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***A Hydroclimatic Indexing Concept for Monitoring Drought Derived from the Climate of the Southwestern United States.***

As an improvement over current drought indices, a method for indexing the hydroclimate of any location over any period of time is presented. The method was derived from the hydroclimate of the southwestern United States, specifically the approximate area of the Colorado River Basin. The indices are based on the truest representation of a hydroclimate, which is the difference between the natural input of water, or precipitation, and the natural climatic demand for water, or potential evapotranspiration. For time frames of less than 1 year, aggregates of the monthly input and demand were constructed and translated to a historical ranking as a percentile. For 1-year or multiple-year periods, similar aggregates of the hydroclimatic condition were created, but the individual months used to construct the aggregates were weighted depending on their importance to the mean annual hydroclimatology across the region. This places emphasis on the hydroclimatically critical portion of the year for a given location. The hydroclimatic index is directly compared to the popular Palmer Drought Severity Index (PDSI) and the Standardized Precipitation Index (SPI). For short time frames, the inclusion of the climatic demand for water in the hydroclimatic index 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 hydroclimatic index in the coldest and wettest areas in winter and the warmest and driest areas in summer due to its upper and lower limits on soil moisture and the inherent lag in soil moisture. The relationships of the indices on the intermediate and long terms show that the weighted hydroclimatic index most closely resembles precipitation over a 12-month period, but more closely resembles the PDSI when considering multiple years, taking on more of a hydrologic characteristic. Comparison of the indices during recent drought conditions suggests that the hydroclimatic index will respond more quickly to short term hydroclimatic changes than the PDSI while improving upon the SPI by accounting for the effect of temperature in the form of climatic demand for water. For longer time frames, the PDSI was again slow to reflect changes in the hydroclimate compared to the hydroclimatic index as illustrated with runoff on a sample watershed. In reflecting total precipitation across a time frame, the SPI overemphasized wetter years within the drought period even though much of the precipitation fell outside the runoff season, as reflected by low runoff values.

# A Hydroclimatic Indexing Concept for Monitoring Drought

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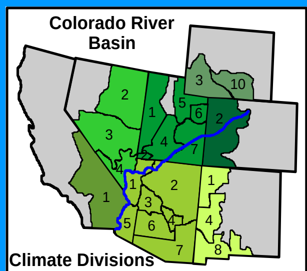
## *Introduction*

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*



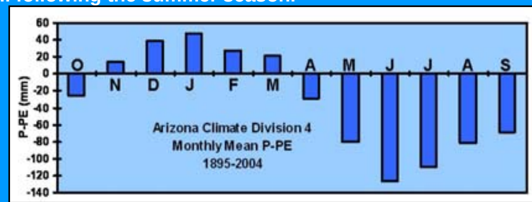

Monthly temperature and precipitation data were gathered in support of representing the hydroclimate of the Colorado River Basin (CRB) from 1895 through 2004. Data were collected for the 23 “climate divisions” that are at least partially contained within the CRB. The wetness or dryness of a location 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.

## *Method*

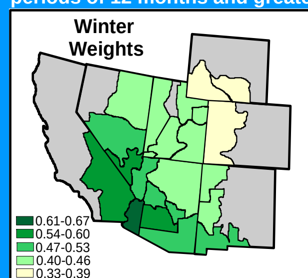
The Thornthwaite-Mather Climatic Water Budget Model was used to create records of monthly PE from the temperature and precipitation data. Once monthly P-PE values were constructed, aggregate means were calculated for periods of 3-, 6-, 12-, 24-, 36-, and 48-months to represent the running short-, intermediate-, 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.

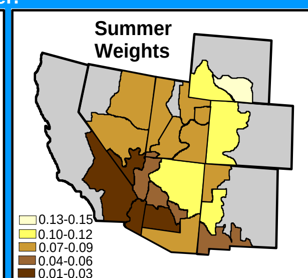
To further improve upon the SPI specifically, we wanted to devise a method for emphasizing the more important portions of the annual hydroclimatology when representing conditions for periods of 12 months or greater.

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.



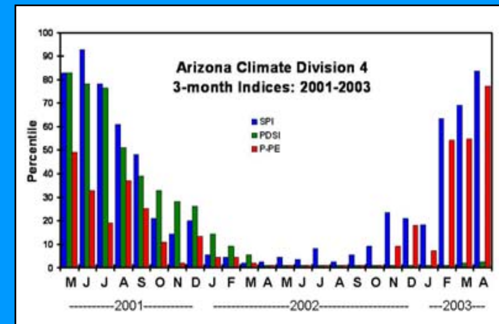

To determine the mean importance of each month to the annual hydroclimatology within each climate division across the CRB, we first ran the full climatic water budget model to simulate soil moisture through the 110-year record of each climate division in order to produce a monthly climatology of soil 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.



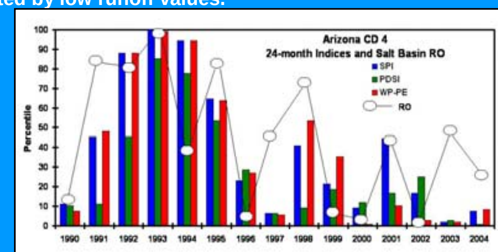




## *Results*

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.




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.




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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