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IMPROVEMENTS IN EXTENDED-RANGE TEMPERATURE AND PROBABILITY OF PRECIPITATION GUIDANCE

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1. INTRODUCTION

Using the Model Output Statistics (MOS) approach, the Meteorological Development Laboratory (MDL) of the National Weather Service (NWS) has been producing extended-range forecast guidance for daytime maximum (max) and nighttime minimum (min) temperature since April 1994, and probability of precipitation (PoP) since January 1995. The equations used to generate the forecast guidance are based on the National Centers for Environmental Prediction's Global Forecast System (GFS) numerical model (Kalnay et al. 1990). Forecast guidance from the 0000 UTC cycle is valid for projections out to 192 hours in advance. In May 2000, MDL implemented updated temperature and PoP MOS guidance, and increased the number of sites for which forecasts are issued by a factor of four, to approximately 1,000 sites. The equations to produce the new guidance were based on more recent samples of the GFS model, which had undergone several enhancements to increase model resolution and accuracy. In January 2002, MDL enhanced the MOS max/min temperature equations, and added new forecast sites. In December 2003, new max/min temperature and PoP equations were implemented and even more sites added.

In this paper, we discuss the MOS technique, the development of the daytime max and nighttime min temperature and PoP equations, and the verification of the guidance over the last 7 years, from 1997 to 2004. Accuracy of temperature forecasts is shown in terms of mean absolute error. PoP forecasts are verified in terms of percent improvement over the Brier Score (Brier 1950) of climatology. Finally, we discuss future goals of MDL in developing extended-range temperature and PoP statistical forecast products, which are largely driven by the increasing demand for very high resolution gridded, rather than station-oriented, guidance.

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2. THE MOS APPROACH

In the MOS approach (Glahn and Lowry 1972), observations of the weather element to be predicted (the predictand) are correlated to variables forecast from a numerical weather prediction model (the predictors). The first and second harmonics of the day of the year are also used as geoclimatic predictors. These become increasingly important as projection time increases.

3. EQUATION DEVELOPMENT AND PREDICTAND DEFINITIONS

Developmental data for the daytime max, nighttime min, and PoP are stratified into two seasons: warm (April through September) and cool (October through March). The developmental data also include, when available, the 15 days prior and subsequent to the defined season. This is done to provide more data, and smooth the transition between seasons. The extended-range MOS guidance is only available from the 0000 UTC cycle of the GFS model run. Forecast projections for max/min temperature and PoP are valid every 12 hours from 24 to 192 hours after model initialization at 0000 UTC.

The primary GFS model predictors used in the max/min temperature development include thickness, temperature, dewpoint, relative humidity, and wind speed and direction. These predictors were offered at 2 meters and various low-level isobaric surfaces. Primary PoP predictors include model precipitation amount, vertical velocity at various isobaric surfaces, and mean relative humidity between selected isobaric levels.

3.1 *Maximum/minimum temperature*

For the extended-range MOS system, the max temperature is valid during the daytime period, which is defined as 7 a.m. to 7 p.m. Local Standard Time (LST). The min temperature is valid during the nighttime period, which is defined as 7 p.m. to 8 a.m. LST. Since the standard METAR observations of the max/min temperature do not correspond to these definitions, MDL has developed an algorithm that estimates the predictand values from the 6-h max/min and hourly temperature reports.

3.2 *Probability of precipitation*

The predictand for PoP is the occurrence of at least 0.01 inches (liquid equivalent) of precipitation in a 12-h period. As a binary predictand, a value of one indicates the accumulation of at least 0.01 inches of precipitation in the period of interest; a value of zero indicates that measurable precipitation did not occur.

4. VERIFICATION OF GUIDANCE

MDL began producing extended-range statistical guidance for max/min temperature and PoP for approximately 250 stations in December 1992 (Jensenius et al. 1995). The initial implementation depended on perfect-prog equations, but by January 1995, the guidance was based exclusively on the MOS approach.

The archive of MDL's extended-range max/min temperature and PoP guidance available for verification began with the warm season of 1997. Verification was done for temperature and PoP for the warm and cool seasons independently on 255 stations in the CONUS and Alaska. From the 1997 warm season through the 2002-03 cool season, the older FOX GFS MOS system was available (Jensenius et al. 1993), and from the 2000 warm season through the 2003-04 cool season, the new (MEX) system (Erickson and Dallavalle 2000) was verified. The FOX MOS system was discontinued at the end of the 2002-03 cool season.

