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NGM-Based MOS Guidance for Maximum/Minimum Temperature, Probability of Precipitation, Cloud Amount, and Surface Wind

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FIRST BULLETIN ON THIS SUBJECT

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This bulletin, prepared by Eli Jacks, J. Brent Bower, Mary C. Erickson, and James C. Su of the Techniques Development Laboratory, describes the development and use of new NGM-based MOS guidance that has been available since July 26, 1989 for 204 stations in the contiguous United States. The new guidance, which replaced the NGM-based perfect prog package that had been operational since May 1987, consists of forecasts of maximum/minimum temperature, probability of precipitation, cloud amount, and surface wind. Guidance for all four elements is transmitted over AFOS as the FWC product (FOUS14 bulletin), and is available for projections of 1 and 2 days in advance from 0000 and 1200 UTC. The LFM-based MOS guidance package is still available as the FPC product (FOUS12 bulletin) and was not affected by this change. A summary sheet that outlines the most important developmental and operational aspects of the new NGM-based MOS product is found at the end of this document.

Since July 1989, verification on independent data shows that LFM-based MOS temperature forecasts are usually more accurate than the NGM-based MOS. However, for the probability of precipitation, cloud amount, and wind forecasts, the NGM-based MOS is generally superior to the LFM-based MOS guidance.

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Mary M Heffernan

Mary M. Heffernan
Chief, Services Development Branch

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

NGM-BASED MOS GUIDANCE FOR MAXIMUM/MINIMUM TEMPERATURE, PROBABILITY OF PRECIPITATION, CLOUD AMOUNT, AND SURFACE WIND

by Eli Jacks, J. Brent Bower, Mary C. Erickson, and James C. Su

1. INTRODUCTION

In May 1987, the National Weather Service (NWS) implemented the first statistical guidance package (National Weather Service, 1987a) designed for application to the Nested Grid Model (NGM) (Phillips, 1979; National Weather Service, 1986; Hoke et al., 1989). Forecast equations for maximum/minimum (max/min) temperature, probability of precipitation (PoP), cloud amount, and surface wind were developed at the Techniques Development Laboratory (TDL) by using a modified perfect prog technique (Erickson, 1988). In July 1989, a new NGM-based Model Output Statistics (MOS) package (Glahn and Lowry, 1972) for these same four elements *replaced* the perfect prog system. Here, we describe how these new forecast equations were developed, how the NGM-based MOS (NGM MOS, from here on) equations differ from the LFM-based MOS (LFM MOS, from here on) equations, and how these differences are likely to be reflected in the statistical forecasts.

2. BACKGROUND

The National Meteorological Center (NMC) of the NWS has made several significant changes to the NGM during the past few years, including the implementation of a hemispheric temperature correction scheme (National Weather Service, 1987b) in October 1987. The purpose of this modification was to reduce a cold bias that increased with forecast projection at all levels of the model. Since this correction was made, few changes have been made to the NGM. Until that time, the rapidly changing nature of the NGM since its inception had precluded development of NGM MOS equations because experience has shown that *at least* 2 years of stable dynamical model data are needed in order to derive useful MOS equations. For example, by using the 2 year criterion alone, we would have had to delay NGM MOS warm season (April-September) equation development until October 1989.

To reduce the waiting period and expand the data base, we reran the August 1988 version of the NGM for virtually all dates between October 1986 and October 1987. This effort yielded the second year of data needed for the development of warm season equations and ensured that a third year of cool season (October-March) data would be available by the time we began cool season equation development in July 1989. With the assistance of NMC, we completed the task of rerunning the NGM in January 1989 and we commenced warm season equation testing immediately thereafter. NGM MOS warm season equations for max/min temperature, PoP, wind, and cloud amount were implemented on July 26, 1989. We devoted the remainder of the summer to cool season equation testing and development, and NGM MOS cool season equations for the same four elements were implemented on October 4, 1989.

3. GENERAL INFORMATION FOR ALL ELEMENTS

The MOS approach correlates predictand data (local weather observations) to combinations of predictor data (output from dynamical models, surface observations, and climatic information). A linear least-squares regression technique is used to determine statistical relationships between each predictand and the predictors. A "master list" of potential model and climatic predictors that were made available to the NGM MOS development is given in Figure 1. Not all predictors were used for all weather elements. We developed NGM MOS forecast equations for the same 204 stations (Figure 2) used in the NGM perfect prog system.

As mentioned in Section 2, NGM MOS equations are valid during two 6-month seasons (April 1 through September 30 for the warm season; October 1 through March 31 for the cool season) for all four elements. For both seasons, however, data from outside the seasonal bounds were included in the developmental sample to enhance equation stability, particularly at the beginning and end of the seasons. For the warm season, we included data from the last eight days of March and the first eight days of October of each developmental year. Similarly, data from the last 15 days of September and the first 15 days of April for each developmental year were used in the cool season development. Thus, we had available approximately 400 (600) days of data for the warm (cool) season development. While we consider these data samples to be adequate (especially for the cool season), far more data were available to develop the LFM MOS equations.

4. EQUATION CHARACTERISTICS FOR SPECIFIC ELEMENTS

a. Daytime Max and Nighttime Min Temperature

We developed NGM MOS equations to predict the daytime max and nighttime min temperature valid at projections verifying approximately 24, 36, 48, and 60 hours after 0000 and 1200 UTC. For the warm season, daytime is defined as the period from 8 a.m. to 7 p.m. Local Standard Time (LST), while nighttime is defined as the period from 7 p.m. to 8 a.m. LST. For the cool season, the only change in the daytime/nighttime definition is that nighttime is extended to 9 a.m. LST, at which time daytime begins. Thus, max/min temperature forecasts from the 0000 (1200) UTC cycle are valid for today's max (tonight's min), tonight's min (tomorrow's max), tomorrow's max (tomorrow night's min), and tomorrow night's min (the day after tomorrow's max). The same predictand definitions were used for development of the corresponding LFM MOS equations.

