CENTRAL REGION TECHNICAL ATTACHMENT 94-16

Application of the Dual Jet-Streak Conceptual Model via PCGRIDDS

Daniel G. Noah
National Weather Service
Bismarck, North Dakota

1. Introduction

Recently, dual jet-streak interactions have become a "hot topic" in heavy precipitation forecasting. Crawford (1994) discussed the role of a dual jet-streak in a heavy rain episode in Louisiana. In-depth case studies by Hakim and Uccellini (1991) discuss its role in developing a narrow band of heavy snow in the Northern Plains. Uccellini and Kocin (1987) discussed five cases that illustrated dual jet-streak interactions to be a consistent signature for heavy snow storms that affect the East Coast.

This paper will present a brief overview of the dual jet-streak conceptual model and how PCGRIDDS can be used to illustrate the effects of such a conceptual model. The Eta-X gridded data from 0000 UTC, March 23, 1994 will be used to study dual-jet streak circulations during a heavy snow event in the Northern Plains from March 22-24, 1994. This storm produced a 200-300 km wide band of heavy to moderate snow across southern Montana, southern North Dakota, central Minnesota, northern Wisconsin and Upper Michigan. Figure 1 shows the water equivalent precipitation for a 48-hour period ending at 1200 UTC, March 24. In the same figure are the contours of snowfall during this period with the solid line representing two inches or more and the dashed line representing five inches or more. Figure 2 displays the surface pressure, frontal boundaries and average low-level moisture from the Eta-X 0000 hour forecast valid at 0000 UTC, March 23, 1994. The snow band began nearly 500 km north of the Nebraska warm front deep inside a cold Canadian air mass. Initially the average moisture in the lower atmosphere (1000-850 mb) was limited to 2-4 g kg^{-1}. The interactions of a dual jet-streak pattern created the conditions necessary to produce and sustain the heavy snowfall over this narrow elongated area.

2. The Dual Jet-streak Conceptual Model

The dual jet-streak conceptual model depicts the merging of the direct circulation at the entrance region of the jet with the indirect circulation at the exit region of a second jet to the south (Figure 3). This merged circulation pat tern leads to a tightening of the low level thermal gradient as colder air is advected southward at the lower levels of the direct circulation and warmer air is advected northward at the lower layers of the indirect circulation. The combined areas of divergence aloft not only enhance the upward vertical velocity between the two jets but also strengthen the low-level jet, which can increase the moisture transport into the area. Uccellini and Kocin (1987) did their study using 300 mb radiosonde data. Problems were encountered with missing data and the lack of radiosondes, especially over the Atlantic ocean. Gridded model output provided the resolution necessary to analyze dual jet-streak features.