4.1 *Temperature Verification*

The mean absolute error (MAE) was used to evaluate the accuracy of the daytime max and nighttime min for both the warm and cool seasons. A higher MAE indicates a less accurate forecast. Verifications of the max/min temperature guidance for both warm and cool seasons were analyzed for days 3 through 8 after model run time. For discussion purposes, we'll use the following convention: the day 4 min/max temperatures are valid approximately 84 and 96 hours, respectively, after 0000 UTC; the day 5 min/max are valid approximately 108 and 120 hours, respectively, after 0000 UTC; etc. Subsequent max/min temperatures are in 12-h increments out to the day 8 max of 192-h.

Figures 1a and 1b show the verification of the 84-h min and 96-h max temperature in terms of mean absolute error for the cool season. The improvement in accuracy of the MEX over the FOX is on the order of 0.2 to 0.5 °F for the 84-h nighttime min. The relative increase in accuracy is less for the 96-h daytime max, on the order of 0.1 to 0.3 °F. Figures 2a and 2b show mean absolute errors for the 132-h min and the 144-h max. The improvements for these projections are not as large; the MEX is about 0 to 0.3 °F more accurate for both the max and min. Finishing out the cool season, Figs. 3a and 3b show mean absolute errors for the 180-h min and 192-h max. While the 180-h MEX min was worse the first season, the newer guidance showed 0.2 °F more accurate forecasts for the subsequent seasons. The MEX 192-h max performed slightly better for all seasons, by 0.1 °F or less.

For the warm season max/min temperatures, Figs. 4a and 4b show the verifications of the 84-h min and 96-h max. We see that, in both cases, the relative improvement in accuracy of the newer guidance increases with each season. The 2000 warm season was about 0.1 °F more accurate; the 2001 season, 0.4 °F; and the 2003 season, 0.6 °F more accurate. Enhancements made through the life of the MEX, both to the GFS model and the guidance package, are the likely cause of the improvements. Figures 5a and 5b show the errors for the 132-h min and 144-h max. Again, we see improvements in time, but not as large as for the earlier projections. The MEX 132-h max goes from being only slightly better than the FOX in 2000, to 0.3 °F more accurate in 2002. Similarly, the MEX 144-h max goes from being slightly better in 2000, to about 0.3 °F more accurate in 2002. Finally, Figs. 6a and 6b show errors for the 180-h min and the 192-h max. For the min, we see a small increase in the accuracy of the MEX for the 2001-02 warm season, after being slightly worse in 2000. Errors for the max temperature show that the FOX and MEX systems are essentially equal in accuracy. The 2003 warm season shows an increase in accuracy of 0.3 °F for the MEX, but no basis of comparison can be made with the old system which was no longer available by 2003.

4.2 *PoP Verification*

The percent improvement in the Brier Score over a forecast based on climate is utilized to assess the skill of PoP guidance. The climatic relative frequencies used to compute the percent improvement were based on precipitation records from 1972 through 1985 (Jensenius and Erickson 1987). Brier scores have been calculated for both the old MRF MOS system (FOX) and the new MRF MOS system (MEX) for every cool and warm season for which 12-h PoP guidance was available. For brevity, scores from only three "days" are shown here: 84/96 h (Day 4), 132/144 h (Day 6), and 180/192 h (Day 8). However, the scores for each projection show similar patterns.

Figures 7, 8, and 9 show the improvements over climate for both the FOX and MEX PoP systems for all cool seasons for which guidance was available. The scores show oscillation from season to season, due to mean relative frequency of precipitation changing between seasons. When the MEX was implemented, it immediately outperformed the older FOX, showing an accuracy increase of 6-8% for Day 4 (Fig. 7). The improvements were not as marked in the later projections. By Day 6 (Fig. 8), the MEX is only slightly better than the FOX, though both outperform climate by roughly 10%, and by Day 8 (Fig. 9), the two systems are virtually equally skillful, with only a slight improvement over climate. Interestingly, scores for MEX PoPs covering nighttime hours have better scores than PoPs during the daytime hours.

Warm season PoP verifications are plotted in Figs. 10, 11, and 12. For the 3 warm seasons with both FOX and MEX guidance, the newer MEX guidance was more skillful. Again, though, the skill improvements were not quite as great as for the cool season – 4-5% in the earlier projections, 2-4% in the later projections.

