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## AIR MASS TEMPERATURES IN THE TROPOSPHERE OVER

## MACQUARIE ISLAND

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Abstract: McIntyre (1950) has indicated that the shape of seasonal frequency polygons of temperature at a particular level and station depends on the relative frequency of different air masses at the level. For a summer and a winter month the temperature distribution in various air masses at four levels in the troposphere at Macquarie Island were examined, the stable layers being regarded as air mass boundaries. The histograms show, as expected, that the frequency of occasions of cold air decreases and of warm air increases with height. Given large enough samples, the temperature distribution within air masses at Macquarie Island appears to be normal. This is supported by significance tests. However most of the total distributions below 300 mb, particularly in winter, probably are not normal. As this probably applies at most stations outside equatorial areas, total distributions of temperature will not be adequately defined by their means and standard deviations but could be represented by the means, standard deviations and total frequency of each air mass class contained in the total distribution. This information would be valuable for general studies of the frontal and air mass structure of the atmosphere.

## 1. INTRODUCTION

In middle latitudes at least, the distribution of temperature in the upper air is not normal (see e.g. Durst, 1951). Skewed and double-humped distributions are quite common. McIntyre (1950) has indicated that the shape of seasonal frequency polygons of temperature at a particular level and station will depend on the relative frequency of different air masses at the level. When a front moves through a level a wide range of temperatures will occur there due to the baroclinicity of the front. When a level is unaffected by fronts, particular temperatures will occur more frequently in the comparatively barotropic air outside fronts.

In this paper frequency distributions of tropospheric temperatures at Macquarie Island ( $54^{\circ} 30'S$ ,  $158^{\circ} 57'E$ ), where fronts are a persistent feature in the troposphere, are discussed for a summer and a winter month.

## 2. ANALYSIS OF DATA

Data for the years 1953 to 1956 were selected for study, as this is the longest period of complete years with radiosonde soundings made at approximately the same time each day. This eliminates the possibility of the distributions being affected by diurnal variation of both temperature in the lower levels and radiation error.

In a frontal layer the lapse rate of temperature is smaller, i.e. the stability is greater, than in the air above and below the layer. On this basis temperatures at 850, 700, 500 and 300 mb were classified according to whether the level was below a front (in cold air), above a front (in warm air), between two fronts or in a front. When previous and the current soundings indicated that a front had merged with the stratosphere and no stable layer existed in the troposphere, the temperature was included in the cold air distribution. Occasional cases occurred when, although no stable layer was present, previous soundings indicated that a front had descended to the surface. Temperatures on these days were included in the warm air distribution.

## 3. DISCUSSION OF RESULTS

McIntyre has stated that a sloping front or baroclinic field will be revealed in frequency polygons for any one station by a double maxima to varying degrees at different levels. In any situation with warm air at a lower level there will also be warm air at higher levels, but with cold air at lower levels there may be either warm or cold air at higher levels. Therefore, as well as exhibiting a double maxima, frequency polygons should also show the maximum corresponding to warmer temperatures decreasing with height at the expense of the colder peak.

Temperature frequency polygons for all observations at 850, 700, 500 and 300 mb for January and July 1953-56 are shown in Figs. 1 and 2. Weak double maxima are evident at all levels in the summer, but only at 700 mb in winter. The histograms for 850, 700 and 500 mb for the various air mass classes (Figs. 1 and 2) and Table 1 show that the frequency of cases of cold air decreases and of warm air increases with height. Table 1 shows that the difference between the mean temperature of the warm and cold air masses is about  $10^{\circ}C$  in January and  $8^{\circ}C$  in July at the three levels, while the standard deviation in January is, contrary to expectations, greater in the warm than in the cold air at all three levels, but in July, as is normally the case,

