**Western Region Technical Attachment**
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# DO CANADIAN/ARCTIC FRONTS MOVE FASTER AT NIGHT?

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## 1. INTRODUCTION

When a forecast involves a cold front, the timing of the frontal passage is critical. Familiarity with the factors that affect the rate of frontal movement will improve confidence and accuracy when forecasting the passage of a front. The air masses behind these discontinuities will move according to dynamic and thermodynamic processes involved. The goal of this paper is to focus on fronts that are arctic or Canadian in nature, examining cases in the Southern Plains where there was an increase (decrease) in velocity during the nighttime (daylight) hours. Some physical reasoning will be proposed which will hopefully assist forecasters in their decision making.

## 2. DISCUSSION

Southward penetration of cold air masses into the Southern Plains is quite common, especially during the cooler months. My initial experience in the NWS has been in Midland, Texas, where I have observed that fronts moving from north to south often appear to do so more rapidly at night. Is this real, or just an illusion? Three examples from the cool season are presented. There is evidence that *in the absence of upper air support*, each cold front covered the greatest distance in its southward migration between the hours of 0000 UTC and 1200 UTC, occasionally until 1800 UTC. In the following paragraphs, I will discuss some possible reasons which may affect diurnal frontal motion changes.

If we consider a cold air mass, especially dry arctic air over a snowfield, radiational cooling overnight will increase the density. According to the hydrostatic equation, this will increase hydrostatic pressure. If there is no dynamical forcing from an upstream short wave trough, the major driving force for the front will be from hydrostatic pressure differences. This type of front is called a "passive front" by Djurić (1993). The resulting increase in density behind the front should produce a southward surge of the cold air. If the warmer air mass preceding the front has a higher moisture content, its radiational cooling will not be as pronounced, creating an even greater density contrast. Some arctic fronts fit this moisture pattern.

To illustrate this density contrast, assume that the diurnal temperature range in a cold dry air mass behind an arctic front is 3 deg greater than in a warm moist air mass preceding an arctic front. If we also assume the pressure remains constant, we obtain from the equation of state a density increase of $0.12\ g/cm^3$. Reversing the problem, pressure would increase about 10 mb.

However, Djurić states that "a dynamic pressure excess appears in the warm air, due to compression from the approaching cold front. The front moves with *constant speed* since a balance arises between the pressure increase in the warm air and the hydrostatic pressure increase in the cold air." In such cases, there may be a time lag before this balance in pressures is achieved, allowing for an acceleration of the front.

A more important potential contribution to differences between nighttime and daytime motion of arctic fronts is daytime deceleration due to heating. If there is a boundary layer wind ahead of the front that has a component opposing frontal advance, a dynamic pressure will be produced in the warm air *in addition* to that created by compression. After sunset, this flow will likely be decoupled from the surface. The following day, solar radiation will again heat the lowest layer ahead of the cold air mass, causing momentum aloft to mix down through the boundary layer. The result is increased resistance to southward moving air which will slow down, or even stall the front. However, at night this restriction is removed, allowing the front to resume a faster pace to lower latitudes. **This is under the very important assumption that no major dynamical forcing occurs through the diurnal cycle.** Dynamical forcing in this paper is defined as a dynamic pressure from surface winds caused by an upper trough ("pushing" the front from upstream or opposing the front from downstream).

## 3. THREE EXAMPLES OF DIURNAL CHANGES IN ARCTIC FRONT SPEED

In order to determine diurnal changes in frontal speed, one must first eliminate all "random" sources for frontal diurnal changes. Namely, we either need to (1) examine fronts over at least a 24- hour period which appear to have no dynamical forcing changes through that 24 hours, or (2) average together a large number of frontal speeds over various parts of the diurnal cycle with the hope that random diurnal speed biases are eliminated. Although the second option is by far the most effective method, it is extremely time consuming. I will show three events where time changes in dynamical forcing appear to be minimal. This is consistent with option 1.

### CASE 1

Although dynamical forcing was present at the onset of this case, it was absent in the latter stages. Passage of a short wave trough at 700 mb occurs between 0000 UTC and 1200 UTC on the 12th. Between 0000 UTC and 0600 UTC, prior to this passage, the front stalled in the Central Plains when it would normally be expected to move rapidly. After the shortwave passed, the resulting dynamical push ushered the front southward. Although its progress slowed somewhat during the day, the distance covered was still substantial. With the upper trough out of the way, however, nighttime speed-up and daytime slow-down was more apparent on the 13th. During this period, density appeared to be the main factor in movement, making this an example of a passive front.