5. FUTURE WORK

MDL has a number of projects planned to enhance the extended-range MOS guidance. MDL will begin to produce high resolution gridded MOS to satisfy NWS field office requirements in producing grids as part of the Interactive Forecast Preparation System (Ruth 2002). With the use of better predictors, a high resolution gridded MOS product should be more skillful for grid initialization than simply using direct model output. Work will continue, as resources permit, to improve the station-oriented MOS guidance as well, with the use of higher resolution model archives and larger samples of dependent data.

6. SUMMARY AND CONCLUSIONS

For nearly a decade, MDL has produced extended-range MOS guidance for temperature and PoP. As the verifications in this paper show, the guidance has become more accurate than it was in its infancy. In general, temperature extrema have improved by up to one-half degree Fahrenheit in mean absolute error, and PoP is up to 5% more skillful. MDL will continue to improve the extended-range MOS guidance by implementing high resolution gridded MOS products.

7. REFERENCES

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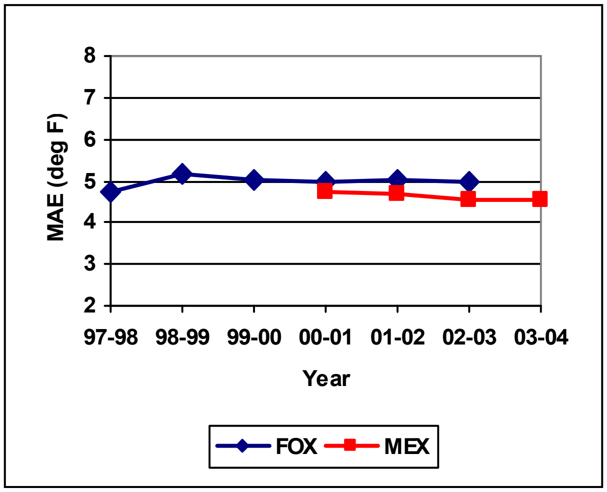

Figure 1a. Mean absolute error for the 84-h cool season nighttime min temperature.

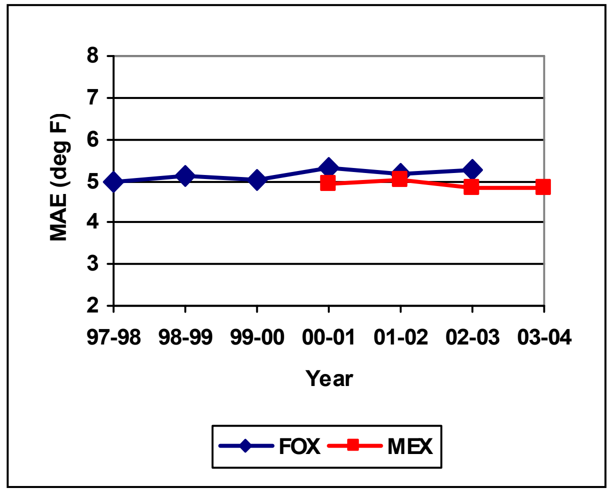

Figure 1b. Mean absolute error for the 96-h cool season daytime max temperature.

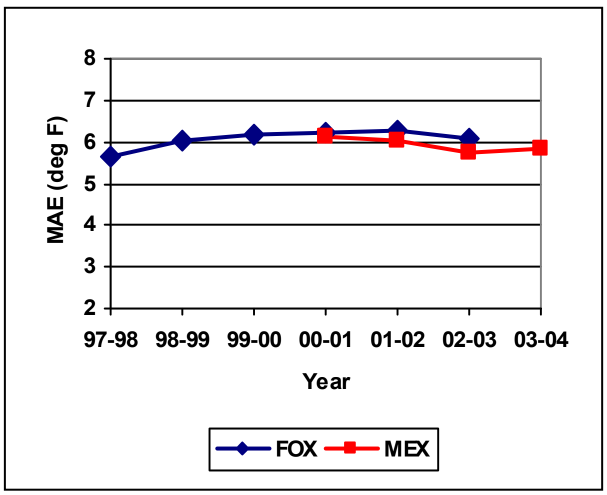

Figure 2a. Same as Fig. 1a, except for 132 h.

