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THE 8 FEBRUARY 1995 HEAVY SNOW EVENT OVER NORTHEASTERN NORTH CAROLINA

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1. INTRODUCTION

During the early morning of 8 February 1995, a swath of heavy snow 30- to 50-miles wide fell across northeast North Carolina and extreme southeast Virginia. Snow accumulations greater than 1 inch occurred in this portion of the Nexrad Weather Service Office Wakefield, VA (NWSO AKQ) county warning area. The snowfall distribution for this event is shown in Figure 1. The heaviest snow accumulations in northeast North Carolina included Elizabeth City (4 inches), Hertford (6 inches), and Point Harbor (7 inches). Even an isolated report of 3 inches of snow occurred across the southern portion of Virginia Beach, while only a trace of snow fell across the rest of the Hampton Roads region.

In this paper, a brief description of the synoptic conditions that caused the heavy snow to develop will be provided. Most of the emphasis of this study will be given to the mesoscale analysis of numerical guidance utilizing the PC-GRidded Interactive Diagnostic and Display System software (PC-GRIDDS). The analysis from PC-GRIDDS will include atmospheric vertical motions and moisture content associated with model time-sections. The diagnosis of ageostrophic jet streak circulations is used to illustrate the potential for heavy snow over northeast North Carolina and southeast Virginia. In addition, the potential for conditional symmetric instability (CSI) and corresponding banded mesoscale precipitation will also be examined. An initial snowfall estimate empirical technique developed at the Nexrad Weather Service Forecast Office in Milwaukee, WI (NWSFO MKX) will also be illustrated (Garcia 1994). This technique relates snow amounts to average mixing ratio values on an isentropic surface that intersects the 750-700 mb layer.

2. SYNOPTIC ENVIRONMENT

At 1200 UTC 7 February 1995, the 00-h NGM 500 mb analysis indicated a broad longwave trough over the eastern United States with several weak shortwaves moving through the trough axis across the Tennessee Valley (Fig. 2). Each shortwave was forecast to move quickly northeastward across North Carolina. The 1500 UTC surface pressure and frontal analysis (Fig. 3) indicated a weak area of low pressure over northern Alabama that was producing an area of light to moderate snow over the Tennessee and Ohio river valleys. The surface low moved steadily northeast and reached southwestern North Carolina (near Charlotte) by 0000 UTC 8 February. Also by 0000 UTC, a 300 mb jet streak (not shown) was moving through the base of the trough across Mississippi and Alabama. Based on the 18-h forecast from the 1200 UTC NGM (valid 0600 UTC), this jet streak was to move over the South Carolina coast, placing North Carolina and southeast Virginia in the left exit region, which favors upper-level divergence (Kocin and Uccellini 1990). The lower levels of the atmosphere, which constitute 850 mb and below, were conducive for snow. The 850 mb temperatures were forecast to be between -5° and -8°C from 0000 to 1200 UTC 8 February.

3. MODEL TIME-SECTIONS

An early indication of the potential for a heavy precipitation event was indicated through the use of PCGRIDDS time sections. These time-sections, which are centered on a specified location, are very useful in showing the vertical structure of the atmosphere given a particular dynamical model prediction. The time-sections used for this event are from the 1200 UTC 7 February run of the NGM. Figure 4 depicts a time-section (in 6-h forecast increments) for Cape Hatteras, NC, while Figure 5 shows a time section for Elizabeth City, NC. Note the forecast of a rapid increase in vertical velocities for each location at 18-h into the model run (valid 0600 UTC 8 February). At Cape Hatteras, the vertical velocity increased to around -14 μbs^{-1}, while an increase to about -9 μbs^{-1} occurred at Elizabeth City. In both instances, a substantial increase in relative humidity in the low- and mid-levels of the troposphere corresponded with the onset of the strong upward velocities. A further investigation of the dynamic forces behind the strong vertical motion is discussed in the following sections.

4. ROLE OF AGEOSTROPHIC CIRCULATIONS

Ageostrophic circulations in the exit and entrance regions of jet streaks have played a major role in many east coast snowstorms (Kocin and Uccellini 1990). This was the case for this particular snow event, except the ageostrophic circulations appeared to be in association with a singular upper-level jet streak.

