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DEVELOPMENT OF 0000 GMT CYCLE STATISTICAL 3-HR TEMPERATURE FORECAST EQUATIONS FOR THE FALL SEASON

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1. INTRODUCTION

Last winter (December-February) the Techniques Development Laboratory (TDL) of the National Weather Service experimented with making automated 3-hr temperature forecasts at a number of cities in the United States (see Grayson and Dallavalle, 1977). In order to improve TDL's computer-worded forecast (Glahn, 1976), we decided to derive equations from 0000 GMT cycle data for other 3-month seasons. This report describes our development of equations for the fall season of September through November.

2. PROCEDURE

For the computer-worded forecast, we needed equations to predict the surface temperature at a station every 3 hr from 6 to 30 hr after 0000 GMT. We used the Model Output Statistics (MOS) technique (Glahn and Lowry, 1972) to derive 10-term multiple linear regression equations for each station and each projection. In brief, this approach requires that output (forecast fields) from various numerical models be interpolated to the station of interest. These interpolated values are then used as potential predictors for the specific meteorological parameter that we wish to forecast. We rely on a forward, stepwise regression program to compute a linear equation by screening the predictors. In the development of 3-hr temperature equations, the predictand is the observed station surface temperature at 6, 9, 12, ..., and 30 hr after 0000 GMT. The screening process continues until 10 predictors have been selected.

As potential predictors for the temperature equations, we used model output from the 0000 GMT run of the Limited-area Fine Mesh (LFM) model (Howcroft, 1971). We also added station surface observations taken at 0300 GMT and the first and second harmonics of the day of the year as possible predictors. To ensure some consistency among the 3-hr forecasts, we derived the equations for the nine forecast projections at each station simultaneously. As a result, the individual equations for any station contain the same 10 predictors at each projection, but, of course, with different regression coefficients. We had discovered earlier (Grayson and Dallavalle, 1977) that this method of simultaneous derivation provided as accurate forecasts as deriving the equations for each projection separately. Thus, in the developmental screening we offered only one list of model predictors for all nine temperature forecast projections.

Table 1 shows the LFM model forecast fields we screened. These were valid from 6 to 24 hr after 0000 GMT. We also screened some LFM analyzed fields at 0000 GMT. In particular, as we will show later, the LFM surface temperature field was a very significant predictor for the 3-hr forecasts. There are two other important points concerning Table 1. First, some of the fields that had been used as predictors for the winter season equations were omitted here. In particular, we dropped a few model heights and vertical velocities because they seemed to be relatively unimportant. We added thickness forecasts for several additional atmospheric layers to replace the height forecasts. Secondly, we smoothed fewer fields in order to take advantage of the LFM's finer resolution. We did, however, use a five-point filter on model forecasts of relative humidity, vorticity, and divergence because these fields tend to contain meteorological "noise". In addition, since the station observations are not always available operationally, we derived a set of backup equations that did not require surface observations.

Four seasons (September-November, 1973-76) of LFM data were used. For most of the stations this amounted to over 300 items of developmental data. The stations for which we derived equations (Table 2) were primarily those that were already maximum/minimum temperature forecast sites (see Hammons, et. al., 1976). To these 228 stations, we added another eight locations (PNS, ESF, STJ, BHL, FMN, EKO, ACV, WAL). However, because of data limitations, we were not able to develop equations for each of the 236 stations for all nine projections. Due to station closings in recent years, data were unavailable for Dallas, Texas (DAL) and Zuni, New Mexico (ZUN). For the other 234 cities, equations were developed for some and, in most cases, all nine projections. Of course, there were instances where an equation using 0300 GMT stations surface observations could not be developed (i.e., DBQ, BVE, STJ among others), because the necessary 0300 GMT observations were unavailable.

3. RESULTS

The average standard errors of estimate and the mean reduction of variance at all available stations for nine projections are given in Table 3. As in the winter test (Grayson and Dallavalle, 1977), the standard errors generally increase with increasing projection. However, the standard errors for 15 and 24 hr after 0000 GMT are slightly less than those at projections either before or after those times. The equations that use surface observations as potential predictors have much lower standard errors of estimate during the first two projections (6 and 9 hr) than the equations that do not use these observations. After that, any differences between the two equation sets are relatively small. After 15 hr, the difference is always 0.1°F or less.

