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Drought Network News

May–Aug.
1999

**A Newsletter of the International Drought Information Center
and the National Drought Mitigation Center**

Volume 11
No. 2

From the Director

With increased understanding of El Niño and La Niña events and growing awareness of the wide range of potential impacts, as well as the increased reliability of seasonal climate forecasts for some regions of the world, there is growing interest in the use of climate information to help reduce risk for some weather-sensitive industries, especially agriculture. The National Drought Mitigation Center (NDMC) is currently involved in a project sponsored by the UNDP Office to Combat Desertification and Drought (UNSO) and the World Meteorological Organization, with additional support from NOAA and USAID. The next phase of this project will be a workshop, *Coping with Drought in Sub-Saharan Africa: Best Use of Climate Information*, that will be held near Harare, Zimbabwe, October 4–6, 1999. This workshop will bring together local, regional, and international experts to discuss the use of both contemporary and indigenous climate information by farmers in Africa. The objectives of the workshop are to (1) define elements of a program that will address gaps that exist between climate information products provided by meteorological, agricultural, and hydrological services and the ability of farmers to access and use this information in support of decision making; (2) demonstrate how climate information can be incorporated in farm-level decisions to reduce the impacts of drought and other climatic extremes on agriculture and maximize productivity during more favorable growing conditions; and (3) develop a strategy to implement pilot studies in selected countries in sub-Saharan Africa that will demonstrate the value of climate information in decision making at the farm level and enhance the drought knowledge of farmers. Farmer surveys on the use and sources of climate information have been conducted in six sub-Saharan African countries: Kenya, Ethiopia, Mali, Senegal, Zimbabwe, and Mozambique. The workshop will serve as a forum to bring together potential partners for the next phase of the project. I will try to include a summary of this workshop and its findings in the next issue of this newsletter. If you would like to obtain more information on the project, contact the National Drought Mitigation Center or the UNDP/UNSO web site (http://www.undp.org/seed/unso/tables.htm).

I would like to express my appreciation to Dr. Martin Yerg of the International Affairs Office of NOAA for his continuing sponsorship of this newsletter. I also appreciate the support and interest in this activity by

Published in cooperation with the World Climate Program of the WMO

Dr. Michael Coughlan, Director of the World Climate Program of WMO. *Drought Network News*, first published in 1989, is distributed to readers worldwide, and feedback continues to be extremely positive. I am also encouraged by the flow of articles that are submitted to us for review and publication. This publication continues to serve as a valuable resource for scientists and policy makers.

This issue of the newsletter contains articles covering drought-related subjects in India, Iran, Spain, and Vermont. I trust readers will find this information helpful. *Drought Network News* readers are invited to submit articles for the September–December issue to us no later than November 10. Readers are also encouraged to submit announcements of workshops, conferences, and other information of interest to our network members.

Donald A. Wilhite

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A Drought Watch System for Southeast Spain

Introduction

One of the main climatological characteristics of the region of Murcia (11,300 km^2), located almost entirely in the Segura Basin (in southeast Spain), is the great temporal and spatial irregularity of its precipitation. Average annual precipitation values range between 200 and 500 mm, and coefficients of variation (CV) are high, with some values about 50%. It is a semiarid region (including a small arid area), and agriculture plays a major role in its economy. Because of this, drought is one characteristic of the region's climate that has far-reaching consequences, from unemployment to social conflicts.

It is important to define drought and identify appropriate indicators for the region of Murcia as part of a drought watch system. This system will define the temporal and spatial limits of drought conditions. It would help policy makers and government officials establish policies for the provision of aid to farmers and cattlemen, as in Australia (White and O'Meagher, 1995).

Because of the wide range of drought impacts, there are many definitions of this phenomenon. However, one characteristic seems common to all of them: drought is caused by a deficiency in precipitation for a fairly long period of time. For simplicity, and keeping in mind that precipitation is, without doubt, the most important variable in the process, the watch system developed for the region of Murcia uses only this variable at the moment, establishing a comparison with a climatological reference (1961–90) that we consider "normal."

Regarding Some Precedents

Up to now, the National Institute of Meteorology in Spain has used a method of quintiles of the cumulative distribution function (c.d.f.) of precipitation, with normal precipitation corresponding to the second and third quintiles (c.d.f. between 40% and 60%). Using this method, the region is usually (80% of the time) facing a situation that is not normal. The watch system for Australia by Gibbs (1987) extends the "normal" category from the third through seventh deciles (c.d.f. between 30% and 70%), but the criteria that are used to establish the beginning and end of a drought do not apply in the southeast Iberian Peninsula.

On the other hand, using the Palmer Drought Severity Index (PDSI) would require more data and assume hypotheses that are not always suitable. Another added inconvenience would be that certain situations, such as extreme or severe drought, would occur more frequently in some areas than in others (Willeke et al., 1994). Furthermore, the category of extreme drought occurs too frequently for some regions, in excess of 10% for some areas (Wilhite, 1993).

The use of the Standardized Precipitation Index (SPI) (McKee et al., 1993) would introduce the great advantage of standardization, allowing us to determine the rarity of an episode in terms of probability. However, the fixed limits among the categories do not arise in an intuitive way (there is a mixture of whole and fractional numbers) and the normal category seems too extensive (68% of all occasions), so that some descriptive power would be lost.

The Drought Watch System in the Region of Murcia

To incorporate the descriptive power of the PDSI and the advantages of the standardization of the SPI, we have created the Normalized Precipitation Index (NPI), which is calculated with the following equation (Garrido, 1998):

$$F(x) = \frac{1 + Erf\,(NPI / \sqrt{8})}{2}$$

where *F(x)* is the empirical c.d.f. and *Erf* ( ) is the error function (this equation must be solved by means of numerical methods). Imposing threshold values of ±4 for the NPI for the extreme categories, as happens in the case of the PDSI, we obtain the classification in Table 1. The values of the index and the names of the categories generally coincide with those of the Palmer classification. The most probable category is the normal one, even using a wider classification that groups drought or wet cases, while the percentages or probabilities of the moderate, severe, and extreme categories coincide with those of the SPI. In the extreme categories, only 2.3% of the situations are included, which is a typical percentage of an extreme event (Wilhite, 1995).

Of course, this methodology can be applied to other variables, such as the precipitation volume in a region, hydrographic basin, or catchment area, leading, in this case, to a Normalized Volume of Precipitation Index (NVPI). It can be applied on various temporal scales, like a month, season, or year.

In the region of Murcia, given the great variability and seasonal distribution of the rain, it is essential to use an index that removes seasonal data, like the precipitation collected in the last 12 months. Such an index has the advantage of stability, and it allows a prediction (not a prediction in the usual sense of the word, but rather a trend) of its future values, since, at any moment, these values can be inferred from climatological references. A simulation showed that the prediction of the 12-month NVPI can extend for a term of 5 months, with an average absolute error inferior to the unit.

The watch system, which was instituted in January 1998, consists of two parts. The first part (Figure 1) is limited to the consideration of the NVPI on scales of 1 and 12 months, offering information about what happened in the last 4 years, with special emphasis on the previous 2 years. It also offers a prediction of the values of the index, up to 5 months ahead, and it establishes the excess or deficit quantities of precipitation in relation to the threshold values of the 12-month NVPI.

In the second part, to study the geographical distribution, the NPI values are also represented (Figure 2) on temporal scales of 1 and 12 months. The average value of those indexes in the region should always be similar to the corresponding NVPI values.

NPI	Category	c.d.f. (%)	Time in category (%)	
4 or more	4: Extremely wet	97.7 (100)	2.3	30.9
3 to 4	3: Very wet	93.3 (97.7)	4.4	
2 to 3	2: Moderately wet	84.1 (93.3)	9.2	
1 to 2	1: Slightly wet	69.1 (84.1)	15.0	
-1 to 1	0: Normal or near normal	30.9 (69.1)	38.3	38.3
-2 to -1	-1: Mild drought	15.9 (30.9)	15.0	30.9
-3 to -2	-2: Moderate drought	6.7 (15.9)	9.2	
-4 to -3	-3: Severe drought	2.3 (6.7)	4.4	
-4 or less	-4: Extreme drought	0 (2.3)	2.3	

Table 1. NPI classifications for dry and wet periods.

