Temporal characteristics of evaporation trends and their attribution to meteorological drivers in Roorkee (India)

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Abstract

Pan evaporation is an important indicator of atmospheric evaporative demand, and its long-term variation is of much concern in studies of climate change. Estimation of evaporation is also important for water budgeting and yet is difficult to quantify because of the combined effects of four meteorological variables: net radiation, wind speed, atmospheric humidity, and air temperature. This work considered the temporal trends of pan evaporation and the meteorological variables that affect them for a station located in Roorkee (India). In this study, observed meteorological data at NIH observatory for the period from 1987 to 2018 was used for trend analysis of the data (rainfall, relative humidity, maximum temperature, minimum temperature, average temperature, wind speed and pan evaporation). Evaporation was also estimated using Penman method, Meyer method and other empirical equations, and compared with the observed evaporation values. Anomalies in the time series of meteorological variables were computed to find out the magnitude of rise or fall in the series. Pettitt-Mann-Whitney (PMW) test for detection of shift in the time series has been carried out, and the trend and shift in meteorological data is correlated with the same in evaporation. Based on this research, a number of conclusions are drawn: (1) minimum temperature and relative humidity have been increasing whereas maximum temperature and wind speed have been decreasing during the period 1987-2018, (2) pan evaporation series has not shown any significant trend, except during post-monsoon when it decreased, (3) significant change points (shifts) in the time series of temperature, relative humidity and wind speed may attribute the influence of fast urbanization and enhanced anthropogenic activities in Roorkee town after creation of Uttarakhand as a separate State in the year 2000.

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Parameter	Winter (JF)		Pre-monsoon (MAM)		Monsoon (JJAS)		Post- monsoon (OND)		Annual	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Rainfall (mm)	66.1	49.1	74.3	47.3	880.7	258.5	19.0	27.2	1040	249.4
T min (°C)	8.6	0.8	18.9	1.0	25.2	0.6	15.4	1.2	17.8	0.7
T max (°C)	26.8	1.4	38.4	1.1	37.5	1.7	32.0	2.7	34.1	1.3
T average (°C)	17.7	0.7	28.6	0.7	31.3	0.8	23.7	1.3	26.0	0.5
Wind speed (km/hr)	1.2	0.6	2.0	1.0	1.6	0.8	0.7	0.4	1.5	0.7
Relative Humidity (%)	87.5	4.4	58.3	4.3	79.4	3.3	79.2	4.8	76.1	3.4
Evaporation (mm)	112.1	16.5	459.2	60.8	451.9	70.1	125.6	16.8	1148.8	132.7

Month	Pan evaporation (mm)	Open surface evaporation (0.7*pan evaporation)	Penman method	Meyer Method	Empirical formula (EI)	Empirical formula (EII)
Jan	29.6	20.7	17.4	21.7	10.1	14.9
Feb	52.6	36.9	36.0	44.0	22.2	30.2
Mar	97.0	67.9	97.7	117.5	62.2	80.7
Apr	165.6	116.0	218.9	261.8	140.8	179.9
May	196.6	137.6	280.9	332.8	181.2	228.5
Jun	163.0	114.1	197.1	233.6	127.0	160.2
Jul	111.5	78.1	81.3	99.1	50.3	68.1
Aug	90.4	63.3	65.4	80.9	40.6	55.6
Sep	86.8	60.8	67.0	84.3	40.5	58.1
Oct	80.2	56.1	77.5	101.2	44.3	69.7
Nov	45.4	31.8	44.8	59.7	24.8	41.1
Dec	29.7	20.8	21.5	28.3	12.0	19.4

Performance Parameters	Penman Method	Meyer Method	Empirical equation (E-I)	Empirical equation (E-II)
Percentage error (monthly values)	4.96	27.53	-34.19	-12.38
Coefficient of Determination (R^2)	0.88	0.87	0.84	0.86

