# A COMPARISON OF FORECAST ERRORS OF SURFACE ANTICYCLONES IN THE NESTED GRID MODEL AND THE AVIATION RUN OF THE GLOBAL SPECTRAL MODEL, JANUARY 1990

**Richard H. Grumm and Anthony L. Siebers**

National Weather Service
National Meteorological Center
Camp Springs, MD

### Abstract

*The performance of the Nested Grid Model (NGM) and the Aviation run of the Global Spectral Model (AVN) in predicting surface anticyclones in January, 1990 was examined. The results show that the AVN position errors were smaller than the position errors in the NGM.*

*The NGM tended to underpredict the central pressure of surface anticyclones. Part of this error is due to the NGM's inability to properly simulate weakening anticyclones. The NGM overpredicted the central pressure of weakening surface anticyclones.*

*The AVN tended to overpredict the central pressure of surface anticyclones. This error is due to the AVN's over intensification of surface anticyclones which are strengthening and an inability of the AVN to stimulate weakening anticyclones. The AVN also had a tendency to intensify anticyclones which were weakening.*

## 1. Introduction

The purpose of this paper is to assess the operational performance of surface anticyclone forecasting in the Nested Grid Model (NGM) and the Aviation run (AVN) of the Global Spectral Model (Sela 1980). In an earlier study, Grumm and Siebers (1989b) examined systematic surface anticyclone errors in the NGM from December of 1988 through August of 1989. Their results showed that the NGM tended to move surface anticyclones too fast and underforecast central pressures over most of North America, especially along the track of transient anticyclones. In this paper we directly compare the operational AVN to the operational NGM during January, 1990. A description of the NGM component of the Regional Analysis and Forecast System (RAFS) is given by Hoke et al. (1989). The AVN is the spectral model component of the National Meteorological Centers (NMC) Global Data Assimilation and Forecast System, a description of which is given by Kanamitsu (1989).

Grumm and Siebers (1990) examined systematic errors in NGM and AVN forecasts of surface cyclones during January, 1990. They found that the AVN outperformed the NGM in forecasting cyclone central pressures and placement. Both models were better able to forecast the characteristics of deepening cyclones than filling cyclones. Furthermore, the NGM had a tendency to continue deepening surface cyclones which were observed to fill.

Surface anticyclones can dominate the weather over large geographical areas for several days. Persistent surface anticyclones over the western Atlantic and eastern Pacific can dominate the weather over large portions of North America on the order of weeks during the warm season. In the cold season, surges of arctic air are often associated with transient surface anticyclones. Therefore, forecasters need to be as familiar with the systematic forecast errors of surface anticyclones as they are with the systematic forecast errors of surface cyclones in operational numerical weather prediction models.

Several other studies have examined systematic surface cyclone and anticyclone errors in numerical weather prediction models. Grumm and Gyakum (1986) examined systematic errors in 48-h forecasts in the Limited-area Fine Mesh (LFM) Model and an older version of the AVN[1]. Their results showed that the spectral model was slightly superior to the LFM and that spectral model forecasts of surface anticyclones were positioned 494 km, on average, from the verifying position. The spectral model moved anticyclones too fast, underforecast anticyclone central pressures and forecast the thickness to be too high (warm bias) over anticyclones.

A study of 36-h forecast errors in the Japan Meteorological Agency's (JMA) Fine Mesh Limited Area Model (JFLM) and the United States Navy's Operational Global Atmospheric Prediction System (NOGAPS) of surface anticyclones (Chen et al. 1987) revealed a 422 km and 396 km position error in the NOGAPS and JFLM, respectively. Both models moved anticyclones too slowly and overforecast anticyclone central pressures. In examining 36-h deepening rates they found that the models were better able to predict the sign of the 36-h pressure change for anticyclones than cyclones.

In this study surface anticyclones were tracked on an interactive computer workstation as described by Grumm and Siebers (1989a). Systematic errors in surface pressure, thickness, and distance errors were examined. What makes this study unique is that the errors were computed separately for intensifying and weakening anticyclones.

Overall, the AVN produced smaller position errors than the NGM. Both the AVN and NGM were able to properly predict the direction of 12-h pressure change more than 70% of the time. The NGM tended to underpredict and the AVN tended to overpredict the central pressure of surface anticyclones. The 1000- to 500-mb thickness errors revealed a distinct cold bias in the AVN and a slight warm bias over anticyclones in the NGM.

## 2. Method

An anticyclone in this study is defined as a point of relatively high sea level pressure, surrounded by at least one closed isobar (analyzed at 4 mb intervals) in the NGM or AVN analysis or forecast. The corresponding NGM or AVN analyses at 0000 and 1200 UTC were used to represent the verifying atmosphere for the period during January 1990. A

[1]Spectral model with limited Physics. For history of current version see Caplan and White (1989).

total of 62 complete forecast cycles were available during this period. A complete description of how anticyclones were tracked and the data collected is provided in Grumm and Siebers (1989a). A description of how track numbers were assigned in the NGM and AVN databases for direct comparisons is provided in Grumm and Siebers (1990).

Given our strict criteria of what constituted an anticyclone, the AVN had fewer anticyclones than the NGM at the shorter forecast periods (12 and 24 h). In most instances the AVN would depict a ridge without a closed circulation as defined by our criteria. A similar difference in the number of verifiable cyclones was found in Grumm and Siebers (1990).

Strengthening and weakening rates statistics were computed as described in Grumm and Siebers (1990). The categories for anticyclones were based on the forecast and analyzed 12-h pressure changes and were defined as follows: forecast to strengthen, observed to strengthen (SS), forecast to strengthen, observed to weaken (SW), forecast to weaken, observed to strengthen (SW), forecast to weaken, observed to weaken (WW). Surface anticyclones which maintained a constant pressure were classified as strengthening.

