NMC NOTES

Systematic Surface Anticyclone Errors in Nested Grid Model Run at NMC: December 1988–August 1989

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ABSTRACT

A quantitative assessment has been made of the surface anticyclone forecast errors found in the operational nested grid model (NGM) run at the National Meteorological Center (NMC). Preliminary results covering a period from 1 December 1988 to 31 August 1989 reveal that the NGM predicts the central pressure of surface anticyclones to be too low over much of central and eastern North America during the winter and spring, especially along the track of transient anticyclones. The NGM tends to predict surface anticyclone pressure to be too high over the eastern Pacific and portions of the western Atlantic during winter, spring and summer. Pressure errors grow by forecast length and season. The 48-h forecast errors are larger in magnitude and better defined than the 24-h forecasts. The winter and spring pressure errors are better organized and have larger magnitudes than in summer.

Thickness (1000–500 mb) errors over the anticyclone center indicate an overall warm bias, especially over the North American continent and the adjacent western Atlantic Ocean, where anticyclones tend to be transient. Areas of negative thickness errors (cold bias) are found over the oceans and the elevated terrain of western North America. In general, the model places surface anticyclones too far south and east of the verifying position in the colder months.

1. Introduction

A study of systematic surface cyclones in the National Meteorological Center (NMC) nested grid model (NGM) (Grumm and Siebers 1989, hereafter referred to as GS) revealed that the NGM tended to overdevelop surface cyclones over North America and underdevelop surface cyclones over the oceans. In this note, systematic errors are examined for surface *anticyclones* using the methods described in GS.

The purpose of this note is to present preliminary findings from an examination of NGM surface anticyclone pressure, thickness, and displacement errors. These errors were examined for the winter, spring, and summer seasons of 1988 through 1989. Previous studies of anticyclone forecasts in NMC models focused on the limited fine mesh model (LFM) and the six-level primitive equation model (Colucci and Bosart 1979), and the LFM and spectral models (Grumm and Gyakum 1986, hereafter GG).

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 analysis or forecast. Tracking and data storage were as described in GS. The NGM initialized analyses at 0000 and 1200 UTC were used to represent the verifying atmosphere for the period from 0000 UTC 1 December 1988 to 1200 UTC 31 August 1989. During this period nine full model cycles were lost, one in May and eight in July. An additional six 42- and 48-h forecasts were not available.

Errors in sea-level pressure, thickness, and 850 mb temperature of the cyclone are defined as forecast − observed. A negative (positive) error in pressure corresponds to underprediction (overprediction) of the anticyclone central pressure. Anticyclone displacement and directional errors were also computed by comparing the forecast to the observed position, as in GS. The frequency of events and the forecast errors were computed for 5 × 5 lat and long boxes, as described in GS.

3. Characteristics of anticyclones during winter, spring, and summer 1988–89

In this note, the winter season is defined as the months of December 1988–February 1989, spring is defined as March–May 1989, and summer is defined as June–August 1989.

Figure 1 shows the number of anticyclones per season, as diagnosed from the NGM initialized analyses. The primary tracks of anticyclones as observed for each season are depicted by the large arrows while the

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smaller arrows indicate secondary anticyclone tracks. The seasonal tracks were derived from monthly composite tracks.

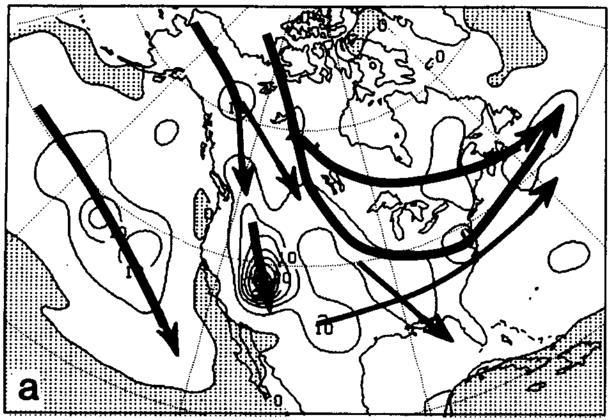
In the winter season (Fig. 1a), the arctic source region was very active. Anticyclones tracked from northwestern Canada and eastern Alaska into the United States. Anticyclones were numerous over the eastern Pacific and the Rocky Mountains during the winter. The arctic anticyclone track split in central Canada with approximately an equal number of systems tracking across southern Canada and the other systems tracking across the central and eastern United States; both tracks converged over the western Atlantic, south of Nova Scotia. Note that these two primary tracks did not cross Hudson Bay and the Great Lakes. In February (not shown), the anticyclone track north of the Great Lakes disappeared and anticyclone activity in the eastern Pacific decreased.

