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This Bulletin, written by Benjamin Sfanos describes the regression equations to predict the surface wind direction and speed by applying the Model Output Statistics (MOS) technique from output from the Aviation (AVN) run of the Global Spectral Model. These new equations were implemented operationally in May 2000.

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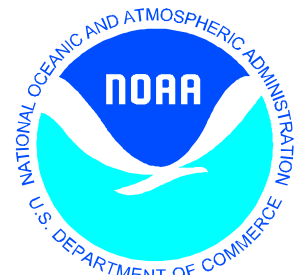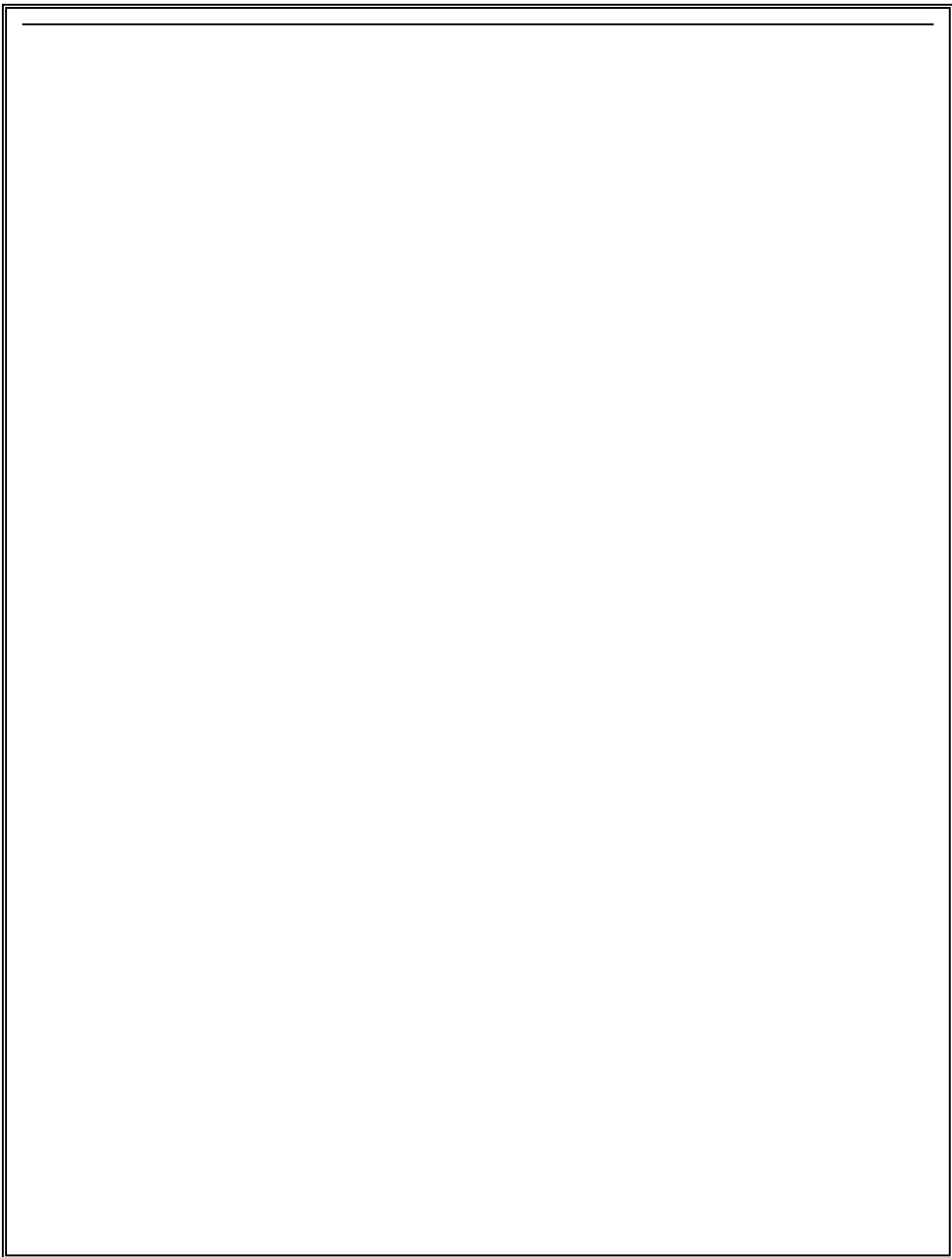
AVN-BASED MOS WIND GUIDANCE FOR THE UNITED STATES AND PUERTO RICO

