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On the use of hill stations data for drawing contours on isobaric surfaces

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1. Introduction

The technique of constant pressure analysis has been brought into daily synoptic use in several countries. For preparing constant pressure charts a well-distributed network of radiosonde stations is required. As the present network of such stations in India and neighbourhood is not sufficiently close, it will be helpful if the data of hill stations can be projected on constant pressure charts to make these charts more comprehensive. The present paper gives the results of efforts to find how far this procedure will be useful.

Hariharan (1949) studied whether day to day heights corresponding to 850 and 700-mb surfaces could be calculated over all the pilot-balloon stations in India from the normal contour charts, knowing the departure from normal of pressure and temperature at the station on the day and assuming that the departure from normal of the mean temperature of the air column was same as departure from normal of surface temperature. The heights so calculated, however, did not agree with the actual radiosonde heights and showed no relation to them.

In this paper the possibility of making use of day to day pressure and temperature data of hill stations for obtaining the heights of standard isobaric surfaces over them, and using these height values on contour line charts, has been examined.

2. Method of reduction of hill station data

The geodynamic height G of the isobaric surface P above the station level P_0 is given by

$$G = RT_{mv} \log \frac{P_0}{P} \qquad (1)$$

where

$$T_{mv} = \frac{T_m}{1 - \frac{3}{8}\frac{e}{p}},$$

is the mean virtual temperature of the air column between the station level and the isobaric surface, T_m the mean temperature of the column, p the total pressure of damp air and e the partial pressure of water vapour.

The heights of the standard isobaric surfaces over the hill stations were calculated from the above equation under the following simplifying assumptions—

(*i*) The lapse rate in the air column between the station level and the standard isobaric surface was taken to be the same as that obtained from the nearest radiosonde ascent

(*ii*) The mean relative humidity of the air column was taken as 50 per cent and

(*iii*) The air column was taken as one layer for computing the height.

The data of 13 hill stations in northwest India (most of these in West Pakistan now) were investigated for a period of 3 months January 1946 to March 1946. The hill stations were divided into two groups—Group I consisting of those projected on 850-mb level and Group II of those projected on 700-mb level.

3. Heights of isobaric surfaces from constant pressure charts

For the same days for which heights of standard level surfaces were calculated as in the above method of reductions, the contour line charts for 850 and 700-mb surfaces were drawn with the data available from the radiosonde stations and the pilot-balloon observations in the region. The contour lines were drawn by free hand at fixed interval of separation of 30 feet (corresponding to an interval of 1 mb on the surface chart) between successive lines, the spaces between the lines being adjusted to correspond with the wind speed at that level, assuming winds to be geostrophic.

4. Comparison of heights given by the two methods

The heights of standard isobaric surfaces over hill stations as determined from the method of reductions were compared with those obtained from the contour line charts and the day to day differences were noted. Table 1 gives the number of occasions on which such differences were within a particular range, each range being of 30 feet. The probable range of such differences for each hill station and the mean difference corresponding to this range are given in Table 2.

5. Order of errors

The order of errors involved on account of the simplifying assumptions mentioned in Section 2 are indicated below—

(a) Error in height from error of lapse rate

Errors in height from an error of 10°C in the mean virtual temperature of the air column when a station is projected from one level to another level are given below :

($\triangle T$ = 10°C)

$\triangle p$	$\triangle h$
(mb)	*(ft)*
900—850	50
850—820	33
750—700	70

TABLE 1

Frequency table of height differences (*ft*)

Ht. range (*ft*)	Cherat	Drosh	Dalbandin	Fort Sandeman	Gilgit	Loralai	Miran Shah	Parachinar	Samungli	Srinagar	Kalat	Murree	Simla
	No. of occasions examined												
	71	67	77	75	70	72	32	68	78	78	70	70	70
—240 to —211	..	4	..	..	6	..	..	..	..	..	..	1	..
—210 to —181	..	6	..	..	2	..	..	..	..	1	..	..	..
—180 to —151	..	8	..	..	6	..	..	..	1	6	..	1	..
—150 to —121	..	16	..	..	16	..	..	..	2	4	..	3	2
—120 to —91	..	20	1	..	6	2	1	..	5	8	1	4	3
—90 to —61	4	3	5	..	7	..	..	1	6	20	2	17	8
—60 to —31	14	6	11	4	10	2	4	4	11	17	7	15	25
—30 to 0	43	4	5	11	13	6	5	14	18	17	13	27	30
0 to 30	10	..	28	36	2	7	14	34	16	3	30	2	2
31 to 60	..	..	14	12	..	25	7	8	15	2	8	..	..
61 to 90	..	..	9	9	1	21	1	5	1	..	7	..	..
91 to 120	..	..	4	3	..	5	..	2	3	..	1	..	..
121 to 150	..	..	..	..	..	4	..	..	..	..	1	..	..

