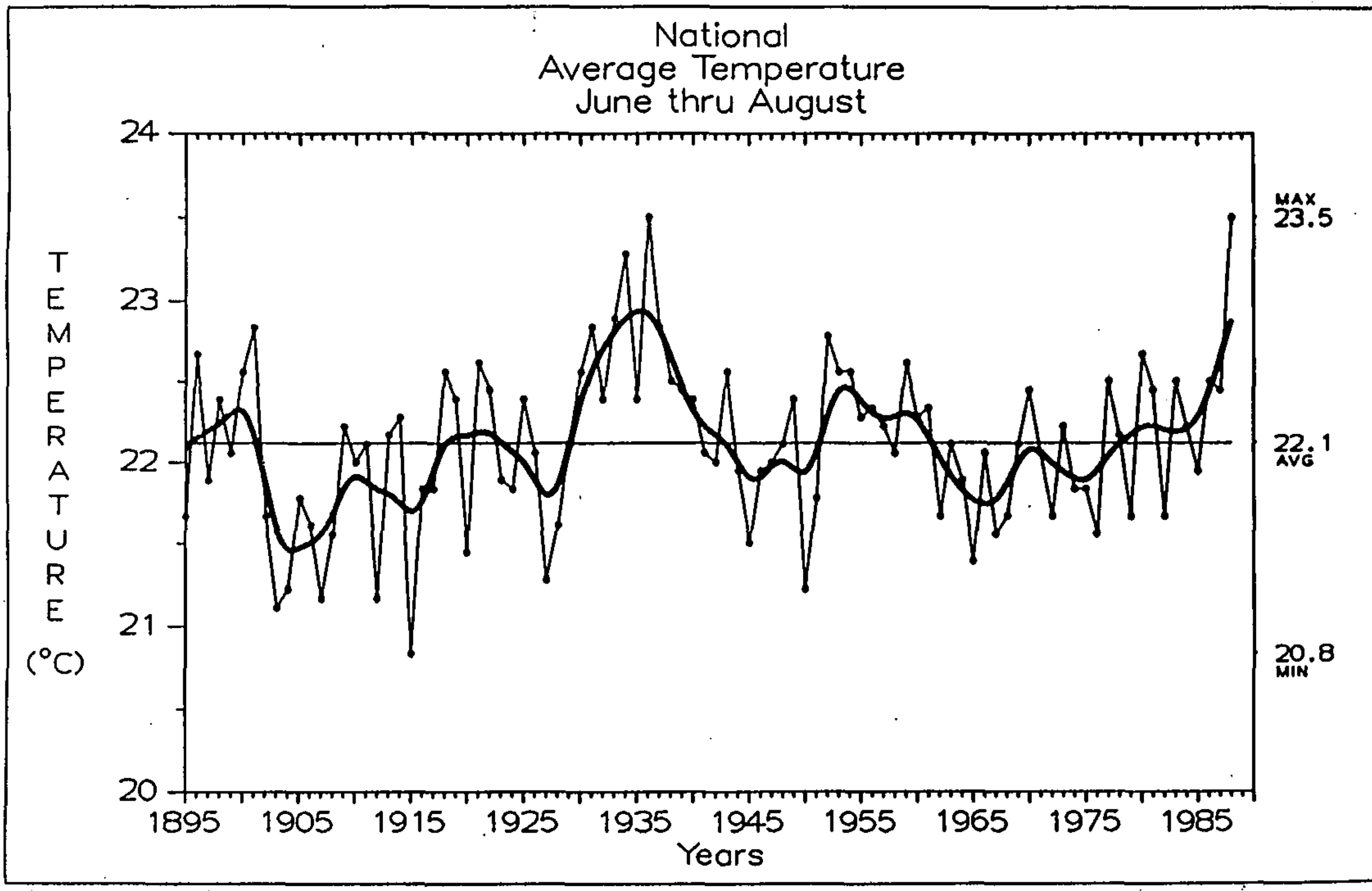


Figure 8. National average Summer temperatures (°C) over the contiguous United States. Figure is based on temperatures from June-August, 1895-1988. The average is represented by the horizontal line at 22.3°C. Note the overall rise in temperatures since 1965. (NCDC/NOAA).

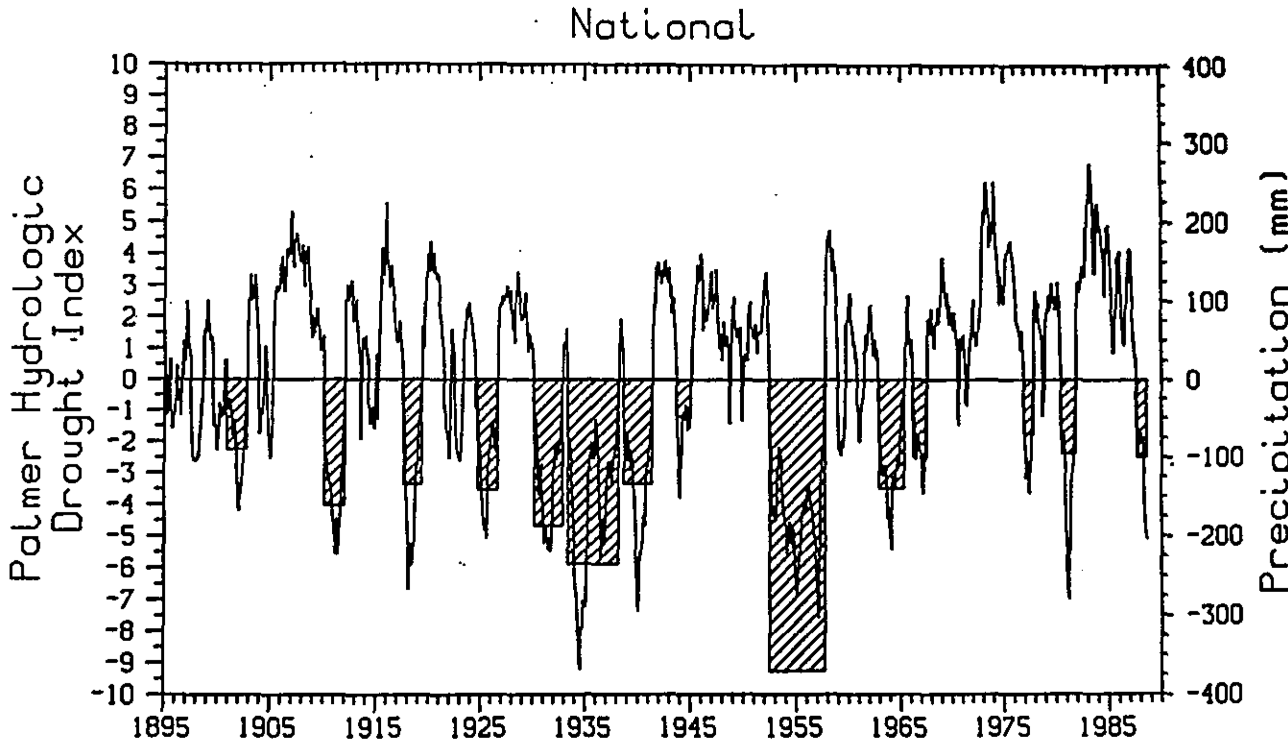
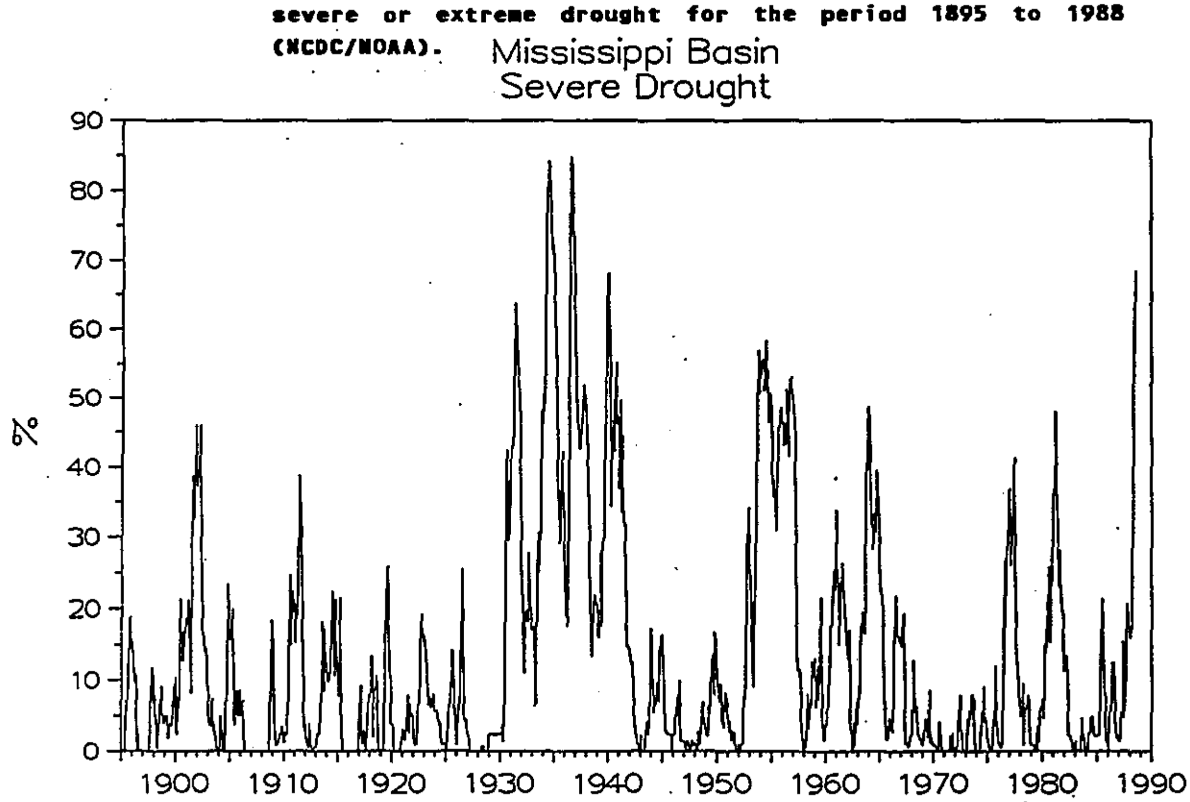


Figure 9a. Palmer Hydrological Drought Index (PHDI) for the United States from 1895 to 1988. Periods of severe drought are cross-hatched. (NCDC/NOAA).

Figure 9b. Annual percentage of the Mississippi River Basin affected by severe or extreme drought for the period 1895 to 1988 (NCDC/NOAA).



and PHDI index of -3 compared to previous drought periods, especially the droughts occurring in the 1930's and mid-1950's. Figure 9b shows the monthly percentage of the Mississippi Basin having experienced severe drought during the past 94 years. For 1988 about 66% of the Mississippi River Basin experienced severe drought. The magnitude compares only with that which occurred in the 1930's. This suggests that it might be very difficult for the midwest to recover from the 1988 drought even if precipitation is normal. The midwest drought will be explored more fully in the section devoted to the regional climate centers. It is interesting to observe that periods of severe national drought shown in Figure 9a correspond very well with episodes of severe drought experienced by the Mississippi Basin as shown in Figure 9b. This is because periods of severe national drought tend to be centered over the American heartland, which includes the Mississippi Basin.

MOST SEVERE DROUGHTS THIS CENTURY	
Most Severe	1930's
Next Most Severe	1950's
Third Most Severe	1980's*

*Still in progress - could become worse

RELATIONSHIP OF DROUGHT TO GREENHOUSE WARMING

It is not possible to directly attribute the causes of the 1988 drought in the United States and Canada to increasing levels of greenhouse gases in the atmosphere. The timing, extent and duration of the 1988 drought are well within the range of historical events.

Nevertheless, the drought of 1988 provides an example of conditions which may become more frequent in the future as the levels of greenhouse gases continue to increase in the atmosphere. Numerical modeling studies of the atmosphere, with a doubling of CO_2, suggest that soil moisture will decrease during the Summer over extensive regions of both North America and Eur-Asia in the middle and high latitudes (see Manabe, Appendix A). Thus, the drought of 1988 might serve as a model of future climate for the environmental and social systems in both the United States and Canada to develop response strategy case studies. It should be noted that the impact of the drought of 1988 was detrimental for both the United States and Canada.

DROUGHT - A GLOBAL PERSPECTIVE

Rather than being a direct manifestation of climate change, this Summer's precipitation and temperature anomalies apparently were the result of La Nina. As contrasted to El Nino, La Nina refers to the occurrence of cooler water over the central Pacific Ocean. The Climate Analysis Center identified a shift in the Southern Oscillations to its "positive phase," i.e., low-level easterlies strengthened with a wide-spread decrease in Pacific sea surface temperatures. Trenberth et al.[6] (abstract in Appendix A) found that the relatively cold Sea Surface Temperatures (SST's) that developed along the equator in the Pacific in the Northern Hemisphere Spring of 1988, combined with the warmer than normal Pacific waters from 10° - 20°N, led to a northward displacement of the Inter-Tropical Convergence Zone (ITCZ) southeast of Hawaii. They were able to demonstrate that the atmospheric heating associated with the ITCZ convection can force anomalous wave trains across North America. This was in fact observed as a strong anti-cyclone at upper levels over the midwest with a subsequent northward displaced westerly jet stream.

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[6]Trenberth, K., Grant W. Branstator, and Phillip A. Arkin, 1988: Origins of the 1988 North American Drought. SCIENCE, 242, 1640-1645.

IMPACTS OF THE 1988 DROUGHT

The United States experienced one of its more costly crop failures in 1988 because of the extreme heat and lack of precipitation in the midwest. The U.S. Department of Agriculture reported more than a third of the American corn crops had been destroyed, a loss put at 4.7 billion dollars (see Donald, Appendix A). Damage to soybeans totalled at least $3.7 billion. The overall 1988 American grain harvest amounted to no more than 192 million metric tons, the smallest since 1970, and smaller than the Soviet harvest for the first time in decades. World grain stocks fell to 288 million metric tons, representing a 63-day supply - the lowest since the mid-1970's.

Because the drought of 1988 was a nationwide event, it seems appropriate to examine impacts from the various regions of the country. Each of the Regional Climate Centers (RCC's) shown in Figure 10 has provided a description of a major impact within their region. There are clear examples of each type of drought (i.e., meteorological, agricultural, hydrologic, and economic).

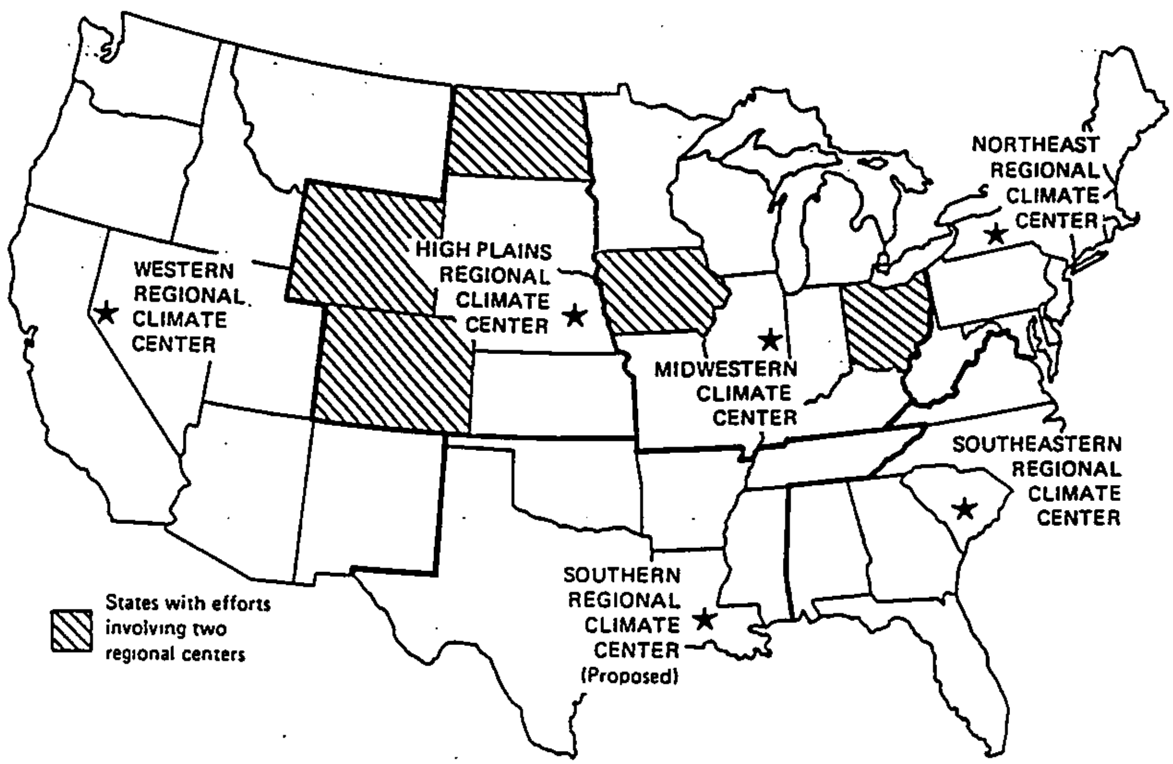

Figure 10. Existing regional climate centers for the United States. Each center acts as a focal point for data collecting, archiving, and analysis in each region (NCPO/NOAA).

SUMMARY OF IMPACTS

Western Regional Center

"If the current drought continues for a third year, hydroelectric power production in the west will most likely drop significantly."

High Plains Regional Center

"Agriculture may be severely stressed during the 1989 growing season if insufficient precipitation is received during the 1988-89 Winter to recharge soil moisture."

Midwest Regional Climate Center

"More than 700 barges were backed up at Mound City (Illinois). By June 15, 1988, the level of the Mississippi River passing Memphis was the lowest since records began in 1872."

Northeast Regional Climate Center

"The precipitation for the northeast central states during 1988 was the second worst on record. The worst year was 1936."

Southeast Regional Climate Center

"Precipitation deficit had reached the magnitude of an approximate year's normal rainfall over Western Virginia, the Western Carolinas, Northern Georgia, and Northeast Alabama."

Southern Region (proposed climate center)

"The Spring deficits and droughts of 1988 were the most severe since 1931 over sections of Northwestern Mississippi and Northern Louisiana."

Water Management and Hydroelectric Power Impacts in the West
(Western Regional Climate Center)

University of Nevada
Desert Research Institute
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Reno, Nevada 89506

Many parts of the far western United States are arid. The agriculture and urban activities in these regions depend on reserves of water collected in the mountain areas. These reserves are replenished by snowpack melting during the Spring months and precipitation - particularly on the Pacific side of the mountains. Drought, especially of long duration and wide spread, can seriously impact the region's water reserves.

The drought period of 1986-88 was compared with other critical dry years - such as those of 1976 and 1977 when very serious water shortages occurred in California. The 1986-87 and 1987-88 drought in California ranked among the severest over the past 100 years. However, water supplies were in relatively better condition during 1988 than 1977 because of responses (added storage) the state made after the drought problems of 1976-77.

Precipitation over the western states averaged 125 to 150% greater than normally expected during the period April 1 to June 30, 1988. This helped charge the reservoirs to their full capacity. The period of July 1 to August 31, 1988, saw precipitation fall to less than 50% of the normal expected for this period, and less than 25% in much of the western area. The seasonal departure of average temperature from normal for the period June 1 to August 31, 1988, was less than two degrees above normal for most of the region except the Great Basin where temperatures averaged 2 to 4 degrees above normal.

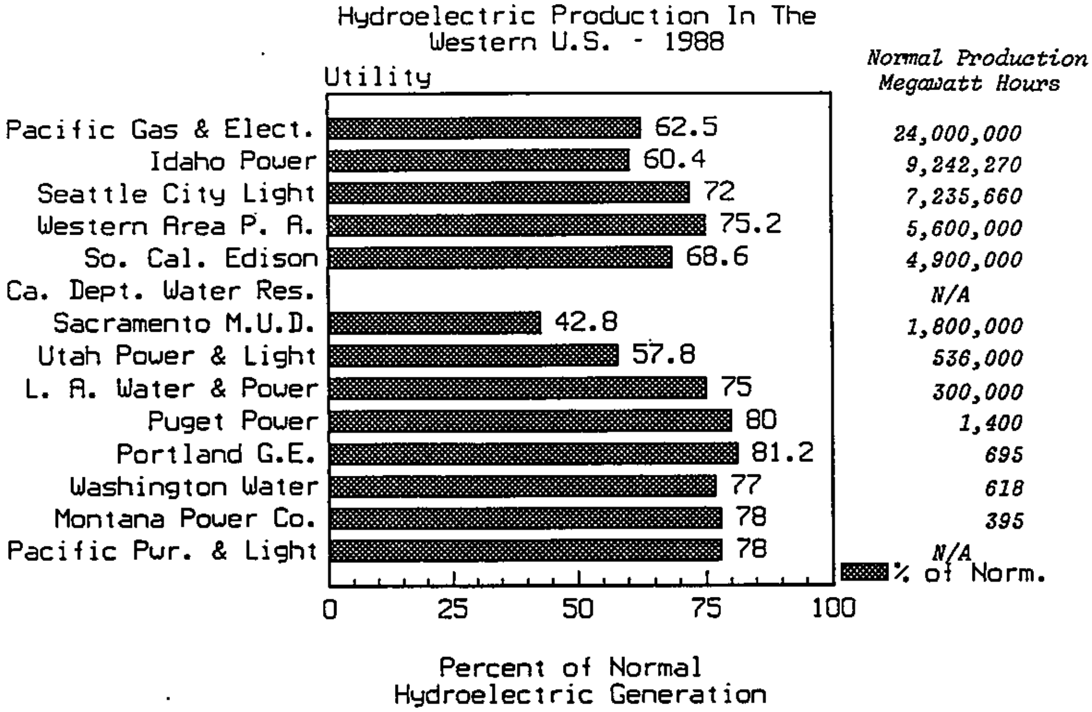
The PSDI showed moderate to severe drought for the western region and particularly California for most of 1988. This is primarily a result of the relatively dry previous year. However, California planned no major drought related action, except in certain regions of the state under the assumption that the 1988-89 Winter precipitation will be no worse than that of 1987-88. However, the San Francisco Bay area has been experiencing some salt water intrusion. High pollutant levels have occurred in a number of rivers carrying agricultural waste as these rivers have not been properly flushed due to lack of precipitation.

The reservoirs are used to supply water primarily for irrigation, domestic uses, and hydroelectric generation. Hydroelectric power contributes significantly to total power generation in the Western United States, (i.e. Washington, Oregon, California, Nevada, Montana, Idaho, Utah, and Arizona). However, the majority of power is supplied by thermal sources such as coal, oil, gas, geothermal, and nuclear power.

Major power companies in the west were contacted to determine the effect of the drought on their hydroelectric power production in 1988. All organizations in the northwest reported reduced generation of hydro-power. This reduction ranged from nineteen to fifty-seven percent shown in Figure 11, with twenty-nine percent as the mean. Hydroelectric power generation in the southwest was not impacted by the drought. In fact, water storage capacity is above normal there. And, in the near future, no problem meeting energy demands is anticipated. The percentage of total power generation attributable to hydroelectric sources varies considerably among the different producers. Nonetheless, all utilities were able to either purchase supplemental power or generate their own power from thermal sources to meet peak energy demands.

Through the "Intertie" system in British Columbia, the Pacific Northwest, and California, the utilities are able to transfer and store power (that is, use excess electricity to pump additional water into reservoir storage) between themselves to offset seasonal shortages. This system is also used to store surplus power at peak generation periods. Most utilities reported a reduction in surplus power available to sell on the Intertie. However, the surplus power available for sale was slightly higher priced.

Presently, the impact of this drought is not felt to be as severe as the 1976-77 drought when there was no power available for sale at any price. This was due in part to a greater reduction in streamflows and less reservoir storage capacity during the 1976-77 drought. Also, the power industry was still adjusting to the effects of the Arab oil embargo. The latter condition prompted a major conservation effort in the United



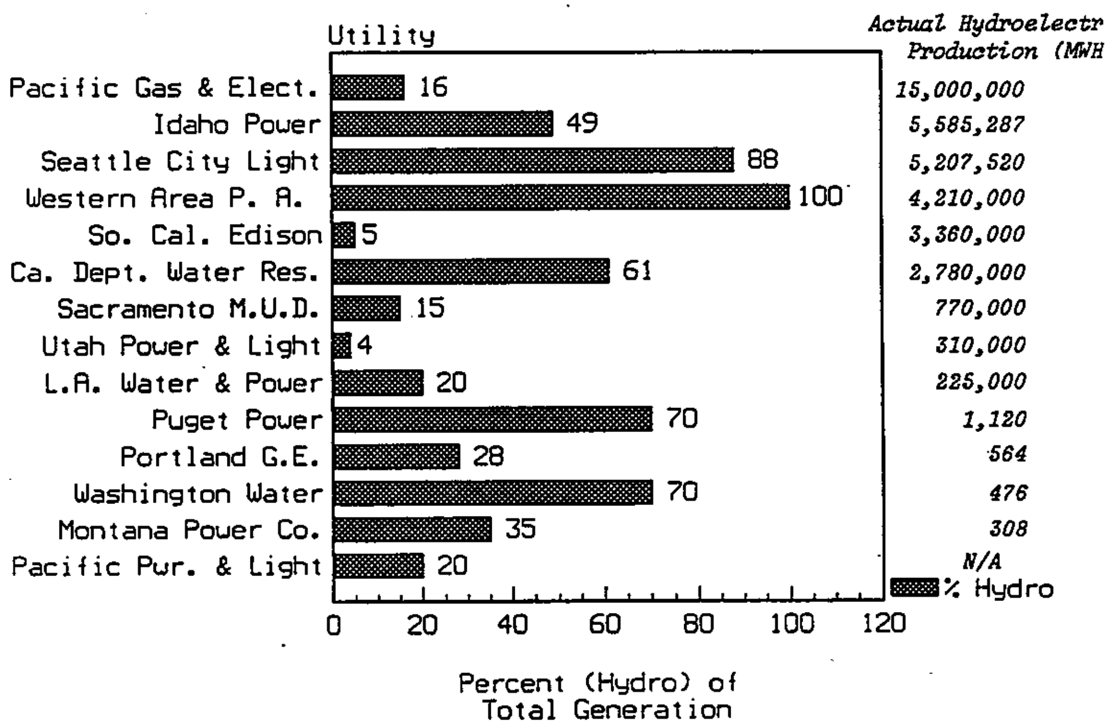
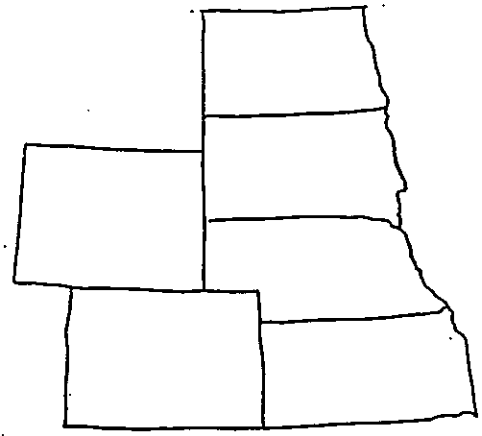


Figure 11. **Production of hydroelectric power in the Western United States by various utilities. Top figure shows percentage of normal production capacity. Bottom figure shows percentage of hydroelectric to other forms of electricity generation in each utility (Western Regional Climate Center).**

States. The mid-70's drought encouraged the improvement of cooperative activities such as the construction of additional reservoir storage to mitigate the impacts of future droughts. However, if the drought continues for a third year, hydroelectric power production in the west will most likely drop significantly.



Agricultural Drought in the High Plains
(High Plains Regional Climate Center)

University of Nebraska
237 Chase Hall
Lincoln, Nebraska 68583-0728

Drought conditions developed during the Summer of 1988 over most of the High Plains. The situation became extreme in North Dakota, the northern third of South Dakota and in Iowa. Moist conditions were present in a small area that included parts of Eastern Colorado and Western Nebraska. Weather variables from the High Plains Automated Weather Data Network (AWDN) revealed high potential evapotranspiration values shown in Figure 12a over most of the High Plains states and large precipitation deficits, Figure 12b, particularly in Colorado, South Dakota, Wyoming, Northeast Nebraska and Northwest Iowa.

Loss of water from the soil root-zone was considerable in the 1988 growing season. Rain-fed agriculture was particularly hard hit and low soil moisture levels resulted in crop stress and yield reductions in many areas. An example is shown in Figure 13 of the depletion of water in the crop root zone at Clay Center, Nebraska. Soil water was adequate during most of 1987-88 but fell to fairly low levels near the end of the growing season.

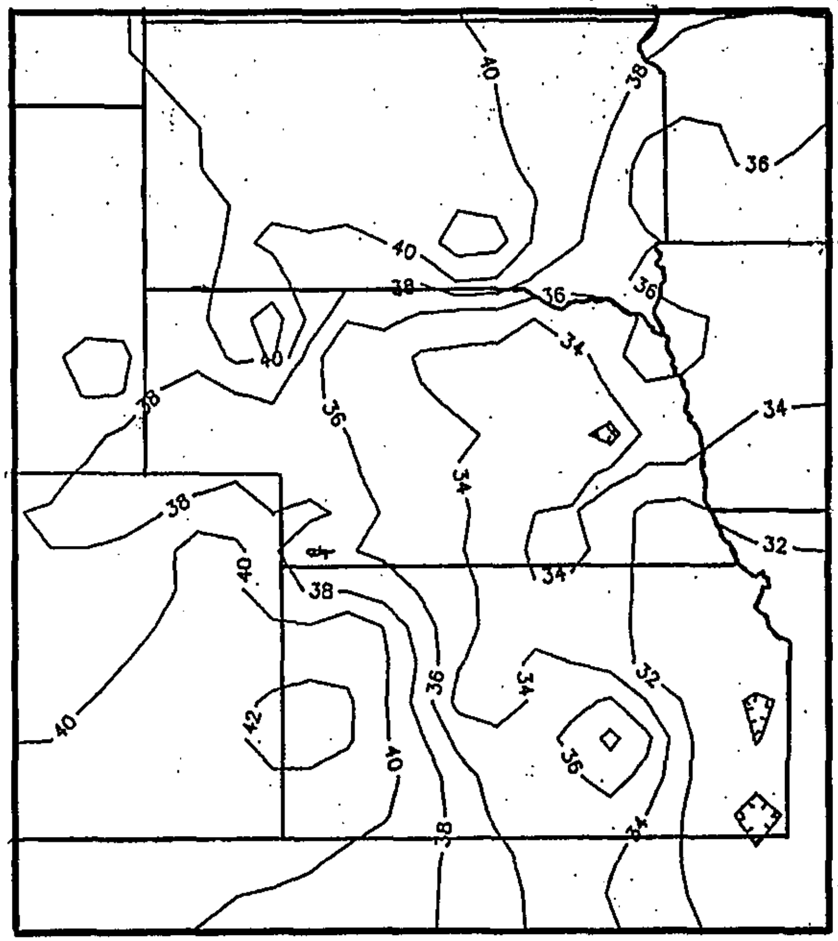


Figure 12a. Potential evapotranspiration values (cm) for the Summer, 1988 (High Plains RCC).

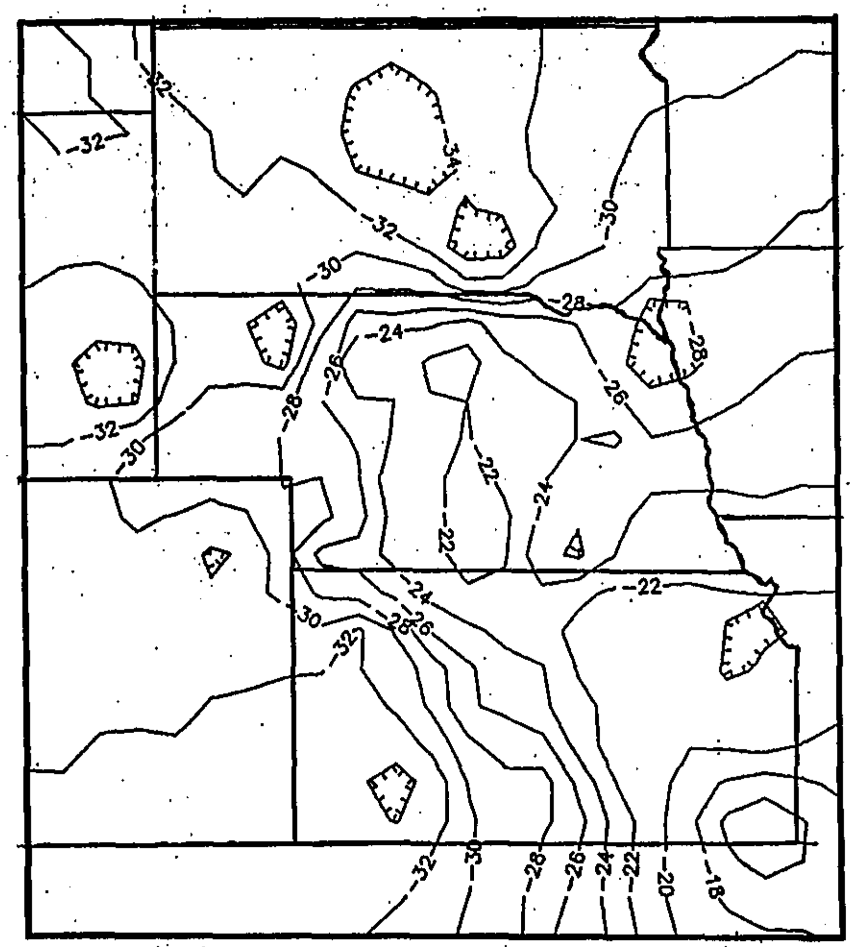


Figure 12b. Precipitation deficits (cm) from the annual normal (High Plains RCC).

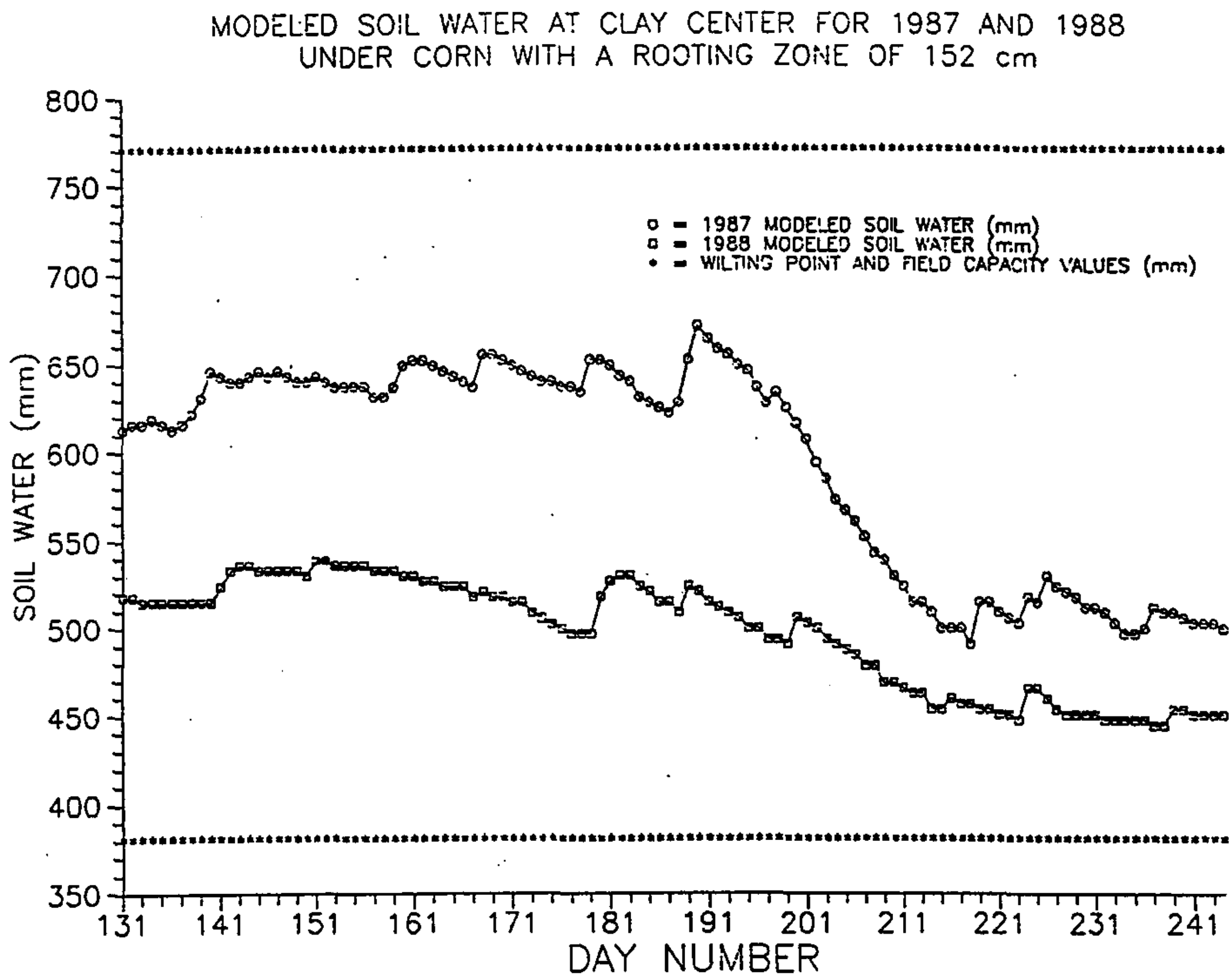


Figure 13. Comparison of 1987 and 1988 soil moisture (mm of water) available to corn roots from May 11 (Julian day number 131) to September 1 (Julian day number 243), the approximate growing season of corn. The dotted horizontal line is the plant's wilting point. (High Plains Regional Climate Center).

Below normal precipitation during the Winter resulted in very small recharge to the soil profile. High evaporative demand and low growing season precipitation resulted in low soil moisture supplies for the duration of the 1988 growing period. This scenario was common in many parts of the High Plains. Agriculture may be severely stressed during the 1989 growing season if insufficient precipitation is received during the 1988-89 Winter to recharge soil moisture.

The High Plain Regional Center provided data, summaries and advisories to many parties during the months June-September. A compilation of some of the impacts caused by the drought in the High Plains region are given below:

Seed Insurance	Policies sold with seed had to be withdrawn by the Company.
Seed Production	Reduction in seed production means possible seed shortage in 1989. Some companies decide to move future seed production to irrigated areas.
Rain-fed Agriculture	Reduction in yield. Federal assistance programs initiated.
Agricultural Markets	Hay prices up. Grain prices rise. Livestock flood market in Dakotas.
Irrigated Agriculture	Farmers with irrigation maintained high yields. Irrigation equipment manufacturers increase sales. Some shortage of irrigation repair and manufacturing parts. Increase in number of new wells. Irrigation frequency up. Maintenance costs up.

Livestock Production	Higher livestock mortality. Reduction in available feed supply. Danger of nitrate poisoning from drought affected alfalfa hay.
River Management	Low water levels cause reduced barge traffic. Water from rivers withdrawn from irrigators. Fish kills reported due to low water levels.
Conservation	Haying allowed on set-aside acres increases vulnerability of new grass stands and increases erosion potential. Ground water pumping reaches high level.

Hydrologic Drought in the Great River Basins
(Midwestern Regional Climate Center)

Illinois State Water Survey
2204 Griffith Drive
Champaign, Illinois 61820-7495

The Midwest Regional Climate Center is geographically situated to observe the climatic and hydrologic condition over the Missouri Basin, the upper Mississippi-Ohio Basin, and the Tennessee-lower Mississippi Basin, which collectively drain 40% of the contiguous United States. The great extent of extreme dryness across most of these major river basins is revealed in Figure 14 by patterns of severe and extreme drought for mid-June 1988. Eighty-three percent of the Mississippi Basin was covered by both severe and extreme drought with 17% of the basin area experiencing extreme drought. Severe drought seldom exists in the midwest during Spring and less seldom does its areal extent cover most of the total basin of the Mississippi (Karl, 1988).[7] Furthermore, intensification of midwest droughts during Spring is extremely unusual; only 3% of all 3-month droughts in Illinois

[7]Karl, T., 1988. See Appendix B, this report.

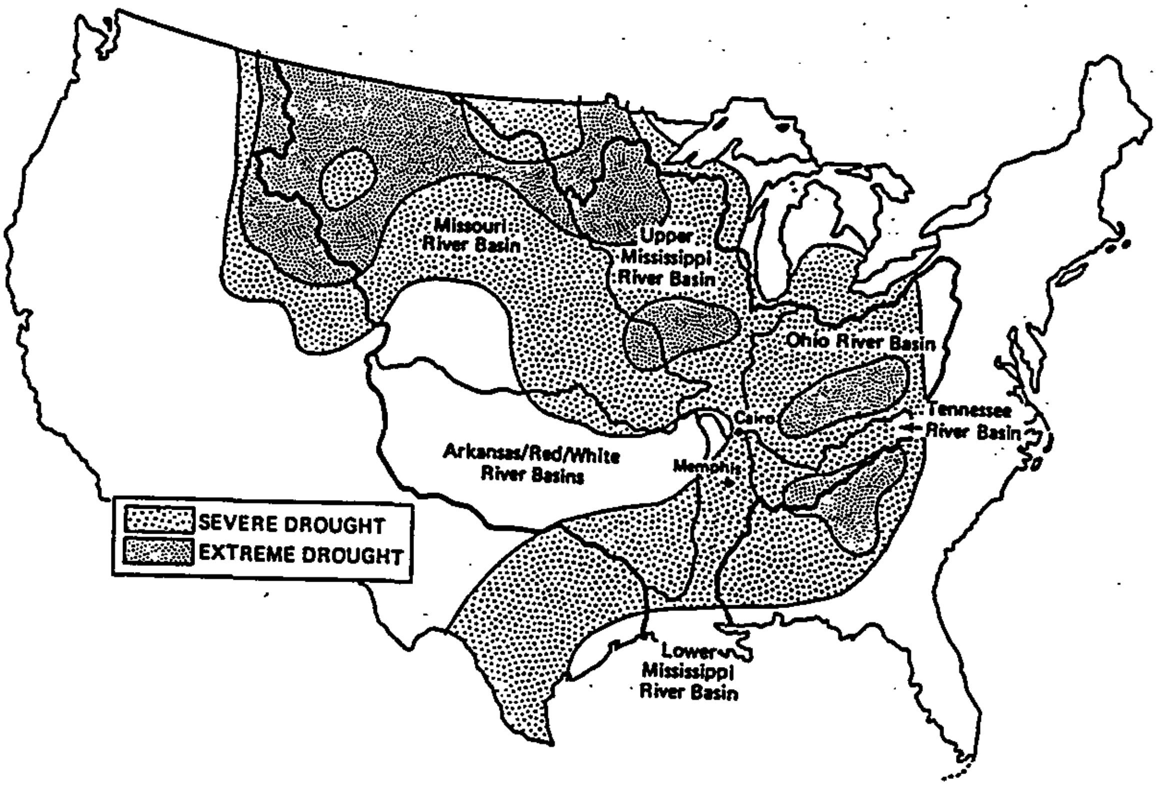


Figure 14. The Great River Basins of the United States with areas experiencing severe or extreme drought during the 1988 Summer. The Mississippi River was seriously affected. (Midwest Regional Climate Center).

since 1905 occurred during March-May (Huff and Changnon, 1963).[8]

The Midwest Climate Center analyzed daily temperature and precipitation data collected by the National Weather Service's cooperative observer climatological network of over 1500 stations in the nine state region of Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin. This region includes 68% and 62% of the U.S.'s corn and soybean acreage, respectively (USDA, 1987).[9] Figure 15a shows the spatial pattern of precipitation as a percentage of the 1951-1980 mean for the prime growing season of April-August 1988. Virtually the entire area received less than 75% of average precipitation and some areas less than 50%.

Figure 15b gives the rank of April-August 1988 precipitation as compared with 93 years of historical records. A rank of 1 indicates the driest. Of the 75 climate divisions, 55 have a ranking of 9 or lower, which puts 1988 in the driest 10 percentile of years for those climate divisions. Ten divisions experienced their driest April-August period on record. These were located in Eastern Iowa, Southern Wisconsin, Northern Illinois, and Western Indiana.

Figure 15c shows the deviation of average temperatures from the 1951-1980 mean temperatures during June-August, 1988. Northern sections were typically 2-3°C above average while

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[8]Huff, F.A. and S.A. Changnon, 1963: Drought Climatology of Illinois. Bulletin 50, Ill. Water Survey, Champaign, 80 pp.

[9]USDA, Agricultural Statistics 1987, U.S. Government Printing Office, Washington, D.C., 1987.

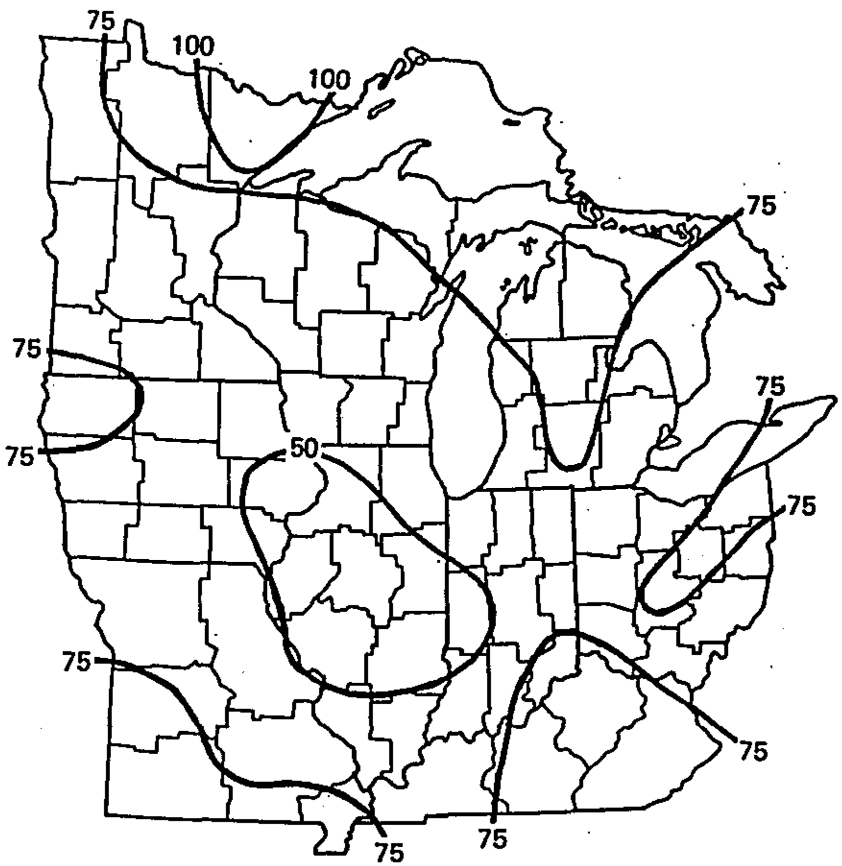


Figure 15a. Spatial patterns of precipitation as a percentage of the 1951-1980 mean for the prime growing season of April-August, 1988.

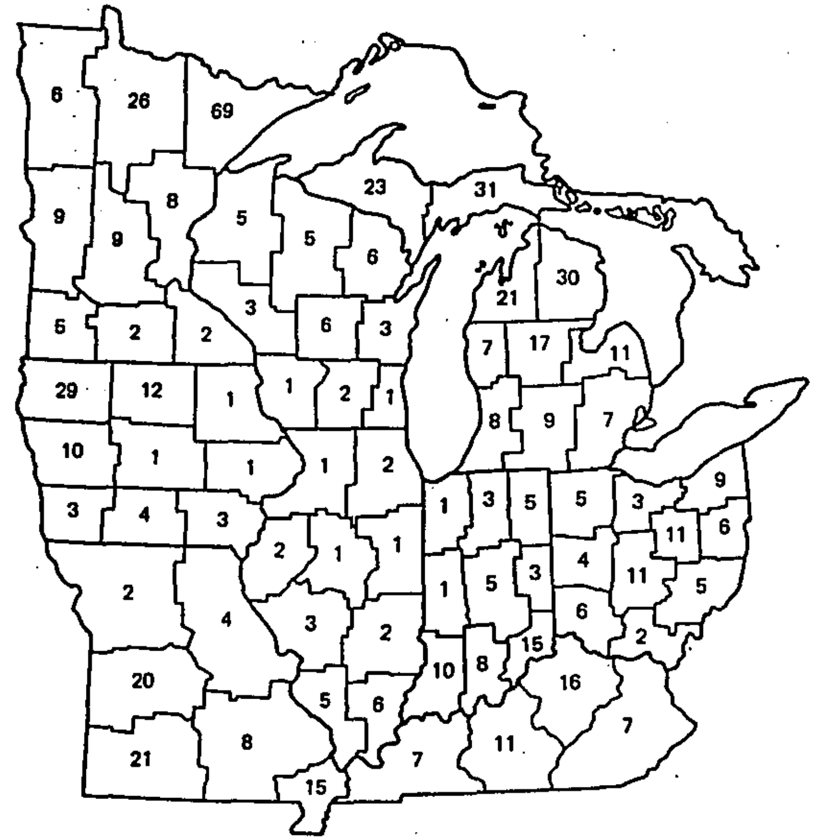


Figure 15b. Numerical rank (1 is the driest) of the April-August 1988 precipitation as compared to 93 years of historical records (Midwest Regional Climate Center).