by Benjamin Sfanos

1. INTRODUCTION

The Meteorological Development Laboratory (MDL) of the National Weather Service (NWS) has developed regression equations to predict the surface wind direction and speed by applying the Model Output Statistics (MOS) technique (Glahn and Lowry 1972) to output from the Aviation (AVN) run of the Global Spectral Model (Kanamitsu 1989, Kanamitsu et al. 1991, Iredell and Caplan 1997, Caplan and Pan, 2000). The MOS approach correlates predictand data (local weather observations) with combinations of predictor data (output from dynamical models, surface observations, and climatic information). These new equations were implemented operationally in May 2000. MOS wind forecasts are generated for 3-h projections from 6 to 72 hours after the initial model times of 0000 and 1200 Universal Coordinated Time (UTC). The guidance is initially available for the 0000 and 1200 UTC cycles only; guidance for the 0600 and 1800 UTC cycles will be developed and made available at a later date.

2. DEVELOPMENT

a. Predictands

Wind direction and speed are observed and reported every hour at surface reporting stations. The METAR observation represents a 2-minute average wind direction and speed. From these reports, the u- and v- wind components were computed. In the MOS wind development, we are predicting the u- and v- wind components and the speed; the direction is computed from the wind components. The METAR observations valid at 0000, 0300, ..., and 2100 UTC provided the data sample and were then used to develop predictands valid 6, 9, ..., and 72 hours after either 0000 and 1200 UTC for 1060 stations in the United States and Puerto Rico. The reader is referred to the website **http://www.nws.noaa.gov/tdl/synop/stadrg.htm** for further details on the station list.

b. Predictors

Potential model predictors included AVN forecasts of the earth oriented u- and v- wind components as well as the wind speed at 1000, 925, 850, 700, and 500 mb. The 10-m speed and u- and v- wind components were also included. Vertical velocity, mass divergence, and relative vorticity at 925, 850, 700, and 500 mb were added as possible predictors. Finally, we included indicators of stability, such as the K index and temperature differences between 1000 and 925 mb, 1000 and 850 mb, and 1000 and 700 mb. Humidities for layers between 1000 and 850 mb and 850 and 700 mb were also included. Generally, the projections of the model variables were valid at the same time as the predictand. The model data were interpolated to the stations from a polar stereographic grid with a resolution of 95.25 km at 60^{B}N.

Climatic predictors for all projections included the first and second harmonics of the day of the year, that is, the sine and cosine of the day of the year (converted to radians) and twice the day of the year.

As potential predictors for the 6-, 9-, 12-, and 15-h forecast equations, the observations of the surface wind speed, the u-wind component, and the v-wind component valid three hours after initial cycle times of 0000 or 1200 UTC were used. Since observations were offered at the 6-, 9-, 12- and 15-h projections as predictors, "secondary" equations were also developed for these projections. The secondary equations, which do not have observations as predictors, are used operationally when the observed wind reports are not available for use in the primary equations.

The most frequently chosen predictors were generally the 10-m wind speed and the u- and v-wind components. The observations valid three hours after initial cycle time were frequently chosen for equations through 15 hours. The AVN 10-m speed and the u- and v-wind components, as well as the 1000-mb speed and the earth-oriented u- and v-wind components were the primary predictors for equations out to 72-hours.

c. Seasons

Data from April 1997 through September 1999 were used for this development. The data were stratified into two, 6-month seasons: cool (October-March) and warm (April-September). Equations were developed for each season. Three seasons of data (approximately 600 days) were used to develop the warm season equations, and two seasons of data (approximately 400 days) were used for the cool season equations. When feasible, data from approximately 2 weeks before the start of each season and 2 weeks after the end of each season were included to smooth the transition between seasons.

d. Equation Characteristics

Single-station equations were derived for all projections and cycles and for both seasons. In the single-station approach, observational data from a station are correlated with certain predictors that are interpolated to that station. Equations are then developed for individual sites by exclusively using data for that site.

Forecast equations for the u- and v- wind components and the wind speed were developed simultaneously. Because of this, the forecast equations for a particular station and projection contain the same predictors, although the regression coefficients vary depending on the predictand. As mentioned in Section 2.b, two sets of equations were derived for the 6-, 9-, 12-, and 15-h projections. Generally, the primary wind speed equations at 6 hours produced forecasts with an average mean absolute error (MAE) that was 0.3 knots less than forecasts made by the secondary equations; by 15 hours, the difference between the accuracy of the primary and secondary forecasts was negligible. The primary equations used to generate wind direction at 6 hours produced forecasts with an average MAE that was 1.5 degrees less than that produced by the secondary equations; by 15 hours, the difference in the average MAE was 0.05 degrees. Operationally, if observations are unavailable as predictors, the secondary equations are used to

generate forecasts; otherwise, the primary equations are always used.

