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A global study of satellite observations of clouds in the tropics and their relationship with dew point temperatures

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ABSTRACT. Charts showing isopleths of long-term monthly mean dew points over the world at sea level between 75°N and 65°S have been prepared for the months January, April, July and October. The isopleths on these charts between 30°N and 30°S have been compared with the isopleths of average cloudiness based on satellite observations of 2 years over the same range of latitudes. It has been shown that the sea level dew point isopleths have a high correlation with the cloudiness gradients and with the orientation of the isopleths of cloudiness in the tropics in the northern as well as the southern hemispheres. A general examination has also been made of the isopleths of dew points over the northern hemisphere at the 850 and 700-mb levels as available in recent published literature for the months January and July. It has been found that the isopleths at the 850-mb level resemble those at sea level in regard to their orientation and thus resemble the isopleths of average cloudiness, although to a less satisfactory extent than the sea level patterns. The patterns at the 700-mb level differ appreciably from those at the 850-mb level particularly north of 15°N. The significance of these factual findings and the possible usefulness of the dew point temperatures in studies of the moisture-field and the water-budget of the atmosphere are discussed.

1. Introduction

Although satellite observations of clouds in the tropics became available as early as in 1960, it is only very recently (Sadler 1969) that reliable monthly averages of the cloud amount in the tropical areas of the world have been worked out. The study of these averages, especially over the vast ocean areas have led to certain fundamental findings by Sadler in regard to cloud-cover in the northern hemisphere as against those in the southern hemisphere. For instance, it has been pointed out by Sadler that—

(*i*) The gradients of average cloudiness in the tropics are "as steep or steeper in the southern hemisphere as those in the northern hemisphere."

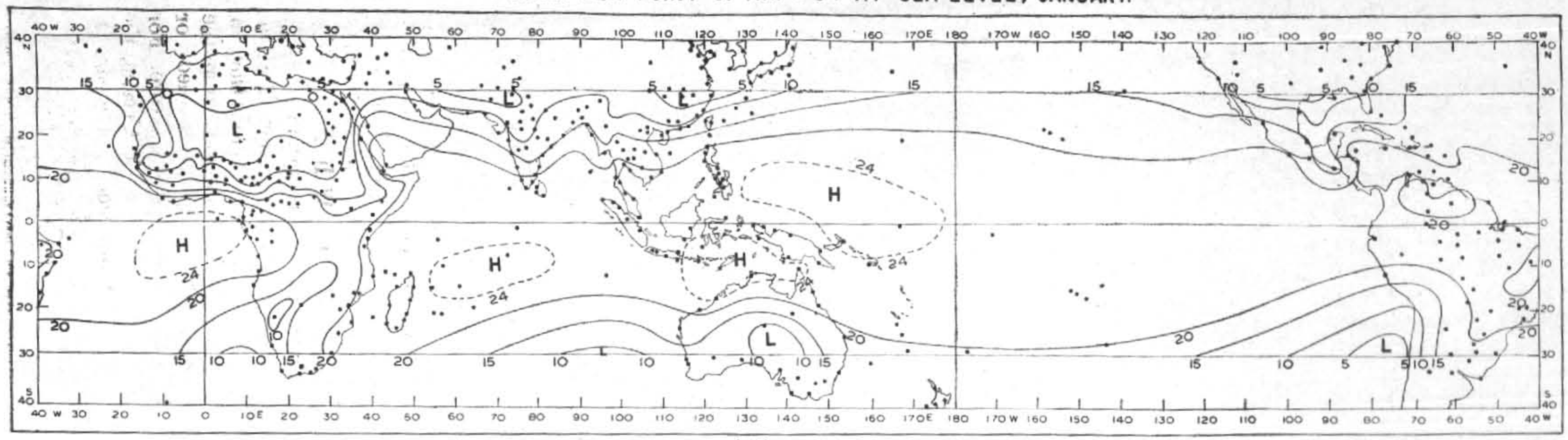
(*ii*) "The maxima and minima" in cloudiness "have a general east to west orientation in the northern hemisphere in contrast to a more north to south orientation in the southern hemisphere".

The present study is an attempt to find explanations for the above important findings on the basis of dew point data especially those at sea level. The choice of dew point was guided by the fact that its values at sea level are reliable and readily available at the dense network of observatories over most of the land-areas of the world besides those available over the ocean areas in the northern hemisphere (Navair 1966). Apart from the above, many workers (Telegadas and London 1954, Smagorinsky 1960, McClain 1966 and Adem 1967) have shown reasonaly good correlations between cloudiness and relative humidity in various layers in the troposphere. It therefore appeared worthwhile to the author to examine whether the dew point which is a more conservative meteorological element than relative humidity could be used instead of relative humidity in studies of the moisture field and the water-budget of the atmosphere.

