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14. Abstract/Notes

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ON THE ZONALLY AVERAGED TEMPERATURE IN THE SOUTHERN HEMISPHERE

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ABSTRACT

The observed meridional temperature gradients in the middle and high latitudes of the Southern Hemisphere are much higher than the critical gradients necessary for the manifestation of baroclinic instability in a two-level quasi geostrophic model. This is in contrast to the "baroclinic adjustement" observed in the Northern Hemisphere by Stone (1978).

KEY WORDS: Baroclinic Adjustment, Southern Hemisphere

RESUMO

Os gradientes observados de temperatura nas latitudes médias e altas no Hemisfério Sul são muito maiores que os gradientes críticos necessários para a manifestação da instabilidade baroclínica num modelo quase geostrófico de duas camadas. Este resultado contraria o ajustamento baroclínico obtido no Hemisfério Norte por Stone (1978).

1. Introduction

Recent observational studies (e. g., Oort and Peixoto, 1983) suggest that the mean atmospheric state in the Southern Hemisphere (S. H.) differs considerably from that of the Northern Hemisphere (N. H.). One aspect of the mean atmosphere which has interesting implications is the zonally averaged temperature. Flohn (1980) noted that the meridional, equator to pole, temperature difference during southern winter is much higher in S. H. than the value in the N. H. during northern winter. He discussed extensively the possible climatic consequences of a man-made global warming and suggested the implications of a possible coexistence of an ice free Arctic and a glaciated Antarctic.

Since the mean atmospheric state forms the so-called basis state for the instability studies, some interesting differences could be expected in the development of transient eddies and their associated processes in the S. H.

Stone (1978) noted that the zonal mean midtropospheric meridional temperature gradients in the middle latitudes of N. H. agree closely with the local values of the critical gradient as given by the two-layer Phillips (1954) model. Stone interpreted this observation as the indication of a negative feedback between the meridional eddy flux of heat and the meridional temperature gradient. He termed the associated process as "baroclinic adjustment".

In view of the aforesaid Flohn's observation, it would be interesting to compare the observed and critical temperature gradients for the S. H. case, which is the objective of the present note.

2. Comparison of the observed and critical temperature gradients in the S. H.

The critical shear for a two-layer model (Holton, 1979) is given by

$$U_c = \frac{\beta \, \sigma_2 \, \Delta p^2}{2 \, f_o^{\,2}}, \tag{1}$$

where $U_c = (U_1 - U_3)/2$; σ_2, the static stability at level 2 is given by

$$\sigma_2 = - \frac{RT_2}{p_2} \left[\frac{1}{T_2} \frac{T_3 - T_1}{\Delta p} - \frac{R}{P_2 \, C_p} \right]. \tag{2}$$

Subscripts 1, 2, 3 refer respectively to upper, middle and lower levels of a two layer model. $\Delta p = p_3 - p_1$. Using the thermal wind relation, the critical shear can be written in terms of potential temperature. The final expression of the critical gradient at level 2 for a 5^o latitude interval is given by

$$\Delta T_c = \frac{\pi}{36} \operatorname{Cot} (\phi) \; \frac{R \, T_2}{g} \; \frac{\Theta_1 - \Theta_3}{Z_1 - Z_3}, \tag{3}$$

where ϕ is the latitude and g is the acceleration of gravity.

In order to calculate $\Delta \, T_c$, we used temperature data given by Taljaard et al (1969). These are given at standard pressure levels. We have chosen the same pressure levels as in Stone (1978) to represent levels 1, 2 and 3, namely 400, 600 and 800 mb respectively. Also, as in Stone (1978), we have taken the mass weighted average temperature in the layer 200-600 mb as the temperature at 400 mb and the mass weighted average in the layer 600 - 1000 mb as the temperature at 800 mb level. The observed temperature gradients at 600 mb level are compared with the critical gradients calculated by (3) and these are shown in Figs. 1 - 5 for various seasons and for the annual mean. In these figures continuous lines are the values of the critical gradients and the crosses give the observed gradients.

3. Discussion

In the month of July (winter), the observed values of temperature gradient around $37^{o}S$ are approximately equal to the critical gradient values. But, in general the observed temperature gradients are much higher than the critical gradients south of about $45^{o}S$. This is different from what has been noted by Stone (1978) for the N. H.

