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Evaporation over India

K. N. RAO, C. R. V. RAMAN, C. E. J. DANIEL and S. VENKATARAMAN

Meteorological Office, Poona

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ABSTRACT. Evaporation observations recorded with wire-mesh covered Class A pans at about 80 stations in India for a period of five years or more have been used to present monthly and annual evaporations maps. Highest evaporation values of 16-17 mm per day are recorded in north Maharashtra, southwest Madhya Pradesh and Rajasthan in May, while daily evaporation is lowest (<2 mm) in January along the foot of the Himalayas.

1. Introduction

Investigations in recent years have shown that measurements of the evaporative power of air recorded by pan evaporimeters are related to moisture losses from enclosed and free water bodies on the one hand and bare and vegetation-covered soils on the other (Kohler *et al.* 1955, Stanhill *et al.* 1968). In India, systematic observations of evaporation from pan evaporimeters commenced during the International Geophysical Year (1957). Data are now available for 5 to 10 years from a network of about 80 stations equipped with wire-mesh covered standard Class A Pan evaporimeters (Gangopadhyaya *et al.* 1966).

So far, most of the work on evaporation presented and discussed in India have been based on various empirical or theoretical formulae (Venkataraman and Krishnamurthy 1965). An attempt has, therefore, been made in this paper, to present monthly and annual evaporation over India from actual recorded pan evaporation data.

2. Data

Monthly and annual means of daily evaporation have recently been compiled and published as *Evaporation Data—India*, Parts I and II, 1970 (Part I contains, in addition, standard deviation for the monthly and annual mean values). As evaporation is nearly conservative, short period averages based on data of 5 to 10 years are helpful in giving a broad idea of the distribution of this parameter in space and time.

3. Maps

Monthly maps of daily evaporation and total annual evaporation are presented in Figs. 2 to 14. On the monthly maps, isolines of daily evaporation are drawn at intervals of 1 mm upto 6 mm and thereafter, at interval of 2 mm. Stations whose elevations exceed 3000 ft have not been taken into consideration. In drawing isopleths, observations made at some stations started recently with less than 5 years' data have also been kept in view.

The annual chart gives the total evaporation for the year in cm. Isolines on this chart are drawn at intervals of 50 cm.

A locator map (Fig. 1) showing the States and Meteorological Sub-divisions is also included.

4. Analysis

The available data are analysed and the principal monthly and annual features are mentioned below—

4.1. *Winter* (*January and February*)

The pattern of distribution of evaporation in January and February is nearly similar, the winter-time features being well brought out by the map for January (Fig. 2).

In January, evaporation is lowest (<2 mm) along the foot of the Himalayas, extending from the Punjab to Assam. It increases gradually southwards and attains its highest value over Saurashtra. Over Peninsular India, evaporation is generally in excess of 5 mm per day especially over interior north Mysore and north Marathwada and shows a tendency to decrease along the coastal belts.

The above features begin to show up in December, while in February (Fig. 3) insolation tends to increase evaporation generally by 1 mm with the highest daily evaporation (>8 mm) occurring over Bellary, Jalgaon and Ahmadabad.

Fig. 1

States	*Sub-divisions*
	1. Bay Islands
Assam, Nagaland and Meghalaya	2. North Assam (including NEFA) 3. South Assam (including Meghalaya Nagaland, Manipur and Tripura)
West Bengal	4. Sub-Himalayan West Bengal 5. Gangetic West Bengal
Orissa	6. Orissa
Bihar	7. Bihar Plateau 8. Bihar Plains
Uttar Pradesh	9. East Uttar Pradesh 10. Plains of West Uttar Pradesh 11. Hills of West Uttar Pradesh
Haryana	12. Haryana (including Chandigarh and Delhi)
Punjab	13. Punjab
Himachal Pradesh	14. Himachal Pradesh
Jammu & Kashmir	15. Jammu & Kashmir
Rajasthan	16. West Rajasthan 17. East Rajasthan
Madhya Pradesh	18. West Madhya Pradesh 19. East Madhya Pradesh
Gujarat	20. Gujarat Region (including Daman Dadra, and Nagar Haveli) 21. Saurashtra & Kutch (including Diu)
Maharashtra	22. Konkan (including Goa) 23. Madhya Maharashtra 24. Marathwada 25. Vidarbha
Andhra Pradesh	26. Coastal Andhra Pradesh 27. Telangana 28. Rayalaseema 29. Tamil Nadu (including Pondicherry)
Mysore	30. Coastal Mysore 31. North Interior Mysore 32. South Interior Mysore
Kerala	33. Kerala 34. Arabian Sea Islands

