A study on recent changes in weekly evaporation at selected locations in India

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ABSTRACT. Thirty years evaporation time series data (1971-2000) recorded from US class-A evaporation pans for ten well distributed locations in India, have been utilized in the present study. For these locations, basic statistical parameters of weekly evaporation [minimum, maximum, range, mean, standard deviation (S.D.) and coefficient of variation (C.V.)] have been computed. Variations in average weekly evaporation in different weeks and at different locations have been plotted and discussed. Changes in weekly evaporation have been studied using linear trend analysis technique on weekly evaporation time series data for standard meteorological weeks (1 to 52). Graphs have been plotted, for all ten different locations, to study week wise distribution of changes in weekly evaporation trends and to identify the specific periods when significant changes occur.

The highest average weekly evaporation of 107.5 mm has been observed at Jodhpur in standard week 21 (21-27 May). The lowest average weekly evaporation of 14.5 mm has been observed at Karimganj in standard week 3 (15-21 January). The peak in average weekly evaporation, at most of these locations is achieved around standard week 20 (14-20 May). The coefficient of variation (C.V.) at these locations varied between 18.7 and 51.8 percent. The highest C.V. of 51.8 % has been observed at Bikramganj, whereas the lowest C.V. of 18.7 % has been observed at Rajamundry. Out of 52 weeks, Pune and Rajamundry have shown significant decreasing trend in weekly evaporation in maximum number of weeks (37) and Bhubaneswar has shown significant decreasing trend in weekly evaporation in minimum number of weeks (10). At six locations (Bikramganj, Hissar, Jodhpur, Pattambi, Pune and Rajamundry), the
number of weeks showing significant decreasing trend in weekly evaporation have been found to be more than 23 weeks. At more than five locations significant decreasing trend in weekly evaporation occur, in almost all weeks, between standard weeks 1 to 19 (1 January - 13 May) and also between standard weeks 40 to 52 (1 October - 31 December). In almost all the locations, significant decreasing trend in weekly evaporation occur, in standard week numbers 1-2, 9-10, 13 and 15.

Key words – Weekly evaporation, Weekly evaporation trend, Trend analysis for evaporation.

1. Introduction

The change of state of water from solid or liquid to vapour and its diffusion into the atmosphere is referred to as evaporation. It plays a major role in redistribution of thermal energy between the earth and atmosphere. Evaporation is one of the important components of the hydrological cycle. As it is indicative of atmospheric demand for water vapour it plays an important role in agrometeorological studies. Any major changes in evaporation will have profound implications for hydrological processes, water budget and agricultural crop performance. In this context, studies related to long term changes in evaporation are very important.

In India, studies related to long term changes in temperature and rainfall have been carried out by many researchers (Hingane et al., 1985; Thapliyal and Kulshreshtha, 1991; Srivastava et al., 1992; Rupakumar et al. 1994 and Govinda Rao et al., 1996). However, studies related to long term changes in evaporation over India are scanty. Sumbasiva Rao and Vamadevan (1986) have studied evaporation rates from different pans under humid tropical conditions. Amirul Hussain (1986) has studied evaporation over Bangladesh. Biswas and Khambete (1988) have studied water consumption by dry land crops as related to pan evaporation. Rathore and Biswas (1991) have prepared climatological maps of daily evaporation and weekly evaporation. These maps give a fairly good idea about the spatial variation in evaporation over India. Chowdhury et al., (1999) have studied the relative contribution of different meteorological elements on evaporation. Chattopadhyay and Hulme (1997) have studied the influence of different meteorological variables on changes in evaporation and found that as compared to other variables relative humidity is strongly associated with changes in evaporation. Long term changes in evaporation have been studied in different parts of the world (Peterson et al., 1995; Roderick and Farquhar, 2004).

In order to understand the implications of long period changes in evaporation on agriculture, there is need to understand the weekly distribution of these changes and to identify the specific periods when significant changes occur. Hence, in this paper, an attempt has been made to study the changes in weekly evaporation for standard meteorological weeks (1 to 52), using linear trend analysis technique and to identify the specific periods when significant changes occur.

2. Data and methodology

In the present study, thirty years evaporation time series data (1971-2000) recorded from US class - A evaporation pans for ten well distributed locations in India, have been utilized. Map showing location of different stations in India is given in Fig. 3. The distribution of the stations is reasonably representative of different regions of the country. The data were collected from National Data Center, India Meteorological Department, Pune. In this paper, for all ten stations, the basic statistical parameters [minimum, maximum, range, mean, standard deviation (S.D.) and coefficient of variation (C.V.)] of weekly evaporation have been computed. Variations in average weekly evaporation in different weeks and at different locations have been plotted and discussed. Changes in weekly evaporation have been studied using linear trend analysis technique on weekly evaporation time series data for standard meteorological weeks (1 to 52). Graphs have been plotted, for all ten different locations, to study week wise distribution of changes in weekly evaporation trends and to identify the specific periods when significant changes occur.

