Challenges for assessing the risk of compound extremes

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Background and Motivation

- India has witnessed compound dry and hot summers that occurred during 1957, 1972, 1979, 2002, 2009 and 2014, causing a significant crop yield reduction[1].

- The severity of such events depends on the marginal distribution of drivers and their dependence[2]

- Study demonstrates compound extremes severity is a function of reference period.

Compound Dry Hot Events (1961-1990)
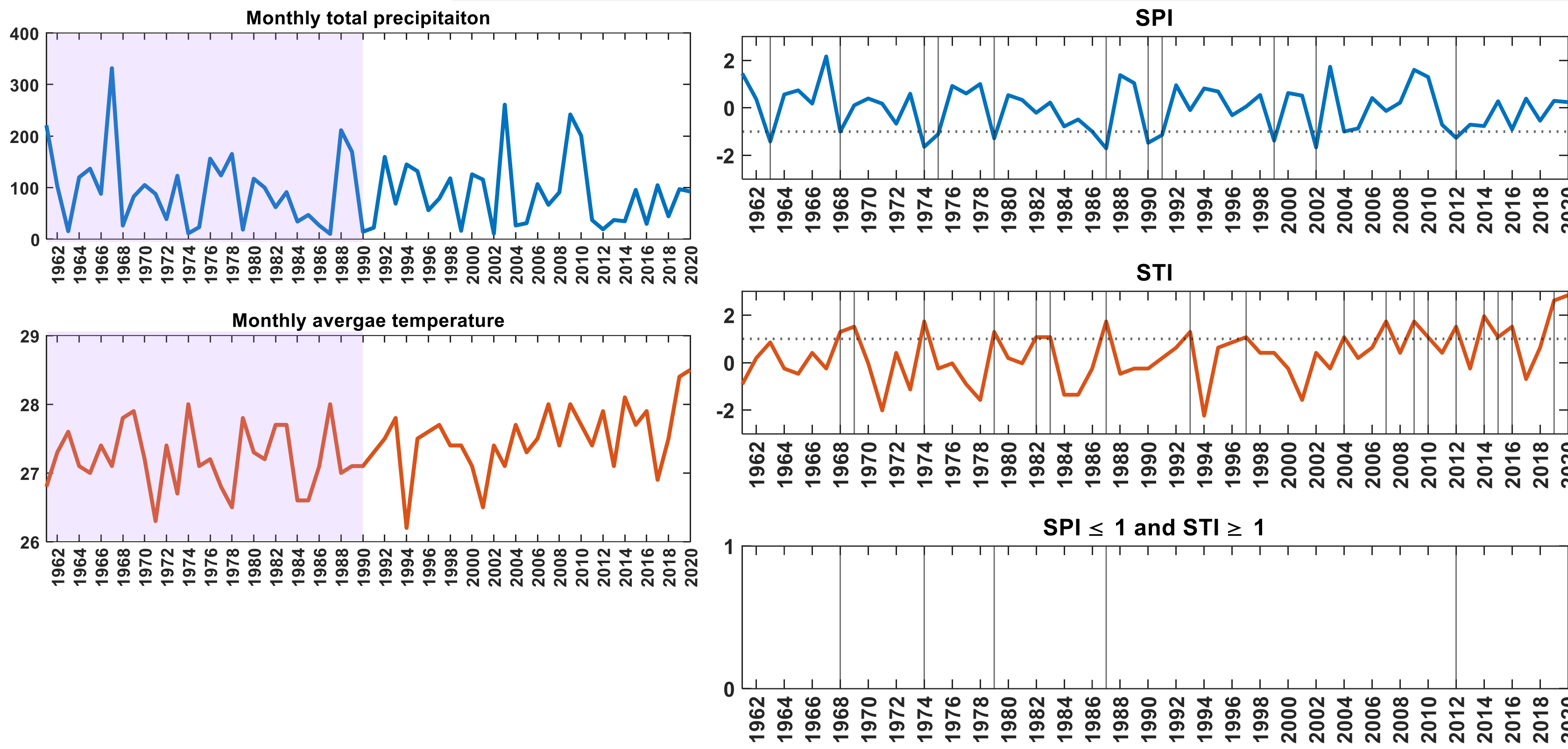
Compound Dry Hot Events (1991-2020)
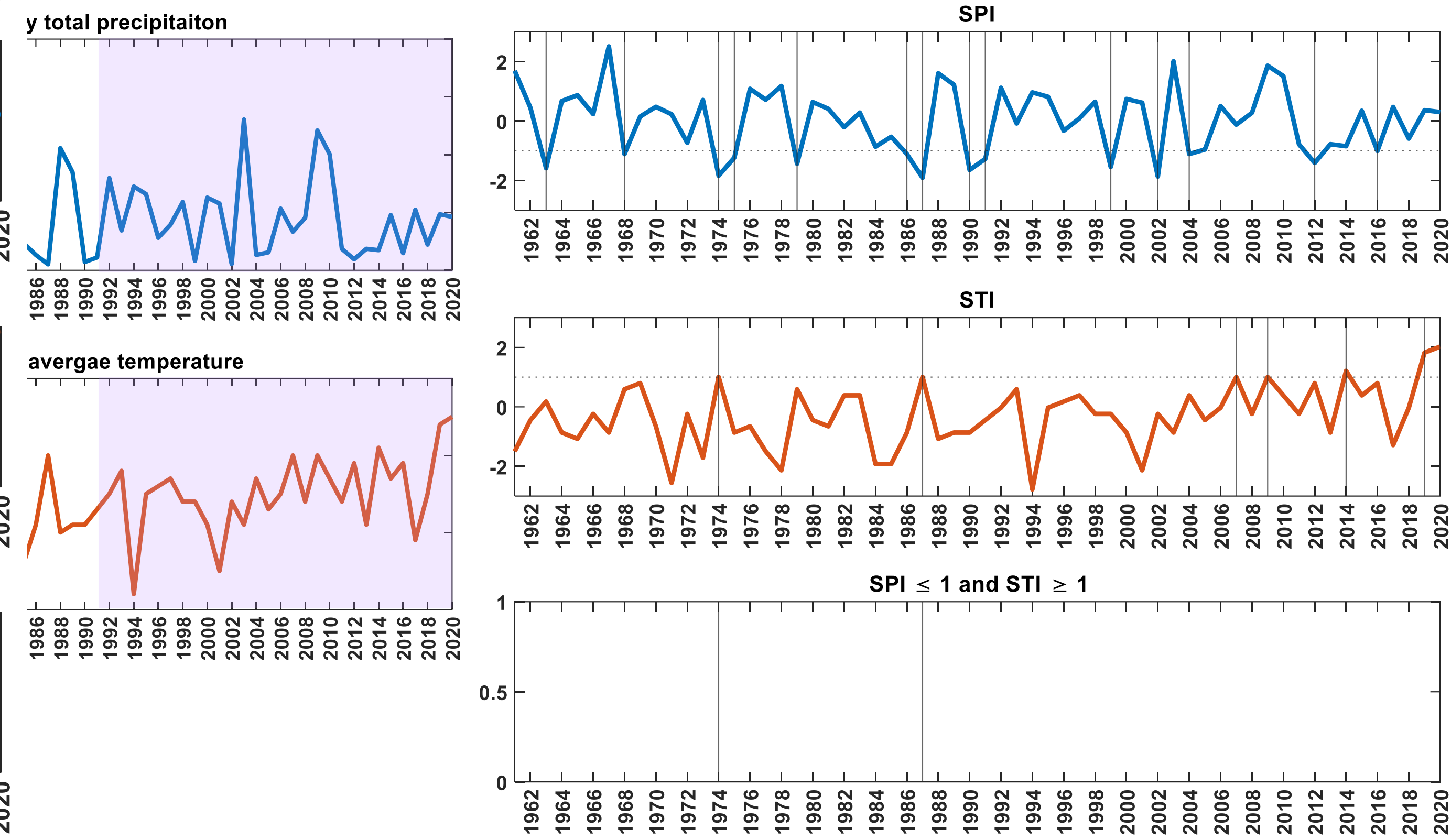
How to derive Standardized value for Compound Dry Hot Index (SCDHI)?

