Standardized Precipitation Index User Guide

World Meteorological Organization
Weather • Climate • Water

WMO-No. 1090

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2012

EDITORIAL NOTE

METEOTERM, the WMO terminology database, may be consulted at: http://www.wmo.int/pages/prog/lsp/meteoterm_wmo_en.html. Acronyms may also be found at: http://www.wmo.int/pages/themes/acronyms/index_en.html.

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PREFACE

Over the years, there has been much discussion on what drought indices should be used in a particular climate and for what application. Many drought definitions and indices have been developed and attempts have been made to provide some guidance on this issue.

With this in mind, the Interregional Workshop on Indices and Early Warning Systems for Drought was organized and held at the University of Nebraska-Lincoln, United States of America, from 8 to 11 December 2009. It was jointly sponsored by the School of Natural Resources (SNR) of the University of Nebraska, the United States National Drought Mitigation Center (NDMC), the World Meteorological Organization (WMO), the United States National Oceanic and Atmospheric Administration (NOAA), the United States Department of Agriculture (USDA) and the United Nations Convention to Combat Desertification (UNCCD). The workshop brought together 54 participants representing 22 countries from all over the world. They reviewed the drought indices currently in use in different regions of the world to explain meteorological, agricultural and hydrological droughts; assessed the capacity for collecting information on the impacts of drought; reviewed the current and emerging technologies for drought monitoring, and discussed the need for consensus standard indices to describe different types of droughts.

The experts at the meeting elaborated and approved the Lincoln Declaration on Drought Indices, which recommended that the Standardized Precipitation Index (SPI) be used by all National Meteorological and Hydrological Services (NMHSs) around the world to characterize meteorological droughts, in addition to other drought indices that were in use in their service. The Lincoln Declaration also recommended the development of a comprehensive SPI user manual. In June 2011, the Sixteenth World Meteorological Congress adopted a resolution that endorsed both of these recommendations. The Congress also requested that the SPI manual be published and distributed in all official languages of the United Nations.

The full Lincoln Declaration on Drought Indices can be found on the WMO website at http://www.wmo.int/pages/prog/wcp/agm/meetings/wies09/documents/Lincoln_Declaration_Drought_Indices.pdf.

WMO would like to thank Mark Svoboda, Michael Hayes and Deborah A. Wood of the National Drought Mitigation Center (NDMC) at the University of Nebraska for preparing this user guide on the Standardized Precipitation Index[1]. We hope that it will help countries and institutions to understand how to calculate and use the SPI in order to develop or further enhance their own drought monitoring and early warning capabilities.

For any questions or comments on the content of this guide, including any suggestions for improvement, please email the WMO Agricultural Meteorology Division at agm@wmo.int.

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[1] This guide should be cited as: World Meteorological Organization, 2012: *Standardized Precipitation Index User Guide* (M. Svoboda, M. Hayes and D. Wood). (WMO-No. 1090), Geneva.

1. BACKGROUND

Drought is an insidious natural hazard that results from lower levels of precipitations than what is considered normal. When this phenomenon extends over a season or a longer period of time, precipitation is insufficient to meet the demands of human activities and the environment. Drought must be considered a relative, rather than absolute, condition. There are also many different methodologies for monitoring drought. Droughts are regional in extent and each region has specific climatic characteristics. Droughts that occur in the North American Great Plains will differ from those that occur in northeast Brazil, southern Africa, western Europe, eastern Australia, or the North China Plain. The amount, seasonality and form of precipitation differ widely between each of these locations.

Temperature, wind and relative humidity are also important factors to include in characterizing drought. Drought monitoring also needs to be application-specific because drought impacts will vary between sectors. Drought means different things to different users such as water managers, agricultural producers, hydroelectric power plant operators and wildlife biologists. Even within sectors, there are many different perspectives of drought because impacts may differ markedly. Droughts are commonly classified by type as meteorological, agricultural and hydrological, and differ from one another in intensity, duration and spatial coverage.

2. INTRODUCTION TO THE STANDARDIZED PRECIPITATION INDEX

Over the years, many drought indices were developed and used by meteorologists and climatologists around the world. Those ranged from simple indices such as percentage of normal precipitation and precipitation percentiles to more complicated indices such as the Palmer Drought Severity Index. However, scientists in the United States realized that an index needed to be simple, easy to calculate and statistically relevant and meaningful. Moreover, the understanding that a deficit of precipitation has different impacts on groundwater, reservoir storage, soil moisture, snowpack and streamflow led American scientists McKee, Doesken and Kleist to develop the Standardized Precipitation Index (SPI) in 1993.

The SPI (McKee and others, 1993, 1995) is a powerful, flexible index that is simple to calculate. In fact, precipitation is the only required input parameter. In addition, it is just as effective in analysing wet periods/cycles as it is in analysing dry periods/cycles. The program can run in both Windows and UNIX environments. This SPI user guide describes the Windows version.

Ideally, one needs at least 20-30 years of monthly values, with 50-60 years (or more) being optimal and preferred (Guttman, 1994). The program can be run with missing data, but it will affect the confidence of the results, depending on the distribution of the missing data in relation to the length of the record. More information on usage can be found in section 6, Computational methodology.