### CASE 2

Case 2 was a situation where the polar jet stream and associated dynamics were well to the north of the surface front. There was a weak wave at 700 mb passing over the front between 1200 UTC the 2nd and 0000 UTC the 3rd. This allowed the front to drop south during the time of maximum solar heating (1800 UTC and 0000 UTC). After the upper wave moved away to the east, the front continued to move rapidly southward overnight, but slowed considerably and weakened the following day. It is likely that surface heating either mixed down light westerly flow aloft at the top of the boundary layer, or modified the cold air to a point where density differences across the front were no longer a factor. If the former were true, then the diurnal cycle of momentum aloft being mixed down (daytime), then becoming decoupled from the surface (nighttime), was the predominant contribution to frontal movement once synoptic scale dynamical forcing was removed.

### CASE 3

Case 3 was similar to Case 2 in that the polar jet stream was north of the front. This is yet another example where synoptic scale dynamics had an influence on frontal movement early on. A trough at 700 mb passing through the Central Plains between 1200 UTC the 18th and 0000 UTC the 19th gave support for a southward surge of the front during that time. Frontal speed decreased somewhat between 1800 UTC and 0000 UTC, then increased during the night before slowing the next day. Again, density was the main driving force for frontal motion after the upstream synoptic scale dynamical push diminished.

## 4. CONCLUSION

**Table 1** shows frontal speeds for each of the above cases, averaged over 6-hour and 12-hour periods. However, since dynamical forcing was included in these averages, a clear conclusion cannot be made that southward moving arctic fronts travel more rapidly at night. With so few examples, the question of whether or not there is a diurnal variation in frontal movement remains unanswered. A future paper will composite at least 100 cases which will remove most of the synoptic bias.

Synoptic scale dynamical forcing, especially from polar jet stream shortwaves, is likely to either enhance or mask diurnal frontal speed signatures. When "random" dynamical forcing on synoptic time-scales occurs in phase (overnight), a front should undergo greatest acceleration in darkness. On the other hand, an arctic front may actually move faster during the *daylight* hours if such forcing takes place in that time frame. Great care should be taken by the forecaster to include frontal motion changes associated with synoptic scale dynamical forcing, which may or may not be in phase with the apparent diurnal cycle.

How about Convection?

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## REFERENCE

Djurić, Dušan, *Weather Analysis*, 1993 (In Press)

| ALL TIMES ARE UTC | CASE 1 | CASE 2 | CASE 3 | 3 CASE AVERAGE |
|---|---|---|---|---|
| 0000 - 0600 (NIGHT) | 11 MPH | 26 MPH | 22 MPH | 20 MPH |
| 0600 - 1200 (NIGHT) | 30 MPH | 21 MPH | 19 MPH | 23 MPH |
| 1200 - 1800 (DAY) | 15 MPH | 13 MPH | 11 MPH | 13 MPH |
| 1800 - 0000 (DAY) | 27 MPH | 28 MPH | 7 MPH | 21 MPH |
| 0000 - 1200 (NIGHT) | 20 MPH | 23 MPH | 20 MPH | 21 MPH |
| 1200 - 0000 (DAY) | 19 MPH | 18 MPH | 9 MPH | 15 MPH |