## 3. Distribution of Anticyclones, January 1990

The geographical distribution of anticyclones during January 1990 from the AVN initialized analyses is shown in Figure 1. The geographical distribution of anticyclones in the initialized analyses from the NGM was very similar to the AVN and is not shown. Both models had two distinct anticyclone maxima, one over the central Rocky mountains and the other over the eastern Pacific. Secondary maxima occurred over the eastern United States, the western Atlantic, the Gulf of Mexico and southwestern Canada. Shaded areas in the figure depict regions where no anticyclones were observed. These distributions correspond with the 29-year anticyclone climatology over North America (Harman 1987) for the month of January. The only exceptions were the lack of anticyclones in the southern plains of Canada and the northern plains of the United States and the unseasonable maxima over the

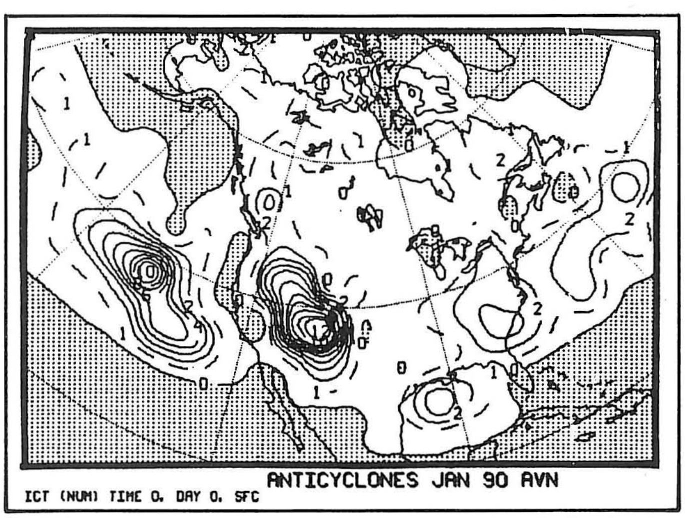


Fig. 1. The number of anticyclones observed in the initialized analyses from the 0000 and 1200 UTC runs of the AVN model during January, 1990. The counts are based on the number of anticyclone centers found in each 5° latitude longitude quadrangle. Contour interval is 1 event, the 1 event contour is dashed. Shading depicts regions of no events.

Rocky Mountains in 1990. The large maxima over the Rocky Mountains is believed to be the result of both transient anticyclones in this region and model pressure reduction errors.

The tracks of anticyclones during January 1990 from the NGM are shown in Figure 2. The anticyclone tracks from the AVN were almost identical to the tracks in the NGM and are not shown. The tracks of anticyclones are similar to those shown by Zishka and Smith (1980) with the exception of the track they show from northwestern Canada west of the Great Lakes into the eastern United States and western Atlantic. In January, 1990 no anticyclones followed this track, leading to the relative minima over the plains in Figure 1. During January, 1990, anticyclones in northern Canada tracked eastward across Canada. Anticyclones which tracked across the eastern United States and western Atlantic originated in the eastern Rocky mountains and western plains. The lack of a pronounced anticyclone track extending from western Canada into the plains of the United States was the result of an anomalously warm circulation pattern which occurred in January of 1990 (Grumm and Siebers 1990).

## 4. Overall Comparisons Between the NGM and the AVN

Tables 1 and 2 show the overall errors for 12-, 24-, 36- and 48-h forecasts, for the NGM and AVN respectively. For each forecast time, the number of cases, mean and standard deviations of the pressure (mb), thickness (m) and distance (km) errors are shown. All errors were computed as forecast minus observed. Negative (positive) numbers indicate underprediction (overprediction) in the forecasts relative to the verifying value.

Tables 1 and 2 show that the NGM tended to underpredict and the AVN tended to overpredict surface anticyclone central pressures. The AVN had a stronger bias toward overpredicting anticyclone central pressures than the NGM did toward underpredicting anticyclone central pressures. The standard deviation of the pressure errors was slightly larger in the AVN than in the NGM at 24 h. After 24 h, the standard deviations of the errors were smaller in the AVN than in the NGM.

The 1000- to 500-mb thickness errors in Tables 1 and 2 show that the AVN, with the exception of the 12-h forecast period, had a distinct cold bias which increased with forecast length. The NGM showed an overall warm bias in its 1000- to 500-mb thickness forecasts over surface anticyclones. The standard deviation of the thickness errors were comparable in both models.

The distance errors in Tables 1 and 2 show that the AVN was superior to the NGM in forecasting the position of surface anticyclones during all forecast periods. The corresponding displacement errors for 48-h forecasts are shown in Figure 3. Displacement errors were computed as described in Grumm and Gyakum (1986). The directional component of the vector mean error in both models placed surface anticyclones south and east of the verifying position. In the NGM, 41% of all anticyclones were forecast south and east of the verifying position. The $\chi^2$ values for the NGM indicate that this NGM distribution was substantially different from an unbiased one. This means that the NGM's preponderance of forecasted anticyclones located south and east of the observed anticyclone position was statistically significant. The AVN had nearly the same directional component of the vector mean error but did not have a statistically significant bias in its forecasts.