Climatologists would prefer to see serially complete data sets, which means there should be no missing data. However, it is more than likely that data sets would only have 90% or even 85% complete records. In reality, many users don’t have this luxury and may have to settle for less (75-85% complete) unless they look to estimation techniques to fill in the gaps in the record. Of course, long and pristine data records are neither practical nor typical in many cases, so the user needs to be aware of the statistical limitations of extreme events when dealing with shorter periods of records for various locations. In the end, users have to make a subjective decision as to what tolerance of missing data they are willing to incorporate into the SPI calculations and analyses. Depending on the confidence and method of calculation, the use of estimated data is acceptable. Naturally, the fewer estimated data used the better.

3. DESCRIPTION OF THE STANDARDIZED PRECIPITATION INDEX

Overview: The SPI is based on the probability of precipitation for any time scale. The probability of observed precipitation is then transformed into an index. It is being used in research or operational mode in more than 70 countries.

Who uses it: Many drought planners appreciate the SPI's versatility. It is also used by a variety of research institutions, universities, and National Meteorological and Hydrological Services across the world as part of drought monitoring and early warning efforts.

Strengths: Precipitation is the only input parameter. The SPI can be computed for different time scales, provide early warning of drought and help assess drought severity. It is less complex than the Palmer Drought Severity Index and many other indices.

Weaknesses: It can only quantify the precipitation deficit; values based on preliminary data may change, and values change as the period of record grows.

Developed by T.B. McKee, N.J. Doesken and J. Kleist, Colorado State University, 1993.

The SPI was designed to quantify the precipitation deficit for multiple timescales. These timescales reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, streamflow and reservoir storage reflect the longer-term precipitation anomalies. For these reasons, McKee and others (1993) originally calculated the SPI for 3-, 6-,12-, 24- and 48-month timescales.

The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero (Edwards and McKee, 1997). Positive SPI values indicate greater than median precipitation and negative values indicate less than median precipitation. Because the SPI is normalized, wetter and drier climates can be represented in the same way; thus, wet periods can also be monitored using the SPI.

McKee and others (1993) used the classification system shown in the SPI value table below (Table 1) to define drought intensities resulting from the SPI. They also defined the criteria for a drought event for any of the timescales. A drought event occurs any time the SPI is continuously negative and reaches an intensity of -1.0 or less. The event ends when the SPI becomes positive. Each drought event, therefore, has a duration defined by its beginning and end, and an intensity for each month that the event continues. The positive sum of the SPI for all the months within a drought event can be termed the drought's "magnitude".

Table 1. SPI values

2.0+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

Based on an analysis of stations across Colorado in the United States, McKee determined that the SPI indicates mild drought 24% of the time, moderate drought 9.2% of the time, severe drought 4.4% of the time and extreme drought 2.3% of the time (McKee and others,1993). Because the SPI is standardized, these percentages are expected from a normal distribution of the SPI. The 2.3% of SPI values within the "extreme drought" category is a percentage that is typically expected for an "extreme" event. In contrast, the Palmer Drought Severity Index reaches its "extreme" category more than 10% of the time across portions of the central Great Plains in the United States. This standardization allows the SPI to determine the rarity of a current drought (Table 2), as well as the probability of the precipitation necessary to end it (McKee and others, 1993). It also allows the user to confidently compare historical and current droughts between different climatic and geographic locations when assessing how rare, or frequent, a given drought event is.

Table 2. Probability of recurrence

SPI	Category	Number of times in 100 years	Severity of event
0 to -0.99	Mild dryness	33	1 in 3 yrs.
-1.00 to -1.49	Moderate dryness	10	1 in 10 yrs.
-1.5 to -1.99	Severe dryness	5	1 in 20 yrs.
< -2.0	Extreme dryness	2.5	1 in 50 yrs.

Some key points:

- Because the SPI is normalized, wetter and drier climates can be represented in the same way; thus, wet periods can also be monitored using the SPI. However, it must be stressed that the SPI is not suitable for climate change analysis because temperature is not an input parameter.

- The SPI was designed to quantify the precipitation deficit for multiple timescales.

- These timescales reflect the impact of drought on the availability of the different water resources, which was the initial intent of the SPI's creators.

- Soil moisture conditions respond to precipitation anomalies on a relatively short timescale. Groundwater, streamflow and reservoir storage reflect the longer-term precipitation anomalies. So, for example, one may want to look at a 1- or 2-month SPI for meteorological drought, anywhere from 1-month to 6-month SPI for agricultural drought, and something like 6-month up to 24-month SPI or more for hydrological drought analyses and applications.

4. STRENGTHS AND WEAKNESSES

The strengths and weaknesses of the SPI can be summarized as follows:

Strengths

- It is flexible: it can be computed for multiple timescales
- Shorter timescale SPIs, for example 1-, 2- or 3-month SPIs, can provide early warning of drought and help assess drought severity
- It is spatially consistent: it allows for comparisons between different locations in different climates
- Its probabilistic nature gives it historical context, which is well suited for decision-making.

Weaknesses

- It is based only on precipitation
- No soil water-balance component, thus no ratios of evapotranspiration/potential evapotranspiration (ET/PET) can be calculated.
- A new variation of the index by Vicente-Serrano and others (2010) attempts to address the PET issue by including a temperature component in the calculation of their new index called the Standardized Precipitation and Evapotranspiration Index (SPEI). The inputs required to run the program are precipitation, mean temperature and latitude of the site(s). Further information on the SPEI is available at http://sac.csic.es/spei/index.html.

