maize oil which can be used for soap-making and other purposes.

The existing Starch Factories can be used for the Production of Processed Maize Food

Some years ago, a number of starch factories were started in different parts of the country to meet the increasing demand for starch from textile and other industries. There are now about twenty fair-sized factories in India with a capacity for handling hundreds of tons of maize per day. These factories were working very actively during the war, but, recently they have been thrown mostly out of commission because of the necessity for distribution all available maize as an article of human food. As already mentioned, the results of this change have not been as happy as was originally expected. While the starch factories have been mostly idle, maize is not finding much favour as human food and quite large quantities are perishing in different parts of the country.

A modern starch factory has the necessary equipment for the steeping, efficient removal of the skin, separation of the germ and other processing of maize. These operations form a part of the process connected with starch manufacture. It appears very desirable, therefore, that instead of keeping the starch factories idle, their equipment could be utilised for processing the maize in such a way that they will turn out acceptable articles of human food. It should be possible for an average starch factory to turn out a flour that would exclude the skin and the germ, but include the rest of the grain as a fine flour. This flour would be attractive and can be used for a variety of purposes. There is strong justification for preparing bulk specimens of the finished products and conducting consumer tests with them over different parts of the country.

The Maize Grit

The above would be a wet method of processing the grain. That would necessitate the drying of the final product. There is also some risk of a part of the maize oil being carried along with the maize gluten which would form a part of the flour. There are also dry methods which could be used for the removal of the skin and the germ. The remaining part of the grain could be converted into a form which is commercially known as maize grit and which can be used for a variety of purposes. The equipment for the manufacture of maize grit is available and can be easily obtained from abroad. If some maize grit could be prepared in India or imported from America, some consumer-trials could be carried out with it and the public given the benefit of demonstrations in regard to its varied uses. Arrangements could then be made for the importation of the necessary machinery.

The Industry can be Easily Started and Extended

Some of the manufacturing firms in the country are already familiar with the methods of producing processed maize flour and also maize grit. They could obtain the required equipment and set them up if the necessary assistance is given. Once maize products could be made popular to the average rice and wheat-eating sections of the population, its future would be quite assured, and there will be enormous demand for maize products all over the country. The various factories in the country will have also have plenty of work to do; in fact many more new factories will be needed. The Government can investigate the matter through its Food Technical Panel and plan the organisation through its appropriate Food Industrial Panel.

Any important process successfully applied in the case of maize would also be generally applicable in the case of jowar and other coarse cereals. By suitable processing both human food in popular forms and also concentrated animal food out of the coarser fractions can be obtained. In this manner a balanced system of food production can be evolved with increasing benefit both to man and to

Note.—The cost of printing this article has been met from a generous grant-in-aid from the Imperial Council of Agricultural Research, New Delhi.

AIR MASS INTERPRETATION OF SEN'S VORTEX METHOD OF WEATHER FORECASTING

By S. L. MALURKAR
(*Poona* 5)

IN his review of Indian Weather in Köppen Band, Normand[1] pointed out that the concept of different air masses is old and implicit in the terms usually employed by the weather forecasters in India, but lacked the pictorial appeal of the theories which had then recently become common in the extra-tropical latitudes. A deep coist of monsoon current and a dry current were the main distinctions employed. Simpson and earlier workers[2] considered the monsoon stream as the continuation of the S.E. Trades of the southern hemisphere. Many workers tried to find out the different sectors and air masses that were required in the period of S.W. monsoon and for the cyclonic storms at other periods.[3] Roy and Roy[4] found that the monsoon depressions could be considered as consisting of three sectors with the following air masses; (*a*) fresh monsoon air, (*b*) monsoon air deflected by the hills in N.E. India and (c) the dry continental air. The very nomenclature restricted the scope of enquiry into the ultimate origin and properties of the air masses. Due to various reasons the origin of the air masses was left vague by other workers also. The position could not be described as satisfactory. Many forecasters including the author were content to find facts which could be used as simple criteria and sometimes use the concept of air mass when the signs for the latter were definite. The analysis of extensive weather charts and a technique of uniquely drawing isobars,[5] even when pressure gradients were weak and the number of ob-

servations few and far, showed that taking account of the sequence of the isobaric situation, weather and upper winds, the Indian weather could probably be attributed to three air masses :[6]