Figure 6 shows the 18-h forecast of 300 mb wind and isotachs from the 1200 UTC 7 February cycle of the NGM. Note the forecast of two 120 kt speed maxima over Georgia and South Carolina and the western Atlantic ocean. As revealed in Figure 6, eastern North Carolina was forecast to be under the left front quadrant (exit region) of a jet speed max where thermally indirect circulations commonly develop (Kocin and Uccellini 1990). This case was an excellent illustration of this type of circulation. Figure 7 shows a PC-GRIDDS vertical cross-section that extends from Richmond, VA southeastward to near Wilmington, NC. In this cross-section, the vertical ageostrophic circulations resulting from the exit region of a jet speed max over eastern North Carolina are apparent. The thermally indirect circulation is noted by the letter "I". The forecasted area of strong ageostrophic induced upward motion was generally over northeast North Carolina. Figure 8 depicts in plan view, the resulting 850 mb ageostrophic winds overlaid with the 850-700 mb layer Q vector forcing associated with the NGM 18-h forecast valid at 0600 UTC 8 February. The 850 mb ageostrophic winds were strongly convergent off the Atlantic Ocean and were directed toward the North Carolina coast. This configuration advected moisture from the Atlantic ocean over the study area. The moisture advection, coupled with the deep-layered, large-scale upward vertical motion, as indicated by the Q-vector convergence centered over north central North Carolina, contributed to the heavy precipitation.

5. CONDITIONAL SYMMETRIC INSTABILITY

The relationship between heavy snowfall and conditional symmetric instability (CSI) was illustrated for the 12-13 March 1993 "Storm of the Century" (Bradshaw 1994) and by others for previous snow events. According to Moore (1993), CSI is determined by comparing the geostrophic angular momentum **(Mg)** and equivalent potential temperature **(theta-e)** from a vertical cross-section of the atmosphere, which is aligned perpendicular to the 1000-500 mb thickness field. Overlaying relative humidity values on this cross-section reveals where the air is saturated, which results in moist symmetric instability. CSI is determined in saturated regions where the slope of the **Mg** surface is less than **theta-e**. Figure 9 illustrates an NGM 18-h forecast cross-section displaying Mg, theta-e, and relative humidity. The orientation of the cross-section extends from around Elkins, WV to 170 n mi southeast of Wilmington, NC. The cross-section runs normal to an 850 mb theta-e ridge axis. The region of CSI is encircled and encompasses all of eastern North Carolina.

6. GARCIA TECHNIQUE

The Garcia Technique (Garcia 1994) was used for this event to determine how much snow was possible for northeast North Carolina. The first two steps in this technique are to determine the "area of concern" and to find the isentropic surface, which intersected this area between 750 and 700 mb. Through model time sections and an analysis of ageostrophic circulations, it was determined northeast North Carolina was the "area of concern." Plotting potential temperature surfaces on a cross-section that dissects the "area of concern" from north to south, revealed that the best isentropic surface for this case was 282 K. Figure 10 shows the 12-h forecast pressure levels (valid 0000 UTC 8 February) on the 282 K isentropic surface and the wind along that surface. Note the air moving from higher pressure to lower pressure from South Carolina to off the Virginia/North Carolina coastline, which implies upward vertical motion along the isentropic surface. The best lift is achieved when the wind is oriented perpendicular to the constant pressure surfaces. In this case, the air is moving at a 30° to 50° angle with respect to the constant pressure surfaces. This cross contour flow was likely due in part to the ageostrophic circulation in the exit region of the jet streak moving toward South Carolina.

The third step of the Garcia Technique is to calculate an *average* mixing ratio value that should be over the "area of concern" during the next 12-h period. Figure 10 reveals that the forecast mixing ratios valid at 0000 UTC were just below 1 g/kg. However, southwest winds along the isentropic surface were convergent and averaged 40 kt. These winds would most likely result in the advection of higher mixing ratio values across northeast North Carolina during the next 12-h period. To approximate the highest mixing ratio value that could be over the "area of concern" within the next 12-h, it is necessary to examine mixing ratio values that are present upstream. The average forecast wind speed over the "area of concern" (40 MPH in this case) needs to be multiplied by 12-h in order to approximate this upstream distance. Using this methodology, it was determined that mixing ratios from about 480 n mi upstream of the "area of concern" could advect across northeast North Carolina by 1200 UTC 8 February. The highest mixing ratio in this time frame was found to be approximately 3 g/kg, with the *average* mixing ratio for the 12-h period estimated to be about 2 g/kg. The empirical formula for snow amounts used in the Garcia technique is roughly a 2:1 ratio of snowfall vs. the *average* mixing ratio values. Based on this technique, an average 4 inch snowfall was possible over northeast North Carolina during the 12-h period. It must be noted that this technique does not take into account the potential for additional low-level moisture advection from the Atlantic Ocean. For this event, snow amounts over parts of North Carolina were higher.