$$SCDHI = \emptyset^{-1}\left(P\big(Pre \leq x\,(dry) \cap Temp > y\,(hot)\big)\right)$$

Considering $Pre = X$ and $Temp = Y$

$$SCDHI = \emptyset^{-1}\big(P(X \leq x).P(Y > y)\big)$$
$$SCDHI = \emptyset^{-1}\big(P(X \leq x).[1 - P(Y \leq y)]\big)$$
$$SCDHI = \emptyset^{-1}\big(P(X \leq x) - P(X \leq x).P(Y \leq y)\big)$$
$$SCDHI = \emptyset^{-1}\big(P(X \leq x) - C(P(X \leq x), P(Y \leq y), \theta)\big)$$

Considering Frank Copula,

$$C(P_x, P_y, \theta) = \frac{-1}{\theta} ln\left(1 + \frac{(exp(-\theta P_x) - 1)(exp(-\theta P_y) - 1)}{exp(-\theta) - 1}\right)$$
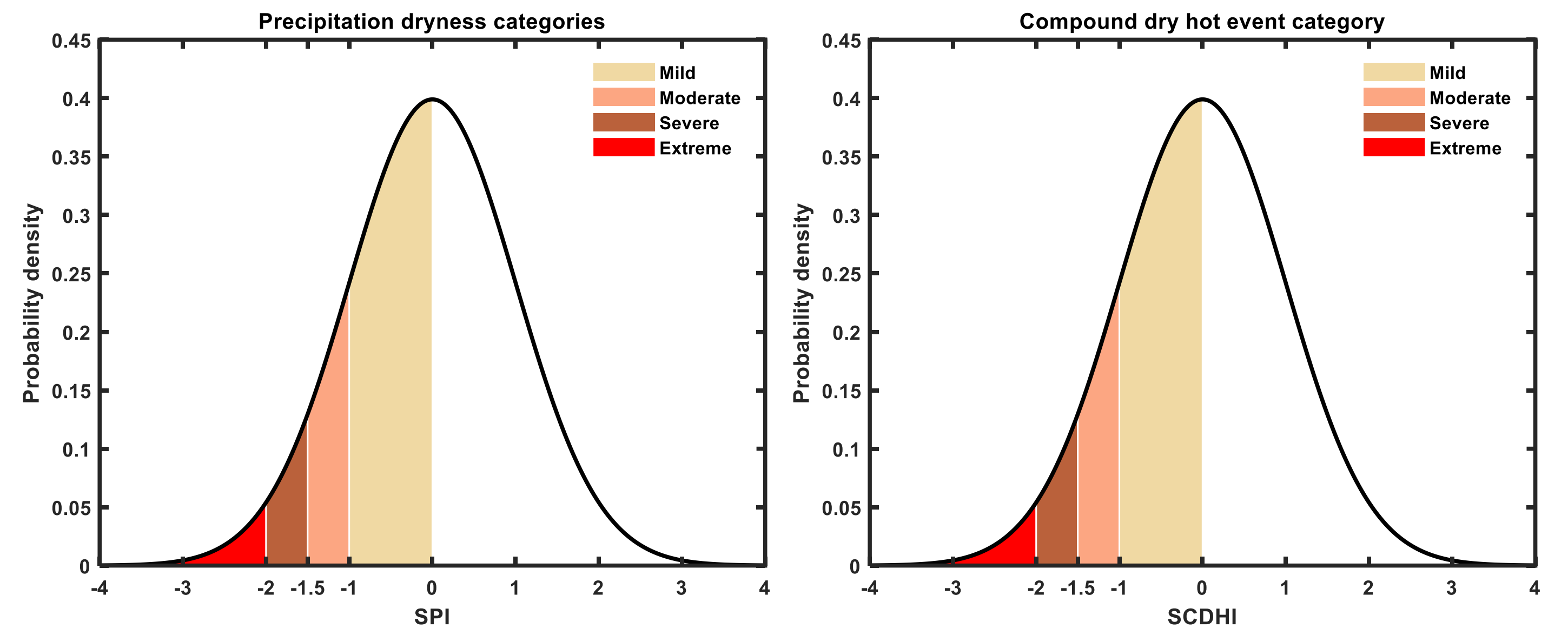
SPI/SCDHI	Category	Severity
0 to -0.99	Mild	1 in 3 yrs.
-1.00 to -1.49	Moderate	1 in 10 yrs.
-1.50 to -1.99	Severe	1 in 20 yrs.
<-2.0	Extreme	1 in 50 yrs.

$Year$	P_x	SPI	P_y	STI	$C(P_x,P_y,\theta)$	$P_x - C(P_x,P_y,\theta)$	$SCDHI$
1968	0.1585	**-1.00**	0.9050	1.31	0.1253	0.0332	**-1.84**
1974	0.0505	**-1.64**	0.9601	1.75	0.0451	0.0451	**-2.56**
1979	0.0993	**-1.28**	0.9050	1.31	0.0772	0.0772	**-2.01**
1987	0.0443	**-1.70**	0.9601	1.75	0.0396	0.0396	**-2.60**
2012	0.1036	**-1.26**	0.9372	1.53	0.0879	0.0879	**-2.15**

Role of reference period

$Year$	1961 − 1990			1971 − 2000			1991 − 2020		
	SPI	STI	SCDHI	SPI	STI	SCDHI	SPI	STI	SCDHI
1968	-1.00	1.31	-1.84						
1974	**-1.64**	**1.75**	**-2.56**	**-1.70**	**1.63**	**-2.61**	**-1.84**	**1.00**	**-2.45**
1979	-1.28	1.31	-2.01	-1.31	1.21	-2.07			
1987	**-1.70**	**1.75**	**-2.60**	**-1.76**	**1.63**	**-2.66**	**-1.91**	**1.00**	**-2.51**
2012	-1.26	1.53	-2.15	-1.28	1.42	-2.19			

Conclusions

Thus, modelling of single extreme

➢**Underestimate** the risk of compound extreme

➢Compound dry hot event in history **is becoming normal** in the recent period

Acknowledgement

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Co-PREPARE

[1] R.K. Guntu, and A. Agarwal, Scientific reports, **11**, 16447 (2021)

[2] Guntu et al., Accepted in Atmospheric Research