NPS-51MR72101A

NAVAL POSTGRADUATE SCHOOL

Monterey, California

DEVELOPMENT OF REGIONAL EXTREME MODEL ATMOSPHERES FOR AEROTHERMODYNAMIC CALCULATIONS (I)

by

Frank L. Martin

20 October 1972

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral M. B. Freeman
Superintendent

M. U. Clauser
Provost

ABSTRACT

A group of stations in the North American Arctic region have been analyzed for statistical determination of temperatures at mandatory pressure levels p_i. For each station the temperature at a key level (called the forcing-level temperature) peculiar to the station has been forced in at the first step, and retained at each subsequent step in the development of the stepwise regression equations giving temperature at the mandatory levels. In general, eight-step prediction equations in terms of other temperatures in the vertical were found to give specification of $T(p_i)$, with percentage explained variance of close to 0.99. As a result of this definitive property, the best-estimate of the regional atmosphere which is conditionally dependent upon the existence of an extreme 1% probability of the forcing-level temperature is obtained with a high degree of confidence.

TABLE OF CONTENTS

1. Introduction

A preliminary set of model atmospheres giving both the warm and cold extremes at certain reference elevations with a 1% level of expectancy has been proposed as the Preliminary MIL-STD-210B by ETAC (Environmental Technical Applications Center of the USAF). In essence this model of cold and warm extreme temperatures is based upon listing the coldest (warmest)temperatures at each of the eight standard levels listed in Table 1. These extreme temperatures are based upon observations of the location of extreme temperature noted on global temperature maps at the level noted. The extremes are observed to occur at the geographically diverse locations listed in Table 1.

The values of the extremes in Table 1 were computed from the assumed existence of a normal distribution of temperature in both the coldest (January, N. Hemisphere) and warmest (July, N. Hemisphere) months. Thus these extremes have been computed based upon the expectancy (true for a normal distribution) of finding 1% of all temperature-departures from the sample mean at each location and level at 2.3267 times the standard deviation σ at that level and location. In the process of making the estimation of temperature-extremes, no allowance has been made for the possibility of inter-level correlations which have been shown to exist at typical stations (Cole and Nee, 1965).

Because of the neglect of vertical consistency in assembling the temperature-extreme data for the Preliminary MIL-STD-210B climatic model, an unrealistic range of temperatures is required in design of equipment needed to operate in these atmospheres. As a result, it has been proposed that the geographical sites which are proposed in Table 1, as corresponding to world-wide temperature extremes at the given levels, be used to

TABLE 1. Locations of proposed extreme temperatures in the cold world-wide and warm world-wide cases (after ETAC).

		Cold-Extreme				Warm-Extreme				
	Level	Location	January Mean (°C)	STD. DEV. (°C)	1% Extreme (°C)	Location	July Mean (°C)	STD. DEV. (°C)	1% Extreme (°C)	
	SFC	Oymyakon, USSR	-50.6	4.4	-60.6	Insalah, Algeria	40.9	3.9	49.0	
	850mb	Oymyakon, USSR	-35.1	5.5	-47.0	Insalah, Algeria	28.9	2.2	34.0	
C1	700mb	Hall Beach, NWT	-27.3	6.5	-42.4	Babylon, Iraq	17.0	2.2	22.1	
C1	500mb	Resolute, NWT	-43.0	4.6	-53.2	New Delhi, India	-4.3	3.9	4.0	
C1	300mb	Thule, Greenland	-60.6	2.2	-66.0	New Delhi, India	-25.8	3.9	-16.0	
C1	200mb	Thule, Greenland	-59.7	7.2	-75.0	Alert, NWT	-42.3	2.5	-36.5	W1
	150mb	Karachi, Pakistan	-65.0	6.0	-79.0	Alert, NWT	-43.3	2.5	-37.5	W1
	100mb	Singapore	-83.0	3.0	-90.0	Thule, Greenland	-43.8	2.2	-37.2	W1

provide "forcing temperatures" at the level. Based upon inter-level temperature-statistics at each station, the most likely temperatures at the eight additional levels (the 70 mb level is to be included) in the atmosphere are then to be estimated with optimal accuracy.

It is to be noted that Table 2 lists only six different stations in definition of the cold-extreme, and five in definition of the warm-extreme atmosphere. Hence, a real-time data analysis would require a detailed climaticalogical examination of 11 different stations for the purpose of establishing regional extremes.

2. A statistical model for regional extreme atmospheres.

As indicated in the study by Cole and Nee (1965), high values of inter-level simple correlations of temperature frequently exist. It was decided in this study to obtain an initial data file on magnetic tape for the two-a-day rawinsonde stations (all in the North American sector) identified by code symbols C1 and W1 in Table 1. These symbols are employed to suggest the cold and warm atmosphere feasibility study. The data was provided by the Environmental Data Service, National Climatic Center, through the financial assistance and kind cooperation of the Commander, Naval Weather Service.

The other stations in Table 1 not bearing the code symbols C1 or W1 have also been provided through the data sources just listed. However, these secondary data records are not available in the convenient summary form, nor in such abundant population samples as those stations which were coded C1 or W1 so that more care is required in the data-handling of these secondary stations. This second set of data-stations is the subject of ongoing work which will appear as a later report in this series.

For the stations marked code symbols Cl and Wl, a stepwise multiple regression technique was employed. This program, known as BIMED 02R, is available in the Program Library of the W. R. Church Computer Center of the Naval Postgraduate School. The temperature data was arranged in a decreasing pressure sequence but with standard pressure-spacings as follows (Table 2):

TABLE 2.

	J=1	J=2	J=3	J=4	J=5	J=6	
	1000mb	950	900	850	800	750	
J = 7	700	650	600	550	500	450	J = 12
J = 13	400	350	300	250	200	175	J = 18
J = 19	150	125	100	80	70		J = 23

Actually, each Cl and Wl radiosonde was listed with both a height and temperature at each of these levels. Over the four year data sample (1967-70), these stations provided the following population samples:

C-1 Stations

Hall Beach (700mb) 243 samples
Resolute (500mb) 237 samples
Thule .....(300mb) 213 samples
Thule .....(200mb) 213 samples

W-1 Stations

Alert .....(200mb) 244 samples
Alert .....(150mb) 244 samples
Thule .....(150mb) 236 samples

The program BIMED 02R permits for each station, the specification of a different dependent variable or predictand in each subproblem. Also, the number of independent variables to be tested for admission to regression equation can be limited. In the problems considered here an upper limit of eight independent variables was found to be given optimal specification of each of the dependent variables. Another convenient feature of the BIMED 02R program is that the forced entry into the regression of the temperature value being tested as an extreme (the so-called "forcing temperature") is allowed, even though its contribution to the explained variance may become small. For example, in the case of Resolute, which corresponds to a winter extreme at 500 mb, the multiple regression equations at the various "mandatory levels" were set up in the forms:

$$T_M = A + B\,T_{11} + C\,X_M \qquad (1)$$

Here T_M is the 8-level predictand chosen alternately as

$$T_M = T_1, T_4, T_7, T_{15}, T_{17}, T_{19}, T_{21}, T_{23}$$

where the subscript M is the temperature identifier associated with the pressure level indicated in Table 2. In summary, the predictands desired are

T_1, the temperature at 1000 mb

T_4, the temperature at 850 mb

T_7, the temperature at 700 mb

T_{11}, the temperature at 500 mb

T_{15}, the temperature at 300 mb

T_{17}, the temperature at 200 mb

T_{19}, the temperature at 150 mb

T_{21}, the temperature at 100 mb

T_{23}, the temperature at 70 mb

The form X_M represents here a linear combination of up to 7 independent variables, apart from the forced temperature T_{11} in the case of Resolute, NWT. The variable X_M varies from case to case, as the predictand is changed from T_1 to T_4, to T_7, etc. X_M usually involves temperature predictors which are physically close to the level being specified as the dependent variable T_M. For example, at Resolute, T_4 [= T(850)] was best-fit by the following expression:

$$T_4 = .3745 - .0849\ T_{11} + 1.0\ X_4$$

$$X_4 = .3614T_3 + .8577T_5 - .2892T_6 + .0819T_7 + .0902T_9 + .0598T_{14} - .0486T_{17}$$

with a multiple regression coefficient R = .9861. In general, somewhat similar results applied at each of the other mandatory pressure levels 1000, 700, 500, 300, 200, 150, 100, 70 mb except that the multiple R expressing T_1[= T(1000)] and T_{15}[= T(300)] in terms of T_{11} and X_M were somewhat lower than the remaining correlations in the set. Similar statements applied to all stations at both extreme-times January and July.

The function X_M is called in this study a "structure-function" in that to a large degree it accounts for most of the variation of the T_M being predicted, even though the part played by the forcing variable is by no means negligible.

