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# HOW TO USE THE NGM MOS GUIDANCE EFFECTIVELY: PART I - PROBABILITY OF PRECIPITATION

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## 1. INTRODUCTION

The Model Output Statistics (MOS) guidance system is undergoing a major change. Since the late 1970's, MOS forecasts have been generated by equations based on LFM data as input. These predictions have served as the main source of statistical guidance provided to field forecasters. In the late 1980's, the NWS Techniques Development Laboratory (TDL) began the process of developing MOS guidance from NGM data. This effort is nearly complete, and during 1993, it is expected that the LFM MOS guidance will be phased out and the NGM MOS guidance, described in Technical Procedures Bulletin No. 408 (Dallavalle et al. 1992), will become the primary statistical guidance package used by field forecasters. As a result, I have prepared a series of technical attachments (similar to the earlier series--Maglaras 1986, 1987a, 1987b, 1987c), which includes information and guidelines on how forecasters can use the NGM MOS guidance effectively.

Forecasters generally know how to diagnose and then adjust MOS forecasts when they suspect the NGM is inaccurate for a given region or area (e.g., the NGM is too wet or dry, too fast or slow). However, even when the NGM is on target, there will be times when the MOS guidance will be inconsistent or erroneous. These situations are usually difficult to diagnose, so this series of technical attachments will seek to help forecasters spot and correctly interpret these NGM MOS forecasts. Each article will provide general information about a particular weather element, tips and guidelines on how to use the guidance effectively, a discussion of any differences between the LFM and NGM versions of the MOS guidance, and, finally, a description of the new refinements (or enhancements) that were included in the NGM MOS guidance. I begin this series with a discussion of the MOS probability of precipitation (PoP) guidance.

## 2. BACKGROUND AND DEFINITIONS

The equations (Su 1993) that produce the PoP forecasts are based on developmental data, stratified into two seasons, warm and cool, valid April-September and October-March, respectively. This means that different sets of equations are used for each of these seasons. Tables 1 and 2 show sample NGM MOS PoP equations for the cool and warm seasons, respectively. This stratification is necessary in order to try to take into account seasonal variations in weather patterns and the different relationships between model variables and precipitation occurrence.

MOS PoP guidance is a regionalized system. This means that the same equation produces an entire set of probability forecasts for a particular projection for a group of stations. For the regional equations, only the values of the predictors from the NGM vary from station to station. The regions used operationally for the warm and cool seasons are considerably different than those associated with the LFM MOS PoP guidance. Figures 1 and 2 show the regions used to develop the NGM and LFM PoP equations, respectively, for the cool season. Figures 3 and 4 are analogous, but for the warm season.

The 6-hr PoP equations are derived simultaneously with the corresponding 12-hr PoP equation. As a result, the three equations for each 12-hr period contain the same predictors, but the coefficients for each predictor are different, as shown in Tables 1 and 2. Simultaneous derivation is used in order to minimize inconsistent forecasts such as a 6-hr PoP being higher than the corresponding 12-hr PoP. Despite simultaneous derivation, inconsistent MOS PoP forecasts still occur. In fact, inconsistencies may appear to occur more often now because the NGM-based PoP values are rounded only to the nearest whole percent. (Note: the LFM MOS PoP forecasts are rounded to the nearest 10 percent and this tends to hide minor inconsistencies.)

MOS PoP equations have always used a combination of predictors in continuous and binary form; however, the NGM MOS PoP equations also make use of a new kind of predictor known as a grid-binary predictor, which will be described later. For continuous predictors, the NGM variables are multiplied directly by the coefficient in the equation. As a result, the MOS forecast changes linearly as the value of the predictor increases or decreases. Predictor one in Table 2, the NGM 18-hr mean relative humidity (MEAN RH) forecast, is a continuous predictor.

