AMS Statement on Meteorological Drought*

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Drought is universally identified with periods of insufficient water resources initiated by reduced precipitation. Other meteorological elements, including temperature, wind, evapotranspiration, clouds, and radiation, play a role, but their contributions are smaller and not always easily defined. Impacts of drought on society and natural ecosystems are the real issue but are not easily quantified. The result is that the term "drought" does not have a universal definition. Drought, as used in the present discussion, is defined as a "meteorological drought" and is defined as a sustained period of deficient precipitation with a low frequency of occurrence.

There have been several major North American droughts in this century. The 1988 North American drought had widespread impacts, including \$40 billion in estimated direct economic losses and costs in the United States. The 1988 drought was the worst since 1936 in the midwestern United States and parts of the northern Plains. Overall, during the height of the drought of 1988 (July), 40% of the country was experiencing either severe or extreme drought as measured by the Palmer Drought Severity Index.¹ Only in a few drought years—during the 1930s, 1950s, and a brief period in the late 1970s—have similar or larger areas experienced such conditions. The severity of the 1988 drought was not unprecedented and it followed a number of wet years, which led to record-high lake levels and abundant water supplies in many parts of the country. Thus, the 1988 drought should be regarded as the latest in a series of extreme climatic fluctuations that are characteristic of the climatic history.

At any given time, drought will usually affect some areas of the world and some recent examples follow. In 1987, the summer monsoon was weak in India and Pakistan, with many areas receiving less than half of the normal rainfall. In 1988, Italy suffered one of the worst droughts in the last 175 years. The last three months of 1988 were the driest in at least 114 years

in some regions of eastern China. In some regions of Turkey, January through April 1989 was the driest on record since 1951 (when reliable records began). The drought in the western regions of the African Sahel persisted from 1970 well into the mid-1980s. At times, drought has affected major world agricultural areas simultaneously. For example, during the central United States droughts of the 1930s and the 1950s, the wheat-growing regions of the Soviet Union also experienced droughts.

It is important to note that drought in one region is often associated with heavy rains elsewhere. For example, the southwestern United States received significantly above-normal precipitation during the summer of 1988, caused by the same atmospheric circulation patterns that resulted in drought in much of the rest of the United States. During the extreme drought of 1936 in the Midwest and Great Plains, the central Rocky Mountains received abundant precipitation.

There is a wide range of time scales over which deficient precipitation can occur. Many crops can be damaged by a lack of precipitation and high temperatures in just a few weeks when it occurs at critical crop-development stages, but such short periods are not considered droughts. However, a season (three months) of deficient precipitation has a large impact on soil moisture and streamflow in many areas of the world and is considered the shortest period that can be identified as a drought. Deficient precipitation over longer periods, one or more years, will affect important components of the water supply, such as streams, shallow groundwater tables, and small lakes and reservoirs. Thus, the time scale from a season to a few years constitutes one of the most important for drought. Deficient precipitation over longer periods—a decade to a several decades—will affect other components of the water supply, such as deep groundwater tables, and large lakes and reservoirs. There may also be an extended period of decades in which dry periods are more frequent and have a great impact on agriculture. A final time scale is that of centuries, where prolonged dryness is important, but this is usually considered as a change in climate rather than as drought.

Major drought episodes are manifestations of persistent large-scale disruptions in the global-circula-

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¹ This index is based on temperature and precipitation measurements and is widely used by the National Weather Service to monitor drought conditions.

tion patterns of the atmosphere. The fundamental causes of these disruptions are not well understood. Several potential causal mechanisms have been identified for periods of a season to a few years. They are discussed in the following paragraphs.

a. El Niño/Southern Oscillation (ENSO)

