A QUIZ ON THE INTERPRETATION AND USE OF THE NATIONAL WEATHER SERVICE'S STATISTICAL GUIDANCE PRODUCTS

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Abstract

In addition to the tasks of developing, maintaining, and improving the quality of the statistical guidance system that provides forecasts of sensible weather elements for several hundred sites across the contiguous 48 states and Alaska, the Techniques Development Laboratory of the National Weather Service has also expended considerable effort in training forecasters on the use and interpretation of the statistical guidance. This paper is another installment in our training effort and is based largely upon questions we have received from forecasters over the years. Section 2 consists of a review on how to read and interpret the LFM MOS bulletin. Section 3 of the paper consists of a quiz that tests the reader's knowledge on how to interpret and use statistical guidance. Used in conjunction with the answer key and explanations, Section 4, the quiz is designed to provide forecasters with background information that will help them to decide when (and when not*) to adjust the statistical forecasts.*

1. Introduction

The Techniques Development Laboratory (TDL) of the National Weather Service (NWS) is responsible for the development and maintenance of statistical prediction equations that produce forecasts of sensible weather elements. These products are disseminated to NWS field forecasters and to other meteorologists in the private and academic sectors. As of this writing, LFM-based guidance produced by the MOS approach (Glahn and Lowry, 1972) is still TDL's flagship short-range (1–2 day) statistical guidance product for over a dozen individual weather elements. While an initial NGM-based MOS guidance package was implemented during the summer of 1989 (Jacks et al., 1990), it will be a year or two before NGM-based guidance becomes available for all elements. Carter et al. (1989) describe the current statistical guidance system.

In this paper, we first present a review on how to decode and interpret the matrix that contains the LFM MOS forecasts. Armed with this information, the reader can then proceed to the remainder of the text, which consists of a quiz on the interpretation and use of these forecasts along with an answer key for reference. This quiz is based upon our experience in training forecasters and upon the results of a survey that TDL sent to NWS forecast offices in the contiguous 48 states during October 1987. In the survey, we asked forecasters to list any questions they had about the interpretation or application of the statistical guidance. A complete description of the survey and its results can be found in Jacks (1988).

2. Decoding and Interpreting the LFM-MOS Bulletin

The goal of this section is to explain how to decode and interpret the LFM MOS bulletin. Each line of the bulletin is explained by using Figure 1 for reference. The weather element(s) under discussion as we proceed through the matrix are shown in bold type. The station being used in the example is Washington National Airport (DCA).

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HDNG FOUS12 LFM-MOS GUIDANCE    12/32/90   1200 UTC
DY/HR      32/18  01/00  01/06  01/12  01/18  02/00  02/06  02/12  03/00
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This is the heading that appears at the top of the LFM MOS bulletin. The hypothetical LFM MOS message shown in Figure 1 is based on LFM data initialized at 1200 UTC on December 32, 1990. (We have extended the year by one day to underscore the fact that these are hypothetical data designed for the purpose of example.) The "FOUS12" refers specifically to the LFM MOS bulletin. (Note that "FOUS14" refers to the NGM MOS bulletin.) The date/hour line (hours shown are in UTC) provides a reference as to the date and hour at which the guidance is valid. In this example, the guidance is valid from December 32, 1990 at 1800 UTC through January 3, 1991 at 0000 UTC. For some of the elements described here, the forecasts are valid at the exact date/hour indicated at the top of each column, while for others the forecasts are valid for 6- or 12-h periods ending at that date/hour. Details on valid times/periods are provided for each element discussed here.

HDNG FOUS12 LFM-MOS GUIDANCE 12/32/90 1200 UTC

DY/HR	32/18	01/00	01/06	01/12	01/18	02/00	02/06	02/12	03/00
POP06		0	40	80	60	30	10	0	
POP12				90		60		10	0
QPF06		000/1	110/1	421/3	210/2	110/1			
QPF12				6321/4		3100/2		2100/1	
TSTM				18		8		2	
POPT	0058/2	0060/2	0158/2	0350/2	0056/2	0065/2	0075/2	0076/2	
POSA				9850/8443/2312/4					
MN/MX				29		34		14	26
TEMP	35 36	35 34	34 33	32 31	32 32	33 32	26 22	18 16	
DEWPT	14 15	17 19	23 24	27 27	28 25	23 20	14 10	9 6	
WIND	1405	1210	0813	0520	0223	3328	3425	3516	
CLDS	7300/1	6310/1	2214/3	0019/4	0127/4	0334/3	3422/2	8200/1	
CIG	000009	000009	000117	014430	013430	011324	000018	000009	
VIS	000009	000009	001018	003214	002105	001018	000009	000009	
C/V	6/6	6/6	3/3	2/3	2/3	4/6	6/6	6/6	
OBVIS	90X0/1	90X0/1	30X6/4	40X6/4	80X3/1	80X3/1	90X0/1	90X0/1	

Fig. 1. Hypothetical FPC message for use with Section 2.

HDNG FOUS12 LFM-MOS GUIDANCE 12/32/90 1200 UTC

DY/HR	32/18	01/00	01/06	01/12	01/18	02/00	02/06	02/12	03/00
POP06		**0**	**40**	**80**	**60**	**30**	**10**	**0**	
POP12				**90**		**60**		**10**	**0**

The POP (probability of precipitation) lines provide forecast probabilities (in percent) of 0.01 in or more of precipitation occurring in a given time period. In particular, the POP06 line provides forecast probabilities for 6-h periods ending at 12, 18, 24, . . . , and 48 h after model initialization, while POP12 forecasts are valid for 12-h periods ending at 24, 36, 48, and 60 h after initialization.

The POP forecasts from Figure 1 indicate that the best chance for precipitation over the 6 to 60-h period is from about the time the apple drops over Times Square through about midday on New Year's Day. In fact, the POP12 valid for the 12-h period ending January 1 at 1200 UTC is 90%. The POP06 provides the additional clue that precipitation is more likely during the second half of this 12-h period (80%) than during the first half (40%). The POP06 also indicates that there is still a 60% chance that precipitation will linger after 1200 UTC on January 1, although that chance decreases to 30% by afternoon.