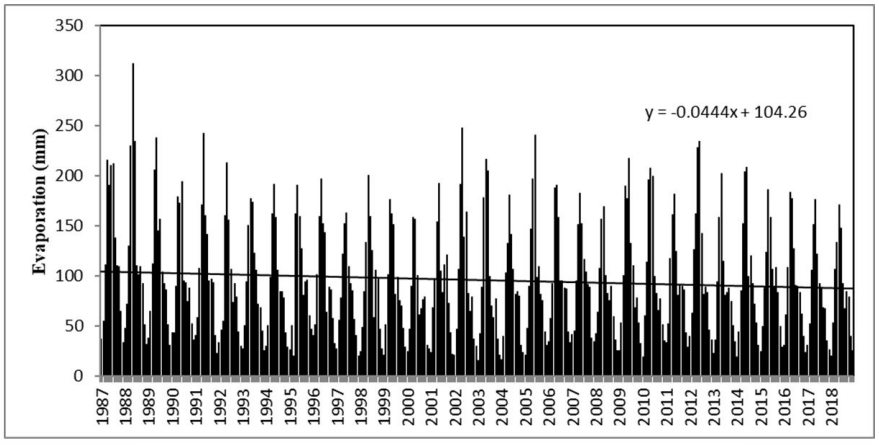
Season	**Penman Method**	**Meyer Method**	**Empirical formula (EI)**	**Empirical formula (EII)**
Pre-monsoon	**30.12**	**55.08**	**-16.32**	**6.51**
Monsoon	**-9.07**	**10.20**	**-42.81**	**-24.30**
Post-monsoon	**-2.57**	**28.07**	**-45.03**	**-11.80**
Winter	**-33.16**	**-16.07**	**-60.53**	**-42.44**

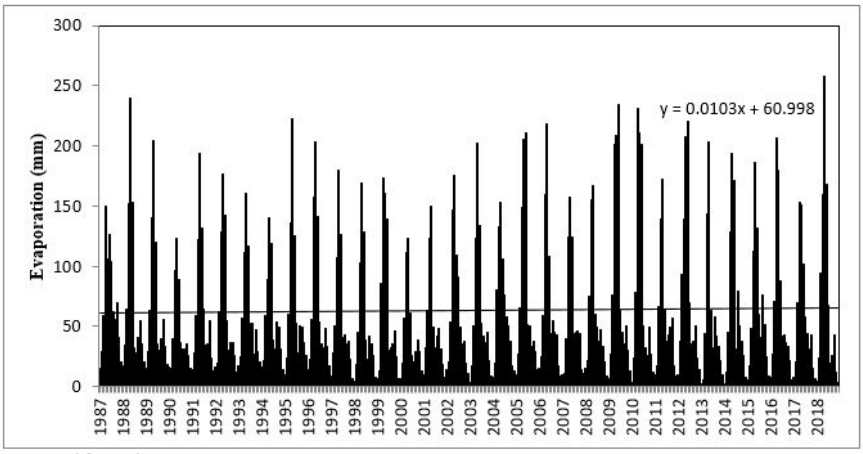
Parameter	Winter			Pre-monsoon			Monsoon		
	S	τ	P	S	τ	P	S	τ	P
Rainfall	-147.0	-0.297	**0.018**	-49.0	-0.099	0.435	-7.0	-0.014	0.922
T min	124.0	0.250	**0.046**	232	0.468	**0.000**	56.0	0.113	0.372
T max	-182.0	-0.368	**0.003**	-77.0	-0.155	0.218	-157.0	-0.318	**0.011**
T average	-68.0	-0.137	0.277	110.0	0.222	0.077	-148.0	-0.298	**0.017**
Wind speed	-260.0	-0.524	**<0.0001**	-226.0	-0.456	**0.00**	-300.0	-0.605	**<0.0001**
Humidity	306.0	0.617	**<0.0001**	120.0	0.242	0.054	68.0	0.137	0.277
Evaporation	-78.0	-0.157	0.212	-54.0	-0.109	0.39	-98.0	-0.198	0.116