2. Data sources

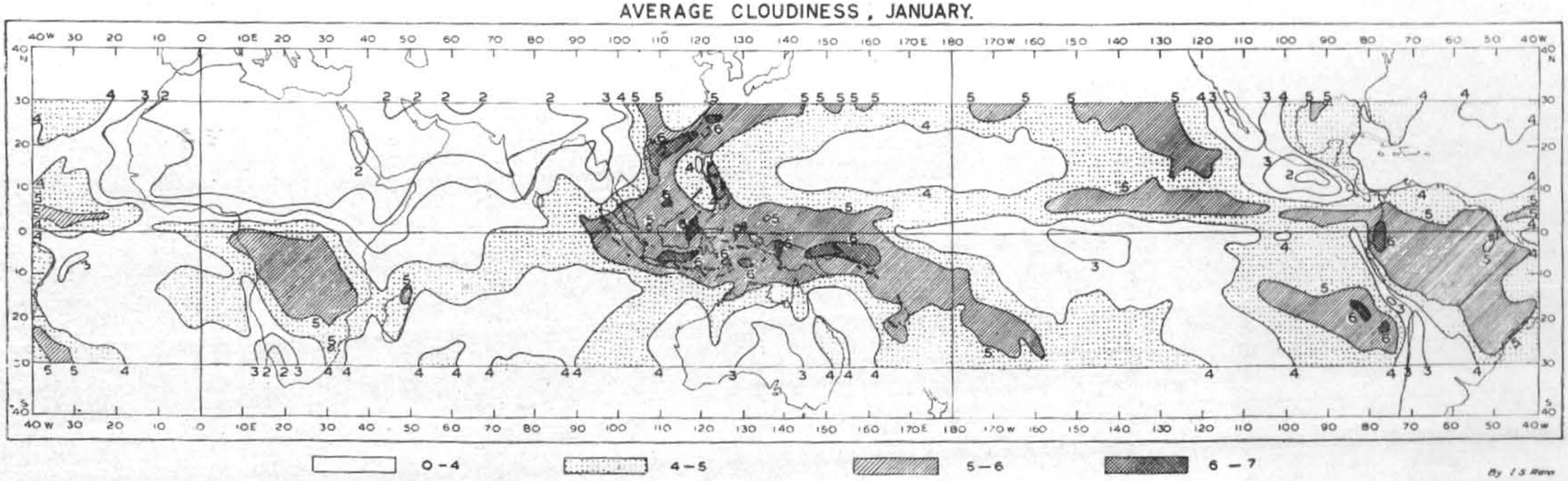
For this purpose, maps containing mean dew point temperatures at sea level over the globe between 75°N and 65°S, based on the data of a large number of years were prepared for the months, January, April, July and October. The basic data for the preparation of the maps were taken mainly from a recent WMO publication (1962) of climatological normals, including an unpublished supplement to it which was made available to the author by the WMO on request. Data of period-averages for important regions (*e.g.*, Indian Ocean, Indonesia, New Zealand etc) not contained in the WMO publication or its supplements were specially obtained from the National Meteorological Services concerned or extracted from available published literature. For the North Pacific and North Atlantic Oceans, the isopleths of mean dew points over these oceans as published jointly by U.S. Weather Bureau and U.S. Hydrographic Office (Navair 1966) were taken into account in addition to the

MEAN DEW POINT OF AIR (°C) AT SEA-LEVEL, JANUARY.



(a)

AVERAGE CLOUDINESS, JANUARY.



(b)

Fig. 1

(a) The shaded circles show the meteorological observatories between 40°N and 40°S. The isopleths of average cloudiness are in oktas.

(b) Published with the kind permission of Dr. James C. Sadler of the University of Hawaii, U.S.A. [Compare the orientation of the isopleths of average cloudiness and of the areas of cloud-maxima and minima with the orientation of the lines of equal dew point temperatures (isodews) in the corresponding latitudes and longitudes in the upper diagram].

data of Climat and Climat Ship stations available in the WMO publication referred to earlier. In the analysis, dew point data of stations at altitudes of *more than 800 gpm a.s. l. were omitted* so that a truly representative sea level map could be obtained. As far as the author is aware, previous *global* maps of dew points at sea level were published by Shaw (1936) more than three decades ago but he had very much scantier data than are available now.