A least squares fit of form Eq. (1) may be shown to produce residuals (computed against the observed values) which are distributed normally relative to the regression-value, together with a variance given by the standard error of estimate $\sigma_E = \sigma \sqrt{1 - R^2}$. In the set of dependent variable regressions tested here, most of the multiple regression coefficients had values well in excess of .99 (with the exception of the two levels already noted, 1000 mb and 300 mb), so that a near functional relationship existed between the predictor and the predictand set. The specification statistics for the different stations in the North American sector of Table 1 are listed in Section 3.

3. Regression-specification of mandatory-level temperatures using the forcing-level temperature.

The stepwise regression procedure of BIMED 02R was employed with the appropriate forcing-level temperature required at the first step of the regression and retained in the selection of the following seven predictors. These seven predictors were allowed to enter the stepwise regression in accordance with the programmed requirement that at each step k, the variable added explained a maximum of the unexplained variance remaining after (k-1) selections (k=2,...,...,8).

Tables 3a, 4a,...,9a show the results of the stepwise regression applied to the specification of the temperatures T_1, T_4, T_7, T_{11}, T_{15}, T_{17}, T_{19}, T_{21}, T_{23} at mandatory levels by an equation of form (1), using an eight-predictor equation for each T_M just listed. Table 3a lists for the January full data-sample at Hall Beach the mean, standard deviation, multiple correlation coefficient and standard error σ_E at each level other than at forcing level. Table 3b lists analogous results for a nominal 10% of the January data sample corresponding to the 10% cold extreme sample.

Table 4a and 4b list similar results for Resolute in January with T_{11}[= T(500)] as the forced variable. Tables 5 and 6 list analogous results for Thule, using T_{15} and T_{17} as forcing variables, respectively. It is to be noted that the fractional explained variance R^2 of the predictand in each case, does not fall of appreciably, in general, as one proceeds along any row of these tables from part (a) to part (b).

Tables 7, 8, 9 similarly list the July-warm statistics, using respectively the full data-samples at Alert [with forcing temperature T_J= T(200)], Alert [T_J = T(150)] and Thule [T_J = T(100)] in the left half of the tables. The prediction results corresponding to the nominal 10% of the warmest July forcing-level temperatures appear on the right half of these tables.

The selection of nominal 10% extreme cases was made by separating out of the full sample all cases where the forcing temperature T_J lay in the ranges

$$T_J < \bar{T}_J - 1.2817\sigma_J \text{ for cold extremes}$$

$$T_J > \bar{T}_J + 1.2817\sigma_J \text{ for warm extremes}$$

The criteria used in establishing these 90% nominal extremes was that the full data samples were normally distributed, a valid first approximation. The actual number of extreme data cases is listed at the top of Tables 3b, ..., 9b, for each case under consideration.

In order to determine the multiple correlation coefficients and standard errors for the right-side 10% extreme samples of Tables 3b,...,9b, a regression equation of identical form to that developed for the full data-base predictands was generated for testing the 10% extreme-case data samples. The test-predictors for the extreme-data were then considered to be the forcing variable T_J and the structure-variable X of form determined for the full-sample cases. The high values of the multiple correlations thus determined for the January extreme-data cases serves to verify the concept that the predictands corresponding to the extreme-data may be anticipated through a joint knowledge of the forcing variable T_J and of the structure function. The somewhat smaller correlation coefficients for the July data is due to the much smaller values of variance in summer, particularly in the lower stratosphere.

A listing of the nominal extremes of the forcing temperature for other probability levels of interest, e.g., the 5%, the 1% was also made assuming the existence of a Gaussian distribution of temperature, and appears in Table 10. A separation of the 10% nominal extremes of T_J was then made wherever possible into the classes suggested in Table 10, that is beyond the .01 probability level; in the probability range .05 to .01 and in the range .10 to .05. The results of these probability stratifications on the predictands at T_1, T_4, T_7, T_{11}, T_{15}, T_{17}, T_{21}, T_{23} are discussed in Section 4. These additional critical extremes are given by

$$T_J(.05) = \bar{T}_J \pm 1.640\ \sigma_J \qquad (2)$$

$$T_J(.01) = \bar{T}_J \pm 2.3267\sigma_J \qquad (3)$$

Equations 2 and 3 tend to give excessive estimates of the critical extremes when the observed σ_J is too large to be representative of a normal distribution. This happens primarily in the winter season at low stratospheric levels, e.g., Thule at 300 mb. At this locale there tends to be bimodal alternations between warm and cold stratospheric regimes and an unrepresentatively large σ_J results from this sample. The ETAC estimate (Table 1) of the 1% extreme temperature at Thule at 300 mb in winter also seems to reflect this same difficulty.

The following temperature classes were then considered as input data at the C1 and W1 station forcing levels, respectively

Cold classes: (a) $T_J < T_{.01}$; (b) $T_{.01} < T_J < T_{.05}$; (c) $T_{.05} < T_J < T_{.10}$

Warm classes: (a) $T_J > T_{.01}$; (b) $T_{.01} > T_J > T_{.05}$; (c) $T_{.05} > T_J > T_{.10}$

In most cases studied, reasonable sample-sizes existed in each class (a), (b), (c). However, in several cases, the extremes did not reach the 1% nominal-value predicted from an assumed Gaussian distribution.

TABLE 3. Regression statistics at mandatory pressure levels at Hall Beach using $T_J = T(700)$ as the forcing-level temperature. Part (a) refers to the full-data January sample; part (b) refers to the nominal 10% cold extreme sample of T(700).

(a) N = 243 cases					(b) N = 26 cases				
Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)	Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)
1000mb	-26.11	7.602	.8992	3.383	1000mb	-35.04	3.893	.7238	2.801
850	-22.63	7.238	.9937	.824	850	-35.60	3.295	.9757	.753
700	-27.35	6.467			700	-39.68	3.186	-	
500	-39.93	4.994	.9952	.496	500	-45.98	2.847	.9750	.659
300	-55.09	5.578	.9773	1.201	300	-45.45	4.965	.9878	1.094
200	-53.53	6.071	.9897	.883	200	-45.88	5.279	.9878	.858
150	-53.71	6.517	.9920	.836	150	-47.40	6.796	.9867	1.151
100	-55.49	7.689	.9943	.835	100	-51.11	7.847	.9941	.887
70	-57.38	8.942	.9946	.944	70	-54.41	8.936	.9936	1.048

TABLE 4. Regression statistics at mandatory pressure levels at Resolute using $T_J = T(500)$ as the forcing-level temperature. Part (a) refers to the full-data January sample; part (b) refers to the nominal 10% cold extreme sample of T(500).

	(a) N = 237 cases					(b) N = 25 cases			
Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)	Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)
1000mb	-29.10	6.349	.8522	3.379	1000mb	-35.52	4.273	.7260	3.069
850	-24.56	5.631	.9861	.953	850	-31.18	3.457	.9925	.440
700	-28.87	4.856	.9920	.625	700	-35.71	3.175	.9941	.360
500	-41.92	4.043			500	-48.68	1.573		
300	-55.85	5.225	.9778	1.115	300	-57.26	5.916	.9879	.958
200	-53.89	6.121	.9883	.950	200	-56.04	6.043	.9924	.777
150	-54.56	7.036	.9946	.740	150	-58.68	5.517	.9962	.499
100	-56.48	8.510	.9965	.728	100	-61.95	6.982	.9958	.665
70	-58.34	7.578	.9962	.856	70	-64.48	7.541	.9958	.725

TABLE 5. Regression statistics at mandatory pressure levels at Thule using $T_J = T(300)$ as forcing-level January temperature. Part (a) refers to the full-data sample; part (b) refers to the nominal 10% cold extreme sample of T(300).

	(a) N = 213 cases					(b) N = 13 cases			
Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)	Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)
1000mb	-20.50	7.097	.9336	2.593	1000mb	-21.41	5.931	.8765	3.127
850	-21.91	7.622	.9924	.954	850	-22.55	6.079	.9971	.505
700	-27.04	6.187	.9937	.707	700	-28.68	6.095	.9991	.267
500	-40.28	4.758	.9941	.528	500	-42.41	3.887	.9958	.390
300	-55.58	5.049			300	-63.03	0.880		
200	-54.86	6.791	.9863	1.143	200	-61.88	2.375	.9871	.417
150	-55.22	7.216	.9907	.999	150	-63.02	2.809	.9913	.405
100	-57.10	9.084	.9968	.744	100	-67.51	2.493	.9576	.787
70	-59.12	10.804	.9979	.720	70	-70.57	3.197	.9740	.793

TABLE 6. Regression statistics at mandatory pressure levels at Thule using $T_J = T(200)$ as forcing-level temperature. Part (a) refers to the full-data January sample; part (b) refers to the nominal 10% cold extreme sample of T(200).