**TABLE 1:** Average frontal speed for 6- and 12-hour time increments.

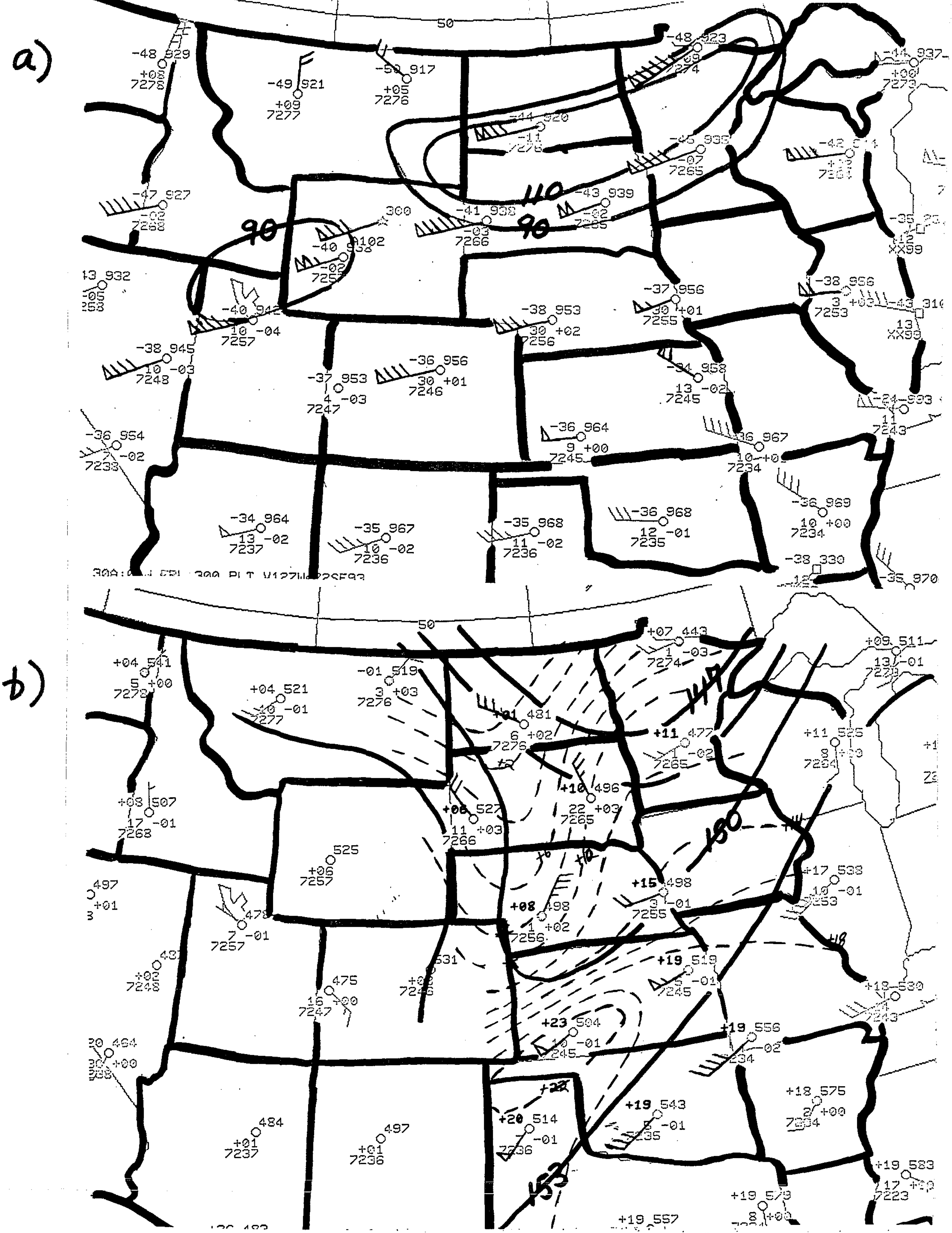

**Fig. 1** 22 September 1993 analysis of a) 300 mb, 90 and 100 kt isotachs contoured; and b) 850 mb, isotherms contoured every 2°C and heights contoured every 30 dam.