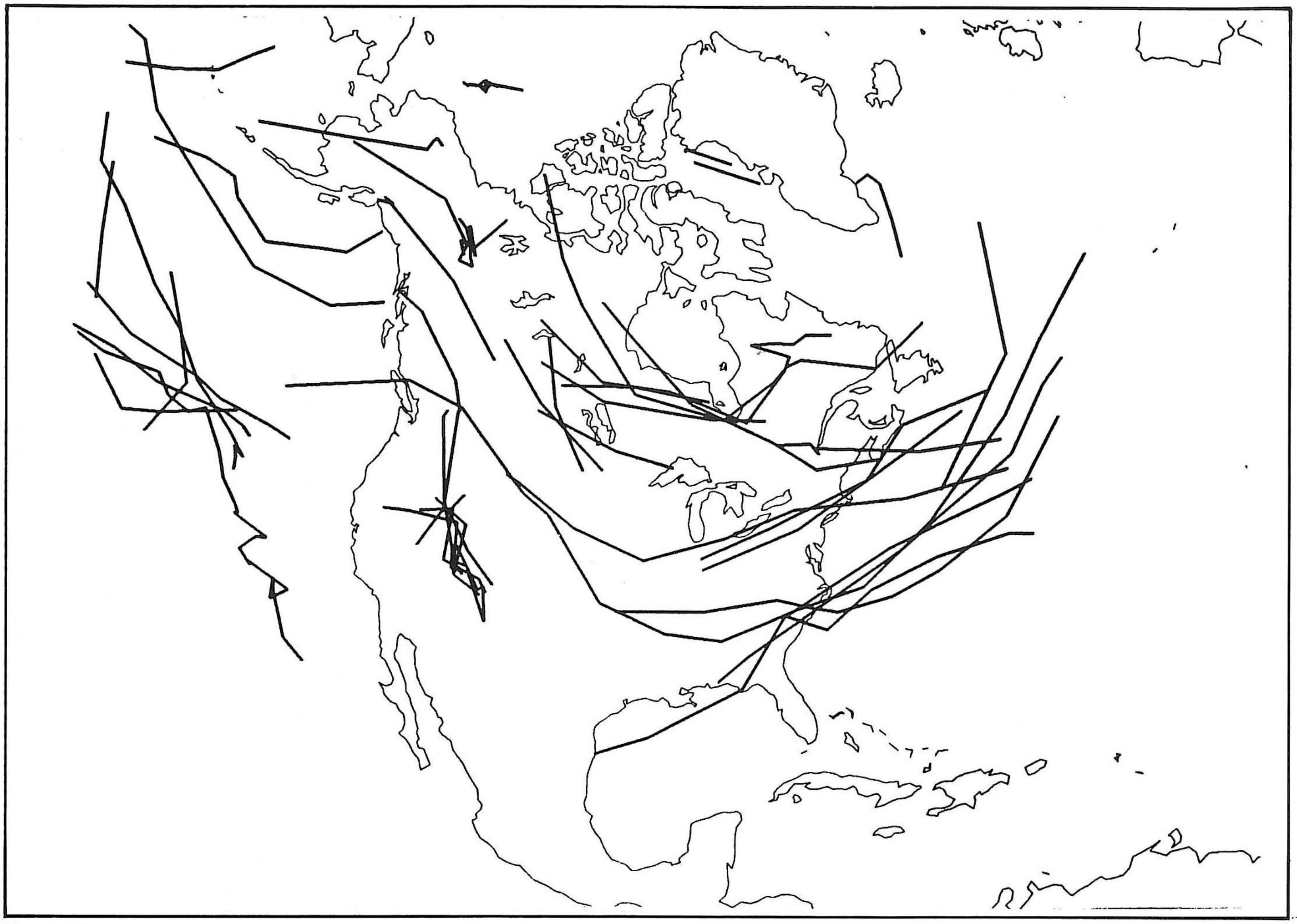

Fig. 2. The track of all surface anticyclones from the NGM initialized analyses for January, 1990.

NGM Forecast Errors

| Model | Fcst | Number | Pressure (mb) | | Thickness (m) | | Distance (km) | |
|---|---|---|---|---|---|---|---|---|
| | | | mean | std | mean | std | mean | std |
| NGM | 12 | 185 | -0.39 | 2.12 | 3.41 | 36.39 | 206 | 164 |
| NGM | 24 | 149 | -0.01 | 2.47 | 0.74 | 47.05 | 278 | 237 |
| NGM | 36 | 140 | -0.15 | 3.25 | 7.86 | 53.50 | 352 | 299 |
| NGM | 48 | 123 | -0.33 | 3.92 | 6.26 | 61.56 | 413 | 287 |

Table. 1. The mean pressure, thickness, and distance error by forecast hour (fcst) in NGM anticyclones for January, 1990. Data include the model, the number of cases, the mean pressure (mb), thickness (m) and distance (km) errors and standard deviations.

AVN Forecast Errors

| Model | Fcst | Number | Pressure (mb) | | Thickness (m) | | Distance (km) | |
|---|---|---|---|---|---|---|---|---|
| | | | mean | std | mean | std | mean | std |
| AVN | 12 | 179 | 1.00 | 2.09 | 10.06 | 35.69 | 157 | 113 |
| AVN | 24 | 148 | 1.76 | 2.65 | -8.72 | 42.46 | 197 | 132 |
| AVN | 36 | 141 | 1.71 | 2.89 | -12.62 | 47.99 | 230 | 166 |
| AVN | 48 | 133 | 1.62 | 3.37 | -17.37 | 57.70 | 311 | 212 |

Table. 2. As in Table 1 except for the AVN.

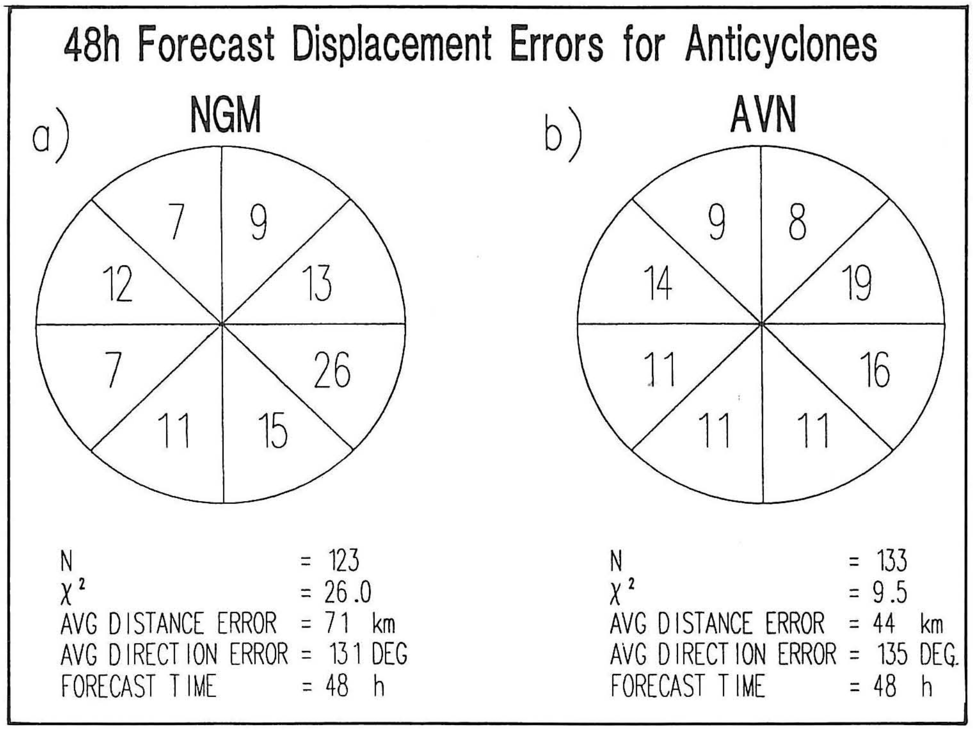


Fig. 3. Summary of (a) NGM and (b) AVN displacement and directional error statistics. The number in each 45° sector is the percent of the total number of cases (N) forecast more than 50 km from the observed position.