HDNG FOUS12 LFM-MOS GUIDANCE 12/32/90 1200 UTC

DY/HR	32/18	01/00	01/06	01/12	01/18	02/00	02/06	02/12	03/00
POP06		**0**	**40**	**80**	**60**	**30**	**10**	**0**	
POP12				**90**		**60**		**10**	**0**
QPF06		**000/1**	**110/1**	**421/3**	**210/2**	**110/1**			
QPF12				**6321/4**		**3100/2**		**2100/1**	

The QPF (quantitative precipitation forecast) lines provide forecast probabilities for various categories of precipitation amount occurring in a given time period, along with a "best category" forecast. For QPF06, probability forecasts for three categories ($\geq$0.25, $\geq$0.50, and $\geq$1.00 in, from left to right) are provided for 6-h periods ending at 12, 18, 24, 30, and 36 h after model initialization. At 0000 UTC, QPF06 for the period ending at 42 h is also available. For QPF12, a $\geq$2.00 in category is added at the extreme right before the slash; forecasts are valid for 12-h periods ending at 24, 36, and 48 h after model initialization. All probabilities are in tens of percent rounded to the nearest 10%. For example, the probability forecast of $\geq$0.25 in for the 6-h period ending at 1200 UTC on January 1 is 40%. Similarly, there is a 10% chance that $\geq$2.00 in will occur during the 12-h period ending at that same time.

The "best category" forecast for quantitative precipitation is given after the slash for both QPF06 and QPF12. These best category forecasts are determined by comparing the probability forecasts for each category with statistically determined threshold values. For QPF06 and QPF12, a best category forecast of "1" corresponds to $<$0.25 in, "2" corresponds to 0.25 to 0.49 in, and "3" indicates a forecast of 0.50 to 0.99 in. For QPF06, a best category forecast of "4" corresponds to $\geq$1.00 in, while this same value corresponds to a QPF12 forecast amount between 1.00 and 1.99 in. Finally, a best category forecast of "5" (available for QPF12 only) indicates a forecast of 2.00 in or more.

In this case, the heaviest precipitation is forecast to occur during the period when, according to the POP forecasts, precipitation is most likely. (While this is a desirable attribute of the guidance, note that POP and QPF are not forced to be consistent with each other in this manner.) In particular, the best category forecast is for a "3" (between 0.50 and 0.99 inches) for the 6-h period ending at 1200 UTC on January 1, while a "4" (between 1.00 and 1.99 in) is predicted for the 12-h period ending at that same time.

NOTE: Threshold values for heavier amount categories are set lower than those for lighter amount categories so that heavier categories are selected at least as frequently as they occur in nature.

HDNG FOUS12 LFM-MOS GUIDANCE 12/32/90 1200 UTC

DY/HR	32/18	01/00	01/06	01/12	01/18	02/00	02/06	02/12	03/00
POP06		**0**	**40**	**80**	**60**	**30**	**10**	**0**	
POP12				**90**		**60**		**10**	**0**
QPF06		**000/1**	**110/1**	**421/3**	**210/2**	**110/1**			
QPF12				**6321/4**		**3100/2**		**2100/1**	
TSTM				**18**		**8**		**2**	

LFM MOS probability of thunderstorm forecasts are found on the TSTM line. These forecasts, which are valid for 12-h periods ending at 24, 36, and 48 h after model initialization, estimate the probability of at least a VIP level 3 radar echo occurring within approximately a 48 × 48 km square that contains the station. The manner in which the TSTM equations were developed is significantly different from the manner in which POP and QPF equations were developed. Thus, we do not recommend comparing the probability forecasts between TSTM and these other elements for meteorological consistency. For example, there are sometimes cases where the TSTM probabilities exceed those for POP. Since it rains without thundering much more often than it thunders without raining, this is the reverse of what one would normally expect.

HDNG FOUS12 LFM-MOS GUIDANCE 12/32/90 1200 UTC

DY/HR	32/18	01/00	01/06	01/12	01/18	02/00	02/06	02/12	03/00
POP06		**0**	**40**	**80**	**60**	**30**	**10**	**0**	
POP12				**90**		**60**		**10**	**0**
QPF06		**000/1**	**110/1**	**421/3**	**210/2**	**110/1**			
QPF12				**6321/4**		**3100/2**		**2100/1**	
TSTM				**18**		**8**		**32**	
POPT	**0058/2**	**0060/2**	**0158/2**	**0350/2**	**0056/2**	**0065/2**	**0075/2**	**0076/2**	

The POPT (probability of precipitation type) line provides forecasts of the conditional probability of freezing and frozen precipitation valid at spot times every 6 h from 6 to 48 h after model initialization. By *conditional,* we mean that the occurrence of at least 0.01 in of liquid-equivalent precipitation is assumed. We managed to build this assumption into the equations by including only dates in the developmental sample when precipitation occurred. Thus, POPT guidance is not meaningful in situations where there is little or no chance of precipitation.

For developmental purposes, an observation was considered as "freezing" if it contained freezing rain or freezing drizzle, either alone or in combination with any other type of precipitation. "Frozen" precipitation was defined as any combination of snow and sleet. Conditional probabilities of freezing (POZ) and frozen (POF) precipitation are given by the first two and second two digits, respectively, in percent. (The forecast conditional probability of liquid precipitation for a given projection can be obtained by subtracting the sum of the freezing and frozen forecast probabilities for that projection from 100%.) A "best category" forecast is given after the slash.

As with QPF, a thresholding technique is used to determine the best category forecast (1 = freezing, 2 = frozen, 3 = liquid). In figure 1, category 2, or "frozen," is selected at each forecast projection. Thus, snow is expected, if precipitation occurs. Because freezing precipitation occurs much less frequently than frozen or liquid precipitation, the threshold values for freezing precipitation were set quite low—sometimes to even less than 10%! As with QPF, we lowered the thresholds for the relatively rare event to ensure that "freezing" would be chosen as the best category with approximately the same frequency as actually occurs. Thus, a best category of "freezing" may be chosen even when the POZ is far less than the POF. Even so, freezing precipitation seems quite unlikely anytime during the figure 1 forecast period, as the highest value is for 3% at 1200 UTC on January 1.

HDNG FOUS12 LFM-MOS GUIDANCE 12/32/90 1200 UTC

DY/HR	32/18	01/00	01/06	01/12	01/18	02/00	02/06	02/12	03/00
POP06		**0**	**40**	**80**	**60**	**30**	**10**	**0**	
POP12				**90**		**60**		**10**	**0**
QPF06		**000/1**	**110/1**	**421/3**	**210/2**	**110/1**			
QPF12				**6321/4**		**3100/2**		**2100/1**	
TSTM				**18**		**8**		**32**	
POPT	**0058/2**	**0060/2**	**0158/2**	**0350/2**	**0056/2**	**0065/2**	**0075/2**	**0076/2**	
POSA		**9850/8443/2312/4**							

The probability of snow amount (POSA) guidance is valid for only one 12-h period, ending at 24 h after model initialization. The equations produce conditional probability forecasts for ≥2, ≥4, and ≥6 in of frozen precipitation. In this case, the condition is not only that precipitation occurs, but that it occurs in frozen form. Thus, only cases where frozen precipitation occurred were included in the developmental sample. Conditional forecasts in percent for each of the three amount groups are given by the first two digits in each 4-digit grouping. For example, there is an 84% conditional probability that ≥4 in of snow will fall.

The second two digits in each 4-digit grouping are the unconditional POSA forecasts, in percent. The unconditional forecasts are obtained by multiplying each conditional forecast by the POP12 for that same 12-h period and by a weighted average of the POF's (from POPT) for the 12-, 18-, and 24-h projections. (In particular, the POF for the 18-h projection is given a weight of two, while the POF's for the 12- and 24-h projections are each given a weight of one.) In this manner, the chance that precipitation may take a form other than snow *and* that precipitation may not occur at all are taken into account. Note that the unconditional probability of ≥4 in of snow is only 43%—much less than the conditional forecast of 84%!

Admittedly, applying the concept of conditional and unconditional probabilities can be confusing. Thus, as with QPF and POPT, a POSA best category forecast is also provided. The four possible categories are 0, 2, 4, and 6, which denote forecasts of ≤1 in, 2 or 3 in, 4 or 5 in, and ≥ 6 in of snow, respectively. Thus, in the case of the data provided in figure 1, the best category forecast is for 4 or 5 in of snow.

HDNG FOUS12 LFM-MOS GUIDANCE 12/32/90 1200 UTC

DY/HR	32/18	01/00	01/06	01/12	01/18	02/00	02/06	02/12	03/00
POP06		**0**	**40**	**80**	**60**	**30**	**10**	**0**	
POP12				**90**		**60**		**10**	**0**
QPF06		**000/1**	**110/1**	**421/3**	**210/2**	**110/1**			
QPF12				**6321/4**		**3100/2**		**2100/1**	
TSTM				**18**		**8**		**32**	
POPT	**0058/2**	**0060/2**	**0158/2**	**0350/2**	**0056/2**	**0065/2**	**0075/2**	**0076/2**	
POSA		**9850/8443/2312/4**							
MN/MX				**29**		**34**		**14**	**26**
TEMP	**35 36**	**35 34**	**34 33**	**32 31**	**32 32**	**33 32**	**26 22**	**18 16**	
DEWPT	**14 15**	**17 19**	**23 24**	**27 27**	**28 25**	**23 20**	**14 10**	**9 6**	

LFM MOS forecasts of surface temperature (TEMP) and dew point (DEWPT) are provided (in degrees F) for spot times at 3-h intervals from 6 to 51 h after model initialization. Forecasts for maximum and minimum temperature (MN/MX from 1200 UTC, MX/MN from 0000 UTC) are provided for projections valid approximately 24, 36, 48, and 60 h after model initialization. However, note that the maximum and minimum temperature equations produce forecasts that are valid for daytime and nighttime periods, respectively. Thus, the forecast max for the daytime period ending approximately 0000 UTC on January 2 is for 34° F. To ensure meteorological consistency, we use a technique that guarantees that a dew point forecast will never exceed a concurrent temperature forecast, and that a spot temperature forecast will never exceed (be less than) a max (min) temperature forecast within a given daytime (nighttime) period. Details on this point are provided in the answer key of the quiz.

HDNG FOUS12 LFM-MOS GUIDANCE 12/32/90 1200 UTC

DY/HR	32/18	01/00	01/06	01/12	01/18	02/00	02/06	02/12	03/00
POP06		**0**	**40**	**80**	**60**	**30**	**10**	**0**	
POP12				**90**		**60**		**10**	**0**
QPF06		**000/1**	**110/1**	**421/3**	**210/2**	**110/1**			
QPF12				**6321/4**		**3100/2**		**2100/1**	
TSTM				**18**		**8**		**32**	
POPT	**0058/2**	**0060/2**	**0158/2**	**0350/2**	**0056/2**	**0065/2**	**0075/2**	**0076/2**	
POSA		**9838/8433/2311/4**							
MN/MX				**29**		**34**		**14**	**26**
TEMP	**35 36**	**35 34**	**34 33**	**32 31**	**32 32**	**33 32**	**26 22**	**18 16**	
DEWPT	**14 15**	**17 19**	**23 24**	**27 27**	**28 25**	**23 20**	**14 10**	**9 6**	
WIND	**1405**	**1210**	**0813**	**0520**	**0223**	**3328**	**3425**	**3516**	

The WIND line provides LFM MOS forecasts of surface wind direction and speed valid at spot times every 6 h from 6 to 48 h after model initialization. The first two digits of each four-digit group are the compass direction (in tens of degrees) from which the wind is forecast to come, while the corresponding surface wind speed forecasts are given by the second two digits (in kt). For example, the wind is forecast to be 5 kt out of the southeast (from 140°) at 1800 UTC on December 32, while a shift to north-northwest is expected by the end of the forecast period. The drop in temperature and dew point accompanying this wind shift implies that a cold front is forecast to pass through the area towards the end of the period.