Since the PoP is not always linearly related to the NGM predictors, predictors are also used in binary form. Predictor seven in Table 2, the NGM 12-hr MEAN RH forecast with a binary limit of 70%, is a binary predictor. A binary predictor is set to zero or one depending on the value of a model predictor. If the value of the NGM 12-hr MEAN RH (the model predictor) is less than or equal to 70% (the binary limit), then this binary predictor is set to one; otherwise, it is set to zero. As a result, there could be a large change in the PoP if the forecast for the model predictor was slightly different. For example, the coefficients of predictor seven indicate that 10.9%, 0.4% and 6.6% will be subtracted from the 12-18, 18-24, and 12-24 hr PoP forecasts, respectively, when the NGM 12-hr MEAN RH is 70% (the binary predictor is given a value of one). If the NGM 12-hr MEAN RH is 71% (the binary predictor is given a value of zero), then 0% will be contributed to each PoP forecast and effectively, the PoP is 10.9%, 0.4% and 6.6% greater respectively, for just a 1% change in the mean RH.

In order to avoid large changes to the PoP forecast associated with small variations in the forecast value of a model predictor, the grid-binary predictor was developed. Unlike the simple binary predictor, which involves the value of the model predictor at a single point (the station location), the grid-binary predictor examines the value of the model predictor at numerous grid points around the station. Based on the value of the model predictor, each grid point is given a value of zero or one, then the entire grid point field of zeros and ones is smoothed and interpolated to the station location. Thus, grid-binary predictors can be assigned a value between zero and one. This means that a slight difference in the model predictor will cause only a slight change to the value of the grid-binary predictor, and this will result in only a slight change to the PoP forecast. (Note: at each grid-point, grid-binary predictors are assigned a value of one when the model predictor is greater than or equal to a given binary limit, and zero otherwise. This is the reverse of the method used for simple binary predictors). Predictor one in Table 1 is a grid-binary predictor, the NGM 12-24 hr precipitation amount (P AMT) forecast with a binary limit of .01. If this grid-binary predictor is assigned a value of 0.5, then 13.6%, 8.1% and 23.7% will be added to the 12-18, 18-24, and 12-24 hr PoP forecasts, respectively.

For both the cool and the warm seasons, by far the most important predictors in the PoP equations are the MEAN RH, "850 and 700 mb relative humidity (RH)," and P AMT. Other frequently used predictors (but of secondary importance) are precipitable water (P WATER) and K index, and for various levels, the "moisture divergence (M DIV)," U and V wind components, vertical velocity (VV), and relative vorticity (VORT). (The predictors in quotes denote the ones that were not used by the LFM MOS PoP equations.) It should also be noted that the NGM MOS PoP equations do not use weather elements from surface observations as predictors (Su 1993).

## 3. TIPS AND GUIDELINES

The regionalized, MOS PoP equations generally do not take into account local effects such as upslope-downslope flow, lake effect, etc., unless these influences are the same throughout the entire region. Field forecasters should examine the regions and note any stations within a region that have a frequency of precipitation significantly different from the average for the region. If the difference in the frequency of precipitation for these stations appears to be caused by elevation, or some local effect not common throughout the region, then forecasters should adjust the MOS PoP guidance for the stations accordingly. Another reason why it is important to be aware of regional boundaries within the forecast area is that, given relatively similar NGM forecasts for two neighboring stations, the PoP forecasts for the two stations might differ considerably because the stations are in separate regions and two different equations produced the PoP forecasts.

As discussed earlier, despite simultaneous equation development, inconsistent 6-hr and 12-hr MOS PoP forecasts can occur. When inconsistencies do occur, they are usually the result of very rapid movement of weather systems, or some other situation that results in a very rapid decrease in moisture and precipitation early in the 12-hr period, or a rapid increase late in the 12-hr period. The equations for the 12-hr PoP tend to give more weight to variables in the center of the period. Thus, when rapid changes occur at the beginning or end of the 12-hr period, the 12-hr PoP forecast is less likely to reflect a rapid change than the corresponding 6-hr PoP forecast. For example, assume the NGM precipitation amount forecast is .08 for the first 6 hours of the 12-24 hr period after 0000 GMT, and that all RH fields are near 100% at 12 hours, but drop to less than 70% at 18 and 24 hours (not an unusual situation). In such a scenario, Table 1 shows that grid-binary predictors one, three and seven would likely be given values near one, while predictors two, four, five, eight and 10 would be given values near zero. As a result, the total contribution by all RH and P AMT predictors would be around 69%, -12%, and 56% for the 12-18, 18-24 and 12-24 hr PoP forecasts, respectively. Since the contributions from the other predictors is generally small, it is likely that the 6-hr PoP for the 12-18 hr projection would be 14% higher than the corresponding 12-hr PoP. (To better understand how this calculation was made, the reader may wish to move ahead to section 4, which shows an example of how MOS forecasts are calculated).

