AIR POLLUTION POTENTIAL OVER SOUTH INDIA

(*Research Note*)

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Abstract. The potential of the atmosphere to disperse and dilute pollutants emitted into it by myriad sources, depends upon various factors such as wind, vertical mixing, inversion of temperature in the vertical, etc. A study of such parameters is attempted in the present article over south India. The spatial distribution of isothermals, inversions, lapse conditions, mixing heights and ventilation coefficients over south India is studied for the months of January, April, July and October, which are typical of winter, premonsoon, monsoon and post monsoon seasons, respectively. Diurnal variations are also studied.

1. Introduction

The capacity of the atmosphere to disperse and dilute pollutants emitted into it from various sources depends upon prevailing meteorological conditions. The vertical variations of temperature and horizontal wind are most important in determining the atmospheric dispersal capacity for any given region. While strong lapse conditions enhance atmospheric dispersion, isothermal and inversion conditions inhibit it.

Mixing heights (MH) which are defined as the heights to which vigorous mixing occurs in the atmosphere, are a very useful tool in directly interpreting the vertical extent of dispersal, while the ventilation coefficients (VC) which are defined as the product of MH and mean horizontal wind through the MH, combine the effects of horizontal and vertical mixing.

In the present note, the method used follows that of Holzworth (1964, 1967, 1972). Other applications of Holzworth's approach are due to Szepsesi (1967), Hosler (1961), Bilello (1966), Padmanabhamurty and Mandal (1976, 1980), Sadhuram (1982), Vittal Murty *et al.* (1980a, b) and Viswanadham (1980). The surface-based and elevated isothermal, inversions and lapse conditions for every 50 mb up to 500 mb are compared with their intensities. In addition, the spatial variations of MH and VC are investigated as well as their diurnal and seasonal variation. South India is essentially peninsular in nature, having a very vast

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coastline and a potential for industrial development. Hence South India has been chosen for the present study.

2. Materials and Methods

The period of data is from 1977 to 1981. The radiosonde observations at 00 and 12 GMT were collected for all ten radiosonde stations in South India. The surface wind and temperature at every hour were also collected for the same ten stations. The data were obtained from the India Meteorological Department for the months of January, April, July and October which are typical of winter, premonsoon, monsoon and postmonsoon seasons, respectively. Sunrise and sunset are 0100 and 1207 GMT for January, 0020 and 1245 for April, 0000 and 1315 for July and 0020 and 1217 for October, respectively.

Isothermal, inversion and lapse conditions were counted for every 50 mb layer up to the 500 mb level with their intensities. Frequency tables were prepared for the intensities of 0, <2, 2–4, 4–6 and >6 °C for 00(0530 IST) (just before sunrise) and 12 GMT (just before sunset), for the layers 1000–950, 950–900, 900–850, 850–800, 800–750, 750–700, 700–650, 650–600, 600–550 and 550–500 mb layers in addition to surface to 1000 mb wherever necessary. The total percentage frequency of isothermals, inversions and lapse conditions irrespective of their intensities was obtained for all stations at 00 and 1200 GMT and isopleths were drawn for these times for the four months mentioned above.

MHs were computed by extending a dry adiabat from the urban temperature up to the lifting condensation level (LCL) and a saturated adiabat thereafter to cut the early morning temperature profile. The height at which it cut the temperature profile was taken as the MH. A HII (heat island intensity) of 5 °C was assumed by Holzworth and Vittal Murty *et al.* to compute morning MH. However, if one wishes to compute the MH at any other time of day, the HII cannot be taken as 5 °C as that is a maximum value occurring only around the time of minimum temperature. However, Viswanadham (1983) measured the surface temperature variation in space and time within the city of Cochin for a few days in January and February for two years 1981 and 1982. With the help of the above, the following HIIs were assumed. For inland stations, 1 °C was added at 11, 12, 18 and 19 hr, 2 °C at 10, 20, 21 and 22 hr, 3 °C at 08, 09, 23, 24 and 01 hr, 4 °C at 07 hr and 5 °C at 05 and 06 hr for January, April and October. For July, 1 °C at 10, 20, 21 and 22 hr, 2 °C at 08, 09 and from 23 to 01 hr and 3 °C from 02 to 07 hr were added. For coastal stations in January, April and October, 1 °C at 09, 10 and from 21 to 23 hr, 2 °C at 07, 08, and 24 to 02 hr and 3 °C from 03 to 06 hr were added. For July, 1 °C was added at the times mentioned above. At other hours, no correction was made. Though surface observations were not available, and absolute values might be different from those assumed here, the relative trends would certainly be maintained. It may be noted here that except for Madras, Cochin and Trivandrum, all of the stations have rural exposure for radiosonde. For the above three stations which are either urban or semi-urban, the HII added is not high in view of their coastal characteristics.

VC was computed by multiplying MH by the surface wind speed. The vertical variation of wind was not available at all hours and hence the surface wind speed was used to compute VCs, which are consequently likely to be underestimates.