For max/min temperature, we developed single-station equations for 200 out of the possible 204 stations shown in Figure 2. Because single station equations for a specific site were developed by using data from that site only, forecasts generated by such equations include the effects of local topography and climate. However, for the other four stations (ACV, LGB, LFK, CXY), the archive of observed max/min temperatures was insufficient to do a single station derivation. For these stations, we developed regionalized max/min forecast equations.

In the regionalized approach, we pool predictor and predictand data for all stations within a given region to develop one equation. This equation is then used operationally to produce forecasts for each station in that region for a given cycle and projection. Because the developmental data are pooled, regionalized equations are not tailored to any particular station. Thus, for temperature forecasting, we do not generally expect forecasts produced by regionalized equations to be as skillful as those produced by single station equations. The NGM MOS max/min regions, shown in Figure 3a, were subjectively determined by considering variations in topography *and* the correlation at each station between the max or min temperature predictand and the most important NGM predictors. Thus, the regions do not always strictly follow topographic boundaries. Note that while we derived the regionalized max/min temperature equations by using data from all available stations, these equations are used only for ACV, LGB, LFK, and CXY. The same regional divisions were used for both the warm and cool seasons.

Some of the variables used in the regression program for max/min temperature (over 50 different meteorological variables in all) were not available in the LFM MOS max/min temperature development. Examples of new variables include forecasts of temperature and temperature advection at constant pressure levels below 850 mb. We allowed the predictor selection process to proceed either until a maximum of 10 terms had been chosen or until the inclusion of an additional term failed to increase by a specified amount the correlation between the max or min temperature predictand and the predictors. Except at the 60-h projection, we allowed three predictor projections to be offered for each variable (at 12 hours prior to, 6 hours prior to, and concurrent with the approximate valid time of the predictand). For the 60-h max or min temperature, only model predictors valid at the 48-h projection were offered.

Interestingly, none of the NGM MOS max/min temperature equations contains 10 terms. In fact, most of the warm season equations contain only three to five predictors, while only about three out of every 10 equations contain more than five terms. The number of predictors chosen for inclusion in the cool season max/min temperature equations averaged somewhat higher overall, but was still well below the average of 10 to 12 terms found in the operational LFM MOS max/min temperature equations. Note that the LFM MOS max/min temperature equations generally contain more terms than the corresponding NGM MOS equations because the LFM MOS equations for max and min temperature were developed simultaneously with equations for surface temperature and dew point. The simultaneous development approach will be explained in more detail in Section 4.c.

For both the warm and cool seasons, the most important predictor in the NGM MOS max temperature equations is a forecast of temperature at a specific level in the lower troposphere, while a forecast of a low-level thickness was usually chosen as the first predictor in the min temperature equations. Other predictors chosen frequently in both the max and min temperature equations were forecasts of the mean relative humidity (surface to approximately 500 mb), 850-mb relative vorticity, 1000-500 mb thickness, and 10-m wind components.

For the forecast of today's max (tonight's min) temperature from 0000 (1200) UTC for both seasons, we also derived a separate set of "primary" forecast equations in which surface observations of temperature, wind, and dew point were included as potential predictors. In addition, we used the observation of the previous day's max temperature as a potential predictor to forecast today's max from 0000 UTC. In order to make use of the latest available data, we used observations from 0300 (1500) UTC in the equations for today's max (tonight's min). The operational system always attempts to use the primary equations first. However, "backup" equations were developed for those times when the observations needed by the primary equations are missing. Although observations were chosen for inclusion in the primary equations, the previously mentioned NGM forecast variables were still chosen first most often. Note that climatic predictors, such as sine and cosine of the day of the year, were chosen at all projections, but increased in importance with increasing projection.

Although we tested warm season max/min temperature equations for 40 stations in the Rockies by removing "below ground" thermal predictors, we noticed that forecasts produced by these equations were no more accurate than those produced by equations with all thermal predictors included. Consequently, in the development of warm season max/min temperature equations, we used the identical predictor list for both low *and* high elevation stations. Following the implementation of the warm season equations, however, we found that the NGM constant pressure level temperature forecasts at elevated stations are not statistically consistent across all temperature ranges due to the method used in the NGM to estimate "below ground" temperatures (e.g., the 950-mb temperature at Denver). Thus, for the cool season, we decided to use different predictors for elevated stations in the Rockies. In the single station development, for the 40 stations shown in Figure 4, we excluded all temperature and temperature advection terms at 850 mb and below from the potential predictor list. In the regionalized development, we omitted these same predictors for all stations in regions 4 through 13. Note that the four stations for which regionalized max/min temperature forecasts are produced fall into low elevation regions. The final deviation from the warm season approach was that we excluded forecasts of 1000-mb temperature from the cool season potential predictor list for *all* 204 stations to protect further against terrain-related data problems.

b. PoP

We developed NGM MOS equations to predict the probability of 0.01 inches or more of liquid equivalent precipitation for 12-h intervals ending at 24, 36, 48, and 60 hours after 0000 and 1200 UTC. Because of the relatively infrequent occurrence of precipitation and the binary nature of the predictand, we developed regionalized equations to forecast PoP. The NGM MOS warm season PoP regions (Figure 3b) are quite similar to those that were used for the warm season LFM MOS development, although the regions were adjusted somewhat according to topography and the correlation at each station between the observed 12-h precipitation amount and the most important NGM predictors. The NGM MOS cool season PoP regions (Figure 3c) are *exactly* the same as the cool season LFM MOS PoP regions.