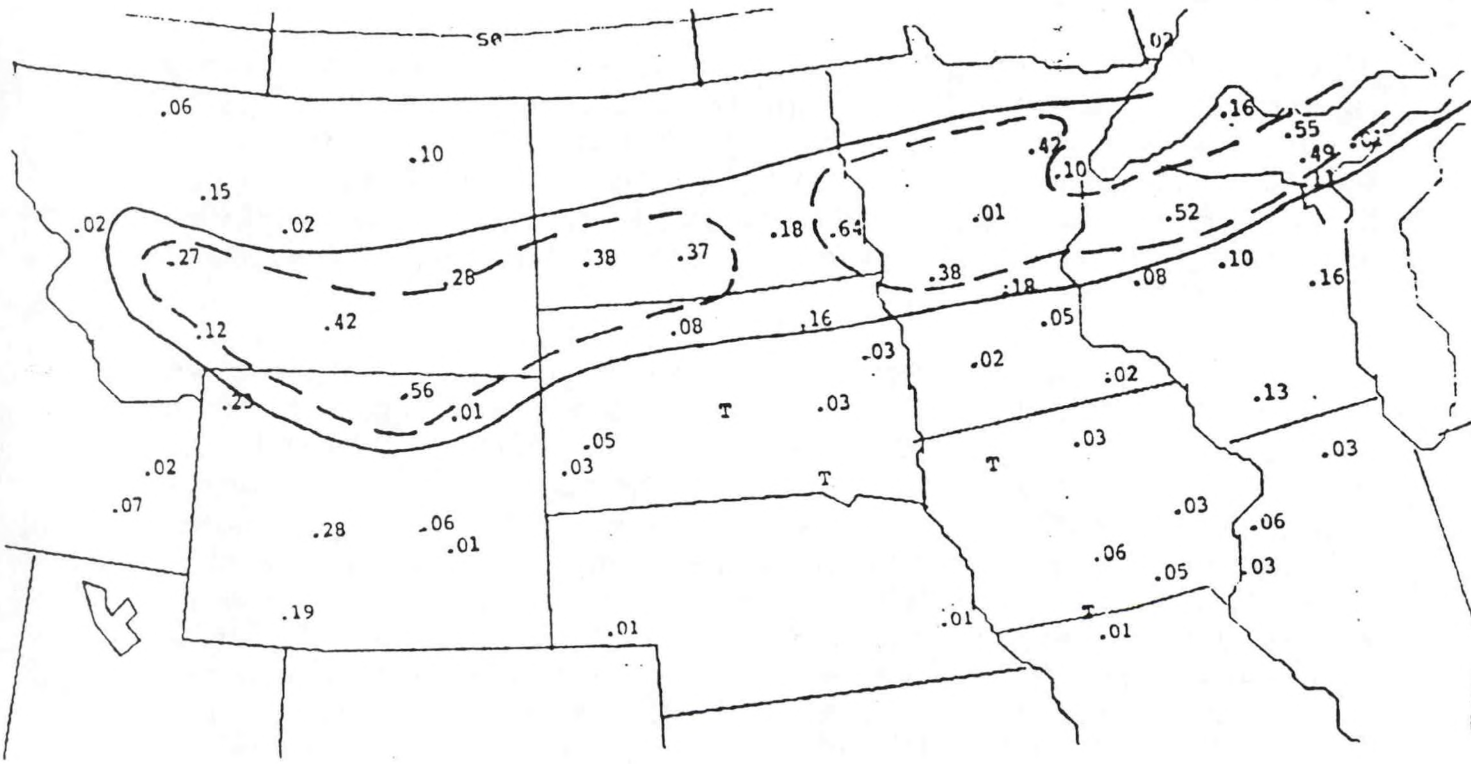

Figure 1. The actual 48-hour water equivalent precipitation in inches from 1200 UTC, March 22 to 1200 UTC, March 24, 1994. Snow fall ending 1200 UTC, March 24 of 2 inches or greater is displayed by the solid line and greater than 5 inches displayed by the dashed line.