3. Results and Discussion

Figure 1 is a map of South India showing the positions of stations. There are three inland stations and the rest are coastal.

3.1. INVERSIONS, ISOTHERMALS AND LAPSE CONDITIONS

Figure 2 shows the spatial variation of the percent frequency of occurrence of total number of inversions for 00 and 12 GMT. The isolines are drawn at 4%

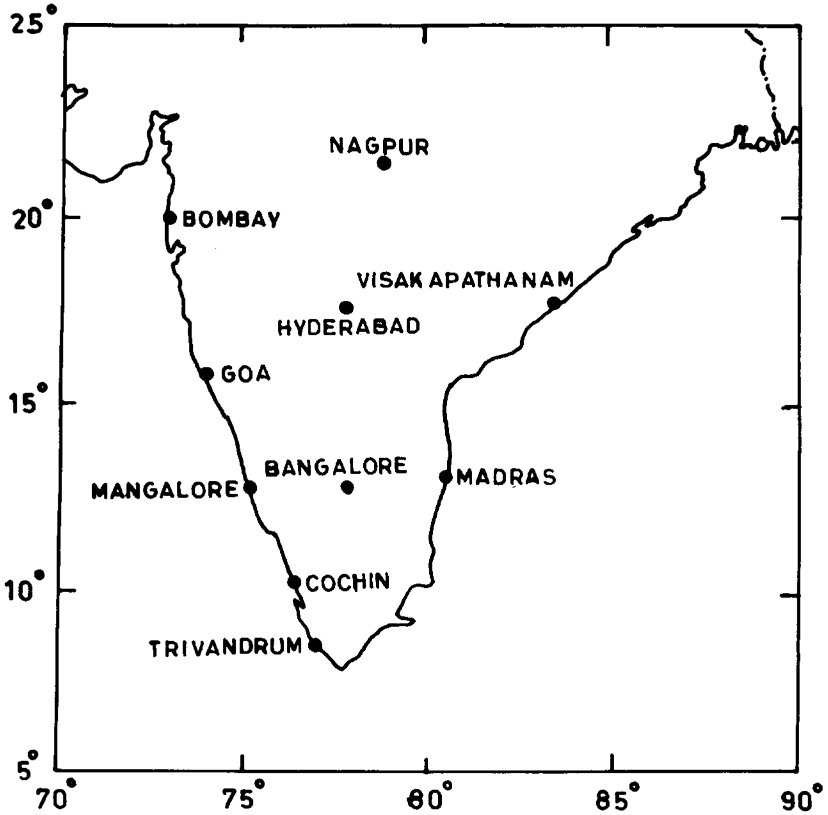

Fig. 1. Map of South India with position of stations.

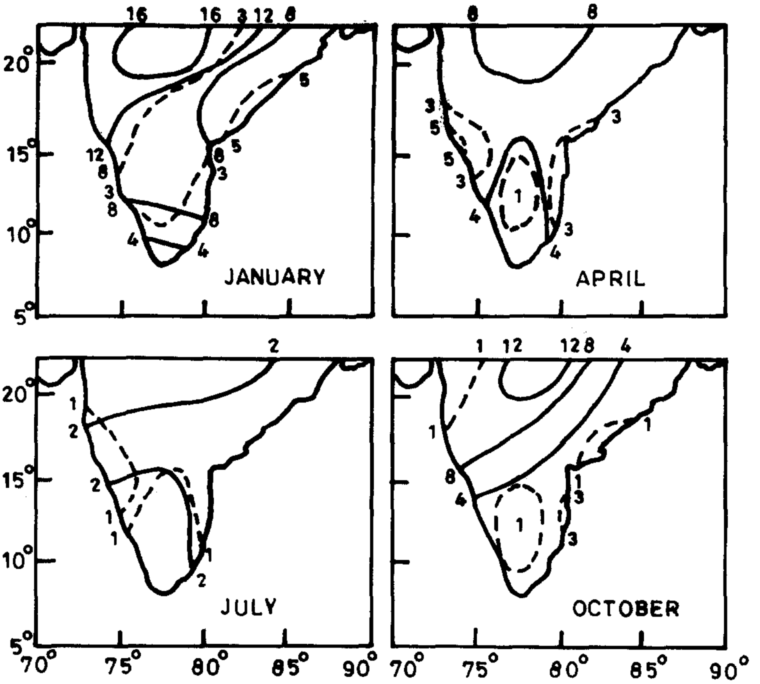

Fig. 2. Spatial variation of percent frequency of inversions over South India at 00 GMT (———, even values) and 12 GMT (---, odd values).

intervals for 00 GMT except for July, for which they are drawn at 2% intervals; the isolines are drawn at 2% intervals for 12 GMT in all months. To distinguish, the isolines are drawn for even values for 00 GMT and odd values for 12 GMT. The inversion frequency is a maximum in January for both 00 and 12 GMT. The frequency increases from south to north. In relative terms, the west coast shows higher frequency than that of the east coast at 00 GMT, while the east coast shows relatively higher values at 12 GMT. The northern interior parts show the highest values at 00 GMT. The frequency at 12 GMT is much lower than that at 00 GMT.

