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INTERIM NOTE ON THE ACCURACY OF METEOROLOGICAL PRESSURE-HEIGHT FORECASTS

B. N. Charles

SANDIA SYSTEMATIC DECLASSIFICATION REVIEW	
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ABSTRACT

Verification summaries of pressure-height forecasts over USSR and other stations considered to be in difficult forecasting areas are presented. Results indicate that the root-mean-square error for 24-hour forecasts in winter are in excess of 200 feet. The rms errors of subjective forecasts are about 70 percent of those for the purely climatological forecasts, but larger errors in the latter are two to three times as frequent as in the subjective forecasts.

There is some indication that drastic curtailment of weather data during hostilities may not excessively degrade forecasting capabilities, as the available weather data over the area of concern during peace time is relatively sparse.

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INTRODUCTION

SC-1959 (TR)[1] estimated the anticipated root-mean-square error inherent in subjective* pressure-height predictions. Forecasters involved were assumed to be representative of the 'upper ten percent of skill' available to the weather services. A somewhat conjectural analysis was necessary, simply because available verification data were neither adequate nor completely pertinent.

One conclusion of SC-1959 (TR) was that selected forecasters can make 12-hour forecasts having a root-mean-square error of less than 150 feet for the most difficult forecast areas during hostilities. It was also pointed out that forecasts are less accurate during winter, because of the greater inherent weather variability in that season.

Since publication of SC-1959 (TR), additional forecast verification data have become available, and the 'upper ten percent of skill' concept has been de-emphasized in military weather operations. One aim of the USAF Air Weather Service, for example, is to achieve uniformity of forecast quality in spite of the subjective uncertainties which remain after critical selection of personnel and relatively excessive personnel turnover. The current means of minimizing these problems includes the use of a 'team system' in Weather Centrals. Under this system, the objective and subjective opinions of team members are reconciled to produce the most acceptable prognosis. Accuracy of forecasts is therefore not necessarily dependent upon any specific individual and the indications are that teams can be adjusted to provide uniform quality of forecasts. There is also reason to believe that forecast capabilities can be more realistically evaluated when participating forecasters are anonymous.

The figure of 150 feet has been widely adopted as a universal measure of forecasting capability. It appears that the significance of the prognostic period associated with this capability is too frequently overlooked. As customarily used by weather forecasters, the prognostic period begins with the valid time of the weather charts used for the prognosis, <u>not the time of issue of the forecast</u>. The lag between map time and issue time of the forecast is from four to six hours, usually closer to the latter figure. For the 12-hour forecast, this implies only six to eight hours between time of receipt by a combat unit and verification time over the target. If further account is taken of the appreciable time consumed by crew briefing, emplaning, and final technical preparations for take-off, it becomes apparent that a 12-hour forecast is applicable to tactical missions, but not to strategic missions. For strategic aircraft missions, forecasting capabilities should be based upon prognostic periods at least 24 hours in duration.

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*Denotes forecasts prepared for specific missions, based upon available current weather map analyses.

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The intent of this paper is to present newly available data in an interim assessment of the usefulness of the forecasting capability given in SC-1959 (TR). A comprehensive Forecast Capabilities Program has been undertaken by the USAF Air Weather Service, and will ultimately provide more adequately substantiated results.

SAC VERIFICATION PROGRAM

Offutt Weather Central (previously known as Global Weather Central) provides weather service to Hq, Strategic Air Command. Weather data for SAC missions would be prepared by this unit, at least in the initial stages of any conflict. Twenty-four hour forecasts of the pressure at 7000 feet above the locations in TABLE I were verified during the 12-month period between January 1951 and February 1952. The choice of sites was based upon qualitative considerations designed to select areas representative of possible targets and, for comparison, difficult forecast areas.

TABLE I

Forecast Sites

Potential Targets		Difficult Forecast Areas	
Moscow	56°N, 37°E	Lerwick	60°N, 01°W
Sverdlovsk	57°N, 61°E	Misawa	41°N, 141°E
Astrakhan	46°N, 48°E	Annette Is	55°N, 132°E
Irkutsk	52°N, 105°E		

The forecasting difficulty attributable to the non-USSR stations was presumed to arise from marked weather variability at Lerwick and Annette, and paucity of data west of Misawa. (Inadequate data to the west are also a factor at Lerwick and Annette.) When stations listed in TABLE I were selected, little quantitative data were available dealing with pressure variability outside of the U. S. Comprehensive studies of pressure variability on a hemispheric scale have since been published by Klein[2] and Schumann[3].

TABLE II lists standard deviations of the daily pressure and the interdiurnal pressure change* for the stations involved.

*The difference between the pressures at any time, and 24 hours later.