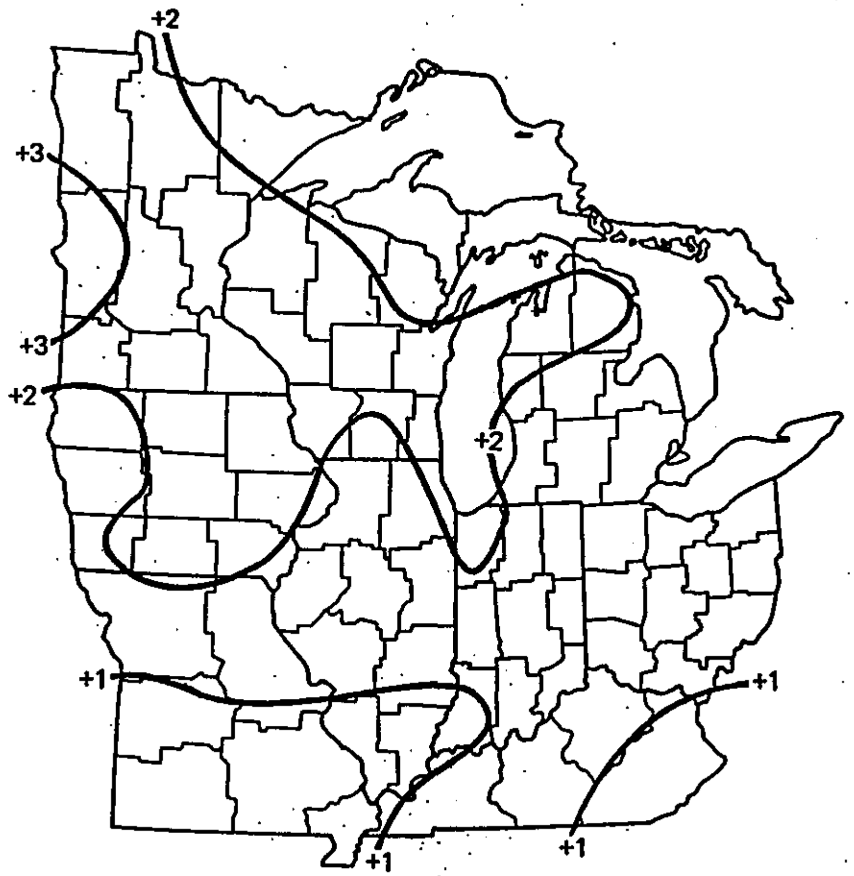


Figure 15c. Deviation of average temperatures from the 1951-1980 mean temperatures during June-August 1988 (Midwest Regional Climate Center).

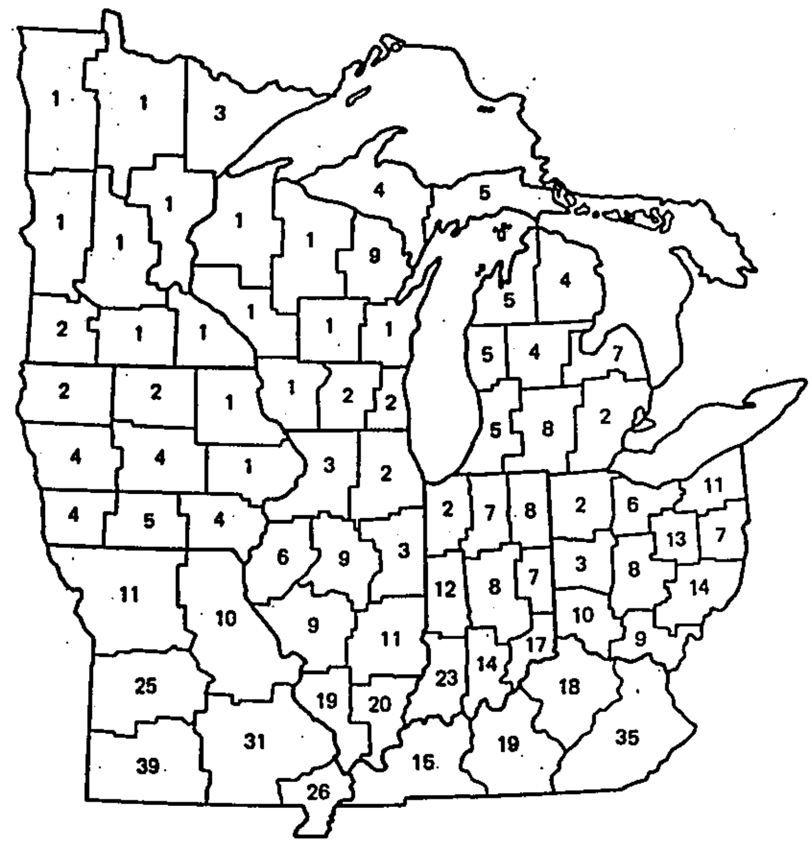
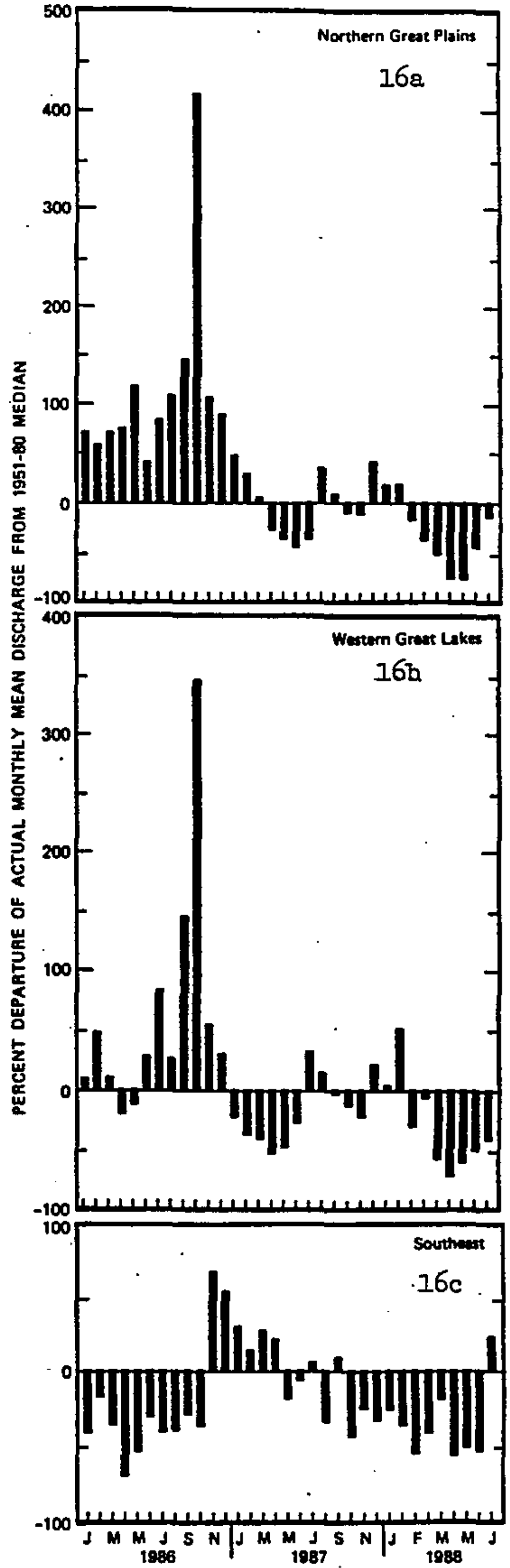


Figure 15d. Numerical rank (1 is the warmest) of 1988 compared to 1895-1987 historical data (Midwest Regional Climate Center).

southern sections were 1-2^{o}C warmer than average. Figure 15d gives the rank of 1988 compared to 1895-1987 historical data. A rank of 1 is the warmest. Fifteen climate divisions in the northwest experienced their warmest Summer ever, while 54 divisions were in the warmest 10 percentile (a rank of 1-9). For the May-June period, 1988 was the driest year of the 93-year record. Only the droughts of 1930, 1933, 1934, and 1936 have equalled or exceeded the combination of heat and dryness experienced in 1988 over the midwest region.

The ensuing river flow problems and crop losses during the Summer of 1988 actually were rooted in the weather conditions over the midwest during 1987. The average monthly flows of all gaged streams in the Northern High Plains (North Dakota, South Dakota, Minnesota, Iowa, and Nebraska), the Western Great Lakes (Illinois, Wisconsin, Indiana, Ohio, and Michigan), and the Southeast (Kentucky, Tennessee, West Virginia, North Carolina, South Carolina, Georgia, Alabama, and Mississippi) are shown in Figure 16a, b, and c and expressed as percentage departures from the median discharge for 1951-80. The departures of flows in the Northern High Plains (Figure 16a) and Western Great Lakes (Figure 16b) were both consistently well above median levels during 1986, but flows in both areas fell below median levels during the Spring and Summer of 1987. Heavy rains in August restored flows to near median levels. The above average precipitation in November and December, 1987 produced, with normal lags, slightly above median flows in both areas in December, 1987 - February, 1988. Thereafter, streamflows in



Figures 16a,b,c. Percentage departures of 1988 from the median discharge for 1951-80 for three main river basins (Midwest Regional Climate Center).

these large areas rapidly fell to less than 50% of median levels by May 1988.

The average flow in the southeast area (Figure 16c) illustrates the effects of severe drought conditions during 1985-86 (Bergman et al., 1986)[10] causing the prolonged low-flows in 1986. A return to above average precipitation in the fall of 1986 led to above median flows in early 1987, but this was followed by warm and dry conditions in 1987 leading to below median flows (25 to 50% of median) by mid-1987. Thus, all three areas were experiencing low-flows during most of 1987, and the shallow ground water supplies were at average or below average as 1988 began.

The drought of 1988 exacerbated already low flow problems in the Mississippi, Missouri, and Ohio river systems. The warm and dry conditions during most of 1987 resulted in reduced runoff in these major basin areas. The situation was again compounded by the lack of heavy snowfalls after January 1, 1988. Spring snow melt is a key input to the river flows. The 1988 snowfall in the states in the upper Mississippi drainage area ranged from 57% (Illinois) to 89% (Minnesota) of the long term averages. The basin wide value was only 70% of the average Spring snow melt.

In general, precipitation was below normal in all the major basins in February, and amounts were 25% to 75% below average over 90% of the northern Great Plains, midwest, and southeast. March continued the dry tendency with above normal temperatures and below normal precipitation over 68% of the total basin.

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[10] Bergman, K.H., Ropelewski, C.F., and M.S. Halpert, 1986: The Record Southeast Drought of 1986. Weatherwise, 39, 262-266.

Higher than average temperatures in the upper Mississippi and Missouri Basins after February increased evapotranspiration above normal levels. Thus, at the beginning of April 1988, the PDSI showed that either moderate or severe drought conditions existed in 1) Montana, the Dakotas, and Minnesota (i.e., the upper portions of the Mississippi and Missouri Rivers); 2) in Kentucky, West Virginia, and Tennessee (portions of the Ohio and Tennessee Rivers); and, 3) in Arkansas (portions of the lower Mississippi and Arkansas Rivers). By mid-May these areas of very severe drought had expanded to include Iowa, Illinois, Indiana, and Ohio. Precipitation was much below normal (>50%) in April and May and dryness extended across all regions comprising the Mississippi Basin.

Barge movements were restricted by low streamflows in portions of the lower Ohio and Mississippi Rivers in channels south of the lock and dam systems on each river, essentially south of Cairo, Illinois. This series of lock and dams controls the movement of water, helps prevent flooding, and sustains flows for water-borne transportation, power generation, irrigation, and urban water supplies. South of these controlled flow systems, river levels became minimal by late May 1988, and the slow water movement led to increased sediment deposits. Both rivers developed shallow areas where barges and tows became stuck. The river depth during parts of June and July was too slight to permit the movement of loaded barges and their tows. Barge traffic was stopped at several locales over a four-week period, with traffic reduced throughout the Summer.

Fully loaded barges must have 9 feet (2.7 m) of water for movement. In several channels near and south of Cairo, Illinois the depth of the rivers fell to less than 8 feet (2.4 m) by early June. Barges became stuck. The rivers were moving slowly leading to shoaling, the deposition of sediment in some channels, helping to make the rivers more shallow. By June 15, 1988, the level of the Mississippi River passing Memphis was the lowest since records began in 1872. A 10-mile (16-km) stretch of the Ohio River from Cairo to Mound City, Illinois (just north of the confluence with the Mississippi), was also subject to shoaling and it had river levels of less than 8 feet (2.4 m) by June 14 (News-Gazette, June 20).[11]

On June 14, 1988, the U.S. Coast Guard closed the stretch of the Ohio River north of Cairo (News-Gazette, June 17).[12] More than 700 barges were backed up at nearby Mound City, and intensive dredging began on June 14. The river was reopened by June 17, 1988. Mound City is a "river port" where three firms load midwestern grain on barges. The inability to maintain barge movements and hence to have empty barges available led to the storage of 200,000 bushels of grain on city streets. By June 27, 1988, there was more than $1 million worth of grain in open storage on city streets as elevators were unable to store the regional influx of grain that could not be moved by barges (News-

[11]Champaign-Urbana News-Gazette, June 20, 1988: "Barges Resume Trips", p. A-3.

[12]Champaign-Urbana News-Gazette, June 17, 1988: "Dry Spell Hurts River Traffic", p. B-7.

Gazette, June 27).[13] This situation confirmed Koellner's (1988)[14] earlier prediction that low Mississippi system water levels could cause many tows and barges to be stranded near areas used for fleeting and loading, and that port storage systems would accordingly be inadequate to handle incoming shipments.

> One barge hauls the equivalent of the load of 15 railroad cars or 60 semi-trailor trucks (American Waterways Operators, 1988).

By June 17, 1988, 700 barges were backed up at Greenville, Mississippi, and dredging had begun there to clear a 2000-ft (600 m) channel. By June 19, 1988, 130 tows and 3,900 barges were backed up in the Mississippi River at Memphis, but dredging temporarily opened the blockage on June 20. The barge traffic was again halted in the Cairo area of the Ohio River on June 27, 1988, and 2,000 barges were halted by low flows for several days in early July at Memphis (Farm Week, July 4).[15] Other blockages occurred along the lower Mississippi at Helena, Arkansas, at river mile post 437, and at five other locales south of Cairo

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[13]Champaign-Urbana News-Gazette, June 27, 1988: "Delays in Barge Traffic Cause Million Dollar Grain Pile Up", p.2.

[14]Koellner, W., 1988: Climate Variability and the Mississippi River. In: Societal Responses to Regional Climate Change, Forecasting by Analogy, Ed., M.H. Glantz, Westview Press, 243 p.

[15]Farm Week, July 4, 1988: "Channel Shipping Blocked in Rivers", p. 1.

(Helpa, 1988).[16]

The blockages in the Ohio and Mississippi Rivers greatly reduced the movement of bulk commodities. By early July, river traffic was down by 20%, and the Summer loss of loads shipped represented 27.3 million metric tons (Helpa, 1988). Shippers, as well as barge and tow owners, experienced these problems and the resulting economic losses. Most river ports along the central and upper river system were experiencing reduced shipments and commodity backups such as those at Mound City.

As the difficulties of moving loads became widely known in mid-June, movement of many commodities was shifted to railroads and some moved north to Great Lakes ports, bringing a loss of business to most river ports. By late July the river flows had increased sufficiently due to heavy July rainfalls in the eastern Corn Belt. This helped to avert further major blockages. However, the flow of the Mississippi at Vicksburg on August 11, 1988, was only 80,000 cfs (3,920 m^3/sec), as compared to a normal of 320,000 cfs (8,960m^3/sec), and barge loads remained less than average (Chicago Tribune, August 2).[17]

The barge and tow business in the United States is sizable. More than 300 tow and barge companies operate on the Ohio, Mississippi, and Illinois River systems, and many river ports serve the barges. The annual revenue of the barge industry is

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[16]Helpa, M.J., 1988: Corps of Engineers Briefing on Drought. Paper, Conference on Strategic Planning for Drought, Washington, D.C., 10 pp.

[17]Chicago Tribune, August 2, 2988: "Drought Toll, Opportunity", p.1.

approximately $1 billion per year (News-Gazette, August 1).[18] The barge industry carries 60% of the grain exported from the U.S., 40% of all petroleum transported within the United States, and 20% of all the coal shipments in the United States (American Waterways Operators, 1988).[19] Barge shipments typically represent 45% of all the midwestern grain crop (Chicago Sun Times, July 24).[20] Thus, the industry is one of the nation's major means for hauling bulk commodities, and as such is a key U.S. transportation industry whose viability is subject to climatic variations.

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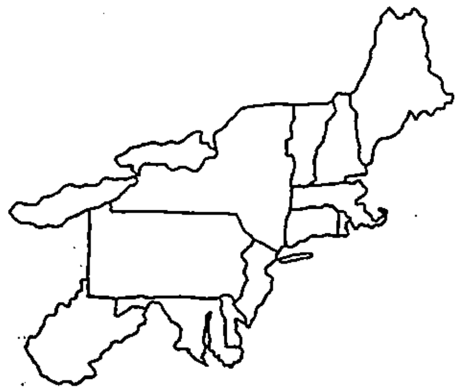
[18]Champaign-Urbana News-Gazette, August 1, 1988: Barge Operators Estimate Losses from Drought", p. A-3.

[19]American Waterways Operators, August 1, 1988: Barge Industry Reveals Drought Economic Impacts. Arlington, VA, 30p.

[20]Chicago Sun Times, July 24, 1988: "Drought Long Shadow", p.4.



Economic Drought in the Northeast
(Northeast Regional Climate Center)

1113 Bradford Hall
Cornell University
Ithaca, New York 14853

Although the drought in the northeast during the 1988 Summer season was not as severe as that occurring in other portions of the United States, above average temperatures and below average precipitation in the region produced significant economic and social impacts. However, some parts of the northeast experienced the worst drought to occur during the growing season since the devastating and prolonged drought of the mid-1960's. The late Winter and early Spring of 1988 brought only limited amounts of moisture to the northeast. Although total precipitation for the month of February was near normal, each of the months of January, March, and April produced below normal amounts. This left the northeast with a ground water deficit going into the growing season. A significant amount of rain fell in mid-May, especially over the mid-Atlantic States. The drought conditions then set in during the period from June to mid-July. Figures 17 and 18 show

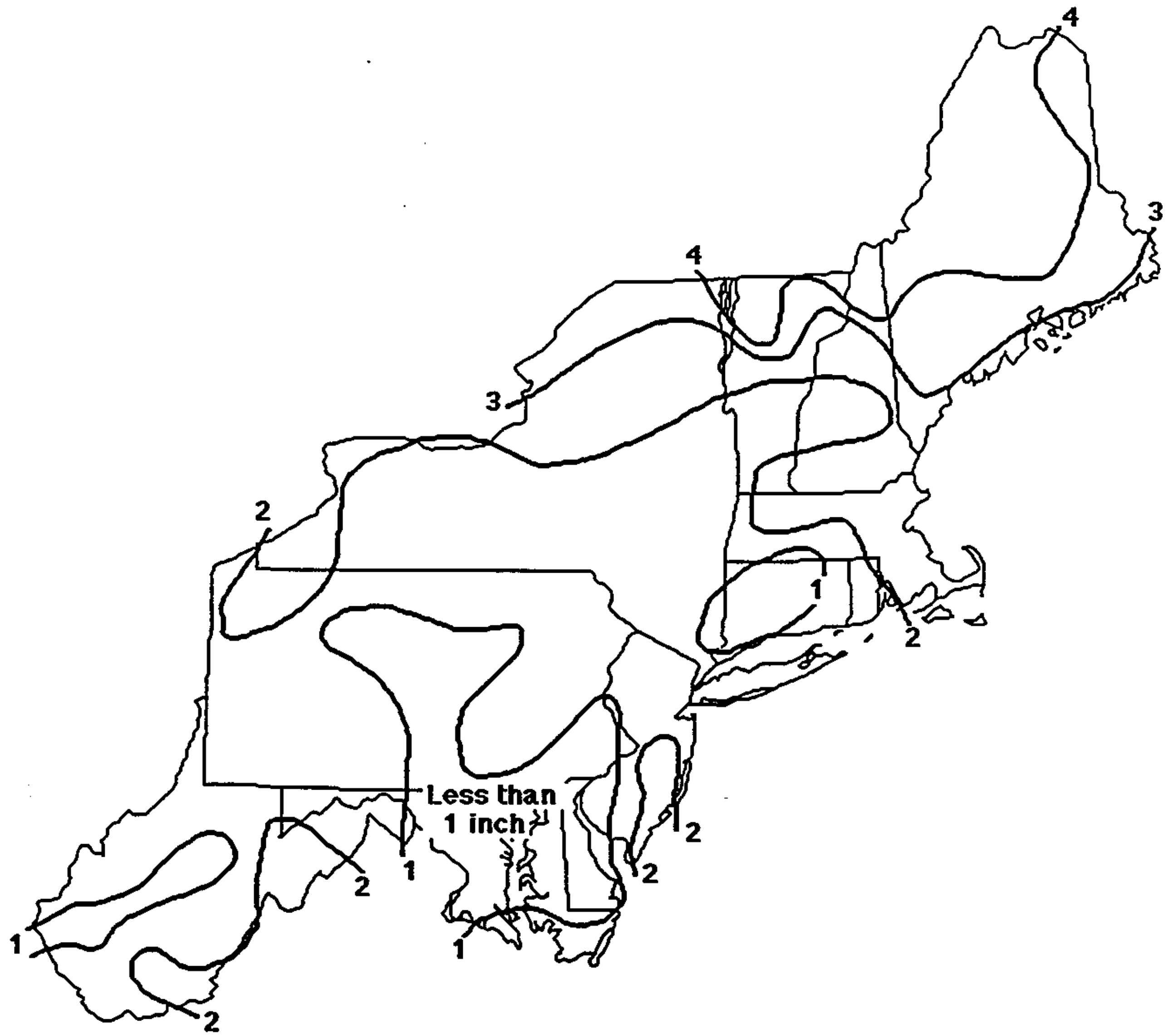


Figure 17. Total precipitation (inches) for the period 29 May to 9 July, 1988. (Northeast Regional Climate Center).

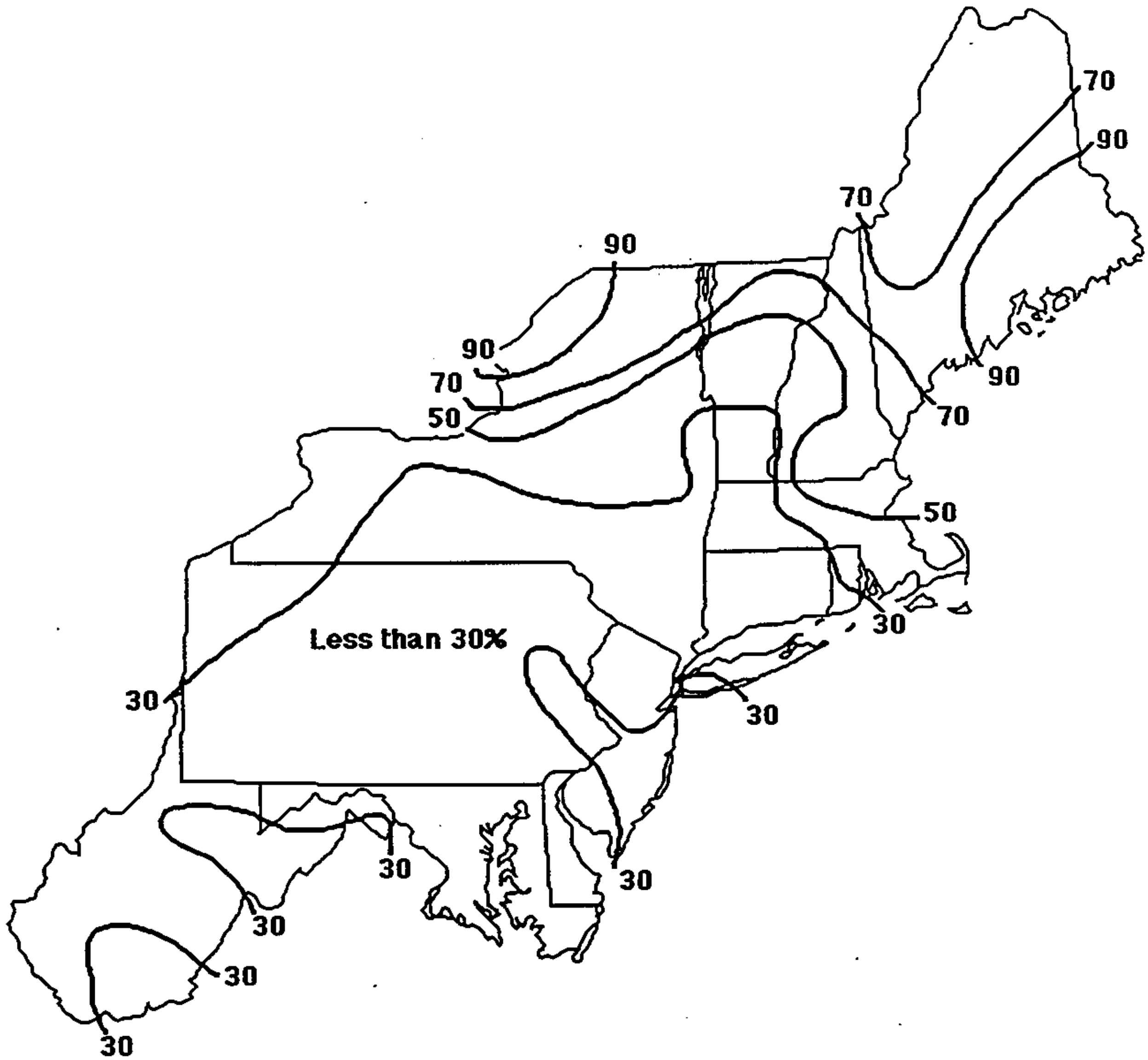


Figure 18. Percent of normal precipitation for the period 29 May to 9 July, 1988. (Northeast Regional Climate Center).

the total precipitation and percent of normal precipitation for the period May 1 to June 30, 1988. Much of the northeast received less than 70% of the normal precipitation for this two month period. A large percentage of the precipitation deficit occurred during the month of June, when some locations received less than an inch (2.54 cm) of rain for the entire month. Heavy rains at the beginning of July helped to ease drought conditions in New York's St. Lawrence and Vermont's Champlain Valley areas. The other drought stricken portions of the region, however, did not receive precipitation in amounts sufficient to have any impact on the long-term drought situation. Very beneficial rains arrived in the northeast in mid-July. These rains brought relief to some of the drought-stressed crops in the northern part of the region, but were too little, too late for some of the more southerly locations. August followed a pattern similar to that of July, with a dry first half of the month followed by substantial rainfall in the north during the second half of the month. In the south, however, precipitation was once again below the monthly normal.

In terms of temperature, June had a couple of cool weeks, but heat was the word for the remainder of the Summer. Warmer than normal temperatures were reported throughout the region each week from the end of June to mid-August. In mid-August, there was an abrupt change to a much cooler weather pattern which persisted into Autumn.

In the northeast it is quite common to expect ample soil moisture at the beginning of the growing season. This year, however, most of the northeast was experiencing mild or moderate drought conditions, while portions of Maryland and West Virginia were already experiencing severe drought at this critical time. The dryness of June into the first half of July was compounded by evaporative losses and heat stress due to the very hot weather which was also experienced during this period. As a result the existing drought conditions were exacerbated. When the drought reached its peak in mid-July, almost the entire region was suffering from at least moderate drought. Most of West Virginia and parts of Maryland experienced extreme drought (the worst class of drought) for much of the growing season.

Some crops were severely impacted by the Drought of 1988. Grain corn, for instance, had estimated yields of only 56% to 77% of average. Sweet corn, especially the earlier planted fields, suffered from the drought. In New York State, sweet corn production was down 46% from 1987. Agricultural experts in New York also reported the worst pasture conditions in twenty-six years. Due to the abnormally dry conditions twenty-one counties in New York State applied for and were granted permission to make emergency use of land for haying and grazing that had been set aside as part of the "Acreage Conservation Reserve" and "Conserved Use for Payment" programs. Farmers reported a good first cutting of hay. The pea crop in New York was very poor in terms of both quality and yields. In general, crops that were planted before or toward the middle of May benefitted from the rain that fell at the end of May and thus were in much better condition than those planted later.

Other crops, however, were unaffected or, in some cases, benefitted from the drier than normal conditions. The grape crop, although yielding smaller than normal berry size, has a very high sugar content. It should be a good vintage year. Winter wheat, which is grown in every state in the northeast except those in New England, is estimated to have yields of up to as much as 25% above average. This is in large part due to the fact that it was already established before the drought conditions set in.

The 1988 Summer rainfall distribution was reflected in the hay crop. Most of the region reported average first cuttings of hay during June. The second cutting (in mid or late July) was very poor and in some cases non-existent due to inadequate rains during the regrowth period. The rains of late July and late August, however, were very beneficial and the third and fourth cuttings were very good. In some cases, the higher yields of these later cuttings nearly made up for the poorer second cutting. Overall hay production averaged 90 to 95% of average, except in West Virginia where it was 76% of normal.

The southern portion of the region was more severely impacted by the drought. New Jersey, Delaware, and West Virginia were declared drought disaster areas. A large portion of the region's agricultural areas, with the exception of New England, were eligible for various types of assistance including the Emergency Feed Program and the emergency use of land for haying and grazing that had been set aside as part of various conservation programs.

The drought had an immense economic impact on the agricultural community in the southern half of the northeast region of the United States. State agricultural officials in Pennsylvania estimate agricultural losses of about $522 million in that state. In Maryland, losses are estimated to be in the $269 million range. The corresponding figure for New Jersey is $122 million, while West Virginia officials estimate losses of from $8 million to over $12 million.

Meteorological Drought in the Southeast
(Southeast Regional Climate Center)

South Carolina Water Resources Commission
1201 Main Street, Suite 110
Columbia, South Carolina 29201

The year 1988 began in the southeast against a backdrop of a drier than normal Winter without the full seasonal recharge of ground water. Many reservoirs remained well below average as as Winter ended. The dry Winter had some benefits. It was conducive to lumbering operations of swamplands, to land preparation for Spring planting, and to many off season farm activities. It did, however, have an adverse impact on hydro-electric power generation, navigation of streams, storage of irrigation water, and other lake and river related activities.

Drought conditions intensified with the approach of warm weather. The heat and lack of precipitation were most noticeable in extreme Western Virginia, the Western Carolinas, Northern Georgia and Northeast Alabama. Rainfall in these areas through late Summer averaged between 40 and 60 percent of normal.

Precipitation was heavier in the coastal plains, but still below normal. Figure 19 shows the percent of normal precipitation received at National Weather Service Cooperative Stations during the Summer of 1988 (June-August).

The rainfall deficiency over the southeast increased during April. A month later, Palmer Drought computations indicated that much of the southeast was in some type of a drought alert stage. During early June, cooler than normal temperatures kept evapo-transpiration demands below normal and provided some relief. By late June hotter than usual weather had become well established over the region. July and August were very hot with the intensity of the drought at a maximum for the year over the area. Figure 20 shows a PDSI analysis for the southeast on July 30, 1988. Drought conditions in isolated areas of the mountains and Piedmont region were as severe in August 1988 as the peak of the 1986 drought. The 1988 drought in the southeast, as measured by the PDSI, was severe or extreme throughout the growing season. Precipitation deficit had reached the magnitude of an approximate year's rain fall over Western Virginia, the Western Carolinas, Northern Georgia, and Northeast Alabama.

In general, corn was the crop that was hit hardest, due to the dry soil at planting time, and continued dry and hot conditions throughout the growing season. There was a bumper peach crop, although the size of the fruit was smaller than the previous harvest, due to the lack of soil moisture. Cotton yields were down from the previous year. In some places, growers found it more profitable to take the government subsidy instead

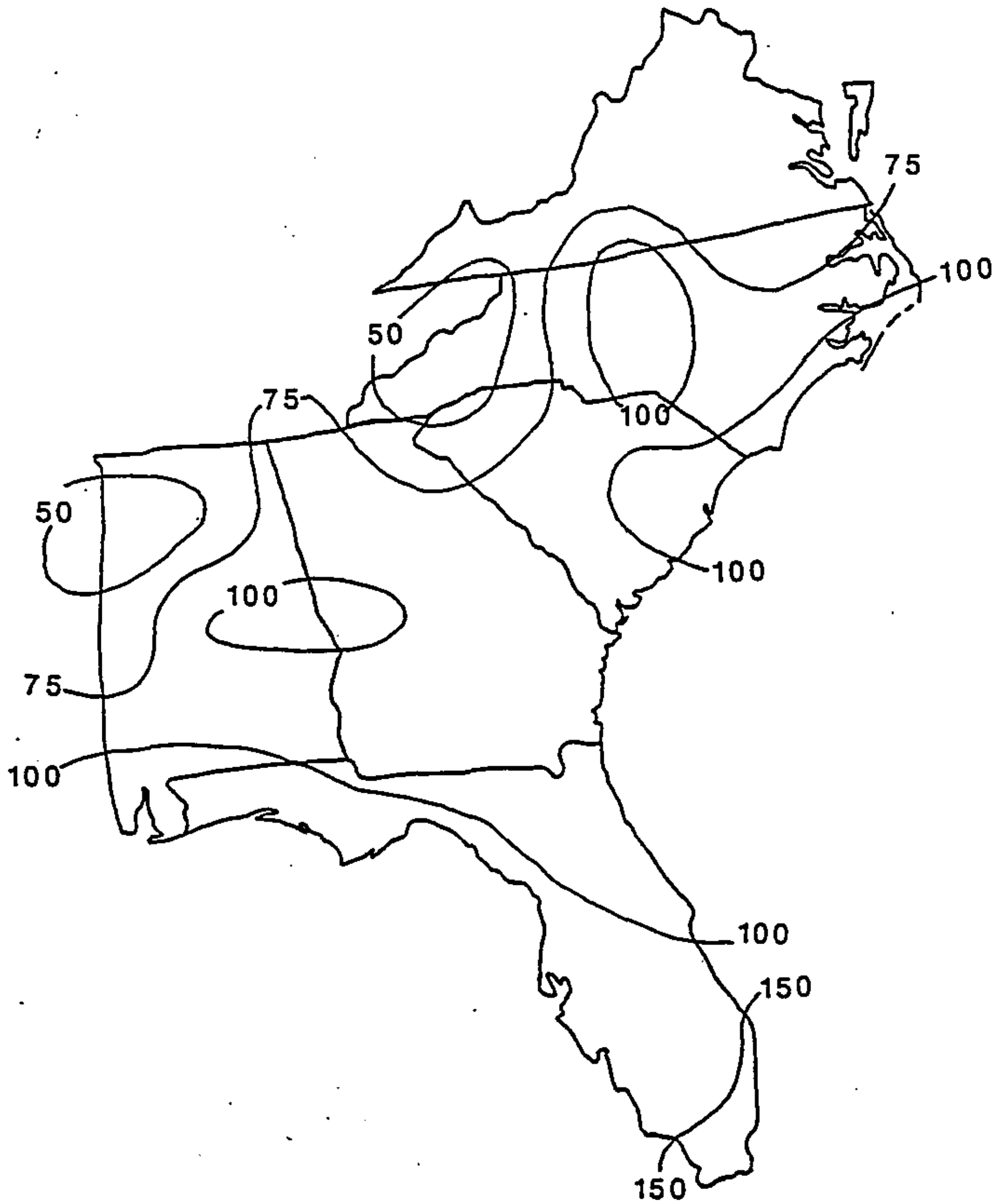


Figure 19. Percent of normal precipitation for the period June-August, 1988 (Southeast Regional Climate Center). The precipitation deficit was greatest to the northwest of this region.

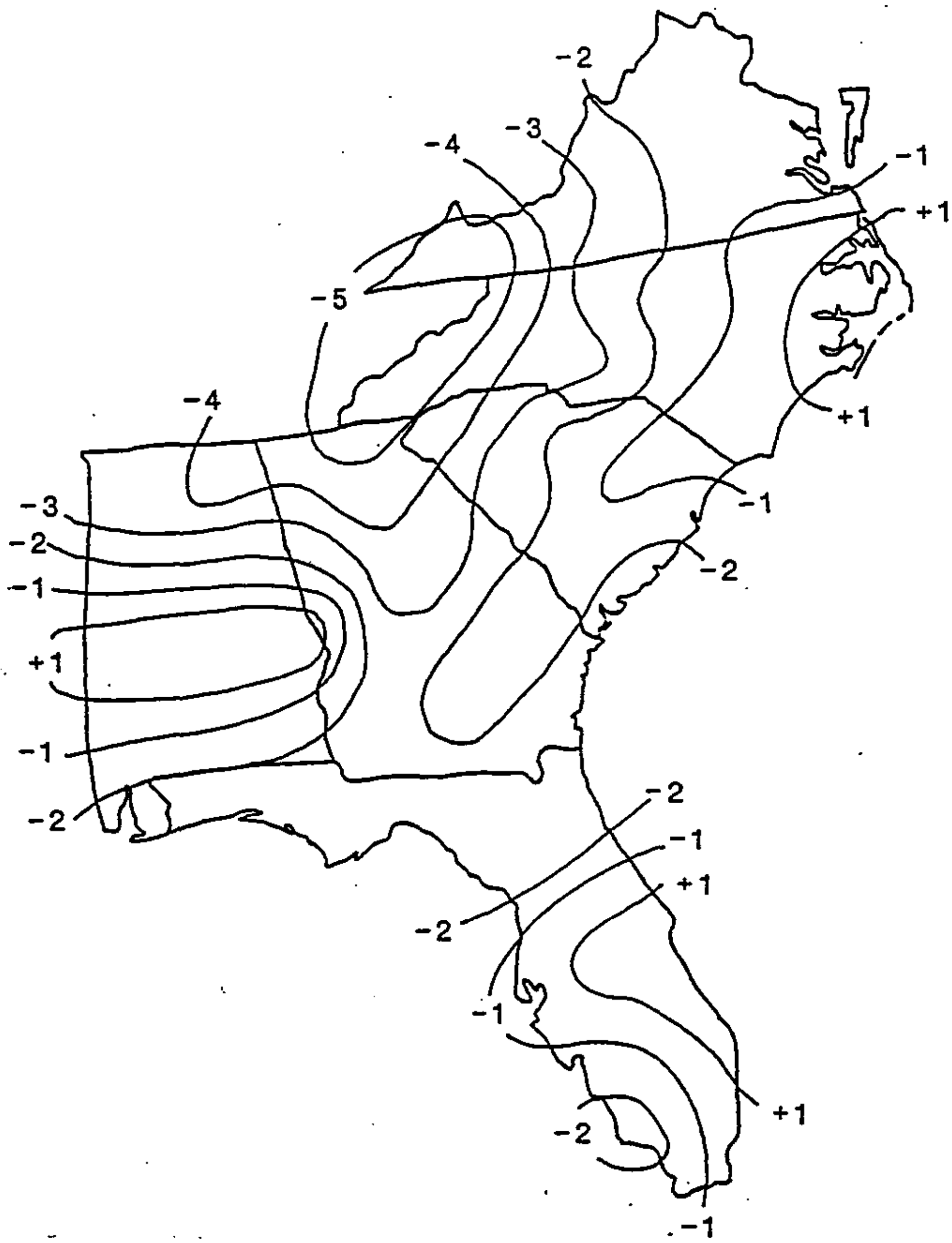


Figure 20. Palmer Drought Severity Analysis as of July 30, 1988 (Southeast Regional Climate Center). The PDSI pattern is consistent with the year's moisture deficit pattern shown in Figure 19.

of risking damage to their machinery by trying to harvest the smaller than normal stalks. Early tobacco suffered in North Carolina and Southwest Virginia, as those areas have remained dry for the past few years.

Most states experienced water supply shortages during some period of the drought. The water shortages were concentrated in the areas previously described as being most affected. Public water supplies dependent upon shallow wells and/or small watersheds were the most severely affected. Many communities had water use restrictions in place at some time during the period. Streamflow and reservoir levels in those areas were at or near record low flows during the drought. Due to these low levels, navigation on some of the inland waterways of the region were slowed or stopped completely. Public water suppliers in the drier portions of the region had difficulty in meeting peak demands during the hotter portions of the year. Many cities enacted water conservation measures. Some suppliers in areas of the most intense drought were forced to invoke mandatory restrictions.

What follows is a state-by-state summary, based on interviews with each state's Agricultural Statistical Service. Virginia harvested record oats, wheat and barley crops. Corn yields were down, as were soybeans. The ground was dry for planting row crops early in the season. Beans planted late were good until an early frost came. The worst pasture and hay conditions were in the livestock region. Peanuts, cotton, and tobacco yielded very well. Peanuts, at one point, were bad due to too much rain.

Burly tobacco was damaged in the southwestern portion of the state. South of Richmond, the corn crop was rated as good at the end of the season; everywhere else the crop's condition was spotty. Fruit crops were fair to good, with the size of the fruit smaller than average.[21] As of a mid-September, 27 counties petitioned the governor for federal disaster relief. Six counties were declared federal disaster areas by the president.

The state issued four drought status reports during the Summer, with the latest being September 23. As of September 16, one NWS cooperative station was 12 inches (30 cm) below normal for the year. The groundwater tables dropped throughout the period to being about a foot (1/3 meter) below normal as of early November. The water tables fell throughout the state during July and began August about 0.7 (1/5 meter) feet below normal. Unlike other states of the region, very few water suppliers depend on reservoirs in Virginia. Some reservoirs during late fall had elevations below normal. Some cities called for voluntary water conservation and the state encouraged utilities to implement voluntary water conservation as needed.[22]

The drought in North Carolina forced no major reduction in agriculture. 1988 was a very good year in Eastern North Carolina. It was the third highest yield on record for peanuts and corn. As with Virginia, North Carolina had a record high

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[21] Mr. Jim Lawson, Deputy State Statistician, Virginia Agricultural Statistics Service, P.O. Box 1659, Richmond, Virginia 23213.

[22] Ms. Erlinda Patron, Water Control Engineer, Virginia Water Control Board, P.O. Box 11143, Richmond, Virginia 23230.

yield of oats and barley. Soybeans were expected to yield 29 bushels/acre. The previous record high yield was 26 bushels/acre. The price of corn was up because of the drought in the midwest, thereby increasing the growers income despite a bumper crop for the state. In Western North Carolina, apples were hurt by the drought and the forecast yield was about 15% below normal. Early tobacco yields were down considerably below normal but up 15 pounds/acre over 1987. Hay crops were affected by the drought but showed considerable recovery later in the season.[23]

Compared to 1986, the eastern part of the state was much wetter. Some parts of the western Piedmont and mountains were drier than 1986. The levels of the major reservoirs paralleled the levels of 1986 until the end of August. In July and August, quite a few systems had water use restrictions - some voluntary, some mandatory. One system had water rationing.[24]

South Carolina's corn was down 22% from the five-year average, with an expected yield of 55 bushels/acre (the five-year average is 70.4 bushels/acre). Sorghum was down 14% from the five-year average. Cotton yields were also down 14% from the five-year average. The quality of cotton was affected by heavy rains during the last few days of August and early September. Many stalks had Boll rot. Fruits, including apples and peaches, were harvested at well above the five-year average rate, but the

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[23]Mr. Carl Cross, North Carolina Statistics Service, P.O. Box 27767, Raleigh, North Carolina 27611.

[24]Mr. John Wray, Deputy Director, North Carolina Department of Natural Resources and Community Development, Division of Water Resources. P.O. Box 27687, Raleigh, North Carolina 27611.

quality of the fruit was down considerably, due to a lack of soil moisture in the Spring. There was no widespread frost damage, as there has been in previous years. Soybeans were expected to yield 22% higher than the five-year average. Tobacco and hay were expected to yield 1% higher than the five-year average. Peanuts were expected to yield 3% greater than the five-year average.[25] All counties were eligible to apply for payment under the crop disaster relief program.[26]

In 1988, most South Carolina reservoirs were kept at relatively constant levels. The only exception to this was the Savannah River reservoirs (Lakes Keowee, Jocassee, Hartwell, Russell, and Thurmond). All of these reservoirs remained well below full. The main culprit of this was the dry Winter of 1987-88. Inflows on the Savannah River were consistently below average for the year. Other inflows remained below average throughout the period. Several cities had voluntary water conservation measures in place from June 13 to September 12, in response to the state's declaration of a moderate drought during that time in three counties.

Georgia corn and other vegetables suffered substantial damage in South Georgia during May and June, mainly due to the lack of soil moisture. Soybeans were rated good at harvest with above

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[25]Mr. Melvin Rogers, South Carolina Agricultural Statistics Service, Strom Thurmond Federal Building, 1835 Assembly Street, Columbia, South Carolina 29201.

[26]Mr. Bernard Radcliffe, Program Specialist, South Carolina Agriculture Stabilization and Conservation Service, Strom Thurmond Federal Building, 1835 Assembly Street, Columbia, South Carolina 29201.

average yields expected. Peanuts were expected to have an average yield. Tobacco was of good quality and yield. Cotton was damaged by the substantial rains late in the period, but its weed was smaller than normal due to the drought in the early Summer. Peaches had no frost or freeze damage; however, the quality of peaches was reduced due to dry weather.[27]

Atlanta's water comes from several sources: Lakes Lanier and Alatoona and the Chattahoochee River. All were full in July 1987. Normal operations and lack of inflow caused significant draw down of the reservoirs by October 1987. By the end of November 1987, there were substantial cutbacks in the releases by the Corps of Engineers from each lake. By January 1988, Lake Lanier was being operated for water supply and water quality only for the Atlanta region. This operation continued through the Spring and Summer of 1988. The state imposed conservation requirements in May 1988. The numerous water utilities in the Atlanta region adopted a variety of water use restrictions. Later in the Summer, a majority of the suppliers agreed on uniform restrictions.[28]

In the remainder of Georgia, more than one hundred communities throughout the state had water use restriction during 1988. Thirty-nine of them were critical, i.e., they had the

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[27] Mr. Larry Snipes, State Statistician, Georgia Agricultural Statistics Service, Stephens Federal Building, Suite 320, Athens, Georgia 30613.

[28] Ms. Patricia Stevens, Chief of Environmental Planning, Atlanta Regional Commission, 100 Edgewood Avenue, Northeast, Suite 1801, Atlanta, Georgia 30335.

potential for running out of water due to a small watershed or shallow well. North Georgia was more affected than South Georgia, due to South Georgia's almost normal precipitation. Streamflows set record low levels in North Georgia with average flows of one-third to one-fourth normal throughout the drought. Streamflows and reservoirs were at or near normal throughout the drought in South Georgia.[29]

The Alabama crop most severely affected was corn. The major corn areas of the state never got the rain needed for development. As a result, corn yields were expected to be 42 bushels/acre. The previous yield was 72 bushels/acre. The cotton crop in the Tennessee Valley was hurt by the dry spell and rains in September. Problems caused by the dry weather included reductions in the average yield and size of the plant which in turn caused harvesting difficulties. Some growers abandoned their fields. Wheat, soybeans and peanuts were not significantly affected by the drought. Peach yield totalled 19 million pounds. In 1985 through 1987, peaches were hurt by a late freeze. In 1988, there was very limited frost damage to the peach crop, but dryness cut down the size of the fruit.[30,31] All 67 counties

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[29]Mr. David Word, Chief, Water Resources Branch, Georgia Department of Natural Resources, 205 Butler Street, Atlanta, Georgia 30334.

[30]Mr. Duffy Barr, State Statistician, Alabama Statistics Service, P.O. Box 1071, Montgomery, Alabama 36192.

[31]Mr. Joel Moore, Alabama Agricultural Statistics Service, P.O. Box 1071, Montgomery, Alabama 36192.

were declared federal disaster areas in mid-August.[32]

There were voluntary and mandatory water conservation measures in place in several counties. The Alabama National Guard hauled water to 13 communities in 5 counties. Mandatory water use restrictions were in place in different portions of 8 other counties. Birmingham had mandatory water use restrictions. Portions of 14 counties had voluntary water use restrictions in effect at some time during the Summer. Moderate sized cities with small watersheds and reservoirs saw their water levels fall throughout the Summer.

A main concern of the Governor's Drought Task Force was the falling reservoir levels. Lake Martin, owned by Alabama Power Company, was down 5 feet (1 1/2 meters) by July 25. The United States Army Corps of Engineers Mobile, Alabama District is responsible for the maintaining the navigability of the Alabama River System. Navigation did not resume until mid-September. The Appalachicola-Chatahoochee-Flint River System was shut to navigation for the same time period, due to low streamflows. There were eight public information meetings held in the state during the Summer.[33]

Most drought effects were in the northern part of Florida counties. Citrus was satisfactory. Hay was an issue with the livestock producers. Alfalfa hay was needed for horse farms.

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[32] Mr. Gill Gilder, Demographer, Alabama Department of Community and Economic Affairs, P.O. Box 250347, Montgomery, Alabama 36125-0347.

[33] See number 9.

Early vegetables and corn were the most affected.[34] There was no report of major water shortages at the time of preparation of this report.

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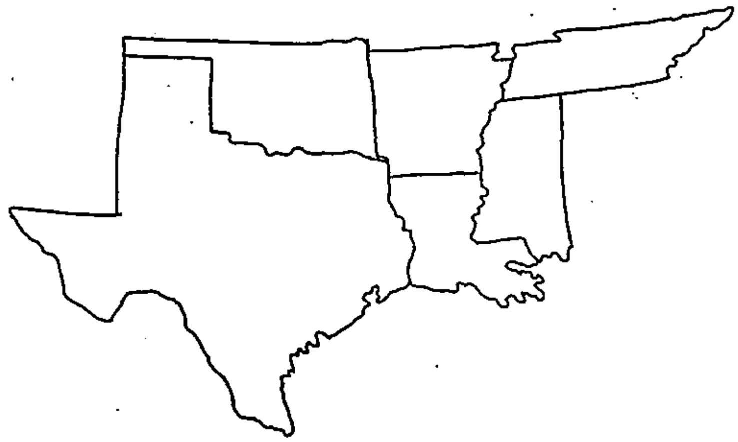
[34]Mr. Bob Freie, State Statistician, Florida Agricultural Statistics Service, 1222 Woodward Street, Orlando, Florida 32803.



REGIONAL DROUGHTS IN THE SOUTHERN REGION: 1988 IN PERSPECTIVE
(Southern Regional Climate Center, proposed)

Louisiana Office of State Climatology
Department of Geography & Anthropology
Louisiana State University
Baton Rouge, Louisiana

This discussion of drought in the Southern Region is from the perspective of water-budget components, specifically the moisture deficit (D) and the moisture surplus (S), rather than in terms of the more widely used Palmer Drought Severity Index (PDSI). On a full seasonal basis for 1988 neither the moisture deficit nor the moisture surplus were the most extreme of the standard climatic data set back through 1931. However, in most of the region the drought was most intense during Spring. The accumulated deficits through June 30, 1988, for three climatic divisions in the region - Northwest Louisiana, Northeast Louisiana, and Northwest Mississippi - were the greatest of the data.

The deficit represents an index of moisture shortage and irrigation potential for crops and even wildland vegetation, and the surplus represents an index of rainfall directly available for groundwater recharge and runoff to streams and rivers (Muller and Thompson, 1986).[35] This analysis is based on the official climatic division temperature and precipitation data from the National Climatic Data Center (NCDC) for the years 1931 to date. The deficits and surpluses were calculated by our standard monthly climatic water-budget model (McCabe et. al., 1985).[36] The same climatic division estimates of soil moisture storage capacities used by NCDC to calculate the PDSI were used in this analysis.