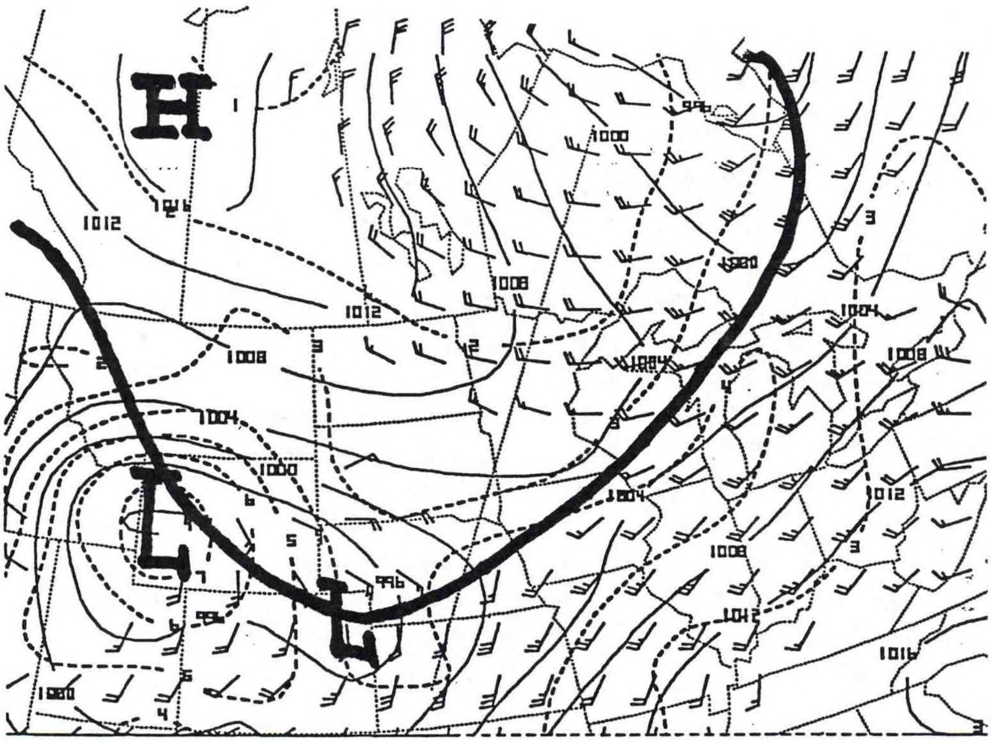

Figure 2. The Eta-X 0000-hour forecast valid at 0000 UTC, 23 March 1994. Solid lines represent the surface pressure (mb) and frontal boundaries. Dashed lines show the average moisture (g kg^{-1}) from 1000-850 mb.

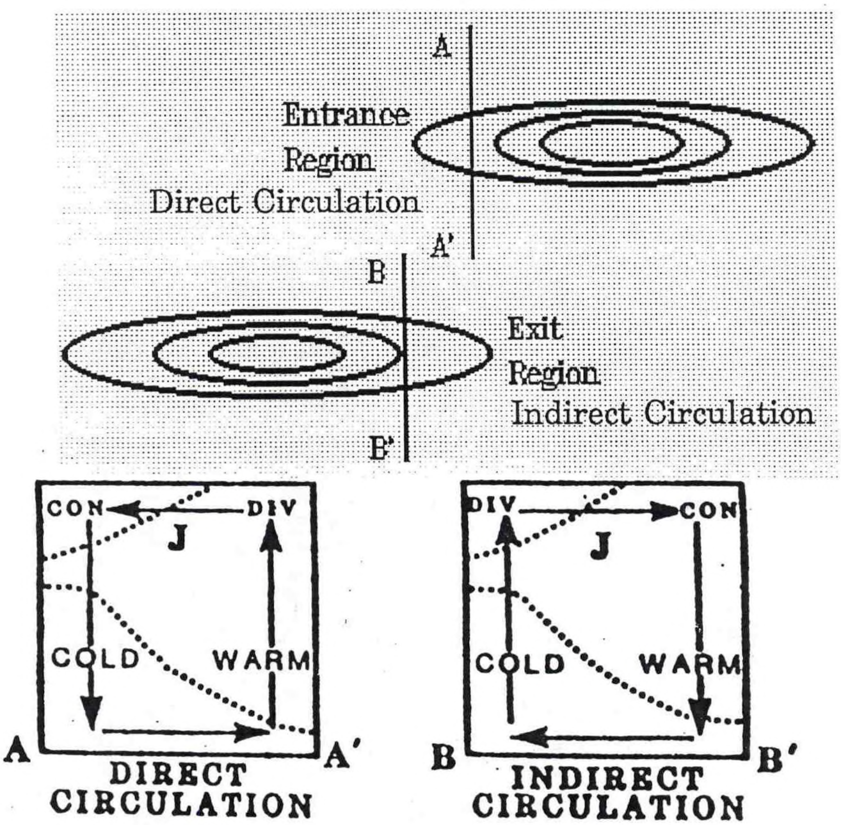

Figure 3. Dual jet-streak circulation patterns. Adapted from Uccellini and Kocin (2987).

3. Using PCGRIDDS to Analyze Dual Jet-Streak Interactions in the March 23-24, 1994 Heavy Snow Storm

The Eta-X data set from 00 UTC March 23 1994 was chosen in place of the RAFS data because it performed better with the precipitation field. Both models handled the heavy precipitation location well but extended light precipitation 300-500 km too far north. Compare the precipitation chart in Figure 1 with the 36 hour Eta-X quantitative precipitation forecast (QPF) in Figure 4. The Eta-X QPF showed precipitation amounts of .1-.4 inches across the northern parts of North Dakota and Minnesota, where not even a trace of precipitation was recorded. The southern half of the Eta-X QPF field fared much better. Forecasted precipitation was about 50% more than the actual amounts reported.

