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

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सार – इस शोध पत्र में भारत में फैले हुए दस प्रमुख स्थानो पर संस्थापित यू. एस. श्रेणी–ए के वाष्पीकरण पात्रों (पैन्स) से निर्धारित समय पर प्राप्त किए गए तीस वर्षों (1971–2000) के वाष्पीकरण आंकड़ों का उपयोग किया गया है। इन स्थानों के लिए साप्ताहिक वाष्पीकरण के आधारभूत सांख्यिकीय प्राचलों [जैसेः–न्यूनतम, अधिकतम, अवधि, औसत, मानक विचलन (एस. डी.) और विक्षेप गुणांक (सी.वी.)] का आकलन किया गया है। इस शोधपत्र में भिन्न–भिन्न सप्ताहों में भिन्न भिन्न स्थानों के औसत साप्ताहिक वाष्पीकरण की भिन्नताओं को दर्शाया गया है तथा इसका विवेचन किया गया है। नियत समय पर लिए गए साप्ताहिक वाष्पीकरण आंकड़ों पर आधारित रैखिक प्रवृति विश्लेषण प्रणाली का उपयोग करते हुए साप्ताहिक वाष्पीकरण में हुए परिवर्तनों का मानक मौसम विज्ञान सप्ताहों (1 से 52) के अनुसार अध्ययन किया गया है। साप्ताहिक वाष्पीकरण प्रवृतियों में हुए परिवर्तनों का सप्ताहवार अध्ययन करने तथा महत्वपूर्ण परिवर्तनों वाली विशिष्ट अवधियों का पता लगाने के लिए सभी दस स्थानों से प्राप्त आंकड़ों के रेखाचित्र तैयार किए गए हैं।

107.5 मि.मी. का अधिकतम औसत साप्ताहिक वाष्पीकरण 21वें मानक सप्ताह (21–27 मई) में जोधपुर में प्रेक्षित किया गया है। 14.5 मि. मी. का न्यूनतम औसत साप्ताहिक वाष्पीकरण तीसरे मानक सप्ताह (15–21 जनवरी) में करीमगंज में प्रेक्षित किया गया है। इनमें से अधिकांश स्थानों से साप्ताहिक वाष्पीकरण के उच्चतम मान 20वें मानक सप्ताह (14–20 मई) के आस–पास प्राप्त किए गए हैं। इन स्थानों के विक्षेप गुणांक (सी. वी.) 18.7 तथा 51.8 प्रतिशत के बीच बदलते रहे हैं। बिक्रमगंज में उच्चतम विक्षेप गुणांक 51.8 प्रतिशत प्रेक्षित किया गया है जबकि न्यूनतम विक्षेप गुणांक 18.7 प्रतिशत राजामुंद्री में प्रेक्षित किया गया है। कुल 52 सप्ताहों में से पुणे और राजामुंद्री में अधिकतम सप्ताहों में (37 सप्ताहों में) साप्ताहिक वाष्पीकरण में महत्वपूर्ण रूप से गिरावट की प्रवृति पाई गई है और भुवनेश्वर में न्यूनतम सप्ताहों में (10 सप्ताहों में) साप्ताहिक वाष्पीकरण में महत्वपूर्ण रूप से गिरावट की प्रवृति पाई गई है। छः स्थानों (बिक्रमगंज, हिस्सार, जोधपुर, पट्टाम्बी, पुणे और राजामुंद्री) पर 23 से अधिक सप्ताहों में साप्ताहिक वाष्पीकरण में महत्वपूर्ण रूप से गिरावट की प्रवृति पाई गई है। पाँच से अधिक स्थानों पर 1 से 19 तक के मानक सप्ताहों (1 जनवरी–13 मई) तथा 40 से 52 तक के मानक सप्ताहों (1 अक्तूबर–31 दिसम्बर) के बीच प्रायः सभी सप्ताहों में साप्ताहिक वाष्पीकरण में महत्वपूर्ण रूप से गिरावट की प्रवृति पाई गई है। इस प्रकार प्रायः सभी स्थानों पर मानक सप्ताहों 1–2, 9–10, 13 तथा 15 में साप्ताहिक वाष्पीकरण में महत्वपूर्ण रूप से गिरावट की प्रवृति पाई गई है।

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 Bhubaneshwar 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.