The geographical distribution of the mean sea level pressure errors in the 24-h forecasts in the NGM and AVN are shown in Figures 4a and 4b, respectively. Both models tended to overforecast (pressures too high) anticyclone central pressures over North America, the northern Pacific and the western Atlantic coast of Canada. The AVN overforecasting error extended over most of Alaska where the NGM underforecast (pressures too low) anticyclone central pressures. The AVN also had an overforecasting error over the eastern Gulf of Mexico, Florida and the western Atlantic coast of the southeastern United States. Areas of underforecasting occurred over much of the eastern third of the United States in both models. The AVN underforecast anticyclone central pressures in the western Gulf, where the NGM tended to overforecast them.

The geographical distribution of the mean sea level pressure errors in the 48-h forecasts in the NGM and AVN are shown in Figures 5a and 5b, respectively. The NGM overforecasting error over North America decreased in areal extent by 48 h. The negative error in eastern Alaska and western Canada grew in magnitude and increased in areal extent. In the AVN, the overforecasting error over western

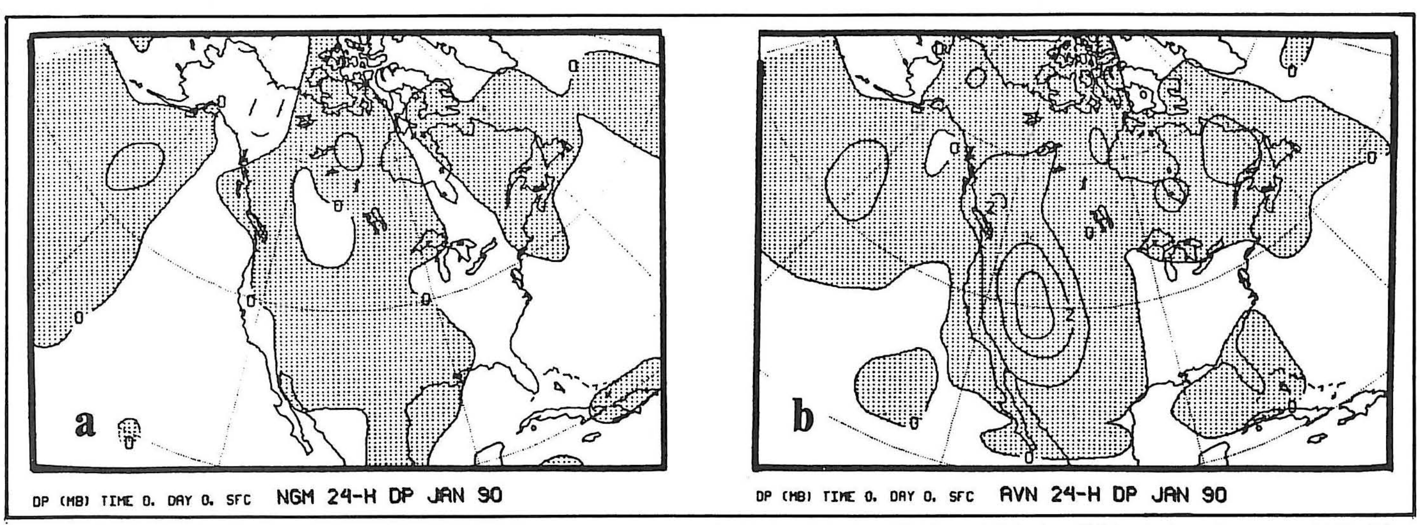


Fig. 4. The mean 24-h anticyclone sea-level central pressure error (mb) for (a) the NGM and (b) the AVN, during January, 1990. The contour interval is every 1 mb. Solid contours denote positive (overprediction) errors and are shaded. Dashed contours denote negative (underprediction) errors.

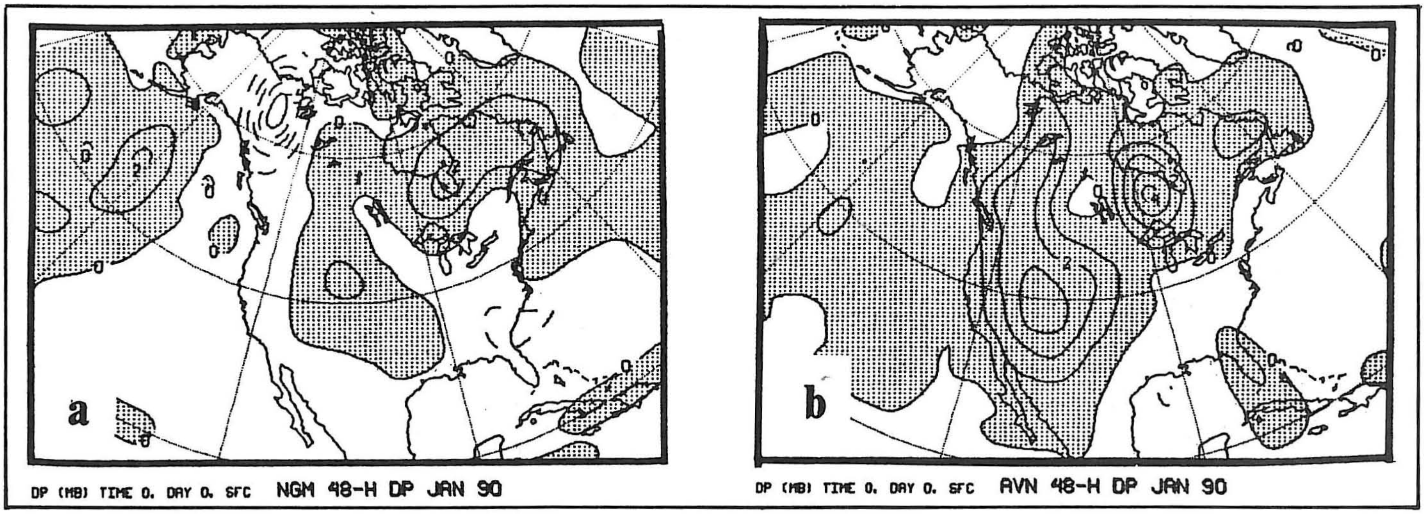


Fig. 5. As in Figure 4 except for 48-h forecast length.