In the spring (Fig. 1b), anticyclone activity increased in the eastern Pacific in early March and the region stayed active through May. The primary North American anticyclone track, with its source in the Arctic, shifted slowly northward from March to May. The primary track in March and April was similar to the track in the winter season. The secondary track from the Beaufort Sea to central Hudson Bay primarily was due to an increase in anticyclone activity in May. The anticyclone maximum over the Rocky Mountains was still present.

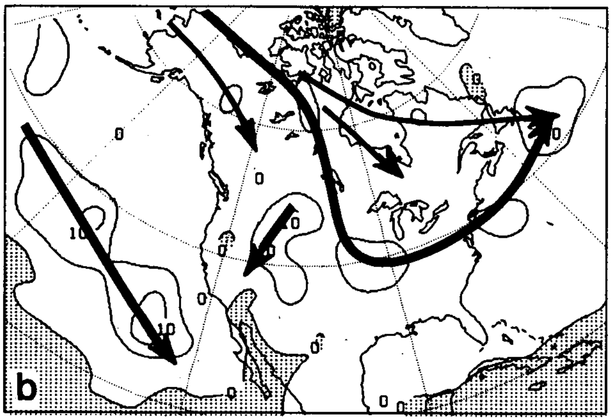
In the summer, (Fig. 1c), there was a continued decrease in anticyclones tracking across the southern half of North America. The primary North American anticyclone track was from the Beaufort Sea to the west shore of Hudson Bay. Anticyclone activity continued over the Rocky Mountains and the eastern Pacific. The nature of the Pacific anticyclone activity shifted from transient systems to slow-moving, meandering systems.

In summary, the eastern Pacific and Rocky Mountains exhibited the largest concentration of anticyclones for all three seasons. The high concentrations reflect both the semipermanent nature and slow movement of the anticyclones that occur in these two regions. During the winter and spring seasons (Figs. 1a and 1b), secondary maxima from northwestern Canada southward toward eastern Canada and the central and eastern United States, and the offshore waters reflected the primary North American anticyclone tracks. The secondary maxima over the western Atlantic off the northeastern United States and southeastern Canadian coast was near the confluence of the two North American anticyclone tracks during both winter and spring.

INITIALIZED NGM ANALYSIS



WINTER



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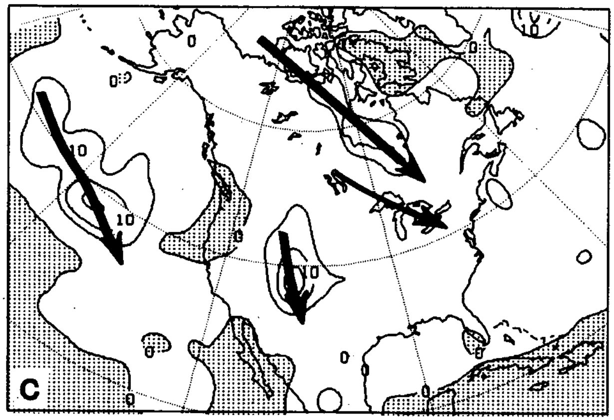

SUMMER

FIG. 1. Geographical distribution of anticyclones used to compute NGM error statistics. The analysis is based upon smoothed frequencies found in each 5° lat-long quadrangle: (a) winter 1988–89, (b) spring 1989, and (c) summer 1989. The counts were made from the available twice-daily forecasts for the period 1 December 1988–28 February 1989 for winter, 1 March–31 May 1989 for spring and 1 June–31 August 1989 for Summer. The contour interval is five events. Areas of shading indicate regions were no anticyclones were observed. Thick and thin arrows depict the primary and secondary anticyclone tracks, respectively, observed during each season.

The secondary maxima over northwestern Canada shifted to near Hudson Bay by summer, along the primary summertime North American anticyclone track.