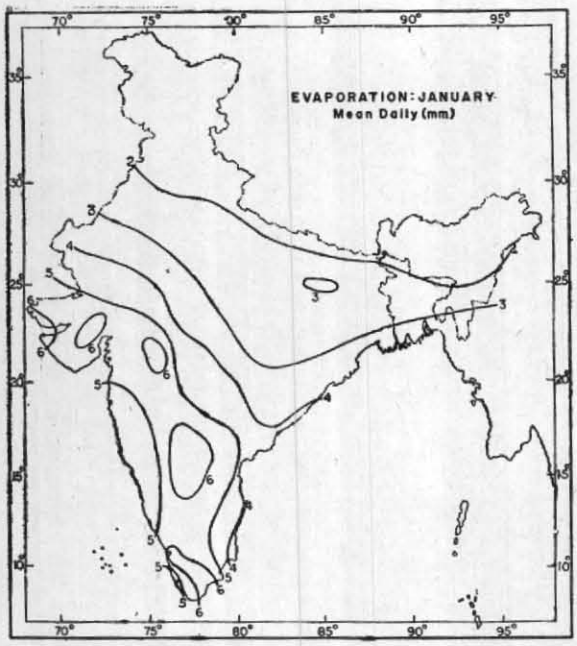

Fig. 2

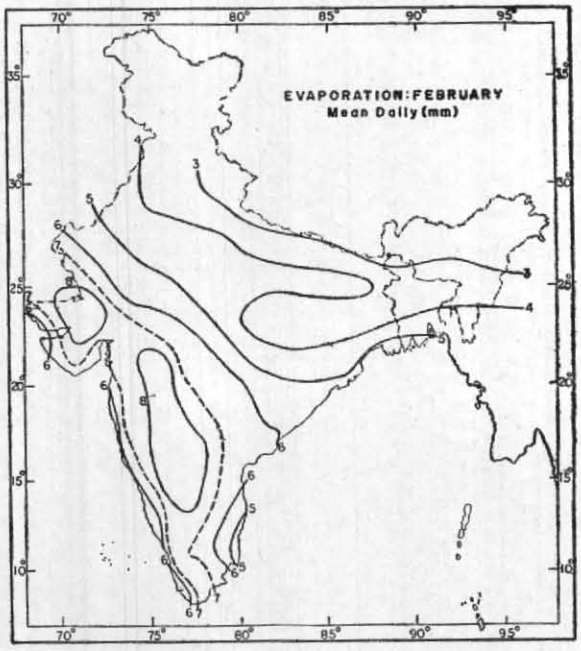

Fig. 3

Figs. 2 & 3. Monthly maps of daily evaporation

4·2. *Hot Season (March — May)*

By March (Fig. 4) the region of high evaporation shifts slightly to the north with the isoline for 8 mm including the southern portions of Rajasthan. A new zone of 7 mm evaporation extends as a narrow corridor into Uttar Pradesh and the Bihar plains. Deccan plateau and Saurashtra register high evaporation with Jalgaon in Madhya Maharashtra registering the highest value of 12·5 mm.

In April (Fig. 5), there is a marked increase in evaporation. The highest values of 14-16 mm appear over northeast Maharashtra, south Madhya Pradesh and Saurashtra/north Gujarat. The areas of lowest evaporation (<5 mm) are over northeast Assam and south Kerala Coast. A notable feature is the comparatively low evaporation over east Madhya Pradesh and adjoining Orissa and Bihar Plateau as well as the entire east coast.