7. THE SNOW EVENT

Light to moderate snow initially began falling over the mountains and western piedmont of North Carolina shortly after 0000 UTC 8 February. At 2345 UTC 7 February, a Winter Weather Advisory was issued by the Nexrad Weather Service Forecast Office in Raleigh, NC (NWSFO RAH) for the western piedmont of North Carolina, with expected snow accumulations of 1-2 inches. The snow spread eastward to the North Carolina coastal plain and expanded in coverage. Areas of moderate snow became widespread over eastern North Carolina, mainly from near Elizabeth City south to the Albemarle Sound, and east to the northern Outer Banks by 0800 UTC 8 February and continued through 1400 UTC. There were indications that moderate snow fell for a short time across extreme southern sections of Virginia Beach resulting in the local 3 inch accumulation.

Snow accumulations of 2-4 inches were noted over a large area in eastern North Carolina, extending from Raleigh eastward to the northeast coastal areas. Isolated snow amounts in excess of 6 inches were noted along the northern shore of the Albemarle Sound in Camden, Pasquotank, and Currituck counties, with Point Harbor in Currituck county receiving 7 inches of snow. Unofficial reports of 8 inches were observed from the northern North Carolina Outer Banks near Corolla. There was also a report of 3 inches of snow in Blackwater in extreme southern sections of Virginia Beach.

8. CONCLUSION

Snow events such as the one examined in this study are uncommon for northeast North Carolina or extreme southeast Virginia. This event illustrates the importance of utilizing PC-GRIDDS and numerical gridded model data in diagnosing the potential for heavy precipitation. Although the traditional constant pressure level meteorological charts provided a quick but limited perspective of the numerical model output, the versatility of PC-GRIDDS allowed for a more thorough mesoscale analysis. The use of location-specified time sections showed the vertical depth and timing of significant lift and moisture. From cross-section analyses, ageostrophic circulations and CSI potential were also examined.

Also, PC-GRIDDS provides forecasters with a quick method to view isentropic surfaces. It has been shown in this study that, based on the empirical technique of Garcia (1994), average mixing ratios values related to a specific isentropic surface provides a starting point for forecasting possible snow accumulations.

ACKNOWLEDGMENTS

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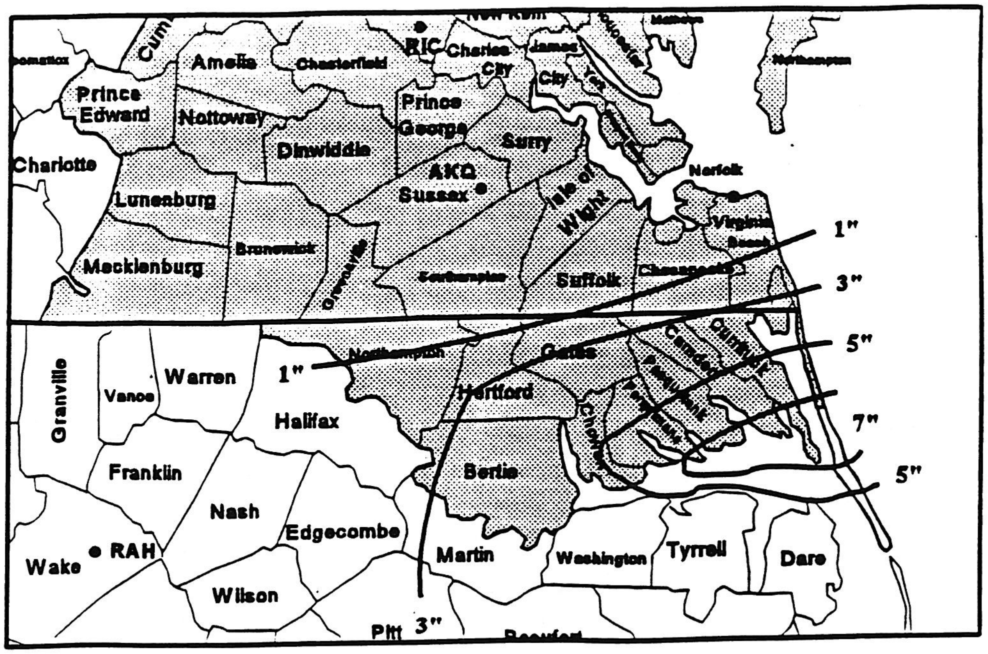

Figure 1. Snow totals (in inches) for the 8 February 1995 heavy snow event. The shaded area denotes the NWSO Wakefield county warning area.

