Recent Developments in Automated Max/Min Temperature Forecasting

WILLIAM H. KLEIN, FRANK LEWIS AND GORDON A. HAMMONS

Techniques Development Laboratory, NOAA, Silver Spring, Md.

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ABSTRACT

Recent changes in the National Weather Service's automated system of forecasting maximum and minimum surface temperatures are described and illustrated. Modifications include use of the primitive equation model, later surface reports, computer-analyzed isotherms, and climatologically-determined forecast limits. Verification figures are presented to show the improvement of the new system over the old and to justify the replacement of centralized subjective temperature forecasts by completely objective ones.

1. Introduction

The basic system for automated prediction of maximum and minimum surface temperatures described by Klein and Lewis (1970) continues in operation at the U. S. National Weather Service in Suitland, Md. However, several changes have been implemented during the past year to achieve improved performance; these will be described briefly in this paper.

2. Modified forecast system

The modifications to the forecast system discussed in Section 7 of the Klein-Lewis (1970) paper have been put into operation. These involve:

1) Application of the regression equations to height and thickness forecasts made by the primitive equation (PE) model of Shuman and Hovermale (1968) rather than the barotropic-Reed model.

2) Use of maximum and minimum temperatures from synoptic reports 6 hr later than previously utilized as surface input into the forecast equations.

TABLE 1. System for preparation of operational PE maximum and minimum temperature forecasts for 12–60 hr in advance.

Forecast	Output	Height/thickness input	Surface temperature input
		From the 1200 GMT PE run	
12-hr*	Max.	Observed 12Z today	18Z (12Z) min, 12Z (06Z) max
24-hr	Min.	12-hr PE prog	18Z (12Z) min, 12-hr max prog
36-hr	Max.	24-hr PE prog	24-hr min prog, 12-hr max prog
48-hr	Min.	36-hr PE prog	24-hr min prog, 36-hr max prog
60-hr	Max.	48-hr PE prog	48-hr min prog, 36-hr max prog
		From the 0000 GMT PE run	
12-hr*	Min.	Observed 00Z today	00Z (06Z) min, 06Z (00Z) max
24-hr	Max.	12-hr PE prog	12-hr min prog, 06Z (00Z) max
36-hr	Min.	24-hr PE prog	12-hr min prog, 24-hr max prog
48-hr	Max.	36-hr PE prog	36-hr min prog, 24-hr max prog
60-hr	Min.	48-hr PE prog	36-hr min prog, 48-hr max prog

* Not transmitted
Values in parentheses are used if desired reports are missing.

3) Elimination of statistical conversion from 700–500 mb to obtain prognostic heights and thicknesses.

The revised forecast system is illustrated in Table 1. The 1200 (all times GMT) run now uses the minimum temperature for today reported at 1800 as surface temperature input, and the 0000 run utilizes the maximum temperature for yesterday reported at 0600 as surface input. These values are generally more representative of the actual maximum and minimum, especially on the west coast, than the 1200 and 0000 reports used previously. Another advantage of the new system is that, if any of the desired temperature reports is missing, the adjacent observation (made 6 hr earlier or later) is utilized, as indicated in parentheses in Table 1.

3. Computer-analyzed isotherms

Fig. 1 illustrates the latest form of facsimile display of the maximum and minimum temperature forecasts transmitted from Suitland twice daily. The isotherms shown are generated by computer at 10F intervals by applying the successive approximation technique of objective analysis (Cressman, 1959) on a 30 by 22 grid of points with mesh length of 169 km at 45N (Fig. 2). Notice the additional heavier contour at 32F in Fig. 1; the 90F contour is drawn heavy in warm seasons. In addition, the individual forecast station temperatures are plotted by computer. If there are any inconsistencies between these temperatures and the isotherms, the station temperatures should take precedence because a five-point smoother has been used in drawing the isotherms.

