TIME-VARYING METEOROLOGICAL DROUGHT FOR A CHANGING CLIMATE

Dr. Vinnarasi R.

Researcher

Department of Civil Engineering

Indian Institute of Technology Delhi
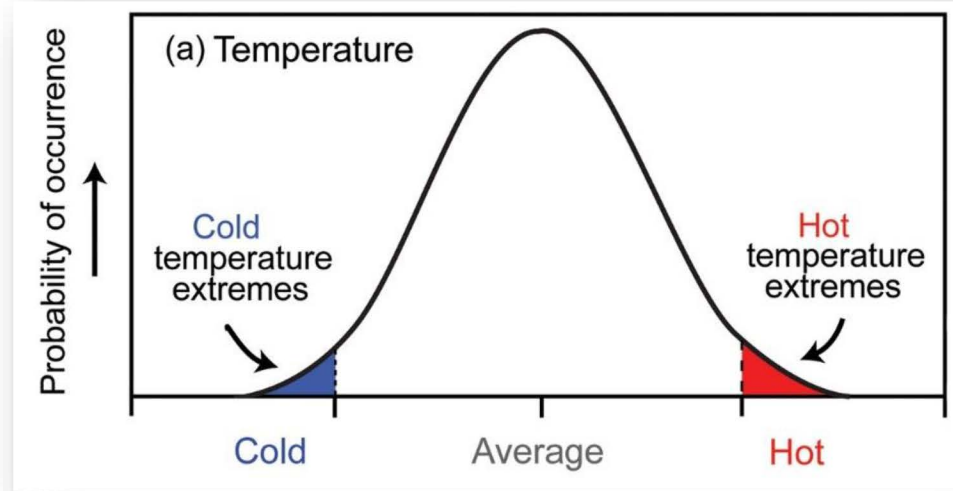
Prof. C.T. Dhanya

Associate Professor

Department of Civil Engineering
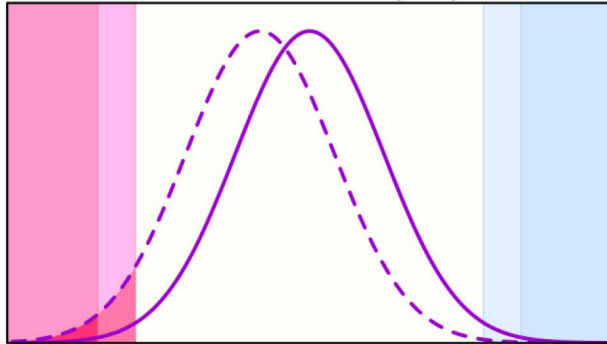
Indian Institute of Technology Delhi

Introduction

- The assessment and quantification of drought is crucial as it is one of the major and costly extreme events.

- The prediction of drought and its characteristics like severity, duration, etc... is important for its planning and mitigation.

- Commonly used drought index is Standardardized Precipitation Index – based on stationary assumption.

- Precipitation series has undergone remarkable changes, which emphasizes the need for developing a drought index incorporating the dynamic behavior (Non-stationarity) of the precipitation

Non-stationarity in Extremes ???