4. Systematic anticyclone errors

a. Pressure errors

The geographical distribution of anticyclone central-pressure errors for the two forecast periods of 24 and 48 h are shown in Figs. 2 and 3. The 24- and 48-h pressure error fields show less amplitude than the equivalent cyclone pressure errors shown by GS. Negative errors (underprediction) were confined mainly to North America in all seasons (Figs. 2a–c). Positive errors (overprediction) dominated most of the oceanic regions in all seasons.

In Fig. 2a, the 24-h NGM forecasts underpredicted anticyclone central pressure during the winter over the Rocky Mountains, a region where anticyclone occurrences were maximized (see Fig. 1). However, the trend was reversed during the spring and summer (Figs. 2b–c).

The pressure errors for the 48-h forecasts (Fig. 3) are significantly larger in magnitude than at 24 h. Values of errors in the summer are smaller in magnitude than those in winter and spring. Underprediction errors in the winter (Fig. 3a) occurred in northwestern Canada and from Hudson Bay south to the Great Lakes. Overprediction of anticyclone central pressures occurred across the western United States, much of the eastern Pacific, the western Atlantic, and Alaska. These features are remarkably similar to the anticyclone pressure errors found for the spectral model during the winter of 1981/82, as shown by GG, with the exception of the large area of underprediction found over the central Pacific. However, the anticyclone pressure errors found for the LFM during the winter of 1981/82, as shown by GG, showed significant differences from the results shown here.

By the spring (Fig. 3b), the areas of underprediction expanded across western Canada into Alaska and much of the continental United States. The regions of overprediction decreased in areal coverage. In the summer (Fig. 3c), the 48-h pressure errors were relatively small in magnitude. Overprediction across the eastern Pacific, the southern Rocky Mountains and the western Atlantic became the predominant error features during summer. It is interesting to note that the overprediction error across the eastern Pacific and the Rocky Mountains corresponded to the two areas with the largest frequency of anticyclones (Fig. 1c).