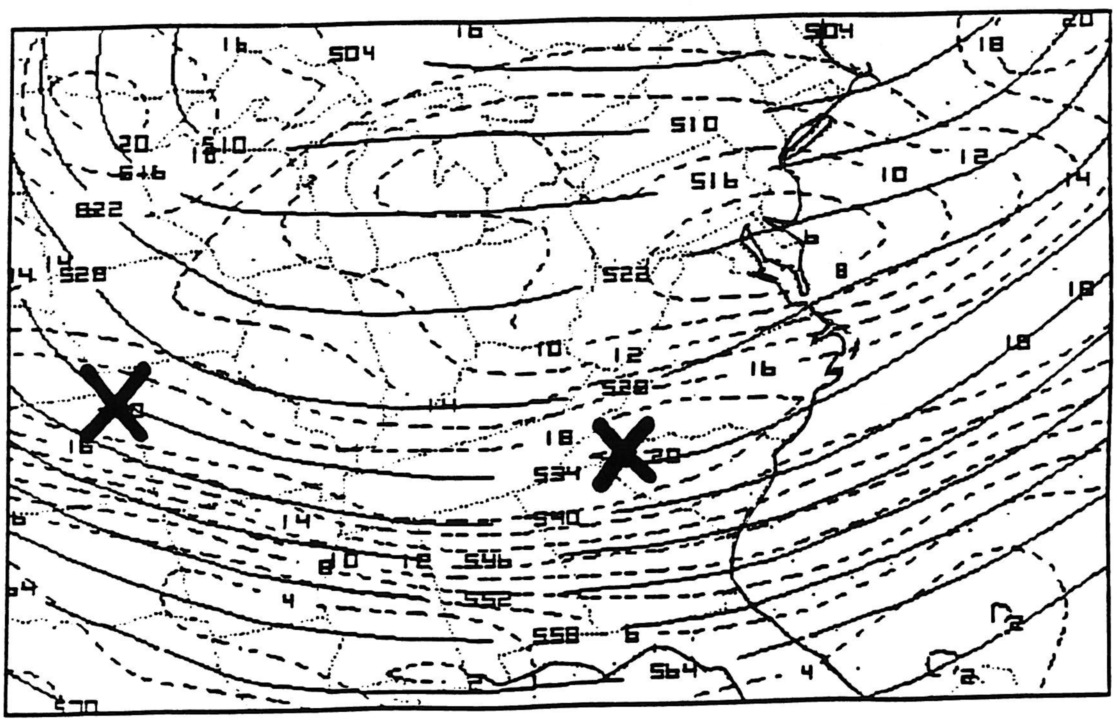

Figure 2. 1200 UTC, 8 February 1995, NGM initial 500 mb (dm, solid lines) and vorticity ($x10^{-5}s^{-1}$, dashed lines) analysis (from PC-GRIDDS).