(a) Temperature

Probability of occurrence

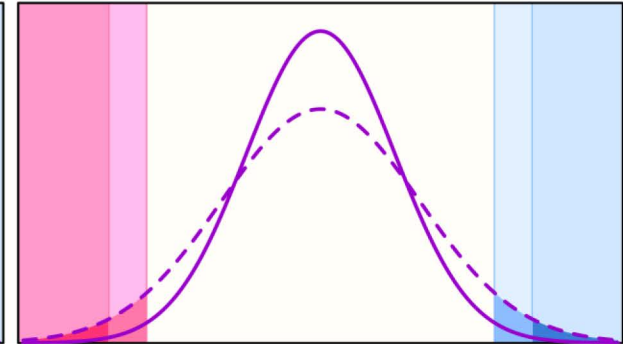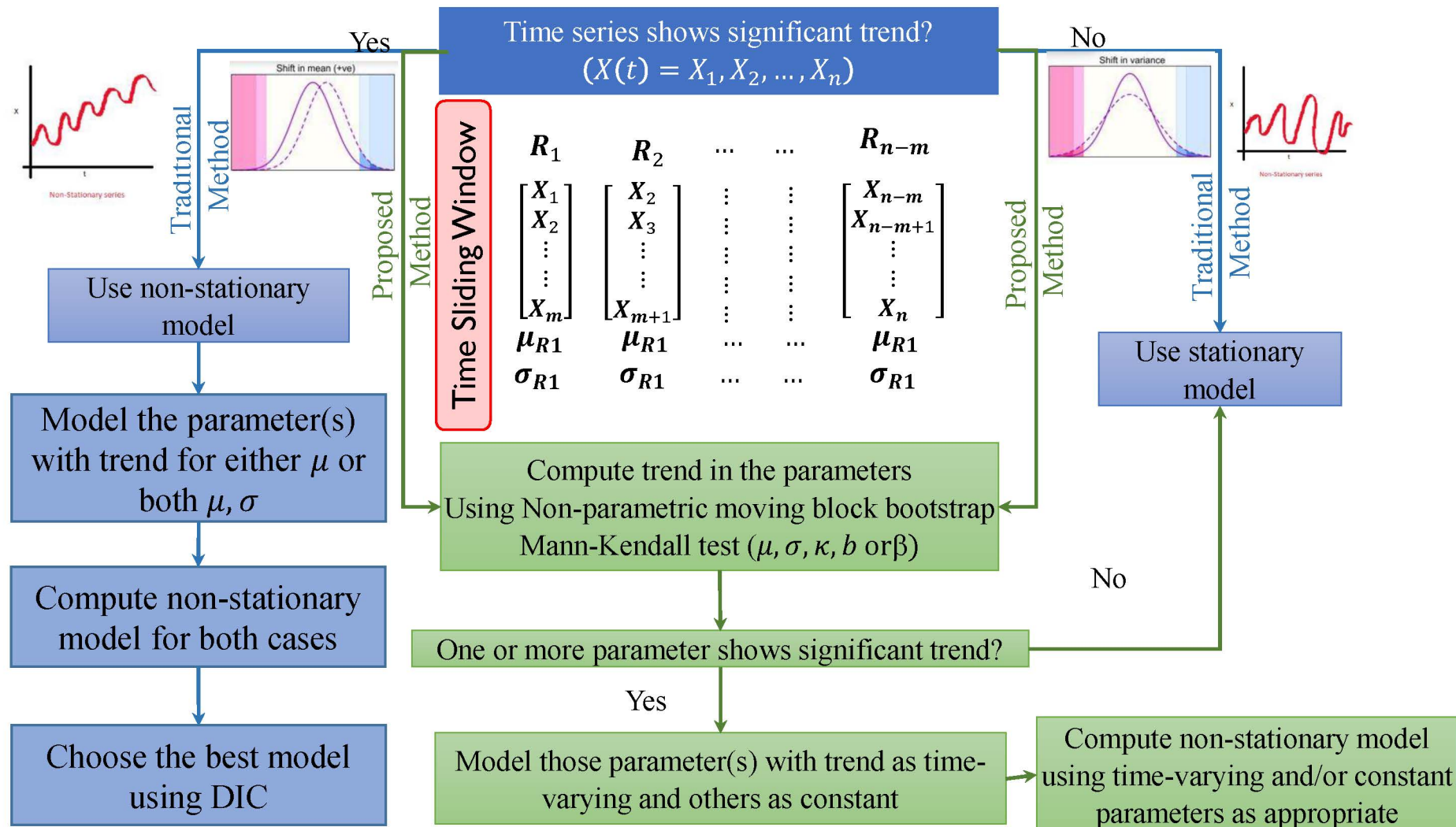Cold temperature extremes

