The Moisture Balance Drought Index and Efforts to Improve Drought Indicator Reporting

U.S. Drought Monitor Forum
October 8, 2009

Gregg Garfin and Melanie Lenart

Andrew Ellis and Kevin Murphy
Outline

- MBDI methods and validation
- Website and sustainability
- AZ DroughtWatch
- CHANGE
Wildland Fire
Courtesy of Ron Smallwood

Lake Powell’s decline
J. Dohrenwend, USGS

Southwest U.S. forest die-off
T. Degomez, UA Cooperative Extension

Soil desiccation
Arizona Daily Star
Moisture Balance Drought Index: MBDI

\[ PE = 13.97dD^2W_t \]

- **d** = days in month
- **D** = mean monthly daylight hours
- **\( W_t \)** = saturated water vapor density

\[ W_t = \frac{4.95e^{0.062T}}{100} \]

- **T** = mean monthly temperature (°C)
- **e** = natural log
Moisture Balance Drought Index: MBDI

- Input data: PRISM
- Multiple time scales
  - 1- 3- 6- 12- 24- 36- and 48-month periods
- Historic perspective
  - translated to percentiles
Basin Climatology

Lower Basin 2Xs warmer than Upper Basin – pronounced in cool season

Upper Basin wetter in fall and spring; Lower Basin wetter during monsoon season
Basin Climatology

Lower Basin 1.5Xs the PE of the Upper Basin

\[ P > PE \]

Nov-Mar on Upper Basin
Dec-Jan on Lower Basin
Validating MBDI
Validation Sub Basins

Virgin

Verde

Yampa

Tomichi

Animas

Little Colorado

Salt

Gila
Mean Monthly Runoff
Gila River, Little Colorado River,
Salt River, Verde River Watersheds

Runoff Volume (af)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Gila
LittleCO
Salt
Verde

Chris Castro, University of Arizona
Optimum Timeframe
Monthly Runoff v. SPI

Timeframe (months)

Gila
Verde
LittleCO
WET SEASON

October-April, May

DRY SEASON

May, June-September
WET SEASON

October-April, May

DRY SEASON

May, June-September

Explained Variance Difference
Seasonal Runoff
MBDI minus SPI

Variance (%)

Gla  Verce  LittleCO  Selt  Virgin  Animas  Tomichi  Yampa

Wet Years

Dry Years

*
WET SEASON  

October-April, May

DRIY SEASON  

May, June-September
Variance Explained
Fall/Winter Groundwater

Optimum time frame 3-7 years
Validation Summary

- MBDI, SPI: comparable
- MBDI slightly better for dry side
  - Dry years in wet season
  - Dry season runoff
- MBDI better for groundwater
- MBDI better for warmer part of record
- MBDI worse for wet season runoff
- MBDI worse for reservoir storage
Time series for Santa Cruz
2002 Bullock Fire

Santa Cruz
June 1, 2002
3-Month HI

Santa Cruz
June 1, 2002
6-Month HI

Santa Cruz
June 1, 2002
12-Month HI

Santa Cruz
June 1, 2002
24-Month HI
Extreme Drought, 1895-2006

Percent of CRB in Extreme Drought
1-month MBDI

Linear Trend
3-year Moving Average
A hydroclimatic index for examining patterns of drought in the Colorado River Basin

Andrew W. Ellis, Gregory R. Constable, and George M. Turbin

A persistent drought in the southwestern US has taken a heavy toll on the Colorado River Basin (CRB). With a decreasing water supply, the CRB has experienced prolonged drought conditions in the past two years. The drought has resulted in decreased river flow, reduced water storage in reservoirs, and increased stress on water resources. This study introduces a hydroclimatic index (HCl) to examine drought patterns in the CRB. The HCl combines precipitation, temperature, and river flow data to identify drought episodes. The results show that the CRB has experienced significant drought conditions, with episodes lasting more than one year. The index can be used to monitor drought conditions and inform water management decisions. DOI: 10.1002/joc.1882

1. Introduction

1.1. Drought and the Colorado River Basin

Drought scenarios project significant losses of economic and social values to the southwestern US. The 2002-2004 drought, for instance, resulted in a 10% decrease in agricultural production and a 25% decline in water demand. The Colorado River Basin (CRB) is a critical source of water for millions of people and wildlife. The CRB includes the drainage areas of the Colorado River, the Gila River, the Rio Grande, and the San Juan River. The CRB is a major source of water for the United States and Mexico, and it plays a critical role in the economy and ecosystems of the region. The CRB covers an area of approximately 654,500 km², which is a significant portion of the southwestern United States.