Figure 21a shows the mean annual moisture deficits in centimeters (cm) for the climatic divisions of the six states in the region. On the average the deficits over the eastern two-thirds of the region normally occur in Summer and Fall, but over the much drier western one-third of the region, especially in western and Southern Texas, deficits occur during all seasons. The figure shows that average deficit ranges from less than 4 inches (10 cm) a year over most of Tennessee and Southern Mississippi and Louisiana to more than 12 inches (30 cm) over Western Oklahoma and 24 inches (60 cm) over western and Southern Texas. Along the coasts of the Western Gulf of Mexico the deficit gradient is especially steep from Houston southwestward towards Corpus Christi and Brownsville.

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[35]Muller, R.A. and R. Thompson, 1986. Water Budget Analysis, The Encyclopedia of Climatology, ed. J.E. Oliver and R.W. Fairbridge. New York: Van Nostrand Reinhold, 914-921.

[36]McCabe, G.J. et al., 1985: Thornthwaite Continuous Monthly Water Budget: Program is Basic for Micro-computers. Climate Paper 85-1, Dept. Geog. & Anthro., LSU, Baton Rouge, LA, 19pp.

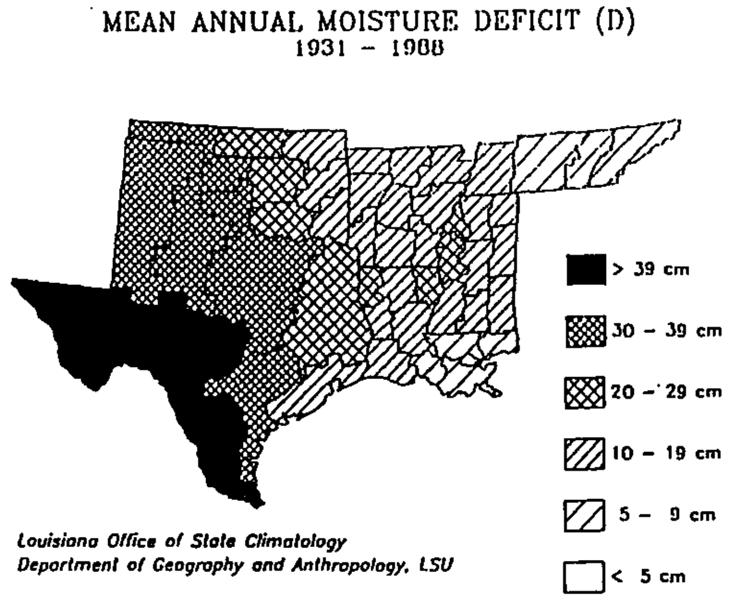

Figure 21a. The mean annual moisture deficits (cm) for the climatic divisions of the six states in the proposed southern region.

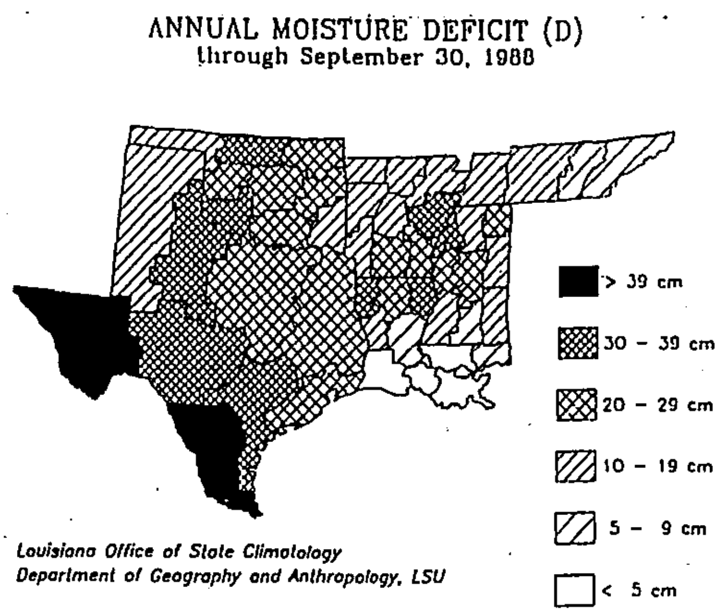

Figure 21b. The 1988 deficit (cm) of the average for the years 1931-1988 for the climatic divisions in the proposed southern region.

Figure 21b shows for each climatic division the 1988 mean seasonal moisture deficit (cm) through September, 1988. The deficit pattern ranged from less than (5 cm) in Southern Mississippi and Louisiana, where deficits were below average, to more than 20 inches (50 cm) across western and Southern Texas. The particularly unusual feature of the deficit pattern for 1988 was the secondary maximum of 12 inches (30 cm) or more over the Southern Mississippi River Valley south of Memphis in Arkansas, Mississippi, and Northern Louisiana.

The intensity and impacts of the 1988 drought in the south was greatest by far during the Spring when there was little rainfall or residual soil moisture to support newly seeded crops in some areas. Figure 22a shows the accumulated moisture deficits through June 30 by climatic divisions. As should be expected, deficits ranged between 11 and 14 inches (25 and 35 cm) across the steppes and deserts of western and southern Texas. But the more remarkable feature is the arc-like area along the lower Mississippi River Valley from near Memphis south to Vicksburg and west to Shreveport where the Spring deficits ranged between 3 1/2 and 4.7 inches (9 and 12 cm). All of the deficits in Southern Louisiana and Mississippi were accumulated during the Spring and early Summer, no later than June 30. The latter area received ample rainfall during the Summer and early Fall for plant growth and crop yields.

Figure 22b shows the seasonal moisture surplus (cm) accumulated by September 30, 1988, by climatic divisions. The map shows that a large area had received only between 40 to 60

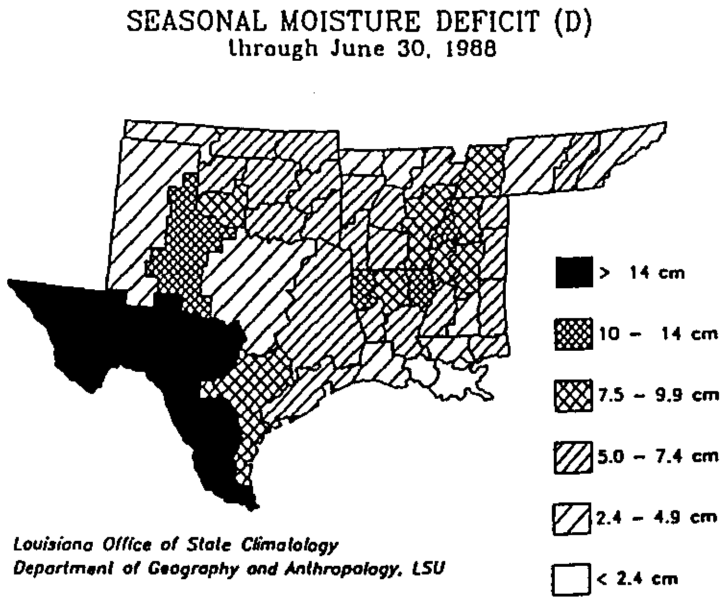

Figure 22a. **The accumulated moisture deficits (cm) through June 30, 1988 for the climatic divisions in the proposed southern region.**

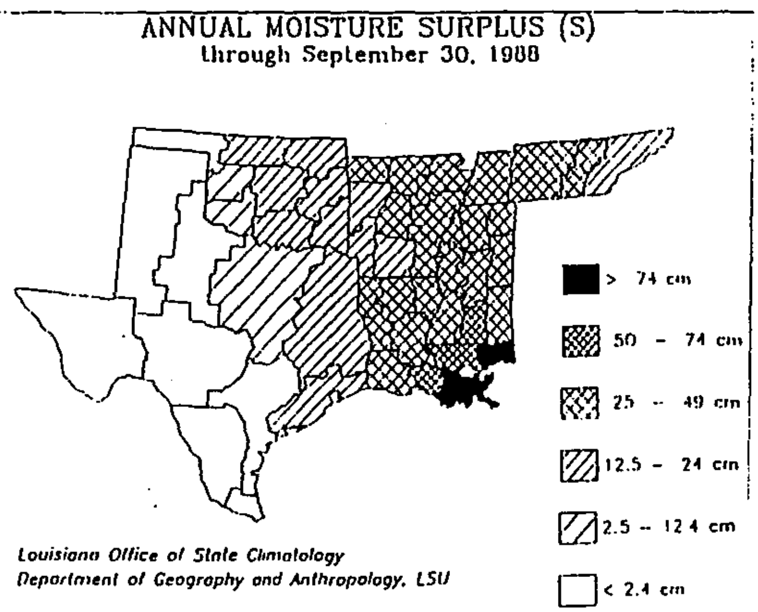

Figure 22b. **The seasonal moisture surplus (cm) accumulated through September 30, 1988 for the climatic divisions in the proposed southern region.**

percent (25-49 cm) of the annual surplus by the end of September. This area included Tennessee, the northern half of Mississippi, the southeastern half of Arkansas, the northern third of Louisiana, and Eastern Texas. Since less than 20 percent of the annual surplus is normally generated after September 30, the water available for groundwater recharge and streamflow is likely to be well below average for the year. In contrast, the surpluses by September 30, were well above the annual averages over Southern Mississippi (>74 cm) and Southeastern Louisiana (>750 cm), and over Central Oklahoma (>2.4 cm).

The seasonal moisture deficits for 1988 ranged between 6 and 12.6 inches (15 and 32 cm) over a broad area with a northeast-southwest orientation more-or-less astride the lower Mississippi River Valley where cotton and soybeans are the primary crops. A second drier than normal area included much of Central Oklahoma. But deficits were much less than average across Southern Louisiana and Mississippi, extreme Eastern Tennessee, and over the high plains of Texas and Oklahoma.

In the lower Mississippi River Valley, seasonal deficit departures ranged up to 5 inches (13 cm). In this same region the 1988 seasonal deficits ranged commonly between 130 and 160 percent of the long term average, with maximum divisional values of 173 and 200 percent in Central Mississippi and Central Tennessee respectively. For the climatic data set extending back 58 years to 1931, divisional deficit percentile ranks over the Tennessee and the lower Mississippi River Valleys ranged between 10 and 25, with return periods for this seasonal event of once every 4 to 10 years.

The Spring deficits and drought of 1988 were the most severe since 1931 over sections of northwestern Mississippi and northern Louisiana. A much broader area of Tennessee, Mississippi, Arkansas and eastern Oklahoma, and northern Louisiana and eastern Texas also experienced severe droughts that ranked second or third for the same time period.

Summary of Congressional Action:
Drought Legislation of the 100th Congress

Only one bill dealing entirely with drought was enacted into Public Law in 1988. Legislation originating in the Senate (S. 2631) and The House of Representatives (H.R. 5015) on July 12, 1988 in both houses was signed into law by the President on August 11, 1988. The new law (P.L. 100-387) was titled: "A Bill to Provide Drought Assistance to Agricultural Producers, and for Other Purposes". In October, 3.9 billion dollars were made available for distribution.

Another bill, H.R. 5026, dealing with drought and other emergencies was also enacted into law. This bill was introduced on July 13, 1988. It allows for supplemental appropriations to meet dire emergencies caused by drought, disaster, financial, and refugee conditions. On August 12, 1988, both houses passed the measure and it was presented to the President. On August 14, 1988 the bill became Public Law 100-393.

Several other drought-related bills were introduced, but none were enacted into law. In the House, four resolutions and eighteen additional bills were considered. Of the eighteen, nine bills were actually incorporated into H.R. 5015 as amendments. In the Senate, one resolution, eleven additional bills and numerous amendments were considered. Most of these were incorporated into S. 2631 on its way to becoming Public Law 100-387.

The House held five subcommittees and committee hearings and a portion of the testimony was included in H.R. 5015. Likewise, the Senate held four subcommittee and committee hearings and a portion of the testimony was included in S. 2631. There were two joint hearings and the most important points are included in the bill which eventually became Public Law 100-387. In addition to the hearings, there were 148 entries in the Congressional Record dealing with the 1988 drought.

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Washington, D.C.

APPENDIX A

A Strategic Planning Seminar on the Drought of 1988 and Beyond was held October 18, 1988 at the Sheraton Grand Hotel in Washington, D.C. It was sponsored by the National Climate Program Office, the Board on Atmospheric Sciences of the National Academy of Sciences, and Resources for the Future. The program is attached along with abstracts of papers presented.

Strategic Planning Seminar

THE DROUGHT OF 1988 AND BEYOND

October 18, 1988

The Sheraton Grand on Capitol Hill
525 New Jersey Avenue NW, Washington, DC

Sponsored by: **National Climate Program Office, NOAA**
Board on Atmospheric Sciences, National Academy of Sciences
Resources For the Future

PROGRAM

8:30 Introductions
Alan Hecht, Director, National Climate Program Office, NOAA
Richard Anthes, Chairman, Board on Atmospheric Sciences and Climate, National Academy of Sciences

9:00 Film "Eyewitness: A Dust Bowl Retrospective" with introduction by Wayne Rasmussen, Agricultural Historian, USDA (retired), Annandale, VA

9:30 Keynote Address
To be announced

10:00 Temporal and spatial severity of the drought: historical perspective
Thomas Karl, National Climatic Data Center, NOAA, Asheville, NC

10:30 Break

10:45 The 1988 drought and prospects for climate prediction
David Rodenhuis, Director, Climate Analysis Center, National Meteorological Center, NWS, Suitland, MD

11:15 Origins of the 1988 North American drought
Kevin Trenberth, National Center for Atmospheric Research, Boulder, CO

11:45 Discussion

12:00- 1:30 Lunch (on your own)

1:30 Drought and greenhouse warming: What is the relation?
Suykuro Manabe, Geophysical Fluid Dynamics Laboratory, NOAA, Princeton, NJ

2:00 Drought effects on crop production and the economy
James Donald, Chairperson, World Agricultural Outlook Board, U.S. Department of Agriculture, Washington, DC

2:30 Response of state governments and regional organizations to the 1988 drought
Don Wilhite, University of Nebraska, Lincoln, NE

3:00 Discussion

3:15 Break

3:30 Drought impacts in the Prairie Provinces of Canada
Rick Lawford, National Hydrology Research Center, Saskatoon, Saskatchewan, Canada

4:00 Panel discussion: Improving response to drought emergencies by state and federal agencies

Panel Chairman

Norman Rosenberg, Resources For the Future

Panelists

Michael Helpa, Army Corps of Engineers, Washington, DC
Stanley Changnon, Illinois State Water Survey, Champaign, IL
John Byrne, Colorado Disaster Emergency Services, Golden, CO
William Sprigg, NOAA Climate Office, Rockville, MD
Jon Bartholic, Michigan State University, East Lansing, MI

5:30 Reception immediately following program

Eyewitness: A Dust Bowl Retrospective

Wayne Rasmussen

Abstract

Drought is a feature of the climate of North America, particularly in the large midcontinent region and even more specifically in the Great Plains. Such droughts as those of the late 1880s and early 1890s, of the 1930s, and now, of 1987-88, are remembered as landmarks. The drought of the 1930s was a major force leading to Federal legislation dealing with planning, grazing, soil and water conservation, farm security (now the Farmers Home Administration program), crop insurance, shelter belts, irrigation, and drought relief. Most of these programs are still in effect over fifty years later. The drought itself is still remembered in songs, novels, motion pictures, and still photographs such as the classics by Arthur Rothstein and some of his colleagues.

The Drought of 1988

Final Report of the President's Interagency Drought Policy Committee

December 30, 1988
Washington, D.C.

Monitoring the United States Drought of 1988
By
Norton D. Strommen

The White House announced the establishment of the Interagency Drought Policy Committee on June 15, 1988, consisting of the Department's of Agriculture, Interior, Army, and Energy, Tennessee Valley Authority, Federal Emergency Management Agency, Office of Management and Budget, and the Office of the Vice President. The Department's of State and Transportation, Council of Economic Advisors, and National Oceanic and Atmospheric Administration were added later. The Committee's initial meeting was held on June 20, 1988, at the Department of Agriculture and chaired by Secretary Richard E. Lyng.

The Committee was briefed on the work completed by the U.S. Department of Agriculture's Drought Task Force which had been meeting weekly since March 1, 1988, under the chairmanship of Deputy Secretary Peter C. Myers. After briefing summaries of work underway at other agencies, it was agreed that an initial report on the situation and actions taken should be completed and delivered to President Reagan on July 1, 1988. Subsequent committee reports to the President followed on July 15, August 15, and September 16 with the final committee report expected to be completed by December 1, 1988.

Secretary Lyng accompanied President Reagan to drought areas of Illinois and Iowa on July 14. During the visit, the President announced that Secretary Lyng would lead members of the Interagency Drought Policy Committee and other officials in on-site visits of 10 States to assess the full dimensions of the drought.

Secretary Lyng and the Interagency Drought Policy Committee completed the 10-State, 3-day tour beginning July 19, 1988. Stops on July 19 included Mansfield, Ohio; Lafayette, Indiana; Jackson, Tennessee; Cape Girardeau, Missouri; and overnight in St. Joseph, Missouri. Stops on July 20 included farms near St. Joseph, Missouri; Cedar Rapids, Iowa; Aberdeen, South Dakota; Jamestown, North Dakota; and St. Cloud, Minnesota. Stops on July 21 included Eau Claire, Wisconsin and Midland, Michigan.

The Drought Committee visited 13 farm families and received a detailed briefing on navigational management of the Mississippi River and the work undertaken by the Corps of Engineer to keep barges moving. This briefing was conducted on a barge at Cape Girardeau, Missouri, where the Mississippi River at the time was just slightly above the lowest level on record. Ironically, rain of varying intensity fell during or just a few hours before the visits in 8 of the 10 States. Secretary Lyng briefed President Reagan on the findings of the tour and indicated the rains may have come too late to help the corn crop but may have eased the stress on soybeans.

The work of the committee continued with weekly meetings and timely coordinated reports to the Executive and Legislative Branches into September. The last interim report was delivered to the President on September 16, 1988.

The work of the Committee may best be summarized by four words: preparations, timely communication, and responsiveness. Under the guidance of Secretary Lyng, I believe the nation was well served during the devastating Drought of 1988. This feeling has also been expressed often by key members of the White House and Congress.

EXECUTIVE SUMMARY

Drought Overview

The 1988 drought was one of the worst on record for the central United States and adversely affected many other areas. The area of the conterminous United States designated as having a severe or extreme drought was smaller than the great droughts of the 1930's and 1950's. However, the precipitation deficits and extreme heat were especially pronounced during critical crop growth stages in the Northern Plains and Midwest, resulting in record or near-record reductions from normally expected yields for major crops. Extremely low streamflows in these regions impaired barge transportation on the Ohio and Mississippi Rivers.

The area covered by the drought in these regions was exceeded only in 1934 and 1936. Drought conditions continued from previous years for the Southern Appalachian and Tennessee Valley Regions. The Southwest was the only region with above-normal precipitation. Because of the large soil moisture deficits in the Northern Plains and parts of the western Cornbelt, those regions will likely enter the 1989 growing season with far less than normal soil moisture.

Profiles of areas receiving less than 50 percent of normal precipitation illustrate the intensity and geographic coverage of the drought. Large parts of the Midwest, South, and Northern Plains received less than half of normal precipitation between April 1 and June 30. In general, wide bands adjoined these areas where the rainfall was 50-75 percent of normal. July rains helped ease the extreme deficits in the Southeast and eastern Cornbelt, but the drought continued to intensify in the western Cornbelt and Northern Plains. Beginning in August and continuing into September, the geographic coverage of the drought was considerably reduced, albeit too late to alleviate the extensive damage to early forage, feed grain, and soybean crops. However, favorable rains in many parts of the country during August were accompanied by extremely high temperatures in the East and Midwest, leaving subsoil moisture levels very low. The lack of significant rainfall into September over parts of Illinois, Iowa, and Montana added to the severe conditions in those areas.

The cumulative effect of favorable rains in September sharply reduced the areas with extreme rainfall deficiencies. By the end of September, the drought, which had at one time stretched from Oregon across the northern tier of States through the Great Lakes to the mid-Atlantic coast and curled back to east Texas, had broken up considerably.

Streamflows were below normal in 45 percent of southern Canada and the conterminous United States for water year 1988 (October 1987 through September 1988), about the same as in 1981 and 1977. These 3 years are essentially tied for the third driest in the last 68 years as measured by the area coverage of below-normal streamflow. Only 1931 (66 percent) and 1934 (63 percent) were drier.

On a monthly basis, the area with below-normal streamflow during June 1988 (60 percent) was about the same as that during June 1977 and February 1977. For one month of the 1988 drought, the area of below-normal streamflow was as great as any that has occurred in the last 44 years.

The Mississippi River, which drains 1.1 million square miles of the United States and Canada, had flow rates during June and July that were the lowest on record for those months (measured at Vicksburg, Miss.). Flow rates for August and September were the second lowest on record for those months. These extremely low flow rates occurred even though monthly flow rates for the 1988 water year averaged near the median through April.

The primary inland waterways were greatly impaired by the drought. The Apalachicola, Chattahoochee, and Flint Rivers system was closed when navigation depths dropped below 6 feet. The most visible and most severe impediments to navigation, however, occurred on the Mississippi and Ohio Rivers. Short closures on main rivers created significant delays for the towing industries. Late in the summer, navigation conditions stabilized along the inland rivers. The Apalachicola, Chattahoochee, and Flint Rivers system was reopened because of improved hydrologic conditions which allowed releases from upstream reservoirs for limited navigation.

Water reclamation projects in the West were generally able to meet water needs of authorized service areas, though reservoir storage has been significantly depleted by the drought. In the Pacific Northwest Region, reservoir storage ended the year at far below normal. Over the past 2 years, reservoir storage in the mid-Pacific Region has been used to augment the water supplies from deficient runoff and reservoir storage is well below average at all major reservoirs.

Reservoir storage dropped significantly in nearly all reclamation projects in the Great Plains over the 1988 and 1989 water years. Several projects in Montana and Wyoming experienced irrigation shortages as a result of the low water supply in 1988. A number of other irrigation projects experienced minor shortages toward the end of the irrigation season.

Reservoir storage remains below average in most of the Army Corps of Engineers reservoir projects. The California Central Valley Corps reservoirs, Lake Lanier on the Chattahoochee River, Lakes Hartwell and Thurmond on the Savannah River, and Lake Allatoona on the Coosa River all remain significantly below pool levels normal for this time of year. Mainstem Missouri River reservoir storage volumes are at record-low levels, and average inflows over next spring would only bring the reservoirs up to their historic minimum levels.

Drought Impacts

Agriculture

As the summer progressed, the drought and searing heat increasingly took their toll on grain and soybean harvests. USDA crop reports in July and August, which cover critical periods in the growing season for corn and soybeans, showed substantial declines in the production of those crops. With favorable rain in late July and August and as harvesting progressed, corn and soybean production forecasts improved slightly by season's end.

Indicative of the drought's severity, the 1988 average corn yield was 31 percent below trend, the largest drop since the mid-1930's, and the soybean yield was 17 percent below trend, the largest decline over the past 60 years.

Based on November 1 conditions, 1988 crop production was down from 1987 as follows:

	Percent
Corn	-34
Feed grains	-34
Soybeans	-21
Spring wheat	-54
All wheat	-14

Although the year's grain and soybean harvests were reduced by the drought, total supplies, including relatively large carryin stocks from 1987/88, are adequate to meet domestic and foreign demand, but at higher crop prices. Wheat, corn, and soybean stocks carried into 1989/90 will be low relative to use, with soybean stocks especially tight at less than one month's use.

As a result of the large drop in U.S. and Canadian output, world grain production is expected to be down 4 percent from 1987/88. World grain stocks at the end of 1988/89 will be a third below beginning stocks and are projected to be 16 percent of total use, well below the average of 23 percent from 1980-87 and the lowest since 1973/74.

The drought's effect on livestock was moderated by Government actions to bolster forage and feed supplies. Hay production in 1988 dropped 13 percent but would have been even lower if there had not been a 10-percent increase in acreage due mainly to haying on acreage withdrawn from production under acreage reduction and conservation reserve programs.

The drought slowed the expansion in the U.S. cattle herd as some heifers were slaughtered rather than added to the breeding herd, but the overall effect was small. Both cattle and hog slaughter in 1988 were about 1 percent larger than expected, reflecting producers' reactions to smaller forage supplies and rising grain prices which discouraged herd expansion.

Net cash income to farmers in 1988 was near the record level of $57.1 billion in 1987. Sales from inventories and higher crop prices increased crop cash receipts from a year ago. While cash income to the sector was near a record level, the drought affected some producers severely. Producers with poor crops and small inventories fared much worse than other producers who gained from higher prices, while livestock and poultry producers' profits were cut by higher feed prices. Federal disaster relief will provide $6-$7 billion of support to agriculture in 1988 and 1989. Disaster assistance reduced by half the 20,000-30,000 commercial farmers (annual sales of $40,000 or more) that would have otherwise had financial losses which threatened continued operations. Rural communities in farm-dependent areas benefited as well.

The United States currently has a substantial acreage of cropland idled under Government programs that can be returned to production. In 1988, the combination of 78 million acres idled under Government programs and the severe drought reduced harvested cropland to about 284 million acres--the smallest harvested crop acreage this century. Of the 78 million acres, about 54 million acres were idled under annual programs and can be brought back into production rather quickly. Acreage reduction programs for the 1989 wheat and feed grain crops have been sharply lowered.

Food Prices

Food prices in 1988 are projected to average 4 percent above 1987, comparable to the increase last year. Above-average increases are being recorded for fruit, vegetables, and cereal and bakery products because of the drought. The drought added about 0.5 percentage point to 1988 food prices. Food prices in 1989 are expected to increase 3-5 percent but the effect of this year's drought will be too small to measure. Relatively large food supplies, including larger supplies of poultry and expanded 1989 crop output will dampen food price gains.

Forestry

Extremely low fuel moisture conditions, prolonged drought conditions, periodic strong winds, and lightning storms in Wyoming, Montana, Oregon, California, Washington, and Idaho combined to generate a severe fire season. The mobilization of fire suppression resources far exceeded that of previous years. In August, all previously trained civilian fire suppression resources were committed to existing wildfires, and it became necessary to mobilize military and Canadian resources. In 1988 to date, there have been nearly 73,000 fires which burned more than 5 million acres.

Range

Range forage production varied from 50-80 percent of normal in the most severely affected drought areas, largely the Northern Plains and parts of Utah, Idaho, and Nevada. The early removal of livestock from western rangelands administered by the USDA was minimal. However, where livestock removal was required because of the drought, the effects in most cases were harmful to livestock producers. Next year the same areas are likely to be severely affected, even with adequate water supplies, due to the inability of the drought-stressed plants to respond quickly without a season's growth to rebuild plant vigor.

Transportation

Extremely low streamflow caused by the lack of late spring and early summer rainfall produced record low water levels in the middle and lower reaches of the Mississippi River and the lower reaches of the Ohio River. Streamflow rates fell rapidly in June and early July. During this period, severe navigation maintenance problems occurred. As the river shrank in width, it sustained a rather narrow but fairly constant depth channel throughout summer and fall. The stable condition of the river, together with increased dredging by the Corps of Engineers, a 50-percent increase in the level of Coast Guard aids to navigation, and reduced barge tow sizes and drafts allowed navigation to continue.

Following an unprecedented number of groundings on the Mississippi River system, the Corps of Engineers and the Coast Guard in late June consulted with industry officials and imposed restrictions on the draft and number of barges per tow on segments of the lower Mississippi and lower Ohio Rivers. While these restrictions facilitated safe cargo movement, they reduced the volume moved by a single tow by as much as 50 percent. The barge movements of bulk cargoes, particularly grain over the lower Mississippi and lower Ohio Rivers, were hard hit temporarily and coal movements were also disrupted.

Concerns that the movement of farm products would be disrupted did not materialize. Through June, farm products moving through the upper Mississippi, Illinois, and Ohio rivers followed a very similar pattern to that of a year ago, which was more than 40 percent above 1986 levels. Declines in July and August, a seasonally slow time for farm product shipments, were significant, but 1988 shipments still exceeded 1986 levels.

In June, the Army Corps of Engineers was requested to consider directing a temporary increase in the amount of water diverted from Lake Michigan into the Illinois River. It was concluded that any additional water in the lower Mississippi from the diversion would not make a significant difference in navigability or in the need for continued dredging.

The Corps of Engineers, Coast Guard, and the barge operators worked closely to coordinate traffic demands, monitor channel conditions, and minimize delays. Restrictions on tow sizes and draft were imposed when navigation conditions were severely limited. The barge industry adjusted to the limitations and disruption caused by the drought. Most of the restrictions had been removed by late fall and tonnage moved at near normal levels. However, normal navigation conditions have not been restored and voluntary restrictions on tow size and draft are still recommended.

In mid-December, the Mississippi River was closed to barge traffic between St. Louis, Mo., and Cairo, Ill. River levels dropped dramatically as a result of low temperatures and lack of rain in the upper Mississippi basin. River levels have stabilized and dredges are working to remove shoaling. Such closures are uncommon over this part of the river at this time of the year.

Railroads reported some pickup in shipments that would normally move by barge during the summer. However, there were no reports of general shortages of freight cars or any significant problems in the rail system related to the drought and the diversion of traffic from the rivers. Although some cargoes were diverted to alternate routings, the volume of cargo being moved by barge had returned to near normal levels by mid-July.

Wildlife and Recreation

Waterfowl. The severe and continuing drought of 1988 has limited the size of duck breeding populations and production in the northern prairies. The loss of water resulted in a 53-percent decline in breeding pairs and the birds that did remain in the area were crowded into smaller wet areas. The reduced breeding population and the diminished breeding effort resulted in an even more drastic 75-percent reduction in the number of young produced. Loss of ponds and breeding populations occurred throughout but was more severe in the West.

Fisheries. Effects of the 1988 drought were most pronounced on intermittent streams, small streams, headwaters of larger systems, and small impoundments. Many have small drainages that have limited or no reserves to safeguard against droughts. The many sport and commercial fish species of the central United States use intermittently flooded habitats during the spring as spawning sites and nursery areas for production of their young. Many reaches of the Nation's large rivers, areas that routinely produce walleye, northern pike, and yellow perch, were dry in 1988.

Aggregate Economic Activity

In an economy as large and diversified as that of the United States, sectors most directly affected by the drought account for a relatively small share of aggregate output. For example, all farming industries combined represented about 2.2 percent of the gross national product (GNP) in 1987. Therefore, while the drought had significant negative effects on important sectors of the economy, the impact on aggregate economic activity was relatively small. The direct loss of farm production due to the drought subtracted about $13 billion (in terms of 1982 farm prices) from the real GNP (of around $4 trillion) that would have otherwise occurred in 1988. GNP growth was reduced on a fourth-quarter to fourth-quarter basis by about 0.7 percentage point. Indirect effects and impacts outside of the farm sector are apparent but have not been measured separately.

Crop output is expected to rebound sharply in 1989 from the drought-induced 1988 losses (partly because additional acreage is being brought back into production). This rebound will translate into an aggregate GNP growth for 1989 that will be higher by approximately the same amount that was subtracted from growth in 1988.

Federal Response to the Drought

In late winter, Federal Government agencies organized efforts to address the drought in the Pacific Northwest. Secretary of Agriculture Lyng established the USDA Drought Task Force on March 1 to monitor the potential drought situation. In May, the Senate and House Agriculture Committees began to monitor drought conditions and options for assistance. As the drought progressed, Federal agencies intensified their efforts. On June 15, the President established the Interagency Drought Policy Committee to monitor the drought and coordinate the Federal response. Secretary Lyng and others worked closely with the bipartisan Congressional Drought Task Force in forging the Disaster Assistance Act of 1988 which was signed by the President on August 11, 1988.

Department of Agriculture

In the early stages of the drought, a high priority was assistance to livestock producers. Deteriorating spring hay crops, worsening pasture and range conditions, drying stock ponds, and rising feed costs were increasing pressures on livestock producers to liquidate herds. In response, USDA acted through a number of livestock assistance programs. As the drought worsened and production losses became more evident, attention focused on financial aid to crop producers under current Federal crop insurance, emergency loans, and new legislation.

The Emergency Feed Program (EFP) and the Emergency Feed Assistance Program (EFAP) are providing access to feed. By early November, these programs had been approved for 2,076 counties in 41 States. By the end of October, 121,000 livestock producers had applied for aid under the EFP, and about $100 million had been paid out to producers. Also, about 10,000 producers had purchased 220,000 tons of reduced-price CCC grain under the EFAP. Other actions, such as emergency haying and grazing on set-aside acres, were taken to improve farmers' access to forage supplies.

The Disaster Assistance Act of 1988 will provide about $3.9 billion for drought assistance in addition to nearly $3 billion budgeted under existing programs for emergency feed assistance and Federal crop insurance payments.

Payments will be made to crop producers for production losses beyond 35 percent due to weather perils. Payment rates for crops eligible for Federal program support are 65 percent of support prices. For soybeans and other nonprogram crops, the payment rate is 65 percent of the average market price over the last 5 years. For production losses in excess of 75 percent, the payment rates increase to 90 percent of the applicable support level or price.

The act also streamlines feed assistance programs, provides incentives for producers receiving assistance to purchase crop insurance, places limits on the amount of aid, and expands producer eligibility for FmHA loans.

The 1988 fires added substantially to efforts underway on campground rehabilitation, timber salvage, reforestation, soil and water restoration, and other conservation and environmental efforts as a result of 1987 fires. Emergency seeding and erosion control is necessary to prevent damage from fall and winter storms.

The Forest Service and Park Service are coordinating emergency recovery activities. These activities involve emergency and long-term recovery of the Yellowstone Park and the parts of the Shoshone, Grand Teton, Targhee, Custer, and Gallatin National Forests within the Greater Yellowstone Area. More than $3.1 million has been approved for emergency recovery efforts.

Department of the Interior

The Department of the Interior is responsible for a broad range of water, land, and wildlife management programs, many of which were used to respond to the drought. The agency coordinated Federal and State efforts to suppress wildfires and efforts to recover and preserve forestry resources.

Drought actions included maintaining the quantity and quality of existing water systems and securing water supplies at National Parks, on Indian and public lands and at multi-purpose water projects. Several water resource management and monitoring activities were modified during the year to assist Federal, State, and local agencies in drought response activities. The Geological Survey provided information on streamflow, reservoir, and groundwater conditions which were utilized in water management decisions and analyses of the drought. The Bureau of Reclamation was required to closely monitor and manage reservoir storage and water supplies to meet authorized and contract commitments and assist nonproject users if possible. In addition to this type of assistance, the Bureau of Reclamation has assisted State and local water user groups in water conservation efforts and development of emergency plans to respond to a continuation of the drought.

The Reclamation States Drought Assistance Act of 1988 generally directed the Secretary of the Interior to perform and report to Congress water conservation studies for Federal reclamation and Indian water projects by March 1, 1990; undertake, within existing contracts, State laws, and Federal authority, construction management and conservation activities that will mitigate 1987, 1988, and 1989 drought conditions; assist willing sellers and purchasers in marketing water; make emergency loans for water management and conservation; and undertake other water management actions.

Army Corps of Engineers

The Corps of Engineers managed reservoir projects to best use the drought-reduced water resources. In the Ohio River basin, reservoir operations throughout the summer and fall focused on meeting the authorized project purposes while also maintaining minimum flows for fish and wildlife and water quality in the rivers below the projects. The Corps and the Tennessee Valley Authority worked together in setting release schedules, considering the multiple purposes of hydropower, downstream navigation, water quality for fish and wildlife, and wastewater assimilation, while at the same time producing benefits to the Mississippi River at Cairo. The drawdown of storage out of the Corps headwater projects in the Ohio basin has been extended in accordance with the Ohio River Division's drought contingency plans. Normal releases from the Missouri River mainstem reservoirs for navigation purposes on the Missouri River also produced a significant benefit to the Mississippi River.

While monthly runoff from the Missouri River basin averaged only 50 percent of normal and at times was zero, water released from the reservoirs allowed navigation on the Missouri River to continue unimpeded throughout the summer. Of further importance is the fact that the Missouri River contributed 65 percent of the flow in the Mississippi River at St. Louis during most of the summer and fall and that the mainstem Missouri River reservoir releases provided about 75 percent of that amount. Without the flow contribution from those reservoirs, the middle reach of the Mississippi River would have been closed to navigation by June and remained so to date.

The Corps undertook extensive dredging operations to maintain the principal rivers of the inland waterway system that experienced record low levels. Up to 13 dredges worked in the most severely shoaled areas of these rivers. The Corps, Coast Guard, and the barge operators worked closely to coordinate traffic demands, monitor channel conditions, and minimize delays. While the Mississippi River mainstem experienced numerous closures, the Tennessee Tombigbee Waterway provided an alternative route from Cairo, Ill., to the Gulf for some shippers.

The Corps of Engineers regulated flows from Lake Lanier to maintain water supply and quality for metropolitan Atlanta and constructed an underwater barrier in the Mississippi River below New Orleans to stop the upstream migration of the saltwater wedge which threatened the water supply intakes in the vicinity of New Orleans.

Department of Transportation

The Department of Transportation response to the drought included operational activities and interdepartmental planning and coordination. Coast Guard Headquarters monitored overall safety conditions on the river system. Lower water levels required the Coast Guard District at St. Louis to increase the number of buoys marking river channels, deploy additional buoy tenders, and staff round-the-clock command centers to assure communication of river advisories.

The DOT Intra-Departmental Task Group maintained an overview of drought conditions on the river system, considered policy and legislative issues, and coordinated all DOT responses to the Interagency Drought Policy Committee. A above-average precipitation for most of the forest resources to fully recover from the drought. Fires will be very difficult to control and many acres and resources could be destroyed if recovery does not begin in 1989. Losses due to insect infestations are likely to mount.

Water

Water supply projects have prevented significant losses to farmers and other users. Recurrence of drought will place added pressure on existing water projects, especially with the unplanned private development of groundwater irrigation supplies. In response, States, which have the primary responsibility for water resource planning, may choose to use Federal resources for development of water conservation and water-use efficiency plans.

Many reservoirs in drought-affected areas of the West and Northern Plains will require normal and above-normal spring runoff to meet contract and other uses. A continuation of the drought could have a severe and widespread impact because of the low storage levels at many reservoirs.

In many areas, plans are being developed to manage water project operations in the event of continued drought. Low soil moisture conditions will add to problems of low reservoir shortage conditions.

However, recent storm activity across the Northwest, Rockies, and upper Midwest has provided a good start for winter snowpack. Continuation of these weather patterns and normal weather elsewhere will greatly aid a return to reservoir and streamflow conditions. However, shortage conditions are highly likely in some areas. For example, inflows in the range of those exceeded only 10 percent of the time are required to bring Missouri River mainstem reservoirs back to their long-term average levels. Average inflows during the next spring runoff would only bring the reservoirs up to their historic minimum levels. Reservoirs in the Ohio River basin are expected to refill to normal seasonal levels given normal precipitation.

Transportation

A high degree of coordination, extensive dredging by the Corps of Engineers, and water control management were required to keep the inland navigation system open to commerce. Many reservoirs in principal waterway systems are, however, at lower than normal levels for this time of the year. They may not be able to support navigation to the same extent next year if below-normal levels of precipitation occur during this winter.

Wildlife

The prognosis for next year's duck-breeding season is bleak because a reduced number of breeders are expected to return to the northern prairies and, without far-above normal fall and winter precipitation, pond conditions will be worse at the beginning of 1989 than in 1988. This loss of residual cover for upland-nesting ducks will further exacerbate poor waterfowl production conditions expected in 1989.

report was prepared for the Secretary examining the impact of the drought and the policy questions that may be anticipated if the drought persists.

Department of Commerce

The Department of Commerce closely monitored meteorological conditions associated with the drought and disseminated data and information on current and forecast weather conditions. Drought advisories describing meteorological and hydrological conditions were prepared weekly and widely distributed for public and private use. Special assessments were conducted which provided useful historical perspectives on the 1988 drought.

Tennessee Valley Authority

The TVA acted early to offset the effects of the continuing drought. Reservoir operating priorities were established to give precedence to water supply, water quality, navigation, and hydropower generation. A regional task force was formed to monitor water quality, alert the public about drought conditions, and to develop plans to ensure a stable reservoir system. Due to conservative management of water resources, many potentially harmful effects of the drought were avoided.

Prognosis

Agriculture

Large production shortfalls are being offset by large carryin stocks which are moderating prices and helping cushion producers' incomes and food prices. Moreover, timely Federal feed and forage assistance, crop insurance payments, and newly legislated disaster payments and other relief are helping drought-stricken producers.

This year's production losses mean that crop supplies will be much tighter at the end of the 1988/89 crop year than they have been for some time. As a result, crop prices may be quite sensitive to changes in production expectations. Soil moisture deficits are likely to persist in some regions as farmers approach the 1989 planting season. Irrigation supplies from both groundwater and surface water sources are likely to be reduced in many areas and possibly more costly.

No one knows for sure what the weather will be in 1989. If pockets of drought persist into the next growing season, yields could be below trend. Parts of the Northern Plains and western Cornbelt will very likely enter the 1989 crop planting period with significant soil moisture deficits. However, historical data suggest that crop production will rebound and stocks will start to reaccumulate. Moreover, there is no evidence that the drought has changed the long-term tendency for agricultural productivity to outpace the growth in demand for farm products.

The amount of timber that is harvested from public lands may have to be reduced for the next decade or two to compensate for tree mortality (insect attack and fire kill) and growth loss. Major salvage efforts for burned and insect-infected trees will take place in accessible areas.

Some forestry impacts of the drought will not be known for several months or even a year or more. It will take 2 successive years of average or

Temporal and Spatial Severity of the 1988 Drought: Historical Perspective

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The historical aspects of the 1988 drought are examined from various climatological perspectives using the modern climate record (1895-present). The 1988 drought stands in sharp contrast to the unusually wet weather of the past 20 years. Nationwide, May of 1988 was the fourth driest May on record and June 1988 was the second driest June. The drought manifested itself most strongly in an inverted "U" pattern from the Pacific Coast through the Northern Rockies, and east-southeast to the Ohio and Tennessee River Valleys and the southern Appalachians. Although the first three months of 1988 were generally dry also, the drought intensified at its greatest rate during the first half of the growing season (May-July) in the top portion of the inverted "U". Unlike the edges of the inverted "U", these northern areas were not in a long-term drought at the beginning of 1988. For many localities of the northwestern Great Plains and Midwest, the dryness during March-July was record breaking, but for broader space-scales such as the Mississippi River Drainage Basin the dryness was of only near-record proportions.

The climate record was searched for similar anomaly patterns. The search was made using the absolute value and the sum-of-squares of the differences of the area-weighted anomalies within each of 344 climate divisions in the United States. The most nearly matching patterns were identified for a sequence of months: January-August, January-March, April-June, and for individual months within 1988. These results indicate that similar patterns of dryness across the entire United States have occurred in the modern climate record, but not with the intensity of 1988 drought. On the other hand, the intensity of previous droughts has been stronger across many portions of the inverted "U" pattern, but during years which had differing patterns of dryness.

The areal-extent of the 1988 drought was quite large, but still smaller than the great droughts of the 1930s and 1950s. The severity of the 1988 drought and the frequency of droughts in the United States over the past century suggests that the drought of 1988 cannot be distinguished from the normal climate variability of the past century.

DROUGHT ADVISORY 88/12
SUMMARY OF CONDITIONS AND IMPACTS

September 29, 1988

EXECUTIVE SUMMARY

The United States Drought of 1988 was the most severe in the Midwest since 1936. Major crop areas, covering over 25% of the contiguous 48 states, received less than one-half of their normal rainfall during the critical growing period from April through June 1988. The driest and/or hottest periods in over 90 years were recorded in parts of the Plains, Midwest and lower Mississippi Valley. Agricultural impacts were most severe in the Midwest and Great Plains. For example, spring wheat yield was about 50% below the latest five-year average. Below normal river flows and reservoir storage hindered navigation in the lower Mississippi Valley, caused increased restrictions on water usage and reduced the use of irrigation over much of the nation. Forest fires damaged over four millions acres, nationwide, which is more than twice the acreage affected in 1987.

Although the severity of the midwest drought peaked in early July, the origins of drought can be traced back one or more years in different sections of the country. By April 1988, long-term drought conditions already existed over the Tennessee Valley and the southern Appalachians, the northern Plains and much of the West. During the period April-June, these conditions worsened and became extreme. This was caused by record rainfall deficits over the northern Plains and the Mississippi and Ohio River Valleys and record high temperatures across the northern half of the country from the Rockies to the Ohio Valley.

Since the end of June, normal rainfall has returned to some parts of the central United States. This has improved short-term water deficiencies and the agricultural outlook, near the end of the growing season, in the Midwest. Western states, however, continued to receive below normal rainfall from July through the end of August. September precipitation has improved short-term drought conditions and has aided the forest fighting efforts. Long-term drought conditions, however, have improved only slightly. It will take months or years of above normal precipitation in some areas to return riverflow and reservoir conditions back to normal.

This Advisory concludes the series of Drought Advisories issued by the Climate Analysis Center, NOAA beginning on June 21, 1988.

Presented by David Rodenhuis
Presentation and slides extracted from NOAA CAC's:
Drought Advisory 88/12: Summary of Conditions and Impacts, September 29, 1988. 8 pages plus 32 figures.

METEOROLOGICAL CONDITIONS

The most intense phase of the United States Drought of 1988 occurred in late spring and early summer and was accompanied by major crop damage and severe navigational problems on the lower Mississippi River. Later in the summer, large-scale forest fires occurred over areas of the Northwest and Rocky Mountains. Many chronic drought problems still exist, although the critical stage has now passed. This Advisory is intended to sum up the drought situation and present some of the historical significance of conditions during the period from April through August.

ACUTE DROUGHT PERIOD: The period April-June was abnormally dry over a large part of the United States. As shown by Figure 1, a large area of the Mississippi/Missouri watershed had less than 50% of normal precipitation. These precipitation deficiencies were as great as six inches in the Mississippi Valley area (Figure 2). Deficits generally existed throughout the country, except for small areas of excess precipitation in the normally dry Southwest and the far West.

The significant change to more normal rainfall occurred during July-August, as shown in Figures 3 and 4. However, an additional deficit of about four inches (Figure 4) amplified the drought problems in some midwestern areas, especially parts of Illinois.

A view of the temporal variation of the areas covered by the severe dryness is shown in Figure 5. As can be seen, up to 26% of the contiguous United States was abnormally dry at the end of June, but this was followed by a steady decrease in the area of dryness after that time.

Rankings of the precipitation deficiencies for the April-June 1988 period are shown in Figure 6. They were calculated by using 58 years (1931-1988) of surface observations. Many climate divisions experienced the driest three-month period on record. An equally large area was in the 2nd-5th driest category.

ASSOCIATED CIRCULATION FEATURES: The causes of this extreme dry period over such a large portion of the United States cannot be directly determined. However, it is clear that this drought was associated with an unusual displacement of the jet stream. The prevailing jet stream track during June 1988 is shown in Figure 7. The June 1988 position is also fairly representative of the two previous months and indicates an upper-air ridging pattern over the north-central States and south-central Canada. Such ridges deflect rain bearing storms away from the center of the United States. The normal flow, usually associated with adequate precipitation throughout the United States, is also depicted. By July (Figure 7), a change to near normal is evident with the reduction of amplitude of the persistent ridge. This re-established a more normal storm-track pattern.

SUMMER HEAT: While the spring and early summer of 1988 were among the driest on record, the summer season can be characterized as one of the hottest on record, predominately within the northern half of the United States. This is shown by the seasonal departure of average temperature from normal (Figure 8). Several short-term heat waves resulted in the hottest summer in the northern Plains in at least the last 38 years (Figure 9). Only a small area over Texas and New Mexico recorded temperatures more than 2°F below normal.

Many heat records were broken during the summer of 1988. As can be seen from Figure 10, the normal number of days with maximum temperatures of 90°F or higher in the northern part of the United States is less than 40 days. Parts of the northern Plains, the Great Lakes and the Northeast normally have less than 10 days. However, Figure 11 shows that practically all of the United States experienced at least 20 days with maximum temperatures of 90°F or higher. Most of the central Plains and the Midwest experienced 40-60 days with temperatures reaching 90°F or above, which is at least 20 days more than normally expected.

PERFORMANCE OF THE OUTLOOKS: Precipitation outlooks issued for the period April through mid-July correctly indicated dryness in the Midwest in almost every case, but these forecasts generally understated the areal coverage and indicated conservative probabilities. Figures 12 and 13 show the most relevant 90-Day Precipitation Outlook and its verifying pattern, respectively. Except for April, the monthly rainfall outlooks scored well because of the emphasis on midwestern dryness.

The 90-Day Temperature Outlook for the summer (June-August) correctly pointed toward warmer than normal weather in many of the areas that experienced intense heat. Figures 14 and 15 show the summer Temperature Outlook and the verification. This forecast attained a much better than average score, as did the monthly outlooks from June to August taken as a group.

LONG-TERM DROUGHT: Although the focus has been on the period beginning in April as the most acute phase of 1988 Drought, the roots of some of this anomaly were already in place much earlier. This is reflected by the Palmer Drought Severity Index (PDSI) chart for April 30, 1988 (Figure 16). The PDSI represents the longer term groundwater balance and, even in April, indicated some extreme drought conditions in the Tennessee Valley and the northern Plains. Dry conditions in the Southeast already had a three or four year history. Conditions in the northern Plains steadily worsened due to the previous dry autumn and winter, followed by a lack of snow runoff in spring of 1988. The mountains of the far West experienced a shortage of winter snow. Some areas of the Pacific Northwest had similar deficits over the past two winters.

Especially evident from the PDSI of July 9, 1988 (Figure 17) is the large expanse of the extreme drought rating, especially in the northern Plains. Most of this extreme rating resulted from the lack of sufficient precipitation during a normally dry period. One inch (or less) per month fell in many locations which usually receive about two inches per month.

Changes in the PDSI were rapid between the end of April and the middle of July, as shown by Figure 18. The percent of area covered by ratings of severe or extreme drought rose rather dramatically to a high of about 40% of the total area of the contiguous United States.

HISTORICAL PERSPECTIVE

PRECIPITATION: When precipitation is averaged across the entire country, the April-June 1988 period was the driest for that period since at least 1895, the earliest year for which a national average can be reliably calculated. The April-June periods of 1934 and 1936 were second and third driest (see Figure 19). Although rainfall increased during the last half of summer, the June-August period in 1988 was still considerably below normal. Rainfall deficiency in 1988 was severe enough to rank the nationally averaged precipitation during the January-August period as the second driest on record, just behind 1934.