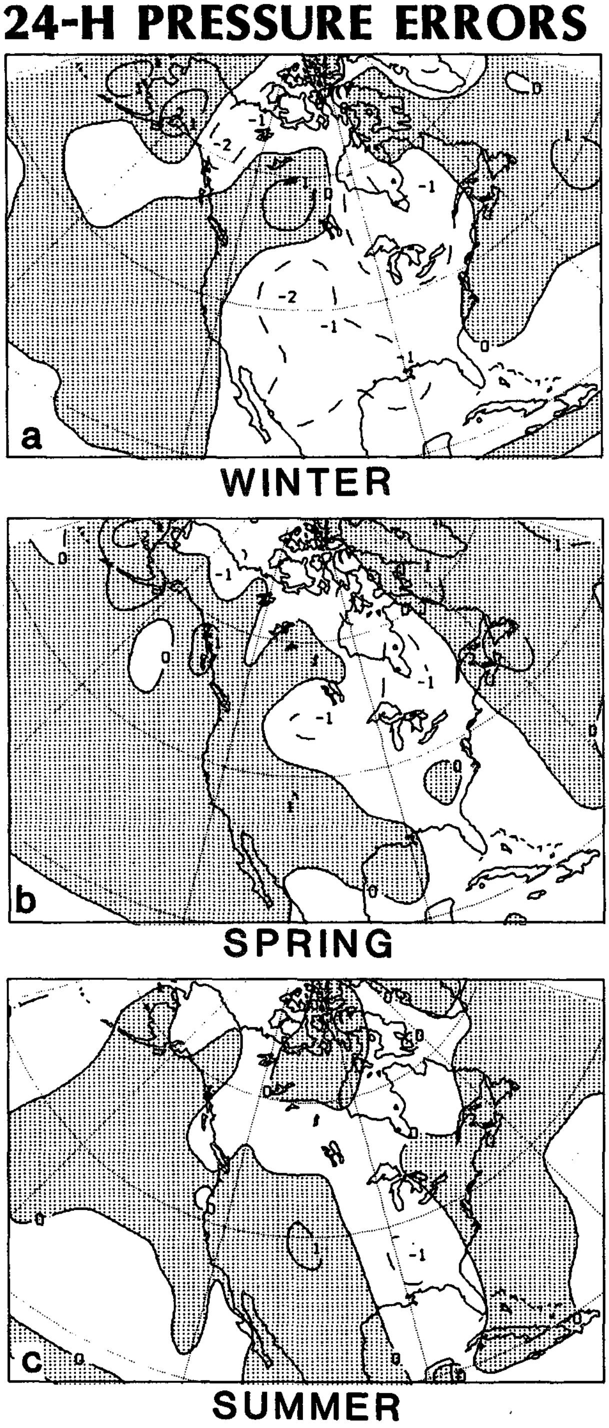

FIG. 2. Mean 24-h anticyclone sea-level central pressure error (mb) for (a) winter 1988/89, (b) spring 1989, and (c) summer 1989. Solid contours and shading denote positive (overprediction) errors. Dashed contours denote negative (underprediction) errors. The contour interval is 1 mb.

b. Thickness errors

Figures 4 and 5 show the geographical distribution of thickness errors at the anticyclone centers in the NGM 24- and 48-h forecasts. In general, the NGM overpredicts (warm bias) the thickness and 850 mb temperature (not shown) over the anticyclone centers over land, and underpredicts the thickness (cold bias) over the anticyclone centers over the oceans. In the

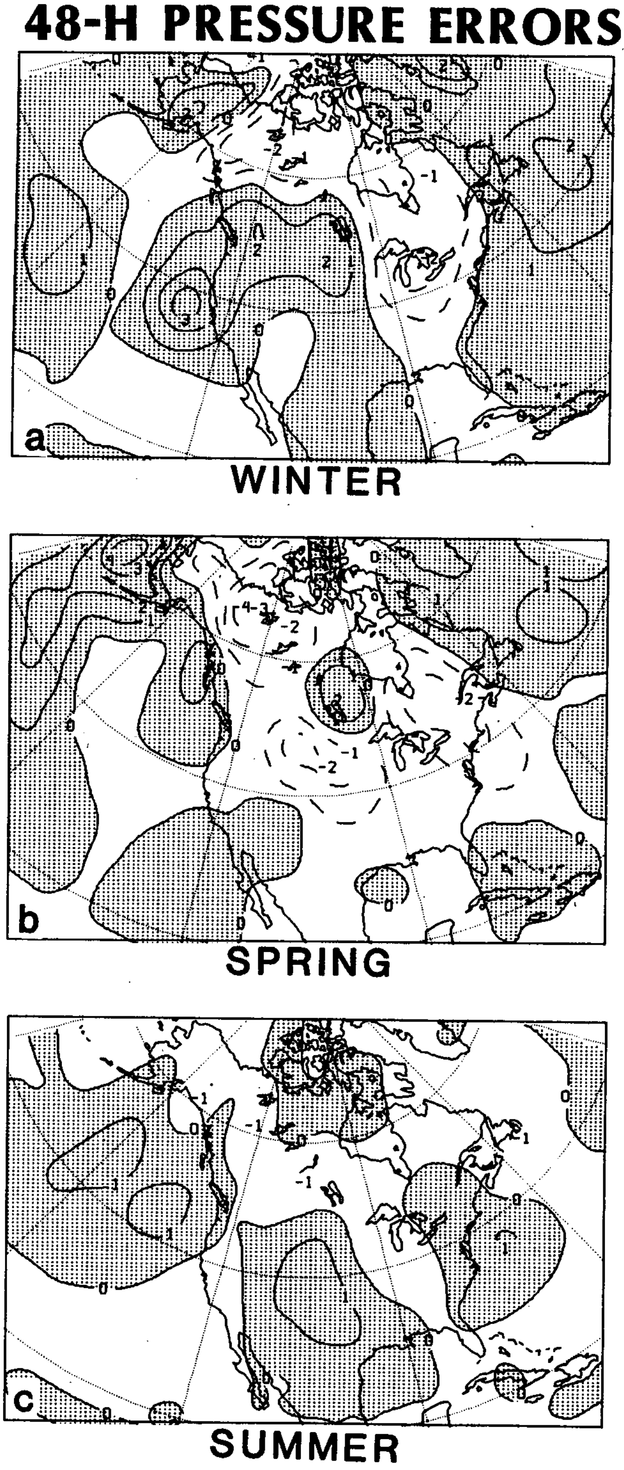

FIG. 3. As in Fig 2 except for 48-h forecast.