The 24-hour forecast of the 0000 UTC, March 23 Eta-X gridded model output was chosen for this study of dual jet-streak circulations because all of the patterns were easily recognizable at this time. Figure 5 shows the location of the two jet streaks and the strength of the divergence between the two jets. The dotted line from Kansas to Ontario Canada represents the cross-section location chosen for this study. The remainder of this study will focus on three effects dual jet-streaks have on the atmosphere; tightening of the low-level temperature gradient, strengthening the low-level jet and moisture transport, and finally enhancing upward vertical motion.

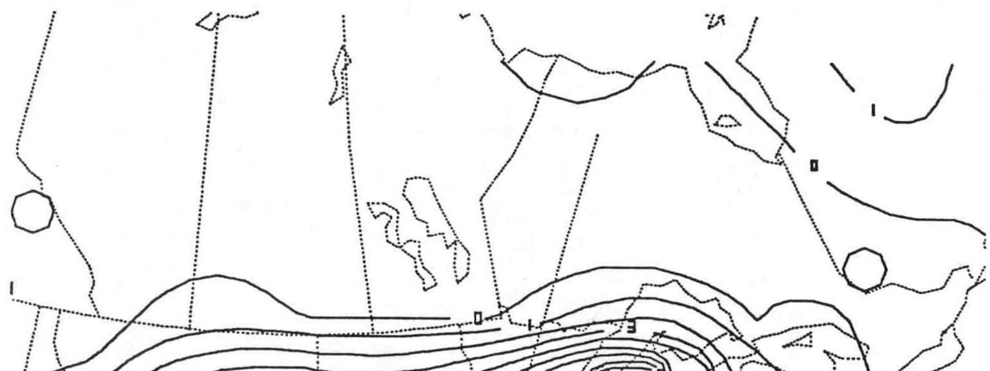

Figure 4. The Eta-X 0000-hour to 36-hour quantitative precipitation forecast produced from the 0000 UTC, 23 March 1994 gridded model output. Units are tenths of an inch.

