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551.515 : 551.509.39 (540 : 25.24)

A procedure for computation of vertical velocity in the Indian region including the Himalayan region

K. V. RAO*

Meteorological Office, Pune and

S. RAJAMANI

Indian Institute of Tropical Meteorology, Pune

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ABSTRACT. A procedure for calculation of vertical velocities at various isobaric levels by means of ω-equation in the Indian region including the Himalayas is presented. Computations suggest that the boundary conditions adopted for inclusion of the Himalayan region are realistic and acceptable.

1. Introduction

While computing vertical velocities in the Indian region by means of a geostrophic baroclinic model in an earlier investigation, Rao and Rajamani (1970) had indicated that the area north of 26°N was not considered in order to exclude the boundary effects of the Himalays. This procedure had the disadvantage that vertical velocities in the Indo-Gangetic plains north of 26°N could not be computed.

For making computations with an electronic computer, it is easy to deal with a rectangular matrix of grid points. If the region between 26°N and 36°N were to be considered, the region of grid points with observational data in ABCDFG will be L shaped, (Fig. 1) and the region east of 80°E, i.e., BCDE, (shaded area) is the Himalayan region. It was, therefore, examined whether a procedure could be evolved with the x, y, p system for computing the vertical velocities, over the L shaped region at 850 mb and 700 mb surfaces and over the entire region AEFG at 500 mb and 300 mb surfaces.

2. Procedure

Since the Himalayan terrain generally lies below the level of 500 mb, there cannot be any observations at the grid points on 1000 mb, 850 mb and 700mb surface over the region BCDE overlain by the Himalayas. Therefore, we can specify the quantities wind, vorticity and horizontal advection of vorticity at these grid points in the shaded area, as zero. However, vertical velocity along the boundary BC, CD is not assumed to be zero, as there could be vertical motion due to upslope motion. As in the earlier investigation, vertical velocity has been assumed to be zero at 1000 mb and 150 mb along the sides excluding BC and CD. The equation used for computation of vertical velocity is

$$\sigma \nabla^2\omega + f_0^2 \frac{\partial^2\omega}{\partial p^2} = f_0 \frac{\partial}{\partial p}\left[\mathbf{V}.\nabla(\xi + f)\right] - \nabla^2\left[\mathbf{V}.\nabla\left(\frac{\partial\phi}{\partial p}\right)\right]$$

where,

σ = Static stability
ω = Vertical velocity
f_0 = Standard value of the coriolis parameter (at 20°N)
$\mathbf{V}$ = Geostrophic wind
ξ = Geostrophic relative vorticity
f = Coriolis parameter
ϕ = Geopotential
∇^2 = Laplacean operator

*The work was done while the senior author was working at the Indian Institute of Tropical Meteorology, Pune.