Hot temperature extremes

Cold — Average — Hot

Shift in mean (-ve)	Shift in mean (+ve)	Shift in variance
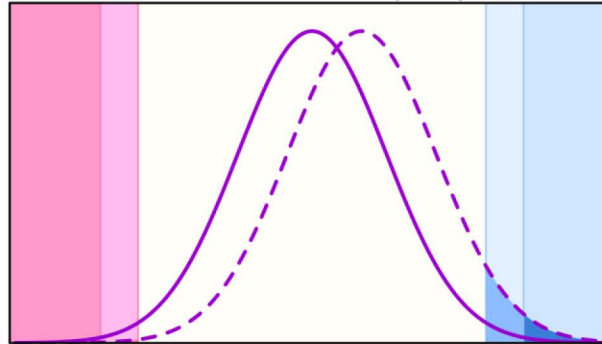
Non-stationarity: Change in the statistical parameters over time

Time series shows significant trend?
$$(X(t) = X_1, X_2, \ldots, X_n)$$

Yes — No

Traditional Method

Proposed Method

Time Sliding Window

Proposed Method

Traditional Method

Shift in mean (+ve)

Shift in variance

Non-Stationary series

Non-Stationary series

Use non-stationary model

Use stationary model

$$
\begin{array}{ccccc}
R_1 & R_2 & \ldots & \ldots & R_{n-m} \\[4pt]
\begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_m \end{bmatrix} &
\begin{bmatrix} X_2 \\ X_3 \\ \vdots \\ X_{m+1} \end{bmatrix} &
\vdots & \vdots &
\begin{bmatrix} X_{n-m} \\ X_{n-m+1} \\ \vdots \\ X_n \end{bmatrix} \\[4pt]
\mu_{R1} & \mu_{R1} & \ldots & \ldots & \mu_{R1} \\
\sigma_{R1} & \sigma_{R1} & \ldots & \ldots & \sigma_{R1}
\end{array}
$$

Model the parameter(s) with trend for either μ or both μ, σ

Compute non-stationary model for both cases

Choose the best model using DIC

Compute trend in the parameters Using Non-parametric moving block bootstrap Mann-Kendall test (μ, σ, κ, b or β)

One or more parameter shows significant trend?

No

Yes

Model those parameter(s) with trend as time-varying and others as constant

Compute non-stationary model using time-varying and/or constant parameters as appropriate

Non-stationary Standardized Index

SI modified

Month	Rainfall	ATS (3 months)
Sep-51	248.2	
Oct-51	341.39	
Nov-51	381.89	
Dec-51	436.17	
Jan-52	442.31	878.48
Feb-52	384.78	827.09
Mar-52	394.13	778.91
Apr-52	318.71	712.84
May-52	282.15	600.86

TS = 3 months	Jan	. . .	Mar
1952	433.6	. . .	394.4
1953	374.99	. . .	374.17
1954	409.99	. . .	390.69
1955	394.51	. . .	391.82
. . .	. . .	. . .	. . .
. . .	. . .	. . .	. . .
2011	471.7	. . .	453.28
2012	433.35	. . .	460.4
2013	455.72	. . .	441.69
Distribution parameters			
α	446.35	. . .	436.65
β	1.9319	. . .	1.8358

Precipitation timeseries
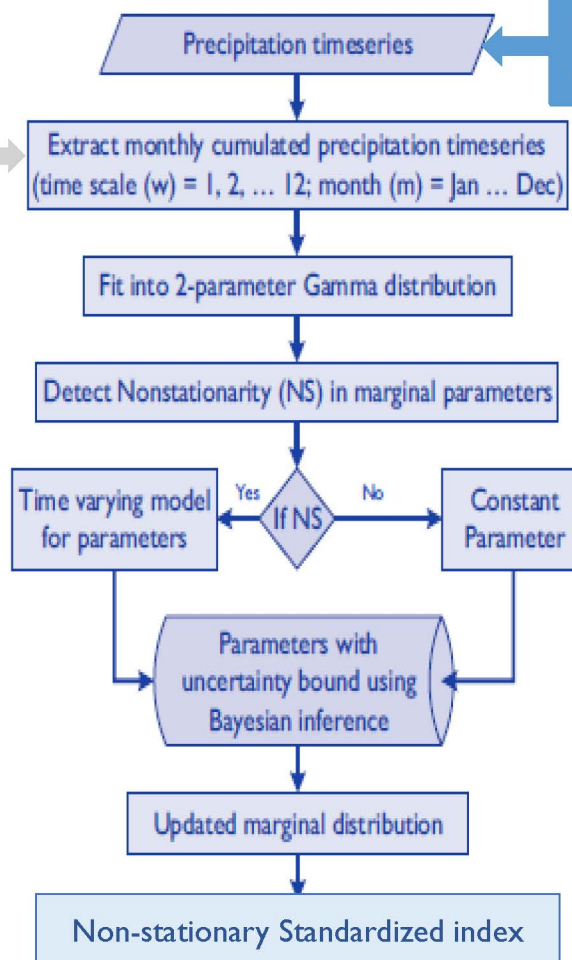
- 0.25*0.25 IMD gridded rainfall
- Period: 1901 to 2013