5. INTERPRETATION: SPATIAL AND TEMPORAL FLEXIBILITY DESCRIBED

There is no single definition of drought (Wilhite and Glantz, 1985). We can generally group them into meteorological, agricultural, hydrological and socioeconomic droughts. Drought is a very complex hazard to define and detect. It spans multiple sectors and timescales. Just as there is no single definition of drought, there is no single drought index that meets the requirements of all applications.

That said, a real strength of the SPI is its ability to be calculated for many timescales, which makes it possible to deal with many of the drought types described above. The ability to compute the SPI on multiple timescales allows for temporal flexibility in the evaluation of precipitation conditions in relation to water supply.

As mentioned earlier, the SPI was designed to quantify the precipitation deficit for multiple timescales, or moving averaging windows. These timescales reflect the impacts of drought on different water resources needed by various decision-makers. Meteorological and soil moisture conditions (agriculture) respond to precipitation anomalies on relatively short timescales, for example 1-6 months, whereas streamflow, reservoirs, and groundwater respond to longer-term precipitation anomalies of the order of 6 months up to 24 months or longer. So, for example, one may want to look at a 1- or 2-month SPI for meteorological drought, anywhere from 1-month to 6-month SPI for agricultural drought, and something like 6-month up to 24-month SPI or more for hydrological drought analyses and applications.

The SPI can be calculated from 1 month up to 72 months. Statistically, 1–24 months is the best practical range of application (Guttman, 1994, 1999). This 24-month cutoff is based on

Guttman's recommendation of having around 50–60 years of data available. Unless one has 80–100 years of data, the sample size is too small and the statistical confidence of the probability estimates on the tails (both wet and dry extremes) becomes weak beyond 24 months. In addition, having only the minimum 30 years of data (or less) shortens the sample size and weakens the confidence. Technically, one could run the SPI on less than 30 years of data bearing in mind, however, the statistical limitations and weaker confidence pointed out above.

5.1 Short- versus long-term Standardized Precipitation Index values

5.1.1 *1-month SPI*

A 1-month SPI map is very similar to a map displaying the percentage of normal precipitation for a 30-day period. In fact, the derived SPI is a more accurate representation of monthly precipitation because the distribution has been normalized. For example, a 1-month SPI at the end of November compares the 1-month precipitation total for November in that particular year with the November precipitation totals of all the years on record. Because the 1-month SPI reflects short-term conditions, its application can be related closely to meteorological types of drought along with short-term soil moisture and crop stress, especially during the growing season. The 1-month SPI may approximate conditions represented by the Crop Moisture Index, which is part of the Palmer Drought Severity Index suite of indices.

Interpretation of the 1-month SPI may be misleading unless climatology is understood. In regions where rainfall is normally low during a month, large negative or positive SPIs may result even though the departure from the mean is relatively small. The 1-month SPI can also be misleading with precipitation values less than the normal in regions with a small normal precipitation total for a month. As with a percent of normal precipitation map, useful information is contained in the 1-month SPI maps, but caution must be observed when analysing them.

NOTE: In theory, the SPI can be calculated on a sub-monthly basis, but in practice this is not recommended. It is highly recommended that the user look at a minimum averaging window of 4 weeks. One could compute a 1-week SPI, but the reality is that one will likely encounter many dry day events (0.00 rainfall even in non-arid climates), which makes the SPI behave erratically (Wu and others, 2006), therefore this approach is not recommended. However, updating the SPI every day or every week for a 1-month up to a 24-month time frame is acceptable. This "moving window" approach does not compromise the program as it is still looking at a minimum of 4 weeks of data each day it moves.

5.1.2 *3-month SPI*

The 3-month SPI provides a comparison of the precipitation over a specific 3-month period with the precipitation totals from the same 3-month period for all the years included in the historical record. In other words, a 3-month SPI at the end of February compares the December–January–February precipitation total in that particular year with the December–February precipitation totals of all the years on record for that location. Each year data is added, another year is added to the period of record, thus the values from all years are used again. The values can and will change as the current year is compared historically and statistically to all prior years in the record of observation.

A 3-month SPI reflects short- and medium-term moisture conditions and provides a seasonal estimation of precipitation. In primary agricultural regions, a 3-month SPI might be more effective in highlighting available moisture conditions than the slow-responding Palmer Index or other currently available hydrological indices. A 3-month SPI at the end of August in the United States Corn Belt would capture precipitation trends during the important reproductive and early grain-filling stages for both corn and soybeans. Meanwhile, the 3-month SPI at the end of May gives an indication of soil moisture conditions as the growing season begins.

It is important to compare the 3-month SPI with longer timescales. A relatively normal or even a wet 3-month period could occur in the middle of a longer-term drought that would only be visible over a long period. Looking at longer timescales can prevent misinterpretation believing that a drought might be over when in fact it is just a temporary wet period. Continuous and persistent drought monitoring is essential to determine when droughts begin and end. This helps avoid "false alarms" when going into and coming out of drought. Having a set of "triggers" in place, which are tied to actions within a drought plan, can help ensure this.

As with the 1-month SPI, the 3-month SPI may be misleading in regions where it is normally dry during any given 3-month period. Large negative or positive SPIs may be associated with precipitation totals not very different from the mean. This caution can be explained with the Mediterranean climate of California and around northern Africa and southern Europe, where very little rain falls or is expected over distinct periods of the year. Because these periods are characterized by little rain, the corresponding historical totals will be small, and relatively small deviations on either side of the mean could result in large negative or positive SPIs. Conversely, this time period can be a good indicator for some monsoon regions around the world.