While much of the country was experiencing drought, about one percent of the Climate Divisions (sections of Louisiana and New Mexico) recorded the wettest summer and wettest January-August periods on record in 1988.

TEMPERATURE: When temperatures are averaged across the entire United States, (using preliminary Climate Division data) the summer of 1988 (June-August) ties with 1934 for second hottest (see Figure 20). The hottest summer was 1936. Nationally-averaged temperatures for the first eight months of 1988 (January-August) were also significantly above normal.

DROUGHT RECOVERY: The near-term prospects for recovery from the long-term drought vary from state to state. In order to estimate precipitation needed to relieve long-term drought conditions by November 30, 1988, the PDSI at the end of August was used (Figure 21). A PDSI drought is considered to have ended when the index approaches zero. The seasonal total precipitation for September through November (1895 to 1987) was examined in order to provide a historical measure of the chances of receiving adequate precipitation to end the PDSI drought by November 30. The amount required, in this case, varies from under 10 inches in parts of the West and northern Plains to 21-25 inches in the normally wetter Southeast. The probabilities associated with these required amounts range from 1 in 50 in the West and Southeast to 1 in 1000 in the northern Plains (see Figure 22). Thus, while we have seen some improvement in recent weeks for some areas affected by drought, the chances are not favorable for ending the long-term drought by November 30 in the areas of the United States most severely affected.

REGIONAL CONDITIONS: Precipitation rankings from the Midwest Regional Climate Center (Figure 23) show how significantly the midwest agricultural area was affected by drought. Many areas experienced one of their five driest growing seasons (April-August) in 93 years. A report by the High Plains Regional Climate Center indicates that lack of rainfall in the late growing season of 1987 resulted in low soil moisture at the beginning of the 1987-88 winter. Below normal winter rainfall in many parts of the Plains and the Midwest prior to planting time in 1988 resulted in no soil moisture recharge. These conditions added to the impact of the dryness during April-August which followed in many areas.

Climate Division information back to 1895 indicates the regions which recorded their driest April-June period in 93 years (Figure 24). (Note that this is a longer reference period than was used in Figure 6). The dry areas covered parts of the Mississippi River drainage basin and Great Lakes region.

Record-setting heat occurred this year in 45 Climate Divisions during the summer. The areas having the hottest summer in 1988 were generally in the central Rockies to northern Plains region, the Great Lakes area, and the Northeast (see Figure 24). Two Climate Divisions (in New Mexico and Wyoming) had the hottest January-August period in 1988.

A comparison with past years is shown in Figure 25. The April-June period was among the driest in modern times over large sections of the country. In comparison, 1987 is viewed as a relatively dry year over much of the southeastern portions of the country and the analysis shows only small areas with precipitation deficiencies comparable to the current year. The areal extent of extreme precipitation deficiencies for April-June 1988 even surpassed that of the dust bowl years of 1934 and 1936.

For the nation as a whole, the summer of 1988 was among the hottest on record. It ranked 3rd warmest since 1930 (using a slightly different method than in Figure 20) and far surpassed last year's Southeast United States heat wave. The pattern of extreme temperatures was comparable to the summers of 1936 and 1934 (Figure 26).

DROUGHT IMPACTS

SUMMARY: Significant drought impacts during 1988 are depicted in Figure 27. While the primary causes may be the meteorological conditions during 1988, in many areas unfavorable conditions began in earlier years. The situation in 1988 amplified these conditions.

AGRICULTURE: The yields per acre of spring wheat, corn and soybeans were especially influenced by the drought (Figure 27). Final yields are not yet available, but United States Department of Agriculture estimates as of September 1, 1988 indicate that spring wheat yield will likely be the most strongly reduced. Spring wheat yield is expected to be about 49% of the average over the past five years (1983-1987). Similarly, the corn yield is expected to be about 64% and the soybean yield about 76%.

RIVERFLOW AND RESERVOIR CONDITIONS: Below normal runoff during the past two years in the West has resulted in below normal streamflow and reservoir levels. Many of the reservoirs did not fill this season and a significant impact was reported in the agricultural communities. Record low flows were also reported in the Columbia River Basin (Figure 27). Many hydrologic regions showed sizable rainfall deficits, for example, during the period April-June 1988 (Figure 28). Five zones had record low (area averaged) amounts.

Low flows and below normal reservoir storage severely impacted agricultural communities, especially in non-irrigated areas in the Midwest and West. Navigation has been severely hindered, particularly along the lower Mississippi River below St. Louis, the lower Ohio River near the confluence with the Mississippi River and along the lower end of the Apalachicola River in northwest Florida. Water restrictions, voluntary or involuntary, have been reported in areas impacted by water supply shortages.

Below normal precipitation and runoff in the central United States during the past year have resulted in some of the lowest river levels seen in the past 50 years on the Mississippi River system. For example, all-time record lows have occurred at Memphis, Tennessee and Helena, Arkansas along the lower Mississippi River. Numerous streams and smaller rivers completely dried up during the summer months. Water routed through the Missouri River system from reservoir releases in South Dakota played a major roll in preventing the lower Mississippi River from experiencing even lower levels than occurred this summer. The Ohio River system, which is normally a major contributor to the Mississippi River system, was supplying 20% of its normal input to the Mississippi during one period. The upper Mississippi River also experienced very low flows.

In the Southeast, as a result of below normal precipitation during the past two years, record low river levels were reported throughout much of the region, with less than desirable inflow to reservoirs. Throughout Florida, however, recent rains have resulted in near normal to above normal streamflows.

River and lake levels continue to decline over much of the Great Lakes region. During July, Lake Michigan and Lake Huron levels dropped below the long term average for the first time since October 1977 while Lake Superior continued below the long term average.

As for the Southwest and the Northeast, normal to above normal snowpack and above normal runoff this past winter, and intermittent heavy rain events this spring and summer, have resulted in near average streamflow throughout much of the region. Average to above average inflow into reservoirs has occurred in the lower Colorado and Rio Grande Basins.

During the first part of September, river levels either remained unchanged or continued to decline over much of the country. The exceptions were central and north Florida, where major flooding occurred, and in the Gulf Coast region from Louisiana to northwest Florida, where heavy rains from Hurricane "FLORENCE" caused moderate flooding.

FOREST FIRES: The satellite image of smoke plumes created by the forest fires within and around Yellowstone National Park was acquired on 7 September 1988 by the AVHRR Data Acquisition and Processing System at the United States Geological Survey's EROS Data Center in Sioux Falls, SD (Figure 29). The image includes a portion of the scene from the NOAA-9 satellite at approximately 16:32 P.M., Mountain Daylight Time. Smoke from the forest fires in Wyoming extended into eastern regions of North Dakota, South Dakota and Nebraska.

The acreage burned and the number of forest fires (as of September 19) are depicted in Figures 30 and 31 with similar data for 1987 also shown. More than twice the acreage has burned during 1988 as compared with the same period in 1987.

The National Interagency Forest Fire Center (NIFFC) has provided the following interim data on forest fire activity. More detailed summaries are available from NIFFC and a final summary will be published by NIFFC at the end of the forest fire season (by late December 1988).

FOREST FIRE SUMMARY FOR WESTERN STATES - 1988 SEASON THROUGH SEPTEMBER 27

STATE	LARGEST FIRE	ACRES	FIRES>10K ACRES	>300	TOTAL ACRES
ALASKA	A043	566,800	26	52	2,213,000
ARIZONA	PEAK	12,025	1	16	35,900
CALIFORNIA	49ER	35,300	5	42	184,700
COLORADO	I DO	16,000	1	19	45,100
IDAHO	SILVER CREEK	69,400	8	26	337,700
MONTANA	CANYON CREEK	247,200	14	44	824,300
NEVADA	USAF 4	12,100	1	28	67,100
OREGON	TEPEE BUTTE	59,900	2	33	110,400
S.DAKOTA	GALENA	16,300	1	2	20,200
TEXAS	ALBANY	265,000	1	2	267,000
UTAH	WHITE ROCKS	15,800	1	22	42,900
WASHINGTON	DINKLEMAN	53,500	3	14	112,600
WYOMING	CLOVER/MIST	411,500	11	27	1,645,300

OUTLOOKS

FOREST FIRE OUTLOOK: According to the daily situation report (September 26) from the Forest Service/USDA, recent wet, cool weather over much of the northern Rockies was assisting crews in containment and mop up of remaining fires. There have been few new starts and resource availability is improving. With favorable weather dominating the northern Rockies, the Forest Service expects continued improvement in the fire situation as many fires are brought under containment.

WEATHER OUTLOOK (90-Day): The 90-day Outlook for October through December (Figure 32) places cool weather in the Plains and moves the warm conditions away from many of the summer's heat wave areas to the Southeast. It brings wet weather to most of the Mississippi Valley, but leaves uncertain the prospects for early precipitation in either the mountains of the West or the drought-stricken northern Plains.

HYDROLOGIC OUTLOOK During the fall months, average to above average streamflow is expected throughout the Atlantic regions as well as in the Texas Gulf, the Rio Grande, and the Arkansas-White-Red River Basins. Elsewhere, streamflow is expected to continue to be below to much below average (Figure 33). However, isolated heavy rainfall events may produce short term localized flooding on smaller rivers and streams. Considering historical precipitation-producing weather systems and runoff patterns over various parts of the country, the following is the best estimate of what would be needed to bring the water supply back to normal:

Ohio/Lower Mississippi Basins: A series of systems producing at least 8-12 inches of rain over much of the Ohio River Basin over a 2-4 week period. Historically, the probability of experiencing this weather scenario is very low during summer with the chances increasing during fall and extending through early spring.

Missouri Basin: Two to three years of above normal winter precipitation over the mountainous headwaters of the basin followed by above normal snowpack runoff for each of the years.

California: One year of normal winter precipitation followed by normal spring snowpack runoff.

Upper Mississippi/Great Lakes Basin: Two to three years of above normal winter and spring precipitation followed by above normal runoff for each of the years.

The Reservoir Storage Outlook for Fall 1988 is depicted in Figure 33.

This Advisory is a technical summary of the spring and summer United States drought conditions. The analyses are preliminary and have been produced from recent weather and climate data. The Climate Analysis Center (CAC) will continue to monitor drought conditions in the United States using input from other NOAA offices, Regional Climate Centers and State Climatologists in addition to normal data analyses of the National Weather Service. The CAC does not expect to issue any further Drought Advisories during 1988.

Questions should be directed as follows:

Area of Concern	Source	Number
Technical/Current Climate	NWS, Climate Analysis Center	301-763-8071
Public Information	NWS, Public Affairs	301-427-7622
Hydrology	NWS, Hydrologic Services	301-427-7624
Fire and Aviation Management	USDA, Forest Service	703-235-3838
Historical Perspective	NESDIS, National Climatic Data Center	704-259-0251
Regional Perspectives	High Plains Regional Climate Center (RCC)	402-472-6706
	Midwest RCC	217-244-1488
	Northeast RCC	607-255-1749
	Southeast RCC	803-737-0811
	Southern RCC	504-388-6184
	Western RCC	702-972-1676

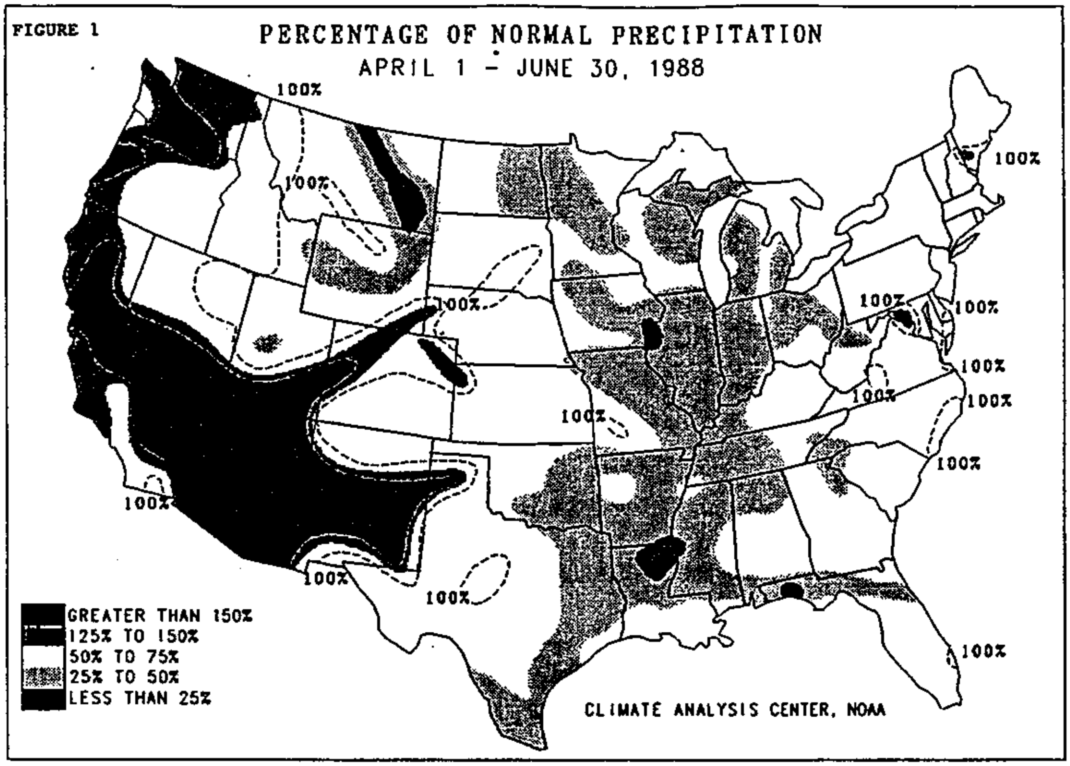


FIGURE 1
PERCENTAGE OF NORMAL PRECIPITATION
APRIL 1 - JUNE 30, 1988
100%
GREATER THAN 150%
125% TO 150%
50% TO 75%
25% TO 50%
LESS THAN 25%
CLIMATE ANALYSIS CENTER, NOAA

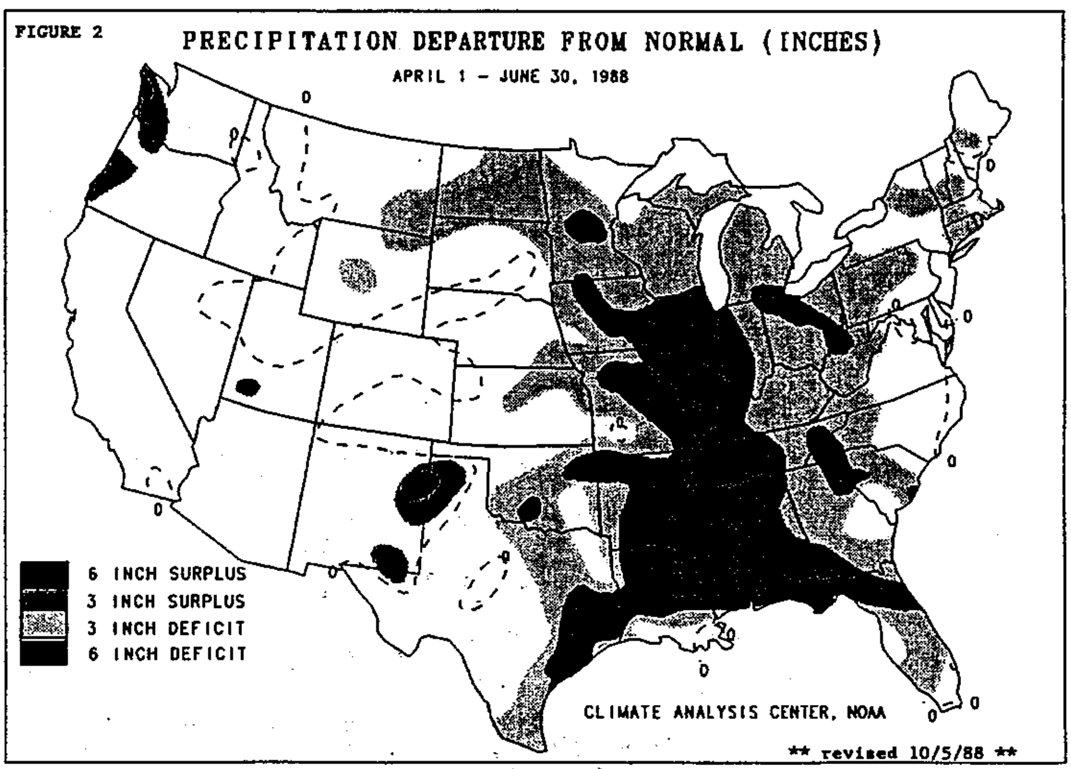


FIGURE 2
PRECIPITATION DEPARTURE FROM NORMAL (INCHES)
APRIL 1 - JUNE 30, 1988
0
6 INCH SURPLUS
3 INCH SURPLUS
3 INCH DEFICIT
6 INCH DEFICIT
CLIMATE ANALYSIS CENTER, NOAA
** revised 10/5/88 **

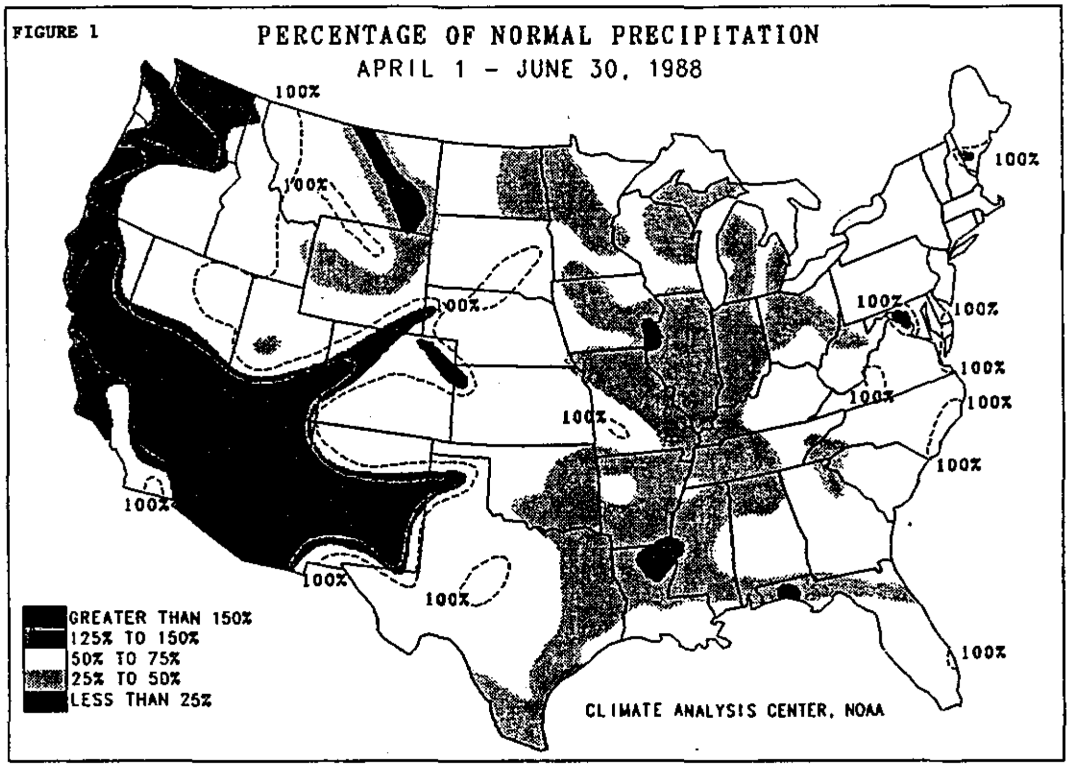


FIGURE 1
PERCENTAGE OF NORMAL PRECIPITATION
APRIL 1 - JUNE 30, 1988
100%
100%
100%
100%
100%
100%
100%
100%
100%
100%
100%
100%
100%
100%
GREATER THAN 150%
125% TO 150%
50% TO 75%
25% TO 50%
LESS THAN 25%
CLIMATE ANALYSIS CENTER, NOAA

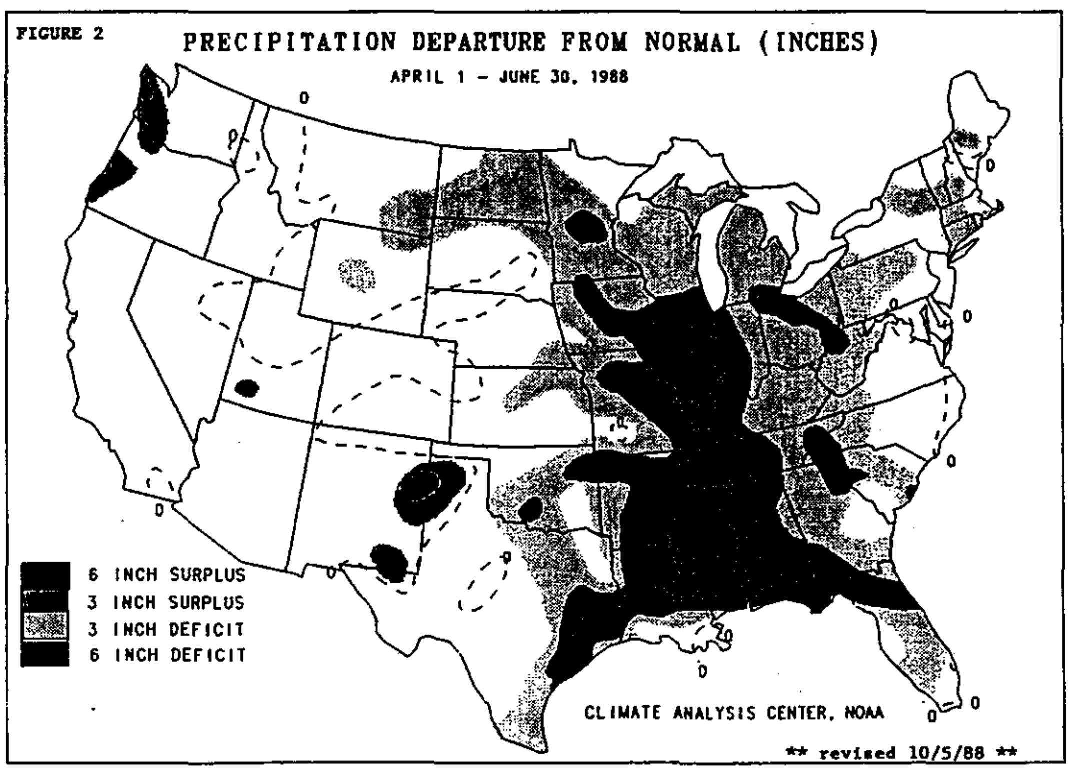


FIGURE 2
PRECIPITATION DEPARTURE FROM NORMAL (INCHES)
APRIL 1 - JUNE 30, 1988
0
0
0
0
0
0
0
0
6 INCH SURPLUS
3 INCH SURPLUS
3 INCH DEFICIT
6 INCH DEFICIT
CLIMATE ANALYSIS CENTER, NOAA
** revised 10/5/88 **

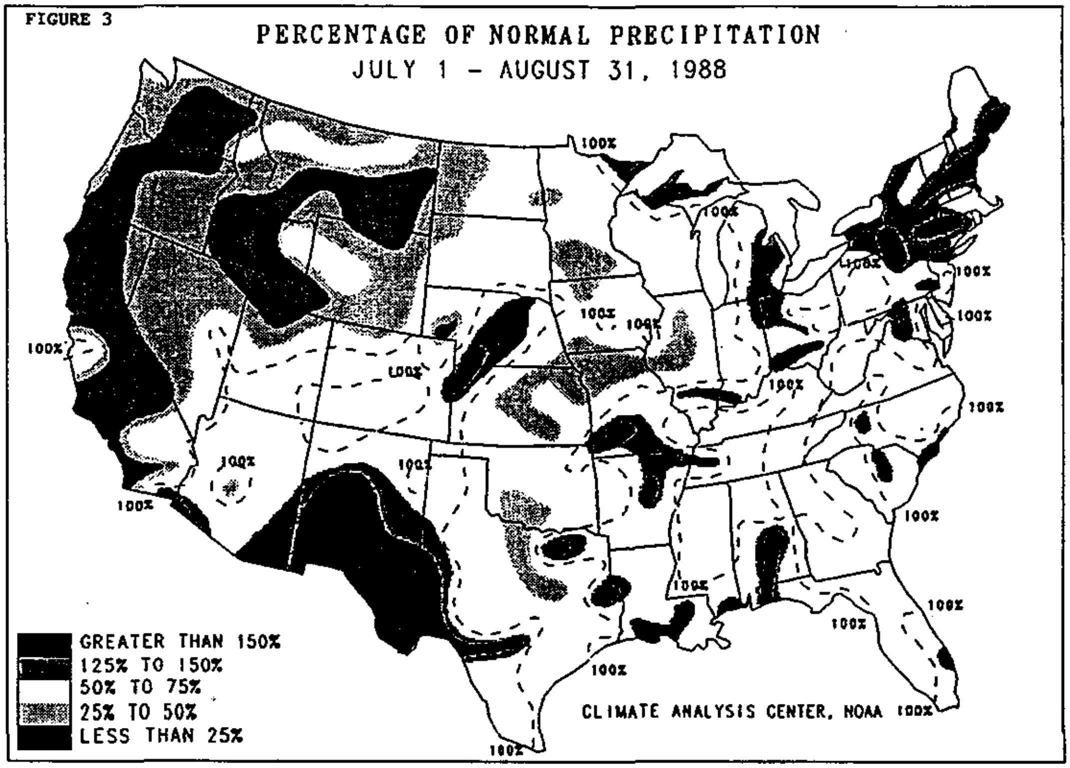


FIGURE 3
PERCENTAGE OF NORMAL PRECIPITATION
JULY 1 - AUGUST 31, 1988
GREATER THAN 150%
125% TO 150%
50% TO 75%
25% TO 50%
LESS THAN 25%
CLIMATE ANALYSIS CENTER, NOAA

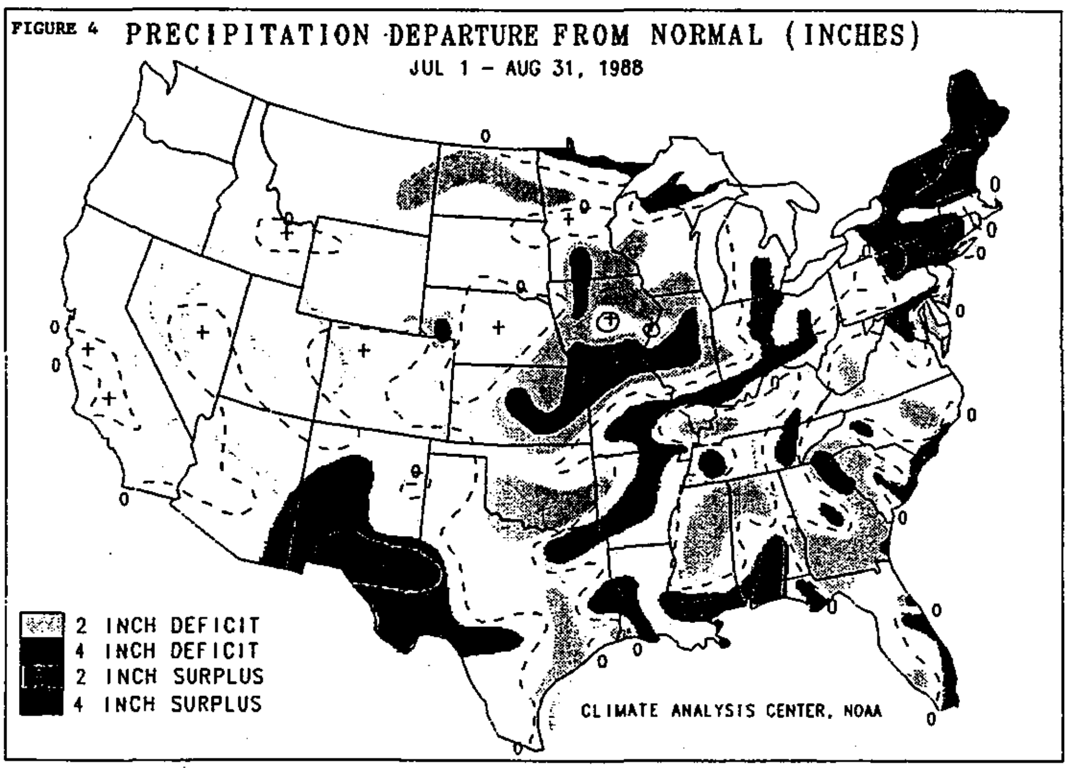
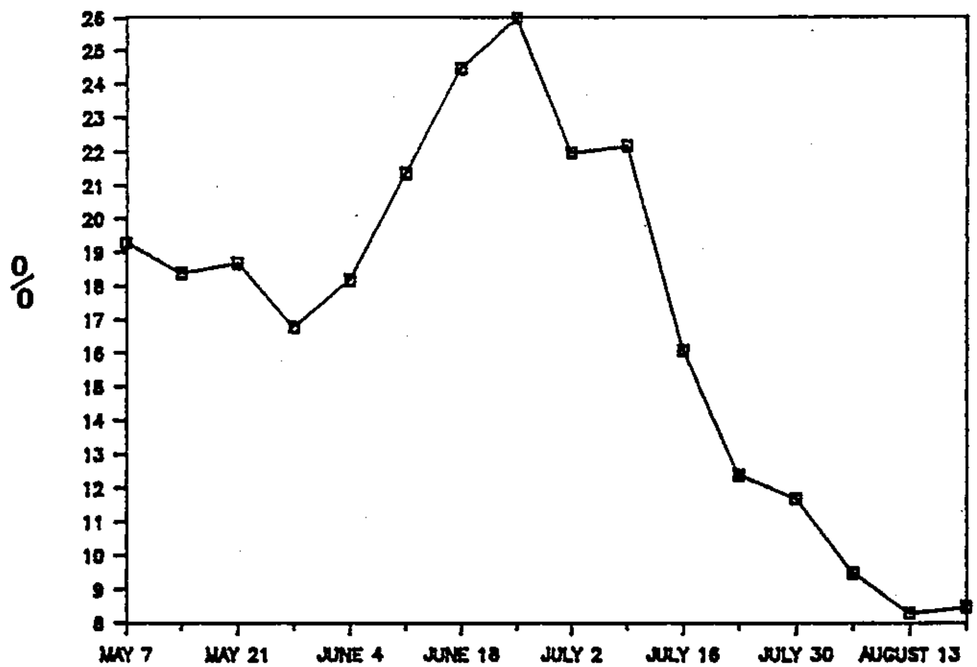


FIGURE 4
PRECIPITATION DEPARTURE FROM NORMAL (INCHES)
JUL 1 - AUG 31, 1988
2 INCH DEFICIT
4 INCH DEFICIT
2 INCH SURPLUS
4 INCH SURPLUS
CLIMATE ANALYSIS CENTER, NOAA

FIGURE 5

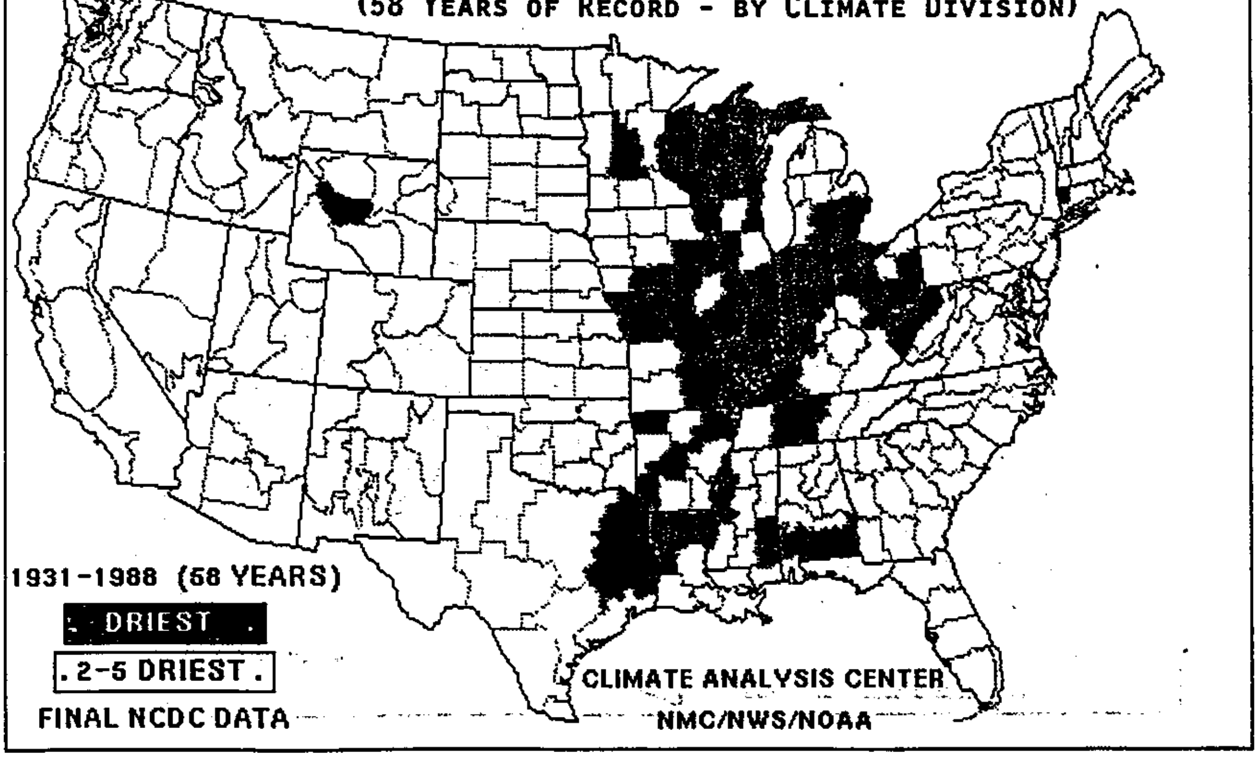
PERCENT OF AREA OF UNITED STATES WITH <50% OF NORMAL RAINFALL
(EACH CASE IS FROM APRIL 1 TO DATE INDICATED)



CLIMATE ANALYSIS CENTER, NOAA

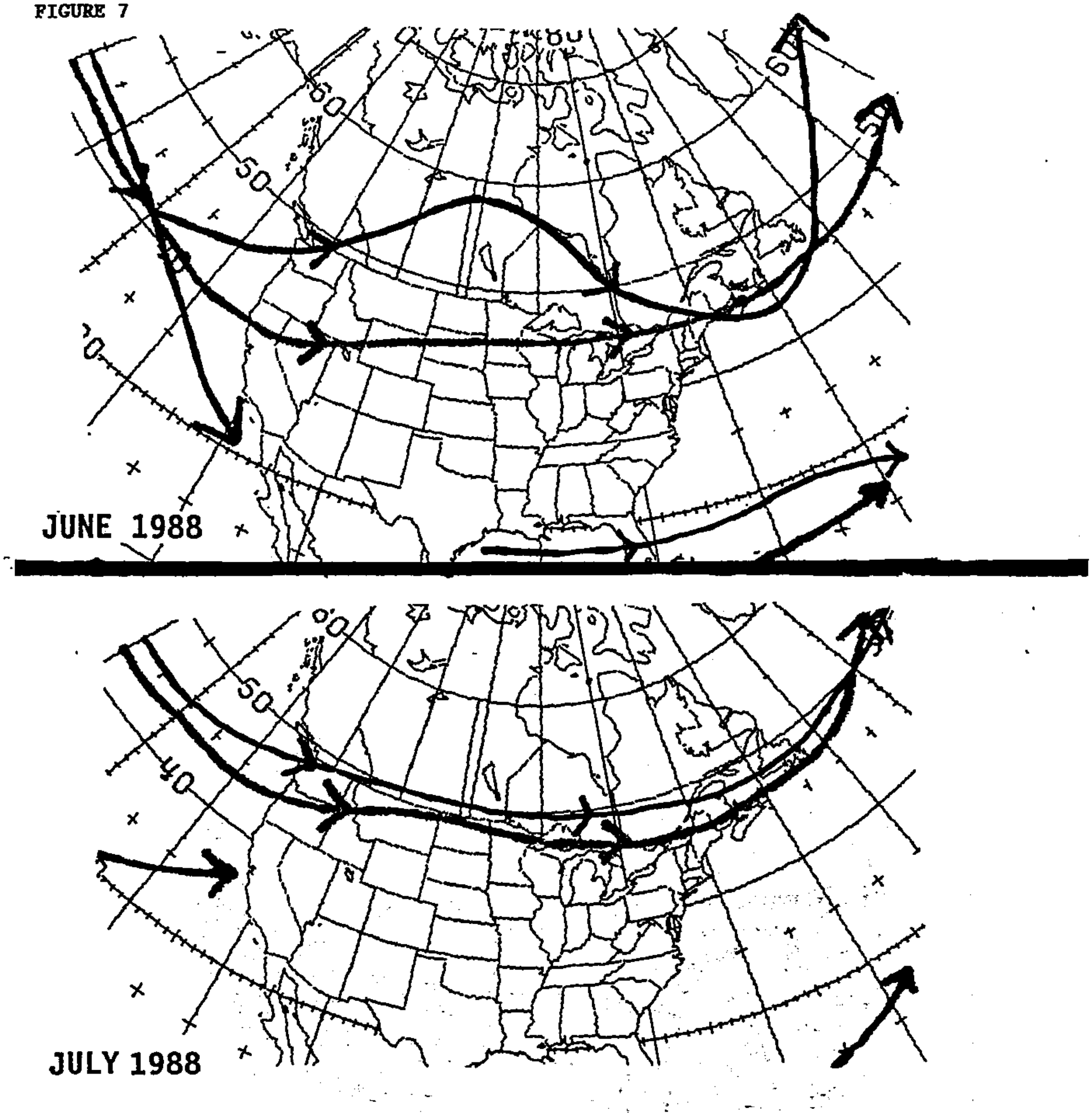
FIGURE 6

APRIL - JUNE PRECIPITATION RANKINGS
(58 YEARS OF RECORD - BY CLIMATE DIVISION)



MONTHLY JET STREAM POSITIONS

FIGURE 7



MEAN JET STREAM POSITION — CLIMATOLOGICAL POSITION OF JET STREAM FOR SAME TIME PERIOD

CLIMATE ANALYSIS CENTER, NOAA

FIGURE 8

SEASONAL DEPARTURE OF AVERAGE TEMP FROM NORMAL

JUNE 1-AUGUST 31, 1988

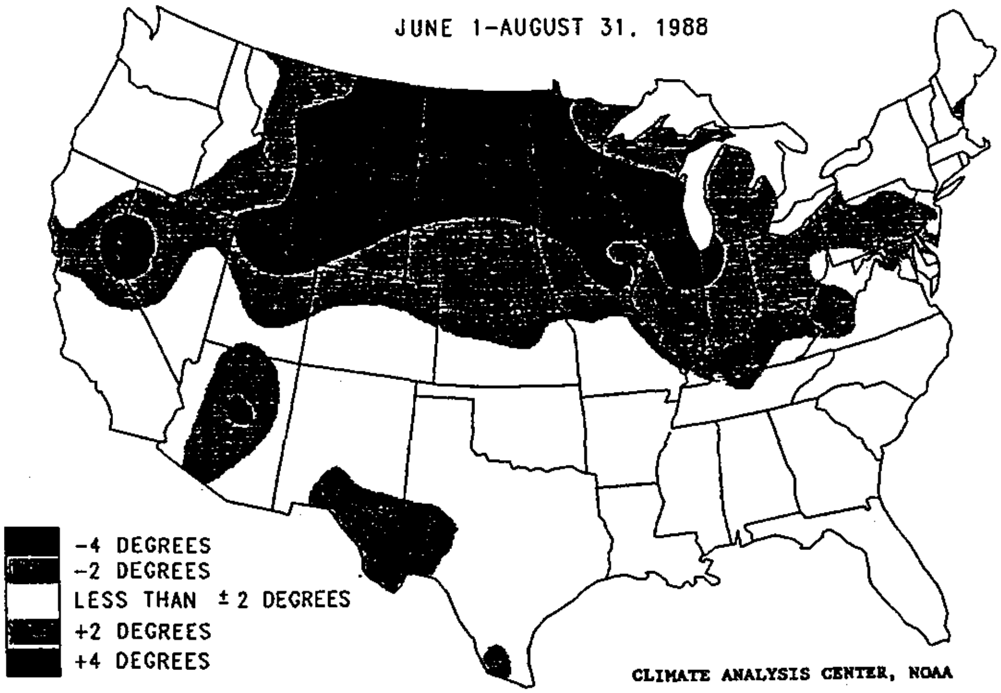
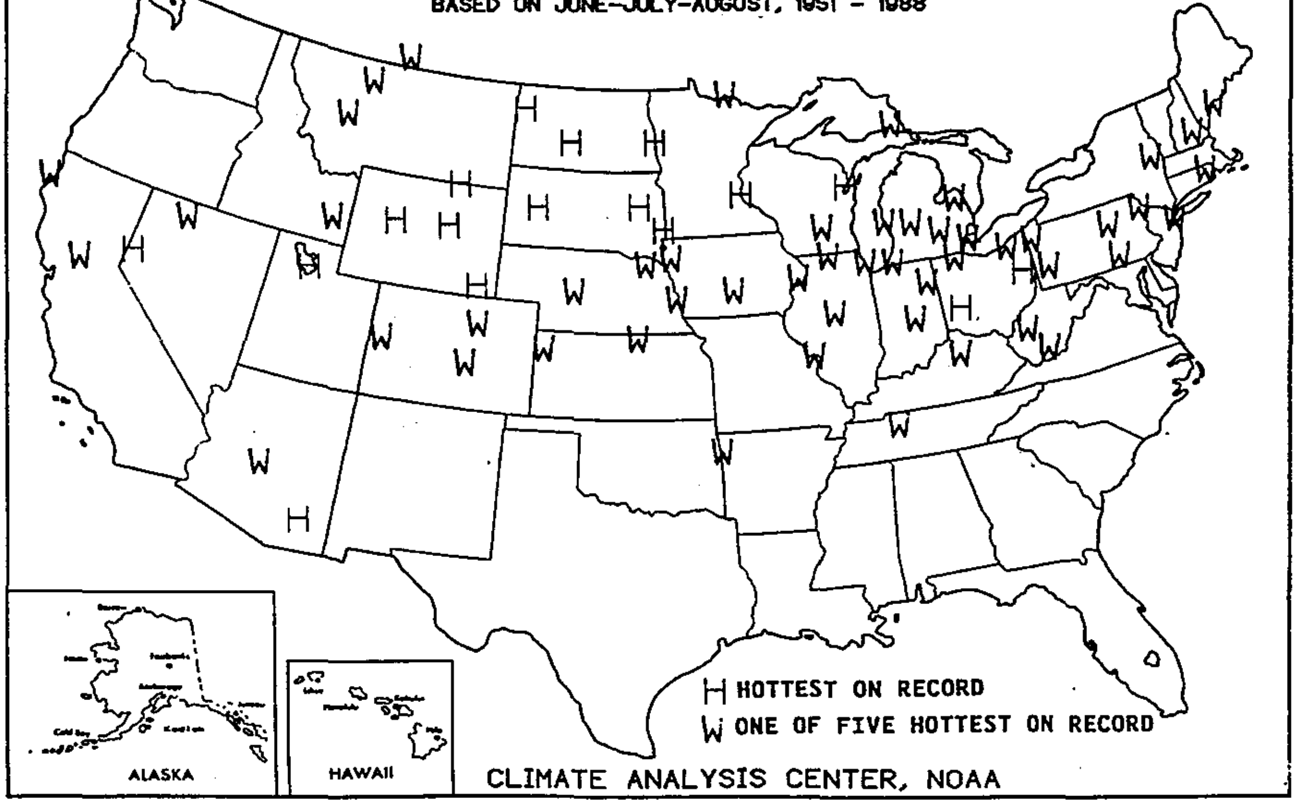
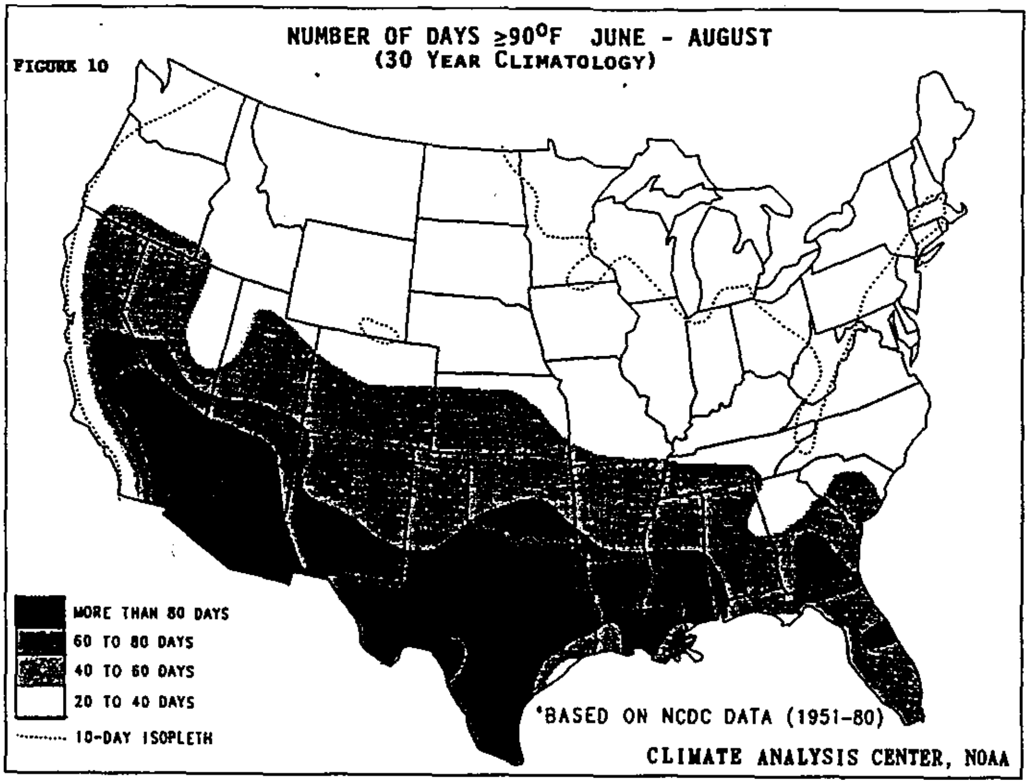


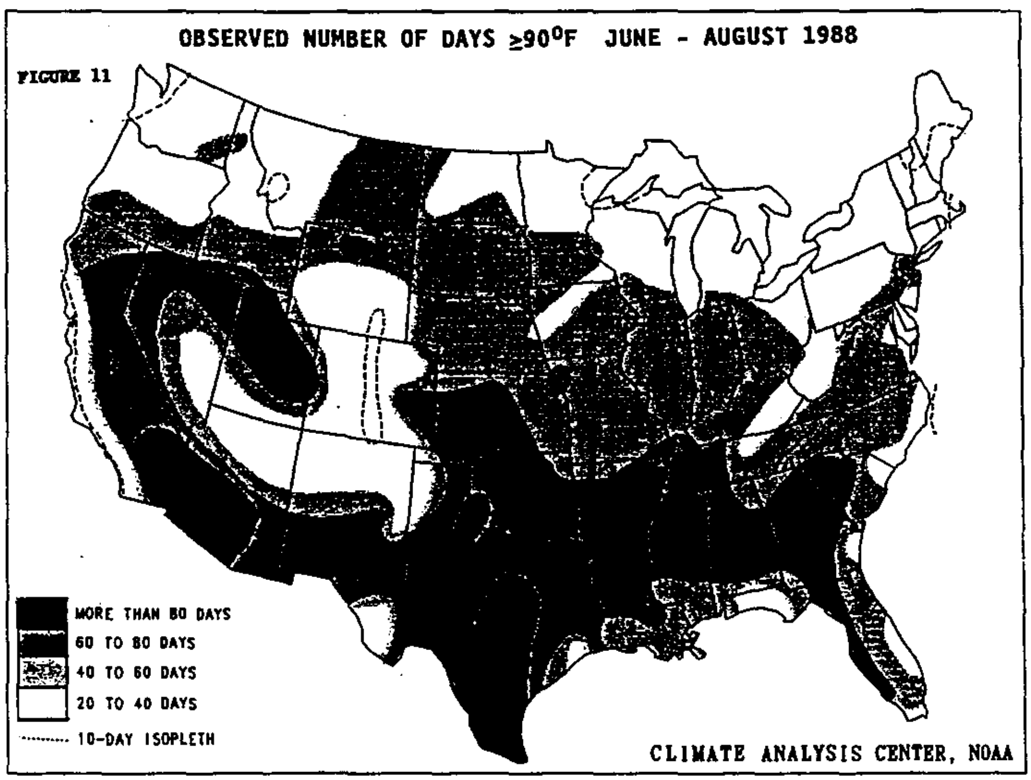
FIGURE 9

SUMMER 1988 TEMPERATURE RANKINGS (BY STATION)

BASED ON JUNE-JULY-AUGUST, 1951 - 1988




NUMBER OF DAYS ≥90°F JUNE - AUGUST
(30 YEAR CLIMATOLOGY)
FIGURE 10
MORE THAN 80 DAYS
60 TO 80 DAYS
40 TO 60 DAYS
20 TO 40 DAYS
10-DAY ISOPLETH
*BASED ON NCDC DATA (1951-80)
CLIMATE ANALYSIS CENTER, NOAA


OBSERVED NUMBER OF DAYS ≥90°F JUNE - AUGUST 1988
FIGURE 11
MORE THAN 80 DAYS
60 TO 80 DAYS
40 TO 60 DAYS
20 TO 40 DAYS
10-DAY ISOPLETH
CLIMATE ANALYSIS CENTER, NOAA