Extract monthly cumulated precipitation timeseries (time scale (w) = 1, 2, … 12; month (m) = Jan … Dec)

Fit into 2-parameter Gamma distribution

Detect Nonstationarity (NS) in marginal parameters

Time varying model for parameters — Yes — If NS — No — Constant Parameter

Parameters with uncertainty bound using Bayesian inference

Updated marginal distribution

Non-stationary Standardized index

- NSI^{mod} for 12-month time scale is computed as,

$$SI_s^{mod} = \Phi^{-1}(U_{12,t})$$

- Modified SI index is used
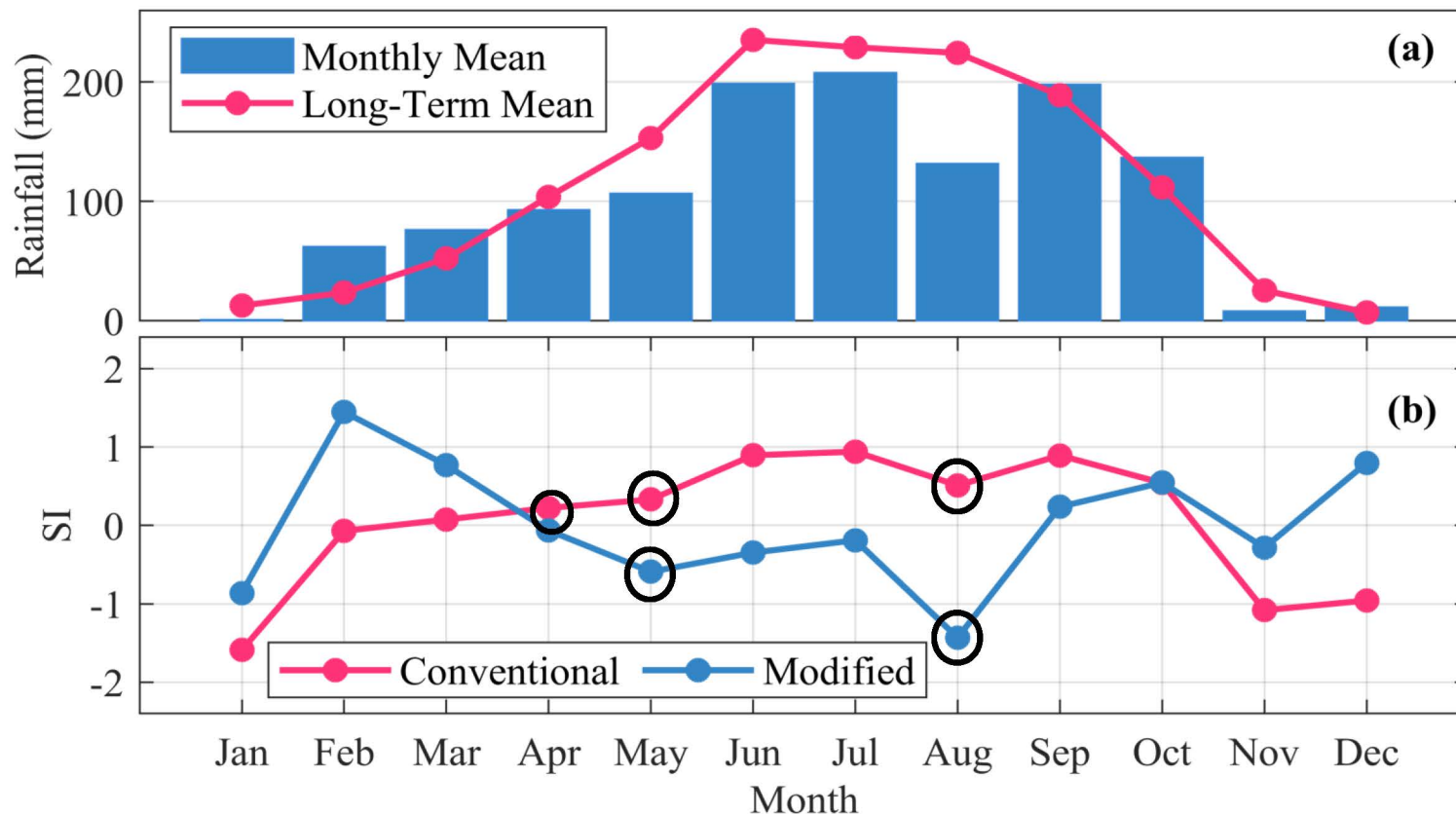
Comparison between conventional and modified 1-month SI (26°N, 93 °E)