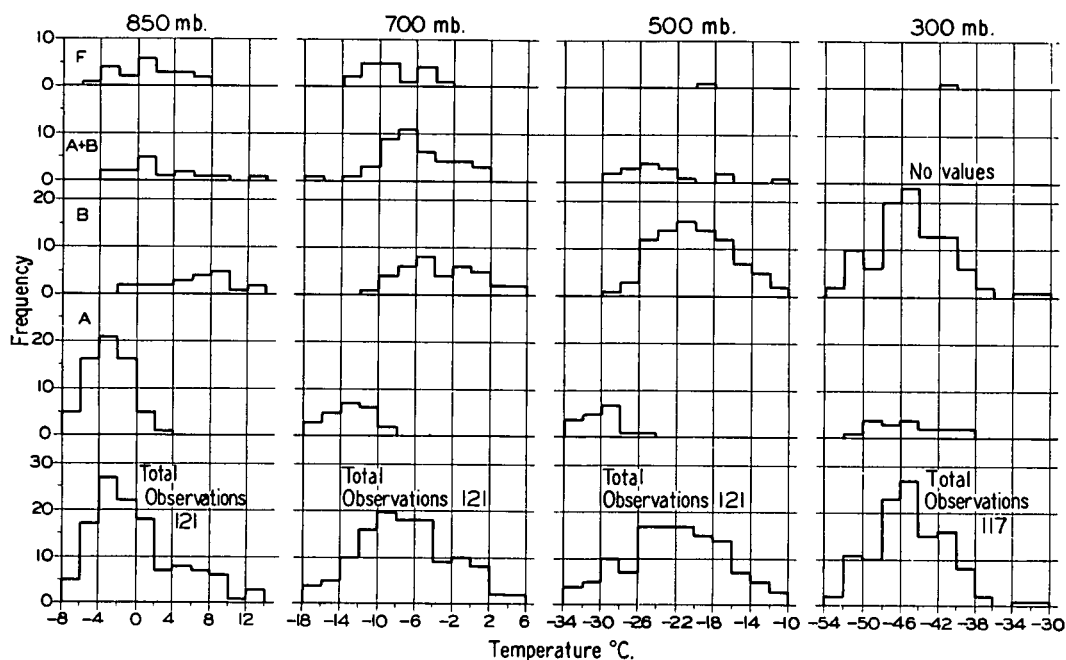


Fig. 1. Temperature frequency polygons for Maquarie Island for January 1953-56 for all observations, and temperatures classified as follows—A=front above level, B=front below level, A+B=front above and below level, and F=front at level.

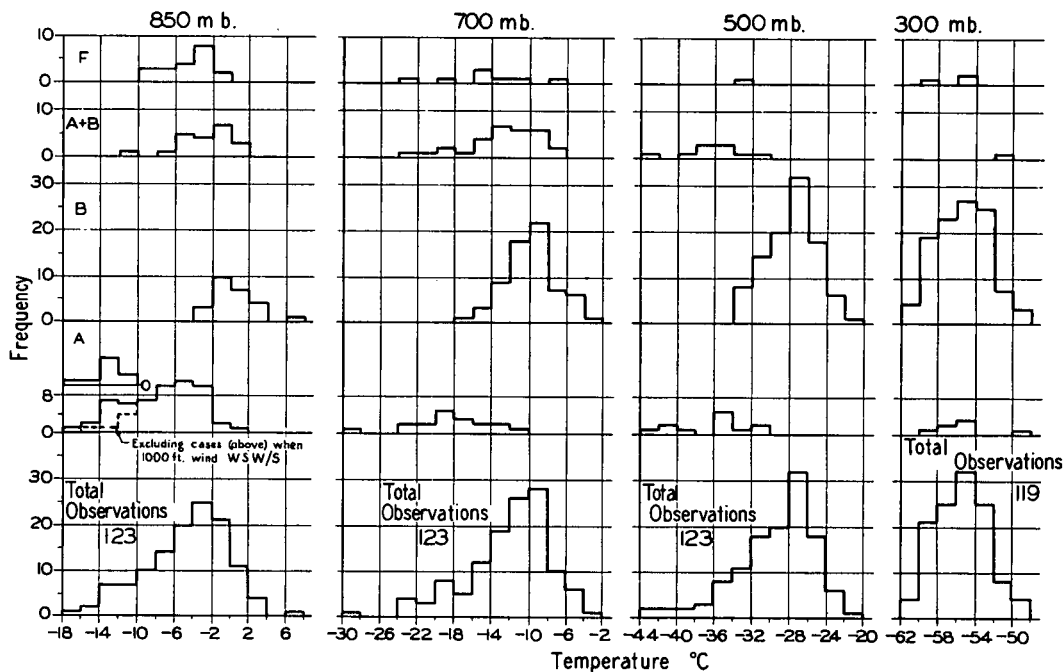


Fig. 2. Temperature frequency polygons for Maquarie Island for July 1953-56. See Fig. 1. for explanation.

the standard deviation is greater in the cold air. The means of temperatures between and in fronts are generally between the mean temperatures of the warm and cold air masses but closer to the mean in the warm air, except at 500 mb in July.

At 300 mb the range of temperatures below stable layers does not extend outside the range of the temperatures above stable layers, so these classes might well be combined, indicating as McIntyre found for high latitudes in the northern hemisphere, absence of baroclinity at 300 mb at Macquarie Island.

In Table 2 values of the skewness parameter  $\mu_3/\sigma^3$  (where  $\mu_3 = \sum f(t - \bar{t})^3 / \sum f$  and  $f$  is the frequency of the temperature  $t$ , whose mean is  $\bar{t}$ , and  $\sigma$  is the standard deviation of  $t$ ) are given. Brooks and Carruthers state that if  $\mu_3/\sigma^3$  is not greater than

$$2 \left( \frac{6N(N-1)}{(N-2)(N+1)(N+3)} \right)^{\frac{1}{2}}$$

where  $N = \sum f$ , there is some doubt as to whether the apparent skewness is real. Where this value is exceeded the values in Table 2 have been underlined. For the two cases of air mass classes A + B at 500 mb in January and 700 mb in July the value is exceeded, due to isolated cases with large departures from the mean temperature of the classes (see Figs. 1 and 2), in classes whose total frequency is small. The skewness is not significant in any of the other air mass classes.

