August 1999

Drought Follows the Deluge in Vermont

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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.

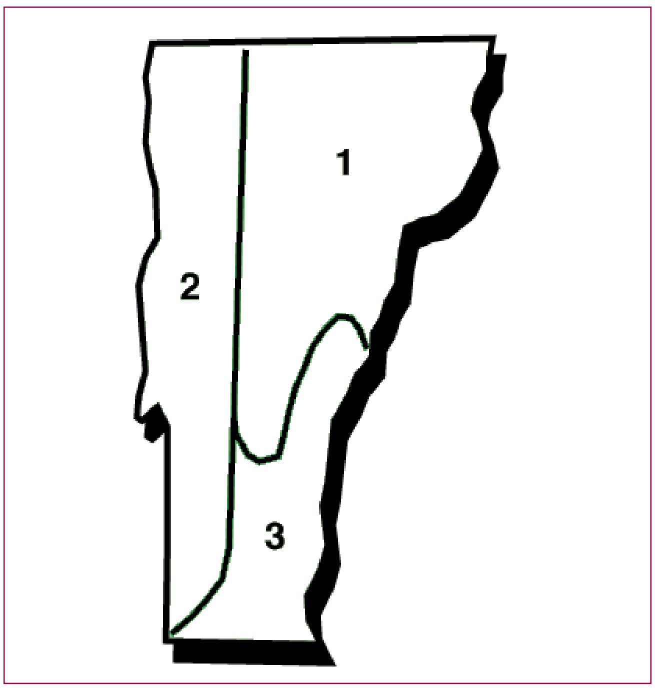


Figure 1. Map of Vermont showing its three climatic divisions. Courtesy of the National Climatic Data Center.

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.

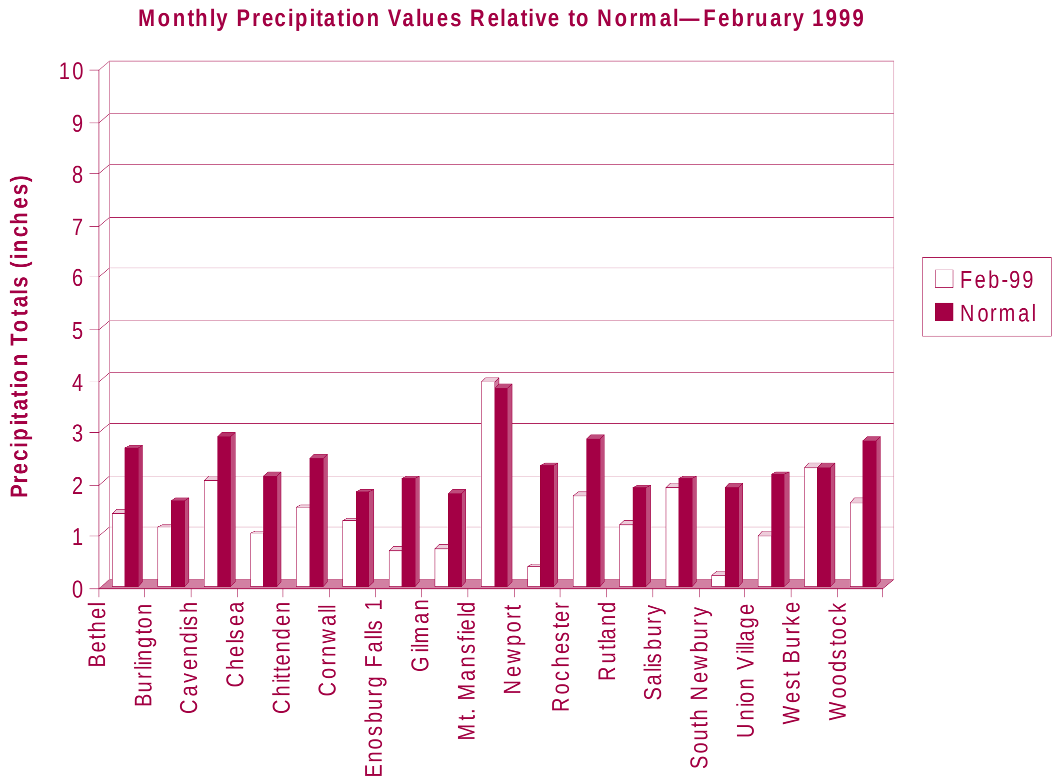
Table 1 summarizes the precipitation totals, percent of normal, and ranking relative to the driest year on record for Vermont as a whole. Unlike many of the surrounding states, the area-weighted state average for Vermont for September 1998 showed that above-average precipitation was received, following 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.