North America increased from the 24-h values. Except for an increase in magnitude, the 48-h pressure error in the AVN is very similar to the 24-h distribution. One notable exception was the weak negative error over Alaska at 48-h. Both models continued to underforecast the central pressure of anticyclones over the eastern United States.

## 5. Pressure Change Errors

The results in this section focus on 12-h pressure change errors in the two models. The categories are based on the forecast and analyzed pressure changes and are defined as follows: forecast to strengthen, observed to strengthen (SS); forecast to weaken, observed to strengthen (WS); forecast to strengthen, observed to weaken (SW); forecast to weaken, observed to weaken (WW). The percent of occurrence of the four categories for the NGM and AVN are shown in Figure 6. The NGM and AVN correctly forecast the 12-h pressure change of surface anticyclones 74 and 78% of the time respectively. The most striking thing about Figure 6 is how similar the 12-h pressure changes are forecast by both models. The data in Figure 6 were for all 12-h deepending rates independent of forecast length.

### a. Forecast to strengthen, observed to strengthen (SS)

In this category, all anticyclones which were both forecast and observed to strengthen during the 12-h period were examined. The results are shown in Table 3. Negative (positive) pressure change errors indicate that the 12-h pressure change forecast was too slow (fast) to strengthen the anticyclone.

The NGM 12-h pressure change errors were all negative for SS anticyclones indicating that the NGM was too slow to forecast the strengthening of surface anticyclones. The mean and standard deviation of the 12-h pressure change error varied little with forecast length. The distance, pressure and thickness errors for SS anticyclones in the NGM are also shown in Table 3. The overall pressure error was negative at all forecast periods. The thickness errors indicate an overall warm bias, with the exception of a cold bias at 12 h. The distance errors for SS anticyclones in the NGM are comparable to the NGM total sample distance errors (Table 1).

The AVN 12-h pressure change errors (Table 4) were positive for SS anticyclones at 12, 24 and 36 h, indicating that the AVN was too fast to forecast the strengthening of surface anticyclones. At 48 h the AVN 12-h pressure change error was negative, indicating that the AVN was too slow to forecast anticyclone intensification at 48 h. The distance, pressure and thickness errors for SS anticyclones in the AVN are also shown in Table 4. The overall pressure error was positive at all forecast periods. The thickness errors indicated an overall cold bias at all forecast lengths. The distance errors for SS anticyclones in the AVN were comparable to the AVN sample total (Table 2) distance errors. The AVN distance errors for SS anticyclones were *substantially* smaller than the distance errors for SS anticyclone errors in the NGM at all forecast lengths, especially at 48 h.

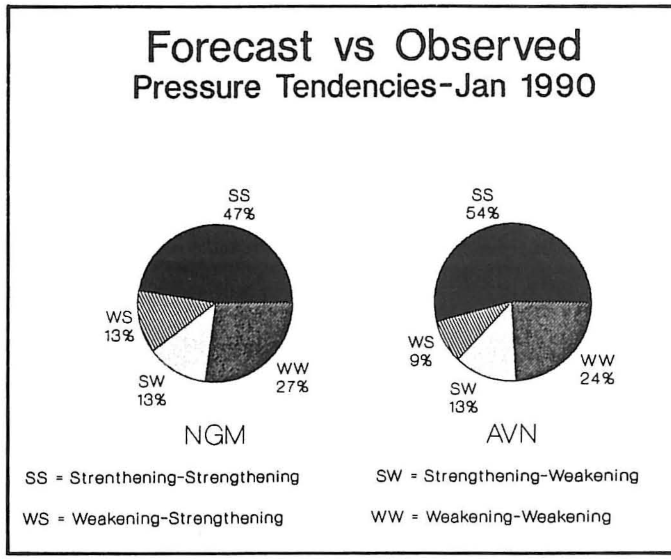


Fig. 6. Forecast versus observed 12-h pressure tendencies in the NGM and AVN for January, 1990. The percent occurrence in each category is shown. A description of the categories is given in the text.

NGM Forecast Errors: Forecast to Strengthen, Observed to Strengthen

| Model | Fcst | Cat | Number | Pressure chg (mb) | | Distance (km) | | Pressure (mb) | | Thickness (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mean | std | mean | std | mean | std | mean | std |
| NGM | 12 | SS | 75 | -0.46 | 1.76 | 205 | 144 | -0.47 | 1.76 | -2.00 | 38.85 |
| NGM | 24 | SS | 58 | -0.22 | 1.97 | 281 | 221 | -0.48 | 2.16 | 3.60 | 45.25 |
| NGM | 36 | SS | 45 | -0.82 | 1.75 | 291 | 180 | -1.27 | 3.10 | 11.33 | 51.23 |
| NGM | 48 | SS | 42 | -0.38 | 1.85 | 425 | 303 | -0.97 | 2.98 | 10.00 | 66.58 |

Table. 3. The mean 12-h pressure change, distance, pressure, and thickness errors by forecast hour (fcst) in NGM anticyclones for January, 1990. Data include the model, cyclone pressure change category (explained in text), the number of cases, the mean 12-h pressure change (mb), distance (km), pressure (mb) and thickness (m) errors, and standard deviations.

AVN Forecast Errors: Forecast to Strengthen, Observed to Strengthen

| Model | Fcst | Cat | Number | Pressure chg (mb) | | Distance (km) | | Pressure (mb) | | Thickness (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mean | std | mean | std | mean | std | mean | std |
| AVN | 12 | SS | 89 | 0.89 | 2.01 | 145 | 110 | 0.89 | 2.01 | -14.94 | 35.98 |
| AVN | 24 | SS | 59 | 0.71 | 1.91 | 171 | 103 | 1.85 | 2.48 | -17.12 | 41.42 |
| AVN | 36 | SS | 52 | 0.00 | 1.92 | 217 | 143 | 1.77 | 3.04 | -24.81 | 47.09 |
| AVN | 48 | SS | 49 | -0.14 | 1.80 | 306 | 197 | 0.94 | 3.09 | -17.96 | 54.62 |

Table 4. As in Table 3 except for the AVN anticyclone category SS.

NGM Forecast Errors: Forecast to Weaken, Observed to Strengthen

| Model | Fcst | Cat | Number | Pressure chg (mb) | | Distance (km) | | Pressure (mb) | | Thickness (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mean | std | mean | std | mean | std | mean | std |
| NGM | 12 | WS | 19 | -2.60 | 2.41 | 209 | 98 | -2.58 | 2.41 | 21.05 | 34.63 |
| NGM | 24 | WS | 12 | -2.08 | 0.95 | 216 | 119 | -2.17 | 1.46 | -5.83 | 30.13 |
| NGM | 36 | WS | 11 | -3.00 | 2.05 | 561 | 528 | -3.00 | 2.37 | 14.54 | 25.71 |
| NGM | 48 | WS | 11 | -3.09 | 1.98 | 325 | 189 | -3.36 | 4.27 | 8.18 | 23.28 |

Table 5. As in Table 3 except for the NGM anticyclone category WS.

AVN Forecast Errors: Forecast to Weaken, Observed to Strengthen

| Model | Fcst | Cat | Number | Pressure chg (mb) | | Distance (km) | | Pressure (mb) | | Thickness (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mean | std | mean | std | mean | std | mean | std |
| AVN | 12 | WS | 7 | -1.57 | 0.73 | 144 | 41 | -1.57 | 0.73 | -5.71 | 28.65 |
| AVN | 24 | WS | 10 | -1.70 | 1.01 | 252 | 96 | -1.00 | 1.34 | -4.00 | 19.60 |
| AVN | 36 | WS | 12 | -2.17 | 1.14 | 181 | 100 | -0.33 | 1.89 | 2.50 | 34.67 |
| AVN | 48 | WS | 12 | -2.75 | 1.53 | 247 | 209 | -0.08 | 3.04 | 17.50 | 30.59 |

Table 6. As in Table 3 except for the AVN anticyclone category WS.

### b. Forecast to weaken, observed to strengthen (WS)

In this category, all anticyclones which were forecast to weaken and observed to strengthen were examined. The results are shown in Tables 5 and 6 for the NGM and AVN, respectively. Due to the small sample size in both models, the results should be interpreted with caution.

Both models underforecast the 12-h pressure changes for WS anticyclones. The 12-h pressure change errors were larger in the NGM at all forecast periods but the error varied by less than 1 mb. In the AVN, the 12-h pressure change error increased with forecast length. Both models underforecast the central pressure of WS anticyclones, with the NGM having a larger underprediction error than the AVN at all forecast periods. Thickness errors for WS anticyclones in the NGM show a slight warm bias at the 12-, 36- and 48-h forecast periods. The AVN had a warm bias at the 36- and

48-h forecast periods. The AVN had a cold bias at the 12- and 24-h forecast periods. The NGM had a cold bias at the 24-h forecast period. Distance errors indicate that the AVN was better able to forecast the position of WS anticyclones than the NGM at all forecast lengths with the exception of the 24-h forecast length.

### c. Forecast to strengthen, observed to weaken (SW)

In this category, all anticyclones which were forecast to strengthen and observed to weaken were examined. The results are shown in Tables 7 and 8 for the NGM and AVN, respectively. Due to the small sample size in both models, the results should again be interpreted with caution.

Both models overforecast the 12-h pressure changes for SW anticyclones. The 12-h pressure change errors were larger in the NGM at he 24-, 36- and 48-h forecast periods. Both models overpredicted the central pressure of SW anticyclones. The AVN pressure errors were larger than the pressure errors in the NGM at all forecast periods for SW anticyclones. Thickness errors for SW anticyclones in the NGM showed a slight cold bias at 12 and 24 h and a warm bias at 36 and 48 h. The AVN had a cold bias at all forecast periods with the exception of the 24 h forecast period. Distance errors indicate that the AVN was better able to forecast the position of SW anticyclones than the NGM at all forecast periods.

### d. Forecast to weaken, observed to weaken (WW)

In this category, all anticyclones which were forecast and observed to weaken were examined. The results are shown in Tables 9 and 10 for the NGM and AVN, respectively.

The NGM 12-h pressure change errors (Table 9) were slightly positive for WW anticyclones at 24, 36 and 48 h indicating that the NGM was too slow to forecast the weakening surface anticyclones. The mean and standard deviation of the 12-h pressure change errors varied little with forecast length. The overall pressure errors were slightly negative at all forecast lengths with the exception of the 36-h forecast period. The standard deviation of the pressure errors increased with forecast length after 24 h.

The distance and thickness errors for WW anticyclones in the NGM are also shown in Table 9. The thickness errors indicate a warm bias at 12, 24 and 36 h, and a cold bias at 48 h. The distance errors for WW anticyclones in the NGM are comparable to the NGM sample total (Table 1) distance errors at 12 and 24 h. The 36- and 48-h distance errors for WW anticyclones were smaller than the overall NGM sample, particularly at 48 h.

The AVN 12-h pressure change errors (Table 10) were positive for WW anticyclones at all forecast periods, indicating that the AVN was too slow to forecast the weakening of surface anticyclones. The overall pressure errors for WW anticyclones show that the AVN overpredicted the central pressure of surface anticyclones at all forecast periods.

The distance and thickness errors for WW anticyclones in the AVN are also shown in Table 10. The thickness errors indicate an overall cold bias at all forecast periods. The distance errors for WW anticyclones in the AVN are comparable to the AVN sample total (Table 2) distance errors at 12, 24 and 36 h and smaller than the NGM forecasts for WW anticyclones at all forecasts after 12 h. Except for the 12-h forecast, the AVN was better able to forecast the position of WW anticyclones compared to the AVN (Table 2) sample total. The differences were statistically significant after 24 h.

## 6. Discussion

The results in this study reveal that the AVN outperformed the NGM in its ability to forecast the position of surface anticyclones in January, 1990. The NGM had a smaller overall error in forecasting the central pressure of surface anticyclones. Furthermore, the AVN was better able to forecast the sign of the 12-h pressure change of surface anticyclones than the NGM.

Overall, the NGM had a tendency to underforecast the central pressure of surface anticyclones at all forecast periods. The AVN had a strong tendency to overforecast the central pressure of surface anticyclones.