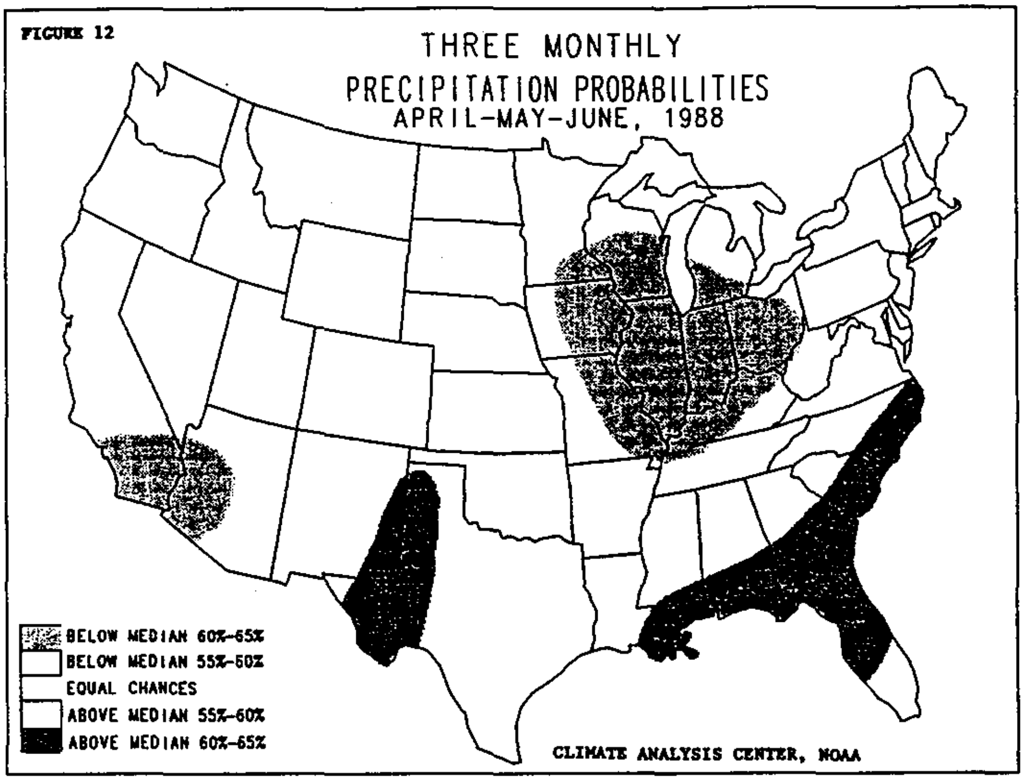


FIGURE 12
THREE MONTHLY
PRECIPITATION PROBABILITIES
APRIL-MAY-JUNE, 1988
BELOW MEDIAN 60%-65%
BELOW MEDIAN 55%-60%
EQUAL CHANCES
ABOVE MEDIAN 55%-60%
ABOVE MEDIAN 60%-65%
CLIMATE ANALYSIS CENTER, NOAA

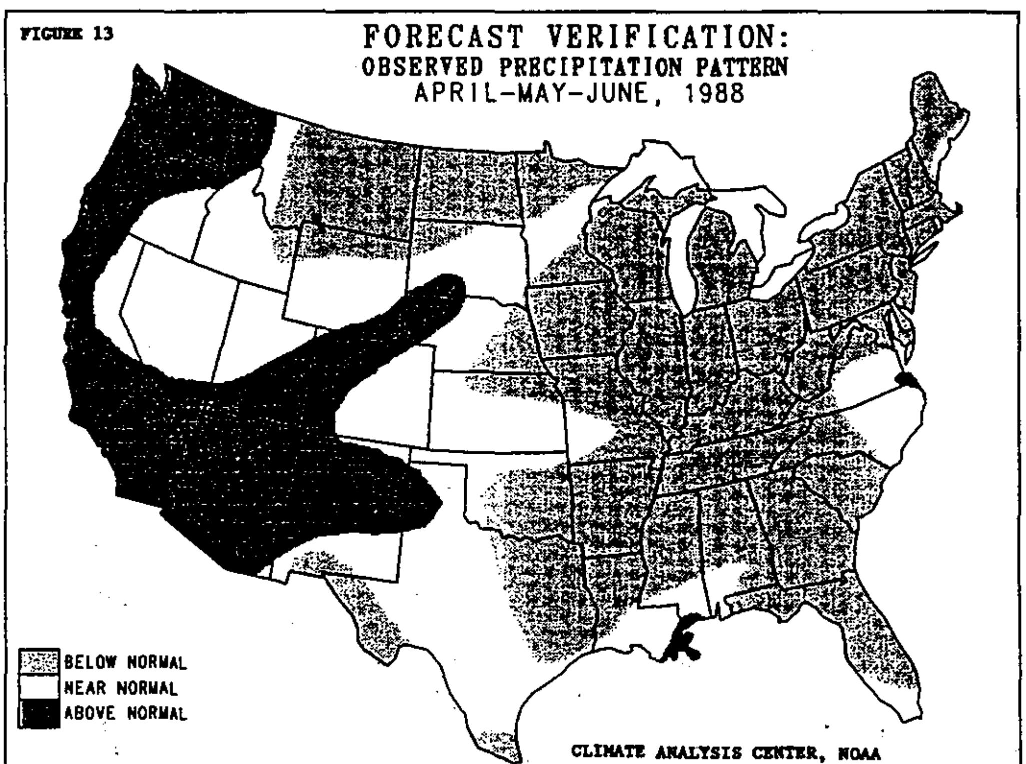


FIGURE 13
FORECAST VERIFICATION:
OBSERVED PRECIPITATION PATTERN
APRIL-MAY-JUNE, 1988
BELOW NORMAL
NEAR NORMAL
ABOVE NORMAL
CLIMATE ANALYSIS CENTER, NOAA

FIGURE 14

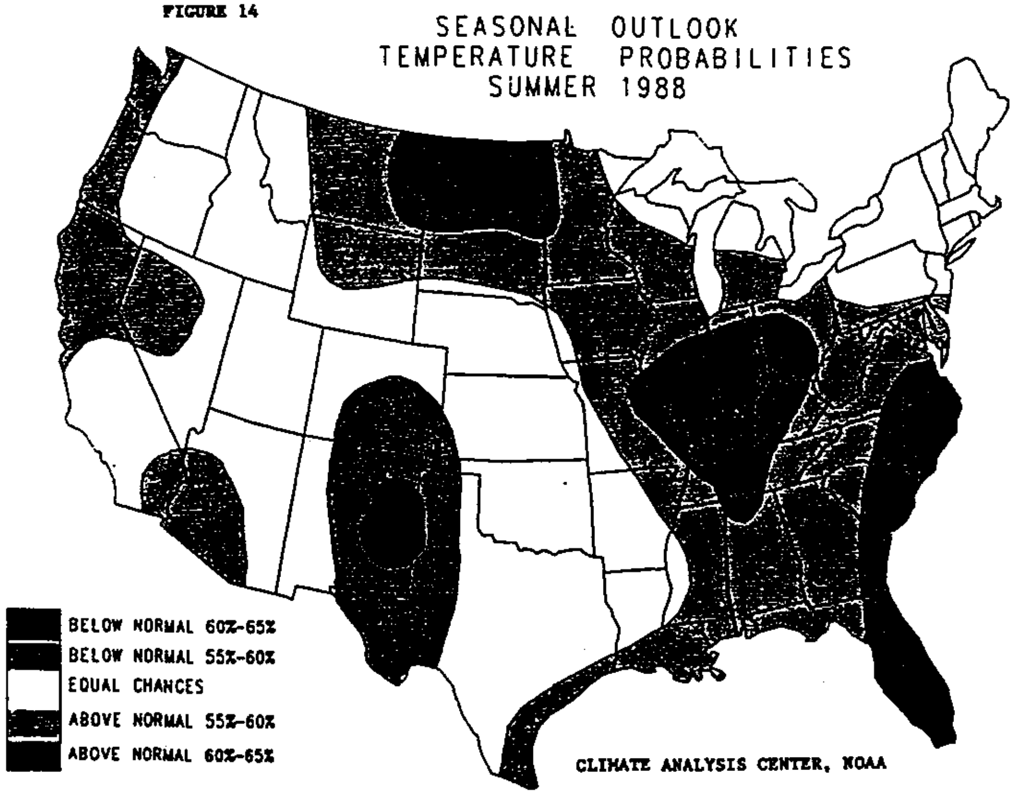
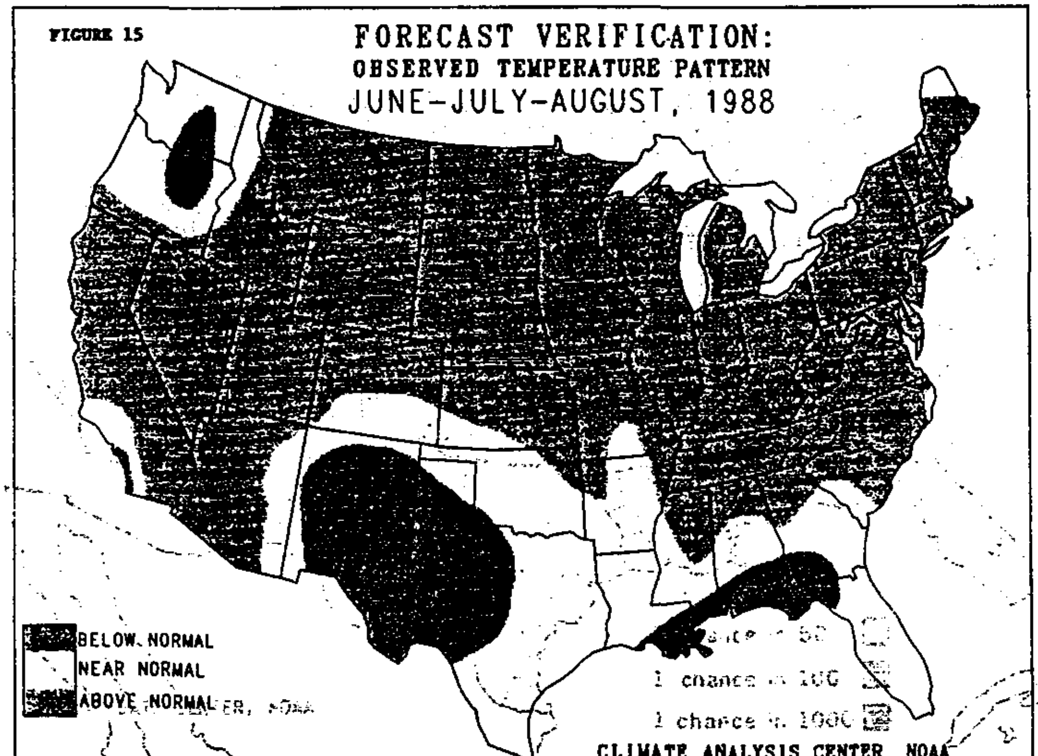


FIGURE 15



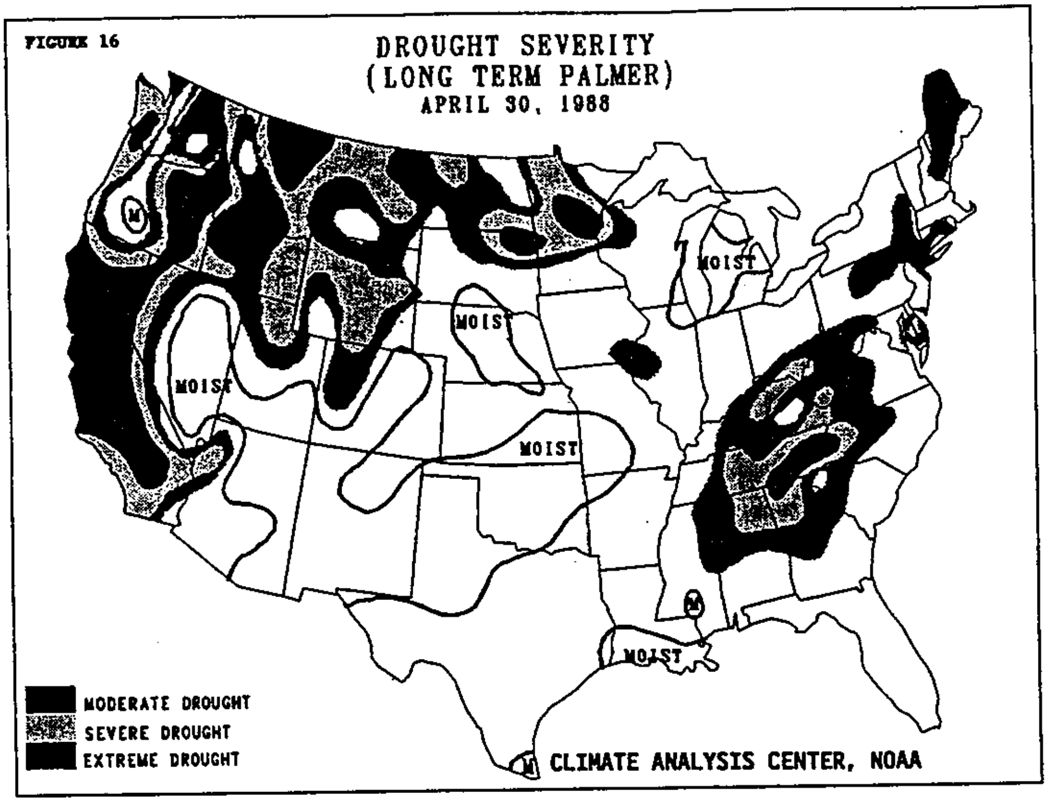


FIGURE 16
DROUGHT SEVERITY
(LONG TERM PALMER)
APRIL 30, 1988
MOIST
MOIST
MOIST
MOIST
MOIST
M
M
M
MODERATE DROUGHT
SEVERE DROUGHT
EXTREME DROUGHT
CLIMATE ANALYSIS CENTER, NOAA

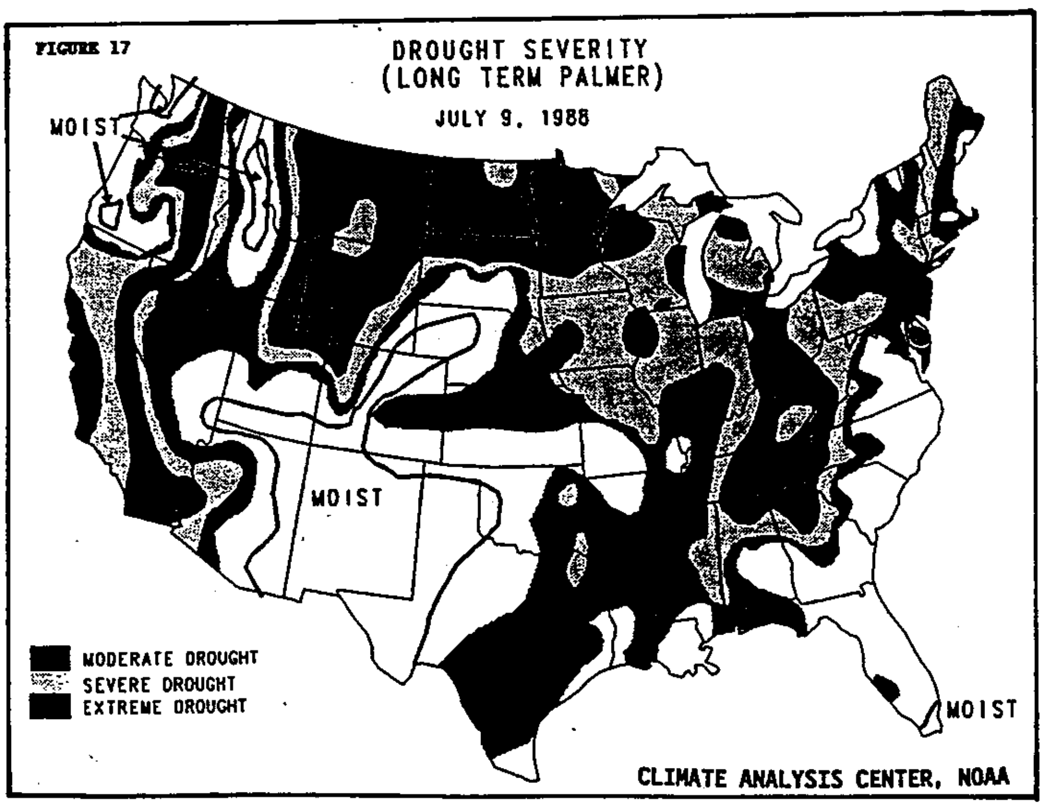
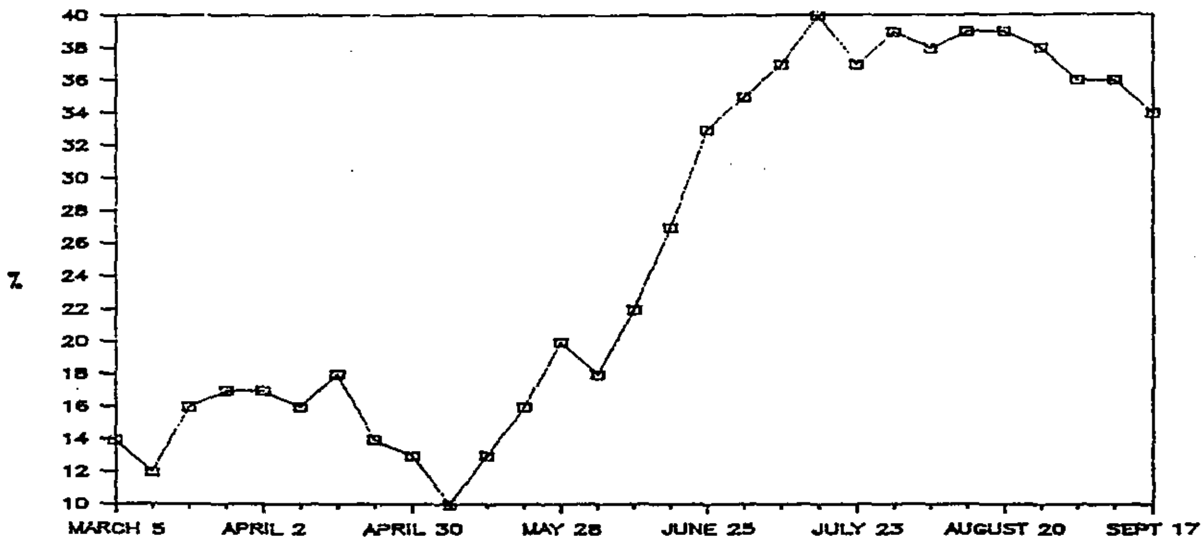


FIGURE 17
DROUGHT SEVERITY
(LONG TERM PALMER)
JULY 9, 1988
MOIST
MOIST
MOIST
MODERATE DROUGHT
SEVERE DROUGHT
EXTREME DROUGHT
CLIMATE ANALYSIS CENTER, NOAA

FIGURE 18

AREAL PERCENTAGE OF CONTIGUOUS UNITED STATES EXPERIENCING SEVERE OR EXTREME DROUGHT

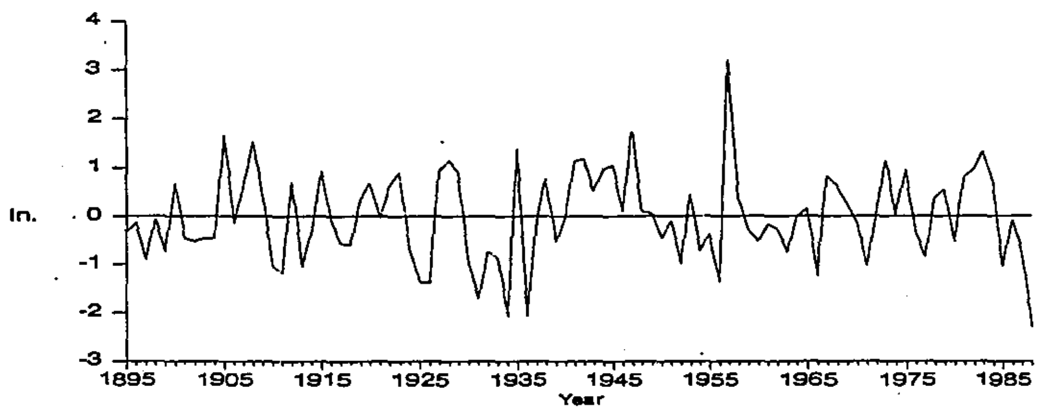
(BASED ON PALMER DROUGHT SEVERITY INDEX ON DATES INDICATED)



CLIMATE ANALYSIS CENTER, NOAA

FIGURE 19 **AREALLY AVERAGED NATIONAL**

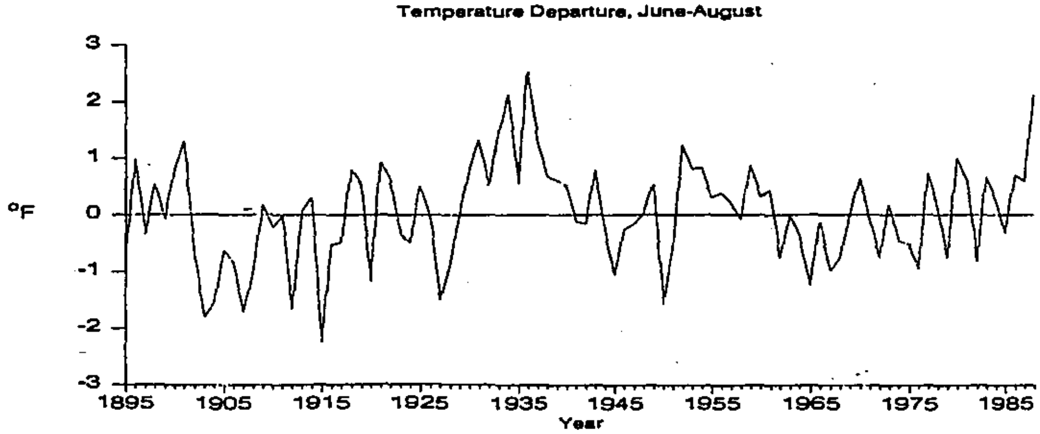
Precipitation Departure, April-June



NATIONAL CLIMATIC DATA CENTER, NOAA

FIGURE 20 **AREALLY AVERAGED NATIONAL**

Temperature Departure, June-August



NATIONAL CLIMATIC DATA CENTER, NOAA

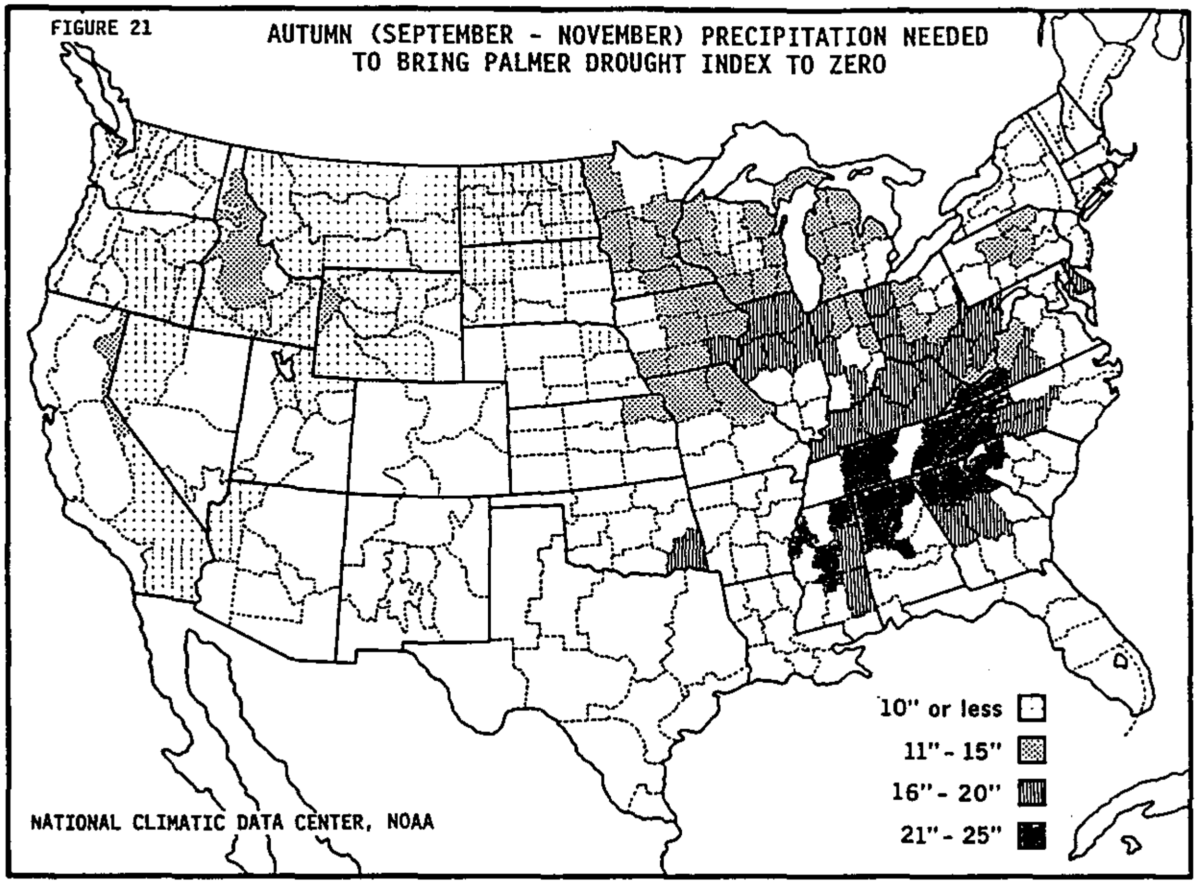


FIGURE 21
AUTUMN (SEPTEMBER - NOVEMBER) PRECIPITATION NEEDED TO BRING PALMER DROUGHT INDEX TO ZERO
10" or less
11" - 15"
16" - 20"
21" - 25"
NATIONAL CLIMATIC DATA CENTER, NOAA

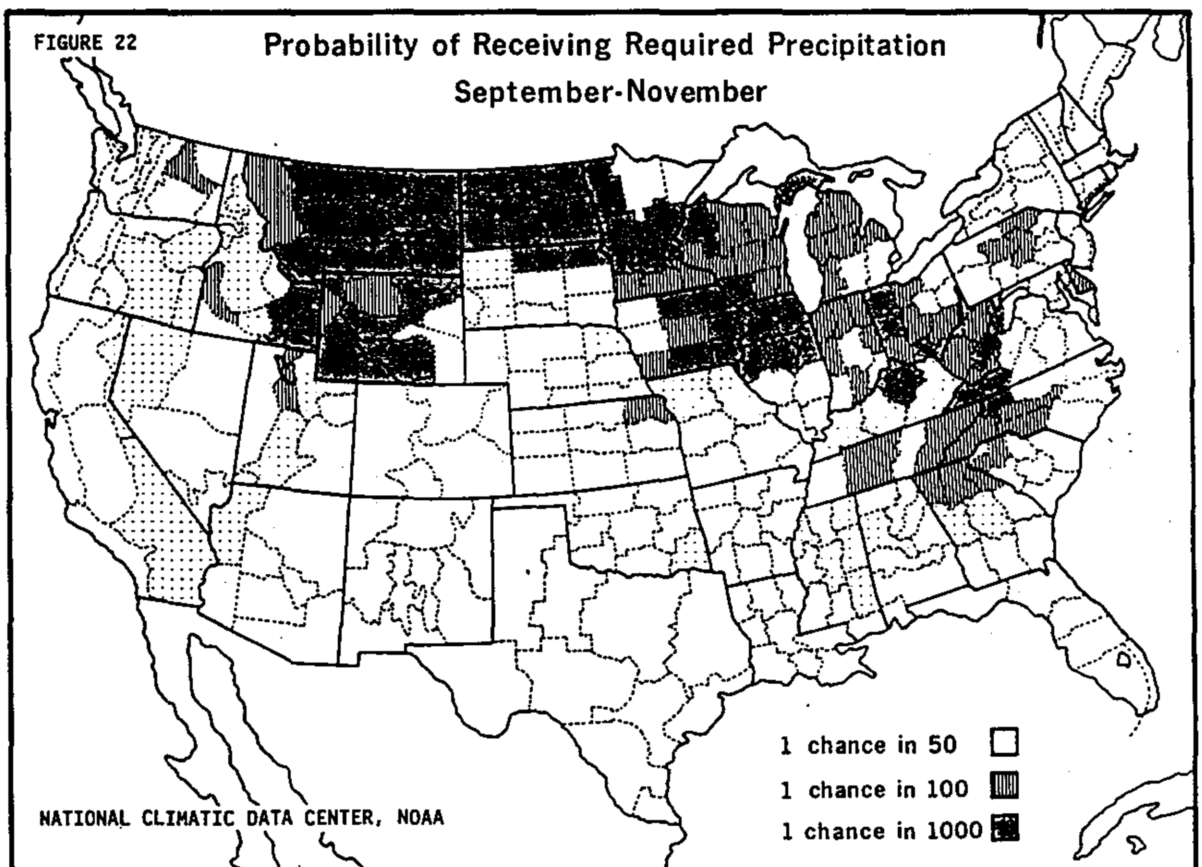


FIGURE 22
Probability of Receiving Required Precipitation
September-November
1 chance in 50
1 chance in 100
1 chance in 1000
NATIONAL CLIMATIC DATA CENTER, NOAA

FIGURE 23

PRECIPITATION RANKINGS

APRIL - AUGUST, 1988

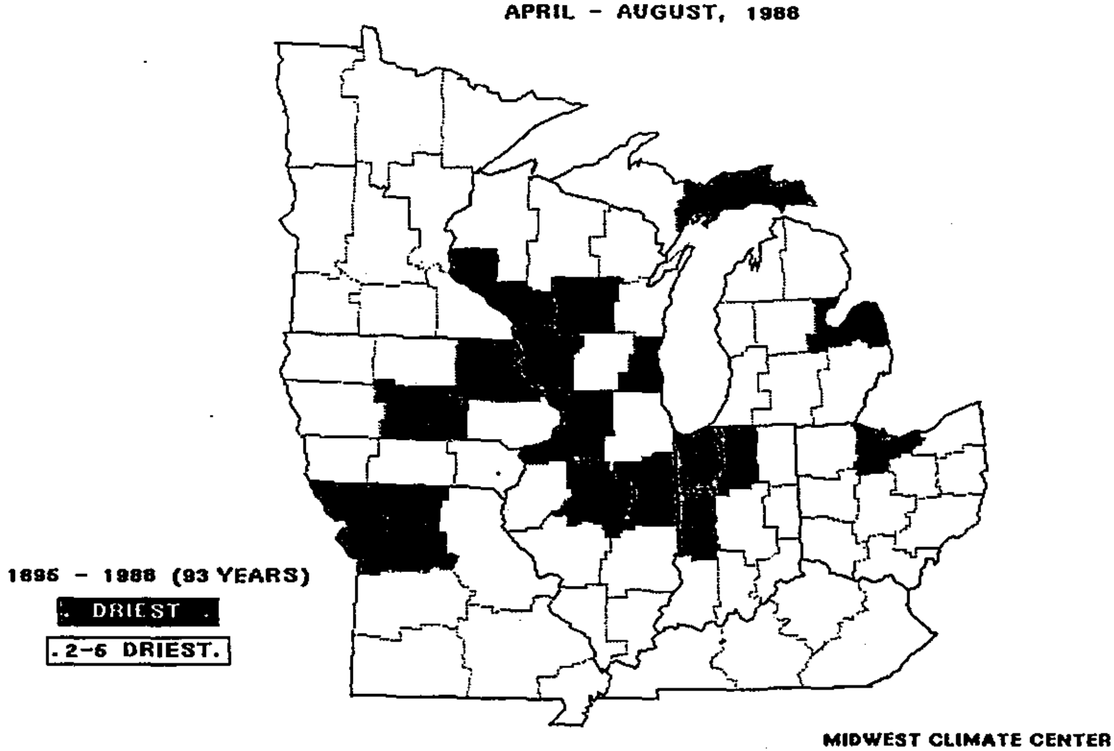


FIGURE 24

1988 WEATHER EXTREMES

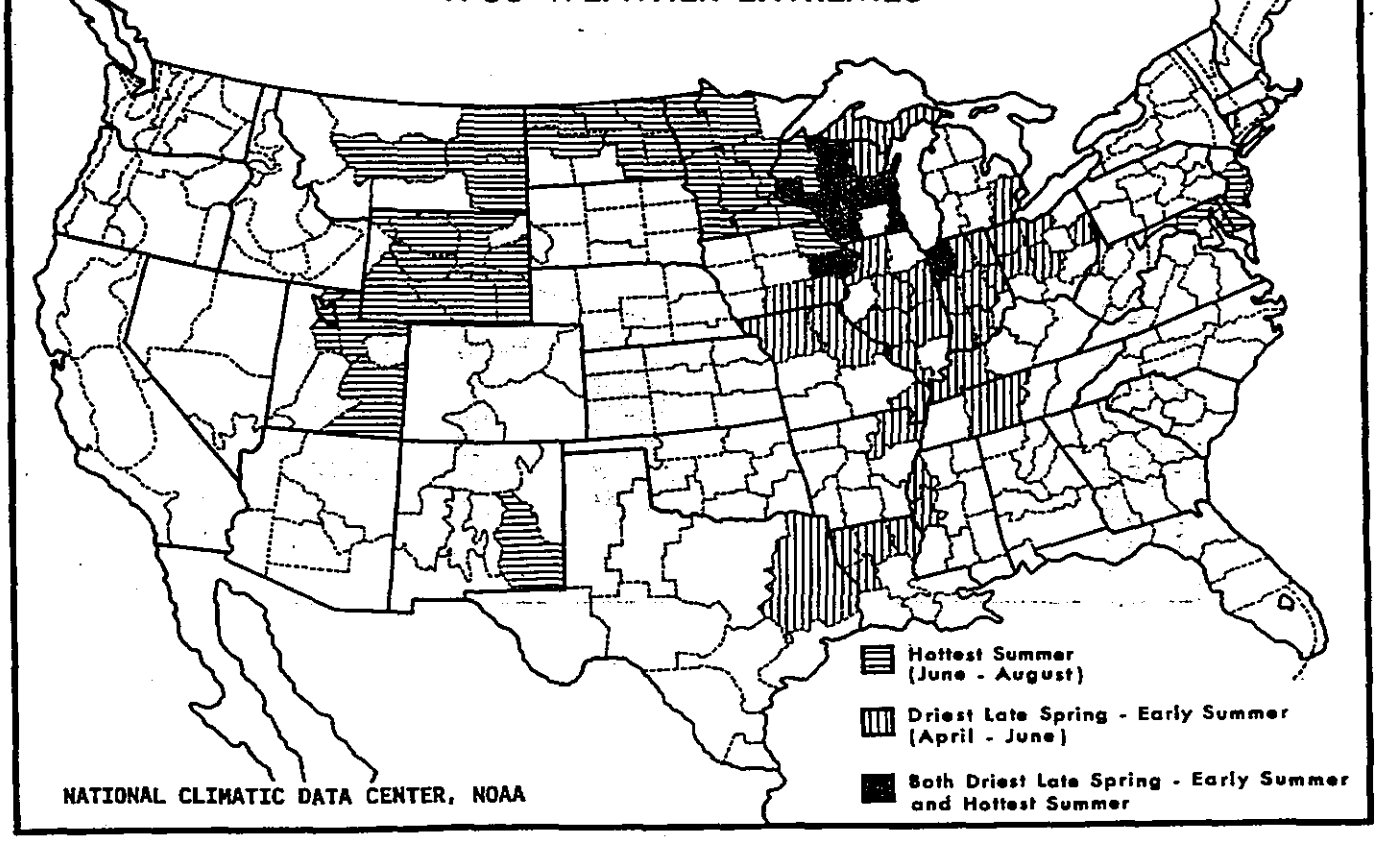
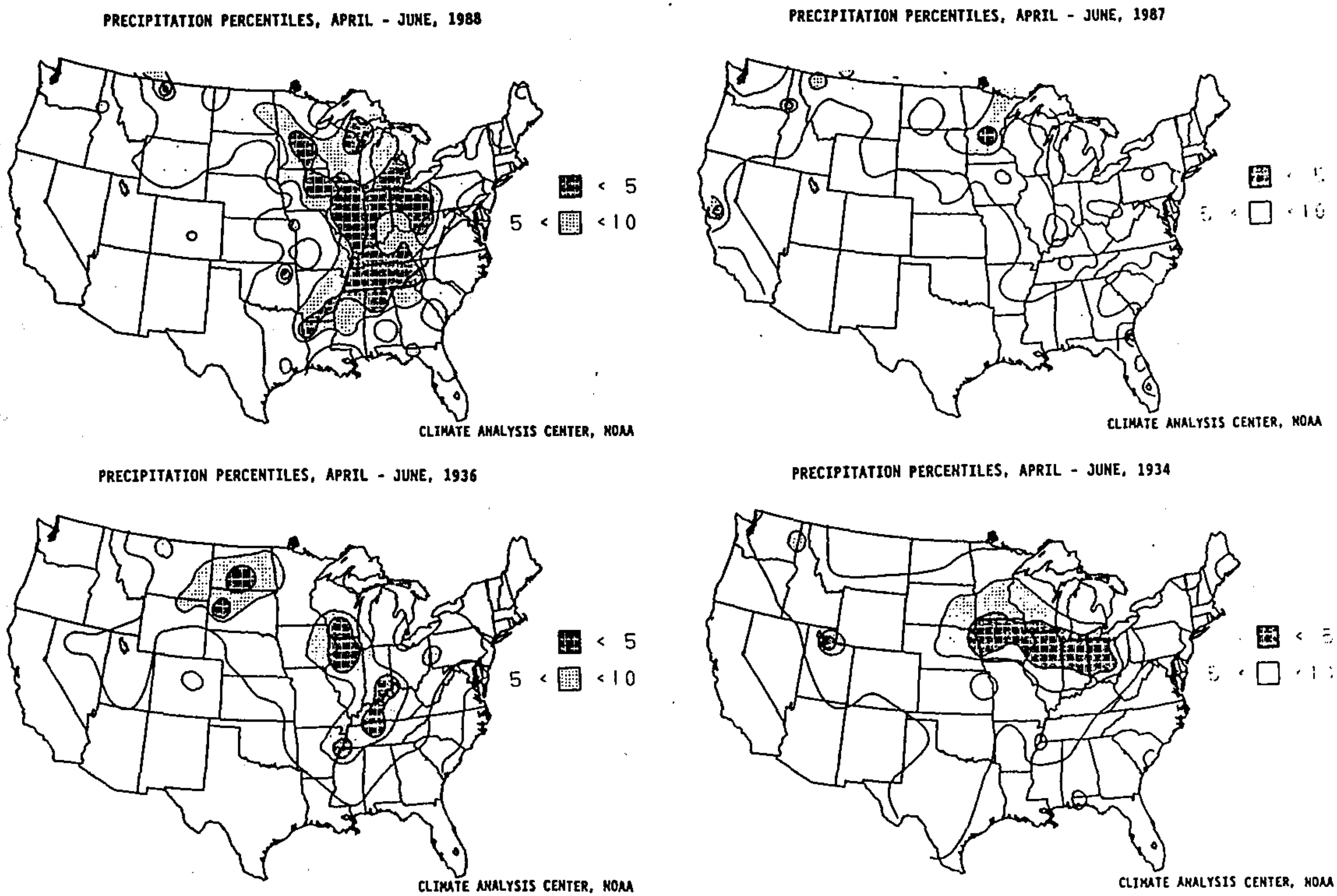


FIGURE 25

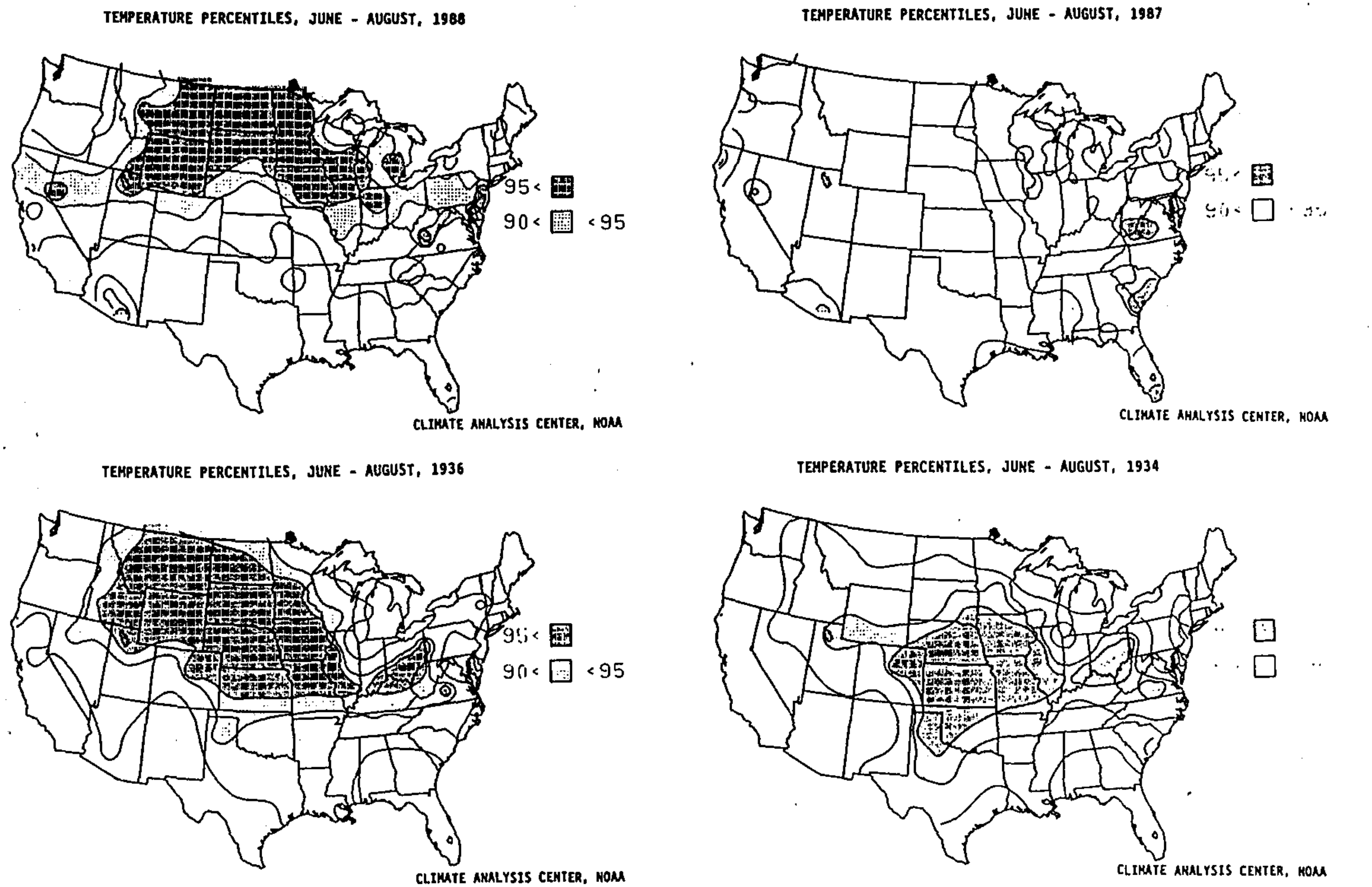
HISTORICAL PERSPECTIVE - PRECIPITATION APRIL-JUNE



PRECIPITATION DEFICIENCY FOR THE APRIL THROUGH JUNE PERIOD EXPRESSED AS A PERCENTILE. THE 5 (10) PERCENTILE REGIONS ARE SHOWN IN DARK (LIGHT) SHADING.

FIGURE 26

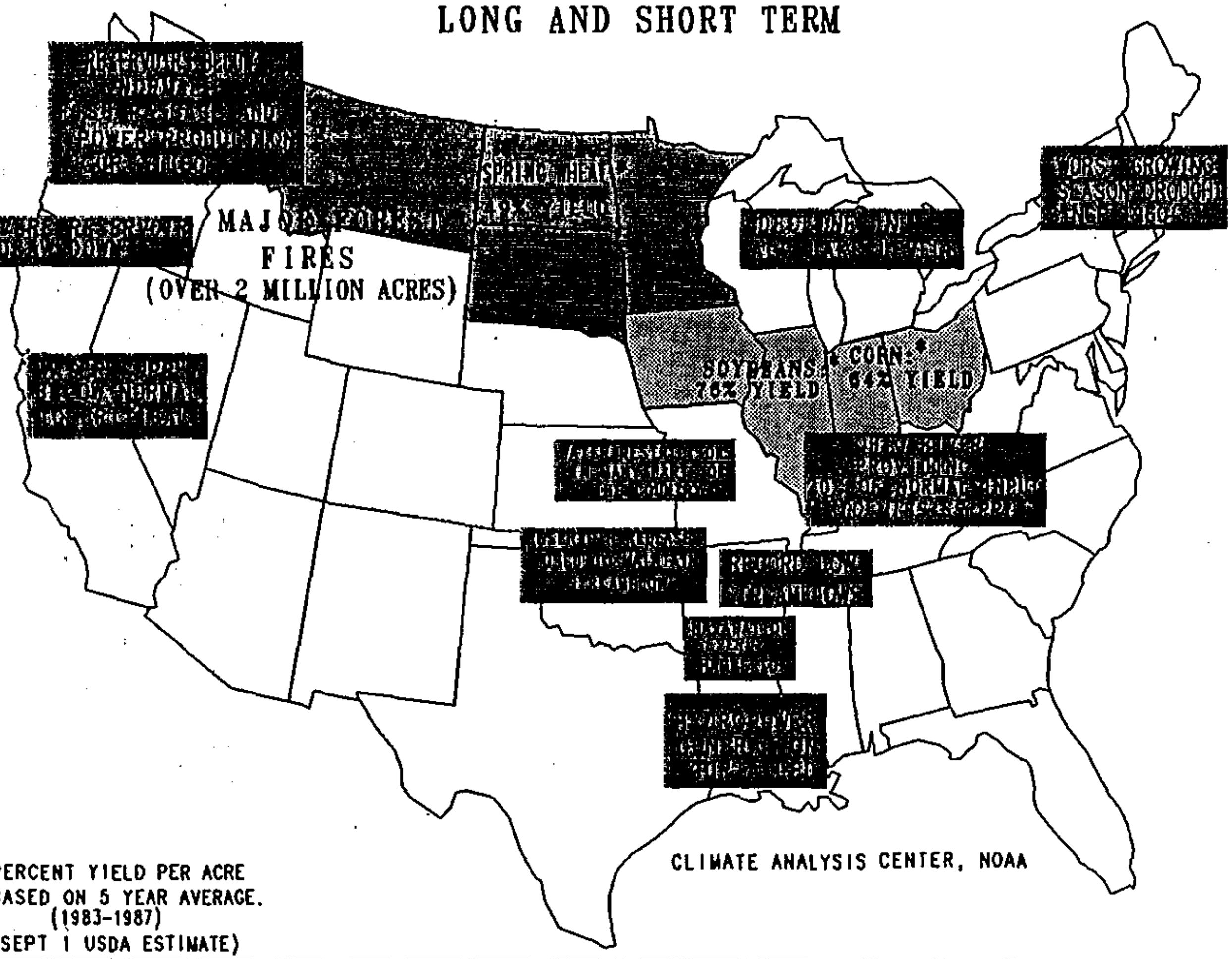
HISTORICAL PERSPECTIVE - TEMPERATURE JUNE-AUGUST



TEMPERATURE EXPRESSED AS PERCENTILES FOR THE SUMMER MONTHS. THE 95 (90) PERCENTILE REGIONS ARE SHOWN IN DARK (LIGHT) SHADING.

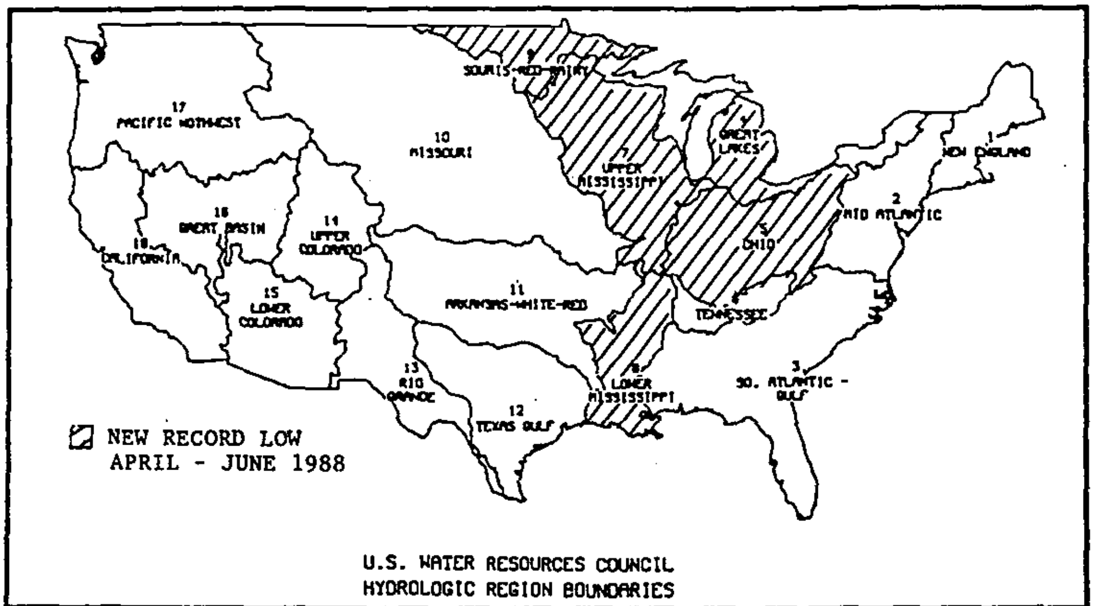
FIGURE 27

DROUGHT IMPACTS-1988
LONG AND SHORT TERM



* PERCENT YIELD PER ACRE
BASED ON 5 YEAR AVERAGE.
(1983-1987)
(SEPT 1 USDA ESTIMATE)

FIGURE 28



Hydrologic Services, NWS

PRECIPITATION AVERAGES FOR HYDROLOGIC REGIONS

REGION	SEASONAL AVERAGES	HISTORICAL AVERAGE (1931-1987)	PERCENT OF AVERAGE	PROBABILITY OF LESS	PREVIOUS RECORD LOW/YEAR
EAST OF CONT. DIVIDE -- (Spring) Season averages, April thru June '88					
1	7.88	11.00	72	14%	6.49 / 1965
2	10.35	11.02	94	44%	6.54 / 1965
3	8.82	12.83	69	3%	7.95 / 1986
4	* 3.88	9.52	41	1%	5.90 / 1934
5	* 6.15	12.05	51	1%	7.00 / 1936
6	8.39	12.87	65	3%	8.14 / 1941
7	* 4.13	11.11	37	1%	5.91 / 1934
8	* 7.16	13.98	51	1%	7.50 / 1931
9	* 2.64	7.69	34	1%	3.64 / 1980
10	5.10	8.33	61	5%	4.84 / 1936
11	7.75	11.82	66	5%	7.03 / 1936
12	6.20	9.85	63	8%	4.98 / 1984
13	2.91	2.57	113	63%	0.98 / 1974
WEST OF CONT. DIVIDE -- (Winter) Season averages, Nov. '87 thru Apr. '88					
14	6.37	5.92	# 108	62%	2.23 / 1976
15	7.32	5.88	# 125	74%	1.92 / 1971
16	6.43	6.07	# 106	57%	1.93 / 1966
17	17.72	20.96	# 85	16%	9.34 / 1976
18	14.24	19.98	# 71	19%	6.77 / 1976

* = New Record Low
# = Minimal high elevation snow data used in computing averages. (Generally low snow pack last winter influencing lower streamflow in many areas than these averages may indicate.)