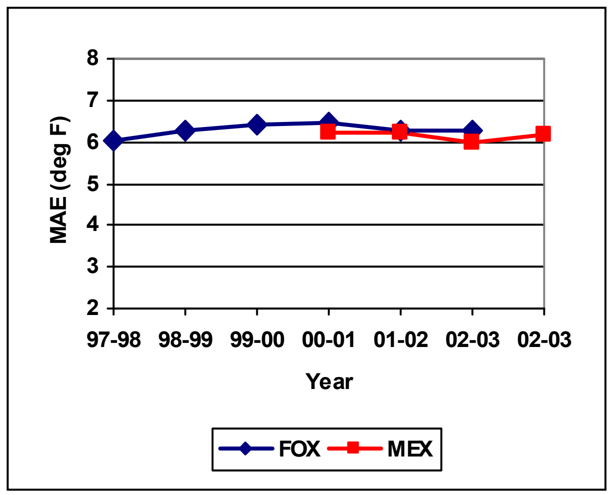

Figure 2b. Same as Fig. 1b, except for 144 h.

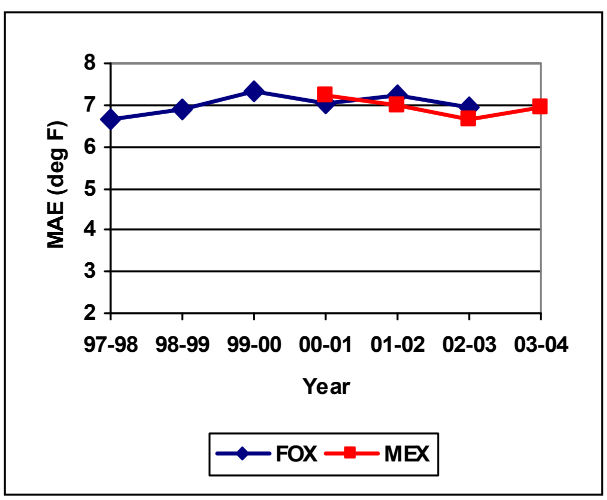

Figure 3a. Same as Fig. 1a, except for 180 h.

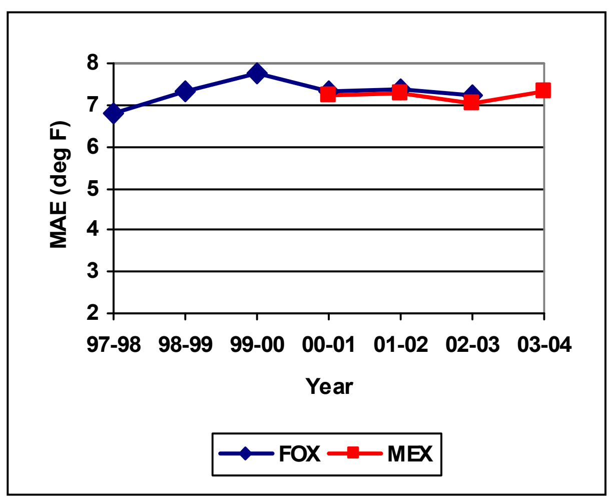

Figure 3b. Same as Fig. 1b, except for 192 h.

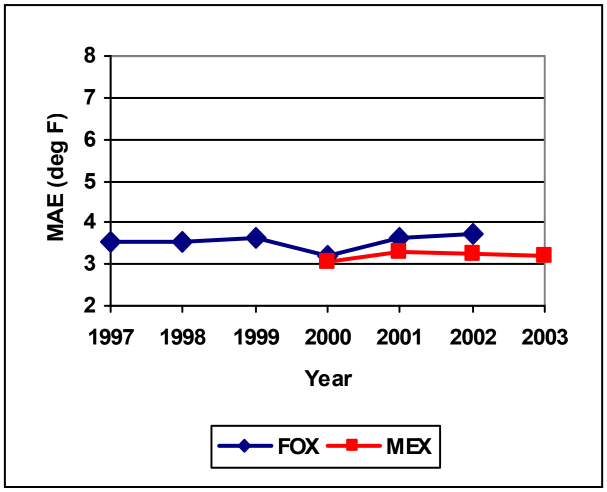

Figure 4a. Mean absolute error for the 84-h warm season nighttime min temperature.