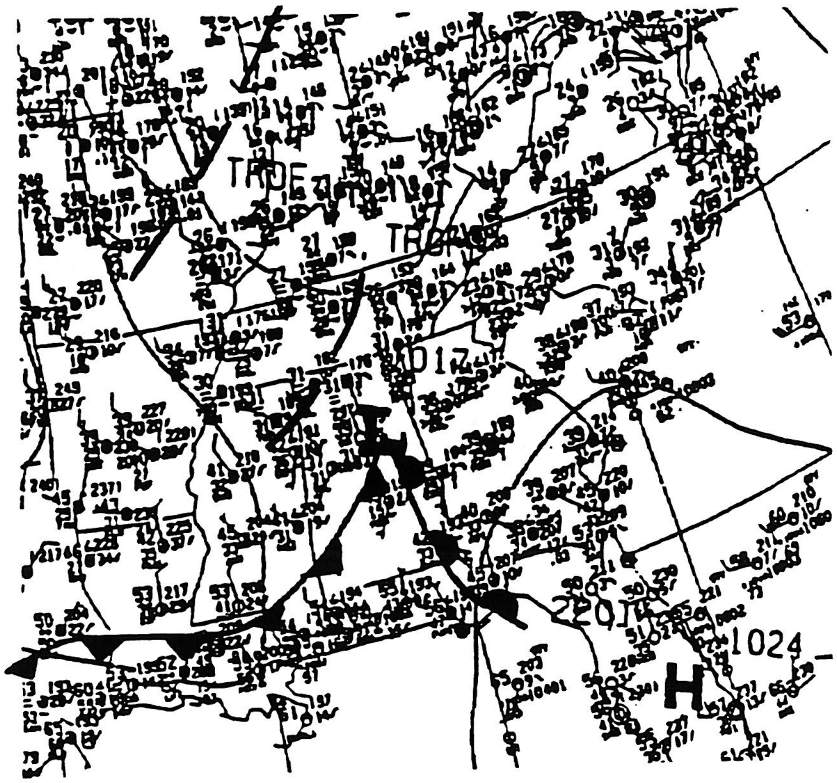

Figure 3. 1500 UTC 8 February 1995 surface frontal and pressure analysis.

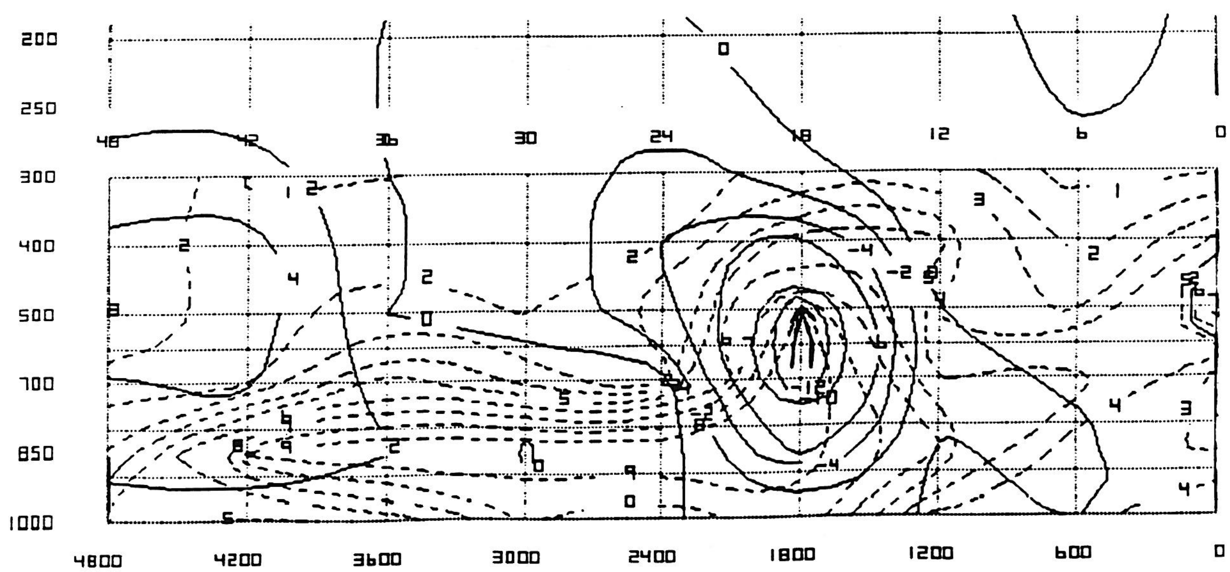

Figure 4. Time-section of vertical velocity (solid lines) and relative humidity (dashed lines) for Cape Hatteras, NC, valid from 1200 UTC 7 February (00-h) to 1200 UTC 9 February, 1995 (48-h). Note the upward vertical motion of -12 μbs^{-1} at approximately 18-h into the model run. The time increments are every 6-h (from PC-GRIDDS).