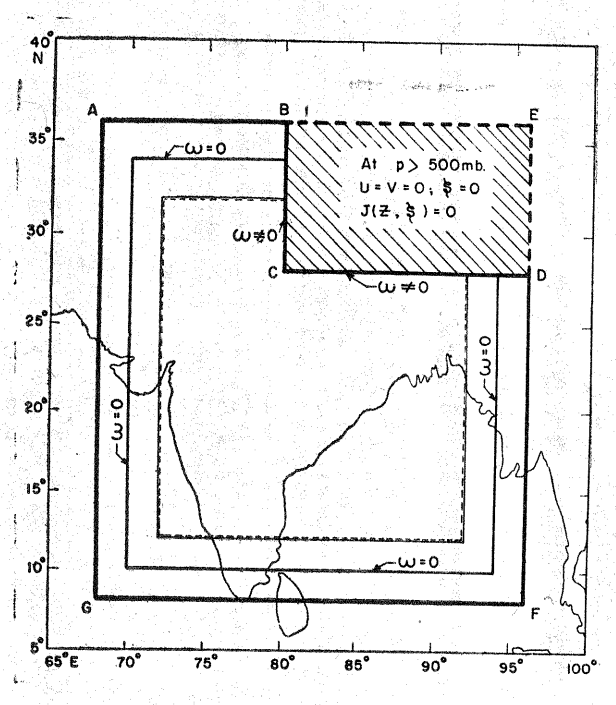

Fig. 1. Area of computations with boundaries indicated

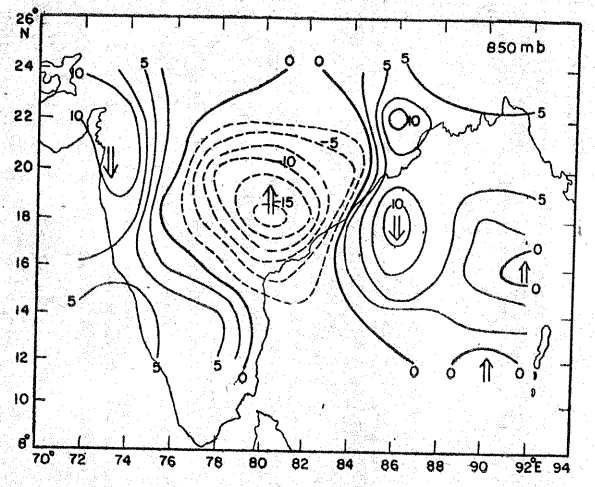

Fig. 2(a). Vertical velocity at 850 mb level at 1200 GMT on 25 Jul 1966. ω in units of 10^{-5} mb/sec

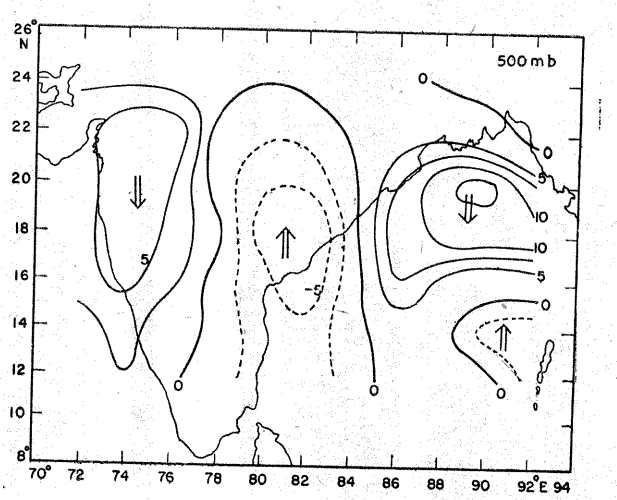

Fig. 2(*b*). Vertical velocity at 500 mb level at 1200 GMT on 25 Jul 1966. ω in units of 10^{-5} mb/sec

While computing the vertical velocity at 500 mb the differential vorticity advection term is com-

$$f_0 \frac{\partial}{\partial p}\left[\mathbf{V}.\nabla(\xi + f)\right]$$

puted for the layer 500-300 mb and not for the layer 700-300 mb, *i.e.*, as in the case of the time differencing, only the forward difference (*i.e.*, between 500 and 300 mb) is used.

3. Discussion

The synoptic situation for which computations have been made is the same situation as was studied earlier (Rao and Rajamani 1970). The vertical velocities at 850 and 500 mb surfaces are given in the two sets of Figs. 2 and 3, Fig. 2 giving the computed values for the region south of 26°N, and Fig. 3 for the entire region including the Himalayan area. On a comparison of

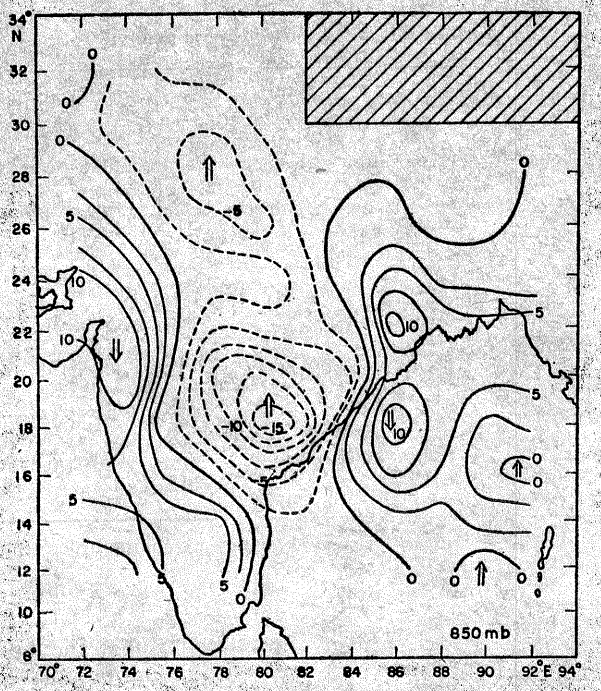

Fig.3(a). Vertical velocity at 850 mb level at 1200 GMT on 25 Jul 1966 (inclusive of Himalayan Region). ω in units of 10^{-5} mb/sec