	(a) N = 213 samples					(b) N = 18 samples			
Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)	Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)
1000mb	-20.50	7.097	.9336	2.592	1000mb	-12.83	7.471	.9298	2.928
850	-21.91	7.622	.9924	.958	850	-13.18	6.948	.9933	.856
700	-27.04	6.187	.9938	.703	700	-20.51	5.885	.9981	.383
500	-40.28	4.758	.9941	.528	500	-35.74	5.012	.9955	.491
300	-55.58	5.049	.9739	1.168	300	-59.37	2.170	.9486	.731
200	-54.86	6.791			200	-67.93	3.750		
150	-55.22	7.216	.9908	.995	150	-66.57	4.252	.9460	1.467
100	-57.10	9.084	.9968	.745	100	-70.32	3.135	.9812	.644
70	-59.12	10.804	.9979	.719	70	-74.05	3.804	.9949	.410

TABLE 7. Regression statistics at mandatory pressure levels at Alert using $T_J = T(200)$ as forcing-level temperature. Part (a) refers to the full-data July sample; part (b) refers to the nominal 10% warm extreme of T(200).

(a) N = 236 samples					(b) N = 18 samples				
Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)	Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)
1000mb	3.26	3.673	.8418	2.016	1000mb	1.30	1.317	.8924	.633
850	- 0.91	3.203	.9764	.703	850	- 4.40	2.363	.9831	.460
700	- 9.02	3.396	.9797	.693	700	-13.43	2.296	.9479	.779
500	-23.97	3.211	.9916	.422	500	-28.11	2.435	.9930	.305
300	-47.59	2.545	.6836	1.889	300	-44.93	3.775	.6857	2.925
200	-42.19	2.789			200	-38.13	0.644		
150	-42.04	1.779	.9308	.6613	150	-39.58	0.714	.6876	.552
100	-41.87	1.263	.8921	.580	100	-40.58	0.867	.7086	.651
70	-40.87	1.104	.9175	.447	70	-39.64	1.526	.9916	.210

TABLE 8. Regression statistics at mandatory pressure levels at Alert using $T_J = T(150)$ as the forcing-level temperature. Part (a) refers to the full-data July sample; part (b) refers to the nominal 10% warm extreme sample of T(150).

(a) N = 236 samples					(b) N = 22 samples				
Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)	Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)
1000mb	3.26	3.673	.8399	2.027	1000mb	2.19	2.434	.7853	1.585
850	- 0.91	3.203	.9763	.704	850	- 3.54	2.320	.9796	.490
700	- 9.02	3.396	.9796	.694	700	-12.25	2.644	.9440	.917
500	-23.97	3.211	.9916	.423	500	-26.43	2.209	.9762	.504
300	-47.59	2.545	.6851	1.885	300	-47.16	3.210	.5905	2.772
200	-42.19	2.789	.9529	.860	200	-38.93	0.939	.8574	.508
150	-42.04	1.779			150	-39.24	0.537		
100	-41.87	1.263	.8921	.581	100	-40.27	0.498	.3888	.482
70	-40.87	1.104	.9172	.447	70	-39.59	1.325	.9840	.248

TABLE 9. Regression statistics at mandatory pressure levels at Thule using $T_J = T(100)$ as the forcing-level temperature. Part (a) refers to the full-data July sample; part (b) refers to the nominal 10% warm extreme sample of T(100).

	(a) N = 236 samples					(b) N = 18 samples			
Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)	Level	Mean °C	Std.dev. °C	Multiple Correl. Coeff.	Std. Error of Estimate (°C)
1000mb	3.70	3.199	.7686	2.082	1000mb	2.19	1.889	.7675	1.289
850	- 0.73	3.033	.9736	.705	850	- 3.43	2.551	.9830	.498
700	- 7.76	3.147	.9704	.774	700	-11.13	3.555	.9805	.744
500	-23.05	3.097	.9862	.522	500	-26.48	3.409	.9902	.508
300	-47.54	2.399	.7794	1.530	300	-46.58	2.853	.7898	1.863
200	-44.17	3.778	.9294	1.419	200	-39.84	1.590	.8789	.808
150	-43.57	2.770	.6735	2.083	150	-40.62	1.035	.8113	.644
100	-43.20	1.429			100	-40.95	0.427		
70	-43.08	1.237	.9507	.390	70	-40.62	0.626	.8721	.326

TABLE 10. Nominal temperature-extremes at the indicated stations and pressure levels at the 10%, 5% and 1% extreme values according to a Gaussian distribution.

Station	$T_{.10}$	$T_{.05}$	$T_{.01}$ (°C)	Forcing Level T_J	90% extreme sample size
Hall Beach	-35.6	-37.9	-42.3	T_J = T(700)	26
Resolute	-47.1	-48.5	-51.3	T_J = T(500)	25
Thule, Wi	-62.0	-63.8	-67.3	T_J = T(300)	13
Thule, Wi	-63.5	-66.0	-70.6	T_J = T(200)	18
Thule, Su	-41.3	-40.8	-39.8	T_J = T(100)	18
Alert, Su	-39.7	-39.1	-37.9	T_J = T(150)	22
Alert, Su	-38.6	-37.6	-35.7	T_J = T(200)	18

4. Temperature-estimates at mandatory levels corresponding to 1% extremes of forcing-level temperatures.

a. Winter extreme atmospheres

Corresponding to the four winter extreme cases, the multiple regression methods which led to Tables 3, 4, 5, 6 also lead to the results of Tables 11, 12, 13, 14. In the latter tables, the nominal 10% extreme sample is decomposed into the subsample extreme-classes (a), (b), (c). These classes were defined in Section 3, but their definition is also implicitly given in the top row of each table (e.g., Table 11: (a) $T_{.01}$; (b) $T_{.01}$ - $T_{.05}$; (c) $T_{.05}$ - $T_{.10}$. Corresponding to the stratified data-sample at each forcing level there exist also conditional data-sets at each of the mandatory levels above and below the forcing level. In virtually all cases, the mandatory-level data sets in classes (a), (b), (c) exhibit well-defined trends between the class-mean temperatures at all levels. This discovery afforded credibility to the listed extreme values of the class (a) mandatory-level results of Tables 11, 12, 14. Note that in each stratification (a), (b), (c), the same sample size exists at each level within each class regardless of the level under consideration.

As noted in Section 3, no nominal 1% data class was realized in Table 13; however, the class (b) sample T_J = T(300) comprised a de facto extreme 1% data-sample by actual count. In the comparison of $\overline{T}_b$ with $\overline{T}_c$ at mandatory levels over Thule (Table 13), there existed consistent inter-class temperature differences, again at all levels. In all cases, the reason for these consistent inter-class temperature deviations is that the mandatory level temperatures have been found to be strongly correlated with the forcing-levels temperature through the multiple regression

Level (mb)	Temperature-means (°C) in classes			Std. deviations (°C) relative to class-mean		
	(a) $T_{.01}$	(b) $T_{.01}-T_{.05}$	(c) $T_{.05}-T_{.10}$	σ_a	σ_b	σ_c
1000	-35.24	-35.22	-34.62	2.588	4.047	3.876
850	-39.52	-35.71	-32.34	1.421	2.475	1.943
700*	-44.96	-39.55	-36.60	1.746	1.175	0.799
500	-44.04	-45.90	-47.32	0.948	3.363	1.233
300	-41.02	-45.95	-47.41	0.937	5.472	3.315
200	-42.96	-46.22	-47.16	0.924	6.064	4.327
150	-45.20	-47.32	-48.91	0.767	7.804	6.220
100	-48.64	-51.40	-52.25	1.284	8.999	6.849
70	-50.28	-55.47	-55.42	2.047	10.185	6.527
Number in class	5	13	8			

TABLE 11. Temperature means at mandatory levels at Hall Beach (winter), corresponding to temperature extremes of $T_J(700)$ at the (a) 1% class, (b) 1-5% class and (c) 5-10% class of probability. The standard deviations σ_a, σ_b, σ_c of the observed temperatures within each class are shown in the right half of the table.