In April most of the region shows frequencies between 4 and 8% while the southernmost parts continue to show the lowest and northern the highest values at 00 GMT. At 12 GMT, the frequency varies between 1 to 5%, with the coastal belt showing higher values.

In July, the frequency is lowest at 00 GMT as well as at 12 GMT. The entire region shows values around 2% at 00 GMT and 1% at 12 GMT. In October, however, the frequency is considerable and is second to January, as far as 00 GMT is concerned. The southernmost parts once again show low values and the northern parts high values. The west coast shows relatively higher frequency than that of the east coast at 00 GMT. At 12 GMT, the pattern is not very much different from that of July, showing almost 1% throughout the region except for a small kink along the east coast.

The spatial variation of the frequency of occurrence of isothermal conditions is shown in Figure 3. The isolines are labelled at 2% intervals. In January, the frequency decreases from south to north at 00 GMT. The frequency varies mostly between 8 and 10%. At 12 GMT, the frequency is greater along the coasts with a minimum in the interior. In April, the pattern remains the same as far as 12 GMT is concerned but at 00 GMT it differs significantly. Along both coasts, higher frequencies are noticed both at 00 and 12 GMT with a maximum in the Central parts. In July, the southern interior shows the maximum frequency at 00 GMT while the west coast shows a maximum at 12 GMT. In October, the pattern is more or less similar to that of January, showing higher values along the coasts at 12 GMT and a maximum in the southern parts at 00 GMT.

Figure 4 depicts the spatial variation of percent frequency of occurrence of lapse conditions for South India. The isolines are labelled at 4% intervals. The frequency decreases from south to north at 00 GMT in January, while at 12 GMT it is more or less uniform except for the small kinks in the northernmost parts and along the coasts with a maximum in the interior at 12 GMT. In July, the frequency is between 88 and 92% at 00 GMT and 91 and 95% at 12 GMT, with most parts showing around 95% at 12 GMT. In October, the variation is between

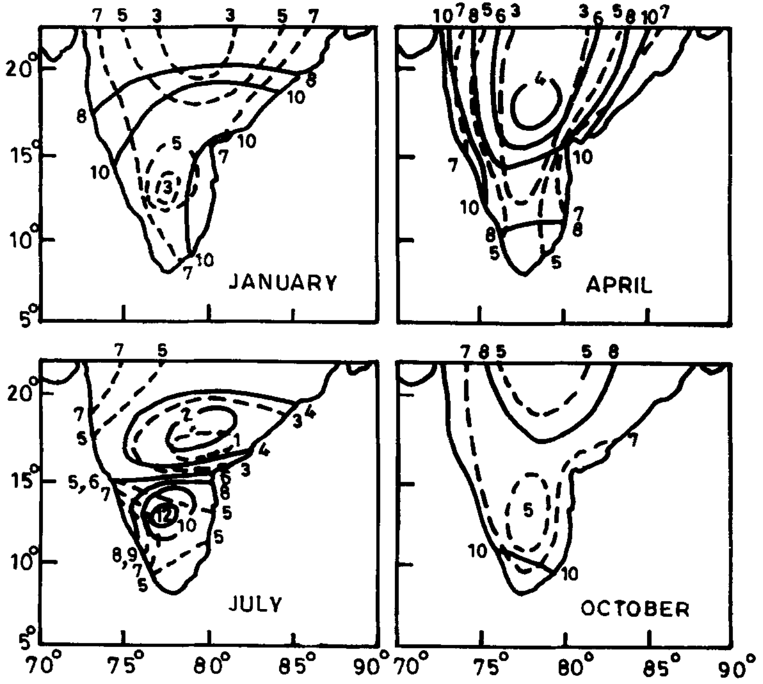

Fig. 3. Spatial variation of percent frequency of isothermals over South India at 00 GMT (———, even values) and 12 GMT (---, odd values).