4. Missing data

When required surface temperature reports are missing, the system replaces them with the best available substitutes: either earlier reports that are still

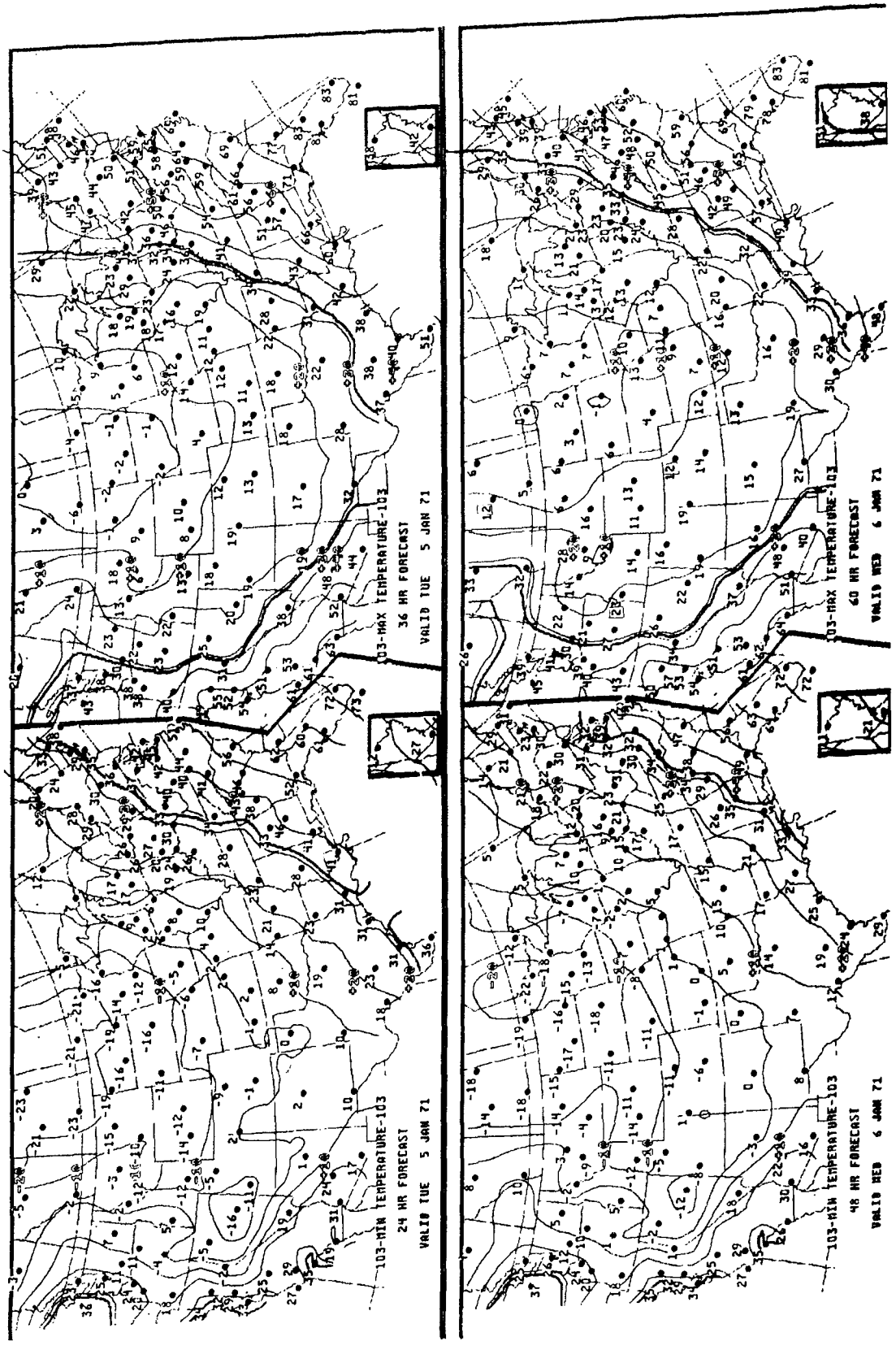

FIG. 1. Operational facsimile transmission of automated maximum and minimum temperature (°F) forecasts for 24–60 hr in advance prepared from 1200 GMT upper air data and 1800 GMT surface data on Monday, 4 January 1971. Inset in lower right corner is northern New England.