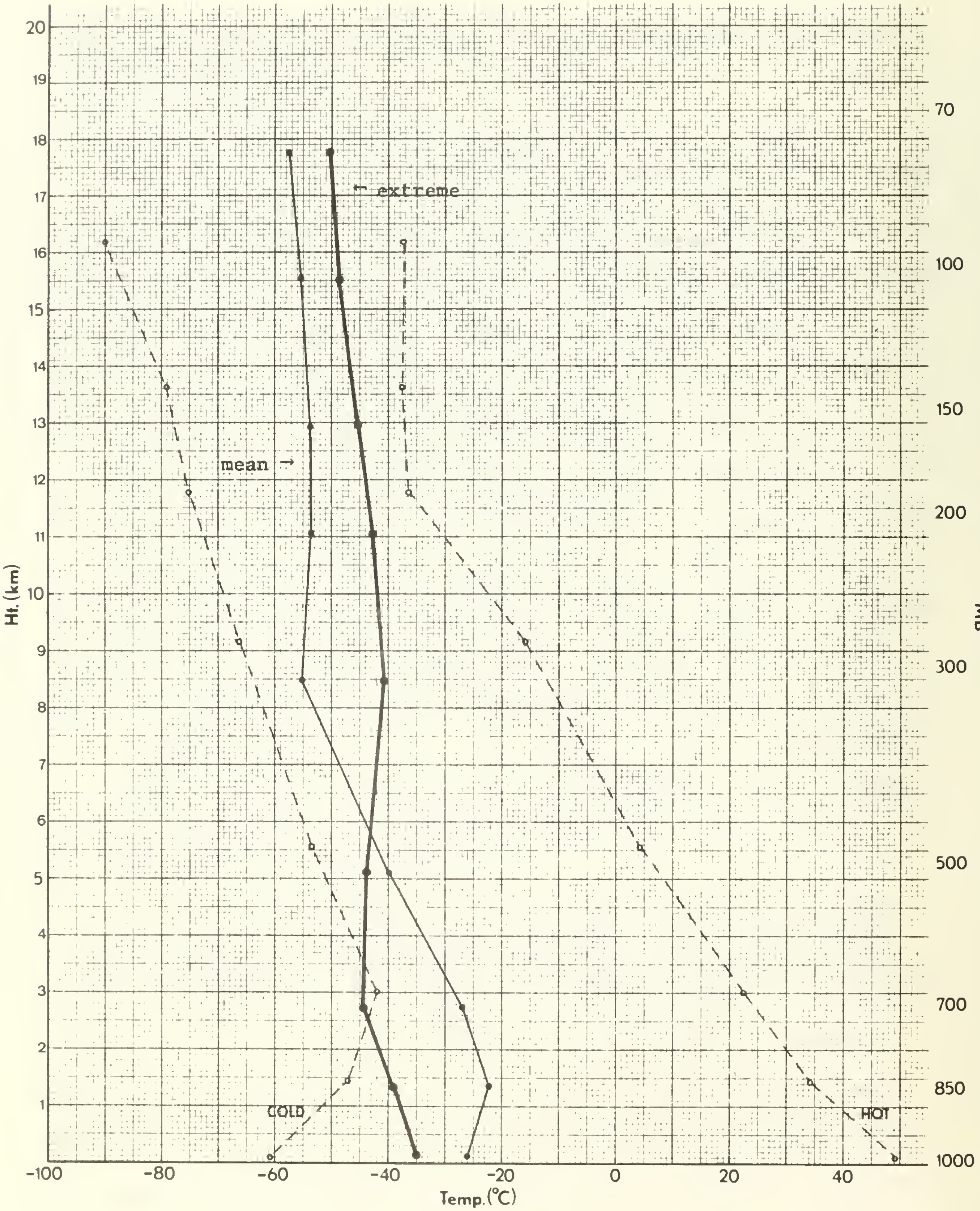

FIG. 1. The heavy solid line shows the mean regression-determined vertical temperature sounding over Hall Beach, NWT, corresponding to the class (a) set of 1% cold extreme occurrences of $T_J(700)$ of Table 11. The thin solid line depicts the January mean Hall Beach vertical sounding (1967-70). The dashed curves the world-wide Preliminary MIL-STD 210 extreme atmospheres.

Level (mb)	Temperature-means (^oC) in classes			Std. deviations (^oC) relative to class-mean		
	(a) $T_{.01}$	(b) $T_{.01}-T_{.05}$	(c) $T_{.05}-T_{.10}$	σ_a	σ_b	σ_c
1000	-39.00	-38.77	-33.31	0.748	2.125	3.718
850	-35.50	-31.57	-30.14	0.698	1.463	3.038
700	-40.37	-36.43	-34.45	0.742	1.308	2.274
500*	-51.73	-49.70	-47.59	0.173	0.782	0.342
300	-54.03	-56.20	-60.48	1.225	2.027	4.070
200	-55.20	-55.24	-59.15	0.648	2.280	3.561
150	-59.37	-58.09	-61.12	0.881	2.489	3.098
100	-65.70	-61.00	-64.59	0.860	3.745	3.248
70	-70.77	-62.50	-65.88	0.480	5.748	4.064
Number in class	3	7	15			

TABLE 12. Temperature means at mandatory levels at Resolute (winter), corresponding to temperature extremes of $T_J(500)$ at the (a) 1% class, (b) 1-5% class and (c) 5-10% class of probability. The standard deviations σ_a, σ_b, σ_c of the observed temperatures within each class are shown in the right half of the table.

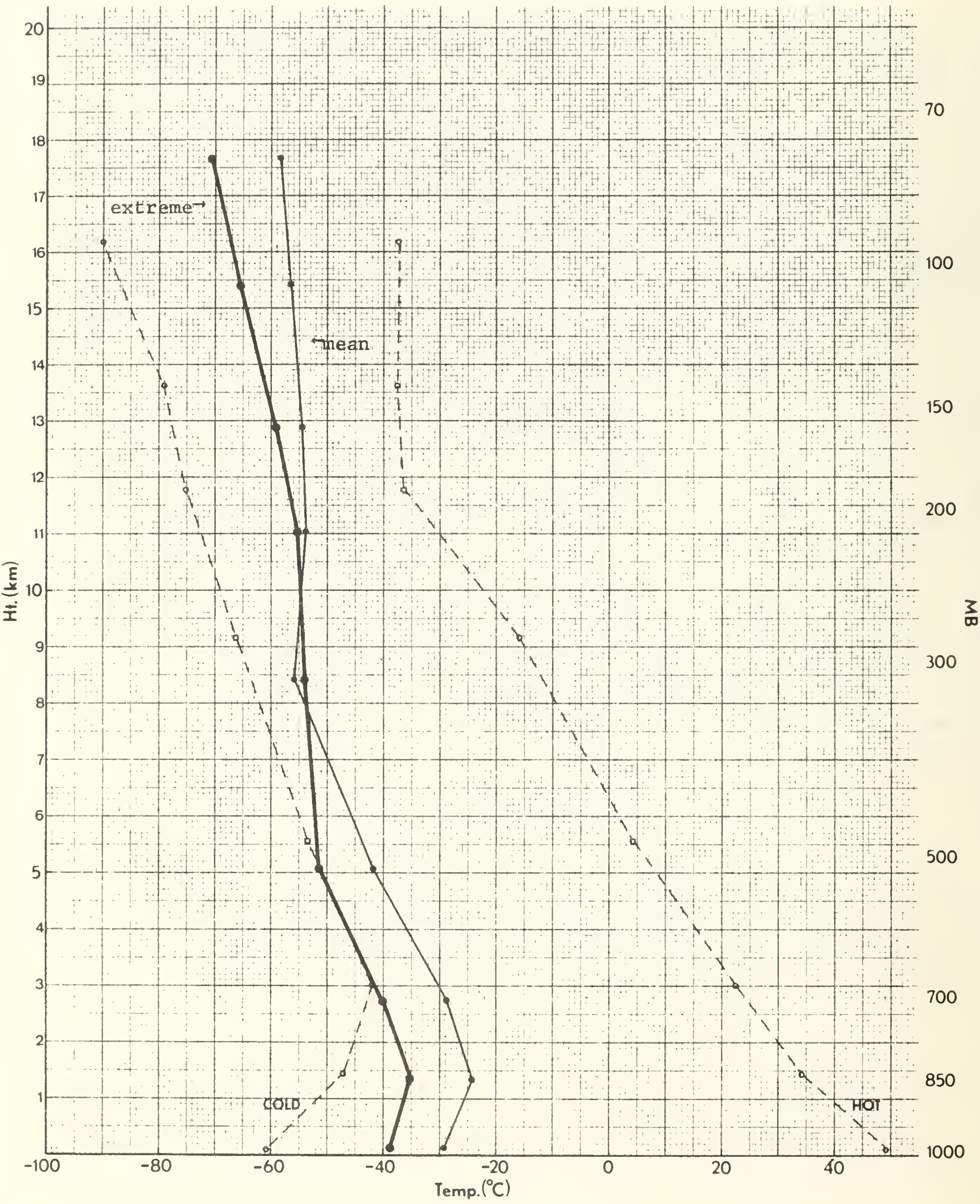

FIG. 2. The heavy solid line shows the mean regression-determined vertical temperature sounding over Resolute, NWT, corresponding to the class (a) set of 1% cold extreme occurrences of $T_J(500)$ of Table 12. The thin solid line depicts the January mean Resolute sounding (1967-70). The dashed curves are identical to those of Figure 1.

relationships summarized in Tables 3 through 9. These relationships also apply across classes (a), (b), (c), and give rise to the inter-class differences found in Tables 11,..., 17.

The listings in Tables 11, 12, 13, 14 of the class (a) set of temperatures [or the (b)-class if class (a) is non-existent] at mandatory levels makes possible the presentation of the results in graphical form. Thus the expected (cold) temperature data corresponding to the 1% forcing temperature appropriate to Tables 11, 12, 13 and 14 have been reproduced as Figs. 1, 2, 3, 4. Here the heavy solid line depicts the cold or 1% "extreme"atmosphere in each case, whereas the thin solid line depicts the January (1967-70) mean sounding in each case. Note that the temperature deviations between "mean" and "extreme" in Figs. 1, 2, 3, 4 are indicative also of the class (a) to (c) deviations at the mandatory levels of Tables 11, 12, 13, 14.

b. Warm extreme atmospheric cases.