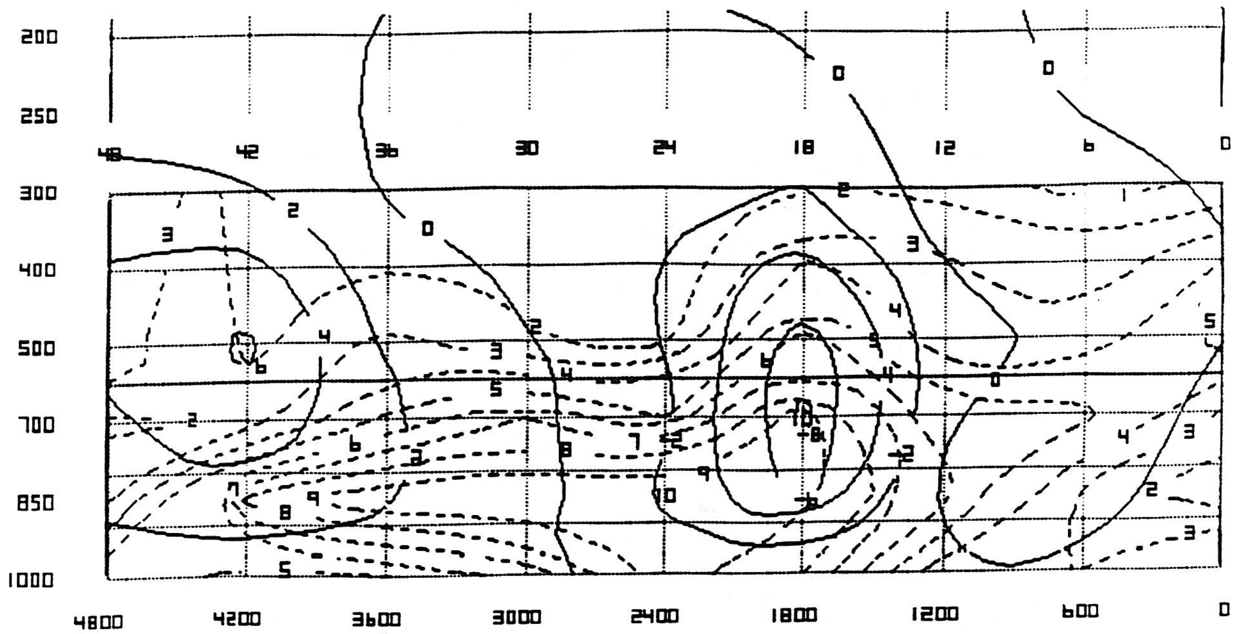

Figure 5. As in Figure 4, except for Elizabeth City, NC. Note the upward vertical motion of -10 μbs^{-1} at approximately 18-h.

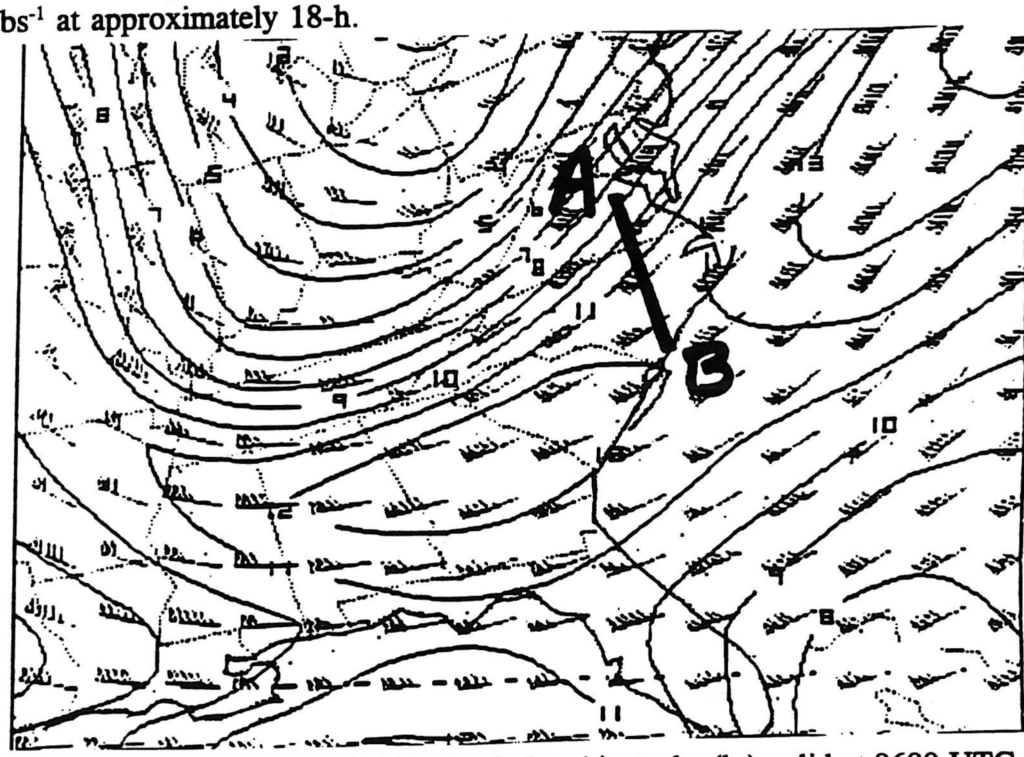

Figure 6. NGM 18-h forecast of 300 mb wind and isotachs (kt) valid at 0600 UTC 8 February, from the 1200 UTC 7 February 1995 run of the NGM. Note the speed maxima of 120 kt located over South Carolina and Georgia, and over the western Atlantic ocean. The line A-B illustrates the area covered by the cross-section in Figure 7 (from PC-GRIDDS).

