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THE DISTRIBUTION OF BAROCLINITY WITHIN THE ATMOSPHERE

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ABSTRACT

A three dimensional numerical interpolation scheme which resolves frontal gradients with high fidelity has been developed and is being applied to the study of atmospheric upper baroclinic zones.

INTRODUCTION

The aim of our research is to improve understanding of the structure and evolution of atmospheric fronts. Achievement of this goal requires the representation of frontal intensity with a dynamically significant parameter for which we have selected the baroclinity,

$$\vec{B} = \frac{g}{\theta} \vec{\nabla}_p \theta \qquad (1)$$

where $\vec{B}$ is the baroclinity vector, g the acceleration of gravity, and θ and $\vec{\nabla}_p\theta$ are the potential temperature and its isobaric gradient. Furthermore, we may define local frontogenesis to be the local tendency of the baroclinity which may be shown to be (to good approximation)

$$\frac{\partial \vec{B}}{\partial t} = \frac{g}{\theta} \vec{\nabla}_p \left[\frac{d\theta}{dt} - \vec{\nabla}_p \cdot (\vec{v}\theta) - \frac{\partial}{\partial p} (\omega\theta) \right] \qquad (2)$$

where $\omega = \frac{dp}{dt}$.

Because of the small horizontal scale of fronts compared with the spacing of sounding stations the magnitude of the baroclinity may be considerably underestimated in the vicinity of intense fronts if only horizontal or isobaric data are utilized. This difficulty may be largely obviated through use of cross-section analyses which effectively apply the high resolution information available in the vertical over each sounding station to improvement of horizontal resolution. (Shapiro, 1970).

METHOD

The considerable expenditure of effort required for manual analysis of cross-sections has led to the development of successful numerical interpolation schemes for cross-section analysis (Shapiro and Hastings, 1973 and Whittaker and Petersen, 1975); however, these are two dimensional techniques from which one can obtain isobaric analyses only by laborious combination of many independently analysed cross-sections. We propose instead to apply a fully three dimensional scheme based on a straight forward extension of the Barnes (1973) horizontal method.

We extend the Barnes scheme by redefining his weight as

$$W_i = \frac{1}{4\pi kD} \exp\left[\frac{-d_i^2}{4k} - \frac{Z_i^2}{4D}\right] \qquad (3)$$

where W_i is the weight factor for the i^{th} observation, d_i and Z_i are the horizontal and vertical distances between the observation and a given grid point, and k and D are weight parameters controlling the smoothness of the output. To facilitate selection of k and D, we have coded a two dimensional cross-section analysis method based on (3) having a horizontal grid spacing of one latitude degree (111 km) and a vertical spacing of 50 mb.

The resulting potential temperature analysis on a cross section through the complex hyperbaroclinic zone studied by Frank and Barber (1977) is shown in Fig. 1 together with the component of the baroclinity in the plane of the cross-section estimated by finite difference method. For comparison, Fig. 2 reproduces the careful manual analysis of Frank and Barber. The numerical scheme has reproduced not only the gross features, but also most of the details with considerable fidelity. Further improvement would be possible (at the expense of more computer time) if the vertical resolution were increased.

A quantitative demonstration of the efficacy of the cross-section scheme is illustrated in Fig. 3. The baroclinity estimated from the cross section at the 500 and 800 mb levels is shown by the dashed lines. The solid lines are the results obtained through application of a horizontal Barnes analysis on a one latitude degree by one longitude degree grid. The magnitude of the baroclinity estimated from the cross-section program is fifty to one hundred percent greater in the hyperbaroclinic zones than that obtained from the isobaric analyses.

CURRENT WORK

We are now coding the full three dimensional scheme for application to the AVE II data. Furthermore, we intend to demonstrate its usefulness through application to operationally available