Similar to the LFM MOS PoP equations, NGM RH forecasts are by far the most important predictors in the NGM MOS PoP equations for the Eastern Region during the warm season. However, in addition to MEAN RH forecasts, the NGM MOS PoP equations also include the RH forecasts for the 850 and 700 mb levels, which are useful for events where moisture is confined to a narrow layer. In most cases, these three RH predictors dominate the warm season equations to such an extent that it is difficult to get a PoP above 30% when none of these variables are forecast to be 70%, or more. As a result, precipitation events which occur even though the RH variables are correctly forecast to be below 70%, will be associated with low probabilities. Warm season convective events, of course, often occur when the RH variables are correctly predicted to be less than 70%.

For the cool season, the NGM RH and P AMT forecasts are equally important. The combination of these two variables dominates the cool season equations. Hence, if the NGM does not forecast any of the RH variables to be 70% or more, and the P AMT forecasts are less than .01, then the PoP forecast will be near zero. On the other hand, even if the P AMT forecast is zero, PoP forecasts of 70% or 80% are still possible if the RH is high. During the cool season, lake effect and low level easterly flow off the Atlantic are examples of weather patterns that can produce precipitation events even though the RH variables are correctly forecast to be less than 70%.

Knowledge of the predictors that were not included, or were not very important, in the PoP equations can reveal what type of events will not be forecast well by the guidance. For the cool season, variables below the 850 mb level are not very important in the PoP equations. This can produce low PoPs where the moisture and forcing mechanisms initiating the precipitation are below 850 mb such as low-level easterly flow off the Atlantic or lake effect events. Similarly, the PoPs could be low during the warm season, especially for summertime convective events where the moisture source and primary forcing mechanisms are based very close to the surface. However, many of the PoP equations for the warm season make use of the 950 mb moisture convergence as a predictor, and this should help to reduce the problem to some degree. (This is also the case for the cool season, but to a lesser extent.)

The most likely time of day for warm season precipitation in the Eastern Region is during the late afternoon and evening, especially for convective events. Forecasters should keep in mind that the MOS 12-hr PoP forecasts are valid from 0000-1200 UTC and 1200-0000 UTC. As a result, the two 12-hr PoP forecasts may be lower than a single 12-hr PoP forecast would have been if it was valid for the period from 1800-0600 UTC.

Maglaras (1987b) noted that considerable variations in the LFM MOS PoP forecasts can occur for two nearby stations in the same region, even though the synoptic situation is similar at both stations, possibly because a simple binary predictor was turned "ON" at one station and "OFF" at another station due to a very small difference in the value of the model predictor from one station to the other. This situation will rarely occur with the NGM MOS PoP equations because most predictors in the equations are in continuous or grid-binary form.

## 4. SAMPLE MOS POP CALCULATION

When an inaccurate MOS PoP forecast occurs, and the apparent reason is not that the NGM model is too fast (or slow) or too wet (or dry), then recreating the MOS forecast may point to a particular weakness in the equations, which could occur again for similar events. Thus, a sample forecast calculation is provided to help forecasters better understand how the MOS system works. This approach can also be used for case studies.