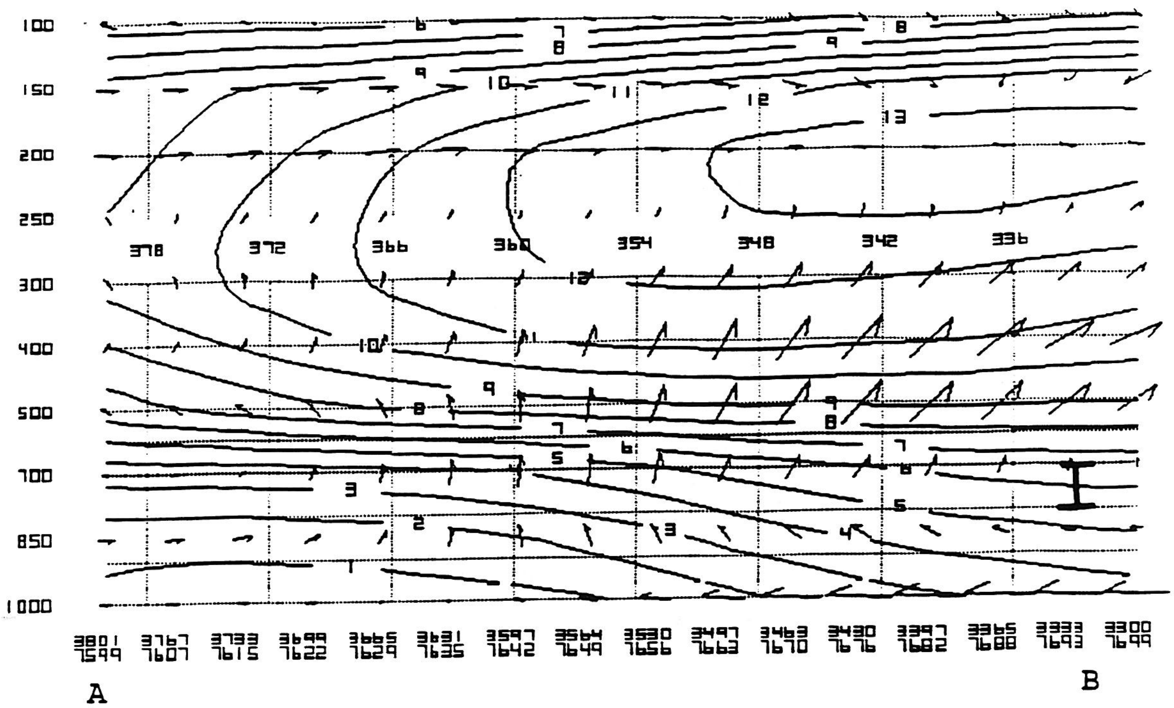

Figure 7. NGM 18-h forecast of ageostrophic circulations resulting from the exit region of a jet streak, valid at 0600 UTC 8 February 1995. The cross-section extends from A) Richmond, VA, to near B) Wilmington, NC. The thermally indirect circulation is marked by the letter "I" (from PC-GRIDDS).

Figure 8. NGM 18-h 850 mb ageostrophic winds (arrows) and 850-700 mb layer Q-vector divergence, valid at 0600 UTC 8 February 1995 (dashed negative lines denote Q-vector convergence; from PC-GRIDDS).

