# Hydroinformatics: Extreme Events (Droughts)

# Introduction

- Water Scarcity is a human-made phenomenon.
- Drought is a natural phenomenon
- Drought is temporary for a period of time over a large region and deviation from average conditions
- Water Scarcity is a recurrent imbalance of water due to overuse of water resources, natural renewable availability and aggravated during droughts

# Introduction

- Drought is a natural disaster causing large-scale human suffering and huge economic loss globally
- Considered as one of the most important hydrologic extreme after floods
- Floods are region specific, but droughts are of the creeping kind.
- They develop in a region over a length of time and sometimes may extend to continental scale.
- Consequences: agriculture, hydropower generation and economy, environmental and health problems

# Droughts

- Recurrence of drought is unavoidable, as the phenomenon seems to be an inevitable and permanent part of the world's climate, especially with the recent indications of potentially increasing instability in the environment (greenhouse effect, ozone depletion, etc.).
- Anticipatory measures may include pre-drought preparation and planning drought description and forecasting; mitigation, relief and recovery adjustments; post-drought measures such as additional recommendations, revisions in planning, etc.
- Emergency conservation measures, drought relief activities, supply reallocation, etc.

# Drought as Extreme Event

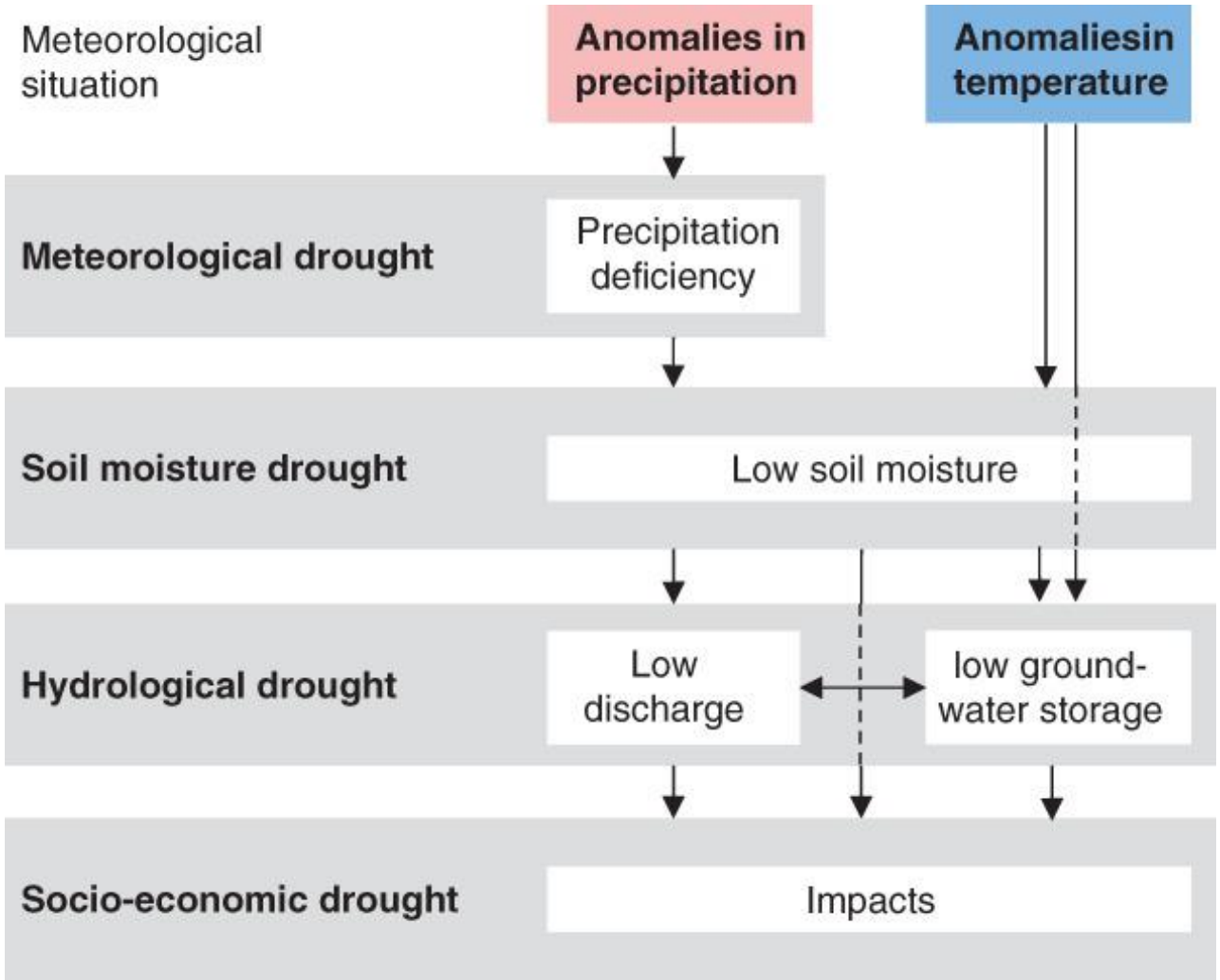
Among the extreme events, droughts are the most widespread and slowly developing atmospheric natural hazards which remain for a long duration affecting natural resources, environment, and people.