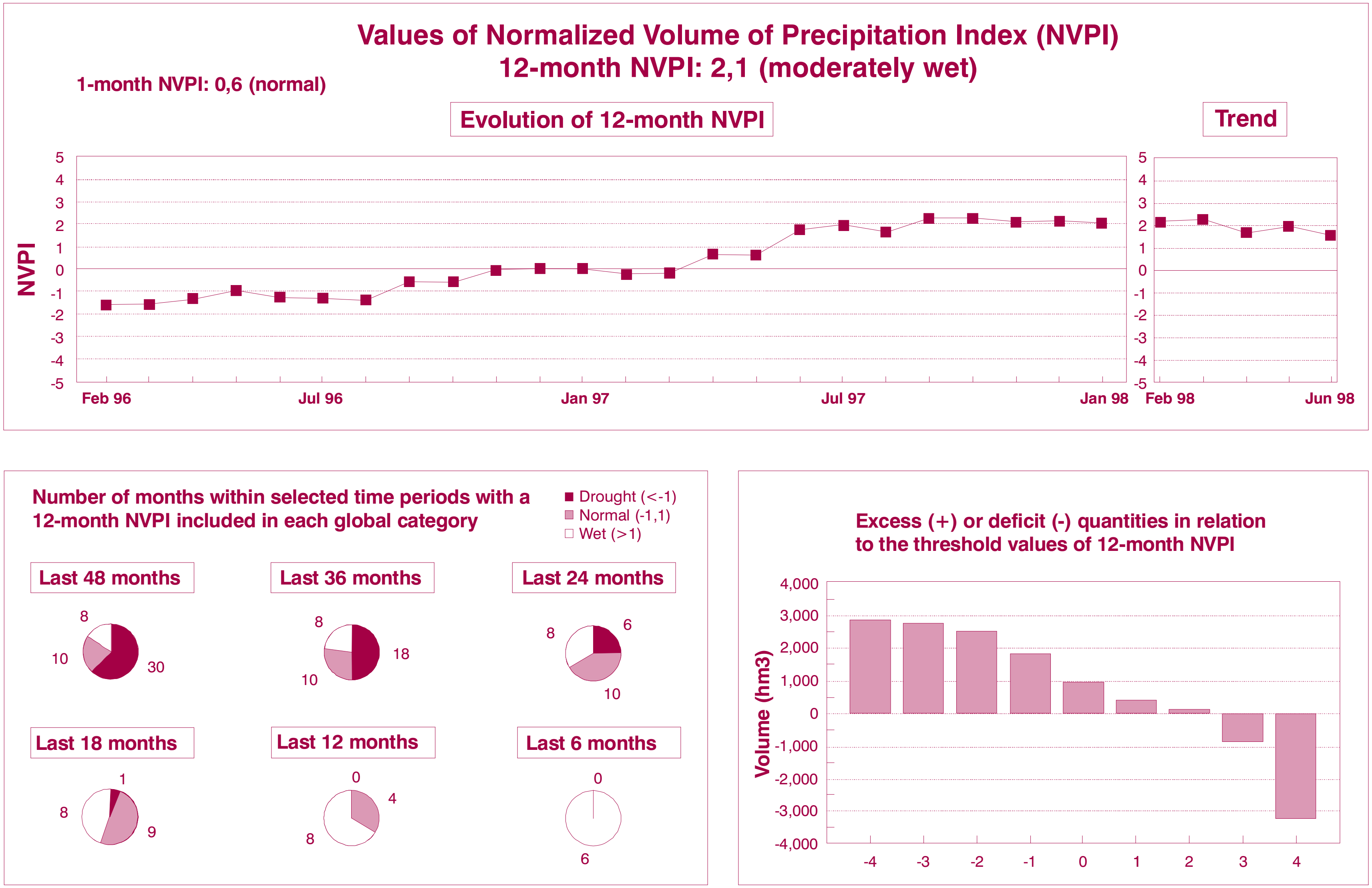

Figure 1. Drought watch system in the region of Murcia, January 1998.

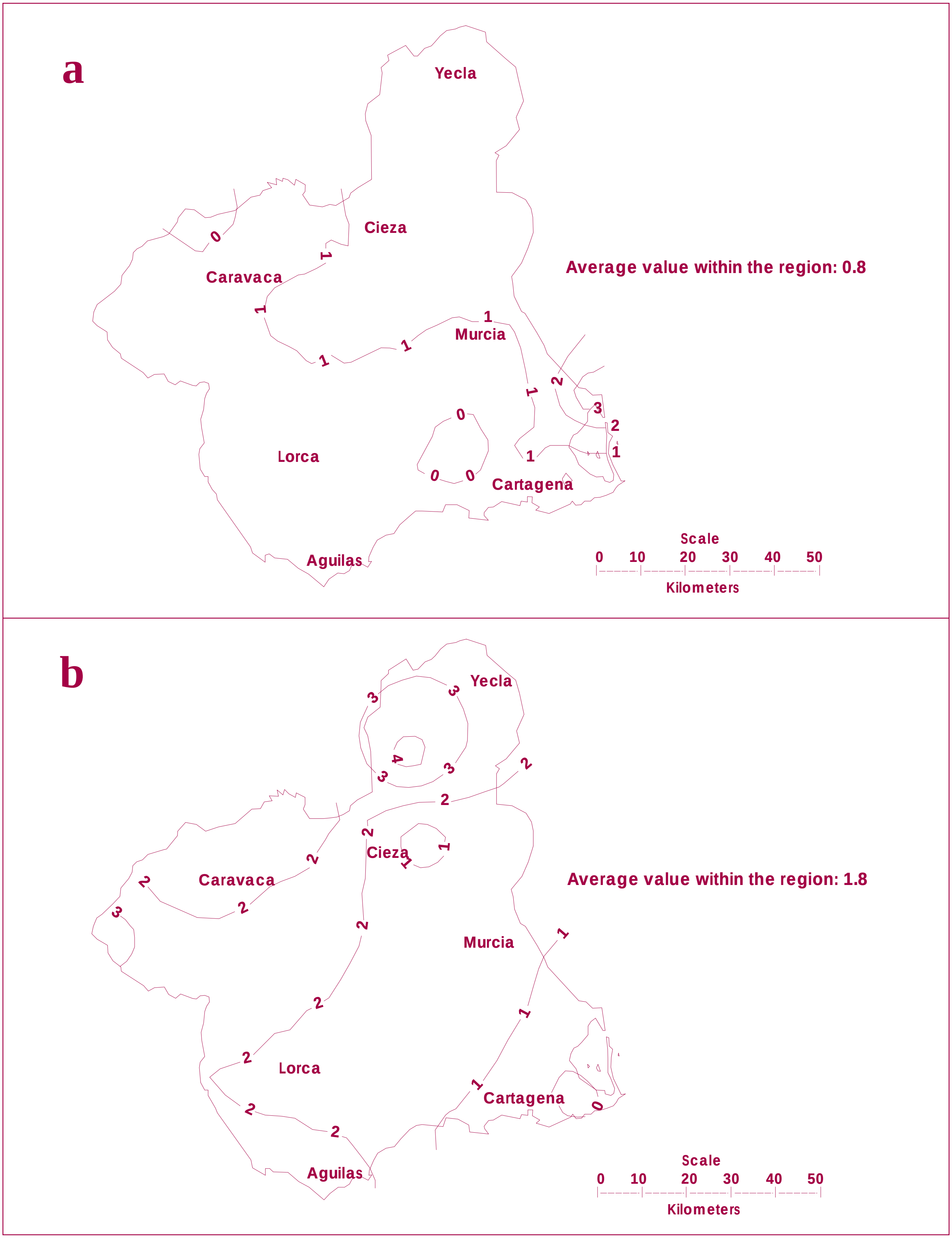

Figure 2. Normalized Precipitation Index values, January 1998: (a) 1-month; (b) 2-month.

Future Development

The system will be extended to the whole Segura Basin, and it will be developed to expedite the capture of precipitation data (appealing to automatic observation networks, for example); to increase the number of temporal scales, mainly those of 3 and 6 months time; and to extend the term of the forecasts, incorporating information based on the climatic teleconnections. Designing a watch system based on some type of normalized water balance would also be a future objective.

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Drought Follows the Deluge in Vermont

Introduction

The incidence of both drought and flooding on the Vermont landscape within the same calendar year is not an uncommon occurrence. The year 1998 was no exception, in that the ice storm of January and statewide flooding of June/July finally gave way to drought conditions as the year drew to a close. These dry conditions continued into late June/early July1999, when a series of convective and frontal systems brought steady rainfall amounts that were helpful in reducing the surface moisture deficits. Hydrologic deficits, however, still existed in mid-July.

With the exception of the most severe events, which can span entire years (e.g., 1961–69, 1980–81, 1988–89 and 1995), droughts in Vermont tend to be a summer phenomenon. When they occur during the cooler time of the year (winter and spring), their impacts, intensity, and other characteristics are somewhat different from droughts that occur during the warmer months. In a climate that is best described as changeable, it is sometimes challenging to interpret climate signals from one season to the next. The dry conditions that have plagued the state since October 1998 have alternated with periods of above-average precipitation receipt. As such, the intensity and occurrence of drought among the state's three climatic divisions (Northeastern = 1; Western = 2; and Southeastern =3), as shown in Figure 1, have varied over the period of interest. The quest for determining the drought signal is even further complicated by the fact that the monthly time scale may be inappropriate for adequately describing the nature of dry conditions across Vermont during the cooler time of the year.

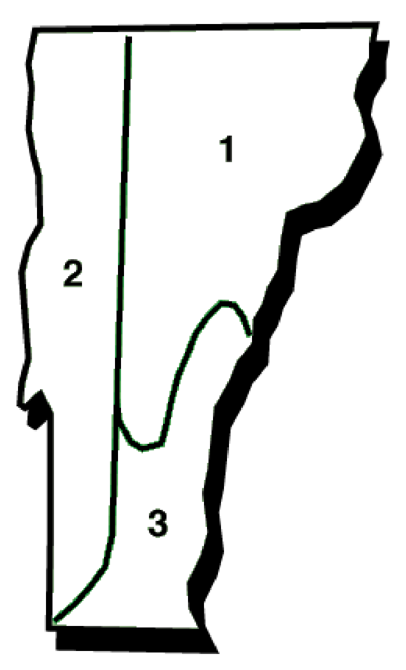


Figure 1. Map of Vermont showing its three climatic divisions. Courtesy of the National Climatic Data Center.

Vermont's recent dry conditions stand out as an anomaly against the backdrop of the surrounding states in terms of the onset and severity. Whereas drought conditions have been observed in much of the New England and mid-Atlantic states since August 1998, dry conditions were really first observed in Vermont in December 1998. Another striking difference between Vermont and its environs is the fact that ongoing dry conditions contain elements of atmospheric drought and surface soil moisture deficits, but the impacts on the subsurface hydrology are related to both the naturally low recharge levels during the cooler season as well as to additional precipitation shortfalls this year. This is in contrast to the drought severity in parts of Pennsylvania, where in some cases reservoirs have already been depleted.

The character of Vermont's existing drought as well as the issues raised by the methodology used to quantify it will now be addressed.