This complex phenomenon consists of a disruption of the normal atmospheric flow patterns in the tropical and southern hemispheric areas of the Pacific Ocean, and a substantial change in the sea-surface temperatures of the eastern and central equatorial Pacific. A notable feature of the ENSO phenomenon is that it can cause disruptions in the weather of areas well beyond the confines of the equatorial Pacific where it originates. There are two opposite patterns that have large weather effects. A so-called "warm episode" occurs when warmer-than-normal sea-surface temperatures are present in the eastern and central equatorial Pacific. This pattern has been related to drought in southeastern Africa, northeastern South America, central and northern India, and much of the western equatorial Pacific, including Indonesia, the Philippines, and eastern Australia. A "cold episode" occurs when colder-than-normal sea-surface temperatures are present in the eastern and central equatorial Pacific. This pattern has been related to droughts in the southeastern United States, northeastern Mexico, central equatorial Pacific, Sri Lanka and southern India, east-central Africa, and southeastern South America. Although such "episodes" typically last for one to two years, they do not occur with any regularity. About 40% of all years are characterized by either a warm or cold pattern.

b. Abnormal sea-surface temperature patterns in areas other than the eastern equatorial Pacific

For instance, below-normal sea-surface temperatures in the North Pacific appear to be related to drought in the Great Plains. Computer-model simulations suggest that the 1988 drought was related to warm equatorial waters in the eastern subtropical Pacific.

c. Soil-moisture desiccation

Once a dry pattern has resulted in depletion of soil-moisture reserves, the pattern may be self-reinforced because the incoming solar energy is used more for direct heating of the atmosphere than evaporation of water. Therefore, the air near the surface becomes warmer and drier than normal. This helps to perpetuate drought by reducing the amount of atmospheric water vapor available to precipitation-producing weather systems. Such systems produce less precipitation under these circumstances than under normal conditions.

d. Nonlinear behavior of the climate system

The nonlinear nature of the physical laws that govern atmospheric motions can result in abnormal circulation patterns, even in the absence of external factors, such as those identified in points a, b, and c. These abnormal patterns can result in deficient precipitation in some areas. The locations where such patterns develop is random. At certain times of the year, the normal seasonal forcing may make such patterns very stable.

The length of observational weather records are generally less than 100 years in North America and this has limited extensive investigation of decade-scale droughts. Firm physical concepts to establish drought mechanisms for decades are not well-established at this time. Analysis from tree-ring data has revealed dry conditions on the decadal scale for the Midwest. Attempts to relate these droughts to sunspot cycles have not been entirely successful. However, recent work has identified surprisingly strong relationships between the 11-year solar cycle and certain atmospheric circulation patterns. However, no credible physical explanation for this relationship has been discovered. Decadal-scale precipitation variations have been identified for both the West Coast of the United States and the Northeast United States. Temporal variations in volcanic eruptions certainly have the potential to lead to variations in precipitation. Model simulations of global warming caused by carbon dioxide doubling indicate larger amounts of precipitation globally but some regions will probably be drier. Global warming could produce effects on the decadal and century scales.

Understanding of the initiation, perpetuation, and termination of drought has not advanced to a state that accurate prediction is possible. However, some situations occur in which some predictive capability is present:

- Even though ENSO episodes occur at irregular periods, computer models have been developed that can anticipate the onset of a warm or cold episode by up to 15 months in advance. This is of potentially great benefit in those areas of the world that experience drought related to these equatorial Pacific episodes
- In some seasons, drought exhibits a great deal of persistence. For example, when dry conditions develop in the central United States in the spring and summer, the likelihood of their persistence for three to six months in the future is high

For many parts of the world, drought remains a threat that may occur with little or no warning. Until substantial improvements in long-term predictive ca-

pability occur, the economic structure of society must be prepared to cope with the effects of drought at any time. The impacts of past droughts have been exacerbated by an absence of plans to cope with drought. The American Meteorological Society strongly recommends that responsible government institutions develop a plan of action for drought response. The plan should include the development of systems for monitoring drought and delivering drought information, assessment of the impacts of drought, identification of research needs, development of means to

facilitate communication between scientists and policymakers, identification of response options, development of educational and training programs, and the development of procedures for evaluation of the entire process. This type of strategic planning has the potential to ease the impacts of future droughts. Unfortunately, most institutions fail to make plans during nondrought periods and are therefore unprepared to cope with drought when it occurs. The AMS urges those institutions to begin the process of developing a greater level of drought preparedness.

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