NGM-BASED MOS VISIBILITY AND OBSTRUCTION TO VISION GUIDANCE FOR THE CONTIGUOUS UNITED STATES

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1. INTRODUCTION

This document describes the visibility and obstruction to vision forecasts produced operationally since July 1993 by the Techniques Development Laboratory (TDL) of the National Weather Service (NWS). TDL has derived regression equations to predict the probabilities of five categories of visibility and three categories of obstruction to vision. The equations were developed by applying the Model Output Statistics (MOS) technique (Glahn and Lowry 1972) to output from the Nested Grid Model (NGM) (Hoke et al. 1989). In addition to the probability forecasts, categorical forecasts are produced by a selection scheme designed to maximize the threat score while retaining a bias value near 1.0. NGM MOS visibility and obstruction to vision forecasts are produced for projections from 6 to 36 hours at 3-h intervals and for projections from 42 to 60 hours at 6-h intervals after 0000 and 1200 UTC. The 54- and 60-h forecasts are disseminated only to stations supported by the United States Air Force (USAF).

2. METHOD

The MOS approach correlates predictand data (local weather observations) with combinations of predictor data (output from dynamical models, surface observations, and geoclimatic information). In applying MOS to the prediction of visibility and obstruction to vision, the visibility and the obstruction to vision were treated as categorized predictands. For obstruction to vision, we first eliminated from the sample all observations of blowing phenomena and smoke. All remaining reports, including no reported obstruction to vision, were divided into mutually exclusive and collectively exhaustive categories. This means that each obstruction to vision value in the sample was placed into one and only one category; all values in the sample (except for blowing phenomena and smoke) were accounted for. For the same data sample, the range of visibility values was divided into mutually exclusive and collectively exhaustive categories. After dividing the visibility and obstruction to vision predictands into categories, the visibility predictand was then set equal to 1 if the visibility observation occurred within a particular category and was set equal to 0, otherwise. The same procedure was done for the obstruction to vision predictand. A multiple linear regression screening procedure (forward selection) was then used to derive the prediction equations. Operationally, the equations produce probability forecasts of the various visibility and obstruction to vision categories. An objective technique determines a categorical visibility forecast and a categorical obstruction to vision forecast from the probabilities. Only the categorical forecasts are disseminated to the users. Since blowing phenomena and smoke were excluded from the developmental data sample, no explicit forecasts of these phenomena are made.

3. DEVELOPMENT AND DEFINITIONS

a. Seasons

Developmental data from October 1986 through March 1993 were stratified into two, 6-month seasons: cool (October-March) and warm (April-September). Seven seasons of data (approximately 1260 days) were used to develop the cool season equations and six seasons of data (approximately 1100 days) were used for the warm season equations. When feasible, we included 8 days of seasonal overlap on either side of the warm season in an effort to increase the number of occurrences of the rare events. This was not done for the cool season because it was deemed unnecessary.

b. Predictands

Observed visibility was divided into the categories shown in Table 1. NGM MOS visibility categories 1 and 2 combined match the aviation visibility definition for Low Instrument Flight Rules (LIFR), namely, visibility less than 1 mi. Visibility category 3 matches the definition for Instrument Flight Rules (IFR); category 4, Marginal Visual Flight Rules (MVFR); and category 5, Visual Flight Rules (VFR). Likewise, obstruction to vision was divided into the categories shown in Table 1.

TDL archives the hourly surface aviation observation (SAO) reports for all available stations in the contiguous United States. For the 439 cool season and 440 warm season stations available in the TDL hourly data archives and included in the MOS forecast system, we extracted the visibility and obstruction to vision reports for the developmental period. Observations valid at 0000, 0300, 0600, 0900, 1200, 1500, 1800, and 2100 UTC provided the predictand data sample. These observations were used to form predictands valid every 3 hours from 6 to 36 hours and every 6 hours from 42 to 60 hours after either 0000 or 1200 UTC. Observations at 0200 and 1400 UTC were used as predictors (see Section 3.c).