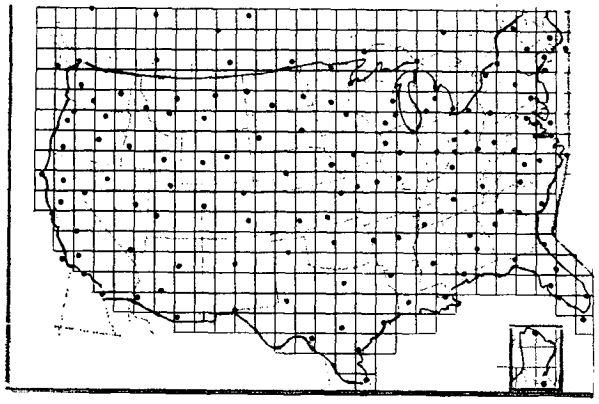

FIG. 2. Location of forecast stations and grid points used in objective analysis of predicted isotherms transmitted over facsimile. Inset in lower right corner is northern New England.

valid, or appropriate forecasts made earlier, or daily normals. Since the absence of surface information may diminish the quality of the forecasts, a change was made in the teletypewriter message to identify missing reports, thus alerting recipients to possible shortcomings in the products.

Fig. 3 is a recently transmitted message which illustrates the tagging procedure. The X following station BNO's call letters indicates that its latest maximum temperature was not available to the system; similarly, an N after a station's call letters indicates its minimum temperature was missing. A letter B following a station's call letters, such as at station PDX, indicates that both maximum and minimum reports were missing for that station.

Occasionally a forecast run is missed due to computer trouble. To maintain continuity, the 36-hr forecast made 12 hr earlier is transmitted in place of the missing 24-hr prediction, the earlier 48-hr forecast replaces the missing 36-hr one, and similarly for other time periods. In such a case the word "BACKUP" is added to the title of the forecast bulletin.

5. Extreme temperature forecasts

Monitoring of the automated forecasts has indicated that occasionally they are outside the range of observed extremes. We therefore designed a procedure to constrain the forecasts to within an acceptable range. Briefly defined, this range is a time-smoothed interval within which approximately 98% of the observations have fallen in an 18-year period. The range is computed separately for each station and each day, and separately for the maximum and minimum temperatures. A forecast which would be outside this range is changed to the limiting value of the acceptable range. Application of this procedure to extreme forecasts made during May and June 1970 would have reduced their average errors by 1–2F.

This change in the operational system was implemented on 16 March 1971. We are now listing on the teletypewriter message those stations whose temperature forecasts have been altered by the truncation

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FMUS1 KWBC 011200

     MAX MIN TEMP FCST
HRS  24 36 48 60  HRS   24 36 48 60  HRS   24 36 48 60
STA  MN MX MN MX  STA   MN MX MN MX  STA   MN MX MN MX

GEG  31 46 23 39  PDT   34 49 28 43  YKM   31 54 26 49
PDX B 39 49 35 46 SEA   39 50 34 45  TTI   38 46 35 43
BNO X 21 44 14 35 MFR   28 46 25 43  SLE   39 49 33 46

SAC B 35 54 33 54 SFO   39 57 37 57  WMC   19 52 13 40
RNO  19 57 14 48  RBL   38 62 37 57  EKA   39 52 37 50
BFL  37 55 35 52  FAT   37 51 34 48  SMX   39 69 37 66

LAS  41 68 37 61  SAN   48 69 46 68  LAX   51 69 49 67

GGW -02 19-05 13  BIL   28 37 07 28  GTF X 21 33 04 19
HLN  17 37 04 23  MSO   26 41 14 31

PIH  25 42 20 30  BOI   29 46 22 41  SLC   26 48 22 39
MLF  24 53 19 42  ELY   19 48 12 36

ABQ  29 57 28 53  INW   28 56 24 53  TUS   41 73 37 69
PHX  45 73 42 70  YUM   48 77 47 74

CPR  17 36 06 24  LND   20 40 08 26  DEN   18 48 14 35
PUB  18 49 18 37  GJT   32 53 31 46

MAF  30 64 35 63  ELP   34 64 35 63  SAT   46 61 48 72
DRT  42 59 48 69  HOU   43 60 48 70  CRP   52 66 54 73
BRO  55 68 56 75