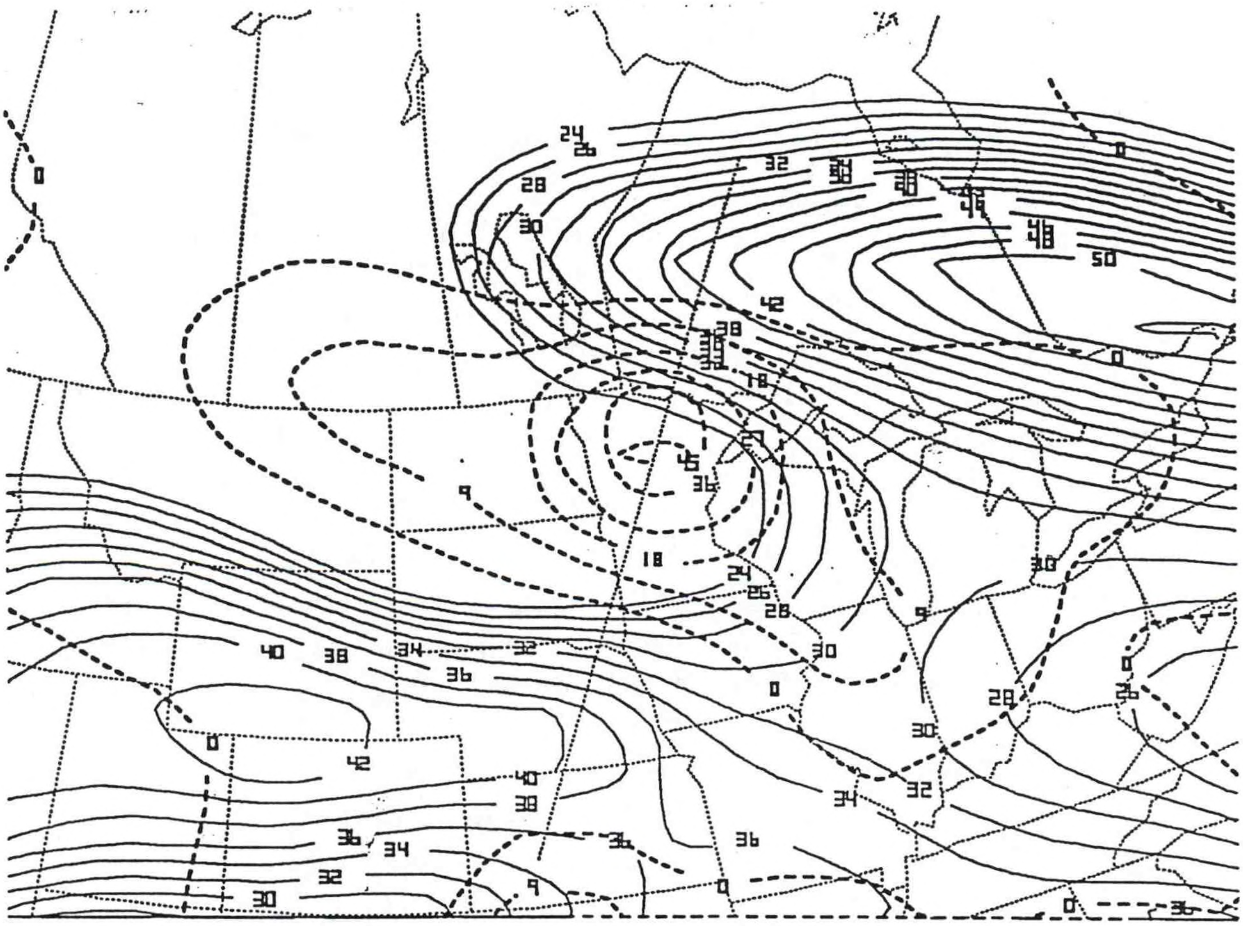

Figure 5. The Eta-X 24-hour forecast of the 300 mb isotachs greater than 24 ms^{-1} (solid lines) and 300 mb divergence (dashed lines).

A tight thermal gradient was maintained across the Northern Plains in response to the direct and indirect transverse circulations about the jet streams. Figure 6 shows the 24-hour forecast of the 850 mb temperature and ageostrophic winds. The low level confluence between these two features helped to maintain or possibly enhance the thermal gradient from South Dakota to upper Michigan. Figure 7 shows the corresponding ageostrophic winds at 300 mb. Strong divergence was indicated with maximum velocities of 14 ms^{-1} and 10 ms^{-1} north and south of Minnesota, respectively.

The 24 hour Eta-X forecast displayed a surface low in Iowa and low-level moisture of 4-7 g kg^{-1} moving into Minnesota with values of 9-10 g kg^{-1} in Iowa and Missouri (Figure 8). The increase in moisture was due to the strengthening of the low-level jet. Model forecasted winds of 30 to 40 knots were found near and east of the moist axis (winds not shown in figure to reduce clutter).