Data and Highlights

Using the three climatic divisions (Figure 1) as the spatial unit of interest on a monthly time frame, the following data were analyzed: statewide precipitation totals and the corresponding percent of normal from the Northeast Regional Climate Center; monthly precipitation totals from a variety of stations across the state, acquired from the National Weather Service, Burlington International Airport; the Standardized Precipitation Index (SPI) of McKee et al. (1993) from the Western Regional Climate Center; and the modified Palmer Drought Severity Index (PMDI) and Palmer Drought Hydrological Index (PDHI) from the National Climatic DataCenter.

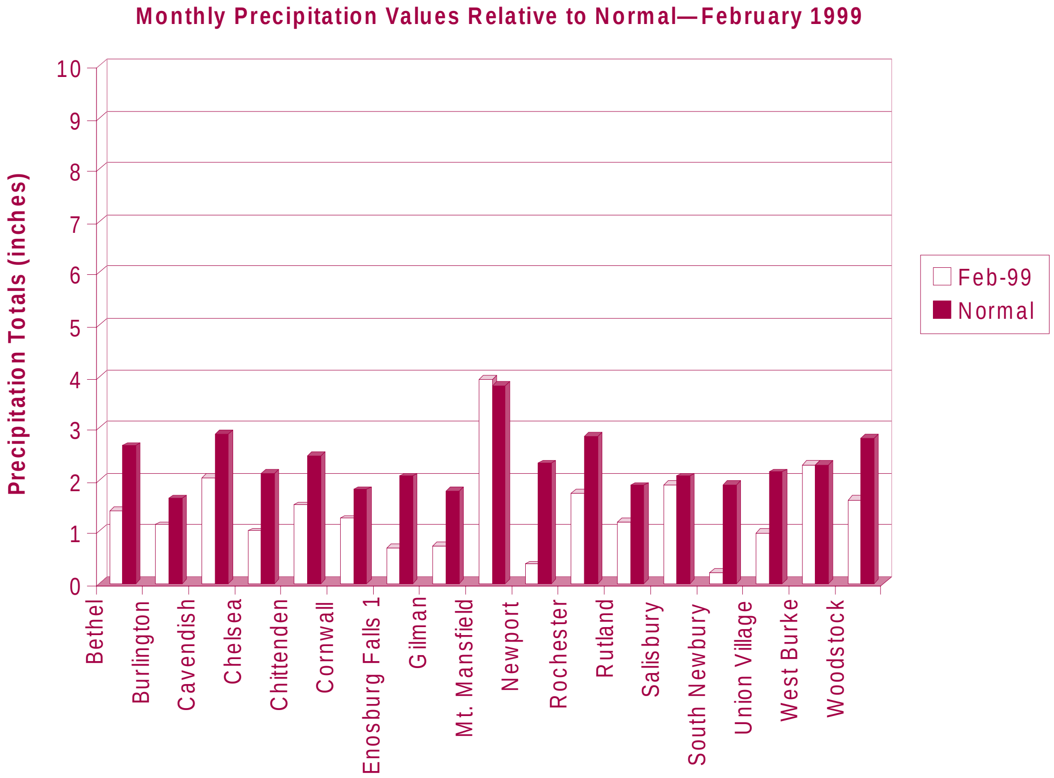
Table 1 summarizes the precipitation totals, percent of normal, and ranking relative to the driest year on record for Vermont as a whole. Unlike many of the surrounding states, the area-weighted state average for Vermont for September 1998 showed that above-average precipitation was received, following one the wettest summers on record for the state. This precipitation surplus would be followed by three months of below-average conditions, culminating in December 1998 when the total precipitation receipt was only 32% of normal. Although this was followed by a return to above-average precipitation totals in January and March 1999, dry conditions would again be observed in February, April, and May 1999. April 1999 was the second driest year on record and it was during this month that the impacts of the drought became evident.

An examination of the precipitation amounts relative to normal at individual stations reinforces the general statewide analysis, with December totals echoing the aforementioned low precipitation receipt for the state as a whole. Similarly, above-normal precipitation totals were globally observed during January 1999. In particular, stations such as Cavendish, Chelsea, Cornwall, and West Burke (all of which are in the central portions of the state) received more precipitation relative to normal than the global figure of 131% would suggest. During February, precipitation deficits (Figure 2a) were not uniform across the state and Mount Mansfield (the state's highest elevation, located in central Vermont) actually received slightly above-normal precipitation. This non-uniformity in precipitation receipt became even more evident in March (Figure 2b), when a variety of conditions ranging from above-normal values at Mount Mansfield to normal at Burlington and below normal at Salisbury (central) and Enosburg Falls 1 (northern) were observed. Such a scattered picture tends to obscure the fact that very little precipitation was received after March 22. April marked a continuation of the shortfalls in rainfall (Figure 2c). It was a particularly dry month at all stations, even more so than the global figure of 42% of normal would indicate. Precipitation deficits continued into May and were finally interrupted on May 19 by a conveyor belt system that brought substantial rainfall amounts to northern New England, including Vermont, with totals ranging from 0.5 inches to over 3 inches (12.7 –74.2 mm) in some locales. The following week would bring more convective rainfall across the state so that precipitation totals for the month of May

Month	Precipitation inches (mm)	Percent of normal	Ranking (1 = driest)
September 1998	4.17 (105.9)	121	66
October 1998	2.61 (66.3)	78	45
November 1998	2.62 (66.55)	70	32
December 1998	1.06 (26.9)	32	4
January 1999	3.26 (82.8)	131	72
February 1999	1.63 (41.4)	71	21
March 1999	3.71 (94.2)	134	74
April 1999	1.34 (34.04)	42	2
May 1999	3.51 (89.15)	95	57

Data compiled by the Northeast Regional Climate Center. 1998 represents 104 years of record and 1999 represents 105.

Table 1. Statewide precipitation totals and statistics for Vermont, September 1998 to May 1999.