Equatorial Maritime Air (*Em*).—During the S.W. monsoon and in the pre- and post-monsoon months fresh maritime air crosses the equator from the south, at intervals depending on other meteorological conditions. It crosses the equator in a spurt (in a small interval of time) and there is a good interval of a few days before the next crossing can occur. To indicate this discontinuous and short-period crossing, the word 'pulse' of fresh maritime air has been employed. Before crossing the equator the character of the air mass is not the same throughout its history. It starts from one of the high pressure cells in the southern hemisphere as almost a dry continental stream (Tc) and in its westward travel gradually picks up moisture and some further additions of dry continental air. Later, due to the moisture content, it can be detected as a 'shallow' (in the sense of barometric defect at the centre and not as the height to which it extends) low pressure area moving in an almost west or west-north-west direction. The air corresponds to the far-eastern transitional or mixed air (see below). When just about to cross and certainly after crossing, its properties would be Em. It can be made easily unstable and thunderstorms occur all along its path and weather over the sea would be squally. The diurnal variation of temperature in its mass is very small or even negligible as shown by observations at hill-stations. The temperature at sea-level is about 80° F. The air is not hot, but due to its becoming easily unstable it can release energy and act as a 'source' among the air masses.[7]

Far-Eastern Transitional or Mixed Tropical Air.—This contains a mixture of tropical maritime air and tropical continental air in varying proportions depending on the locality and season of the year. Though it may be hotter in some seasons (e.g. northern summer) than Em, it is more stable. Near the hills of N.E. India it can, however, cause thunderstorms. Its properties are described elsewhere.[8] The monsoon 'pulse' (much before it crosses the equator to the other side) would resemble this air mass and this was the reason why the name transitional (transition from the Tc to Em in the course of the travel from one of the high pressure areas in the southern hemisphere to the northern hemisphere and reciprocally from the northern hemisphere to the southern hemisphere) was given and put as Tr.

Tropical Dry Air.—It has mostly a land origin and can be usually described as Tc with an occasional mixture of Pc. Its humidity is small and it shows a large diurnal range of temperature on the ground. It brings in unusually hot or unusually cold days over the region it passes over according as it is summer or winter period. For depressions forming in Bay of Bengal or in Arabian Sea the air gets slightly modified due to its partial Sea travel.[9]

The three air masses could be separated, their effects and characters can be studied. In the height of northern winter (January or February), the first air mass rarely enters the Indian area and few tropical cyclonic storms (with a westward motion) form. Recently, the existence of the three air masses has been verified by the use of temperature and humidity data over the region S. China to N.E. India and Ceylon to Peninsular India.[10]

Sen and Puri worked a simple air mass technique for daily weather forecasting.[11] Later Sen discarded the method and introduced a theory of "Vortex Method".[12] With a weather chart which was limited in extent, the last method sometimes gave successful results, more so in detailed forecasting. There have been critics. As much thought has been spent to evolve the ideas and positive success attained, it is necessary to look deeper into the methods. As idea of air masses cannot be discarded, Sen's method must essentially be a part of a more complicated analysis where air masses are implicit and dominant. The restricted nature of Dr. Sen's analysis must cater to the finer details of weather forecasting.

It is, perhaps, useful to digress here, why the air mass concept becomes 'unconvincing' to many weather forecasters in the tropics when working with limited number of observations.

In the northern winter, the shallow low pressure areas or 'pulses', that cross into the southern hemisphere to feed into the tropical cyclonic storms or depressions there, are in the wind field of the "N.E. Trades". The winds are moving towards the equator and due to latitudinal divergence are gaining in stability, and the lines of partition between this (Tr) and other air masses are getting obliterated. (Just as in the case of cold fronts getting diffuse due to subsidence in the cold sector.) The N.E. Trades are passing over the sea before crossing the equator and would be absorbing moisture and getting heated. They cross as 'pulses' thereafter to the southern hemisphere. At this stage the air is unstable. This can only be unmistakably noticed within five or six degrees of the equator, a region generally ignored as 'doldrums' or as outside the area of many working charts. Occasionally this instability may be detected upto ten degrees or more in latitude, but it can be easily missed; as one is not out to look for it. The western disturbances indicate fronts on some occasions, but if the air is traced, it often happens that the partition is between sections of tropical air which had very nearly the same origin in the high pressure of west Asia but with different travels. (Both approximately eastwards, one over the land and the other partly over sea.) Occasionally, the N.E. Trades feed into the maritime part of the tropical air[13] but may be missed due to the limited extent of the chart of a forecaster catering for N.W. India. The latitudinal convergence of air with a northward travel and the orography would seem to explain all his doubts.