In the total temperature distributions the skewness is significant at 850 mb in January and at 700 and 500 mb in July. From considerations of the normal seasonal disposition of the major (polar) frontal zone it was expected that the January total histograms would show positive skewness and the July total histograms negative skewness with the skewness decreasing with height in both months. This is more or less so below 500 mb in January and above 850 mb in July.

Where cases were sufficient to apply to  $\chi^2$  test, Table 2 gives, in brackets, the percentage probability that the distribution is normal. The probability is low for the total distributions at 700 and 500 mb in July and at 850 mb in January, in agreement with the indication from the skewness test that the skewness is real. At 300 mb, in view of the apparent absence of baroclinicity, the high probability of normality found there is to be expected.

Table 1: Frequencies, means and standard deviations of January and July, 1953-56, temperatures at 850, 700, 500 and 300 mb for air mass classes used in Figs. 1 and 2. Statistics for all classes are shown in columns headed "T".

J A N U A R Y 1953-56															
PRESSURE	FREQUENCY				MEANS (°C)				STANDARD DEVIATIONS (°C)						
	A	B	A+B	T	A	B	A + B	F	T	A	B	A + B	F	T	
850	64	21	15	21	121	- 2.9	+ 6.2	+ 2.6	+ 1.2	+ 0.1	2.3	4.0	4.3	3.4	4.7
700	23	38	42	18	121	-13.1	- 3.3	- 6.3	- 8.7	- 7.0	2.3	4.1	3.8	2.8	4.8
500	18	86	16	1	121	-30.1	-20.1	-23.4	-19.0	-22.0	2.1	3.9	4.5	-	5.2
300	18	98	-	1	117	-45.0	-44.8	-	-41.0	-44.8	3.4	4.0	-	-	3.9
J U L Y 1953-56															
850	57	25	21	20	123	- 7.4	+ 0.3	- 2.8	- 4.7	- 4.6	4.1	2.3	2.9	2.5	4.5
700	18	67	30	8	123	-18.3	- 9.8	-12.8	-14.7	-12.1	4.2	2.8	3.9	4.5	4.6
500	12	100	10	1	123	-36.2	-27.8	-36.2	-33.0	-29.3	3.8	2.7	3.1	-	4.3
300	7	108	1	3	119	-55.3	-55.5	-51.0	-56.3	-55.4	2.9	2.8	-	-	2.8

Table 2. Values of the skewness parameter  $\mu_3/\sigma^3$  (see text) and, in brackets, the percentage probability according to the  $\chi^2$  test that the distribution is normal, for temperature distributions in the air mass classes of Figs. 1 and 2 and for the total distribution "T" for various levels at Macquarie Island in January and July 1953-56. See text regarding underlined values.

	A	B	A + B	F	T
	J a n u a r y				
850	+0.29 (85)	-0.06	+0.90	+0.01	<u>+0.83</u> (.1)
700	-0.16	+0.22 (50)	-0.04 (30)	+0.08	+0.19 (70)
500	+0.85	+0.23 (80)	+1.27	--	-0.09 (80)
300	+0.12	+0.45 (20)	--	--	+0.42 (40)
	J u l y				
850	-0.18 (20)	+0.87	-0.89	-0.32	-0.41 (20)
700	-0.36	+0.15 (20)	<u>-0.94</u> (20)	-0.11	<u>-1.01</u> (1)
500	-0.36	+0.02 (15)	-0.54	--	<u>-0.49</u> (1)
300	+0.26	+0.09 (20)	--	--	+0.15 (50)

For air mass classes, where calculation was possible, the  $\chi^2$  test indicates a high probability of normality. However, inspection of the histogram for class A at 850 mb in July suggests that there might well be two distributions. It was found that most of the coldest temperatures occurred with winds between WSW and S. Separation of these from temperatures occurring with 1000 ft winds outside this sector gives two distributions which are approximately normal. However the existence of two air mass classes of cold air requires confirmation from a larger sample than used here. Judging from the four years

analysed this possible secondary cold distribution within class A is not a feature of the January 850 mb temperature distribution.

Before the air mass temperature distributions had been separated by the method used here, an attempt was made to effect separation by statistical methods. It was found that several combinations of normal distributions could be fitted equally well to the total frequency polygon. While the method might be effective for much larger samples than used here, it is just as time consuming and leaves doubt as to whether the separation effected is the correct one.

#### 4. CONCLUSIONS

At Macquarie Island, particularly in winter, more than one air mass occurs below 300 mb where, consequently, the distributions of temperature are skewed or double humped and not adequately defined by the mean and standard deviation of the total observations. This probably applies at most stations outside equatorial regions.

Although desirable the presentation of temperature frequency polygons for standard pressures at all stations would be rather cumbersome. If, as seems likely, temperatures within air mass classes are normally distributed everywhere, the distributions could then be represented by the means, standard deviations and total frequency of each class.

#### ACKNOWLEDGMENTS

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