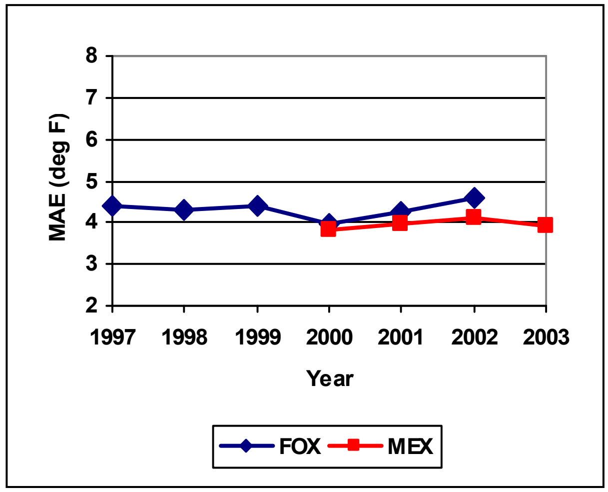

Figure 4b. Mean absolute error for the 96-h warm season nighttime min temperature.

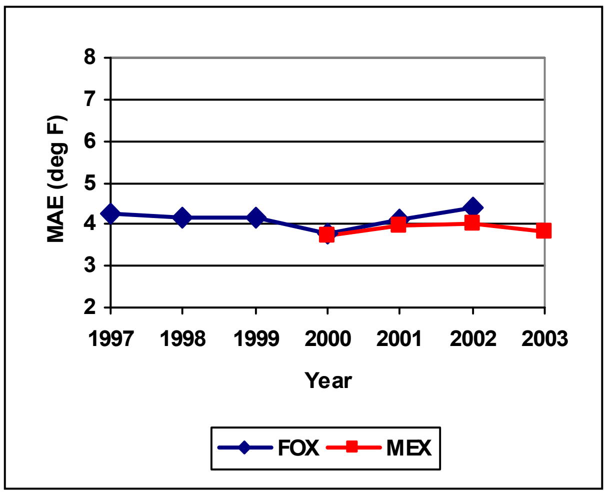

Figure 5a. Same as Fig. 4a, except for 132 h.

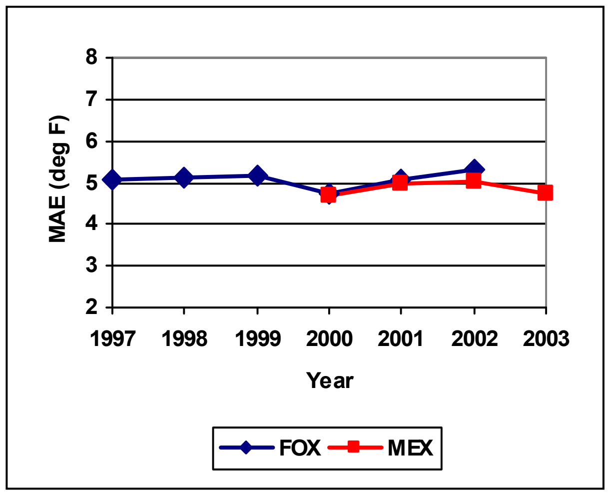

Figure 5b. Same as Fig. 4b, except for 144 h.

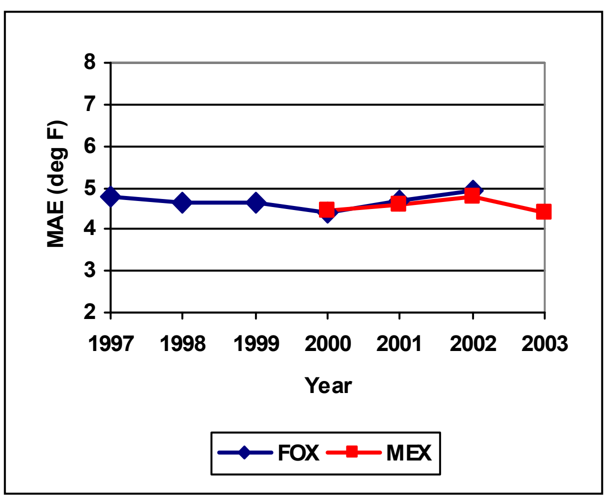

Figure 6a. Same as Fig. 4a, except for 180 h.

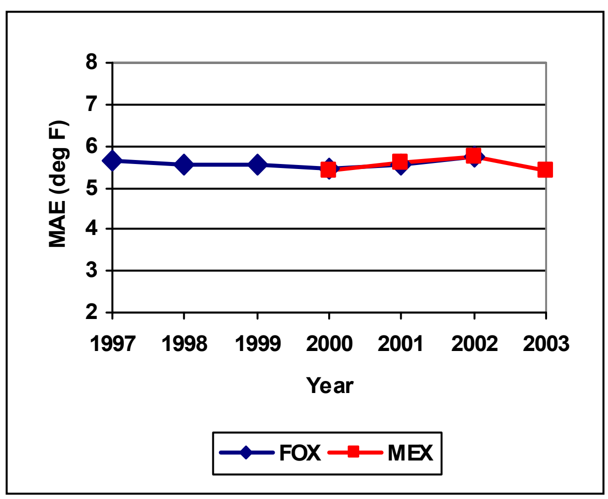

Figure 6b. Same as Fig. 4b, except for 192 h.