c. Predictors

Table 2 lists potential model predictors and climatic variables used to derive the visibility and obstruction to vision forecast equations. Note that the height of the dew-point depression predictor is defined by an algorithm that uses dew-point depression at standard pressure levels from 1000 to 500 mb to find the level where a dew-point depression of 0.5ºC, for example, first occurs. The algorithm converts this pressure level, if available, to a height in hundreds of feet. If not available, a default height of 35,000 ft is used. Similar predictors were defined by using dew-point depressions of 1.0º, 1.5º, 2.0º, 2.5º, and 3.0ºC. Model predictors were available at 6-h intervals from 6 to 48 hours after either 0000 or 1200 UTC. For most of the predictand projections, the model predictors were valid at the time of the predictand observation. Thus, for example, predictors valid at 12 hours after 0000 or 1200 UTC were included for the 12-h MOS forecast equations. For the 54- and 60-h forecast equations, model predictors valid at 48 hours were used. Since the model forecasts were only available at 6-h intervals, for the warm season development we included time-averaged values of some NGM forecasts for predictand projections of 9, 15, 21, 27, and 33 hours. For example, the NGM mean relative humidity forecasts at the 6- and 12-h projections were averaged together to produce a mean relative humidity forecast nominally valid at the 9-h projection. For the cool season development, we added time-averaged values of some NGM forecasts for all predictand projections out to 48 hours.

As potential predictors for the 6-, 9-, 12-, 15-, 18-, 21-, and 24-h forecast equations, we also considered the observed visibility, obstruction to vision, total sky cover, temperature, dew-point depression, surface u- and v-wind components, and surface wind speed reported 2 hours after 0000 or 1200 UTC. We specifically used the 0200 or 1400 UTC observations because they are usually available when the NGM MOS forecasts are produced operationally. Additionally, we computed two predictors based on observed categories of ceiling height and visibility. To obtain these predictors, the observed visibility was divided into four exclusive categories: less than 1 mi, 1 to 2 7/8 mi, 3 to 5 mi, and greater than 5 mi. Likewise, the observed ceiling height was divided into the following four categories: less than 500 ft, 500 to 900 ft, 1000 to 3000 ft, and greater than 3000 ft. One predictor was assigned the value of the lesser of the observed visibility and ceiling height categories, while the second predictor was assigned the value of the greater of the two categories. We used the observed predictors because they incorporate persistence into the regression equations.

Climatic predictors for all projections included the first and second harmonics of the day of the year, the monthly relative frequency of visibility less than 3 mi, and the monthly relative frequency of ceiling less than 1000 ft. The predictors referred to as the first and second harmonics of the day of the year are the sine and cosine of the day of the year (converted to radians) and twice the day of the year, respectively. To obtain the monthly relative frequency, we compiled a 10-year climatology of visibility less than 3 mi and of ceiling less than 1000 ft for the same 440 full-time reporting stations mentioned in Section 3.b. The monthly relative frequencies were valid at 0000, 0600, 1200, and 1800 UTC. The monthly relative frequencies for part-time reporting stations and stations that do not report observations were obtained by spatial interpolation. Use of these predictors attempts to account for seasonal trends in the visibility not accounted for by other predictors. To account for possible differences within regions (see Section 3.d), we also included station latitude, longitude, and elevation as potential predictors.

TDL archives the basic analysis and forecast fields from the NGM on a polar-stereographic grid with a horizontal resolution of 190.5 km at 60 N. Most of the NGM predictors were space-smoothed over 5 or 9 grid points at the 6-, 12-, 18-, 24-, 30-, and 36-h projections. At the 42- and 48-h projections, predictors were space-smoothed over 9 or 25 grid points. For the 54- and 60-h MOS projections, the NGM predictors were space-smoothed over 25 grid points. This spatial smoothing reduces some of the small-scale variability found in model forecasts that is not useful for visibility and obstruction to vision prediction. More smoothing is applied to the predictors at the later projections as the quality of predictive information from the model decreases.

While many of the potential predictors were continuous variables, others were either point-binary or grid-binary (Jensenius 1992) variables. In the point-binary technique, a predictor's value is first interpolated to a specific station, then the interpolated value is compared to a developer-specified cutoff value. The resulting value of the predictor is either 0 or 1, depending on whether the developer-specified binary cutoff value was reached or not. The observed obstruction to vision, for instance, was treated as a point-binary predictor. The grid-binary technique applies the binary cutoff at grid points, and the gridded field of 1's and 0's is then smoothed and interpolated to stations. The resulting value of the predictor is, therefore, between 0 and 1. This technique provides a smoother transition, both spatially and temporally, between the extremes of the predictor than does the point-binary approach. In the equation development, the mean relative humidity and the relative humidity at the 950-, 850-, and 700-mb levels were used as grid-binary predictors.