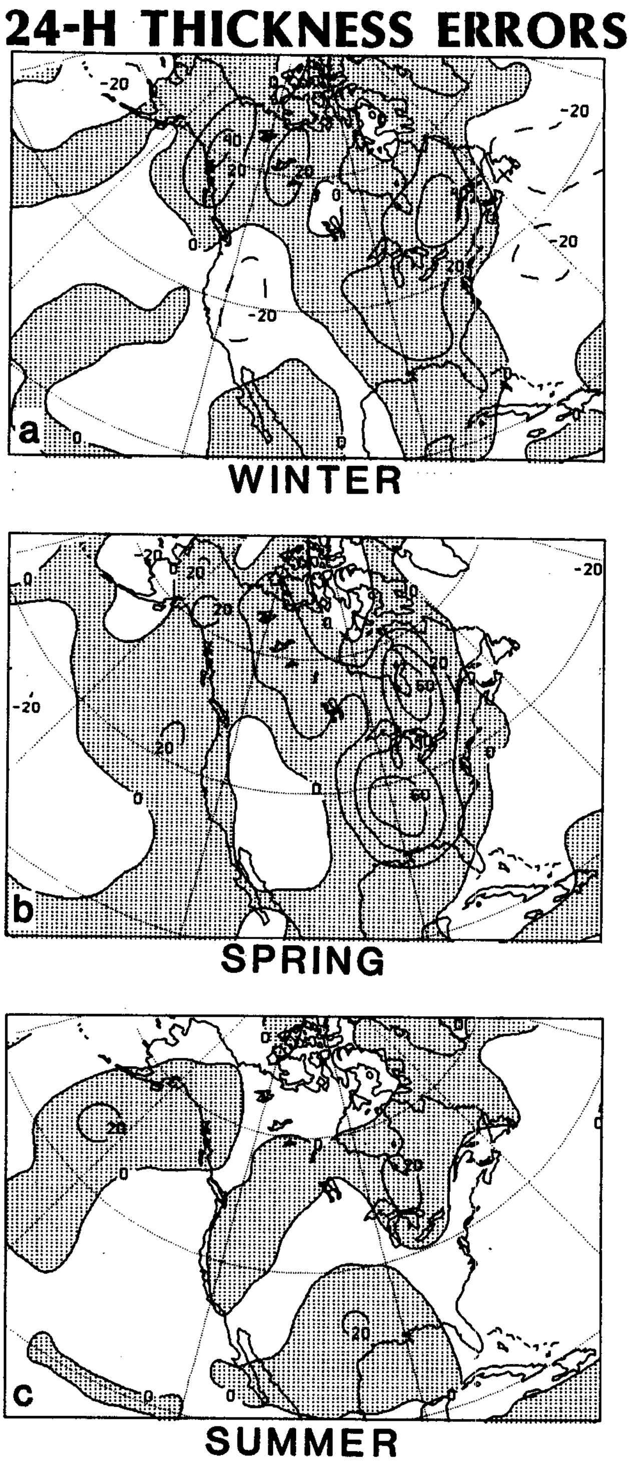

FIG. 4. Mean 24-h anticyclone 1000–500 mb thickness error (m) for (a) winter 1988/89, (b) spring 1989, and (c) summer 1989. Solid contours and shading denote positive (overprediction) errors. Dashed contours denote negative (underprediction) errors. The contour interval is 20 m.

winter (Figs. 4a and 5a) the NGM overpredicts the thickness over the anticyclone center in both the 24- and 48-h forecasts over most of North America and the adjacent oceans. The primary winter and spring (Figs. 4b and 5b) cold bias over North America is confined to the western United States. Underprediction of the thickness dominates forecasts over the eastern Pacific and western Atlantic oceans.