The sample calculation shown below is for the 12-24 hr PoP equation shown in Table 1. For simplicity, we assume that all grid-binary predictors have been assigned a value of 0.5, that the 850 mb VV is -.001, and that the P WATER is 10 (see Table 3 for the units of VV, P WATER and the other variables used by MOS equations).

| | NGM PREDICTOR | TYPE | PREDICTOR COEFFICIENT | | PREDICTOR VALUE | | CONTRIBUTIONS | | |
|---|---|---|---|---|---|---|---|---|---|
| | constant | -- | -- | x | -- | = | .019 | or | 1.9% |
| 1) | 12-24 hr P AMT | grid-binary | .474 | x | 0.5 | = | .237 | or | 23.7% |
| 2) | 24-hr MEAN RH | grid-binary | .038 | x | 0.5 | = | .019 | or | 1.9% |
| 3) | 12-18 hr P AMT | grid-binary | -.044 | x | 0.5 | = | -.022 | or | -2.2% |
| 4) | 18-24 hr P AMT | grid-binary | .224 | x | 0.5 | = | .112 | or | 11.2% |
| 5) | 18-hr MEAN RH | grid-binary | .058 | x | 0.5 | = | .029 | or | 2.9% |
| 6) | 18-hr P WATER | continuous | .0040 | x | 10.0 | = | .040 | or | 4.0% |
| 7) | 12-hr 700mb RH | grid-binary | .125 | x | 0.5 | = | .063 | or | 6.3% |
| 8) | 24-hr 700mb RH | grid-binary | .054 | x | 0.5 | = | .027 | or | 2.7% |
| 9) | 850 mb VV | continuous | -15.13 | x | -.001 | = | .015 | or | 1.5% |
| 10) | 18-hr 700mb RH | grid-binary | .111 | x | 0.5 | = | .056 | or | 5.6% |
| 11) | 24-hr K INDEX | grid-binary | .047 | x | 0.5 | = | .024 | or | 2.4% |
| | PoP FORECAST | | | | | | .619 | or | 61.9% |

The result is a PoP of 62%, which appears to be reasonable since we assumed all grid-binary predictors would have a value of 0.5, indicating a borderline precipitation event. Also note that more than half of the final PoP forecast was the result of contributions from only two predictors (predictors one and four), which are both NGM P AMT forecasts.

## 5. ACKNOWLEDGEMENTS

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## 6. REFERENCES

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| | NGM predictor | type | binary limit | 12-18 hr coefficient | 18-24 hr coefficient | 12-24 hr coefficient |
|---|---|---|---|---|---|---|
| | constant | N/A | N/A | .002 | .022 | .019 |
| 1) | 12-24 hr P AMT | grid-binary | .01 | .272 | .162 | .474 |
| 2) | 24-hr MEAN RH | grid-binary | 90% | -.072 | .173 | .038 |
| 3) | 12-18 hr P AMT | grid-binary | .05 | .285 | -.253 | -.044 |
| 4) | 12-24 hr P AMT | grid-binary | .10 | .130 | .504 | .224 |
| 5) | 18-hr MEAN RH | grid-binary | 80% | .161 | .035 | .058 |
| 6) | 18-hr P WATER | continuous | N/A | .0008 | .0052 | .0040 |
| 7) | 12-hr 700mb RH | grid-binary | 80% | .137 | -.028 | .125 |
| 8) | 24-hr 700mb RH | grid-binary | 90% | -.107 | .123 | .054 |
| 9) | 850 mb VV | continuous | N/A | -6.79 | -21.39 | -15.13 |
| 10) | 18-hr 700mb RH | grid-binary | 90% | .177 | .138 | .111 |
| 11) | 24-hr K INDEX | grid-binary | 20 | .000 | .104 | .047 |

Table 1. NGM MOS 6-hr and 12-hr PoP cool season equations for the 12-18, 18-24, and 12-24 hr projections from 0000 UTC for region 18.