5.1.3 *6-month SPI*

The 6-month SPI compares the precipitation for that period with the same 6-month period over the historical record. For example, a 6-month SPI at the end of September compares the precipitation total for the April–September period with all the past totals for that same period.

The 6-month SPI indicates seasonal to medium-term trends in precipitation and is still considered to be more sensitive to conditions at this scale than the Palmer Index. A 6-month SPI can be very effective in showing the precipitation over distinct seasons. For example, a 6-month SPI at the end of March would give a very good indication of the amount of precipitation that has fallen during the very important wet season period from October through March for certain Mediterranean locales. Information from a 6-month SPI may also begin to be associated with anomalous streamflows and reservoir levels, depending on the region and time of year.

5.1.4 *9-month SPI*

The 9-month SPI provides an indication of inter-seasonal precipitation patterns over a medium timescale duration. Droughts usually take a season or more to develop. SPI values below -1.5 for these timescales are usually a good indication that dryness is having a significant impact on agriculture and may be affecting other sectors as well. Some regions may find that the pattern displayed by the map of the Palmer Index is closely related the 9-month SPI maps. For other areas, the Palmer Index is more closely related to the 12-month SPI. This time period begins to bridge a short-term seasonal drought to those longer-term droughts that may become hydrological, or multi-year, in nature.

5.1.5 *12-month up to 24-month SPI*

The SPI at these timescales reflects long-term precipitation patterns. A 12-month SPI is a comparison of the precipitation for 12 consecutive months with that recorded in the same 12 consecutive months in all previous years of available data. Because these timescales are the cumulative result of shorter periods that may be above or below normal, the longer SPIs tend to gravitate toward zero unless a distinctive wet or dry trend is taking place. SPIs of these timescales are usually tied to streamflows, reservoir levels, and even groundwater levels at longer timescales. In some locations, the 12-month SPI is most closely related with the Palmer Index, and the two indices can reflect similar conditions.

6. COMPUTATIONAL METHODOLOGY

The SPI is determined by normalizing the precipitation for a given station after it has been fitted to a probability density function as described by McKee and others (1993, 1995), Edwards and McKee (1997), and Guttman (1998). A full description of the SPI computational procedure can be found in McKee and others (1993, 1995) and Edwards and McKee (1997). The basics, as taken from Edwards (1997), are described below.

6.1 SPI methodology

- The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero (Edwards and McKee, 1997).

- Positive SPI values indicate greater than median precipitation, and negative values indicate less than median precipitation.

- Drought, according to the SPI, starts when the SPI value is equal or below -1.0 and ends when the value becomes positive.

6.2 How it works

- Precipitation is normalized using a probability distribution function so that values of SPI are actually seen as standard deviations from the median.

- A normalized distribution allows for estimation of both dry and wet periods.

- Accumulated values can be used to analyse drought severity (magnitude).

- At least 30 years of continuous monthly precipitation data are needed but longer-term records would be preferable.

- SPI timescale intervals shorter than 1 month and longer than 24 months may be unreliable.

- It is spatially invariant in its interpretation.

- Its probability-based nature (probability of observed precipitation transformed into an index) makes it well suited to risk management and triggers for decision-making.

7. HOW TO OBTAIN THE PROGRAM

The program is available in a Windows/PC version and can be downloaded for free.

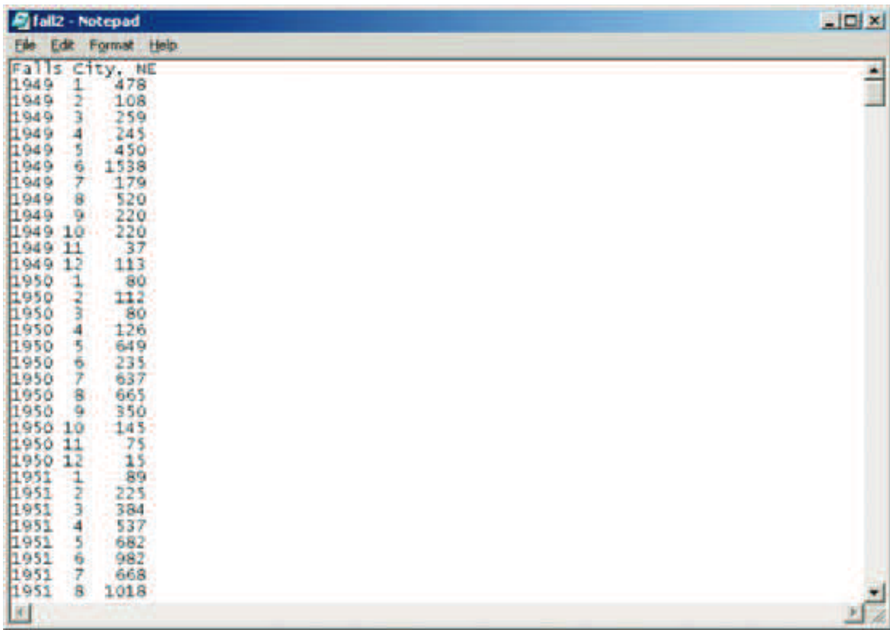
The latest SPI program (SPI_SL_6.exe), sample files such as those described below and instructions for Windows/PC use can be found at http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx.