The ten most important predictors for both the equations that use observations and those that do not are given in Table 4. These terms were chosen both on the frequency and order of selection for the equations in which they are used. When observations were included as potential predictors in the screening, the latest observed surface temperature is the most important predictor. In other words, persistence plays a major role in forecasting surface temperatures at 3-hr intervals. Additionally, LFM forecasts of low-level temperature fields (1000-mb temperature, boundary layer potential temperature, and the 850- to 1000-mb thickness) and humidity parameters (1000-, 850-, and 700-mb dew points, mean and boundary layer relative humidity) are important. The cosine day of the year also appears to provide some climatological information. We have noticed similar response in the transition seasons for the max/min forecasts (Hammons, et. al., 1976).

When observations were not used as potential predictors (see Table 4-b), the types of predictors, namely temperature and humidity forecasts, are similar to those picked earlier. The LFM surface temperature analyzed from the 0000 GMT initial data is also an important predictor. In essence, this field serves as a substitute for the station's surface temperature observation. This particular term is probably responsible for the fact that the standard errors of both sets of equations are nearly identical after the 12-hr projection.

4. FUTURE WORK

These equations will go into operation in October of 1977. The resulting 3-hr temperature forecasts will be used as input for the computer worded program. We plan to derive similar equations for both the spring (March-May) and summer (June-August seasons).

5. REFERENCES

Grayson, T. H., and J. P. Dallavalle, 1977: Development and operational use of 3-hr objective temperature forecasts. Preprints Fifth Conference on Probability and Statistics in Atmospheric Sciences, Las Vegas, Nevada, Amer. Meteor. Soc., 4 pp.

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Hammons, G. A., J. P. Dallavalle, and W. H. Klein, 1976: Automated temperature guidance based on three-month seasons. Mon. Wea. Rev., 104, 1557-1564.

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Table 1. Predictors screened for the fall season 3-hr temperature equations. The star (*) indicates that the field was smoothed by a 5-point filter.

Field	Projection (hr after 0000 GMT)
(a) LFM Model Output	
500-1000 mb thickness	0,6*,12,18,24
850-1000 mb thickness	0,6*,12,18,24
500-850 mb thickness	0,6*,12,18,24
700-1000 mb thickness	0,6*,12,18,24
500-700 mb thickness	0,6*,12,18,24
1000-mb relative vorticity	0*,6*,12*,18*,24*
850-mb relative vorticity	0*,6*,12*,18*,24*
Precipitable water	6*,12*,18*,24*
Surface temperature	0
1000-mb temperature	12,24
850-mb temperature	0,6*,12,18,24
700-mb temperature	0,12,24
1000-mb dew point	6*,12*,18*,24*
850-mb dew point	12*,24*
700-mb dew point	12*,24*
Boundary layer relative humidity	0*,6*,k2*,18*,24*
Layer 1 (1000 mb-720 mb) relative humidity	0*,6*,12*,k8*,24*
Layer 2 (720 mb -490 mb) relative humidity	0*,6*,12*,18*,24*
Boundary layer potential temperature	6*,12,18,24
Boundary layer U wind	6*,12,18,24
Boundary layer V wind	6*,12,18,24
Boundary layer wind speed	6*,12,18,24
850-mb U wind	6*,12,18,24
850-mb V wind	6*,12,18,24
700-mb U wind	12,24
700-mb V wind	12,24
700-1000 mb temperature	12,24
Mean relative humidity (1000-490 mb)	6*,12*,18*,24*
Boundary layer wind divergence	6*,12*,18*,24*
(b) Trigonometric Terms	
Sine day of year	0
Cosine day of year	0
Sine of twice the day of year	0
Cosine of twice the day of year	0
(c) Station Observations	
Ceiling	3
Sky Cover	3
Dew Point	3
Wind Speed	3
U Wind	3
V Wind	3
Temperature	3

Table 2. Call letters of the 234 MOS stations for which fall season 3-hr temperature equations were derived.