d. Regions

Since the occurrences of the lower two visibility categories (Table 1) were relatively infrequent, we combined stations into geographic regions in order to develop stable forecast relationships. In this regional equation approach, the predictand and predictor data from several stations within a similar geographical or climatic area are pooled, and one set of equations is derived for the region. Regional boundaries were established by first grouping stations which displayed similar frequencies of the occurrence of visibility less than 3 mi. We then adjusted the boundaries for similarities in predictor selection and geography. After completing the adjustments, we established 18 regions for the cool season (Fig. 1a) and the warm season (Fig. 1b). The forecast equations derived for a region are applied to each station within that region.

e. Equation Development

As previously mentioned, we derived probability equations for five categories of visibility and three categories of obstruction to vision (Table 1). Equations were developed for both forecast cycles (0000 and 1200 UTC), fifteen projections (6, 9, 12, ..., 33, 36, 42, 48, 54, and 60 hours), and two seasons (warm and cool). Two sets of equations were derived for the 6-, 9-, 12-, ..., 21- and 24-h projections. In the first ("primary") set, surface weather observations at 0200 or 1400 UTC, NGM forecasts, and climatic variables were included as predictors. In the second ("backup") set, we omitted the surface weather observations as predictors. In operations, the primary equations are used wherever possible to generate the forecasts. However, when the observations are unavailable as predictors for a given station, the backup equations are used.

The probability equations for five categories of visibility and three categories of obstruction to vision were derived simultaneously for a given region and projection. During equation development, we allowed the regression process to continue until a maximum of 18 predictors was chosen or until none of the remaining predictors contributed an additional 0.1% to the reduction of variance for any one of the eight predictands. For most regions and projections, 18 predictors were chosen. In the 6- through 12-h primary equations, the obstruction to vision observation or a relative humidity term was often chosen as the first predictor. At later projections, the dew-point depression, the 10-m wind speed, and the relative frequency of visibility less than 3 mi contributed most of the reduction of variance. Additional frequently chosen predictors included the high ceiling height/visibility category derived from observed predictors, wind components at levels below 700 mb, 950-mb relative humidity, and precipitable water. Time-averaged predictors were often chosen for the forecast projections of 9, 15, 21, 27, and 33 hours.

f. Equation Characteristics

Since the visibility and obstruction to vision forecast equations were developed simultaneously, the forecast equations for a given region and projection contain the same predictors, although the regression coefficients vary among the predictands. The expectation is that the use of common predictors for visibility and obstruction to vision will tend to produce forecasts of the two elements which are consistent with each other. For instance, on those occasions when the obstruction to vision is forecast to be fog (an obstruction to vision often is responsible for a visibility of 5 mi or less), the visibility forecast should reflect this by forecasting a visibility of 5 mi or less. Circumstances associated with the definition of an obstruction to vision (see Section 6), however, mean that forecasts of visibility of 5 mi or less and an obstruction to vision of N (neither haze nor fog) can be consistent with each other. This technique also ensures the computed visibility probabilities for a given case sum to 100%, as do the resulting obstruction to vision probabilities. Because probability forecasts greater than 100% or less than 0% are possible for individual categories, we post-process the raw forecasts to eliminate these latter probabilities. All raw probabilities less than 0% are set to 0%, then each probability is divided by the sum of the positive probabilities to obtain normalized values. The resulting probabilities add to 100%, and probability forecasts for individual categories do not exceed 100% or fall below 0%.

g. Transformation of Probability Forecasts to Categorical Forecasts

In daily operations, the prediction equations produce probability forecasts for each visibility and obstruction to vision category. These probability forecasts are used to produce categorical forecasts of visibility and obstruction to vision based on certain predetermined, critical probability values. When the forecast probability of a given category exceeds the critical value (threshold probability), that category is chosen as the categorical forecast. The procedure first compares the forecast probability of category 1 to the threshold probability for category 1. If the forecast probability exceeds the threshold, category 1 is selected as the categorical forecast. If the forecast probability for category 1 does not exceed the threshold probability, the forecast probability of category 2 is added to the forecast probability of category 1 to obtain the cumulative probability. This cumulative probability is compared to the threshold probability for categories 1 and 2 combined. The process continues in a stepwise manner through the probabilities for the first four categories of visibility or the first two categories of obstruction to vision. For visibility, if the threshold probabilities are never exceeded for the first four categories, then category 5, the most common event, is selected as the categorical forecast. Likewise, for obstruction to vision, if the threshold probabilities are never exceeded for H or F, then the most common event, N (neither haze nor fog), is selected as the categorical forecast.