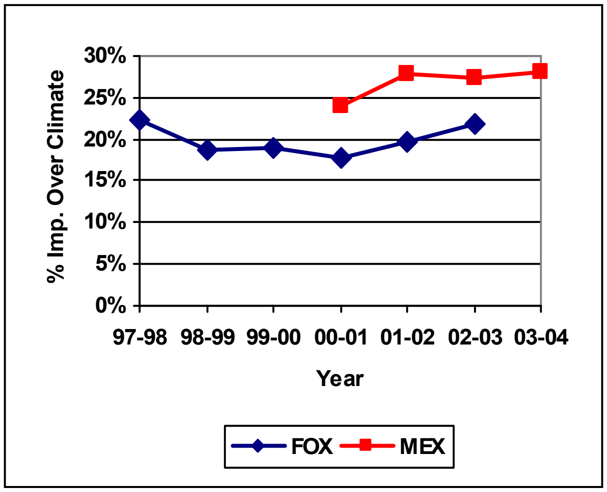

Figure 7a. Percent improvement over climate for 84-h cool season nighttime PoP.

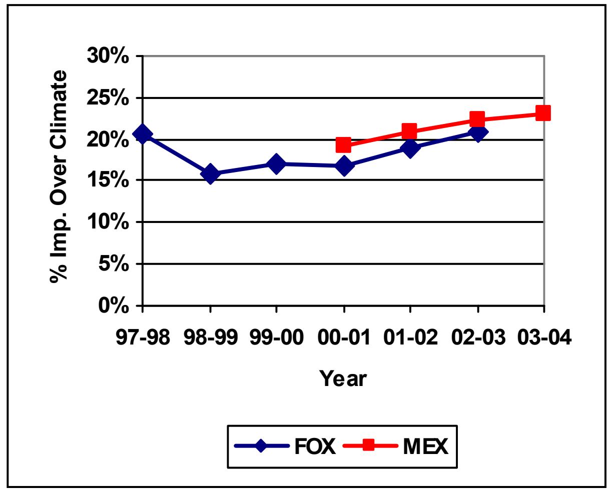

Figure 7b. Percent improvement over climate for 96-h cool season daytime PoP.

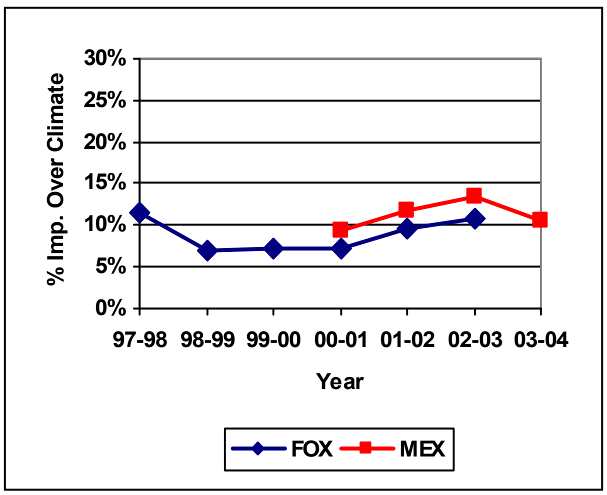

Figure 8a. Same as Fig. 7a, except for 132 h.

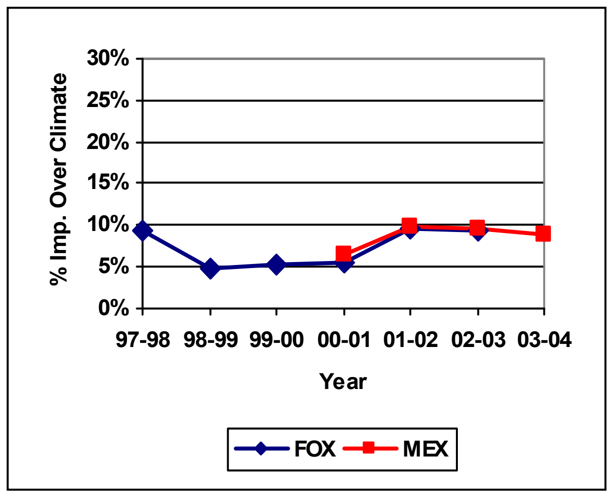

Figure 8b. Same as Fig. 7b, except for 144 h.