Deficit of rainfall over a period of time at a certain location could lead to various degrees of drought conditions, affecting water resources, agriculture and socio-economic activities.

it corresponds to the failure of spatial and temporal precipitation (meteorological drought) and water availability (hydrological drought) and therefore consequent impact on agriculture (agricultural drought), ecosystem and socioeconomic activities of the human being (socio-economic drought).

the state of adverse and widespread hydrological, environmental, social and economic impacts due to less than generally anticipated water quantities.

Source: https://www.thoughtco.com/drought-causes-stages-and-problems-1434940

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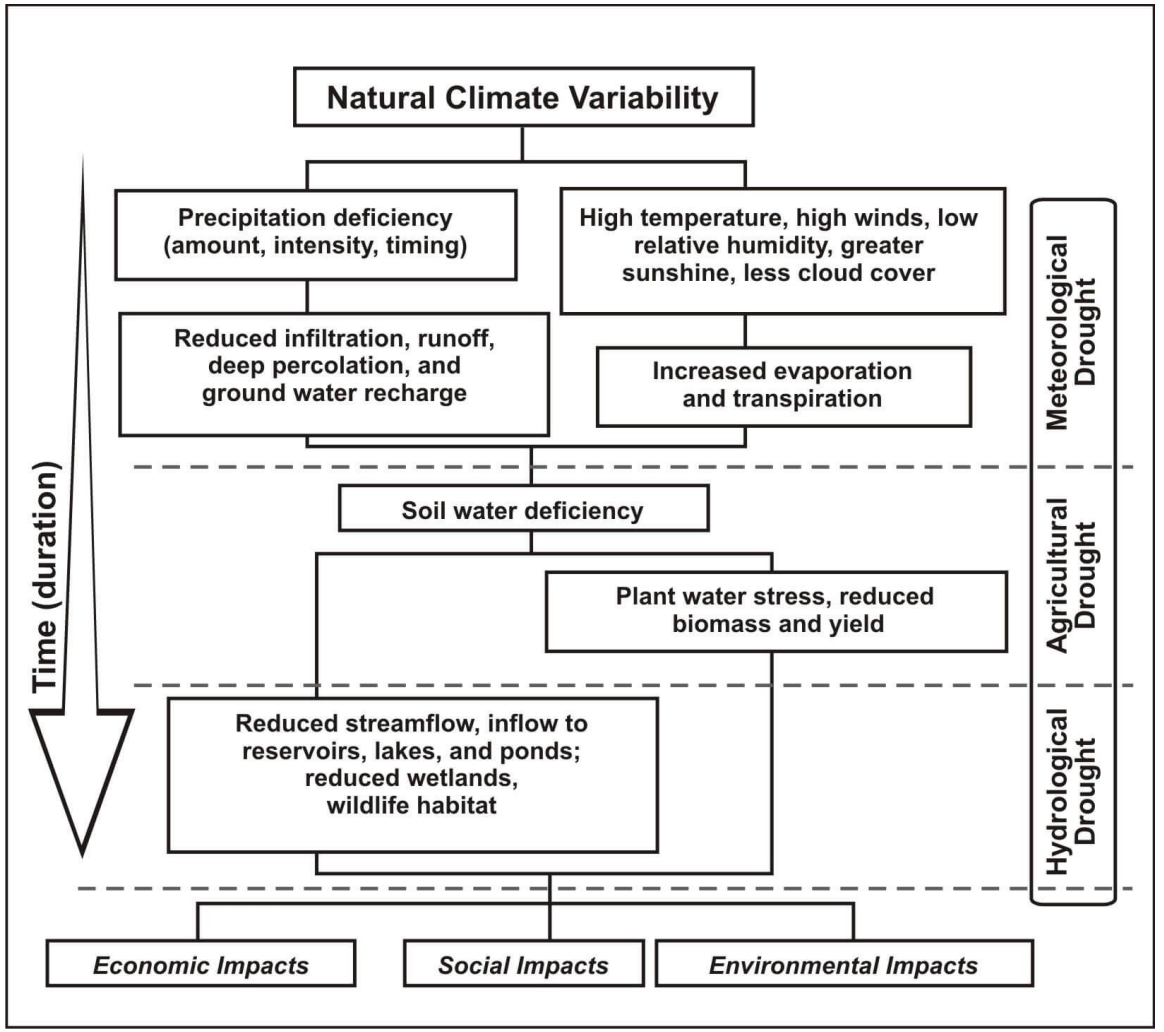
# Drought Sequence




Source: https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx

# United Nations Educational, Scientific and Cultural Organization (UNESCO) (2016)

- Meteorological drought: A temporary, negative and severe deviation from the average precipitation values for a significant period of time across a river basin or a region
- Blue-water drought: unusual and significant deficiency of ground water, stream flow or surface water bodies.
- A green drought: unusual and significant deficiency in water stored in or on the top of the soil or vegetation.