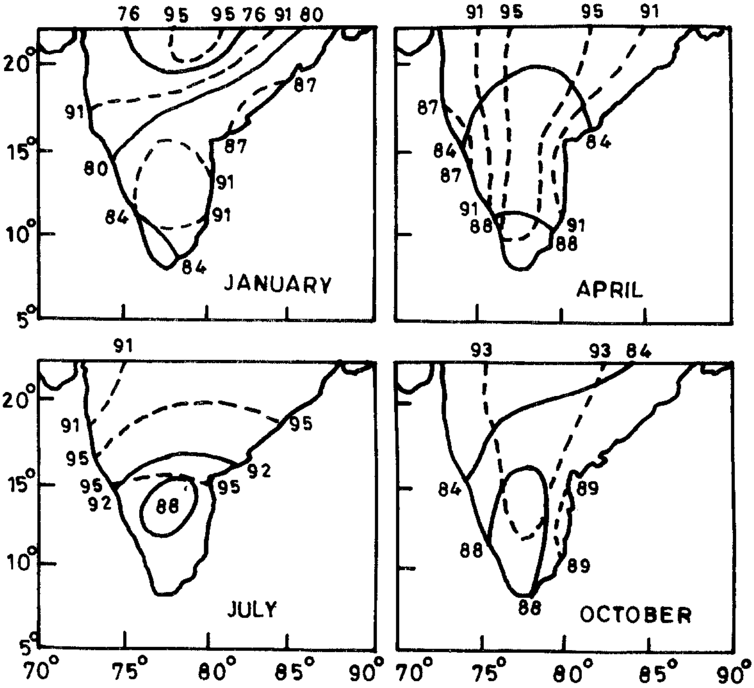

Fig. 4. Spatial variation of percent frequency of lapse conditions over South India at 00 GMT (———, even values) and 12 GMT (- - -, odd values).

84 and 88% at 00 GMT and 89 and 93% at 12 GMT with most parts showing values around 93% at 12 GMT.

In general, inversion frequencies are a minimum in the southern parts and a maximum in the northern parts, which may be because of the influence of the coastal characteristics in the southernmost parts. Interestingly, the frequency along the west coast is almost comparable with that in the interior and sometimes even more so, especially in the central west coast. The frequency at 12 GMT is less than that at 00 GMT. This is mainly because at 12 GMT one observes mostly lapse conditions due to intense surface heating compared to that at 00 GMT. The inversion frequency is a minimum in July, which can be due to the overcast conditions and strong winds in this month, being typical of the monsoon season. The frequencies of lapse conditions are highest in April and July, at both times. As is to be expected, the distribution of lapse conditions is almost opposite to that of inversions.

3.2. MIXING HEIGHTS

03 hr (*Fig.* 5) (*night-time*)

MHs increase from south to north up to the central parts and decrease thereafter northward in January. The MHs are greater along the west coast than along the

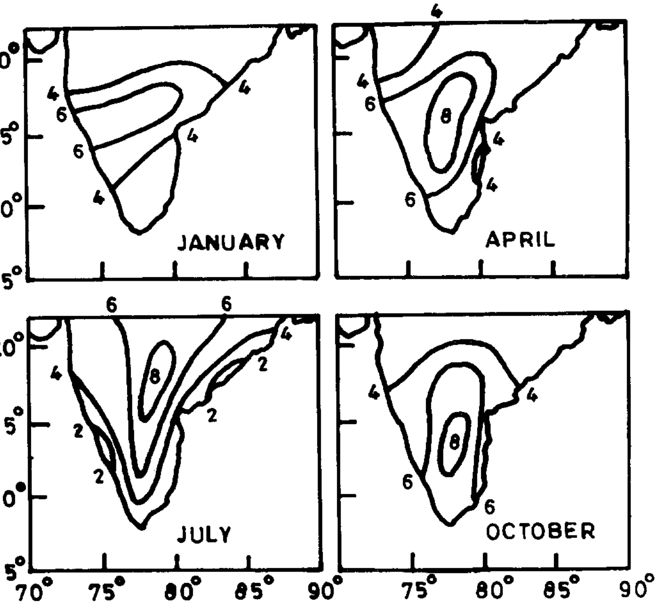

Fig. 5. Spatial variation of mixing heights (×100 mts) over South India at 03 hr IST.

east coast. In April, the MHs are a maximum in the central parts, with a minimum in the northwestern parts. The west coast once again shows relatively high MH. In July, the maximum is noticed over the central parts. The MHs are a minimum along both coasts. The values increase from south to north up to the north central parts. In October, however, the trend is slightly reversed with the maximum occuring over the southern interior, decreasing from south to north and towards both coasts in the east-west direction.

The maximum variation occurs in July, with values varying between 200 and 800 m and is a minimum in January, the values varying between 400 and 600 m. There is no significant seasonal variation of MH. In almost all seasons, the interior shows higher values and the coasts, lower ones.

09 hr (*Fig.* 6) (*late morning*)

The minimum MHs are observed in the northwest and southeast parts while maximum MHs are observed in the central parts in January. In April, values increase from south to north with a maximum occuring over the extreme central north. Most of the southern portions show a value of around 800 m. One can also notice a rapid decrease of values in the east, west directions from the northern central parts. In July, MHs are more or less uniform except for two small kinks, one over the central part and the other along the west coast. In October, the central parts show maximum MHs with a rapid decrease towards both coasts. The values increase from south to north. Both April and October show high values while July and January show relatively low values.