Hydrologic Services, NWS

FIGURE 29

NOAA - 9 AVHRR image of smoke plumes from Yellowstone National Park forest fires, September 7, 1988

FIGURE 30

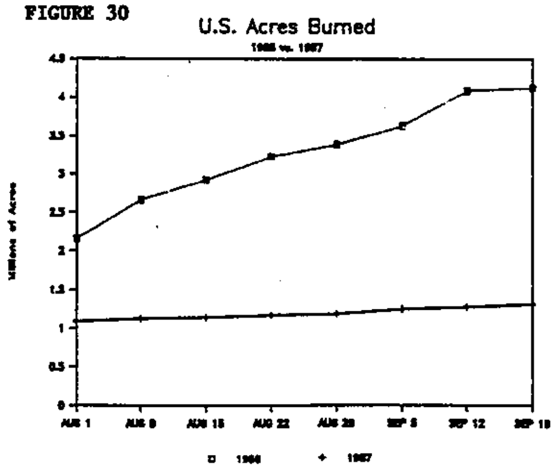


FIGURE 31

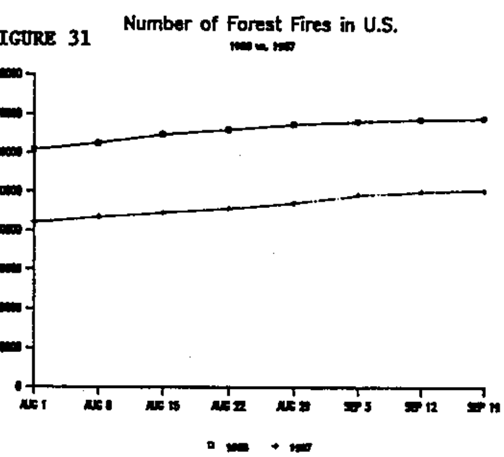
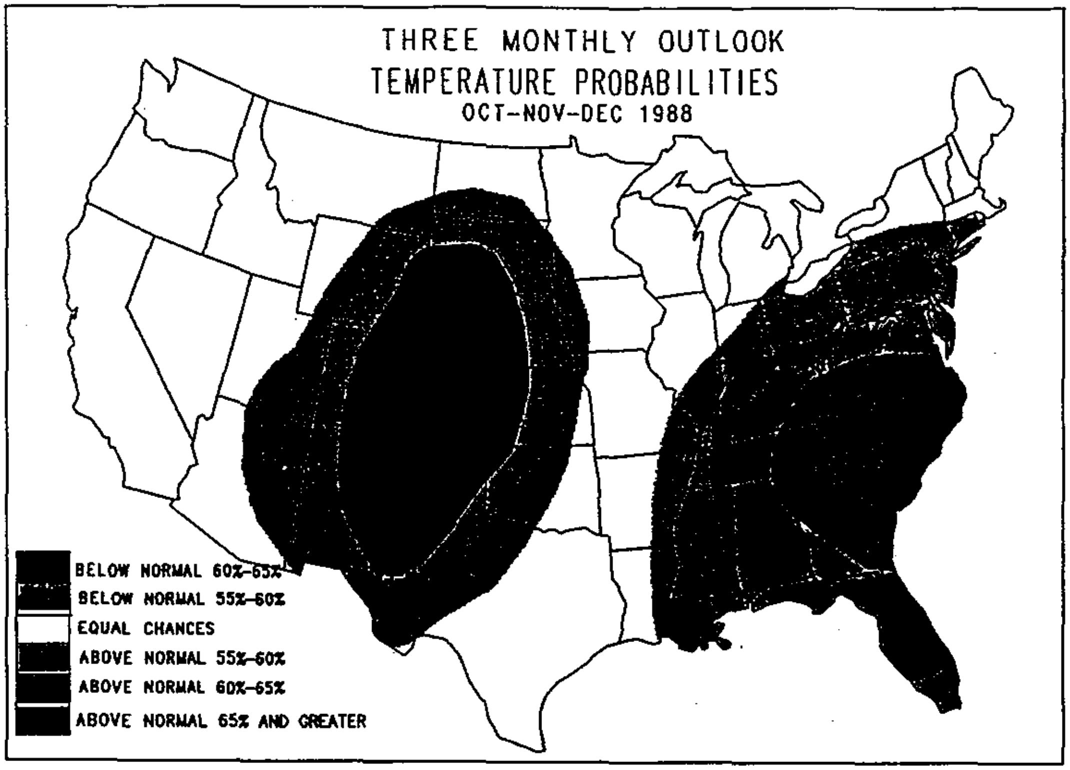
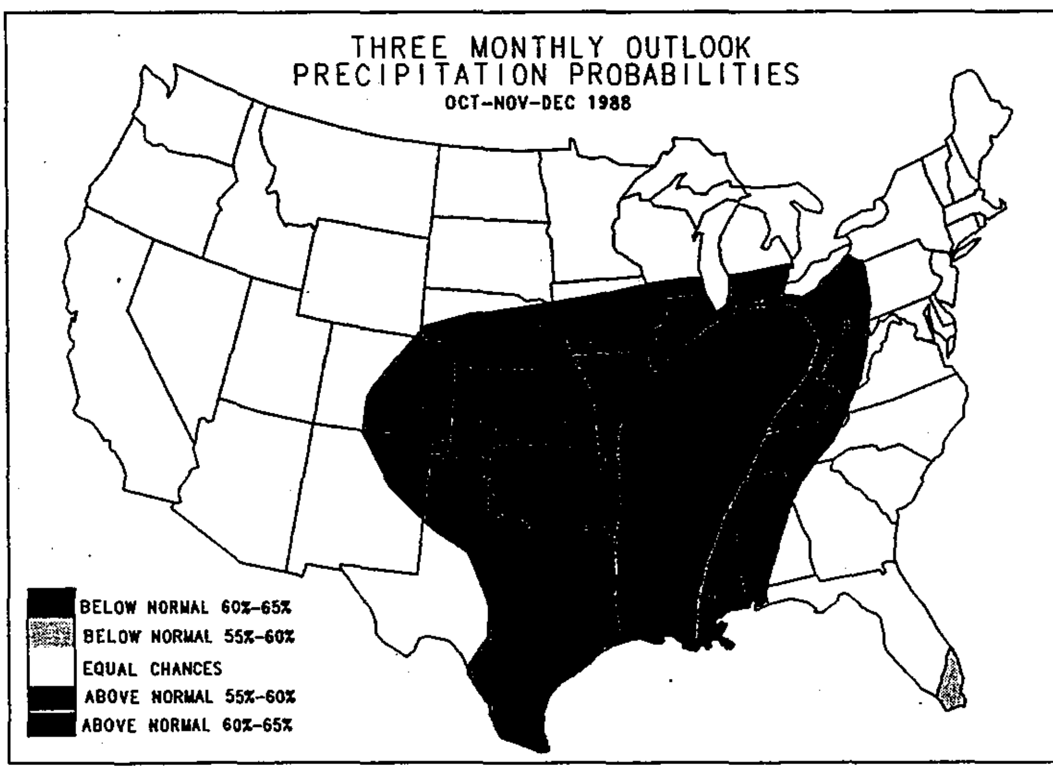


FIGURE 32



CLIMATE ANALYSIS CENTER, NOAA

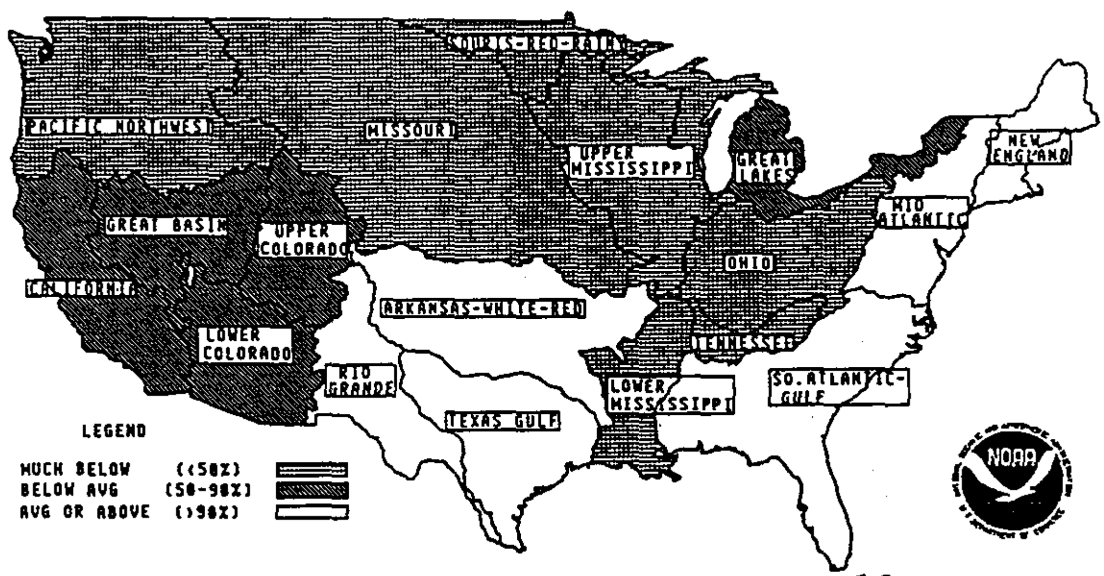


CLIMATE ANALYSIS CENTER, NOAA

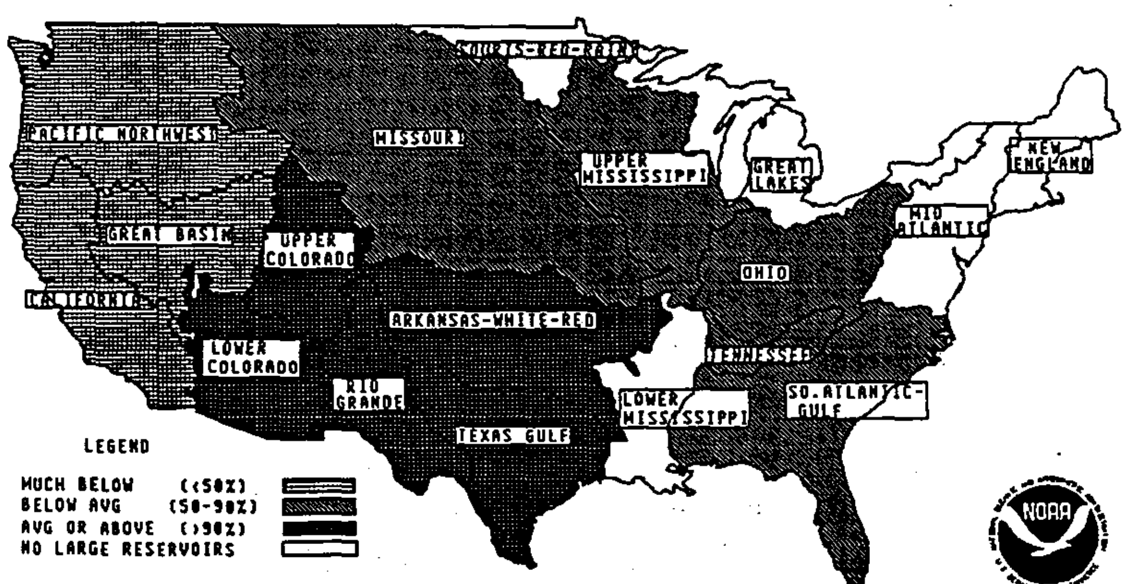
FIGURE 33

FALL STREAMFLOW & RESERVOIR STORAGE OUTLOOKS

BY U.S. WATER RESOURCES COUNCIL HYDROLOGIC REGIONS



STREAMFLOW OUTLOOK FOR FALL, 1988 [1,2]



RESEVOIR STORAGE OUTLOOK FOR FALL, 1988 [1,2]

1. CATEGORY REFLECTS THE MEAN CONDITION FOR EACH REGION.
2. ASSUMES INSUFFICIENT RAINFALL TO PRODUCE SIGNIFICANT RUNOFF.

Hydrologic Services, NWS

Origins of the 1988 North American Drought

by

Kevin E. Trenberth

and

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National Center for Atmospheric Research

and

Phillip A. Arkin

Climate Analysis Center

National Meteorological Center

Summary

The 1988 summer drought in the United States has been the most extensive for many years. Because the drought developed in different places at different times, not all regional effects can be traced to the same cause. Along the West Coast and in northwestern United States drought conditions developed during 1987 in association with the 1986-87 El Niño conditions in the tropical Pacific Ocean. Record low rainfalls in April–June 1988 led to rapid development of the drought in the North Central United States. Strong anticyclonic conditions and a northward displaced jet stream in the upper atmosphere over North America throughout this period were but part of a pronounced and distinctive wavetrain of anomalies in the atmospheric circulation that appeared to emanate from the tropical Pacific. The strong negative sea surface temperature anomalies that developed along the equator in the Pacific in the northern spring of 1988, combined with warmer than normal water from 10-20°N, led to a northward displaced but still very active Inter-Tropical Convergence Zone (ITCZ) southeast of Hawaii. We show, using a steady state planetary wave model of the atmosphere, that the atmospheric heating anomalies associated with the displaced ITCZ can force an anomalous wavetrain across North America similar to that observed. Thus we suggest that the drought is likely to have been primarily due to the large-scale atmospheric circulation perturbations associated with natural variations in the coupled atmosphere-ocean system in the tropical Pacific.

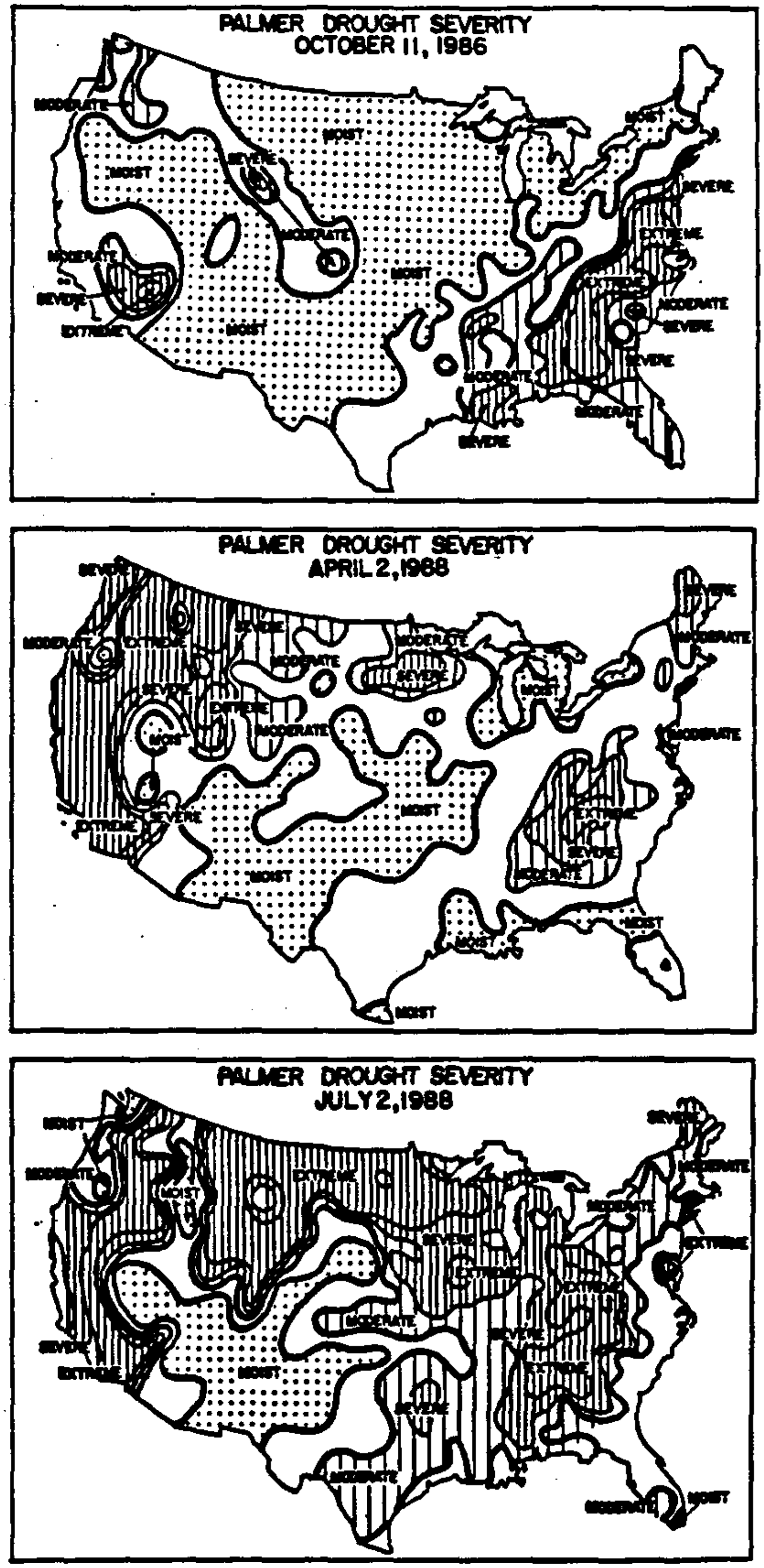

Fig. 1 Maps of the Palmer drought index over the United States for the dates indicated. Categories ranging from moist (stippled), normal, moderate drought (sparse hatching), severe drought and extreme drought (both dense hatching) are classified based upon the index.

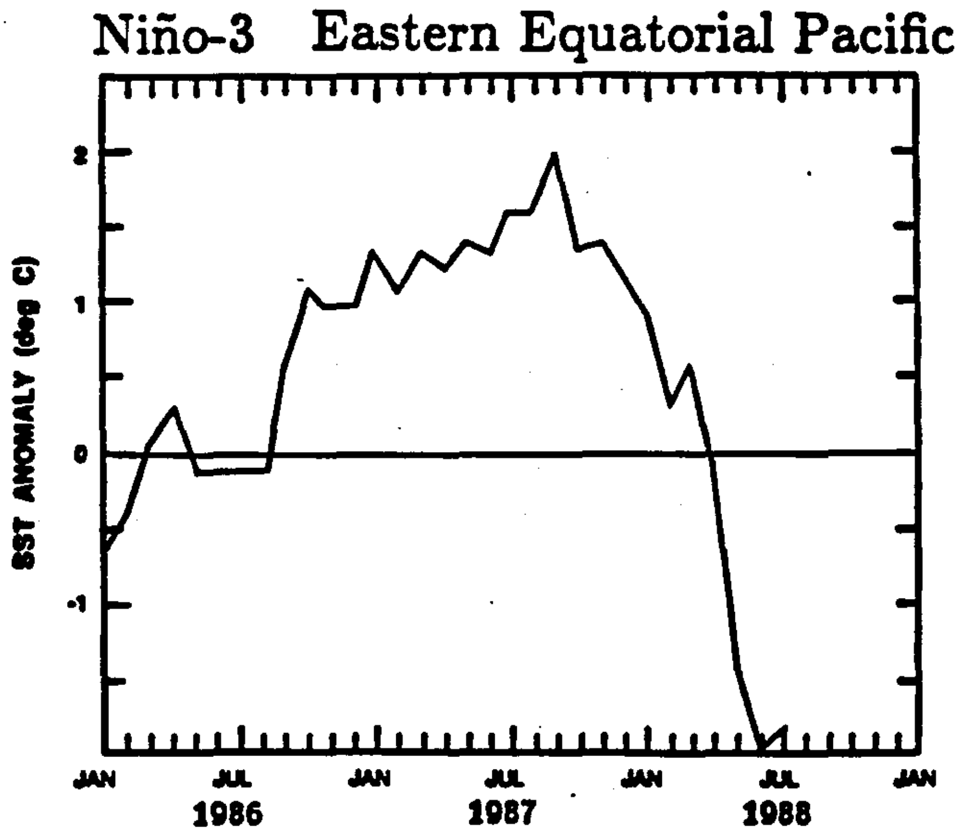

Fig. 2 Sequence of SST anomalies for the "Niño 3" region from 5°N - 5°S 90° - 150°W in the equatorial eastern Pacific Ocean from January 1986 through August 1988.

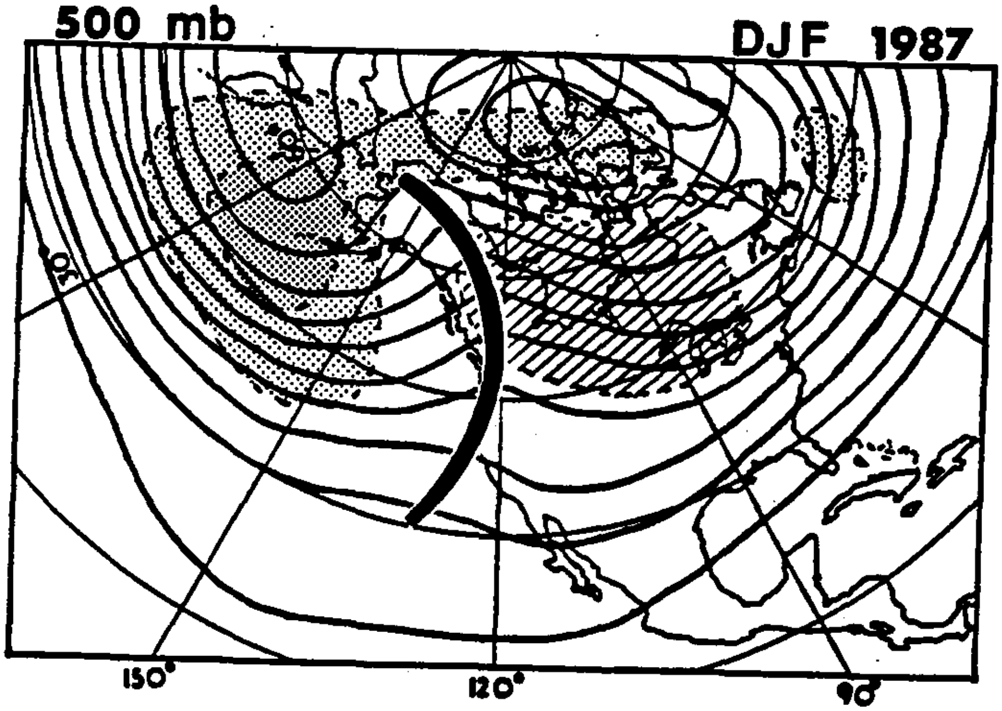

Fig. 3 Geopotential heights at 500 mb for DJF 1987. Shown are the total field with contours every 60 m (which indicate the mean flow) and the departures from normal with hatched areas more than 50 m above normal and stippled regions more than 50 and 100 m (dense stipple) below normal. The heavy black line marks the ridge of high pressure.

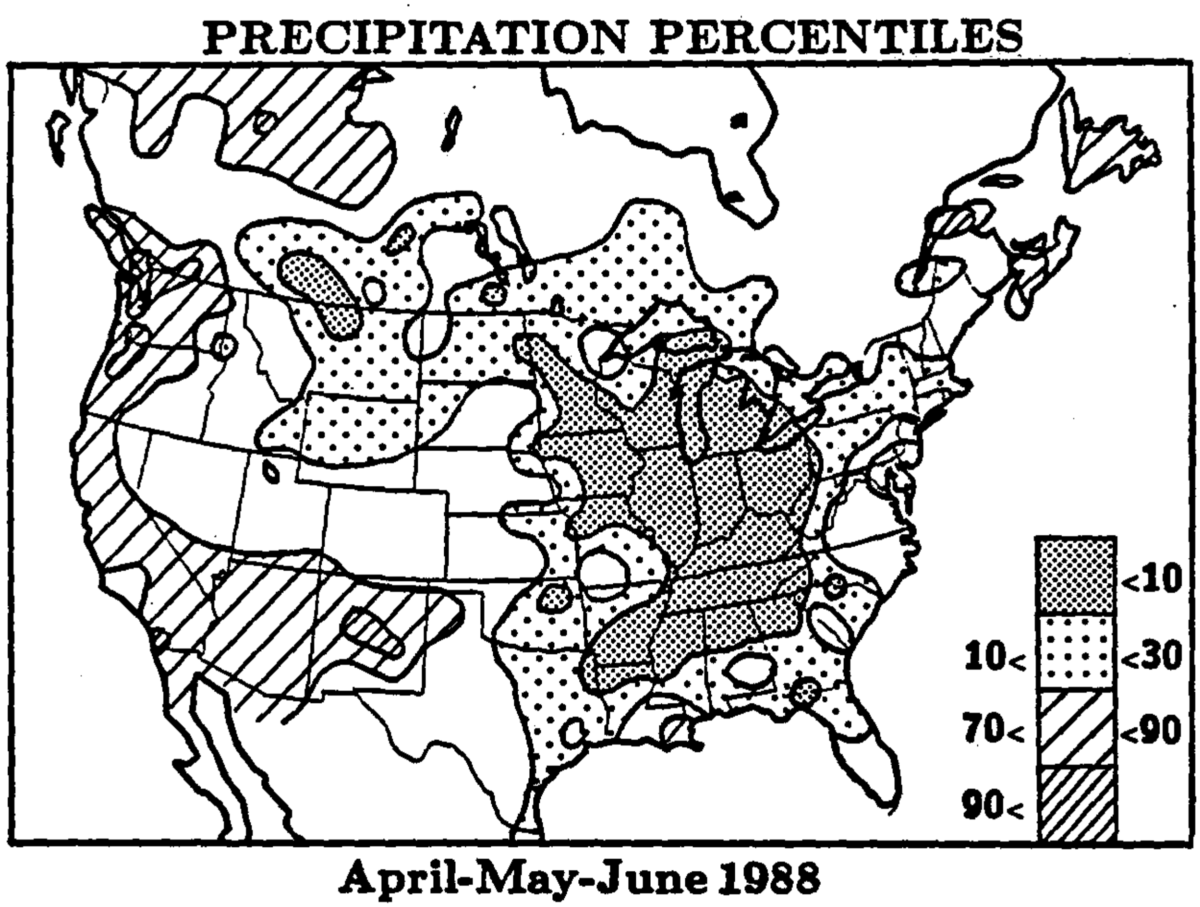

Fig. 4 Precipitation percentiles over North America for April-May-June 1988.

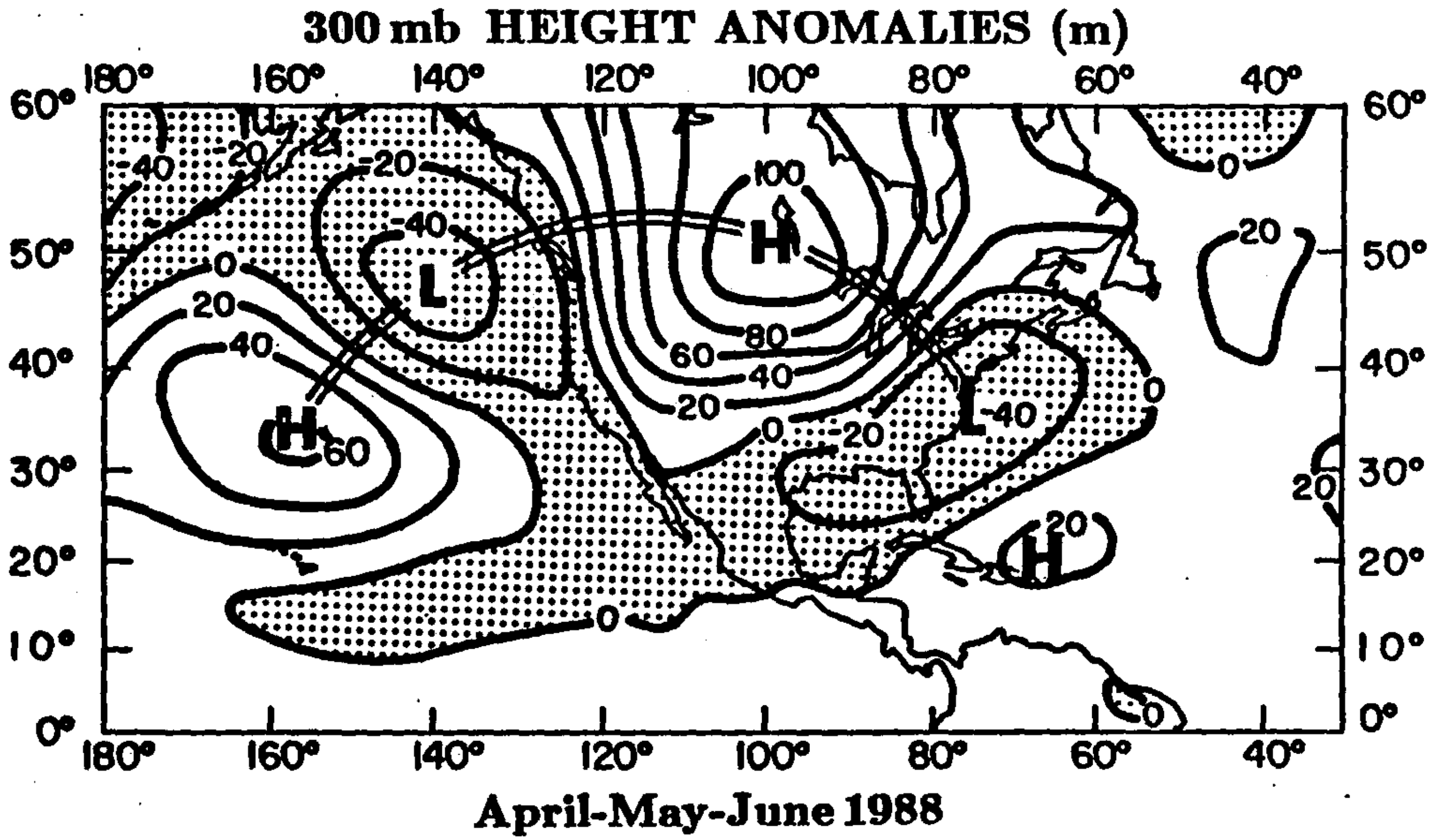

Fig. 5 Average geopotential height anomalies at 300 mb for April-May-June 1988. Contours are every 20 m and negative values are stippled. The High and Low centers that form the wavetrain are linked by the thin double line.

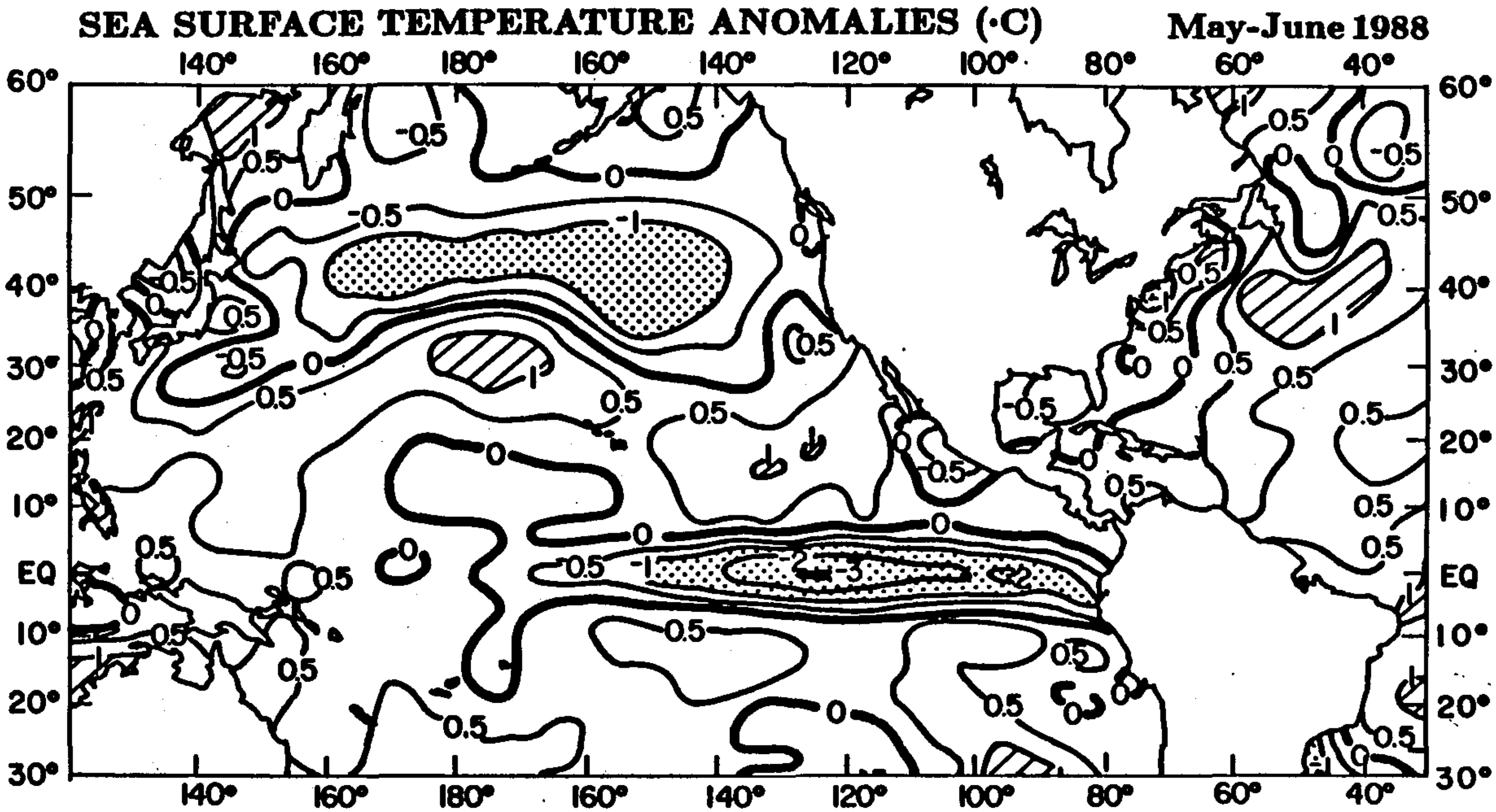

Fig. 6 Average May-June 1988 SST anomalies. The zero contour is the heavy line and contours are at ±0.5, ±1, ±2 and ±3°C. Values exceeding ±1°C are shaded.

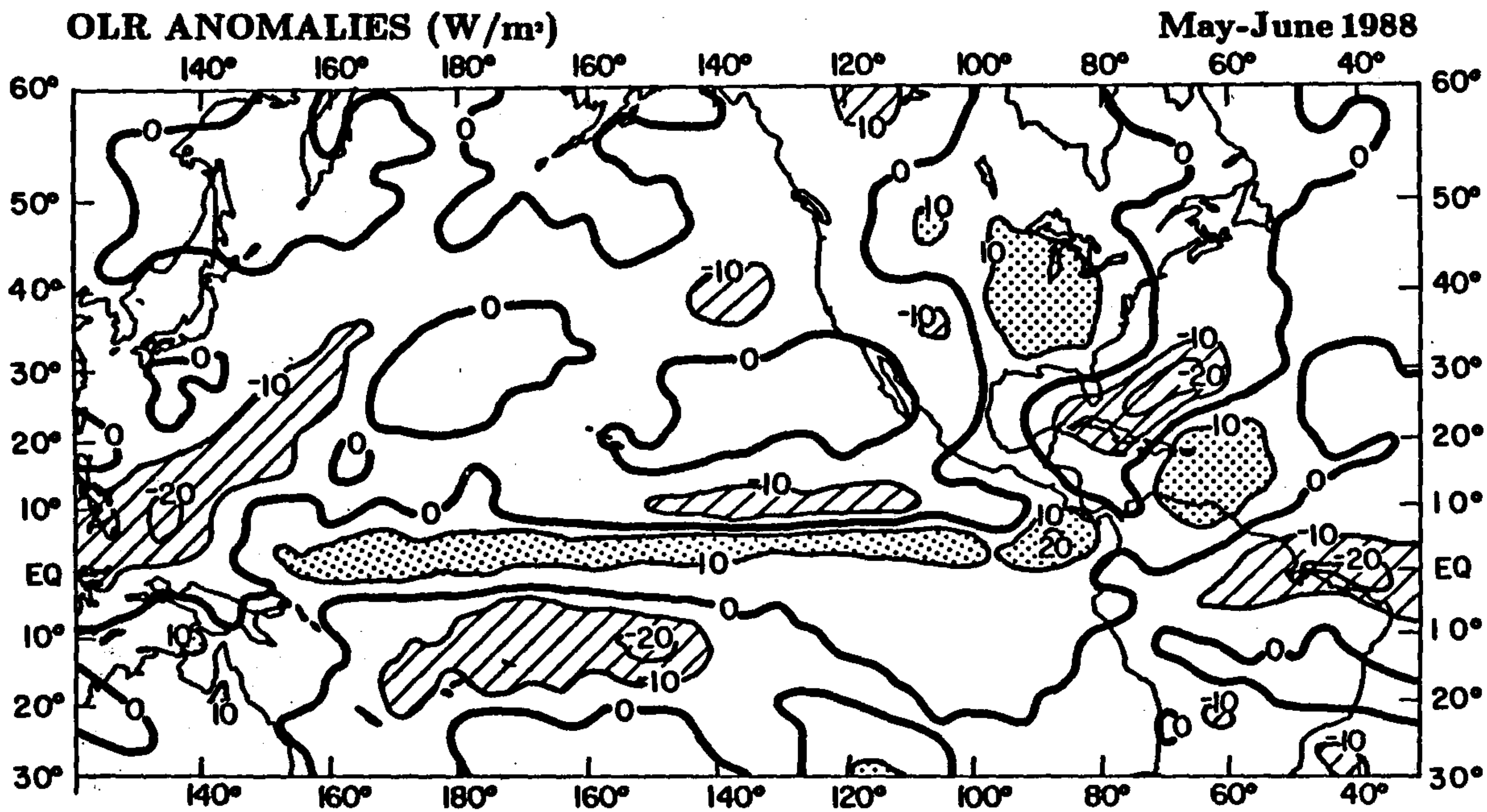

Fig. 7 Average May-June 1988 OLR anomalies. The zero contour is the heavy line and contours are every 10 W/m². Values exceeding ±10 W/m² are shaded.

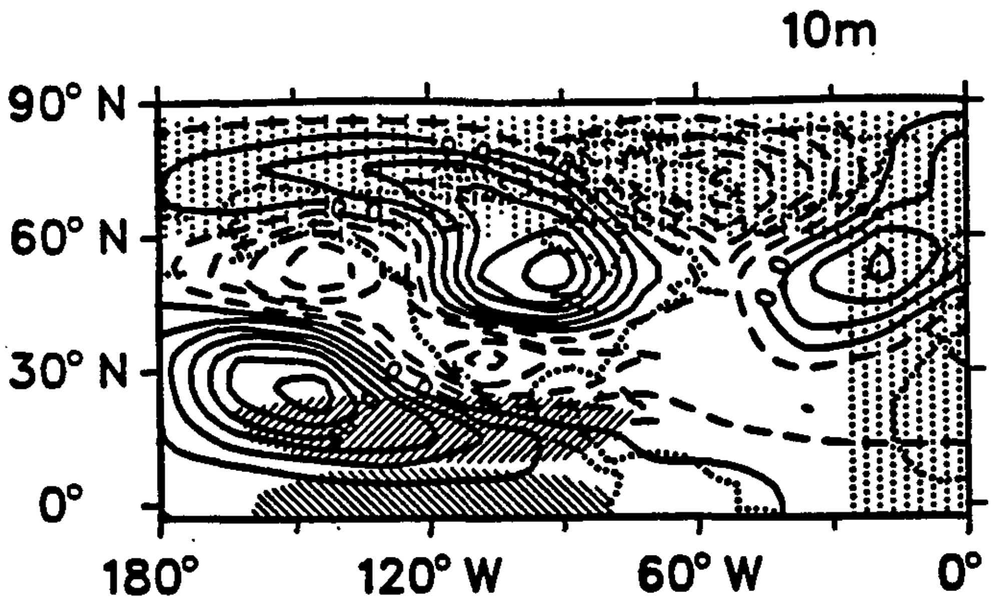

Fig. 8 Geopotential height anomalies at 300 mb resulting from the model simulation with the model linearized about June conditions and forced by heating in the northern hatched region and cooling in the southern hatched region in the tropical Pacific. The boundary of the hatched area indicates where the forcing is 10% of the maximum value. The stippled area denotes the region not shown in Fig. 5. The contour interval is 10 m.

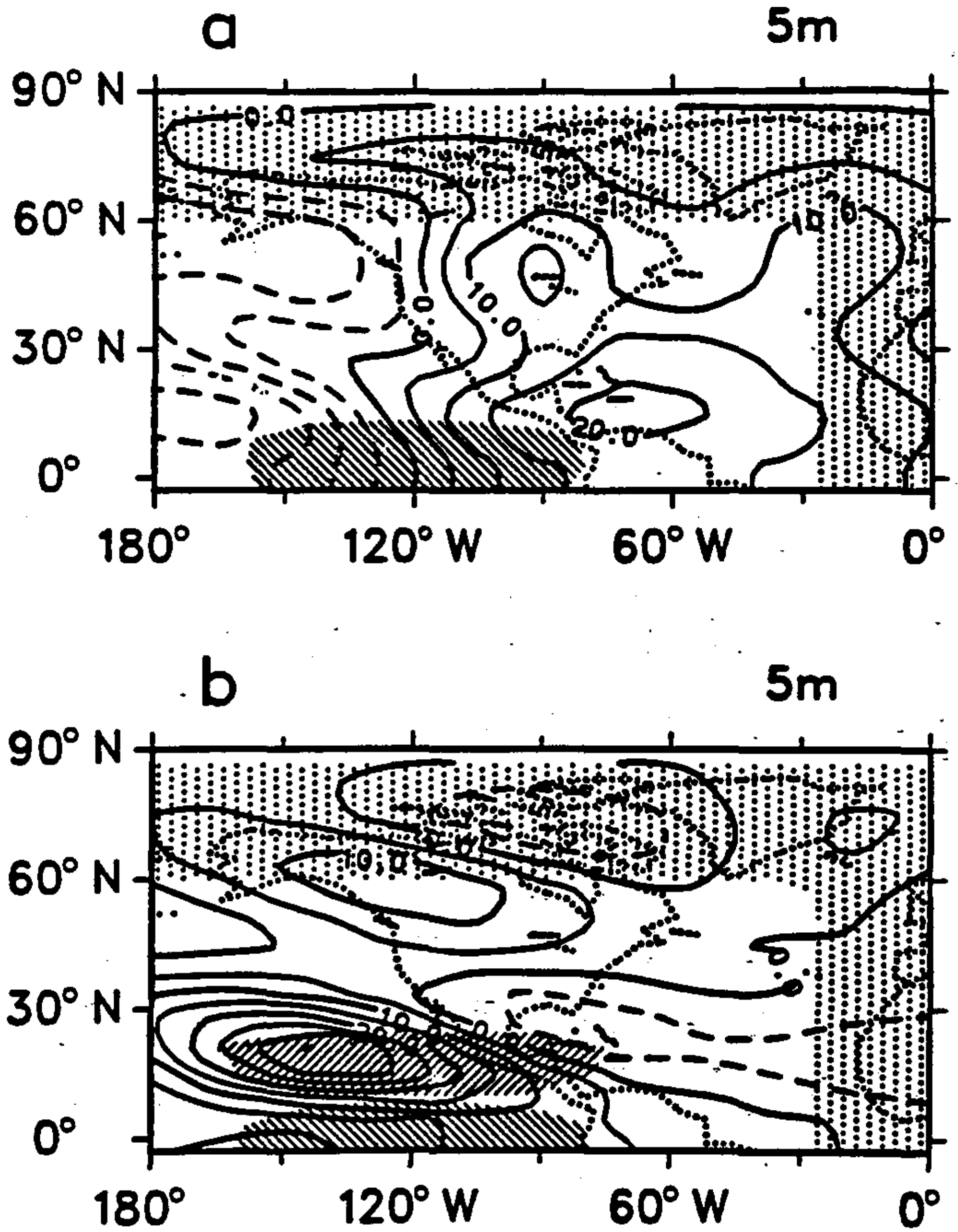

Fig. 9 Geopotential height anomalies at 300 mb resulting from the model simulation but with a) only the cooling region present, and b) with only zonal mean June conditions as the basic state. The contour interval is 5 m.

ALL NORTH AMERICAN DROUGHTS have STRONG ANTICYCLONIC CONDITIONS in the upper atmosphere:
(Klein, Namias, Chang and Wallace)

- **In most previous cases the wavetrain was more east–west**

- **Mechanisms in 1988 drought may not be same as in previous droughts.**

OTHER FACTORS:

- *Other anomalies in heating:*

  1. *Enhanced convection south of Japan*

  2. *Negative SSTs in North Pacific (Namias shows these were often present in previous droughts)*

  3. *Local OLR anomalies indicate local heating anomalies in the form of a wave across North America*

- *Given strong anticyclonic conditions, then:*

  LAND–SURFACE processes become important:

  1. *The partitioning of solar heating into sensible heat and evapotranspiration changes*

  2. *More sensible heating: More heat waves*

  3. *Less moisture: Less precipitation*

= *SELF PERPETUATING DROUGHT MECHANISM*

Each El Niño (or La Niña) has certain things in common, but also has its OWN CHARACTER

(Just as all cyclones and cold fronts have features in common, but are also vitally different)

- *We must appreciate that SMALL, OFTEN SUBTLE, VARIATIONS IN SSTs IN THE TROPICS CAN MAKE PROFOUND DIFFERENCES IN ATMOSPHERIC RESPONSE.*

  Reason: Because of the affects on the location of the tropical convergence zones.

- *WE CAN IMPROVE PREDICTIONS OF SHORT-TERM CLIMATE*

- *To improve predictions, we must*

  * *Accurately MONITOR what is happening (SSTs, OLR, etc)*

  * *IMPROVE MODELS*

    + *Atmospheric: Exploit SST*

    + *Oceanic: Predict SST*

    + *Coupled: Whole system*

* *But resources are needed!*

MID-CONTINENTAL SUMMER DRYNESS
INDUCED BY GREENHOUSE WARMING

S. Manabe

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Princeton University, P.O. Box 308
Princeton, New Jersey 08542

Abstract

The change of soil wetness in response to increased atmospheric carbon dioxide concentration is investigated by climate models which consist of a general circulation model of the atmosphere and a static mixed layer ocean. The CO_2-induced changes of climate and hydrology are evaluated by comparing two quasi-equilibrium climates of a model with normal and above normal concentration of atmospheric carbon dioxide.

The results show that, in response to a doubling (or quadrupling) of atmospheric carbon dioxide, soil moisture decreases during summer over extensive mid-continental regions of both North America and Eurasia in middle and high latitudes. During winter, soil moisture increases poleward of 30°N, whereas it decreases around 25°N. Based upon analysis of the heat and water budgets, the physical mechanisms responsible for the CO_2-induced changes of soil moisture are evaluated.

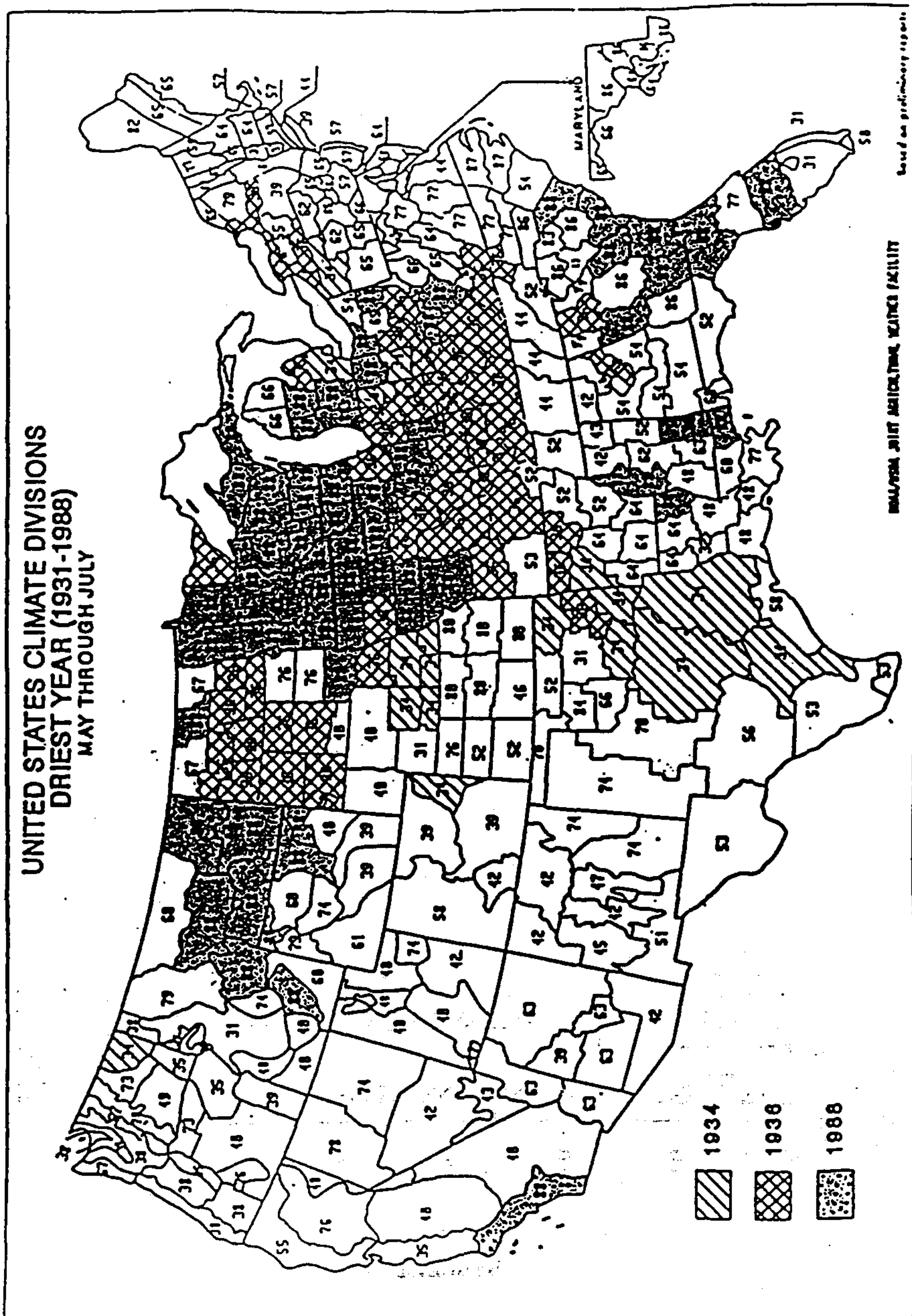
The large scale changes of soil wetness described above have been compared with more recent results from numerical experiments conducted at GFDL and other institutions. The possible causes for both agreement and disagreement are discussed.