By May (Fig. 6) there is a sharp increase in evaporation and a further northward shift of the area of highest evaporation. The isoline for 16 mm encloses north Maharashtra, southwest Madhya Pradesh and Rajasthan. Jalgaon has the highest average of 19·8 mm per day. As a contrast, the lowest values recorded further decrease to less than 4 mm in the north Assam area.

During the hot season as a whole, evaporation over interior peninsular India registers a sharp increase. The high evaporative zones of the winter months over north Interior Mysore and Marathwada coalesce with that over Saurashtra and extend northwards into Rajasthan and southwest Madhya Pradesh. The intensity of evaporation over this high belt increases significantly from March to May. Evaporation at Jalgaon registers a sharp rise from 12·5 mm per day in March to 19·8 mm per day in May. In April and May, a well-marked wedge of relatively high evaporation (8-10 mm) is observed along the Gangetic basin, in the general area of the heat trough. First indications of this wedge appear in March itself. East Madhya Pradesh and adjoining Bihar plateau and Orissa as also the peninsular coastal belts register relatively low evaporation compared to the interior parts of western India.

4·3. *Southwest Monsoon (June to September)*

In June (Fig. 7) when the southwest monsoon sets in over a good portion of the country, evaporation registers a general decrease, whereas the pattern in other parts remains broadly similar to May with high evaporation persisting over north Maharashtra, adjoining Gujarat, west Madhya Pradesh and Rajasthan. Jalgaon still records the highest evaporation of 16·6 mm.