The procedure in these cases consists of an analysis of the nominal 10% extreme-warm July cases at Alert $\left([T_J = T(200)], [T_J = T(150)]\right)$ and at Thule $[T_J = T(100)]$ after these extremes have been subdivided into the nominal probability classes (a), (b), (c), similar to the procedure of Section 4(a).

In two of the three cases, the class (a) nominal probability $T_J < T_{.01}$ did not occur (see Tables 15 and 17), but an actual case count reveals that in either case there were 2 to 4 data-samples in class (b). These samples were taken as representative of the actual 1% extreme warm situation at the respective forcing levels, and also at the regression-dependent mandatory levels.

Level (mb)	Temperature-means (°C) in classes			Std. deviations (°C) relative to class-mean		
		(b) $T_{.01}-T_{.05}$	(c) $T_{.05}-T_{.10}$		σ_b	σ_c
1000		-25.20	-20.27		2.371	4.942
850		-24.83	-21.87		1.637	3.736
700		-29.73	-28.36		5.287	3.858
500		-42.90	-42.26		2.032	3.822
300*		-64.47	-62.60		.173	.341
200		-62.83	-61.60		.526	2.294
150		-63.73	-62.80		.911	2.889
100		-67.93	-67.38		1.496	2.581
70		-71.50	-70.29		2.921	3.026
Number in class		3	10			

TABLE 13. Temperature means at mandatory levels at Thule, Greenland (winter), corresponding to temperature extremes of $T_J(300)$ at the (b) 1-5% class, and (c) 5-10% class of probability. The population of class (a) was zero. The standard deviations σ_b and σ_c of observed temperatures in the (b) and (c) classes are shown in the right side of the table.

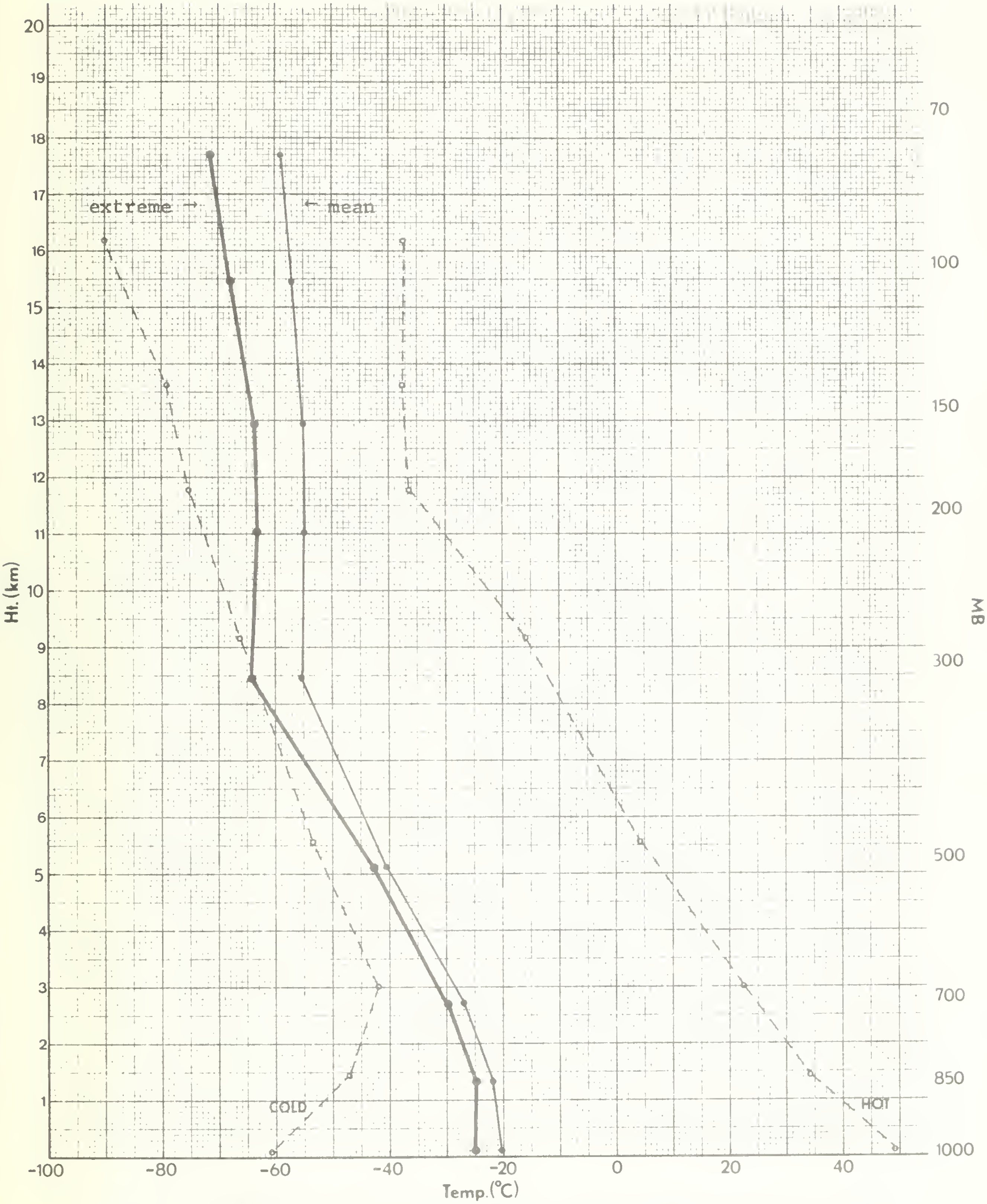

FIG. 3. The heavy solid line shows the mean regression-determined vertical temperature sounding over Thule, Greenland, corresponding to the 1% cold extreme set of forcing temperatures $T_J(300)$ of Table 13. The thin solid line depicts the January mean Thule sounding (1967-70). The dashed curves are identical to those of Figure 1.

Level (mb)	Temperature-means (°C) in classes			Std. deviations (°C) relative to class-mean		
	(a) $T_{.01}$	(b) $T_{.01}-T_{.05}$	(c) $T_{.05}-T_{.10}$	σ_a	σ_b	σ_c
1000	-9.87	-12.17	-14.51	4.302	3.849	8.440
850	-5.30	-15.31	-17.09	2.269	3.179	5.024
700	-12.67	-19.73	-23.68	0.806	1.608	4.870
500	-29.97	-34.99	-38.21	1.304	2.732	3.773
300	-57.03	-59.19	-60.40	0.695	1.041	2.115
200*	-74.70	-68.61	-64.80	.084	1.607	.480
150	-73.57	-66.81	-63.74	0.173	2.496	2.216
100	-73.43	-71.30	-68.29	0.733	2.413	2.339
70	-77.50	-75.46	-71.52	1.145	3.156	2.767
Number in class	3	7	8			

TABLE 14. Temperature means at mandatory levels at Thule (winter), corresponding to temperature extremes of $T_f(200)$ at the (a) 1% class, (b) 1-5% class and (c) 5-10% class of probability. The standard deviations σ_a, σ_b, σ_c of the observed temperatures within each class are shown in the right half of the table.