- Aggregated rainfall series is extracted for all the months and for 12 time scales

- Goodness of fit for gamma distribution of each series is estimated and found 5.6% series failed KS test, which are fitted using empirical distribution

- > 90% of grids undergone term changes
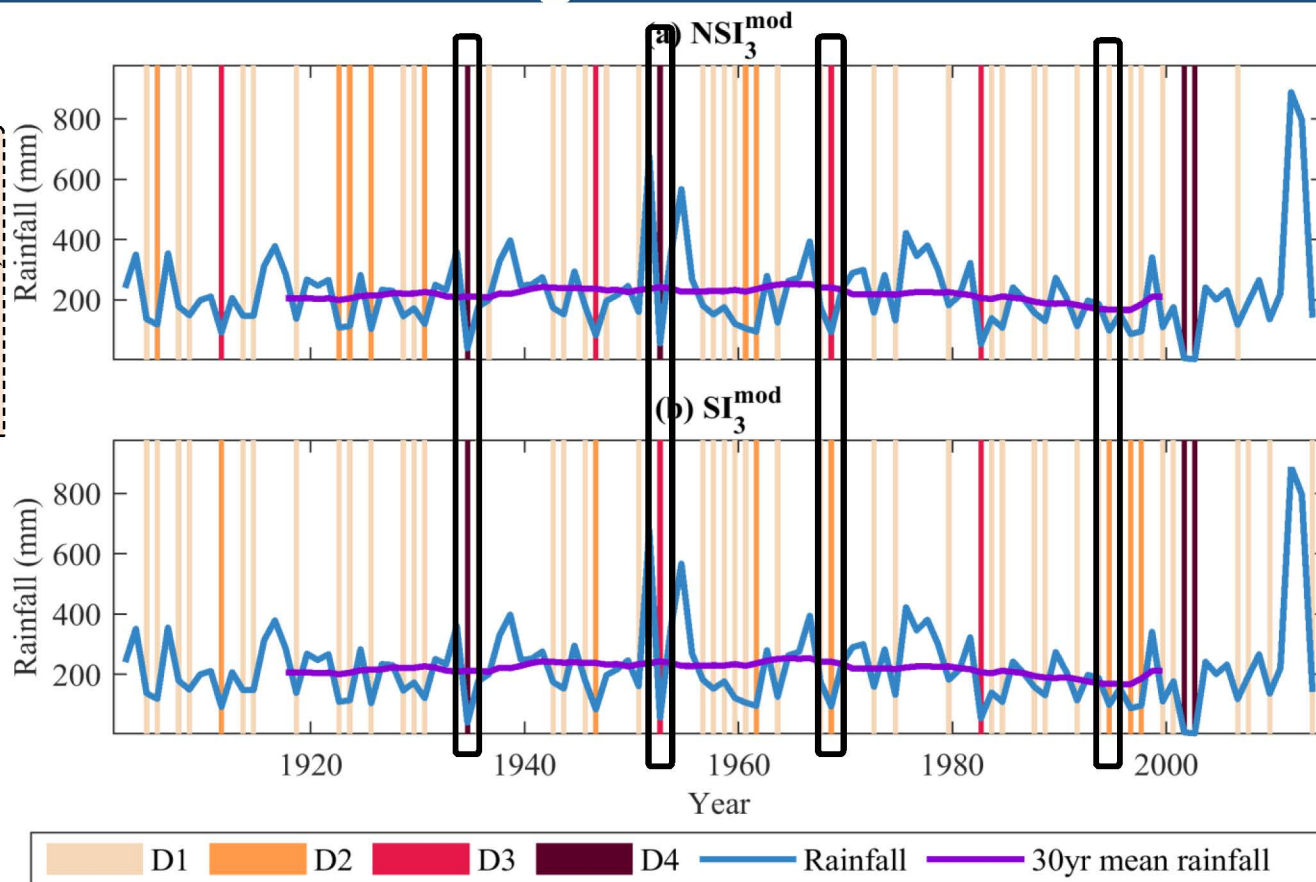
- < 10% grids show no change in the time series
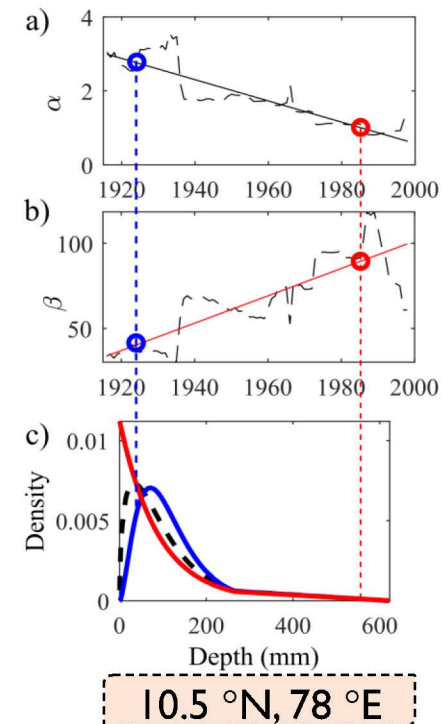
10.5 °N, 78 °E