In the monsoon months, the most important air mass Em is the most elusive one. The

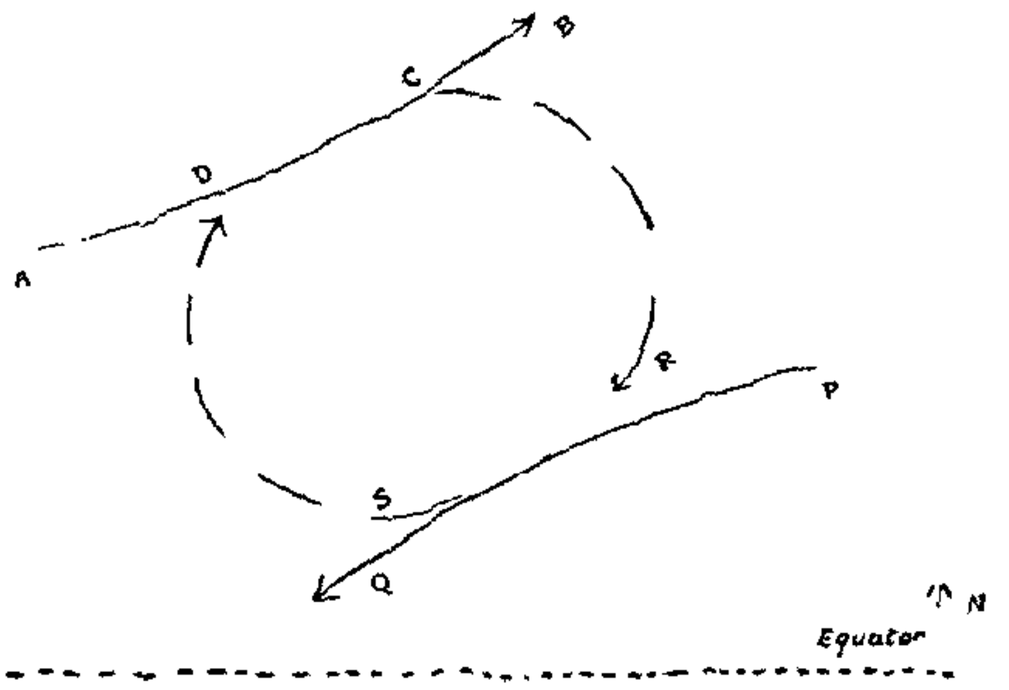
S.E. Trades are towards the equator and the 'pulses' or shallow low pressure areas that bring in the fresh monsoon air to the north become very diffuse as they approach the equator. The pressure changes near the equator are very small and may even be less than the diurnal variation of it, so that its importance would be missed.[5] The direction of wind would be disposed of as 'light and variable'. The time of crossing and the criterion of crossing would need very careful study of observations over a wide area on either side of the equator.[14] The trajectories drawn with the help of pilot balloon observations from stations situated at great distances from one another can give misleading ideas (*e.g.*, the S.E. Trades or 'pulses' go as far as Africa and then curve across the equator to feed into the Arabian Sea—the time sequence, the weather and winds at higher levels are all against it).

As for the far-eastern air Tr, it is partly N.E. Trades displaced northwards due to the shift of the seasonal lows and highs and has a slight equator-ward motion. It tends to gain in stability in the air mass and to make the partition with other air masses diffuse. Except in the neighbourhood of hills, thunderstorms are not common. But for the changing geometry of carefully drawn isobars and the sequence of rain in N.E. India, this air mass can be easily missed or ignored.

The third air mass is the continental dry air—its need is known. Its significance was missed, as with only one air mass which can be followed nothing exciting can result.

It is small wonder, if a forecaster in the tropics, handicapped with a limited chart and more limited number of observations and with air masses whose differences in temperature were much smaller than in the temperate latitudes, became sceptical of *routine air mass technique* in his area.

Consider now the winter conditions over India. Just north of the equator, in the lower levels of the atmosphere, there is an easterly or east-northeasterly flow of air due to the N.E. Trades. At higher latitudes, there is a westerly or west-southwesterly stream (the higher levels can be considered later). The easterly winds strengthen when 'pulses' or low pressure areas travel from the east and cross into the South Indian Ocean to feed the southern tropical cyclonic storm or depression. The westerly winds at higher latitudes feed into one or the other secondary low pressure areas of the western disturbances and themselves strengthen (see Fig.). When there is such a juxtaposition in the northern hemisphere, and easterly flow at a lower latitude and a westerly one at a higher latitude, the high pressure belt, in between, divides itself into cells of high pressure or a series of anticyclones. When there is no disturbance to the south or north of it, the anticyclone may be described as stationary in intensity and approximate position. The subsidence would be small and the air in it generally stable. The details of this configuration are given elsewhere.[15] The anticyclone develops or intensifies when either the easterly or westerly stream strengthens, *i.e.*, when the infeed of the Tr to the southern depression (and sometimes to a secondary low of a western disturbance) or when the infeed into the western disurbances takes place. As