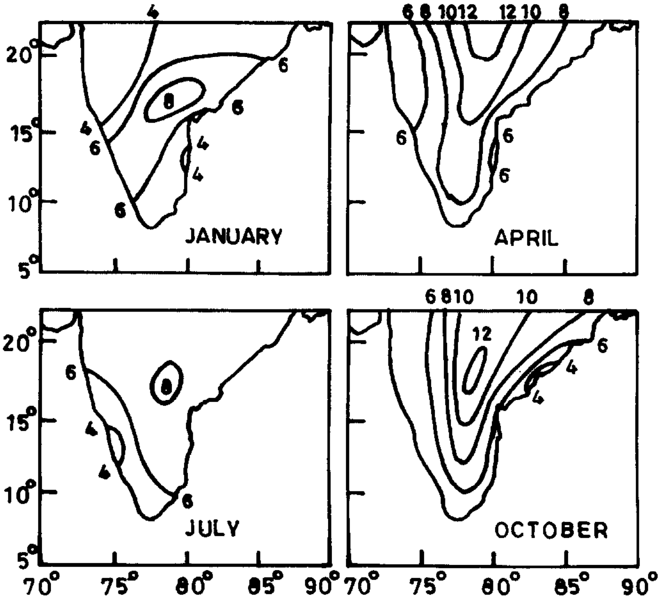

Fig. 6. Spatial variation of mixing heights (×100 mts) over South India at 09 hr IST.

15 hr (*Fig.* 7) (*late afternoon*)

For the first time in January, the range is high. Maximum values are noticed along the west coast and central parts while minima are in the northwest parts. In April, a variation similar to that at 12 hr prevails with a maximum occurring in the northern central parts and a minimum along the coasts. In July, the values once again increase from the west coast to the east coast, especially in the southern parts. A maximum is noticed in the southeast portions, the maximum occuring in the northern central parts and decreasing towards the coasts.

21 hr (*Fig.* 8) (*late evening*)

In all months, the pattern is more or less the same at this hour, showing a maximum in July and October. The values are almost comparable with one another. The maxima are in April followed by January, October and July.

In general, one interesting feature in all the cases is the occurrence of maximum MHs in the central interior and the decrease of values towards the coasts more rapidly in April than in other months. This is mainly because in April, the maximum heat input is in the inland regions, which gives rise to greater mixing in the interior, while the low surface heat input along the coasts gives rise to very low values of MH, thus making a very rapid variation from the central parts towards the coasts. In January, the values are generally low when compared to other months during the day because of the winter characteristics, while at nt night, the values are comparable with those in other months. During the

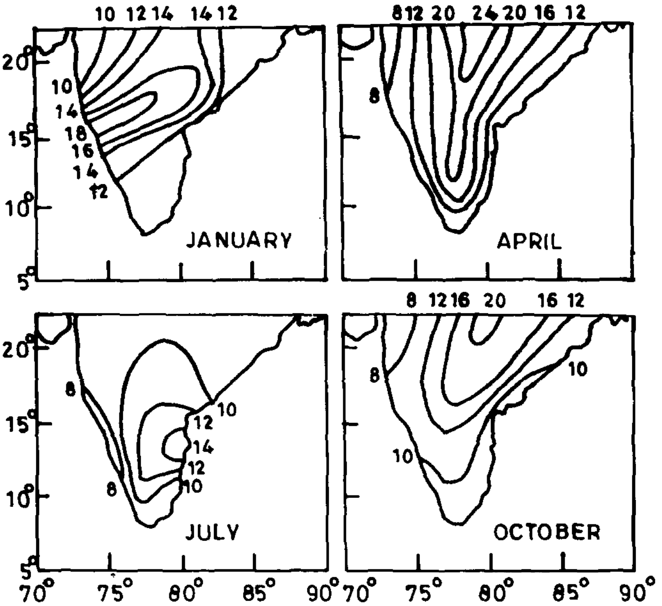

Fig. 7. Spatial variation of mixing heights (×100 mts) over South India at 15 hr IST.

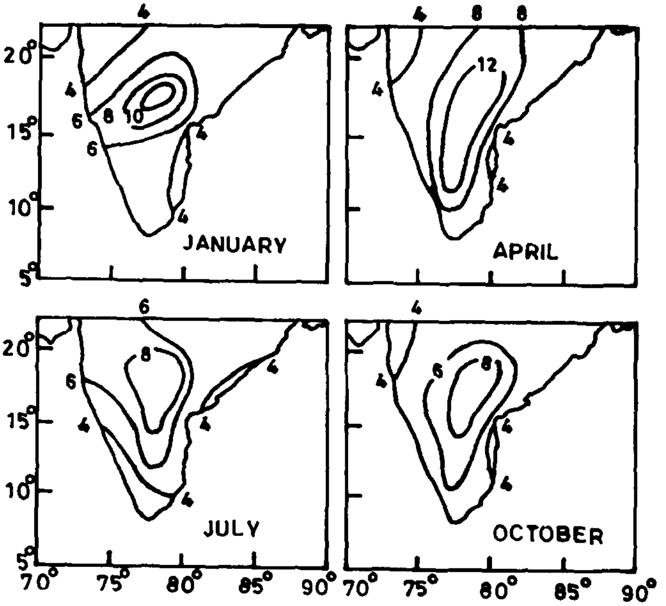

Fig. 8. Spatial variation of mixing heights (×100 mts) over South India at 21 hr IST.

night-time in January, the spatial variation is not very significant mainly because inland night-time surface temperatures are more or less comparable to those of the coastal regions, thereby bringing the range of surface temperature to a minimum. April shows maximum MHs for almost all hours, mainly because of the very high heat input at the surface which gives rise to atmospheric mixing. In July, values are low mainly because of the overcast conditions due to monsoon.