Except for the 60-h PoP equations, model predictors valid at the beginning, at the midpoint, and at the end of the 12-h forecast period were used as potential predictors. For the 60-h equations, only model predictors valid at the 48-h projection were used. We allowed a maximum of 12 predictors in the PoP equations, and all equations contain this maximum number, with the exception of a few cool season equations that contain 11 terms. This compares with a maximum of 18 terms in the LFM MOS PoP equations. We did not use observations as predictors for any projection because tests showed that the inclusion of observations as predictors did not significantly improve the performance of the PoP equations.

The most important predictors selected for the warm season NGM MOS PoP equations were forecasts of precipitation amount and mean relative humidity; forecasts of 900- and 700-mb relative humidity, 850-mb relative vorticity, and 300-mb vertical velocity followed in importance. For the cool season PoP equations, forecasts of precipitation and mean relative humidity were once again most important; forecasts of 850- and 700-mb moisture convergence, 850-mb vertical velocity, and 300-mb relative vorticity were also selected frequently.

c. Surface Wind

For surface wind, we developed NGM MOS equations for three predictands, namely, the surface wind speed, the U (east-west) component, and the V (north-south) component. Individual sets of equations valid every 6 hours from 6 to 48 hours after 0000 or 1200 UTC were derived. We used the simultaneous development approach to derive U, V, and wind speed equations for a given station, cycle, and projection. In the simultaneous approach, equations for each of the three predictands contain the same predictors to enhance meteorological consistency among the forecasts of these elements. However, the predictors' coefficients vary so that each equation is still tailored to the particular predictand. Note that the wind direction forecast is computed from the forecasts of U and V, and that the wind speed forecasts are inflated (National Weather Service, 1985) in order to forecast more occurrences of the strongest winds.

We were able to develop single station NGM MOS surface wind equations for 202 out of the possible 204 stations. For the other two stations (LGB and LFK), we developed regionalized equations to produce the wind forecasts. The NGM MOS wind regions were subjectively determined by considering variations in topography *and* the correlation at each station between the predictands and the most important predictors. The NGM MOS wind regions, which are the same for both the warm and cool seasons, are shown in Figure 3d.

For each projection except 48 hours, the potential predictors were valid at 6 hours prior to, concurrent with, and 6 hours after the valid time of the predictands. For the 48-h equations, only model predictors valid at the 42- and 48-h projections were used. We allowed the predictor selection process to continue until a maximum of 12 terms was chosen or until the inclusion of an additional term failed to increase by a specified amount the correlation between the predictands and the predictors. As with the

LFM MOS wind equations, most NGM MOS wind equations contain 12 terms.

The most important predictors in the surface wind equations include forecasts of 950-mb and 10-m wind components. These two predictors were not available to the LFM MOS equation development. Other predictors chosen include forecasts of wind at various levels up to 500 mb, vertical velocity, relative vorticity, vorticity advection, stability indices, and climatic variables. For the 6- and 12-h projections from each cycle, we also developed a set of primary equations that included as potential predictors station surface wind reports observed 3 hours after model initialization, in addition to the forecast and climatic predictors.

d. Cloud Amount

We developed NGM MOS equations to predict the cloud amount for projections at 6-h intervals from 6 to 48 hours after both 0000 and 1200 UTC. The cloud amount predictand is the opaque sky cover, reported in tenths. For each projection, the equations predict the probability of clear (0 tenths), scattered (1-5 tenths), broken (6-9 tenths), and overcast (10 tenths) cloud amount. As with wind, we used the simultaneous approach to develop equations for each of the four categories.

In addition to the probability forecasts, we provide categorical cloud amount forecasts by comparing these probabilities to three threshold values. We designed these threshold values to produce unbiased categorical forecasts, that is, the number of forecasts of each category roughly equals the number of observations of that category. In determining the categorical forecast, we first compare the probability of clear skies to the first threshold value. If the probability exceeds the threshold value, then clear is the categorical forecast. Otherwise, we add the probability of clear skies to the probability of scattered clouds, and compare this value to the second threshold. Again, if this threshold is exceeded, scattered is the predicted category; otherwise, the process continues. If none of the three thresholds is exceeded, overcast is selected as the categorical forecast.

As with the PoP development, we developed regionalized equations to forecast cloud amount. We considered topography and the correlation at each station between the cloud amount predictands and NGM forecasts of mean relative humidity to determine the warm and cool season NGM MOS cloud amount regions (Figures 3e and 3f, respectively).

As with max/min temperature and wind, some of the predictors considered in the development of NGM MOS cloud amount equations were not available for the LFM MOS development. The most important new predictors in the NGM MOS cloud amount equations are relative humidity forecasts for specific levels in the atmosphere. We included forecasts of 1000-, 950-, 900-, 850-, 700-, 500-, and 300-mb relative humidity as potential predictors, and all were used in one equation or another. For the cloud amount equations, only model predictors valid concurrently with the predictand were used as potential predictors. We allowed the predictor selection process to continue until a maximum of 12 predictors was chosen or until the inclusion of an additional term failed to increase by a specified amount the correlation between the cloud predictands and the predictors. Most equations contain the maximum of 12 predictors. The most important predictor is a forecast of mean relative humidity, followed by forecasts of the various level humidities and the 850-mb vertical velocity. Finally, for the 6- and 12-h projections, we derived primary equations that include as predictors surface observations reported three hours after model initialization, in addition to NGM forecasts and climatic terms. Of these observed predictors, the opaque sky cover is used most often.