# Drought Indices

- Evaluate the deviation of climate variables in a given year from the normal conditions, a long term mean
- Rainfall deviation from normal - Meteorological
- Runoff deviation from normal - Hydrological
- Soil moisture or vegetation from normal - Agricultural
- Population, socioeconomic impact - Socio-economic drought

- ✓ Rainfall deviations cannot be applied uniformly on different areas having varying mean rainfall
- ✓ A high rainfall area and low rainfall area can have the same rainfall deviation for two different amounts of actual rainfall
- ✓ Therefore, rainfall deviations across space and time need to be interpreted with due care

# Standardized Precipitation Index (SPI)

- To calculate the SPI, a long-term precipitation record at the desired station is first fitted to a probability distribution (e.g. gamma distribution), which is then transformed into a normal distribution so that the mean SPI is zero. The SPI may be computed with different time steps (e.g. 1 month, 3 months, 24 months).
- World Meteorological Organization (WMO) recommends

- The standard normal distribution transformation:

  - It can transfer the mean and standard deviation adjusted to zero and one
  - Skewness of the existing rainfall data can be adjusted to zero
  - Transformation help in having SPI values can be interpreted as mean zero and standard deviation as one

**Table 1** Drought classifications based on SPI

| Probability (%) | SPI | Drought category |
|---|---|---|
| 2.30 | SPI ≥ 2.00 | Extreme wet |
| 4.40 | 2.00 > SPI ≥ 1.50 | Very wet |
| 9.20 | 1.50 > SPI ≥ 1.00 | Moderate wet |
| 68.20 | 1.00 > SPI ≥ −1.00 | Normal |
| 9.20 | −1.00 ≥ SPI > −1.50 | Moderate drought |
| 4.40 | −1.50 ≥ SPI > −2.00 | Severe drought |
| 2.30 | −2.00 ≥ SPI | Extreme drought |

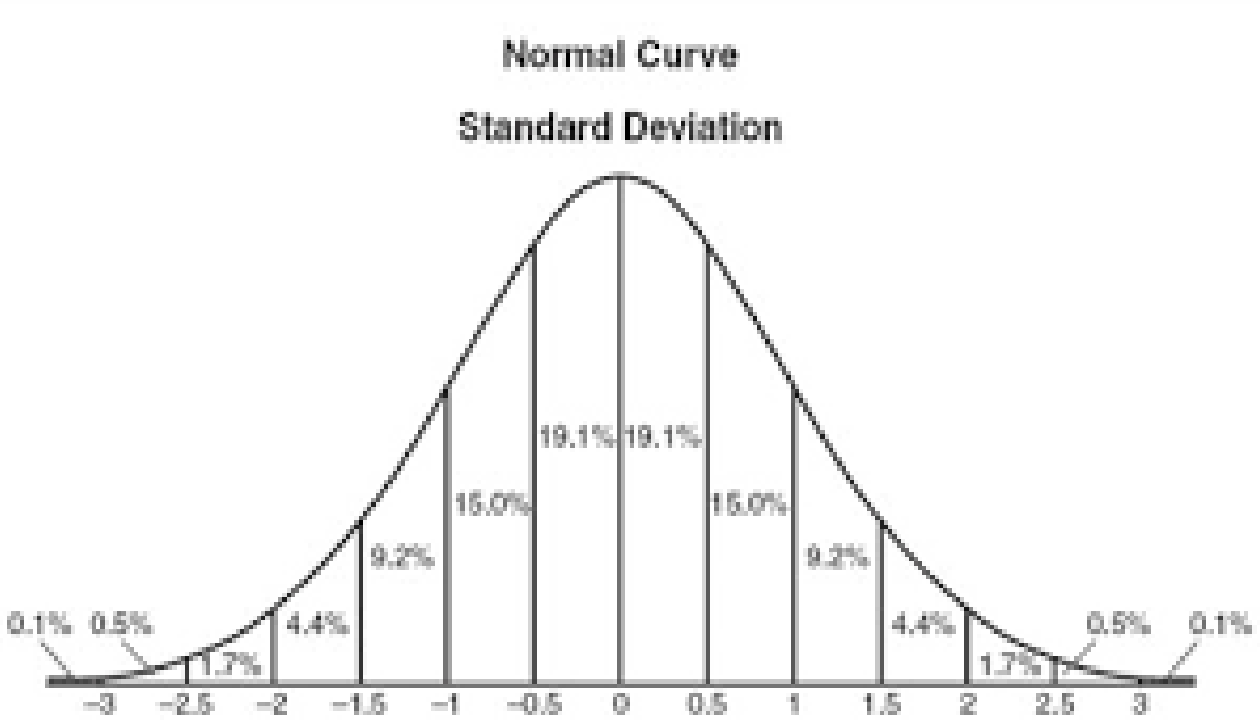
```
function [Z]=SPI(Data,scale,nseas)
%Standardized Precipitation Index
% Input Data
% Data : Monthly Data vector not
matrix (monthly or seasonal
precipitation)
% scale : 1,3,12,48
% nseas : number of season
(monthly=12)
```