For visibility, cumulative threshold probabilities are required for categories 1 to 4, for each region, projection, cycle, and season, and for both primary and backup equations. Similarly, for obstruction to vision, cumulative threshold probabilities are required for categories H and F, for each region, projection, cycle, and season, and for both primary and backup equations. We explored several techniques for obtaining the threshold probabilities and finally developed an objective, iterative algorithm to determine the threshold probabilities. The algorithm, using the developmental data sample, determined the probability that yielded the maximum threat score for a range of developer-specified biases. The iterative algorithm begins with the lowest category and produces categorical forecasts based on a first-guess threshold probability of 0.50. The number of forecasts for that category are then divided by the number of observations of that category, thus determining the bias. If the difference between the computed bias and the developer-specified bias does not fall within a certain tolerance, the algorithm produces a new threshold probability based on a binary search method. This process continues until a threshold probability is found which produces a bias within tolerance to the first developer-specified bias. The threat score that corresponds to use of this threshold probability is also computed. After computing the threat score for all biases in the developer-specified range, the algorithm selects the threshold probability that yielded the maximum threat score. This threshold probability is the value used in daily operations. The algorithm uses the same process to compute four threshold probabilities for visibility and two for obstruction to vision. Threshold probabilities are not needed for the most common category which is the default choice when no other category is appropriate. For all visibility and obstruction to vision categories, we set a bias range of 0.70 to 1.30 for the warm season and 0.85 to 1.15 for the cool season.

h. Sample Equations

Sample regression equations to predict the probability of five visibility categories and three obstruction to vision categories valid 12 hours after 0000 UTC for cool season region 17 (Fig.1a) are included in Tables 3 and 4. The predictors are listed in Table 3 in the order they were selected by the regression procedure. The column labeled TYPE indicates whether the predictor is continuous (C), a point-binary (PB), or a grid-binary (GB) variable. The cutoffs for point-binary and grid-binary predictors are indicated in the predictor description. The TAU column indicates the projection of the predictors in hours after 0000 UTC, the initial model time. In Table 4a and Table 4b, the five columns listed under VISIBILITY CATEGORY provide the regression constant and the coefficient of the predictor in the five regression equations. As mentioned in Section 3.f, the predictors in these visibility and obstruction to vision equations are the same, but the coefficients differ. The probability threshold values for these equations are listed in Table 5. Remember, although it is useful to know which predictors are contained in the forecast equations, meteorological interpretation of individual coefficients in a multiple linear regression equation is generally not recommended. These coefficients reflect not only the relationship of the predictand to the given predictor, but also the relationship of the given predictor to other predictors in the equation. In most instances, the predictors included in the equation are correlated with one another, so discussing the effect on the statistical forecasts of changing one predictor without considering related variables may not be of much value.

4. TESTS ON INDEPENDENT DATA

a. Verification of Categorical Visibility Forecasts

Prior to implementation of the NGM-based MOS visibility forecast system, we developed a set of test equations based on six cool seasons and on five warm seasons of dependent data. We then verified forecasts from these equations on a season of independent data and compared the results to LFM-based MOS visibility forecasts (Hebenstreit 1981). In order to replace the then-operational LFM MOS visibility and obstruction to vision guidance with the NGM MOS guidance, we were required to show that the NGM MOS was superior to the LFM MOS. Table 6 lists the six LFM MOS visibility categories. Since the NGM MOS visibility categories (Table 1) differ from the LFM MOS in the upper categories, we collapsed the three upper LFM MOS categories and the two upper NGM MOS categories into one for comparison. We also could only compare the two MOS systems at the 6-, 12-, ..., 42-, and 48-h projections since the LFM MOS system only produced forecasts at these 6-h intervals. In general, the NGM MOS forecasts were more skillful than the LFM MOS forecasts (not shown). After implementation of the NGM-based MOS visibility forecast system, we verified forecasts from the operational NGM MOS guidance and again compared the results to the LFM-based guidance. Figures 2a and 2b show Heidke skill scores (Dagostaro 1985) for the LFM MOS and the operational NGM MOS guidance for the 1993-1994 cool season and the 1994 warm season, respectively. The Heidke skill score eliminates the influence of forecasts that would have been correct by chance. Higher Heidke skill scores indicate greater skill. Note that the NGM MOS forecasts were more skillful at every 6-h projection for both seasons and both cycles. Figures 3a and 3b compare threat scores for categories 1 and 2 combined for both systems. Again, note that the NGM MOS had higher scores at every 6-h projection for both seasons and both cycles. Since more forecast projections are available in the NGM MOS visibility system, we also verified the skill of just the operational NGM MOS forecasts at all projections. These skill scores were compared with the skill of persistence forecasts, defined as the visibility observed at 0300 (1500) UTC for the 0000 (1200) UTC forecast cycle. Figures 4a and 4b indicate the Heidke skill scores of the NGM MOS visibility forecasts and the persistence forecasts at all projections, both cycles, and both seasons. At the 6-h projection, the persistence forecasts were more skillful than the NGM MOS forecasts. However, at the 9-h projection and all subsequent projections, the NGM MOS visibility forecasts were more skillful than persistence forecasts. This inability of the guidance to improve relative to persistence at the earliest projections is not unusual (see, for example, Dallavalle and Dagostaro 1995).