The regression process that generated equations continued until a maximum of 9 predictors was chosen or until none of the remaining predictors contributed an additional 0.5 % to the reduction of variance for any one of the three predictands. At the majority of stations, the maximum number of predictors was chosen for each equation. Note, also, that a minimum of 200 cases was specified in order to develop a forecast equation.

3. POST PROCESSING

All wind speed forecasts in the operational products go through an inflation routine which increases the standard deviation of the distribution of wind speed forecasts (Carter and Schwartz 1985), and, thus, increases the frequency of higher-speed forecasts. The inflation procedure essentially magnifies the difference between the forecast wind speed and the mean wind speed observed during the developmental sample. As a consequence, wind speeds greater than the mean are increased, while wind speeds less than the mean are decreased. Note, too, that this procedure increases the overall mean absolute error of the speed forecasts.

As mentioned previously, the wind direction forecasts are computed from the forecast u- and v-wind components. Once the direction and speed forecasts are obtained, a final check is made to set all wind forecasts to calm when either the speed forecasts are less than 0.5 knots or when both the u- and v- wind components equal 0.

4. OPERATIONAL FORECASTS

The guidance for the 6- through 60-h, the 66-, and the 72-h projections from the 0000 and 1200 UTC forecast cycles is issued in a set of alphanumeric messages (Dallavalle and Erickson 2000). The guidance for all projections and cycles will eventually be issued in binary products. Because single-station equations are used to predict wind speed and direction, please note that forecasts are not available for every station at every projection; guidance is not available if a site was closed at specific hours during the developmental sample.

5. VERIFICATION

Prior to final development, test equations were generated for both seasons for the 0000 and 1200 UTC cycles. Forecasts were made from the test equations on independent data and compared to the AVN direct model output and the NGM MOS forecasts (Miller 1993). Independent data used for the cool season tests were taken from the last fifteen days of each month from October 1998 through March 1999 while the warm season tests used data from the last fifteen days of April 1998 through September 1998. A comparison with the NGM MOS could only be made for the 6-, 9-, ..., and 60-h projections.

The wind speed forecasts were verified in terms of the mean absolute error (MAE), probability of detection (POD) of a wind in excess of 22 kts, and Heidke skill score (HSS) of various wind speed categories. Fig. 1 shows the cool and warm season MAE of the forecast wind speed from

the 0000 UTC cycle for approximately 330 stations in the continental United States and Alaska. Wind direction forecasts were verified in terms of the MAE and the cumulative relative frequency of a directional error less than or equal to 30 degrees. The wind direction forecasts were verified when the wind speed observation valid at the time of the forecast was greater than or equal to 10 knots. Thus, the direction forecasts associated with light and variable winds do not influence the verification scores. Fig. 2 shows the cool and warm season MAE of the forecast wind direction from the 0000 UTC cycle for approximately 330 stations in the continental United States and Alaska. Other information and verification graphs can be found at:
http://www.nws.noaa.gov/tdl/synop/results.htm.

6. OPERATIONAL CONSIDERATIONS

The MOS wind speed and direction forecasts are based on the AVN output. If a forecaster believes that the AVN output contains errors, he/she should adjust the forecasts accordingly. The multiple linear regression technique can account for some types of biases in the AVN, but cannot correct bad model forecasts.

When predictor observations are not available for the 6-, 9-, 12-, and 15-h forecast equations, forecasts will be made by using the secondary equations. This may produce forecasts that are somewhat less skillful than forecasts based on the primary equations.

Stations that are only open part-time will not have a complete set of wind equations. Similarly, stations that opened or closed during the period of the developmental sample may not have reported enough observations for equation development.