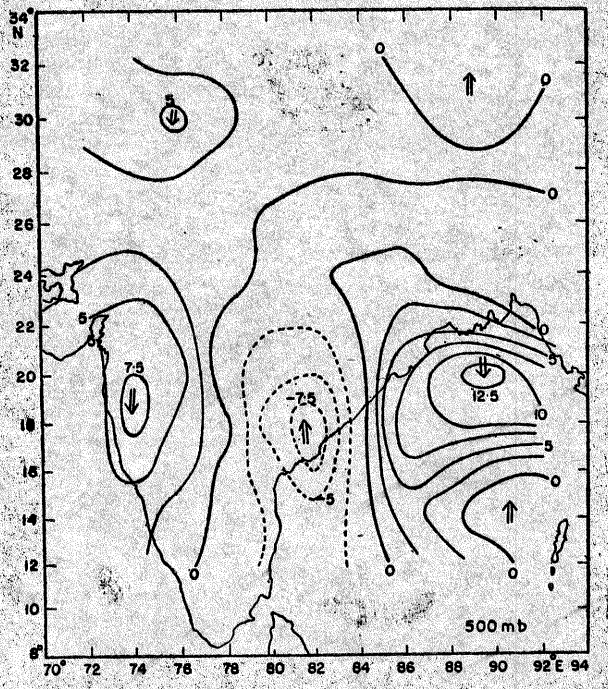

Fig. 3(b). Vertical velocity at 500 mb level at 1200 GMT on 25 Jul 1966 (inclusive of Himalayan region). ω in units of 10^{-5} mb/sec

these two sets of figures the following observations may be made:

(*i*) In both sets of figures, the patterns south of 22°N resemble each other closely, while the pattern to the north of 22°N in Fig. 3 gives the impression of continuity of the pattern south of 22°N in Fig. 2.

(*ii*) The grid points at which maximum upward and downward velocities occur

TABLE 1

Vertical velocities at selected grid points

Surface Pressure (mb)	Without the Himalayan region					With the Himalayan Region				
	Location		Max. upward velocity ($\times 10^{-5}$ mb/sec)	Location		Max. downward velocity ($\times 10^{-5}$ mb/sec)	Location		Max. upward Velocity ($\times 10^{-5}$ mb/sec)	Location		Max. downward velocity ($\times 10^{-5}$ mb/sec.)
	Lat. (°N)	Long. (°E)		Lat. (°N)	Long. (°E)		Lat. (°N)	Long. (°E)		Lat. (°N)	Long. (°E)	
(1)	(2)		(3)	(4)		(5)	(6)		(7)	(8)		(9)
850	18	80	162.3	18	86	127.7	18	80	164.8	18	86	126.3
700	18	80	220.8	18	86	184.8	18	80	224.0	18	86	182.4
500	18	82	95.3	20	90	131.4	18	82	96.0	20	90	132.8
300	12	82	192.8	18	88	93.7	12	82	192.2	18	88	99.9

Values in columns (3) and (7) relating to upward vertical velocities are comparable. Similarly those in columns 5 and 9 relating to downward vertical velocities are comparable.

on each isobaric surface are the same in the two sets of figures (*see* Table 1). Further there is very good agreement in the corresponding values, *e.g.*, the maximum vertical velocity at grid point 18°N, 80°E on 700 mb is -220.8×10^{-5} mb/sec by earlier method, while it is -224.0×10^{-5} mb/sec by the present method, the slight difference being due to extension of the region of computation in Fig. 2 and the possible influence of the boundary values.

4. Conclusion

Since there is good agrement in the pattern as well as the values of the vertical velocity, we may infer that the boundary conditions adopted for computations of vertical velocity for inclusion of the Himalayan region are realistic and acceptable.

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