| | NGM predictor | type | binary limit | 12-18 hr coefficient | 18-24 hr coefficient | 12-24 hr coefficient |
|---|---|---|---|---|---|---|
| | constant | N/A | N/A | .276 | .017 | .090 |
| 1) | 18-hr MEAN RH | continuous | N/A | .0010 | .0005 | .0009 |
| 2) | 24-hr MEAN RH | grid-binary | 80% | .099 | .185 | .159 |
| 3) | 24-hr P WATER | continuous | N/A | -.0168 | -.0009 | -.0168 |
| 4) | 12-24 hr P AMT | grid-binary | .05 | .106 | .219 | .243 |
| 5) | 18-hr MEAN RH | grid-binary | 80% | .259 | .005 | -.012 |
| 6) | 24-h 850mb VORT | continuous | N/A | .012 | .022 | .020 |
| 7) | 12-hr MEAN RH | simple binary | 70% | -.109 | -.004 | -.066 |
| 8) | 700 mb U wind | continuous | N/A | .0035 | .0030 | .0055 |
| 9) | 24-hr MEAN RH | grid-binary | 70% | .024 | .164 | .196 |
| 10) | 18-h 950mb MDIV | continuous | N/A | -.0048 | -.0020 | -.0050 |
| 11) | 18-hr 700mb RH | grid-binary | 80% | .152 | .017 | .139 |
| 12) | 12-18 hr P AMT | simple binary | .01 | -.096 | -.018 | -.024 |
| 13) | 24-hr MEAN RH | grid binary | 90% | .032 | .246 | .082 |

Table 2. Same as Table 1, except for the warm season for region 21.

| | | |
|---|---|---|
| Model Temperatures | - | °K |
| Model Dew Points | - | °K |
| Relative Vorticity | - | $sec^{-1} \times 10^{-5}$ |
| Height | - | meters |
| Thickness | - | meters |
| Pressure | - | mb |
| Temperature Advection | - | $°C\ sec^{-1} \times 10^{-5}$ |
| Vertical Velocity | - | mb/sec |
| Wind Speed | - | m/sec |
| Vorticity Advection | - | $sec^{-2} \times 10^{-10}$ |
| Divergence | - | $sec^{-1} \times 10^{-5}$ |
| Moisture Divergence | - | $sec^{-1} \times 10^{-8}$ (g/g) |
| Precipitable Water | - | $Kgm^{-2}$ |
| Precipitation Amount | - | meters |
| Q-vector Divergence | - | $mKg^{-1}s^{-1} \times 10^{17}$ |

Table 3. Units of the NGM predictor variables used by the NGM MOS guidance.

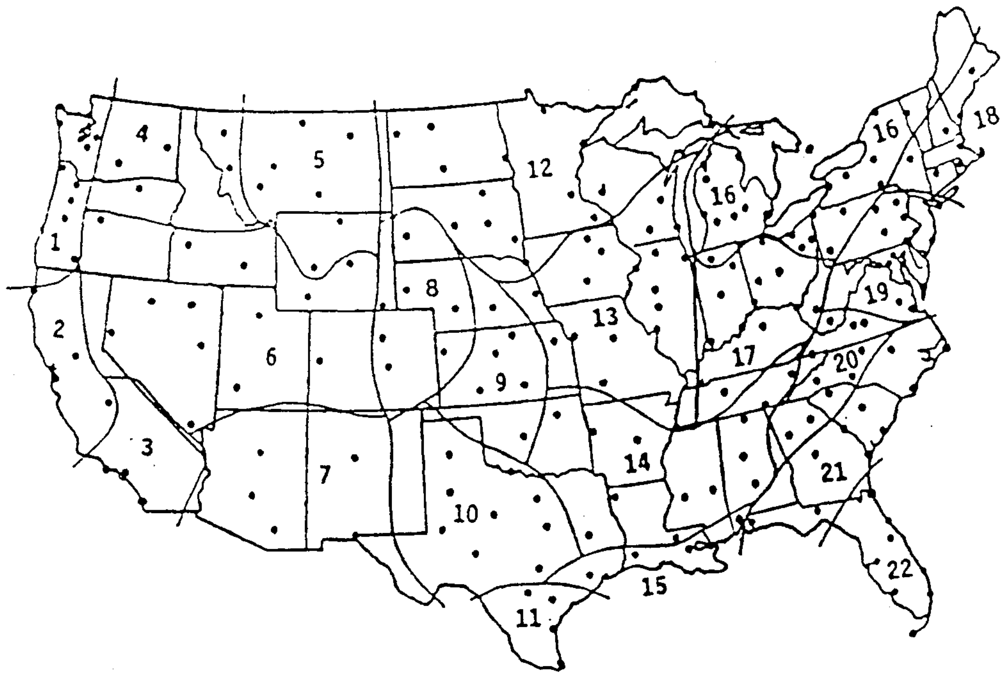


Figure 1. The 22 geographical regions used in the development of NGM MOS PoP equations for the cool season.