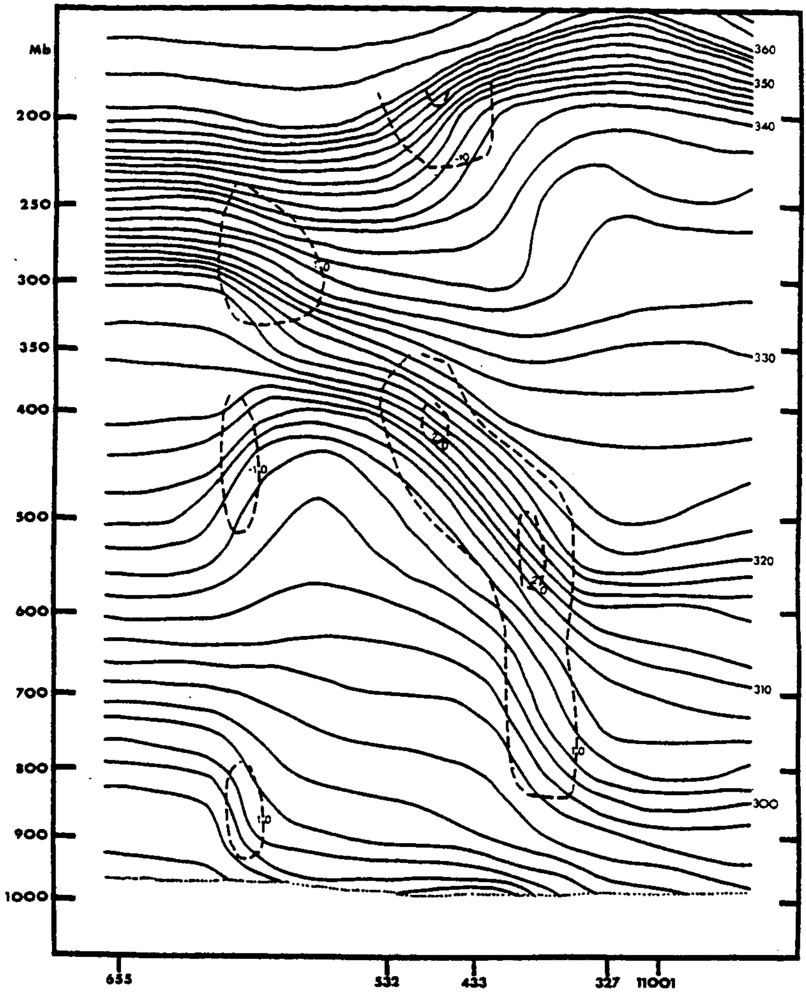

Fig. 1. Objectively analyzed cross-section through hyperbaroclinic zone. Isentropes (κ) solid and baroclinity $(10^{-7}\ s^{-2})$ dashed. 1115 uT, 12 May 1974.

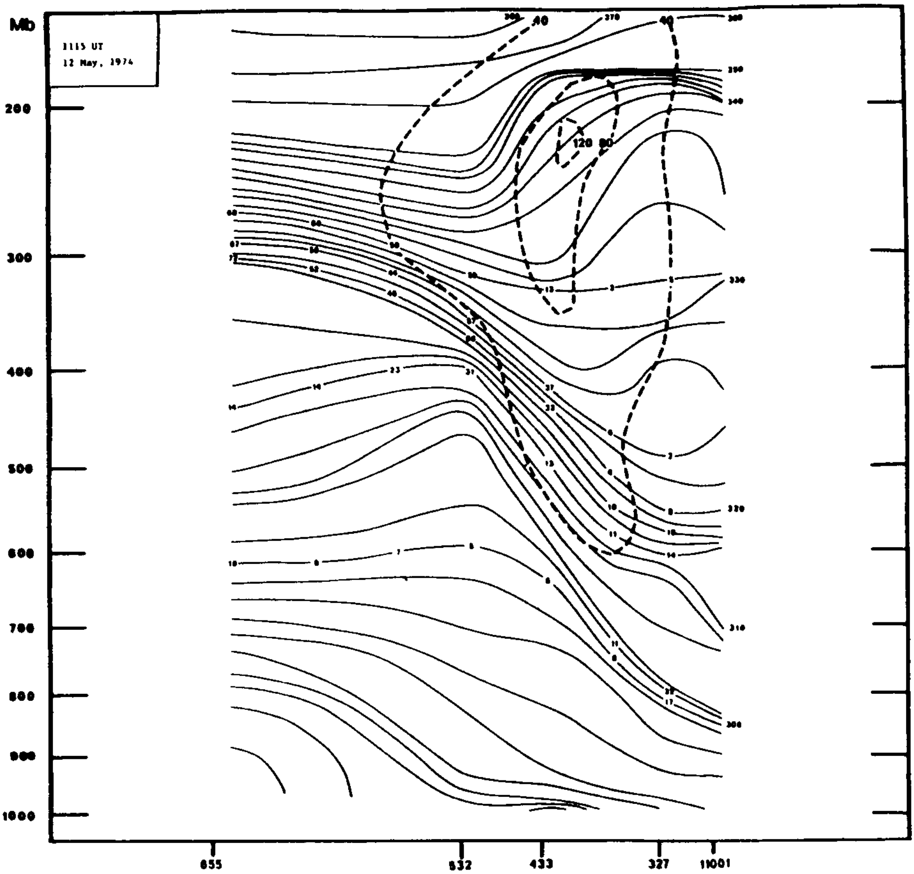

Fig. 2. Manually analyzed cross-section along same line as Fig. 1. Isentropes (κ) solid and isotachs (κt) dashed of flow normal to section (Frank and Barber, 1977).