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TABLE II

Standard Deviation (in Millibars) of
Daily Pressure and Interdiurnal Pressure Change

	Daily Pressure			Interdiurnal Pressure Change
	Sea Level		700 mb	Sea Level
Station	Winter[2]	January[3]	Annual[2]	Winter[2]
Moscow	13.5	13.7	8.5	9
Sverdlovsk	15.0	14.3	8.5	8
Astrakhan	10.0	9.4	6.0	6.5
Irkutsk	11.0	9.3	6.5	(7.0)*
All	12.5	11.9	7.5	7.7
Lerwick	16.5	17.5	9.5	10.5
Misawa	7.0	7.4	6.5	(6.5)*
Annette Is	13.0	12.9	8.0	10.0
All	12.7	13.3	8.1	9.2

*Estimated from available data.

Note: At sea level, 1 mb is about 27 feet.
At 700-mb level, 1 mb is about 37 feet.

On the basis of the above figures, the non-USSR group is not obviously more difficult to forecast for than is the USSR group, unless perhaps the mean interdiurnal pressure changes are used as criteria. When the inaccuracies inherent in the limited data available for hemispheric studies are considered, however, the significance of this measure is questionable. In the following discussion, forecast capability will be considered for the seven stations as a group.

TABLE III shows the cumulative proportion of forecasts which were included in designated error ranges. Figure 1 is the ogive, or cumulative frequency curve, from the last column of TABLE III.

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TABLE III

Summary of 24-hr 7000-ft Pressure Forecast Verification, Offutt Weather Control, January 19, 1951 to February 13, 1952.

Percent of Forecasts not Exceeding the Designated Errors in Millibars*

Station**	MOS	SVER	AST	IRK	LER	MIS	ANN	All
No. of forecasts	405	409	344	384	549	478	543	3112
Percentage of all forecasts:								
Error = 0 mb	8.9	10.0	11.0	12.6	8.4	13.1	10.1	10.6
Error ≤ 2 mb	43.9	45.5	49.4	46.3	40.9	47.9	42.5	44.9
Error ≤ 4 mb	68.4	70.7	76.4	69.5	65.6	74.2	65.0	69.5
Error ≤ 6 mb	84.2	85.1	88.6	86.9	81.8	88.9	78.3	84.4
Error ≤ 8 mb	90.9	90.7	95.1	92.6	90.6	93.9	89.3	91.7
Error ≤ 10 mb	96.0	95.5	98.8	97.0	94.0	96.9	93.6	95.8
Error ≤ 12 mb	97.0	97.4	99.5	97.6	97.4	98.8	95.8	97.6
Error ≤ 14 mb	98.7	98.3	99.8	98.6	99.0	99.6	98.2	98.9
Error ≤ 16 mb	99.0	98.8	99.8	98.9	99.2	99.6	99.1	99.3
Error ≤ 18 mb	99.0	99.5	100.0	100.0	99.8	99.8	99.5	99.7
Mean error (mb)	3.7	3.7	3.2	3.5	4.0	3.3	4.1	3.7
Standard deviation (mb)	5.0	5.1	4.1	4.7	5.3	4.4	5.5	4.9

* At the 7000-ft level, 1 mb is about 34 feet

** MOS = Moscow, USSR
SVER = Sverdlovsk, USSR
AST = Astrakhan, USSR
IRK = Irkutsk, USSR
LER = Lerwick, England
MIS = Misawa, Japan
ANN = Annette Island, Alaska

