

WINTER RAIN IN THE UNITED PROVINCES

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IT is well known that the winter rain over North India is due to the passage of complex low pressure areas (called as western disturbances in India) under the influence of extratropical depressions.¹ These complex low pressure areas can be divided or broken up into a number of distinctly evolving simple low pressure areas each of which move almost ENE.²

While travelling between Delhi and Allahabad, it was noticed that sometimes the weather west of a place between Fatehpur and Cawnpore was dry and almost clear while to the east of the same place, the sky was mostly clouded and was occasionally threatening. Even the past weather of the places to the west of Cawnpore would have been dry. The secondary low pressure area which gave weather to the places east of Cawnpore got the moisture feed from more easterly longitudes.

The pre-monsoon period can also be included under the category of winter here.

The moisture-bearing winds are those that flow at or below 2 km. While the air at higher levels gives a dry feed and is responsible for instability weather. The more equatorward secondary low pressure area of a western disturbance affects only the lower heights³ of the atmosphere which happen to be the moisture-bearing areas, the orography of the central parts of the country should be expected to exercise a directive influence on the weather. It is accepted generally that the effect of the mountains disappears at the height corresponding to two or three times the elevation of the mountain. With an orographic map, it should be possible to draw a sort of free stream lines to determine how the orography affects the weather. With an orographic map of India (0.5 and 1.0 km. contours) some free line curves were drawn (Fig. 1).



FIG. 1

The observations printed in the "Indian Daily Weather Report of the India Meteorological Department" and in the Provincial Raingauge

Reports in the "Gazette of the United Provinces" were used to study in detail over a wide area and over a period of three to four days prior to the development of weather in the U.P. The rainfall recorded at the provincial rain-gauge stations were plotted against stations tabulated in the groups arranged SW to NE and could illustrate well the movement and evolution of the secondary low pressure areas.

Two typical instances were specially studied. In one, for 27th December 1945, Allahabad recorded one inch of rain. Stations in east U.P. had well distributed rain. In the west U.P., the rainfall was scanty or absent even on previous days. The sky at Delhi gave no indication of weather in the period.

In the second case, for 8th April 1946, fairly wide-spread dust or thunderstorms occurred in the east U.P. An airways pilot who flew from Gorakhpur to Lucknow on 8th afternoon saw a line squall following him. The mail plane pilot who left Allahabad to Delhi that evening said that he diverted to the south of Cawnpore and that he saw a line squall to the east of him.

25th December 1945.—0800 hrs. A low pressure area was over west Rajputana and Sind. There was hardly any clouding in the tract of the country covered by the stations Dwaraka, Bhuj, Deesa, Agra and Bareilly or in the tract covered by Jalagaon, Khandwa, Hoshangabad, Jubbulpore, Saugor (C.P.), Sutna and Allahabad.

The upper winds at 1.0 km. in the central parts of the Peninsula had changed since the previous evening. A 'natural' upper air stream line could be drawn from Madras to Bangalore and then northwards upto Ambala, so that a southerly flow which could ultimately be partly traced to the Bay of Bengal was possible. In N.W. India, a low pressure area was indicated in the upper air. The upper air along the west coast of India was determined by a high pressure area over the east Arabian Sea. A corridor of low pressure existed in the upper air at lower levels from south-west Peninsula to south Rajputana. The N.E. monsoon winds were moderate to strong in the southwest Bay of Bengal. The pressure change in the previous 24 hrs. and the pressure departure from normal were negative over northwest India but were not so over the United Provinces. It had rained 1½" at Colombo and less than ten cents at Trincomalee and Hambantota in the previous 24 hrs.

1700 hrs. The northward upper air stream line that could be traced to the Bay of Bengal had shifted northwards: Masulipatam—Hyderabad and then northwards (due to the afternoon low?). The N.E. monsoon had slightly strengthened and gripped the winds at Madras and Bangalore. The area of negative pressure change and negative pressure departure had slightly moved over to the United Provinces. Otherwise, the conditions were the same as in the morning.

26th December 1945.—0800 hrs. Traces of low clouding could be observed west of Hoshangabad and Saugor (C.P.). The area of

negative pressure change was extending from the east United Provinces to Assam and it was positive in northwest India. The lowest pressure departure was in north Central Provinces, near Saugor and Jubbulpore. Less than ten cents of rain had fallen at Nowgong, Sutna, Allahabad, Benares and Alleppy. It was still raining at Allahabad and Benares. Allahabad had an easterly and Benares had a north-westerly wind (force 2).