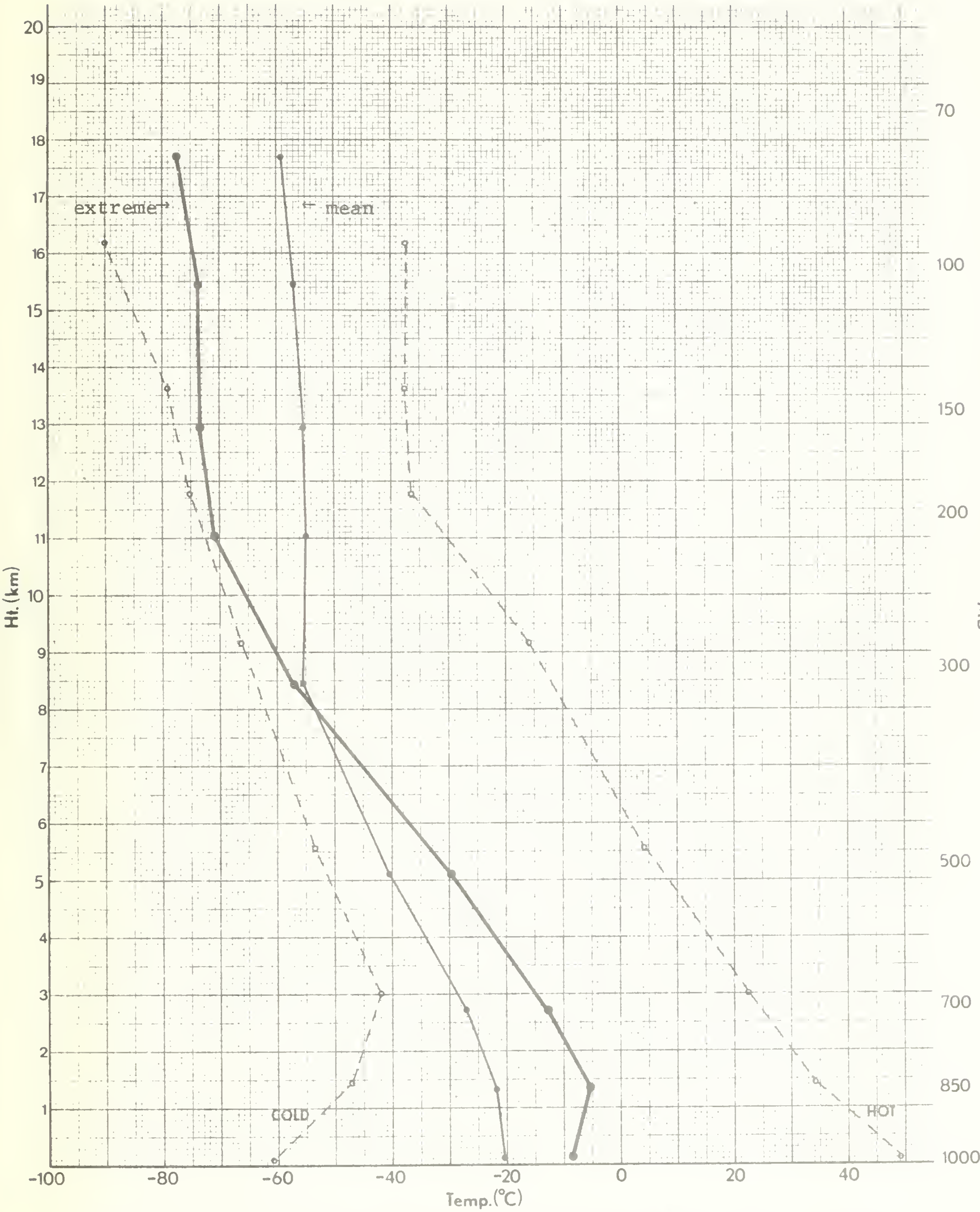

FIG. 4. The heavy solid line shows the mean regression-determined vertical temperature sounding over Thule, Greenland, corresponding to the 1% cold extreme occurrences of $T_J(200)$ of Table 14. The thin solid line depicts the January mean Thule sounding (1967-70). The dashed lines are identical to those of Figure 1.

Level (mb)	Temperature-means (°C) in classes			Std. deviations (°C) relative to class-mean		
		(b) $T_{.01}$-$T_{.05}$	(c) $T_{.05}$-$T_{.10}$		σ_b	σ_c
1000		0.05	1.48		.350	1.147
850		-6.65	-4.07		.650	2.086
700		-16.15	-13.09		.250	1.953
500		-31.30	-27.79		2.000	4.086
300		-40.05	-45.54		2.250	3.443
200*		-36.70	-38.31		.600	.330
150		-38.90	-39.67		1.000	.575
100		-40.95	-40.47		.350	.860
70		-40.25	-39.56		1.150	1.498
Number in class		2	16			

TABLE 15. Temperature means at mandatory levels at Alert (summer), corresponding to temperature extremes of $T_J(200)$ at the (b) 1-5% class and (c) 5-10% class of probability. The population of class (a) was zero. The standard deviations σ_b, σ_c of the observed temperatures within classes b and c are shown on the right side of the table.

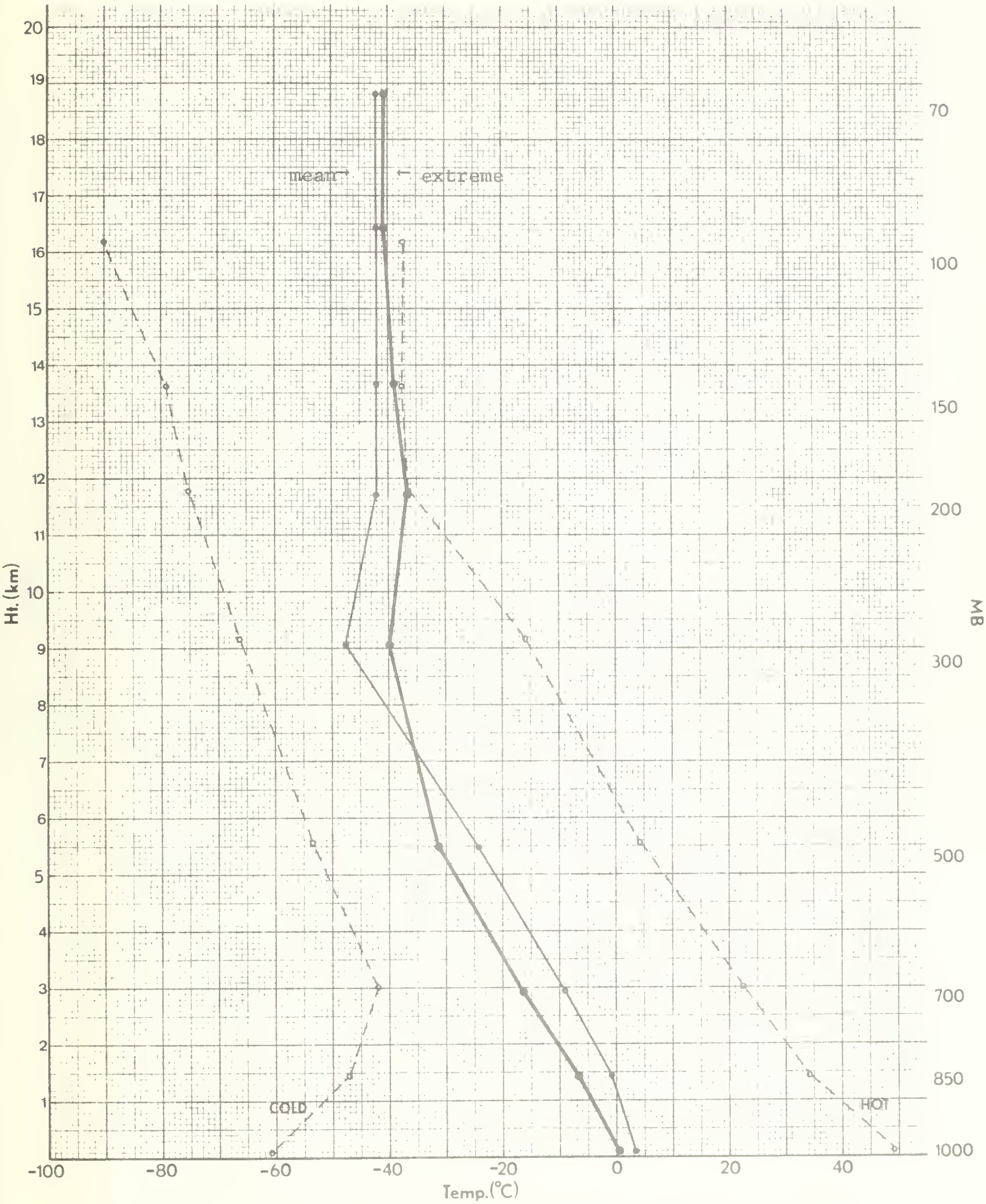

FIG. 5. The heavy solid line shows the mean regression-determined vertical temperature sounding over Alert, NWT, corresponding to the 1% warm extreme occurrences of $T_J(200)$ of Table 15. The thin solid line depicts the July mean Alert sounding (1967-70). The dashed curves are identical to those of Figure 1.

Level (mb)	Temperature-means (^{o}C) in classes			Std. deviations (^{o}C) relative to class-mean		
	(a) $T_{.01}$	(b) $T_{.01}-T_{.05}$	(c) $T_{.05}-T_{.10}$	σ_a	σ_b	σ_c
1000	0.00	2.68	2.29	.030	1.384	2.734
850	-4.65	-3.93	-3.21	2.650	2.318	2.067
700	-13.75	-12.48	-11.94	2.650	2.467	2.689
500	-26.25	-26.42	-26.48	3.050	1.117	2.317
300	-43.50	-49.23	-46.78	1.200	1.168	3.177
200	-38.10	-38.83	-39.09	.800	.619	.909
150*	-38.20	-38.80	-39.57	.300	.224	.226
100	-40.60	-40.33	-40.33	.000	.500	.469
70	-39.45	-39.93	-39.43	.349	.472	1.471
Number in class	2	6	14			

TABLE 16. Temperature means at mandatory levels at Alert (summer), corresponding to temperature extremes of $T_j(150)$ at the (a) 1% class, (b) 1-5% class and (c) 5-10% class of probability. The standard deviations σ_a, σ_b, σ_c of the observed temperatures within each class are shown in the right side of the table.