The observed temperature gradient shows other interesting features. In all the four seasons the temperature gradient shows two maxima. This is in some way is connected to the double maxima of the westerly jet observed by several authors and mentioned recently by Trenberth (1981). The subtropical maximum of temperature gradient shows a clear seasonal variation in position, occupying a more northerly latitude in July and a more southerly latitude in January. However, unlike what is found in N. H., the change in the magnitude from January to July in the subtropical maximum is small. In the annual mean (Fig. 5), the observed gradient has a more or less constant value over a broad belt.

The above mentioned observations raise several questions: 1) what factors explain the supercritical nature of the temperature distribution in the S. H.?; 2) how well a simple two layer model is suited for understanding the baroclinic adjustment process in the S. H.? 3) how far the data inadequacy affected the results shown in Figs. 1 - 5?

Apparently, there are no simple answers to these questions. The values of the critical gradient depend directly on the values of the static stability, which in turn depend on the zonally averaged temperatures in the atmosphere. Estimates of zonal mean temperatures in the S. H. might be biased towards continental values. In any case, the large differences between the critical gradient and the observed gradients noted earlier can not completely be ascribed to the lack of observations. Held (1978) showed that long deep waves are more efficient in transporting heat poleward than shallow short waves. Topographic forcing and baroclinic instability mechanism together seem to be important for these long waves (Yao, 1980; Stone, 1977). In the mainly oceanic S. H., long quasi-stationary waves transport neglibe amount of heat poleward (Vanloon et al., 1973). Transient waves in both hemispheres in winter transfer nearly the same amount of sensible heat poleward and the quasi-stationary waves in middle latitudes of N. H. transfer nearly as much sensible heat as transient waves. Thus the total transport of sensible heat by waves in the S. H. is much smaller than in the N. H. (Vanloon, 1983). This seems to explain the occurrence of higher temperature gradients in higher latitudes of S. H. atmosphere, at least in winter. A similar explanation might be valid for other seasons as well. Further, meridional variation of zonal wind in the model seems to be necessary to take into account the peculiarities of S. H. such as the double jet.

It would be worthwhile to repeat the calculations made here with new data sets, such as the one compiled by the Australian Group (Le Marshall et al., 1983). The new data sets, although not necessary be better than the one used here, might reveal the structure of the zonally averaged temperature for a different period. This is interesting for the S. H., in view of the interannual variations.

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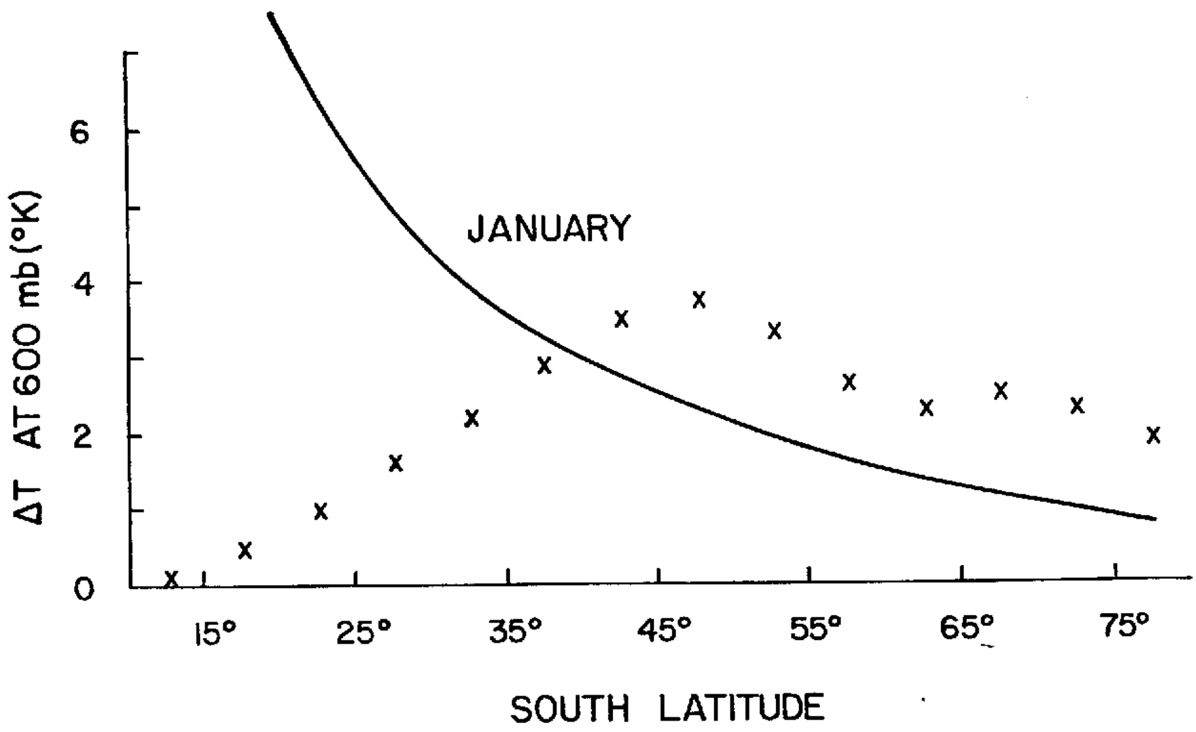
LIST OF FIGURES