Monthly Precipitation Values Relative to Normal—February 1999

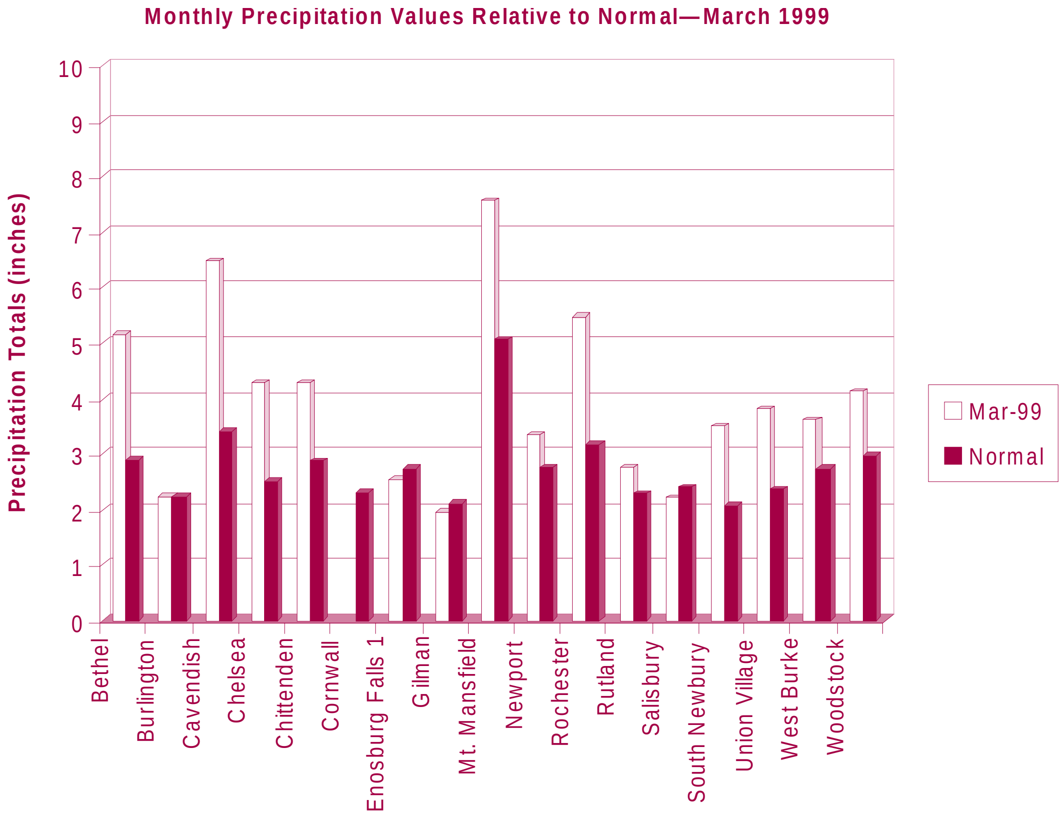
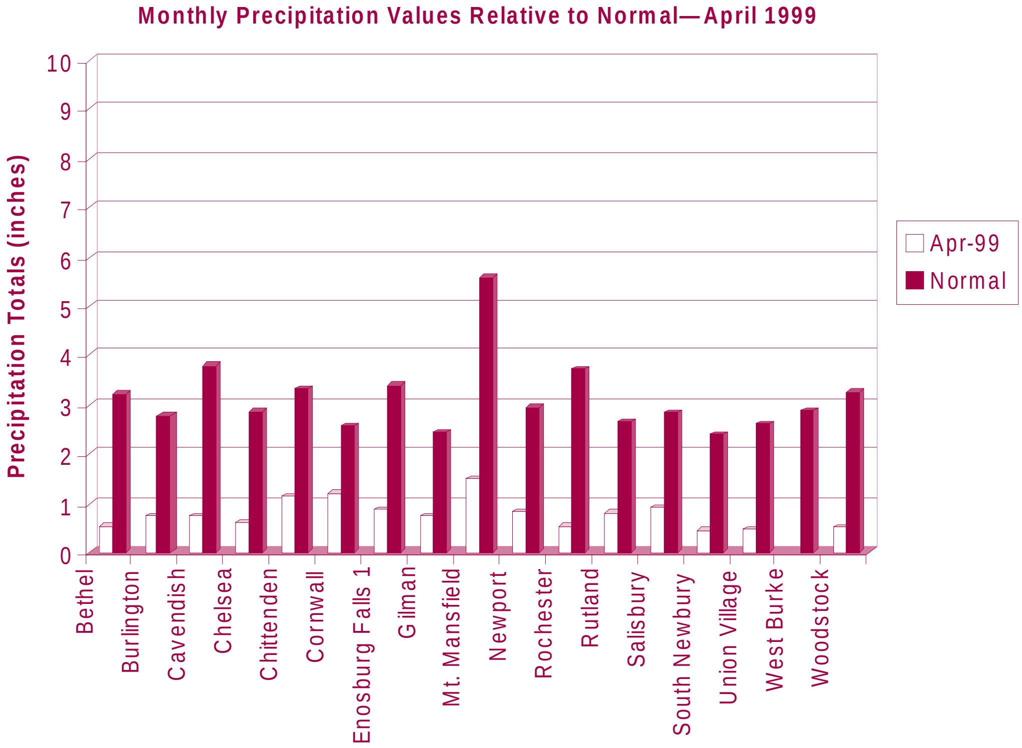
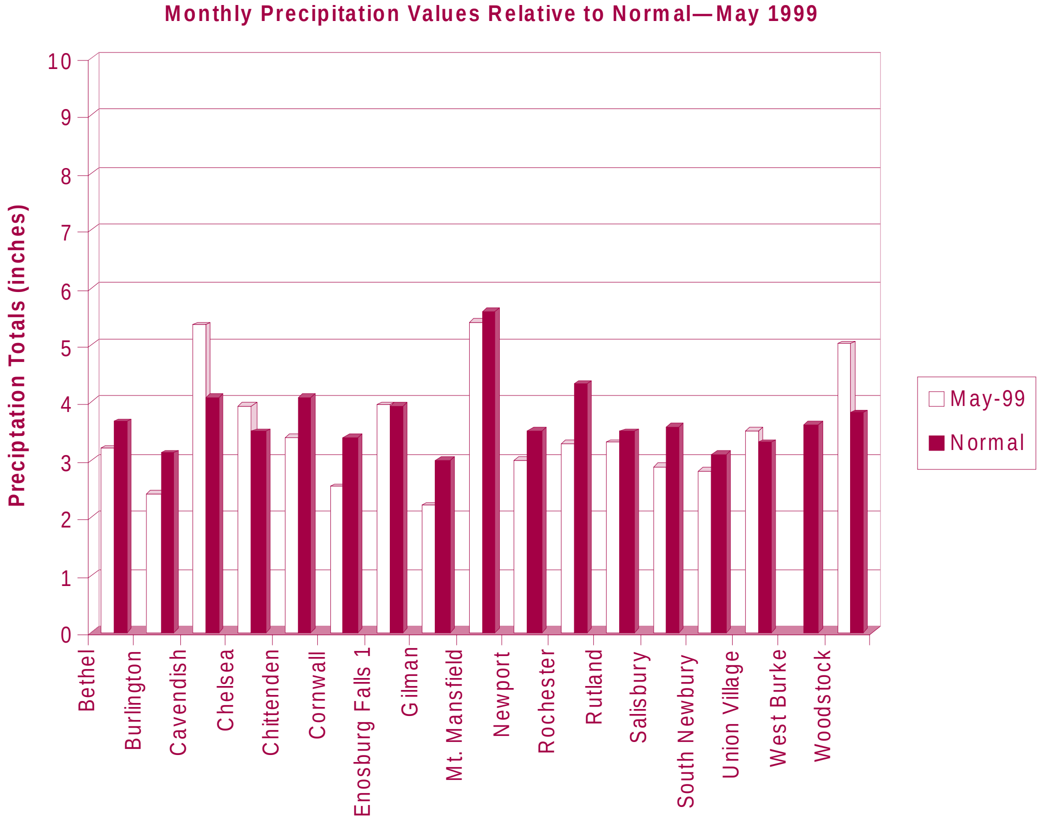

Monthly Precipitation Values Relative to Normal—March 1999

Figure 2. Monthly precipitation totals relative to normal for February–May 1999.


Monthly Precipitation Values Relative to Normal—April 1999
Precipitation Totals (inches)
0
1
2
3
4
5
6
7
8
9
10
Apr-99
Normal
Bethel
Burlington
Cavendish
Chelsea
Chittenden
Cornwall
Enosburg Falls 1
Gilman
Mt. Mansfield
Newport
Rochester
Rutland
Salisbury
South Newbury
Union Village
West Burke
Woodstock


Monthly Precipitation Values Relative to Normal—May 1999
Precipitation Totals (inches)
0
1
2
3
4
5
6
7
8
9
10
May-99
Normal
Bethel
Burlington
Cavendish
Chelsea
Chittenden
Cornwall
Enosburg Falls 1
Gilman
Mt. Mansfield
Newport
Rochester
Rutland
Salisbury
South Newbury
Union Village
West Burke
Woodstock

(Figure 2d), although below average, do not reflect the severity of the shortfalls that characterized the first three weeks. The month of June would mirror that of May, except for the fact that the precipitation events of the final week would continue into July, bringing some recharge to the surface moisture supplies.

Impacts

By the end of April, precipitation deficits across New England were estimated to be 50–130 mm (CPC, 1999). As May progressed and dry conditions persisted, soil moisture supplies became affected. Shallow wells began to run dry and parched leaves in residential gardens attested to the ongoing moisture stress. Some of this moisture stress was related to the high evaporative demand of the atmosphere. Daily maximum temperatures were unseasonably above average, while relative humidities were extraordinarily low. As May drew to a close it was not uncommon to observe daytime temperatures of at least 30°C accompanied by very low relative humidities on the order of 25% or less. By June, drought-related farm losses across the state, especially in Addison County, were financially compensated for by the Farm Service Agency (Jeff Comstock, pers. comm. 1999).

The low relative humidities and high temperatures posed another threat: that of wildfires. During the weekend of May 1–2, forty to fifty wildfires were reported across the state. The wildfire threat was also fueled by the presence of large quantities of dry combustible material on the ground. Much of this debris resulted from damages caused by the ice storm of January 1998. The outbreak of wildfires led to a restriction and eventual rescinding of burn permits during the month of May. In June, state officials did not ban the sparking of fires in state parks even though dry, record-setting temperatures prevailed.

It is instructive to determine the accuracy with which two drought indices (SPI and PDI) captured the incidence of drought on the Vermont landscape.

Drought Indices

A comparison of the SPI and modified Palmer Drought Index (PDI) revealed significant discrepancies. In divisions 1 and 2, the initial period from September to November 1998 was marked by decreasing amounts of precipitation. SPI values were near normal while the PDI values were extremely moist. At the same time in division 3, precipitation totals were somewhat lower than observed in the other two divisions. This may account for the mid-range to moderate drought conditions of the PDI, but not the near-normal SPI values. By the end of December, precipitation deficits lead to moderately dry SPI values in divisions 1 and 3, but near-normal conditions in division 2. By contrast, the PDI showed very moist conditions for division 1 and mid-range conditions for division 2. Only in division 3 did the PDI indicate (severe) drought conditions during this month.

With the temporary return of the precipitation in January 1999, the SPI and PDI values (moderate to extremely wet and very to extremely moist, respectively) were again in agreement for divisions 1 and 2. However, for division 3, the SPI indicated very wet conditions, while the PDI values only registered mid-range values. During February and March, SPI values were near normal for all three divisions while the PDI indicated moderate to very moist conditions in divisions 1 and 2 only. For division 3, mid-range conditions were observed.

The largest divergence between the two indices was observed in April 1999. The dramatic shortfalls in precipitation during this month were adequately captured as extremely dry conditions in all three divisions by the SPI. However, the PDI continued to demonstrate the existence of mid-range conditions in divisions 1 and 2, with moderate drought conditions being observed in division 3.

The foregoing observations illustrate some of the well-documented shortcomings of the Palmer Drought Index. Given that drought conditions developed during the winter and continued into the spring, the PDI failed to capture the onset and continuation of the drought. This is related to the fact that all precipitation is treated as rainfall in the computation of the index (Hayes et al., 1999) even though snow and freezing rain are the predominant forms of winter precipitation in Vermont. The exception to this is division 3, where the PDI indicated moderate drought conditions in October and November, followed by severe drought conditions in December 1998. Again only division 3 showed moderate drought conditions in April 1999, even though by that time the effects of the accumulated precipitation deficits were already being observed in the vegetative response across the state.

The SPI on average performed better than the PDI in terms of detecting the onset of dry conditions in December 1998 and the severity of conditions in April 1999. The one-month SPI has been likened to the percent-of-normal method of examining precipitation totals, yet it is interesting to note that the December 1998 figures do not capture the below-normal conditions to the extent that would be expected from the percent-of-normal values shown in Table 1. March 1999 was somewhat problematic due to the onset of the dry conditions in the last third of the month being overshadowed by the precipitation accumulations from the few, but large in magnitude, snowstorms that struck earlier in the month. Similar conditions existed at the end of May, when the one-month SPI indicated a return to near-normal values across all three divisions, as a result of two or three high-magnitude precipitation events that occurred toward the end of the month.

Discussion

The foregoing observations highlight several key issues. The first is that dry conditions in division 3 differ dramatically from the other two divisions, implying the existence of different atmospheric dynamics or land-surface interactions in southeast Vermont. Not only is this true for the current drought, but this non-congruence of division 3 has been noted in droughts that have affected the state since the turn of the century. As a result, gross statewide analyses would lead to a bias in terms of drought characteristics in this sector of Vermont.