HDNG FOUS12 LFM-MOS GUIDANCE 12/32/90 1200 UTC

DY/HR	32/18	01/00	01/06	01/12	01/18	02/00	02/06	02/12	03/00
POP06		**0**	**40**	**80**	**60**	**30**	**10**	**0**	
POP12				**90**		**60**		**10**	**0**
QPF06		**000/1**	**110/1**	**421/3**	**210/2**	**110/1**			
QPF12				**6321/4**		**3100/2**		**2100/1**	
TSTM				**18**		**8**		**2**	
POPT	**0058/2**	**0060/2**	**0158/2**	**0350/2**	**0056/2**	**0065/2**	**0075/2**	**0076/2**	
POSA		**9850/8443/2312/4**							
MN/MX				**29**		**34**		**14**	**26**
TEMP	**35 36**	**35 34**	**34 33**	**32 31**	**32 32**	**33 32**	**26 22**	**18 16**	
DEWPT	**14 15**	**17 19**	**23 24**	**27 27**	**28 25**	**23 20**	**14 10**	**9 6**	
WIND	**1405**	**1210**	**0813**	**0520**	**0223**	**3328**	**3425**	**3516**	
CLDS	**7300/1**	**6310/1**	**2214/3**	**0019/4**	**0127/4**	**0334/3**	**3422/2**	**8200/1**	

The CLDS (probability of opaque sky cover) line provides LFM MOS probability forecasts of categorical opaque sky cover and a best category cloud amount forecast for spot times at 6-h intervals for projections of 6 to 48 h. The first four digits at each projection give the probability forecasts, in tens of percent, of clear, scattered, broken, and overcast cloud amounts, respectively. The best category forecast (1 = clear, 2 = scattered, 3 = broken, 4 = overcast) is given after the slash. In our example, the best category cloud amount forecasts are for broken to overcast conditions during the period when precipitation is expected. Skies are expected to go to scattered by 42 h and then to clear by 48 h, as the drier, cooler air moves in.

HDNG FOUS12 LFM-MOS GUIDANCE 12/32/90 1200 UTC

DY/HR	32/18	01/00	01/06	01/12	01/18	02/00	02/06	02/12	03/00
POP06		**0**	**40**	**80**	**60**	**30**	**10**	**0**	
POP12				**90**		**60**		**10**	**0**
QPF06		**000/1**	**110/1**	**421/3**	**210/2**	**110/1**			
QPF12				**6321/4**		**3100/2**		**2100/1**	
TSTM				**18**		**8**		**2**	
POPT	**0058/2**	**0060/2**	**0158/2**	**0350/2**	**0056/2**	**0065/2**	**0075/2**	**0076/2**	
POSA		**9850/8443/2312/4**							
MN/MX				**29**		**34**		**14**	**26**
TEMP	**35 36**	**35 34**	**34 33**	**32 31**	**32 32**	**33 32**	**26 22**	**18 16**	
DEWPT	**14 15**	**17 19**	**23 24**	**27 27**	**28 25**	**23 20**	**14 10**	**9 6**	
WIND	**1405**	**1210**	**0813**	**0520**	**0223**	**3328**	**3425**	**3516**	
CLDS	**7300/1**	**6310/1**	**2214/3**	**0019/4**	**0127/4**	**0334/3**	**3422/2**	**8200/1**	
CIG	**000009**	**000009**	**000117**	**014430**	**013430**	**011324**	**000018**	**000009**	
VIS	**000009**	**000009**	**001018**	**003214**	**002105**	**001018**	**000009**	**000009**	
C/V	**6/6**	**6/6**	**3/3**	**2/3**	**2/3**	**4/6**	**6/6**	**6/6**	

LFM MOS probability forecasts for each of six categories of ceiling height and visibility are provided on the CIG and VIS lines, respectively. In the message, each six-digit grouping gives the forecasts of categories one through six, in tens of percent, from left to right. Forecasts valid every 6 h are provided for projections of 6 to 48 h. For ceiling height, categories one through six correspond to heights of <200, 200–400, 500–900, 1000–2900, 3000–7500, and >7500 ft, respectively, For visibility, the six categories (again, counting from one to six) are <½, ½ to ⅞, 1 to 2¾, 3 to 4, 5 to 6, and >6 mi.

The best category forecasts for ceiling height and visibility are determined from the six-category probability forecasts and are given in the row denoted "C/V." The best category ceiling forecast is to the left of the slash; the visibility forecast is to the right. The best category forecast for both ceiling and visibility ranges from 1 to 6. From figure 1, note that the ceilings and visibilities are generally unrestricted at the beginning and the end of the forecast period. However, during the time that clouds and precipitation are expected, the ceilings are forecast to go down to between 200–400 ft while the visibilities are forecast to fall to between 1 and 2¾ mi. Note once again that for those categories where relatively few observations of the predictand occur in the developmental sample (i.e., for the lowest ceilings and visibilities), the probability forecasts are generally rather low and the thresholds reflect this.

HDNG FOUS12 LFM-MOS GUIDANCE 12/32/90 1200 UTC

DY/HR	32/18	01/00	01/06	01/12	01/18	02/00	02/06	02/12	03/00
POP06		**0**	**40**	**80**	**60**	**30**	**10**	**0**	
POP12				**90**		**60**		**10**	**0**
QPF06		**000/1**	**110/1**	**421/3**	**210/2**	**110/1**			
QPF12				**6321/4**		**3100/2**		**2100/1**	
TSTM				**18**		**8**		**2**	
POPT	**0058/2**	**0060/2**	**0158/2**	**0350/2**	**0056/2**	**0065/2**	**0075/2**	**0076/2**	
POSA		**9850/8443/2312/4**							
MN/MX				**29**		**34**		**14**	**26**
TEMP	**35 36**	**35 34**	**34 33**	**32 31**	**32 32**	**33 32**	**26 22**	**18 16**	
DEWPT	**14 15**	**17 19**	**23 24**	**27 27**	**28 25**	**23 20**	**14 10**	**9 6**	
WIND	**1405**	**1210**	**0813**	**0520**	**0223**	**3328**	**3425**	**3516**	
CLDS	**7300/1**	**6310/1**	**2214/3**	**0019/4**	**0127/4**	**0334/3**	**3422/2**	**8200/1**	
CIG	**000009**	**000009**	**000117**	**014430**	**013430**	**011324**	**000018**	**000009**	
VIS	**000009**	**000009**	**001018**	**003214**	**002105**	**001018**	**000009**	**000009**	
C/V	**6/6**	**6/6**	**3/3**	**2/3**	**2/3**	**4/6**	**6/6**	**6/6**	
OBVIS	**90X0/1**	**90X0/1**	**30X6/4**	**40X6/4**	**80X3/1**	**80X3/1**	**90X0/1**	**90X0/1**	

LFM MOS probability forecasts for each of four categories of obstructions to vision are provided on the OBVIS line. Each four-digit group indicates, from left to right, the forecast probability of categories one through four, in tens of percent. Forecasts are provided at 6-h intervals for projections of 6 to 48 h. The four categories (counting from 1 to 4) correspond to no obstructions, haze or smoke, blowing phenomena (dust, snow, spray, or sand), and fog. A value of "X" for the probability of any category means that a prediction equation could not be developed for that element at that station. For example, the OBVIS best category forecast for 0600 UTC on January 1 is "4" (fog), while a "1" (no obstructions) is forecast for 0000 UTC on January 2. Because of a lack of developmental data, equations for blowing phenomena were not developed for DCA.

3. The Quiz

Now it's your turn. Figure 2 contains another LFM MOS bulletin. The date of the message is still the hypothetical December 32, 1990, but this time the initialization time is 0000 UTC. While much of the data in this hypothetical message is not "suspect," the message also purposely contains two other categories of data:

Category A: Some data that could NEVER (we trust) appear in an actual message.

Category B: Some data that might *appear* to be errant, but that could (and do) actually appear.

Take a close look at each line of the message and compare different lines of the message. Your job is to identify as many examples of Category A and Category B data as you can—and to differentiate successfully between the two categories! You will find a list of examples (with explanations) for both categories in the answer key. Perhaps you'll identify a few examples that we missed.

The next part of the quiz focuses on the characteristics of MOS equations and of the statistical forecasts that are produced from these equations. The questions for this part of the quiz are in multiple choice format.

1. Observed values of surface wind, temperature, and dew point valid close to model run time are commonly used as predictors in MOS equations for the earliest projections (6 to 27 h). Of the following choices, which one(s) correctly describes the influence such predictors *generally* exert on the MOS forecasts for these elements?

   The use of surface observations as predictors . . .
   - (a) causes MOS forecasts to tend towards the climatic mean of the element.
   - (b) causes MOS forecasts to tend towards persistence.
   - (c) contributes towards producing errant forecasts when large changes in the observed weather occur during the 6- to 27-h period.
   - (d) does not generally lead to any of the effects described in (a), (b), or (c).
2. Which statement(s) is (are) true?
   - (a) The equations that produce MOS QPF guidance for a given station were developed by using data from that station only.
   - (b) The equations that produce MOS POP forecasts for a given station were developed by using data from a group of stations.

HDNG FOUS12 LFM-MOS GUIDANCE			12/32/90	0000 UTC					
DY/HR	32/06	32/12	32/18	01/00	01/06	01/12	01/18	02/00	02/12
POP06		0	30	70	50	30	10	0	
POP12				80		40		10	0
QPF06		000/1	110/1	443/4	110/2	110/1	100/1		
QPF12				5321/3		3200/2		2100/1	
TSTM				28		8		12	
POPT	0058/2	0060/2	0158/2	0350/2	0056/2	0065/2	0075/2	0076/2	
POSA			8430/2453/1607/4						
MX/MN				35		35		52	56
TEMP	33 33	34 34	34 34	35 35	35 36	36 37	38 45	52 51	
DEWPT	23 26	29 33	35 34	32 32	30 26	23 20	20 22	21 23	
WIND	0000	1210	0813	0520	1614	1715	2420	2500	
CLDS	7300/1	6310/1	2214/3	0019/4	0127/5	0334/3	3422/2	8200/1	
CIG	000009	000009	000117	013330	113330	011324	000018	000009	
VIS	000009	000009	001018	003214	112105	001018	000009	000009	
C/V	6/6	6/6	3/3	2/3	0/1	4/6	6/6	6/6	
OBVIS	90X0/1	90X0/1	30X6/4	40X6/4	80X3/1	80X3/1	90X0/1	90X0/1	

Fig. 2. Hypothetical FPC message for use with Section 3.

(c) The equations that produce max/min temperature forecasts for a given station were developed by using data from that station only.
(d) The equations that produce MOS wind forecasts for a given station were developed by using data from a group of stations.

3. Which set(s) of MOS equations contain the same predictors at similar projections?
   (a) QPF, POP (b) CIG, CLDS (c) TSTM, POP
   (d) POPT, POSA (e) none of the above

4. Which choice(s) is (are) true?
   (a) MOS temperature forecasts cannot account for the effect of snow cover.
   (b) The MOS snow cover analysis is updated in the equations weekly.
   (c) If an usually snowy location experiences a snowless winter, MOS max/min tempertaure forecasts for that location may generally be too cold.
   (d) None of the above.

5. You're locked in a seemingly endless heat wave. Over each of the past seven days, a new record maximum temperature has been set at your location, and the LFM forecasts virtually no change in the 850-mb temperature or 1000–500-mb thickness over the next 48 h. The LFM MOS 24-h max temperature forecast from 0000 UTC calls for more record-breaking heat tomorrow, but the 48-h forecast from that same run calls for considerably cooler conditions the next day. "Hmmm . . . ," says Fred the forecaster, ". . . the LFM isn't forecasting the synoptic-scale thermal conditions to change . . . and there's no reason why the cloud cover should increase over the next few days . . . I'll ignore MOS and call for record heat tomorrow *and* the next day." Which *one* of the following statements best describes Fred's decision?
   (a) Fred probably made an unwise decision because MOS is never wrong.
   (b) Fred probably made a wise decision because the MOS program forbids record conditions to be forecast at 48 and 60 h.
   (c) Fred probably made an unwise decision because MOS may be picking up a local effect that is not evident in the synoptic-scale thermal or moisture fields.
   (d) Fred probably made a wise decision because MOS forecasts generally tend towards the climatic mean with increasing projection.