Parameter	Post-monsoon			Annual		
	S	τ	P	S	τ	P
Rainfall	36.00	0.075	0.566	-10.0	-0.016	0.884
T min	158.00	0.319	**0.011**	176.0	0.355	**0.005**
T max	-198.0	0.402	**0.001**	-194.0	-0.391	**0.002**
T average	-130.0	-0.262	**0.036**	-114.0	-0.230	0.067
Wind speed	-242.0	-0.488	**<0.0001**	-270.0	-0.544	**<0.0001**
Humidity	256.0	0.516	**<0.0001**	200.0	0.403	**0.001**
Evaporation	-127.0	-0.256	**0.041**	-94.0	-0.190	0.132

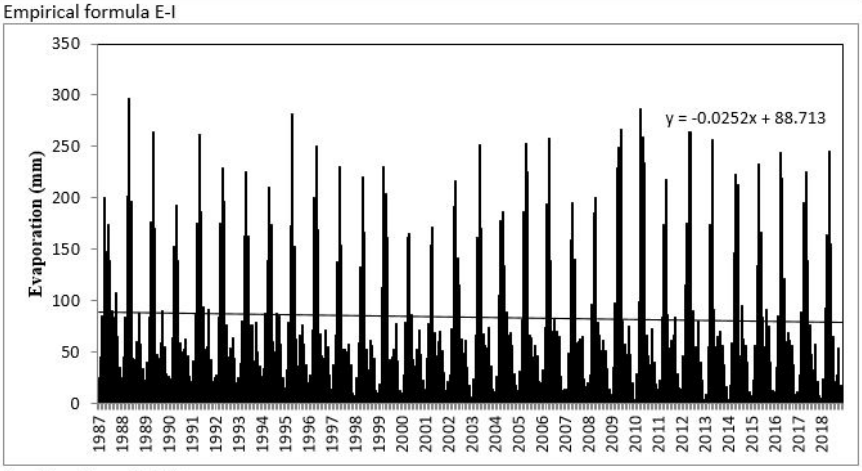
Parameter	Winter		Pre-monsoon		Monsoon		Post-monsoon		Annual	
	Sen's Slope	% Change	Sen's Slope	% Change	Sen's Slope	% Change	Sen's Slope	% Change	Sen's Slope	% Change
Rainfall	-0.723	-0.35	-0.244	-0.11	-0.049	0	0.005	0.01	0.124	0
T min	0.03	0.11	0.066	0.11	0.018	0.02	0.053	0.11	0.039	0.07
T max	-0.069	-0.08	-0.027	-0.02	-0.085	-0.07	-0.103	-0.1	-0.062	-0.06
T average	-0.013	-0.02	0.024	0.03	-0.042	-0.04	-0.049	-0.07	-0.022	-0.03
Wind speed	-0.045	-1.2	-0.065	-1.04	-0.072	-1.44	-0.028	-1.28	-0.057	-1.22
Humidity	0.378	0.14	0.15	0.08	0.083	0.03	0.36	0.15	0.226	0.1
Evaporation	-0.398	-0.11	-0.359	-0.03	-2.028	-0.14	-0.614	-0.16	-2.839	-0.08

Parameter	**Winter**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Annual**
Rainfall	-	No shift	No shift	No shift	No shift
T min	No shift	+	+	+	+
T max	No shift	No shift	No shift	-	-
T average	No shift	No shift	No shift	No shift	No shift
Wind speed	-	-	-	-	-
umidity	+	No shift	No shift	+	+
Evaporation	No shift	No shift	No shift	No shift	No shift