5. MESSAGES AND SCHEDULES

The NGM MOS guidance is produced twice daily around 0330 and 1530 UTC for the 204 stations listed in Figure 2. The AFOS message that contains this guidance may be obtained by typing and entering: FWCxxx where xxx are the call letters of the station requested. The guidance is also available through the NWS Family of Services as the FOUS14 product.

A sample FWC message for Washington, D.C. (DCA) from 0000 UTC data on August 11, 1989 is shown below.

The line following the station call letters contains the PoP (POP) and max/min (MX-MN) temperature forecasts. The max/min temperature forecasts (rounded to the nearest °F) follow the PoP forecasts (in percent). (For the 1200 UTC message, the order of the max and min temperature forecasts are reversed so that the product identifier appears as MN-MX.) Because separate equations were developed for max and min temperature, there could be occasions when a max temperature forecast would be less than a min temperature forecast for an adjacent period or when a min temperature forecast would exceed an adjacent max temperature forecast. In order to ensure that such inconsistent forecasts are not disseminated, a check is applied to all max/min temperature forecasts for adjacent periods. If an inconsistency occurs, post-processor software averages the max and min forecasts and sets both forecasts to this average value. The PoP forecasts are rounded to values of 0, 2, 5, 10, 20, 30,..., or 100 percent. The PoP and max/min temperature forecasts are separated by a slash. Surface wind forecasts (WIND) are presented in the standard DDFF format; direction is rounded to the nearest 10 degrees and speed is rounded to the nearest knot. The first four digits in the cloud amount forecast line (CLDS) are single-digit probability forecasts (in tens of percent) for the exclusive cloud amount categories of clear, scattered, broken, and overcast. The best category cloud amount forecast is given after the slash (1 = clear, 2 = scattered, 3 = broken, 4 = overcast).

6. PRELIMINARY EVALUATION OF PERFORMANCE AND OPERATIONAL CONSIDERATIONS

a. General Comments Regarding the MOS Technique

MOS equations are developed by using forecast data from a particular dynamical model. Thus, the quality of MOS forecasts is strongly dependent upon both the accuracy and the consistent performance of pertinent output fields from that model. While MOS equations can account for the effects of systematic model errors, MOS cannot correct for poor model forecasts that are random in nature. In addition, events that occur relatively infrequently on a scale smaller than can be resolved by the model (i.e., local or mesoscale effects) are not likely to be accounted for by MOS equations. On the other hand, small-scale effects that occur regularly enough in the developmental predictand data to affect the nature of the regression equation itself can be predicted. For example, MOS max temperature forecasts may include the effects of a sea breeze during the warm season at a coastal station if sea breezes occurred fairly regularly during the developmental period. Also, MOS min temperature forecasts may account for enhanced nocturnal radiational cooling at a given station if such enhanced cooling occurred regularly.

Statistical forecasts can (and do) predict record conditions. However, remember that the

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NMCFWCHDG
FOUS14 KWBC 110333
HDNG FOUS14 NGM-MOS GUIDANCE   8/11/89  0000 UTC

DY/HR 11/06   11/12  11/18  12/00  12/06  12/12  12/18  13/00    13/12
NMCFWCDCA
FOUS14 KWBC 110333
DCA  ESC
POP/MX-MN                  90/ 74        60/ 71        50/ 80   60/ 66
WIND   0310   0311   0411    0806   1408   1106   1509   1307
CLDS 0118/4 0019/4 0109/4 1108/4 0129/4 0227/4 0136/4 0226/4
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forecasts may be "conservative" during extreme situations. In addition, the MOS forecasts tend *increasingly toward the mean of the predictand with increasing projection*. This characteristic reflects the lack of information in model forecasts with increasing projection. While MOS may often be correct in warning the forecaster not to wander too far from climate at the longer projections, situations will arise where deviation from MOS is warranted. For example, if a record breaking heat wave is well entrenched and the dynamical model shows no evidence that conditions will change, MOS temperature forecasts may incorrectly point towards a cooling trend with increasing projection. Similarly, since the climatic relative frequency of precipitation at most stations is relatively low, the tendency of MOS forecasts to approach the climatic frequency with increasing projection may cause PoP forecasts to be too low at 48- and 60-h.

While the single station MOS max/min temperature equations can account for the effects of a sea breeze or of enhanced nocturnal radiational cooling at a particular station, we do not generally expect the regionalized MOS cloud amount and PoP equations to account for local or topographic effects that occur on the subsynoptic scale. However, regionalized equations can resolve differences from station to station that occur on the *synoptic* scale if the model predicts meteorological variations across the region.

Finally, statistical equations "assume" that the basic climatic characteristics that define the developmental sample remain unchanged. For example, if soil moisture at a given station was generally normal over the course of the developmental sample, the max/min temperature equations derived from this sample "assume" that soil moisture will continue to be close to normal. Thus, errant forecasts can result during periods when soil moisture departs significantly from normal. If max/min temperature equations developed by using "normal" data were applied during an extended drought, one might expect the resulting max temperature forecasts to be too low and the min temperature forecasts to be too high due to the abnormally low soil moisture. On the other hand, if max/min temperature equations developed from a significant amount of "drought" data were applied to "normal" conditions, the reverse could be true. This same reasoning can be used to adjust cool season max/min temperature forecasts for situations where the observed snow cover departs significantly from normal. For example, if a station which normally has a snow cover experiences bare ground over a period of time, the MOS max and min temperature forecasts during that period may be consistently too cold.

b. Specific Comments Regarding the NGM MOS Development

Before implmenting the NGM MOS equations, we did a series of tests on both warm and cool season independent data. Despite the limited developmental data base available for the NGM MOS equations, the overall accuracy of the NGM MOS test forecasts for all elements met or exceeded our expectations. These results speak well for the predictive skill and increased resolution of the NGM. For specific details about these tests, consult Jacks et.al. (1990).