b. Verification of Categorical Obstruction to Vision Forecasts

Prior to implementation of the NGM MOS obstruction to vision forecast system, we also verified forecasts from a test set of obstruction to vision equations on a season of independent data. The results were compared to LFM MOS obstruction to vision forecasts (Hebenstreit 1981). Since the LFM-based system forecasts blowing phenomena (blowing snow, blowing sand, or blowing dust) in addition to haze and fog, observations of blowing phenomena and LFM MOS forecasts of blowing phenomena were not included in the comparative verification. We also compared the two MOS systems at the 6-, 12-, 18-, ..., 42-, and 48-h projections since the LFM MOS system only produced forecasts at these 6-h intervals. The NGM MOS forecasts were more skillful than the LFM MOS forecasts (not shown). After implementation of the NGM-based MOS obstruction to vision forecast system, we verified forecasts from the operational NGM MOS guidance and again compared the results to the LFM-based guidance. Figures 5a and 5b show Heidke skill scores for the LFM MOS and NGM MOS for the 1993-1994 cool season and the 1994 warm season, respectively. Note that the NGM MOS forecasts were consistently more skillful at every 6-h projection for both seasons and both cycles. Figures 6a and 6b show threat scores for fog and haze combined for both forecast systems.

Since more forecast projections are available in the NGM MOS obstruction to vision system, we also verified the skill of just the operational NGM MOS forecasts at all projections. Figures 7a and 7b indicate the Heidke skill scores of the NGM MOS and persistence forecasts at all projections, both cycles, and both seasons.

5. ALPHANUMERIC AND GRAPHICAL PRODUCTS

Categorical visibility forecasts and obstruction to vision forecasts are part of the FOUS14 KWBC NGM-based MOS guidance message (FWC product on AFOS) described in detail in Technical Procedures Bulletin (TPB) No. 408 (Dallavalle et al. 1992). The forecasts are also part of the NGM-based MOS guidance messages produced for stations supported by the USAF. These stations are listed in Appendix D of TPB No. 399 (Miller 1993). The NGM MOS guidance is produced twice daily around 0400 and 1600 UTC. AFOS users may obtain the guidance through the FWCxxx message, where xxx are the call letters of the station requested. The guidance is also available through the NWS Family of Services and the FAA's Weather Message Switching Center as the FOUS14 product. A sample of the FOUS14 message is shown in Fig. 8. The visibility and obstruction to vision forecast values correspond to the NGM MOS visibility and obstruction to vision categories given in Table 1. For a complete explanation of the FWC/FOUS14 KWBC message, refer to TPB No. 408 referenced above. USAF-supported sites receive the guidance through 33 individual messages (FOUE01- FOUE10, FOUC01-FOUC10, FOUW01-FOUW10), arranged generally by geographical areas. Fig. 9 shows a sample of part of the FOUE01 message. These bulletins are transmitted to the USAF's Automated Weather Network and are then routed to appropriate base weather stations. Note that the NGM MOS visibility and obstruction to vision probability forecasts are unavailable in the FOUS14 and USAF messages. In order to conserve space and accommodate the increased number of forecast projections, only the categorical visibility and obstruction to vision forecasts appear. Note, too, that the NGM MOS categorical visibility and obstruction to vision guidance is available in the FOUS14 at 3-h intervals from 6 to 36 hours and at the 42-h and 48-h projections. In the USAF bulletins, the guidance is available at 3-h intervals from 6 to 36 hours and at 6-h intervals from 42 to 60 hours.