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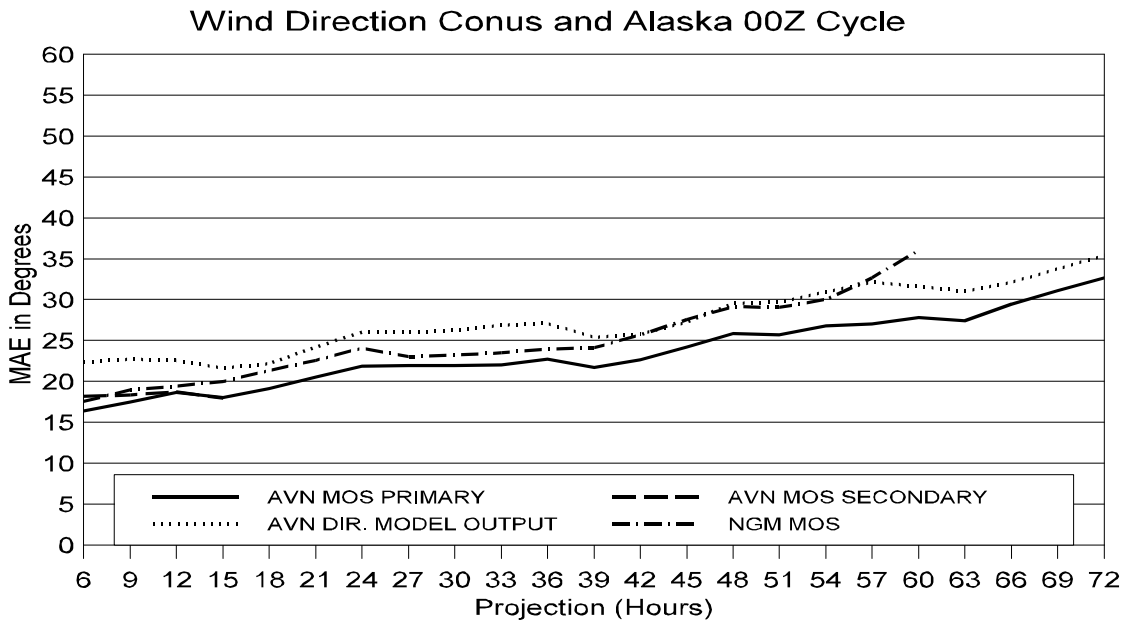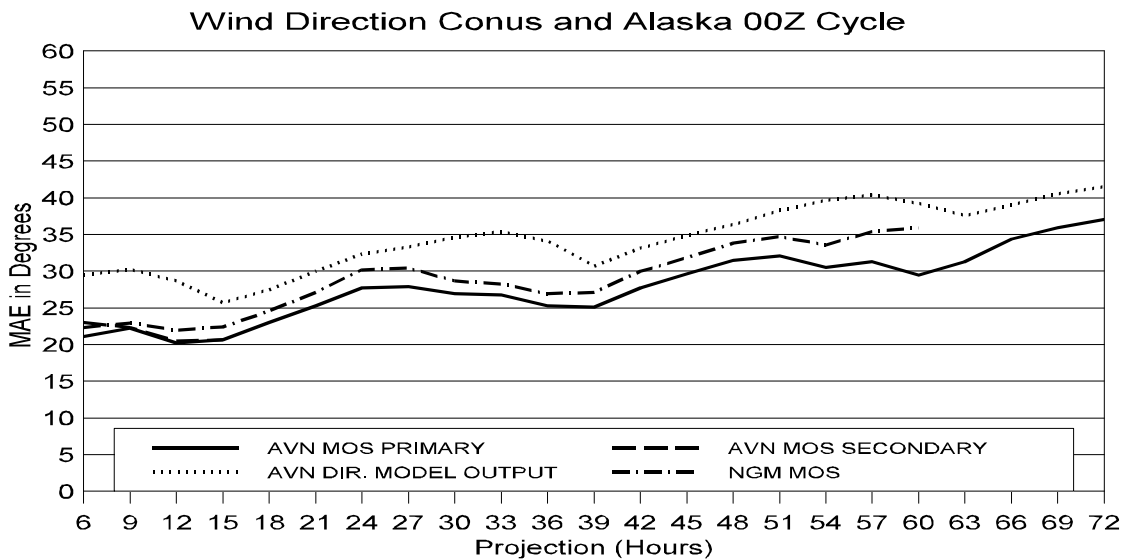   Administration, U.S. Department of Commerce, 19 pp.
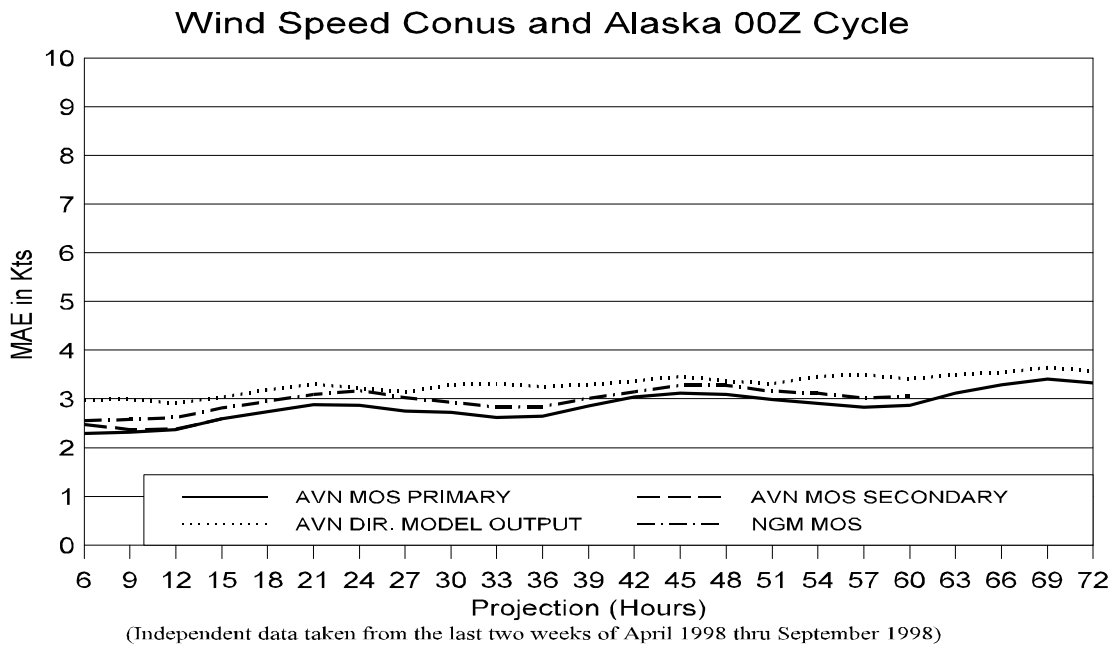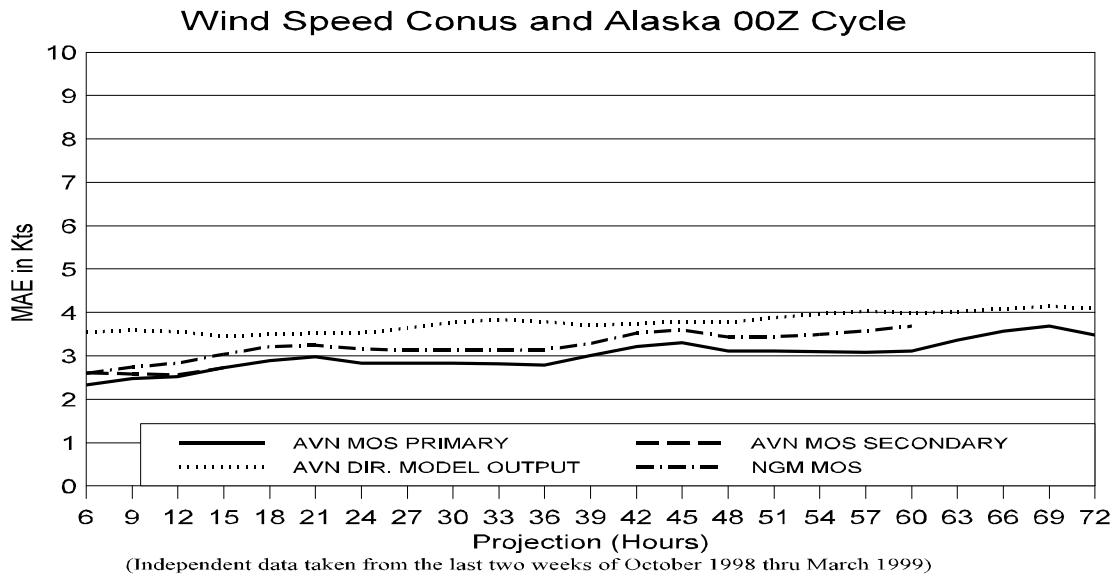
Figure 1. Mean absolute error for the AVN MOS wind speed forecasts, 1998-1999 cool season(top) and 1998 warm season (bottom) 0000 UTC.

Figure 2. Mean absolute error for the AVN MOS wind direction forecasts, 1998-1999 cool season(top) and 1998 warm season (bottom) 0000 UTC.