In the following paragraphs, we shall, for the sake of brevity, refer to the isopleths of dew point as "Isodews".

3. Isodews at sea level in the northern and southern hemispheres in relation to cloud cover

Figs. 1 and 2 show the mean isodews and the average cloudiness in January and July. While studying these diagrams, it has to be remembered that the average cloudiness relates to a period of 2 years only, while the mean isodews are based on data covering a period of 10 to 30 years. It need hardly be added that average cloudiness based on satellite observations are not available for a period of more than 2 years.

The following are the broad-scale features of the isodews at sea level and their relationship with the average satellite-determined cloudiness over the corresponding areas.

(*i*) The gradients of isodews (between 30°N and 30°S) are much steeper in the southern hemisphere than in the northern hemisphere over the vast oceanic areas. The contrast is particularly good in the month of July. This is in agreement with Sadler's findings in regard to the gradients of average cloudiness in the two hemispheres.

(*ii*) The maxima and minima in cloudiness in July are oriented north to south or east to west depending broadly upon the orientation of the isodew patterns over the corresponding areas. This is true of both the hemispheres and it is also consistent with Sadler's findings referred to earlier. In the northern hemisphere, typical examples in July are the cloud-maxima over Africa between 12°N and 3°N and over the near-equatorial belt stretching over nearly half the northern hemisphere between 130°E and 50°W. In the southern hemisphere, the cloud-minima over Africa south of the equator and the cloud-maxima (stratiform clouds) off the west coast of Southern Africa and South America are particularly noteworthy. In certain areas, even the individual isopleths of cloudiness have a tendency to follow the run of the isodews over the same area. Examples of this may be seen in Fig. 2 off the west coast of Northern Africa, over Central Australia and over Southeast Brazil in South America.

(*iii*) The agreement between the orientation of isodew-patterns and of the maxima and minima in cloudiness is not as good in January as in July. One of the reasons for this may perhaps be that the data sample and distribution of satellite data for January were not as good as those for July (Sadler 1969). This is a point for further investigation. However, it may be stated that even in January, there is fair agreement between the orientations of isodew-patterns and maxima and minima in cloudiness. Examples of such associations in the northern hemisphere are the cloud minima over North Pacific between 140°E & 150° W, over the Arabian Sea, the Bay of Bengal and over India east of 80°E, and off the west coast of Mexico and Central America. In the southern hemisphere, the cloud maxima stretching from Indonesia to the south of Cook Islands (*i.e.*, roughly 160°W, 28°S) and the cloud minima over Australia serve as good examples.

(*iv*) The shifting of the mean isodew pattern with the march of the seasons, seems to be associated with a corresponding shift of the isopleths of the average cloud-amount except in regions of stratiform clouds (Sadler 1969). The progressive northward shift of the mean isodews over the same area during that period serves as a good illustration. Likewise, the southeastward extension of the cloud-maximum over Indonesia, New Guinea and Santacruz Islands to the south of Cook Islands from July to January corresponds to a southward shift of the mean 20°C isodew during the same period.

(*v*) Except in regions of stratiform clouds (*e.g.*, over China and over the cold waters off the west coasts of North America, South America, Northern Africa and South Africa) and *subject to other conditions being the same*, areas in which the monthly mean dew points are more than 15°C are favourable regions for the development of average cloudiness of 5 okta or more. The associations between the dew point temperatures and heavy cloudiness are particularly good when the dew points are 20°C or more. It is interesting to add that the highest monthly mean dew points at sea level over the world (25°C) occur over Southeast Asia during the summer monsoon month of July.

The global charts for the transition months, April and October (not reproduced in this article) fully support the broad conclusions stated above. An additional point of special interest in the case of April is that there is a marked near-equatorial cloudiness maximum over the eastern South