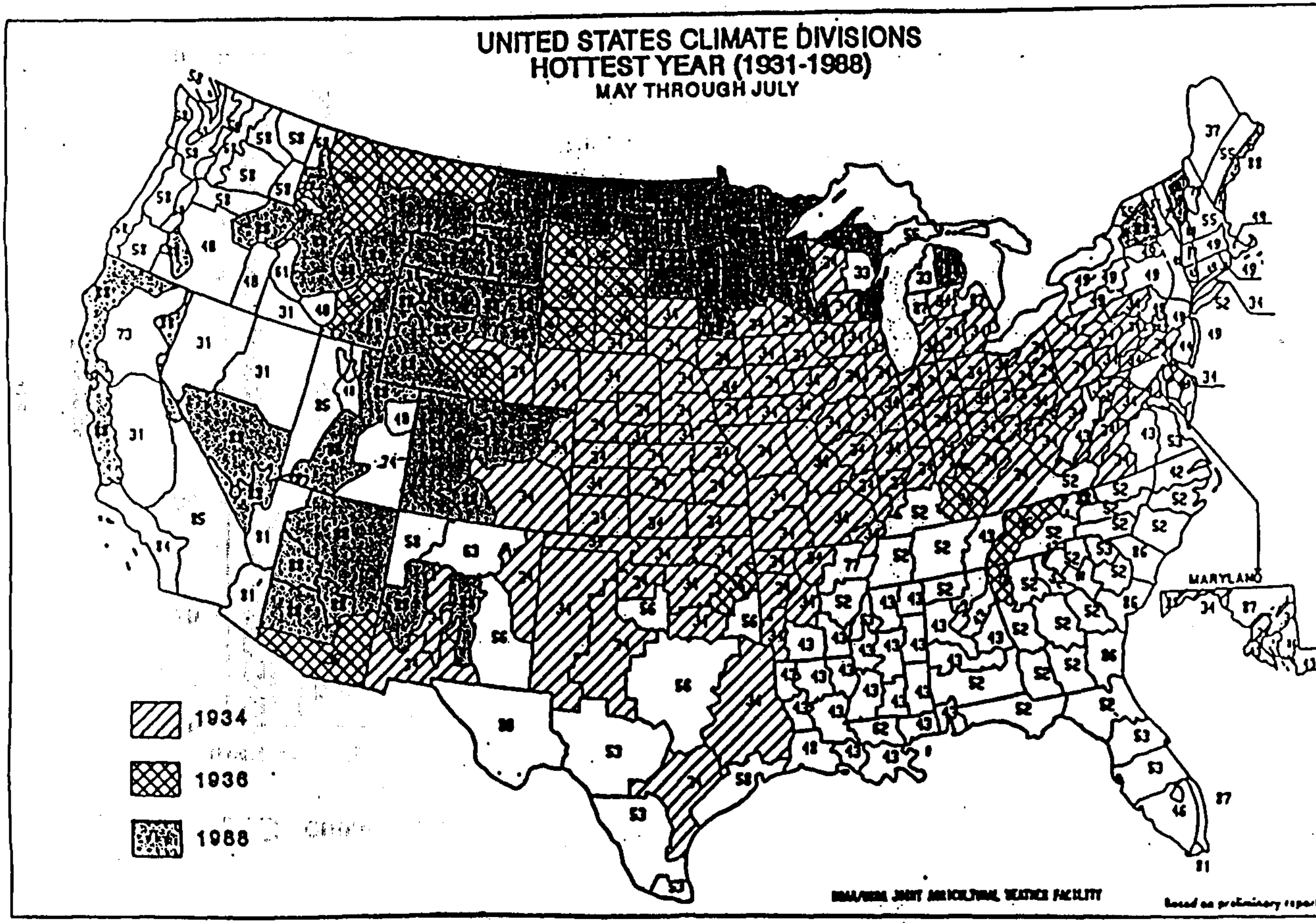
The present analysis suggests that the changes of soil wetness described here are controlled by the warming which increases with increasing latitudes and are very broad scale, mid-continental phenomena.

DROUGHT EFFECTS ON CROP PRODUCTION AND THE U.S. ECONOMY

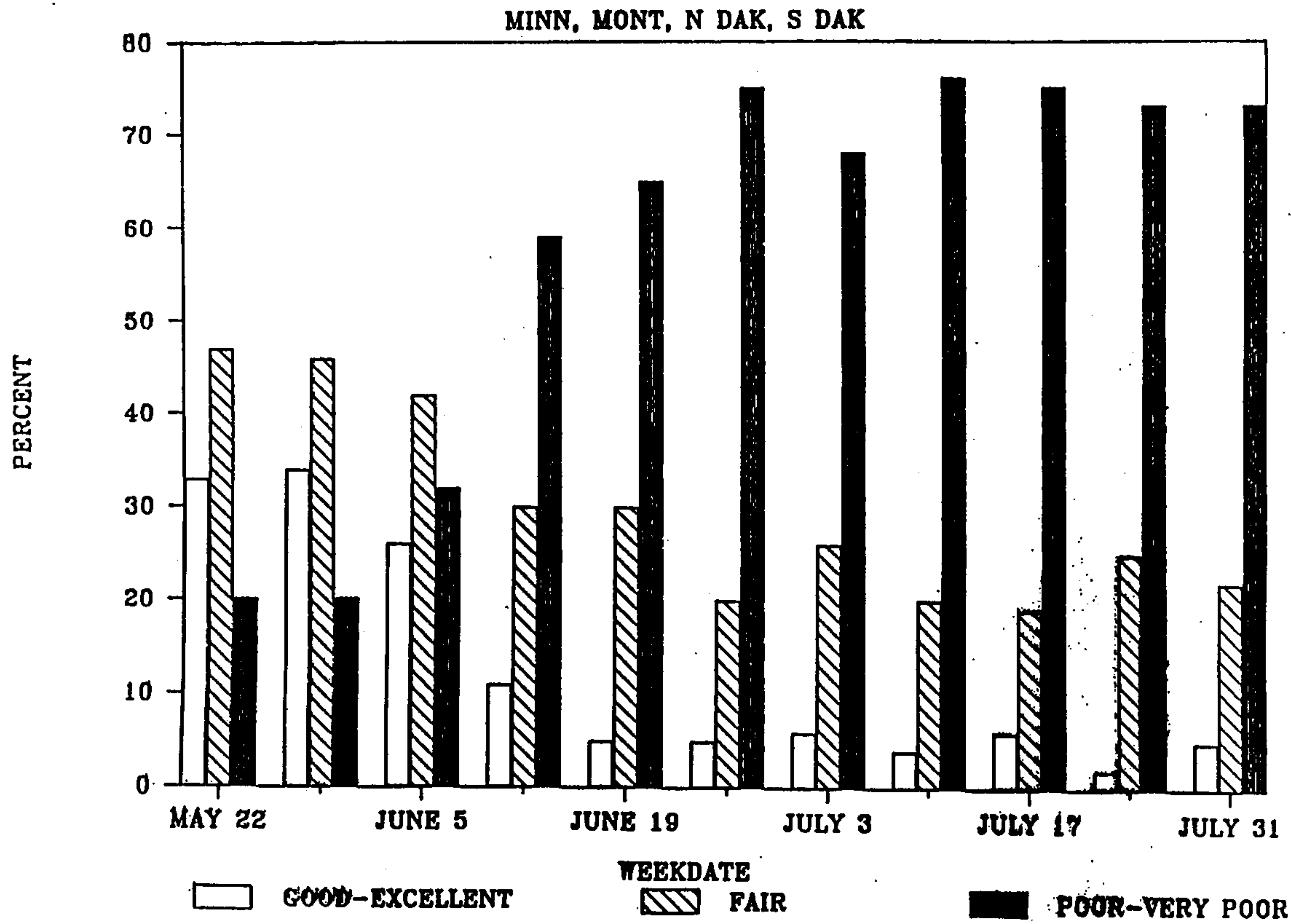
The worst ever early-season drought in major crop areas is reducing U.S. grain production by 30 percent and the soybean crop by 22 percent. U.S. use will decline but the fall will be moderated by large carryin stocks and the availability of government assistance to the livestock industry. The level of use will remain well above the crop. So, both grain and soybean stocks will be cut by more than 50 percent. Crop prices will average 25 to 50 percent above 1987/88. This will mean higher receipts to crop farmers but higher feed costs will trim livestock and poultry returns and dampen output from pre-drought expectations. Higher commodity prices, plus drought assistance, will mean cash U.S. farm income in 1988 that will match or exceed last year's $57 billion, although some farmers will not fare as well because of heavy drought losses. Beyond the farm gate, food prices will average slightly higher in 1988 because of reduced supplies and average moderately higher in 1989 as the impact of reduced livestock production is more fully reflected. The higher crop prices and lower U.S. acreage reduction requirements for program participation should mean expanded U.S. acreage in 1989 and sufficient production to meet market expansion and add to inventory.

Abstract of notes prepared for discussion by James R. Donald, Chairperson, World Agricultural Outlook Board, U.S. Department of Agriculture, Washington, D.C. 20250-3800, at the Strategic Planning Seminar, The Drought of 1988 and Beyond, sponsored by the National Climate Program Office, NOAA, National Academy of Sciences and Resources For the Future, Washington, D.C., October 18, 1988

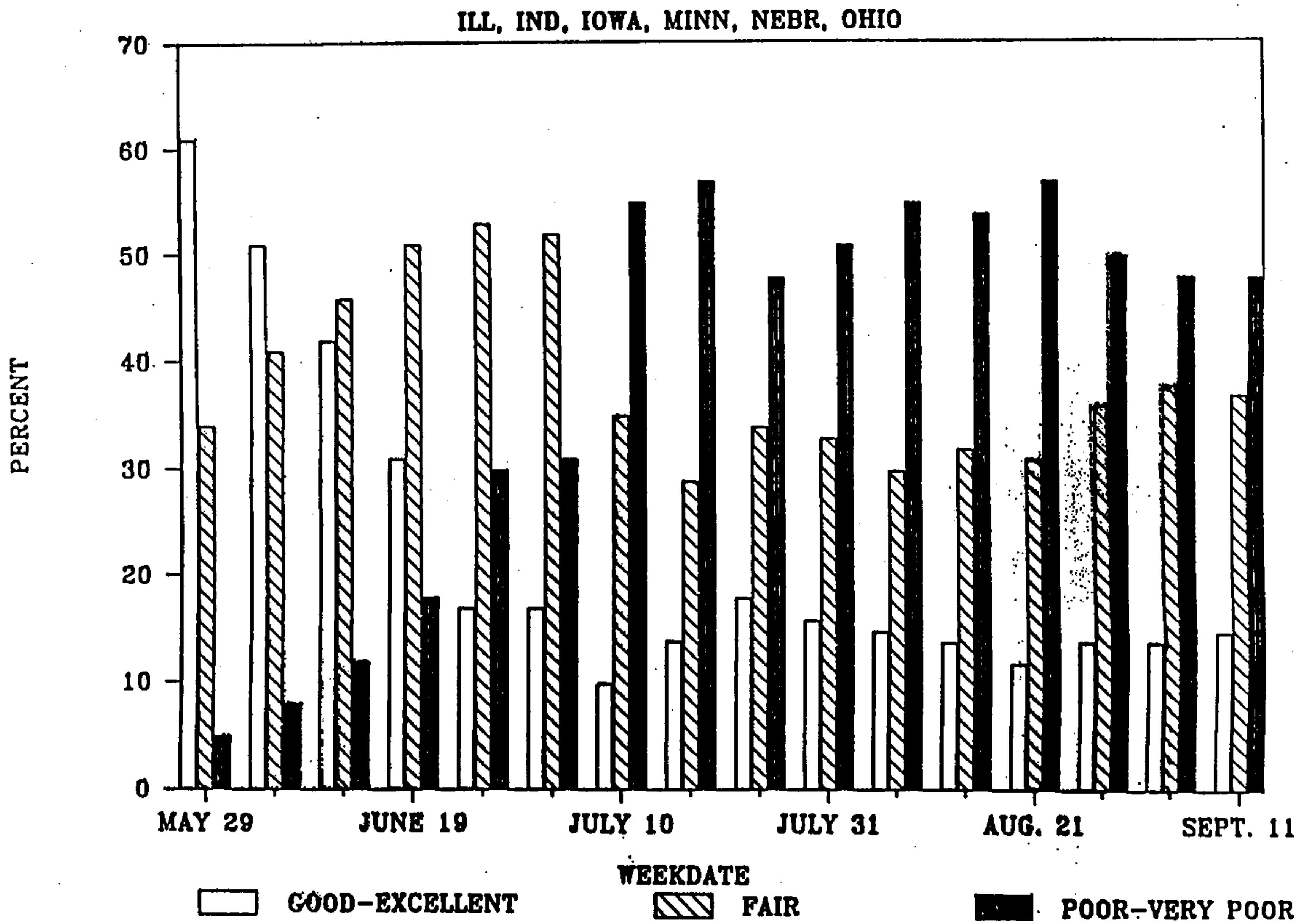

UNITED STATES CLIMATE DIVISIONS
DRIEST YEAR (1931-1988)
MAY THROUGH JULY
1934
1936
1988
MARYLAND
USDA/NOAA JOINT AGRICULTURAL WEATHER FACILITY
Based on preliminary reports


UNITED STATES CLIMATE DIVISIONS
HOTTEST YEAR (1931-1988)
MAY THROUGH JULY
MARYLAND
1934
1936
1988
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY
Based on preliminary reports

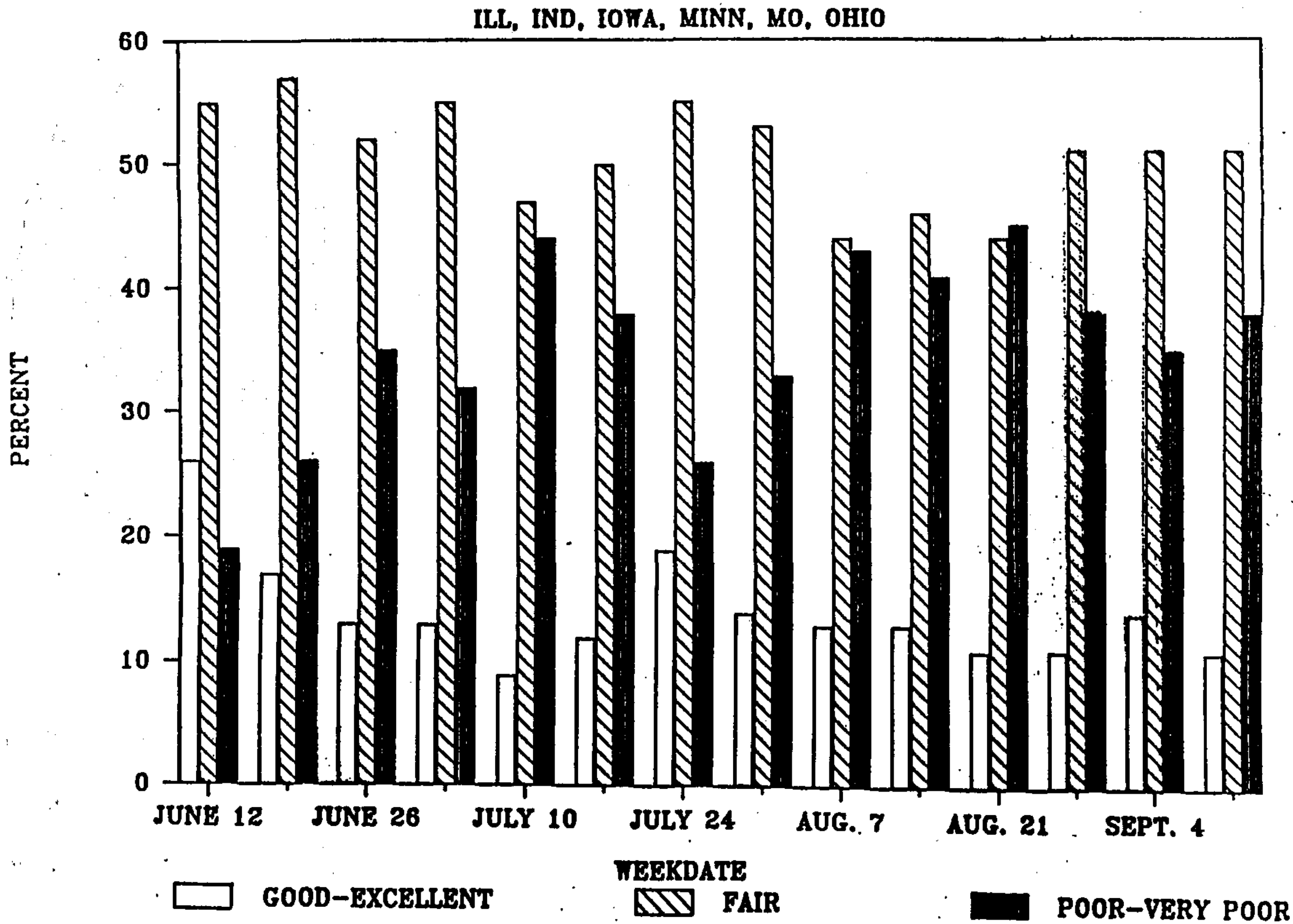
UNITED STATES SPRING WHEAT CONDITION



UNITED STATES CORN CONDITION



UNITED STATES SOYBEAN CONDITION



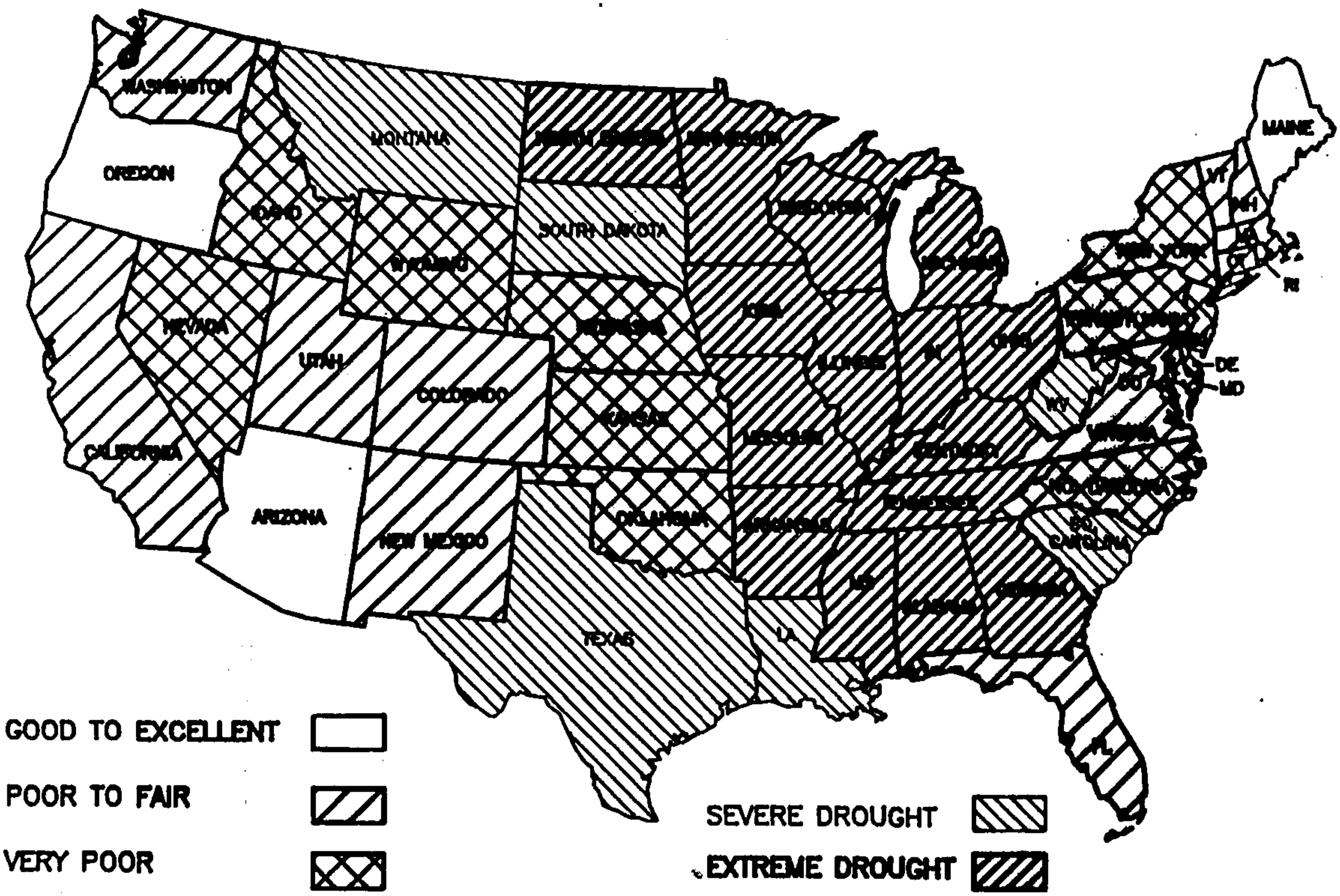
U.S. CROP PRODUCTION

	1987/88	1988/89 JUNE 9	FORECAST OCT 12	CHANGE FROM JUNE 9	CHANGE FROM YEAR AGO
		MIL. BU.			PERCENT
ALL WHEAT (INCL WHITE)	2,107	2,120	1,812	–15	–14
HARD RED	1,021	970	888	–8	–13
SOFT RED	348	415	473	+14	+36
HARD RED SPRING	431	––	182	––	–58
DURUM	93	––	46	––	–50
CORN	7,064	7,300	4,553	–38	–36
SORGHUM	741	650	541	–17	–27
BARLEY	530	500	283	–43	–47
OATS	374	450	211	–53	–44
		MIL. MT			
FEED GRAINS	215.2	219.4	138.6	–37	–36
WHEAT	57.3	57.7	49.3	–15	–14
TOTAL GRAINS	277.0	282.6	193.3	–32	–30
		MIL. BU.			
SOYBEANS	1,923	1,880	1,501	–20	–22

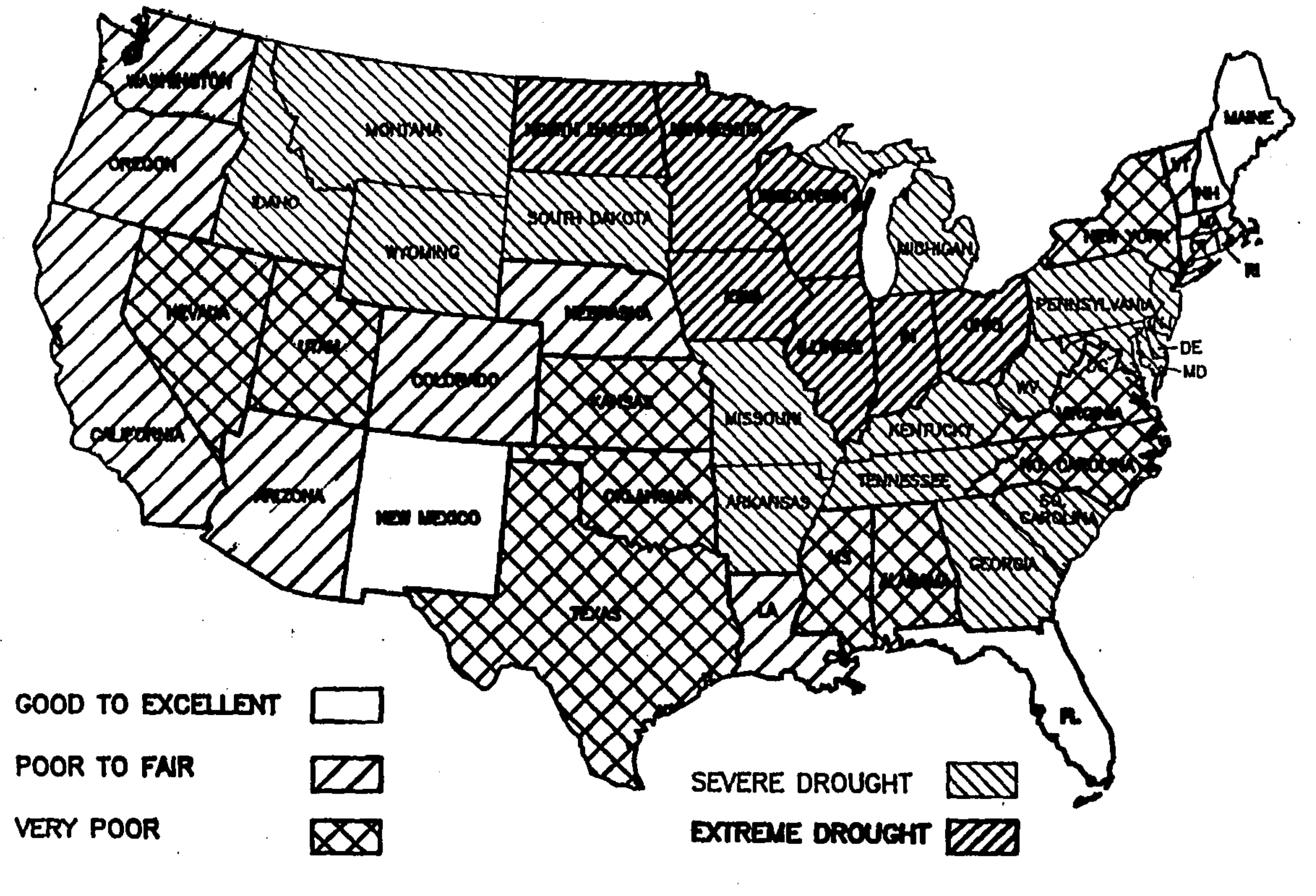
U.S. EXPORTS AS PERCENT OF TOTAL USE

	70/71	79/80	85/86	87/88	88/89 JUNE 6	88/89 OCT 12
			PERCENT			
COTTON	32	59	23	46	44	43
SOYBEANS	50	56	51	52	51	44
RICE	53	60	47	48	48	48
WHEAT	49	64	47	59	58	57
FEED GRAINS	12	31	18	22	22	22

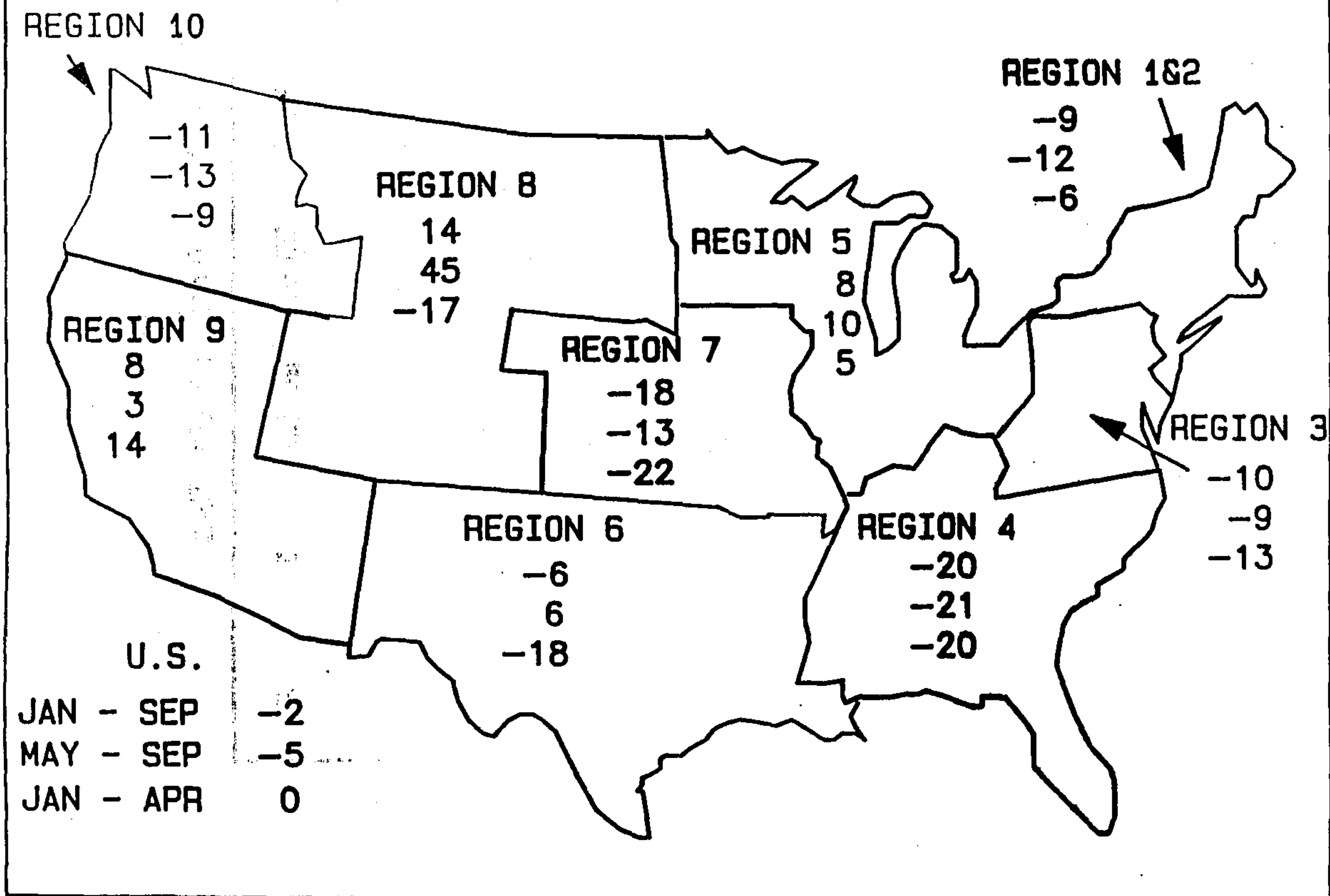
PASTURE AND RANGE FEED CONDITIONS — JULY 1, 1988



PASTURE AND RANGE FEED CONDITIONS – AUGUST 1, 1988



DAIRY COW SLAUGHTER 1988
PERCENT CHANGE FROM A YEAR EARLIER



U.S. MEAT PRODUCTION

Item	1988			1989		
	CURRENT	Change From		CURRENT	Change From	
	Est.	Jun 9 1/	Yr Ago 2/	Proj.	Jun 9 1/	Yr Ago 2/
	— Bil. Lbs —	— percent —		— Bil. Lbs —	— percent —	
Beef	23.2	+1.0	-0.7	21.6	-0.9	-5.9
Pork	15.6	-0.2	+8.9	15.7	-4.4	+0.7
Broilers	16.2	-0.2	+4.4	16.8	-3.0	+3.9
Tot. meat	60.2	+0.2	+3.3	59.6	-2.6	-0.8

1/ Pre-drought simulation, based on October 12 output projection modified to take into account pre-drought feed prices. 2/ Year-to-year changes for 1988 and 1989 are from June 9 simulation.

U.S. AVERAGE MARKET PRICES 1/

Commodity	1987/88	1988/89 Projections June 9	Oct. 12	Oct. 12 change from June 9	Year Ago 2/
	— Dollars Per Bushel —			— Percent —	
Wheat	2.57	2.90-3.30	3.55-3.95	20	45-50
Corn	1.94	1.65-2.00	2.40-2.80	40	30-40
Soybean	6.15	5.75-7.75	7.00-9.00	20	25-35
	— Dollars Per CWT —				
Cattle	68-70	70-76	71-77	1	5-9
Hogs	43-45	38-44	43-49	12	3-7
	— Cents Per Pound —				
Broilers	55-57	48-54	51-57	6	-2 TO 2

1/ Marketing years for crops and calender years 1988 and 1989 for livestock and broilers.

2/ Year-to-year changes for 1989 are from June 9 forecasts

U. S. FARM INCOME

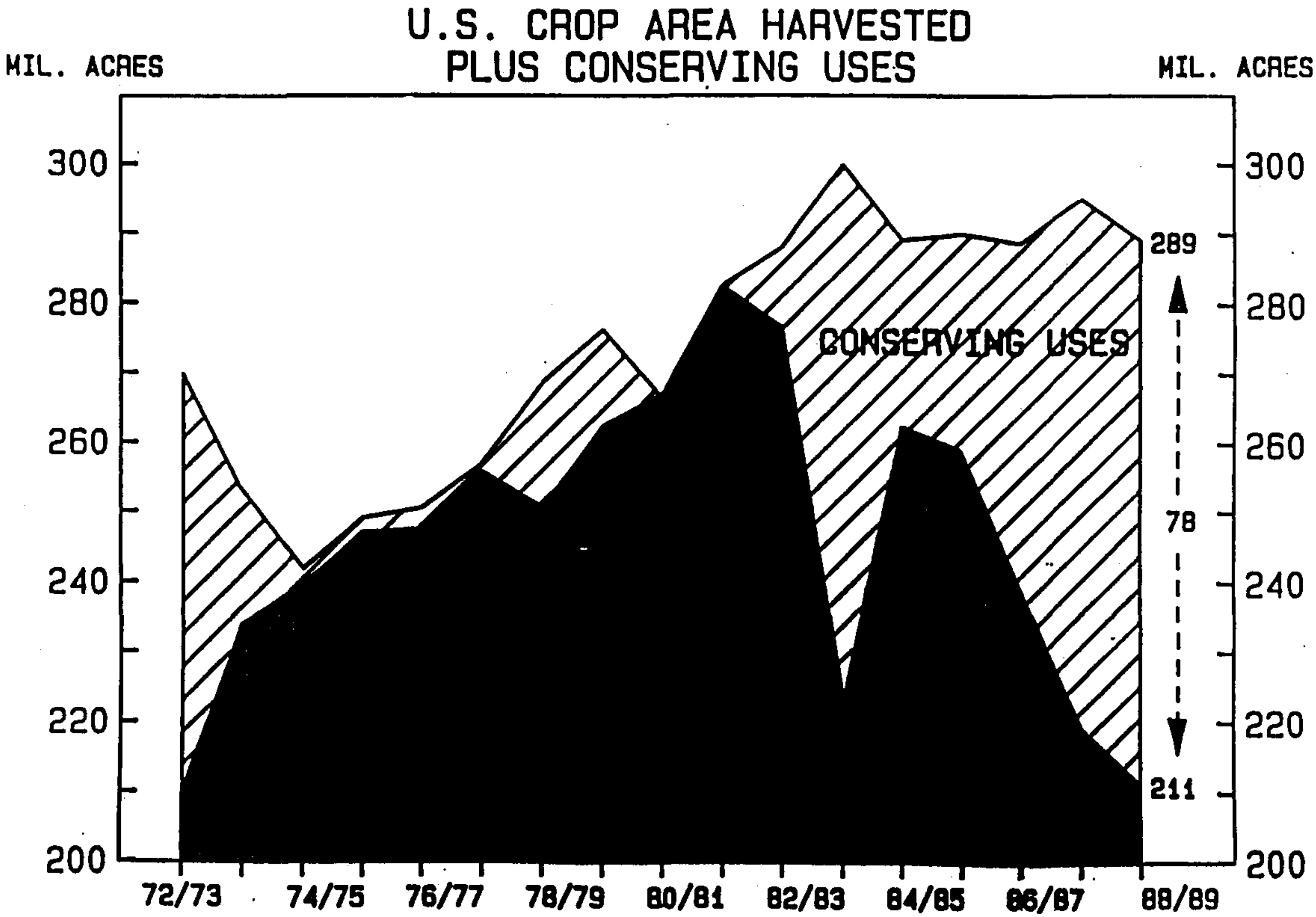
Item	1987	1988 forecast June 9	1988 forecast Oct 12	Oct. 12 forecast Change from June 9	Oct. 12 forecast Change from Yr Ago 1/
		1977=100		Percent	
CROPS					
Prices	106.0	110-116	123-129	12	20
		Bil. Dollars			
Cash Receipts	61.9	64-68	66-68	2	10
		Bil. Dollars			
Crop and Livestock					
Production Expenses	103.3	103-106	106-109	4	4
Net Cash Income	57.1	53-59	55-60	3	3

1/ Change from pre-dought estimate for 1987

U.S. CONSUMER PRICES

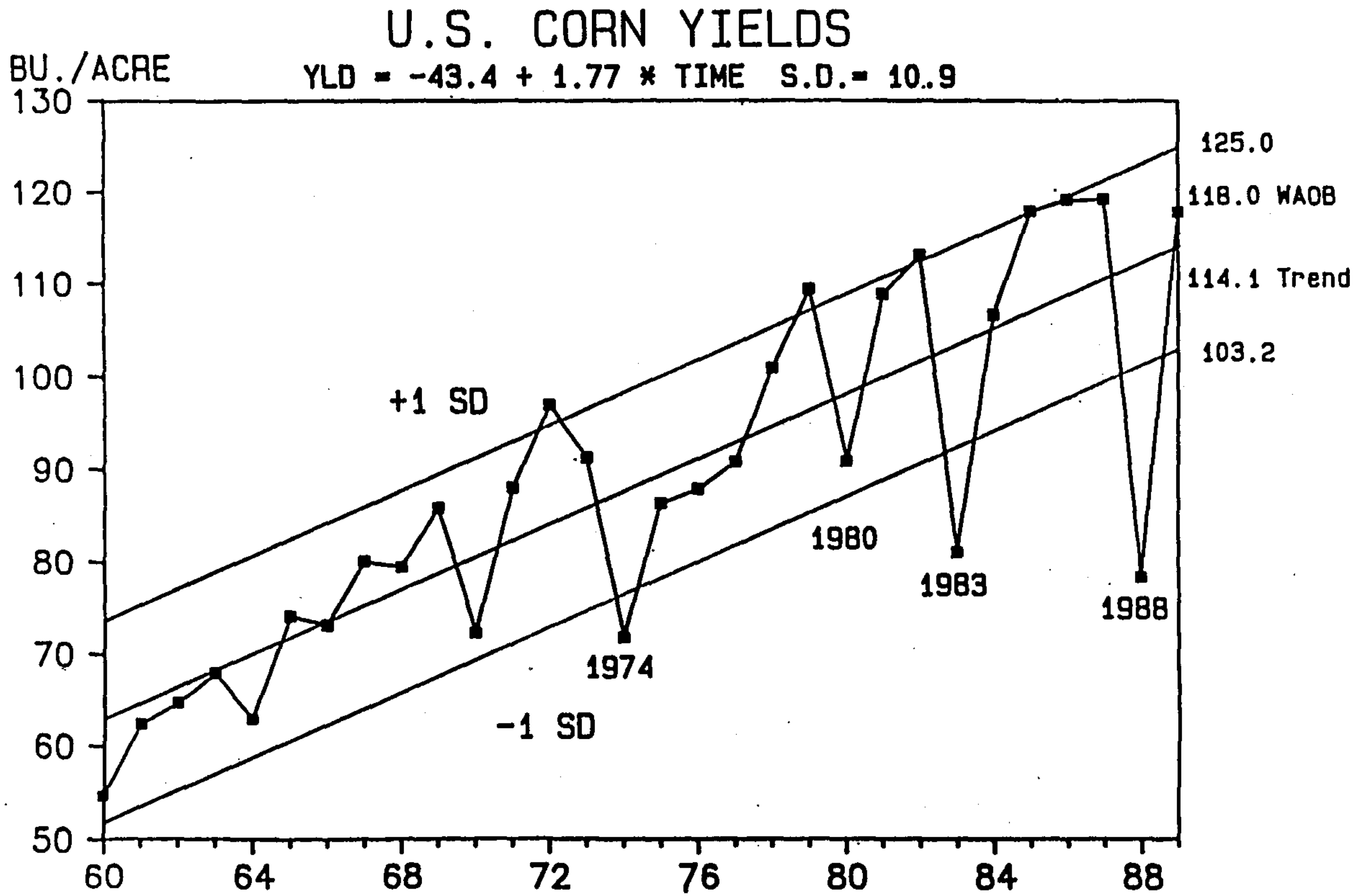
Item	1987	1988 Forecast June 9	1988 Forecast Oct. 12	October 12 forecast Change from June 9	October 12 forecast Change from Yr Ago 1/
	-- Annual pct change --			-- Percent --	
ALL ITEMS	3.7	3-5	3-5	0.3	0.3
ALL FOOD	4.1	2-4	3-5	0.5	-0.1
FOOD-AT-HOME	4.3	2-4	3-5	0.5	-0.4
Meats	7.5	0-3	0-3	0.2	-5.9
Poultry	-1.5	-4 to 0	3-6	6.5	6.0
Fats and Oils	1.5	2-5	3-5	0.5	2.5
Cereals and bakery products	3.5	5-7	5-8	0.7	3.2
Fruits and vegetables	8.8	5-8	5-8	0.1	-2.0

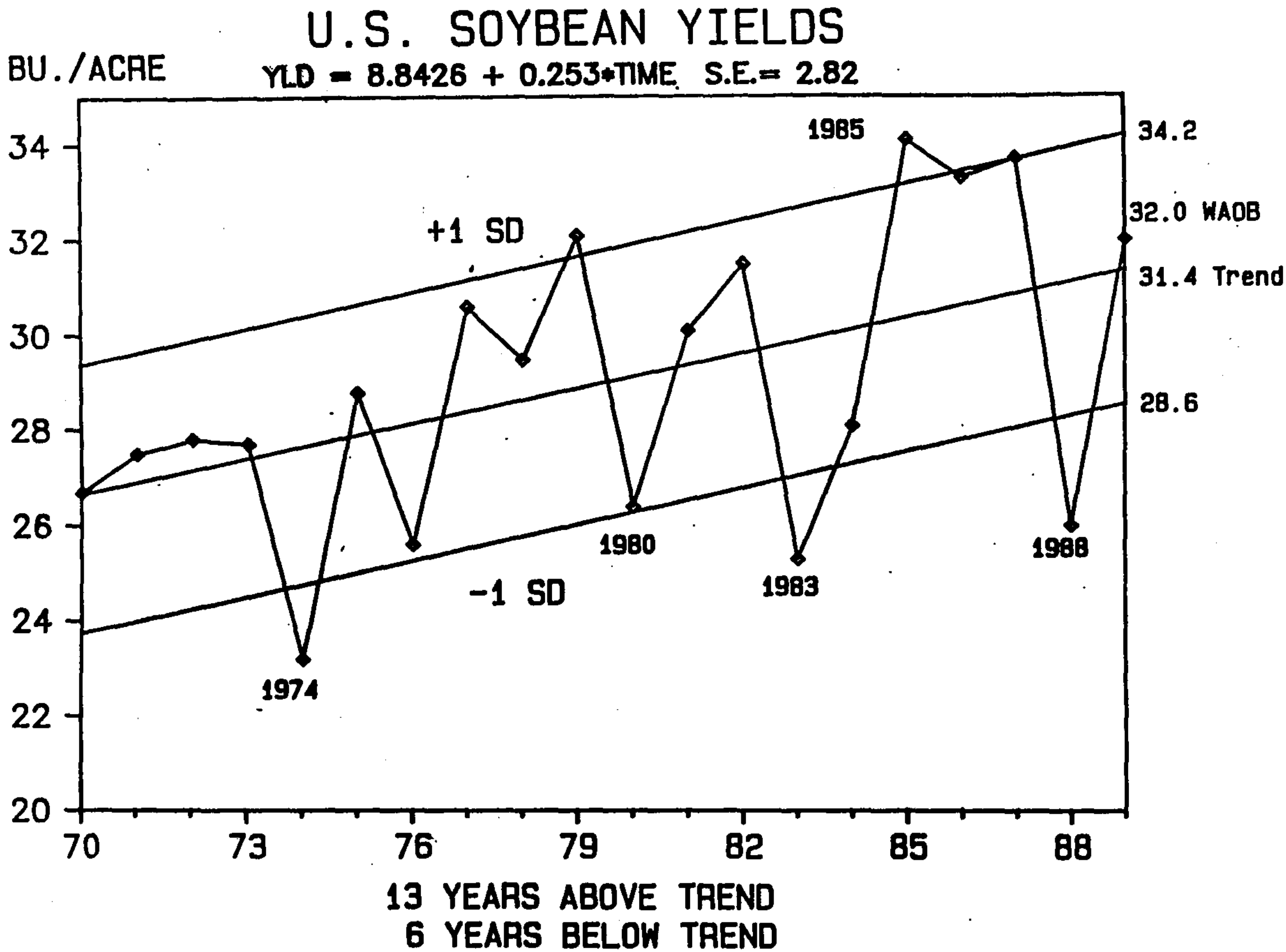
1/ Change from pre-drought forecasts for 1987


U.S. CROP AREA HARVESTED
PLUS CONSERVING USES
MIL. ACRES
MIL. ACRES
300
280
260
240
220
200
289
78
211
CONSERVING USES
72/73
74/75
76/77
78/79
80/81
82/83
84/85
86/87
88/89

ACREAGE REDUCTION REQUIREMENTS FOR GOVERNMENT PROGRAM PARTICIPATION

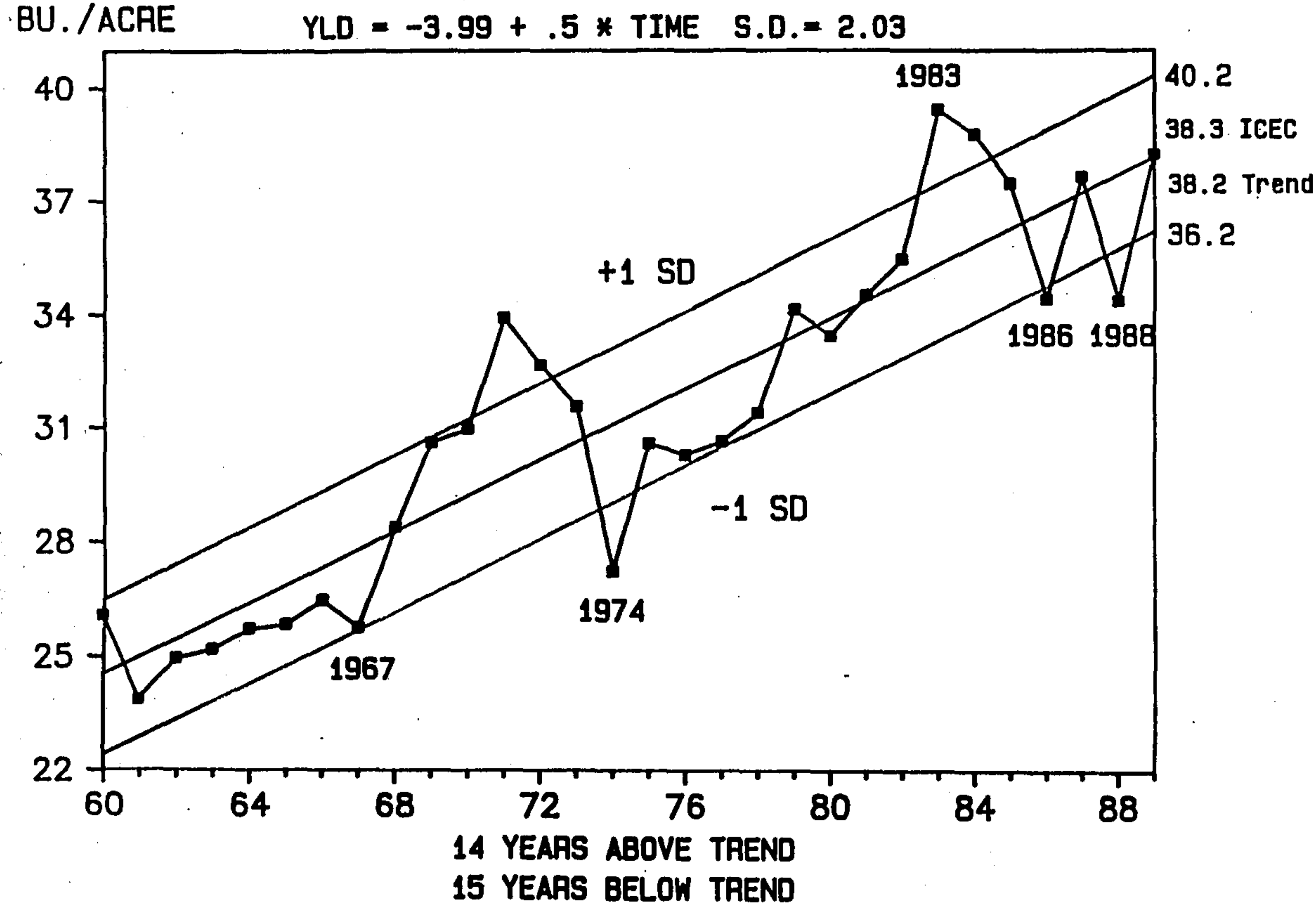
ITEM	WHEAT 88/89	WHEAT 89/90	CORN 88/89	CORN 89/90
	PERCENT			
ACREAGE REDUCTION PROGRAM	27.5	10	20	10
PAID LAND DIVERSION	0	0	10	0
	MILLION ACRES			
ACRES REMOVED FROM PRODUCTION	23	--	21	--
ACREAGE PLANTED	65.7	--	67.5	--


U.S. CORN YIELDS
BU./ACRE
YLD = -43.4 + 1.77 * TIME S.D.= 10.9
130
120
110
100
90
80
70
60
50
60
64
68
72
76
80
84
88
+1 SD
-1 SD
1974
1980
1983
1988
125.0
118.0 WAOB
114.1 Trend
103.2



U.S. SOYBEAN YIELDS
BU./ACRE
YLD = 8.8426 + 0.253*TIME S.E.= 2.82
34
32
30
28
26
24
22
20
70
73
76
79
82
85
88
+1 SD
-1 SD
1974
1980
1983
1985
1988
34.2
32.0 WAOB
31.4 Trend
28.6
13 YEARS ABOVE TREND
6 YEARS BELOW TREND

U.S. WHEAT YIELDS



STATE AND REGIONAL RESPONSE TO THE 1988 DROUGHT

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ABSTRACT

The 1988 drought in the United States was quite severe throughout a large portion of the nation. For the Southeast and parts of the Far West, drought conditions began in 1985 and 1986, respectively, and thus 1988 was just one more in a sequence of below normal precipitation years. Dry conditions in the northern plains states date back to 1985 while drought conditions in the Corn Belt states were more closely associated with 1988, which had one of the driest springs and one of the driest and warmest summer periods on record.