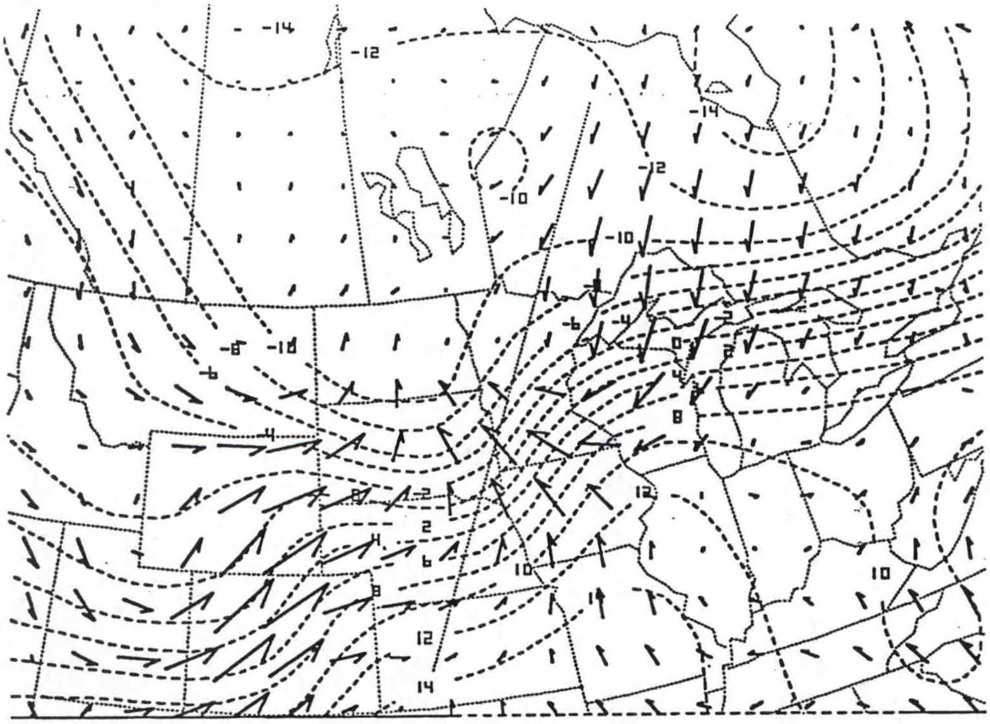

Figure 6. The Eta-X 24-hour forecast of 850 mb ageostrophic winds (arrows) and 850 mb temperatures in Celsius (dash lines).

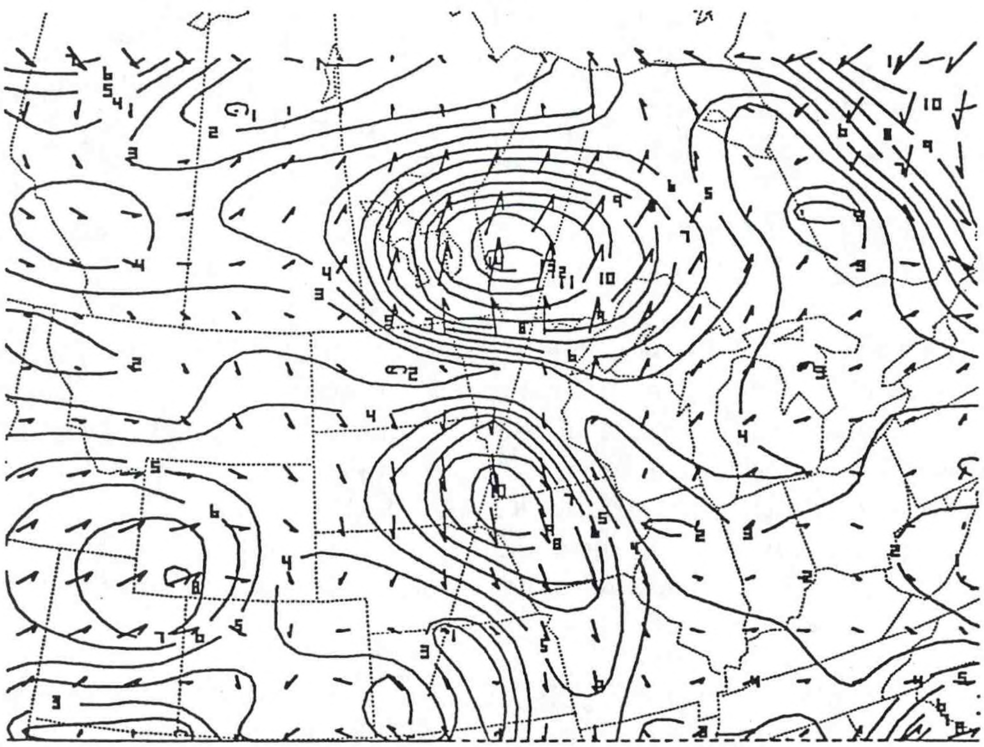

Figure 7. The Eta-X 24-hour forecast of 300 mg ageostrophic wind (arrows) and 300 mb ageostrophic isotachs (dashed lines).