3. Results and discussion

3.1. Variations in weekly evaporation

The basic statistical parameters (minimum, maximum, range, mean, standard deviation (S.D) and coefficient of variation (C.V.) of weekly evaporation have been computed for all ten locations and given in Table 1. The minimum weekly evaporation of 14.5 mm has been observed at Karimganj. The maximum weekly evaporation of 107.5 mm has been observed at Jodhpur. The lowest range of 14.6 mm in weekly evaporation has been observed at Karimganj. The highest range of 74.7 mm in weekly evaporation has been observed at Jodhpur. Large variations in mean weekly evaporation may be observed among these 10 locations. The mean weekly evaporation has been found to be lowest (23.2 mm) at Karimganj. The mean weekly evaporation
TABLE 1

Basic statistical parameters of weekly evaporation (mm) and annual evaporation trend (significant at p > 0.95) at different locations in India (1971-2000)

| Station       | Minimum | Maximum | Range | Mean | S.D. | C.V. (%) | Annual evaporation trend |
|---------------|---------|---------|-------|------|------|----------|--------------------------|
| Bhubaneshwar  | 23.9    | 57.8    | 33.9  | 34.5 | 10.7 | 31.0     | decreasing              |
| Bikramganj    | 15.8    | 69.2    | 53.4  | 33.2 | 17.2 | 51.8     | decreasing              |
| Canning       | 17.4    | 49.5    | 32.0  | 30.9 | 9.8  | 31.5     | decreasing              |
| Hebbal        | 27.1    | 53.9    | 26.8  | 38.1 | 8.5  | 22.4     | decreasing              |
| Hissar        | 18.6    | 88.8    | 70.2  | 43.9 | 21.3 | 48.5     | decreasing              |
| Jodhpur       | 32.8    | 107.5   | 74.7  | 59.6 | 22.5 | 37.8     | decreasing              |
| Karimganj     | 14.5    | 29.1    | 14.6  | 23.2 | 4.6  | 19.6     | decreasing              |
| Pattambi      | 26.0    | 47.1    | 21.1  | 35.7 | 7.0  | 19.6     | decreasing              |
| Pune          | 28.3    | 72.9    | 44.5  | 42.6 | 14.9 | 34.9     | decreasing              |
| Rajamundry    | 34.2    | 63.8    | 29.6  | 44.4 | 8.3  | 18.7     | decreasing              |

* S.D. – Standard deviation, C.V. – Coefficient of variation

has been found to be highest (59.6 mm) at Jodhpur. The coefficient of variation (C.V.) at these locations varied between 18.7 and 51.8 percent. The highest C.V. of 51.8% has been observed at Bikramganj, whereas the lowest C.V. of 18.7% has been observed at Rajamundry.

Variations in average weekly evaporation during standard weeks 1 to 52 and at different locations are given in Figs. 1(a-j). It may be seen that average weekly evaporation values, in general, are low during standard weeks 1 to 8 (1 January – 25 February), the values show a rising tendency between standard weeks 9 and 20 (26 February – 20 May), i.e., when the season changes from winter to summer. The peak in average weekly evaporation, at most of these locations is achieved around standard week 20 (14 – 20 May). The highest average weekly evaporation of 107.5 mm has been observed at Jodhpur in standard week 21 (21 – 27 May). Thereafter, the values show a sharp falling tendency between standard weeks 20 and 32 (14 May – 12 August), i.e., when the climatic conditions change under the influence of monsoon season. A further gradual decrease in average weekly evaporation values is observed between standard weeks 33 and 52 (13 August – 31 December), i.e., when climatic conditions change under the influence of winter season. The lowest average weekly evaporation of 14.5 mm has been observed at Karimganj in standard week 3 (15 – 21 January). The pattern of variations in average weekly evaporation at Pattambi, however, has been found to be different from other locations. The climate of this location is greatly influenced due to the closeness of the seas. At Pattambi, the peak of average weekly evaporation (47.1 mm) is reached earlier around standard week 10 (5 – 11 March). The lowest average weekly evaporation (26.0 mm) has been observed around standard week 30 (23 – 29 July).

3.2. Linear trend analysis of evaporation time series data (1971 – 2000)

To study the changes occurring in annual evaporation at different locations, the annual evaporation time series data (1971 – 2000) was subjected to linear trend analysis by the method of least squares. The trends observed at these locations are given in Table 1. At all these ten locations, annual evaporation showed a decreasing trend, significant at more than 95% probability level. Although, one would expect increase in evaporation, due to rise in mean temperature. However decreasing evaporation trends are the result of increasing relative humidity, which plays a significant role in counterbalancing the effect of rising temperatures (Chattopadhyay et al., 1997). In order to understand the implications of long period changes in evaporation on agriculture, there is need to understand the weekly distribution of these changes. Hence, the weekly evaporation time series data (1971 – 2000) for standard weeks (1 to 52) was subjected to linear trend analysis and the trends were observed.
Figs. 1(a-j). Average weekly evaporation (1971 - 2000) in different weeks and at different locations in India
Figs. 2. (a-j). Variations in correlation coefficient ($r$) of weekly evaporation trends (1971-2000) at different locations in India.
TABLE 2
Results obtained from trend analysis of weekly evaporation (1971-2000) at different locations in India