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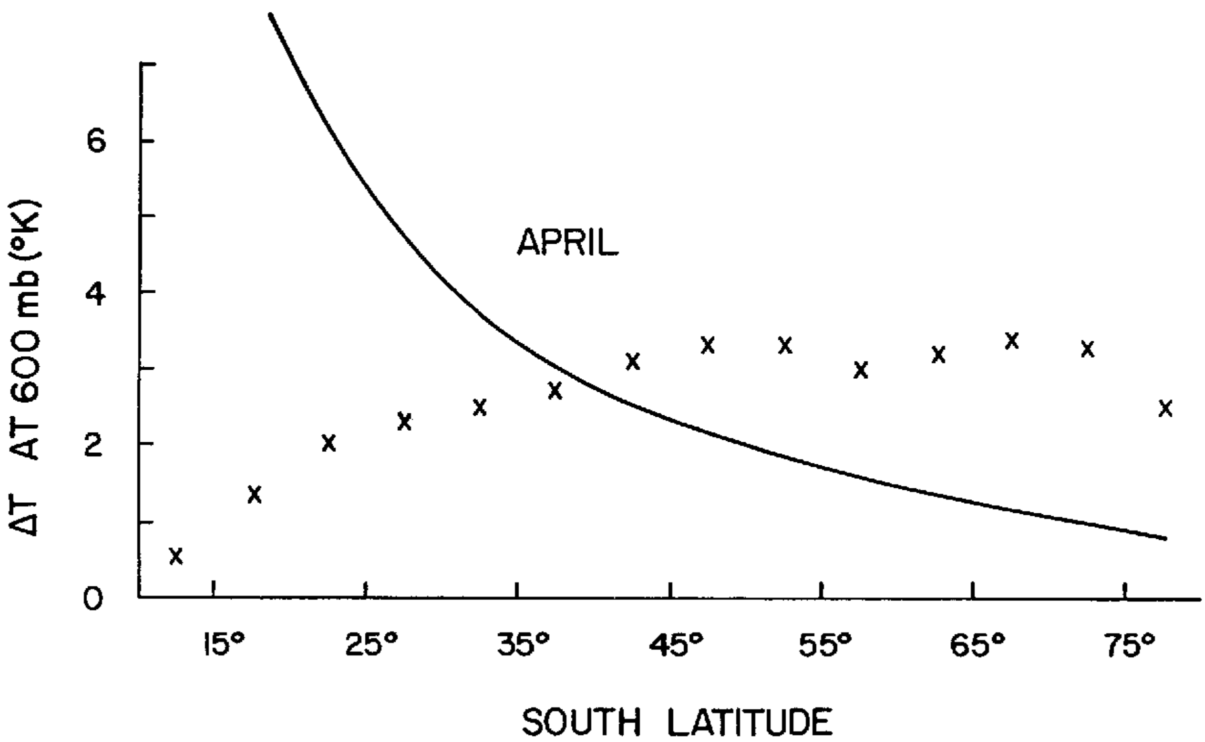