Previous responses to drought in the United States by all levels of government have been characterized by a reactive or "crisis management" approach. Assessment and response procedures have not been outlined in advance, resulting in actions that were ineffective, poorly coordinated, and untimely in most instances. Although a General Accounting Office report published in 1979 called for the development of a national drought plan, little, if any, action has taken place. State government has generally played a minor role in drought assessment and response efforts, relying largely on the federal government for assistance.

Some states are now better prepared to deal with water shortages because of the development of a drought plan. In early 1988, approximately ten states had developed plans. The 1988 drought has stimulated more than ten other states to initiate the planning process. Plans are most effective when developed during nondrought periods, when full attention can be devoted to the planning effort without pressures of severe water shortages.

There now exists considerable momentum for drought planning at the state level. As a result, state government will be better able to anticipate and respond to water shortages resulting from drought. Efforts are currently underway to develop a model drought plan to further facilitate this planning effort.

Regional organizations also have an important role to play in assisting state government to prepare for future episodes of drought. Regional organizations (e.g., Western Governors' Association, Regional Climate Centers) provide an opportunity for states to work together to address common problems. In the case of drought, regional organizations can help state policy makers understand drought, coordinate data collection and information dissemination efforts, enhance the flow of information concerning available drought management technologies, and communicate regional assessment of drought conditions and impacts to the federal government.

IMPACTS OF THE 1988

DROUGHT IN THE CANADIAN PRAIRIES

by R.G. Lawford
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EXTENDED ABSTRACT

The winter of 1987/88 and the spring and summer of 1988 in the southern and central parts of the three prairie provinces were characterized by below average precipitation amounts and above average temperatures. The magnitude of these variations was large and prolonged and their impacts on agriculture, water resources, and other components of the prairie economy were very significant.

The circulation pattern at 50 kPa during the winter and spring were characterized by a strong Pacific North American Oscillation with a low height anomaly centered over the Gulf of Alaska. A quasi-stationary ridge persisted over western North America for a number of months resulting in warmer than average surface temperatures and below average precipitation amounts. Winter snow packs were light across all of the southern Canadian prairies, and 70 - 90% of average in the high water yield areas on the eastern slopes of the Rocky Mountains. The 1988 meteorological drought was characterized by the occurrence of record high temperatures in June at a number of locations in Saskatchewan and Manitoba and isohyet patterns with strong north-south gradients at the northern boundary of the drought area. There was also considerable spatial variation in the build-up of cumulative precipitation deficits. While the 1988 drought was severe, it is not without precedent in the instrumental record. Relief from the drought in the form of above average rainfalls occurred in central British Columbia in May and spread eastward into central Alberta in June and into central Saskatchewan in August. However, the most southerly parts of Alberta and Saskatchewan still remain dry.

The below average precipitation amounts during the growing season combined with the low spring soil moisture conditions resulted in poor germination. The extremely warm temperatures in June caused the crops to mature rapidly under high water stress conditions. Yields in Saskatchewan and Manitoba are estimated to be 50 - 60% of average, although there are many areas of Saskatchewan where individual farm yields are 0 - 20% of average. As a result

of the strong linkages between agriculture and the secondary industries such as fertilizer and herbicides producers and farm machinery dealers, the drought will have a ripple effect throughout the entire Canadian prairie economy.

The hydrological impacts of the drought were also significant. To some extent these impacts were a culmination of the effects of a sequence of years during the 1980's with below average precipitation amounts. The low river flows, lake levels and water tables of 1987 did not return to normal in the spring of 1988 because the melt water from the limited snow pack was inadequate to replenish them. Many reservoirs which had been drawn down to produce hydroelectric power in the winter of 1987/88 remained low throughout the spring and summer of 1988. Hydroelectric generation was well below average in Manitoba. Manitoba Hydro was reduced from a major net exporter to a net importer of electricity. To date, this change has resulted in a net loss of more than $30 million for Manitoba Hydro, with a projected loss for 1988 of as much as $60 million.

Without the spring recharge, many sloughs and even some lakes dried up. Ducks which usually nest in these habitats were forced northward into wetlands in the boreal forests and were unsuccessful in breeding. Low river flows and lake levels also had severe impacts on water quality, municipal water supplies and fish reproduction. Significant impacts were also experienced in forest management as fire fighting costs in 1988 were well above average in Saskatchewan and Manitoba.

Climatological data were used extensively by individuals, private sector companies and government agencies during 1988 in monitoring the progress of the drought and, to a lesser extent, in determining the steps required to mitigate its effects. Near real-time climatological information and data were provided through briefings, information notes, media releases and special maps to government agencies and multi-agency drought committees. In addition, climatic data and consultations were provided to a wide number of users with specific information requests related to operational or financial decisions.

There are other areas where climatological research and information could enable decision makers to more effectively plan for drought both on the medium and the long term. In particular, medium-term drought response planning could be aided greatly by accurate drought forecasts for the next 1-3 month period. Climatological information could also assist in the development of long-term plans for drought-proofing.

While the climatic conditions of 1988 do not constitute proof that drought will become more frequent on the Canadian prairies as a result of the increasing concentrations of greenhouse gases in the atmosphere, they are not inconsistent with that hypothesis. The severity of the 1988 drought impacts indicates that our increasingly complex society is becoming more vulnerable to drought. More work is needed to provide reliable estimates of the nature and timing of climatic change and its consequences for the frequency of drought and the economies of the Canadian prairie provinces.

It should be noted that the estimates of economic impacts presented in this abstract must be regarded as preliminary and subject to revision by the responsible agencies.

The contributions of the following individuals to this presentation are gratefully acknowledged:

Mr. Rick Raddatz - Scientific Services Meteorologist, AES Central Region, Winnipeg, Manitoba

Mr. Ted O'Brien - Drought Officer, Prairie Farm Rehabilitation Administration, Regina, Saskatchewan

Mr. Jim Rogers - Inland Waters Directorate, Western and Northern Region, Regina, Saskatchewan

Mr. Kent Brace - Canadian Wildlife Service, Saskatoon, Saskatchewan

Mr. Ken Jones - Scientific Services Meteorologist, Regina, Saskatchewan.

Mr. Peter Scholefield - Monitoring and Prediction Division, Canadian Climate Centre, Downsview, Ontario.

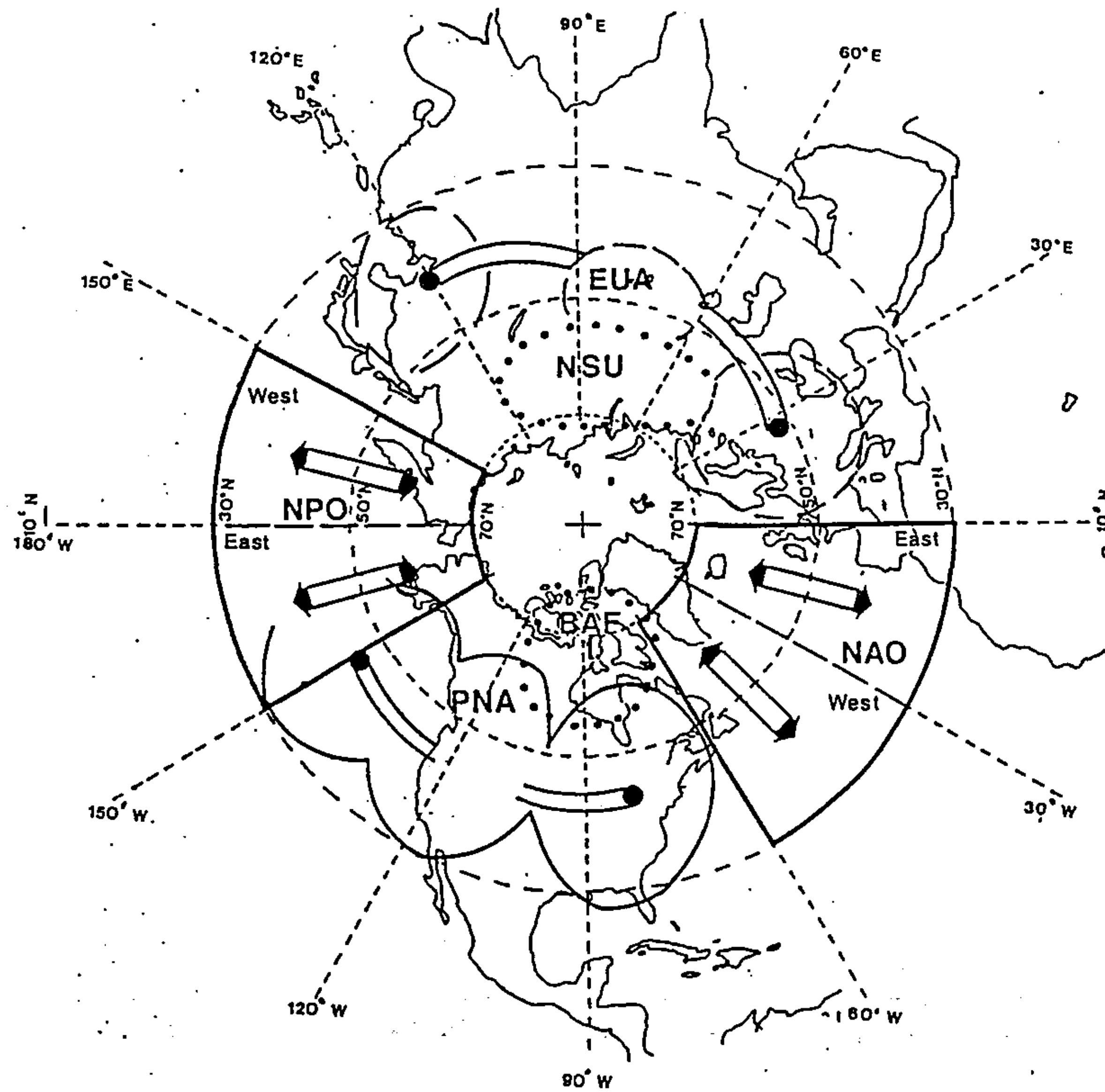
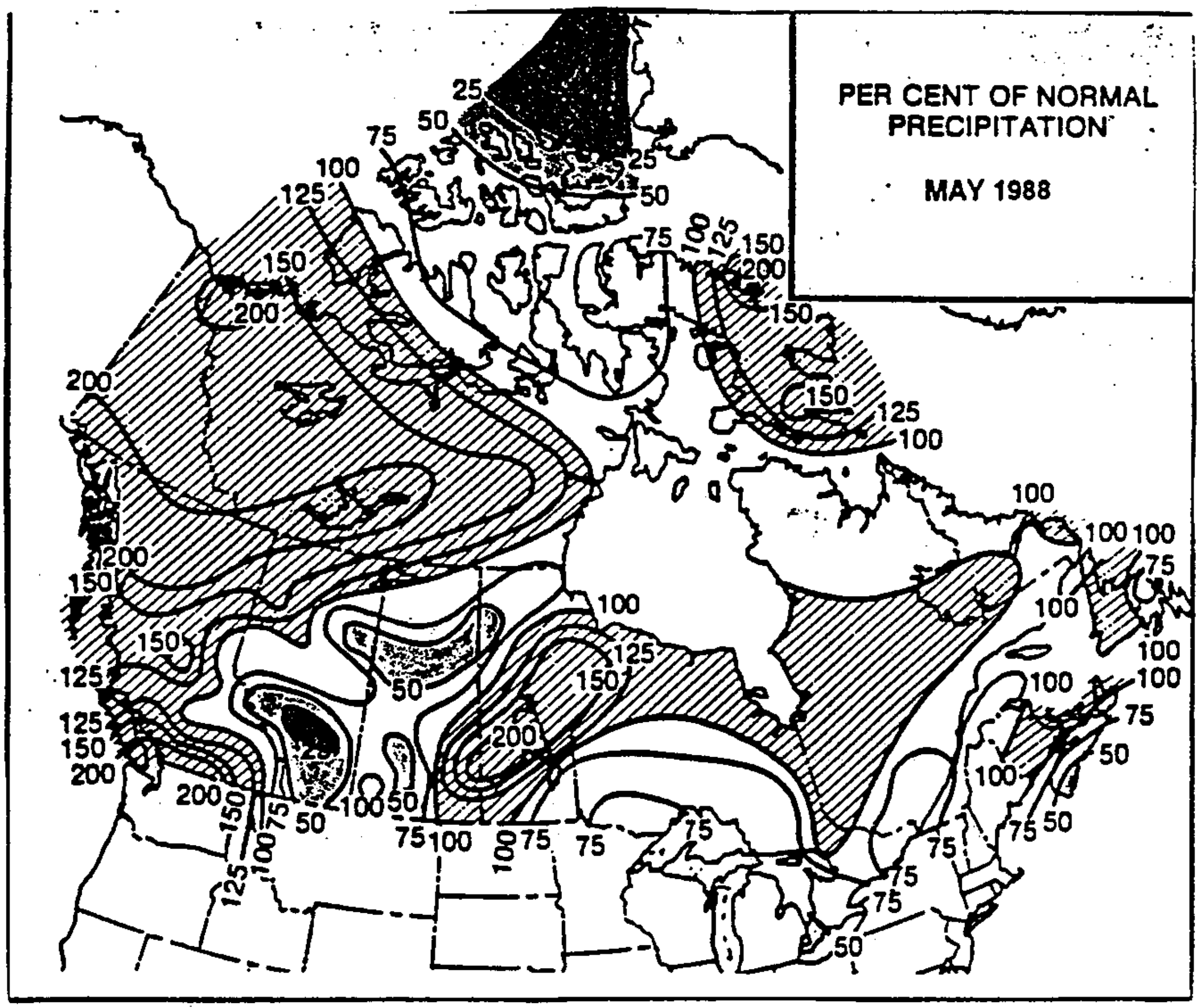
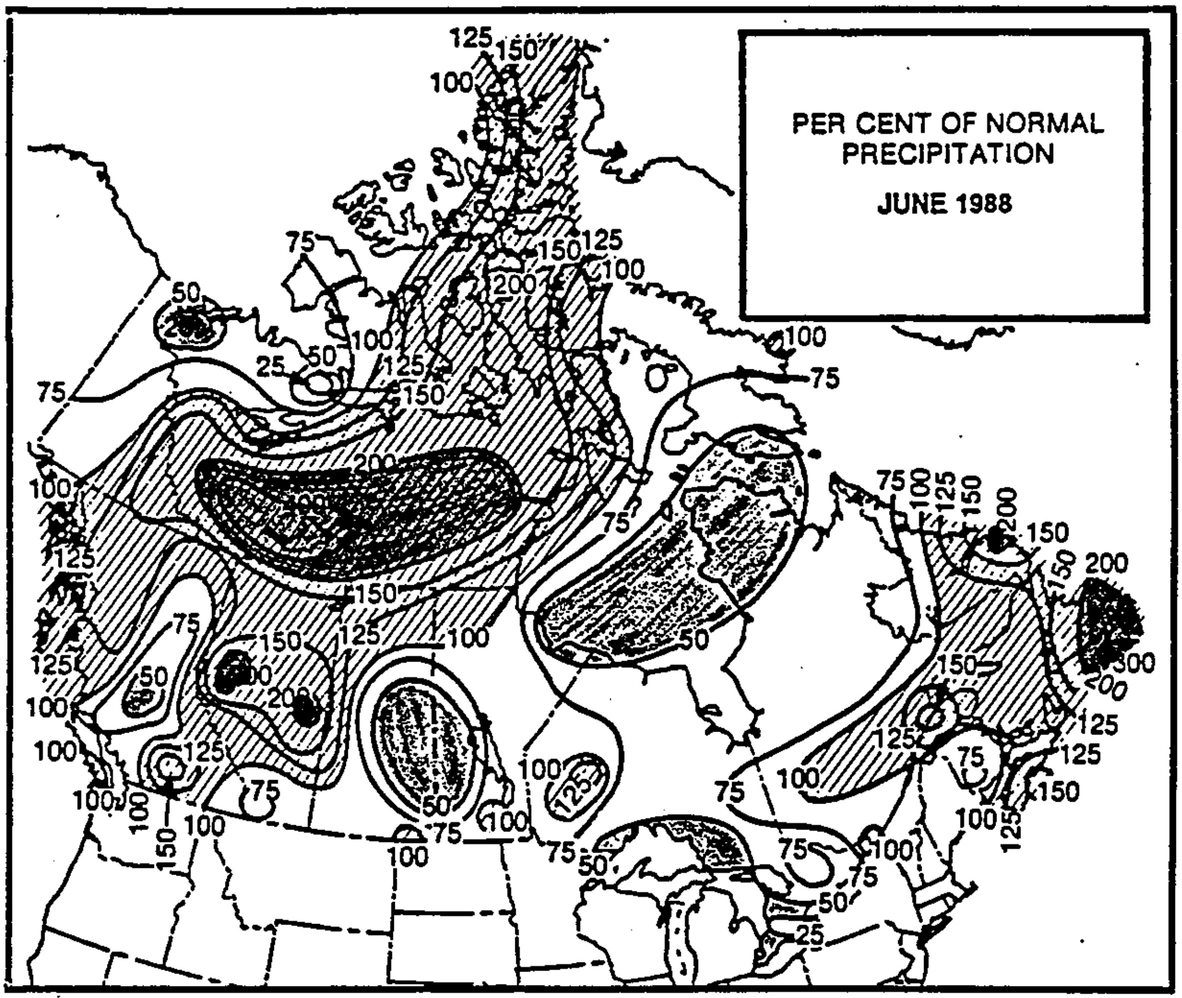
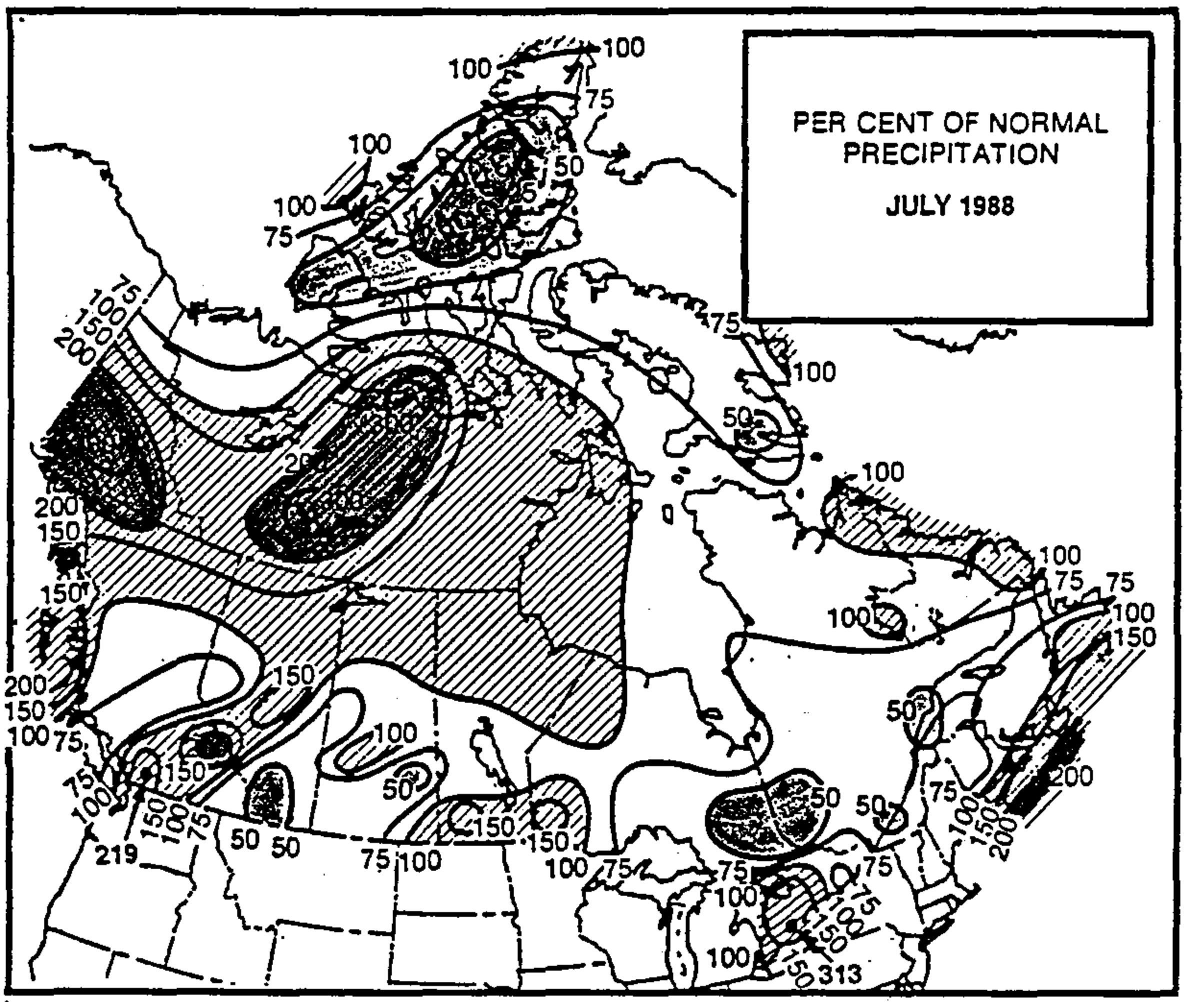


FIGURE 1: Highly idealized representation of characteristic Northern Hemisphere 50kPa height anomaly teleconnection modes adapted to Spring and early Summer. For definitions and phase sign conventions, see text.


PER CENT OF NORMAL
PRECIPITATION
MAY 1988


PER CENT OF NORMAL
PRECIPITATION
JUNE 1988


PER CENT OF NORMAL
PRECIPITATION
JULY 1988

DROUGHT INTENSITY

PRECIPITATION SHORTFALL
September - August

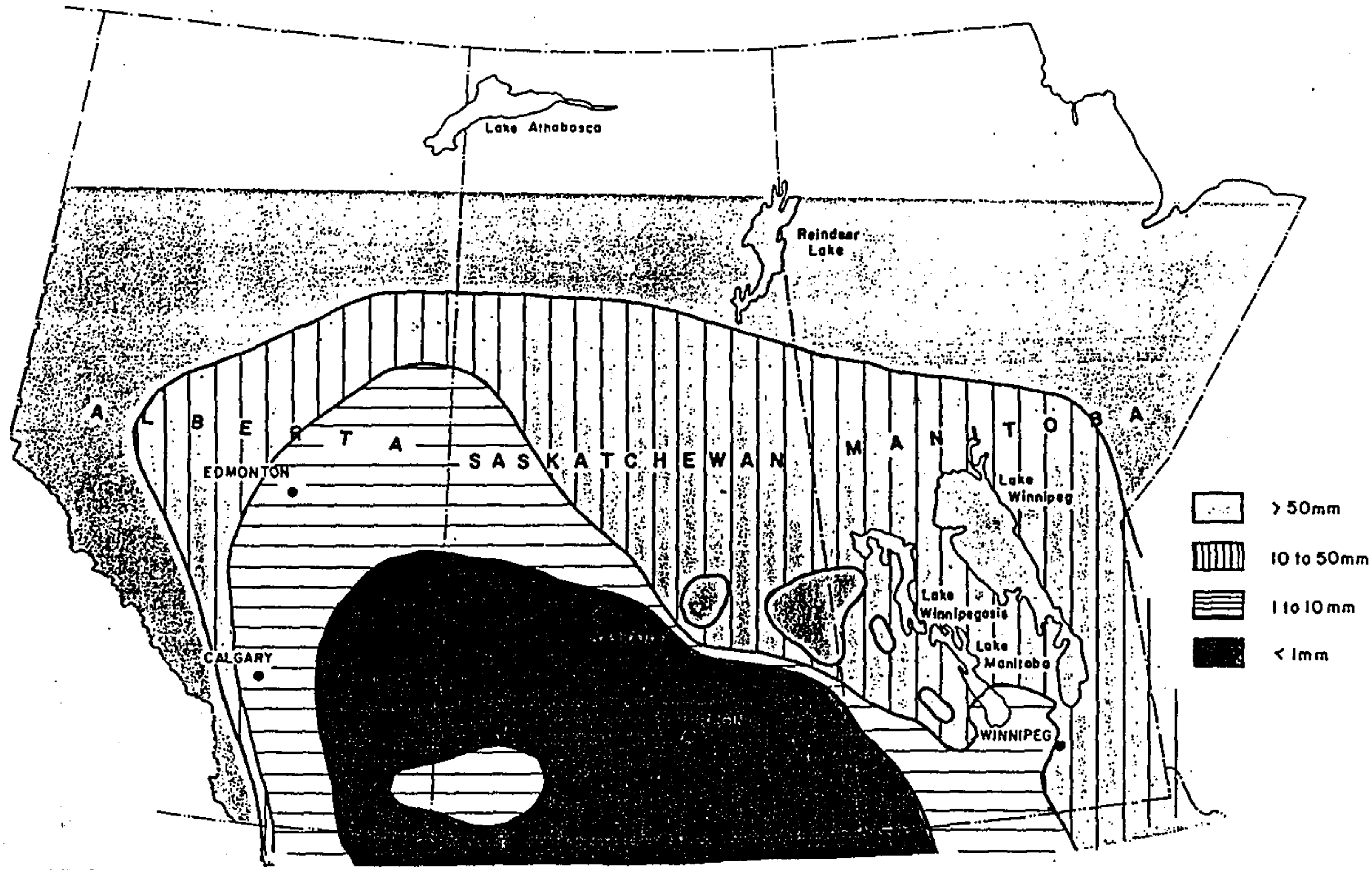
Station	1936	1937	1961	1984	1988
Winnipeg	−0.26	−0.06	−0.42	−0.06	−0.38
Brandon	−0.31	+0.35	−0.43	−0.06	−0.22
Saskatoon	−0.05	−0.19	−0.19	−0.24	−0.21
Regina	−0.16	−0.53	−0.57	−0.34	−0.27
Swift Current	−0.20	−0.50	−0.35	−0.39	−0.25
Prince Albert	−0.33	−0.13	−0.23	+0.34	+0.03
Lethbridge	−0.30	0.00	−0.31	−0.33	−0.45
Calgary	−0.37	+0.01	−0.12	−0.32	−0.10
Edmonton	+0.05	+0.01	−0.20	−0.32	+0.18
Average	−0.25	−0.28	−0.31	−0.26	−0.27

SEPTEMBER TO AUGUST PRECIPITATION HISTORICAL PERSPECTIVE

Station	Precipitation (mm) (% of normal)	# Drier Years (# years record)
Kenora	494.1 (79.3)	4 (50)
Winnipeg	327.8 (62.4)	4 (113)
Portage	334.0 (61.3)	2 (52)
Brandon	352.8 (78.3)	11 (86)
Dauphin	479.7 (96.8)	26 (52)
Yorkton	426.6 (98.3)	17 (45)
Broadview	402.0 (87.0)	18 (49)
Estevan	294.4 (67.9)	5 (51)
Regina	279.8 (72.9)	9 (88)
Saskatoon	275.5 (79.0)	9 (82)
Prince Albert	410.7 (103.1)	53 (97)
La Ronge	433.2 (89.3)	6 (22)
Swift Current	283.9 (74.7)	12 (102)
North Battleford	368.4 (102.6)	23 (46)
Lethbridge	227.2 (53.7)	1 (85)
Calgary	382.7 (90.3)	40 (104)
Edmonton	549.9 (118.0)	89 (105)
Grande Prairie	392.0 (86.5)	13 (49)

August 1988 Estimates of Crop Production and Comparison to Other Years

	1987	1988	88/87	83 - 87 / 88
	(000 bu)		(%)	(%)
wheat	145.0	86.9	60	56
oats	27.0	16.0	59	53
barley	89.0	47.0	53	52
rye	1.8	1.9	104	33
flax	16.0	7.5	47	41
canola	25.8	27	105	114



Environment Canada — Environnement Canada
Conservation and Protection — Conservation et Protection

1988 RUNOFF FOR THE PRAIRIE PROVINCES
(Millimetres of Runoff)

Climatic impacts summarized for southern Saskatchewan in relation to normal (HIST1 OR HIST5)

Model	Scenario			
	HIST2	HIST3	GISS1	GISS2
Degree Days	+10 to +18%	+3 to +16%	+48 to +53%	+48 to +53%
Precipitation Effectiveness	-18 to -53%	-21 to -26%	+1 to +13%	-10 to -12%
Biomass Potential	-53 to -100%	-26 to -60%	+1 to +30%	-19 to +3%
Wind Erosion Potential	+123%	-	-14%	+26%
	HIST2	HIST4	GISS1	GISS2
Spring Wheat Production	-76%	-20%	-18%	-28%
Expenditures by Agric. (million $)	-$1,810	-$599	-$163	-$277
Employment in Agriculture	-8,000	-2,647	-722	-1,224

	PALMER DROUGHT INDEX (PDI)				
	FREQUENCIES			RETURN PERIOD (YEARS)	
	HIST5	GISS3	GISS4	HIST5	GISS3
Severe Drought	0.1%	0.9%	10.8%	15 to 35	8.5 to 17.5
Drought	3.0%	9.1%	39.6%	6.5 to 10	4 to 6

17 OCTOBER 1988

CORPS OF ENGINEERS BRIEFING ON DROUGHT
18 OCTOBER 1988

GOOD AFTERNOON LADIES AND GENTLEMEN. IT'S A PLEASURE FOR ME TO BE HERE TODAY TO DISCUSS THE NATIONWIDE DROUGHT AND THE CORPS OF ENGINEERS ROLE IN COPING WITH ITS IMPACTS. THE CORPS HAS BEEN VERY BUSY OF LATE.

WHILE THE DROUGHT HAS SLIPPED FROM THE FRONT PAGE OF THE WASHINGTON POST, IT IS STILL VERY MUCH IN THE MINDS OF THOSE WHO DRAW THEIR LIVELIHOOD FROM AGRICULTURE OR FROM THE MAIN STEM MISSISSIPPI AND ITS TRIBUTARIES, ESPECIALLY THOSE WHO MOVE GOODS AND SERVICES ON THE INLAND WATERWAYS OF THE NATION. MY PRESENTATION TODAY WILL ADDRESS THE IMPACTS ON THOSE AREAS AND WHAT THE CORPS IS DOING TO HELP SOLVE THOSE PROBLEMS.

THE DROUGHT IMPACTS ALMOST ALL OF USACE CIVIL WORKS MISSIONS.

NAVIGATION PROBLEMS HAVE BEEN THE MOST VISIBLE IMPACT. THIS WAS A COMMON OCCURRENCE IN LATE JUNE AND EARLY JULY.

TO EMPHASIZE THE IMPORTANCE OF THE INLAND NAVIGATION SYSTEM THIS SLIDE SHOWS THE EQUIVALENT NUMBER OF RAILCARS AND TRUCKS TO MATCH THE CAPACITY OF A SINGLE JUMBO BARGE.

EVERY PRESENTATION NEEDS A GEE WHIZ SLIDE AND HERE'S MINE. APPROXIMATELY 275 OF THESE JUMBO BARGES PASS A GIVEN POINT ON THE LOWER MISSISSIPPI RIVER ON A NORMAL DAY. THAT IS COMPARABLE TO 4,100 RAILCARS OR 16,500 TRUCKS. AT ONE POINT THERE WERE 130 TOWS INCORPORATING 3900 BARGES BACKED UP BECAUSE OF A BLOCKAGE ATTRIBUTABLE TO THE DROUGHT. THAT EQUATES TO A TRAIN FROM NEW ORLEANS TO KANSAS CITY. IT ALSO EQUATES TO 234,000 SEMI TRUCKS, A CONVOY FROM NEW ORLEANS ALL THE WAY TO PORTLAND, OREGON. RIVER TRAFFIC WAS DOWN AS MUCH AS 20% AT ONE POINT DURING THE SUMMER. THIS WOULD EQUATE TO 30 MILLION TONS OVER THE ENTIRE SEASON. INDUSTRY HAS RECOVERED FROM THIS DECREASED TONNAGE WITH BETTER RIVER CONDITIONS AND BY USING MORE TOW BOATS. AT SOME PORTS ALONG THE RIVERS TONNAGE IS ACTUALLY UP OVER 1987 LEVELS.

WE, THE CORPS OF ENGINEERS, WORKING CLOSELY WITH THE US COAST GUARD, THE NAVIGATION INDUSTRY AND OTHERS HAVE BEEN ABLE TO MAINTAIN NAVIGATION

ON OUR MAJOR WATERWAYS DURING DROUGHT 88 BECAUSE OF TWO IMPORTANT PROGRAMS:

CONTROLLED RESERVOIR RELEASES, AND
CHANNEL DREDGING AND MAINTENANCE

THE CORPS OF ENGINEERS OPERATES AND MAINTAINS MANY MULTI-PURPOSE RESERVOIRS. ONE OF THE PRIMARY PURPOSES FOR SOME OF THESE RESERVOIRS IS TO PROVIDE WATER NEEDED FOR NAVIGATION. IN THE MISSISSIPPI RIVER BASIN FEDERAL PROJECTS STILL CONTAIN 53.9 MILLION ACRE-FEET OF SEASONAL CONSERVATION STORAGE FOR NAVIGATION, HYDROPOWER, WATER SUPPLY AND WATER QUALITY UPSTREAM FROM KAYRO. THROUGHOUT THE DROUGHT PERIOD, INCLUDING THE PRESENT TIME, CONTROLLED RELEASES OF WATER FROM FEDERAL PROJECTS IN THE MISSOURI AND OHIO RIVER BASINS HAVE KEPT AND ARE KEEPING THE WATER LEVELS IN THE MISSISSIPPI RIVER HIGH ENOUGH TO PERMIT MOVEMENT OF COMMERCIAL AND RECREATIONAL TRAFFIC. AN EXAMPLE OF THE FLEXIBILITY PROVIDED BY CONTROLLED STORAGE IS THAT CURRENTLY WATER IS BEING RELEASED FROM THREE PROJECTS TO INCREASE DEPTHS ALONG THE APALACHICOLA AND CHATTAHOOCHE RIVERS. THIS WAS TO PROVIDE A 7 1/2 FOOT DEEP CHANNEL FOR A THREE WEEK PERIOD FROM 7 – 28 SEP SO THAT CRITICAL FARM AND FERTILIZER PRODUCTS

COULD BE MOVED. FORTUNATELY, MOTHER NATURE HAS PROVIDED SOME MUCH NEEDED RAINFALL IN THE SOUTHEAST AND THE ACF SYSTEM WILL REMAIN OPEN. WATERS STORED IN THE RESERVOIRS ARE INSTRUMENTAL IN KEEPING THE MAJOR WATERWAYS OPEN AND TRAFFIC MOVING.

THE SECOND PROGRAM IS CHANNEL DREDGING. NAVIGATION PROBLEMS HAVE STABILIZED ON THE MISSISSIPPI RIVER, OHIO RIVER AND WHITE/ARKANSAS SYSTEM. BETWEEN 7 JUNE AND 13 JULY WE EXPERIENCED 28 CLOSURES. SINCE 13 JULY WE HAVE HAD ONLY THREE CLOSURES. THE MESSAGE IN THIS IS THAT AFTER THE FIRST MONTH OF THIS SUMMER'S NAVIGATION PROBLEMS, WE HAVE BEEN ABLE TO MAINTAIN THE AUTHORIZED 9 FEET DEEP BY 300 FEET WIDE CHANNEL THROUGH AN AGRESSIVE DREDGING PROGRAM, WISE RESERVOIR REGULATION AND BY COAST GUARD RESTRICTIONS ON THE SIZE OF THE TOWS.

MOST CLOSURES ARE CAUSED BY SHOALING. WHEN THIS OCCURS WE MOVE A DREDGE TO THAT LOCATION TO RESTORE THE REQUIRED DEPTH. IN THIS SLIDE WE HAVE THE CORPS-OWNED DREDGE "BURGESS". IT IS CAPABLE OF MOVING 80,000 CY OF MATERIAL PER DAY. WE HAVE HAD AS MANY AS 13 DREDGES WORKING NIGHT AND DAY TO MAINTAIN THE NAVIGATION CHANNELS.

CURRENTLY, THERE ARE 7 DREDGES WORKING. DEPTH AND TOW SIZE RESTRICTIONS HAVE BEEN LIFTED FOR THE MISSISSIPPI AND OHIO RIVERS BY THE COAST GUARD, BUT THEY HAVE ISSUED ADVISORIES RECOMMENDING THAT THE TOW SIZES AND DRAFTS CONTINUE TO BE REDUCED SINCE CONDITIONS HAVE NOT RETURNED TO NORMAL. RESTRICTIONS ARE IN PLACE ON THE MISSOURI, ALABAMA AND WHITE RIVERS AND THE ACF SYSTEM TO HELP PRE-VENT GROUNDINGS WHICH OFTEN CLOSE THE WATERWAYS.

THERE ARE TWO ROUTES AVAILABLE FROM KAYRO, ILLINOIS TO THE GULF. THE FIRST IS VIA THE MISSISSIPPI RIVER, THE TRADITIONAL ROUTE, SHOWN IN RED, AND THE SECOND IS VIA THE TENNESSEE-TOMBIGBEE WATERWAY, ANOTHER ARMY CORPS OF ENGINEERS PROJECT, SHOWN IN GREEN. AS AN EXAMPLE OF THE VALUE OF THE TENN-TON WATERWAY, DUE TO DROUGHT-CAUSED NAVIGATION PROBLEMS ON THE MISSISSIPPI RIVER, TRAFFIC ON THE TENN-TOM INCREASED TO 2.1 MILLION TONS IN JULY 1988 COMPARED TO JUST UNDER 0.3 MILLION TONS IN JULY 1987. SINCE THEN, WITH IMPROVED MISSISSIPPI RIVER CONDITIONS, TRAFFIC ON THE TENN-TOM HAS MODERATED, BUT STILL REMAINS ABOVE LAST YEARS VOLUME.

ANOTHER CORPS MISSION AFFECTED BY THE DROUGHT IS THE PRODUCTION OF HYDROPOWER. CORPS HYDROPOWER PRODUCTION WAS 25% OF NORMAL DURING THE SUMMER MONTHS. THIS REDUCTION RESULTED IN LOSS REVENUES OF $145 MILLION DOLLARS.

THE MAJOR WATER QUALITY IMPACT TO WHICH WE HAVE RESPONDED IS THE INTRUSION OF A SALT WATER WEDGE FROM THE GULF OF MEXICO UP THE MISSISSIPPI RIVER. AS THE GREATEST CONCENTRATION OF SALINITY IS NEAR THE BOTTOM OF THE RIVER, OUR COMPUTER MODEL INDICATED A SILL OR SUBMERGED BARRIER WOULD HELP REDUCE THE EXTENT OF INTRUSION AND IN CONJUNCTION WITH FLOWS DOWN THE MISSISSIPPI RIVER DILUTE ANY SALINE WATER ALREADY BEYOND THE SILL.

EACH YEAR DURING LOW SUMMER FLOWS A WEDGE OF DENSE SALTWATER MOVES UPRIVER TO APPROXIMATELY MILE 30 TO 40. HISTORICALLY, THE GREATEST INCURSION OF THE WEDGE WAS TO NEAR MILE 120 WHICH IS ABOVE NEW ORLEANS. THAT OCCURRED IN 1936 AND AGAIN IN 1940. MAJOR CONCERN DEVELOPED THAT THIS YEAR THE WEDGE WOULD AGAIN TRAVEL PAST NEW ORLEANS (MILE 96-110) AFFECTING THE CITY'S WATER SUPPLY. ON 5 JULY THE SALTWATER WEDGE WAS AT MILE 91. IT ULTIMATELY REACHED MILE 104.5 AS SHOWN IN GREEN.

THE CONSTRUCTION OF OUR SUBMERGED BARRIER SILL AT RIVER MILE 63.7 WAS SEEN AS THE SOLUTION TO STOPPING THE ADVANCING SALTWATER WEDGE. AS I NOTED, AT ITS MAXIMUM PROGRESSION UPSTREAM, THE TOE OF THE SALT WATER WEDGE REACHED RIVER MILE 104.5. EVEN AFTER ONLY PARTIAL COMPLETION OF THE SILL, THE WEDGE BEGAN TO RECEDE AND DILUTION OF THE WEDGE OCCURRED MORE RAPIDLY THAN PROJECTED DUE TO BOTH THE SILL AND INCREASED FLOWS IN THE RIVER. DILUTION OF THE REMAINING POCKETS IS ESSENTIALLY COMPLETE AND THE WEDGE HAS RETREATED TO MILE 63.7, THE LOCATION OF THE BARRIER SILL.

THE ARMY CORPS OF ENGINEERS IS THE SECOND LARGEST PROVIDER OF RECREATION IN THE FEDERAL GOVERNMENT. OBVIOUSLY, AS LAKE LEVELS DECLINE DUE TO THE DROUGHT, RECREATION IS IMPACTED.

SHOWN HERE IS THE EXTENT OF IMPACTS ON RECREATION FACILITIES AT CORPS PROJECTS.

THE ARMY CORPS OF ENGINEERS PEOPLE AND PROJECTS HAVE BEEN PROACTIVE IN MEETING THE CHALLENGES PRESENTED BY EXTREME DROUGHT SITUATIONS THROUGHOUT THE COUNTRY. AS A MATTER OF FACT, OUR SUCCESSES HAVE BEEN EXCEPTIONAL AND HAVE BROUGHT MUCH CREDIT AND PRAISE TO THE ARMY. AS A FEW EXAMPLES:

1. WE HAVE MAINTAINED A NAVIGABLE CHANNEL ON THE MISSISSIPPI DESPITE RECORD LOW WATER CONDITIONS IN JUNE AND JULY. THIS SUCCESS WAS MADE POSSIBLE BY THE HERCULEAN DREDGING EFFORTS AND THE JUDICIOUS AND WISE USE OF WATER FROM FEDERAL RESERVOIRS. AT THE TIME OF THE MOST EXTREME LOW WATER CONDITIONS 70% OF THE WATER FLOWING PAST NEW ORLEANS WAS COMING FROM CONTROLLED STORAGE IN FEDERAL RESERVOIRS AS DISTANT AS MONTANA. WITHOUT THESE FLOWS FROM FEDERAL RESERVOIRS, NAVIGATION ON THE MISSISSIPPI WOULD NOT HAVE BEEN POSSIBLE.

2. WE WERE EXTREMELY SUCCESSFUL IN INSURING THAT THE CITY OF NEW ORLEANS SUPPLY OF FRESH WATER WAS MAINTAINED.

3. AND ABSENCE OUR LAKE LANIER, THE CITY OF ATLANTA WOULD HAVE HAD INSUFFICIENT WATER TO MEET DEMAND WITH THE ATTENDANT PUBLIC HEALTH, WELFARE AND ECONOMIC IMPACTS.

THESE WERE BUT THREE OF MANY "BUT FOR THE ARMY CORPS OF ENGINEERS STORIES". I HOPE THAT SOUNDS LIKE BRAGGING, BECAUSE THAT IS MY INTENT. OUR PEOPLE AND OUR PROJECTS HAVE PERFORMED MAGNIFICENTLY IN THIS TIME OF EXTREME AND HAVE

BEEN OF GREAT VALUE TO THE NATION. WHILE THE OUTLOOK IS BETTER THAN JUST A MONTH AGO, WE REMAIN HARD AT WORK MANAGING THE CONTINUING DROUGHT EFFECTS AND REMAIN READY TO MEET THE CHALLENGES SHOULD CONDITIONS WORSEN.

NOW, WHAT ARE WE DOING TO PREPARE FOR THE DROUGHT OF 1989? WE HAVE GENERATED SEVERAL INITIATIVES AS A RESULT OF DROUGHT 88 AS SHOWN ON THIS SLIDE.

UNDER THE NEW PUBLIC LAW 100-393, WE HAVE AUTHORITY, SUBJECT TO AVAILABILITY OF FUNDS, TO DO THESE LISTED ACTIVITIES.

ADDITIONALLY, WE ARE ASKING CONGRESS FOR FUNDS TO CONDUCT THESE MAJOR STUDIES. THE FIRST WILL COST $5 MILLION OVER A 3 YEAR PERIOD. THE SECOND STUDY WILL COST $10.2 MILLION OVER A 5 YEAR PERIOD.

AND WE ARE LOOKING AT OUR EXISTING PROJECTS, AS WELL AS FUTURE PROJECTS, TO SEE WHAT MORE WE CAN DO WITH OUR EXISTING RESOURCES TO ALLEVIATE FUTURE DROUGHTS.

THE ARMY CORPS OF ENGINEERS HAS TURNED THE CHALLENGES OF DROUGHT 88 INTO OPPORTUNITIES TO SERVE THE NATION. WE HAVE WORKED HARD AND HAVE ACHIEVED GOOD RESULTS, BUT WE ARE NOT QUITTING NOW. OUR BIGGEST CHALLENGES MAY WELL LIE AHEAD OF US. I AM CONFIDENT THAT OUR PEOPLE AND PROJECTS WILL BE UP TO THOSE CHALLENGES.

THIS COMPLETES MY FORMAL PRESENTATION. I WOULD BE HAPPY TO RESPOND TO YOUR QUESTIONS.

THE DROUGHT OF 1988 AND BEYOND

PANEL DISCUSSION

JOHN P. "PAT" BYRNE, COLORADO

The Colorado Division of Disaster Emergency Services was tasked to prepare a state drought response plan* in 1980. The planning process deliberately built upon proven procedures incorporated in the State Emergency Operations Plan which deals, inter alia, with other natural hazards. A key to successful implementation of the drought plan was recognition of the need for assessment instruments to measure water availability** and provision for constant monitoring of trends by an organized task force.

Detection of emergency drought conditions results in alerts to the public and private sectors, and activation of pre-designated task forces to assess needs for action and develop response strategies. Specific actions are preidentified to be considered at various index values. A capstone task force integrates information and recommendations, and proposes actions to the Governor.

All elements of the drought response organization are multi-disciplinary, inter-agency, and intergovernmental to draw upon expertise wherever it can be found. Attached page illustrates the concept of operations in the Colorado Plan.

The Water Availability Task Force has met at least quarterly for eight years. The plan has been revised based on experience and periodic inter-agency reviews. The plan will guide state actions in 1989 should drought conditions emerge/persist in areas of the state.

* Division of Disaster Emergency Services; The Colorado Drought Response Plan; May 15, 1981 (Revised 1986).

** Climatology Report No. 83-3; "Use of the Palmer Index and Other Water Supply Indexes for Drought Monitoring in Colorado"; Doesken, Kleist, and McKee; Colorado State University; March, 1983.

Western Snow Conference 1982 proceedings document 710-82; "Development of a Surface Water Supply Index (SWSI) to Assess the Severity of Drought Conditions in Snowpack Runoff areas". Shafer and Dezman.

CONCEPT OF OPERATIONS

Colorado Drought Response Plan

Monitoring (detection and measurement of the event)

Water Availability Task Force, using

- .Surface Water Supply Index (mountain dependent water)
- .Modified Palmer Index (mountain water independent; mainly non-irrigated areas)

↕ linkage*. Alerts to emerging conditions and recommendation to activate plan.

Assessment (identification and evaluation of needs)

Impact Task Forces (7 pre-designated)

↕ Linkage*. Review and Reporting Task Force (chairpersons of all activated task forces. Integrates information and recommends actions to Governor.

Response* (application of existing and emergency program authorities)

Interagency Coordination Group (representatives of agencies with response capabilities). Identifies unmet needs and develops requests for federal assistance, as required.

*Continuity of operations is further assured by the designation of the Director of Disaster Emergency Services as the chairperson of each of these groups.

IMPROVING RESPONSE TO DROUGHT EMERGENCIES

BY STATE AND FEDERAL AGENCIES

Abstract

by panelist Jon F. Bartholic
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Many areas of Michigan experienced the worst drought ever recorded. Record low rainfalls were accompanied by recod high temperatures. The response to the drought varied by sectors in society. Urban restrictions were brought on by the need to maintain adequate pressure at city water hydrants for fire protection. Many communities limited watering from 10:00 a.m. to 10:00 p.m. The agricultural sector was well-orgaized structurally, educationally and politically to responde in a united way to facilitate a number of "effective" responses. Many individual homeowners with wells found they needed to extend their well points or drill new wells as water table levels dropped.

The natural resource sector was probably the least prepared, organized and able to discuss in a quantitative way the drought impacts. Yet, the impacts of low soil moisture with reduction or delayed development of natural vegetation was significant. Stream flows were nearing or exceeded all time lows and some creeks dried up. Stream flows were below the design level for municipal and industrial discharge permits, yet discharge continued.

It became clear early in the drought that information (including rapid and complete reporting) was inadequate for stream, lake and, particularly, acquifer conditions. Further, agencies were, and largely remain, geared to respnse actions rather than to practice preplanned strategies. Once rainfall started again, nearly all efforts to report, plan and enhance networking were discontinued. The question of the contribution of the Global Warming Trend to the drought has continued as a question in most individuals' minds. The need for long term strategic planning with well-developed tactical plans is clearly evident.

APPENDIX B

AES	-	Atmosphere Environment Service (Environment Canada)
AWDN	-	Automated Weather Data Network
BASC	-	Board on Atmospheric Sciences and Climate
CAC	-	Climate Analysis Center, NOAA
cm	-	centimeter (1 inch = 2.54 cm)
CO_2	-	Carbon dioxide
EFAP	-	Emergency Feed Assistance Program
EFP	-	Emergency Feed Program
GAO	-	Government Accounting Office
GFDL	-	Geophysical Fluid Dynamics Laboratory
GNP	-	Gross National Product
ITCZ	-	Inter-Tropical Convergency Zone
m	-	meter
mb	-	millibar (unit of atmosphere pressure)
mm	-	millimeter (25.4 mm = 1 inch)
NAS	-	National Academy of Science
NCPO	-	National Climate Program Office
NESDIS	-	National Environmental Satellite and Data Information Service
NOAA	-	National Oceanic and Atmospheric Administration
NWS	-	National Weather Service
OLR	-	Outgoing Longwave Radiation
PDSI	-	Palmer Drought Severity Index
PHDI	-	Palmer Hydrologic Drought Index
RCC	-	Regional Climate Center

RFF	-	Resources For the Future
SST	-	Sea Surface Temperature
SWSI	-	Surface Water Supply Index
TVA	-	Tennessee Valley Authority
USDA	-	United States Department of Agriculture

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA