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USING THE NATIONAL WEATHER SERVICE'S NGM-BASED STATISTICAL GUIDANCE FOR SHORT-RANGE FORECASTING

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1. INTRODUCTION

The Techniques Development Laboratory of the National Weather Service (NWS) recently implemented a new statistical weather forecast system for short-range projections. Based on output from the National Meteorological Center's Nested Grid Model (NGM) (Hoke et al. 1989), this system produces public and aviation guidance for projections of 6 to 60 hours. The new guidance was developed by applying the Model Output Statistics (MOS) approach (Glahn and Lowry 1972) and will replace a MOS guidance package developed in the late 1970's and early 1980's from the Limited-area Fine-mesh Model.

The NGM-based MOS guidance is available for over 300 stations in the contiguous United States during the 0000 and 1200 UTC forecast cycles. Forecasts of maximum/minimum (max/min) temperature, surface temperature, surface dew point, surface wind, probability of precipitation (PoP), precipitation amount, precipitation type, snow amount, thunderstorms, severe thunderstorms, opaque cloud cover, ceiling height, visibility, and obstruction to vision are displayed in an alphanumeric message. In this paper, we discuss the forecast message and provide guidelines for interpreting the guidance.

2. WEATHER ELEMENT DEFINITIONS

In developing the MOS forecast equations, we first define the weather element to be predicted (the predictand). For instance, the max (min) temperature is the highest (lowest) value observed at a station from 7 a.m. to 7 p.m. Local Standard Time (7 p.m. to 8 a.m. Local Standard Time). The surface temperature, dew point, wind direction and speed, ceiling height, opaque cloud cover, visibility, obstruction to vision, and precipitation type predictands are station values observed at specific hours. The precipitation reports used in developing the PoP, precipitation amount, and snow amount equations are station values observed during 6- or 12-h intervals.

In contrast to these station-specific predictands, the thunderstorm and severe thunderstorm predictands are area-specific; that is, the occurrence of a thunderstorm or severe thunderstorm is defined for a rectangular area surrounding a station that is approximately 115 km on a side (Bower 1993). Thus, the thunderstorm probabilities indicate the likelihood of a thunderstorm over a <u>station's area</u>. The PoP indicates the likelihood of precipitation at the <u>station site</u>.

Two elements in the NGM MOS forecast system, namely, precipitation type and severe thunderstorms, are "conditional" predictands. That is, forecasting either precipitation type or severe thunderstorms inherently assumes that precipitation or thunderstorms, respectively, will occur. Only precipitation cases or thunderstorm events are included in the developmental sample. Thus, the MOS conditional forecasts are virtually meaningless if the unconditional event (precipitation or thunderstorms) is not expected.

3. THE MOS ALPHANUMERIC MESSAGE

Figure 1 shows the NGM MOS guidance issued for Roanoke, Virginia, during the 1200 UTC

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ROA         NGM MOS GUIDANCE    2/05/93   1200 UTC
DAY /FEB  5 /FEB   6                 /FEB   7                /
HOUR    18 21 00 03 06 09 12 15 18 21 00 03 06 09 12 15 18 21 00
MN/MX                     33          54          24          38
TEMP    52 56 47 42 39 38 36 46 52 49 42 36 30 27 25 28 35 38 33
DEWPT   21 21 23 24 24 24 24 27 27 24 22 20 19 18 18 17 16 17 18
CLDS    CL XX CL XX CL XX SC XX BK XX SC XX SC XX CL XX CL XX SC
WDIR    17 19 19 27 29 29 30 29 30 33 35 34 01 36 03 11 11 11 12
WSPD    04 07 04 04 06 06 05 07 10 09 12 10 08 07 05 04 02 04 05
POP06          0     2     1     4     4     0     0     0     3
POP12                      3           8           0           2
TSV06       0/11  0/ 3  1/ 1  3/ 0  0/ 4  0/ 0  0/ 1  0/ 1  1/ 0
TSV12             0/11        3/ 0        0/ 4        1/ 2
PTYPE    R  R  R  R  R  R  R  R  R  R  S     S     S     Z     Z
POZP     3  1  5  8  0  0  5  9  3  0  0     4    16    31    23
POSN     3  2  0  2  6  6 10 17 27 45 56    72    68    54    40
CIG      7  7  7  7  7  7  7  7  6  6  6     7     7
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Figure 1. NGM MOS guidance for Roanoke, Virginia, for the 1200 UTC cycle on February 5, 1993.

forecast cycle on February 5, 1993 (see Dallavalle et al. 1992 for an explanation of the message). Note that opaque cloud cover, precipitation type, and ceiling height forecasts are encoded, categorical values. These forecasts are generated by using probability forecasts of categories of these elements in such a way as to optimize a specific measure of skill.

4. DEVELOPMENTAL CONSIDERATIONS

Except for the mean relative humidity between the surface and approximately 500 mb, the precipitation amount, and the precipitable water, all of the predictor variables are interpolated from the NGM's vertical sigma coordinates to constant pressure surfaces. The basic meteorological variables at these pressure surfaces are forecasts of temperature, relative humidity, geopotential height, and the three-dimensional wind field. Furthermore, predictors used in the NGM MOS equations are not taken from the computational grid, but from a grid with half the horizontal resolution. Even with this coarser grid, further spatial smoothing is usually necessary to provide the most useful predictors. Finally, although we produce MOS forecasts such as temperature, dew point, clouds, and wind at 3-h intervals, the NGM variables used as predictors are only available for projections of 6, 12, 18, ..., 42, and 48 hours. To compensate for this lack of temporal resolution, we use time-averaged or time-differenced predictors.

Despite these limitations, we use meteorological forecasts that are seldom seen by the operational forecaster. Thus, the NGM temperature, relative humidity, and wind forecasts are available at pressure surfaces every 50 mb from 1000 to 700 mb. We also generate derived variables that attempt to mimic the forecaster's analysis. Some of these derived predictors are as simple as the 1000-850 mb or 850-500 mb thicknesses. Various stability indices, vorticity, moisture divergence, and the divergence of Q-vectors are some of the more computationally complex variables. Finally, the NGM MOS equations incorporate a number of novel predictors, including variables that indicate shallow cold air topped by a warm (above freezing) layer, the relationship between low-level thickness and snowfall at specific sites, and the combined effects of upward vertical velocity and high relative humidity.

5. GUIDANCE CONSISTENCY

We used two developmental techniques to enhance meteorological consistency in the MOS forecasts. First, we developed equations for certain related weather elements, for example, temperature and dew point, at the same time. This ensured that the same predictors were used, although the coefficients differed. Secondly, similar predictors were used for related predictands. For instance, the same general predictors were used for ceiling height and cloud equations. These techniques, however, do not guarantee consistency in the resulting MOS forecasts. Thus, in post-processing the MOS forecasts before issuance, we perform certain consistency checks for the temperatures and dew points. For example, if the predicted dew point exceeds the predicted temperature for the same projection, both values are set to the average of the original forecasts.

Unlike the temperature and dew point guidance, we make no effort to check most of the MOS guidance, preferring that the forecaster reconcile inconsistencies with his/her interpretation of the meteorological conditions. In Fig. 1, notice that the ceiling and cloud guidance valid at 0000 UTC on February 7 indicate that a ceiling height of category 6 (6500 - 12000 feet) is expected with scattered clouds. These forecasts are inconsistent since a ceiling is defined as opaque cloud cover of 0.6 or more sky coverage, that is, broken sky cover conditions. Other potential inconsistencies (not necessarily seen in Fig. 1) include a 12-h PoP (thunderstorm probability) less than a 6-h PoP (thunderstorm probability) valid during one of the 6-h periods comprising the 12-h period. A third type of inconsistency occurs when precipitation is expected and the precipitation type guidance indicates rain with temperatures predicted below freezing, or freezing rain when temperatures are predicted to be above freezing. An apparent inconsistency in Fig. 1 is actually a function of the predictand definition. Notice that the precipitation type guidance for 0000 UTC on February 7 indicates snow while the temperature forecast is for 42° F. Remember that the precipitation type guidance is conditional upon precipitation occurring and that the 6-h PoP's around this time are near or equal to zero, indicating that precipitation is not likely.

Despite inconsistencies, the MOS guidance generally presents a realistic picture of expected conditions. Note in Fig. 1 that a minor feature is expected around 1800 UTC on February 6. Thus, broken cloud cover is forecast at 1800 UTC with a ceiling between 6500 and 12000 feet. The PoP's, although very low, rise slightly. After the feature passes, the winds veer to a more northerly direction, the temperature and dew point fall, and the ceiling becomes unlimited.

6. GUIDELINES FOR USING MOS

Three approaches can be taken to using the MOS guidance: ignore the guidance, accept the guidance without question, or use the guidance as a tool in helping to make a forecast. We suggest that the third approach is the most valuable. Here are some general guidelines that may help in the analysis process.

- MOS is based on the application of multiple linear regression which minimizes the mean square error. Consequently, MOS forecasts the average observed meteorological conditions, given conditions predicted by the NGM. Thus, the MOS guidance can correct for some of the systematic bias found in the NGM forecasts. However, the MOS guidance will probably not correct for biases that occur only under certain synoptic situations. Thus, it is important for the forecaster to build a local climatology of MOS errors.

- We have attempted to mimic the meteorological thought process, particularly in regard to using the vertical atmospheric structure. Thus, the user is warned not to discard the guidance because it seems inconsistent with the forecast 1000-500 mb thickness or the 500-mb geopotential height. Remember that the use of the NGM in the lower troposphere is extremely important in predicting weather elements such as precipitation type, ceiling height, or temperature. The MOS equations, by using a sophisticated set of predictors, incorporate meteorological information that the human often can not use in an operational environment.

- The forecaster should consult the alphanumeric messages (National Weather Service 1985) that contain direct NGM forecasts from the fine-scale computational grid. The vertical resolution available in these products can assist in assessing the information contained in the NGM MOS forecasts. The forecaster is reminded, however, that smoothing of the NGM predictors, even though extracted from a coarser output grid, is essential for maximizing the accuracy of the MOS guidance. In other words, the detail found in the raw NGM output is not always representative of atmospheric conditions. In the mean, smoothing of the predicted fine-scale features is useful. The challenge to the forecaster is to decide when smoothing of these features, as done in the MOS equations, is not desirable.

- Because of the horizontal and temporal scale of the predictors used in the NGM MOS equations, mesoscale features are unlikely to be predicted well by the MOS guidance. The forecaster should consult NGM forecasts of precipitation amount displayed on the graphical model output (and extracted from the fine-scale computational grid) to determine whether mesoscale features are predicted by the NGM and missed by the MOS guidance.

- The MOS guidance tends toward mean conditions with increasing projection because the NGM is less accurate with increasing model projection. The MOS guidance also uses predictors at 6-h intervals. Nevertheless, we've observed that the NGM MOS forecasts are much sharper and show much more detail, even at later projections, than we've seen with previous statistical forecast packages. This is a direct consequence of the meteorological information contained in the NGM.

-- No NGM forecasts are available at projections beyond 48 hours. Thus, the MOS guidance at the 54- and 60-h projections are extrapolations of conditions predicted at 48 hours. During active meteorological conditions, the MOS forecasts should be modified accordingly.

-- The thunderstorm probabilities are for an area while the PoP's are point probabilities. Particularly in convective situations, the thunderstorm probabilities will exceed the PoP's. We've found the thunderstorm probabilities are good signals of heavy precipitation events, even during the cooler months of the year.

-- The lowest layer in the NGM has a thickness of about 30 mb. Since this thickness indicates the limit in the NGM's vertical resolution, the MOS ceiling height forecasts might not be able to distinguish ceilings in the lowest 300 m of the atmosphere. In fact, the NGM MOS ceiling height forecasts are skillful in distinguishing between ceilings below or above 300 m, but the skill of the guidance decreases substantially in distinguishing among ceiling height categories below 300 m. Nevertheless, the ceiling and cloud guidance are helpful in indicating the presence or absence of specific ceiling layers.

-- The forecaster should consider the temporal and spatial continuity in the MOS forecasts. If the guidance for a particular projection at a station looks anomalous, consideration of the guidance at adjacent projections or adjacent locations can assist in making an informed decision about the quality of the guidance. Similarly, errors in the NGM MOS temperature guidance tend to be associated with specific meteorological features as weather systems migrate across the U.S. Knowledge of the NGM MOS performance during a previous guidance cycle upstream of the forecaster's station should aid in use of the guidance.

-- While the MOS guidance can predict record events on a given day, the user must recognize that the representativeness of the developmental sample contributes to the accuracy of the guidance. By definition, the approaching "storm of the century" will not have been in the MOS developmental sample. Snow cover at a station that normally has no snow may adversely affect the temperature forecasts. The PoP's or precipitation amount forecasts may lack skill at stations that were in drought regimes when the guidance was developed. Knowledge of the local climate is essential to interpreting the MOS guidance.

-- Remember that the "M" in MOS does not stand for Magic. The MOS guidance will not correct for random NGM errors or bad forecasts. If the NGM forecasts err badly in predicting movement or development of meteorological features, the MOS guidance will likely represent these bad forecasts in a faithful manner.

-- Use the MOS guidance as a tool to understand what the NGM is predicting, in view of a history of prior predictions. The meteorologist must critically and intelligently interpret the guidance in view of her/his own knowledge and the availability of other forecast tools.

7. REFERENCES

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