The overall overprediction of surface anticyclone central pressures in the AVN appears to be the result of several

NGM Forecast Errors: Forecast to Strengthen, Observed to Weaken

| Model | Fcst | Cat | Number | Pressure chg (mb) | | Distance (km) | | Pressure (mb) | | Thickness (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mean | std | mean | std | mean | std | mean | std |
| NGM | 12 | SW | 11 | 2.27 | 0.86 | 219 | 160 | 2.27 | 0.86 | -9.09 | 44.41 |
| NGM | 24 | SW | 17 | 2.88 | 1.71 | 280 | 179 | 2.88 | 1.71 | -4.71 | 58.62 |
| NGM | 36 | SW | 15 | 3.33 | 2.21 | 438 | 346 | 3.33 | 2.21 | 12.00 | 77.82 |
| NGM | 48 | SW | 17 | 3.82 | 2.83 | 453 | 312 | 2.84 | 2.83 | 12.35 | 75.03 |

Table 7. As in Table 3 except for the NGM anticyclone category SW.

AVN Forecast Errors: Forecast to Strengthen, Observed to Weaken

| Model | Fcst | Cat | Number | Pressure chg (mb) | | Distance (km) | | Pressure (mb) | | Thickness (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mean | std | mean | std | mean | std | mean | std |
| AVN | 12 | SW | 22 | 2.73 | 1.66 | 160 | 86 | 2.73 | 1.66 | -5.45 | 41.42 |
| AVN | 24 | SW | 16 | 2.75 | 1.09 | 222 | 183 | 2.50 | 1.97 | 18.75 | 39.67 |
| AVN | 36 | SW | 14 | 2.29 | 1.00 | 306 | 286 | 3.64 | 2.47 | -3.57 | 48.05 |
| AVN | 48 | SW | 8 | 3.25 | 1.56 | 289 | 194 | 4.88 | 2.52 | -6.25 | 46.08 |

Table 8. As in Table 3 except for the AVN anticyclone category SW.

NGM Forecast Errors: Forecast to Weaken, Observed to Weaken

| Model | Fcst | Cat | Number | Pressure chg (mb) | | Distance (km) | | Pressure (mb) | | Thickness (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mean | std | mean | std | mean | std | mean | std |
| NGM | 12 | WW | 48 | -0.08 | 2.04 | 198 | 222 | -0.08 | 2.04 | 5.00 | 30.55 |
| NGM | 24 | WW | 29 | 0.10 | 2.17 | 324 | 360 | -0.24 | 1.76 | -2.41 | 42.56 |
| NGM | 36 | WW | 24 | 0.46 | 2.53 | 313 | 326 | 0.63 | 2.93 | 0.83 | 44.99 |
| NGM | 48 | WW | 19 | 0.05 | 2.14 | 300 | 174 | 0.05 | 3.40 | -5.26 | 49.14 |

Table 9. As in Table 3 except for the NGM anticyclone category WW.

AVN Forecast Errors: Forecast to Weaken, Observed to Weaken

| Model | Fcst | Cat | Number | Pressure chg (mb) | | Distance (km) | | Pressure (mb) | | Thickness (m) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | mean | std | mean | std | mean | std | mean | std |
| AVN | 12 | WW | 34 | 0.53 | 1.50 | 204 | 130 | 0.53 | 1.50 | -1.77 | 34.50 |
| AVN | 24 | WW | 23 | 0.30 | 1.20 | 192 | 166 | 2.13 | 2.72 | -16.96 | 44.28 |
| AVN | 36 | WW | 25 | 0.04 | 2.05 | 217 | 135 | 2.04 | 2.96 | -15.20 | 53.30 |
| AVN | 48 | WW | 29 | 0.24 | 1.71 | 257 | 174 | 2.45 | 3.44 | -40.00 | 54.20 |

Table 10. As in Table 3 except for the AVN anticyclone category WW.

problems. First, the AVN tended to overpredict the central pressure of intensifying anticyclones. The mean pressure error for strengthening anticyclones ranged from +0.89 to +1.85 mb at all forecast lengths. A second source for the overprediction error was that the AVN was unable to weaken anticyclones as fast as they weakened. A third possible source of the overprediction error was that the AVN had a tendency to intensify anticyclones which were observed to weaken. When this occurred, the AVN 12-h pressure change errors were on the order of +3 mb at all forecast periods. The most serious anticyclone overprediction problem in the AVN appears to be related to the effects of model terrain. Examination of Figures 4b and 5b reveal that the AVN overprediction error was maximized over the elevated terrain of western North America. Grumm and Gyakum (1986) showed a similar overprediction error during winter in an older version of the AVN over the Rocky Mountains and western plains of the United States.

The overall underprediction error of surface anticyclone central pressures in the NGM appears to be related to the NGM's inability to properly simulate strengthening anticyclones. For example, at 36 and 48 h the 12-h pressure change errors and overall pressure errors for SS and WS anticyclones in Tables 3 and 5 show that the NGM underpredicted the intensification of anticyclones by −1 mb when the model correctly forecast the sign of the 12-h pressure change and by over −2.5 mb when the model incorrectly forecast the sign of the 12-h pressure change. These negative 12-h strengthening rate errors contributed to relatively large negative pressure errors for strengthening anticyclones.

The overall warm bias in the NGM at all forecast periods is expected based on the sign of the pressure errors. However, after the 12-h forecast period, the mean pressure errors cannot account for all of the mean thickness errors.

A summation of the results from this study and the results found by Chen et al. (1987) are shown in Table 11. Both grid point models (the NGM and JFLM) underforecast the central pressure of surface anticyclones at 36 h. Both spectral (the AVN and NOGAPS) models had the smallest central pressure RMS's. The current version of the AVN outperformed all models in forecasting the position of surface anticyclones. The 48-h AVN position errors and the RMS of the errors were smaller than the 36-h position errors in the NGM, JFLM and NOGAPS. The data for the NOGAPS and JFLM were

| Model | Fcst | Pressure Errors (mb) | | Distance Errors (km) | |
|---|---|---|---|---|---|
| | | mean | RMS | mean | RMS |
| NGM | 36 | -0.15 | 3.25 | 352 | 462 |
| AVN | 36 | 1.71 | 3.36 | 230 | 284 |
| JFLM | 36 | -1.30 | 3.40 | 396 | 513 |
| NOGAPS | 36 | 0.10 | 3.30 | 422 | 503 |
| NGM | 48 | -0.33 | 3.93 | 413 | 503 |
| AVN | 48 | 1.62 | 3.74 | 311 | 377 |