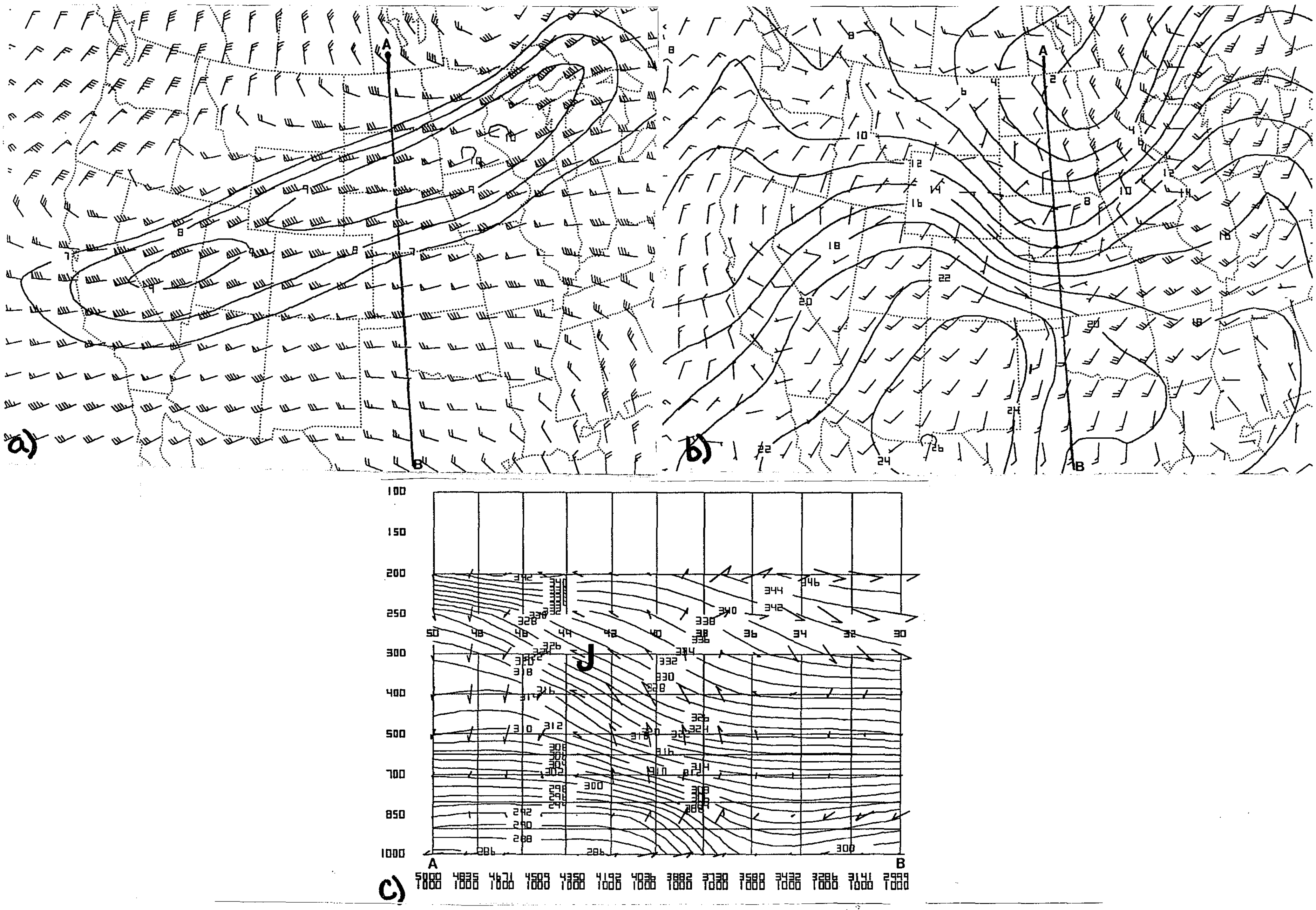

**Fig 2** 1200 UTC 22 September 1993 Eta model 12 hr forecast of a) 300 mb winds and isotachs, contoured every 10 kts greater than and equal to 70 kts; b) 850 mb winds and isotherms, contoured every 2°C; c) cross-section along 100°W, from 50°N to 30°N, of ageostrophic winds and potential temperature, contoured every 2K. The large "J" depicts the approximate location of the upper-level jet.

# Appendum to "Do Canadian/Arctic Fronts Move Faster At Night?"

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John Fausett, of WSO Midland, Texas, recently authored a very interesting Southern Region (SR) Technical Attachment (reprinted as a WR TA) investigating the possibility of diurnally varying propagation speeds of Canadian/arctic fronts. The results of the three cases he presented were unable to show any clear correlation between frontal propagation speed and time of day. Within his conclusions, he stated that synoptic-scale forcing may enhance or mask possible diurnal frontal propagation signatures. In an effort to further illustrate the importance of synoptic-scale forcing on Canadian/arctic frontal propagation, a recent case is briefly examined using PCGRIDS.

On 22 September 1993, a nearly stationary front over the northern Plains began to rapidly move southward over South Dakota, Nebraska, Kansas, and eventually Oklahoma and Texas. The 300 mb analysis for 1200 UTC 22 September 1993 (Fig. 1a) identifies a strong jet oriented in a west-southwest to east-northeast direction with the main jet core stretching across North and South Dakota into the upper Great Lakes region. A weaker secondary jet was centered over northern Utah. At 850 mb (Fig. 1b), strong northerly flow located to the north of the frontal boundary was orientated nearly perpendicular to the front, in the vicinity of southern Nebraska and northern Kansas. In advance of the front, a strong, southwesterly low-level jet was evident over southern Kansas.

In many cases, fronts aligned parallel to the upper-level flow are thought to be quasi-stationary. Typically, this is not the case with Canadian/arctic fronts. This particular case is a very good example of a Canadian/arctic front moving perpendicular to the upper-level flow. The rapid movement of these fronts southward across the Plains is often tied to a dramatic increase in the postfrontal northerlies. In diagnosing a mechanism responsible for the increase in postfrontal northerlies, cross-section analyses can be very useful. Using the 1200 UTC Eta model run for 22 September 1993, cross-sections were computed from forecast data to ascertain possible mechanisms for the increasing low-level northerly winds. A cross-section was chosen nearly perpendicular to the upper-level jet, along 100°W from 50°N to 30°N, in an attempt to diagnose the thermally direct circulation associated with the jet entrance region.

Figure 2a displays the 12 hour forecast of the 300 mb winds. Strong northerly flow was forecast north of the front as shown in Fig. 2b. The cross-sectional analysis (Fig. 2c) of the ageostrophic circulation shows a well-defined, thermally direct circulation centered near 500 mb at approximately 42°N. A thermally direct circulation is most simply defined as warm air rising and cold air sinking, with the low-level (upper-level) flow regime directed toward the warm (cold) air to complete the circulation. The ageostrophic northerlies within the low-level branch of this thermally direct circulation are at least partially responsible for the increase in northerly winds depicted in Fig. 2b.

This is a simple example illustrating that the effective choice of cross-section orientation can assist in analyzing frontal structure and propagation mechanisms. The key is using the correct cross-section orientation. Although this example specifically applies to a Canadian/arctic front over the Plains, broader applications exist.