Secondly, it is problematic to determine the onset and length of a dry period in the cooler season of the year in Vermont from monthly precipitation data alone. The distribution and magnitude of precipitation-producing events should be combined with the information gleaned from monthly totals in order to adequately characterize the drought signal in this regime. The months of March and May illustrate the danger in basing analyses solely on monthly records. During March, most of the stations under study were either at or above the average monthly precipitation totals, largely because of three snowstorms that produced accumulations of at least 15–60 cm during the first few weeks. In May, most stations' totals were slightly lower than average, again reflecting the high-magnitude convective rainfall during the last 13 days of the month. The incidence of these precipitation events means that definitions of meteorological drought based on precipitation alone do not capture the severity of the dry conditions that resulted from consecutive weeks of no or little precipitation receipt.

Concluding Remarks

Drought conditions have been observed since December 1998, although the signal has been "interrupted" by the receipt of above-average rainfall in January 1999 and sporadic, high-magnitude events in March and May 1999. The SPI has proven largely successful in pinpointing the onset and continuation of these dry conditions, while the performance of the PDI has been hampered by previously documented shortcomings in its design and purpose.

The incidence of drought during the winter and spring exhibits different characteristics from summer droughts. It is rare for an early spring period to be so dry. Thus, given that droughts in Vermont tend to be a warm-season occurrence, there exists a widely held perception that precipitation shortfalls in the cooler season do not pose as great a threat. Whereas skiers and other winter enthusiasts may bemoan the lack of snow, the agricultural sector has not as yet been severely affected by the soil moisture deficits and high atmospheric demand, because of the timing of the planting cycle. This should not detract from the potential threat, especially in light of the moisture stress observed in the perennial vegetation. In addition, as many farmers are aware, record-setting temperatures that alternate with brief respites of rainfall can be actually detrimental to crops.

Finally, the ongoing drought in Vermont reveals that the monthly time scale may be too coarse to capture the true character of drought. A weekly timestep may be more appropriate.

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ENSO′s Impact on the Occurrence of Autumnal Drought in Iran

Introduction

Recent extreme rainfall events and the frequent occurrence of worldwide droughts and their associated natural disasters (i.e., devastating bushfires in Australia, Indonesia, and Italy during 1997; the current severe drought in Iran) have increased the scientific community's interest in the broad characteristics of rainfall variation and the potential for rainfall prediction.

On the basis of the Koppen climate classification (Ahrens, 1998), the Islamic Republic of Iran (Figure 1) is categorized as generally having arid (BW) and semiarid (BS) climates. This signifies that the annual precipitation is less than the potential annual loss of water through evapotranspiration. The occurrence of rainfall is unreliable and deviations from the mean are generally more than 40%. The average annual precipitation over the country is estimated to be about 250 mm (about one-third of global annual precipitation).

Iran, with an area of 1,648,000 km^2, lies predominantly within a portion of the Alpine–Himalayan chains, including the major mountain systems of the Alborz and Zagros ranges (Figure 2). As indicated in this figure, the central part of Iran, which is surrounded by these ranges, comprises two uninhabited deserts, Dasht-e Lut and Dasht-e Kavir. In spite of severe dry conditions over these regions, the Zagros and Alborz highlands, like the coastal strip of the Caspian Sea, are classified as having a Mediterranean climate (Csb) and usually receive moderate precipitation.

The occurrence of droughts and floods is common, and the severity and hardships of these natural

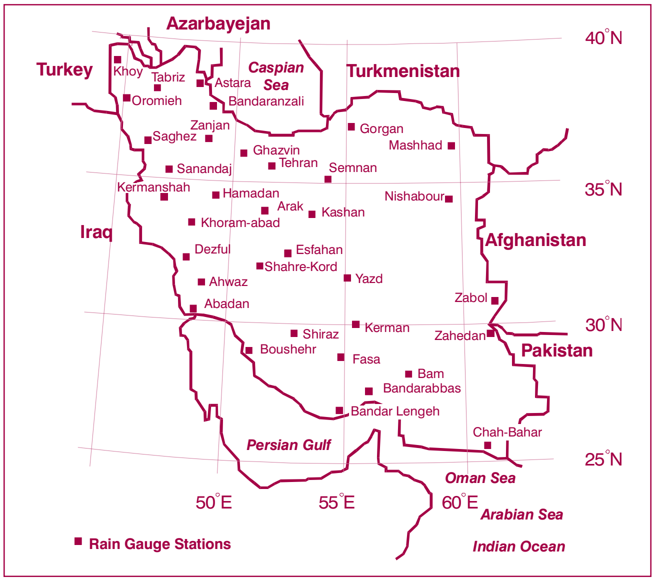

Figure 1. The geographical location of Iran and the position of rainfall stations whose data were analyzed in this study.

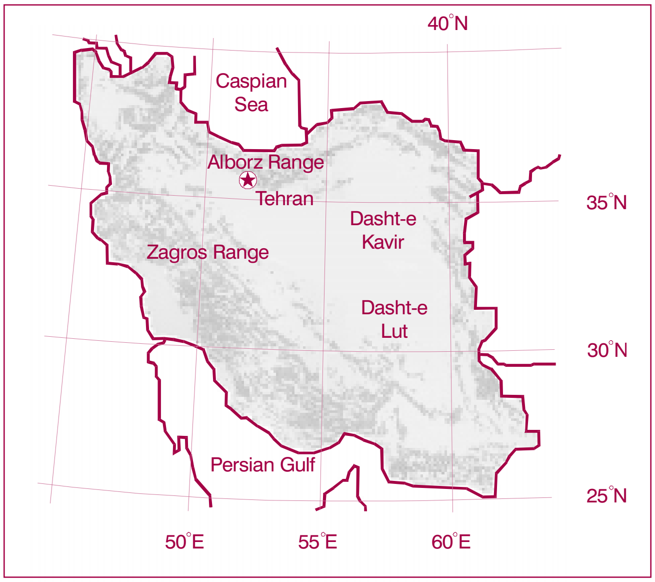

Figure 2. Relief map of Iran. The Alborz and Zagros ranges and the two main deserts (Dasht-e Lut and Dasht-e Kavir) are shown.

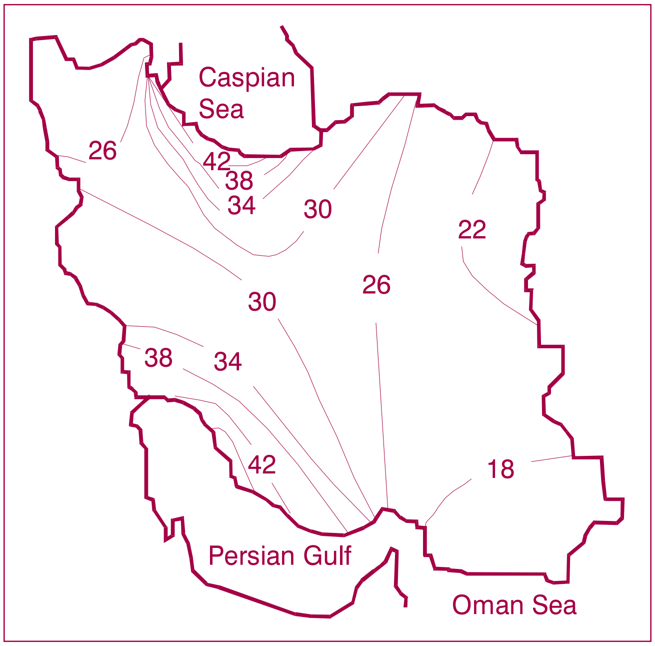

Figure 3. The ratio of autumn rainfall to annual precipitation for different parts of Iran (in percentage). For the western coast of the Caspian Sea, the percentages reach a high of 48.

disasters have frequently affected rural regions as well as urban areas. Drought limits the cultivation of dry farming crops and affects the productivity of irrigated lands. Moreover, due to massive overgrazing, extensive soil erosion can occur during dry periods.

A number of recent studies have confirmed that the El Niño-Southern Oscillation (ENSO) phenomenon has a significant impact on rainfall variability over different parts of the globe (e.g., Lough, 1997; Nazemosadat and Cordery, 1997; Hoedt, 1997). Nazemosadat and Cordery (1999) have recently investigated the influence of ENSO on autumn rainfall in Iran. They have shown that this rainfall is significantly influenced by the Southern Oscillation events. In the present study, the impact of ENSO events on the occurrence of autumnal drought is investigated.

Methodology

The basic data used in this study are mean monthly total rainfall data for 36 synoptic stations (Figure 1) for the period 1951–95, taken primarily from the Meteorological Yearbooks, the official publications of the Iranian Meteorological Organization. Autumn rainfall contributes 16%–48% of the annual precipitation over different parts of the country (Figure 3). As indicated in Figure 3, for the western half of Iran, the ratio of autumn rainfall to annual precipitation is larger than the same ratio for the eastern half of the country. The ratio is relatively higher for the areas near the northern part of the Persian Gulf and western side of the Caspian Sea coasts (42%–48%). The Troup's Southern Oscillation Index (SOI) data, which have been used as the ENSO indicator, were supplied by the Australian Bureau of Meteorology.

The autumn rainfall time series was obtained by averaging the three-month values of precipitation. Best results were obtained by defining autumn as October to December. The same averaging procedure was performed to provide the seasonal time series of SOI data.

A sequential correlation analysis (SCA) was used to examine the strength and temporal stability of the relationship between rainfall and SOI (Nazemosadat and Cordery, 1997). The data lengths employed for the correlation analysis varied from a minimum 15-year window to the total period of available data for every station. For each selected window, coefficients were calculated for continuous data periods of the whole record. For example, for 25-year windows, correlations between Tehran rainfall and SOI were calculated for the periods 1951–75, 1952–76, ..., and 1971–95.