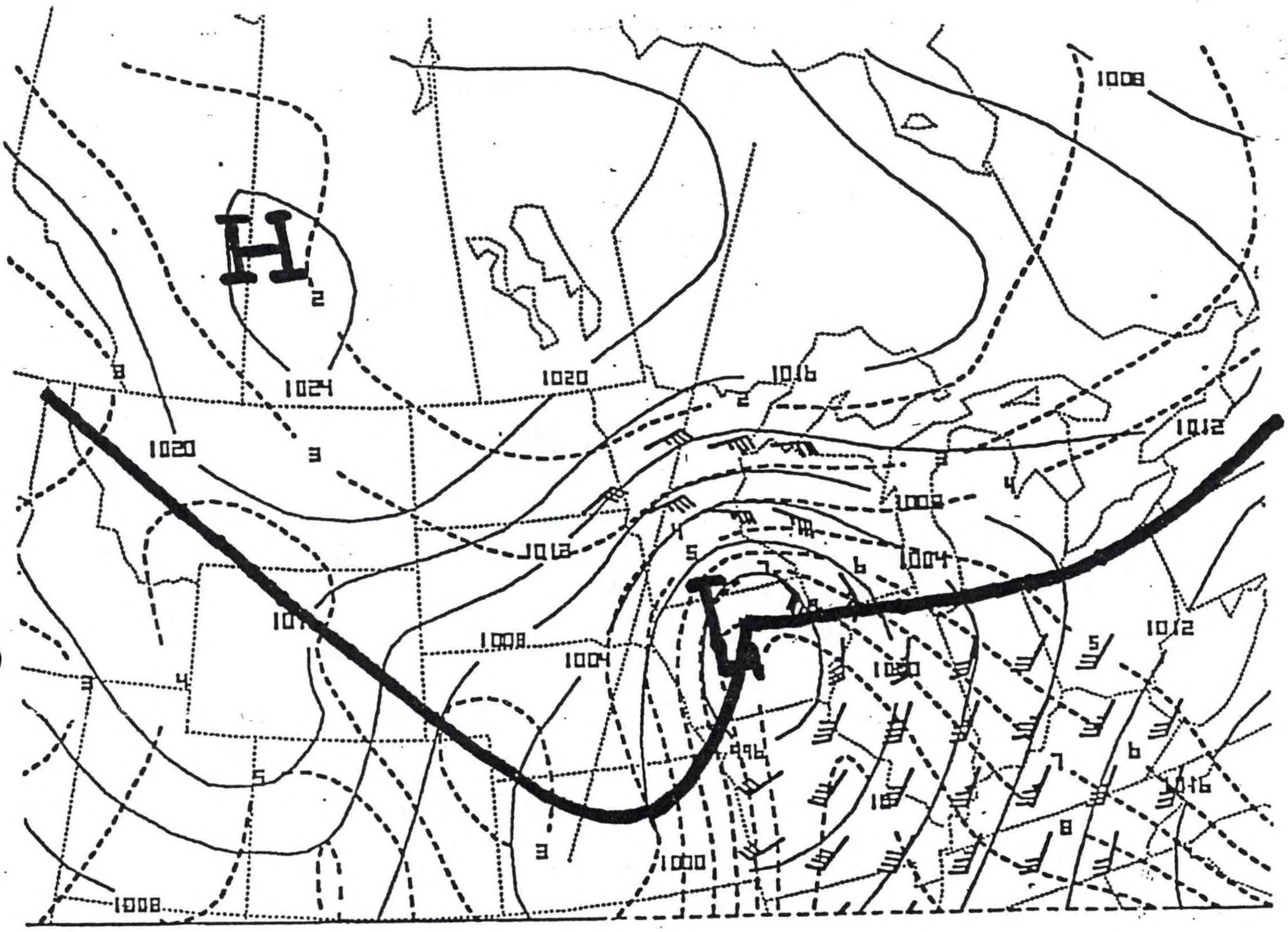

Figure 8. The Eta-X 24-hour forecast valid at 0000 UTC, 24 March 1994. Solid lines represent the surface pressure (mb) and frontal boundaries. Dashed lines show the average moisture g kg^{-1}) from 1000-850 mb.

Enhanced vertical velocities is the last dual jet-streak feature to be explored. Referring to the cross-section at 24 hours (Figure 9) one can see upward vertical velocities up to 8 μbar s^{-1} over central and northern Minnesota. The PCGRIDDS ACRC command was used to obtain the true secondary circulation patterns, found by combining components of the ageostrophic wind with vertical velocity values. The locations of the each upper-level jet is marked by a "J" while the center of the direct and indirect patterns are marked with a "D" and "I", respectively. The enhanced upward vertical velocity is a result of the merger of the direct and indirect circulations. This merger was found throughout the life of the event.