6. Which *one* of the following statements is most likely to be true?
   (a) MOS POP equations can never account for the enhanced likelihood of precipitation caused by upslope winds at individual stations.
   (b) MOS 3-h temperature equations can account for temperature changes due to the onset of a sea breeze at a station where sea breezes frequently occur.
   (c) MOS QPF equations can account for the presence of small hills (say, < 20 km across) that act to induce rain shadows at individual stations.
   (d) MOS wind equations cannot account for locally preferred directions caused by channeling by small hills (say, <20 km across).

7. We often advise forecasters to beware of taking the MOS guidance too literally when strong frontal systems are nearby. Which choice(s) supports this advice?
   (a) The processes that drive the observed weather near frontal systems are often on the mesoscale or local scale, and MOS forecasts are usually most accurate under synoptic-scale regimes.
   (b) MOS equations for some elements (e.g., POP) are developed by using data from a geographically similar group of stations, so they cannot handle variations near fronts as well as can equations developed for use at specific stations.
   (c) Because predictors in the MOS equations are generally valid at specific projections, the values for many predictors may not accurately represent the actual conditions in cases where a front passes during the middle of a forecast period.
   (d) Small errors in timing of the front by the LFM can result in large MOS forecast errors.

8. Which *one* of the following statements is most likely to be true?
   (a) MOS equations can account for random error in the LFM to a large degree, so the MOS guidance should generally remain relatively accurate even in cases where the LFM produces large errors.
   (b) MOS equations "know" about LFM errors that can occur in specific synoptic situations (e.g., not accurately representing shallow cold air), and can adjust for these errors from one situation to another.

(c) If a particular MOS forecast is errant for a given situation and the weather pattern remains basically unchanged, the offending equation can "correct itself" and produce a better forecast the next day.
(d) If the LFM produces a systematic error (i.e., an error that appears consistently regardless of synoptic situation), the MOS equation can correct for the error to some degree.

4. Discussion and Answers

In the first part of the quiz, we asked you to refer to the hypothetical FPC message shown in figure 2. In particular, we asked you to identify all occurrences of data that could never appear in an actual message (Category A), as well as data that might appear to be errant, but that could (and do) actually appear (Category B). We list data for each of the two categories below.

Category A

1. The unconditional POSA forecast exceeds the conditional POSA forecast for the ≥4 inch category (53% vs. 24%).

Recall that the unconditional POSA forecast for a given amount category is determined by multiplying the conditional forecast by the POP12 for the same 12-h period over which the POSA guidance is valid, and then by a weighted average of the POF forecasts. Thus, even if the POP and POF forecasts are 100% across-the-board, an unconditional POSA forecast can at best only *equal* the conditional forecast--never exceed it!

2. The unconditional POSA forecast for the ≥2 inch category is incorrect.

To compute the unconditional probability for this category, take the conditional POSA (84%) and multiply it by the POP12 for the period ending 0000 UTC on January 1 and then by the weighted average of the POF as described in Part 1. Thus, the correct unconditional probability is:

$$(0.84)*(0.80)*((0.60+0.58+0.58+0.50)/4)$$
$$=0.38 \text{ or } 38\%$$

3. The dew point forecast for the 18-h projection exceeds the temperature (35°F vs. 34°F).

Naturally, we wish to avoid the situation where a MOS dew point forecast exceeds the concurrent temperature forecast. In order to reduce the frequency of such occurrences, we forced the equations for 3-h temperature and 3-h dew point for the same projections to contain the same predictors. We call this the *simultaneous* development approach. Still, because the predictor *coefficients* in the forced equations that produce forecasts for these elements are unique, a raw dew point forecast may occasionally exceed a raw temperature forecast for the same projection. To ensure that such guidance is not disseminated to the user, we apply a check to temperature and dew point forecasts in post-processing of the forecasts. If a dew point forecast exceeds a temperature forecast at a given projection, we average the two forecasts and set both equal to that average value.

4. The min temperature forecast for the 60-h projection exceeds the max temperature forecast for the 48-h projection.

In addition to preventing dew point forecasts from exceeding temperatures forecasts at a given projection, we also need to ensure that a min temperature forecast does not exceed a max tempertaure forecast for an adjacent projection. This problem is alleviated by checking the max and min temperatures against the 3-h temperature forecasts between specific projection windows (15–27, 27–39, and 39–51 h for the 24-, 36-, and 48-h max or min temperature forecasts, respectively). If a max (min) temperature forecast is less (greater) than any of the 3-h temperature forecasts valid in the appropriate projection window, the max (min) temperature forecast is set to the largest (smallest) 3-h temperature forecast. For the 60-h projection, inconsistencies are handled by setting the max or min temperature forecast equal to the 3-h temperature forecast valid at the 51-h projection. Because there is overlap in the 3-h projection windows for adjacent max/min temperature projections, consistency between max and min temperature forecasts is ensured by using this method.

5. The wind forecast of 2500 at the 48-h projection could never occur.

Calm wind forecasts are denoted as 0000--no wind direction is assigned.

6. The best category CLDS forecast of 5 at the 30-h projection is not possible.

Recall that the four cloud categories are 1 for clear, 2 for scattered, 3 for broken, and 4 for overcast.

7. The best category CIG forecast of 0 at the 30-h projection is not possible.

Best category forecasts for both CIG and VIS can range from 1 to 6 only. Did you find any other blatant errors that we didn't intend to include?

Category B

1. The POP06 for the period ending 0600 UTC on January 1 exceeds the POP12 for the period ending at 1200 UTC on January 1.

While it is not desirable for either of the POP06 forecasts in a given 12-h period to exceed the POP12 forecast for that same period, such forecasts are occasionally produced. We attempt to minimize these occurrences by developing equations for POP06 and POP12 simultaneously. However, as with the temperature and dew point predictands, this technique enhances but does not ensure meteorological consistency between POP06 and POP12 because the predictor coefficients vary from equation to equation. Note that we do not apply a consistency check to POP06 and POP12 forecasts, so the user may occasionally notice cases where POP06 exceeds POP12.

2. The QPF06 best category for the period ending 0000 UTC on January 1 is larger than the QPF12 best category for the period ending at the same time.