Table 11. The mean and root mean square pressure and distance errors by forecast length (FCST) for NGM, AVN, JFLM and NOGAPS. The data for the JFLM and NOGAPS are from Chen et al (1987).

| Model | Fcst | Pressure Errors (mb) | | Distance Errors (km) | |
|---|---|---|---|---|---|
| | | mean | RMS | mean | RMS |
| NGM | 48 | -0.33 | 3.93 | 413 | 503 |
| AVN | 48 | 1.62 | 3.74 | 311 | 377 |
| SPECTRAL | 48 | -1.59 | 4.85 | 494 | 647 |
| LFM | 48 | -2.23 | 5.86 | 510 | 663 |

Table 12. The mean and root mean square error of the pressure and distance errors by forecast length for the NGM, AVN, SPECTRAL and LFM. Data for the LFM and Spectral are from Grumm and Gyakum (1986).

obtained for the months of May, June and July. Directly comparing warm season to cold season results gives an unfair advantage to the warm season model. Distance and pressure errors typically decrease in the spring and increase in the autumn. The winter months have the largest error and the summer months have smaller errors. With this in mind, the JFLM and NOGAPS results were for months where these models should have had their smallest errors.

The results from this study were compared to the anticyclone forecasts in older versions of the JFLM and NOGAPS (Chen et al. 1987). Both the JFLM and the NOGAPS have been replaced by more sophisticated models since 1983. The JMA upgraded all of its operational numerical models in 1988 (Segami et al. 1989). The Naval Oceanographic and Atmospheric Research Laboratories (NOARL) upgraded the NOGAPS in 1988 (Hogan and Rosmond 1990). Currently, NOARL runs the NOGAPS with an 18-level normal mode initialization spectral model comparable to the operational spectral model used by the NMC for the AVN forecasts. It is probable that both the JMA and NOARL have seen improvements in their respective forecast systems, similar to those seen in NMC's operational models.

Table 12 is a summary of the 48-h forecast errors from this study and the results found by Grumm and Gyakum (1986). All of these data were from cold season months. The data indicate that the spectral model at NMC has improved considerably over the past 8 years. The NGM and the AVN offer improved positions of surface anticyclones relative to the older spectral model and the LFM. The AVN had the best position forecasts of surface anticyclones of any model for which results have been published.

## 7. Conclusions

A quantitative assessment has been made of the surface anticyclone forecast errors found in both the operational NGM and AVN for January 1990. The area of consideration was North America and the adjacent oceans. The results showed that improvements in numerical weather prediction have been made over the past decade. The most important finding was that the AVN was better able to forecast the position of surface anticyclones than the NGM.

The following summarizes the results for this study:

1. The AVN position forecasts of surface anticyclones were substantially better than those produced by the NGM. At 48 h the AVN mean position error is nearly 25% smaller than the mean position error in the NGM.
2. The AVN overpredicted the central pressure of surface anticyclones. This overprediction error was maximized over the elevated terrain of western North America.
3. The NGM tended underforecast the central pressure of surface anticyclones.
4. The NGM forecasts surface anticyclones too far south and east of the observed position.
5. The NGM had a slight warm bias in the 1000- to 500-mb thickness forecasts over surface anticyclones.
6. The AVN had a cold bias in the 1000- to 500-mb thickness forecasts over surface anticyclones.
7. For strengthening anticyclones:
   a. The AVN had better position forecasts than the NGM.
   b. The NGM underpredicted the central pressure.
   c. The AVN overpredicted the central pressure.
   d. The NGM had a warm bias in the 1000- to 500-mb thickness forecasts.
   e. The AVN had a distinct cold bias in the 1000- to 500-mb thickness forecasts.
8. For weakening anticyclones:
   a. With the exception of the 12-h period, the AVN was better able to forecast the position of weakening surface anticyclones.
   b. Both models were too slow in forecasting the rate of weakening of surface anticyclones.
   c. The AVN tended to overforecast the central pressure of weakening anticyclones by over 2 mb from 24 h on.
   d. The NGM had a slight warm bias in the 1000- to 500-mb thickness forecasts at 12, 24 and 36 h.
   e. The AVN had a distinct cold bias at all forecast periods.

Recent research on model forecasts of cyclone and anticyclone pressure, distance, thickness and 12-h pressure change errors has revealed that during January, 1990, the AVN was better able to forecast the movement of surface pressure systems than the NGM. Furthermore, the AVN was better able to forecast the sign of the 12-h pressure change than the NGM. The results presented here, the results of Grumm and Siebers (1990) and the results of Chen et al. (1987) suggest that spectral models are superior to grid point models in predicting the movement of surface cyclones and anticyclones. Further comparisons of the AVN to the NGM will be conducted at NMC to determine if the increased resolution of the Global Spectral model improves the forecasts of the surface cyclones and anticyclones.

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## Authors

Richard H. Grumm received his B.S. degree in meteorology from the State University of New York at Oneonta, in 1979 and his M.S. degree in atmospheric sciences from the State University of New York, at Albany, in 1981. Mr. Grumm began working for the Federal Government in 1982 as a meteorological instructor at Chanute AFB, Rantoul, Illinois after a brief stint as a research assistant at the University of Virginia. In 1984 he began working on climatological studies for the United States Air Force at Scott AFB, Illinois and in 1987 joined the NMC Techniques Development Group. Mr. Grumm is involved in model verification-studies and also works operational forecast shifts at the Meteorological Operations Division.

Anthony L. Siebers received his B.S. degree in applied mathematics and physics from the University of Wisconsin at Milwaukee and his M.S. degree in meteorology from the University of Wisconsin at Madison. He joined NOAA in 1979, working for the satellite service in Washington, D.C. and then moving to the National Severe Storms Forecast Center, Kansas City, Missouri, where he worked extensively with interactive computer systems and in the development of techniques to support severe storm forecasting. Mr. Siebers next assignment took him back to the University of Wisconsin in Madison as the National Weather Service representative to the VISSR Atmospheric Sounder project. Since joining NMC, Mr. Siebers has been involved in the Modernization and Associated Restructuring (MAR) program and has served as the NMC representative to the AWIPS project. He is currently a member of the NWA Committee on Atmospheric Technology.

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