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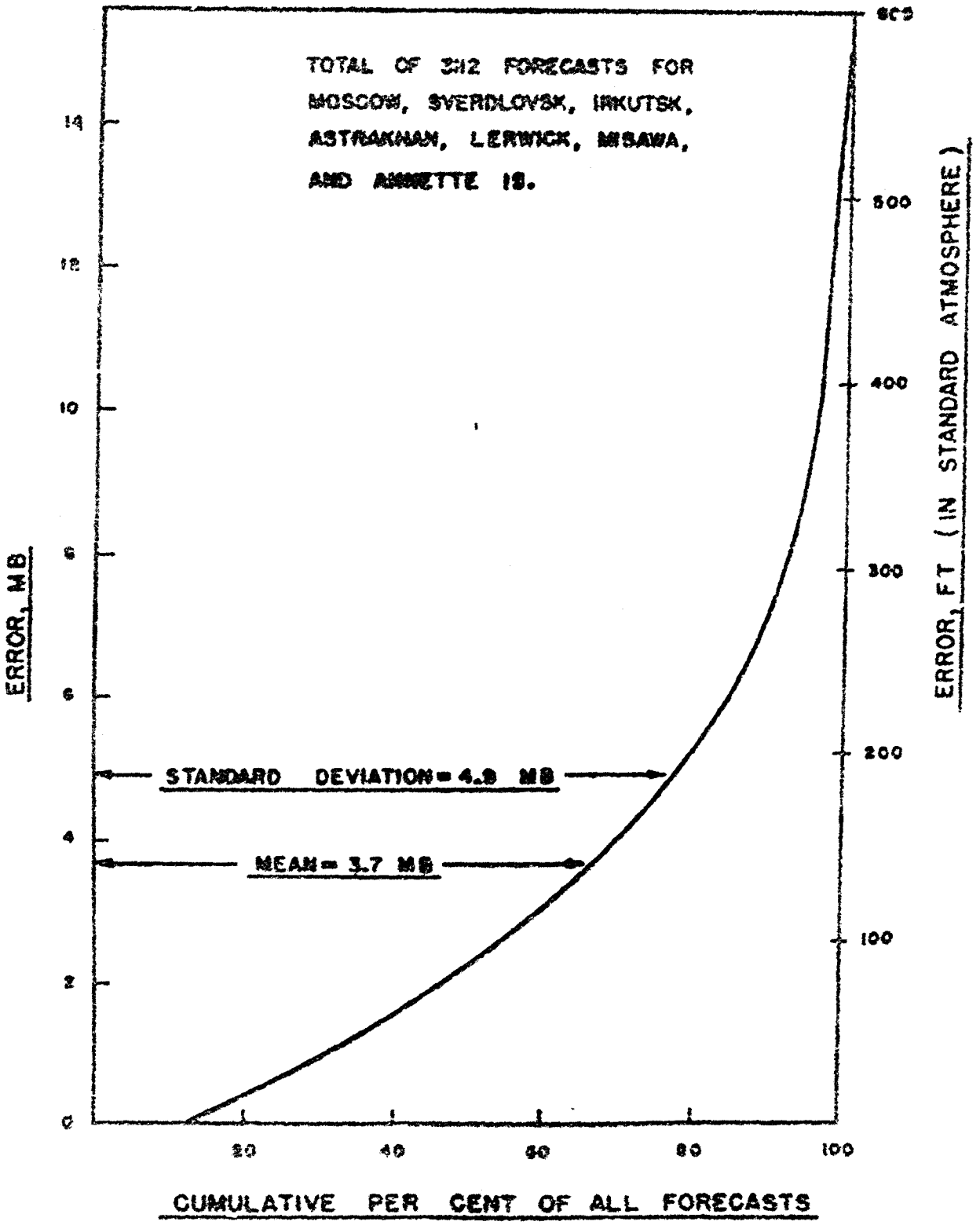

FIG. 1 SUMMARY OF 24-HR 7000-FT PRESSURE FORECAST VERIFICATION PROGRAM AT OFFUTT WEATHER CENTRAL, 19 JAN 51–13 FEB 52

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Several aspects of TABLE III and Fig. 1 are noteworthy:

1. Error distributions for the individual stations are reasonably similar.

2. The grouped error distribution is excessively peaked, compared to the normal curve, since an error range of one standard deviation includes 77 percent of the total distribution.

3. Verifications were based upon heights reported by the stations considered, as received over international communications networks. Two forecasts were prepared daily for each station from January 19, 1951 to February 13, 1952 (i.e., a total of 782 forecasts were attempted for each station). The number of forecasts verified for the USSR stations varied from 344 to 409. Thus, the availability of daily reports from the USSR stations was between 44 and 53 percent, and the average availability was 49 percent. This means that about half of the forecasts were prepared when no report was available from the station concerned, and the current height value employed was determined from the weather map analysis. The results therefore reflect to some extent the validity of the map analysis when some data are missing. While this does not indicate the forecasting difficulties arising from low data availability in a wide area, it does narrow the anticipated gap between data availabilities during peace and war.

AWS FORECAST CAPABILITIES PROGRAM

On June 1, 1952, the USAF Air Weather Service undertook a verification program of unprecedented scope. More than 200 military weather detachments started to prepare and verify surface and upper-air forecasts for designated stations. Included in these are pressure-height forecasts for two different levels, each valid at a different time. The prognostic period varies from six to 72 hours, and forecasts are being prepared for about 38 different locations. The over-all program also includes forecasts of wind and temperature aloft, and conventional surface weather elements. It is planned to maintain this program indefinitely, in order to monitor operational capabilities continuously.

Unfortunately AWS has been unable to obtain the statistical services support necessary for summarization of the data available to date. In the interest of expediting the program, Sandia Corporation has undertaken to transfer the available data to punch cards for ultimate evaluation by USAF agencies. It is anticipated that the results of the first year of the program will be available early in 1954. In the meantime, winter data for a few selected stations have been summarized manually. It can be tentatively assumed that minimum forecasting accuracy exists during winter over the area of interest. TABLE IV lists the available statistics for the 700-millibar level (about 9800 feet).