$$g(x)=\frac{1}{\beta^{\alpha}\Gamma(\alpha)}x^{\alpha-1}e^{-x/\beta} \qquad \text{for } x>0$$

| | |
|---|---|
| $\alpha>0$ | $\alpha$ is a shape parameter |
| $\beta>0$ | $\beta$ is a scale parameter |
| $x>0$ | $x$ is the precipitation amount |
| $\Gamma(\alpha)=\int_0^{\infty}y^{\alpha-1}e^{-y}dy$ | $\Gamma(\alpha)$ is the gamma function |

- [Z] = SPI(Data,scale,nseas)
- parm = gamfit(Data);
- Gam_xs = q+(1-q)*gamcdf(Data,parm(1),parm(2));
- Z(tind)=norminv(Gam_xs);

$$Z=\frac{x-\mu}{\sigma}$$

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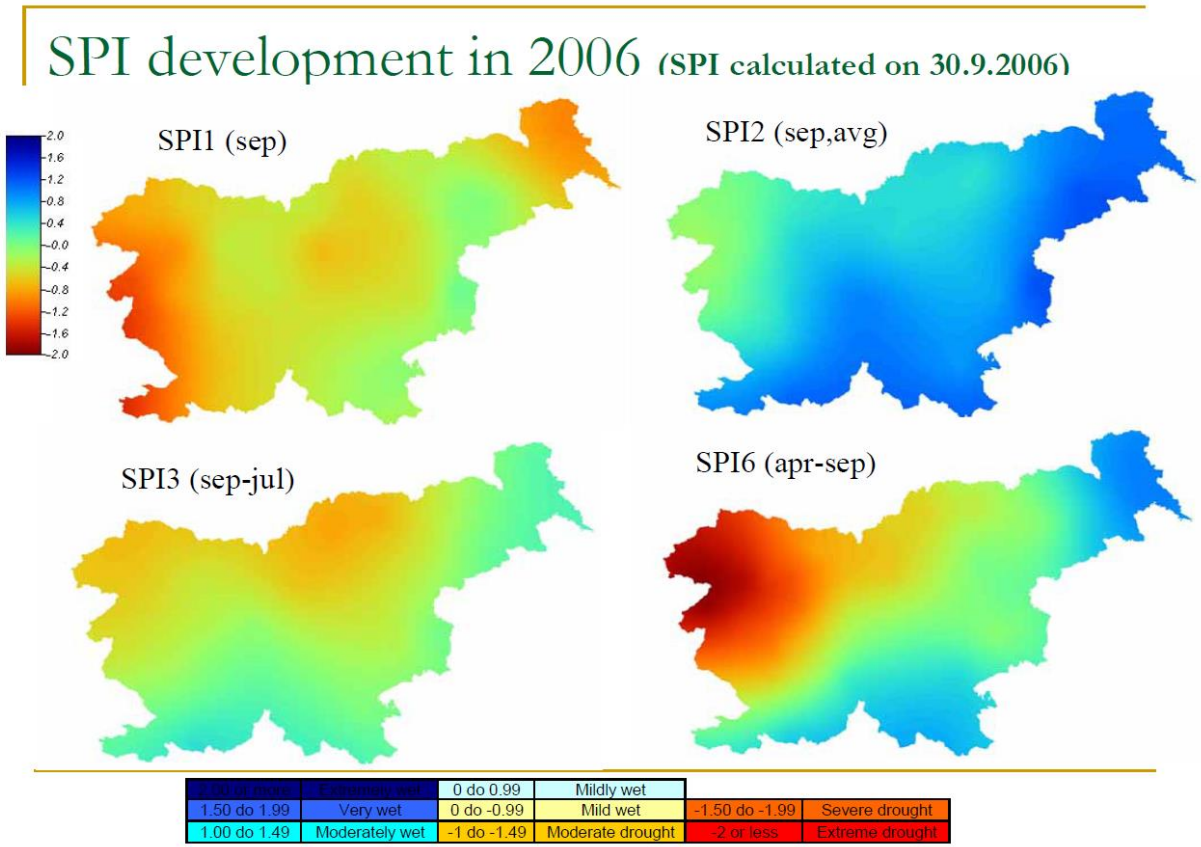
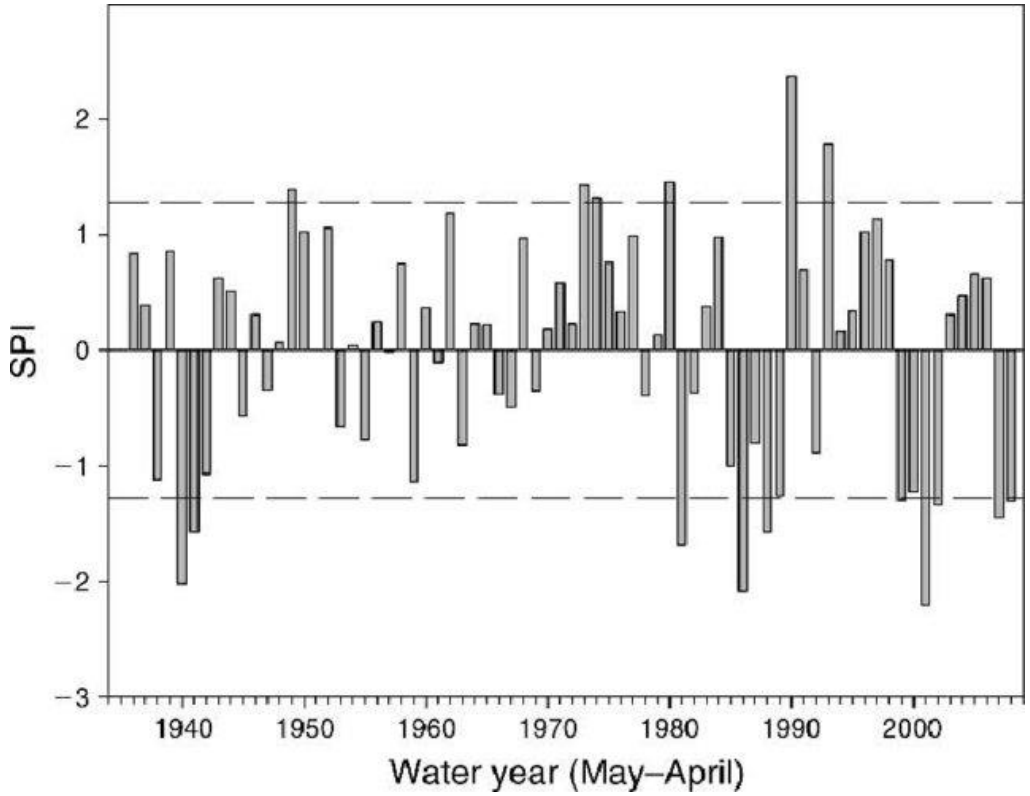
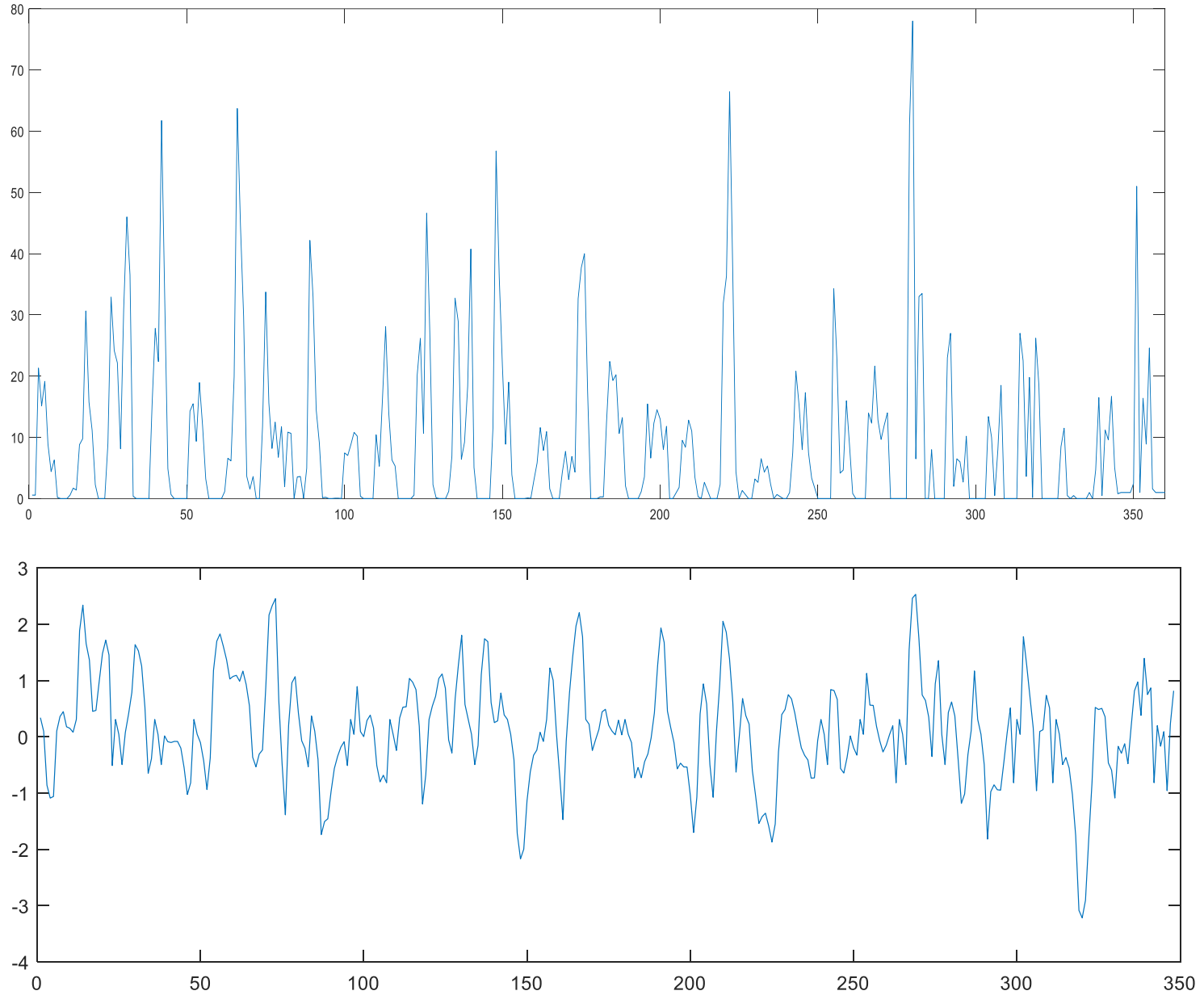