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 Kulshrestha, 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	Basic statistical parameters of weekly evaporation (mm)						
	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.
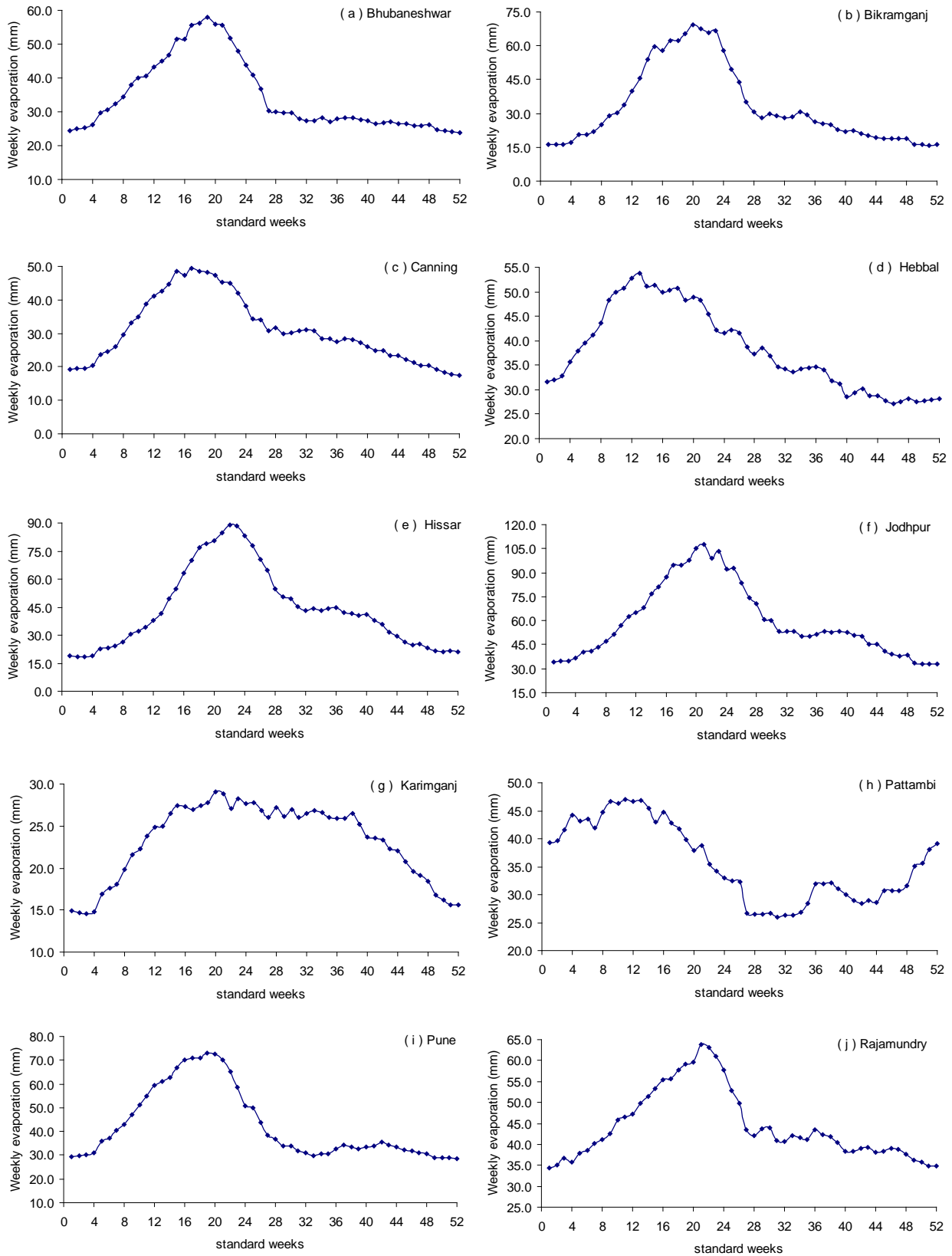