7. DISCUSSION

We recommend that the warm season NGM MOS max/min temperature and PoP forecasts be watched especially carefully at stations where the heat and drought conditions of 1988 were most pronounced. Because the developmental sample only extended from 1987 to 1988 and the drought was especially pervasive during 1988, a good portion of the developmental data for these stations departed significantly from normal. Thus, for these stations, NGM MOS max temperature forecasts for the warm season may exhibit a warm bias, while the min temperature forecasts may be too cool when applied during periods when soil moisture conditions are close to normal. *Please note that this is only educated speculation - we cannot be certain that this effect will actually be observed.*

As mentioned previously, most NGM MOS max/min equations contain relatively few terms. Thus, forecasts produced by these equations can be strongly influenced by individual predictors. While we have always warned forecasters not to place too much weight on individual predictors in statistical equations, especially for equations containing many predictors, a knowledge of the terms that appear in the NGM MOS max/min temperature equations might prove useful in some situations. We encourage NWS forecasters to contact their Regional SSD Chief with any requests for forecast equations.

Although the test results are promising on a nationwide basis, we do not expect that NGM MOS will necessarily be the most accurate statistical guidance in every situation. For example, we produced NGM MOS forecasts at BUF and CLE for April 1989 and found that the NGM MOS max temperature forecasts would have been much too warm on days when the surface wind trajectory was off Lake Erie. Meanwhile, the LFM MOS max temperature forecasts were considerably more accurate for these cases. We suspect that because the LFM MOS max/min temperature equations are available for four individual seasons (spring equations were developed by using data from March 1 through May 31), the effect of the cold lake on the max temperature is better predicted by the LFM MOS spring equations than by the NGM MOS warm season equations.

Based partially on input from forecasters, we did similar case studies for the warm season to evaluate how the NGM MOS guidance performed under specific synoptic regimes. In particular, we evaluated the max temperature guidance for an extreme Santa Ana event, for a situation where a strong warm front was positioned across the Northern Plains and Great Lakes, and for a situation where a late season cold air outbreak intruded into Montana. We also examined the performance of the min temperature guidance during a radiational cooling situation in Texas, and the PoP guidance for a case where the LFM MOS guidance was errant for several stations in Washington and Oregon. All of the cases were taken from April 1989. We expected that the NGM MOS guidance would be clearly superior to LFM MOS in these situations (especially the Texas and Montana cases, where shallow cold air dominated the weather), but this was not the case. Of course, these tests were by no means exhaustive, and we will continue to monitor the performance of the NGM MOS guidance. We encourage NWS forecasters to contact their Regional SSD if they note systematic behavior in the NGM MOS guidance that would be of interest to us or to other forecasters.

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NGM PREDICTOR	**LEVELS OR LAYERS (in mb)**
Relative Vorticity	**850, 700, 500, 300**
Vorticity Advection	**850, 700, 500**
Stability Indices	**---**
Moisture Convergence	**850, 700, 500**
Precipitable Water	**---**
Precipitation Amount	**---**
Temperature	**950, 900, 850, 700**
Temperature Advection	**950, 850, 700**
Thickness	**1000-500, 850-500, 1000-850, 850-700**
Relative Humidity	**1000, 950, 900, 850, 700, 500, 300, Mean (1000-490)**
Vertical Velocity	**850, 700, 500, 300**
U, V, S Wind Components	**950, 850, 700, 500, 300, 10 meters above surface**
SINE, COSINE Day of Year; SINE 2*, COSINE 2* Day of Year; Latitude, Longitude Station Elevation	**---**

Figure 1. List of potential predictors used in the NGM MOS development. (NOTE: not all predictors were used for all elements.)

A. Eastern Region

ABE (EC)
BGM (E)
CAE (ESC)
CRW (EC)
GSP (ES)
IPT (E)
PIT (EC)
SYR (E)
ACY (E)
BGR (E)
CAK (E)
CVG (EC)
HAR (E)
JFK (EC)
PVD (E)
TOL (EC)
ALB (EC)
BKW (E)
CHS (ES)
DAY (EC)
HAT (E)
LGA (EC)
PWM (EC)
YNG (E)
AVL (ES)
BOS (ESC)
CLE (EC)
DCA (ESC)
HTS (E)
LYH (E)
RDU (EC)
AVP (E)
BTV (E)
CLT (ES)
ERI (E)
IAD (E)
MSS (E)
RIC (E)
BDL (E)
BUF (EC)
CMH (EC)
EWR (E)
ILG E)
ORF (E)
ROA (EC)
BFD (E)
BWI (E)
CON (E)
GSO (E)
ILM (E)
PHL (EC)
ROC (E)

B. Southern Region

ABI (S)
AUS (S)
DAB (S)
IAH (S)
MAF (S)
MSY (SC)
SHV (S)
TYS (ES)
ABQ (SC)
BHM (ESC)
DFW (SC)
JAN (SC)
MCN (S)
OKC (SC)
SJT (S)
VCT (S)
ACT (S)
BNA (ESC)
ELP (S)
JAX (ES)
MEI (S)
ORL (S)
SPS (S)
AGS (ES)
BRO (S)
EYW (S)
LBB (SC)
MEM (ESC)
PBI (S)
TLH (S)
AHN (ES)
BTR (S)
FMY (S)
LCH (S)
MGM (ESC)
PNS (S)
TPA (S)
AMA (S)
CHA (ES)
FSM (SC)
LFK (S)
MIA (SC)
SAT (SC)
TRI (ES)
ATL (ESC)
CRP (S)
HSV (S)
LIT (SC)
MOB (S)
SAV (ES)
TUL (SC)