Agricultural drought conditions can be monitored with shorter time periods, such as the SPI for 3 or 6 months, while hydrological or water management might be more interested in SPI values for 12 or 24 months.


80
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60
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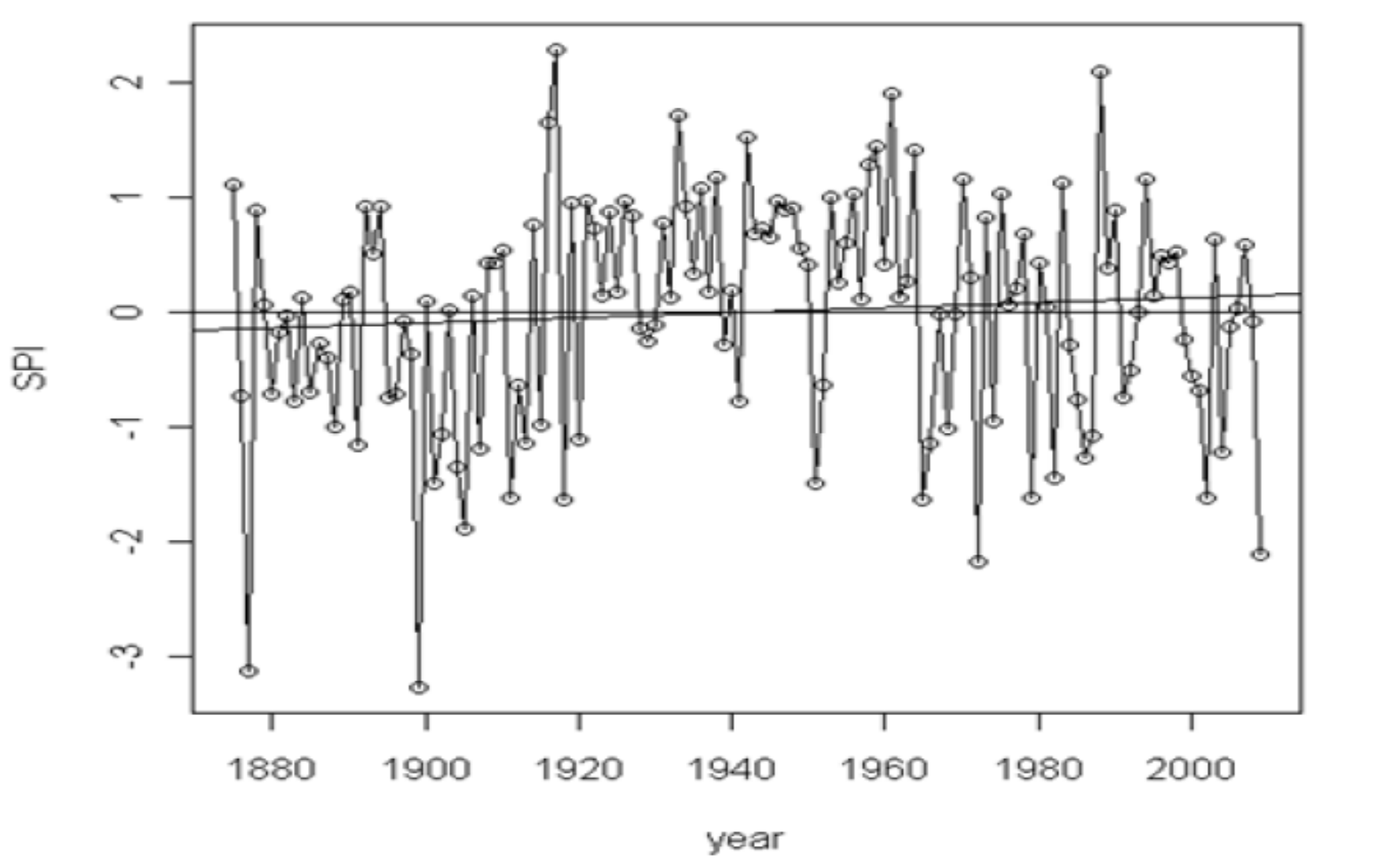