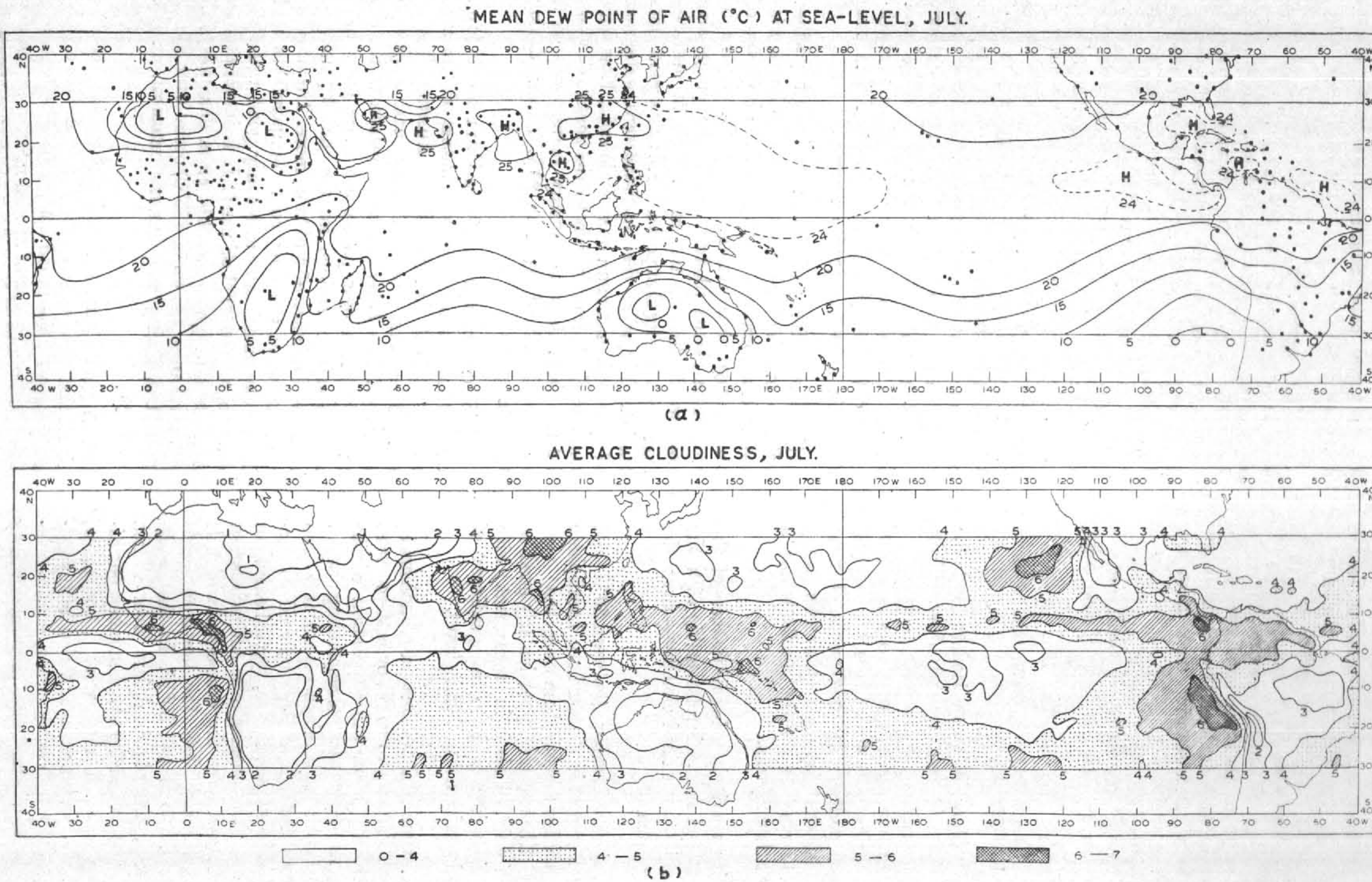


Fig. 2

(a) The shaded circles show the meteorological observatories between 40°N and 40°S. The isopleths of average cloudiness are in oktas.

(b) Published with the kind permission of Dr. James C. Sadler of the University of Hawaii, U.S.A. [Compare the orientation of the isopleths of average cloudiness and of the areas of cloud-maxima and minima with the orientation of the lines of equal dew point temperatures (isodews) in the corresponding latitudes and longitudes in the upper diagram].

Pacific. This feature does not however appear in the opposite transition-months of October and November. The mean dew points over this area in the South Pacific in April as determined from the mean isodew-patterns (based on fairly adequate observations) is about 24°C which is 4°C higher than in October over the same area. It is possible that this is one of the contributory causes for the development of the cloud-maximum in April.