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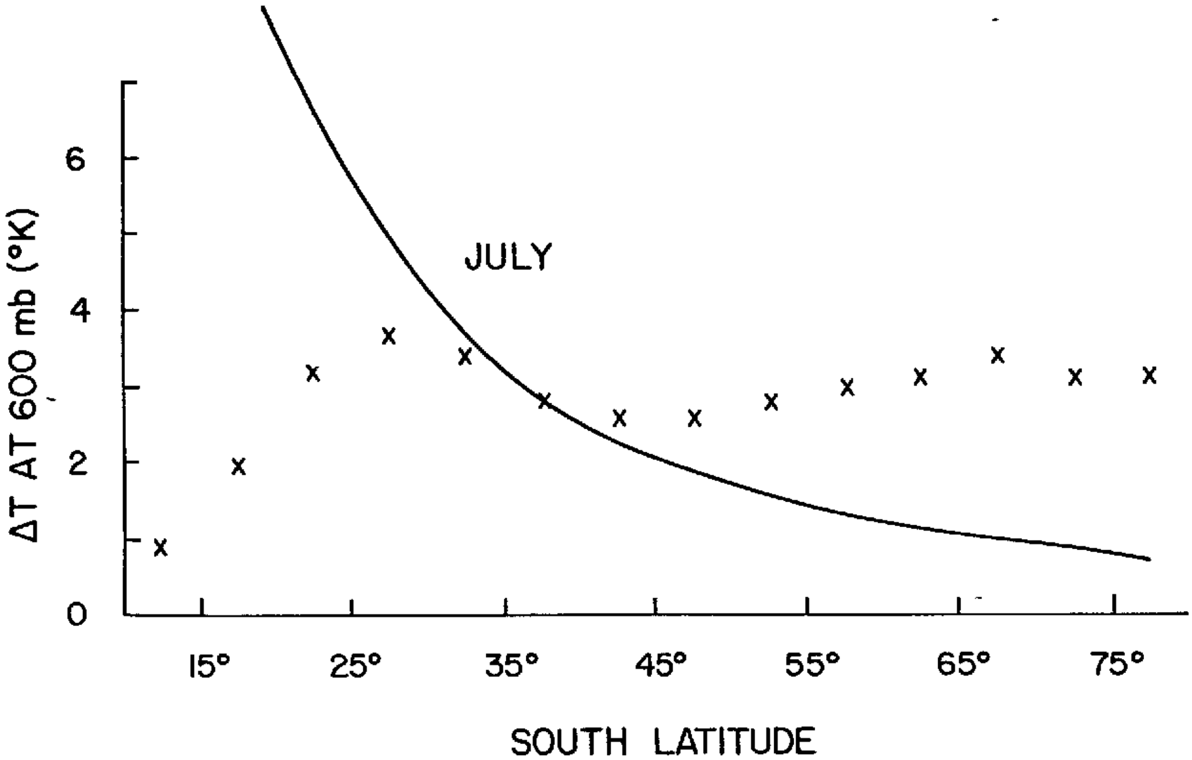

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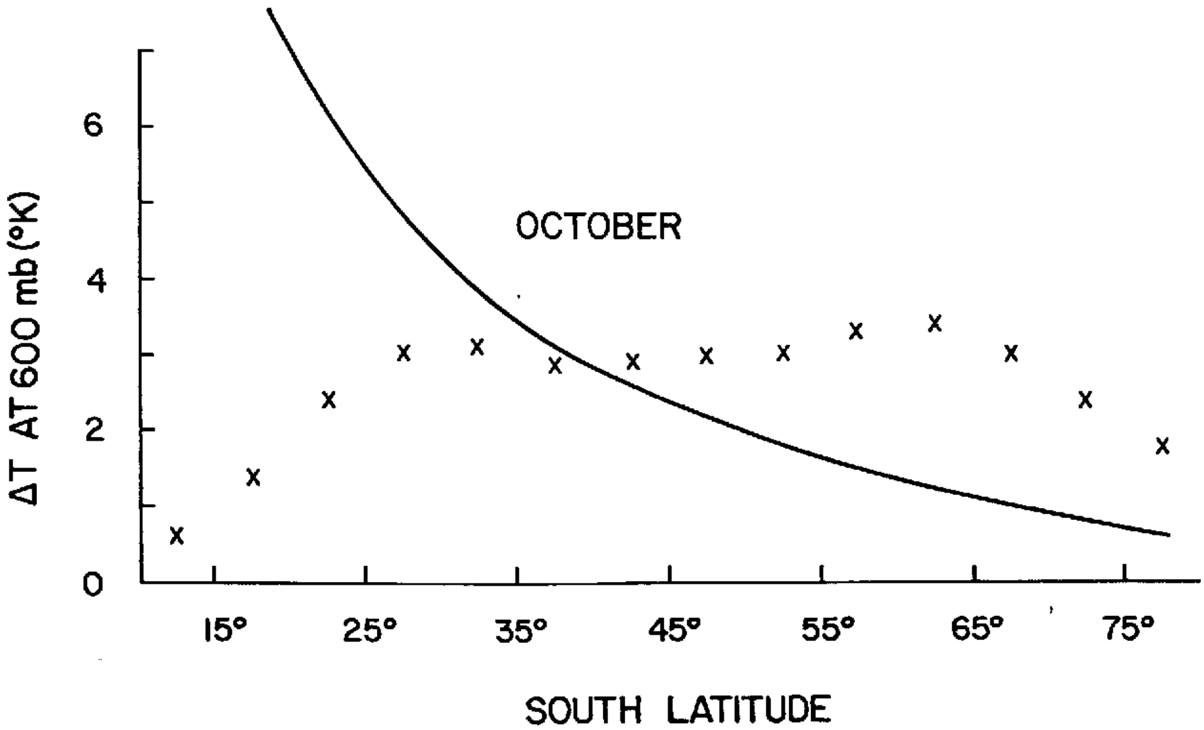