The program can calculate up to 6 SPI time windows at one time for any given location. It was compiled in C++ for PC and all libraries are included.

8. HOW TO RUN THE PROGRAM IN WINDOWS

To run the program in Windows, simply follow the steps indicated below:

1. Set up an input file as in the following sample containing precipitation data from Falls City, Nebraska:



```
Falls City, NE
1949  1   478
1949  2   108
1949  3   259
1949  4   245
1949  5   450
1949  6  1538
1949  7   179
1949  8   520
1949  9   220
1949 10   220
1949 11    37
1949 12   113
1950  1    80
1950  2   112
1950  3    80
1950  4   126
1950  5   649
1950  6   235
1950  7   637
1950  8   665
1950  9   350
1950 10   145
1950 11    75
1950 12    15
1951  1    89
1951  2   225
1951  3   384
1951  4   537
1951  5   682
1951  6   982
1951  7   668
1951  8  1018
```

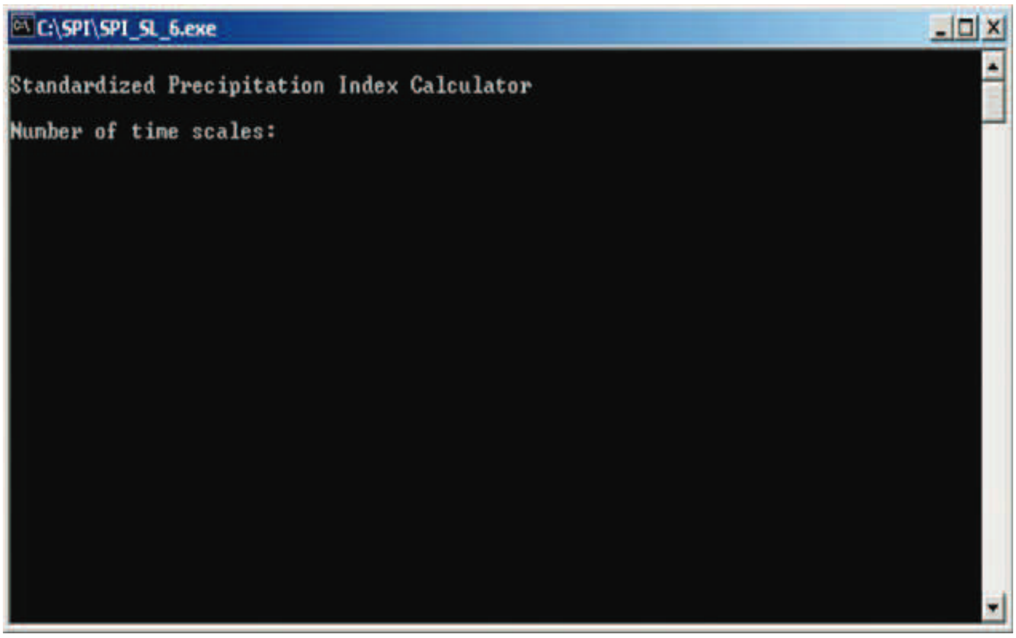
All input files must follow this format, which features three columns indicating respectively the year, month and monthly precipitation value. A header, usually the name of the station, must be included at the top of the input file otherwise the program will produce an empty output file. The precipitation total must NOT include decimals and can be in inches or millimetres.

NOTE: Pay attention to column spacing and missing data in the input file. If the monthly precipitation value is missing for a particular month or months, one must use -99 for the missing data value. Do not use a blank in the precipitation column. Zero is a valid value for typically dry months in arid regions or for those locations having distinct wet or dry seasons. Ideally, one would want at least 30 years of monthly/weekly data in order to have some confidence in the statistics, but that would be the case with most indices when assessing any drought climatology for a given location or region.

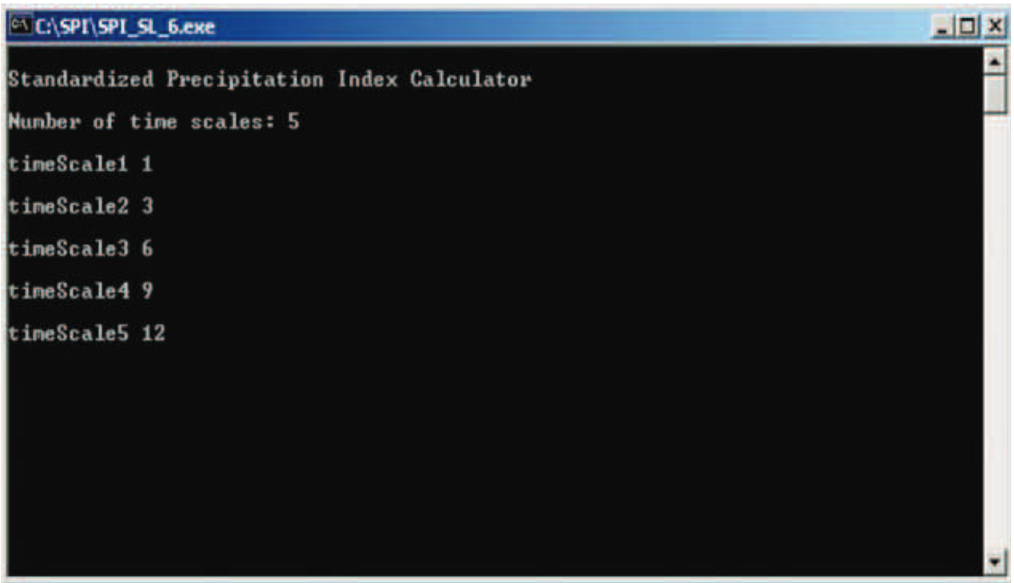
The input files can be generated with Excel or any text editor, but must be renamed with a .cor extension before executing the program.