OKC  24 51 29 51  AMA   23 52 26 49  FTW   32 55 37 62

DSM  04 23 15 27  OMA X 05 32 11 31  LBF   12 41 10 31
MKC  13 39 19 39  TOP   17 41 20 40  ICT   20 49 24 46
DDC  20 49 18 42

INL X-27 01-19 06  DLH  -20 05-10 11  STC X-14 12-08 16
FAR  -12 08-07 11  BIS  -07 14-08 12  ISN  -01 17-07 11
MSP  -10 14-03 19  HON X-05 19-04 16  RAP   13 41 07 22

STL  10 36 16 46  CBI   11 36 17 44

LOU X 06 31 18 51  TYS   16 34 22 46  BNA   15 39 25 58
MEM  23 41 31 59  LIT   24 43 32 61  FSM   23 49 31 57

JAN  31 52 38 65  SHV   34 54 42 66  TLH   31 54 35 64
MSY  40 57 46 69  LCH   39 59 45 65

SSM -14 03-06 15  DET  -01 11 06 26  FNT X-09 05 02 18
GRR B-06 12 07 24  MKE X-09 15 06 26  GRB X-15 07-09 20
MSN X-13 12 05 24  IND  -01 21 10 39  CHI  -06 14 06 29
PIA  -01 21 10 35  MLI B-04 20 08 28

AGS  20 42 26 58  AHN   16 39 24 45  ATL   17 36 26 47
BHM  20 44 32 56  MGM   27 47 36 59  MOB   34 54 41 66

SYR  -06 05-04 15  BUF  -06 07 02 24  PIT  -05 10 04 33
CLE  -05 10 03 30  CMH X-02 16 12 37  DAY X-08 17 14 37
CVG  04 21 15 43

JAX  34 56 39 63  ORL   49 68 52 73  TPA   44 66 48 74
MIA  58 73 62 73  EYW   65 74 67 76

CHS  22 46 29 54  CLT   13 35 21 42  HAT   22 35 25 47
RDU  08 32 14 43  GSO   07 32 15 41

SBY  06 22 09 34  DCA   10 21 13 31  CRW   03 28 13 44
HTS  04 24 15 47  ORF X 14 26 18 40  RIC   07 27 12 38
ROA  08 28 13 40

HFD -09 10-06 16  ALB  -15 08-13 12  NYC   07 18 11 24
PHL  09 20 08 26  IPT  -03 16-03 22

CAR -23-06-23-02  PWM  -12 09-14 13  BTV  -15 04-15 08
ACK B 09 18 09 22  BOS  -08 12-02 18

MISSING REPORTS REPLACED BY
12 HR FORECASTS
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FIG. 3. Operational teletype transmission of automated maximum and minimum temperature (°F) forecasts for 24–60 hr in advance prepared on 1 January 1971, from 1200 GMT upper air data and 1800 GMT surface data.

procedure described above. Of 300 such forecasts changed between 16 March and 30 June, 1971, 82% were improved and only 17% became worse; the average amount of improvement was 1.0F.

6. Verification

Automated temperature forecasts were first prepared by the system outlined in Table 1 on an experimental basis in early 1970. Their relative accuracy is shown in Table 2, which gives mean absolute errors (°F) for 34 cases during the month of February 1970. This table was prepared from verification figures supplied by the Analysis and Forecast Division (A & FD) of the National Meteorological Center (NMC) for 60 cities covering all parts of the conterminous United States.

Although based on only a limited sample, the results were encouraging. Errors produced by the new system (marked PE) were smaller than those produced by the previous system (marked Barotropic) for each forecast period from 24–60 hr in advance and for both maximum and minimum forecasts. The combined results (averages of max and min) show that the advantage of the PE over the barotropic increased with forecast projection from 0.7F at 24 hr to 1.8F at 48 hr.

The last line of Table 2 gives the average errors obtained by experienced forecasters of A&FD, using the barotropic temperature forecasts as guidance. Although the A&FD forecasts were 1–2F better than the barotropic ones, they were not significantly different from the PE forecasts. In fact, the only difference between PE and A&FD greater than 0.5F anywhere in Table 2 was for the 24-hr minimum. Thus, the new PE temperature forecasts appeared to be fully competitive with subjective (centralized) forecasts.