In the spring (Figs. 4b and 5b), the NGM continues

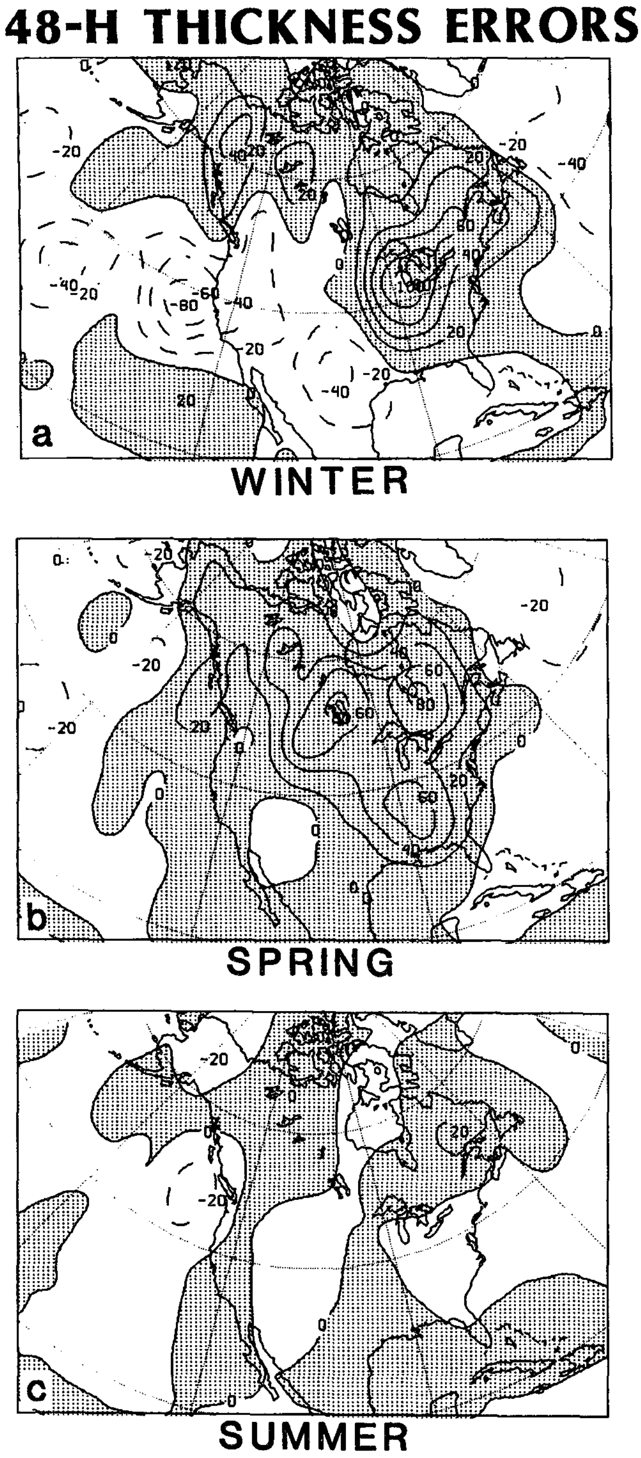

FIG. 5. As in Fig 4 except for 48-h forecast.