2. Right click on the SPI_SL_6.exe file and save it. Then execute (double click) the program and follow the instructions in the pop-up window.

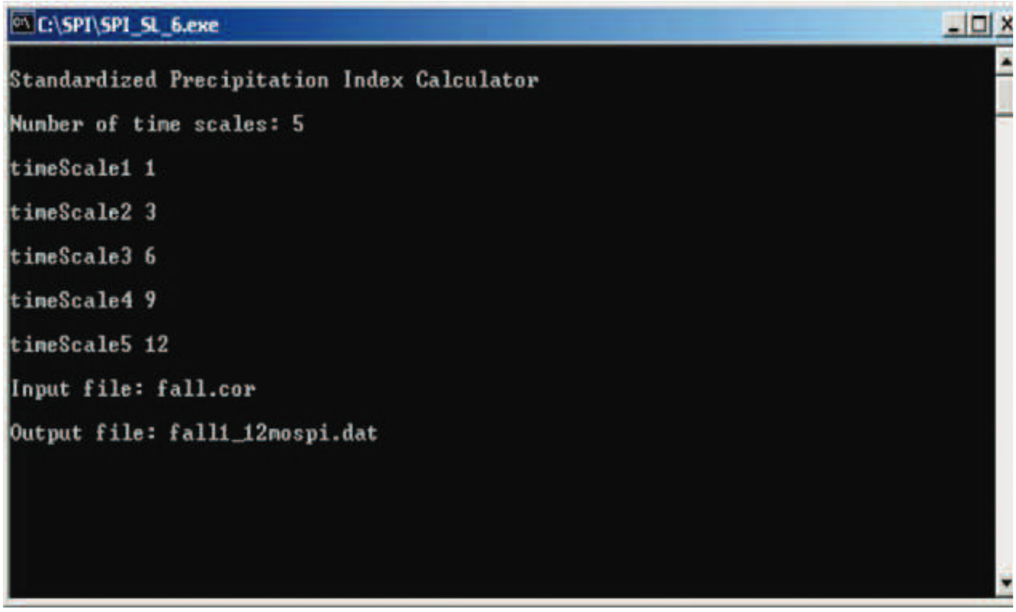
3. Choose the number of SPI timescales to be computed:



4. Specify the SPI timescales to be computed. In the example below, the user will generate five SPI timescales or windows: 1-month, 3-month, 6-month, 9-month and 12-month SPIs:



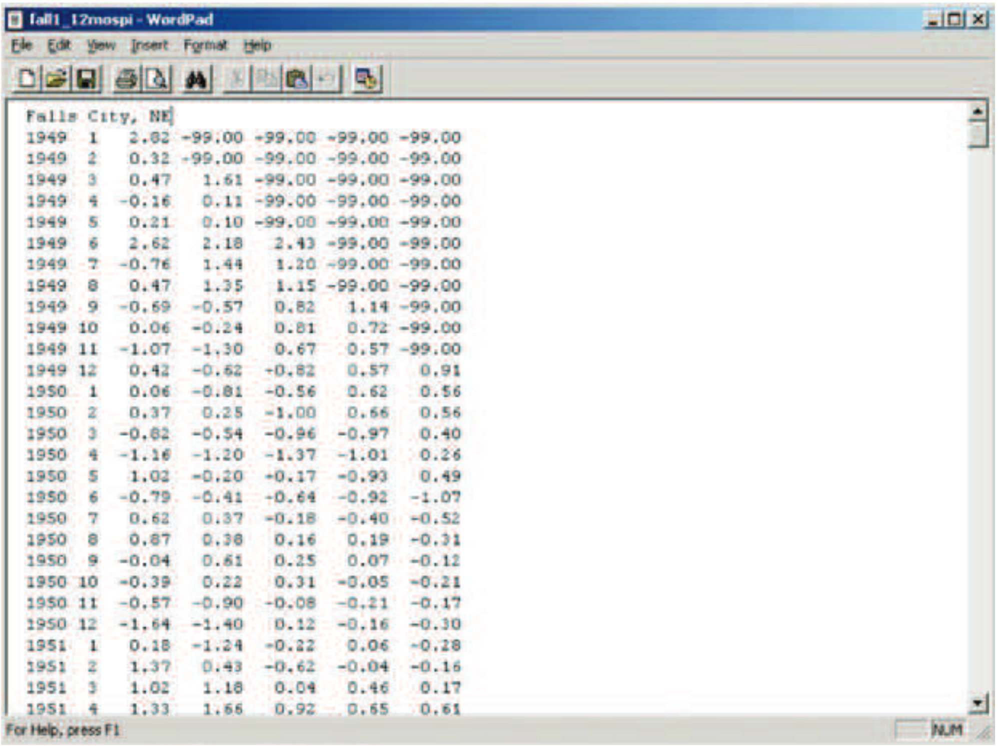
5. Enter an input and an output filename. It is recommended to adopt a naming system that reflects the SPI analyses to be carried out in order to keep the results of each analysis separate:



The output file can be given any name but must have a .dat extension. It will be placed in the same folder where the executable file is located.