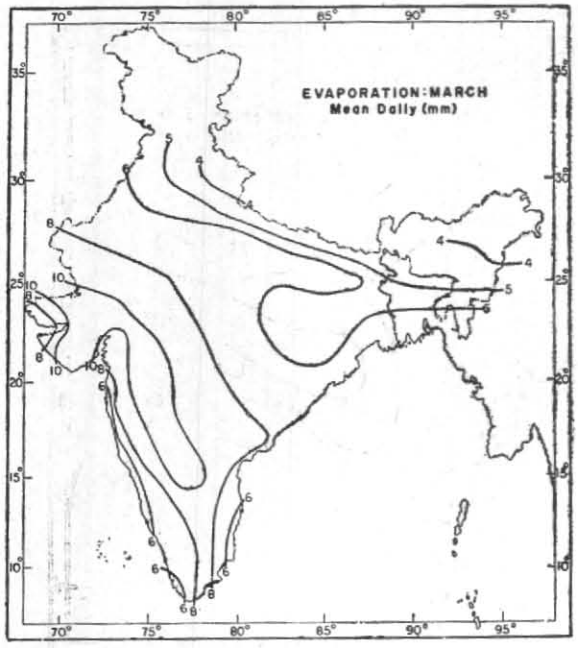

Fig. 4

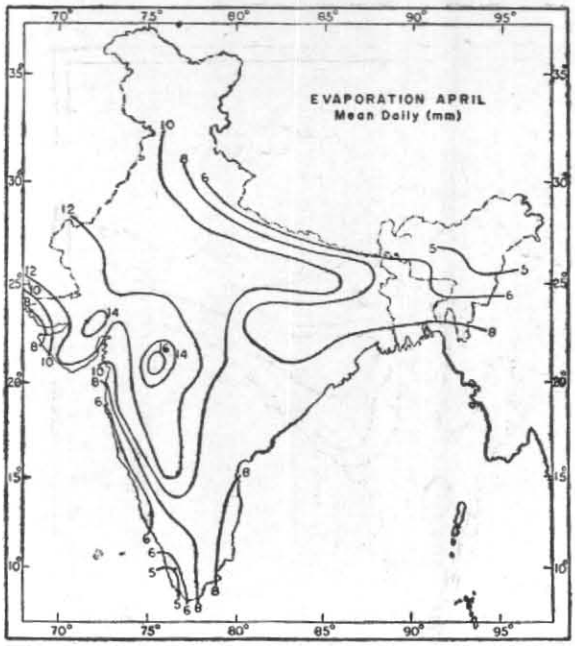

Fig. 5

Figs. 4 & 5. Monthly maps of daily evaporation

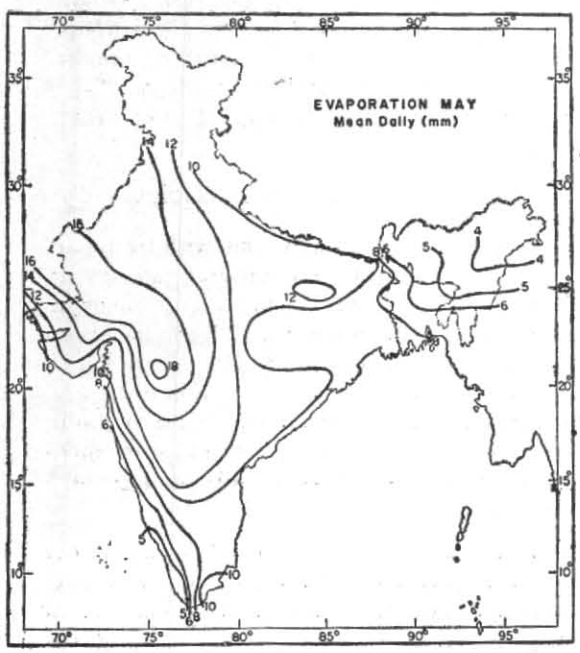

Fig. 6

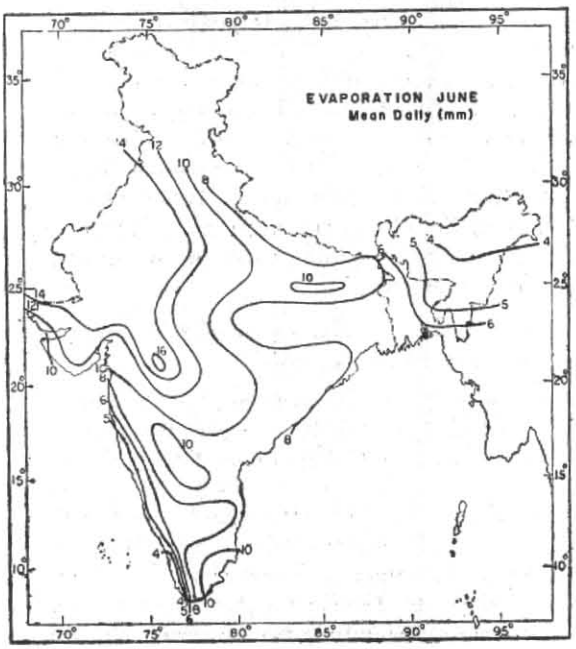

Fig. 7

Figs. 6 & 7. Monthly maps of daily evaporation

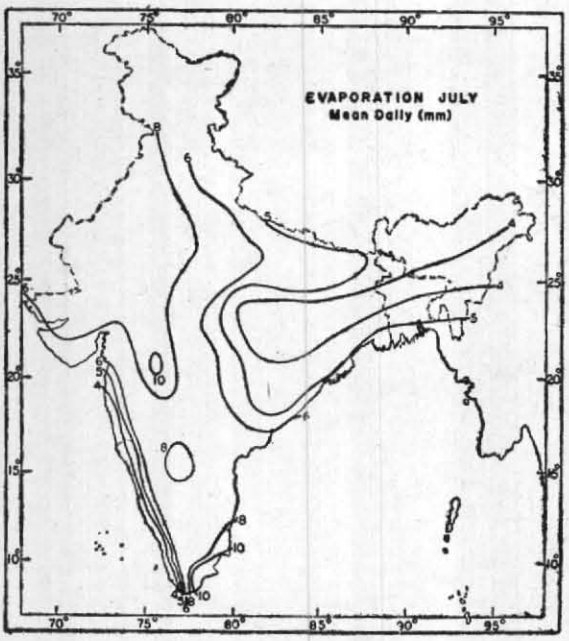

Fig. 8

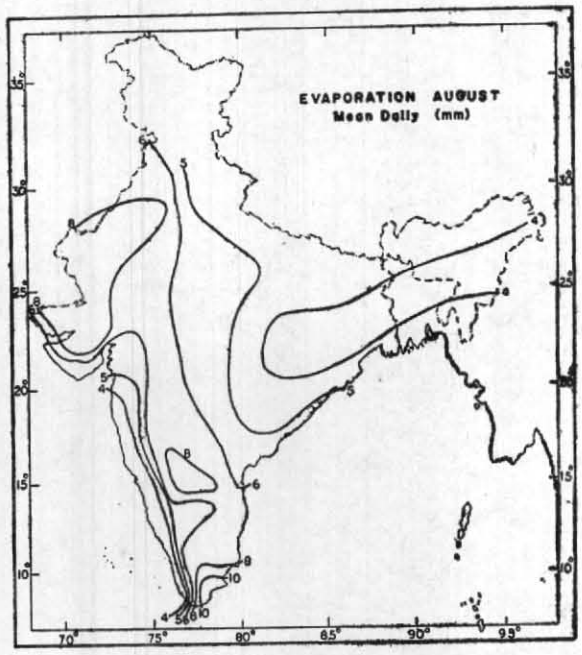

Fig. 9

Figs. 8 & 9. Monthly maps of daily evaporation

By July (Fig. 8), when the monsoon is fully established over the country, evaporation registers a further sharp fall, Rajasthan now recording only 8-10 mm. A second highest evaporation regime (10 mm) lies over extreme southeast Tamil Nadu which is also a region of practically no rainfall. A tongue of low evaporation (< 4 mm) extends eastwest from northeast Assam to east Madhya Pradesh across Bihar plateau flanked immediately to the north by a wedge of high evaporation (5·8 mm) close to the normal axis of monsoon trough.

The west coast of India south of 20°N records an evaporation of 4 mm only.

In August (Fig. 9), the general pattern is similar to July though a further slight decrease in evaporation is noticed. The areas of high values of evaporation (*i.e.*, 8 mm or more) are confined to three zones, *viz.*, Rajasthan and Saurashtra, Mysore and adjoining Rayalaseema and south Tamil Nadu. The areas with less than 4 mm evaporation cover practically the entire west coast and the region extending from Assam through Bengal and Bihar plateau to east Madhya Pradesh and adjoining north Orissa.

In September (Fig. 10) the pattern is similar to that of August with comparable values of evaporation except for the belt of lowest evaporation (<4 mm) which has commenced its appearance along the foot of Himalayas. South Tamil Nadu continues to have the highest evaporation of 10 mm.

4.4. *Post Monsoon (October to December)*

In October (Fig. 11), with the withdrawal of the southwest monsoon, the general pattern of evaporation distribution undergoes a change. Evaporation over southeast Tamil Nadu decreases by 2-4 mm. Evaporation is highest over Saurashtra (8 mm) while it is 7 mm over west Deccan Plateau, Gujarat and extreme south Tamil Nadu. The west coast and practically the entire country east of longitude 80°E have a daily average of 4 mm or less.

By November (Fig. 12), a clear change in the pattern is noticeable and the area of lowest evaporation re-establishes itself all along the foot of the Himalayas. In fact, a good portion of the country from Punjab in the northwest through Uttar Pradesh, Bihar and Bengal to Assam has