the shallow low pressure area representing the 'pulse' approaches the particular anticyclonic cell, the latter continues to develop. The 'pulse' may now cross the equator with a spurt (in a comparatively short period of time) and then the anti-cyclone will definitely weaken till the next low pressure area or 'pulse' approaches it. In the case of monsoon depressions in Indian area, Sen calls this sort of thing which occurs in the southern hemisphere as a strong anticyclogenesis which gives rise to cyclogenesis in Indian area. This may also be compared with the idea of strong surges of high pressure in the Mozambique channel giving rise to depressions in the Indian seas (com. Pendell and others). The main fact is that a 'pulse' of fresh monsoon air crossed the equator to feed into a tropical cyclonic storm or depression. The concomitant circumstance was the high pressure area or the development of the anticyclonic cell and its later recovery. The author has pointed out that (*Forecasting Weather*, etc., pp. 36 & 88) "At the time of crossing the equator (the 'pulse') the value of the morning pressure is generally above 1020 mbs. and shows a good rise from the value on the previous day. The pressure rise is almost contemporaneous with the crossing of the equator by the pulse" and "Just before the transport of the fresh maritime air across the equator, fairly strong pressure gradient may be observed south of the equator and sometimes the steep pressure gradient may be observed to extend as far as Mauritius ..." As the high pressure area or the anticyclone is further away from the equator, it can be observed better but it would not justify to designate it as *the cause.*

If on the other hand, the 'pulse' did not cross the equator and moved westwards further, the next anticyclonic cell would develop and may release itself suddenly if *now* the 'pulse' crossed into the southern hemisphere. Otherwise, the anticyclone would release itself slowly and the next anticyclonic cell to the west of it will begin to develop.

If the 'pulse' or far-eastern air fed into the maritime part of air of the secondary low of an extratropical disturbance the anticyclone would gradually develop and would be displaced

eastwards as a northward travel of Tr would need a southerly stream to the west of an anticyclonic cell. The release would still be gradual. The recovery of the position by the anticyclonic cell would depend on the motion of the low pressure area to the north of it. The shape of the anticyclonic cell would depend on the relative position of Tr and the secondary low pressure areas of the extra-tropical depression.

If on the other hand, due to the secondary of the extra-tropical depression, the westerly stream strengthened, the anti-cyclonic cell would once again be developing. As the secondary low pressure areas travel almost E.N.E.-wards, one anticyclonic cell after another gets developed in an eastward progression. Some of the developed anticyclonic cells *may allow Tr to feed into the secondary while* in others such a contingency may not happen. While the movement of the complex low of the western disturbance is large and erratic, the development and recovery of the almost stationary cells of anticyclones in the seasonal high pressure belt can be observed more closely. If the complex low pressure area of the western disturbance is broken up into a series of distinct low pressure areas each of which is moving E.N.E.-wards and has a separate existence the problem of following the western disturbances would be very greatly simplified[16] and here again this series of secondaries is the cause and the change in the anticyclonic cells a concomitant. When the extent of a weather chart is small, a fast-moving western disturbance can be detected by the changes in the anticyclones. During winter it is possible to hazard a guess that a western disturbance is approaching Iraq when the surface and the lower upper winds at Bahrein become more northerly or northeasterly and no observations from west of Bahrein are available.[17] Similarly even though with the observations on the charts no low pressure area can be drawn, the development of the anticyclonic cell can indicate an approaching disturbance. In the first case the seasonal high is getting narrowed, displaced and intensified due to the approach of a western disturbance and the wind at Bahrein becomes more northeasterly than its usual north-westerly. The footsteps of a camel on a desert allow one to deduce the movement of a camel, as a result of past experience regarding the shape and direction of its footsteps.

In the northern monsoon, the easterlies are shifted northward in latitude (say about 20 to 35° N.) and the westerlies still further north. In the high pressure belt, the anticyclonic cells can still form and the development of the cell would depend on the far-eastern Tr feeding the monsoon depressions or to some western disturbance travelling at a higher latitude. As the western disturbances at a higher latitude 'pull' up' the monsoon depressions and allow it to recurve,[18] this would again be indicated in the displacement of the anticyclonic cell, and is a useful orientation in actual practice. To draw the anticyclonic cell or to see its displacement, it may not always be necessary to have winds all round, as with practice and experience one can judge it.