Results

Figures 4a through 4c show the sequential correlation coefficients between the SOI and autumn rainfall for Tehran, Shiraz, Tabriz, Zanjan, Kermanshah, Oromieh, Bandarabbas, Bandaranzali, and Zabol. A 25-year window was used in the correlation analysis. The stations were selected subjectively, with no attempt made to illustrate the SOI-rainfall relation-

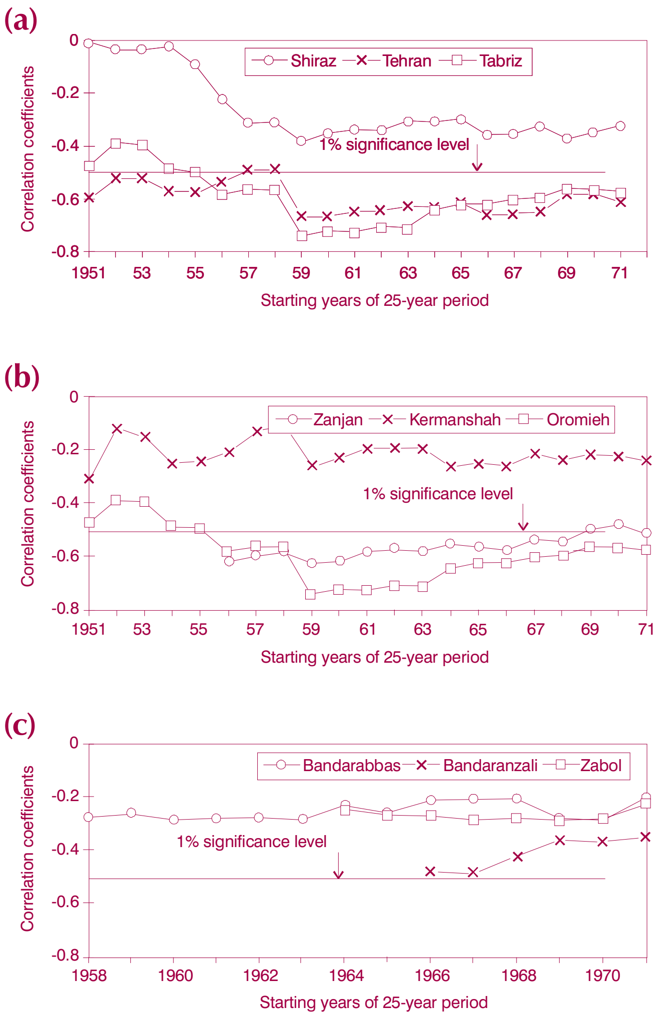

Figure 4. Sequential correlation coefficients between autumn rainfall and (a) Shiraz, Tehran, and Tabriz; (b) Zanjan, Kermanshah, and Oromieh; and (c) Bandarabbas, Bandaranzali, and Zabol. A 25-year window is used. The first years of the sequences are shown in the horizontal axes.

ships in different locations. Since the starting dates of the available rainfall data were varied, the years of the start of the 25-year windows (horizontal axes in Figure 4) are not the same for all stations. To assess the impact of record length on the strength and stability of the correlations, the SCA was also performed with different window lengths. Figure 5 depicts the correlation coefficients between SOI and rainfall in Mashhad, Kerman, and Kashan for 15-year windows. Similar results were generally found when the record lengths were changed.

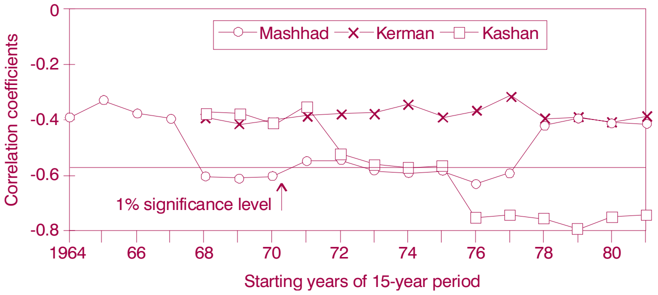

Figure 5. Sequential correlation coefficients between autumn rainfall and Mashhad, Kerman, and Kashan. A 15-year window is used. The first years of the sequences are shown in the horizontal axis.

As indicated in Figures 4 and 5, correlations are generally significant for some stations, such as Oromieh, Tehran, Tabriz, Kashan, and Zanjan. However, autumn rainfall in Shiraz, Kerman, Kermanshah, Zabol, and Bandarabbas is not significantly correlated with the SOI. As indicated in Figure 4c, the SOI–rainfall relationships are also significant (at the 5% significance level) for Banadaranzali, situated over the western margin of the Caspian Sea coasts (Figure 1). In Mashhad, the SOI–rainfall correlations are significant for some spells and weak for others. The results of the SCA suggest that, regardless of window length and geographical location of the rainfall stations, autumn rainfalls over different parts of the country were negatively correlated with the SOI.

The spatial distribution of the correlation coefficients between the SOI and rainfall is presented in Figure 6. The regions with reasonably strong rela-

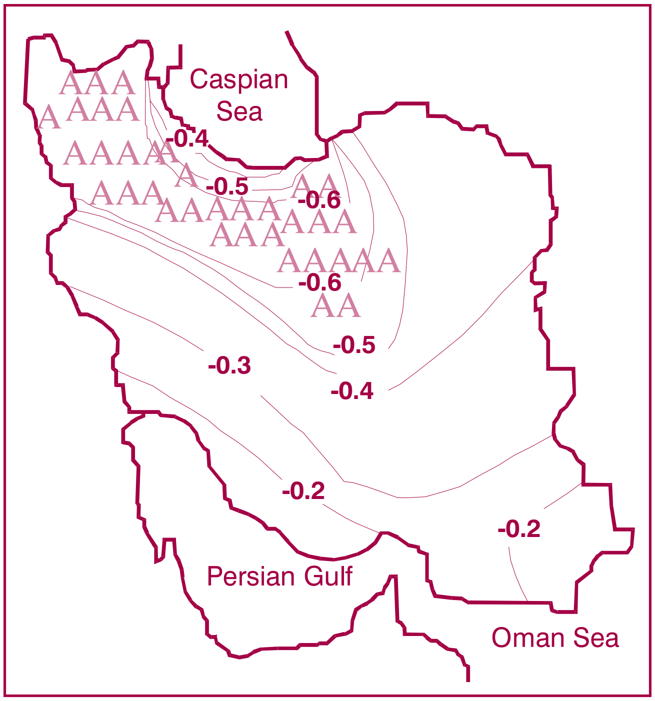

Figure 6. Spatial distribution of the sequential correlation coefficients between SOI and autumn rainfall in Iran. A 25-year window is used. The 5% and 1% levels of significance are 0.34 and 0.47, respectively. Regions with good coherence are denoted by 'A'.

tionships (denoted as Region A) are mainly situated over southern slopes of the Alborz Mountains and the northwestern part of Iran, where the Alborz and Zagros ranges come together (Figure 2). Autumn rainfall over western portions of the Caspian Sea is also negatively associated with the SOI.

Droughts are therefore expected during positive SOI, and abundant precipitation tends to occur when the SOI is negative. The study has also found that severe and widespread autumnal drought is expected during extreme La Niña episodes, when seasonal SOI is larger than 5. For such periods, droughts with extensive socioeconomic hardships are generally anticipated.

Acknowledgments

Parts of this work were funded by grants from the Research Council of Shiraz University and the Iranian Meteorological Organization. The author would like to express his gratitude to these institutions for their help and sincerity.

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Low Temperature and Cold Drought Risks in Crop Production in Temperate Kashmir

Temperature plays a vital role in life processes and crop production. Physical and chemical processes within plants are temperature dependent; these processes in turn control biological reactions in crop plants. Temperature also plays a significant role in some aspects of crop physiological cycles: the diffusion rate of gases and liquids changes with temperature; the solubility of substances is temperature dependent; rapid progress occurs as a result of temperature increases; and the equilibrium and stability of various systems and compounds (including enzymes) is a function of temperature.

Air temperature at the screen level is one of the most important variables affecting crop production in temperate Kashmir. Most crop plants are injured or killed by low night temperatures, especially those plants that are growing rapidly or flowering. Low temperature in combination with wet soil may result in the accumulation of harmful products in plant cells while low temperature coupled with water shortage results in cold drought.

A drought-like situation existed in the latter half of 1998 in temperate Kashmir. Because of decreased rainfall from September onward, when minimum temperature was rapidly decreasing, a cold drought-like situation prevailed, resulting in crop damage. Our earlier analysis had indicated higher reliability in forecasting changes in minimum temperatures (Hasan and Kanth, 1997) and also a significant variability in weekly/monthly precipitation (Hasan, 1997). However, a very unusual situation arose in 1998 when both precipitation and minimum temperature were surprisingly low. We therefore made an objective analysis of the historical weather information available to us.

In the present study, weekly and monthly mean minimum temperature and total precipitation for 1983–97 (15 years) at Shalimar (1,587 m) have been used. The 15-year means have been compared with the data for 1998 (Figures 1 and 2). The “low temperature frequency” analysis has been carried out for 1983–98. The frequency distribution has been done for the number of times that weekly mean minimum temperature was reduced by more than 1°C, compared to the previous week. Finally, the summarized forecast verification analysis (1995–98) for temperature changes is also given to characterize the weather of this region.