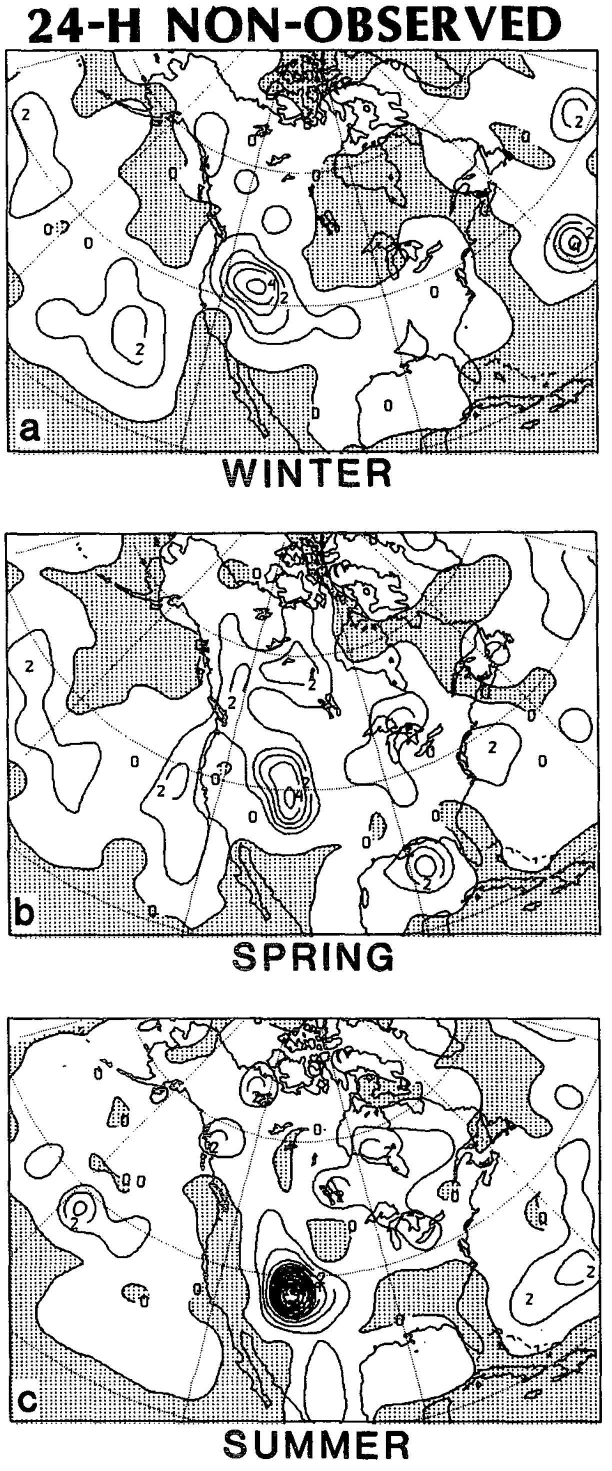

FIG. 6. Forecast but not observed anticyclones for (a) winter 1988–89, (b) spring 1989, and (c) summer 1989. Shading denotes areas of no occurrences. The contour interval is two events.

to show an overprediction error over most of North America and the adjacent oceans in both the 24- and 48-h forecasts. The major area of overprediction extends from central and eastern Canada south to the Gulf coast. The cold bias continues in the spring over most of the oceans away from the continent.

In the summer (Figs. 4c and 5c) the error fields show little amplitude, similar to the summertime pressure error fields (Figs. 2c and 3c). An area of overprediction is still evident between Hudson Bay and the Great

TABLE 1. The mean distance error for the 24-, 36-, and 48-h forecasts of NGM anticyclones for winter, spring and summer 1988–89. Data include the number of cases, mean distance error (km), and standard deviation (km).

	24 h			36 h			48 h		
Season	Cases	Dist	Dev	Cases	Dist	Dev	Cases	Dist	Dev
Winter	554	315	255	513	399	341	467	448	378
Spring	578	266	221	517	353	306	466	417	374
Summer	415	235	218	371	280	228	315	333	284

Lakes and dominates the Gulf coast as well. Underprediction errors still dominate much of the oceans.

c. *Displacement errors*

Displacement errors for the three seasons are displayed in Tables 1 and 2 for the 24-, 36-, and 48-h forecast periods. The mean distance error (Table 1) is largest in the winter and decreases in the spring and summer for all forecast periods. The standard deviation shows the same pattern. Table 2 shows the vector mean errors for the data in Table 1. In the winter (spring and summer), there is a tendency for the NGM to erroneously position anticyclones to the east-southeast (west-southwest) of their observed locations, as evidenced by the directional error of 79° at 24 h and 140° at 48 h. In the winter the magnitude of the vectors is small, indicating considerable scatter. The magnitude of the errors is larger in the spring and summer than during the winter, especially in the 48-hour forecasts, indicating that incorrect positioning of anticyclones is more significant during these seasons.

d. *Forecast but not observed anticyclones*

The forecast, but not observed, anticyclones were also examined (Fig. 6). These nonoccurrences were located primarily in elevated regions of the western United States. Secondary maxima occur over the eastern Pacific. In the winter and spring (Figs. 6a and 6b), the NGM predicts anticyclones that do not verify along the primary North American anticyclone track from eastern Alaska southeastward to the western Atlantic. In the summer (Fig. 6c), there is a large increase in the number of nonobserved anticyclones in the Rocky Mountains. The nonforecast, but observed, anticyclones showed a very similar geographical distribution and seasonal trend and were not shown.