In the upper air at 1.0 km., the northward stream line which could be traced to the Bay of Bengal was again Madras-Bangalore-Hyderabad and then northwards. The upper winds at Bombay, Nagpur and Jubbulpore were SSW and strong at 1.5 and 2.0 km. and gradually veered to west at higher levels. Bhopal had also strong SSW upper winds. A low pressure area in upper air (at 1.0 to 1.5 km.) was over northwest Central Provinces and east Central India.

From the *Provincial Raingauge Reports*: Mau in Jhansi; Rath; Madha and Khajwa in Hamirpur; Banda, Girwan and Baberu in Banda districts; and Fatehpur and Lucknow recorded light rain to the west of Allahabad. There was no rain at the more westerly stations recorded either on 26th or on preceding days.

1700 hrs. Allahabad had a thunderstorm. The belt of negative pressure change had moved further east.

27th December 1945.—0800 hrs. Pressure change in the previous 24 hrs. was positive all over the country, outside Chotanagpur, Orissa and parts of Bengal and Assam. Pressure departure was positive over the central parts of the country.

At 1 km. the upper air stream line which could be traced to the Bay of Bengal was Masulipatam—Sambalpur—Gaya and Gorakhpur. An upper air low could be seen over the east United Provinces and West Bihar. Past weather: Lucknow had less than ten cents rain. Bahraich $\frac{1}{2}$ ", Sutna $\frac{1}{4}$ ", Allahabad 1", Gorakhpur $\frac{1}{2}$ ", Benares $\frac{1}{2}$ " and Gaya $\frac{1}{4}$ ".

From the *Provincial Raingauge Reports*, arranged according to districts lying in groups southwest to north east:

One station out of four recorded very light rain in Sitapur, 3 out of 9 stations had rain in Banda, 1 out of 4 in Gonda and 2 out of 3 in Bahraich districts, 1 out of 3 in Fatehpur, 1 out of 4 in Rae Bareilly, 1 out of 6 in Fyzabad and 2 out of 3 in Pertabgarh districts; 8 stations out of 8 in Allahabad, 5 out of 5 in Jaunpore, 6 out of 6 in Basti, 5 out of 6 in Azamgarh and 5 out of 8 in Gorakhpur districts; 1 station out of 5 in Mirzapur, 2 out of 3 in Benares, 3 out of 4 in Ghazipur and Ballia districts recorded rain.

7th April 1946.—0800 hrs. A low pressure area was over west Rajputana and Sind East of Long. 77° E and north of Lat. 13° N, even the surface winds had a southerly component. It was raining over Assam and north Bengal. It had rained in the western Himalayas and in the S.W. Peninsula. Minimum temperatures were below normal in the southeast United Provinces.

In the upper air at 2.0 km., a low pressure area could be detected extending from the

northeast Punjab to east Central India and the northeast Central Provinces.

From the *Provincial Raingauge Reports*, it is seen that Pharendra in Gorakhpur and Deoria in Deoria (formerly part of Gorakhpur Dist.) districts had each 2".92 rain. On the 6th, fairly widespread rain had been recorded in Ballia, Deoria, Gorakhpur and Basti districts.

1700 hrs. Skies were clear at Benares and Allahabad. They were partly clouded at Guna, Saugor (C.P.), Jubbulpore, Sutna and over Chota Nagpur. At 1.0 km. in the upper air, there was a low over east Central India and adjoining districts of the United Provinces. At higher levels the westerlies were running over the whole of the United Provinces.

8th April 1946.—0800 hrs. The low pressure area on the surface chart extended from north Rajputana to the south west United Provinces. Surface winds continued to show southerly east of Long. 78° E. Skies were partly clouded at Allahabad, Sutna and Nowgong. Delhi was overcast and it had rained in the past hour. It was still raining in Assam and north Bengal. Over the rest of Bengal, skies were partly to mostly clouded. Near the United Provinces, among the departmental observatories, only Nowgong reported rain. Minimum temperatures had risen in the east United Provinces.

Upper air flight at 0900 hrs. at Allahabad gave easterly to east-southeasterly upto 1.5 km. Bareilly was strong east to southeast upto 1.5 km. An upper air low, extending upto a height of 1.5 km. above sea level, was over the United Provinces, the southeast Punjab and north Rajputana.