The results can be processed with Microsoft Notepad or any other text or word processing software. These files are saved as MS_DOS ASCII text files. The output data can then be plotted, graphed or mapped by any means.

A sample output file for Fall City, Nebraska, is shown and described below. The input file was set up to analyse the 1-, 3-, 6-, 9- and 12-month SPIs. The corresponding values appear in the third, fourth, fifth, sixth and seventh columns:



Falls City, NE

1949	1	2.82	-99.00	-99.00	-99.00	-99.00
1949	2	0.32	-99.00	-99.00	-99.00	-99.00
1949	3	0.47	1.61	-99.00	-99.00	-99.00
1949	4	-0.16	0.11	-99.00	-99.00	-99.00
1949	5	0.21	0.10	-99.00	-99.00	-99.00
1949	6	2.62	2.18	2.43	-99.00	-99.00
1949	7	-0.76	1.44	1.20	-99.00	-99.00
1949	8	0.47	1.35	1.15	-99.00	-99.00
1949	9	-0.69	-0.57	0.82	1.14	-99.00
1949	10	0.06	-0.24	0.81	0.72	-99.00
1949	11	-1.07	-1.30	0.67	0.57	-99.00
1949	12	0.42	-0.62	-0.82	0.57	0.91
1950	1	0.06	-0.81	-0.56	0.62	0.56
1950	2	0.37	0.25	-1.00	0.66	0.56
1950	3	-0.82	-0.54	-0.96	-0.97	0.40
1950	4	-1.16	-1.20	-1.37	-1.01	0.26
1950	5	1.02	-0.20	-0.17	-0.93	0.49
1950	6	-0.79	-0.41	-0.64	-0.92	-1.07
1950	7	0.62	0.37	-0.18	-0.40	-0.52
1950	8	0.87	0.38	0.16	0.19	-0.31
1950	9	-0.04	0.61	0.25	0.07	-0.12
1950	10	-0.39	0.22	0.31	-0.05	-0.21
1950	11	-0.57	-0.90	-0.08	-0.21	-0.17
1950	12	-1.64	-1.40	0.12	-0.16	-0.30
1951	1	0.18	-1.24	-0.22	0.06	-0.28
1951	2	1.37	0.43	-0.62	-0.04	-0.16
1951	3	1.02	1.18	0.04	0.46	0.17
1951	4	1.33	1.66	0.92	0.65	0.61

NOTE: The -99.00 value does not indicate missing data in this case. It simply reflects that, for example, in the fourth column, one cannot have a 3-month SPI value until one is 3 months into the period of record. The same applies to the last column where one does not see a 12-month SPI until December 1949, or the twelfth month available for calculation. This becomes the first 12-month SPI generated.

9. MAPPING CAPABILITIES

Many countries are calculating and mapping the SPI and other drought indices or meteorological parameters on a regular basis. Below is an overview of the methods often employed in mapping drought indicators.

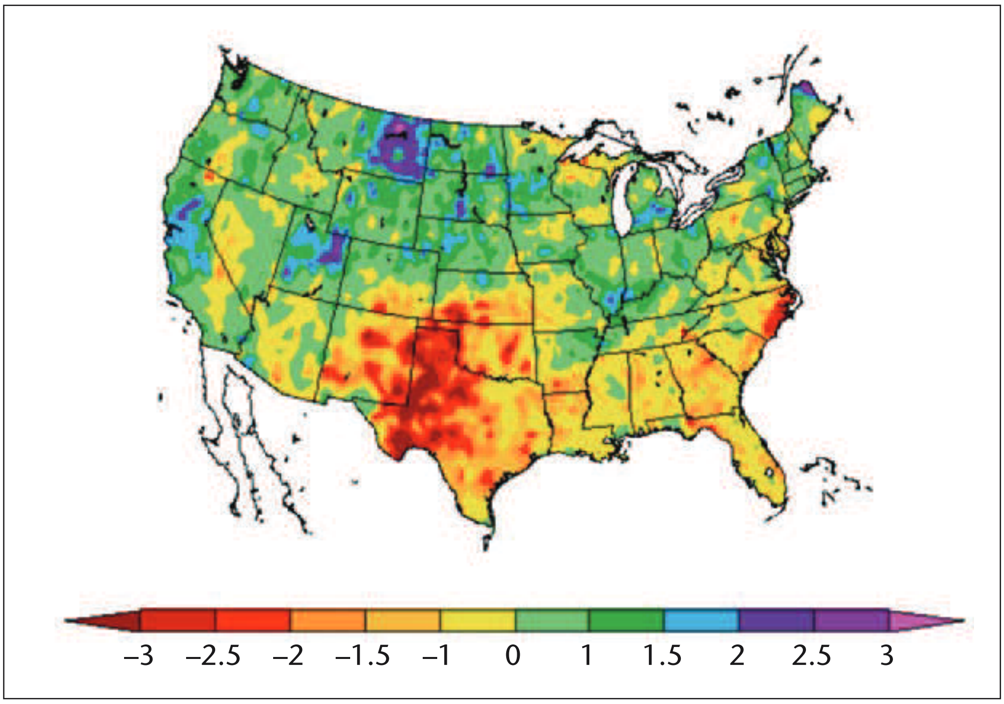
There are multiple ways, such as the standard drought indicators and indices, to map meteorological variables. Most drought-related data originate as point (“station-based” or “site-specific”) data. These data serve their purposes, but it is often in map form that the data best communicate a message based on a geographic context to the decision-maker trying to understand drought severity and spatial extent. The point data can be placed on a map, and derivative products or characteristics of that site can be provided for additional information. This could include, for example, a time series plot of the indicator or index. The limitation of this level of spatial detail is that information on what is taking place between points is not available.