5. Concluding discussion

A quantitative assessment has been made of the surface anticyclone forecast errors found in the operational NGM employed by NMC. Our area of consideration encompasses North America and the adjacent oceans for December 1988 through August 1989. The data were displayed by season.

The NGM initialized analysis is a useful tool for studying monthly and seasonal climatologies of anticyclone tracks and frequencies. For example, the bifurcating track of anticyclones around the Great Lakes (Fig. 1a) is similar to results presented in Harman (1987) and Zishka and Smith (1980). The frequencies and tracks found in the NGM dataset compare well with expected frequencies and tracks based on these earlier studies, with the exception of the preponderance of anticyclones over the elevated terrain of western North America. The overabundance of these analyzed anticyclones suggests that there may be a potentially serious reduction to sea-level pressure error in the NGM, producing the artificially high number of anticyclones in western North America. Data in this region should be viewed with caution.

The NGM tends to underpredict anticyclone central pressure over most of the North American continent. Over the oceans and the elevated terrain, the NGM tends to overpredict anticyclone central pressure. More specifically, the NGM predicts the central pressure of surface anticyclones to be too low over much of central and eastern North America during the winter and spring, especially along the track of transient anticyclones. The NGM tends to predict surface anticyclone pressure to be too high over the eastern Pacific and portions of the western Atlantic during all three seasons. Pressure errors grow by forecast length and season. The 48-h forecast errors are greater and better defined than the 24-h forecasts. The winter and spring pressure errors

TABLE 2. The vector mean errors for the 24-, 36-, and 48-h forecasts of NGM anticyclones for winter, spring and summer 1988–89. Data include the number of cases, magnitude of the vector error (km), and the direction (deg) from the observed to the forecast position.

	24 h			36 h			48 h		
Season	Cases	Dist	Dir	Cases	Dist	Dir	Cases	Dist	Dir
Winter	554	18	79	513	16	154	467	25	140
Spring	578	28	205	517	56	230	466	68	220
Summer	415	20	252	371	31	258	315	77	275

are better organized and have larger magnitudes than in summer.

Over the oceans, the overprediction of anticyclone central pressure may be the result of several factors. One may be the effect of changing from the lower resolution grid-B to the higher resolution grid-C. (See Hoke et al. 1989 for discussion of the grids.) Since both anticyclone *and cyclone* central pressures (see GS) are forecast too high over the oceans, the parameterization of ocean/atmospheric exchanges may be in error.

Thickness errors over the anticyclone center indicate an overall warm bias. This error, like the pressure error has some geographical variability. Over North America and the adjacent oceans, where anticyclones tend to be more transient, the error is generally positive (warm bias). Areas of negative thickness errors (cold bias) are generally found over the oceans and the elevated terrain of western North America, where anticyclones tend to be quasi-stationary. The cold bias over the elevated terrain has a strong winter season preference.

Part of the thickness error over anticyclone centers can be attributed to the pressure errors. With the overall pressure error being negative, an overall warm bias might be expected. In general, areas of negative pressure errors (underprediction) are areas where the warm bias occurs and areas of positive pressure errors (overprediction) are areas where the cold bias occurs.

For example, the areas of anticyclone central pressure underprediction near the Great Lakes (Fig. 3a) compares well with the warm bias concentrated around the Great Lakes (Fig. 5a). Conversely, areas of overprediction over the oceans compare well with areas of cold bias (Figs. 3a and 5a). The direct relationship between surface pressure and thickness errors over anticyclones was not exhibited in the results for cyclones shown by GS over North America.

In the winter, transient anticyclones are forecast to move too fast as shown in Table 2 by the slight south and eastward bias. This is similar to the results found by GG for both the LFM and spectral model for the winter of 1981/82. In the spring and summer, when systems tend to move more slowly, the mean distance errors are considerably smaller than in winter (Table 1) and the displacement errors show a southwest-west bias, indicating that forecast anticyclones move too slow.

The NGM cyclone and anticyclone database is being updated daily. In addition the aviation model (Caplan and White 1989) is also being used to collect similar data over the Pacific basin every 12 h through the 72-h forecast period. These two datasets provide a unique database for research on model performance and analysis of the climatology of cyclones and anticyclones. Future plans include the ability to overlap the NGM and AVN study areas so the performance of the two operational models can be compared.

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