Again, we used the simultaneous approach to develop QPF06 and QPF12 equations valid within each 12-h period to enhance meteorological consistency between the forecasts for these elements. In the case of QPF, however, not only do the predictor coefficients vary from equation to equation, but the threshold values used to determine the best category forecasts also vary. Thus, QPF06 and QPF12 values may not always be meteorologically consistent.

3. The QPF06 best categories for 0600 UTC and 1200 UTC on January 1 are different, but the probabilities used to determine these best categories appear to be the same.

Note that the QPF probabilities are apparently 10% each for the ≥0.25 inches and ≥0.50 inches categories, and 0% for the ≥1.00 inch category for both 0600 and 1200 UTC. However, because these figures represent values rounded to the nearest 10%, the exact values are most likely somewhat different than they appear in the message. Thus, while the probability forecast values for each category are certainly close from one projection to the next, they are obviously different enough to cause the ≥0.25 inches threshold to be exceeded at 0600 UTC, but not at 1200 UTC. Besides, the threshold values are different from one projection to another.

4. The POP12 for the period ending 1200 UTC on January 1 is only 40%, while the QPF12 best category for that same period is 2 (0.25 to 0.49 inches).

It is important to note here that the QPF and POP equations were *not* developed simultaneously. Thus, forecasts among these elements are more likely to be meteorologically inconsistent than are forecasts between, say, POP06 and POP12 or QPF06 and QPF12. Still, we expect that QPF and POP guidance for the same projection will generally tell a similar story because the important predictors used in the equations for POP and QPF are similar (usually, model forecasts of mean relative humidity and precipitation amount).

5. The TSTM probability forecast for the 12-h period ending 0000 UTC on January 2 exceeds the POP12 forecast for the same period.

It would seem logical to assume that if there was a certain chance of observing a thunderstorm, there would be at least that much chance of observing measurable rain. However, the equations used to produce the POP and TSTM guidance are *much* different; in fact, even the predictands are quite different. As mentioned previously, POP forecasts the chance of at least 0.01 inches of liquid-equivalent precipitation occurring at a specific site, while TSTM forecasts the probability of at least a VIP level 3 radar echo occurring within approximately a 48 × 48 km square. The most important predictor used in the TSTM equations is a model forecast of the K stability index, while model forecasts of mean relative humidity and quantitative precipitation predominate in the POP equations. Finally, POP forecasts are rounded to the nearest 10%, while TSTM forecasts are not. Maybe the POP forecast in this case was 14%! In short, forecasts for these two elements should *not* be compared.

6. The POPT best category forecast calls for snow at 0000 UTC on January 2, while the max temperature forecast valid around that time is for 52°F.

We mentioned earlier that because POPT equations were developed by using precipitation cases only, POPT guidance should not be considered when the POP's indicate precipitation is not likely to occur. This advice should be heeded here, as the POP12 for the period ending at 0000 UTC on January 2 is only 10%.

Answers for **Multiple choice questions**

1. Choices (b) and (c) are correct.

It is true that MOS forecasts generally tend towards the climatic mean of the predictand with increasing projection because of the increasing uncertainty in model forecasts at the later projections (see the explanation for question 5 in this section). However, there is no reason to expect that the inclusion of surface observations as predictors has any bearing on the tendency of MOS forecasts to head towards the climatic mean.

Persistence is simply a forecast that current conditions will continue. Thus, it is fair to assume that the use of observations as predictors causes MOS forecasts to tend towards persistence to some degree.

While equations that contain observations as predictors generally perform well, errant forecasts can result when significant changes in the synoptic situation are expected 6 to 27 h following observation time (e.g., in the vicinity of a strong front). In fact, the reason that large errors can occur in such cases is related to the persistence effect described in (b).

2. Choices (b) and (c) are correct.

Where possible, we prefer to develop MOS equations by using data from one site only. In this manner, the effects of local topography and climate can be accounted for by the equations. However, we can not do this type of "single station" development for all predictands because not enough developmental data are available and/or because single station equations for some predictands would not produce reliable guidance.

We have successfully used the single-station approach for max/min temperature, temperature and dew point at 3-h intervals, and wind. For all other elements, we have used the "regionalized" development approach. In this approach, historical data for a group of geographically similar stations are collected, and a single equation for each cycle and projection is developed for all stations in that region. We do not expect regionalized equations to account for the climatic characteristics of individual stations. However, POP forecasts for individual stations within any given region can be (and usually are) distinct from each other because LFM predictor values interpolated to each station are used as input to the equations.

3. Choice (e) is correct--none of the above!

As mentioned in the answers to Part 2, the equations for QPF and POP were developed separately and, thus, contain different predictors. The same is true for the TSTM and POP, and for the POPT and POSA equations. Actually, choice (b) would have been correct until recently because the CLDS equations that were used operationally from 1981 until February 1988 were developed simultaneously with the CIG equations. An updated set of equations to forecast cloud amount was implemented in February 1988, but we did not update the CIG equations at that time. Thus, the CLDS and CIG equations are no longer forced to contain the same predictors.

4. Only choice (c) is true.

This question was included because we have noticed that there is some confusion among forecasters as to exactly how snow cover is accounted for by MOS temperature equations. First, note that there is no MOS snow cover analysis, per se. Thus, choice (b) is incorrect. However, MOS temperature equations *do* account for the effect of snow cover in two different ways.

First, observed snow cover is used as a predictor in *some* of the max/min temperature equations for the first projection *only* and in some of the surface temperature equations for the 6- through 27-h projections. Observed snow cover is not used as a predictor for all stations because: (1) it does not provide enough information and/or (2) it occurs too infrequently in the developmental sample. The predictor operates such that if the observed snow cover at a station exceeds a specified depth (say, 1 or 3 in), the max or min temperature forecast is usually lowered by an amount (usually 3 to 5°F) determined by the predictor coefficient.

The second way that MOS temperature equations account for snow cover applies to all stations and all projections, and requires no special effort on our part. The information is contained in the historical data itself! Consider two nearby stations that are under the same air mass on a given day. If one of the stations has a deep snow cover while the other has bare ground, one would naturally expect the snow-covered station to experience colder temperatures. If the difference in snow cover between these two stations is due to an effect that occurs *frequently* (e.g., due to one station being in the heart of a lake effect snow belt and the other being too far inland), the mean max and min temperatures at the two stations are likely to be different over the long term as well. If this is the case, the least-squares regression technique can account for these differences. However, the regression procedure can not account for effects that occur either randomly or infrequently.