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TABLE IV

Summary of 700-mb 24-Hour Subjective Forecast Verifications, Selected Stations, October 1952 Through January 1953, AWS Forecast Capabilities Program

Station*	A	B	C	All
Number of forecasts	114	122	96	332
Number of forecasts with error in range (ft)				
0 - 99	42	76	32	150
100 - 199	32	22	24	78
200 - 299	16	16	26	58
300 - 399	10	2	8	20
400 - 499	5	2	4	11
500 - 599	6	3	--	9
600 - 699	2	1	2	5
700 - 799	1	--	--	1
800 - 899	--	--	--	--
Mean error (ft)	184	114	179	157
RMS error (ft)	246	166	222	216

*Station Code	Standard Deviation of Daily Sea-Level Pressure in Winter[3]
A: International Falls, Minn.	10 mb (about 270 ft)
B: Thule, Greenland	11.3 mb (about 305 ft)
C: Caribou, Maine	10.9 mb (about 295 ft)

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TABLE V shows the distribution of errors for the same period, level, and stations as TABLE IV, which were characteristic of the climatological forecast. That is, the appropriate monthly normals at 700 mb for each station were taken from normal weather charts[4], and daily errors were computed from the absolute differences between the climatological and actual daily heights.

TABLE V

Summary of Climatological 24-Hour Forecast Errors at 700 mb, Same Stations and Period as in TABLE IV

Station*	A	B	C	All
Number of forecasts	114	122	96	332
Number of errors in range (ft)				
0 - 99	34	31	20	85
100 - 199	35	26	19	80
200 - 299	20	23	22	65
300 - 399	15	16	10	41
400 - 499	5	9	8	22
500 - 599	4	10	11	2[illegible]
600 - 699	1	6	3	10
700 - 799	--	--	3	3
800 - 899	--	1	--	1
Mean error (ft)	187	247	278	237
RMS error (ft)	235	312	339	297

*See TABLE IV for station code.

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TABLE VI is a listing of statistics from TABLES IV and V, for convenient comparison.

TABLE VI

Comparative Summary of Errors in Subjective and Climatological Forecasts; Level, Prognostic Period, and Stations as in Table IV

Number of errors in range (ft)	Subjective	Climatological	Subjective Climatological
0 - 199	228	165	1.4
200 - 399	78	106	0.7
400 - 599	20	47	0.4
600 - 799	6	13	0.5
800 - 999	--	1	0
RMS error (ft)	218	297	0.74

The most important figure in the last column of TABLE VI is the ratio of rms errors. An unpublished report[5] of the AWS estimated the ratio of variances (the square of the root-mean-square) of the subjective and climatological forecasts to be about 0.40 on an annual basis, for the 24-hour forecast. The ratio of variances from TABLE VI is 0.55, but the months involved are the worst in the year, and the areas involved are characterized by inadequate observational networks.

The standard deviation of the differences of the daily mean error for all stations can be computed from the relation:

$$\sigma_d = \left[\frac{\sigma_s^2 + \sigma_c^2}{N - 1} \right]^{1/2}$$

where σ_s and σ_c are the standard deviations of the subjective and climatological daily forecast errors for all stations, respectively, and N = 332 (see TABLES IV and V). If the difference of the mean errors of the subjective and climatological forecasts is significant, it should be $3\sigma_d$ or greater, (assuming a normal distribution of the daily error differences). For the data presented in TABLES IV and V, that difference is $4\sigma_d$, indicating that in less than seven samples out of 100,000 could the difference be due to chance.

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EXTREME ERRORS

The larger errors committed in both verification programs are listed in TABLE VII.

TABLE VII

Extreme Errors

	SAC		AWS Subjective		AWS Climatological	
No. of Forecasts	3112		332		332	
Errors in range (ft)	No.	%	No.	%	No.	%
500 - 599	51	1.6	9	2.7	25	7.5
600 - 699	17	0.5	[illegible]	1.5	10	3.0
700 - 799	8	0.3	1	0.3	3	0.9
800 - 899	3	0.1	0	0	1	0.3
900 - 999	0	0	0	0	0	0
1000 - 1099	0	0	0	0	0	0
1100 - 1199	1	0.03	0	0	0	0

CONCLUSIONS

The widely accepted 150-ft maximum rms error of pressure-height prediction is a reasonably accurate measure of accuracy for 12-hour forecasts. For 24-hour forecasts however, the maximum rms error is about 220 feet, and applies to difficult forecast locations during the worst time of year. It is entirely possible that the 24-hour forecast rms error on an annual basis for the entire Northern Hemisphere will approximate 150 feet.

Ultimate results of the AWS Forecast Capabilities Program will allow more accurate evaluation of forecast capabilities, with greater applicability to specific areas or targets.

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