**Temporal variation of Standardized Precipitation Index (SPI) in India, 1875-2004.**

# Drought Characterization

- Intensity
- Frequency
- Duration
- Areal Extent

# Intensity of Drought

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# Frequency of Drought

- Number of drought events in a given time period
- Moderate Drought Frequency: $-1.5 < \text{SPI/SPEI/SRI/SSI} \leq -1.0$
- Severe Drought Frequency: $-2.0 < \text{SPI/SPEI/SRI/SSI} \leq -1.5$
- Extreme Drought Frequency: $\text{SPI/SPEI/SRI/SSI} \leq -2.0$

# Duration and Severity of Drought

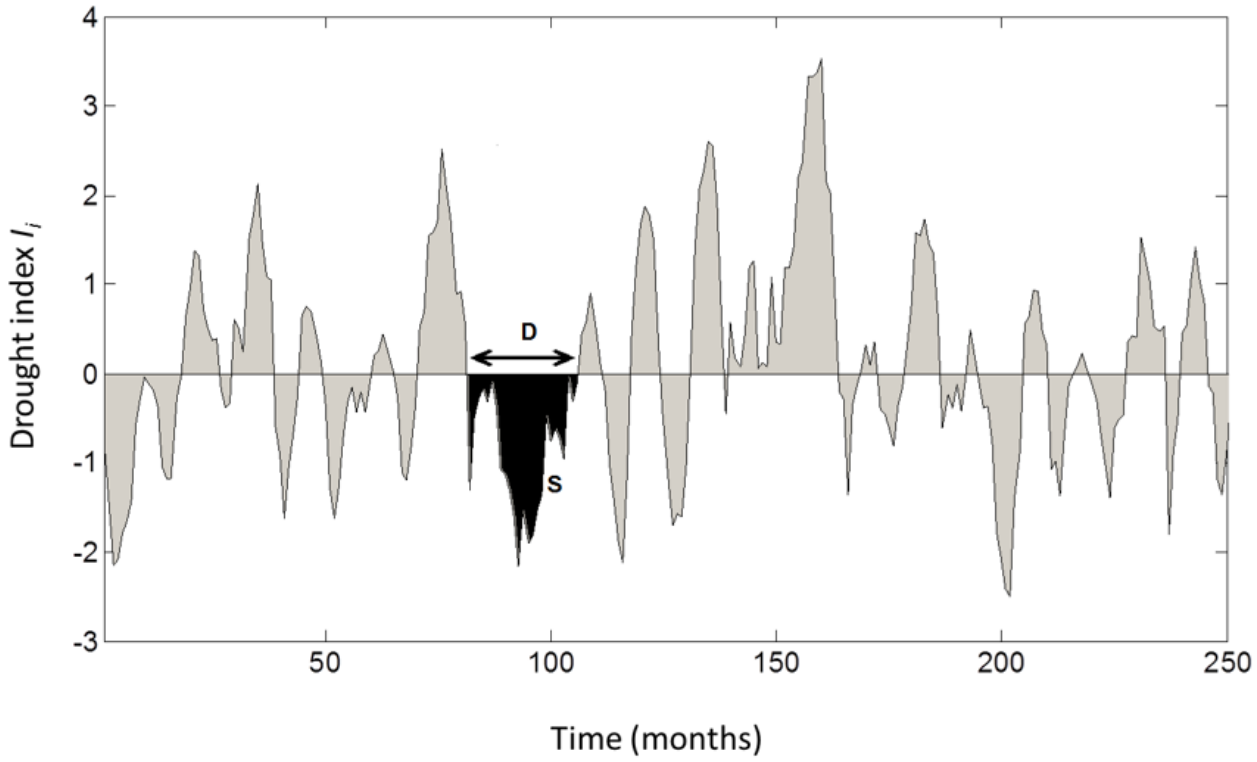
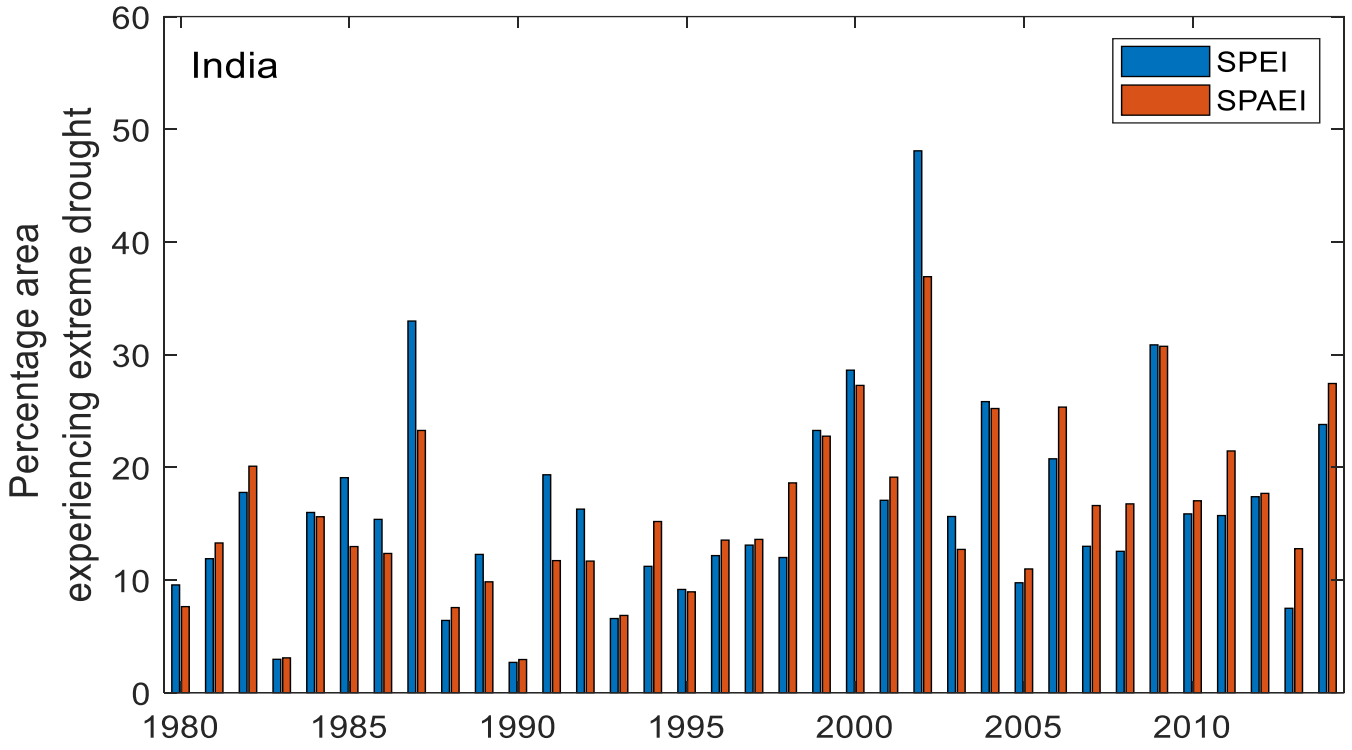