Figs. 1(a-j). Average weekly evaporation (1971 - 2000) in different weeks and at different locations in India
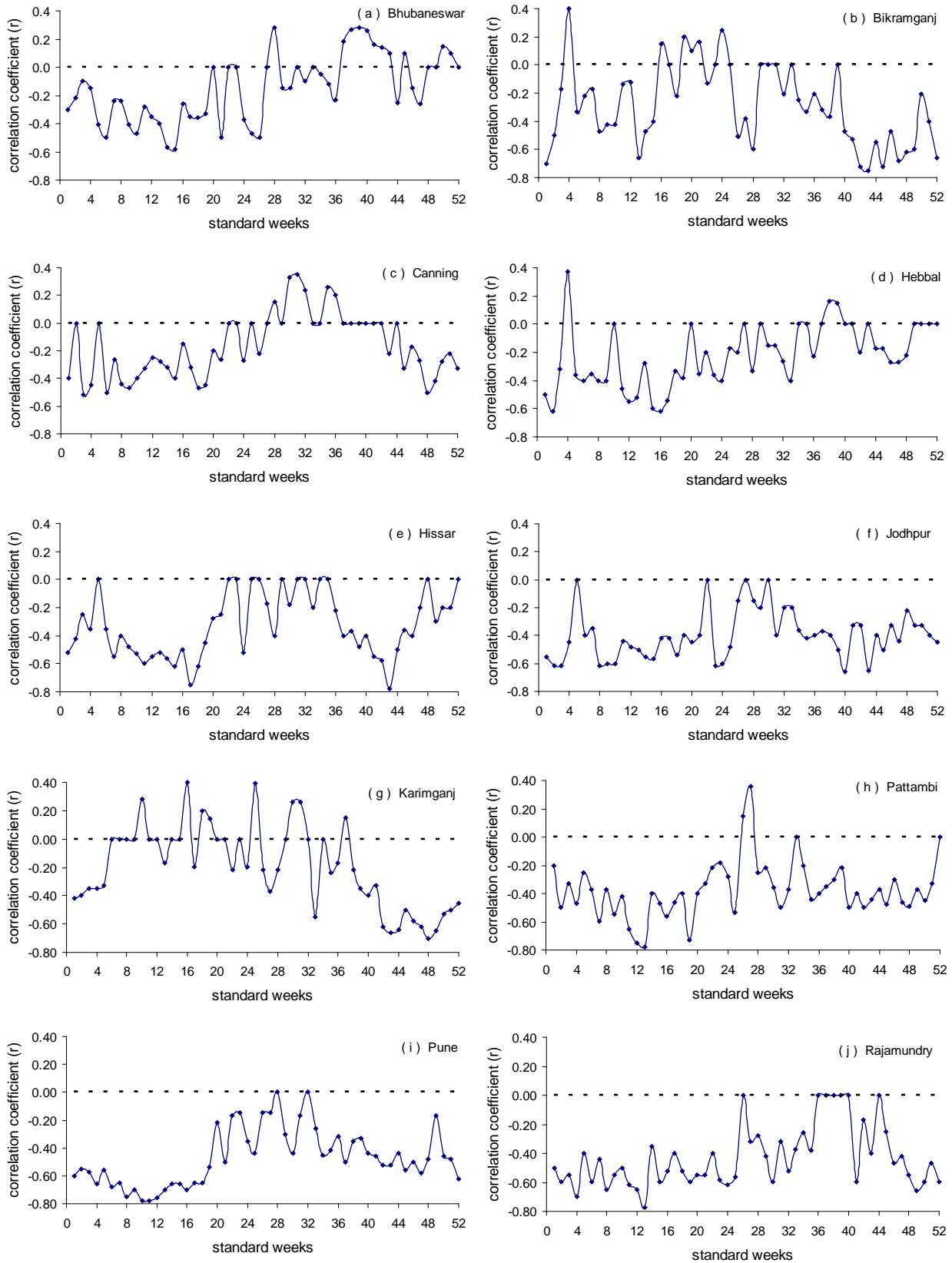
Figs. 2. (a-j). Variations in correlation coefficient (*r*) of weekly evaporation trends (1971-2000) at different locations in India