From the *Provincial Raingauge Reports*. Three out of six stations in Cawnpore district had rain (each more than 0".38), 1 out of 4 had very light rain in Mirzapur district. No other station in the plains of the U.P. recorded any rain.

1700 hrs.—A low pressure area was over the north Central Provinces and east Central India caused partly by the afternoon heating. A high pressure area was enclosing Daltonganj and Hazaribagh which were having thunderstorms at time. Allahabad reported thunder. Cawnpore and Mainpuri had recorded dust or thunderstorms. Agra had a drizzle.

According to newspapers, thundersqualls and dust storms occurred over a wide area from Fatehpur to Benares.

The thick clouding approached Allahabad from west-north-west. It broke out with a severe duststorm at Allahabad at about seven O'clock in the evening and was over Bamrauli about 20 minutes earlier.

9th April 1946. From the *Provincial Raingauge Reports*, it is seen that rain was recorded in 3 out of 4 stations in Ballia, 4 out of 4 in Ghazipur, 3 out of 3 in Benares, 2 out of 4 in Gorakhpur, 3 out of 5 in Deoria, 3 out of 6 in Azamgarh, 2 out of 4 in Jaunpore, 4 out of 5 in Mirzapur, nil in Allahabad, 1 out of 5 in Basti, 1 out of 6 in Fyzabad, 2 out of 3 in Fatehpur, one out of 4 in Sultanpur, 1 out of 8 in Hamirpur, 4 out of 9 in Banda and 1 out of 4 in Jalaun districts.

The main lines of argument and conclusions, are given here.

In the first example 27th December 1945, most of the rain fell to the east of the line drawn from Fatehpur to Basti or Gorakhpur. The pressure changes on the weather chart show the eastward passage of a low pressure area which was over Sind and W. Rajputana on 26th and its secondaries. These produced little precipitation in the plains until they had a S-ly feed from regions east of Long 77° E. In the northern hemisphere a northward moving air stream has latitudinal convergence and tends to become less stable in its mass. If other conditions are suitable, weather is produced. An air stream with a good sea travel, after only a small northward displacement in a given amount of time may cause clouding and even precipitation. Stream lines on 25th and 26th had a run from Madras to Bangalore and then northwards but were not moist enough to give rain in the Central Provinces. The N.E. monsoon was moderate to strong in S.W. Bay of Bengal and an infeed of N.E. Trades occurred into the above stream lines; activating some particular secondary low.⁴ The S-ly feed was not deep and above 2 km. the winds were W-ly. These higher level winds could be associated with the rear of a low of a western disturbance at a higher latitude and would be bringing in fresh cold air at higher levels. In fact, *the strengthening of the westerlies at higher levels can be taken to usher in colder days in winter over N.W. India and in the U.P.*

Fresh incursion of air at higher levels, colder than what existed there previously would decrease the stability in the air along the vertical. The fresh incursion of the S-ly air at lower levels bringing in more moist and warmer air than what existed previously has also a similar effect on stability. Along with latitudinal convergence, the air, now at the locality, can well maintain convection, if once started.⁵ The causes of initial vertical movement in the production of thunderstorms are one or more of: (a) the 'cold front' of these secondary low pressure areas. It is well known that after the thunderstorms in winter the wind shifts to a W-ly or N.W-ly direction from its previous E. or SE. Each secondary has its own wind shift and it is only after the wind shift occurs that drier and cooler days set in. (b) Orography. (c) Wind velocity gradient which express the same condition in more general terms (d) The unequal heating or insolation or (e) the long period oscillations of the isopycnic surfaces.⁵

In April 1946—usually a dry season in the plains of the U.P.—the plains of the west U.P. had little rain. The moist feed came from longitudes further east than on December 26th 1945. The secondary low pressure area was only detectable below 2 km. It was raining in Assam and N. Bengal and thunderstorms had occurred in S. Bihar and Chota Nagpur. Stream lines at lower levels passing over these regions would be moist. At higher levels, the rear of more northerly low pressure area of a western disturbance was exercising its influence, i.e., it was bringing in fresh cold air at higher levels. Hence the vertical structure of air was favourable to maintain convection. The causes of initial convection are the same

as before except that insolation plays a greater part as summer is approaching. When the secondary low pressure area (with a small vertical extent and which was responsible for bringing into juxtaposition of different air streams) passed ENE wards; the weather in the east U.P. cleared up till the next cycle of secondaries appeared.