A variety of techniques can be used to generate a continuous map of meteorological drought. One such technique generates an interpolated surface of estimated values at locations between sites based on mathematical relationships of the indicator or index between the original point data. Often this produces a map that appears “natural”, but is still based on the data from specific points and is only as accurate as the original data and the interpolation technique. No single interpolation method can be applied to all situations, and the most commonly used interpolation techniques include Kriging, Spline, and Inverse Distance Weighting (IDW).

Each interpolation technique has its advantages and disadvantages. Some techniques are more exact than others, but take longer to produce the desired output. The Kriging method, which has its origins in geological applications and the mining industry, assumes that there is a relationship between points that is non-random and changes over space. The Spline method is used when minimizing the overall surface curvature is important. Inverse Distance Weighting (IDW) is used when the data points are scattered but dense enough to represent local variations. The data, as the name implies, are weighted to favour data closer in proximity to the point being processed.

Another technique that has been used for meteorological drought monitoring and mapping is to map point data to grid cells. These data can also originate from airborne, radar, and satellite sources. These gridded data products appear less “natural” than interpolated products, but they are easier to use for comparative purposes because of the common grid cell sizes. These cells can vary in size from degrees down to meter(s) depending on the source and application needed. They also vary in their temporal frequency, with return periods ranging from daily (or multiple times a day) to weekly or longer. In the United States, gridded products for monitoring meteorological drought are becoming much more common, while in other regions, particularly Africa, there has been a long history of using gridded information to determine drought conditions. The Famine Early Warning System (FEWS) and similar networks have utilized gridded data in their analyses. Multiple examples of gridded meteorological drought products exist in Australia, China, the United Kingdom and the United States.

To develop a gridded map product, the point data are aggregated to a grid cell resolution selected for that product using a mathematical relationship. An interpolated surface is then created between the grid cells (not the point data). For example, the High Plains Regional Climate Center, in partnership with the National Drought Mitigation Center, is mapping the Standardized Precipitation Index on a daily basis at state, regional, and national scales across the United States.



Source: United States High Plains Regional Climate Center

Example of 3-month SPI (1 May 2011 – 31 July 2011)

SPI maps are generated by using the Grid Analysis and Display System (GrADS). The discrete station SPI data are interpolated using a Cressman objective analysis with radii of influence of 10,7,4,2,1. The grid resolution is 0.4 degrees. Gridded contour maps are generated at national, regional and state levels for the High Plains region. For national maps, north polar stereographic (nps) projection is applied. Regional and state maps use a latitude/longitude (lat/lon) projection with aspect ratio maintained. This interface and resultant products can be found at: http://www.hprcc.unl.edu/maps/current/.

Successful mapping of meteorological drought depends on the quality of the data. Drought indicator and index data quality is determined by several factors, including the availability of the data, the timing of the recording, the quality of the historical data at a station, the transmission of data in near real time, the maintenance of the station network and the ability to measure precipitation in cold temperatures, particularly in northern or alpine locations. Some of these issues are related to the ability to provide the data in a timely fashion, which can be very important with meteorological drought. Finally, the data density plays a huge role in the spatial resolution that can be achieved in mapping drought.

One of the biggest challenges in mapping meteorological drought is to try and match the spatial resolution that decision-makers need and demand with the information that is available today. This limitation is related to the density of point data, which might not be available at the resolution desired by the decision-makers. Because of this challenge, the promise of potential remote sensing-based products is encouraging. Some remote-sensing products can provide data at spatial resolutions in regions where in situ point data are relatively sparse and unreliable. Most satellite products are already incorporated into a grid cell (or “pixel”) as described above. In the United States, some products are now being developed to utilize a combination of station-based and remote-sensing data. The station data are used to help refine the remote-sensing data, and the resulting “hybrid” maps have a higher level of accuracy.

Topographical issues, particularly those related to mountains and rapid terrain changes, represent a real challenge when mapping meteorological drought. There are two reasons for this. First, data density tends to be lower in mountainous regions. Second, because interpolation methodologies are often based on correlations, the relationship between adjoining regions with regard to precipitation tends to be particularly discontinuous in areas where the terrain changes rapidly and significantly. As a result, smoothed interpolated surfaces on a finished map product may not realistically match natural variability, especially the indicators and indices related to precipitation.

Because of all the complexities involved in meteorological drought data and the characteristics of mapping techniques, it is important that a decision-maker understands these factors when interpreting maps of drought severity and spatial extent.

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OTHER ONLINE RESOURCES

http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx

http://drought.mssl.ucl.ac.uk/spi.html

http://www.wrcc.dri.edu/spi/spi.html

http://ccc.atmos.colostate.edu/standardizedprecipitation.php

http://www.wmo.int/drought

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