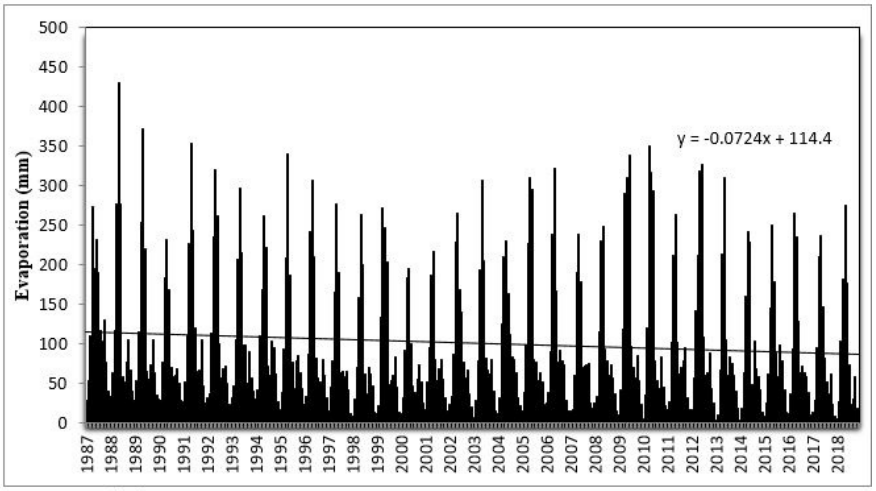




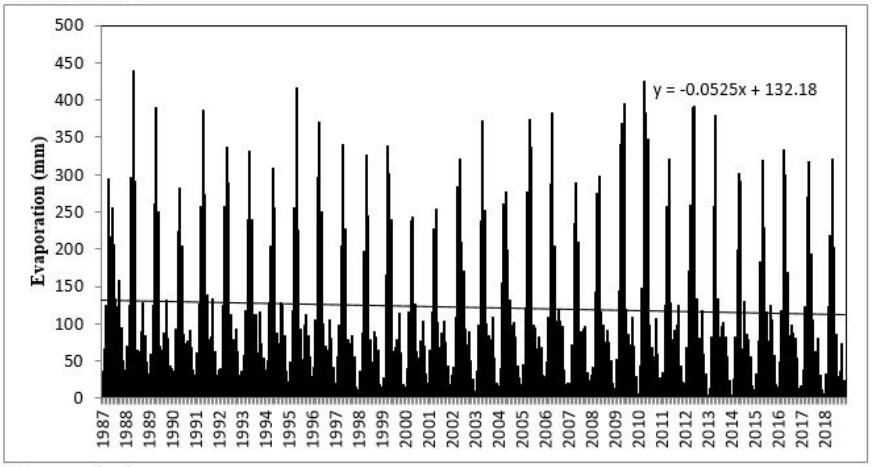
Empirical formula E-I



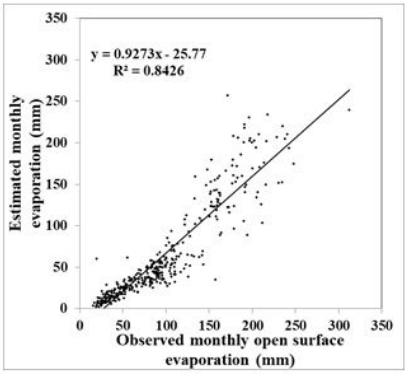
Empirical formula E-II



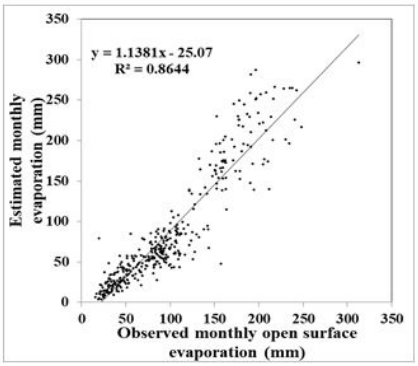
Penman method



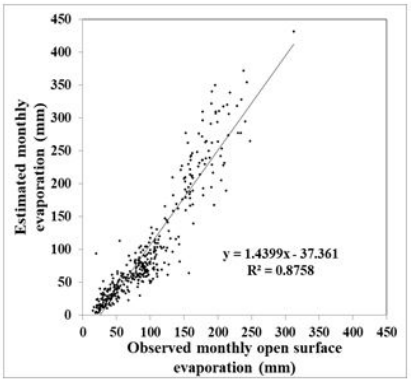
Meyer method



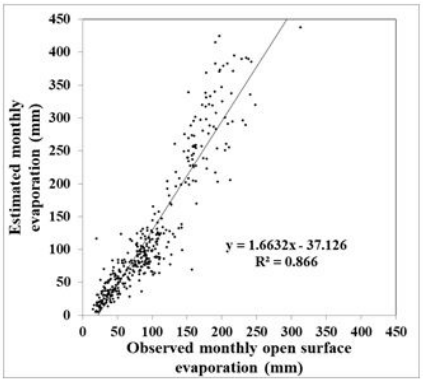
Empirical equation E-I



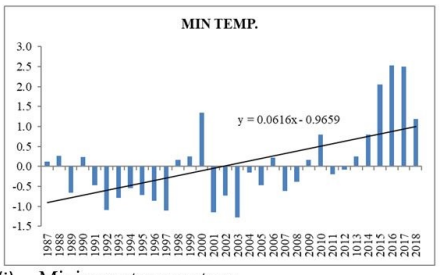
(i) Empirical equation E-II