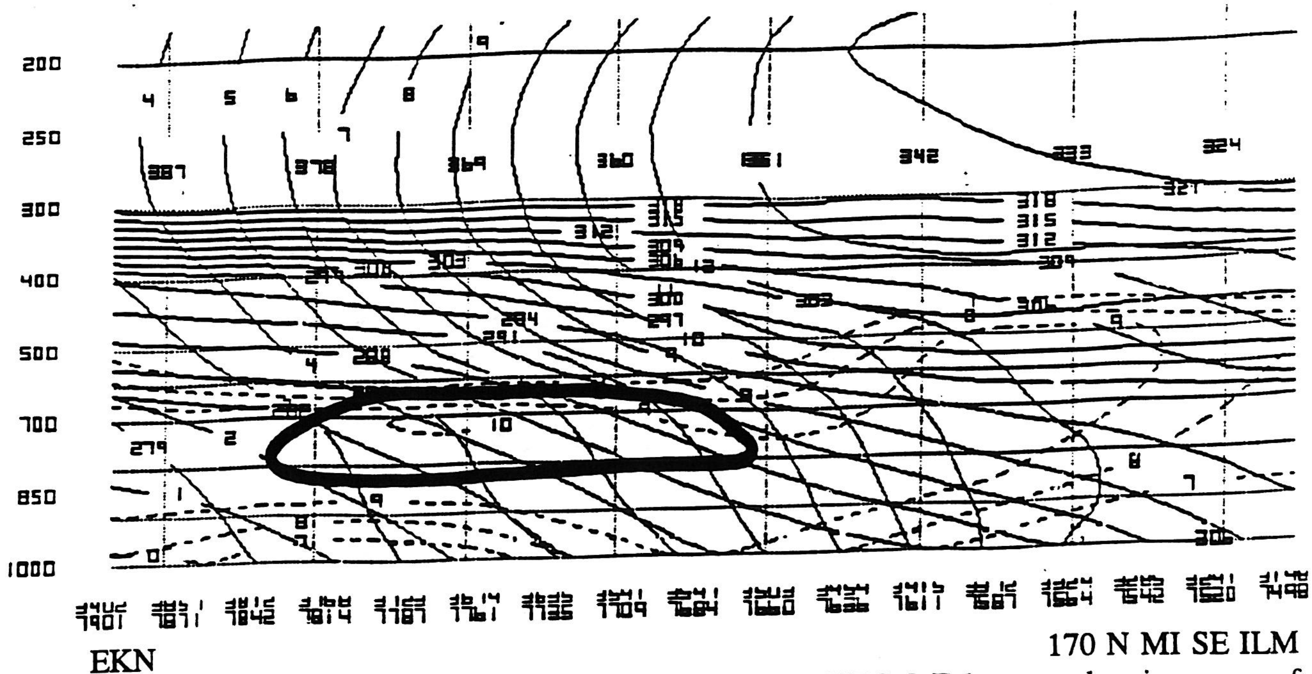

Figure 9. NGM 18-h forecast cross-section valid at 0600 UTC 8 February, showing areas of potential CSI. The geostrophic angular momentum (Mg; solid, semi-horizontal lines), theta-e surfaces (K; solid, nearly vertical lines) and relative humidity (dashed lines). CSI is determined in saturated regions where the slope of the Mg surface is less than the slope of the theta-e surface (area enclosed by thick black line; from PC-GRIDDS).

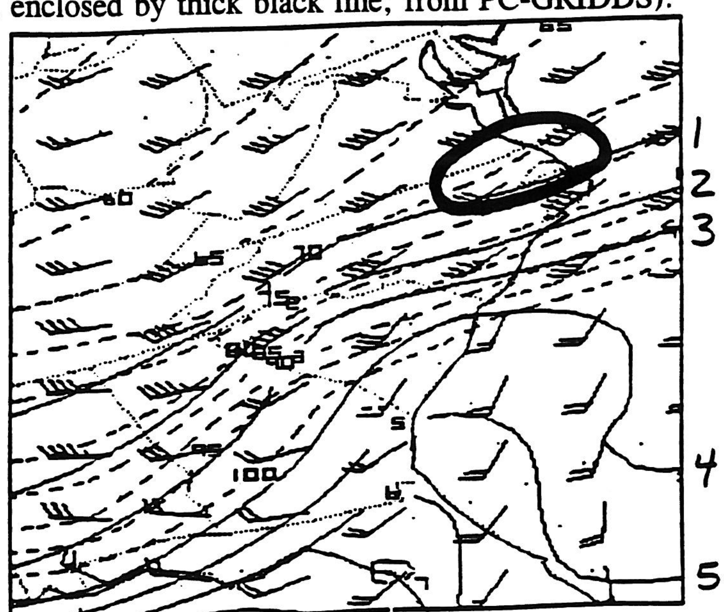

Figure 10. NGM 12-h forecast valid at 0000 UTC 8 February of 282K isentropic surface pressure level (dashed lines), winds along the 282K surface (kt, barbs), and mixing ratio contours (g kg^{-1}, solid lines). Note the air moving from higher to lower pressure from the South Carolina coast to near the Virginia coast. The "area of concern" is enclosed by the thick black line.