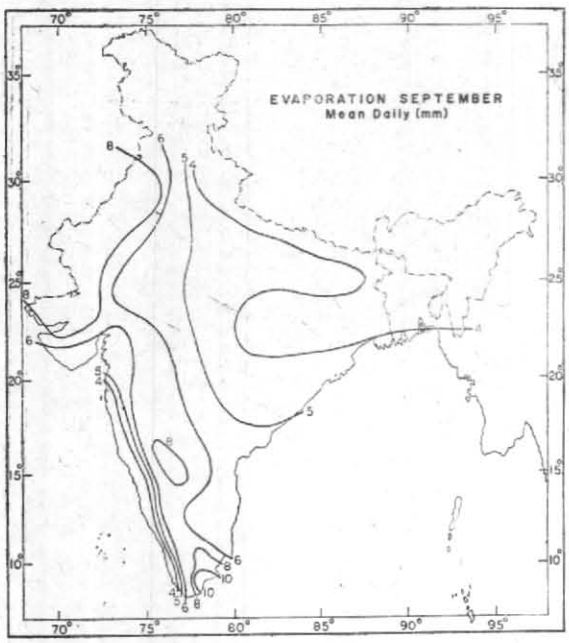

Fig. 10

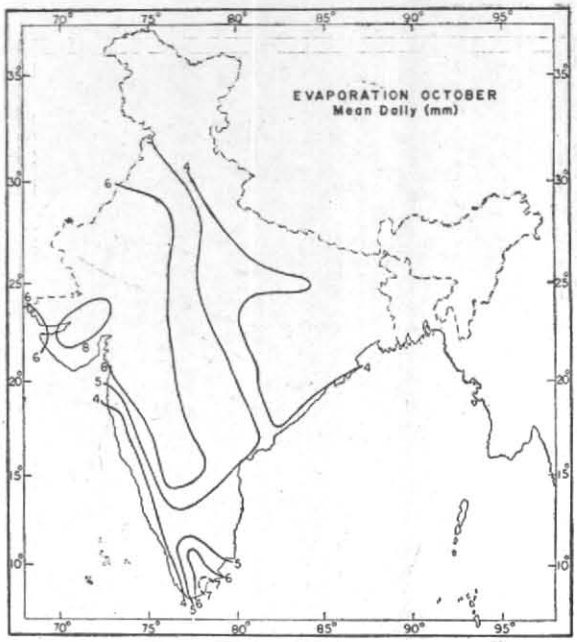

Fig. 11

Figs. 10 & 11. Monthly maps of daily evaporation

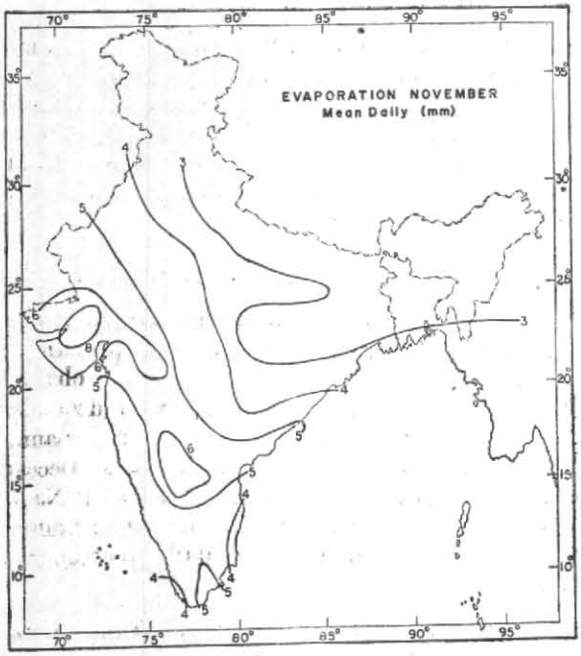

Fig. 12

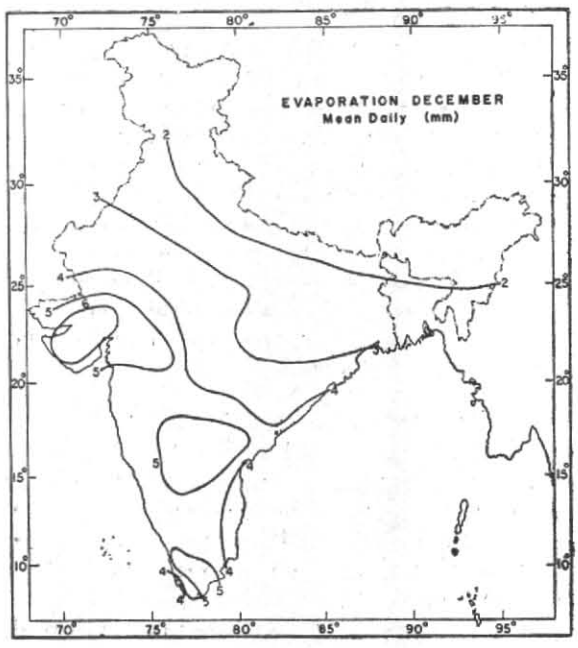

Fig. 13

Figs. 12 & 13. Monthly maps of daily evaporation

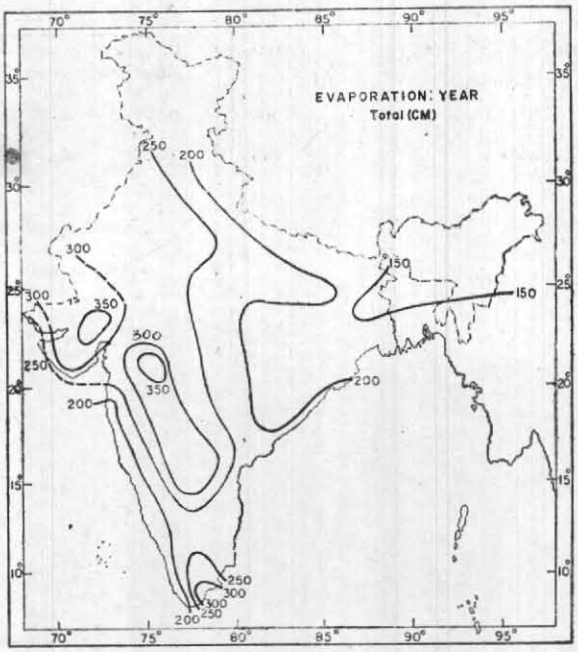

Fig. 14. Map showing total annual evaporation

less than 3 mm of daily evaporation. Evaporation over coastal Tamil Nadu upto 10°N and extreme south Kerala is 4 mm. Areas of 6 mm evaporation are seen over Saurashtra/Gujarat, southwest Madhya Pradesh and central Deccan Plateau. The highest daily average of 8 mm is over northern Saurashtra. Other features during this month are similar to October.

In December (Fig. 13), the pattern is similar to that of November though evaporation values are generally lower by 1 mm. Evaporation of less than 2 mm per day is registered all along the foot of the Himalayas.

4.5. *Annual*

The main features observed in the monthly maps are well reflected in the annual distribution (Fig. 14). Evaporation is lowest over Assam and adjoining Himalayan Bengal (<150 cm). Along the west coast of Peninsular India and generally to the east of longitude 80°E, evaporation is less than 200 mm. Over western India, an extensive belt from south Punjab to Mysore shows very high evaporation (>250 cm). In this belt there are two areas of maximum evaporation exceeding 350 cm— one over north Gujarat and adjoining Saurashtra and the second around Jalgaon. The highest value is 387 cm at Jalgaon and Ahmadabad. The extreme southeast of Tamil Nadu is another area with a high total evaporation of 250-300 cm.

Between these zones of maxima and minima, there is a wedge of high evaporation along the Gangetic plains which is the seat of the summer time heat low and which also lies in close proximity to the normal monsoon trough axis. Immediately to the south of this wedge lies an area of relatively low evaporation extending eastwards into Assam. Along the west coast of Peninsular India where the impact of the southwest monsoon is most felt, the total evaporation gets significantly reduced and is comparable to that along the foot-hills of the Himalayas extending upto the sub-Himalayan belt. The areas of lowest evaporation through the year are the west coast and northeast Assam. Evaporation is as low as 120 cm in upper Assam.

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