The minimum temperature profile is given in Table 1. It indicates extremes of daily minimum temperature (-13.6°C for January 20, 1991, and 24°C for August 1, 1983). The lowest weekly mean minimum temperature is known to occur between the 48th and 5th standard meteorological weeks (SMW)—i.e., during the months of December and January. Favorable and higher minimum temperatures have been recorded between SMW 29 and SMW 33 (i.e.,

1. Lowest weekly mean ever	-7.8°C (SMW 2)
2. Highest weekly mean ever	21.4°C (SMW 31)
3. Lowest weekly means	-2.43 to 0.08°C between SMW 48 and SMW 6
4. Highest weekly means	18.1 to 18.63°C between SMW 29 and SMW 33
5. Lowest average weekly mean, 1983-97	-2.43°C (SMW 4)
6. Highest average weekly mean,1983-97	18.63°C (SMW 31)
7. Lowest daily ever	-13.6°C (Jan. 20, 1991)
8. Highest daily ever	24.0°C (Aug. 1, 1983)

Table 1. Minimum temperature profile at Shalimar (1,587 m) during 1983–97.

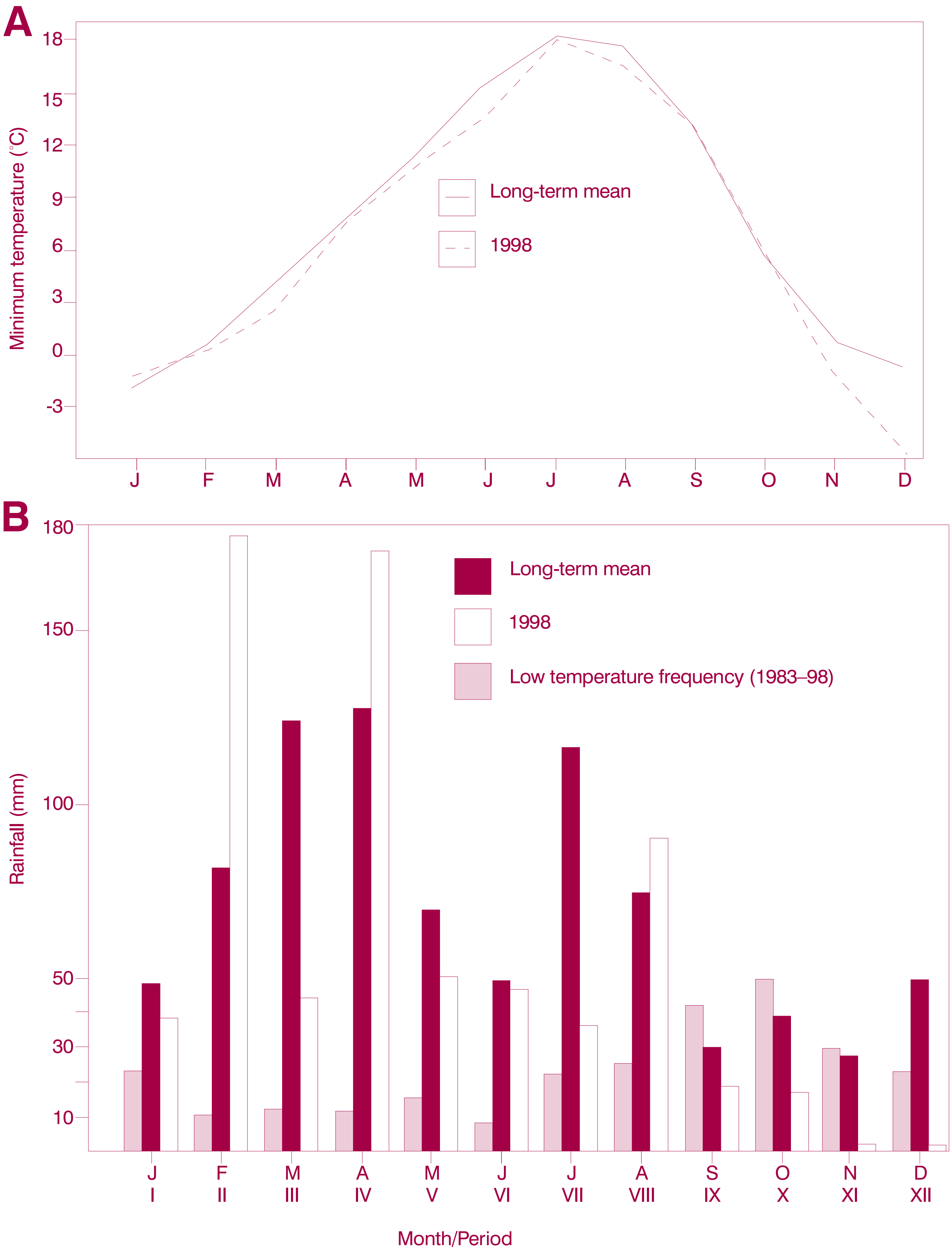

Figure 1. Minimum temperature and rainfall in relation to the long-term mean at Shalimar (1,587 m), Kashmir, India.

mid-July to mid-August). Low temperature frequency analysis for 1983–98 showed minimum frequencies for reduction in minimum temperatures by more than 1°C during June and maximum frequencies during October. Periods V and VII (Figure 1b), corresponding to the months of May and July, do have higher frequencies. During May, the rice crop is in the nursery stage, while in July it completes tillering to enter into the panicle initiation/flowering stages. With such a historical profile for minimum temperature, let us consider further the weekly/monthly behavior of minimum temperature and precipitation during 1998 in relation to the long-term means (Figures 1 and 2). It is clearly evident that 1998 witnessed lower mean monthly minimum temperatures and precipitation, compared to the long-term mean (Figure 1). Likewise, all months except February, April, and August had deficient precipitation, and November and December did not receive any precipitation. A cold drought thus prevailed from SMW 44 on (Figure 2), which proved quite damaging to rabi (winter) crops like rapeseed-mustard. Moreover, the low inherent soil moisture led to poor crop growth, thereby increasing the crops' susceptibility to low temperature damage. Table 2 gives the comparative resistance of crops to sub-zero temperature regimes. It is quite evident from the table that crops are very susceptible to low temperatures during flowering. A study in

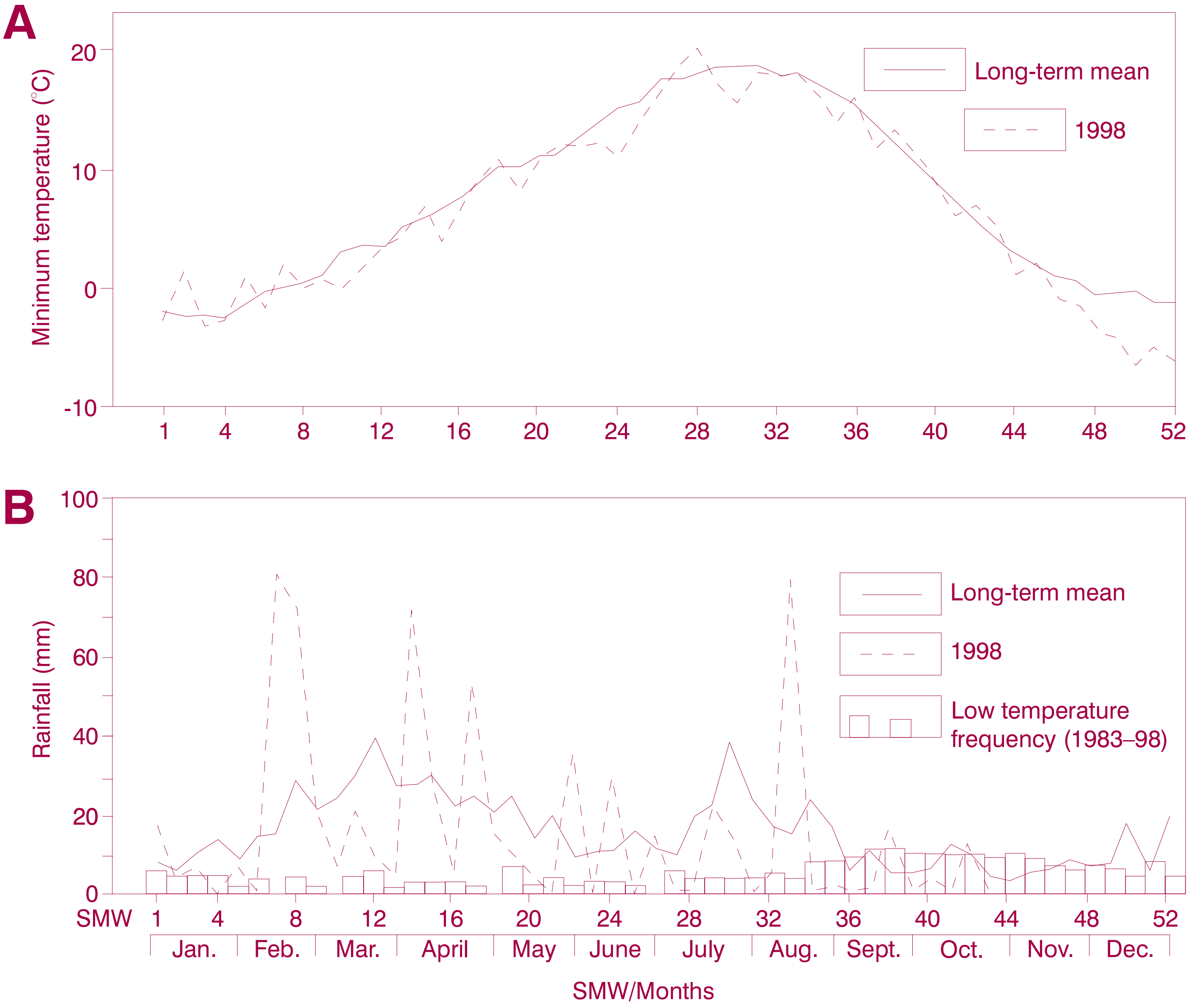

Figure 2. Minimum temperature and precipitation during 1998, in relation to the long-term mean at Shalimar (1,587 m), Kashmir, India (on a weekly basis).