The CRB encompasses the states of Arizona, Nevada, New Mexico, Utah, and Colorado. The basin is characterized by a complex network of tributaries and rivers, including the Colorado River, Gila River, and Rio Grande. The river system is a vital source of water for agriculture, urban areas, and natural ecosystems. The region experiences significant variations in precipitation and temperature, which affect the availability and distribution of water resources. The CRB is a key source of water for the United States and Mexico, and it plays a crucial role in the economy and ecosystems of the region.

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Moisture Balance Drought Index

Soil moisture is the focus of many drought indices, but the Moisture Balance Drought Index (MBDI) stops short of representing soil moisture in its characterization of the hydroclimatic condition. Only a few operational soil moisture sensors exist in the CRB, and the alternative of simulating soil moisture through time is difficult, as climate conditions, land surface characteristics (soil type, vegetation type, topography) and the amount of moisture relative to the soil’s capacity combine to control soil moisture. The MBDI simply represents the difference between precipitation (P) and potential evapotranspiration (PE) (P-PE) through time at a given location. PE is the climatic demand for water, or that amount of evapotranspiration that would occur from a grass-covered soil for which the water content is maintained at capacity. Negative P-PE values indicate the amount by which the climatic demand for water can not be met by precipitation and actual soil moisture would decline if not irrigated. Positive values represent the amount of excess water from precipitation that would recharge soil moisture, percolate to ground water, or run to streams and reservoirs through overland flow or interflow.

Aggregates of P-PE are constructed for periods that represent short-term conditions (1-, 3-month), intermediate conditions (6-, 12-month), and long-term conditions (24-, 36-, 48-month), and the aggregate values are converted to percentiles to form the MBDI. The MBDI can then be stratified into drought categories that represent levels of drought intensity.
Watershed - Little Colorado

Currently Viewing:
Year: 2007

View Different Year (1895-2007):

Hydroclimatic Index

No drought - 30.01+
Abnormally Dry - 20.01-30
Moderate Drought - 10.01-20
Severe Drought - 5.01-10
Extreme Drought - 2.01-5
Exceptional Drought - 0-2
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What’s Ahead?

- Verification case studies
  - Fire, NDVI, Audubon bird counts
- MBDI on the Internet
  - Data
  - Maps
  - Time series
  - Instructions
  - Comparisons
- Usability testing and online survey
Acknowledgments

CLIMATE PROGRAM OFFICE
Understanding climate variability and change to enhance society’s ability to plan and respond

RECLAMATION
Managing Water in the West
Mike Crimmins, University of Arizona
Individual Watershed Report

Report name: Report Name: Turkey Creek - Proxy Report
User: Username: crimmins (Mike Crimmins)

Observer Type: University Researcher
Observation Frequency: 2-5 days

Surface Water Impacts
Unusually low flows in streams, rivers, and springs
A 97 year old lady in the Turkey creek area of the Chiricahua Mountains (Cochise County) reports that the creek was dry this past month. She has lived there since 1932 and every year but this year Turkey creek has run through their ranch in the month of August. (Reported by local agricultural producer and LDIG member)

Individual Watershed Report

Report name: Report Name: High Creek - Proxy Report
User: Username: crimmins (Mike Crimmins)

Observer Type: University Researcher
Observation Frequency: 2-5 days

Surface Water Impacts
Unusually low flows in streams, rivers, and springs
Rancher in Galuro Mountains (northeastern Cochise County) pipes water down from High Creek. Reported that it is almost dry, first time that he knows of. He has lived there since 1975 and he did not think the old timers ever saw it dry up. (Reported by local agricultural producer and LDIG member)

Forage/Vegetation Impacts
Poor forage nutritional quality/increased toxicity of forage
Cochise County rancher lost 18 head of cattle from ingesting burro weed, according to local veterinarian it was due to the drought. When conditions are just right the cattle will eat the budding tips of the burro weed which contain a toxin that causes the central nervous system to break down and can kill cattle.

Mike Crimmins, University of Arizona
International Workshop for CHANGE
(Climate and Hydrology Academic Network for Governance and the Environment)
March 5-6, 2009
México City, D F, México

Project Report
Prepared for:
Foreign Affairs and International Trade Canada (DFAIT)

Authors:
Gregg Garfin, Institute of the Environment, University of Arizona
Nancy Lee, Agriculture and Agri-Food Canada
Víctor Magaña, Universidad Autónoma de México
Ronald Stewart, University of Manitoba
Jamie McEvo, University of Arizona

http://www.environment.arizona.edu/change
Gregg Garfin
Institute of the Environment
gmgarfin@email.arizona.edu
520-626-4372
http://www.environment.edu
2005
Wet winter
Salt and Verde
Reservoirs
Refill
Examples for Salt & Upper Colorado
2002 Rodeo-Chediski Fire

Salt and Verde June 1, 2002
6-mo MBDI

Salt and Verde June 1, 2002
24-mo MBDI