The ability of statistical equations to account for average climatic conditions through the regression procedure itself can result in errant forecasts during unusual climatic regimes. For example, if a normally snow-covered station has a snowless winter one year, the MOS max/min temperature forecasts will probably be too cold because the equations expect that the ground is always snow covered during the winter. Thus, choice (c) is correct. This same reasoning can potentially be applied in understanding MOS forecast errors during other types of unusual climatic regimes, such as during drought periods when the ground is anomalously dry.

5. Choice (d) probably best describes Fred's decision.

Just joking with choice (a). Actually, it's the developers of MOS who are never wrong!

This question was included so that we could stress the characteristic of MOS equations to produce forecasts that *tend towards the climatic mean of the predictand with increasing projection*. Although this effect applies to all predictands, it is most noticeable in the max/min temperature guidance.

The explanation for this tendency is as follows. Usually, the less highly correlated a predictand is to a predictor (or predictors), the greater the tendency for a least-squares regression equation derived from these data to produce forecasts that tend towards the mean of the predictand. The predictand is generally less highly correlated to model forecasts for the longer projections because model forecasts for the longer projections are less accurate. Thus, because MOS equations that produce forecasts for the longer projections include as predictors model forecasts for the longer projections, these equations produce forecasts that tend towards the climatic mean of the predictand. What Fred observed in this case is a textbook example of this effect.

While it would be unusual for MOS to forecast record conditions at the longer projections, there is certainly no "law" against it. Thus, choice (b) is incorrect. Finally, while the effect described in choice (c) is always a possibility when using synoptic-scale guidance, it is not the best answer here.

6. Choice (b) is most likely to be true.

We hope this one took a few minutes of your time--it was designed to be a tough one! While MOS POP equations are regionalized and, consequently, are less likely to account for local climatic effects at individual stations, POP forecasts can account for variations in topography that are "seen" by the dynamical model. For example, if a mountain range is broad enough to be included in the model terrain, the model will be able (to some extent) to generate moisture due to upslope winds. This enhanced moisture can then be picked up in the important PoP moisture predictors. Thus, choice (a) is not the best answer. On the other hand, topographic effects that occur on the sub-grid scale can not be accounted for by regionalized equations. Thus, choice (c) is not correct because the QPF equations are also regionalized.

Choice (d) represents the flip side (or perhaps the edge) of the coin presented in choice (c). If MOS wind equations were regionalized, they would be unlikely to forecast wind channeling caused by small hills at individual stations and the statement would be correct. However, because MOS wind equations were developed for individual stations, the preferred wind directions at individual stations can be built into the regression equations, even if the preference is caused by sub-grid scale effects.

That leaves choice (b). Again, because MOS temperature equations were developed for individual stations, the forecasts produced by these equations can account for frequently occurring local effects to some extent. Thus, if an afternoon sea breeze often occurs at a coastal station during the summer months, the cooling effect of this breeze should be picked up by the temperature equations that are valid during the late afternoon hours. Thus, choice (b) is the best answer.

7. Choices (a), (c), and (d) support this advice.

This question does not require much in the way of explanation because the correct choices themselves contain the explanation! While choice (b) may be tantalizing, bear in mind that although regionalized equations are developed by using data from a variety of stations, the values of the model predictors used operationally are interpolated to the individual stations from the LFM grid. Thus, if a dynamical model indicates that there is a large gradient between two stations in an important predictor field for a given element (say, mean relative humidity for PoP), the statistical guidance can reflect this gradient in the forecasts for this element. Thus, (b) is the only *incorrect* choice for this question.

8. Choice (d) is most likely to be true.

Another tough one, but after all, it *is* the last question! Remember that statistical equations cannot account for random error. If a large random error occurs in the dynamical model, the MOS guidance based on that model will also likely be errant. Thus, choice (a) is incorrect. Second, while statistical equations can account for systematic errors that occur over the entire course of the developmental sample (e.g., a bias in a thermal field that occurs regardless of synoptic situation), the equations cannot adjust for an error that occurs only in specific synoptic situations. Thus, choice (b) is incorrect, and choice (d) is the best answer. Choice (c) will remain incorrect until (or if) such time as we develop artificially intelligent MOS that can adjust for its own errors. No wisecracks, please.

5. Conclusion

Thanks for taking the time to test your MQ (MOS Quotient). Hopefully, we've answered some of your questions about the statistical guidance. If you have additional questions or comments about the National Weather Service's statistical guidance products, please feel free to write the author at:

National Weather Service
Techniques Development Laboratory, W/OSD21
1325 East-West Highway, Room 10378
Silver Spring, MD 20910

For additional details on the development and use of individual MOS forecast elements, we suggest consulting the NWS Technical Procedures Bulletins (TPB's). A list of the most current TPB's for *all* LFM MOS forecast elements (including CLDS and POP) is provided in Table 1. To get a copy of a particular TPB, write to the following address:

National Weather Service
Services Development Branch, W/OM23
1325 East-West Highway, Room 13452
Silver Spring, MD 20910

Table 1. Technical procedure bulletins for reference

TPB #	Subject
283	LFM MOS QPF guidance
303	LFM MOS Ceiling, Visibility, and Obstructions to Vision guidance
318	LFM MOS PoSA guidance
319	LFM MOS PoPT guidance
329	LFM MOS Max/Min, PoP, Wind, Conditional Probability of Frozen Precipitation, and Cloud guidance for Alaska
331	FOUS12 MOS Thunderstorm guidance
338	LFM MOS Ceiling, Visibility, and Obstructions to Vision guidance for Alaska
347	LFM MOS Wind guidance
356	LFM MOS Daytime Max/Nighttime Min, 3-h temperature, and 3-h dew point guidance
378	LFM MOS Cloud guidance
386	LFM MOS PoP guidance
387	NGM MOS Daytime Max/Nighttime Min, PoP, Cloud, and Wind guidance

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