ABE	ABI	ABQ	ABR	ACT	ACV	ACY	AGS	AHN	ALB
ALO	AMA	APN	AST	ATL	AUS	AVL	AVP	BAL	BCE
BDL	BDR	BFD	BFF	BFL	BGM	BGR	BHM	BIL	BIS
BKW	BNA	BNO[b]	BOI	BOS	BRL	BRO	BTR	BTV	BUF
BVE[a c]	CAE	CAK	CAR	CDC	CHA	CHS	CLE	CLT	CMH
CNK	CON	COS	COU	CPR	CRP	CRW	CVG	CYS	DAB
DAG	DAY	DBQ[a]	DCA	DDC	DEN	DFW	DLH	DRT	DSM
DTW	EAU	EKN[a]	EKO	ELP	ELY	ENV[a]	ERI	ESF	EUG
EVV	EWR	EYW	FAR	FAT	FCA	FLG	FMN	FMY	FNT
FSD	FSM	FWA	GEG	GGW	GJT	GLD	GRB	GRI	GRR
GSO	GSP	GTF	HAR	HAT	HLN	HON	HSV	HTL	HTS
HVR	IAD	IAH	ICT	ILG	ILM	IND	INL	INW	IPT
ISN	JAN	JAX	JFK	LAN	LAS	LAX	LBB	LBF	LCH
LEX	LFK	LGA	LGB	LIT	LND	LOL	LSE	LYH	MAF
MCI	MCN	MCW	MDW	MEI	MEM	MFR	MGM	MIA	MKE
MKG	MLI	MOB	MOT	MSN	MSO	MSP	MSS	MSY	OAK
OKC	OLM	OMA	ORD	ORF	ORL	OTH	PBI	PDT	PDX
PHL	PHX	PIA	PIH	PIR	PIT	PNS	PUB	PVD	PWM
RAP	RBL	RDU	RDM	RFD	RIC	RKS	RNO	ROA	ROC
RSL	RST	SAC	SAN	SAT	SAV	SBN	SCK	SDF	SEA
SFO	SGF	SHR	SHV	SJT	SLC	SLE	SMX[c]	SPI	SPS
SSM	STJ[ac]	STL	SUX	SYR	TCC	TCS	TLH	TOL	TOP
TPA	TPH	TRI	TUL	TUS	TVC	TYS	UIL	VCT	WAL[a]
WMC	YKM	YNG	YUM						

a - Equations with observed predictors are unavailable at all projections.

b - Equations are unavailable for the 6-, 9-, and 30-hr projections.

c - Equations are unavailable for the 6-, 9-, 27- and 30-hr projections.

Table 3. Average standard errors of estimate (°F) and reductions of variance (%) for fall season 0000 GMT cycle 3-hr temperature equations.

Projection (Hr after 0000 GMT)	Standard Error of Estimate (°F)		Reduction of Variance (%)	
	With Sfc Obs	No Sfc Obs	With Sfc Obs	No Sfc Obs
6	2.3	3.2	96	92
9	2.9	3.5	93	90
12	3.3	3.6	91	90
15	3.2	3.4	92	91
18	3.8	3.9	91	90
21	4.1	4.1	90	89
24	3.8	3.8	91	91
27	3.8	3.9	90	89
30	4.1	4.2	87	87

Table 4. Most important predictors for the fall season 0000 GMT cycle 3-hr temperature equations: (a) when observations are included; (b) when observations are not screened. This ranking is based on both the frequency and order of selection of the predictors in the 10-term equations. Predictors appearing first in the equations were assigned 10 points, while the second term variables were given nine points, and so on. Points were summed for all equations and then the predictors were ranked according to total number of points accumulated.

(a)

Observed Surface Temperature
LFM 850-mb Dew Point
LFM 850-1000-mb Thickness
Cosine Day of Year
LFM 1000-mb Temperature
LFM Boundary Layer Potential Temperature
LFM 1000-mb Dew Point
LFM Boundary Layer Relative Humidity
LFM 700-mb Dew Point
LFM Mean Relative Humidity (1000-490 mb)

(b)

LFM 850-1000-mb Thickness
LFM Boundary Layer Potential Temperature
LFM Analyzed Surface Temperature
Cosine Day of Year
LFM 850-mb Dew Point
LFM 1000-mb Dew Point
LFM 1000-mb Temperature
LFM Boundary Layer Relative Humidity
LFM Boundary Layer Wind Speed
LFM Precipitable Water