**Figure 3.** Concept of severity $S$ and duration $D$ of a drought event quantified with drought index $I_i$, where $i$ refers to any timescale of interest.

Source: Halwatura, D., Lechner, A. M., and Arnold, S.: Drought severity–duration–frequency curves: a foundation for risk assessment and planning tool for ecosystem establishment in post-mining landscapes, Hydrol. Earth Syst. Sci., 19, 1069–1091, https://doi.org/10.5194/hess-19-1069-2015, 2015

# Areal Extent of Drought




The areal extent of drought was estimated as the ratio of grids affected with various categories (including moderate, severe and extreme) of drought to the total grid points covering the entire river basin

Percentage of extreme drought (SPEI/SPAEI <-2) areal extent estimated by SPEI and SPAEI for each meteorological zone and for all over India for period of 1980 to 2014:

# Recap

- Drought: Deviation from normal conditions
- Drought Types: Meteorological, Hydrological, Agricultural
- Drought Indices: SPI, SPEI, SRI, SSI
- Drought Characterization: Intensity, Frequency, Duration, Areal Extent

# Generalized Procedure of Development of a Drought Index

- Time series: Rainfall
- Fit a probability distribution – Gamma distribution
- Converting into Standard normal probabilities
- Categories the drought based on the classification

# Assignment - 1

- **Spatiotemporal Trend analysis of Droughts for any given Region**
  - Formulate the drought index – SPI
  - User interface: Time of accumulation: SPI-1, SPI-3, SPI-6, etc.
  - Drought Characterization: Intensity, Frequency, duration and spatial extent
  - Drought SpatioTemporal Analysis and trends: Monotonic Trends, Magnitude of Trend and significant change in the trend

# More about the Assignment

- Group Assignment
- Each group will be contributing to the Assignment with equal contributions from each of the group member
- Assignment Presentation and submission: March 1st