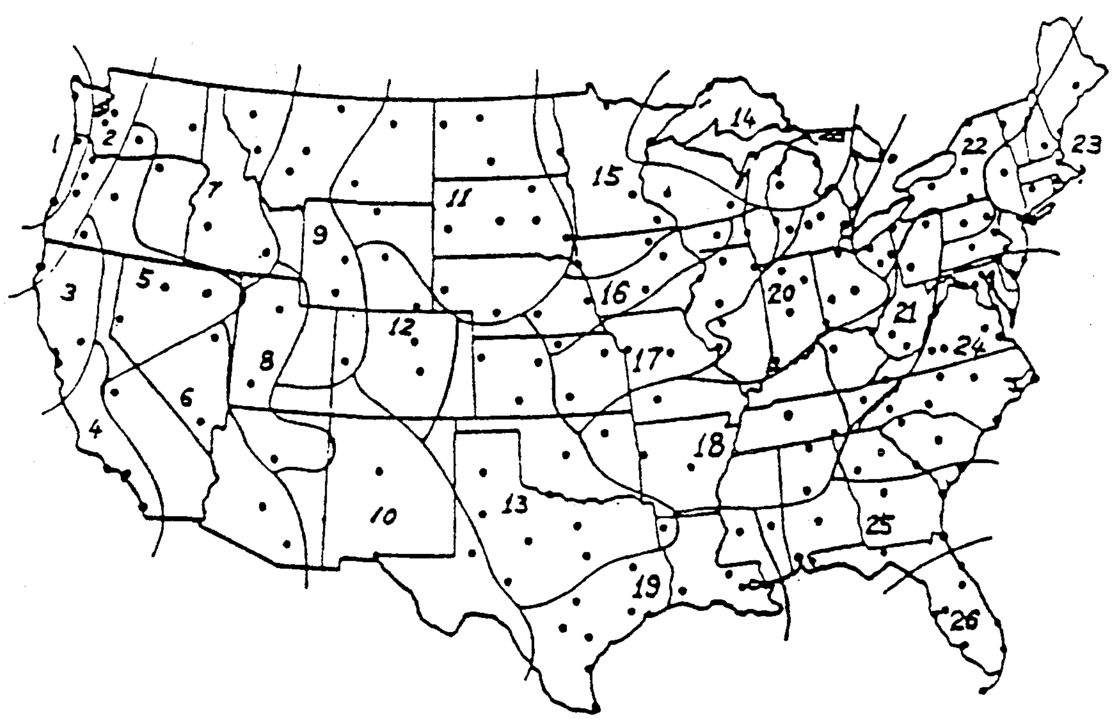


Figure 2. The 26 geographical regions used in the development of LFM MOS PoP equations for the cool season.