Results similar to those shown in Table 2 were obtained during the month of March 1970. A decision was therefore made by the National Weather Service to replace maximum and minimum temperature forecasts prepared subjectively at NMC by completely objective ones. Since 1 April 1970 the objective forecasts have been transmitted twice daily over facsimile (NAFAX 43/103) at 0846 and 2048 GMT. The forecasts are relayed from the CDC 6600 to the IBM 360, where they are automatically put on the facsimile circuit by means of special equipment called the Digital Facsimile Interface. This procedure permits a more efficient utilization of meteorological manpower within NMC and facilitates local modification of the automated guidance at forecast offices throughout the country.

TABLE 2. Mean absolute errors (°F) of maximum and minimum temperature forecasts at 60 cities in the United States for 24–60 hr projections during February 1970 (34 cases) for the current primitive equation (PE) model, the earlier barotropic–Reed model, and subjective forecasts by the Analysis and Forecast Division.

	24-hr	36-hr	48-hr	60-hr
	Minimum			
PE	5.9	6.3	6.9	7.2
Barotropic	6.1	6.9	8.0	8.2
A&FD	4.8	6.3	6.5	7.5
	Maximum			
PE	5.1	5.8	6.1	7.2
Barotropic	6.0	7.6	8.6	9.5
A&FD	5.0	5.7	6.5	7.2
	Combined			
PE	5.4	6.0	6.5	7.2
Barotropic	6.1	7.3	8.3	8.9
A&FD	4.9	6.0	6.5	7.3

TABLE 3. Mean absolute errors (°F) of computer temperature forecasts for 12–60 hr in advance produced by the current system and by the previous model. The scores are averaged over 131 cities in the United States for the fall season of 1970, the winter of 1970–71, and the spring season of 1971.

Forecast projection	Fall		Winter		Spring	
	New	Old	New	Old	New	Old
			Minimum			
12-hr	4.1	4.2	4.6	5.1	3.9	4.1
24-hr	4.3	4.5	4.9	5.5	4.1	4.3
36-hr	4.7	4.9	5.3	6.0	4.4	4.7
48-hr	5.0	5.2	5.7	6.6	4.7	5.1
60-hr	5.2	5.4	6.0	7.3	4.8	5.4
			Maximum			
12-hr	3.7	3.9	4.3	4.9	4.2	4.4
24-hr	3.8	4.1	4.5	5.4	4.3	4.7
36-hr	4.2	4.8	5.1	6.6	5.2	5.7
48-hr	4.7	5.2	5.4	7.7	5.2	6.1
60-hr	5.1	5.6	6.1	8.7	6.2	7.0

Some typical verification statistics yielded by the automated system are given in Table 3, which presents mean absolute errors averaged over 131 cities in the United States for the fall of 1970 (September, October and November), the winter of 1970–71 (December, January and February), and the spring of 1971 (March, April and May). Corresponding statistics obtained by running the old system as a control are given for comparison. Note that the errors of the new system are consistently less than those of the old system, with differences ranging from 0.1–2.6F. The margin of superiority increases with increasing forecast projection, is greater in winter than in the warmer seasons, and is more marked for the maximum than the minimum temperature. Furthermore, the average errors of this winter's operational temperature forecasts were less than either PE or barotropic forecasts made in the previous two winters, as can be seen by comparing Table 3 with Table 2 for 1970 and with Table 6 of Klein and Lewis (1970) for 1969.

7. Extended forecast usage

Since 9 February 1970, the PE model has been run out to 84 hr once a day by NMC, and these extended PE runs have been used as input in producing automated maximum and minimum temperature forecasts

for up to 96 hr in advance by extending the system outlined in Table 1. The resulting objective forecasts have been used as guidance by NMC's Extended Forecast Division in preparing subjective forecasts of temperature anomalies for days 3 and 4. Forecast guidance for day 5 is obtained by running the barotropic and Reed models out to 120 hr. The feasibility of transmitting the automated forecasts of maximum and minimum temperature for periods from 72–96 hr in advance over national teletype is now being evaluated.

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