In the monsoon nearer the equator and south of it there is again a general high pressure area with variations. Further down in southern hemisphere the high pressure area breaks up into cells. It is possible to imagine that with the anticyclonic cells to the north of the monsoon low and with the high pressure cells to the south of it, we have a street of vortices, and whose displacements and variations indicate weather, not easily deducible otherwise, with limited observations.

It follows, therefore, that the main thing is the movement of low pressure areas and the air masses connected with them as far as weather forecasting is concerned; and the anticyclonic cells (or vortices) are the indicators of the movement of air masses and low pressure areas. When this limitation is clarified, the indicative value of the anticyclonic cells can be fully exploited. This is specially useful *to a forecaster whose chart is limited.* The distance between two successive anticyclonic cells is determined from large dynamical considerations and the variation of the position and configuration of these anticyclonic cells is small from day to day so that patterns can be drawn and followed closer. If any cannot be drawn, due to lack of observations, it is possible to make a fair guess, and fill up the lacunæ. A quick and unique way of drawing these anticyclonic cells, whether the wind field is strong or weak and variable, and the cataloguing of the variation in the cell due to types of disturbances that may be passing about it would be highly desirable.

---

1. Normand, *Gerl. Beit. z. Geopys.*, **1931, 34,** 233. 2. Eliot, *Cyclone Memoirs*, **1** to **5**; *Handbook of Cyclonic Storms in the Bay of Bengal*, **1.** Simpson, *Quart. Jr. Roy. Met. Soc.*, 1921, **47.** 3. Ramanathan and Narayana Iyer, *Sc. Notes, Ind. Met. Dept.*, **3, 1.** Ramanathan, *Ibid.*, p. 29. ——— and Banerji, *Ibid.*, **4,** 35. Normand, *loc. cit.* Roy and Roy, *Beitr., Phys. Fr. Atm.*, 1930, **16,** 224. Mal and Desai, *Sc. Notes, Ind. Met. Dept.*, **4,** p. 87. Iherzi, *Gerl. Beit. z. Geophys.*, **1931, 29, 344.** Ramanathan, *Ibid.*, 1932, **35,** 66. Desai and Mal, *Gerl. Beitr. z. Geophys.*, **1933, 40, 12.** Desai and Basu., *Ibid.*, p. **1.** Basu and Desai, *Ibid.*, **42,** 353. Deppermann, "Are there warm sectors in Philippine Typhoons?" Weather Bureau, Manila, 1937. 'Philippine Frontology.' Sen and Puri, *Proc. Nat. Inst. Sc.* (India), 1938, **5,** 43. 4. Roy and Roy, *loc. cit.* 5. Malurkar., *Proc. Ind. Acad. Sci.*, **1946, 25,** 297. 6. —, 'Forecasting Weather in and Near India,' May 1945. (Released Nov.) 7. —, *Ibid.*, pp. 34 and 87. 8. —, *Ibid.*, pp. 39 & 91. 9. —, *Ibid.*, pp. 41 & 90. 10. Malurkar and Pisharoty, "Evidence of three air masses from temperature aloft in tropical cyclenes" (in Press). 11. Sen and Puri, *loc. cit.* 12. Sen, *Science and Culture*, **9,** 453. Sen and Ganesan, *Ibid.*, **10, 54.** Sen and Sircar, *Ibid.*, **10,** 305. Sen, Puri and Mazumdar, *Jour. Phy.*, 1944, **18.** Sen, *Symposium of Nat. Inst., of Sc. (Ind.)* Aug-Sept. 1946. 13. Malurkar, *loc. cit*, p. **111** and *Curr. Sci.*, 1947, **16, 139.** 14. ———, 'Forecasting Weather' (*loc. cit.*), p. 38 and p. 88. 15. ———, *Curr. Sci.*, 1947, **16,** 139. 16. —, 'Forecasting Weather,' p. 101-4. 17. —, *Tech. Note of Ind. Met. Dept.*, **1,** 4 18. Malurkar, 'Forecasting Weather' (*loc. cit.*), pp. 47 and 48 (additional). Also *Curr. Sci.*, **16,** p. 14.

Note.—The cost of printing this contribution has been defrayed by a generous grant from the Rockefeller Foundation for the publication of results of scientific work made to us through the kindness of the National Institute of Sciences, India.