C. Central Region

ABR (C)
COU (SC)
DTW (EC)
GJT (SCW)
IND (EC)
MCI (SC)
MSP (C)
RKS (CW)
SPI (C)
ALO (C)
CPR (CW)
EAU (C)
GLD (SC)
INL (C)
MCW (C)
OMA (C)
RSL (SC)
SSM (C)
APN (C)
CYS (CW)
EVV (C)
GRB (C)
ISN (CW)
MKE (C)
ORD (EC)
RST (C)
STL (SC)
BFF (C)
DDC (SC)
FAR (CW)
GRI (C)
LAN (C)
MKG (C)
PIA (C)
SBN (C)
SUX (C)
BIS (SCW)
DEN (SCW)
FNT (C)
GRR (C)
LBF (C)
MLI (C)
PIR (CW)
SDF (ESC)
TOP (SC)
CNK (SC)
DLH (C)
FSD (CW)
HON (CW)
LEX (ESC)
MOT (C)
RAP (CW)
SGF (SC)
TVC (C)
COS (SCW)
DSM (C)
FWA (EC)
ICT (SC)
LND (CW)
MSN (C)
RFD (C)
SHR (CW)

D. Western Region

ACV (W)
EUG (W)
HLN (CW)
OLM (W)
RNO (CW)
TUS (SW)
AST (W)
FAT (W)
HVR (CW)
OTH (W)
SAC (W)
UIL (W)
BIL (CW)
FCA (W)
LAS (W)
PDT (W)
SAN (W)
WMC (W)
BOI (SCW)
FLG (SCW)
LAX (CW)
PDX (CW)
SEA (CW)
YKM (W)
CDC (SCW)
GEG (W)
LGB (W)
PHX (SCW)
SFO (CW)
EKO (W)
GGW (CW)
MFR (W)
PIH (CW)
SLC (SCW)
ELY (W)
GTF (CW)
MSO (CW)
RDM (W)
SLE (W)

Figure 2. NGM MOS guidance messages are available for the above stations listed alphabetically by call letter and according to National Weather Service region. Letters in parentheses after the station identifiers indicate the AFOS Regional Circuits on which these messages are sent, where E = Eastern, S = Southern, C = Central, and W = Western.