Fig. 2 represent diagrammatically the vertical structure of air mass before dust or thunderstorms.

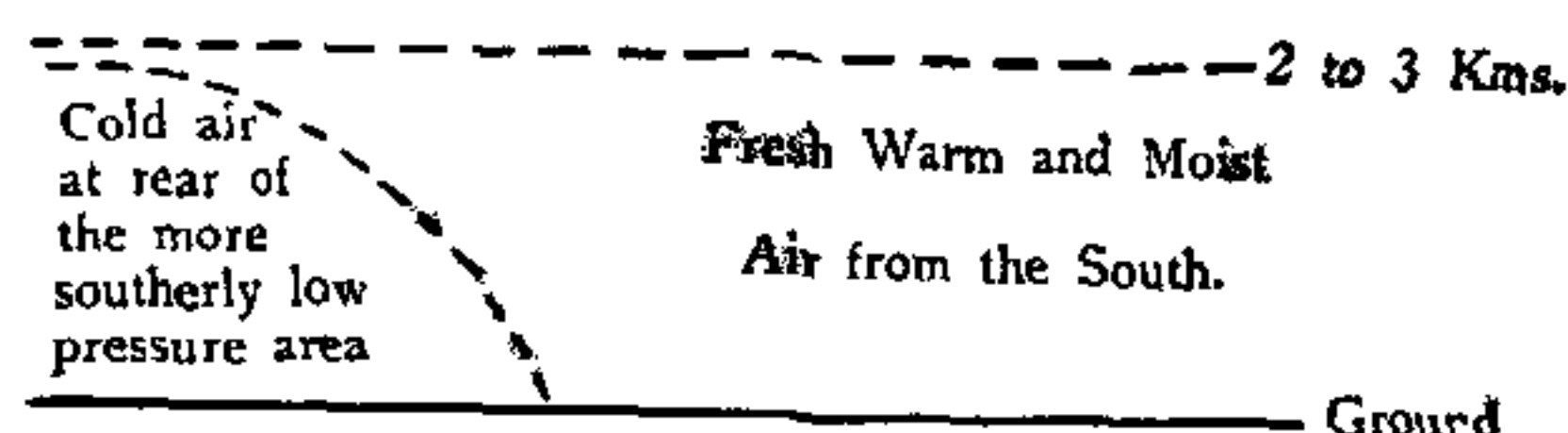


FIG. 2

(Thunderstorm in the U. P. in winter)

Fresh Cold Air at the rear of a Northern Low Pressure Area of a Western Disturbance

If at higher levels, cold air does not establish itself as shown by strong W-ly winds, the weather does not clear up completely and heat thunderstorms result.⁶

With an extensive chart, it is possible to watch the successive secondary low pressure areas. When the weather chart is limited, some working criteria had to be evolved based on the above and Fig. 1.

If a western disturbance was passing over 30° N, rain or clouding in the tract east of the Aravallis and west of the Vindhya (represented by the observatories Dohad, Brijnagar and Jhansi) would show that a secondary low had a moisture feed and in its east-northeastward passage, it would be a pre-indication of weather in the west U.P. and neighbourhood.

Rain or clouding in the tract represented by the observations from Indore, Khandawa, Hoshangabad, Saugor, Jubbulpore and Sutna show that the secondary low further south than in the previous instance has had a moisture feed. This secondary, during its course of movement ENE wards would give weather in the east U.P. and neighbourhood.

The orography must also be kept in view.

If the secondary low pressure area has more closed isobars than usual, due to the anti-clockwise motion of the winds round it, the moist stream would extend to more westerly longitudes and give weather there than if the low was weak.

For the east U.P., a southerly feed would come from longitudes east of Long. 78° E or 80° East. The upper winds of Bangalore, Hyderabad (Deccan) and Nagpur become significant. At lower levels, the upper winds from the more southerly stations must show a SE component, while those from higher latitudes must a SW component. In early summer, the seasonal low gets to be more marked. Then the SE-ly components of winds on the east coast stations become significant, i.e., at stations like Madras, Masulipatam, Vizagapatam, etc.). Sometimes, if Assam and Bengal be raining and a shallow low pressure area is found over east Central India, the belt

of thundershowers would extend from NE India even into the U.P. and these would be more marked in the eastern districts.