4. Isodews at 850 and 700-mb levels in the northern hemispheres in relation to cloud cover

The author has made a general study* of the mean isodews at surface, 850 and 700-mb levels in January and July as recently published by Navair (1966) in their northern hemisphere charts. The study was confined to the sea areas and only those land areas the altitudes of which were *less than* 800 metres above sea level. This enabled the writer to compare his own sea level patterns with those published by Navair. The agreement between the two was good. As regards the higher levels, the isodew-patterns at the 850-mb level (published by Navair) were found** to be similar to the sea level patterns presented in this paper and were consequently similar to the average cloudiness patterns of Sadler (1969) although the agreement was not as satisfactory as in the case of the sea level isodew-patterns. The disagreement became more conspicuous as the 30°N limit was approached where troughs and ridges feebly appeared (charts have not been reproduced here—the reader is referred to Navair's original publication). The mean 700-mb isodew-patterns were less satisfactory than the 850-mb patterns from this point of view especially to the north of 20°N where the waviness in the patterns was more marked than at the 850-mb level. On the basis of these *factual findings,* we arrive at the important conclusion that *the orientation of the isopleths of cloudiness in the areas referred to in the earlier section, fitted in best with the moisture-lines and moisture-gradients between the sea level and the 850-mb level as revealed by the isodews* and that the *lack of* agreement between the two *increased* at the higher levels. This is consistent with the experience of Indian synopticians that the moisture necessary for the development of clouds in the tropics is released mainly from the air layers between the sea level and 850-mb level. It should however be clearly remembered that the isodews at the 850 and 700-mb levels as delineated by Navair over the ocean areas are based on far scantier dew point data than for the sea level and that, therefore, the factual statement made above, may have to be revised when more reliable radiosonde data over a denser network of stations become available in the tropics. In passing, it may be added that the author could not attempt a similar study for the 850 and 700-mb levels over the southern hemisphere as charts similar to those of Navair were not available for the southern hemisphere at the time of preparation of this paper.

5. Role of physical and dynamical processes

It is well-known that the development of cloud maxima and minima and of gradients in cloudiness depends not only on the moisture content of the air and moisture-gradients but also on the physical and dynamical processes which lift the moist air to produce the clouds. For a typical example, we invite attention to the marked cloud minimum between Lat. 10°N and 3°S over the Indian Ocean and extending between 50°E and 90°E, *i.e.*, over 40° of longitude during the height of the Indian southwest monsoon. In this vast near-equatorial sea area of cloud-minimum, dew points at sea level are as high as 22°C to 24°C. One would be tempted to infer that the upward motion of the air over this region is being inhibited by subsidence — a conclusion supported from other considerations by Koteswaram (1958), Pisharoty (1965), Asnani and Pisharoty (1965) and Asnani (1967). Other examples in support of our view-point are the cloud-minima over Arabia and over the South Pacific between 170°E and 110°W.

6. Dew point temperature as a possible new parameter in water-budget and other studies

Adem (1967) has derived a linear relationship between mean relative humidity in the troposphere and the total cloud amount in a representative month in each of the 4 seasons, summer, winter, autumn and spring. His equation involves a constant which varies according to the seasons. For details, his original paper may be referred to. Adem has also stated that his equation is not valid below 20° latitude in spring and summer and below 10°N in autumn. In winter, it is not valid above 70°N. One would have also liked to see a better fit between the individual points and the line drawn to fit them.

Apart from the above, Smigielski and Mace (1970) have very recently emphasized the well-known limitations in the use of relative humidity

*This section of the paper was prepared after the Symposium but it has been included here to make the paper more complete.

**The Navair northern hemisphere charts were on Polar Sterographic Projection. These were replotted on blank maps on Mercator's Projection to make them strictly comparable with the other charts prepared by the author which were al on Mercator's Projection.

in such studies, *e.g.*, the sudden changes in the value of this element as we pass from the outside to the inside of a cloud.

It is a well-established fact that dew point is a more conservative meteorological element than relative humidity. The present writer has also brought out in this paper an *observational fact—which is true on a world-wide scale*—that dew point temperatures have a high correlation with satellite-determined cloudiness especially over the vast ocean areas. It therefore appears worthwhile to pursue this research further on the lines on which Adem (1967) has done in the case of relative humidity and derive a quantitative relationship between the mean dew point in the lower layers of the lower troposphere and satellite-determined cloudiness in the tropics. Such studies may show that the dew point is a more useful parameter than relative humidity for these purposes.

7. Conclusions

The above studies of the mean dew point temperatures during the 4 representative months of the year, January, April, July and October in relation to average cloudiness over the tropics during the respective months, have shown that moisture-gradients as revealed by dew points at sea level and in the lower layers of the lower troposphere are good indicators on a world-wide scale of cloudiness gradients and of the orientation of the isopleths of cloud maxima and minima in the tropics. The above-mentioned associations also suggest that dew point temperature could be used as a new parameter in studies of the moisture-field and the water-budget of the atmosphere.

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