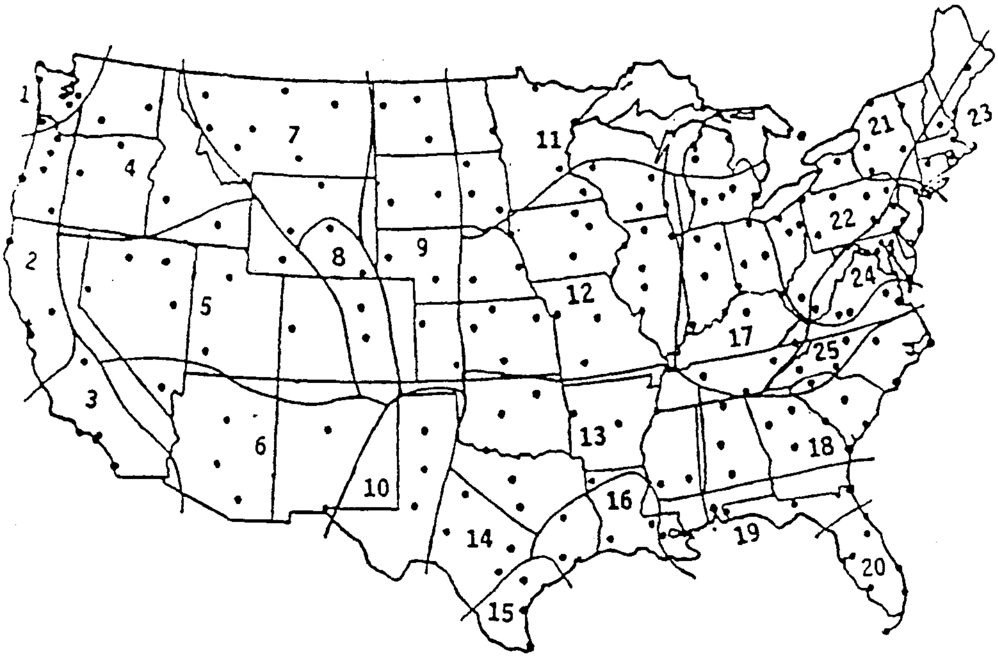


Figure 3. The 25 geographical regions used in the development of NGM MOS PoP equations for the warm season.

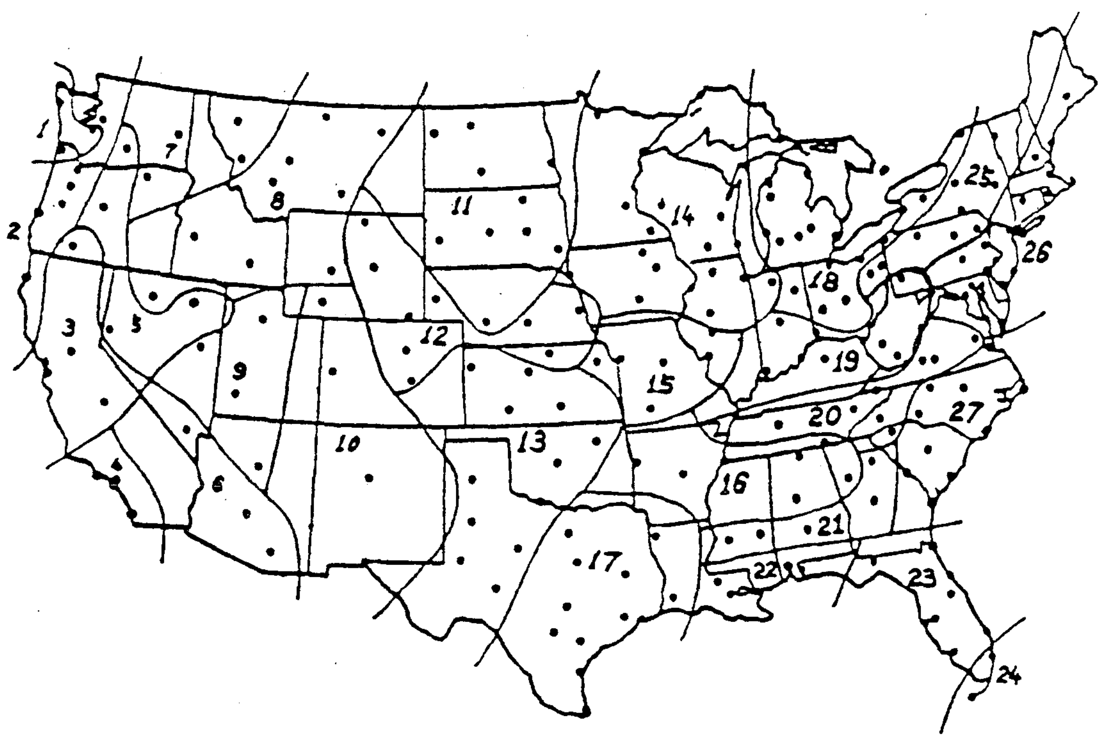


Figure 4. The 27 geographical regions used in the development of LFM MOS PoP equations for the warm season.