Figure 9 depicts the diurnal and seasonal variations of MH for Bangalore, Hyderabad, Mangalore and Nagpur. In Bangalore, the maximum is highest in April followed by July and October, while the minimum is least in July followed by October and April. The range is a maximum in April and a minimum in October. In Hyderabad, the minimum is lowest in January while the maximum is highest in April. The diurnal variation is least in July and a maximum in April. In

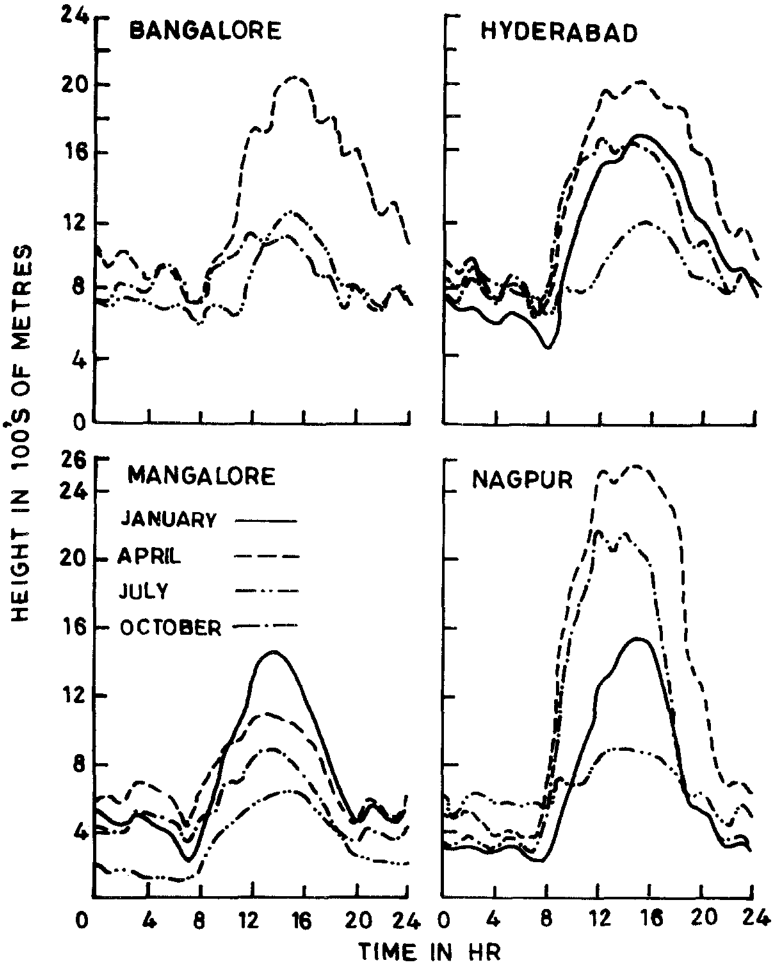

Fig. 9. Diurnal variation of mixing heights.

Mangalore, once again the diurnal variation is a minimum in July but the maximum is in January. At all hours, the MHs are lower than those in the other months. The maximum is higher in January followed by April, October and July. The minimum is least in July followed by January, October and April. January shows lower values than April and October at night but a maximum during day time. In Nagpur, the maximum diurnal variation occurs in April, followed by October, January and July. The minimum MH is in January while the maximum is in April.

In all cases, values are a minimum during the early morning hours and a maximum during the afternoon. The minimum variation in July at all these stations is due to overcast conditions which cause less mixing during the day because of the relatively low surface temperature but greater mixing at night because of the relatively high surface temperature.

3.3. VENTILATION COEFFICIENTS

03 hr (*Fig.* 10)

The VCs are very low, in general, at this hour. The spatial variation in January, shows maximum values in the central west coast. The maximum is only around 1000 m^2/s. In April, though the values are relatively higher than those in January, the range is only 1000 m^2/s with the maximum occuring in the central interior. The minimum is in the northwest and southernmost parts. In July, VCs are a

