A Hydroclimatic Indexing Concept for Monitoring Drought

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Decision Center for a Desert City

Introduction

A method for indexing the hydroclimate of any location on any timeframe was derived from the hydroclimate of the southwestern United States. The focus is on the difference between precipitation (P) and the climatic demand for water, or potential evapotranspiration (PE). The hydroclimatic index (HI) was directly compared to the popular Palmer Drought Severity Index (PDSI) and the Standardized Precipitation Index (SPI). The PDSI has been criticized for spatial variability in its statistical properties, erratic short-term response to drought, and the use of an arbitrary scale. The SPI is limited to one-half of the water budget equation by only representing precipitation. The HI aims to resolve these issues.

Data

Monthly temperature and precipitation data were gathered in support of representing the hydroclimate of the Colorado River Basin (CRB) from 1895 through 2004. Data were collected for the 23 "climate divisions" that are at least partially contained within the CRB. The wetness or dryness of a location can best be described by the difference between moisture input and the climatic demand for moisture, or P-PE. For example, annual precipitation across Arizona fails to meet the natural climatic demand for water by nearly 500 mm on average, indicating the extreme dryness of the climate.


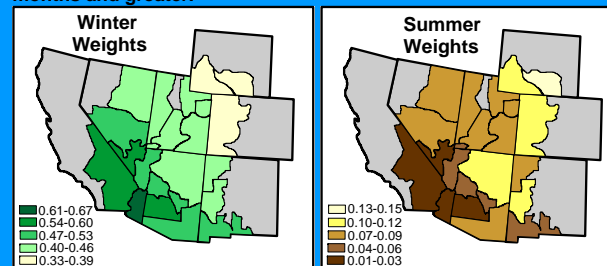Colorado River Basin / Climate Divisions
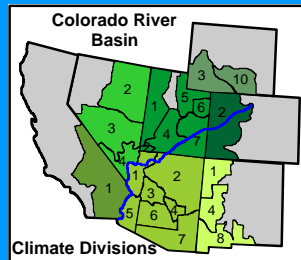
Method

The Thornthwaite-Mather Climatic Water Budget Model was used to create records of monthly PE from the temperature and precipitation data. Once monthly P-PE values were constructed, aggregate means were calculated for periods of 3-, 6-, 12-, 24-, 36-, and 48-months to represent the running short-, intermediate-, and long-term hydroclimatic conditions. Values for each time period were placed within a frequency distribution to assign each a percentile value to create the HI.

To further improve upon the SPI specifically, we wanted to devise a method for emphasizing the more important portions of the annual hydroclimatology when representing conditions for periods of 12 months or greater.

This concept is illustrated by the mean monthly P-PE values for climate division 4 in Arizona. On average, P-PE values are positive only during the period November through March, and it is likely that much of the surplus moisture in November is used to recharge the soil following the summer season.

Arizona Climate Division 4 Monthly Mean P-PE 1895-2004
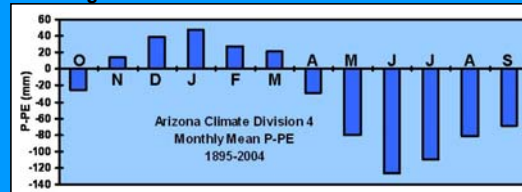
To determine the mean importance of each month to the annual hydroclimatology within each climate division across the CRB, we first ran the full climatic water budget model to simulate soil moisture through the 110-year record of each climate division in order to produce a monthly climatology of soil moisture. The mean monthly soil moisture values were totaled and divided into each monthly value to produce weights for the 12 months that total to one. The monthly weights were then applied to the monthly P-PE data used in constructing aggregate means for the periods of 12 months and greater.

Winter Weights

0.61-0.67
0.54-0.60
0.47-0.53
0.40-0.46
0.33-0.39

Summer Weights

0.13-0.15
0.10-0.12
0.07-0.09
0.04-0.06
0.01-0.03

Results

For short timeframes, the inclusion of the climatic demand for water in the HI significantly differentiates it from the SPI in the warmer portions of the region where climatic demand is greatest. The PDSI is most different from the HI in the coldest and wettest areas in winter and the warmest and driest areas in summer due to the upper and lower limits and inherent lag in soil moisture as calculated in the PDSI.

Arizona Climate Division 4 3-month Indices: 2001-2003
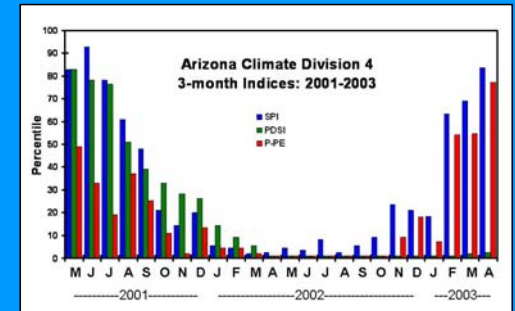
For intermediate and long-term timeframes, the weighted HI most closely resembles precipitation over a 12-month period, but more closely resembles the PDSI when considering multiple years, giving it more of a hydrologic characteristic. The HI seems to respond more quickly to short-term hydroclimatic changes than the PDSI, as evidenced with runoff on a sample watershed. The HI appears to improve upon the SPI by representing the effect of temperature in the form of climatic demand for water, as the SPI overemphasizes wetter years within drought periods even though much of the precipitation fell outside the runoff season, as reflected by low runoff values.

Arizona CD 4 24-month Indices and Salt Basin RO
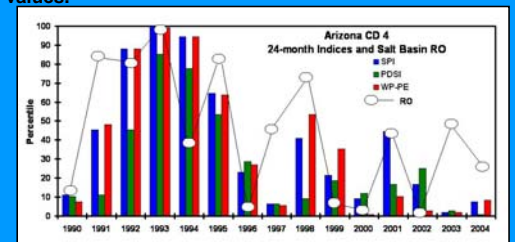
In addition to representing the climatic supply and demand of moisture, the HI employs a simple method and places the hydroclimatic condition in historical perspective, and it is able to be calculated for any type of climate. The ability to calculate the HI for any time frame makes it able to represent drought as it pertains to different sectors.

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