	Temperature (°C) harmful to plant during:					
	Germination		Flowering		Fruiting	
Highest resistance to frost						
Spring wheat	-9	-10	-1	-2	-2	-4
Oats	-8	-9	-1	-2	-2	-4
Peas	-7	-8	-2	-3	-2	-4
Lentils	-7	-8	-2	-3	-2	-4
Resistance to frost						
Beans	-5	-6	-2	-3	-3	-4
White mustard	-4	-6	-2	-3	-3	-4
Turnip	-6	-7	–	–	–	–
Medium resistance to frost						
Soyabeans	-3	-4	-2	-3	-2	-3
Low resistance to frost						
Corn	-2	-3	-1	-2	-2	-3
Potatoes	-2	-3	-1	-2	-1	-2
No resistance to frost						
Rice	-0.5	-1	-0.5	-1	-1	–
Tomatoes	0	-1	0	-1	0	-1

Source: Ventskevich, 1961

Table 2. Resistance of crops to frost in different phases.

France by Lardon and Triboi-Blondel (1995) revealed that freeze and cold treatments in winter rapeseed at the beginning of the flowering period (day/night: 7°/0°C) induced major modifications in plant yield architecture by overcompensating certain yield components. Ram and Singh (1995) studied low temperature risks to cool season crops under Hisar (India) conditions by analyzing 24 years of meteorological data and suggested adjustments in sowing dates so that the crop reaches the double ridge/floral bud initiation stage after January 28 (since the risk of temperatures of less than 2°C at screen level is 45–65% between January 1 and January 28) and maturity/harvesting before March 19.

The forecast verification analysis (Table 3) showed more reliable forecasting for changes in minimum temperature compared to maximum temperature. Furthermore, the seasonal analysis indicated a better forecast reliability for changes in minimum temperatures for summer months than for winter months (during 1995–96 and 1996–97). Thus, when minimum temperatures were drastically reduced during winter months, changes in minimum temperature could not be reliably forecasted for 2 of the 3 years, indicating a probable risk to crop production in temperate Kashmir.

To find a solution to the problem of low temperature risks to crops and for a better understanding of temperature trends expected, we have undertaken a daily low temperature probability analysis by fitting normal distribution to the daily data of the last 18 years. The months of October to May (winter or rabi season) have been considered, and the probability of minimum temperatures below a certain level is being worked out (Table 4). Thus we shall be able to identify critical crop growth stages with associated maximum probabilities.

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I. Overall picture of usable forecasts (%)

T_{max} parameter	1995–96 (120 reports) Total usable	Summer	Winter	1996–97 (99 reports) Total usable	Summer	Winter	1997–98 (84 reports) Total usable	Summer	Winter
T_{max}	55	59	67	57	53	60	52	47	62
T_{min}	71	78	74	70	59	81	66	69	62

II. Correlation between forecasted and actual temperatures

	1996–97			1997–98		
Parameter	Entire year	Summer	Winter	Entire year	Summer	Winter
T_{max}	—	*0.815	*0.869	**0.916	**0.86	**0.87
T_{min}	—	*0.644	*0.828	**0.930	**0.89	**0.87

*** significant at 5%; ** significant at 1%**

III. Daywise analysis (RMSE)

	1996–97						1997–98					
Parameter	Summer			Winter			Summer			Winter		
	d-1	d-2	d-3	d-1	d-2	d-3	d-1	d-2	d-3	d-1	d-2	d-3
T_{max} 2.98	3.51	2.97	2.65	3.31	4.96	4.3	4.5	2.5	3.72	3.46	3.10	
T_{min} 1.61	2.69	2.95	2.58	2.07	2.74	2.0	2.5	2.5	2.60	2.60	2.17	

RMSE = root mean square error

Table 3. Forecast verification analysis of temperature changes at Shalimar, Kashmir (India).

Months	T_{min}, °C	Probability of T_{min} (°C) regime below -4	-3	-2	-1	0	1	2	4	6	8	10
January	all sub-zero	*	*	*	*	*	*					
February	-1 to 1.3	*	*	*	*	*	*					
March	0 to 10					*		*	*	*	*	
April	1-11							*	*	*	*	*
May	5 to 15							*	*	*	*	*
October	sub-zero to 12							*	*	*	*	*
November	sub-zero to 6		*	*	*	*	*					
December	sub-zero to 5		*	*	*	*	*					

*** indicates the probability determination of that particular temperature regime during the month**

Table 4. Low temperature probability analysis—minimum temperature ranges and regimes for various months

Announcements

Disaster Management Workshops

The University of Wisconsin–Madison, Department of Engineering Professional Development, will offer a seminar series, Disaster Management Workshops, September 20–24, 1999, in Madison, Wisconsin. Participants may enroll for 1–5 days.

The program will benefit emergency managers from business, industry, government, service, and community organizations. During the workshops, participants will learn about emergency information management; disaster communications; response planning; damage, needs, and resources assessment; and monitoring, evaluation, and reporting.

For more information, contact Katie Peterson, Department of Engineering Professional Development, University of Wisconsin–Madison, 432 North Lake Street, Madison, Wisconsin 53706; telephone: (800) 462–0876; fax (608)263–3160; e-mail: custserv@epd.engr.wisc.edu; www: http://epd.engr.wisc.edu/.

National Workshop on Dynamic Crop Simulation Modeling

The National Workshop on Dynamic Crop Simulation Modeling for Agrometeorological Advisory Service was conducted at the National Centre for Medium Range Weather Forecasting (NCMRWF), Department of Science and Technology, New Delhi, January 4–6, 1999. The objectives of the workshop were to assess the state of the art of crop simulation model (CSM) studies in India and to bring together scientists to discuss the use of CSM-based expert systems in crop management. Another goal was to prepare strategy for calibration and validation of the existing models in different agroclimatic zones of the country, and to identify the potential users of the crop simulation models calibrated and validated by NCMRWF. The 135 participants represented various agencies, including the NCMRWF, India Meteorological Department, Agrometeorological Advisory units of NCMRWF located at state agricultural universities, Indian Council for Agricultural Research Institutes, and Department of Space. Recommendations emerging from the workshop include the need to: identify the minimum soil, crop and crop management, and weather data required for building and validating the crop growth models in different agroclimatic zones of the country; identify gaps in the data; and prepare programs for filling the gaps (if any). It was also decided to repeat the workshop every two years. For more information, contact: Dr. S. A. Saseendran, Scientist, NCMRWF, DST, Mausam Bhavan, Lodi Road, New Delhi–3, India; e-mail: sas357@ncmrwf.ernet.in.

International Conference on Integrated Drought Management

The International Conference on Integrated Drought Management will be held in Pretoria, South Africa, September 20–22 , 1999. The need for more integrated drought management approaches was identified by the International Hydrological Programme of UNESCO, one of the organizers of the conference. Other organizers are the World Meteorological Organization, Southern African Development Community (SADC) Water Sector, and Drought Monitoring Centre of the SADC Food Security Sector.

The main objective of the conference is to better understand the factors predisposing people and landscapes to heightened drought vulnerability and to work toward strategies and actions that can reduce drought vulnerability and move society toward sustainable development. Sessions will address: Understanding, measuring, and forecasting drought; comparative drought management policies; key principles of integrated drought management; strategies to reduce drought vulnerability; capacity building, devolution of management responsibility, communication, and support; integrated drought management toward sustainable development; and drought research and information needs. A concluding session will synthesize the results of the conference in the form of directions for more effective drought management, with a focus on sub-Saharan Africa.

The conference is aimed at researchers, academics, practitioners, consultants, developers, policy makers, planners, community leaders, and representatives of the media.

An optional pre-conference workshop, Drought Planning, will be held at the Agricultural Research Council in Pretoria on September 16–17, 1999. For more information, please contact Congress Secretariat, Conference Planners, Cilla Taylor/Alyson Lea-Cox, P.O. Box 82, Irene, 0062 South Africa; telephone: +27 (0) 12 667 3781; fax: +27 (0) 12 667 3680; e-mail: confplan@iafrica.com.

15th Annual Conference on Contaminated Soils

The 15th Annual Conference on Contaminated Soils will be held October 18–21, 1999, at the University of Massachusetts at Amherst. Platform and poster sessions will cover the following topics: Analysis, Arsenic, Bioavailability, Bioremediation, Chlorinated Hydrocarbons, Cold and Winter Remediation, Environmental Fate, Environmental Forensics, Heavy Metals, Lead, Massachusetts Military Reservation, MTBE/Oxygenates, Natural Attenuation, Phytoremediation, Radionuclides, RBCA, Remediation, Risk Sediments, Site Assessment, TPH, UXO, Water Containment Systems. Exhibits will bring real world application of technical theory and case studies. Focused workshops will provide attendees applicable practical information. For information, contact Denise Leonard at (413) 545–1239 or dleonard@schoolph.umass.edu.

2000 National Disaster Medical System Conference

The National Disaster Medical System (NDMS) will hold its annual conference at the Alexis Park Hotel in Las Vegas, Nevada, April 29–May 3, 2000. The 2000 NDMS Conference will provide practical information on implementing interdisciplinary strategies for preventing or reducing the health and medical consequences of disasters of any origin. The education will feature counter-terrorism programs, clinical updates, extreme environmental events, disaster team development, information management systems, mass gathering events, critical incident stress management, sheltering and congregate care, health system emergency planning, mass fatality operations, veterinary services in disasters, and new standards in emergency management. The program will offer approximately 20 hours of continuing education credit for a wide range of health practitioners and administrators. For additional information, contact NDMS by calling 1 (800) USA–NDMS and pressing the “star” key, by e-mail at ndms@usa.net, or check their website at www.oep-ndms.dhhs.gov.

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