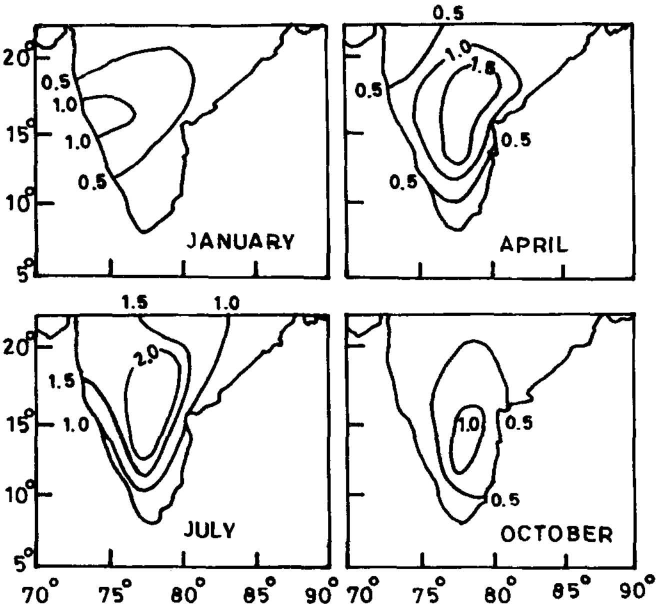

Fig. 10. Spatial variation of ventilation coefficients ($\times 1000\ m^2\ s^{-1}$) over South India at 03 hr IST.

maximum, reaching of 2000 m^2/s over most of the central interior. In October, the range has decreased to 500 m^2/s with the maximum occuring in the south-central parts and the minimum in the extreme south and north-central parts.

09 hr (*Fig.* 11)

Values show an increase in all months, with a maximum in April and a minimum in January. In January, the central parts show a maximum and the southernmost parts a minimum with the range rising to 1000 m^2/s. In April, the maximum occurs in the northernmost central parts, with values decreasing more rapidly towards the west coast. The values increase from south to north. In October, the maximum is once again noticed in the central parts.

15 hr (*Fig.* 12)

Maximum VCs are once again found in April and July. Maximum values are noticed along the central coasts and the minima in the northwest parts in January. The range is as high as 2000 m^2/s. Most of the interior shows a value of 400 m^2/s. In April, the range as well as the gradient of VCs have come down considerably from their values at 12 hr, with the maximum occuring in the northernmost central parts and the minimum along the west coast. The pattern in July is the same as that at 12 hr, with the values increasing from west to east in the southern parts. In October, most of the central parts in the north show higher values while the southernmost areas show low values.

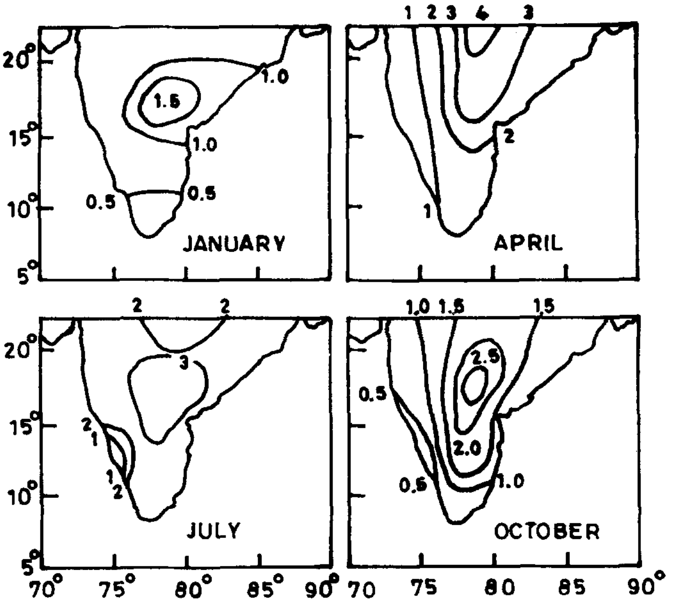

Fig. 11. Spatial variation of ventilation coefficients (×1000 $m^2 s^{-1}$) over South India at 09 hr IST.

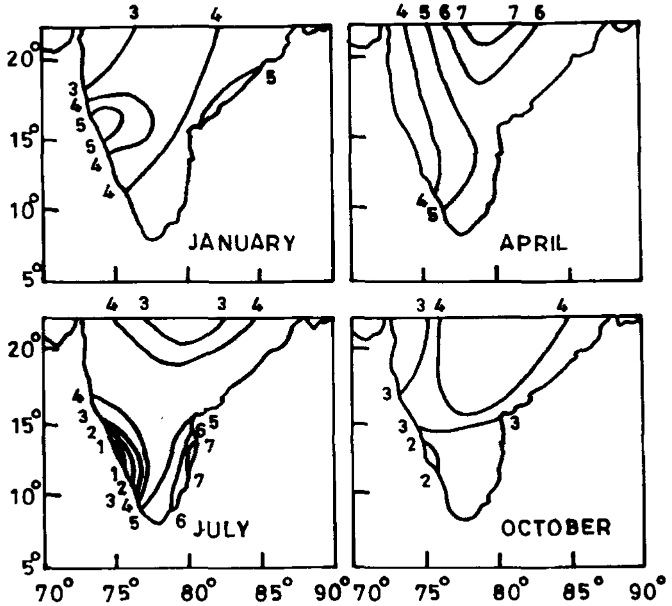

Fig. 12. Spatial variation of ventilation coefficients (×1000 $m^2 s^{-1}$) over South India at 15 hr IST.