A weather forecaster is very much interested in the time sequence between the starting of SE-ly components in upper winds at places east of Long. 78° E. and along N. Madras coast and the subsequent weather in the east U.P. I have been unable to collect statistics. The changing of the wind directions to SE-ly on the east coast of India, the weather in the east U.P. and Chota Nagpur may be contemporary happenings of the weather pattern. It may not be logical to count the time interval after the setting in of the SE-lies. The pressure departure chart may be a better indicator. When a wave of a negative pressure departure passes eastwards across the country, this may be taken as an indicator of the passage of the low pressure area of the western disturbance. This low would some times induce the SE-lies. However, an interval of 24 to 36 hours can be assumed to be the approximate time between the starting of SE-ly upper winds at lower levels east of Long. 78° E. and weather in the east U.P.

A comparison of the periphery of the rain belt with the free line curves drawn in Fig. 1 is quite close. Such instances can be easily multiplied. It is hard to determine theoretically the fanning out of the moist stream by orography of the central parts of the country. It should be possible, however, to carry out a model experiment in a tank or in a wind tunnel.

Squalls near Jubbulpore. Jubbulpore is situated at the crossing of two valleys formed by 0.5 km. contours (SW to NE and nearly SE to NW). The moist feed is directed along either of the valleys to the south of the place. When a 'cold front' of a low pressure area of a western disturbance passes to the north it brings in westerly or northwesterly winds. Owing to a sort of funnel effect of the valleys, more moist and more cold air are put into juxtaposition and produce thunderstorms of more than usual intensity in the neighbourhood. The squalls produced in the pre-monsoon months at Jubbulpore are more severe than in many places in the Central Province; and tornadoes also occur occasionally (*vide* May 1936).

1, 2 and 3. Malurkar, "Forecasting Weather In and Near India," 1945, Bangalore, p. 102; Malurkar, Technical Note No. 1, p. 3. *Ind. Met. Dept.; Curr. Sci.*, 1947, 16, 139, and 1948, 17, 112, and under 1 see also Mal and Desai, *Technical Note No. 25. Ind. Met. Dept.*, 1947. 4. Malurkar, *Curr. Sci.*, 1947, 16, 139. 5. —, *Proc. Ind. Acad. Sci. (Bangalore)*, Sec. A 1943, 18, 20, and 23. 6. —, "Forecasting weather etc." *loc. cit.*, p. 112.

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UNIVERSITY INTERCHANGE BETWEEN U. K. AND INDIA

TO facilitate interchange between the universities of the United Kingdom and those of India, Britain is arranging for a number of travel grants.

The awards will be made on the recommendation of a Committee composed of representatives of the Association of Universities of the British Commonwealth, of the Committee of Vice-Chancellors and Principals of the U.K., and of the Universities Advisory Committee of the British Council.

Recipients will fall under three categories: distinguished scholars and scientists invited by universities for visits of at least 6 weeks' duration to enable them to meet fellow specialists and to mix with rising young workers in their own fields; university teachers on recognised study leave; and post-graduate research workers holding research grants. The latter two categories must undertake to spend at least 6 months of the academic session at the university where they propose to work.

Conditions for eligibility for university teachers and post-graduate research workers include suitable academic qualifications and experience, and a definite programme of work. The university named by the applicant as his proposed place of study must also be willing to receive him.

APPLICATIONS

Applications are to be sponsored by the applicant's own university, and, in the case of university teachers, backed by the necessary

finances—not less than 6 months' leave of absence on full pay. Post-graduate research workers are required to maintain themselves fully, while distinguished visiting scholars and scientists receive the necessary hospitality and costs of travel within the country from the inviting universities.

Grants are equivalent to the average cost of a return sea passage. For scholars and scientists invited by universities, passage may be arranged by air, depending on circumstances. Grants are normally paid in the U.K. in sterling, but in cases of necessity special arrangements may be made to pay part of the grant before sailing.

Particulars of visits which it is desired to arrange for distinguished scholars and scientists are to be sent by the inviting university to the Secretary, Committee for Commonwealth University Interchange, c/o The British Council, 3, Hanover Street, London, W.1. Persons in the other two categories are to send three copies of their application to the Vice-Chancellor or Principal of their own university for forwarding. January 31, 1949, has been fixed as the last date for the guaranteed consideration of applications, and the announcement of awards is expected to be about the end of March.

The most important thing is that this scheme provides for two-way traffic: facilities are provided both for Indians to visit the United Kingdom and for British scholars to undertake research and meet their colleagues in India.