Categorical visibility forecasts are combined with NGM MOS categorical ceiling height forecasts to produce the three-category flight weather forecasts plotted on the computer produced four-panel chart D072 (D229) available around 0415 (1600) UTC for the 0000 (1200) UTC forecast cycle on the Digital

Facsimile (DIFAX) circuit. The flight weather forecasts are given by a category number: 1, LIFR and IFR conditions (ceiling less than 1000 ft and/or visibility less than 3 mi); 2, MVFR conditions (ceiling of 1000 to 3000 ft and/or visibility of 3 to 5 mi); or 3, VFR conditions (ceiling greater than 3000 ft and visibility greater than 5 mi). These category numbers are plotted underneath the station circle wherever possible. Forecasts are depicted for 131 terminals in the contiguous United States for projections of 12, 18, 24, and 30 hours after 0000 or 1200 UTC. NGM MOS forecasts of categorical cloud amount, a four category (clear, scattered, broken, overcast) forecast of opaque sky cover, and surface wind are also plotted on these four-panel charts.

Forecasts for 256 terminals are depicted on a similar set of graphics available in the AFOS system. Four separate displays, corresponding to the four panels on the facsimile chart, are available at approximately 0400 and 1600 UTC each day. AFOS users may access the charts by plotting the products NMCPLTPxW, where x is either 2, 3, 4, or 5 for the 12-, 18-, 24-, and 30-h forecast panels, respectively.

6. OPERATIONAL CONSIDERATIONS

The MOS visibility and obstruction to vision forecasts are based on the NGM output. If a forecaster suspects that the NGM output contains errors, he/she should qualitatively adjust the MOS forecasts accordingly. The multiple linear regression technique can account for some systematic biases in the NGM, but cannot correct bad model forecasts.

Precipitation, which alone can reduce a station's visibility, is classified as weather, not an obstruction to vision, and so is included in obstruction to vision category N. Consequently, a low visibility forecast with an obstruction to vision forecast of N indicates a precipitation event is likely causing the reduced visibility. It is important that forecasters remember that category N represents Neither haze nor fog and so other obscuring phenomena, such as precipitation, are included in this category. Since blowing phenomena and smoke were excluded from the developmental data sample, no explicit forecasts of these phenomena are made. However, the meteorological conditions generally associated with blowing phenomena will likely result in operational forecasts of neither fog nor haze. Although smoke reduces visibility under generally stable meteorological conditions, we suspect that the obstruction to vision guidance will likely indicate category N. Likewise, a reduced visibility due to widely scattered precipitation events, such as isolated thunderstorms or showers, will not be accurately forecast by this guidance. The fact that observed predictors valid at 0200 or 1400 UTC were generally chosen by the regression process for the 06- through 24-h equations (the primary equations) indicates the importance of persistence during the first 24 hours after initial model time. Stations that report observations at 0200 and 1400 UTC will have their visibility and obstruction to vision forecasts influenced by these observations, whereas stations that do not report observations at these times will have their visibility and obstruction to vision forecasts based solely on model and geoclimatic data. Thus, for instance, while the model or geoclimatic information might not indicate a reduced visibility and obstruction to vision for a particular station, a 0200 UTC observation for that station reporting a reduced visibility and obstruction to vision will likely result in a reduced visibility and obstruction to vision being forecast at subsequent projections. In cases such as this, the station's visibility and obstruction to vision forecasts will generally emulate the station's normal climatic conditions regarding the typical dissipation time of a reduced visibility and obstruction to vision after being observed at 0200 UTC. However, a neighboring site that does not report observations at 0200 UTC, but which is also experiencing a reduced visibility and obstruction to vision, will likely not have the same visibility or obstruction to vision forecast as the first station simply because the forecast for the site is not influenced by a weather observation (i.e., the forecast is made from the backup equations described in Section 3.e). This spatial inconsistency will occur more often during a fog event when no synoptic-scale storm system is affecting stations' visibility and obstruction to vision. In the equation development, cases of fog were not stratified by the occurrence of precipitation. Thus, a fog forecast can be associated with appropriate radiation or advection conditions or with precipitation. Furthermore, when the observations used to develop the visibility and obstruction to vision forecast equations were archived, a reported visibility of 6 mi (NGM MOS visibility category 5) required some sort of obscuring phenomena, which was often haze or precipitation, to be reported. Therefore, forecasts at a station of an obscuring phenomenon with a visibility forecast of category 5 are consistent forecasts.

As a final note, some regions will not have forecasts for visibility categories 1 or 2 at some projections. Observations of these categories were so rare that the 6- and 7-year developmental data sets did not contain enough cases to develop an equation. The lack of these observations was more common in the afternoon projections, in the warm season, and in regions west of the Front Range of the Rocky Mountains.

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