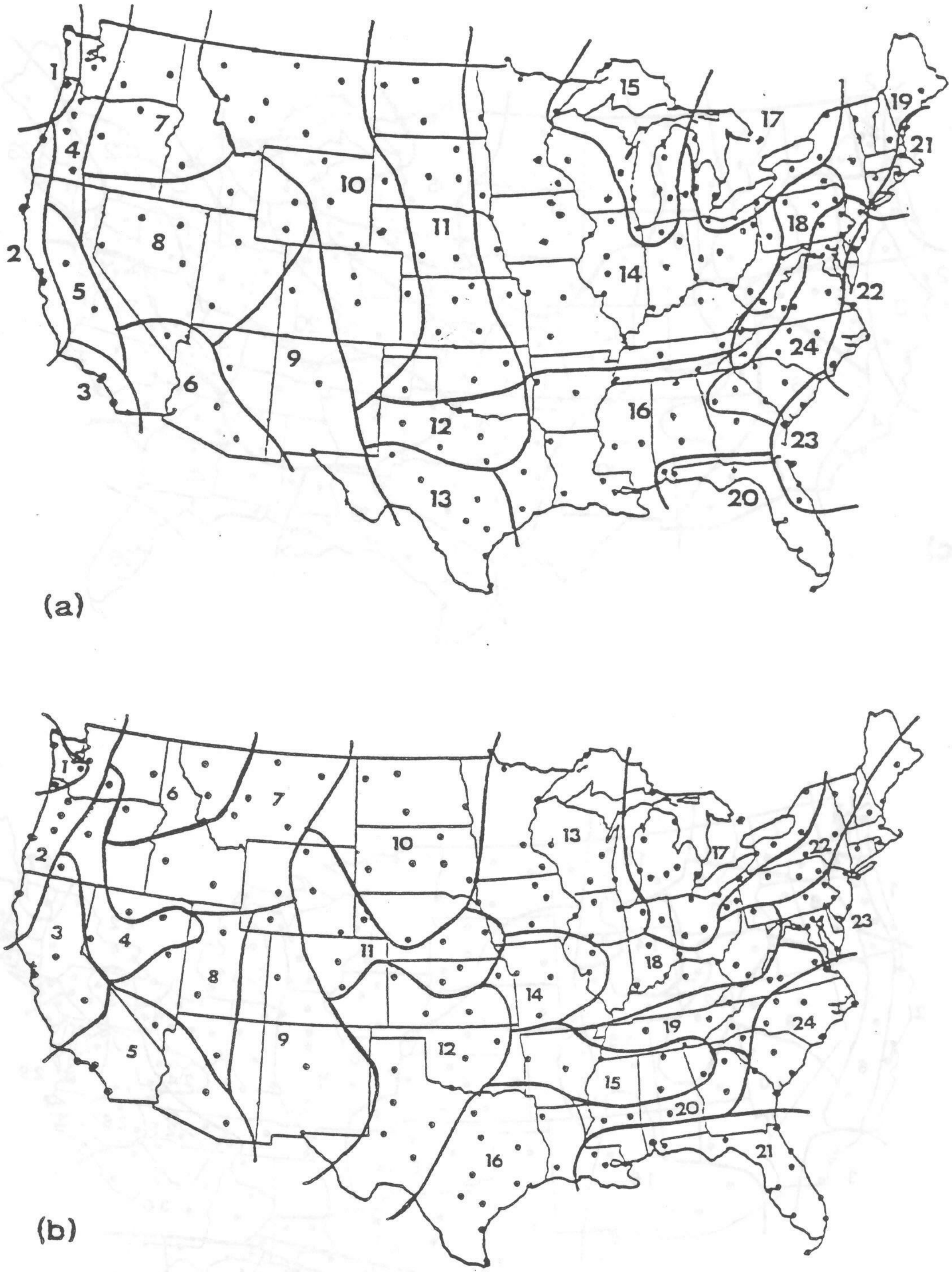


Figure 3. The regions used to develop regionalized NGM MOS equations for (a) max/min temperature, (b) warm season PoP, (c) cool season PoP, (d) wind, (e) warm season cloud amount, and (f) cool season cloud amount.

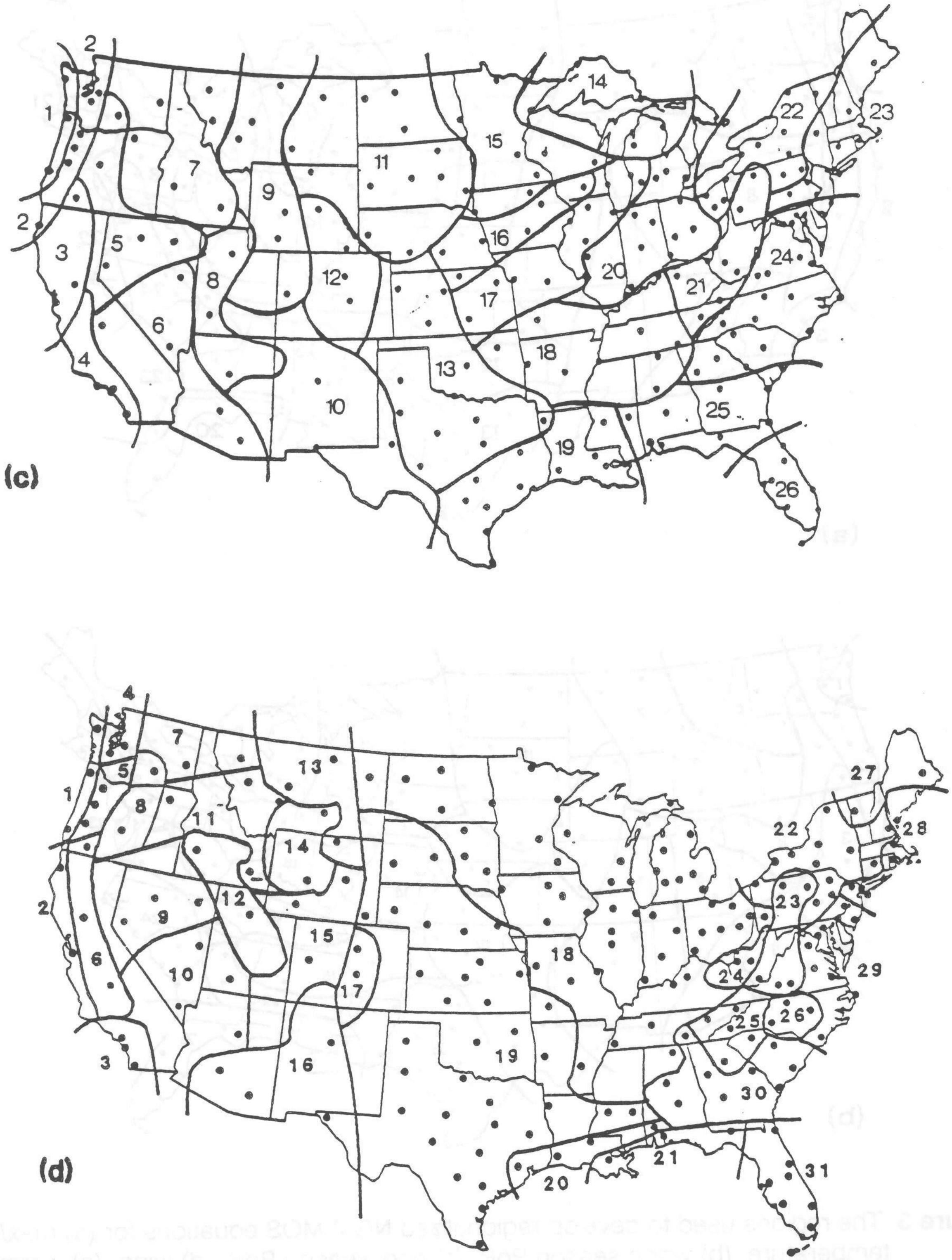


Figure 3. (continued).