TABLE 2

Serial No.	Hill station	Position	Height above sea level (ft)	Nearest radiosonde station	Probable range of height differences (ft)	Mean height difference (ft)
	Group I (850 mb)					
1	Cherat (W. Pakistan)	33° 50′N 71° 54′E	4272	Peshawar (34° 02′N, 71° 37′E)	—30 to 0	—15
2	Drosh (W. Pakistan)	35° 34′N 71° 47′E	4723	Peshawar	—150 to —90	—120
3	Dalbandin (W. Pakistan)	28° 54′N 64° 26′E	2780	Multan (30° 12′N, 71° 31′E)	0 to +60	+25
4	Ft. Sandeman (W. Pakistan)	31° 21′N 69° 27′E	4613	Multan	0 to +30	+15
5	Gilgit (Kashmir)	36° 55′N 74° 23′E	4889	Peshawar	—150 to 0	—75
6	Loralai (W. Pakistan)	30° 22′N 68° 37′E	4698	Multan	+30 to +90	+50
7	Miran Shah (W. Pakistan)	32° 59′N 70° 07′E	3025	Peshawar	0 to +60	+10
8	Parachinar (W. Pakistan)	33° 52′N 70° 04′E	5673	Peshawar	0 to +30	+15
9	Samungli (W. Pakistan)	30° 15′N 66° 59′E	5499	Multan	—30 to +60	—10
10	Srinagar (Kashmir)	34° 05′N 74° 50′E	5214	Peshawar	—90 to 0	—50
	Group II (700 mb)					
11	Kalat (W. Pakistan)	29° 02′N 66° 35′E	6618	Multan	0 to +30	+20
12	Murree (W. Pakistan)	33°N 73° 23′E	7116	Peshawar	—90 to 0	—40
13	Simla (Punjab I)	31° 06′N 77° 10′E	7225	New Delhi (29° 39′N, 77° 17′E)	—60 to 0	—30

Now supposing that the data of a hill station are projected to a level which is 1 km (about 100 mb) higher, and the lapse rate of the air column as obtained from the nearest radiosonde station is dry adiabatic, *i.e.*, 10° C km $^{-1}$, an error of 50 per cent in the lapse rate would introduce an error of 2·5°C in the mean virtual temperature (in the dry season and less in the monsoon season) which would mean an error of 20 ft or less in the heights of the projected level. Many of the hill stations in India are within 20 mb of the 850-mb surface and hence the errors introduced by a 50 per cent error in lapse rate for such stations would not exceed 5 feet.

(*b*) *Error in height from error of relative humidity*

The error in the mean virtual temperature owing to an error in the assumed relative humidity (of 50 per cent) is given by

$$\triangle T = \frac{3}{16}\, T. \triangle H.\ \frac{e_s}{p}$$

where e_s is the saturation vapour pressure at T (dry bulb temperature in °A) and $\triangle H$ is the error in relative humidity. An error of 50 per cent in the assumed relative humidity gives rise to the following errors in the virtual temperature—

T (°A)	(mb) 900	850	800	700
263	—	0·1	0·1	0·1
273	0·1	0·2	0·2	0·3
283	0·3	0·4	0·5	0·5
293	0·7	0·7	0·8	0·9
300	1·1	1·2	1·3	1·5

For values of temperatures obtaining at our hill stations, the above error will not exceed 1·5°C in the hot season and will be less in the cold period. Errors in height corresponding to a change of 50 per cent in the assumed relative humidity will, therefore, be less than 3 feet.

(c) *Error in height in taking the air column as one layer for computation of height*

Strictly speaking, for computing the mean temperature of the air column, the column should be divided into layers of definite thickness and proper weightage given to each layer. An idea of the maximum error which can arise in the height of the standard isobaric surface, due to the column being considered as a whole and not in layers, can be obtained by considering the difference in height between the two cases (*i*) when the whole column is taken as isothermal and (*ii*) when the lapse rate in the whole column is taken as a dry adiabatic (Rare exceptions to this will only be when there is a combination of superadiabatic lapse rate and steep inversion within the column). Assuming the air column to be 1 km (100 mb) high, the difference in the mean temperature in the two extreme cases mentioned above would be 5°C which would introduce an error of less than 40 feet. As many of the hill stations are within 20 mb of the 850-mb surface, the error in height due to this method of computation will not exceed 8 ft and would normally be much less.

6. Conclusions

The radiosonde observations are subject to various errors. The nature and magnitude of such errors for M.O. (Kew M.K.I) radiosonde have been discussed by Sheppard (1944). He has shown that the variations in the height of the 750, 500 and 300-mb surfaces (at Lark hill) are of the order of ±42, ±62 and ±104 ft respectively. Interpolating, the variation in the height of 700-mb surface will be of the order of ±46 ft and ±38 ft for 850-mb surface. The order of such errors in respect of I.M.D. radiosondes has not been determined but we may assume that similar corrections apply to these instruments also. Uncertainty in hill stations data, as seen from Table 2 is, therefore, of the same order generally as the uncertainty in height values obtained from the radiosonde data. The height values of the standard isobaric surfaces as obtained from the hill stations data can, therefore, in most cases be used along with radiosonde data for drawing contours on constant pressure charts.

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