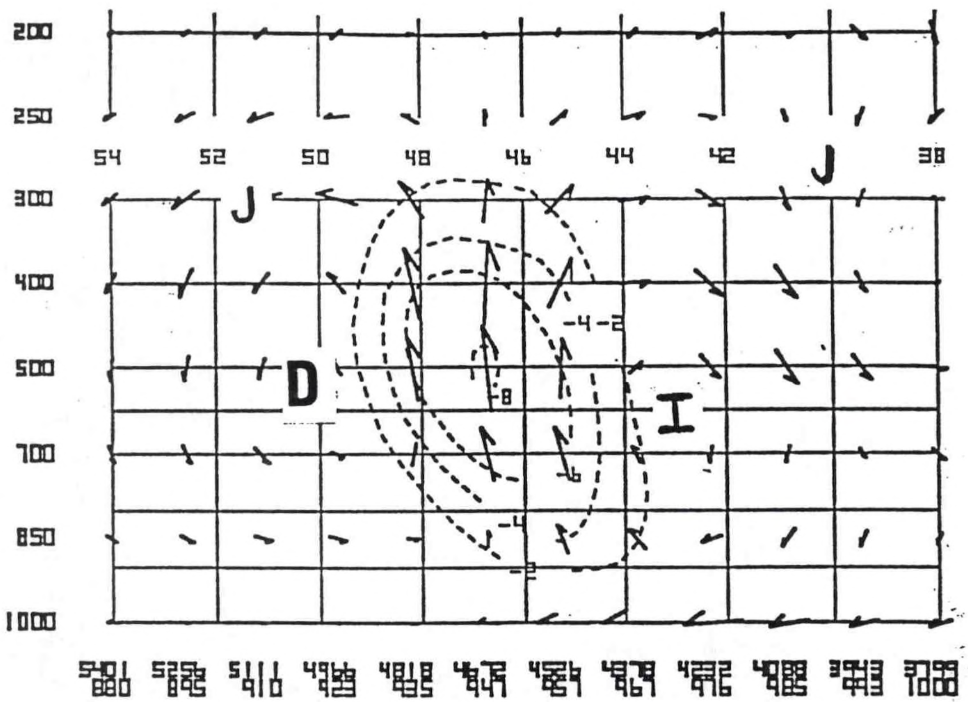

Figure 9. Vertical cross-section from 54°N, 88°W to 38°N, 100°W from the Eta-X 24-hour forecast valid at 0000 UTC, 24 March 1994. Arrows represent a true secondary circulation using the PSGRIDDS ACRC command. Dashed lines display the vertical velocities (μbar s^{-1}). The center of the direct (indirect) circulation is indicated by the D (I), and the jet core by J.

4. PCGRIDD COMMANDS USED TO CREATE FIGURES

Figure 2.	PRES MSL CIN4 F00 MIXR LAVE C1-3 DASH F00 SLYR 1000 850/
Figure 4.	SSUM TPCI F12 SSUM TPCI F24 TPCI F36
Figure 5.	SPED 300 CIN2 GT24 F24 DVRG WIND 300 GT00 DASH F24/
Figure 6.	AGEO 850 CI10 F24 TEMP 850 CIN2 DASH F24/
Figure 7.	SPED AGEO 300 DASH F24 AGEO 300 F24 AROW/
Figure 8.	PRES MSL CIN4 F24 MIXR LAVE C1-3 DASH F24 SLYR 1000 850/
Figure 9.	XSCT 54 88 38 100 AROW CROS VVEL DNEG C2-3 F24/ ACRC/

5. Summary

This paper has presented an overview of the dual jet-streak conceptual model and how PCGRIDDS can be used to apply such a model. High resolution forecast analysis from computer programs such as PCGRIDDS allows an operational forecaster to visualize the strength of the various aspects of this and other conceptual models. If a dual jet-streak feature is present, it should serve as a flag to re-evaluate the model precipitation field in terms of amount and areal extent.

6. References

Crawford, K., 1994: Presentation at 1994 Quantitative Precipitation Workshop (March 22-23) hosted by the National Weather Service Forecast Office in Minneapolis, Minnesota.

Hakim, G.J. and L.W. Uccellini, 1992: Diagnosing Coupled Jet-Streak Circulations for a Northern Plains Snow Band from the Operational Nested-Grid Model. *Wea. and Forecasting,* **7**, 26-48.

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Uccellini, L.W. and P.J. Kocin, 1987: The Interaction of Jet-Streak Circulations During Heavy Snow Events Along the East Coast of the United States. *Wea. and Forecasting,* **2**, 289-308.