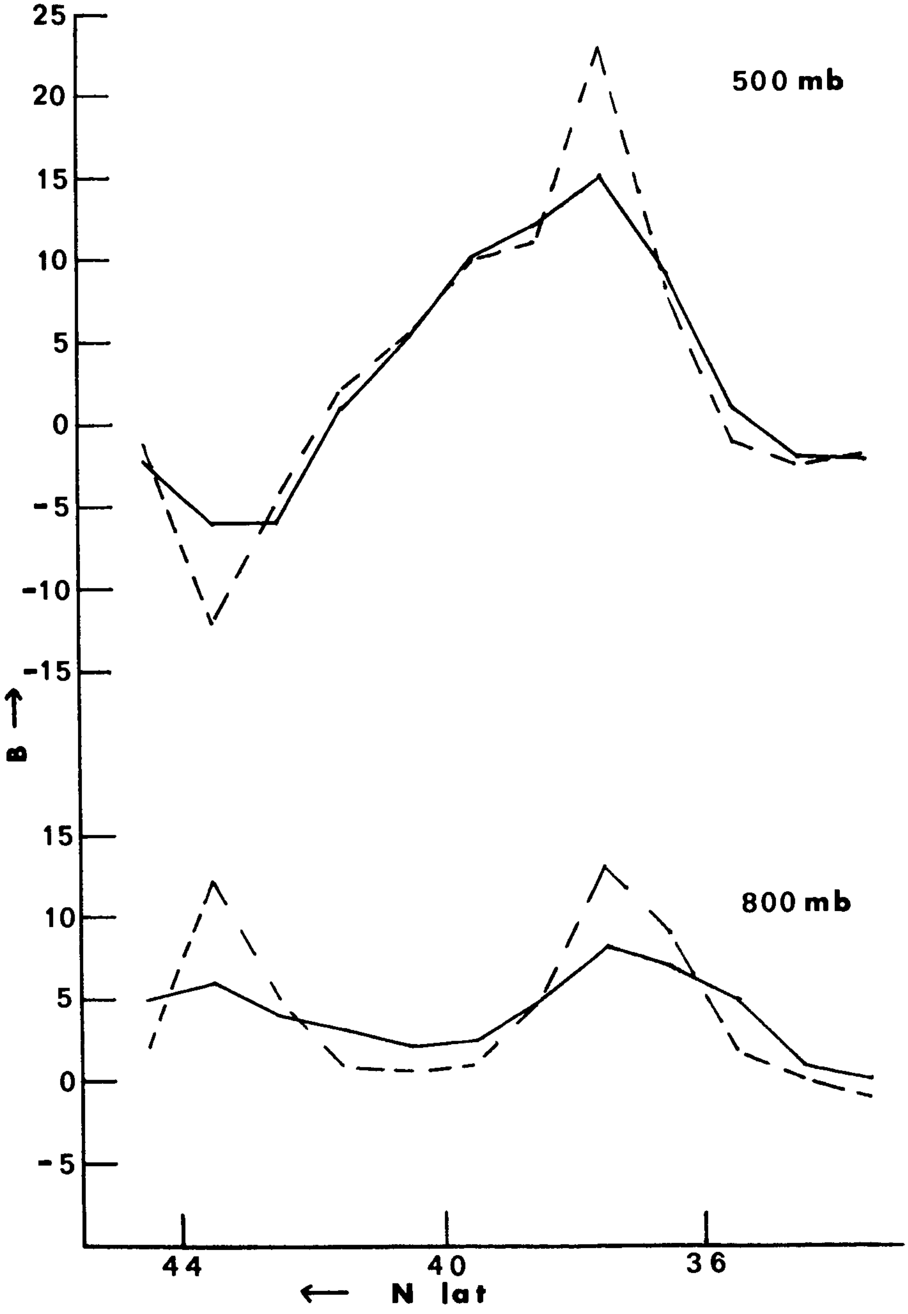

Fig. 3. Baroclinity (10^{-7} s^{-2}) from objective isobaric analysis (solid) and from objective cross-section (dashed) as a function of latitude along line of Fig. 1.

teletype data and comparison with National Weather Service analyses.

In addition to depicting the full three dimensional baroclinity distribution, we plan to apply the method to the wind field. In the case of the wind field, some smoothing of the vertical wind field is desirable (see Schmidt and Johnson, 1972). Therefore, a different set of weight parameters (k and D) will be appropriate.

Finally, we shall apply the improved three dimensional wind and temperature analyses to the evaluation of terms in the frontogenesis equation (2).

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