| Station     | Number of weeks showing type of weekly evaporation trend | Total | Number of weeks showing significant trend (at 95% probability level) | Total |
|-------------|---------------------------------------------------------|-------|---------------------------------------------------------------------|-------|
|             | Decreasing trend | No trend | Increasing trend | Decreasing trend | Increasing trend |             |       |
| Bhubaneswar | 32 | 9 | 11 | 52 | 10 | 0 | 10 |
| Bikramganj | 38 | 8 | 6 | 52 | 23 | 1 | 24 |
| Canning     | 30 | 16 | 6 | 52 | 12 | 0 | 12 |
| Hebbal      | 35 | 14 | 3 | 52 | 14 | 0 | 14 |
| Hissar      | 40 | 12 | 0 | 52 | 25 | 0 | 25 |
| Jodhpur     | 48 | 4 | 0 | 52 | 34 | 0 | 34 |
| Karimganj  | 30 | 14 | 8 | 52 | 15 | 2 | 17 |
| Pattambi    | 48 | 2 | 2 | 52 | 27 | 0 | 27 |
| Pune        | 50 | 2 | 0 | 52 | 37 | 0 | 37 |
| Rajamundry  | 45 | 7 | 0 | 52 | 37 | 0 | 37 |

The weekly evaporation trends have been expressed as correlation coefficients ($r$). For observed increasing trend $r > 0$, for decreasing trend $r < 0$ and $r = 0$ for no trend. Variations in these correlation coefficients of weekly evaporation trends at ten different locations are shown in Figs. 2(a-j). The dotted horizontal line, in the figure at $r = 0$, indicates no trend. The correlation coefficient values varied between +0.4 and -0.8. Most of the locations, except Karimganj [Fig. 2(g)], have shown either decreasing trend or no trend, in almost all the weeks. Karimganj has, however, shown increasing trend in few weeks. The information gathered through these graphs have been tabulated and tested for its significance (at more than 95% probability level). The results obtained from this analysis are given in Table 2. Out of 52 weeks, the number of weeks showing significant decreasing trend in weekly evaporation varied between 10 and 37 (i.e., between 19 and 71 percent). The maximum number of weeks (37) showing significant decreasing trend in weekly evaporation have been observed at Pune and Rajamundry. The minimum number of weeks (10) showing significant decreasing trend in weekly evaporation have been observed at Bhubaneswar. At six locations (Bikramganj, Hissar, Jodhpur, Pattambi, Pune and Rajamundry), the number of weeks showing significant decreasing trend in weekly evaporation have been found to be more than 23 weeks (i.e., more than 44 percent). At remaining four locations (Bhubaneswar, Canning, Hebbal and Karimganj), the number of weeks showing significant decreasing trend in weekly evaporation have been found to be between 10 and 15 weeks (i.e., less than 28 percent). On careful examination of Figs. 2(a-j), it may be seen that at more than five locations significant decreasing trend in weekly evaporation occurs, in almost all weeks, between standard weeks 1 to 19 (1 January - 13 May) and also between standard weeks 40 to 52 (1 October - 31 December). Also, it may be seen that in almost all locations, significant decreasing trend in weekly evaporation occur, in standard week numbers 1-2, 9-10, 13 and 15.

4. Conclusions

(i) The mean weekly evaporation has been found to be lowest (14.5 mm) at Karimganj in standard week 3 (15 – 21 January) and highest (107.5 mm) at Jodhpur in standard week 21 (21 – 27 May).

(ii) The highest C.V. of 51.8% has been observed at Bikramganj, whereas the lowest C.V. of 18.7% has been observed at Rajamundry.

(iii) The peak in average weekly evaporation, at most of these locations, is achieved around standard week 20 (14 – 20 May).

(iv) Out of 52 weeks, Pune and Rajamundry have shown significant decreasing trend in weekly evaporation in maximum number of weeks (37) and Bhubaneswar has
shown significant decreasing trend in weekly evaporation in minimum number of weeks (10).

(v) At six locations (Bikramganj, Hissar, Jodhpur, Pattambi, Pune and Rajamundry), the number of weeks showing significant decreasing trend in weekly evaporation have been found to be more than 23 weeks.

(vi) At more than five locations significant decreasing trend in weekly evaporation occur, in almost all weeks, between standard weeks 1 to 19 (1 January - 13 May) and also between standard weeks 40 to 52 (1 October - 31 December).

(vii) In almost all the locations, significant decreasing trend in weekly evaporation occur, in standard week numbers 1-2, 9-10, 13 and 15.

Acknowledgements

The authors express their sincere thanks to staff of DFR section for their assistance in data collection, analysis and typing of the manuscript.

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