Probability of drier events has increased

In the year 1968 and 1994

- Rainfall depth - 93.1/98.2mm

- Average rainfall - 241.1/168.3mm

- Rainfall deficit - 148/70.1mm

- Deficit of rainfall in 1934/1952 is 171.9/186.9mm

- D4/D3 category in SI

- D4 category in NSI
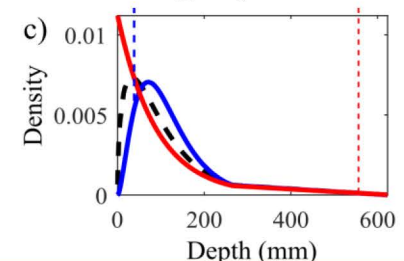
SI identifies higher severity in the latter part and ignores in the initial part

Highlights

1. A dynamic meteorological drought index is proposed to capture the temporal dynamics of the precipitation

2. Unlike traditional-nonstationary modelling, the present approach detects the non-stationarity in each distribution parameter using a time-sliding window

3. NSI captured the historical drought, capturing the temporal dynamics of precipitation series in India and is more reliable than SPI.

4. SPI either over-estimate or under-estimate the drought status

5. The proposed NSI is found to be a potential index for drought monitoring in a nonstationary climate.

Reference

1. Vinnarasi R., Dhanya C.T., 2019, "Bringing realism into a dynamic copula-based non-stationary intensity-duration model", Advances in Water Resources, 130, 325-338

2. Vinnarasi R., Dhanya C.T., 2016, "Changing characteristics of extreme wet and dry spell of Indian rainfall", Journal of Geophysical Research Atmospheres, 121(5), 2146-2160.

3. Mckee, T. B., N. J. Doesken, and J. Kleist (1993), The relationship of drought frequency and duration to time scales, (January), 17–22.