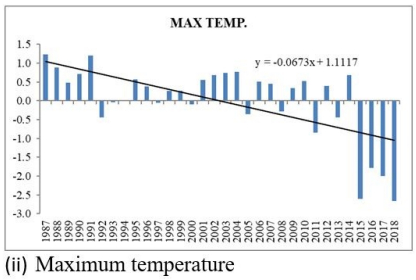
(ii) Penman method



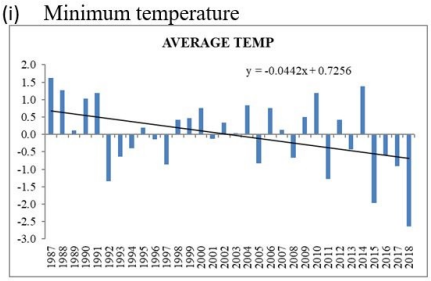
(iii) Meyer method



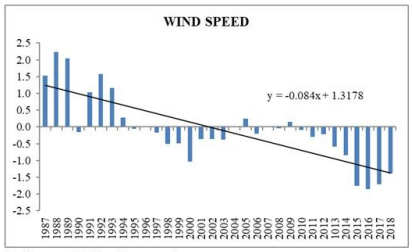
(i) Minimum temperature



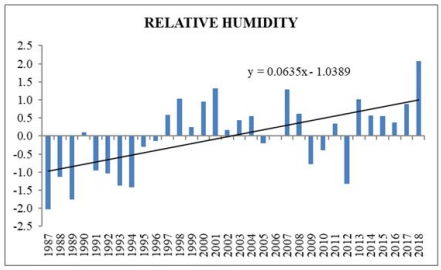
(ii) Maximum temperature



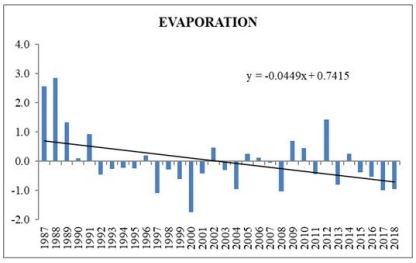
(iii) Average temperature



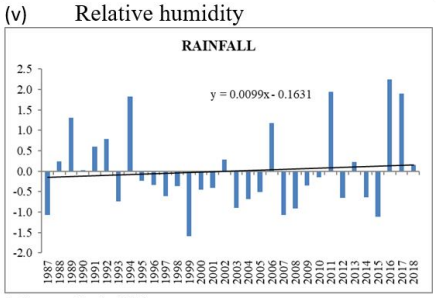
(iv) Wind speed



(v) Relative humidity



(iv) Evaporation



(vi) Rainfall