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 Bhubaneshwar. 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 (Bhubaneshwar, 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 Bhubaneshwar has
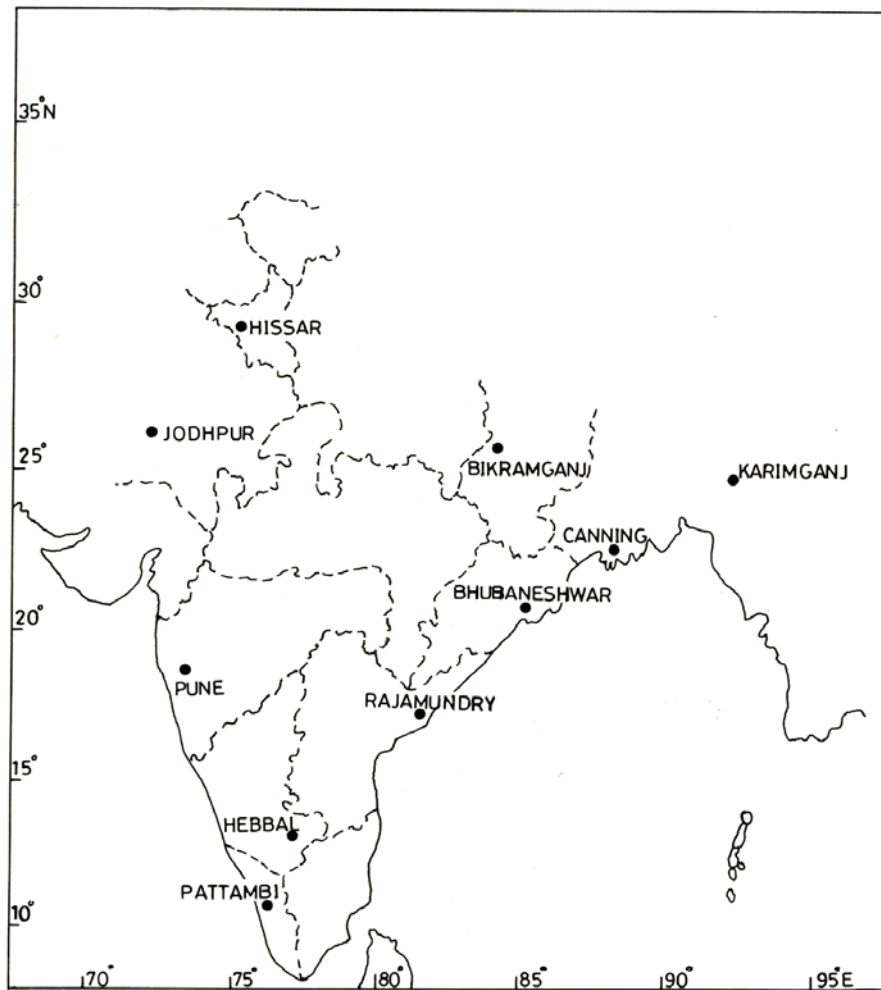
Fig. 3. Map showing location of different stations in India

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.

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