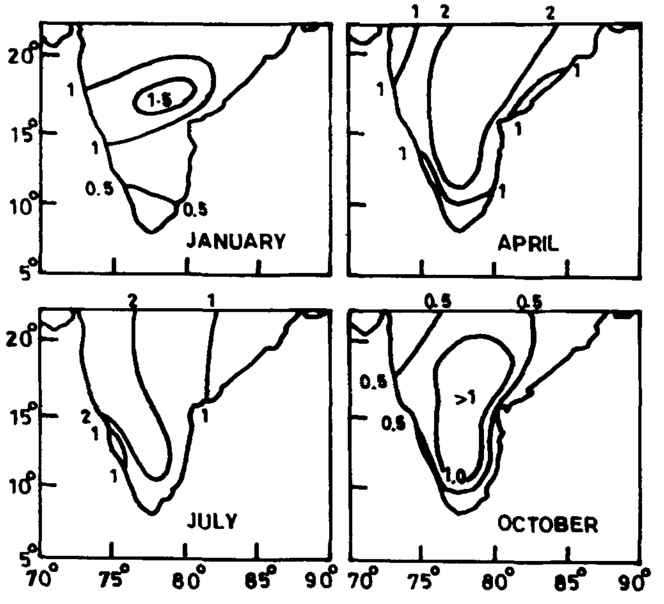

Fig. 13. Spatial variation of ventilation coefficients (×1000 $m^2 s^{-1}$) over South India at 21 hr IST.

In most cases, it can be noticed that at night, the values are a maximum in the interior and a minimum along the coasts (mainly due to the very low wind speeds along the coasts). During the day time, the higher values in the interior are mainly due to the very high MH. The large values along the coast are due to strong winds. The strong winds make the VC larger in July, while the MH is responsible for the large VC in April. The lowest values in the southwest coast are because of the weak winds. In most cases the pattern follows that of MH. Figure 14 shows the well-marked diurnal variation of VC.

The low value in July for Mangalore is mainly because of very low wind speeds in that month, despite being a typical monsoon season. The higher values in July during most of the night-time at the other three stations is mainly because of

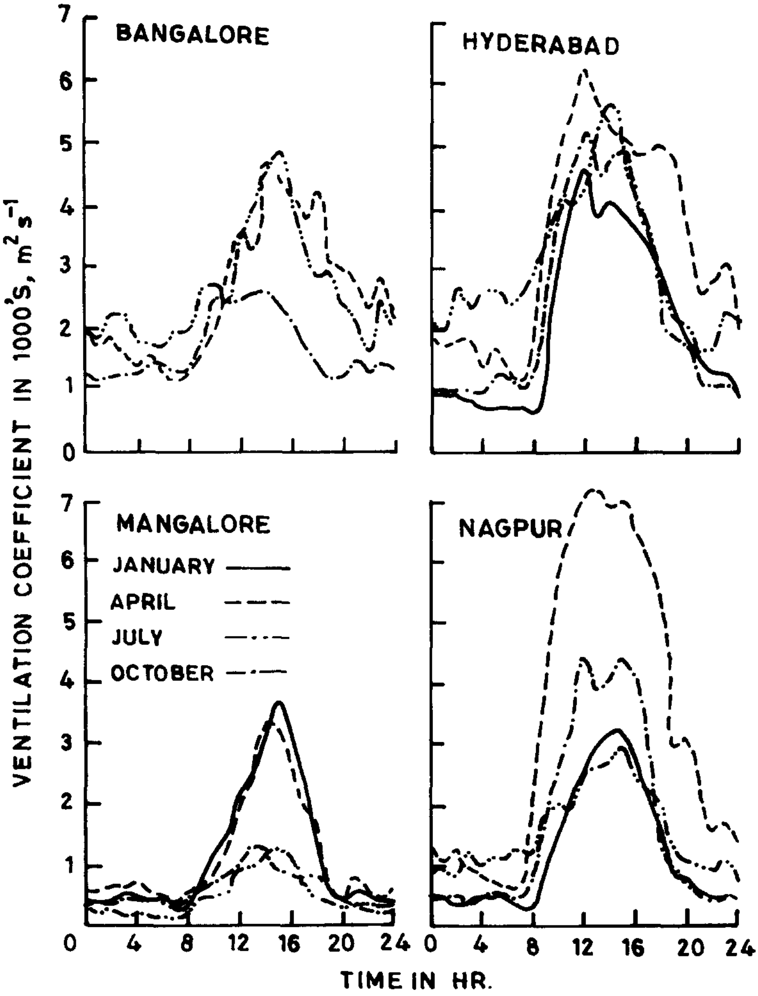

Fig. 14. Diurnal variation of ventilation coefficients.

relatively strong winds. While Mangalore shows the lowest value in July, Bangalore shows higher values than those in the other months. Of all the stations, Mangalore shows the lowest values in all months mainly because of the relatively low winds. Even these values of VC are still underestimates because the surface wind is used to compute VC instead of the mean wind throughout the mixing layer.

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