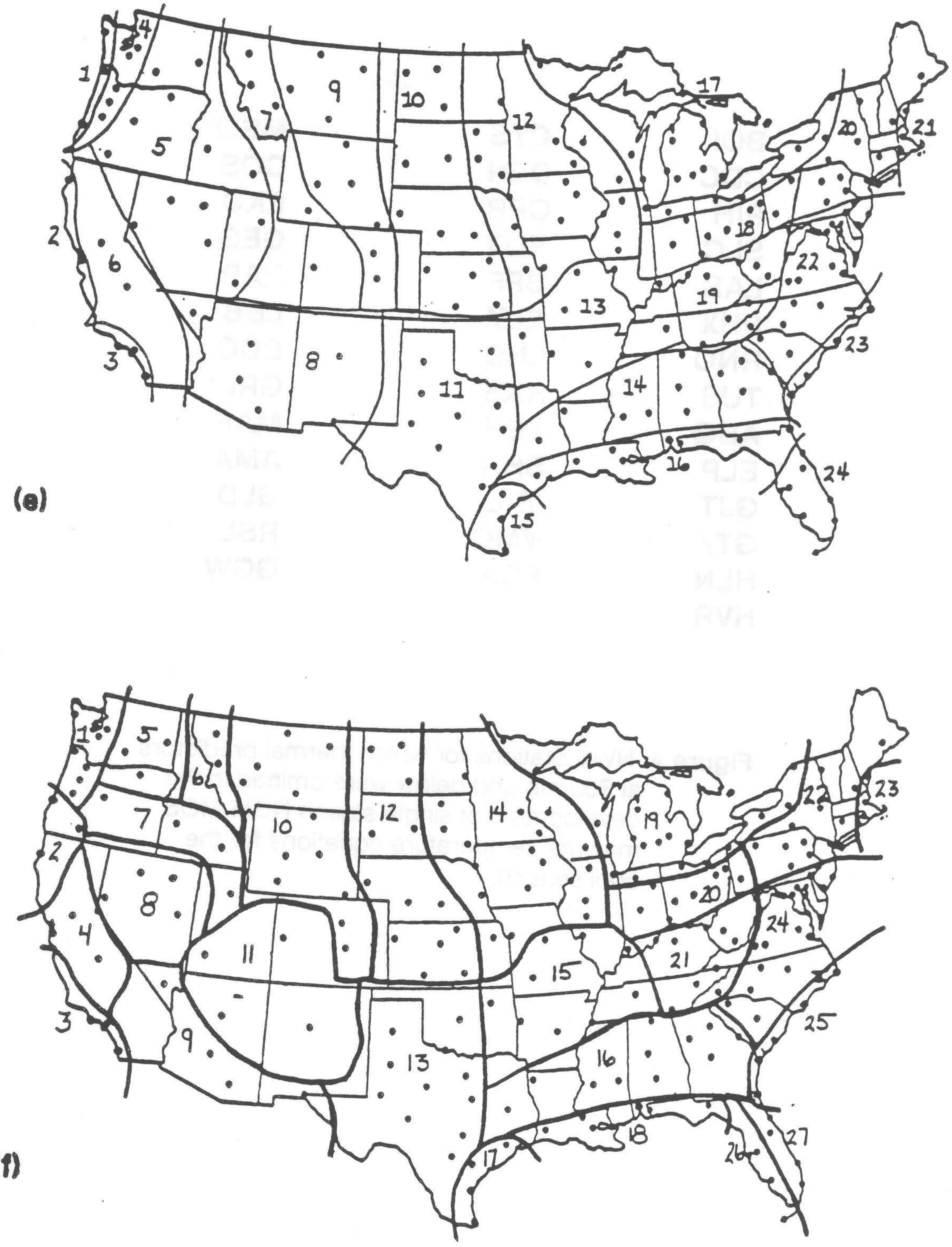


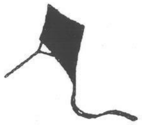
Figure 3. (continued).

BOI
CDC
PIH
SLC
LAS
PHX
RNO
TUS
ABQ
ELP
GJT
GTF
HLN
HVR

CYS
DEN
CPR
FLG
BFF
ELY
LND
RKS
LBF
SHR
BIL
WMC
FCA

MSO
COS
EKO
GEG
RAP
LBB
DDC
GRI
MAF
AMA
GLD
RSL
GGW

Figure 4. NWS Stations for which thermal predictors at 850 mb and below were omitted in the development of single station NGM MOS max/min temperature equations for the cool season.



NGM MOS IS HERE!!

- Warm season (April-September) equations were implemented July 26, 1989 for 204 stations. Cool season (October-March) equations for the same 204 stations were implemented October 4, 1989.

- NGM MOS <u>replaces</u> NGM perfect prog and can be retrieved on AFOS by entering FWCxxx, where xxx is the station desired. Guidance is provided from both the 0000 and 1200 UTC cycles.

-

ELEMENTS	FORECAST PROJECTIONS PROVIDED
- Daytime max/Nighttime min temperature	24-, 36-, 48- and 60-h (approx.)
- Probability of ≥ 0.01" of liq. equiv. precip. (PoP)	12-h periods ending at 24-, 36-, 48-, and 60-h
- Surface wind speed and direction	every 6 hours from 6 - 48 h.
- Probability forecasts of CLR, SCT, BKN, and OVC opaque sky cover, and a best category fcst	every 6 hours from 6 - 48 h

- Tests showed that NGM MOS is superior to NGM perfect prog for max/min, PoP, and sky cover nationwide (skill is about the same for wind) and is competitive with LFM MOS for all elements.

- Use of NGM predictors below 850-mb may give NGM MOS the edge in situations where shallow cold air is present (especially for max/min temperature and wind). However, some model thermal predictors at 850-mb and below were omitted in developing cool season max/min temperature equations for 40 elevated stations across the Rockies.

- Unlike NGM perfect prog, NGM MOS forecasts will tend towards climate with increasing projection.

IN GENERAL, STATISTICAL FORECASTS:

- are as accurate as the models that supply the input.
- cannot account for random model errors.
- can predict, but may underestimate extreme conditions.
- can account for systematic model bias.
- cannot account for effects that occur on the sub-grid scale.