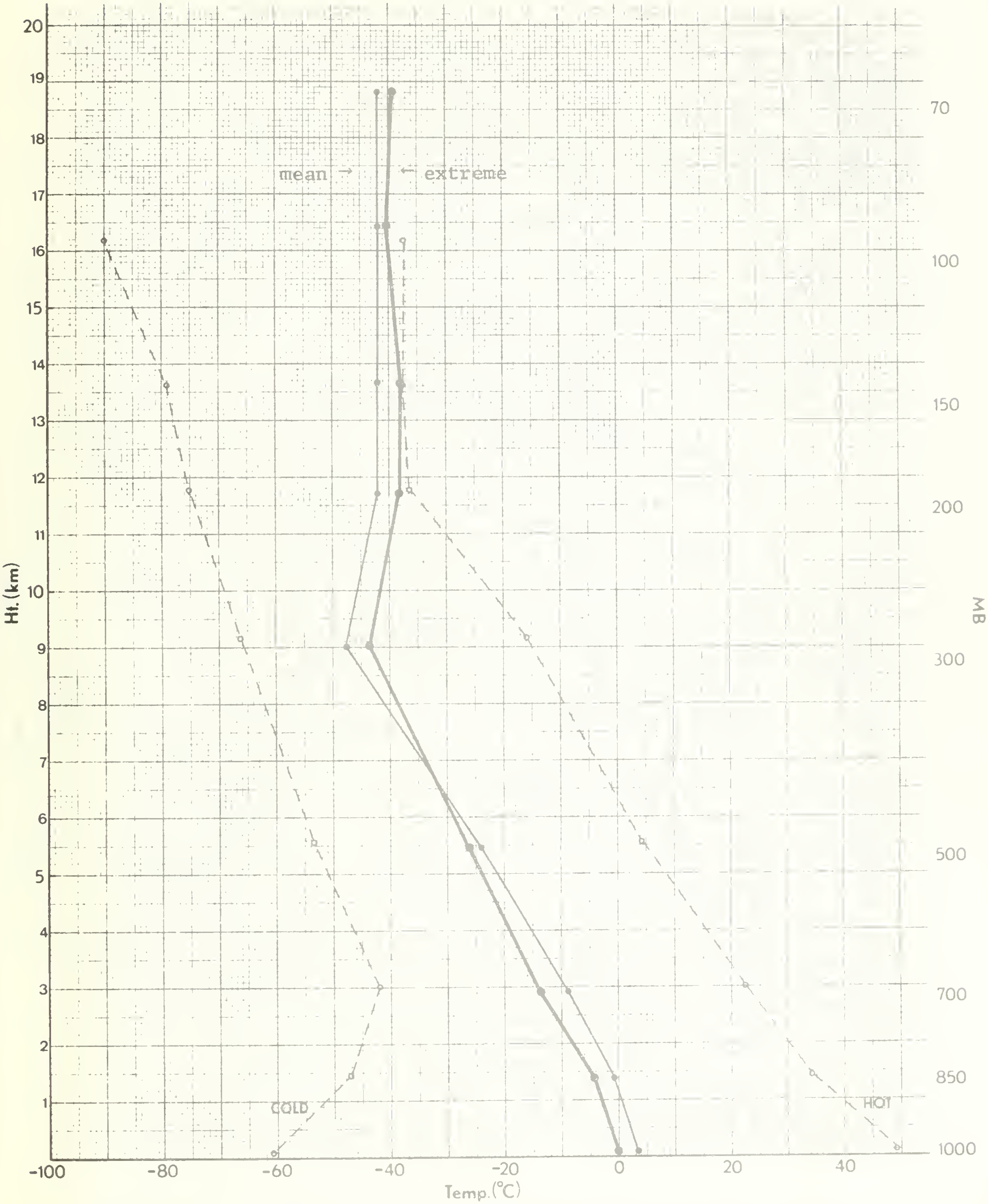

FIG. 6. The heavy solid line shows the mean regression-determined vertical temperature sounding over Alert, NWT, corresponding to the 1% warm extreme occurrences of $T_J(150)$ of Table 16. The thin solid line depicts the July mean Alert sounding (1967-70). The dashed curves are identical to those of Figure 1.

Level (mb)	Temperature-means (°C) in classes			Std. deviations (°C) relative to class-mean		
		(b) $T_{.01}-T_{.05}$	(c) $T_{.05}-T_{.10}$		σ_b	σ_c
1000		0.90	2.56		.100	2.821
850		-2.42	-3.72		3.544	1.943
700		-10.10	-11.43		3.412	3.283
500		-25.80	-26.69		4.513	2.884
300		-45.25	-46.81		2.296	2.772
200		-39.80	-39.85		1.404	1.211
150		-39.80	-40.86		1.931	.875
100*		-40.20	-41.16		.122	.105
70		-39.92	-40.82		1.803	.699
Number in class		4	14			

TABLE 17. Temperature means at mandatory levels at Thule (summer), corresponding to temperature extremes of $T_J(100)$ at the (b) 1-5% class and (c) 5-10% class of probability. The population of class (a) was zero. The standard deviations σ_b, σ_c of the observed temperatures within classes b and c are shown on the right side of the table.

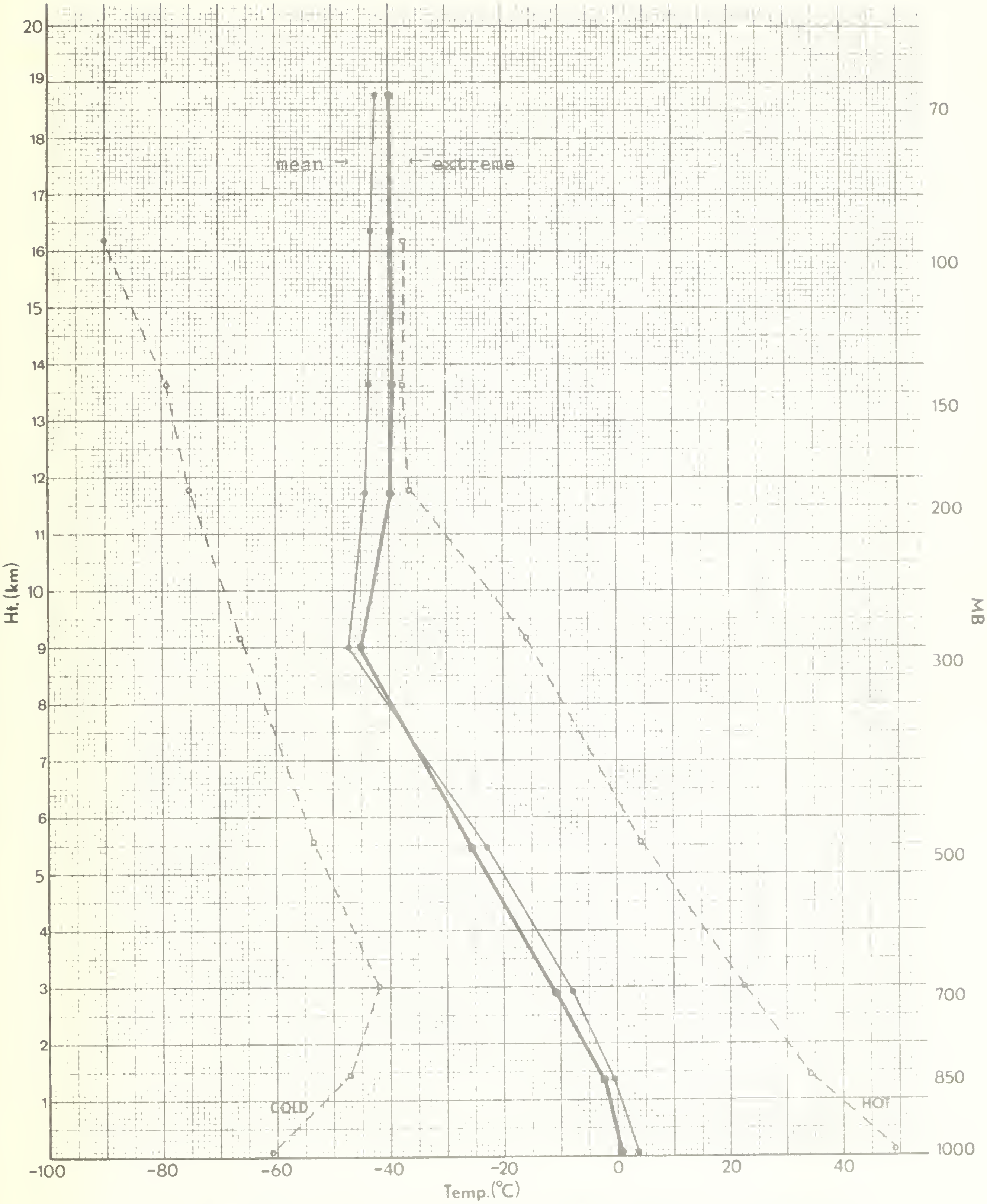

FIG. 7. The heavy solid line shows the mean regression-determined vertical temperature sounding over Thule, Greenland, corresponding to the 1% warm extreme occurrences of $T_J(100)$ of Table 17. The thin solid line depicts the July mean Thule sounding (1967-70). The dashed curves are identical to those of Figure 1.