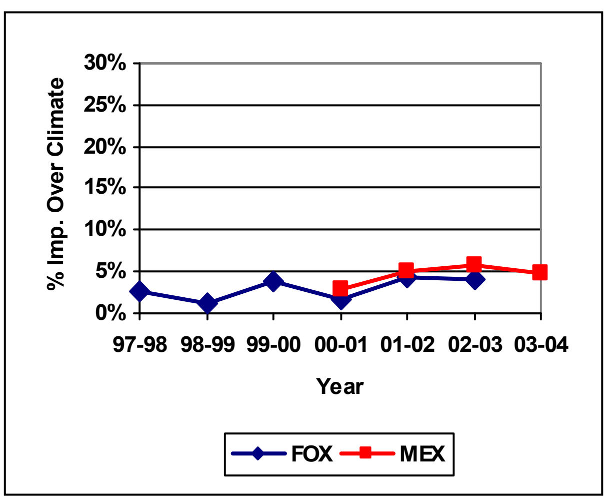

Figure 9a. Same as Fig. 7a, except for 180 h.

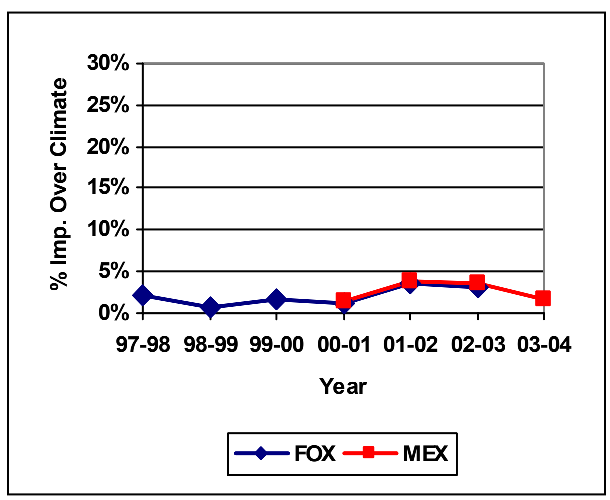

Figure 9b. Same as Fig. 7b, except for 192 h.

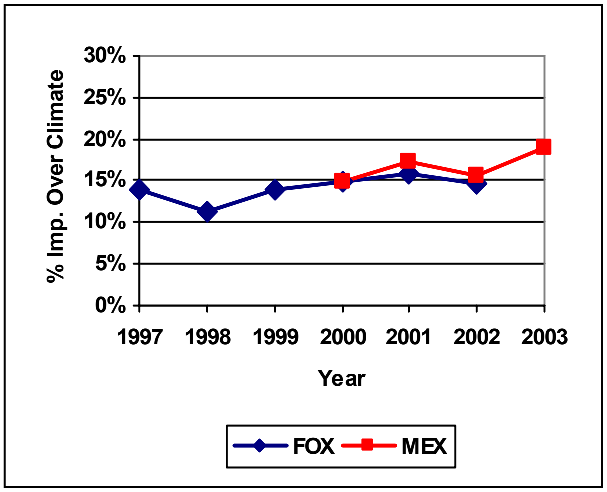

Figure 10a. Percent improvement over climate for 84-h warm season nighttime PoP.

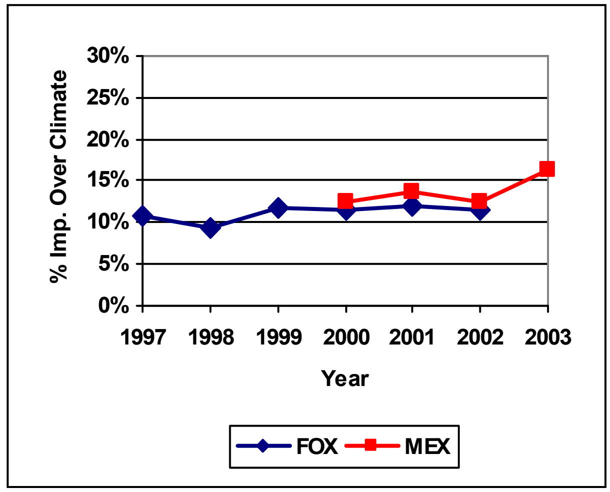

Figure 10b. Percent improvement over climate for 96-h warm season daytime PoP.

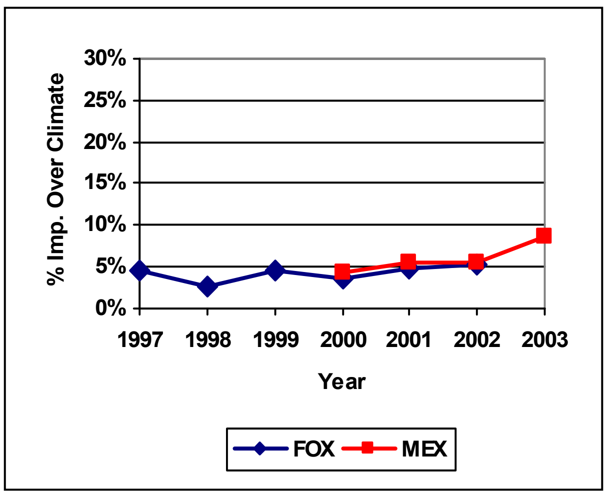

Figure 11a. Same as Fig. 10a, except for 132 h.

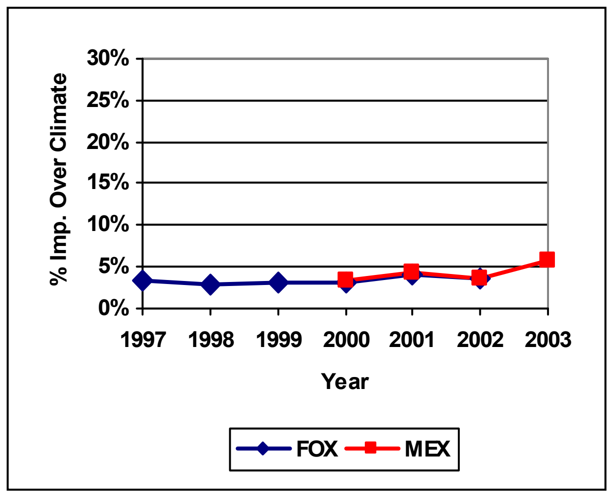

Figure 11b. Same as Fig. 10b, except for 144 h.

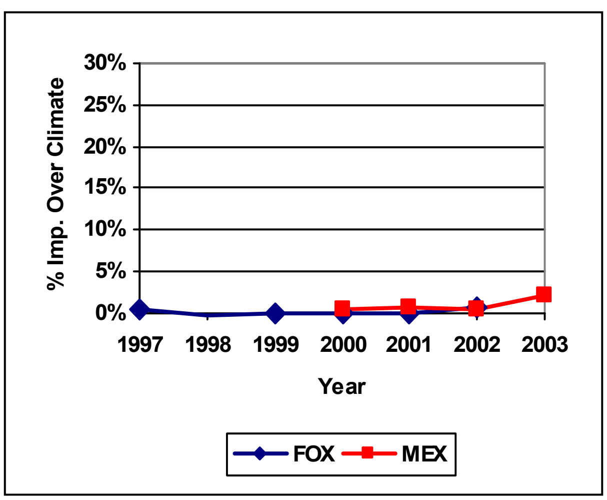

Figure 12a. Same as Fig. 10a, except for 180 h.

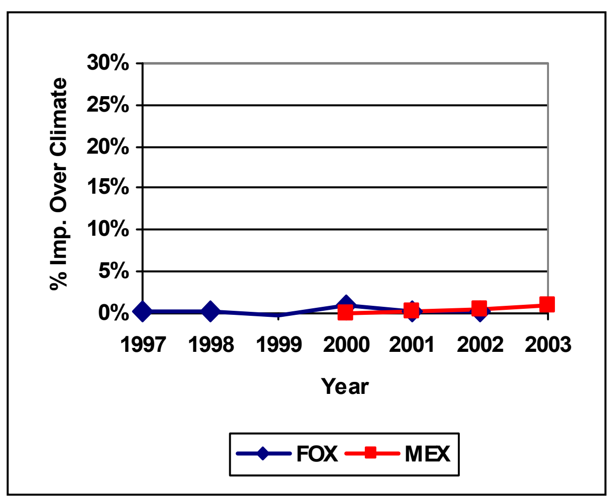

Figure 12b. Same as Fig. 10b, except for 192 h.