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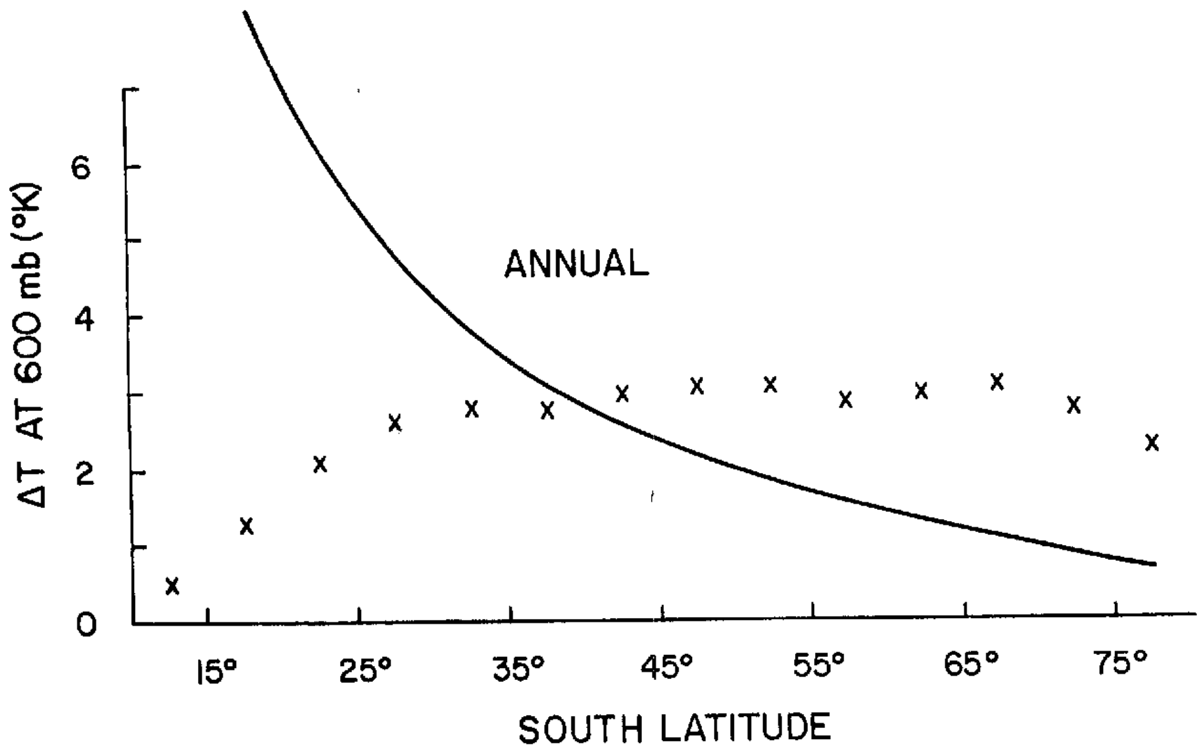

Figure 5