Table 15 shows that class (b) warm atmosphere is warmer than the class (c) case in the layer 400 mb to 125 mb. Above 125 mb Fig. 5 shows that the deviation between the mean case and the listed extreme at any level is small. For example, the standard deviation σ_T at Alert at the 100 mb level is 1.26°C (and is smaller still at 70 mb). Below 400 mb, the temperature of the class (b) "extreme" atmosphere is consistently colder than that of the class (c) atmosphere. All of these features are also to be observed in Fig. 15, which gives a comparison of the 1% warm extreme atmosphere and the July mean (1967-70) over Alert.

A similar set of conclusions applies to the regression-dependent class (a) atmospheres over Alert based upon $T_J = T(150)$ as forcing variable. Here the results included in Table 16 indicate that the 500 mb temperature is a level of small interdiurnal variability, and is in fact the location of a crossover between the T(extreme) and T(mean) curves. Below 500 mb, the inferred temperature structure corresponding to a forcing temperature at the 1% warm extreme at p = 150 mb shows an atmosphere slightly colder than the July mean.

The summer extreme atmosphere at Thule, based upon a forcing-level warm extreme in $T_J = T(100)$ is listed in Table 17 and also graphically depicted in Fig. 7. The results summarized in column (b) of Table 17 show that the extreme warm case at 100 mb is associated with mandatory levels which are consistently warmer at all levels (other than the surface) than in the class (c) atmosphere.

5. Recommendations

For the best estimate of the forced-level extreme atmospheres considered here, one merely reads off the temperature of the left-hand extreme class of Tables 11,...,17. To be more realistic, one should allow a temperature-range of one standard-deviation $\pm \sigma_a$ about any class (a) extreme atmosphere. However, if a single temperature-estimate must be used at each level, the mean T_a-profile as a function of P is to be recommended. If class (a) is lacking, then the T_b-profile should be used.

The work presented here does not include certain other levels listed in the preliminary MIL STD 210-B atmosphere. The four years of climatological data for the years 1967-70 for these additional stations (see Table 2) is still undergoing data analysis. The results for OJMJAKON, Siberia, have been analyzed statistically and have been found to determine regression-generated mandatory-level temperatures much like those derived for the North American stations. It is expected that a study of the additional stations listed in Table 2 will yield fruitful results.

Acknowledgments. My thanks are due to Mr. Frank Markarian of China Lake, Calif., who made available copies of numerous valuable articles containing work on extreme atmospheres. My grateful appreciation is due to the Commander, Naval Weather Service, for his generous provision of the data in taped form, and to LCDR. Donald Frame, who expedited the data acquisition. The invaluable programming assistance of Mr. Russell Schwanz is acknowledged, as is also the excellent graphical presentations provided by Mr. Michael McDermet of the Meteorology Department, Naval Postgraduate School.

APPENDIX

It is not feasible due to the limited sample sizes to employ a t-test on the difference of means for the 1% class relative to the 1-5% class of Tables 11,...,17. However, a well-defined test of significance of class-means is afforded by the t-test applied to the difference of sample-means obtained by the results of the predictions of the means of the 10% extreme relative to the full sample predictions (e.g., the means contained in Tables 3, 4,...,9).

The t-test on the predictions of the full-sample and the 10% extreme involves at every mandatory level and station a test for significance of the pooled t-statistic after prediction,

$$t_p(N+n-11)=(\overline{T}_{full}-\overline{T}_{.10})\Big/\left[\frac{(N-9)\sigma_E^2+(n-2)\sigma_{E,.10}^2}{(N+n-11)}\right]^{1/2}\left[\frac{1}{N}+\frac{1}{n}\right]^{1/2} \qquad \text{(A-1)}$$

Here the $\overline{T}$'s are the sample temperature means at the mandatory levels based upon the identical prediction equations. These means are listed in columns 2 and 7 of Tables 3, 4,...,9. σ_E is the standard error of estimate listed in column 5, and $\sigma_{E,.10}$ is that of column 10, associated with the prediction of the extreme sample. The number of degrees of freedom associated with these σ_E-values are N-9 and n-2 respectively, where

N = full-sample size

n = nominal 10% extreme sample size

The pooled t_p-parameter is then tested using (N + n-11) degrees of freedom for t_p.

At the 70-mb level in Table 3, the t_p-statistic based upon the listed difference of the means is $t_p = 3.113$. Using the number of degrees of freedom $N + n-11 = 258$, the sample t_p-statistic is significant at a level of 99.9% probability.

In a similar manner all sets of differences of full-sample and "extreme" sample means obtained by the prediction method of this study prove to be significant at levels in excess of 99% confidence. This may be verified by applying all the statistics of Tables 3, 4, ...,9(a,b) to the test-statistic t_p of Eq. (A-1).

In this Appendix, t-test procedures for considering definitive tests of significant differences of means between full- and extreme-sample statistics at mandatory levels have been set forth. In defining the extreme-sample, the 10% probability extreme at the forcing level has been considered as the basis of the sample, including the resulting regression-statistics. Beyond the 10% probability level, reduced sample sizes preclude the usual t-test procedures. However, the stratifications based upon extreme sub-samples (a), (b), (c) of Tables 11, 12,...,17 give rise to regression-generated $\overline{T}_a$ (mean) which might well have been extrapolated from the 10% sub-sample results of Tables 3, 4,...,9, respectively.

REFERENCES

1. Cole, A. E., and P. F. Nee, 1965: Correlation of temperature, pressure and density, to 30 kilometers. Air Force Surveys in Geophysics, No. 160. Air Force Cambridge Research Laboratories, Bedford, Mass.

2. Crow, E. L., F. A. Davis, M. W. Maxfield, 1955: Statistics Manual, U.S. Naval Ordnance Test Station, China Lake, Calif., 288 pp.

3. Crutcher, H. L. and J. M. Meserve, 1966: Selected level heights temperatures and dewpoints for the Northern Hemisphere. Published by direction, Commander, Naval Weather Service Command as Navaer 50-1C-52, Washington, D. C.

4. Dixon, W. J., 1966: Biomedical Computer Programs. University of California Press, Los Angeles, Calif., 600 pp.

5. Goldie, N., J. G. Moore and E. E. Austin, 1958: Upper air temperature over the world. Geophysical Memoirs No. 101, British Meteorological Office, London.

6. Richard, O. E. and H. J. Snelling, 1971: Working paper for revision of MIL STD 210A "CLIMATIC EXTREMES FOR MILITARY EQUIPMENT (1 km to 30 km)." ETAC Report 5850. USAF Environmental Technical Applications Center, Washington, D. C.

DISTRIBUTION LIST

Aerothermodynamics Branch Naval Weapons Center ATTN: Mr. Frank Markarian China Lake, California 93555	5
Officer-in-Charge Environmental Prediction Research Facility Naval Postgraduate School Monterey, California 93940	2
Commanding Officer Naval Weather Service Command 3101 Building 200 Washington Navy Yard Washington, D. C. 20390	1
Commanding Officer Fleet Numerical Weather Central Monterey, California 93940	1
Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
Dean of Research Administration, Code 023 Naval Postgraduate School Monterey, California 93940	2
Department of Meteorology Reference Center Naval Postgraduate School Monterey, California 93940	1
Professor F. L. Martin Department of Meteorology, Code 51 Naval Postgraduate School Monterey, California 93940	10
Defense Documentation Center (DDC) Cameron Station Alexandria, Virginia 22314	12

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Naval Postgraduate School Monterey, California 93940	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

Development of Regional Extreme Model Atmospheres for Aerothermodynamic Calculations (I)

4. DESCRIPTIVE NOTES (Type of report and, inclusive dates)

Technical Report 20 October 1972

5. AUTHOR(S) (First name, middle initial, last name)

Frank L. Martin

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
20 October 1972	43	6

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
This research was partially supported by Naval Weapons Center, China Lake, Calif.	Naval Postgraduate School Monterey, California 93940

13. ABSTRACT

A group of stations in the North American Arctic region have been analyzed for statistical determination of temperatures at mandatory pressure levels p_i. For each station the temperature at a key level (called the forcing-level temperature) peculiar to the station has been forced in at the first step, and retained at each subsequent step in the development of the stepwise regression equations giving temperature at the mandatory levels. In general, eight-step prediction equations in terms of other temperatures in the vertical were found to give specification of $T(p_j)$, with percentage explained variance of close to 0.99. As a result of this definitive property, the best-estimate of the regional atmosphere which is conditionally dependent upon the existence of an extreme 1% probability of the forcing level temperature is obtained with a high degree of confidence.

DD FORM 1473 1 NOV 65 (PAGE 1)

S/N 0101-807-6811

Security Classification

A-31408

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Extreme temperatures						
Mandatory pressure levels						
Stepwise regression technique						
Temperature predictors						
Forcing-level temperature						
Verification of predictand temperature						
Regional key stations						