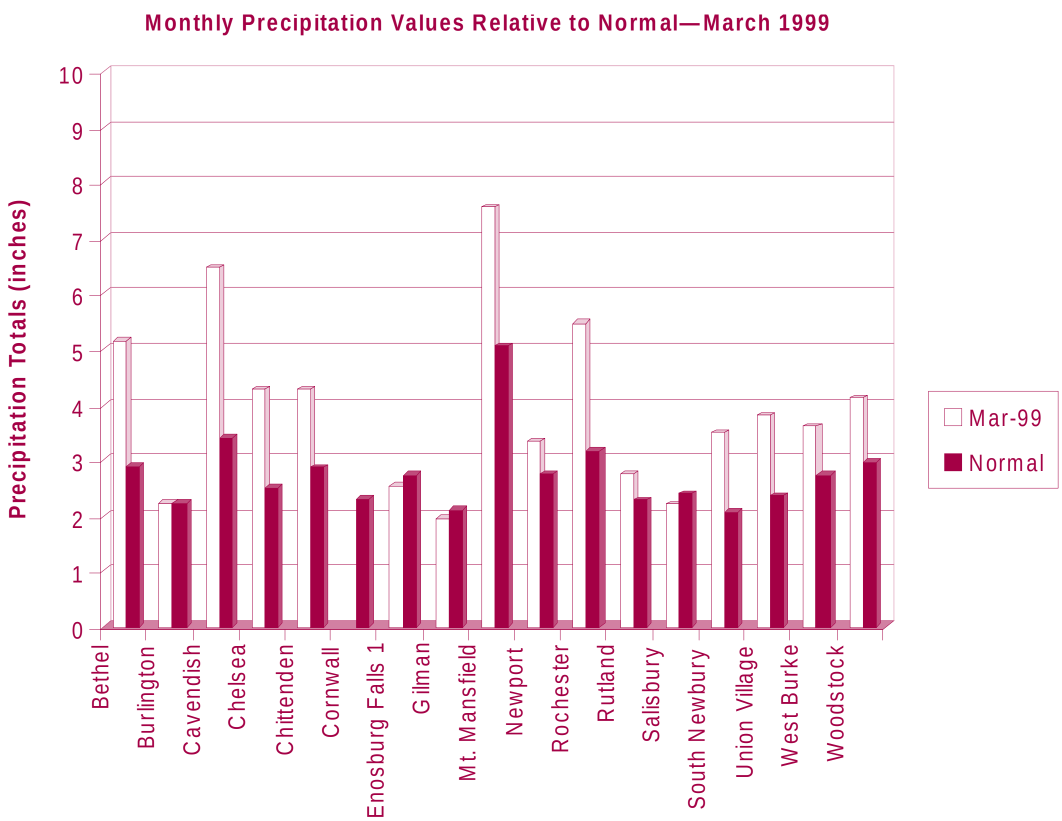
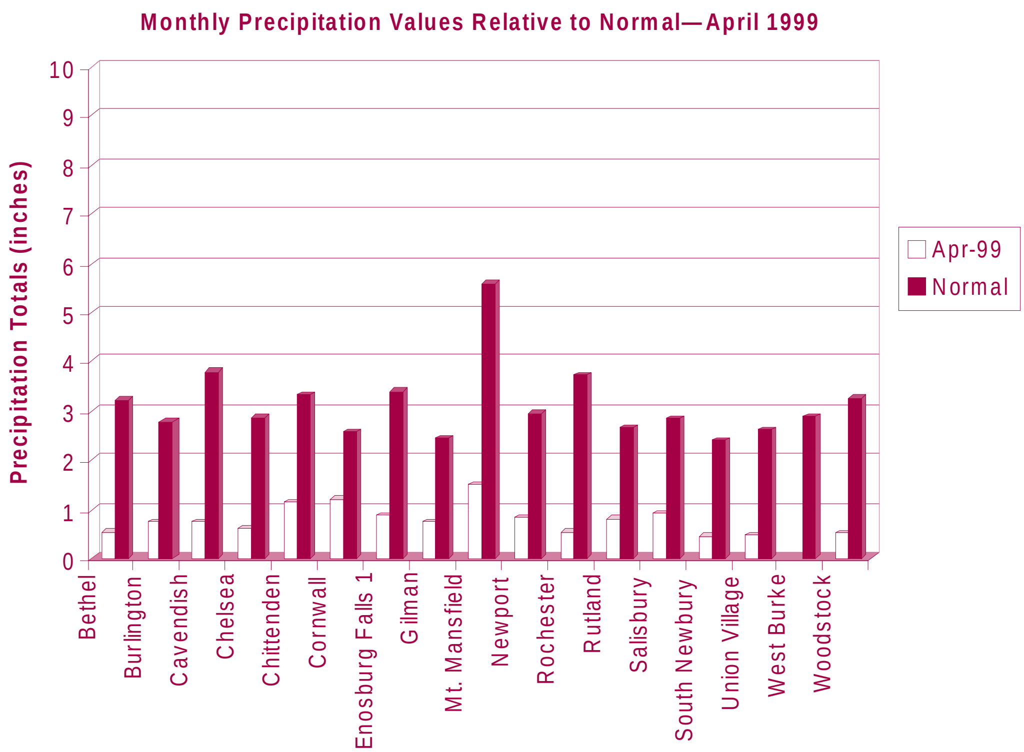
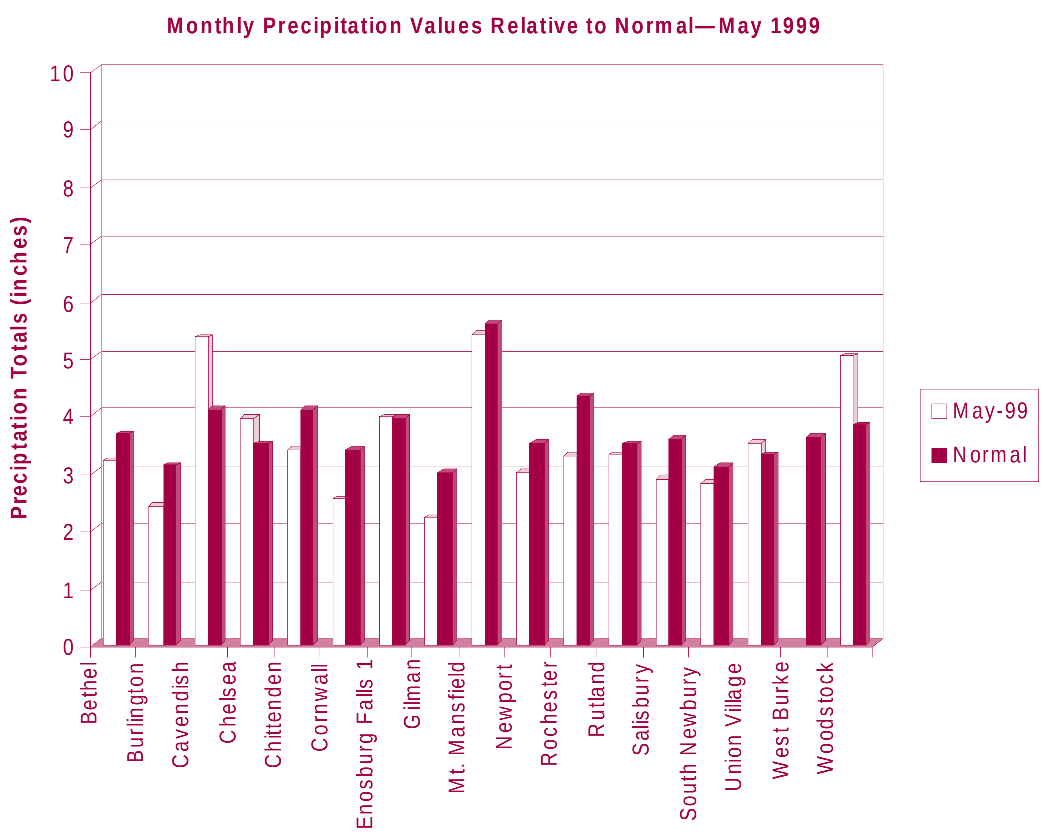


Figure 2. Monthly precipitation totals relative to normal for February–May 1999.


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


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

(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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